TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

INSTITUT FÜR KERN- UND TEILCHENPHYSIK

Fakultät Physik
Institut für Kern- und Teilchenphysik

Granularity and Photomultiplier studies for Prompt Gamma Spectra in Proton Therapy

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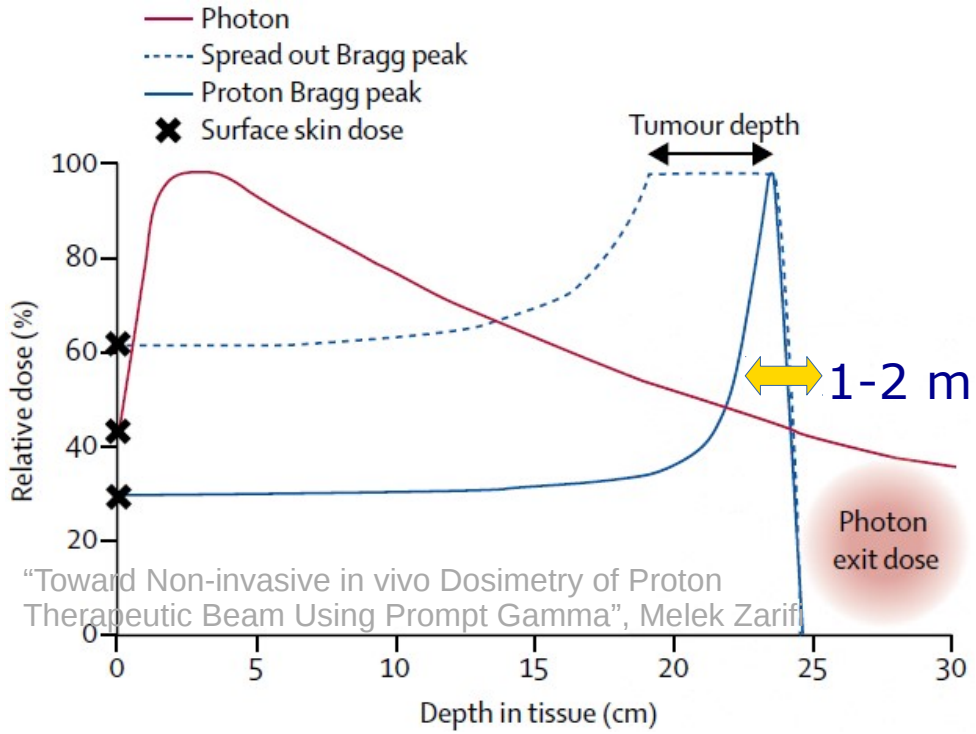
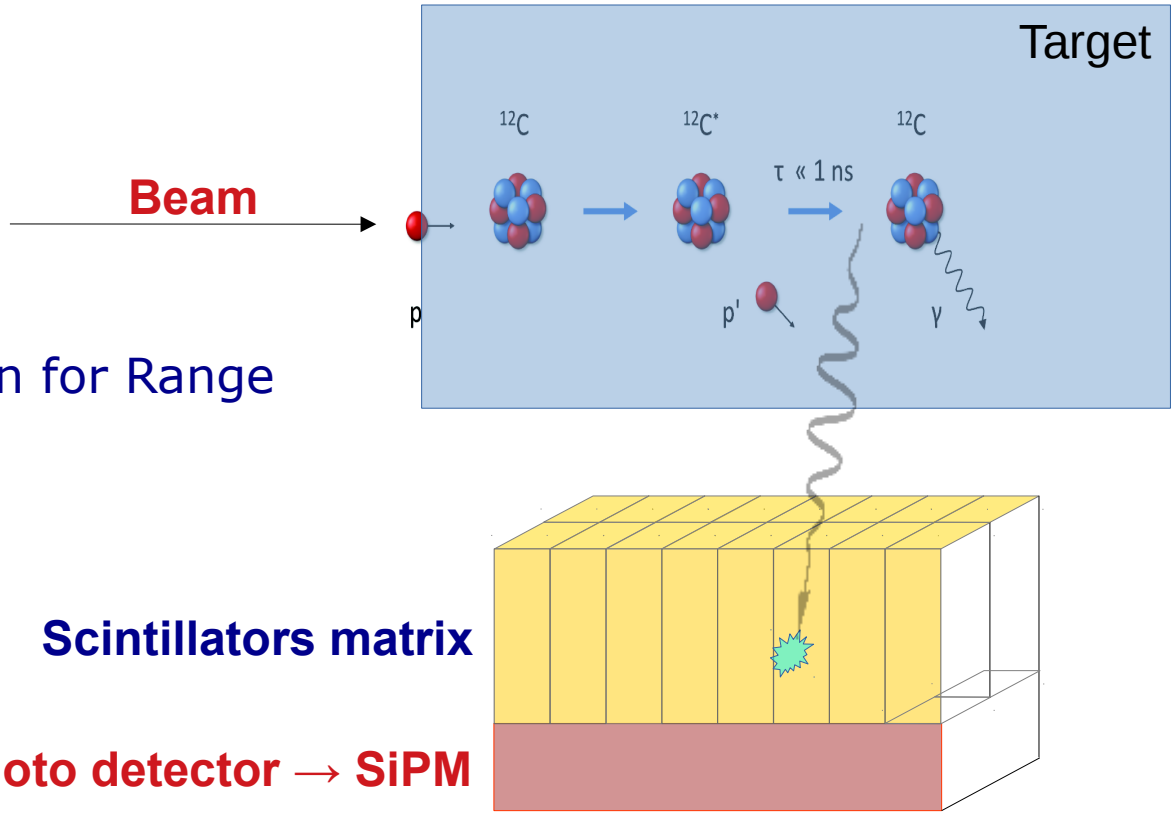
21st March 2022

Range problem in particle therapy



"Toward Non-invasive in vivo Dosimetry of Proton Therapeutic Beam Using Prompt Gamma", Melek Zarifi

1-2 mm precision for Range



Range prediction and verification:

Dual-energy CT or Proton CT, PET, MRI

→ **Prompt gamma-ray timing (PGT)**

→ PETsys: application from PET to PG 3-8 MeV

→ Optimization of scintillator material & size

→ Find fitting SiPM matrix

High statistics with full acceptance

→ ~ 10^6 … 10^8 p^+ / Pencil Beam Spot (PBS)

→ ~ 2 x 10^9 PG's per second

→ Extreme load tolerance

PETsys Setup

Scintillators:

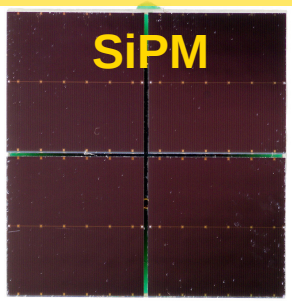
$CeBr_3$

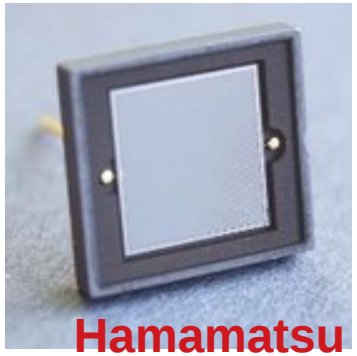
$5\times5\times20\ mm^3$
$10\times10\times30\ mm^3$

$5\times5\times20\ mm^3$

$Gd_3Al_2Ga_3O_{12}$ (GAGG)

+





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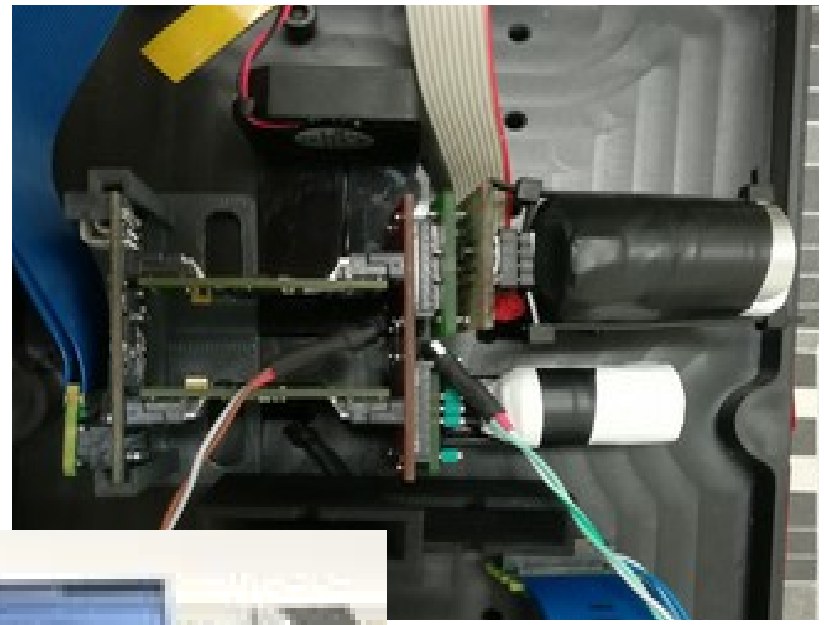
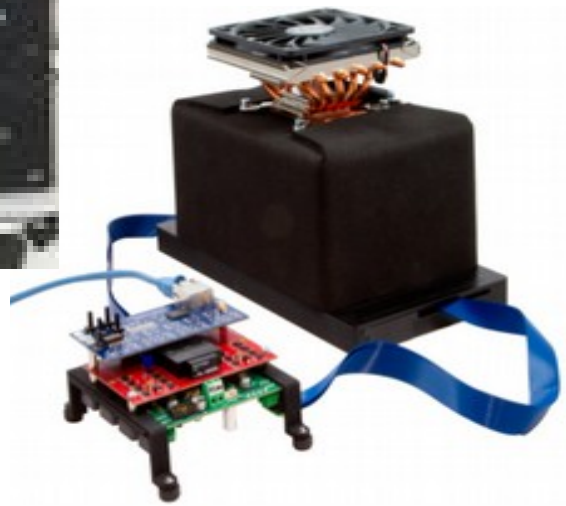
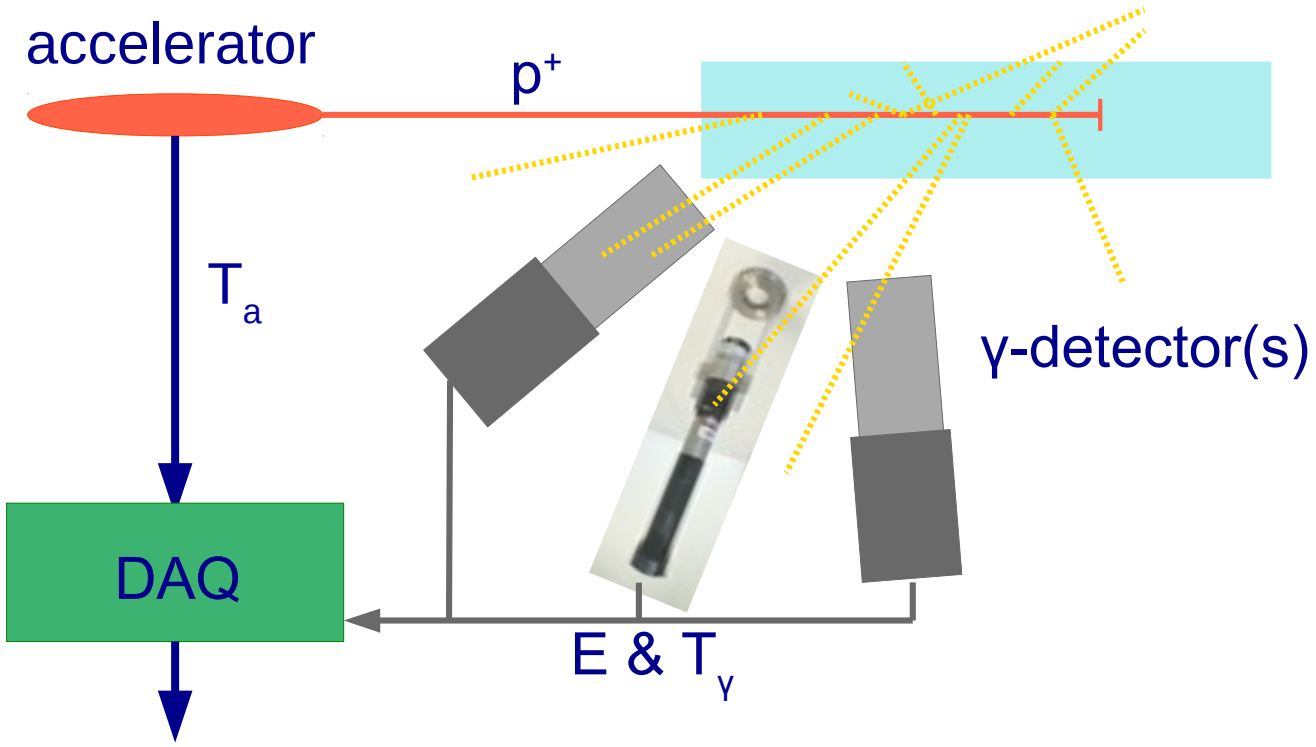
Assembly

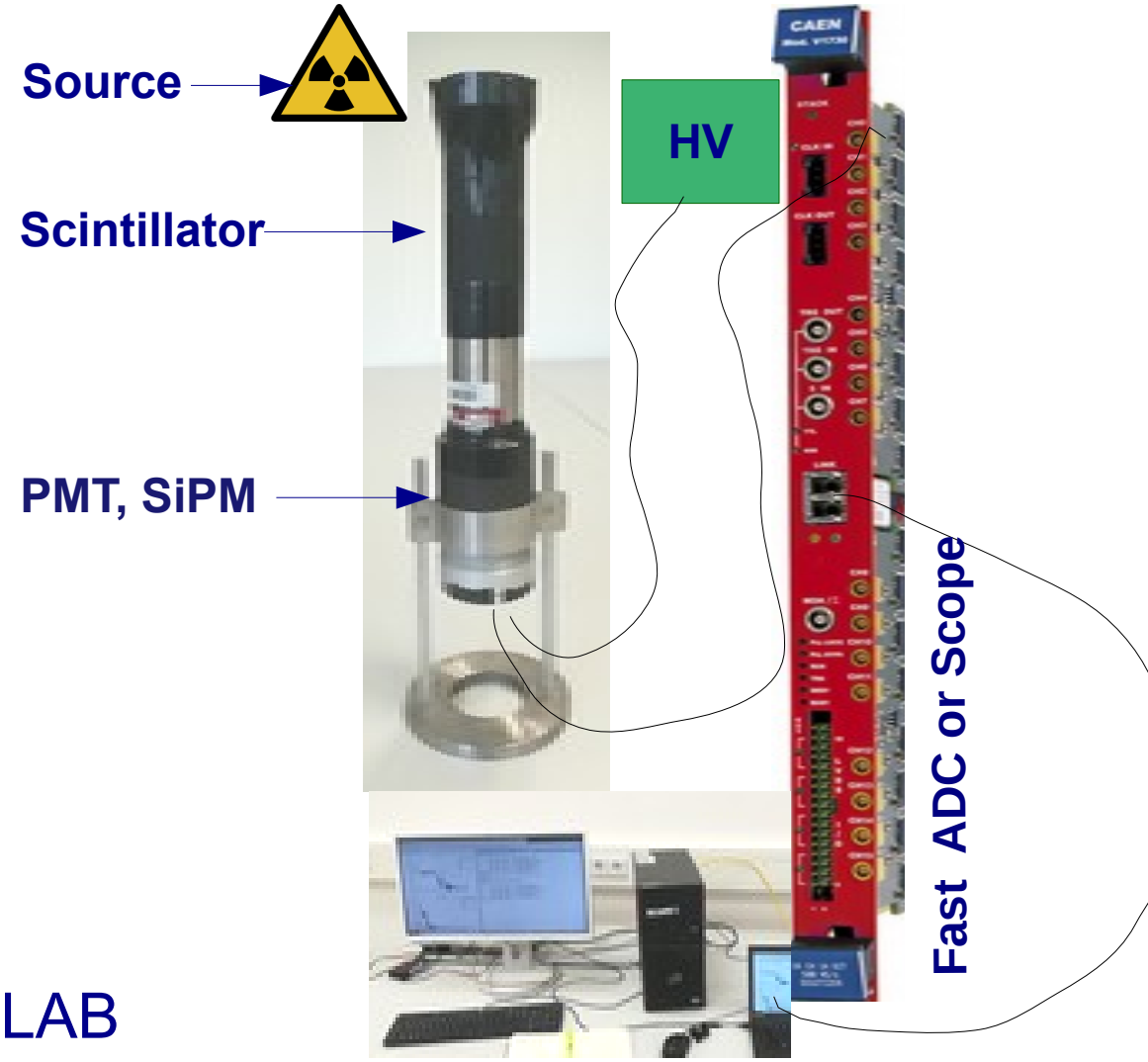


→ cost effective
→ fast
→ scalable



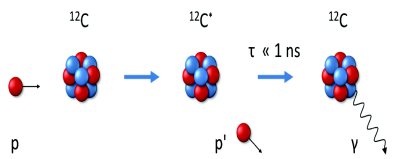
Measurements





Measurements: Accelerator or Sources in the LAB

AmBe Source

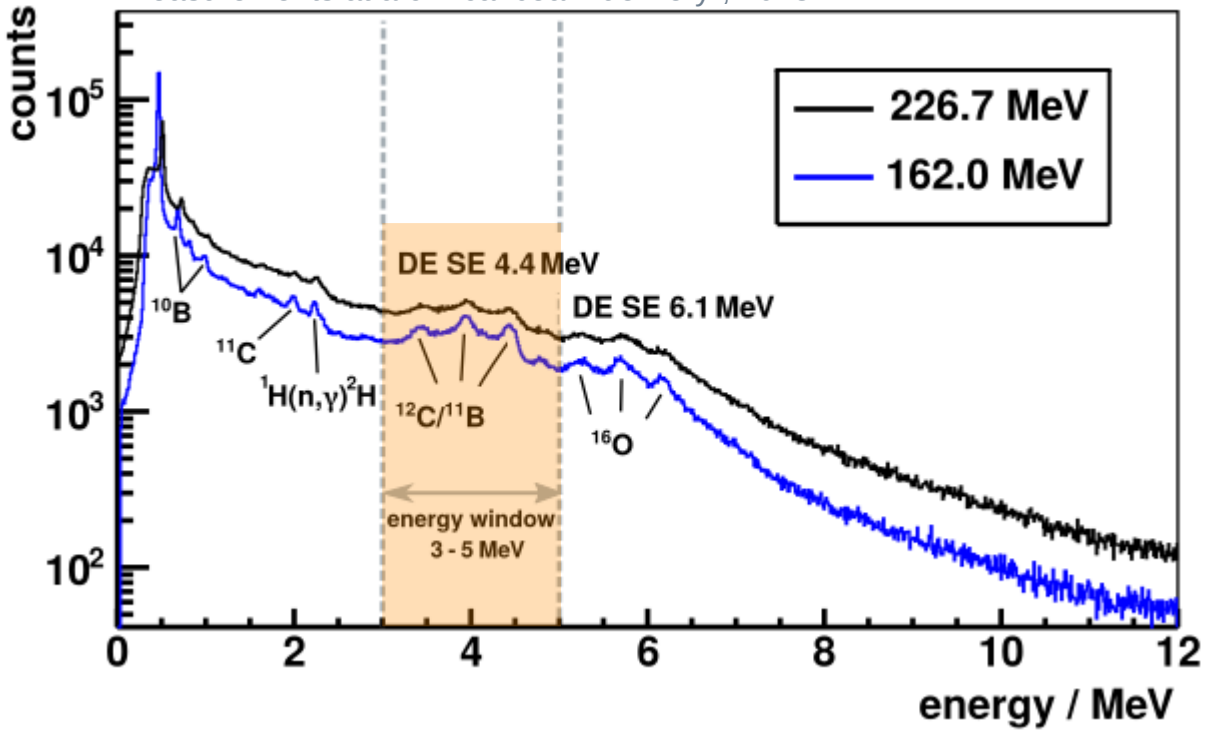


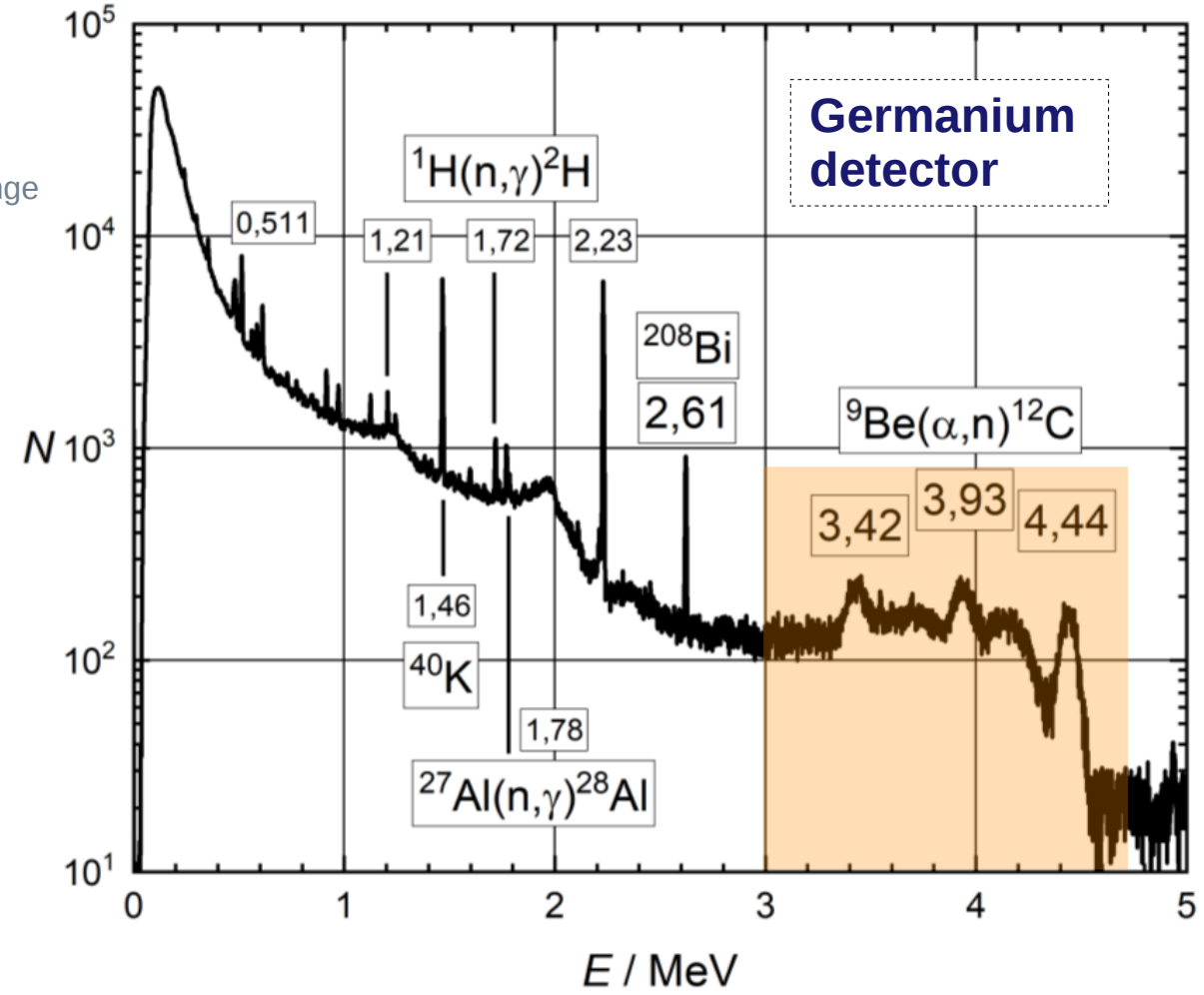
$^{12}C(p, p'\gamma_{4.439})^{12}C$

$^{12}C(p, 2p'\gamma_{4.445})^{11}B$

$^{16}O(p, \alpha\, p'\gamma_{4.439})^{12}C$

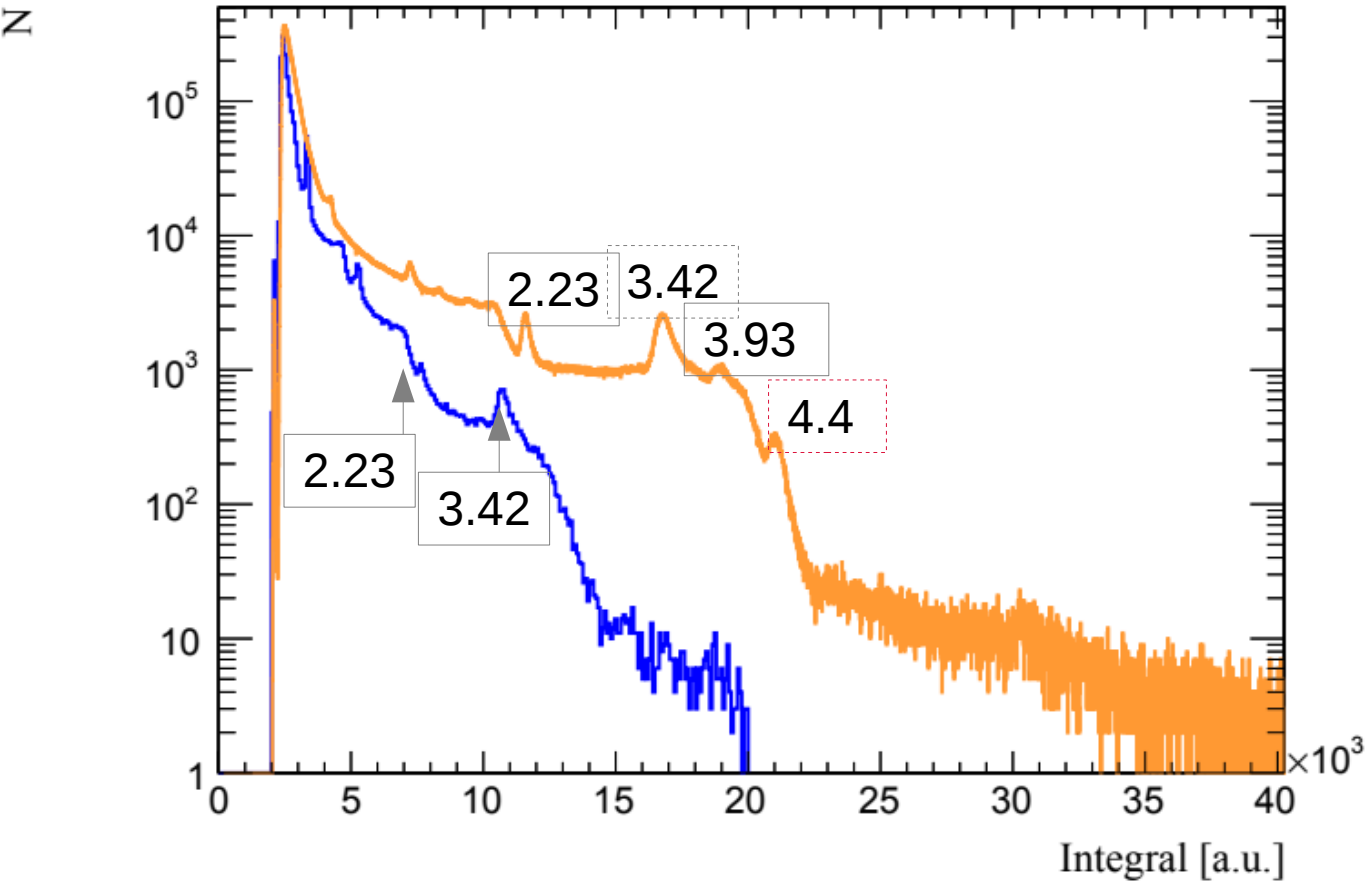
Theresa Werner, “Processing of prompt gamma-ray timing data for proton range measurements at a clinical beam delivery”, 2018

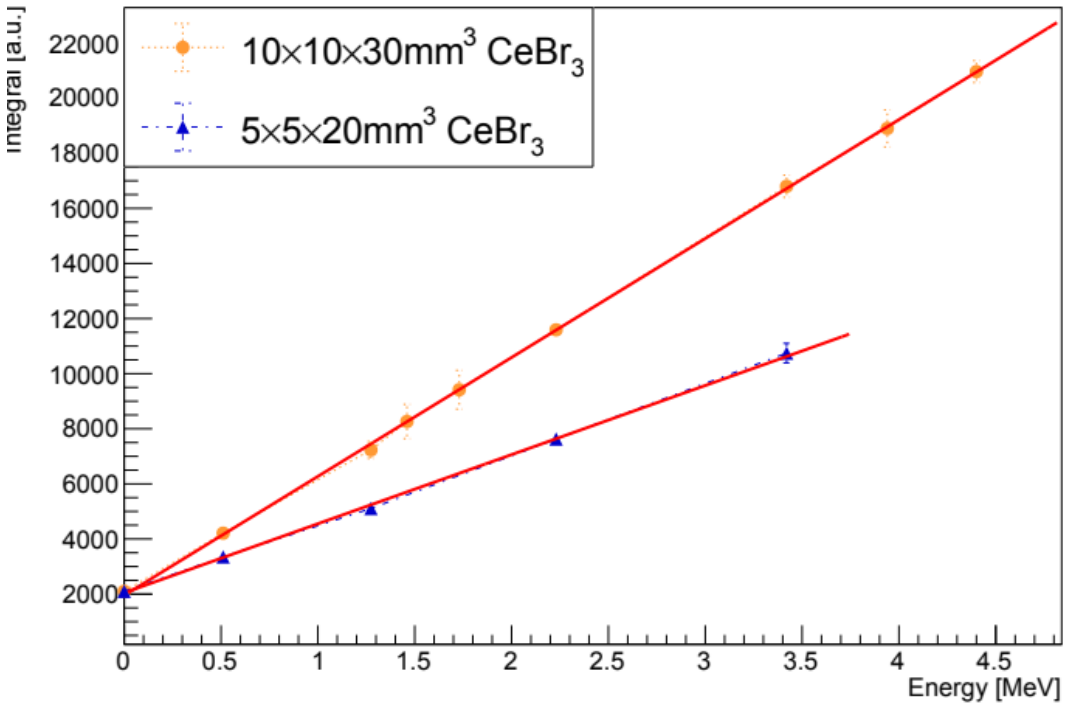




Interesting spectrum up to 3-8 MeV; All measurements with source in the lab.

ADC Measurements with $CeBr_3$

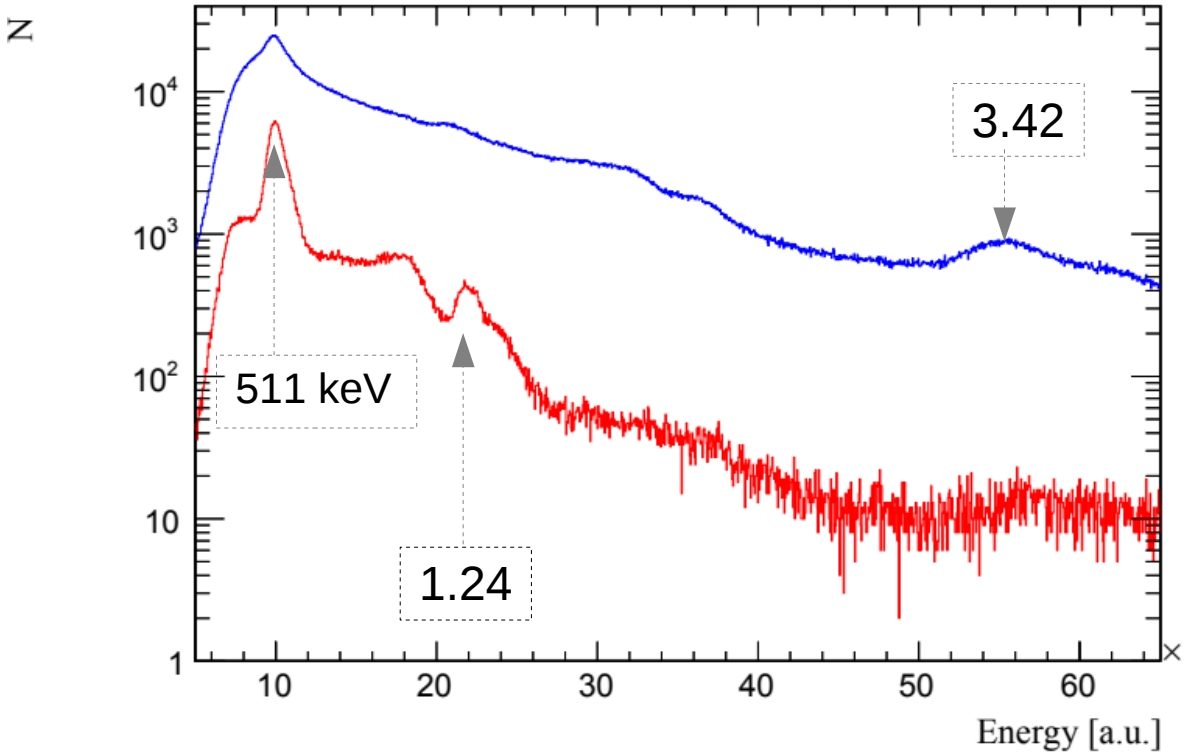


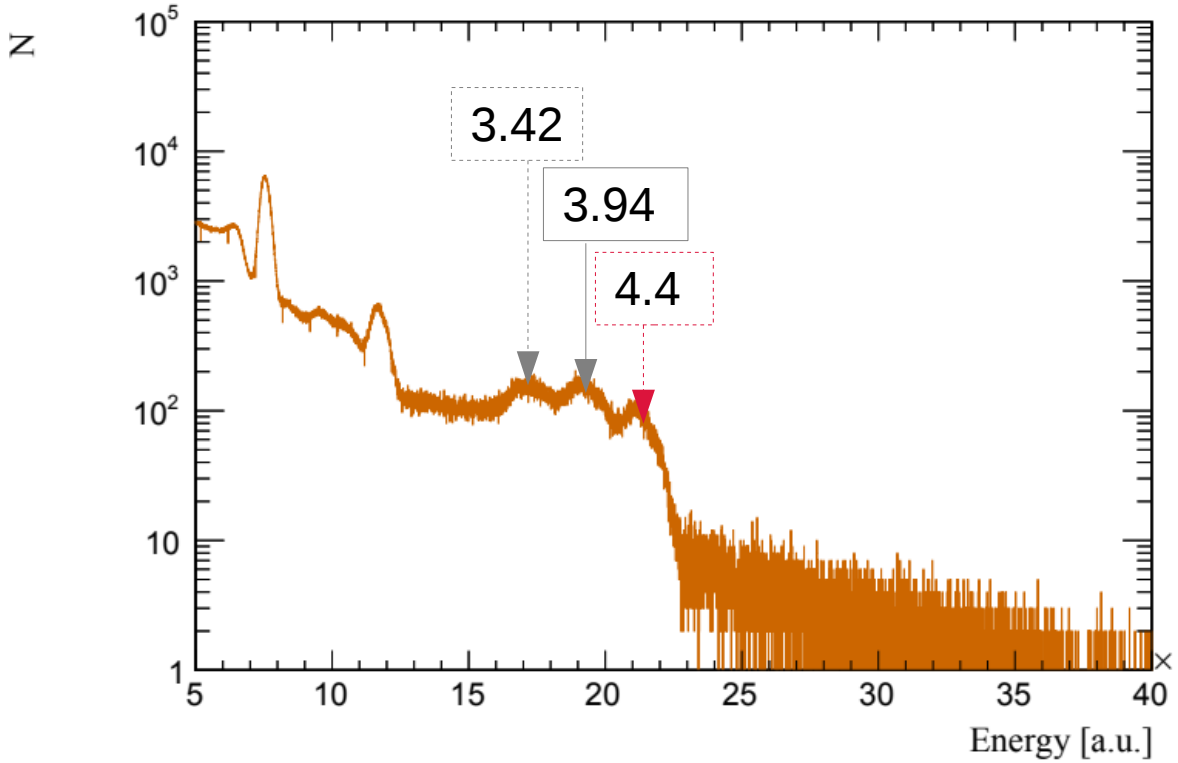


Calibration is linear

Smaller crystals – less signal → no 4.4 MeV and single escape peaks visible

ADC Measurements with GAGG



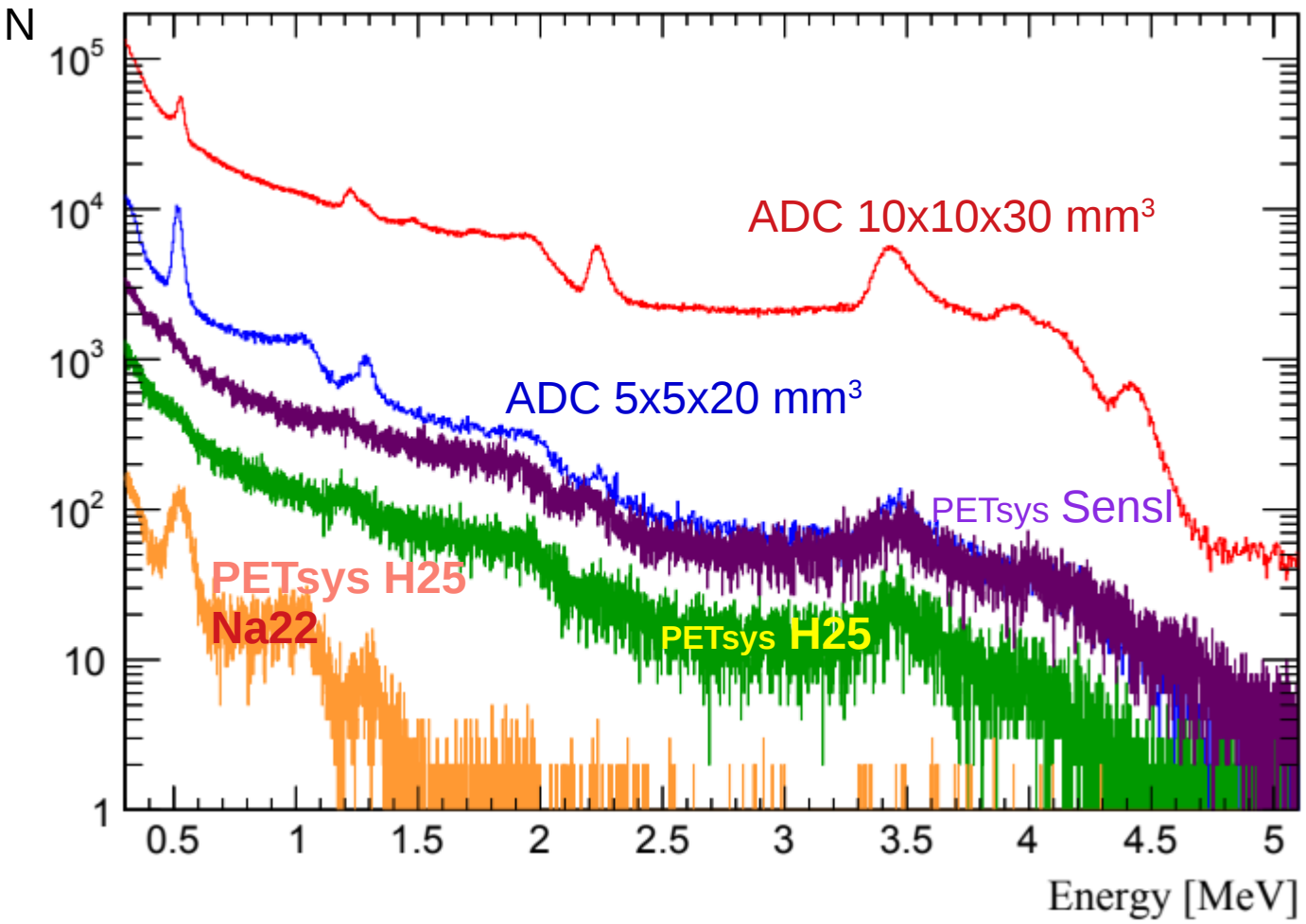


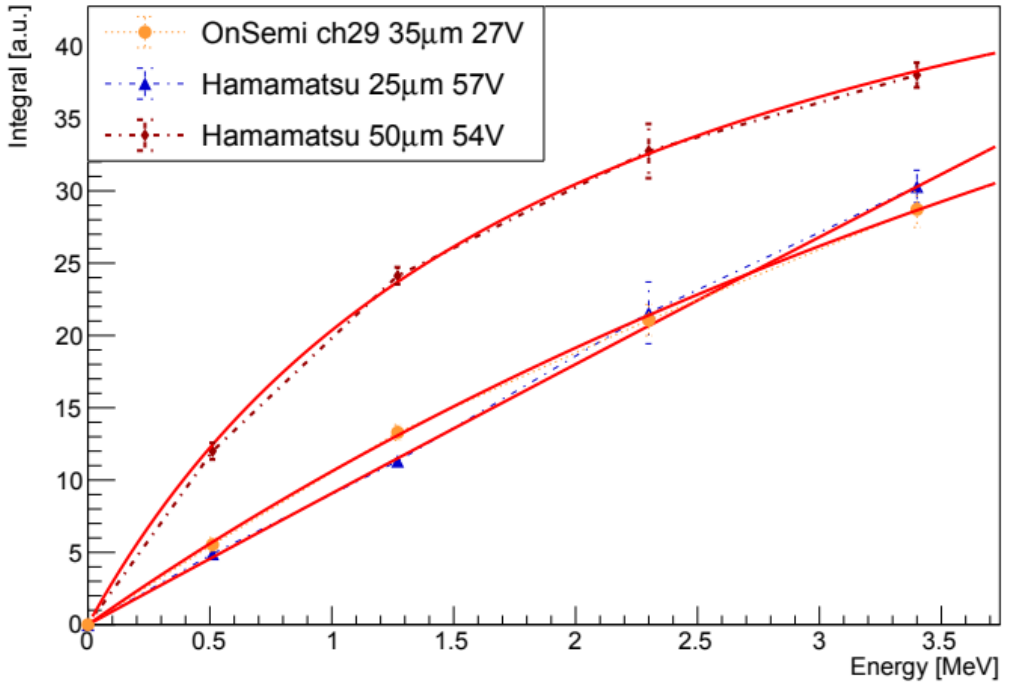
5x5x20 mm^3

33x33x20 mm^3

Small GAGG crystals show poorer energy resolution than bigger crystal

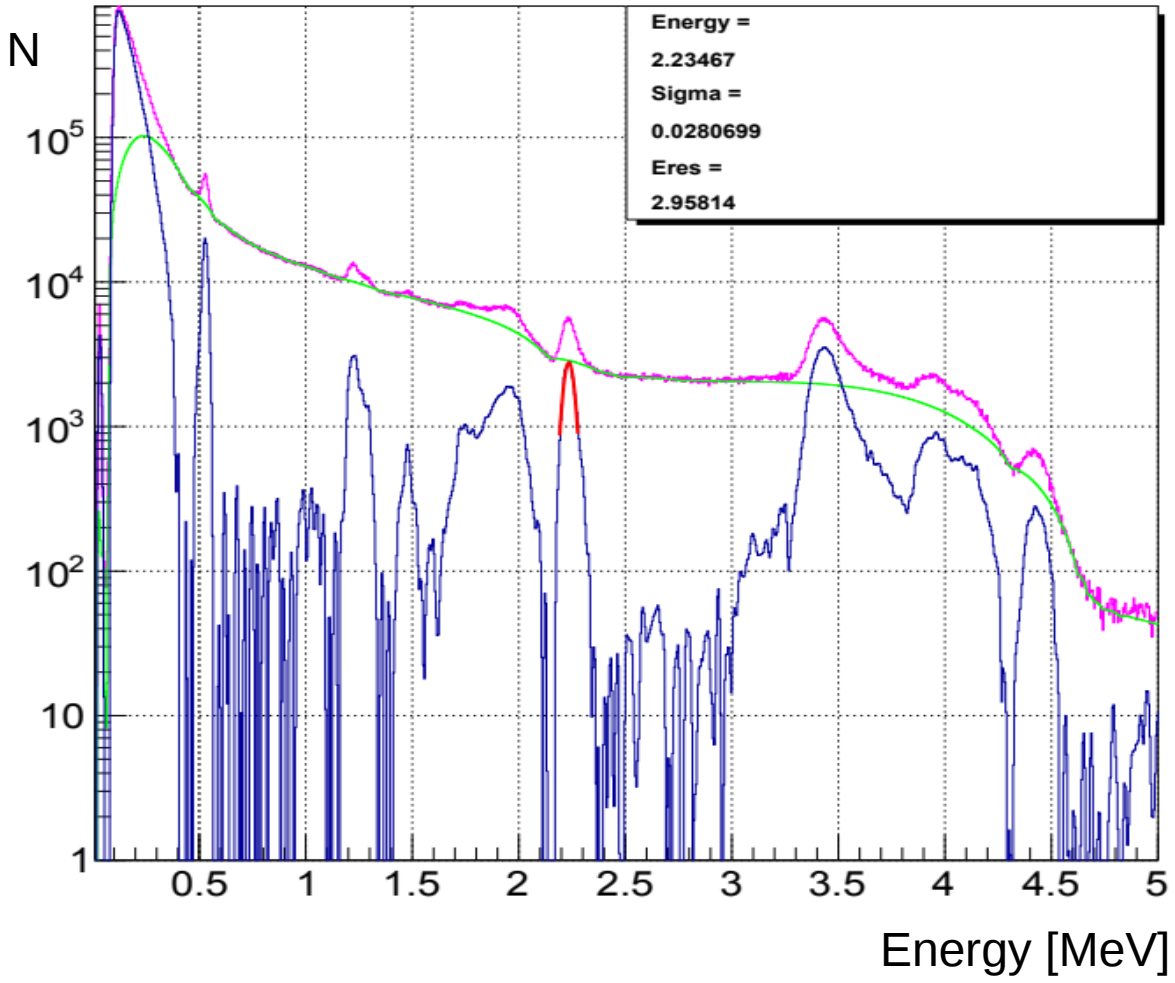
PETsys Measurements





1. Compared 3 different SiPM's matrices
2. PETsys:
   → Hamamatsu 50µm - saturated
   → others – slightly saturated
   & can be corrected
3. 5x5x20 mm³ → double escape peak

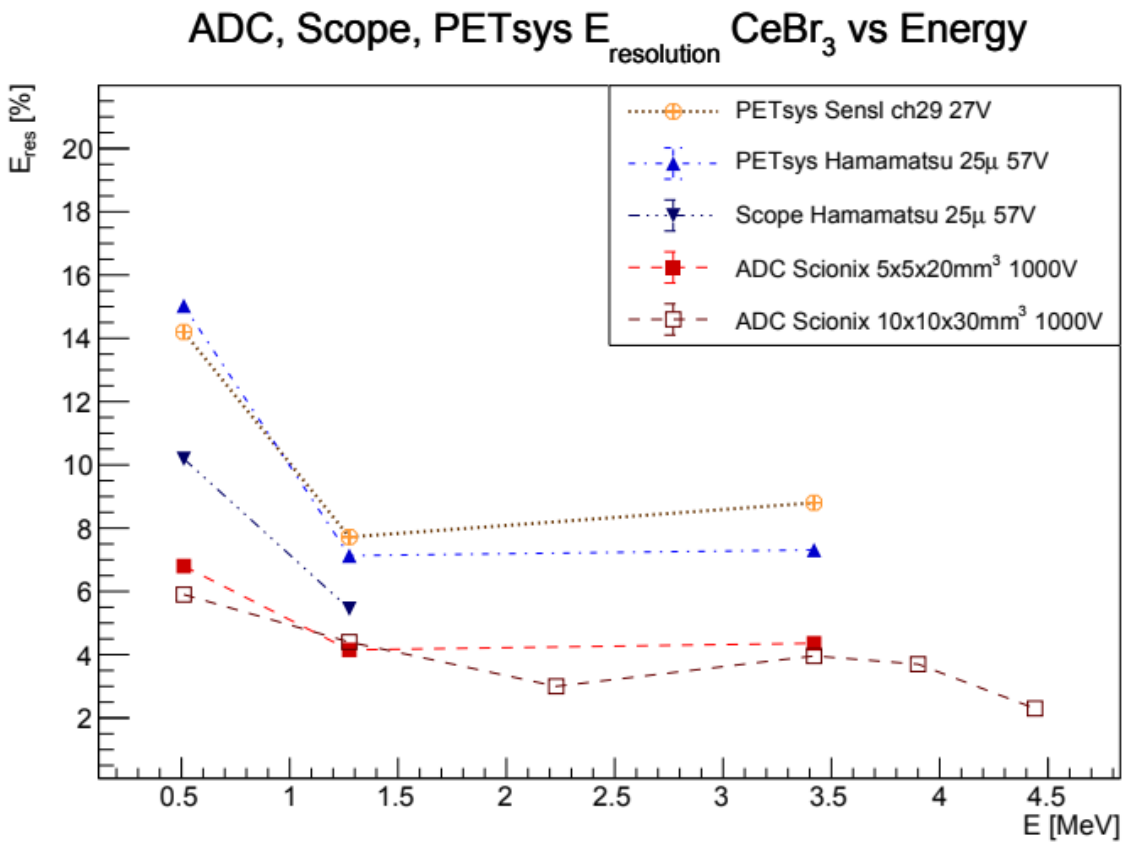
Energy Resolution $CeBr_3$



1. ROOT TSpectrum to estimate background (green)
2. After background subtraction (blue)
3. Gaussian fit (red)
4. $E_{res} = \sigma/\mu * 2.355$
5. 2.355 - conversion factor to calculate full width at half maximum (FWHM)

– due to difficulties to estimate background for the full energy range and low statistics at higher energies.

Energy Resolution $CeBr_3$



Comparison between 3 setups

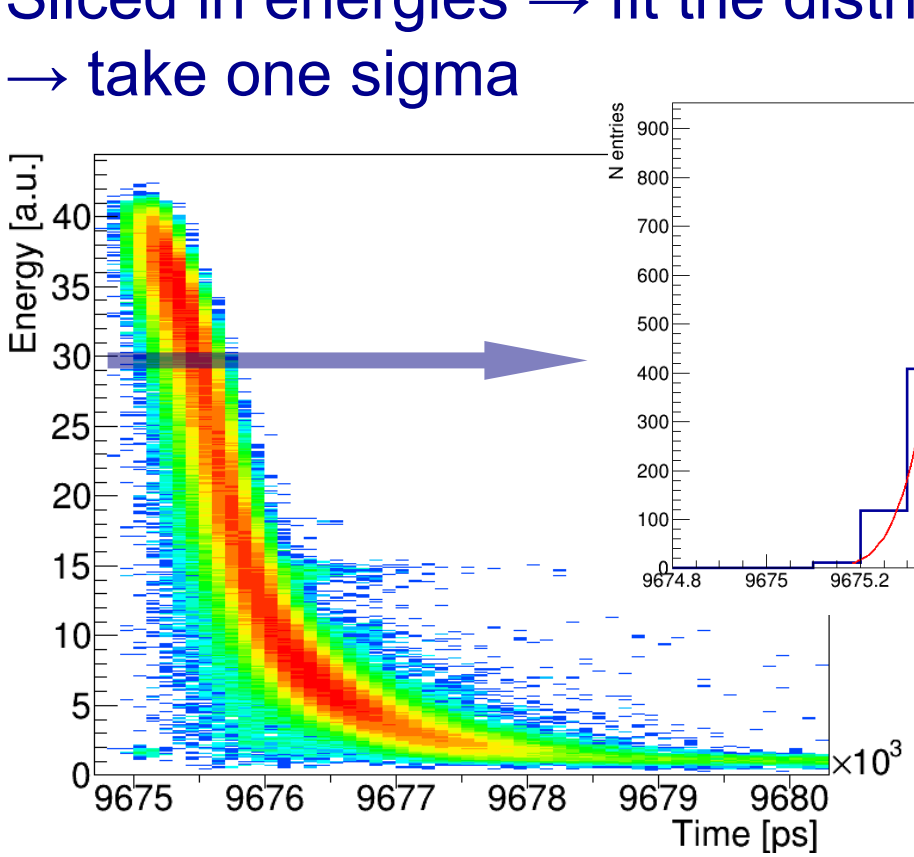
- ADC + PMT + $CeBr_3$
- Scope + SiPM + $CeBr_3$
- PETsys + SiPM + $CeBr_3$

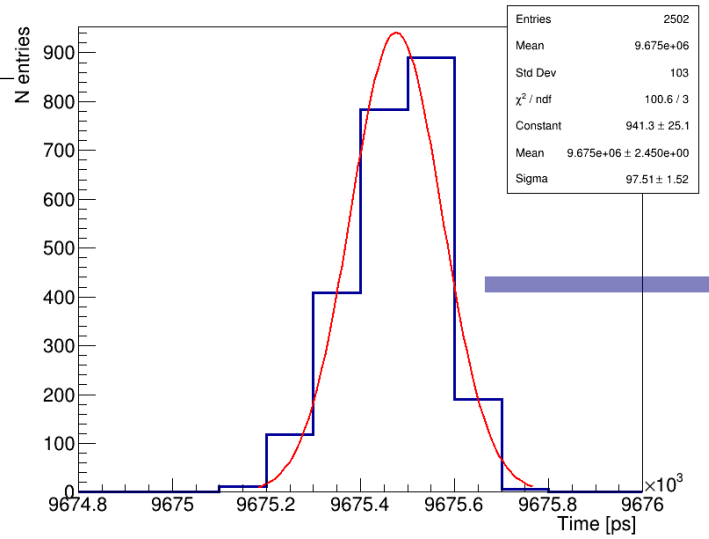
Energy resolution with 2.355 conversion factor

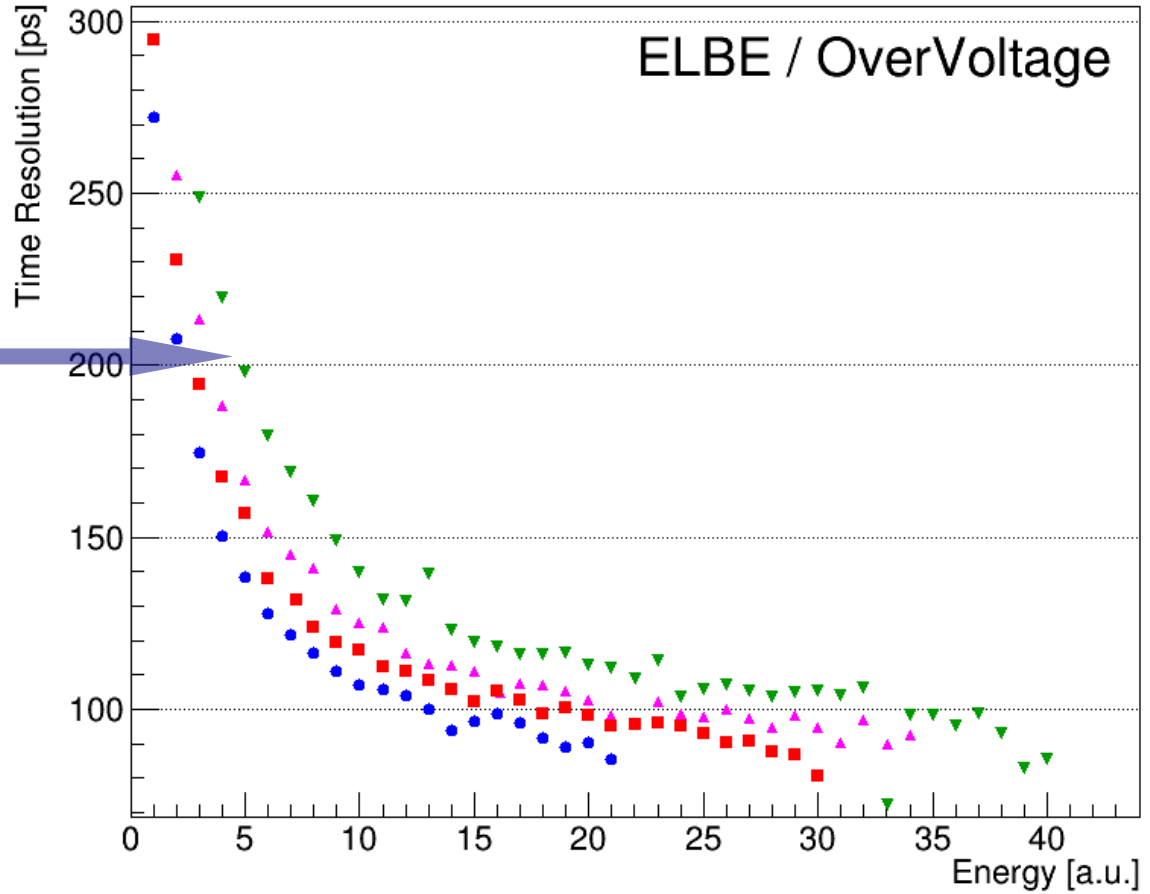
We loose ~ 3% of energy resolution with PETsys

Time Resolution

ELBE at HZDR Rossendorf
Sliced in energies → fit the distribution
→ take one sigma



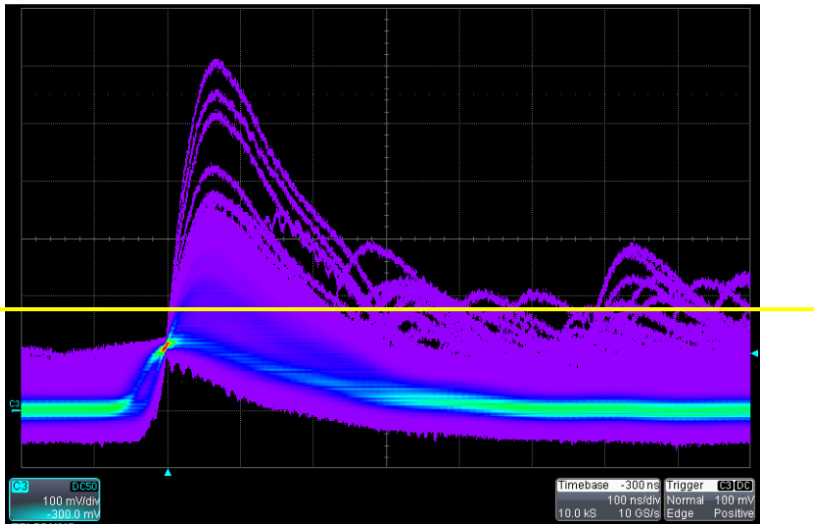




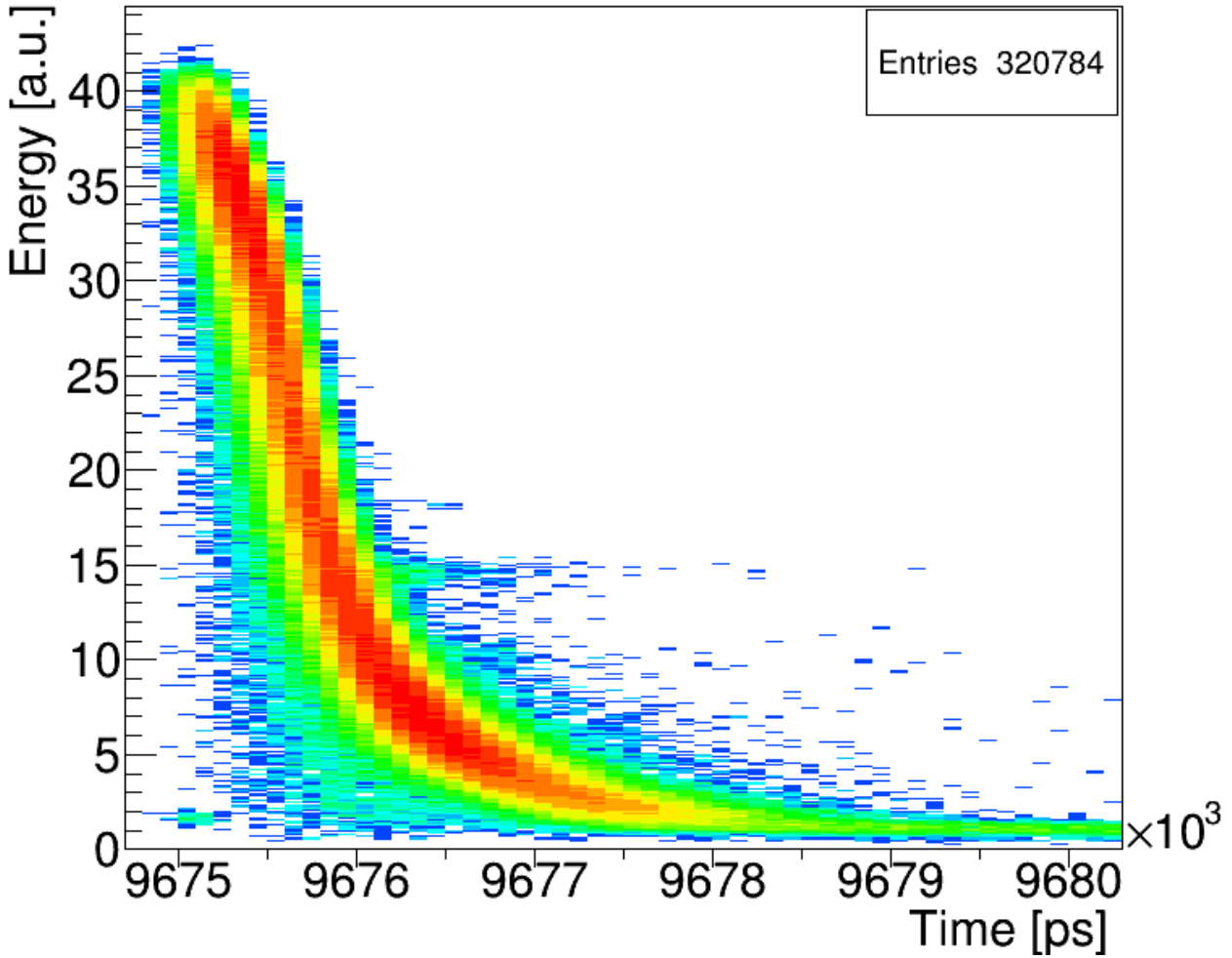
Reach time resolution ~100 ps

Time Walk

Required time resolution few 100 ps – PETsys ~100 ps
Fixed thresholds instead of CFD is a disadvantage:



Time walk up to 500 ps



Conclusions and Plans

Granularity: → 5x5x20 mm^3 only double escape peaks
→ 10x10x30 mm^3 better

→ Increase the width to 1-2 cm and height to 4-5 cm

SiPM: → SensL SiPM matrices are the best available candidates
→ Hamamatsu 25 μm - ideal

→ SensL SiPM matrices
→ Single Hamamatsu SiPM with adapter board for the PETsys
→ to avoid crosstalk and alignment

PETsys: → easy scalable
→ ~100 ps time resolution
→ 3% loss in $E_{resolution}$

→ Time walk correction

Plans: Measurements at the OncoRay – National Center for Radiation Research in Oncology, located in Dresden