Simulations for the High Resolution array

Kathrin Wimmer
ウィマー　カトリン

The University of Tokyo

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The simulation framework

- GEANT 4.10 simulation
- based on the UCGretina code by Lew Riley
- Miniball geometry by Heather Crawford
- adapted for the RIBF geometry
- integrated ZeroDegree spectrometer data
- alternative geometry with MINOS (work in progress)
- output file in GEB (GRETINA Event Builder) format,
  any GRETINA analysis code can be used to analyze the simulated data
- event-building, calibrations, Doppler correction, and γ-ray tracking with modified version of GrROOT

Simple considerations

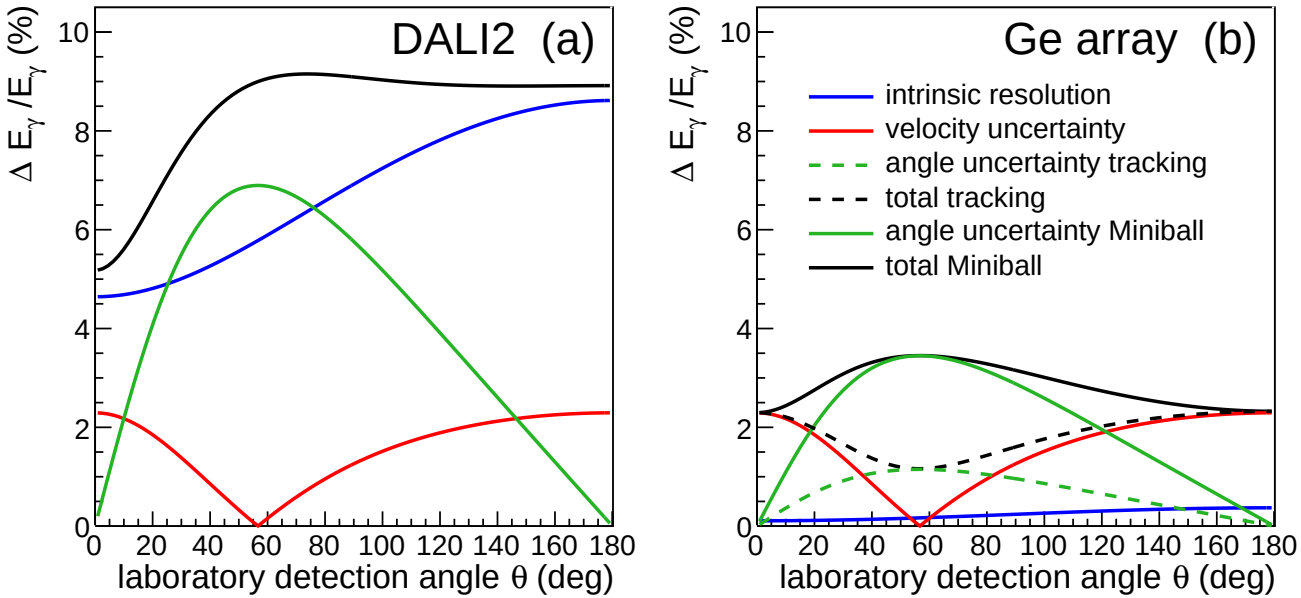
in-beam resolution depends on

- intrinsic resolution
- uncertainty from velocity (where in the target happened the reaction) $\rightarrow$ MINOS

$$\left(\frac{\Delta E}{E}\right)_{\beta} = \frac{\cos\theta - \beta}{(1-\beta\cos\theta)(1-\beta^2)} \cdot \Delta\beta$$

- position resolution $\rightarrow$ signal decomposition and tracking

$$\left(\frac{\Delta E}{E}\right)_{\theta} = \frac{\beta\sin\theta}{(1-\beta\cos\theta)} \cdot \Delta\theta$$

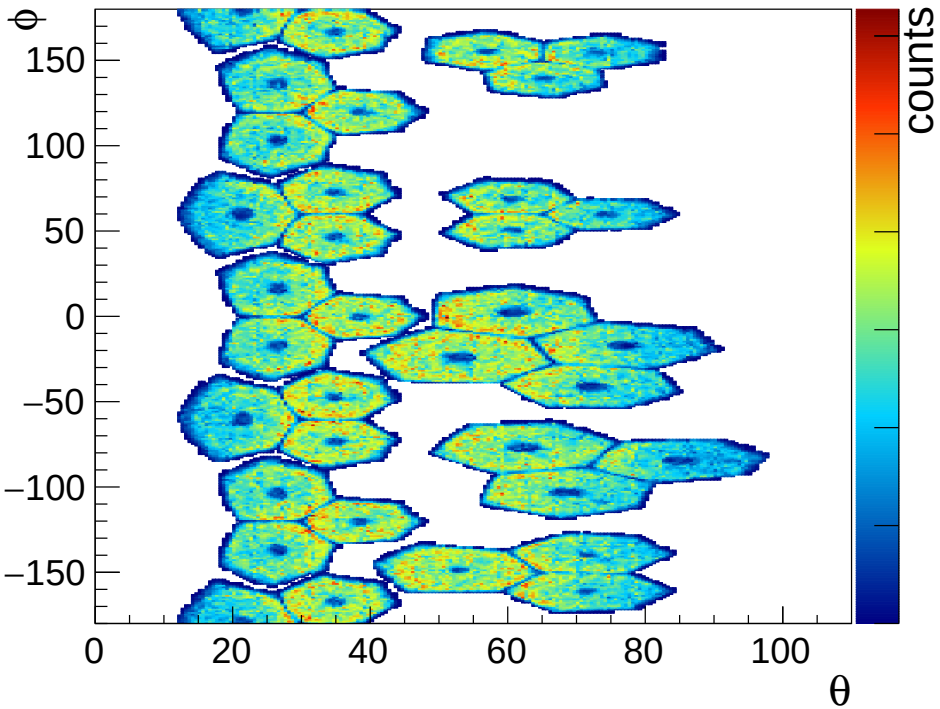


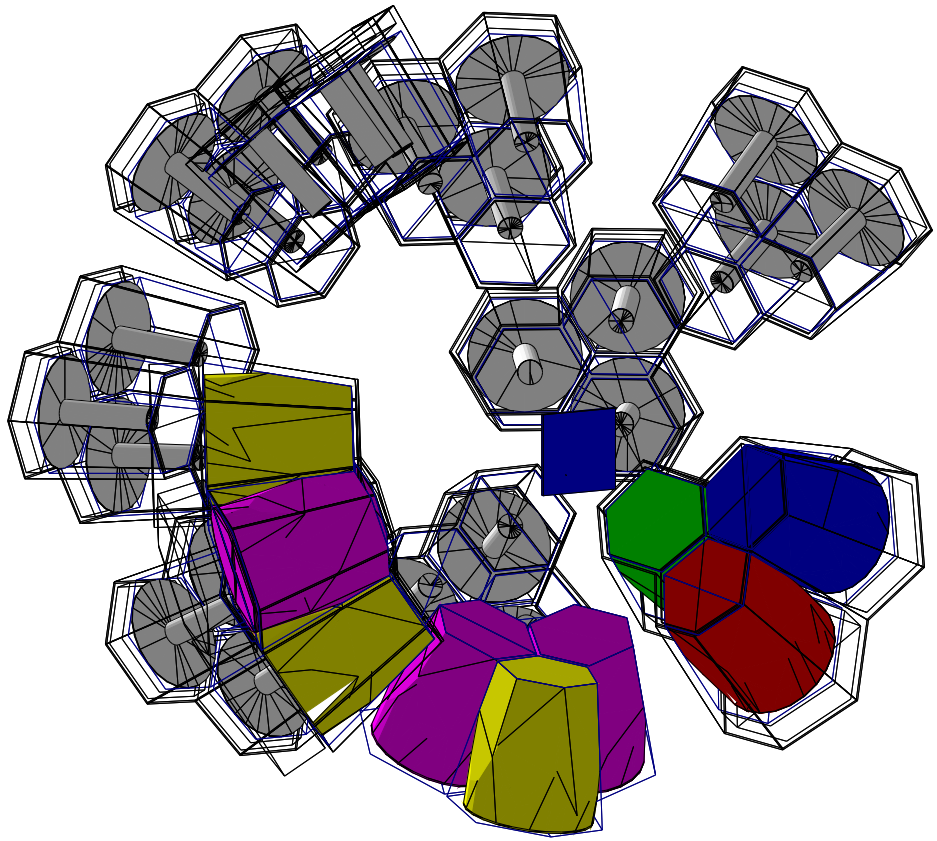
$\rightarrow$ MB at forward angles, tracking detectors at 60°

Geometry

- positioning of the clusters through “aeuler” file
- 6 Miniball clusters at 30°, distance 27 cm with standard beam pipe

- 2 additional Miniball clusters at 65°, distance 20 cm
- Berkeley P3 triple, RCNP quad at 65°, distance 13 cm
- DAGATA triple at 65°, distance 13 cm

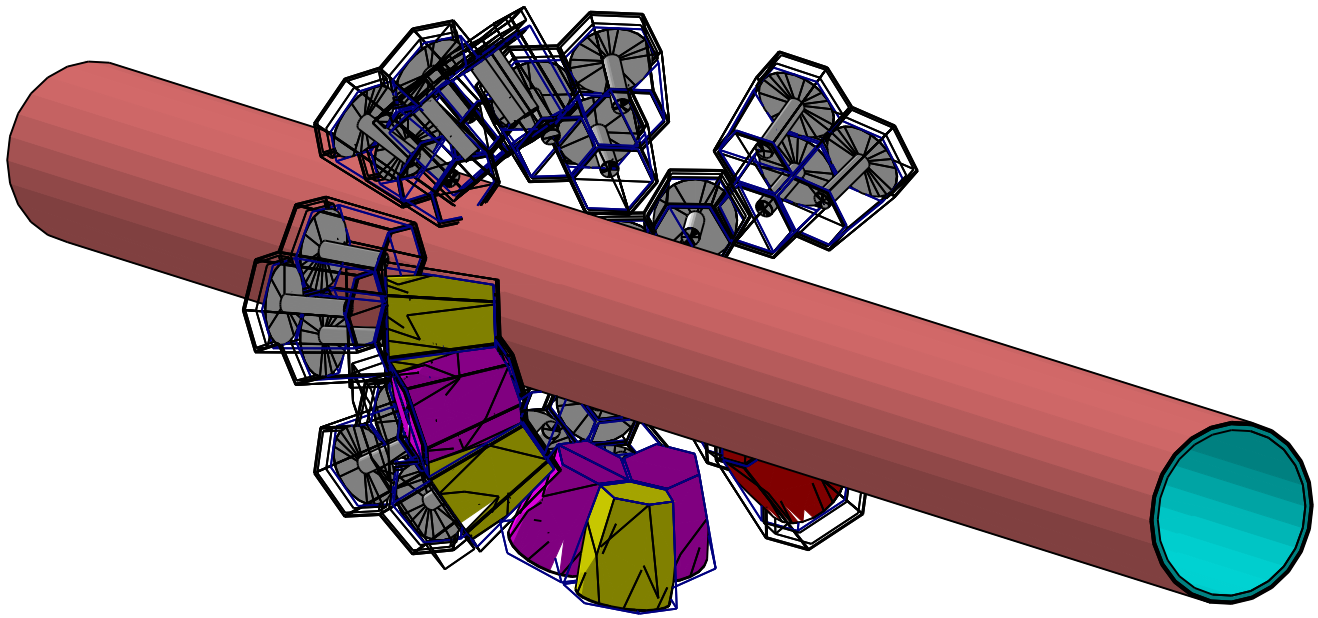




- left: close packed geometry (collides with standard beam pipe)

Geometry

- standard beam-pipe outer diameter 7.5 cm, wall thickness 5 mm
- optional shielding (typical 1 mm Pb, 1 mm Sn)
- simulation standard ^{152}Eu source



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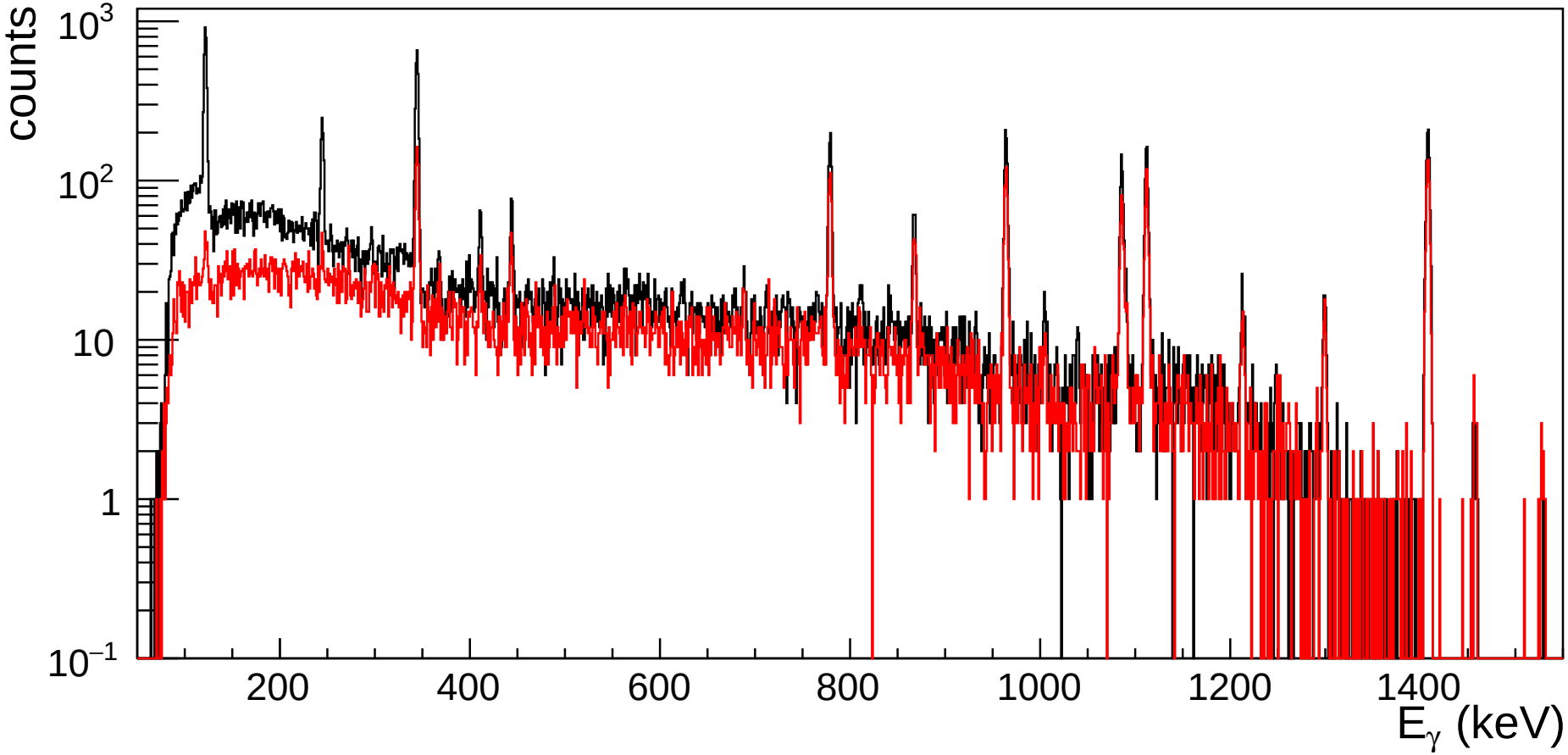

Event generator

- stationary source
- beam particle, energy, momentum, position, and angular distribution on target

```
/BeamIn/A 80
/BeamIn/Z 30
/BeamIn/KEu 200 MeV
/BeamIn/Dpp 0.05
/BeamIn/Focus/DX 5. mm
/BeamIn/Focus/DY 5. mm
```

- reaction kinematics: inelastic scattering, particle removal, transfer

```
/BeamOut/TargetA 9
/BeamOut/TargetZ 4
/BeamOut/DA -1
/BeamOut/DZ -1
```

- angular distribution of outgoing beam
- level scheme file and populated level

```
/BeamOut/LevelDataFile level/cu79.lvldata
/BeamOut/ProjectileExcitation 4580 keV
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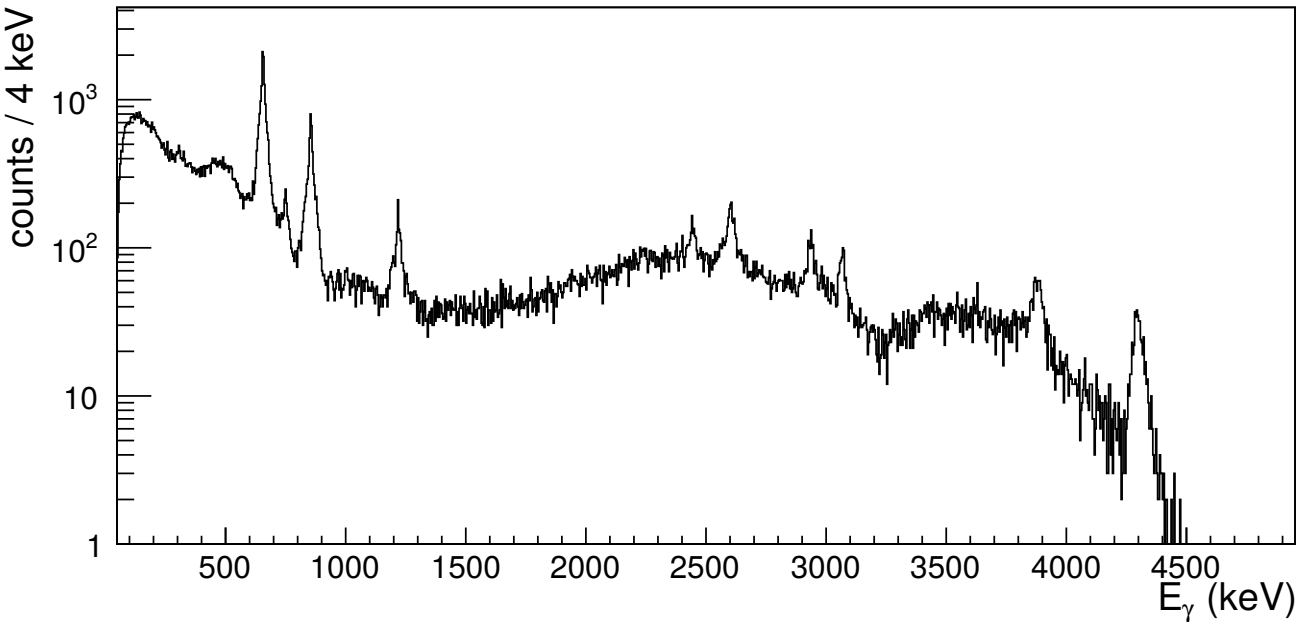
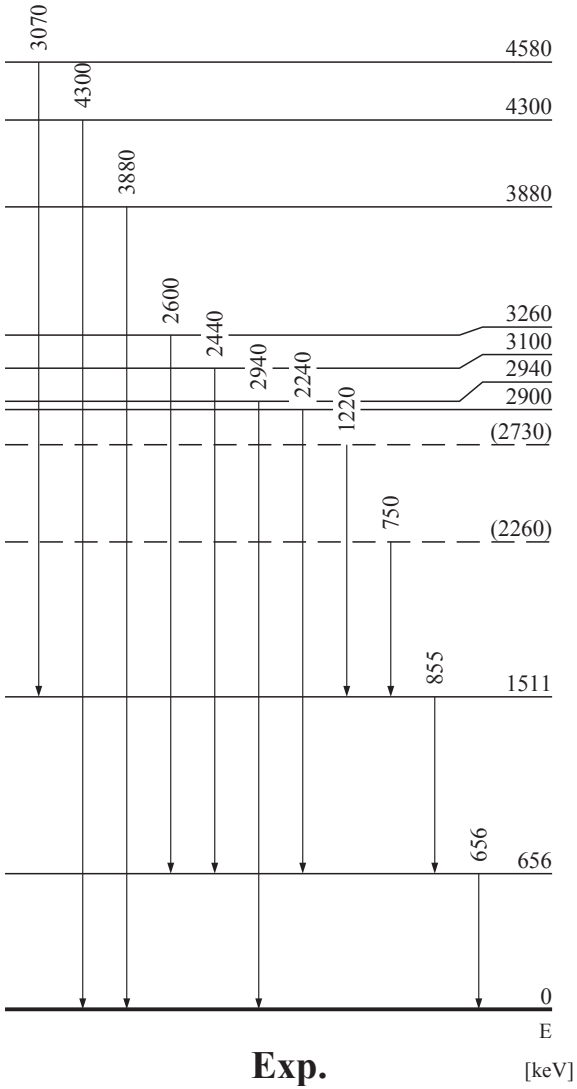
Example

^{80}Zn at 200 *A*MeV on 7 mm Be (MINOS equivalent)





- level scheme and relative intensities from SEASTAR

L. Olivier et al. Phys. Rev. Lett. **119** (2017) 192501.

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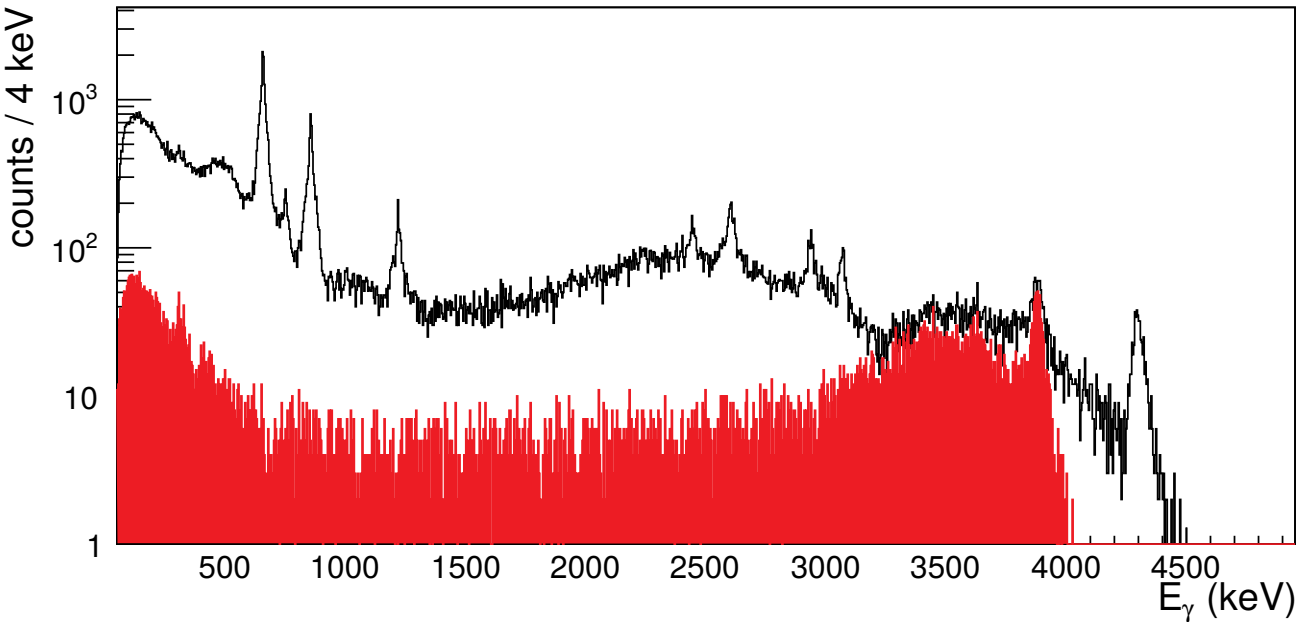

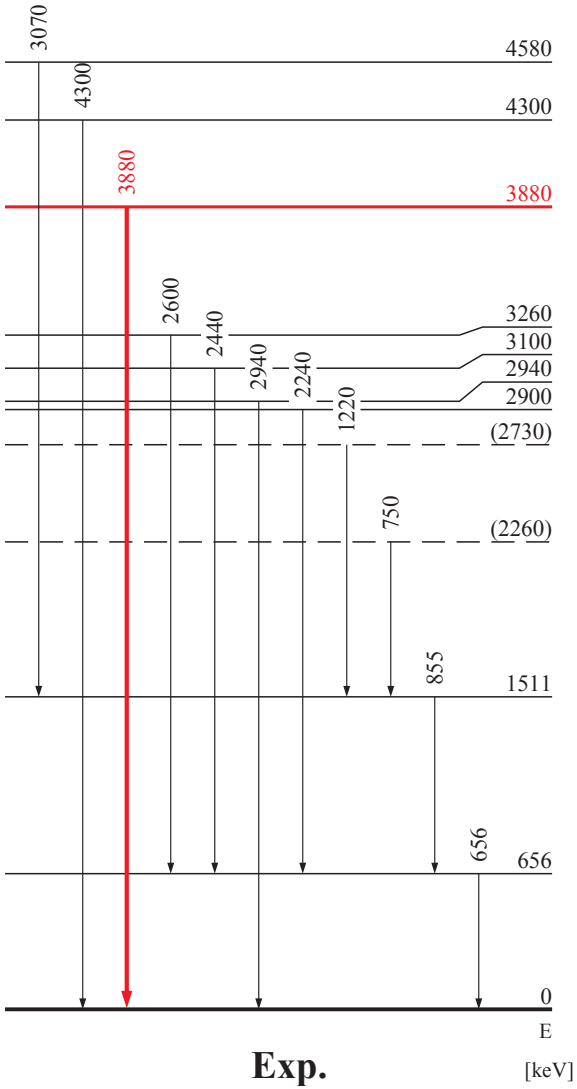

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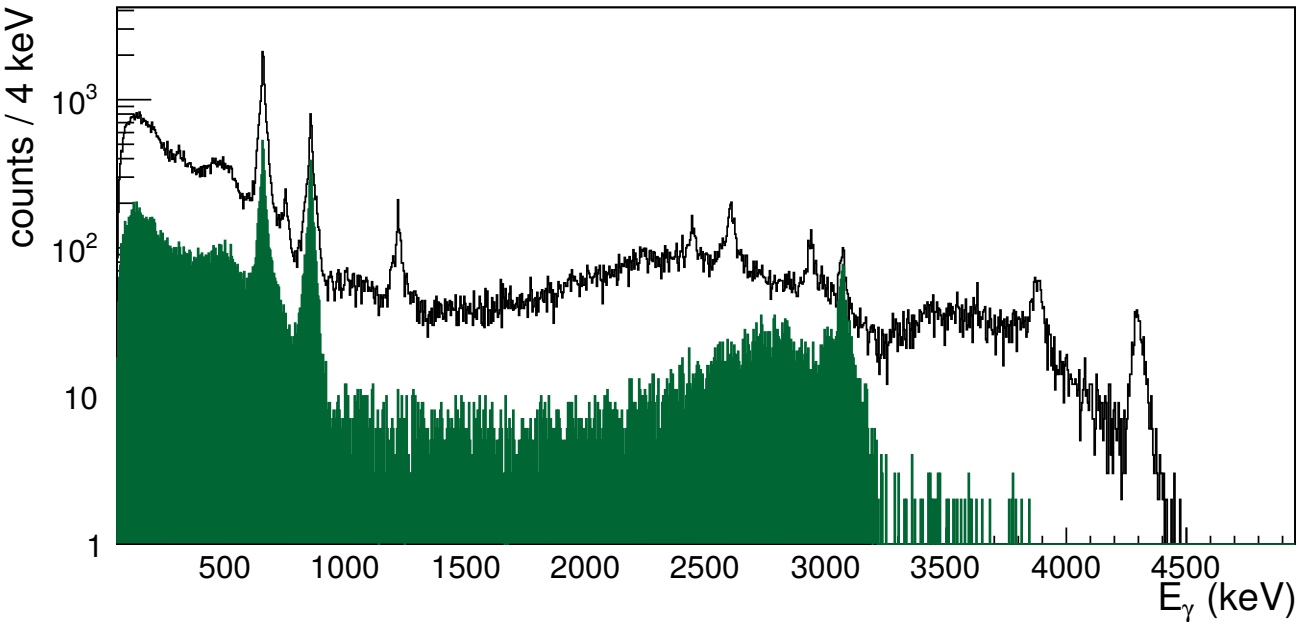

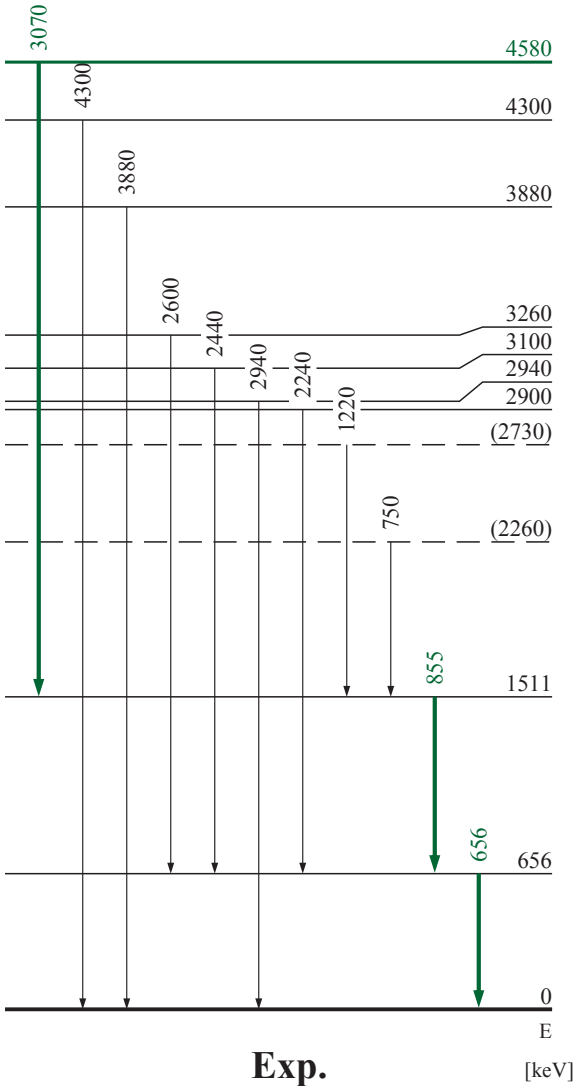

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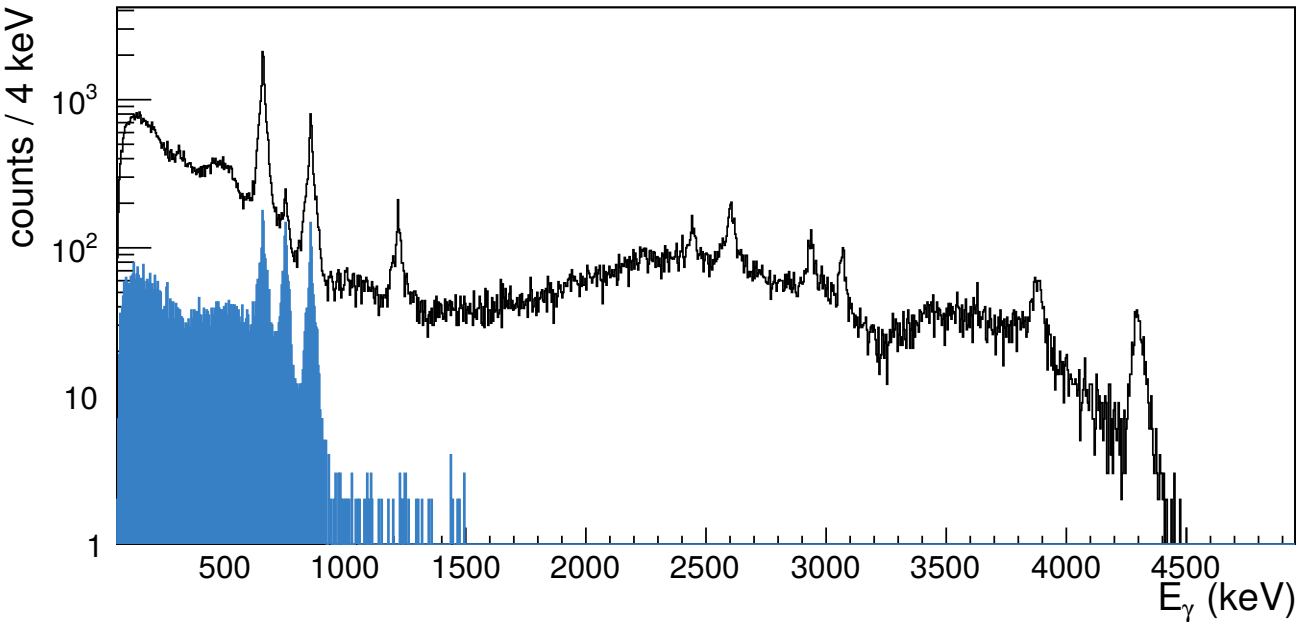

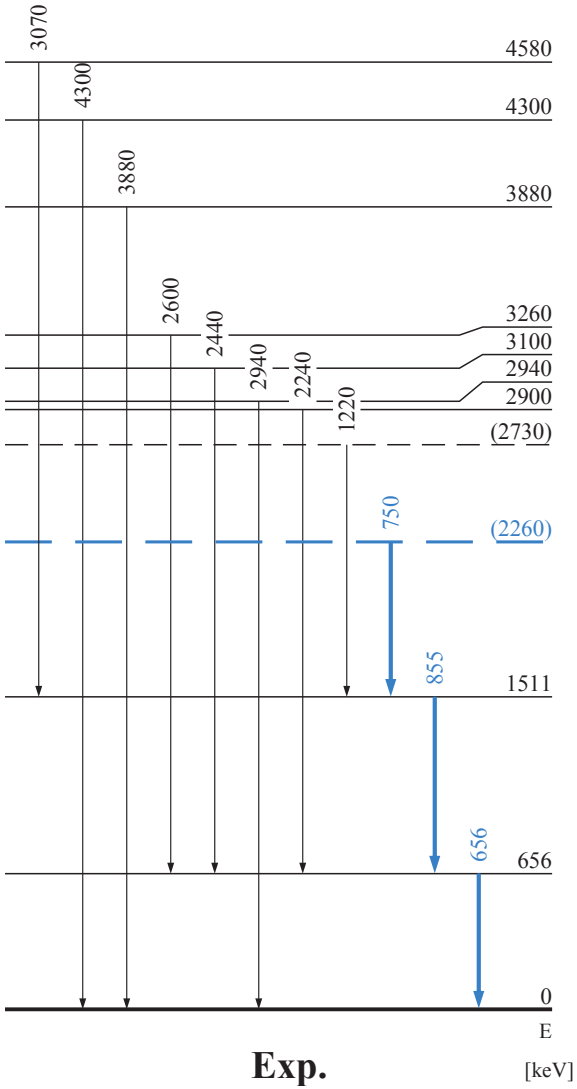

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Output format

- output in GEB format http://gswg.lbl.gov/analysis/geb-headers

```
struct GEBHeader{
  int32_t type;
  int32_t length; /*length of payload following the header, in bytes*/
  int64_t timestamp;
}
```

- same format as actual data
- type and tag identify event (temporary assignment)

```
#define GEB_TYPE_DECOMP          1
#define GEB_TYPE_MINIBALL        7
#define GEB_TYPE_ZEROPHYSDATA   13
#define GEB_TYPE_G4SIM          11
#define GEDECOMPDATA_TYPETAG   0xabcd5678
#define MINIBALLDATA_TYPETAG   0xaffec0c0
#define ZEROPHYSDATA_TYPETAG   0x0de90de9
```

- mode2 data: core energies, interaction point coordinates and energies for tracking detectors
- core energies and segments for Miniball
- events get fake time-stamp to facilitate event building

Analysis

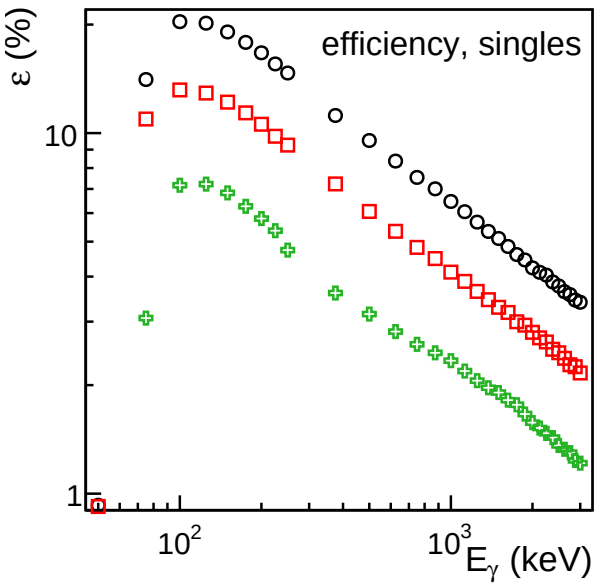
- based on GrROOT (GRETINA at NSCL):
  event building, calibration, reconstruction, Doppler correction, tracking
- required input is provided by simulation step

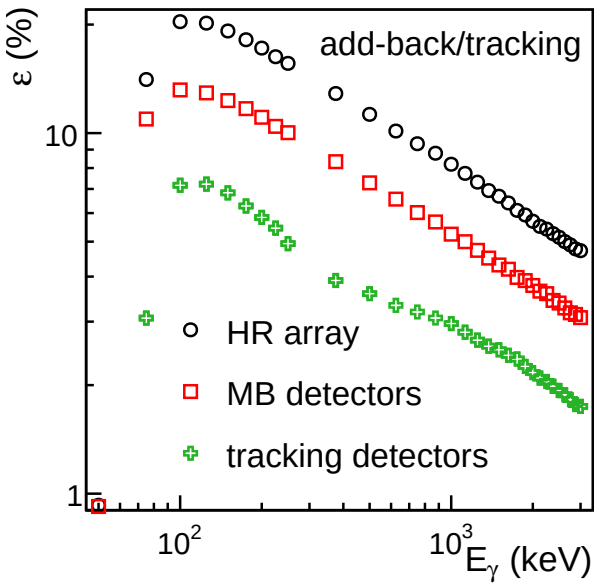
```
Target.Beta:          0.537164
Average.Beta.After:   0.503215
Average.MBPositions: /home/wimmer/simulation/frankenball/settings/cu79_MBcoordi
```

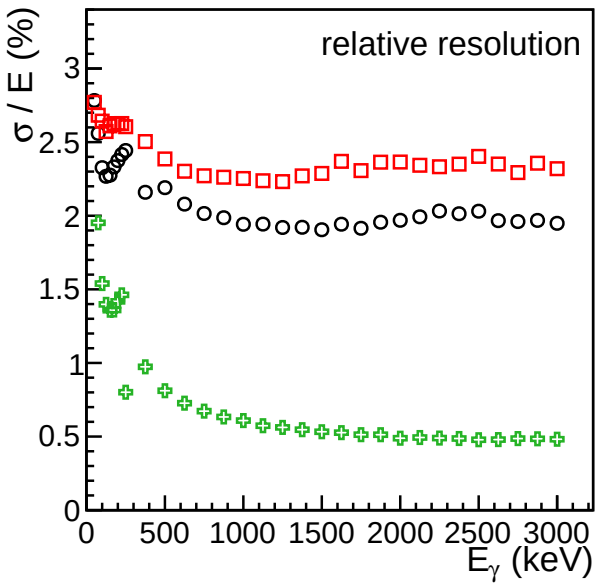
- event-by-event Doppler-correction using:
  ejectile four-momentum after target,
  average emission velocity (from simulation),
  weighted segment center coordinates for Miniball
- cluster add-back for Miniball
- (optional) GrROOT tracking for others

Performance

- typical efficiency in-beam, ^{54}Ca at 170 *A*MeV om 7 mm Be (MINOS equivalent)
- 8 % at 1 MeV using large beam-pipe
- currently assuming three tracking detectors (two triples and a quad)







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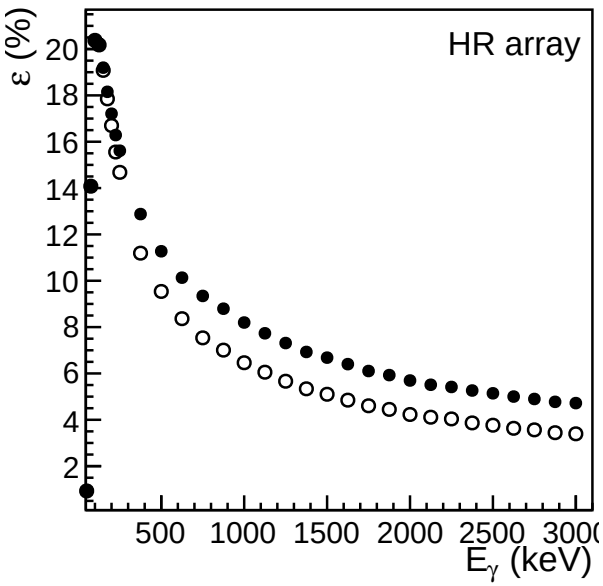
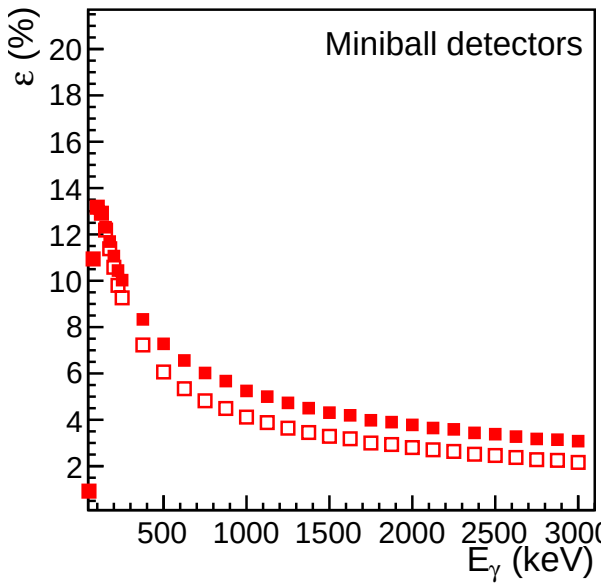
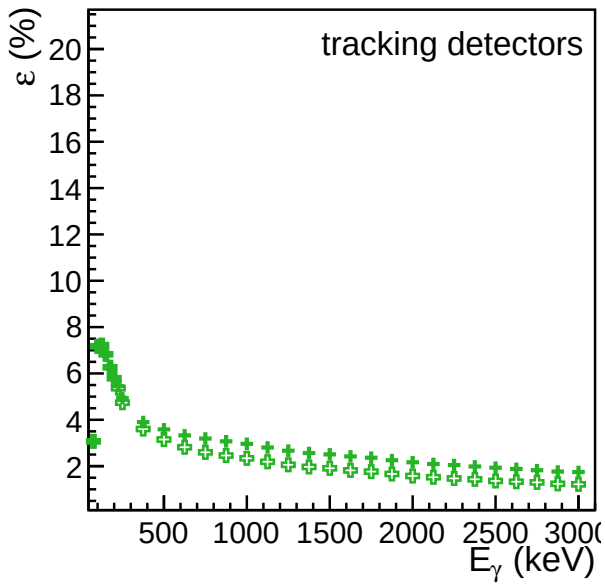


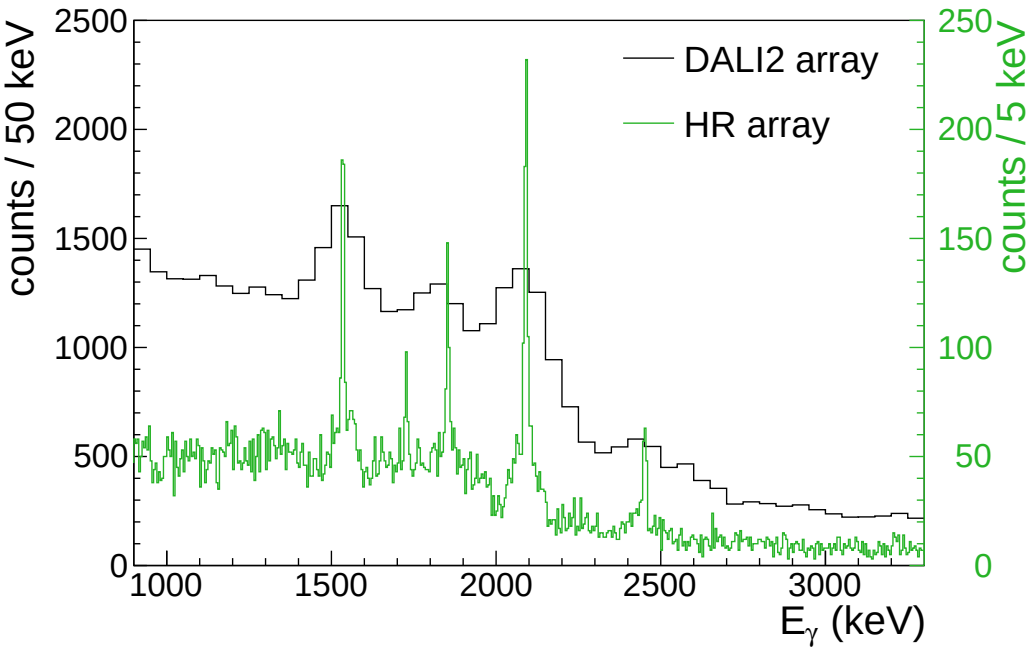


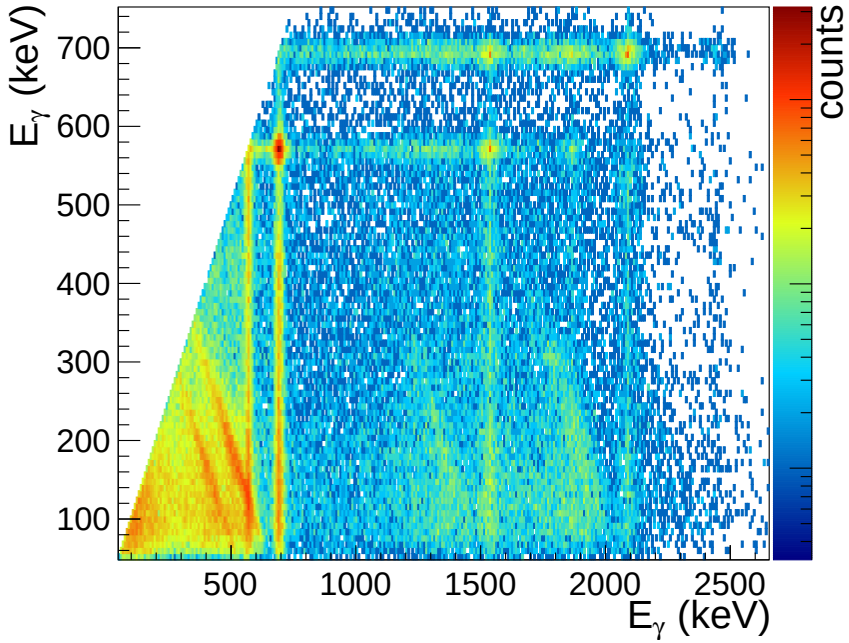


Performance

- ^{55}Sc from proton knockout on Be
- much better resolving power
- clear $\gamma - \gamma$ coincidences

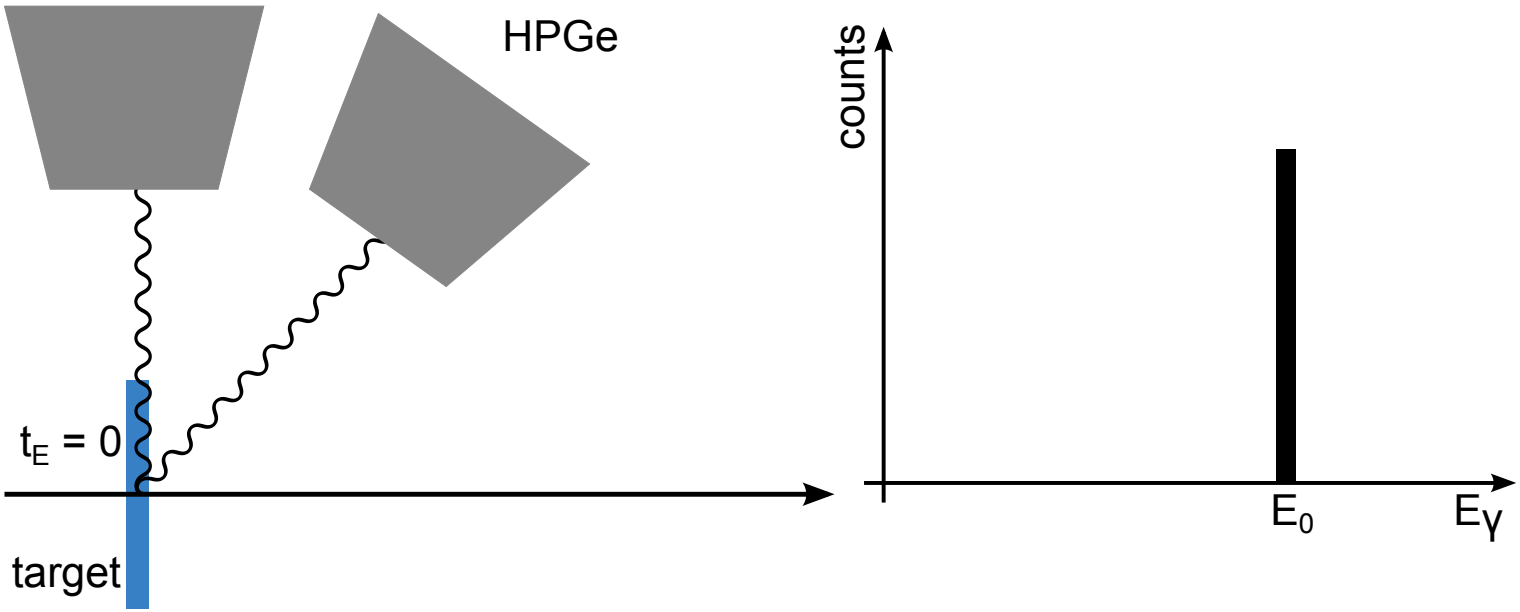
D. Steppenbeck et al., Phys. Rev. C **96** (2017) 064310.





Lifetime effects

- finite lifetimes have an effect on the Doppler corrected energy
- can be used to measure lifetimes of excited states



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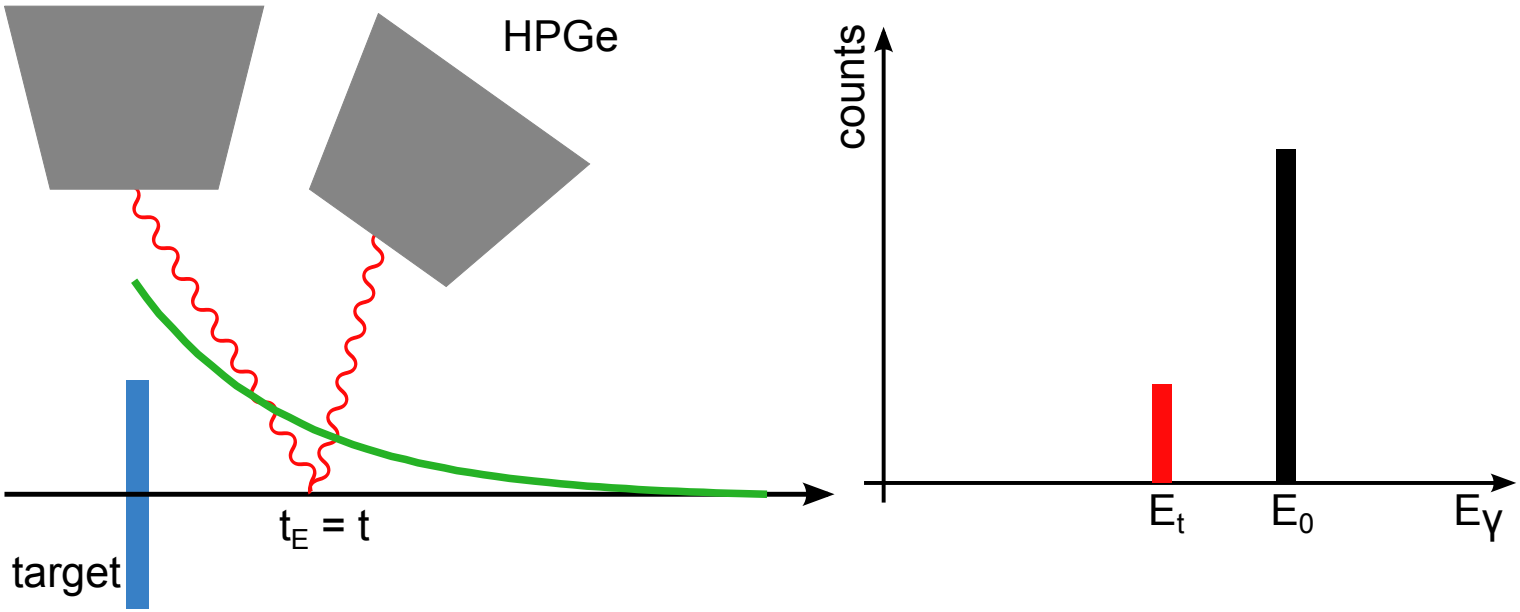

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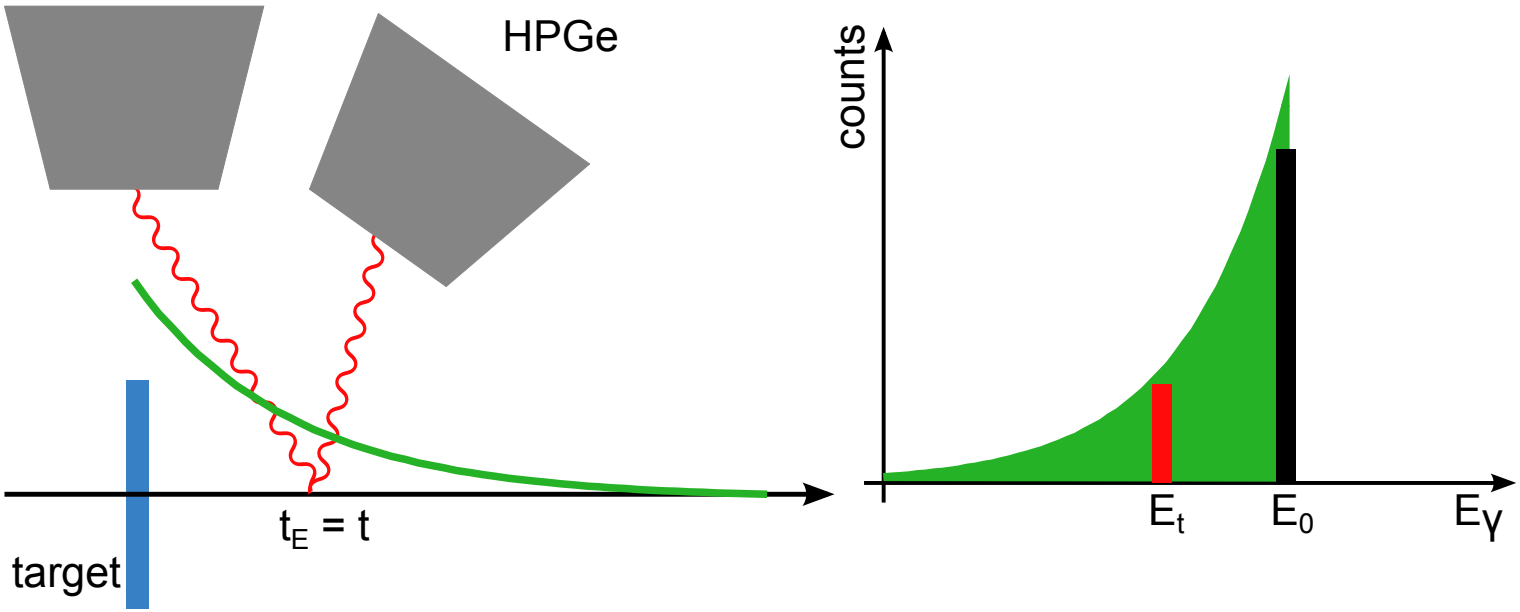

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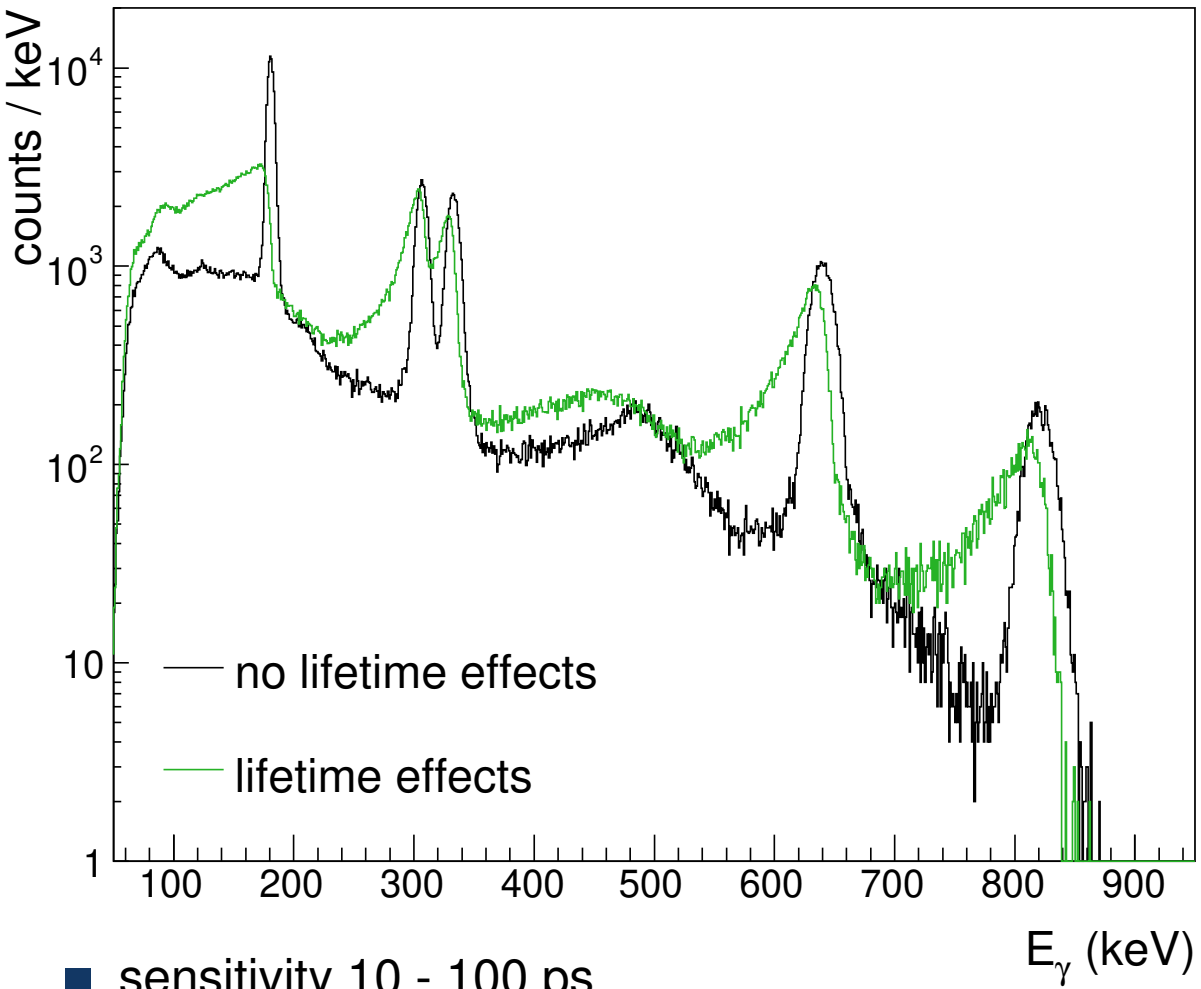
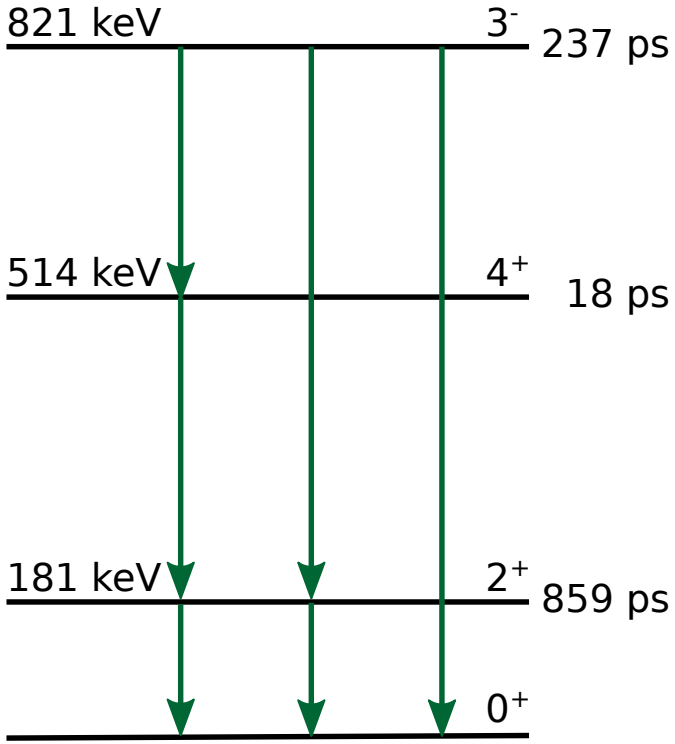
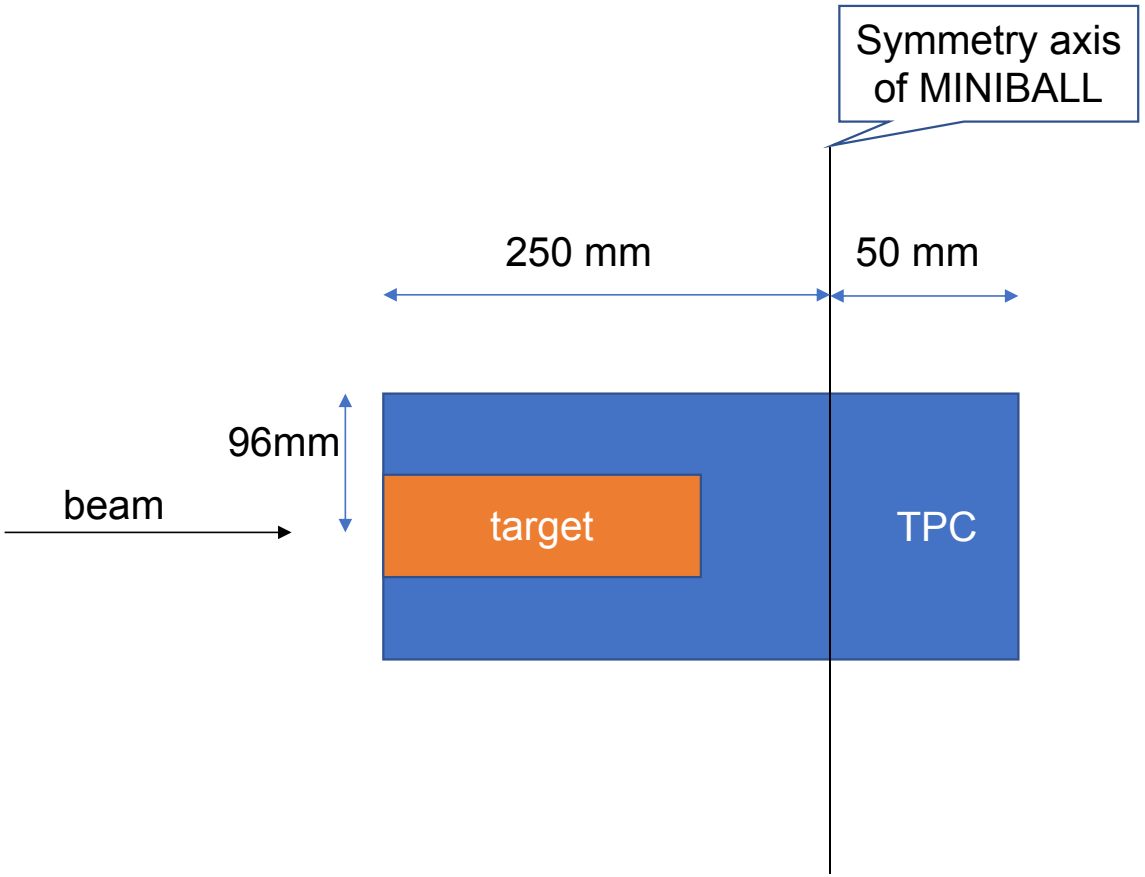


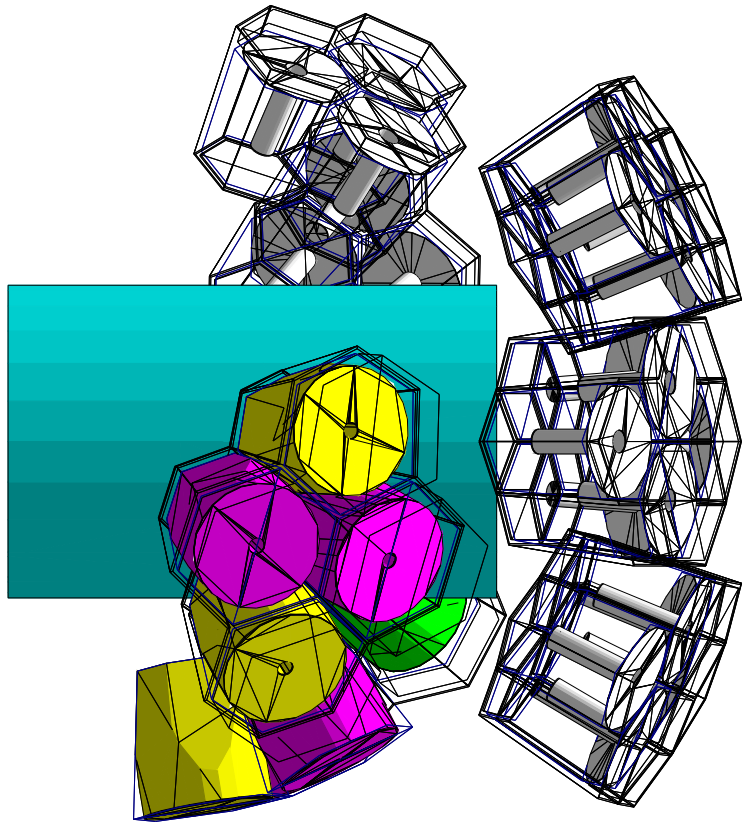


- sensitivity 10 - 100 ps
- shift of peak, transition energy needs to be known

MINOS implantation

- dimensions of the target and TPC from Anna
- possible interference of Miniball frame and cryostat

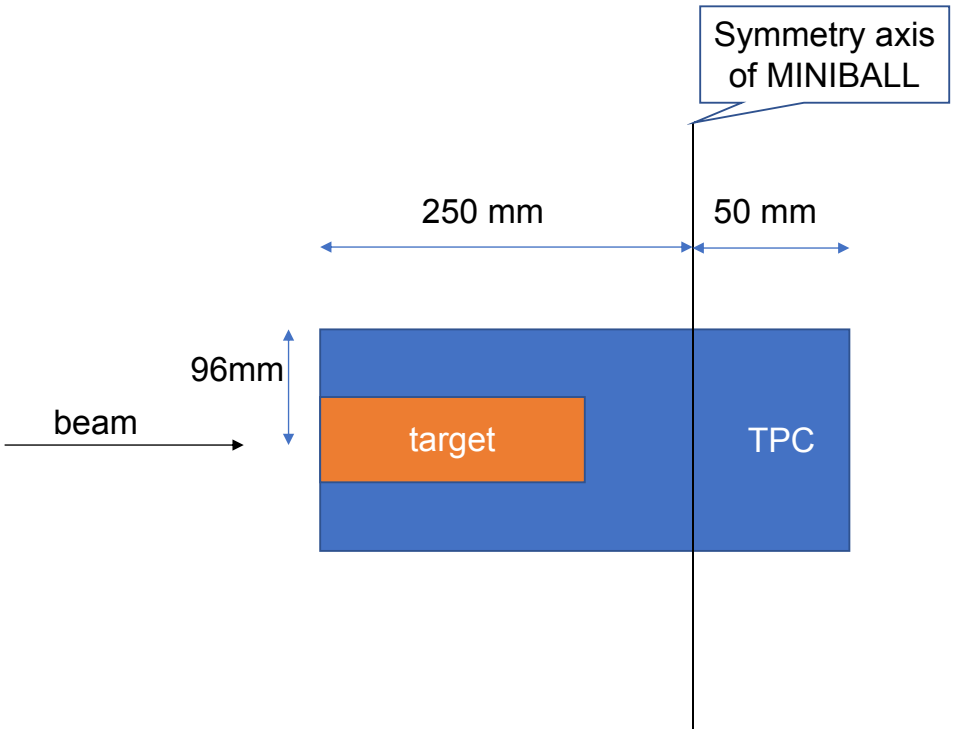


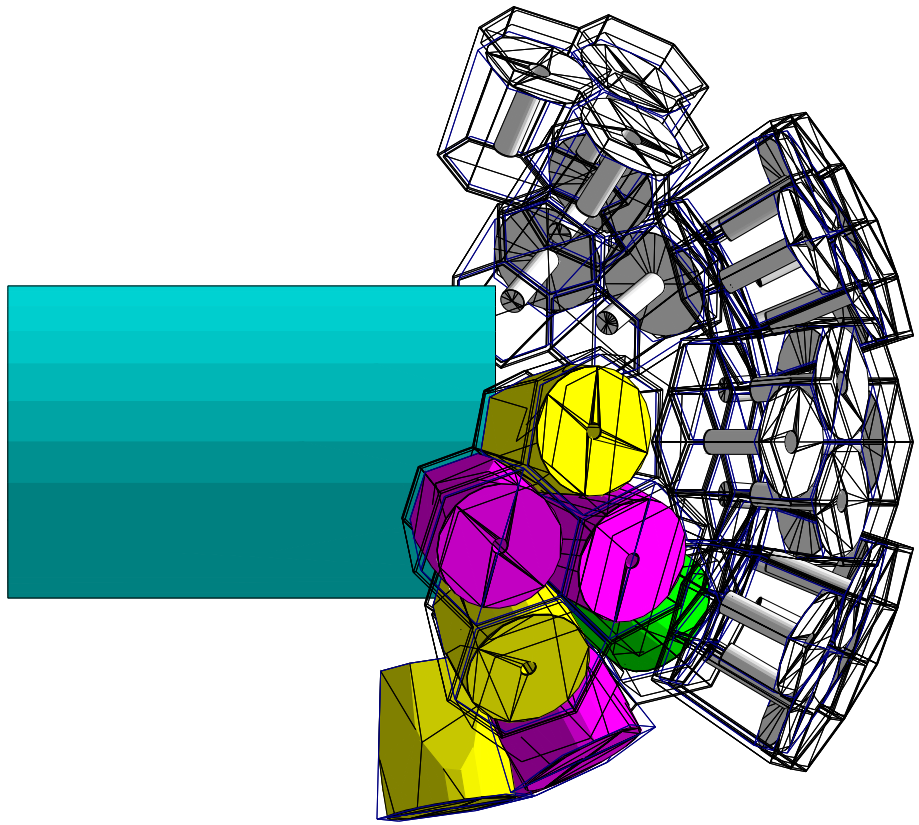


- if MINOS can be move freely, no loss of efficiency compared to standard beam-pipe and solid target

MINOS implantation

- shift upstream to accommodate cryostat
- allows for tight Miniball geometry in forward ring





- average distance to target larger
  → higher resolution, loss of efficiency

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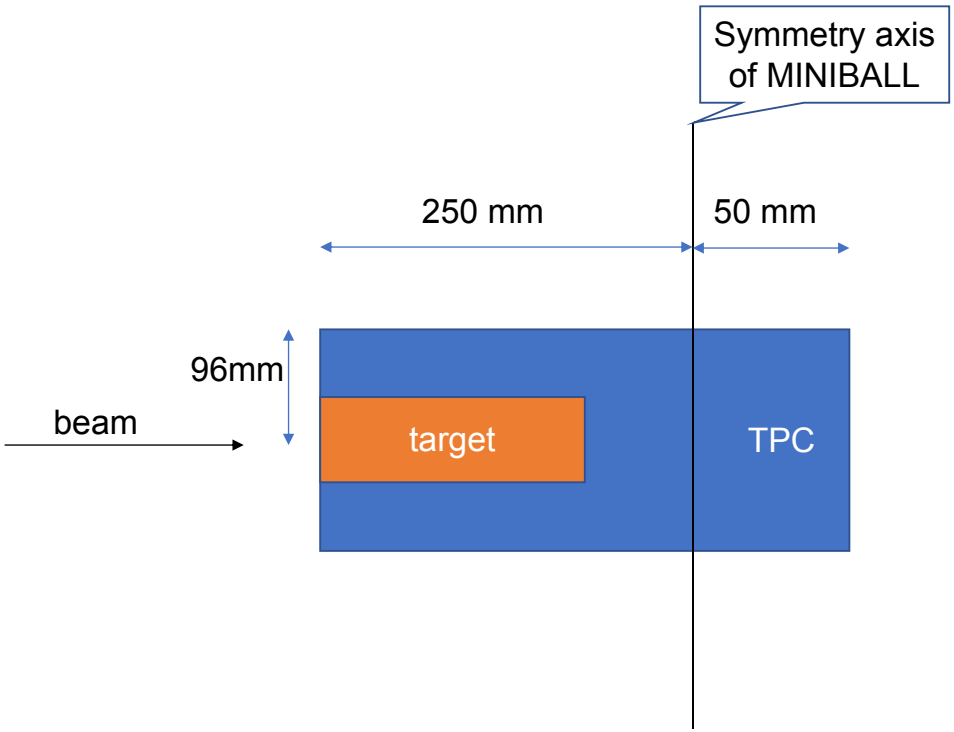

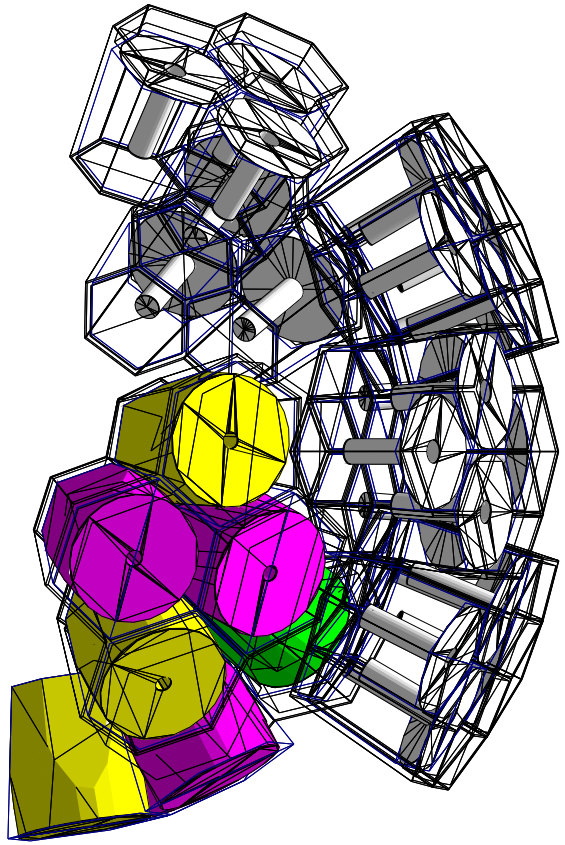

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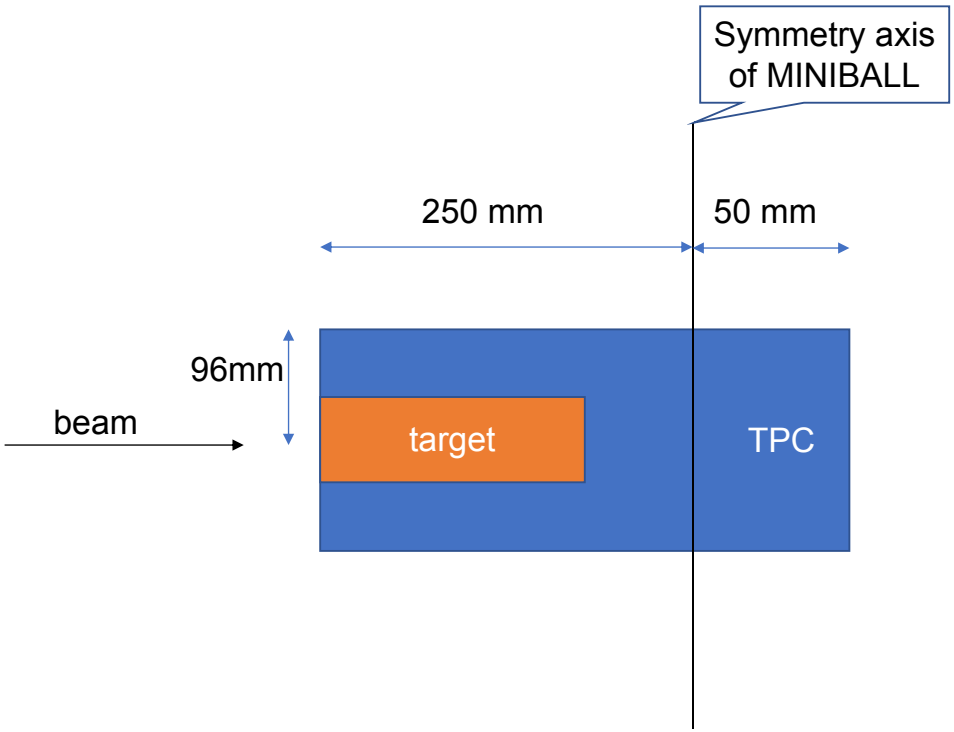

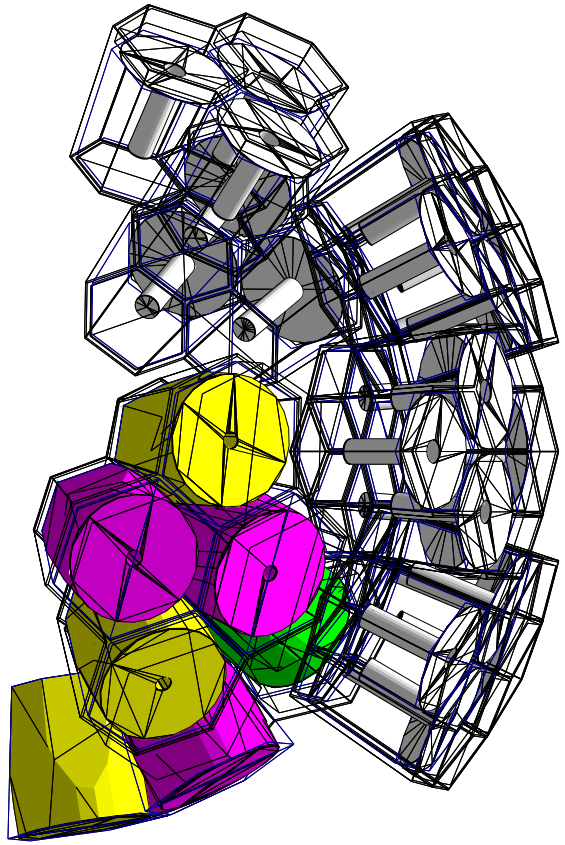

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geometry must be checked carefully

Summary

- simulation and analysis framework will be provided with the call for pre-proposals in a few weeks
- implementation of MINOS ongoing
- manual and test examples

Thanks to

L. Riley, Ursinus College
H. Crawford, LBNL

Thank you for your attention