Proton CT – Development of a medical imaging tool

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Cancer

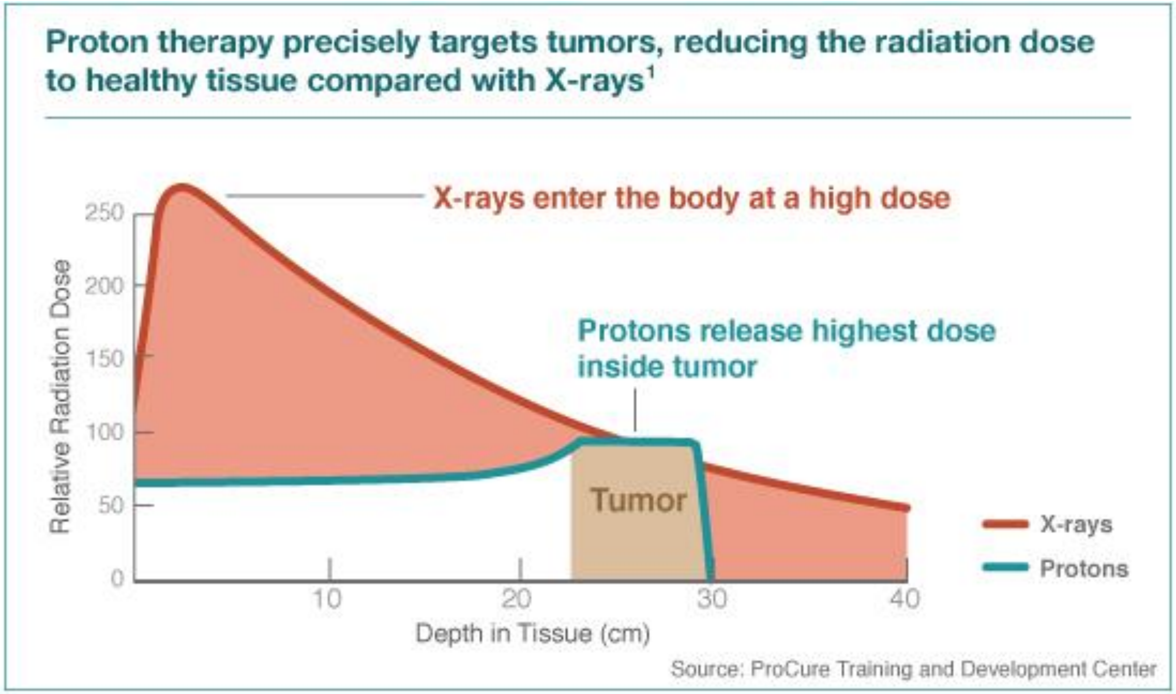
- It causes 26% of all deaths in Hungary
- Usual treatment of cancer:
  - Surgery
  - Radiotherapy
  - Chemotherapy

K. Peach, Heavy Ions in Science and Health workshop, Bergen, 2012

X-ray or hadron

Hadron
- 80 hadron treatment center in the world
- Lower dose in the healthy tissues

X-ray
- Worldwide used technology
- Cheaper equipment



Efstathiou, J A, Gray, P J & Zietman, A L
Proton beam therapy and localised prostate cancer: current status and controversies
British Journal Of Cancer volume 108, pages 1225-1230 (02 April 2013)

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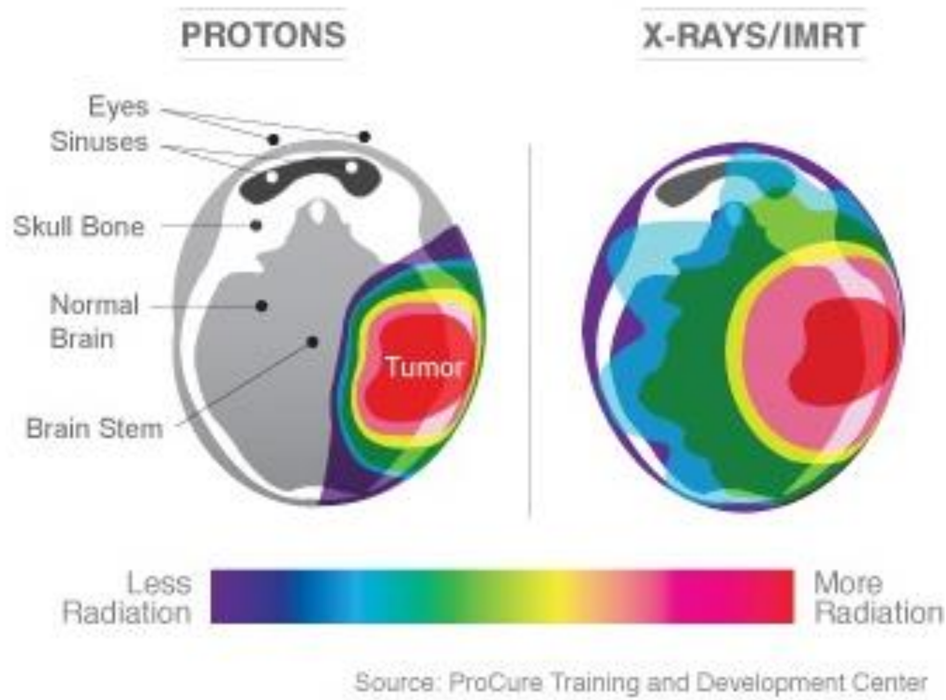


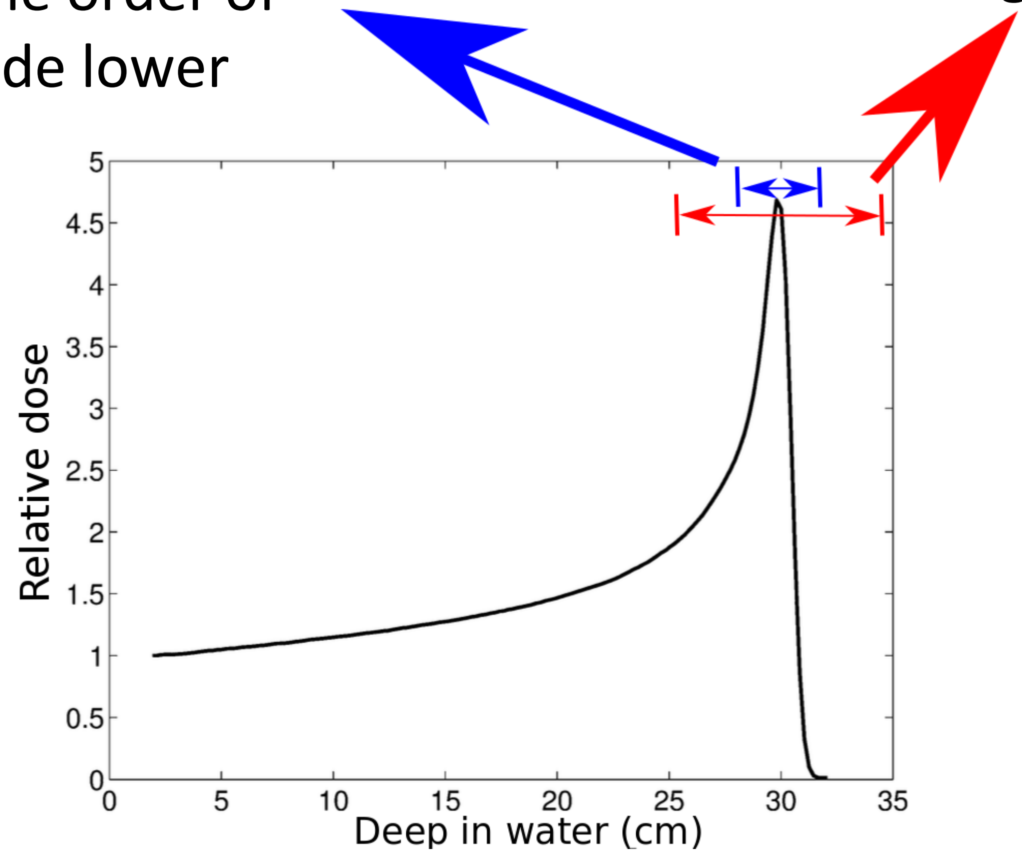
X-ray CT or proton CT

Proton CT

- New imaging tool
- The error of the energy loss is one order of magnitude lower

X-ray CT

- Available imaging tool
- About 3-4% error in the energy loss



Bergen pCT collaboration

- The goal of the collaboration is to develop a proton CT (pCT)
- The collaboration was established in 2017

Organisation

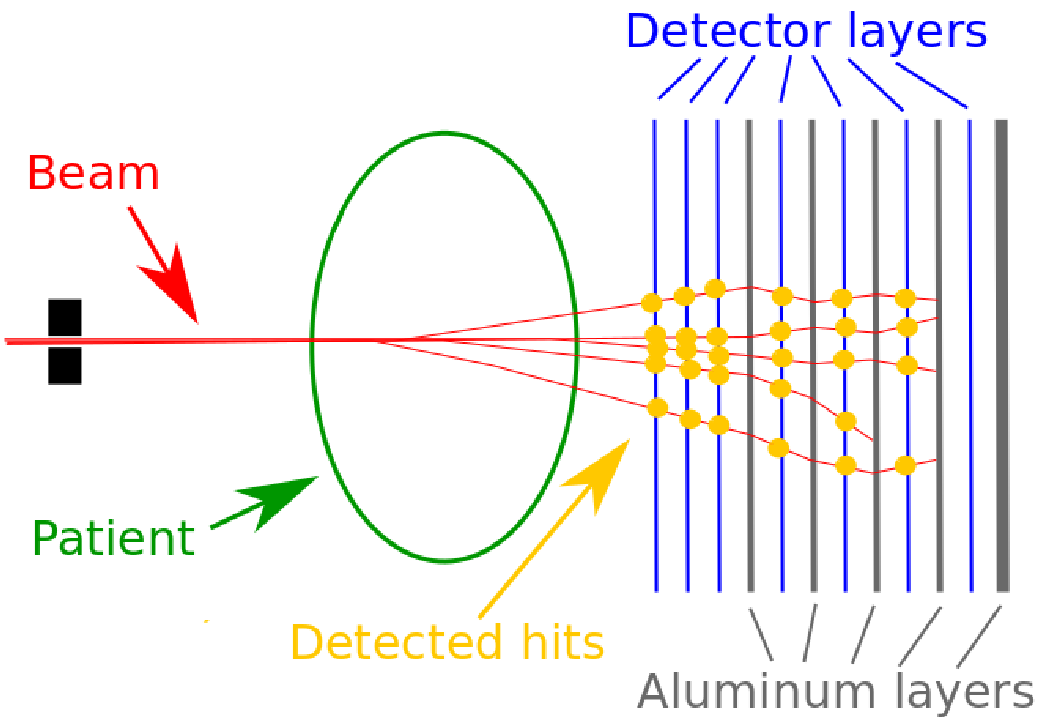
- UiB, HiB, HUS
- Utrecht University
- DKFZ Heidelberg
- Wigner, Budapest

Proton CT and calorimeter

- Calorimeter is a detector to measure the energy of a particle
- Calorimeter is a crucial part of the proton CT

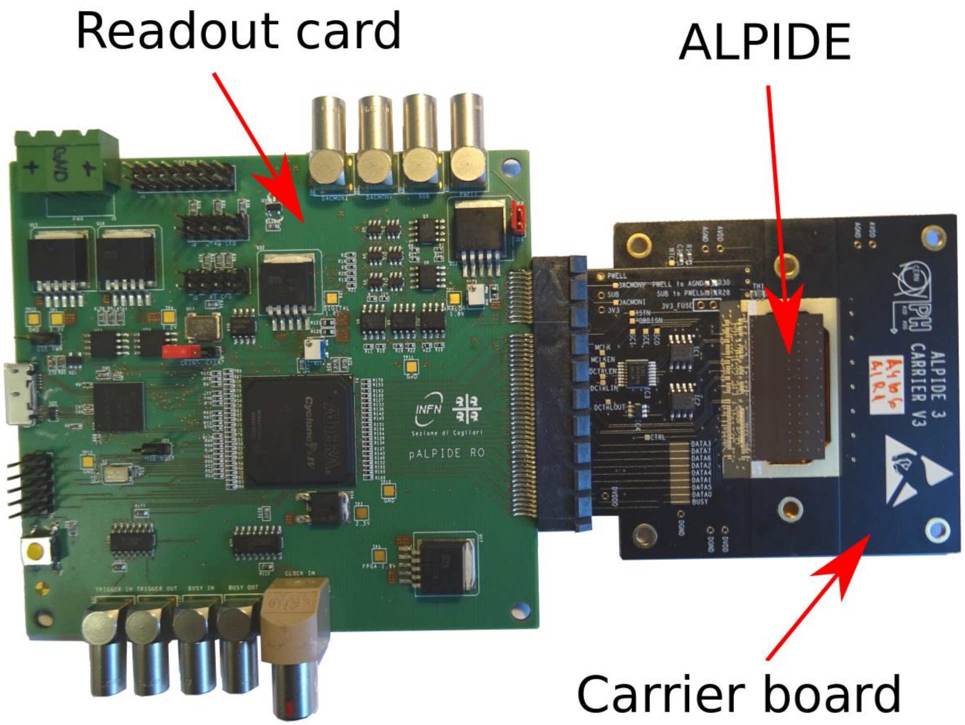
Expectations:

- Good resolution
- Fast readout
- Reliability
- $10^7 - 10^9 \; \frac{particle}{second}$



ALPIDE

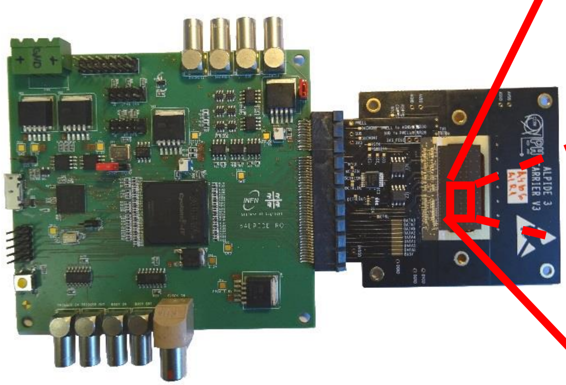
- The ALPIDE was developed for the upgrade of ALICE in 2019-2020
- ALPIDE meets the expectations of pCT



Mónika Varga-Kőfaragó, Anomalous Broadening of Jet-Peak Shapes in Pb-Pb Collisions and Characterization of Monolithic Active Pixel Sensors for the ALICE Inner Tracking System Upgrade (2018)

ALPIDE

- MAPS: the sensitive layer and the readout electronics is on the same wafer
- The ALPIDE is a MAPS type, digital silicon pixel detector
- The electrons can move with diffusion in the sensitive layer
- Cluster: the conglomerate of the pixels fired by the same particle



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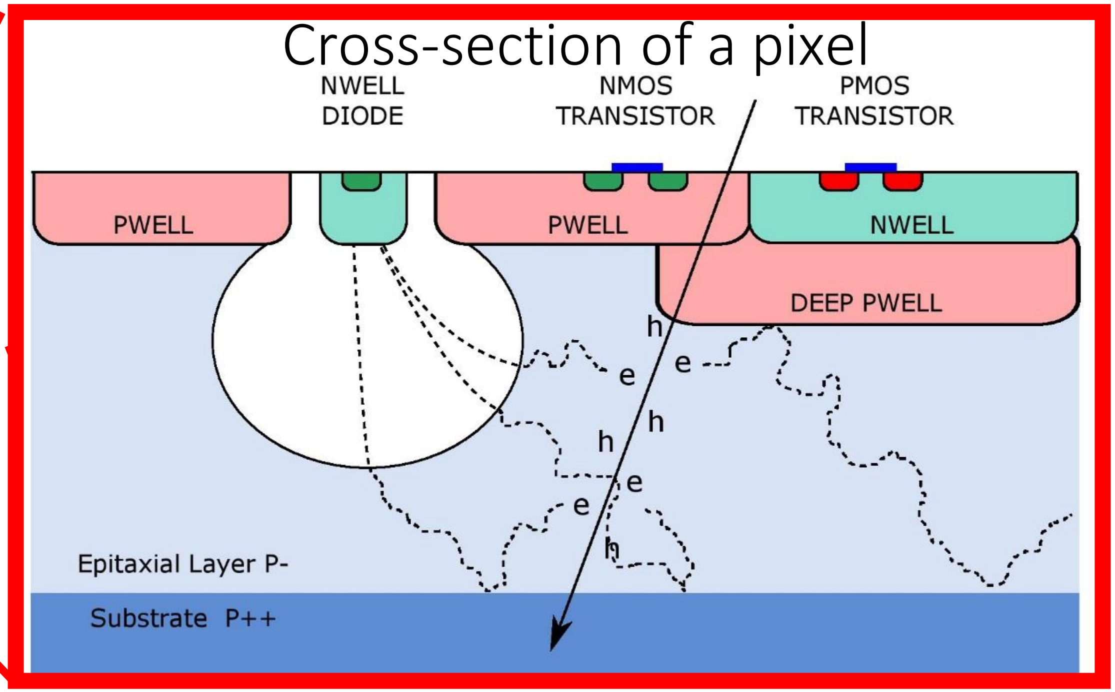
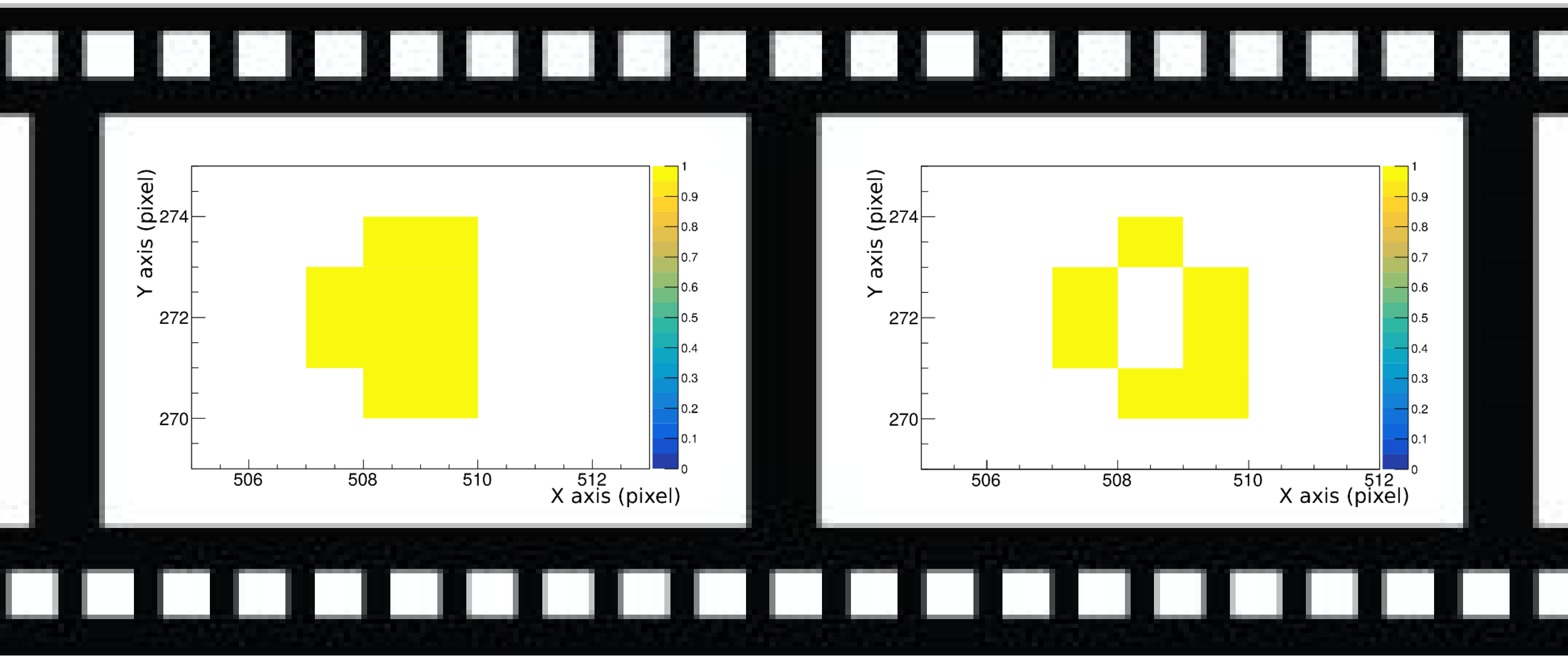


ALICE Collaboration, "Technical Design Report for the Upgrade oh the ALICE Inner Tracking System", Tech. Rep. CERN-LHCC-2013-024. ALICE-TDR-017, CERN, Geneva, Nov, 2013.

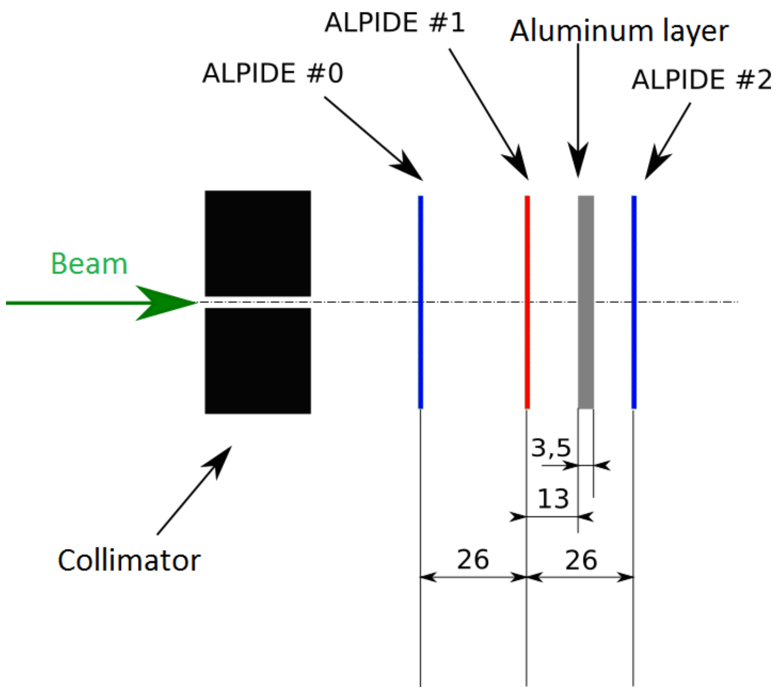
ALPIDE

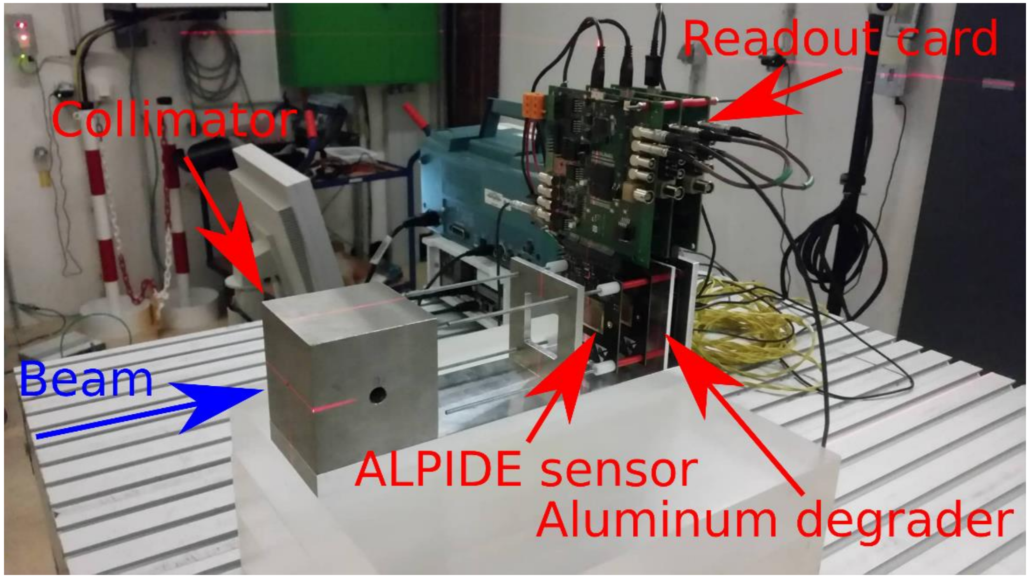
- Event: one read out of the detector(s)
- The analog signal is available for long time
- If the readout fast, we see clusters twice or more



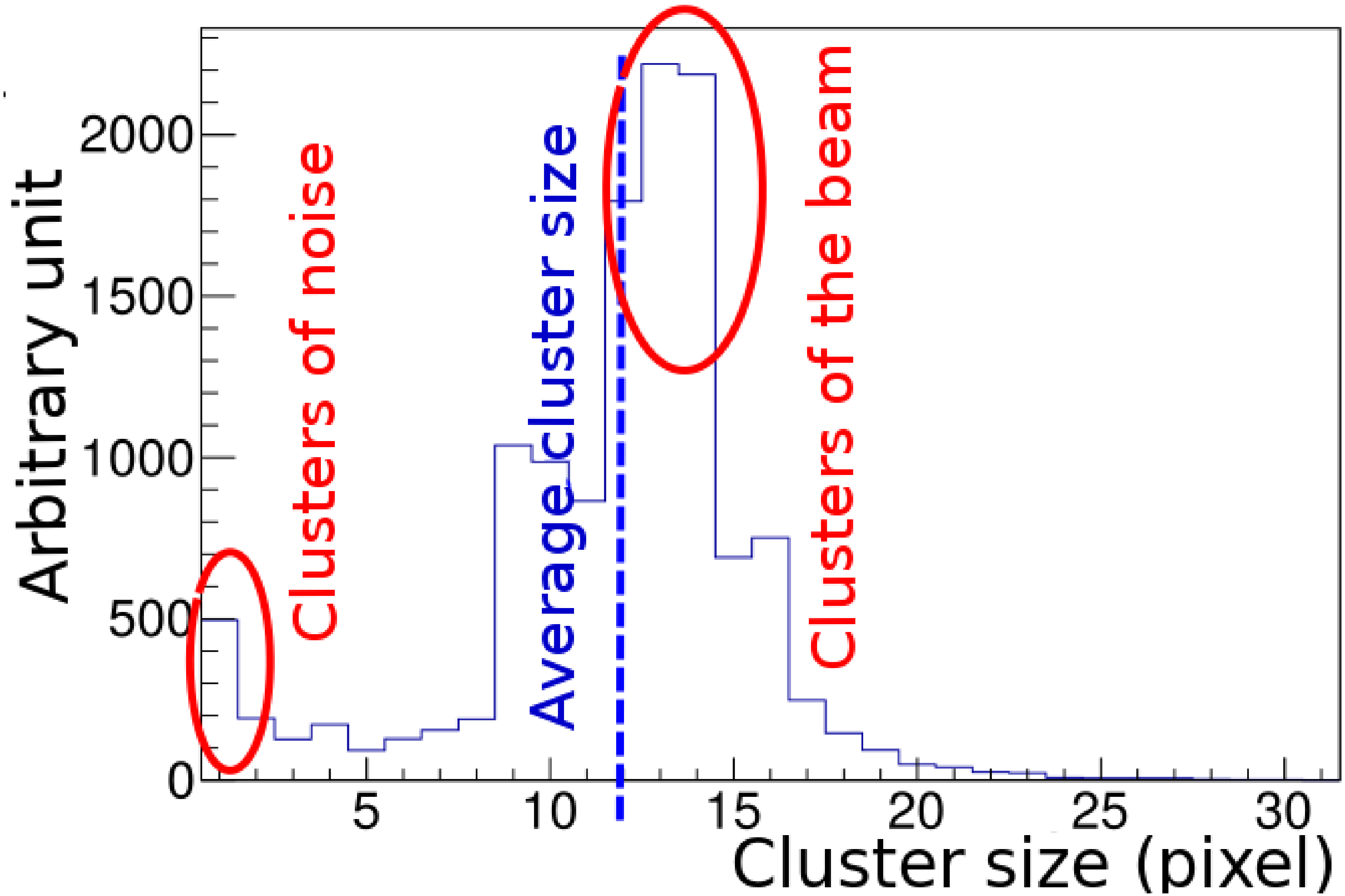
Measurement

- Heidelberg Ion-Beam Therapy Center (HIT) in Germany
- Proton in 80 kHz
- Alpha particle in 20 kHz
- Around $4 \cdot 10^3 \ \frac{particle}{second}, \ 50 - 220 \ \frac{MeV}{u}$



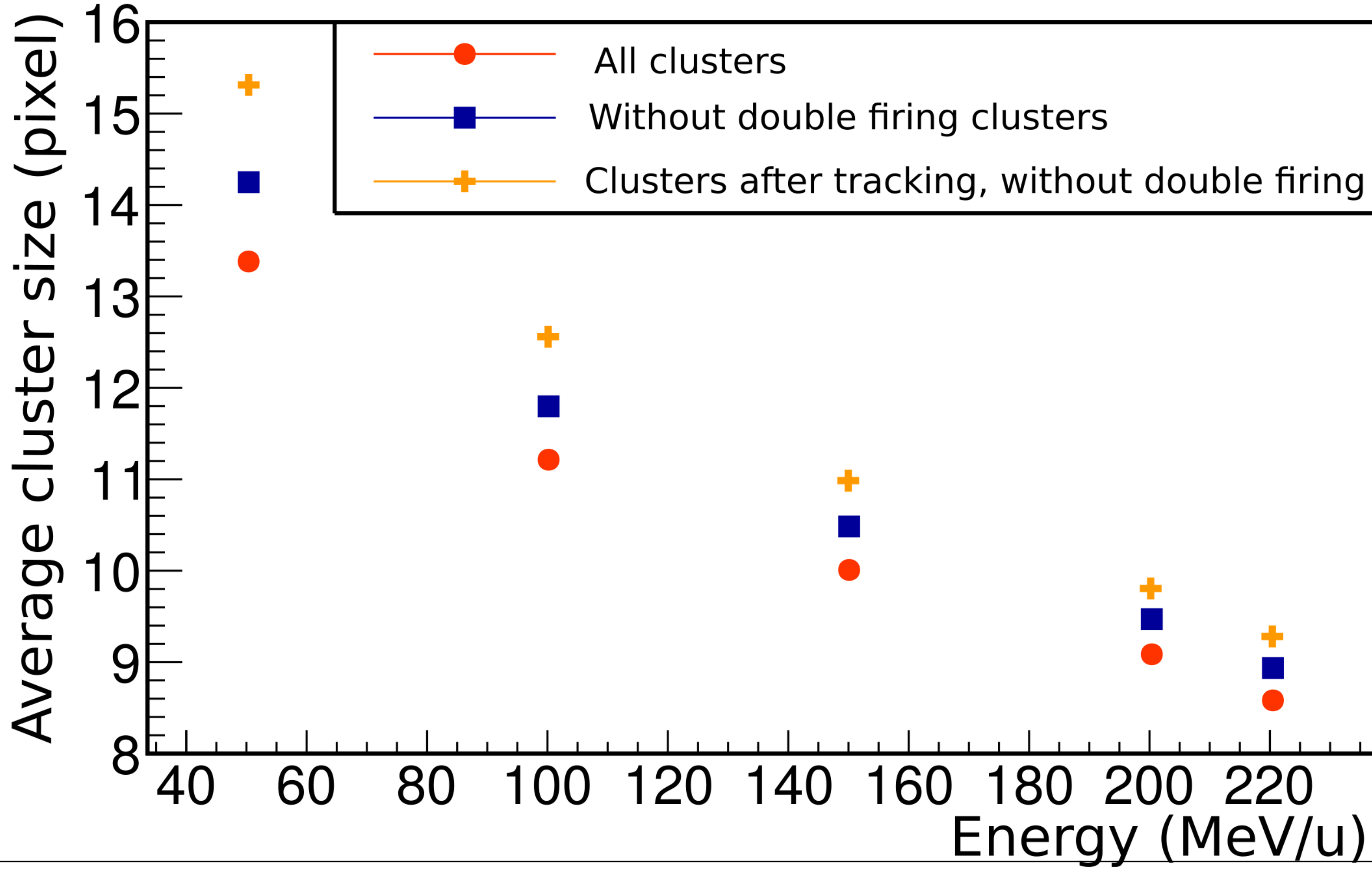


Cluster size distribution



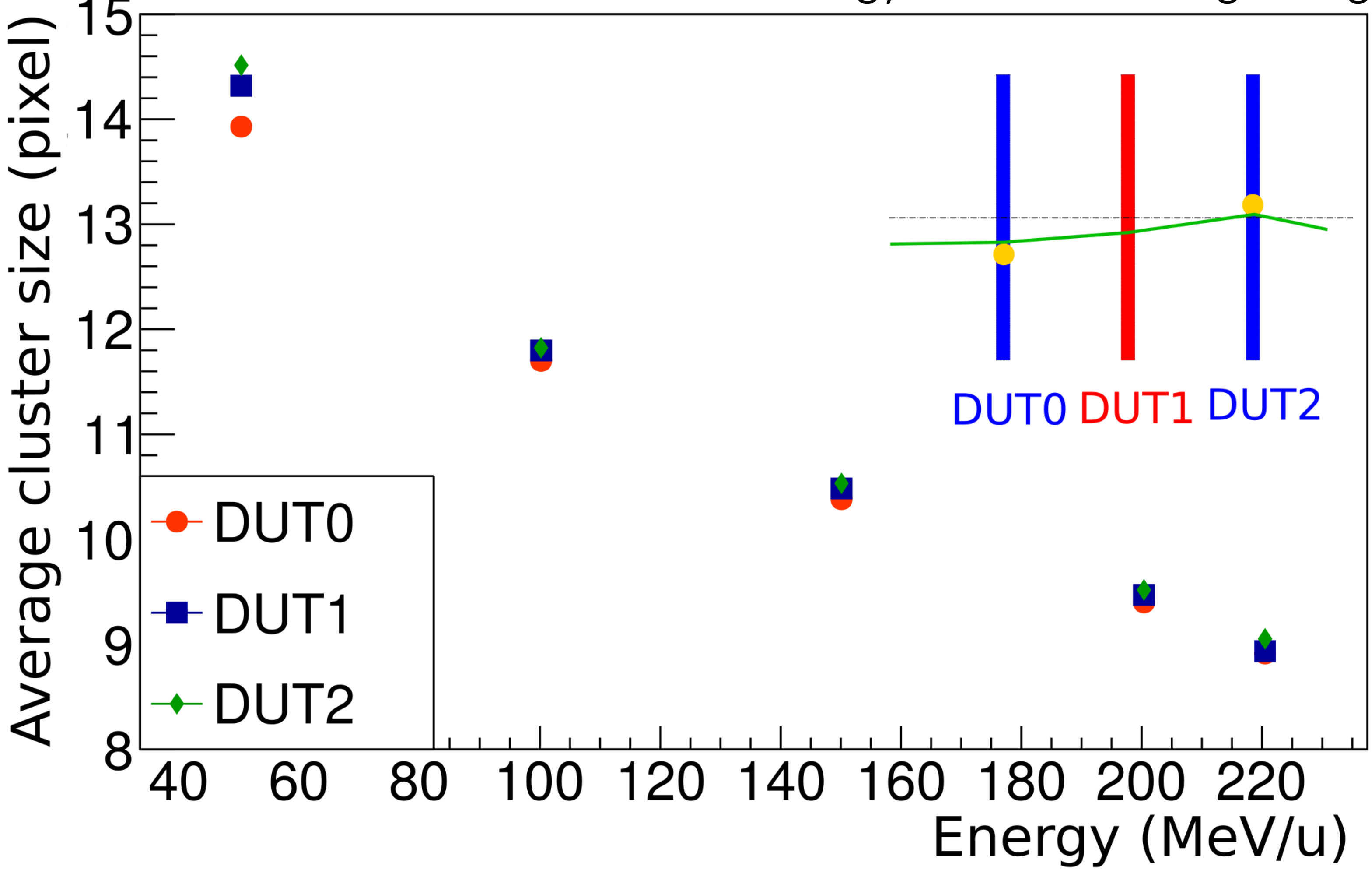
Cluster size energy dependency

- If the energy increases, the average cluster size decreases
- The filter algorithms has a big effect on the average cluster size



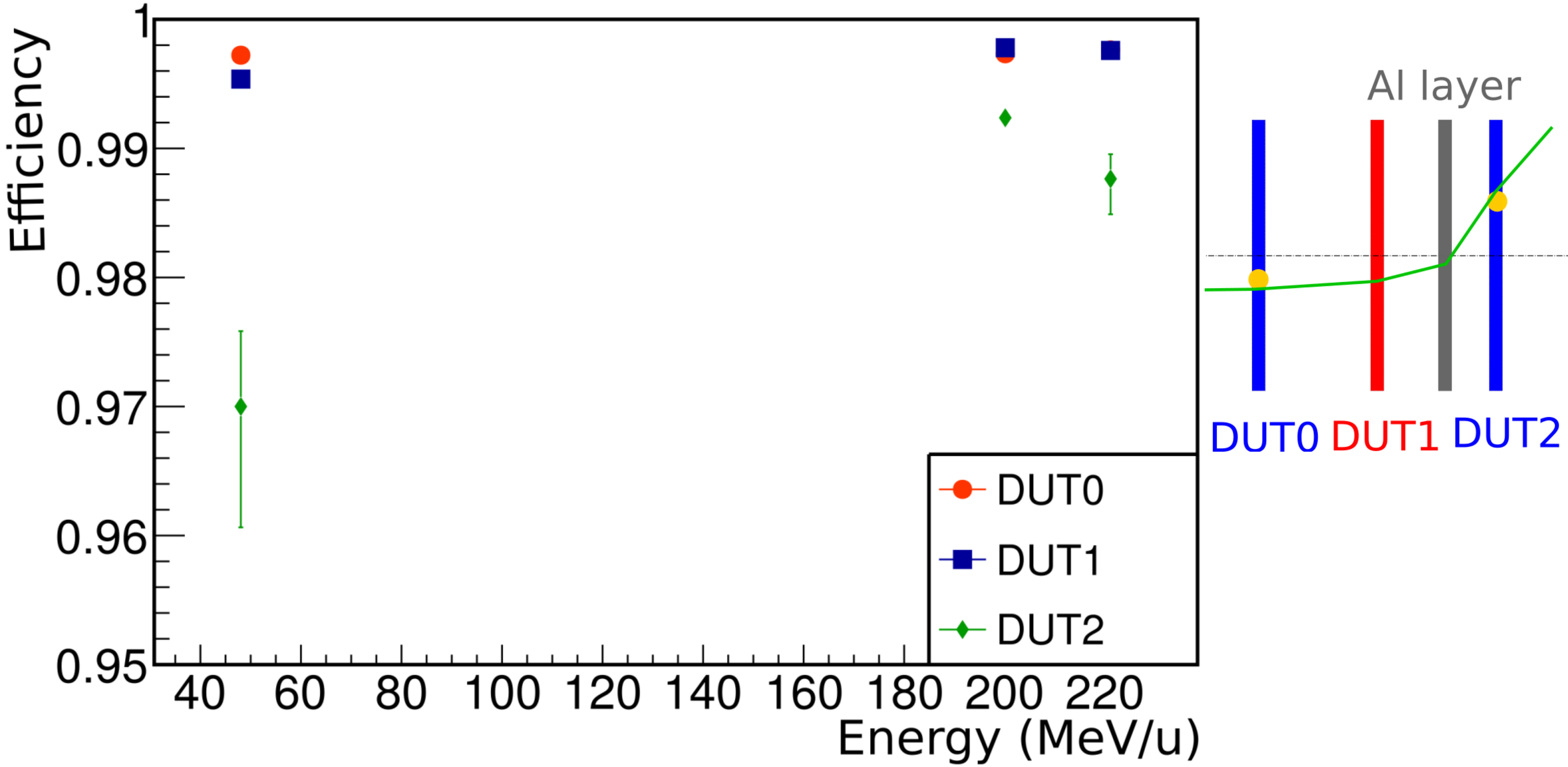
Cluster size in all layers

- Cluster size is about the same at high energy
- The cluster size increases at low energy with decreasing energy



Efficiency of detection

- Expectation: higher than 99%, based on earlier measurements
- We measured it is higher than 99% also in low energy in case of protons
- The tracking algorithm works with aluminum degrader as well



Summary

- The goal of Bergen pCT Collaboration is to develop a pCT
- It is necessary to develop a suitable calorimeter
- Sampling calorimeter made up from alternating ALPIDE and aluminum degrader layers
- We have tested a prototype made of three layer
- Results of this measurement:
  - The average cluster size depends on the energy of the particle
  - The average cluster size has a huge dispersion (based on physics)
  - The efficiency of detection is higher tan 99% in case of proton
  - The efficiency is lower than 99% in case of alpha particle, so we continue the optimization of the algorithms used for the data analysis

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- Thank you for your attention!