MC Simulations for the PreSPEC campaign of AGATA at GSI

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GSI Helmholtzzentrum für Schwerionenforschung

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Outline

- Summary of **simulated geometries** for experiments at GSI-FRS
- Summary on the **performance** of each geometry case
- Conclusion on **best geometry** for experiments at GSI-FRS
- **Benchmark** experiments
- (More) realistic simulation
- Outlook and conclusion

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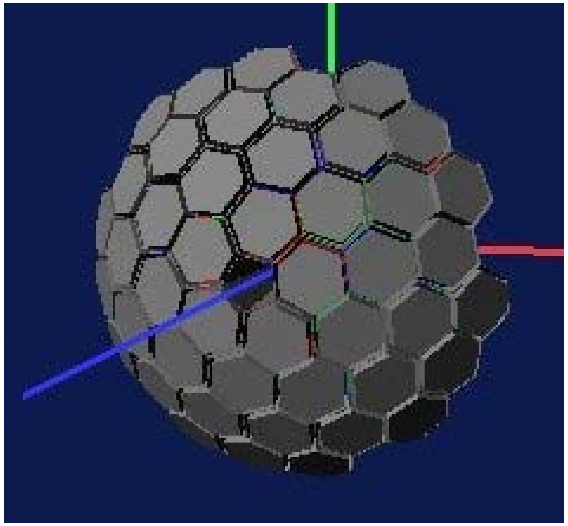
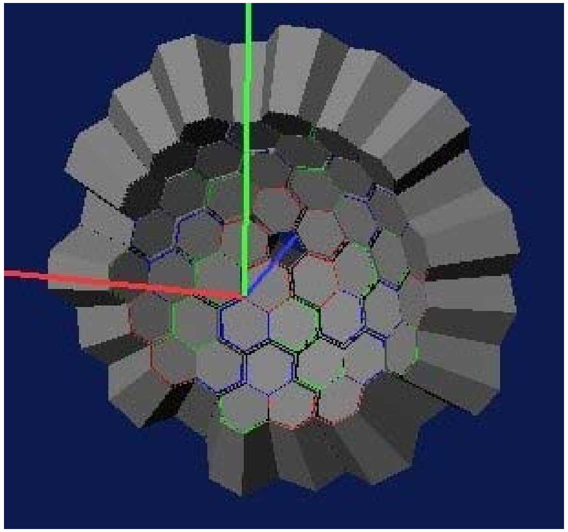
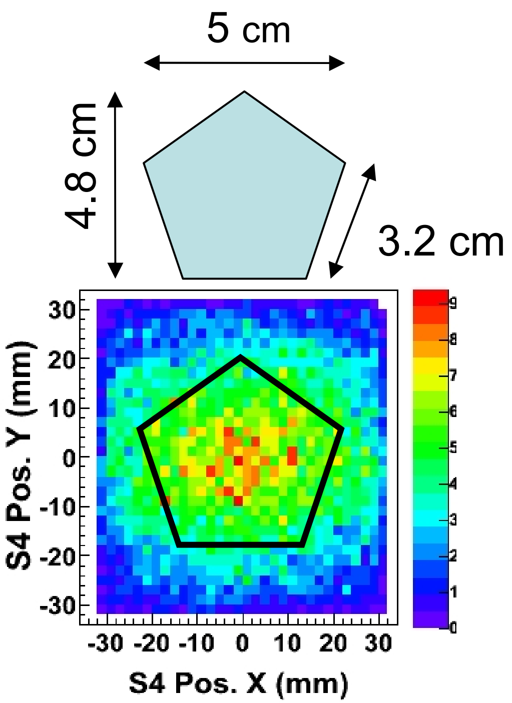
Particular constraints for the setup at GSI

• Ideal geometry (first approach, first step)





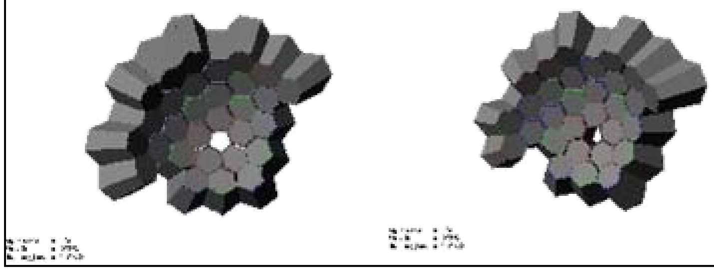


• two main constraints:

1. Number of cluster detectors available in 2011/2012: 10 - 15(?)
2. The beam hole (pentagon) is too small for the GSI beam size

Shell geometries

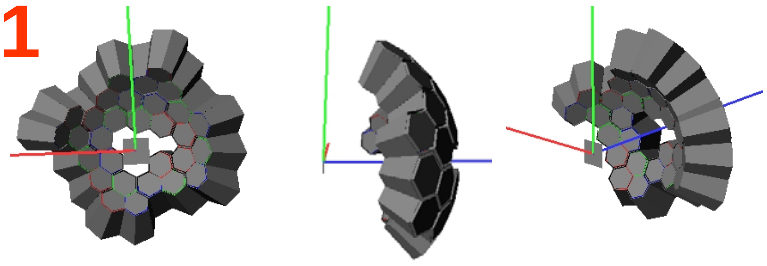
more realistic



10 Clusters

Hole too small (appx. 4 cm)

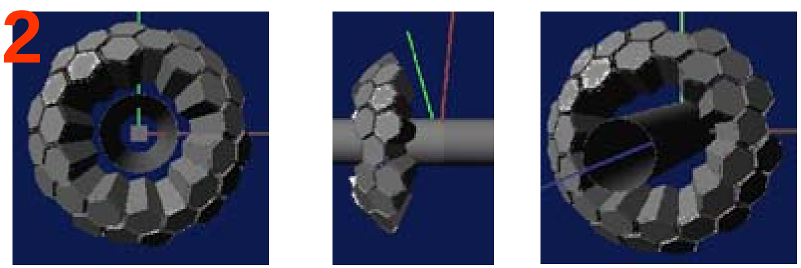
S1



10 Clusters (Hole 1 Cluster)

Hole small (appx. 7 cm)

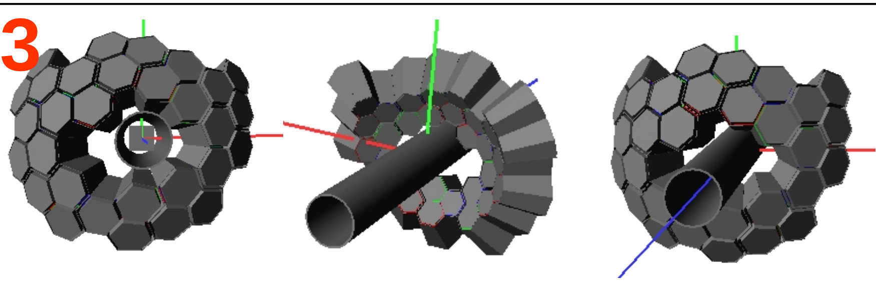
S2



10 Clusters (Hole 5 Clusters)

Hole (22.8 cm) beam-pipe 16 cm

S3

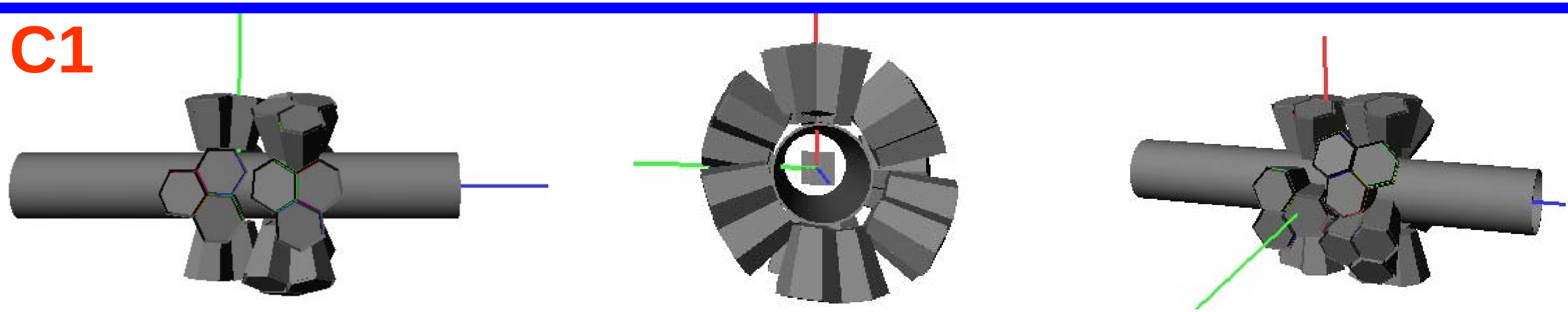


10 Clusters (Hole 2 Clusters)

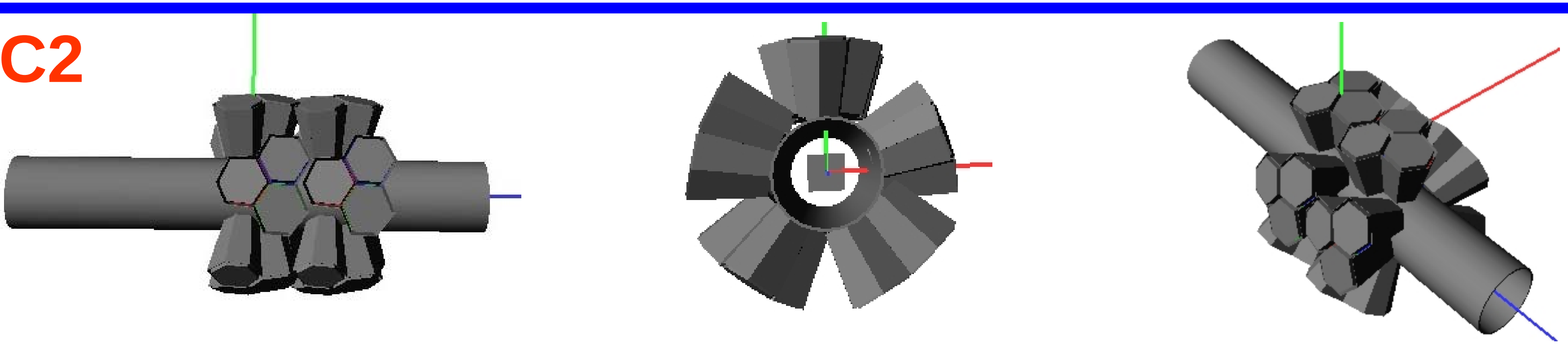
Hole (11.5 cm) beam-pipe **11 cm**

Compact geometries

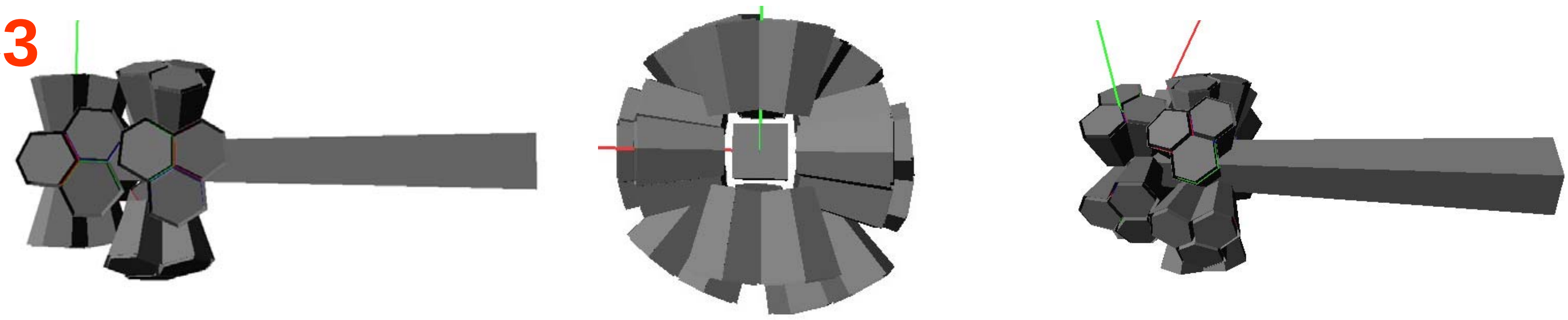
C1



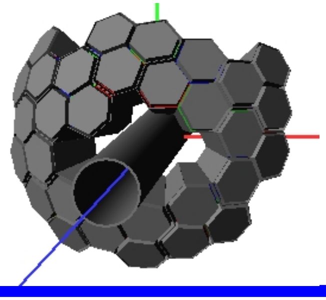
C2



C3

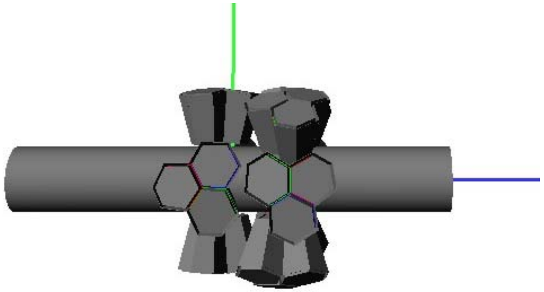


Pros and Cons



- Good resolution
- Tracking between clusters
- Conventional mechanics (LNL)

- Lower efficiency
- Small solid angle (angular std.)



- High efficiency
- γ–γ efficiency
- Larger angular range

- Lower resolution
- No tracking between clusters
- New mechanics

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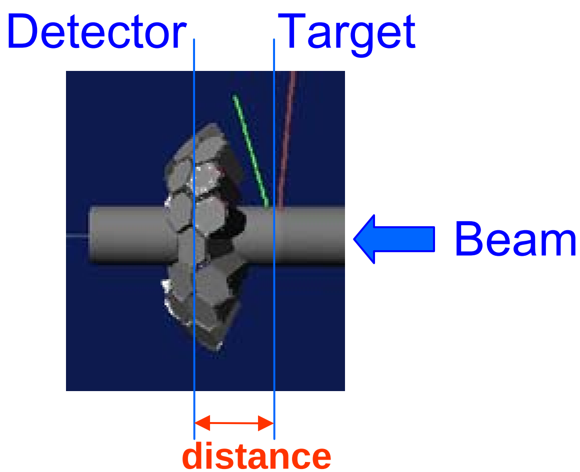
Performance comparison: general aspects

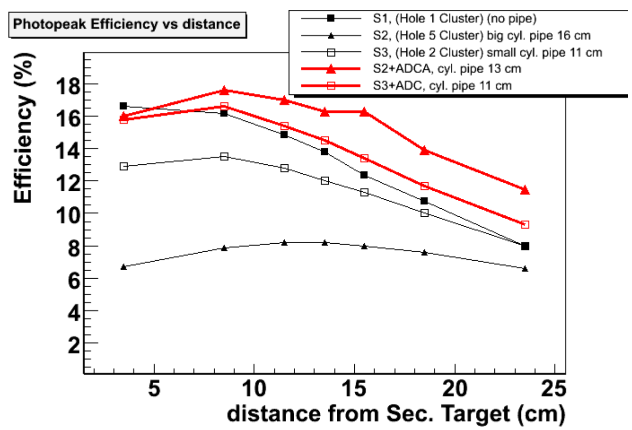
• Systematic study of efficiency and resolution vs. distance for all geometries

• "Reference case": (GEANT4 AGATA code from E.Farnea et al.)

⇨ $E_{\gamma,o}$ = 1 MeV, recoil nucleus at β = 0.43 (E = 100 MeV/u), M_γ = 1

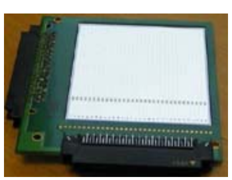
⇨ Systematic study several distances sec. target – detector

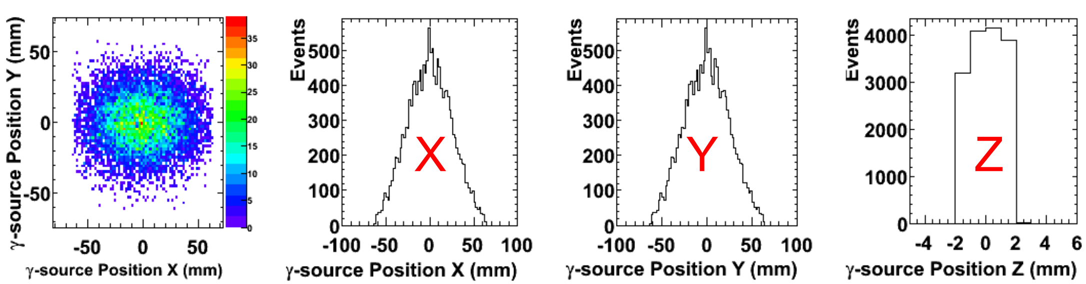




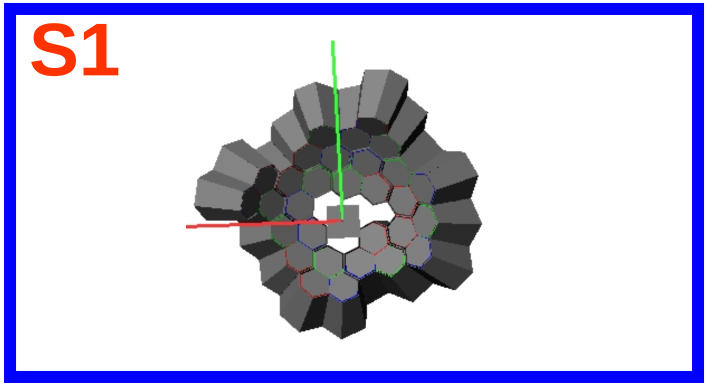
⇨ GSI FRS Spatial Beam Profile FWHM_x = 6 cm FWHM_y = 4 cm

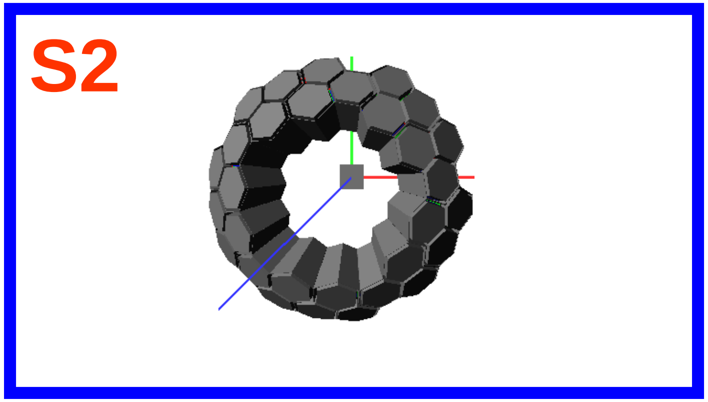
Active target
DSSSD

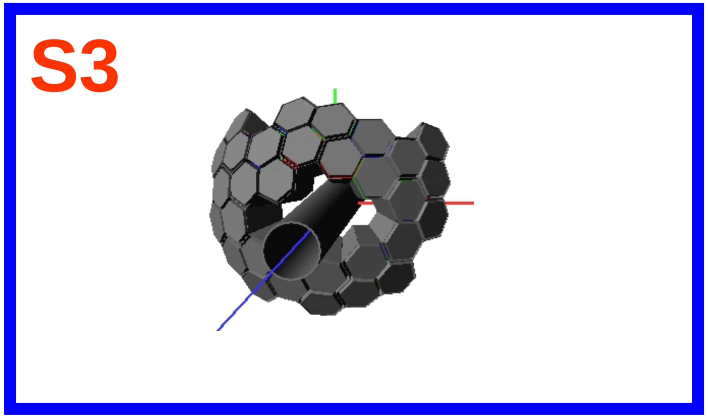


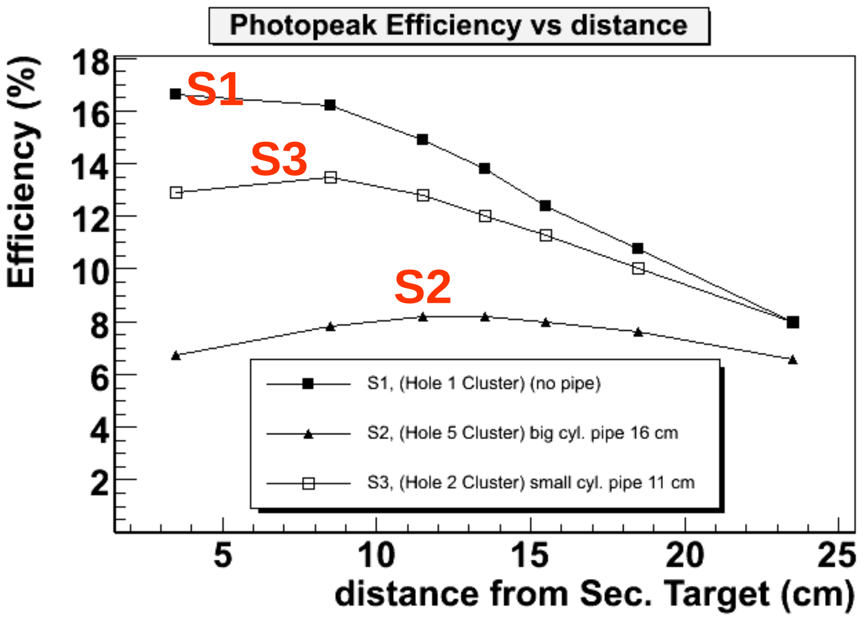


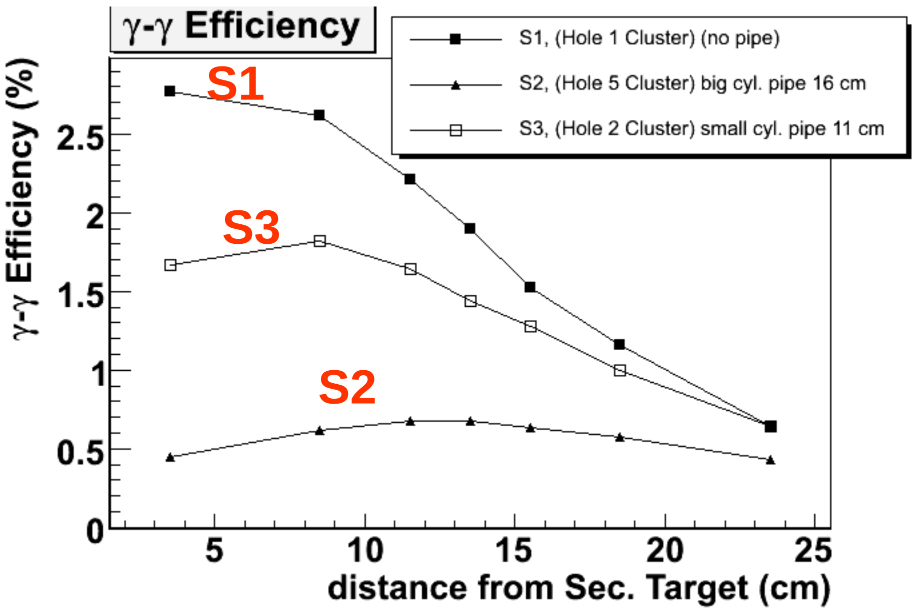
S-Geometries Performance comparison: Efficiency



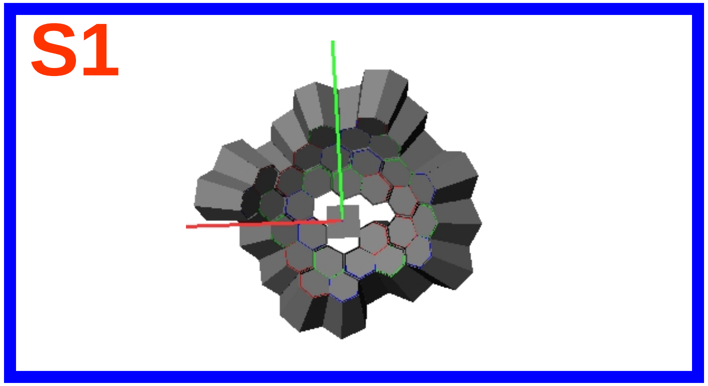


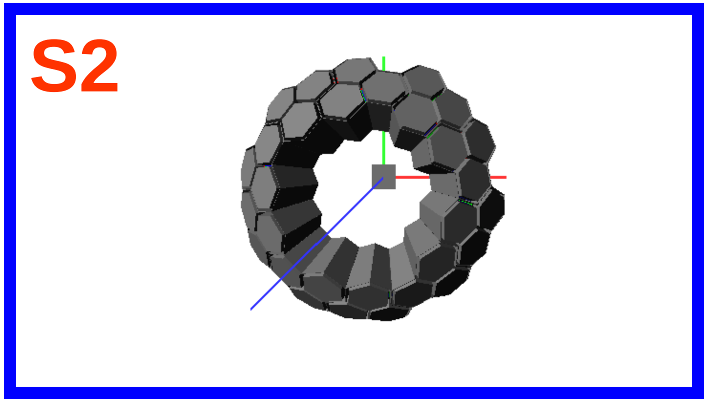


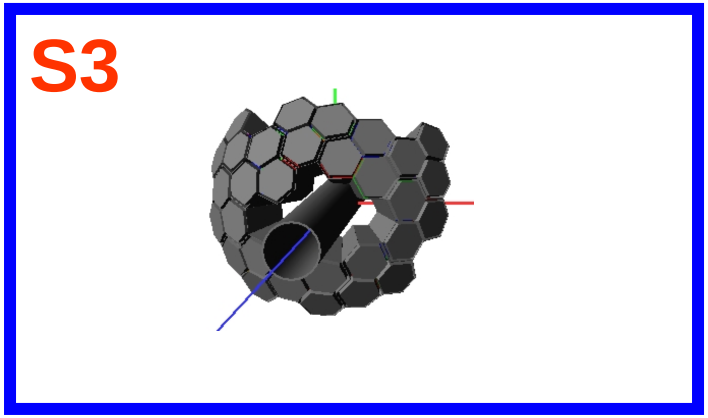


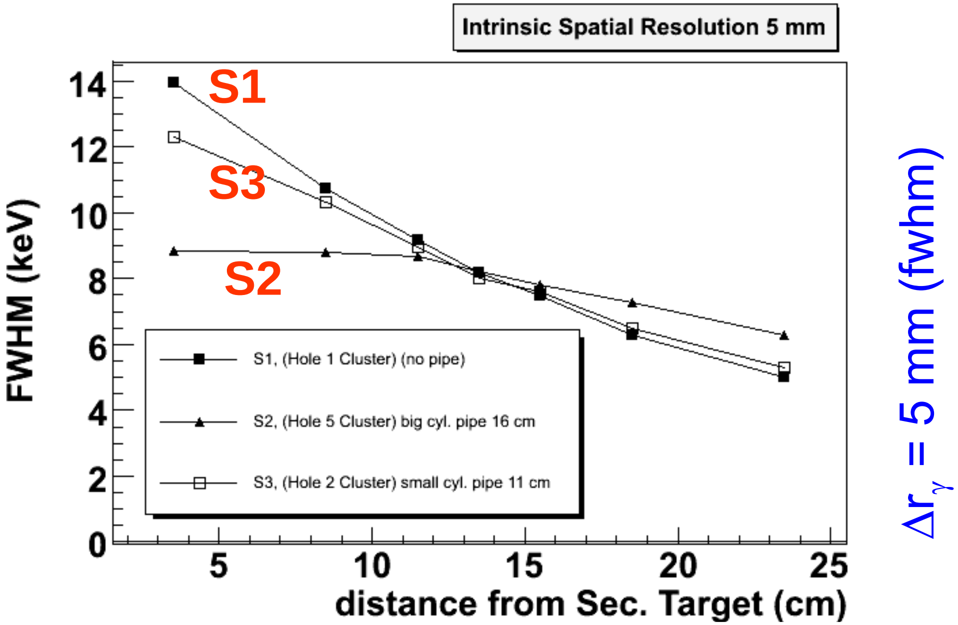


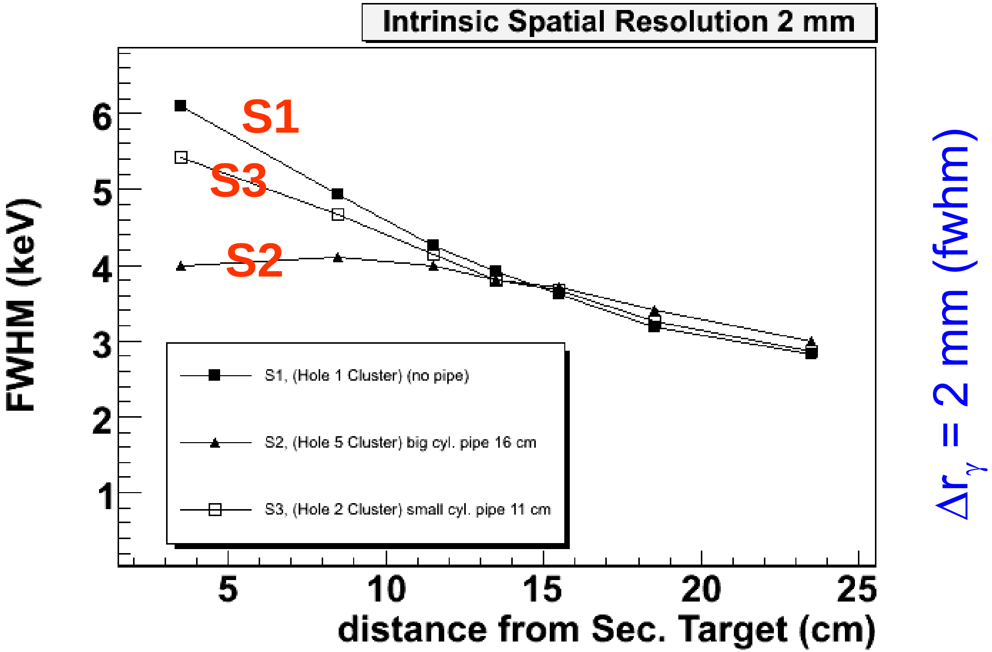
S-Geometries Performance comparison: Resolution



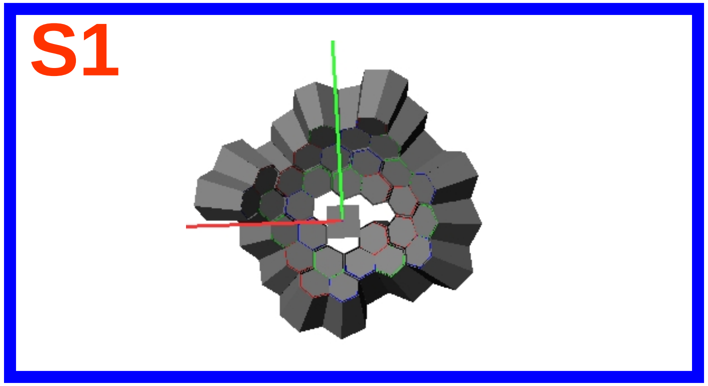


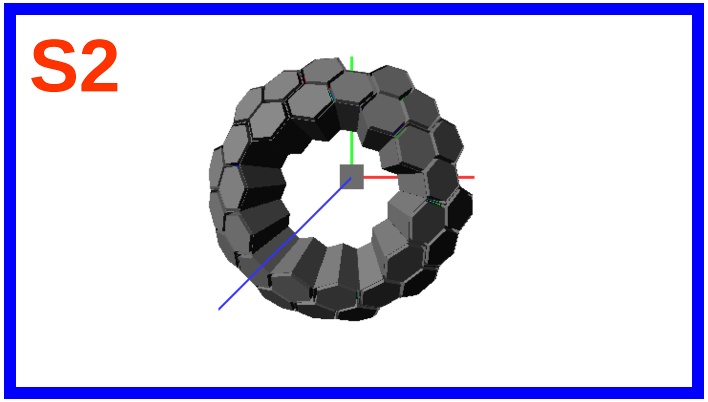


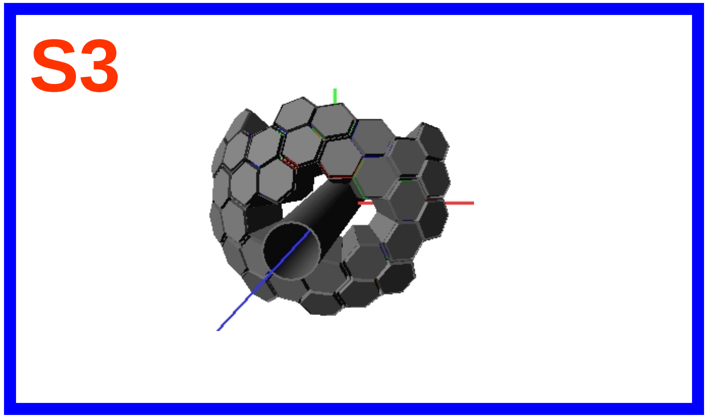


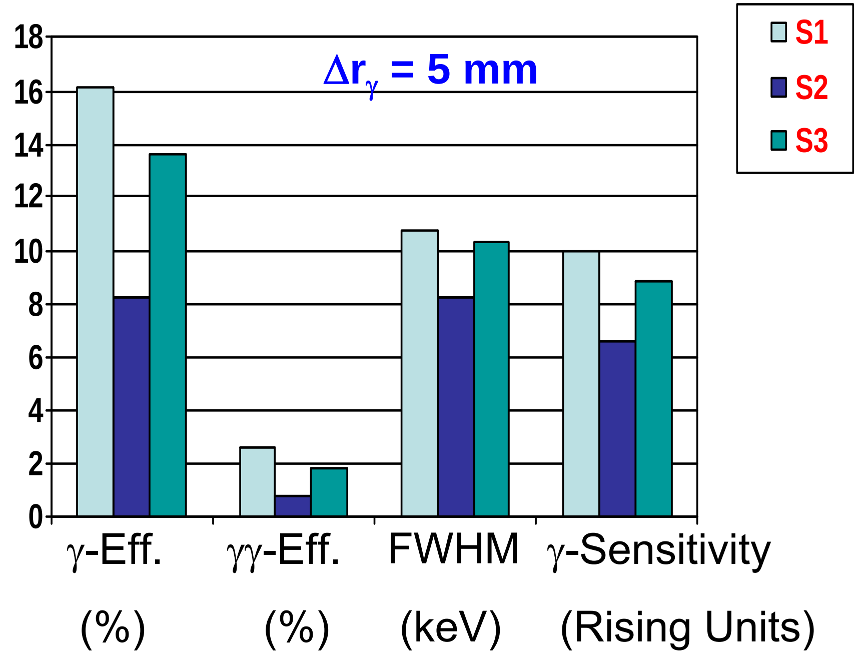


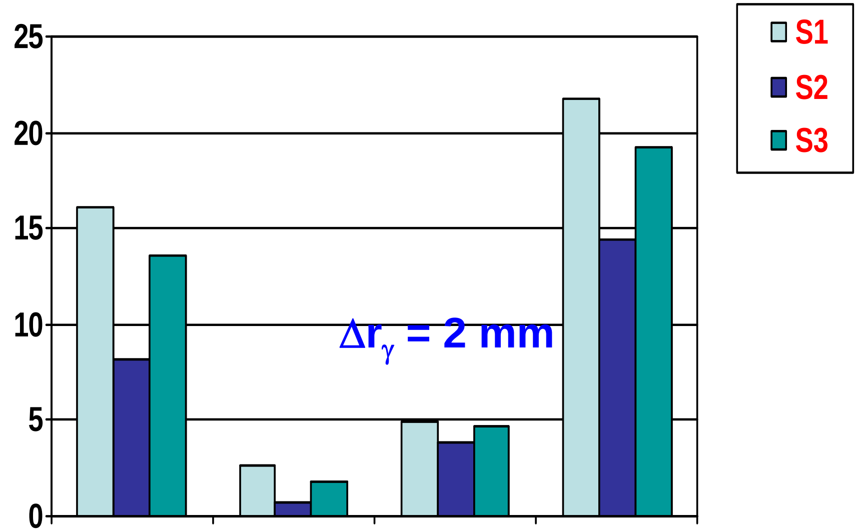
Shell Geometries performance comparison: Summary











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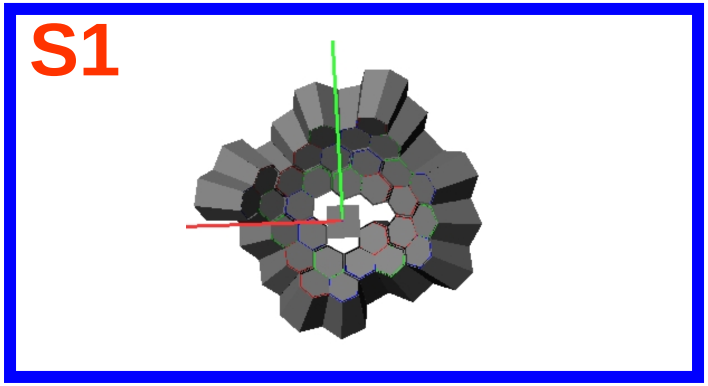
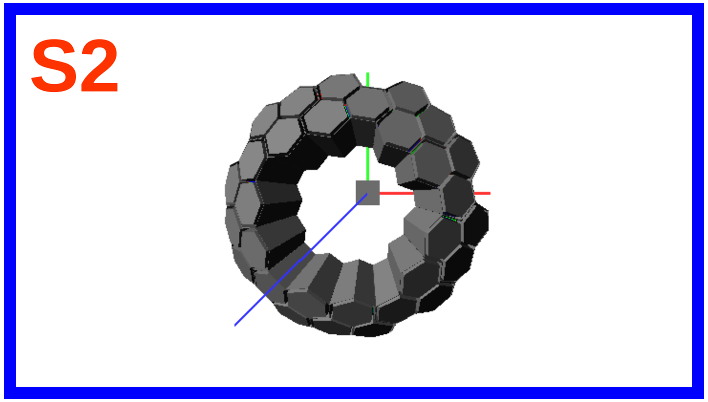
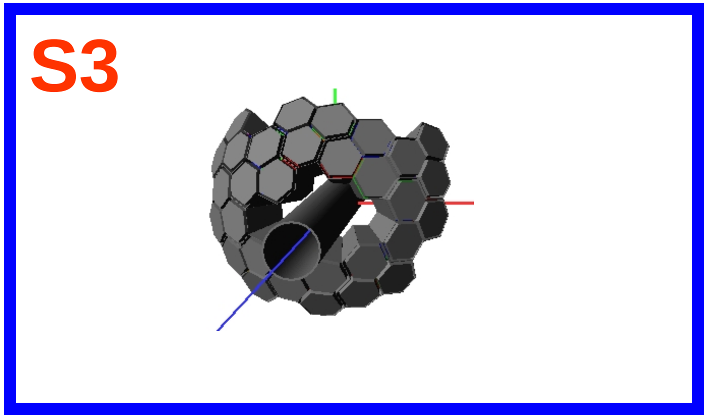
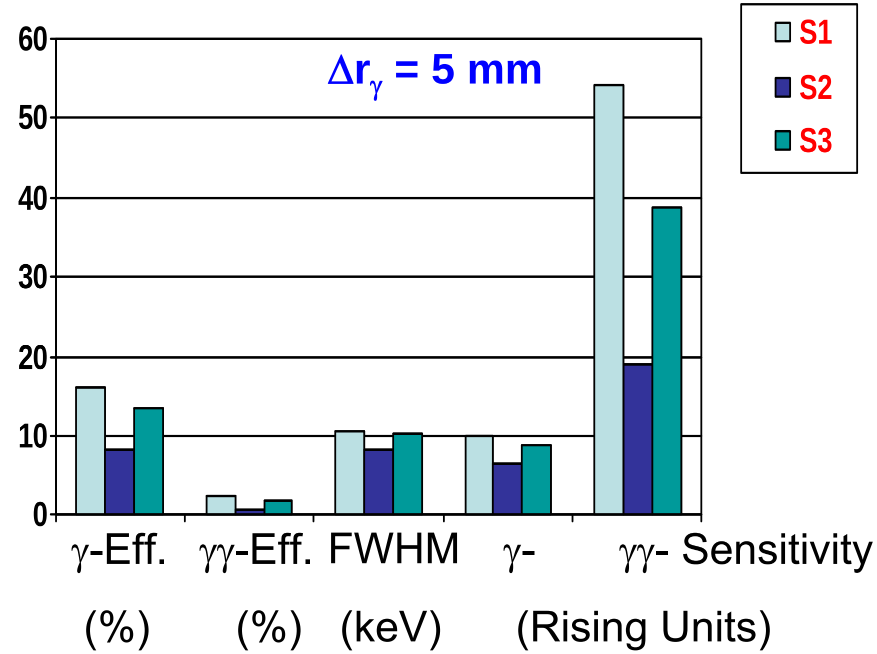
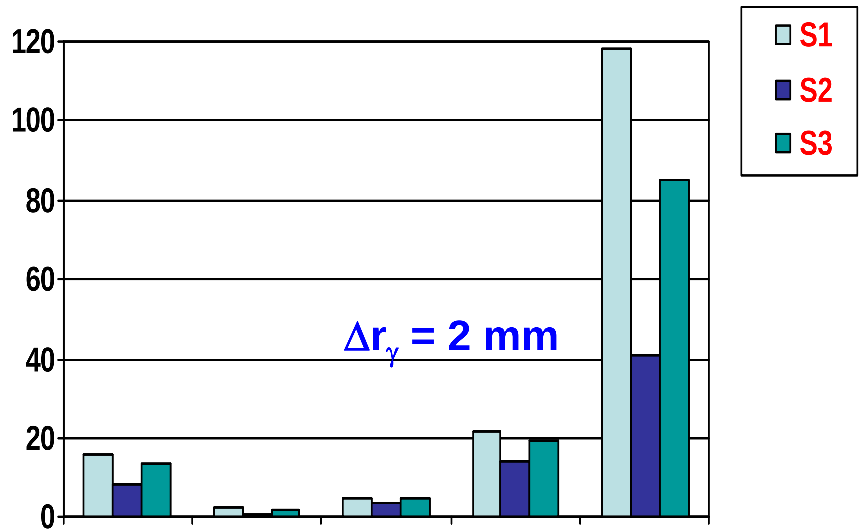


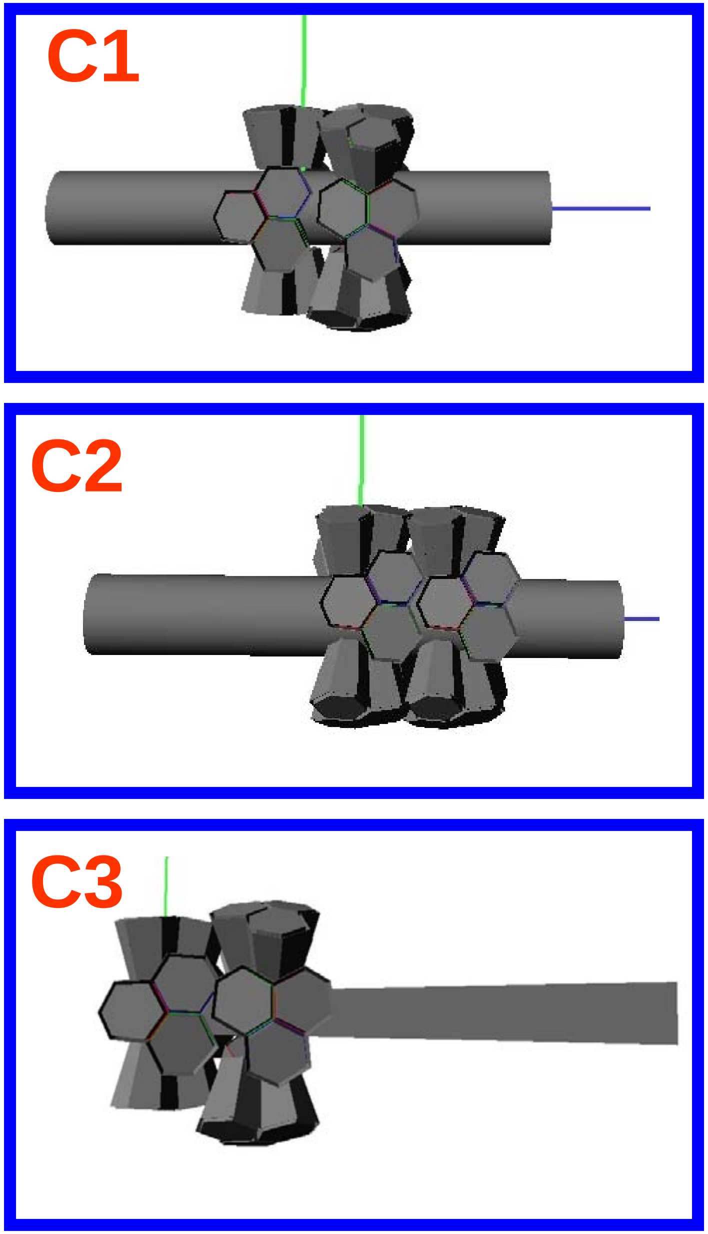


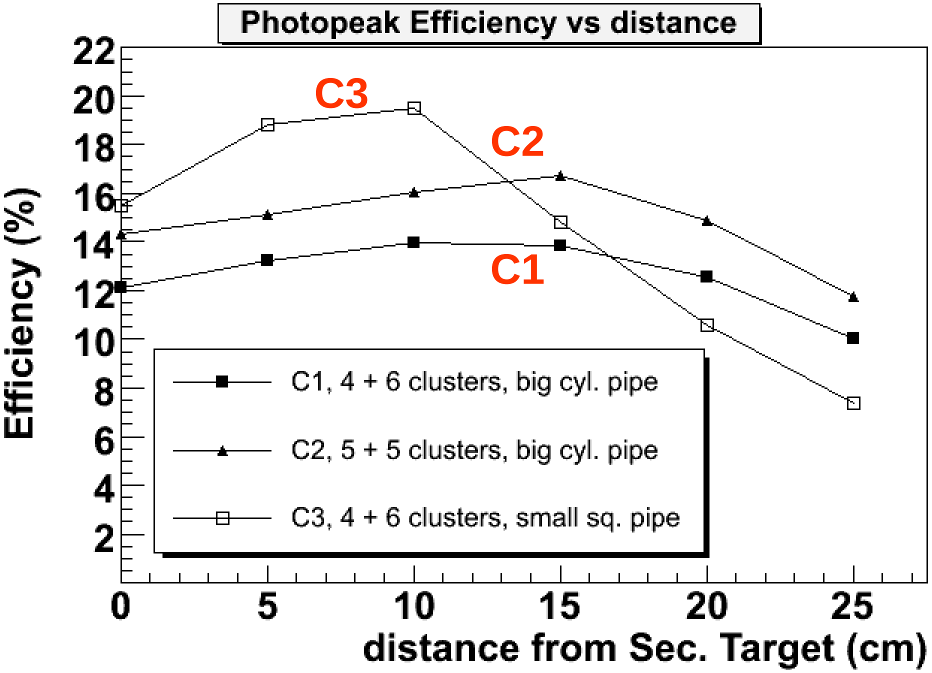


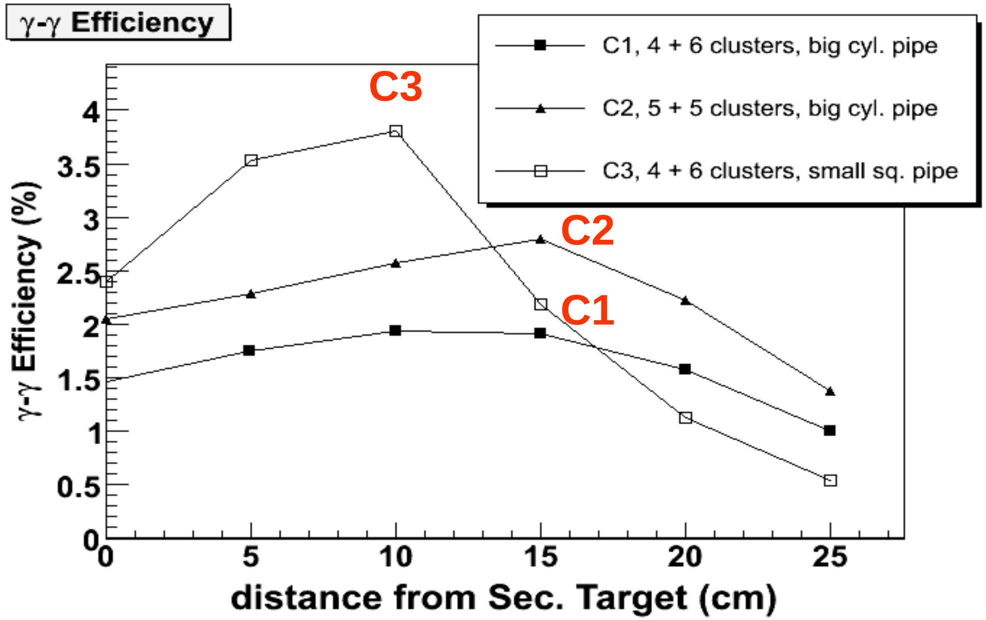




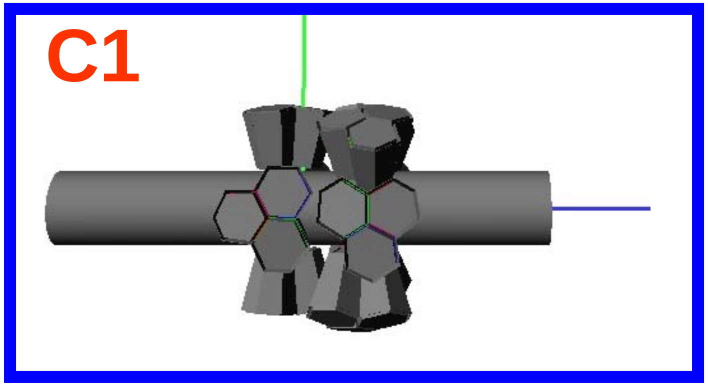
C-Geometries performance comparison: Efficiency

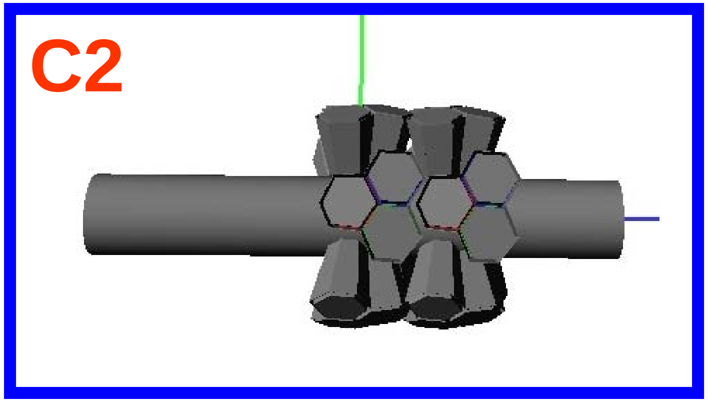


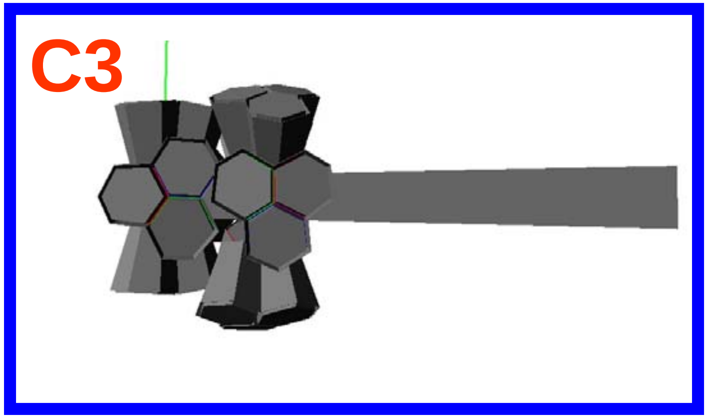


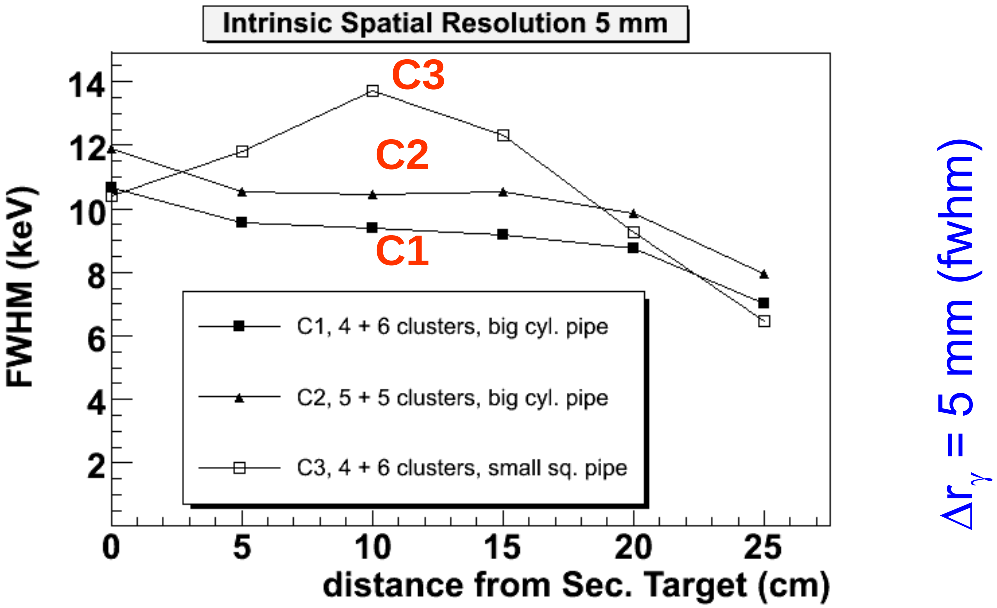


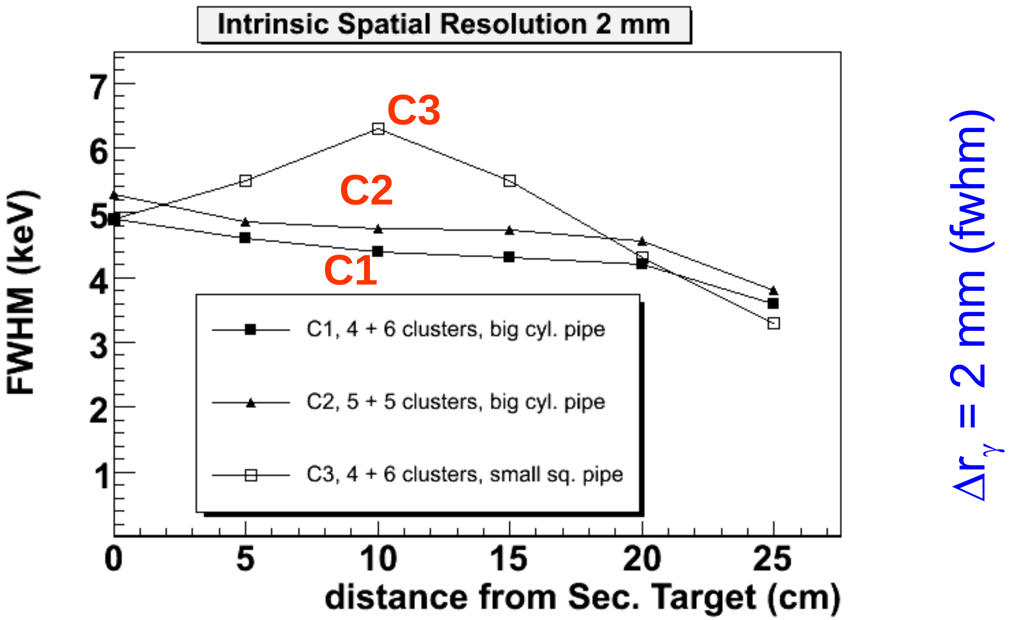
C-Geometries performance comparison: Resolution



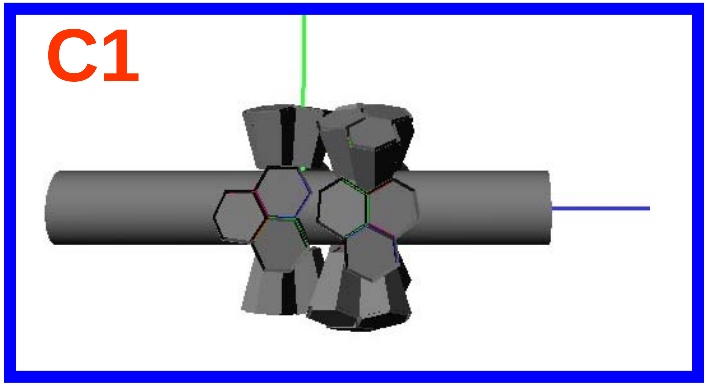


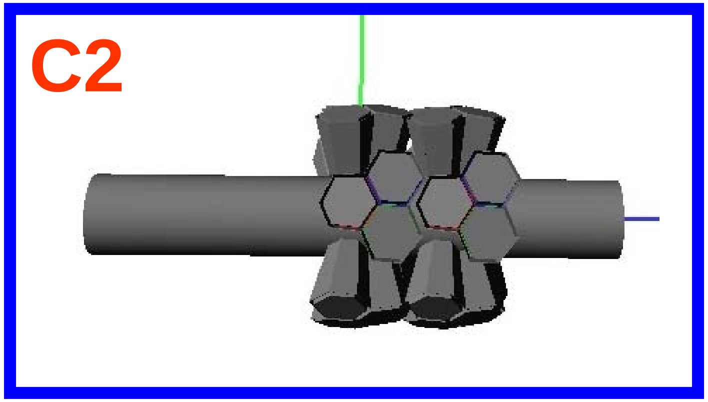


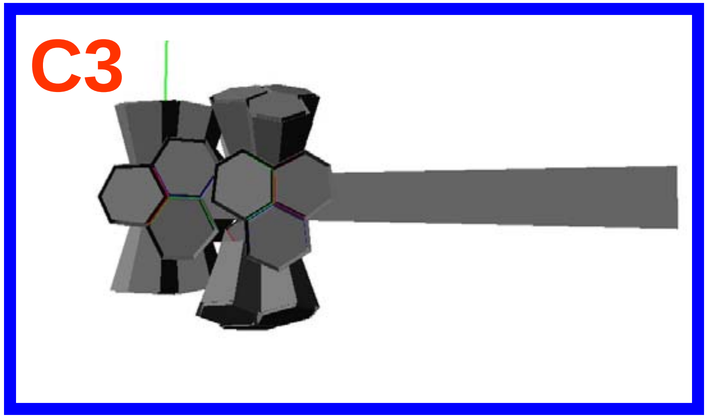


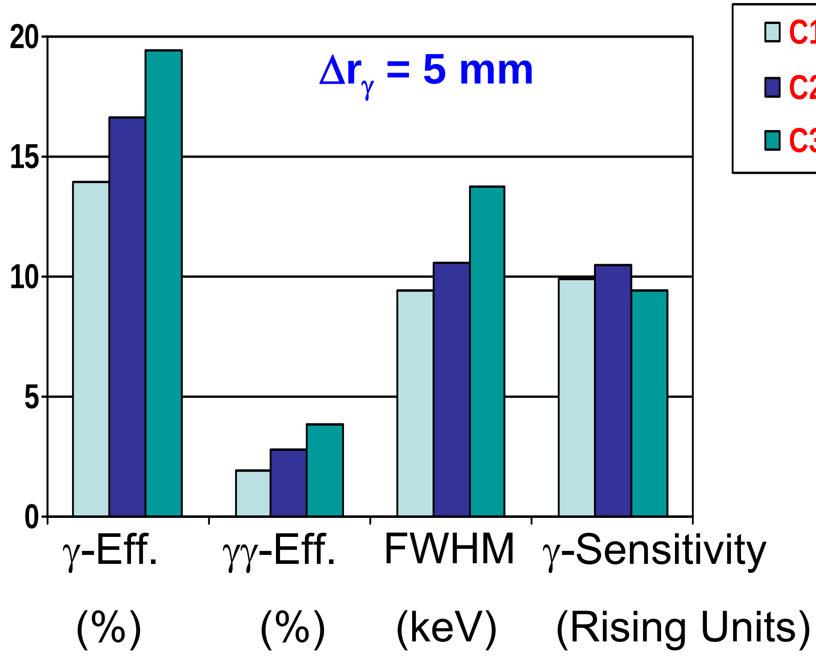


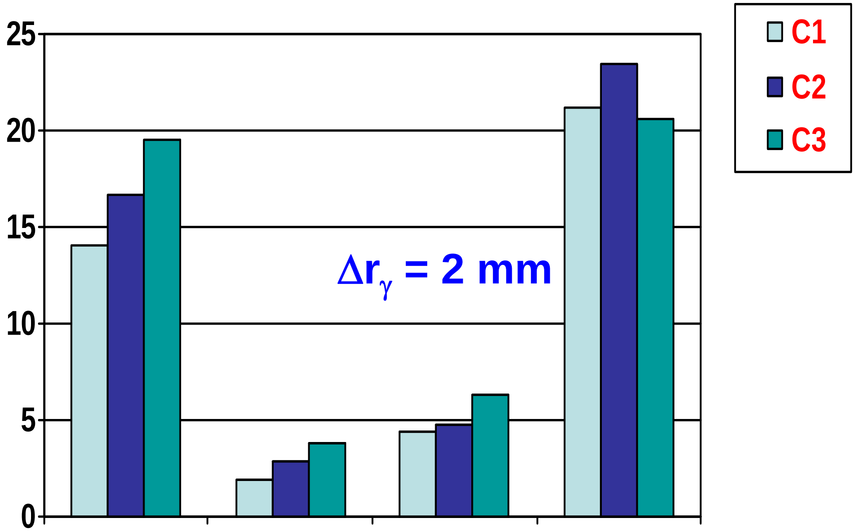
C-Geometries performance comparison: Summary











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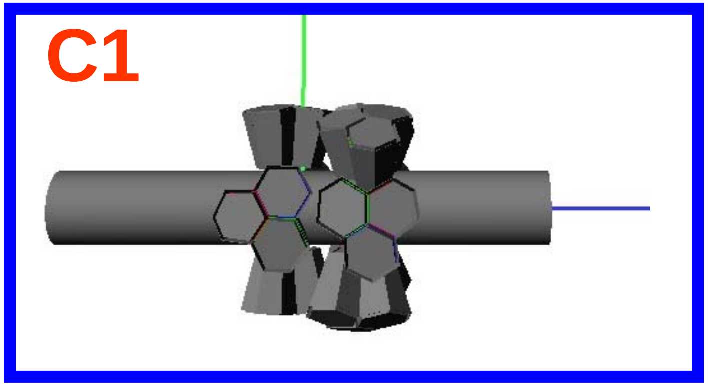
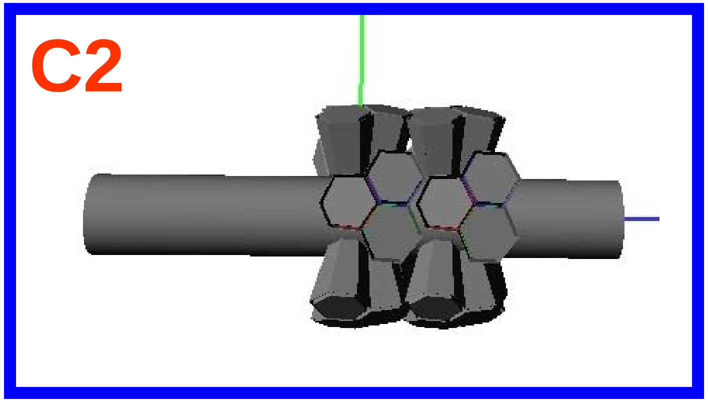
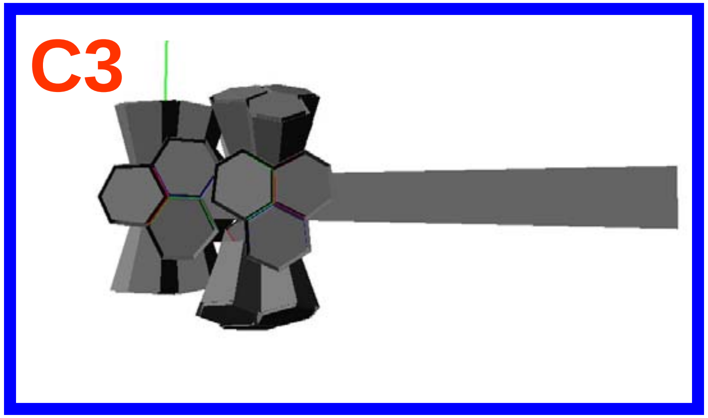
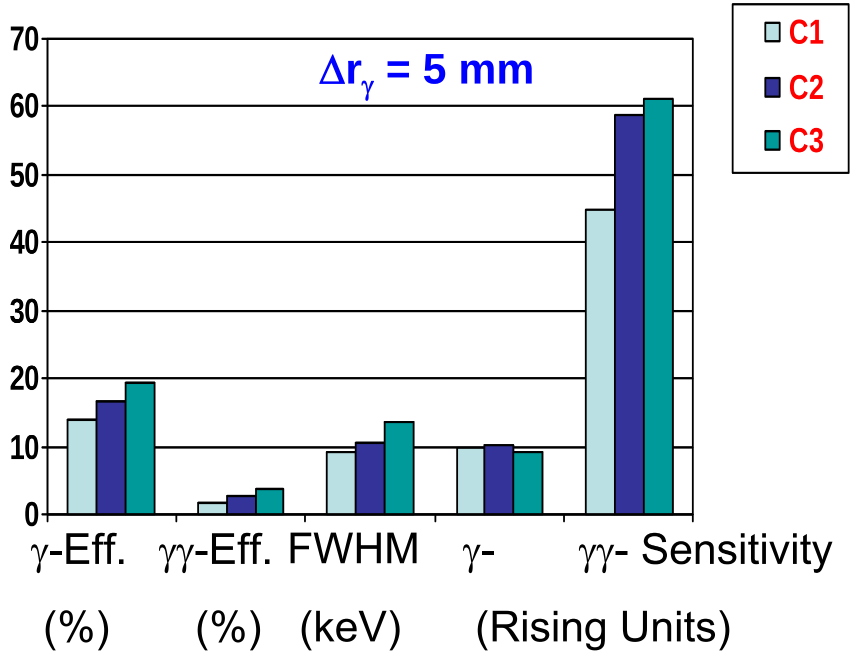
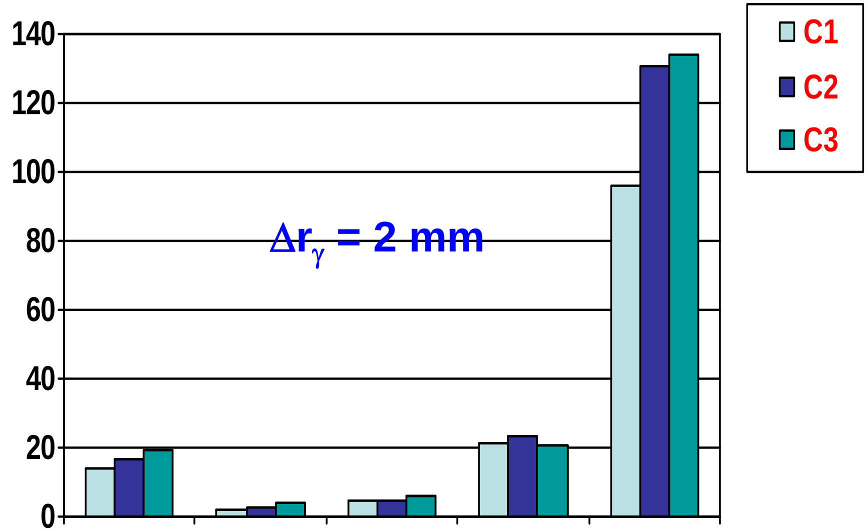


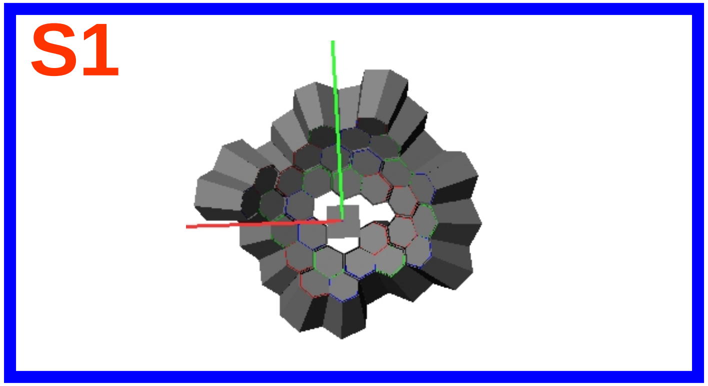


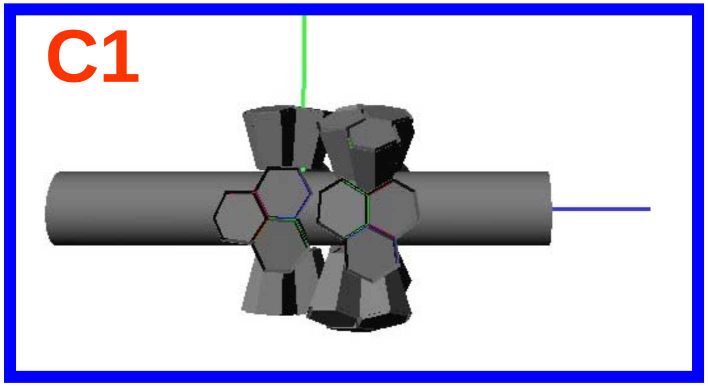


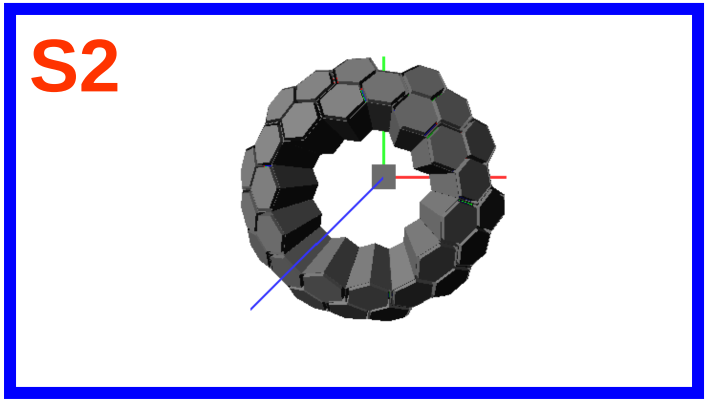


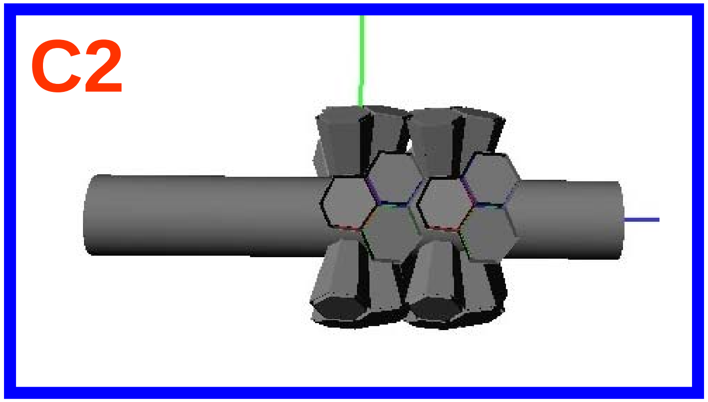


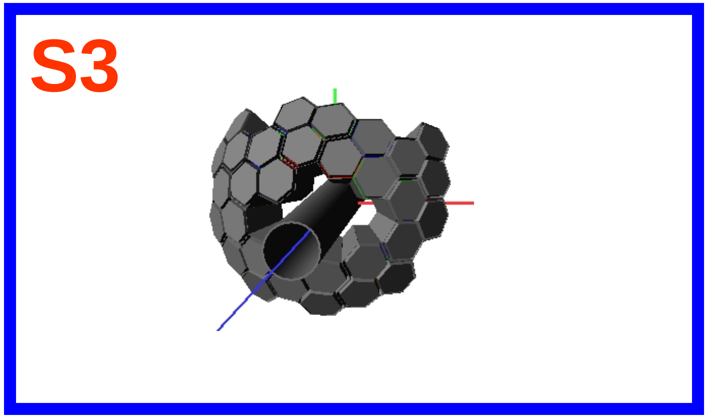
S- and C-Geometry Performance, Quantitative Comparison

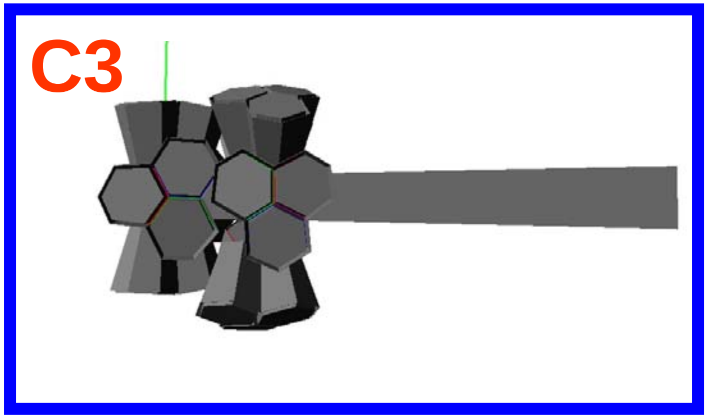




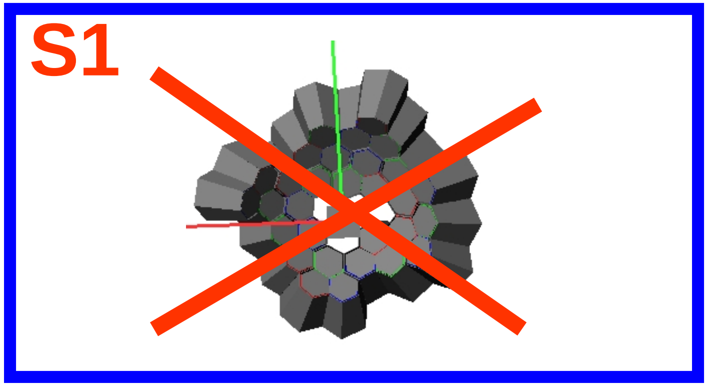


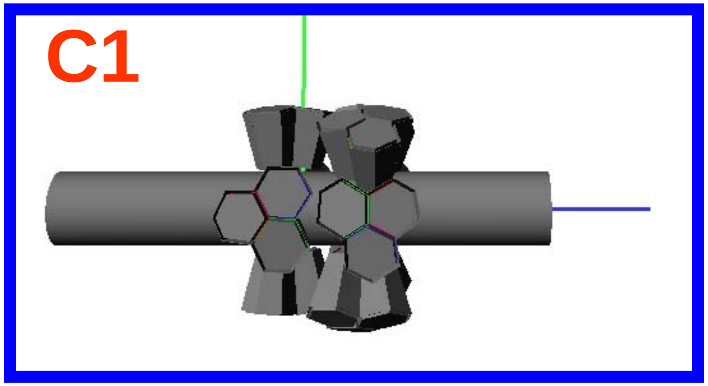




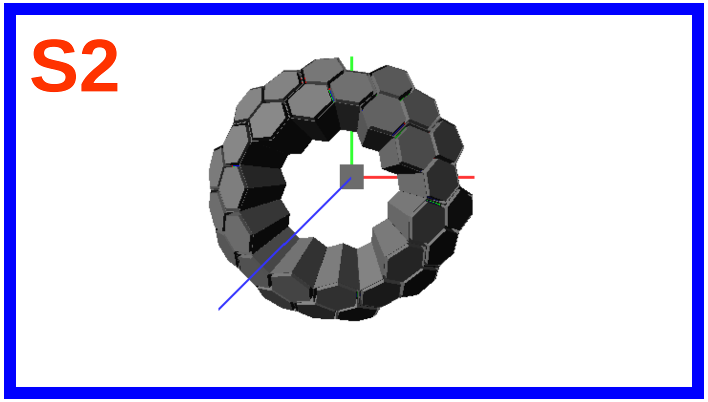


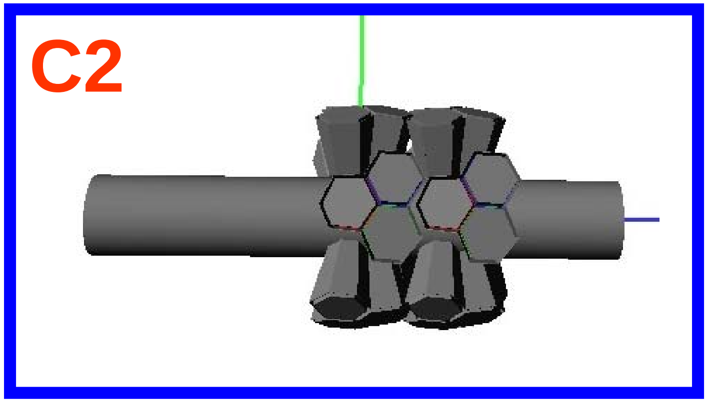
S- and C-Geometry Performance, Quantitative Comparison

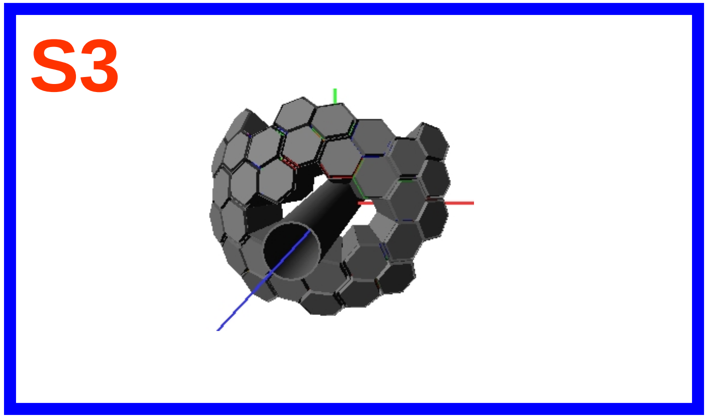


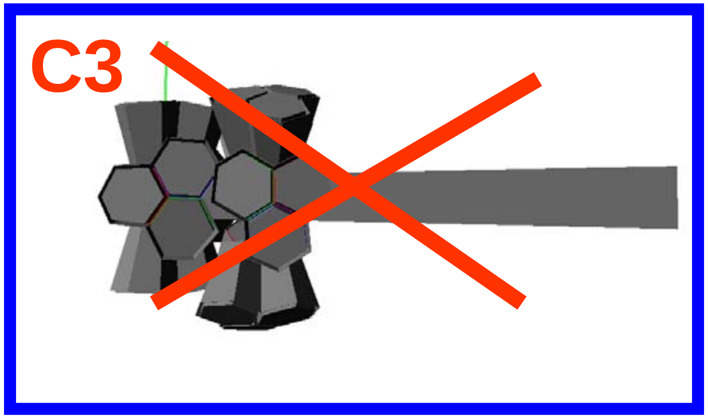


Technically difficult or impossible



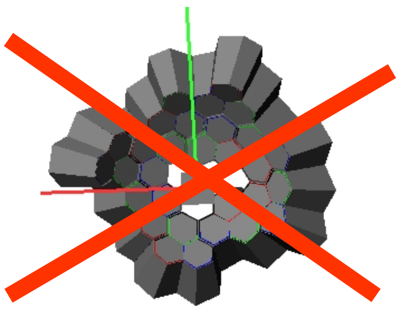






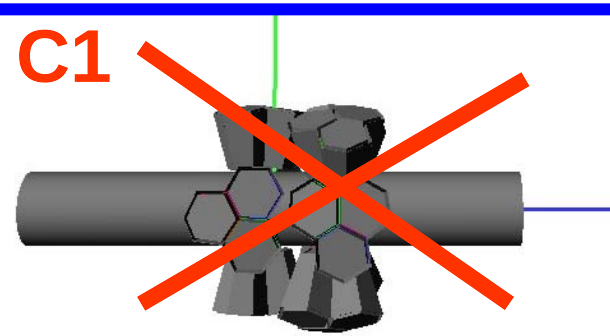
S- and C-Geometry Performance, Quantitative Comparison

S1

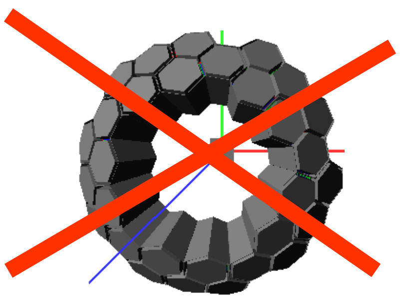


Technically difficult or impossible

C1

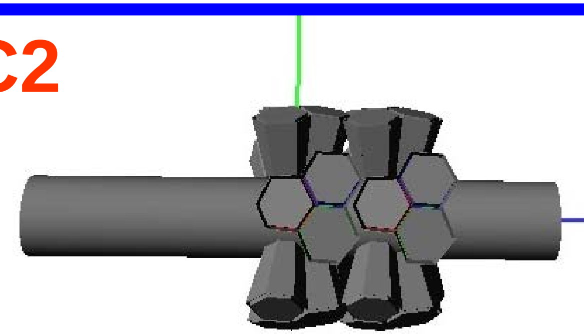


S2

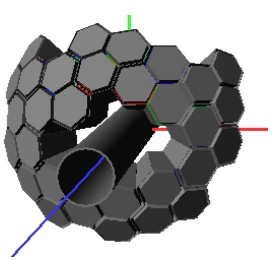


Worse performance than the other option S3 or C2

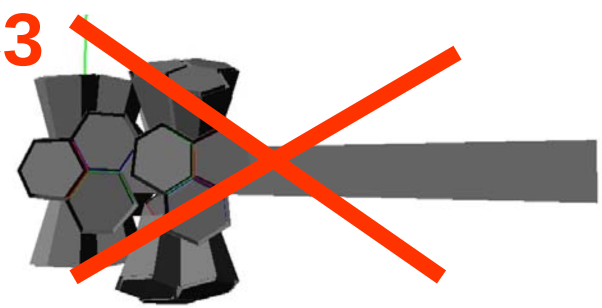
C2



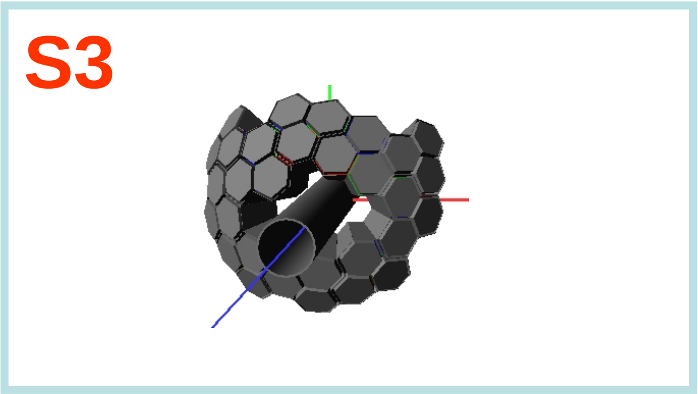
S3

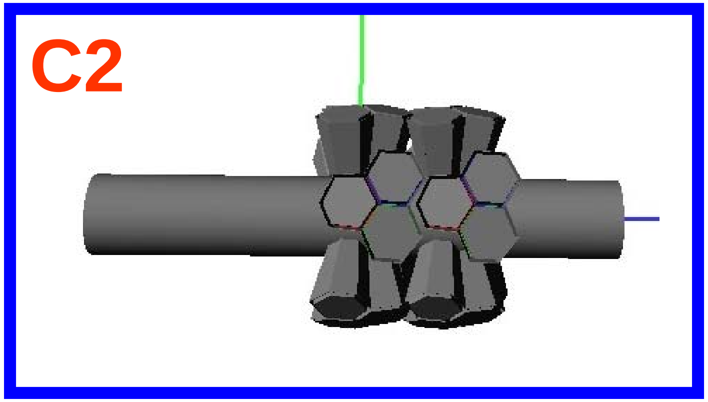


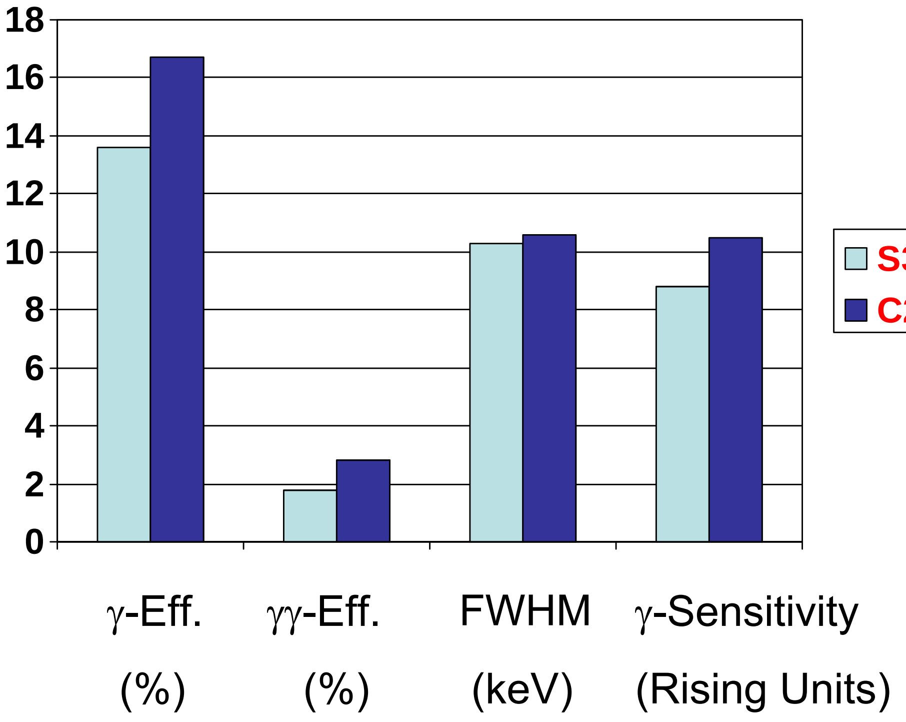
C3



S- and C-Geometry Performance, Quantitative Comparison







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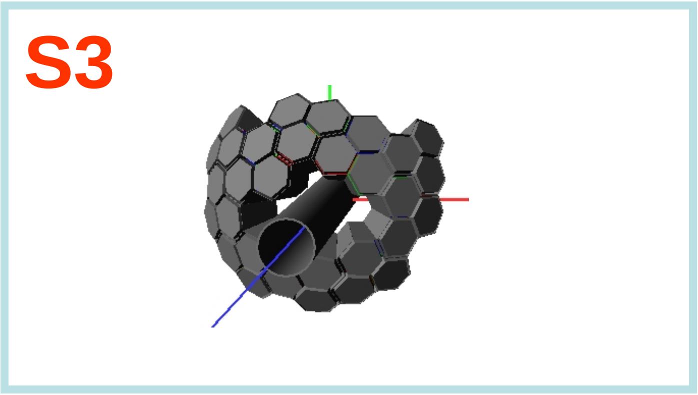

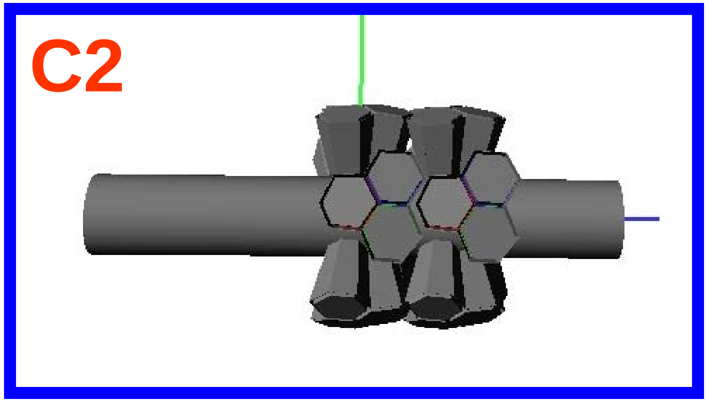

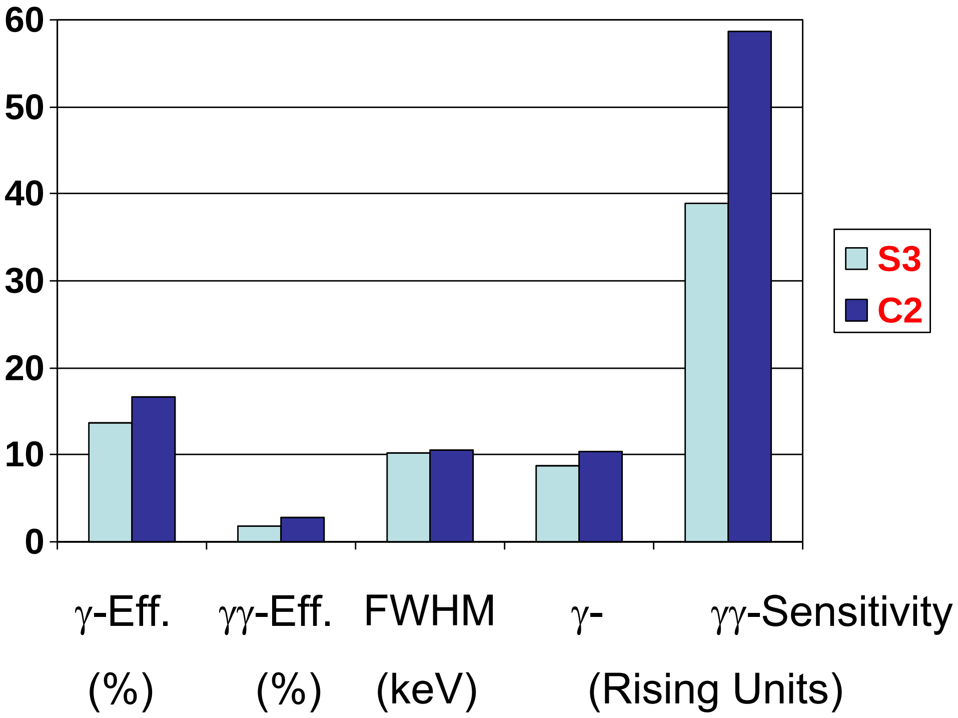

Outlook and conclusion

1. There are two geometry options (S3 and C2) which show an enormous boost in performance when compared to RISING, thus increasing the γ-ray sensitivity by about one order of magnitude in both cases.
2. The compact version C2 shows substantially higher efficiency (16.7%) compared to the S3 shell geometry (13.6%).
   (Absolute difference 3.1%, relative difference 23%.)
3. The $\gamma\gamma$-sensitivity of the C2 geometry is 1.5 times larger than that of the S3 shell.
   (In Rising units, 60 and 40, respectively.)
4. The energy resolution of the C2 geometry is slightly worse (0.3 keV higher) than that of S3.
   (The values for the ref. case simulated are 10.6 keV and 10.3 keV, respectively.)
5. The angular range covered by C2 is about 20deg larger than that of S3.
   (S3 covers from 35deg to 90deg, C2 covers from 25deg to 105deg).
6. From the technical point of view, S3 requires a smaller beam pipe (about 11 cm diameter). C2 is compatible with the GSI standard pipe of 16cm.

Workshop AGATA at GSI (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: C2 geometry, with clusters in 2^{nd} ring pointing to target, and 3^{rd} 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.
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Realistic implementation

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

New results: AGATA S2 + Agata Double Cluster Array (ADCA)

Geometry cases

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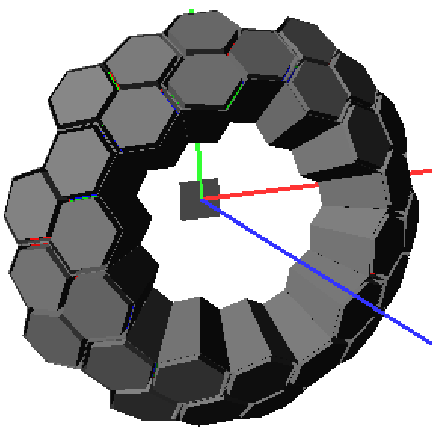
AGATA S2 Geometry



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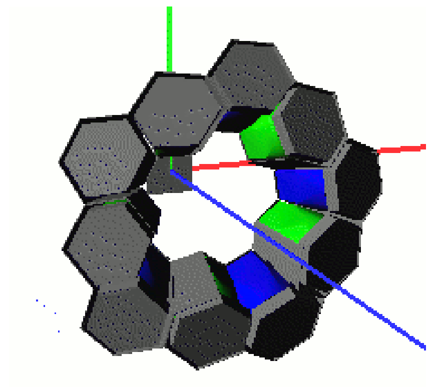

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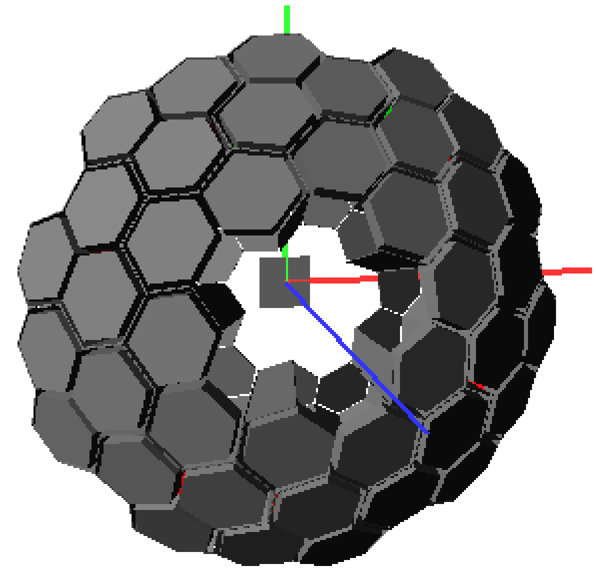

10 triple Cluster + **5 double** Cluster

New results: AGATA S2 + Agata Double Cluster Array (ADCA)

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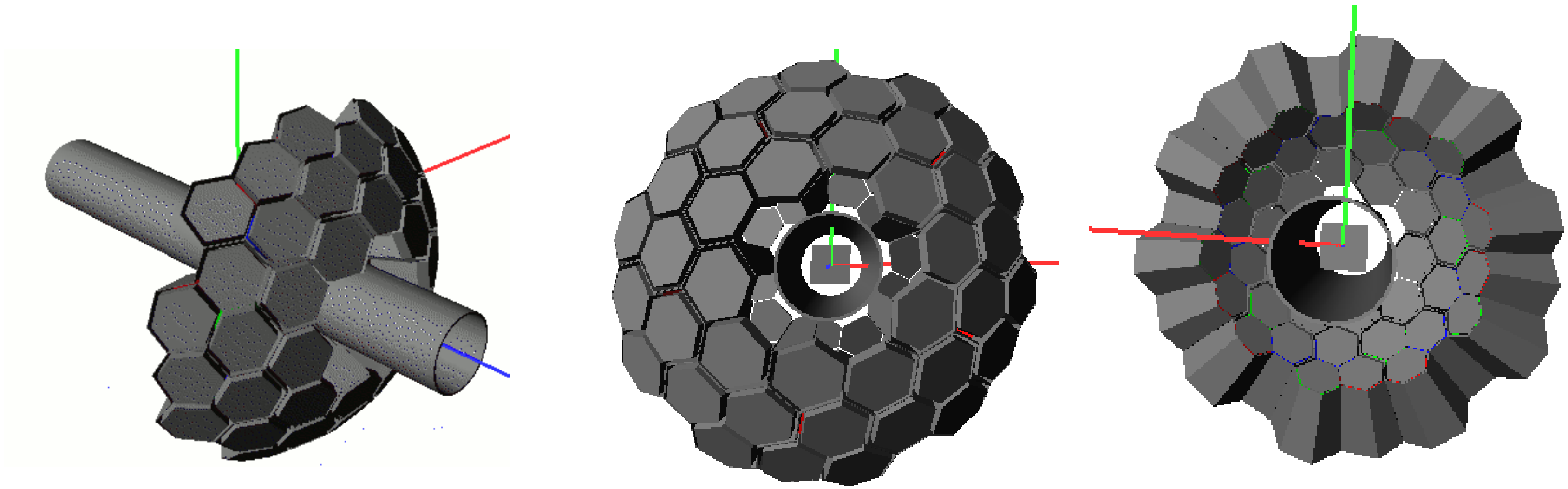

Beam pipe diameter = 9 - 12 cm

New results: AGATA S3 + 1 Agata Double Cluster

Geometry cases

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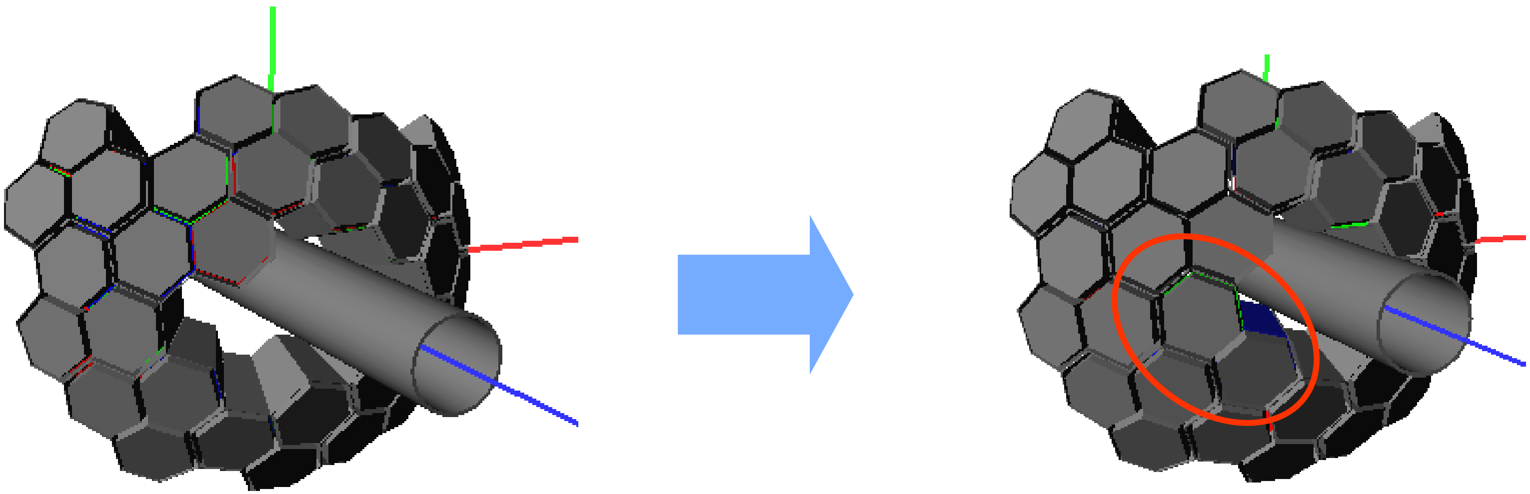
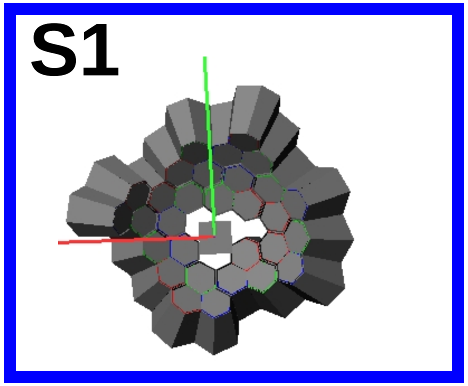
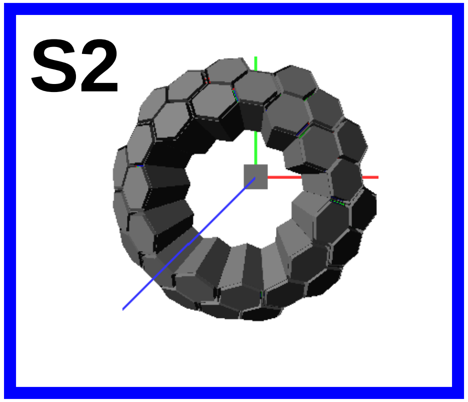


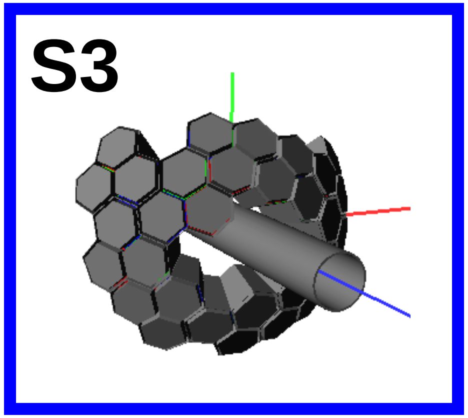
10 triple Cluster (Asym) **+** **1 double** Cluster

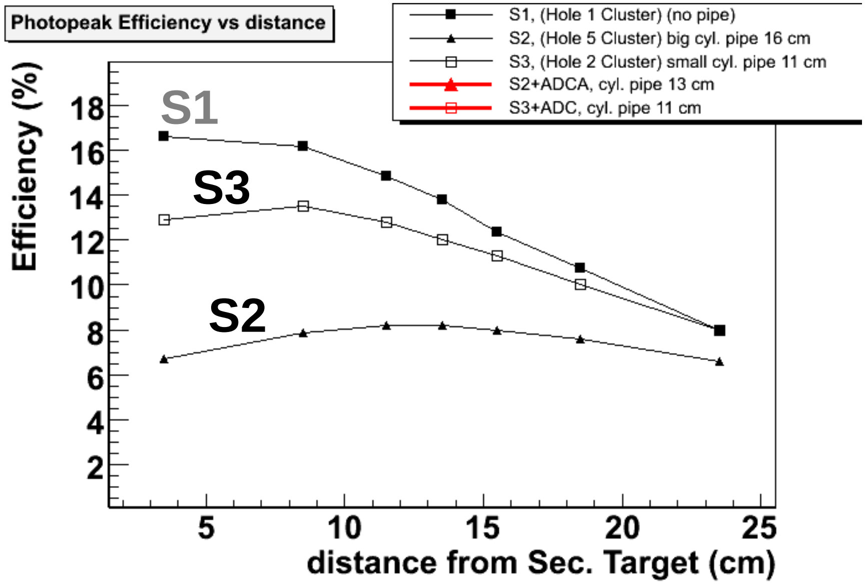
Beam pipe diameter = 10 cm

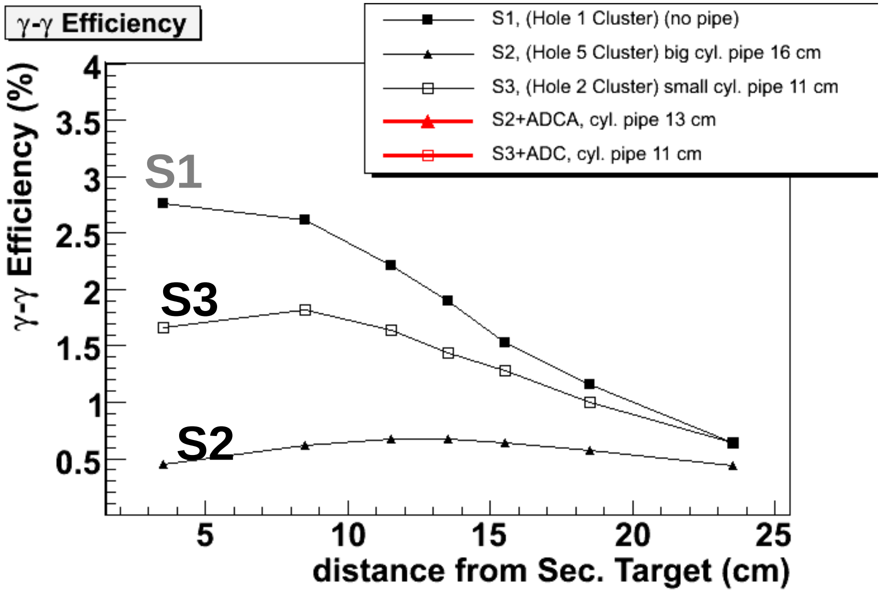
S-Geometries Performance comparison: Efficiency

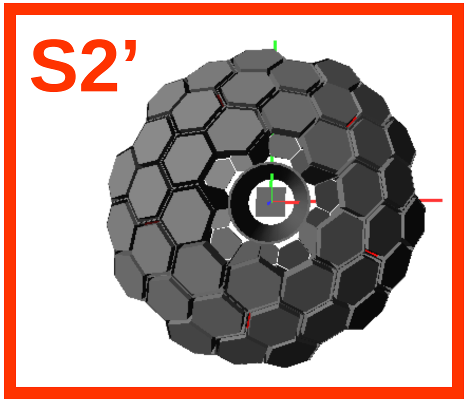


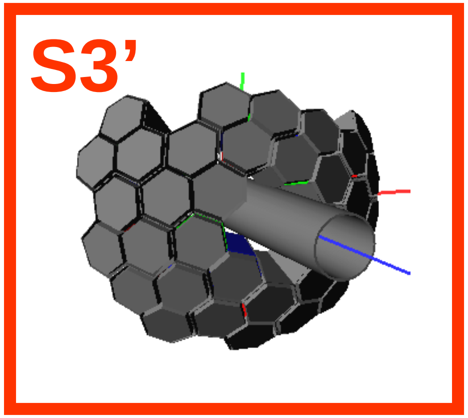




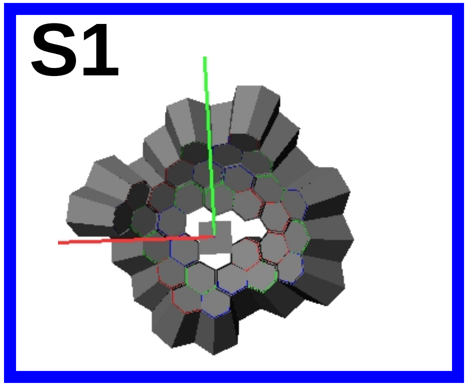


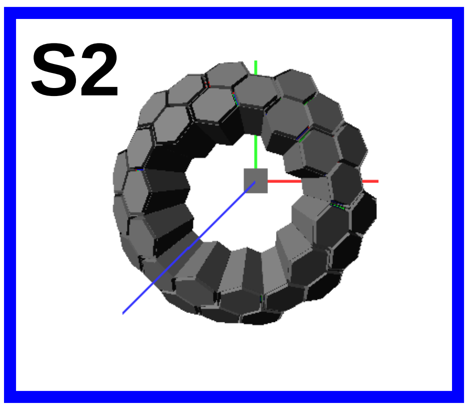


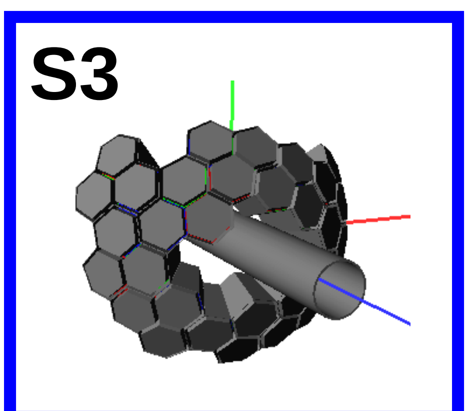


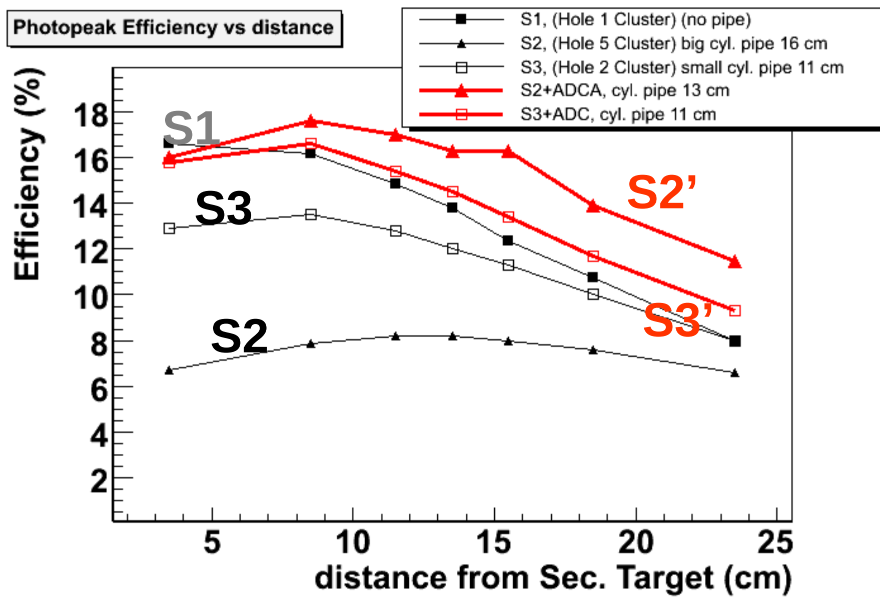


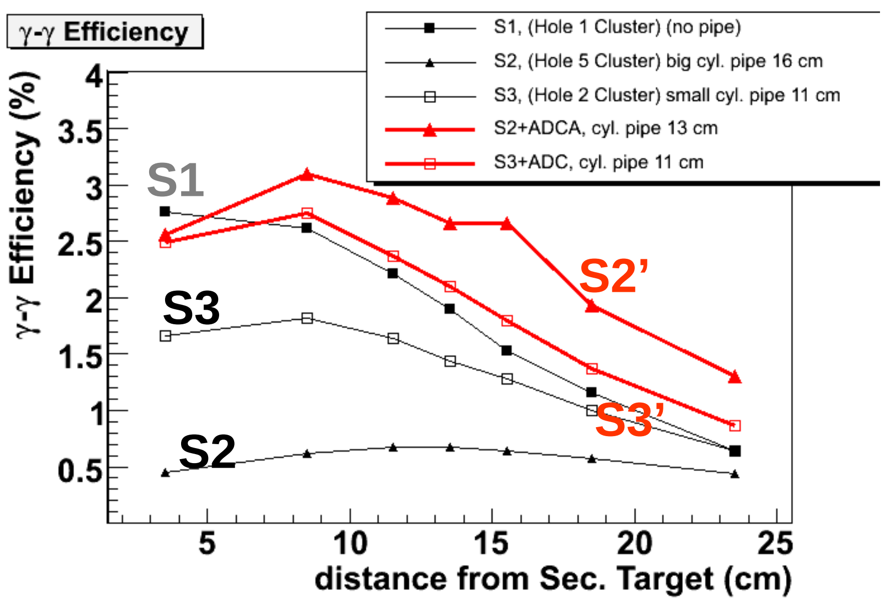
S-Geometries Performance comparison: Efficiency

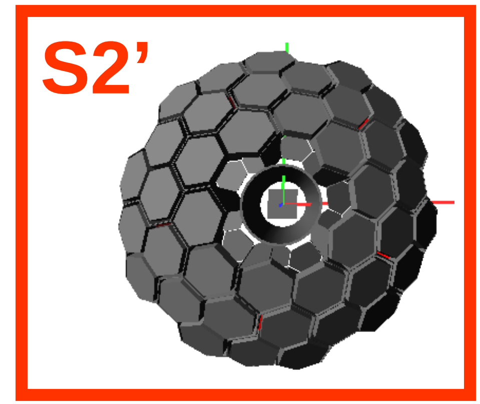


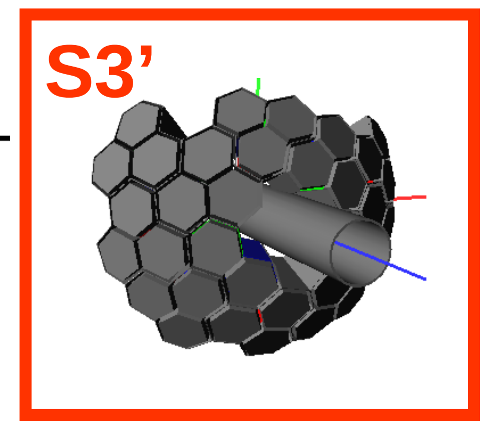




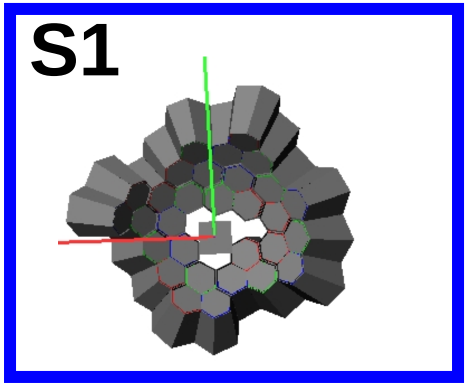


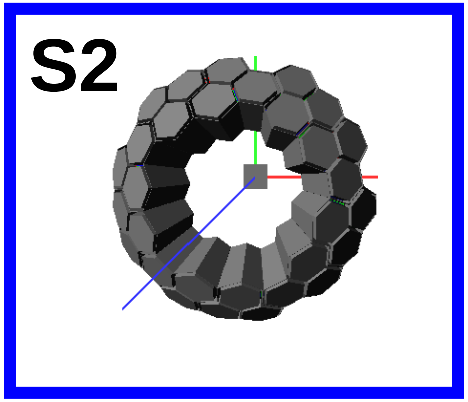


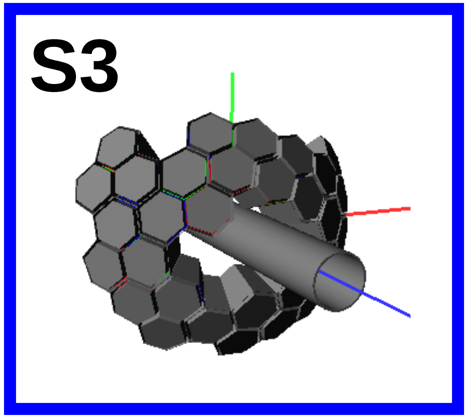


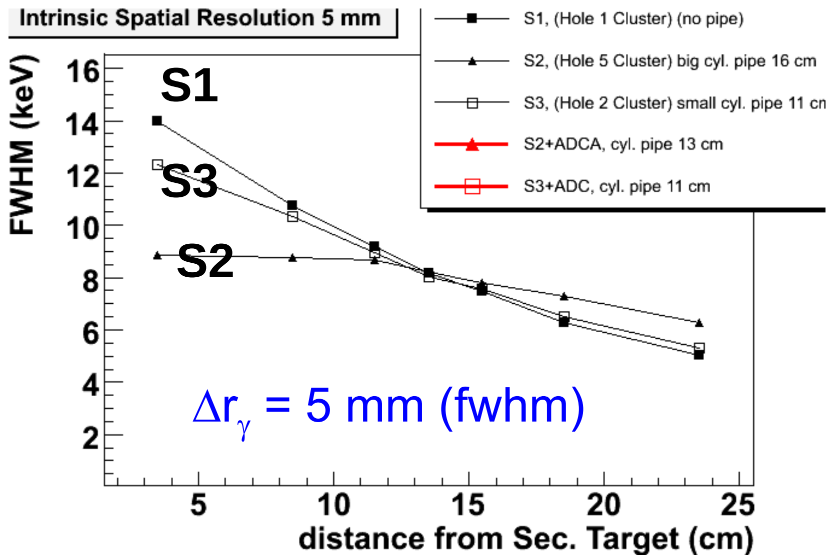


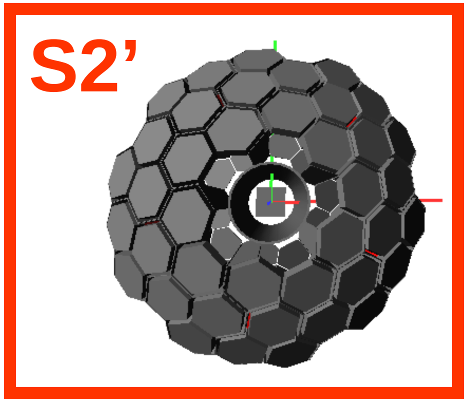
S-Geometries Performance comparison: Resolution

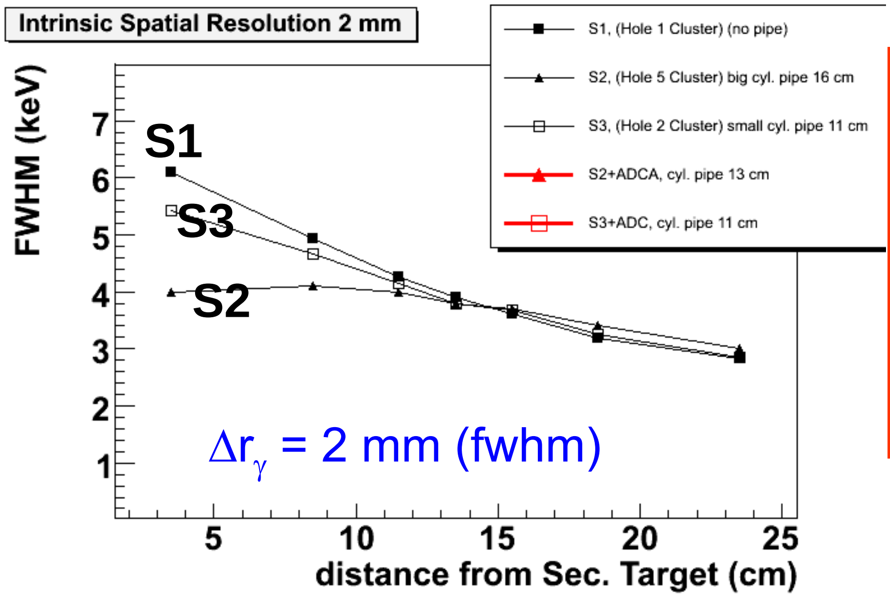


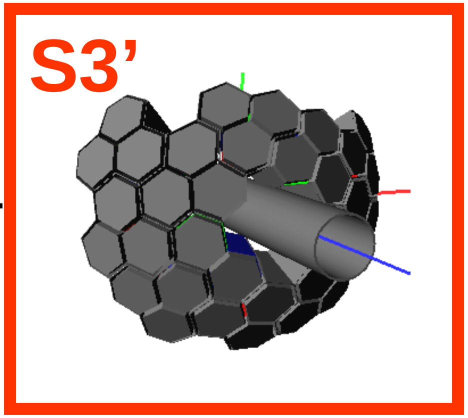












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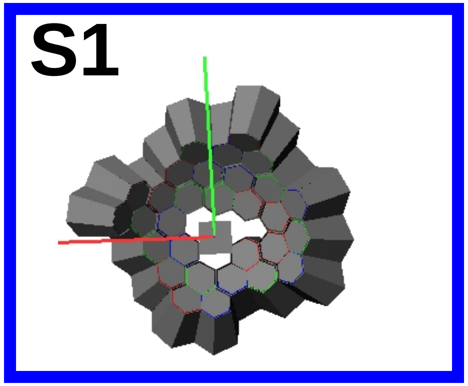
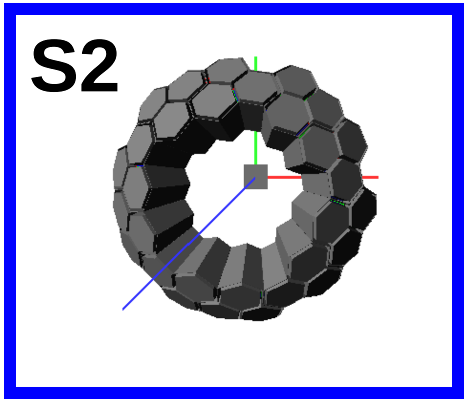
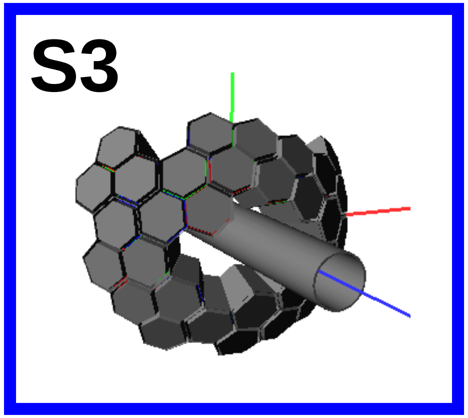
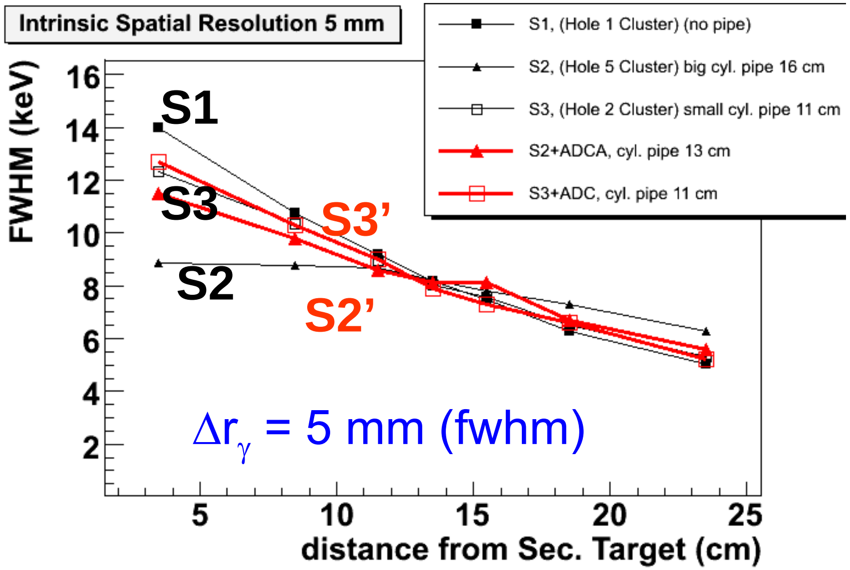
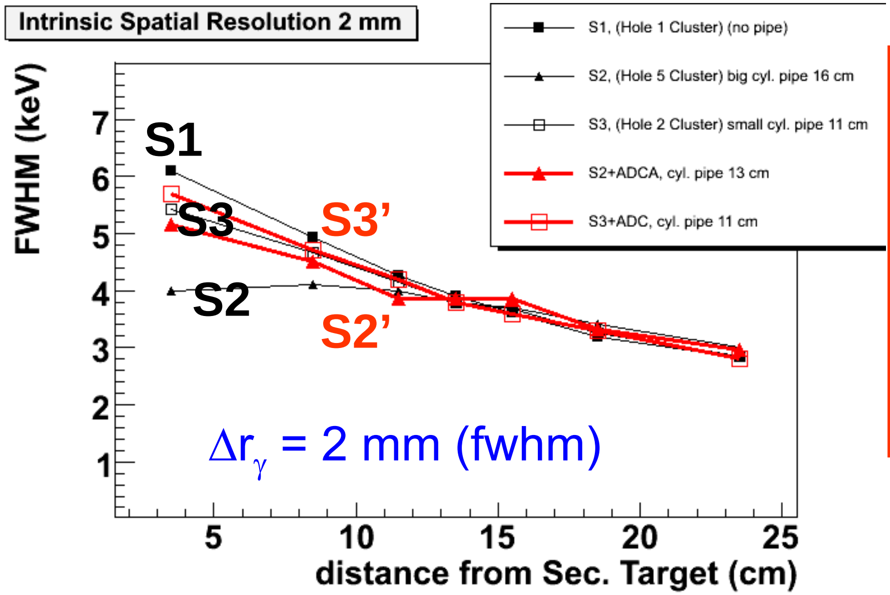
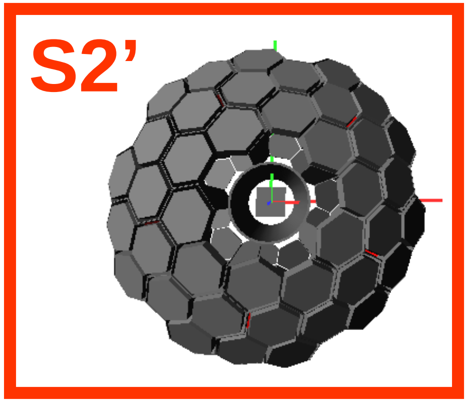


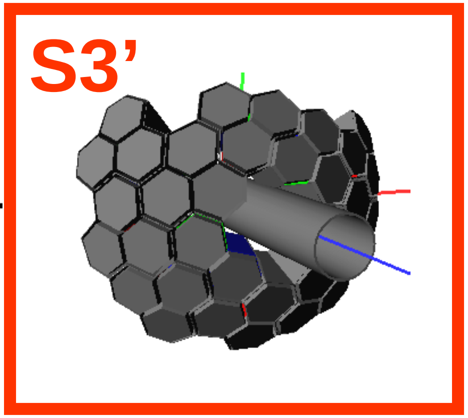




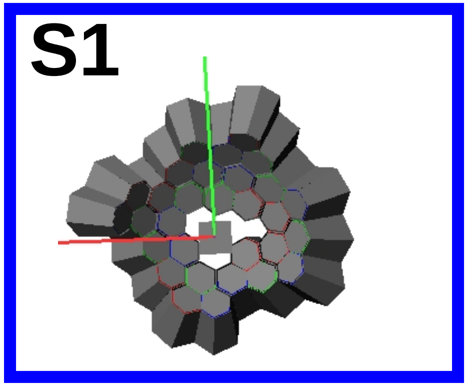


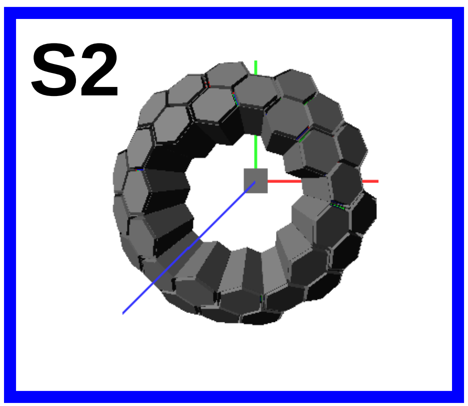


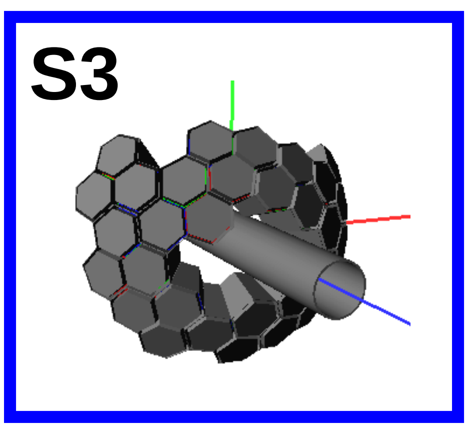


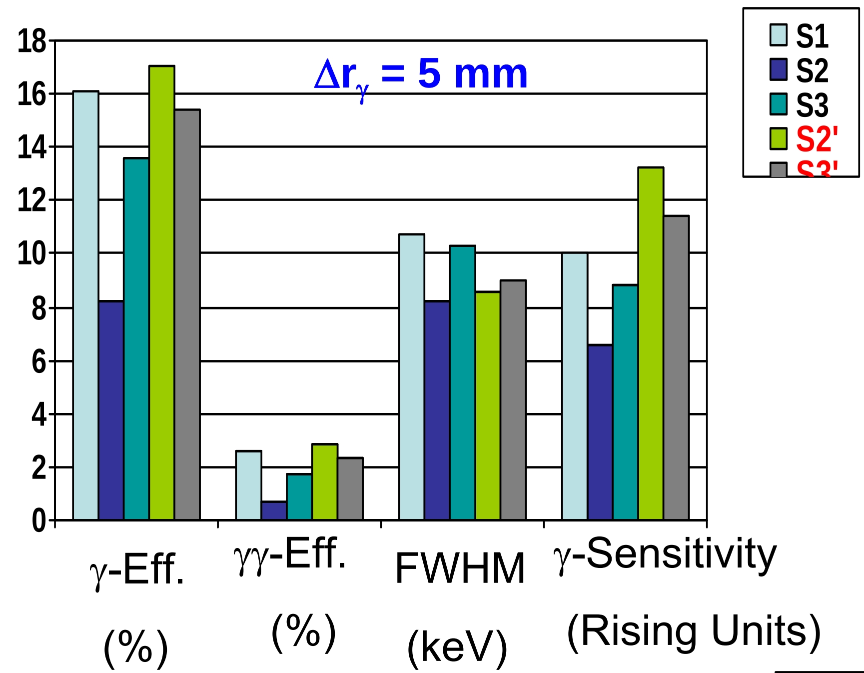


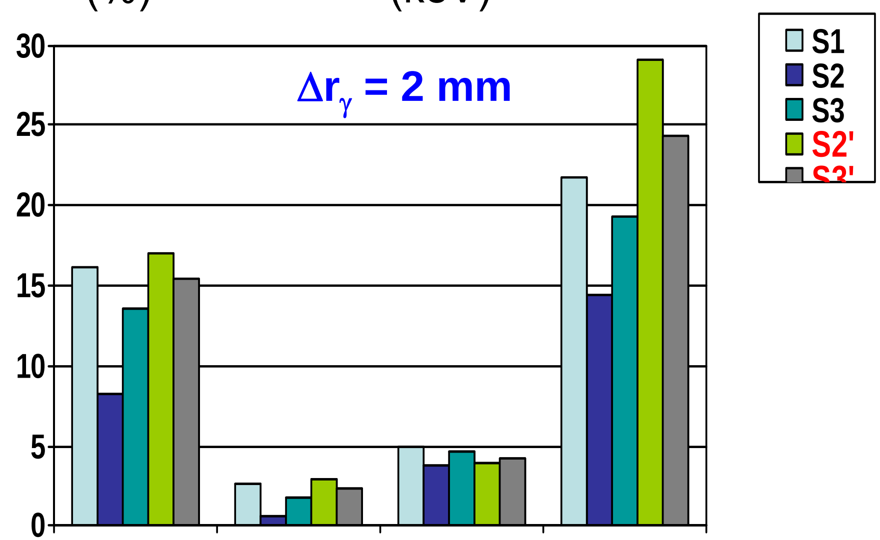
Shell Geometries performance comparison: Summary

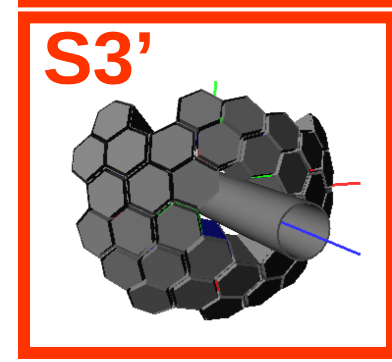












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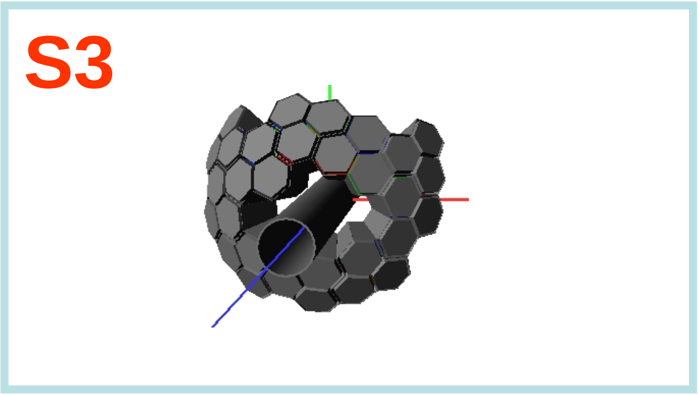

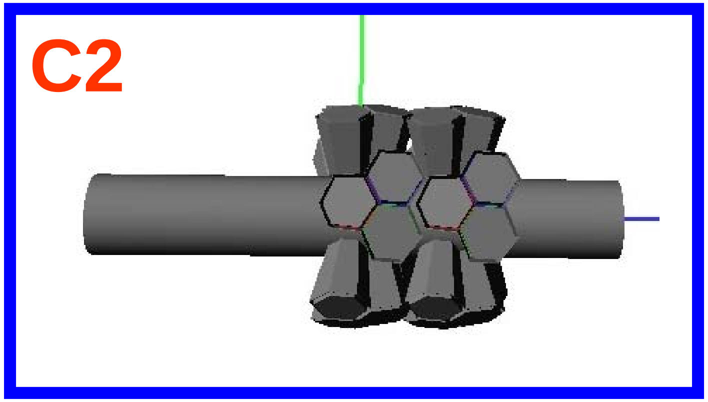

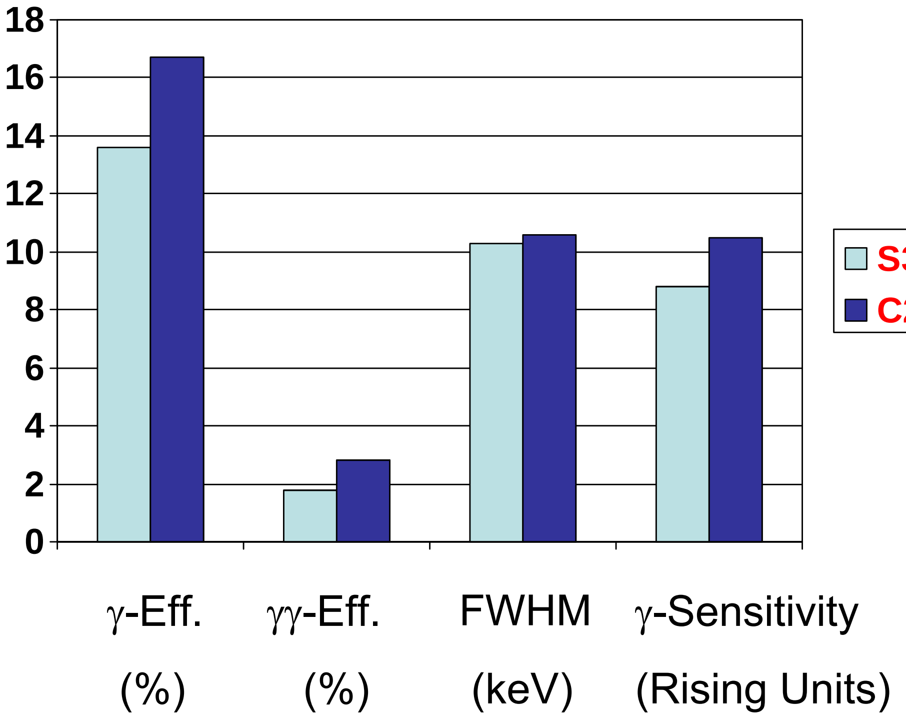

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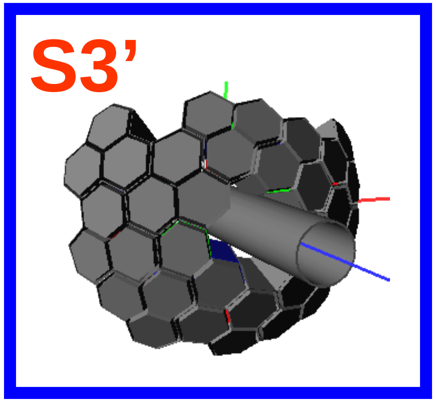

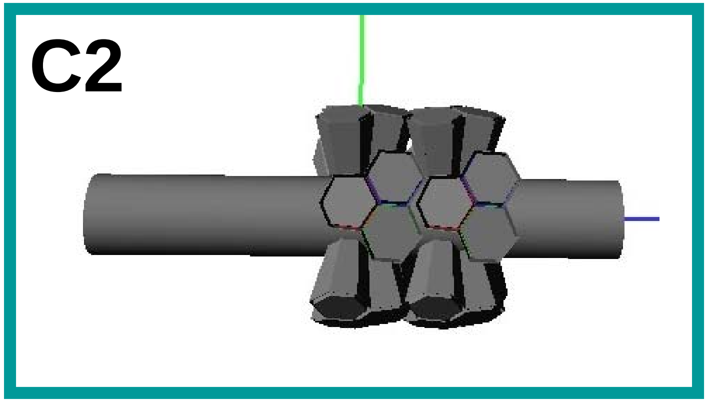

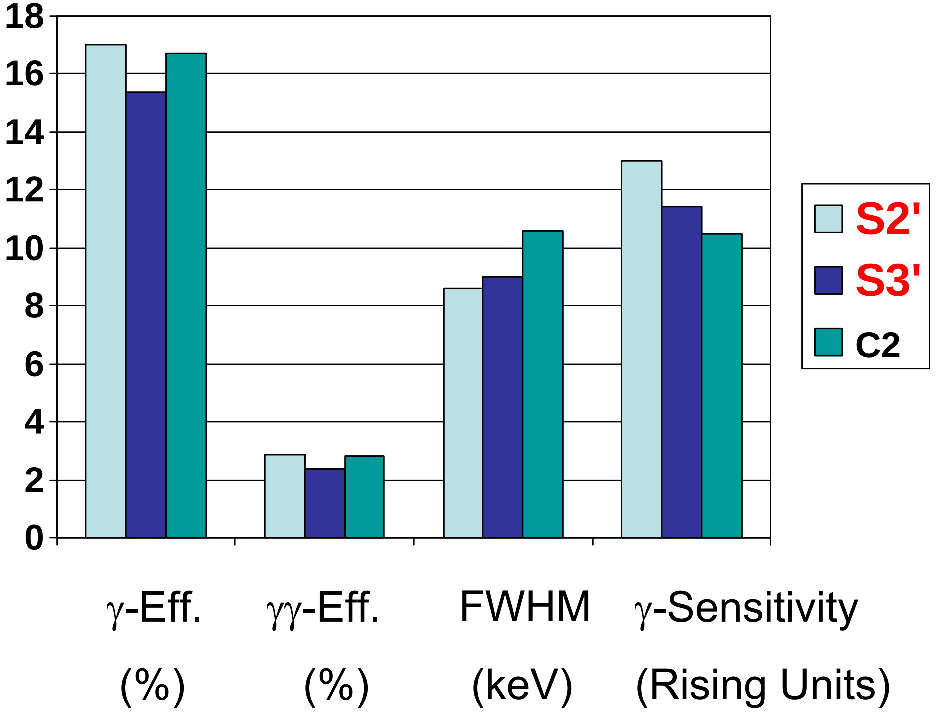

List of Tasks for the **Working Group (17.07.2009)**

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 ✓
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- ~~Task 3~~: 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).

• Typical γ-ray efficiencies between 14% and 17% can be achieved, which in combination with resolutions (FWHM) of 8-9 keV will provide a γ-ray sensitivity of more than 10 times the RISING sensitivity.

Outline

- Summary of **simulated geometries** for experiments at GSI-FRS
- Summary on the **performance** of each geometry case
- Conclusion on **best geometry** for experiments at GSI-FRS
- **Benchmark** experiments
- (More) realistic simulation
- Outlook and conclusion

New results: AGATA S2 + Agata Double Cluster Array (ADCA)

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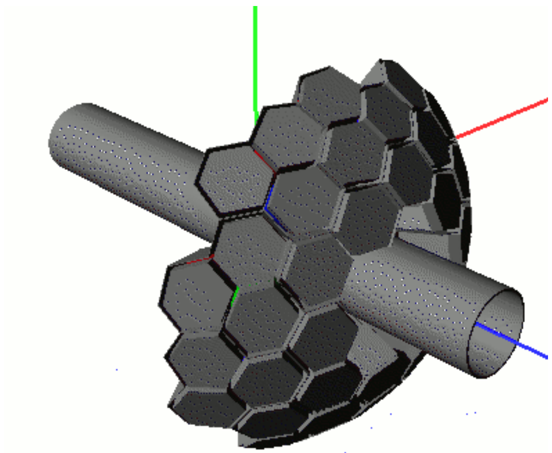
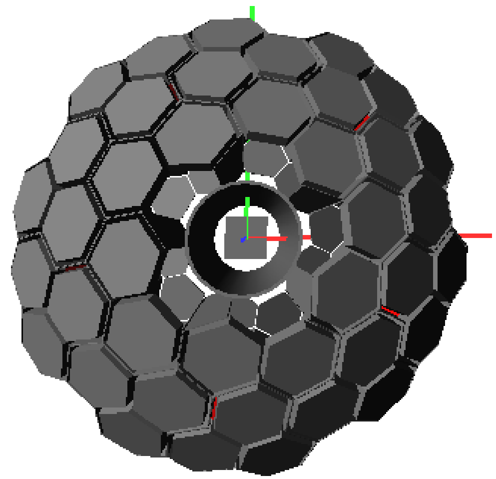
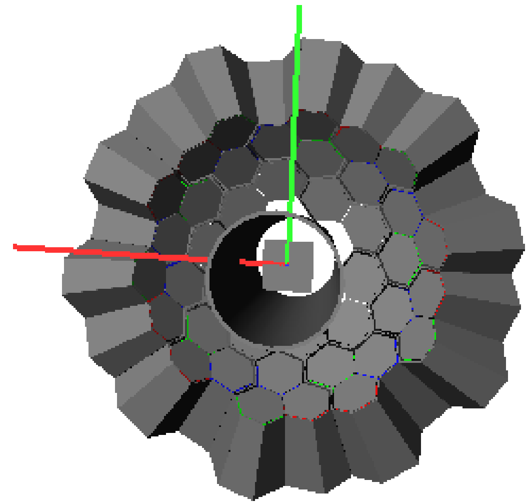

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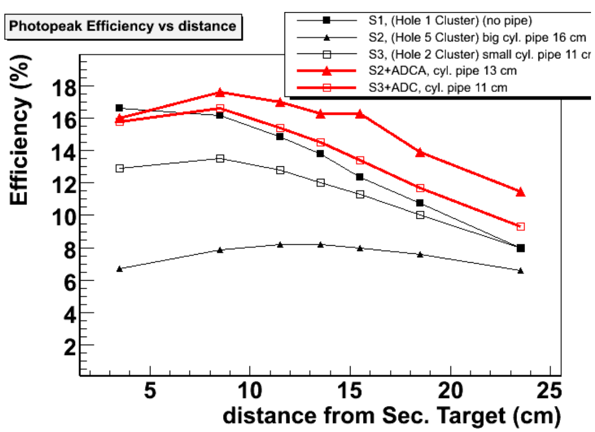

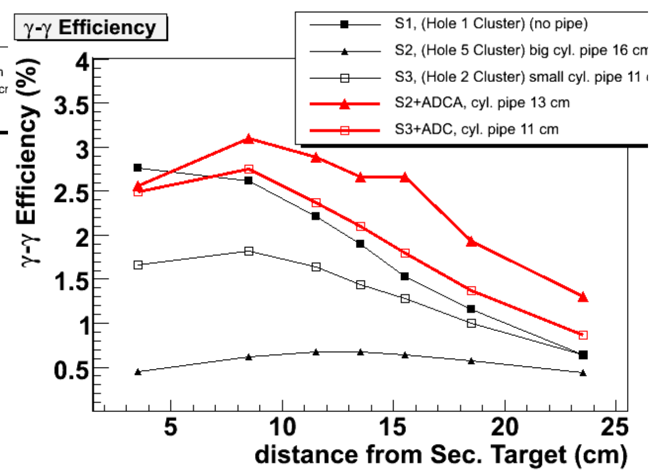

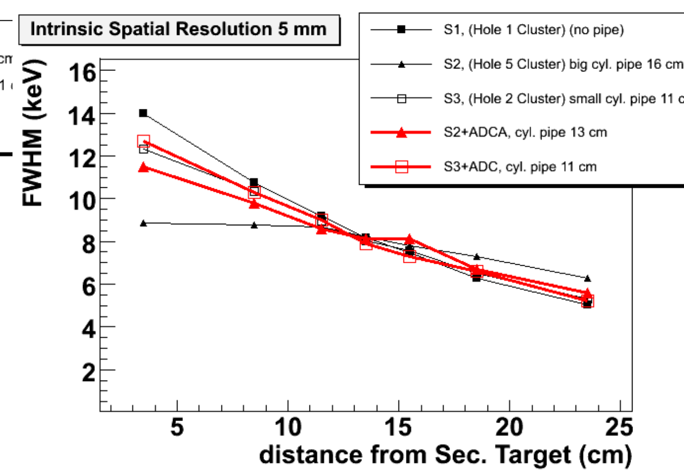

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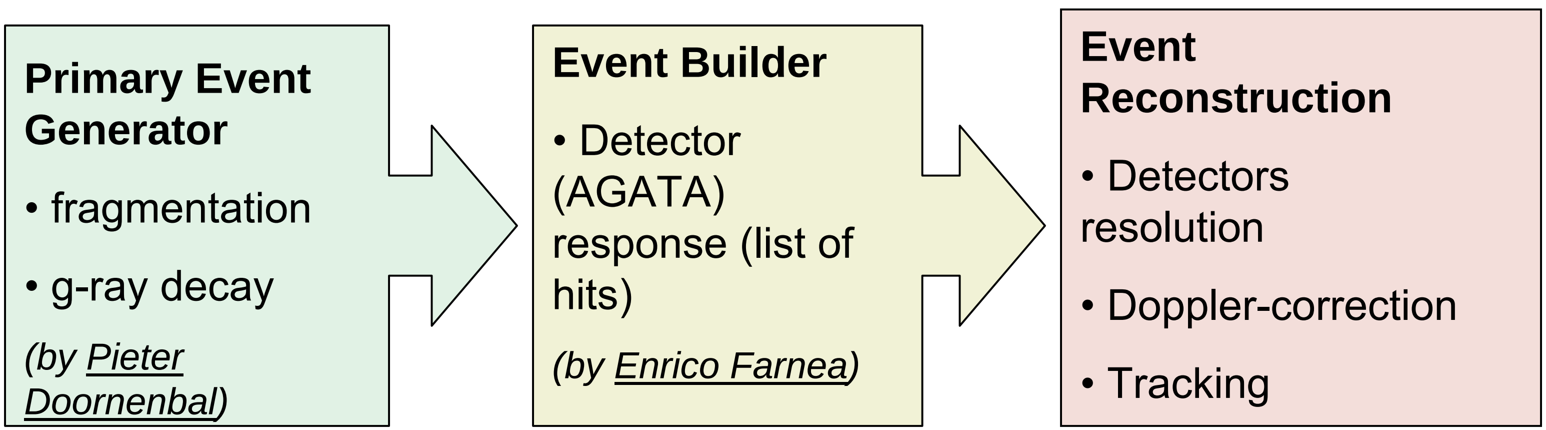
Realistic MC Simulation of a **fragmentation** experiment



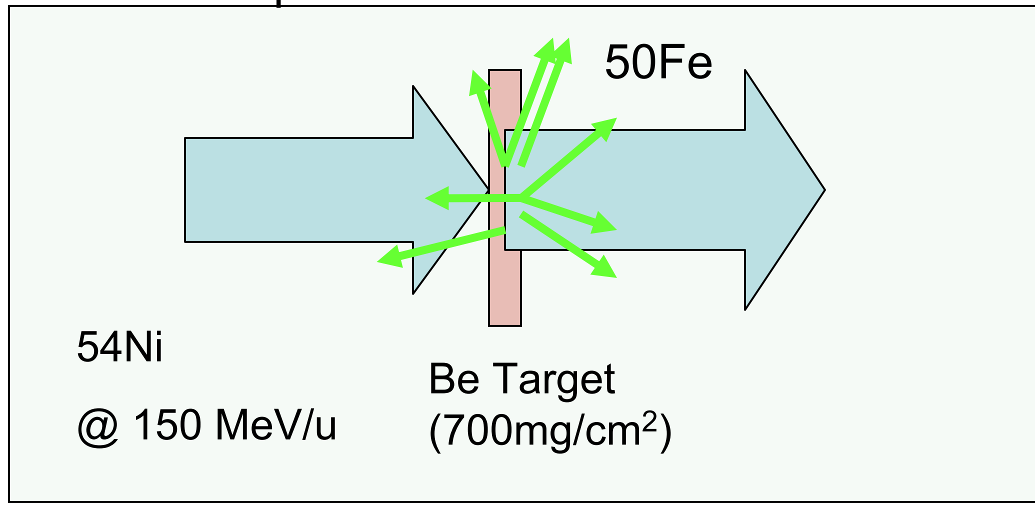
List of Tasks for the **Working Group (17.07.2009)**

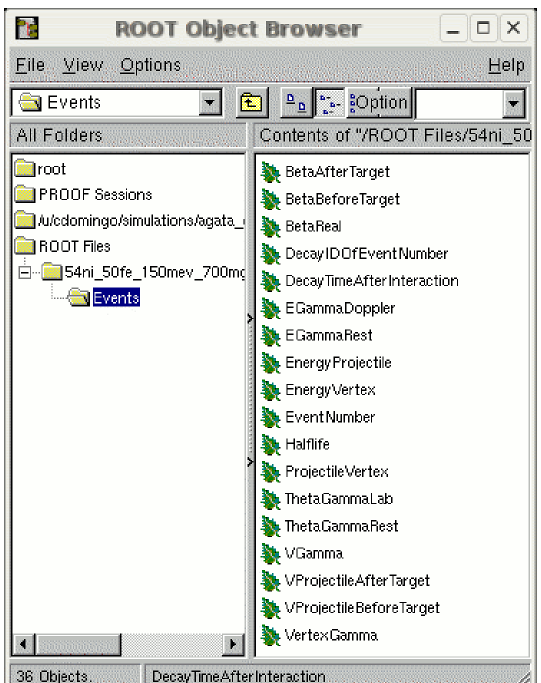
Realistic MC Simulation of a **fragmentation** experiment

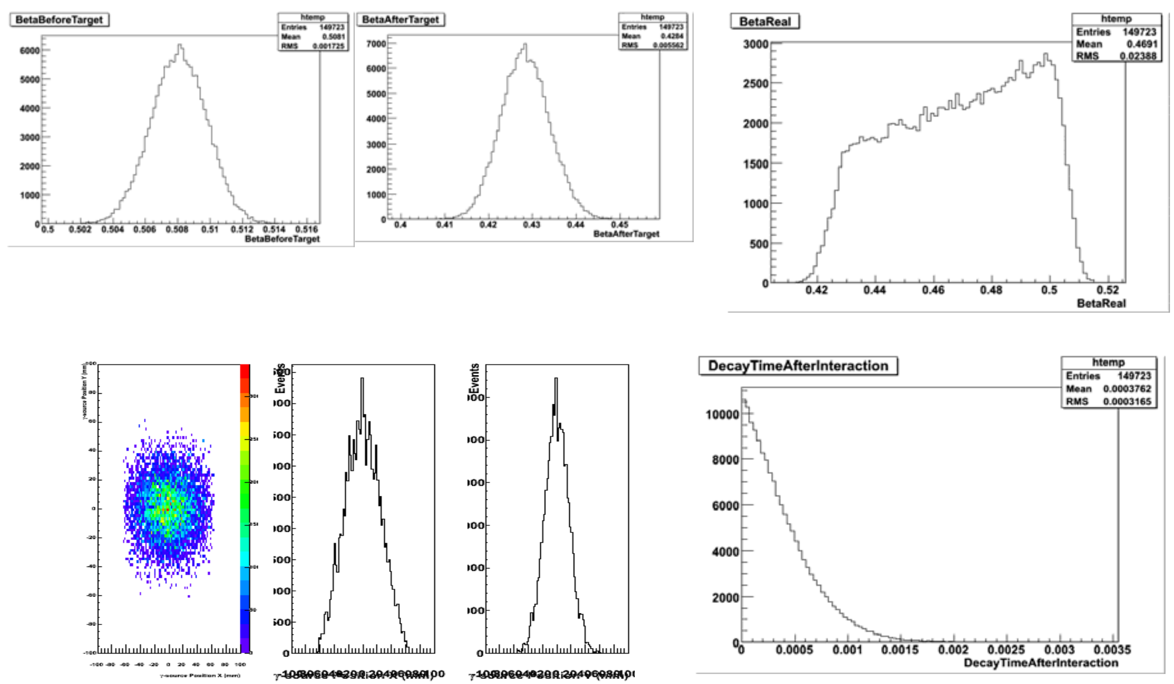
Primary Event Generator

- fragmentation
- g-ray decay

(by Pieter Doornenbal)







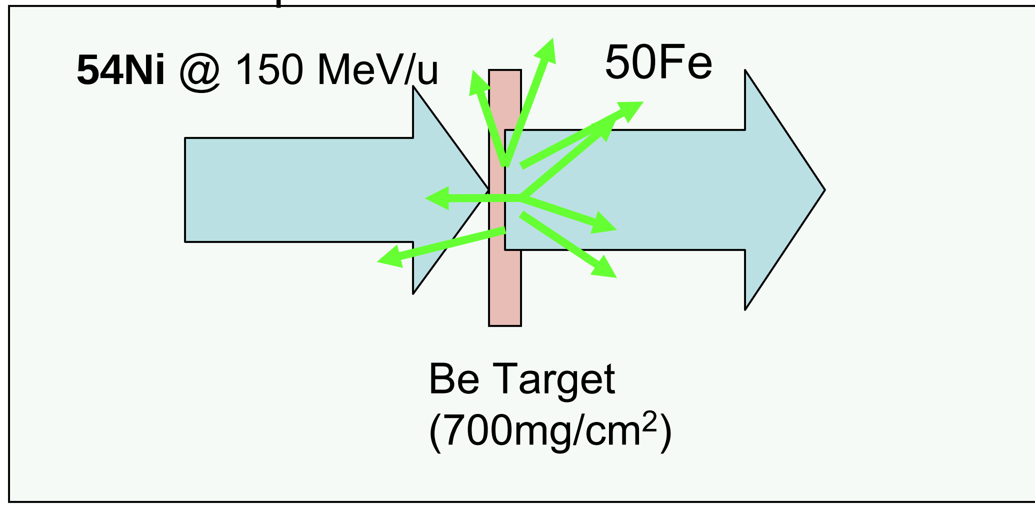
List of Tasks for the **Working Group (17.07.2009)**

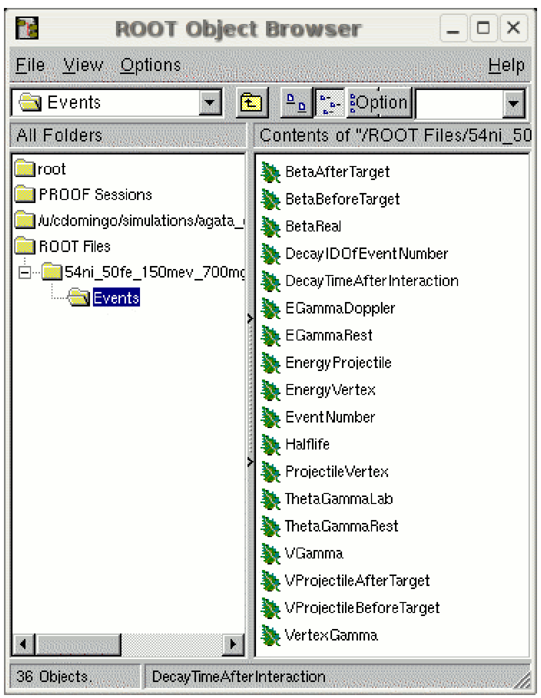
Realistic MC Simulation of a **fragmentation** experiment

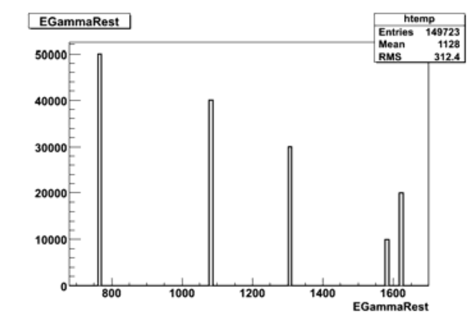
Primary Event Generator

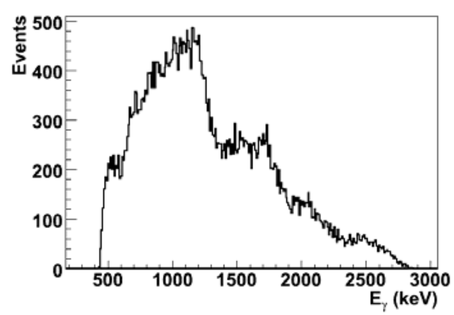
- fragmentation
- g-ray decay

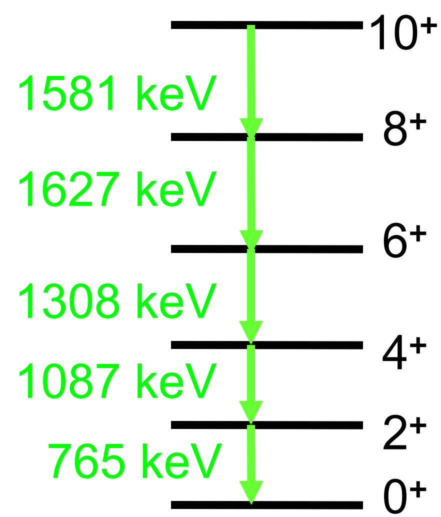
(by Pieter Doornenbal)











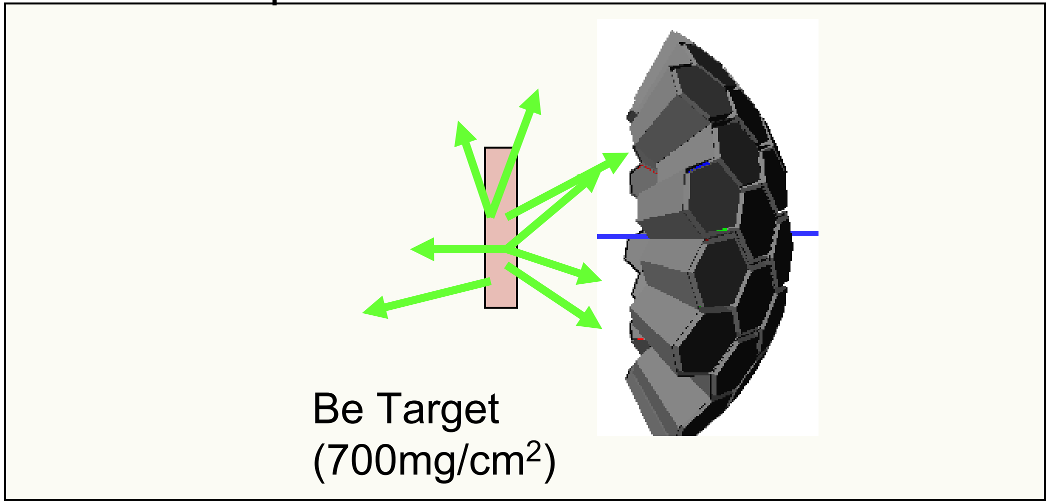
List of Tasks for the **Working Group (17.07.2009)**

Realistic MC Simulation of a **fragmentation** experiment

Event Builder

- Detector (AGATA) response (list of hits)

(by Enrico Farnea)



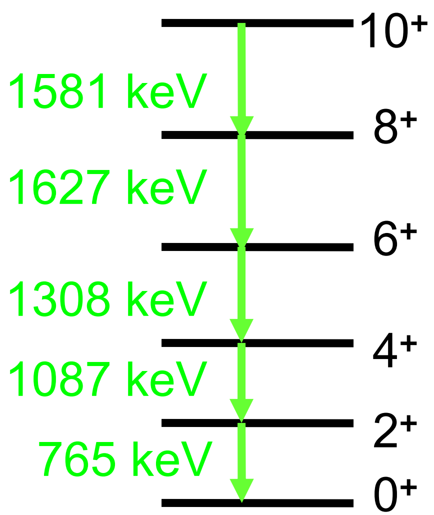

```
GAMMA 1
1000.0000
RECOIL  0.5000  0.0000  0.0000  0.0000  1.0000  0.0000
SOURCE       0       0  0.0000    0.0000    0.0000
$
  -1   1401.723 -0.43045  0.48009  0.76434 0
  29    73.617 -142.729  141.623  234.825 52     1.053
  29    39.475 -143.302  150.765  245.890 52     1.129
  29   148.895 -151.199  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
.
.
.
```

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

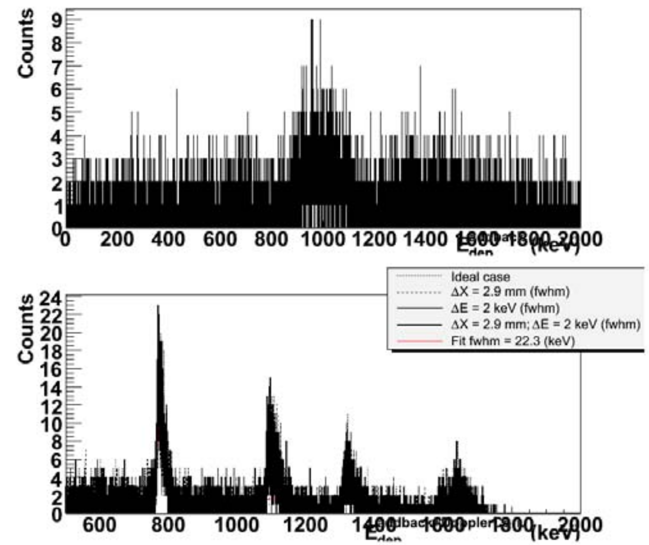
Realistic MC Simulation of a **fragmentation** experiment

Event Reconstruction

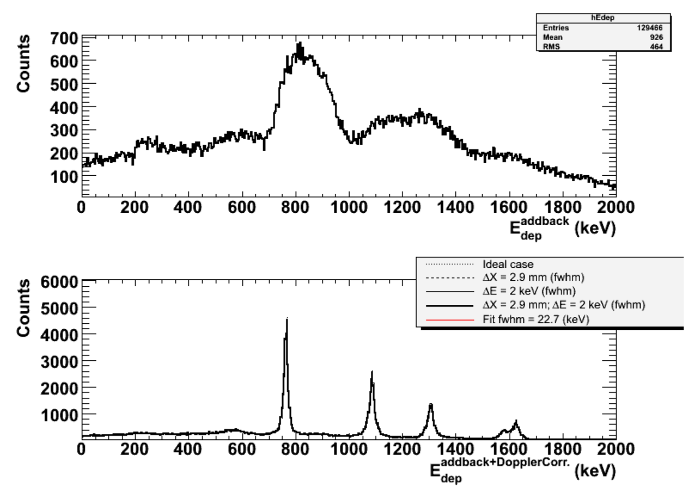
- Detectors resolution
- Doppler-correction
- Tracking



Low Statistics

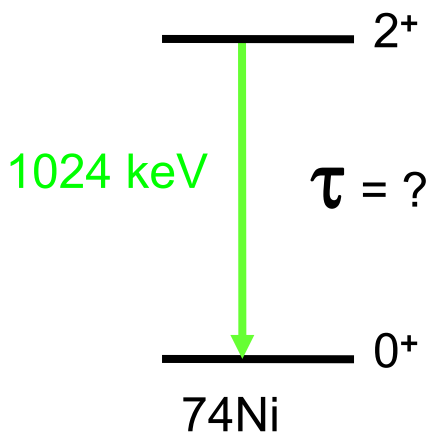


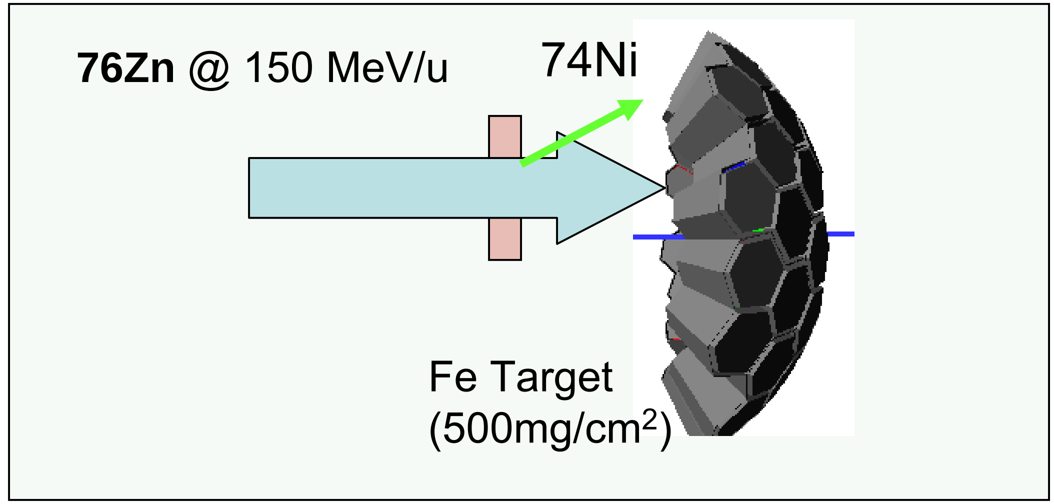
High Statistics

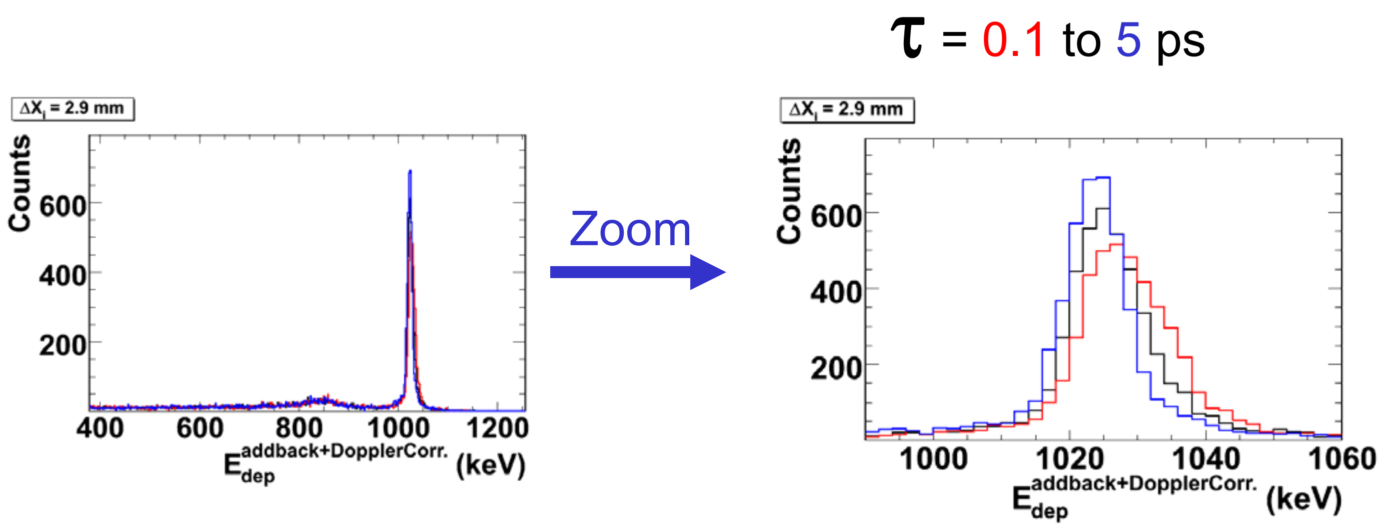


List of Tasks for the **Working Group (17.07.2009)**

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







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: C2 geometry, with clusters in 2^{nd} ring pointing to target, and 3^{rd} 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 (M. Reese TU-Darmstadt, A. Dewald, Uni. Koeln). Enfasis on angular distribution and contribution of RISING at forward angles ✓

See Talk by Michael Reese

Realistic implementation

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

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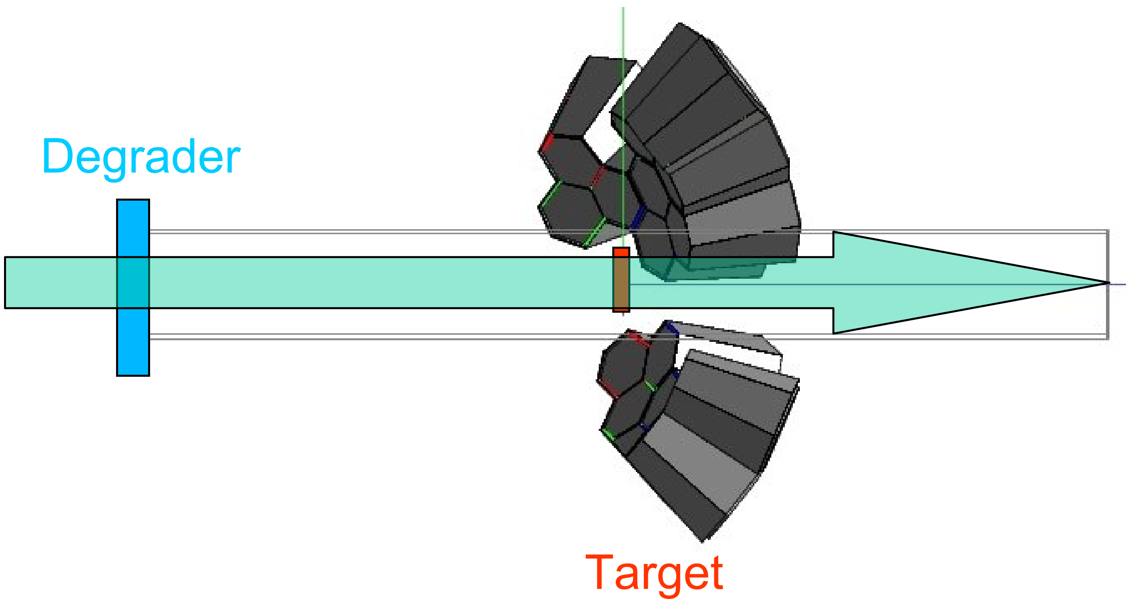
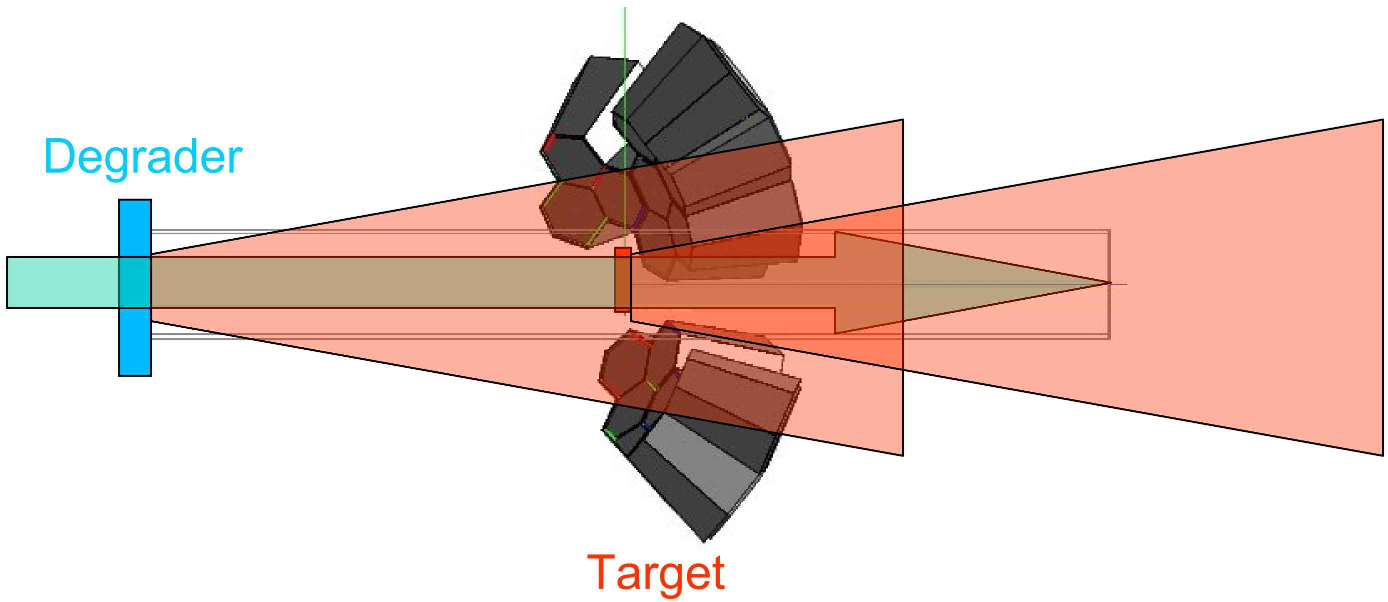
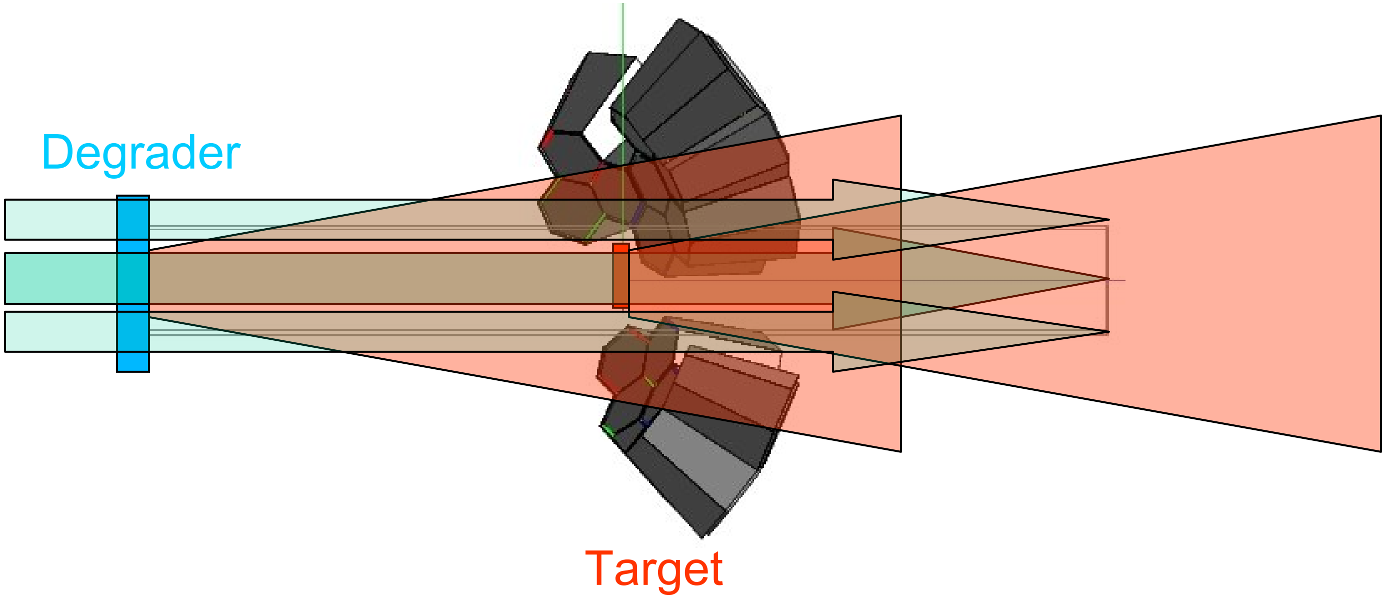
Realistic MC Simulation: Background



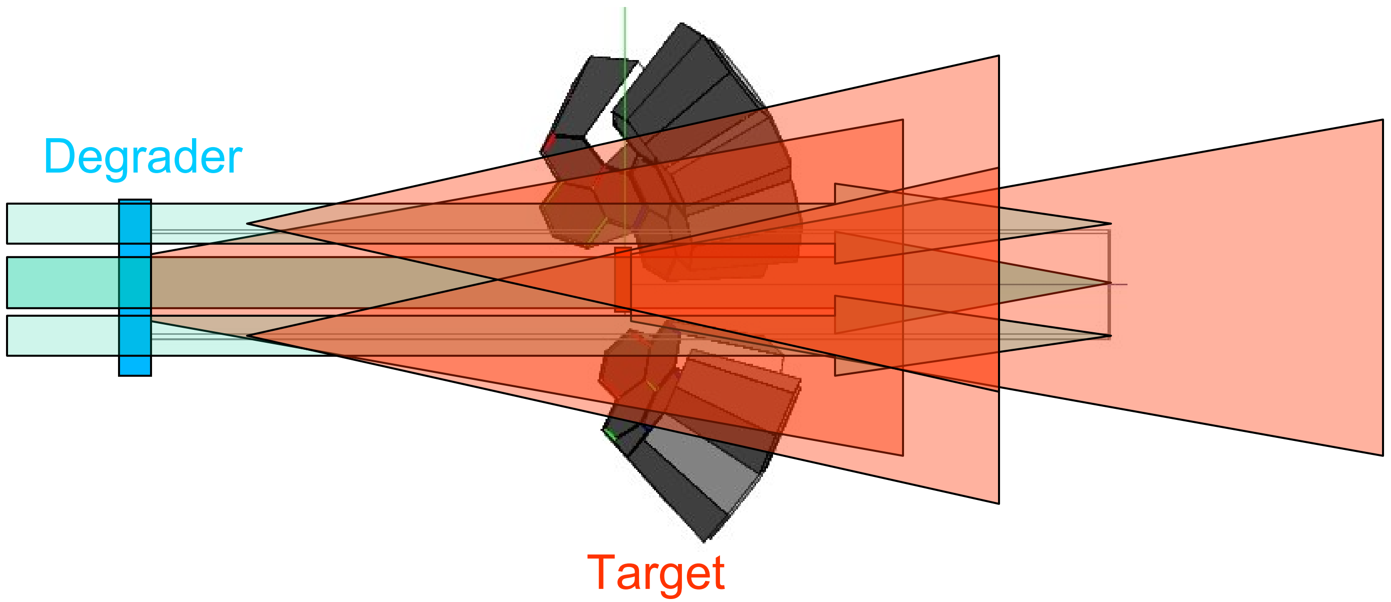
Realistic MC Simulation: Background



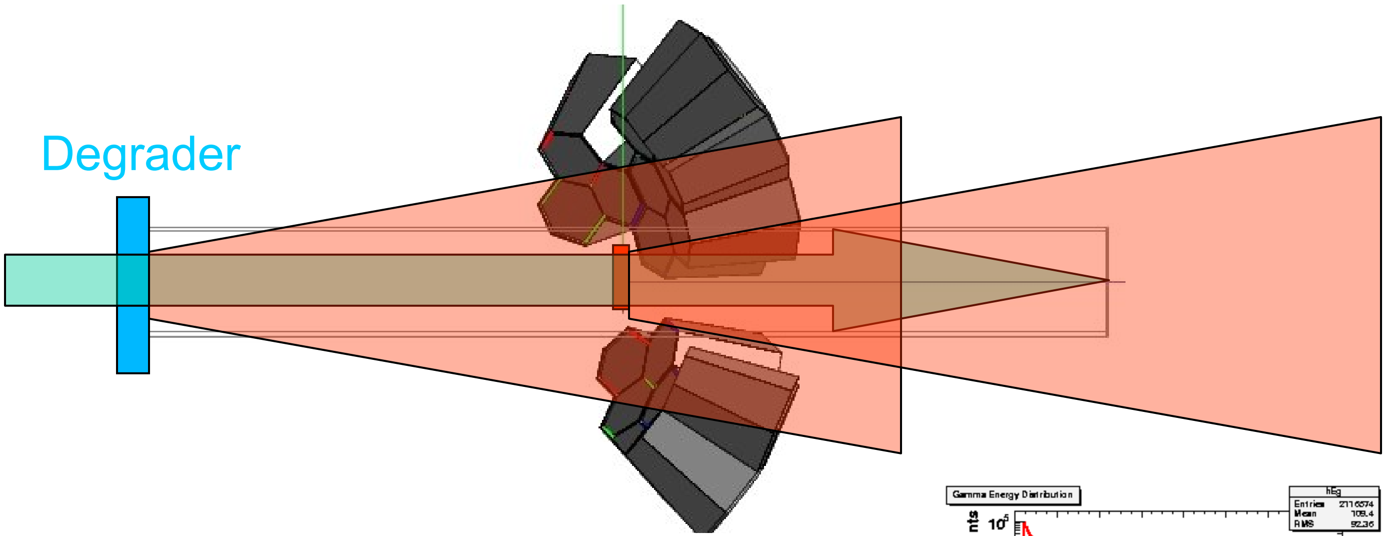
Realistic MC Simulation: Background

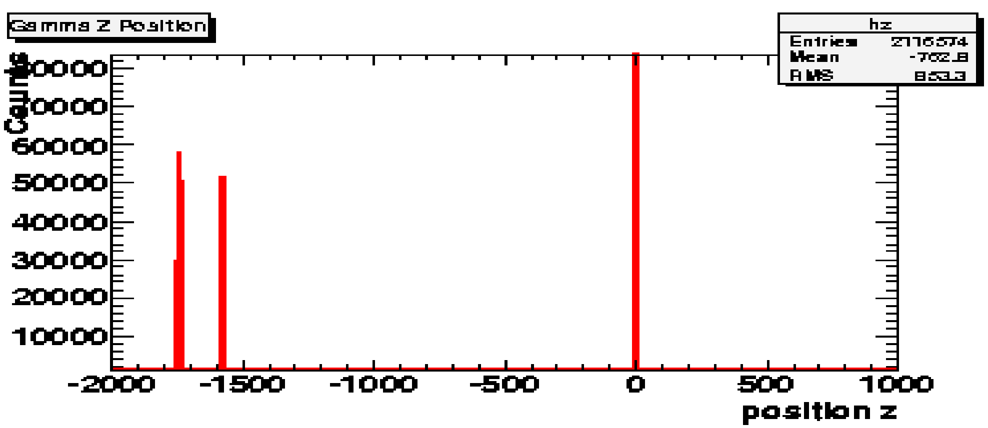


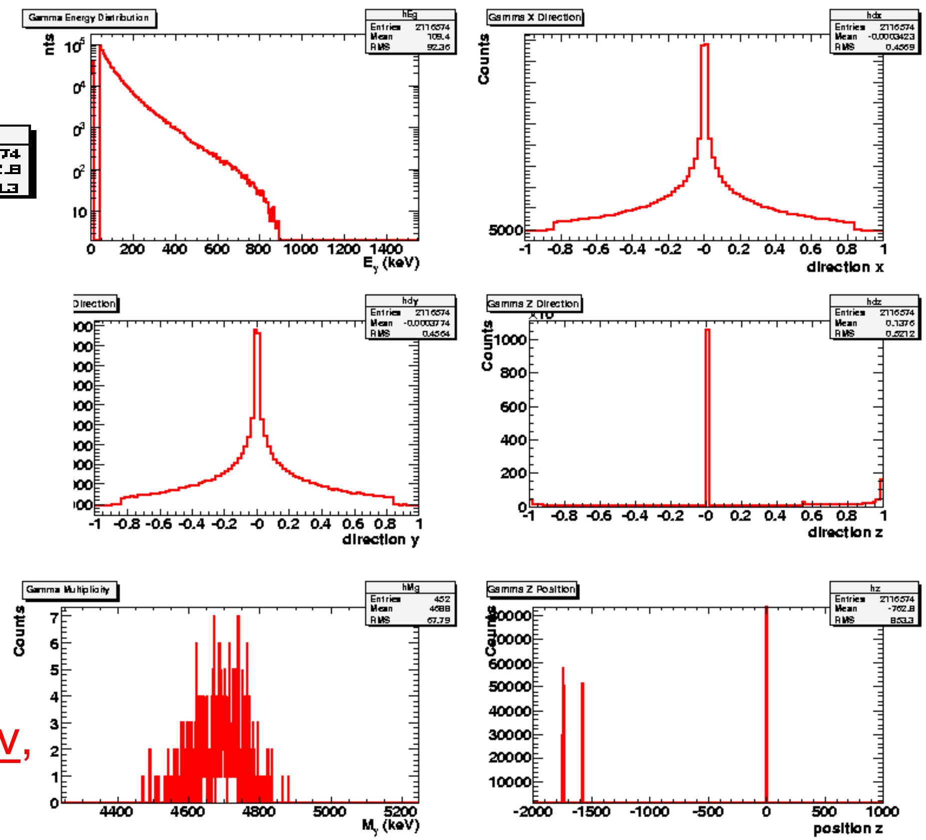
Realistic MC Simulation: Background



Realistic MC Simulation: Background



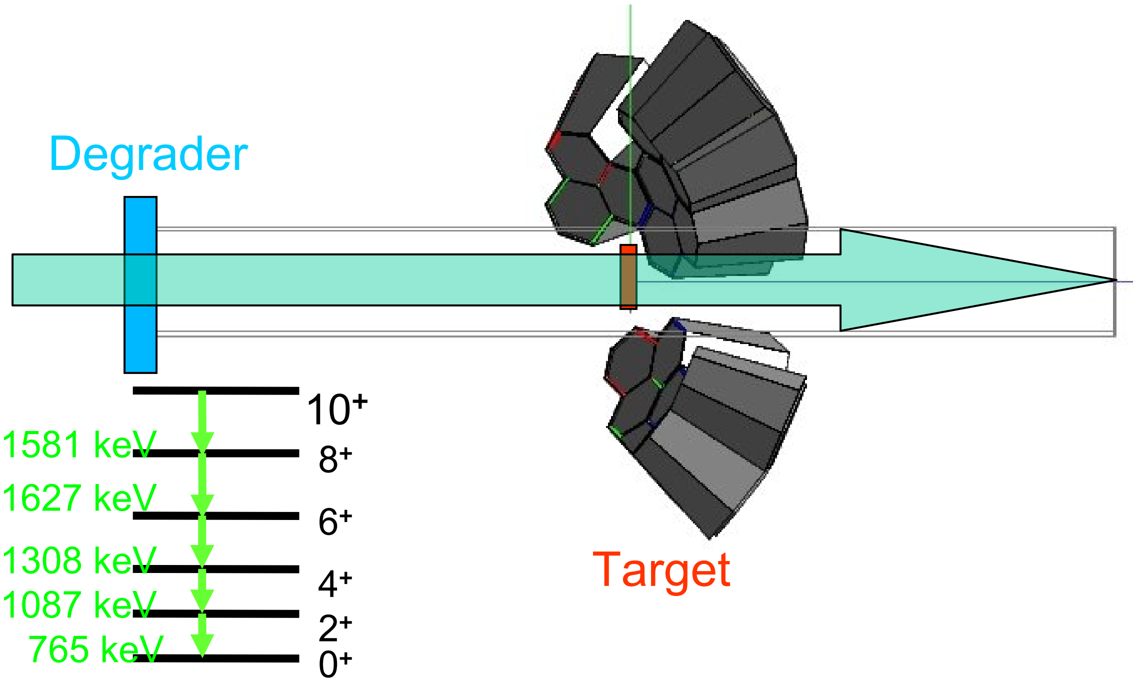


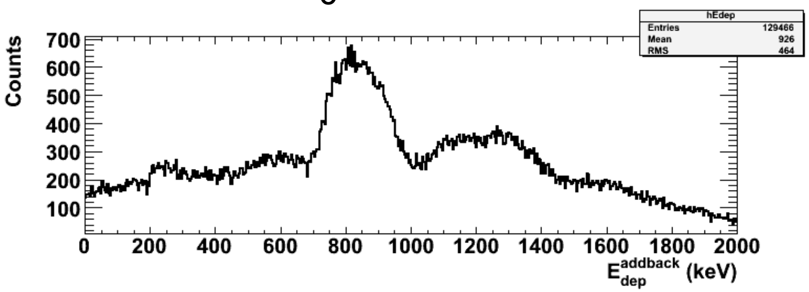


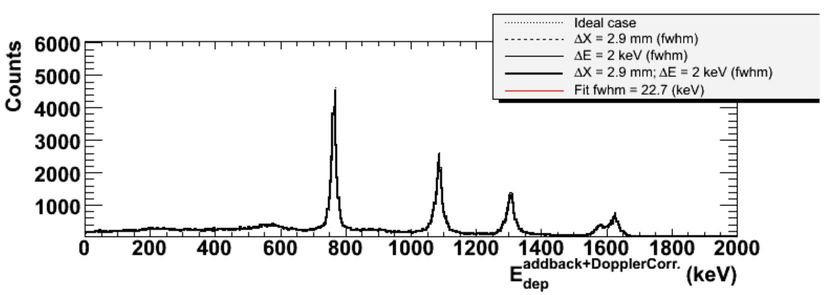
Background Events courtesy of Pavel Detistov,

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

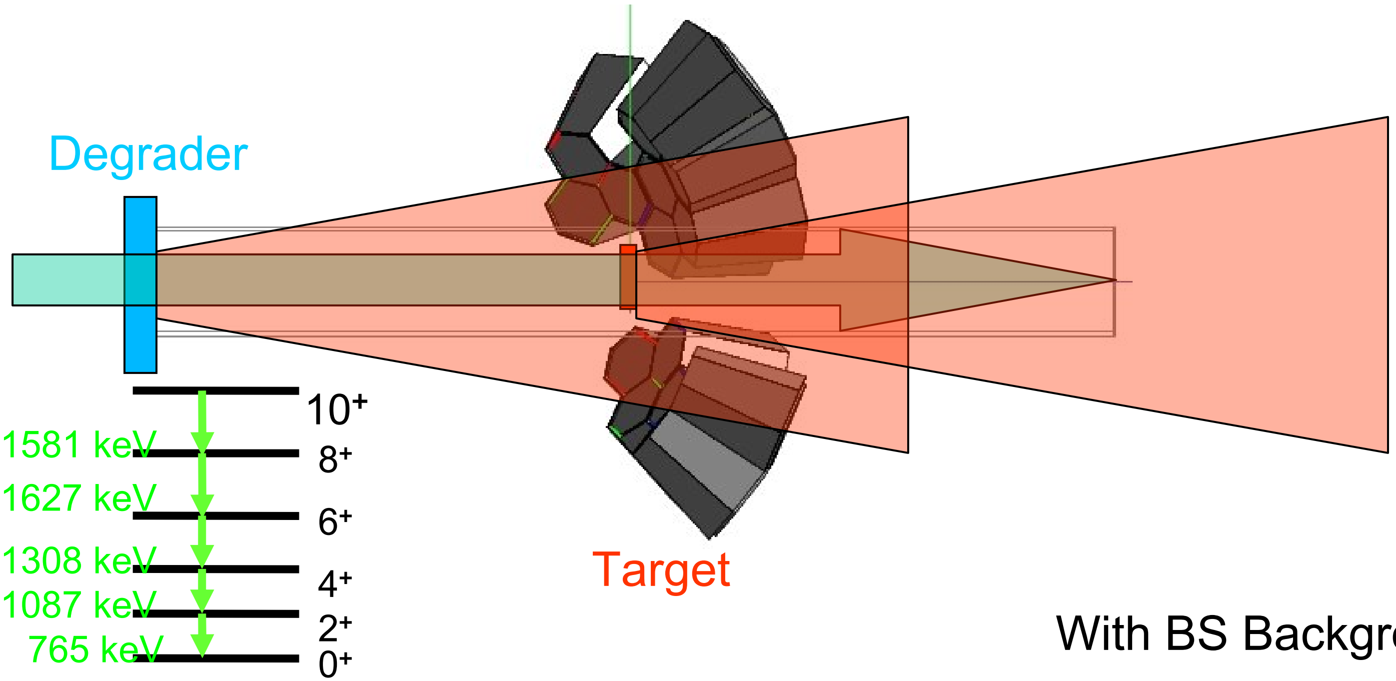
Realistic MC Simulation: Background

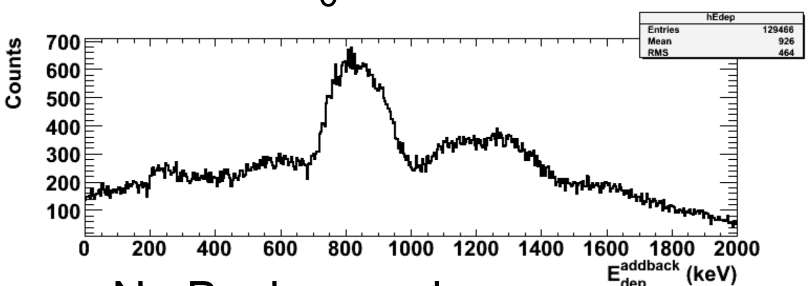




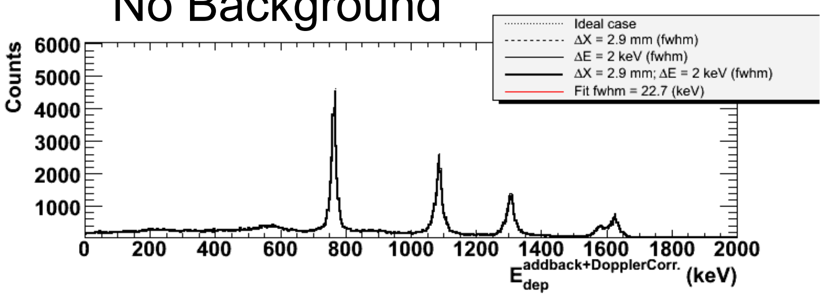


Realistic MC Simulation: Background

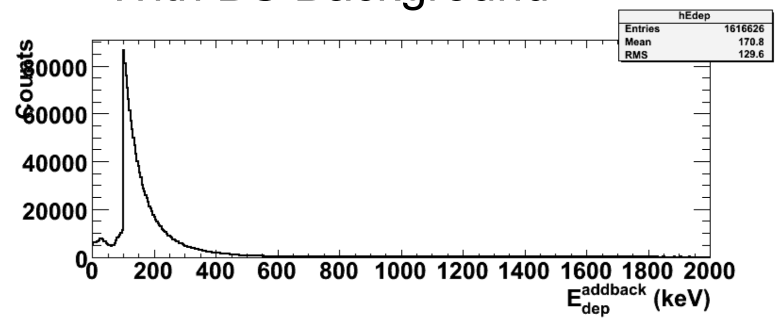


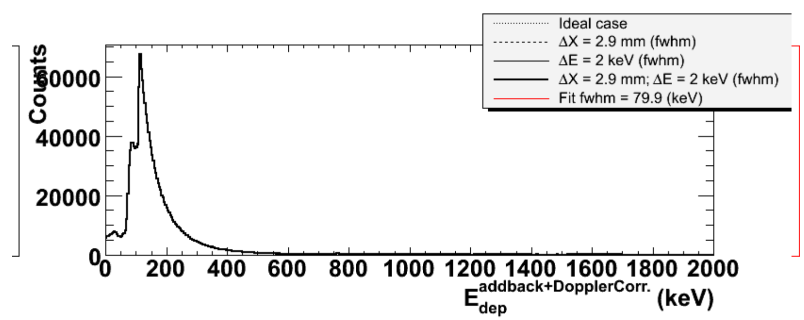


No Background

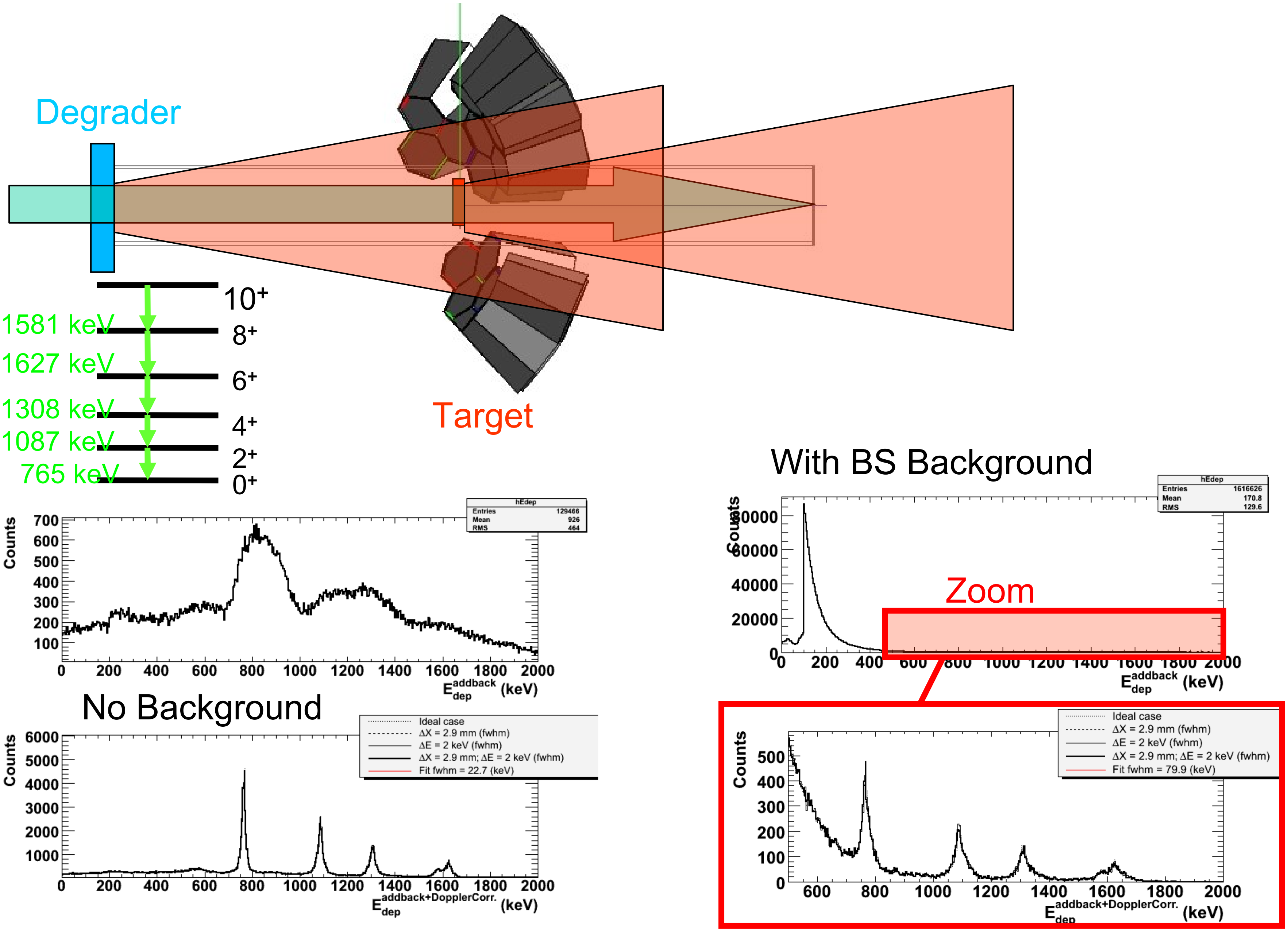


With BS Background

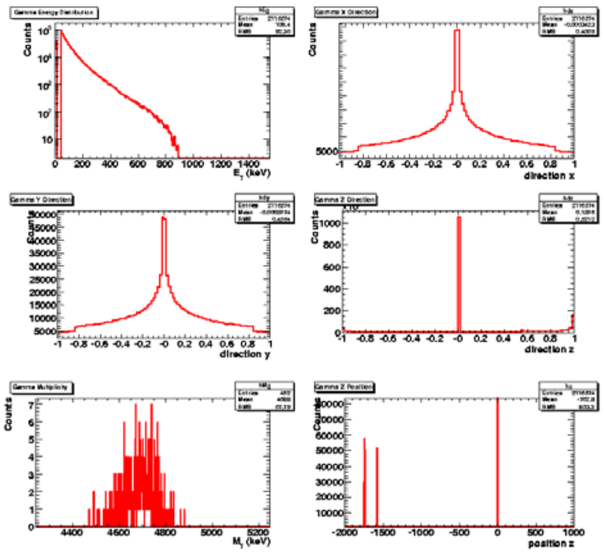


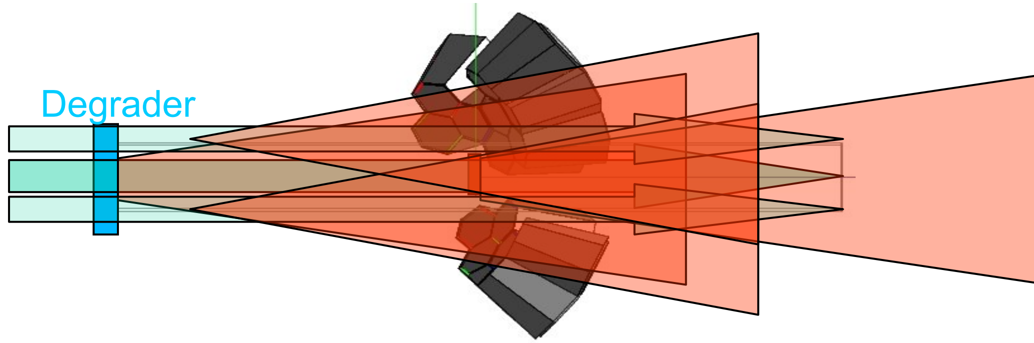


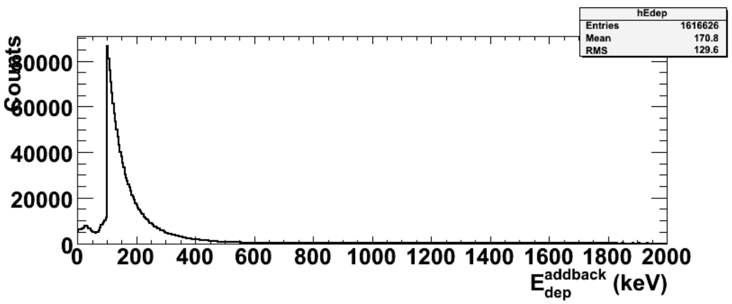
Realistic MC Simulation: Background

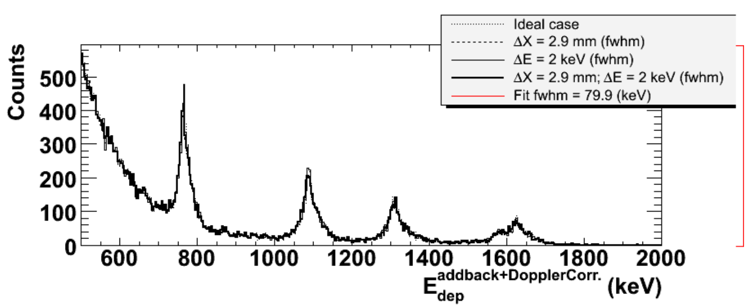


Realistic MC Simulation: Background

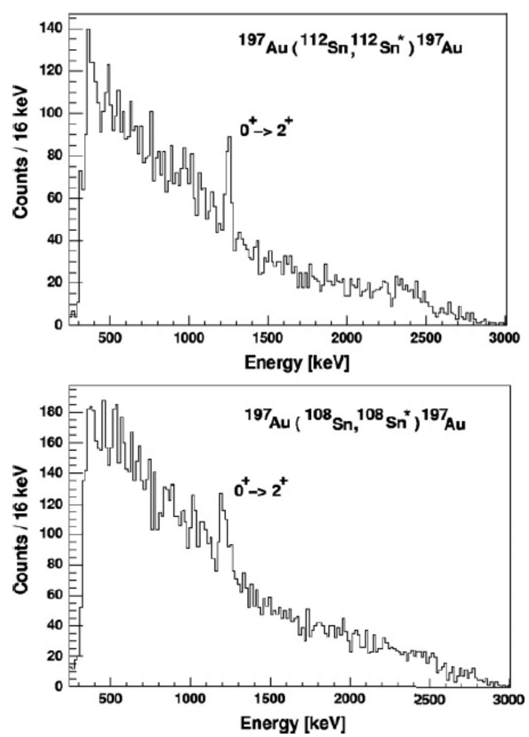




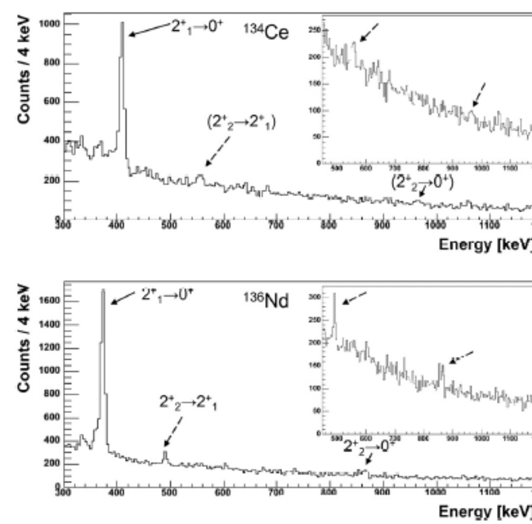




A. Banu et al. PRC 72, 2005



T. Saito et al. PLB, 2008



Summary

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 ✔
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See Talk by Michael Reese

Realistic implementation

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

See Talk by E. Merchan & Pankaj Joshi

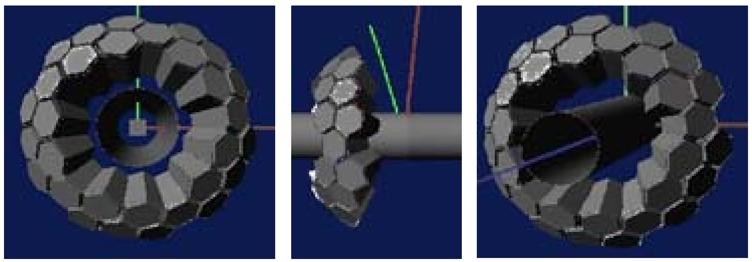
Ersatzfolien

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

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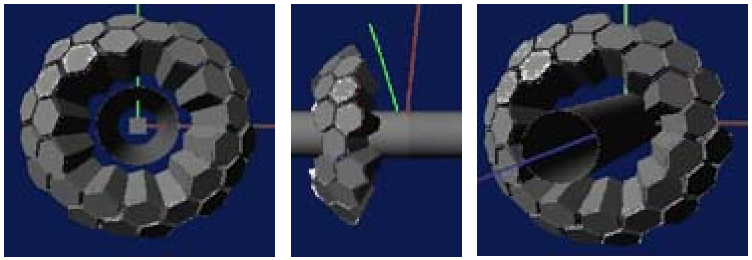

Setup geometry

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
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   1  126.640  125.339  -75.549  240.008 34    1.154
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   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
.
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```
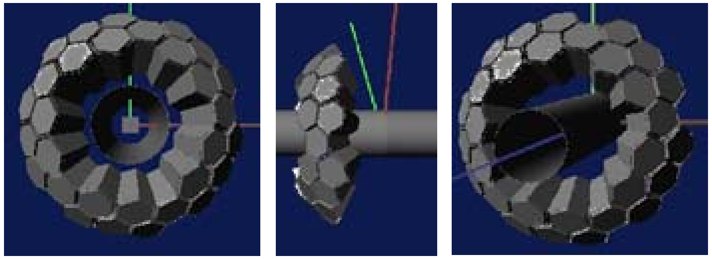

Crystal# Edep X Y Z Segment# (time)

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
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  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
```
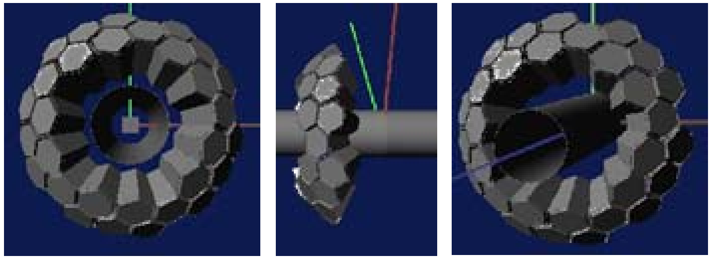

- Total deposited energy at each event:
  - Loop over all hits/event (perfect tracking)
  - mgt code
- Doppler correction:
  - Angle subtended by largest Edep hit

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

General aspects: event reconstruction



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

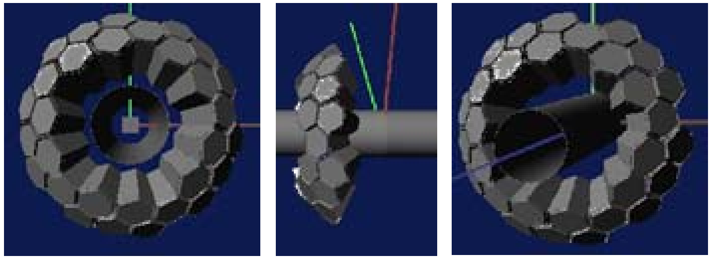
Edep x y z

```
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   148.395 -151.199  143.656  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

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

General aspects: event reconstruction

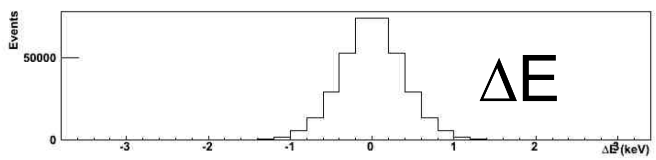


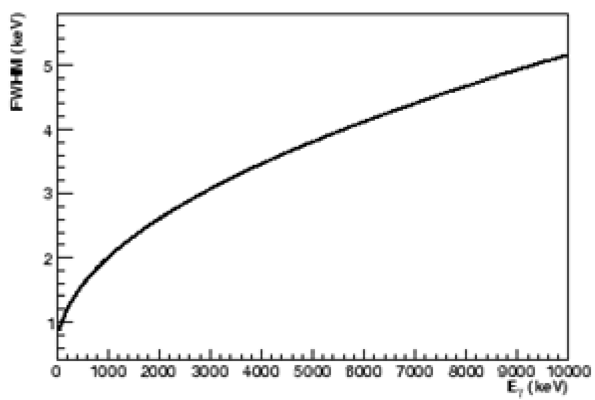
Setup geometry
Primary events,
(e.g. 1 MeV g-ray @ b = 50%)

```
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
```

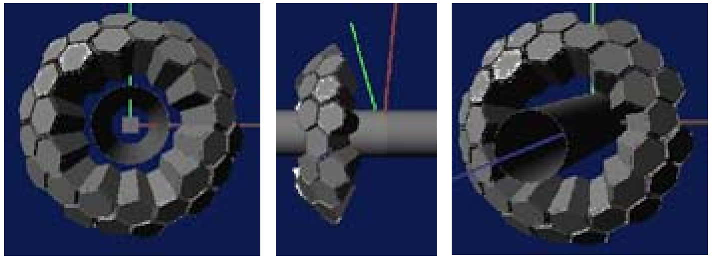
Detector response function (by hand):

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





General aspects: event reconstruction

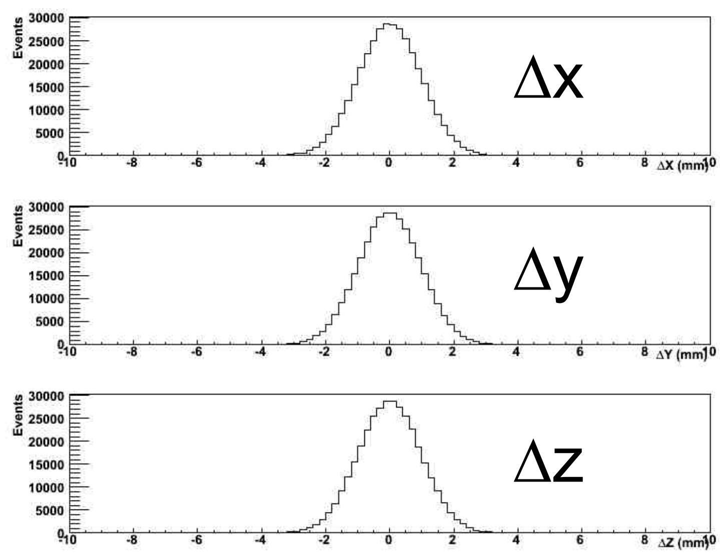


Setup geometry
Primary events,
(e.g. 1 MeV g-ray @ b = 50%)

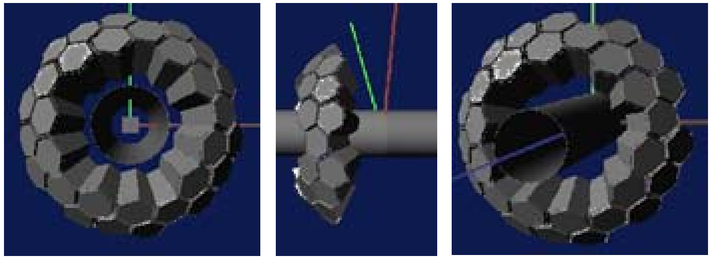
```
GAMMA 1
1000.0000
RECOIL   0.5000  0.0000  0.0000  0.0000  1.0000  0.0000
SOURCE      0      0   0.0000    0.0000    0.0000
$
  -1   1401.723 -0.43045  0.48009  0.76434 0
  29    73.617 -142.729  141.623  234.825 52     1.053
  29    39.475 -143.302  150.765  245.890 52     1.129
  29   148.895 -151.199  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

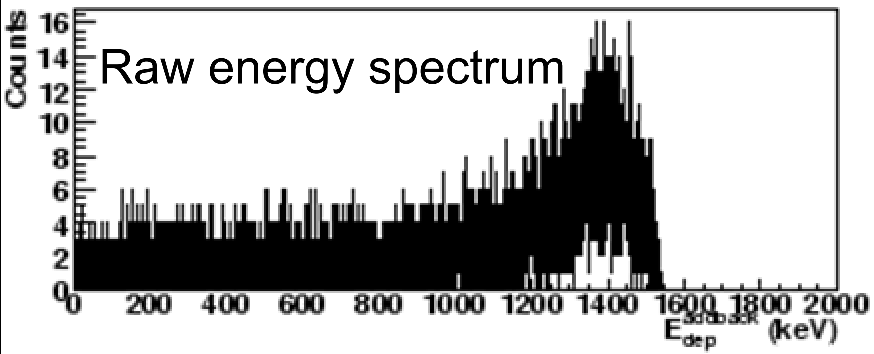


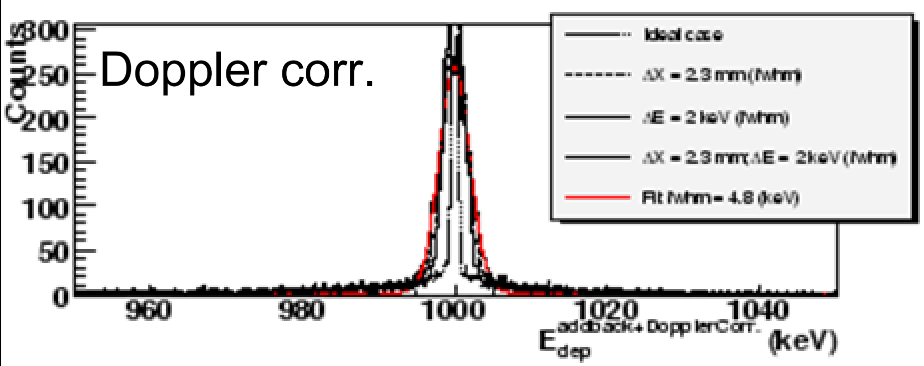
General aspects: event reconstruction (example)



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

d = 23.5 cm





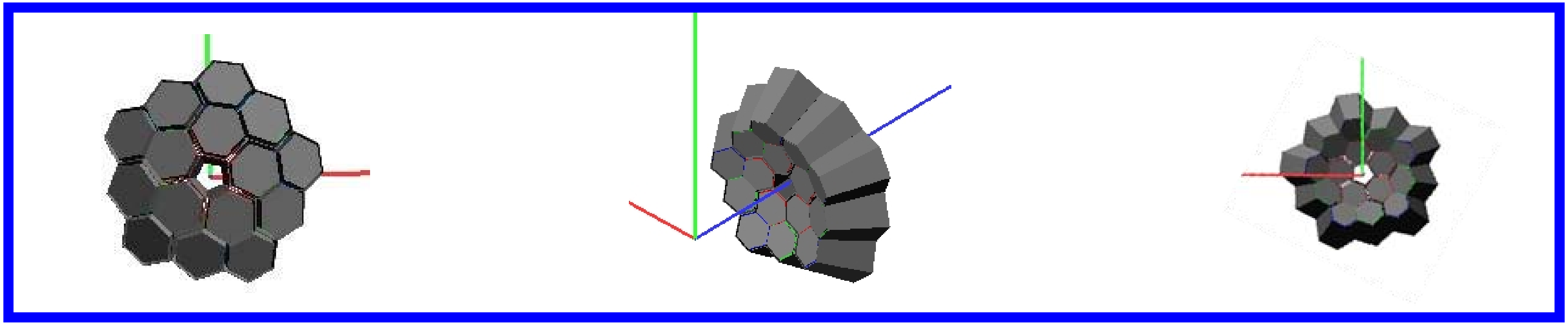
$$E_{\gamma o} = E_{\gamma} \frac{1 - \beta \cos \theta_{\gamma}}{\sqrt{1 - \beta^2}}$$

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

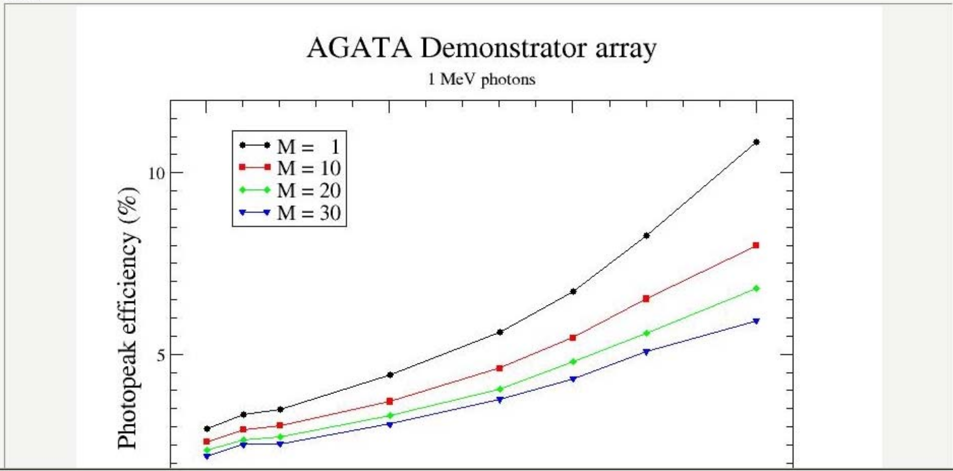
Email Us

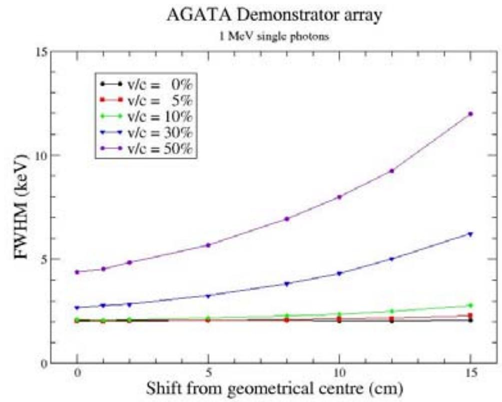
For more information on the simulation code and to obtain the actual code contact Enrico Farnea

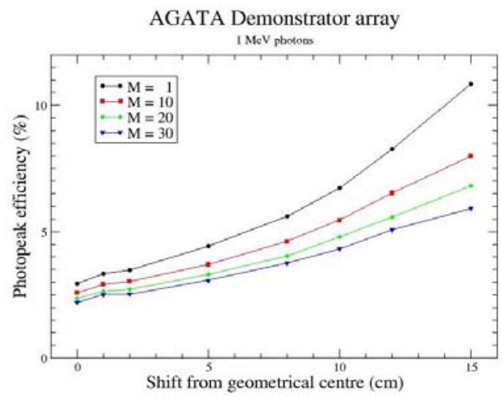
Last updated: November 8th 2005

The AGATA Demonstrator

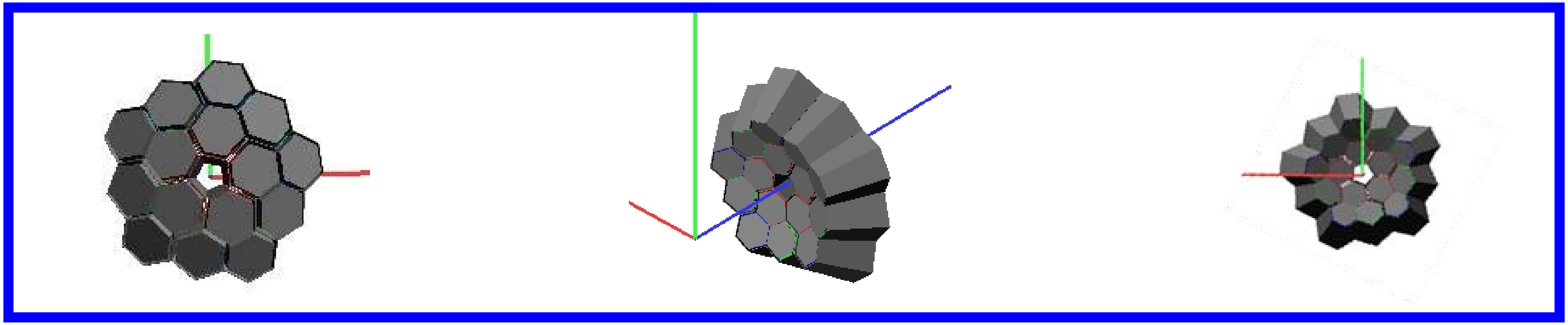
The AGATA Demonstrator Array is an arrangement of five triple clusters of the same kind which will be used to form the final A180 Configuration of AGATA. The performance of such an object will depend in a critical way on its placement relative to the target position. In particular, given the lack of 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:

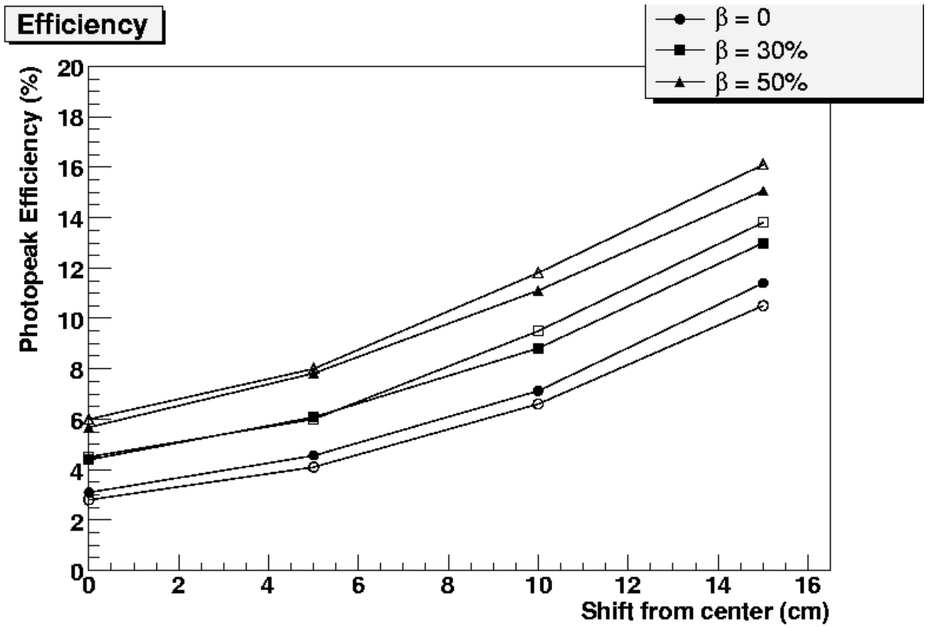


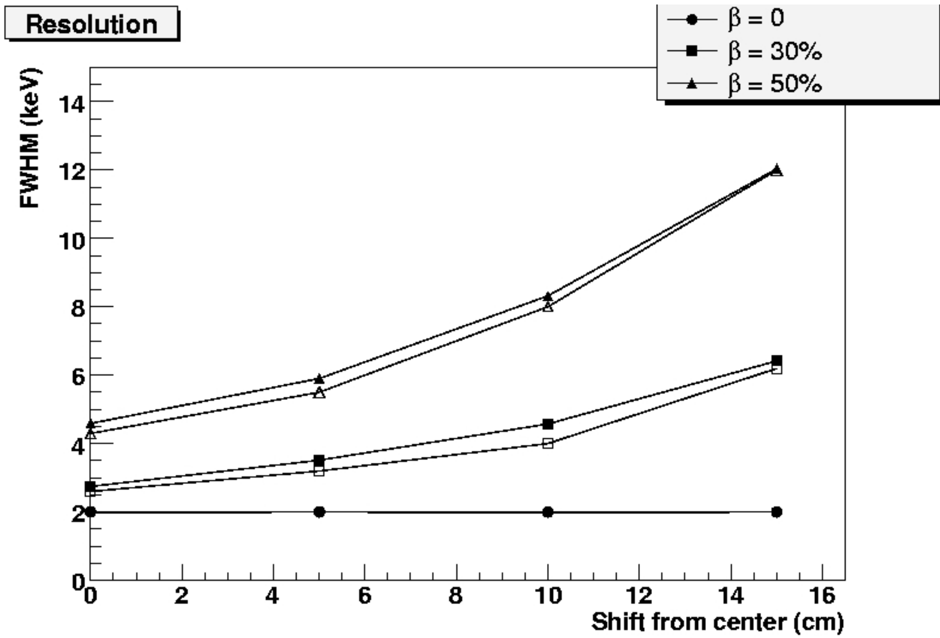




Validation analysis / event reconstruction







Empty symbols: analysis LNL

Solid symbols: analysis GSI

AGATA Geometry @ GSI

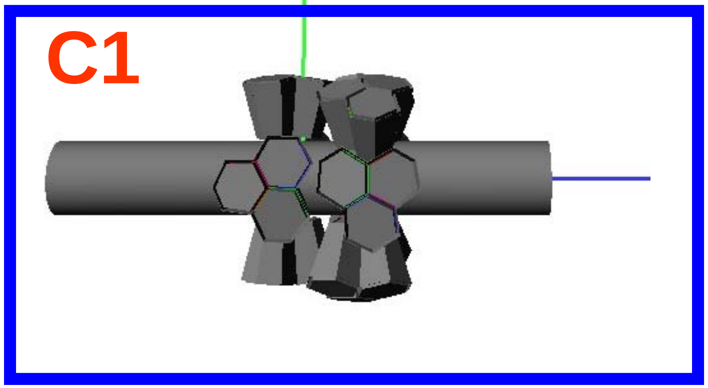
Other aspects

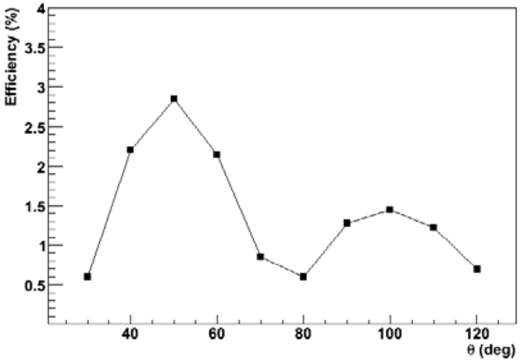
- Background
  - Atomic background (bremsstrahlung) ⇨ Shielding + P. Detistov work
  - Neutron induced background ⇨ Nothing
  - Scatt. Particle background ⇨ Tests October '09

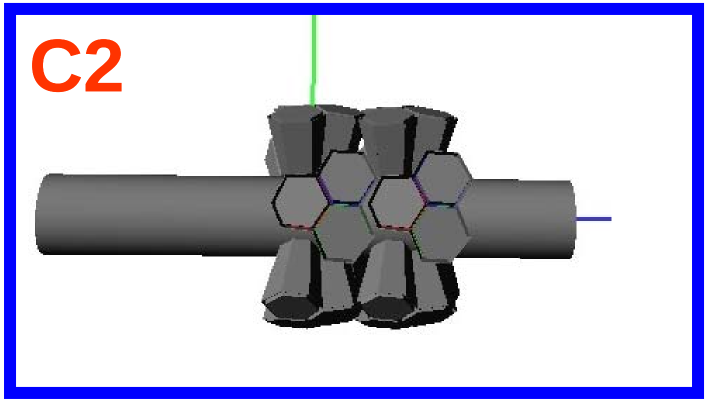
- Mechanical constraints (holding structure)

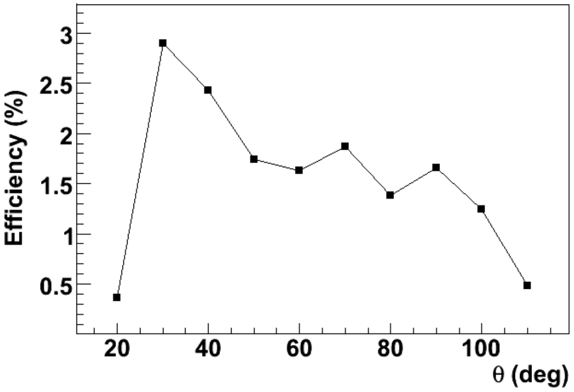
- Technical constraints (square beam pipe, cylindrical pipe smallest size compatibel with DSSSD Sec. Target, No Chamber ?)

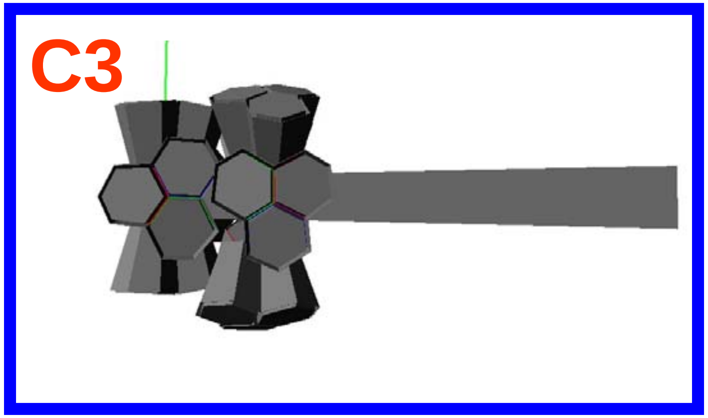
AGATA Geometry @ GSI θ–Diff. Photopeak Efficiency

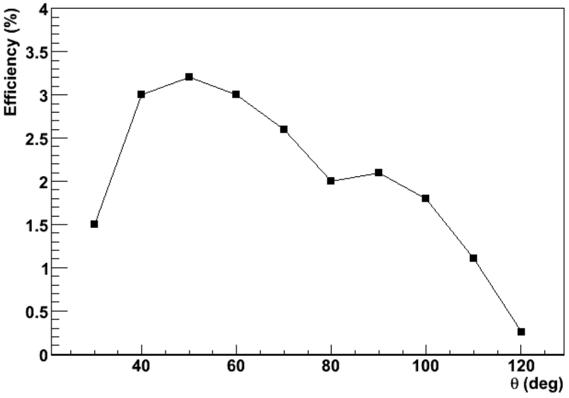




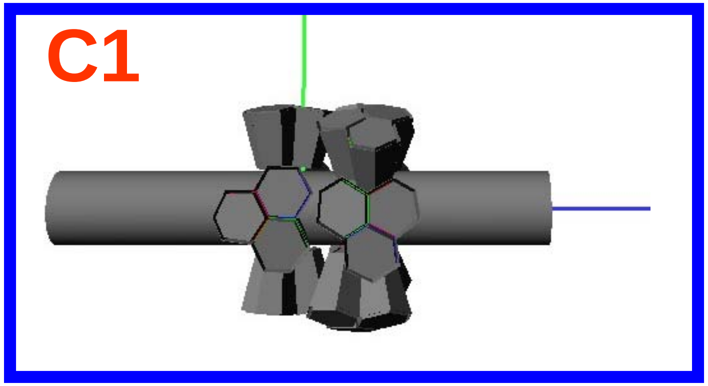


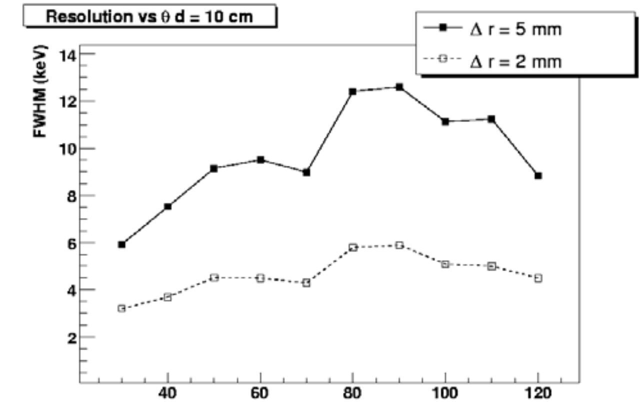


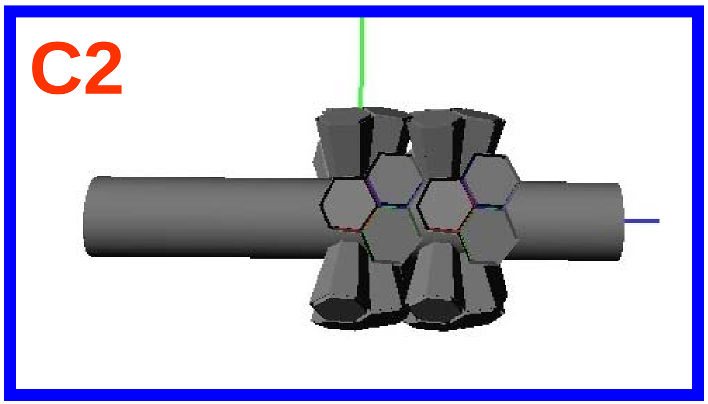


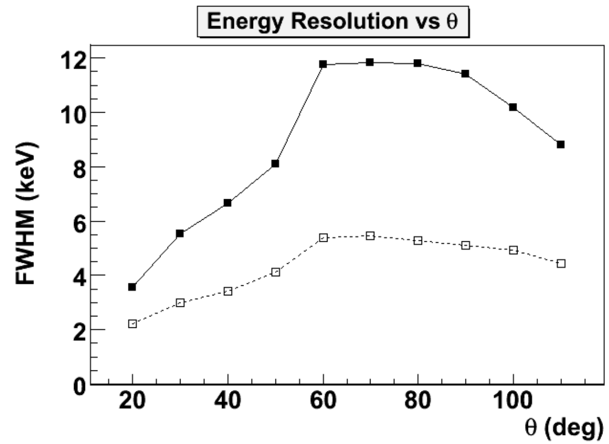


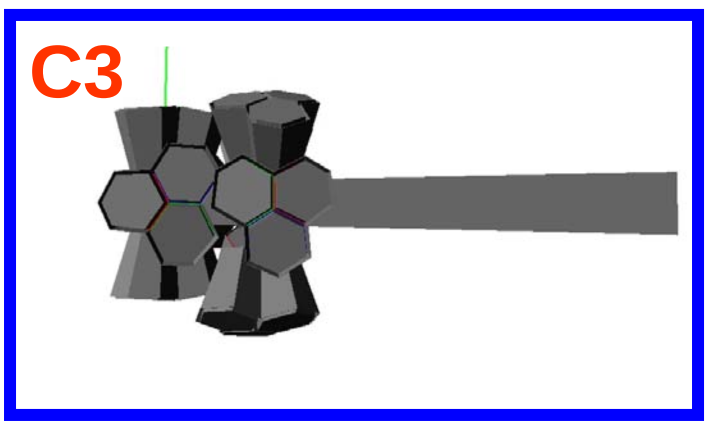
AGATA Geometry @ GSI θ–Diff. Energy Resolution

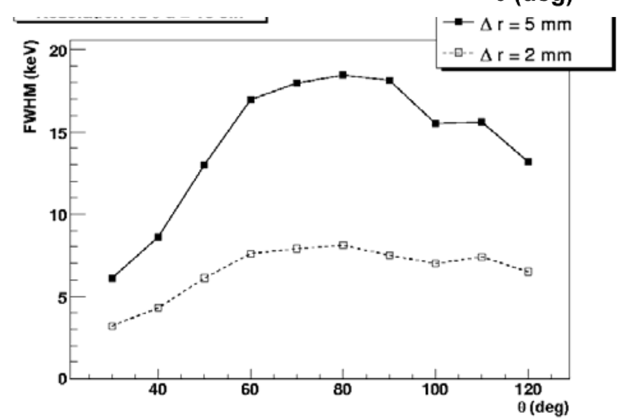






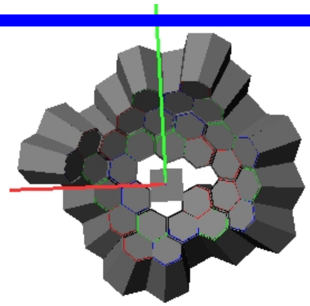






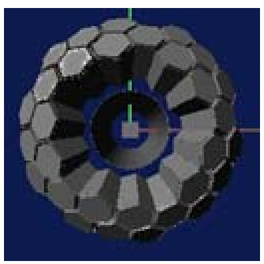
S- and C-Geometries, Optimal Distances

S1



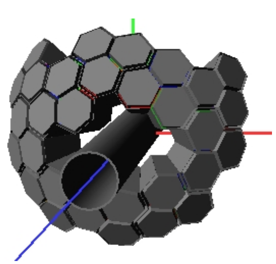
d = 23.5 – 15 = 8.5 cm

S2



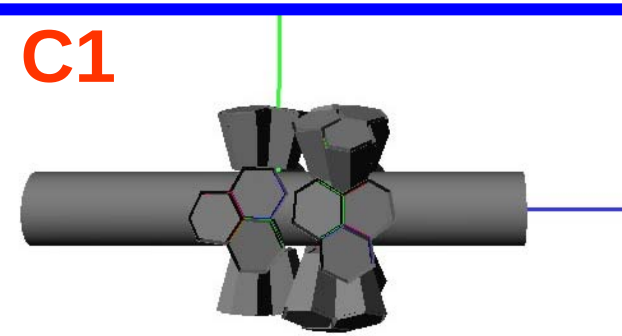
d = 23.5 – 10 = 13.5 cm

S3

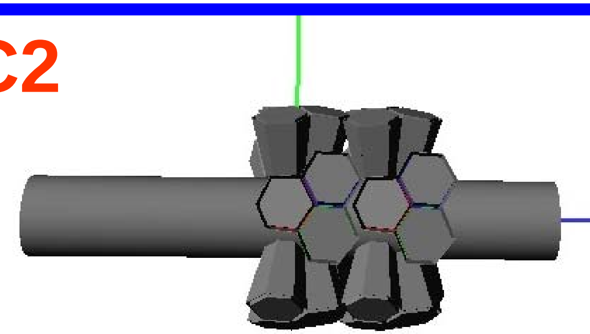


d = 23.5 – 15 = 8.5 cm

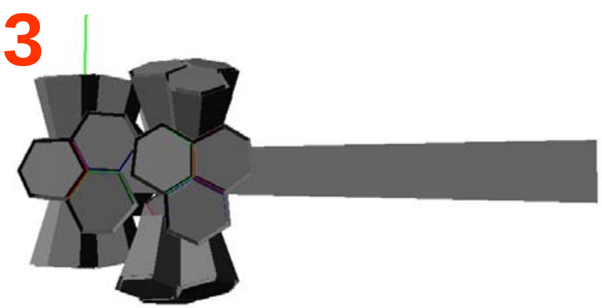
C1



C2

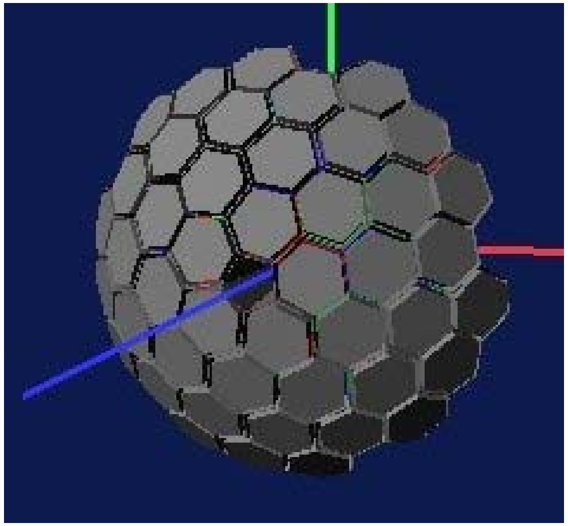


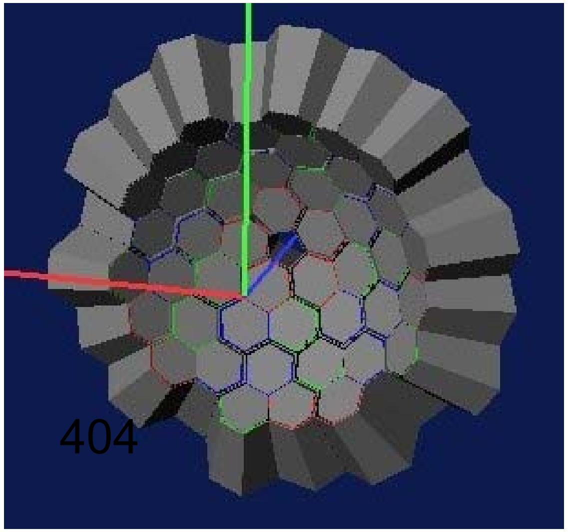
C3



Stepwise geometry optimisation

• Ideal geometry = first approach, first step



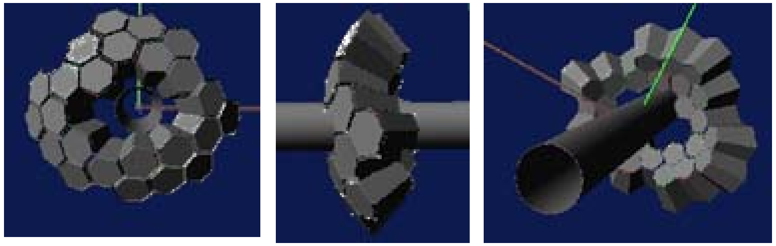


• two main dissadvantages:

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

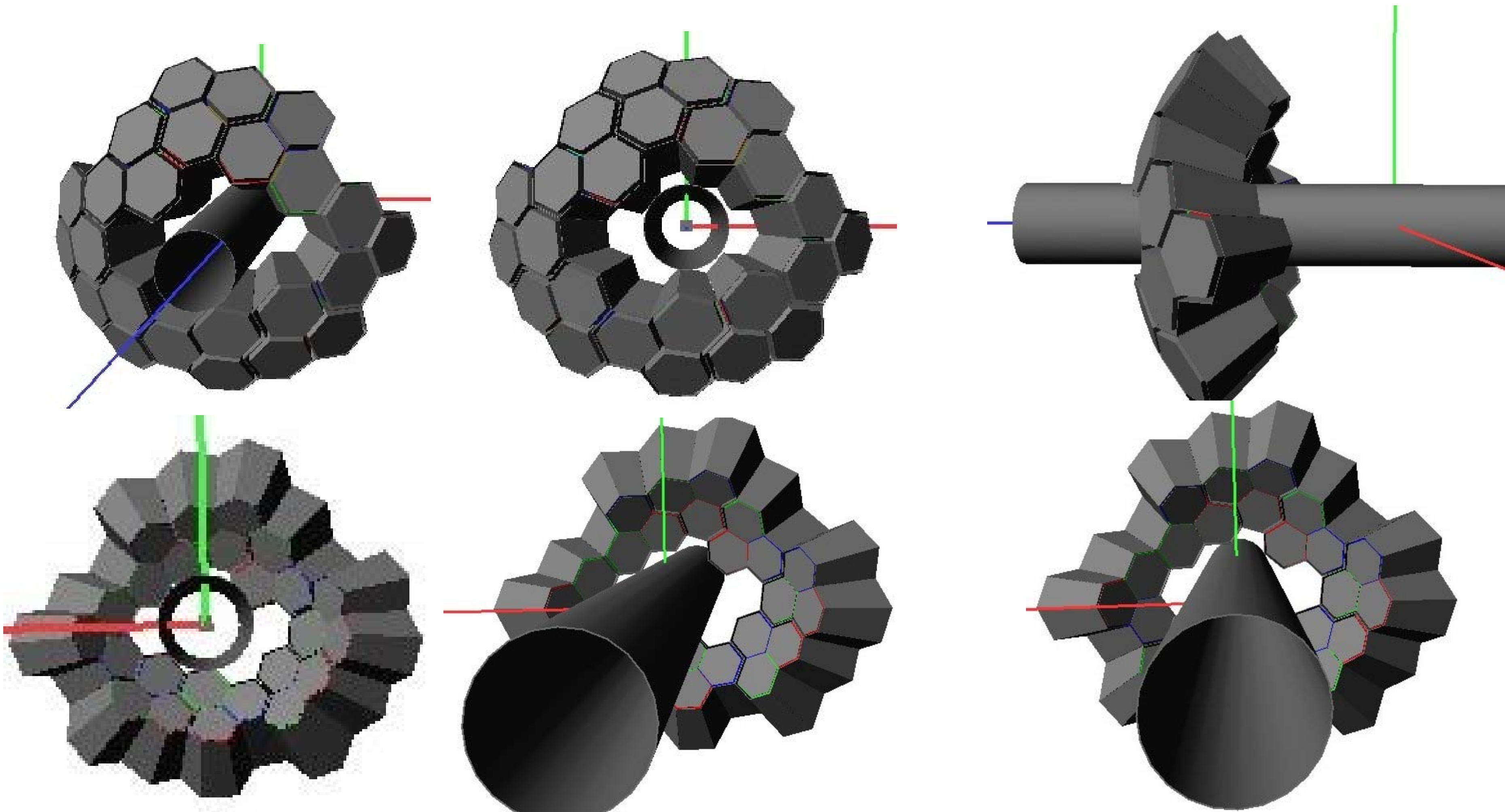
• Geometry constraint: triple clusters (not individual crystals)

8 Clusters Asymmetric Ring Geometry

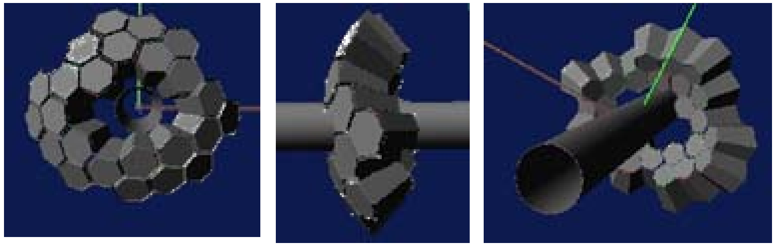


8 Clusters

Hole (11.5 cm) beam-pipe 11 cm



8 Clusters Asymmetric Ring Geometry



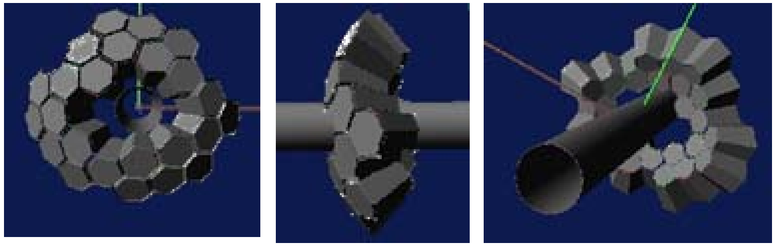
8 Clusters

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



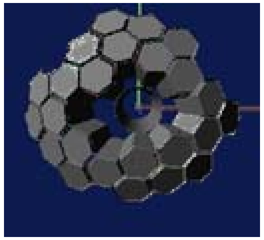
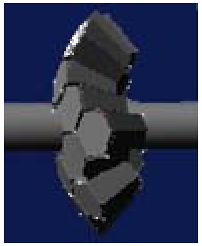
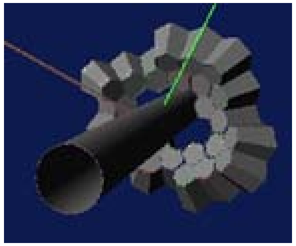
8 Clusters

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)

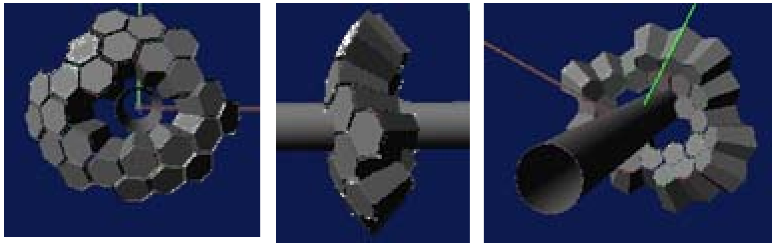
radd.rotateY(thetaShift);
radd.rotateZ(phiShift);

/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



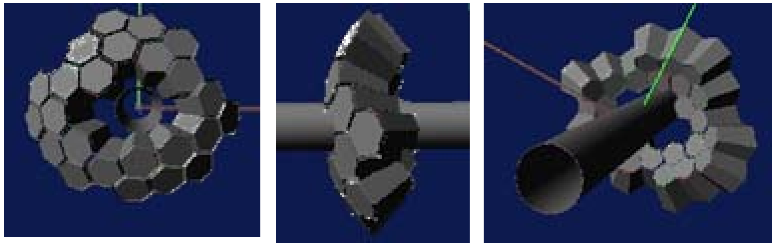
8 Clusters

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
```

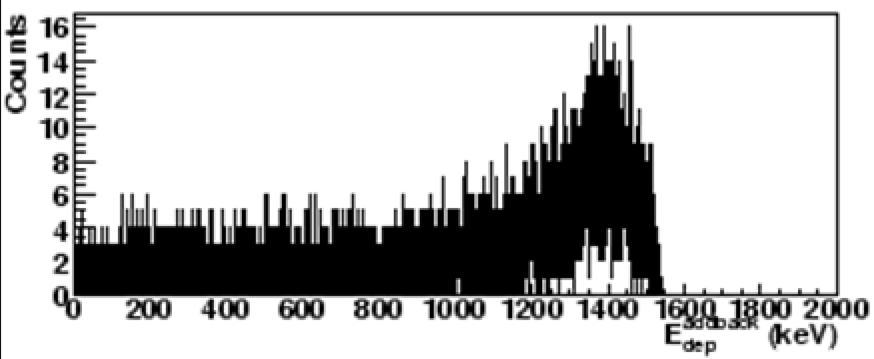
8 Clusters Asymmetric Ring

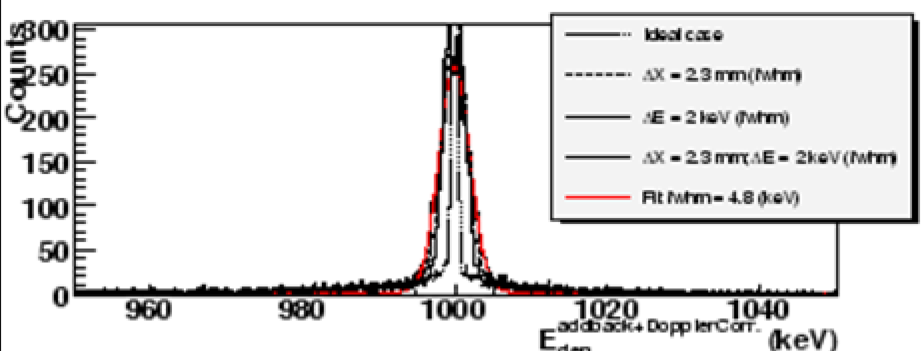


8 Clusters

Hole (11.5 cm) beam-pipe 11 cm

d = 23.5 cm

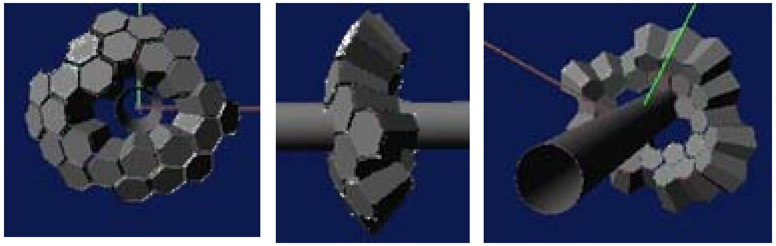




$$E_{\gamma o} = E_{\gamma} \frac{1 - \beta \cos \theta_{\gamma}}{\sqrt{1 - \beta^2}}$$

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

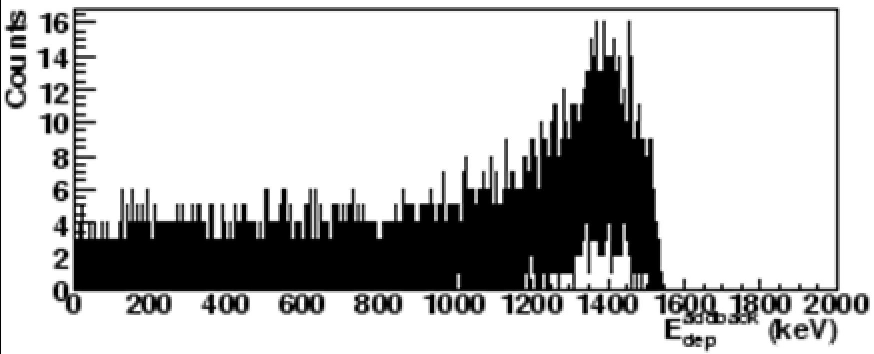
8 Clusters Asymmetric Ring

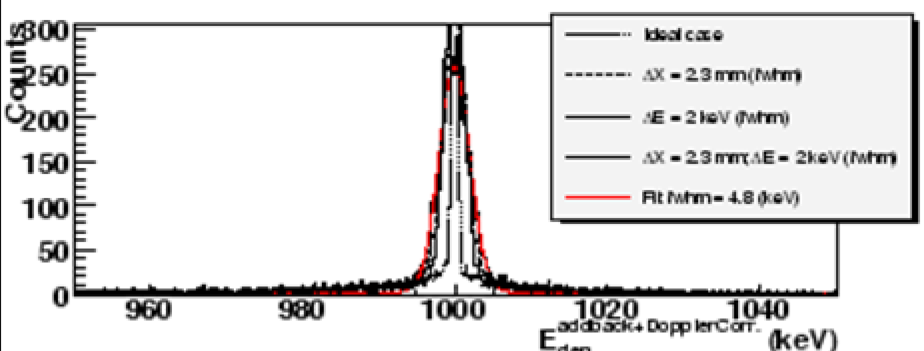


8 Clusters

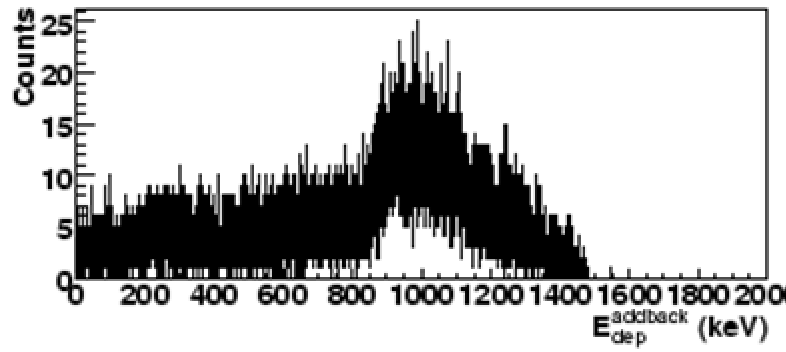
Hole (11.5 cm) beam-pipe 11 cm

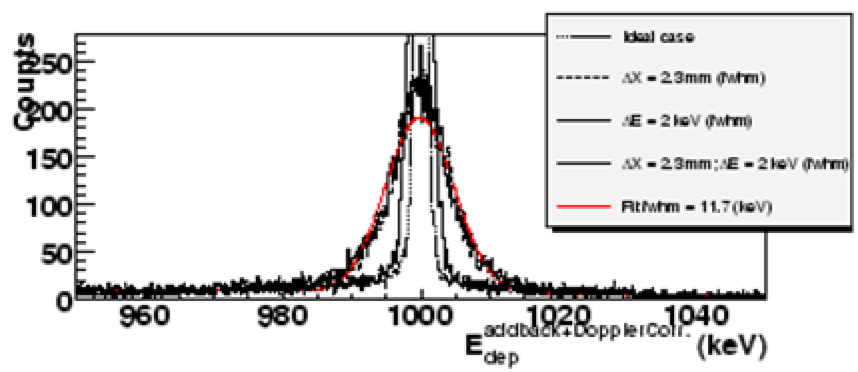
d = 23.5 cm





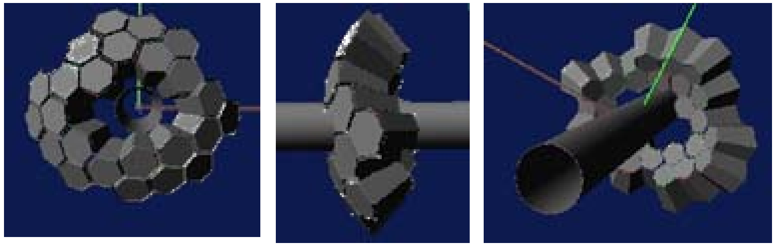
d = 1.5 cm





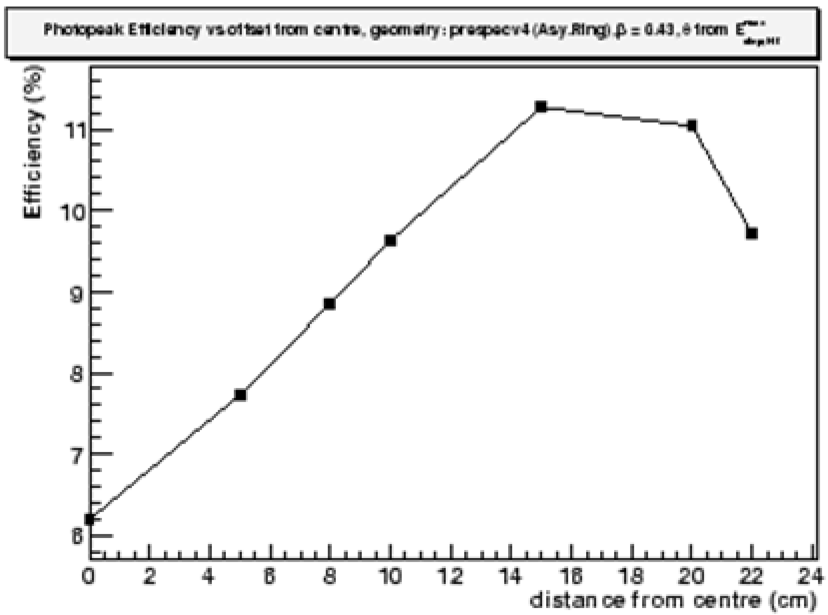
ΔE = 2 keV (fwhm) @ $E\gamma$ = 1 MeV; Δx = 4 mm

8 Clusters Asymmetric Ring

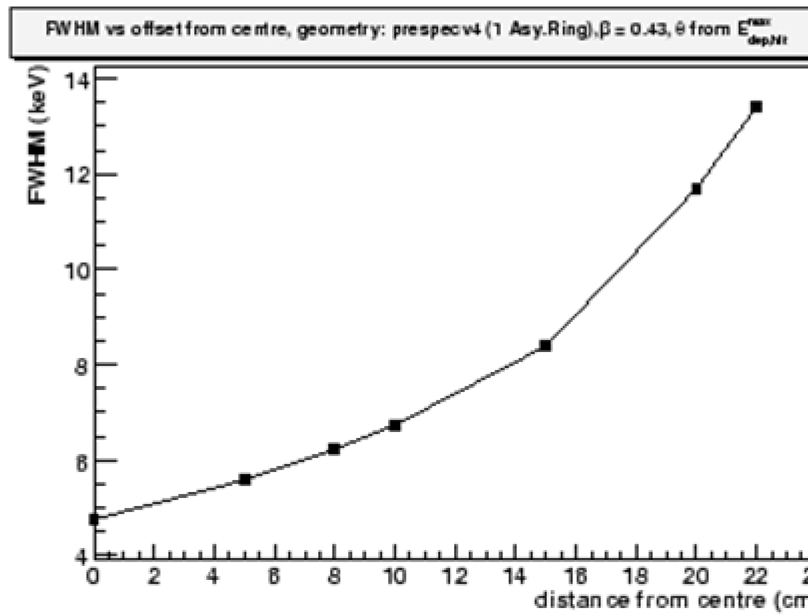


8 Clusters

Hole (11.5 cm) beam-pipe 11 cm



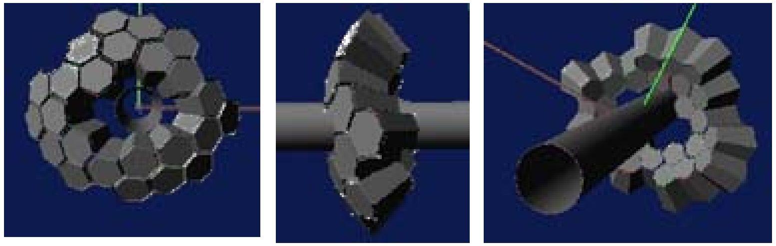
23.5 cm 1.5 cm



23.5 cm 1.5 cm

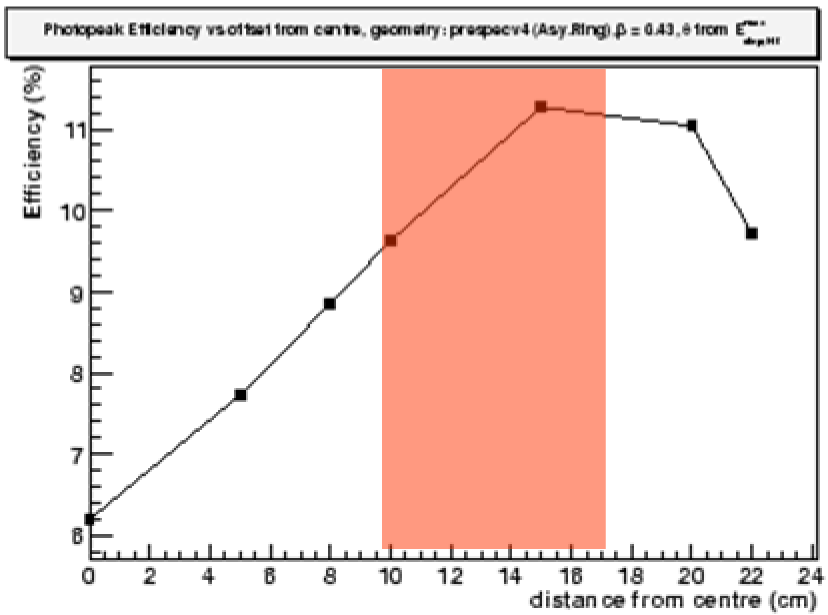
ΔE = 2 keV (fwhm) @ $E\gamma$ = 1 MeV; Δx = 4 mm

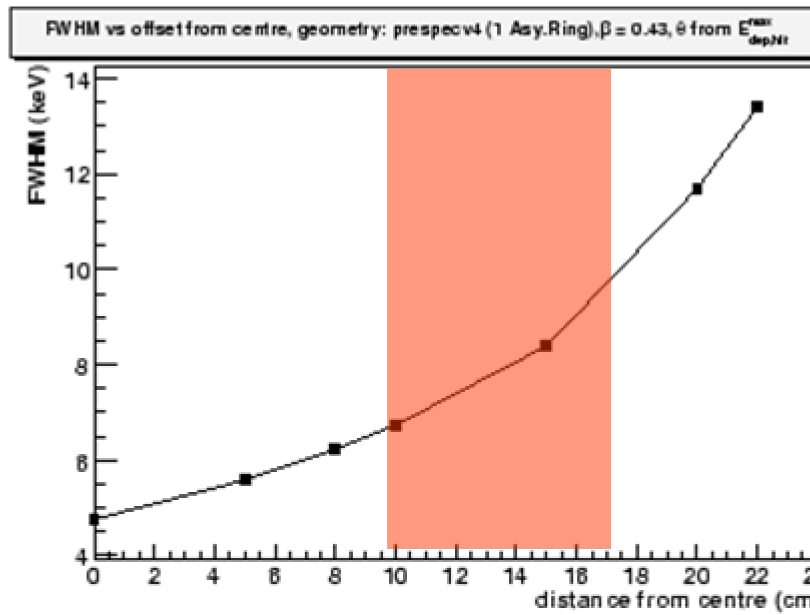
8 Clusters Asymmetric Ring



8 Clusters

Hole (11.5 cm) beam-pipe 11 cm



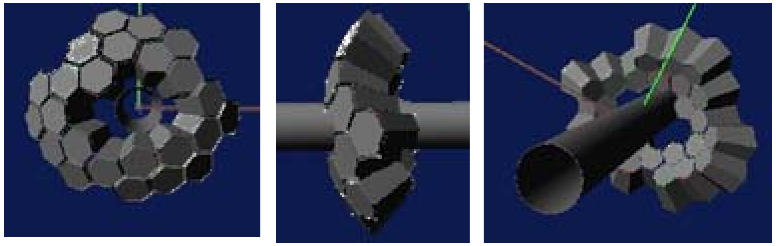


23.5 cm 1.5 cm 23.5 cm 1.5 cm

Efficiency = 10-11% FWHM = 6-8 keV

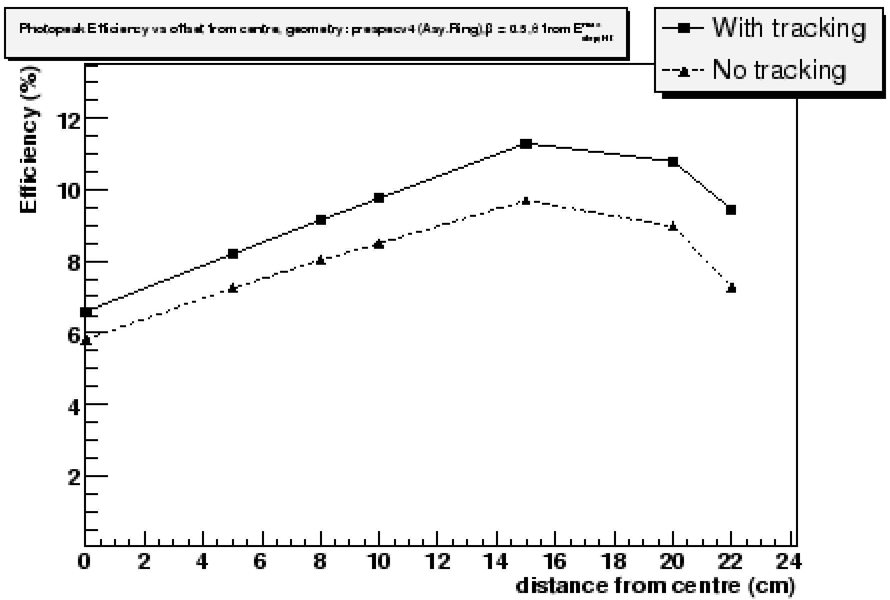
ΔE = 2 keV (fwhm) @ Eγ = 1 MeV; Δx = 4 mm

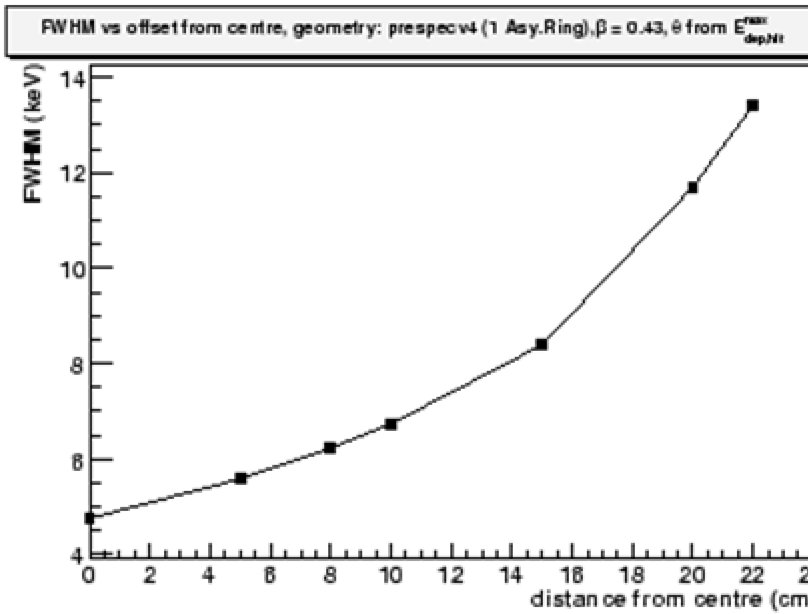
8 Clusters Asymmetric Ring



8 Clusters

Hole (11.5 cm) beam-pipe 11 cm



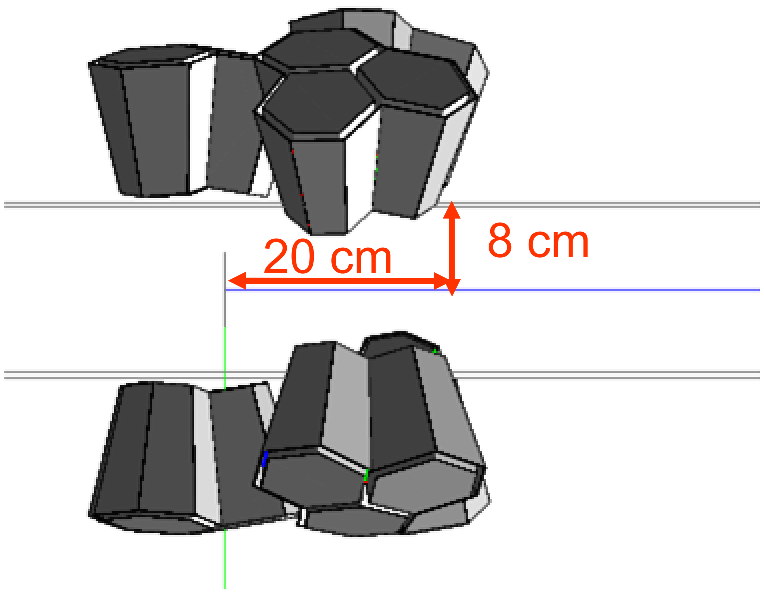


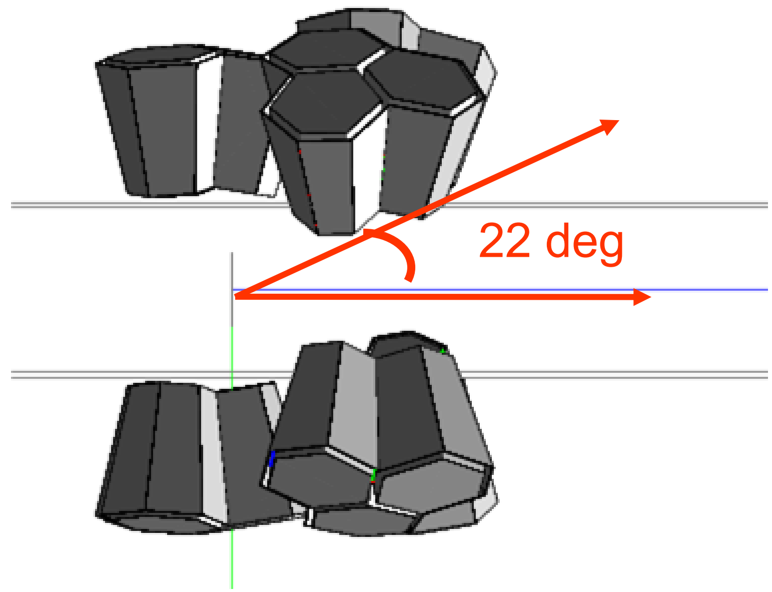
23.5 cm 1.5 cm 23.5 cm 1.5 cm

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

Solid angle occupied and free

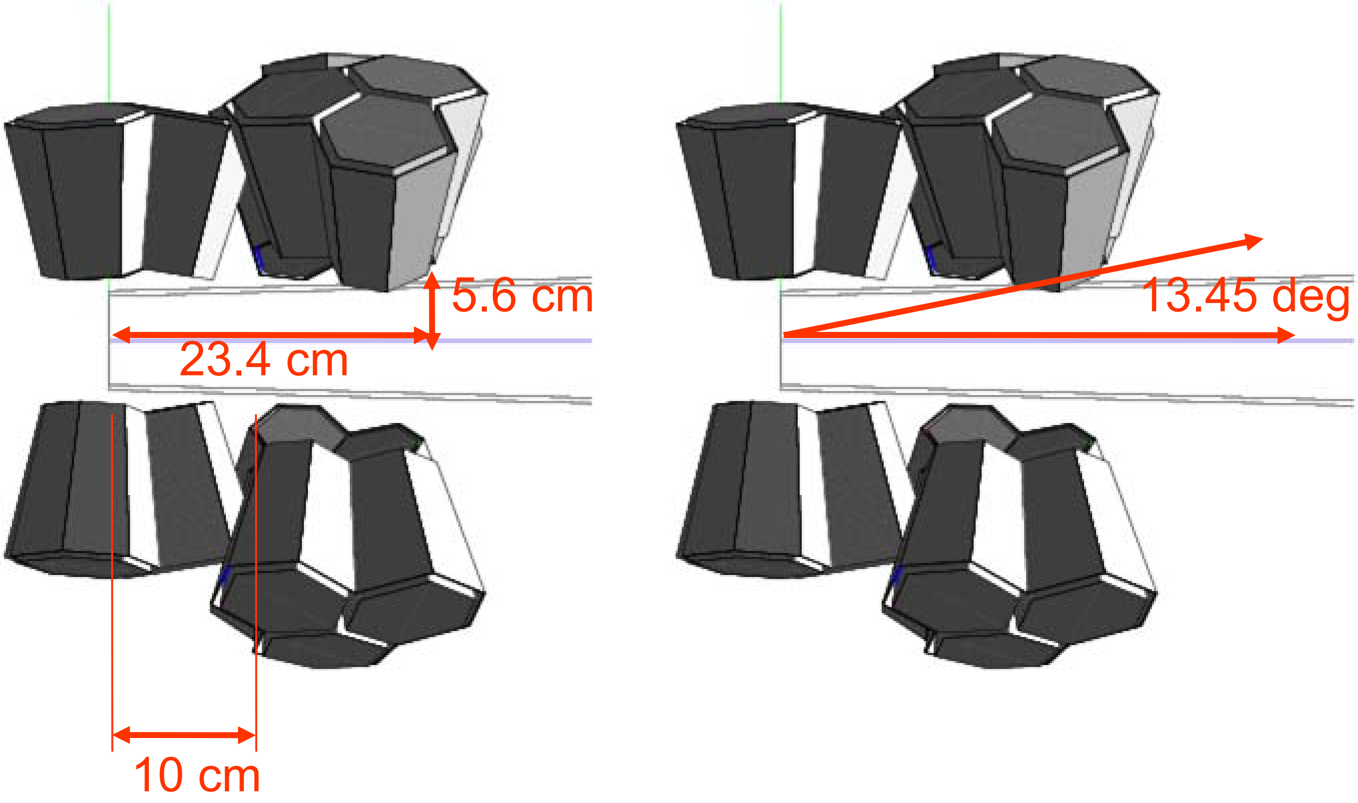
C1



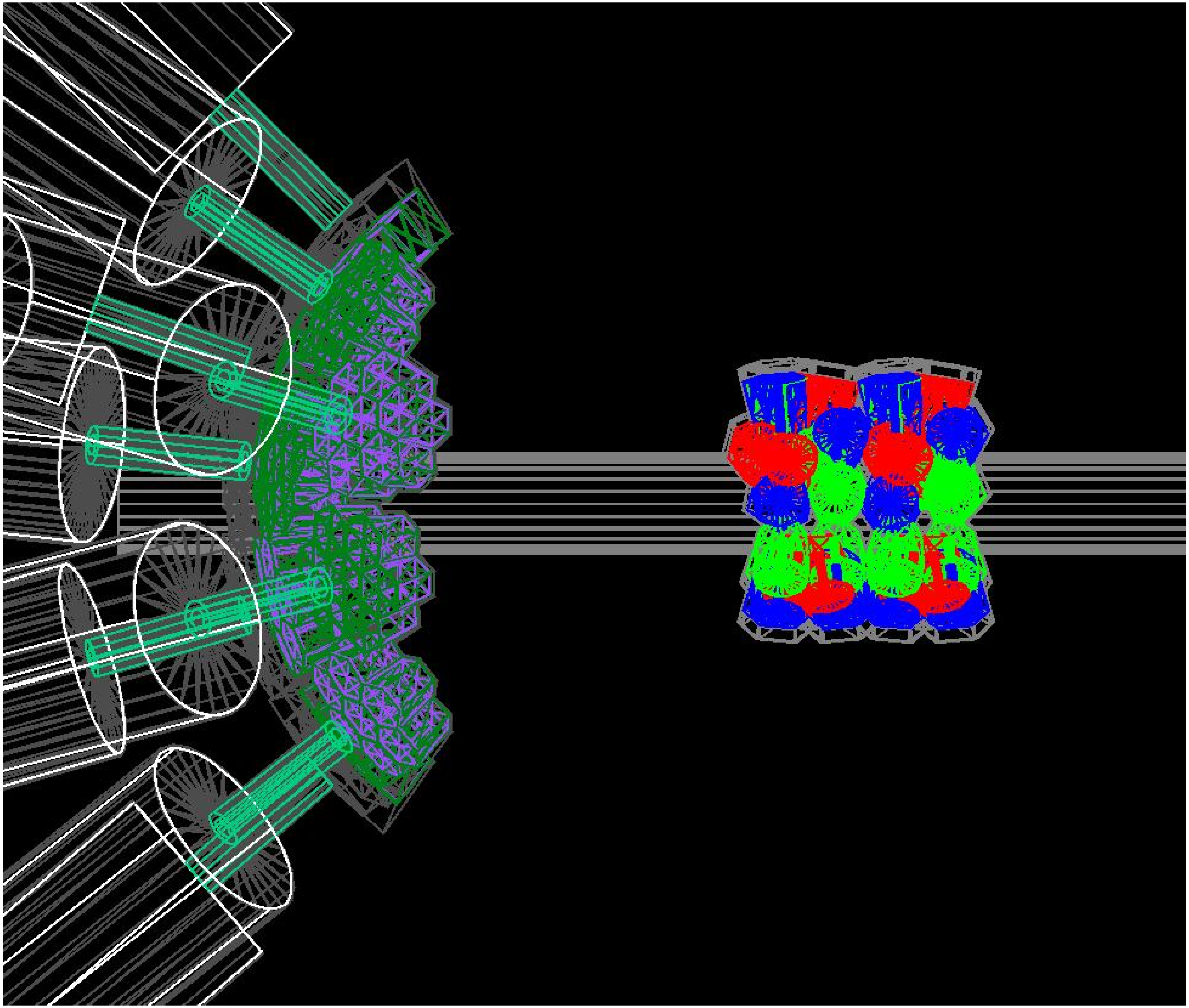


Solid angle occupied and free

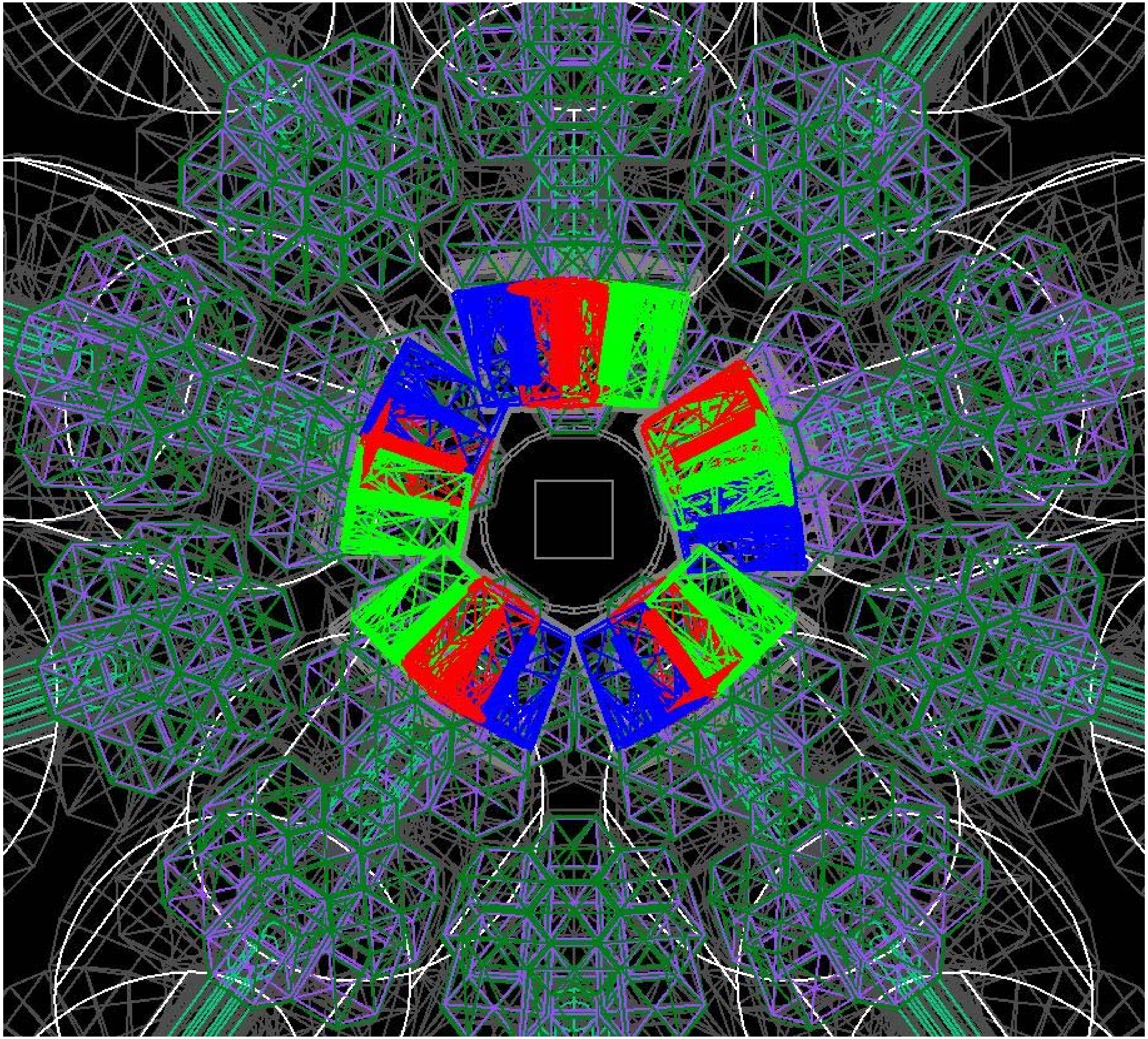
C3



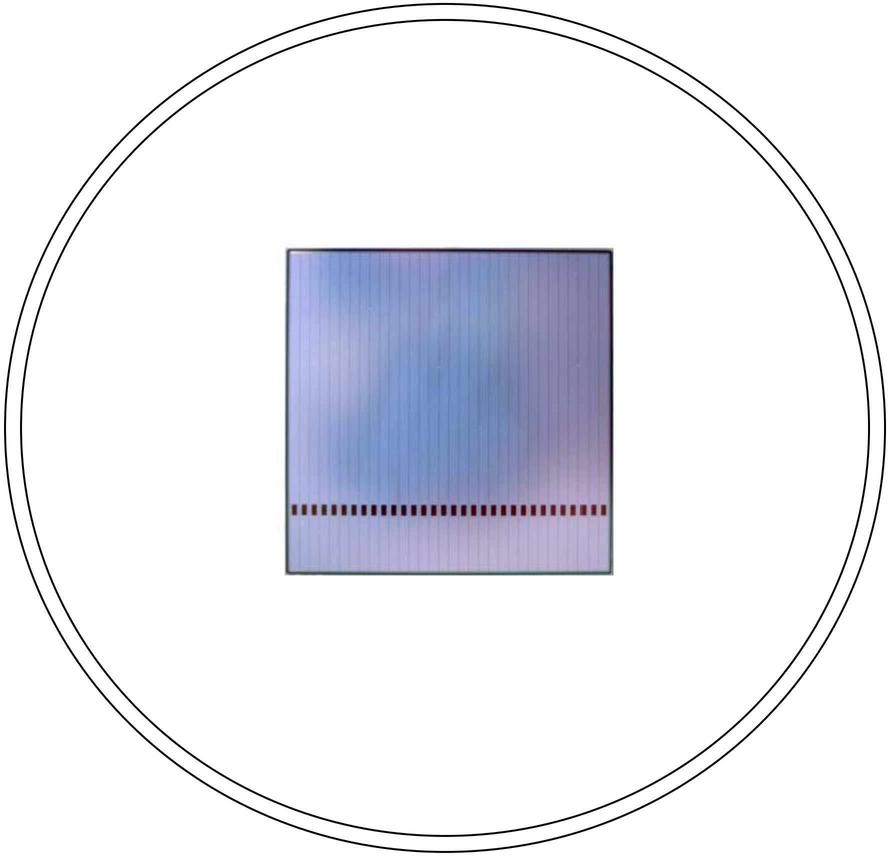
Other viewer's views



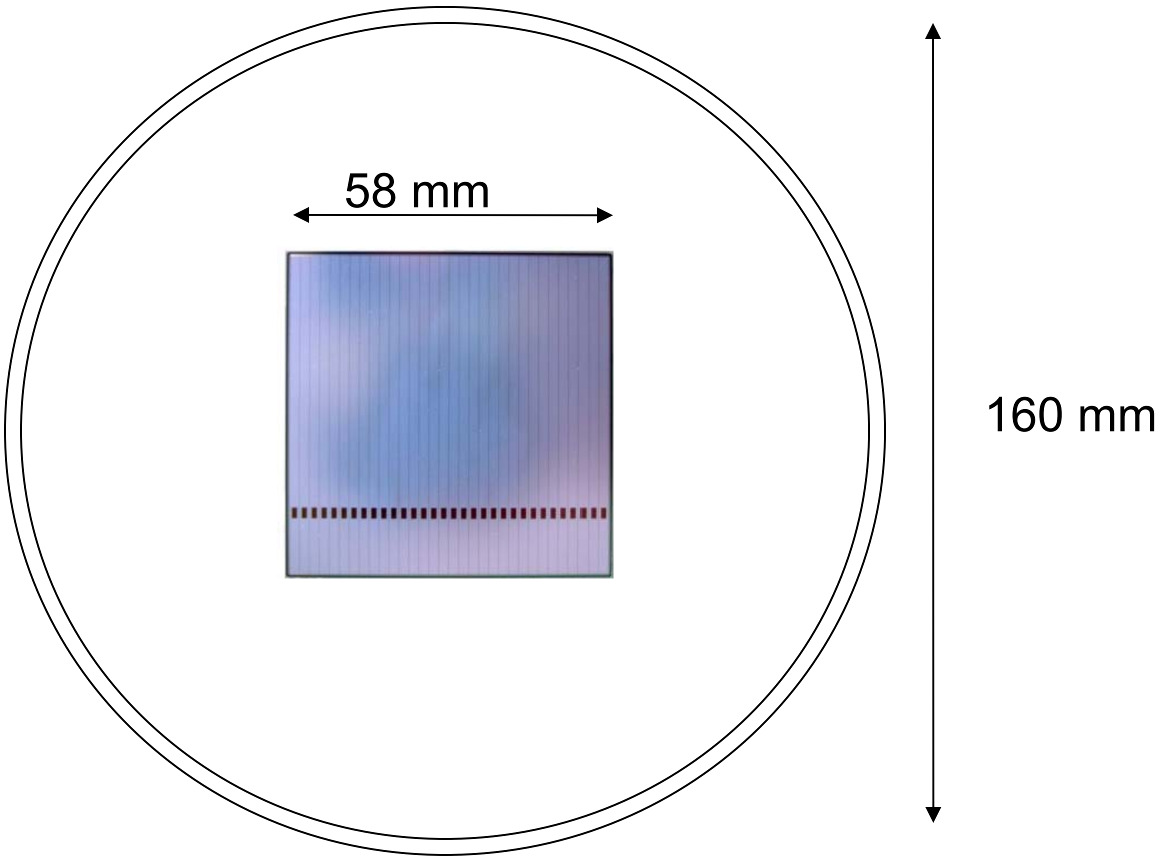
Other viewer's views



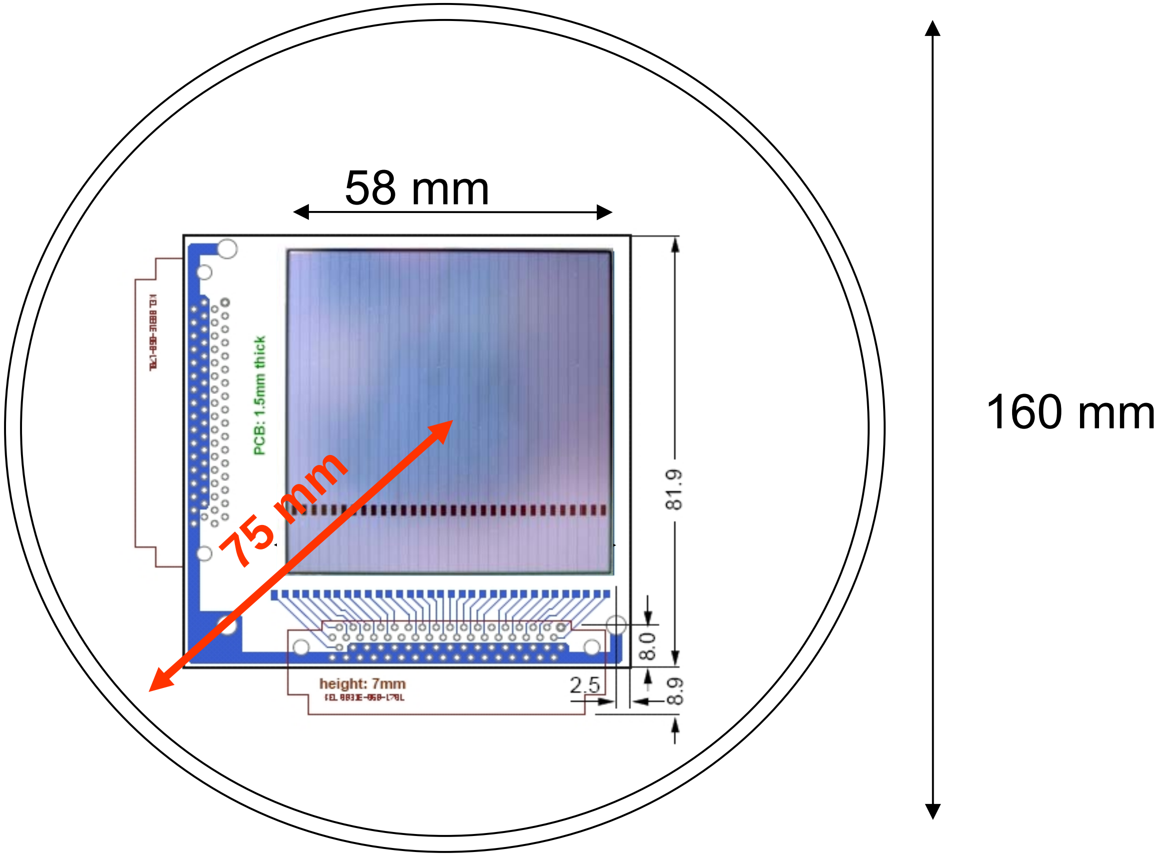
S4 focal plane room constrained by the DSSSD



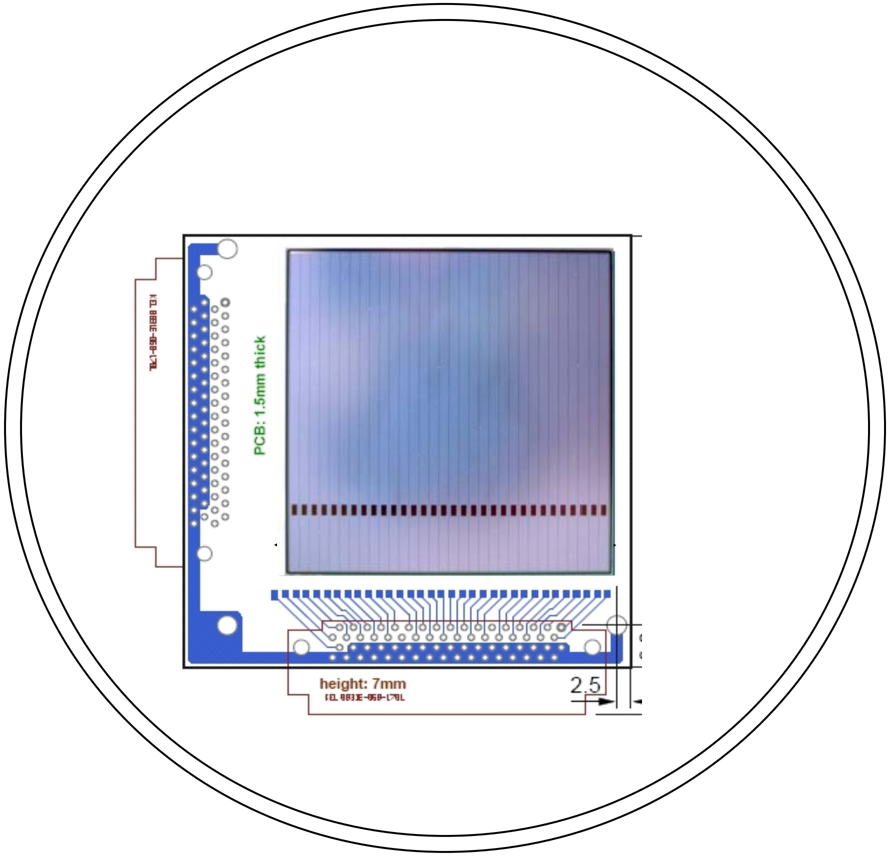
S4 focal plane room constrained by the DSSSD



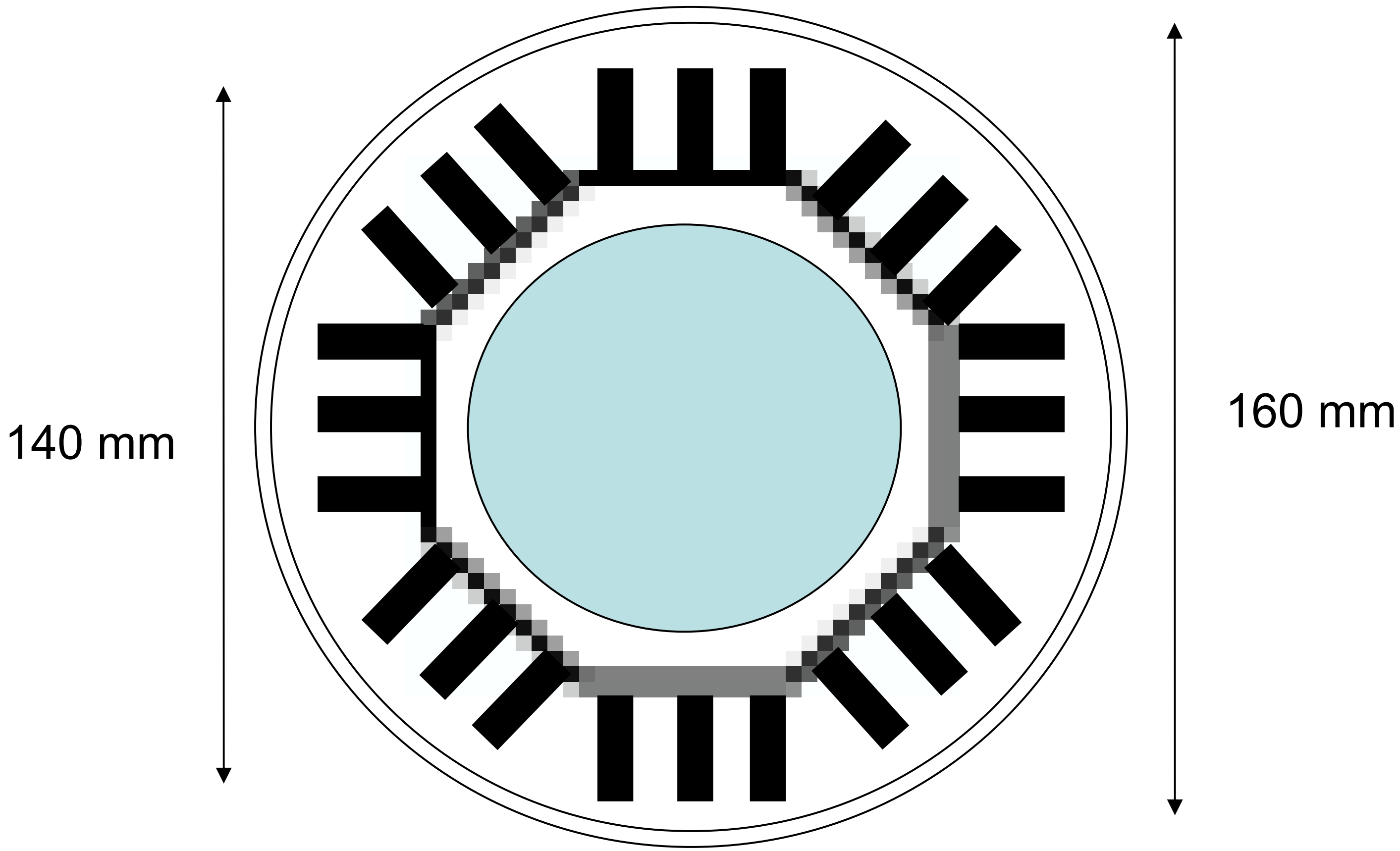
S4 focal plane room constrained by the DSSSD



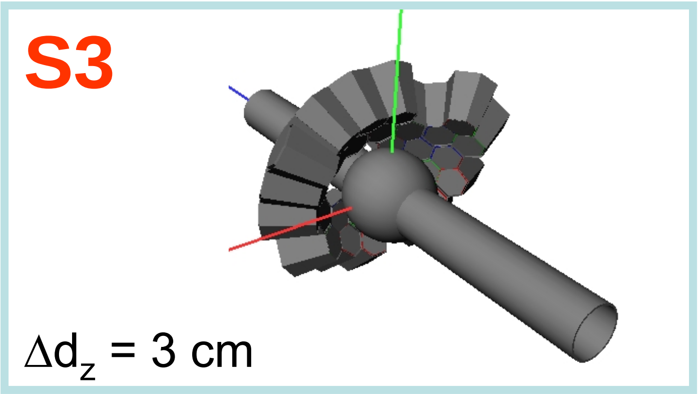
S4 focal plane room constrained by the DSSSD

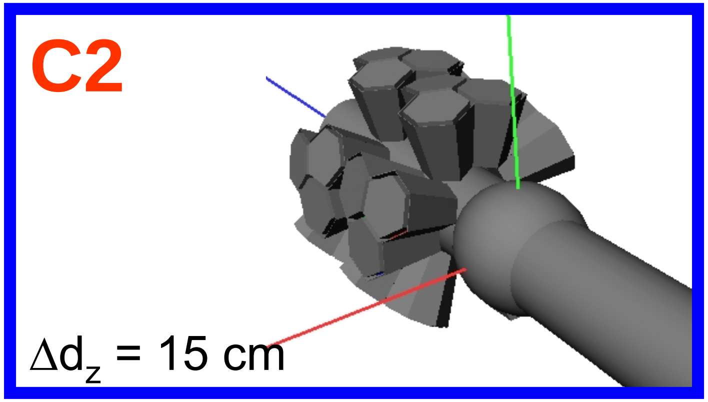


S4 focal plane constrained by the Scintillation membrane

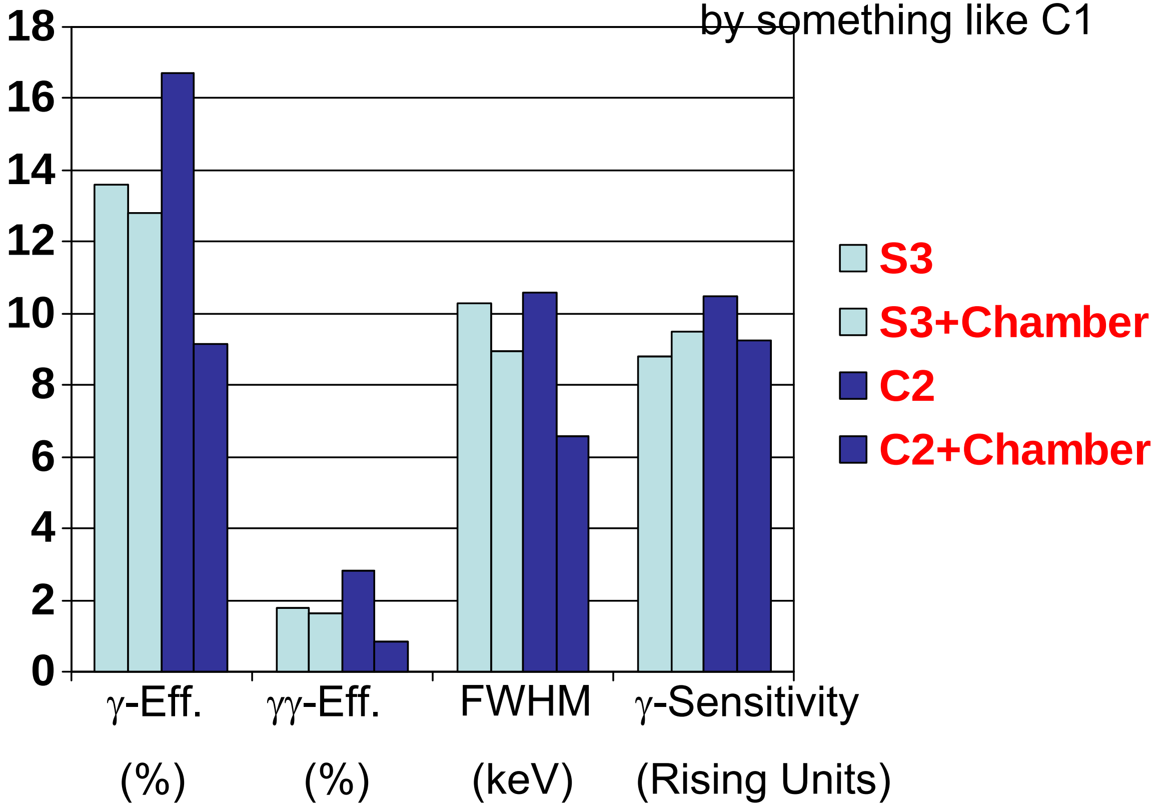


S3- and C2-Geometries + Chamber 20 cm diameter

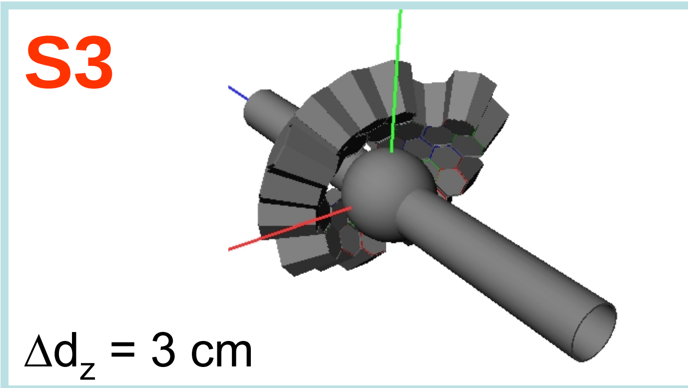


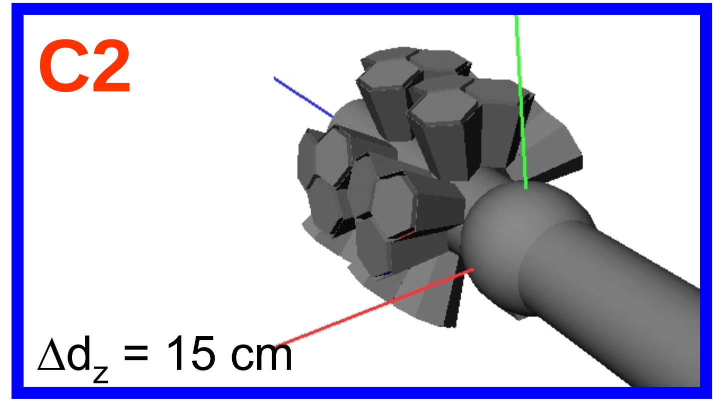


C2 performance could be improved by something like C1

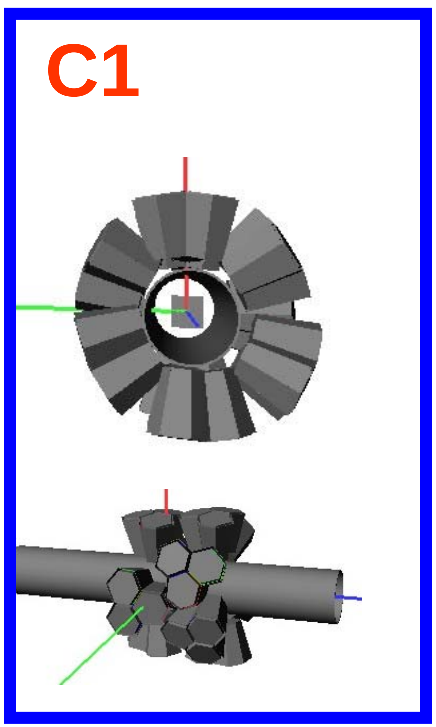


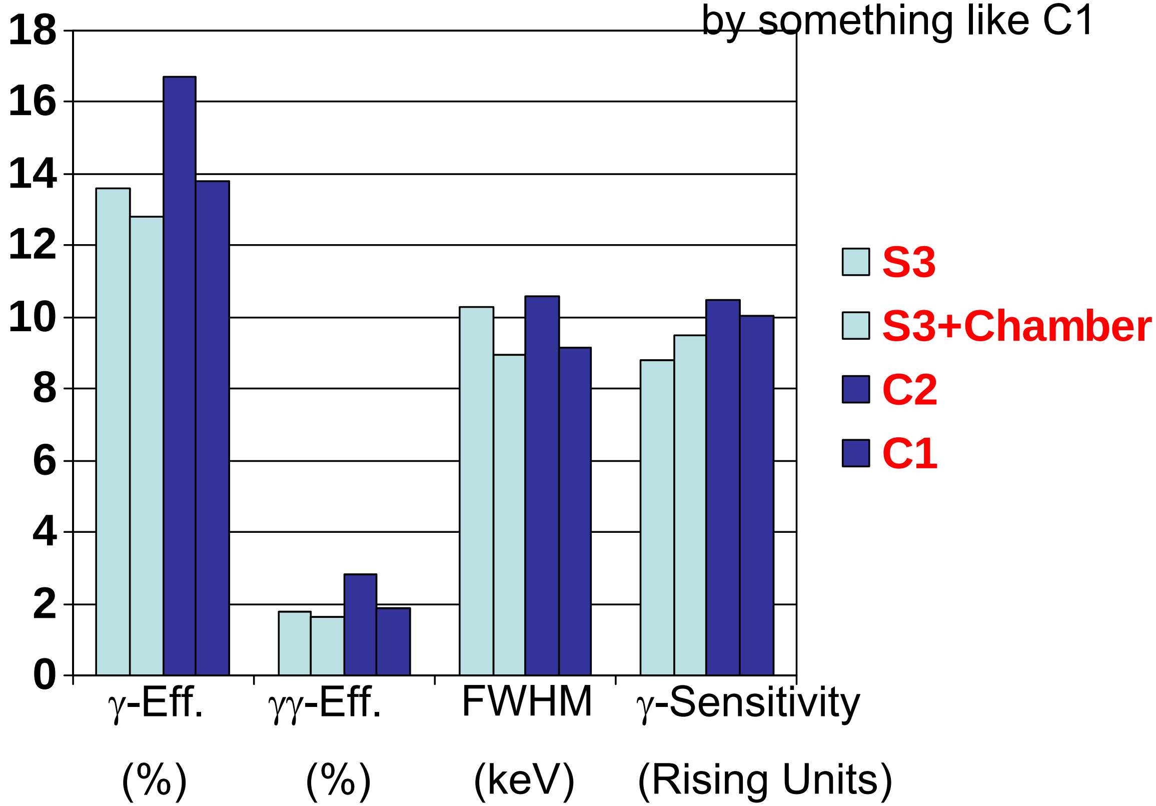
S3- and C2-Geometries + Chamber 20 cm diameter





C2 performance could be improved by something like C1





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 2^{nd} ring pointing to target, and 3^{rd} ring (15 Clusters total)

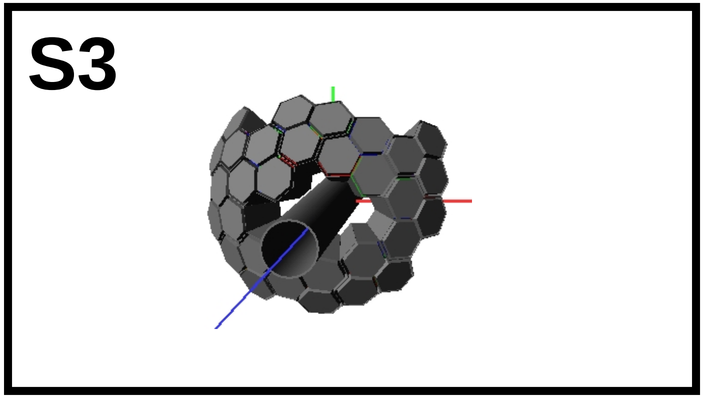
Physics cases evaluate realistically the performance of the optimal detection system in:

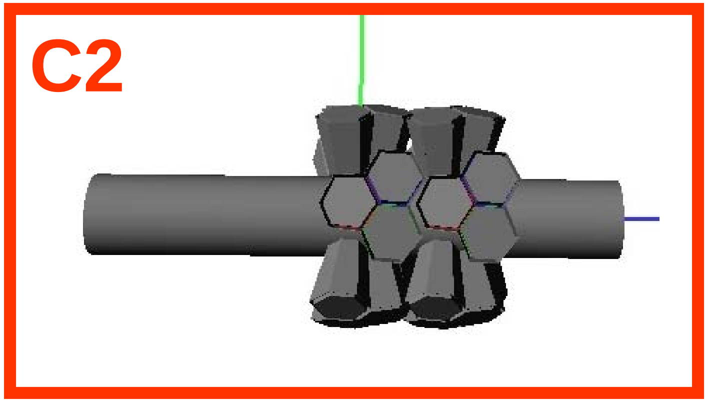
- Task 1: Coulex experiment. Example: Coulex of 104Sn at 100 MeV/u on a 0.4 g/cm2 Au-target. Primary beam 124Xe.
- Task 2: Fragmentation experiment. 54Ni at 100 MeV/u + Be (0.7 g/cm2) -> 50Fe (simulate first 4 excited states up to 8+ level).
- Task 3: Plunger experiment (A. Dewald, Chr. Fransen Uni.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

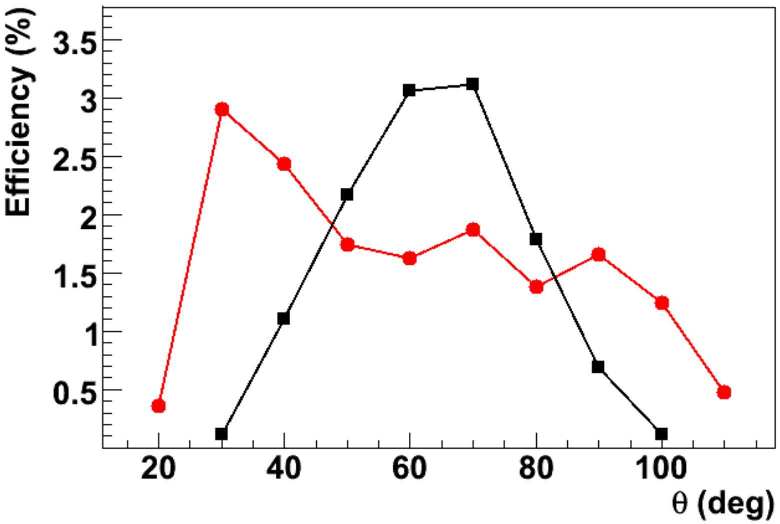
Realistic implementation

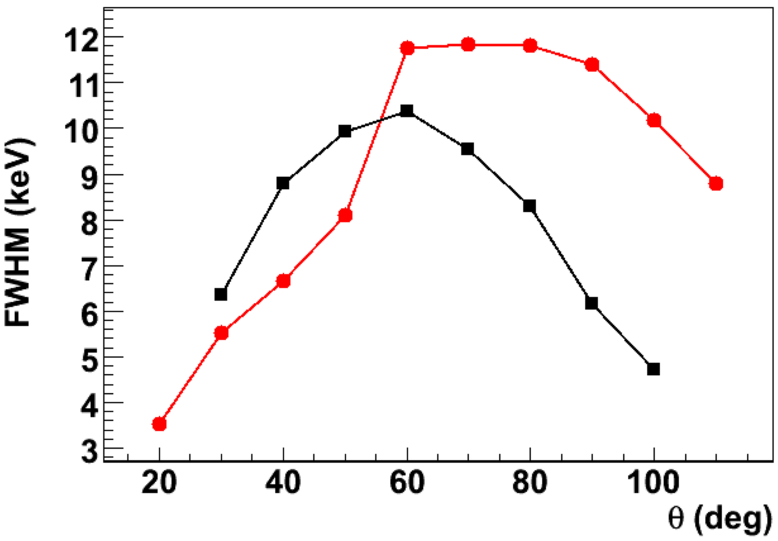
- Task 1: Background model or scaled background spectra from prev. experiments
- Task 2: Realistic tracking for event reconstruction (mgt, etc)

S- and C-Geometry Performance, Quantitative Comparison





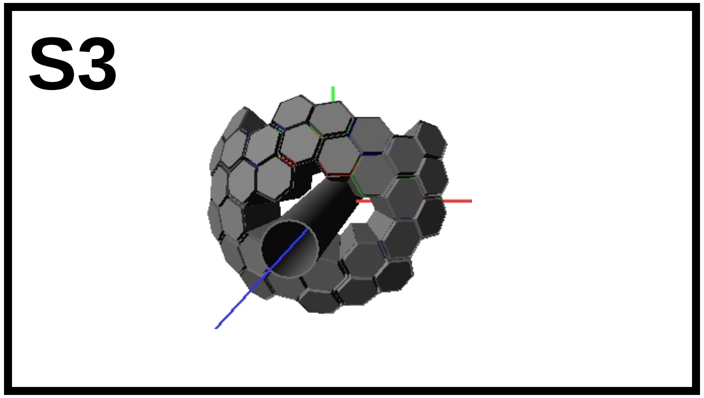


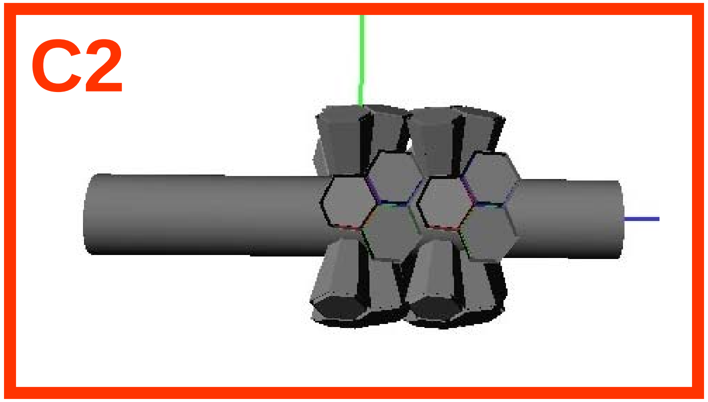


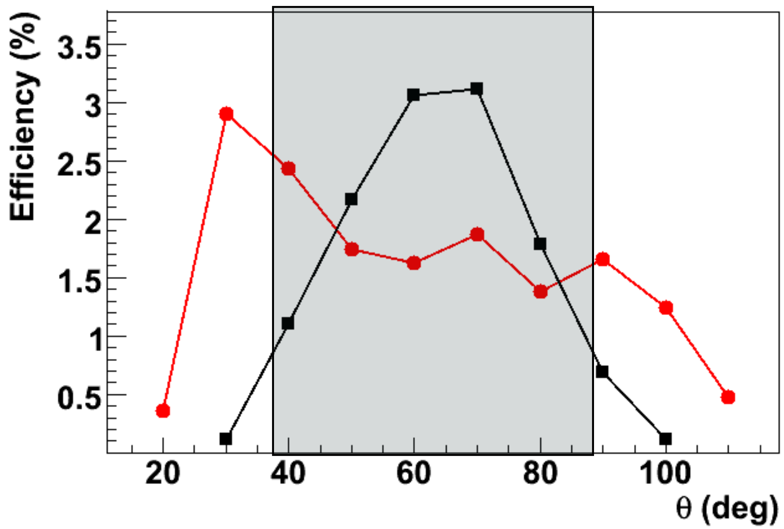
<ΔE(S3)> = 10.3 keV

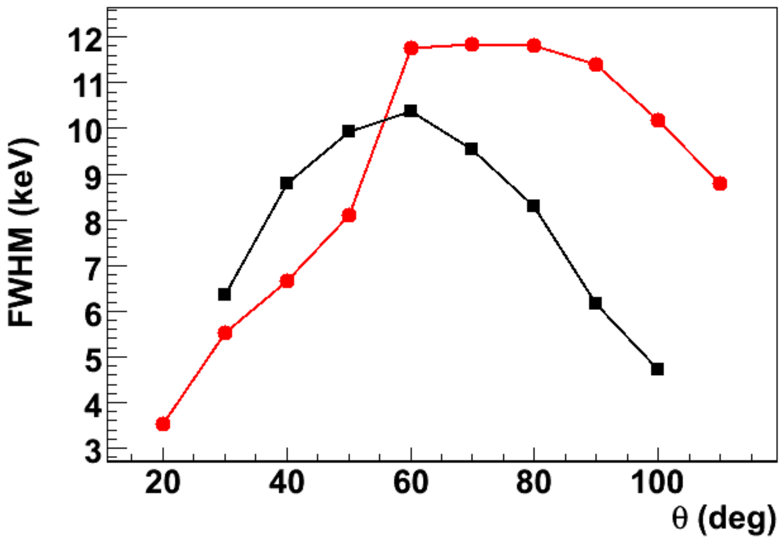
<ΔE(C2)> = 10.6 keV

S- and C-Geometry Performance, Quantitative Comparison





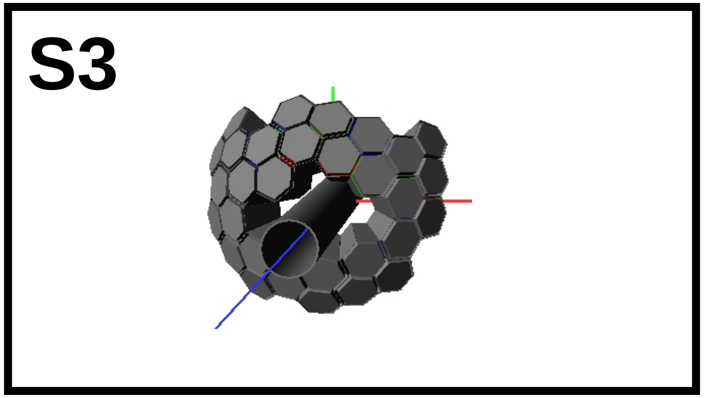


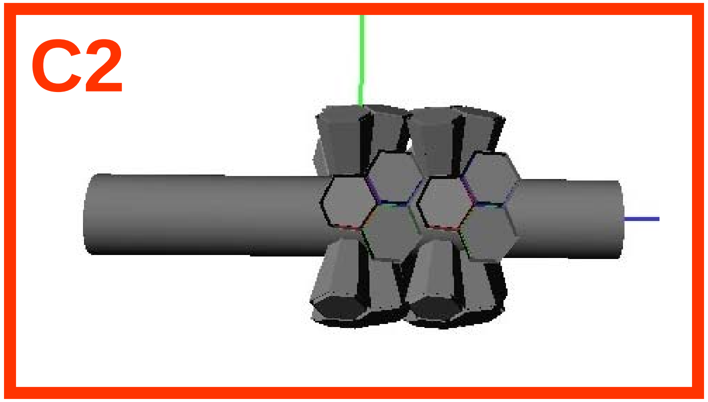


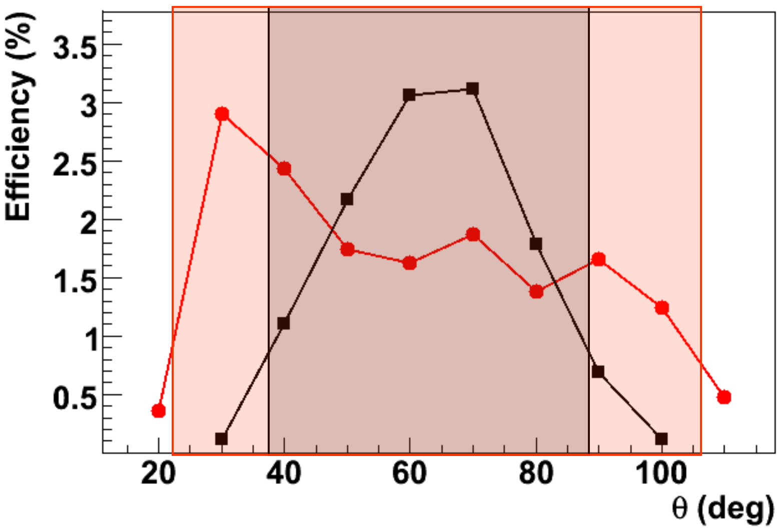
<ΔE(S3)> = 10.3 keV

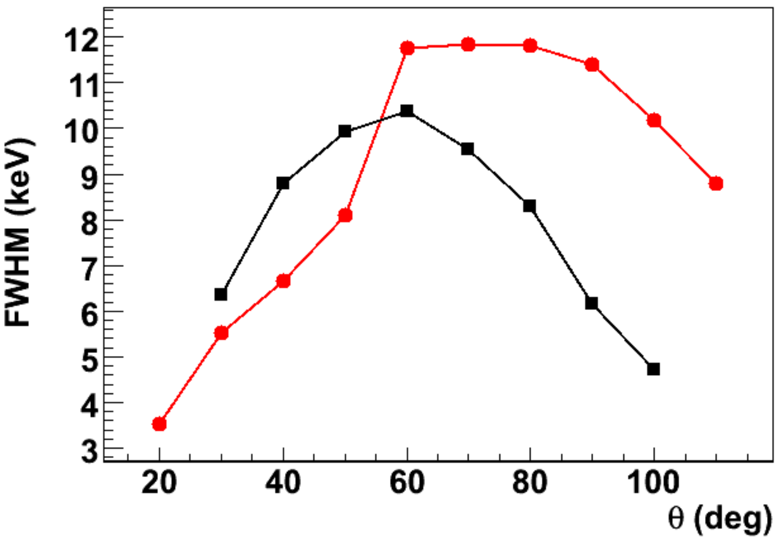
<ΔE(C2)> = 10.6 keV

S- and C-Geometry Performance, Quantitative Comparison









<ΔE(S3)> = 10.3 keV

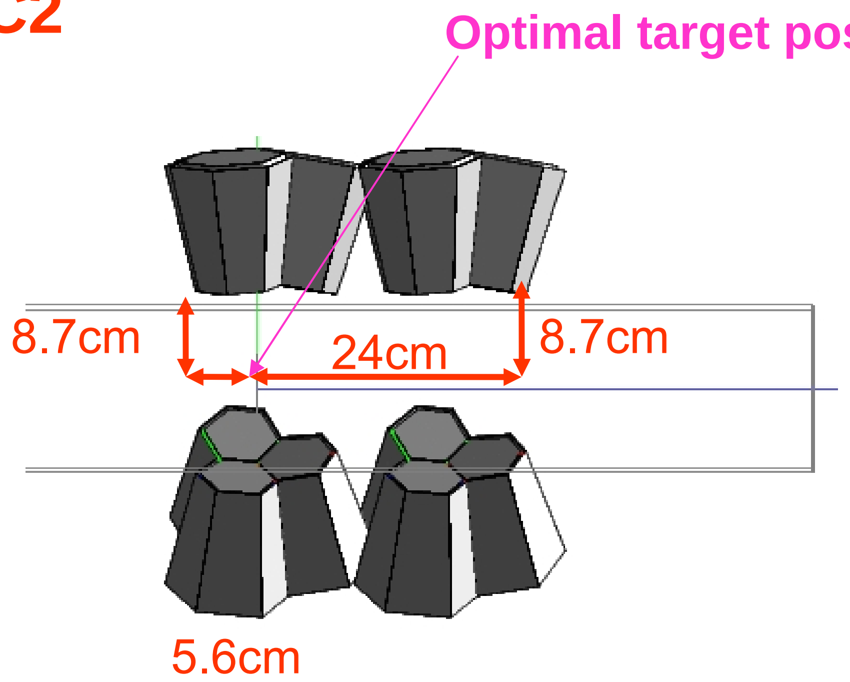
<ΔE(C2)> = 10.6 keV

Outline

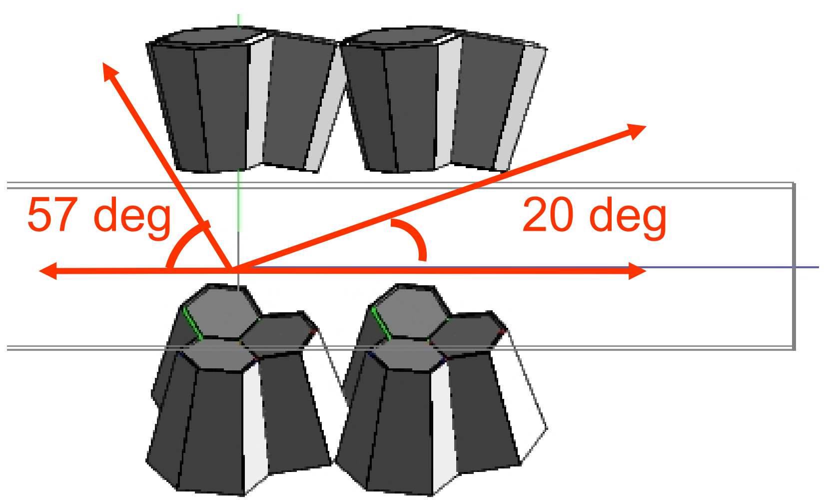
- Particular constraints for the setup at GSI
- Geometries: shell and compact setups
- Performance comparison
- Viability of additional γ-ray detectors: RISING, HECTOR, etc
- Gain in performance from 10 to 12 Clusters
- Outlook and conclusion

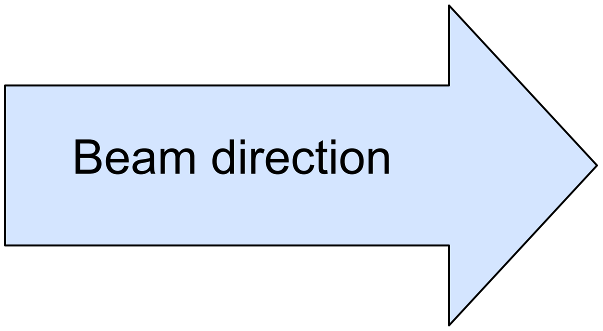
Solid angle occupied and free

C2

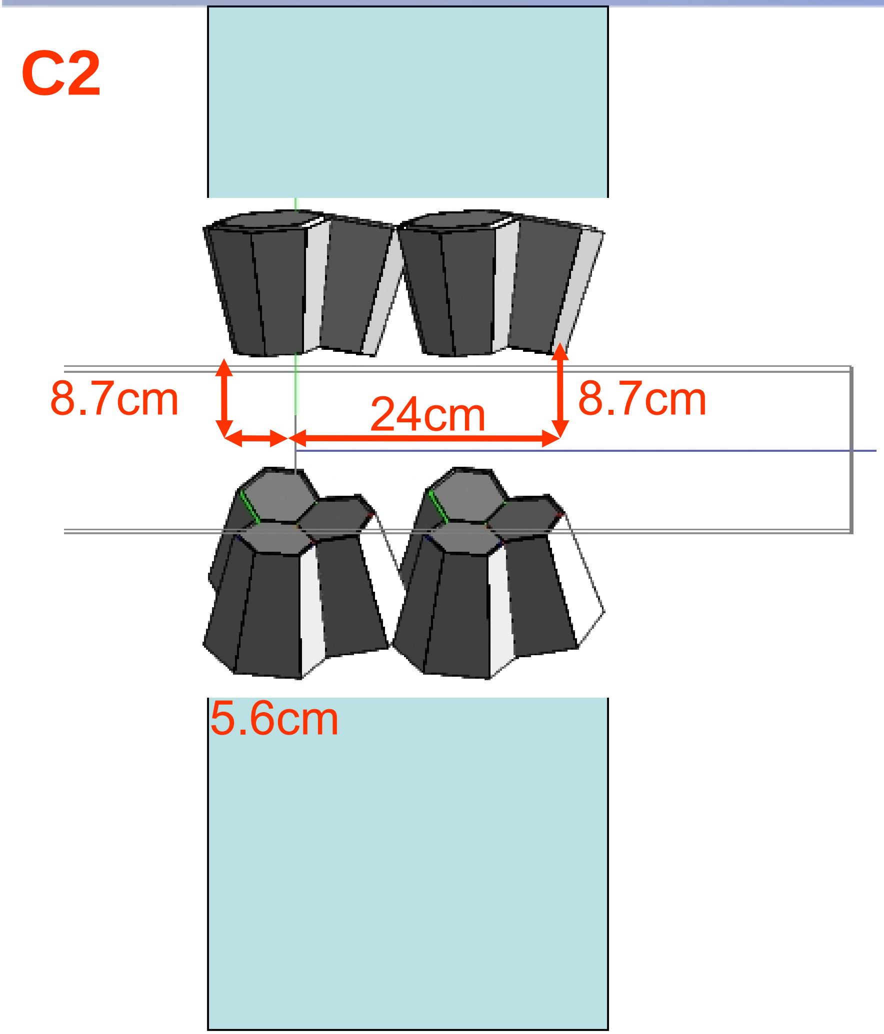


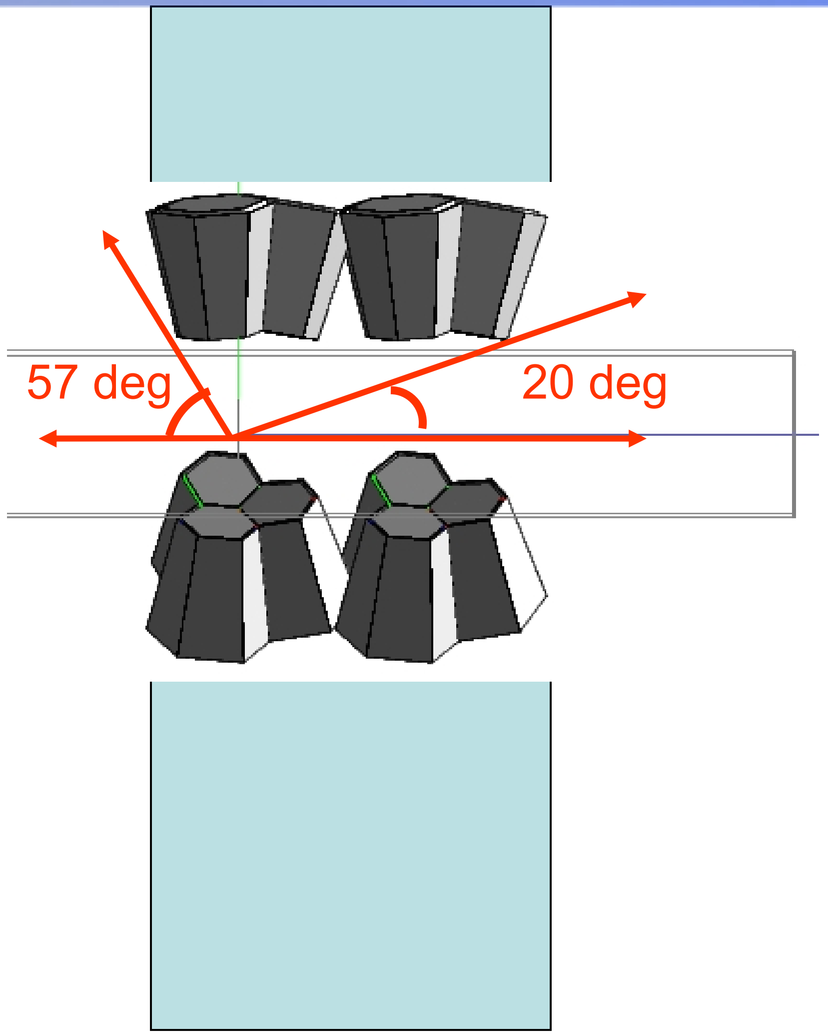
Approximate distances and angles



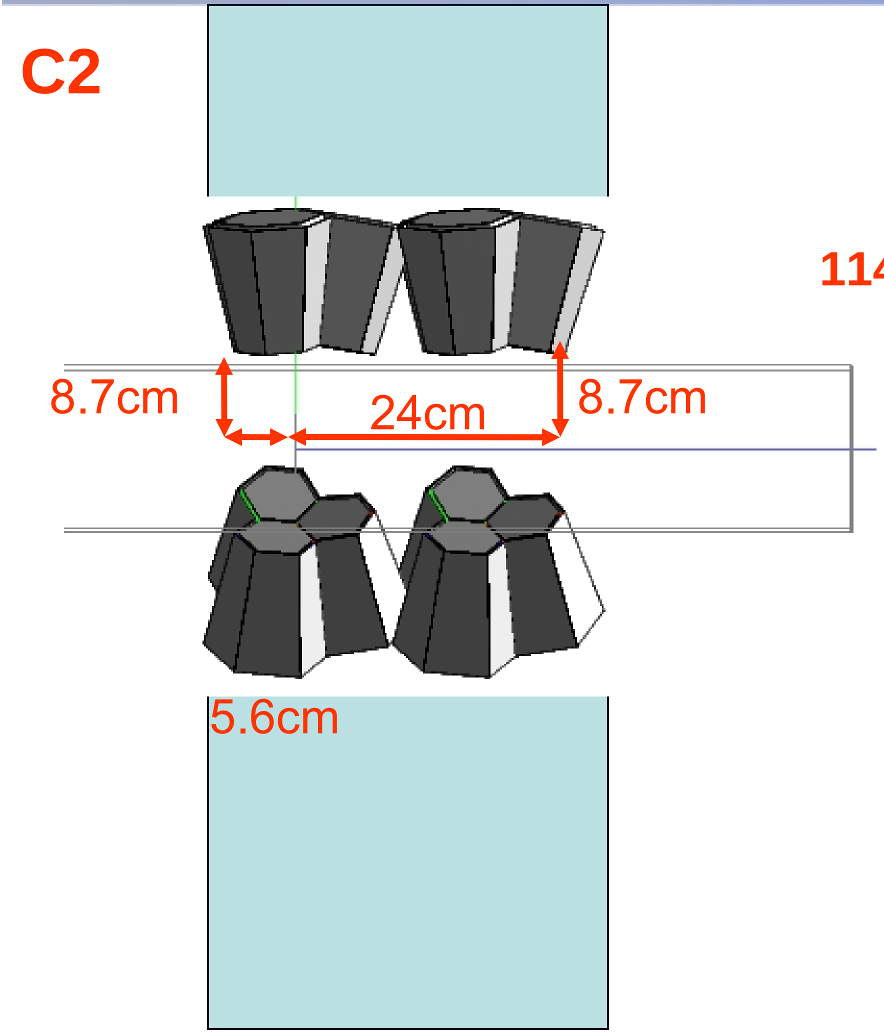


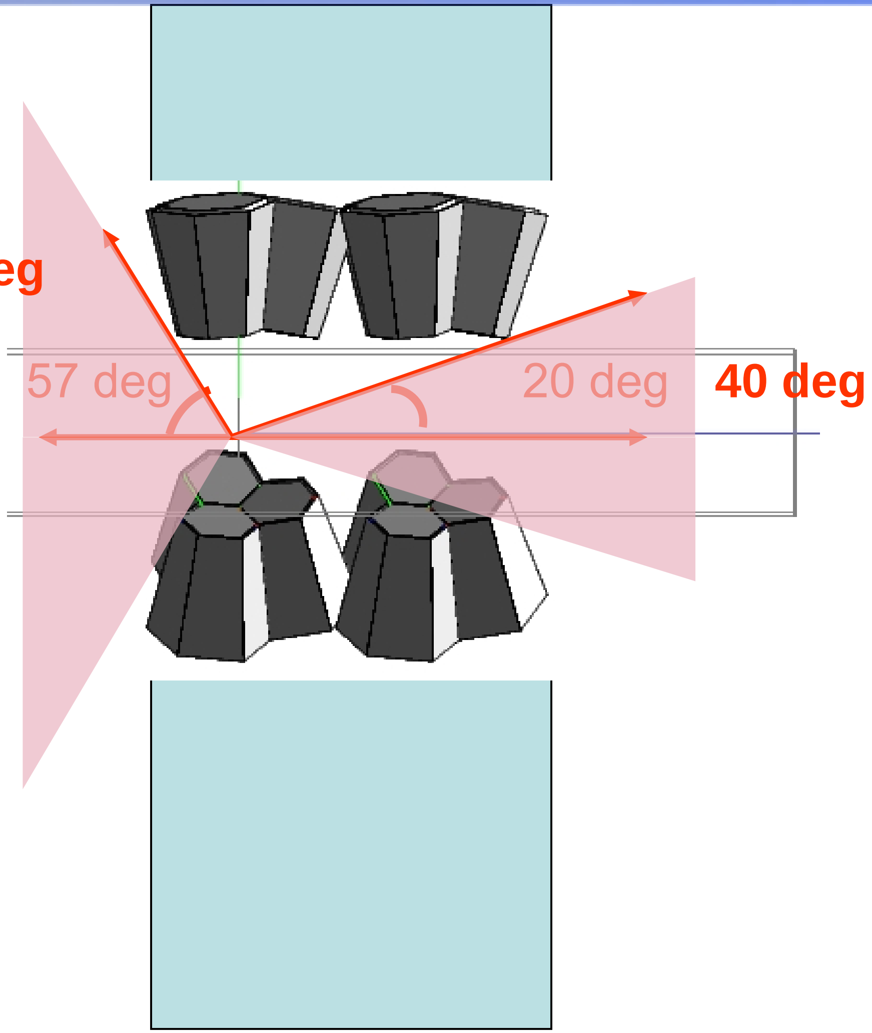
Solid angle occupied and free





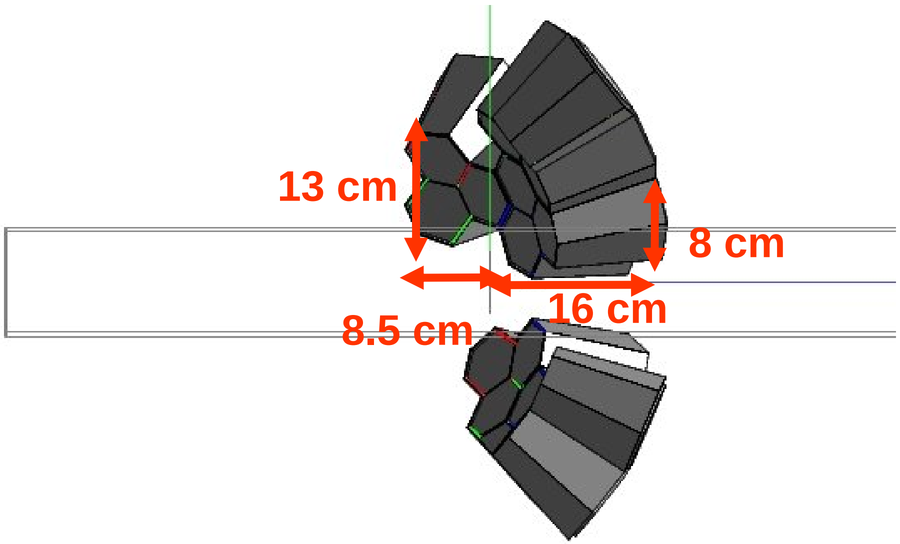
Solid angle occupied and free

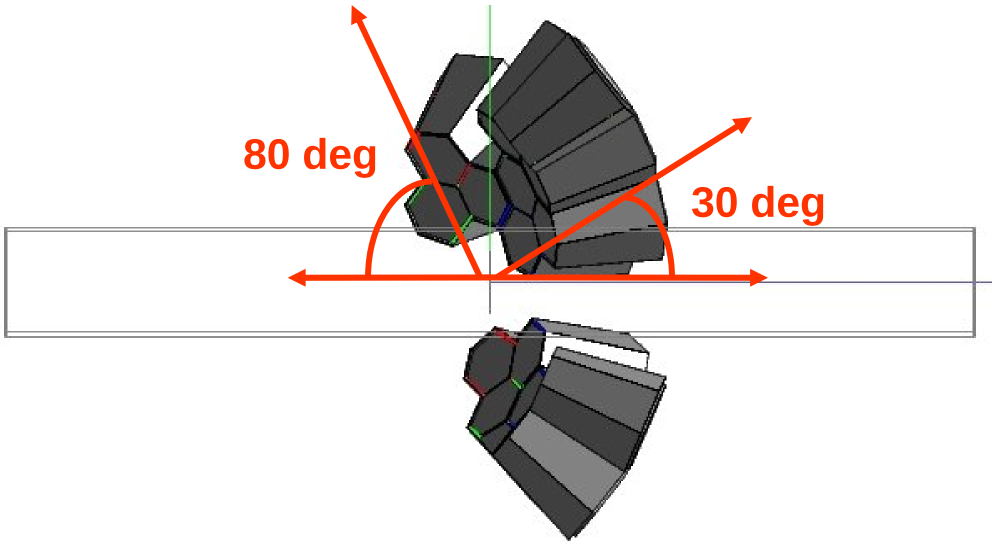




Solid angle occupied and free

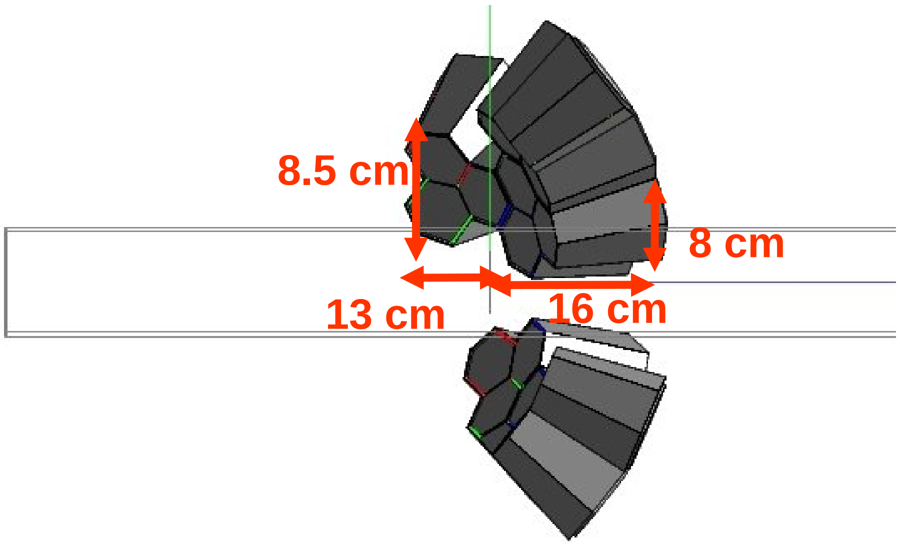
S3

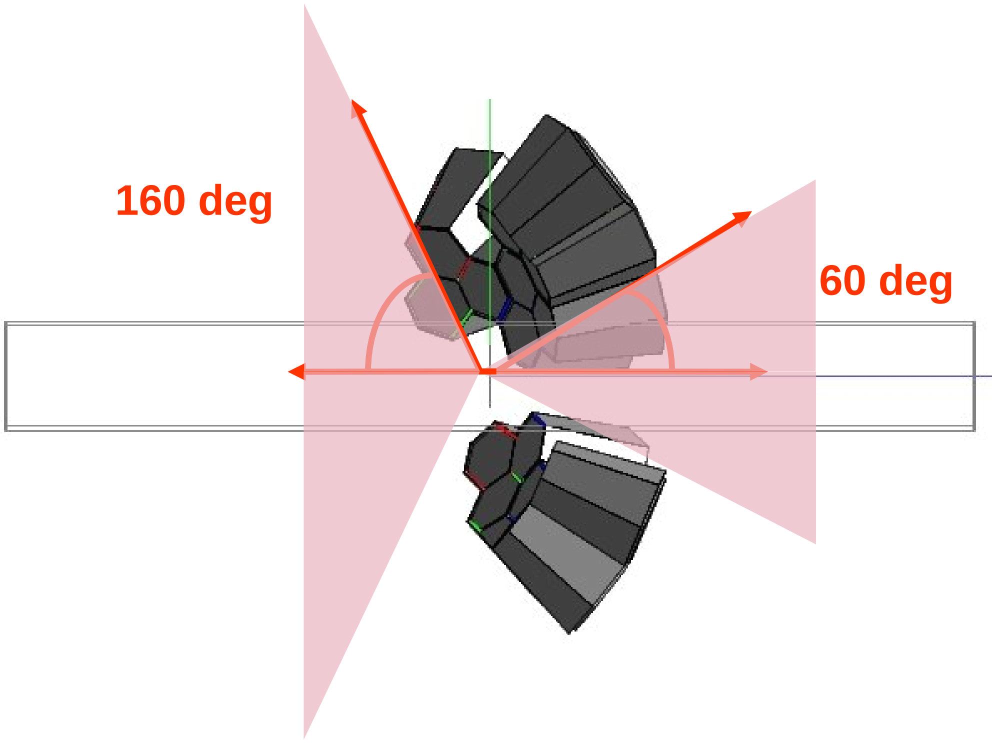




Solid angle occupied and free

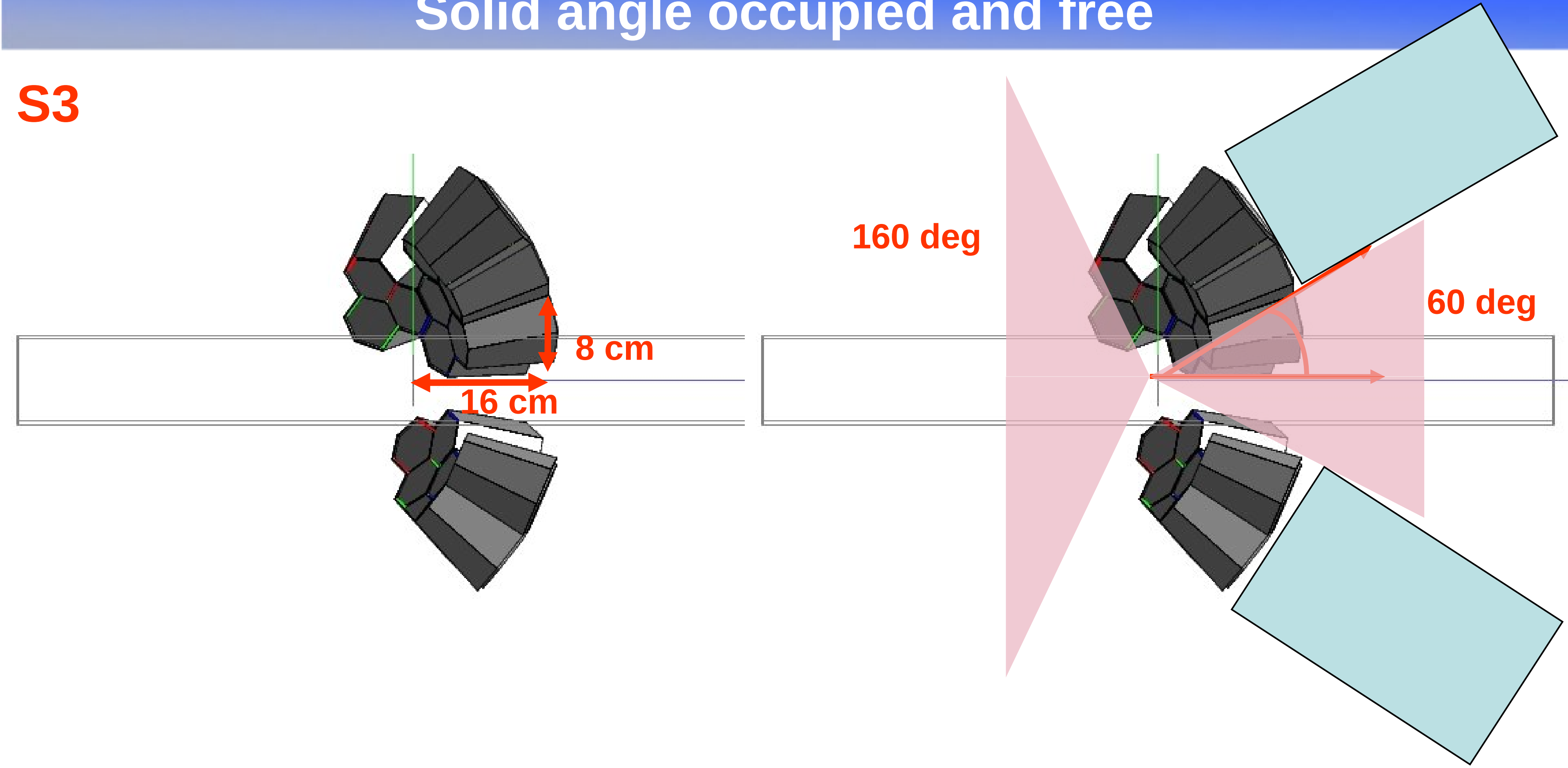
S3



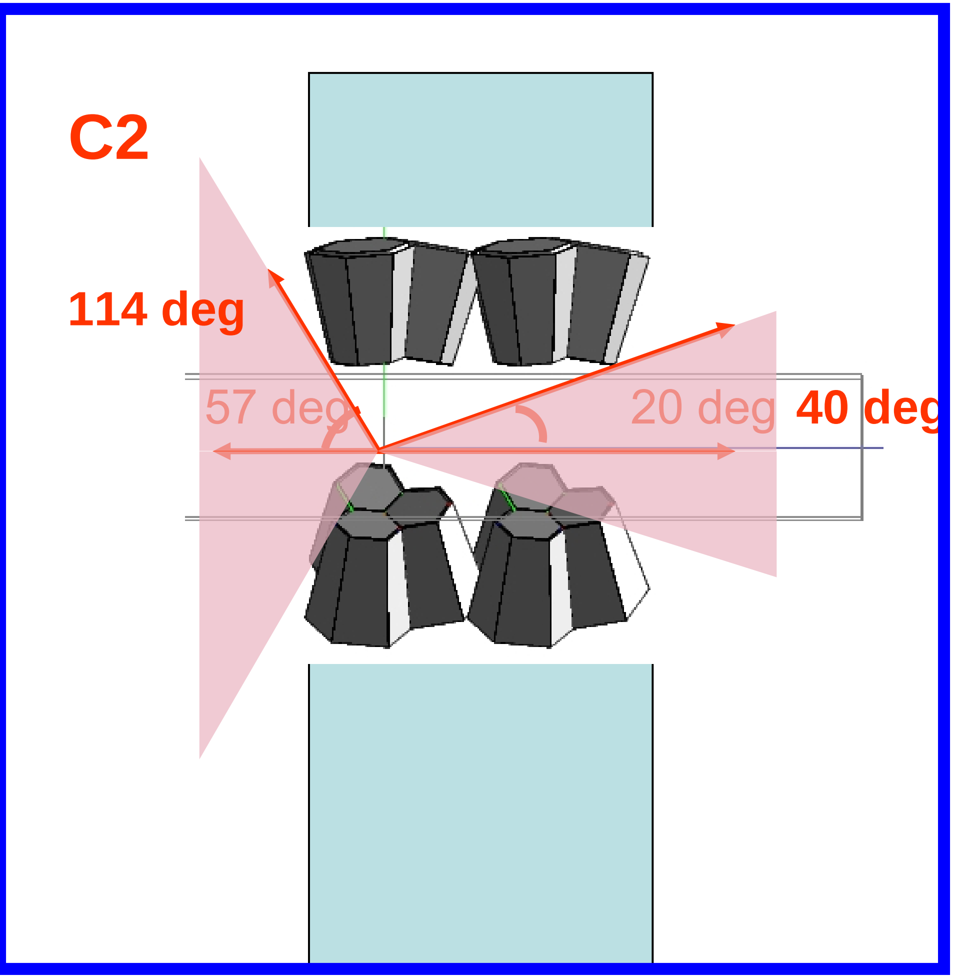


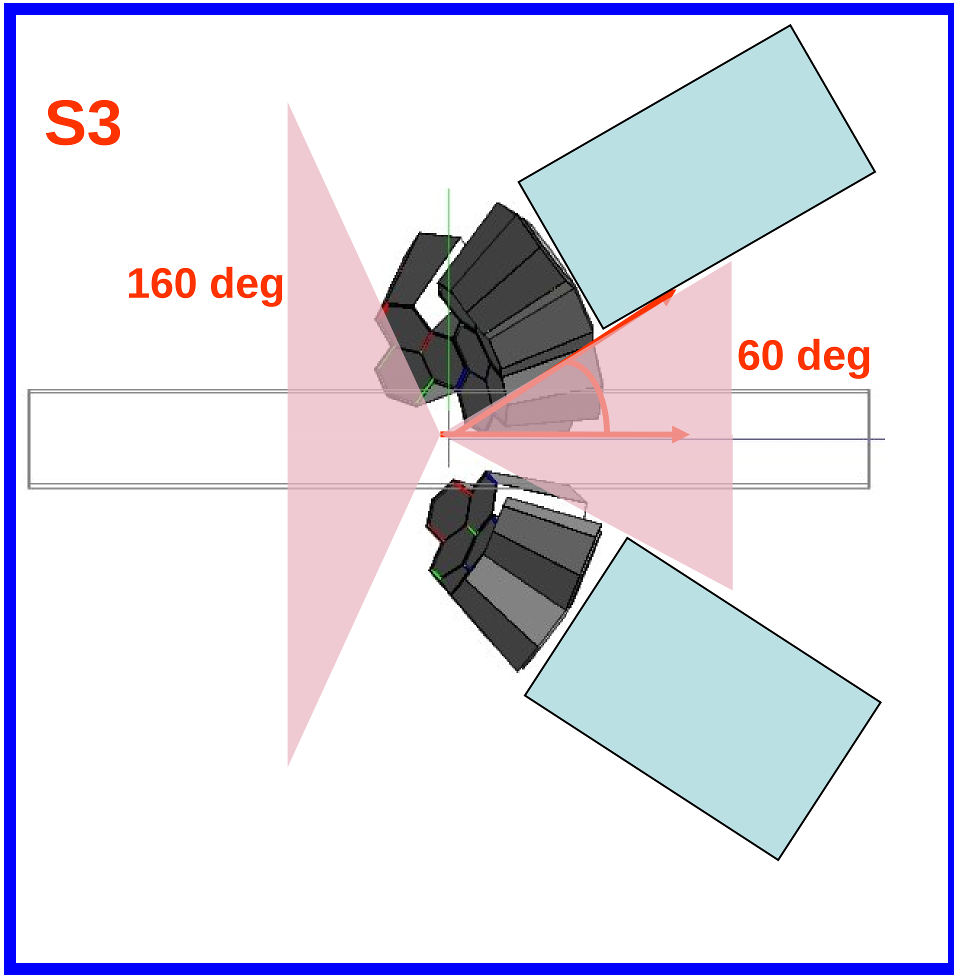
Solid angle occupied and free

S3



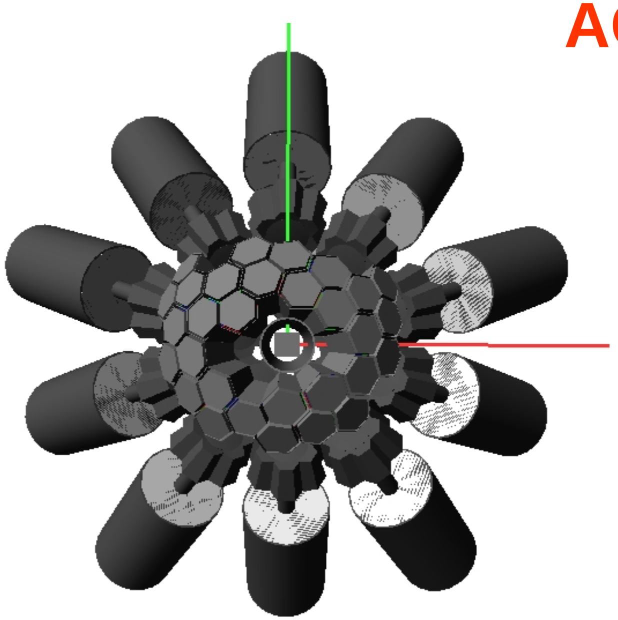
Solid angle occupied and free

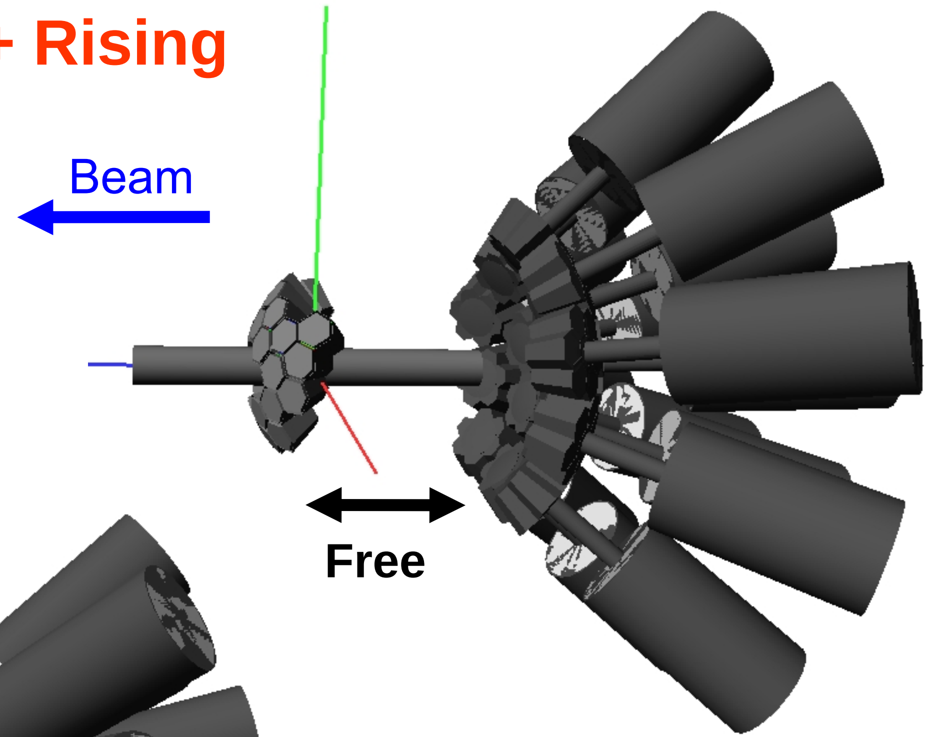


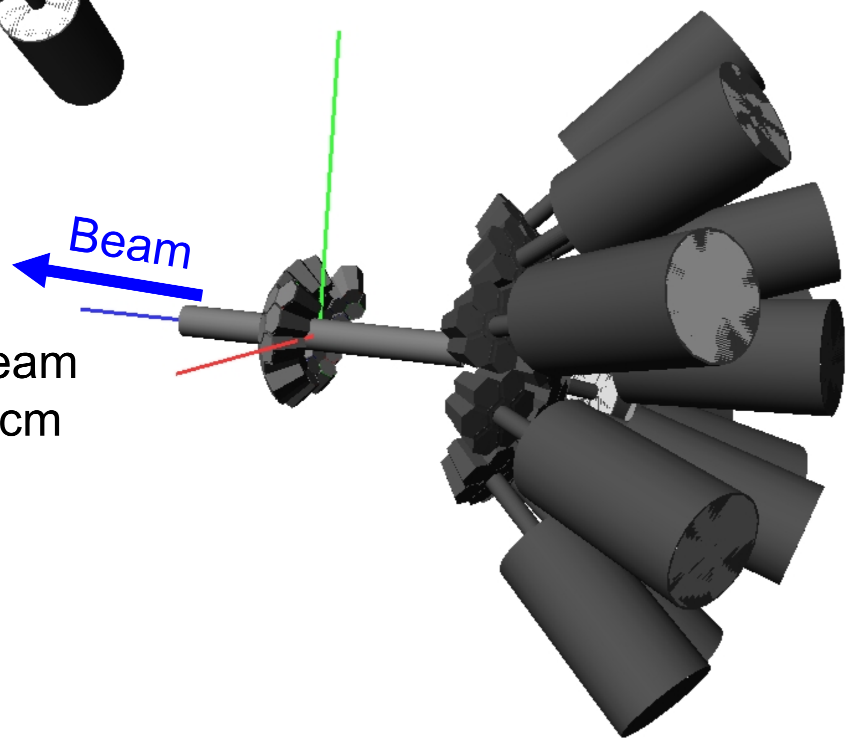


Compatibility with other detection systems

AGATA S3 + Rising





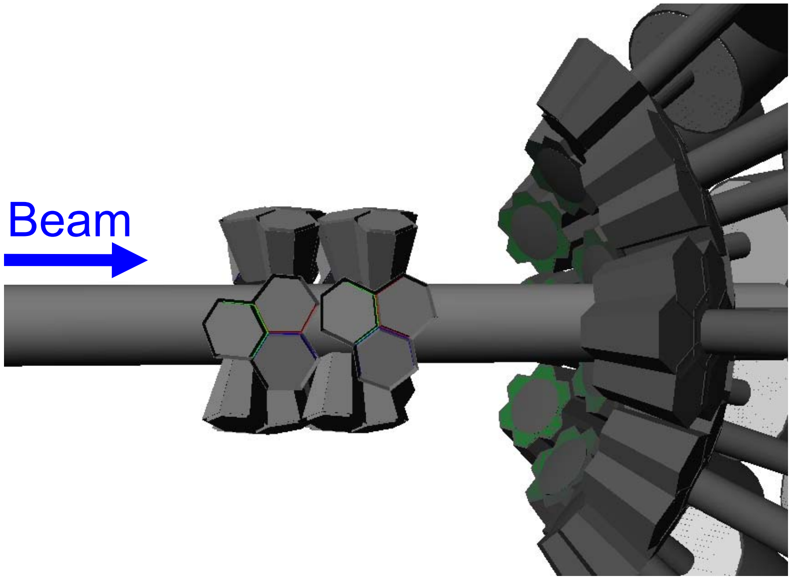


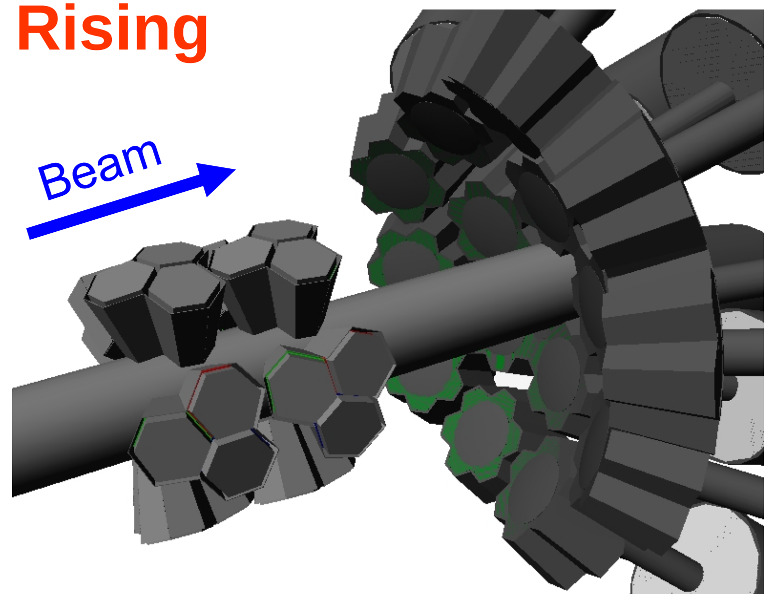
RISING Fast Beam Geometry at 70cm backwards

RISING Geant4 Geometry courtesy of Pavel Detistov

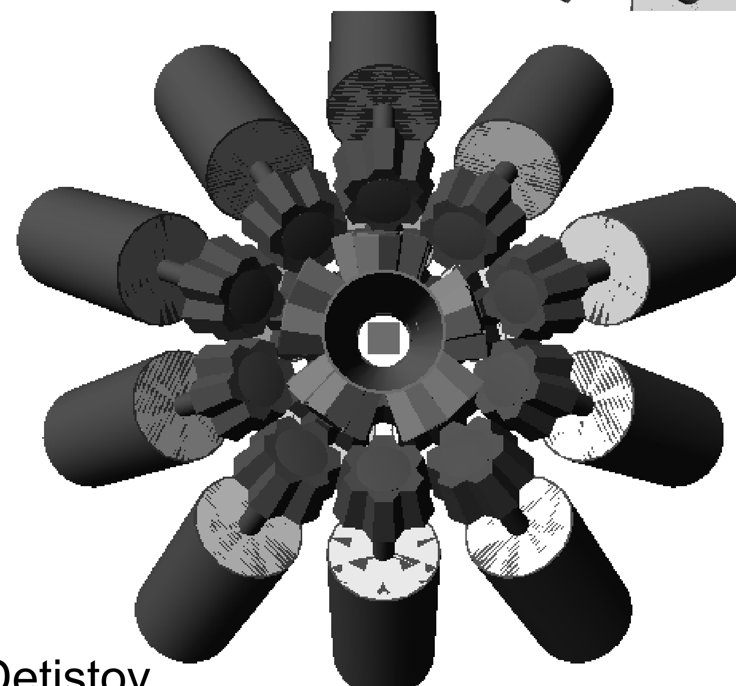
Compatibility with other detection systems

AGATA C2 + Rising



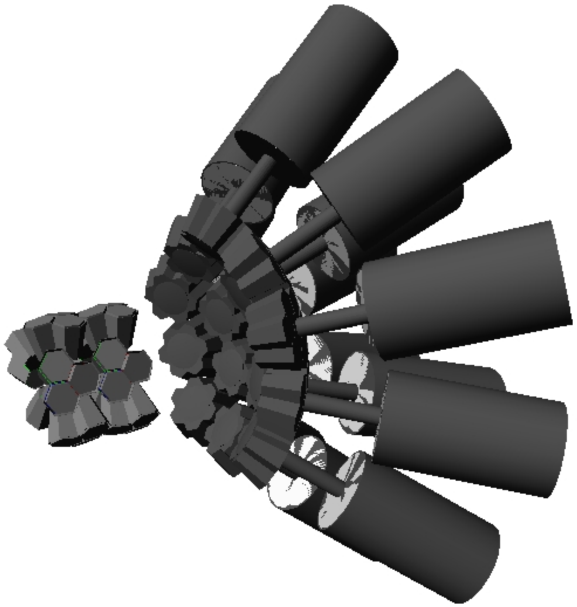


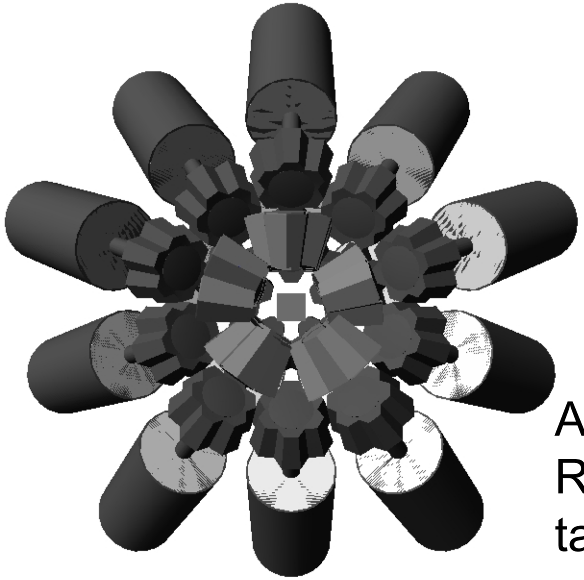
RISING Fast Beam Geometry at 70 cm forwards



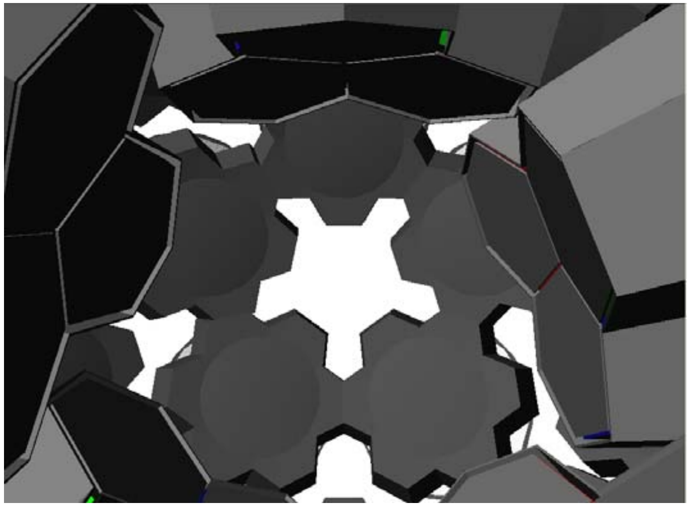
RISING Geant4 Geometry courtesy of Pavel Detistov

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

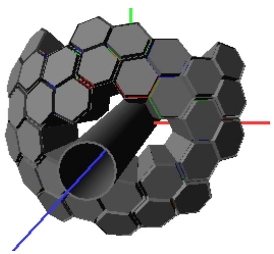
RISING Geant4 Geometry courtesy of Pavel Detistov

Outline

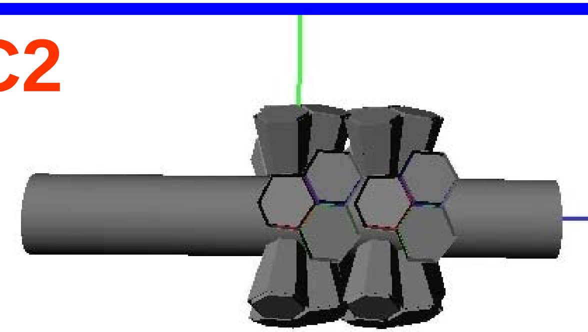
- Particular constraints for the setup at GSI
- Geometries: shell and compact setups
- Performance comparison
- Viability of additional γ-ray detectors: RISING, HECTOR, etc
- Gain in performance from 10 to 12 Clusters
- Outlook and conclusion

S- and C-Geometry Performance 12 Clusters

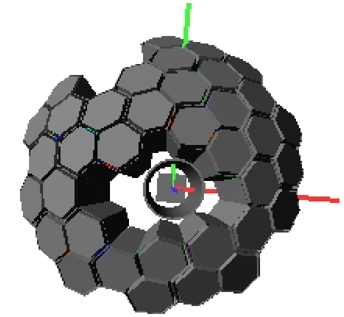
S3

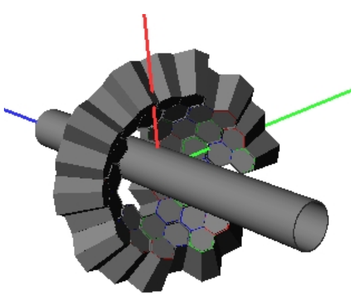


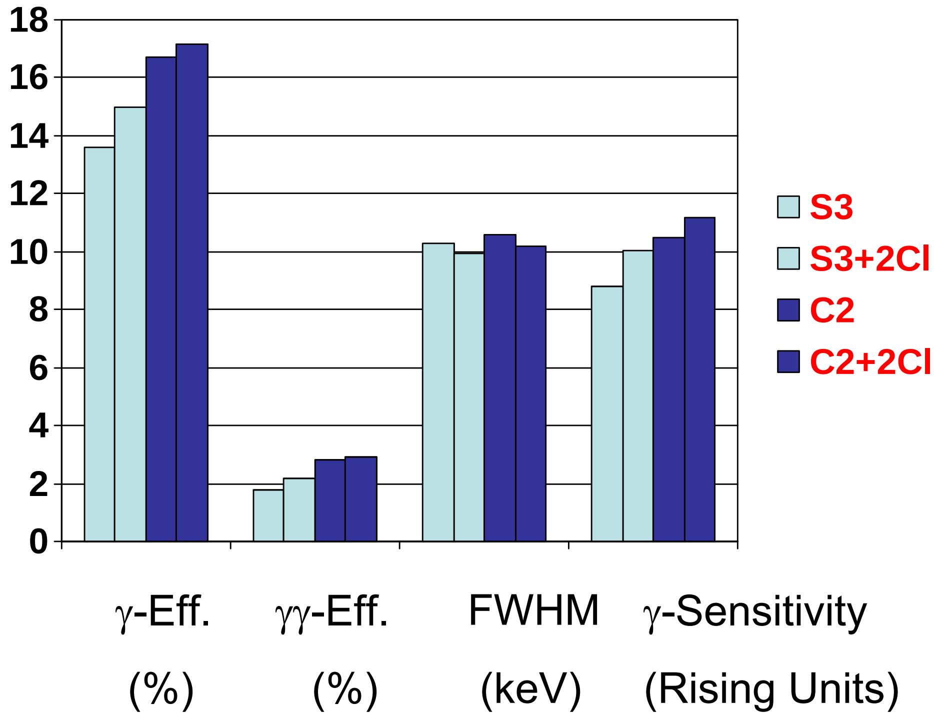
C2



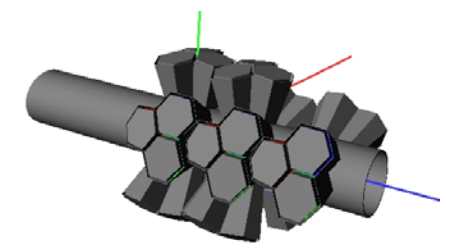
S3 + 2Clusters

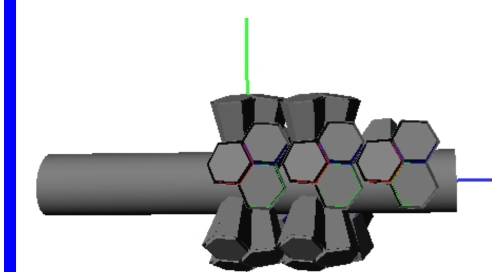






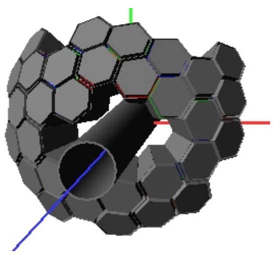
C2 + 2 Clusters



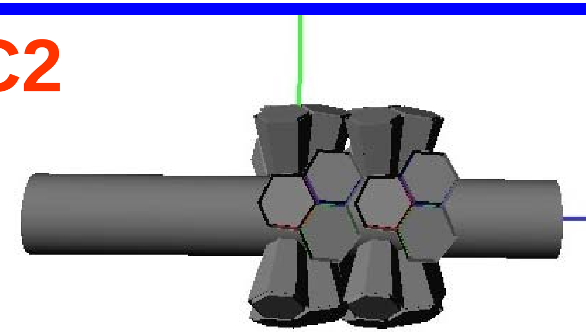


S- and C-Geometry Performance, Quantitative Comparison

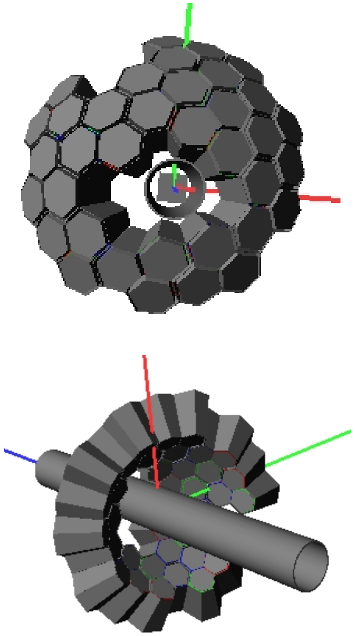
S3

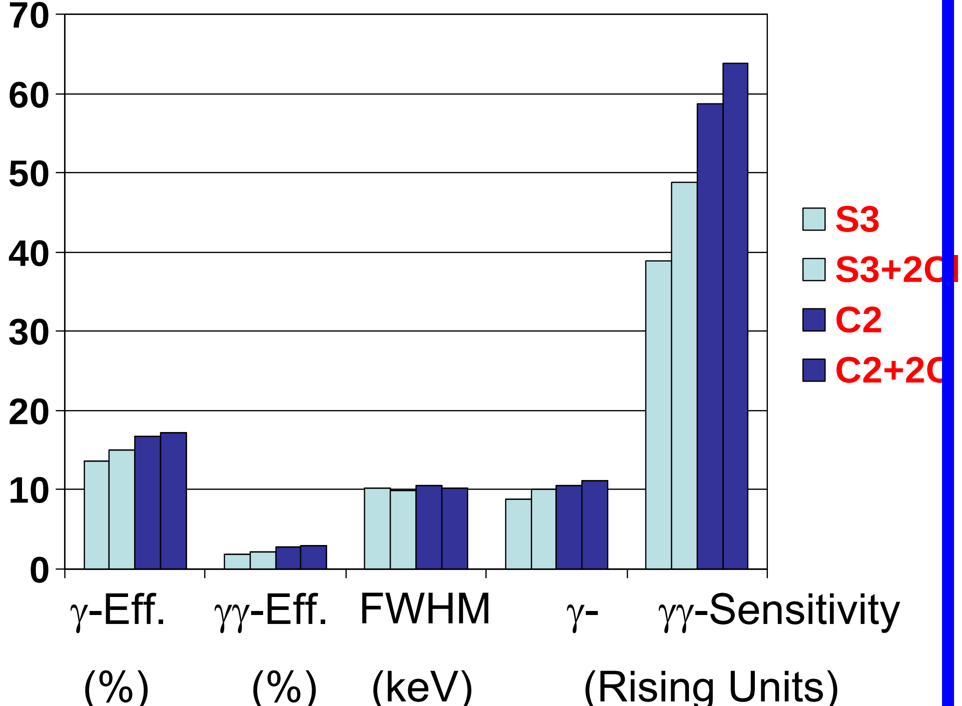


C2

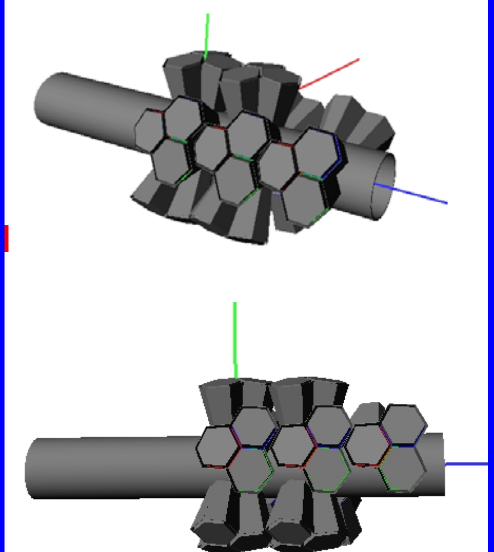


S3 + 2Clusters

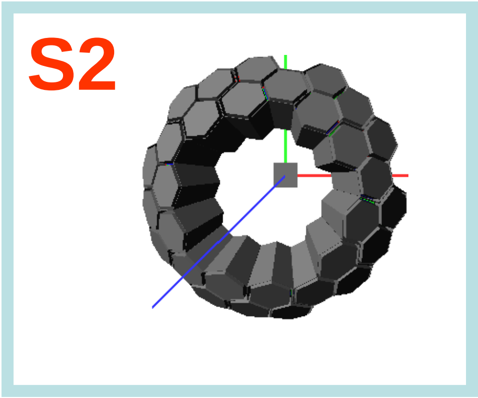


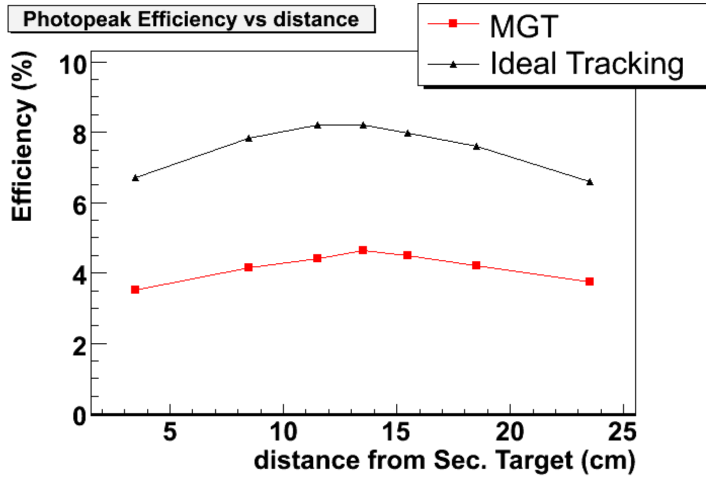


C2 + 2 Clusters

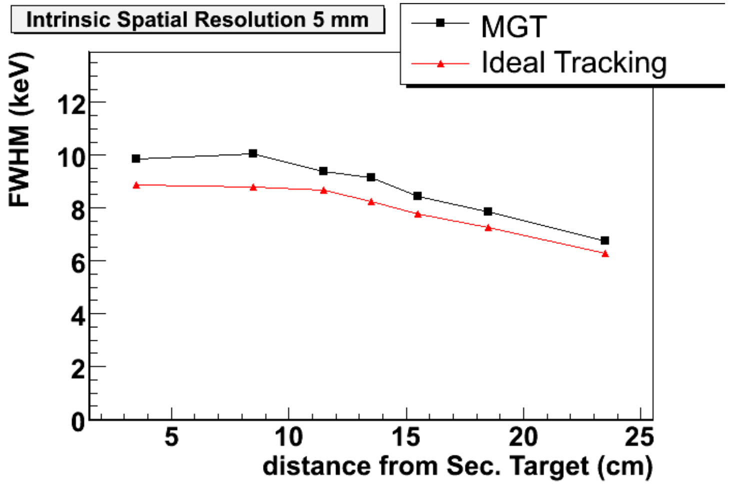


Realistic Tracking (mgt)





50% lower efficiency



10% worse resolution

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

Geometry cases

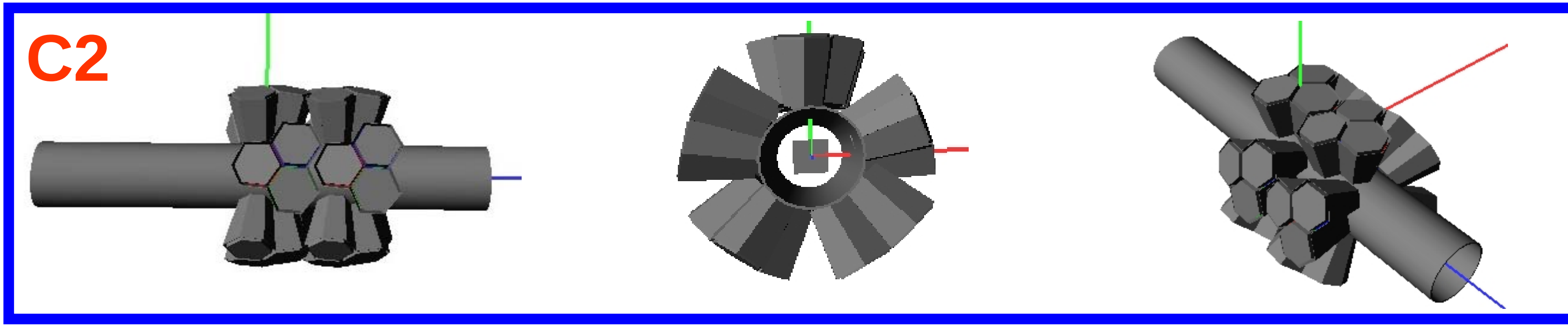
- Task 1: S2 + 5 Double Cluster detectors closing part of the central hole (15-16cm?). Remains shell with 5 crystals hole + pentagon hole
- Task 2: S3 + 1 Double Cluster detector closing part of the central hole (10-11 cm?). Remains shell with 4 crystals hole + pentagon hole.
- Task 3: previous + 4 Triple 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:

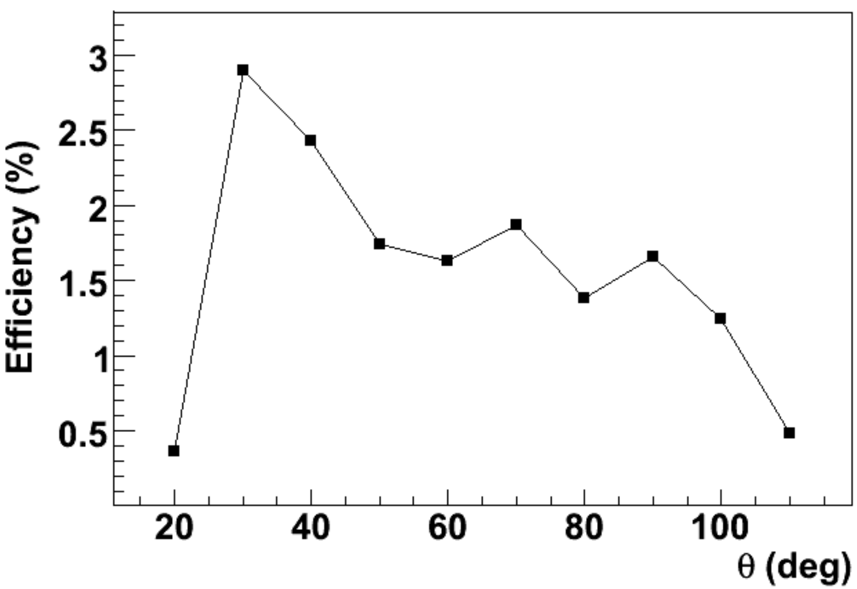
• Provided that 10 ATC detectors and 1 "ADC" detector (or more) are available, then a shell geometry (S3' or S2') shows a superior performance than any other possible cylindrical geometry (e.g. C2).

• 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.

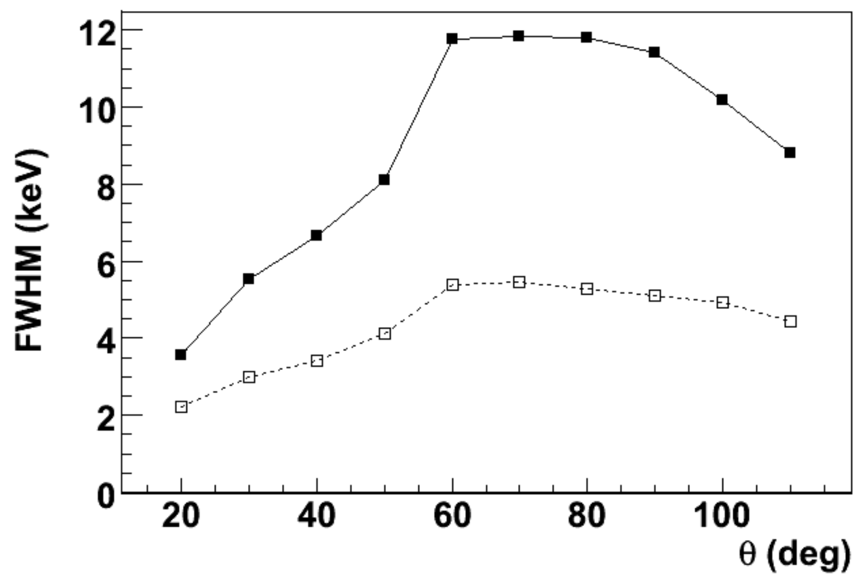
C2: Efficiency and Resolution angular dependence



Photopeak Efficiency

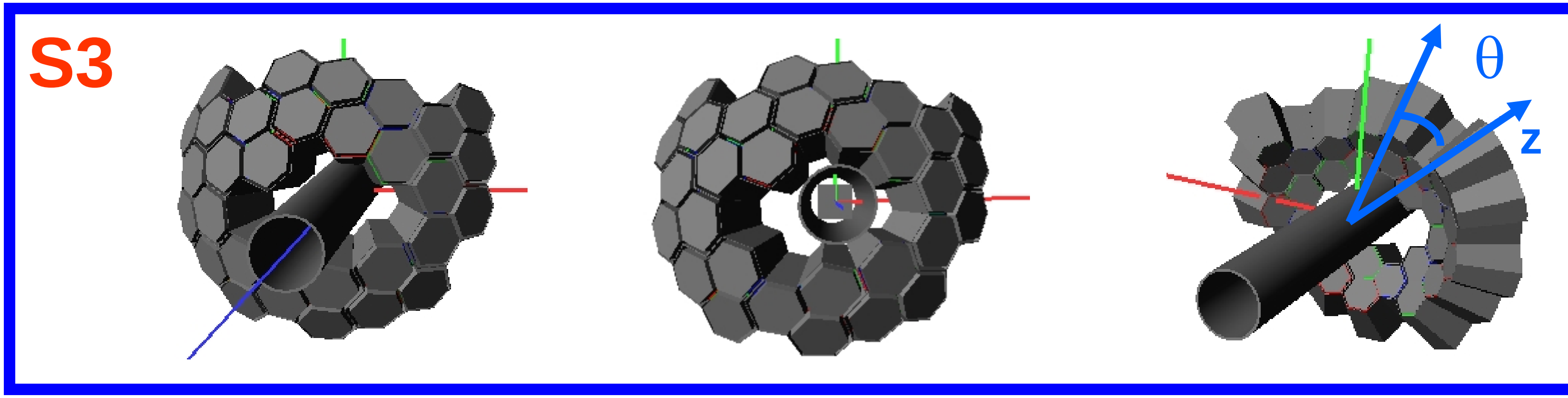


Energy Resolution

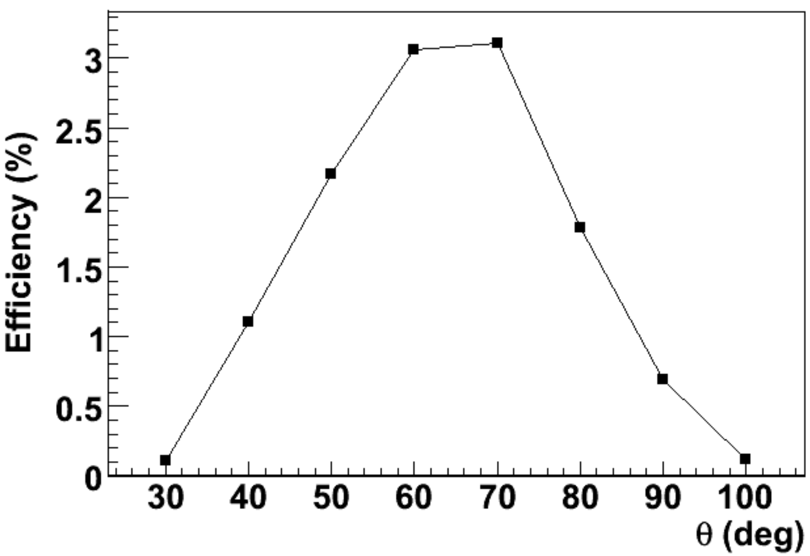


<ΔE(C2)> = 10.6 keV

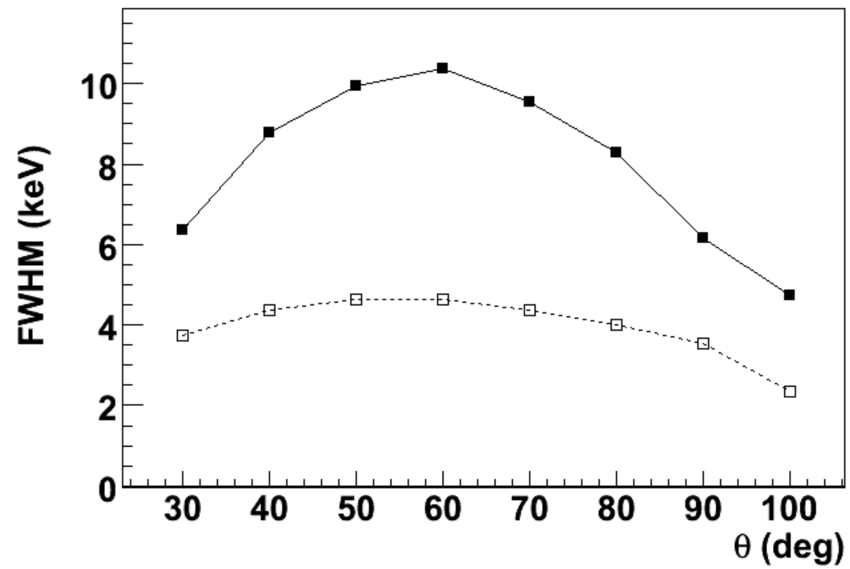
S3: Efficiency and Resolution angular dependence



Photopeak Efficiency



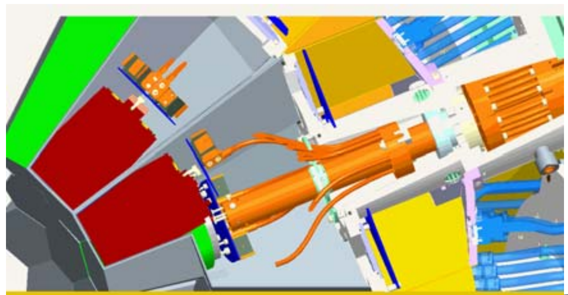
Energy Resolution



<ΔE(S3)> = 10.3 keV

Beam profile at AGATA position... better 120 mm option

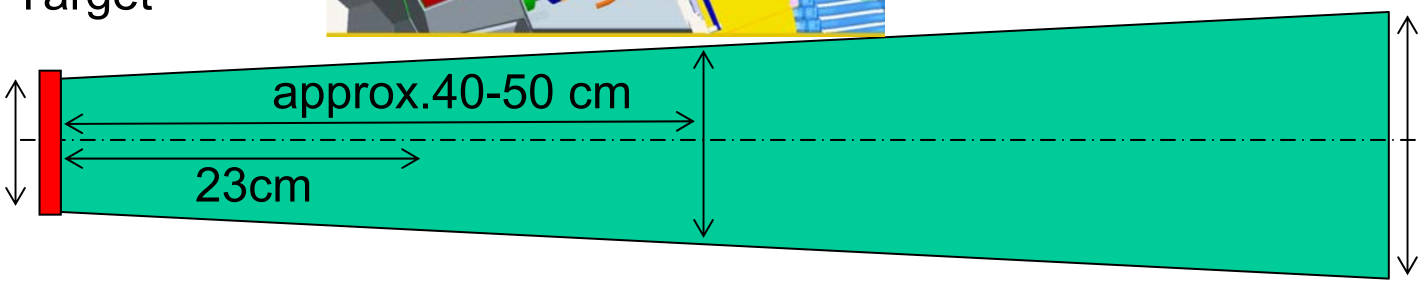
Cross Section View from the TOP



Target

S4 Focal Plane

6 cm $FWHM_X$



LYCCA Size

25-44 cm

Beam angle about 3 deg

$L_{Target\text{-}LYCCA}$ = 3.5 m

Beam Size at ADC-Cryostat Flange approx. 10 cm

Example: θ = 3 deg (depends on $L_{Target\text{-}LYCCA}$ and on LYCCA size)

Beam Size X at Target Position = 6 cm (FWHM)

Beam Size X at 45 cm downstream = 10.7 cm