MC Simulations for the PreSPEC campaign of AGATA at GSI

César Domingo Pardo

GSI Helmholtzzentrum für Schwerionenforschung GmbH

Outline

- Summary of **simulated geometries** for PreSPEC
- Summary on the **performance** of each geometry case
- Conclusion on **best geometry** for experiments at GSI-FRS
- **Benchmark** experiments: Coulex, Fragmentation and Plunger
- Additional ingredients for a realistic simulation: background and tracking
- Outlook and conclusion

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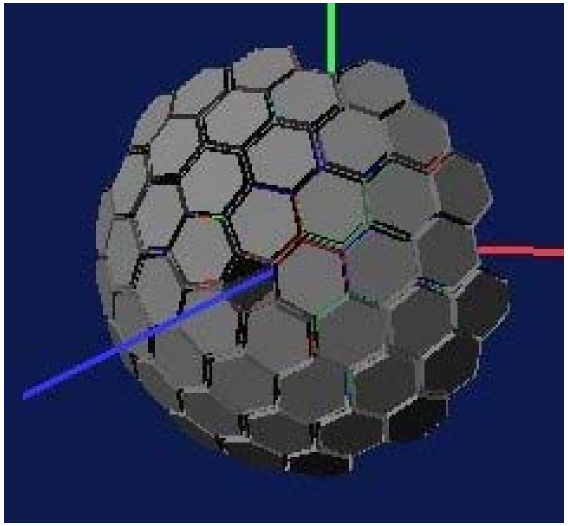
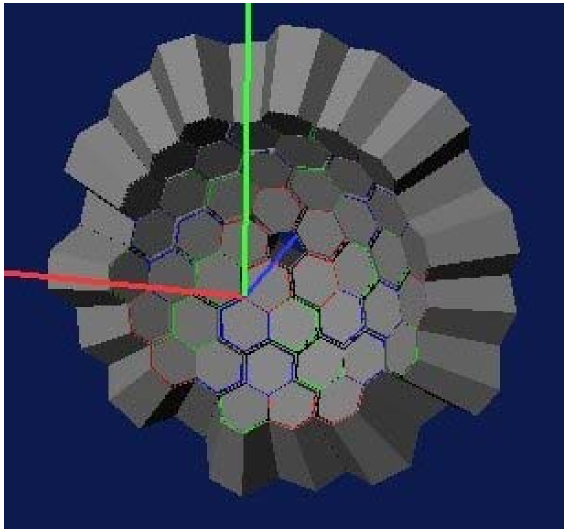
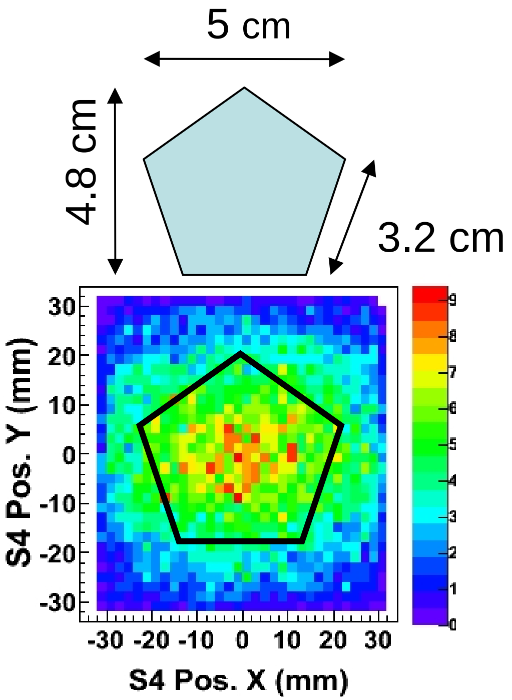
Particular constraints for the setup at GSI

• Ideal geometry (first approach, first step)





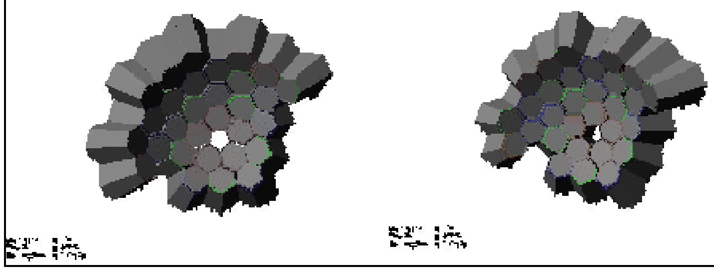


• two main constraints:

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

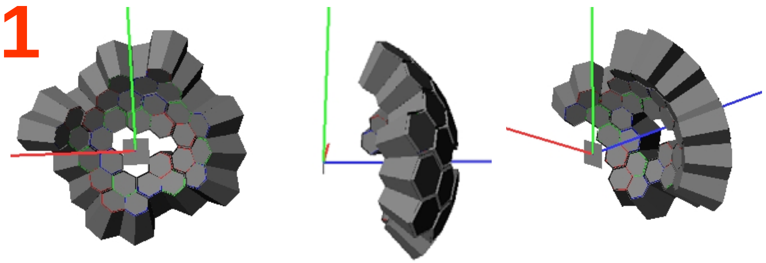
more realistic



10 Clusters

Hole too small (appx. 4 cm)

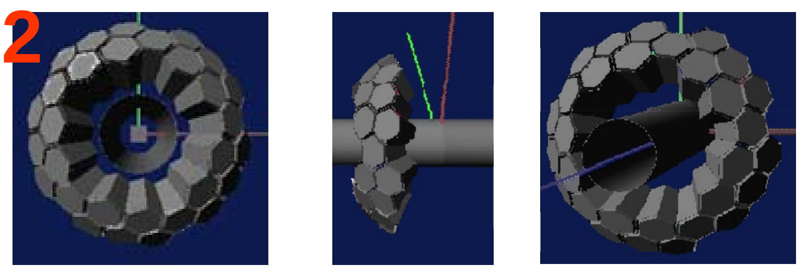
S1



10 Clusters (Hole 1 Cluster)

Hole small (appx. 7 cm)

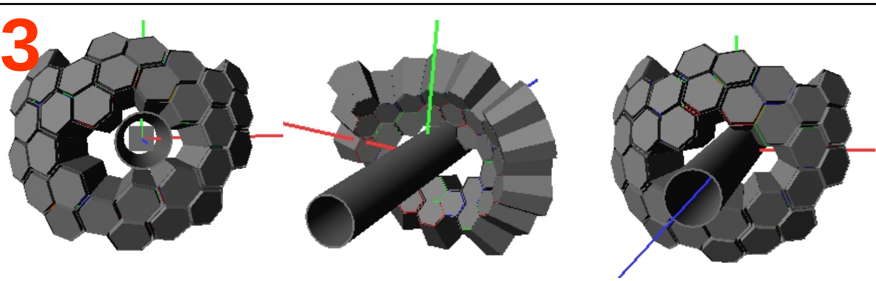
S2



10 Clusters (Hole 5 Clusters)

Hole (22.8 cm) beam-pipe 16 cm

S3

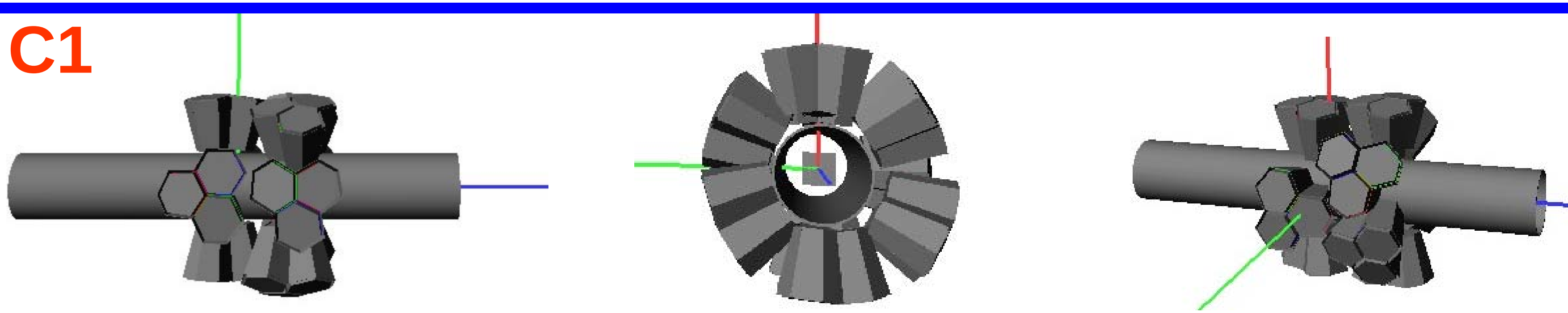


10 Clusters (Hole 2 Clusters)

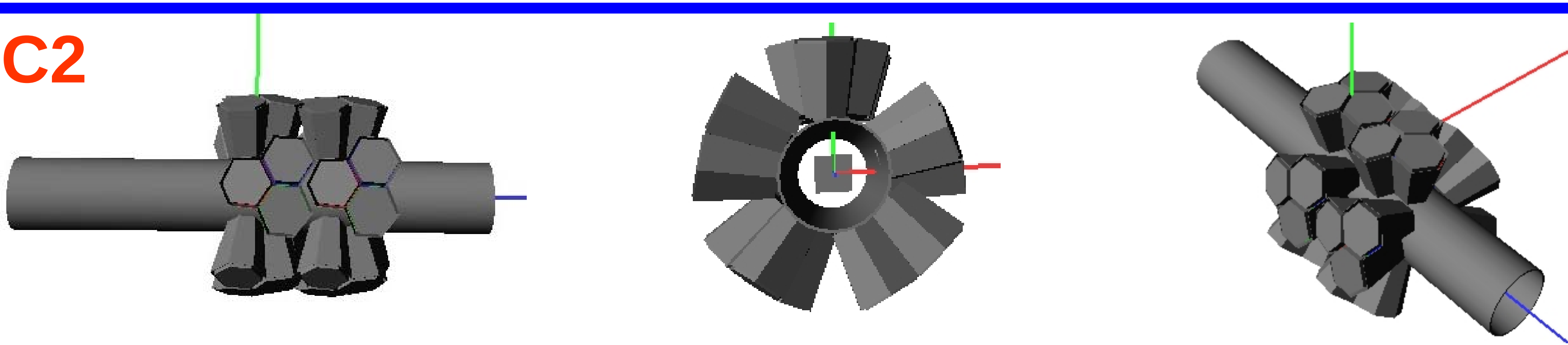
Hole (11.5 cm) beam-pipe **11 cm**

Compact geometries

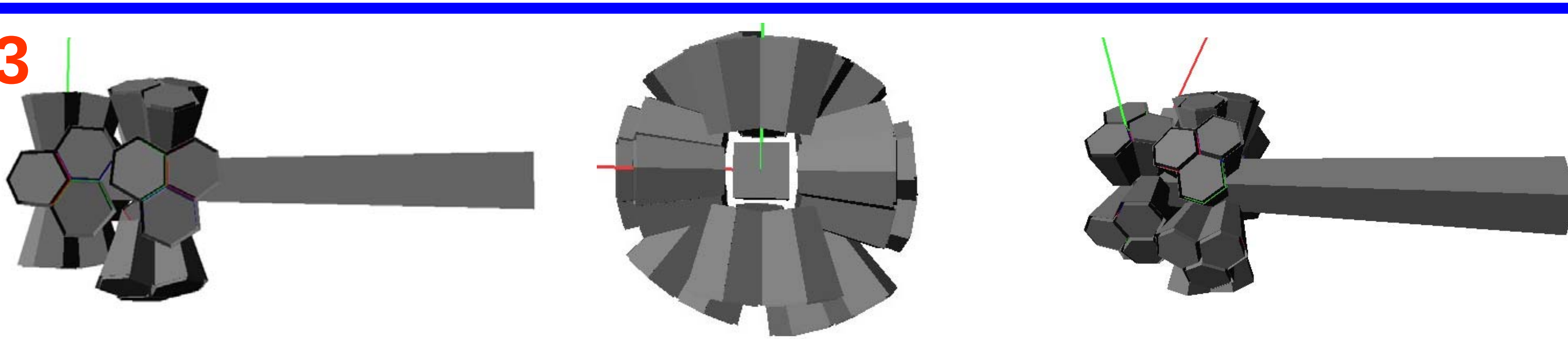
C1



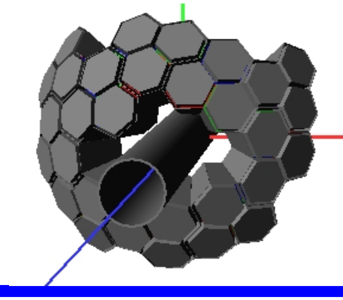
C2



C3

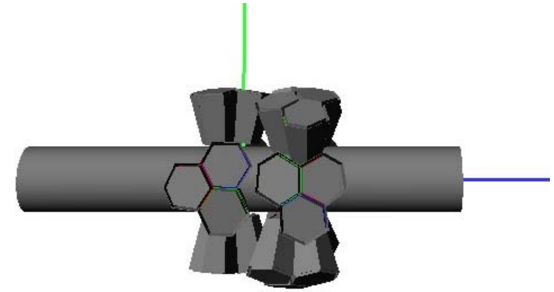


Pros and Cons



- 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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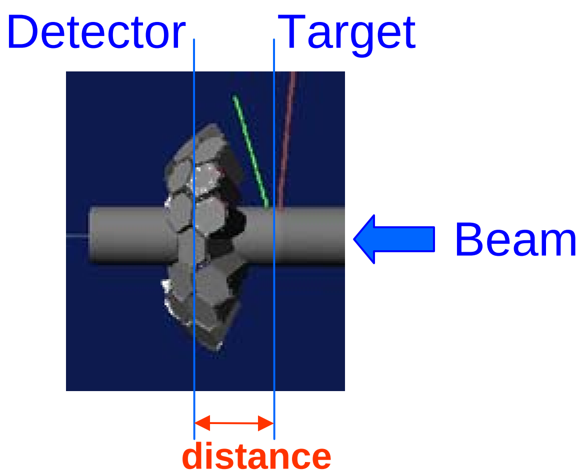
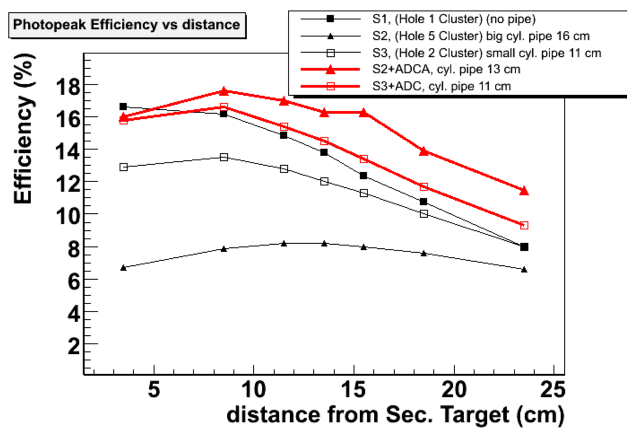
Performance comparison: general aspects

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

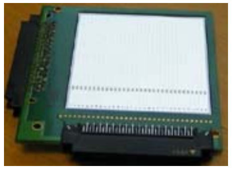
- "Reference case": (GEANT4 AGATA code from E.Farnea et al.)
  - ⇨ $E_{\gamma,o}$ = 1 MeV, recoil nucleus at β = 0.43 (E = 100 MeV/u), Mγ = 1
  - ⇨ Systematic study several distances sec. target – detector

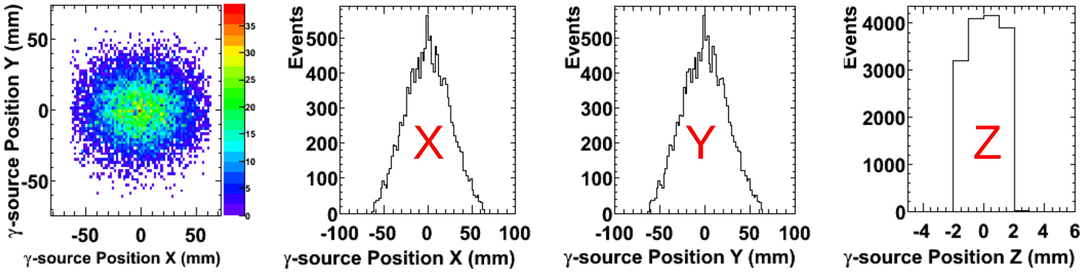




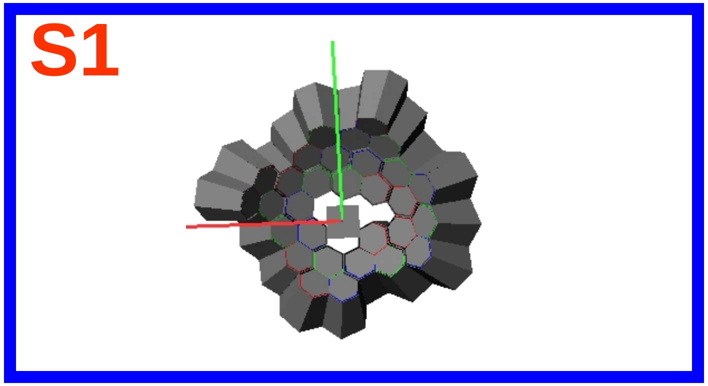
  - ⇨ GSI FRS Spatial Beam Profile FWHM_x = 6 cm FWHM_y = 4 cm

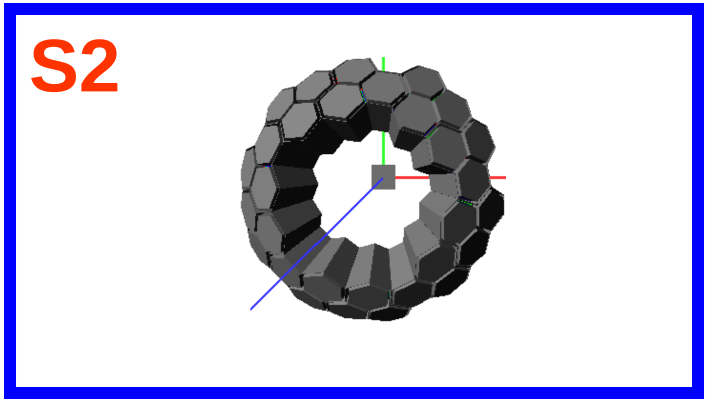
Active target
DSSSD

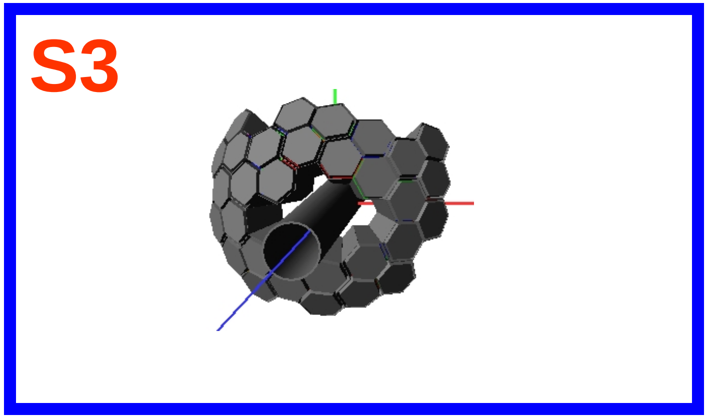


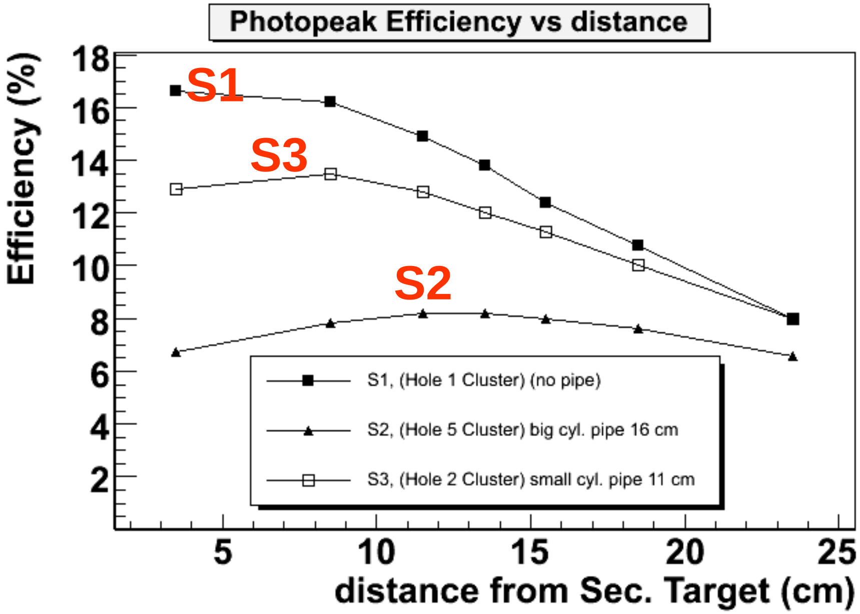


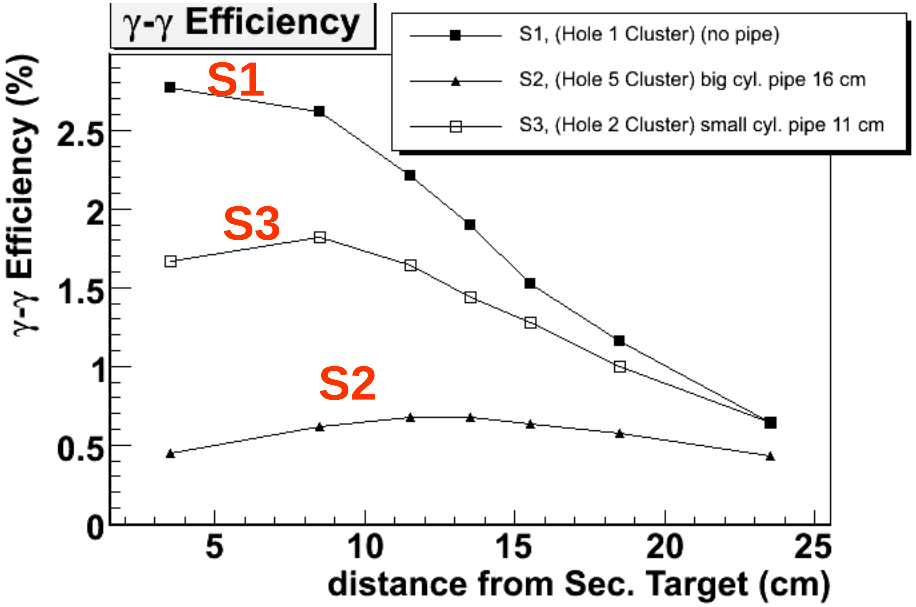
S-Geometries Performance comparison: Efficiency











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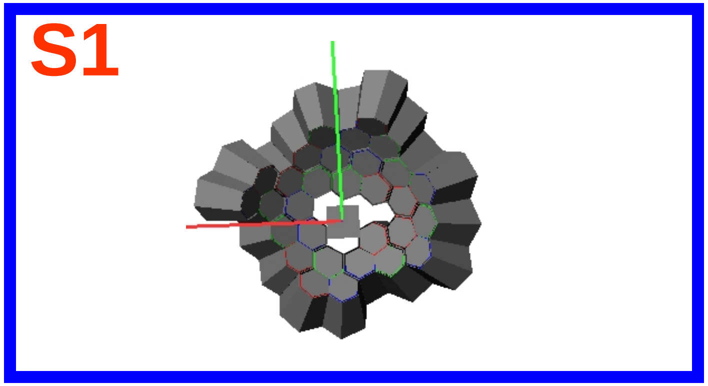
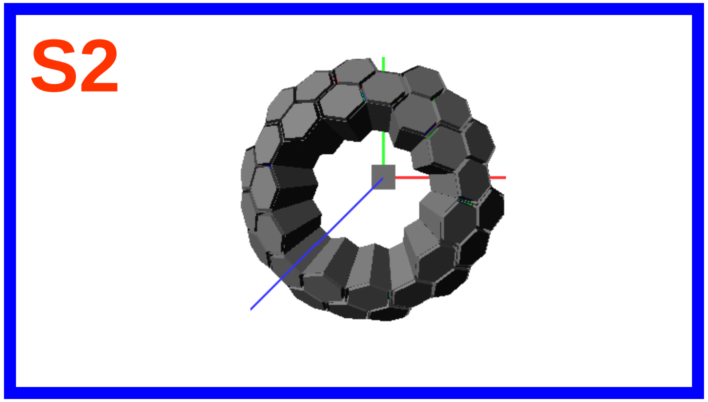
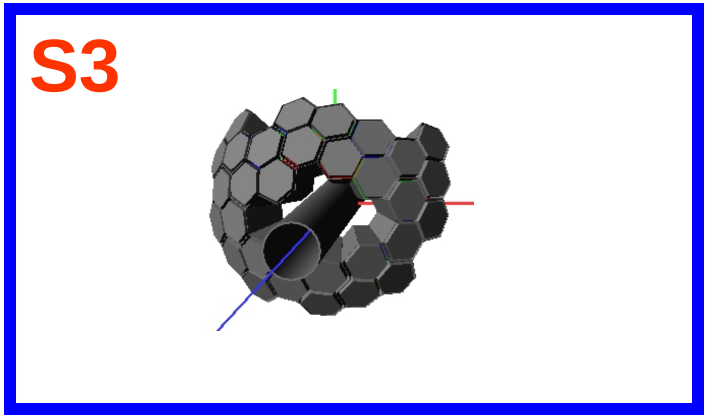
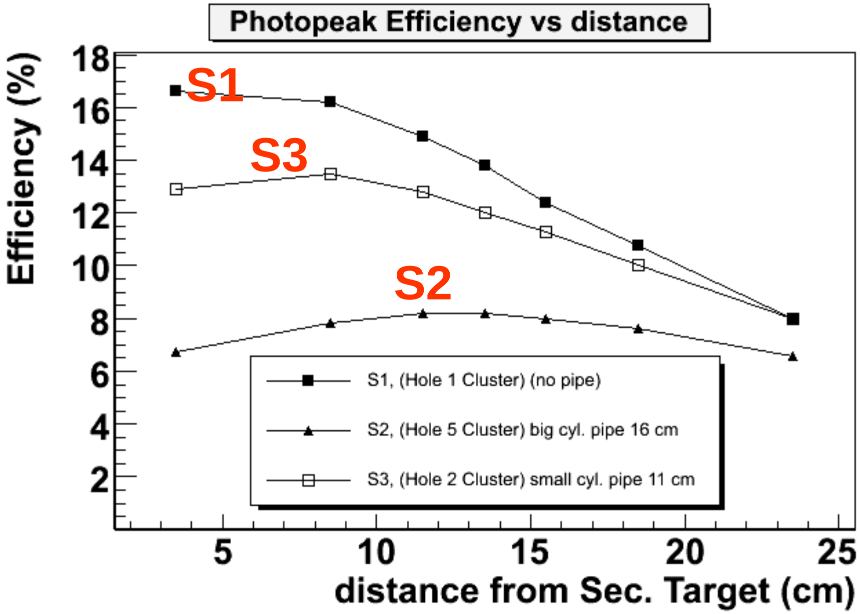
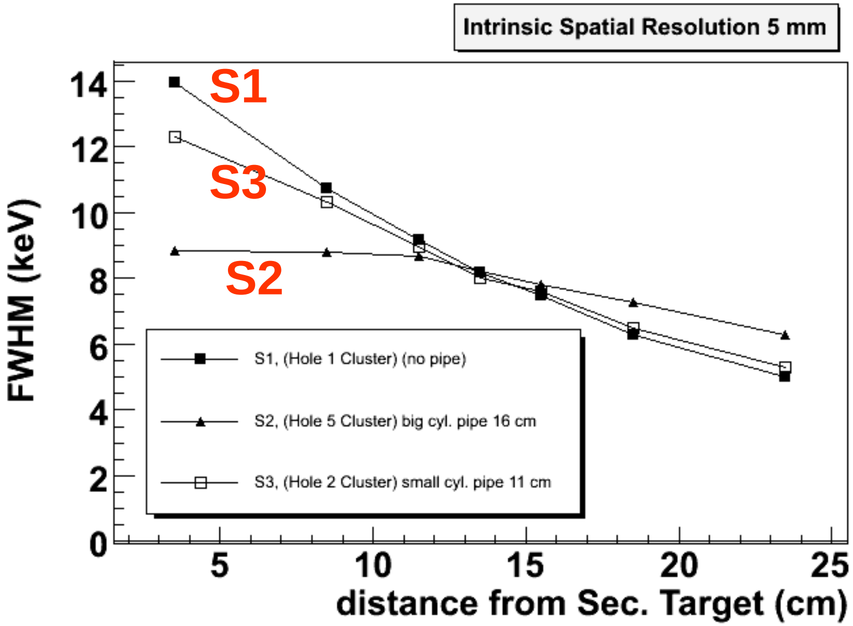




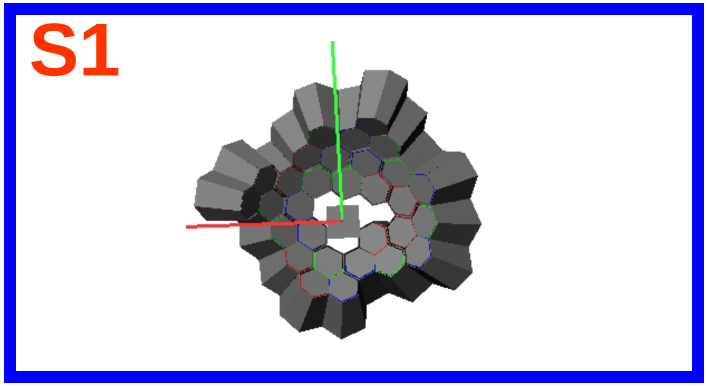


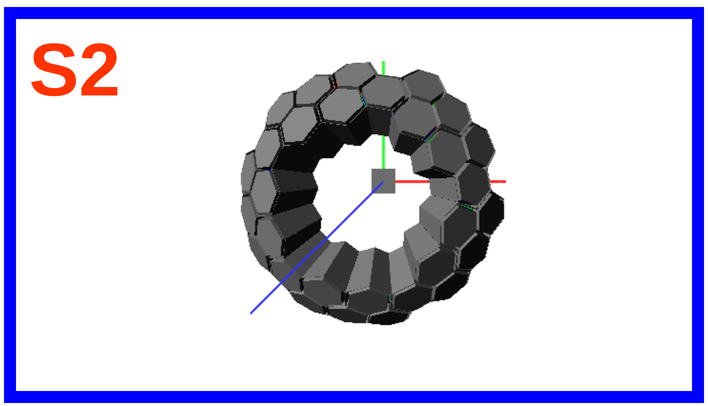


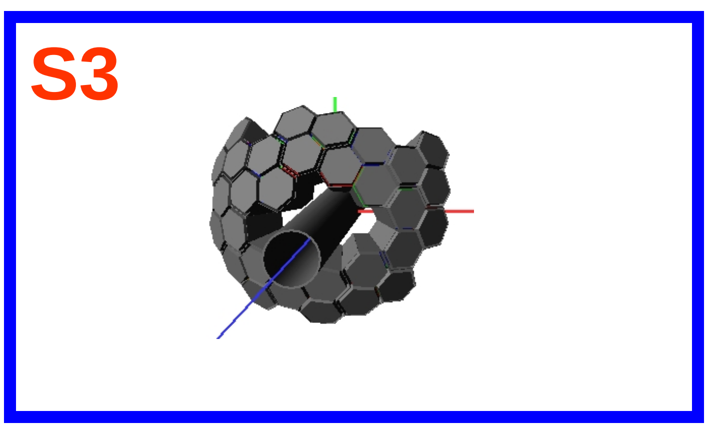


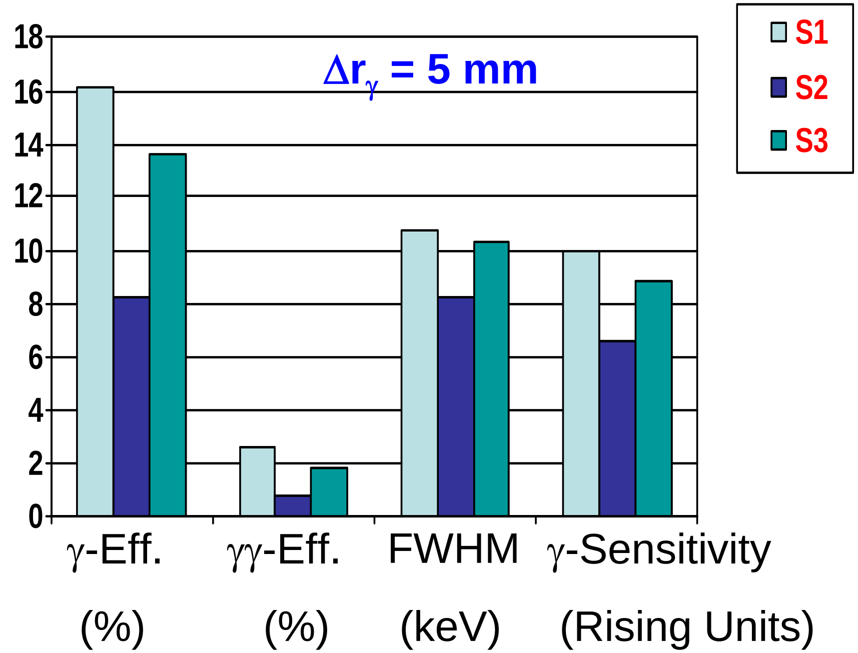
$\Delta r_{\gamma} = 5$ mm (fwhm)

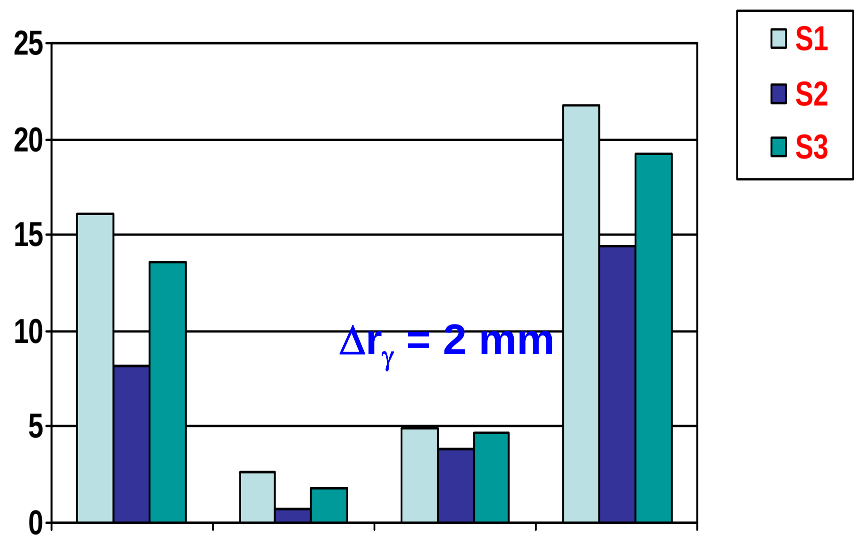
Shell Geometries performance comparison: Summary



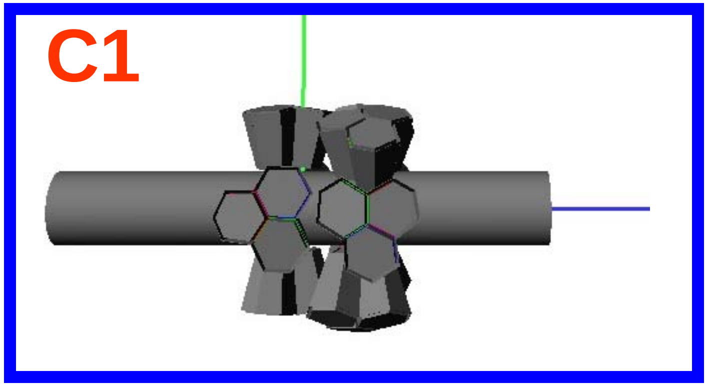


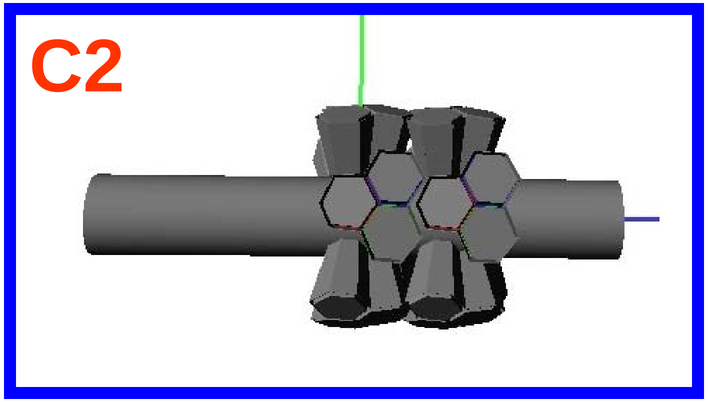


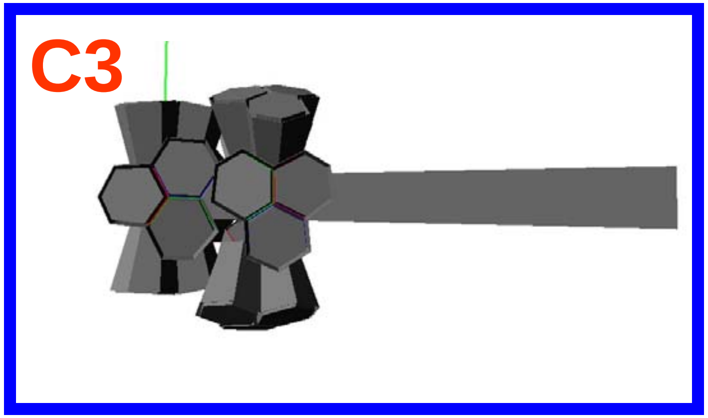


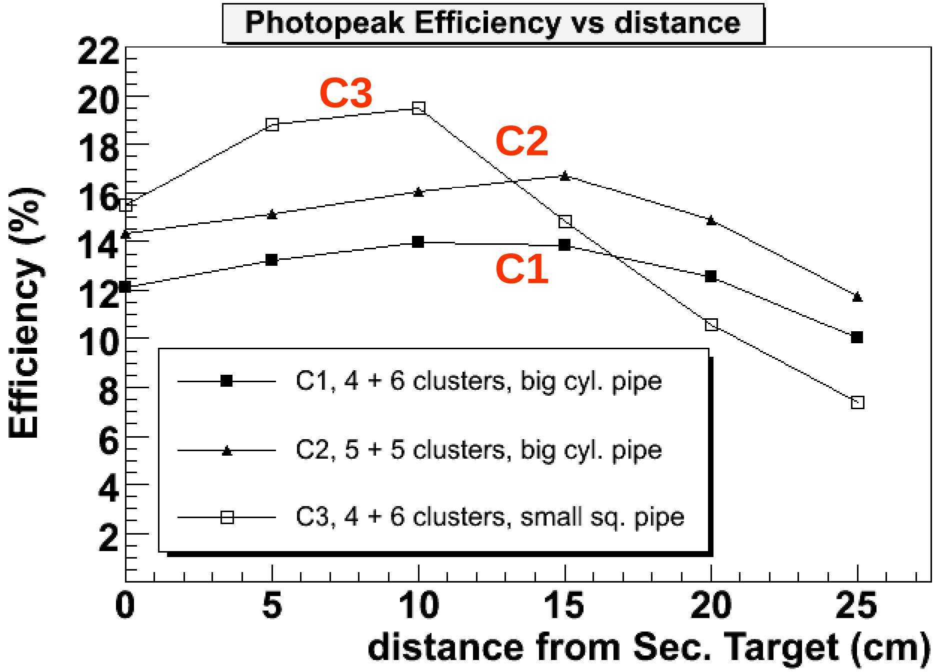


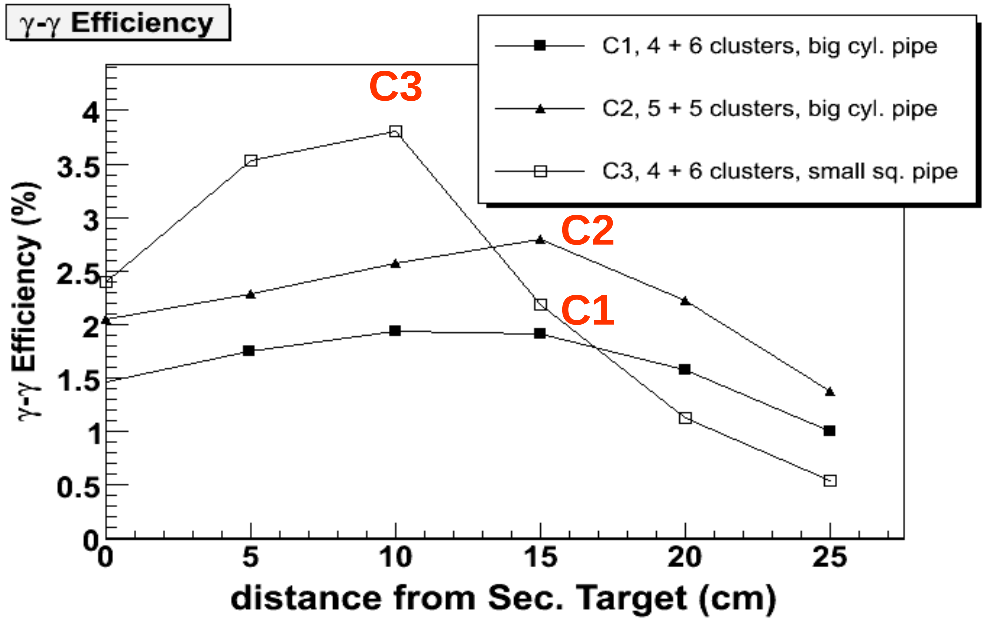
C-Geometries performance comparison: Efficiency



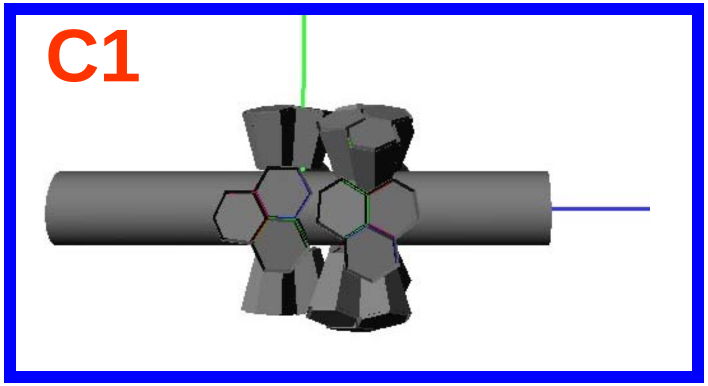


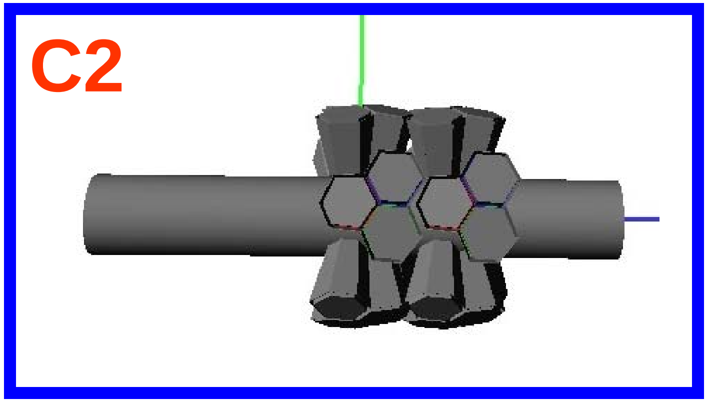


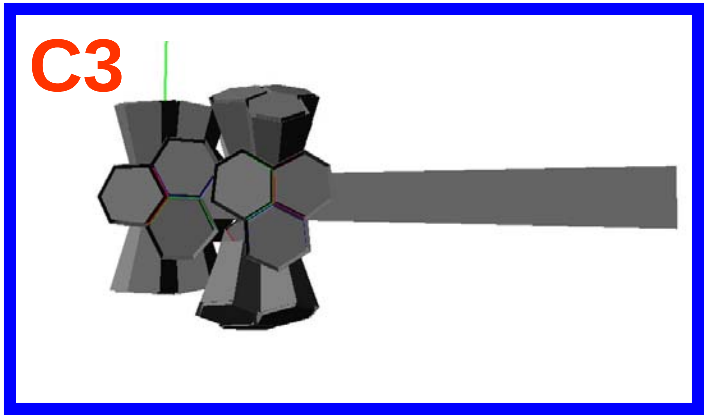


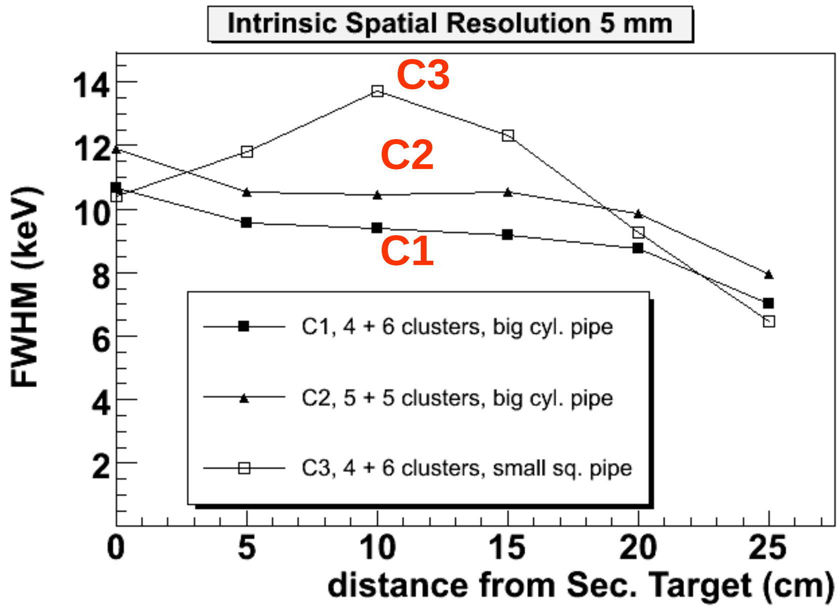


C-Geometries performance comparison: Resolution

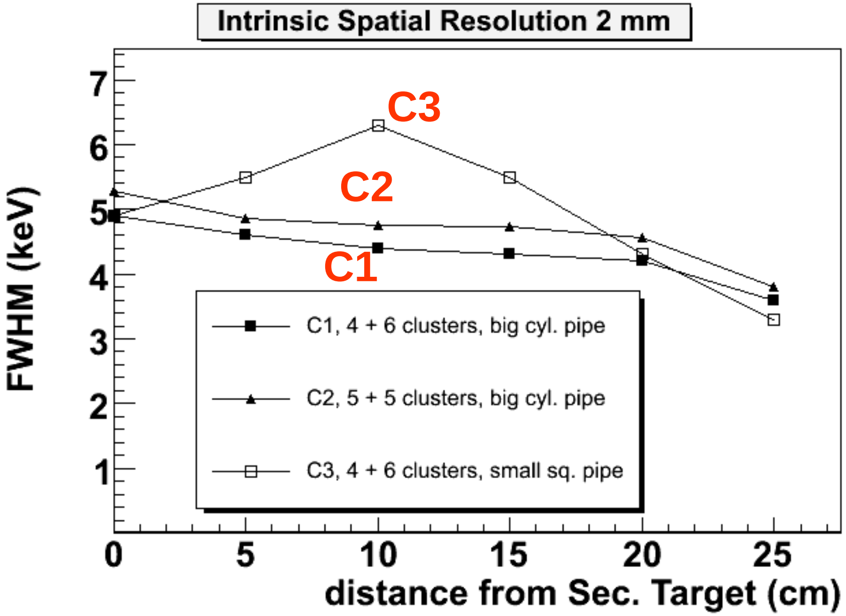






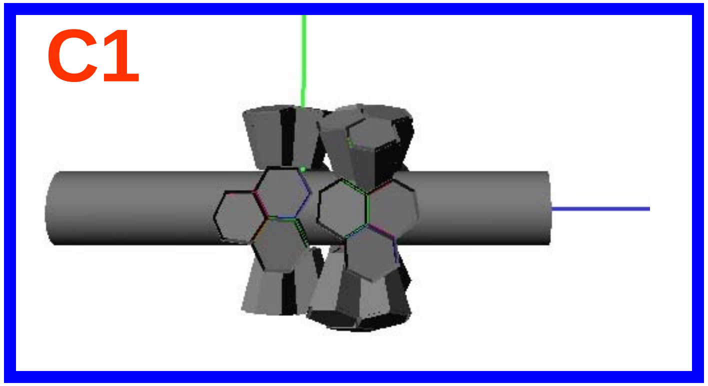


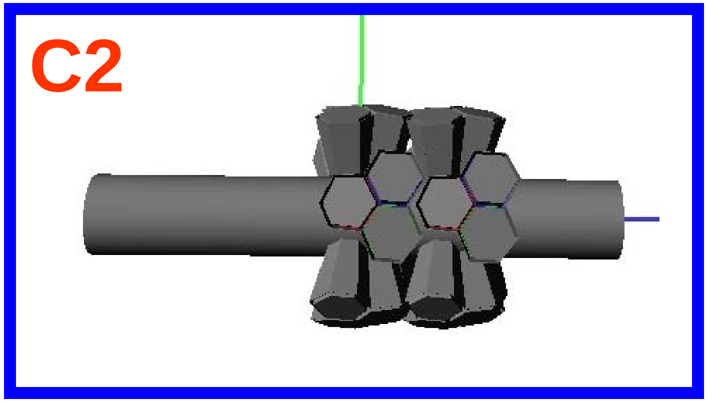
Δr_γ = 5 mm (fwhm)

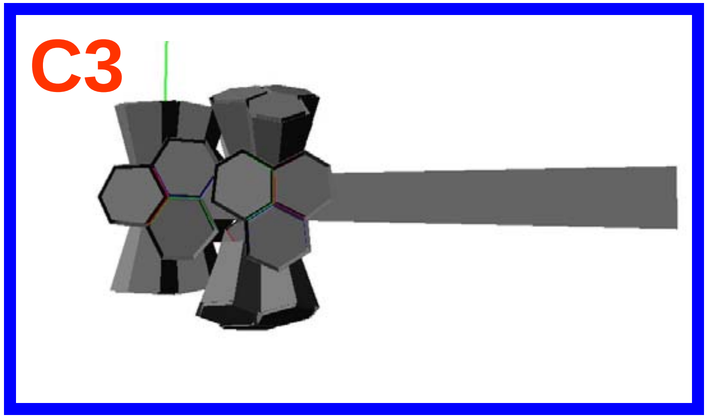


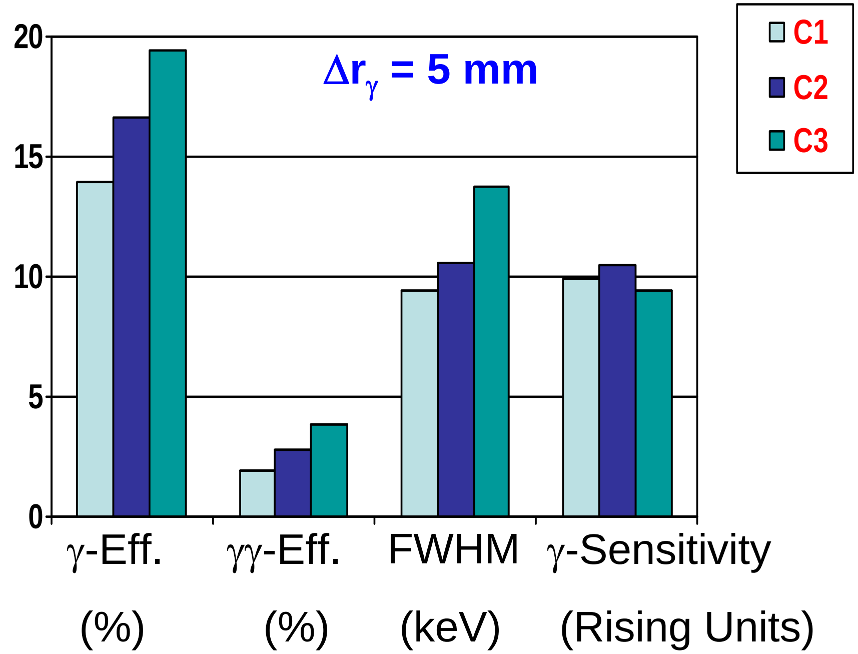
Δr_γ = 2 mm (fwhm)

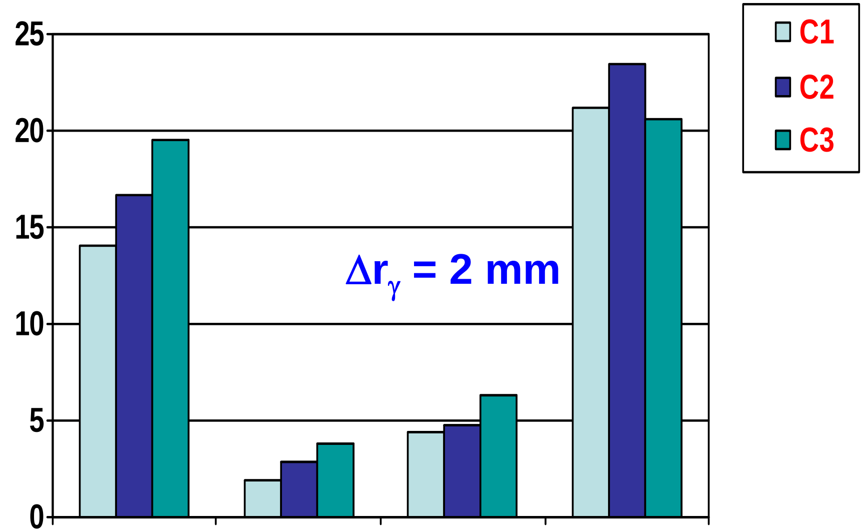
C-Geometries performance comparison: Summary





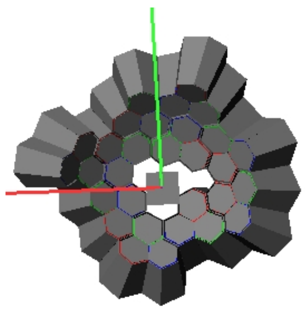




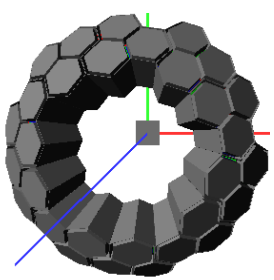


S- and C-Geometry Performance, Quantitative Comparison

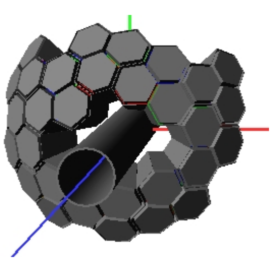
S1



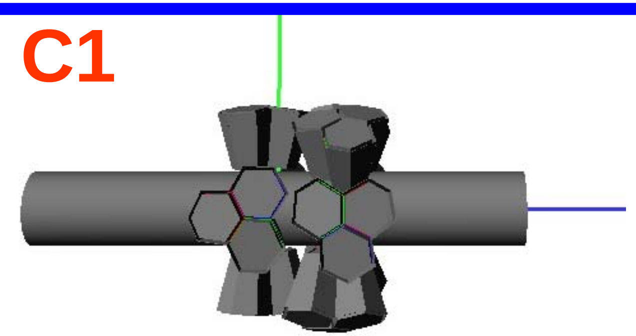
S2



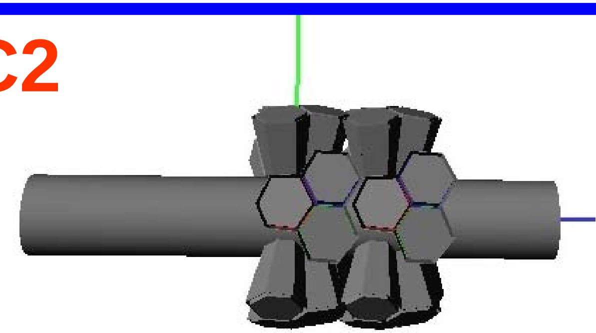
S3



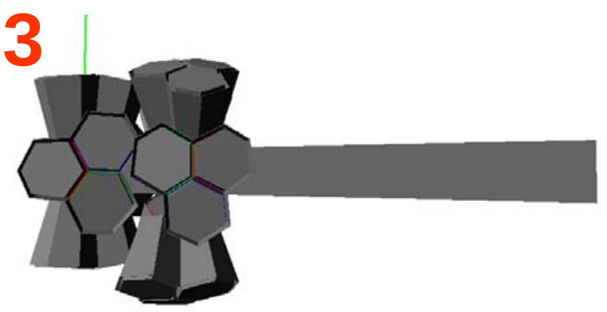
C1



C2



C3



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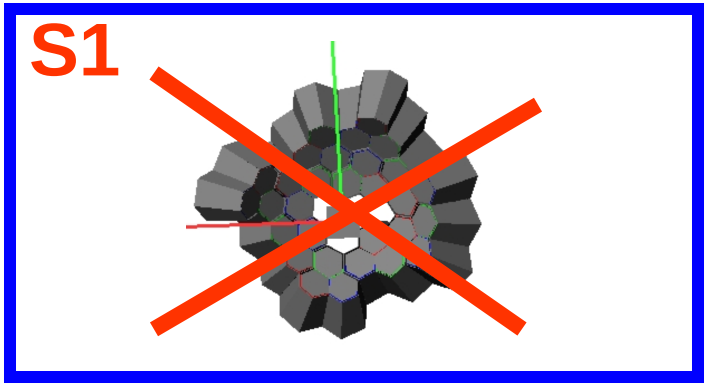
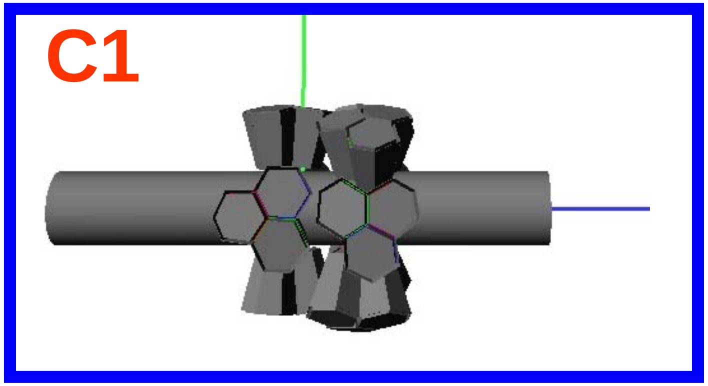
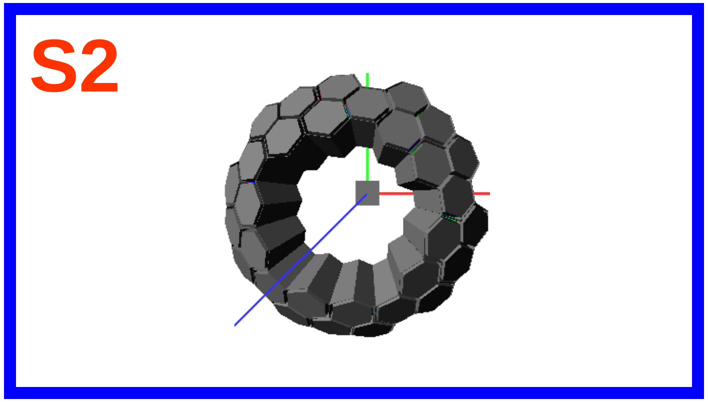
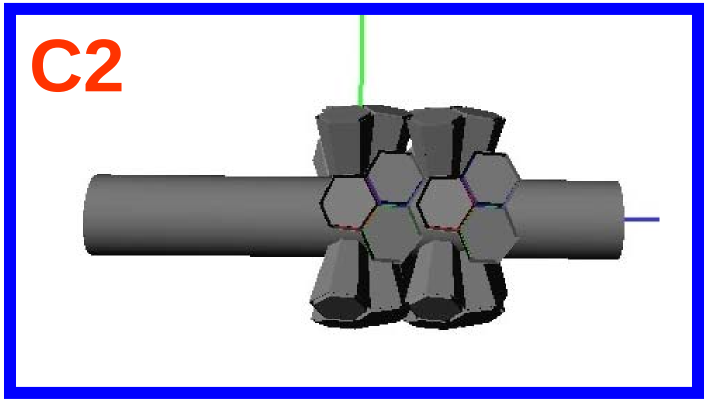
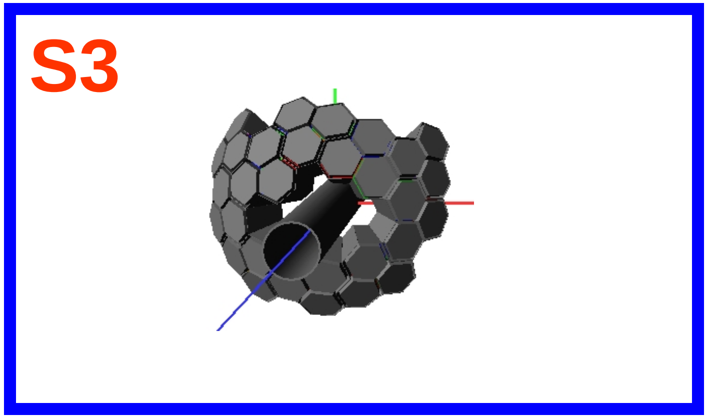


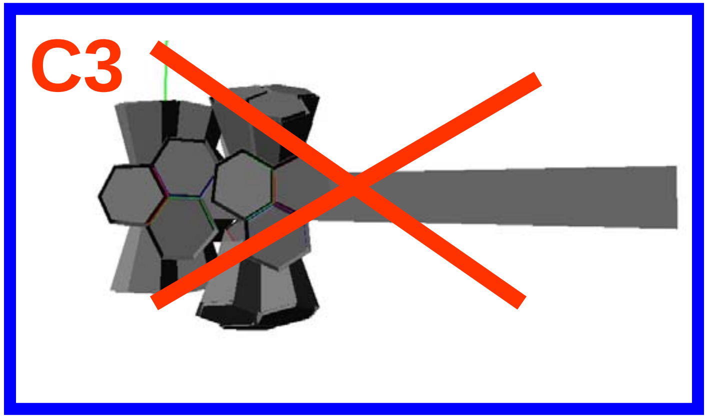
Technically difficult or impossible











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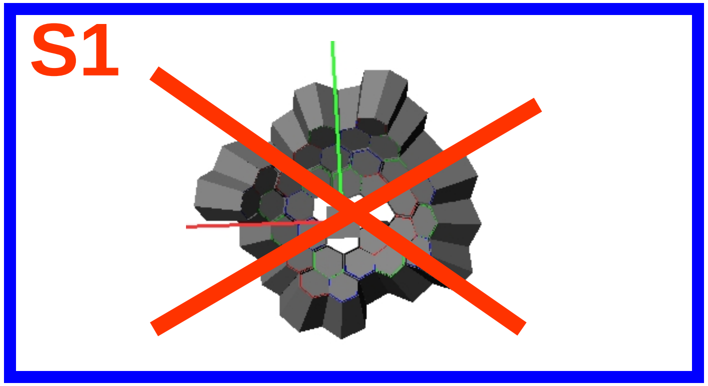

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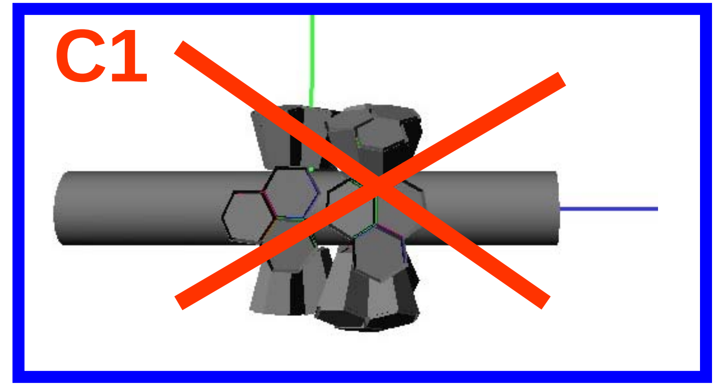
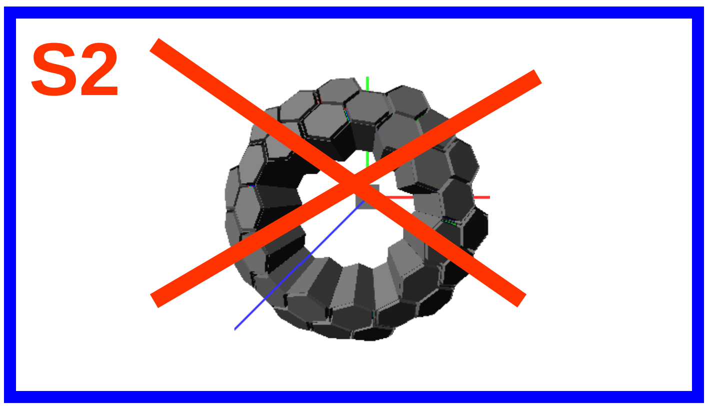
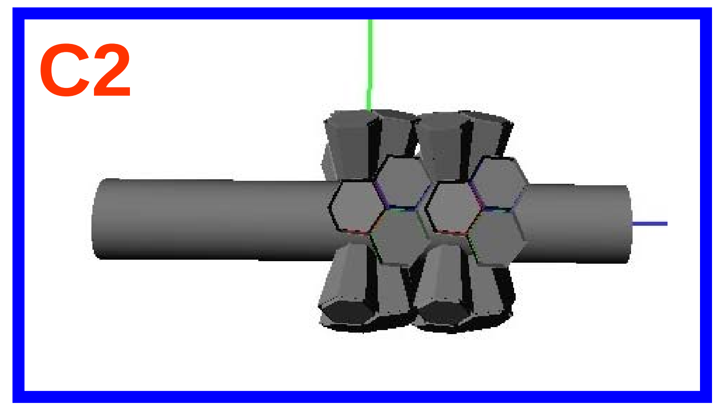
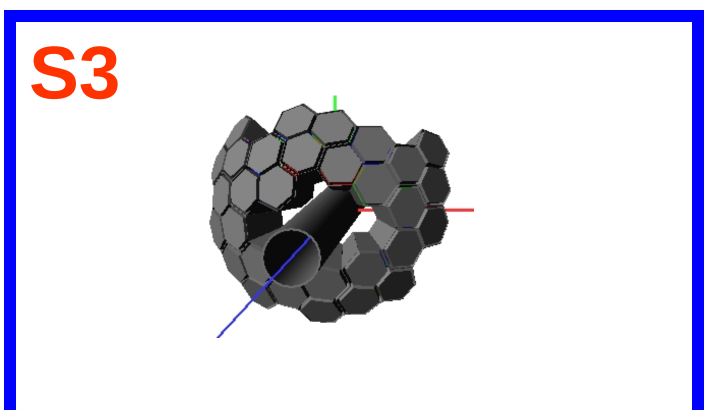
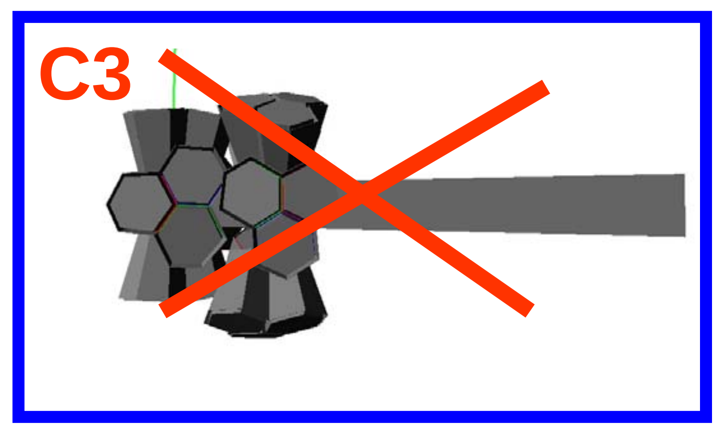




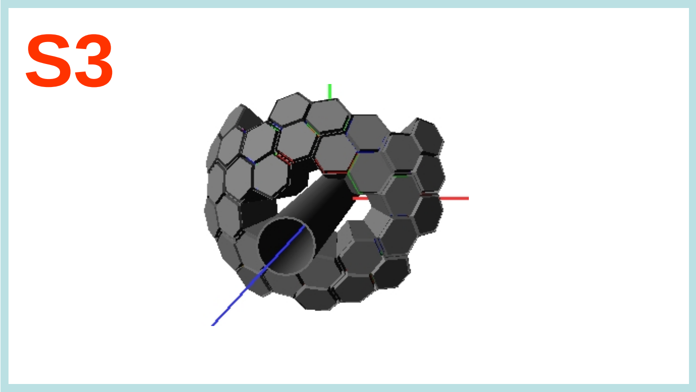
Worse performance than the other option S3 or C2

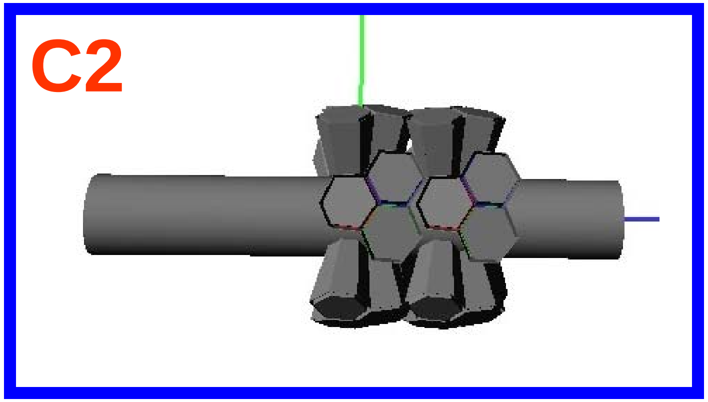


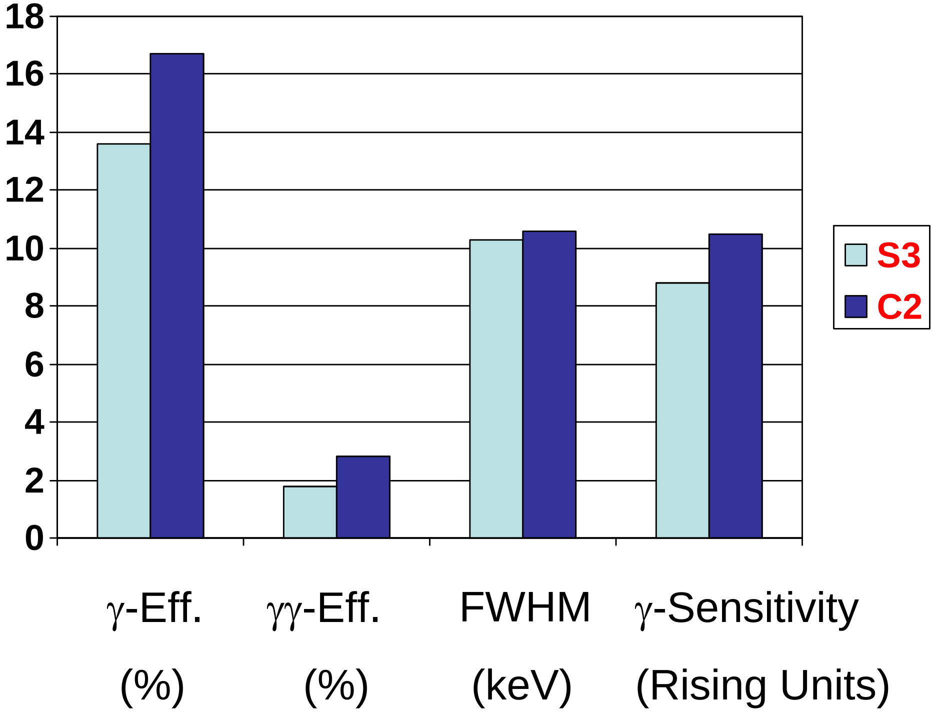




S- and C-Geometry Performance, Quantitative Comparison







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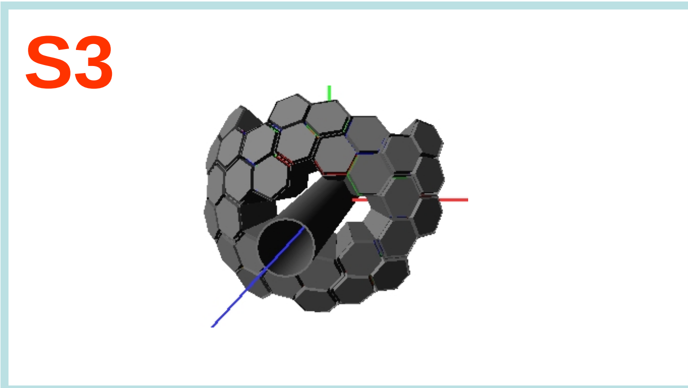

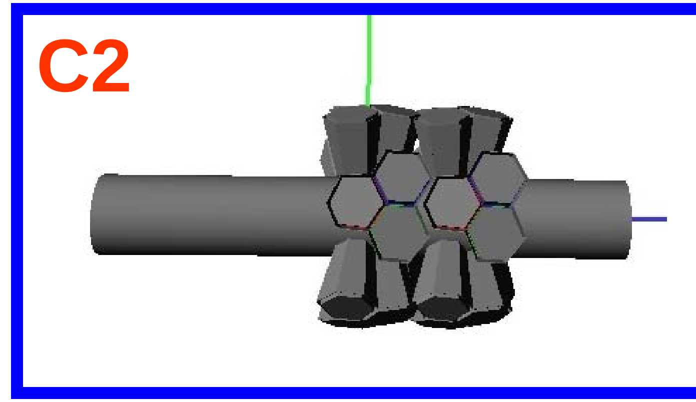

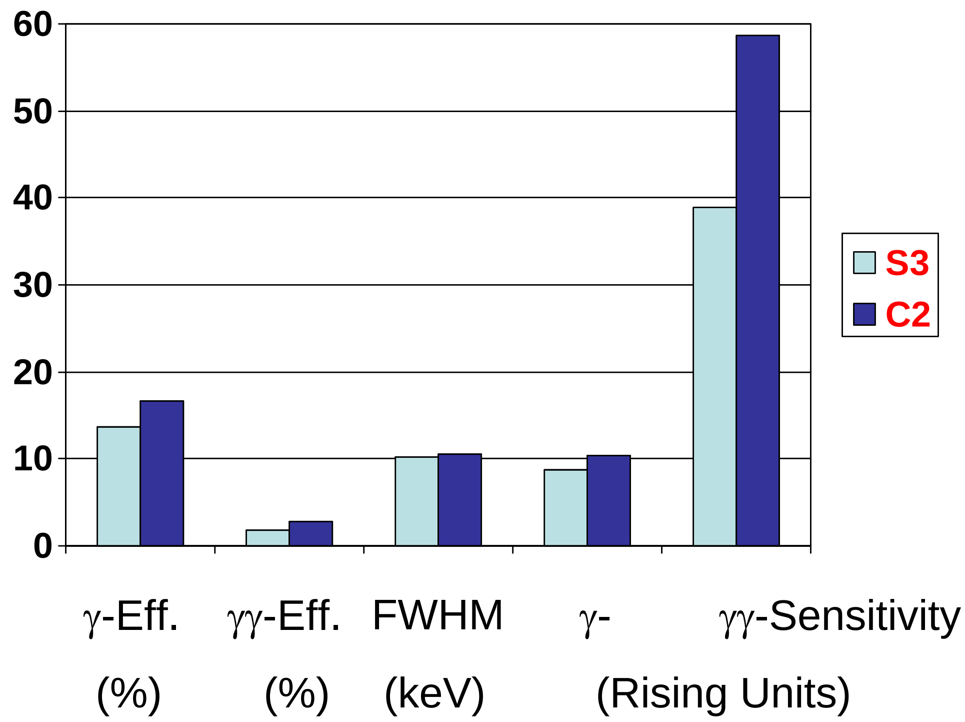

Conclusion (based on Triple Cluster Detectors!)

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 on 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 ^{104}Sn at 100 MeV/u on a 0.4 g/cm2 Au-target. Primary beam ^{124}Xe.
- Task 2: Fragmentation experiment. ^{54}Ni at 100 MeV/u + Be (0.7 g/cm2) -> ^{50}Fe (simulate first 4 excited states up to 8+ level).
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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)

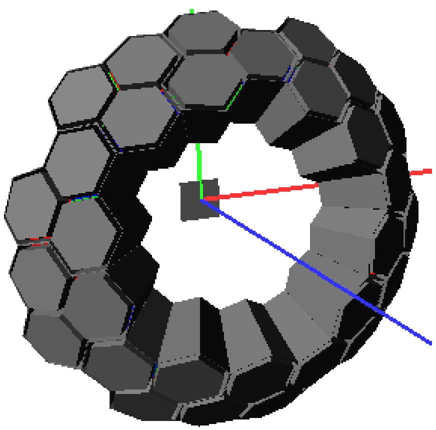
AGATA S2 + 5 Double Cluster Detectors = S2'

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

AGATA **S2'** Geometry

AGATA S2 Geometry



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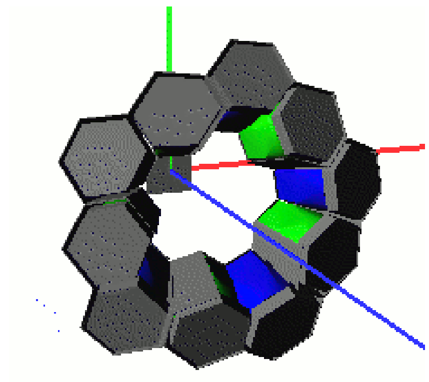

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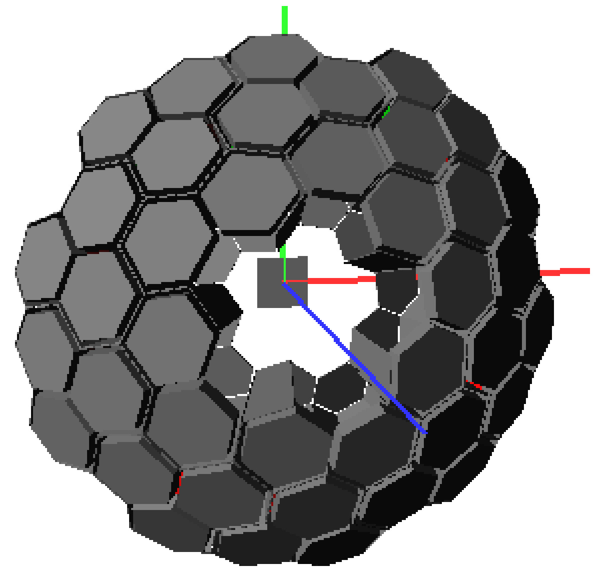

10 triple Cluster + **5** **double** Cluster

AGATA S2 + 5 Double Cluster Detectors = S2'

Geometry cases

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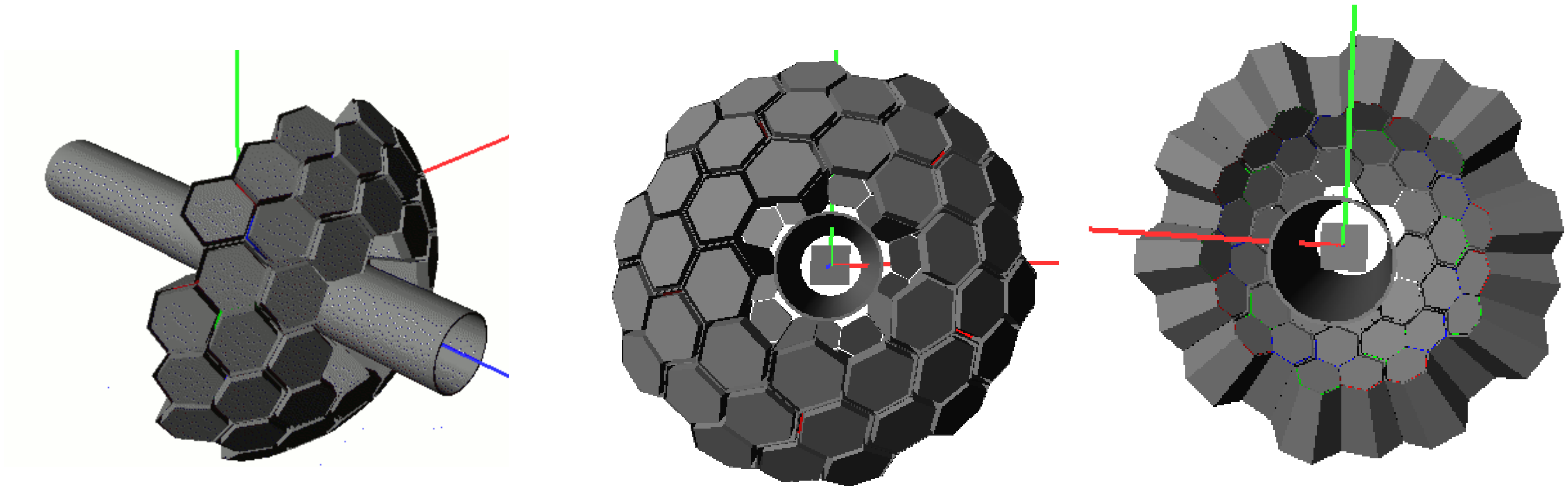


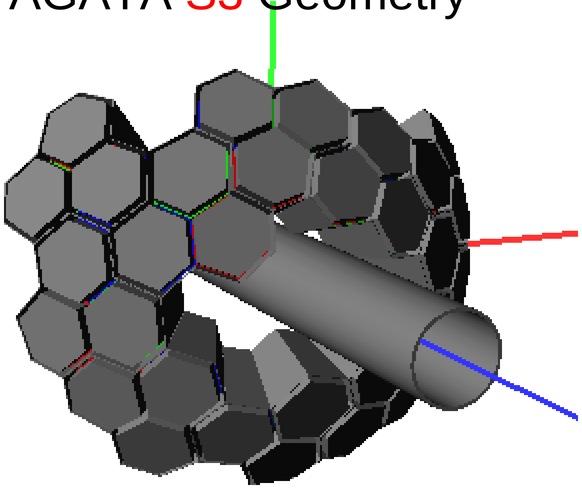
Beam pipe diameter = 9 - 12 cm

AGATA S3 + 1 Agata Double Cluster = S3'

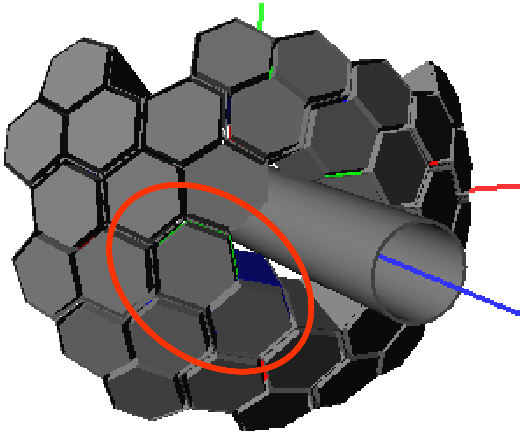
Geometry cases

- 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.

AGATA S3 Geometry



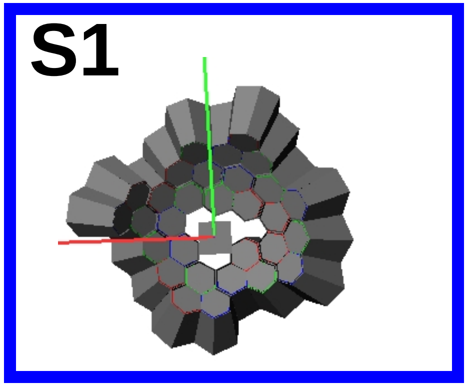
AGATA S3' Geometry

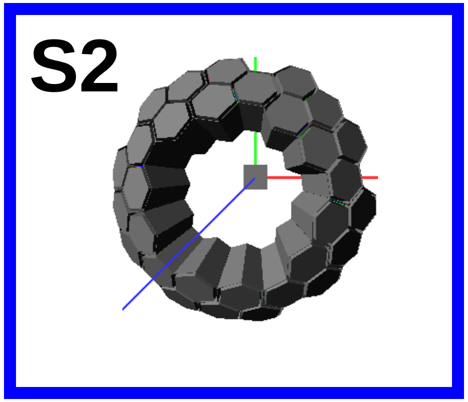


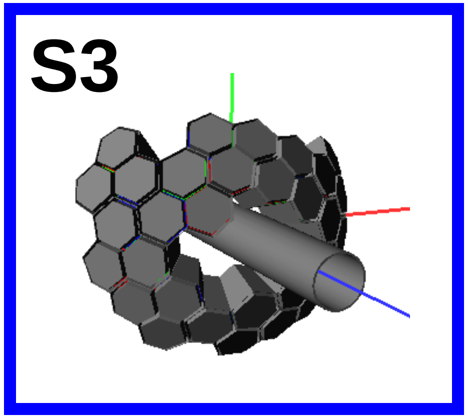
10 triple Cluster (Asym) + **1** **double** Cluster

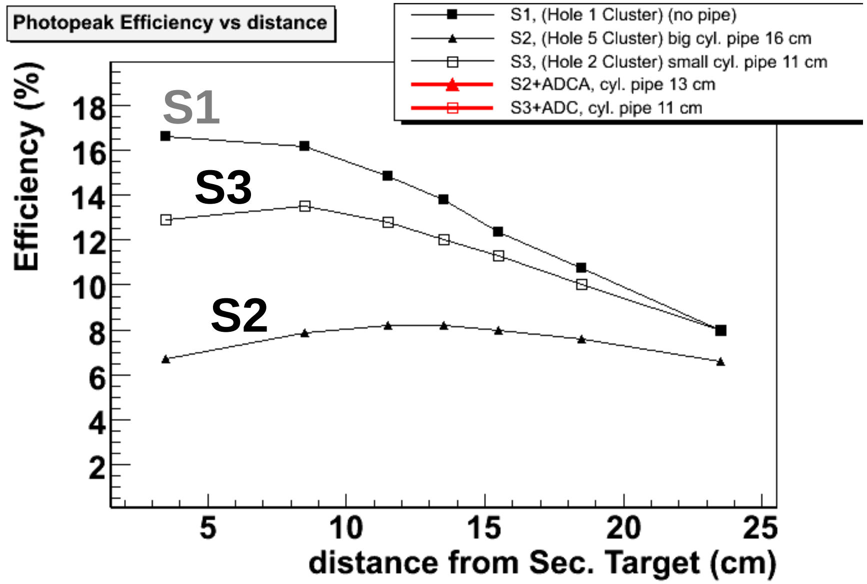
Beam pipe diameter = 10 cm

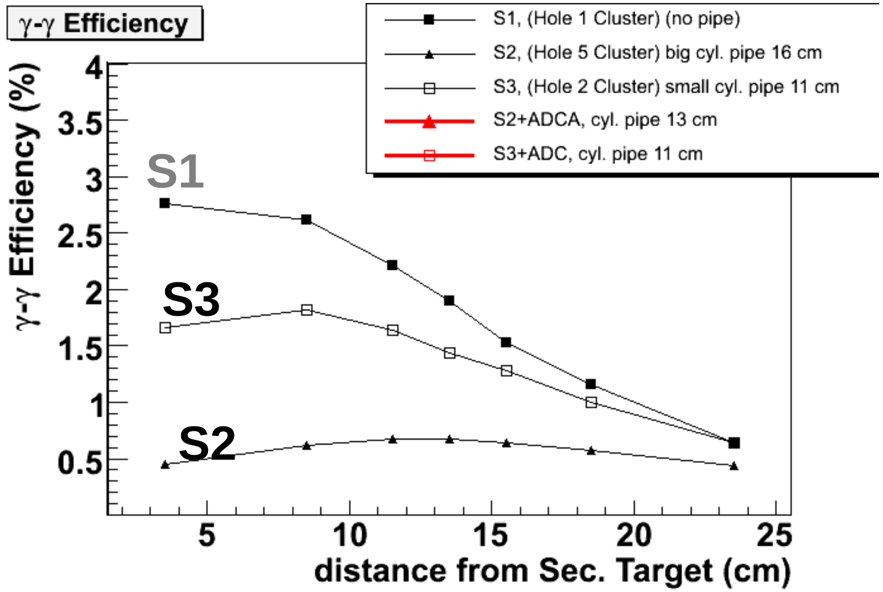
S-Geometries Performance comparison: Efficiency

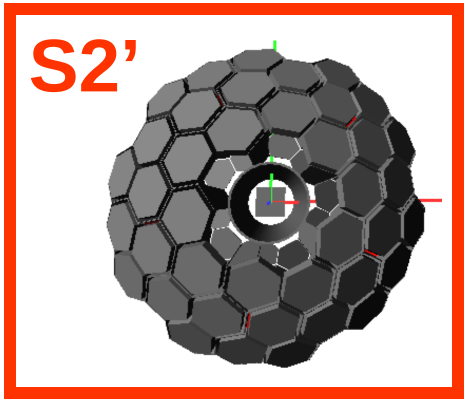


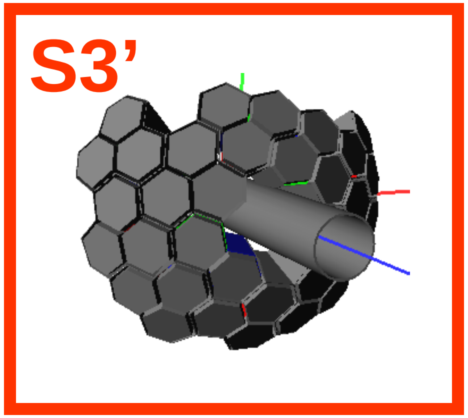






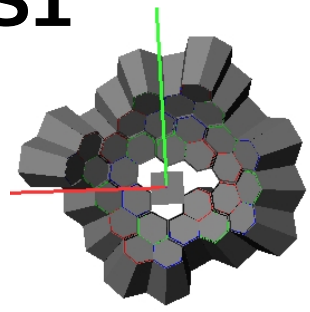




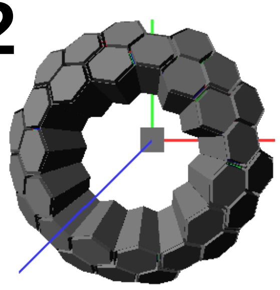


S-Geometries Performance comparison: Efficiency

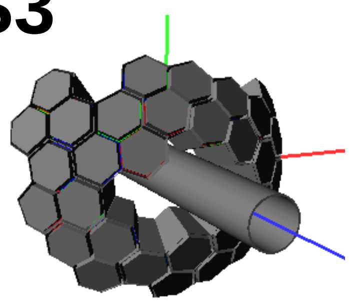
S1

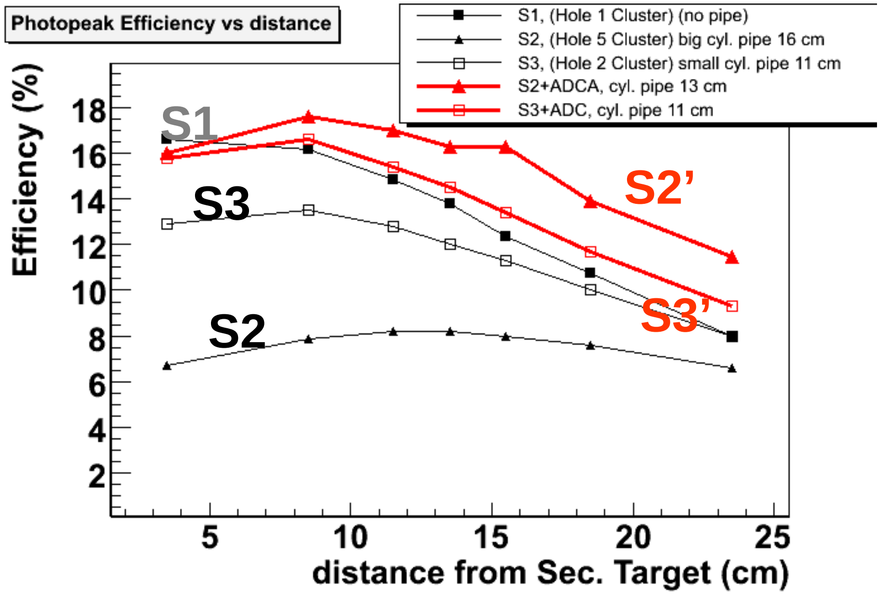


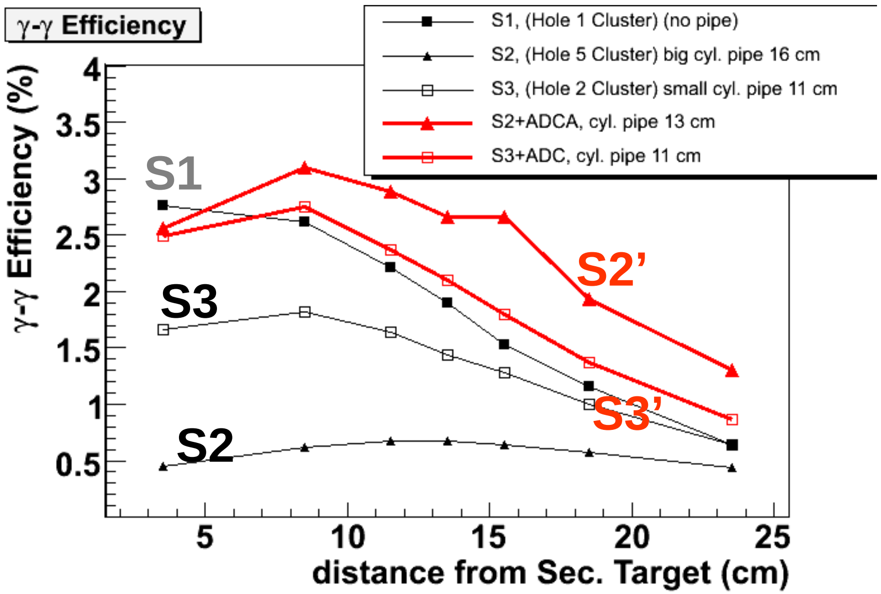
S2



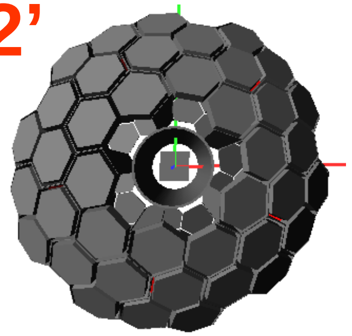
S3



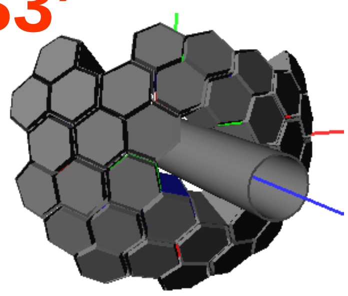




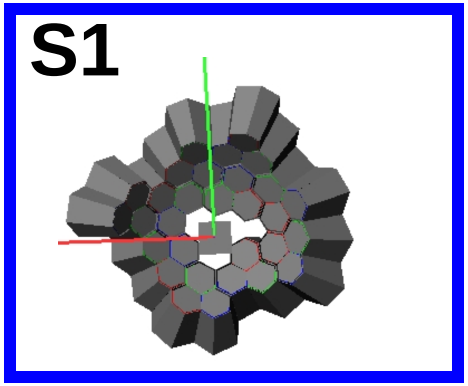
S2'

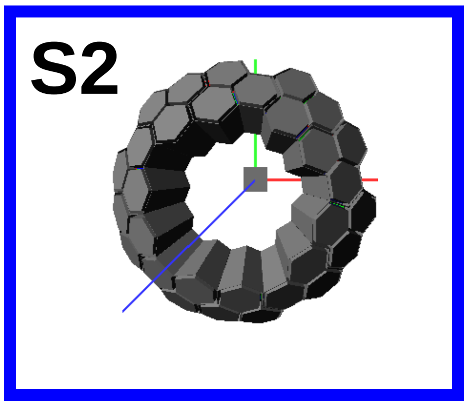


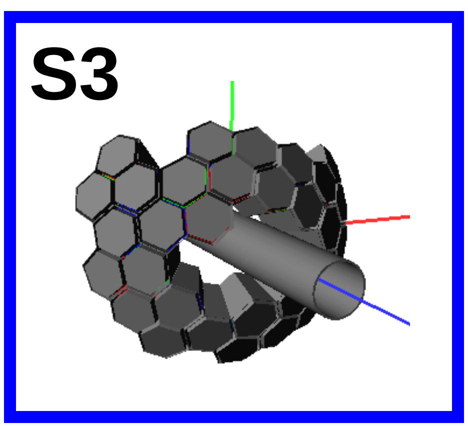
S3'

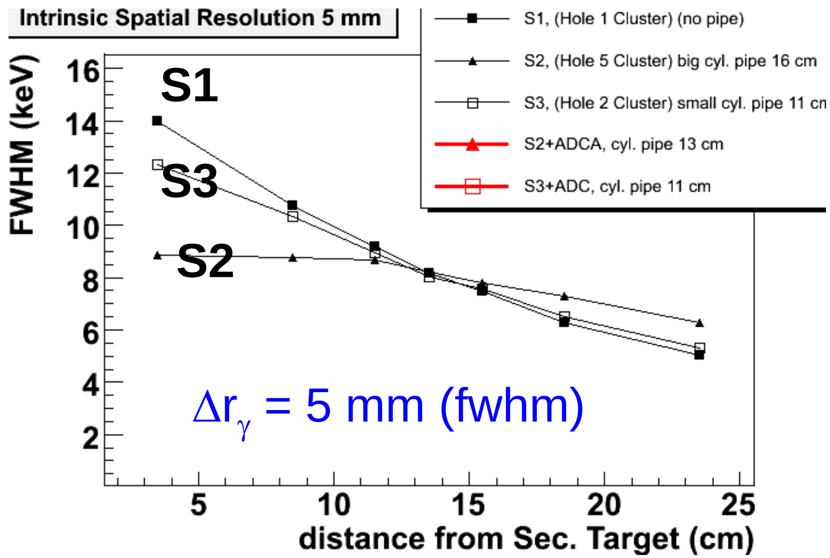


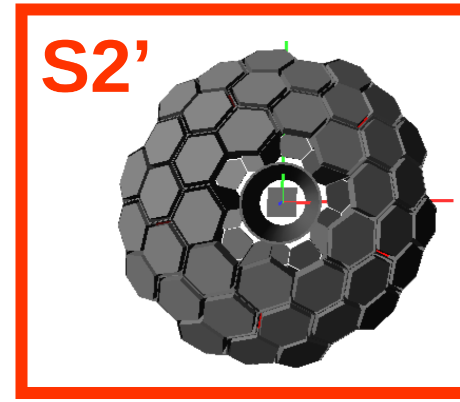
S-Geometries Performance comparison: Resolution

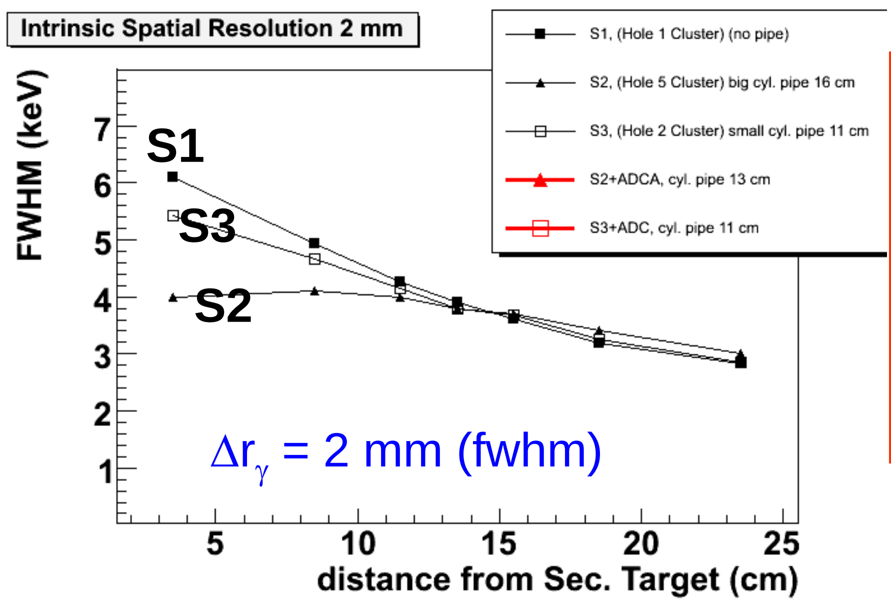


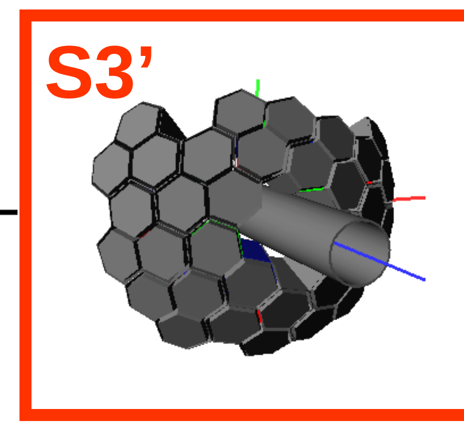




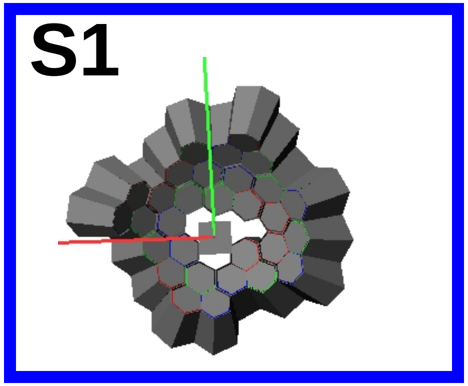


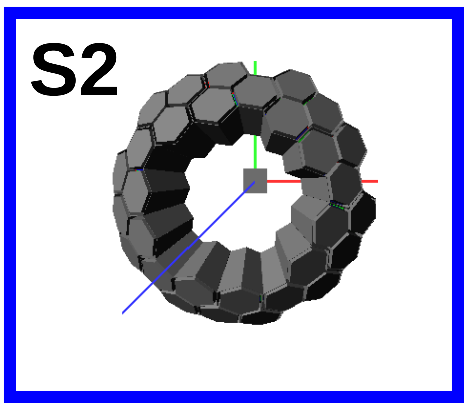


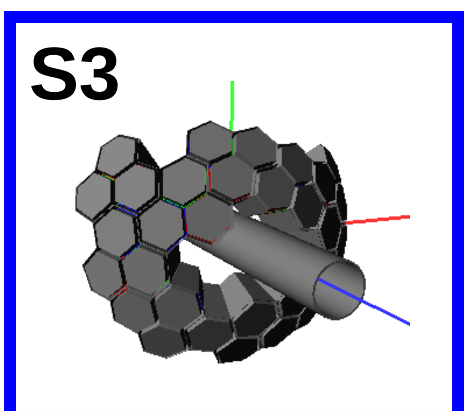


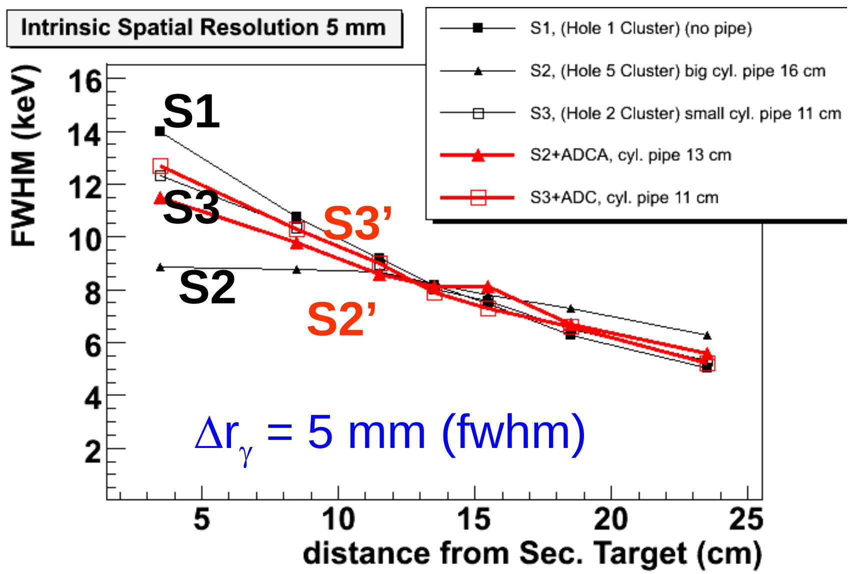


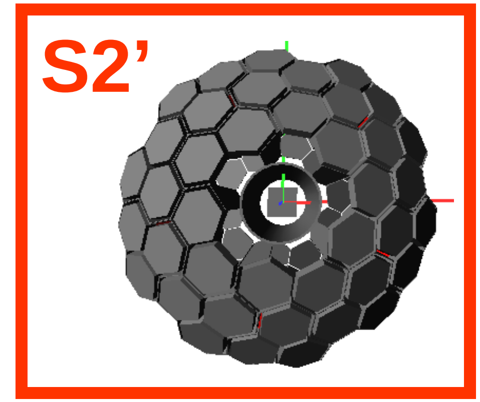
S-Geometries Performance comparison: Resolution

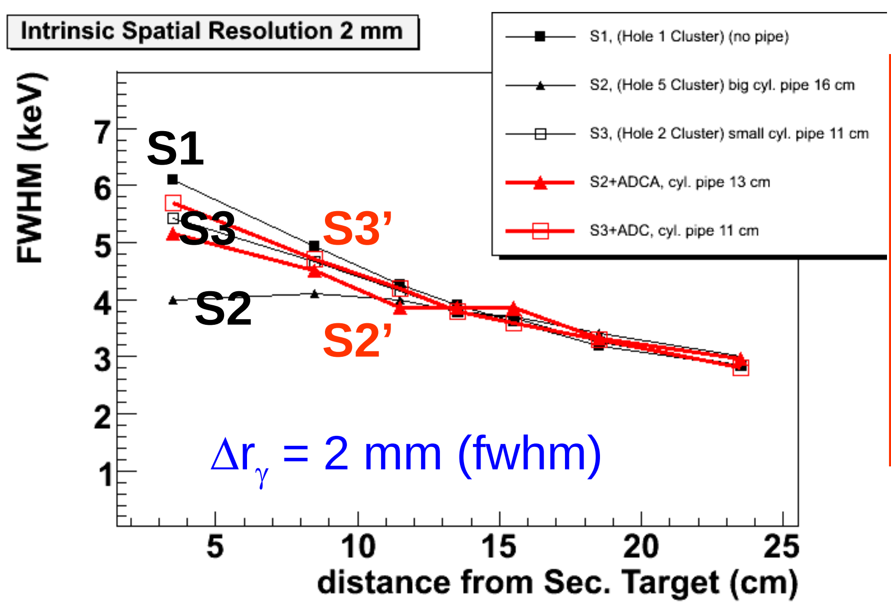


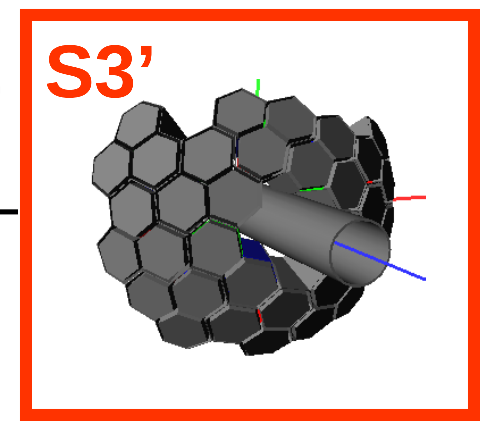






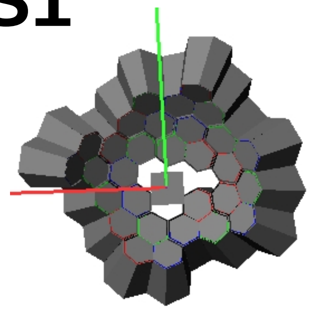




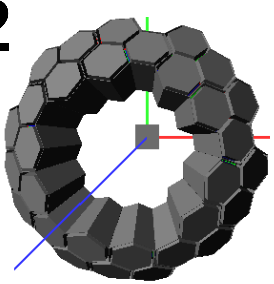


Shell Geometries performance comparison: Summary

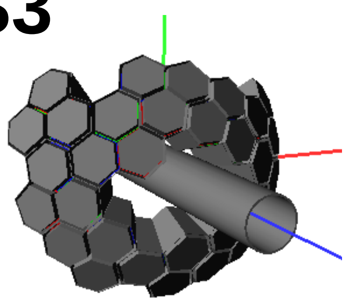
S1

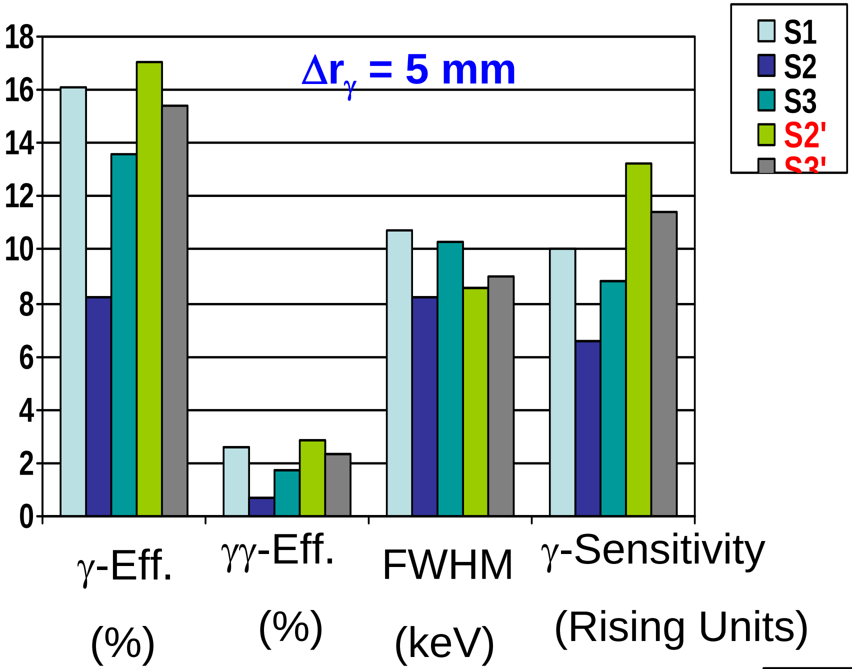


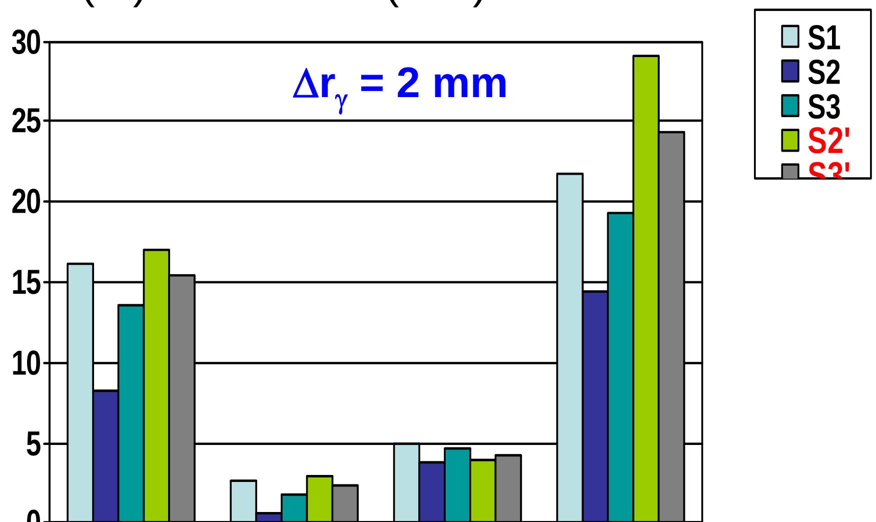
S2



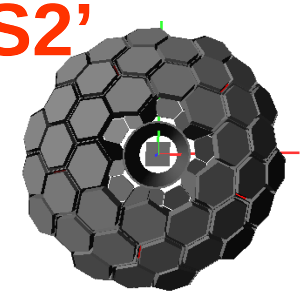
S3



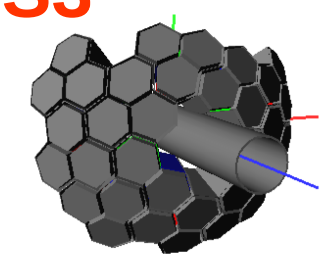




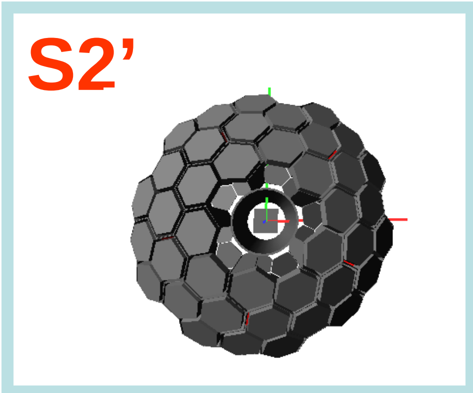
S2’

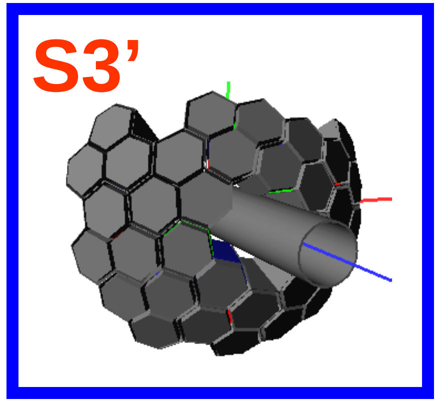


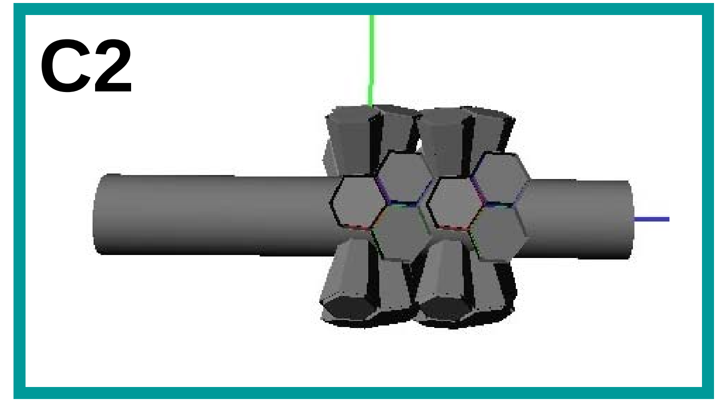
S3’

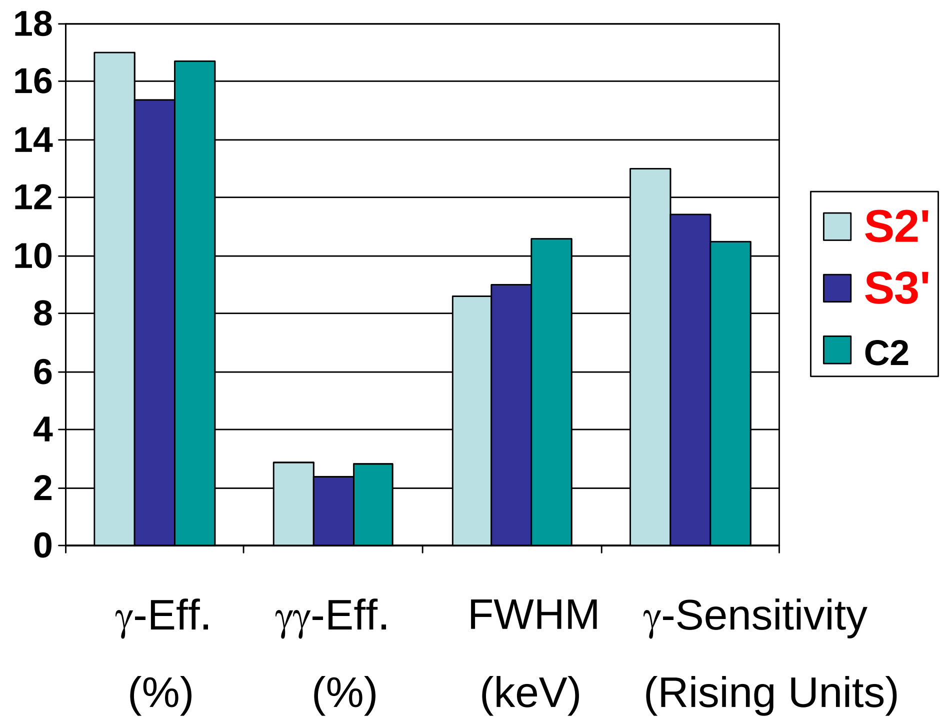


S'- and C-Geometry Performance, Quantitative Comparison









Geometry cases

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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: Coulex, Fragmentation and Plunger
- Additional ingredients for a realistic simulation: background and tracking
- Outlook and conclusion

AGATA S2 + 5 Double Cluster Detectors

Geometry cases

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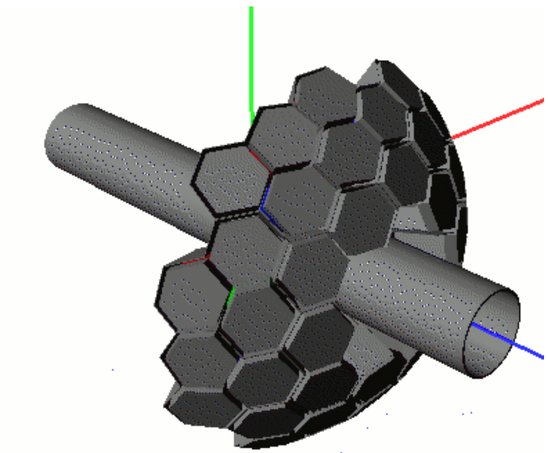
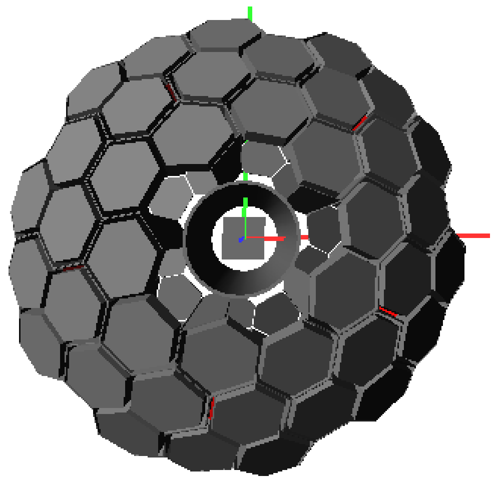
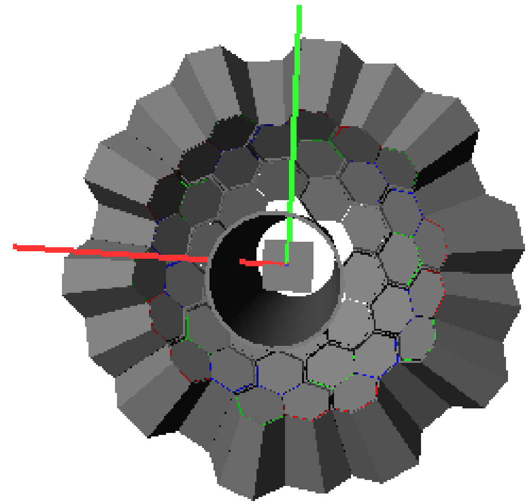
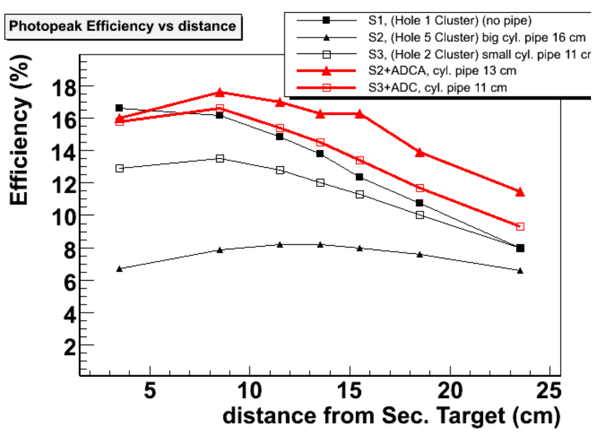
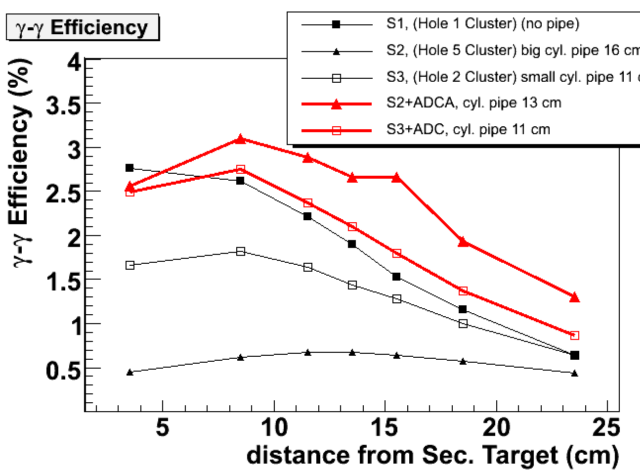


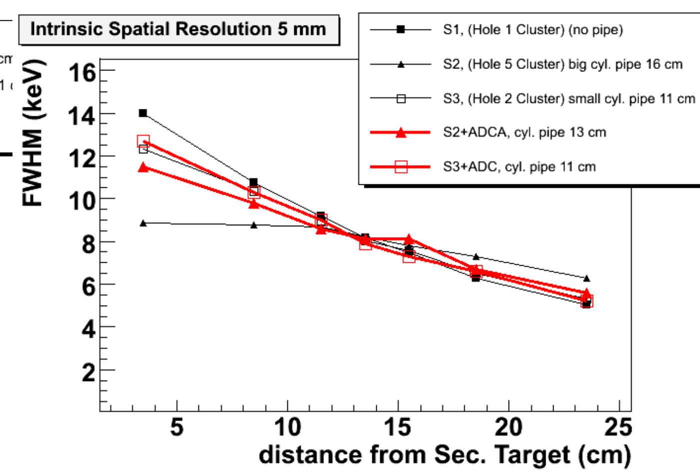




Beam pipe diameter = 9-12 cm







Workshop on AGATA at GSI: reference physics cases

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- Task 1: Coulex experiment. Example: Coulex of ^{104}Sn at 100 MeV/u on a 0.4 g/cm^2 Au-target. Primary beam ^{124}Xe.
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- Task 2: Realistic tracking for event reconstruction (mgt, etc)

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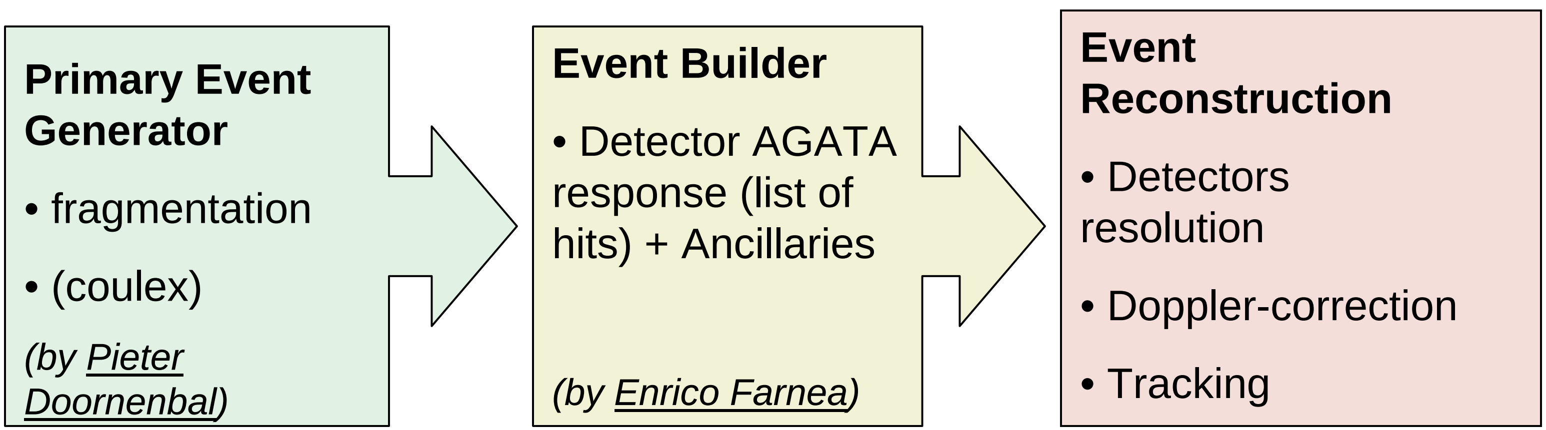
Realistic MC Simulation of a **fragmentation** experiment



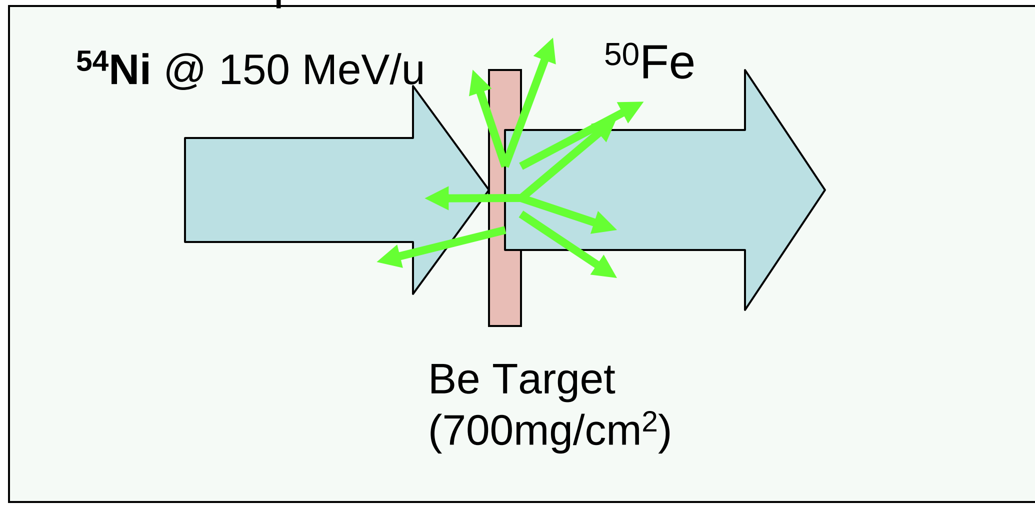
Fragmentation Experiment Benchmark: ^{54}Ni -> ^{50}Fe*

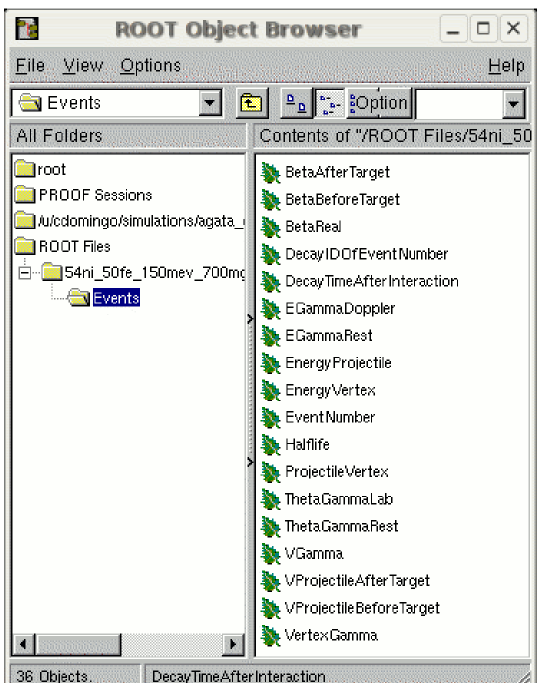
Realistic MC Simulation of a **fragmentation** experiment

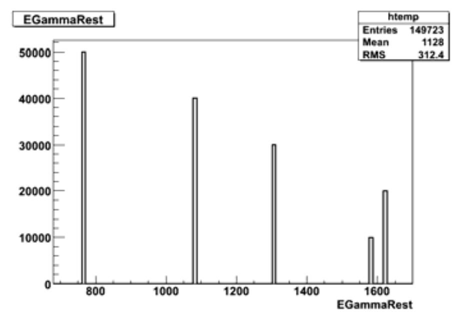
Primary Event Generator

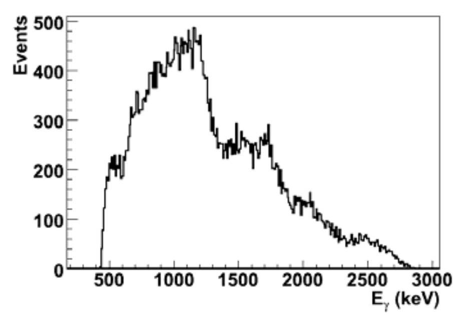
- fragmentation
- g-ray decay

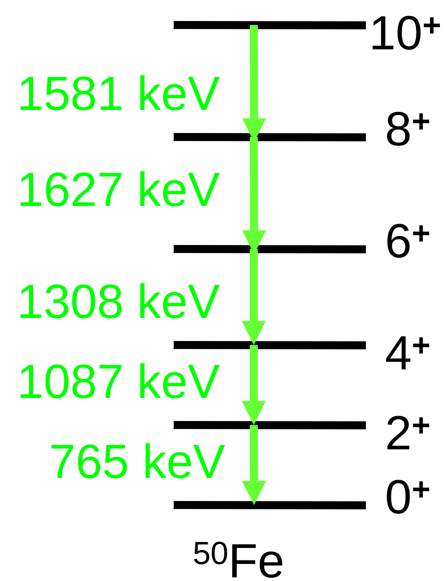
(by Pieter Doornenbal)











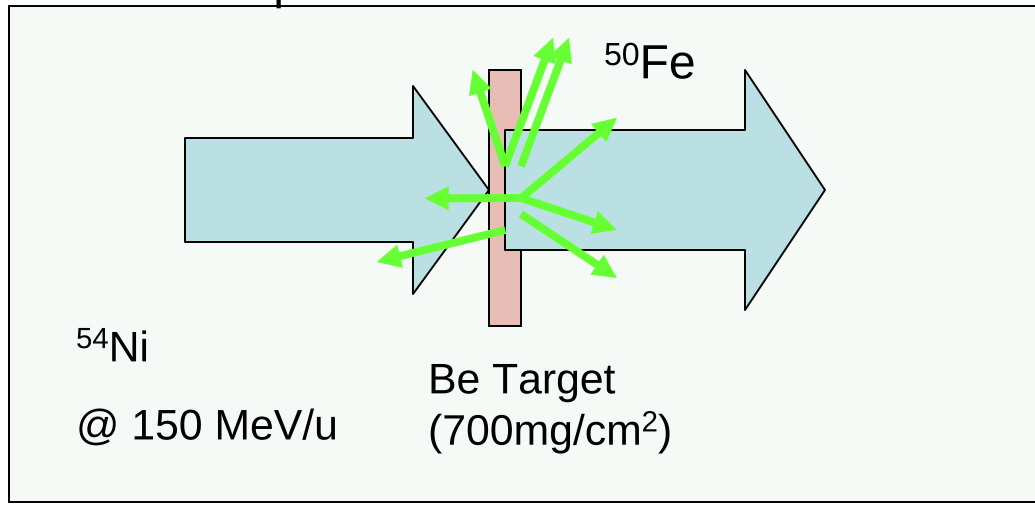
Fragmentation Experiment Benchmark: ^{54}Ni -> ^{50}Fe*

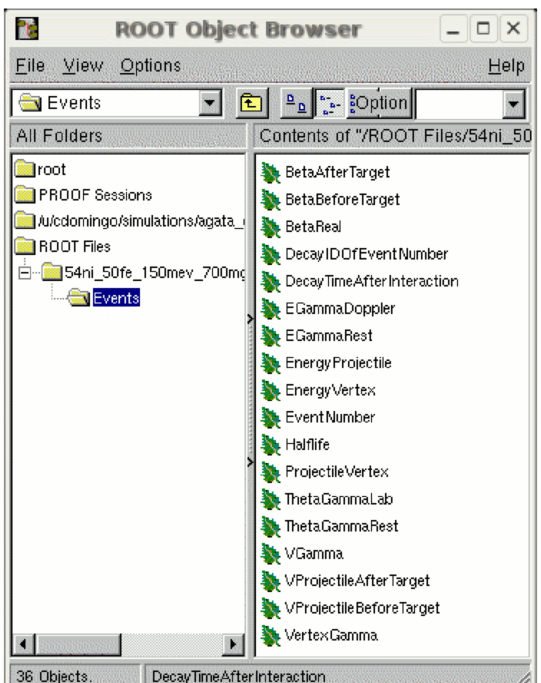
Realistic MC Simulation of a **fragmentation** experiment

Primary Event Generator

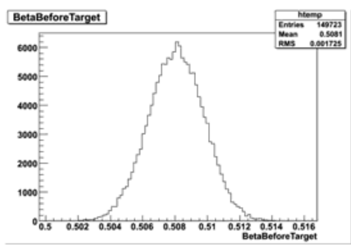
- fragmentation
- g-ray decay

(by Pieter Doornenbal)

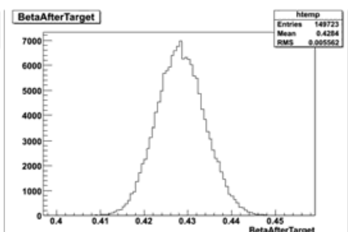


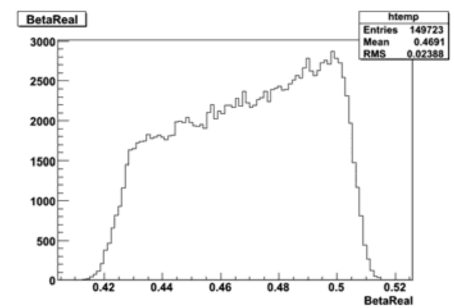


β before

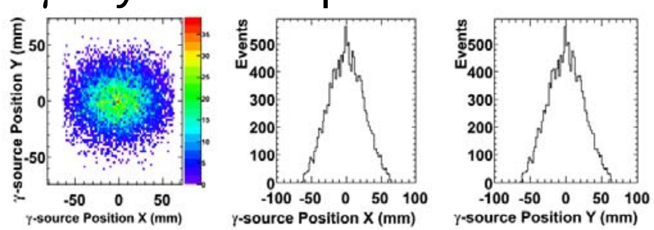


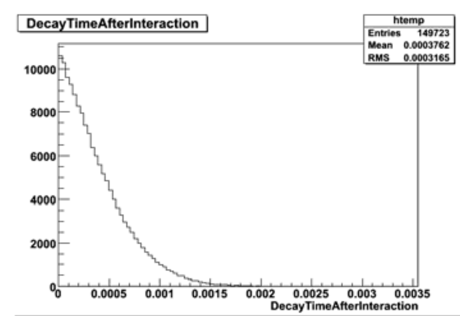
β after





γ-ray vertex spatial distribution





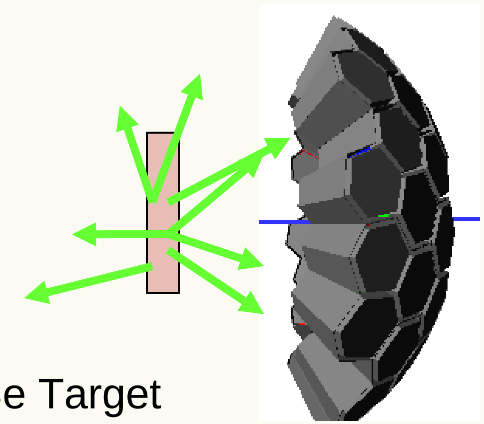
Fragmentation Experiment Benchmark: $^{54}Ni \rightarrow {}^{50}Fe^*$

Realistic MC Simulation of a **fragmentation** experiment

Event Builder

- Detector (AGATA) response (list of hits)

(by Enrico Farnea)



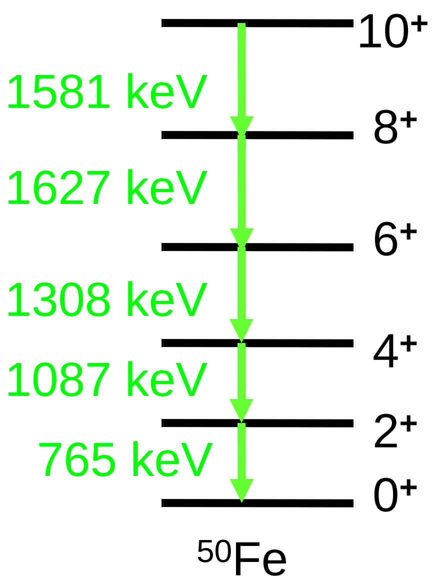

```
GAMMA 1
1000.0000
RECOIL  0.5000  0.0000  0.0000  0.0000  1.0000  0.0000
SOURCE       0       0   0.0000    0.0000    0.0000
$
  -1   1401.723 -0.43045  0.48009  0.76434 0
  29    73.617 -142.729  141.623  234.825 52     1.053
  29    39.475 -143.302  150.765  245.890 52     1.129
  29   148.895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

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

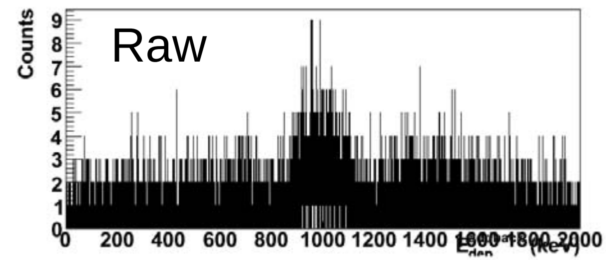
Realistic MC Simulation of a **fragmentation** experiment

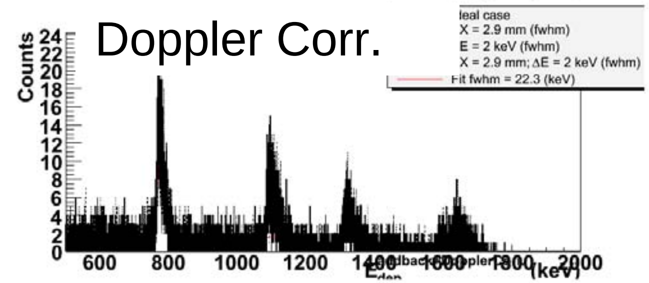
Event Reconstruction

- Detectors resolution
- Doppler-correction
- Tracking

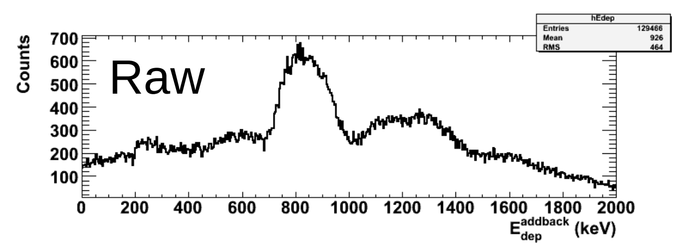


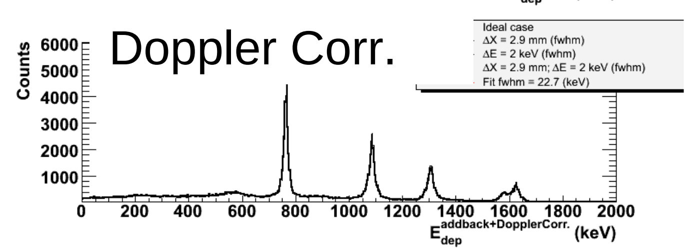
Low Statistics





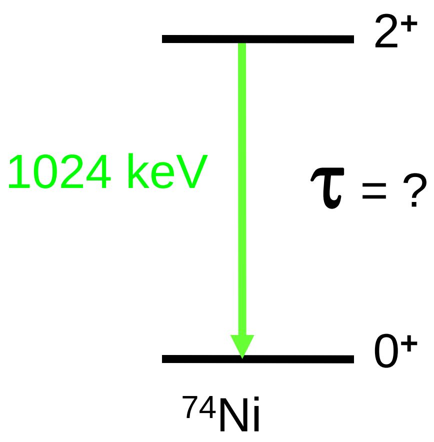
High Statistics

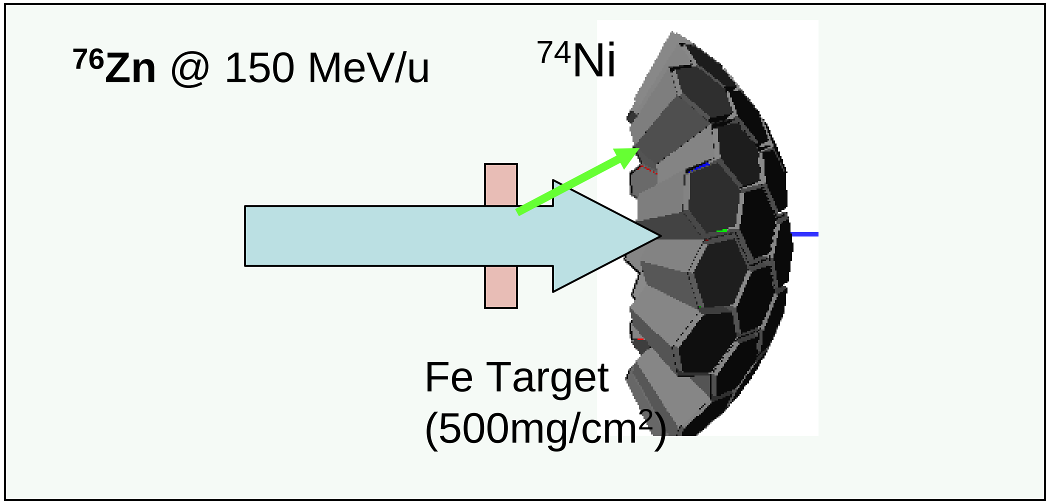




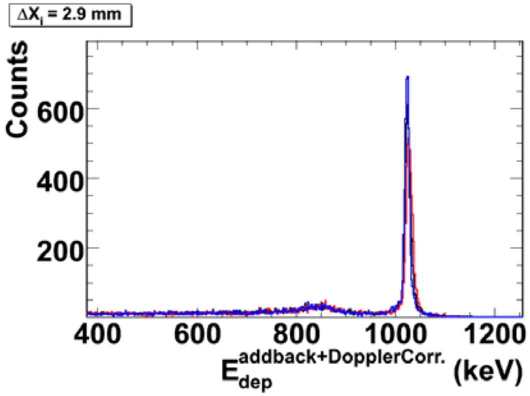
Another example: line shape analysis on first 2^+ of ^{74}Ni

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

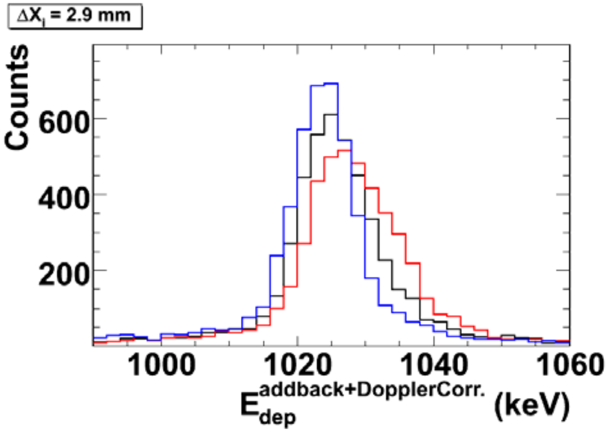




τ = 0.1 to 5 ps



Zoom



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)

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

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

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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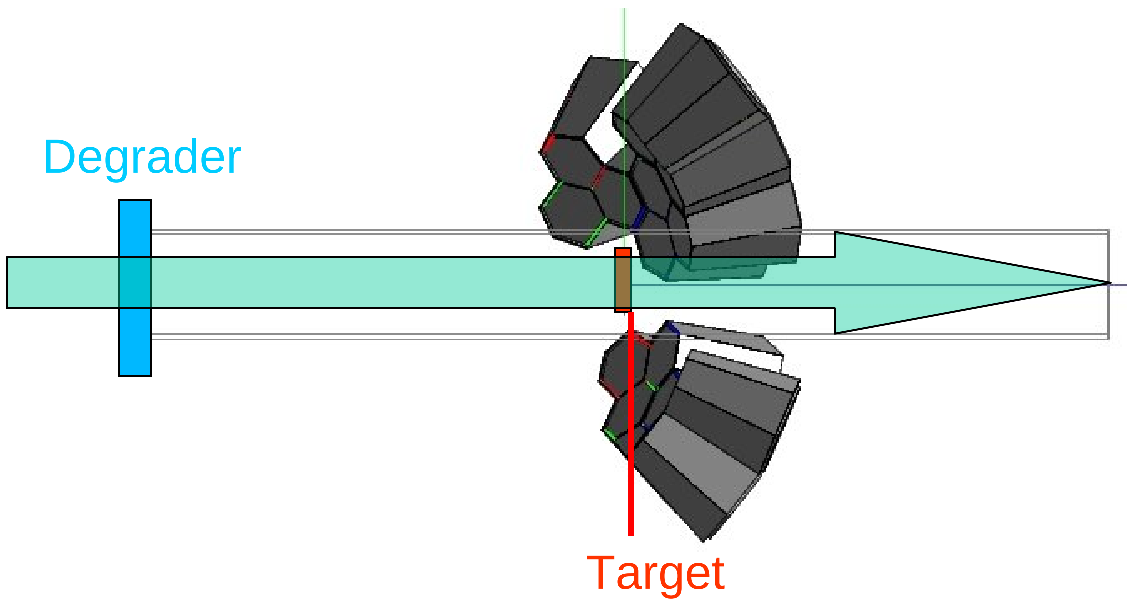
Realistic MC Simulation: Background



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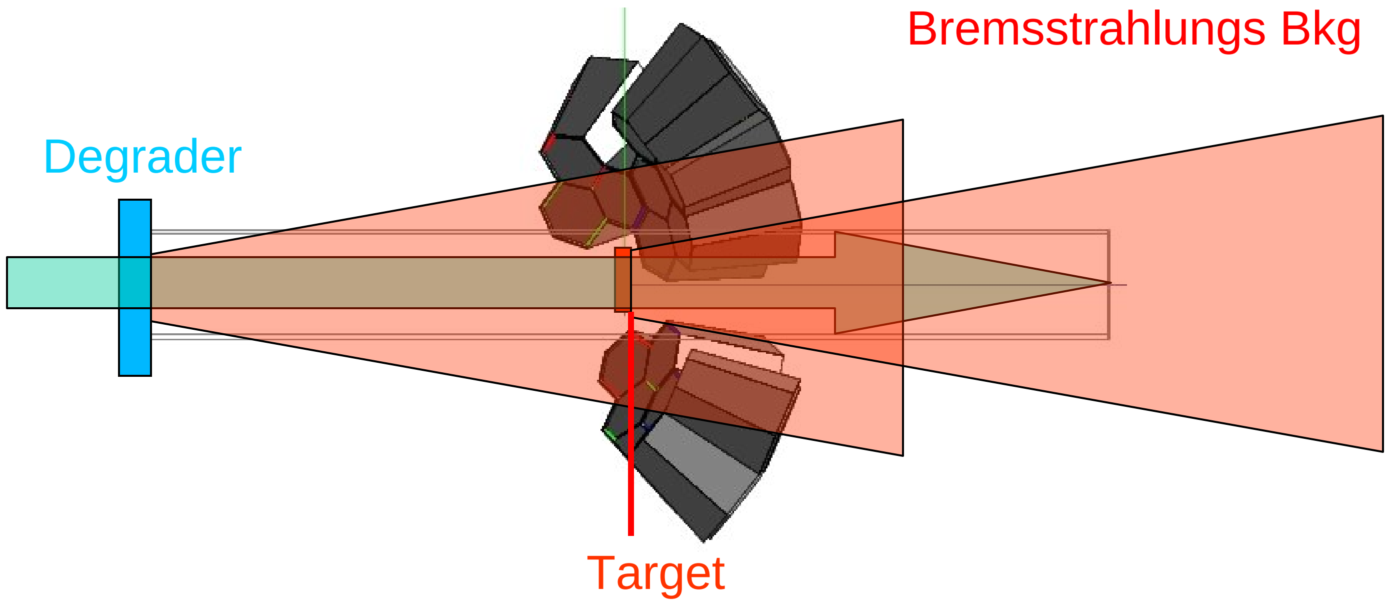

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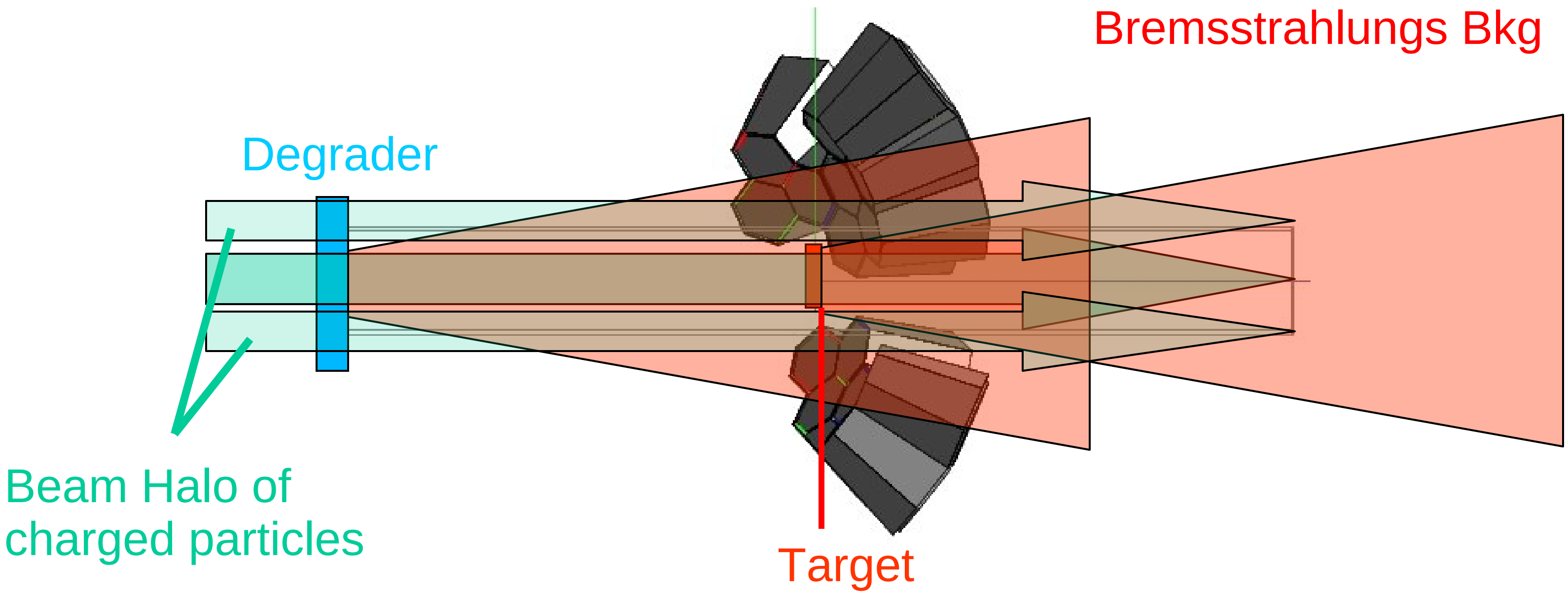

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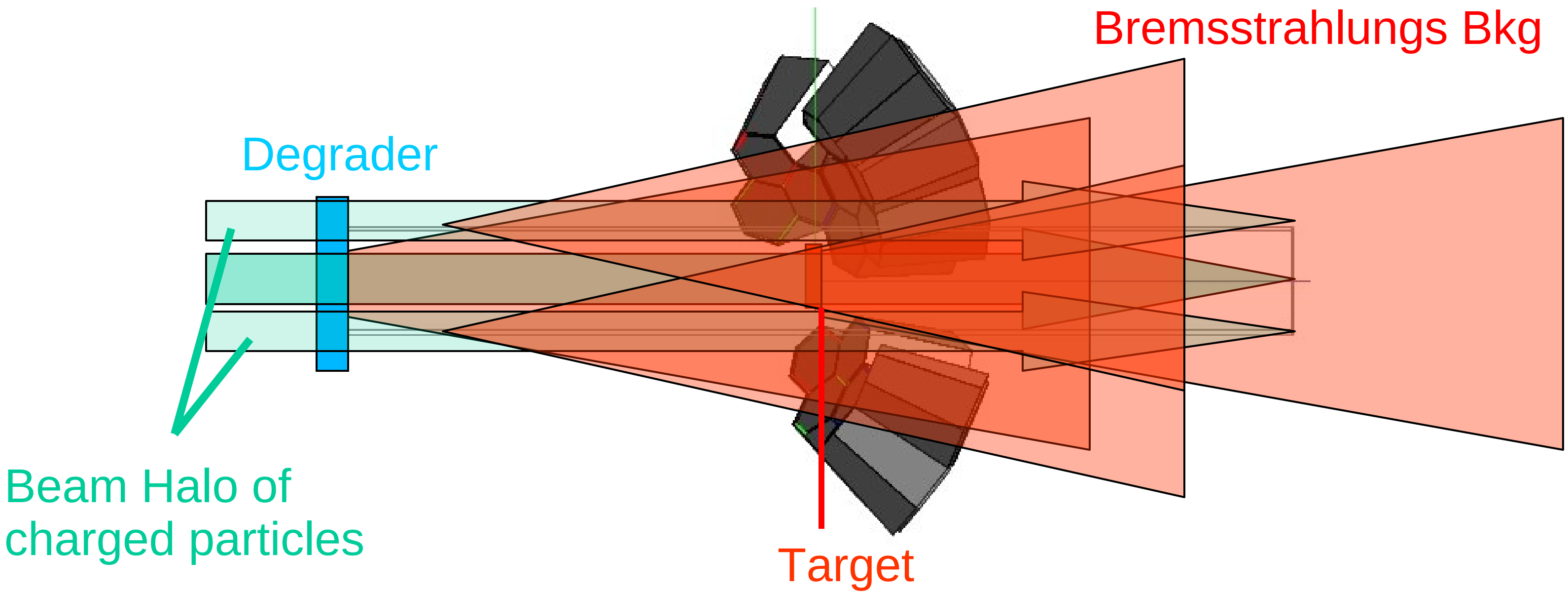

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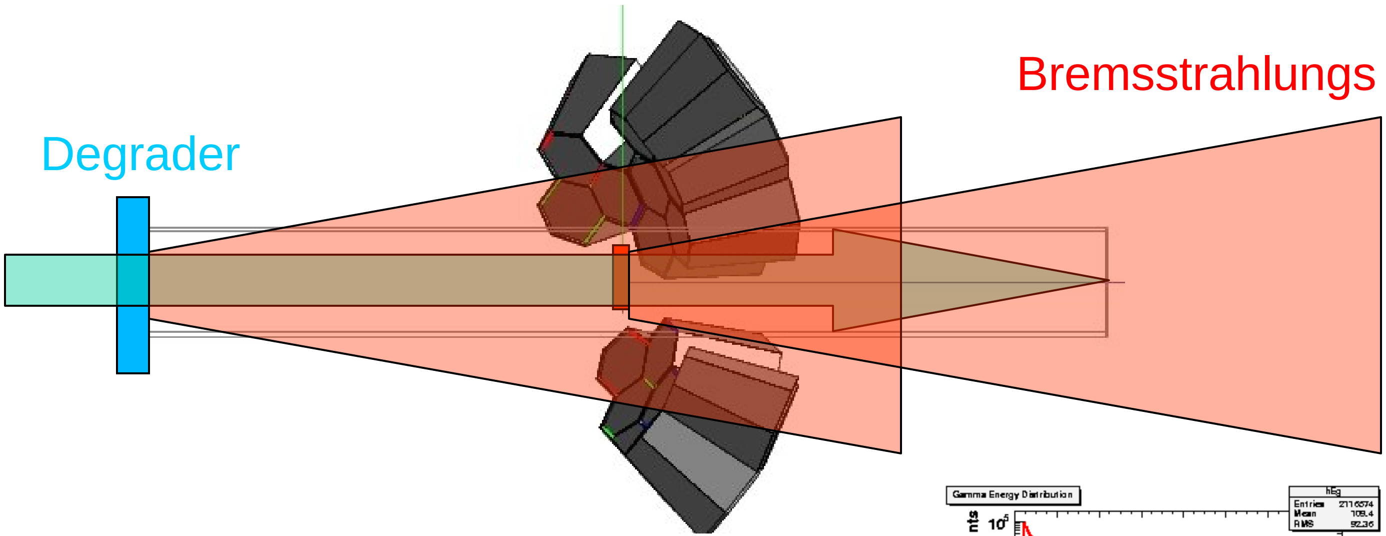
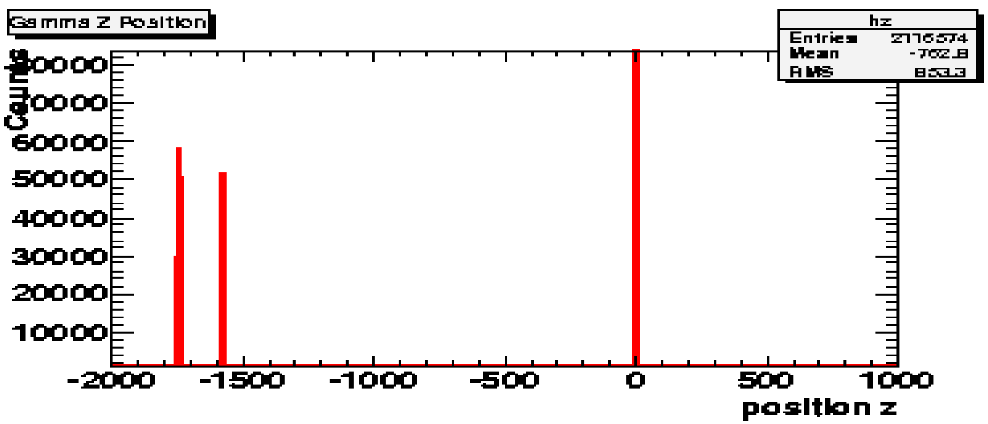
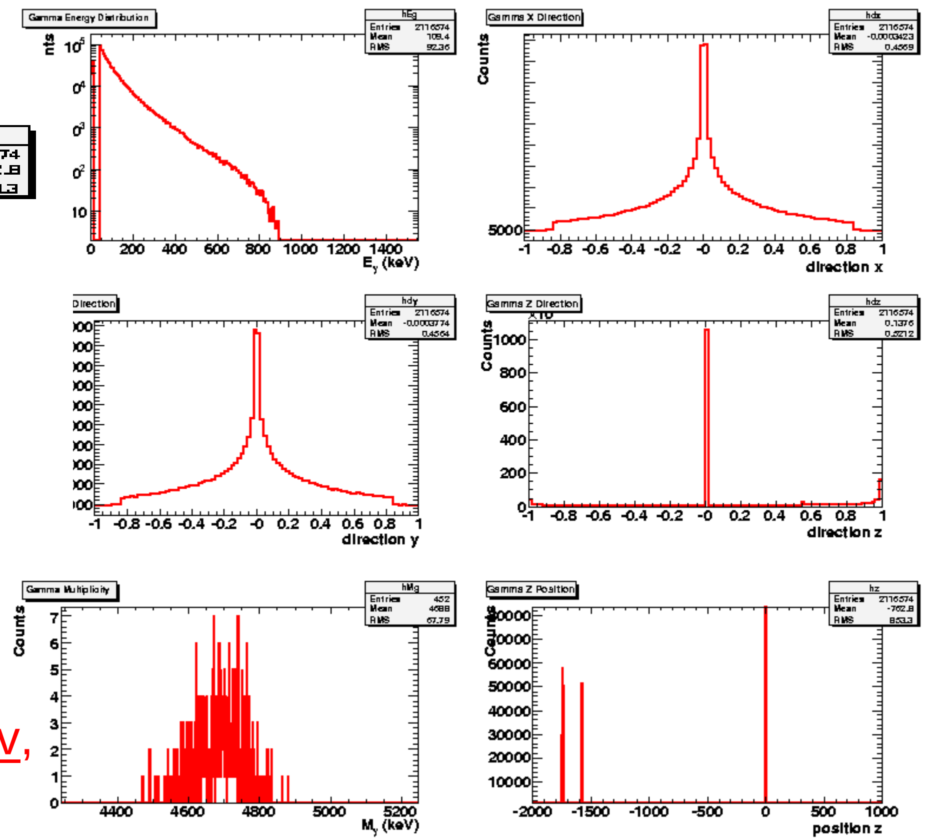


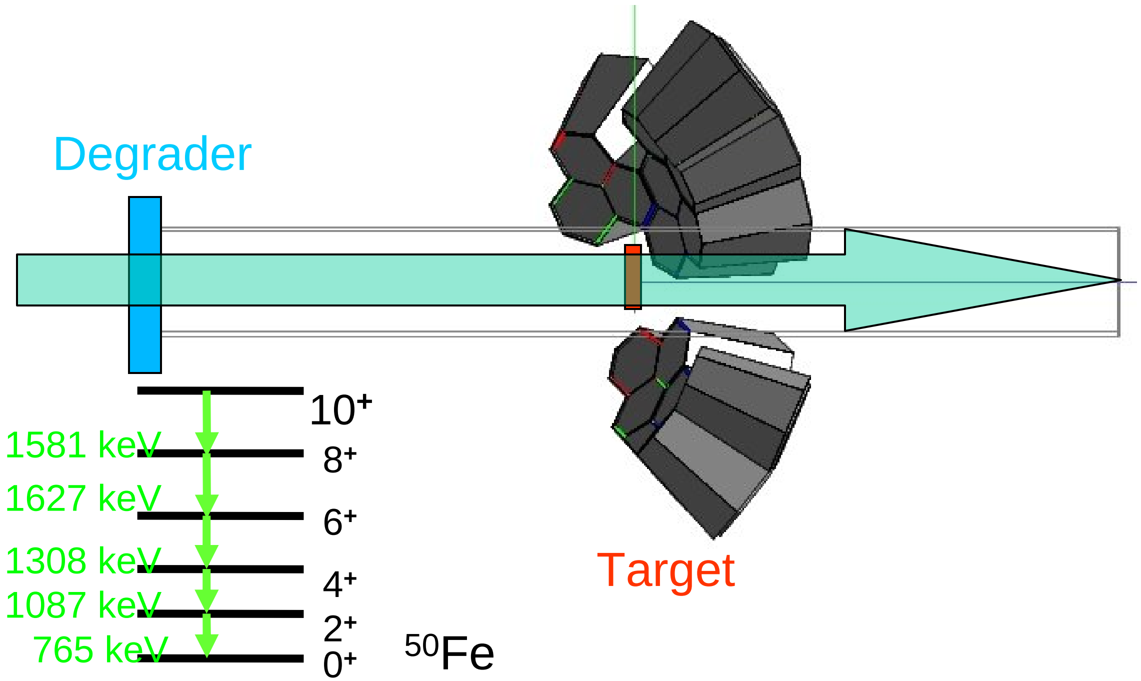


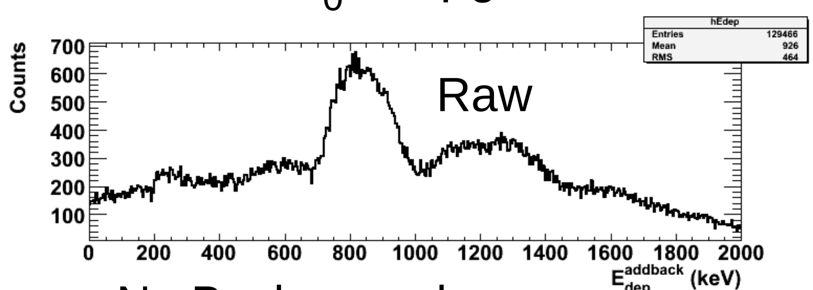


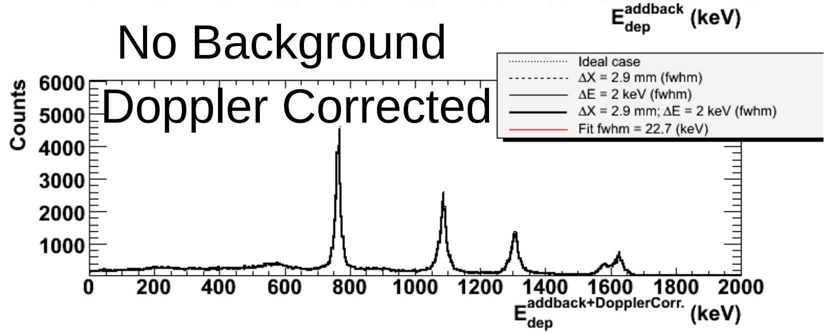
Background Events courtesy of Pavel Detistov,

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

Realistic MC Simulation: Background







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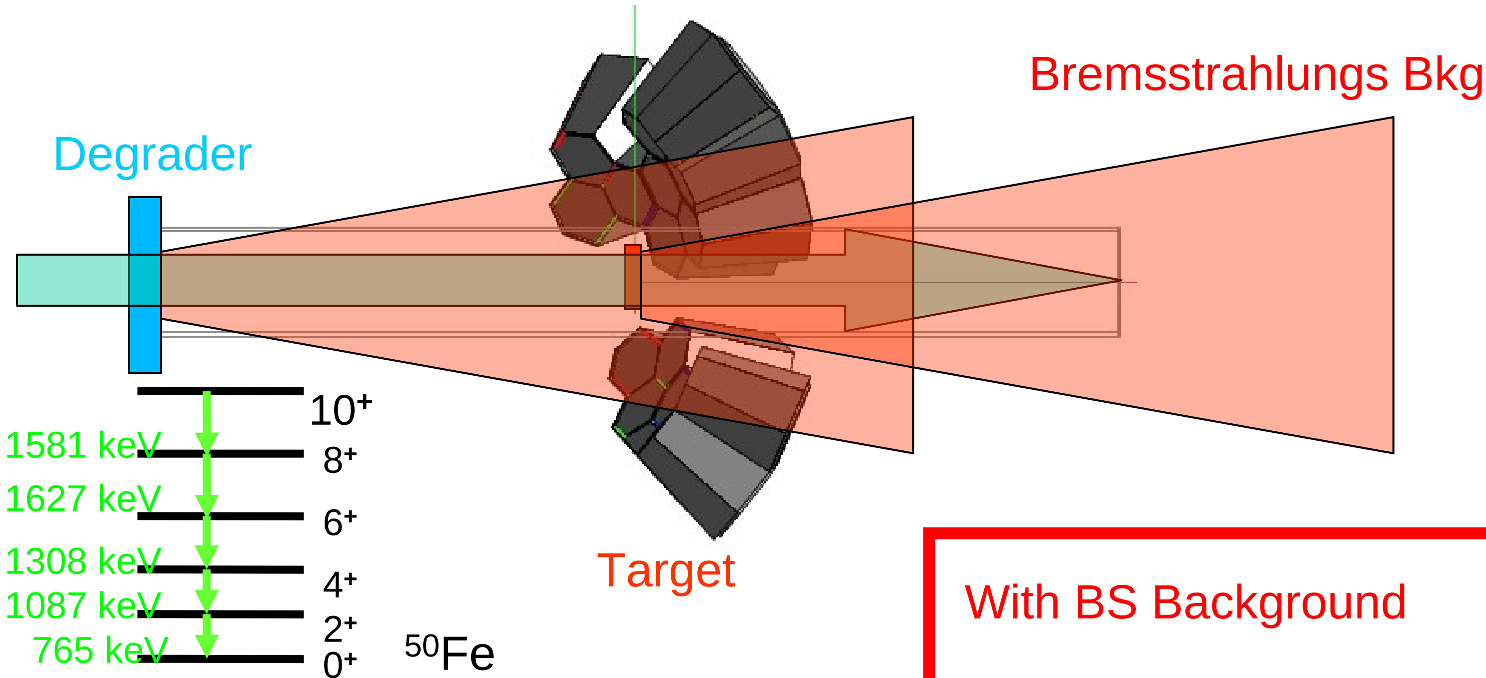
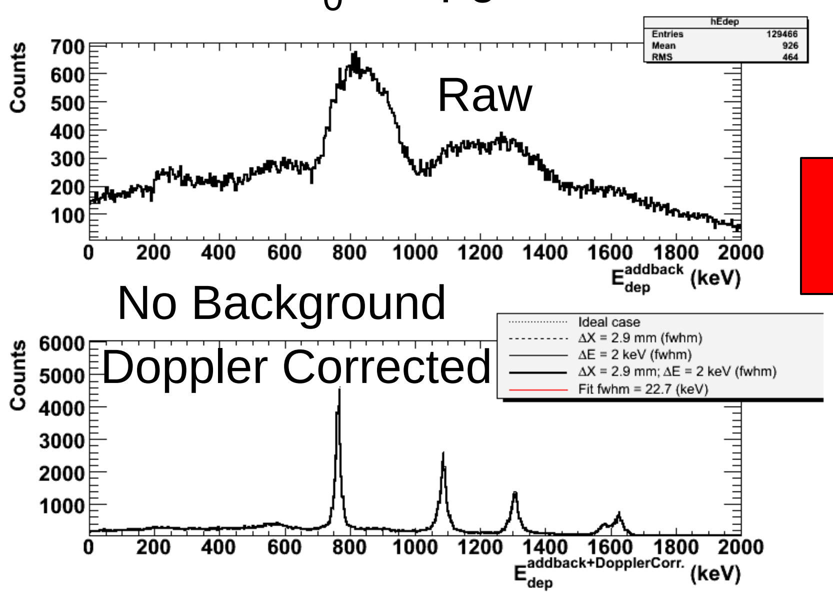
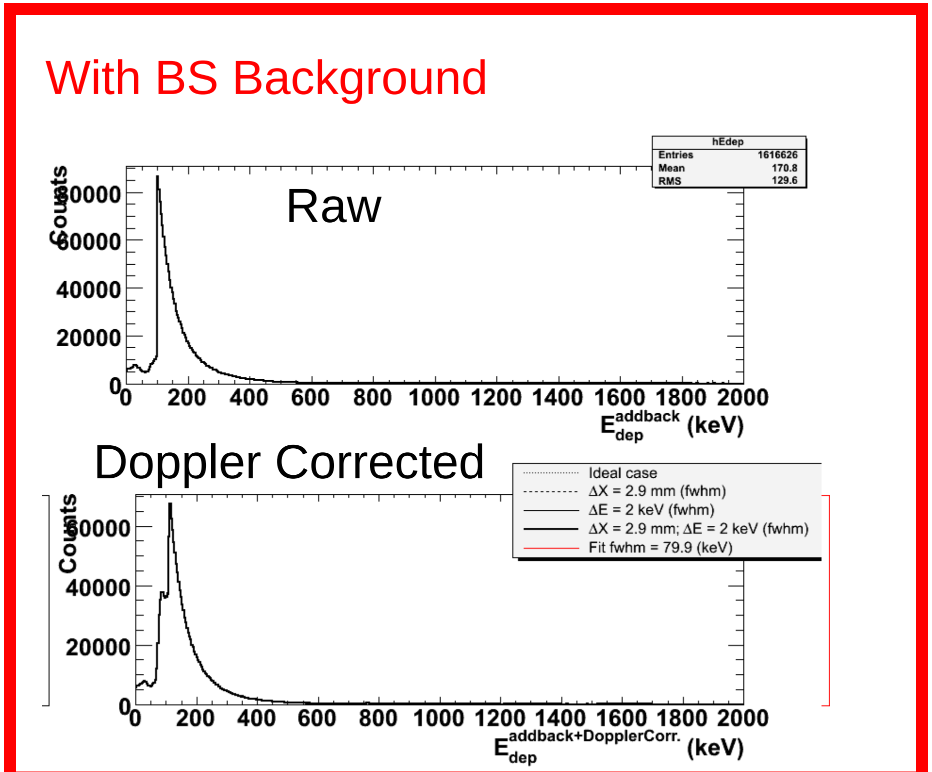
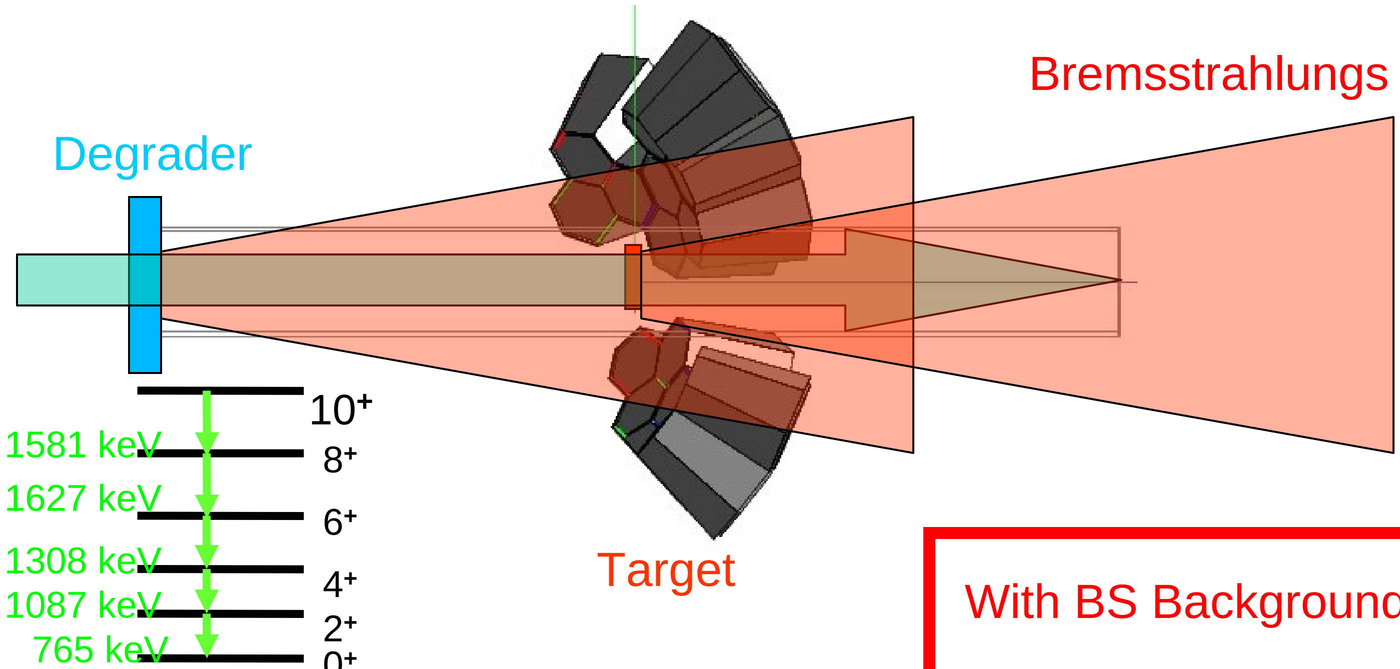
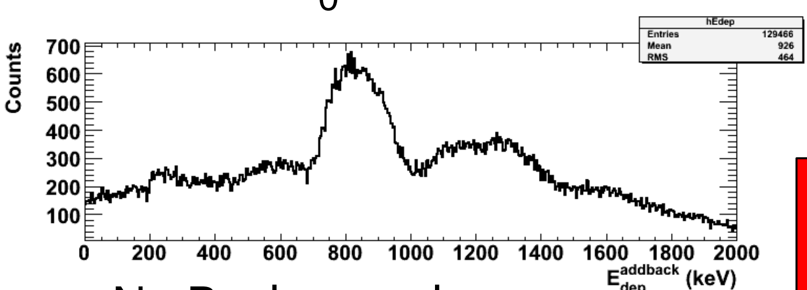




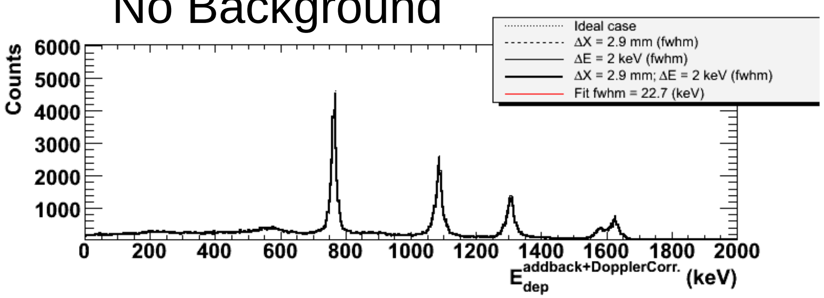


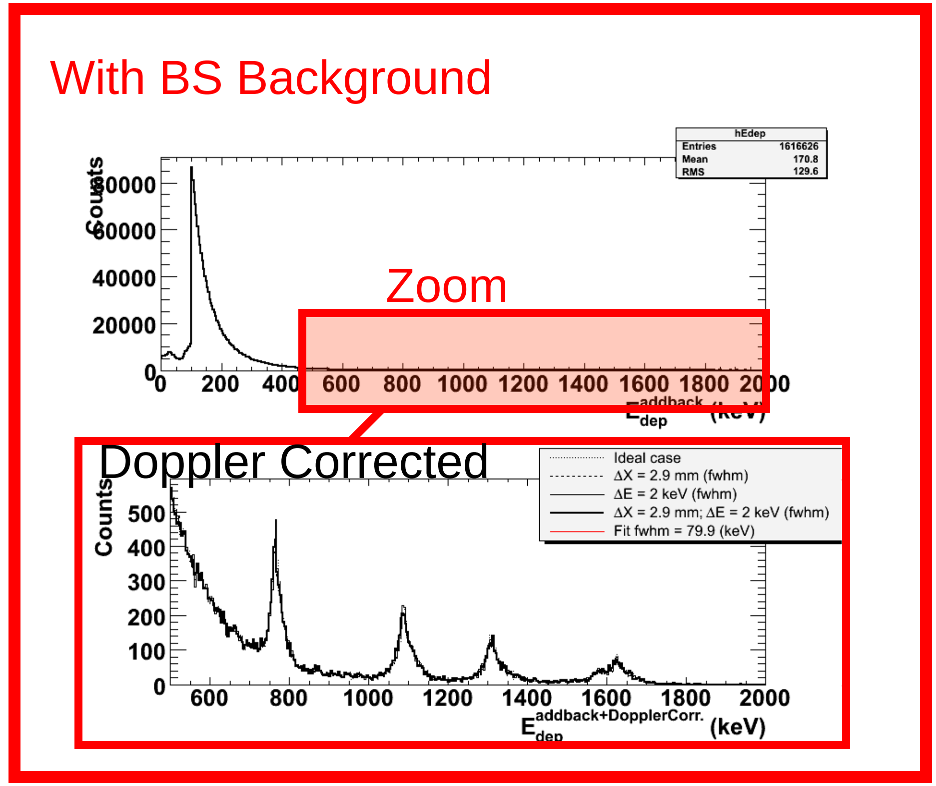
Realistic MC Simulation: Background





No Background





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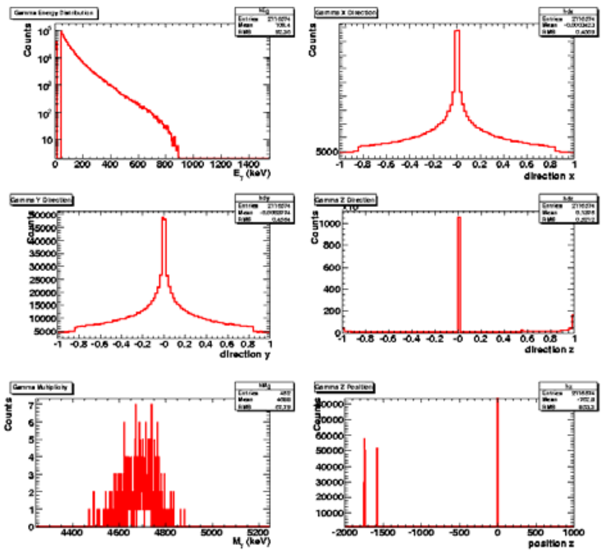
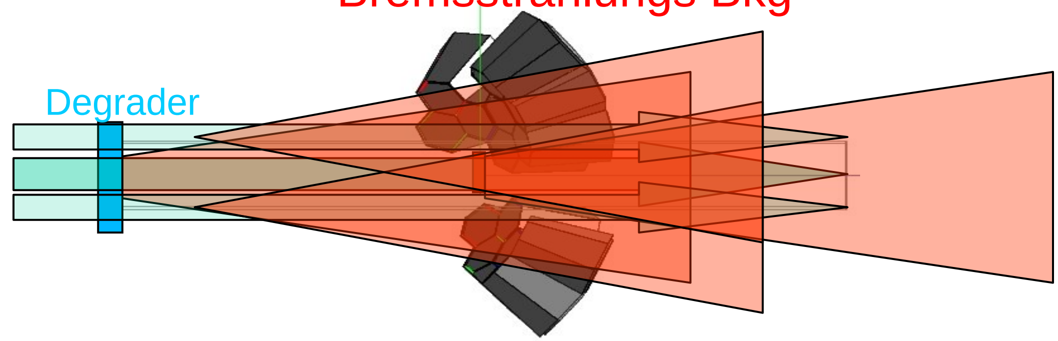
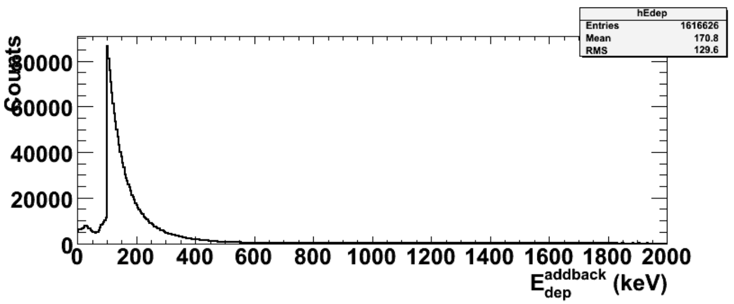
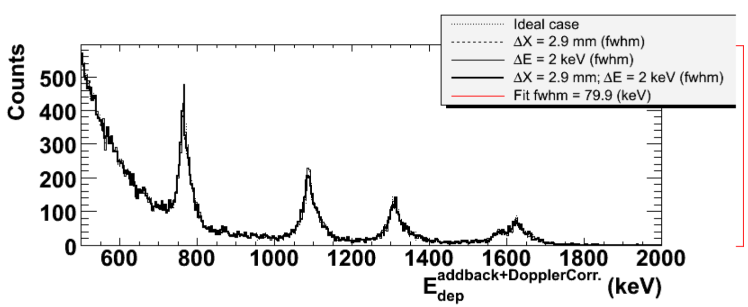
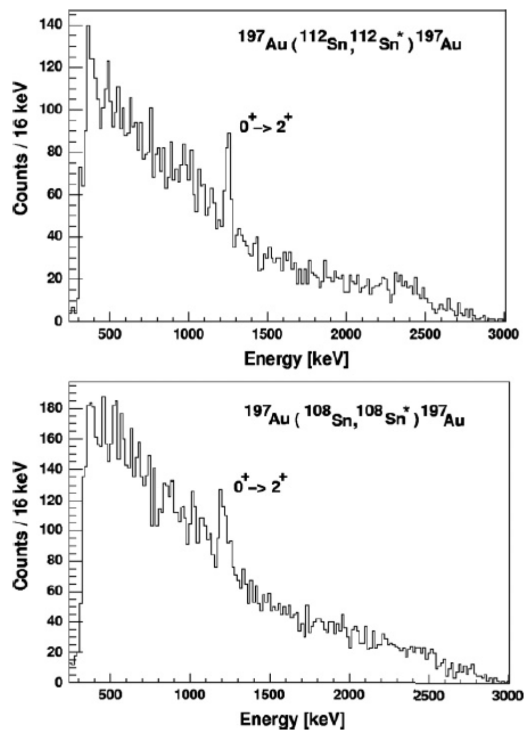




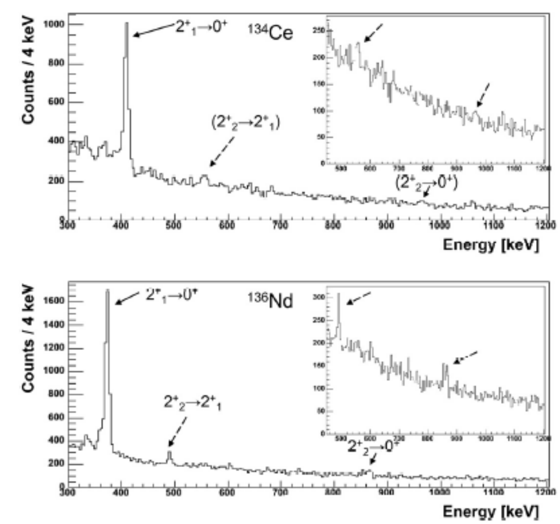




A. Banu et al. PRC 72, 2005



T. Saito et al. PLB, 2008



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See Talk by E. Merchan & Pankaj Joshi

Thanks to

- Pavel Detistov (Univ. Sofia)
- Pieter Doornenbal (RIKEN)
- Enrico Farnea (LNL)
- Jürgen Gerl (GSI)
- Pankaj Joshi (York)
- Edana Merchan (GSI)
- Michael Reese (TU-Darmstadt)