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Bergen proton CT system

A High-granularity digital tracking calorimeter developed for proton CT (pCT)

Viljar Nilsen Eikeland
on behalf of the **Bergen pCT collaboration**
Department of Physics and Technology,
University of Bergen
Viljar.eikeland@uib.no

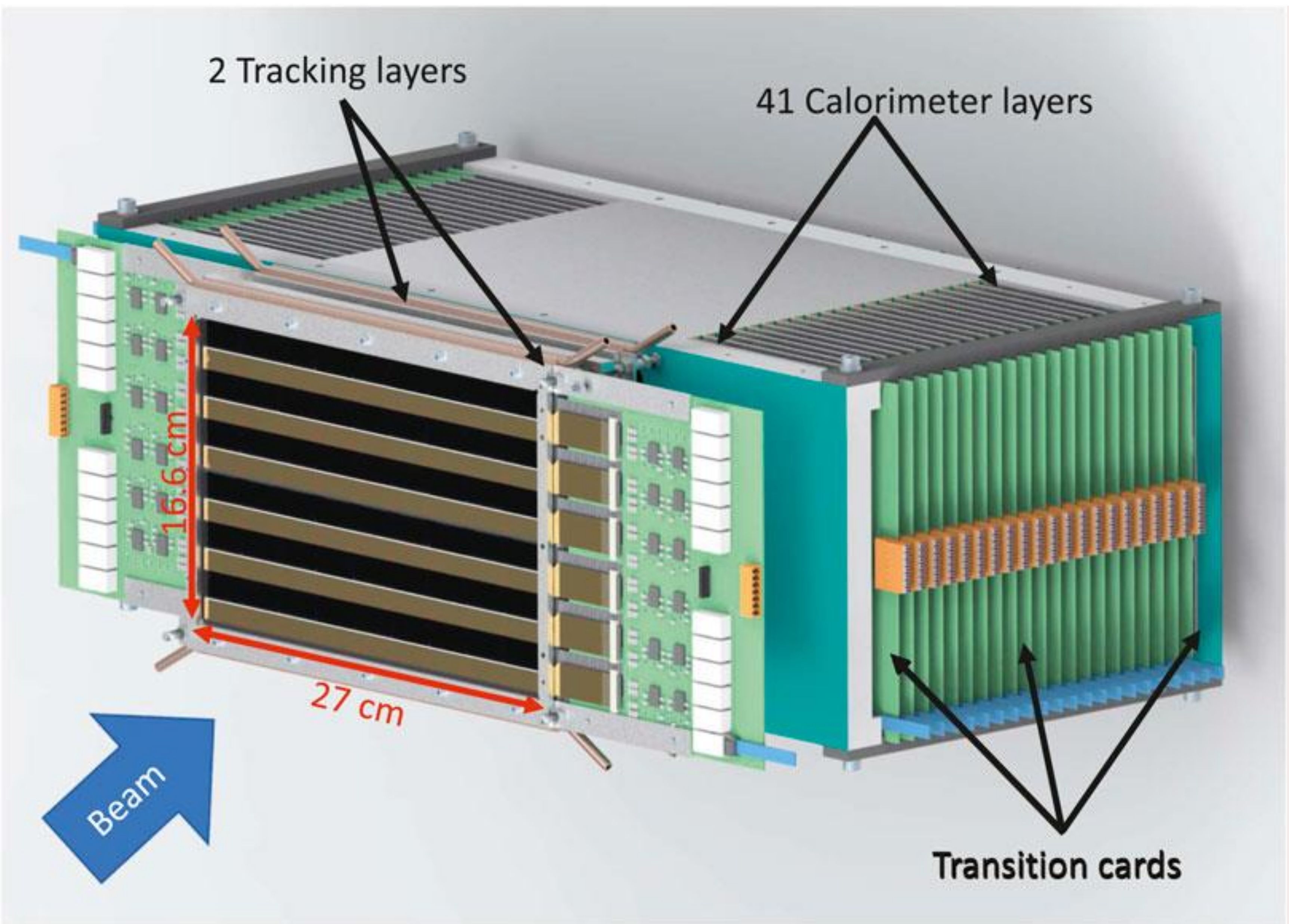

Figure 1: Schematic drawing of the Bergen pCT detector [1]

ABSTRACT

Hadron therapy is a treatment method that utilizes the energy deposition of protons or heavier ions to concentrate the dose delivered to a patient during the treatment of a malignant tumor. Proton computed tomography (pCT) is an imaging technique used to directly reconstruct the relative stopping power (RSP) of an object of interest by tracking single proton histories crossing the object and measuring their residual energy. (The direct reconstruction of the RSP allows for treatment planning uncertainties reduction.) The Bergen proton Computed Tomography (pCT) collaboration is constructing a prototype detector capable of both tracking and measuring the energy deposition of ions in order to minimize uncertainty in proton treatment planning. The designed detector is a high granularity digital tracking calorimeter, where the first two layers will be used to obtain positional information of the incoming particle and act as tracking layers. The remainder of the detector will act as a calorimeter. This work aims to present the implementation of the design, the mechanical and electronic layout, results obtained from beam experiments, and some selected simulations. [1]

Design:

- The prototype consists of 2 tracker layers and 41 calorimeter layers
- The tracking layers consists of a ~300 µm thick carbon-epoxy fiber carrier
- The calorimeter layers consist of a 3.5 mm Al carrier which also acts as an absorber
- In total there are 108 ALPIDE chips per layer
- Each layer is made of two half layers
- Each of the half layers consists of six 9-chip strings. The half-layers are rotated 180 degrees when facing each other in order to cover the full area
- A string consists of 9 ALPIDEs which are single-point tape-automated bonded on a flex cable [2]
- For further reading see [1][3]

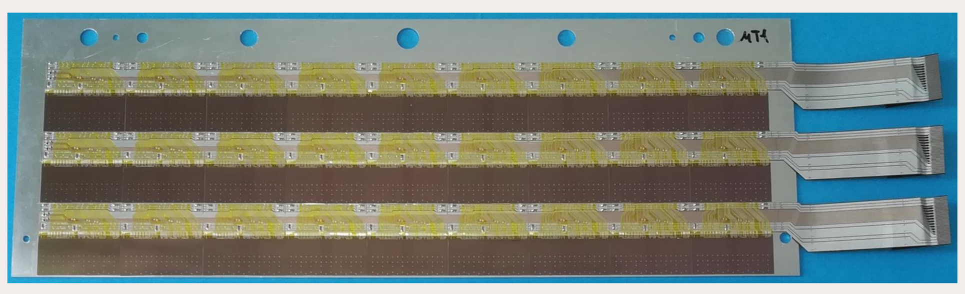

Figure 2: ALPIDEs mounted on flex cables making up a pCT slat. Image courtesy of [4]

Electronics:

- The clock and trigger signals are generated by a motherboard and shared among all the sensors
- The system is capable of interfacing 108 × 43-pixel sensors with both slow control and high-speed data capture
- A custom-made transition card is used as an intermediate between the 9-chip string and the readout unit
- All the components applied in the system are pre-tested radiation-hard [1]

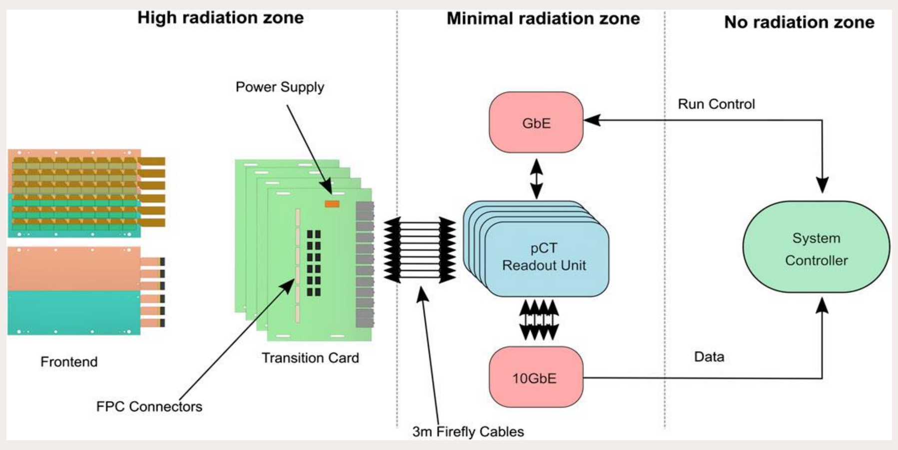

Figure 3: The pCT system electronics architecture

ALPIDE:

- MAPS detector developed for ITS2 upgrade of ALICE [5]
- 180 nm CMOS by Tower Jazz
- 1024 × 512 pixels with 3-bit memory
- ~2 µs peaking time of analog signal in front-end
- Detection efficiency of 99.99%
- Fake hit rate of less than 10^{-5} event/pixel
- Digital readout
- 1.2 Gbps serial output

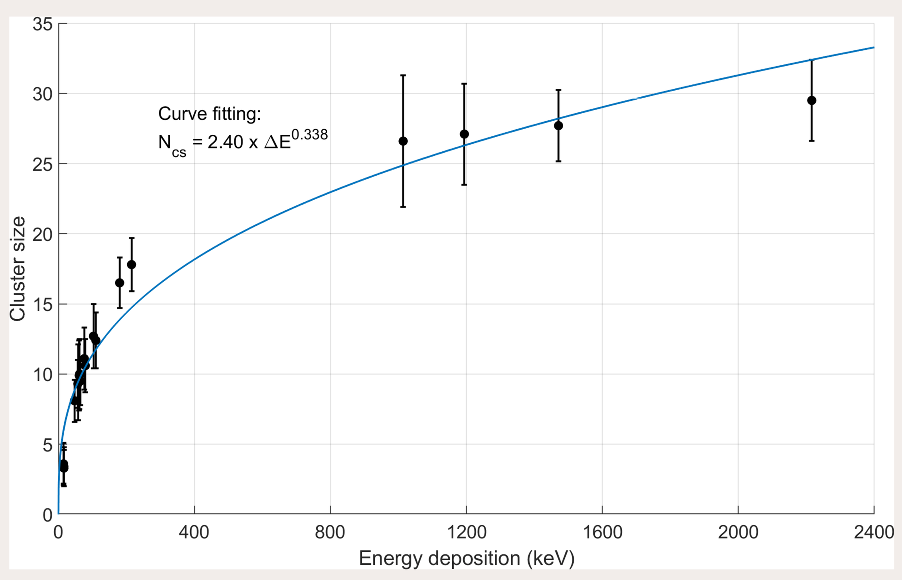

Figure 4: Cluster size as a function of energy deposition in the epitaxial layer of the ALPIDE chip [1]

Results:

- ALPIDE response is dependent on impact position of incoming particle
- Cluster size increases as a function of the deposited dose from an incoming particle
- Similar cluster size distribution for 15 kHz and 145 kHz for a 50.57 MeV/u helium indicates that the ALPIDE response is independent of occupancy
- The ALPIDE has demonstrated its capability to successfully differentiate between nuclear species based on energy deposition in the epitaxial layer

pRad and pCT reconstruction:

- GATE version 8.2 [6][7] with Geant4 version 10.5.1[8][9]
- Full material budget of the DTC accounted for
- Proton radiographs (pRad) and full pCT scans with different phantoms

Figure 5: A full pCT reconstruction of a simulated head phantom [1]

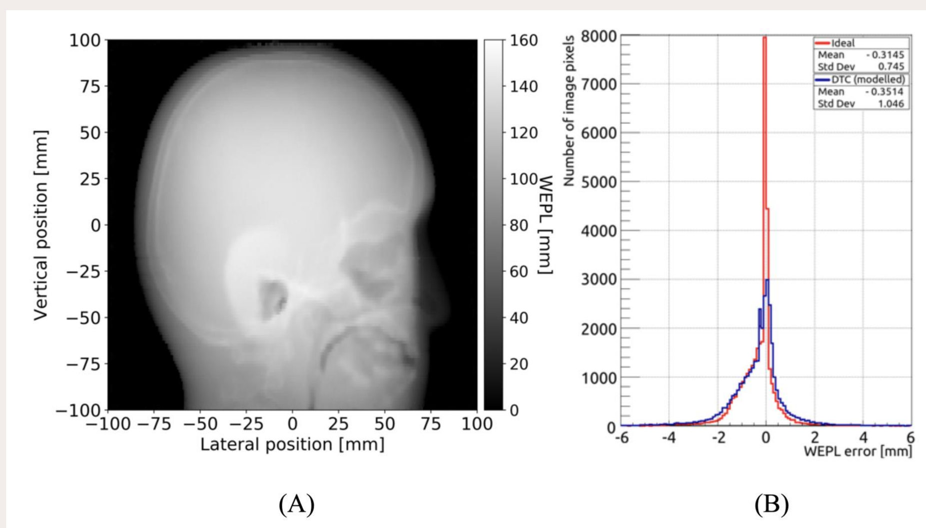

Figure 6: Reconstruction of a pRad of a head phantom [1]

REFERENCES

[1] Alme J, et al., Frontiers in Physics. 2020;8(460); [2] Borshchov VM, et al., Met Funct Mater (2017) 23(4):143–53; [3] S. Mehendale et al. Poster at PSD12; [4] Dr. Ihor Tymchuk, LTU, Kharkiv, Ukraine, Personal communications; [5] Aglieri Rinella G., Nucl Instrum Methods Phys Res B (2017) 845:583–7; [6] Jan S, et al., Phys Med Biol (2011) 56(4):881–901; [7] Jan S, et al., Phys Med Biol (2004) 49(19):4543–61; [8] Agostinelli S, et al., Nucl Instrum Methods Phys Res A (2003) 506(3): 250–303; [9] Allison J, et al., IEEE Trans Nucl Sci (2006) 53(1): 270–8;

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The Bergen pCT collaboration members: University of Bergen, Helse Bergen; Western University of Applied Science; Wigner Research Center for Physics; DKFZ; Saint Petersburg State University; Utrecht University; RPE LTU; Suranaree University of Technology; China Three Gorges University; University of Applied Sciences Worms; University of Oslo; Eötvös Lorand University; Technical University Kaiserslautern;