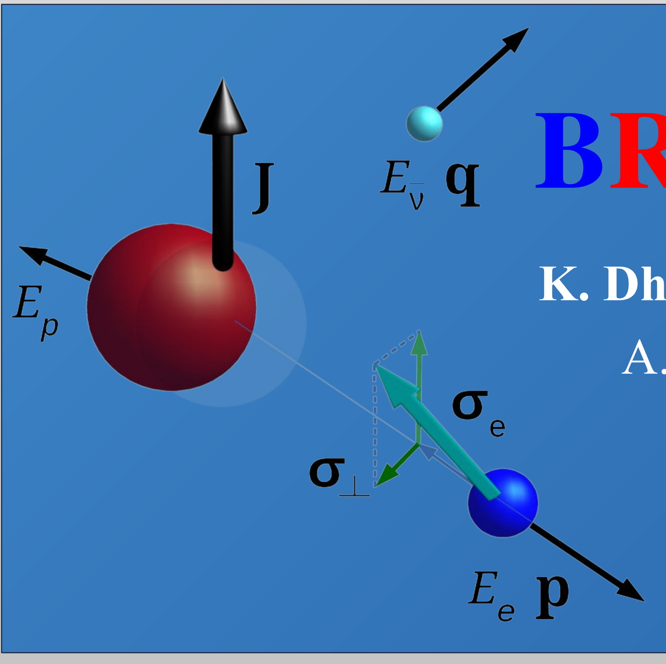


BRAND – A detection system for β-decay correlation measurements

K. Dhanmeher[2], K. Bodek[1], J. Choi[5], L. De Keukeleere[3], M. Engler[6], G. Gupta[1], A. Kozela[2], K. Łojek[1], K. Pysz[2], D. Ries[6], A. R. Young[5], D. Rozpędzik[1], N. Severijns[3], T. Soldner[4], N. Yazdandoost[6], J. Zejma[1]

karishma.dhanmeher@ifj.edu.pl

1) *M. Smoluchowski Institute of Physics, Jagiellonian University, Kraków, Poland*
2) *H. Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland*
3) *Institute of Nuclear and Radiation Physics, KU Leuven, Belgium*
4) *Institut Laue-Langevin, Grenoble, France*
5) *Dep. of Physics and Astronomy, North Carolina State University, Raleigh, USA*
6) *Dep. of chemistry TRIGA site, J. Gutenberg University, Mainz, Germany*

Motivation

Idea !

- Measurement of the **angular correlations in the decay of polarized cold neutron** with full kinematic reconstruction of event
- Differential decay rate of polarised neutron:

$$\frac{d^3\Gamma}{dE_e d\Omega_e d\Omega_\nu} \sim 1 + a\frac{\mathbf{p}}{E_e}\cdot\frac{\mathbf{q}}{E_\nu} + b\frac{m_e}{E_e} + \frac{\langle \mathbf{J}\rangle}{J}\cdot\left[A\frac{\mathbf{p}}{E_e} + B\frac{\mathbf{q}}{E_\nu} + D\frac{\mathbf{p}}{E_e}\times\frac{\mathbf{q}}{E_\nu}\right] + \sigma_\perp\left[H\frac{\mathbf{q}}{E_\nu} + L\frac{\mathbf{p}}{E_e}\times\frac{\mathbf{q}}{E_\nu} + N\frac{\langle\mathbf{J}\rangle}{J} + R\frac{\langle\mathbf{J}\rangle}{J}\times\frac{\mathbf{p}}{E_e} + S\frac{\langle\mathbf{J}\rangle}{J}\frac{\mathbf{p}}{E_e}\cdot\frac{\mathbf{q}}{E_\nu} + U\frac{\mathbf{q}}{E_\nu}\frac{\langle\mathbf{J}\rangle}{J}\cdot\frac{\mathbf{p}}{E_e} + V\frac{\mathbf{q}}{E_\nu}\times\frac{\langle\mathbf{J}\rangle}{J}\right]$$

Why ?

"Search for BSM physics via transverse electron polarisation"

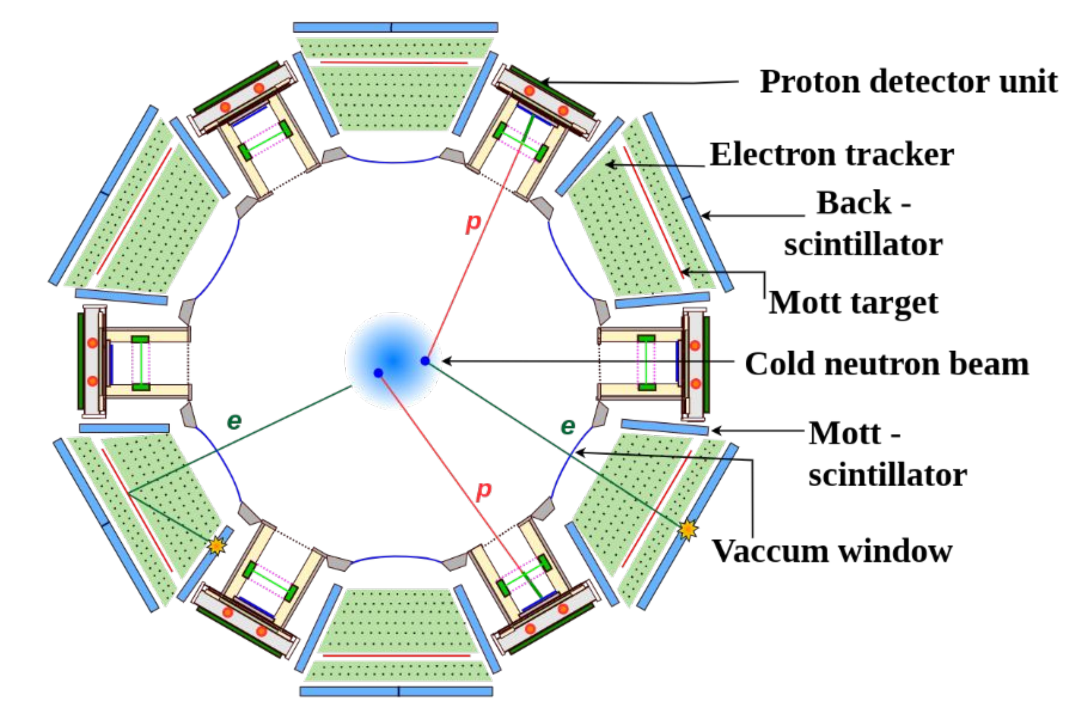
- Measurement of $\sigma_\perp$ ⇒access to coefficients X (= *H, L, N, R, S, U, V*) which are linear combination of BSM - scalar and tensor couplings:

$$X = X_{SM} + X_{FSI} + c_{ReS}\,\mathrm{Re}S + c_{ReT}\,\mathrm{Re}T + c_{ImS}\,\mathrm{Im}S + c_{ImT}\,\mathrm{Im}T$$

where, $S = \frac{C_S + C_S'}{C_V}$, $T = \frac{C_T + C_T'}{C_A}$

- Significant improvement of constraints on ReS, ReT, ImS, ImT if precision of *H, L, N, R, S, U, V* measurement: **5 x 10^-4**
- Stringent constraints on e.g. leptoquark exchange model, R-parity violating Minimal Supersymmetric Standard Model (MSSM) and parameters of Effective Field Theories (EFT)

How ?



The ultimate BRAND - 3 experimental setup

BRAND - 0 : The initial phase

In Sept-Oct 2021 first experiment with the prototype of the BRAND apparatus was performed at Institut Laue-Langevin (ILL), Grenoble.

Decay source :

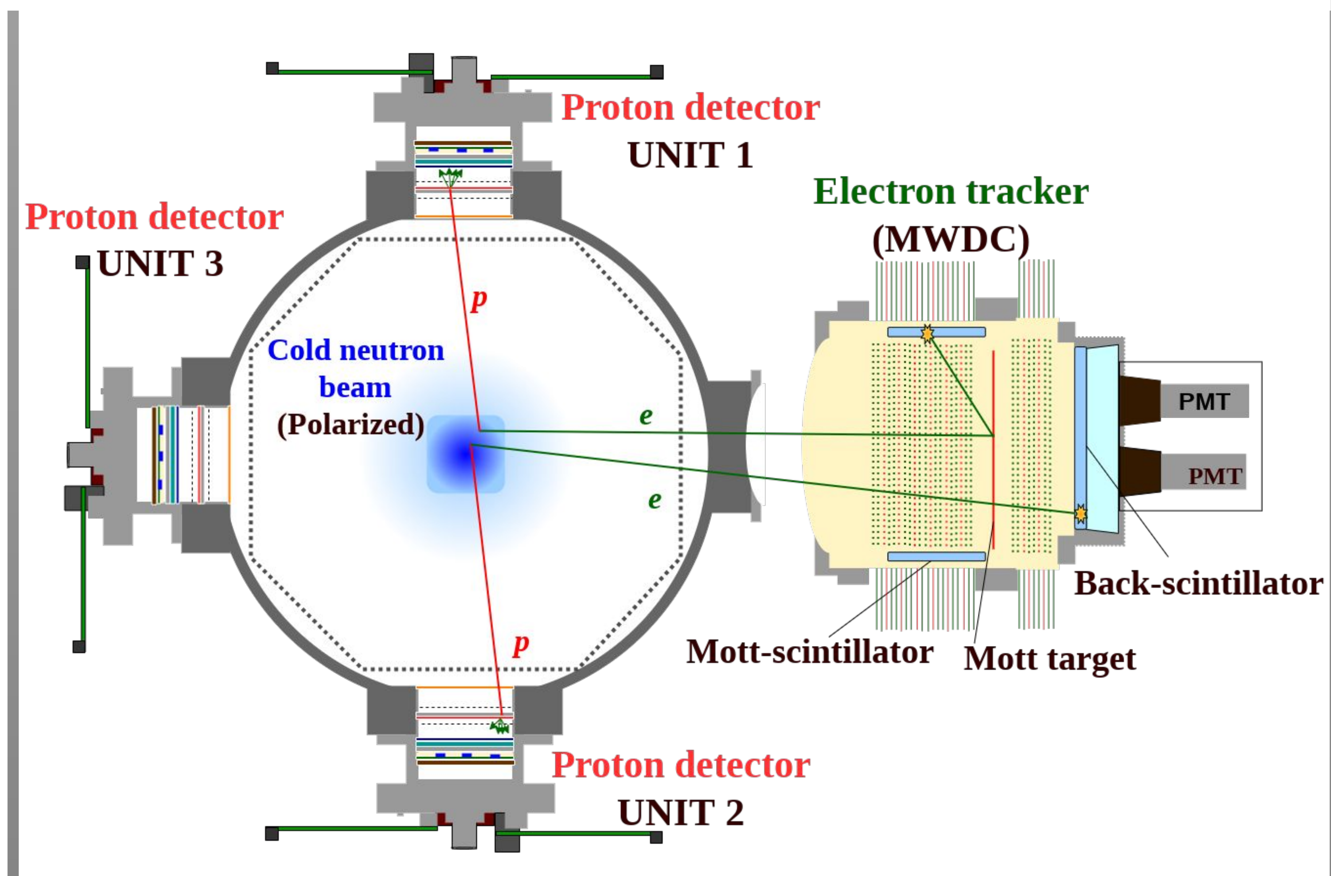
- Longitudinally **polarised cold neutron beam** (PF1B, ILL, Grenoble).
  Polarization > 99.0 %
  Flux ~ 4 x 10^8 n/cm^2 s
- Neutron polarisation was guided by arrangement of **permanent magnets and magnetic coils**
- Passes through decay chamber with **vacuum ~ 10^-4 - 10^-5 mbar**
- **Vacuum tight thin window** for transfer of β particles (with supporting Kevlar mesh)

Electron detection:

- **3D-Tracking** in low mass, low Z Multi Wire Drift Chamber (MWDC)
  XY-plane → Drift-time
  XZ-plane → Charge division method
- Plastic scintillator for **energy measurement** & **Trigger**
  Back-scintillator : PM readout
  Mott-scintillators : SiPM readout
- **Transverse electron polarization** with Mott scattering
  Pb-coated Mylar foil as Mott target (thickness~6 μm)

Proton detection:

- **Acceleration of recoil protons** in external electric field (10-25 keV)
- **Conversion of proton to electron bunches with LiF foil**
- Detection of electron bunches in **plastic scintillators (25 μm thin)** with SiPM readout
- **Vertex reconstruction** with time of flight (TOF) and reconstructed electron trajectory

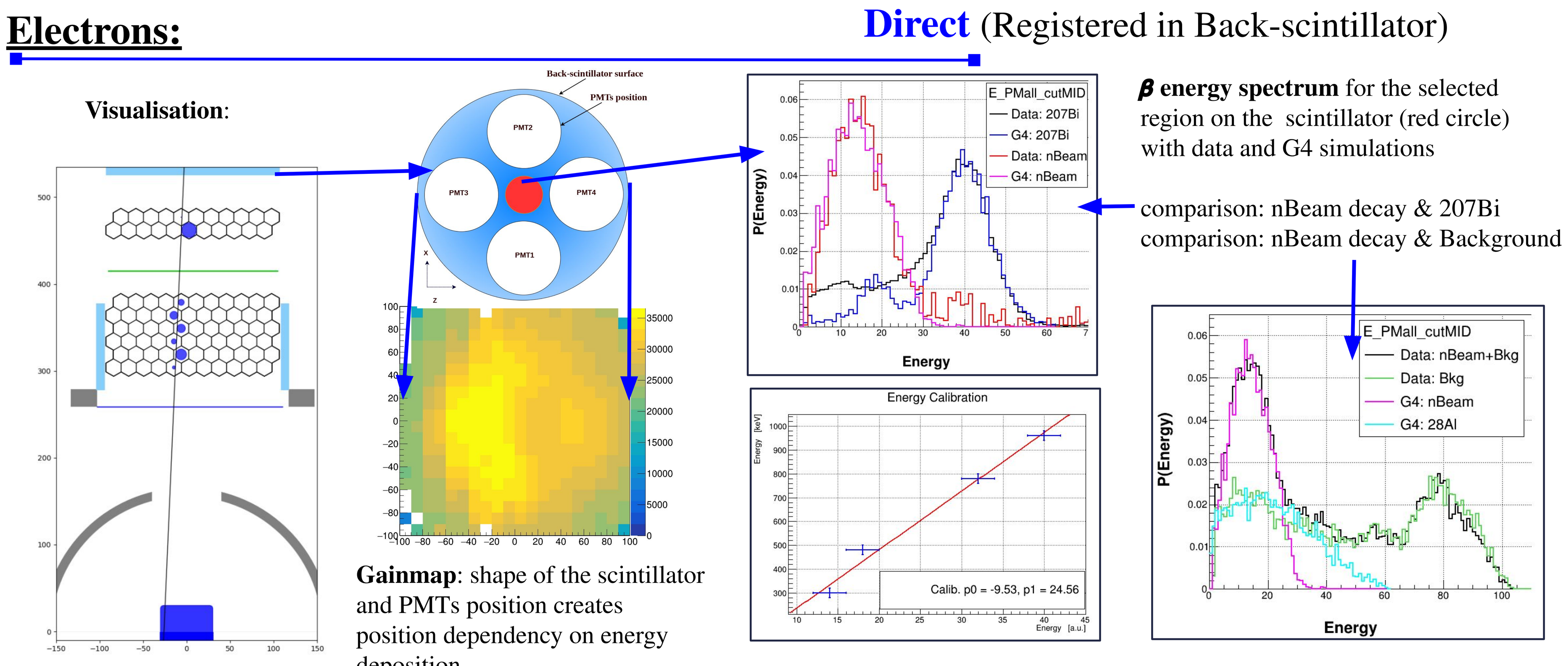


BRAND-0 Experimental setup, ILL 2021

Setup & Preliminary Analysis

Electrons:

Direct (Registered in Back-scintillator)

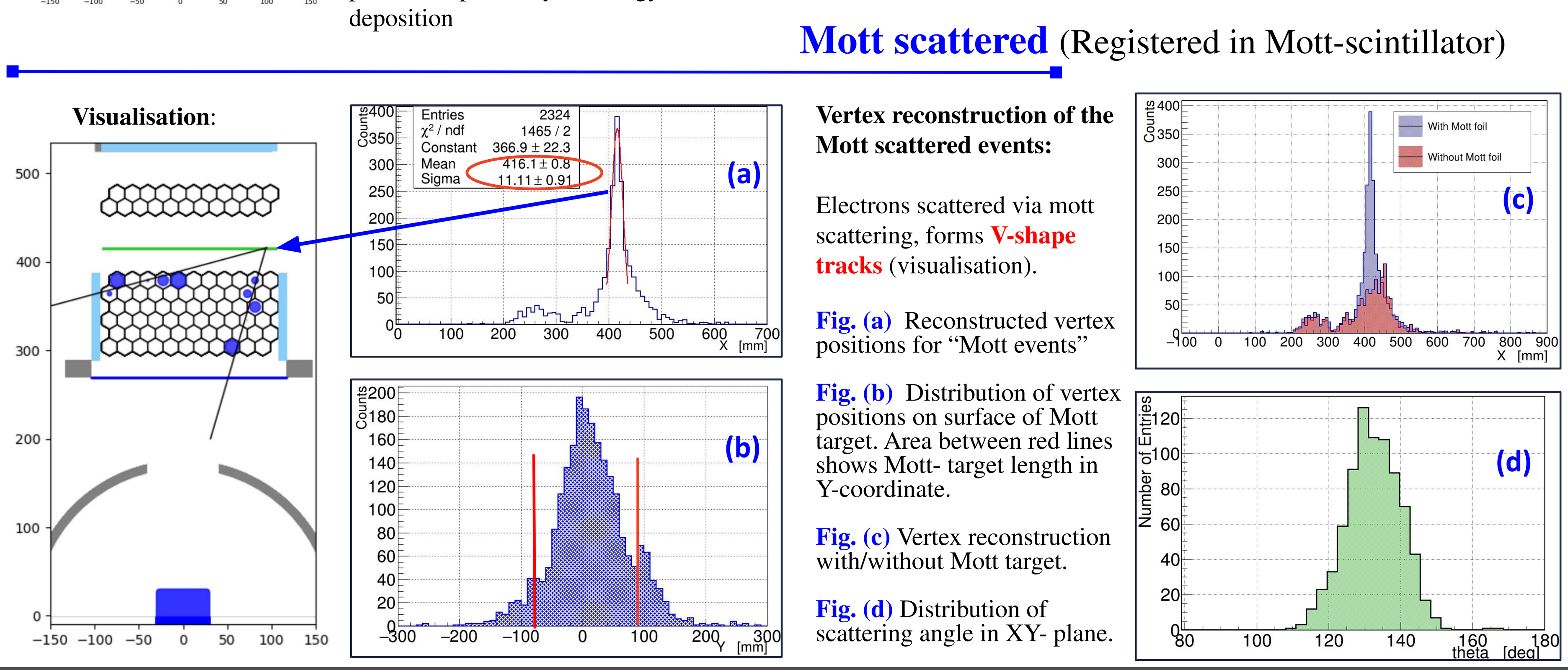


Gainmap: shape of the scintillator and PMTs position creates position dependency on energy deposition

β energy spectrum for the selected region on the scintillator (red circle) with data and G4 simulations

comparison: nBeam decay & 207Bi
comparison: nBeam decay & Background

Mott scattered (Registered in Mott-scintillator)



Vertex reconstruction of the Mott scattered events:

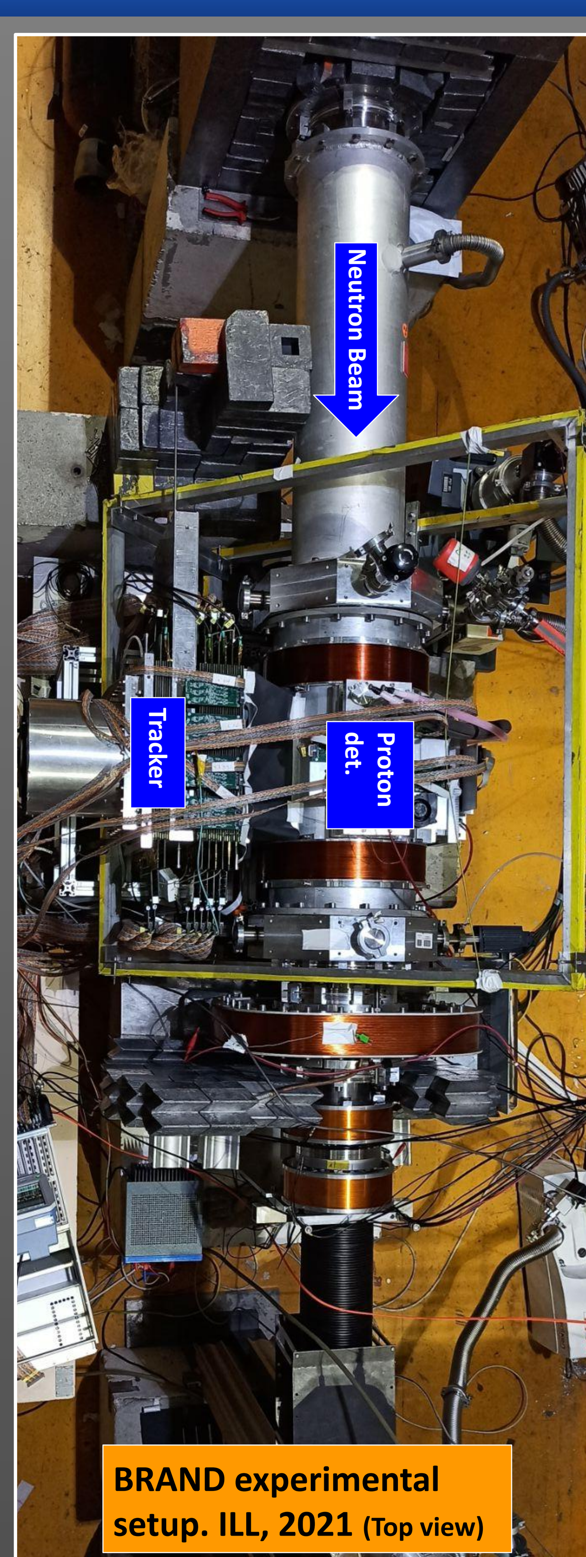
Electrons scattered via mott scattering, forms **V-shape tracks** (visualisation).

Fig. (a) Reconstructed vertex positions for "Mott events"

Fig. (b) Distribution of vertex positions on surface of Mott target. Area between red lines shows Mott- target length in Y-coordinate.

Fig. (c) Vertex reconstruction with/without Mott target.

Fig. (d) Distribution of scattering angle in XY- plane.

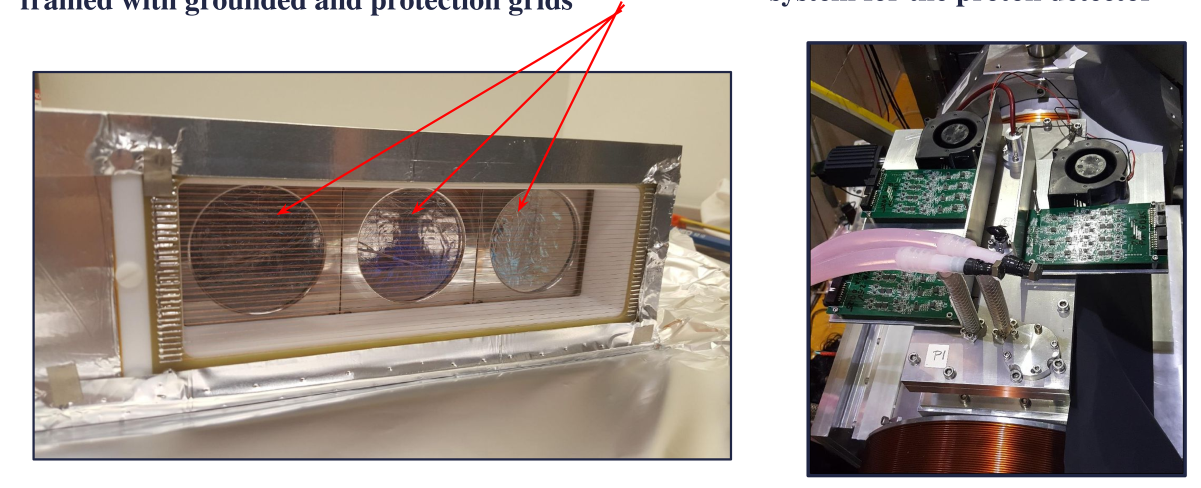


BRAND experimental setup. ILL, 2021 (Top view)

Protons:

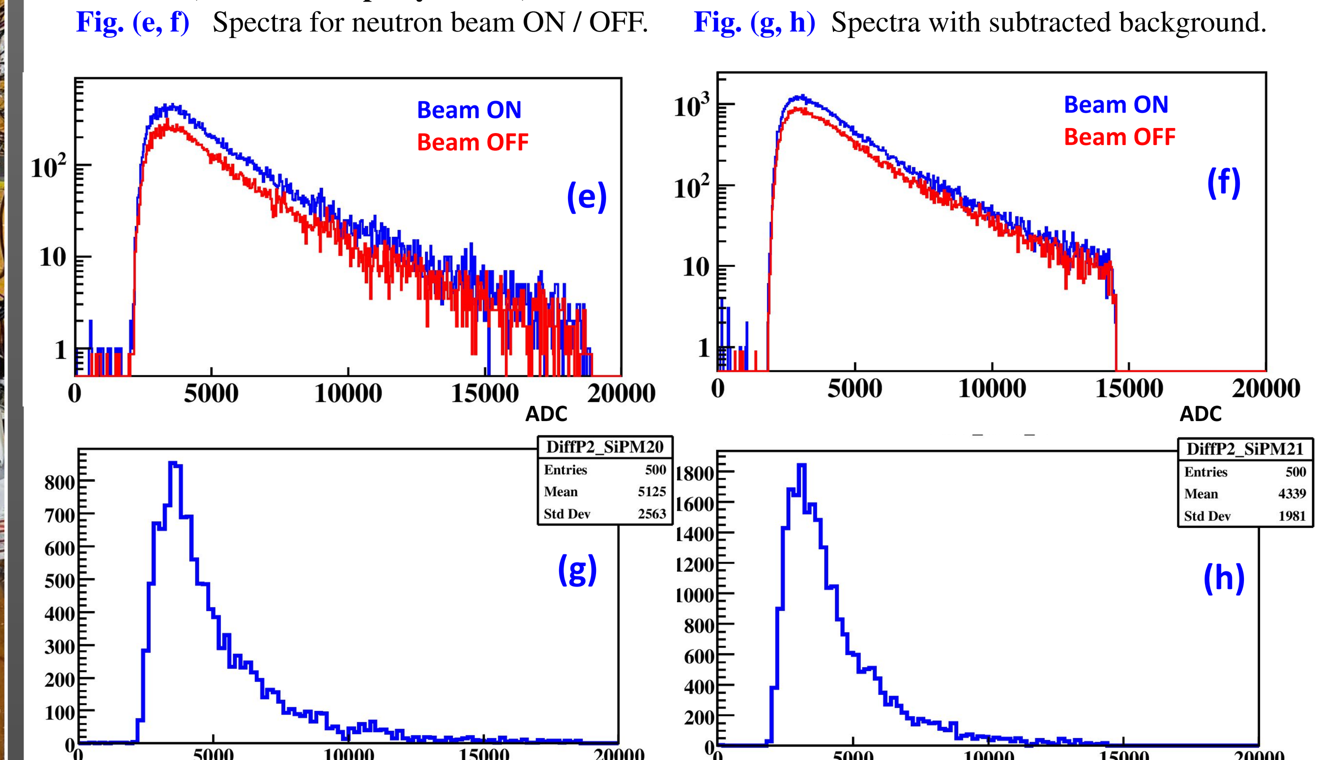
One of the proton detectors with 3 *p-e converter foils* framed with grounded and protection grids

Front-end electronics with cooling system for the proton detector



Typical ADC spectrum (pulse-charge distribution) of the converted electrons from proton detector (for two exemplary SiPMs) :

Fig. (e, f) Spectra for neutron beam ON / OFF. **Fig. (g, h)** Spectra with subtracted background.



Conclusion

Results from the first experiment are promising. Some experimental problems are identified and solutions are under development. Necessary improvements are foreseen. (Analysis is ongoing…).

More information

- K. Bodek et al., EPJ Web of Conference, 262, 01014 (2022).
- K. Dhanmeher. et al., Pos PANIC2021 (2022) 099.
- D. Rozpędzik. et al., Pos PANIC2021 (2022) 432.

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