Doppler-Shift based experimental techniques with AGATA at relativistic energies

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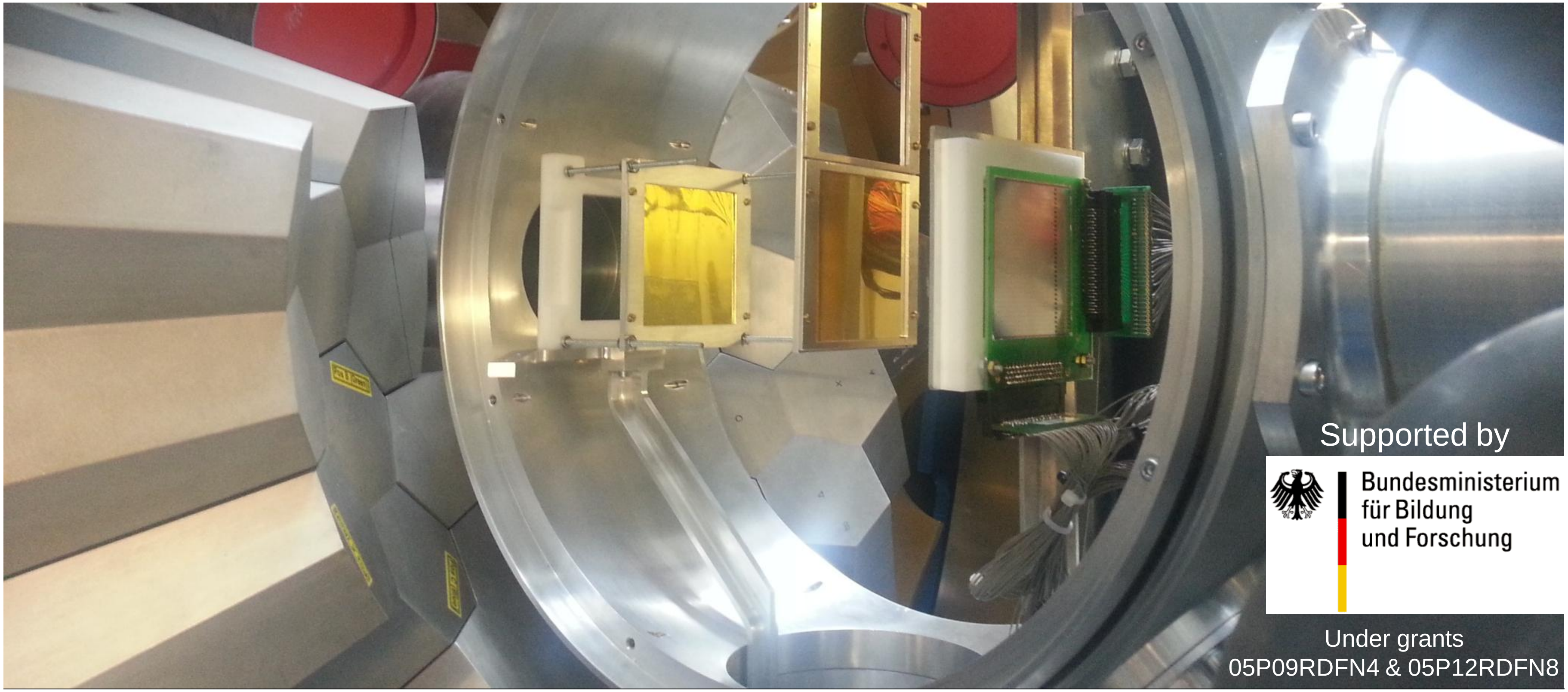

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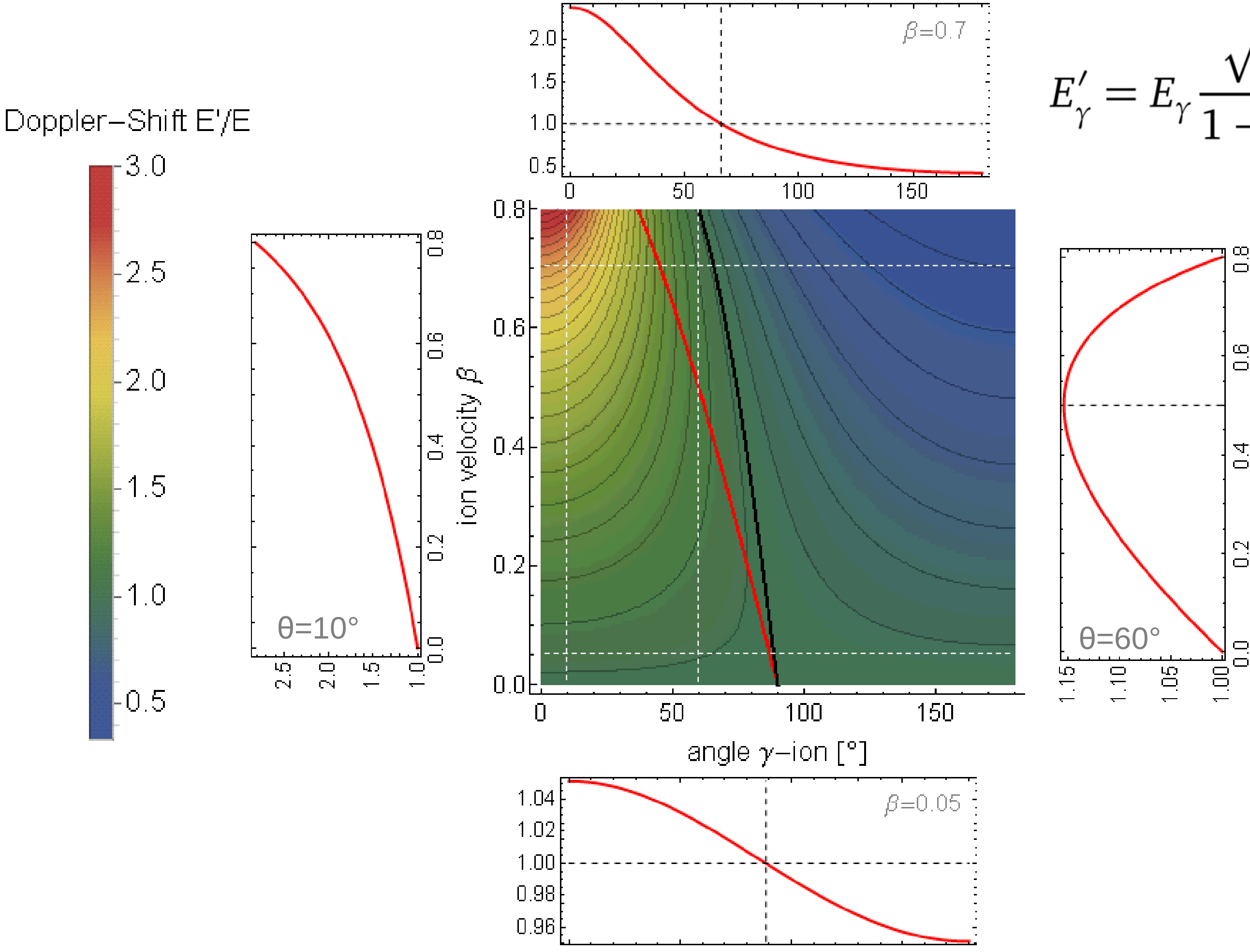
Topics

- Doppler-Shift revisited
- Lifetime measurements
- Measurement of multipole-mixing ratios

Doppler-Shift revisited

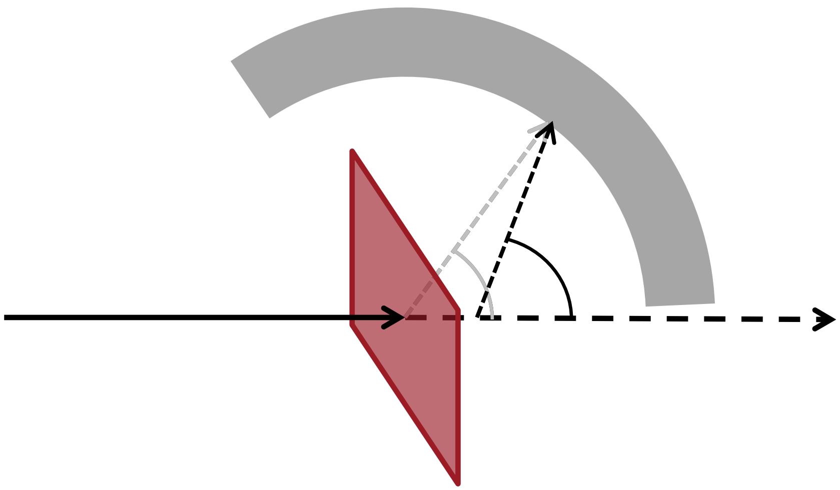


$$E'_\gamma = E_\gamma \frac{\sqrt{1-\beta^2}}{1-\beta\cos\alpha} \approx E_\gamma\,(1+\beta\cos\alpha)$$

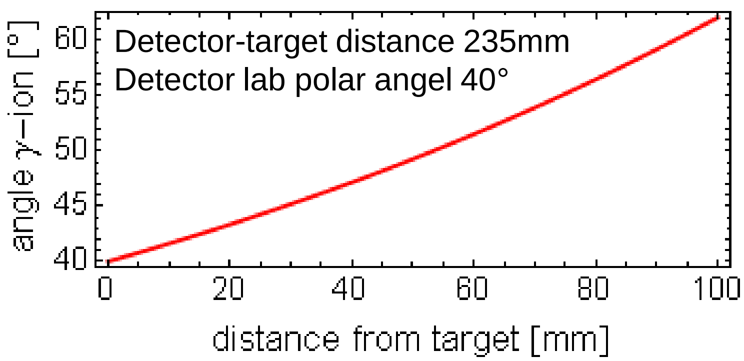
Independent from β

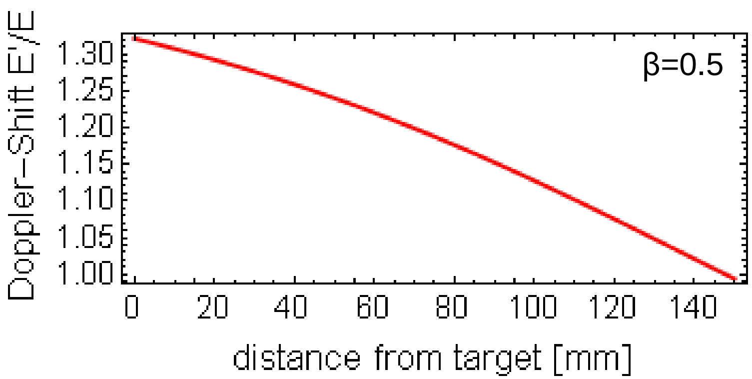
No Shift

Doppler-Shift revisited



Longitudinal Point of de-excitation usually **unknown**!





Doppler-Shift revisited

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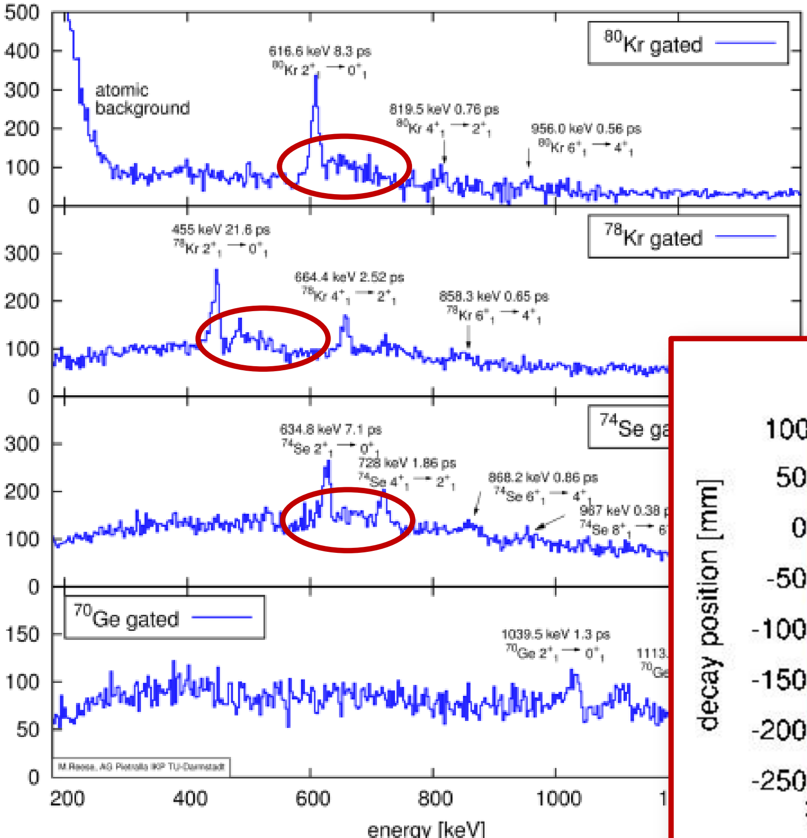
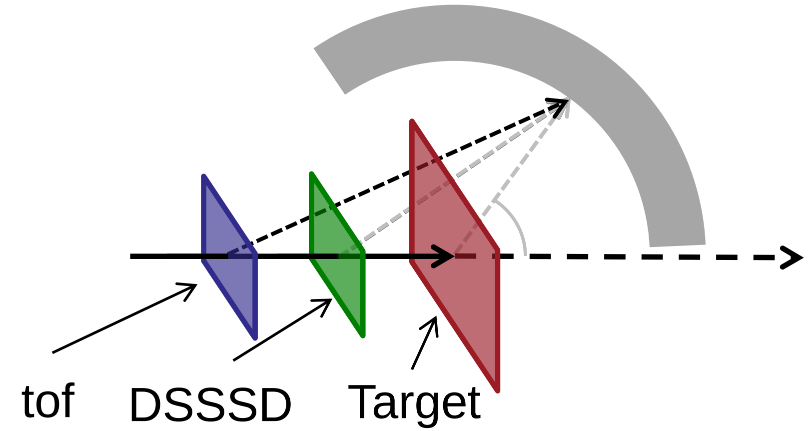
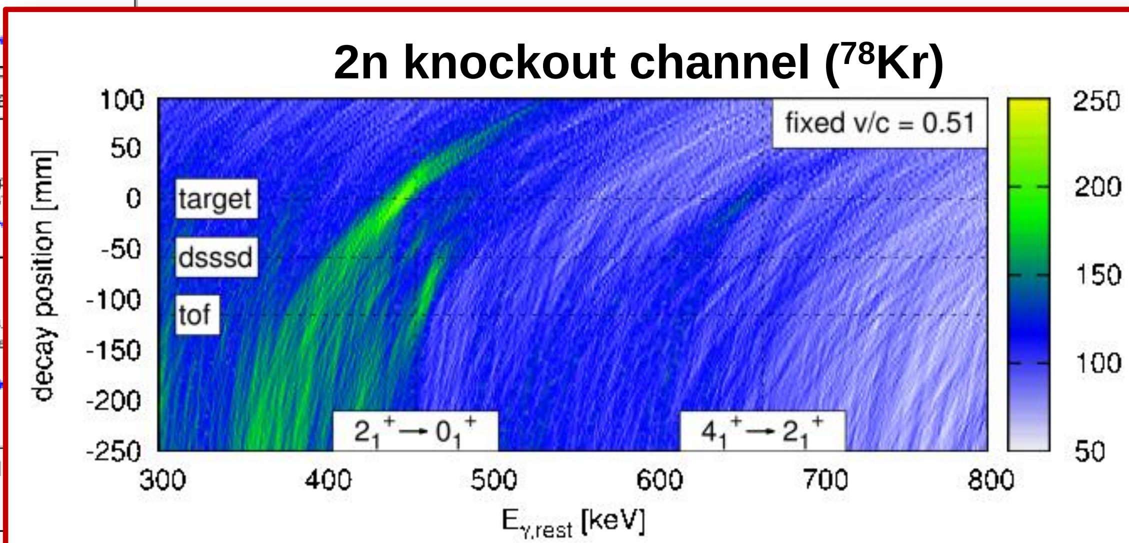
Observed in PreSPEC commissioning:

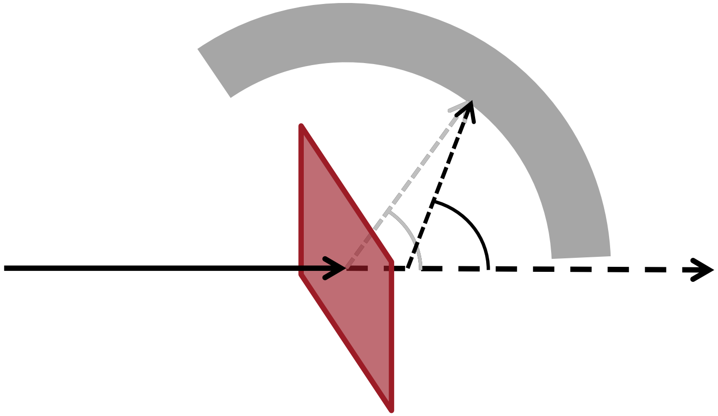
Detectors serve as additional targets







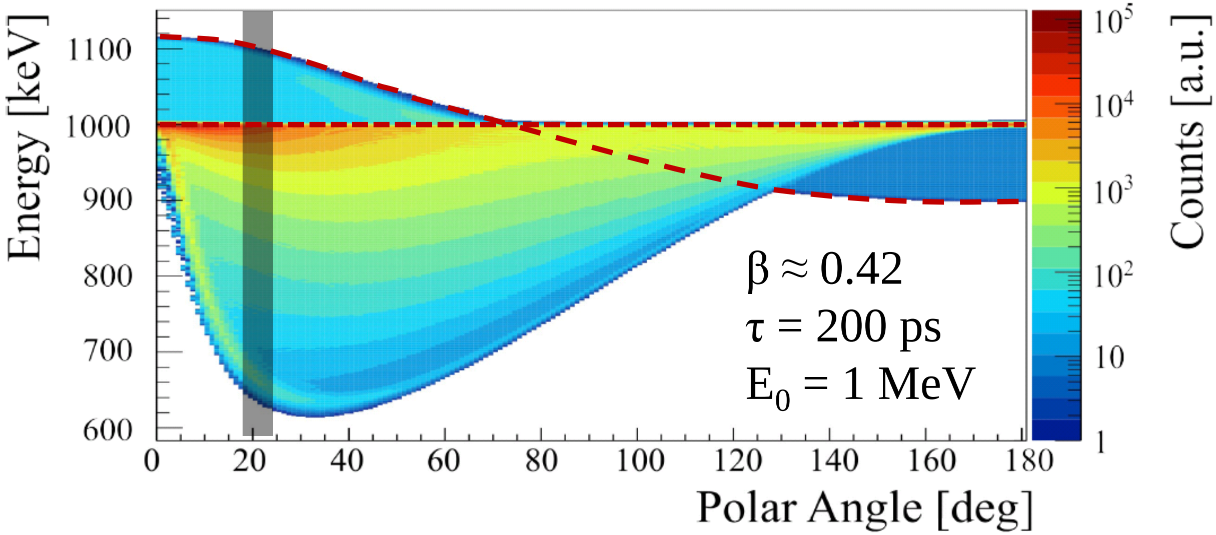
Lifetime measurements



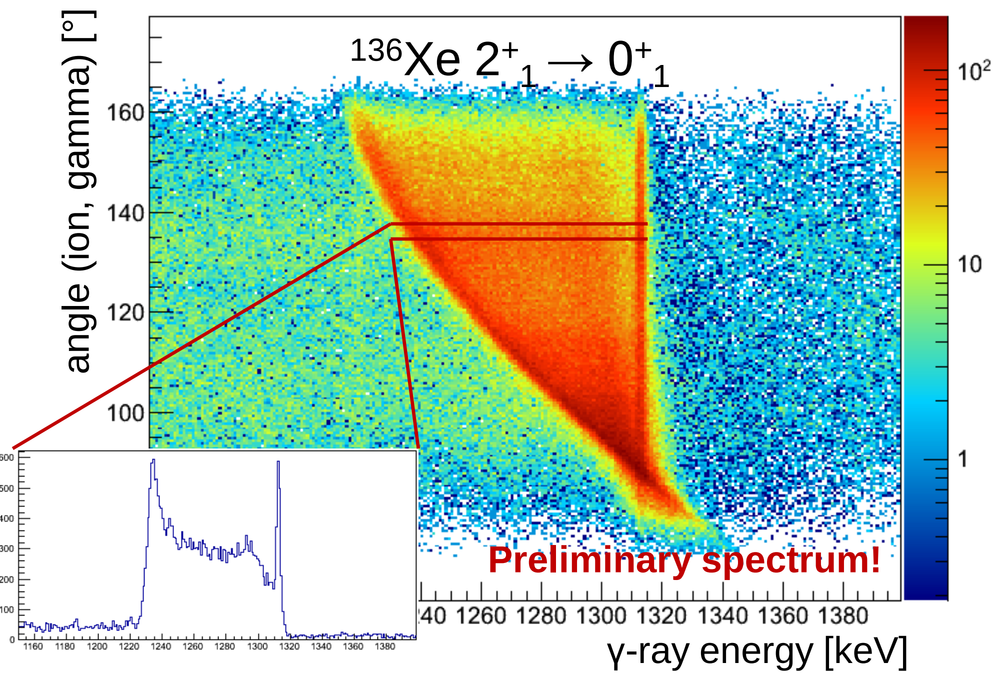
Longitudinal Point of de-excitation is a measure for the **level-lifetime**!

P. Doornenbal et al., NIM A 613 (2010) 218–225
C. Domingo-Pardo et al., NIM A 694 (2012) 297–312

Mean distance to target: $d=\beta\cdot\tau$
Example: $\beta=0.5$, $\tau=200\text{ps} \rightarrow d=30\text{mm}$

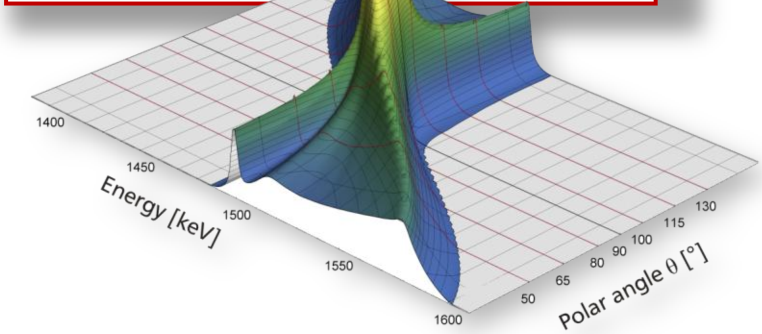


Lifetime measurements



Data from experiment 09.08 at LNL taken with the AGATA demonstrator

Analysis of Doppler-broadened lineshapes as function of energy and detection position



Example lineshape calculated with computer code APCAD

Measurement of multipole-mixing ratios

- E2/M1 Multipole mixing ratio: $\delta_{E2/M1} = \frac{\sqrt{3}}{10}\frac{E_\gamma}{\hbar c} \times \frac{\langle J_f || \hat{T}(E2) || J_i \rangle}{\langle J_f || \hat{T}(M1) || J_i \rangle}$
- Usually measured by analysis of γ-ray angular distributions
- New technique based on Coulomb-excitation cross-section measurement

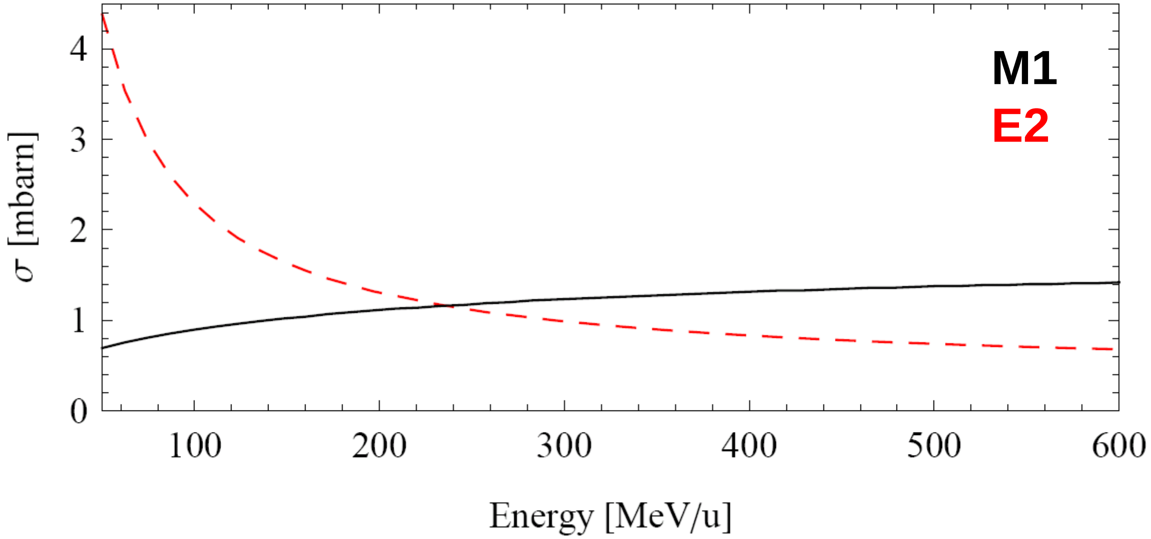


Fig.: Coulomb-excitation cross-section of the 1191 keV-level of ^{85}Br. Assuming 1 W.u. for both M1 and E2 transition strength. Target material: Gold.

Measurement of multipole-mixing ratios

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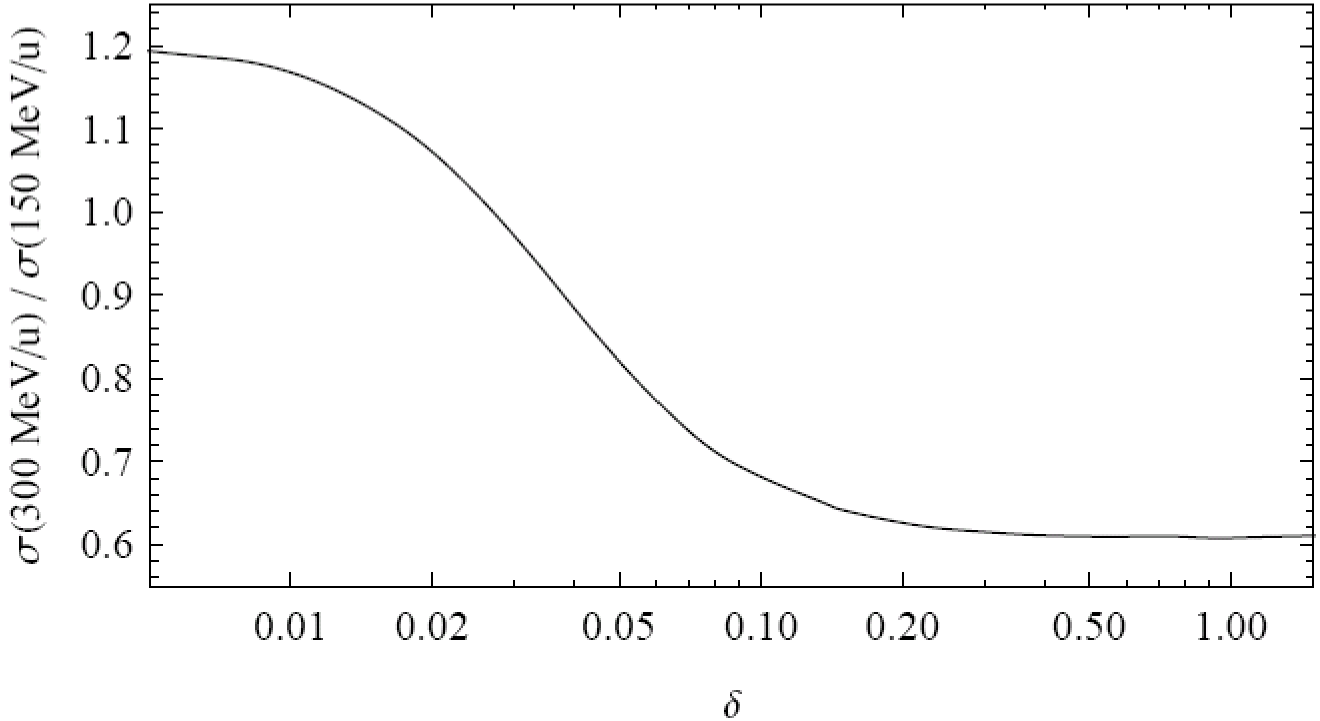
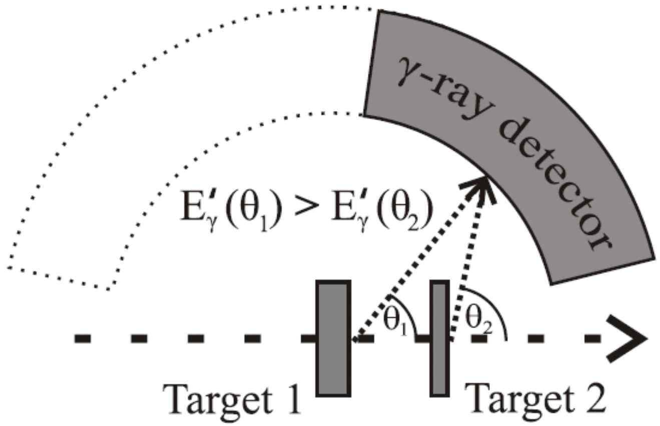
- Measure Coulomb-excitation cross-section at two different beam energies
- Ratio of cross-sections is a measure for the multipole mixing-ratio

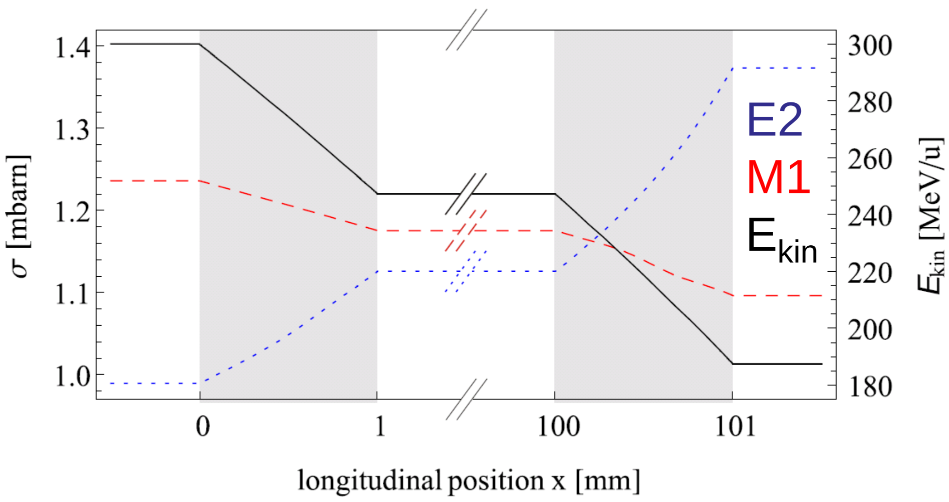


- **Drawback:** Need lot of beamtime for two measurements

Measurement of multipole-mixing ratios

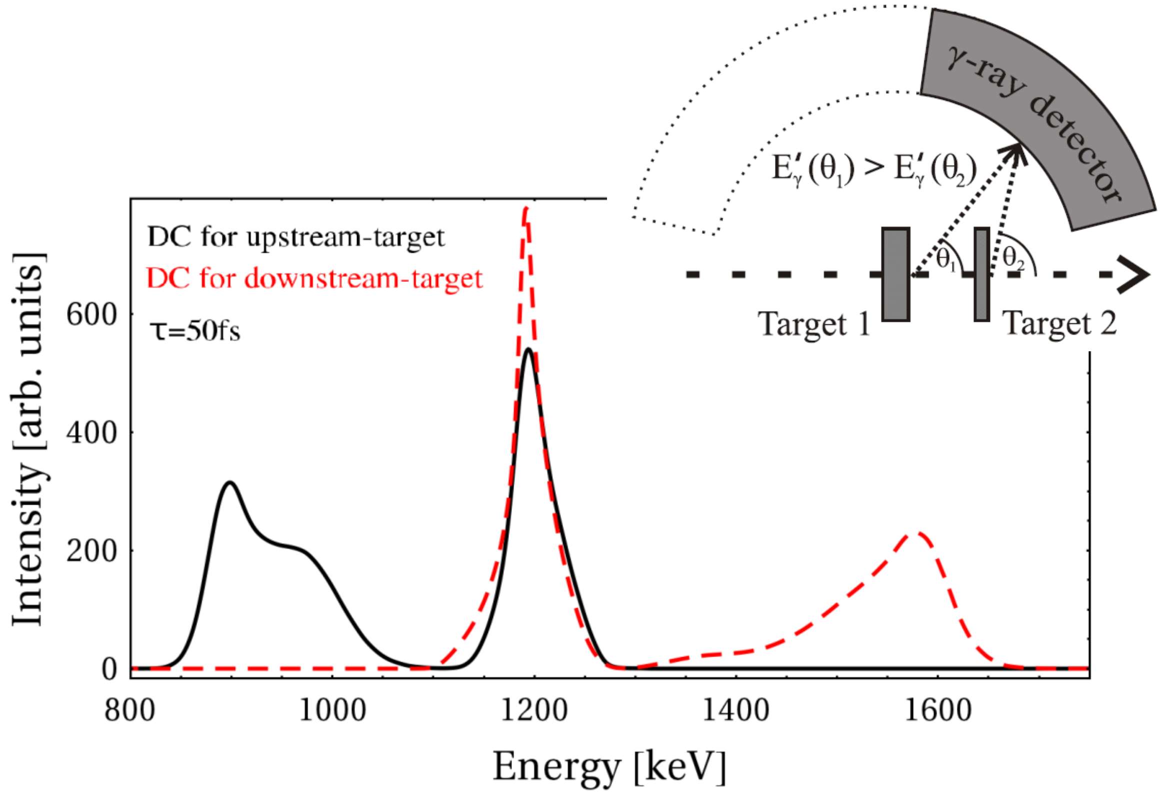
- **New approach:** Perform both measurements in one experiment by using two thick targets

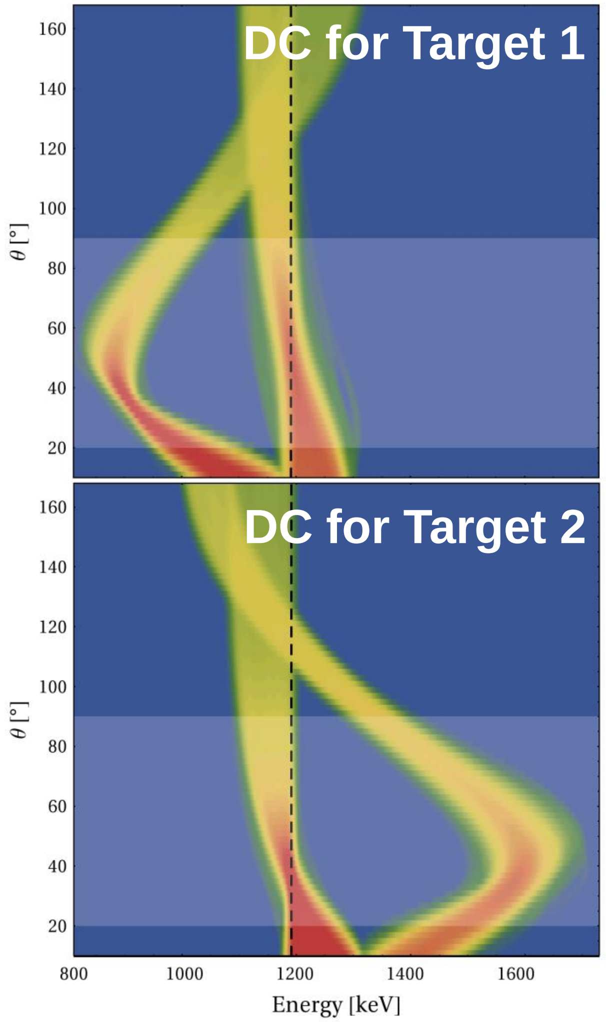




Measurement of multipole-mixing ratios

- Distinguish γ-rays from the two targets by their Doppler-shift





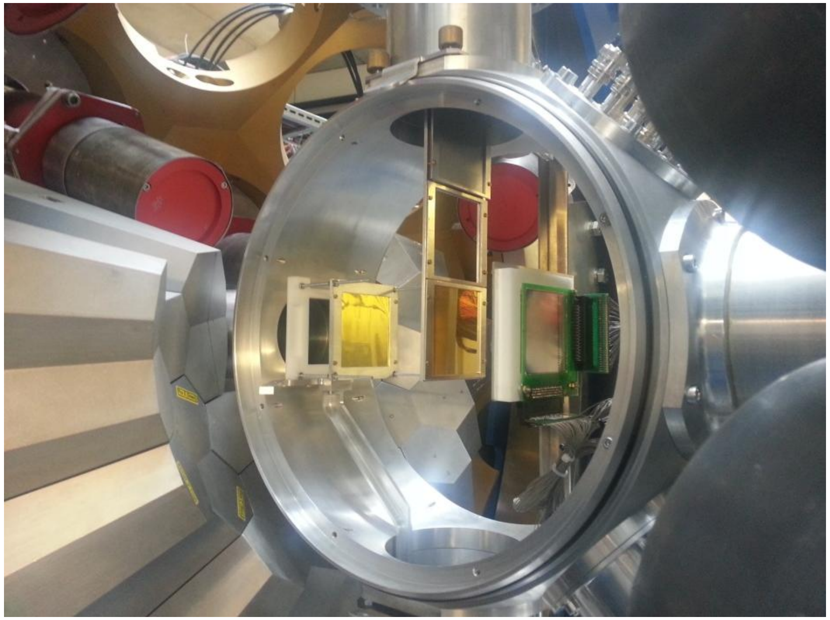
Summary

- AGATA's position resolution produces high sensitivity to the longitudinal position of γ-ray emission

- Basis for new experimental techniques:

  "geometric DSAM"

  "Coulex-multipolarimetry by the Two-Thick-Targets-Method"



Setup of experiment S426: (Pietralla, Rainovski et al.)
Relativistic M1 Coulomb-excitation of ^{85}Br

M1-Coulex:
AGATA vs. “standard” - HPGe

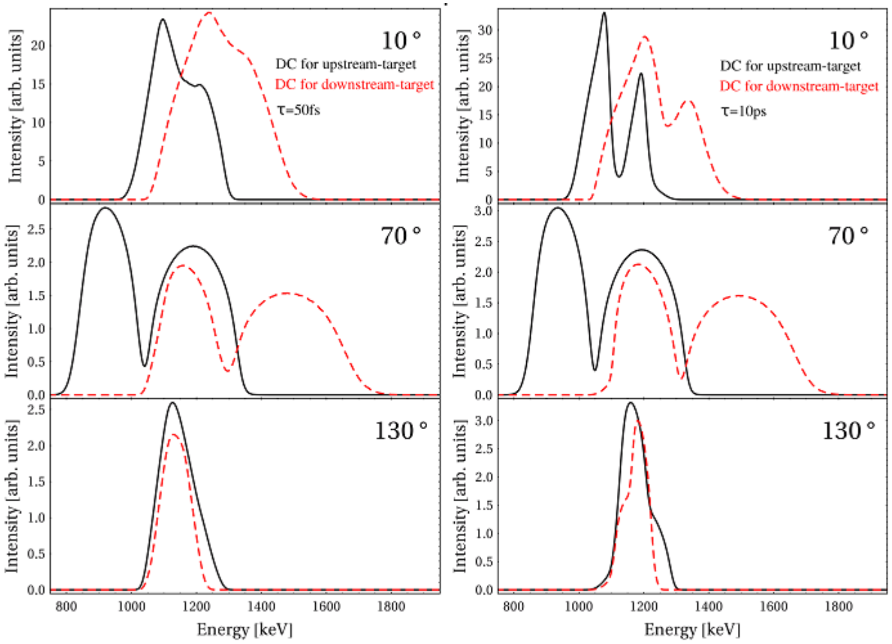
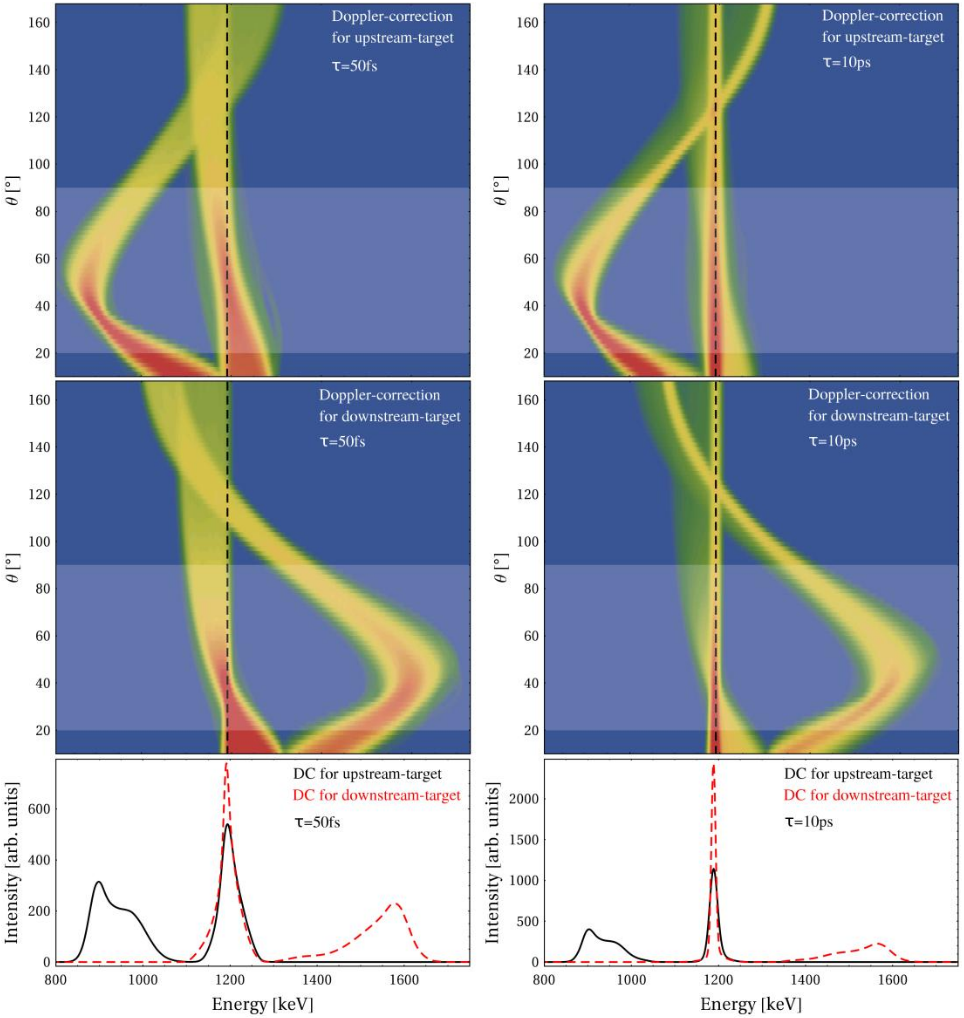


Figure 7: γ-ray spectra simulated with a modified version of the computer code *APCAD* [13] for the 1191-keV transition from the $\frac{1}{2}^-$ to the $\frac{3}{2}^-$ ground-state in ^{85}Br. Parameters are as in figure 6, but position in-sensitive, cylindrical detectors with a diameter of 8 cm places in a distance of 23.5 cm around the center of the upstream target were assumed. Spectra are shown for detectors places at angles $\theta = 10°, 70°, 130°$ with respect to the beam axis.



"Geometric" DSAM

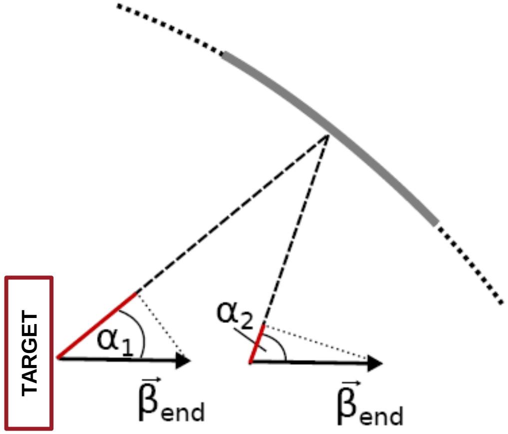
Application of the DSA Method with relativistic, radioactive ion beams

- **Another sensitivity region with "geometric DSAM" in the order of 100ps:**

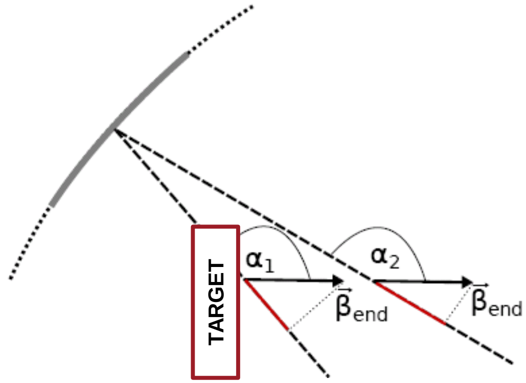
  Doppler-correction on exit velocity "fails", if decay occurs far behind the target (assumed angle between direction of ion motion and gamma detection is wrong)

  P. Doornenbal et al., NIM A 613 (2010) 218–225; C. Domingo-Pardo et al., NIM A 694 (2012) 297–312

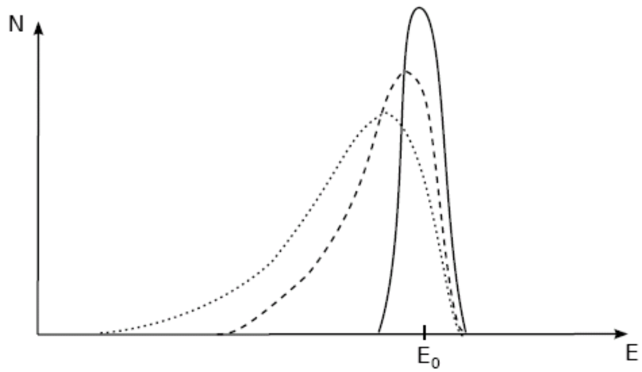
  → **A "continuous Plunger":**



Detector under forward-angle:
Over-estimation of Doppler-shift

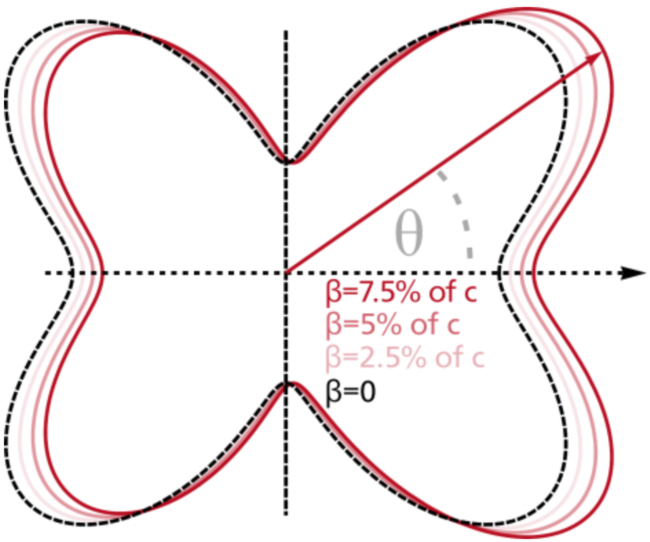


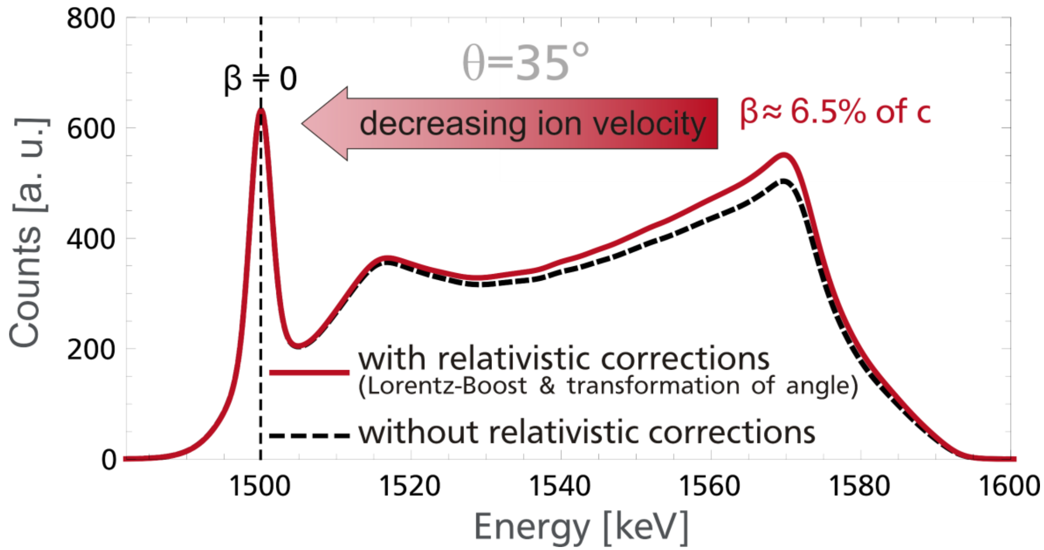
Detector under backward-angle:
Under-estimation of Doppler-shift



Importance of angular distribution in the analysis of DSAM experiment

- Relativistic corrections of the detector **solid angle** (Lorentz boost)
- Transformation of the **angular distribution** from the ion rest frame to the lab frame





LNL experiment 09.08 (Oct 2011)

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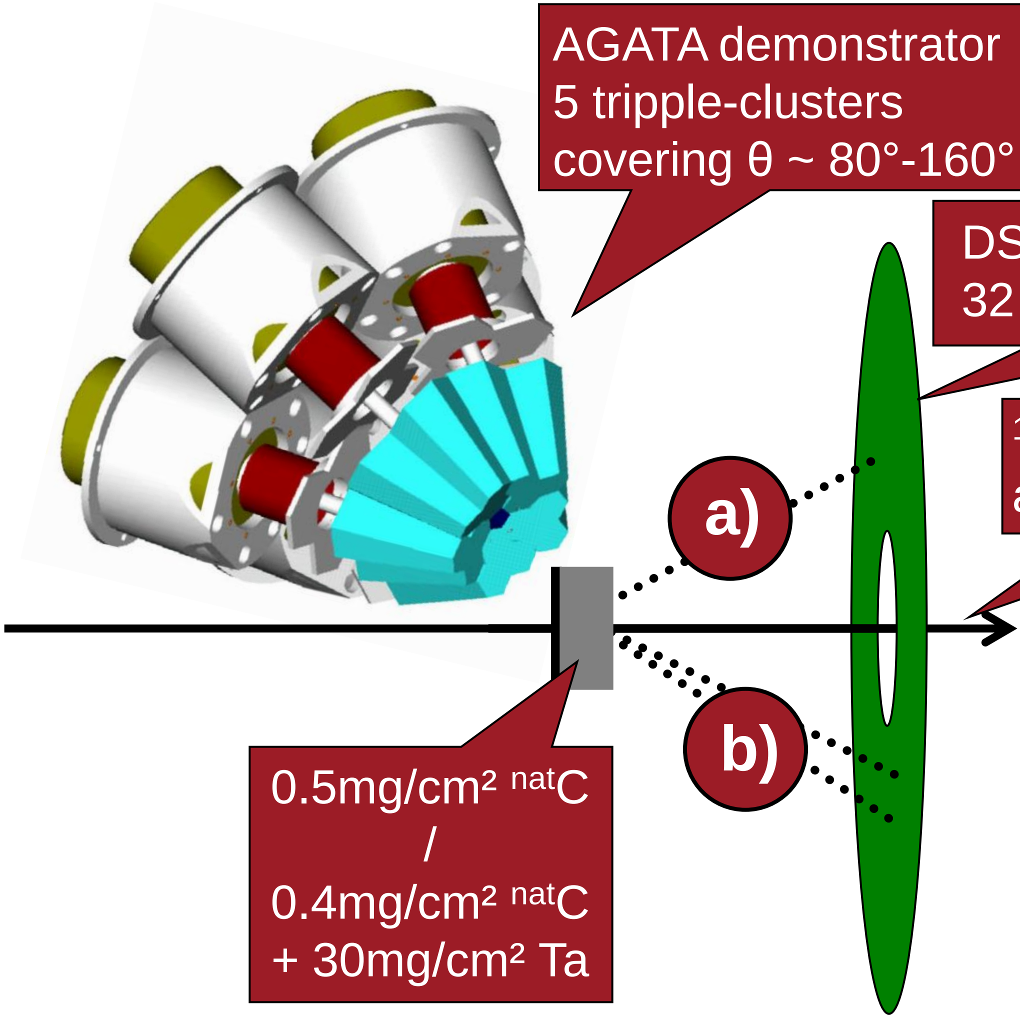


Two reactions:

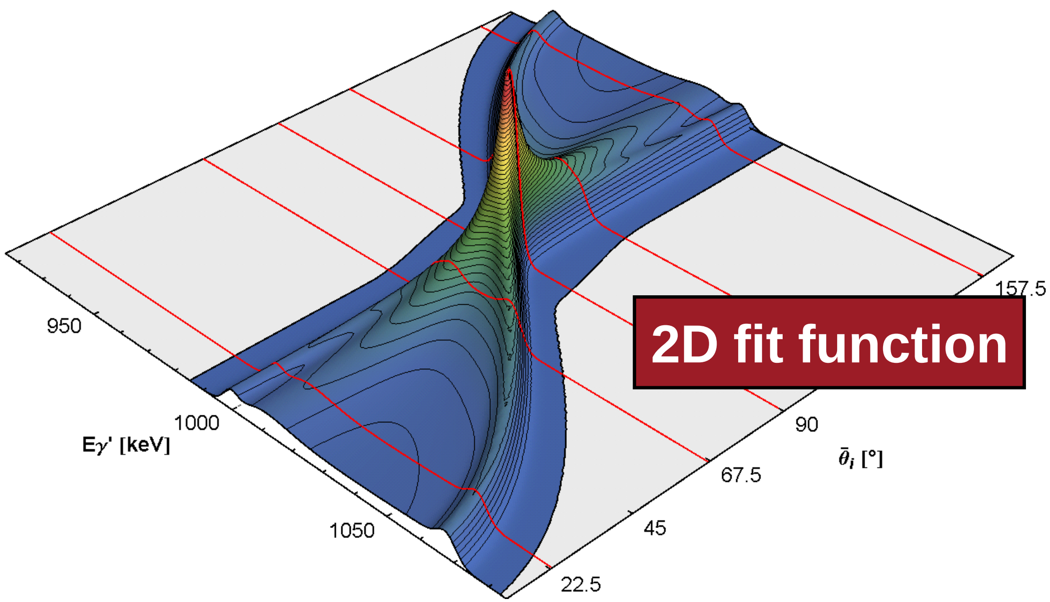
a) Coulomb excitation of ^{136}Xe
(register Carbon recoil)

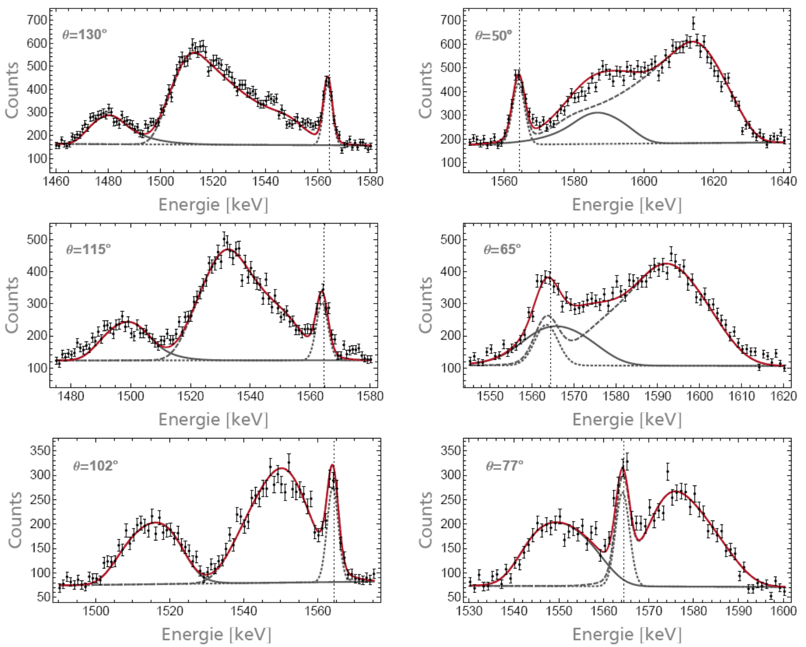
b) α-transfer reaction
^{12}C(^{136}Xe, ^{8}Be) ^{140}Ba*
(register 2α from ^{8}Be decay)

- Do not observe a lineshape at one polar angle only, but **continuously** at **many polar angles simultaneously**

Continuous-angle DSAM:

calculate a **2-dimensional fit function** for a **2-dimensional data set**





^{86}Kr: 2^+_1 and 3^-_1 lineshapes

Choice of excitation situation