Mott-polarimeter for electrons from Neutron decay in BRAND experiment

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Introduction & 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 :

$$\frac{d^5\Gamma}{dE_e d\Omega_e d\Omega_\nu} \sim 1 + a\frac{\vec{p}_e}{E_e}\frac{\vec{q}}{E_\nu} + b\frac{m_e}{E_e} + \frac{\langle\vec{J}\rangle}{J}\cdot\left[A\frac{\vec{p}_e}{E_e} + B\frac{\vec{q}}{E_\nu} + D\frac{\vec{p}_e}{E_e}\times\frac{\vec{q}}{E_\nu}\right]$$

Components foreseen in standard model

$$+\sigma_\perp\left[H\frac{\vec{q}}{E_\nu} + L\frac{\vec{p}_e}{E_e}\times\frac{\vec{q}}{E_\nu} + N\frac{\langle\vec{J}\rangle}{J} + R\frac{\langle\vec{J}\rangle}{J}\times\frac{\vec{p}_e}{E_e} + S\frac{\langle\vec{J}\rangle}{J}\cdot\frac{\vec{q}}{E_\nu} + U\frac{\langle\vec{J}\rangle}{J}\frac{\vec{p}_e}{E_e}\cdot\frac{\vec{q}}{E_\nu} + V\frac{\vec{q}}{E_\nu}\times\frac{\langle\vec{J}\rangle}{J}\right]$$

Potential BSM Physics ?

Why ?

"Search for BSM physics via transverse electron polarisation"

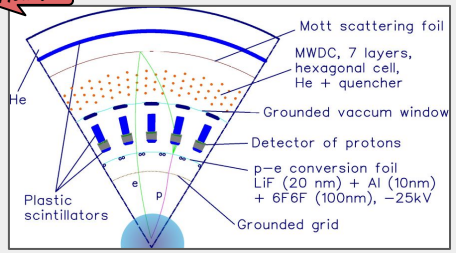
If $\sigma_\perp \neq 0$ → access to coefficients X(=*H, L, N, R, S,U,V*), which are linear combination of BSM - *scalar* and *tensor* couplings:

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

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} → impact on constraints of models of leptoquark exchange model, R-parity violating MSSM and parameters of EFT.

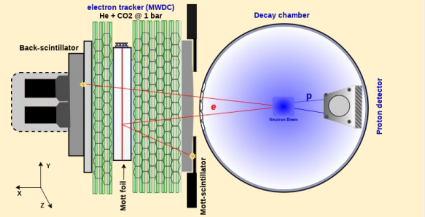
How ?



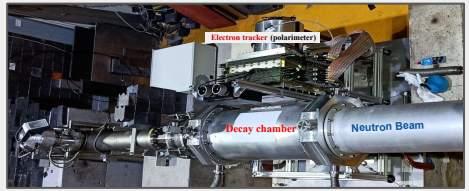
One sector (1/6) of BRAND ultimate setup

Pilot run (BRAND-0)

In September 2020, first short test (5 days) measurement of prototype of BRAND apparatus has been performed at neutron facility (PF1B) of Institut Laue-Langevin (ILL), Grenoble.



Schematic of BRAND-0 setup



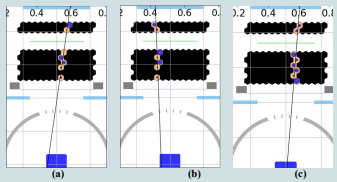
Experimental setup of BRAND-0 with polarised cold neutron beam in PF1B areal at ILL, Grenoble in Sept -2020.

Mott-Polarimeter
(Electron detection system)

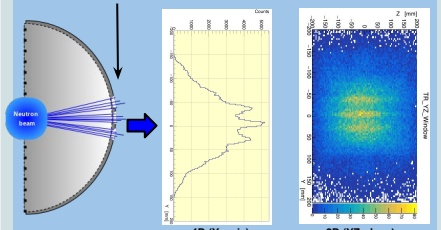
- ✔ Optimized **low mass, low -Z**, hexagonal cell structured **Multi Wire Drift Chamber (MWDC)** with double readout.
  XY → Drift-time
  Z → Charge division technique
- ✔ **" Mott foil "** ~ 4μm (Pb) for measurement of transverse electron polarisation
- ✔ **Plastic scintillator** for energy measurement

Detector performance

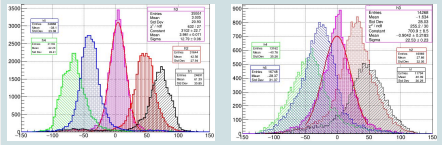
Electron track reconstruction in the polarimeter triggered by the back-scintillator



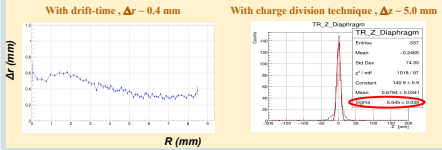
Projection of events triggered by the back scintillator on chamber window



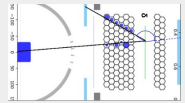
By setting cuts on PMT signal of the back scintillator it is possible to select events.



Effective position resolution of the tracking methods :



Results



Mott scattered electron registered in Mott scintillator *(V-track event)*

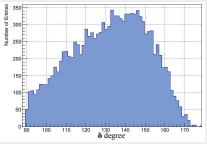
The asymmetry in Mott scattering is the key factor to measure the transverse electron polarisation:

$$\text{Asymmetry} = S_{\text{eff}}(\delta)\cdot\sigma_\perp$$

$S_{\text{eff}}(\delta)$ - Effective Sherman function

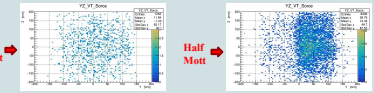
Vertex reconstruction from *V-tracks* of Mott scattered electrons shows the exact position of the Mott foil. (~ 370 mm)

Angular distribution of **scattering angles (δ)** from Mott scattered events (in drift-time plane) with vertex reconstructed close to the Mott foil position.



During the experiment two different thickness of Mott scatterer were used (1) 4 μm (2) 16 μm. Former covered full area and the latter covered half area of the detection system.

3D reconstruction of vertex on mott foil



Conclusion

Results from the first test run are promising. They prove that the experimental techniques applied in BRAND experiment are efficient and precise.
The next four weeks long experimental campaign dedicated for real measurement of the correlation coefficients will start on *15th September 2021.*

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