MC Simulations for the PreSPEC campaign of AGATA at GSI

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GSI Helmholtzzentrum für Schwerionenforschung GmbH

Outline

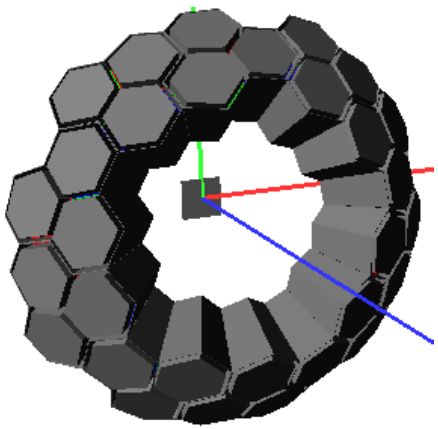
- AGATA Geometry for experiments at GSI FRS (PRESPEC)
- Performance in terms of efficiency and resolution
- Angular dependence of the g-ray efficiency for several distances
- Relativistic dependence of the efficiency on β
- Performance vs. number of double and/or triple cluster available
- Efficiency performance for pure E2 transitions
- MC Simulation of a Fragmentation experiment
- MC Simulation of the line-shape for DSAM analysis
- First steps towards implementation of background in the simulations
- Outlook
- Conclusion

AGATA S2 + 5 Double Cluster Detectors = S2'

Geometry cases

- S2 + 5 Double Cluster detectors closing part of the central hole (15-16cm?). Remains shell with 5 crystals hole + pentagon hole

AGATA S2 Geometry



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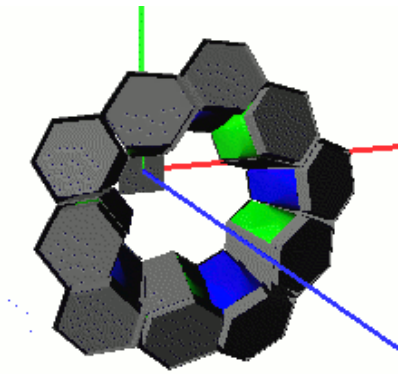
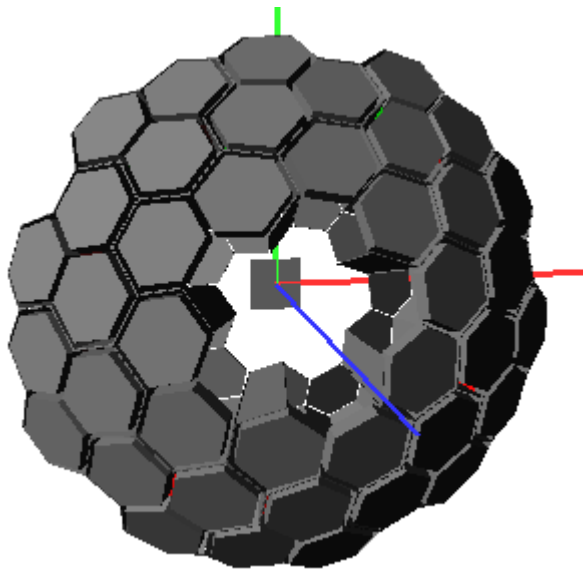


=

AGATA **S2'** Geometry

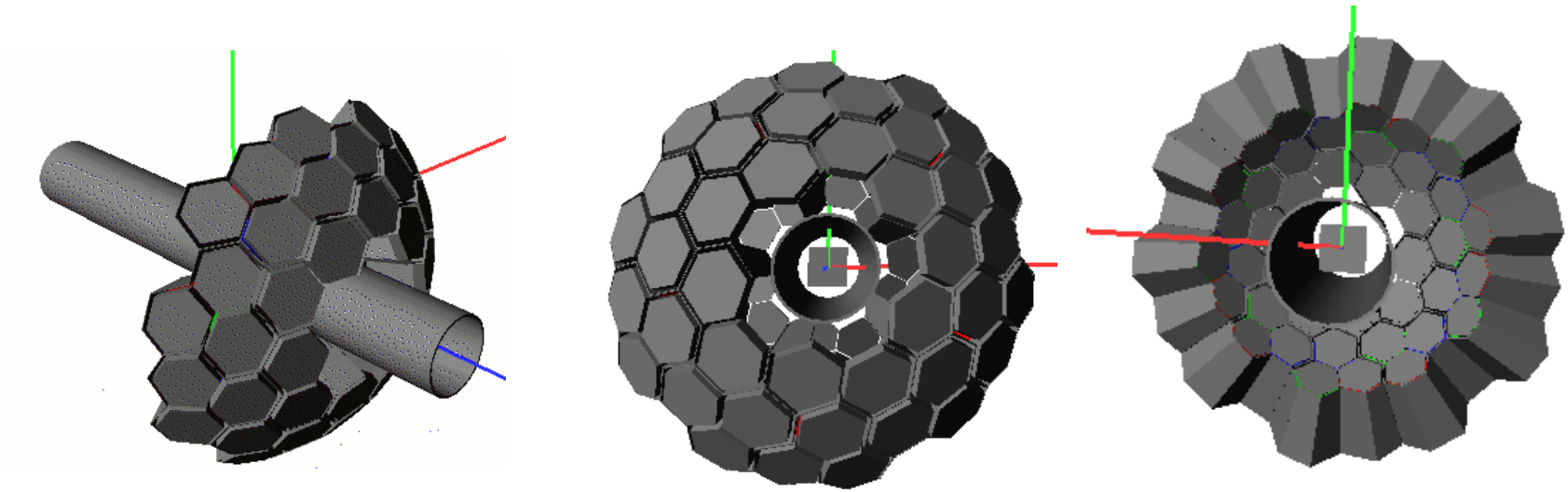


10 triple Cluster + **5 double** Cluster

AGATA S2 + 5 Double Cluster Detectors = S2'

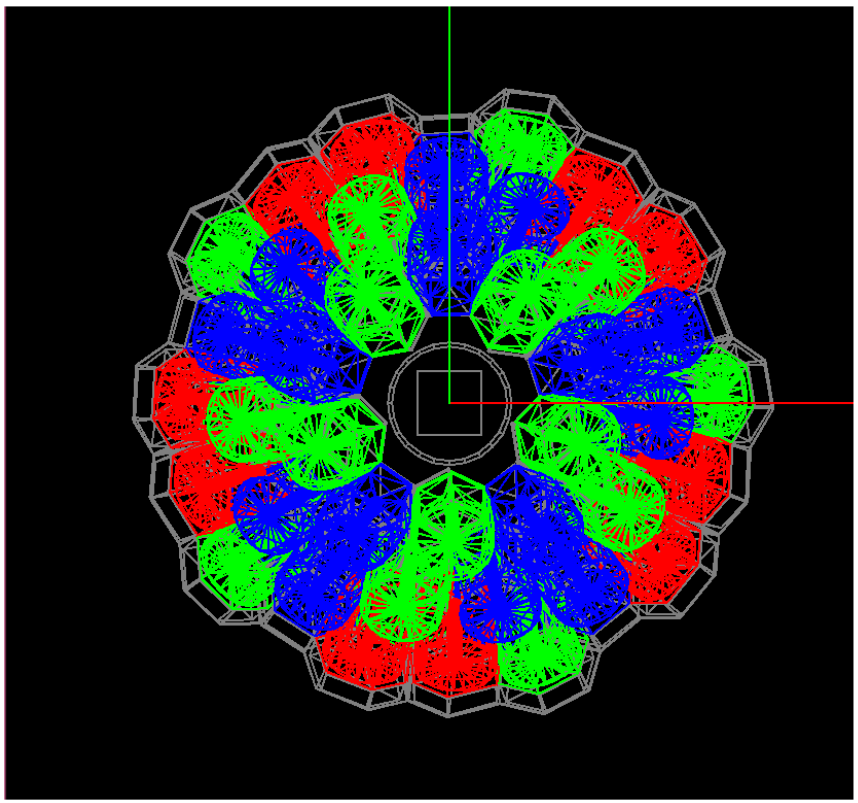
Geometry cases

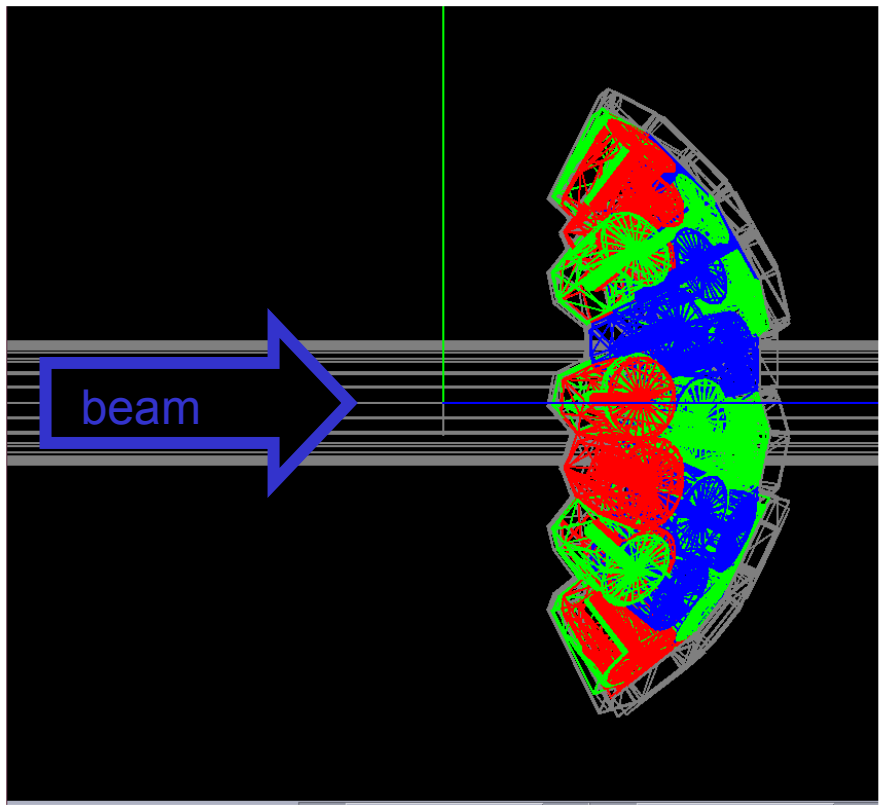
- S2 + 5 Double Cluster detectors closing part of the central hole (15-16cm?). Remains shell with 5 crystals hole + pentagon hole



Beam pipe diameter = 9 - **12** cm

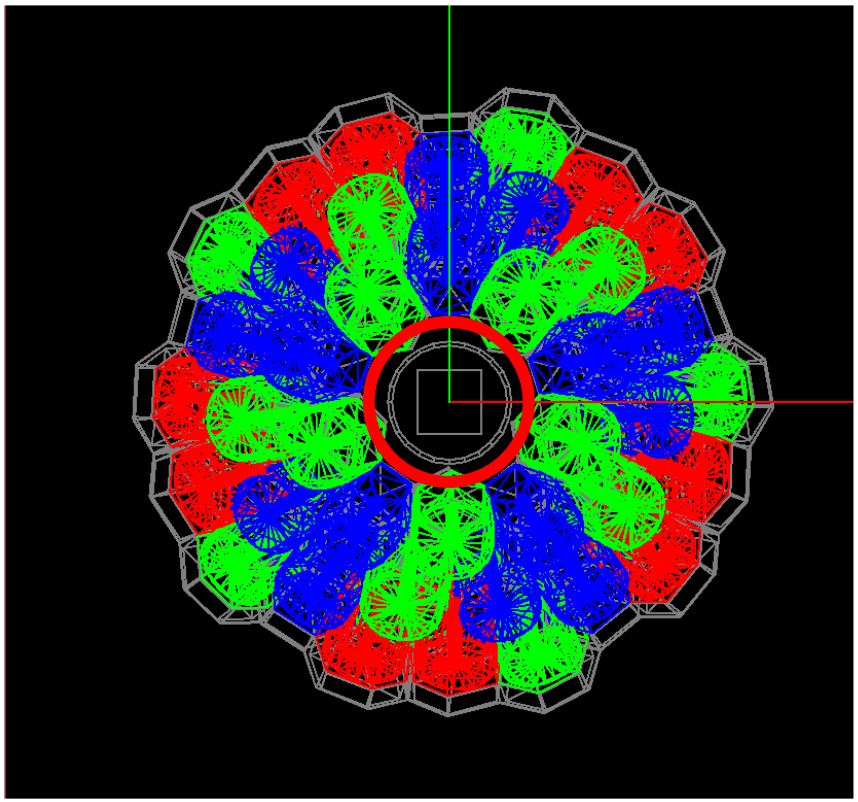
AGATA S2 + 5 Double Cluster Detectors = S2'



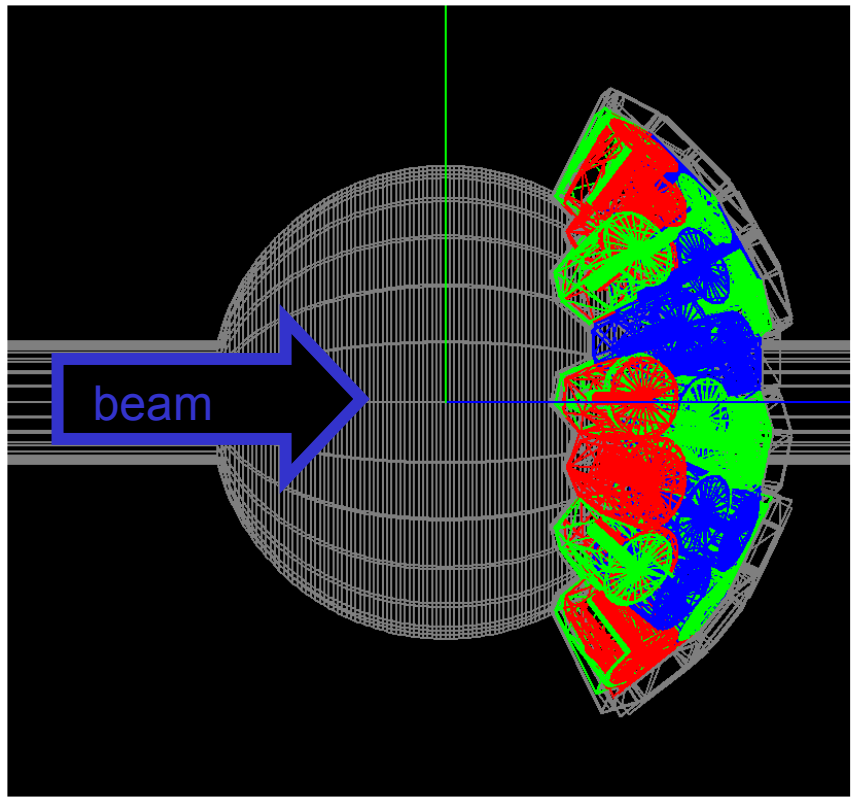


AGATA S2 + 5 Double Cluster Detectors = S2'

Blue crystals are at diameter = 17 cm

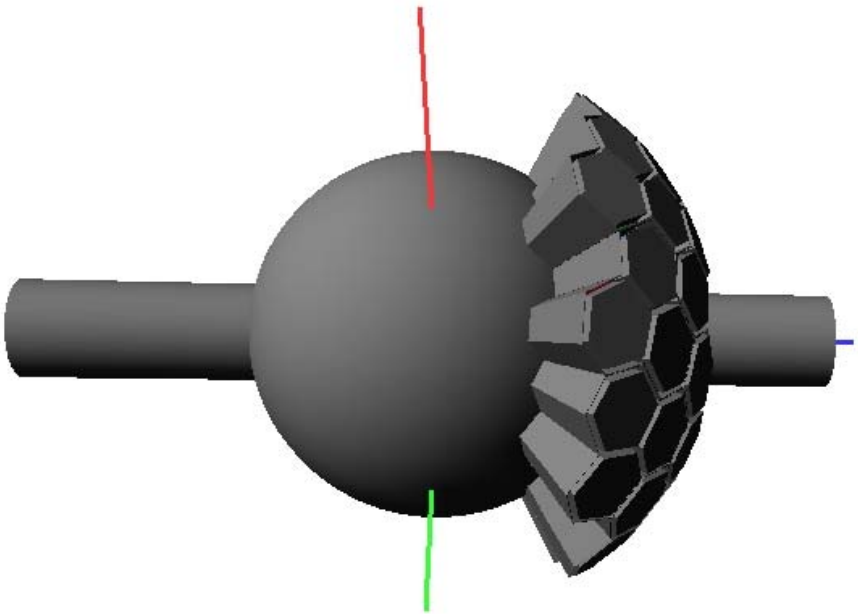


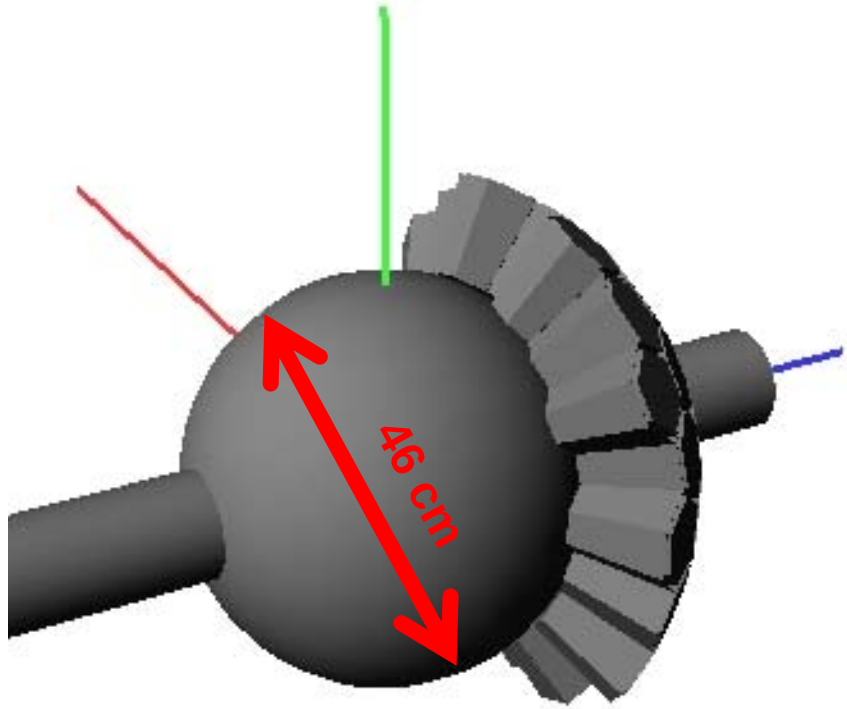
Room for a chamber 46cm diameter



AGATA S2 + 5 Double Cluster Detectors = S2'

- S2’ Geometry + Spherical Chamber



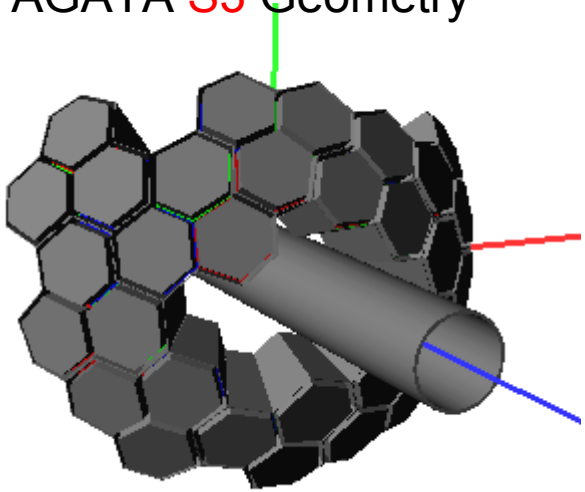


AGATA S3 + 1 Agata Double Cluster = S3'

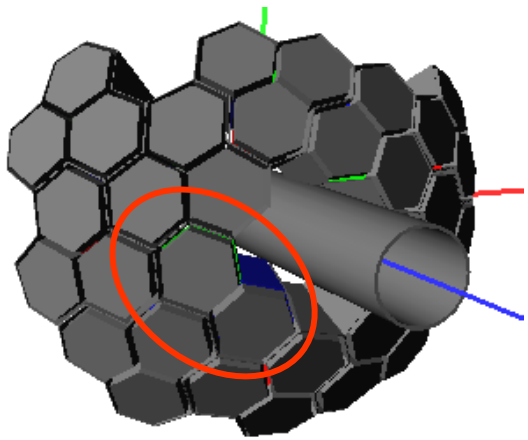
Alternative geometry:

- S3 + 1 Double Cluster detector closing part of the central hole (10-11 cm?). Remains shell with 4 crystals hole + pentagon hole.

AGATA S3 Geometry



AGATA S3' Geometry



10 triple Cluster (Asym) **+** **1 double** Cluster

Beam pipe diameter = 10 cm

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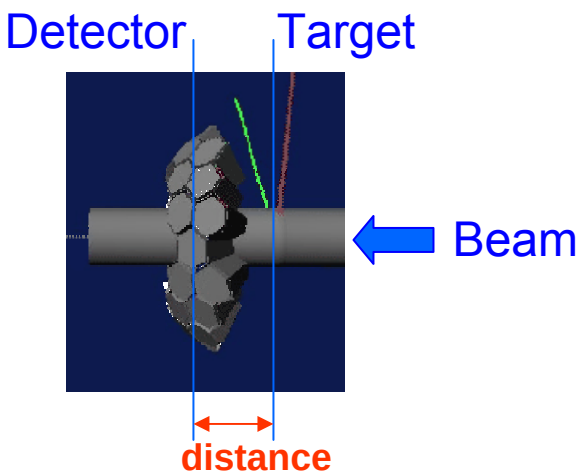
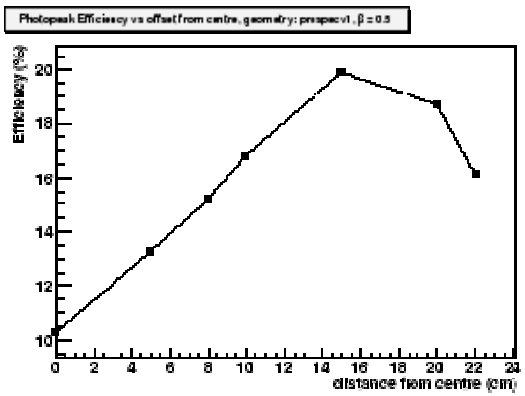
Performance comparison: general aspects

- Systematic study of efficiency and resolution vs. distance for all geometries

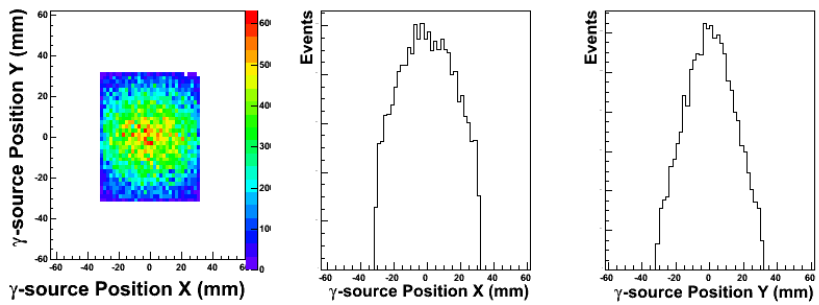
- "Reference physics case": (GEANT4 AGATA code from E.Farnea et al.)
  - ➡ **$E_{\gamma,o}$ = 1 MeV**, recoil nucleus at **β = 0.43** (E = 100 MeV/u), **Mγ = 1**
  - ➡ Systematic study several distances sec. target – detector





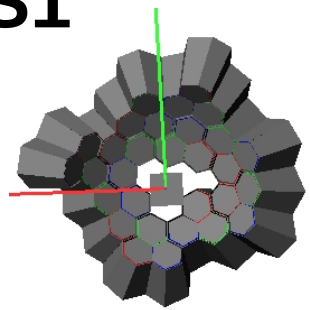
  - ➡ GSI FRS Spatial Beam Profile $FWHM_x$ = 6 cm $FWHM_y$ = 4 cm

Active target
DSSSD

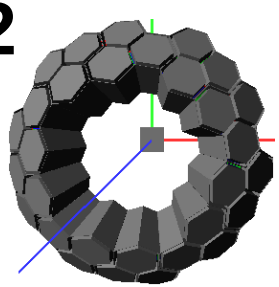


S-Geometries Performance comparison: Efficiency

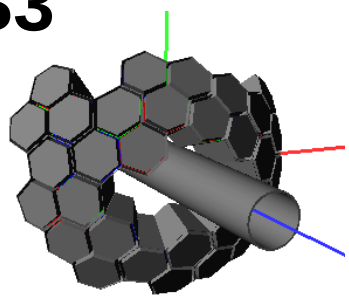
S1

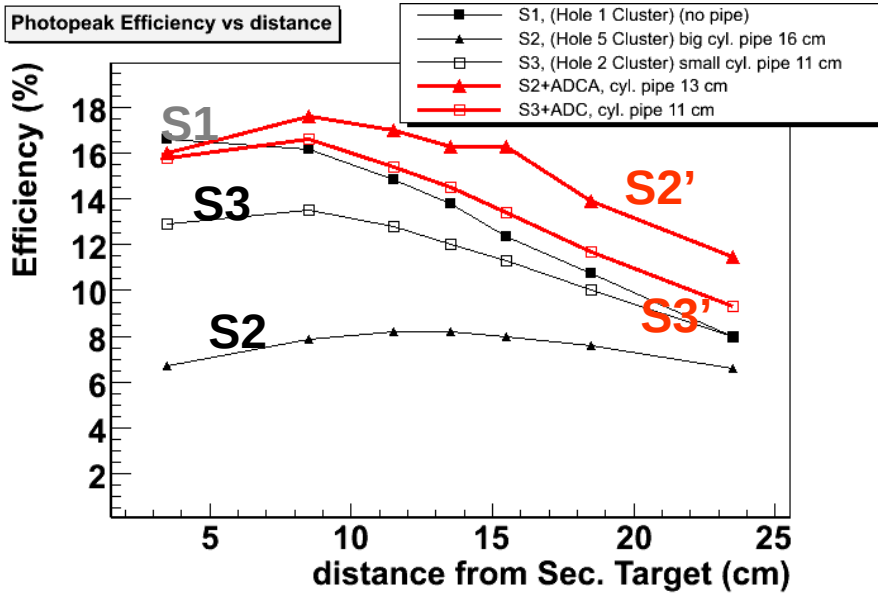


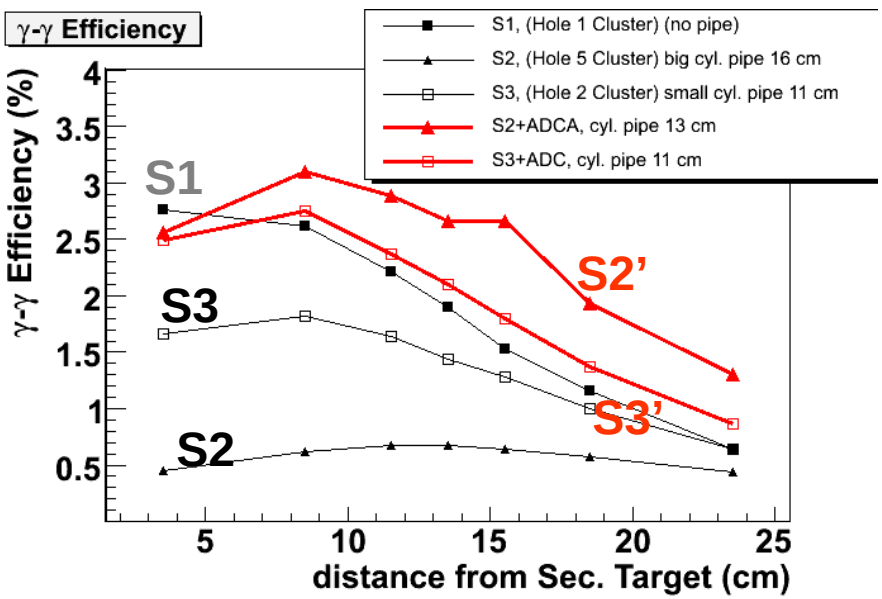
S2



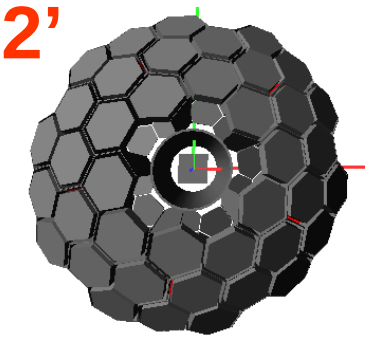
S3



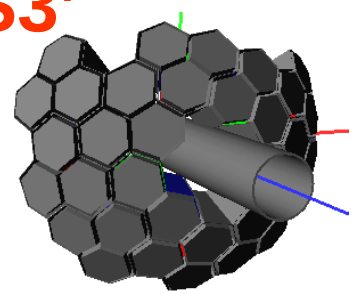




S2'

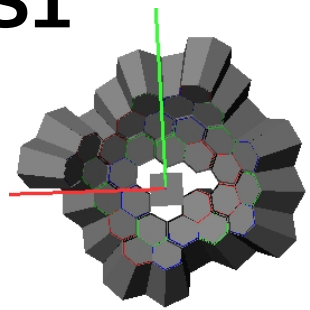


S3'

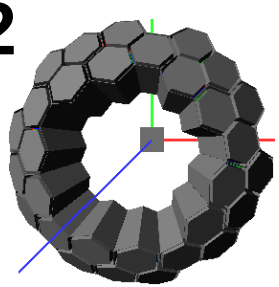


S-Geometries Performance comparison: Resolution

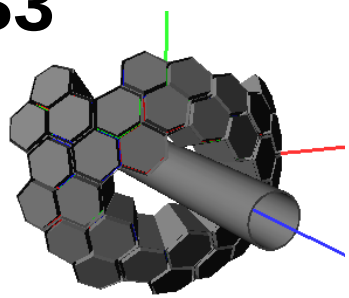
S1

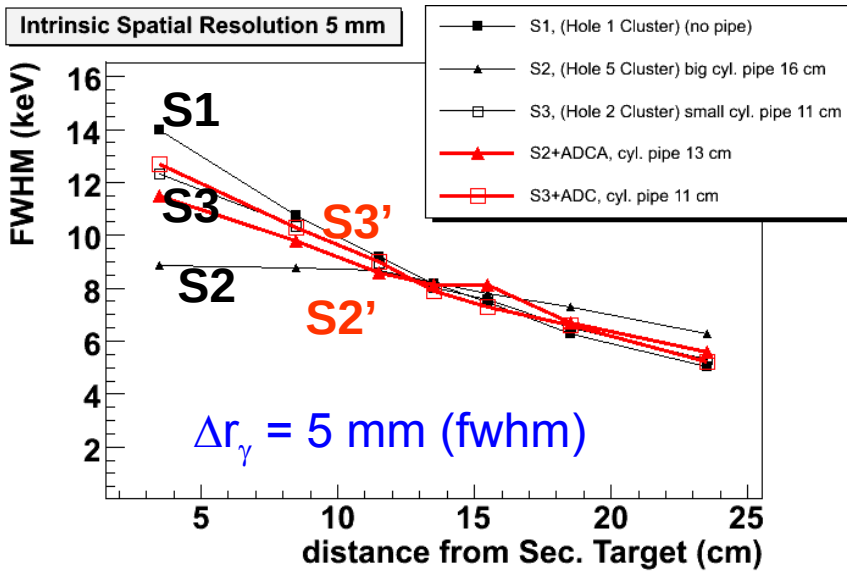


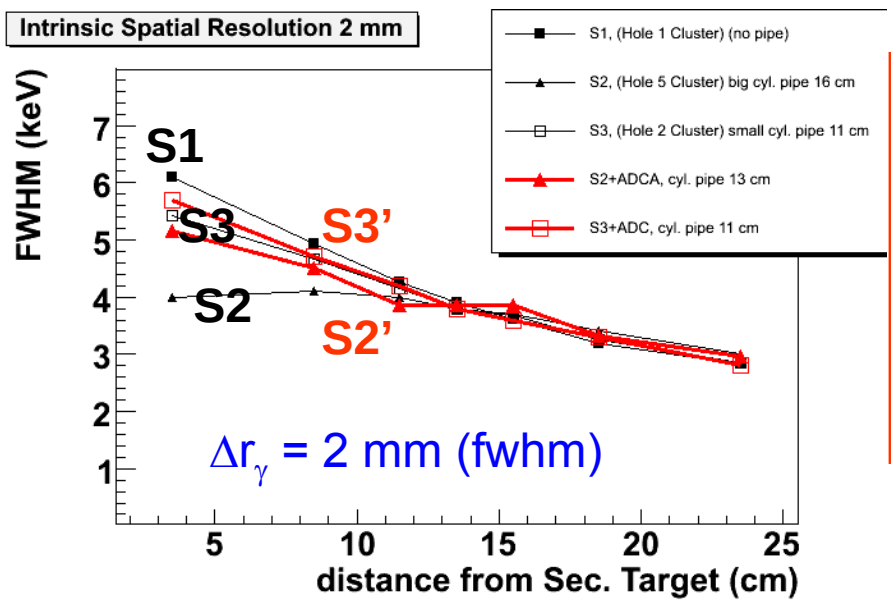
S2



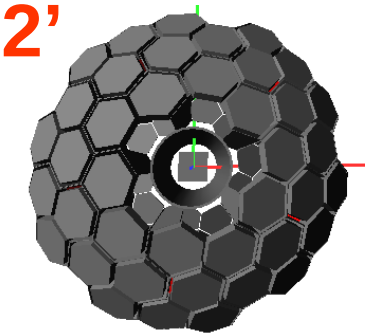
S3



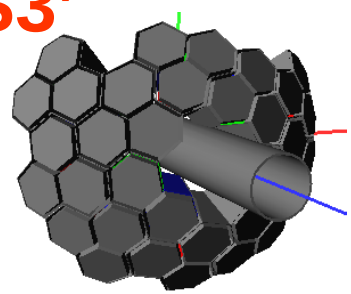




S2'

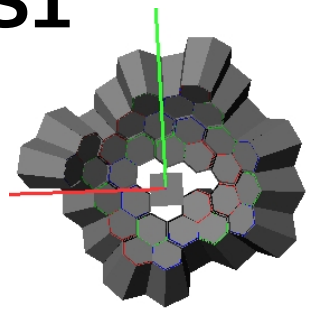


S3'

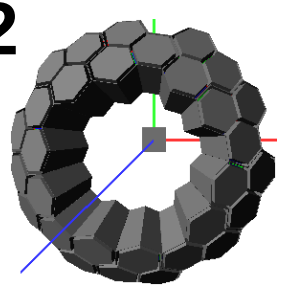


Shell Geometries performance comparison: Summary

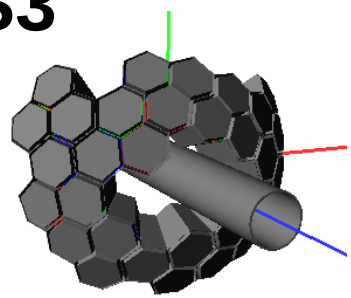
S1

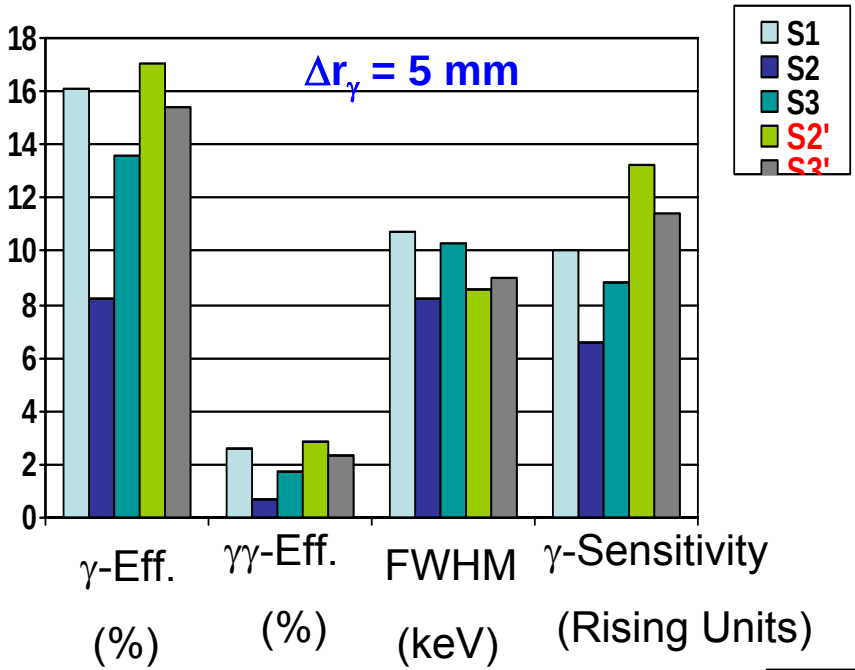


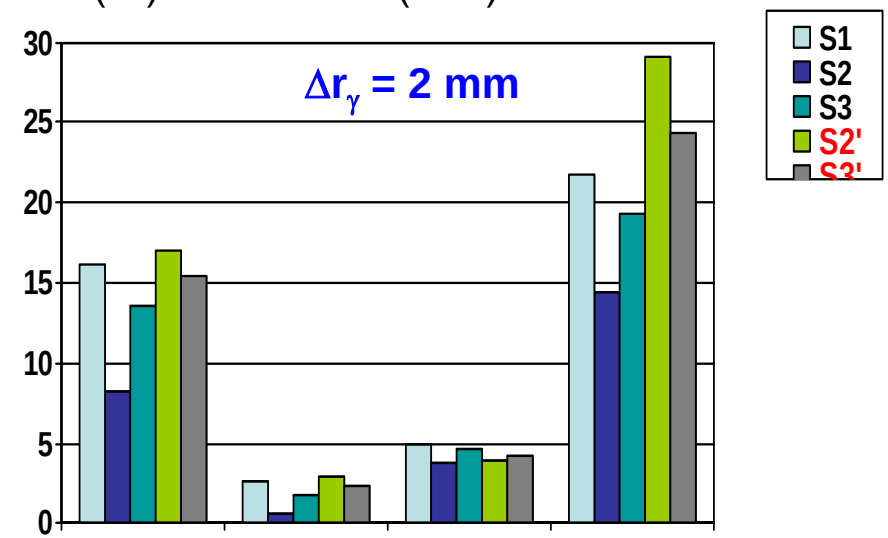
S2



S3

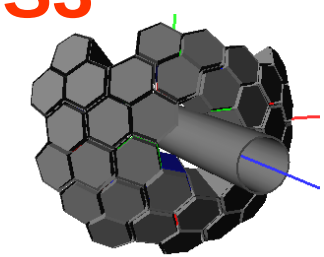






S2'

S3'



AGATA S2 + 5 Double Cluster Detectors

Geometry cases

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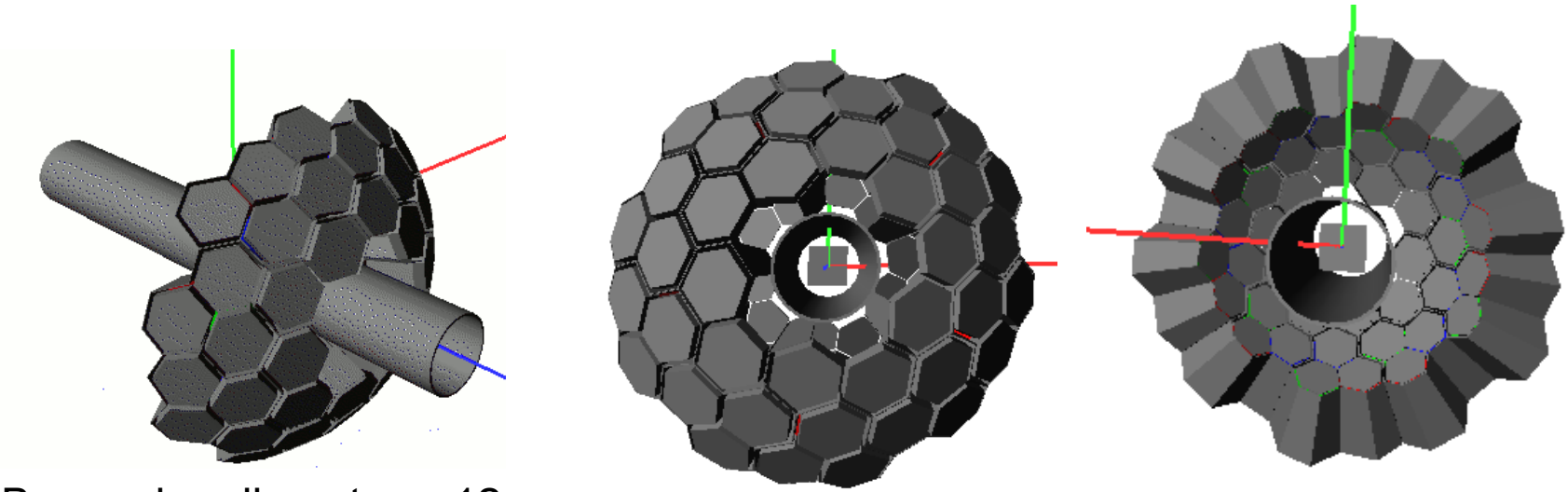
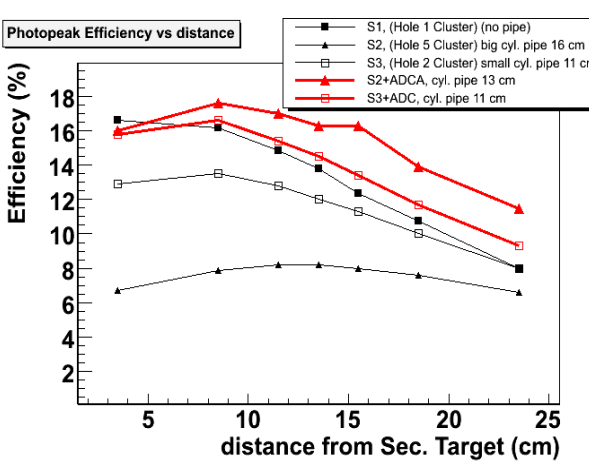
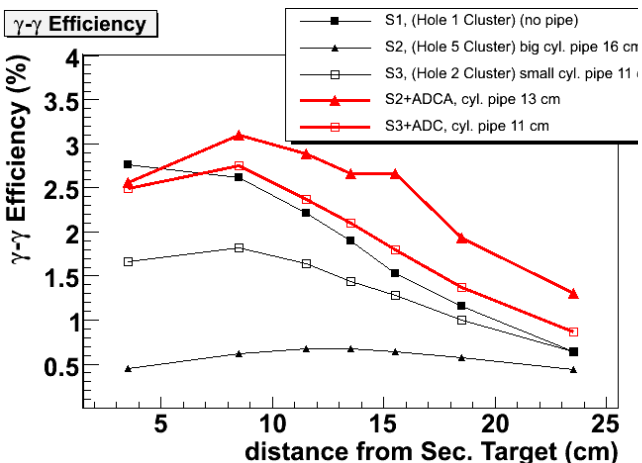
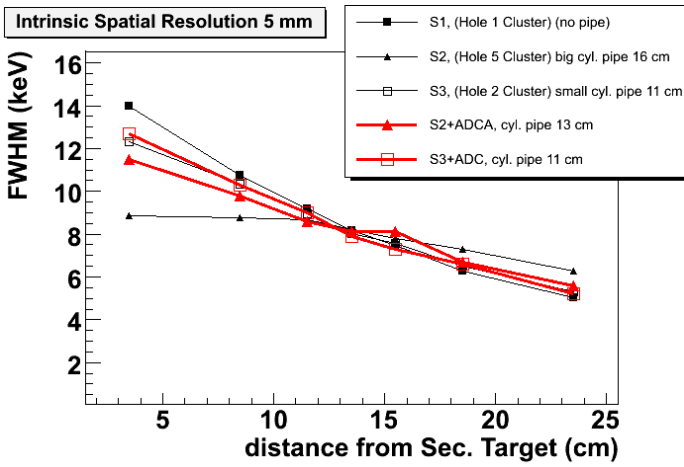


Beam pipe diameter = 12 cm







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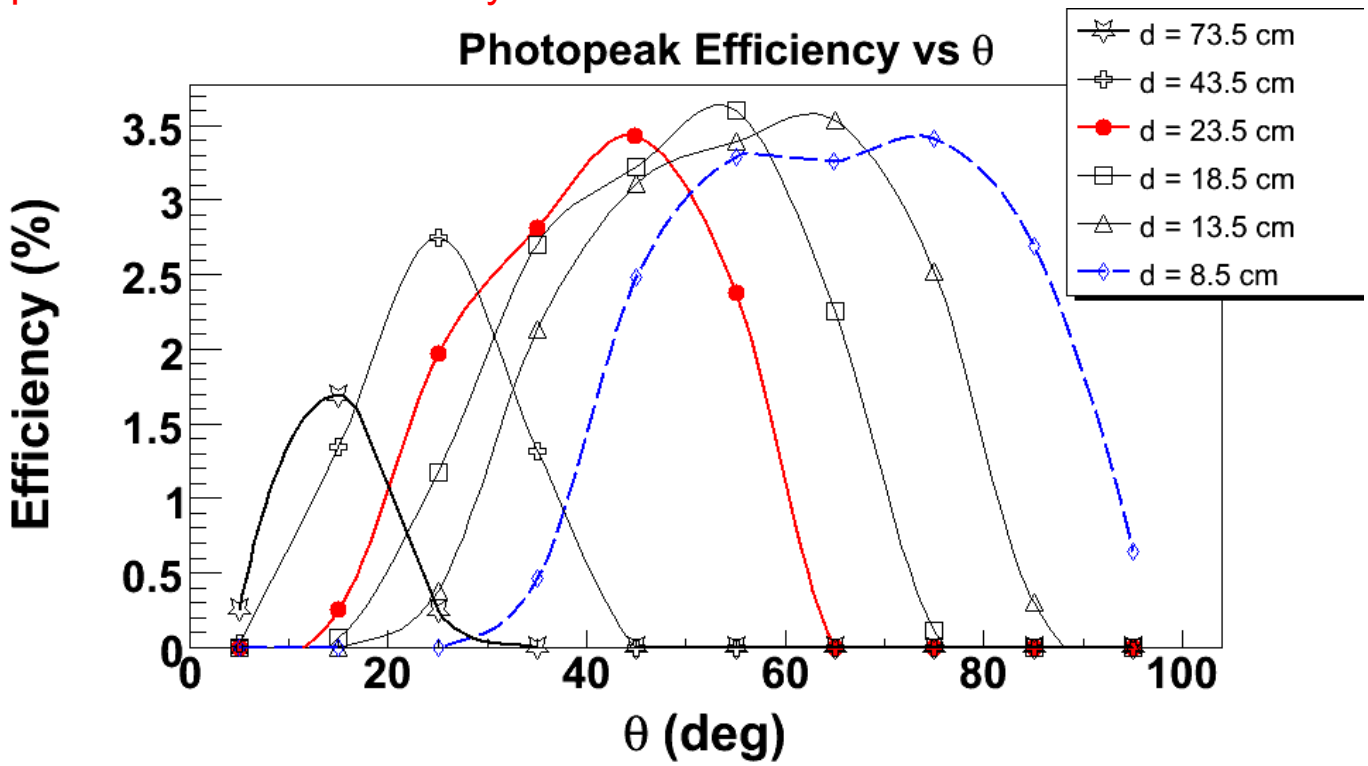
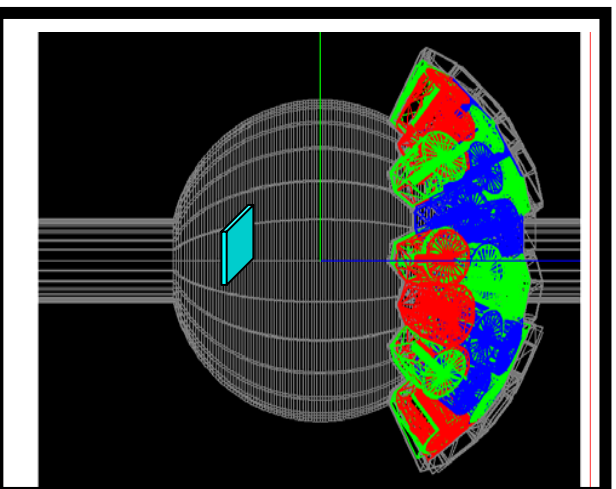
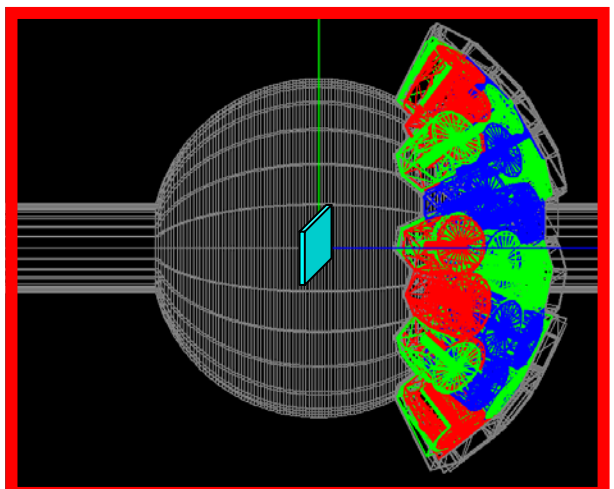
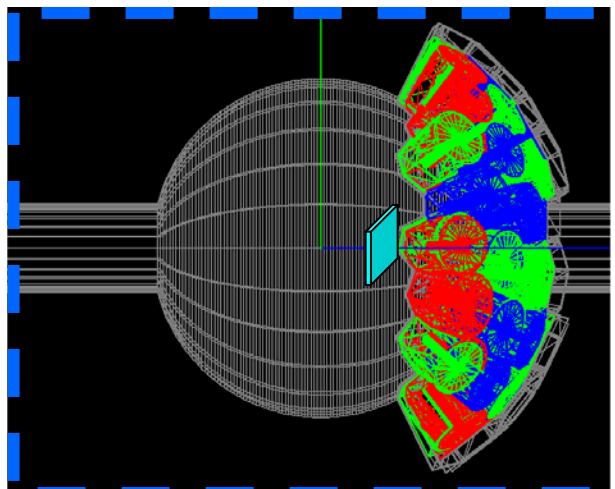
AGATA S2 + 5 Double Cluster Detectors

- **Angular** dependence of the efficiency:









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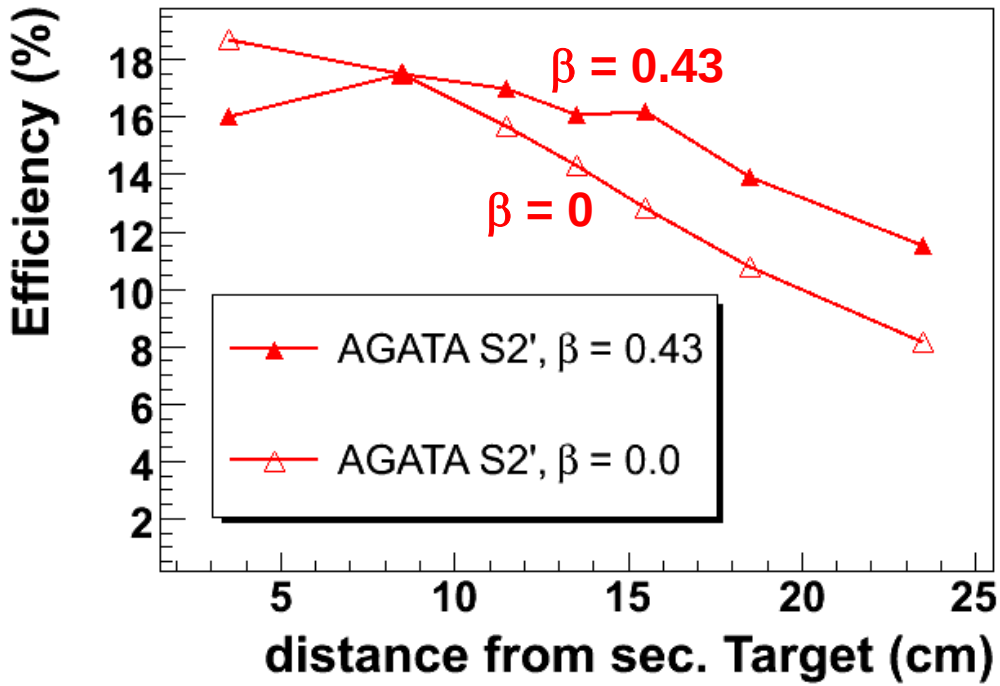
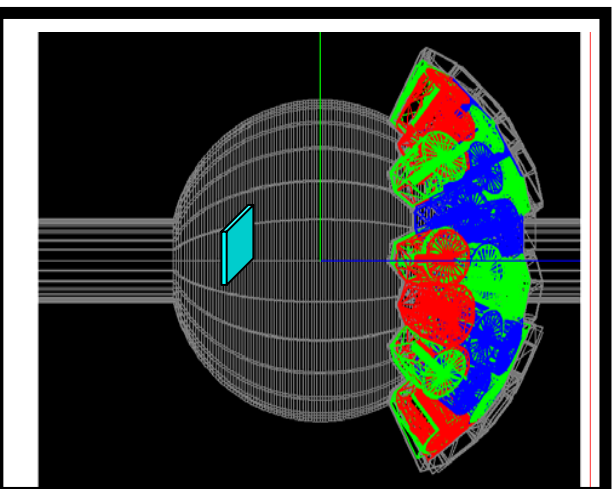
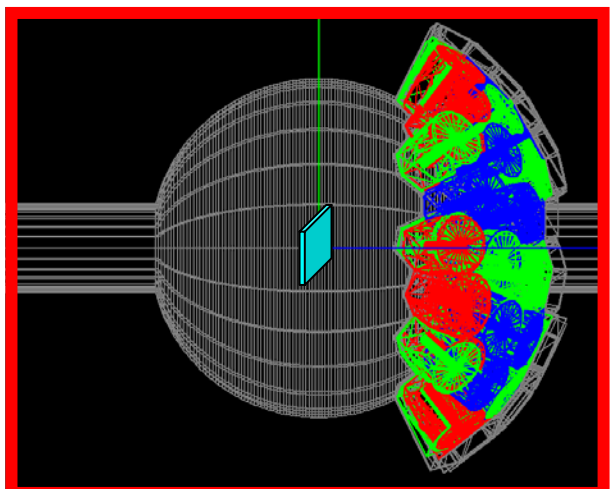
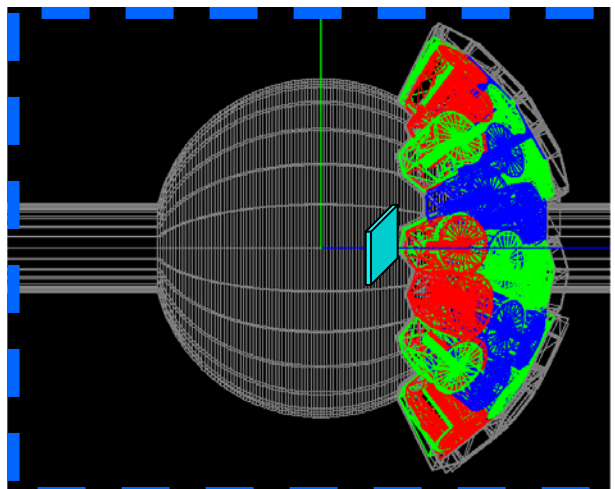
- **Relativistic** dependence of the efficiency:









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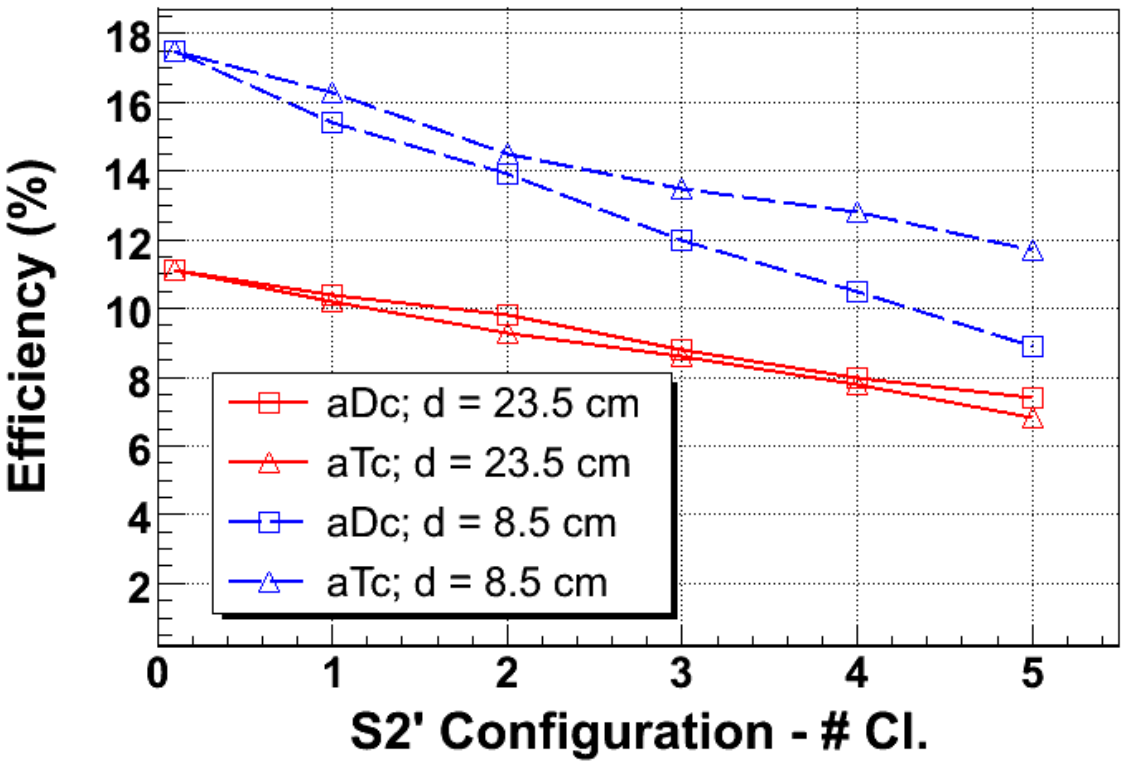
AGATA S2 + 5 Double Cluster Detectors

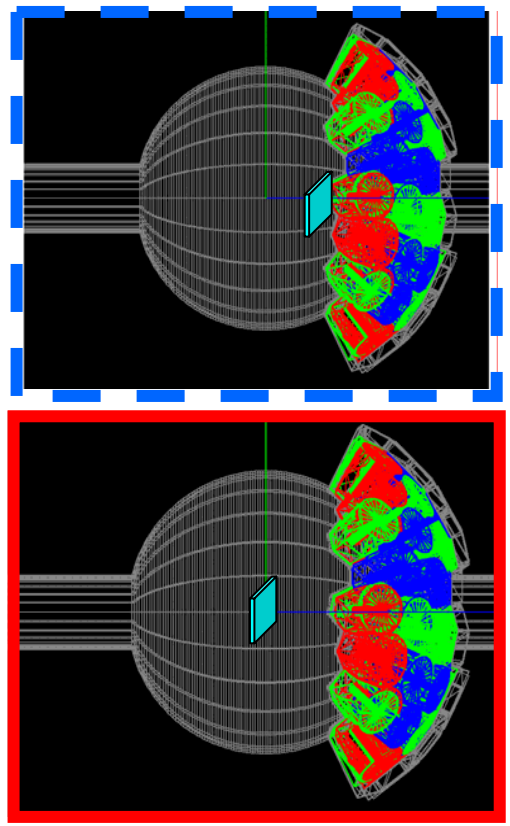
Dependence of the efficiency on the number of triple (double) clusters

S2' Configuration = 10 ATC + 5 ADC

△ ATC (Agata Triple Cluster)

□ ADC (Agata Double Cluster)





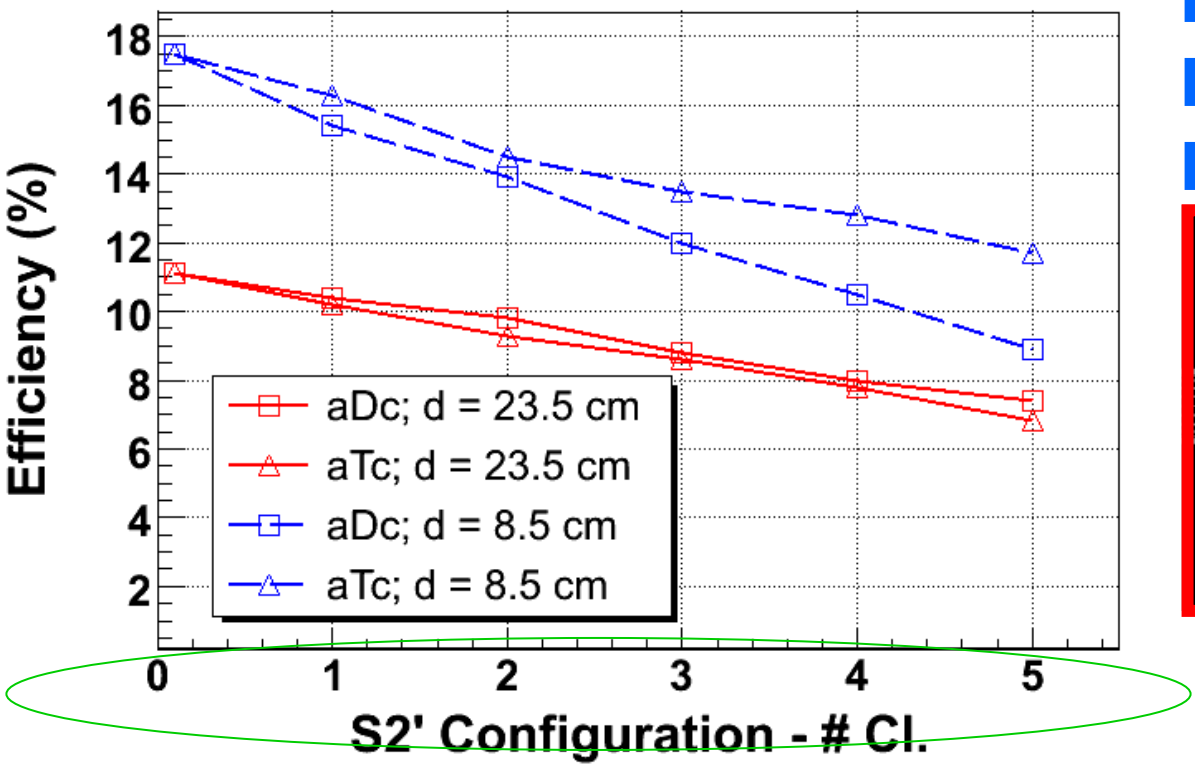
AGATA S2 + 5 Double Cluster Detectors

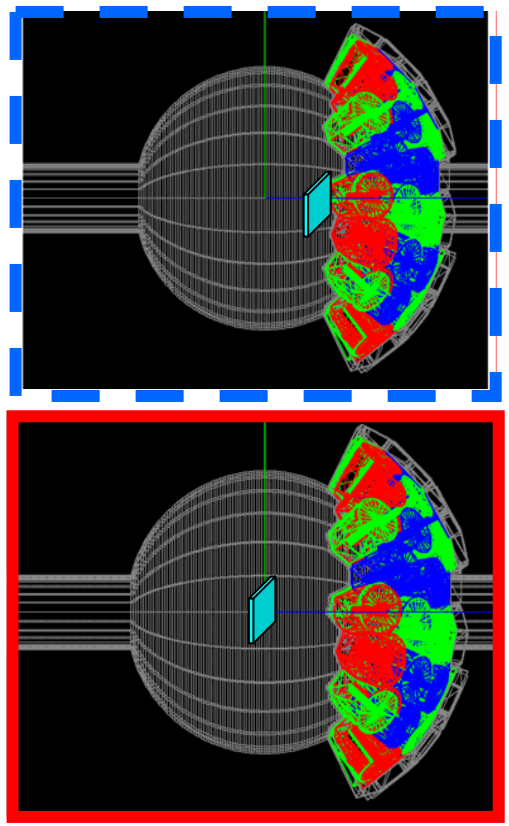
Dependence of the efficiency on the number of triple (double) clusters

S2' Configuration = 10 ATC + 5 ADC

△ ATC (Agata Triple Cluster)

□ ADC (Agata Double Cluster)





Number of clusters missing in the S2' configuration !

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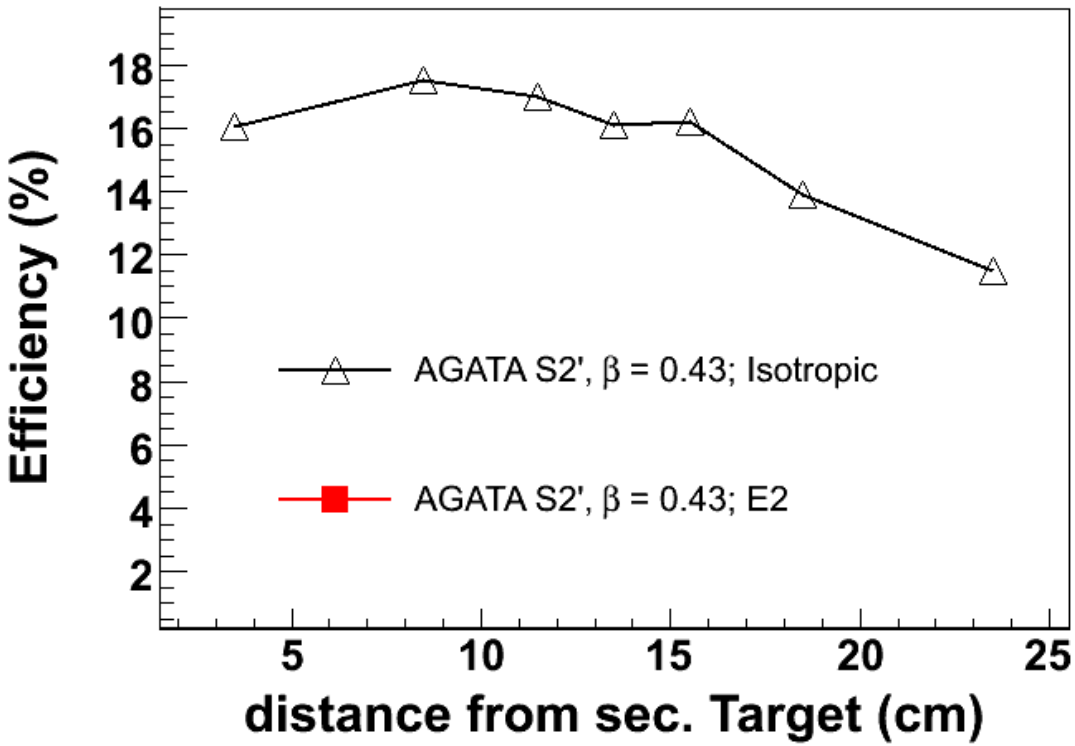
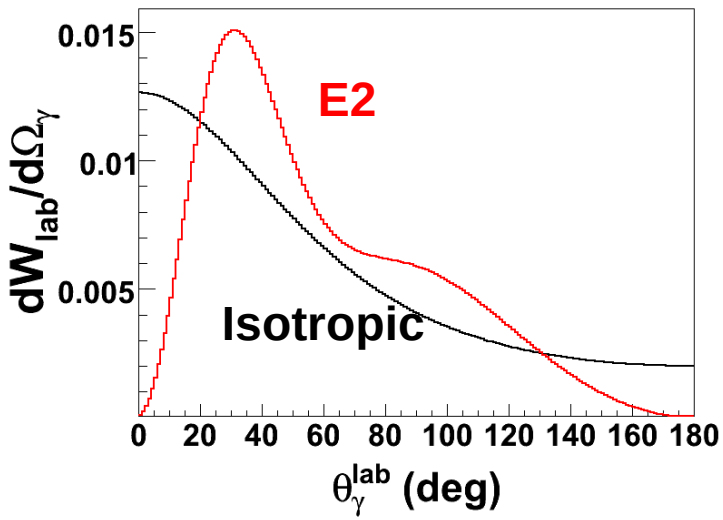
AGATA S2 + 5 Double Cluster Detectors

Dependence of the efficiency on the g-ray multipolarity (Isotropic vs. pure E2)





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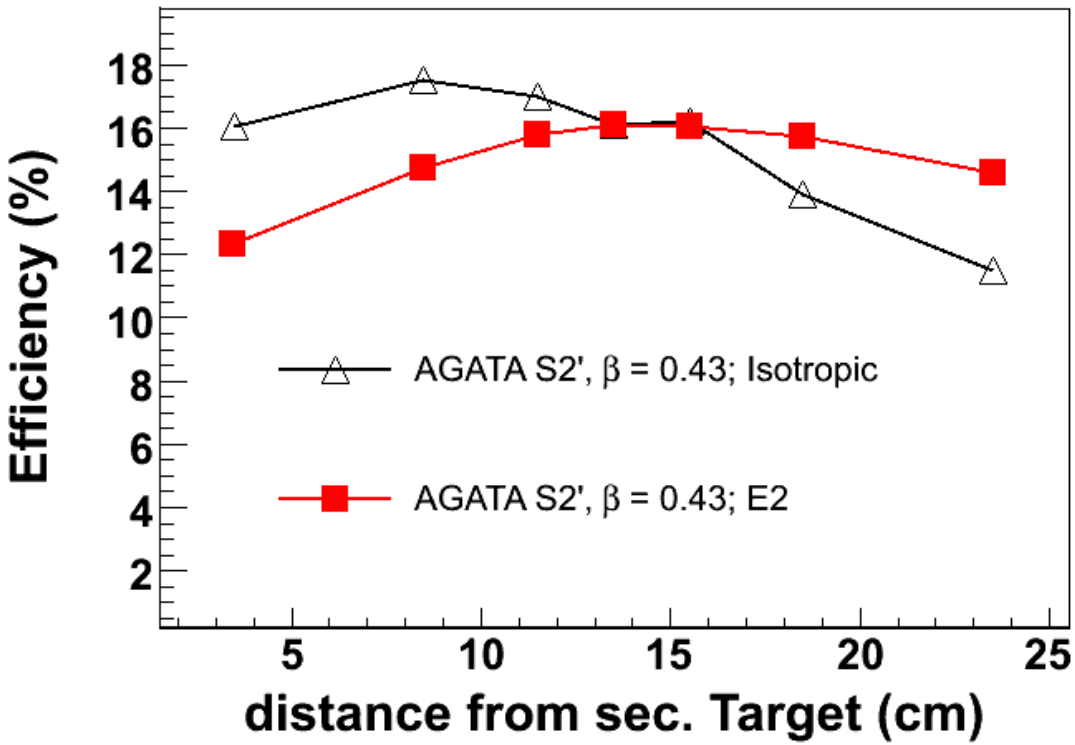
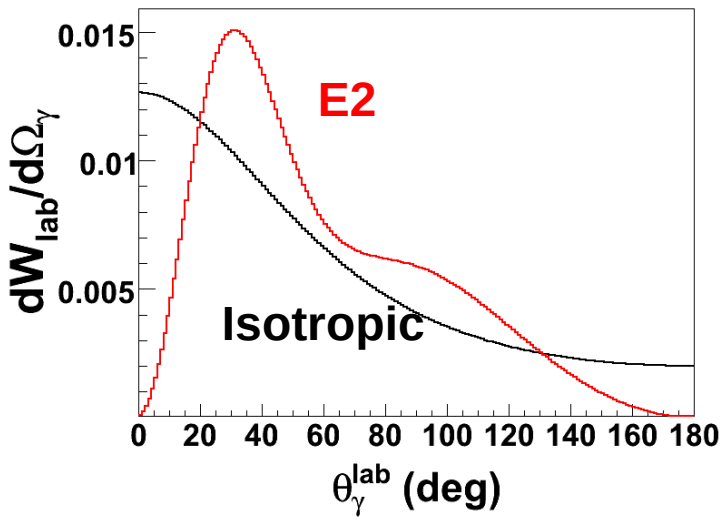
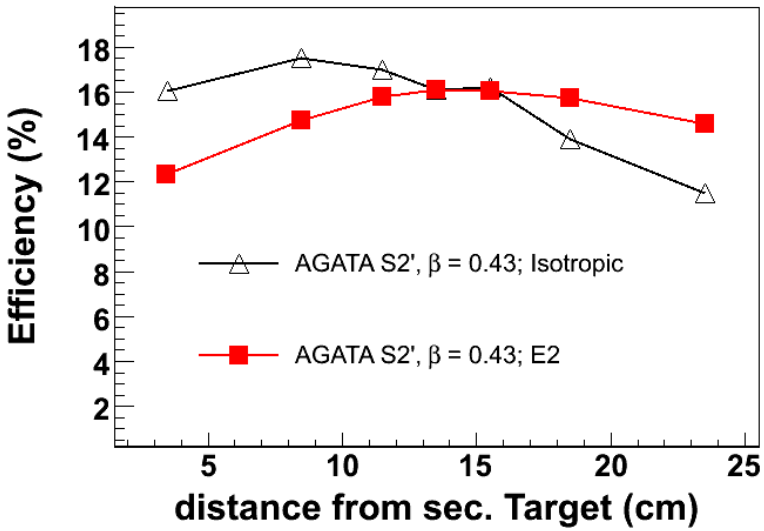
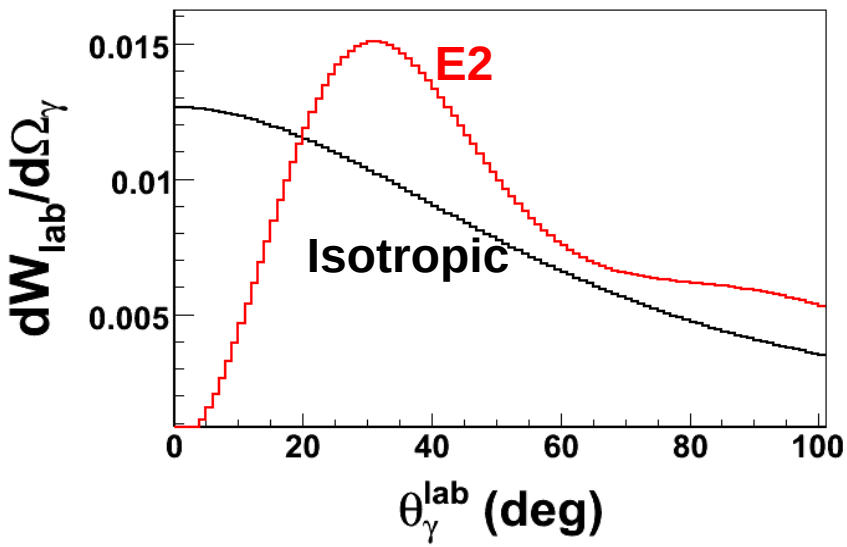
Dependence of the efficiency on the g-ray multipolarity (Isotropic vs. pure E2)

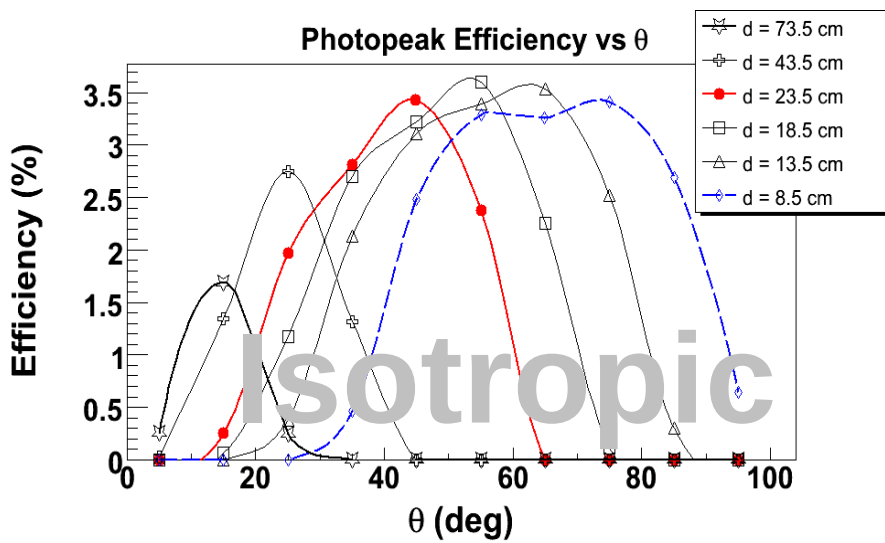




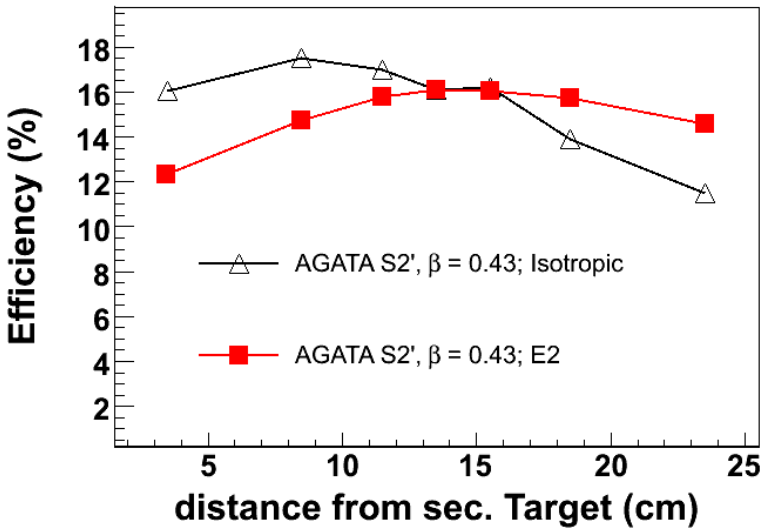
Dependence of the efficiency on the g-ray multipolarity (pure E2)

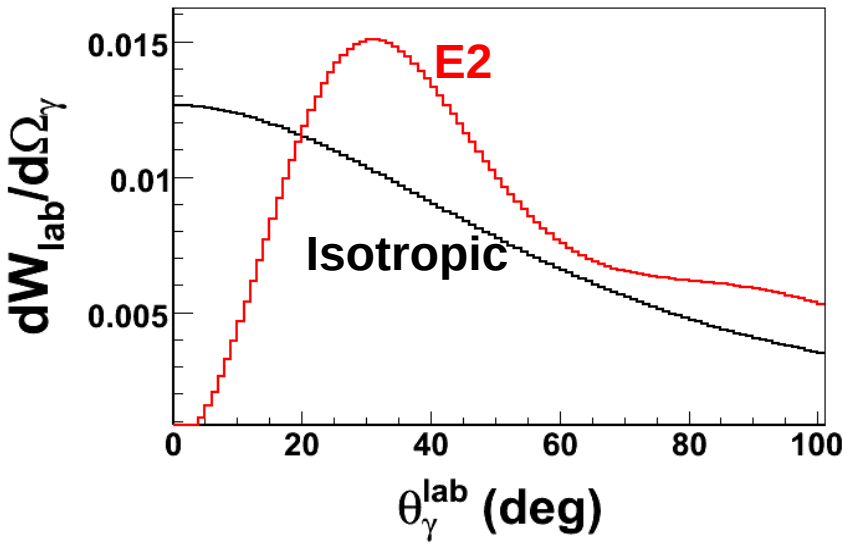


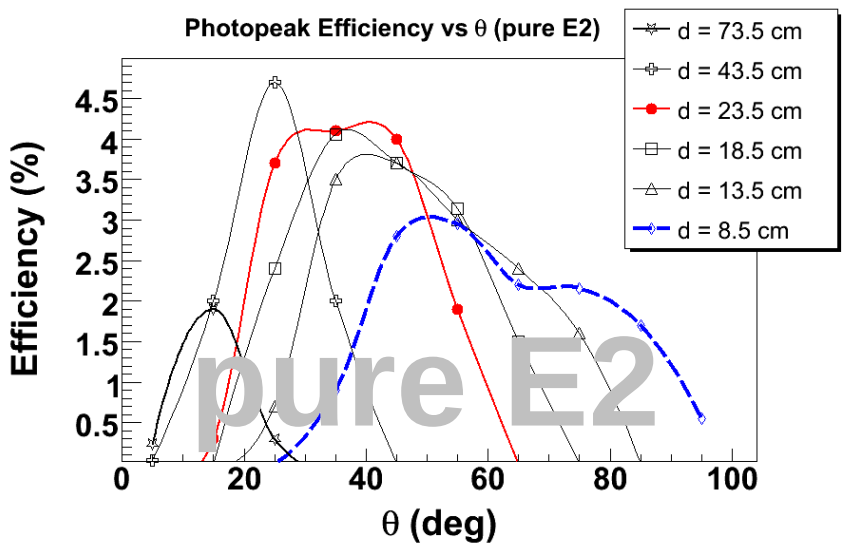


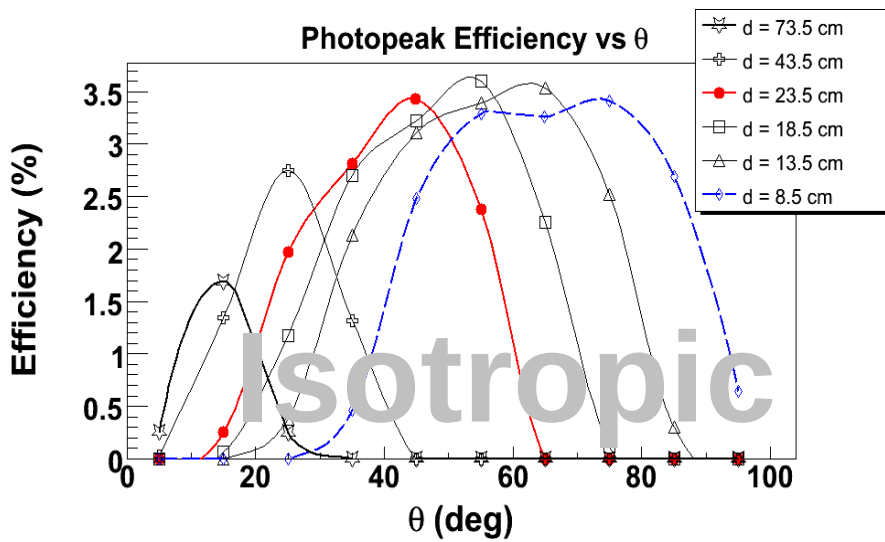


Dependence of the efficiency on the g-ray multipolarity (pure E2)









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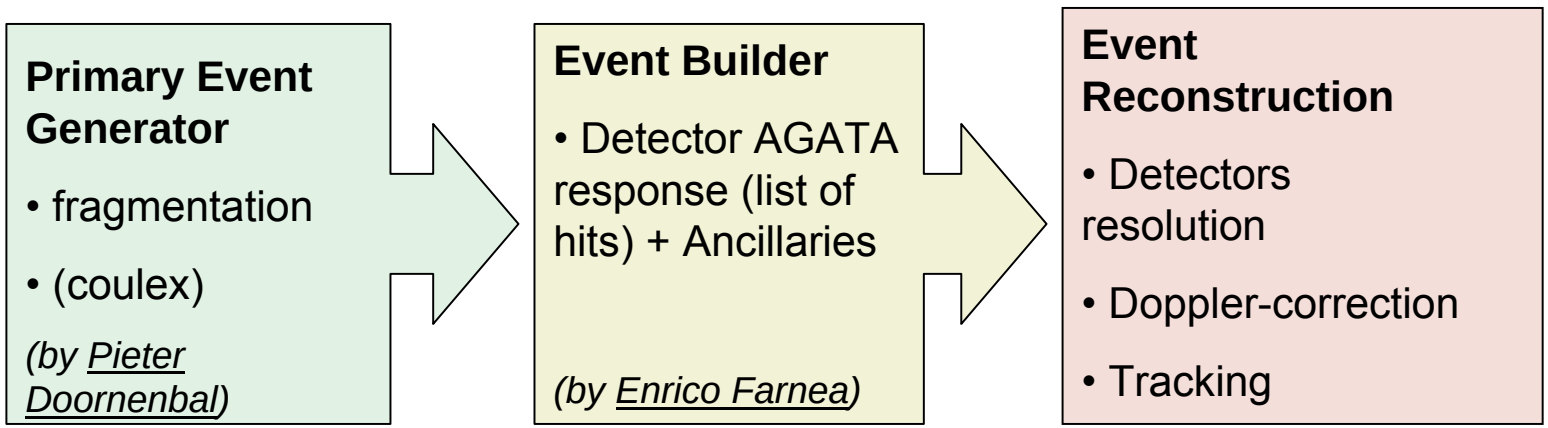
MC Simulation of a reference fragmentation experiment

Realistic MC Simulation of a **fragmentation** experiment



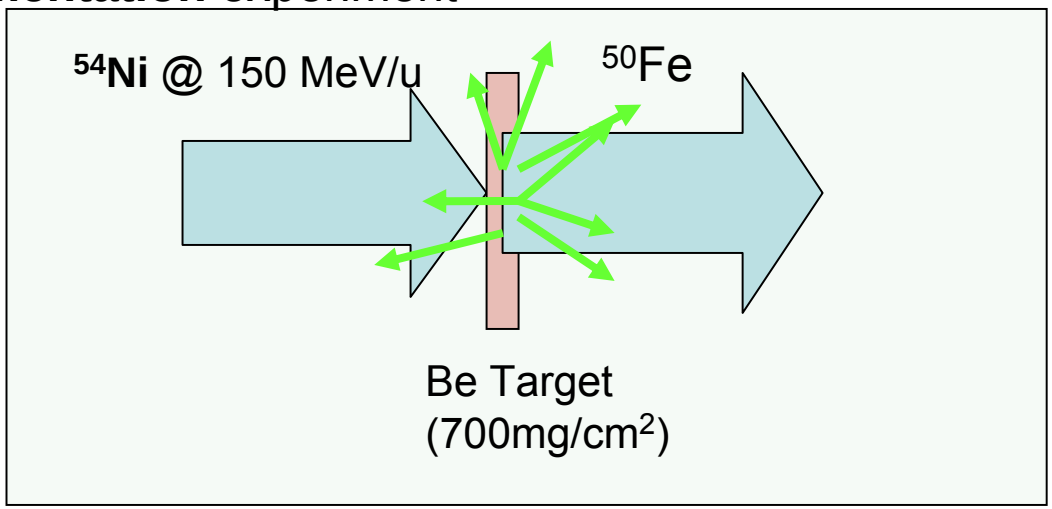
Fragmentation Experiment Benchmark: ^{54}Ni -> ^{50}Fe*

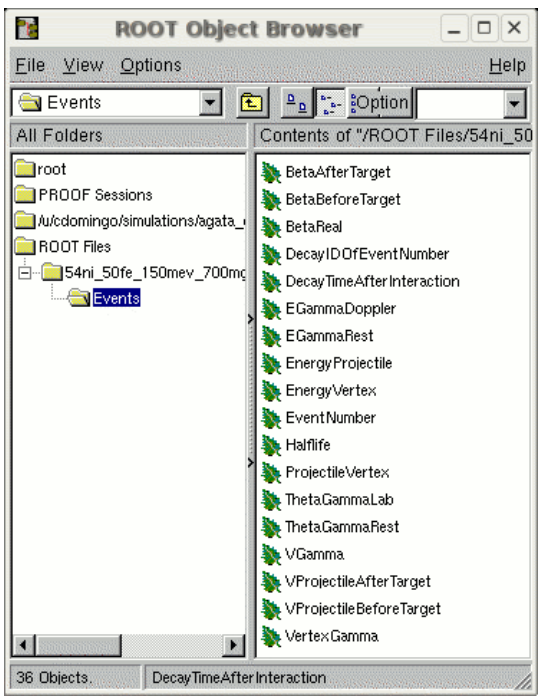
Realistic MC Simulation of a **fragmentation** experiment

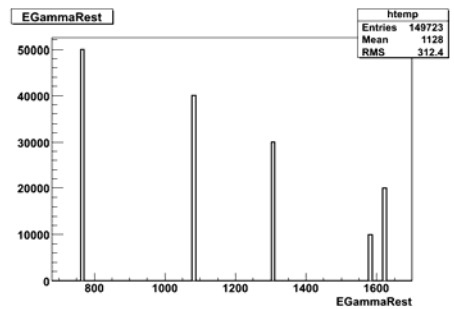
Primary Event Generator

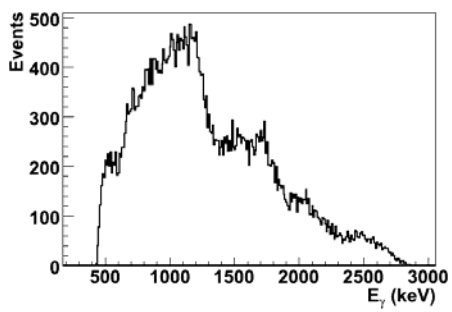
- fragmentation
- g-ray decay

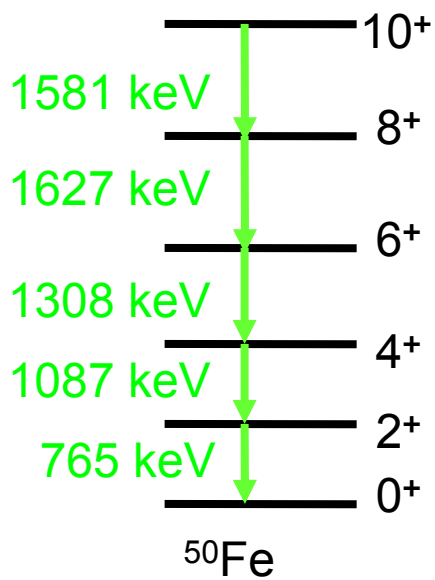
(by Pieter Doornenbal)











Fragmentation Experiment Benchmark: ^{54}Ni -> ^{50}Fe*

Realistic MC Simulation of a **fragmentation** experiment

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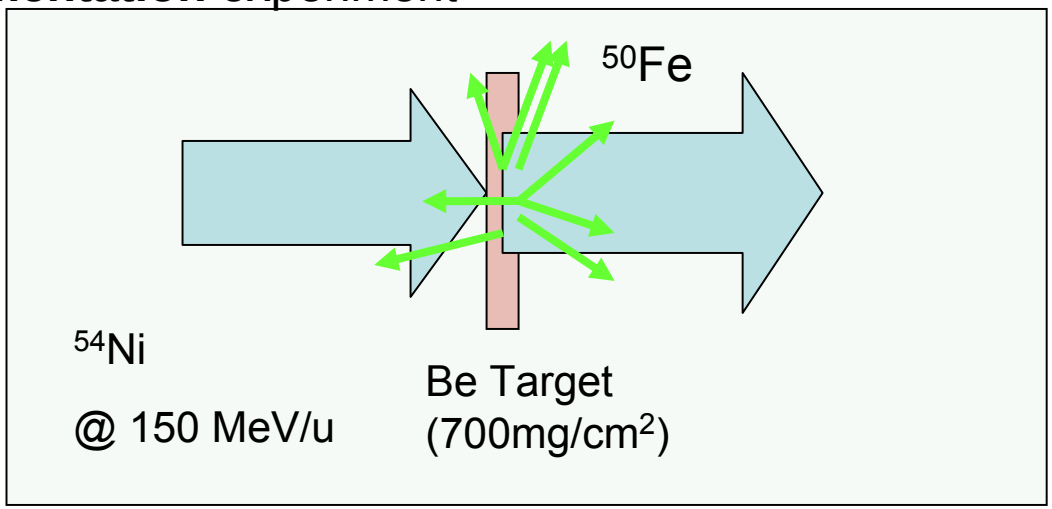
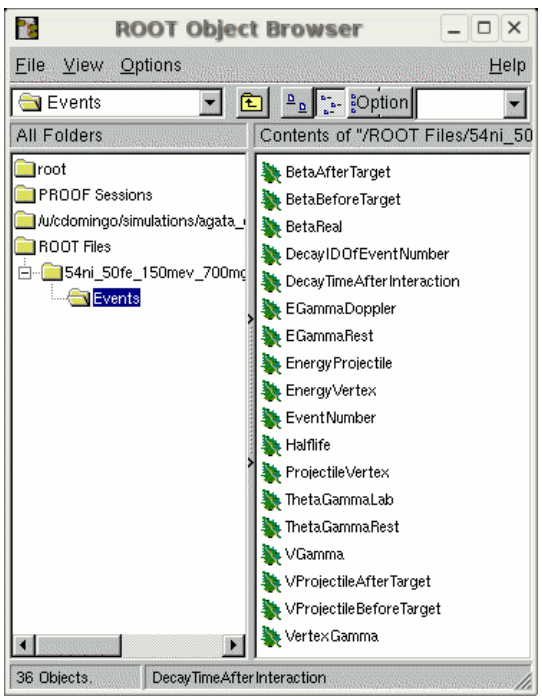
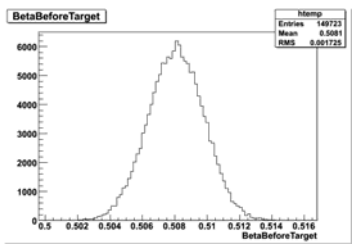
- fragmentation
- g-ray decay

(by Pieter Doornenbal)

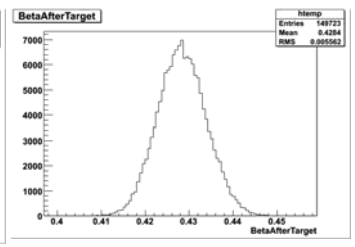


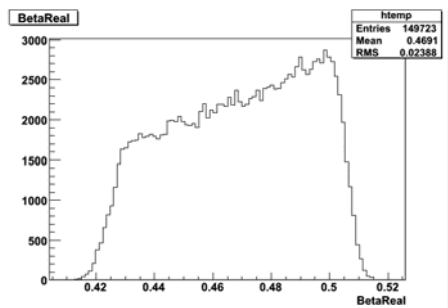


β before

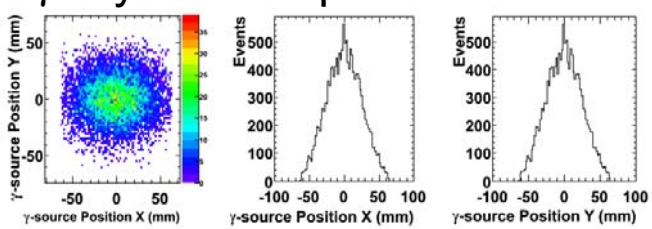


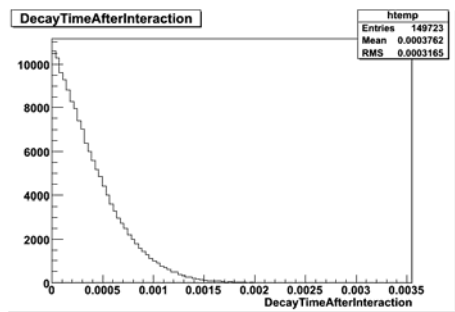
β after





γ-ray vertex spatial distribution





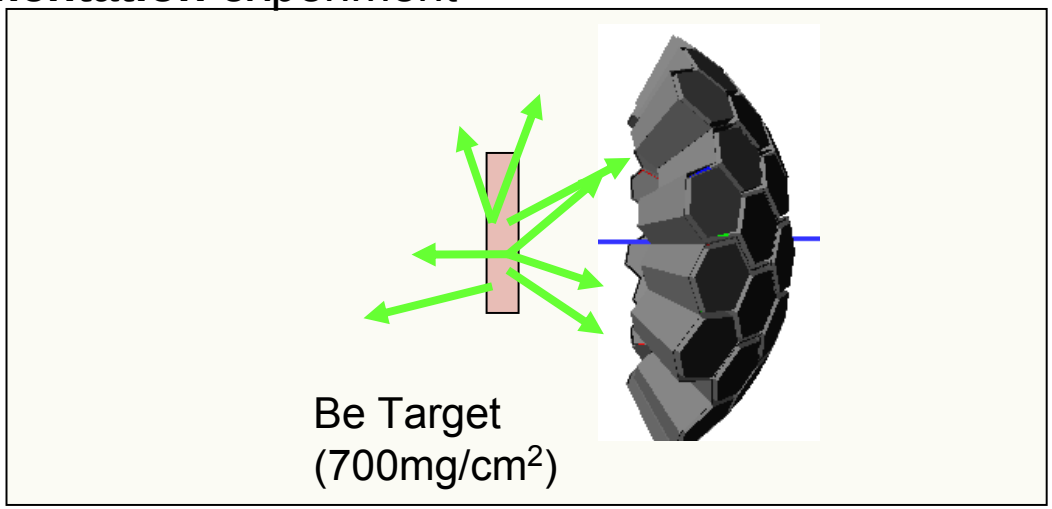
Fragmentation Experiment Benchmark: ^{54}Ni -> ^{50}Fe*

Realistic MC Simulation of a **fragmentation** experiment

Event Builder

- Detector (AGATA) response (list of hits)

(by Enrico Farnea)




```
GAMMA 1
1000.0000
RECOIL   0.5000  0.0000  0.0000  0.0000  1.0000  0.0000
SOURCE       0       0   0.0000   0.0000   0.0000
$
  -1   1401.723 -0.43045  0.48009  0.76434 0
  29    73.617 -142.729  141.623  234.825 52     1.053
  29    39.475 -143.302  150.765  245.890 52     1.129
  29   148.895 -151.199  143.686  236.472 51     1.083
  29   155.373 -151.207  143.675  236.479 51     1.083
  29   251.516 -129.956  144.860  230.891 41     1.007
  29   166.208 -129.833  144.792  230.981 41     1.008
  29   163.364 -129.791  144.692  230.949 41     1.008
  29   132.162 -129.764  144.711  230.911 41     1.008
  29    86.873 -129.765  144.716  230.913 41     1.008
  -1   1627.135  0.23197 -0.26644  0.93552 1
   1   126.640  125.339  -75.549  240.008 34     1.154
   1   334.250  120.598  -82.006  265.573 43     1.065
   1    71.117  120.608  -81.984  265.633 43     1.065
   1   160.091  120.600  -81.997  265.637 43     1.065
   1    11.067  120.642  -81.972  265.678 43     1.065
   1    45.200  120.643  -81.971  265.679 43     1.065
  -1   1087.822 -0.71426 -0.56881  0.40778 2
  -1   1257.962 -0.08354  0.77764  0.62313 3
  24   129.869  -24.004  192.131  156.311 05     0.836
  24    30.817  -34.318  197.026  157.088 15     0.874
.
.
.
```

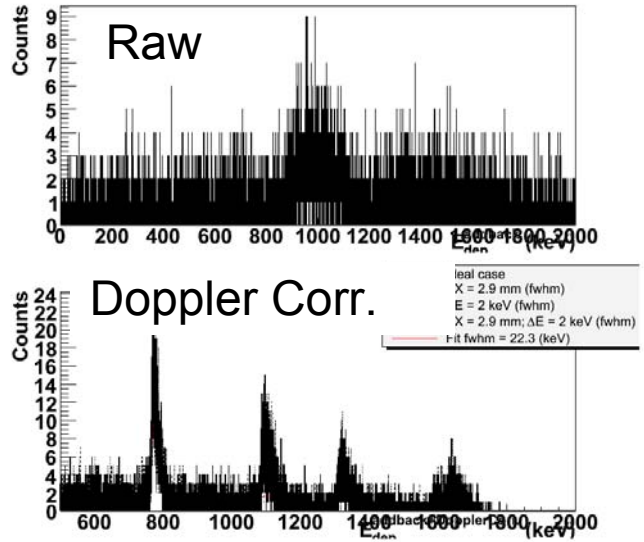
Fragmentation Experiment Benchmark: ^{54}Ni -> ^{50}Fe*

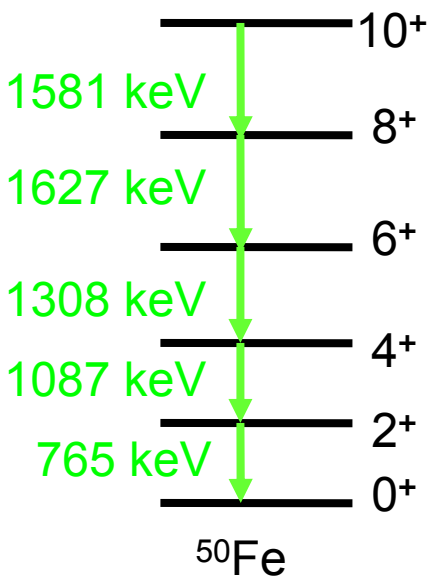
Realistic MC Simulation of a **fragmentation** experiment

Event Reconstruction

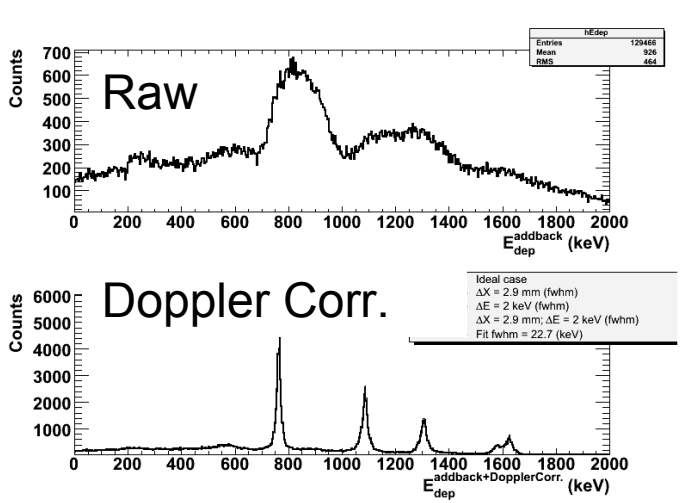
- Detectors resolution
- Doppler-correction
- Tracking

Low Statistics



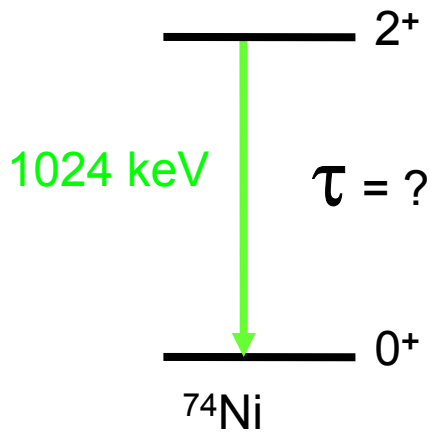


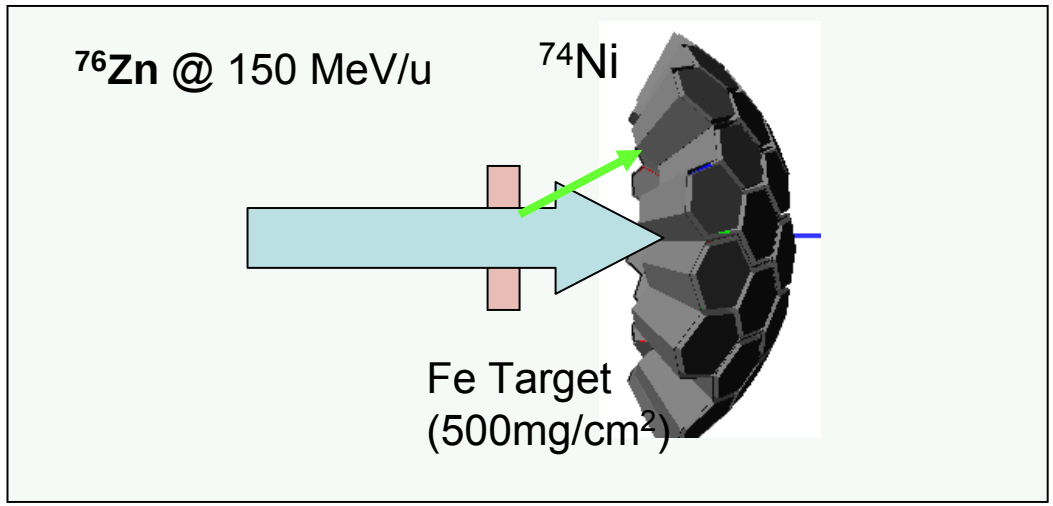
High Statistics

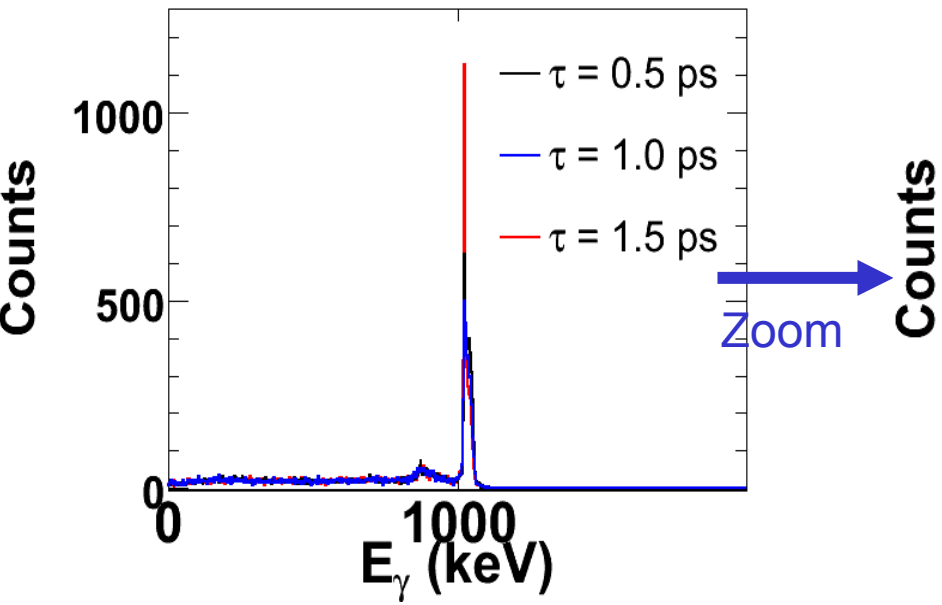


Another example: line shape analysis on first 2^+ of ^{74}Ni

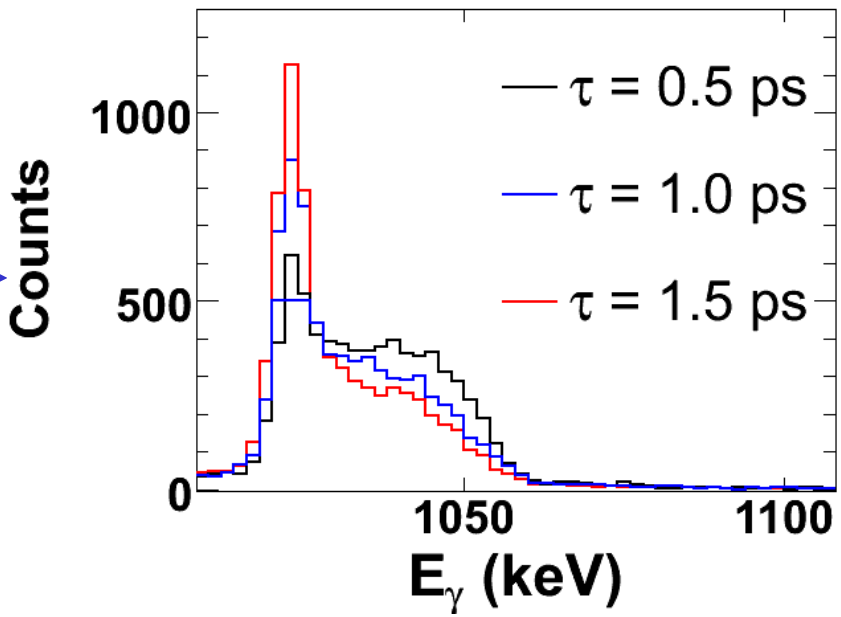
Realistic MC Simulation of a **fragmentation** experiment: DSAM Analysis







Zoom



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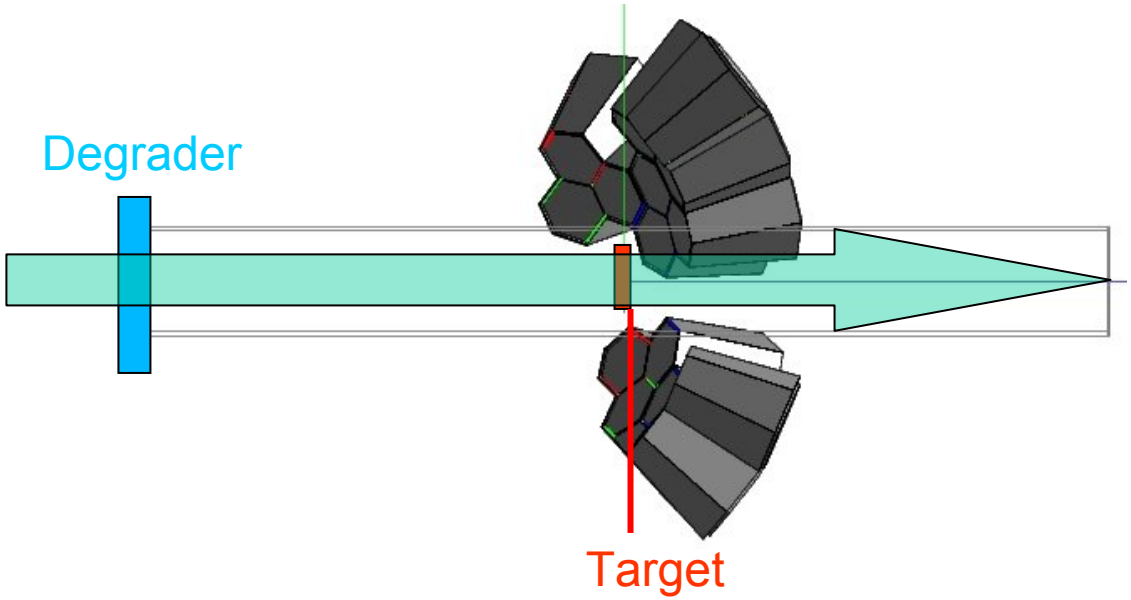
Realistic MC Simulation: Background



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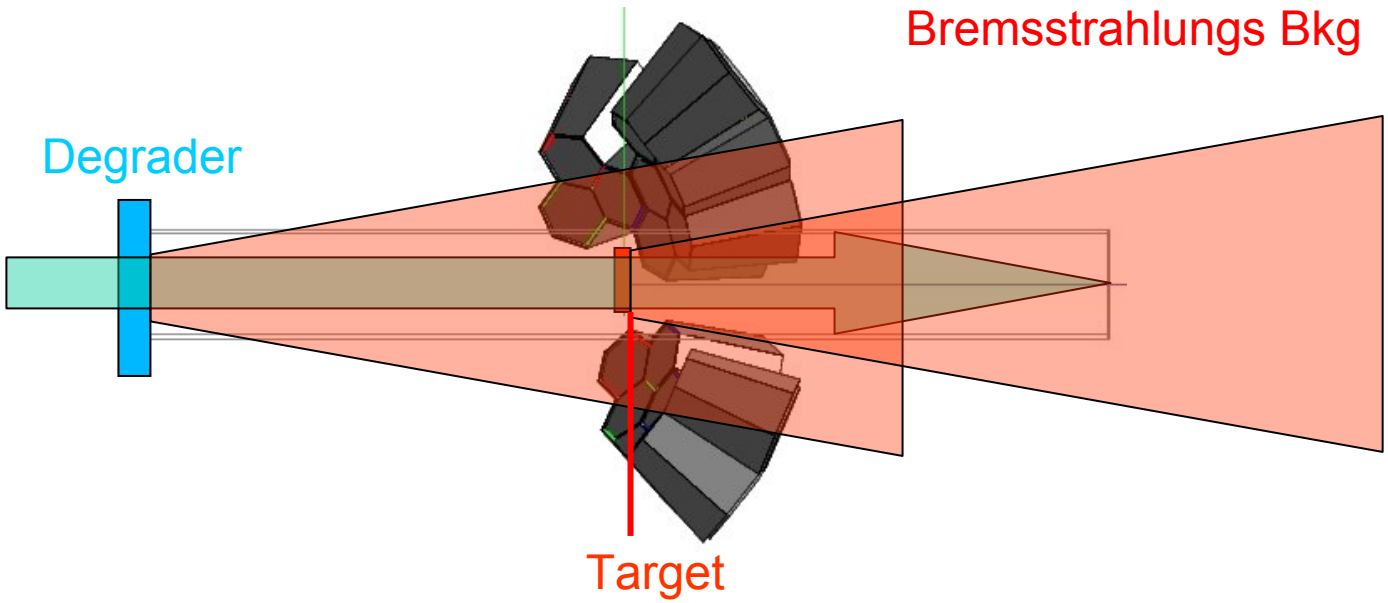

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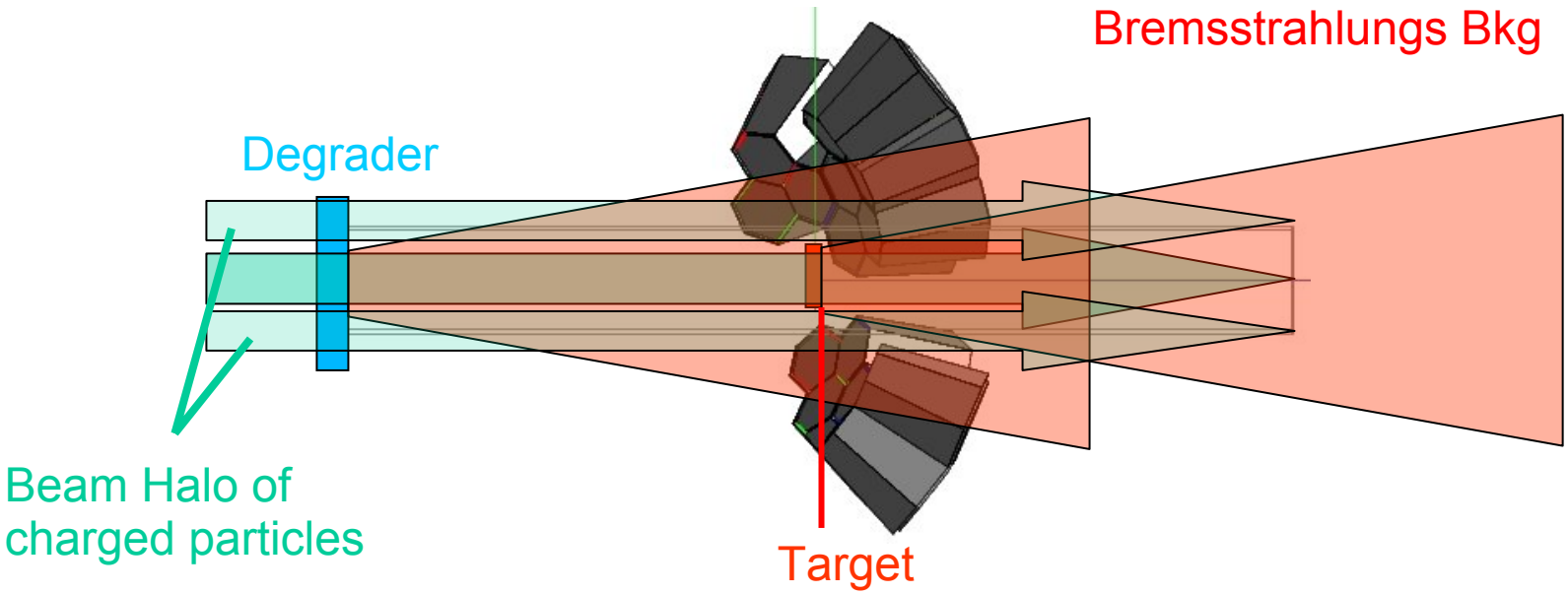

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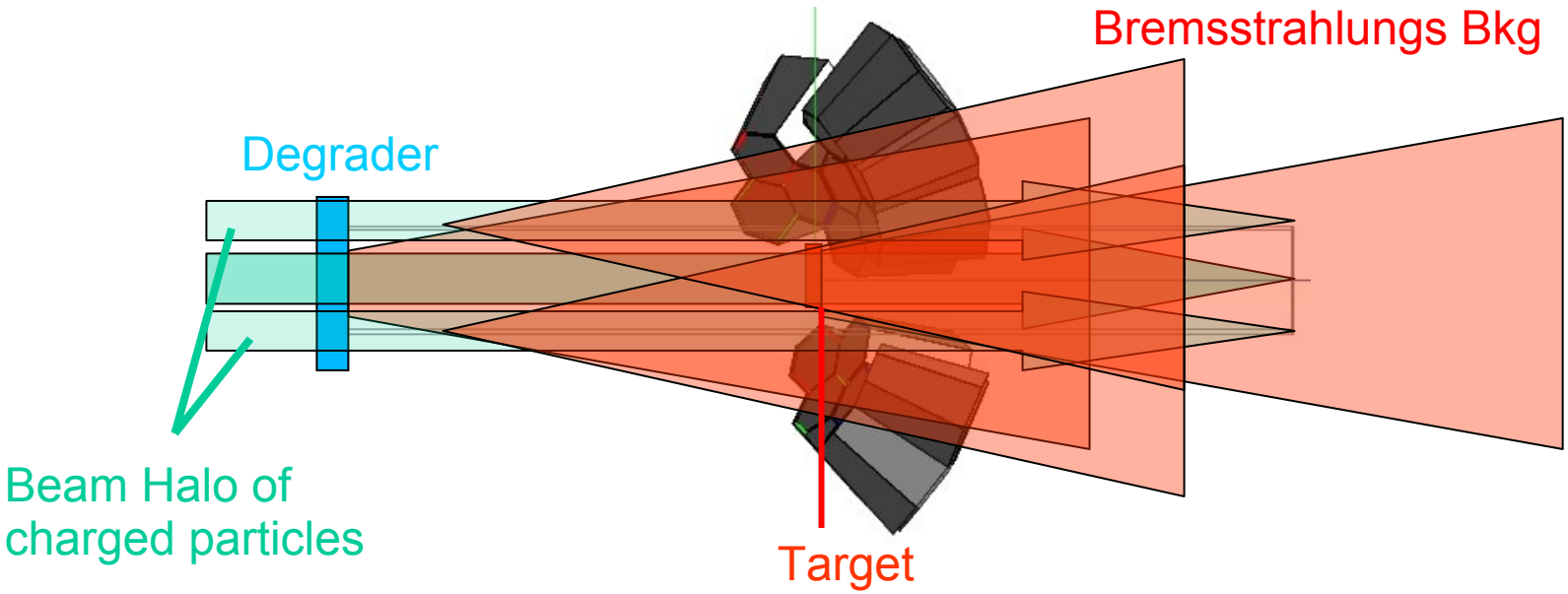

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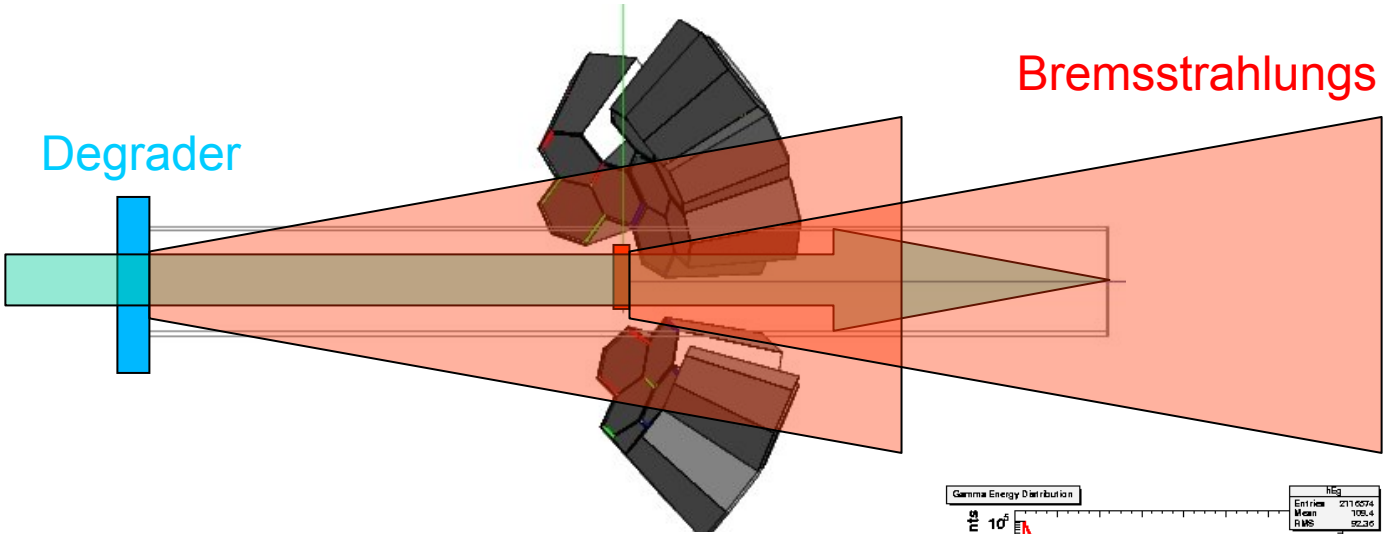
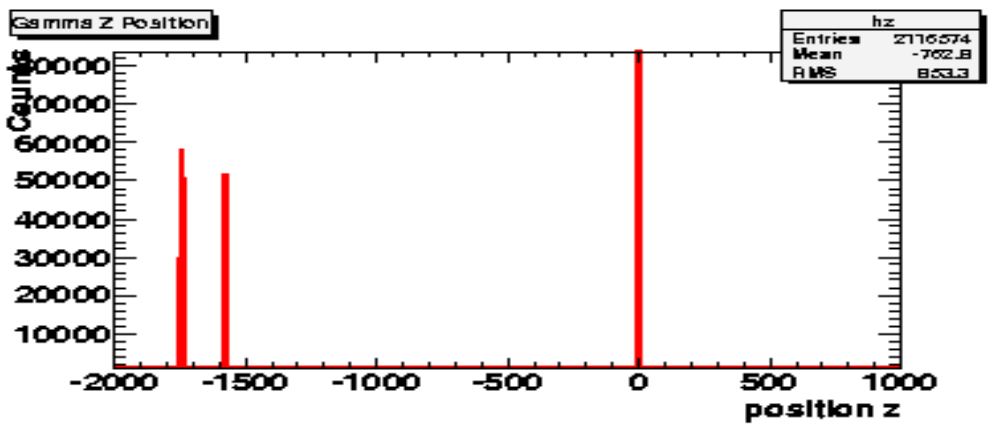
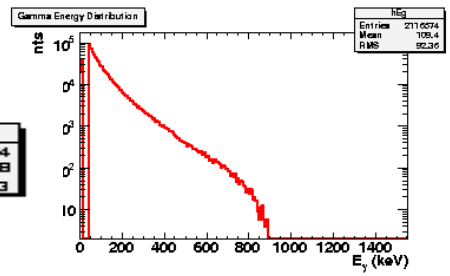
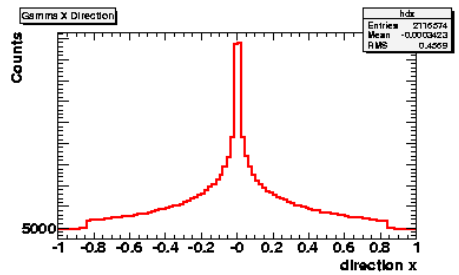
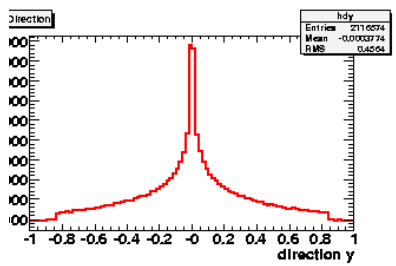
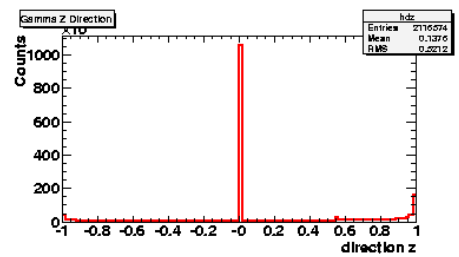


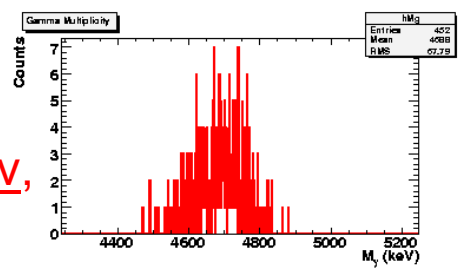


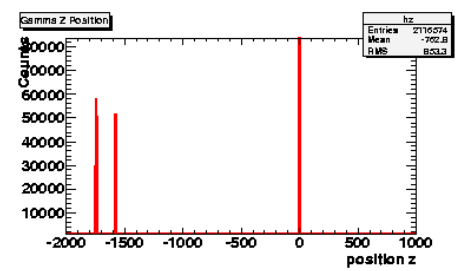








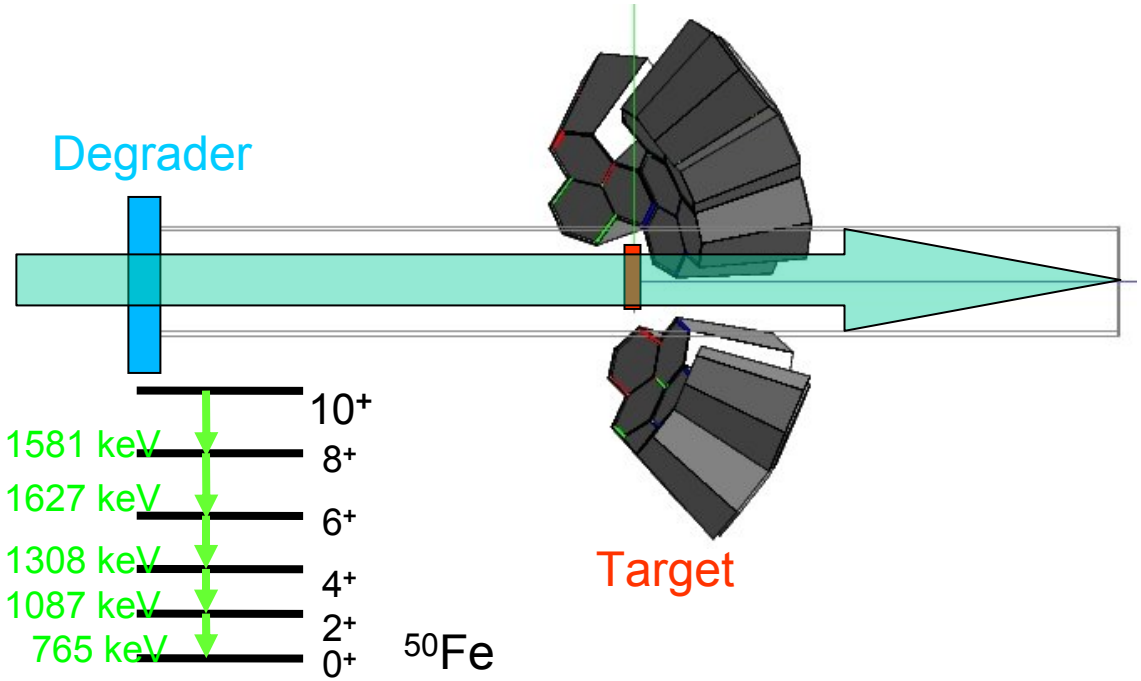


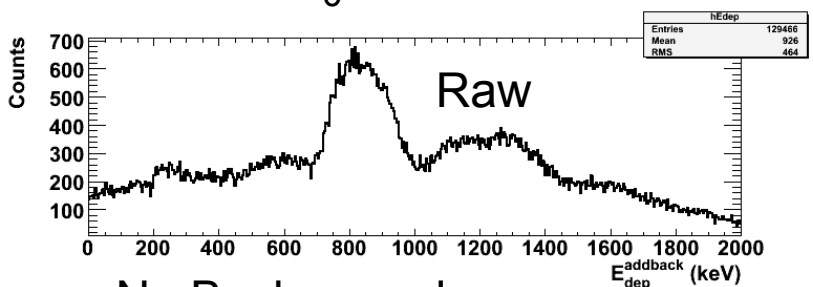


Background Events courtesy of Pavel Detistov,

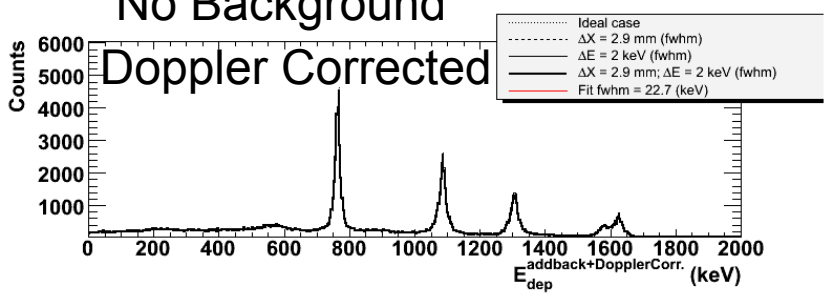
See e.g. (Acta Phys. Pol. B, No4, 2007)

Realistic MC Simulation: Background

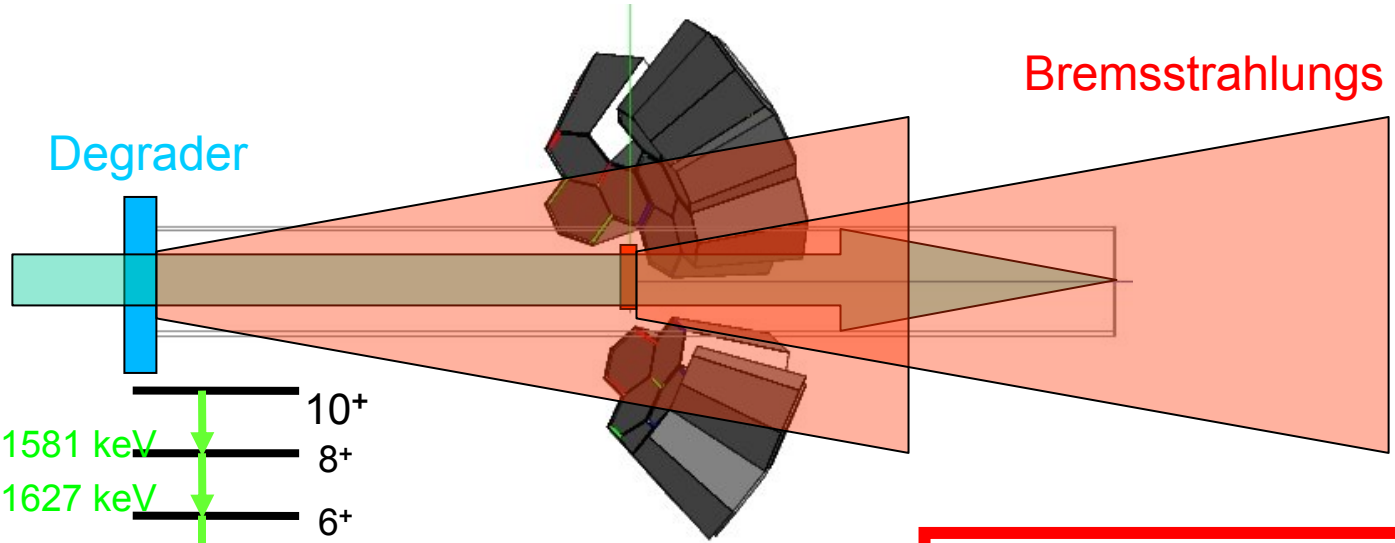


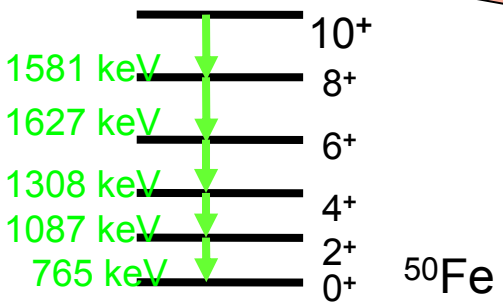


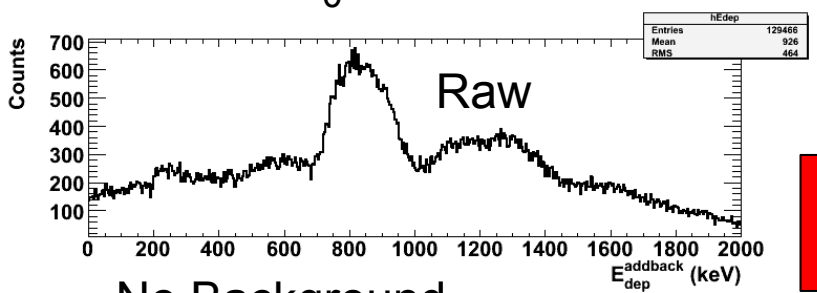
No Background



Realistic MC Simulation: Background







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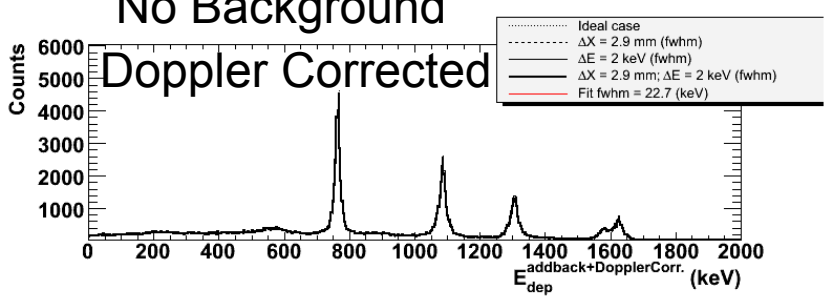
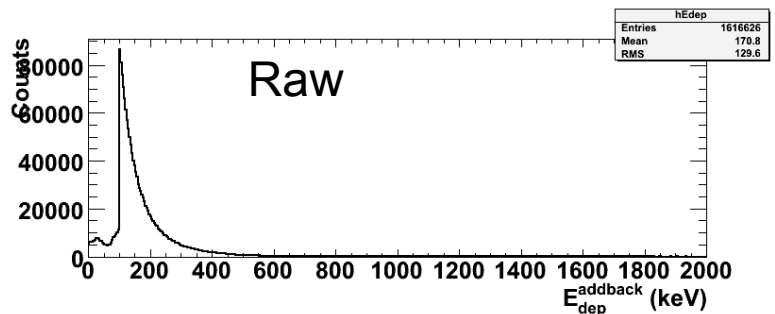
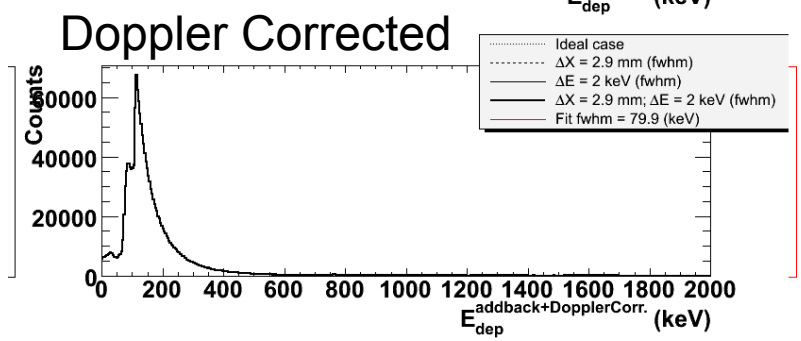
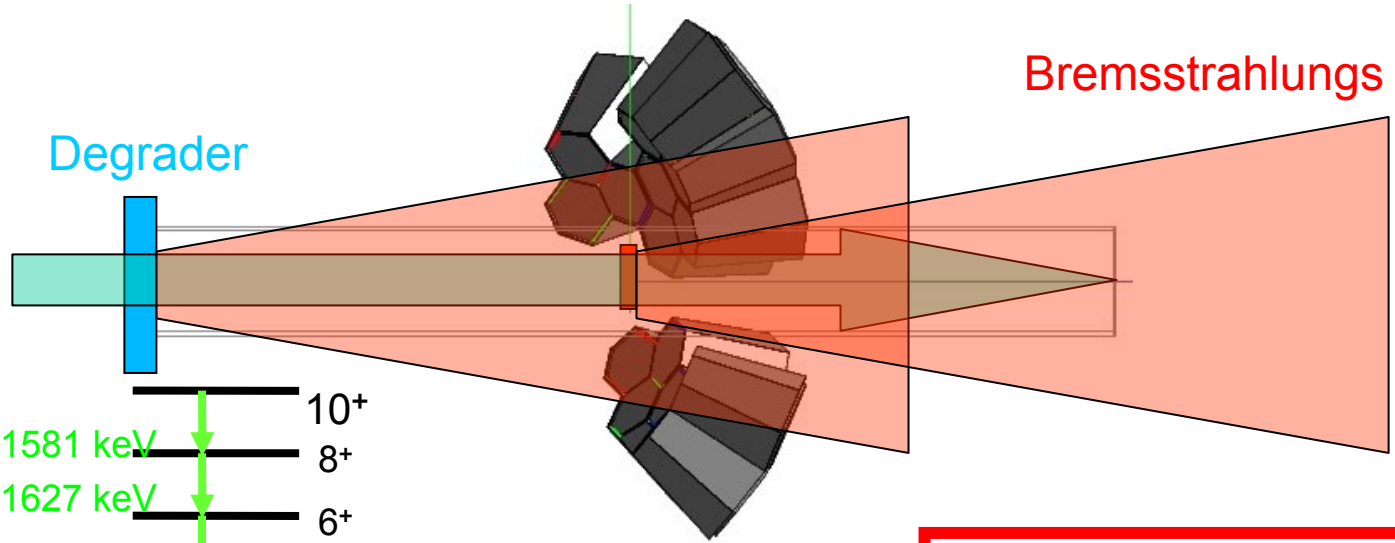


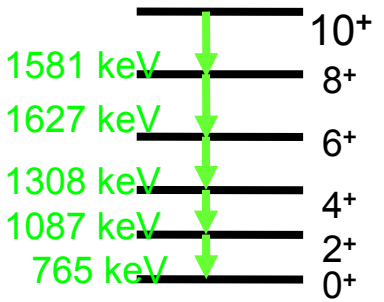
With BS Background

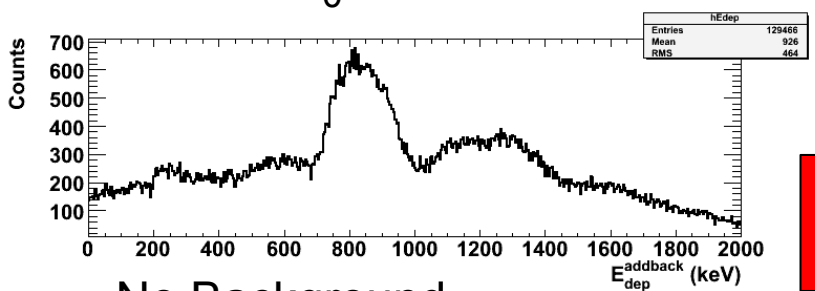




Realistic MC Simulation: Background







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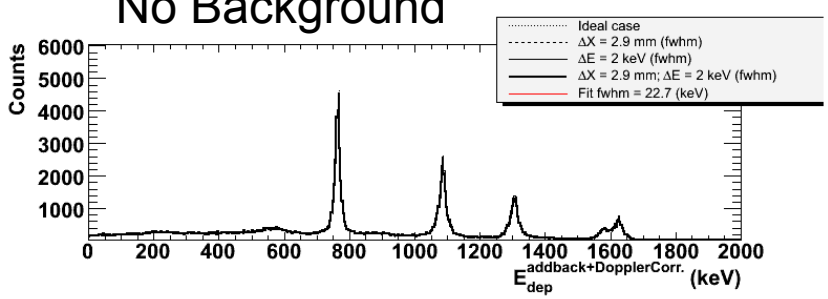
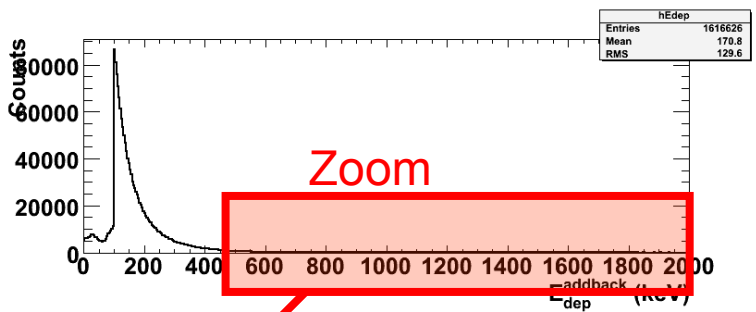
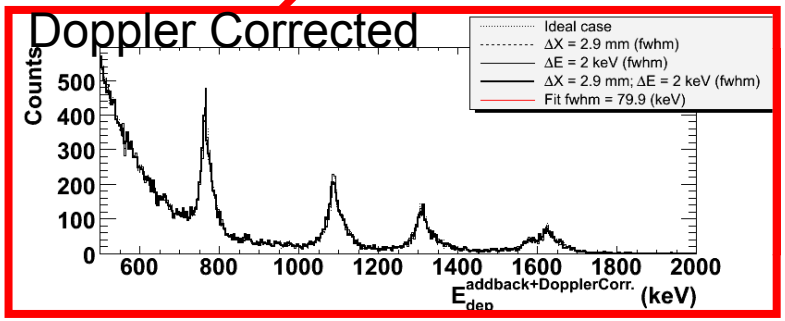


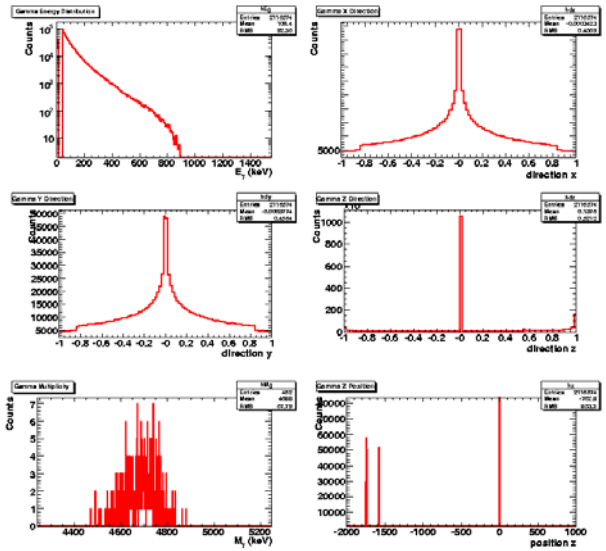
With BS Background

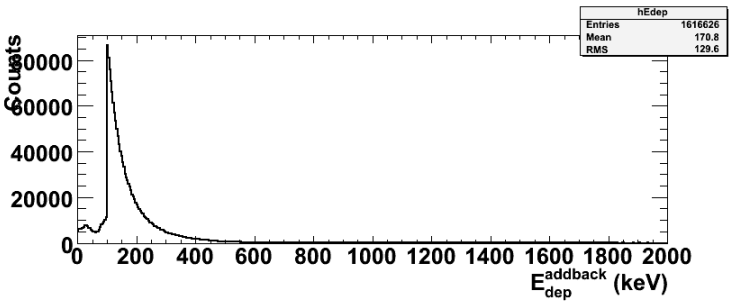


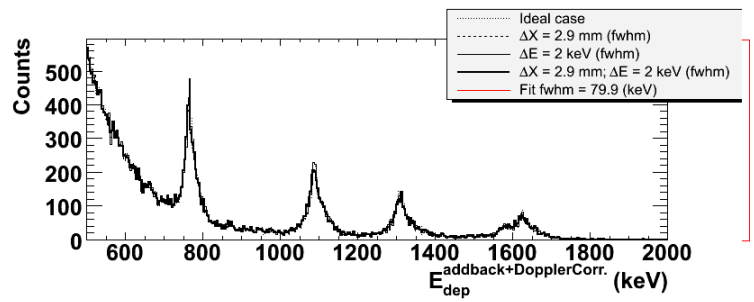
Doppler Corrected

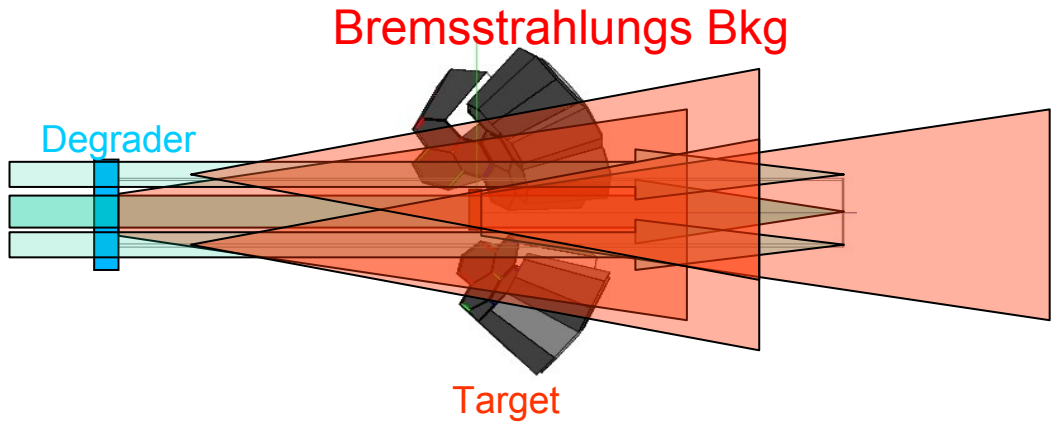


Realistic MC Simulation: Background

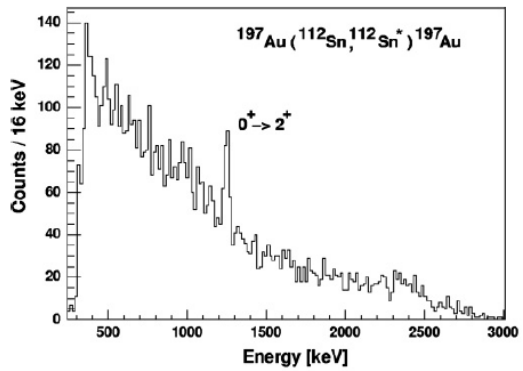


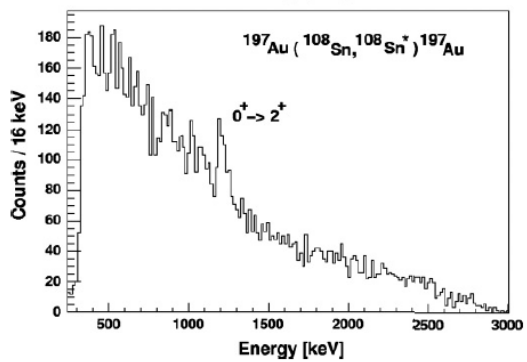




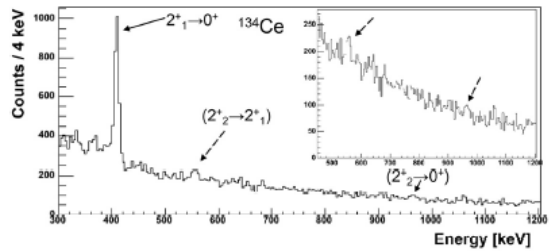


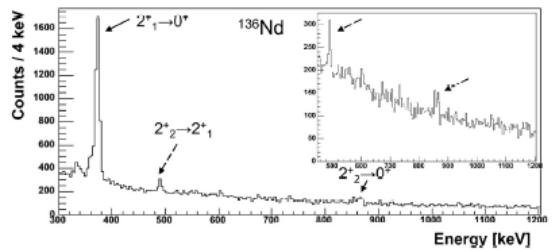
A. Banu et al. PRC 72, 2005





T. Saito et al. PLB, 2008

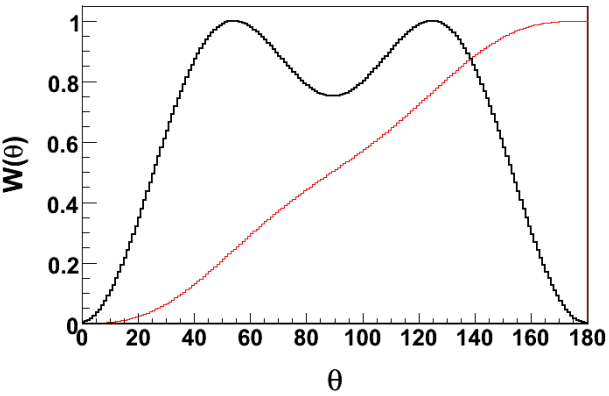


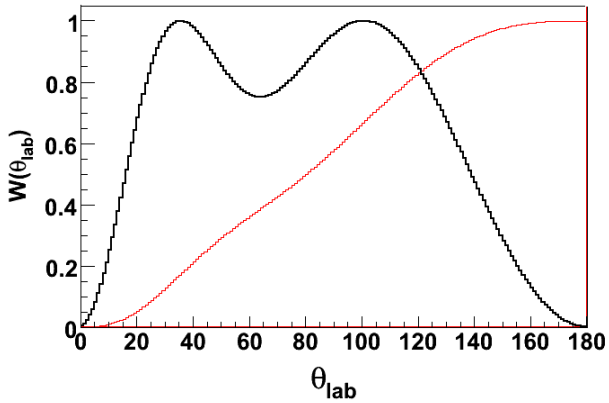


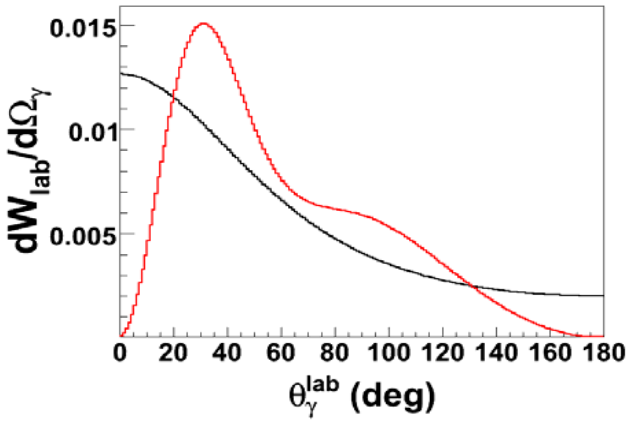
Outlook & Conclusion

- The AGATA S2' configuration (10 ATC + 5 ADC) shows the best performance in terms of efficiency (11% to 17.5%) and γ-ray resolution (6 keV to 10 keV FWHM).
- The angular range between $\theta = 15$deg and $\theta = 90$deg can be effectively covered for target-array distances between 43.5 cm and 8.5 cm, respectively. Such distances are compatible with an spherical target-chamber, 46cm in diameter.
- The maximum efficiency (distance = 8.5 cm) decreases (in absolute terms) by about 2% (1%) for each Double (Triple) Cluster missing from the S2' configuration (10 ATC + 5 ADC). The "nominal" efficiency (distance = 23.5 cm) decreases about 1% for each missing Double or Triple cluster.
- For pure E2 transitions, the efficiency seems to remain constant at about 16% in the distance range from 10 cm to 23.5 cm (preliminary result).
- The present code allows one to simulate easily fragmentation experiments, and study line-shape effects and optimize the setup accordingly.
- Still pending, the simulation of a representative Coulex experiment, and to include properly background events and gamma-ray and particle tracking (LYCCA).
- A lot of work has been made for plunger and DSAM experiments (M. Reese TU-Darmstadt, Group of A. Dewald, Uni. Koeln, E.Farnea, C.Michelagnoli, LNL).

E2







$$\frac{dW}{d\Omega^{cm}} = 1 - \frac{5}{14}\frac{I+1}{2I-1}P_2(\cos\theta) - \frac{9}{56}\frac{(I+1)(I+2)}{(2I-3)(2I-1)}P_4(\cos\theta)$$

$$\cos\vartheta^{lab} = \frac{\cos\theta + \beta}{1+\beta\cos\theta}$$

$$\frac{dW}{d\Omega^{lab}} = \frac{dW}{d\Omega^{cm}}\frac{d\Omega^{cm}}{d\Omega^{lab}}$$

$$\frac{d\Omega^{cm}}{d\Omega^{lab}} = \left(\frac{E_\gamma}{E_{\gamma 0}}\right)^2 = \frac{1-\beta^2}{(1-\beta\cos\theta)^2}$$

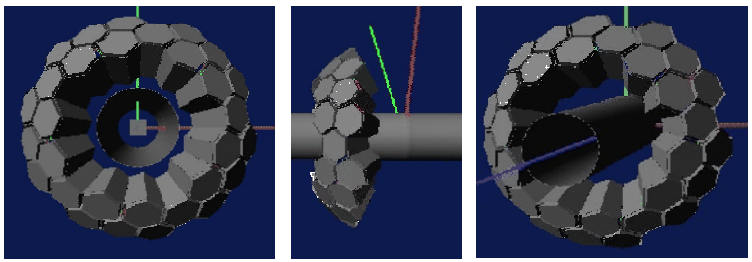
Ersatzfolien

Outline

1. Basics: MC code & event reconstruction
2. Cross check of the results
3. Particular constraints for the setup at GSI
4. Geometries: shell and compact setups
5. Performance comparison
6. Viability of additional γ-ray detectors: RISING, HECTOR, etc
7. Gain in performance from 10 to 12 Clusters
8. Outlook and conclusion

General aspects: MC code

- AGATA Code from Enrico Farnea et al. http://agata.pd.infn.it/ **GEANT4**



Setup geometry

Primary events,

(e.g. 1 MeV γ-ray @ β = 43%)

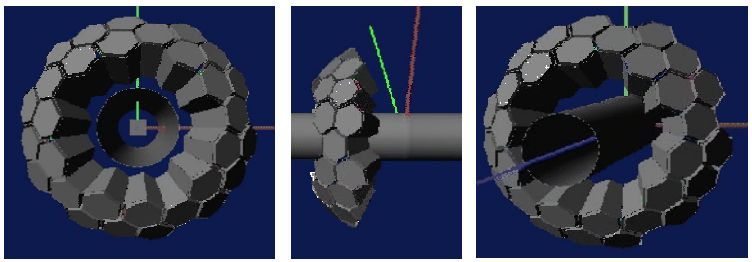
```
GAMMA 1
1000.0000
RECOIL   0.5000  0.0000  0.0000  0.0000  1.0000  0.0000
SOURCE       0       0    0.0000    0.0000    0.0000
$
  -1   1401.723 -0.43045  0.48009  0.76434 0
  29     73.617 -142.729  141.623  234.825 52     1.053
  29     39.475 -143.302  150.765  245.890 52     1.129
  29    148.895 -151.199  143.686  236.472 51     1.083
  29    155.373 -151.207  143.675  236.479 51     1.083
  29    251.516 -129.956  144.860  230.891 41     1.007
  29    166.208 -129.833  144.792  230.981 41     1.008
  29    163.364 -129.791  144.692  230.949 41     1.008
  29    132.162 -129.764  144.711  230.911 41     1.008
  29     86.873 -129.765  144.716  230.913 41     1.008
  -1   1627.135  0.23197 -0.26644  0.93552 1
   1    126.640  125.339  -75.549  240.008 34     1.154
   1    334.250  120.598  -82.006  265.573 43     1.065
   1     71.117  120.608  -81.984  265.633 43     1.065
   1    160.091  120.600  -81.997  265.637 43     1.065
   1     11.067  120.642  -81.972  265.678 43     1.065
   1     45.200  120.643  -81.971  265.679 43     1.065
  -1   1087.822 -0.71426 -0.56881  0.40778 2
  -1   1257.962 -0.08354  0.77764  0.62313 3
  24    129.869  -24.004  192.131  156.311 05     0.836
  24     30.817  -34.318  197.026  157.088 15     0.874
.
.
.
.
.
```

Simulation output:

list mode ascii file

General aspects: MC code

- AGATA Code from Enrico Farnea et al. http://agata.pd.infn.it/ **GEANT4**



Setup geometry

Primary events,

(e.g. 1 MeV γ-ray @ β = 50%)

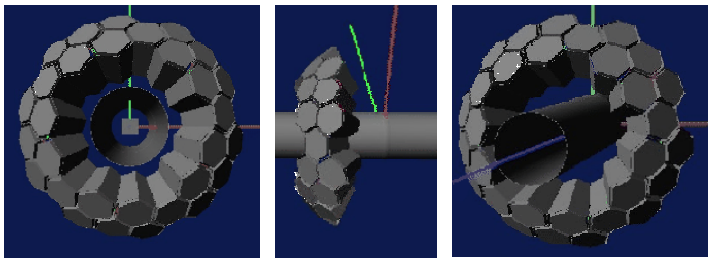
```
GAMMA 1
1000.0000
RECOIL   0.5000  0.0000  0.0000  0.0000  1.0000  0.0000
SOURCE       0       0   0.0000   0.0000   0.0000
$
  -1   1401.723 -0.43045  0.48009  0.76434 0
  29     73.617 -142.729  141.623  234.825 52     1.053
  29     39.475 -143.302  150.765  245.890 52     1.129
  29   148.895 -151.199  143.686  236.472 51     1.083
  29   155.373 -151.207  143.675  236.479 51     1.083
  29   251.516 -129.956  144.860  230.891 41     1.007
  29   166.208 -129.833  144.792  230.981 41     1.008
  29   163.364 -129.791  144.692  230.949 41     1.008
  29   132.162 -129.764  144.711  230.911 41     1.008
  29    86.873 -129.765  144.716  230.913 41     1.008
  -1   1627.135  0.23197 -0.26644  0.93552 1
   1   126.640  125.339  -75.549  240.008 34     1.154
   1   334.250  120.598  -82.006  265.573 43     1.065
   1    71.117  120.608  -81.984  265.633 43     1.065
   1   160.091  120.600  -81.997  265.637 43     1.065
   1    11.067  120.642  -81.972  265.678 43     1.065
   1    45.200  120.643  -81.971  265.679 43     1.065
  -1   1087.822 -0.71426 -0.56881  0.40778 2
  -1   1257.962 -0.08354  0.77764  0.62313 3
  24   129.869  -24.004  192.131  156.311 05     0.836
  24    30.817  -34.318  197.026  157.088 15     0.874
.
.
.
.
.
```

Crystal# Edep X Y Z Segment# (time)

Simulation output:

list mode ascii file

General aspects: event reconstruction



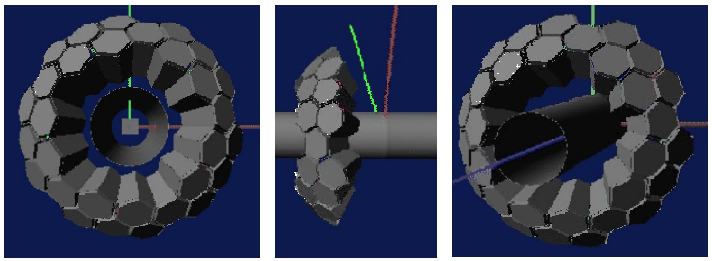
Setup geometry
Primary events,
(e.g. 1 MeV g-ray @ b = 50%)

```
GAMMA 1
1000.0000
RECOIL   0.5000  0.0000  0.0000  0.0000  1.0000  0.0000
SOURCE       0       0   0.0000   0.0000   0.0000
$
  -1   1401.723 -0.43045  0.48009  0.76434 0
  29     73.617 -142.729  141.623  234.825 52     1.053
  29     39.475 -143.302  150.765  245.890 52     1.129
  29    148.895 -151.199  143.686  236.472 51     1.083
  29    155.373 -151.207  143.675  236.479 51     1.083
  29    251.516 -129.956  144.860  230.891 41     1.007
  29    166.208 -129.833  144.792  230.981 41     1.008
  29    163.364 -129.791  144.692  230.949 41     1.008
  29    132.162 -129.764  144.711  230.911 41     1.008
  29     86.873 -129.765  144.716  230.913 41     1.008
  -1   1627.135  0.23197 -0.26644  0.93552 1
   1    126.640  125.339  -75.549  240.008 34     1.154
   1    334.250  120.598  -82.006  265.573 43     1.065
   1     71.117  120.608  -81.984  265.633 43     1.065
   1    160.091  120.600  -81.997  265.637 43     1.065
   1     11.067  120.642  -81.972  265.678 43     1.065
   1     45.200  120.643  -81.971  265.679 43     1.065
  -1   1087.822 -0.71426 -0.56881  0.40778 2
  -1   1257.962 -0.08354  0.77764  0.62313 3
  24    129.869  -24.004  192.131  156.311 05     0.836
  24     30.817  -34.318  197.026  157.088 15     0.874
```

- Total deposited energy at each event:
  - Loop over all hits/event (perfect tracking)
  - mgt code
- Doppler correction:
  - Angle subtended by largest Edep hit

$$E_{\rho} = E_{\gamma} \frac{1 - \beta \cos\theta_{\gamma}}{\sqrt{1 - \beta^2}}$$

General aspects: event reconstruction



Setup geometry
Primary events,
(e.g. 1 MeV g-ray @ b = 50%)

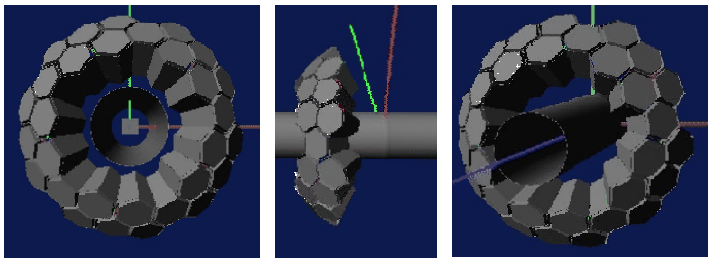
```
GAMMA 1
1000.0000
RECOIL   0.5000  0.0000  0.0000  0.0000  1.0000  0.0000
SOURCE       0       0  0.0000  0.0000  0.0000
$
  -1   1401.723 -0.43045  0.48009  0.76434 0
  29     73.617 -142.729  141.623  234.825 52     1.053
  29     39.475 -143.302  150.765  245.890 52     1.129
  29    148.895 -151.199  143.636  236.472 51     1.083
  29    155.373 -151.207  143.675  236.479 51     1.083
  29    251.516 -129.956  144.860  230.891 41     1.007
  29    166.208 -129.833  144.792  230.981 41     1.008
  29    163.364 -129.791  144.692  230.949 41     1.008
  29    132.162 -129.764  144.711  230.911 41     1.008
  29     86.873 -129.765  144.716  230.913 41     1.008
  -1   1627.135  0.23197 -0.26644  0.93552 1
   1    126.640  125.339  -75.549  240.008 34     1.154
   1    334.250  120.598  -82.006  265.573 43     1.065
   1     71.117  120.608  -81.984  265.633 43     1.065
   1    160.091  120.600  -81.997  265.637 43     1.065
   1     11.067  120.642  -81.972  265.678 43     1.065
   1     45.200  120.643  -81.971  265.679 43     1.065
  -1   1087.822 -0.71426 -0.56881  0.40778 2
  -1   1257.962 -0.08354  0.77764  0.62313 3
  24    129.869  -24.004  192.131  156.311 05     0.836
  24     30.817  -34.318  197.026  157.088 15     0.874
```

Edep x y z

- Total deposited energy at each event:
  - Loop over all hits/event (perfect tracking)
  - mgt code
- Doppler correction:
  - Angle subtended by largest Edep hit

$$E_{\rho} = E_{\gamma} \frac{1 - \beta \cos\theta_{\gamma}}{\sqrt{1 - \beta^2}}$$

General aspects: event reconstruction

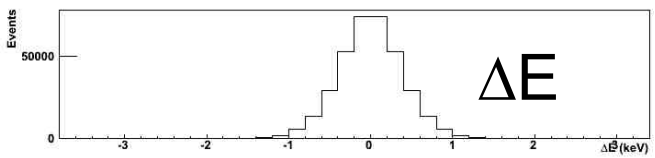


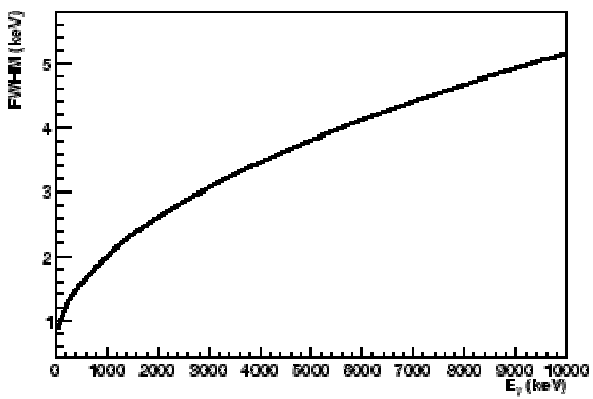
Setup geometry
Primary events,
(e.g. 1 MeV g-ray @ b = 50%)

```
GAMMA 1
1000.0000
RECOIL   0.5000  0.0000  0.0000  0.0000  1.0000  0.0000
SOURCE       0       0   0.0000   0.0000   0.0000
$
  -1   1401.723 -0.43045  0.48009  0.76434 0
  29     73.617 -142.729  141.623  234.825 52     1.053
  29     39.475 -143.302  150.765  245.890 52     1.129
  29    148.895 -151.199  143.686  236.472 51     1.083
  29    155.373 -151.207  143.675  236.479 51     1.083
  29    251.516 -129.956  144.860  230.891 41     1.007
  29    166.208 -129.833  144.792  230.981 41     1.008
  29    163.364 -129.791  144.692  230.949 41     1.008
  29    132.162 -129.764  144.711  230.911 41     1.008
  29     86.873 -129.765  144.716  230.913 41     1.008
  -1   1627.135  0.23197 -0.26644  0.93552 1
   1    126.640  125.339  -75.549  240.008 34     1.154
   1    334.250  120.598  -82.006  265.573 43     1.065
   1     71.117  120.608  -81.984  265.633 43     1.065
   1    160.091  120.600  -81.997  265.637 43     1.065
   1     11.067  120.642  -81.972  265.678 43     1.065
   1     45.200  120.643  -81.971  265.679 43     1.065
  -1   1087.822 -0.71426 -0.56881  0.40778 2
  -1   1257.962 -0.08354  0.77764  0.62313 3
  24    129.869  -24.004  192.131  156.311 05     0.836
  24     30.817  -34.318  197.026  157.088 15     0.874
```

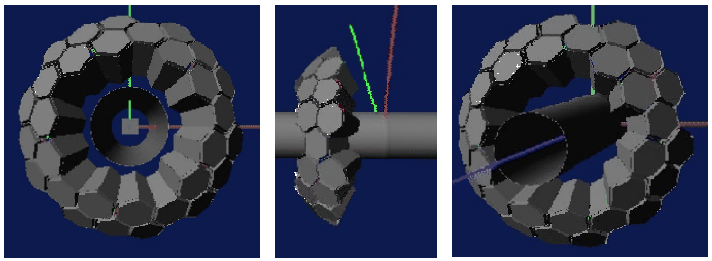
Detector response function (by hand):

Intrinsic energy resolution: deposited energy folded with a Gauss distribution to introduce energy resolution (2 keV @ Eγ=1 MeV)





General aspects: event reconstruction

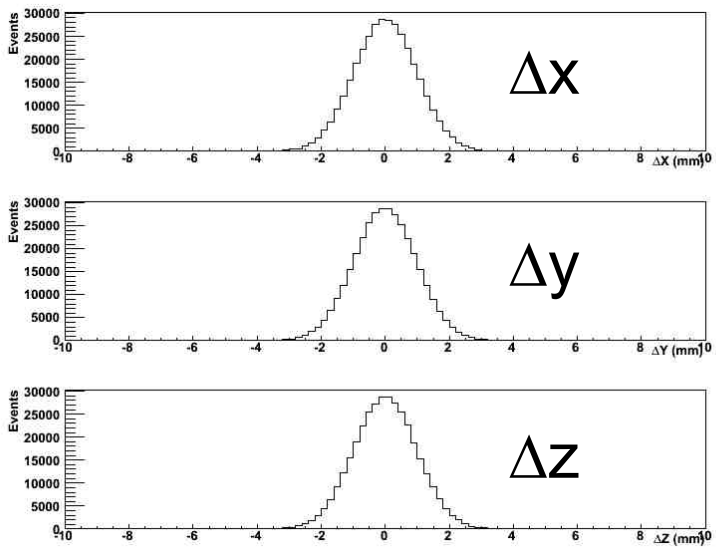


Setup geometry
Primary events,
(e.g. 1 MeV g-ray @ b = 50%)

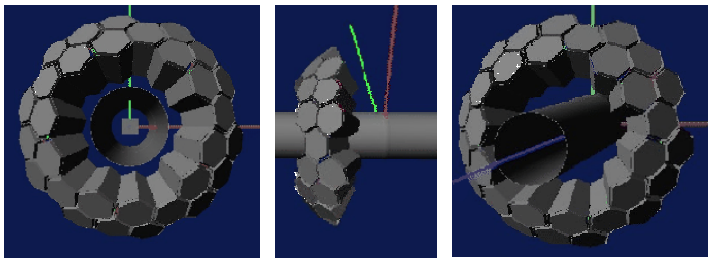
```
GAMMA 1
1000.0000
RECOIL   0.5000  0.0000  0.0000  0.0000  1.0000  0.0000
SOURCE      0       0    0.0000    0.0000    0.0000
$
  -1   1401.723 -0.43045  0.48009  0.76434 0
  29     73.617 -142.729  141.623  234.825 52     1.053
  29     39.475 -143.302  150.765  245.890 52     1.129
  29    148.895 -151.199  143.686  236.472 51     1.083
  29    155.373 -151.207  143.675  236.479 51     1.083
  29    251.516 -129.956  144.860  230.891 41     1.007
  29    166.208 -129.833  144.792  230.981 41     1.008
  29    163.364 -129.791  144.692  230.949 41     1.008
  29    132.162 -129.764  144.711  230.911 41     1.008
  29     86.873 -129.765  144.716  230.913 41     1.008
  -1   1627.135  0.23197 -0.26644  0.93552 1
   1    126.640  125.339  -75.549  240.008 34     1.154
   1    334.250  120.598  -82.006  265.573 43     1.065
   1     71.117  120.608  -81.984  265.633 43     1.065
   1    160.091  120.600  -81.997  265.637 43     1.065
   1     11.067  120.642  -81.972  265.678 43     1.065
   1     45.200  120.643  -81.971  265.679 43     1.065
  -1   1087.822 -0.71426 -0.56881  0.40778 2
  -1   1257.962 -0.08354  0.77764  0.62313 3
  24    129.869  -24.004  192.131  156.311 05     0.836
  24     30.817  -34.318  197.026  157.088 15     0.874
```

Detector response function (by hand):

Intrinsic spatial resolution: x, y, z folded with a Gauss distribution to introduce spatial resolution of 2-5 mm FWHM

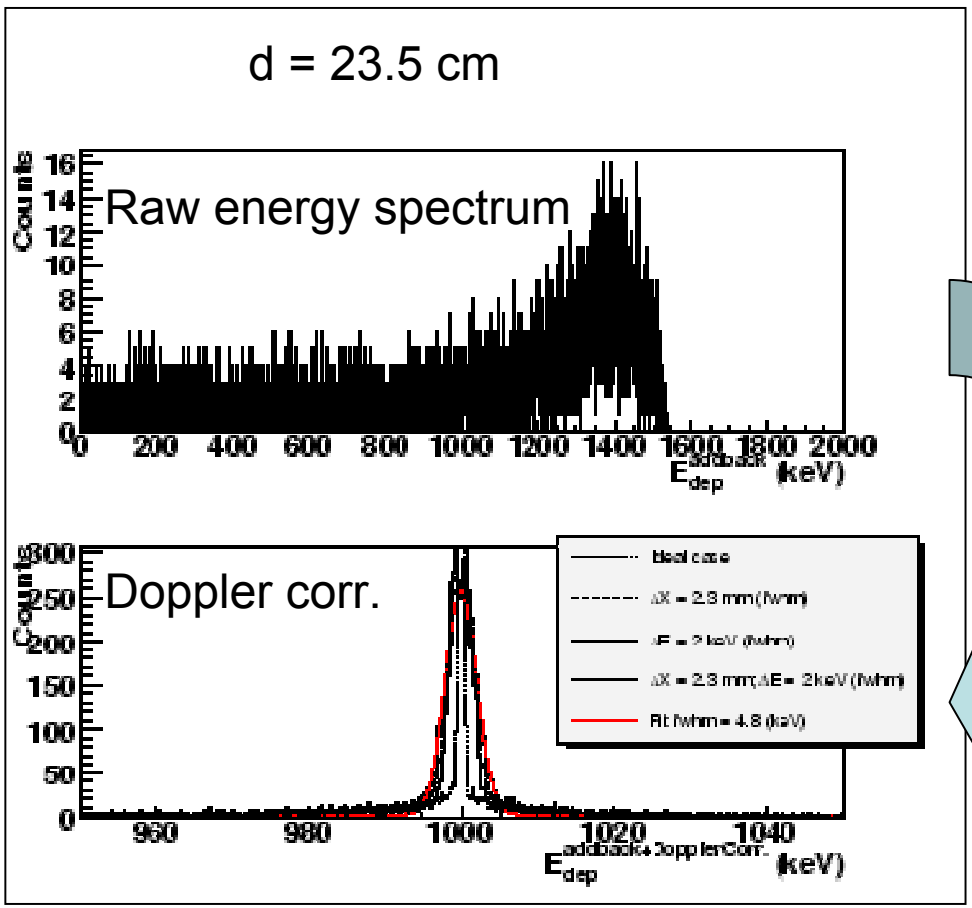


General aspects: event reconstruction (example)



Setup geometry
Primary events,
(e.g. 1 MeV g-ray @ b = 50%)

d = 23.5 cm



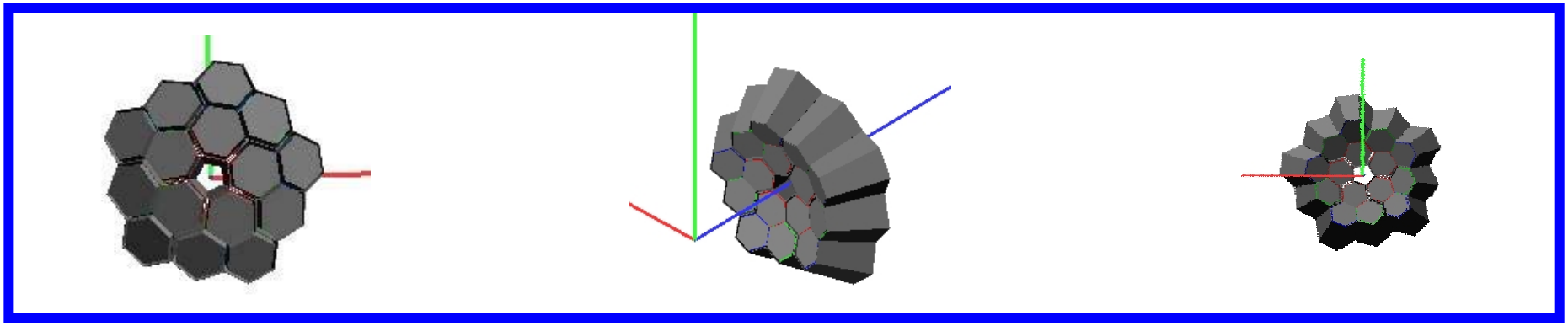
$$E_{\gamma b} = E_{\gamma} \frac{1 - \beta \cos\theta_{\gamma}}{\sqrt{1 - \beta^2}}$$

ΔE = 2 keV (fwhm) @ Eγ = 1 MeV; Δx = 4 mm

Outline

1. Basics: MC code & event reconstruction
2. Cross check of the results
3. Particular constraints for the setup at GSI
4. Geometries: shell and compact setups
5. Performance comparison
6. Viability of additional γ-ray detectors: RISING, HECTOR, etc
7. Gain in performance from 10 to 12 Clusters
8. Outlook and conclusion

Validation analysis / event reconstruction



http://agata.pd.infn.it/documents/simulations/demonstrator.html

INFN Istituto Nazionale di Fisica Nucleare

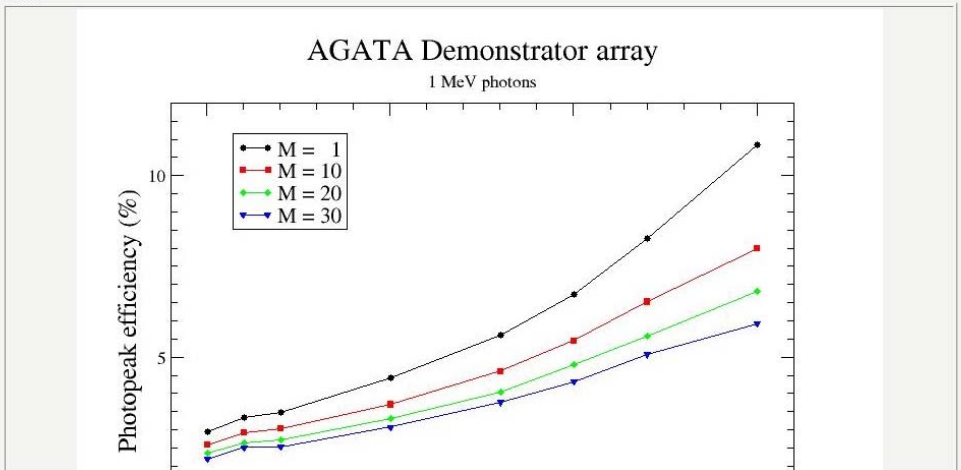
AGATA: Performance of the Demonstrator Array

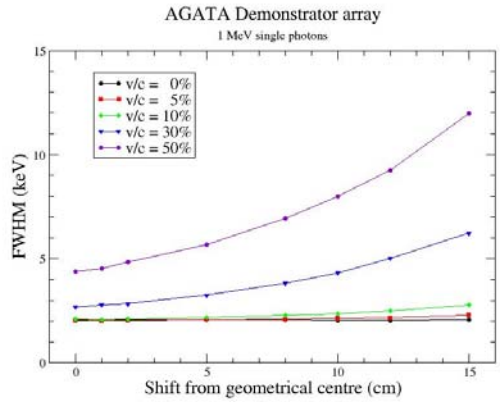
For more information on the simulation code and to obtain the actual code contact Enrico Farnea

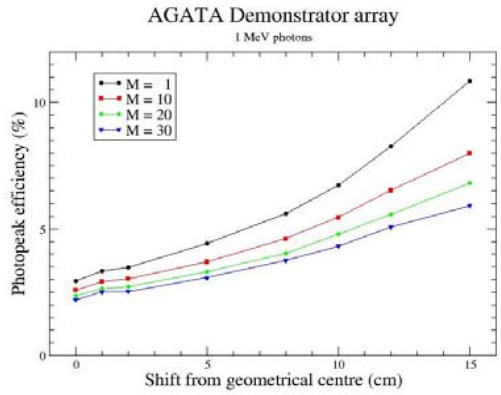
Last updated: November 8th 2005

The AGATA Demonstrator

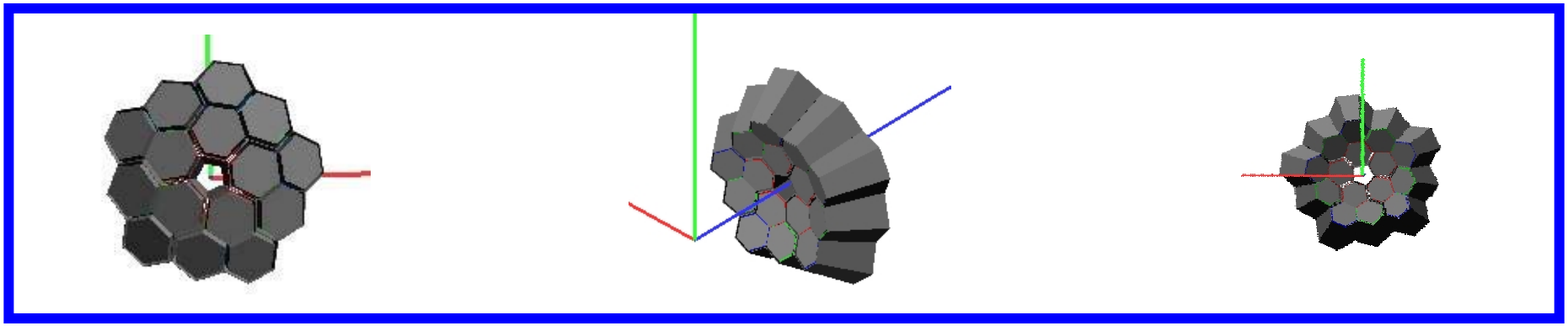
The AGATA Demonstrator Array is an arrangement of five triple clusters of the same kind which will be used to form the final A180 Configuration of AGATA. The performance of such an object will depend in a critical way on its placement relative to the target position. In particular, given the lack of a spherical symmetry, it is sensible to place the detectors closer to the target position compared to the "reference" distance being the target-detector distance of the full A180 Configuration, that is, 23.5 cm. The photopeak efficiency and the P/T ratio as a function of the shift from the geometrical centre are shown in the following plots, where it is assumed that 1 MeV photons are emitted from a point source at rest in the Laboratory reference frame:

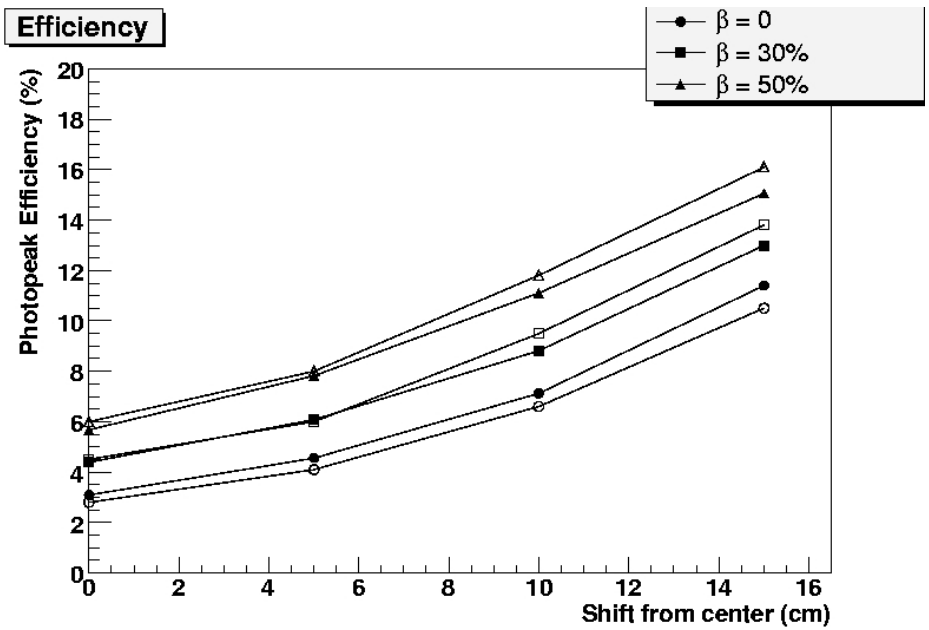


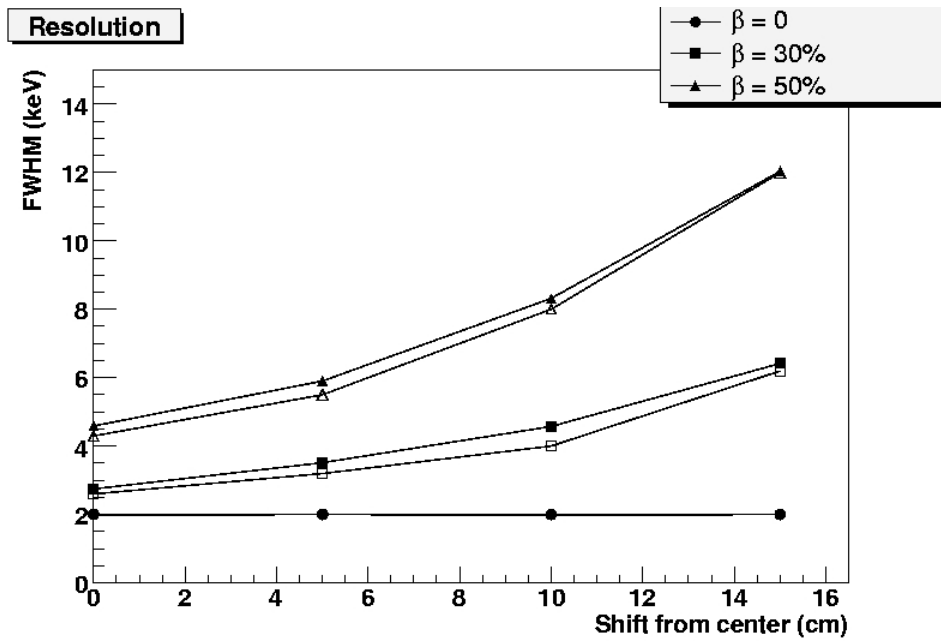




Validation analysis / event reconstruction







Empty symbols: analysis LNL

Solid symbols: analysis GSI

AGATA Geometry @ GSI

Other aspects

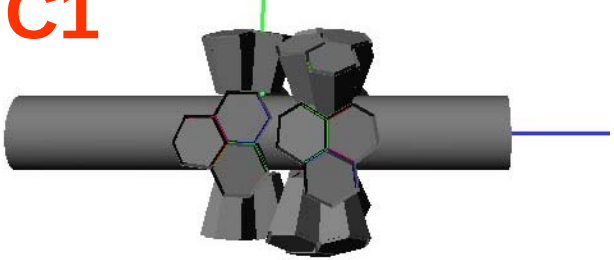
- Background
  - Atomic background (bremsstrahlung) ⇒ Shielding + P. Detistov work
  - Neutron induced background ⇒ Nothing
  - Scatt. Particle background ⇒ Tests October ’09

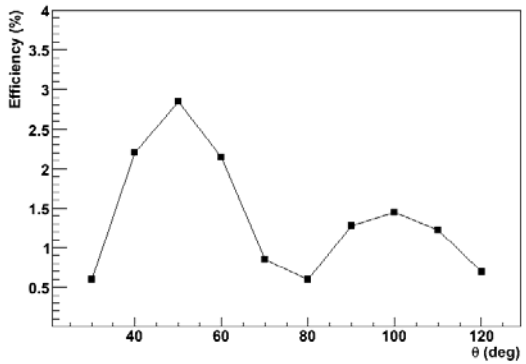
- Mechanical constraints (holding structure)

- Technical constraints (square beam pipe, cylindrical pipe smallest size compatibel with DSSSD Sec. Target, No Chamber ?)

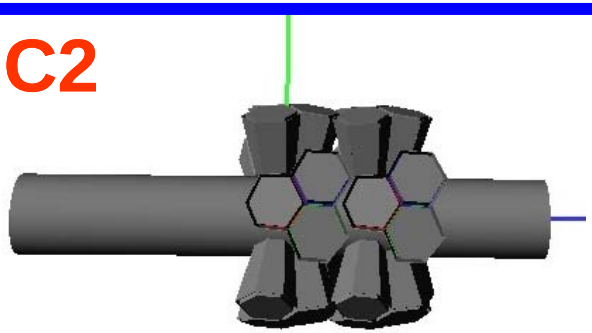
AGATA Geometry @ GSI θ–Diff. Photopeak Efficiency

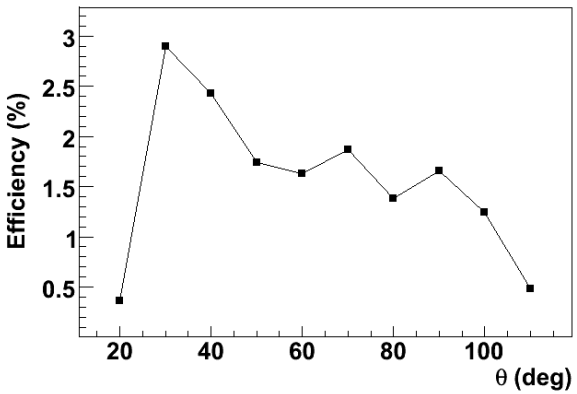
C1



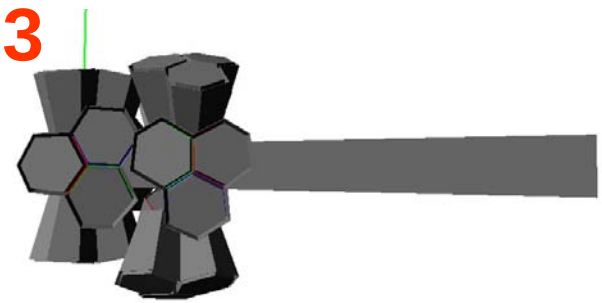


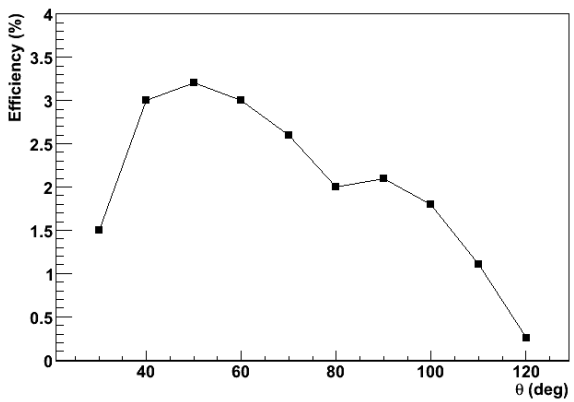
C2





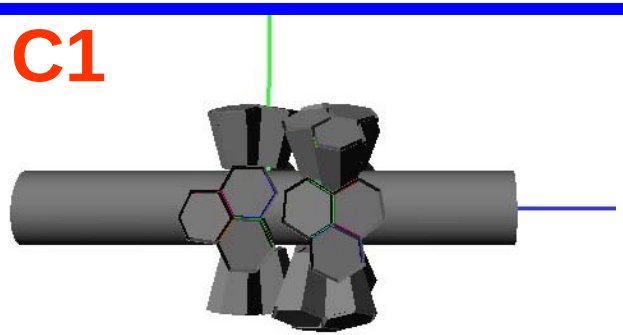
C3



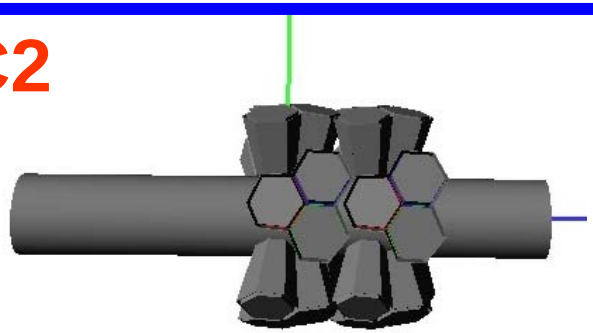


AGATA Geometry @ GSI θ–Diff. Energy Resolution

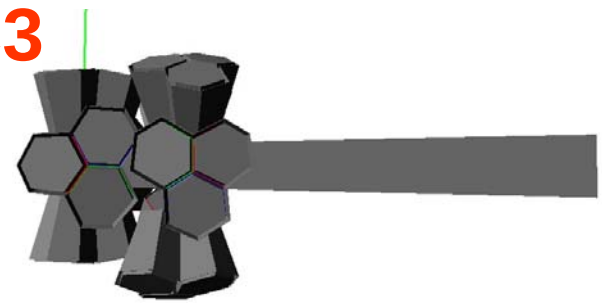
C1

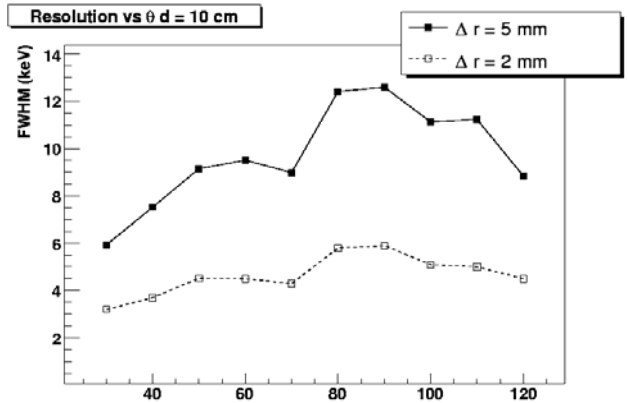


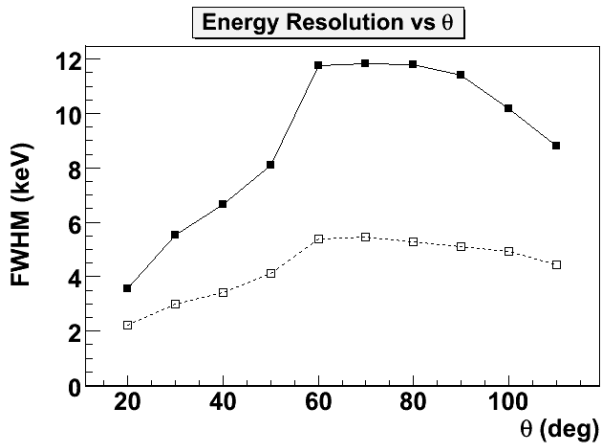
C2

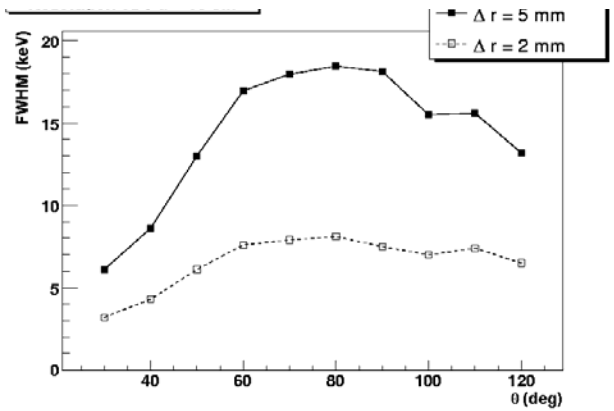


C3



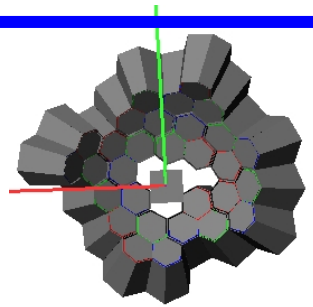






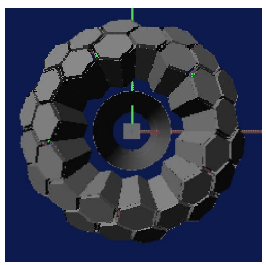
S- and C-Geometries, Optimal Distances

S1



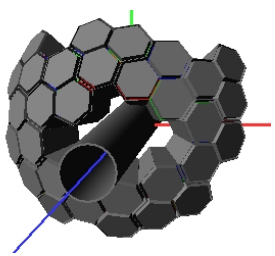
d = 23.5 – 15 = 8.5 cm

S2



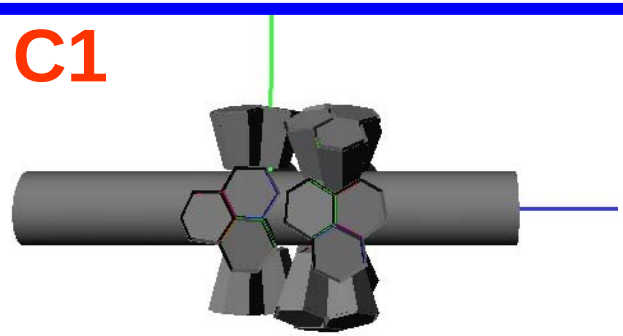
d = 23.5 – 10 = 13.5 cm

S3

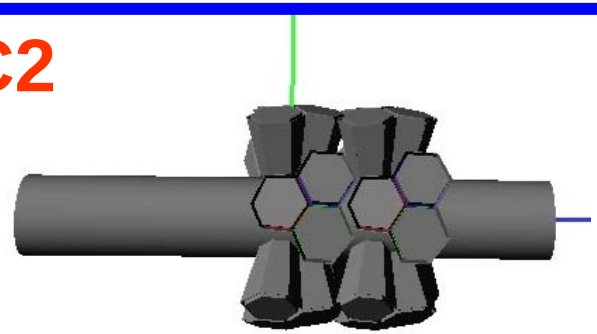


d = 23.5 – 15 = 8.5 cm

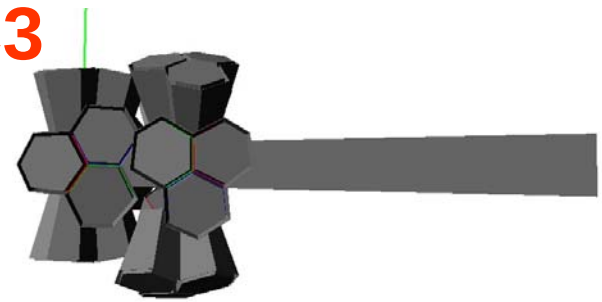
C1



C2

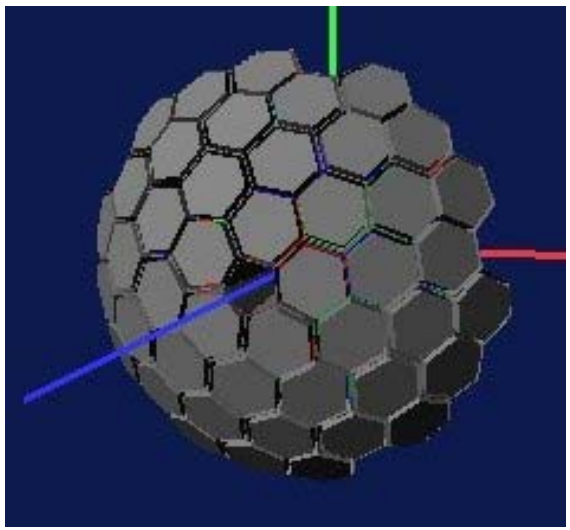


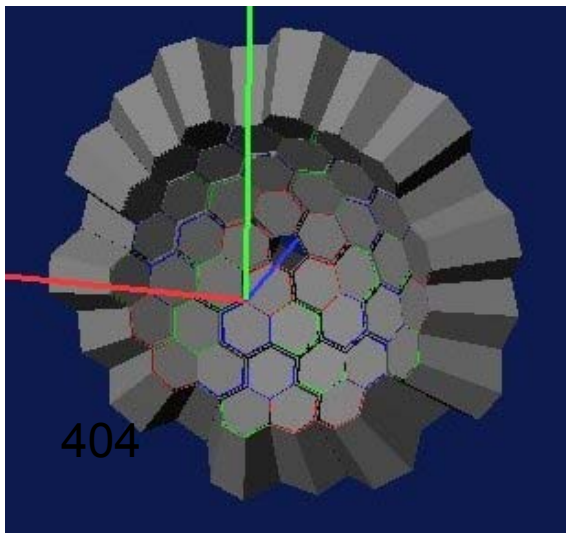
C3



Stepwise geometry optimisation

- Ideal geometry = first approach, first step



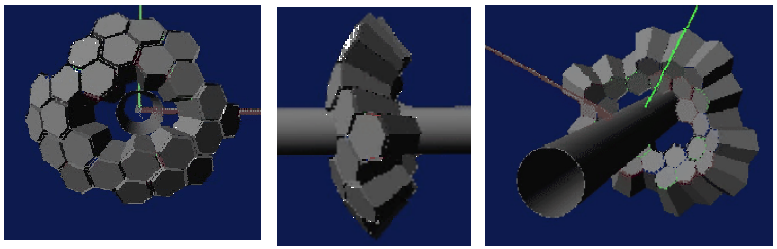


- two main dissadvantages:

1. 15 cluster detectors will not be available yet in 2011/2012
2. The beam hole (pentagonal hole) is too narrow for the GSI beam size

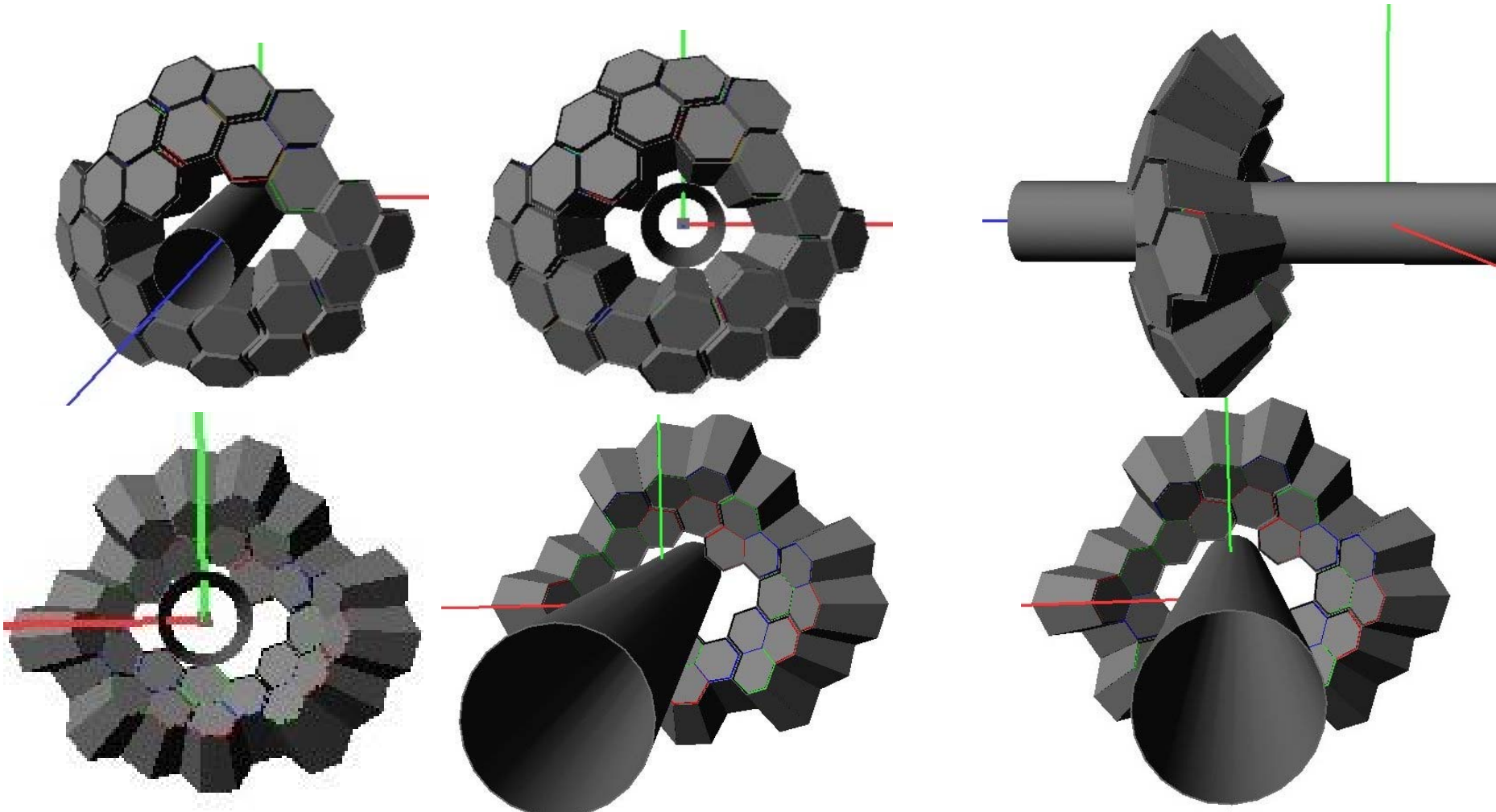
- Geometry constraint: triple clusters (not individual crystals)

8 Clusters Asymmetric Ring Geometry

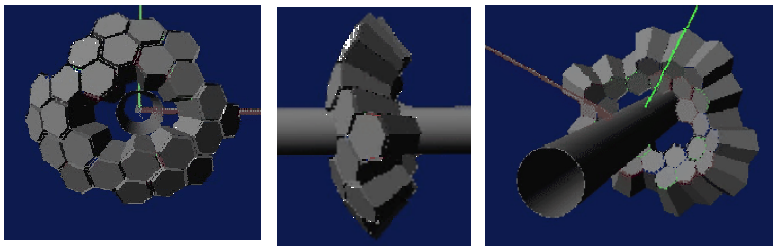


8 Clusters

Hole (11.5 cm) beam-pipe 11 cm



8 Clusters Asymmetric Ring Geometry



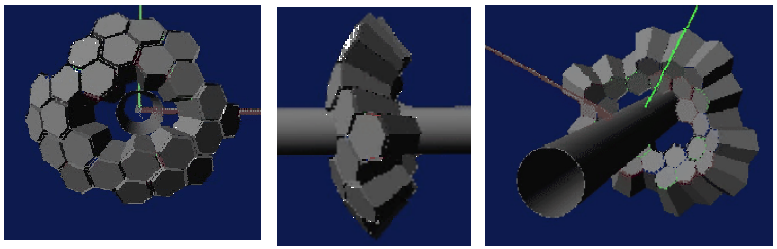
8 Clusters

Hole (11.5 cm) beam-pipe 11 cm

A180euler.list ⟶ A180eulerprespecv4.list

```
# The Euler angles (degree)  and shifts (mm) of the 60 clusters
#  cl  cl#     psi(Rz)    theta(Ry)      phi(Rz)        dx          dy          dz
#    0   0    164.302488    21.967863    -5.649422    102.935572   -10.182573   256.432015
.
.
.
#   44   0     42.906217   106.291521   -20.916343    247.916020   -94.750958   -77.567377
   45   0   -156.210622   134.706892    15.424027    189.440679    52.266136  -194.518058
#   46   0    111.584005   131.663878    52.562301    125.572067   164.017668  -183.811468
#   50   0    111.584005   131.663878  -163.437699   -197.997103   -58.883672  -183.811468
   51   0   -156.210622   134.706892  -128.575973   -122.539465  -153.634630  -194.518058
   52   0    111.584005   131.663878   -91.437699     -5.182770  -206.502490  -183.811468
   53   0   -156.210622   134.706892   -56.575973    108.248439  -164.017668  -194.518058
   54   0    111.584005   131.663878   -19.437699    194.793975   -68.741886  -183.811468
   55   0    -15.697512   158.032137    41.649422     77.291461    68.741886  -256.432015
   56   0    -15.697512   158.032137   113.649422    -41.493043    94.750958  -256.432015
   57   0    -15.697512   158.032137  -174.350578   -102.935572   -10.182573  -256.432015
#   58   0    -15.697512   158.032137  -102.350578    -22.124639  -101.044134  -256.432015
#   59   0    -15.697512   158.032137   -30.350578     89.261793   -52.266136  -256.432015
```

8 Clusters Asymmetric Ring Geometry



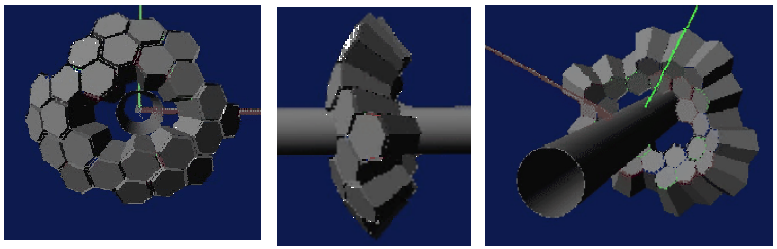
8 Clusters

Hole (11.5 cm) beam-pipe 11 cm

A180euler.list ⟶ A180eulerprespecv4.list

```
# The Euler angles (degree)  and shifts (mm) of the 60 clusters
#  cl  cl#     psi(Rz)    theta(Ry)      phi(Rz)        dx          dy          dz
#    0   0    164.302488    21.967863    -5.649422    102.935572   -10.182573   256.432015
.
.
.
#   44   0     42.906217   106.291521   -20.916343    247.916020   -94.750958   -77.567377
    45   0   -156.210622   134.706892    15.424027    189.440679    52.266136  -194.518058
#   46   0    111.584005   131.663878    52.562301    125.572067   164.017668  -183.811468
#   50   0    111.584005   131.663878  -163.437699   -197.997103   -58.883672  -183.811468
    51   0   -156.210622   134.706892  -128.575973   -122.539465  -153.634630  -194.518058
    52   0    111.584005   131.663878   -91.437699     -5.182770  -206.502490  -183.811468
    53   0   -156.210622   134.706892   -56.575973    108.248439  -164.017668  -194.518058
    54   0    111.584005   131.663878   -19.437699    194.793975   -68.741886  -183.811468
    55   0    -15.697512   158.032137    41.649422     77.291461    68.741886  -256.432015
    56   0    -15.697512   158.032137   113.649422    -41.493043    94.750958  -256.432015
    57   0    -15.697512   158.032137  -174.350578   -102.935572   -10.182573  -256.432015
#   58   0    -15.697512   158.032137  -102.350578    -22.124639  -101.044134  -256.432015
#   59   0    -15.697512   158.032137   -30.350578     89.261793   -52.266136  -256.432015
```

8 Clusters Asymmetric Ring Geometry



8 Clusters

Hole (11.5 cm) beam-pipe 11 cm

/Agata/detector/rotateArray Ry(theta) Rz(phi)

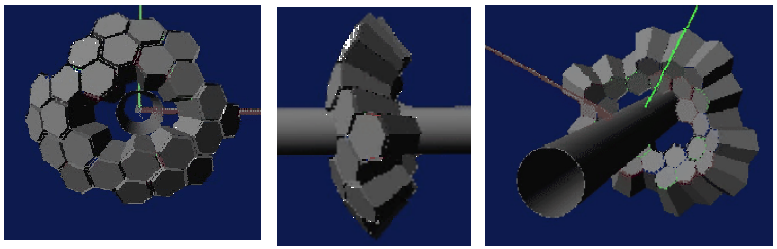
radd.rotateY(thetaShift);
radd.rotateZ(phiShift);

/Agata/detector/rotateArray Ry(theta) Rz(phi) Rx(psi)

/Agata/detector/rotateArray 175.0 30.0 -17.0

radd.rotateY(thetaShift);
radd.rotateZ(phiShift);
radd.rotateX(psiShift);

8 Clusters Asymmetric Ring Geometry



8 Clusters

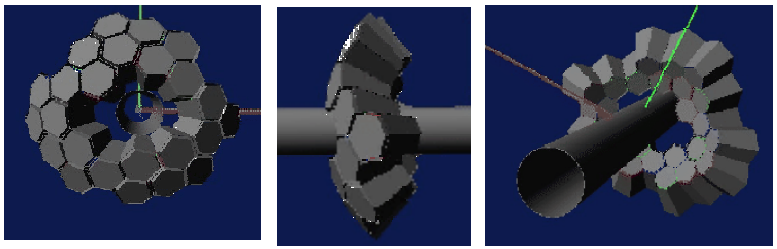
Hole (11.5 cm) beam-pipe 11 cm

/Agata/detector/rotateArray 175.0 30.0 -17.0

The Euler angles (degree) and shifts (mm) of the 60 clusters

#	cl	cl#	psi(Rz)	theta(Ry)	phi(Rz)	dx	dy	dz
#	0	0	164.302488	21.967863	-5.649422	102.935572	-10.182573	256.432015
.								
.								
.								
#	44	0	42.906217	106.291521	-20.916343	247.916020	-94.750958	-77.567377
	45	0	-156.210622	134.706892	15.424027	189.440679	52.266136	-194.518058
#	46	0	111.584005	131.663878	52.562301	125.572067	164.017668	-183.811468
#	50	0	111.584005	131.663878	-163.437699	-197.997103	-58.883672	-183.811468
	51	0	-156.210622	134.706892	-128.575973	-122.539465	-153.634630	-194.518058
	52	0	111.584005	131.663878	-91.437699	-5.182770	-206.502490	-183.811468
	53	0	-156.210622	134.706892	-56.575973	108.248439	-164.017668	-194.518058
	54	0	111.584005	131.663878	-19.437699	194.793975	-68.741886	-183.811468
	55	0	-15.697512	158.032137	41.649422	77.291461	68.741886	-256.432015
	56	0	-15.697512	158.032137	113.649422	-41.493043	94.750958	-256.432015
	57	0	-15.697512	158.032137	-174.350578	-102.935572	-10.182573	-256.432015
#	58	0	-15.697512	158.032137	-102.350578	-22.124639	-101.044134	-256.432015
#	59	0	-15.697512	158.032137	-30.350578	89.261793	-52.266136	-256.432015

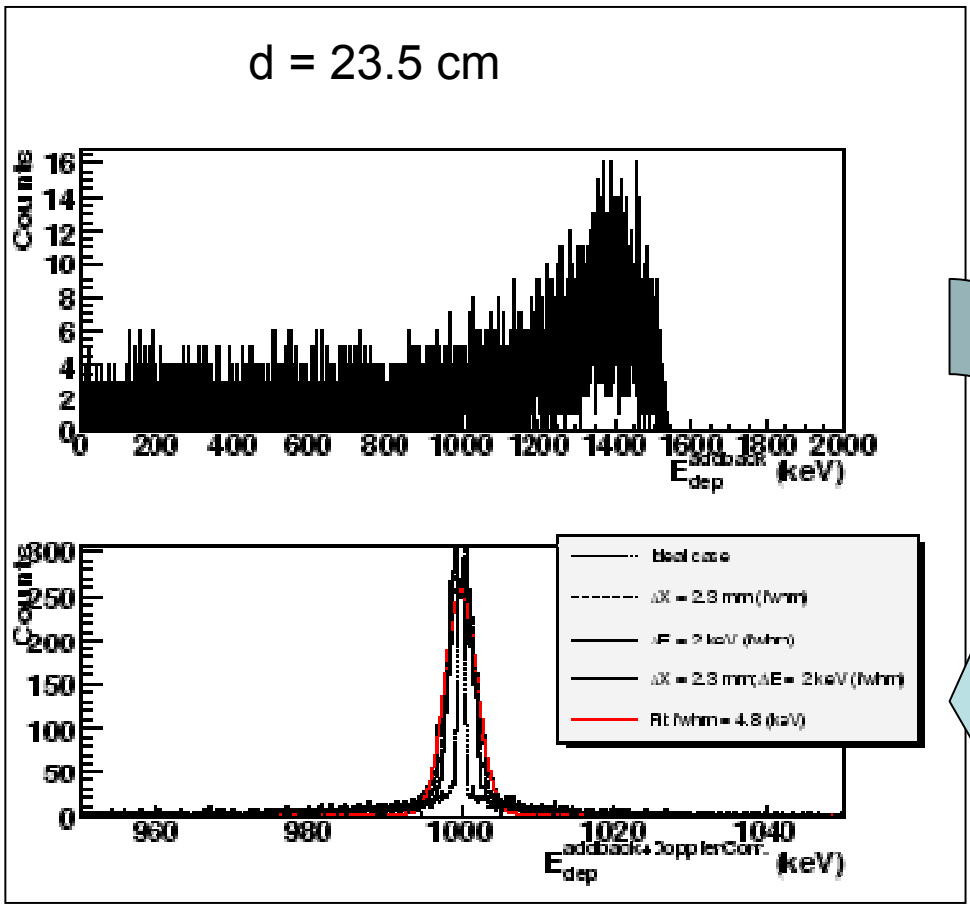
8 Clusters Asymmetric Ring



8 Clusters

Hole (11.5 cm) beam-pipe 11 cm

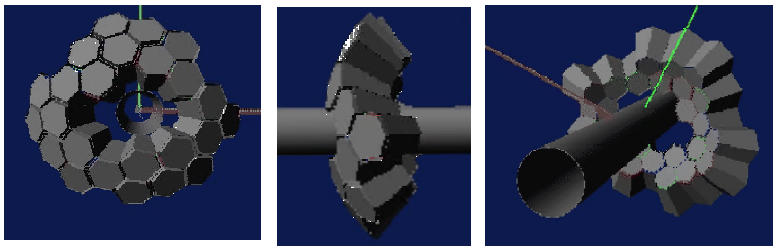
d = 23.5 cm



$$E_{\gamma} = E_{\gamma 0} \frac{1 - \beta \cos\theta_{\gamma}}{\sqrt{1 - \beta^2}}$$

ΔE = 2 keV (fwhm) @ $E\gamma$ = 1 MeV; Δx = 4 mm

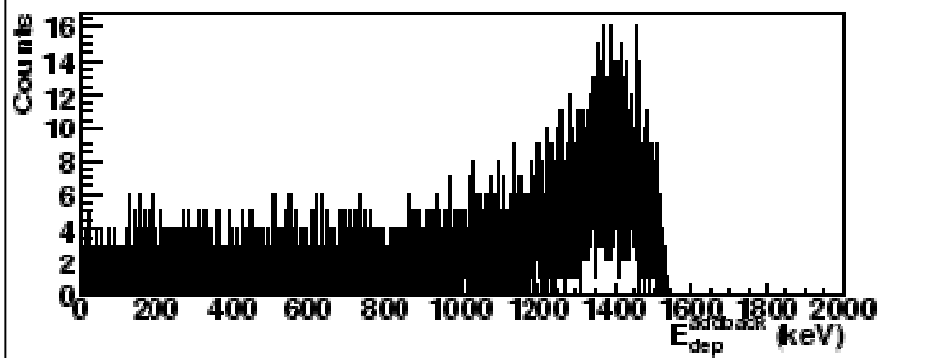
8 Clusters Asymmetric Ring

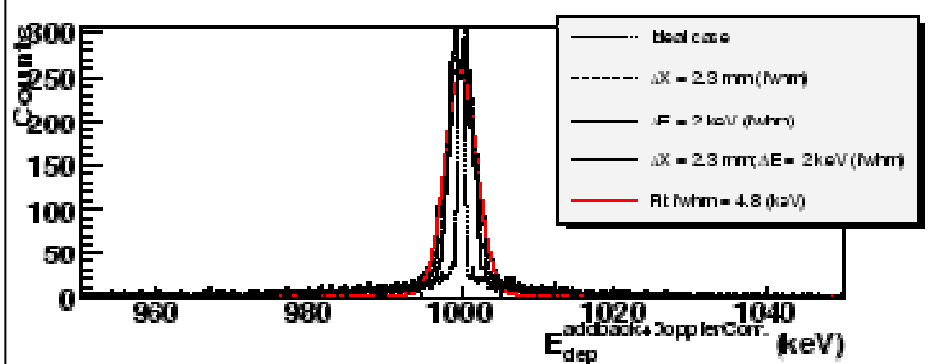


8 Clusters

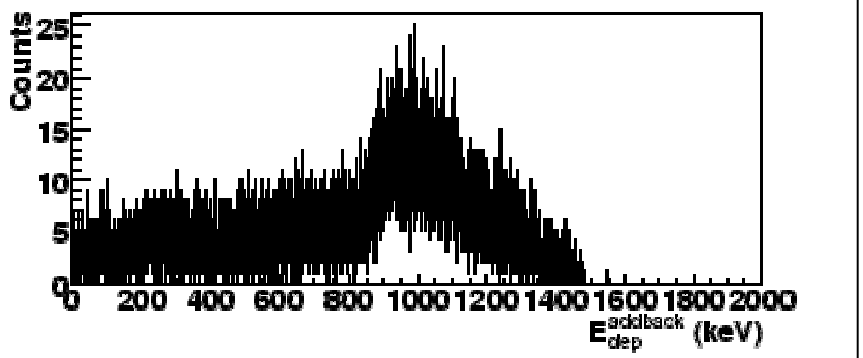
Hole (11.5 cm) beam-pipe 11 cm

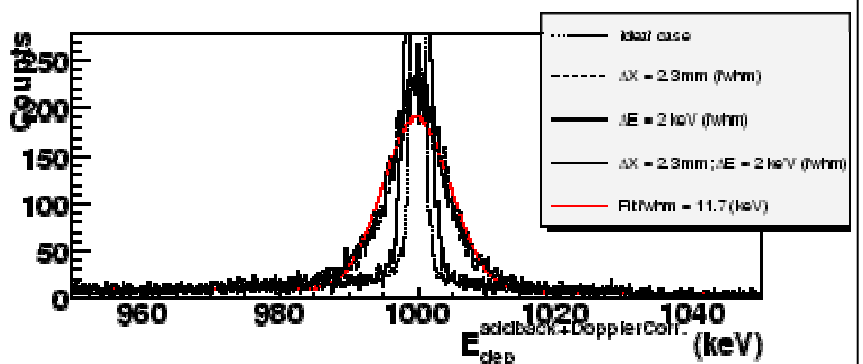
d = 23.5 cm





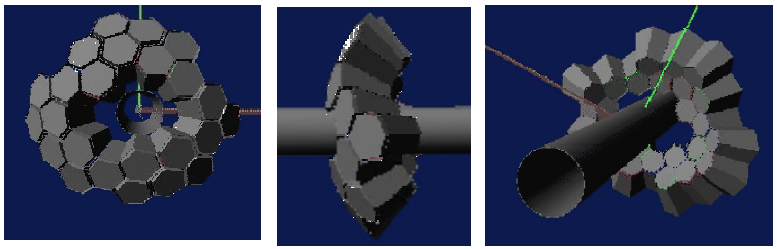
d = 1.5 cm





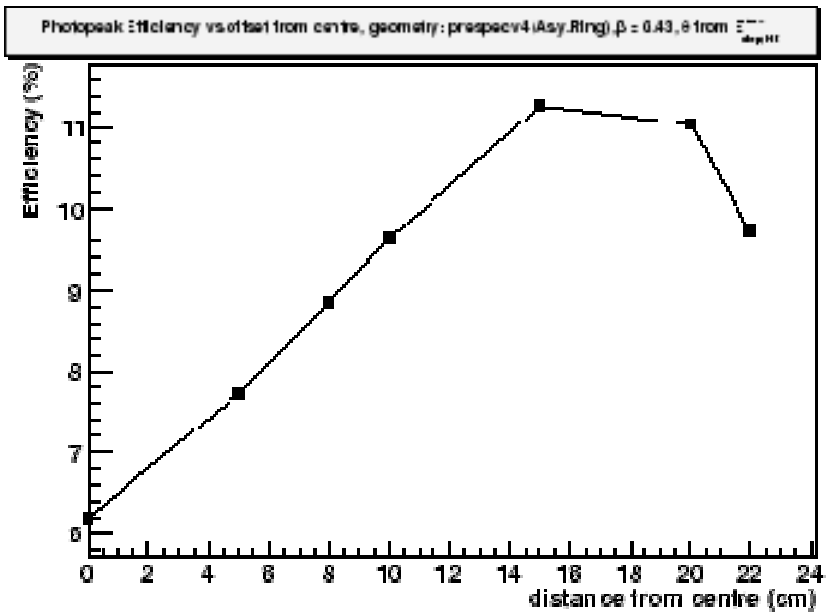
ΔE = 2 keV (fwhm) @ $E\gamma$ = 1 MeV; Δx = 4 mm

8 Clusters Asymmetric Ring

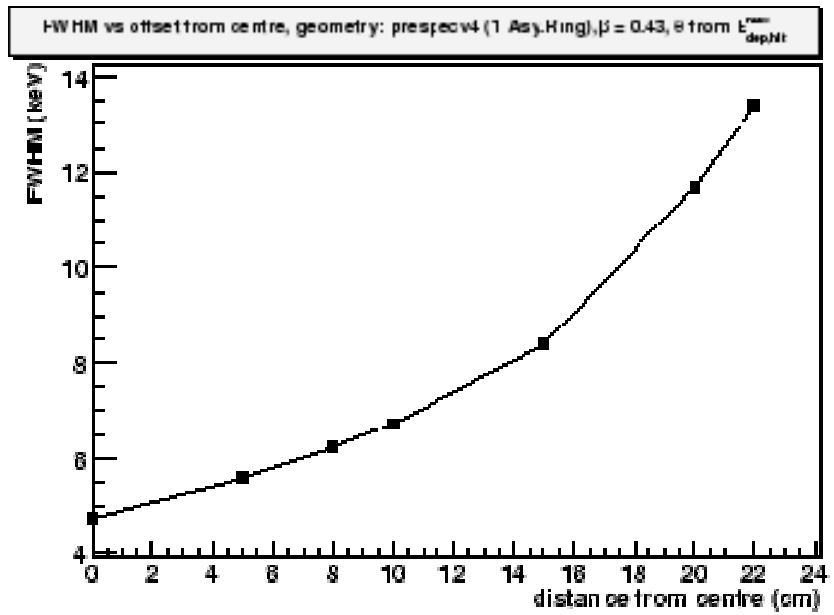


8 Clusters

Hole (11.5 cm) beam-pipe 11 cm



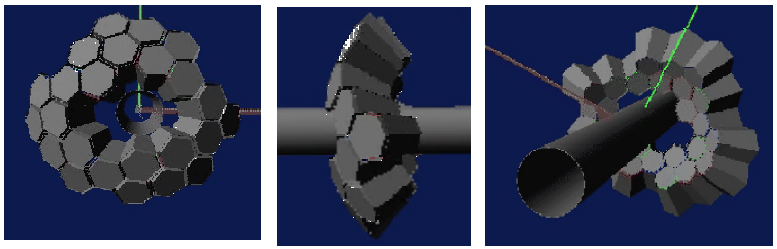
23.5 cm 1.5 cm



23.5 cm 1.5 cm

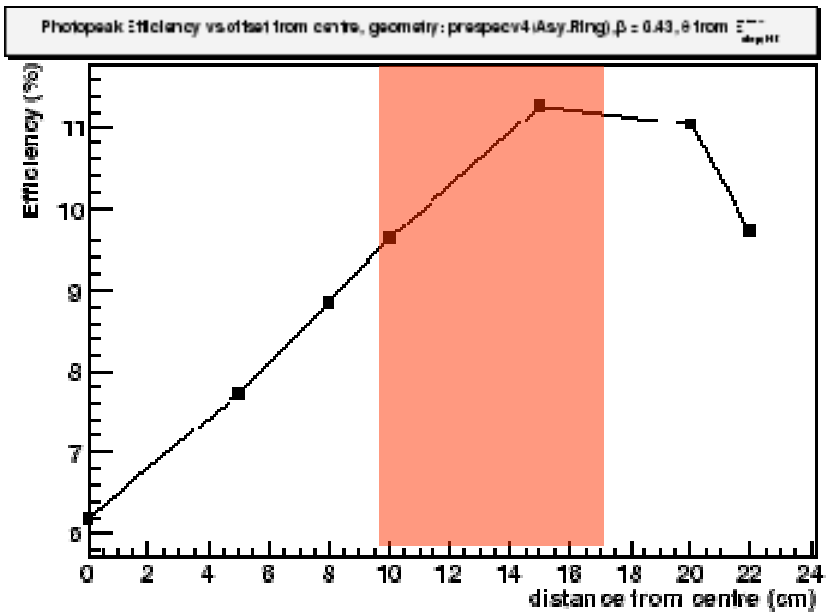
ΔE = 2 keV (fwhm) @ $E\gamma$ = 1 MeV; Δx = 4 mm

8 Clusters Asymmetric Ring

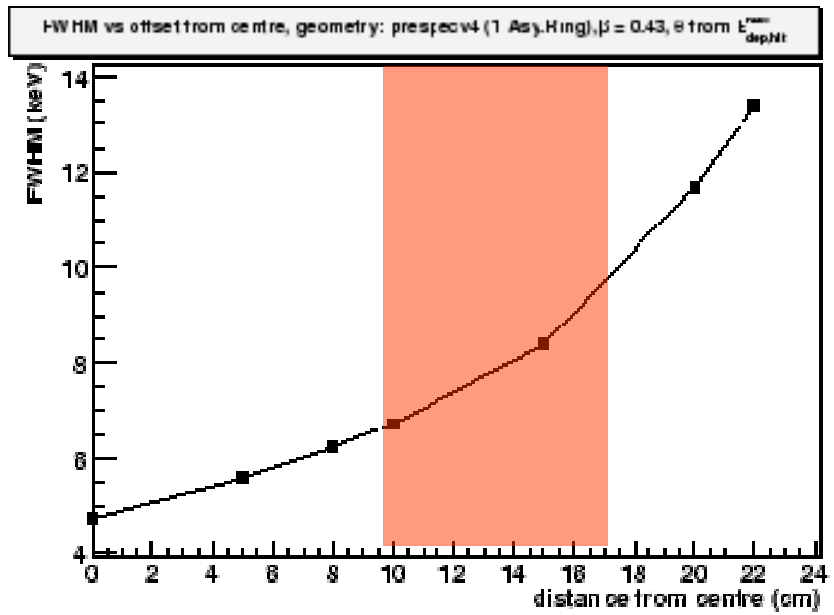


8 Clusters

Hole (11.5 cm) beam-pipe 11 cm



23.5 cm 1.5 cm



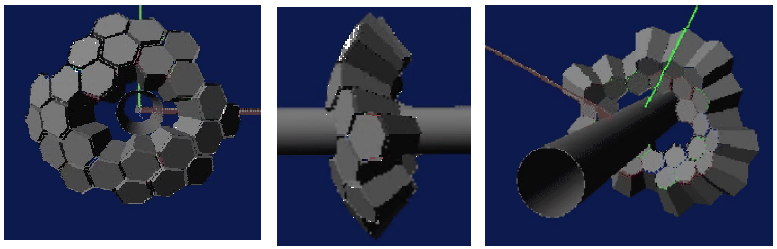
23.5 cm 1.5 cm

Efficiency = 10-11%

FWHM = 6-8 keV

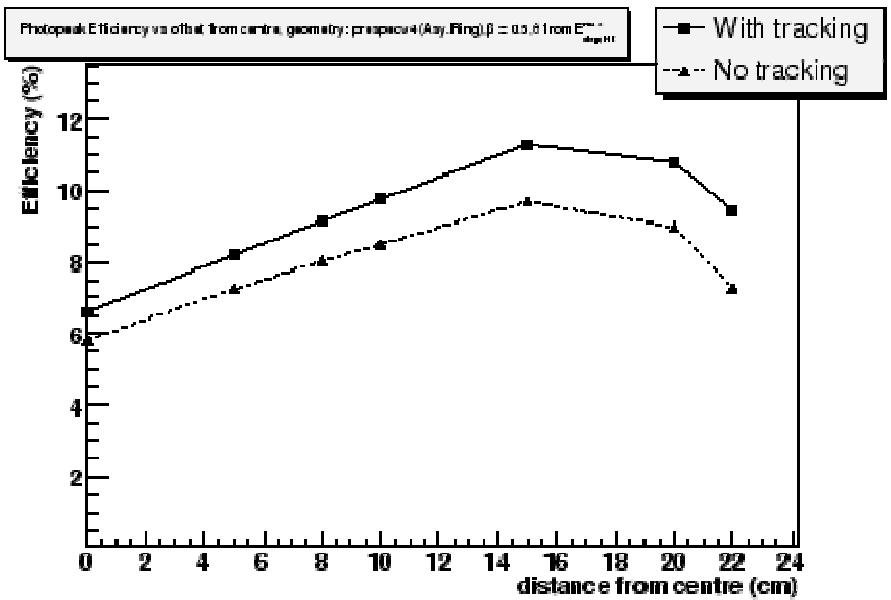
ΔE = 2 keV (fwhm) @ $E\gamma$ = 1 MeV; Δx = 4 mm

8 Clusters Asymmetric Ring

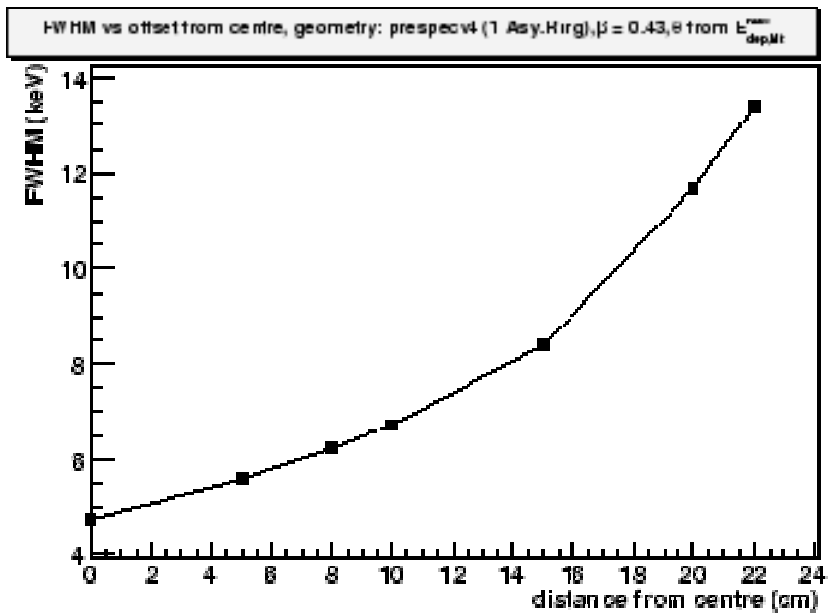


8 Clusters

Hole (11.5 cm) beam-pipe 11 cm



23.5 cm 1.5 cm

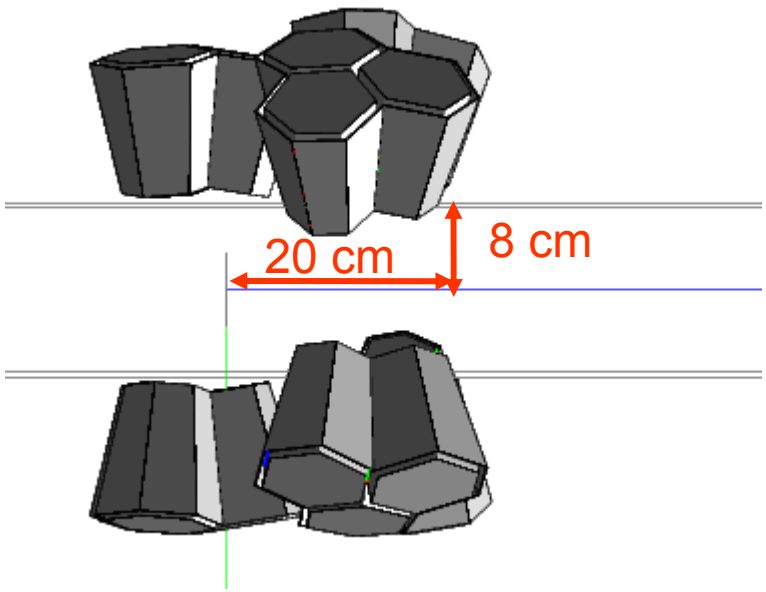


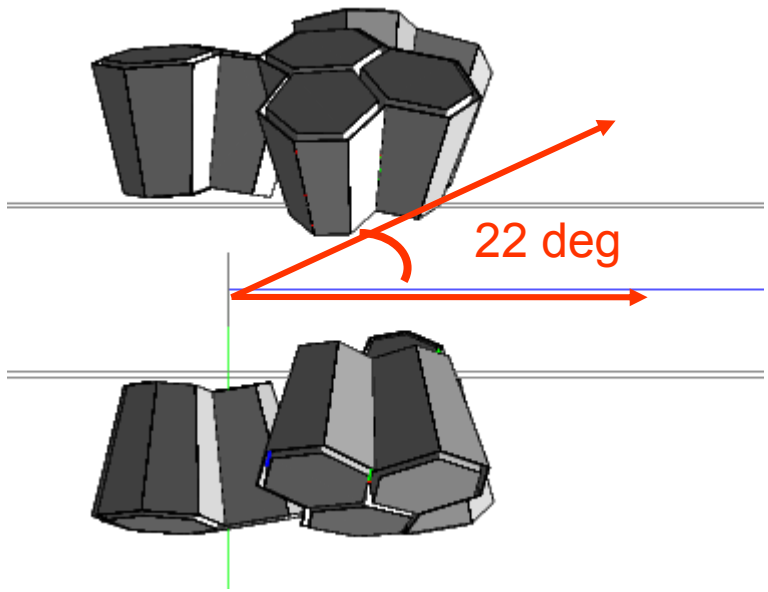
23.5 cm 1.5 cm

ΔE = 2 keV (fwhm) @ $E\gamma$ = 1 MeV; Δx = 4 mm

Solid angle occupied and free

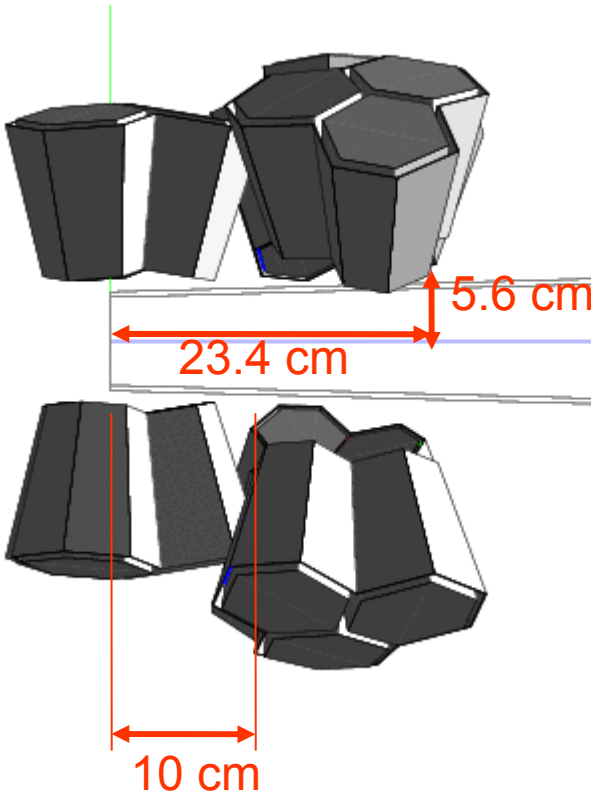
C1

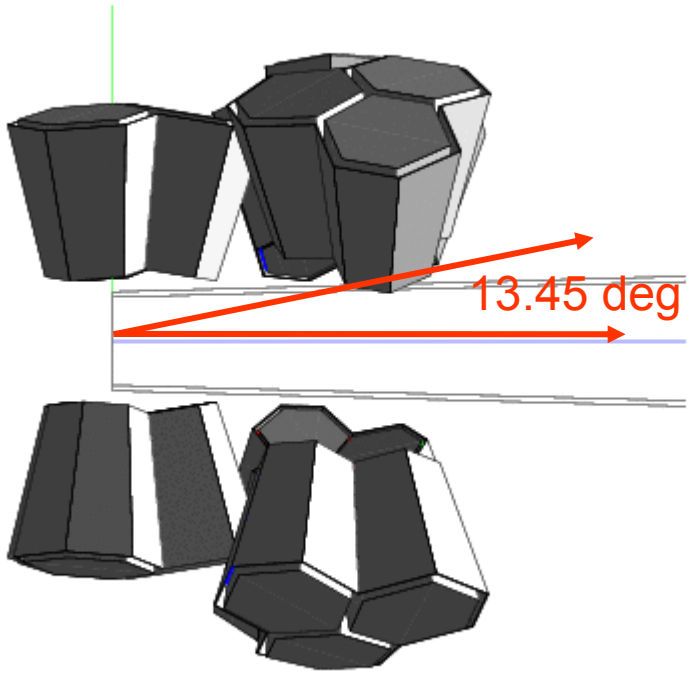




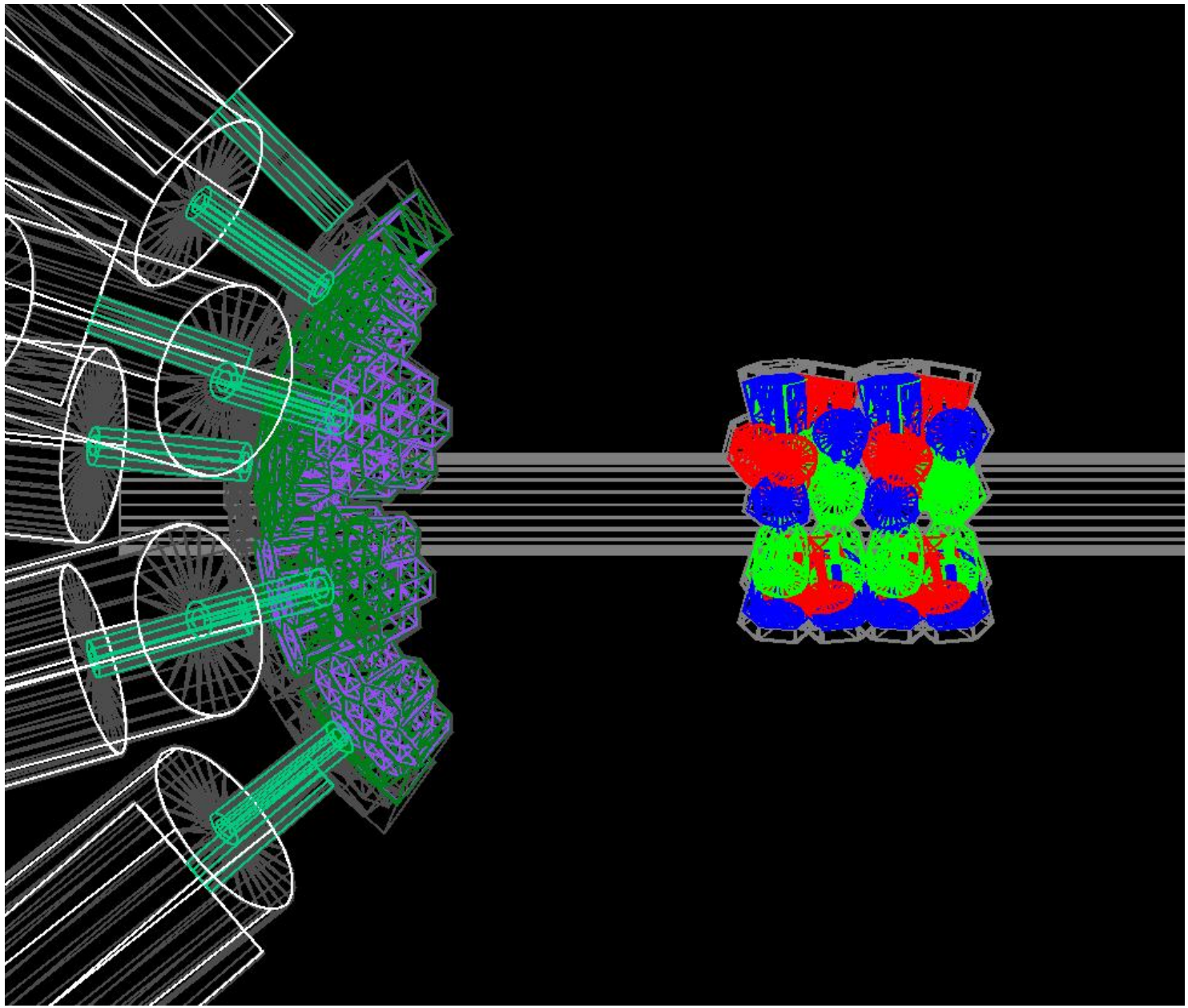
Solid angle occupied and free

C3

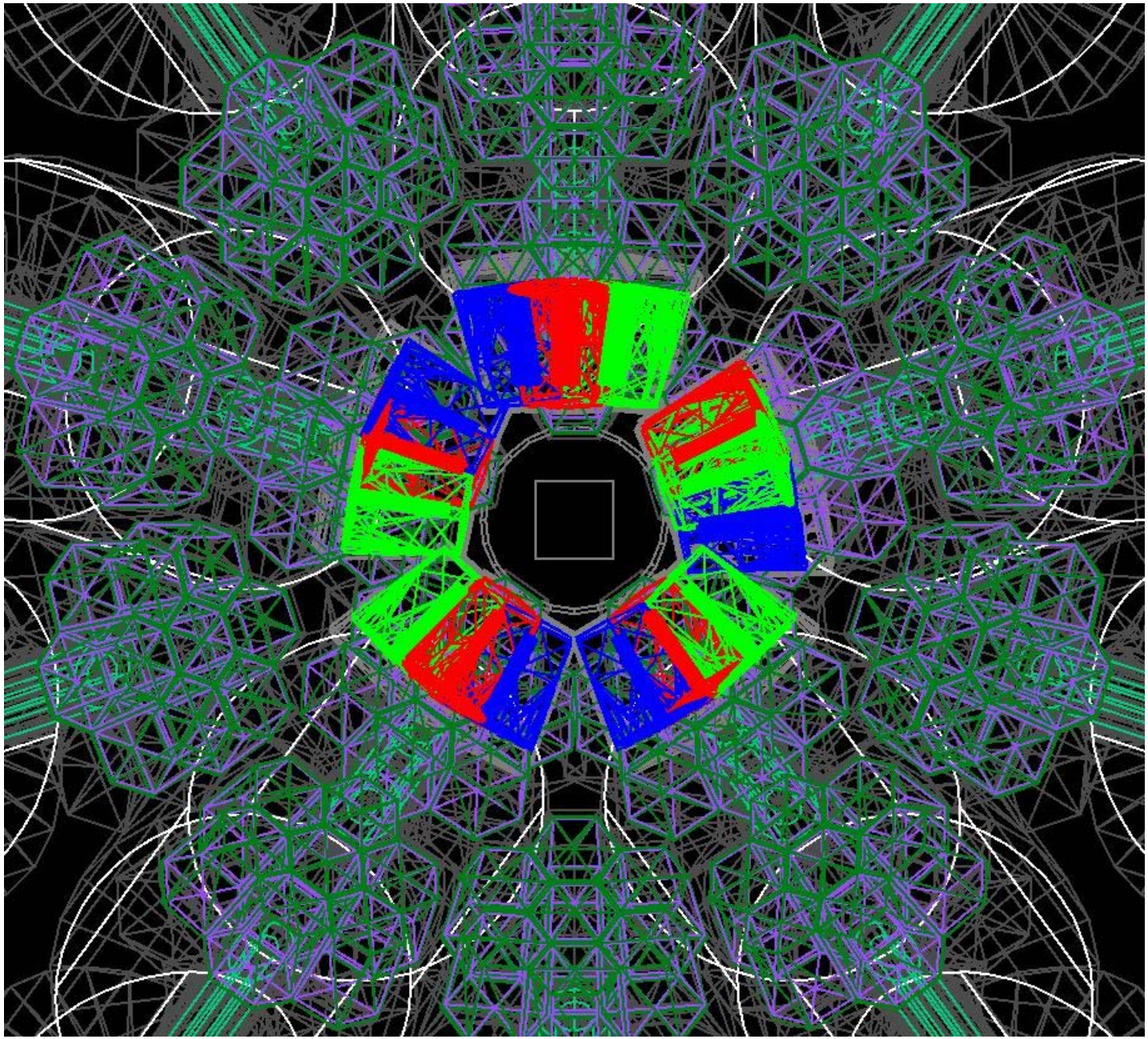




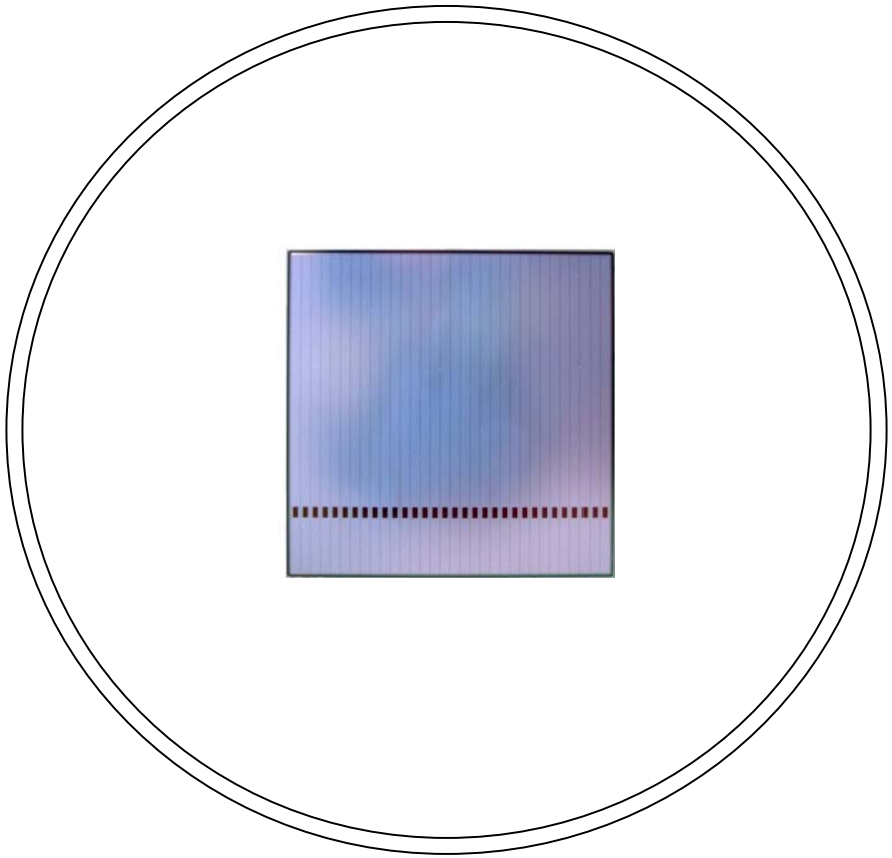
Other viewer’s views



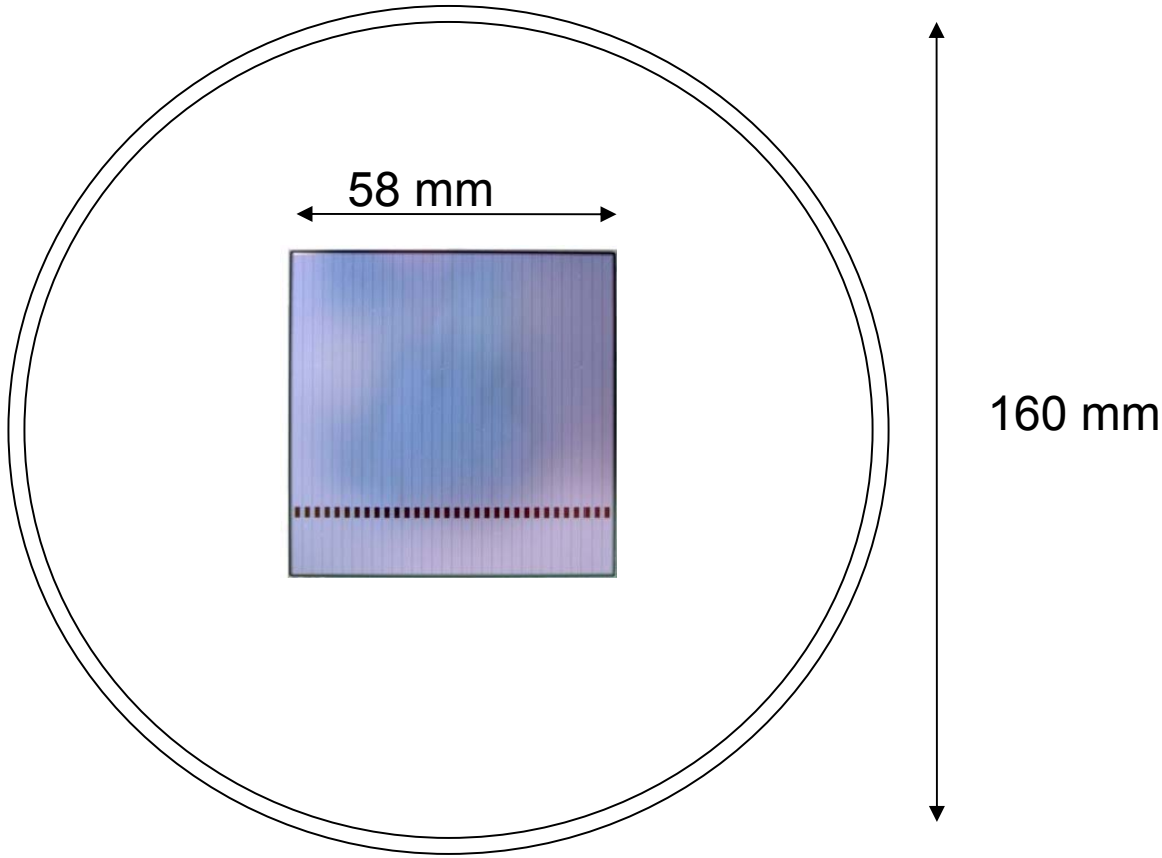
Other viewer’s views



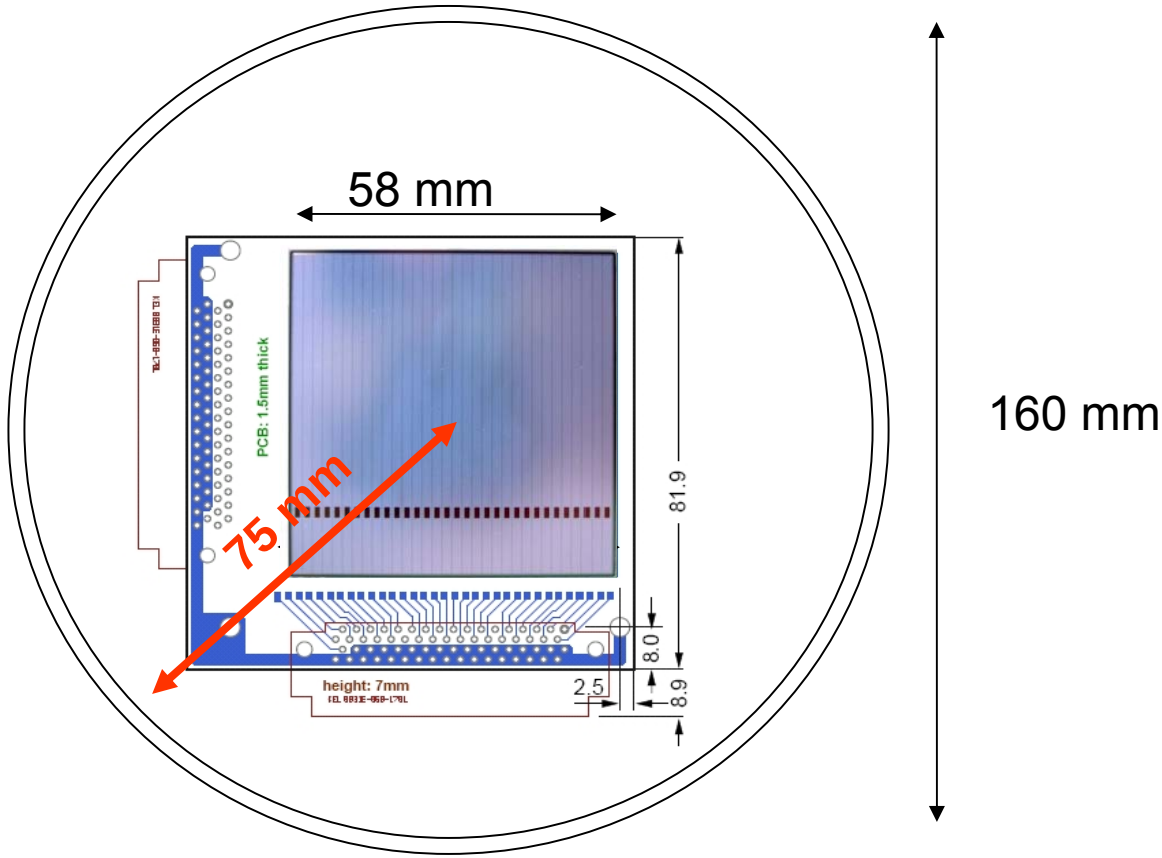
S4 focal plane room constrained by the DSSSD



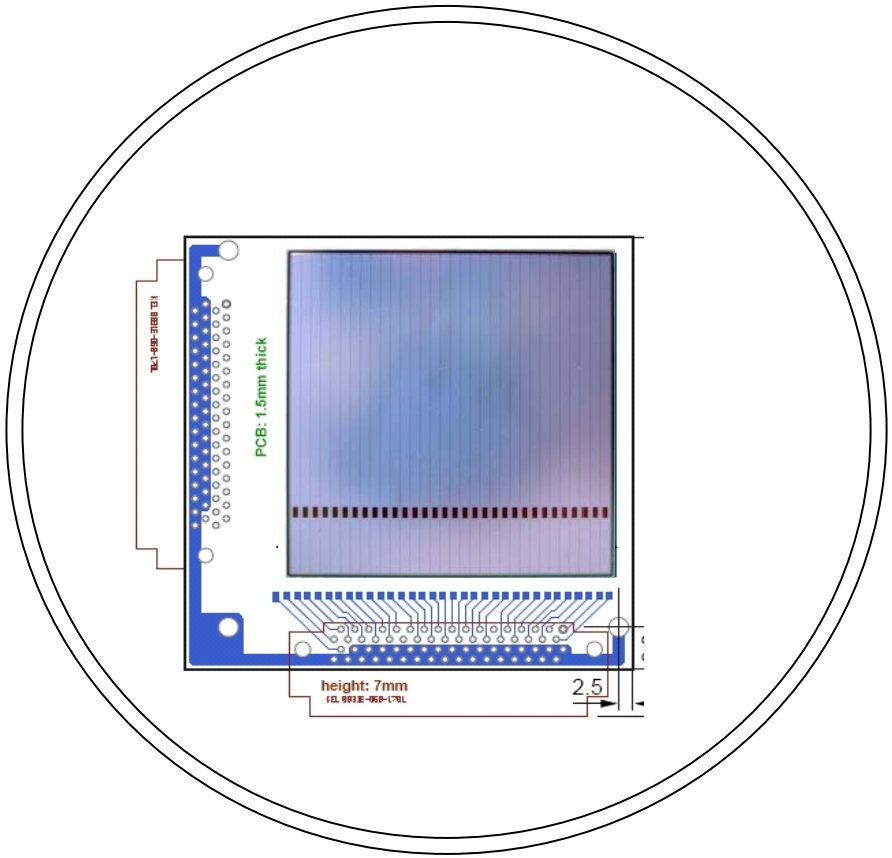
S4 focal plane room constrained by the DSSSD



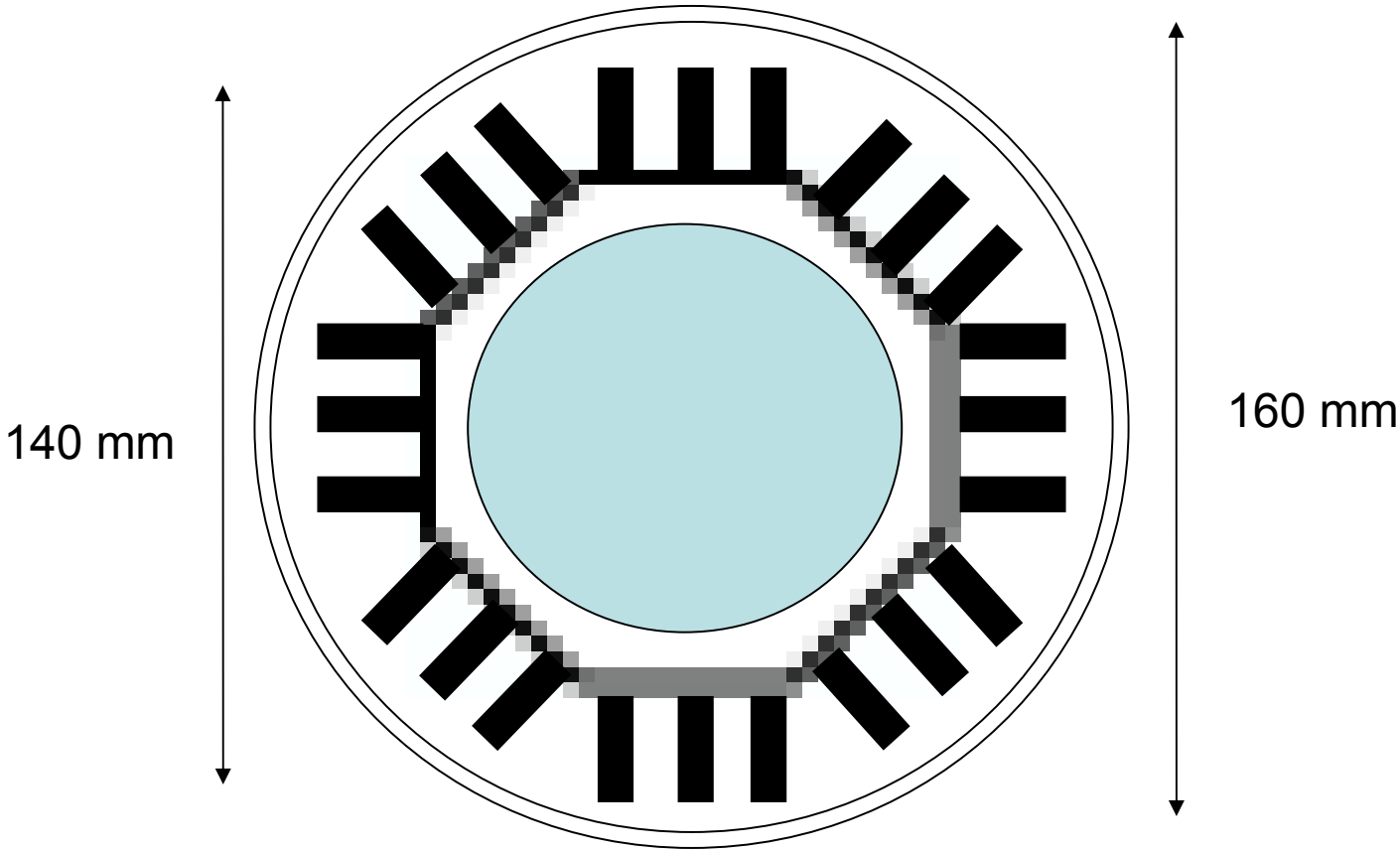
S4 focal plane room constrained by the DSSSD



S4 focal plane room constrained by the DSSSD

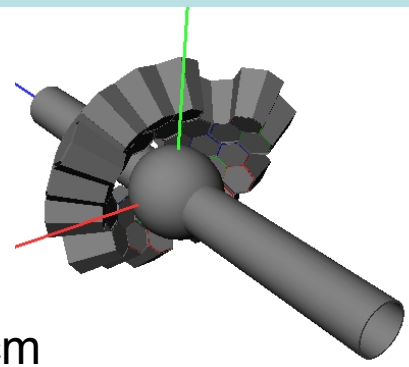


S4 focal plane constrained by the Scintillation membrane



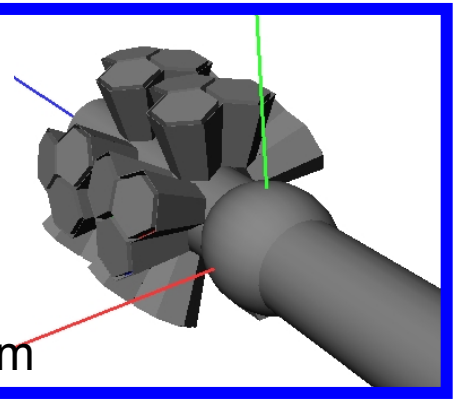
S3- and C2-Geometries + Chamber 20 cm diameter

S3



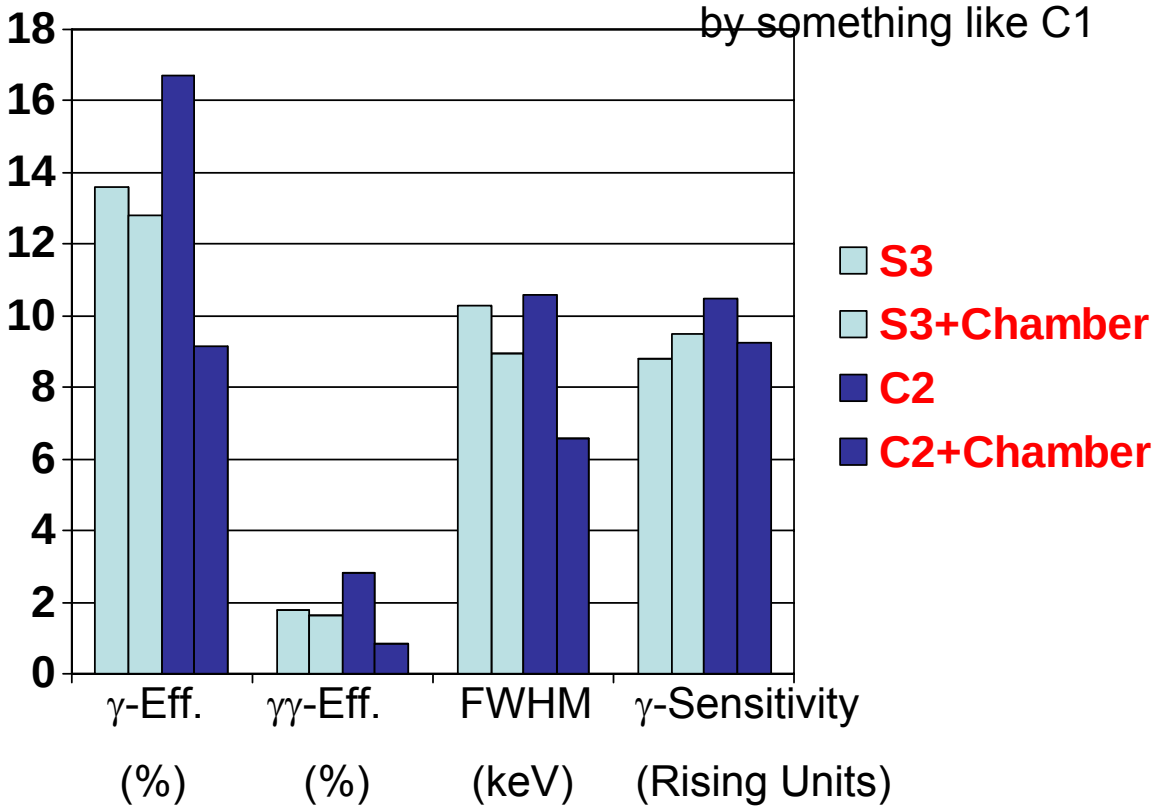
Δd_z = 3 cm

C2



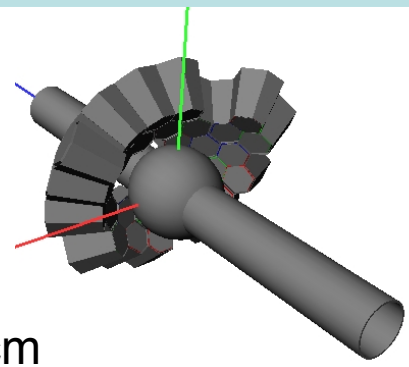
Δd_z = 15 cm

C2 performance could be improved by something like C1



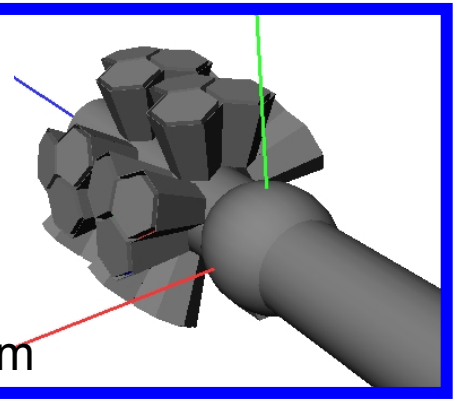
S3- and C2-Geometries + Chamber 20 cm diameter

S3



Δd_z = 3 cm

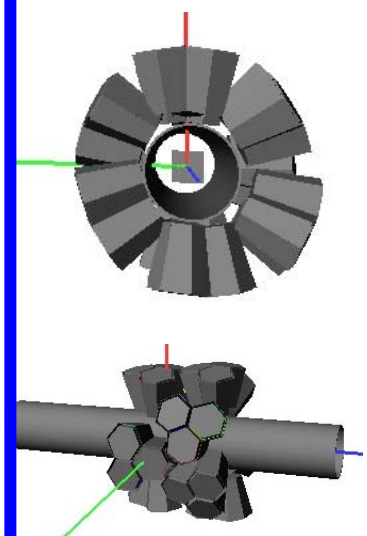
C2

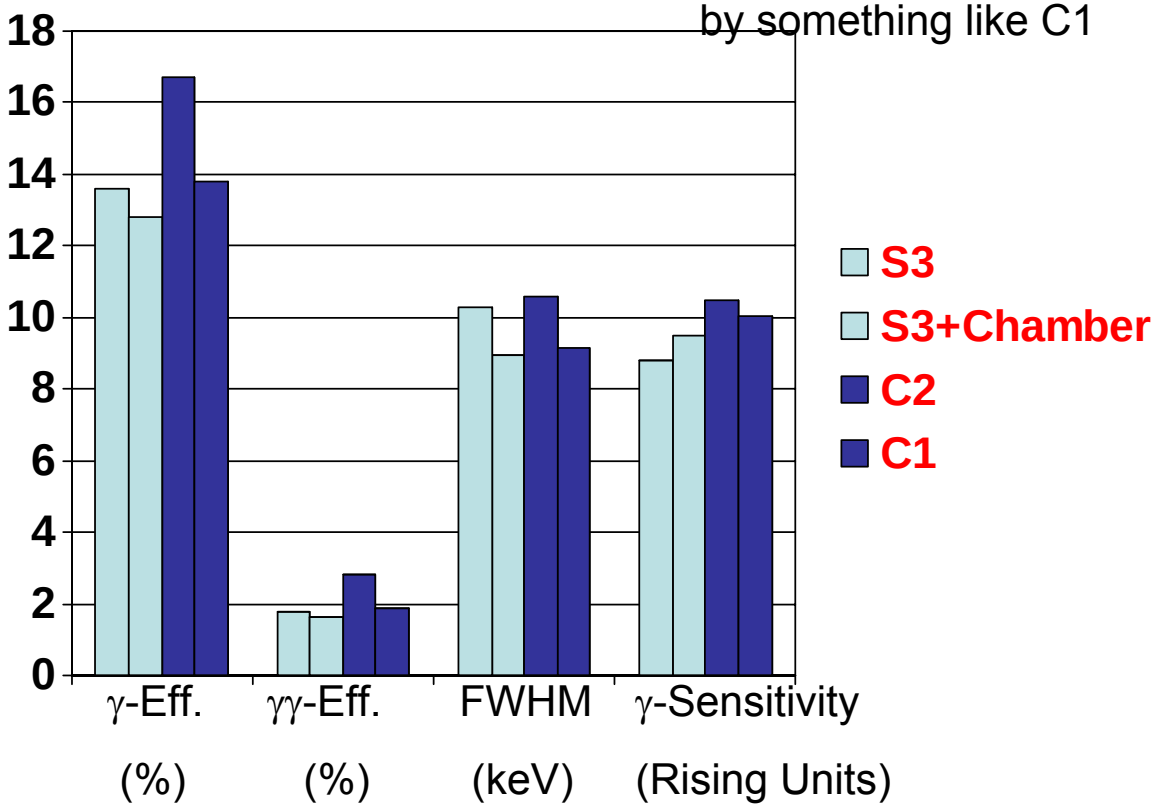


Δd_z = 15 cm

C2 performance could be improved by something like C1

C1





Workshop on AGATA at GSI: reference physics cases

Geometry cases

- Task 1: S2 + 5 Double Cluster detectors closing part of the central hole (15-16cm?). Remains shell with 5 crystals hole + pentagon hole
- Task 2: S3 + 1 Double Cluster detector closing part of the central hole (10-11 cm?). Remains shell with 4 crystals hole + pentagon hole.
- Task 3: C2 geometry, with clusters in 2nd ring pointing to target, and 3rd ring (15 Clusters total)

Physics cases evaluate realistically the performance of the optimal detection system in:

- Task 1: Coulex experiment. Example: Coulex of ^{104}Sn at 100 MeV/u on a 0.4 g/cm^2 Au-target. Primary beam ^{124}Xe.
- Task 2: Fragmentation experiment. ^{54}Ni at 100 MeV/u + Be (0.7 g/cm2) -> ^{50}Fe (simulate first 4 excited states up to 8+ level).
- Task 3: Plunger experiment (M. Reese TU-Darmstadt, A. Dewald, Uni. Koeln). Enfasis on angular distribution and contribution of RISING at forward angles

Realistic implementation

- Task 1: Background model or scaled background spectra from prev. experiments
- Task 2: Realistic tracking for event reconstruction (mgt, etc)

List of Tasks for the **Working Group (17.07.2009)**

Geometry cases

- Task 1: S2 + 5 Double Cluster detectors closing part of the central hole (15-16cm?). Remains shell with 5 crystals hole + pentagon hole
- Task 2: S3 + 1 Double Cluster detector closing part of the central hole (10-11 cm?). Remains shell with 4 crystals hole + pentagon hole.
- Task 3: previous + 4 Triple Clusters enlarging shell (for case one has 15 Clusters available).
- Task 4: C2 geometry, with clusters in 2nd ring pointing to target, and 3rd ring (15 Clusters total)

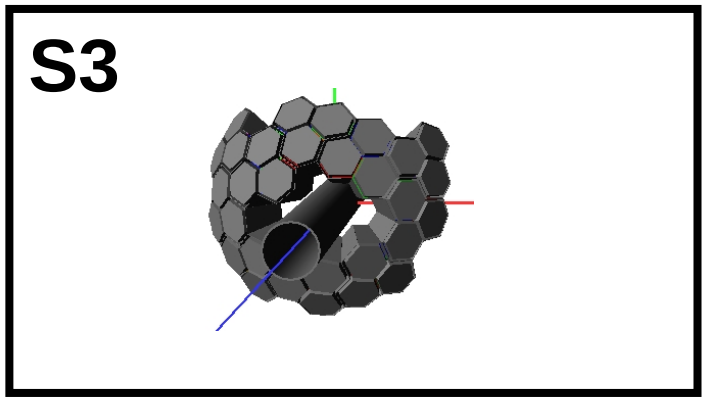
Physics cases evaluate realistically the performance of the optimal detection system in:

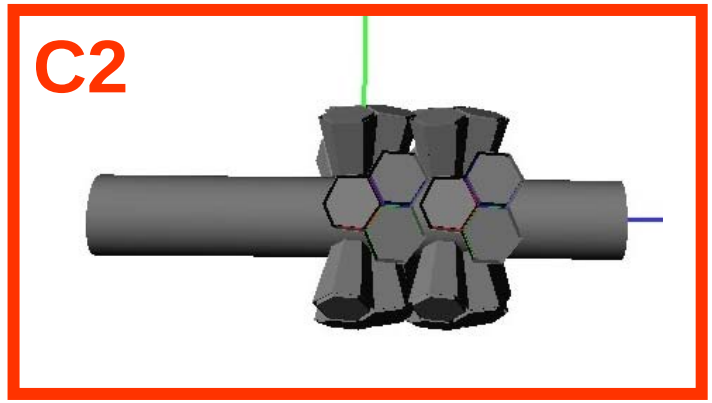
- Task 1: Coulex experiment. Example: Coulex of 104Sn at 100 MeV/u on a 0.4 g/cm2 Au-target. Primary beam 124Xe.
- Task 2: Fragmentation experiment. 54Ni at 100 MeV/u + Be (0.7 g/cm2) -> 50Fe (simulate first 4 excited states up to 8+ level).
- Task 3: Plunger experiment (A. Dewald, Chr. Fransen Uni. Koeln). Enfasis on angular distribution and contribution of RISING at forward angles

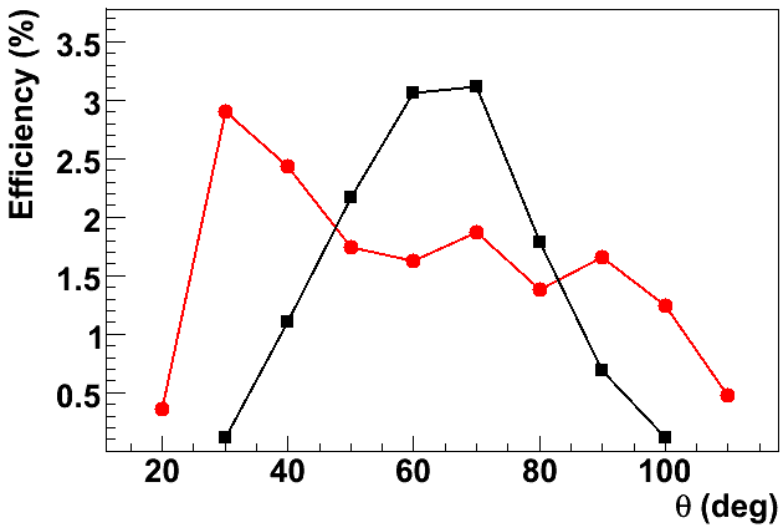
Realistic implementation

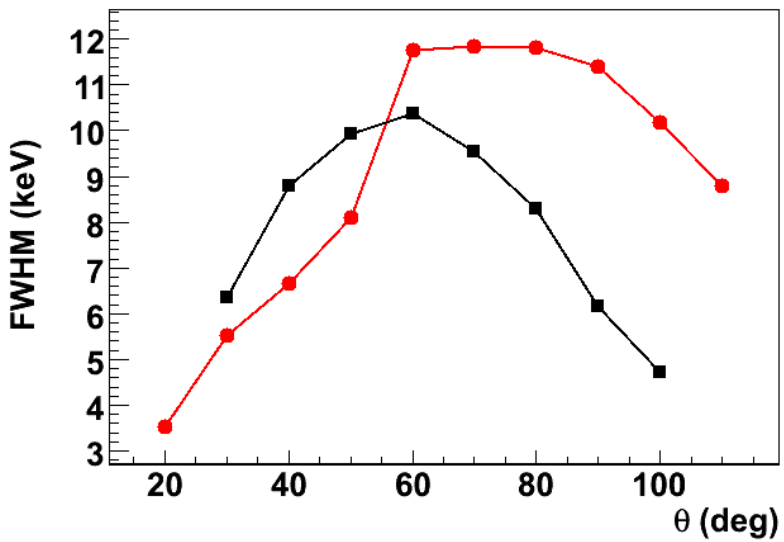
- Task 1: Background model or scaled background spectra from prev. experiments
- Task 2: Realistic tracking for event reconstruction (mgt, etc)

S- and C-Geometry Performance, Quantitative Comparison





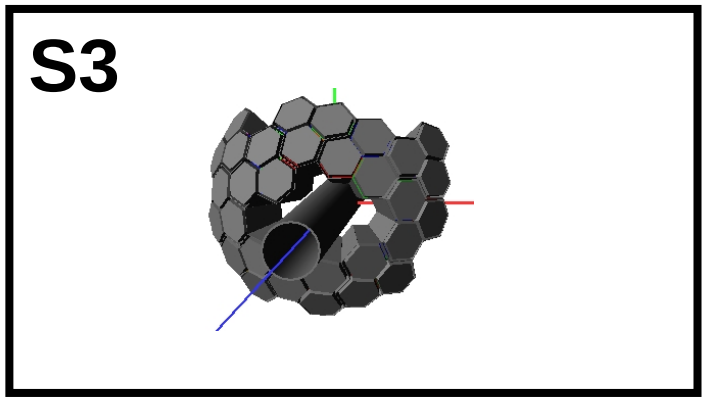


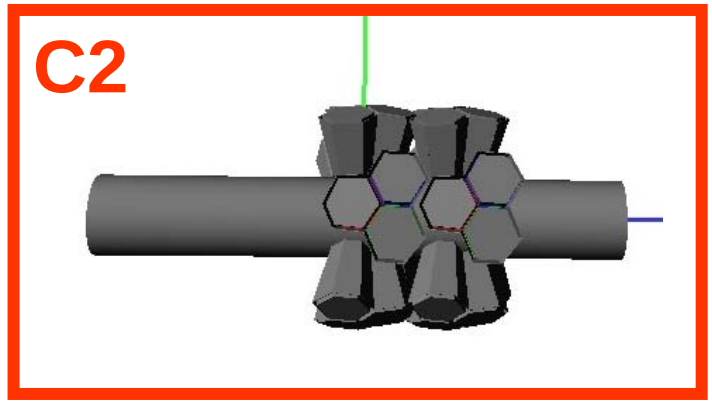


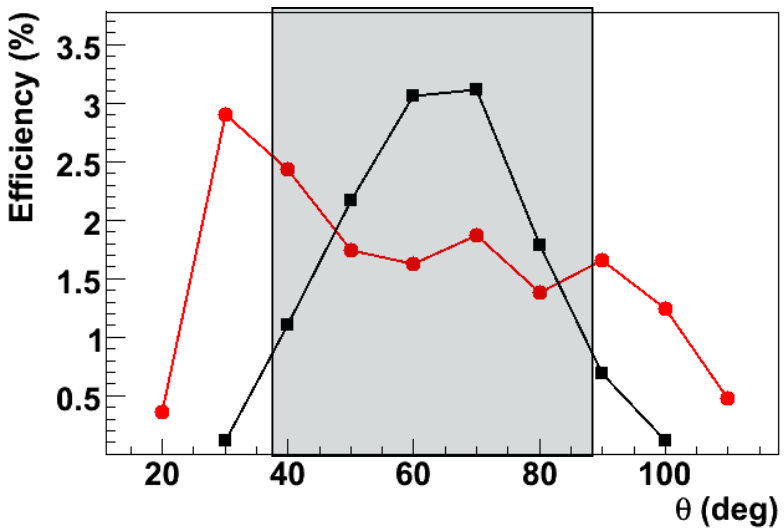
<ΔE(S3)> = 10.3 keV

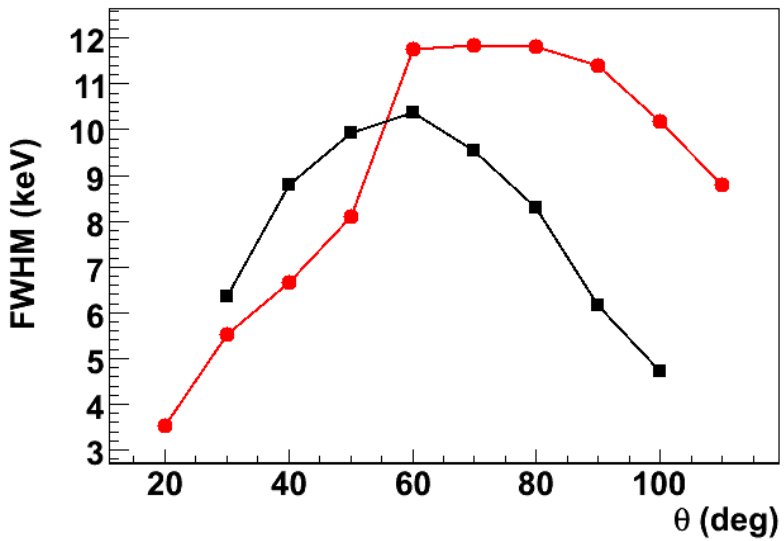
<ΔE(C2)> = 10.6 keV

S- and C-Geometry Performance, Quantitative Comparison









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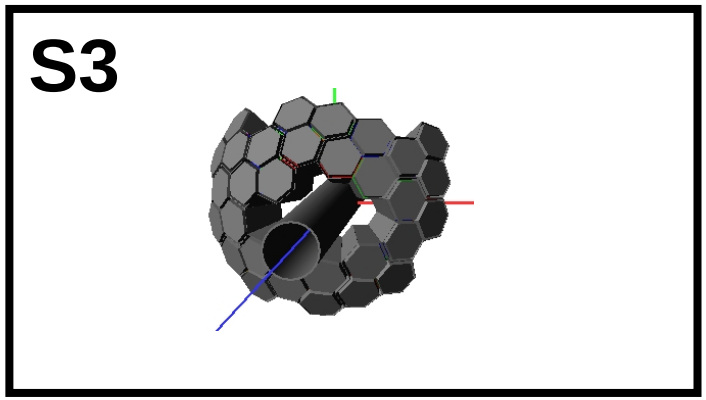
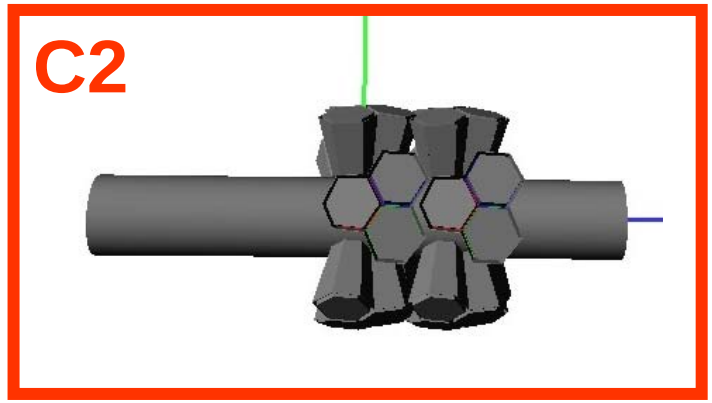
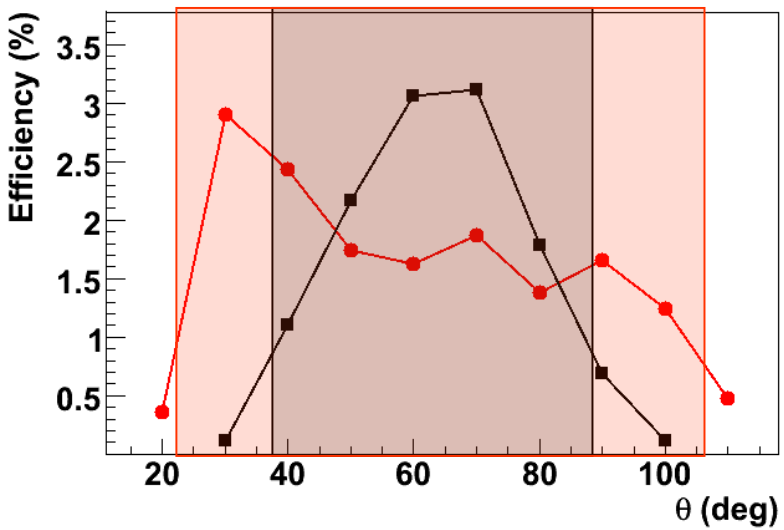
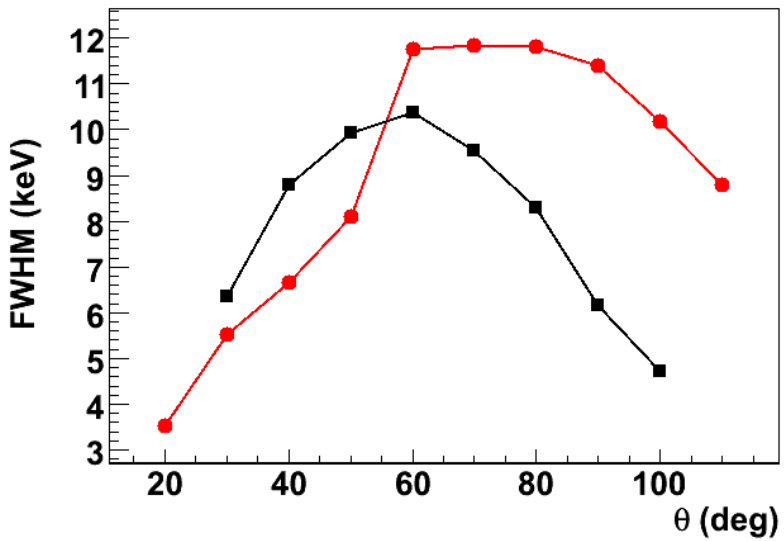
S- and C-Geometry Performance, Quantitative Comparison









<ΔE(S3)> = 10.3 keV

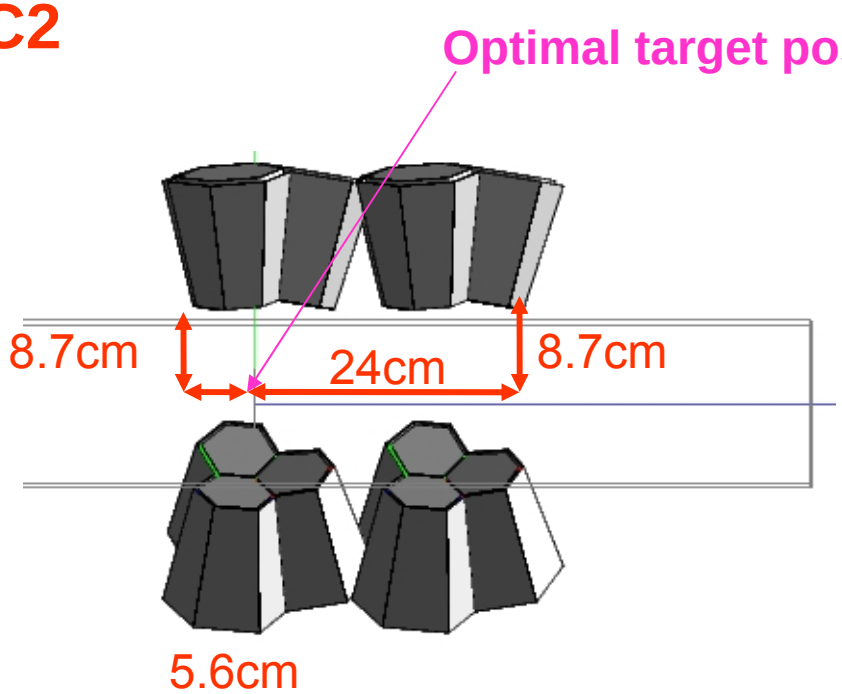
<ΔE(C2)> = 10.6 keV

Outline

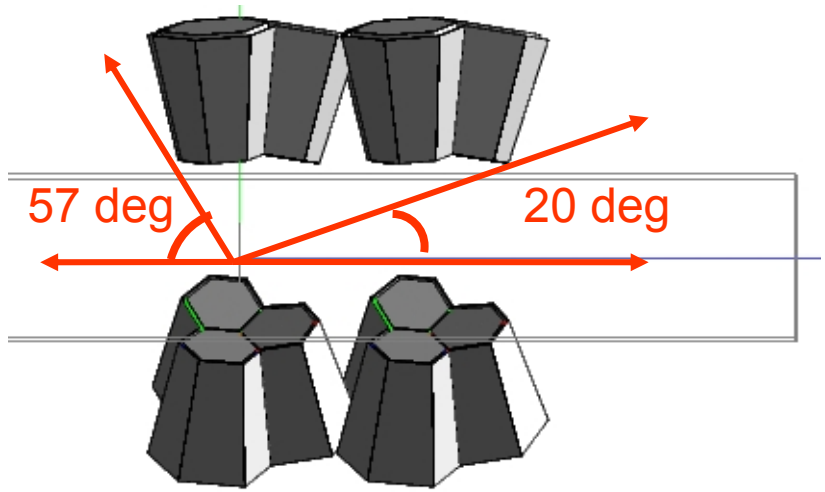
- Particular constraints for the setup at GSI
- Geometries: shell and compact setups
- Performance comparison
- Viability of additional γ-ray detectors: RISING, HECTOR, etc
- Gain in performance from 10 to 12 Clusters
- Outlook and conclusion

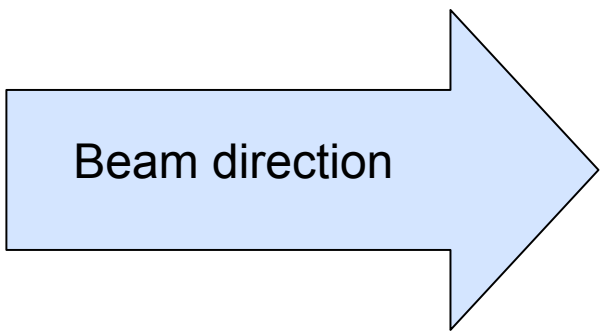
Solid angle occupied and free

C2



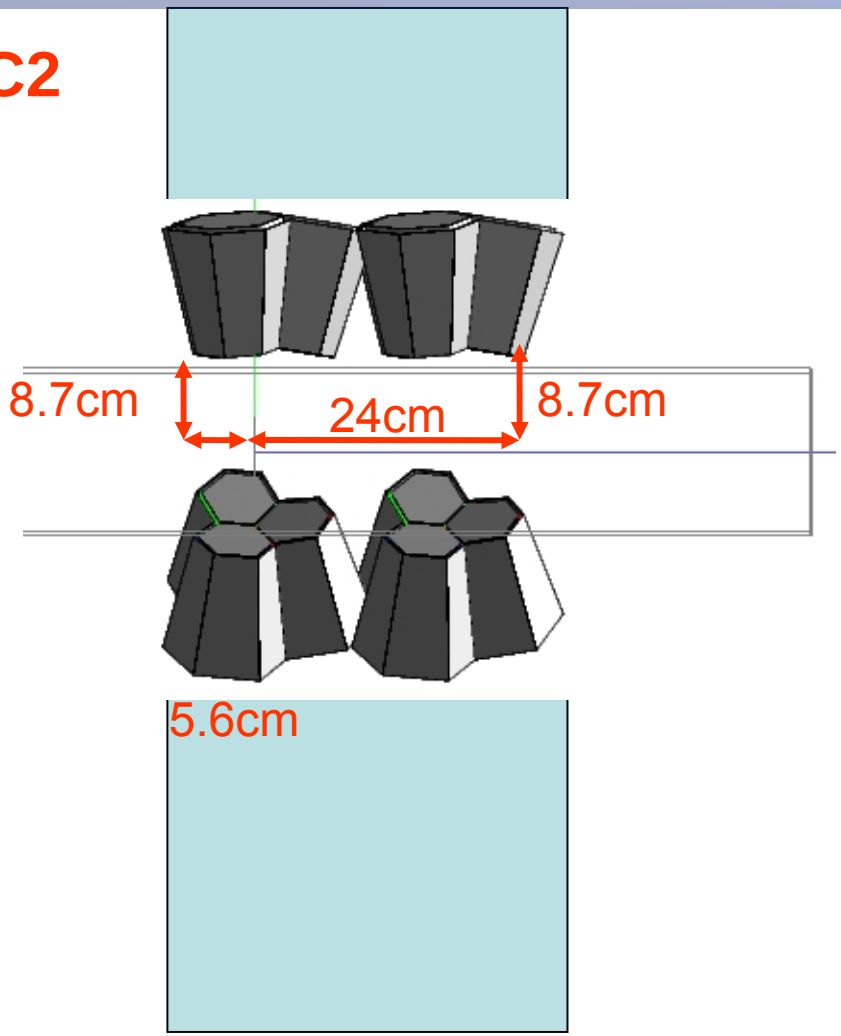
Approximate distances and angles

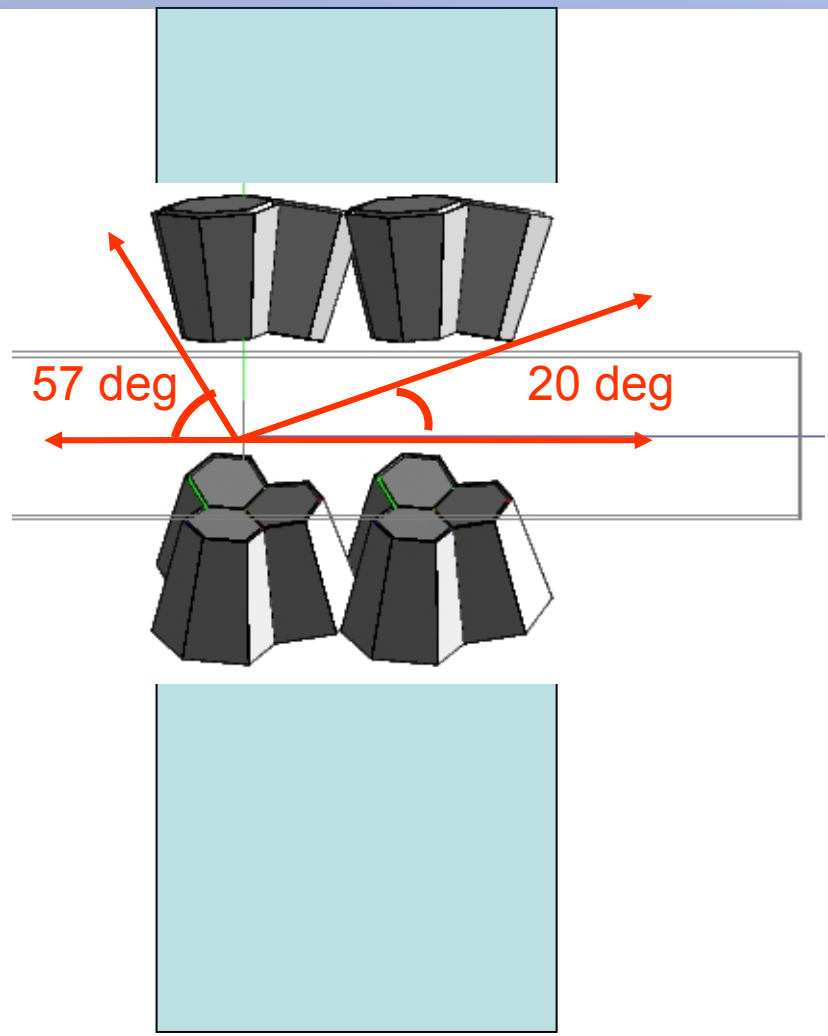




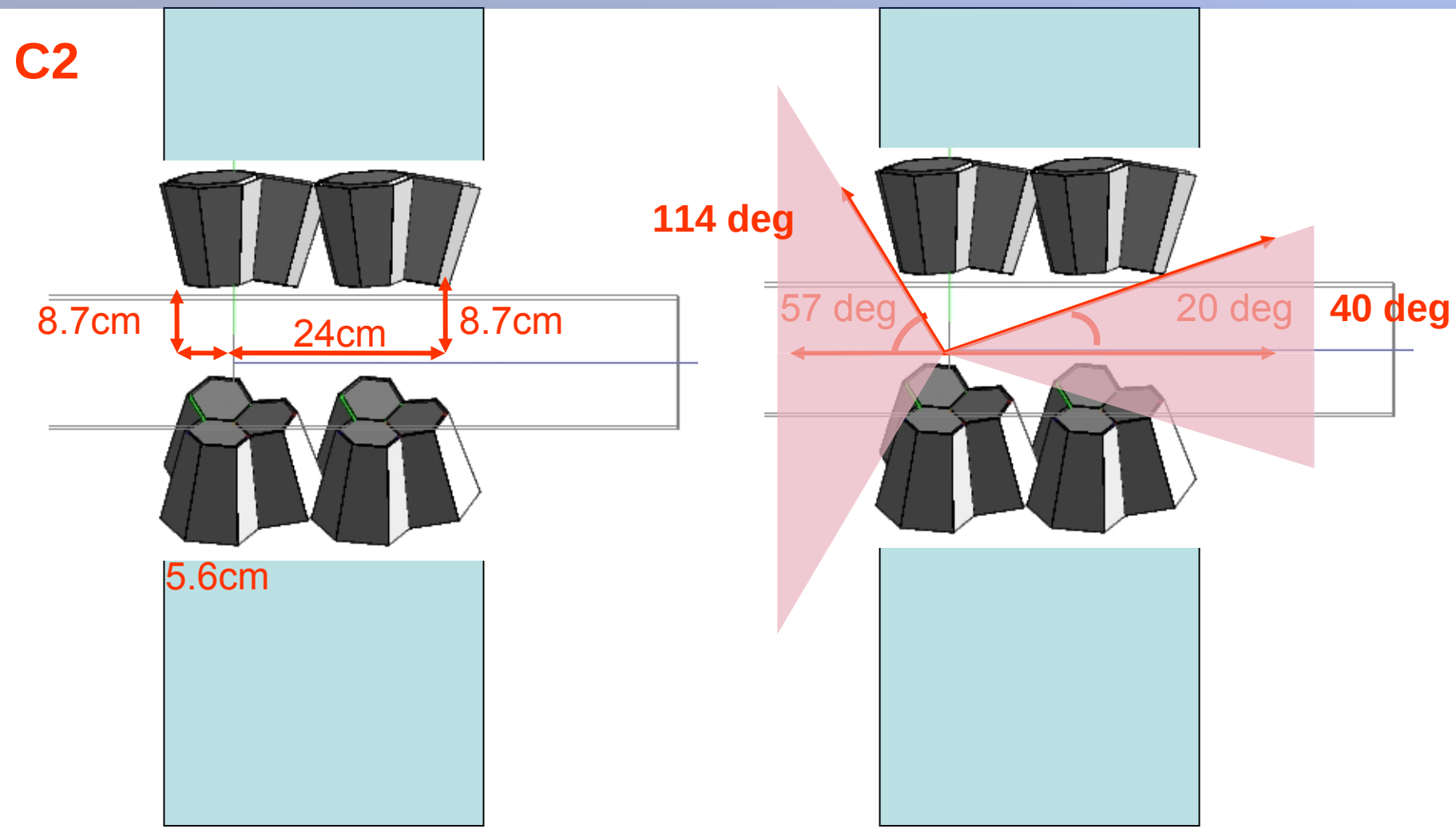
Solid angle occupied and free

C2



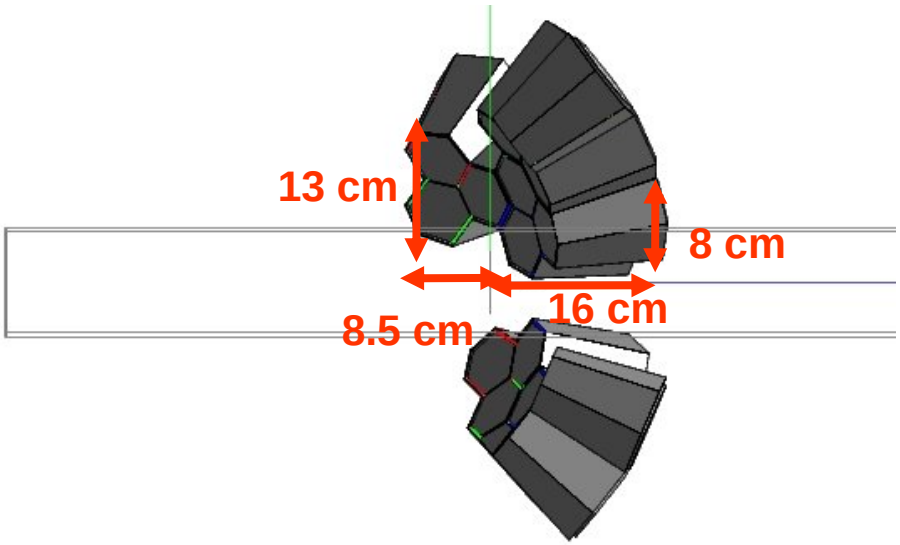


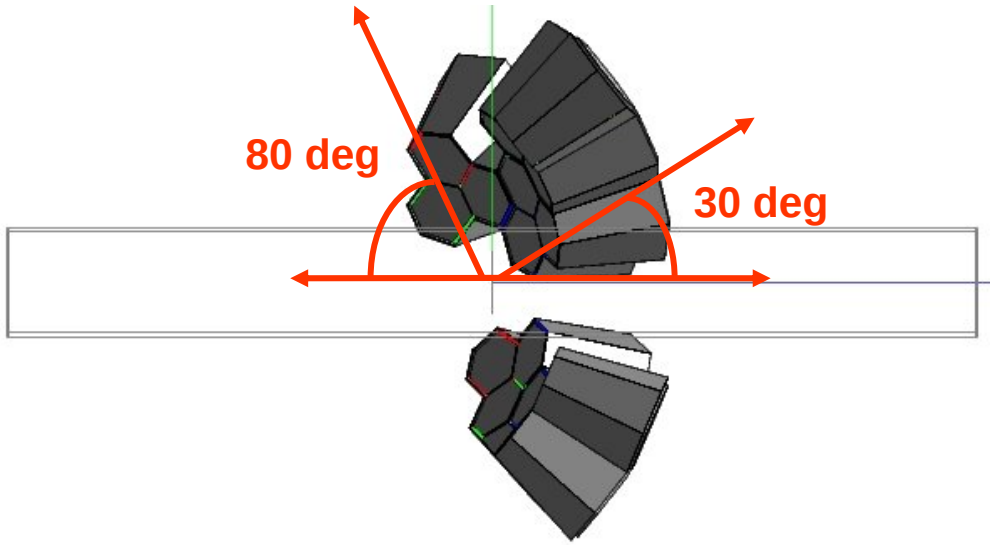
Solid angle occupied and free



Solid angle occupied and free

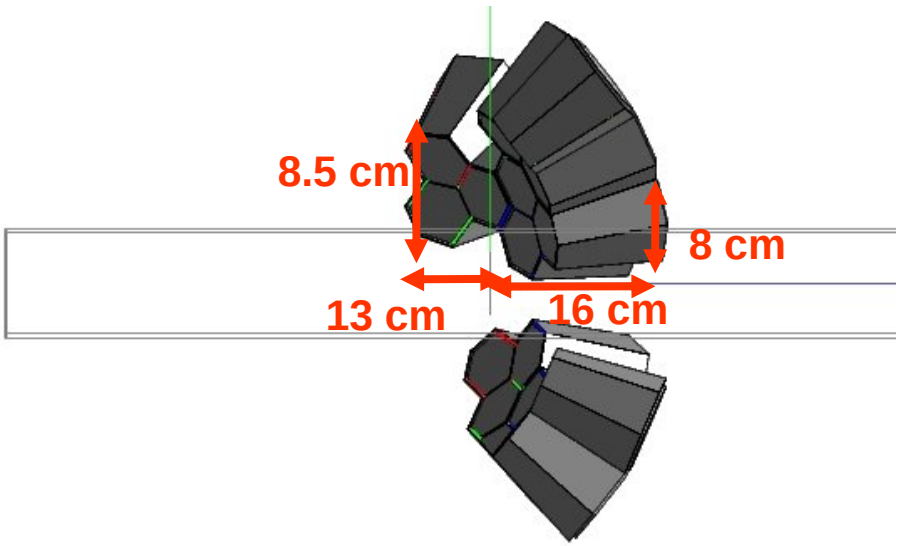
S3

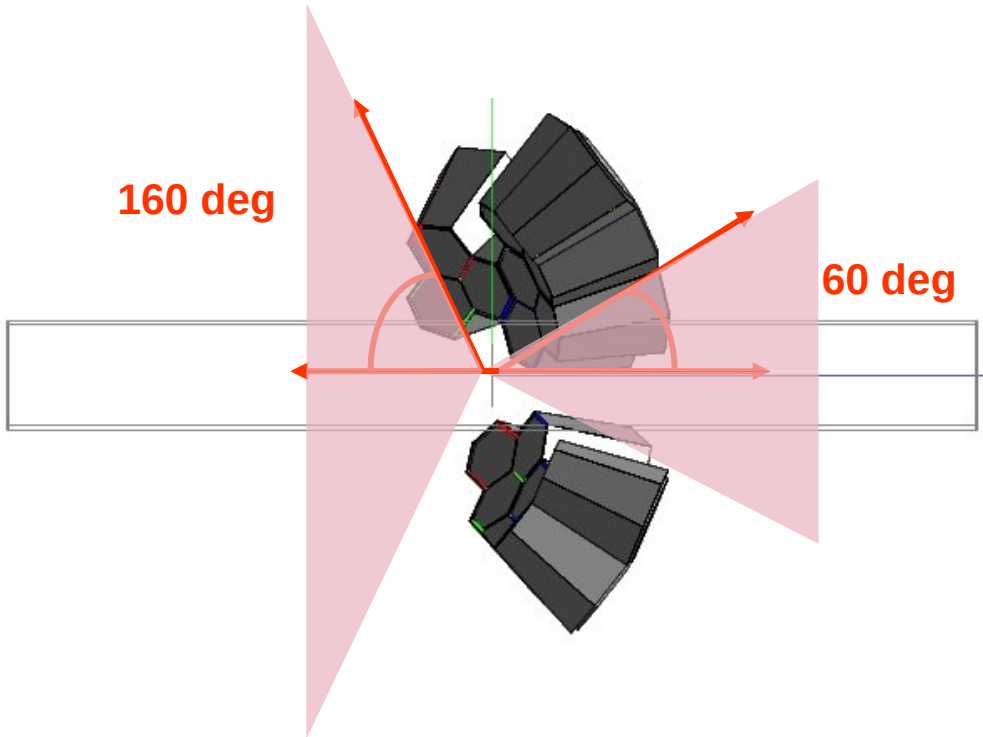




Solid angle occupied and free

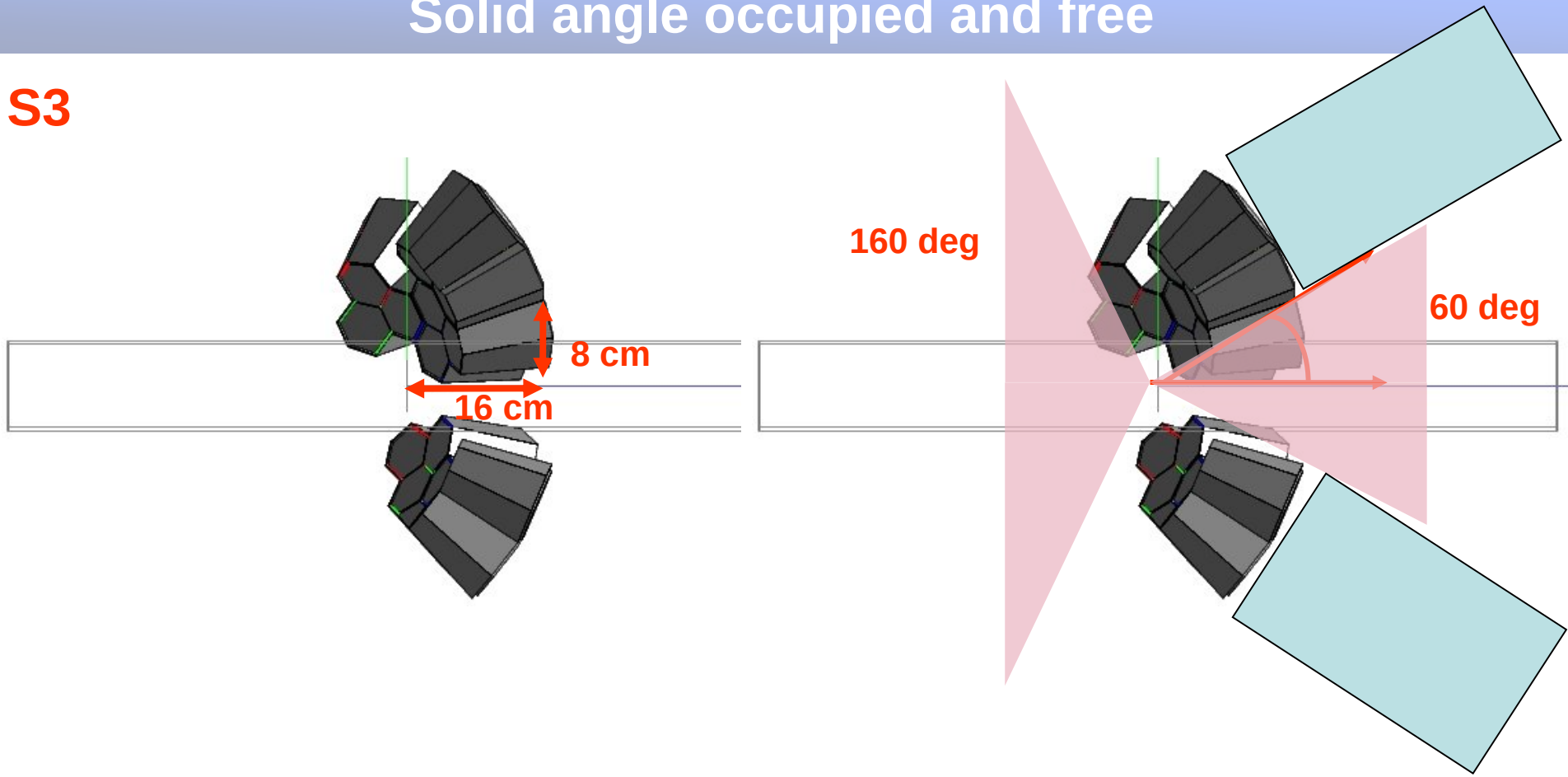
S3



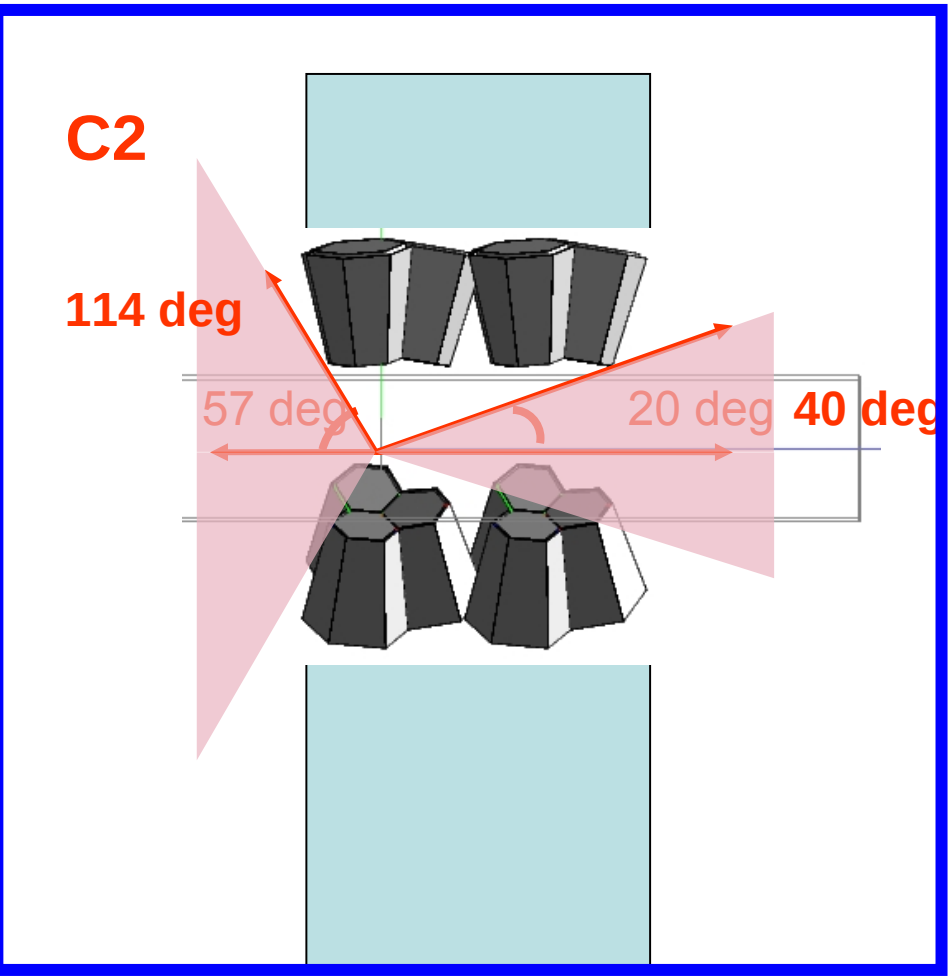


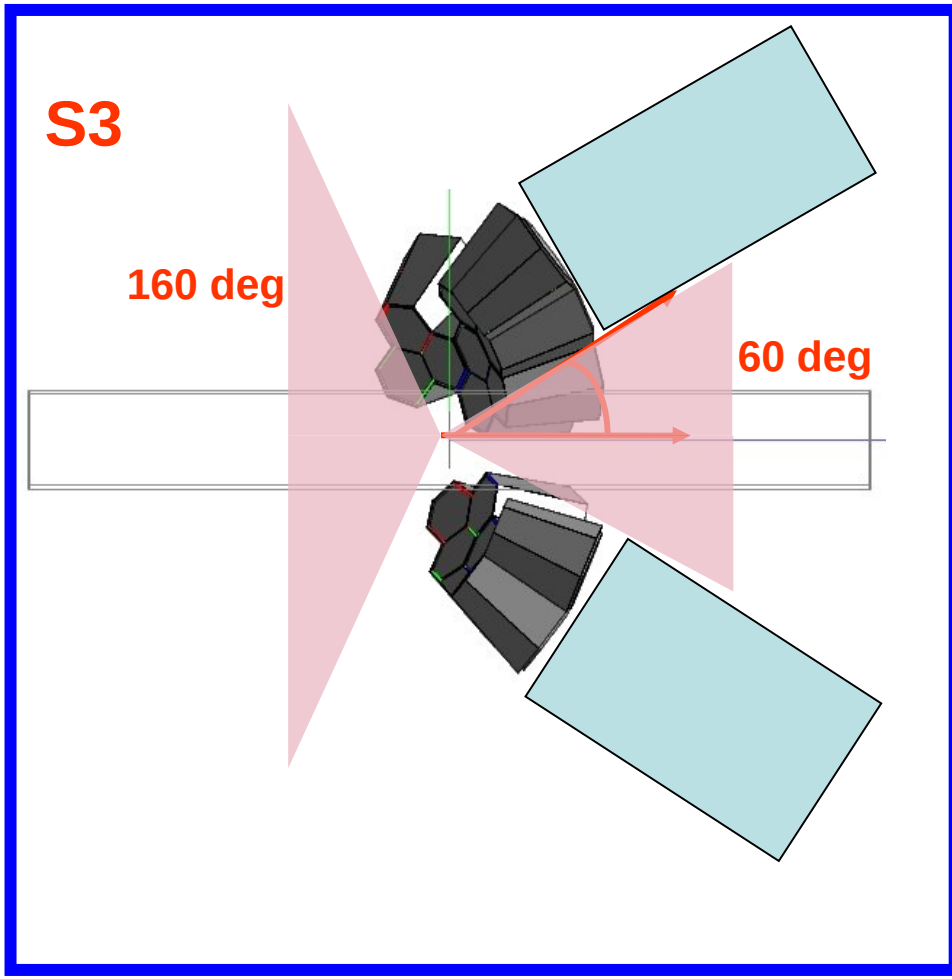
Solid angle occupied and free

S3

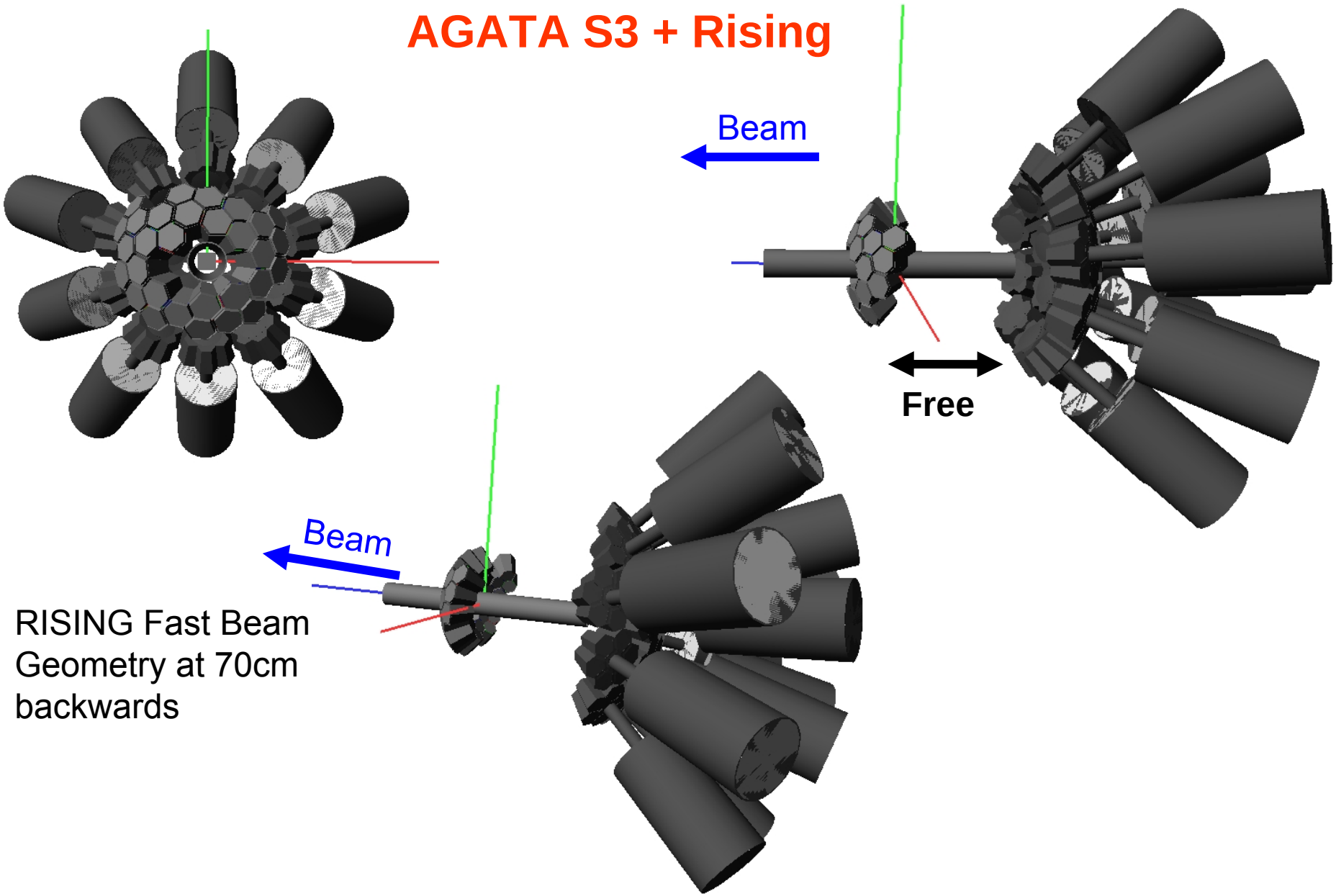


Solid angle occupied and free





Compatibility with other detection systems

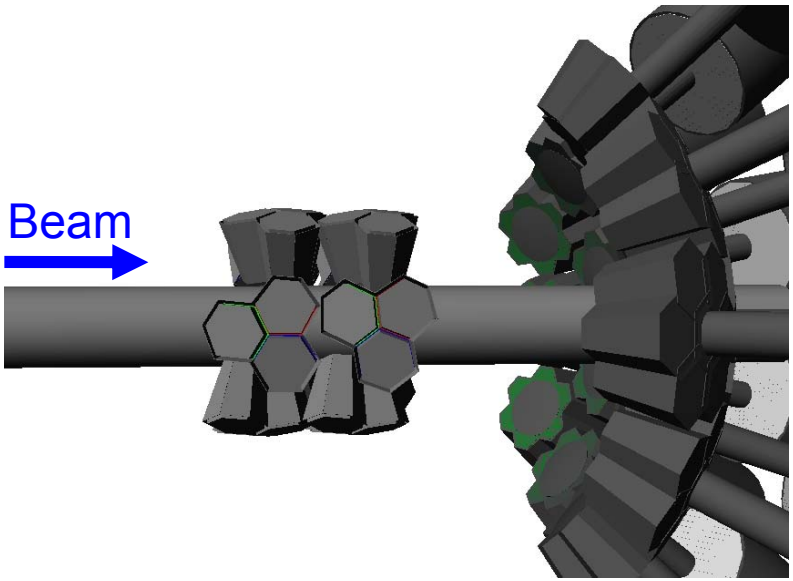


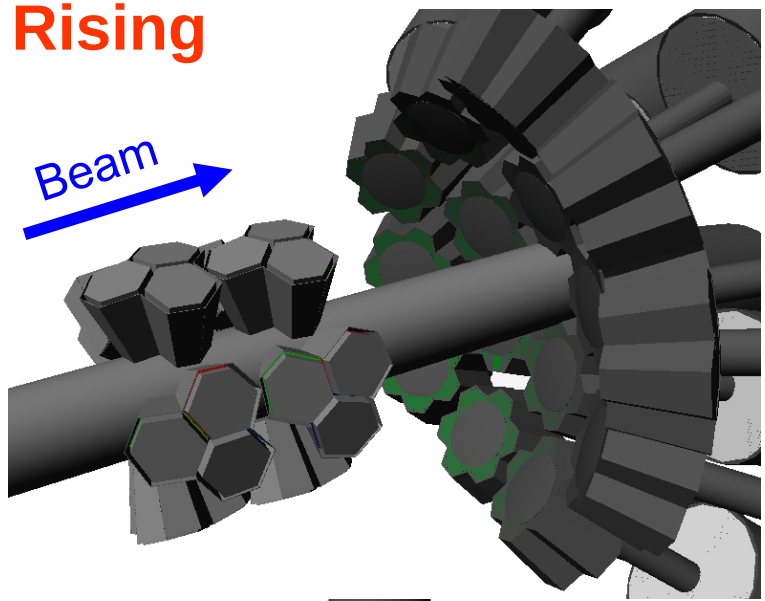
RISING Fast Beam Geometry at 70cm backwards

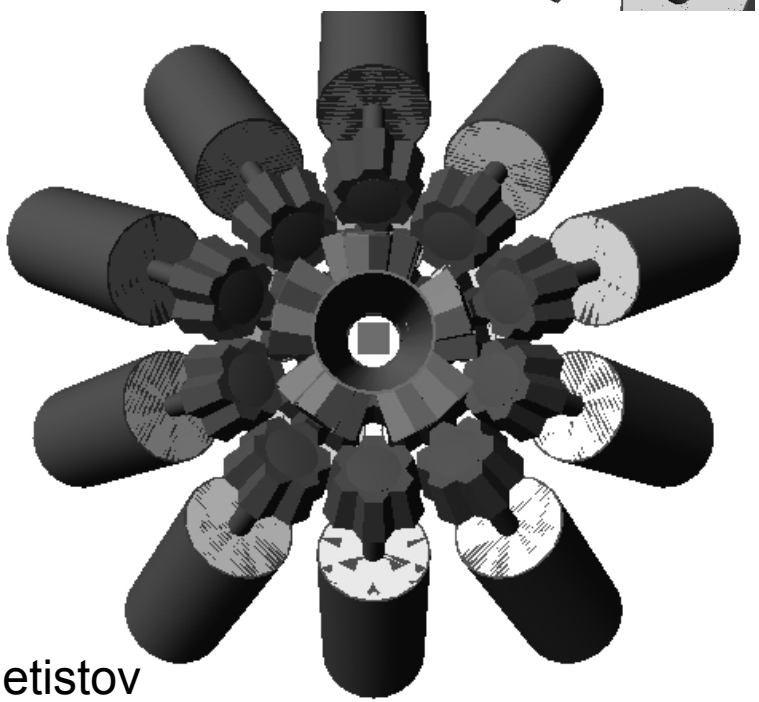
RISING Geant4 Geometry courtesy of Pavel Detistov

Compatibility with other detection systems

AGATA C2 + Rising



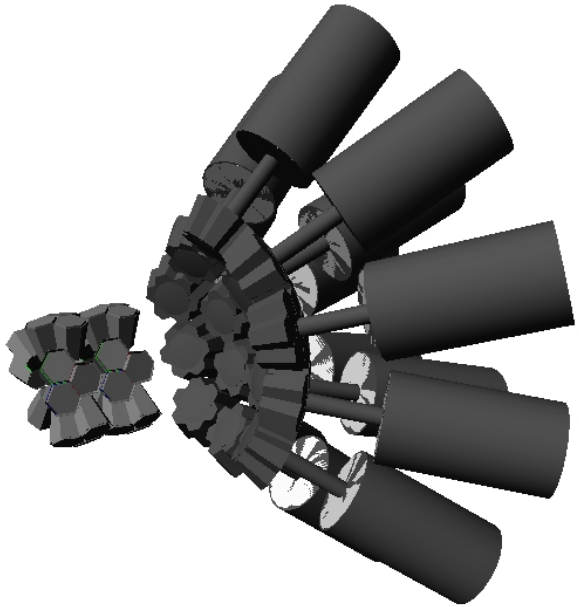


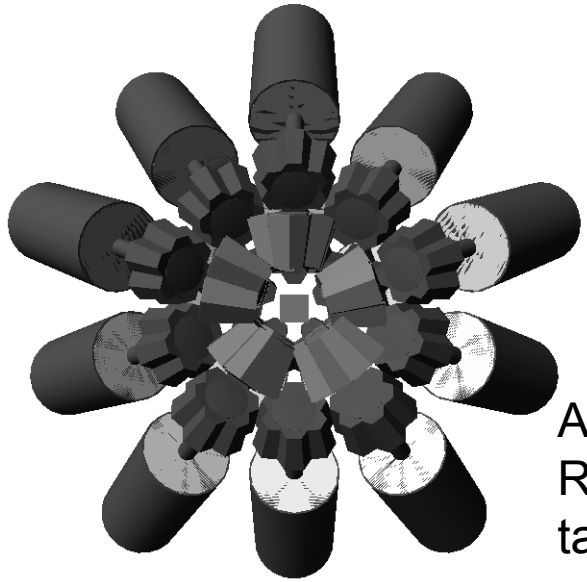


RISING Fast Beam Geometry at 70 cm forwards

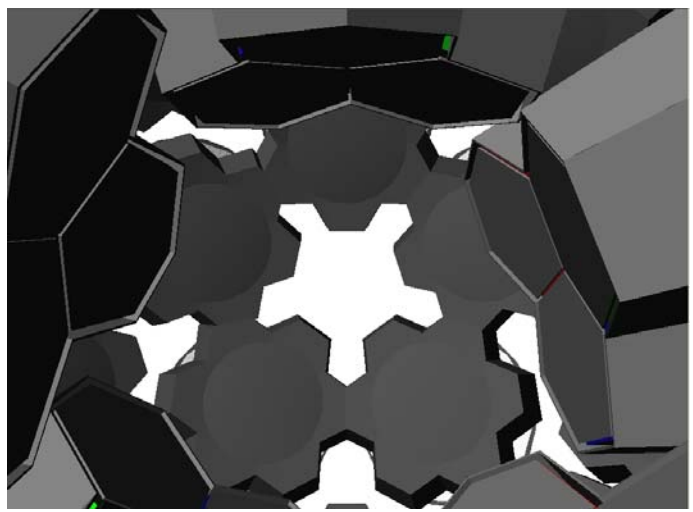
RISING Geant4 Geometry courtesy of Pavel Detistov

Compatibility with other detection systems





At least the inner ring of RISING is visible from the target position, 1% gain in efficiency (?)



RISING Fast Beam Geometry at 70 cm forwards

RISING Geant4 Geometry courtesy of Pavel Detistov

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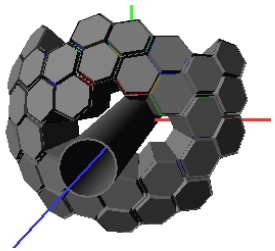
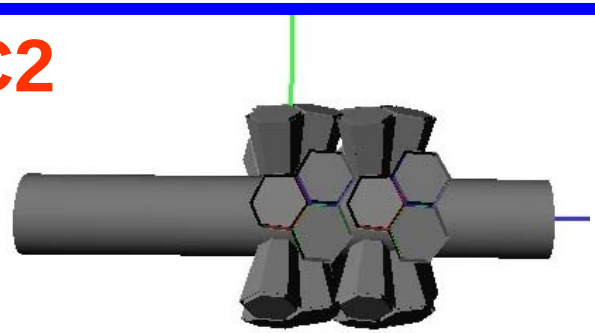
S- and C-Geometry Performance 12 Clusters

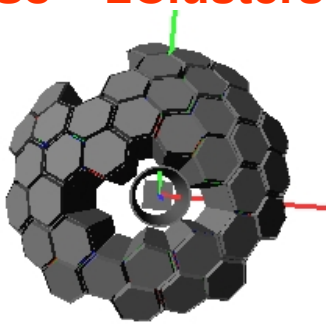
S3

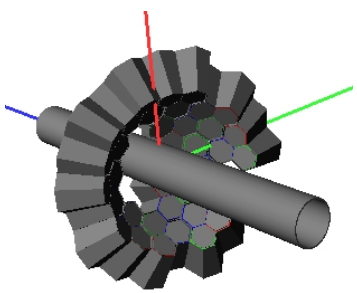


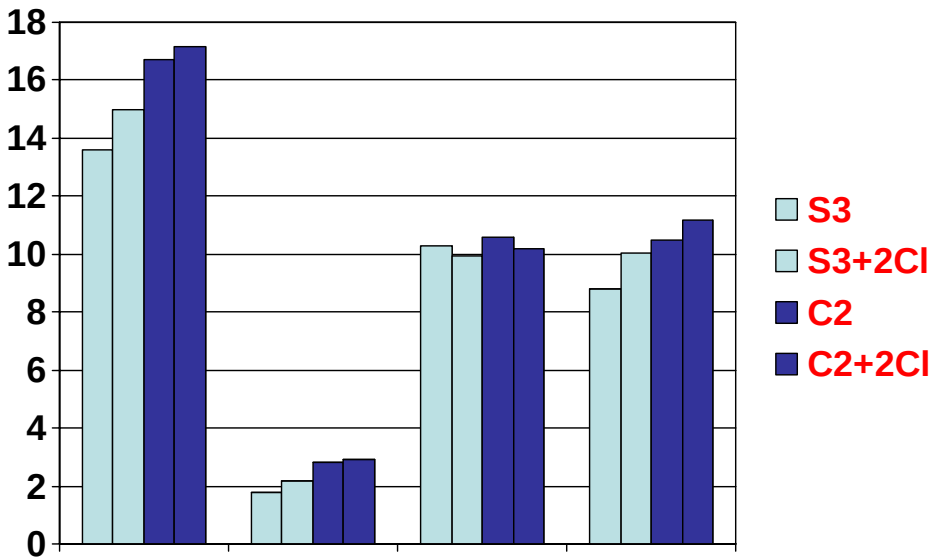
C2



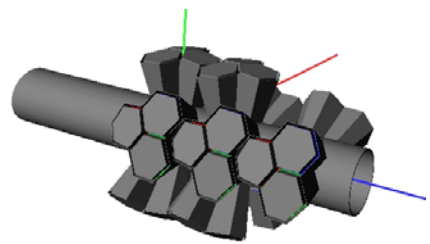
S3 + 2Clusters

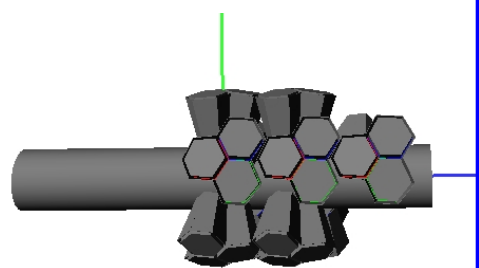






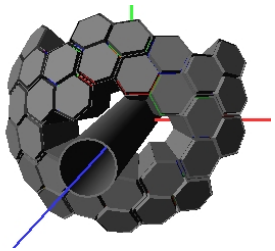
C2 + 2 Clusters



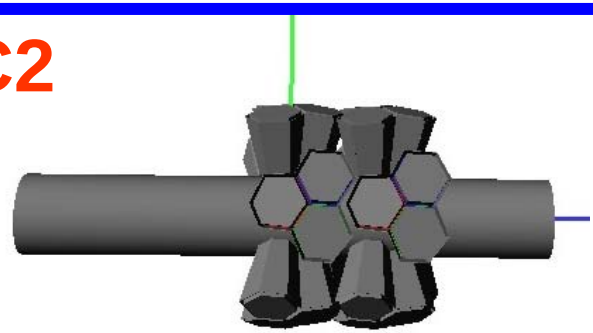


S- and C-Geometry Performance, Quantitative Comparison

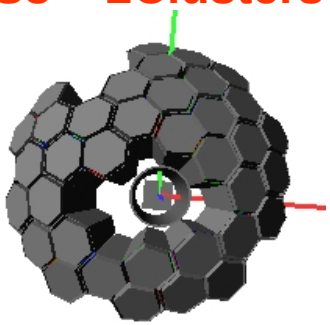
S3

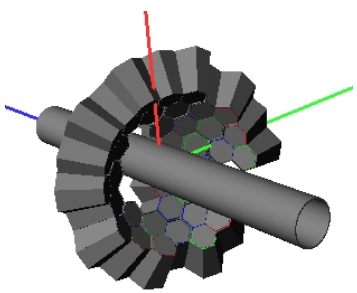


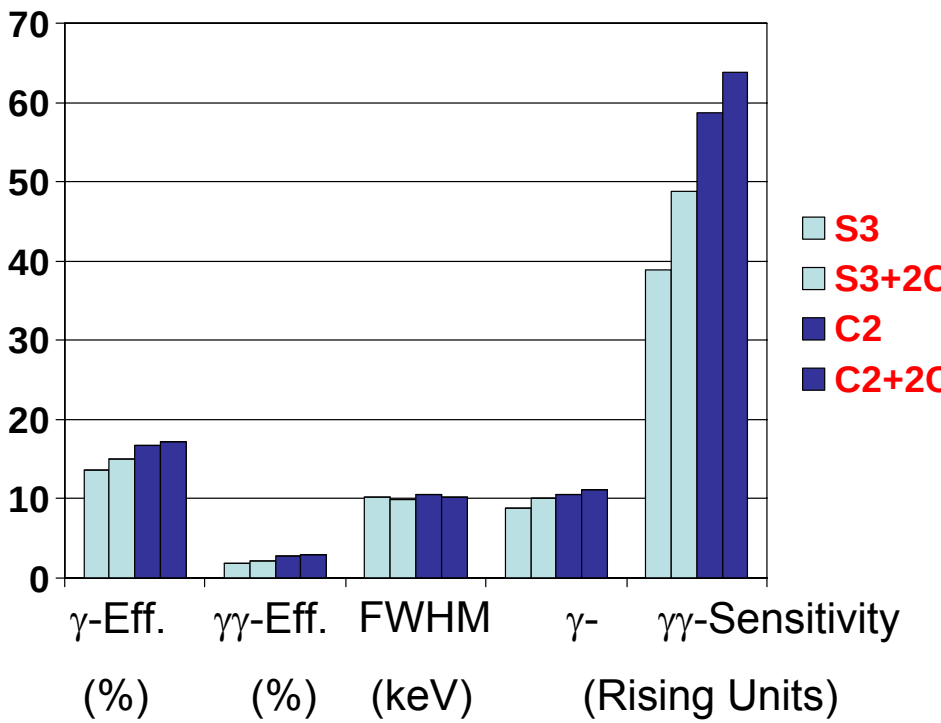
C2



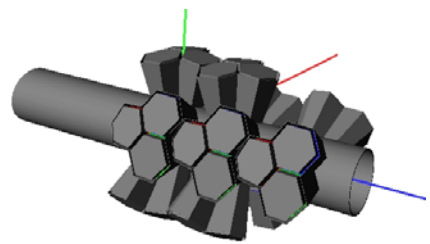
S3 + 2Clusters

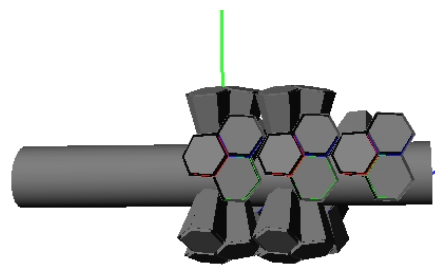




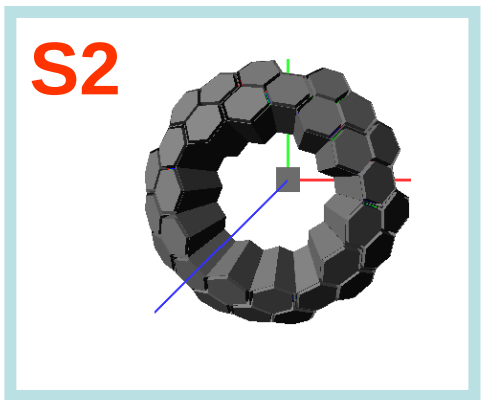


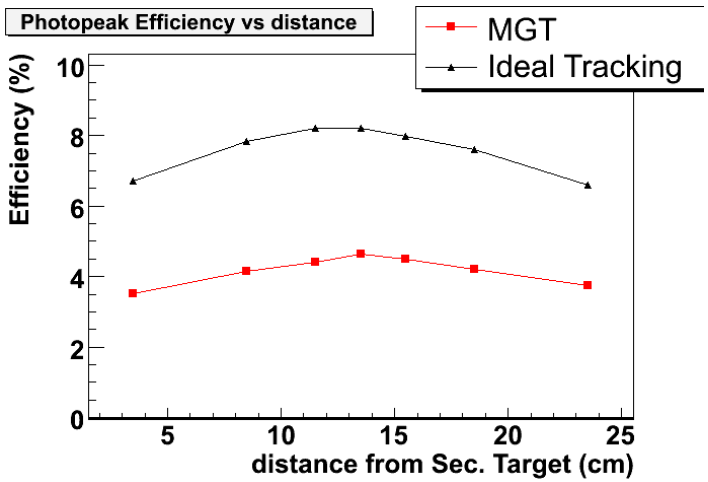
C2 + 2 Clusters



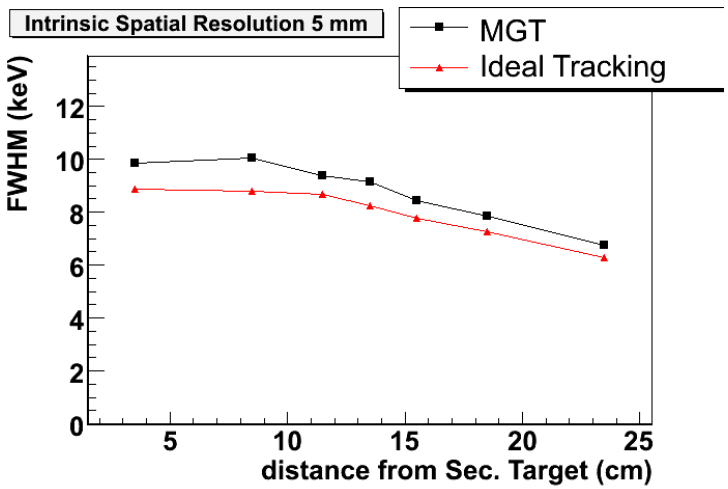


Realistic Tracking (mgt)





50% lower efficiency



10% worse resolution

List of Tasks for the **Working Group (17.07.2009)**

Geometry cases

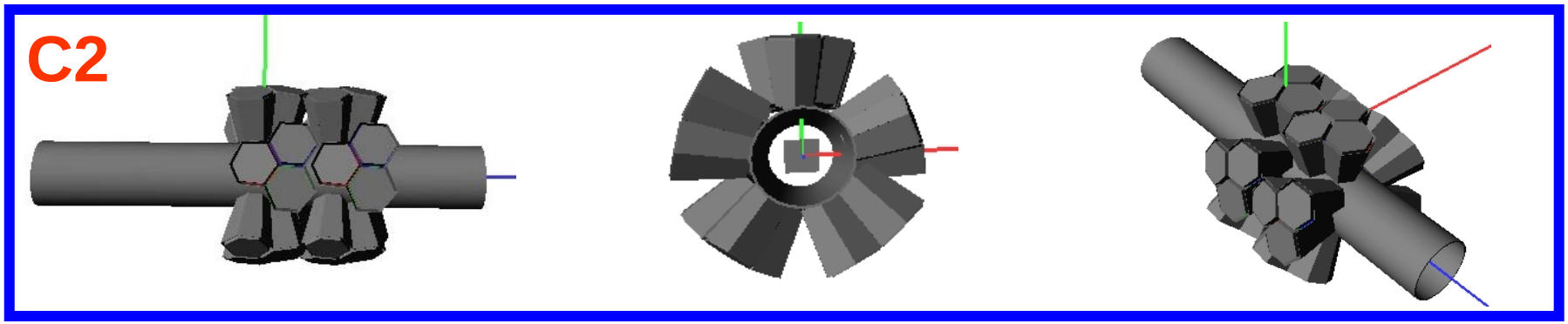
- Task 1: S2 + 5 Double Cluster detectors closing part of the central hole (15-16cm?). Remains shell with 5 crystals hole + pentagon hole
- Task 2: S3 + 1 Double Cluster detector closing part of the central hole (10-11 cm?). Remains shell with 4 crystals hole + pentagon hole.
- Task 3: previous + 4 Triple Clusters enlarging shell (for case one has 15 Clusters available).
- Task 4: C2 geometry, with clusters in 2nd ring pointing to target, and 3rd ring (15 Clusters total)

Conclusion:

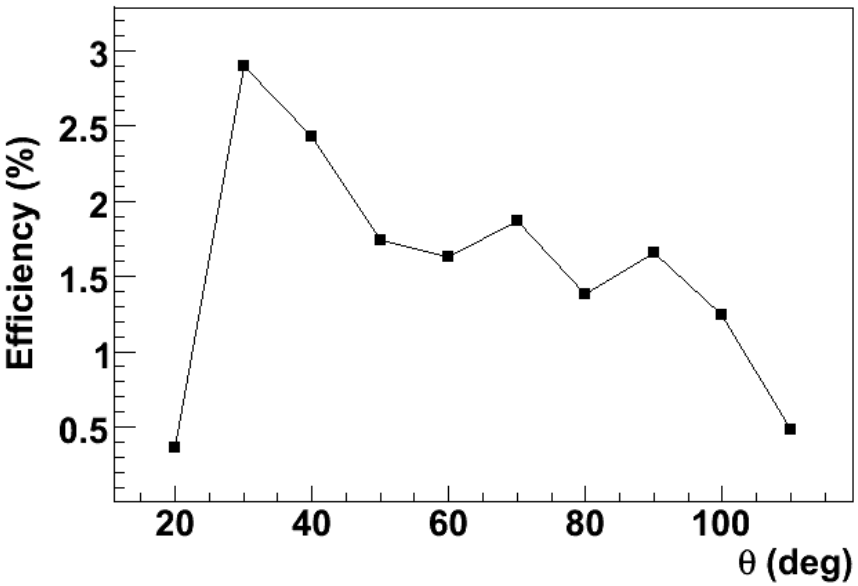
• Provided that 10 ATC detectors and 1 “ADC” detector (or more) are available, then a shell geometry (S3’ or S2’) shows a superior performance than any other possible cylindrical geometry (e.g. C2).

• REALISTIC γ-ray efficiencies between 7% and 9% can be achieved, which in combination with resolutions (FWHM) of 9-10 keV will provide a γ-ray sensitivity of more than 5 times the RISING sensitivity.

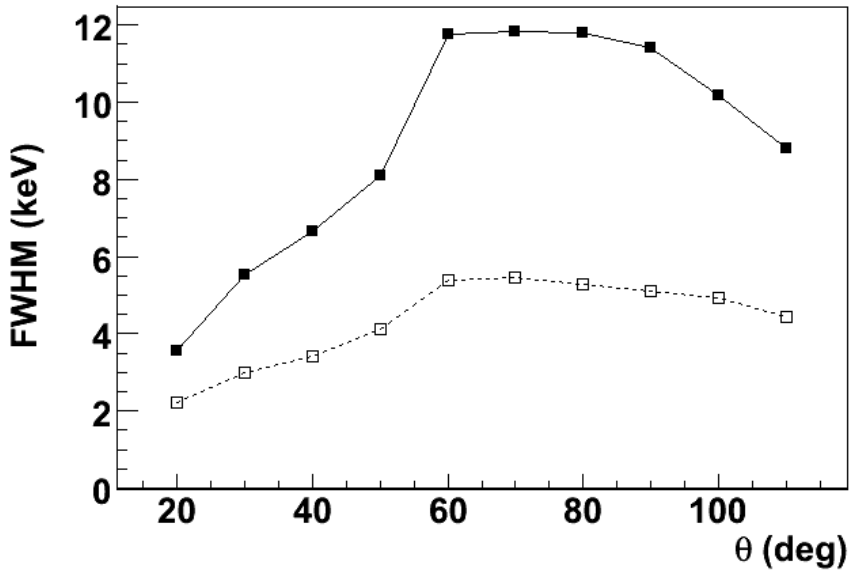
C2: Efficiency and Resolution angular dependence



Photopeak Efficiency

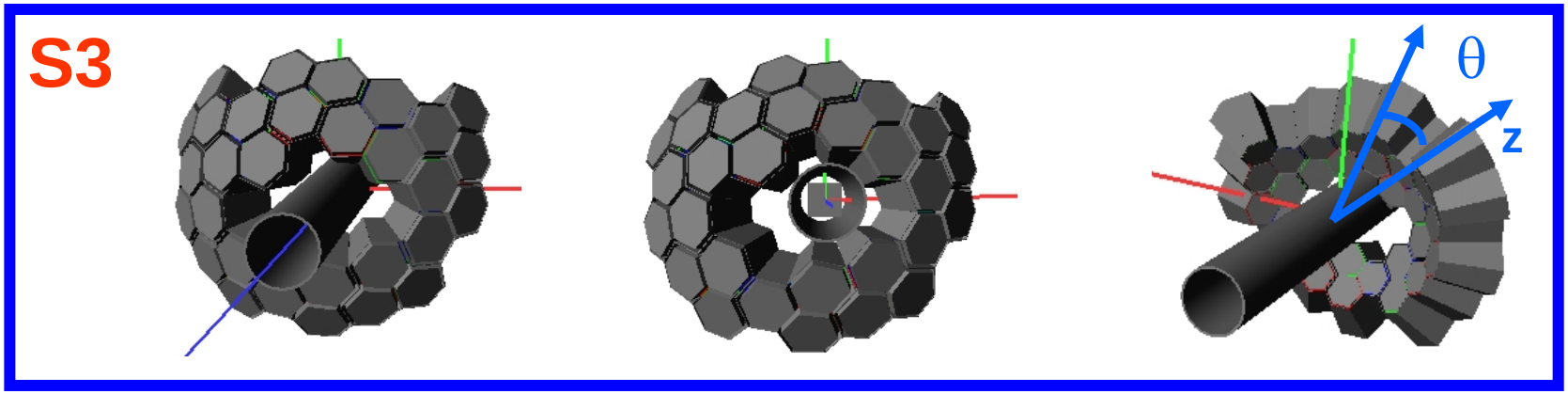


Energy Resolution

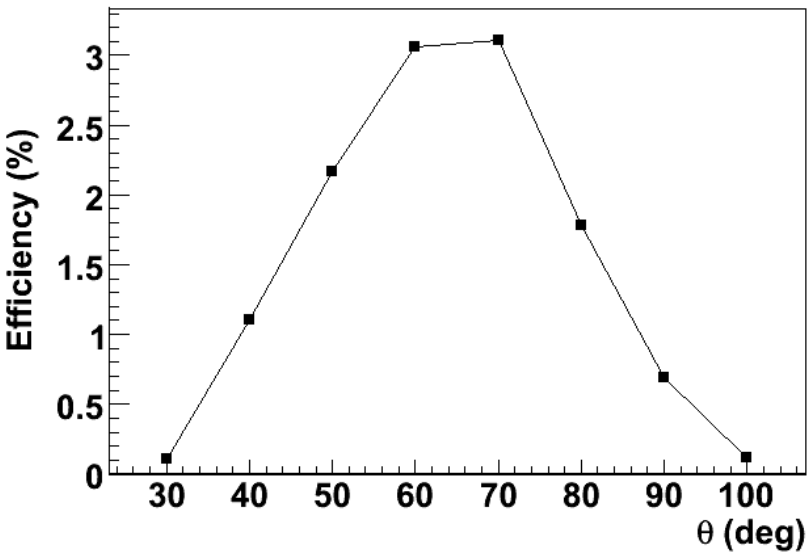


<ΔE(C2)> = 10.6 keV

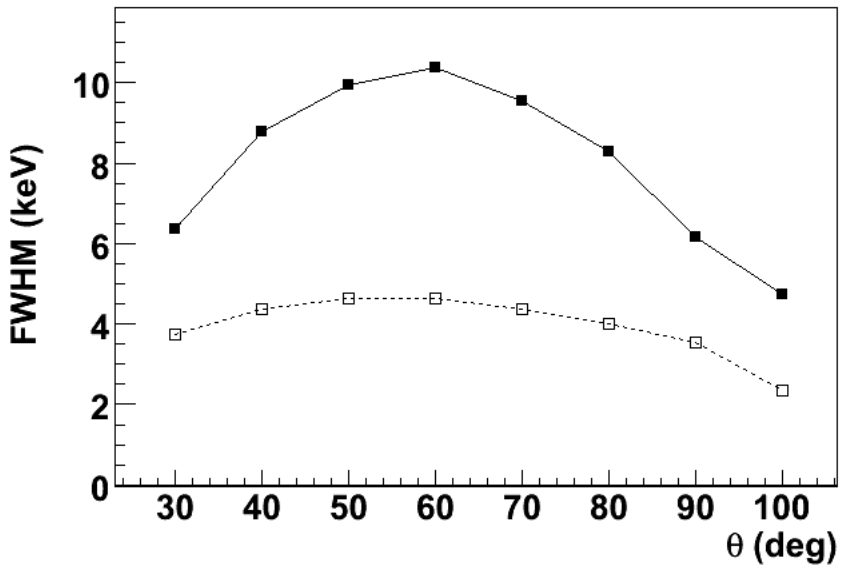
S3: Efficiency and Resolution angular dependence



Photopeak Efficiency



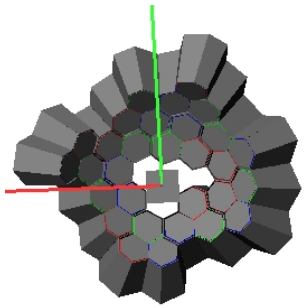
Energy Resolution



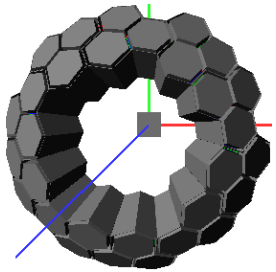
<ΔE(S3)> = 10.3 keV

S-Geometries Performance comparison: Resolution

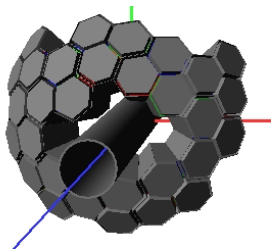
S1

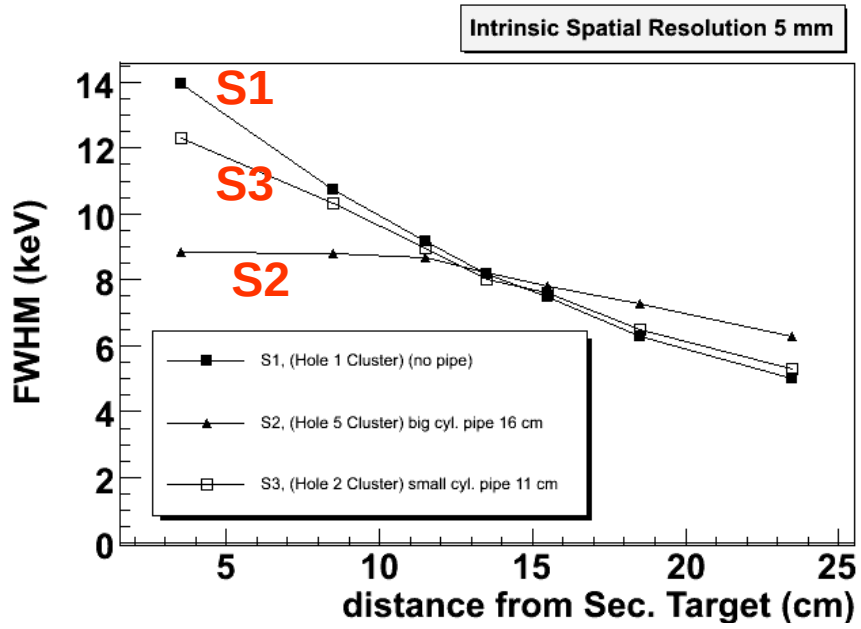


S2

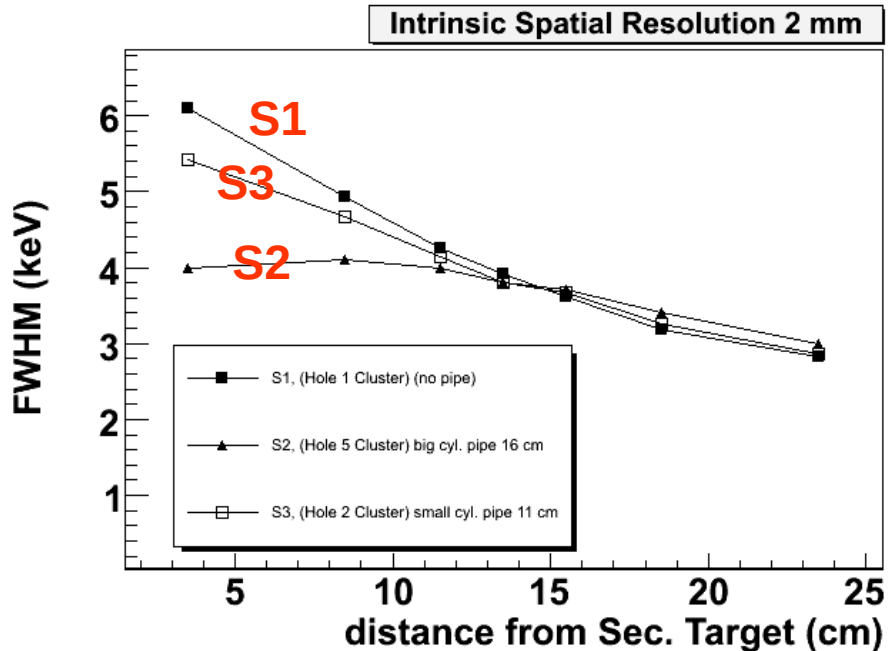


S3





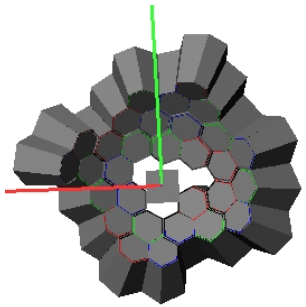
Δr_γ = 5 mm (fwhm)



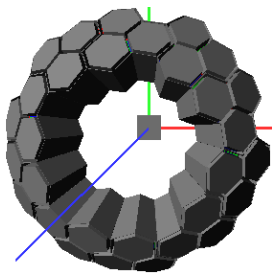
Δr_γ = 2 mm (fwhm)

Shell Geometries performance comparison: Summary

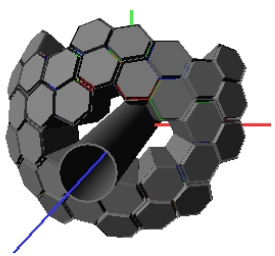
S1

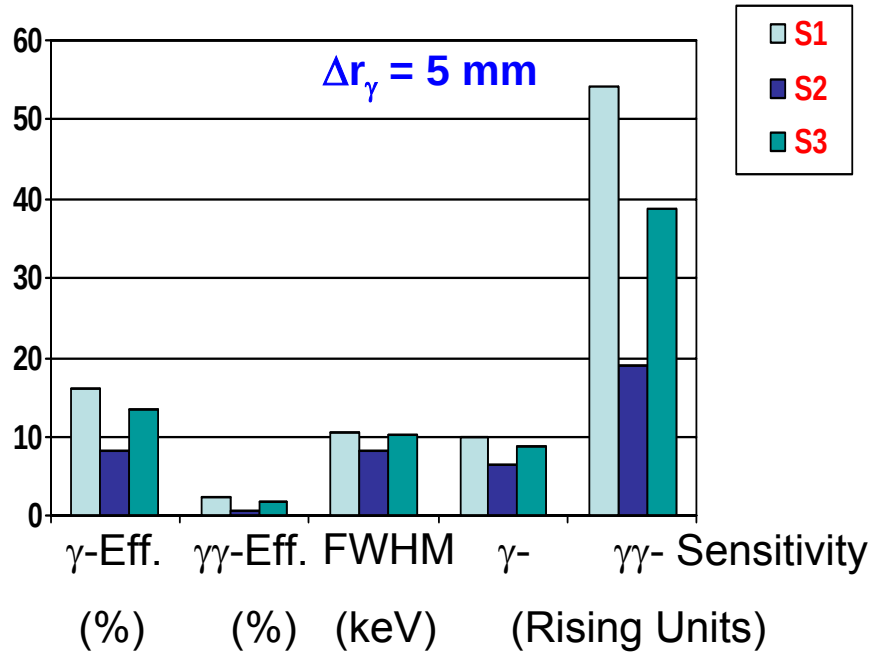


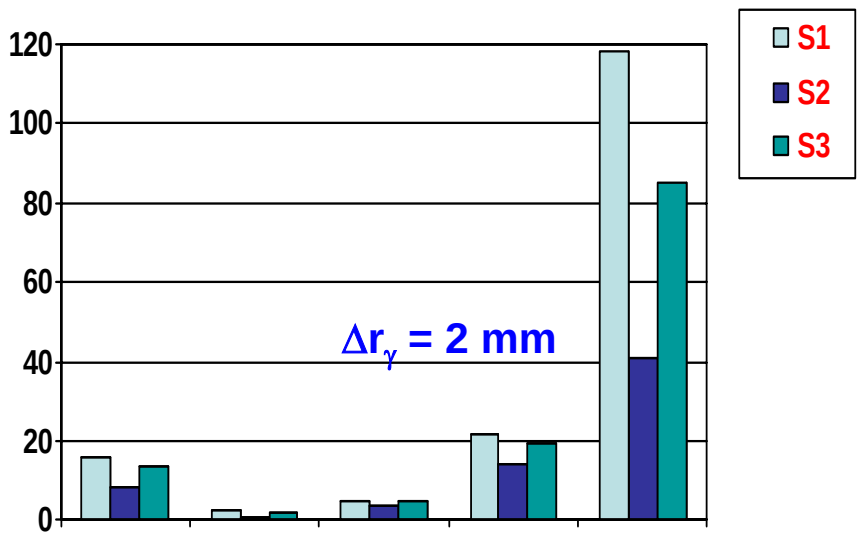
S2



S3

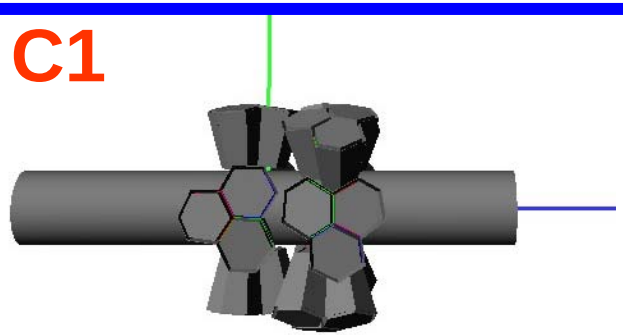




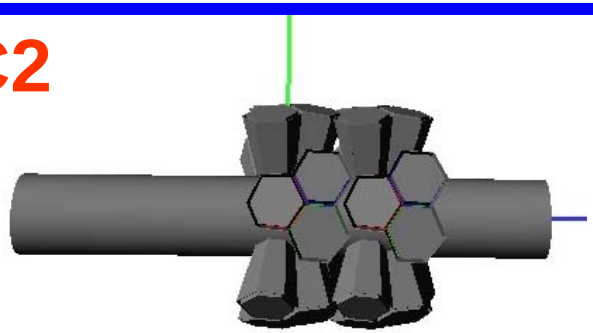


C-Geometries performance comparison: Summary

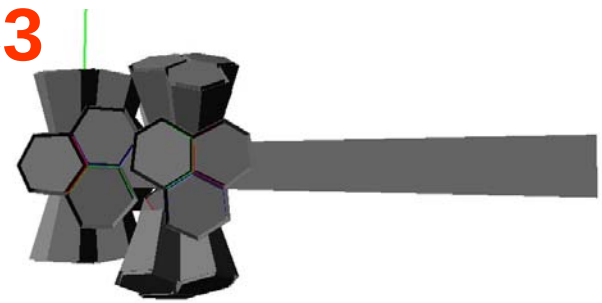
C1

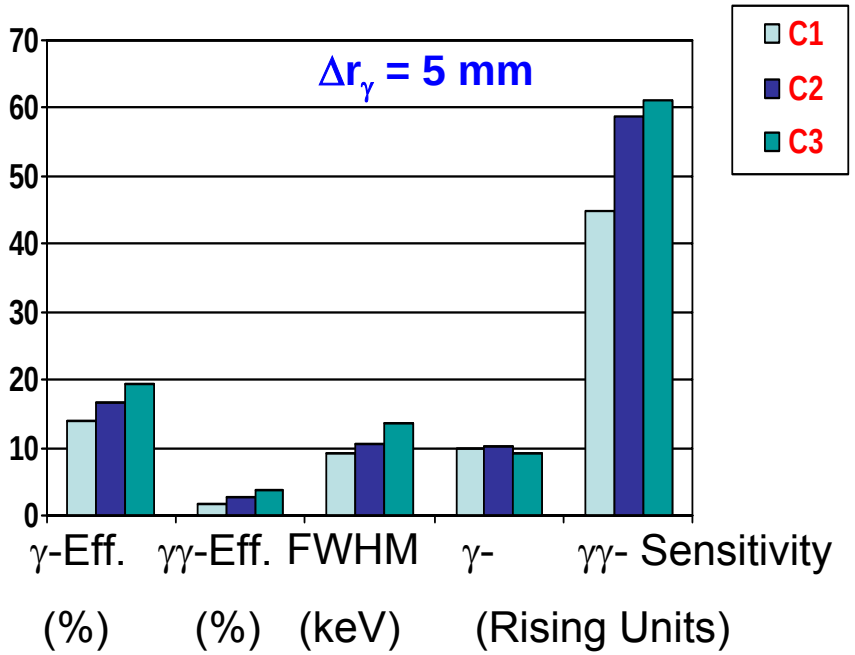


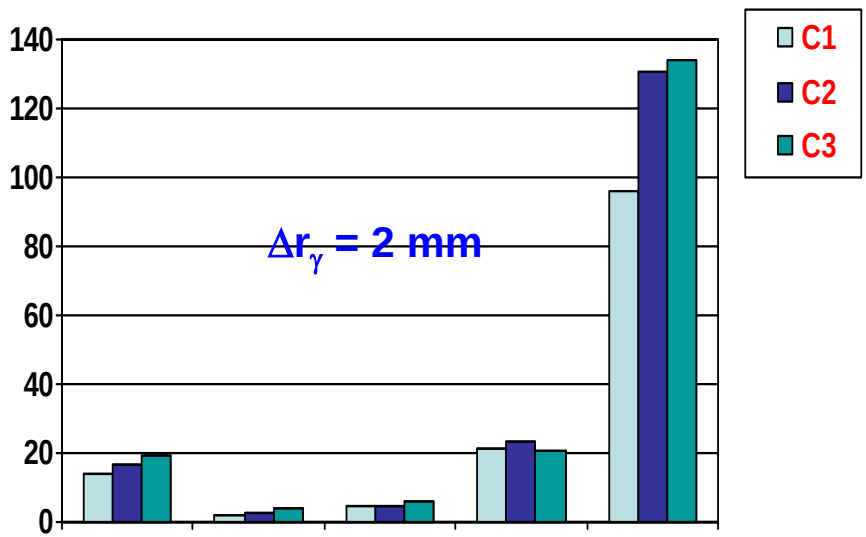
C2



C3

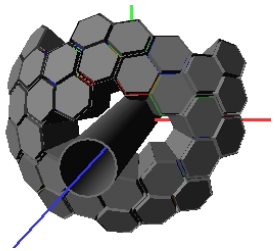




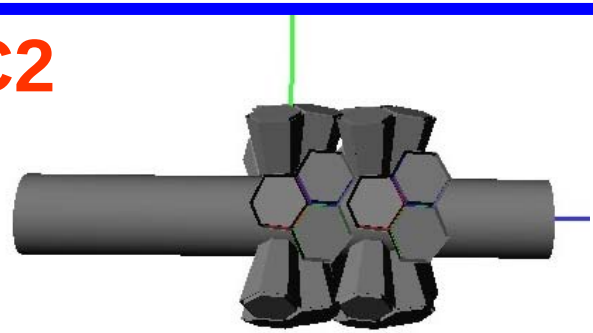


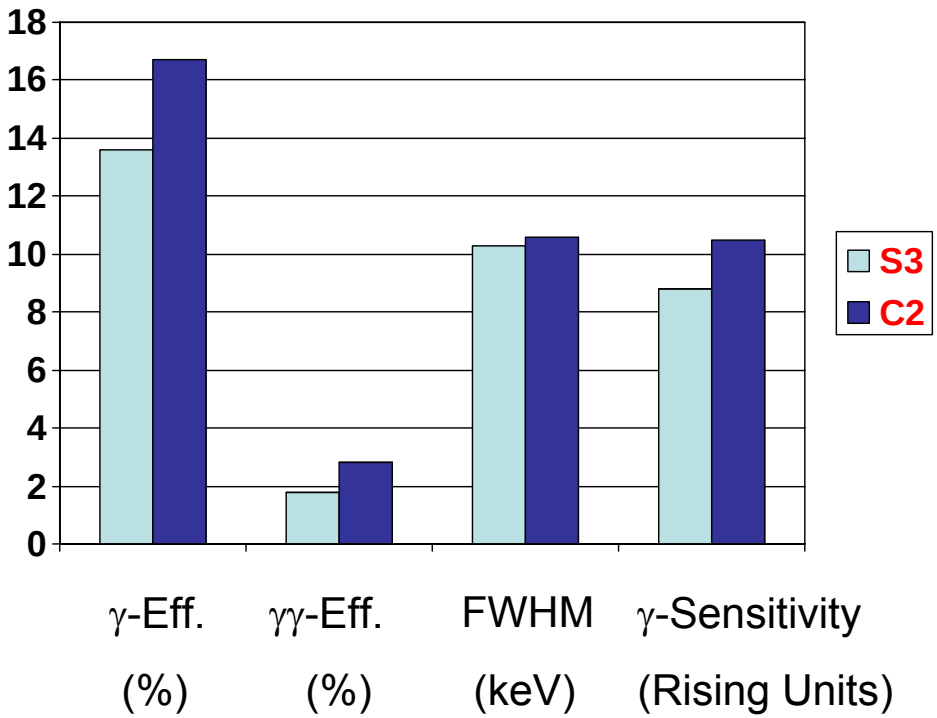
S- and C-Geometry Performance, Quantitative Comparison

S3

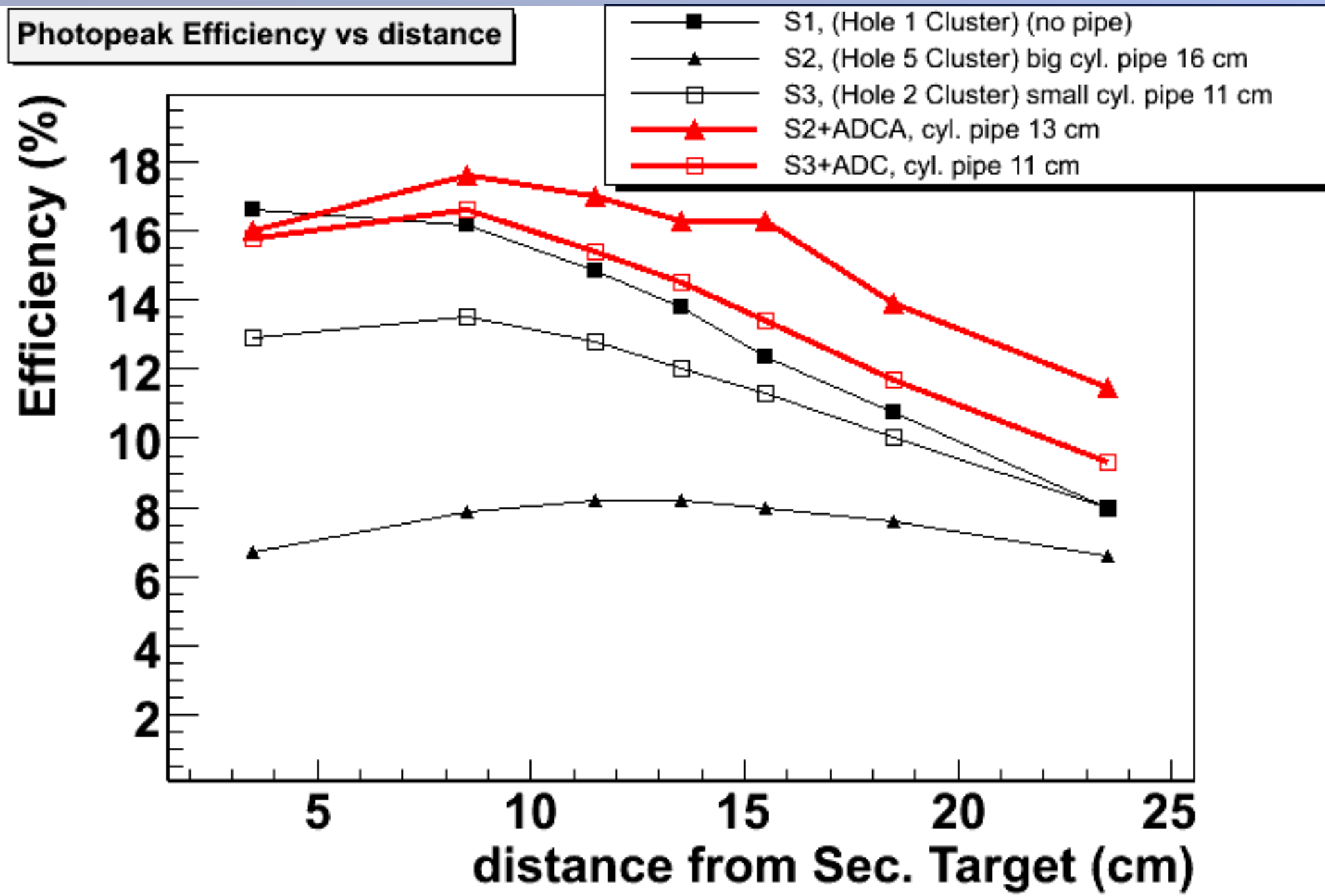


C2





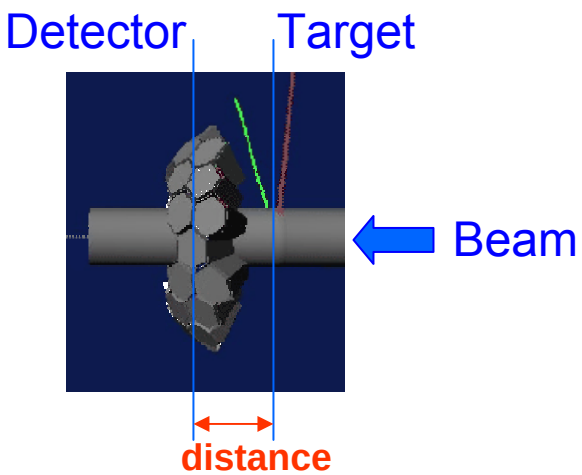
S-Geometries Performance comparison: Efficiency

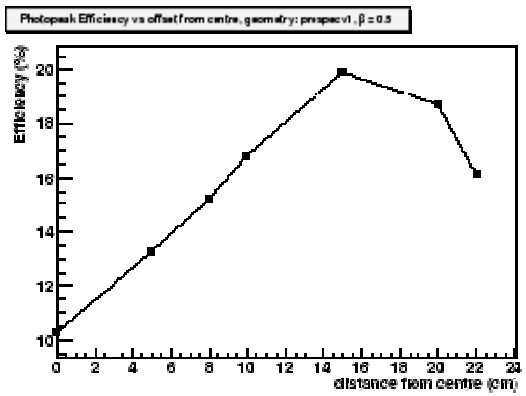


Performance comparison: general aspects

- Systematic study of efficiency and resolution vs. distance for all geometries

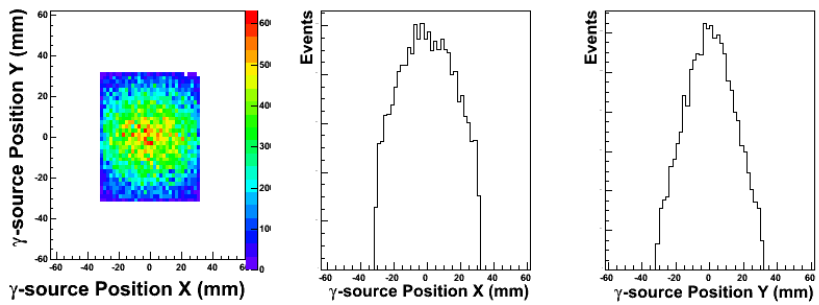
- "Reference physics case": (GEANT4 AGATA code from E.Farnea et al.)
  - ➡ $E_{\gamma,o}$ = 1 MeV, recoil nucleus at β = 0.43 (E = 100 MeV/u), Mγ = 1
  - ➡ Systematic study several distances sec. target – detector





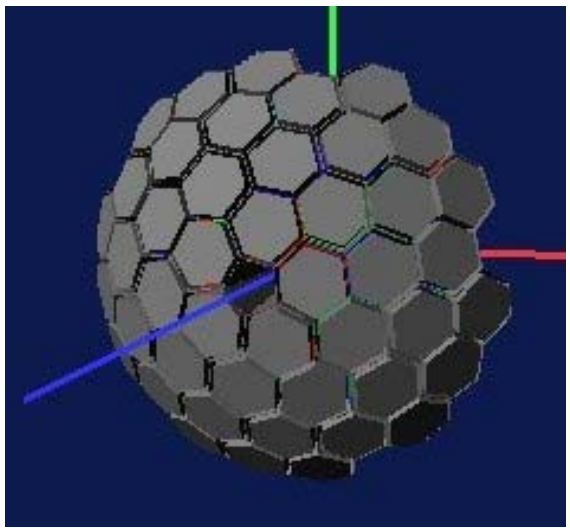
  - ➡ GSI FRS Spatial Beam Profile FWHM_x = 6 cm FWHM_y = 4 cm

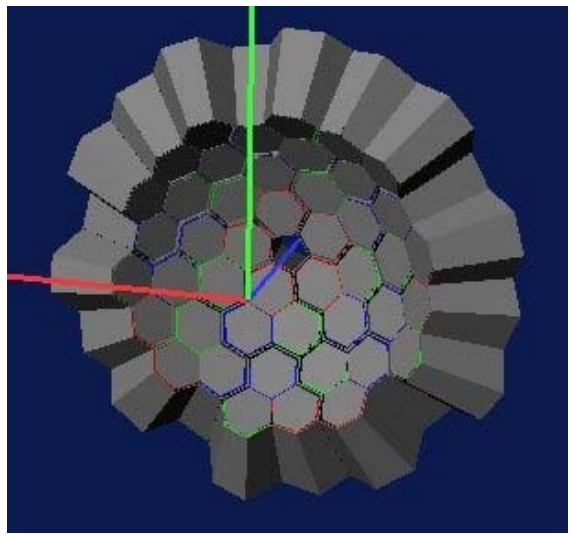
Active target
DSSSD

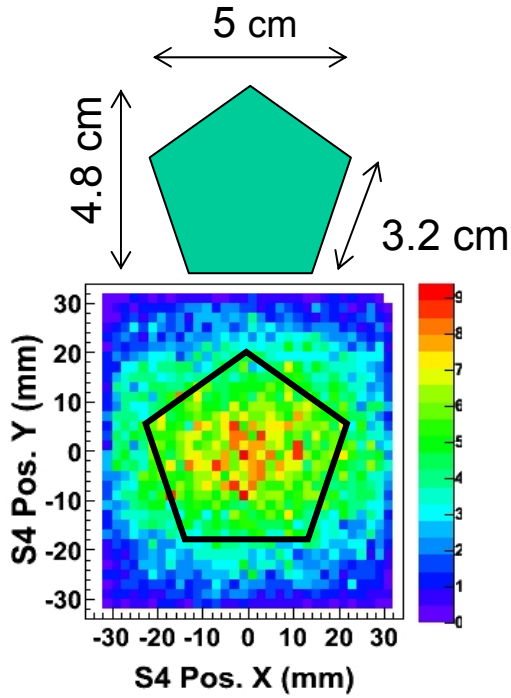


Particular constraints for the setup at GSI

- Ideal geometry (first approach, first step)







- two main constraints:

1. 15 cluster detectors will not be available yet in 2011/2012 (10-12 instead)
2. The beam hole (pentagon) is too small for the GSI beam size

AGATA + Plunger Simulation (Legnaro experiment)

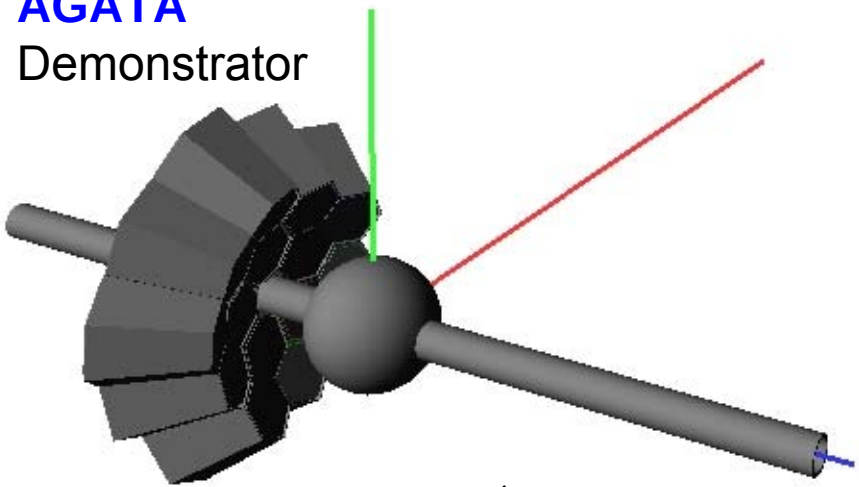
- AGATA Demonstrator (5 triple cluster) + Köln Plunger

AGATA
Demonstrator

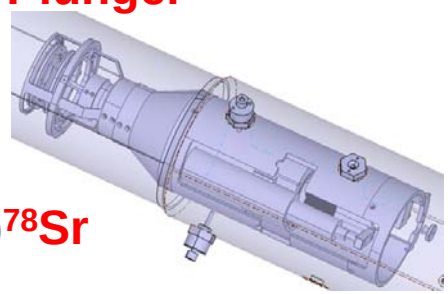
^{40}Ca

XTU-ALPI

120 MeV ^{40}Ca-Beam 1 pnA



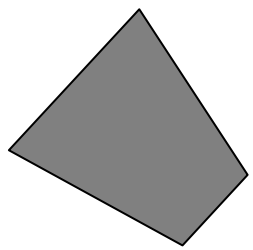
Köln Plunger

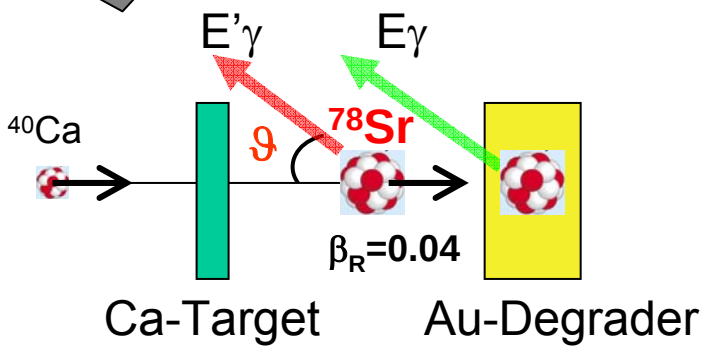


^{40}Ca(^{40}Ca, 2p)^{78}Sr

Ca-target 400 μg/cm^2

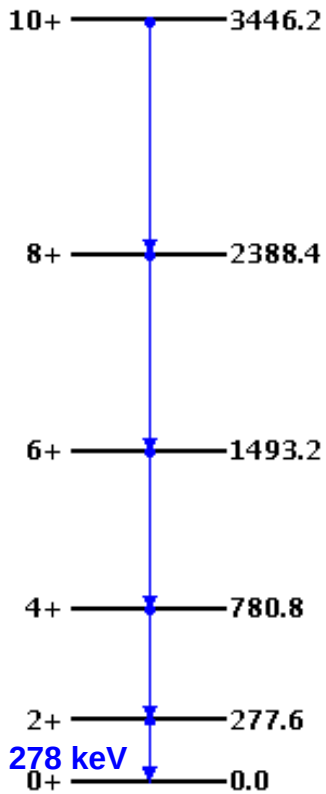
Au-Degrader 10.5 mg/cm^2

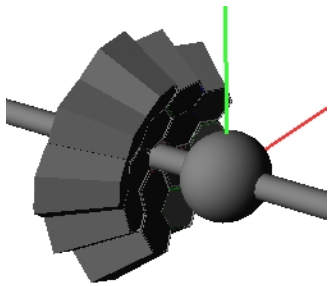




Experiment (a)

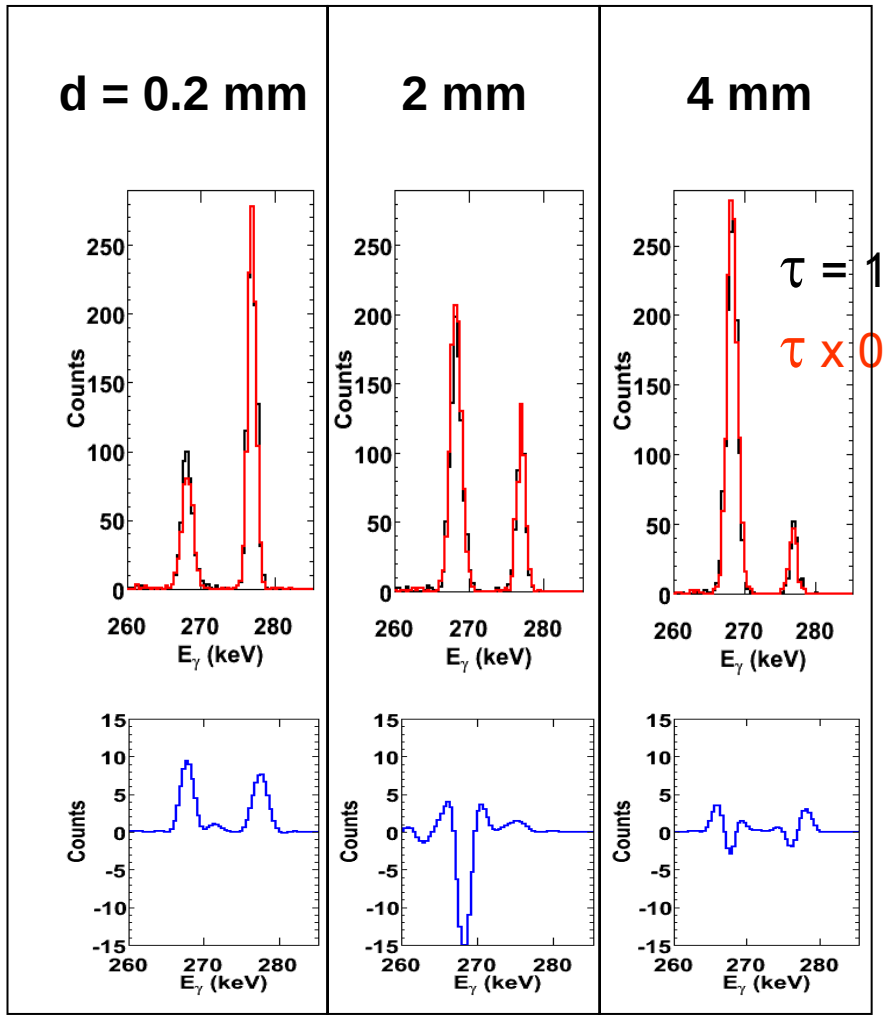
- AGATA Demonstrator (5 triple cluster) + Köln Plunger





τ = 155(19) ps

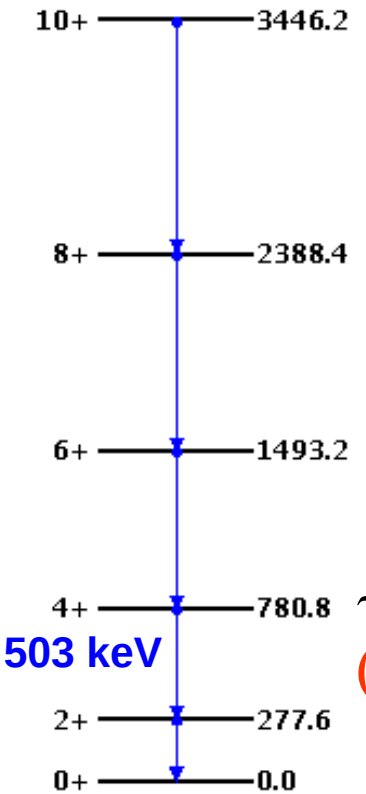
(τ x 0.95)

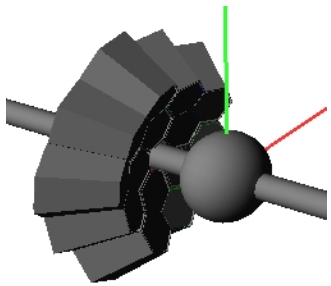


MC Code by E. Farnea and C. Michelagnoli

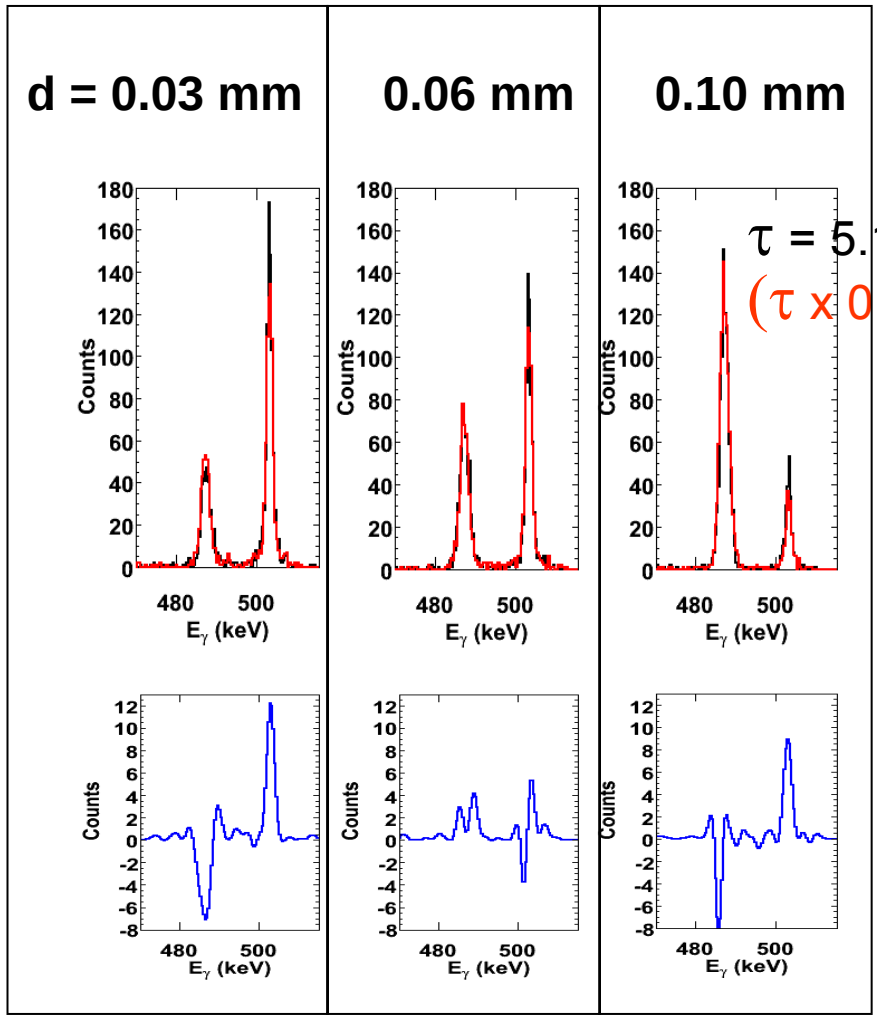
Experiment (a)

- AGATA Demonstrator (5 triple cluster) + Köln Plunger





τ = 5.1(5) ps
(τ x 0.95)

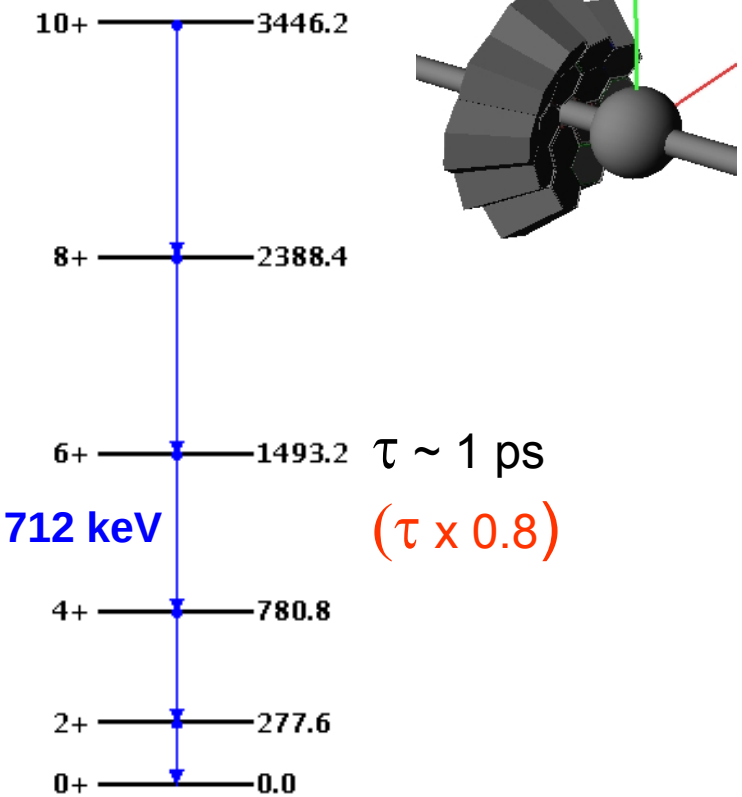


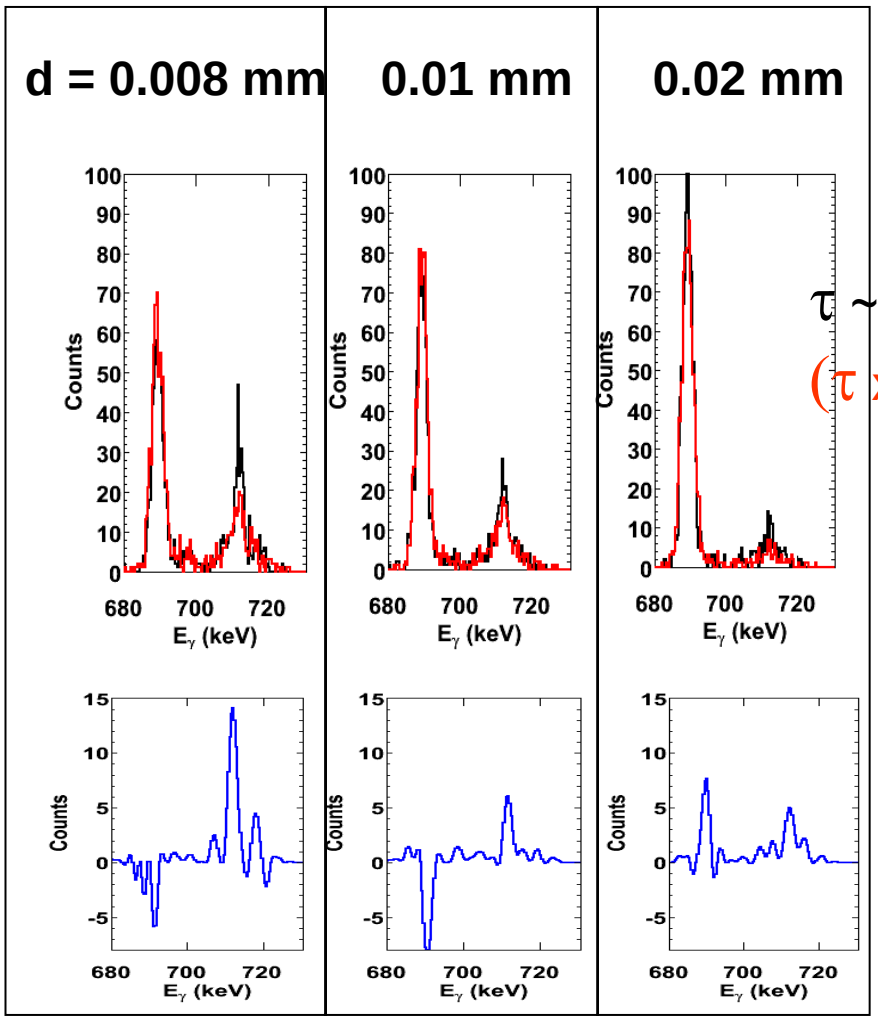
τ = 5.1(5) ps
(τ x 0.95)

MC Code by E. Farnea and C. Michelagnoli

Experiment (a)

- AGATA Demonstrator (5 triple cluster) + Köln Plunger





+ Information from thick-target measurement