



# Status of Day-1 Experiment at HESR

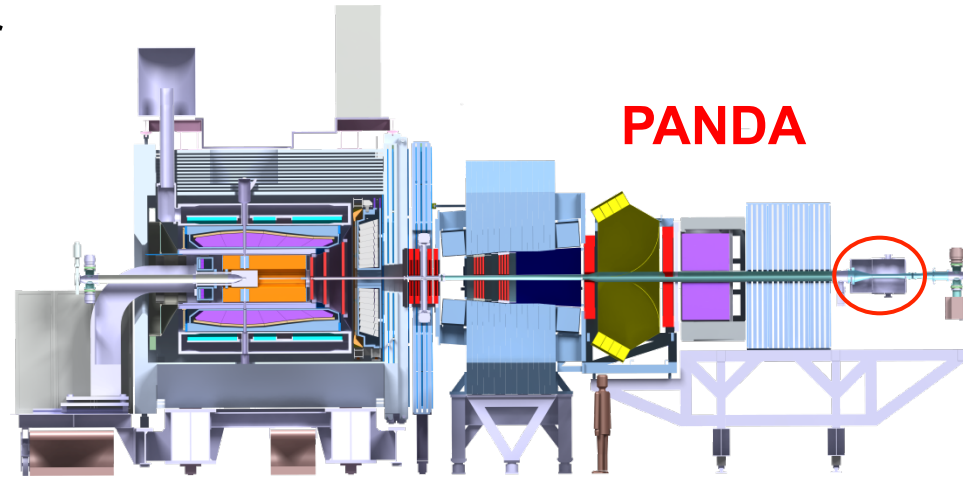
Huagen Xu  
for the PANDA collaboration

# Outline

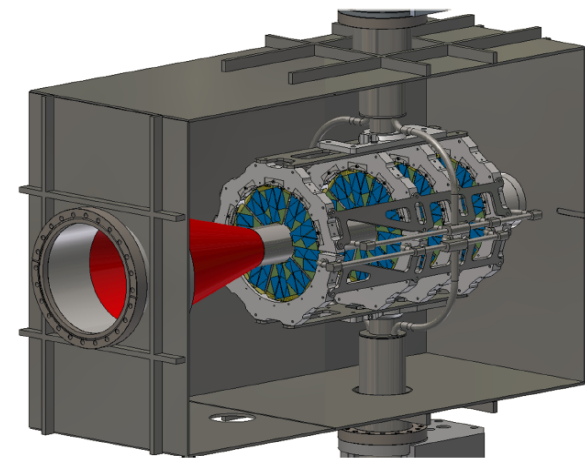
1. Proposal of Day-1 experiment
2. Design, construction and test of recoil detector
3. Beam commissioning of recoil detector at COSY
4. Preliminary results of pp elastic scattering
5. Summary and outlook

# 1.1 Introduction to PANDA luminosity monitor

- Goal of PANDA luminosity monitor
  - Integrated luminosity with  $\sim 3\%$  absolute precision

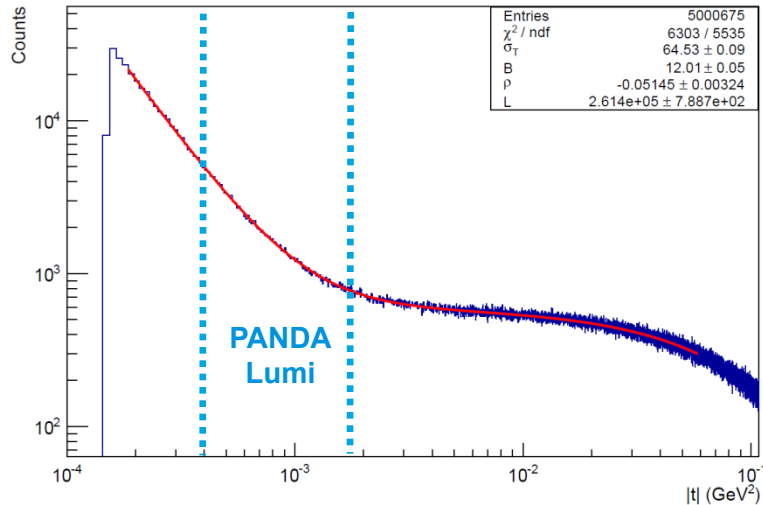


- Concept
  - Low  $t$  elastic scattering
  - Coulomb interference region
  - Forward going antiprotons,  $3 < \theta < 8$  mrad
  - 4-layer HV-MAPS telescope at  $Z \sim 10$  m



- HV-MAPS on Diamond
- Retractable halfplanes
- Two vacuum compartments
- Inner beampipe

# 1.2 Performance of PANDA luminosity monitor



**Small range of  $t$  to be measured.**

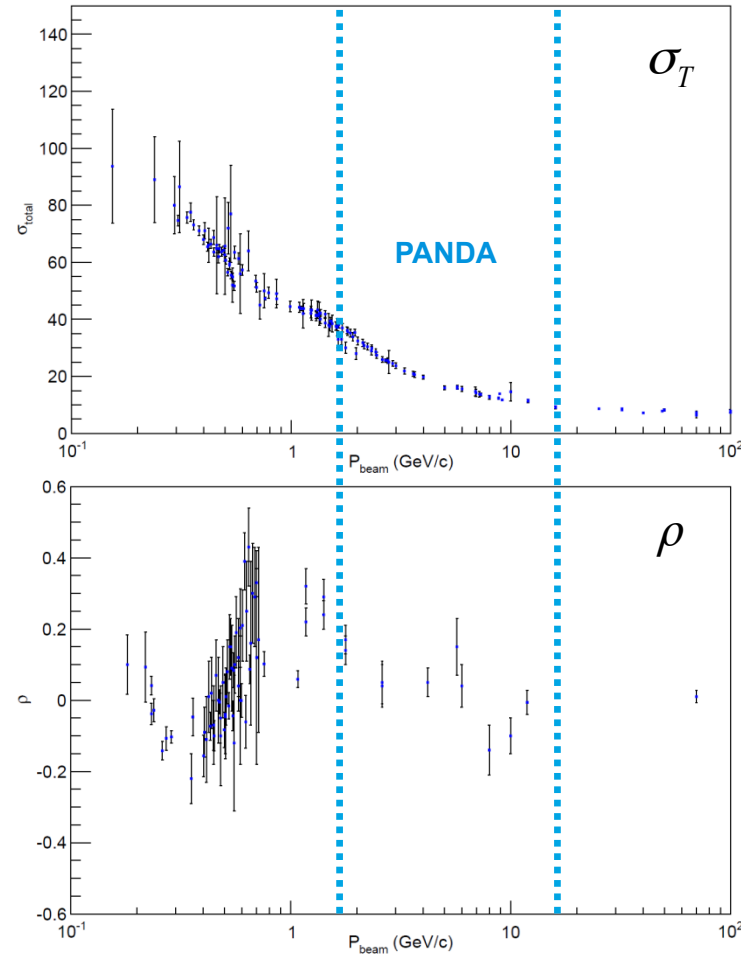
$$\frac{dN}{dt} = L \left( \frac{d\sigma_c}{dt} + \frac{d\sigma_{int}}{dt} + \frac{d\sigma_n}{dt} \right)$$

$$\frac{d\sigma_c}{dt} = \frac{4\pi\alpha^2 G^4(t)(\hbar c)^2}{\beta^2 t^2}$$

$$\frac{d\sigma_n}{dt} = \frac{\sigma_T^2 (1 + \rho^2) e^{-b|t|}}{16\pi(\hbar c)^2}$$

PLB 385 (1996) p479

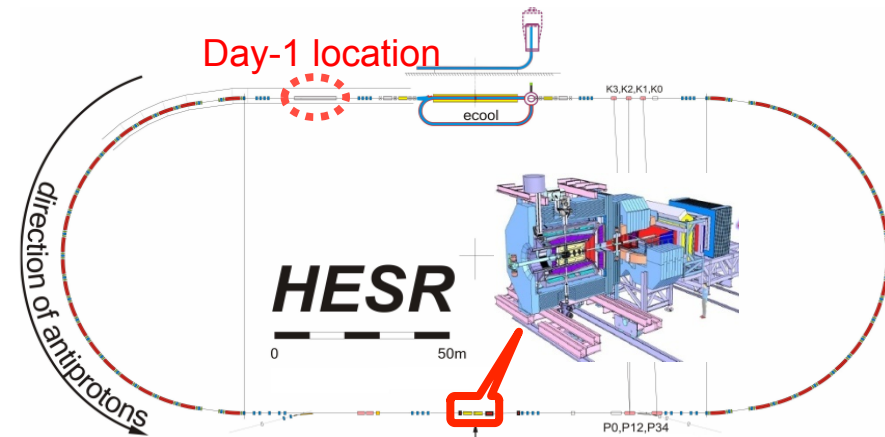
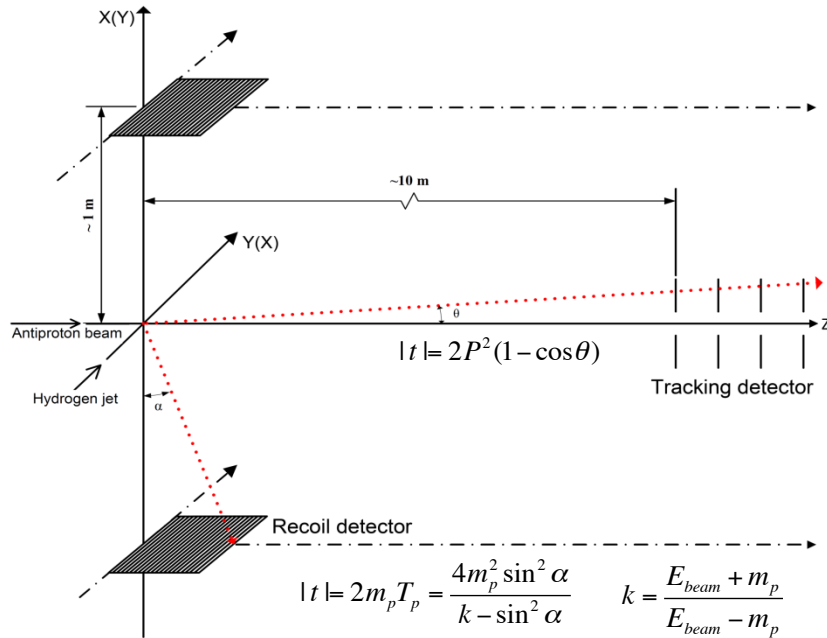
$$\frac{d\sigma_{int}}{dt} = \frac{\sigma_T G^2(t)(\hbar c)^2}{\beta|t|} e^{-\frac{1}{2}bt} (\rho \cos\delta + \sin\delta)$$



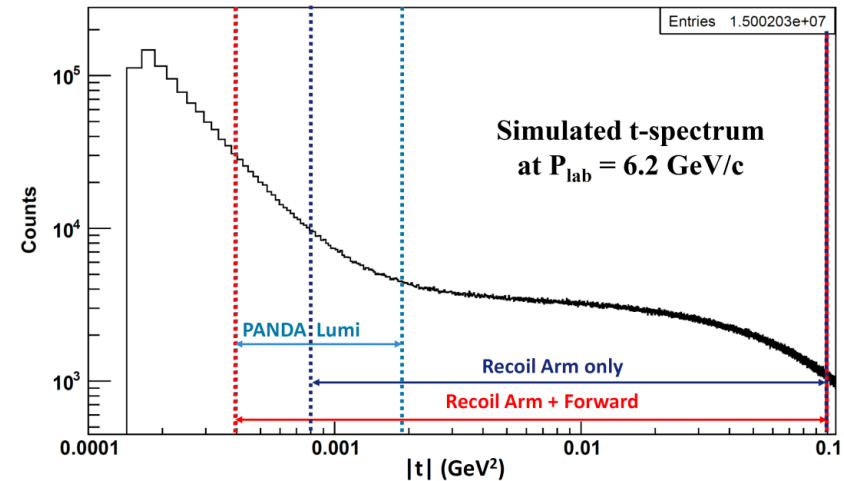
Data of  $\sigma_T$  and  $\rho$  are from PDG, The Review of Particle Physics, PRD 86, 010001 (2012)

**Lack of data for parameters  $\sigma_T$ ,  $\rho$  and  $b$**

# 1.3 Proposal of Day-1 Experiment at HESR

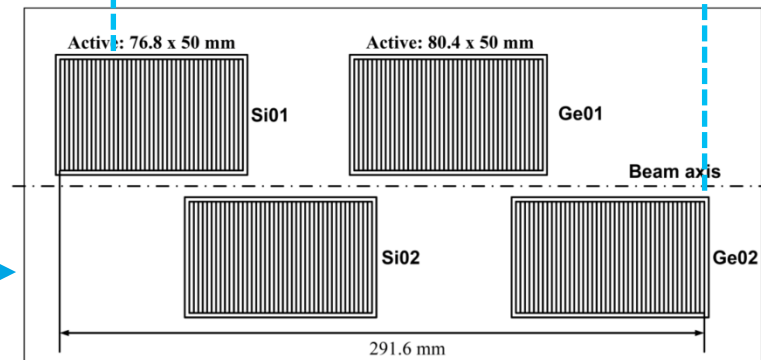
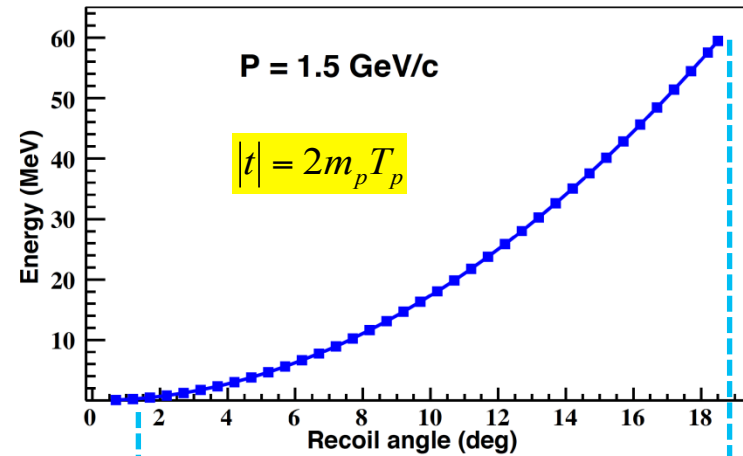
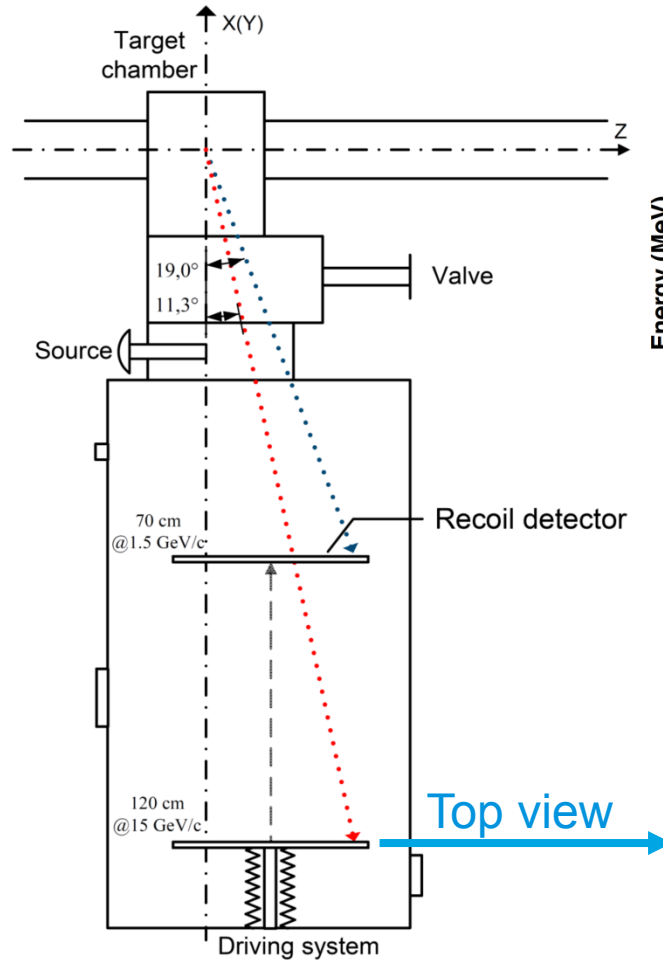


- Antiproton-proton elastic scattering
- Coincidence (Forward & Recoil)
- Large range of  $t$ 
  - Recoil arm only: 0.0008-0.1  $\text{GeV}^2$
  - + Forward : 0.0004-0.1  $\text{GeV}^2$



**A large range of  $t$  can be achieved by coincidence measurement at HESR!**

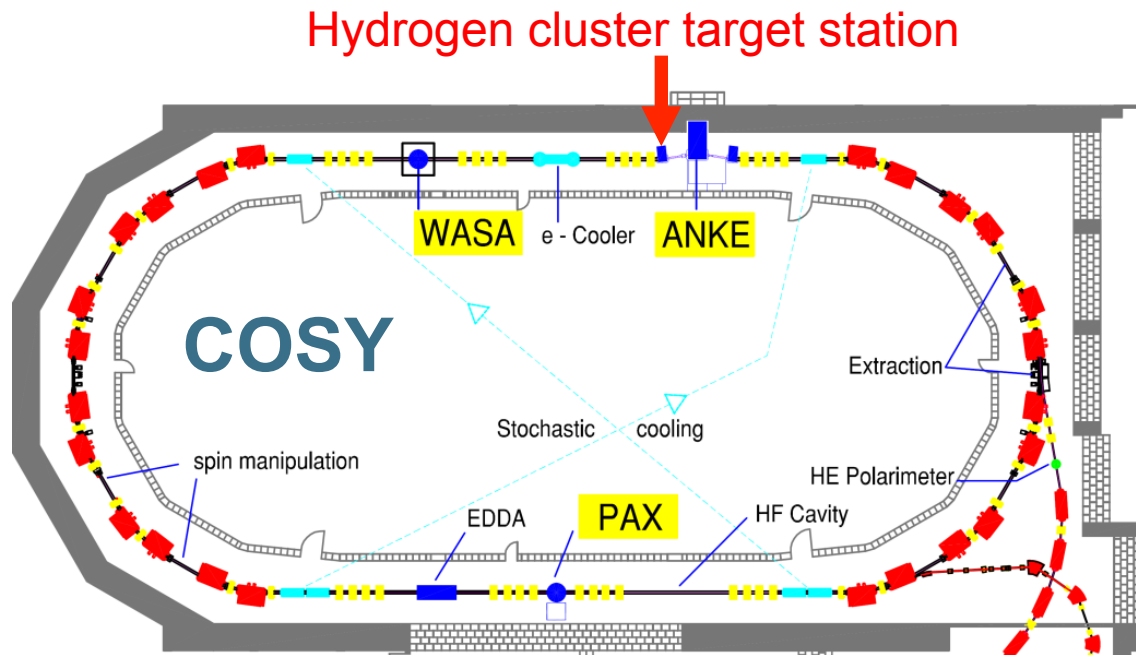
# 2.1 Sketch of Recoil Arm



**Recoil arm will cover the entire range of the expected t-spectrum.**

## 2.2 Goals of Commissioning at COSY

- To validate the detector concept by measuring pp elastic scattering
- To answer the key questions
  - What is the minimum energy of recoil protons to be measured?  
*e.g. 400 keV protons possible to be measured by recoil detector alone?*
  - What precision of luminosity of PANDA could be expected?  
*e.g. 3% of absolute precision feasible?*

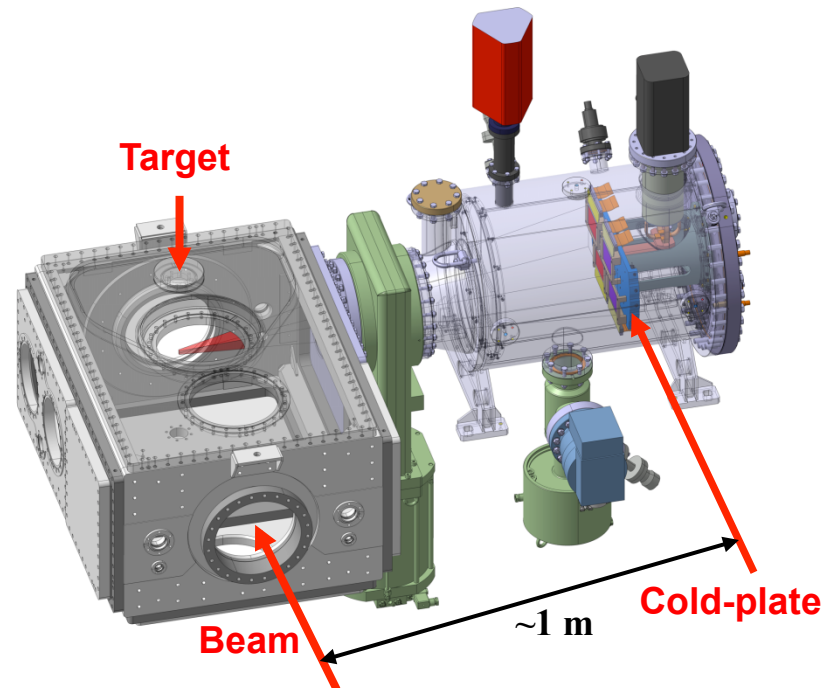


## 2.3 Chamber Design for Commissioning

- Proton beam maximum 3.7 GeV/c at COSY
- Expected  $t$  range at max recoil angle 13.6°

P (GeV/c)	$t$ expected (GeV <sup>2</sup> )
2.5	0.0008-0.0921
3.7	0.0008-0.1161

- Assessment of existing Hydrogen cluster target at ANKE target station
  - Density: 10E14 atoms/cm<sup>2</sup>
  - Thickness: ~1 mm by modifying collimate
  - Space: available for Day-1 chamber

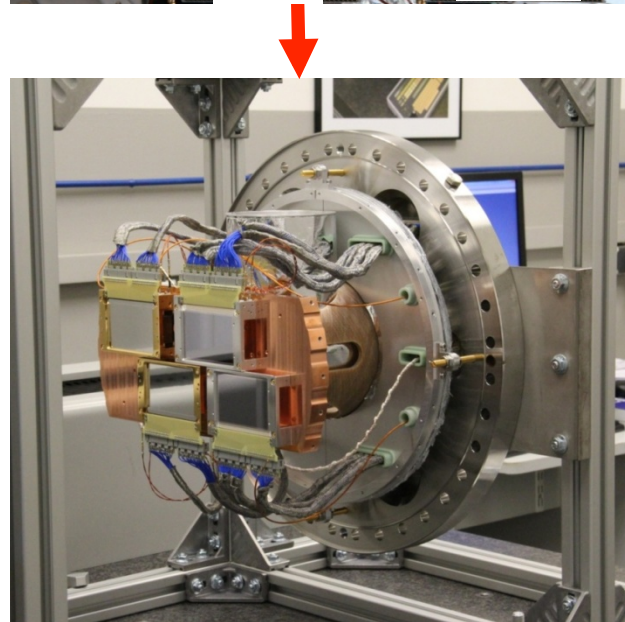
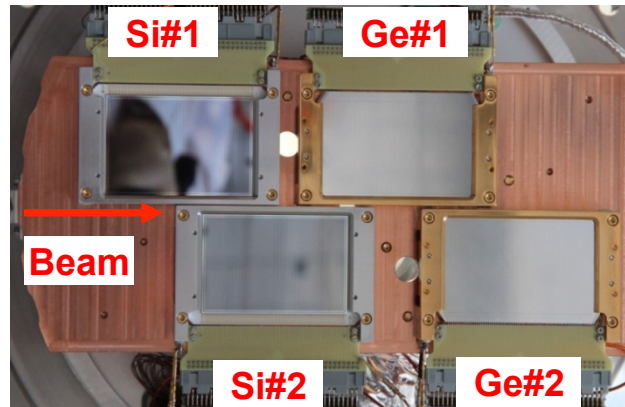


by F. Klehr  
ZEA, Juelich

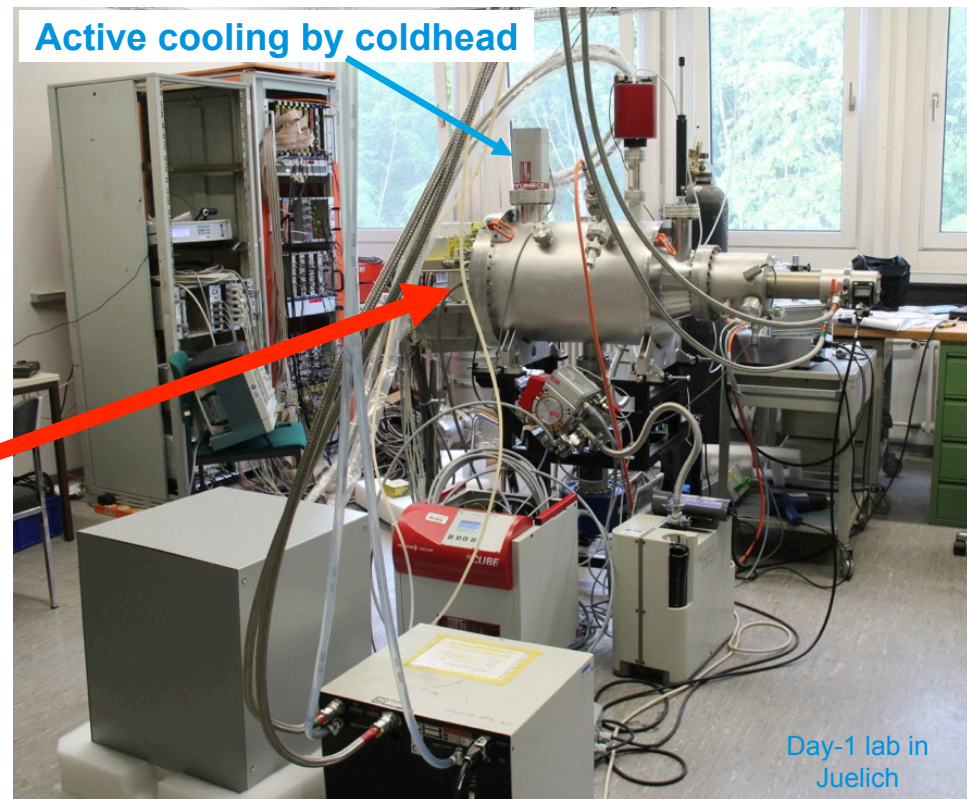
**Existing Hydrogen cluster target is suitable for commissioning.**



## 2.4 Setup for Laboratory Test



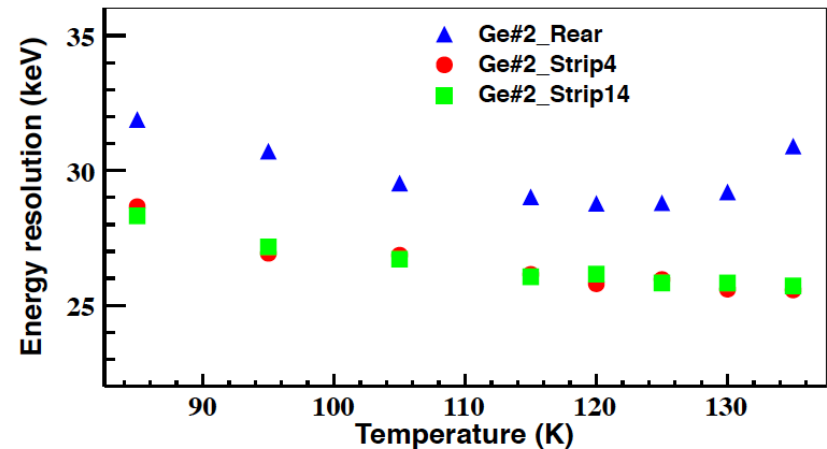
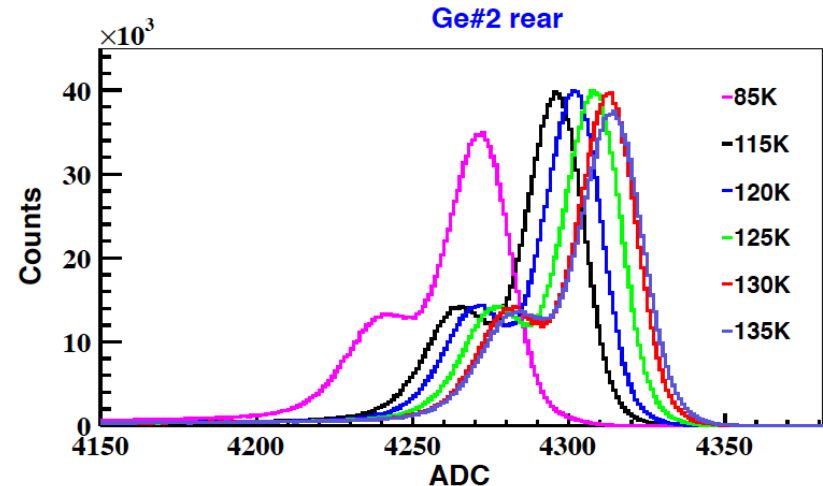
- Si( $\sim 12$  MeV):  $76.8 \times 50 \times 1$  (mm<sup>3</sup>) (64 / 1.2 mm pitch)
- Ge( $\sim 60$  MeV):  $80.4 \times 50 \times 5/11$  (mm<sup>3</sup>) (67 / 1.2 mm pitch)



**Expected energy resolution:  $\sim 22.5$  keV of Si and  $\sim 30$  keV of Ge**

## 2.4.1 Temperature Dependence

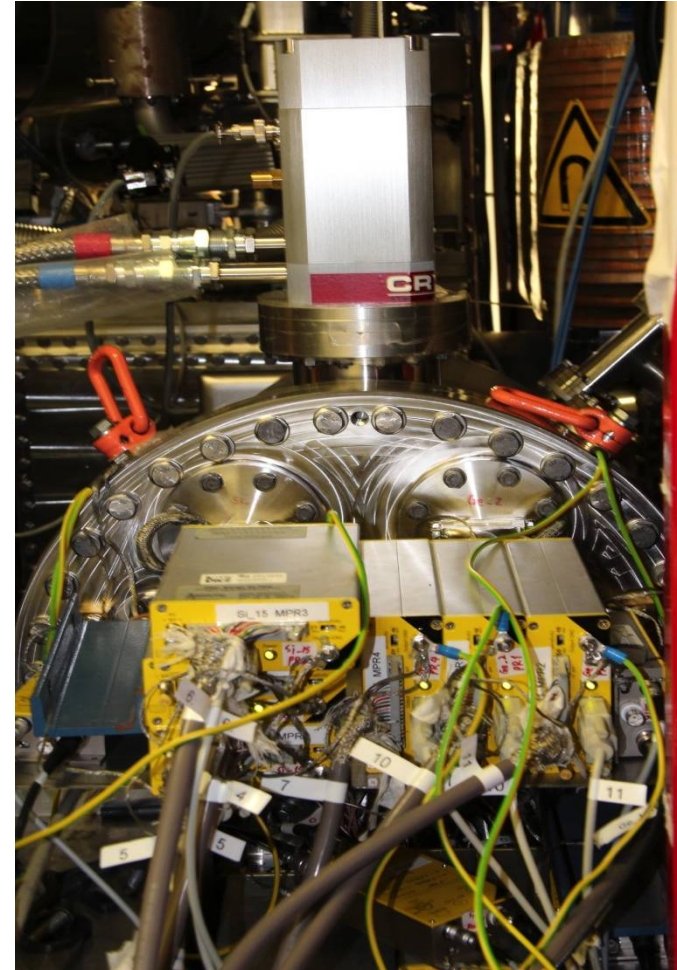
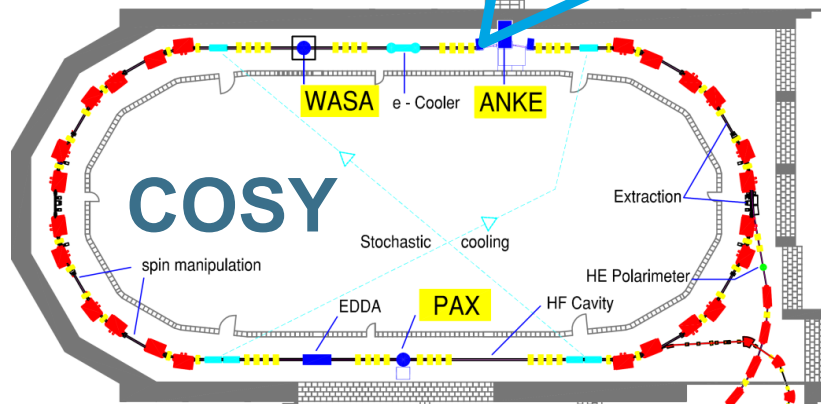
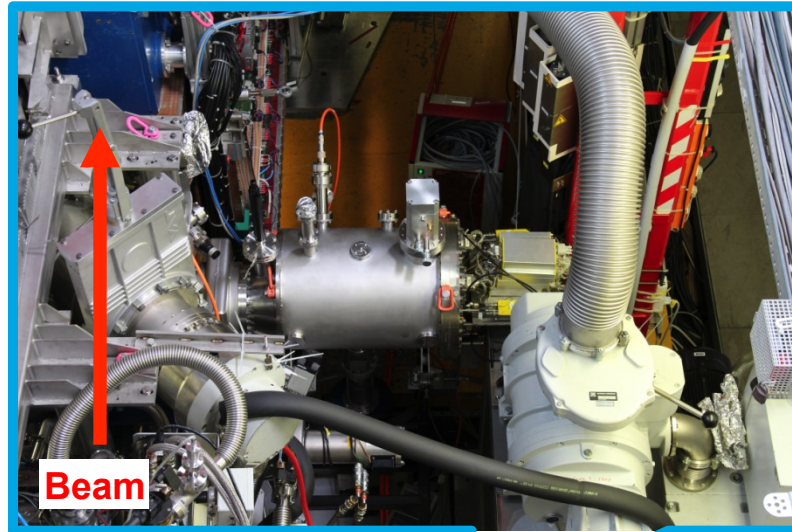
- Response of detectors at different temperature
  - Si:
    - ✓ *Small leakage current below 250 K*
    - ✓ *Higher temperature higher amplitude but no significant improvement on resolution*
  - Ge (typically working at 77-100K):
    - ✓ *Leakage current increasing fast above 130 K*
    - ✓ *Amplitude and resolution benefit from higher temperature*
- Energy resolution of  $^{244}\text{Cm}$  at 125 K
  - Si strips: <20 keV (FWHM)
  - Ge strips: <30 keV (FWHM)



**Detector performance fulfills the design requirements.**



# 3 Commissioning at COSY

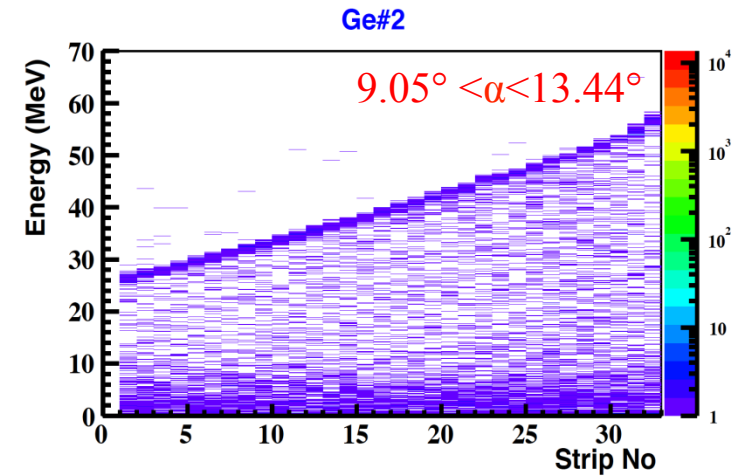
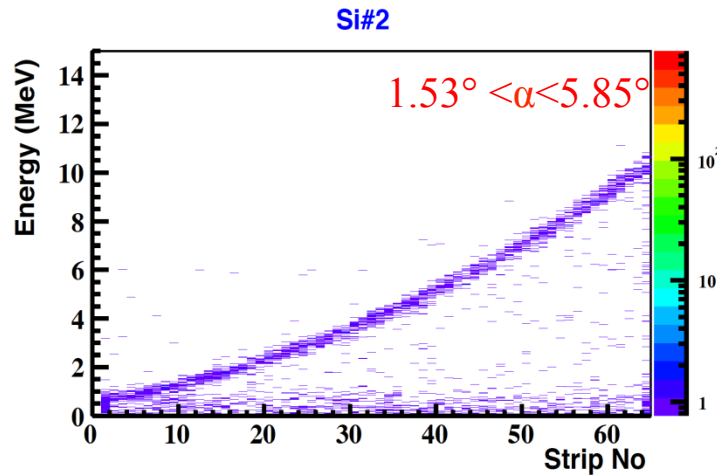
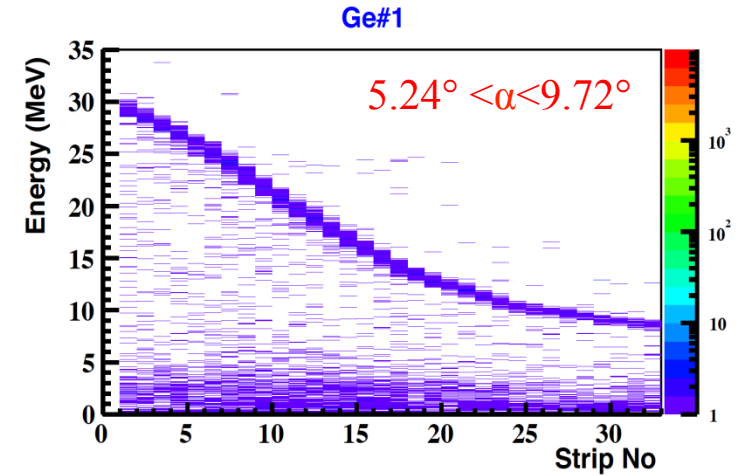
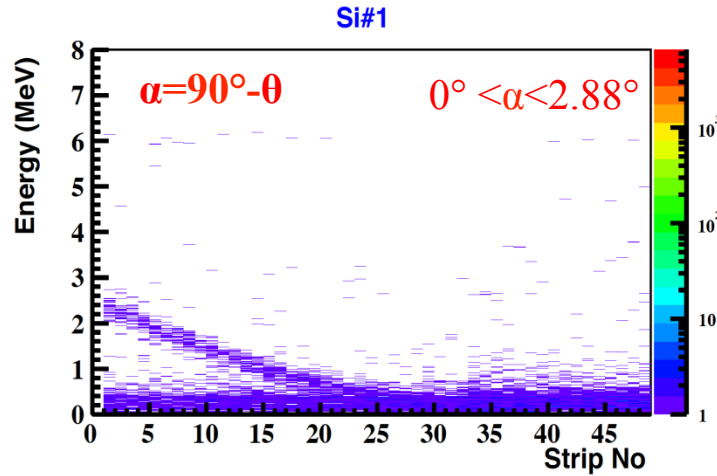


**Detector chamber installed at ANKE target station for commissioning.**

# 3.1 Online Plots from Commissioning



$P = 3.2 \text{ GeV}/c$



**Energy of recoil protons clearly observed.**

## 3.2 Data Acquired

- Data have been taken at 1.7 GeV/c, 2.5 GeV/c, 2.8 GeV/c and 3.2 GeV/c.

	Run1, 2013	Run2, 2013
Beam intensity	1E10 protons	2-3E10 protons
Data file size	27 GB @ P = 3.2 GeV/c 19 GB @ P = 1.7 GeV/c (1GB ~1M entries)	41 GB @ P = 3.2 GeV/c 53 GB @ P = 2.8 GeV/c 24 GB @ P = 2.5 GeV/c
Elastic events	~ 60% of entries	~ 50% of entries

- Schottky measurements have been performed at 2.5 GeV/c and 3.2 GeV/c

# 4.1 Luminosity Determination

## By Day-1 (online estimate)

Parameters	P = 3.2 GeV/c	P = 2.5 GeV/c
Elastic events on Ge5 (background incl.)	389900	314300
DAQ dead time factor	0.622	0.689
Integrated time, s	6279	6261.5
Cross section, mb	3.487±0.15	3.179±0.15
t range, GeV <sup>2</sup>	0.0165-0.0571	0.0141-0.0488
Acceptance	0.785%	0.785%
Luminosity, cm <sup>-2</sup> s <sup>-1</sup>	(3.647±0.157)E+30	(2.917±0.138)E+30

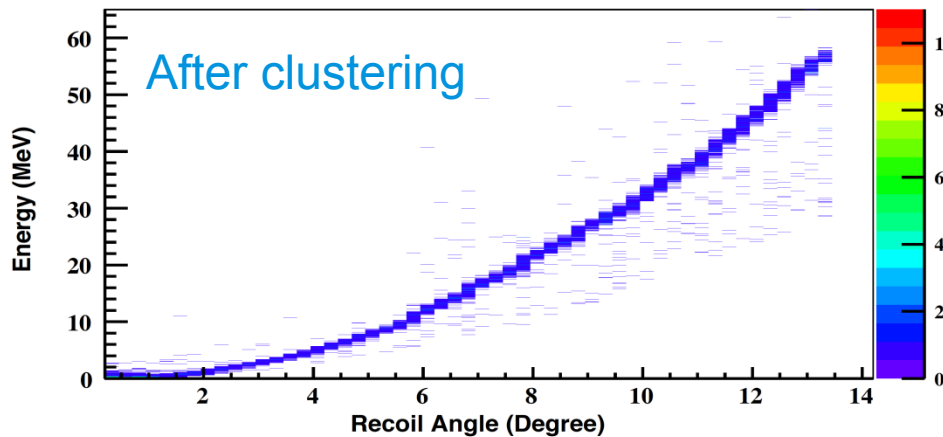
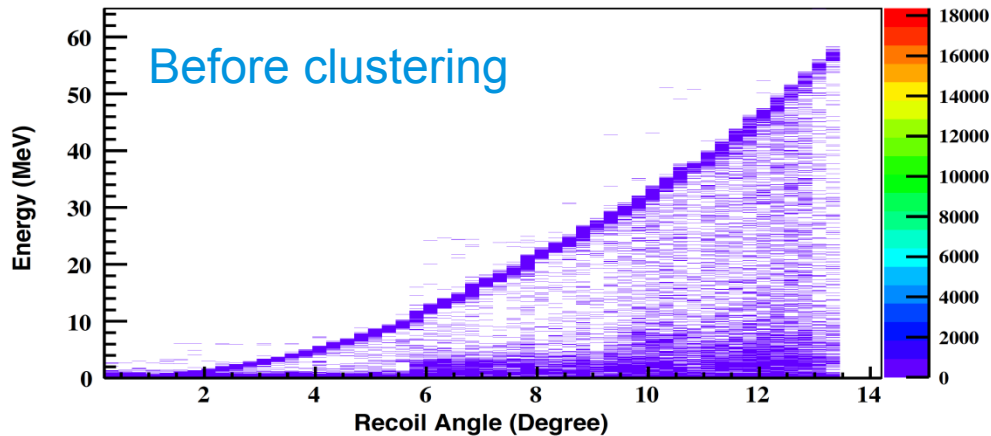
**~1.25**

## By Schottky measurement

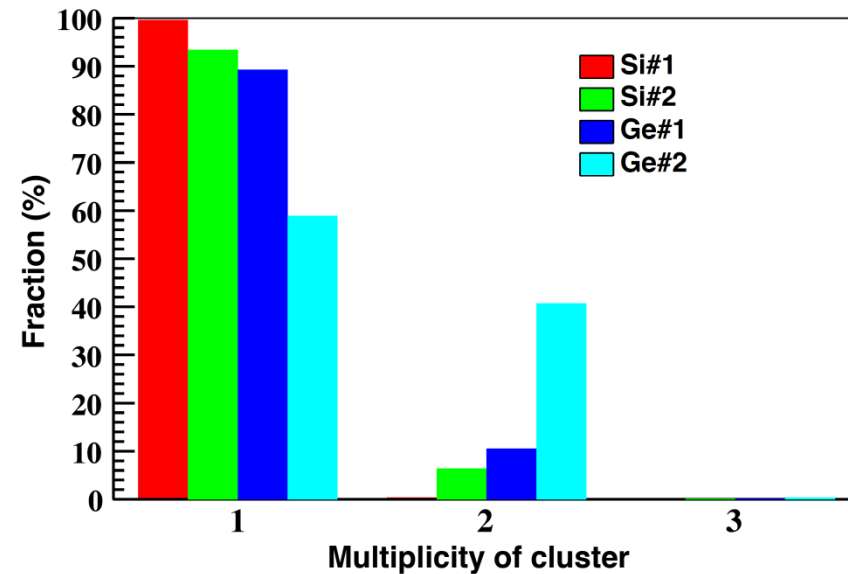
Parameters	P = 3.2 GeV/c	P = 2.5 GeV/c
Target thickness $n_T$ , atoms/cm <sup>2</sup>	8.867E+13	<b>1.310E+14 ?</b>
Beam current $n_B$	2.711E+10	2.180E+10
Initial beam frequency $f_0$ , Hz	1567975	1529797
Luminosity $n_T * n_B * f_0$ , cm <sup>-2</sup> s <sup>-1</sup>	(3.769±0.169)E+30	(4.350±0.247)E+30

**~1.24**

## 4.2 Analysis: Clustering



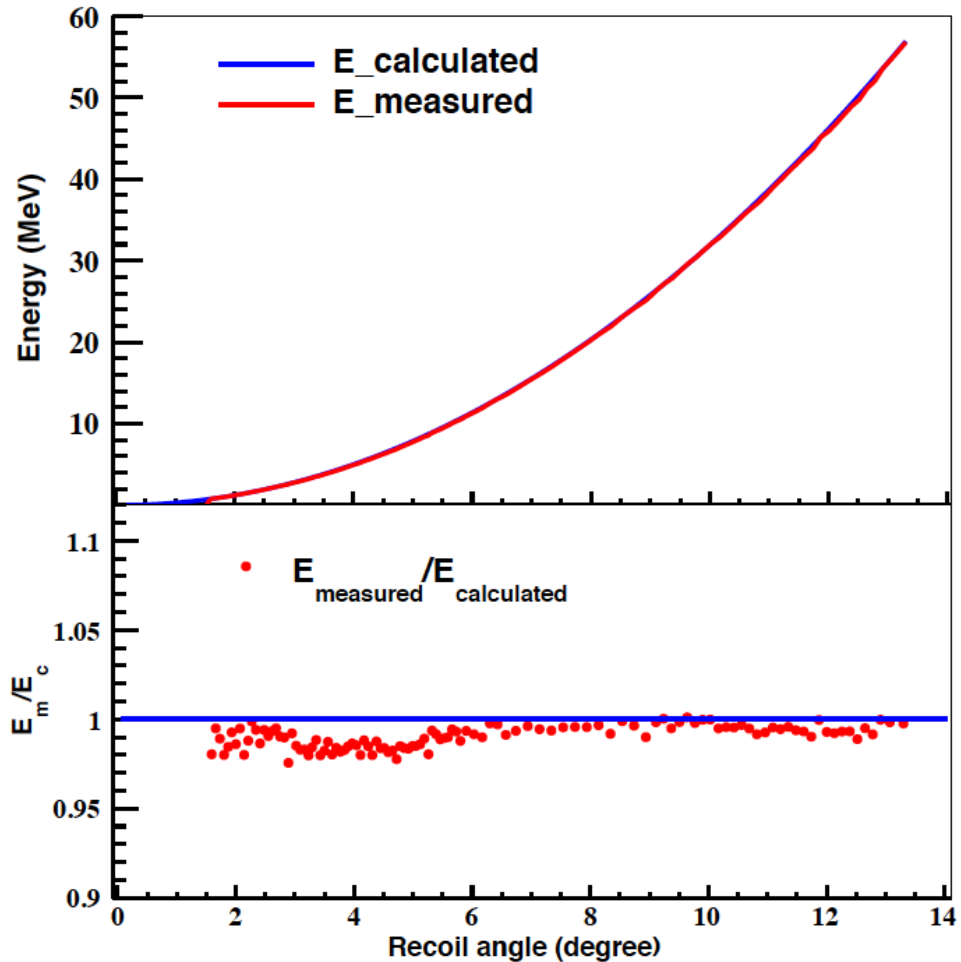
Example at  
 $P = 3.2 \text{ GeV}/c$



**Clustering algorithm implemented for energy reconstruction.**

## 4.3 Analysis: Energy vs Recoil Angle

$P = 3.2 \text{ GeV}/c$



To be corrected:

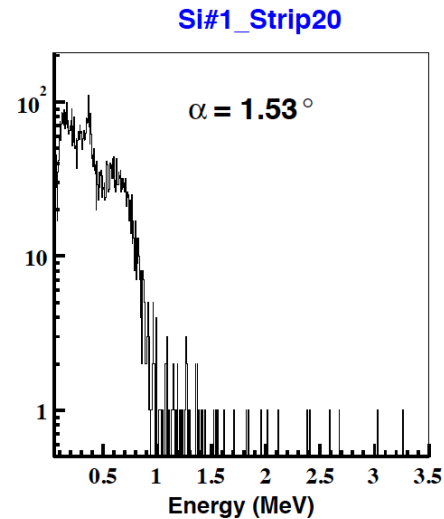
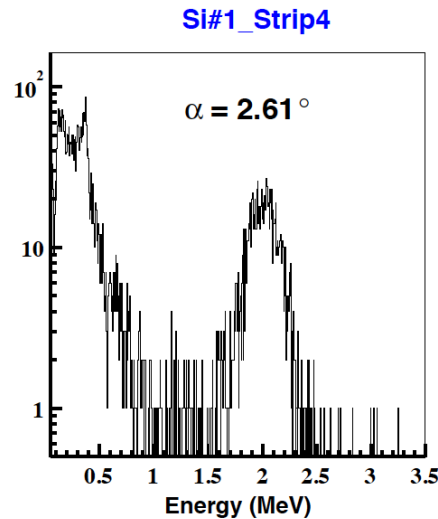
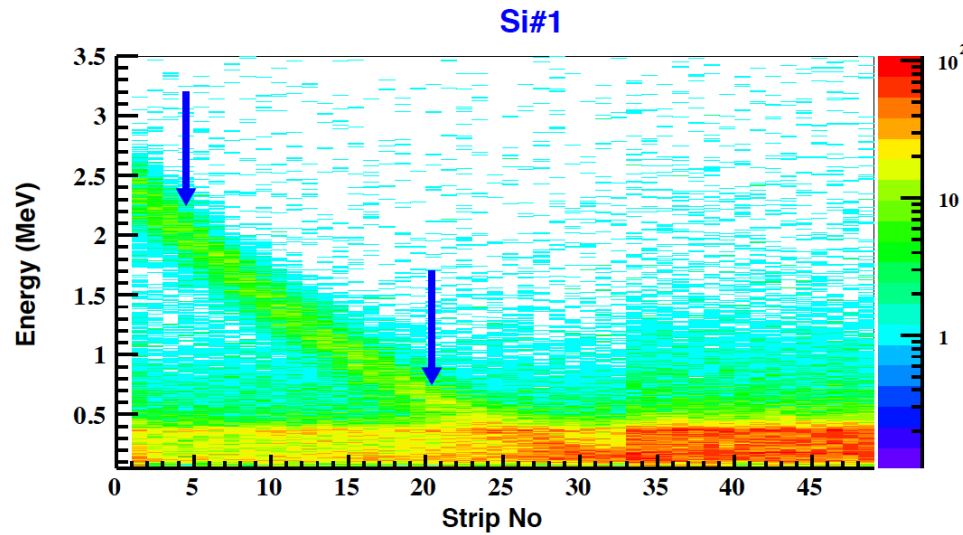
- Detector alignment
- Beam target overlapping

**Energy of recoil protons precisely reconstructed.**



## 4.4 Analysis: Detection Threshold

$P = 3.2 \text{ GeV}/c$



Threshold:  $\sim 600 \text{ keV}$

**Forward measurement is required for a coincidence.**

## 5 Summary and Outlook

- A recoil detector has been designed and constructed in order to validate the method of the Day-1 experiment at HESR.
  - Laboratory tests prove that the recoil detector fulfills the requirements.
  - Preliminary results of commissioning at COSY.
  - Forward measurement is expected for a complete coincidence in order to suppress background.
- 
- Data analysis for the construction of a full range of the t-spectrum.
  - Determination of luminosity as well as forward elastic scattering parameters.

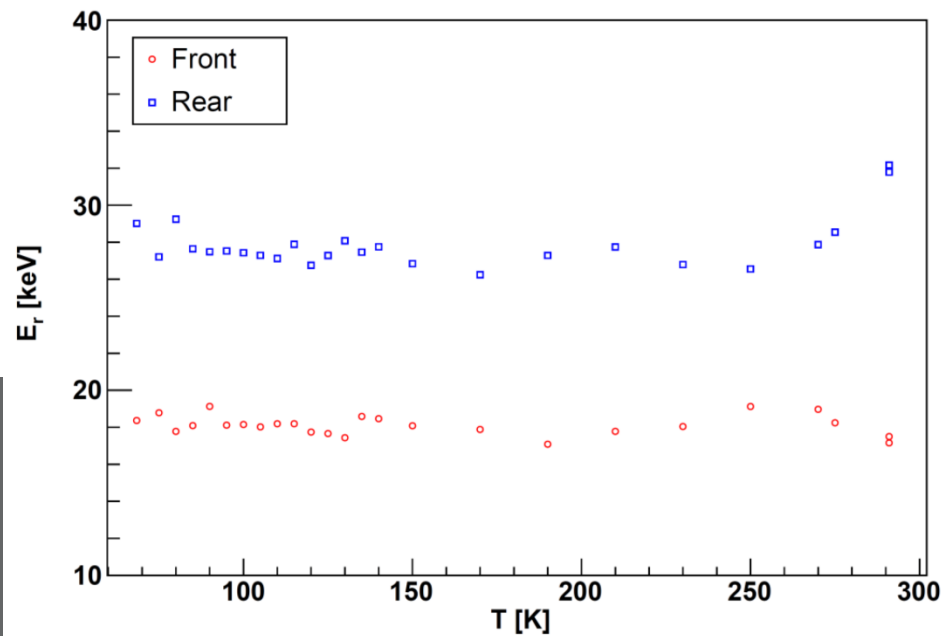
**The Day-1 Experiment with full set-up will be performed as soon as the first antiproton beams are available at HESR!**

# Backup

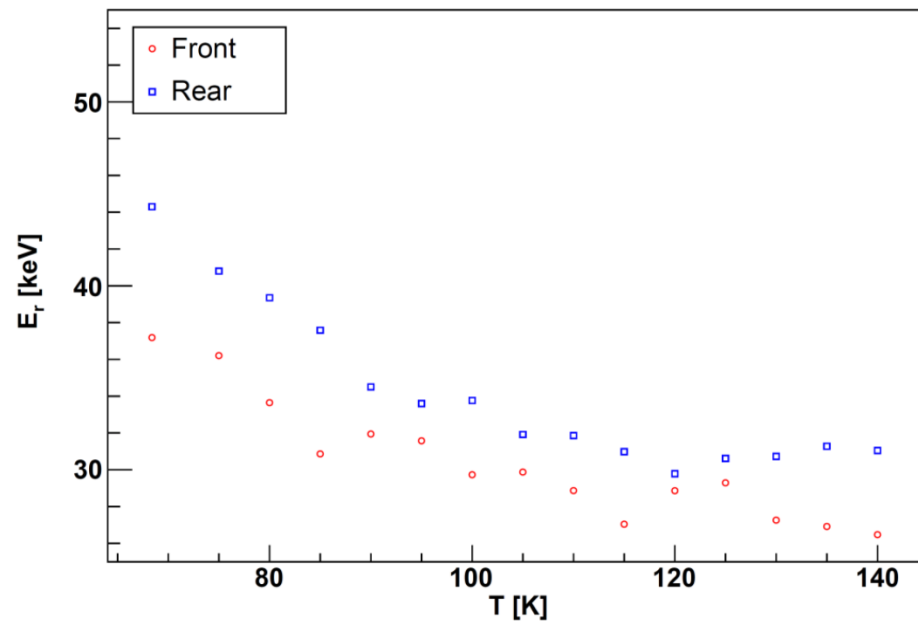
## 2.3.2 Detector Energy Resolution

- Silicon strips: ~20 keV (FWHM) achieved
- Germanium strips: ~30 keV (FWHM) achieved

Si\_#2



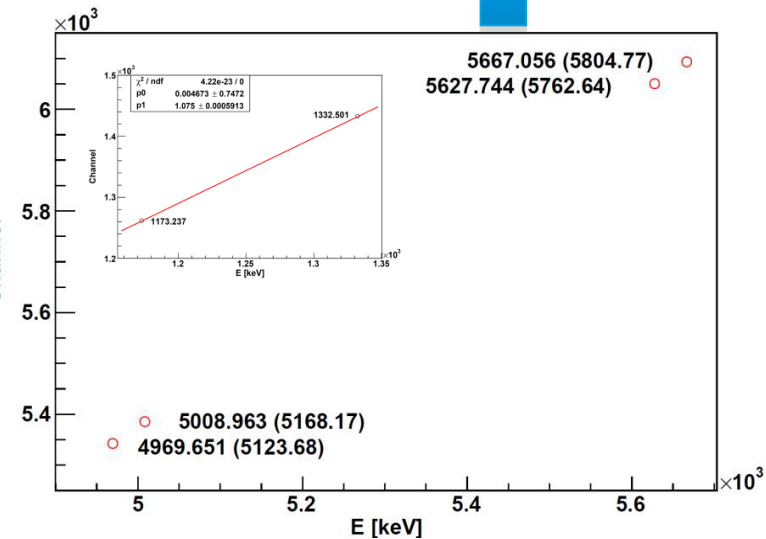
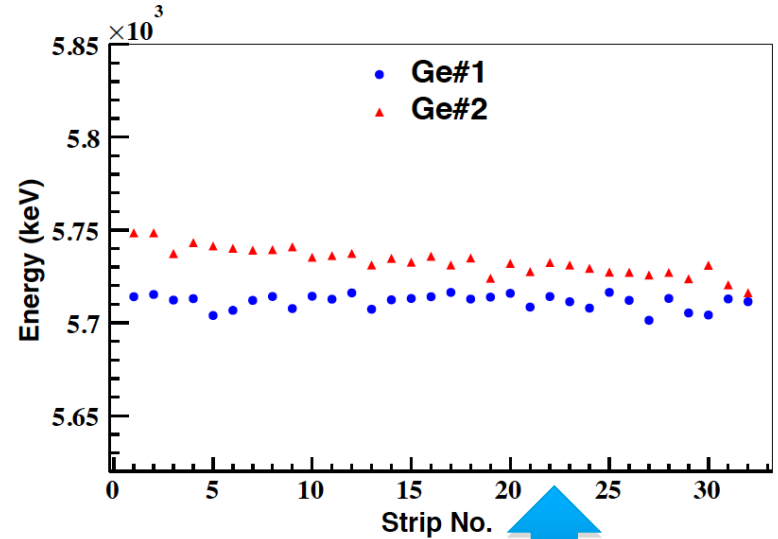
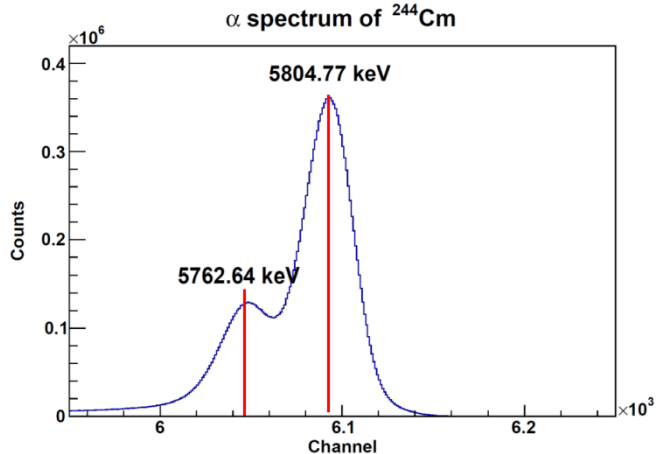
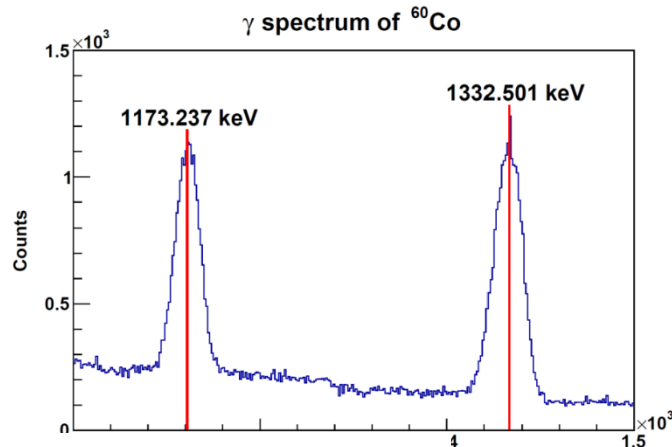
Ge\_#2



by Q. Hu, PhD student  
in IKP, Juelich

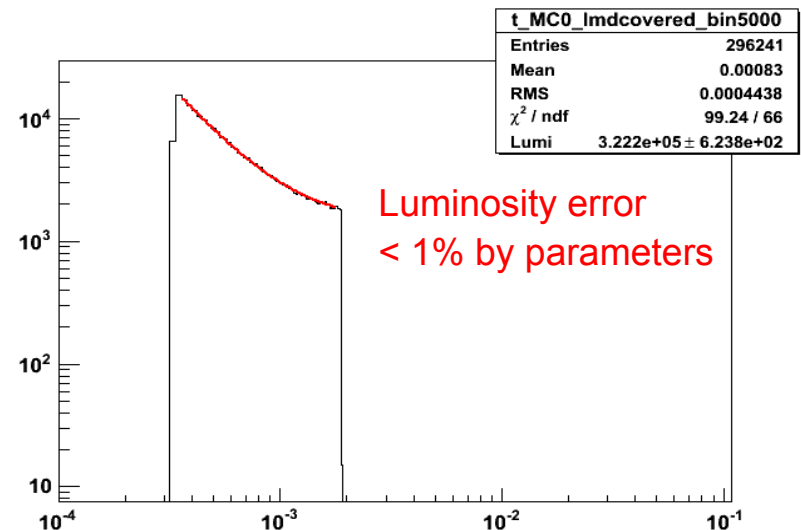
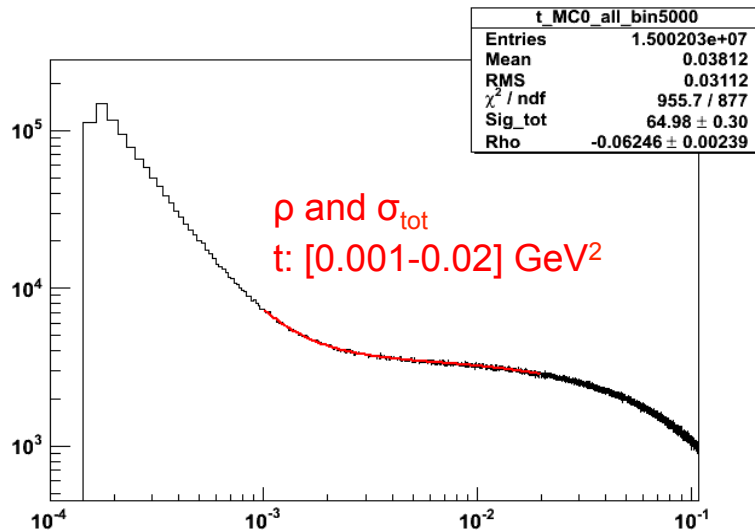
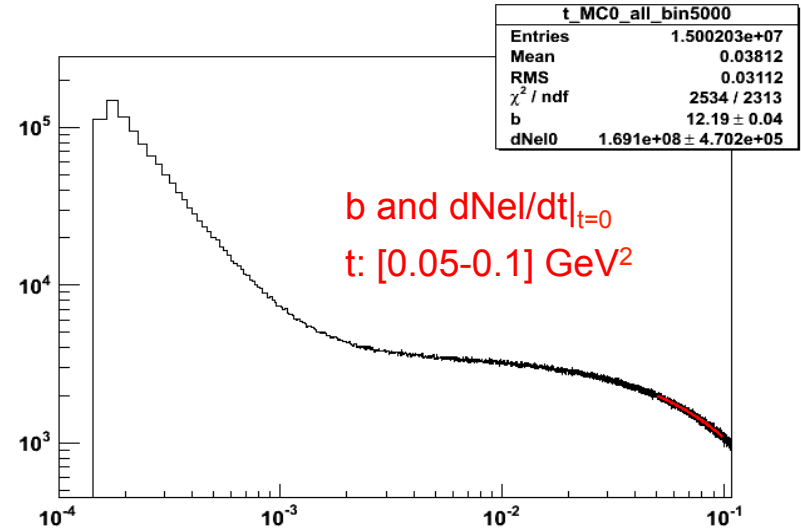
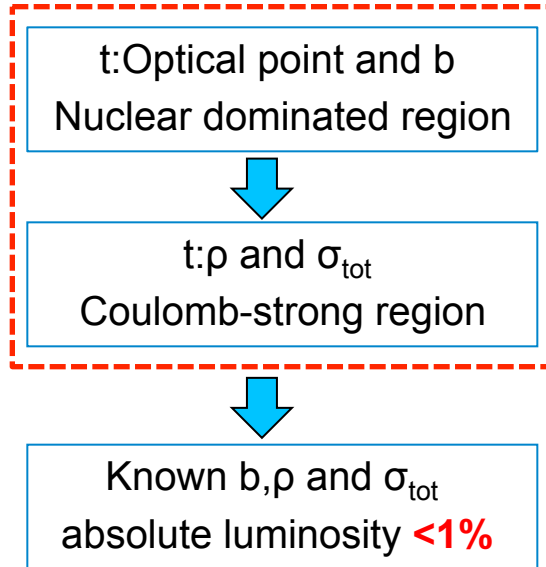
## 2.3.3 Energy Calibration

- Silicon: dead layer <math>< 0.1 \mu\text{m}</math>
- Germanium: dead layer <math>< 1 \mu\text{m}</math>
- (Ge1:  $\sim 0.72 \mu\text{m}$ , Ge2:  $\sim 0.45 \mu\text{m}$ )



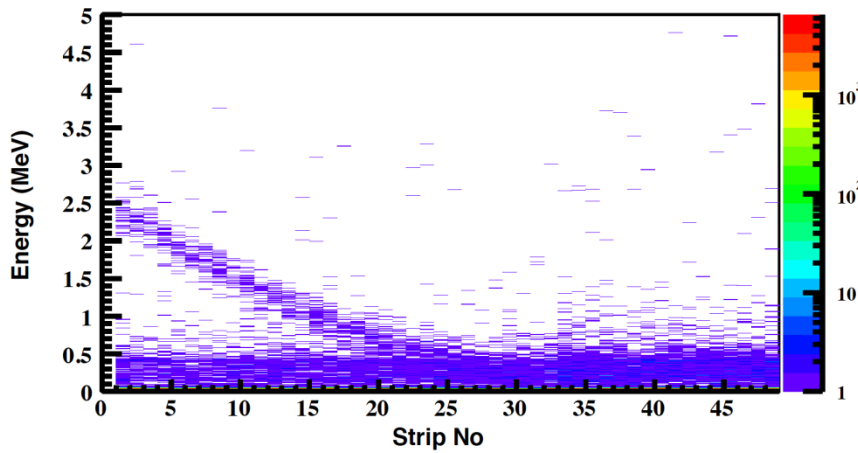
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# Required t-range

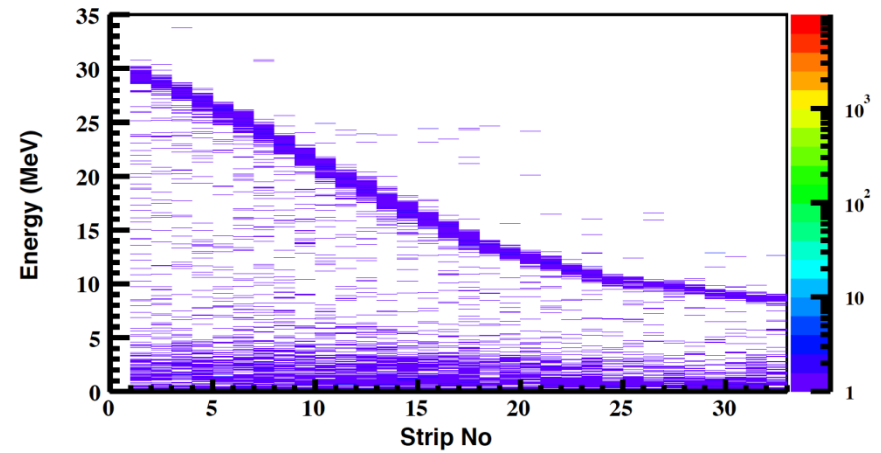


# Raw spectrum

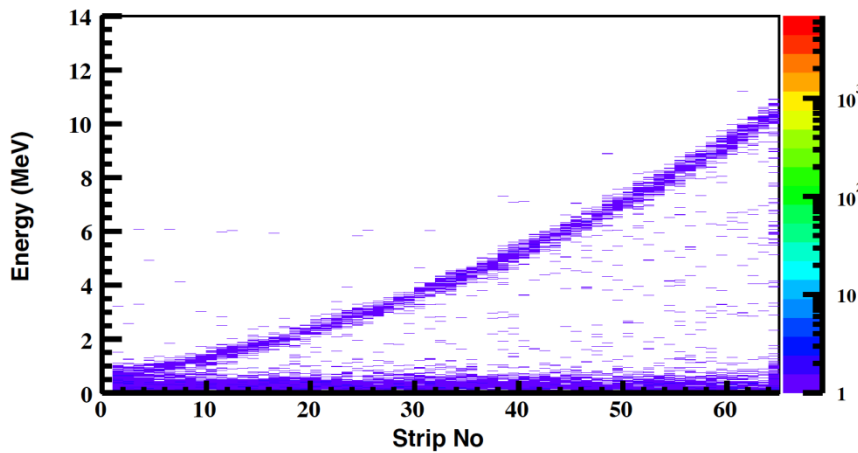
Si#1\_Raw



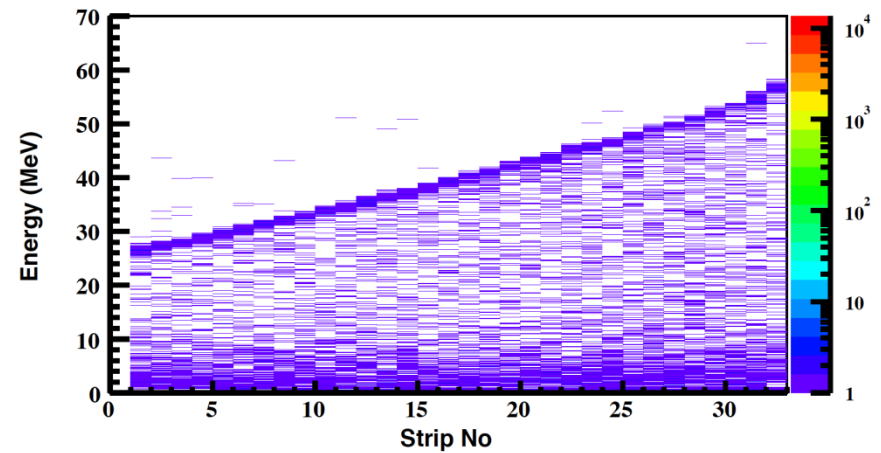
Ge#1\_Raw



Si#2\_Raw

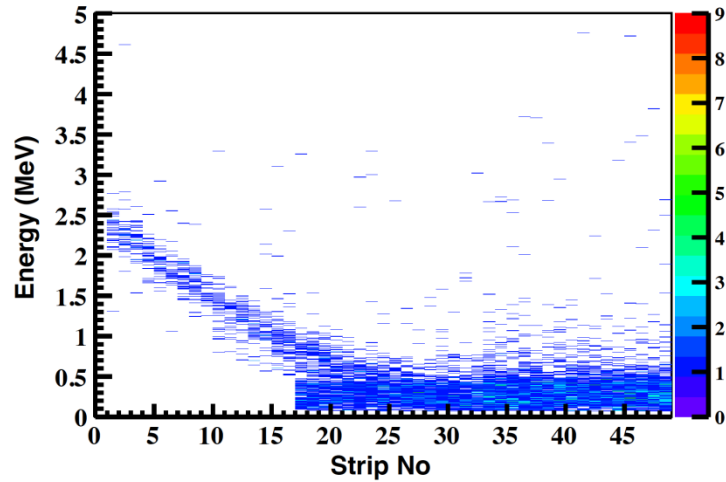


Ge#2\_Raw

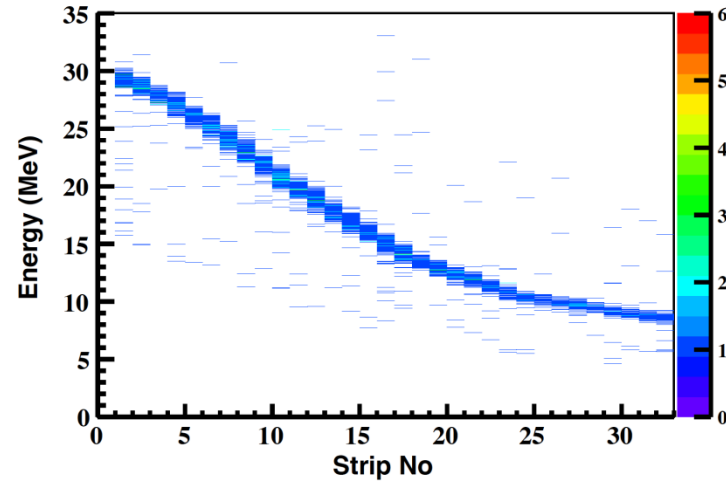


# After clustering

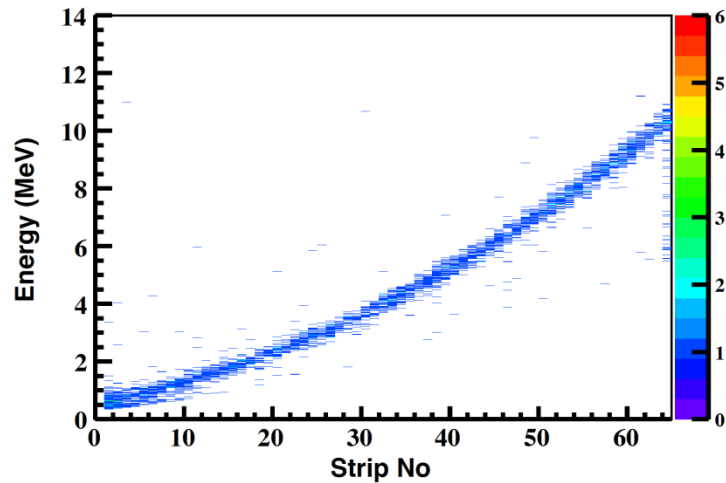
Si#1\_Clustered



Ge#1\_Clustered



Si#2\_Clustered



Ge#2\_Clustered

