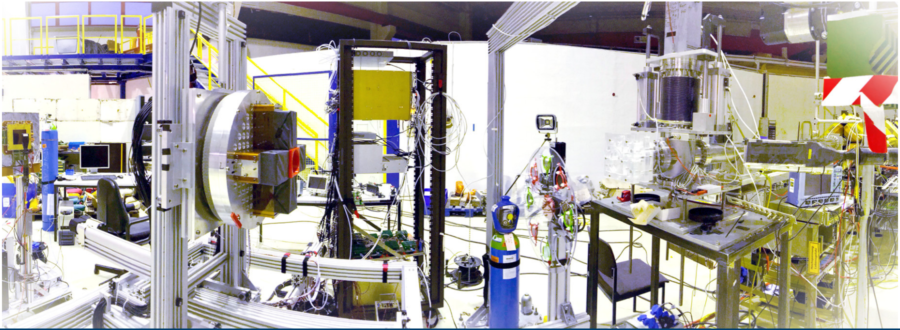


A NEW APPROACH: LYSO BASED POLARIMETRY FOR THE EDM MEASUREMENTS

I. Keshelashvili *on behalf of JEDI collaboration*

CALOR 2018 — *University of Oregon, Eugene*

Member of the Helmholtz Association

JÜLICH Forschungszentrum

OUTLINE

- Short introduction into ***EDM***

  challenges for srEDM case

- **COSY** Accelerator Facility

  Spin gymnastic & operating polarimeters

- New Polarimeter Concept

  dedicated polarimeter for srEDM experiment

- Experimental Results

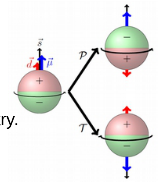
  4 beam time since CALOR 2016

- Summary

ELECTRIC DIPOLE MOMENT

of the elementary particles

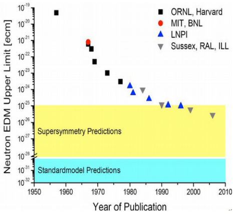
In the **SM**, the **CP** violation originates from the complex phase in the Cabibbo-Kobayashi-Maskawa (***CKM***) matrix, *which couples the quarks' weak and the mass eigenstates, and the θ term in the QCD Lagrangian.*



CP (K^o decays) violation means **T** is also violated assuming **CPT** symmetry. The existence of a non-zero EDM is a violation of P and T simultaneously & the search for a EDM is a search for **CP** violation and a search for **direct T** symmetry violation.

SM CP violation is enough to explain what has been observed in the *K & B* meson systems
but orders of magnitude smaller than observed in the universe

$$\eta = \frac{N_B - N_{\bar{B}}}{N_\gamma} = \sim 10^{-18}(SCM) \sim 6 \cdot 10^{-10}(BAU)$$



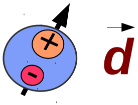
1967: Sacharov conditions for the Baryon Asymmetry of the Universe

1) At least one N_B violating process.
2) **C** and **CP** violation
3) Interactions outside of thermal equilibrium.

*Measurement of the non zero **EDM** → physics beyond **SM***

STORAGE RING – EDM

method differs strongly from *nEDM*



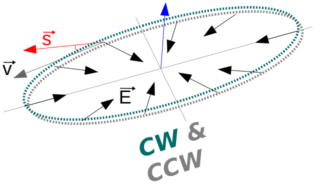
For all ***EDM*** experiments
Interaction of ***d*** with ***E***
is necessary!

$$\frac{d\vec{s}}{dt} \propto d \cdot \vec{E} \times \vec{s}$$

a) Store longitudinally polarized ***protons***

b) Interact with a radial E-field

c) *Analyze Polarization Build-up (this talk)*



build-up of vertical polarization $\quad \vec{s}_{\perp} \propto |d|$

COSY ACCELERATOR FACILITY

Internal and **external** beams

High **polarization** (*p, d*)

Spin manipulation !!!

Energy range (min.-- max.):

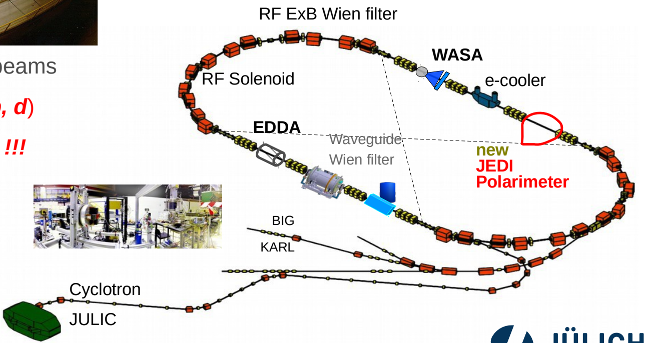
0.045 – 2.8 GeV (p)

0.023 – 2.3 GeV (d)

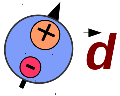
Max. momentum ~ **3.7 GeV/c**

Electron & ***Stochastic*** cooling

Feed-forward machine



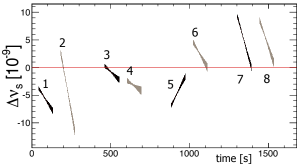
RECENT RESULTS OF JEDI

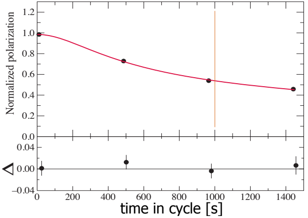


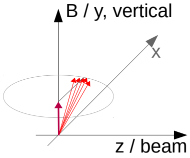
Phys. Rev. Lett. 119, 014801 (**2017**) Phase Locking

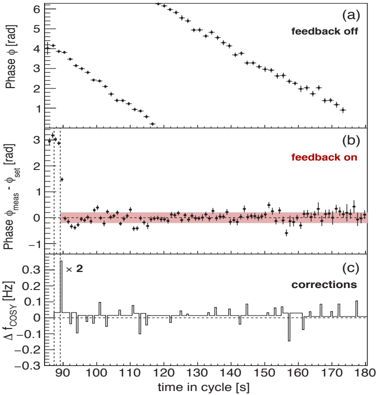
Phys. Rev. Lett. 117, 054801 (**2016**) 1000s in-plane

Phys. Rev. Lett. 115, 094801 (**2015**) New method







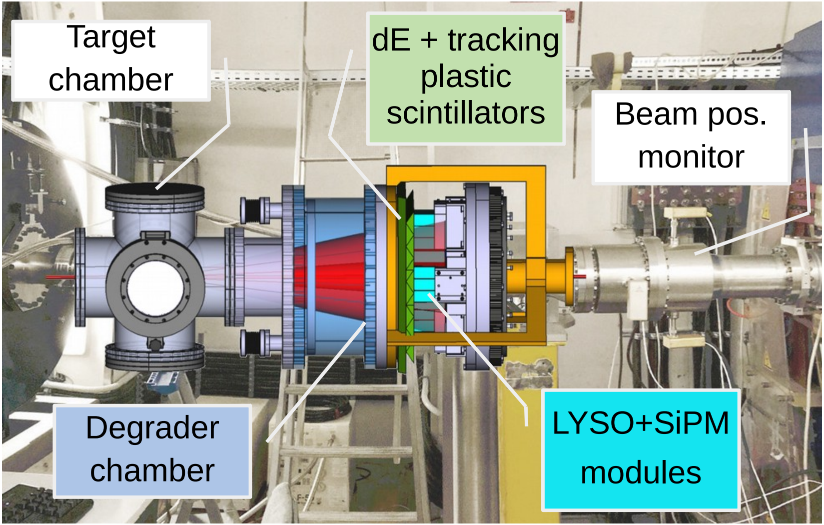


REQUIREMENTS

srEDM – *Precision Experiment !*

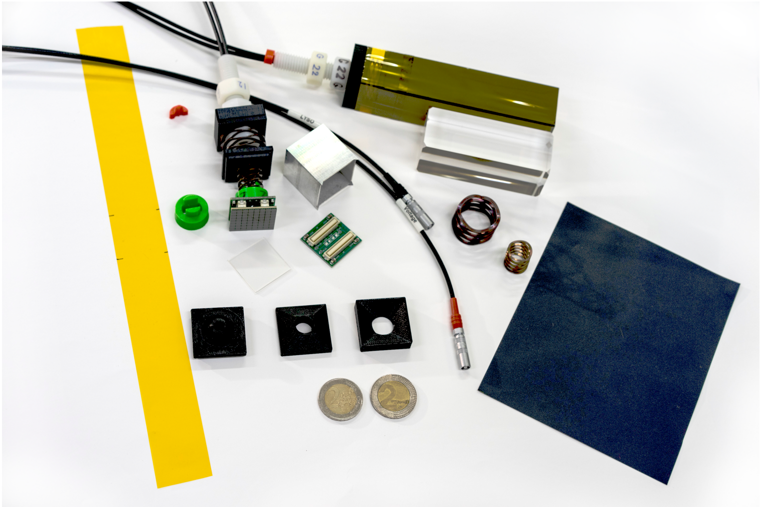
- Reaction with Large ***FOM*** (σA_y^2) & ($\sigma_{ela}/\sigma_{tot}$): Best *dC → dC*
- Maximum Detection & Data Taking Efficiency
- Full ϕ in Reasonable ***FOM***(θ) region
- No strong Magnetic / Electric Field
- Stability – Long / Short Term

INTERNAL POLARIMETER

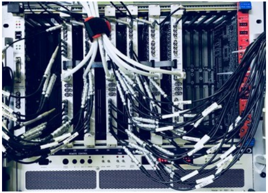


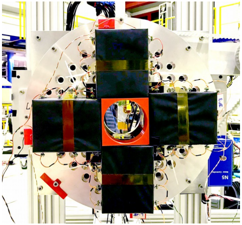
LYSO MODULE

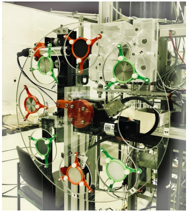
New improved mechanics and electronic components

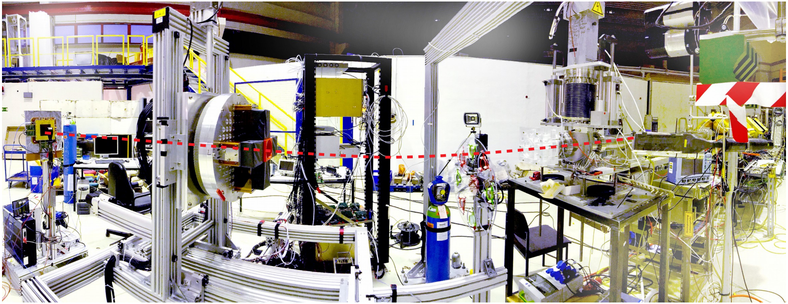


BIG KARL EXPERIMENTAL HALL

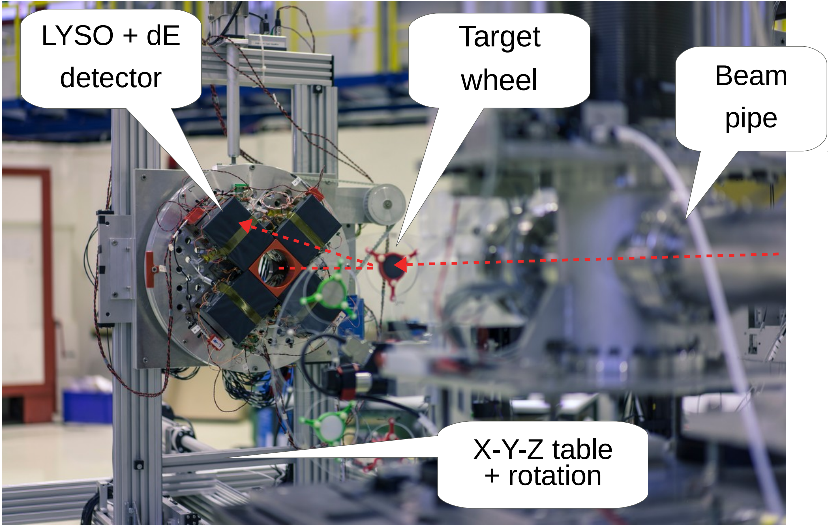




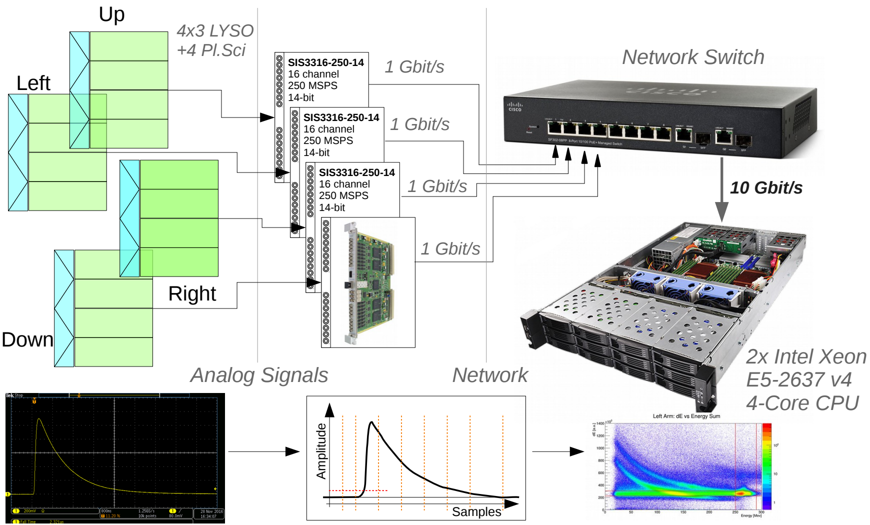




FORWARD VIEW

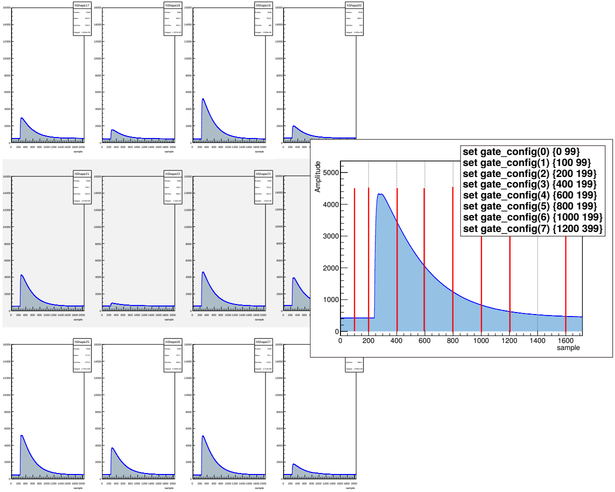


SADC BASED DAQ SYSTEM



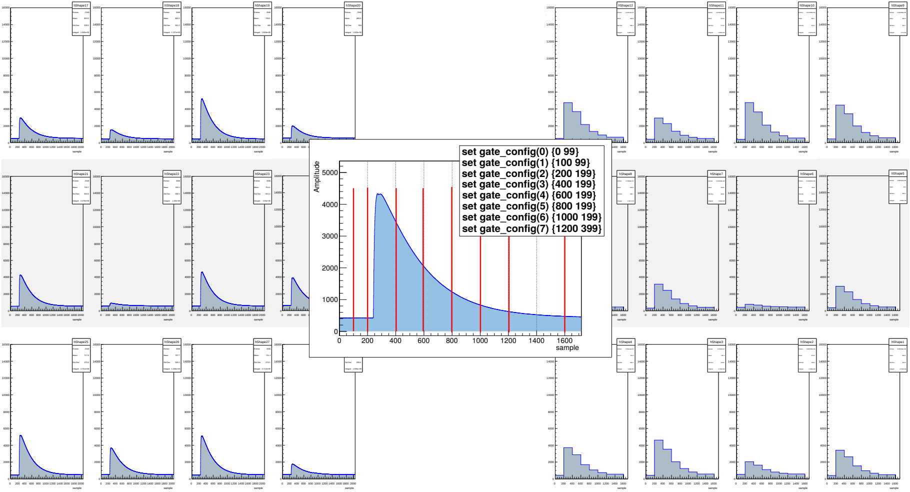
SIGNAL SHAPES

Full signal shape vs 8 accumulator/integral region



SIGNAL SHAPES

Full signal shape vs 8 accumulator/integral region



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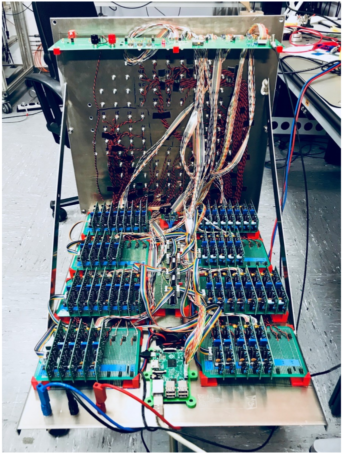
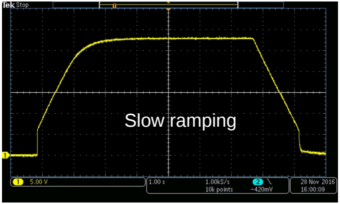
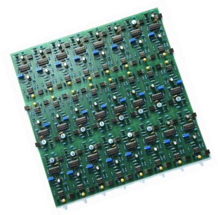
SIPM VOLTAGE SUPPLY

Stability: short $\sim 50\mu V_{pp}$ / long $\sim 5mV_{pp}$

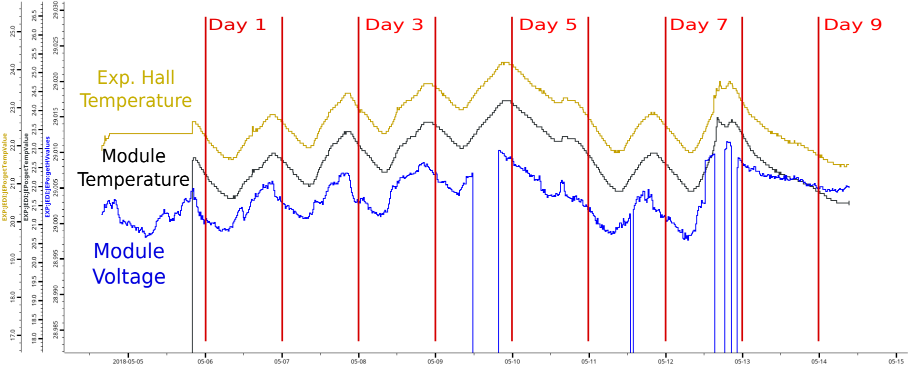






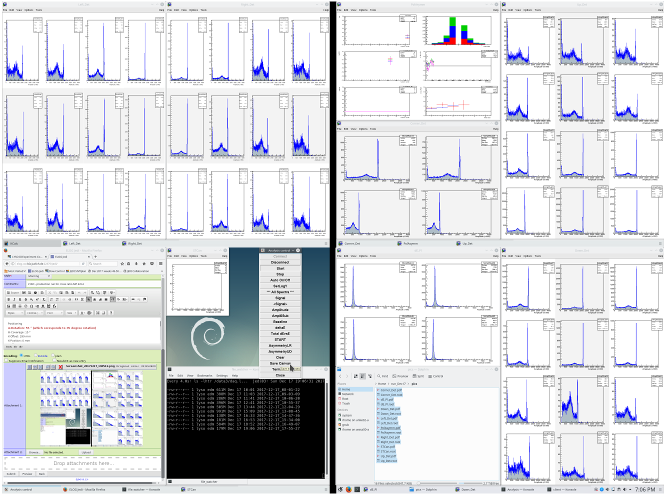
VOLTAGE MONITORING

Continuous monitoring of all channels



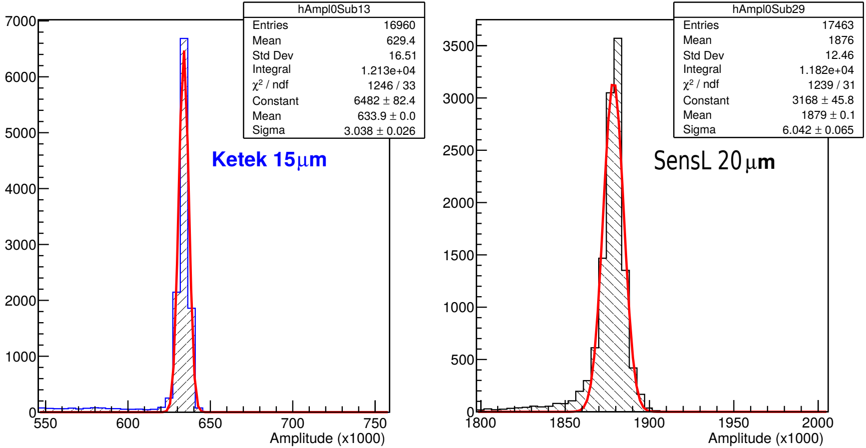
ONLINE MONITORING SYSTEM

Continuous monitoring of all amplitudes



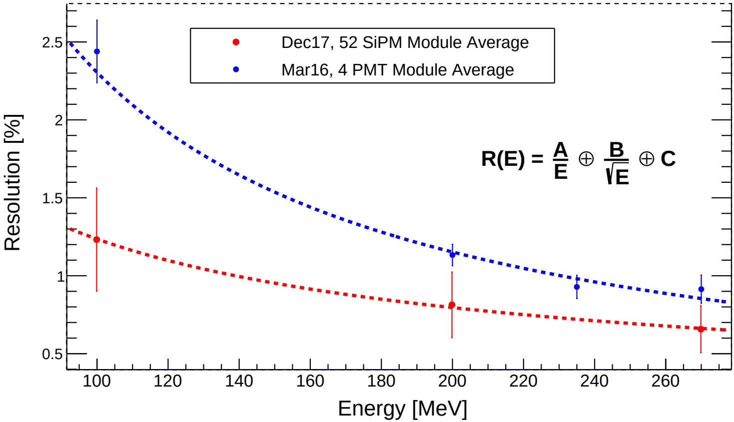
LYSO-SIPM PERFORMANCE

Direct 300 *MeV* deuteron beam



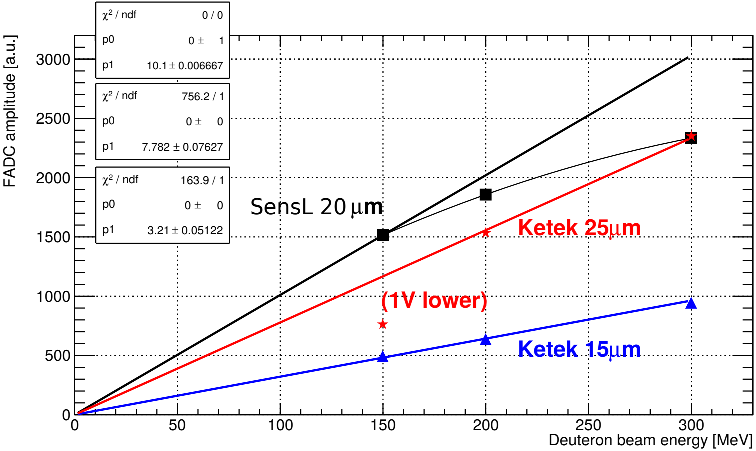
LYSO-SIPM RESOLUTION

defined as FWHM/Ampitude



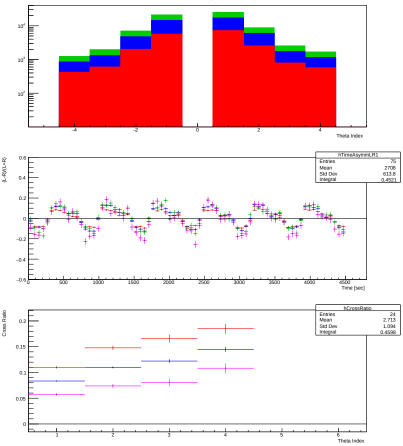
LYSO-SIPM LINEARITY

note: Fittings are in only lower ranges!



ASYMMETRY

Different target materials (left Nickel; right Tin)



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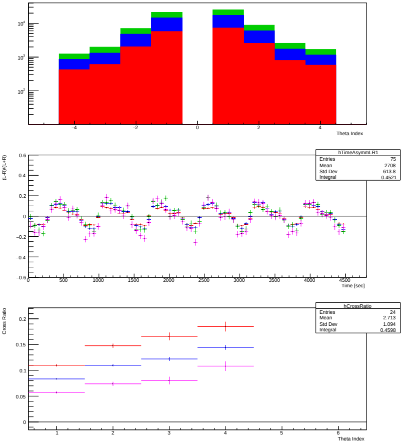
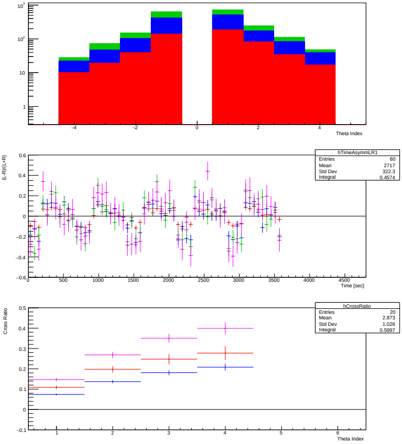
ASYMMETRY

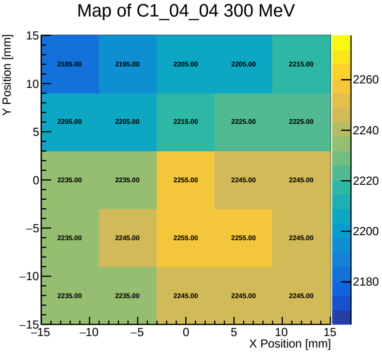
Different target materials (left Nickel; right Tin)

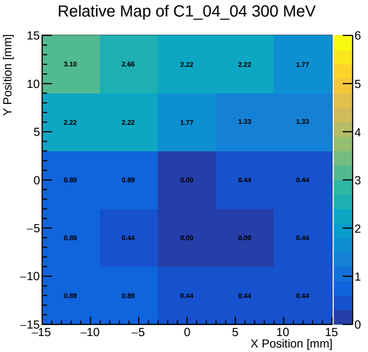




LYSO FRONTAL MAPPING

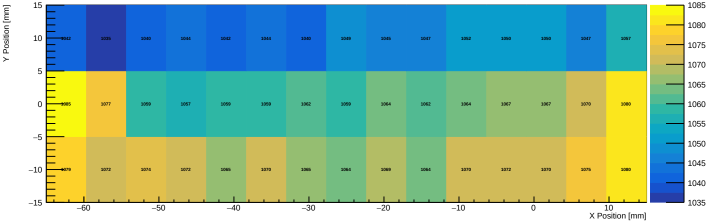
Direct 300 *MeV* deuteron beam

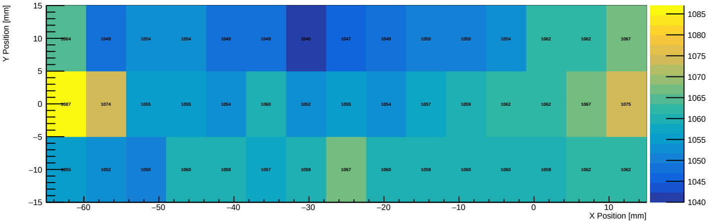




LYSO SIDE MAPPING

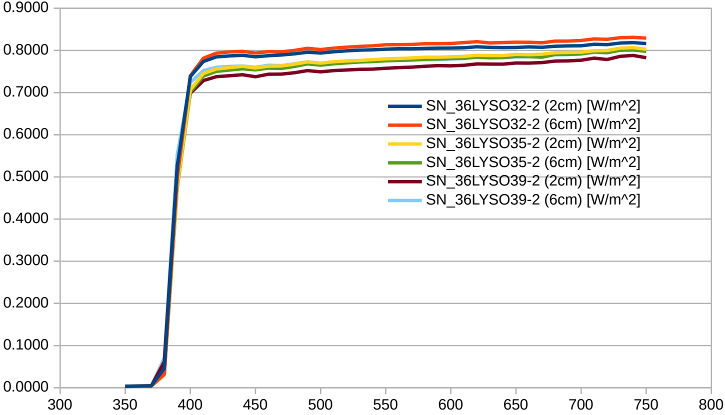
Direct 300 *MeV* deuteron beam





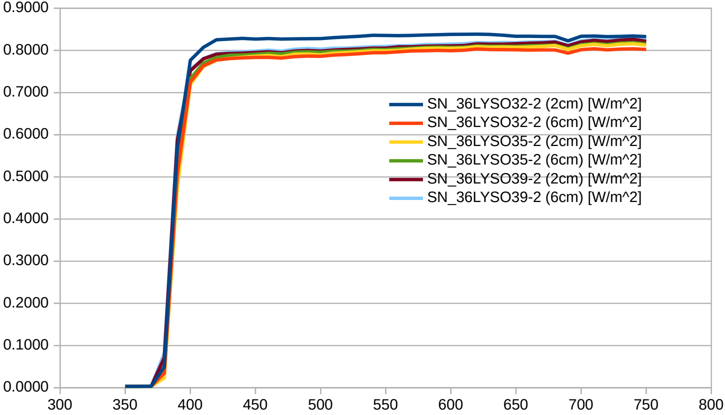
LYSO TRANSITION MEASUREMENT

Before beam time



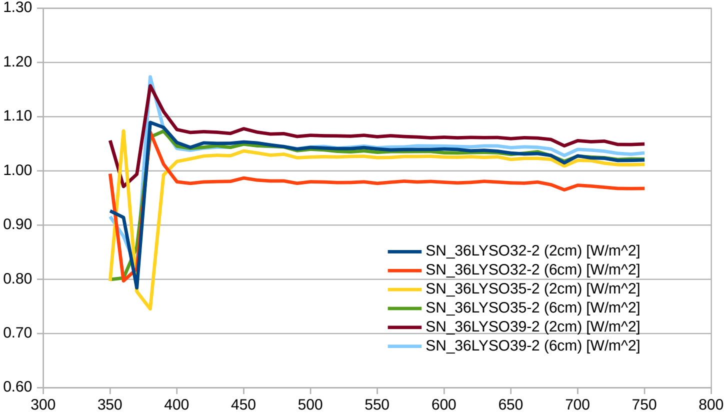
LYSO TRANSITION MEASUREMENT

After beam time



LYSO TRANSITION MEASUREMENT

Ratio



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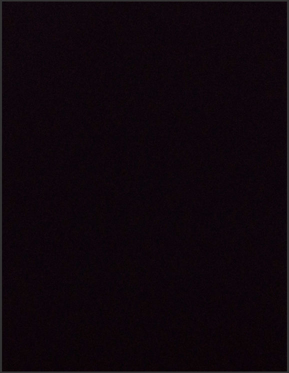
LYSO

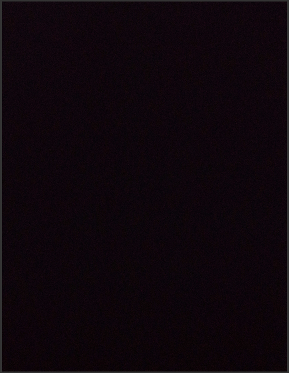
SONY A7R – white balance manually corrected with sunlight



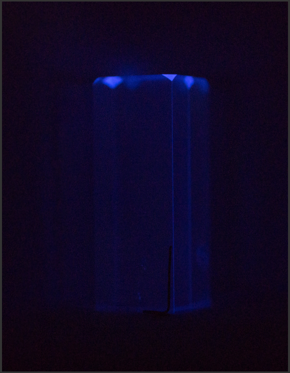
Dark box

LYSO

SONY A7R – white balance manually corrected with sunlight



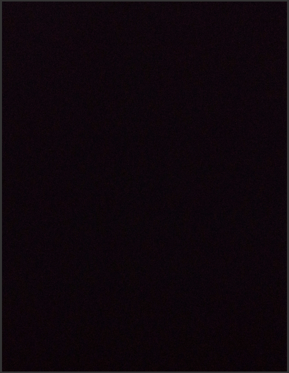
Dark box



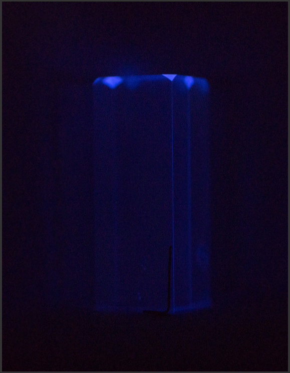
LYSO internal

LYSO

SONY A7R – white balance manually corrected with sunlight



Dark box

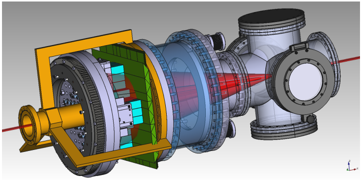


LYSO internal

LYSO internal + ^{22}Na

SUMMARY

- We have completed 5 beam time
  – during 3 years.
  – 3 different experimental setup...



- We are working on the next steps:
  Integrated *dE* to tracking detector
- FADC based DAQ system performs dead-time less and is very relable...
- We have assembled and tested new LYSO and SiPM vendors **in total 48+4 Modules**
- **Next major step is to install a tracking system made with the triangular scintillator bars**

Appendix

ACKNOWLEDGMENT

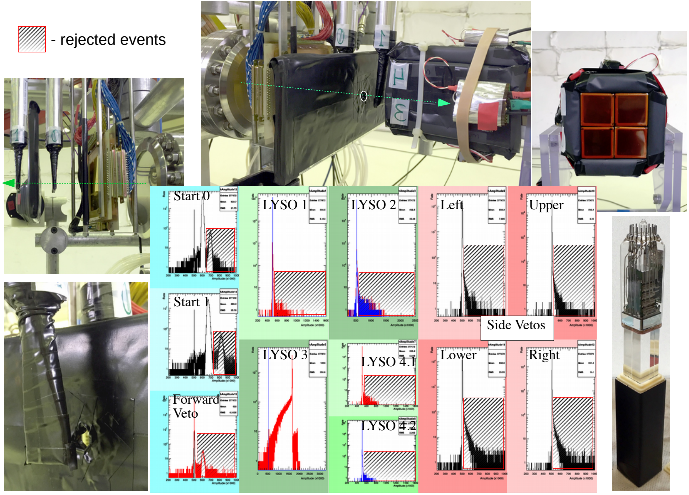
People contributing to the experiment

- Mechanics: N. De Mary, M. Maubach, G. D'Orsaneo & D. Spölgen
- Electronics: Tanja Hahnraths-von der Gracht & T. Sefzick
- DAQ & FEE: D. Mchedlishvili, & P. Wüstner
- G4: G. Macharashvili, P. Maanen & N. Lomidze
- **Ms & Bs: O. Javakhishvili, M. Gagoshidze, & D. Kordzaia**
- **PhD: F. Müller, D. Shergelashvili, H. Jeong & S. Basile**

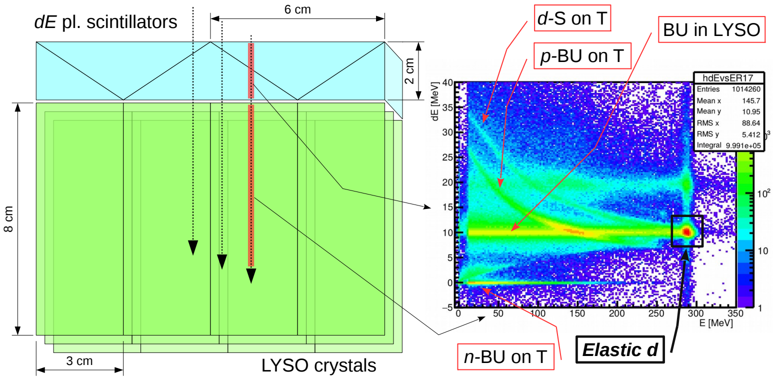
LYSO + PMT MODULE

Test of: Linearity, Efficiency, Resolution, Bragg

- rejected events



LYSO MODULES



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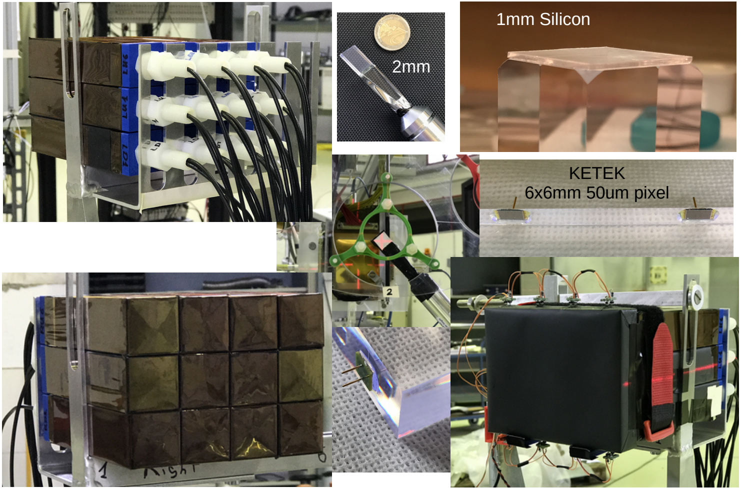
LYSO MODULES



GENERAL FORMALISM

$$PA_y(\theta) = \frac{\sigma^L(\theta)-\sigma^R(\theta)}{\sigma^L(\theta)+\sigma^R(\theta)} \approx \frac{N^L(\theta)-N^R(\theta)}{N^L(\theta)+N^R(\theta)} \text{ – between } -1 : 1$$

$$\sigma^{\textbf{pol}}(\theta,\phi) = \sigma_0(\theta)[1 + \tfrac{3}{2} PA_y(\theta)\cos\phi \quad +\{\tfrac{1}{3}\sum P_{ii}A_{ii}\} \ ]$$

$$CR(\theta) = \frac{\sqrt{N^{L\uparrow}N^{R\downarrow}}-\sqrt{N^{R\uparrow}N^{L\downarrow}}}{\sqrt{N^{L\uparrow}N^{R\downarrow}}+\sqrt{N^{R\uparrow}N^{L\downarrow}}} \approx PA_y \text{ – known } A_y \text{ : calculate } P$$

$$FOM(\theta) = \sigma A_y^2 \text{ – max. } FOM \text{ : monitor } \frac{d\vec{s}}{dt}$$