JÜLICH
FORSCHUNGSZENTRUM

Development of High Precision Polarimeter for the charged particle EDM Experiment

*on behalf of the **JEDI** collaboration*

TIPP 2017 | Beijing

May 23rd, 2017 | Irakli Keshelashvili |

Outline

- Mission of ***JEDI*** Collaboration
- **COSY** Accelerator Facility
- New Polarimeter Concept
- Experimental Results
- Summary

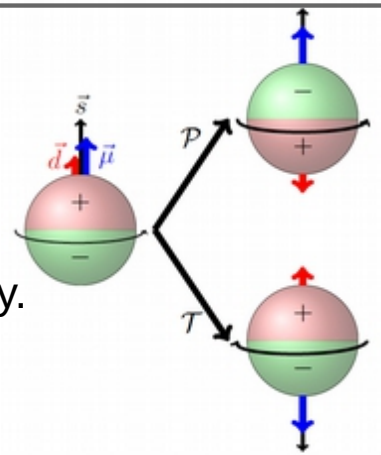
Jülich Electric Dipole moment Investigation

http://collaborations.fz-juelich.de/ikp/jedi/

> 100 members & different Institutes from 7 country

Logo

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.



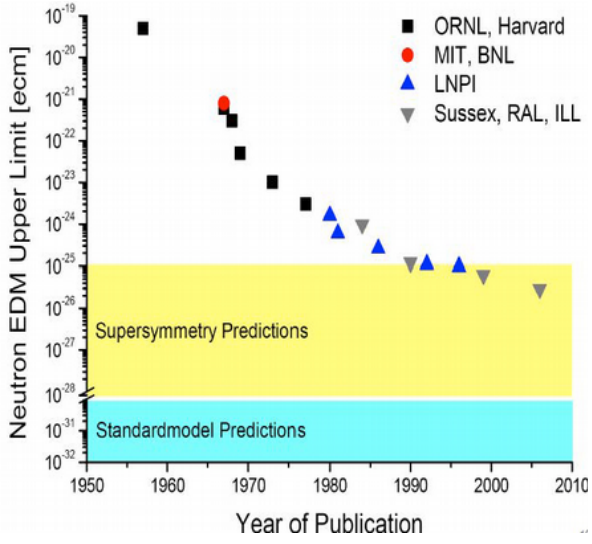
CP (K^o decays) violation means **T** is also violated assuming **CPT** symmetry.
The existence of a non-zero EDM is a violation of P and T simultaneously & the search for a EDM is a search for **CP** violation and a search for **direct T** symmetry violation.

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

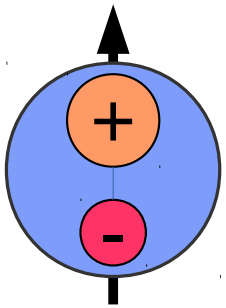
1) At least one N_B violating process.
2) C and CP violation
3) Interactions outside of thermal equilibrium.



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

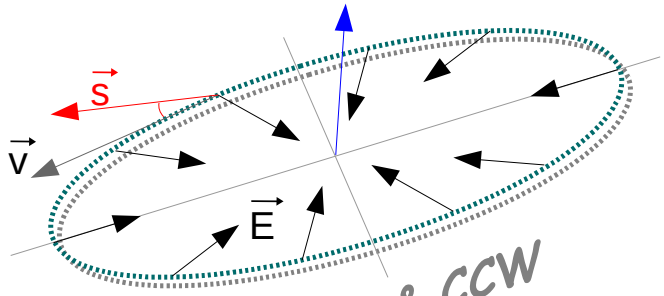
Member of the Helmholtz-Association

Storage Ring – srEDM



$\vec{d}$

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



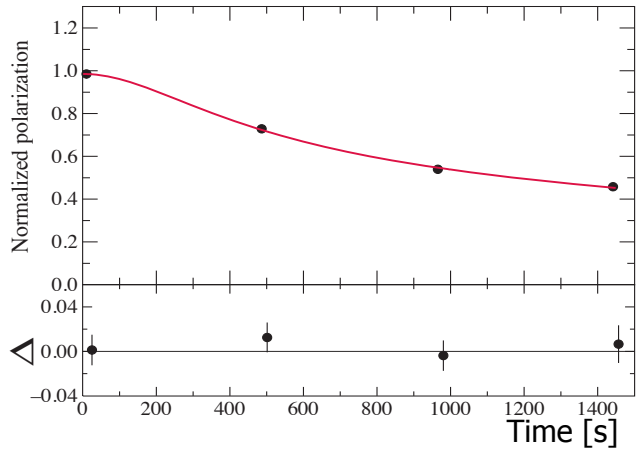
CW & CCW

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

Store polarized deuterons (COSY)

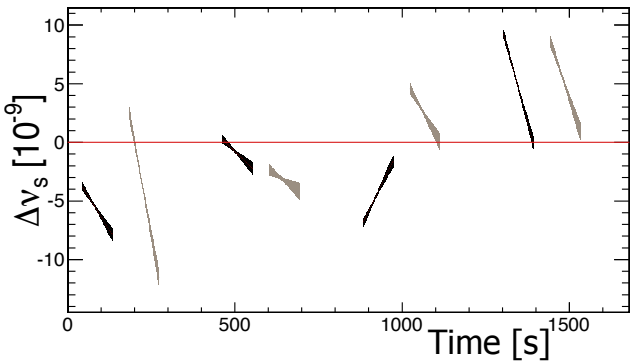
Phys. Rev. Lett. XXX (2017) **Feed-Back**
Phys. Rev. Lett. 117, 054801 (2016)
Phys. Rev. Lett. 115, 094801 (2015)
o o o

Interact with an E-field (*Wien-Filter*)



Analyze Polarization Build-up (this talk)

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



COSY Accelerator Facility

Cooler Sychrotron

Energy range (min.-- max.):

0.045 – 2.8 GeV (p)

0.023 – 2.3 GeV (d)

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

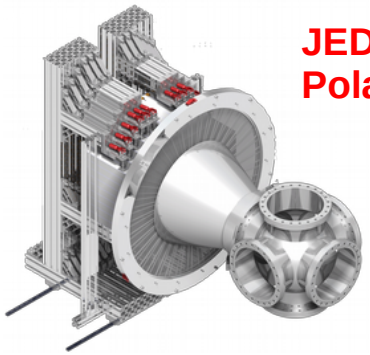
Electron & ***Stochastic*** cooling

Feed-forward machine

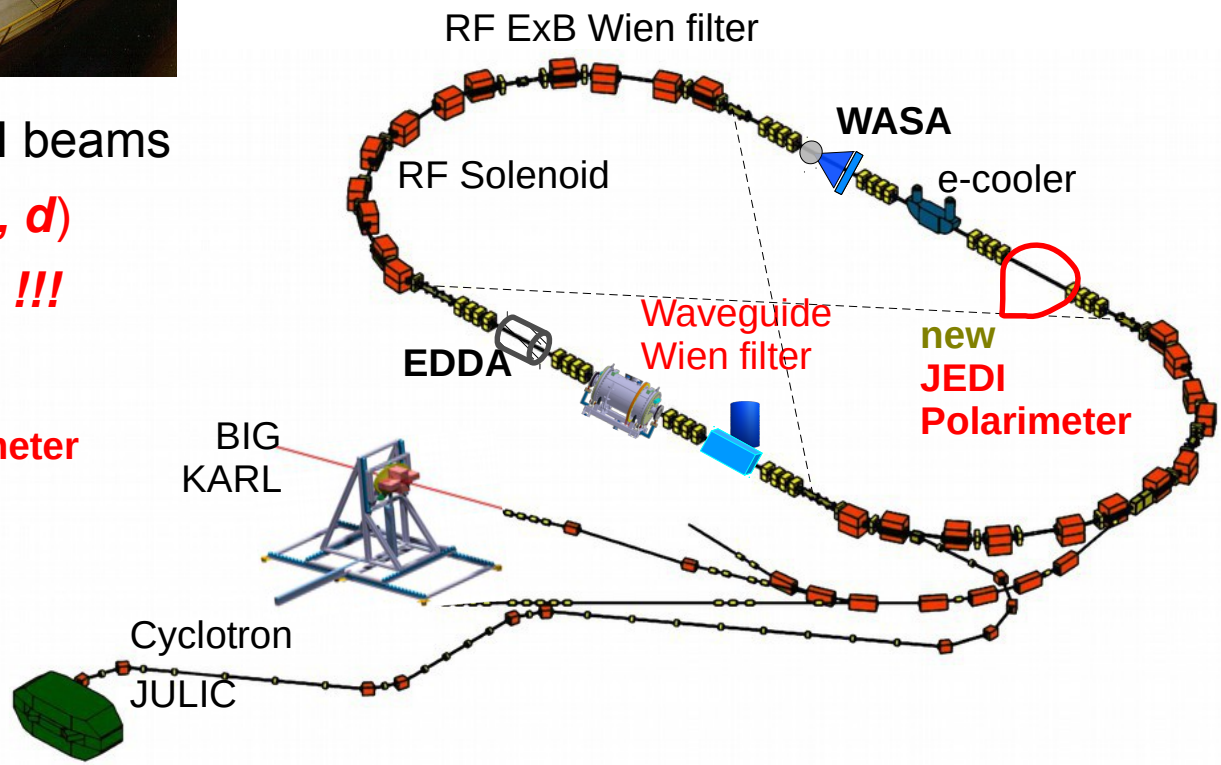
Internal and **external** beams

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

Spin manipulation !!!

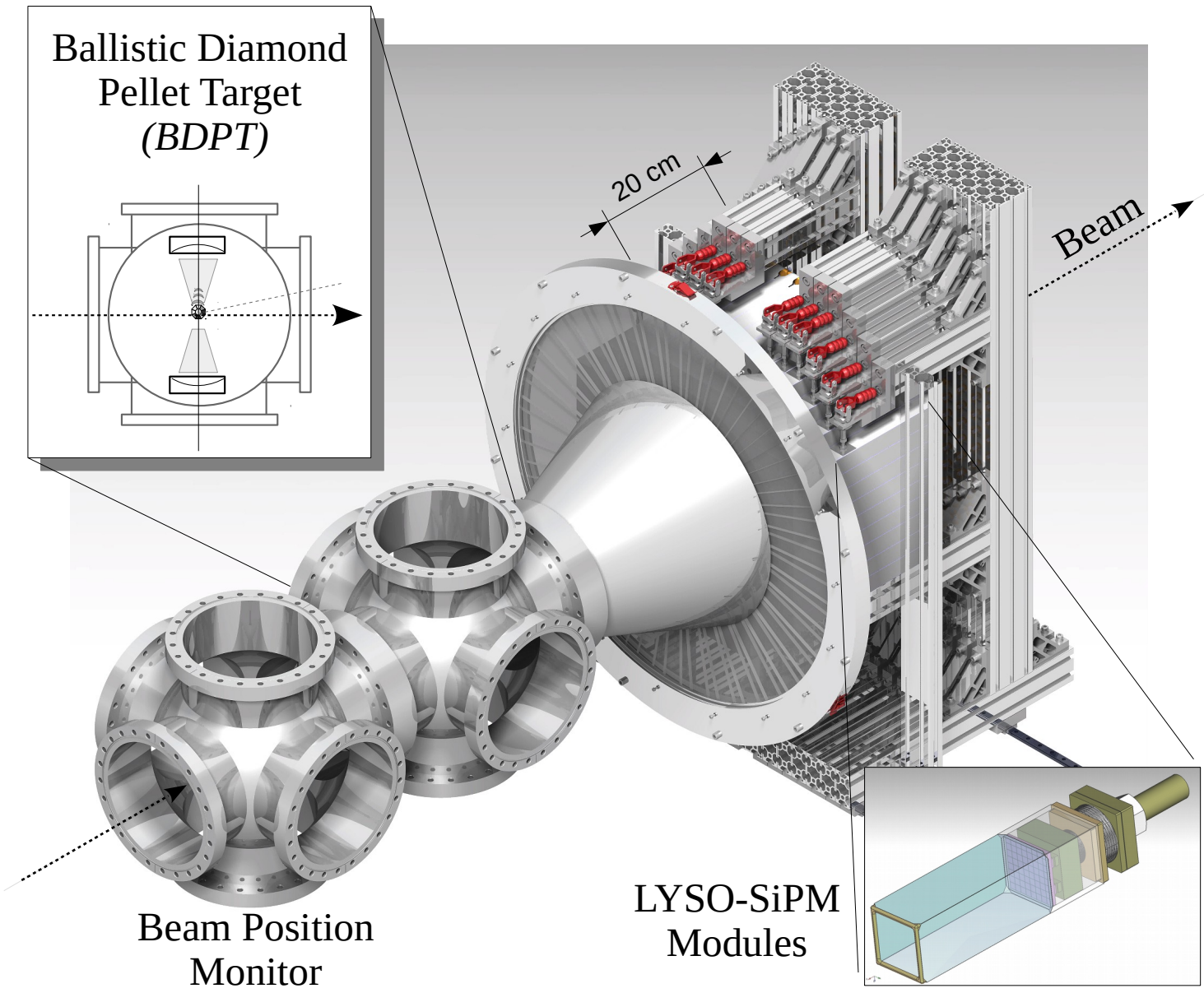


JEDI Polarimeter

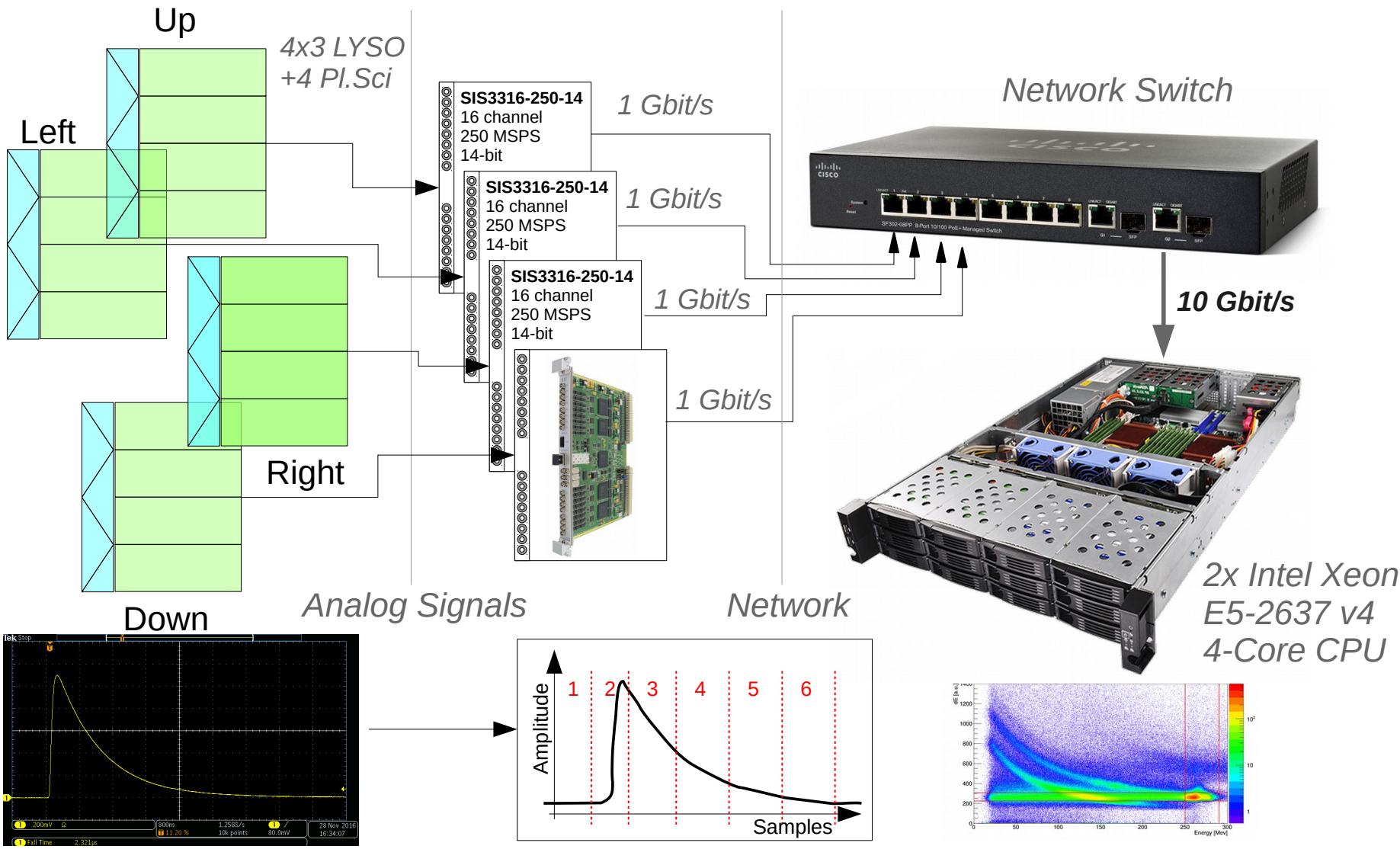


JEDI Polarimeter

High Precision Polarimeter Concept



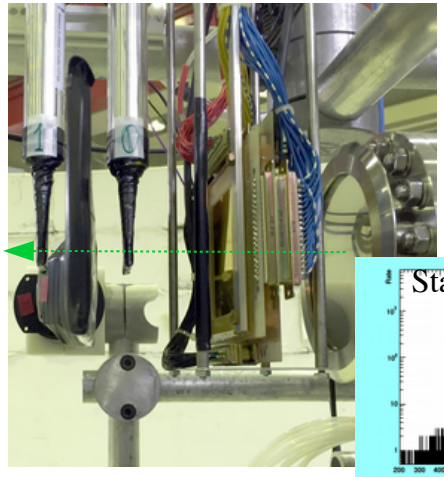
Data Acquisition System
Flash ADC Based System

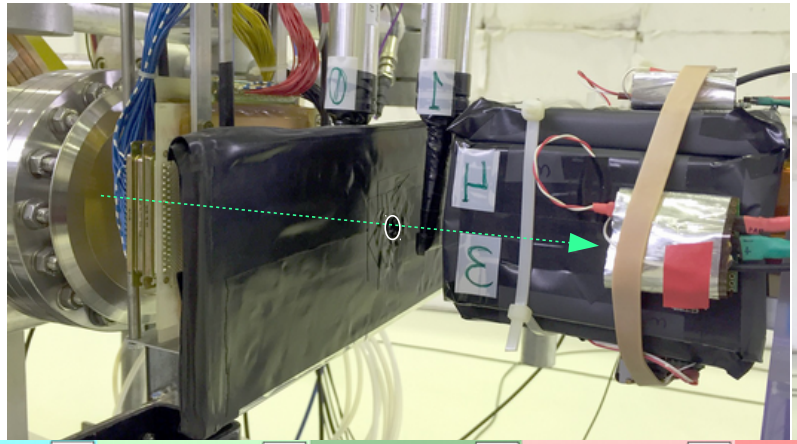


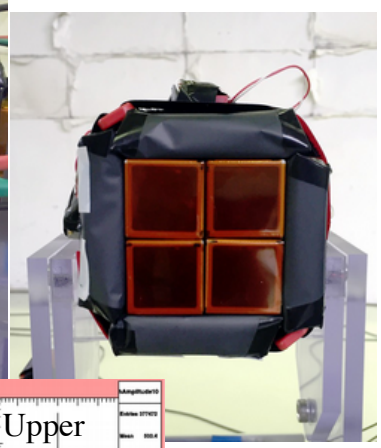
First Step: LYSO Crystal Test

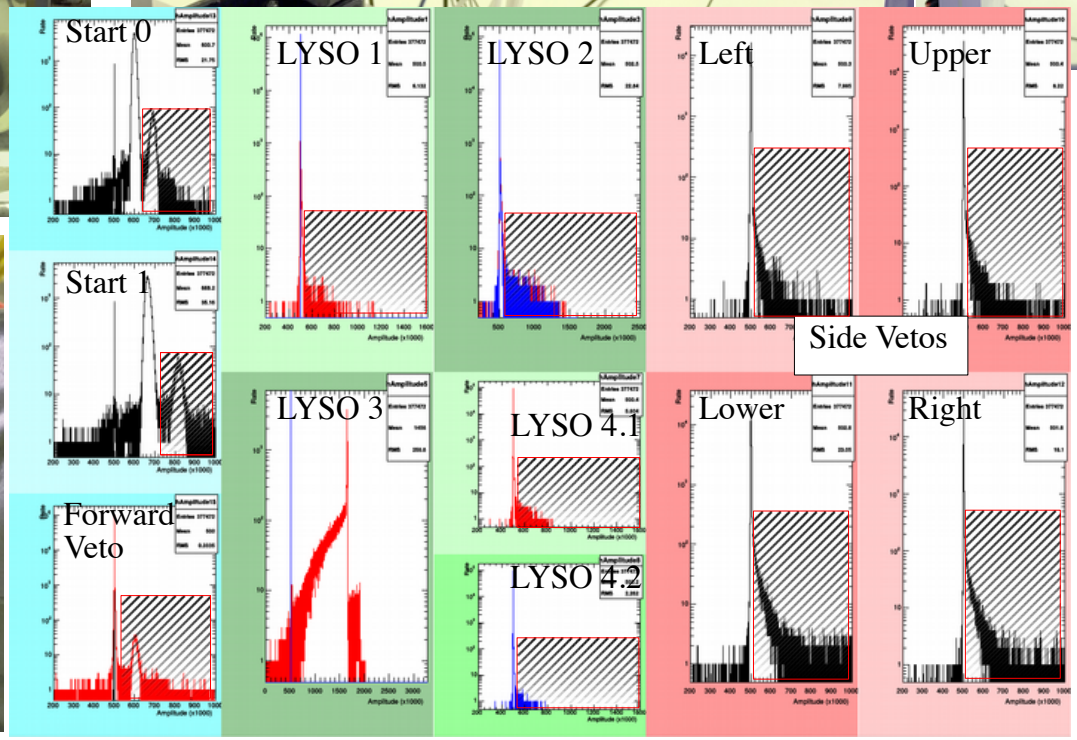
E-Linearity, E/T-Resolution, d-Efficiency, DAQ, Bragg Peak, Vendors,...

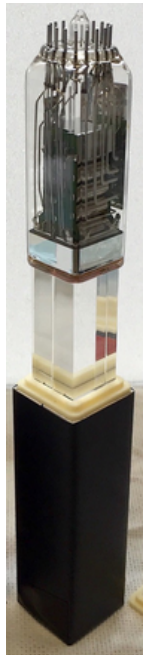
- rejected events





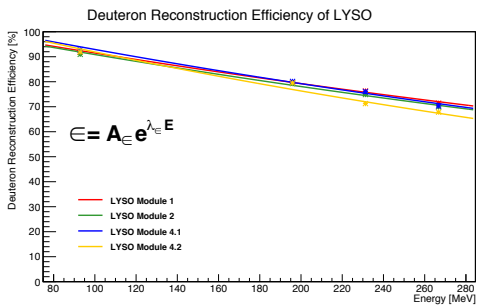


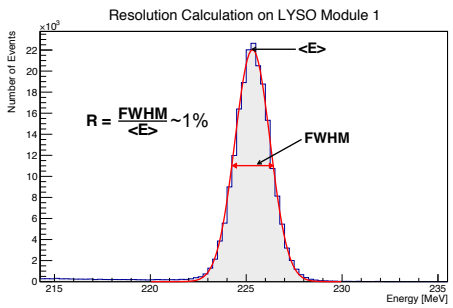


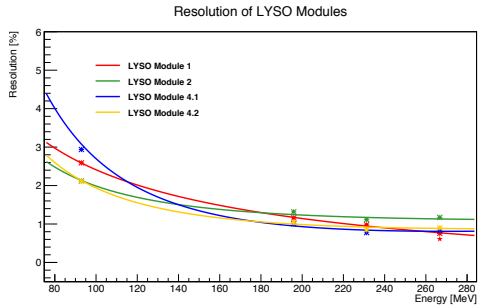


Results of LYSO Tests
Study of the LYSO Properties

- Test of FADC (250 MS/s, 14-bit) 'dead-time less' **DAQ** system
  Full signal shape were recorded
- Linearity of **particle energy** *vs.* **light output** up to 270 *MeV*
- Energy Resolution ($\frac{FWHM}{Amp} \sim 1\%$), time resolution $\Delta t \sim 300ps$
- *d* detection/reconstruction eff. @ 270 *MeV* drops ~ 70%
- Measuring Bragg-Peak by rotating split LYSO,
  peak @ 6 cm @ 270 *MeV* → crystal length 8 *cm* (can be flipped)
- Tests of Saint-Gobain and EPIC Crystals with **PMT & SiPM (C)**

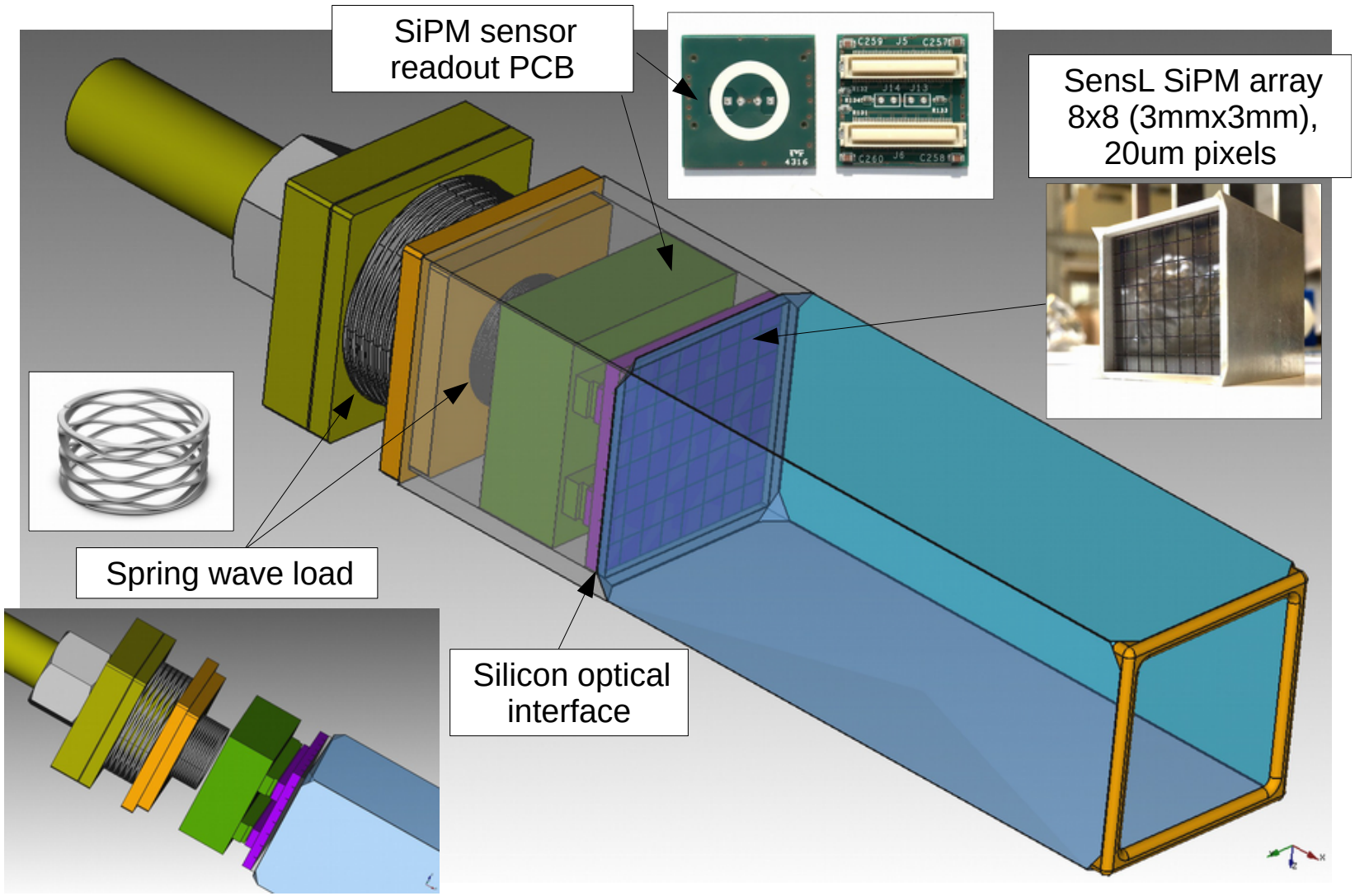






Second Step: New Modules

LYSO+SiPM Module Concept



24 x LYSO+SiPM Module

Tested December 2016/March 2017 Beam Time

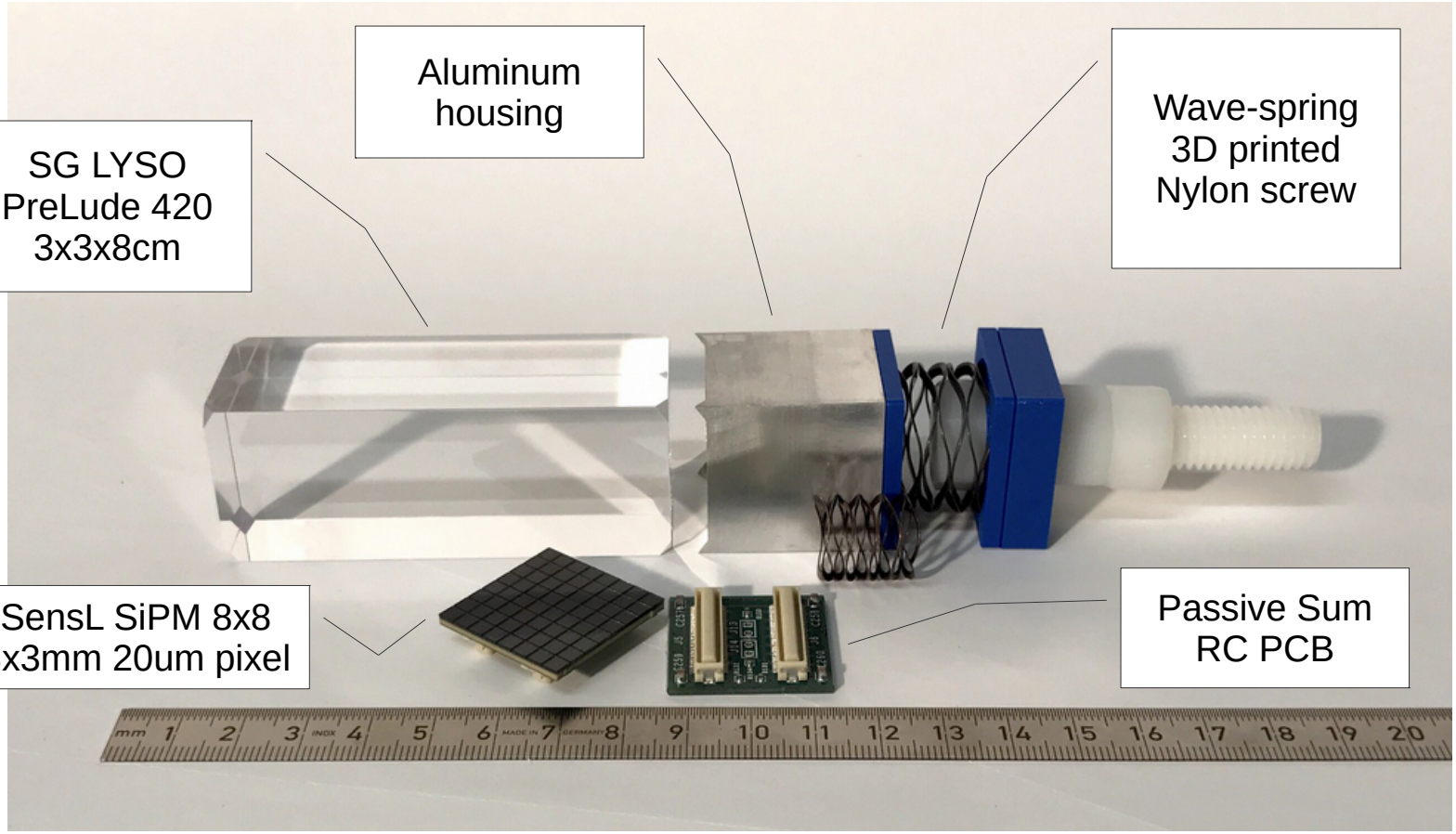
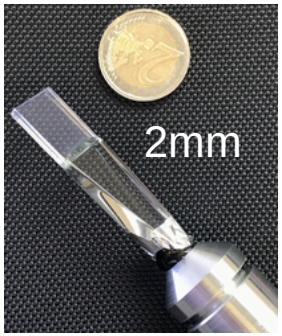
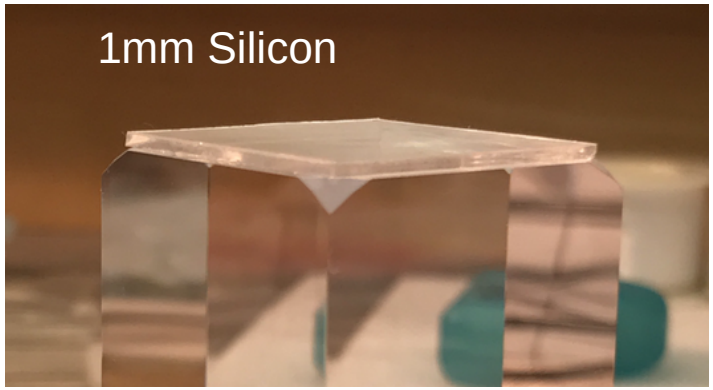
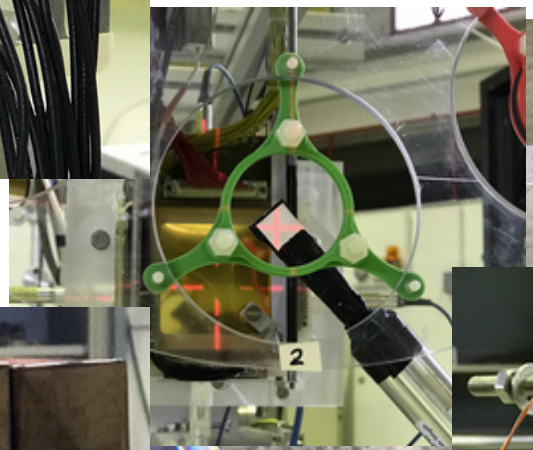
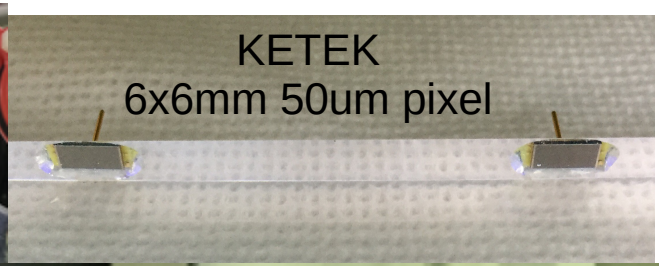


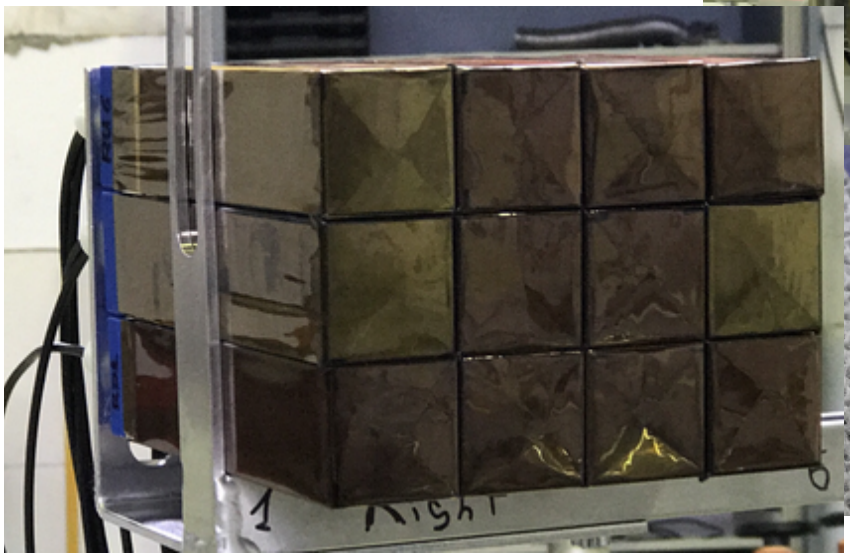
Photo Gallery

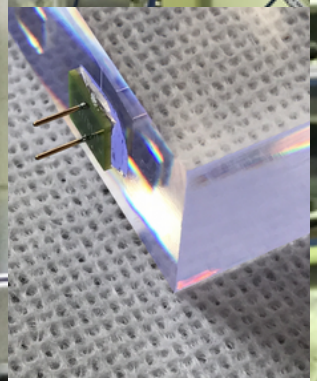


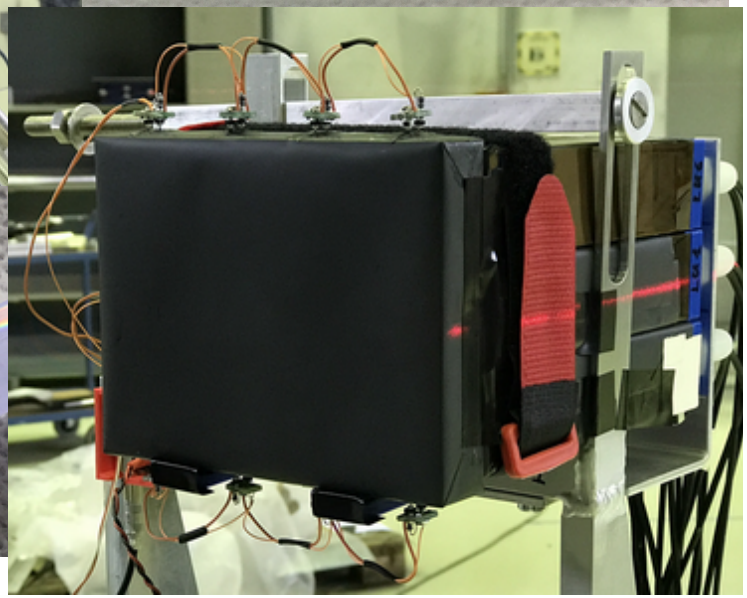








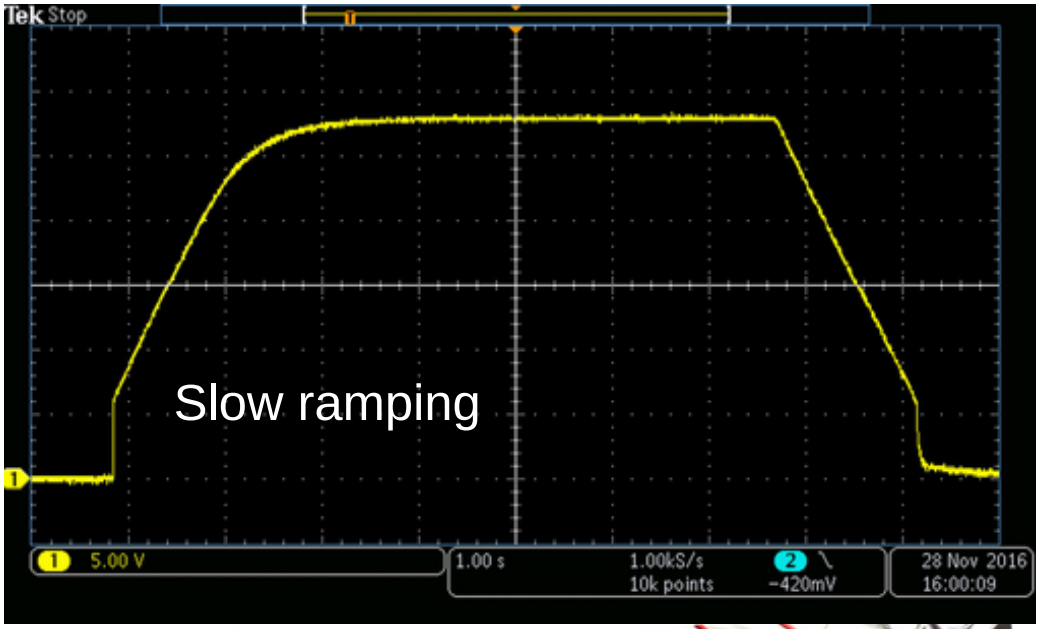


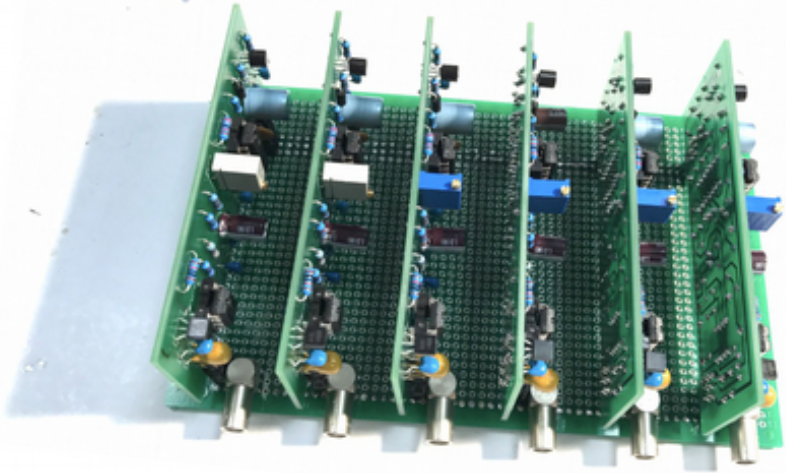


SiPM Voltage Supply

Very Good Long Term Stability ~ $1\mu V_{pp}$

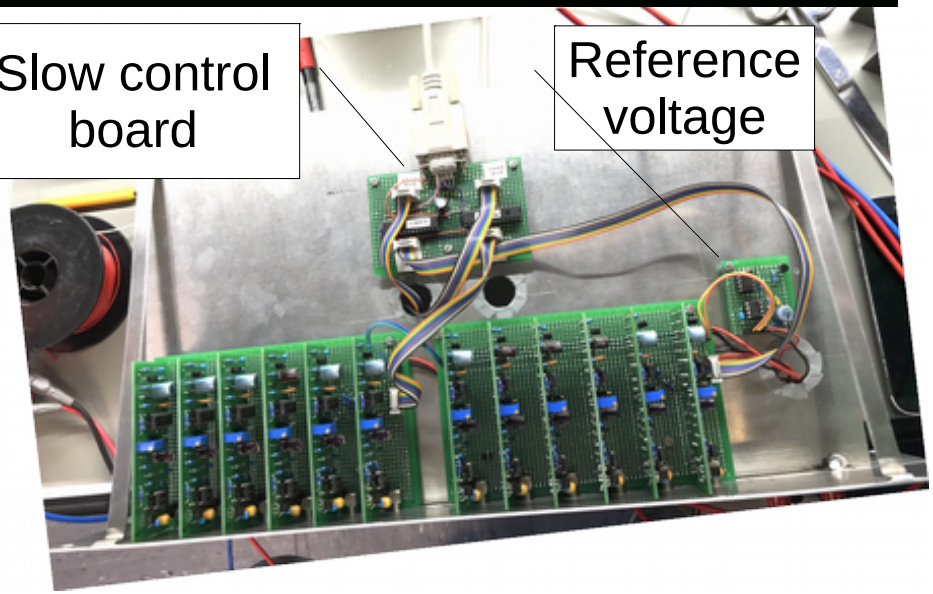
24 Channels





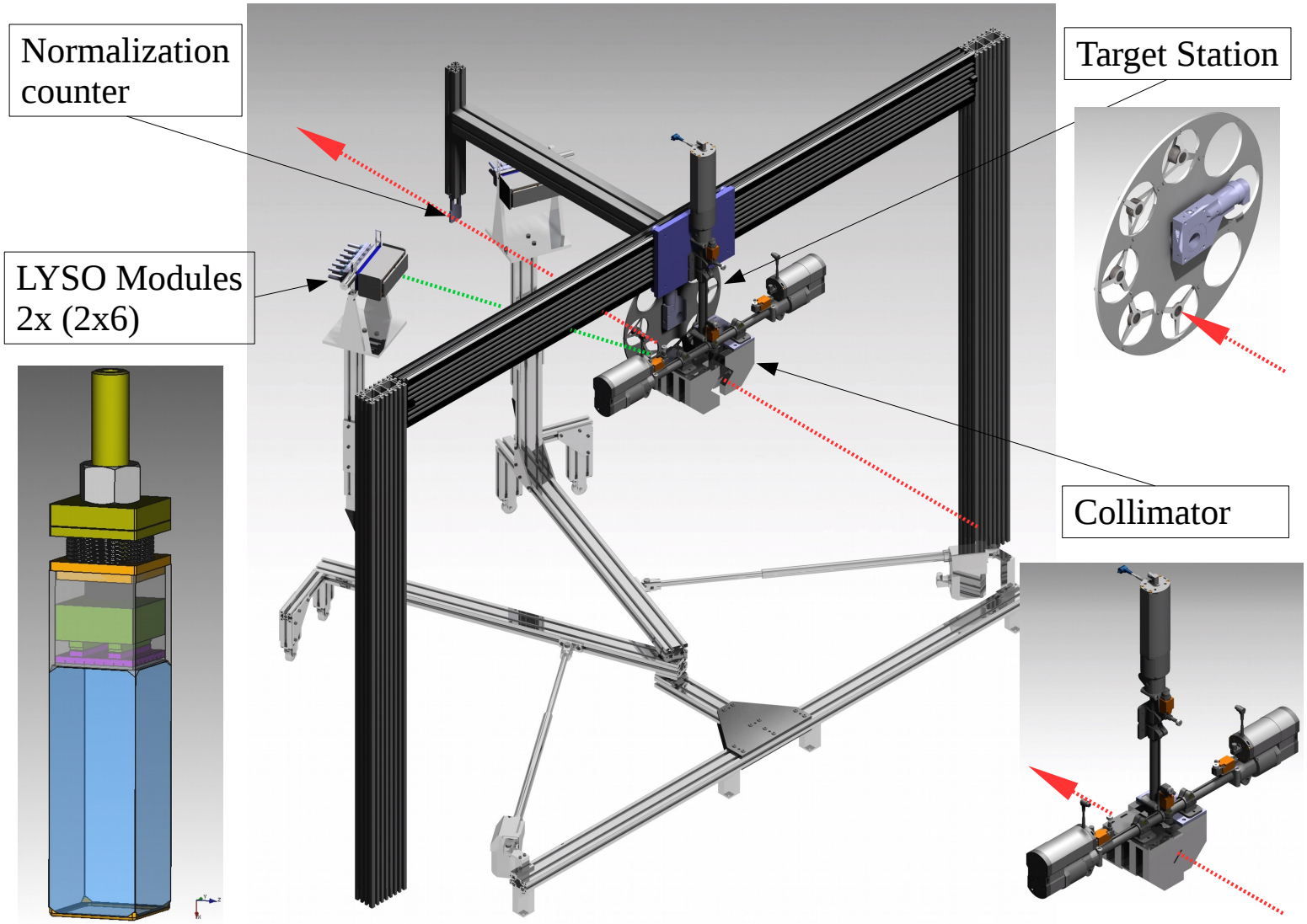
Slow control board

Reference voltage

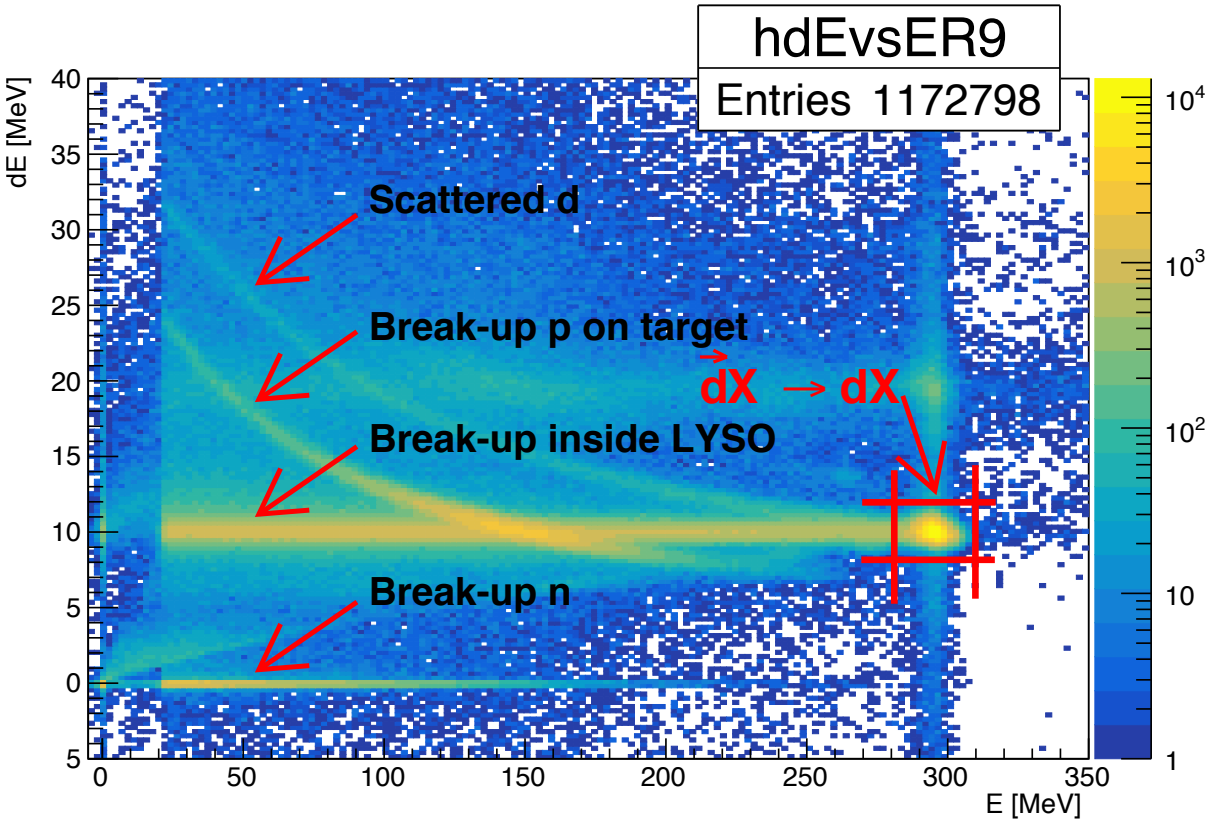


Experimental Setup

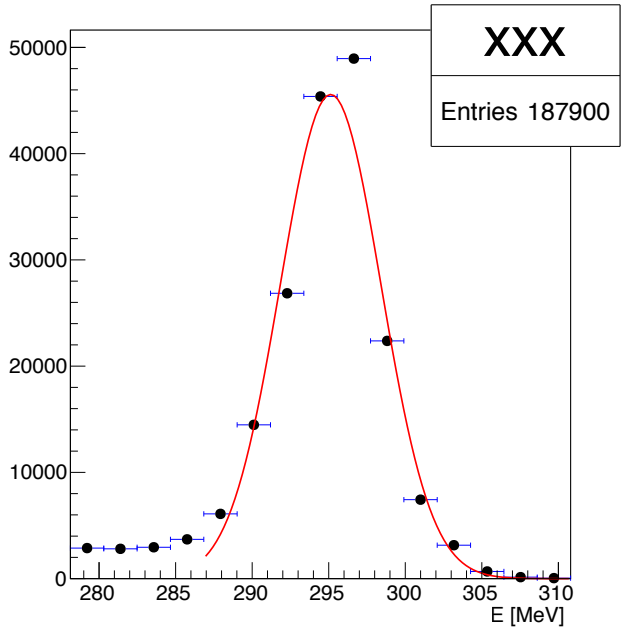
Asymmetry Measurements & Target Material Test



Event Selection
Online cuts



$$A_y(\theta) = \frac{\sigma^{\uparrow}(\theta) - \sigma^{\downarrow}(\theta)}{\sigma^{\uparrow}(\theta) + \sigma^{\downarrow}(\theta)}$$

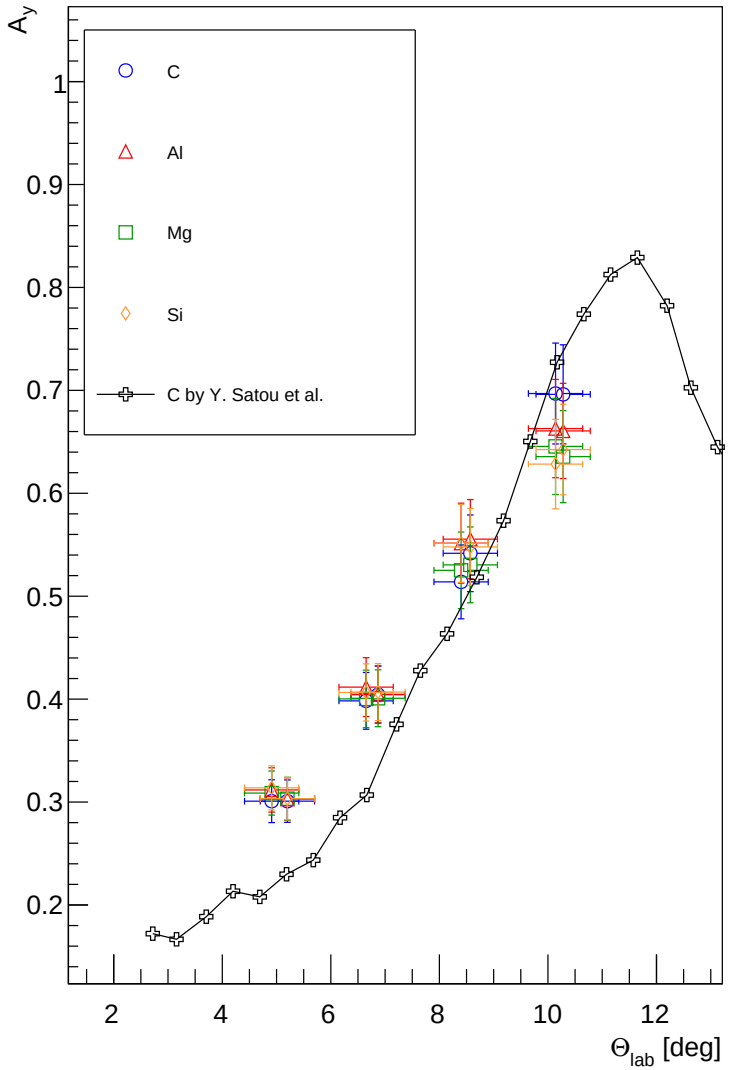


$$\sigma^{pol}(\theta, \phi) = \sigma_0(\theta)\left[1 - \frac{3}{2} P A_y(\theta) \sin\phi\right]$$

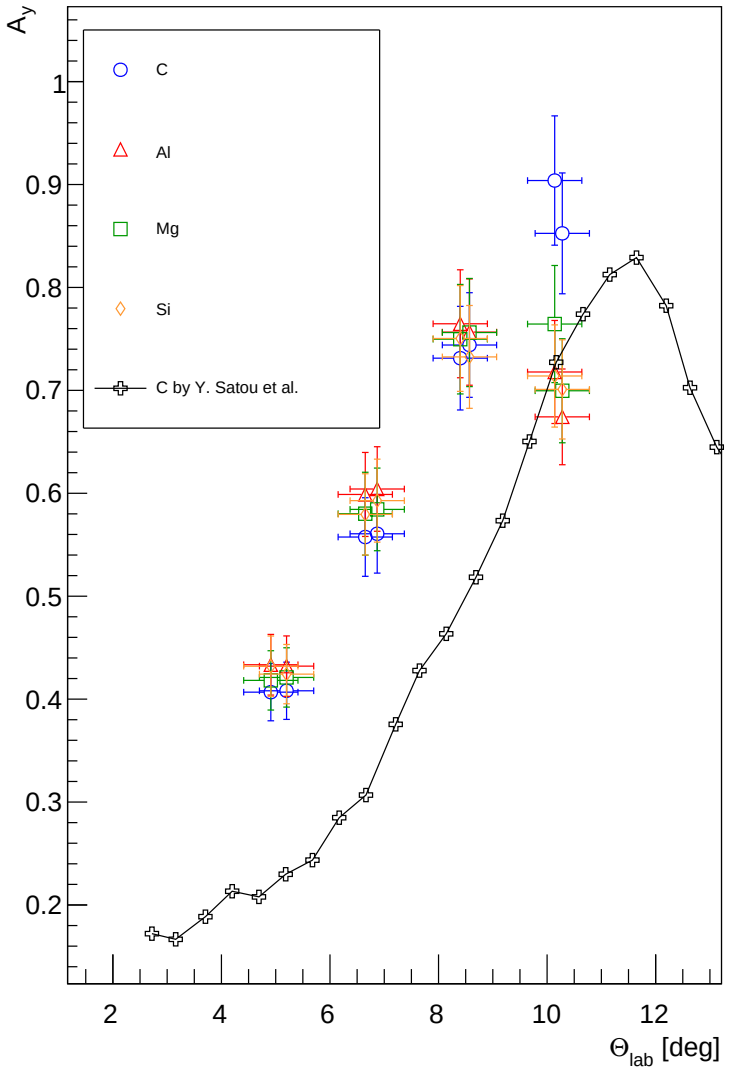
Preliminary Results

$A_y(\Theta)\ \ \vec{d}X \rightarrow dX$

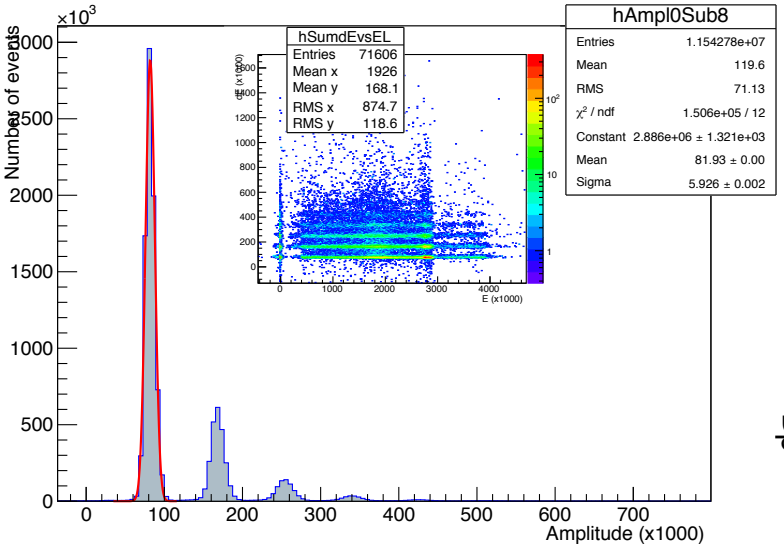
Vector Analyzing Power, Deuteron Scattering at 270 MeV



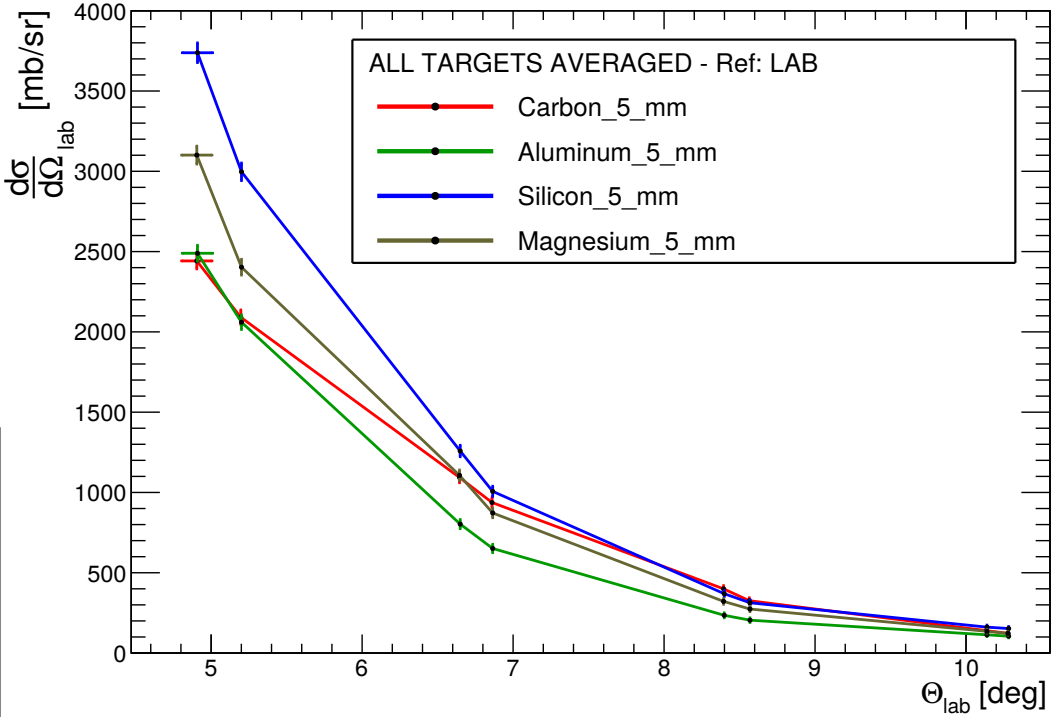
Vector Analyzing Power, Deuteron Scattering at 300 MeV

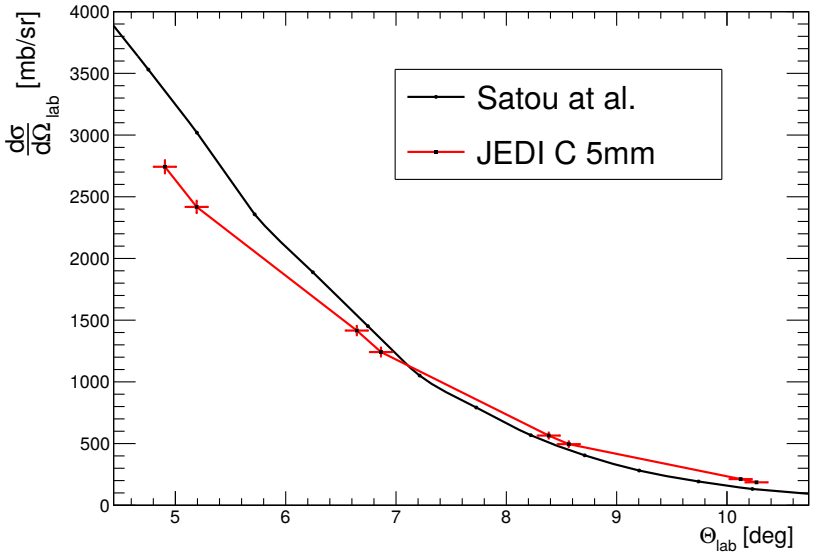


Preliminary Results



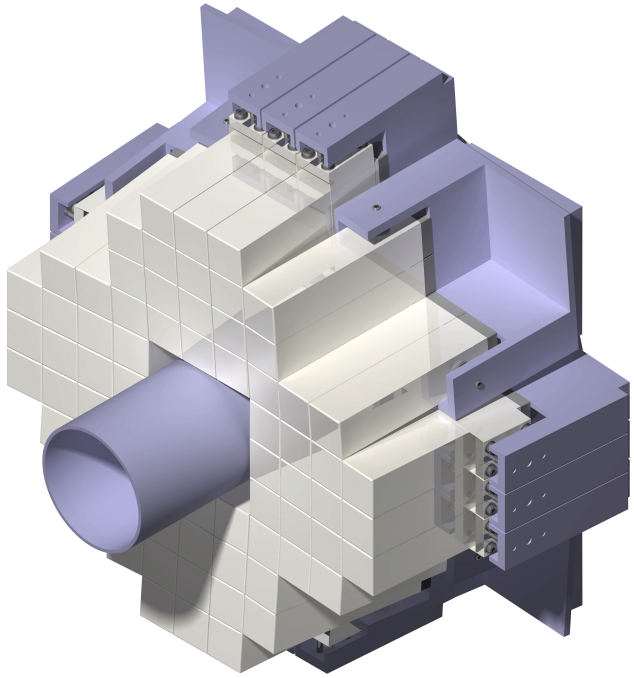
$\vec{d}X \rightarrow dX$ at $T_d = 300\ MeV$





$$FOM(\theta) = \sigma(\theta) \times A_y^2(\theta)$$

Summary



- We had 3 very successful beam times. Preparing 4^{th}, end of 2017 ☺
- LYSO-SiPM - Excellent Performance
- $\Delta E(x)$ Plastic scintillator modules are under development...
- New 24 modules will be assembled and tested in 2017 **in total 48 (4x12) Modules**
- **Now we have universal external beam experimental setup with various measurement possibilities.**

Appendix

Acknowledgment
People contributing to the experiment

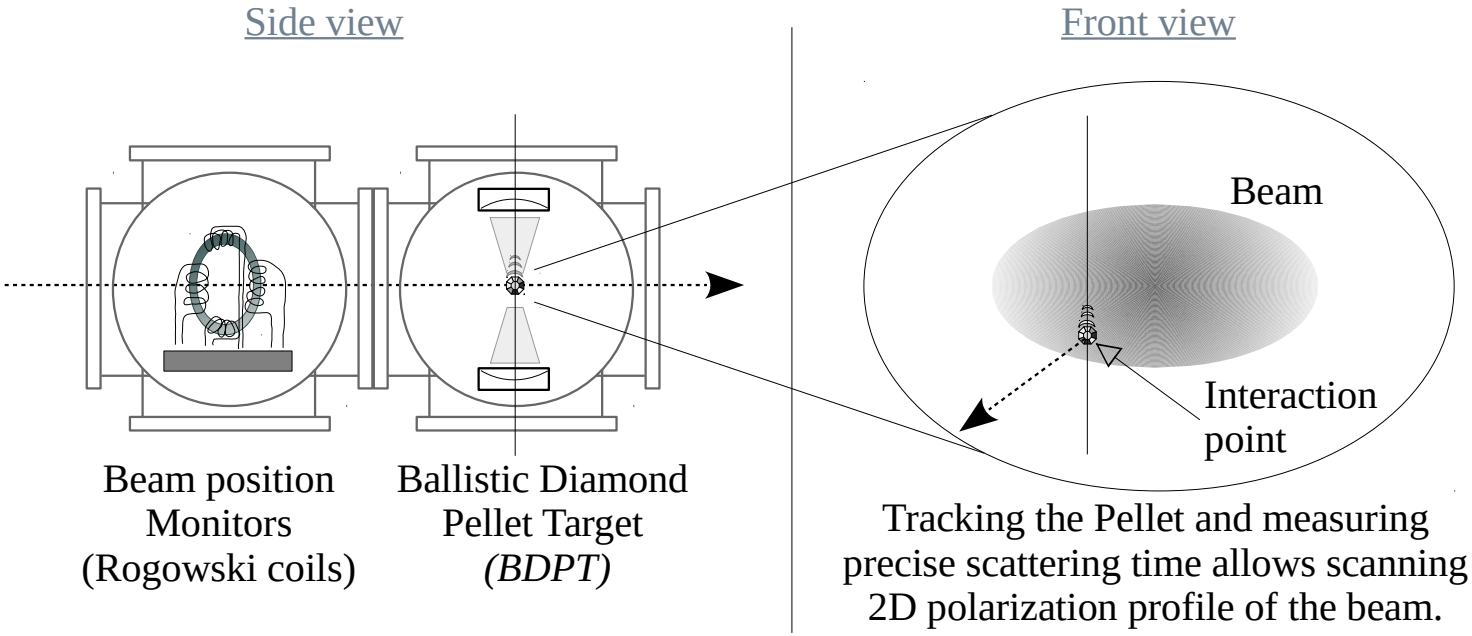
- **PhD: F. Müller, S. Basile, & D. Shergelashvili**
- Mechanics: N. Giese, M. Maubach, G. D'Orsaneo & D. Spölgen
- Electronics: Tanja Hahnraths-von der Gracht & T. Sefzick
- DAQ & FEE: D. Mchedlishvili, L. Barion & P. Wüstner
- G4: G. Macharashvili, P. Maanen & N. Lomidze
- **Ms & Bs: O. Javakhishvili,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

EDM – *Precision Experiment !!!*

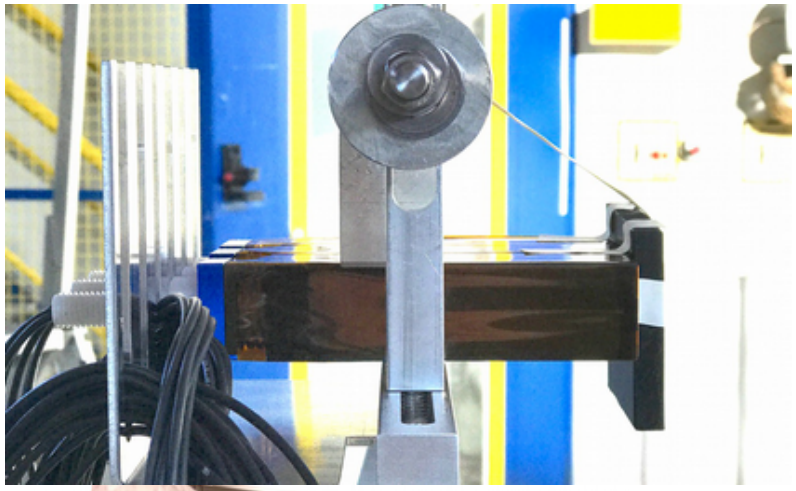
- Reaction with Large A_y: Best $dC \rightarrow dC$!!!
- Maximum Detection & Data Taking Efficiency !!!
- Full ϕ in Reasonable FOM(θ) region !!!
- No Magnetic / Electric Field !!!
- Stability – Long / Short Term !!!

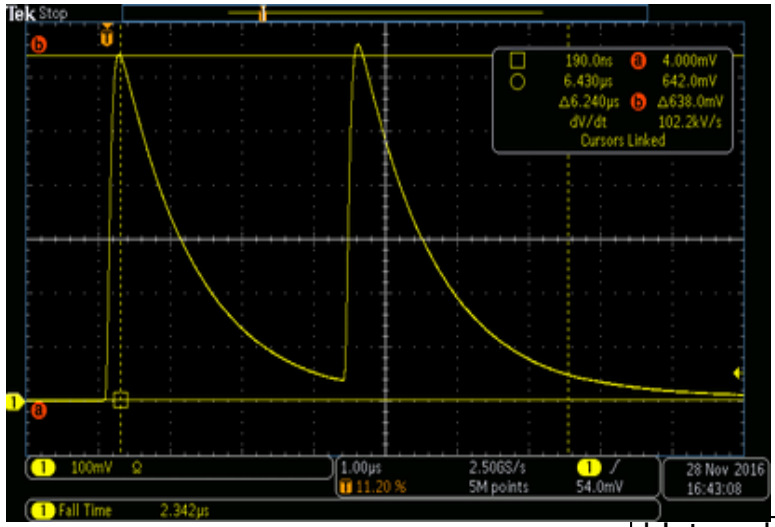
JuDiT
Jülich ballistic Diamond pellet Target

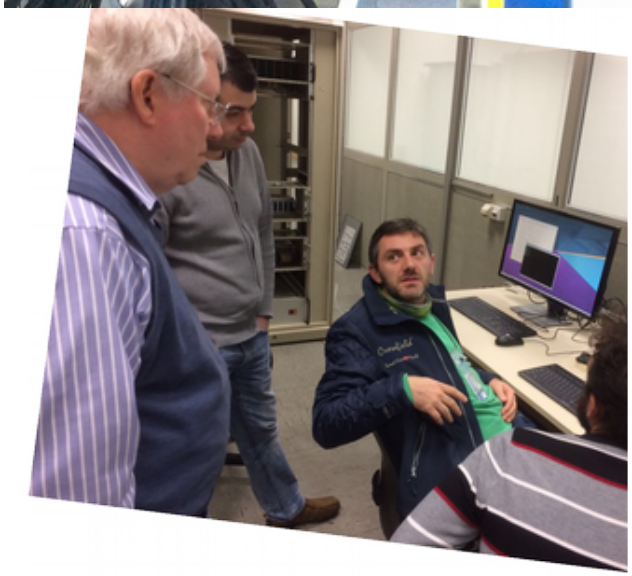
- Target capable to measure polarization profile
- Huge dynamic range in effective target thickness
- Non-invasive, no rest gas

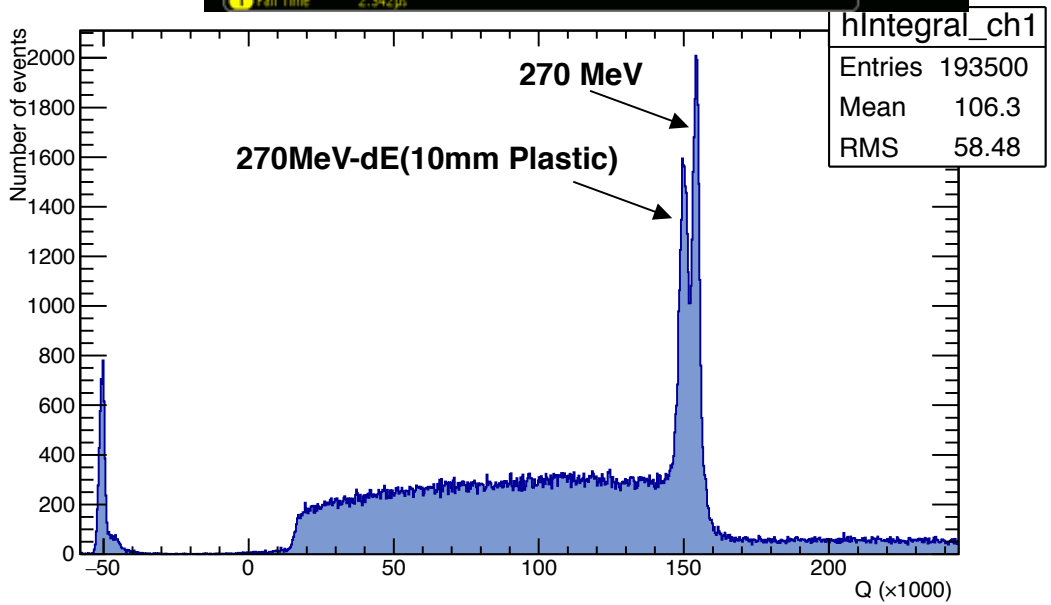


First Saturation Test
December 2016 Beam Time

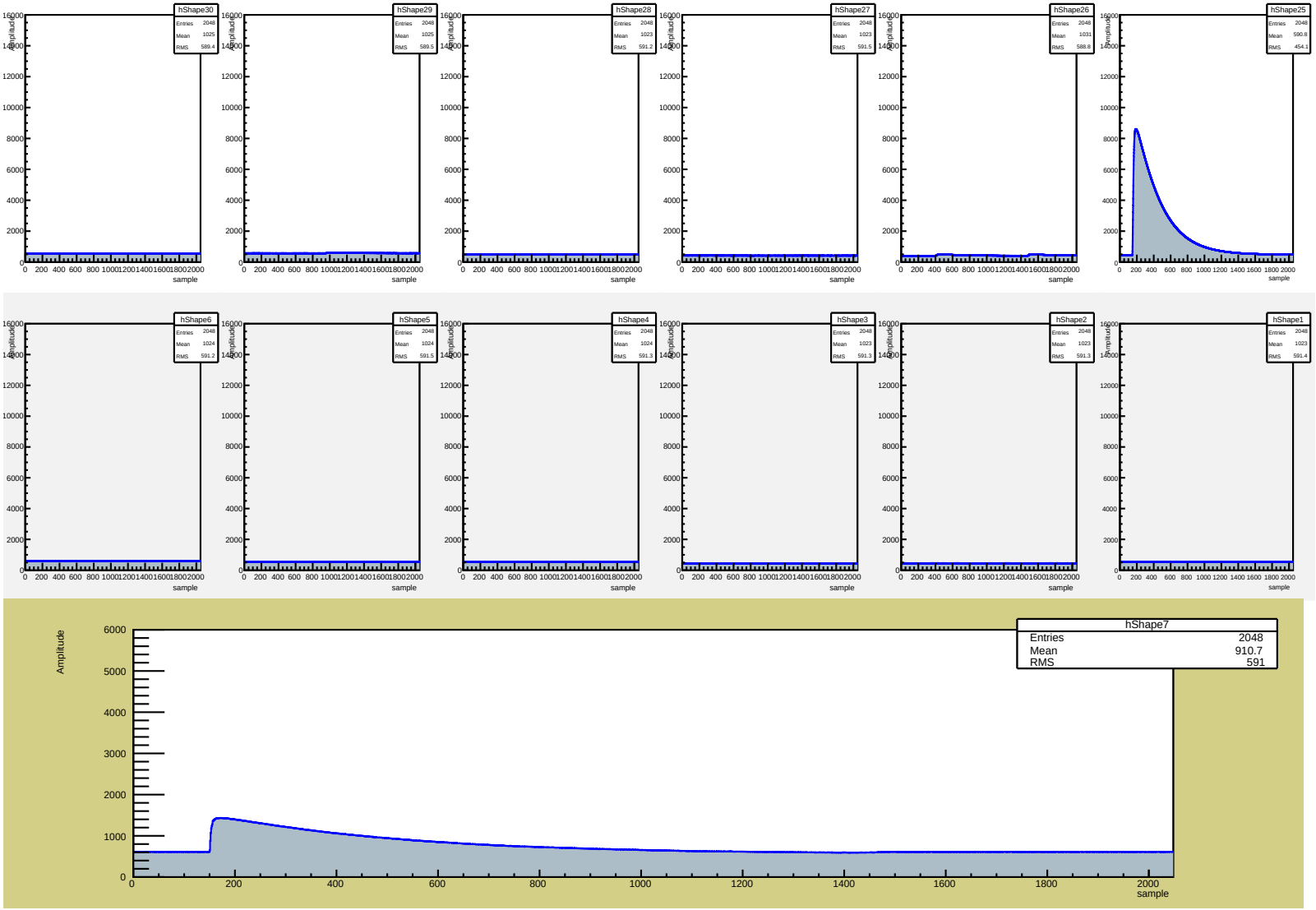




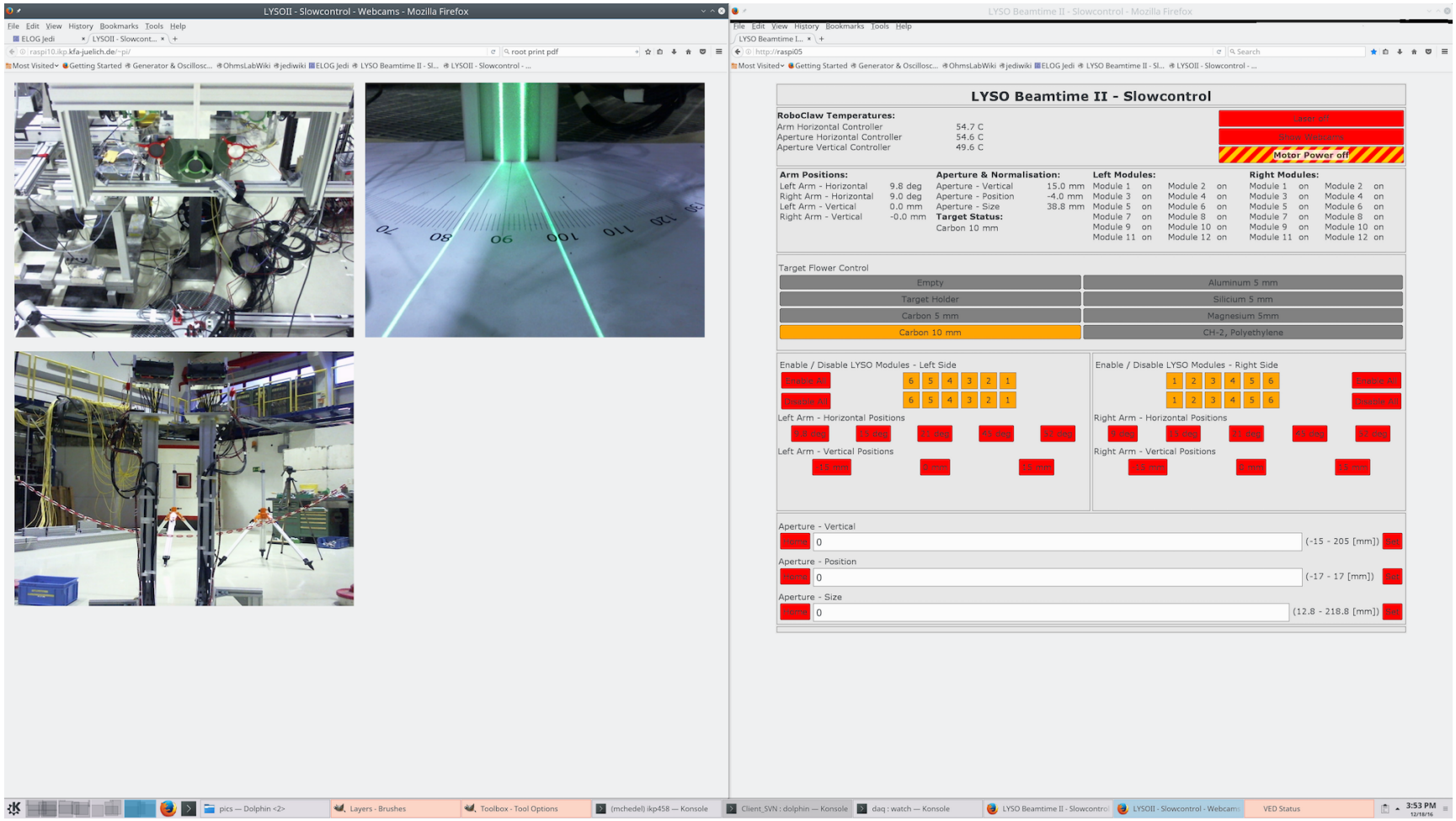




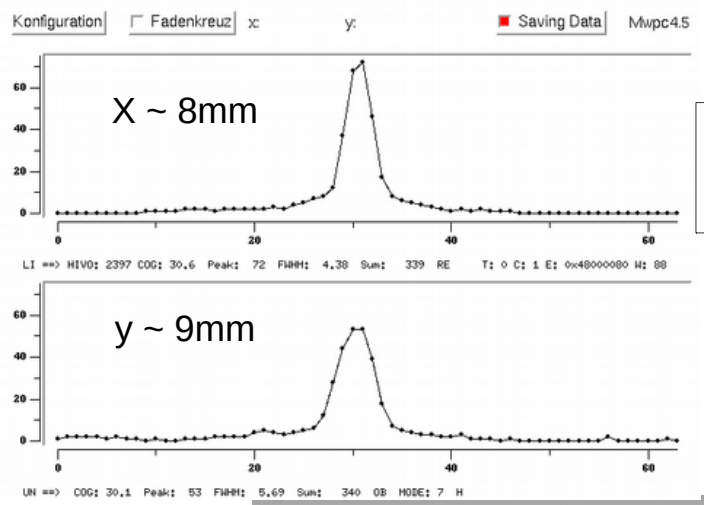
Online Monitoring
December 2016 Beam Time



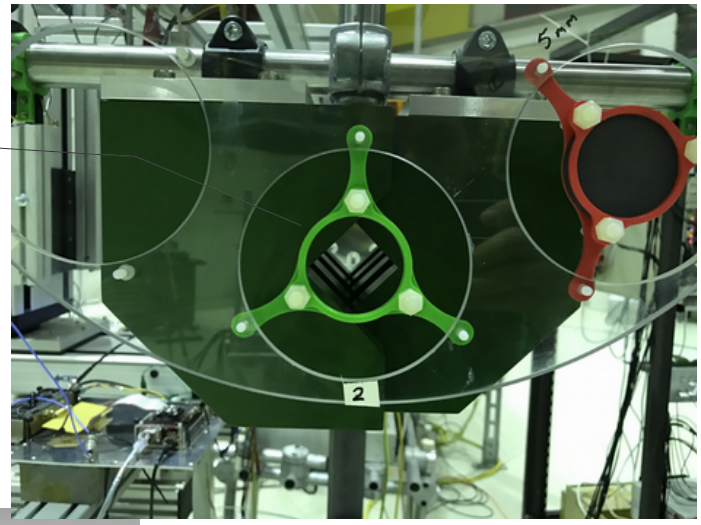
Slow Control System
December 2016 Beam Time

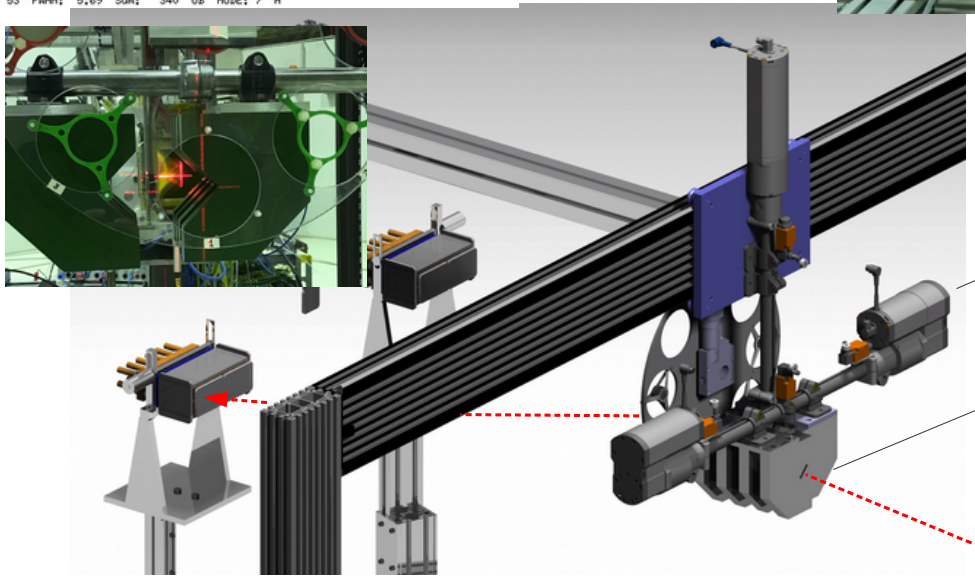


Collimator System
December 2016 Beam Time



Empty target holder



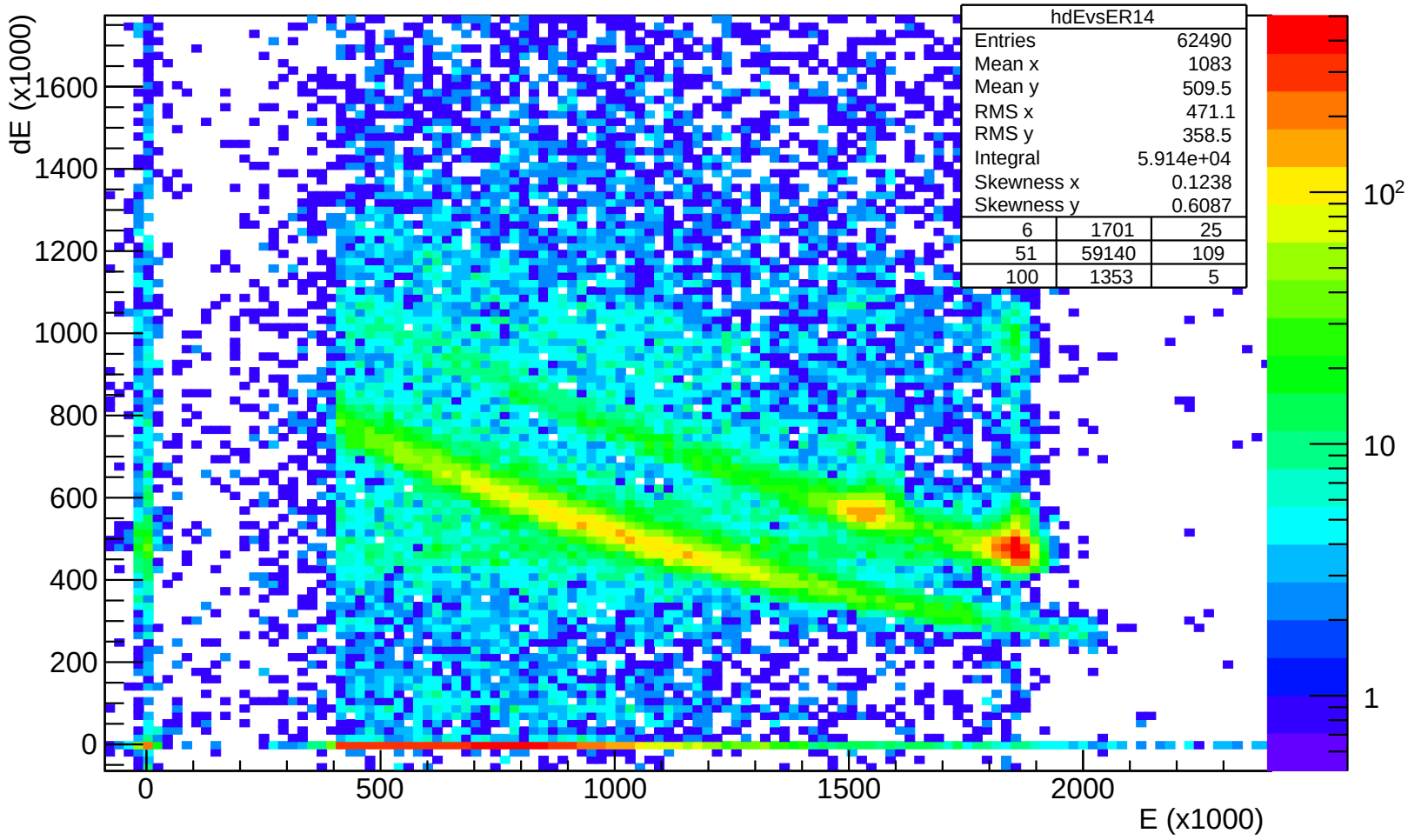


2D movement
Spot diameter

4x2.5cm Iron collimator blades

Preliminary results at 150 *MeV*
December 2016 Beam Time

Measurement on CH_2 Polyethylene target

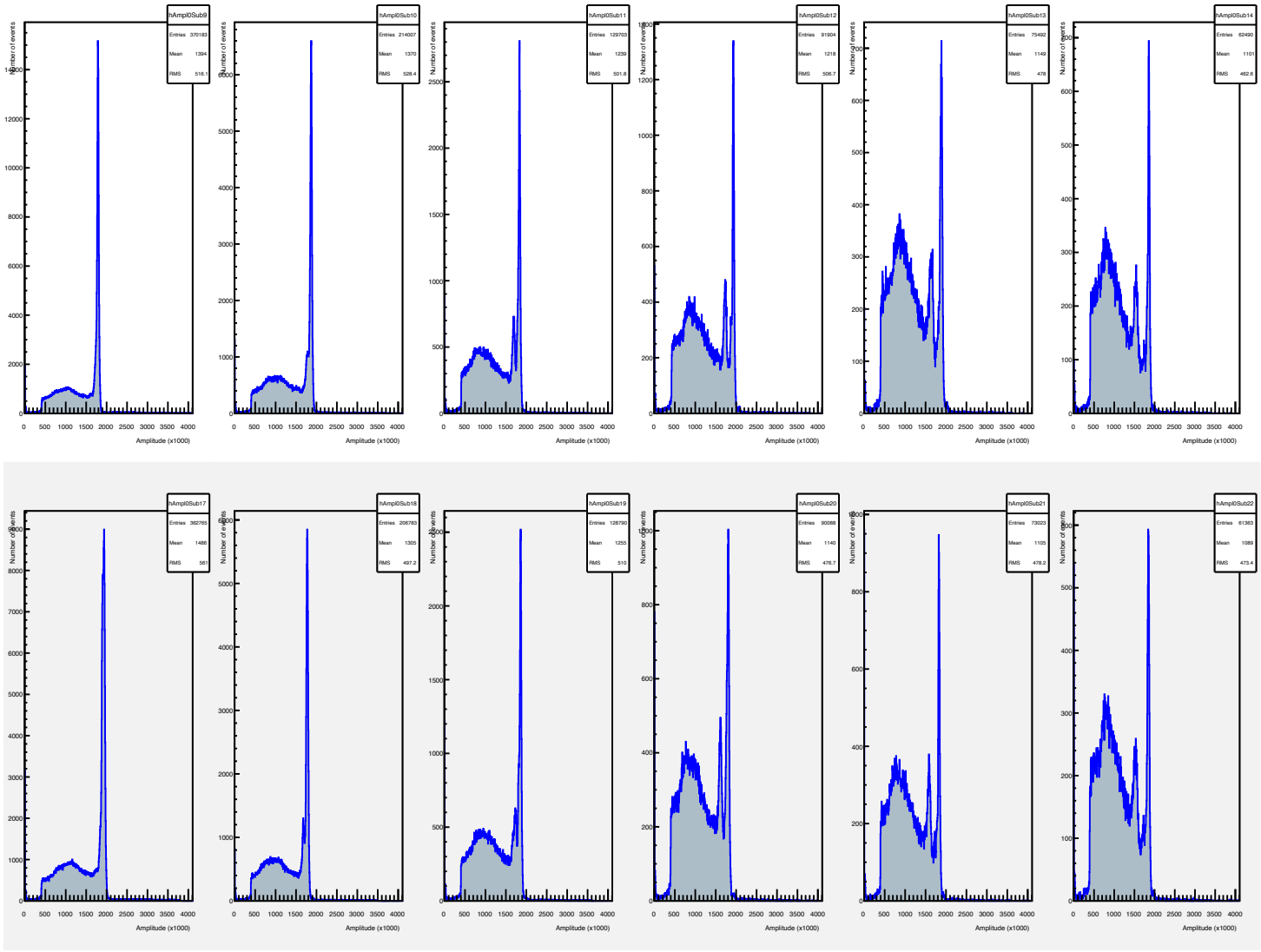


Preliminary results
December 2016 Beam Time

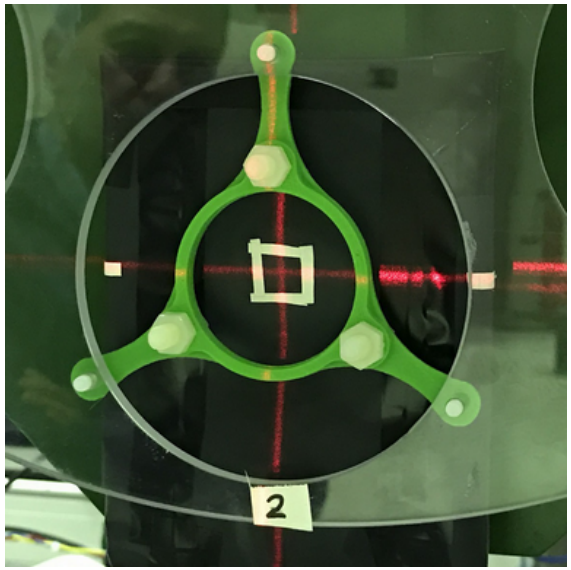
JEDI

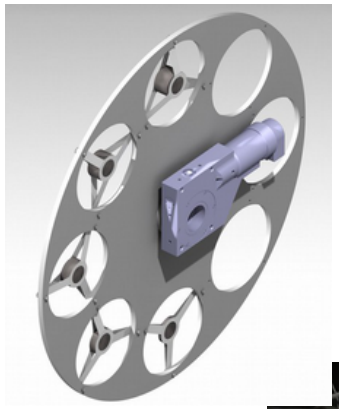
JÜLICH FORSCHUNGSZENTRUM

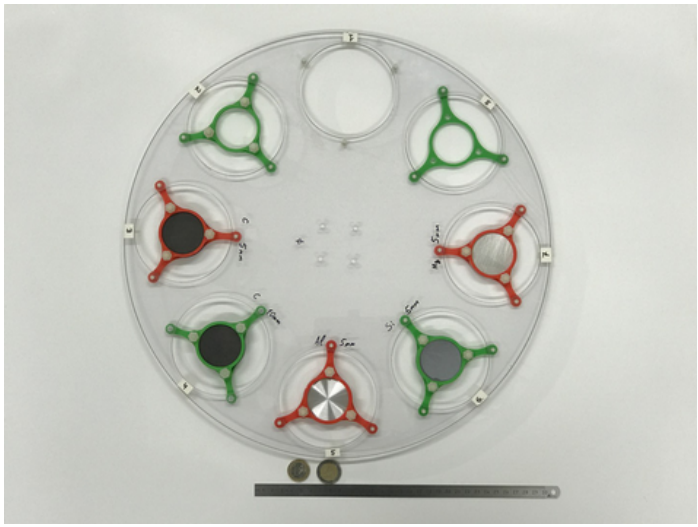
Measurement on CH_2 Polyethylene target

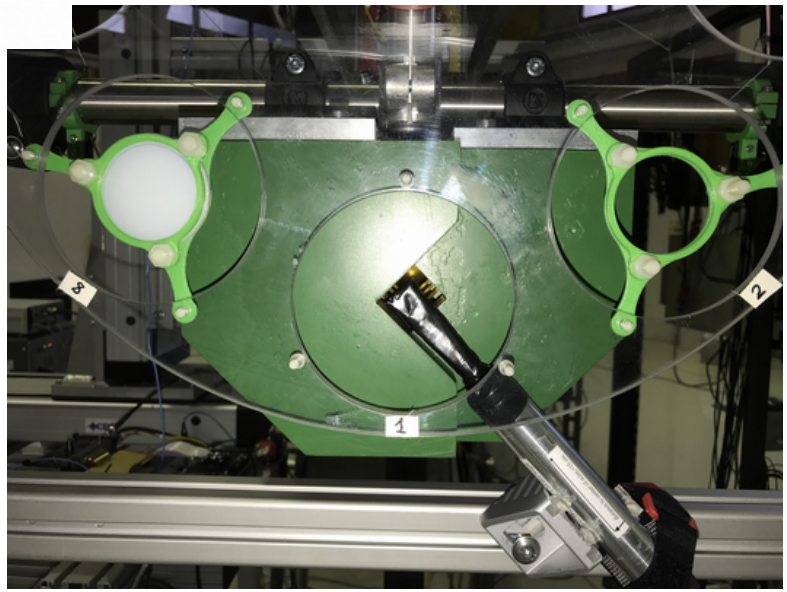


Target System + Start Counter
December 2016 Beam Time

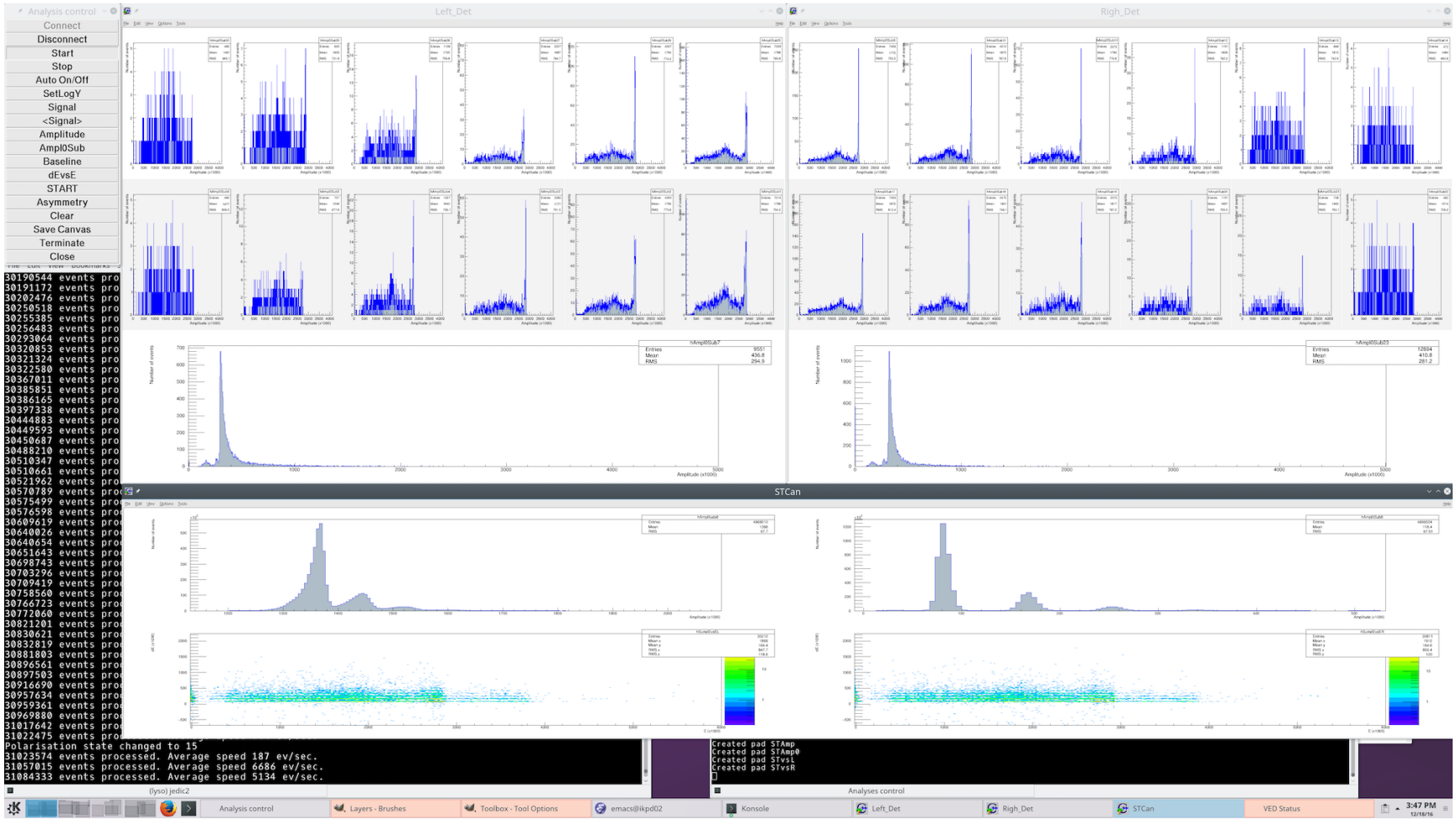








Online Analysis Software
December 2016 Beam Time



DAQ

Signal shapes *Struck FADC: 14 bit, 250 MS/s, 200 samples*