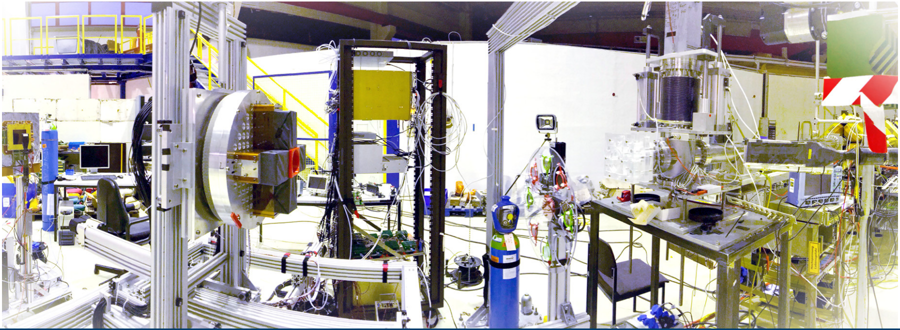


A NEW APPROACH: LYSO BASED POLARIMETRY FOR THE EDM MEASUREMENTS

Speaker: I. Keshelashvili

GGSWBS'18 — Tbilisi State University

- ***Introduction***
  challenges for srEDM case

- **COSY** Accelerator Facility
  Spin gymnastic & operating polarimeters

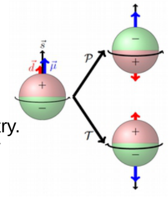
- New Polarimeter Concept
  dedicated polarimeter for srEDM experiment

- 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.

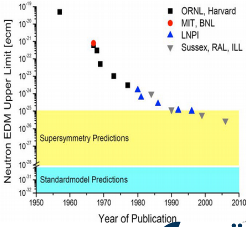
SM CP violation is enough to explain what has been observed in the *K & B* meson systems
but orders of magnitude smaller than observed in the universe

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

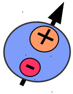
1967: Sacharov conditions for the Baryon Asymmetry of the Universe

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***



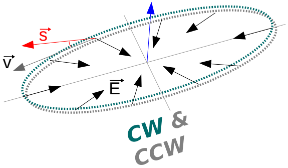
method differs strongly from nEDM



$\vec{d}$

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 $\vec{s}_{\perp} \propto |d|$

POLARIMETER & WIEN FILTER SETUP @ COSY

Energy range (min.-- max.):

0.045 – 2.8 GeV (p)

0.023 – 2.3 GeV (d)

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

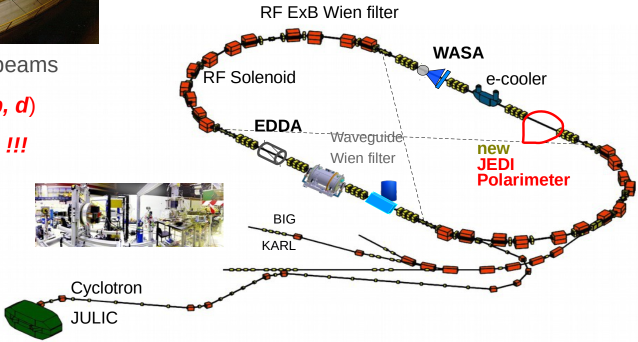
Electron & ***Stochastic*** cooling

Feed-forward machine

Internal and **external** beams

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

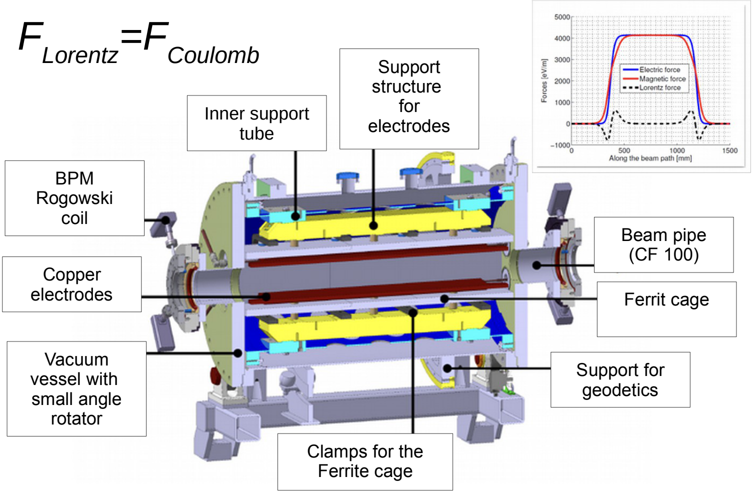
Spin manipulation !!!



RF-WIEN-FILTER

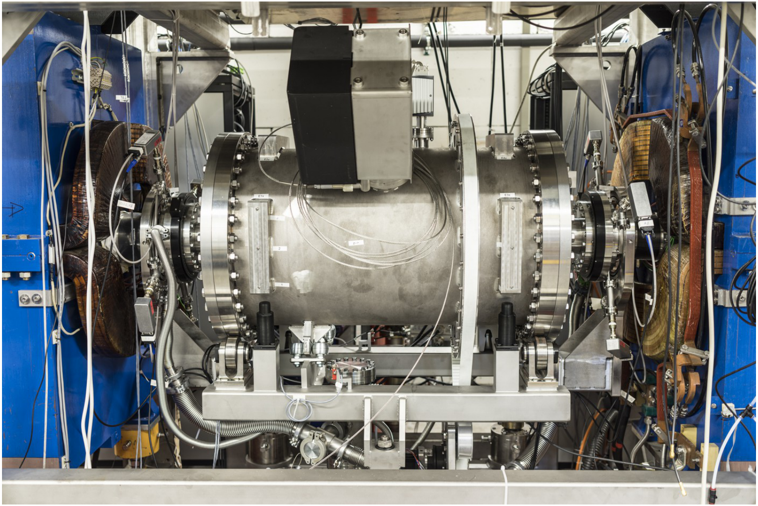
second generation at COSY

$$F_{Lorentz} = F_{Coulomb}$$



RF-WIEN-FILTER

commissioning beam time done



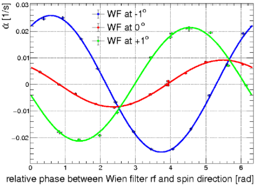
WF at nominal angle 0°

FIRST MEASUREMENT OF EDM-LIKE BUILDUP SIGNALS

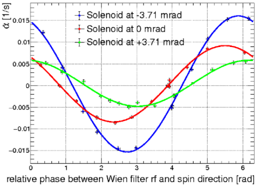
EDM induced vertical polarization oscillations

Rate of out-of-plane rotation angle $\dot{\alpha}(t)|_{t=0}$ as function of Wien filter RF phase ϕ_{RF}

- B field of RF Wien filter normal to the ring plane.
- Wien filter operated at $f_{\mathrm{WF}} = 871\,\mathrm{kHz}$.
- Variations of $\phi_{\mathrm{rot}}^{\mathrm{WF}}$ and $\chi_{\mathrm{rot}}^{\mathrm{Sol\,1}}$ affect the pattern of observed initial slopes $\dot{\alpha}$.



$\dot{\alpha}$ for $\phi_{\mathrm{rot}}^{\mathrm{WF}} = -1^\circ, 0^\circ, +1^\circ$ and $\chi_{\mathrm{rot}}^{\mathrm{Sol\,1}} = 0$.

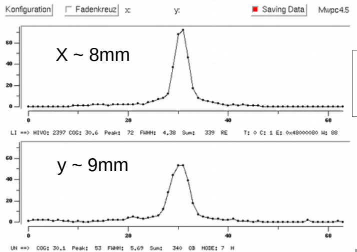


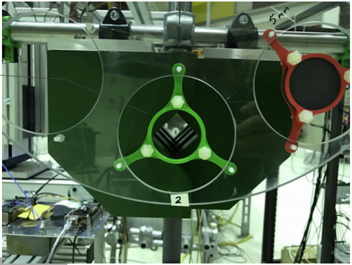
$\dot{\alpha}$ for $\chi_{\mathrm{rot}}^{\mathrm{Sol\,1}} = -1, 0, +1^\circ$ and $\phi_{\mathrm{rot}}^{\mathrm{WF}} = 0$.

Planned measurements:

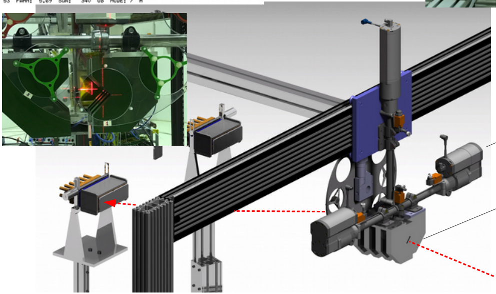
- 1st EDM measurement run Nov-Dec/2018 (6 wk).
- 2nd run planned for Fall/Winter 2019 (6 wk).

COSY BEAM MWPC PROFILE





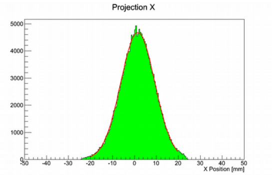
Empty target holder

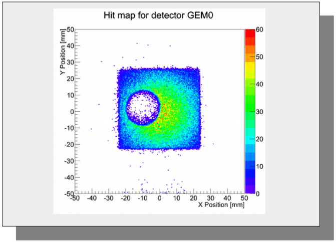


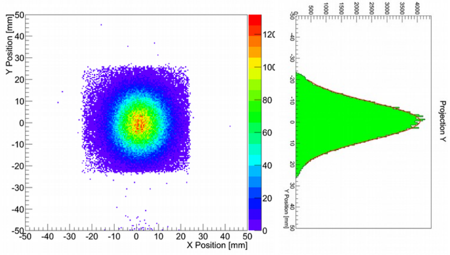
2D movement
Spot diameter

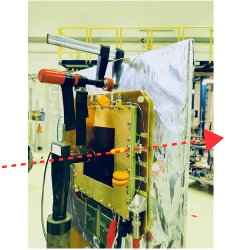
4x2.5cm Iron collimator blades

COSY 2D PROFILE

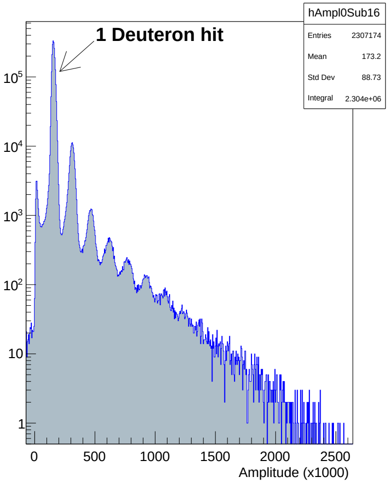


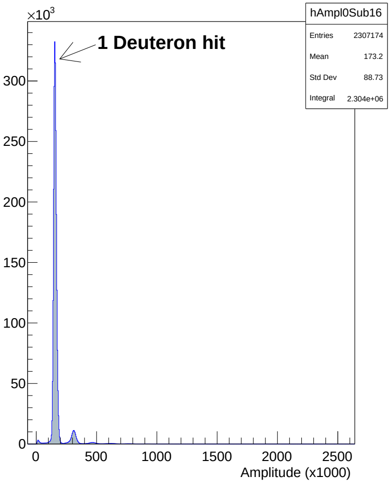




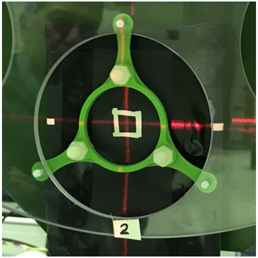


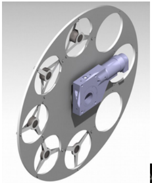
Clearly seen deuteron pile-ups

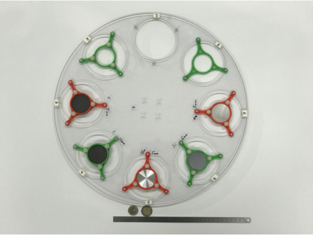


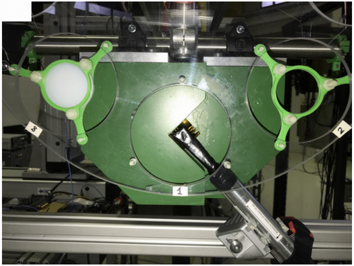


Materials: D=50mm and 5mm [C, Mg, Al, Si], 2mm [Ni, Sn] thickness









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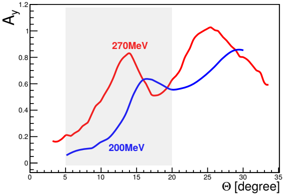
srEDM – *Precision Experiment !*

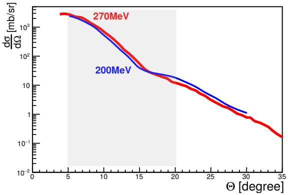
- Reaction with Large ***FOM*** (σA_y^2) & ($\sigma_{ela}/\sigma_{tot}$): Best $dC \rightarrow dC$
- Maximum Detection & Data Taking Efficiency
- Full ϕ in Reasonable ***FOM***(θ) region
- No strong Magnetic / Electric Field
- Stability – Long / Short Term

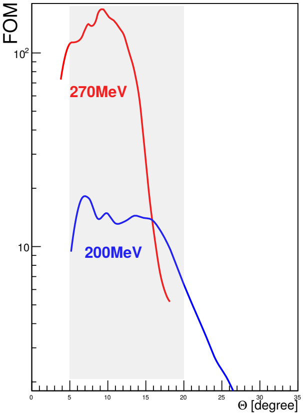
Y.SATOU AT AL.

deuteron carbon ellastic scattering

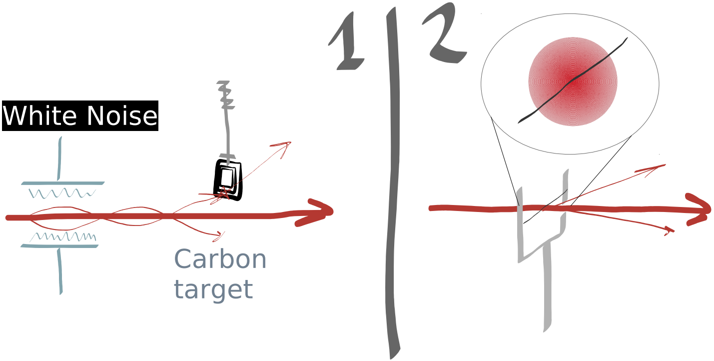
$$FOM = A_y^2 \cdot \sigma_{ela.}$$



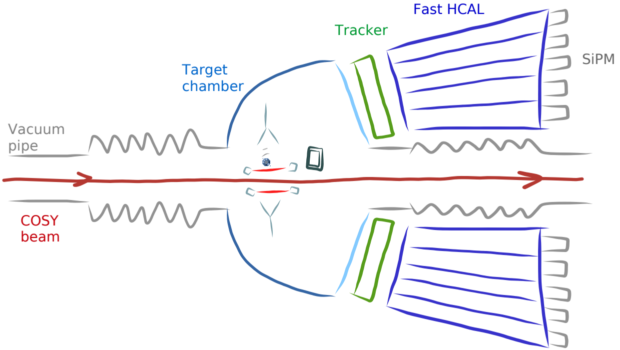




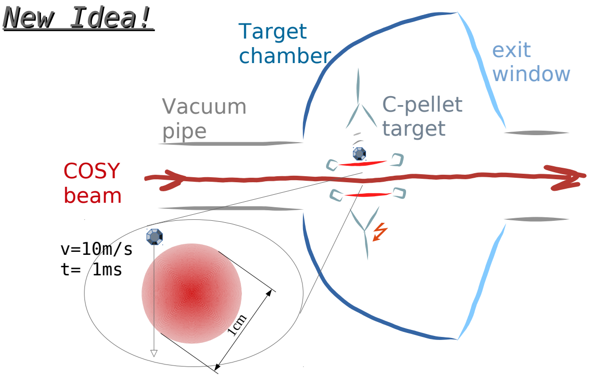
Carbon block 18mm or fiber 25μm



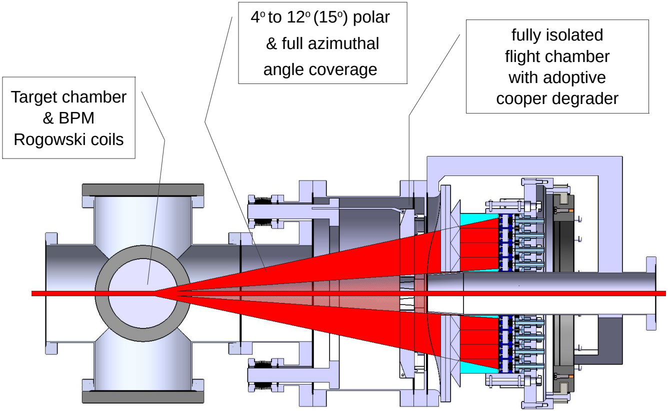
POLARIMETER SKETCH



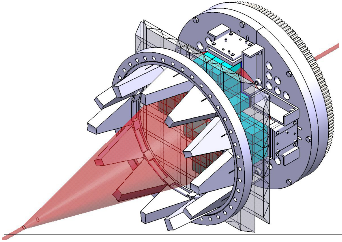
Juelich ballistic Diamond pellet Target



POLARIMETER

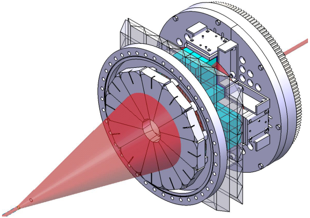


POLARIMETER



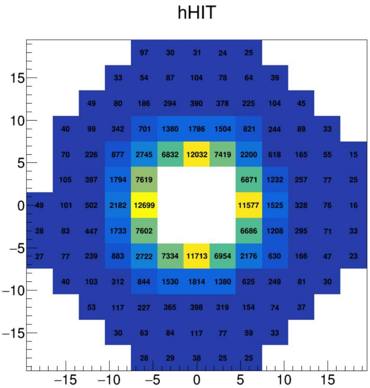
only LYSO + 4cm plastic can cover 320 MeV kinetic energy + cooper degrader can increase up to 350 MeV kinetic energy

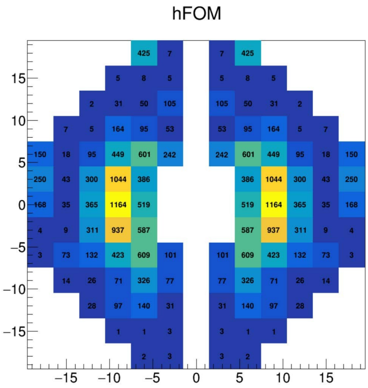
degrader will be adjusted for the proton magic momentum and used for the deuteron energy calibration too



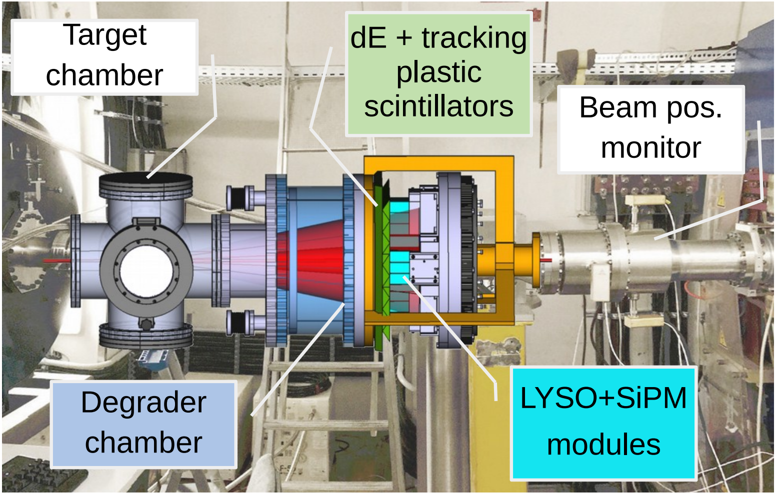
GEANT 4

Figure of merit

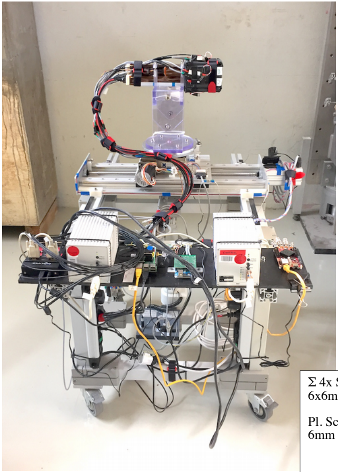


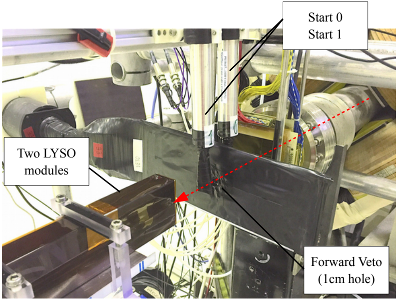


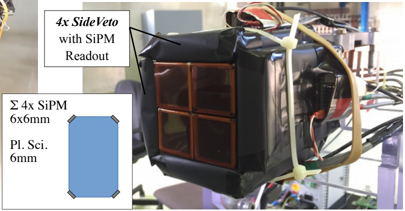
INTERNAL POLARIMETER



STEP 1

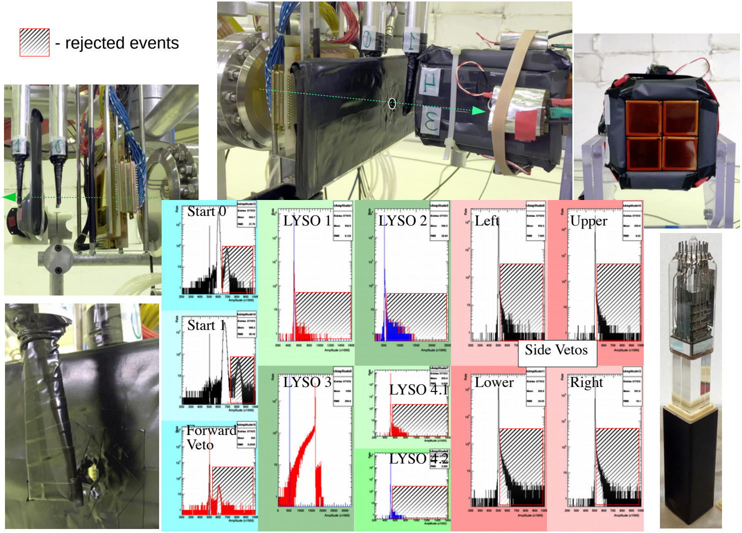



Start 0
Start 1
Two LYSO modules
Forward Veto (1cm hole)

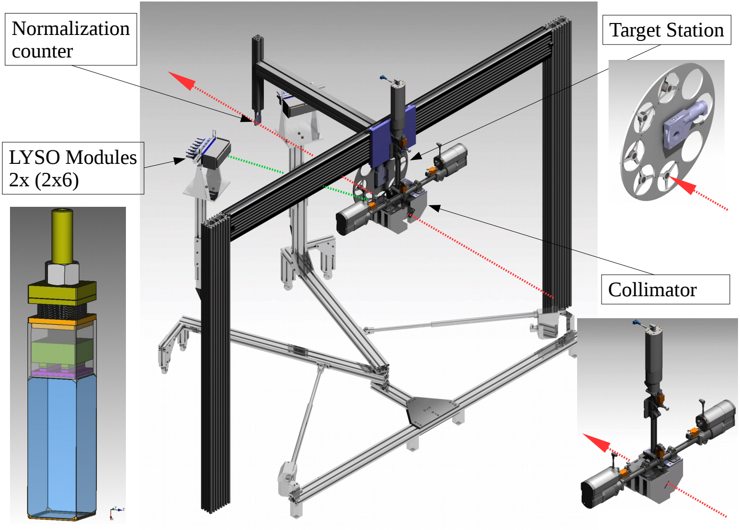

4x SideVeto with SiPM Readout
Σ 4x SiPM 6x6mm
Pl. Sci. 6mm

STEP 1

- rejected events

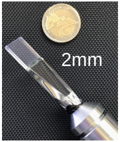


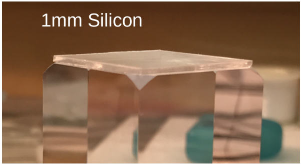
STEP 2

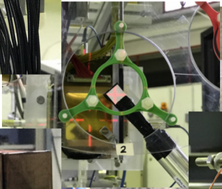


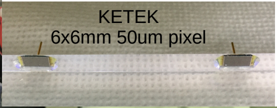
Normalization counter
LYSO Modules 2x (2x6)
Target Station
Collimator

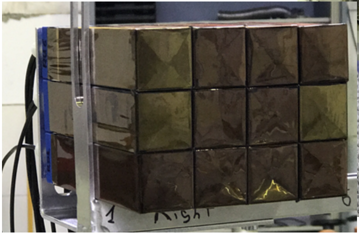
STEP 2

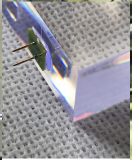


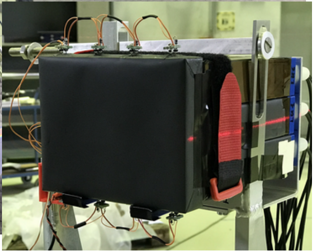




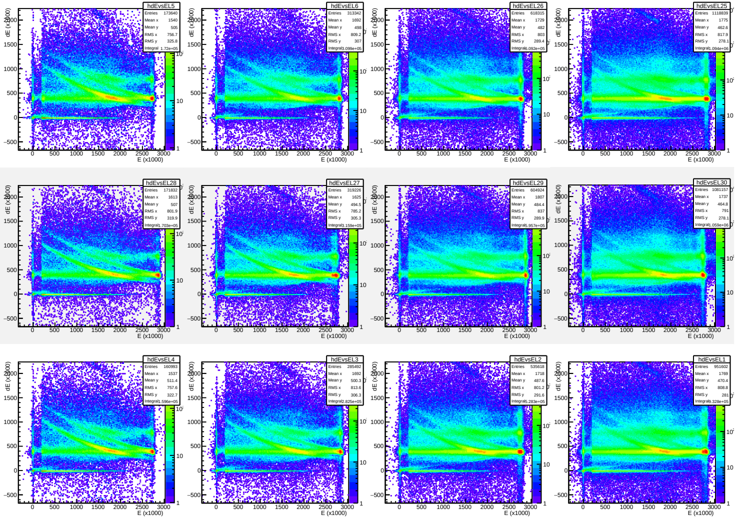








STEP 2



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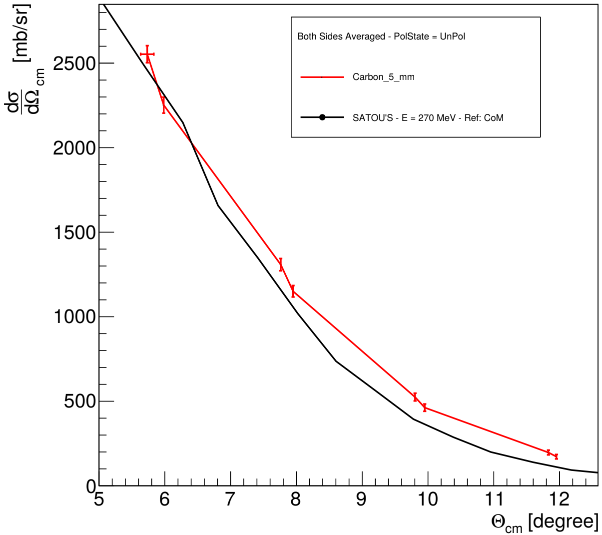
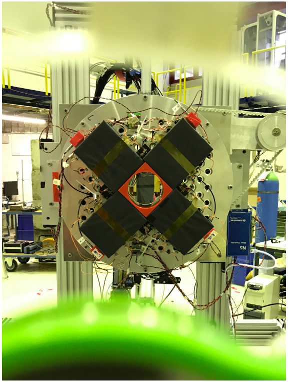
STEP 2

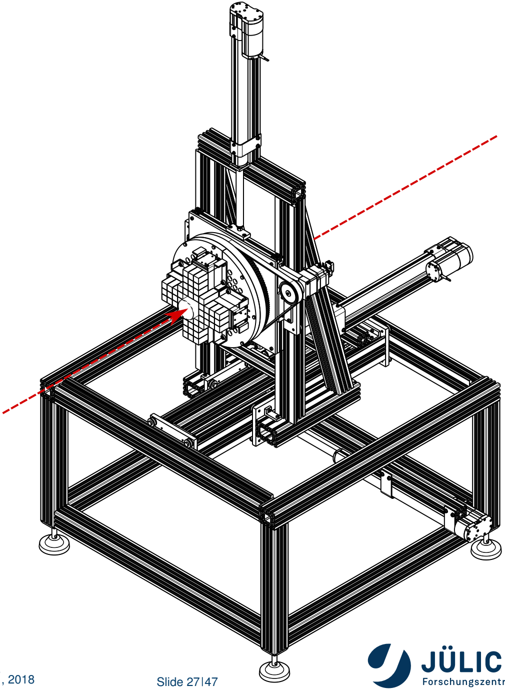


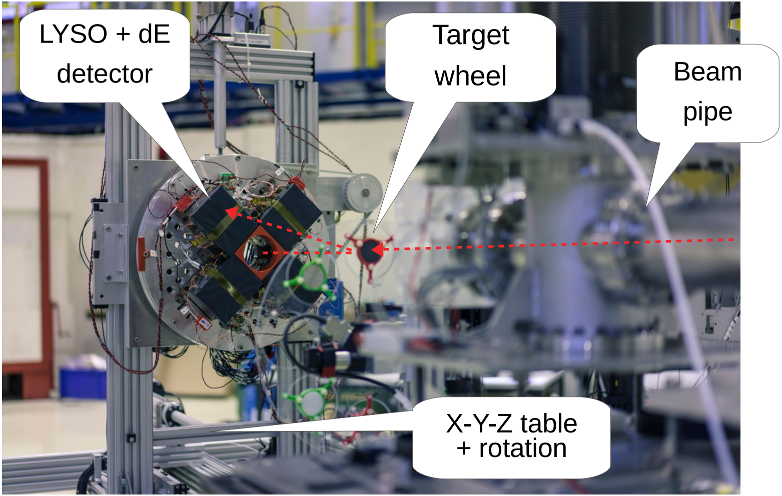
Both Sides Averaged - PolState = UnPol
Carbon_5_mm
SATOU'S - E = 270 MeV - Ref: CoM
dσ/dΩcm [mb/sr]
Θcm [degree]
0
500
1000
1500
2000
2500
5
6
7
8
9
10
11
12

STEP 3

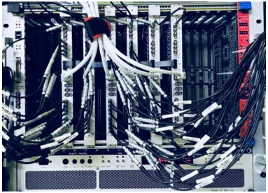
Test setup for polarimeter

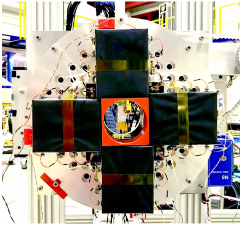


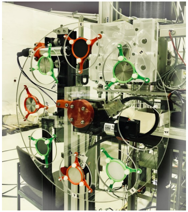


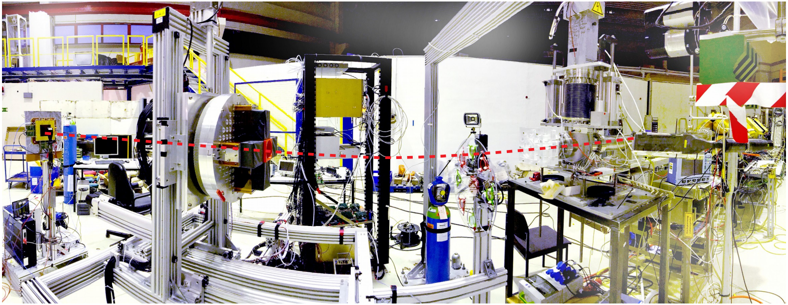

LYSO + dE detector
Target wheel
Beam pipe
X-Y-Z table + rotation

BIG KARL EXP. HALL

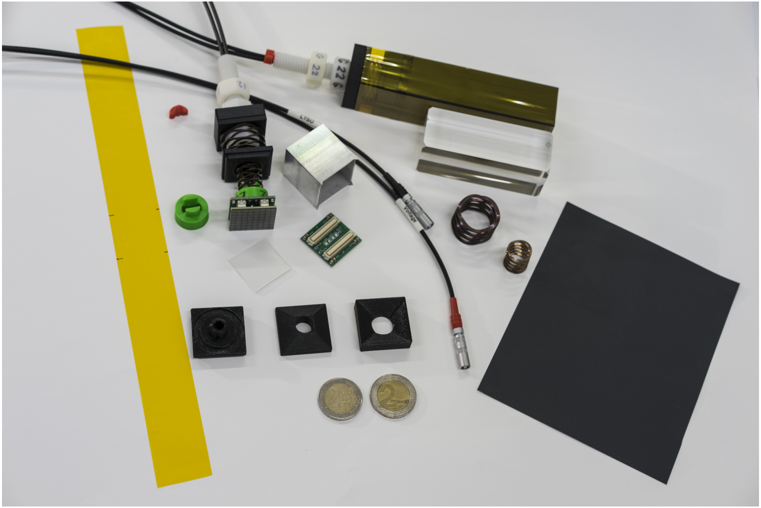




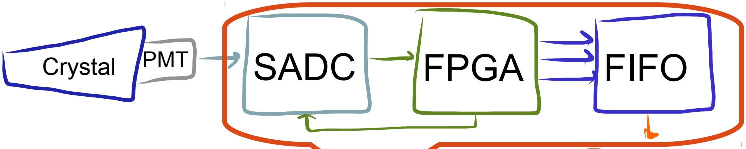




New improved mechanics and electronic components



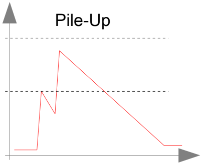
SADC BASED DAQ SYSTEM

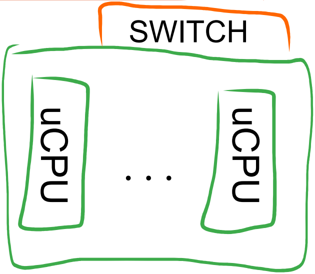


Struck SIS 3316

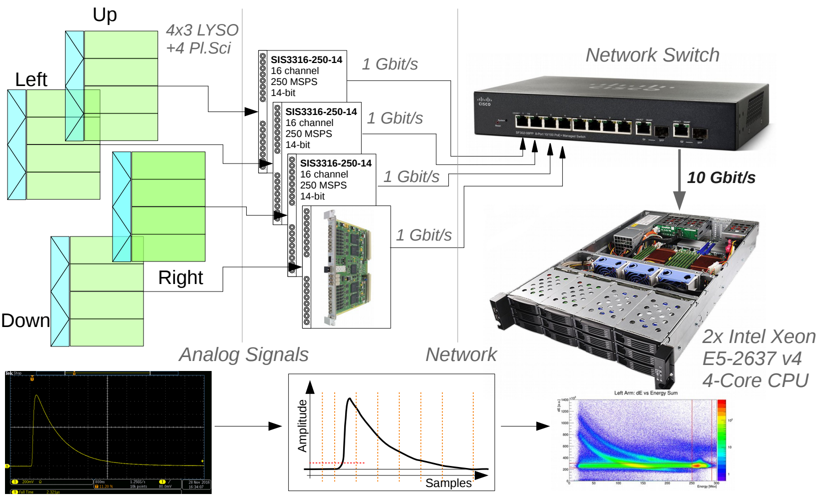
16 channel – 64MS/ch

250MS/s – 4ns per S.





SADC BASED DAQ SYSTEM



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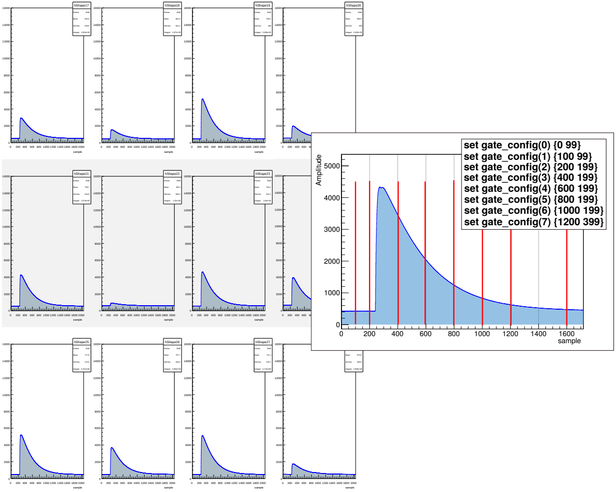
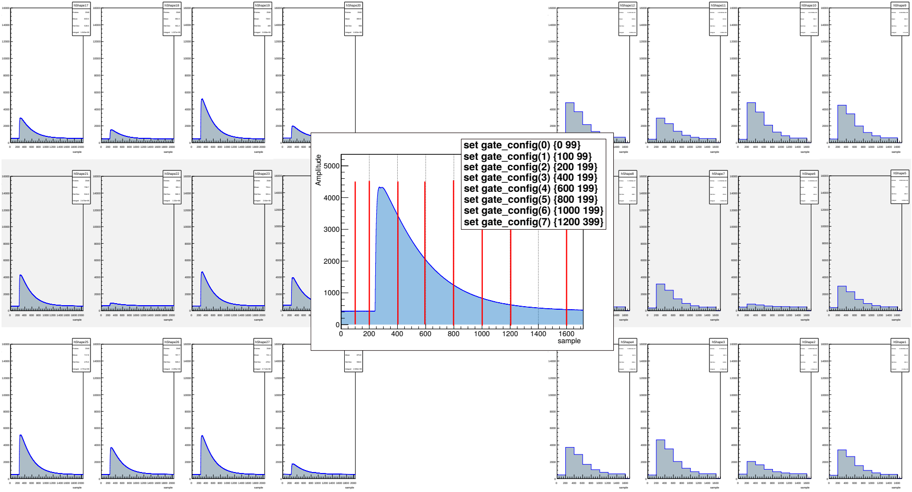
Full signal shape vs 8 accumulator/integral region



SIGNAL SHAPES

Full signal shape vs 8 accumulator/integral region



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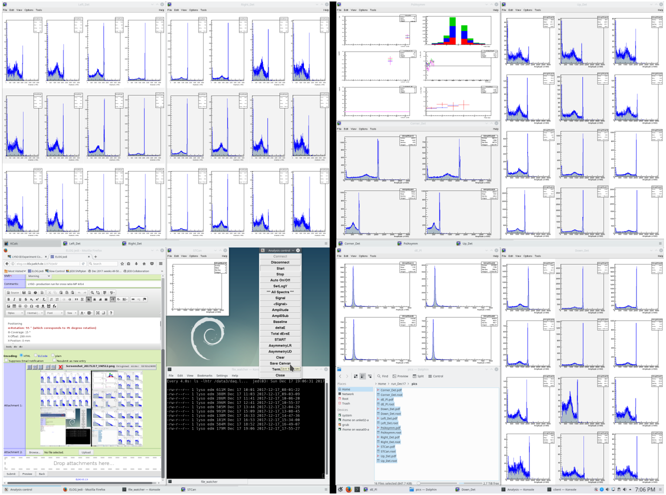
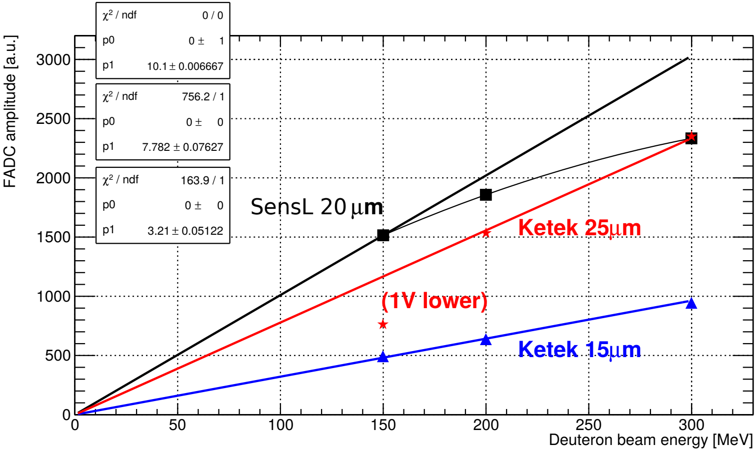
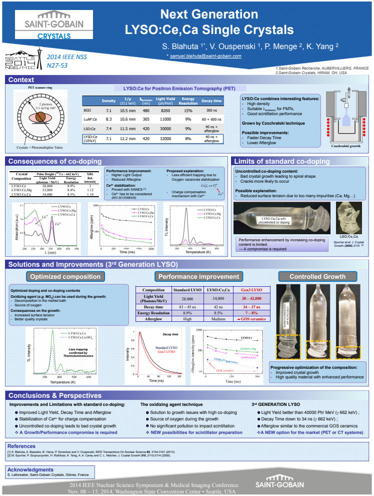
Monitoring of all amplitudes



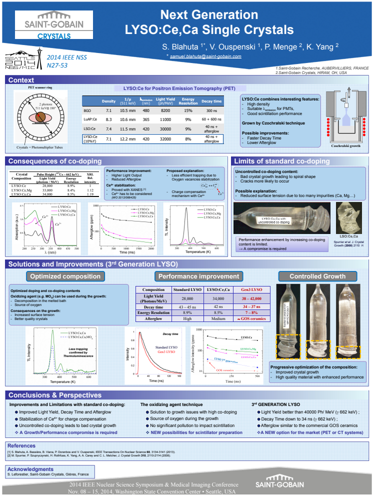
Comparison of different SiPM sensors

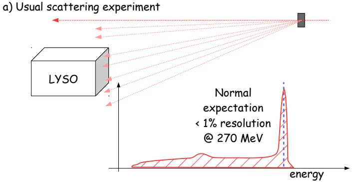


SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)

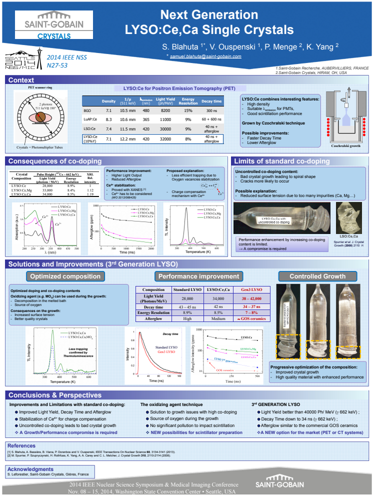


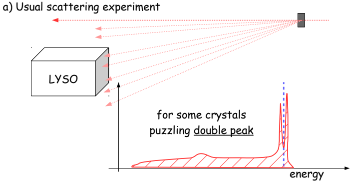
SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)





SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)





It was actually appearing

almost randomly…

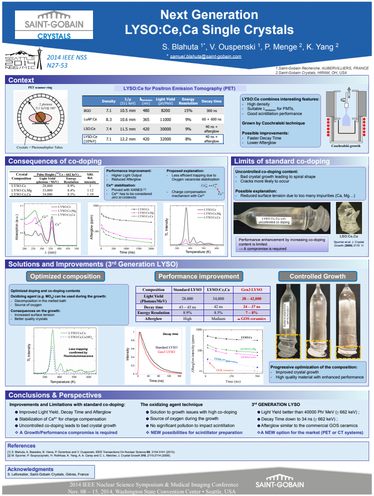
The same crystal time to time had

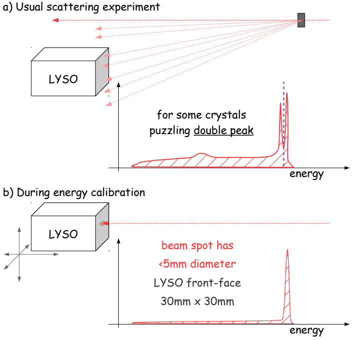
absolutely **clean signal**

but in some situations manifesting

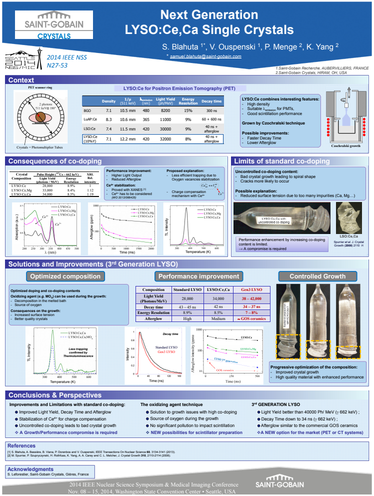
double peak!

SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)

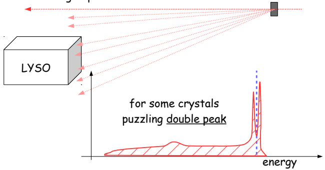




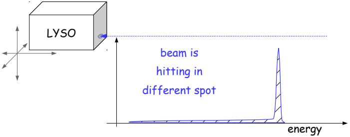
SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)



a) Usual scattering experiment



b) During energy calibration



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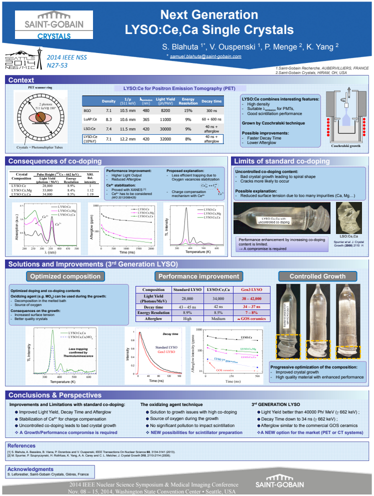
SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)



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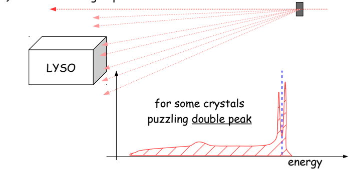
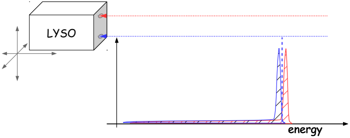
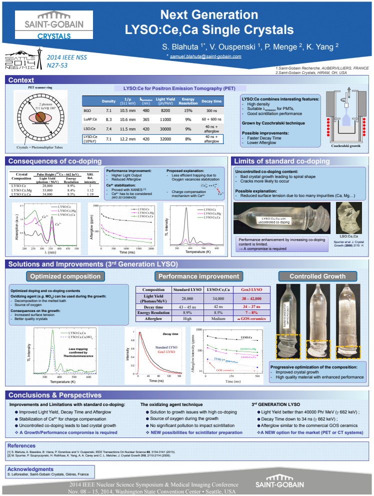


b) During energy calibration

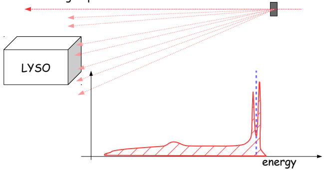


Peak is front face
position dependent!
Is it also energy dependent?
not really...

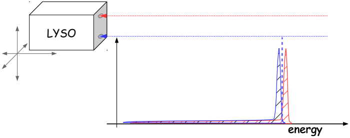
SAINT-GOBAIN PRELUDE^{TM} 420 (LYSO)



a) Usual scattering experiment



b) During energy calibration



c) Different hypotheses

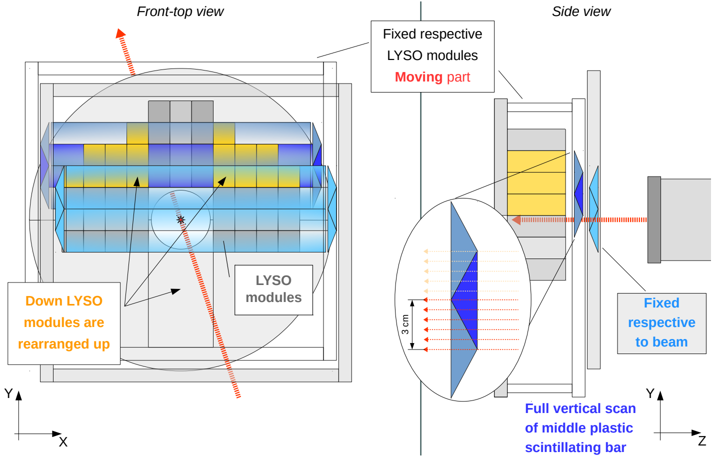
We spend <3 days of March beam time
to clarify this problem
very successfully !

We measured 2D maps for all crystals at
150, 200, 300 MeV

PLASTIC SCINTILLATOR TRACKER

Consisting of the overlapping triangular scintillator bars. The upstream (forward) frame is installed to be fixed vertically relative to the beam while the downstream (backward) frame can scan the beam.

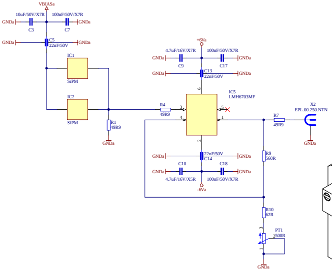
All scintillators were scanned vertically and horizontally (along the bar).

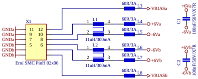


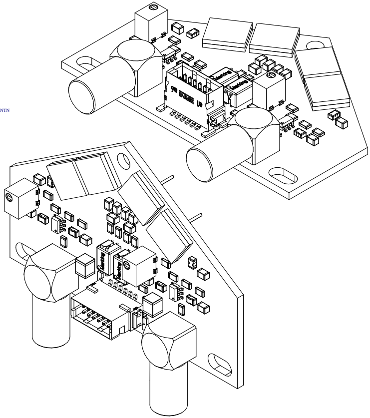
PLASTIC SCINTILLATOR TRACKER READOUT PCB

Dual channel operational amplifier based SiPM signal preamplifier PCB

The supply voltage $\pm 6V$ and reverse bias voltages $+29V$ is shared for each PCB







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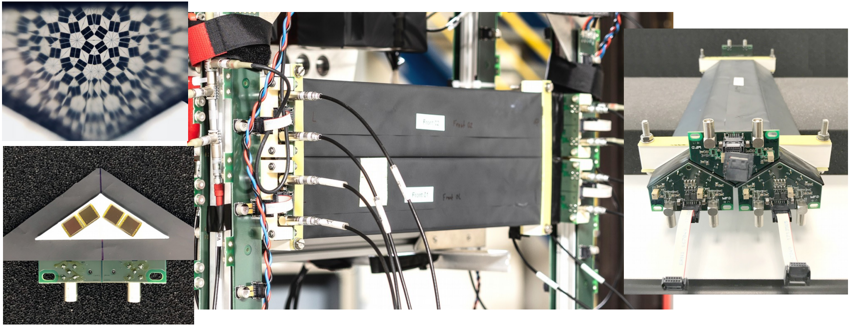
PLASTIC SCINTILLATOR TRACKER

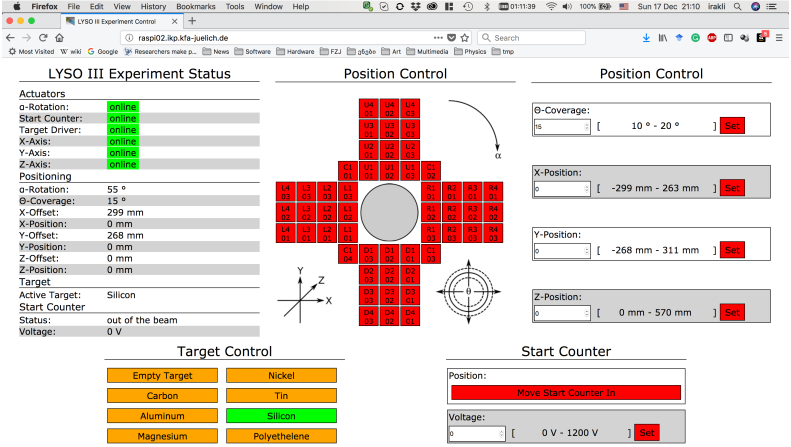
Left-up: the view through the wrapped triangular scintillator bar where the kaleidoscopic picture of the SiPM's is seen from another end.
Left-down: the end cup of the bar is shown with four SiPM's split into two independent preamplifier channels.
Middle: already attached tracker in front of LYSO modules.
Right: one of the layers with three bars after assembly.

Each counter has 4 independent preamplifier output, 2 each end, and eight 6×6 *mm* SiPM's four each end.



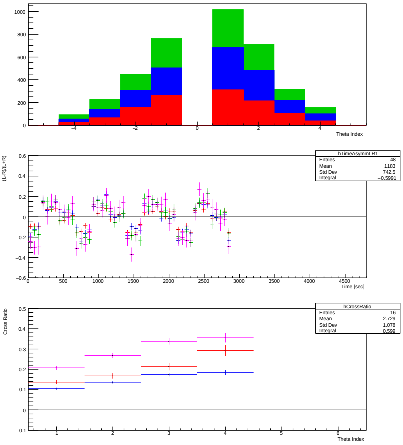
SLOW CONTROL SYSTEM

Controls all movements



ASYMMETRY

Carbon at $\Theta_{max} = 10^o$ and $\Theta_{max} = 15^o$



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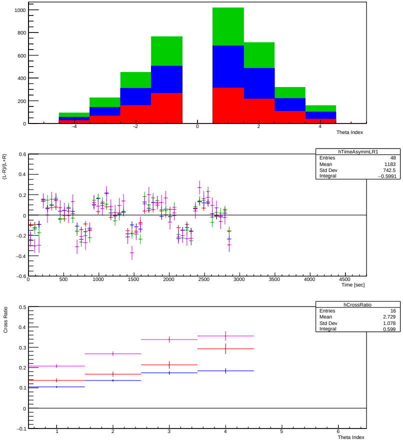
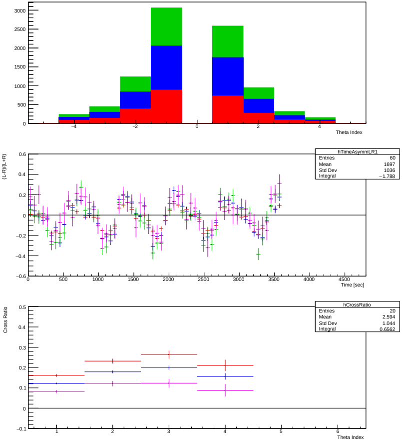
ASYMMETRY

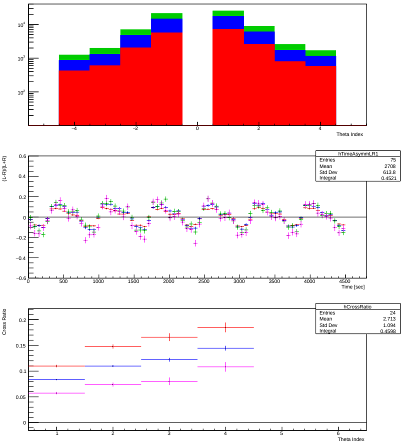
Carbon at $\Theta_{max} = 10^o$ and $\Theta_{max} = 15^o$





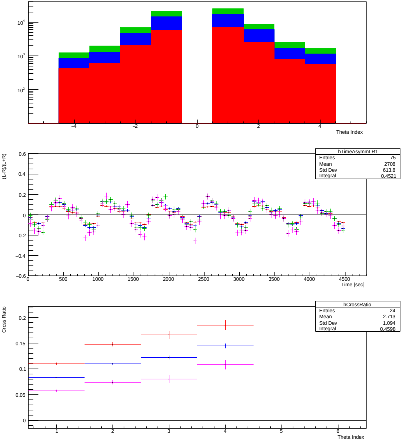
ASYMMETRY

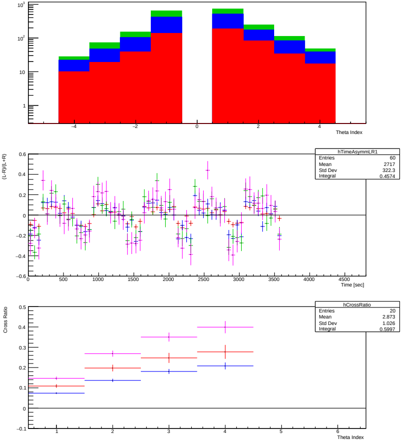
Different target materials (left Nickel; right Tin)

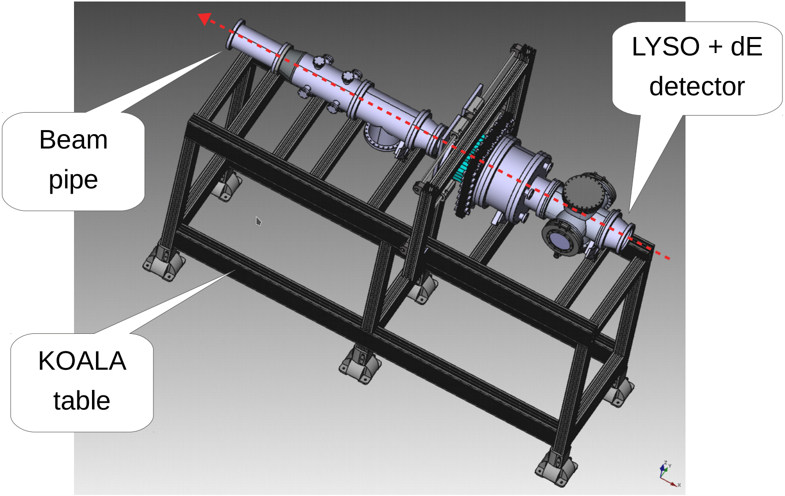


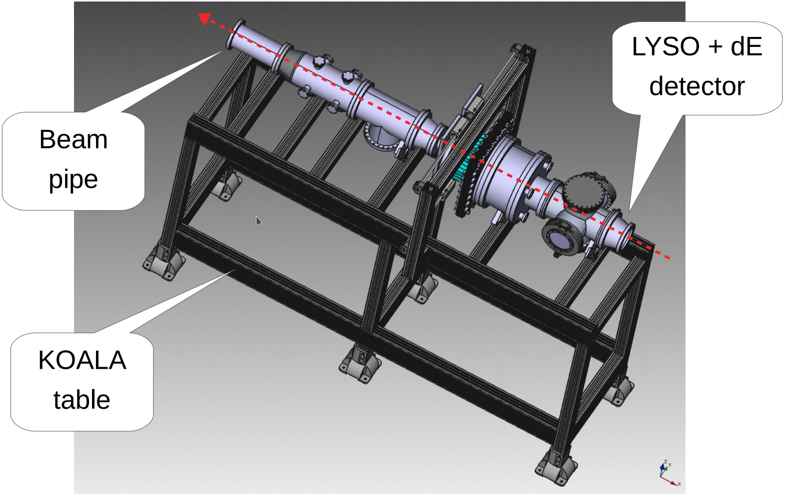
ASYMMETRY

Different target materials (left Nickel; right Tin)

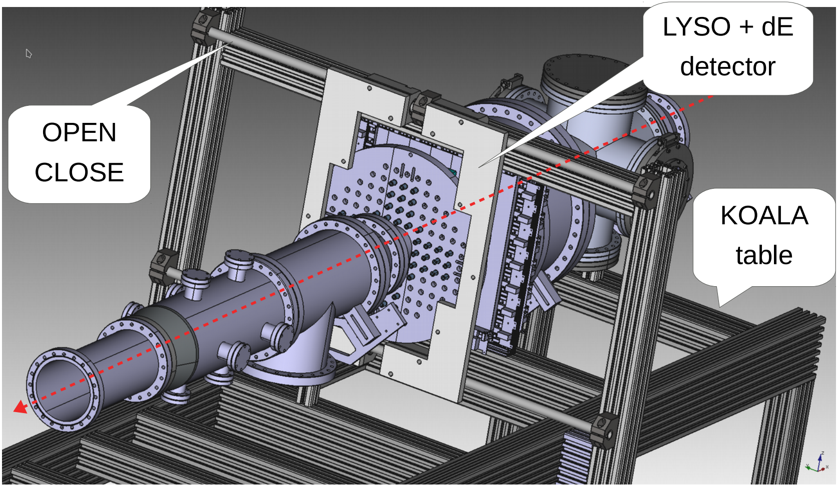





Beam
pipe
LYSO + dE
detector
KOALA
table


LYSO + dE detector
Beam pipe
KOALA table

JEPO AT ANKE



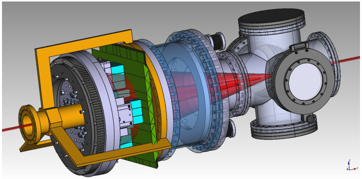
ACKNOWLEDGMENT

People contributing to the experiment

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

SUMMARY

- We have functional online polarimeter
  –needs further software development!



- Mechanical support & slow control
  shows excellent performance

- New DAQ system reached its
  max. designed data transfer of 400 MB/s

- We have assembled and tested new LYSO and SiPM vendors
  in total 48+4 Modules

- **Next step: installation at ANKE**

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Appendix

CONTACT

Contacting me via e-mail

Click here: `i.keshelashvili@fz-juelich.de`

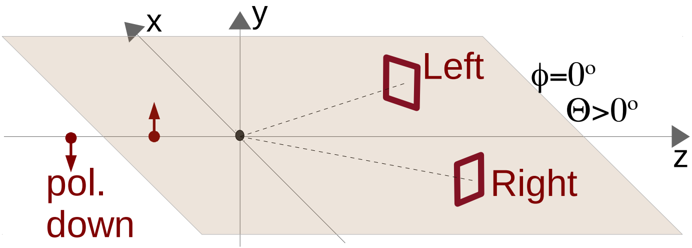
GENERAL FORMALISM

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

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

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

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



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