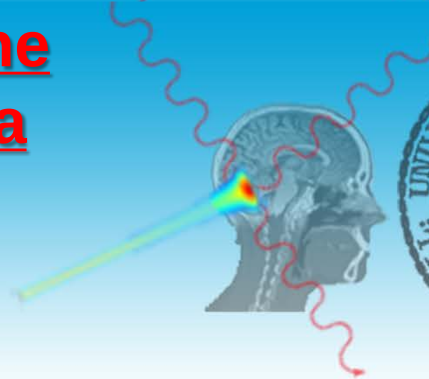
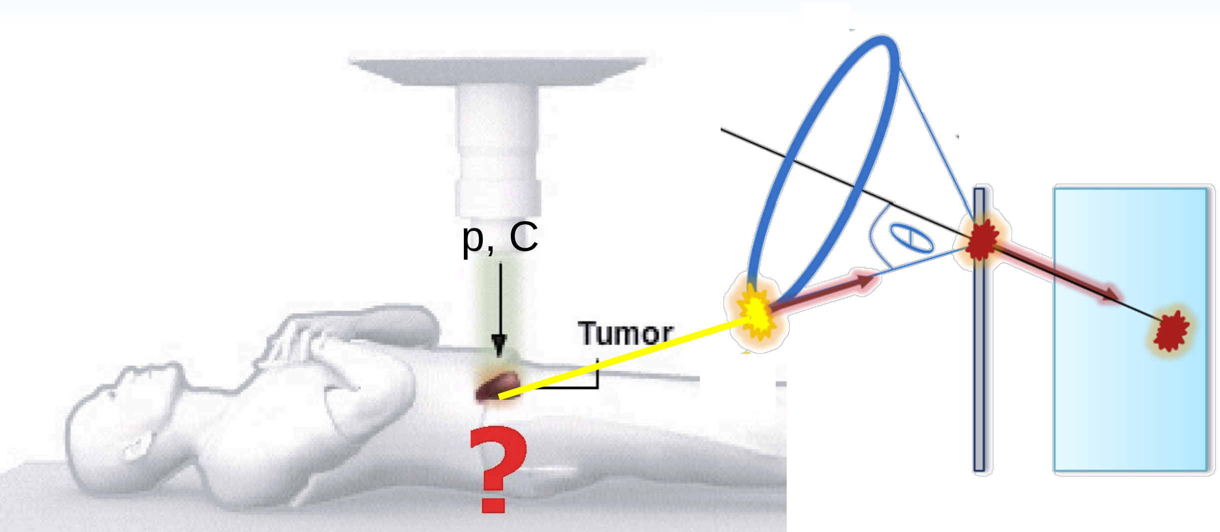
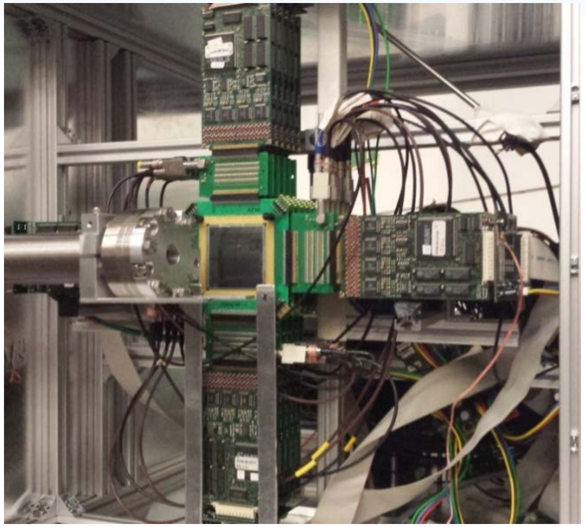
Recent developments for the Garching Compton Camera Prototype



P.G. Thirolf, LMU Munich





- Detector performance: spatial resolution of monolithic scintillator
- Ongoing developments:
  - upgrade of signal processing and DAQ electronics

  [- alternative absorber detector: $CeBr_3$ compared to $LaBr_3(Ce)$

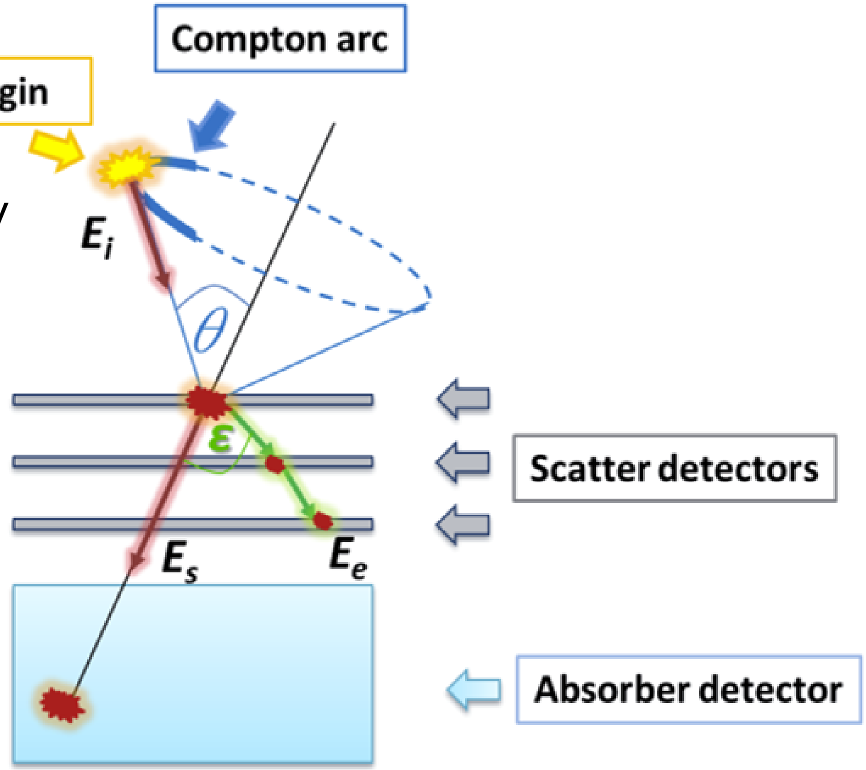
  [- alternative readout: SiPM compared to MA-PMT

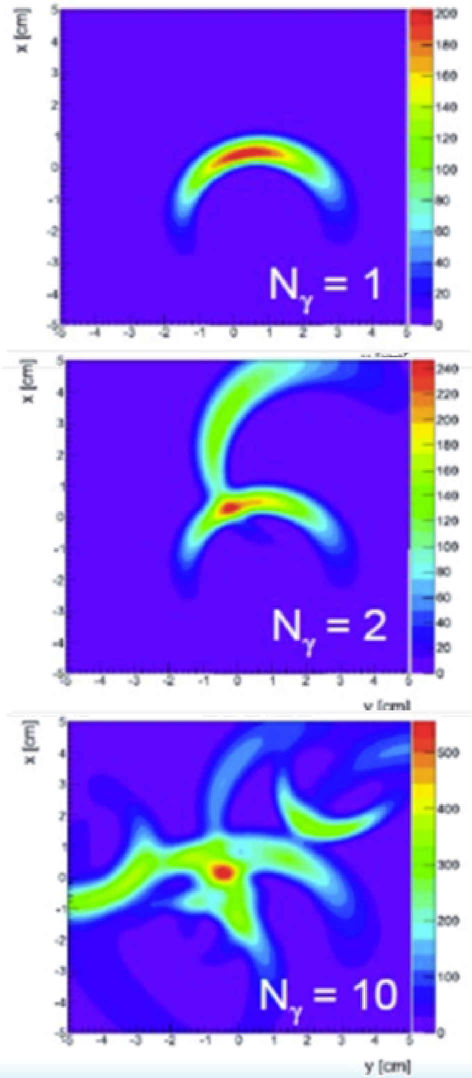
  [- alternative scatterer: pixelated GAGG array (for $E_\gamma < 1.5$ MeV)

(Prompt) Gamma Imaging: Compton Camera

Compton camera with electron tracking:

$E_\gamma \geq$ 1-2 MeV





advantage:

- reconstruction of incompletely absorbed events

→ increased reconstruction efficiency

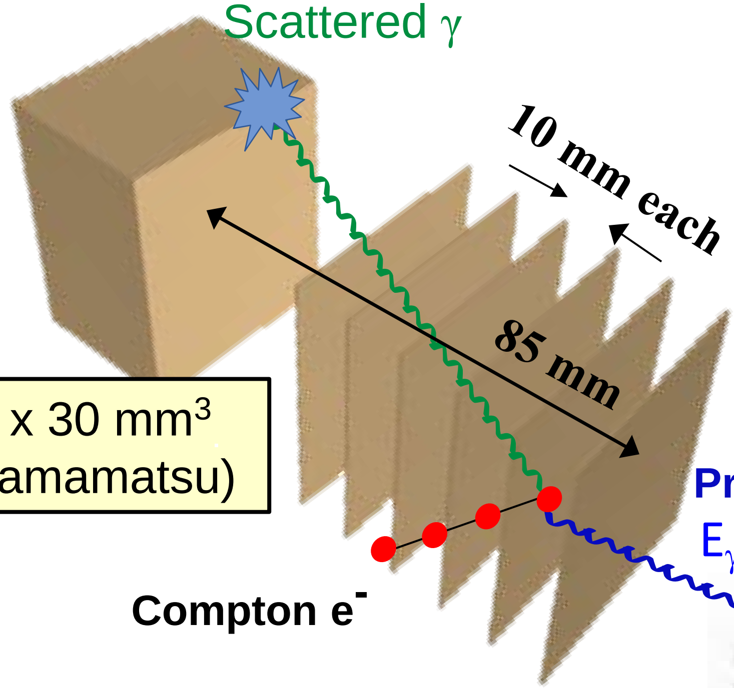
Garching Compton Camera Prototype

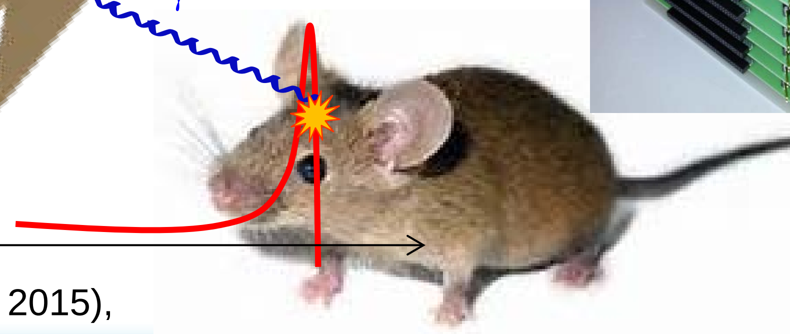
- **Garching Compton camera layout:**

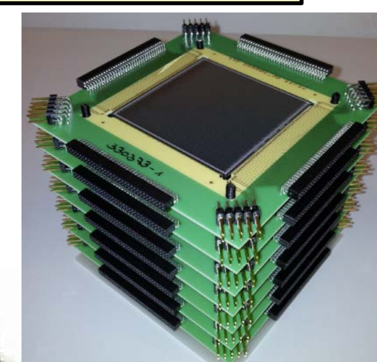
Scatterer/Tracker Array (DSSSD)

6x DSSSD
→ active area 50 x 50 mm^2
→ thickness : 500 μm
→ 128 strips on each side
→ pitch size 390 μm
→ resistivity > 10 kΩcm

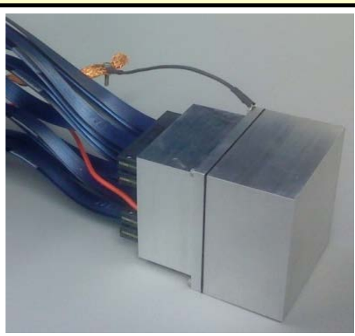
Absorber
($LaBr_3$:Ce + PMT)







$LaBr_3$(Ce): 50 x 50 x 30 mm^3
16x16 MA-PMT (Hamamatsu)



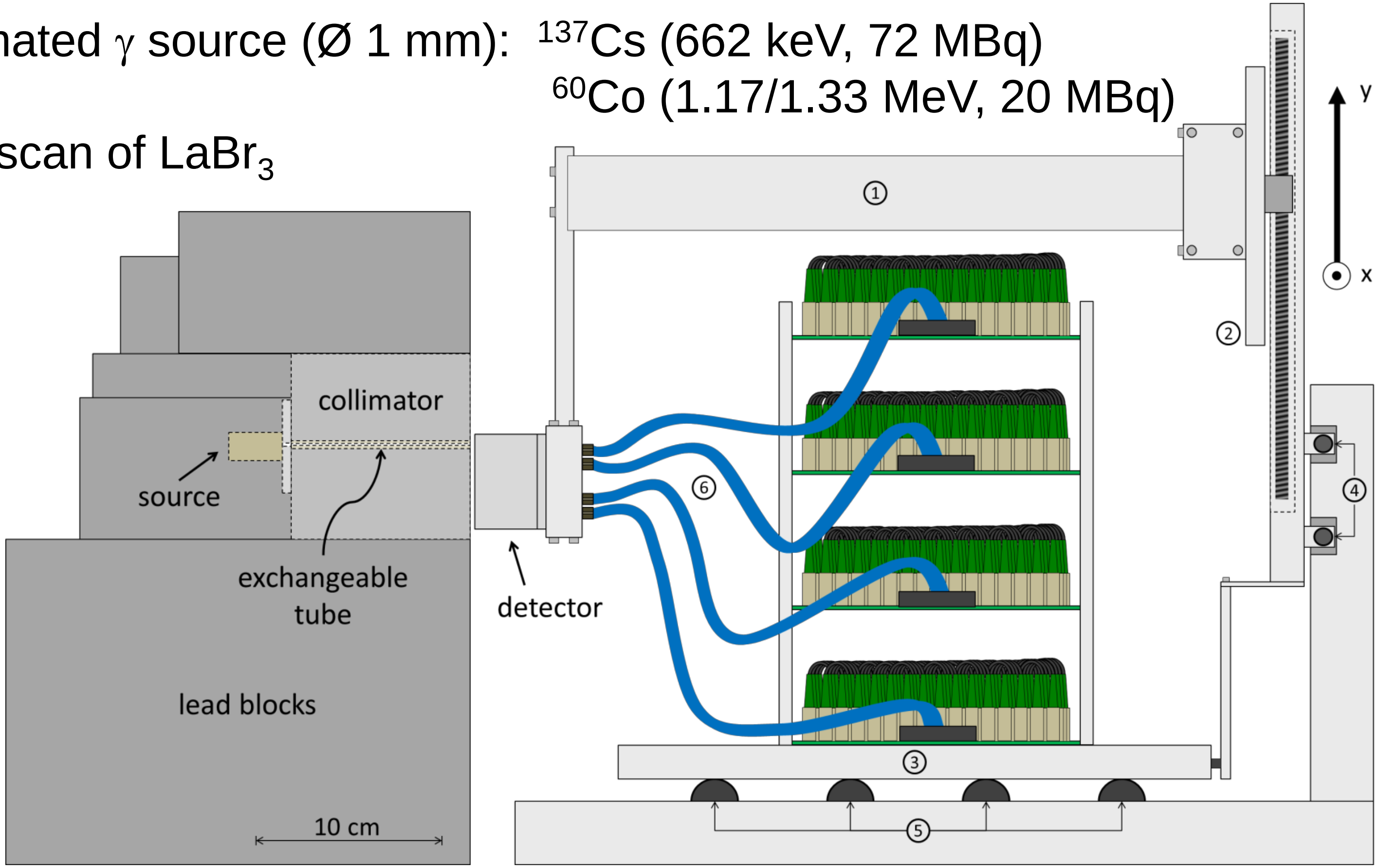
C. Lang et al., JINST 9 (2014) P01008, PhD thesis (LMU, 2015),
S. Aldawood, PhD thesis, LMU 2016

Spatial resolution from monolithic $LaBr_3$ absorber

- spatial resolution: based on 2D detector response

  - collimated γ source (Ø 1 mm): ^{137}Cs (662 keV, 72 MBq)
    ^{60}Co (1.17/1.33 MeV, 20 MBq)

  → 2D scan of $LaBr_3$



- data analysis:

  → "k-nearest neighbour" algorithm (TU Delft)

H.T. van Dam et al., IEEE Trans. Nucl. Sci. 58, 2139 (2011)

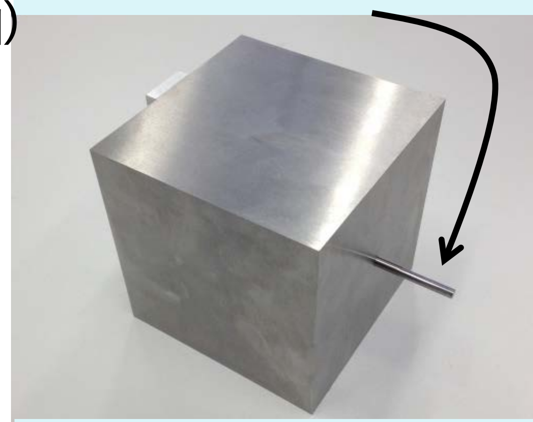
Experimental setup for collimated source scan

- spatial resolution: based on 2D detector response

  - collimated γ source (Ø 1 mm): ^{137}Cs (662 keV, 72 MBq)
  ^{60}Co (1.17/1.33 MeV, 20 MBq)

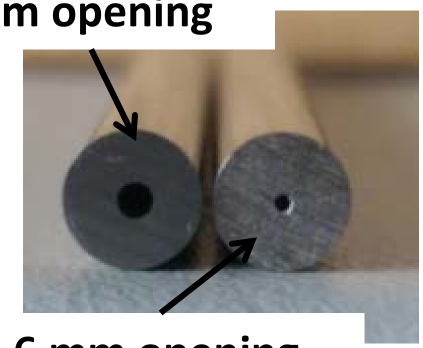
  → 2D scan of $LaBr_3$ (mounted on translational stage)

Exchangeable WC collimator tube



100x100x100 mm^3 DENSIMET®

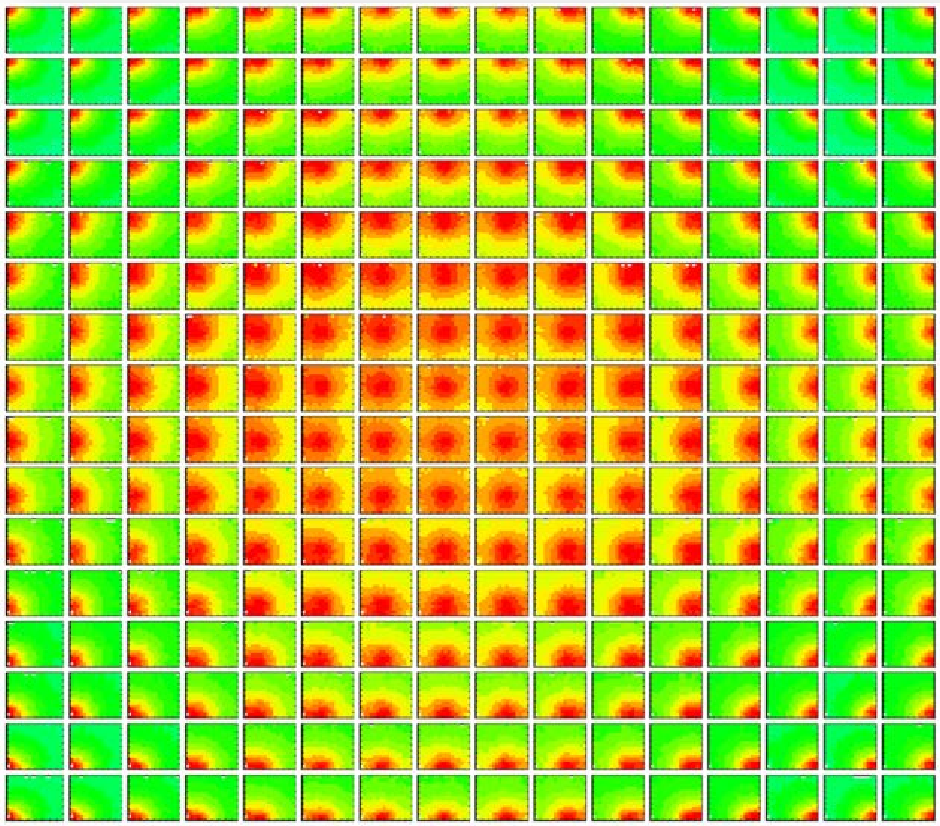
1 mm opening



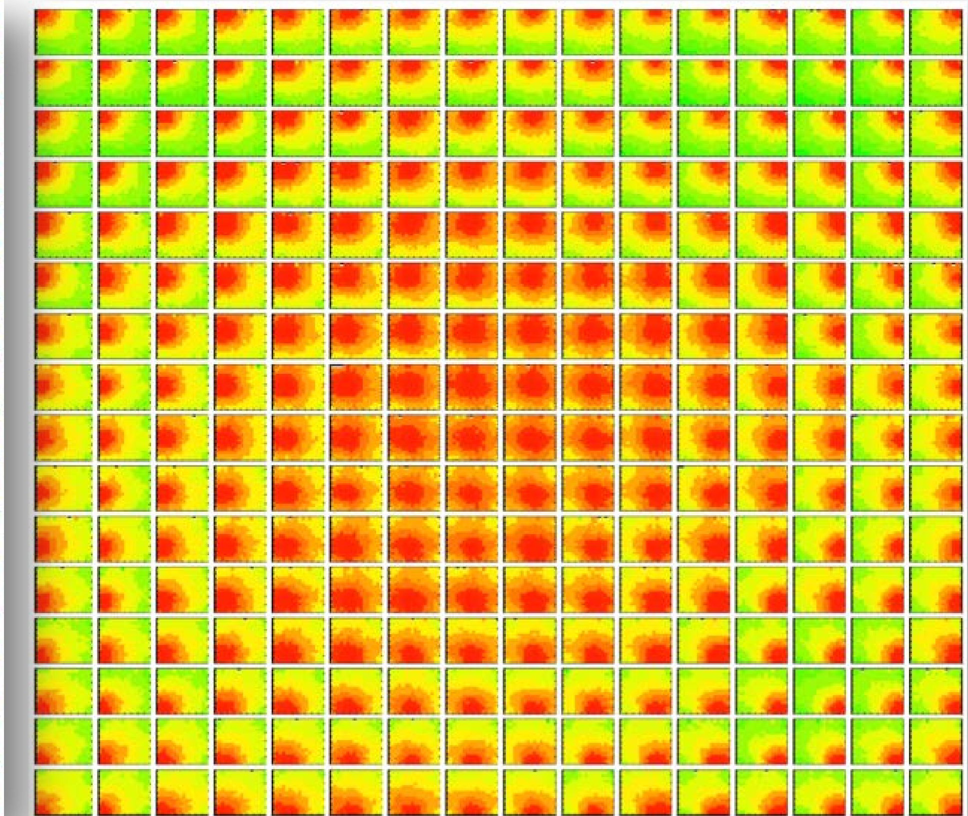
0.6 mm opening

2D Light Amplitude Distributions

^{137}Cs: 0.662 MeV



^{60}Co:1.3MeV

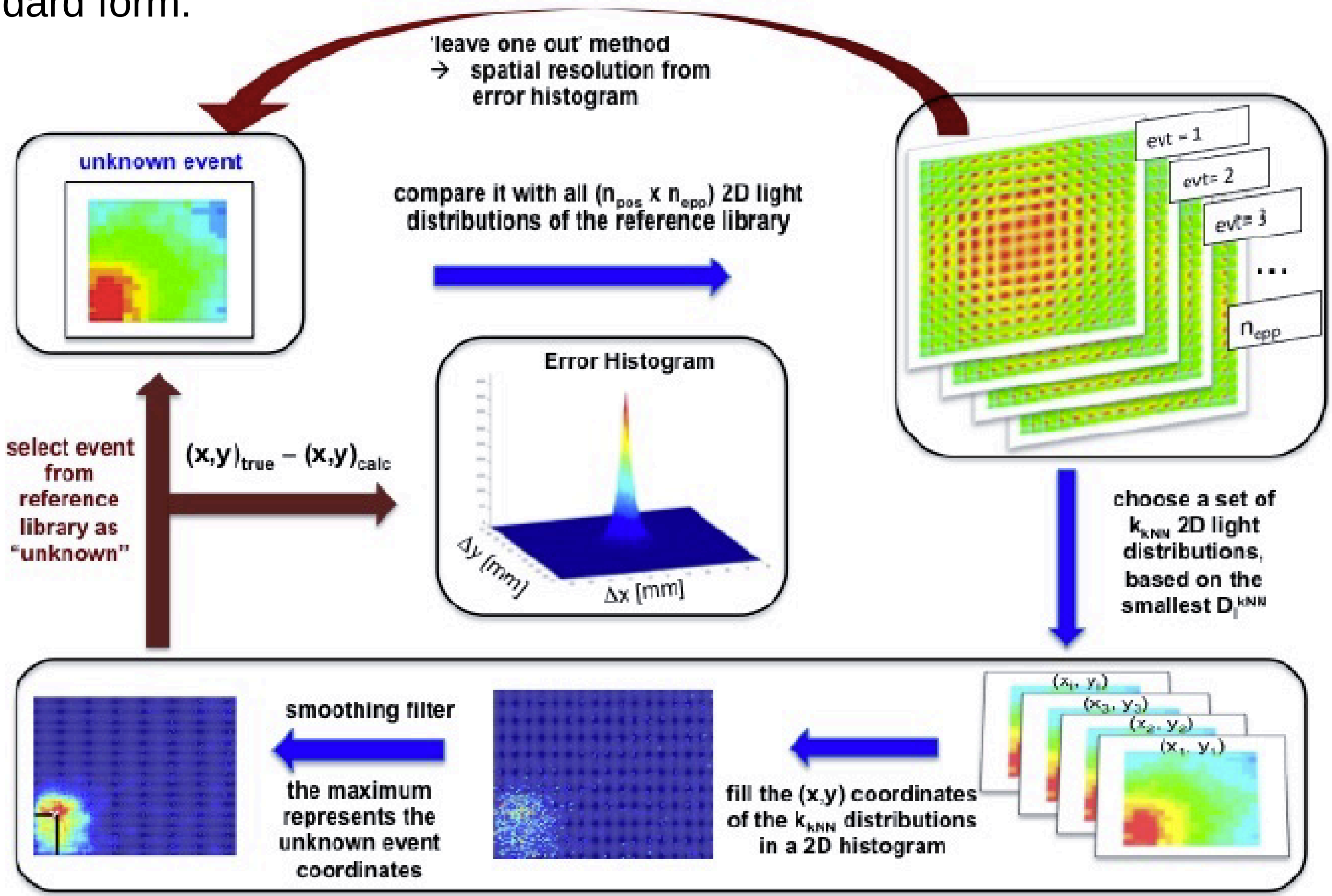


- 16x16 pixel source grid: step size 3 mm
- for full reference library: 0.5 mm step size = 10000 irradiation positions

S. Aldawood, PhD 2016, M. Mayerhofer, MSc 2017, A. Miani, MSc 2016, T. Marinšek, MSc 2015

k-Nearest Neighbour (kNN) Algorithm

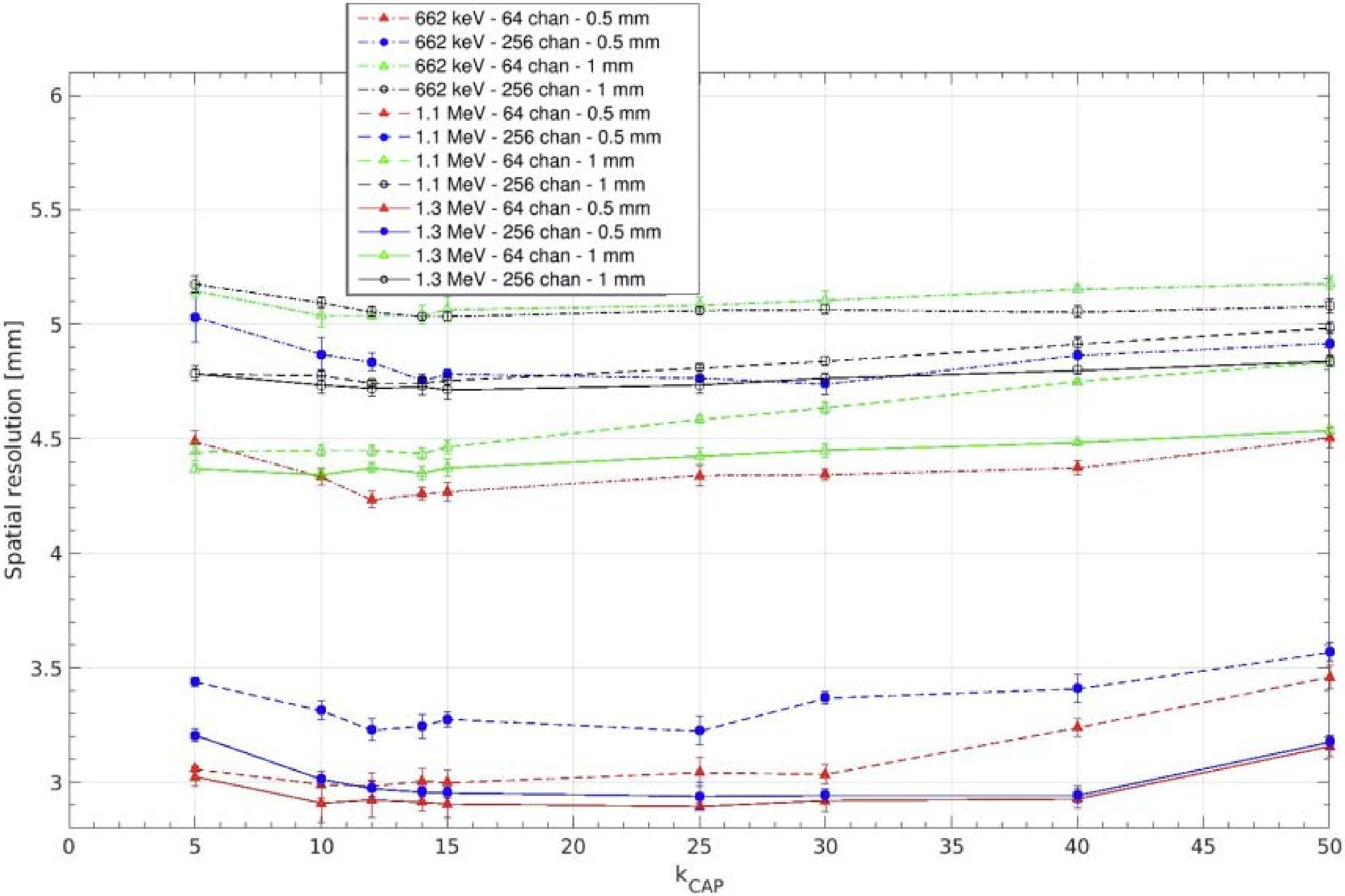
standard form:



S. Aldawood, PhD 2016, M. Mayerhofer, MSc 2017

Systematical Parameter Studies

CAP algorithm, 400 photopeak events per irradiation position:



662 keV: 256

662 keV: 64

1.17 MeV: 64/256

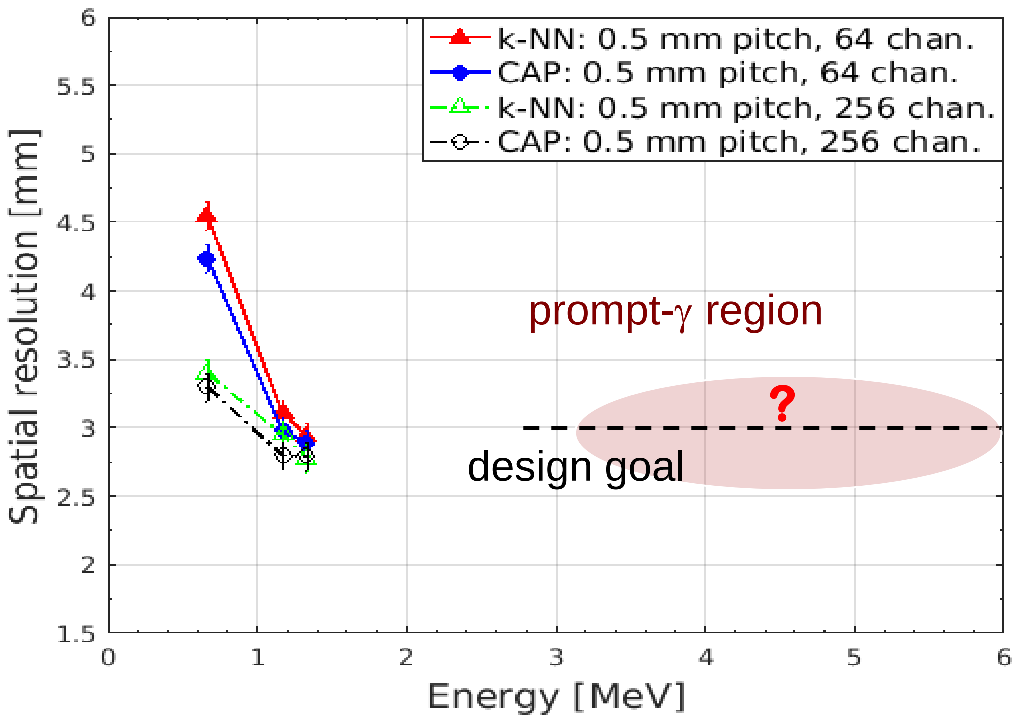
1.33 MeV: 64/256

- **findings: - energy dependent improvement of resolution**
  - 64-fold PMT segmentation: similar/better compared to 256-fold

S. Aldawood, PhD 2016, M. Mayerhofer, MSc 2017

Spatial Resolution from Monolithic Scintillator

design goal for spatial resolution reached for 1.3 MeV:

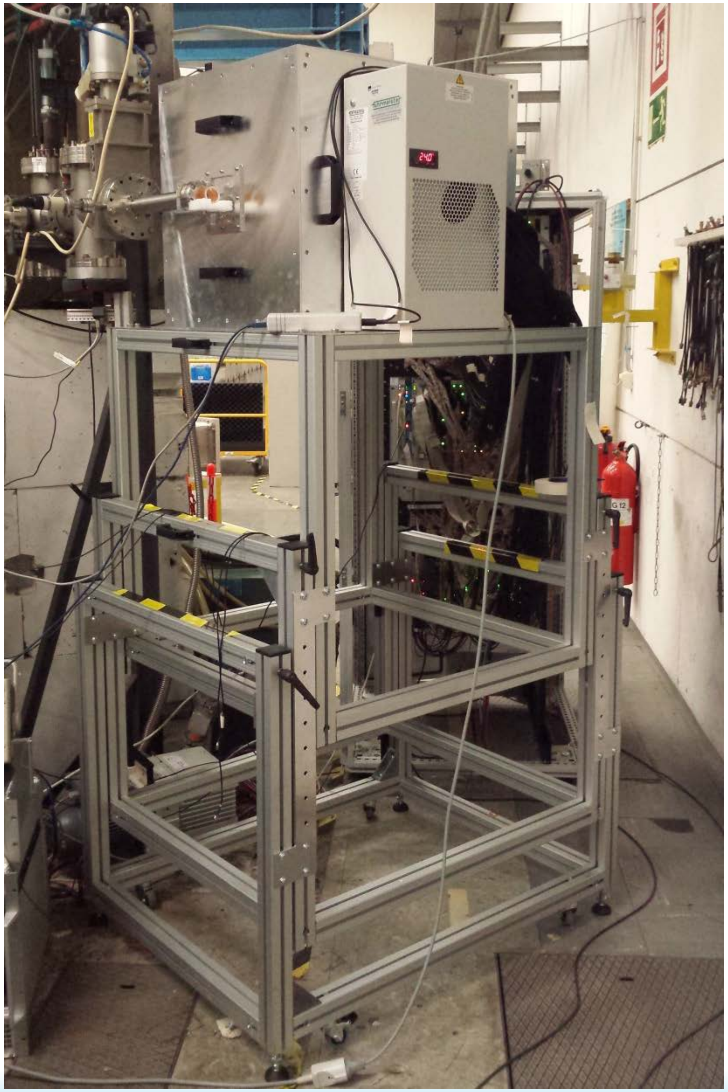


Energy [MeV]	Spatial res. CAP [mm]
0.662	3.3(1)
1.1	2.9(2)
1.3	**2.8(1)**

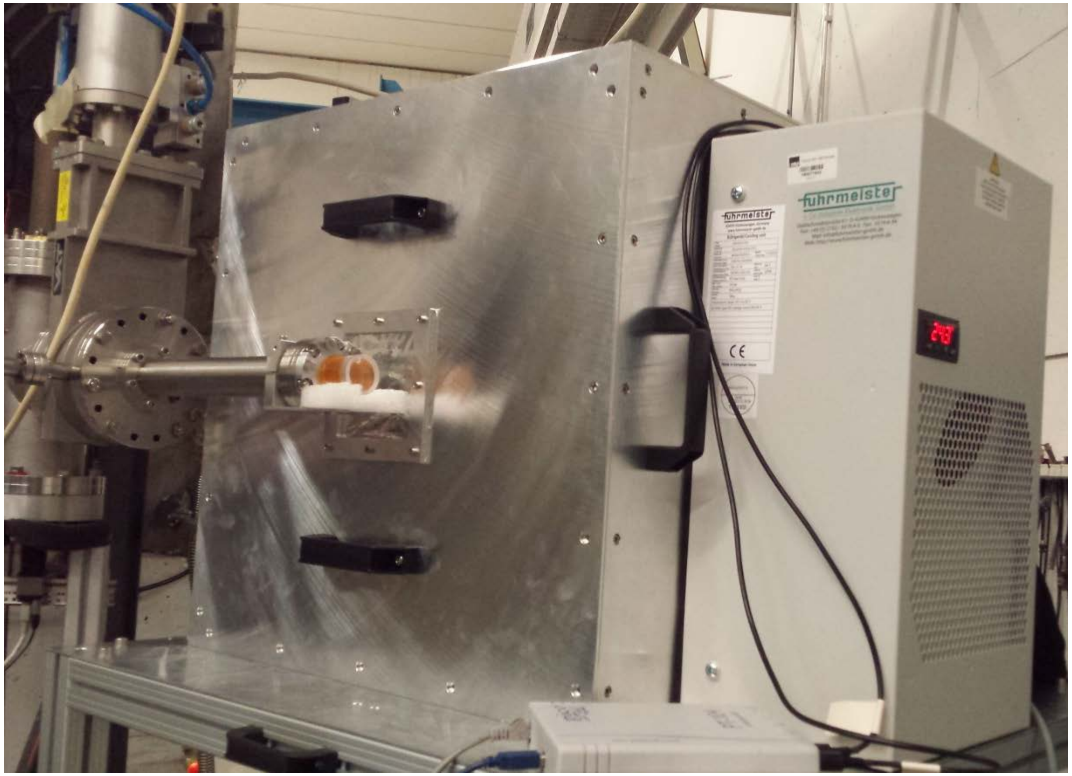
→ **so far very promising behaviour; higher photon energies ?**

M. Mayerhofer, MSc Thesis LMU 2017

Upgrade of signal processing / DAQ electronics



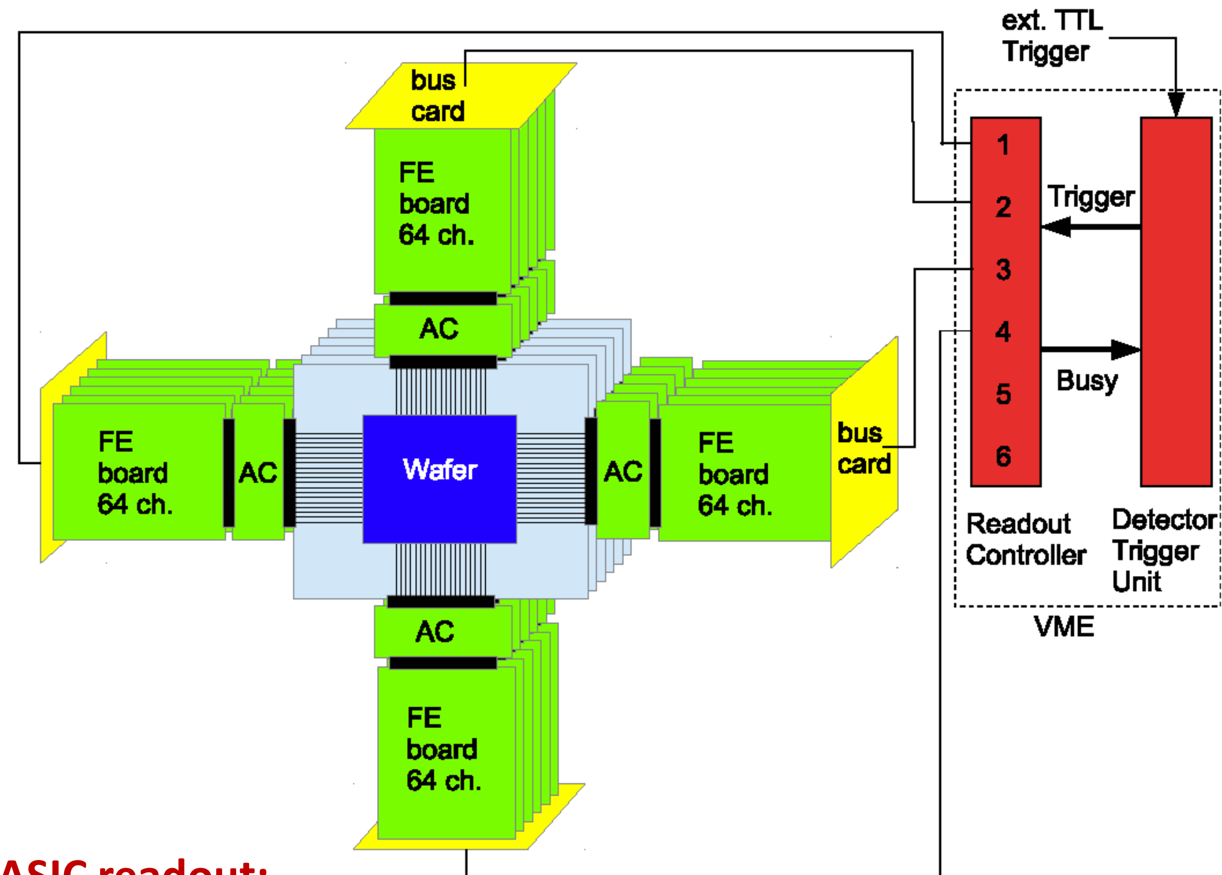
- Faraday cage equipped with compressor cooler: from ca. 28° → 15°-17° : reduction of noise level



Upgrade of Readout for Scatter/Tracker Array

- (Present) DSSSD readout:

  Gassiplex (4x16 ch. ASIC):



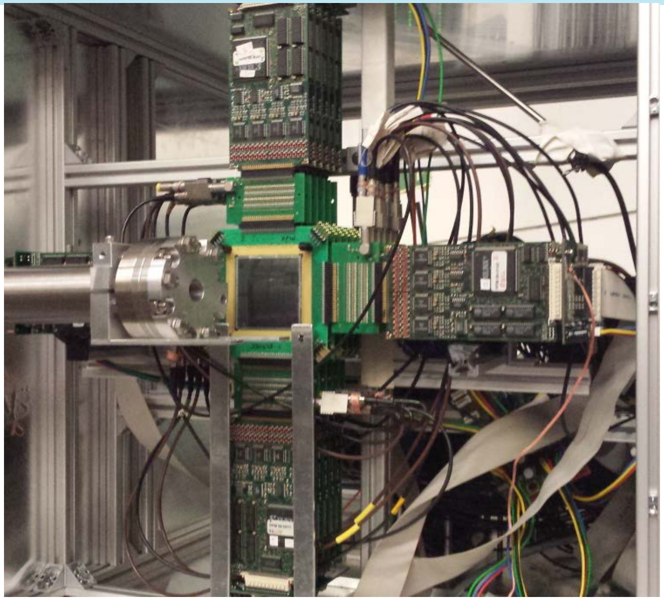
→ **replacement by modern non-ASIC readout:**

accepts both polarities, wider ADC dynamics (10 -> 12 bits), trigger capability, optimized shaping, higher data throughput capability

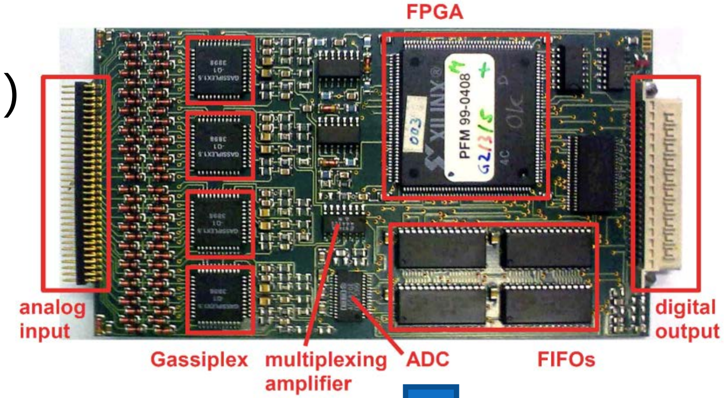
(AC coupler integrated, same dimensions)

S. Liprandi, PhD thesis in preparation

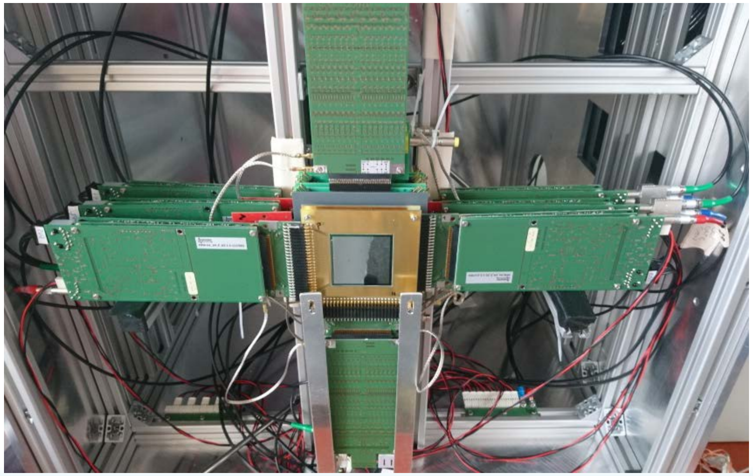
Upgrade of signal processing / DAQ electronics



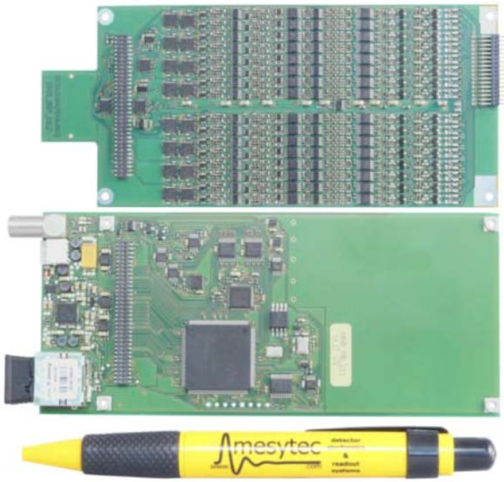
GASSIPLEX ASIC:
(frontend board: 64 ch.)



Individual components:
(FE board: 64 ch.)

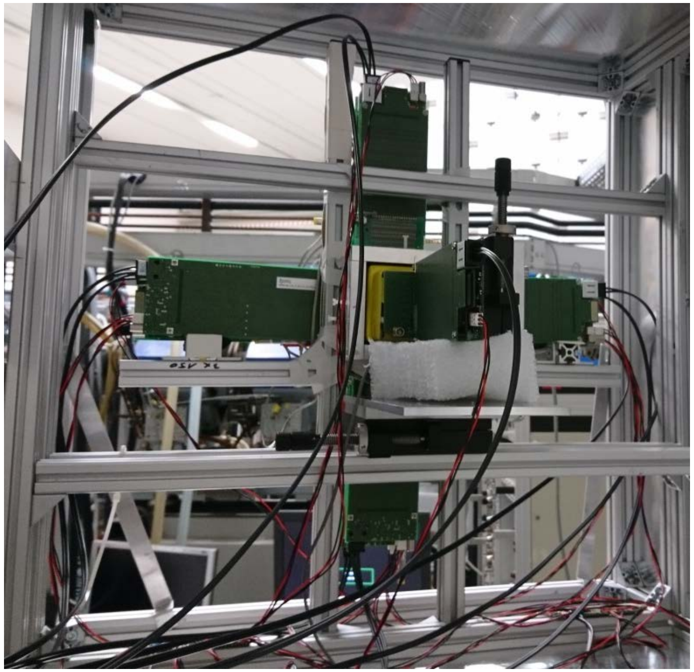


optical link (64 ch.)



Upgrade of signal processing / DAQ electronics

new frontend boards can be modified to also process PMT signals from absorbing scintillator



→ 256 or 64 cables replaced by 1 optical link

- VME-based readout: SIS controller can (presently) transfer up to 30 MB/s
- now provided: trigger capability for scatter component (DSSSDs)

→ improvement of coincident data contents by ca. factor 10^3 !

Signal processing and DAQ for the full Compton Camera

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Absorbing scintillator readout by multi-anode PMT

MA - PMT segments

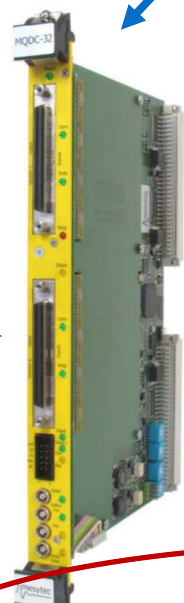
Scatter array (DSSSD)

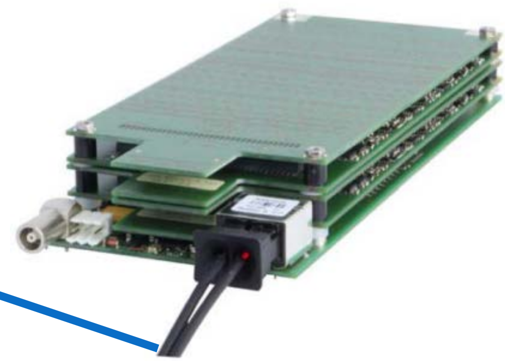
ethernet

MA-PMT sum dynode output

256 ch PMT

64 ch PMT





MMR: 64 ch. frontend board (optional input polarity); *opt. link*

MCFD: 16 ch. fast preamplifier and CFD

MQDC 32 ch. charge integrating digitizer

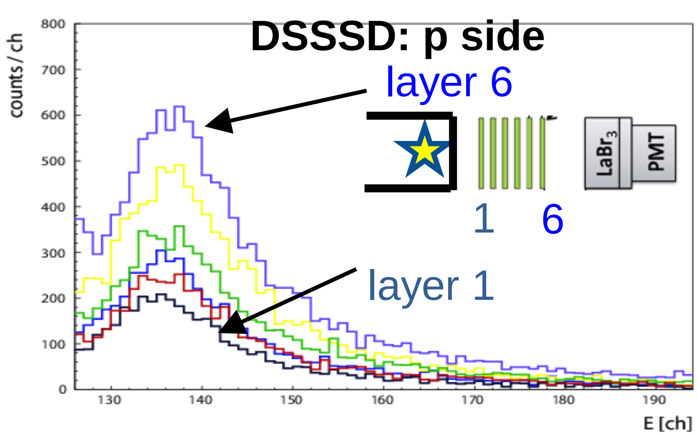
VMMR : 16 ch. optical link receiver/trigger gener.

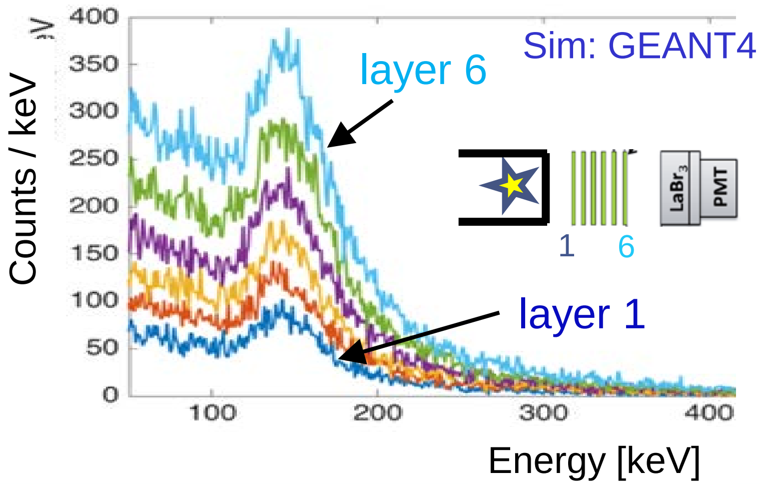
VME controller: (SIS3153):
<= 30 MB/s

Energy Deposition in Scatterer @ OncoRay

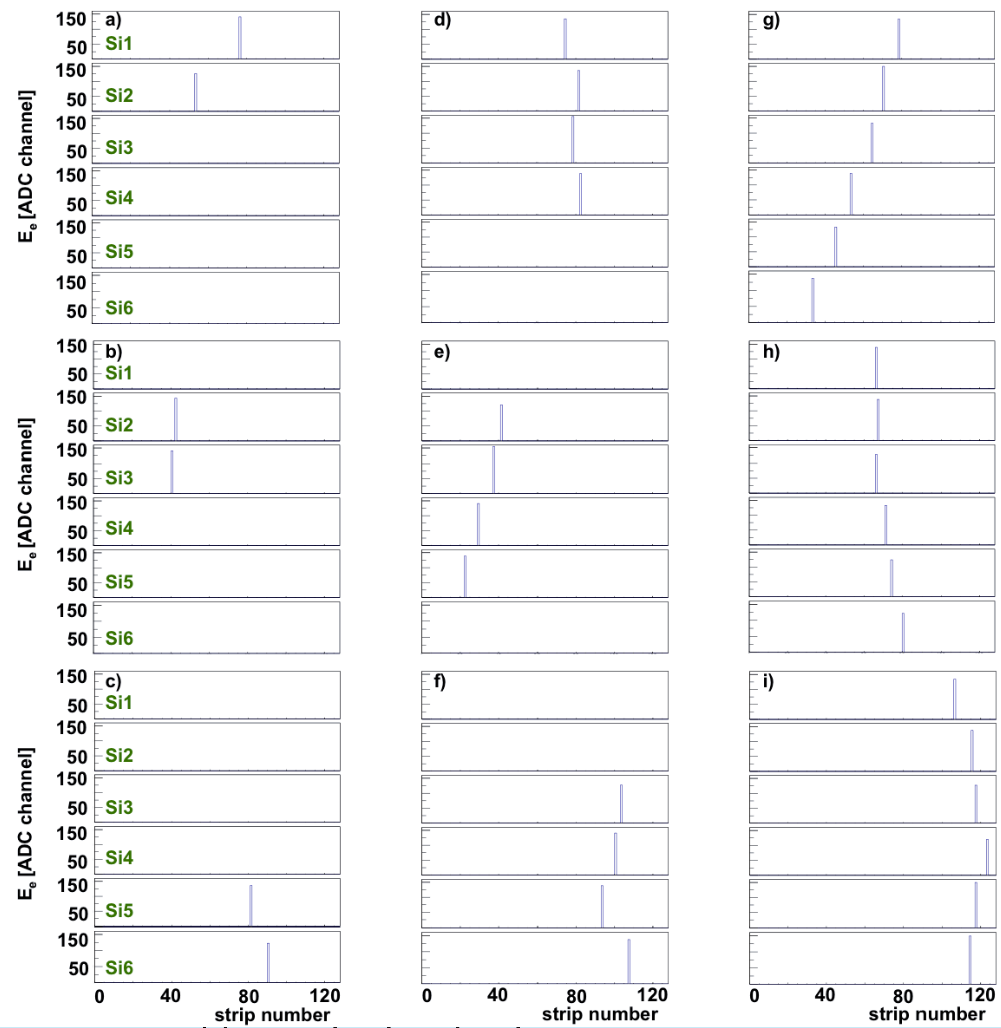
- DSSSD: Compton electron energy deposition (225 MeV)

Tracks:





I. Valencia Lozano, PhD in prep.

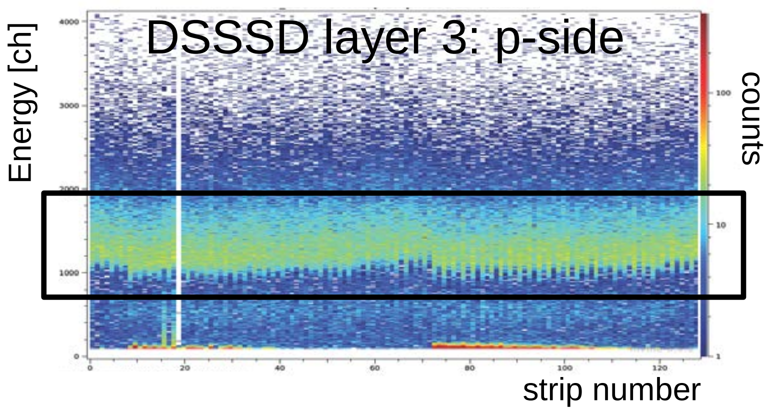


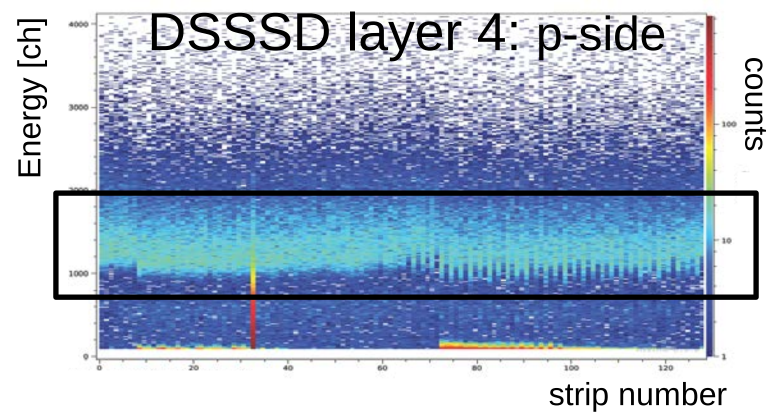
S. Aldawood, PhD thesis, LMU 2016

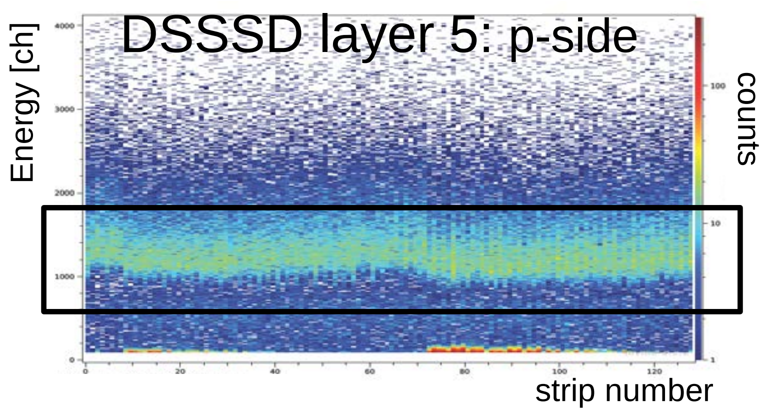
Signal processing and DAQ for the full Compton Camera

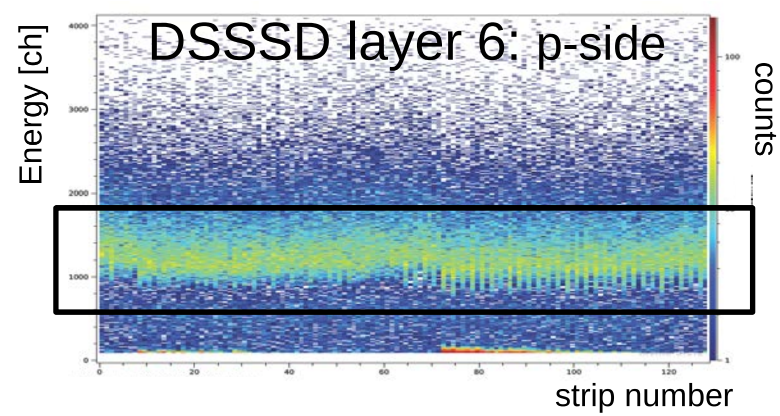
20 MeV protons; I_{beam} = 0.3 – 0.35 nA, water target, trigger: OR of all silicon detectors

ΔE (in 0.5 mm Si) ~ 130 keV









S. Liprandi, PhD thesis in preparation

Summary and Outlook

- Compton camera prototype: designed for (γ +) electron tracking
  - spatial resolution of monolithic absorber : < 3 mm @ 1.3 MeV

- Ongoing upgrade activities:
  - thicker scatterers: 1 mm DSSSDs (high resistivity wafers needed)
  - pixelated scintillator array as scatterer for low-energy (PET) applications: GAGG ? (poster: Silvia Liprandi)
  - $CeBr_3$ instead of $LaBr_3$ (cheaper, no internal radioactivity)
  - SiPM array (3x3 mm^2 modules) instead of MA-PMT: applicability near magnetic stray fields (poster: Tim Binder)
  - implement compact electronics for both scatterer and absorber (poster Silvia Liprandi)
  - consolidation of analysis software platform (poster: Maria Kawula)

- Outlook: - study impact of multiple photon detection in absorber
  - study impact of Compton electron to spatial absorber resolution

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Thanks to …

- LMU Munich: S. Aldawood, S. Liprandi, T. Binder, I. Castelhano, H. v.d. Kolff, C. Lang, T. Marinsek, M. Mayerhofer, A. Miani, M. Kawula, B. Tegetmeyer, G. Dedes, I. Valencia Lozano, R. Lutter, J. Bortfeldt, R. Viegas, K. Parodi
- TU Munich: L. Maier, M. Böhmer, R. Gernhäuser
- OncoRay/ HZDR, Dresden: G. Pausch, K. Römer, J. Petzoldt, F. Fiedler, T. Werner
- TU Delft: D.R. Schaart

Supported by DFG Cluster of Excellence MAP
(Munich-Centre for Advanced Photonics)

Thank you for your attention !