Resolution Studies in Simulation for the IDEA Dual-Readout Calorimeter

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On behalf of the IDEA Dual-Readout Collaboration

1. Introduction

For precision measurements of Z, W, and H decays at the next generation of circular lepton colliders the hadronic jet energy resolution needs to achieve ~30-40%/$\sqrt{E}$. Additionally, a high transverse granularity is needed for a good e-γ-π^0 separation and enables the implementation of particle flow algorithms. Dual-Readout calorimetry has been established as a candidate to fulfil these requirements.

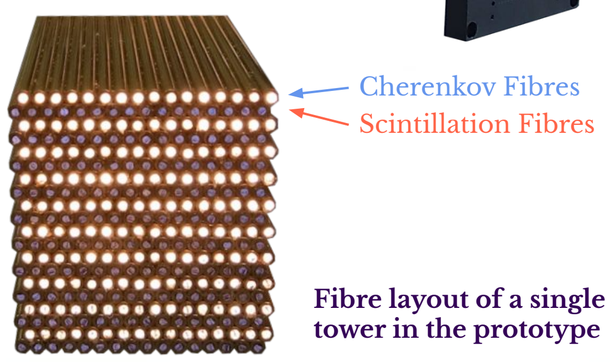
2. Dual-Readout Calorimetry

- Alternating Scintillation (S) and Cherenkov (C) fibres within passive material
- Each fibre connected to a Silicon-PhotoMultiplier (SiPM) allows for shower sampling in $\mathcal{O}$(mm)
- Measures electromagnetic and hadronic component of shower event-by-event
- Combination of channels allows for improved energy resolution

3. Prototype for Testbeams

- Prototype based on capillary brass tubes of 2 mm outer diameter built for Testbeams (SPS@10-125 GeV & DESY@1-6 GeV)
  - Aim to test **electromagnetic performance** with 'Bucatini' structure
- Dimension to contain an electromagnetic shower (10x10x100 cm^3)
- 3x3 towers, each containing 16x20 brass fibre tubes (160 Scintillation and 160 Cherenkov fibres of 1 mm diameter)
- Only central tower connected to SiPMs with each fibre read out individually by CAEN FERS-5200 system (A5202 readout boards)
- For surrounding eight towers: bundled fibres read out by two PMTs (one for S and one for C)

Dual-Readout Calorimeter Prototype for Testbeams

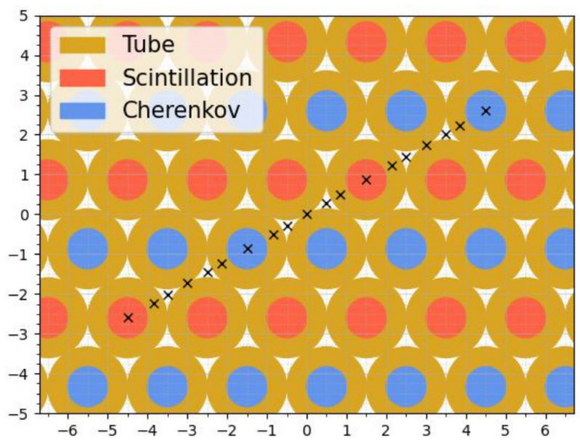


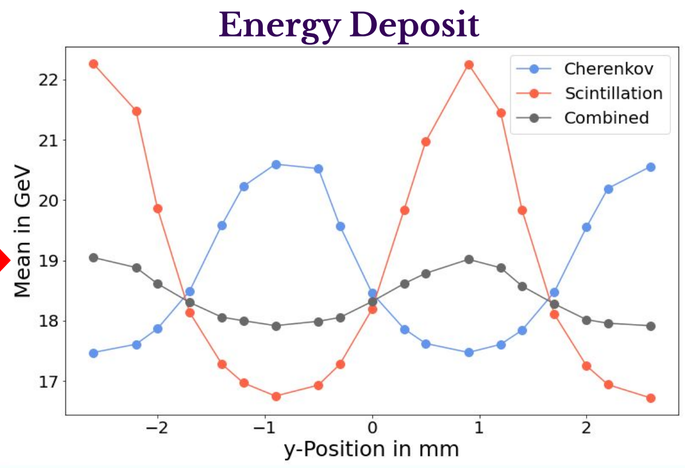
Fibre layout of a single tower in the prototype

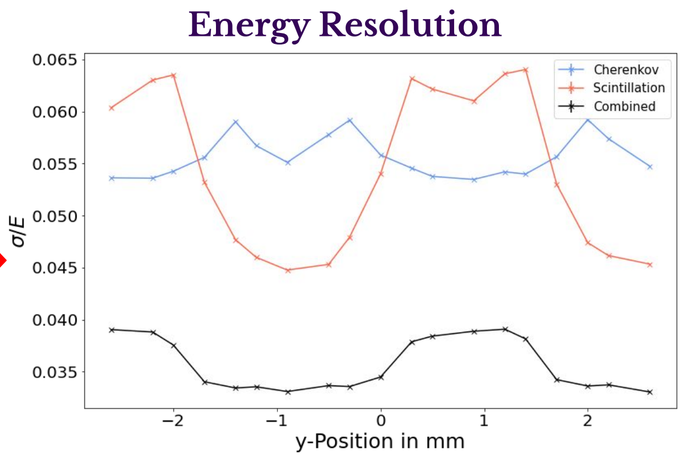
4. Electromagnetic Energy Resolution

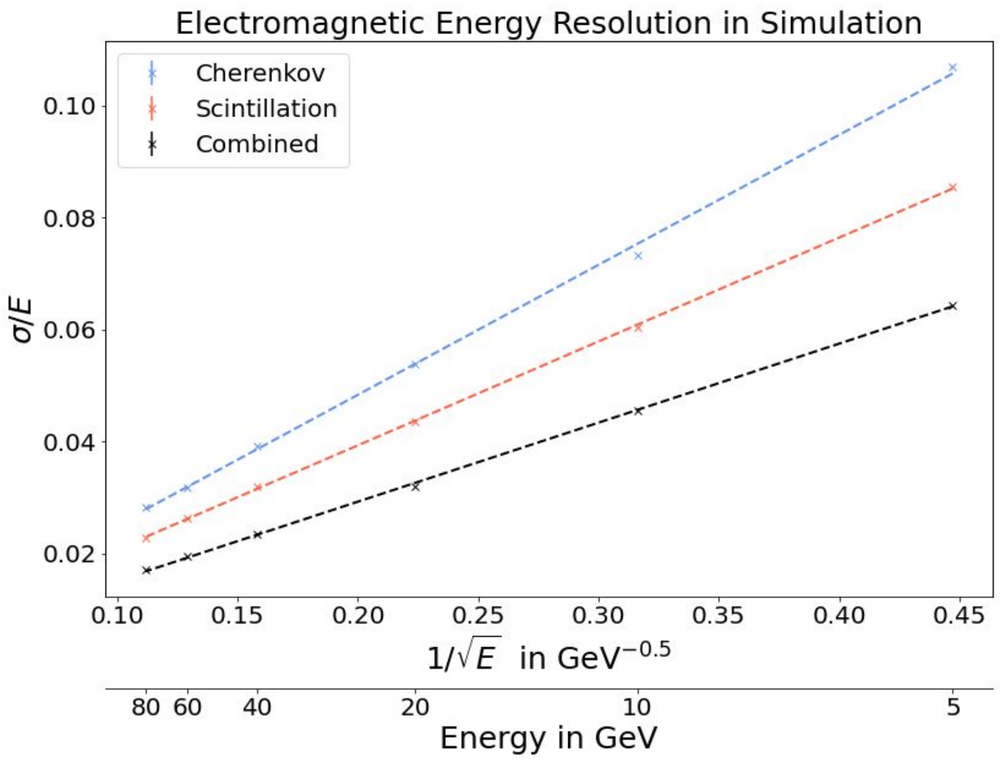
Impact Point Dependence

- Simulation was run in 'ideal configuration' with no material in front of the prototype with rotation of 1° with respect to the beam axis and a pencil-like beam of no radial extension @ 20 GeV (50k e^+ events per position)
- **Oscillating behaviour** in calorimeter response based on position of impact point can clearly be seen in the mean energy deposit as well as the energy resolution
- Oscillation present in combined channel
  - ► **Position-dependent equalisation** needed
- Effect has been observed both in testbeam data and simulation









$$\frac{\sigma}{E} = \frac{23.2\%}{\sqrt{E}} + 0.2\%$$

$$\frac{\sigma}{E} = \frac{18.6\%}{\sqrt{E}} + 0.2\%$$

$$\frac{\sigma}{E} = \frac{14.1\%}{\sqrt{E}} + 0.1\%$$

Energy Dependence

- Simulation with same 'ideal configuration' at fixed impact point
- Electromagnetic energy resolution can be inferred from linear fit
- Combined channel yields an electromagnetic energy resolution of **14.1%/$\sqrt{E}$** for this prototype

$$E_{comb} = \frac{\left(\frac{E_C}{\sigma_C^2} + \frac{E_S}{\sigma_S^2}\right)}{\left(\frac{1}{\sigma_C^2} + \frac{1}{\sigma_S^2}\right)}$$

5. Closing Remarks

- Many studies with this iteration of the prototype are still ongoing
- Preparation for upcoming testbeams has started
  - New modules with different assembly structures are tested
  - Online Monitoring for the prototype with EUDAQ2 is being developed
- Building of Hidra2 prototype for hadronic containment in progress

CALOR 2022
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[1] Antonello, M. "IDEA: A detector concept for future leptonic colliders." *Il nuovo cimento C* 43.2-3 (2020): 1-6.
[2] Antonello, M., et al. "Tests of a dual-readout fiber calorimeter with SiPM light sensors." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 899 (2018): 52-64.
[3] Lee, S., Livan, M., & Wigmans, R. (2018). Dual-readout calorimetry. Reviews of Modern Physics, 90(2), 025002.