Analysis status of ASGARD for the in-beam gamma-ray spectroscopy experiments at RAON

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Progress Overview

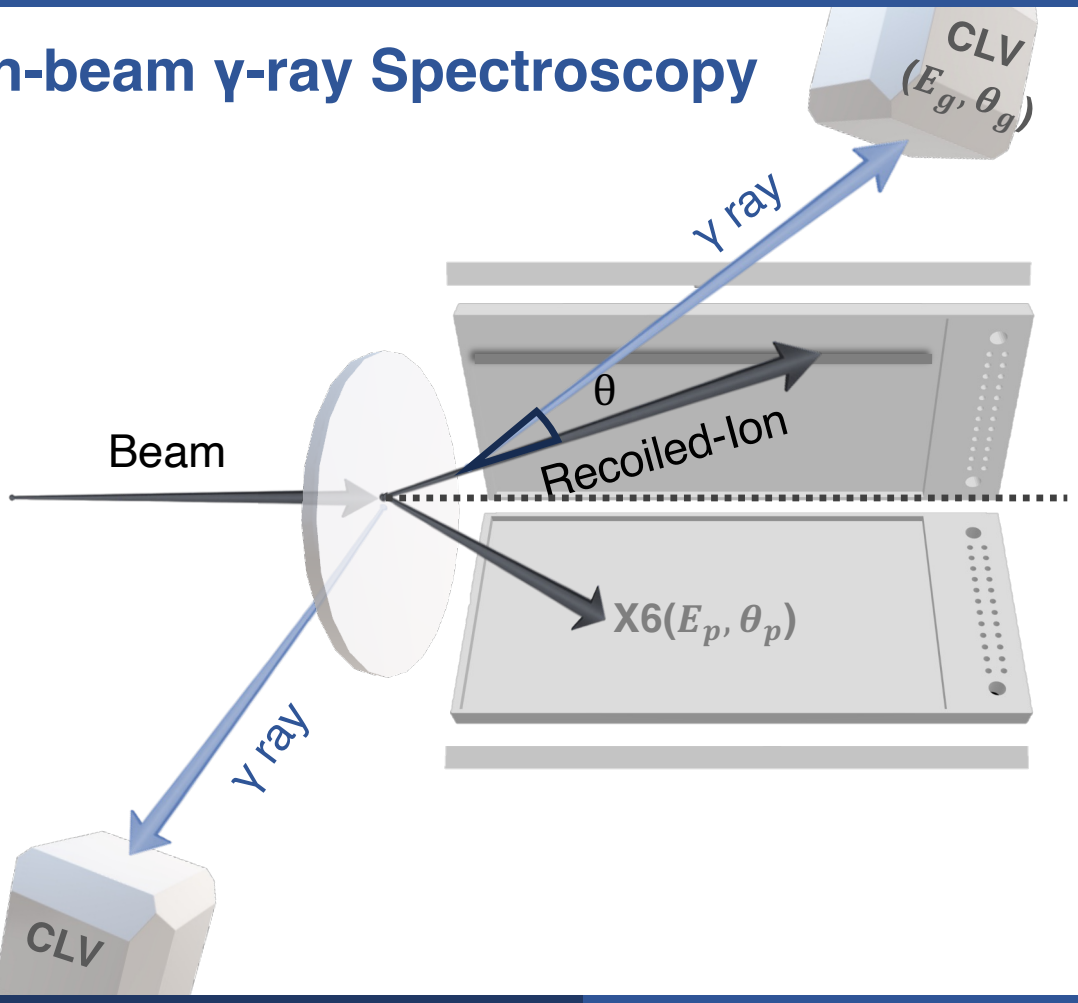
1. **Experimental Setup**
   - ASGARD Detector System
   - Detector Specifications

2. **Commissioning Results (NIM Paper - Accepted)**
   - Data Preprocessing
   - Doppler Corrected Results

3. **Ongoing Research**
   - KO-24-26: Coulomb Excitation
   - KO-25-07: Fusion Evaporation

Experimental Setup

In-beam γ-ray Spectroscopy



Spectroscopic Observables

- γ-ray energies → Excited states
- γ–γ coincidences → Level schemes
- Transition strengths → Nuclear collectivity

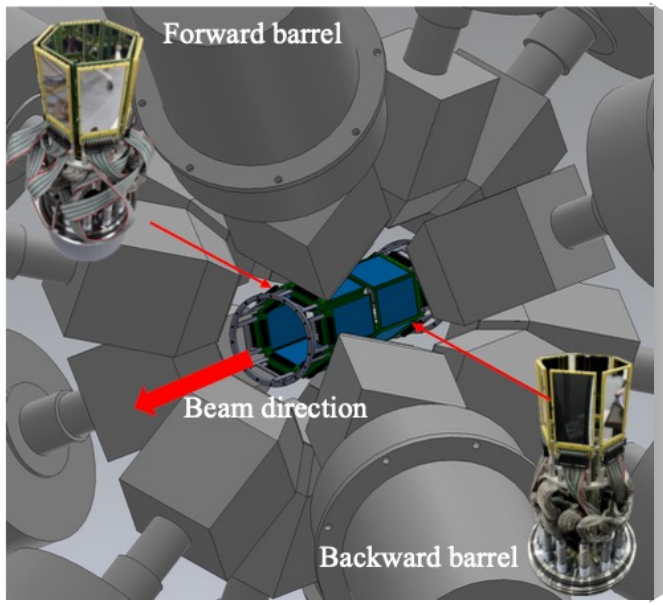
Particle–γ coincidence

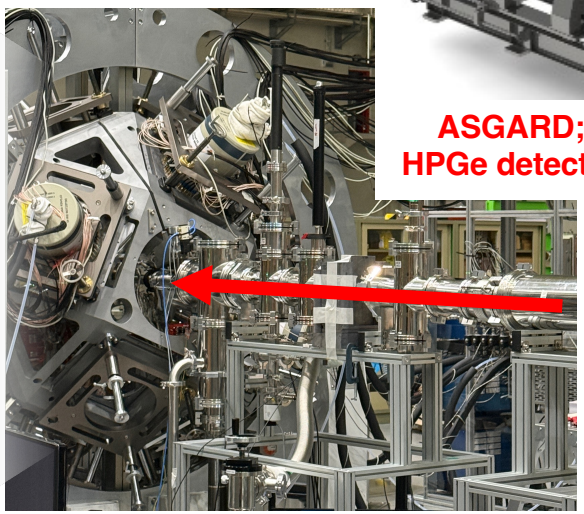
: Reaction identification
& Doppler correction

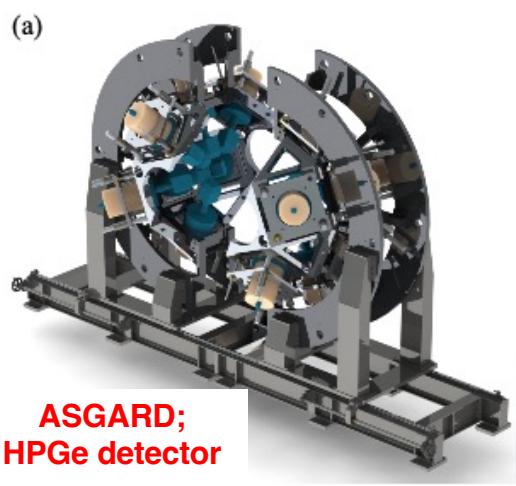
Experimental Setup

RAON KoBRA facility & Installation

ASGARD array and Stark Jr. chamber were installed
beyond F3 focal point*



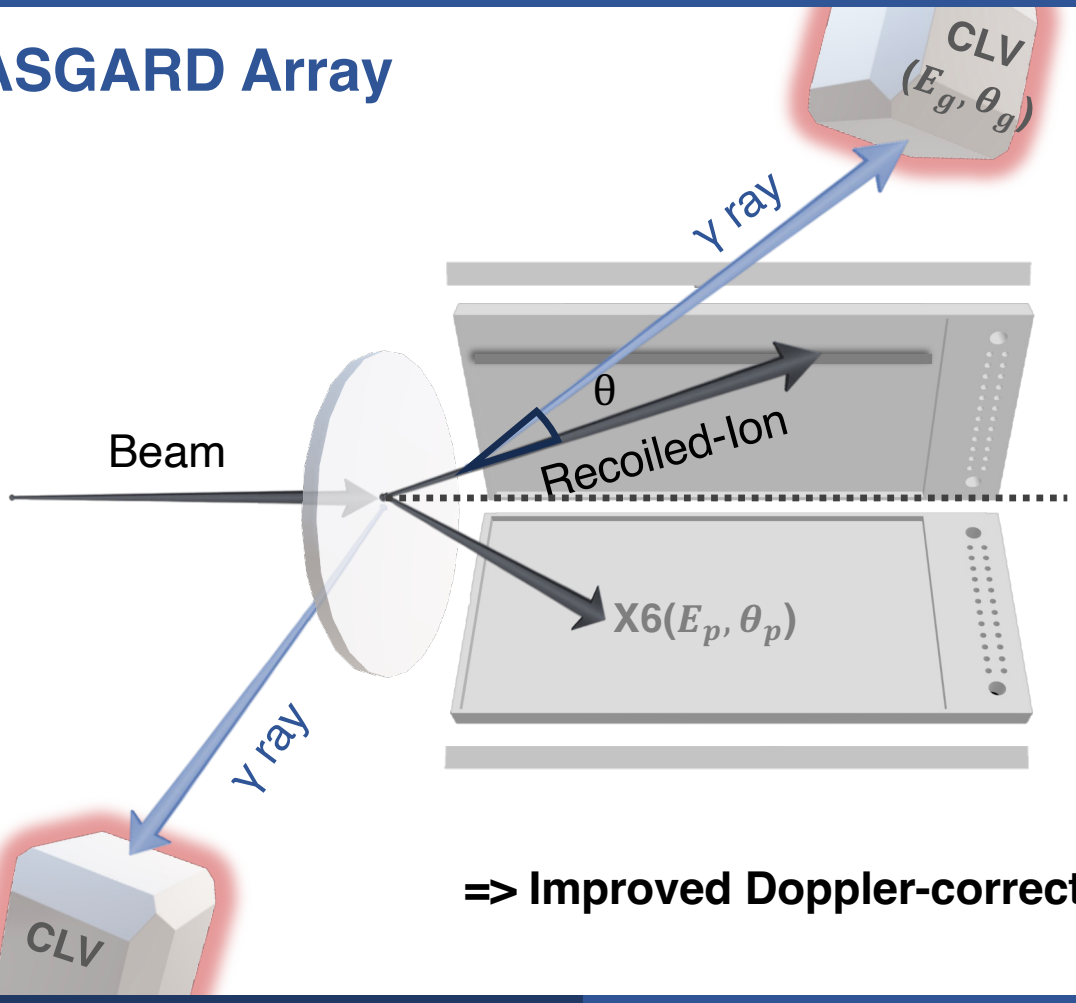




ASGARD;
HPGe detector

Detector System

ASGARD Array



ASGARD array

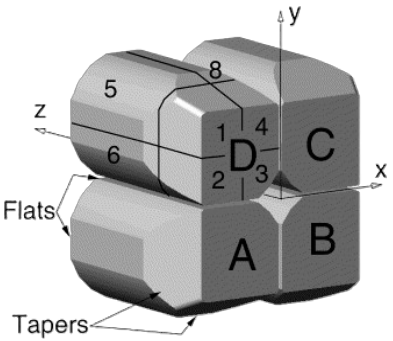
- 10 clover-type HPGe detectors (Max. 16 detectors)

HPGe Clover Detector

- High Energy resolution(~2.5 keV FWHM)
- 4-fold 32 segmentation

Segment : Hit Position

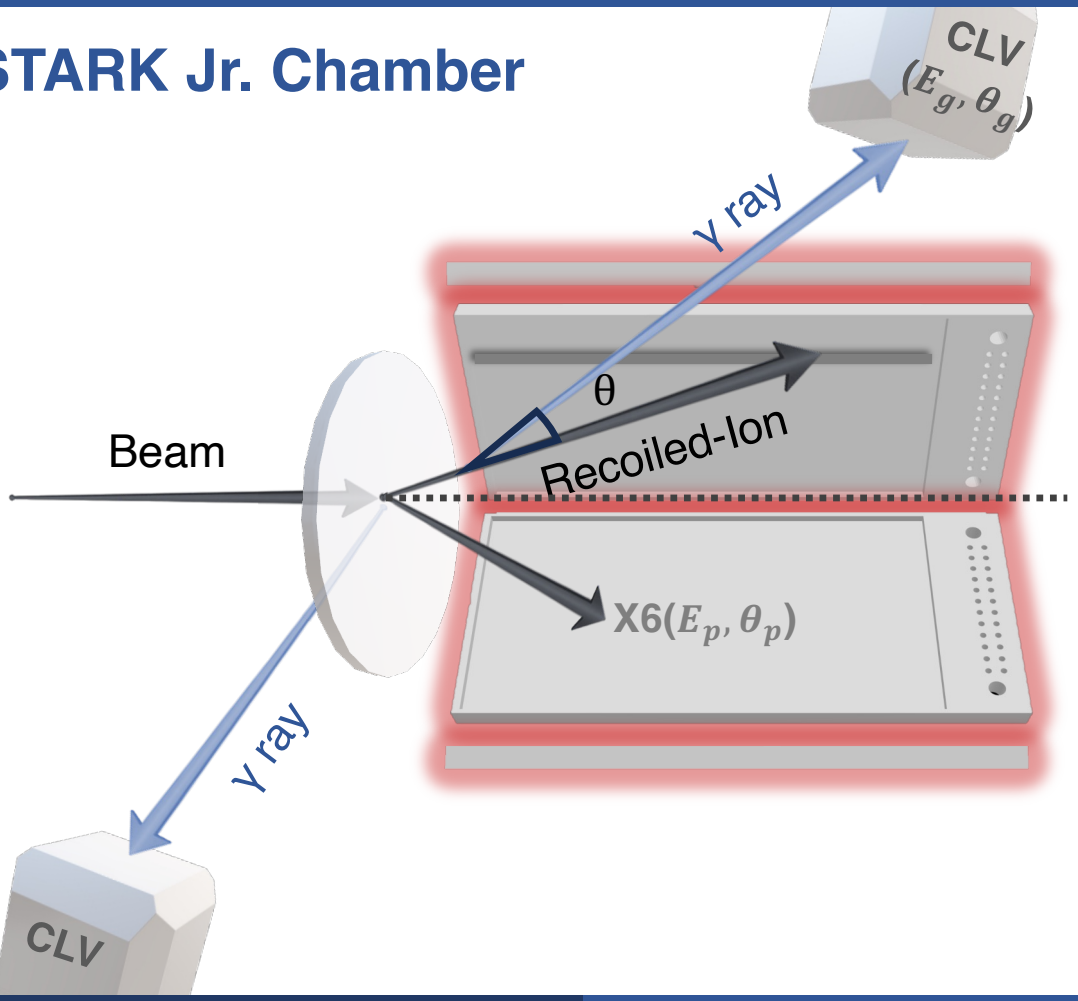
Crystal : Deposit Energy



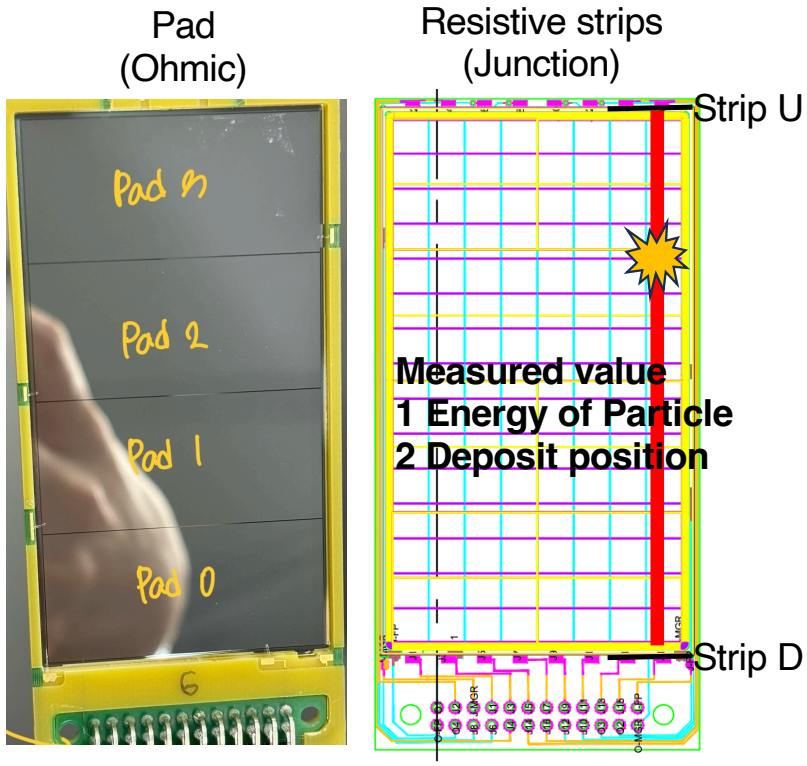
=> Improved Doppler-correction capability

Detector System

STARK Jr. Chamber



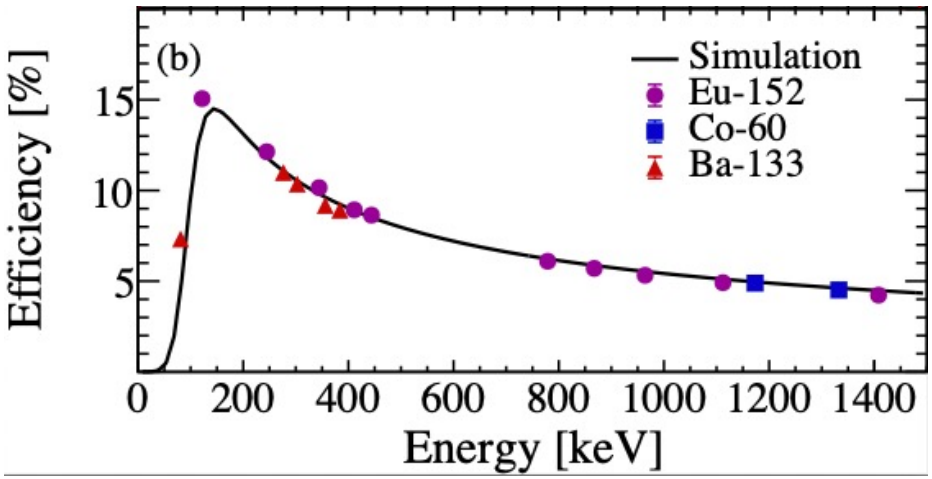
- heavy-ion detection
- 12 X6 detectors in hexagonal

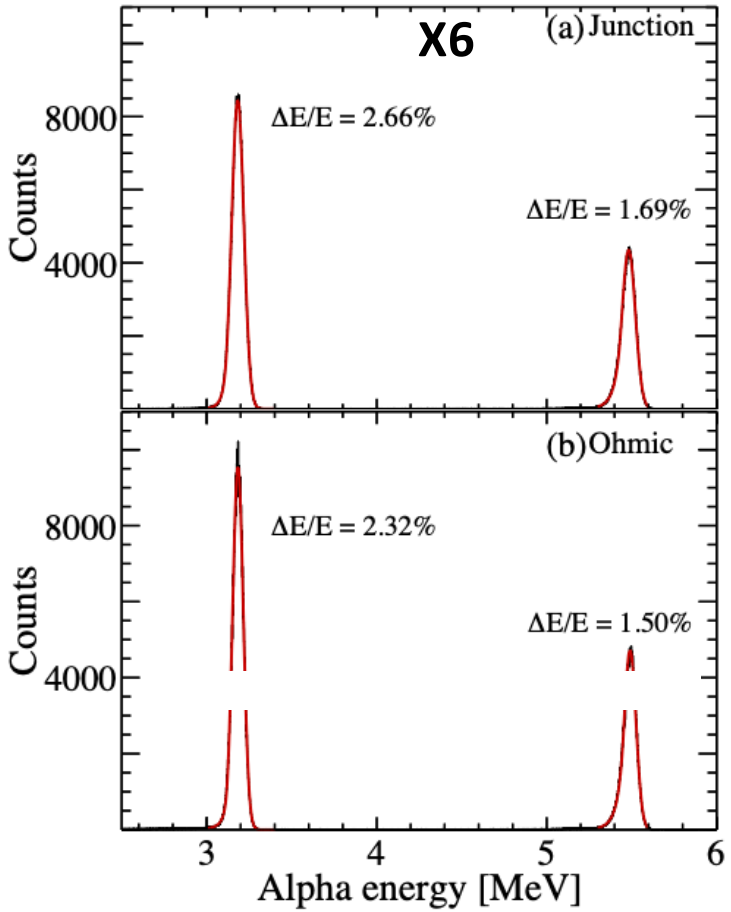


Detector System

Detector Energy Calibration & Efficiency

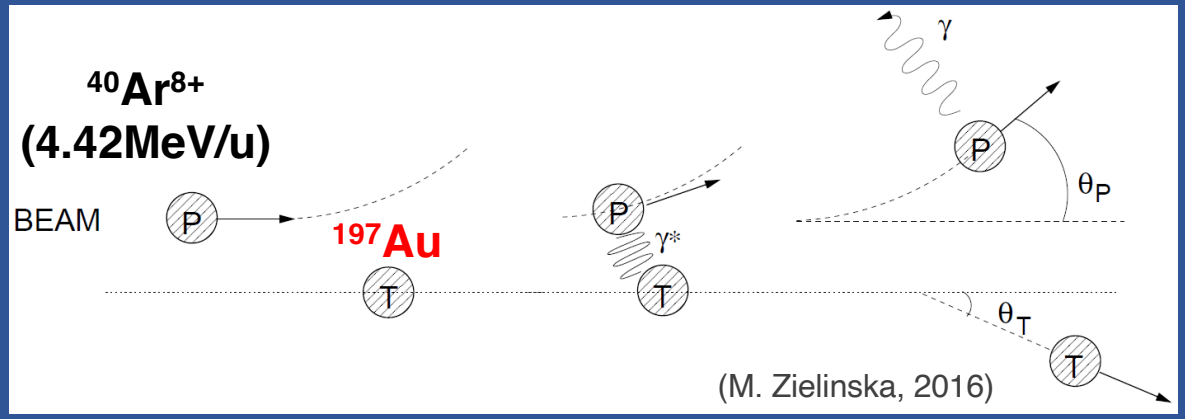
CLV





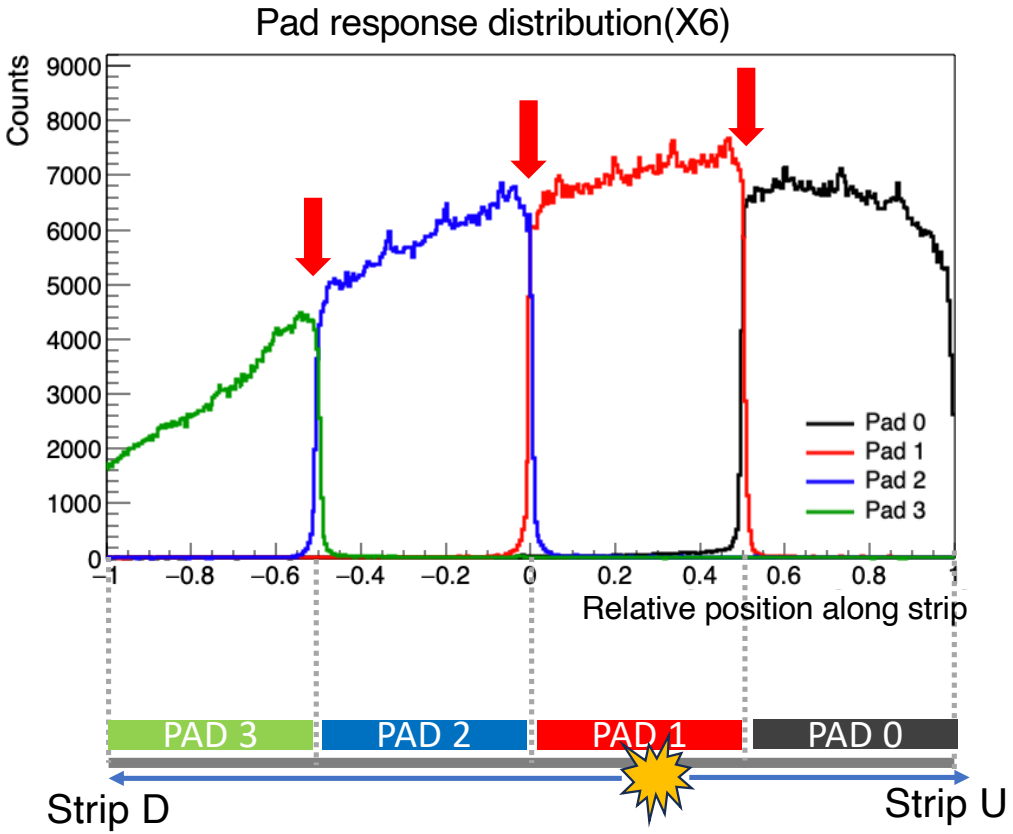
- Energy Resolution
  : 0.24%(FWHM), 1.36keV(sigma) @1332.5 keV ^{60}Co
- Detection Efficiency (for 37 Crystals)
  : 8.0% (@0.5 MeV), 5.5% (@1.0 MeV)

Data Analysis procedure : Coulomb Excitation for ^{40}Ar



Data Preprocessing(STARK Jr.)

Position Calibration



Using Physics Run

Pad boundaries -> {-0.5, 0, 0.5}

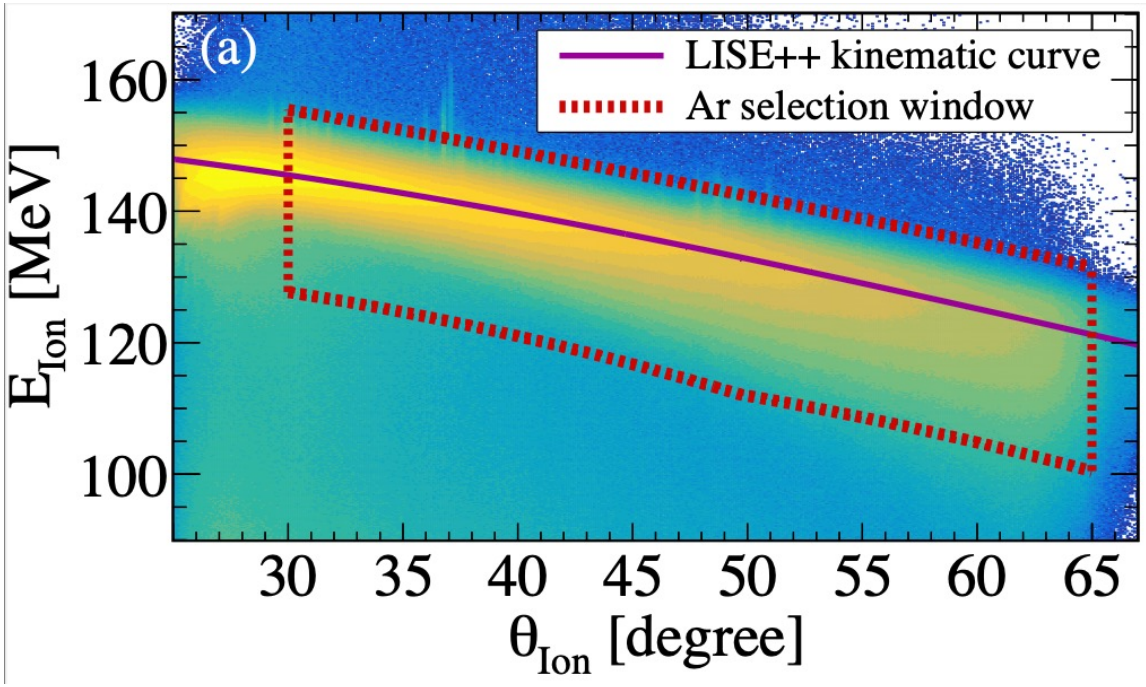
Position Calibration

- Overlap region = Pad boundary
- FWHM of X6 Strip = **0.5mm**

$$Relative\ position = \frac{ADC\ U\ - ADC\ D}{ADC\ U + ADC\ D}$$

Data Preprocessing(STARK Jr.)

Energy Calibration



L1) Pad Signal Saturation

-> Only using Strip Signal
-> Ion Energy = Strip U + Strip D

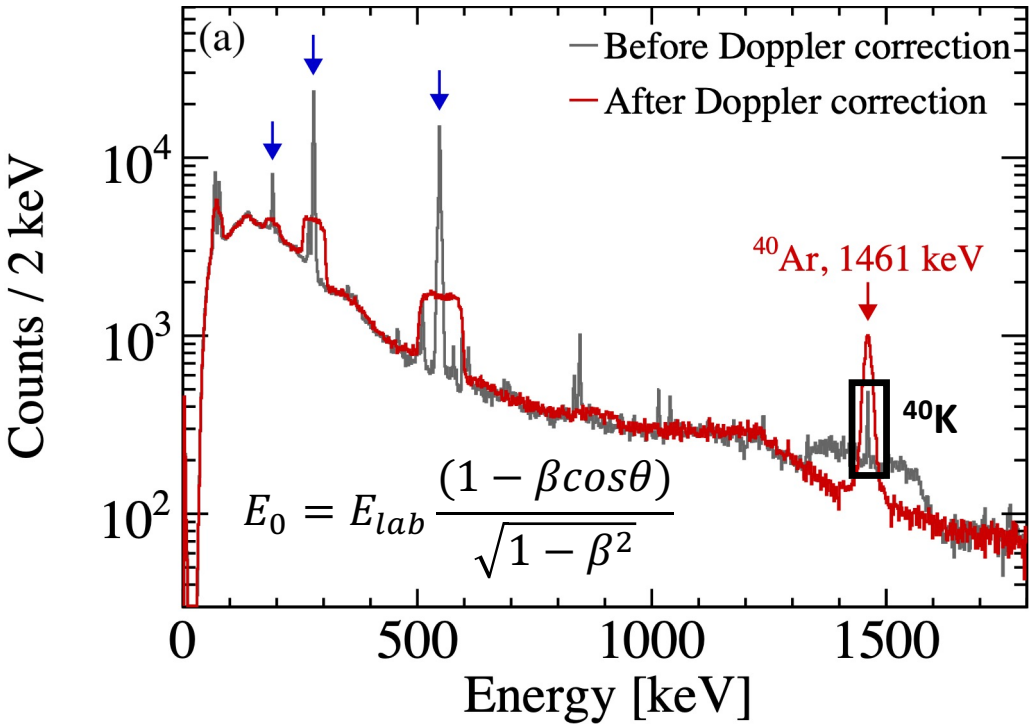
L2) Low gain mode(x1)

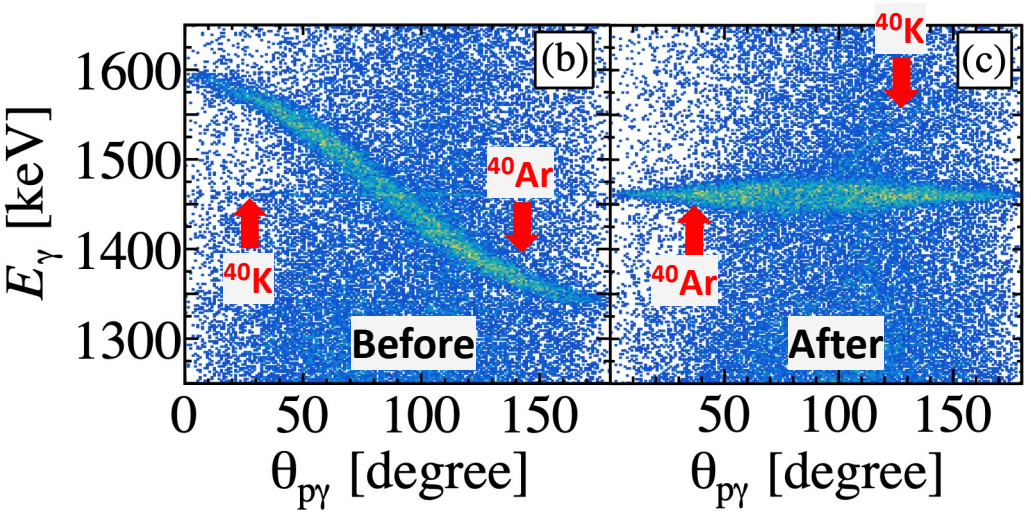
-> Alpha source X
-> Physics Run Calibration for X6

- Reference = LISE++ Kinematic Curve (38° - 45 °)
- FWHM of X6 Strip = **5.25MeV (at 30 °)**
- Extracted range = 30-65 degree

Doppler Correction

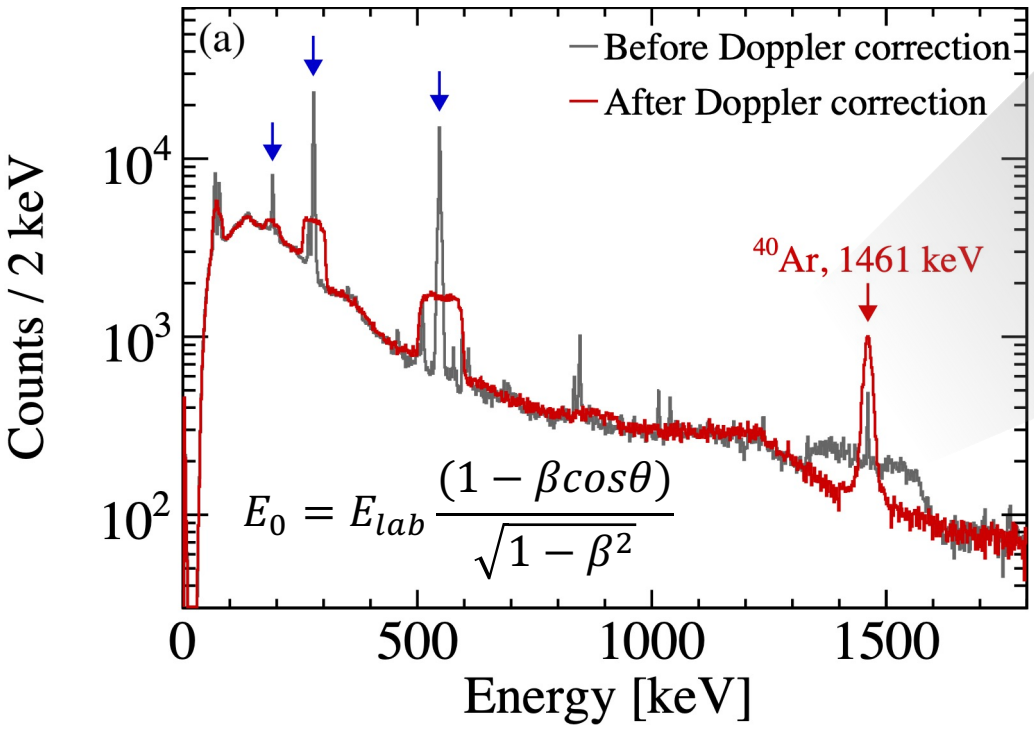
Doppler Corrected Spectra

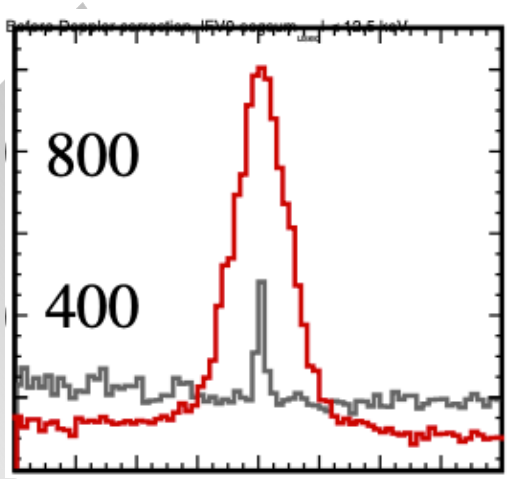




Doppler Correction

Doppler Corrected Spectra





Energy Resolution

= **1.5%** (FWHM)
@1461 keV

*Doppler-corrected in-beam resolution

Development and commissioning of the ASGARD and STARK Jr systems for in-beam γ-ray spectroscopy at RAON

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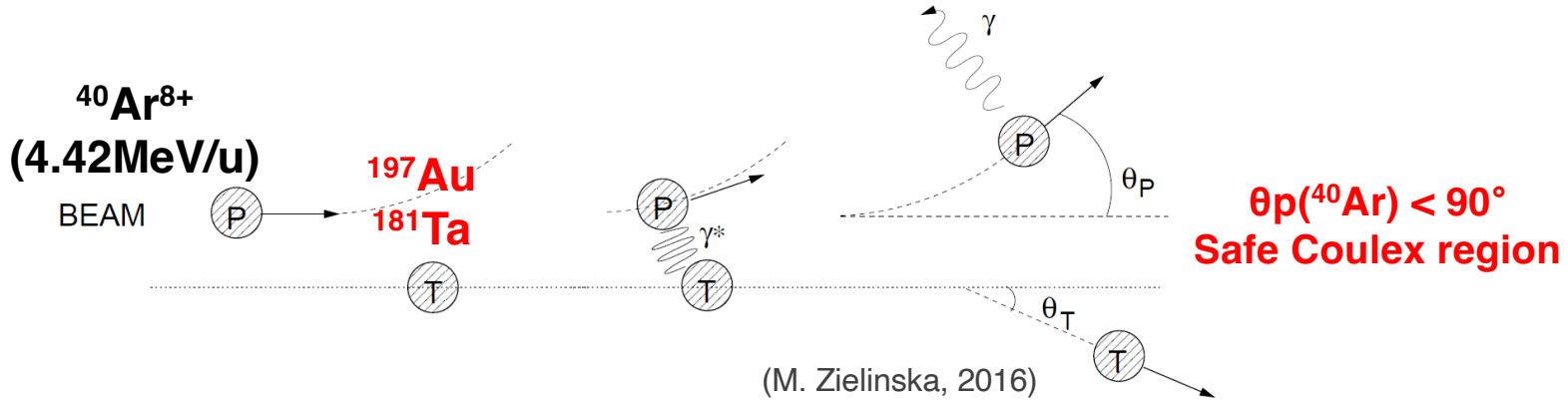
NIM Paper Accepted

Further Research and Application for Preprocessing Methods (KO24-26, KO25-07)

KO24-26 (Jason Park)

Coulomb Excitation for ^{40}Ar



θp(^{40}Ar) < 90°
Safe Coulex region

- **Method**
  Safe-Energy Coulomb excitation
  In-beam gamma-ray spectroscopy
  (ASGARD + STARK Jr.)

- **Goals**
  1. B(E2), B(M1)
  2. Q_s
  3. Comparison with models

KO24-26 (Jason Park)

Analysis Workflow

1. Timing & Selection
Optimize particle–γ coincidence timing and energy cuts

2. Background Analysis (non-DC)
Identify background γ rays and optimize background subtraction

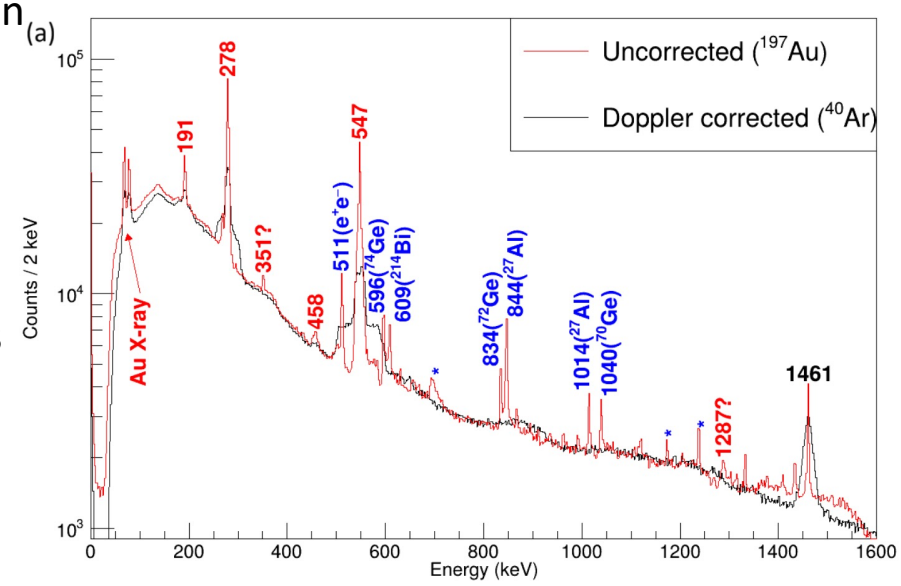
3. ^{40}Ar γ-ray Analysis (DC)
Identify γ-ray transitions using Doppler-corrected spectra

4. ^{197}Au γ-ray Analysis
Develop recoil Doppler correction and identify γ-ray transitions

5. Angular Binning & Yield Extraction
Extract angular-dependent γ-ray yields for GOSIA analysis

*** ^{40}Ar yield normalization**

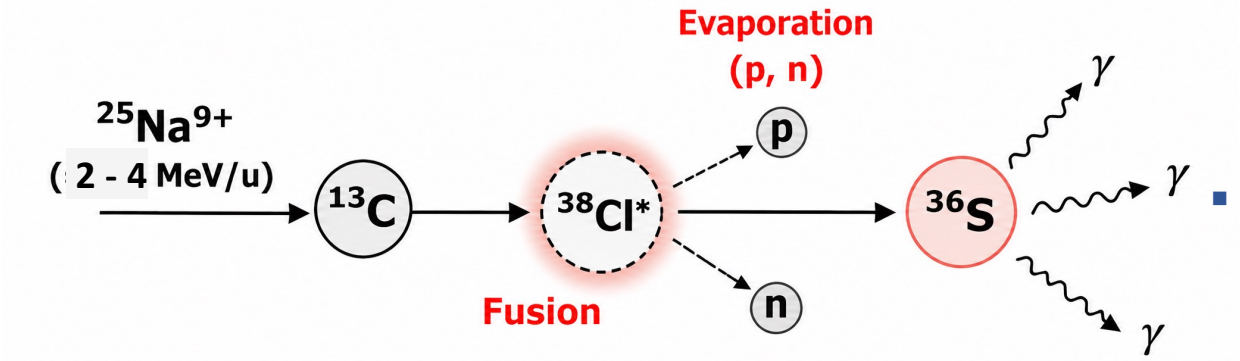
*** Energy-independent yield extraction**

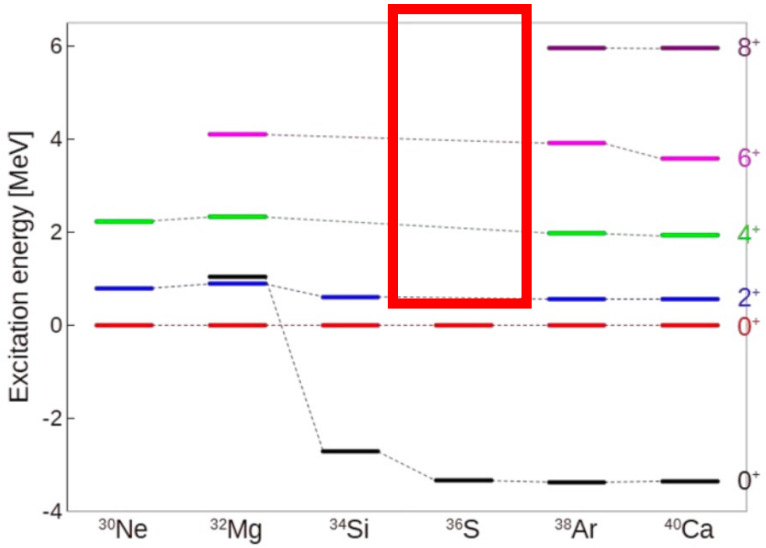


KO25-07 (Hiroshi Watanabe)

Fusion Evaporation of ^{36}S

- **Shape transition & coexistence near N=20**
- **Unobserved rotational band built on 0^{2+} (3346 keV)**
- **Predicted superdeformation(β_2 ~= 0.6)**





- **Goals**
  1. Identify Deformed Rotational Bands
  2. Search for Superdeformation
  3. Extend High-Spin Level Structure

KO25-07 (Hiroshi Watanabe)

Analysis Workflow

1. Calibration & Event Building
Unpack raw data and calibrate γ-ray and particle signals
*High-gain mode enables source-based energy calibration

2. Particle–γ Analysis
Identify evaporation particles and optimize recoil Doppler correction
*Reaction-specific recoil Doppler correction is required

3. γ–γ Analysis
Identify γ-ray coincidences and construct the ^{36}S level scheme

4. Nuclear Structure Study
Investigate rotational bands, superdeformation, and shape coexistence

Summary

- Development of an in-beam γ-ray spectroscopy system at RAON (ASGARD + STARK Jr.)
- Successful particle–γ coincidence measurements
- Precise event-by-event Doppler correction of ^{40}Ar γ-rays
- Successful demonstration of high resolution in-beam γ-ray peaks (e.g., 1461 keV)
- Future studies: KO-24-26 (Coulomb excitation) and KO-25-07 (Fusion-evaporation)

Collaborators

M. Kim (Ewha W. University), B. Moon (CENS, IBS), J. Lee (Korea University), Y. Jang (Korea University), H. Watanabe (CENS, IBS), Y. Kim (CENS, IBS), J. Hwang (CENS, IBS), J. Park (Hope College), K. I. Hahn (CENS, IBS), T. Ahn (CENS, IBS), H. Arora (CENS, IBS), N. Aoi (CNS), S. Bae (IRIS, IBS), S. Cha (CENS, IBS), A. Chekhovska (CENS, IBS), J. Ha (CENS, IBS), J. Huh (CENS, IBS), N. Imai (CNS), D.G.Kim(IRIS,IBS), D.Kim(IRIS,IBS), M. Kim (IRIS, IBS), M.Kwak(IRIS,IBS), R. Kojima (CNS), J.Lee(IRIS,IBS), K.Lee(IRIS,IBS), A. Montes Plaza (CNS), A. Mukherjee (CENS, IBS), X. Pereira-Lopez (CENS, IBS), C. Park (IRIS, IBS), S. Kim (CENS, IBS)

Thank you for your attention