Neuromorphic Readout for Homogeneous Hadron Calorimeters

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Objective

Investigating the **readout of light signals** from hadronic showers in a homogeneous calorimeter by a network of nanowires.

We aim to offer:
- fast, energy-efficient **local computation**
- generation of **informative high-level primitives**

using neuromorphic computing.

Neuromorphic Computing

Computing approach that mimics the structure and function of the **human brain** using artificial neurons and synapses. [1]

Studies new **software** and **hardware** solutions to achieve:
- higher speed
- significantly lower energy consumption

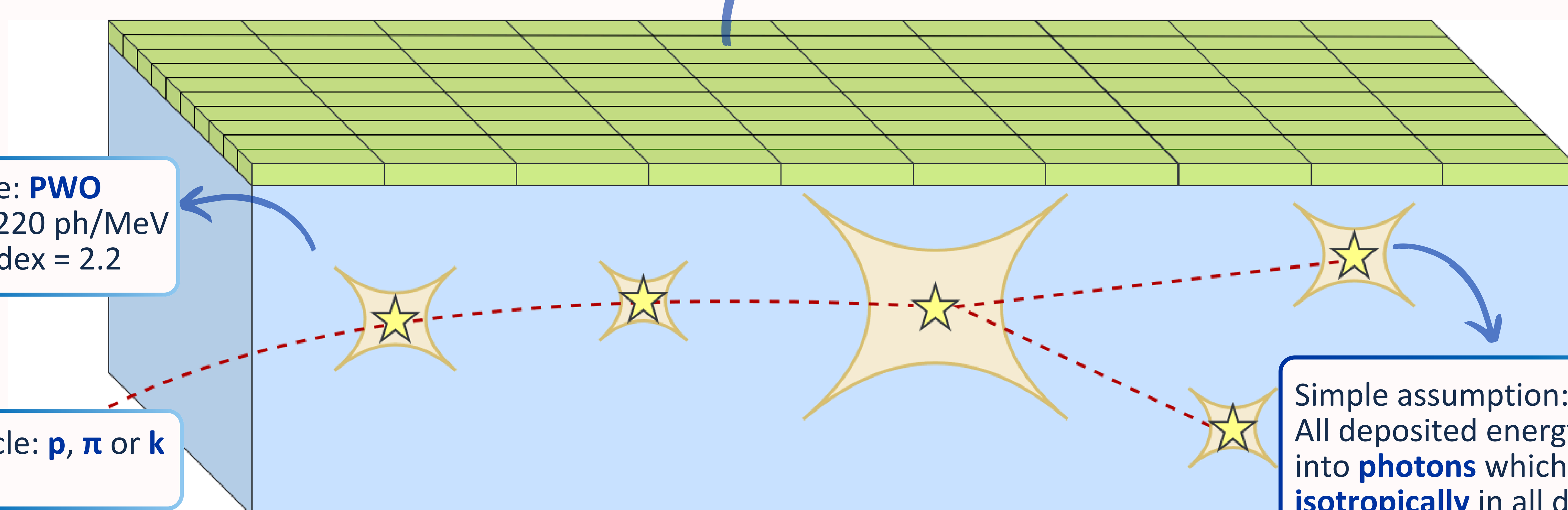
compared to traditional methods. [2]

Detector Configuration

The detector is divided into blocks called "**cubelets**":
- Arranged in a 10 x 10 x 10 matrix
- Size: 3 cm x 3 cm x 12 cm

Here is a schematic view of one cubelet...

Segmented readout: **10x10 light sensors grid** on the upper face of each cubelet.
Sensors are blind to the light coming from other cubelets (all other sides are reflective)



Material of choice: **PWO**
- Light Yield ≈ 220 ph/MeV
- Refraction index = 2.2

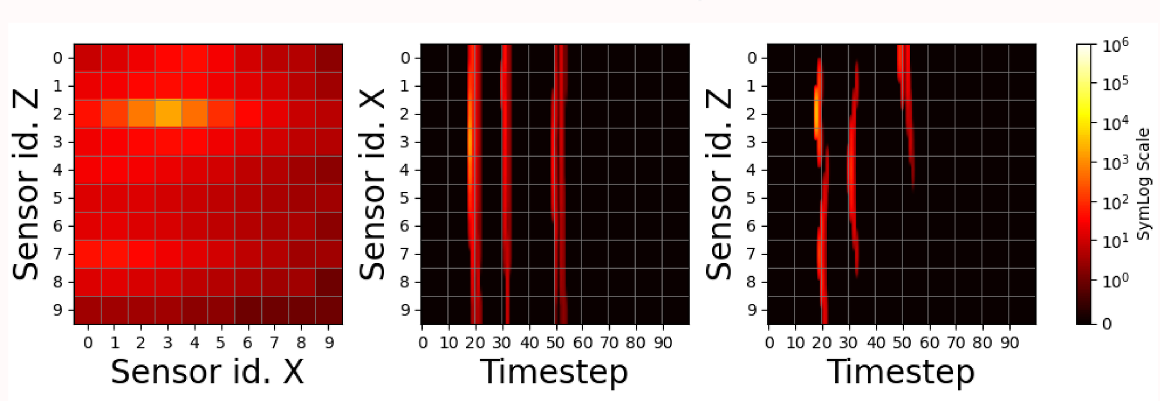
Incoming particle: **p**, **π** or **k** at 100 GeV

Simple assumption:
All deposited energy is converted into **photons** which travel **isotropically** in all directions

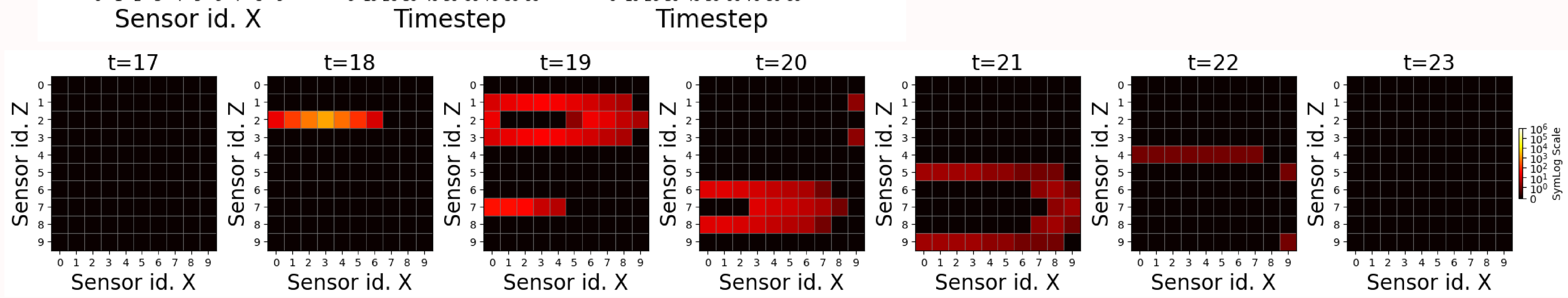
Please also look at Andrea De Vita's poster for more information on the detector simulation.

Light Signals

Photons are collected for a total of 20 ns and the signal is discretized into 100 bins. Here is how one example event looks like:



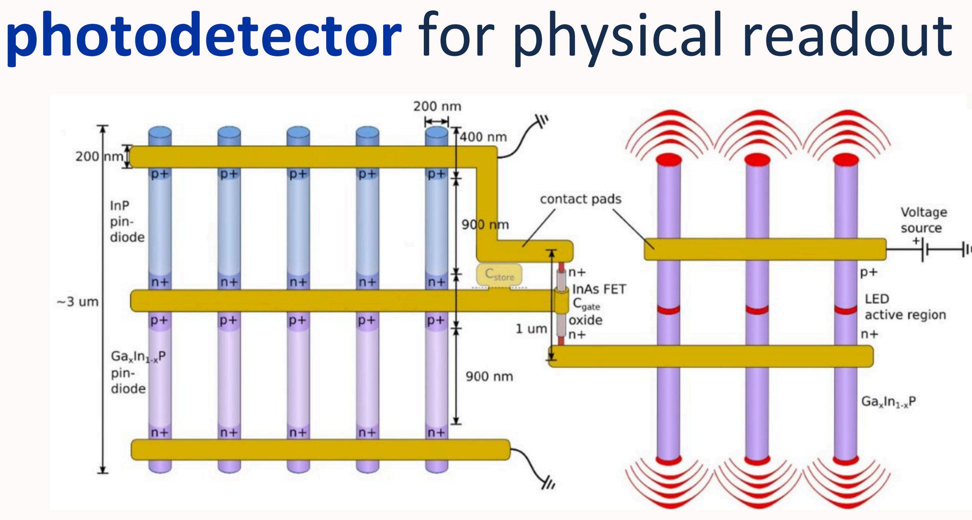
Signal integrated over *t*, *z* and *x* coordinates respectively. Different interactions produce multiple signals across time.



Successive frames that show how the photons produced in the first two interactions in the event above propagate inside the detector.

Outlook

- **First ever attempt** to use neuromorphic solutions for calorimetry readout!
- Development of **multi-nanowire photodetector** for physical readout [3]



- Employ **Spiking Neural Network** for:
  - precise measurement of shower energy
  - particle species identification

References:
[1] C. Mead. (1990). "Neuromorphic electronic systems." *Proceedings of the IEEE*, doi:10.1109/5.58356
[2] "Neuromorphic computing" available at www.humanbrainproject.eu. URL consulted on Sept.19, 2024
[3] David Winge et al. (2023). "Artificial nanophotonic neuron with internal memory for biologically inspired and reservoir network computing." *Neuromorph. Comput. Eng.* **3** 034011, doi:10.1088/2634-4386/acf684

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