

A NEW APPROACH: LYSO BASED POLARIMETRY FOR THE EDM MEASUREMENTS

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GGSWBS'18 — Tbilisi State University

OUTLINE

- ***Introduction***

challenges for srEDM case

- **COSY Accelerator Facility**

Spin gymnastic & operating polarimeters

- **New Polarimeter Concept**

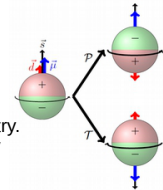
dedicated polarimeter for srEDM experiment

- **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^0 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.



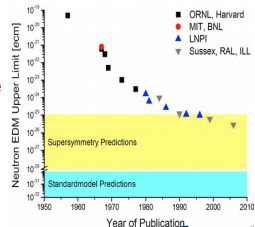
SM CP violation is enough to explain what has been observed in the K & B meson systems but orders of magnitude smaller than observed in the universe

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

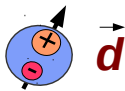
1967: Sacharov conditions for the Baryon Asymmetry of the Universe

- 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 \rightarrow physics beyond SM



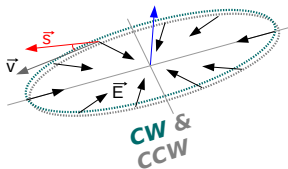
method differs strongly from nEDM



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

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

- Store longitudinally polarized **protons**
- Interact with a radial E-field
- Analyze Polarization Build-up (this talk)



**build-up of vertical
polarization**

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

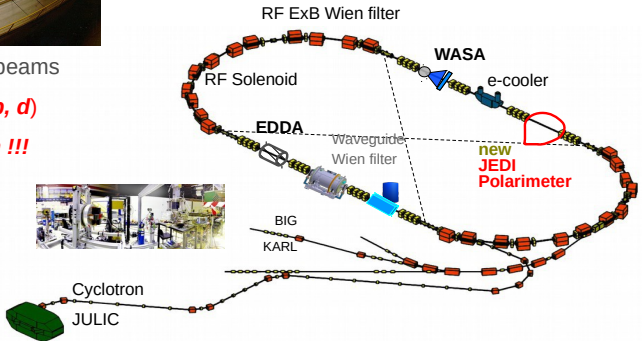
POLARIMETER SETUP @ COSY



Internal and external beams

High polarization (*p*, *d*)

Spin manipulation !!!



Energy range (min.-- max.):

0.045 – 2.8 GeV (p)

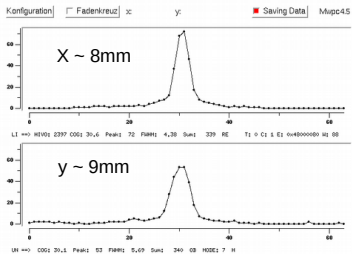
0.023 – 2.3 GeV (d)

Max. momentum ~ 3.7 GeV/c

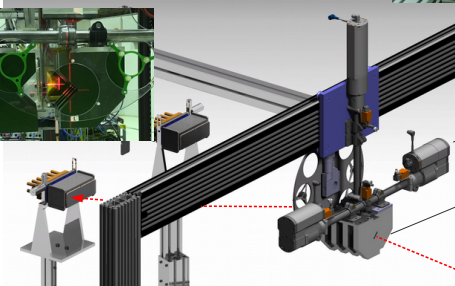
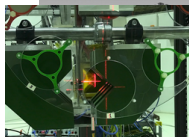
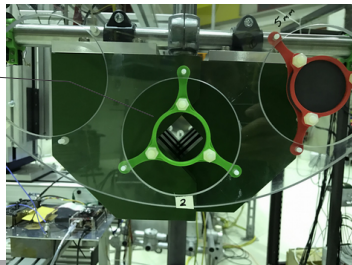
Electron & Stochastic cooling

Feed-forward machine

COSY BEAM MWPC PROFILE



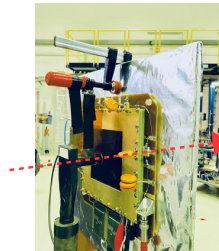
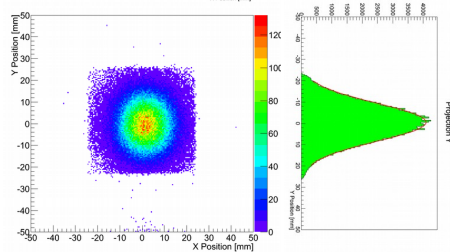
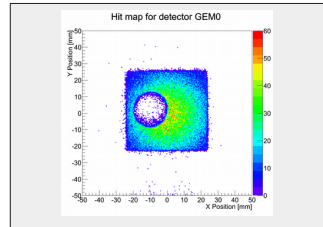
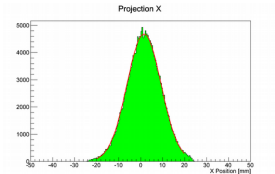
Empty target holder



2D movement
Spot diameter

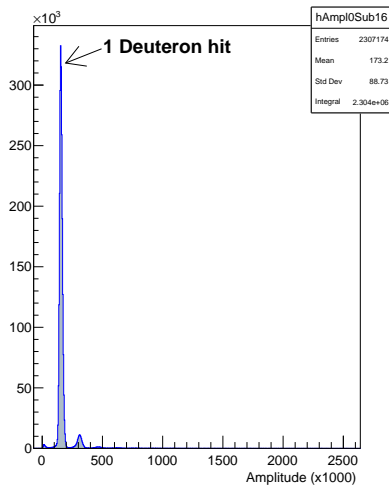
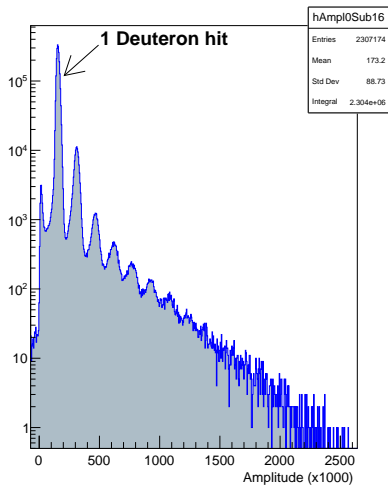
4x2.5cm Iron
collimator blades

COSY 2D PROFILE



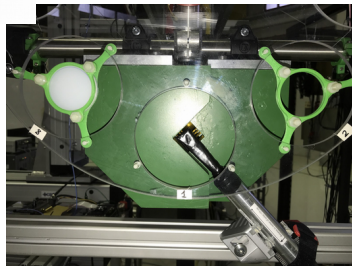
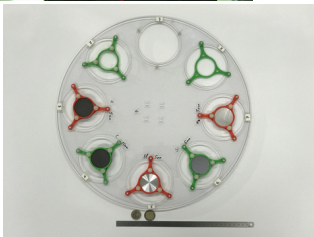
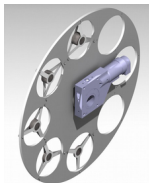
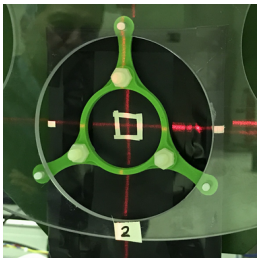
START COUNTER

Clearly seen deuteron pile-ups



TARGET WHEEL

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

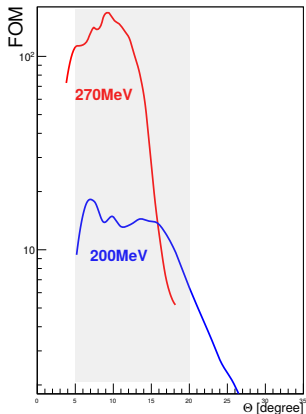
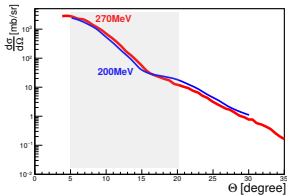
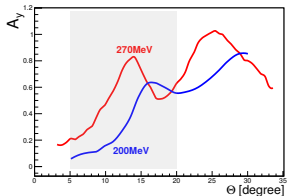


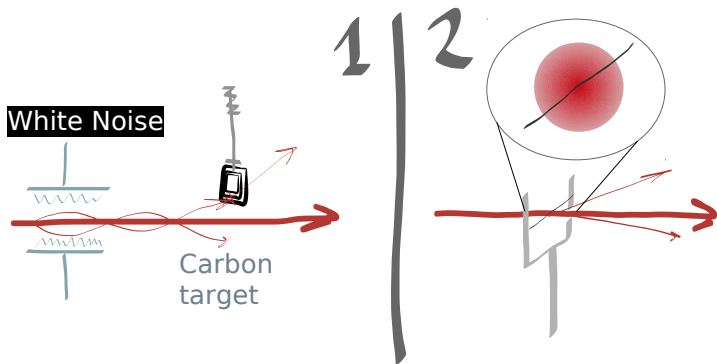
srEDM – Precision Experiment !

- Reaction with Large **FOM** (σA_y^2) & ($\sigma_{\text{ela}}/\sigma_{\text{tot}}$): 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

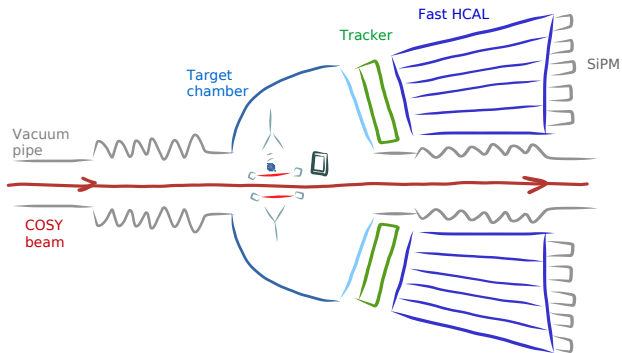
deuteron carbon elastic scattering

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



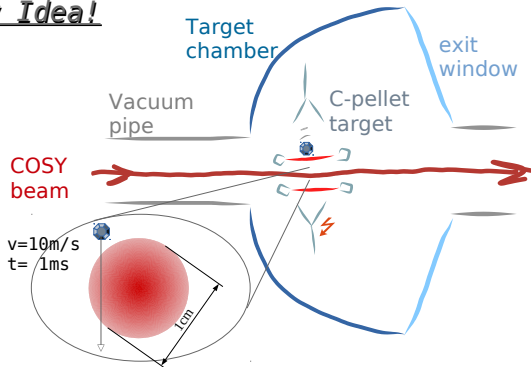


POLARIMETER SKETCH

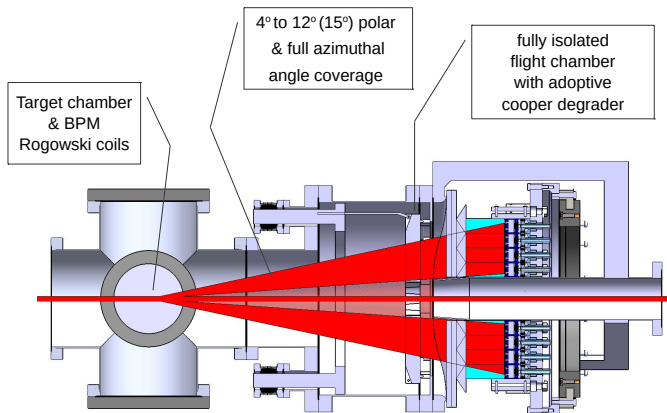


Juelich ballistic Diamond pellet Target

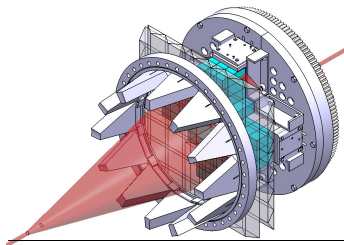
New Idea!



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*

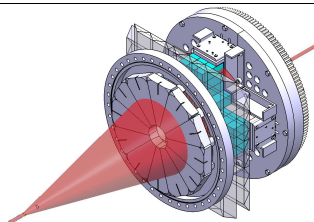
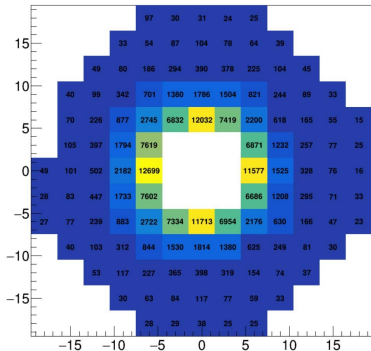
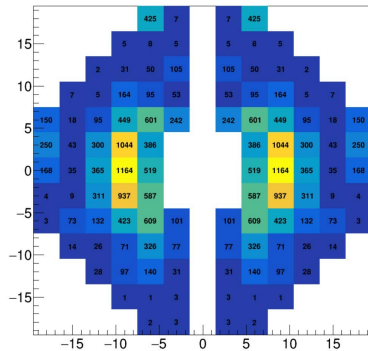


Figure of merit

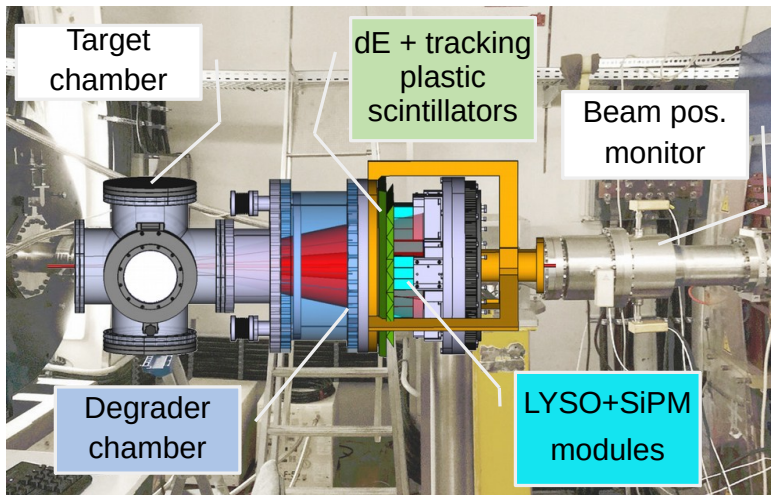
hHIT



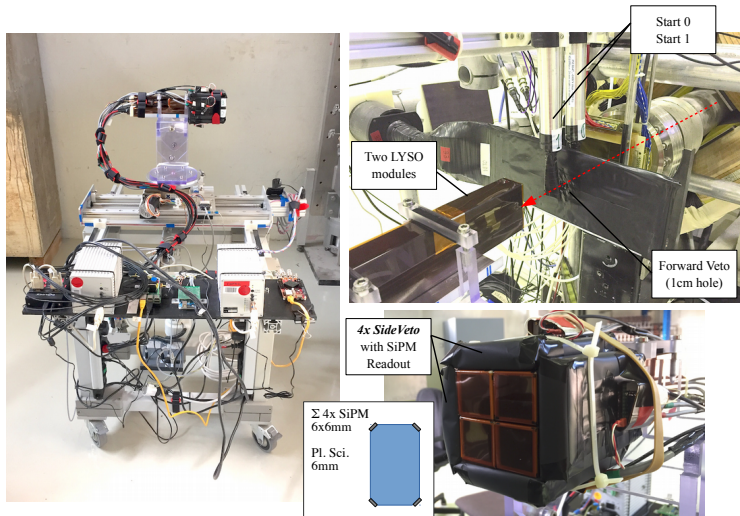
hFOM



INTERNAL POLARIMETER

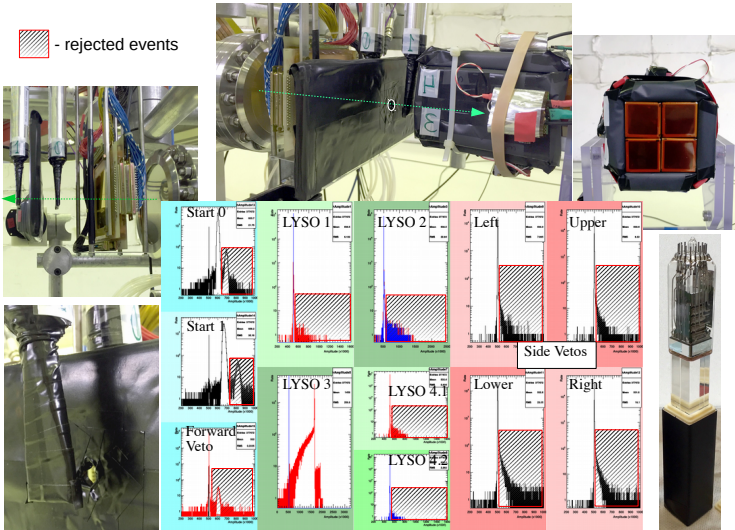


STEP 1

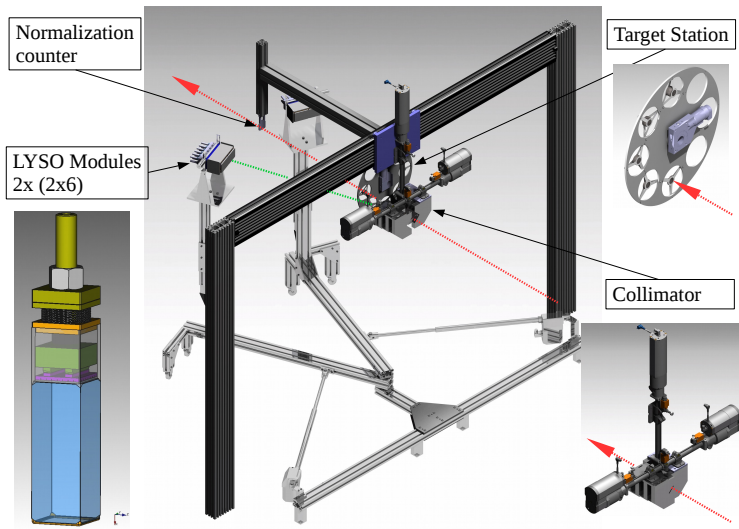


STEP 1

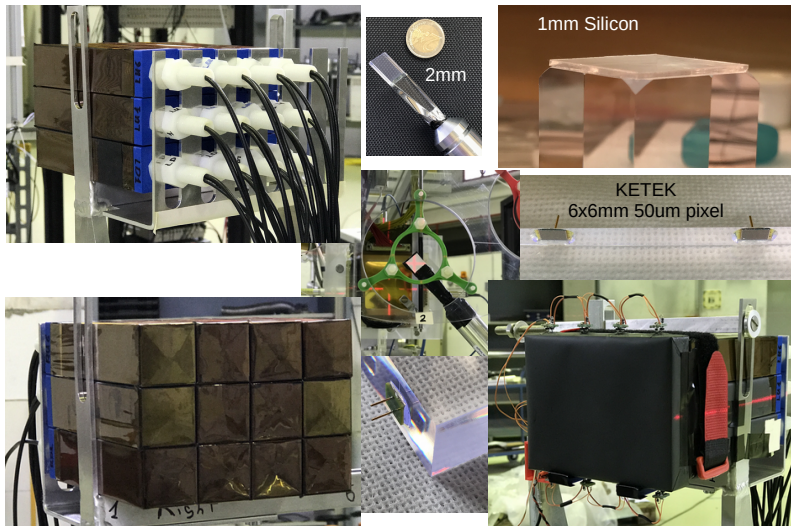
 - rejected events



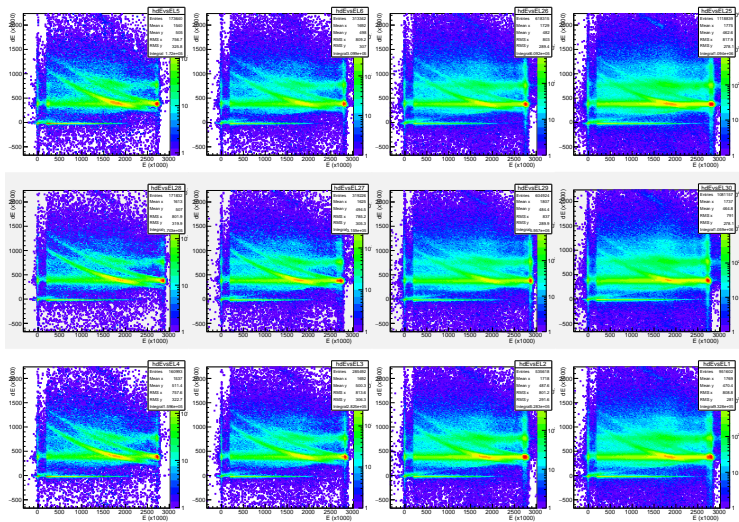
STEP 2



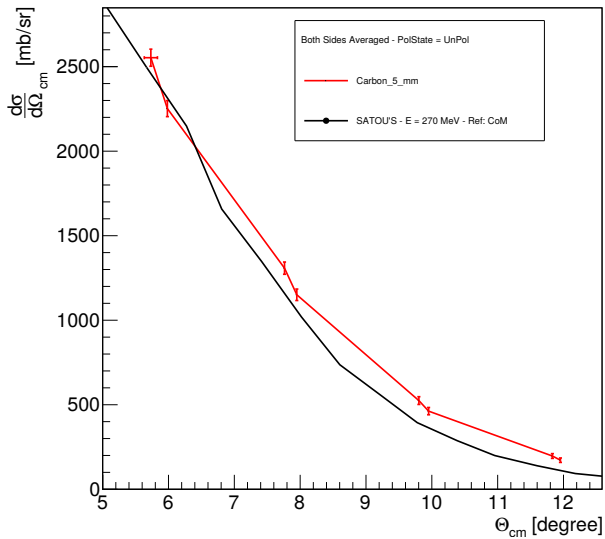
STEP 2



STEP 2

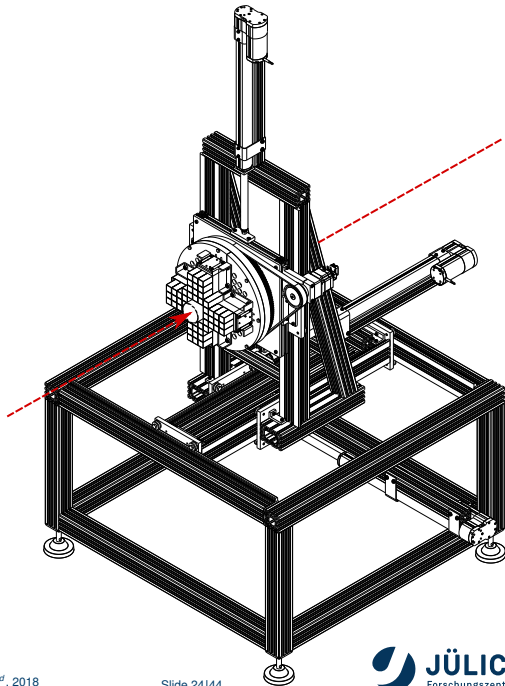
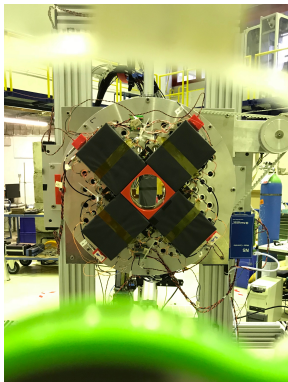


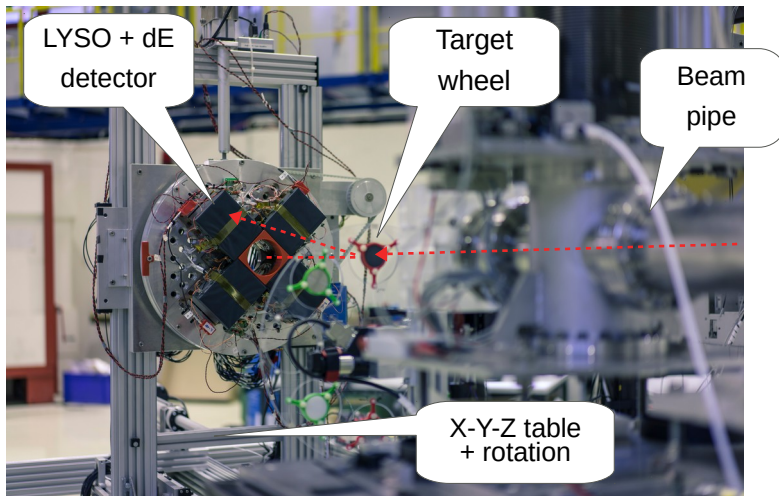
STEP 2



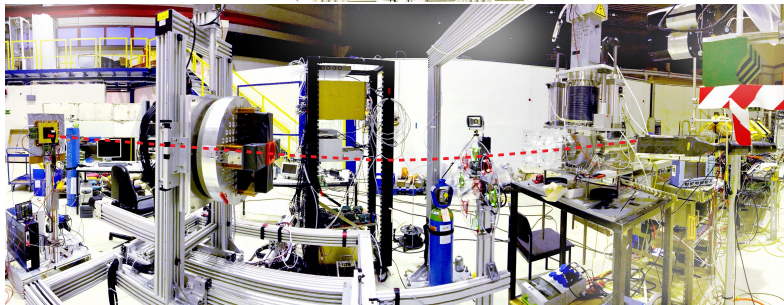
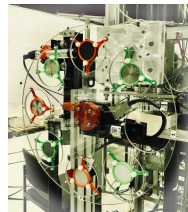
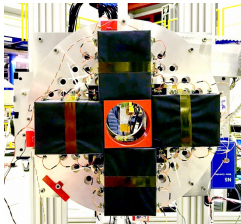
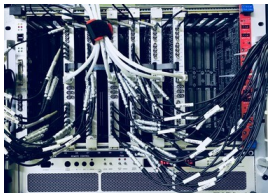
STEP 3

Test setup for polarimeter

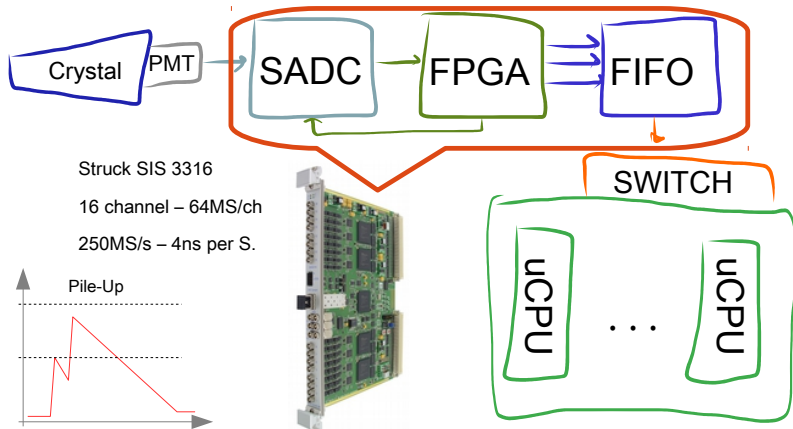




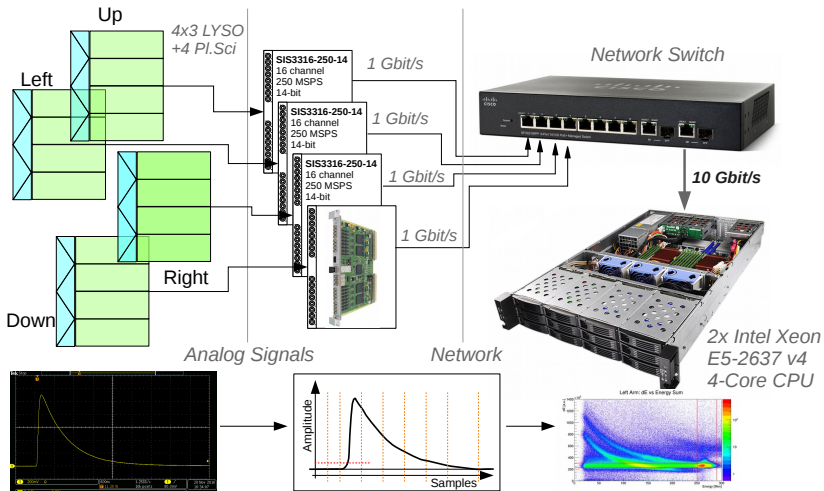
BIG KARL EXP. HALL



SADC BASED DAQ SYSTEM

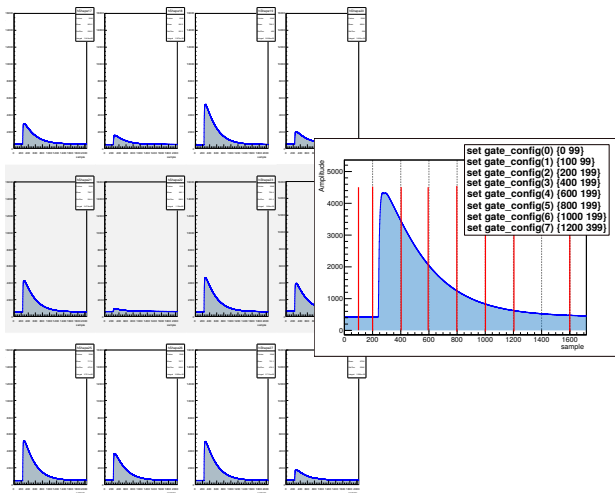


SADC BASED DAQ SYSTEM



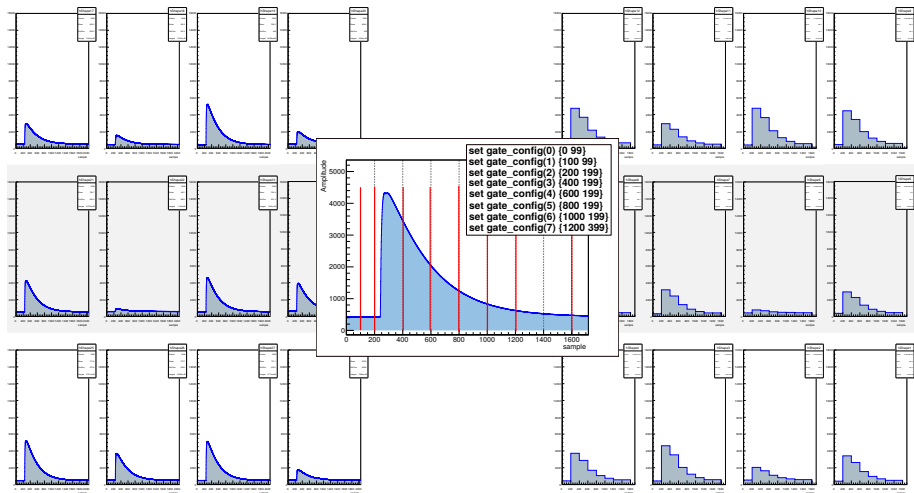
SIGNAL SHAPES

Full signal shape vs 8 accumulator/integral region



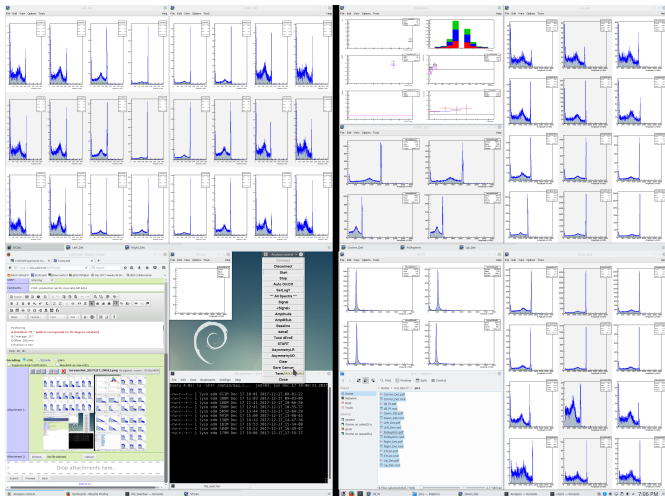
SIGNAL SHAPES

Full signal shape vs 8 accumulator/integral region

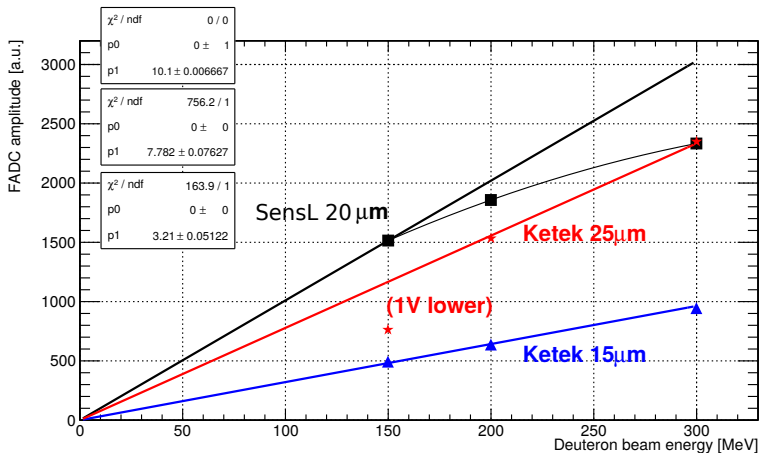


ONLINE MONITORING SYSTEM


Monitoring of all amplitudes



Comparison of different SiPM sensors



SAINT-GOBAIN PRELUDE™ 420 (LYSO)




Next Generation LYSO:Ce,Ca Single Crystals

S. Bhatta¹, V. Ouspenski¹, P. Menge², K. Yang²

1. Saint-Gobain Crystals, 427-53 | 2. Saint-Gobain Crystals, 427-53

Context




Crystal (Photomicrograph)

Property	LYSO	LYSO:Ce	LYSO:Ce,Ca	LYSO:Ce,Ca	LYSO:Ce,Ca
Density	7.1	7.1	7.1	7.1	7.1
MOI	32.0	32.0	32.0	32.0	32.0
MOI/Co	8.3	8.3	8.3	8.3	8.3
MOI/Co	7.4	7.4	7.4	7.4	7.4
MOI/Co	7.1	7.1	7.1	7.1	7.1

LYSO:Ce combines interesting features:
High density
Stable crystal, for PMTs
Good electronic performance
Grown by Czochralski technique

Possible improvements:
Faster Doping Time
Lower Defectivity




Consequences of co-doping

Performance improvement:
Higher light yield
Higher energy resolution
Higher timing resolution
Higher radiation hardness
Higher thermal stability
Higher mechanical strength

Practical application:
Same effort to grow same size crystals
Change composition
Same effort to grow same size crystals

Limits of standard co-doping:
Fast crystal growth, leading to higher defectivity
Controlled growth is needed


Possible explanation:
Production surface defect due to too heavy dopants (Ca, Mg)



Solutions and Improvements (3rd Generation LYSO)

Optimized composition


Optimized doping and co-doping systems
Doping agent (e.g. Mg) can be used during the growth
Doping agent for defect control
Compensation on the growth
Compensation for radiation



Performance improvement

Composition	Standard LYSO	LYSO:Ce,Ca	LYSO:Ce,Ca
Light Yield (Photo/MeV)	20,000	24,000	24,000
Energy Resolution	10.0%	9.0%	9.0%
Timing Resolution	100 ps	100 ps	100 ps

Controlled Growth



Progressive optimization of the composition:
Optimized crystal growth
High quality material with enhanced performance

Conclusions & Perspectives

Improvements and Limitations with standard co-doping:

- Improved light yield, Decay Time and Afterglow
- Introduction of Ca for charge compensation
- Controlled co-doping leads to fast crystal growth
- A Growth/Performance compromise is required

The existing agent technique

- Solution to growth issues with high co-doping
- Absence of oxygen during the growth
- No significant pollution to impact scintillation
- NEW possibilities for scintillator preparation

3rd GENERATION LYSO


- Light Yield better than 20000 Ph/MeV (> 400 wt%)
- Decay Time close to 30 ns (> 400 wt%)
- Afterglow similar to the commercial GOS ceramics
- A NEW option for the market (PMT or CT application)

References

[1] S. Bhatta, V. Ouspenski, P. Menge, K. Yang, Proceedings of the 2014 IEEE Nuclear Science Symposium and Medical Imaging Conference, Nov. 02 - 11, 2014, Washington State Convention Center, Seattle, USA

Acknowledgments

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SAINT-GOBAIN
CRYSTALS

Next Generation
LYSO:Ce,Ca Single Crystals

S. Blahuta¹, V. Ouspenski¹, P. Menge², K. Yang²

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2 Saint-Gobain Crystals, 94044 CRYSTALS, USA

Context

LYSO:Ca for Positron Emission Tomography (PET)

Locality	Type	Volume	Light Yield	Energy	Scatter Ratio
LYSO	1:1	30.0 mm	400	0.33%	100%
LYSO:Ca	8:2	30.0 mm	300	1.000%	9%
LYSO:Ca	2:8	30.0 mm	400	0.999%	9%
LYSO:Ca	1:1	30.0 mm	400	0.999%	9%

LYSO:Ca combines interesting features:
• High density
• Suitable for PET, PAET, dual-modality applications
• Grown by Controlled Growth technique
Possible Impurities:
• Fluorine
• Lead
• Oxygen

Consequences of co-doping

Performance improvement:
• Increased light yield
• Improved energy resolution
• Improved timing resolution

Proposed explanation:
• Lower defect trapping due to charge recombination
• Charge compensation
• Enhancement of light yield

Controlled co-doping method:
• Best crystal growth leading to optimal shape
• Checks more likely to succeed

Possible explanation:
• Reduced surface recombination due to low density (LYSO:Ca Mg)

Solutions and improvements (3rd Generation LYSO)

Optimized composition

Optimal doping and no-doping systems:
• Operating up to 100°C crystal used during the growth
• Compensation in the initial bath
• Controlled growth
• Compensation on doping levels
• Higher quality crystals

Performance improvement

Composition	Volume (L)	LYSO:Ca (%)	LYSO:Ca (%)
LYSO:Ca	30.0 mm	0.33%	100%
LYSO:Ca	30.0 mm	0.33%	100%
LYSO:Ca	30.0 mm	0.33%	100%
LYSO:Ca	30.0 mm	0.33%	100%

Controlled Growth

Progressive optimization of the composition:
• Improved crystal growth
• High quality material with enhanced performance

Conclusions & Perspectives

Improvements and Limitations with standard co-doping:

- Increased light yield, Energy Time and Absorption
- Distribution of Ca²⁺ for charge compensation
- Uncontrolled on doping levels to lead crystal growth
- Inhomogeneous performance (compensation is required)

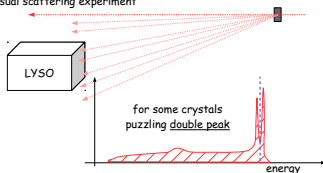
The stabilizing agent technique

- Addition to growth issues with high co-doping
- Source of oxygen during the growth
- No significant pollution to impact crystallization
- Better preparation for excellent preparation

3rd GENERATION LYSO

- Light Yield better than 40000 Ph (BEP), 400 kcps
- Energy Time lower to 30 ns (40, 400 kcps)
- Behavior similar to the commercial OCS crystals
- 8-100% option for the standard (PET) or CT systems

a) Usual scattering experiment



It was actually appearing
almost randomly...

The same crystal time to time had
absolutely clean signal
but in some situations manifesting
double peak!

**Next Generation
LYSO:Ce,Ca Single Crystals**

S. Blahuta^{1*}, V. Ouspenski¹, P. Menge², K. Yang²

¹ Saint-Gobain Prelude, ² Jülich Research Centre

Context

LYSO:Ce for Positron Emission Tomography (PET)

Locality	Type	Volume	Height/Width	Energy	Scatter Ratio
100	10	10.0 mm	400	0.025	10%
100	10	10.0 mm	300	1.000	9%
100	10	10.0 mm	400	0.025	9%
100	10	10.0 mm	400	0.025	9%

LYSO:Ce combines interesting features:
 • High density
 • Suitable τ_{decay} for PET
 • Good scintillation performance
 • Grown by Controlled Growth technique
 Possible Impurities:
 - Fluorine
 - Oxygen
 - Lead
 - Tellurium

Consequences of co-doping

Performance improvement:
 - Increased light yield
 - Improved energy resolution
 - Improved timing resolution

Proposed explanation:
 - Increased light yield due to charge compensation
 - Improved energy resolution due to charge compensation
 - Improved timing resolution due to charge compensation

Controlled co-doping method:
 - Best crystal growth leading to optimal shape
 - Charge compensation
 - Reduced surface stresses due to low density (Prelude Co. Mg)

Solutions and improvements (3rd Generation LYSO)

Optimized composition

Composition	Yield (1000)	Energy Res.	Time Res.
LYSO:Ce	20,000	12.5%	200 ps
LYSO:Ce,Ca	25,000	11.5%	180 ps
LYSO:Ce,Ca,Mg	28,000	10.5%	160 ps

Controlled Growth

Progressive optimization of the composition:
 - Improved crystal growth
 - High quality material with enhanced performance

Conclusions & Perspectives

Improvements and Limitations with standard co-doping:

- Increased light yield, energy resolution and timing resolution
- Introduction of Ca for charge compensation
- Uncontrolled co-doping leads to best crystal growth
- Ca distribution (Performance compromise to improve)

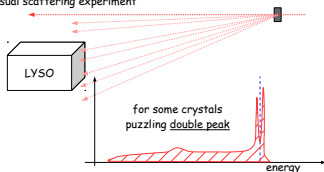
The stabilizing agent technique

- Addition to growth issues with high co-doping
- Source of oxygen during the growth
- No significant pollution to impact scintillation
- Better preparation for excellent preparation

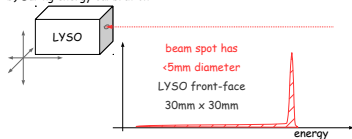
3rd GENERATION LYSO

- Light yield better than 20000 Ph (BEP) (400 mm)
- Energy Res. better than 10.5% (400 mm)
- Timing Res. better than 160 ps (400 mm)
- High quality material with enhanced performance

a) Usual scattering experiment



b) During energy calibration



**Next Generation
LYSO:Ce,Ca Single Crystals**

S. Blahuta¹, V. Ouspenski¹, P. Menge², K. Yang²

¹ Saint-Gobain Prelude, ² Jülich Forschungszentrum

Context

LYSO:Ce for Positron Emission Tomography (PET)

Locality	Type	Volume	Crystal	Energy	Scatter Ratio
100%	100%	400	0.025	10%	100%
LYSO:Ce	8.7	35.8 mm	300	1.000%	9%
LYSO:Ce	2.0	23.0 mm	400	0.000%	9%
LYSO:Ce	1.1	12.2 mm	400	0.000%	9%

LYSO:Ce combines interesting features:
 • High density
 • Suitable τ_{decay} for PET
 • Good scintillation performance
 • Grown by Controlled Growth technique

Possible Improvements:
 • Faster Decay Time
 • Lower Afterglow

Consequences of co-doping

Performance improvement:
 • Increased light yield
 • Reduced decay time
 • Reduced afterglow

Proposed explanation:
 • Increased light yield due to charge compensation
 • Reduced decay time due to charge compensation
 • Reduced afterglow due to charge compensation

Limits of standard co-doping:
 • Uncontrolled co-doping method
 • Bad crystal growth leading to spiral shape
 • Checks more likely to succeed

Possible explanation:
 • Reduced surface tension due to low density (LYSO:Ca Mg)

Solutions and improvements (3rd Generation LYSO)

Optimized composition

Optimized doping and no-doping systems:
 • Optimizing doping in 3rd Gen by using the growth technique
 • Optimizing the ratio of the dopants
 • Optimizing the growth technique
 • Optimizing the crystal quality

Performance improvement

Composition	Decay Time	Light Yield	Afterglow
LYSO:Ce	~100 ns	~20,000	~10%
LYSO:Ce,Ca	~100 ns	~25,000	~5%
LYSO:Ce,Ca,Mg	~100 ns	~30,000	~2%

Controlled Growth

Progressive optimization of the composition:
 • Improved crystal growth
 • High quality material with enhanced performance

Conclusions & Perspectives

Improvements and Limitations with standard co-doping:

- Increased light yield, decay time and afterglow
- Distribution of Ca²⁺ for charge compensation
- Uncontrolled co-doping leads to bad crystal growth
- Inhomogeneous performance (composition is required)

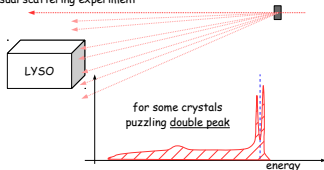
The stabilizing agent technique

- Addition to growth issues with high co-doping
- Source of oxygen during the growth
- No significant pollution to impact scintillation
- Better preparation for scintillator preparation

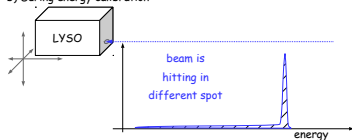
3rd GENERATION LYSO

- Light yield better than 20000 Ph (BEP), 40000 Ph
- Decay time lower to 30 ns (40000 Ph)
- Afterglow similar to the commercial GSO scintillator
- 3rd GEN option for the medical PET or CT systems

a) Usual scattering experiment



b) During energy calibration



**Next Generation
LYSO:Ce,Ca Single Crystals**

S. Blahuta¹, V. Ouspenski¹, P. Menge², K. Yang²

¹ Saint-Gobain Prelude, ² Jülich Forschungszentrum

Context

LYSO:Ce for Positron Emission Tomography (PET)

Locality	Type	Volume	Light Yield	Decay Time	Energy Res.
100%	100%	100%	4000	400	10%
LYSO:Ce	8.7	35.8 mm	300	1.000	9%
LYSO:Ce	2.0	23.8 mm	420	900	9%
LYSO:Ce	1.1	32.2 mm	420	900	9%

LYSO:Ce combines interesting features:
 • High density
 • Suitable τ_{decay} for PET
 • Good scintillation performance
 • Grown by Controlled Growth technique

Possible Improvements:
 • Faster Decay Time
 • Lower FWHM

Consequences of co-doping

Performance improvement:
 • Higher light yield
 • Lower decay time
 • Better energy resolution

Proposed explanation:
 • Lower defect trapping rate
 • Higher scintillation efficiency
 • Charge compensation
 • Compensation band gap

Limits of standard co-doping:
 • Uncontrolled co-doping content
 • Bad crystal growth leading to spiral shape
 • Checks more likely to succeed

Possible explanation:
 • Reduced surface stresses due to low density (LYSO:Ce Mg)
 • Reduced surface stresses due to low density (LYSO:Ce Mg)

Solutions and improvements (3rd Generation LYSO)

Optimized composition

Optimal doping and no-doping systems:
 • Doping species in 3d⁰ configuration during the growth
 • Compensation in the lattice site
 • Charge compensation
 • Compensation for the growth
 • Better quality crystals

Performance improvement

Composition	Decay Time	Light Yield	Energy Res.
LYSO:Ce	~400 ns	~3000	~10%
LYSO:Ce,Mg	~300 ns	~4000	~9%
LYSO:Ce,Mg	~250 ns	~4500	~8%
LYSO:Ce,Mg	~200 ns	~5000	~7%

Controlled Growth

Progressive optimization of the composition:
 • Improved crystal growth
 • High quality material with enhanced performance

Conclusions & Perspectives

Improvements and Limitations with standard co-doping:

- Reduced light yield, decay time and FWHM
- Distribution of Ca²⁺ for charge compensation
- Uncontrolled co-doping leads to bad crystal growth
- Inhomogeneous performance (compensation is required)

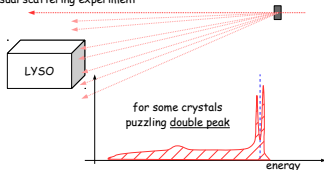
The stabilizing agent technique

- Addition to growth issues with high co-doping
- Source of oxygen during the growth
- No significant pollution to impact scintillation
- Better preparation for excellent preparation

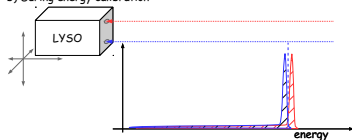
3rd GENERATION LYSO

- Light yield better than 4000 Ph (300 Ph, 400 Ph)
- Decay time lower than 300 Ph (300 Ph, 400 Ph)
- Energy similar to the commercial LYSO crystals
- 3d⁰ solution for the standard PET or CT systems

a) Usual scattering experiment



b) During energy calibration



SAINT-GOBAIN PRELUDE™ 420 (LYSO)

SAINT-GOBAIN CRYSTALS

Next Generation LYSO:Ce,Ca Single Crystals

S. Blahuta¹, V. Ouspenski¹, P. Menge², K. Yang²

¹ prelude@stg.com

1 Saint-Gobain Precedence, 42000 LORRE, FRANCE
2 Saint-Gobain Crystals, 44100 CHA, USA

Context

LYSO:Ce for Positron Emission Tomography (PET)

Locality	Type	Volume	Height/Width	Energy	Scatter Ratio
100	1	20.0 mm	400	0.025	10%
LYSO:Ce	0.2	20.0 mm	300	1.000	9%
LYSO:Ce	0.4	20.0 mm	400	0.020	9%
LYSO:Ce	0.1	20.0 mm	400	0.020	9%

LYSO:Ce combines interesting features:
- High density
- Suitable ρ_{MOSI} for PMTs
- Good scintillation performance

Grown by Controlled Growth technique

Possible Improvements:
- Faster Decay Time
- Lower Afterglow

Consequences of co-doping

Performance improvement:
- Lower afterglow
- Higher light yield
- Higher energy resolution

Proposed explanation:
- Lower afterglow due to charge recombination
- Higher light yield due to charge recombination
- Higher energy resolution due to charge recombination

Mechanism of co-doping:
- Red color growth leading to rapid decay
- Charge recombination

Possible explanation:
- Reduced surface recombination due to low energy (LYSO:Ce: Mg)

Solutions and improvements (3rd Generation LYSO)

Optimized composition

Optimized doping and co-doping systems:
- Optimizing doping by 3D mapping and during the growth
- Optimization of the initial dose
- Optimization of the growth conditions
- Optimization of the growth rate

Performance improvement

Composition	Decay Time	Energy Res.	Light Yield
LYSO:Ce	~200 ns	~10%	~20,000
LYSO:Ce:Ca	~100 ns	~5%	~25,000
LYSO:Ce:Ca:Mg	~50 ns	~2%	~30,000

Controlled Growth

Progressive optimization of the composition:
- Improved initial growth
- High quality material with enhanced performance

Conclusions & Perspectives

Improvements and Limitations with standard co-doping:

- Reduced light yield, decay time and afterglow
- Introduction of Ca for charge compensation
- Uncontrolled co-doping leads to fast crystal growth
- Inhomogeneous performance (composition to regulate)

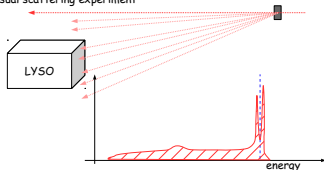
The stabilizing agent technique

- Addition to growth results with high co-doping
- Increase of oxygen during the growth
- No significant pollution to impact scintillation
- 100% possibilities for excellent preparation

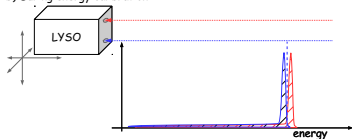
3rd GENERATION LYSO

- Light yield better than 20000 Ph (MPP: 400 keV)
- Decay Time lower to 30 ns (MPP: 400 keV)
- Afterglow similar to the commercial LYSO crystals
- 0.5 MPP option for the standard PET or CT systems

a) Usual scattering experiment



b) During energy calibration



c) Different hypotheses

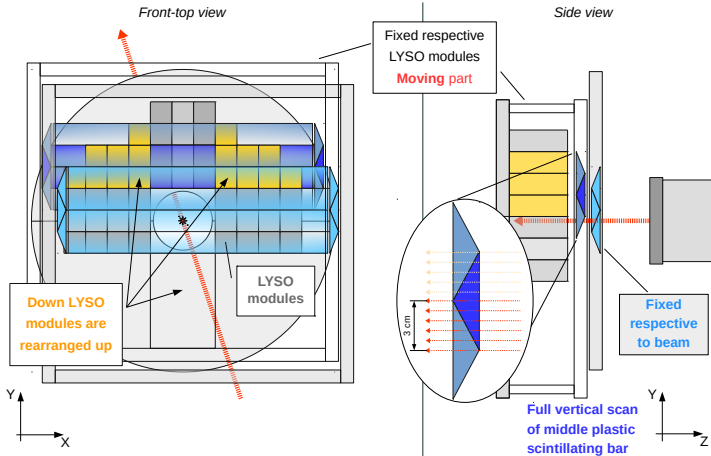


We spend <3 days of March beam time to clarify this problem very successfully!

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

PLASTIC SCINTILLATOR TRACKER

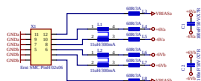
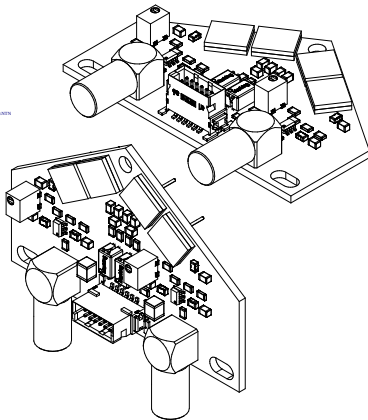
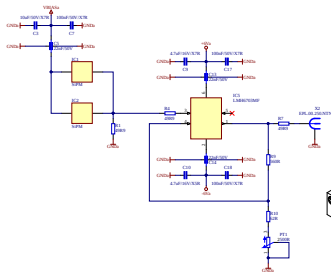
Consisting of the overlapping triangular scintillator bars. The upstream (forward) frame is installed to be fixed vertically relative to the beam while the downstream (backward) frame can scan the beam. All scintillators were scanned vertically and horizontally (along the bar).



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



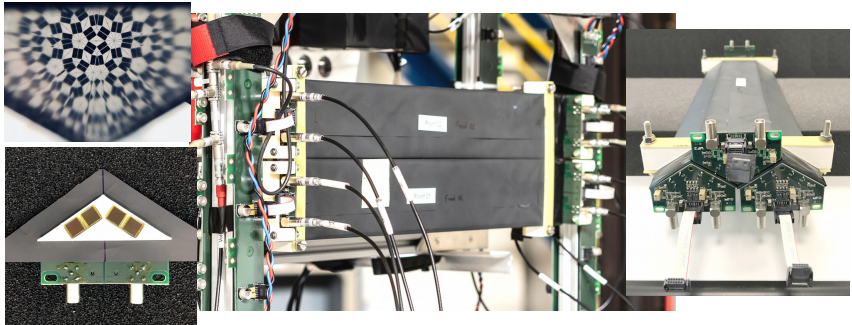
PLASTIC SCINTILLATOR TRACKER

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.

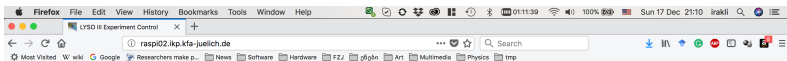
Middle: already attached tracker in front of LYSO modules.

Right: one of the layers with three bars after assembly.



SLOW CONTROL SYSTEM

Controls all movements



LYSO III Experiment Status

Actuators

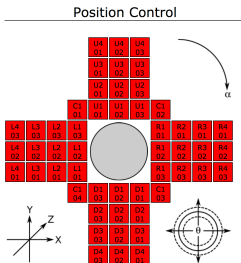
- α-Rotation: online
- Start Counter: online
- Target Driver: online
- X-Axis: online
- Y-Axis: online
- Z-Axis: online

Positioning

- α-Rotation: 55 °
- Θ-Coverage: 15 °
- X-Offset: 299 mm
- X-Position: 0 mm
- Y-Offset: 268 mm
- Y-Position: 0 mm
- Z-Offset: 0 mm
- Z-Position: 0 mm

Target

- Active Target: Silicon
- Start Counter
- Status: out of the beam
- Voltage: 0 V



Position Control

Θ-Coverage: [10 ° - 20 °] Set

X-Position: [-299 mm - 263 mm] Set

Y-Position: [-268 mm - 311 mm] Set

Z-Position: [0 mm - 570 mm] Set

Target Control

Empty Target	Nickel
Carbon	Tin
Aluminum	Silicon
Magnesium	Polyethelene

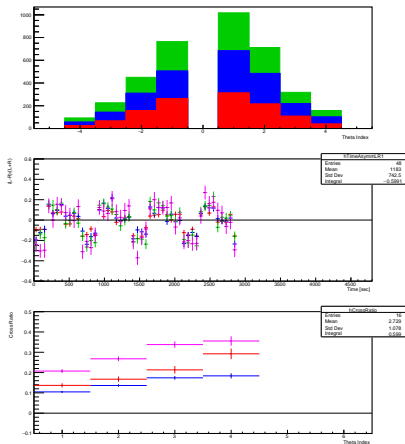
Start Counter

Position: Move Start Counter In

Voltage: [0 V - 1200 V] Set

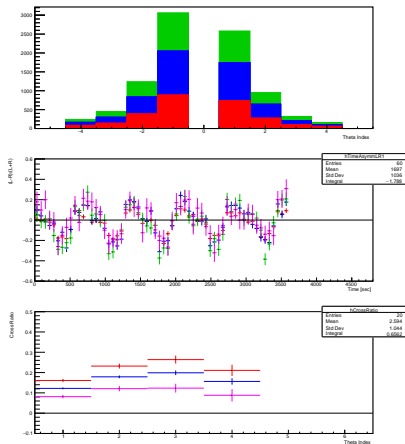
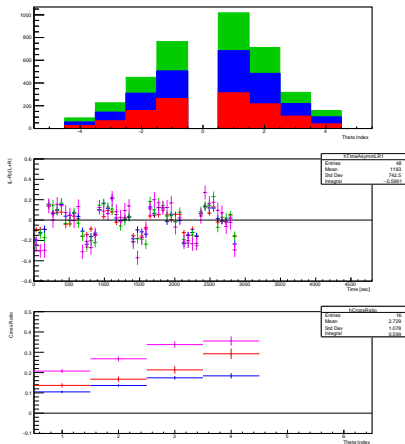
ASYMMETRY

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



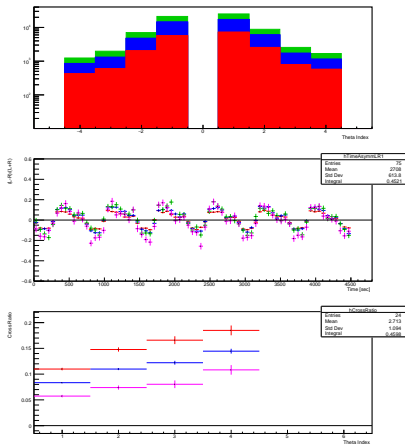
ASYMMETRY

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



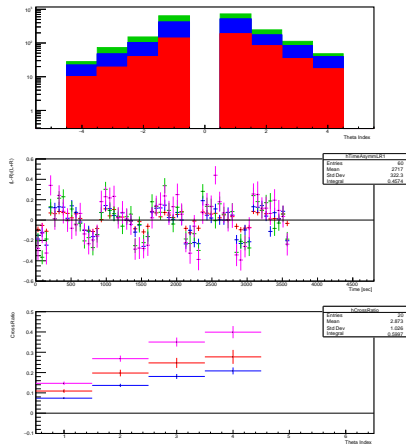
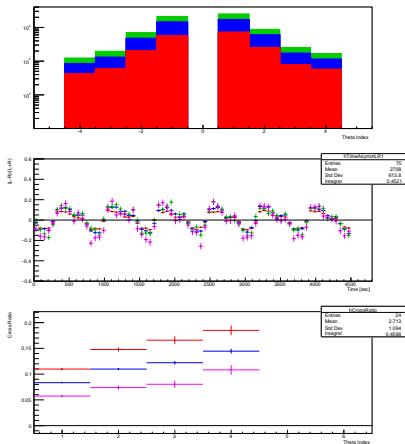
ASYMMETRY

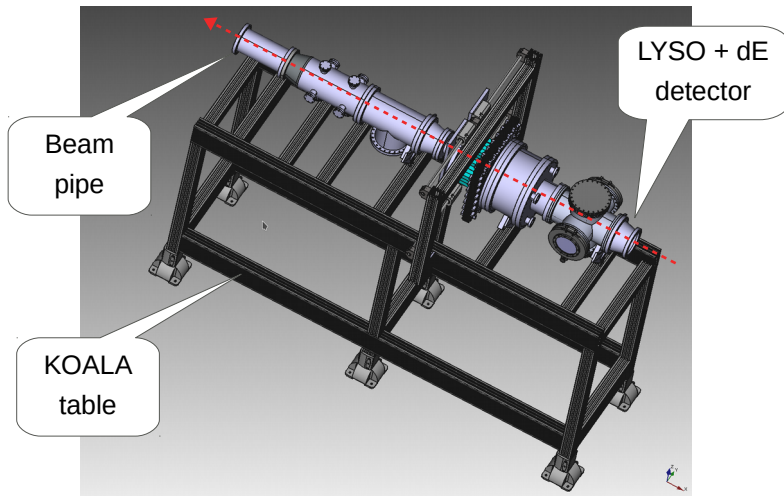
Different target materials (left Nickel; right Tin)

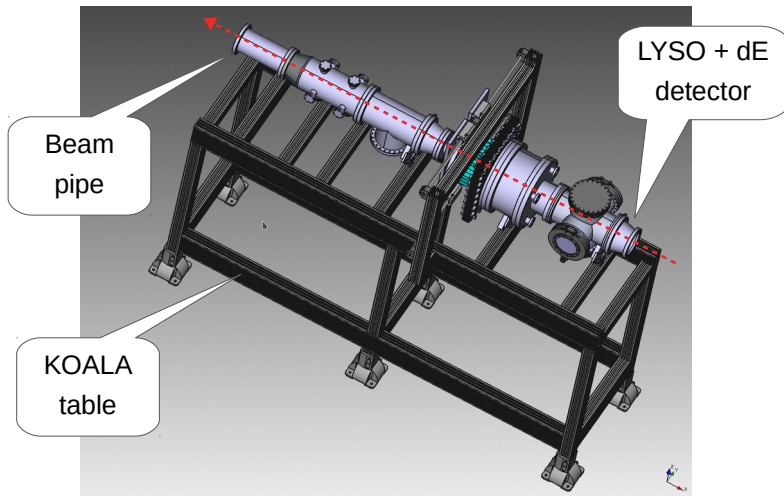


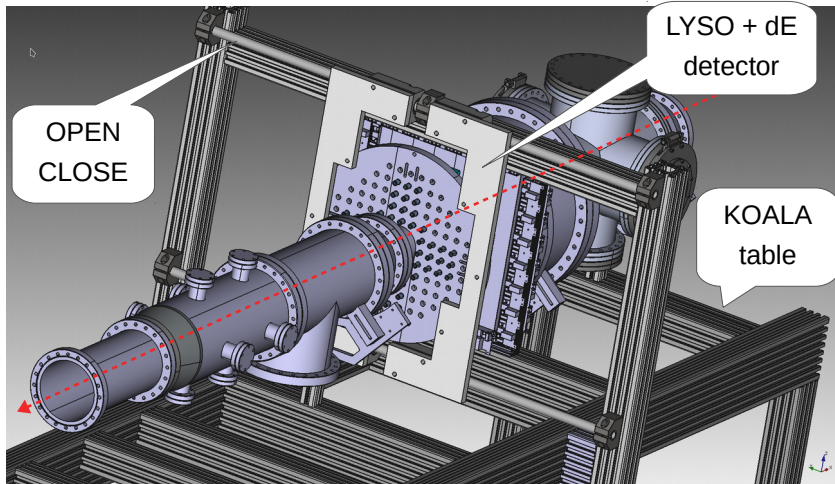
ASYMMETRY

Different target materials (left Nickel; right Tin)









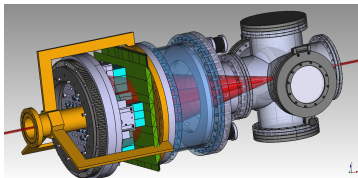
ACKNOWLEDGMENT

People contributing to the experiment

- Mechanics: N. DeMary, M. Maubach, G. D'Orsaneo & D. Spölgem
- Electronics: Tanja Hahnrahts-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**



Appendix

CONTACT

Contacting me via e-mail

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GENERAL FORMALISM

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

$$\sigma^{\text{pol}}(\theta, \phi) = \sigma_0(\theta) \left[1 + \frac{3}{2} PA_y(\theta) \cos \phi + \left\{ \frac{1}{3} \sum P_{ij} A_{ij} \right\} \right]$$

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

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

