GEANT4 Simulations for the EXL Project

Juan Carlos Zamora Cardona
for the EXL collaboration

Institut für Kernphysik
Technische Universität Darmstadt

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Outline

TECHNISCHE UNIVERSITÄT DARMSTADT

Motivation

In-Beam Test

E105 Experiment

Summary

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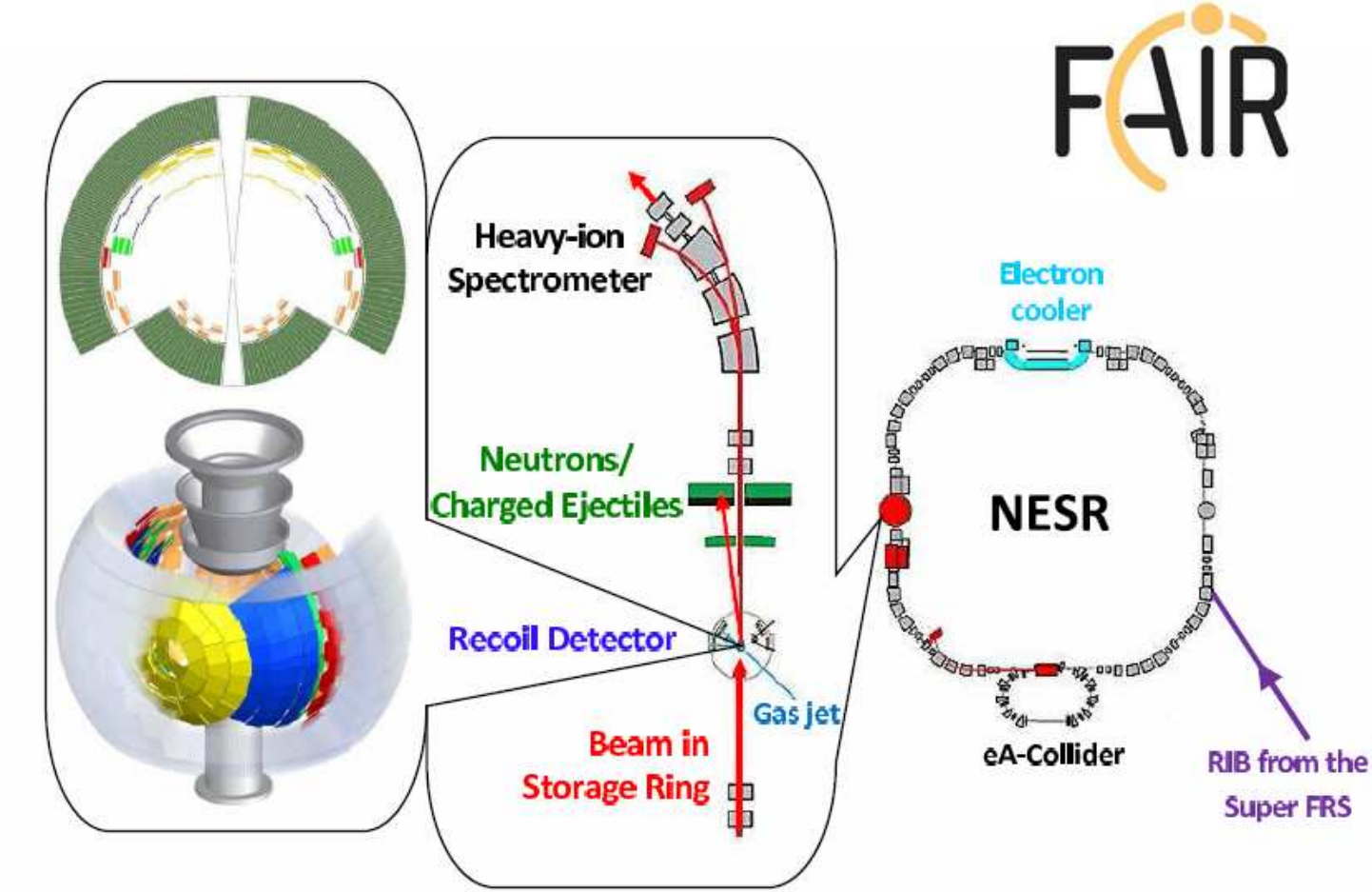
Summary

EXL: EXotic nuclei studied in Light ion induced reactions at the NESR storage ring

TECHNISCHE UNIVERSITÄT DARMSTADT

- **ESPA**
  Silicon array

- **EGPA**
  Scintillators array



EXL: EXotic nuclei studied in Light ion induced reactions at the NESR storage ring

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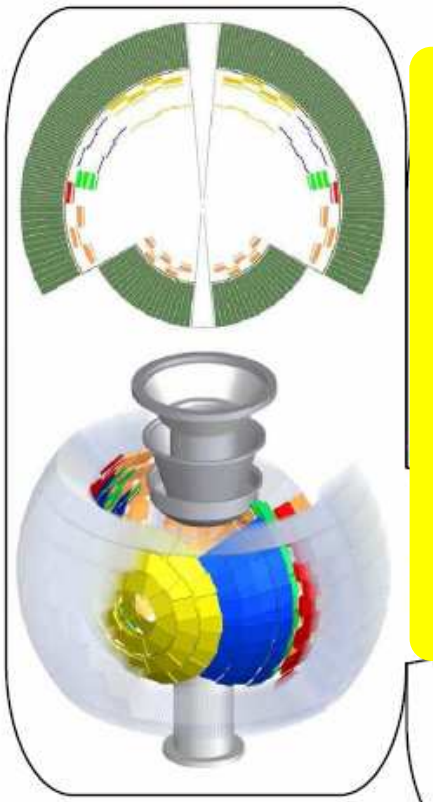
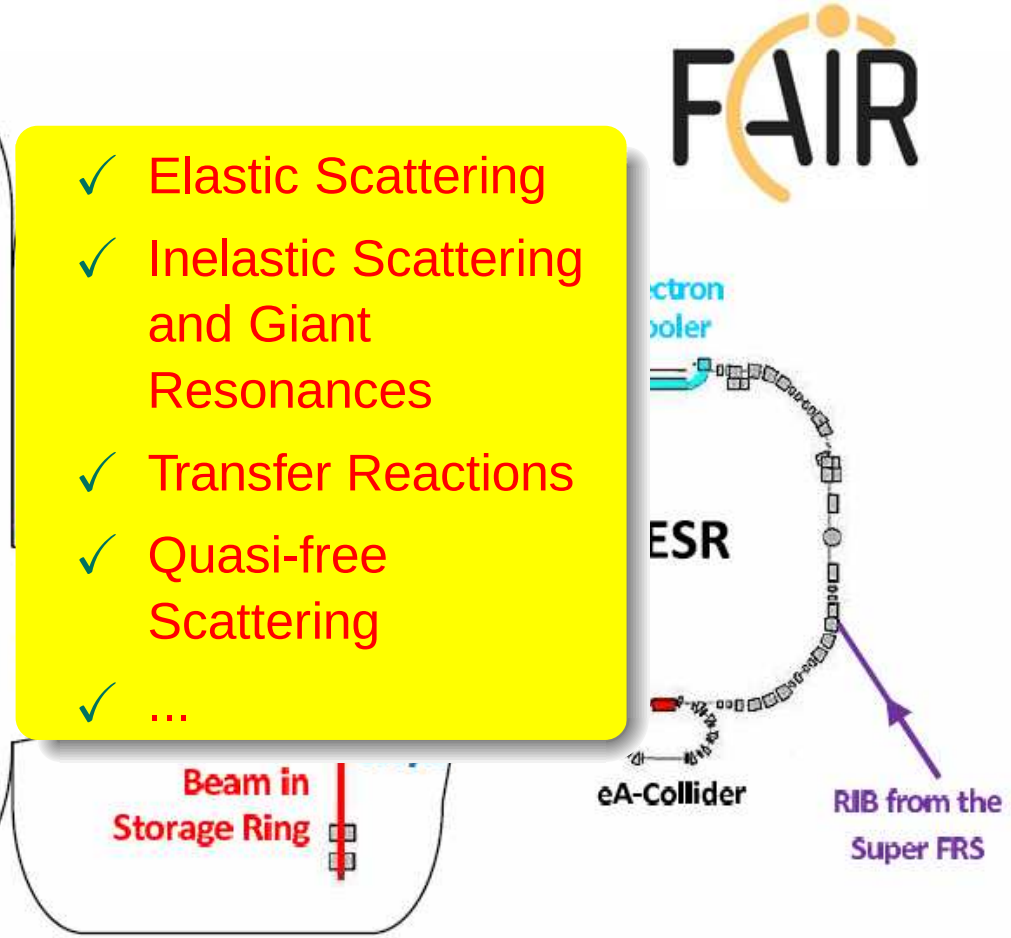


- ✓ Elastic Scattering
- ✓ Inelastic Scattering and Giant Resonances
- ✓ Transfer Reactions
- ✓ Quasi-free Scattering
- ✓ ...



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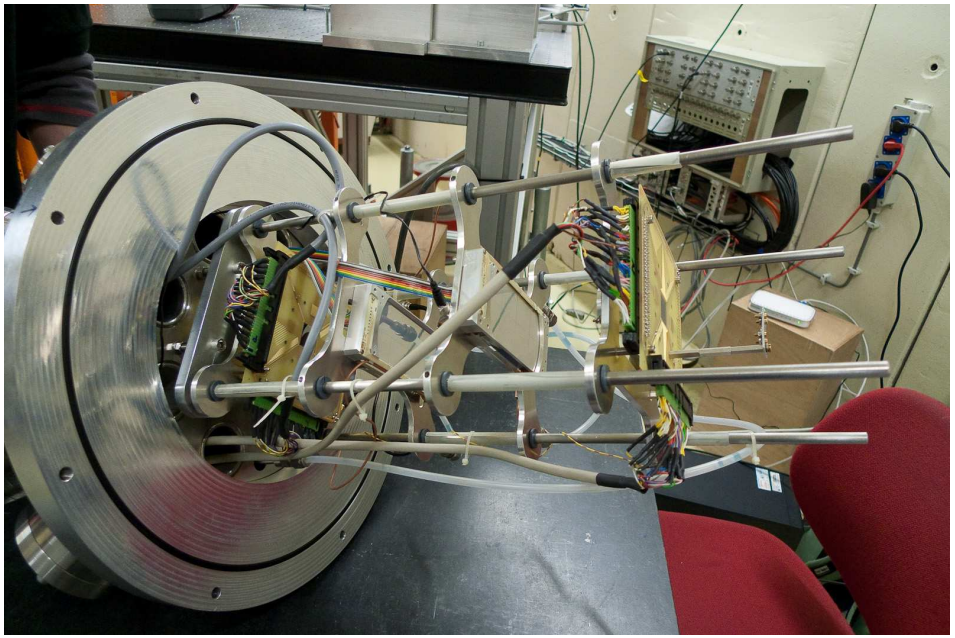
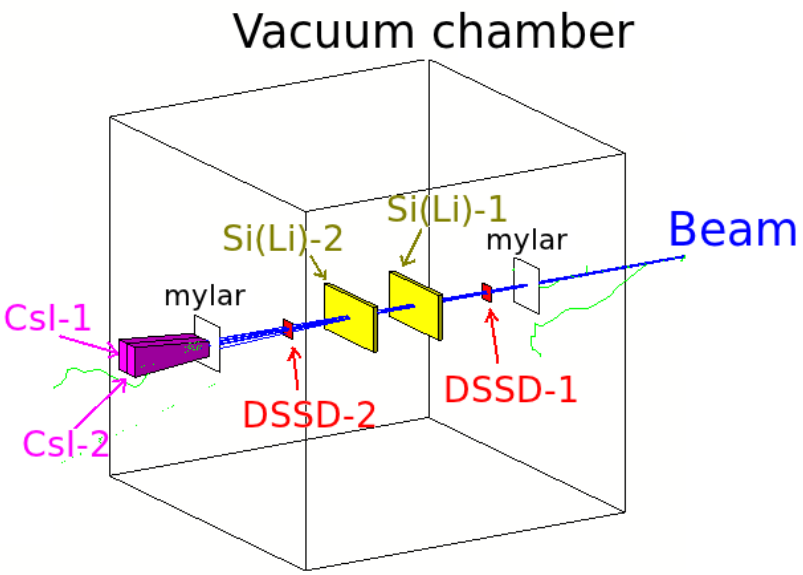
In-Beam Test

TECHNISCHE UNIVERSITÄT DARMSTADT

KVI cyclotron
135 MeV protons
Detectors tested: Si(Li), DSSD, CsI(Tl)





- Check the detector response
- Compare with GEANT4 simulations

A Basic Simulation (independent sensitive volumes)

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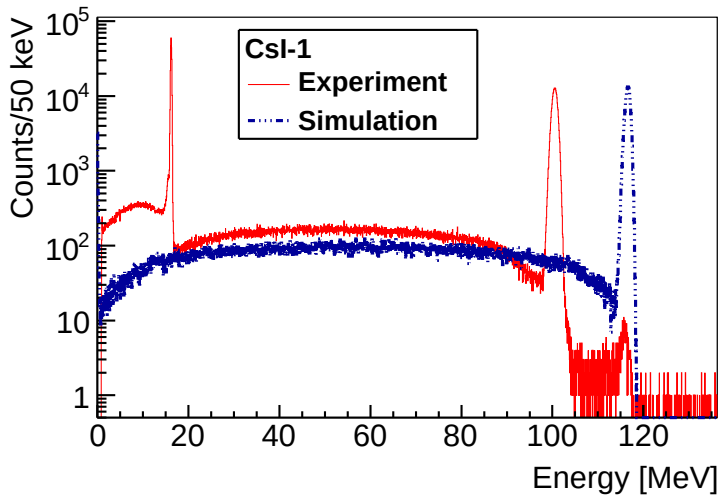

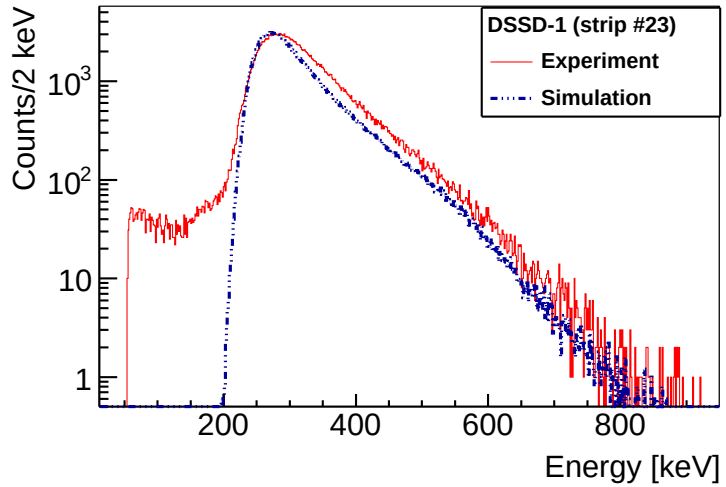

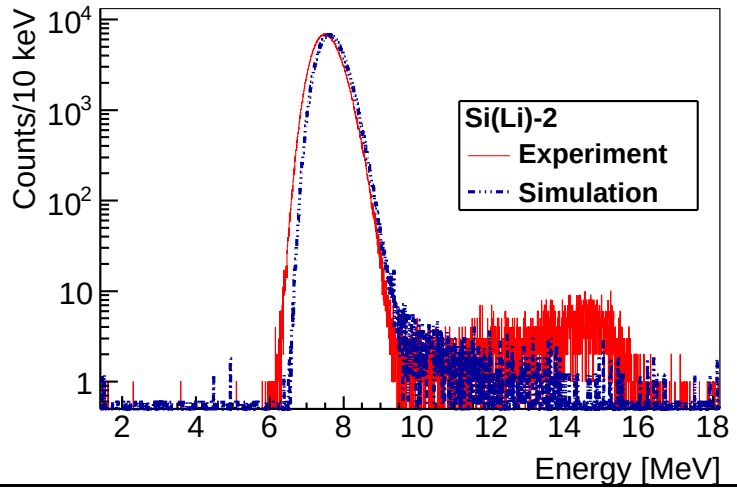

A Basic Simulation (independent sensitive volumes)

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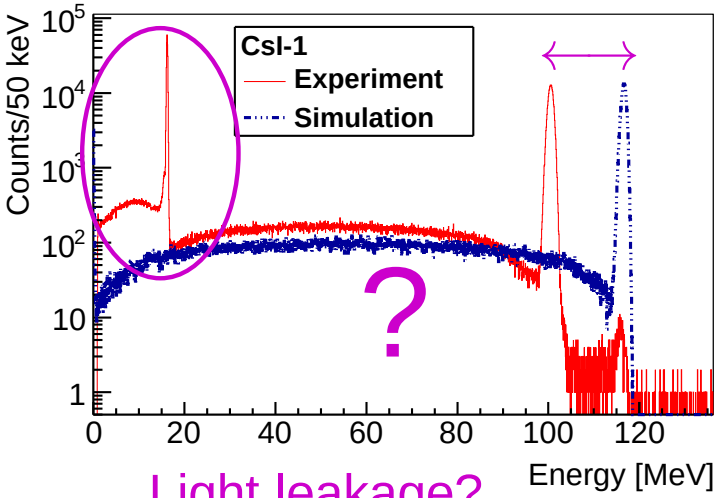
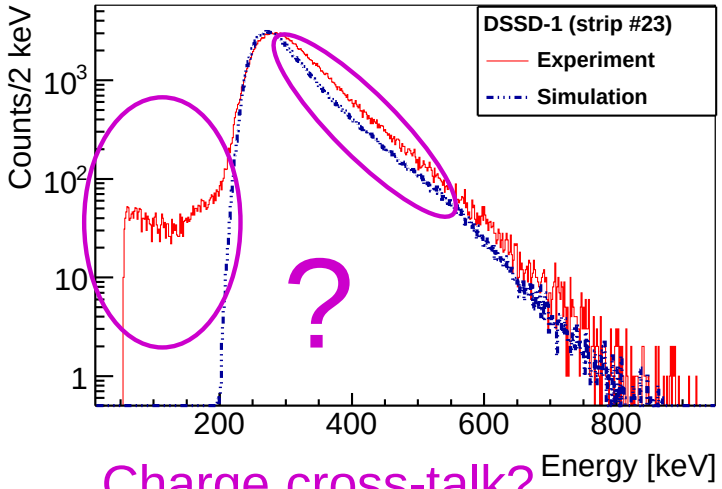
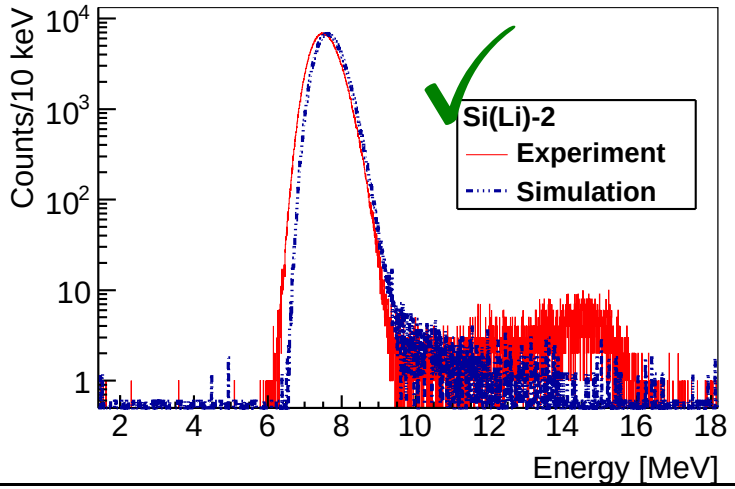


Light leakage?



Charge cross-talk?



The Crystals and Photomultipliers (from IPN, Orsay)

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CsI(Tl) scintillators

- Trapezoidal shape,11 cm (long), 2×4 cm^2 (front face)
- Aluminum wrapping

Double photomultiplier

- Two channels
- A common borosilicate window thickness ~ 1 mm

The Crystals and Photomultipliers (from IPN, Orsay)

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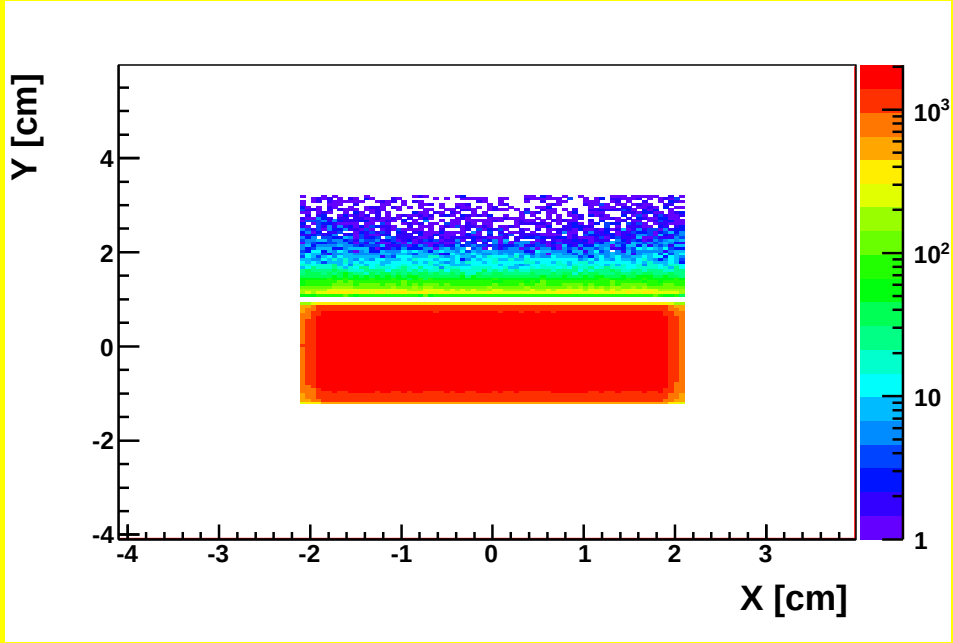
Scintillation process Simulation

Light spot on photocathodes



thickness ~ 1 mm

How it was simulated...

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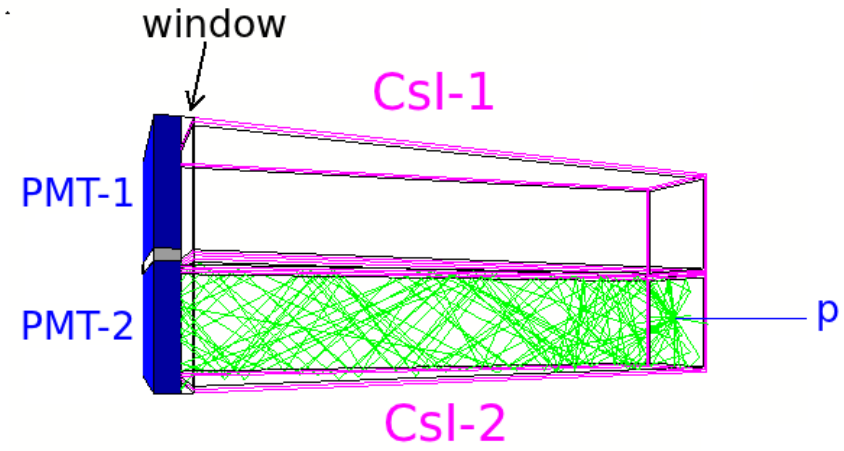
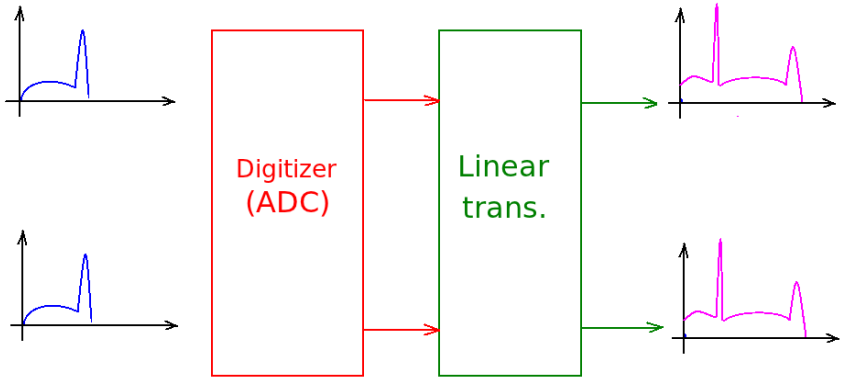


Assuming that a percentage α of photons escape to the neighbor det. The resulting number of photons:

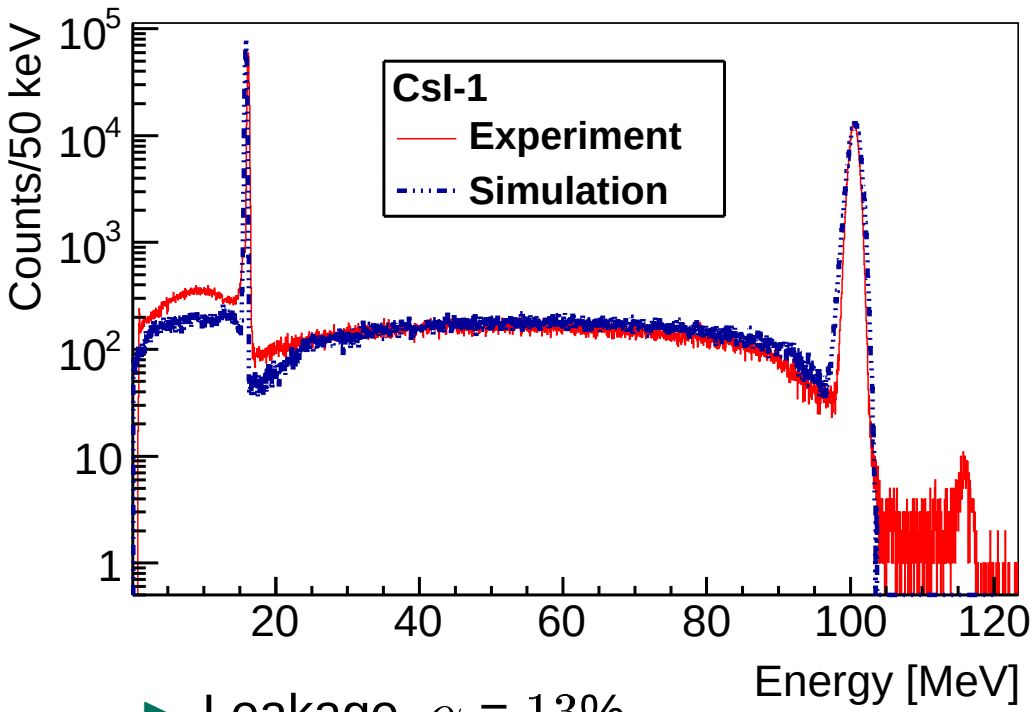
$$
\begin{aligned}
N_1' &= (1-\alpha)N_1 + \alpha N_2, \\
N_2' &= \alpha N_1 + (1-\alpha)N_2.
\end{aligned}
$$

α can be obtained from the ratio of the channel position of the peaks. In summary, a linear transformation is applied in each event:

$$\mathbb{N}' = \mathbb{L}\mathbb{N}$$

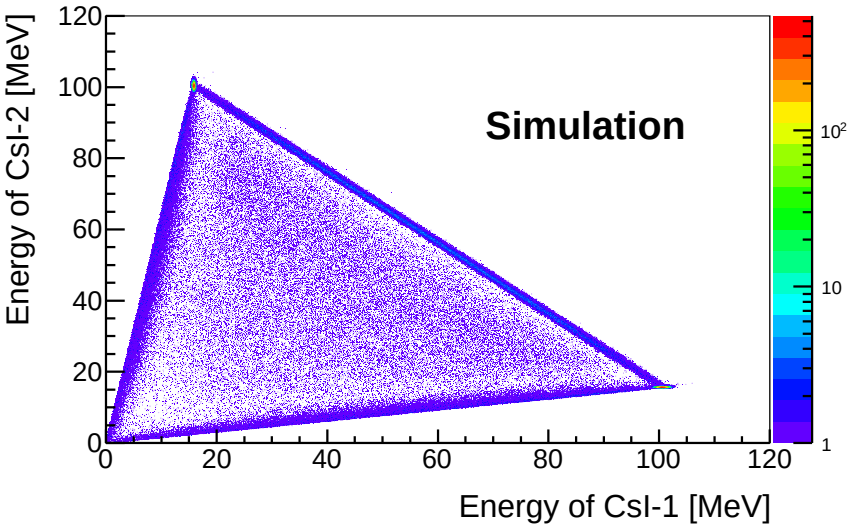


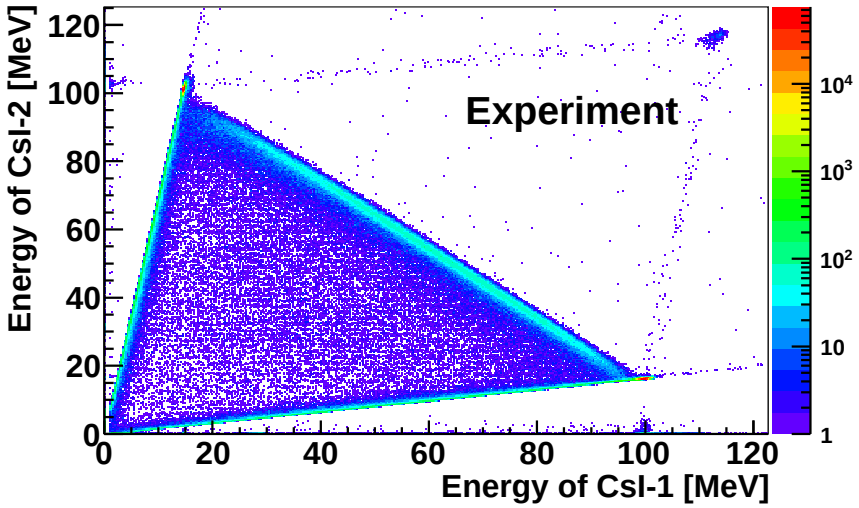
Spectrum of one crystal



- Leakage, α = 13%
- At low energy, the projection CsI-2
- Simulation describes completely the experimental spectra

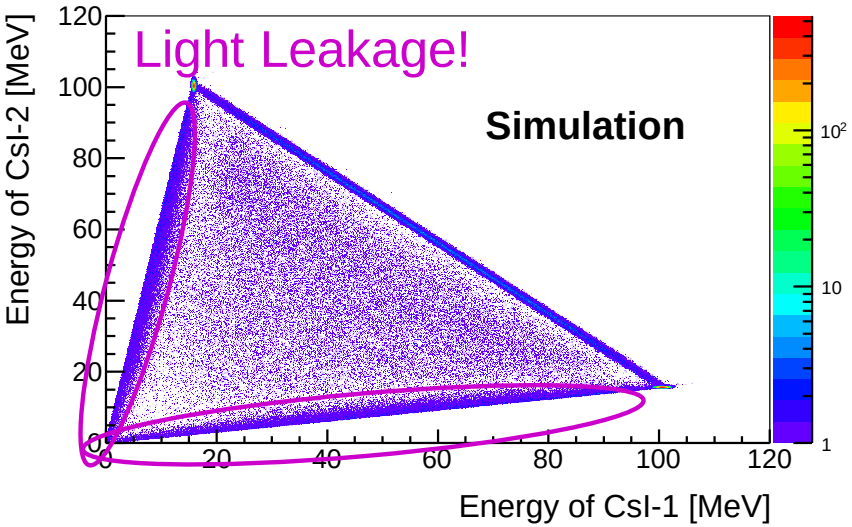
Energy correlation of both crystals

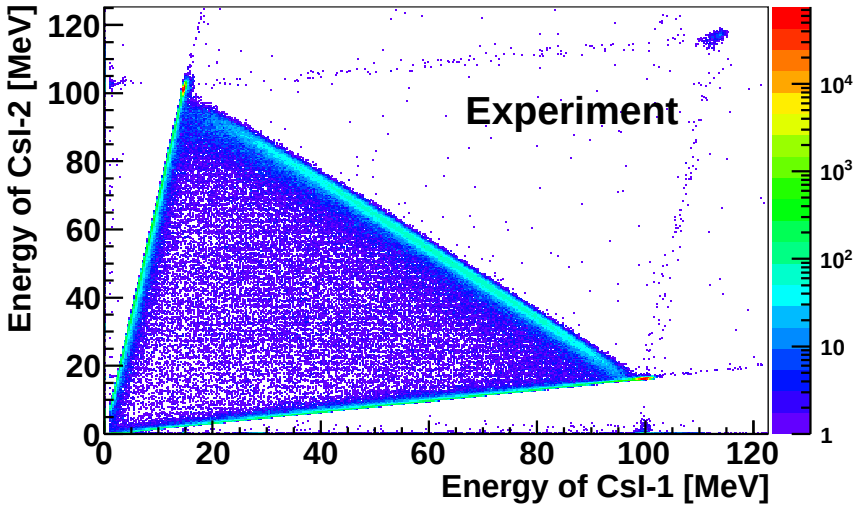




Correlation $(CsI)_{1,2}$; $\rho' = -0.82$

Energy correlation of both crystals





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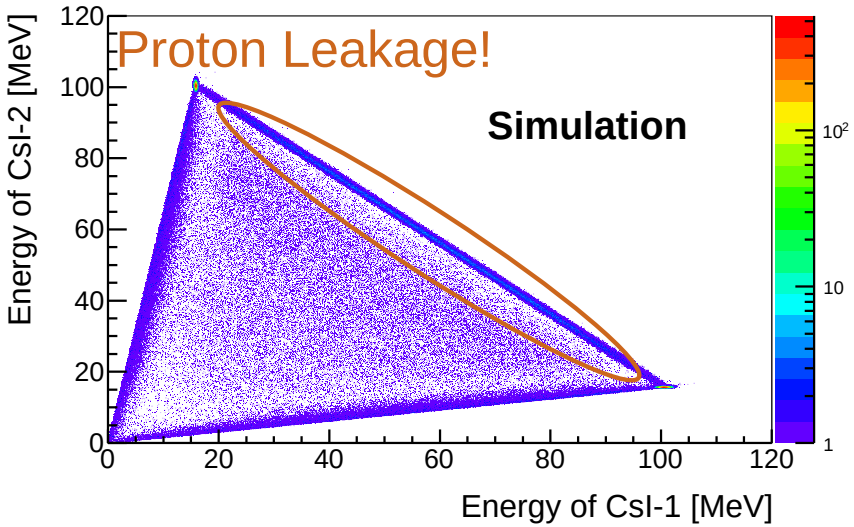

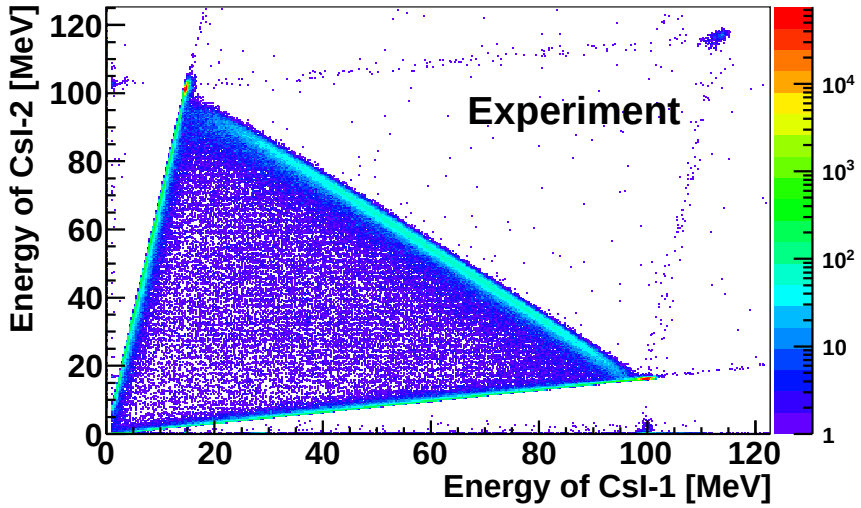

Correlation $(CsI)_{1,2}$; $\rho' = -0.82$

DSSD: double-sided silicon-strip detector (from PTI, St. Petersburg)

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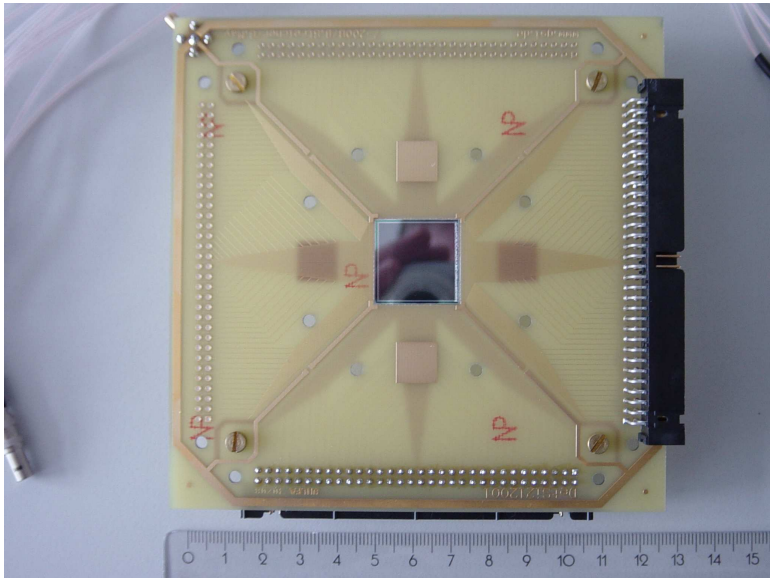
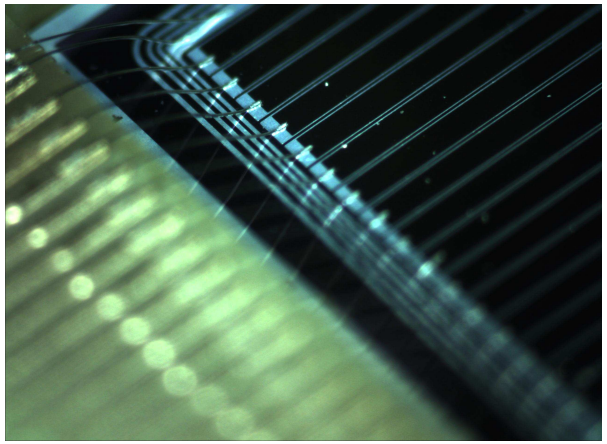
DSSD 64×64

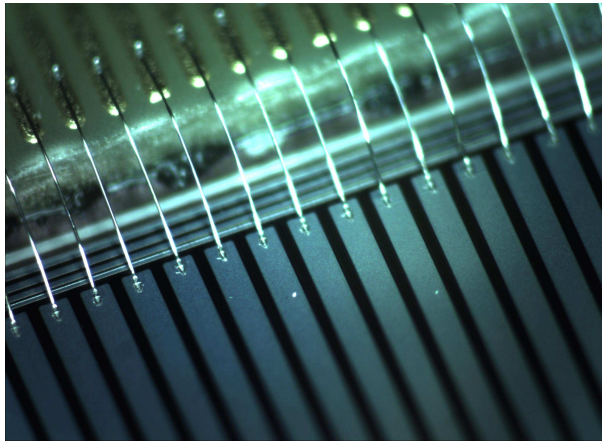
- 21×21 mm^2, 285 μm thickness
- p-Side: 15 μm interstrip gap
- n-Side: 65 μm interstrip gap



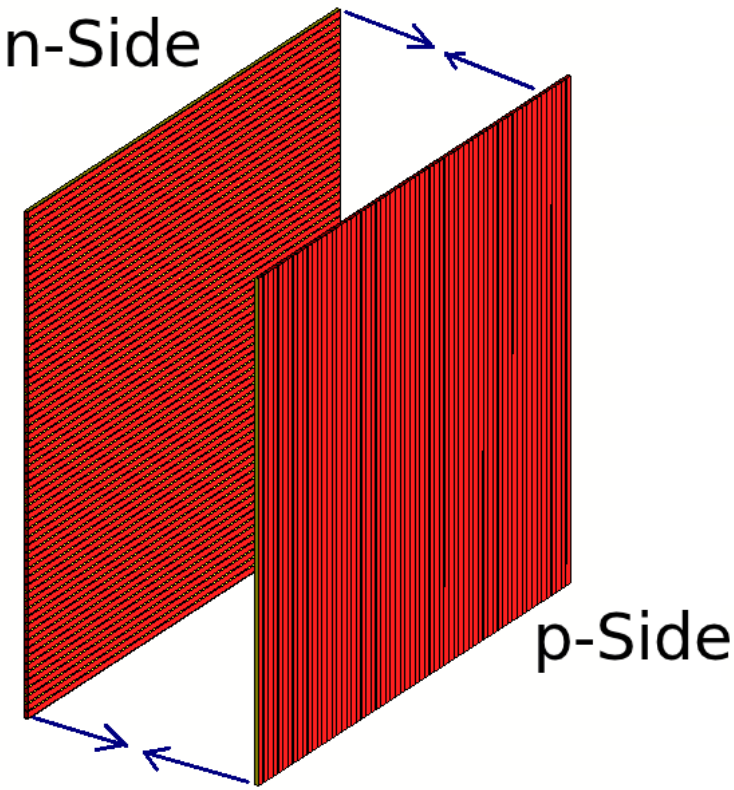
p-Side



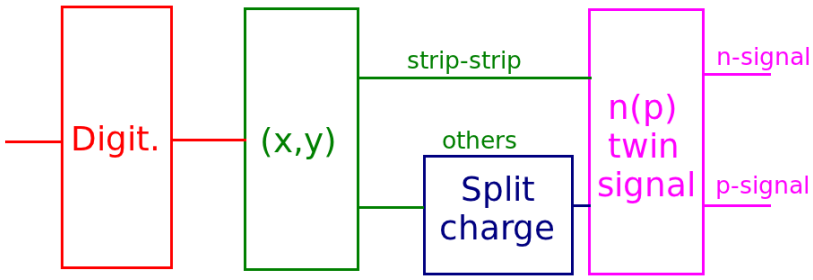
n-Side



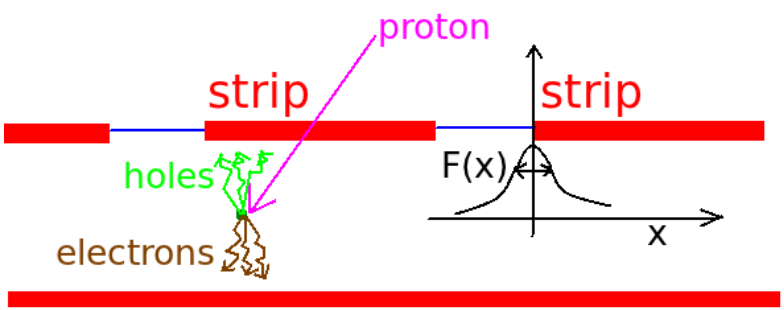
How simulation was done...

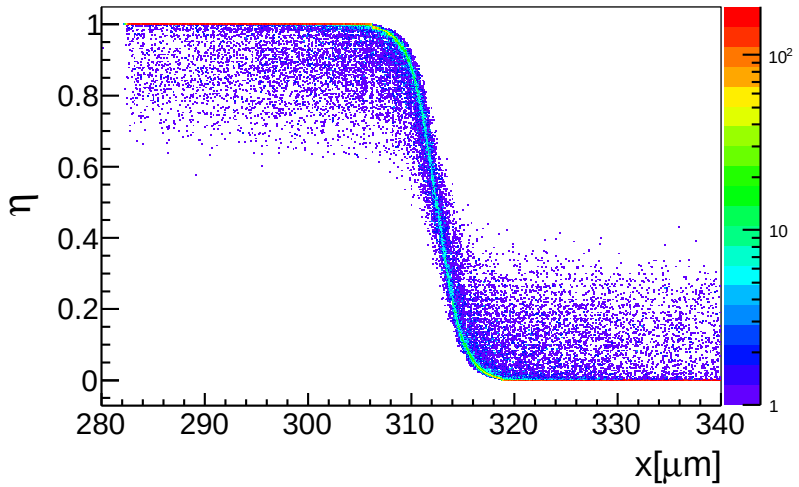


- 2 one side-strip det: $\circlearrowleft 90^{o}$
- Interstrip hit$\rightarrow$ split charge
- Generate *twin* signal n(p)-side.



Interstrip Hits



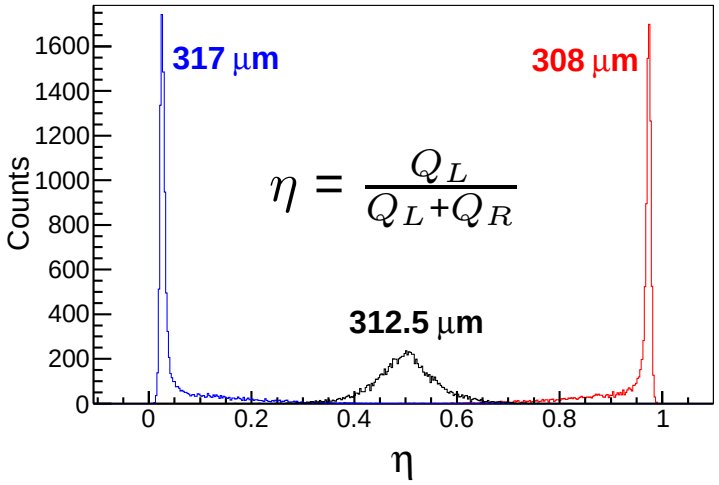


Fermi distribution employed:

a =10% interstrip gap

$$Q_{L(R)} = \frac{Q_0}{1+\exp\left(\frac{x-x_m}{a}\right)}$$

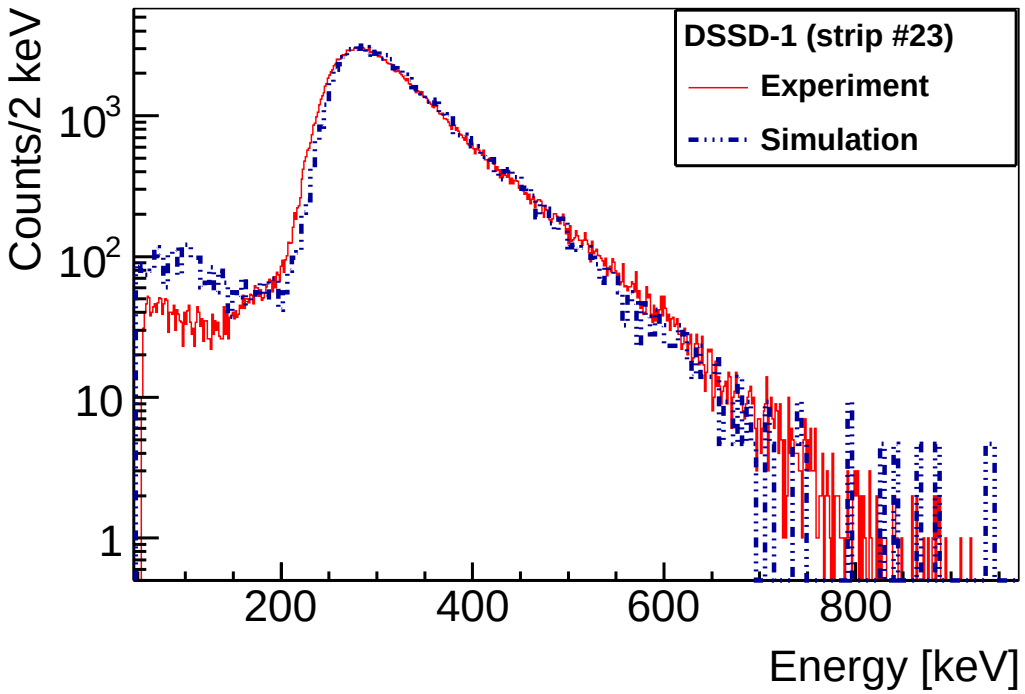
$$Q_{R(L)} = Q_0 - Q_{L(R)}$$



$$\eta = \frac{Q_L}{Q_L+Q_R}$$

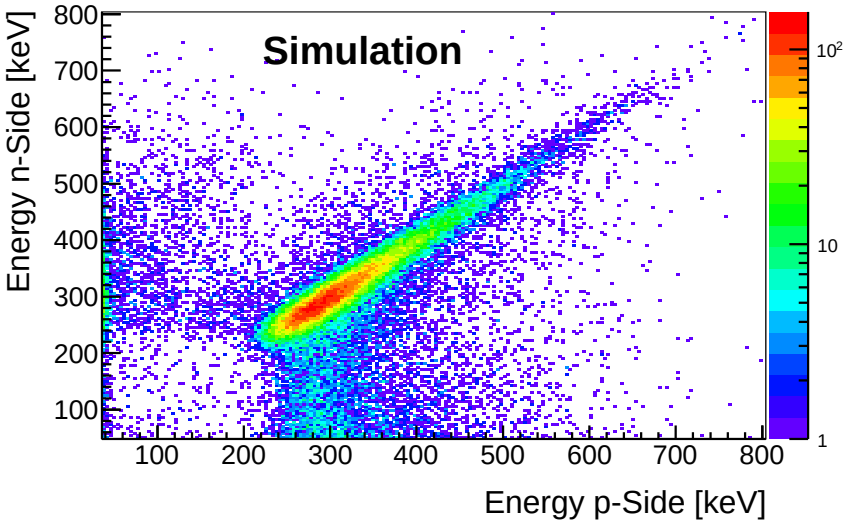
Belau et.al. NIM 214 (1983) 253

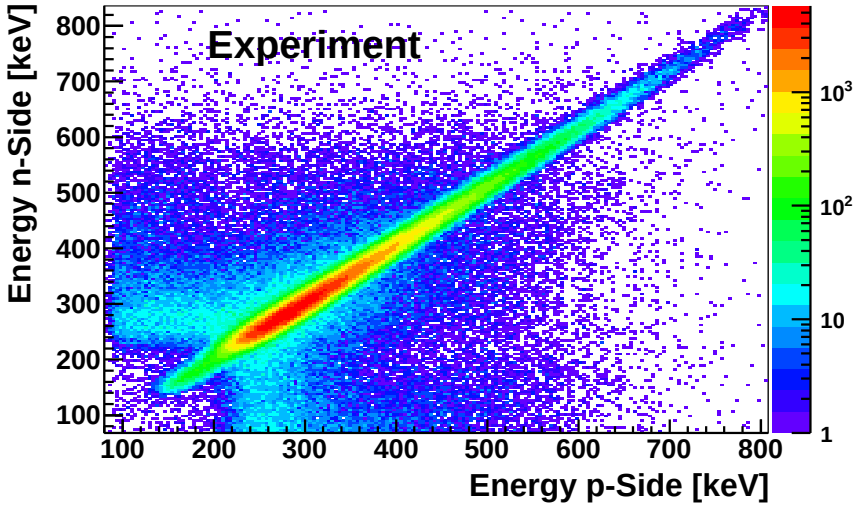
Energy spectrum of one strip



- Interstrip background obtained
- Overall shape well described

p-Side *vs* n-Side





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Setup

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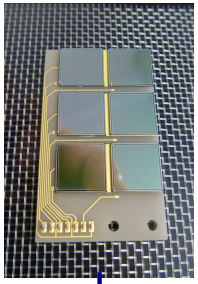
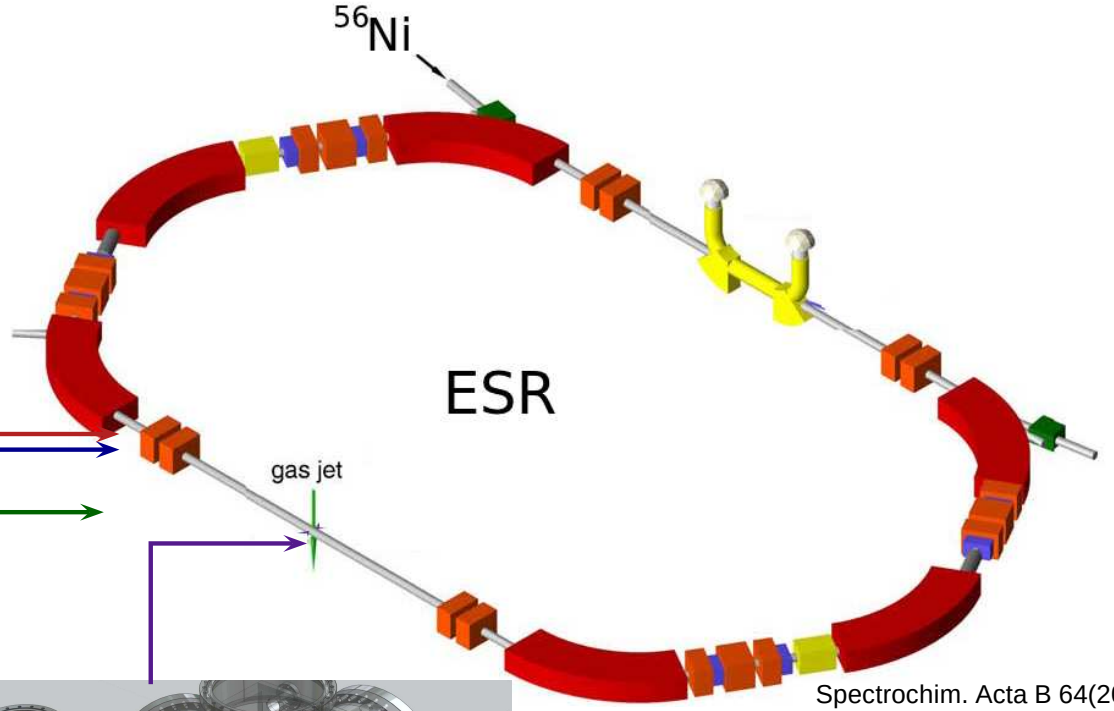
PIN-diode



SSD



Spectrochim. Acta B 64(2009)736

ELENS

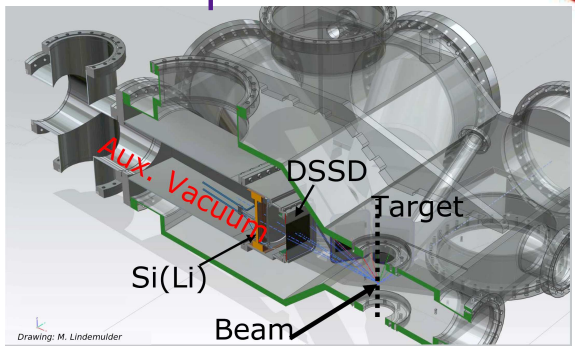
NIM A 659(2011)411

Vacuum Chamber

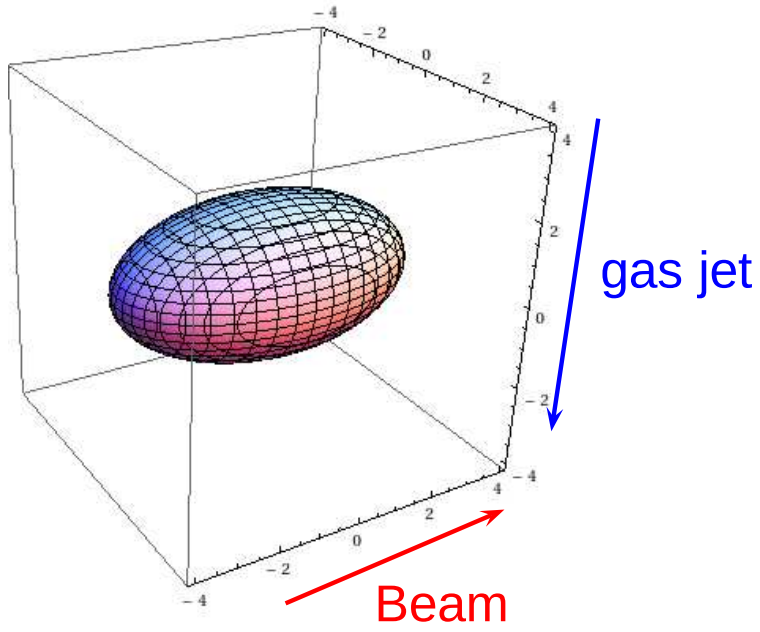
B. Streicher et al NIM A 654(2011)604

2 DSSDs

2 Si(Li)s



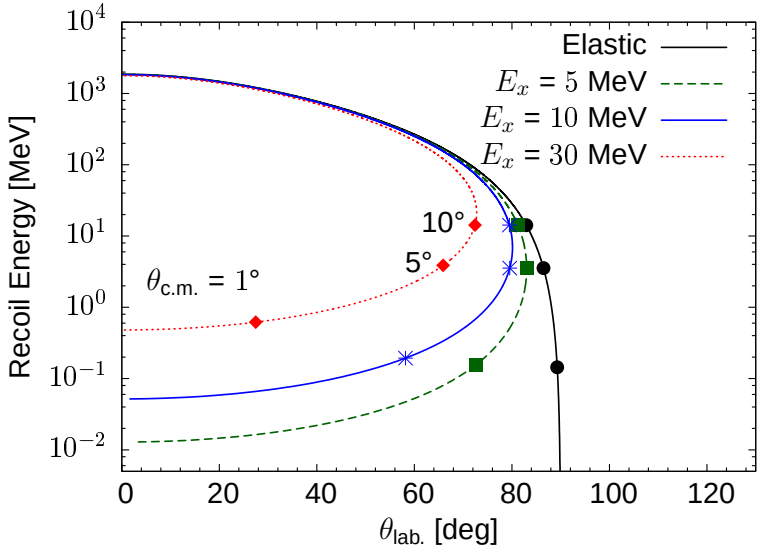
Event generator



Reaction point

Superposition of two Gaussians:

- Beam: FWHM = 3 mm
- Target: FWHM = 5 mm



Inverse kinematics

- Cross section transformation to laboratory system
- Sorted primaries: $n_i \rightarrow (\theta, E)$

Slit plate

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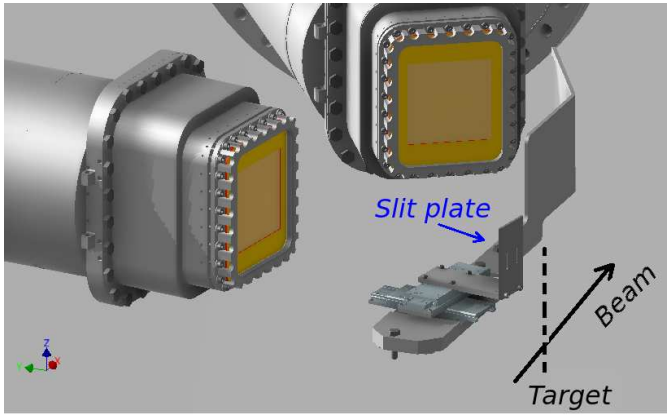
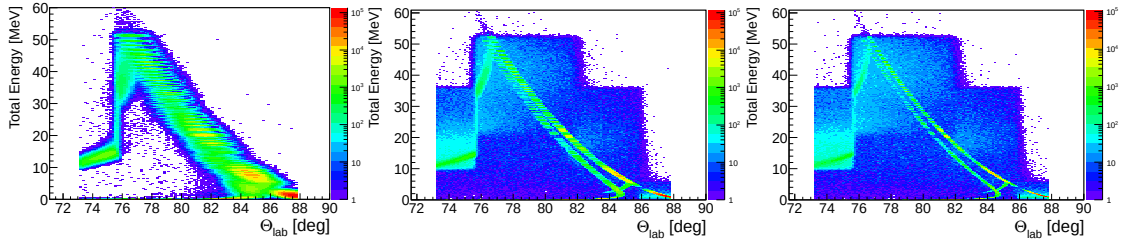
Slit plate for improving angular resolution

- Tantalum, 2 mm thick
- In front of 90 deg. pocket (1st)

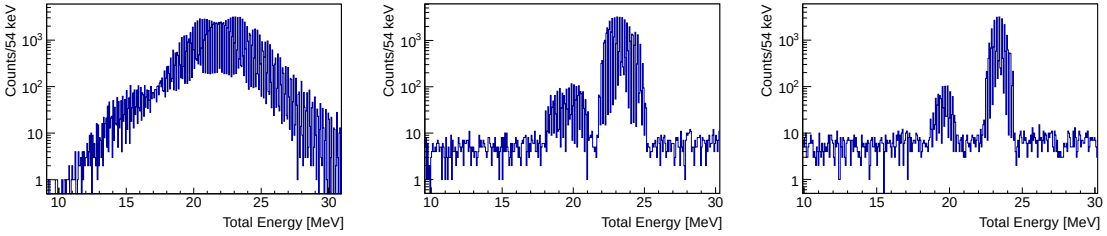
- At 3 cm from target
- 1 mm and 2 mm slits
- DSSD1 rate reduced in a factor 5



Without slit plate | **Slit width of 2 mm** | **Slit width of 1 mm**



Projection at 80.5 ° | **Projection at 80.5 °** | **Projection at 80.5 °**



Slit plate (nominal position)

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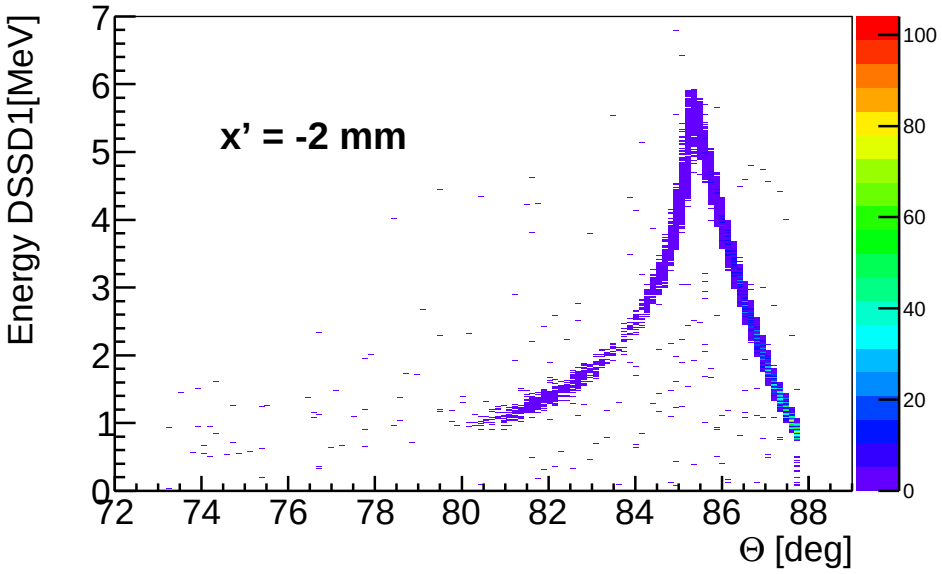
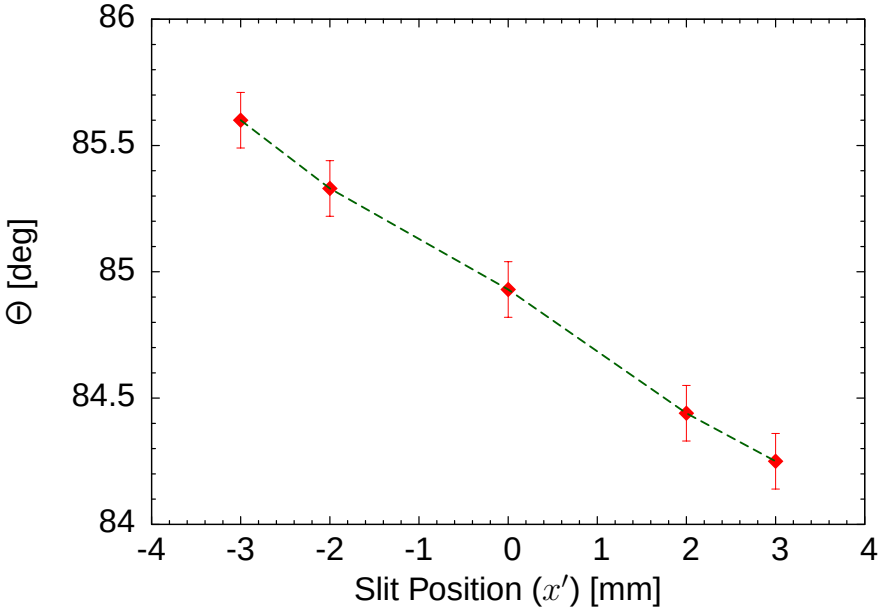
- During the experiment: different x' slit plate positions measured
- Useful for angular corrections.





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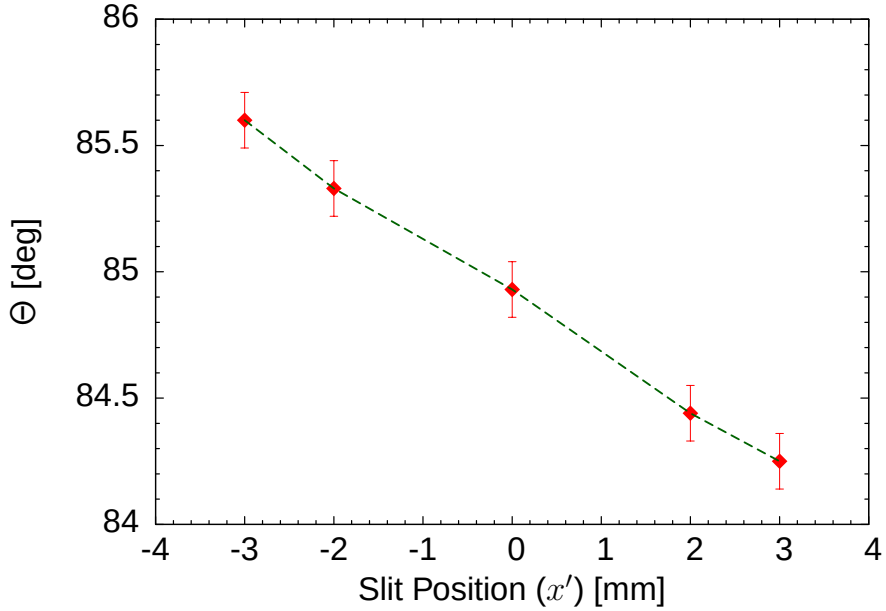

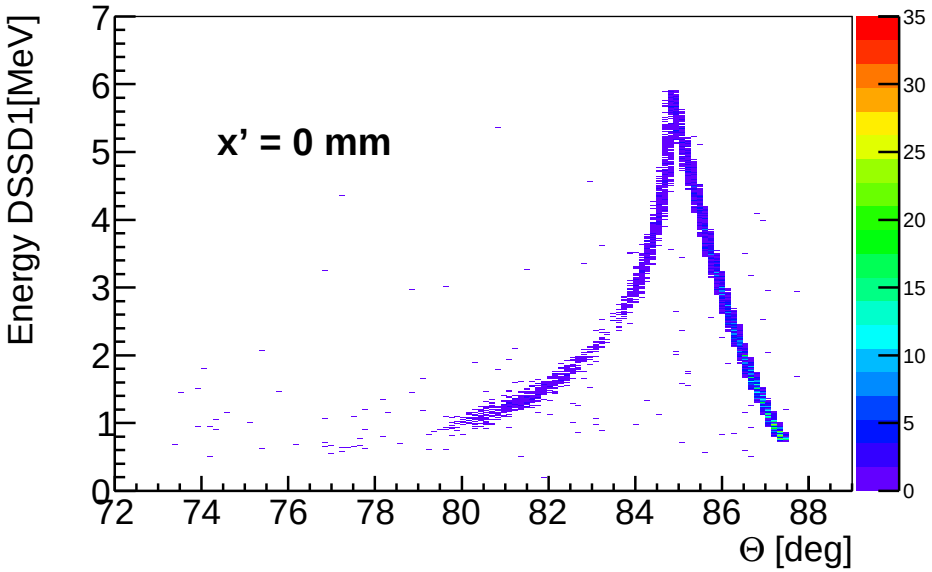

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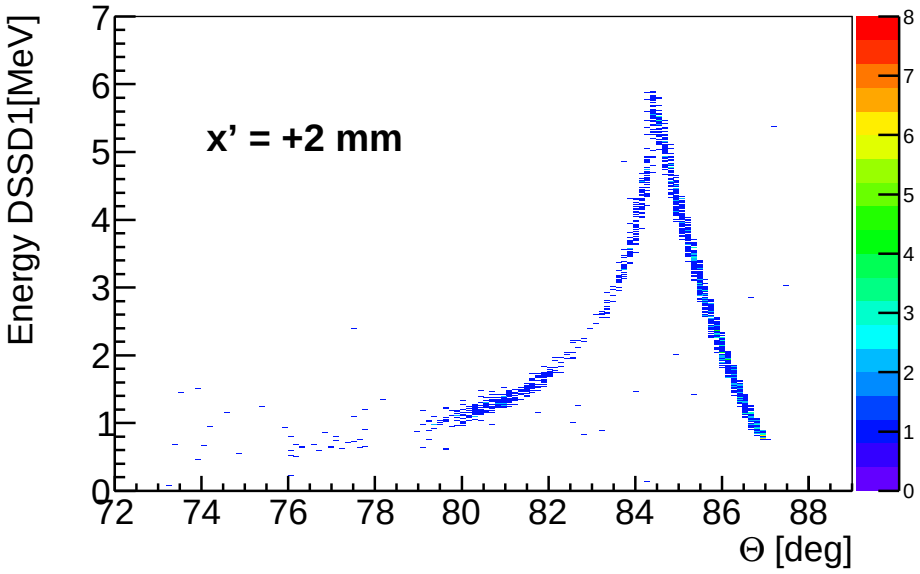
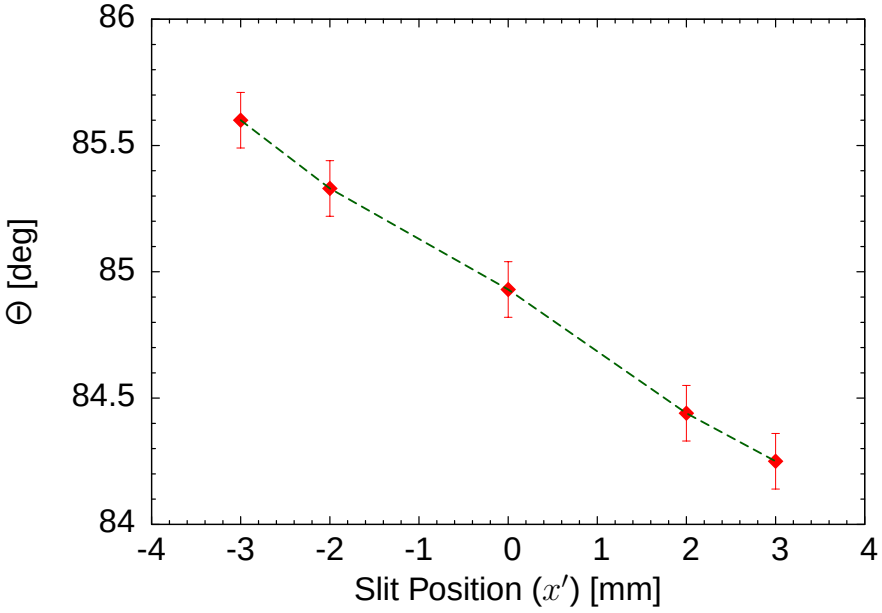
- Useful for angular corrections.





^{56}Ni + p (400 MeV/u)

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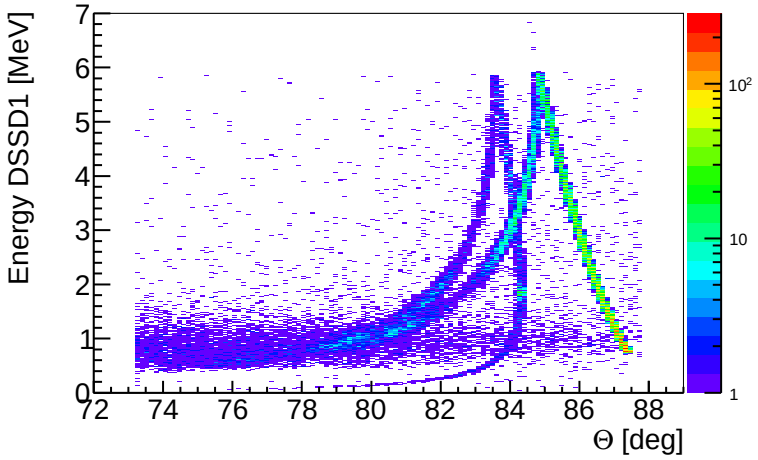
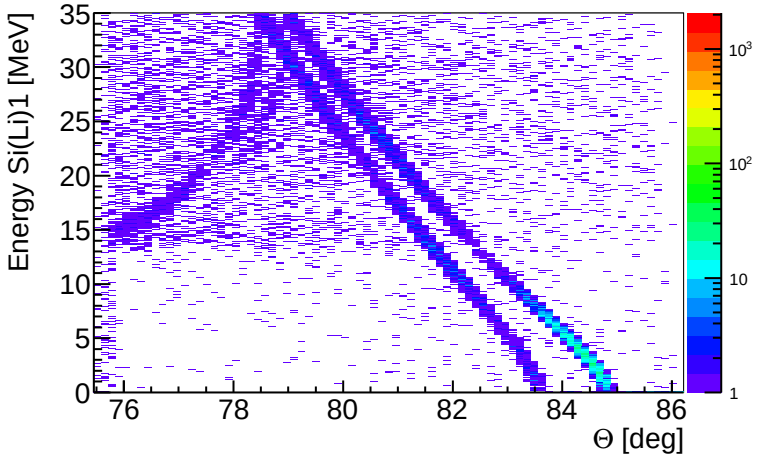
DSSD1



Si(Li)1



- Elastic scatt. and 2_1^+ state
- Punch through DSSD $E > 6$ MeV
- Punch through Si(Li) $E > 35$ MeV

^{56}Ni + p (400 MeV/u)

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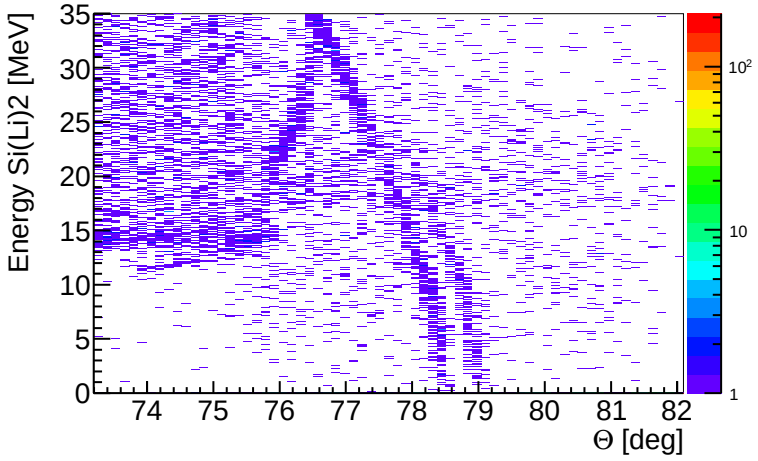
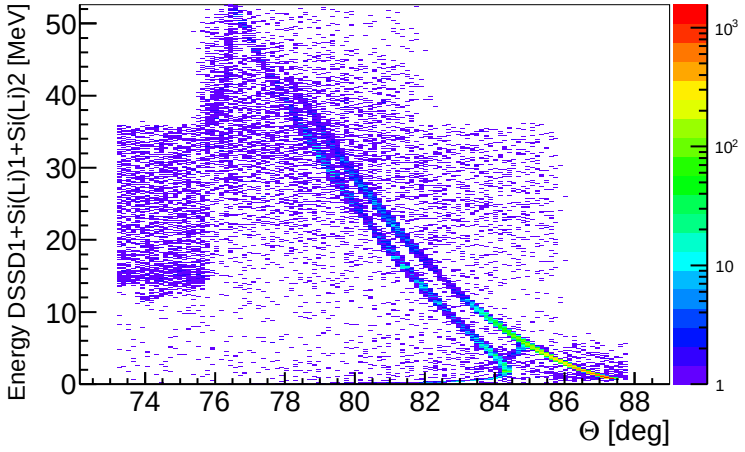
Si(Li)2

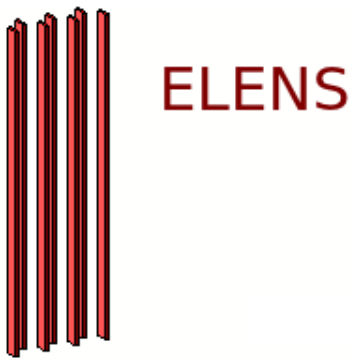


Energy reconstruction

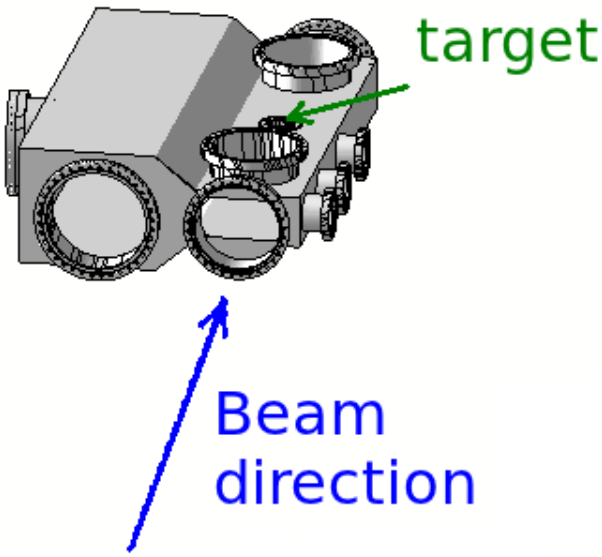


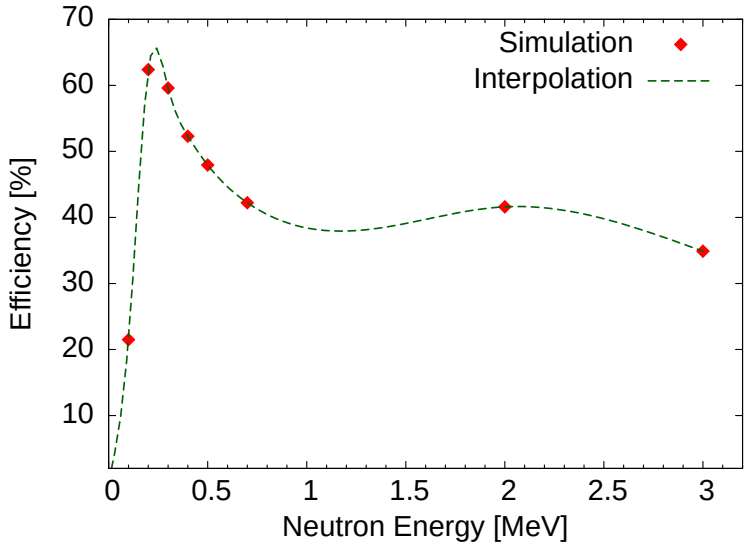
- Elastic scatt. and 2_1^+ state
- Punch through DSSD $E > 6$ MeV
- Punch through Si(Li) $E > 35$ MeV

Neutron detection
(p, n) reactions

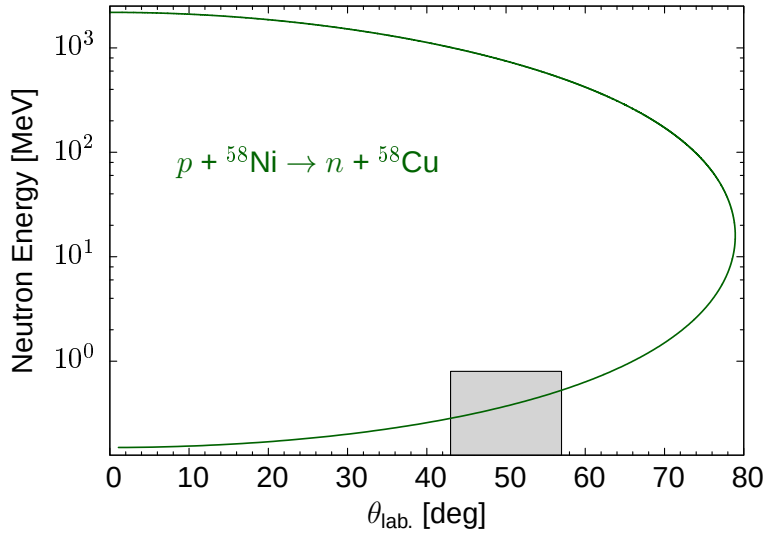


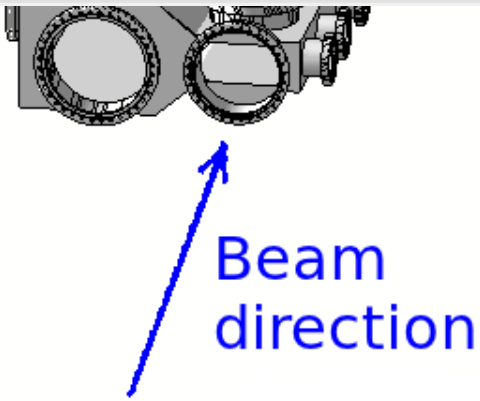
- An array of plastic scintillator bars. Type EJ-200
- $1000 \times 45 \times 10\,\text{mm}^3$.
- Fast response. Good for time measurements.





Neutron detection
(p, n) reactions





- An array of plastic scintillator bars. Type EJ-200
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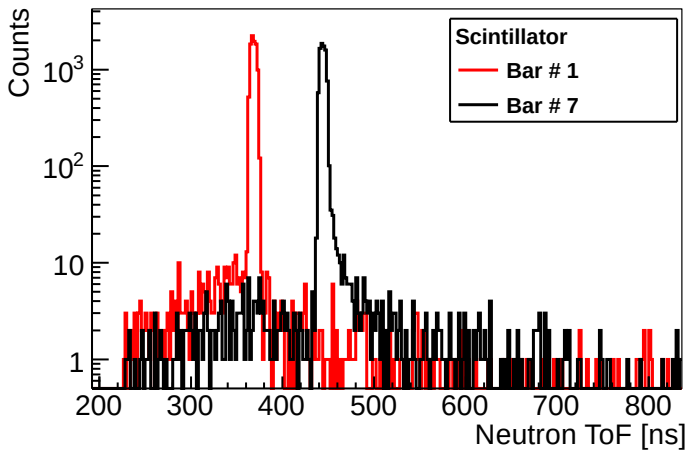
- Fast response. Good for time measurements.

^{58}Ni(p, n) ^{58}Cu



In-ring detectors (Quadrupoles)

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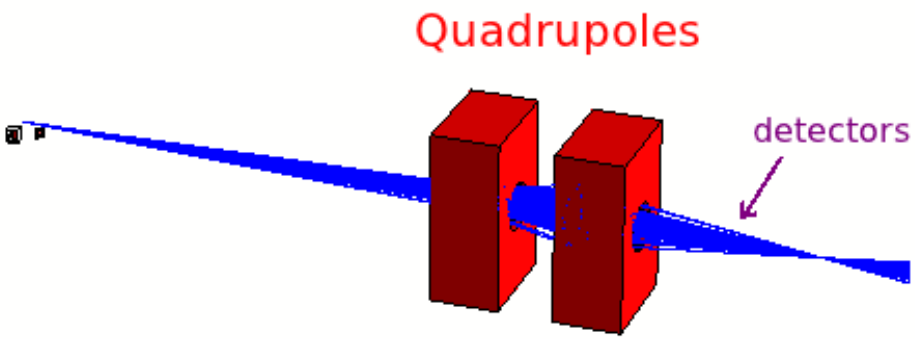
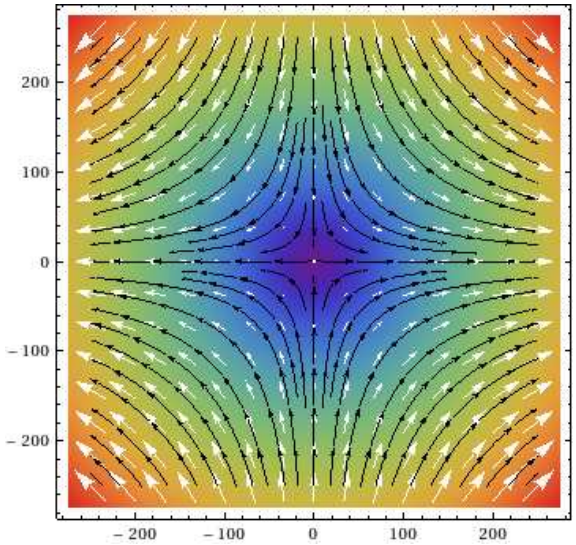


- Detectors are next to the quadrupoles
- Field: focusing and defocusing transversally
- Bore radius 256 mm



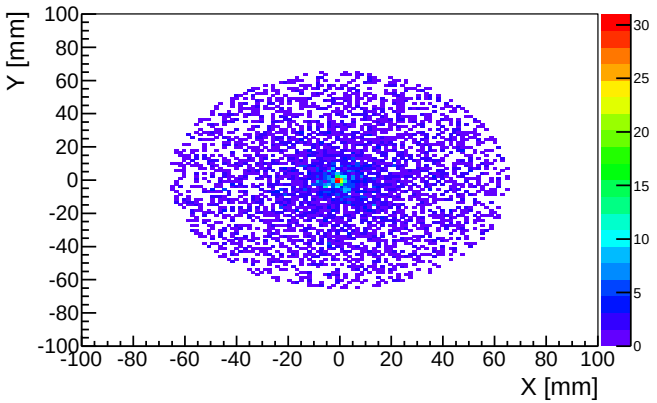
$$B_x = y\frac{\partial B_x}{\partial y}$$

$$B_y = -x\frac{\partial B_y}{\partial x}$$

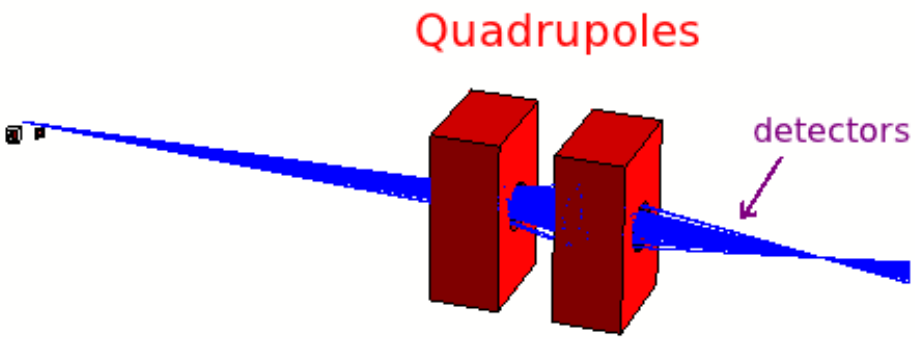
$$B_z = 0$$

Dipole entrance

k = 0.80 1/m



In-ring detectors (Quadrupoles)



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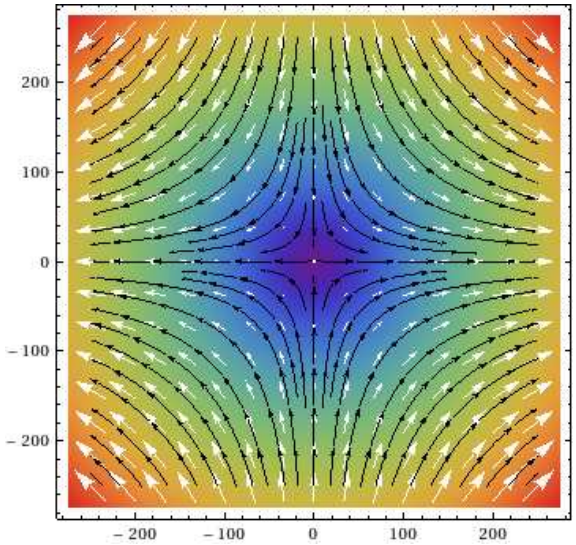


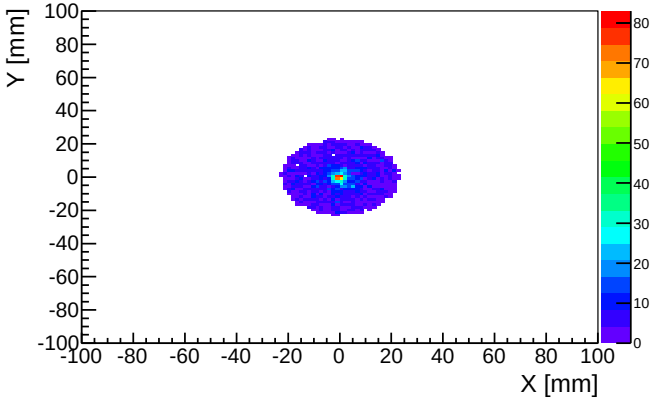
$$B_x = y\frac{\partial B_x}{\partial y}$$

$$B_y = -x\frac{\partial B_y}{\partial x}$$

$$B_z = 0$$

Dipole entrance

$k = 0.90$ 1/m



In-ring detectors (Quadrupoles)

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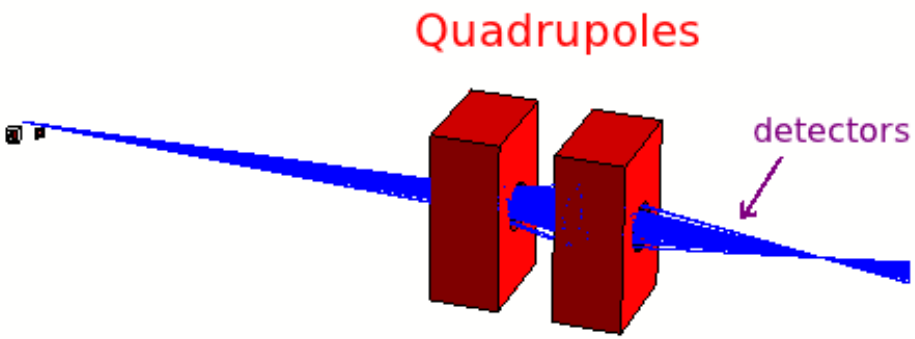

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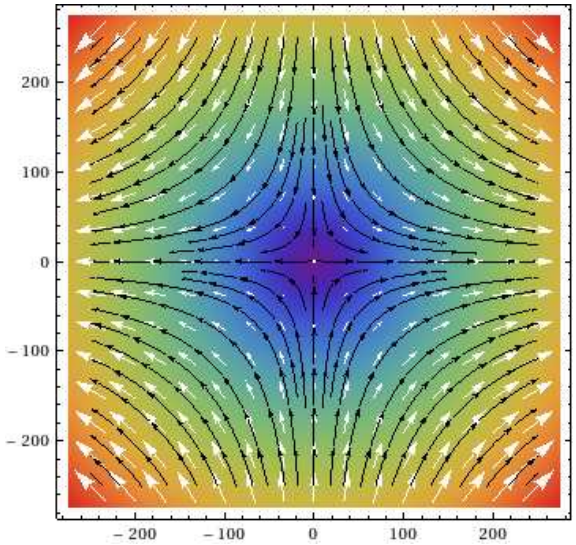
- Field: focusing and defocusing transversally
- Bore radius 256 mm



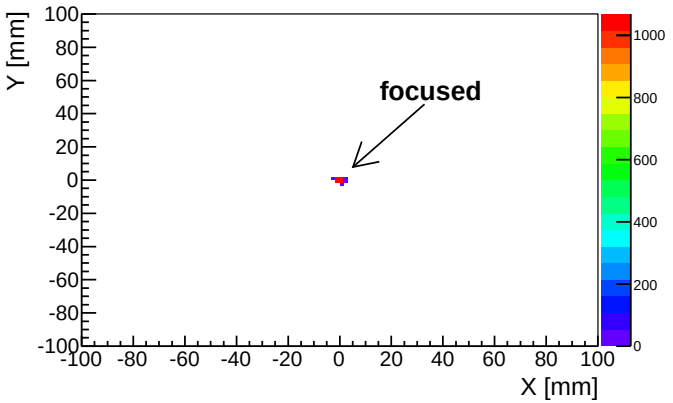
$$B_x = y\frac{\partial B_x}{\partial y}$$

$$B_y = -x\frac{\partial B_y}{\partial x}$$

$$B_z = 0$$

Dipole entrance

$k = 0.95$ 1/m



PIN-DSSD2 coincidences

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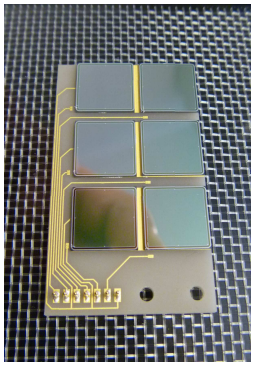
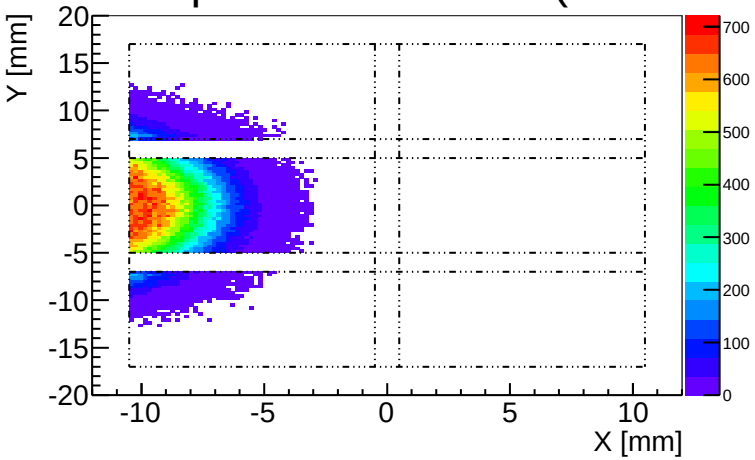
- PIN-diode: 6 pads of 1×1 cm^2.
- Beam like particles detection.
- Movable perpendicular to beam direction.
- Useful for coincidences with recoil detectors, e.g.

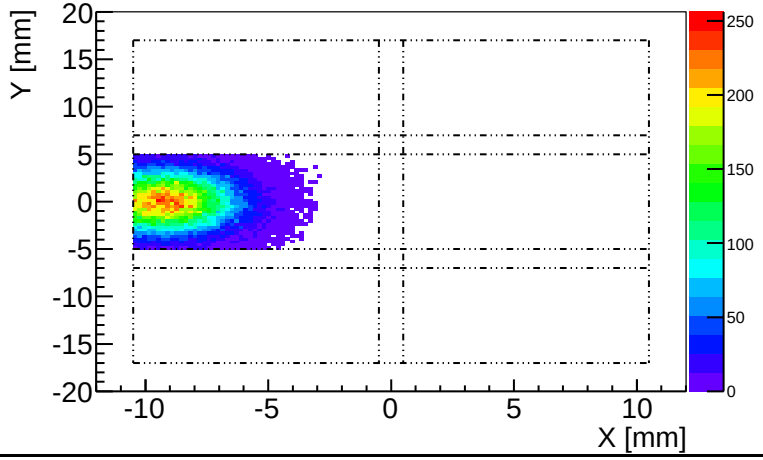
$$^{58}\text{Ni}(\alpha, \alpha')\,^{58}\text{Ni}^*$$



Particles spot on PIN-diode (x = 5 mm)



PIN-DSSD2 coincidences



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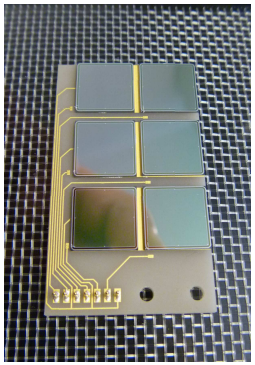

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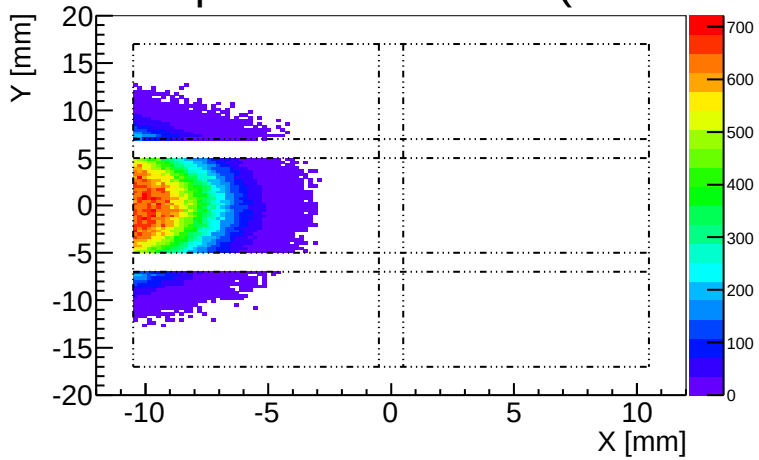

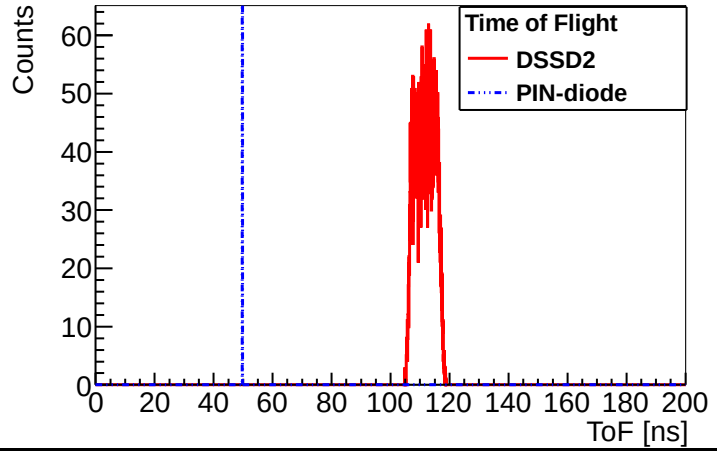

Outline

TECHNISCHE UNIVERSITÄT DARMSTADT

Motivation

In-Beam Test

E105 Experiment

Summary

Summary

TECHNISCHE UNIVERSITÄT DARMSTADT

In-beam test

- After including a 13% of light leakage, simulation describes successfully the CsI exp. data.
- The first neighbor cross-talk simulation of DSSD shows satisfactory results by comparison with exp. data.

E105 experiment

- Angular resolution improved with the slit plate. Elastic scattering and first excited state of ^{56}Ni are separable.
- Many reaction channels can be studied by coincidences with low energy neutrons and/or beam like particles.

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Thank you!

Work supported by HIC for FAIR, GSI-TUD cooperation agreement, BMBF (06DA9040I, 05P12RDFN8) and KVI.

HIC for FAIR Helmholtz International Center

GSI

Federal Ministry of Education and Research

KVI

List of Participants

TECHNISCHE UNIVERSITÄT DARMSTADT

- IKP, TU Darmstadt
  S. Bönig, M. von. Schmid, T. Kröll, A. Hartig, S. Ilieva, M. Thürauf, J.C. Zamora
- GSI, Germany
  P. Egelhof, M. Mutterer, O. Kisilev, H. Kollmus, B. Streicher Y. Ke, I. Dillmann, C. Dimopoulou, H. Geissel, C. Kozhuharov, S. Litvinov, Yu.A. Litvinov, C. Nociforo, F. Nolden, U. Popp, C. Scheidenberger, M. Steck, M. Takechi, H. Weick, J.S. Winfield, D. Winters
- KVI,Groningen
  S. Bagchi, M.N. Harakeh, N. Kalantar-Nayestanaki, A. Kluttig, M. Kuilman, M. Mahjour-Shafiei, M. Najafi, C. Rigollet, S. Roy
- University of Edinburgh
  T. Davinson, D. Doherty, P. J. Woods
- PTI, St. Petersburg
  V. Eremin
- Atomki, Debrecen
  M. Csatlós, A. Krasznahorkay, L. Stuhl
- University of Tsukuba
  D. Nagae
- RIKEN Nishina Center
  T. Uesaka, J. Zenihiro
- Saitama University
  T. Yamaguchi

Backup Slides

Probability interstrip events

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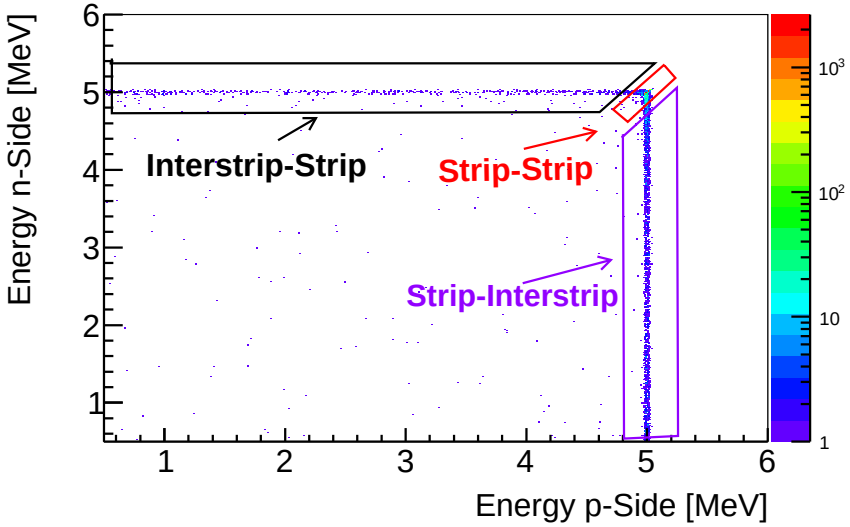
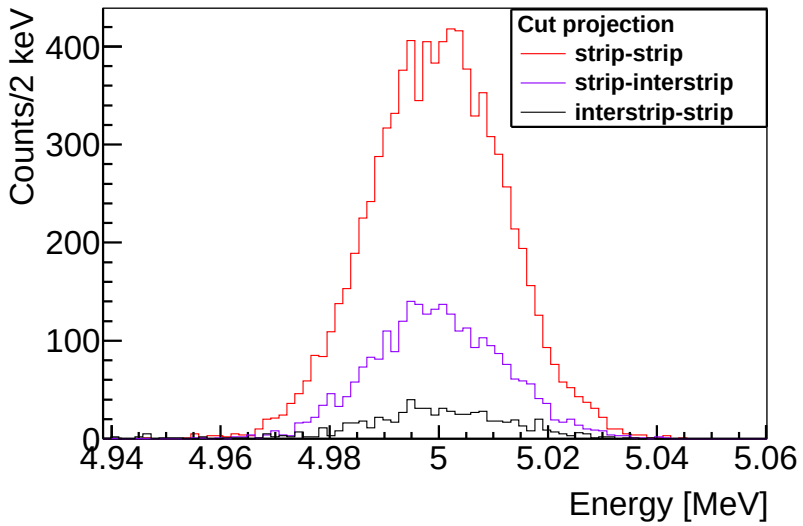
Simulation of 5 MeV alpha beam

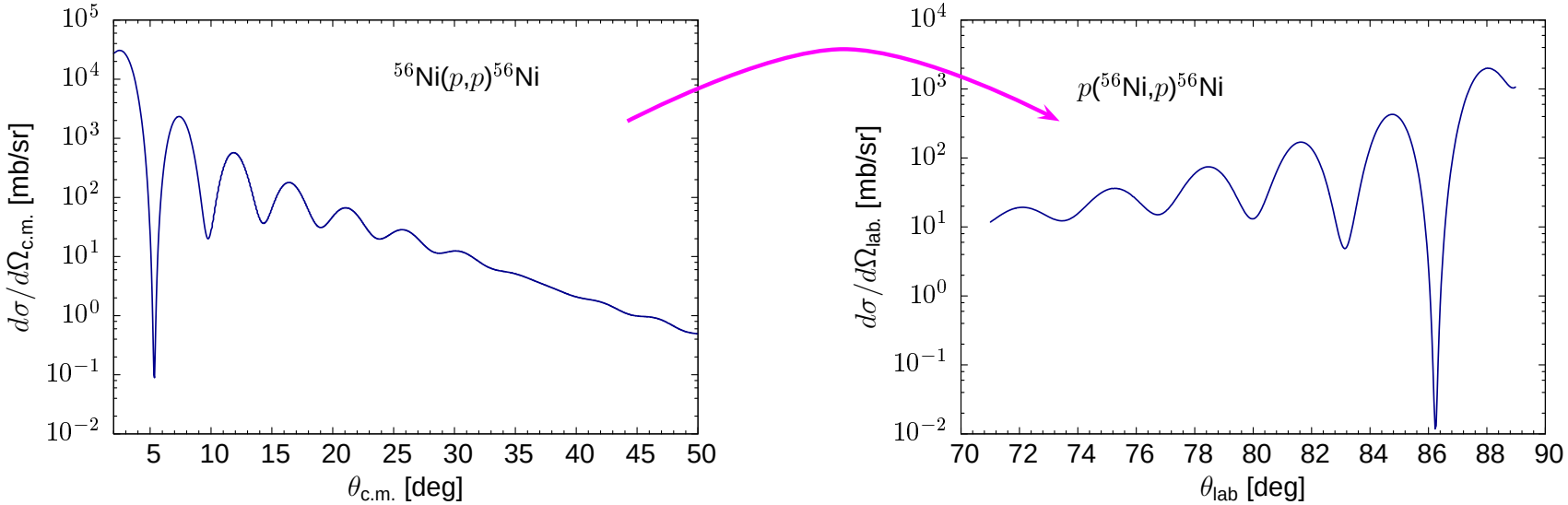




- (p)Strip-(n)Strip: 71%
- (p)Strip-(n)Interstrip: 22%
- (p)Interstrip-(n)Strip: 6%
- (p)Interstrip-(n)Interstrip: 1%

Same result in exp. test, ^{241}Am source

Sorting primaries



$$r = \frac{\int_{\theta_1}^{x} \left(\frac{d\sigma}{d\Omega}\right)_{\text{lab}} 2\pi \sin\theta d\theta}{\int_{\theta_1}^{\theta_2} \left(\frac{d\sigma}{d\Omega}\right)_{\text{lab}} 2\pi \sin\theta d\theta}$$

$$r \in [0,1] \longrightarrow x \in [\theta_1, \theta_2]$$