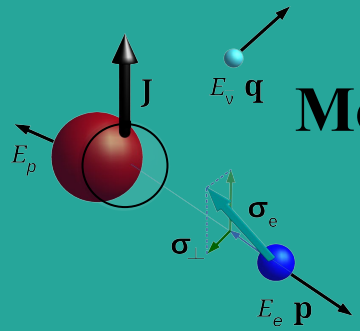


# Mott-polarimeter for electron transverse spin component in the *BRAND* experiment

***Karishma Dhanmeher*** **on behalf of the *BRAND* collaboration…**

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## Overview:

- $\beta$-decay correlation coefficients
- The *BRAND* experiment
- Initial phase experimental run at ILL, Grenoble
- Mott-Polarimeter: Electron detection system
- Analysis


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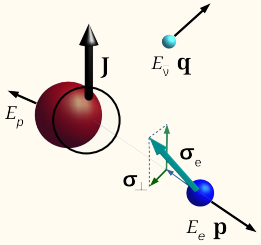
# $\beta$-decay correlation coefficients

**Differential decay rate of polarised neutron:**

SM

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

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




**p , q** :electron & anti-neutrino momenta
**$E_e$ , $E_\nu$** :electron & anti-neutrino energy
**J** :neutron polarization
**$\sigma_\perp$** :transverse component of electron polarization

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

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

**Why it is important ?**

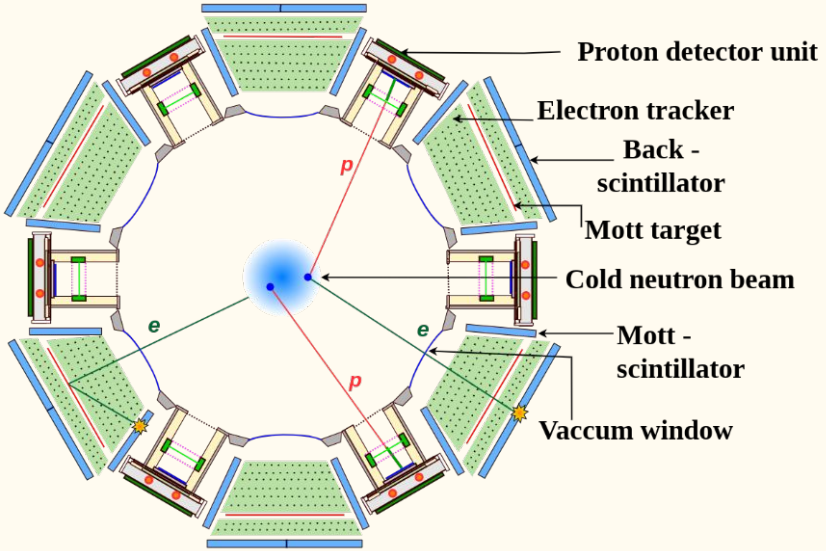
**"Search of BSM Physics with transverse electron polarisation"**

- Significant improvement of constraints on Re*S*, Re*T*, Im*S*, Im*T* 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)

# The *BRAND* experiment: Idea

**“ Simultaneous measurement of 11 correlation coefficients, among them, 5 : *H, L, S, U* and *V* are never attempted experimentally before. ”**

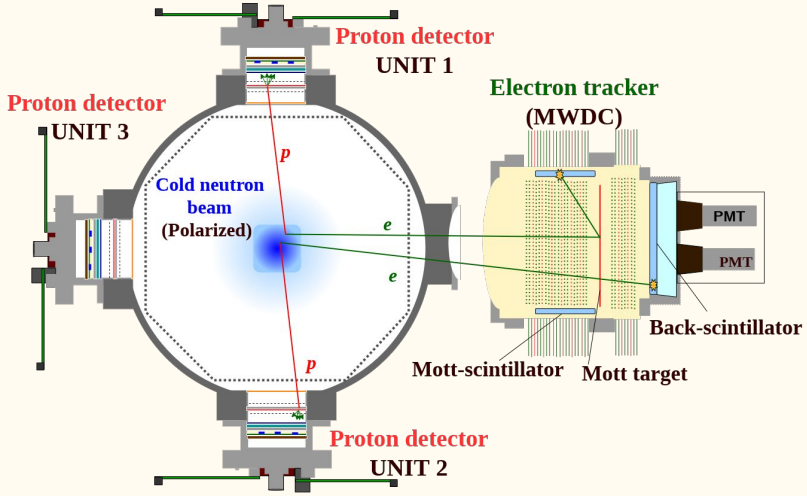
- Cold polarised **neutron beam**
- 360° coverage of detectors for decay products (electrons and protons)
- **Electron detection system (Mott polarimeter):**
  - 3D-tracking in Multi Wire Drift Chamber (MWDC)
  - Energy measurement (Plastic scintillators)
  - Thin Pb-foil as a Mott scatterer
- **Proton detection system:**
  - Acceleration and subsequent conversion of recoil protons into bunches of electrons in a thin LiF foil.
  - Detection of converted electrons in plastic scintillators with SiPM readout.
- **Deacy vertex reconstruction** with proton time of flight (TOF) and reconstructed electron trajectory



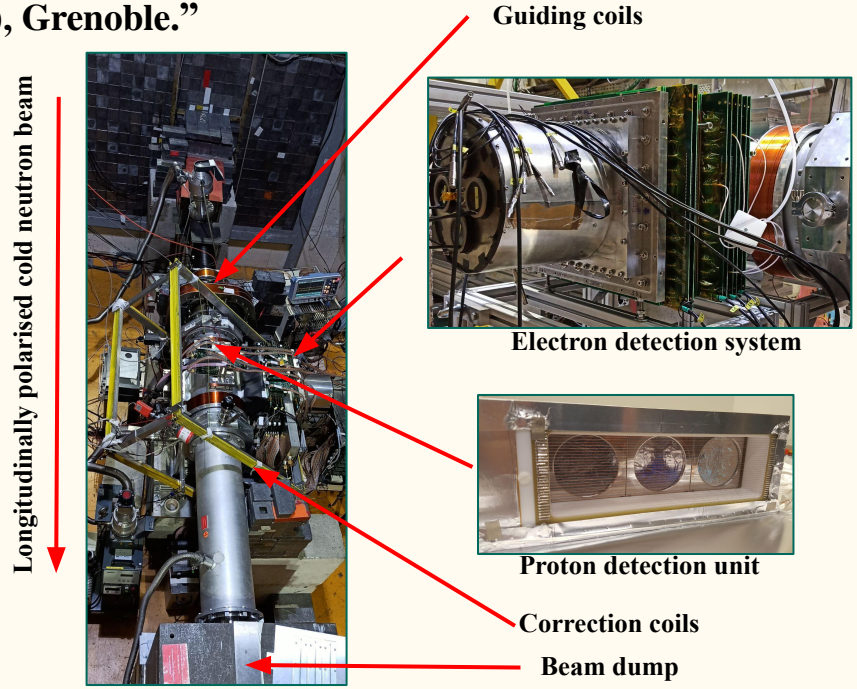

**Schematic cross-section of the ultimate *BRAND* experimental setup**

# *BRAND*-0: The initial phase experiment at ILL, Grenoble

**"In Sept-Oct 2021, experiment with the prototype of the *BRAND* apparatus was performed at the cold neutron facility (PF1B) at the Institut Laue-Langevin (ILL), Grenoble."**




Schematic cross-section of the prototype *BRAND* experimental setup

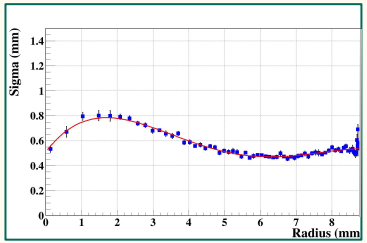



The experimental setup

# Mott polarimeter: Electron detection system (*BRAND* prototype experiment)

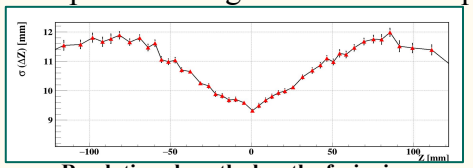
**Low mass, low-Z MWDC**

XY-plane : Drift-time



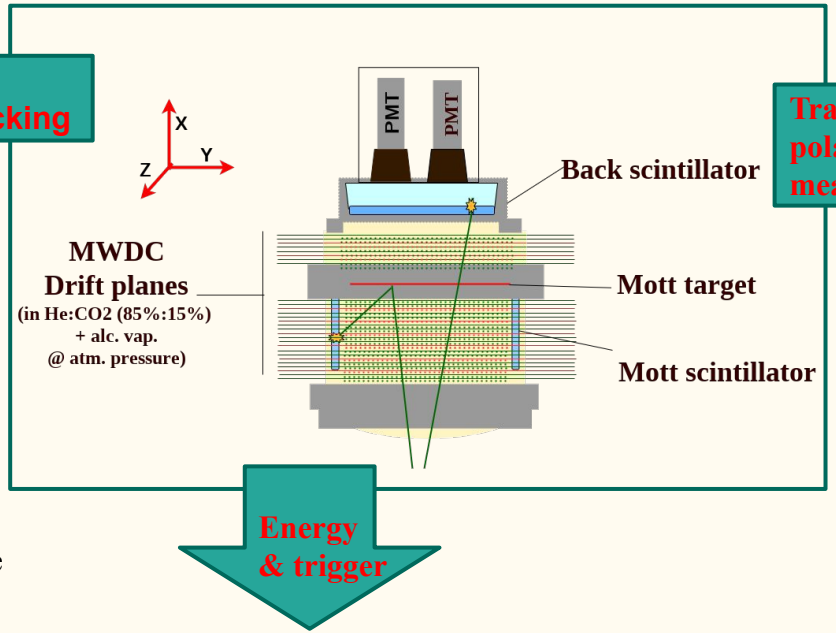

**Resolution along the radius of the drift cell in XY-plane**

ZY-plane : Charge division technique




**Resolution along the length of wire in ZY-plane**

**3D tracking**




**Transverse polarisation measurement**

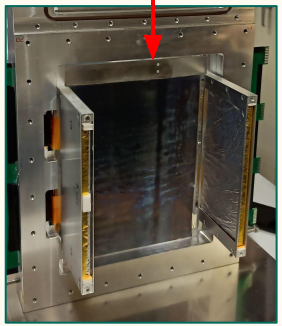
**Energy & trigger**

**Plastic scintillators**

Back scintillator : PM readout
Mott scintillator : SiPM readout

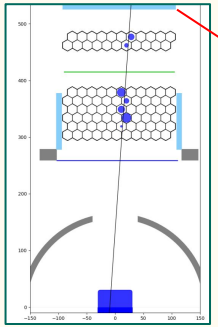
**Pb-coated Mylar**
foil as a Mott-target
(thickness ~ 6 μm)

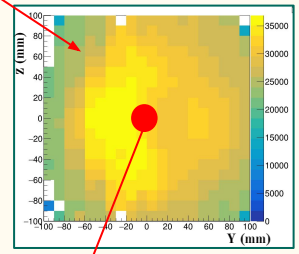
**Asymmetry = $S_{eff}(\delta)$ . $\sigma_{\perp}$**
$S_{eff}$ :Effective Sherman function
δ :Angle of scattering



# Analysis:(Electrons)

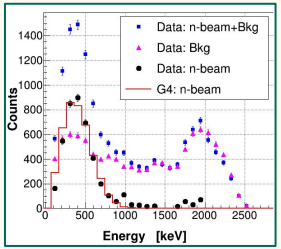
## Direct electrons:



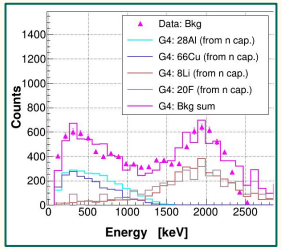



**Gain-map for the back scintillator :**
Represents position dependency of the energy measurement on the scintillator surface.

**Track** registered in the back scintillator (XY-plane)



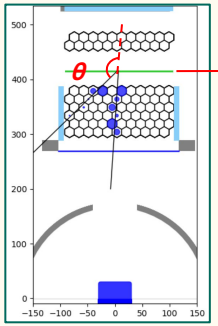

(a)



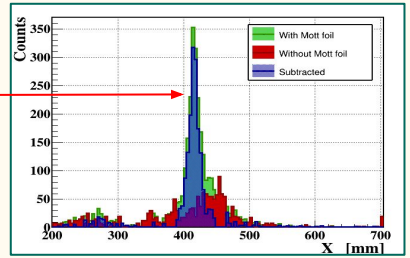

(b)

**Neutron $\beta$-decay energy spectrum and background :**
(a) energy spectrum recorded in the back scintillator, identified background spectrum and resulting $\beta$ spectrum compared with GEANT4 simulations ; (b) identified background spectrum with the possible components simulated with GEANT4. (Preliminary!)

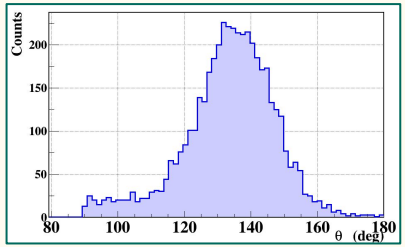
## Mott scattered electrons:



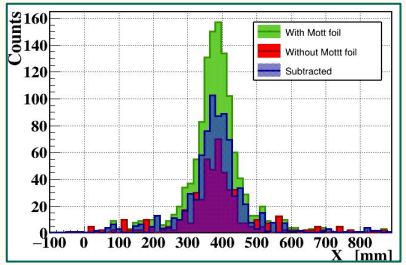

**Track** registered in the Mott-scintillator after scattering on the Mott scatterer (XY-plane).
Such a tracks leave "*V- shaped*" trajectories in the chamber.




**Mott vertex (XY-plane):**
The reconstructed vertices shows exactly the position of the Mott foil (XY-plane)




**Scattering angle distribution:**
Distribution of scattering angle ($\theta$) for the events identified as Mott scattered (XY-plane)




**Mott vertex (ZY-plane):**
Vertex reconstruction in ZY-plane

**The further analysis is ongoing…**

# Thank you for your attention!