

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

Introduction

Detector concept

Simulation studies

Summary & Outlook

Motivation

Where is the Antimatter in our Universe?

- One precondition for Baryogenesis: \mathcal{CP}
- Standard Model prediction: $\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 10^{-18}$
- WMAP and COBE (2012): $\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 10^{-10}$

⇒ Not enough \mathcal{CP} in Standard Modell

$$\begin{aligned}\mathcal{H} &= -d_{\vec{S}} \cdot \vec{E} \\ \mathcal{P}: \mathcal{H} &= +d_{\vec{S}} \cdot \vec{E} \\ \mathcal{T}: \mathcal{H} &= +d_{\vec{S}} \cdot \vec{E}\end{aligned} \quad \boxed{d = EDM}$$

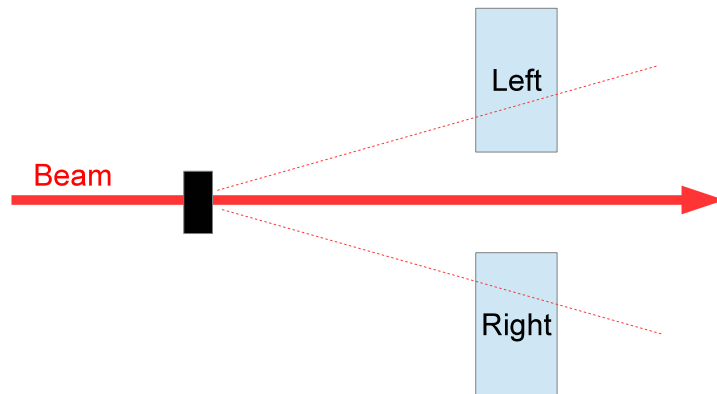
⇒ Electric Dipole Moments violate \mathcal{CP} (assuming \mathcal{CPT})

⇒ Probe into the physics of the early universe

Nuclear scattering polarimetry

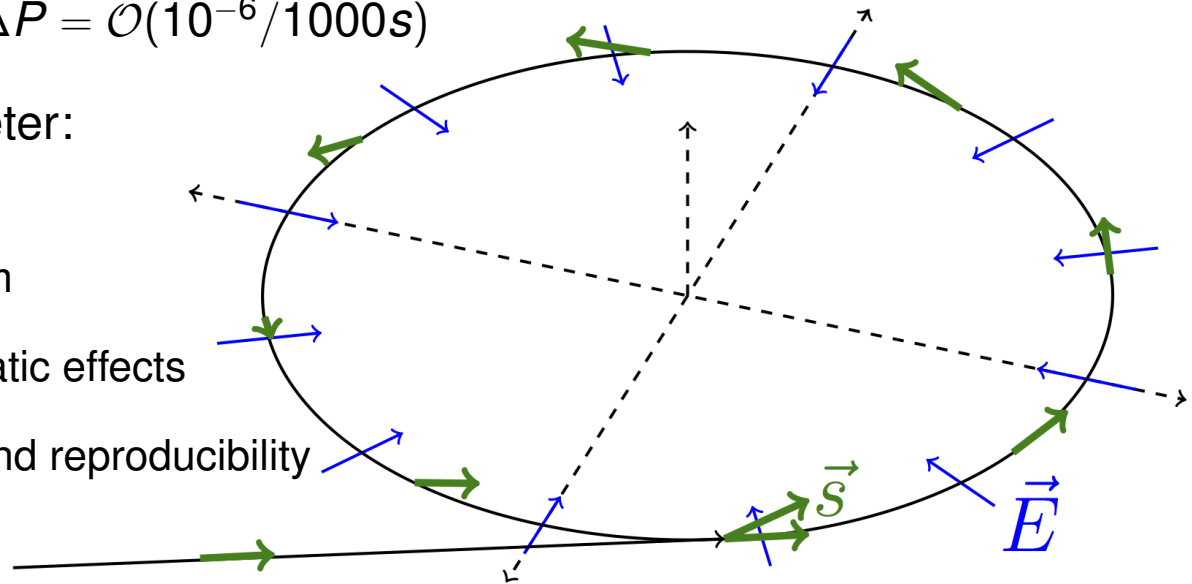
- Nuclear scattering cross section for scattering of polarized particles:

$$\sigma(\theta, \phi) = \sigma_0(\theta) \cdot (1 + P_y A_y(\theta) \cdot \cos(\phi))$$
- 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

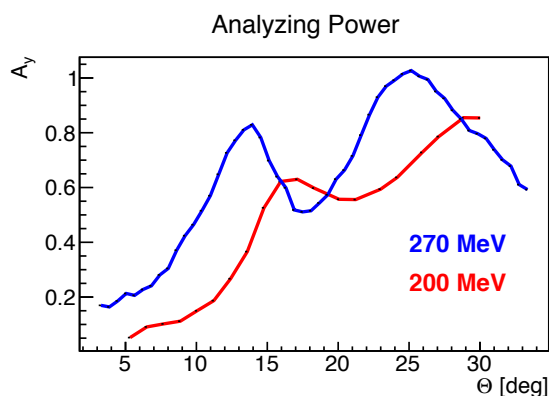
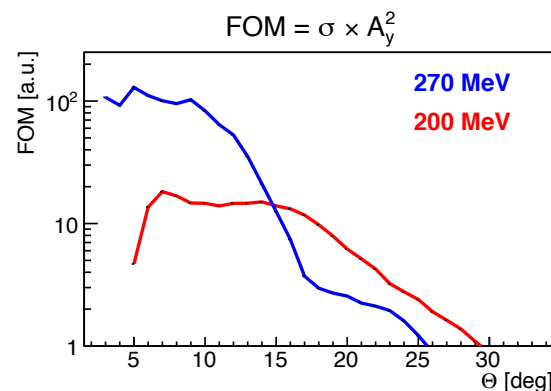
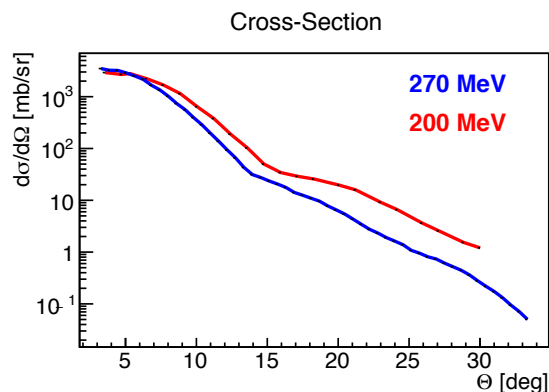


Design goals for an EDM polarimeter

- EDM search in storage rings: Let EDM interact with fields, wait for polarization change: $\frac{d\vec{S}}{dt} \propto d\vec{E} \times \vec{S}$
- 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



Target choice

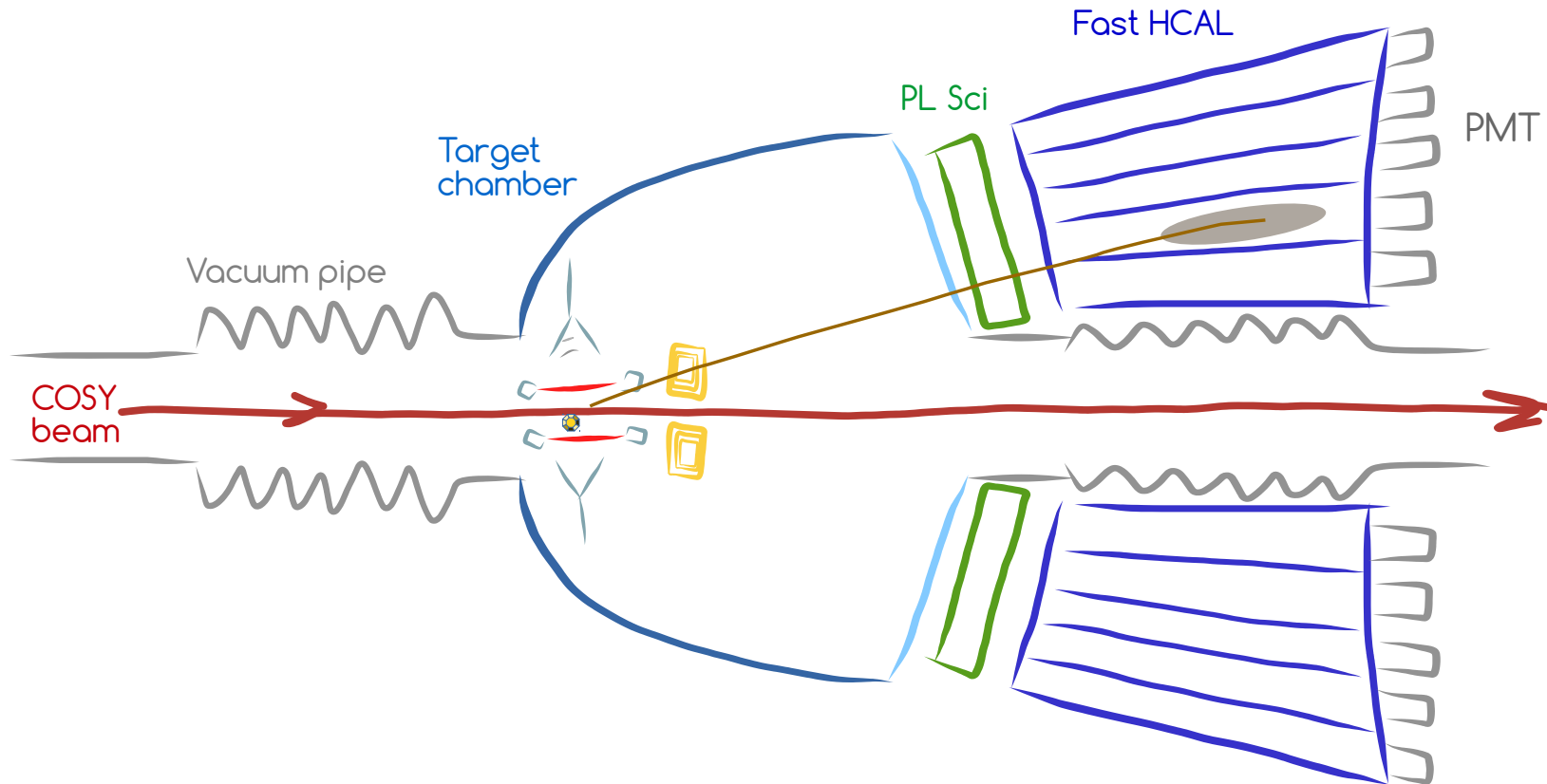


200 MeV: T. Kawabata et al. Phys. Rev. C 70, 034318

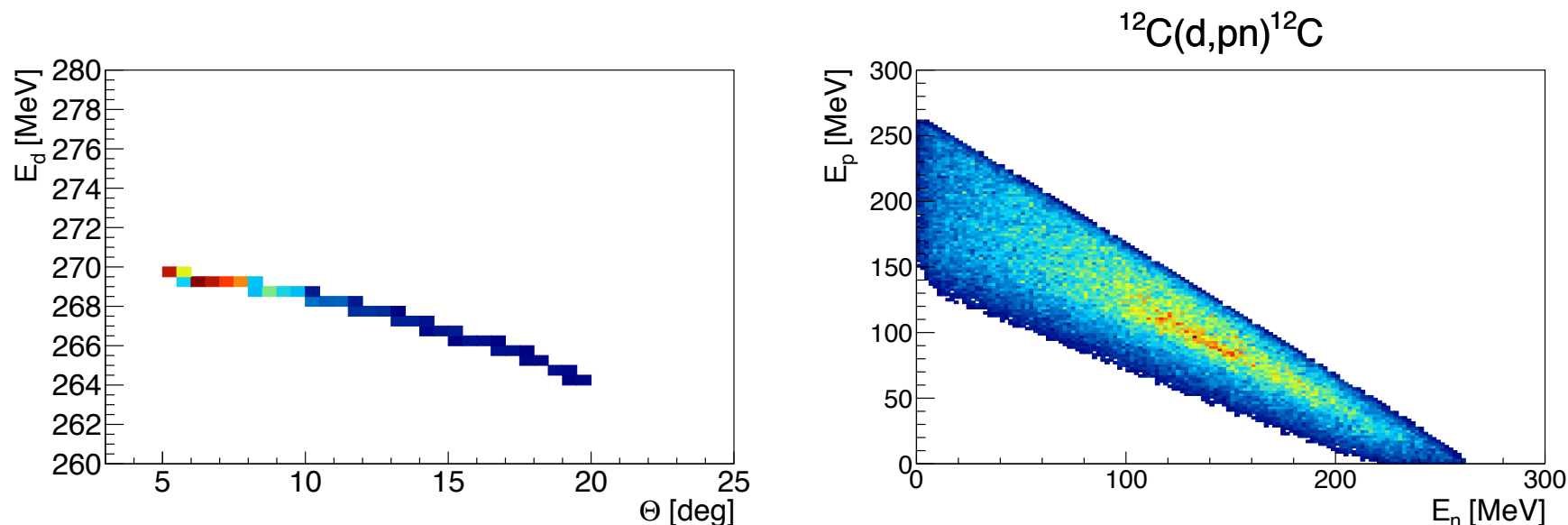
270 MeV: Y. Satou et al. Phys. Let. B 549, 307

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

Detector concept

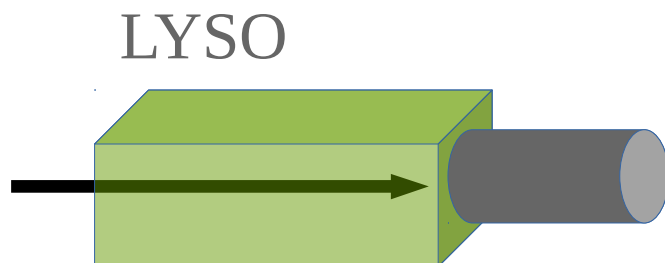


Signal generation



- 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
 \Rightarrow Complete stop of particles provides good signal separation
- Inelastic reactions carry some analysing power, so maybe keep these

Candidate Materials: LYSO/Plastic Scintillator



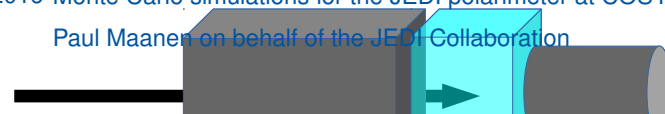
	LYSO	Plastic
Density [g/cm ³]	7.3	1.05
Decay [ns]	40	2.4
L. Y. % NaI(Tl)	75	25
S. Peak [nm]	420	420
N ref.	1.82	1.58
Melt. [°C]	2050	75
Hygrosc.	No	No
Radioact	Yes	No

Fe + Pl.

March 18, 2016 Monte Carlo simulations for the JEDI polarimeter at COSY

9/18

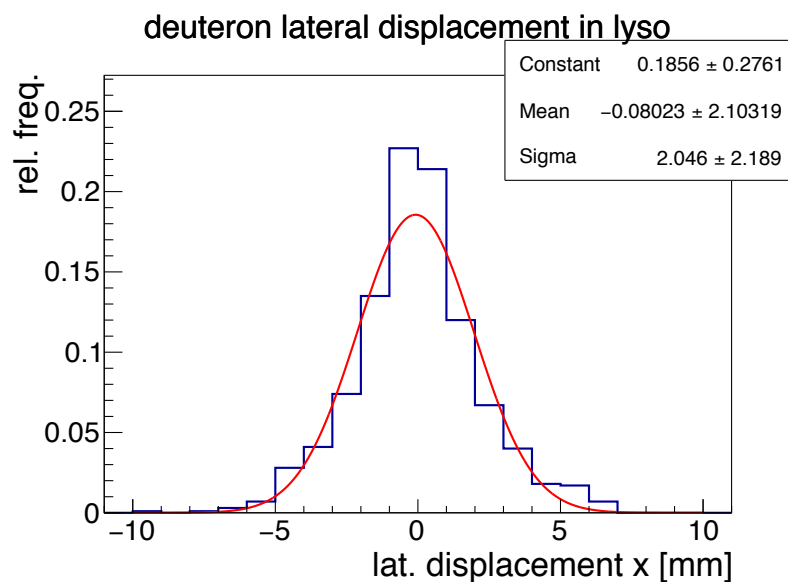
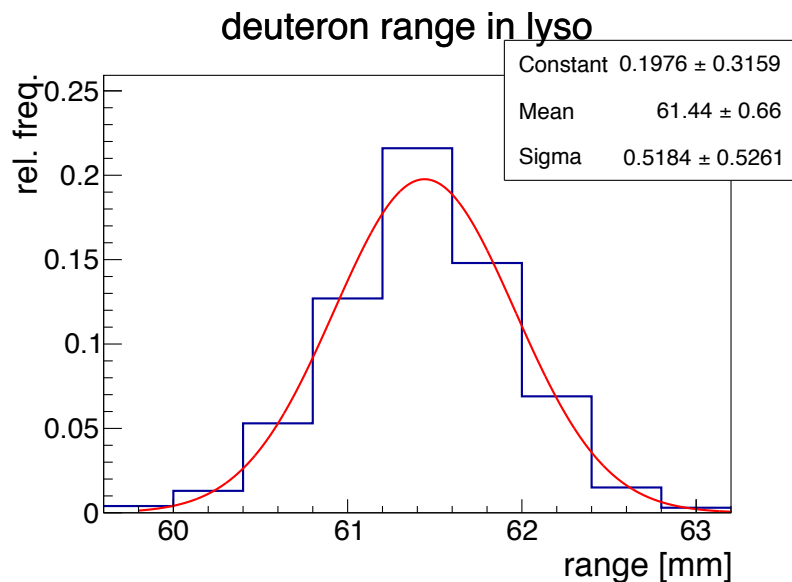
Paul Maanen on behalf of the JEDI Collaboration



Simulation setup

- Geometry: Single detector element
- Generated 100k events each at $T_d = 270 \text{ MeV}$, $5^\circ < \Theta < 20^\circ$, $0^\circ < \phi < 360^\circ$
 - Signal: $^{12}\text{C}(d, d)^{12}\text{C}$
 - Background: $^{12}\text{C}(d, pn)^{12}\text{C}$
- $\mathcal{FOM} \propto (\sigma_{el}\epsilon_{el} + \sigma_{bg}\epsilon_{bg}) \times \left(\frac{A_{y,el}\sigma_{el}\epsilon_{el} + \sigma_{bg}\epsilon_{bg}A_{y,bg}}{(\sigma_{el}\epsilon_{el} + \sigma_{bg}\epsilon_{bg})} \right)^2$

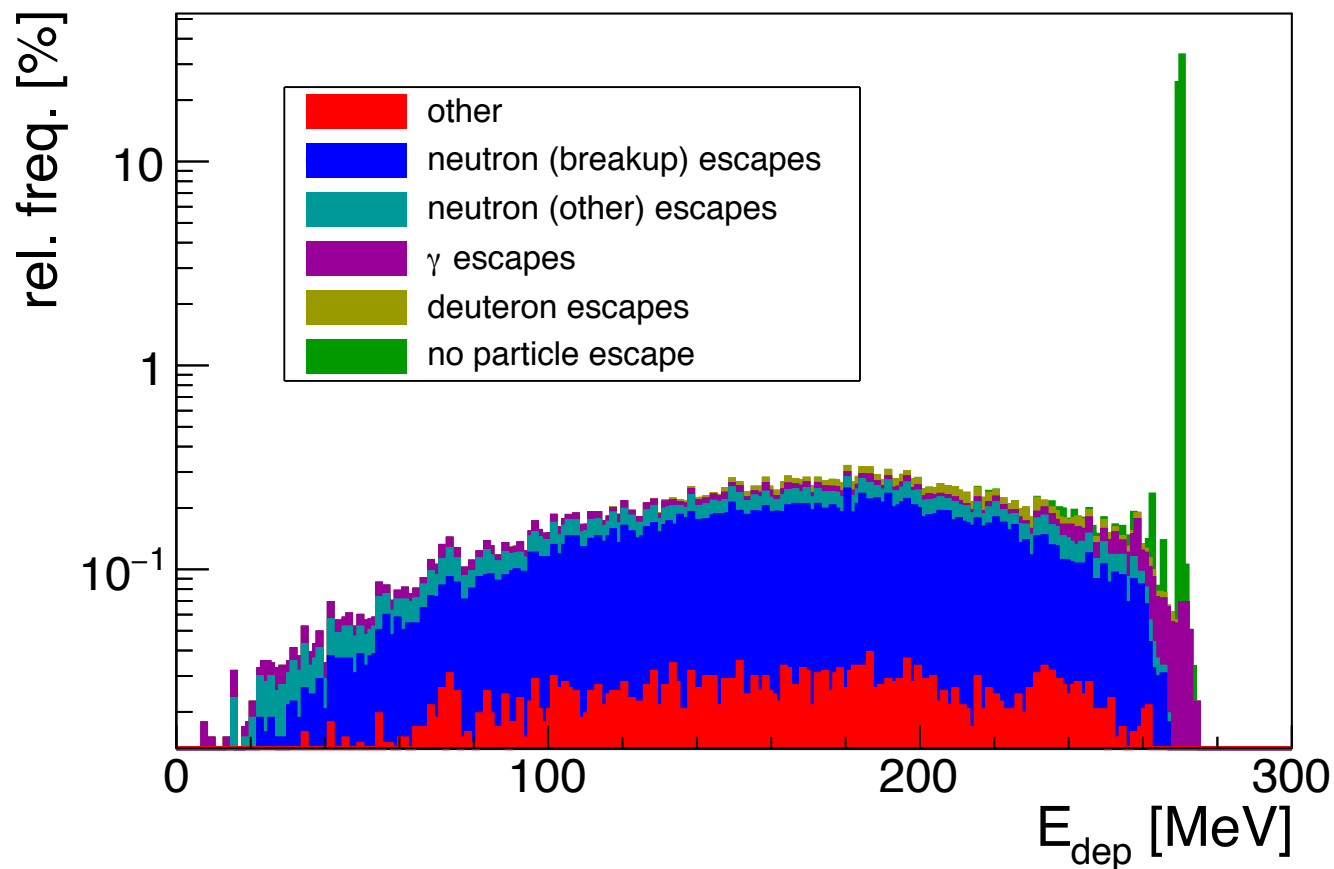
Lyso scintillators



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

Detector response - lyso

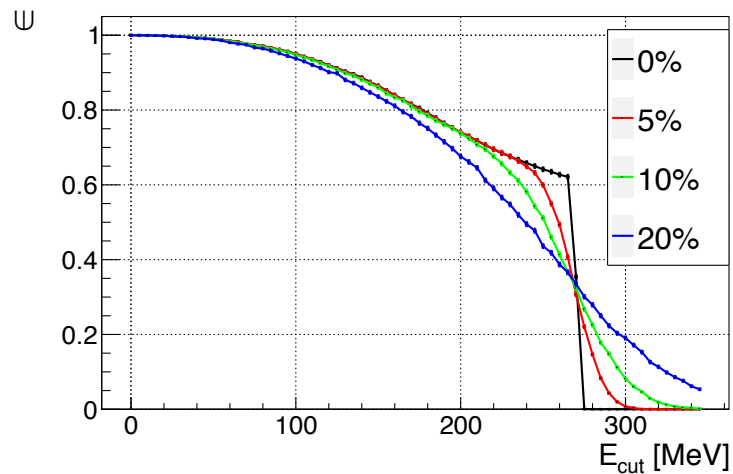
Edep in lyso - elastic events



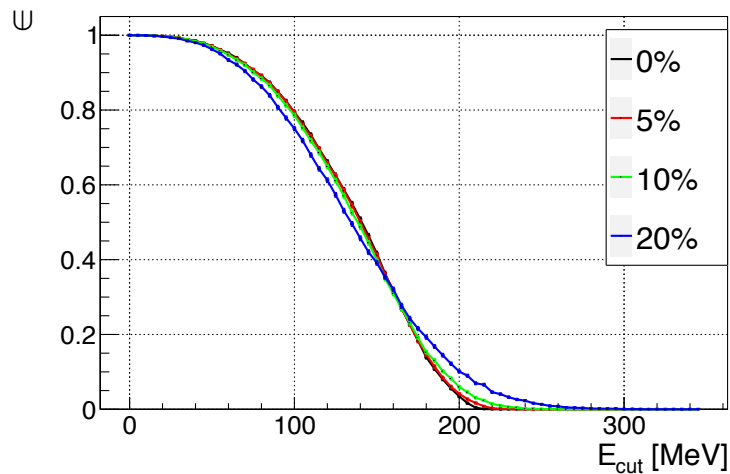
- Breakup is main cause of efficiency loss

Detection efficiencies (lyso)

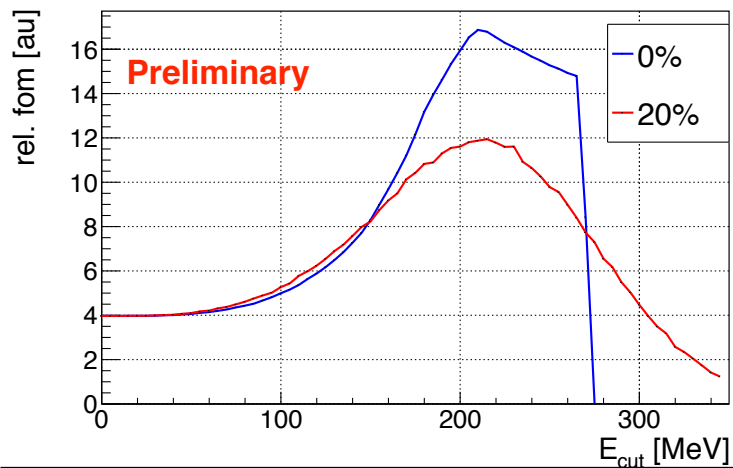
dcelastic detection efficiency in lyso



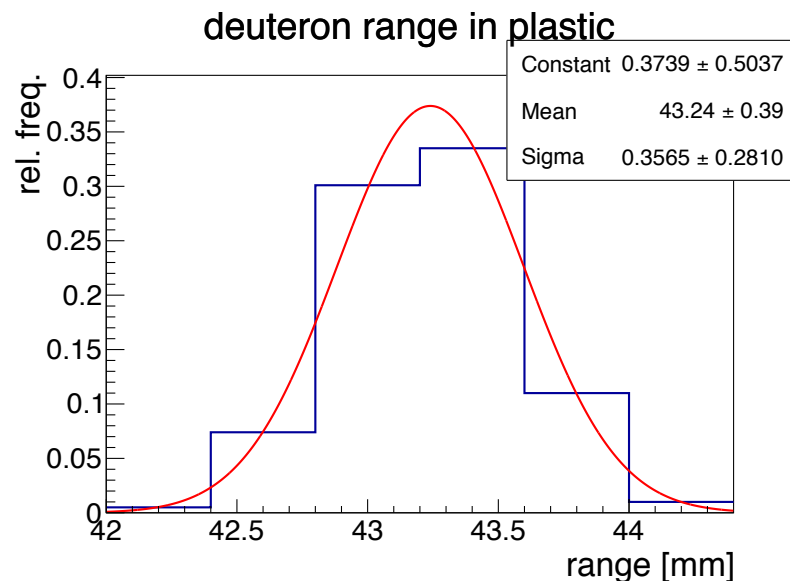
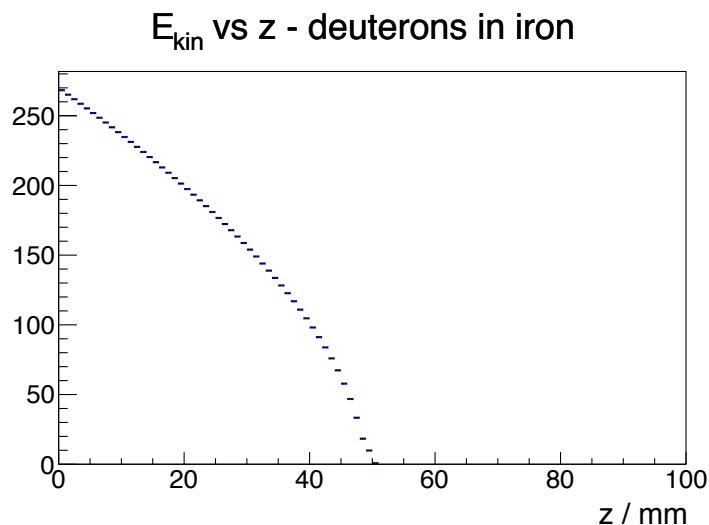
dc breakup detection efficiency in lyso



relative fom in lyso



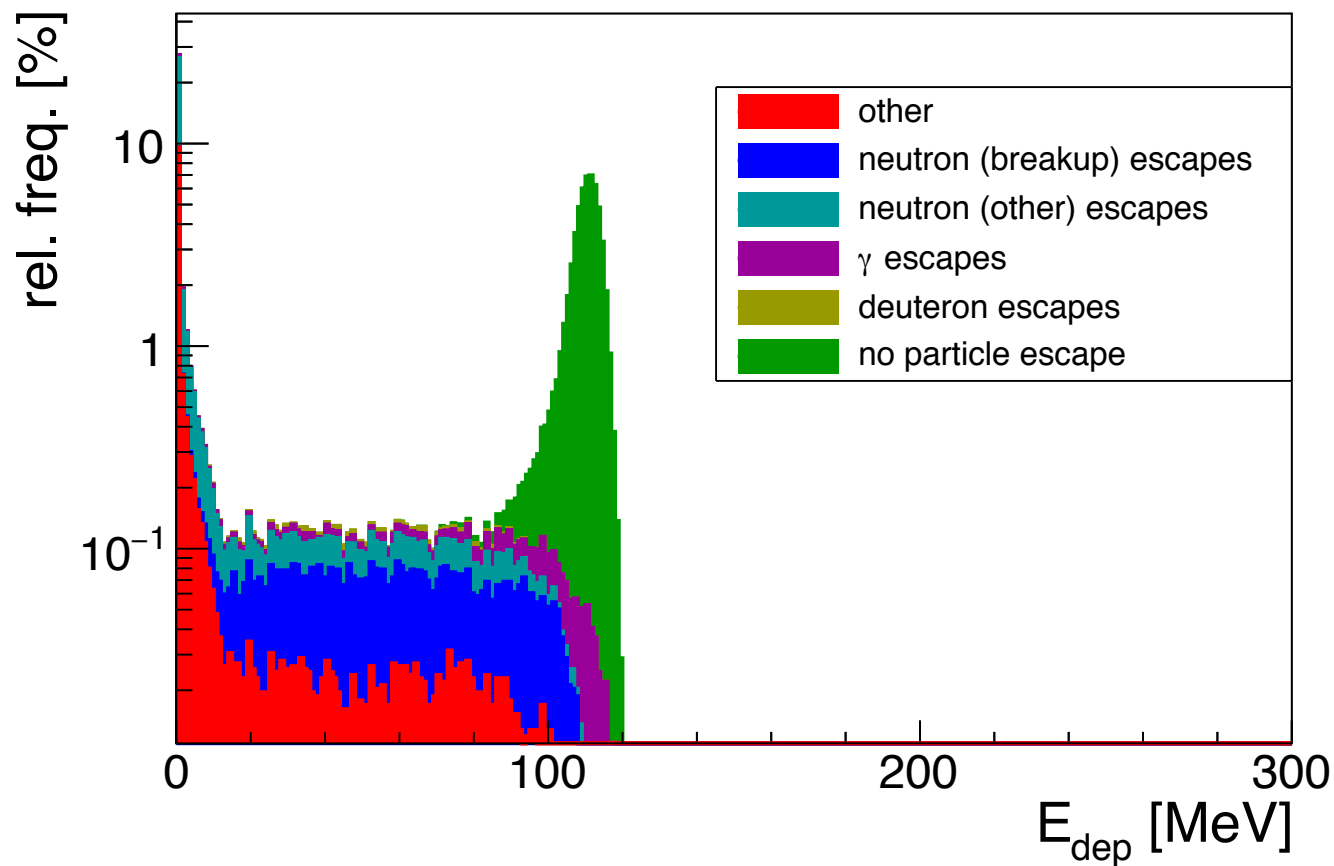
Plastic scintillators



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

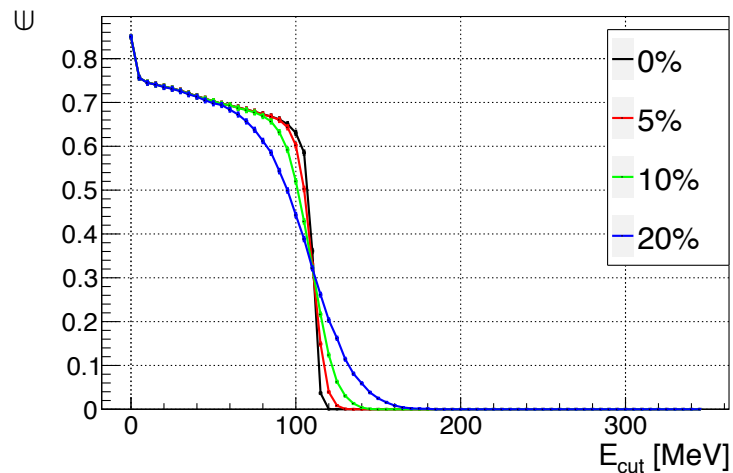
Detector response - plastic

E_{dep} in plastic- elastic events

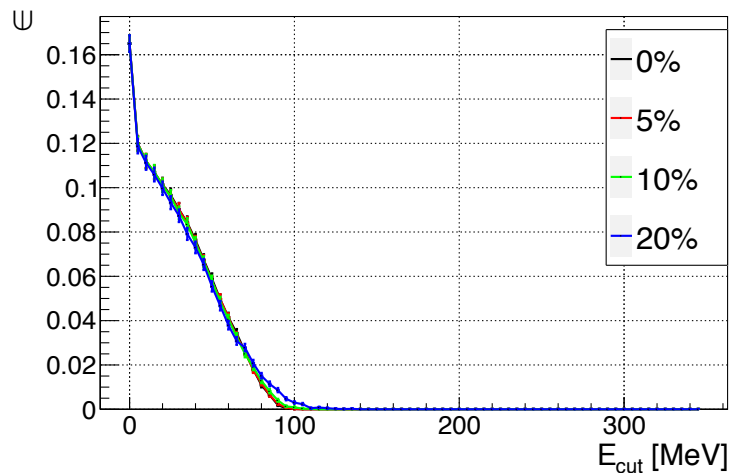


Detection efficiencies (plastic)

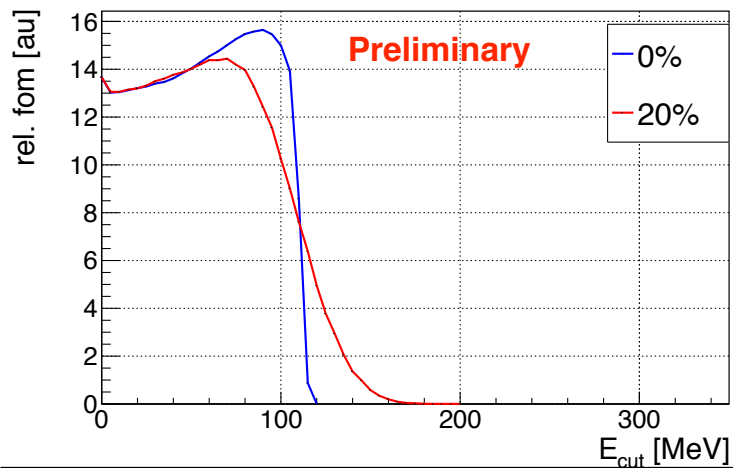
dcelastic detection efficiency in plastic



dc breakup detection efficiency in plastic



relative fom in plastic



Results

- Main cause of efficiency loss is breakup in detector
- Maximum relative FOM:

	0%	20%
Plastic	15.5	14.5
LYSO	17	12

- LYSO and plastic scintillators provide comparable performance
- 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 include inelastic scattering in simulation