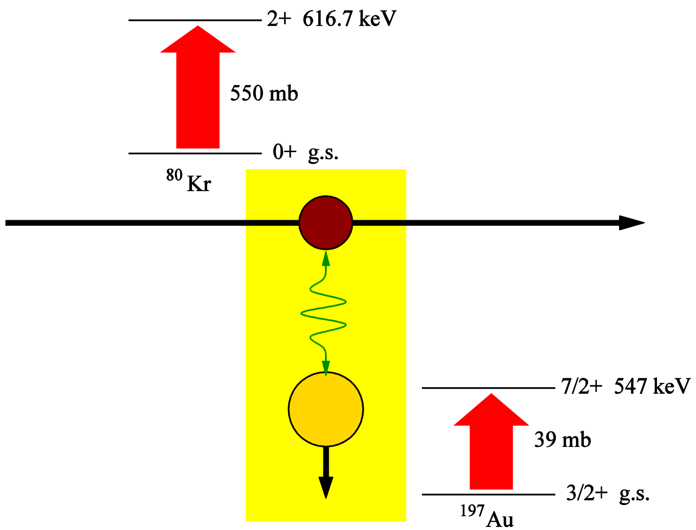
Results of the PreSPEC Commissioning Run

M. Reese on behalf of the PreSPEC and AGATA collaborations

AG-Pietralla, TU-Darmstadt

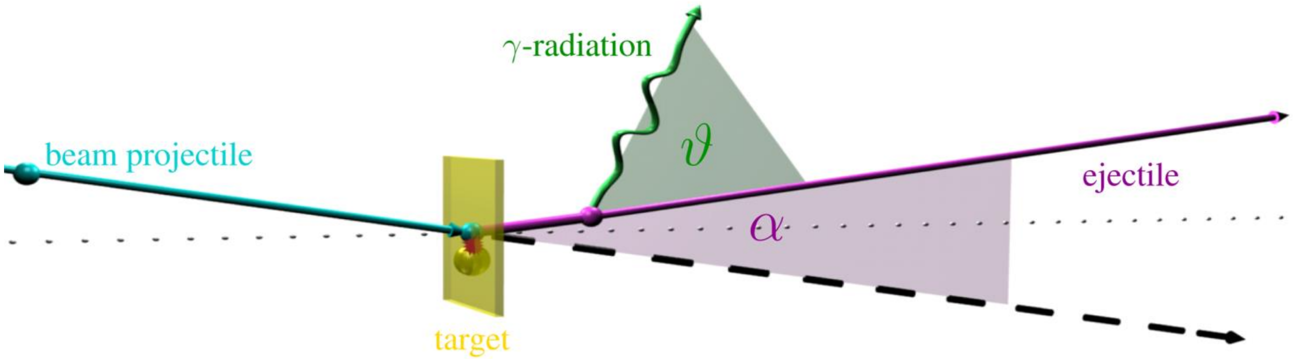


Outline of Presentation

- In-beam γ-spectroscopy
- AGATA data analysis
- Particle identification and tracking in the target area
- Gamma spectra of ^{80}Kr: Fragmentation & Coulex
- Efficiency and beam properties
- Data analysis software

Experimental Challenges

1. Beam from accelerator (or in-flight separator)
2. Nuclear reaction in a fixed target
3. Excited reaction products leave the target (flight direction changes)
4. Emission of Doppler-shifted γ-Radiation



- Need γ-energy in the rest frame of the emitting nucleus (Doppler-correction)
- Need the tracks of particle and γ-ray
- Spectroscopic resolution depends on **accurate track reconstruction of both, γ-ray and particle!**

The PreSPEC-AGATA Performance Commissioning Run

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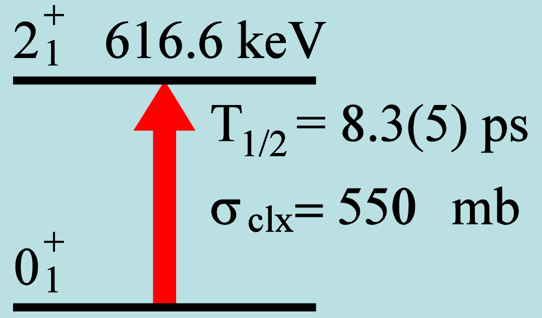
Goals

- **Demonstrate performance** of AGATA at relativistic beam energies
- **determine** typical **background** and detection sensitivity
- Obtain first data for the **optimization** of Pulse-Shape Analysis and Gamma-Ray Tracking algorithms

^{80}Kr



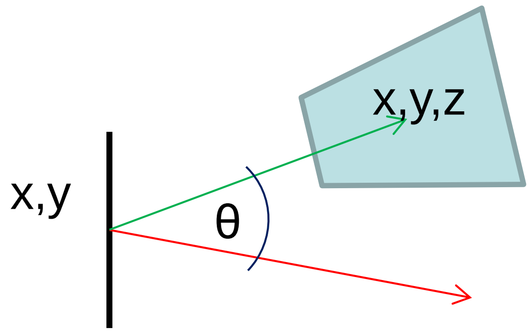
- Large Coulex cross section
- Reasonably long lifetime (no decay inside the target)

Different Runs

- 0.4 mg/cm² Au target in central position (22h, Coulex)
- 0.4 mg/cm² Au target 12cm downstream of center (51h, Coulex)
- 0.150 mg/cm² Be target in central position (29h, Fragmentation)

AGATA Data Analysis, Calibration & PSA

- AGATA DAQ writes pre-amplifier traces to disk
- Improvement of pulse-shape analysis is possible after the experiment
- Not done (so far) with the performance commissioning data
- Results shown here are based on the online PSA
- final results should improve (resolution, efficiency) with optimized PSA



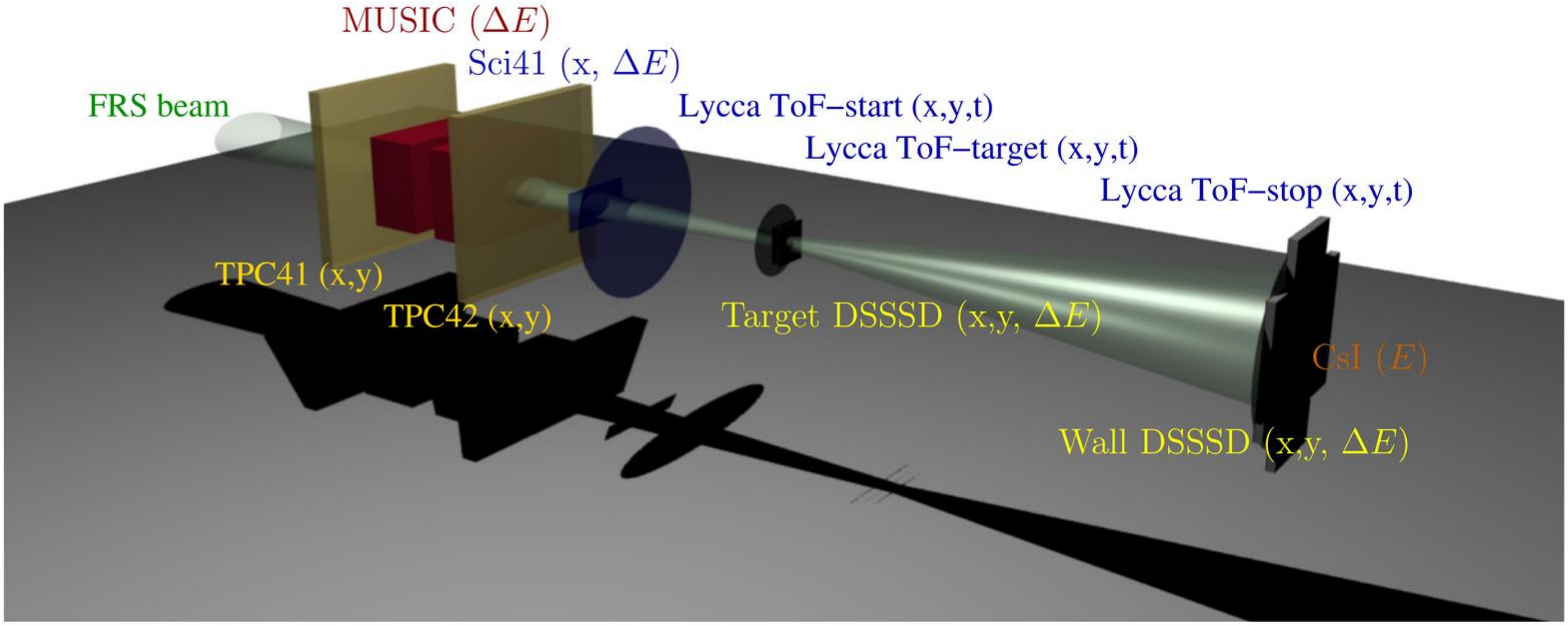
Particle Tracking & Identification at Secondary Target

FRS detectors

- 2 TPCs for particle trajectory
- 2 Ionization chambers for Z identification

LYCCA detectors

- 17 silicon DSSSD detectors for tracking and energy loss
- 144 CsI scintillators for particle energy
- 3 fast plastic scintillators for time of flight and tracking



Outgoing Particle Identification with LYCCA

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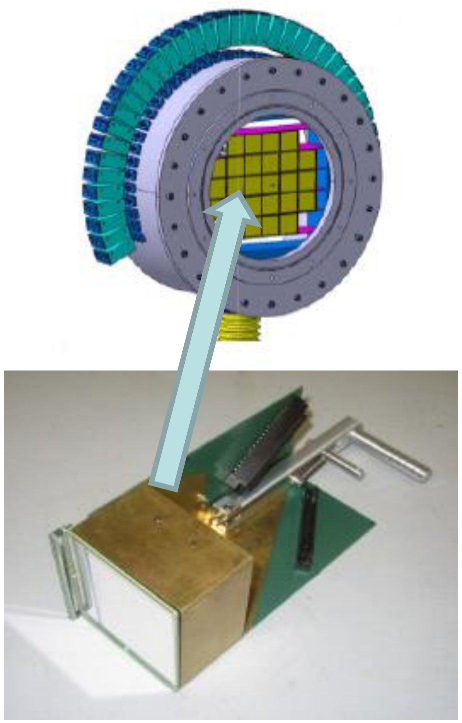
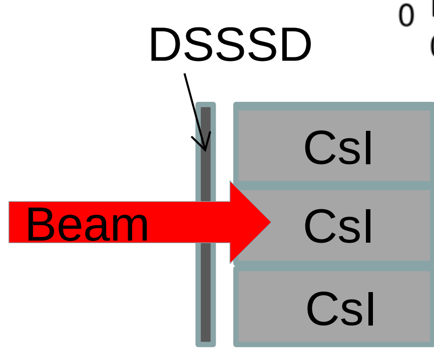
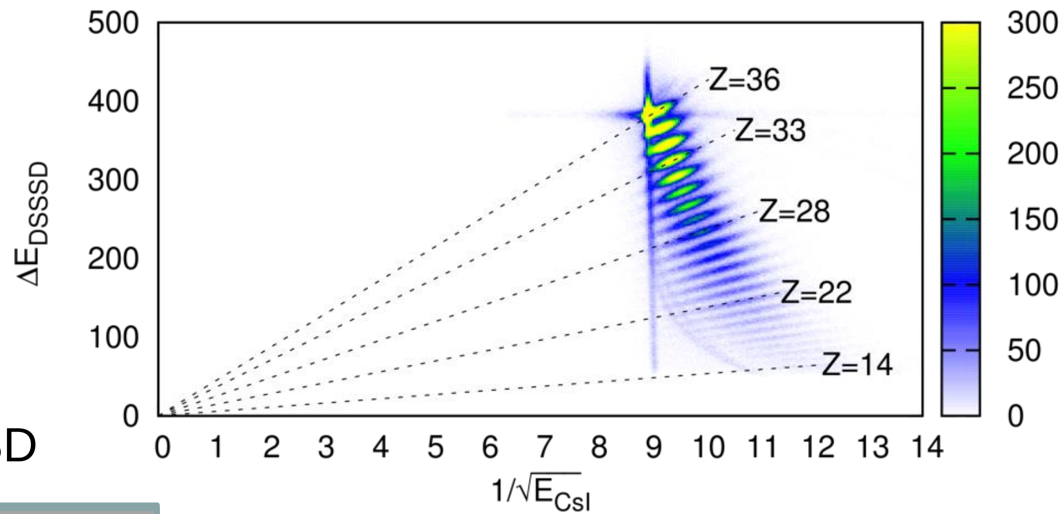
Z identification with ΔE-E method:

- ΔE measured as energy loss in a planar Silicon-strip detector
- E measured as the energy deposition in a CsI stopper





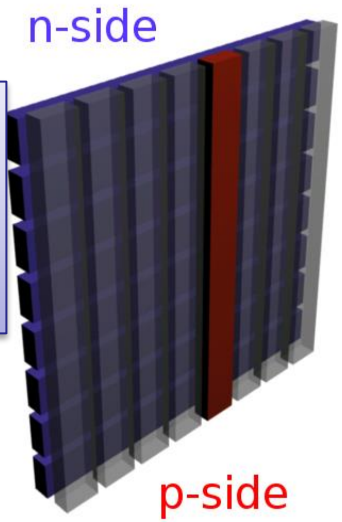


CsI gain matching (calibration) has to be done „by hand“

DSSSD Calibration: Problem & Solution

LYCCA Double-Sided Silicon-Strip Detectors (DSSSD) measure for each particle after the target position (x,y) and energy-loss (ΔE).

- x,y important for Doppler-correction
- ΔE important for particle identification, calibration of individual strips required (512 channels)
- Individual strips are small (low statistics in singles spectra)
- Long calibration runs are needed with a mono energetic beam.



New algorithm to gain-match all strips within one module:

- all n-side strips are matched to one p-side strip
- all p-side strips are matched to the gain-matched n-side
- works with production beam without calibration run

Automatic DSSSD Calibration

Definition of gain-matched DSSSD module:

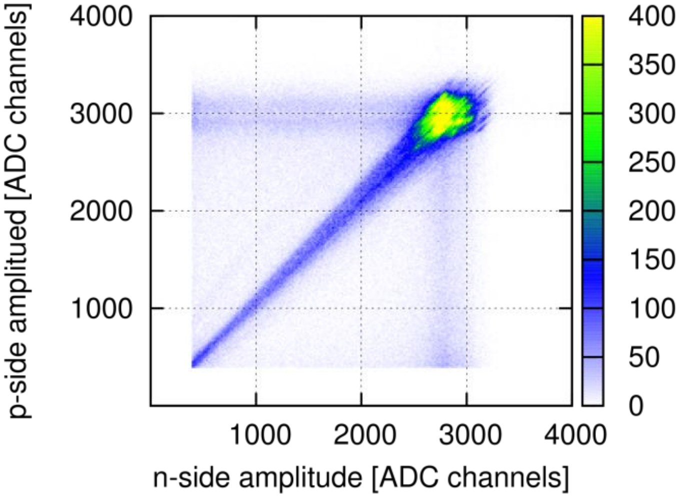
For any pixel that was hit, p-side and n-side agree in the energy that was measured

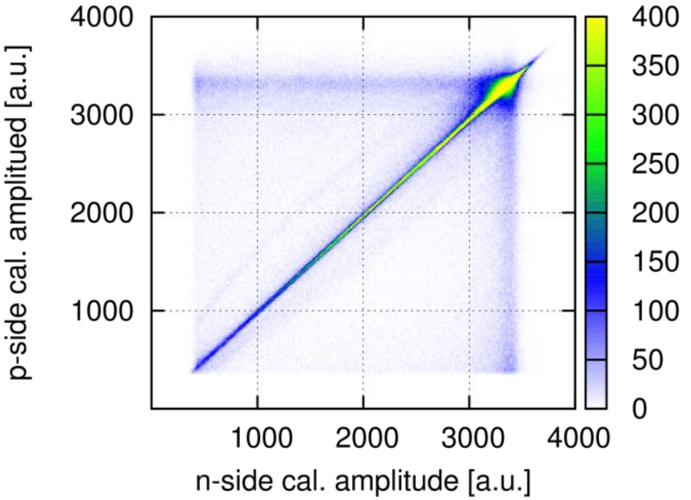
Algorithm:

- For each pixel, determine the ratio between n-side and p-side amplitude $S_{pn} = An/Ap$
- Choose the calibration parameters (slopes) for p-side s_p and n-side s_n to minimize

$$\sum_{p,n} \left(\frac{S_{pn} - \frac{s_p}{s_n}}{\Delta Sp_n} \right)^2$$

- s_p, sn are then the best gain matching coefficients (assumption: no offset)
- Implementation is very robust and works without any human supervision!





Outgoing Particle Identification with LYCCA: Masses

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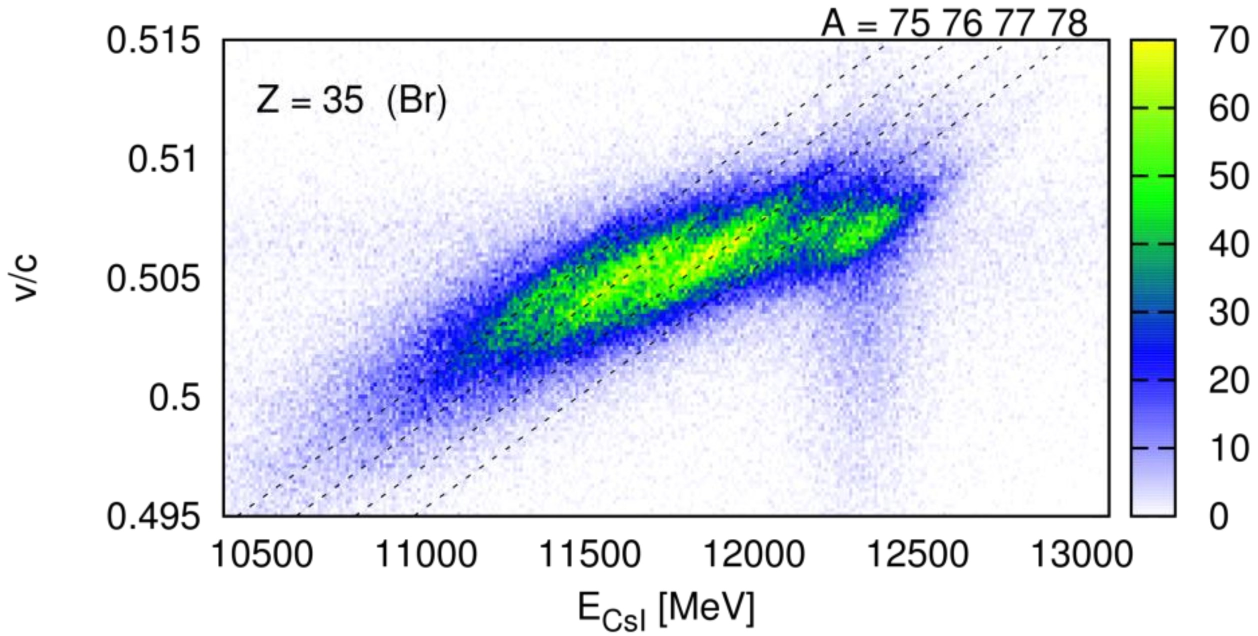
Mass identification with time-of-flight (ToF) measurement:

- Time-of-flight between two fast scintillation detectors
- ToF vs. E (CsI) with condition on a single Element
- Projection along diagonal lines gives mass (or neutron number)



LYCCA ToF Detector calibration

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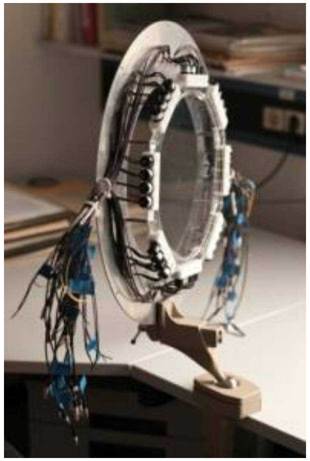
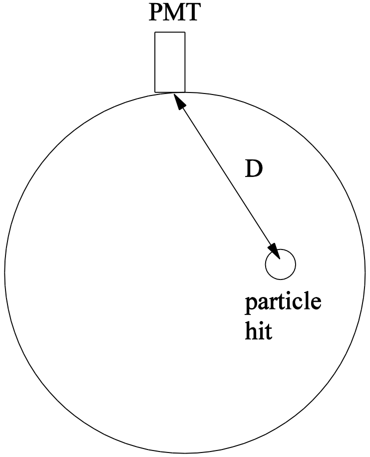
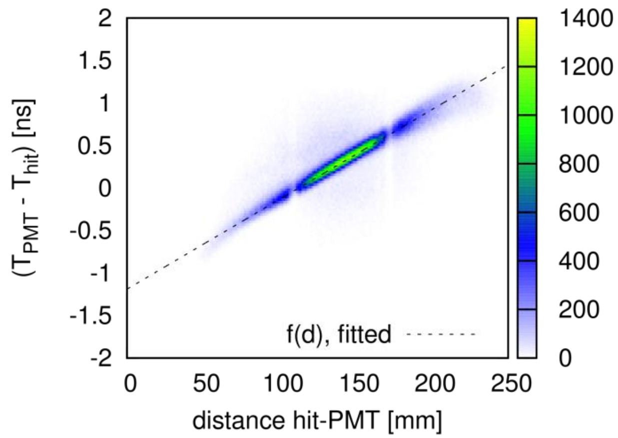
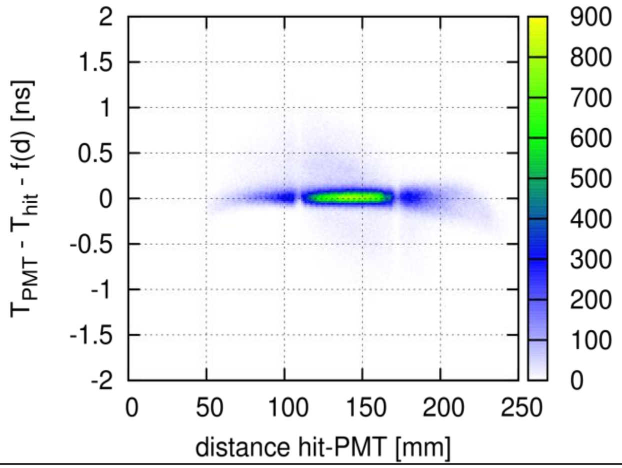


picture: R. Hoischen et al., NIM A 654 (2011) 354-360

- correlation bewtween the distance (particle – PMT)
- after correcting for that Detector resolution is about $\frac{\Delta T_{PMT}}{\sqrt{N_{PMT}}} = 25\ \mathrm{ps}$
- Individual PMT resolution can be determined with particle time as reference.
- The detector can measure intrinsic resolution by itself!



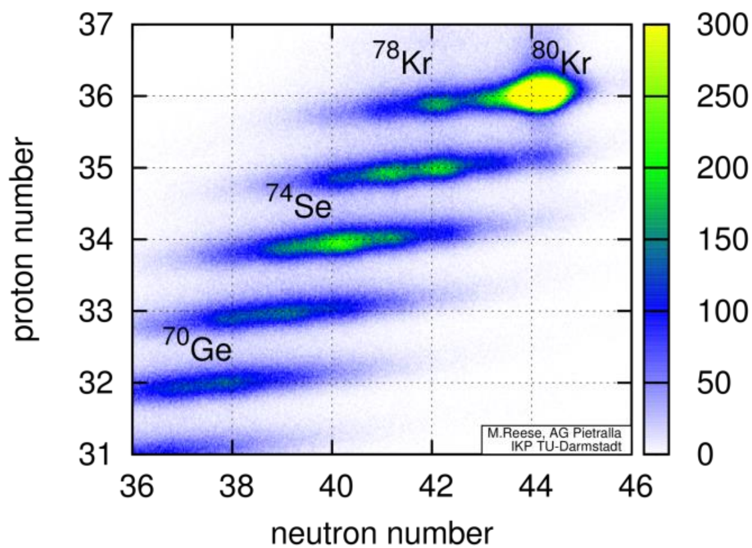


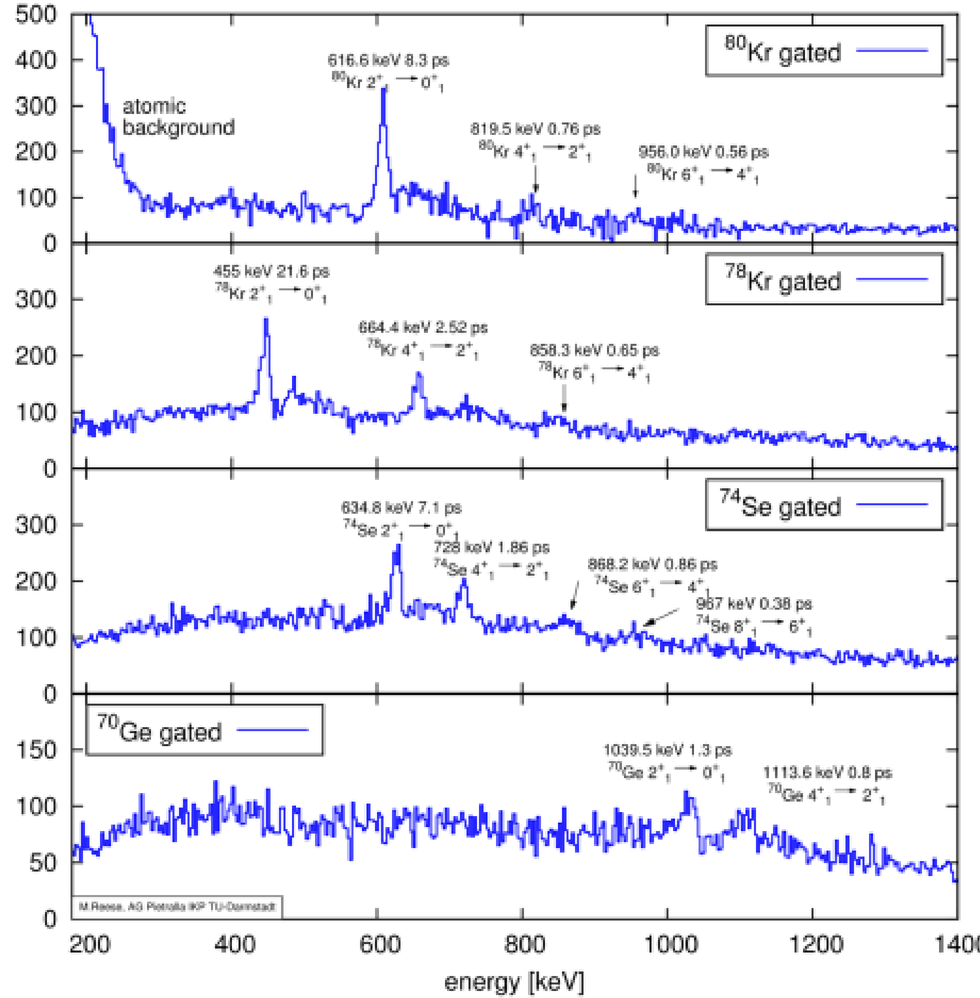


80Kr Secondary Fragmentation

Gates on the most abundant even-event nuclei after secondary Be-target

- First Yrast states visible



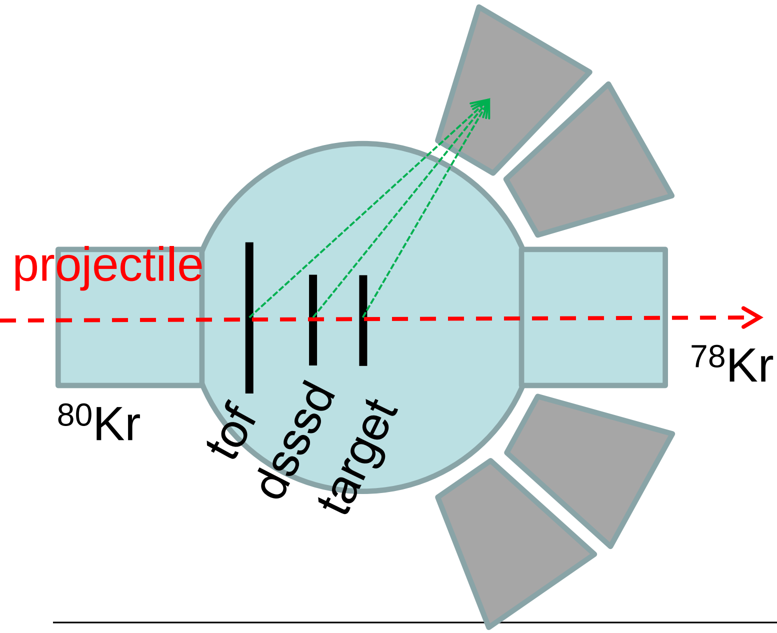


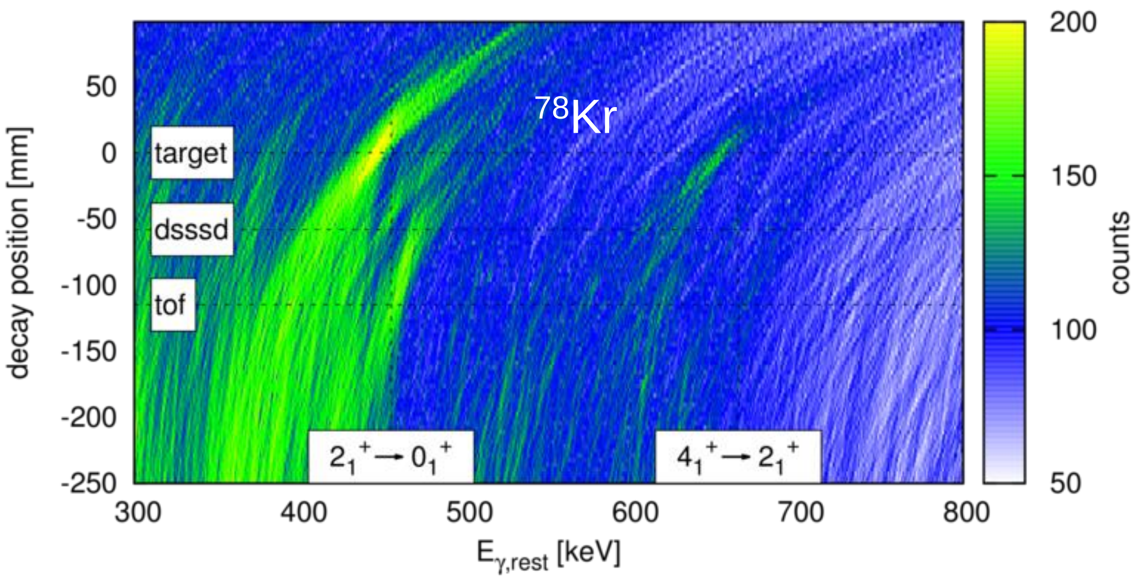
The Location of Gamma Emission

Reminder: Doppler effect

$$E_{\text{laboratory}} = E_{\text{rest}} \frac{\sqrt{1-\beta^2}}{1-\beta\cos(\vartheta_{\text{lab}})}$$

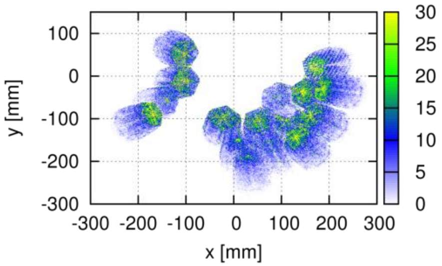
- For each detected gamma event: Guess the location of de-excitation along the particle trajectory.
- Gamma lines will appear if the de-excitation point is correct

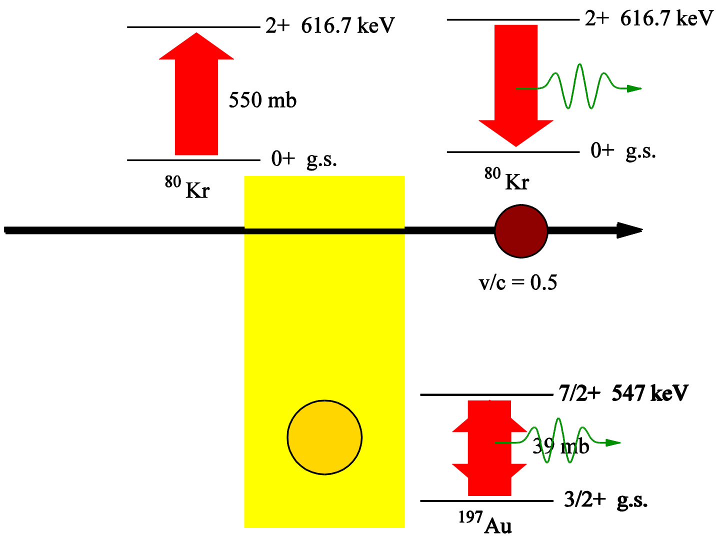


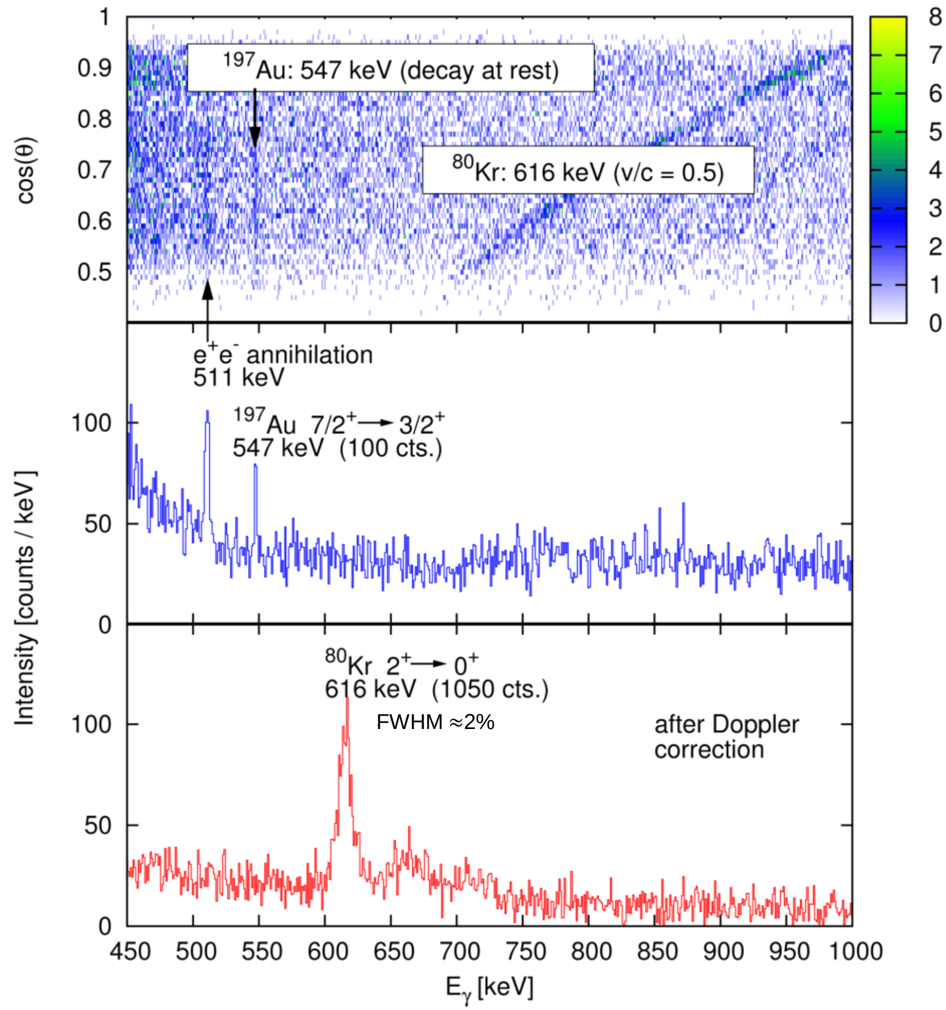


Coulomb Excitation of ^{80}Kr on Gold

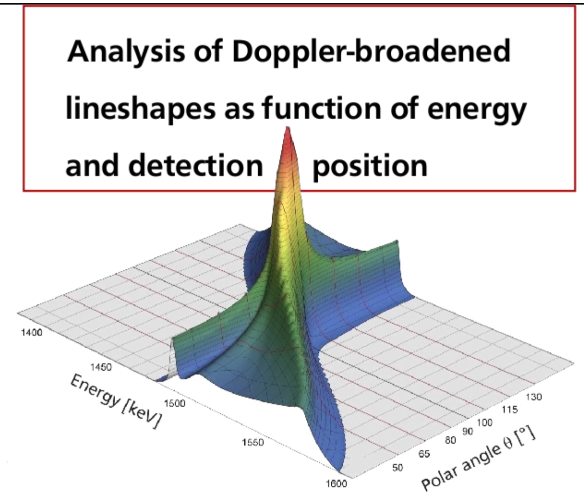
Coulomb excitation of ^{80}Kr





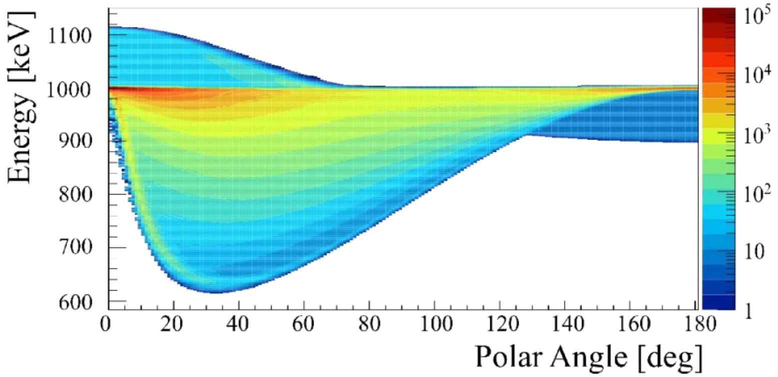


Analysis of Spectra: Special Software



Example lineshape calculated with computer code APCAD

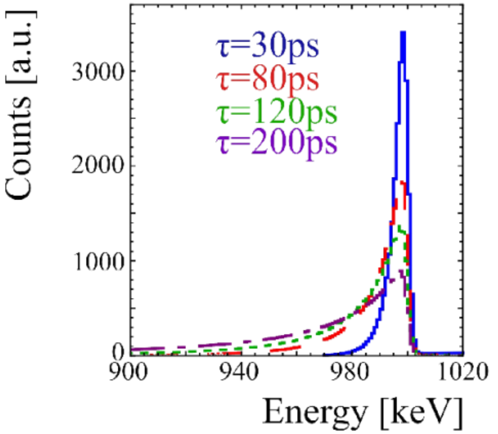
(C. Stahl, MSc thesis, AG Pietralla, TU Darmstadt, 2011)



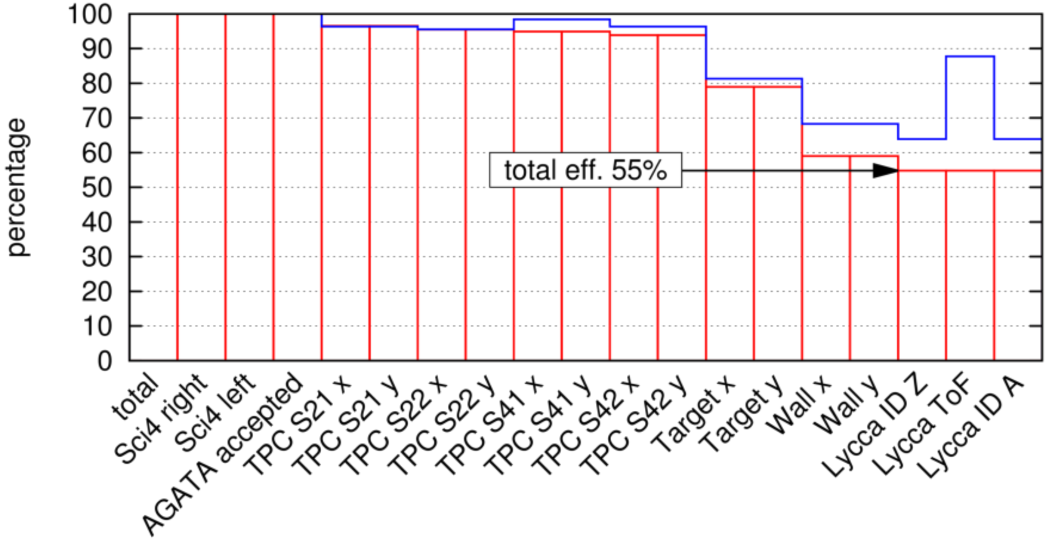
(M. Lettmann, MSc thesis, AG Pietralla, TU-Darmstadt 2013)

Software (C. Stahl / M. Lettmann) describes and fits Doppler-broadened lineshape as function of gamma-ray energy and detection angle for a relativistic emitter, i.e. an excited exotic ion from the FRS.

Shapes are lifetime dependent.
Lifetime measurements of excited states!



Efficiency Considerations



Hits in different detectors

Hits in a detector AND all previous

Estimate number of Expected counts (no Gamma-Ray Tracking)

- Expected number of counts

  $= N_{part.}\ P_{excit.}\ eff_{part.}\ eff_{DAQ}\ eff_{AGATA}$

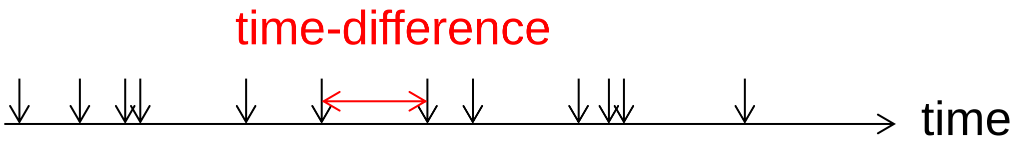
  $= 370e6 * 5.8e\text{-}4 * 0.55 * 0.85 * 14 \times 0.0021$

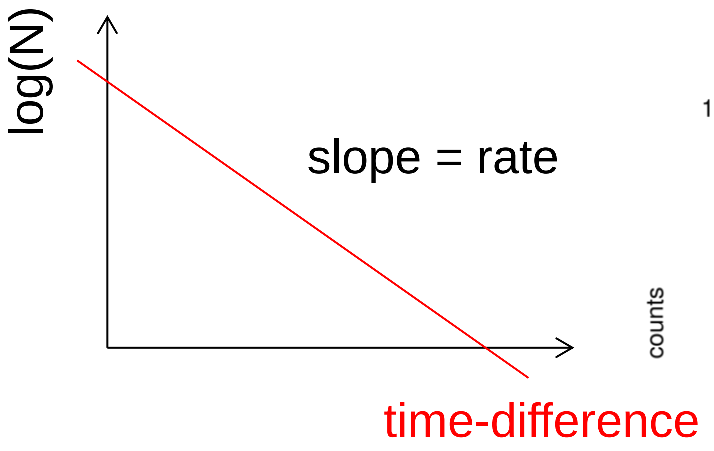
  $= 3000$

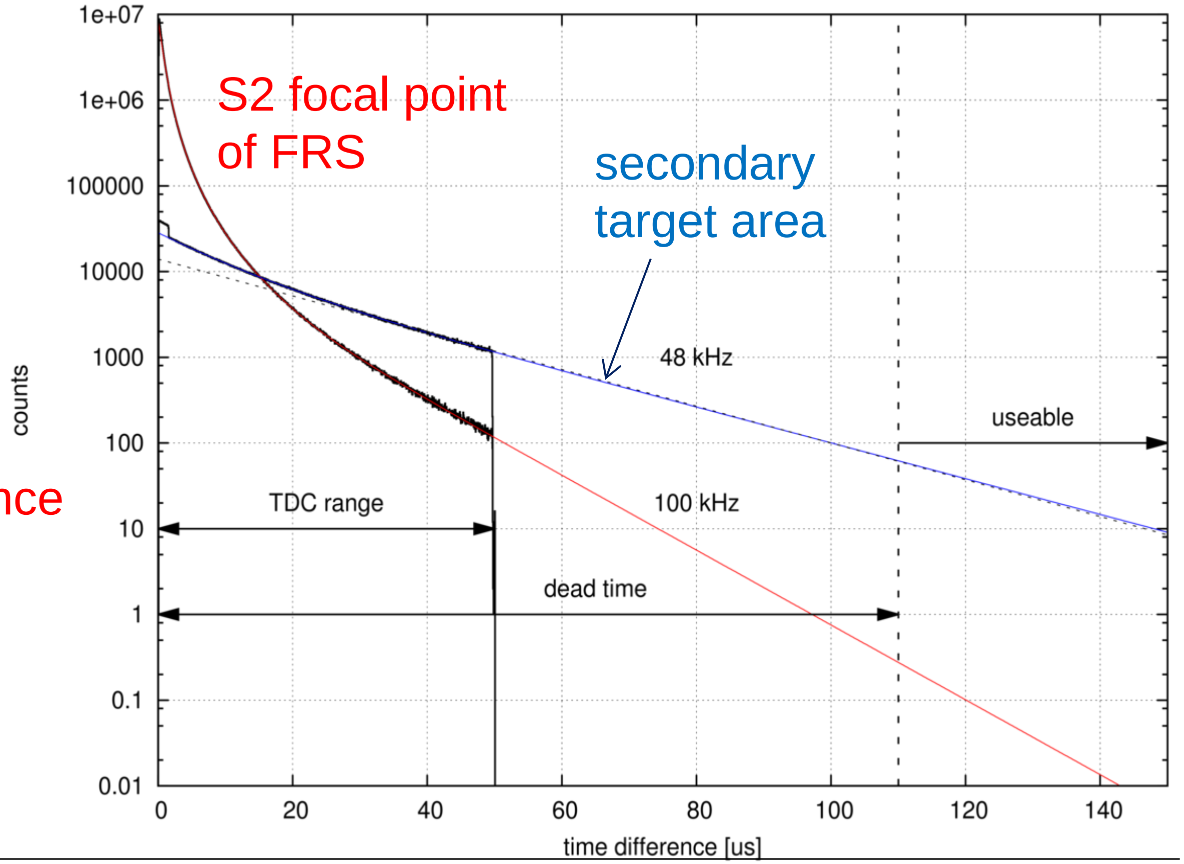
- Observed number of counts = 1000

Discrepancy !

Time Structure of Beam



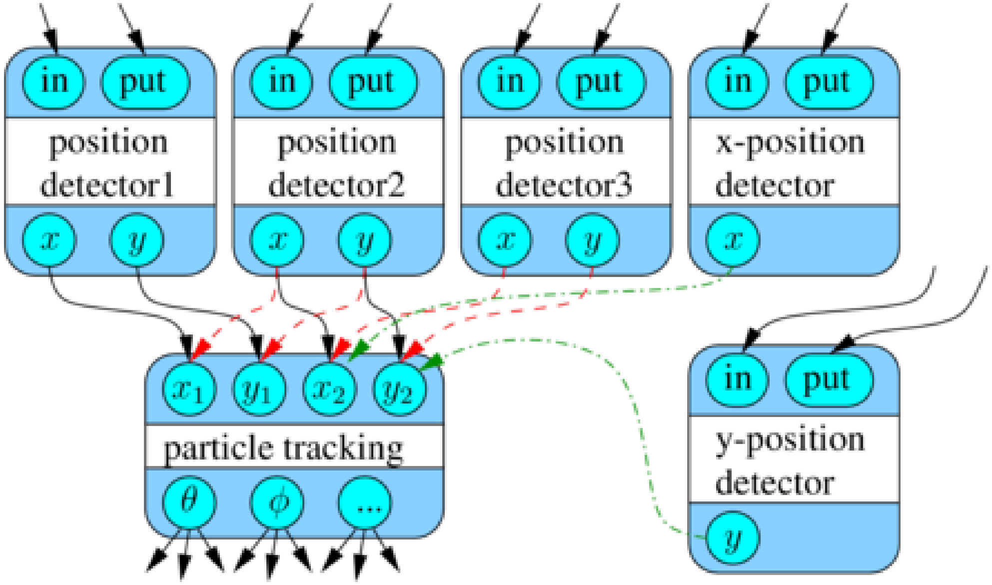




Data Analysis Software

An abstract view on data analysis of nuclear physics experiments:

- Data flow on a directed graph, event by event
- Data processing happens inside the graph nodes
- Flow can be conditional, based on properties of event-data
- Visualization of data in histograms



A Generic Solution

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PreSPEC data analysis is running on a framework that focuses on the idea of a directed graph.
Framework connects two main components:

1. Graph nodes are C++ classes, implementing a given interface
2. A script language that
   - allows to describe data flow between nodes
   - supports high-level data types (numbers, and lists of numbers)
   - can visualize selected parts of the data flow
   - has a simple syntax

The framework can be used as a backend of other programs, e.g. Go4

The main advantages:

- Algorithms can be implemented without knowing in what environment they will be used. They are guaranteed to work when used (and reused) inside the framework.
- Data analysis can be defined without knowing the details of an algorithm. Only the interface has to be known
- If visualization is script-based, definition (or modification) of new histograms doesn‘t require recompilation of the software

Summary & Outlook

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- Experimental setup is working
- Data analysis is working
- Observation of new effects, that can be exploited in new kinds of experiments
- Software development

To Do

- Finalize the results with optimized AGATA-PSA
- Obtain final values for achievable resolution & efficiency
- Test lifetime analysis for the observed transitions
- Study the influence of particle time distribution in beam

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End

Thanks to all people involved in the PreSPEC and AGATA project!

Thank you for your attention!