Monte Carlo simulations for the JEDI polarimeter at COSY

Paul Maanen on behalf of the JEDI Collaboration
JEDI Collaboration | Physics Institute III B, RWTH Aachen University
DPG Frühjahrstagung 2016

Physics Institute III B | RWTH AACHEN UNIVERSITY

Outline

Motivation

Where is the Antimatter in our Universe?

- One precondition for Baryogenesis: $\not{\mathcal{CP}}$
- Standard Model prediction: $\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 10^{-18}$
- WMAP and COBE (2012): $\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 10^{-10}$

$\Rightarrow$Not enough $\not{\mathcal{CP}}$ in Standard Modell

$$\mathcal{H} = -d\frac{\vec{S}}{S} \cdot \vec{E}$$

$$\text{P: } \mathcal{H} = +d\frac{\vec{S}}{S} \cdot \vec{E}$$

$$\text{T: } \mathcal{H} = +d\frac{\vec{S}}{S} \cdot \vec{E}$$

$\Rightarrow$Electric Dipole Moments violate $\mathcal{CP}$ (assuming $\mathcal{CPT}$)

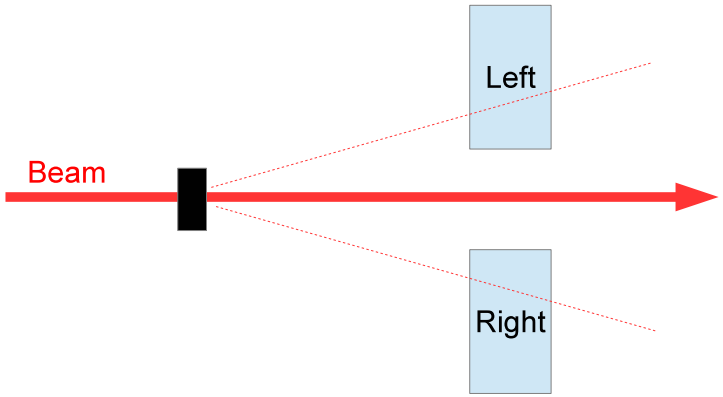
$\Rightarrow$Probe into the physics of the early universe

Design goals for an EDM polarimeter

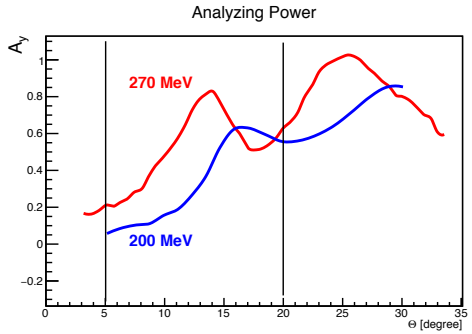
- EDM search in storage rings: Let EDM interact with fields, wait for polarization change.
- Current candidate method for EDM search implicates a linear buildup of polarization with time at $\Delta P = \mathcal{O}(10^{-6}/1000s)$
- Design goals for polarimeter:
  - Large FoM
  - Minimal influence on beam
  - High sensitivity to systematic effects
  - Good long term stability and reproducibility

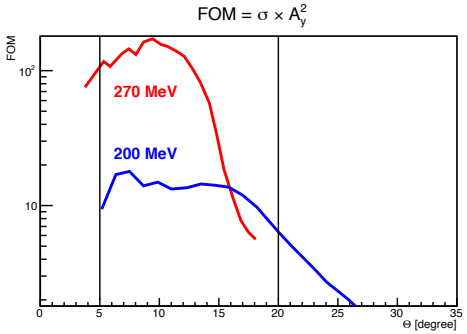
Nuclear scattering polarimetry

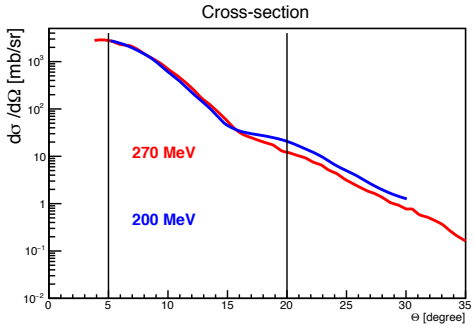
- Nuclear scattering cross section for scattering of polarized particles:
  $\sigma(\theta, \phi) = \sigma_0(\theta) \cdot \left(1 + P_y A_y(\theta) \cdot cos(\phi)\right)$
- Measure left-right asymmetries in cross section: $P_y = \frac{1}{A_y} \frac{L-R}{L+R}$
- May need to also include up, down to account for tensor polarization.
- Currently using elastic deuteron-carbon scattering.



Target choice



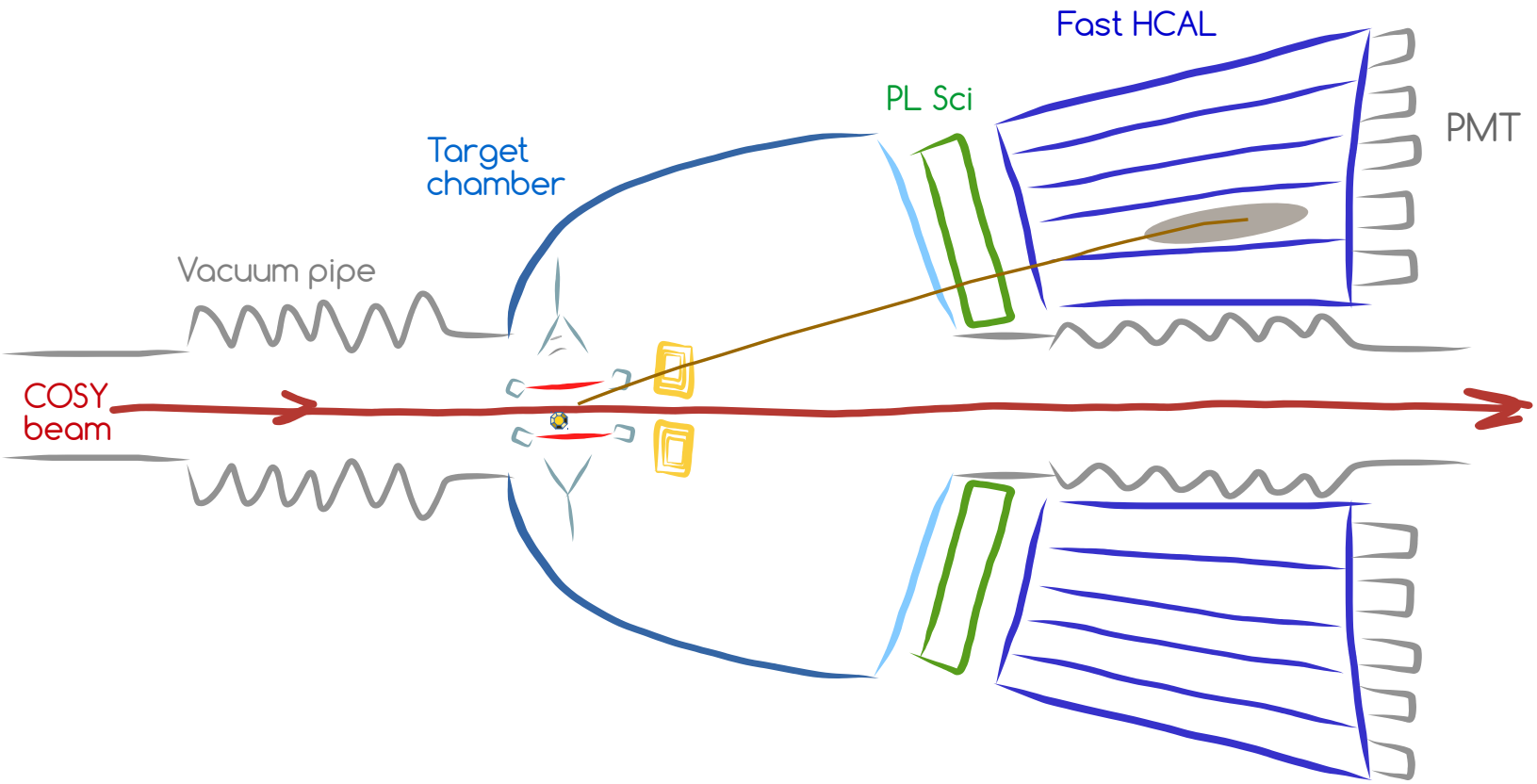




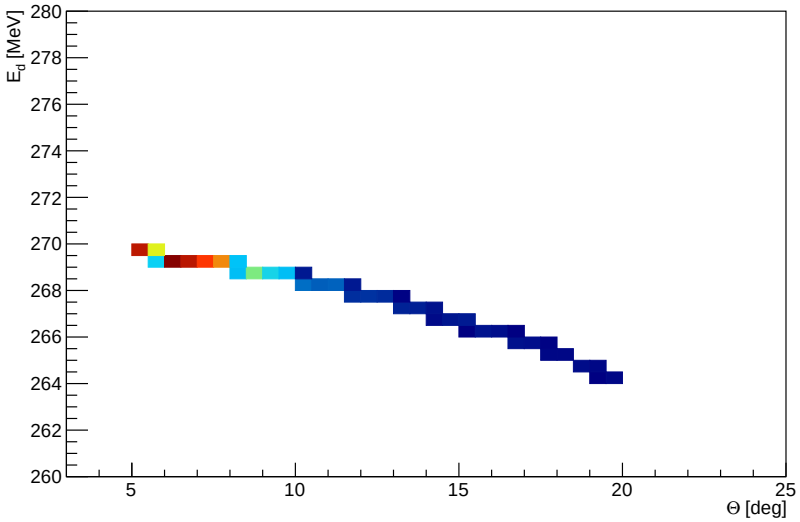
200 MeV: T. Kawabata et al. Phys. Rev. C 70, 034318
270 MeV: Y. Satou et al. Phys. Let. B 549, 307

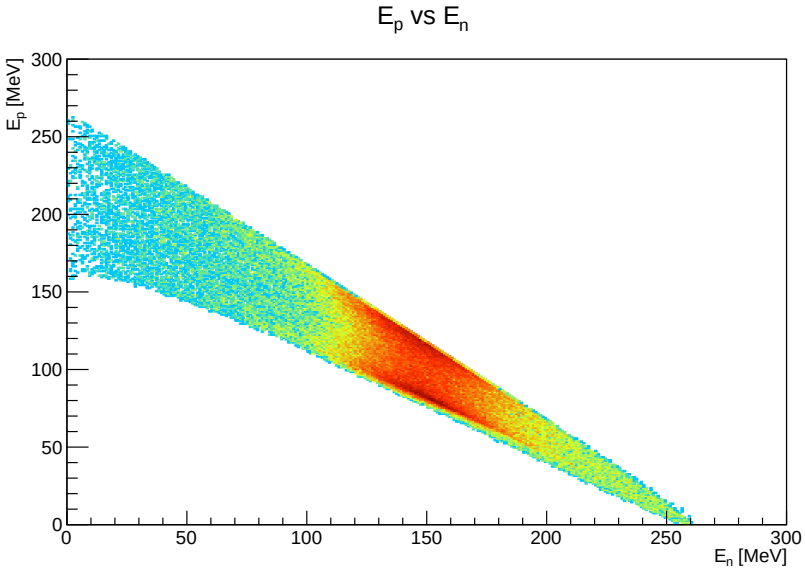
- Carbon was chosen as working choice
- Large analysing power, high elastic cross section
- FOM for Protons also concentrated in the forward region

Detector concept



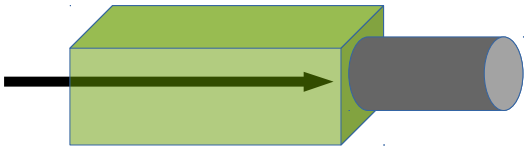
Signal generation

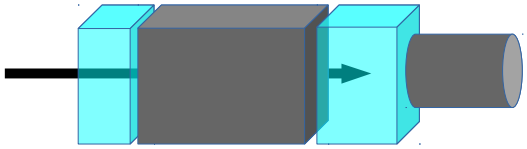




- Elastically scattered deuterons retain almost complete beam energy.
- Break-up has almost no analyzing power, so discard it.
- Protons and neutrons from break-up are energetically well separated.
  ⇒Complete stop of particles provides good signal separation.
- Inelastic reactions carry some analysing power, so maybe keep these.

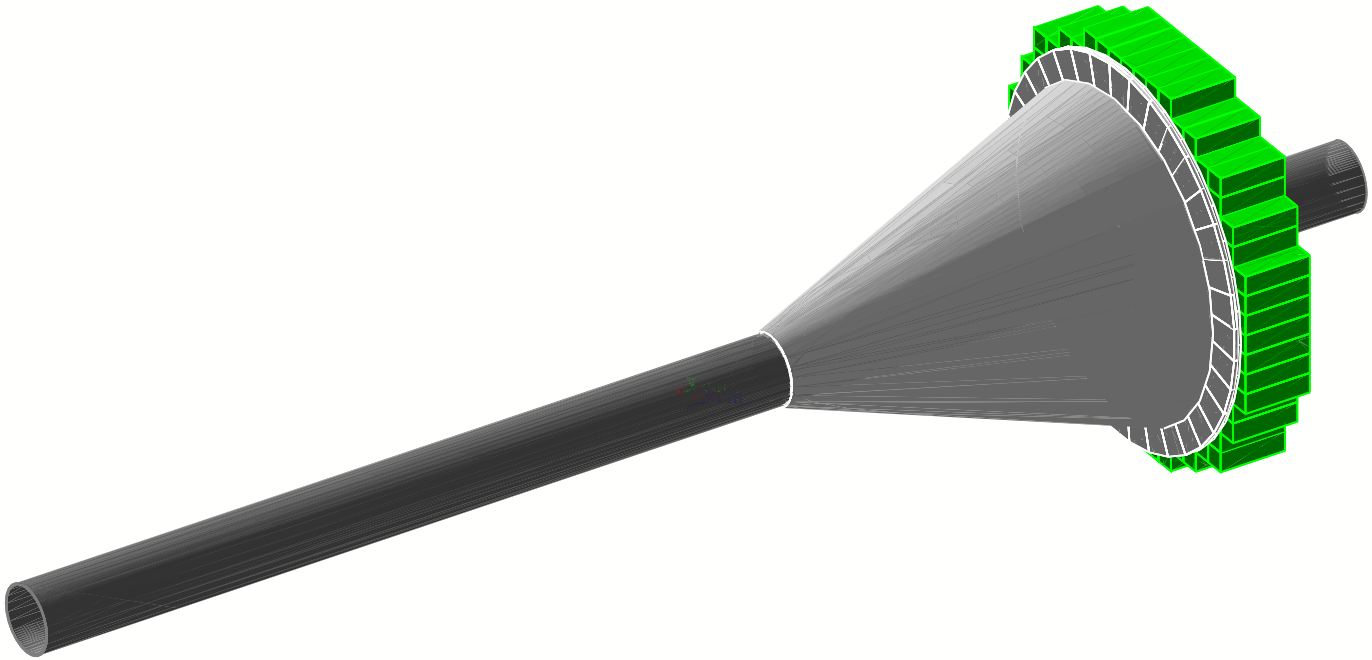
Candidate Material: LYSO/Plastic Scintillator





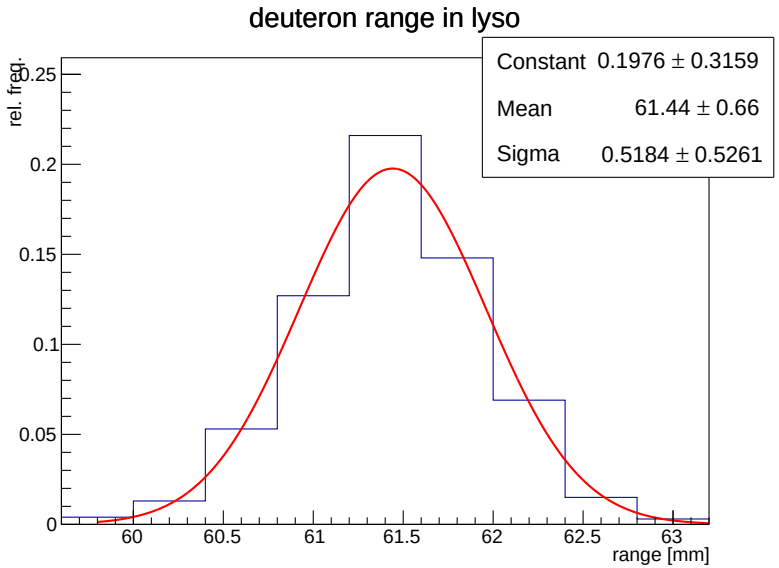
	LYSO	Plastic
Density [g/cm3]	7.3	1.05
Decay [ns]	40	2.4
L. Y. % NaI(Tl)	75	25
S. Peak [nm]	420	420
N ref.	1.82	1.58
Melt. [řC]	2050	75
Hygrosc.	No	No
Radioact	Yes	No

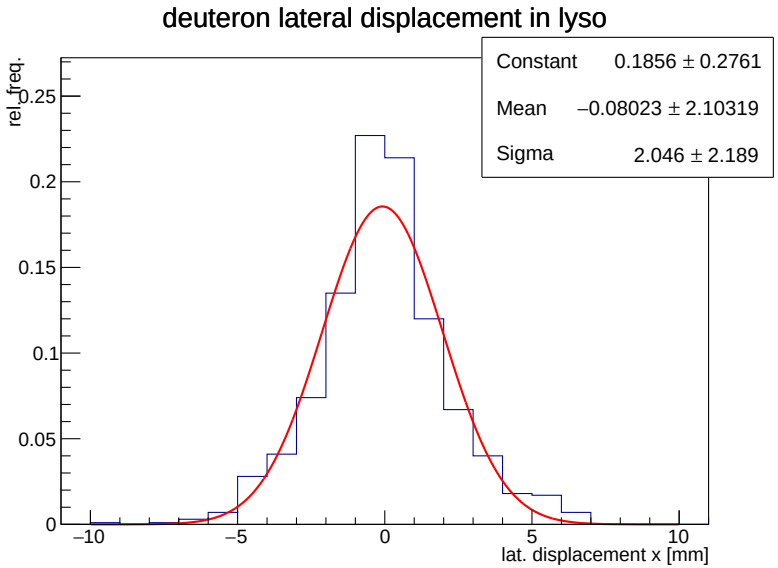
Simulation setup



- Generated 10k events of elastic and breakup each at $T_d = 270\,\text{MeV}$
- Detector acceptance: 5ř<Θ<20ř, 0ř<ϕ<360ř

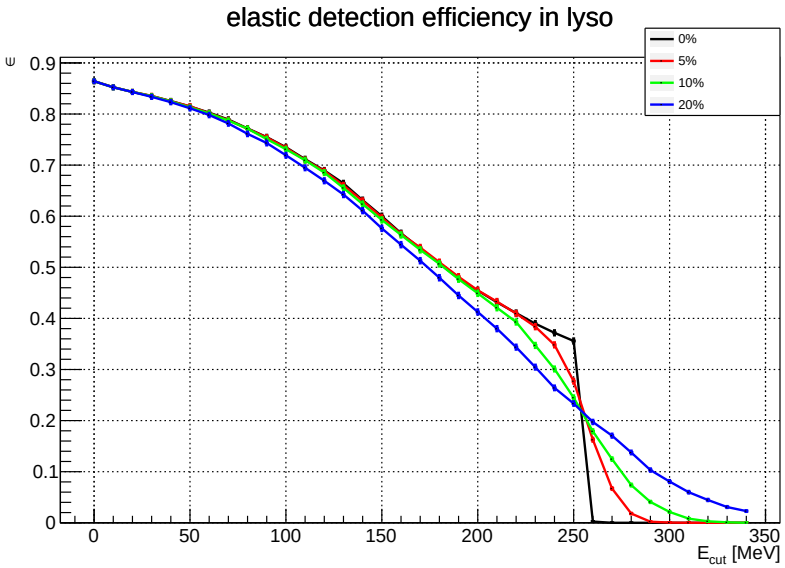
Lyso scintillators

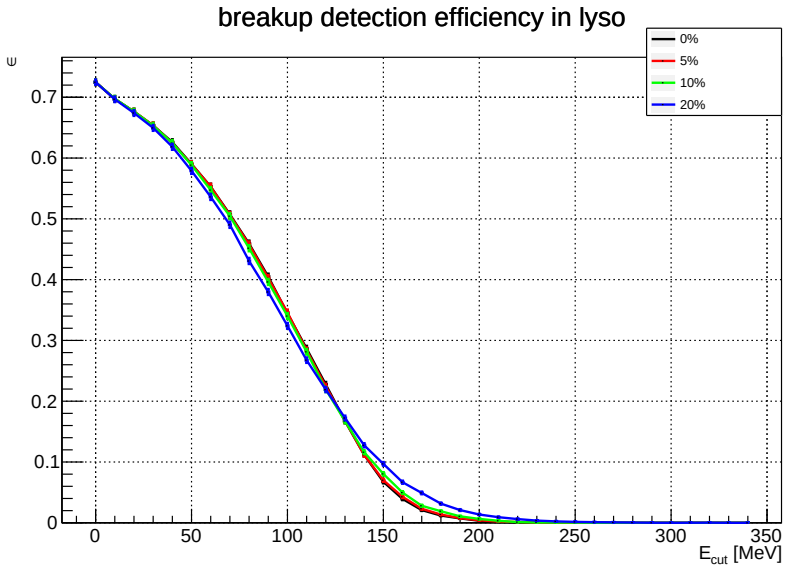




- Chosen detector size of $3 \times 3 \times 10\,\mathrm{cm}^3$as starting value

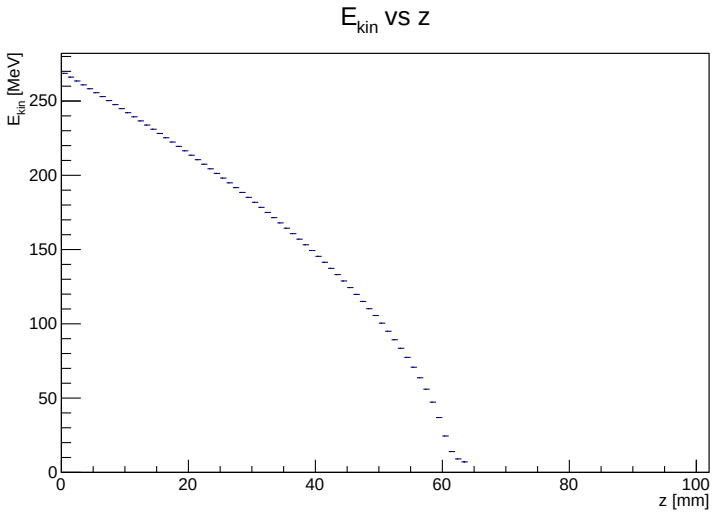
Detection efficiencies (lyso)

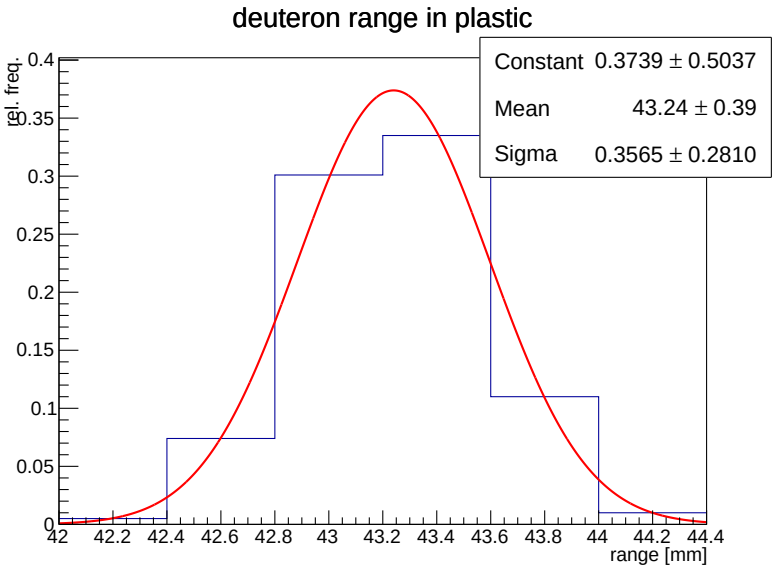




- Efficiency is lost because of breakup in detector
- No strong dependence on energy resolution

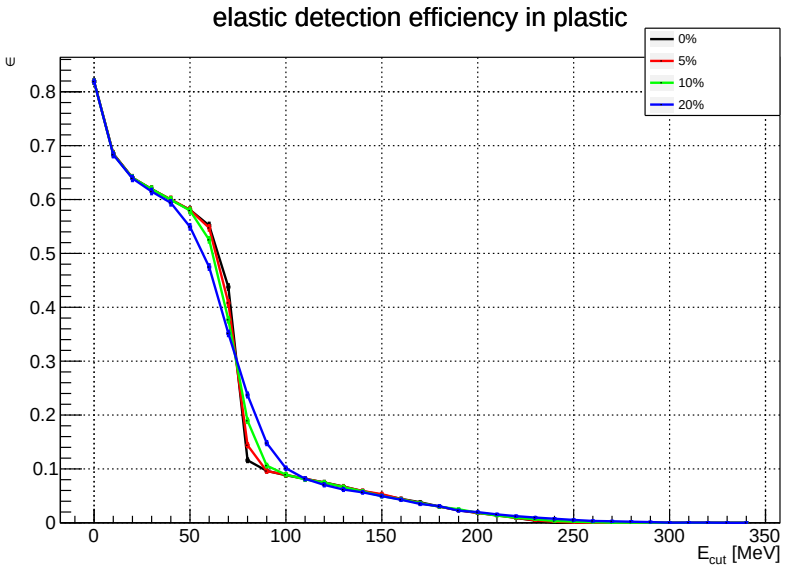
Plastic scintillators

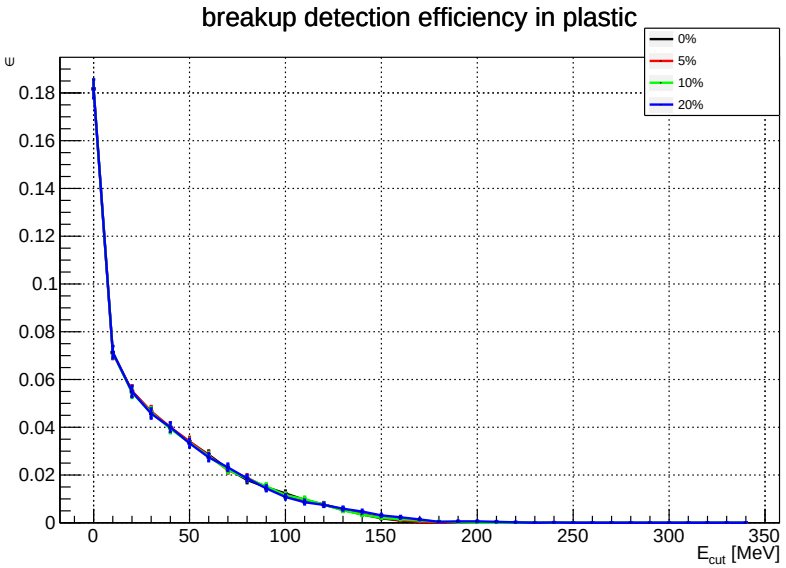




- Use degrader to suppress photon background and reduce length of plastic detector.
- $T_d = 270\,\mathrm{MeV}$
  - Absorber thickness $\approx 40\,\mathrm{mm}$
  - Scintillator thickness $\approx 50\,mm$

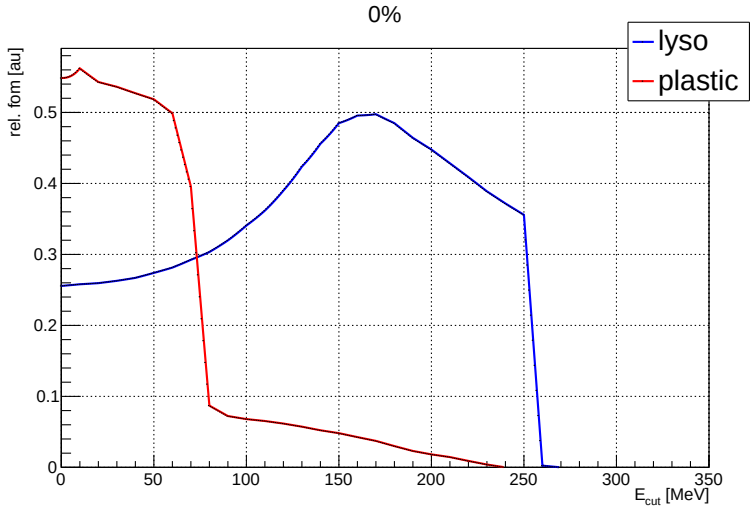
Detection efficiencies (plastic)

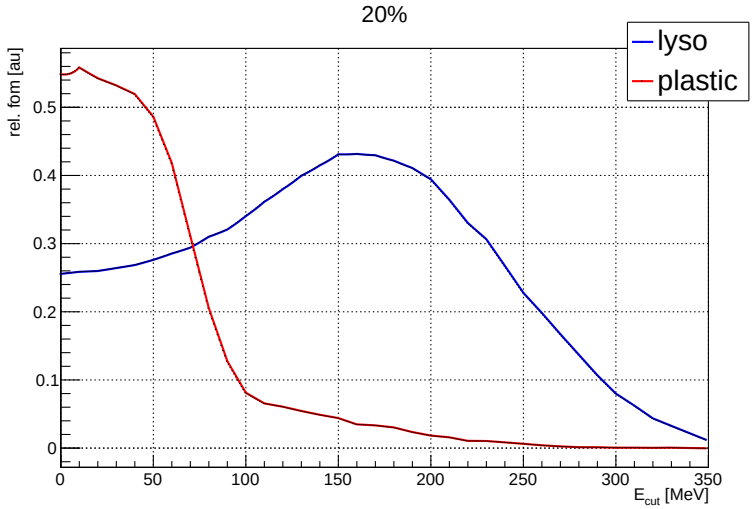




- Breakup background strongly suppressed

Results





- Assuming AP of breakup is zero, $\mathcal{FOM} \propto \epsilon_{el} \left(\frac{\epsilon_{el}}{\epsilon_{el}+\epsilon_p} \right)^2$
- LYSO and plastic scintillators provide comparable performance
- Again no strong dependence on energy resolution

Summary & Outlook

- We have a candidate layout for JEDI polarimeter
- Simulations suggest promising performance
- Hardware tests with LYSO crystals are in progress
- Will include $\Delta E - E$ particle identification technique
- Will look include inelastic scattering in simulation