Target Profile Determination in the Data Analysis of KOALA

Yong Zhou

IKP-1, Forschungszentrum Jülich

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Outline

- **KOALA preliminary results**
  - KOALA setup at COSY
  - Elastic event selection with TOF-E
  - Target thickness issue at small recoil angles

- **Determination of target density profile in KOALA**
  - Method description
  - Result obtained at one reference energy
  - Systematic study with the results from various reference energies

- **Summary**

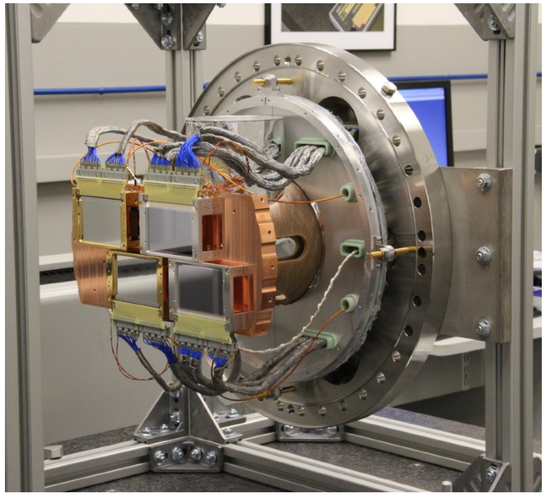
KOALA@COSY

Goals:

- **(anti)proton-proton elastic scattering differential cross section**
- **$0.0008 < |t| < 0.1$ (GeV/c)^2**

Recoil Detector:

- 2 Si + 2 Ge strip sensors
- Strip width: 1.2 mm



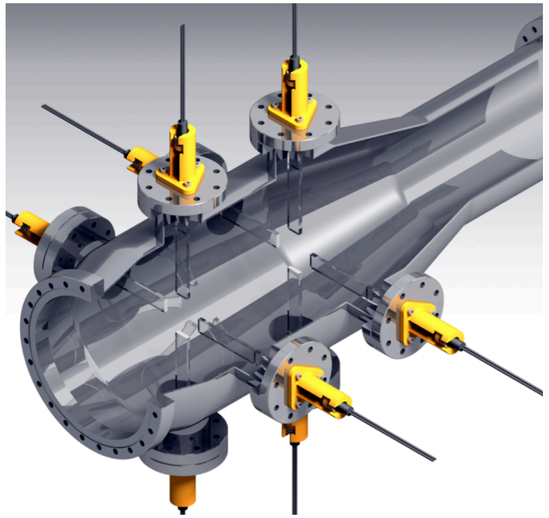
Hydrogen Cluster Jet Target:

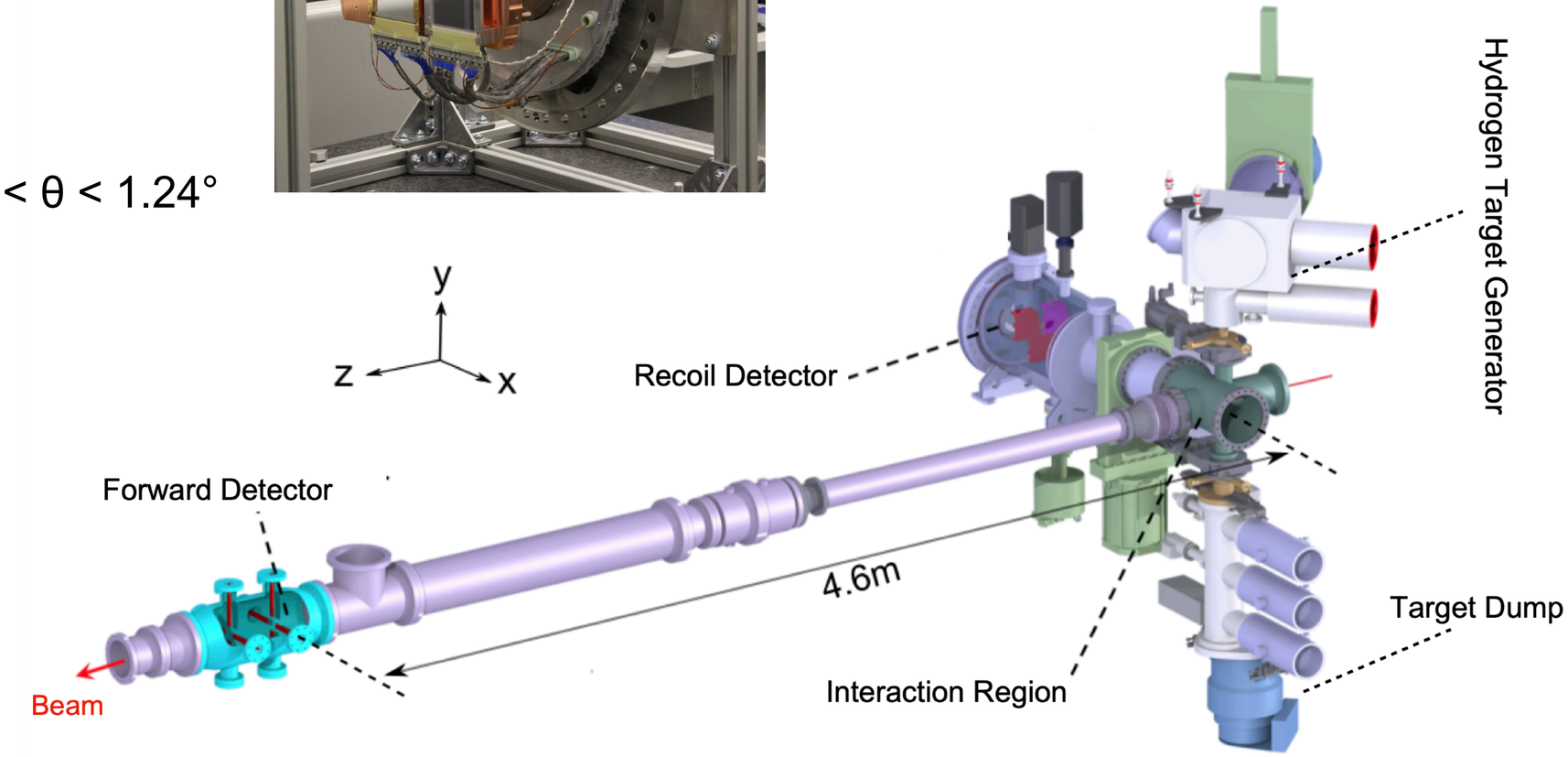
- Upgraded from ANKE target
- Intensity: 10^{14} atoms/cm^2
- Thickness* (FWHM): 1.5~1.6 mm

* Measured with the rod method

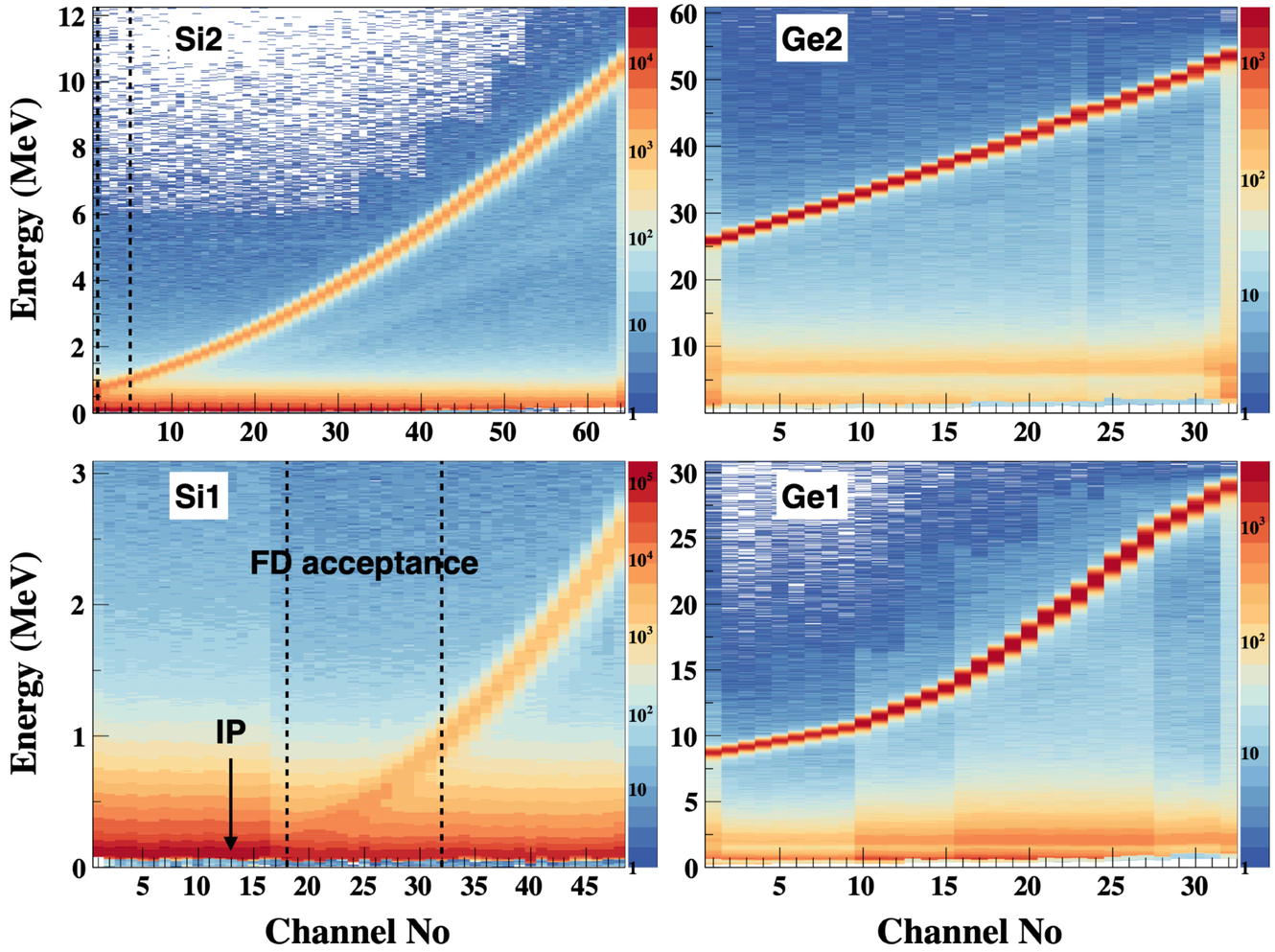
Forward Detector:

- Scintillator: 90 x 20 x 6 mm^3
- Scattering angle (@4.6 m) : $0.4° < \theta < 1.24°$

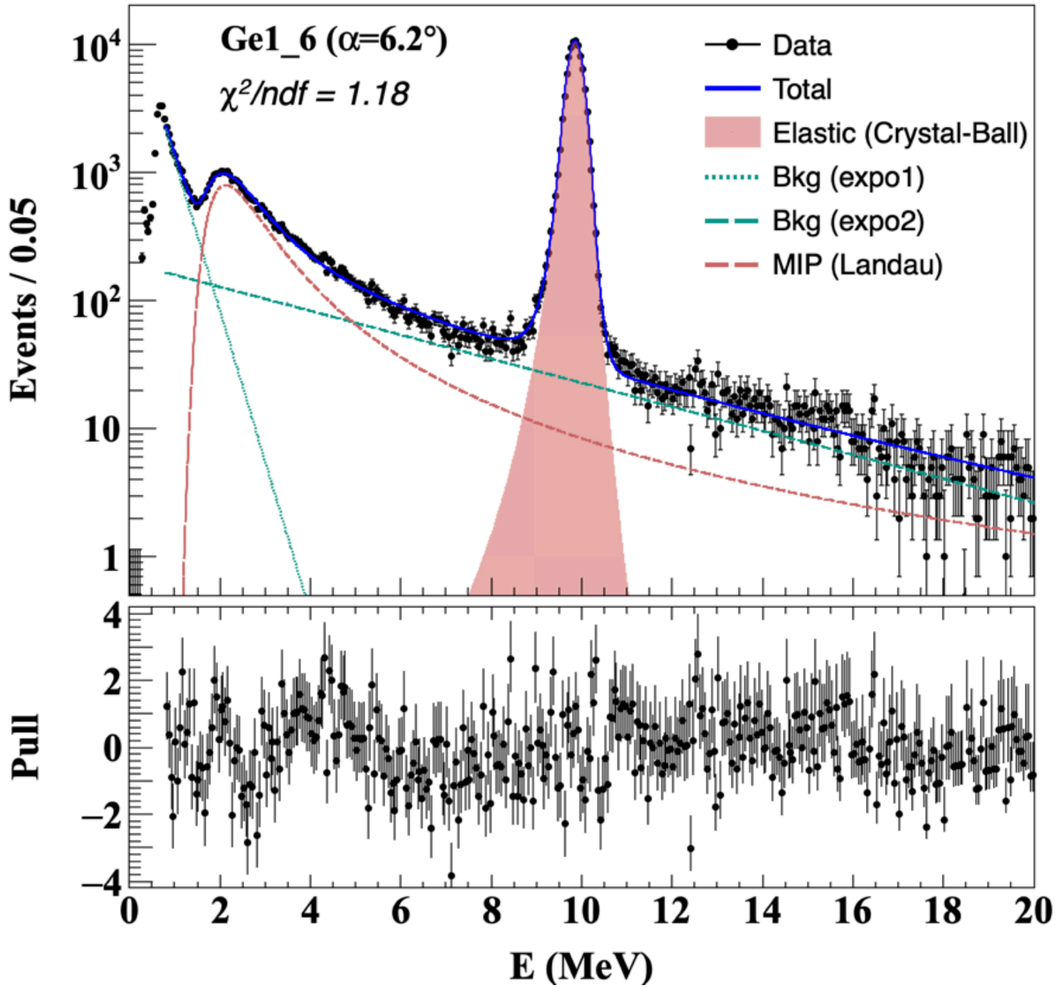




Extraction of the elastic peak at large recoil angles



Energy spectra for all channels from the 4 recoil sensors.

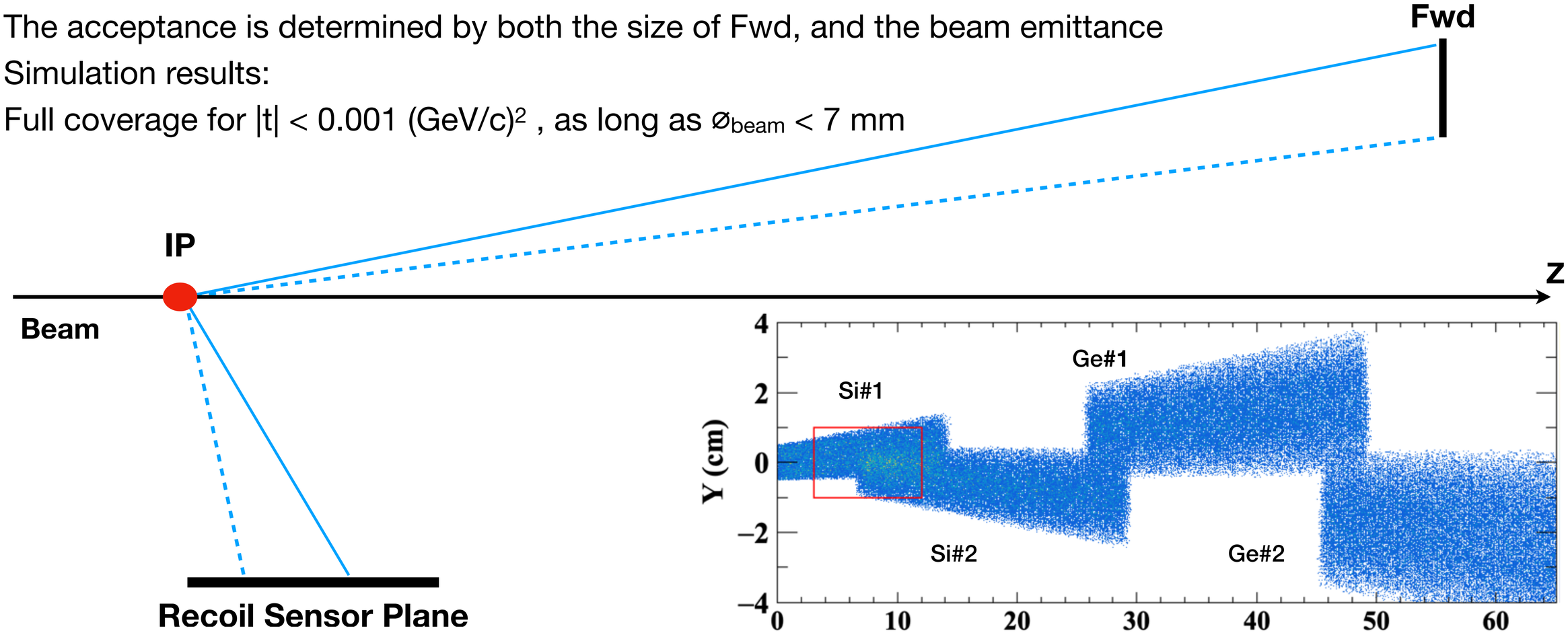


a) Elastic peak: Crystal-Ball function
b) Backgound: expo1 + expo2 + Landau*

* MIPs: maily charged pions from inelastic scattering

Acceptance of forward detector

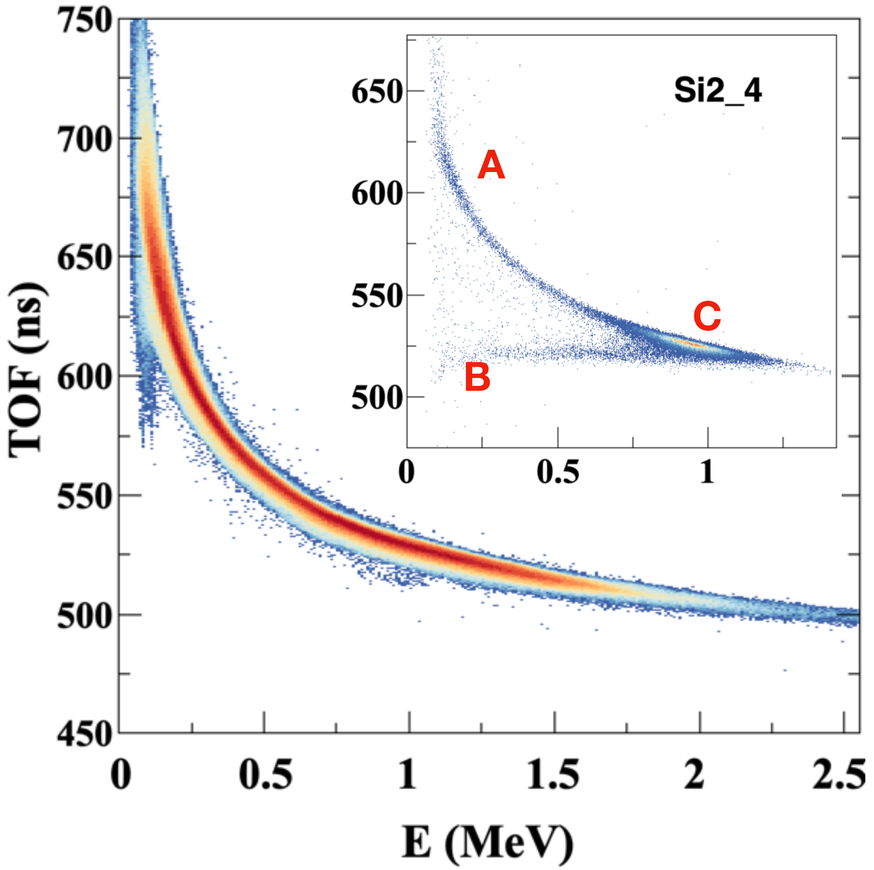
1. TOF-E of recoil protons is used for the selection of elastic scattering events, for strips within the acceptance of the forward detector.
2. The acceptance is determined by both the size of Fwd, and the beam emittance
3. Simulation results:
   Full coverage for $|t| < 0.001$ $(GeV/c)^2$, as long as $\varnothing_{beam} < 7$ mm



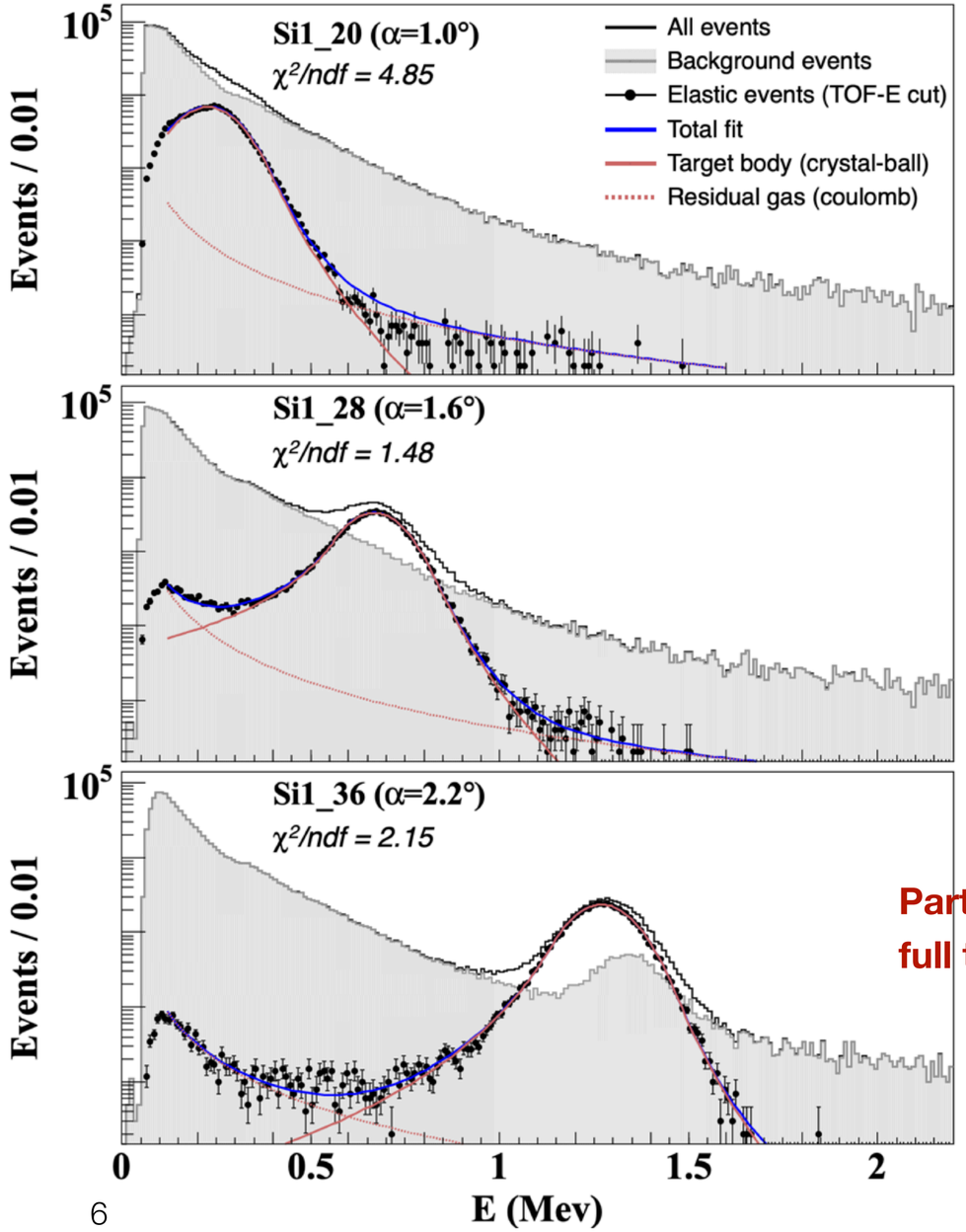
Acceptance of forward detector at 2.2 GeV/c ($\varnothing_{beam}$ = 10 mm)

TOF-E selected events

1) TOF-E spectrum of elastic events from all strips
2) Inset: typical TOF-E spectrum for a single strip
   C: elastic peak
   A: elastic events from residual gas interaction
   B: elastic events hitting the edge of the sensor



Extraction of elastic peak: Coulomb + Crystal-Ball



Fully-covered by Fwd, partial target profile.

Fully-covered by Fwd, full target profile.

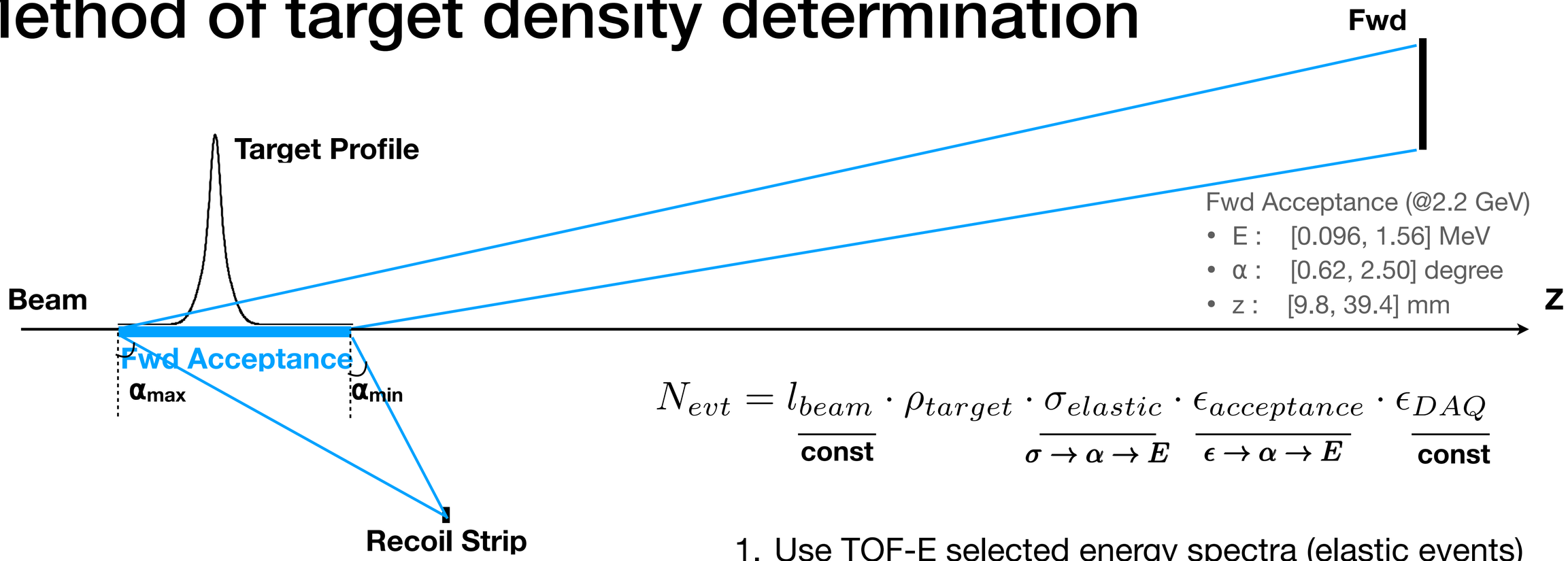
Partially-covered by Fwd, full target profile.

The issue about target thickness

1. The finite target thickness imposes an extra constraint of the lower limit of |t| measurement.
2. The lower limit is reached at a larger recoil angle than the design value
3. Information about the target profile distribution along the beam axis is needed to unfold the correct event rates for strips with partial coverage of the target profile.

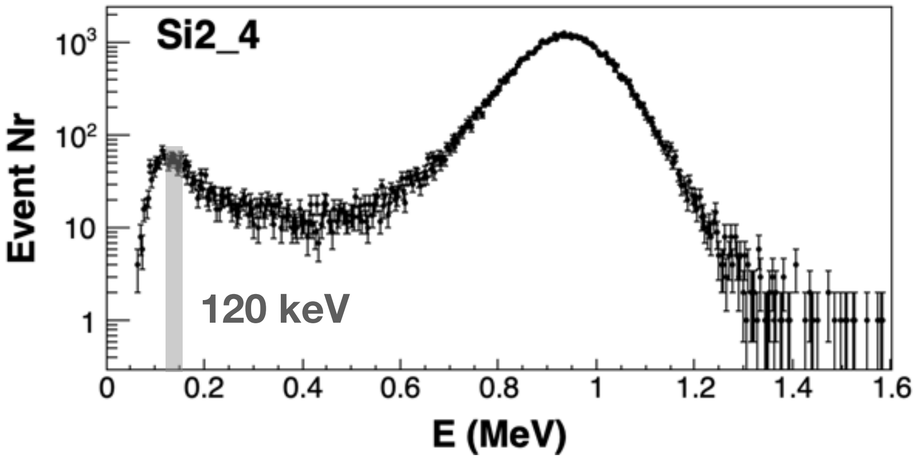
A method of determining the (relative) target density distribution along beam axis is developed using the same datasets of the experiment.

Method of target density determination



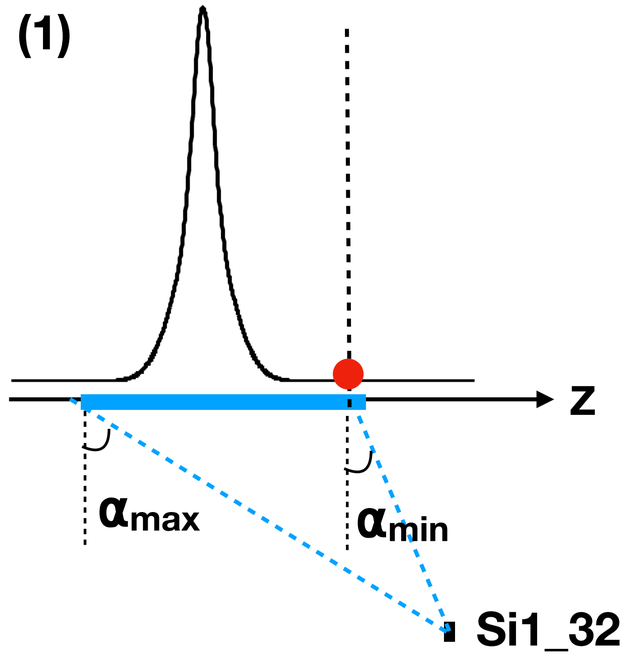
Fwd Acceptance (@2.2 GeV)
- E : [0.096, 1.56] MeV
- α : [0.62, 2.50] degree
- z : [9.8, 39.4] mm

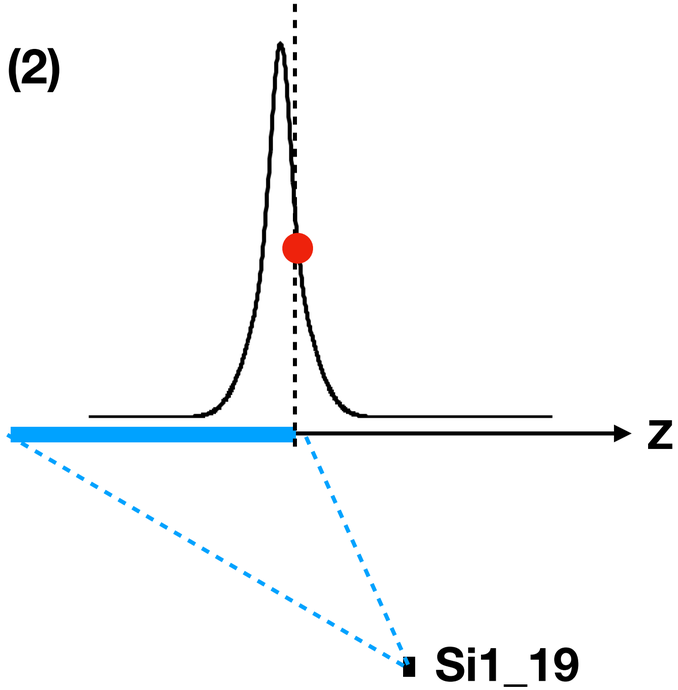
$$N_{evt} = \underbrace{l_{beam}}_{\text{const}} \cdot \rho_{target} \cdot \underbrace{\sigma_{elastic}}_{\sigma \to \alpha \to E} \cdot \underbrace{\epsilon_{acceptance}}_{\epsilon \to \alpha \to E} \cdot \underbrace{\epsilon_{DAQ}}_{\text{const}}$$

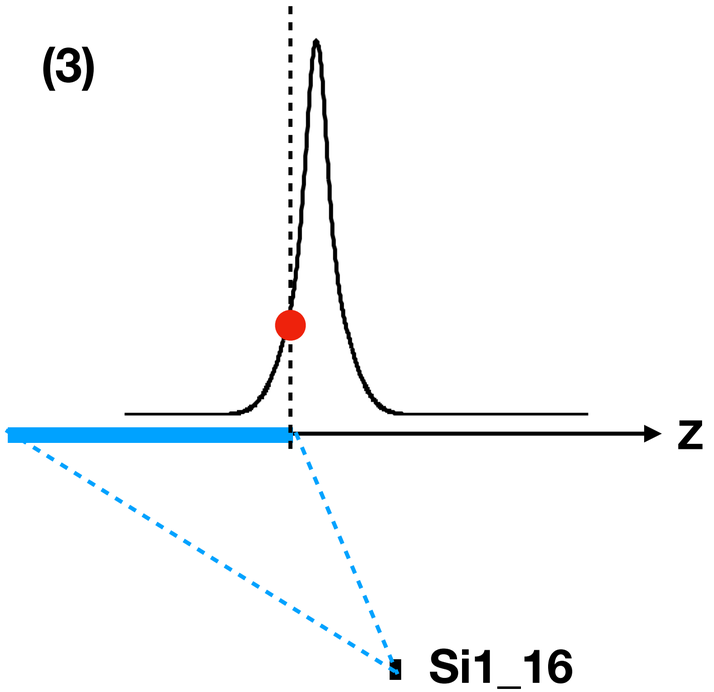


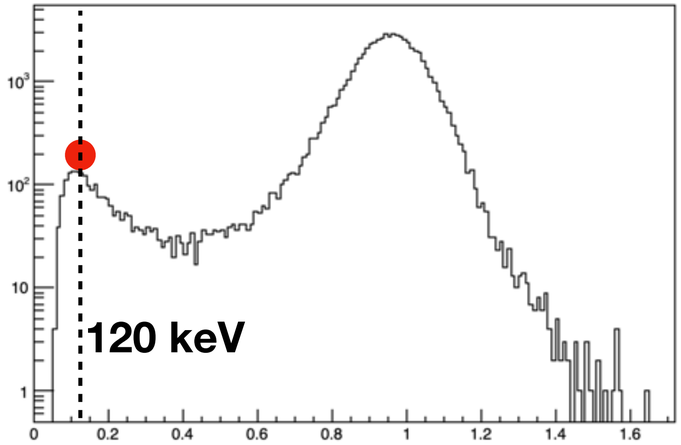
1. Use TOF-E selected energy spectra (elastic events)
2. Set a reference E_{ref} , which is within Fwd's full-coverage
3. Record the event counts on each strip
   within a 10 keV window around E_{ref}
4. The event counts are proportional to integrated ρ_{target}
5. Covert E_{ref} to a position in front of the strip,
   and get the profile distribution along beam-axis

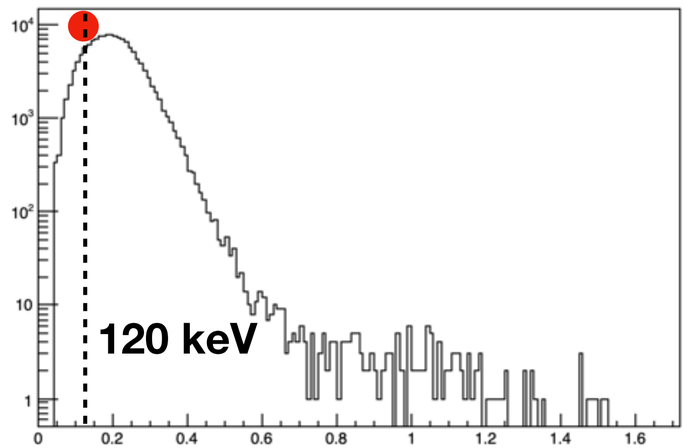
Illustration of the target profile determination

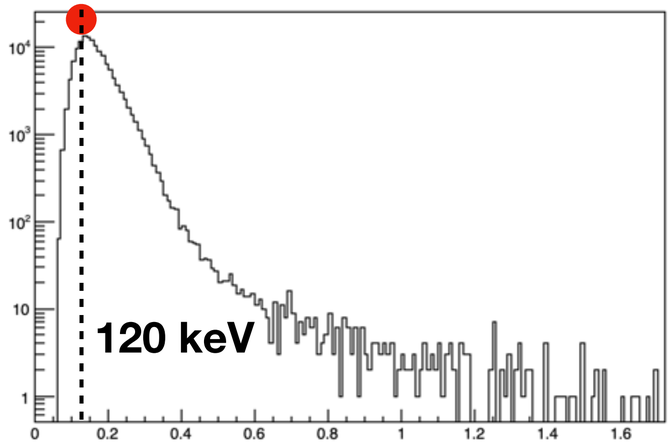






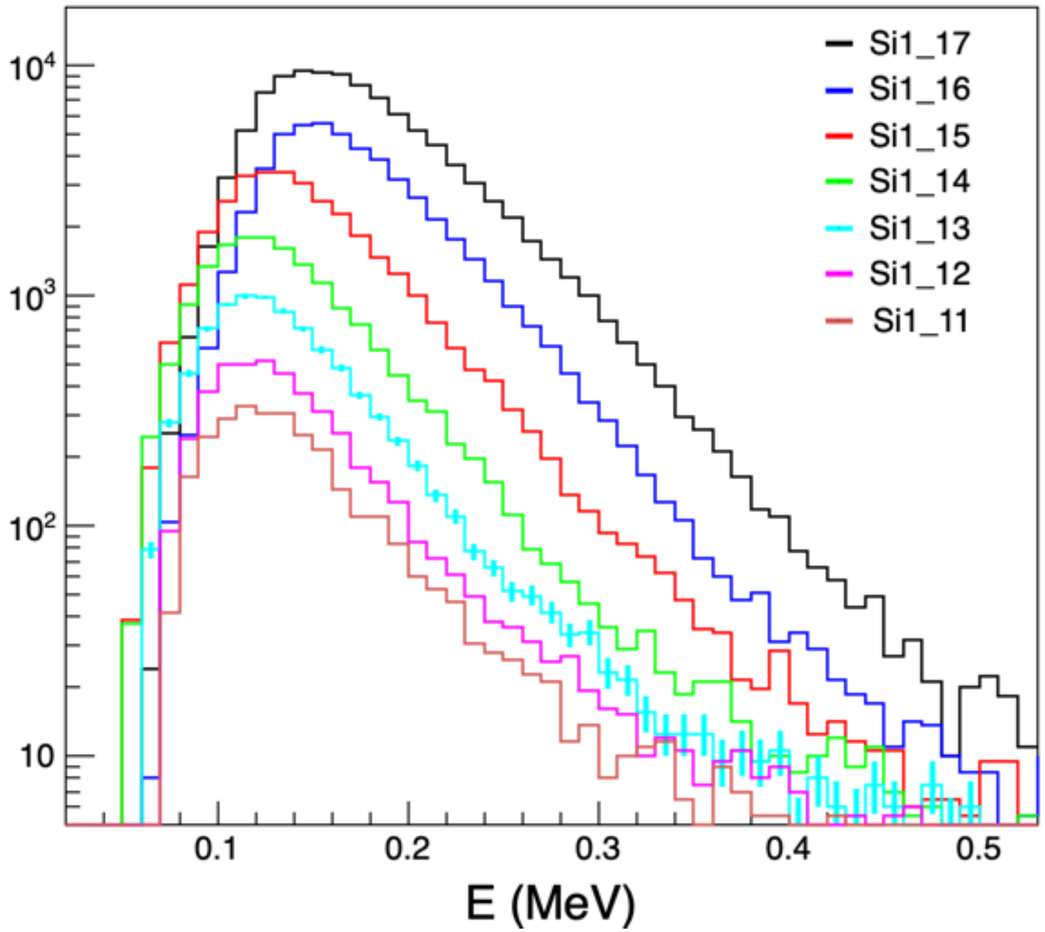




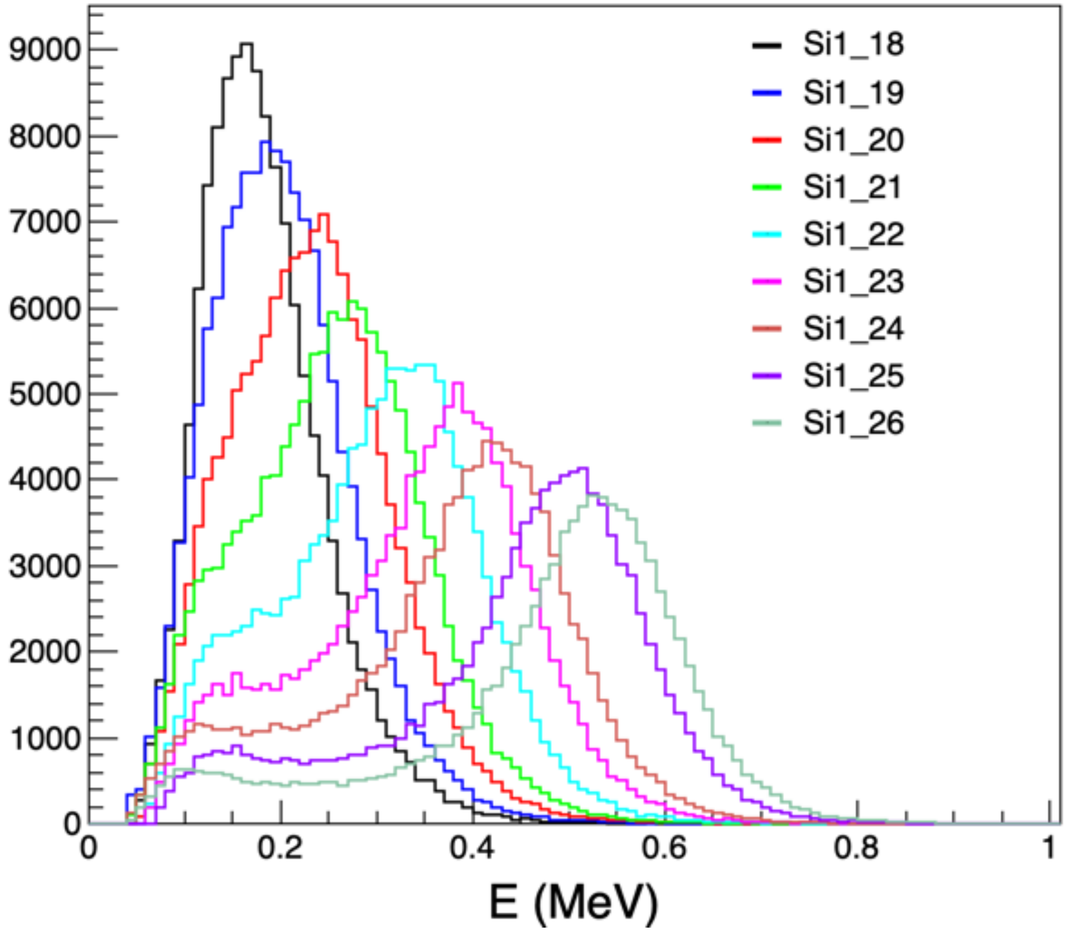


Category of Energy spectrums: peak@Si1_18

Before Si1_18: target peak not covered



After Si1_18: target peak covered



Determination of the target position

(Principle: energy can be converted to a z-position before the strip center)

Method 1 (Peak-based) :

- Use energy peak as reference, get the profile relative to the target peak
- Only get first half of the profile shape

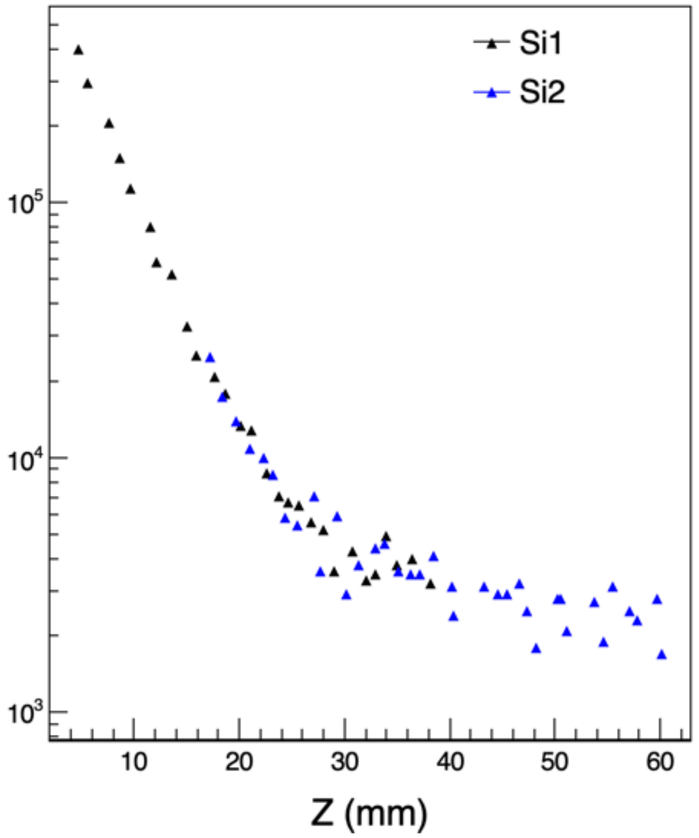
Method 2 (Strip-based):

- Use each strip’s ideal geometry position as reference, get the profile in the lab reference frame
- The whole shape of the target density profile

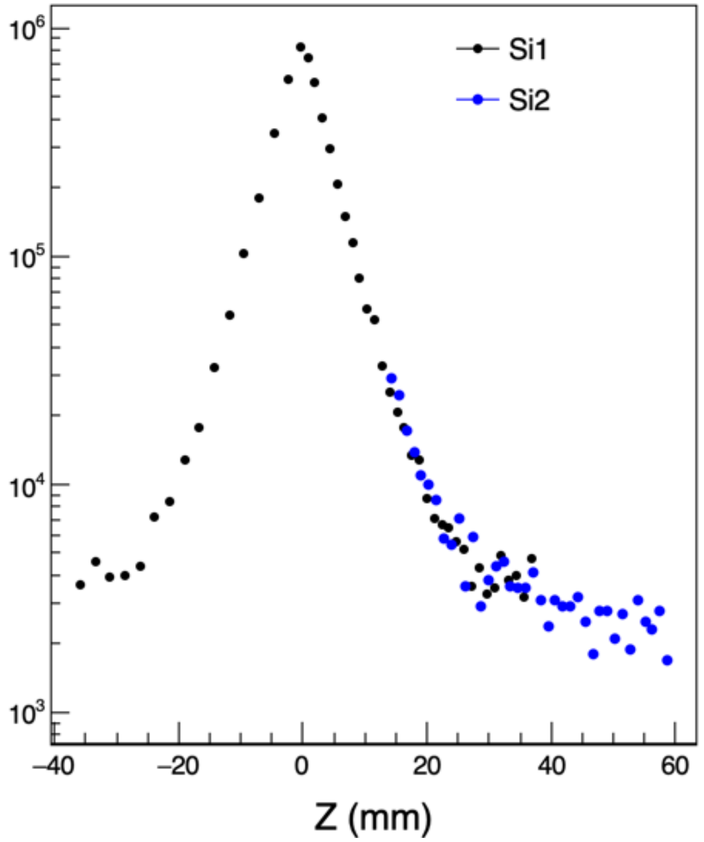
Comparison between the two determination methods

(E_{ref} =120 keV)

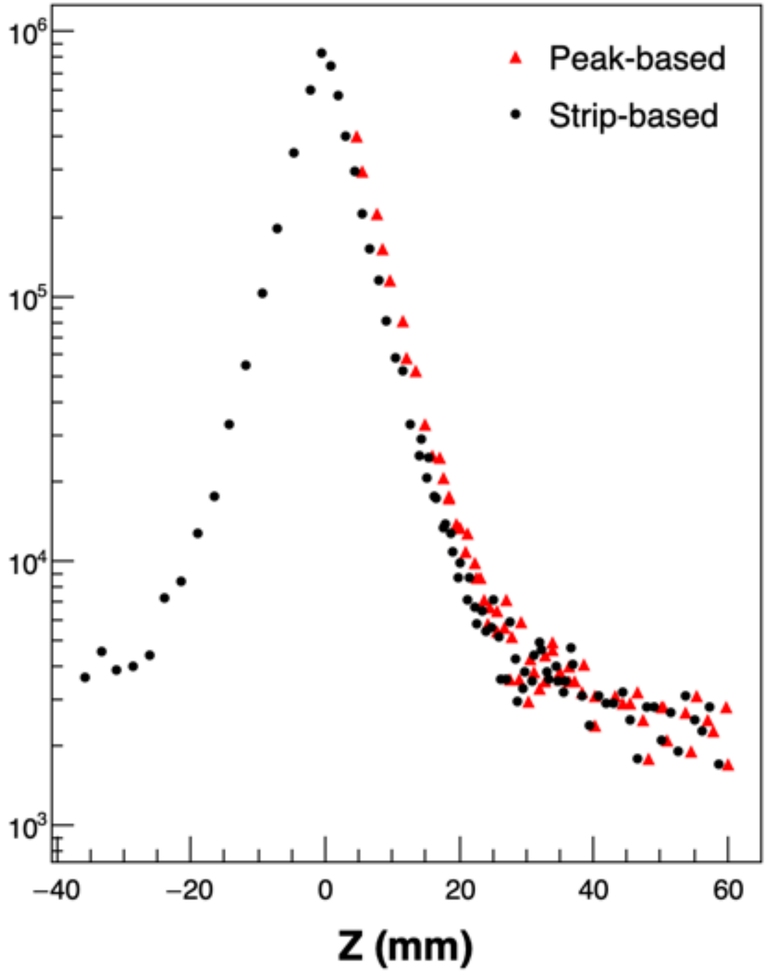
Method 1 (peak-based)



Method 2 (strip-based)



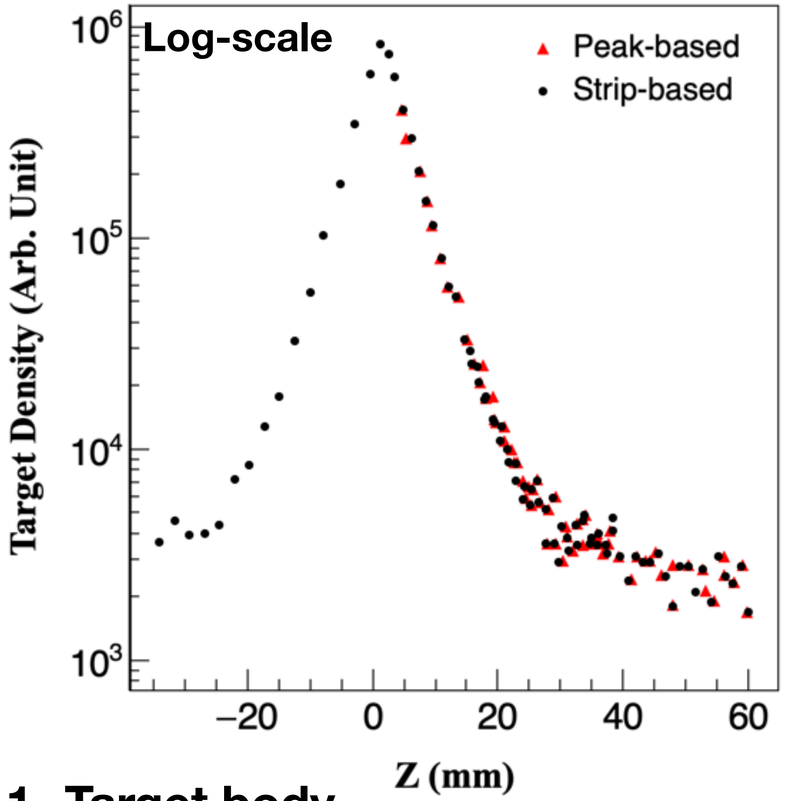
Method 1 VS Method 2

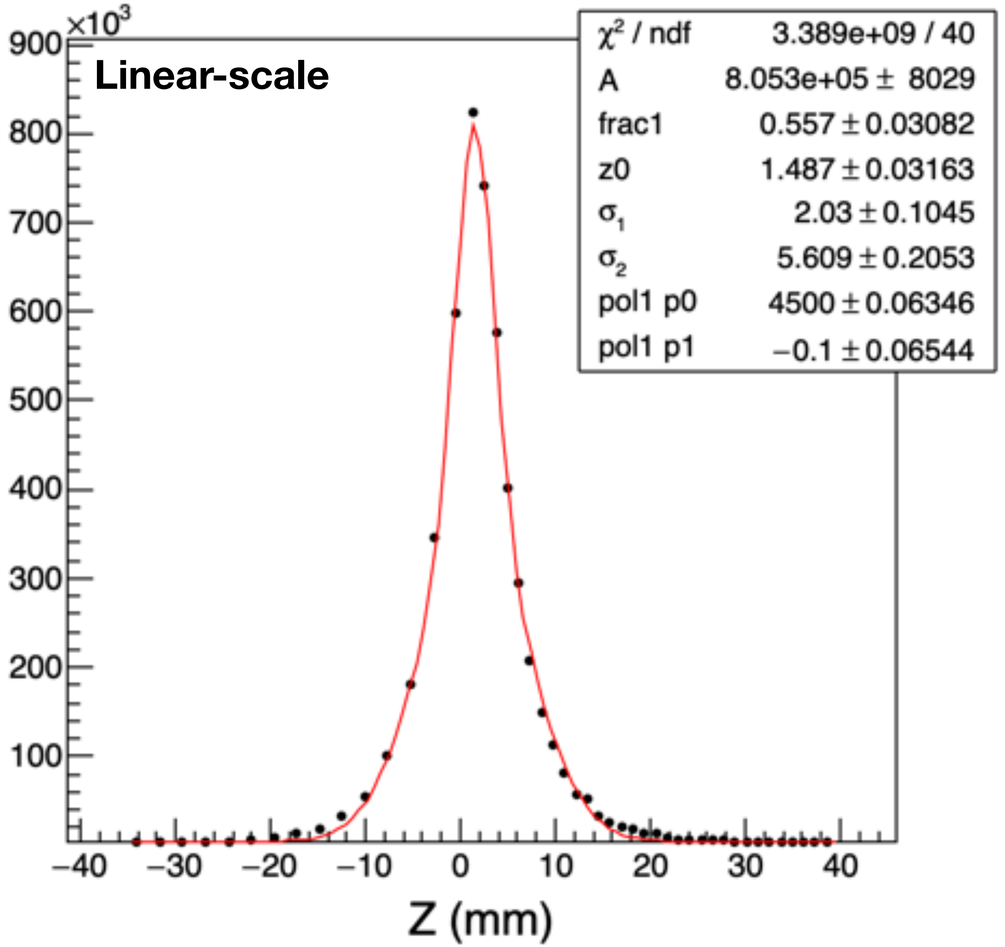


The misalignment between the two methods is used to align the target center to the origin in the lab reference frame.

Target density profile

(E_{ref} =120 keV, after alignment)





1. **Target body**
   - Wide and symmetric distribution
   - FWHM: 5.6 mm; 10% width: 18.8 mm
2. **Residual gas**
   - Wide and flat
   - Peak/residual ratio: ~200

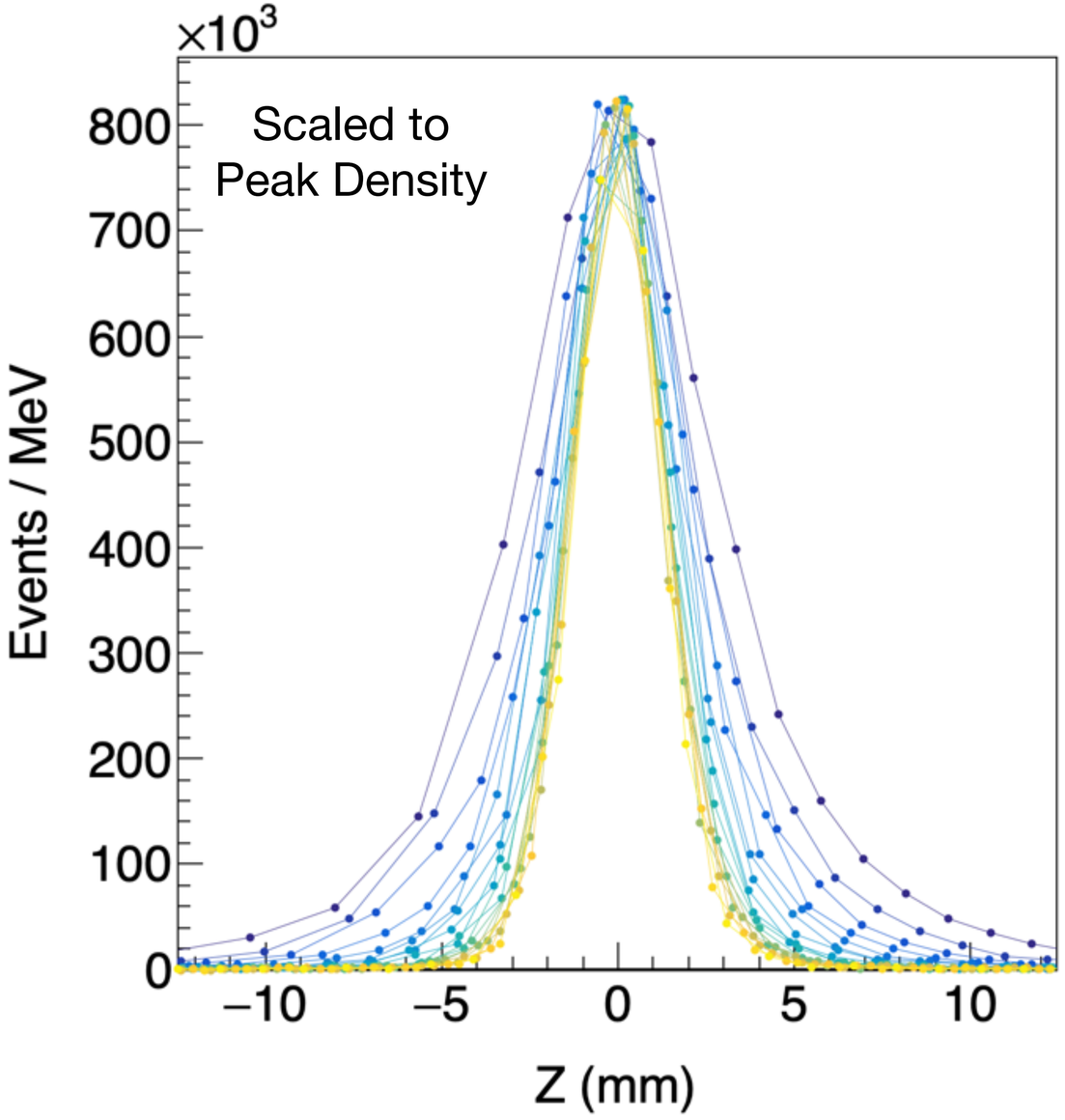
$$A(f_1\mathcal{N}(z;z_0,\sigma_1)+(1-f_1)\mathcal{N}(z;z_0,\sigma_2))$$

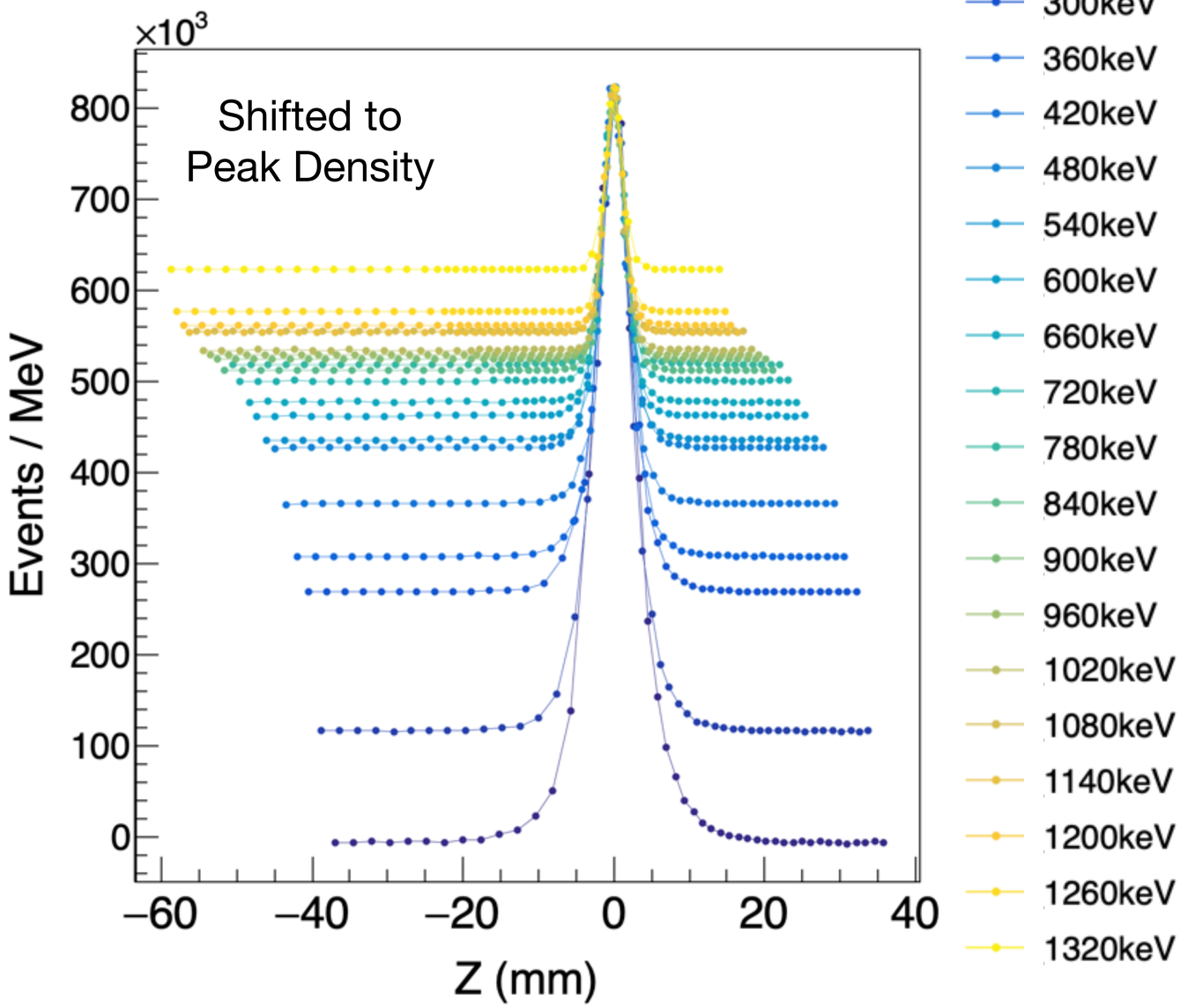
- A: Relative peak density
- f_1: fraction of first Gaussian
- z_0: peak position
- σ_1, σ_2 : sigma of the two Gaussian

Results from other E_{ref}

(180~1320 keV, 60 keV step, after alignment):

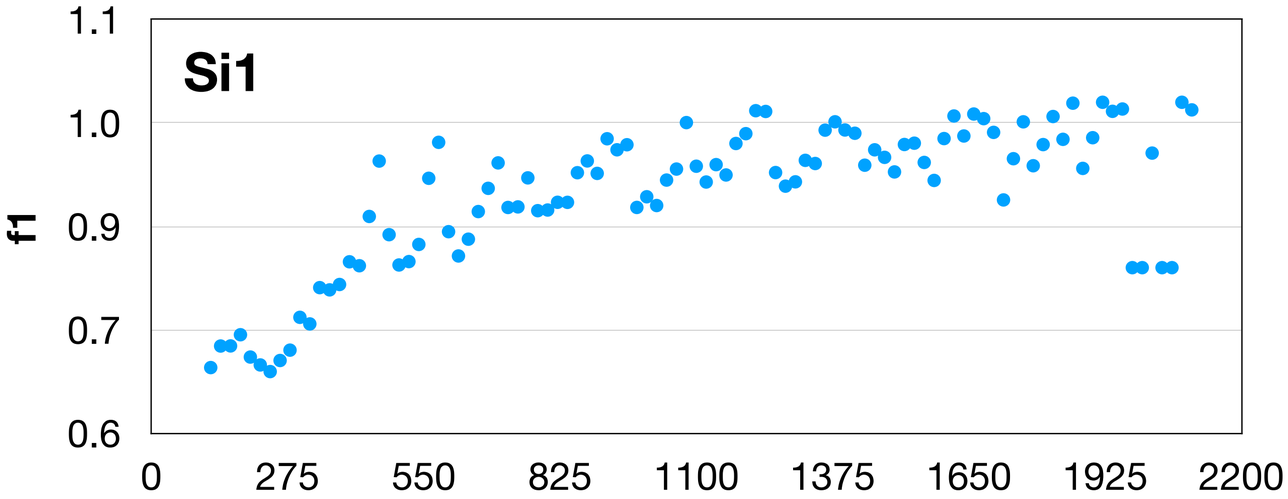
Smaller E_{ref} -> Higher $\sigma_{elastic}$ ->
Higher event rate -> Higher Sensitivity

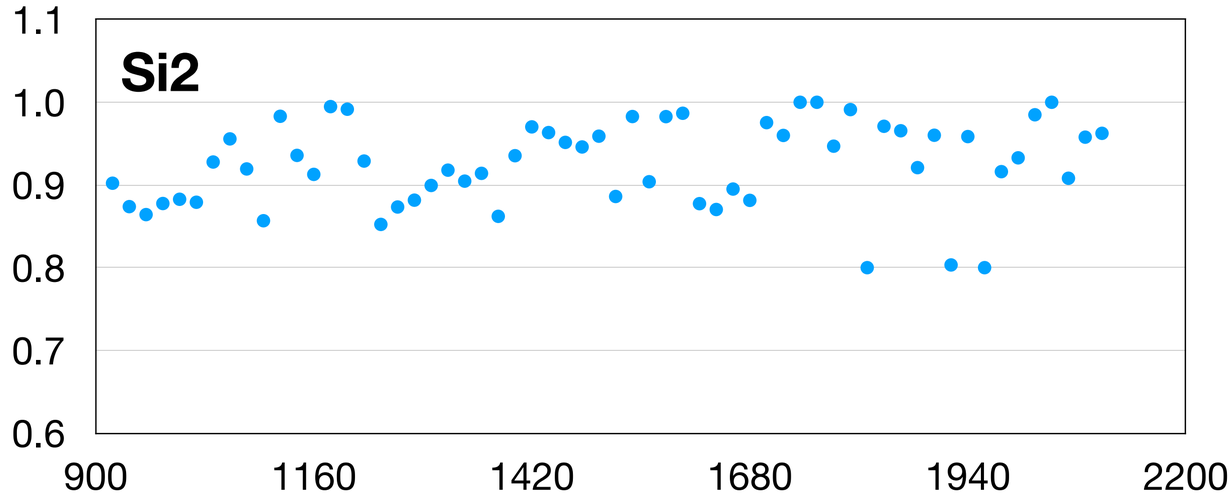


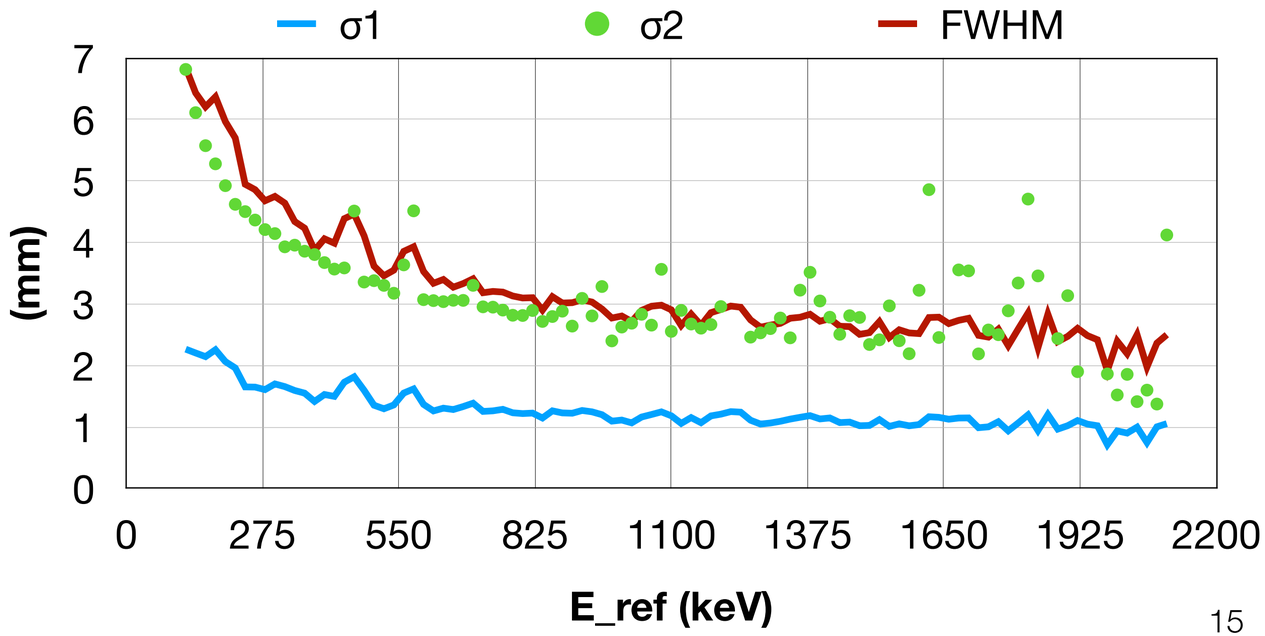


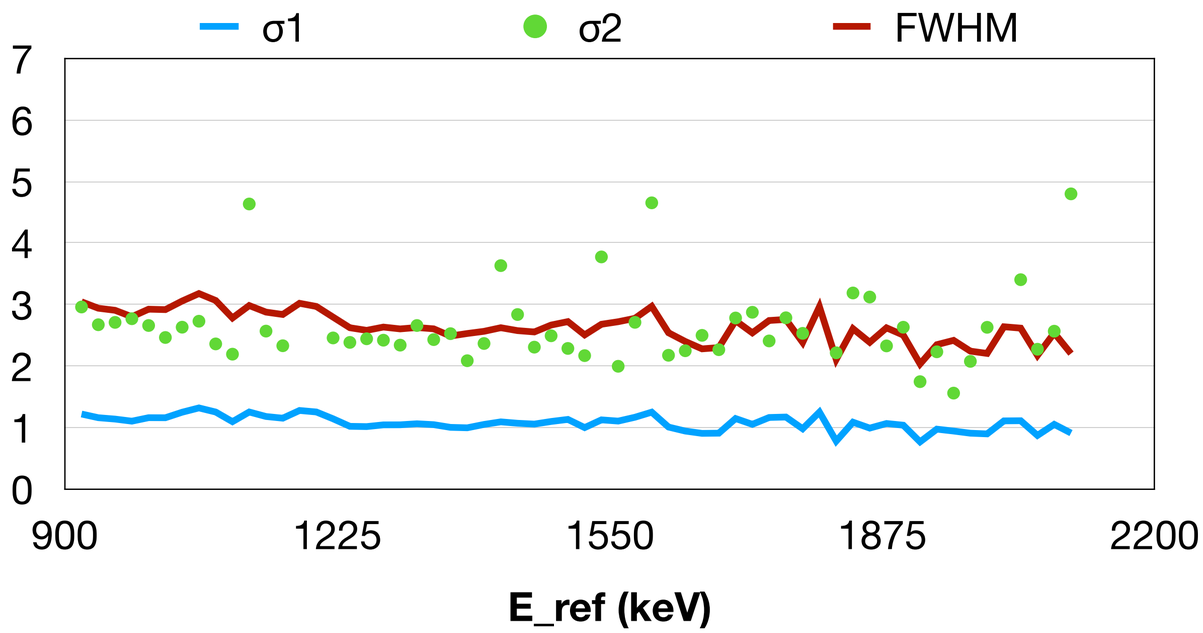
Fit parameter: f1, σ_1, σ_2 and FWHM

Aymptotic FWHM at large E_{ref}: ~2 mm









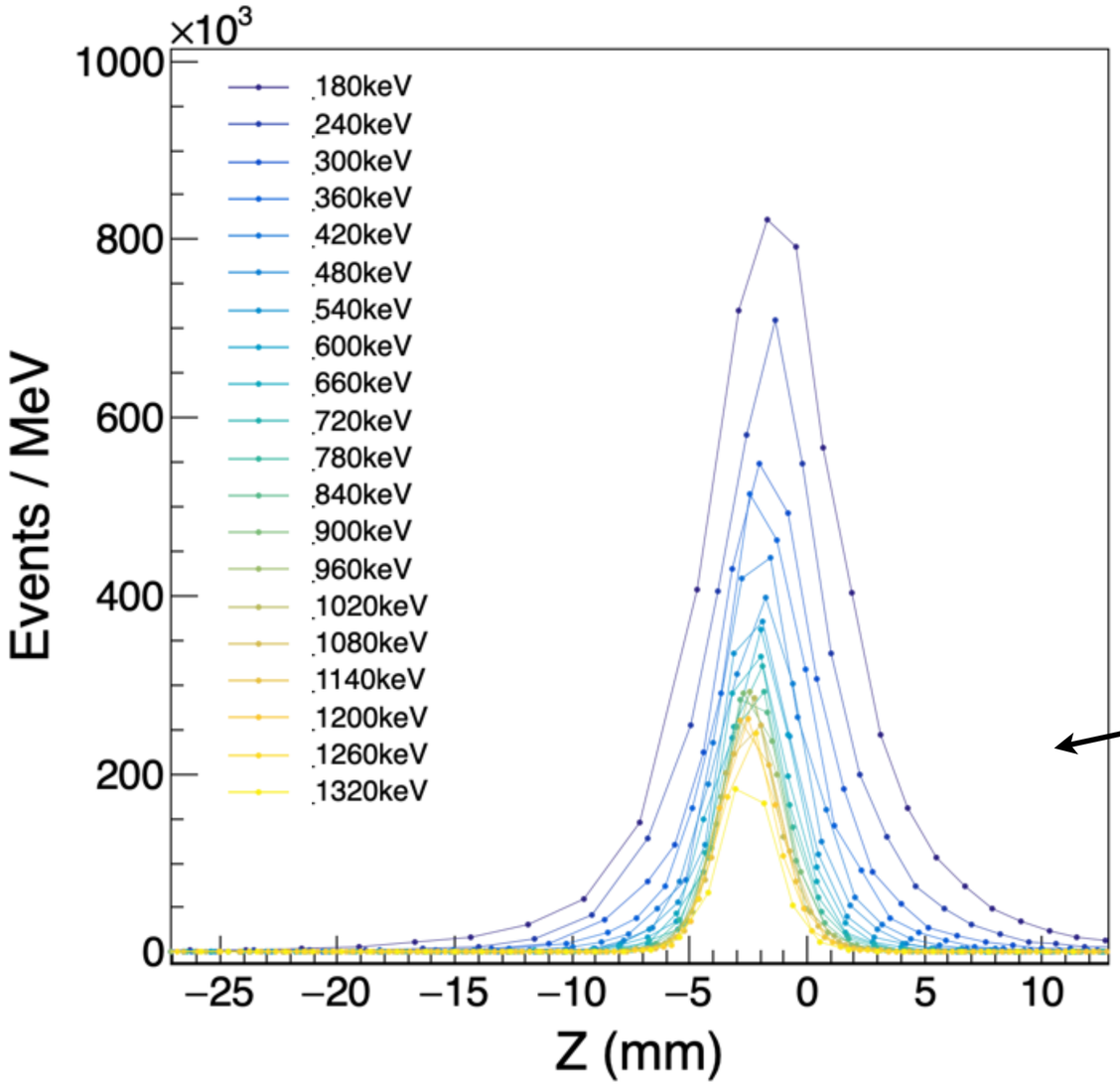
Summary

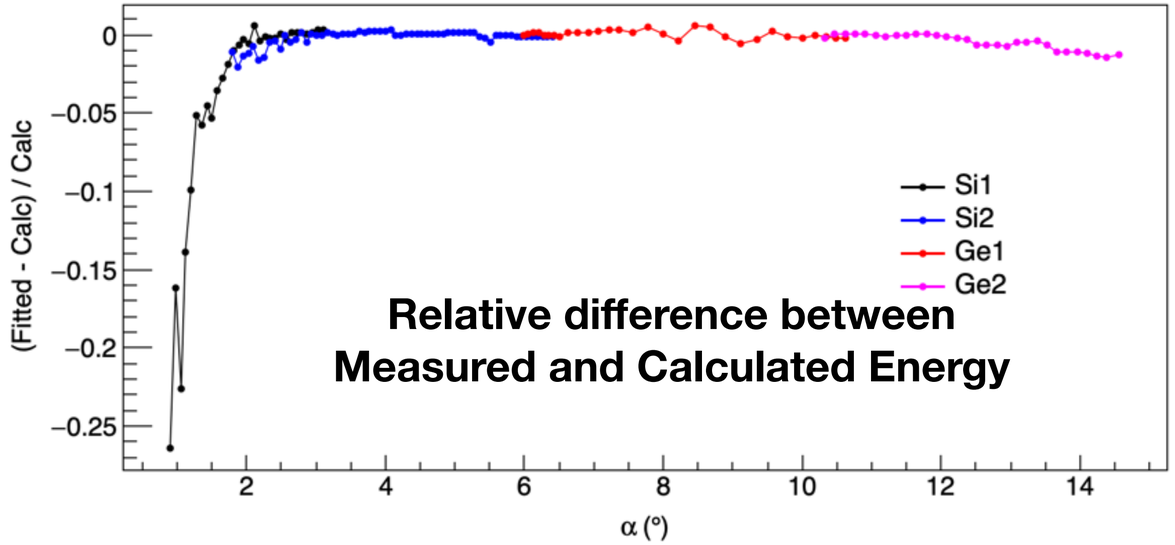
1. Lower range of |t| measurement is observed to be limited by the thickness of cluster jet target
2. A method of determining the target density profile along beam-axis is developed
3. The obtained target profile thickness is sensitive to the E_{ref}, which in turn is determined by the corresponding cross-section of elastic scattering (large derivative in Coulomb region)
4. The obtained target density distribution is an integral result over X-Y plane, thus
   - Combined effect of the target beam tilting and a large diameter of beam spot may explain Discrepancy between the results from the rod method and the current method.
5. The current target profile obtained is preliminary result, since the folding effect of the finite energy resolution of recoil sensors is not considered

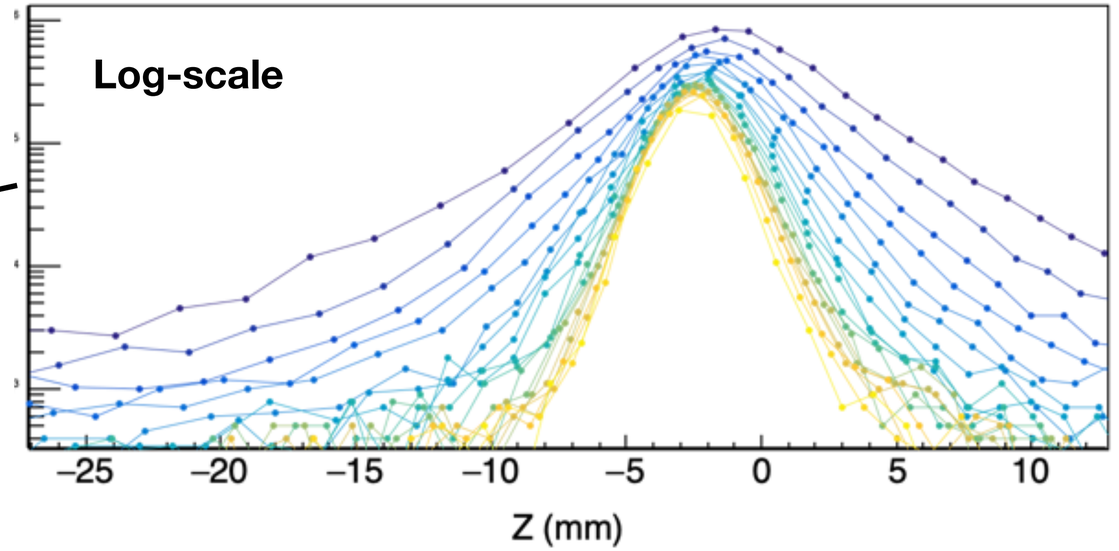
Backup

Results from other E_{ref}

(180~1320 keV, 60 keV step, before alignment):

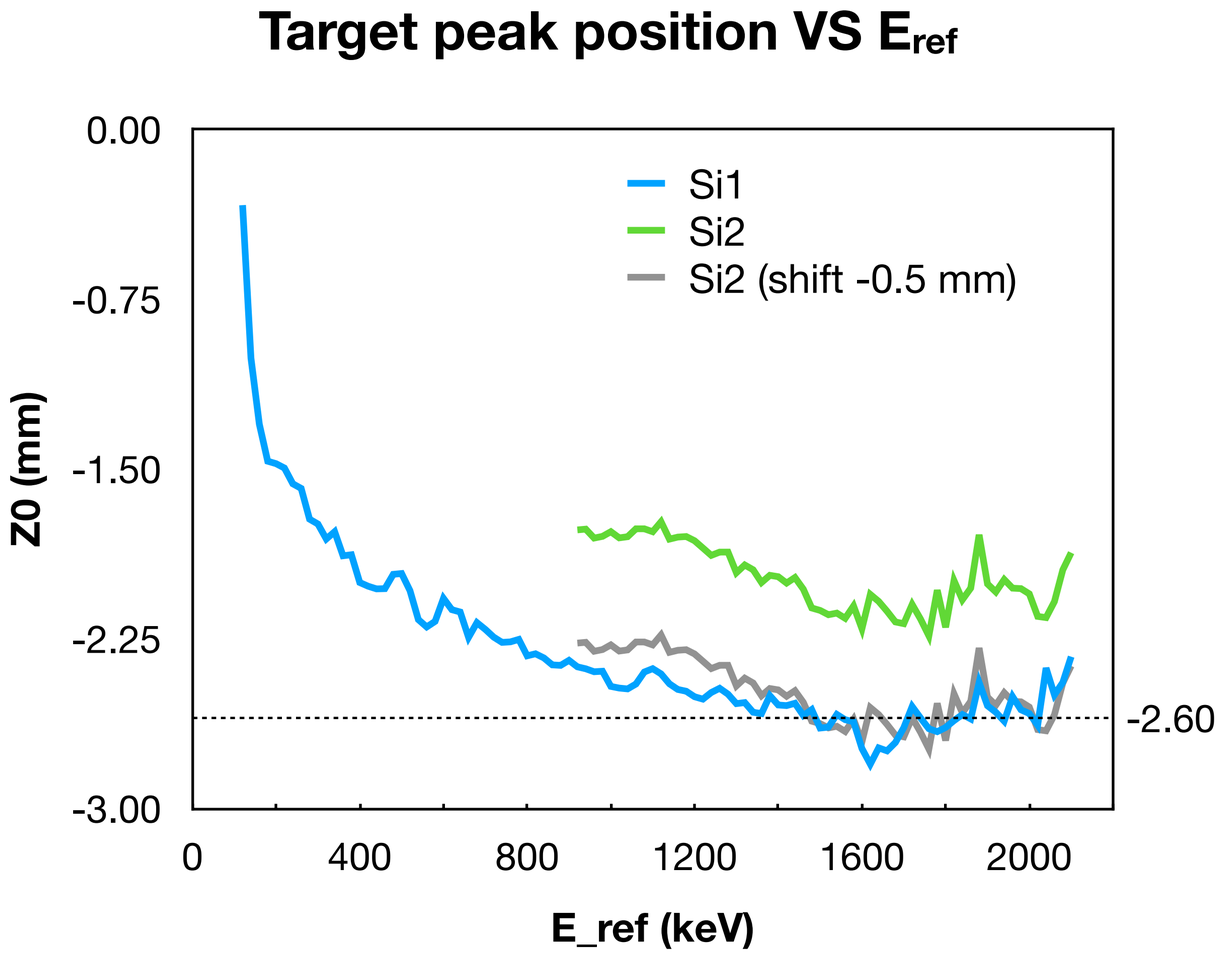


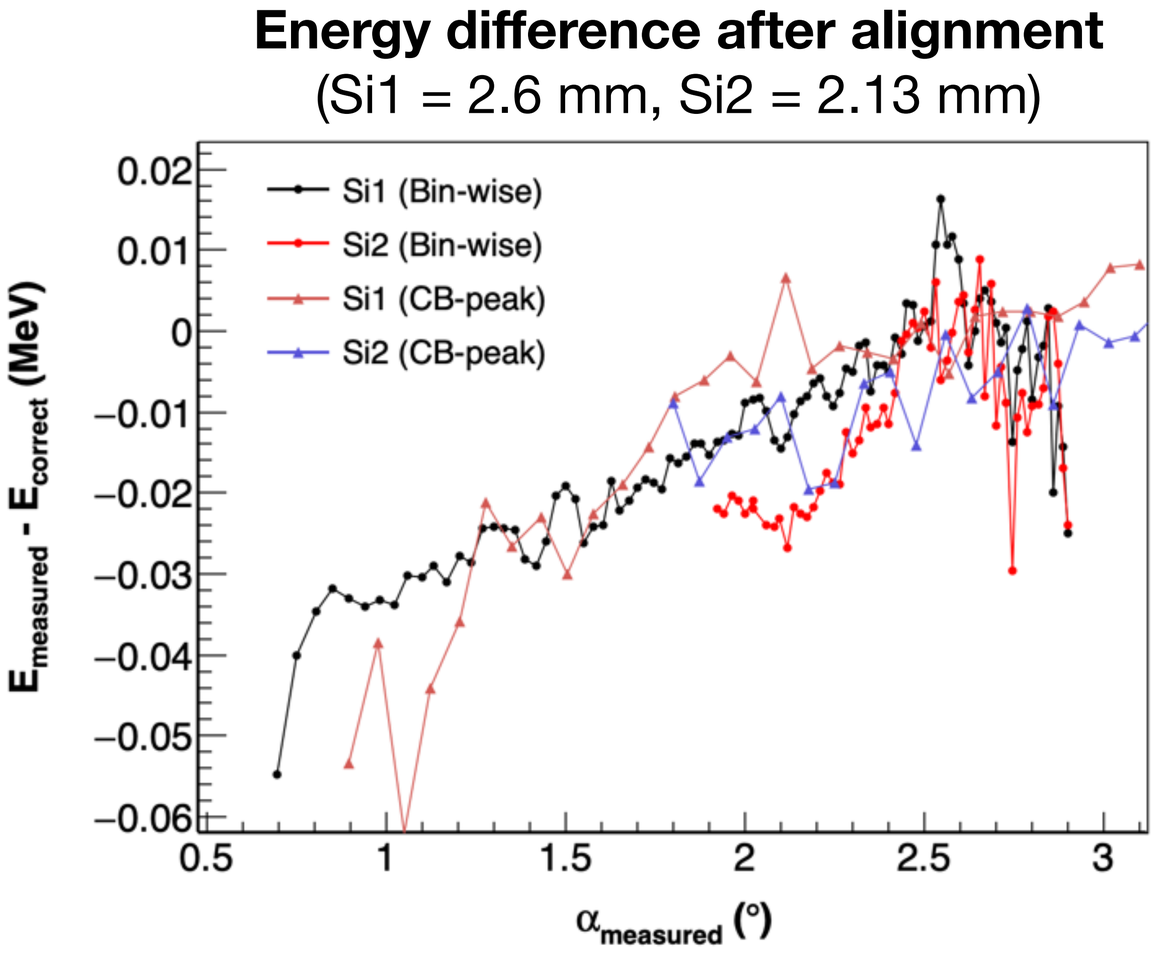




Peak position discrepancy due to energy loss in the thin protection layer of recoil sensors

Fit parameter: Z0





Cross section of elastic scattering at $|t| < 0.004$ (GeV/c)^2