PANGEA –
The PANda GErmanium Array

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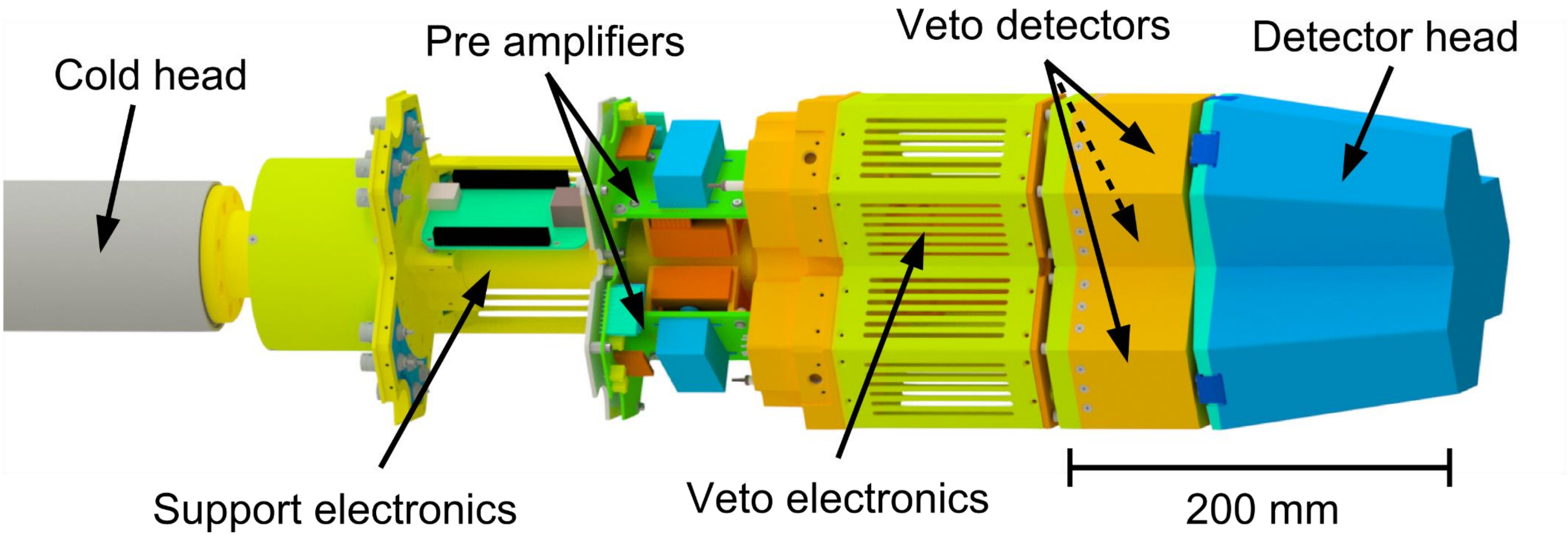
REIMEI Seminar 23.09.2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 824093.

Triple Detectors

- Common development with DEGAS (NuStar@FAIR)

Details on the detectors by Ivan next week!



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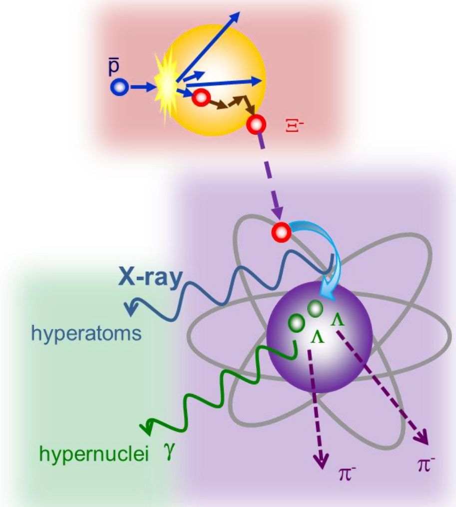
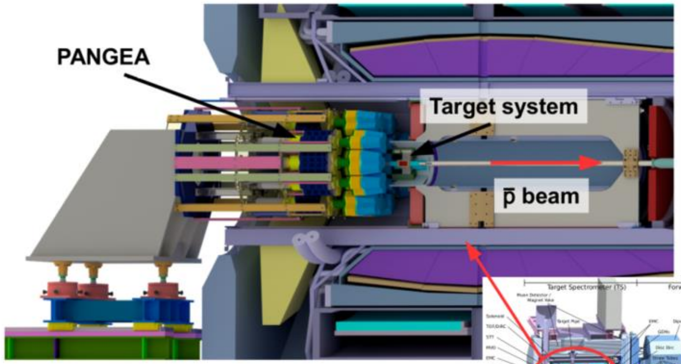
Outline

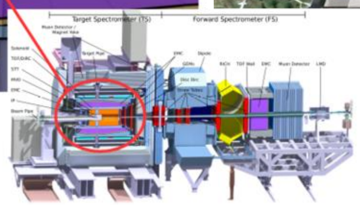
- Integration into PANDA
- Detector control system
- Digital DAQ system

PANGEA

- Study of Ξ^- hyperatoms and $\Lambda\Lambda$ hypernuclei
  - Energy range < 1 (10) MeV
- PANGEA integrated into PANDA
  - Limited space
  - Strong magnetic field
  - High hadronic background (≤ 4 MHz $\bar{p}$C)





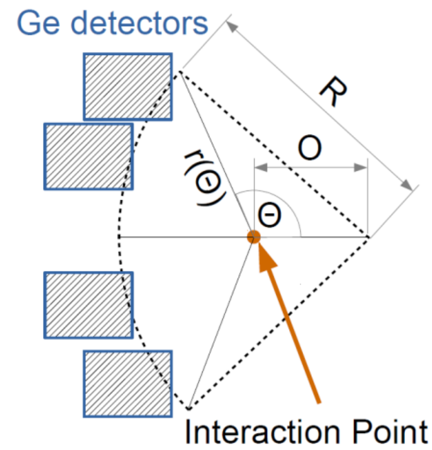


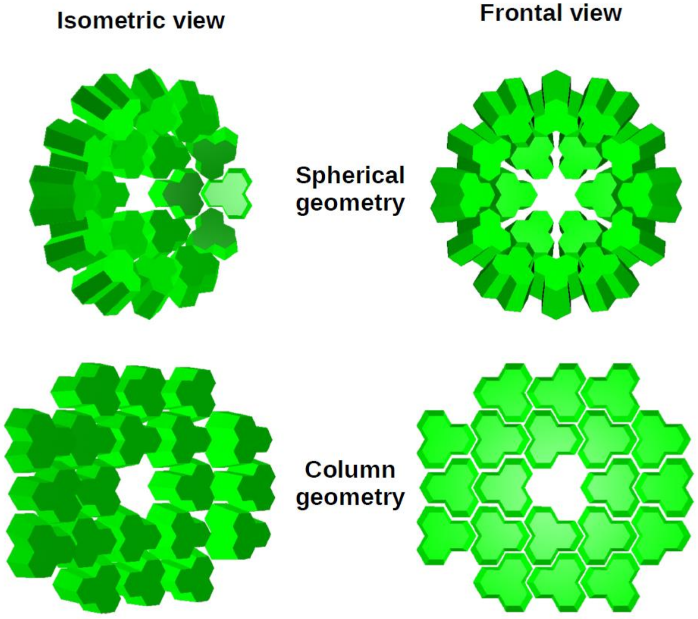
Integration - Optimization

- Fixed target experiment
  – Background peaking forward
- Hyperatoms/-nuclei at rest:

  Isotropic distribution of γ

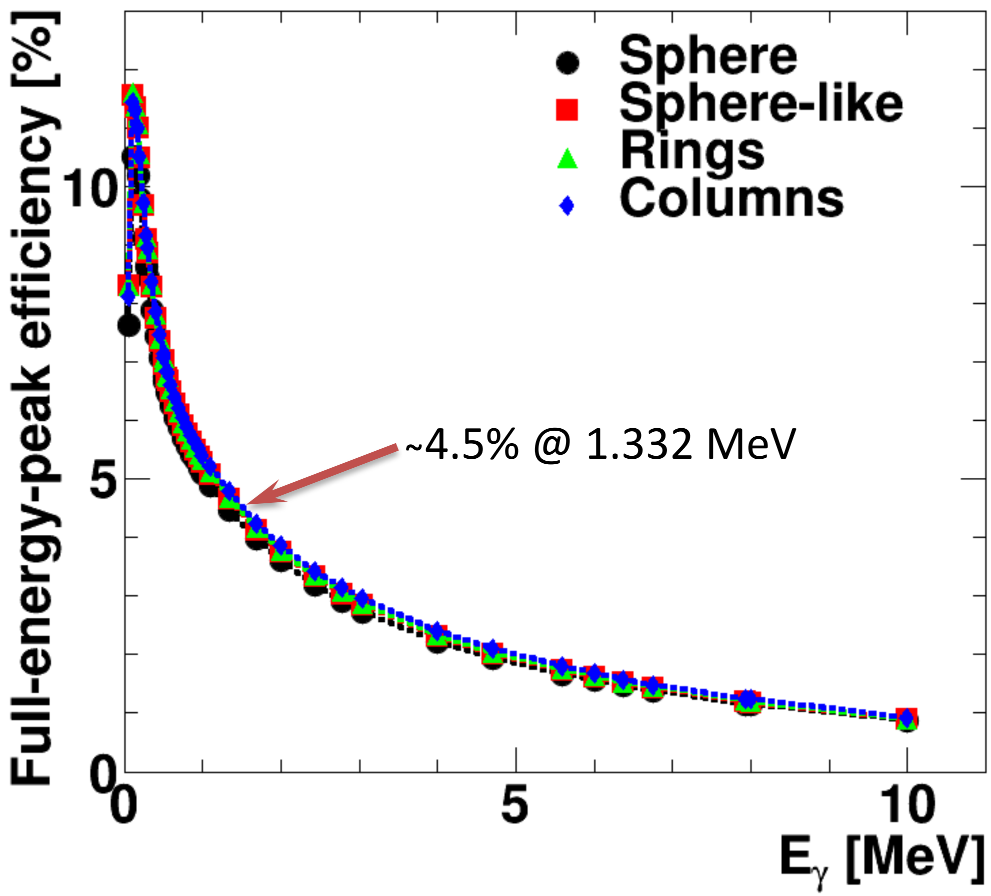
  →Shifted spherical geometry to even out background (R=40 cm, O = 20 cm)

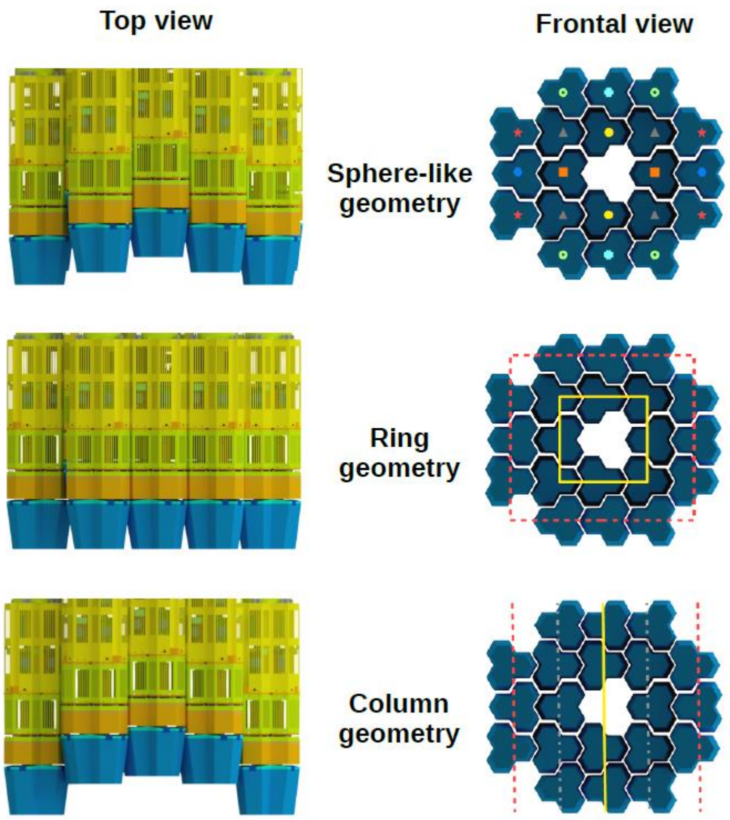




- Placement options:
  – Tilted detectors (18 x 3)
  – Straight detectors (20 x 3)

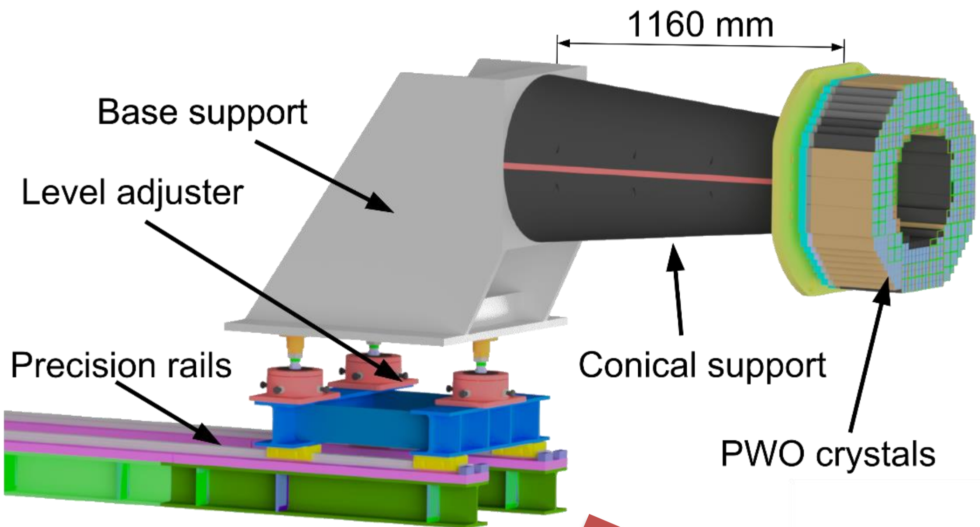
Integration - Efficiency

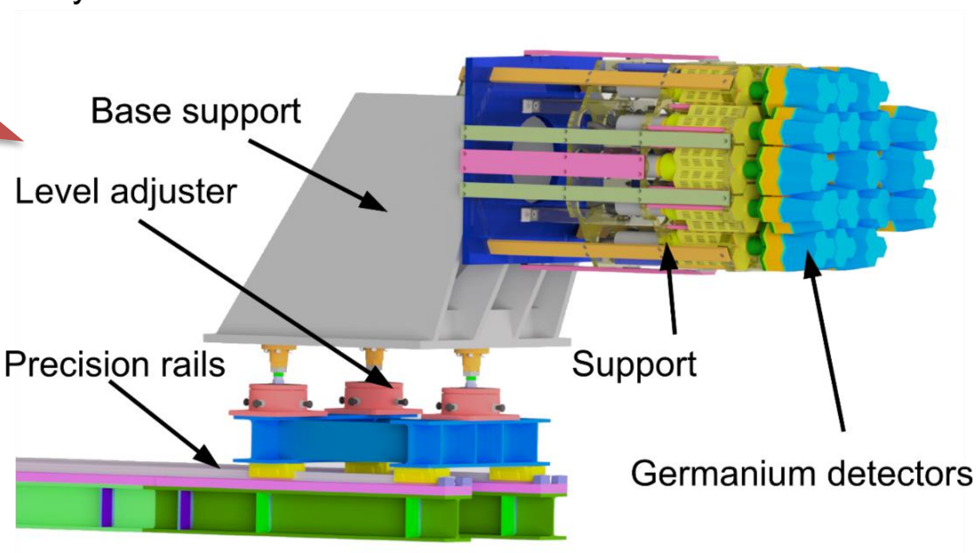


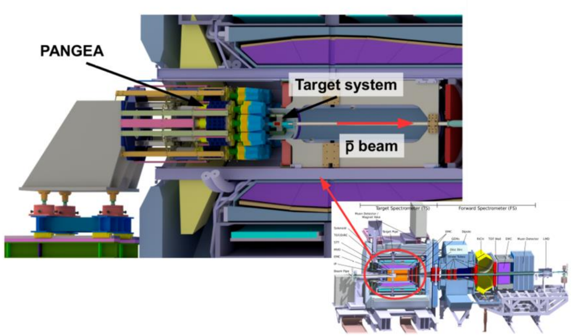


Absorption in target system included!

Mechanical Integration

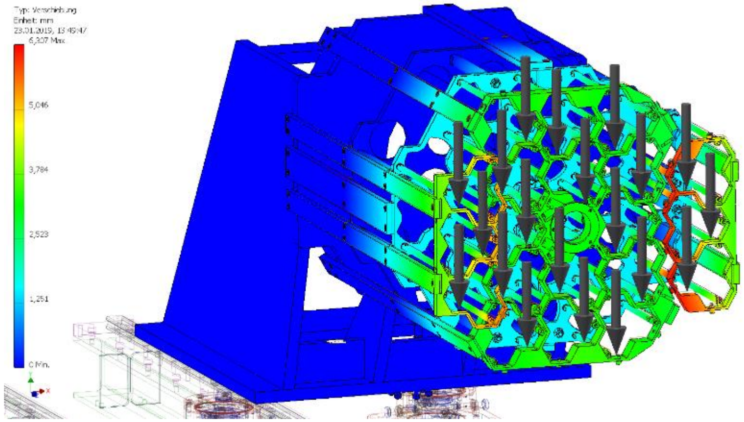


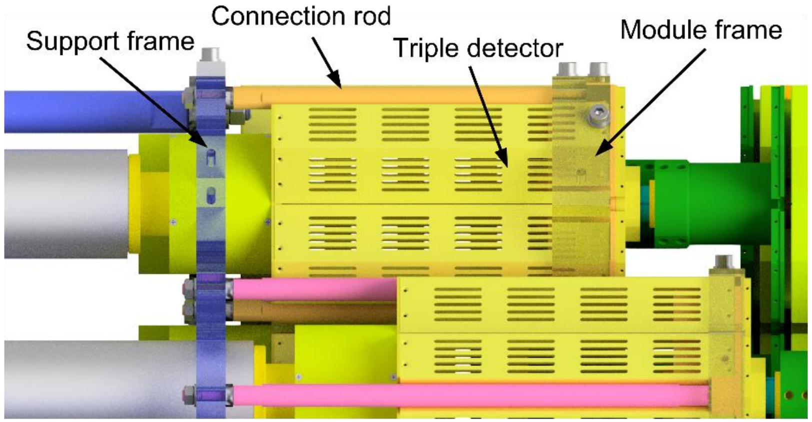


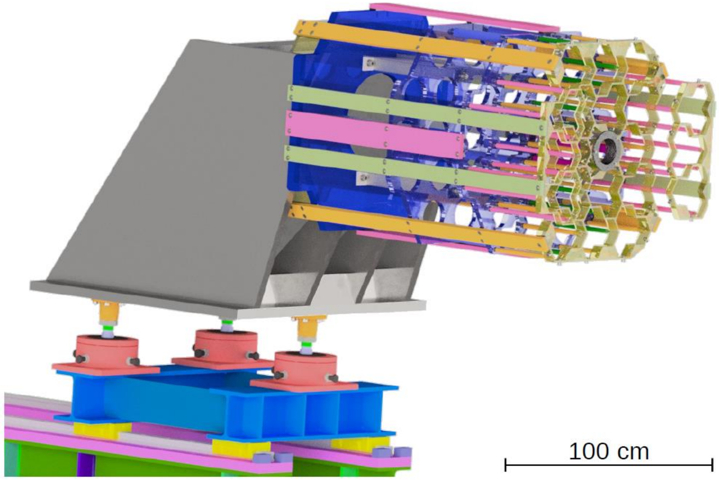


Mechanical Integration

- Stability tested in simulations
- Flexible setup allows modifications of geometries

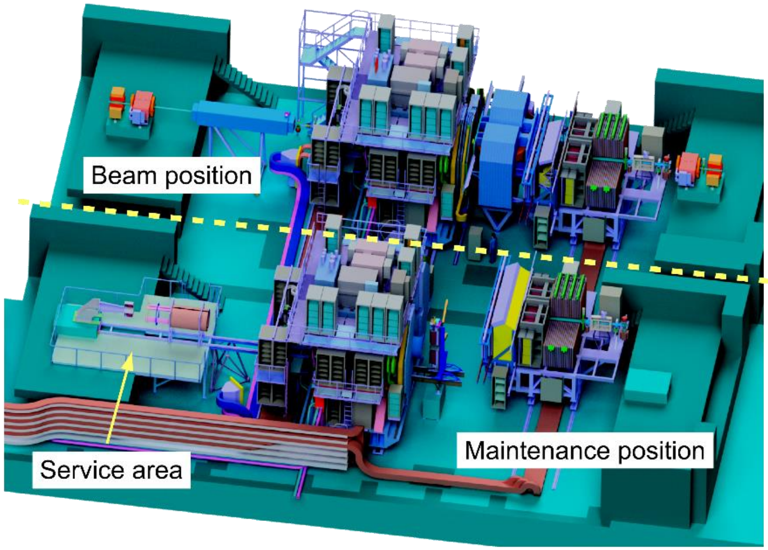


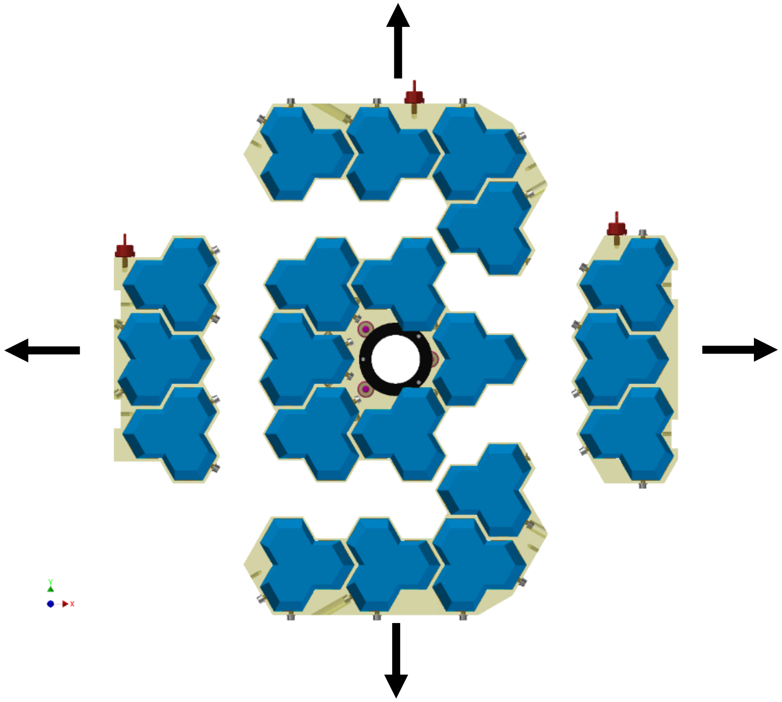




Transformation of setup

- Quick transformation of setups required
- Modules simplify accessibility and maintainability of the germanium detectors

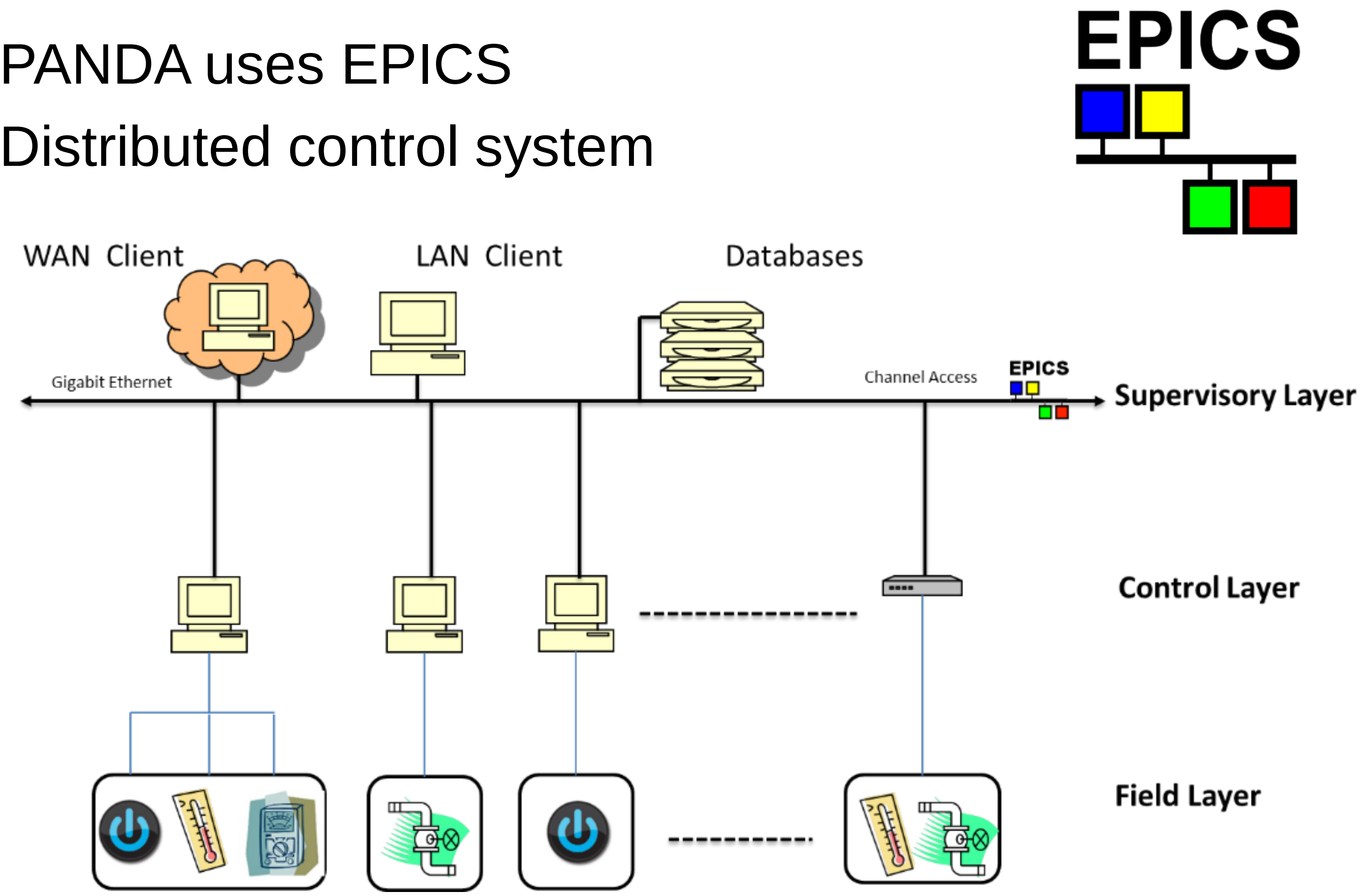




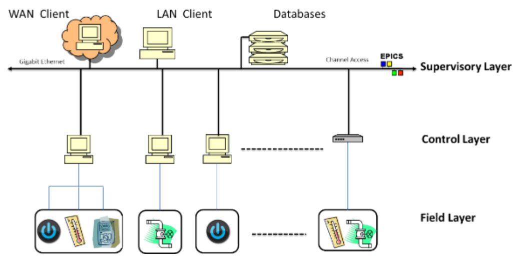
Process	Time requirement
Move $\overline{\text{P}}$ANDA to maintenance position	1 week
Remove EMC endcap	1-2 weeks
Detach STT and remove MVD and beam pipe (central frame)	2-3 weeks
Install target system and beam pipe (central frame), reattach STT	1 week
Build up PANGEA	1 week
Move and calibrate hyperatomic/hypernuclear setup into target spectrometer	1 week
Move $\overline{\text{P}}$ANDA to beam position	1 week
Cool down magnet, pumping, final calibration and commissioning	2 weeks
Total	10-12 weeks

DCS - PANDA

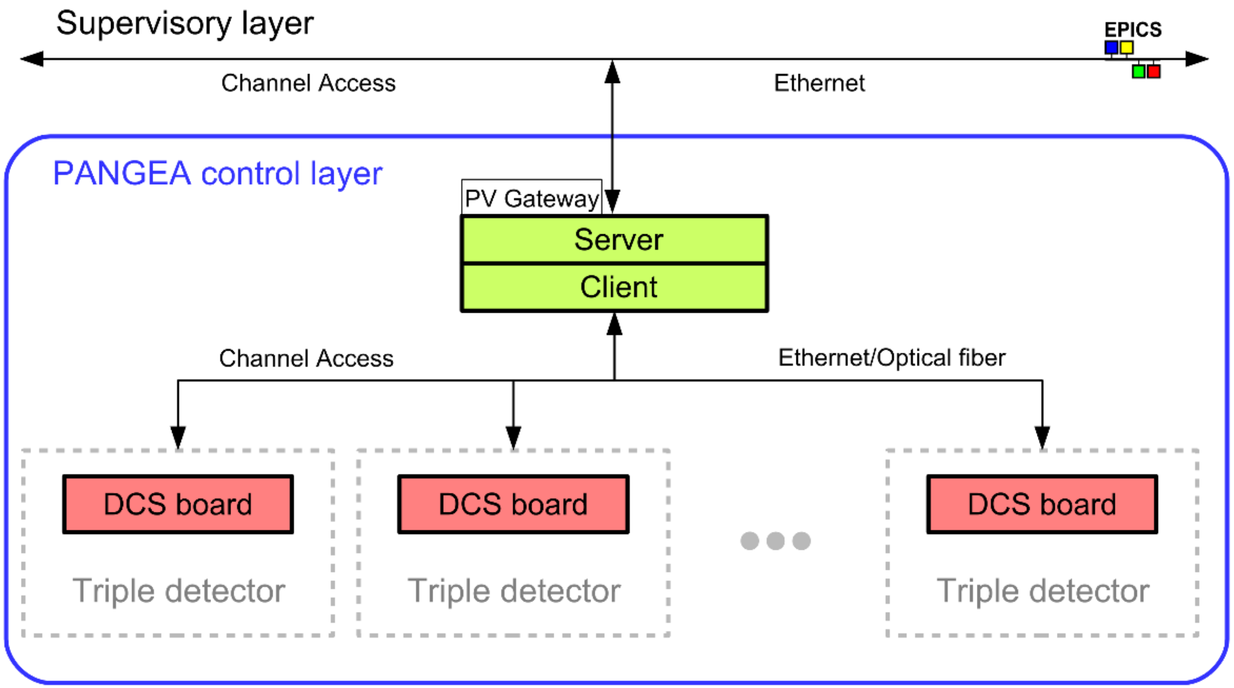
- PANDA uses EPICS
- Distributed control system



DCS - PANGEA



- DCS subnet for PANGEA
- IOC for each individual triple detector



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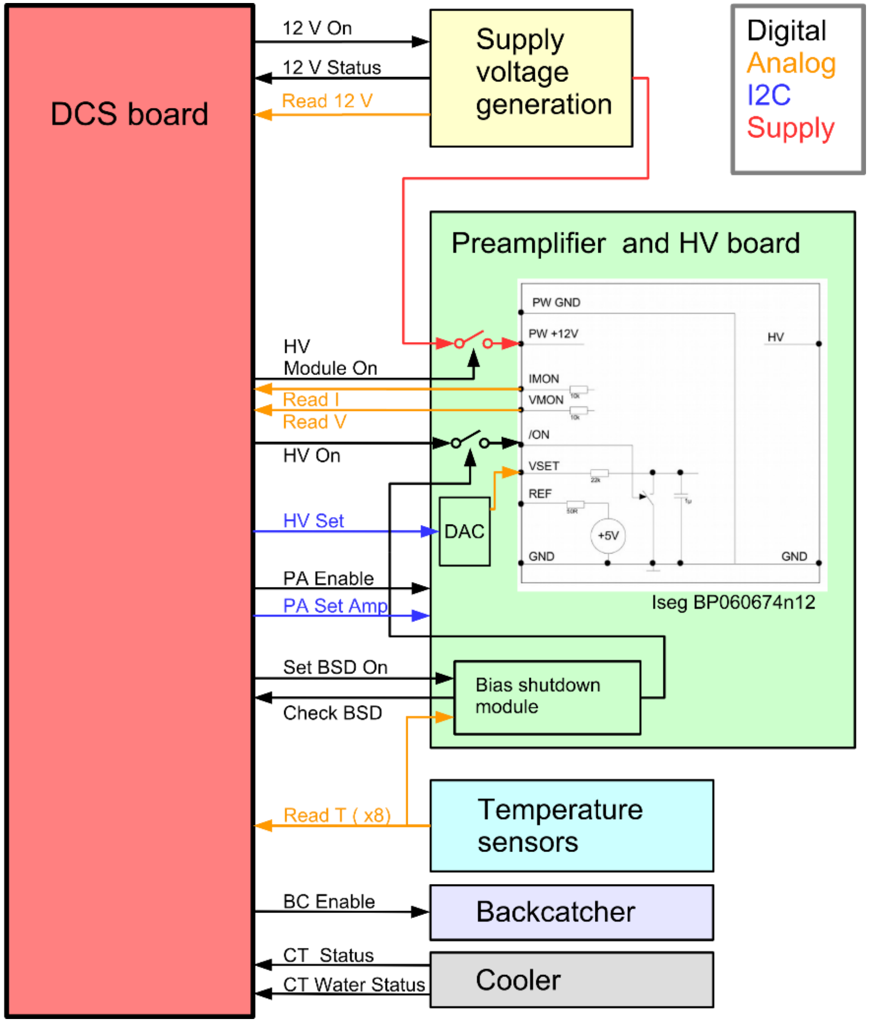
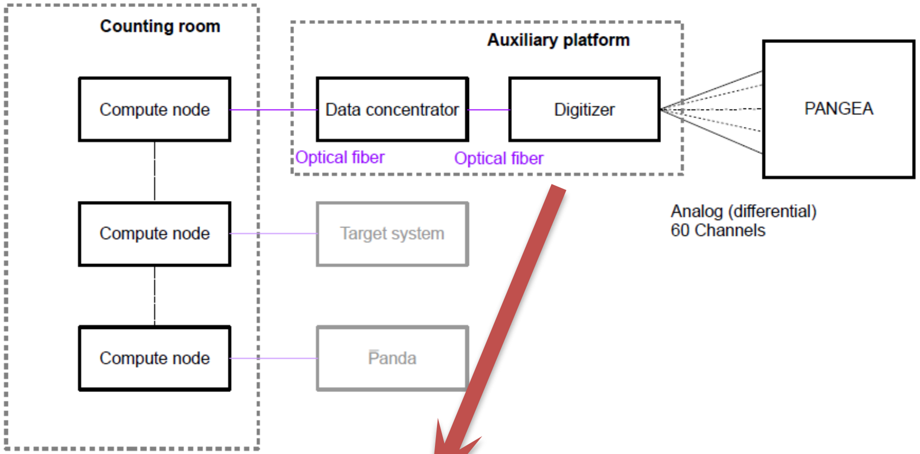
DCS - PANGEA detectors

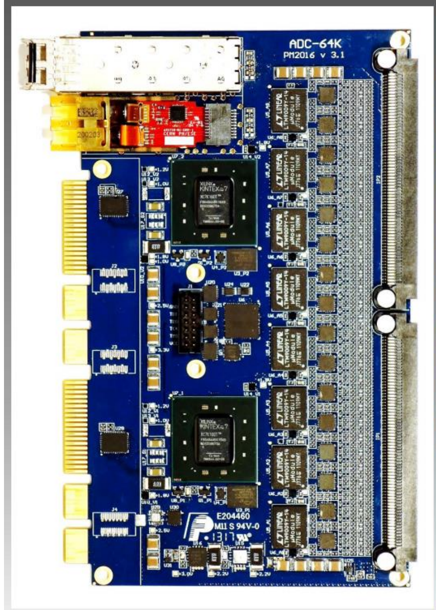
- DCS Board
  - Control and monitoring
  - Prototyping with BBB
  - Common FAIR development of radiation hard board (RISC-V under investigation)

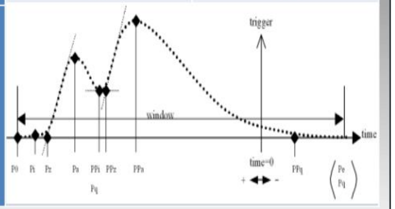


DAQ of PANGEA

- Digital readout
- EMC digitizers suitable:
  - 14 bit
  - 80 MSa/s
  - 64 channels
    - → single module for full PANGEA
  - Adjustable firmware
    - → Energy extraction implementable in firmware





ADC Model	ADC_64K EMC-FE	ADC_64K SHASHLYK
No. of channels	32 (64)	64
Sampling rate	80 MSPS	125 MSPS
Input coupling	AC, DC, positive, negative, diff	
Resolution ENOB	14-bit (dual range)	11.5-bit
Input Connector	Samtec	
Baseline	0V	
Input range (dual)	±2.2V, ±140 mV	±1.0V
Noise (rms)	100uV	
Data retention/ch.	25us	
Input filter	Active-filter/Amplifier	
Interface	Optical, SFP, LC-type, 2 Gbit/s	
Power	18W	21W
Feature extraction:		

Pawel Marciniewski, TWEPP-2017

Moving window deconvolution

- Original signal with exp. Decay

$$f(t) = \begin{cases} A\,\exp(-\frac{t}{\tau}) & t \geq \\ 0 & t < \end{cases}$$

- Deconvolution

$$A[n] = x[n] + \frac{1}{\tau}\sum_{k=-\infty}^{n-1} x[k]$$
$$= x[n] - \left(1 - \frac{1}{\tau}\right) x[n-1] + A[n-1]$$

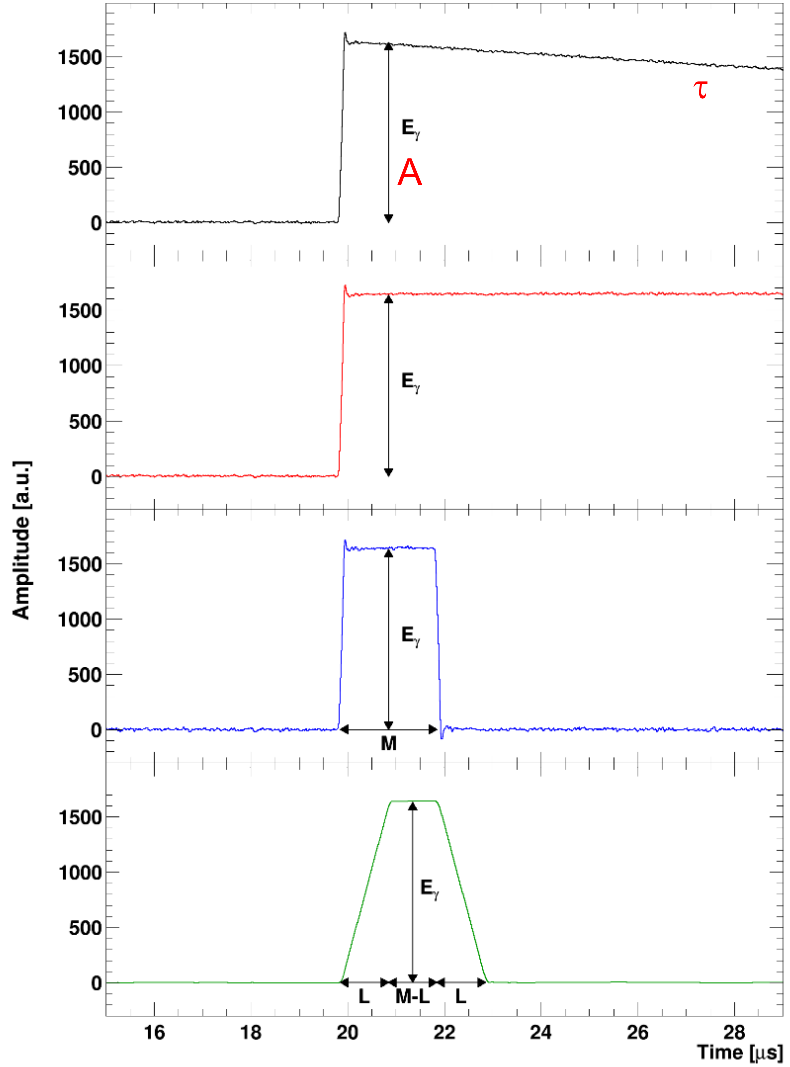
- Shortening of the signal (high rate)

$$MWD_M[n] = \nabla_M A[n]$$
$$= A[n] - A[n-M]$$

- Low pass (trapezoidal) filter

$$MA_L[n] = \frac{1}{L}\sum_{k=n-M}^{n-1} MWD_M[k]$$
$$= MA_L[n-1] + \frac{1}{L}(MWD_M[n] - MWD_M[n-L])$$

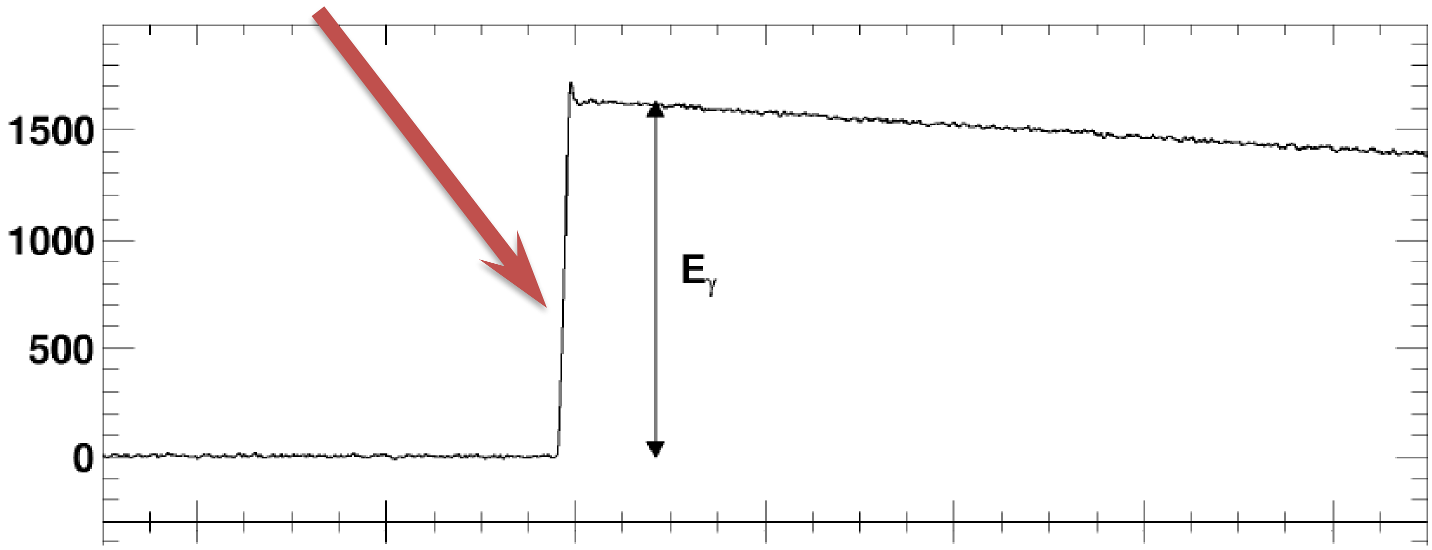
- Applicable in FPGA



Pulse shape analysis

- More information entangled in signal
- Digitization allows to analysis the full signal

  →Study of the rising edge

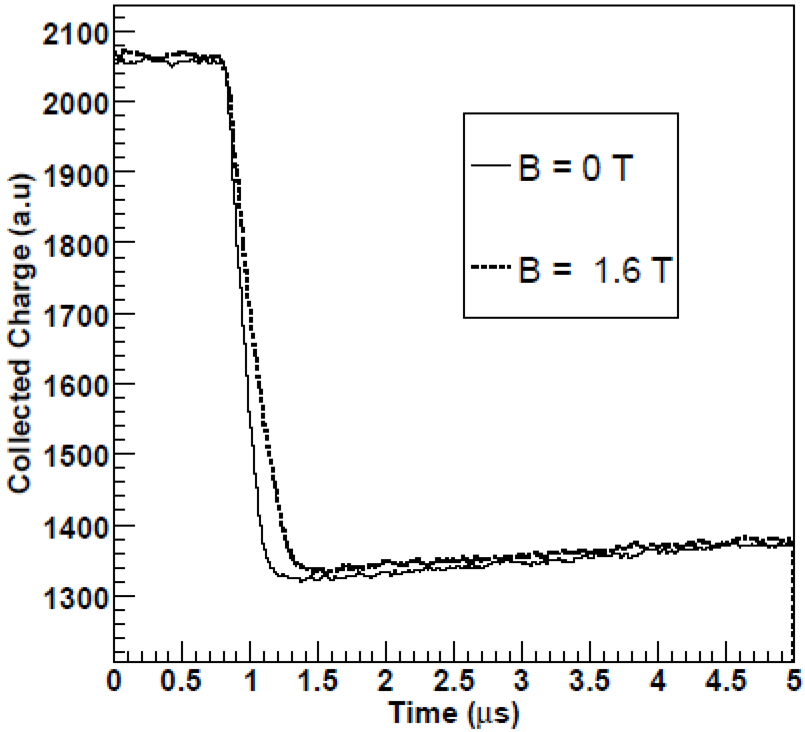


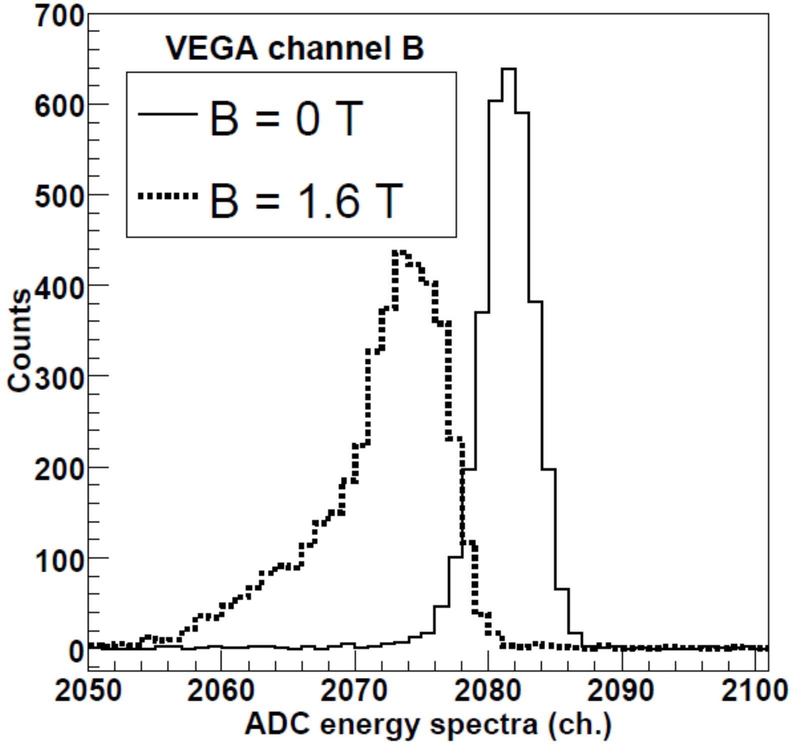
- Recover effects of magnetic fields
- Recover radiation damage

HPGe in Magnetic field

- Increased rise time by curling of charge carriers within the crystal
- Broadened and shifted Co-60 line

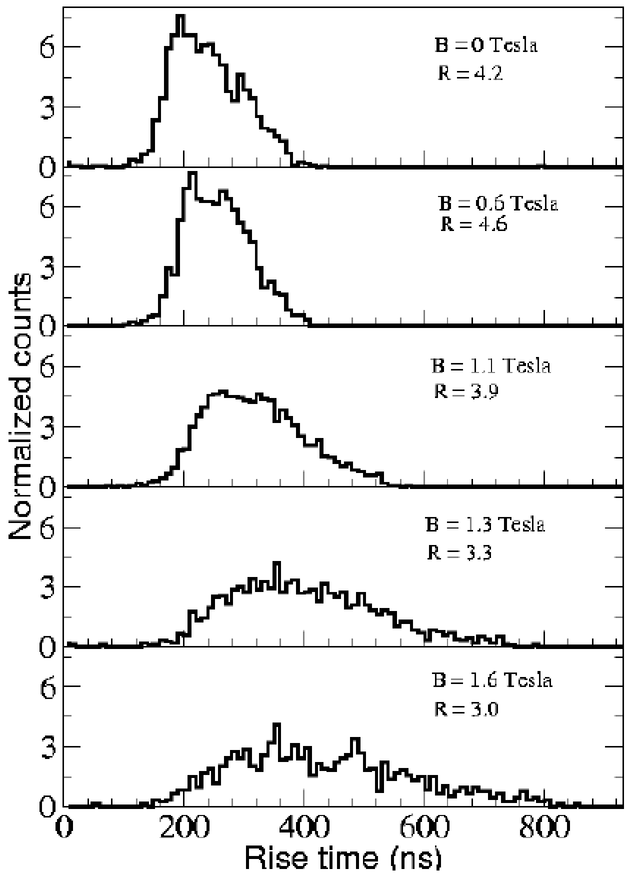
fADC: Struck SIS3300, 8 chan., 100 MSa/s, 12 bit

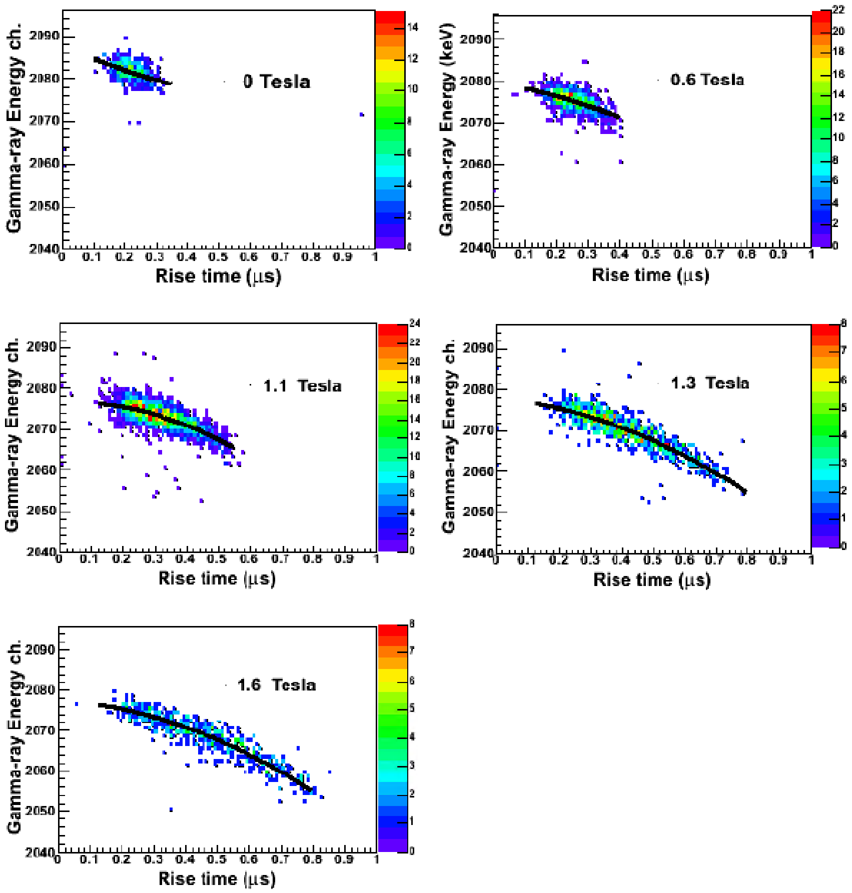




A. Sanchez Lorente et al. , NIM A 573.3 (2007)

Rise time dependance

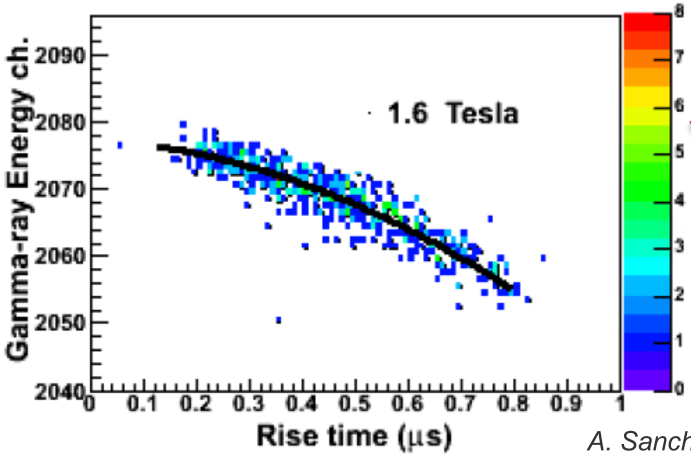


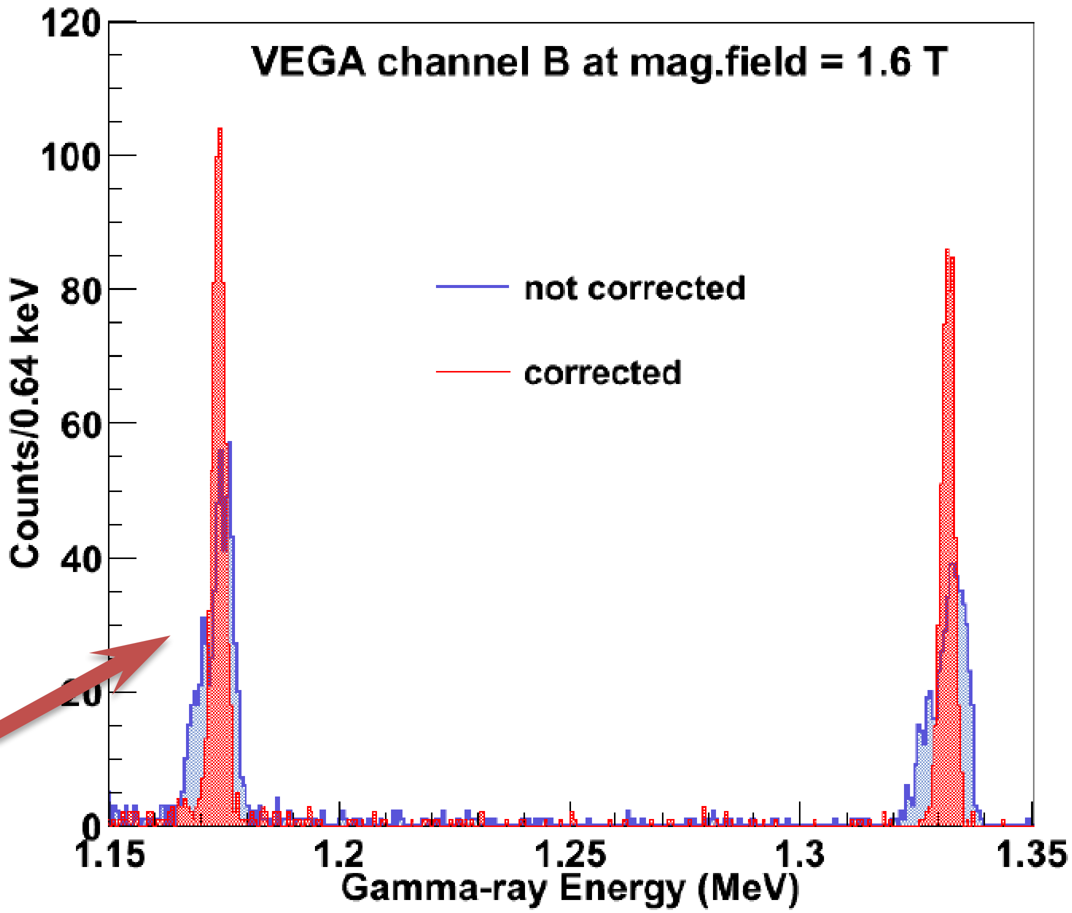


A. Sanchez Lorente et al. , NIM A 573.3 (2007)

Rise time correction

- Fit of data and event-wise correction

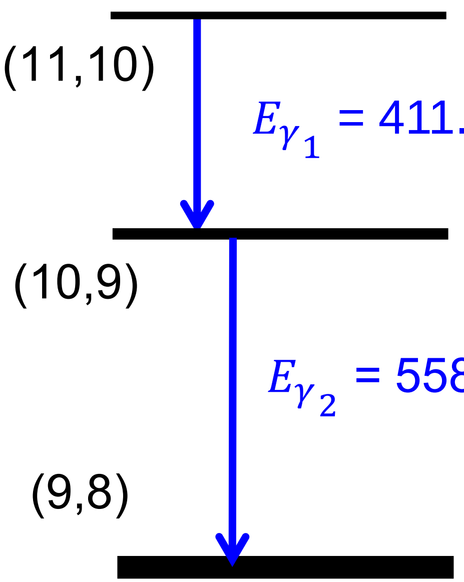


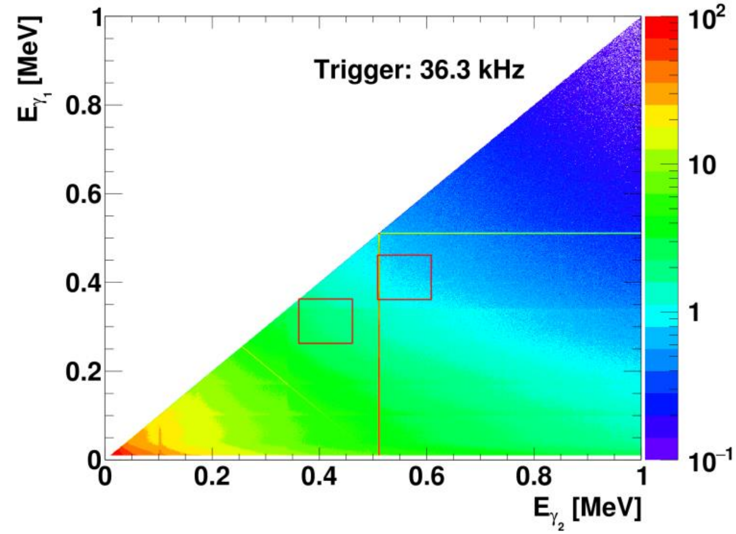


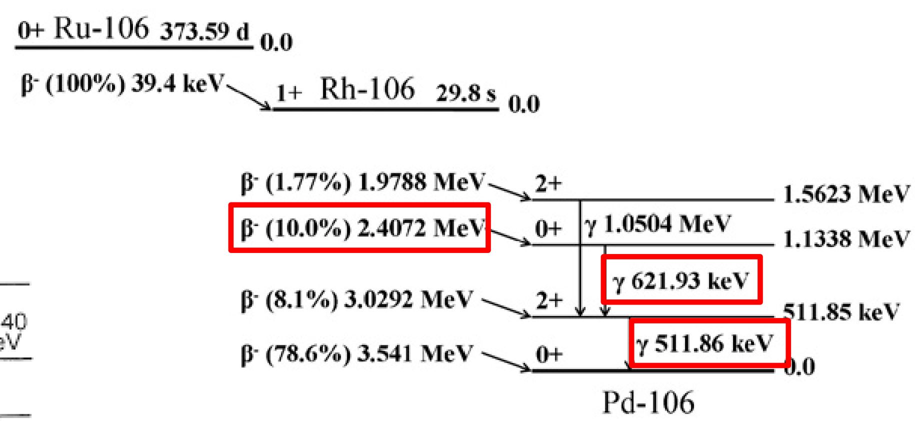
A. Sanchez Lorente et al. , NIM A 573.3 (2007)

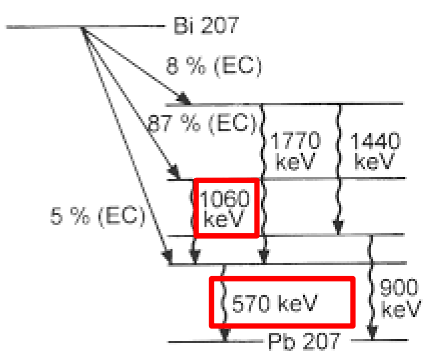
Ξ^{-} - ^{208}Pb - Online calibration

Ξ^{-} - ^{208}Pb Hyperatom



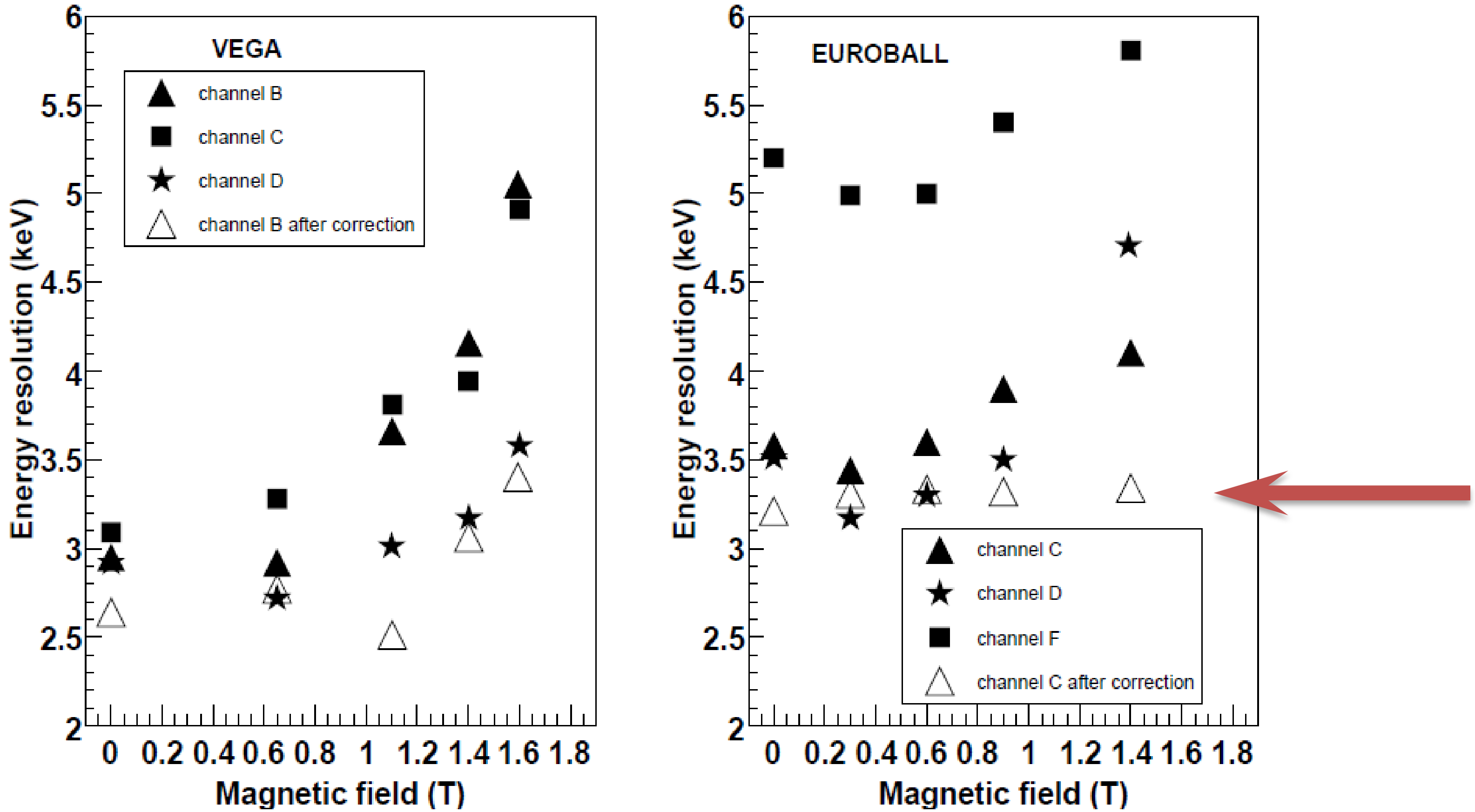






M.C: Fuss et al. Applied Radiation and Isotopes 69 (2011)

Magnetic fields results



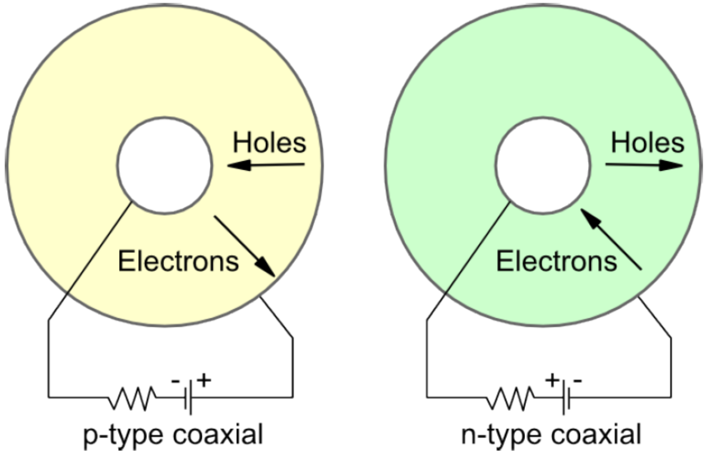
- Correction allows recovery

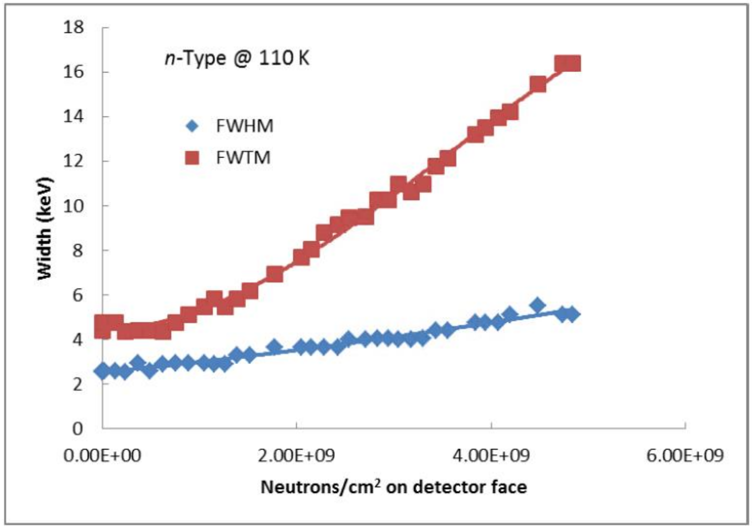
A. Sanchez Lorente et al. , NIM A 573.3 (2007)

Radiation damage

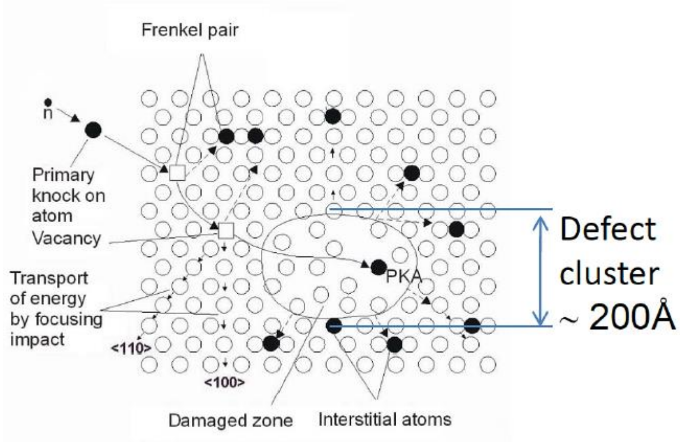
- Neutron irradiation:
  - Decrease of HPGe performance
  - Trapping of charge carriers (holes)

→ n-type more resistant





E. H. Seabury et al. 2013 IEEE Nuclear Science Symposium and Medical Imaging Conference (2013 NSS/MIC), Seoul, 2013,



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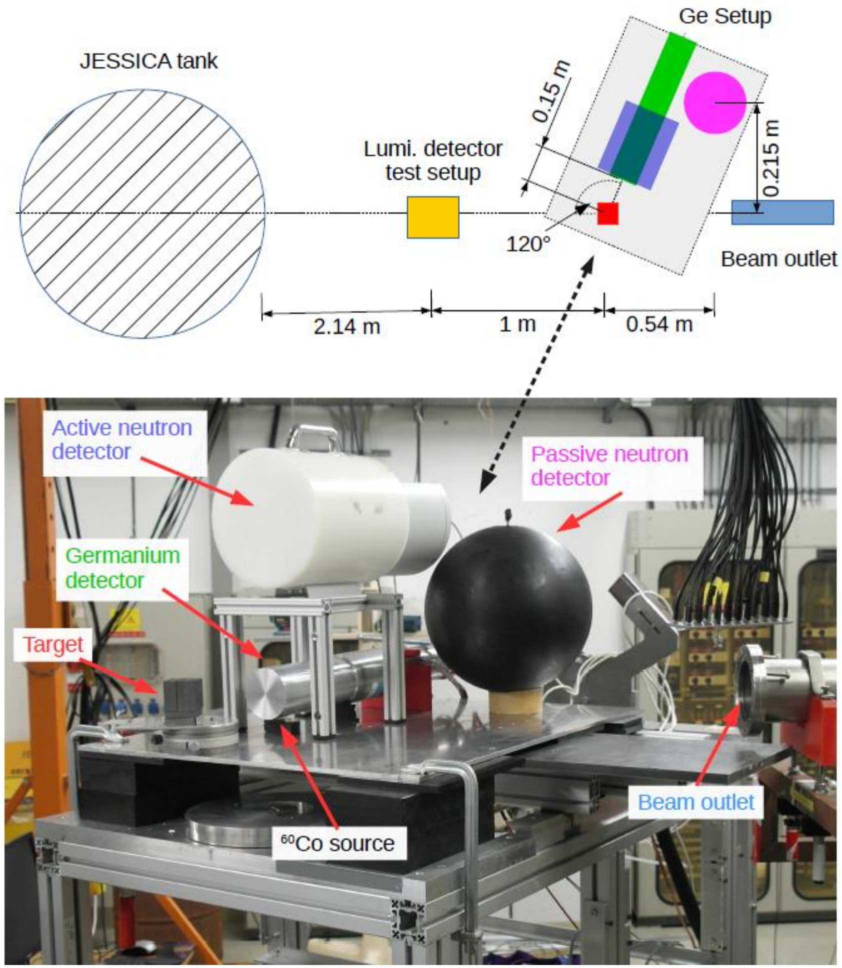
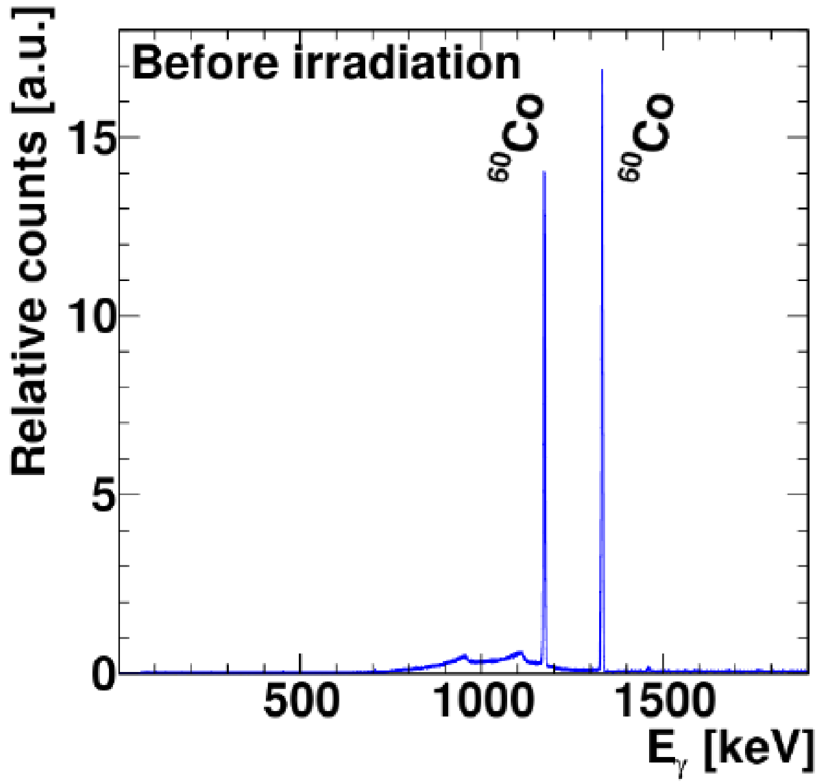
PANGEA - radiation damage

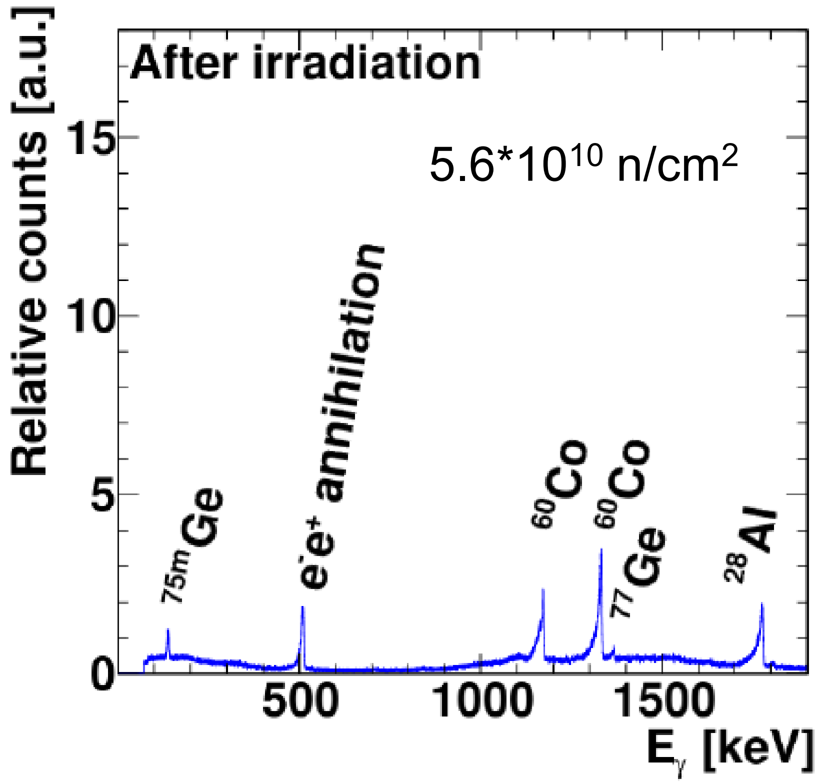
- $\overline{\text{P}}$ANDA: crystals with up to $1*10^{10}$ n/cm^2 within experiment (180 days)

- Test beam @ COSY (FZ Jülich, Germany)
- E.-m.-cooled prototype with 1 EUROBALL crystal (n-Type)
  – Neutrons produced in p(2.78 GeV/c)+C: similar to $\bar{p}$+C @ $\overline{\text{P}}$ANDA
  – $5.6*10^{10}$ n/cm^2 in 5.5 days → 94 days of $\overline{\text{P}}$ANDA



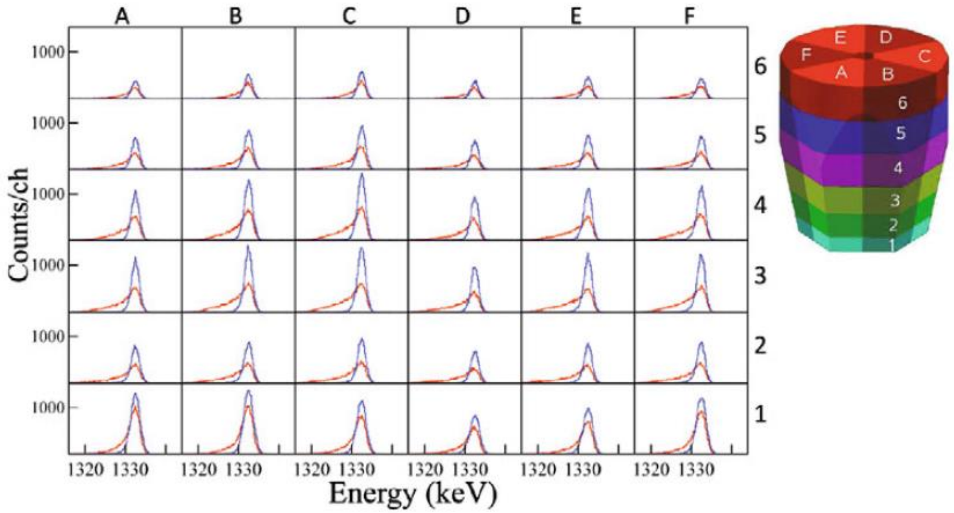
γ Spectrum after irradiation

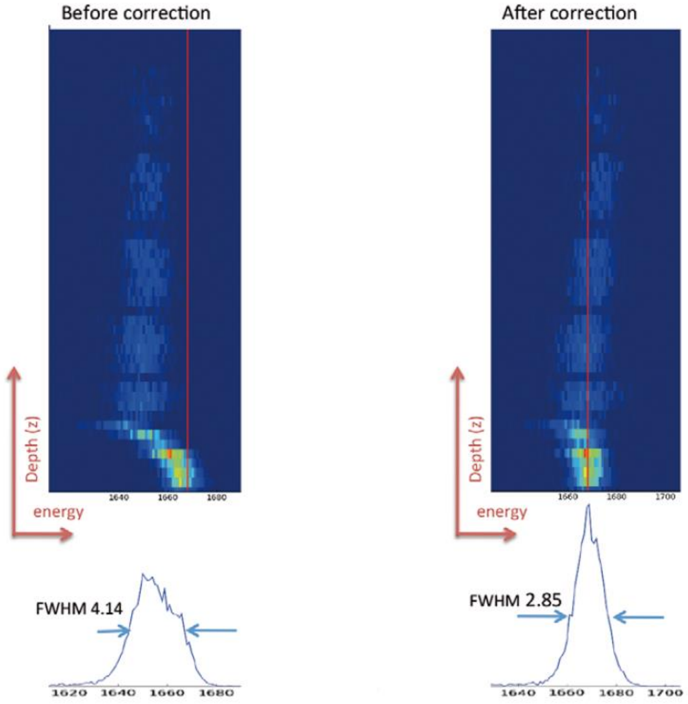




AGATA – radiation damage

- Segmented detectors
- Extract interaction position within the crystal



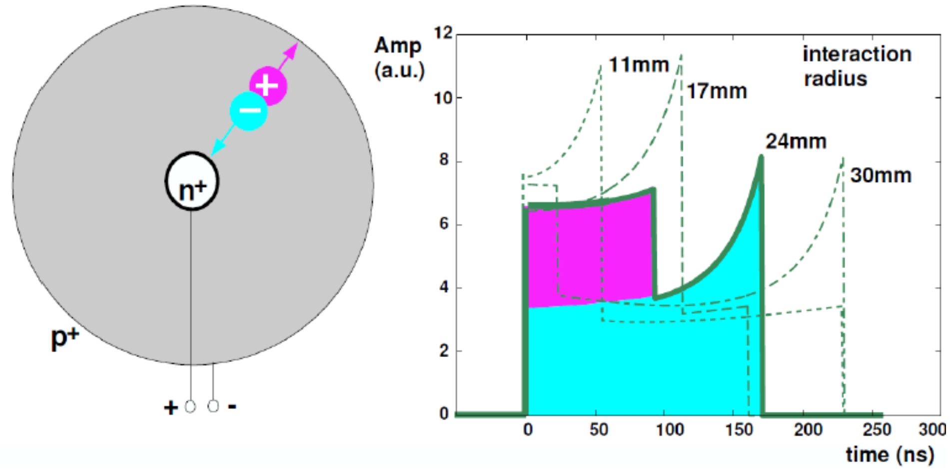


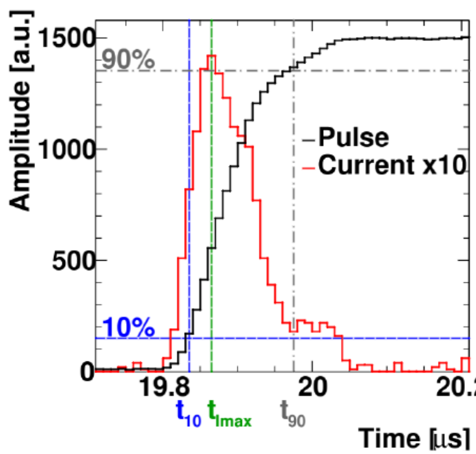
B. Bruyneel et al. Eur. Phys. J. A (2013) 49: 61

Pulse shape analysis

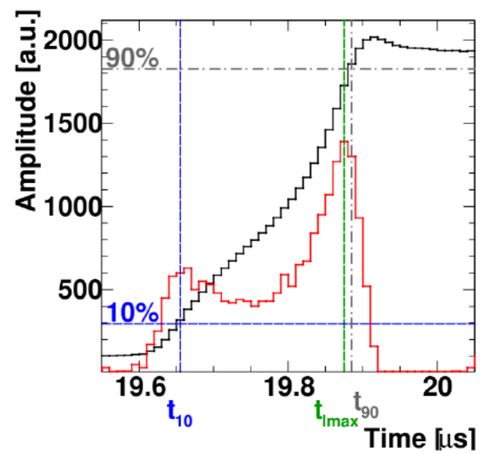
- EUROBALL crystals not segmented!
- PSA allows to extract interaction depth
  - Information in rising edge
  - Rise time not unique
  - Current signal has unique r dependence

    → $T(I_{max}) - T(q_{10})$





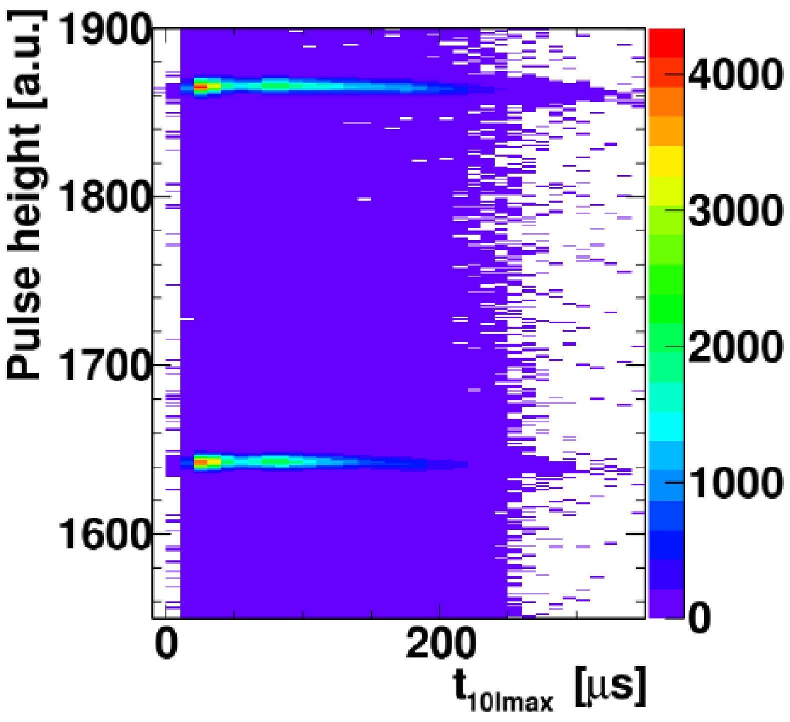
Small r



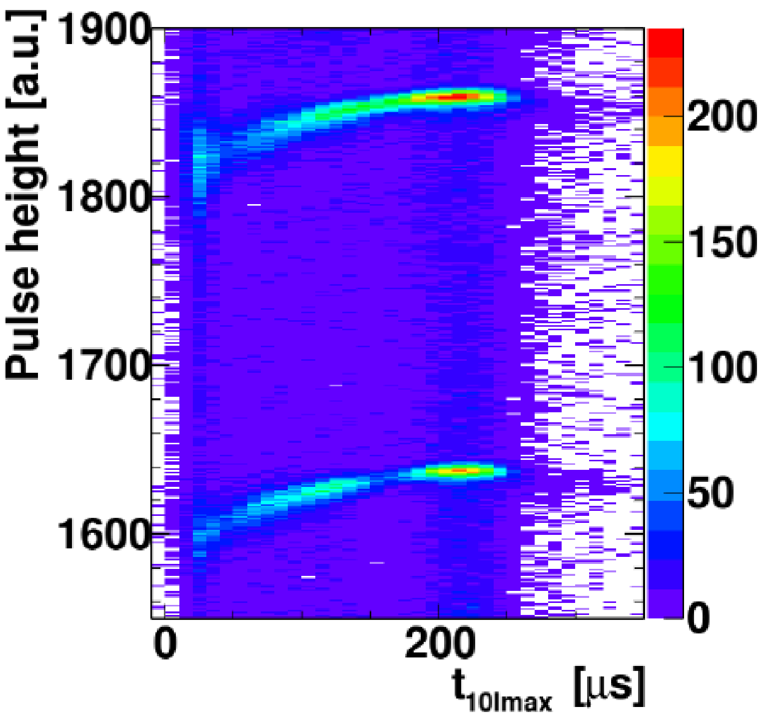
big r

fADC: CAEN v1724, 8 channel,
100 MSa/s, 14 bit

Data analysis



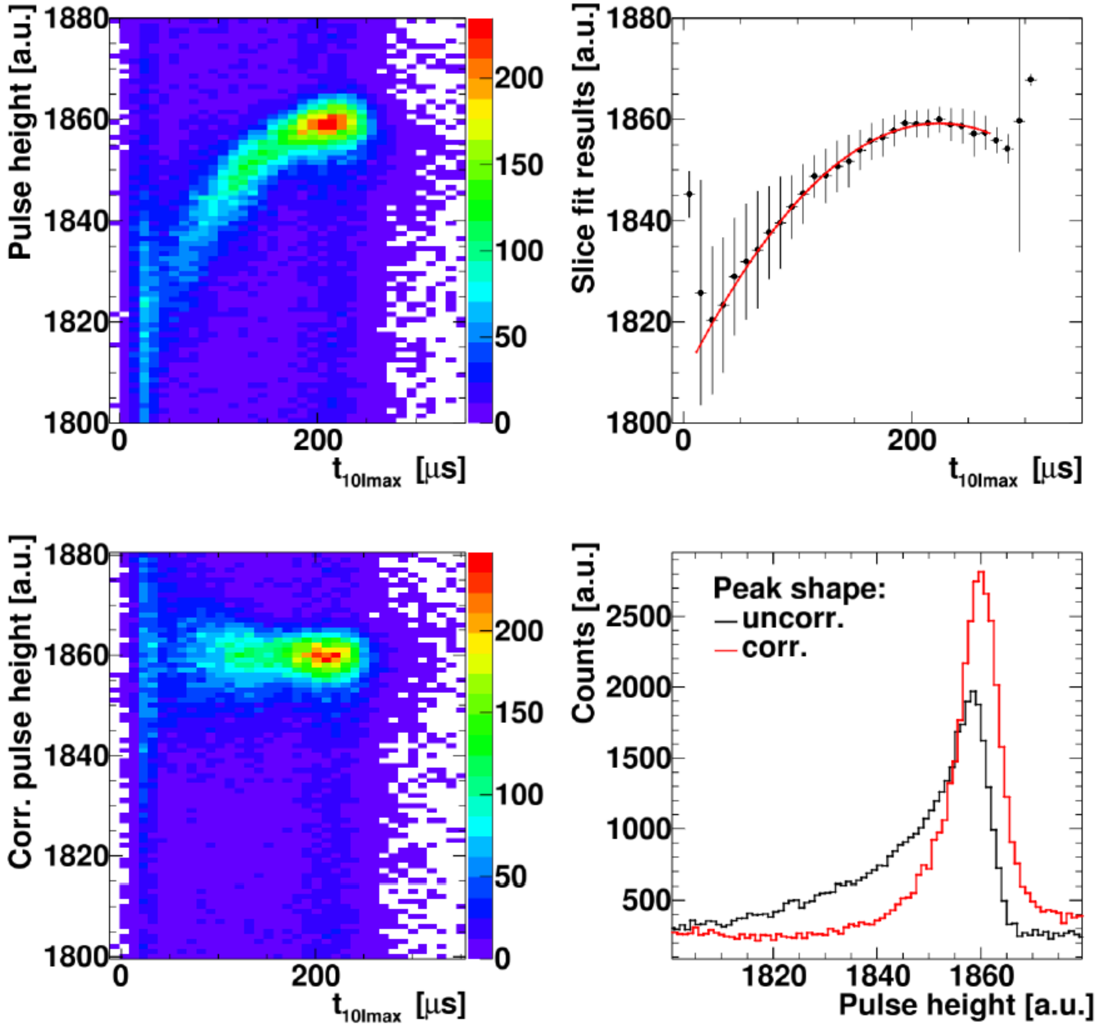
Before irradiation



after irradiation

Application of the correction

after irradiation



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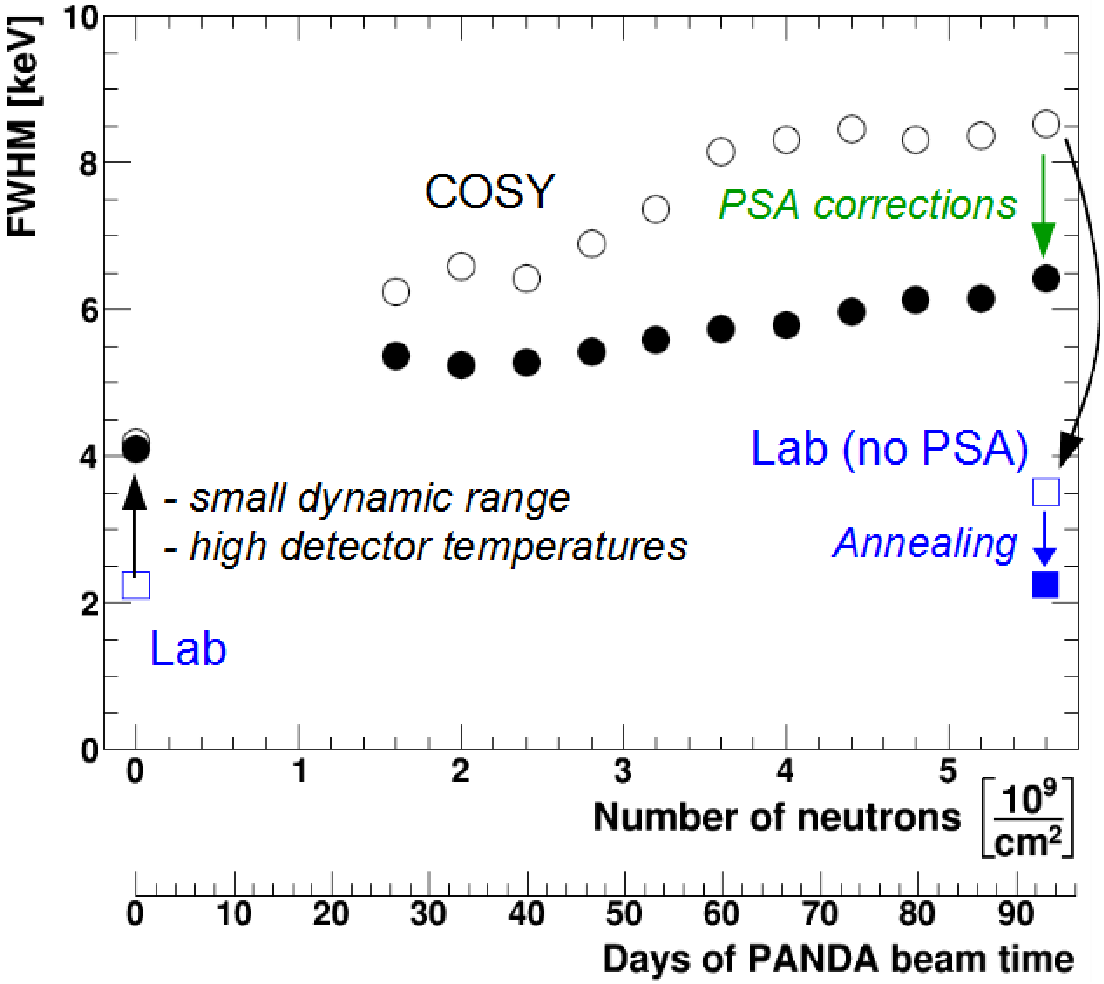
Results



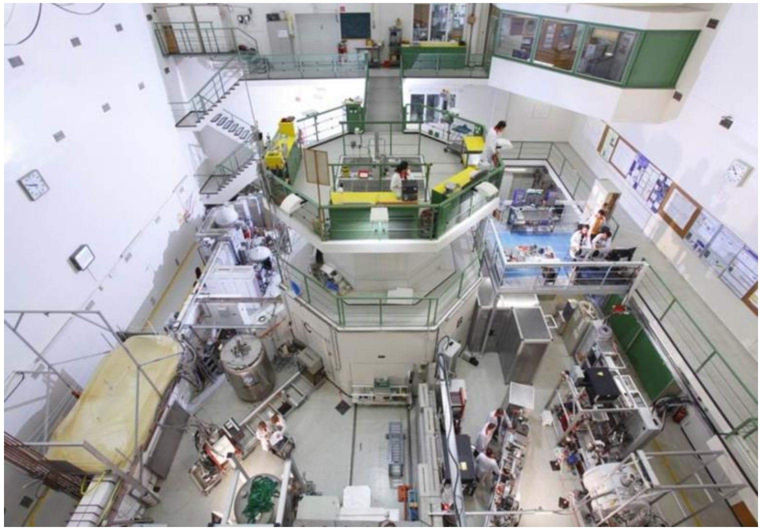
FWHM [keV]
10
8
6
4
2
0
COSY
PSA corrections
Lab (no PSA)
- small dynamic range
- high detector temperatures
Annealing
Lab
0
1
2
3
4
5
Number of neutrons $\left[\frac{10^9}{cm^2}\right]$
0
10
20
30
40
50
60
70
80
90
Days of PANDA beam time

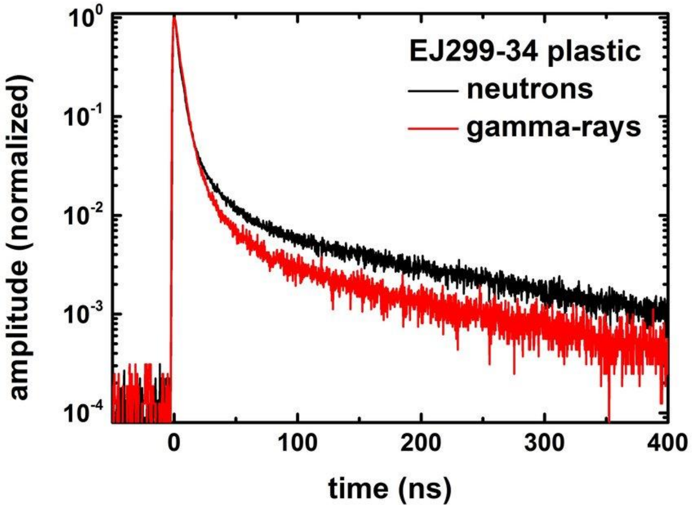
TRIGA – new tests

- More systematic test required

- TRIGA - fission reactor at Mainz university
  - Up to 100 kW
  - High flux of neutrons
  - Fast neutron spectrum poorly known

- Pre-test with scintillating detector performed in january
  - Analysis ongoing





Summary

- PANGEA shares its detectors with DEGAS
- PANGEA designed to perform within $\overline{\text{P}}$ANDA spectrometer
- Distributed DCS system using EPICS
- Digital PSA useful to recover from the effects of the magnetic field and radiation damage