The progress of FIT optical simulation

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Motivation

- A deeper understanding of the general behavior of scintillating fibers.
- Provide more information to optimize the models in the following fast simulation.

Content

- FIT Module Introduction
- Optical Simulation
- Beamtest Simulation
- Conclusion and Further Plan

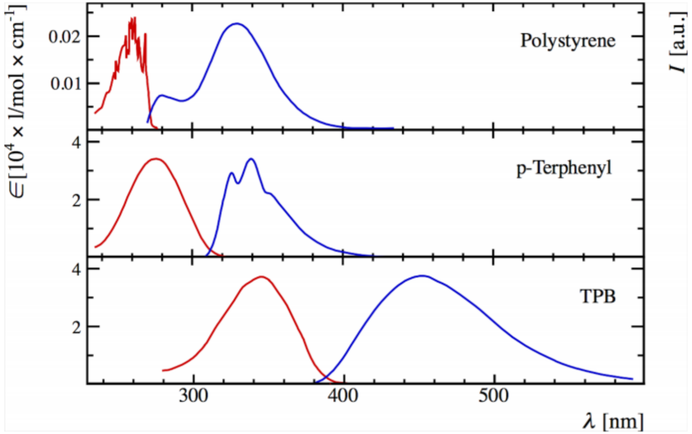
Part 1: FIT Module Introduction

Scintillating Fibers

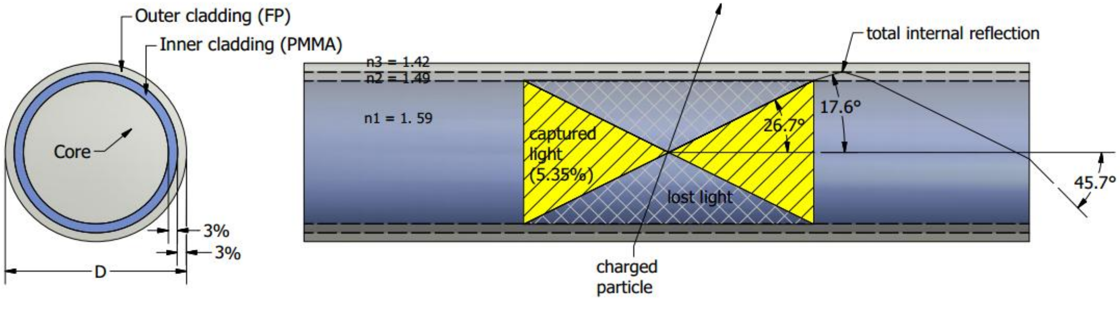
- Basic properties:

SCSF-78MJ from Kuraray

- Organic scintillator Polystyrene core
- Acrylic cladding of lower refraction index for light capture
- Core doped with scintillating dyes for improved light yield and timing characteristics.
- Fiber Diameter 250 µm



Absorption(red) and emission(blue) spcetra of
Core: polystyrene
Primary dye: p-terphenyl (PT)
Secondary dye: tetraphenyl-butadiene(TPB)



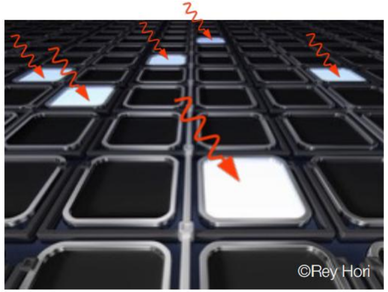
(a) end view (b) side view

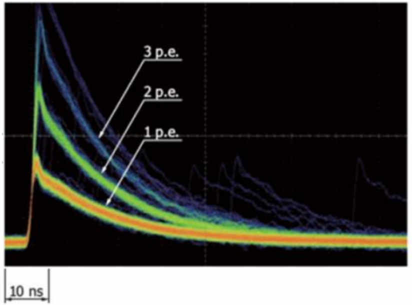
LHCb Scintillating Fibre Tracker Engineering Design Review Report : Fibres , Mats and Modules. LHCb Internal Note, (July), LHCb--PUB--2015--008.

Silicon Photomultiplier(SiPM)

SiPMs are arrays of Avalanche Photon-Diodes(APD) operated in Geiger-mode.

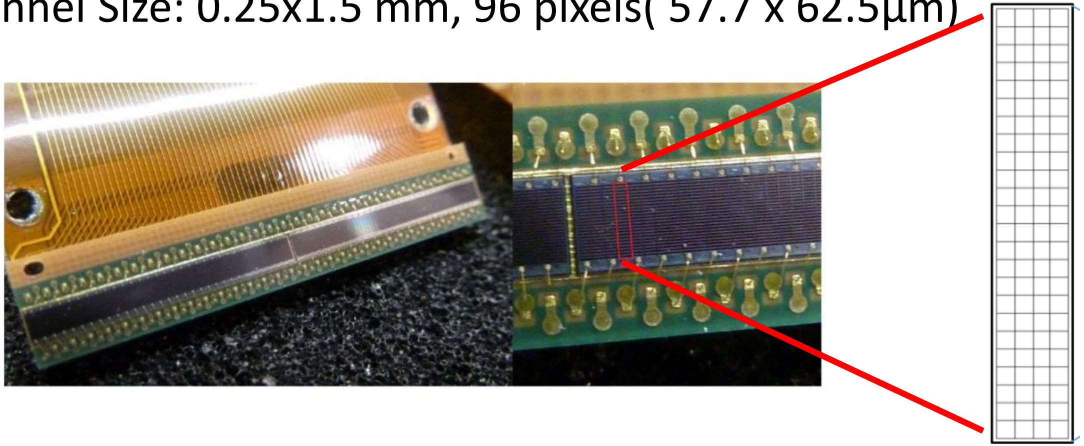
- Each pixel fires independently
- Output is a sum of signals from triggered pixels.





Properties:

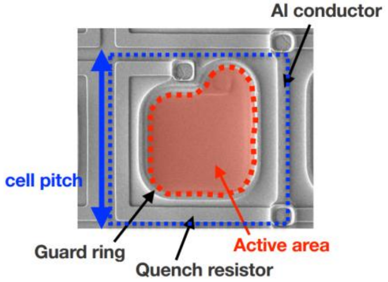
- Each chip contains 128 channels
- Channel Size: 0.25x1.5 mm, 96 pixels(57.7 x 62.5µm)



4 x 24 pixels = 96 pixels

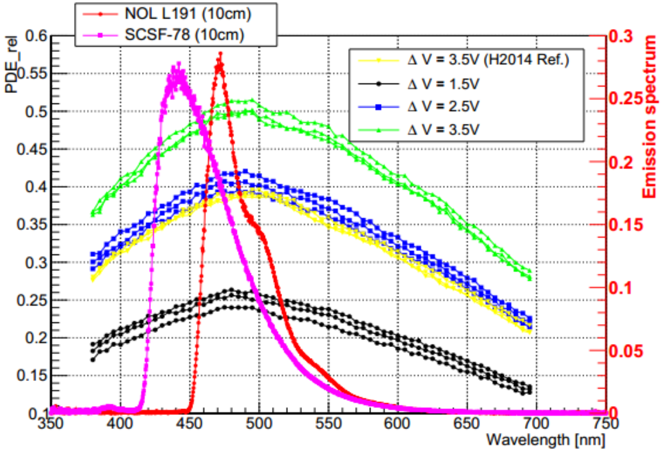
SiPM characteristics: Photon Detection Efficiency

$$PDE = \varepsilon \cdot QE \cdot P_{trigger}$$



- ε(geometric factor);
- QE(quantum efficiency)

  probability of the photon to produce a photon-electron
- $P_{trigger}$: probability of a primary photon–electron to trigger the pixel avalanche

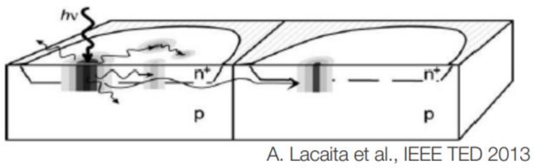


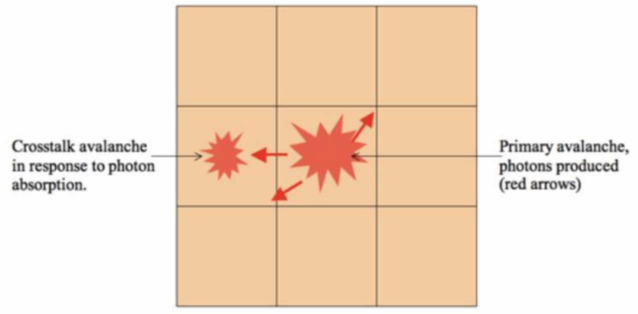
It depends on the wavelength(λ) of the incoming photon and the applied overvoltage(V)
The PDE peak at ~50% for wavelength of 480nm with overvoltage ΔV=3.5V

A. K. Kuonen et al., LHCb Scintillating Fibre Tracker Engineering Design Review: Silicon Photomultipliers, LHCb-INT-2016-019.

SiPM characteristics

- **Saturation/Linearity**: a pixel can only fire once per event
- **Cross-talk**: photons absorbed in the adjacent pixel and triggered an avalanche

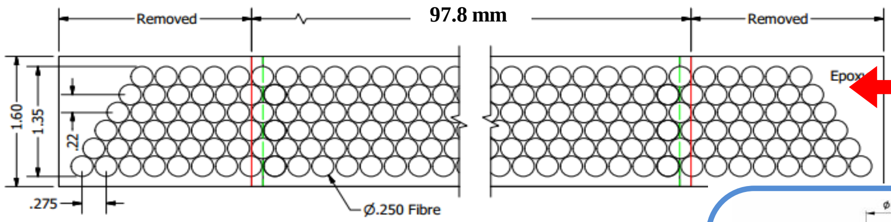


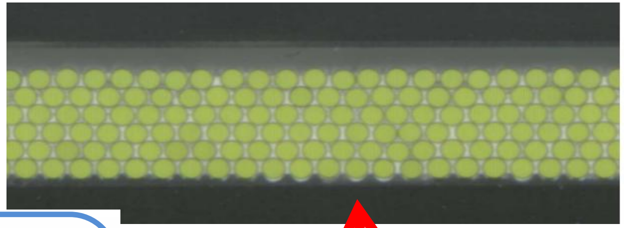


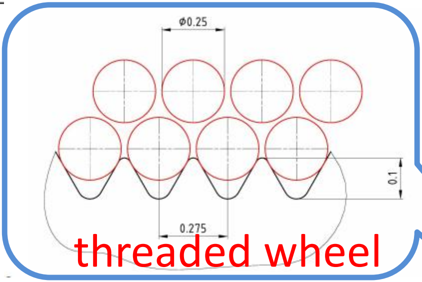
- **Dark count rate(DCR)**: pulses triggered by thermal carriers
- **After-pulsing**: carriers trapped during an avalanche to be released and triggered another avalanche.

Fiber Mat

A single cast mat



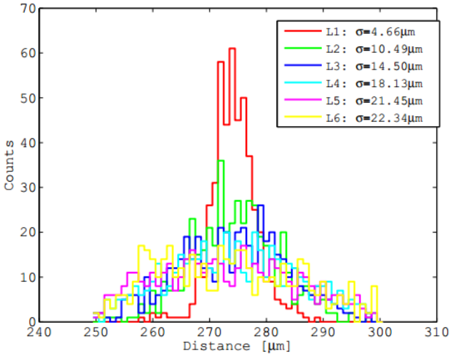


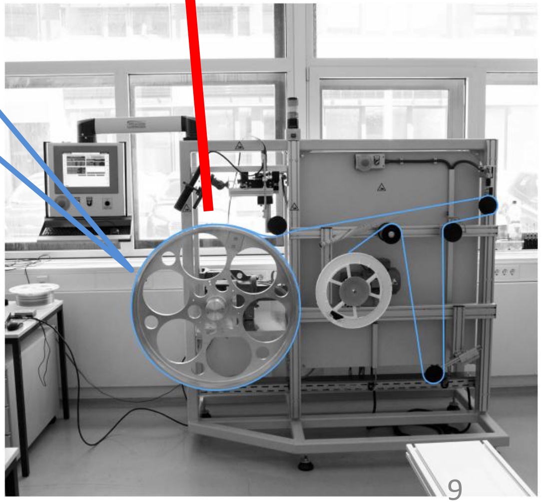


Mat width:97.8cm

Mat thickness: 6 layer+ gule, ~1.7mm

Fiber pitch 275 µm

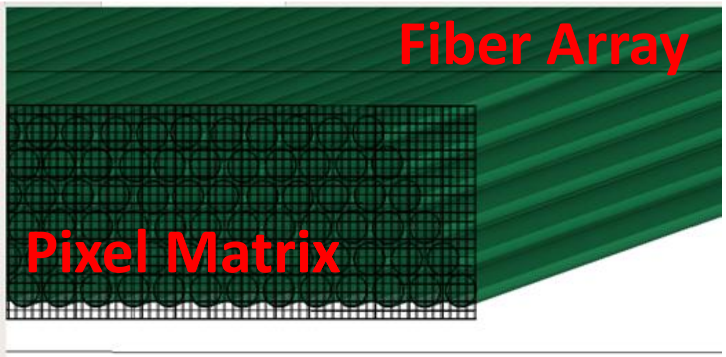




Part 2: Optical Simulation

Geometry Setup

- Only one fiber mat and one SiPM chip
- Gap ~1 mm (epoxy glue + air)
- Fiber position, Gaussian distribution with diff sigma for diff layers
- Pixel size: 62.5 x 62.5 μm^2
- A mirror with user-defined reflectivity optionally on the other end.



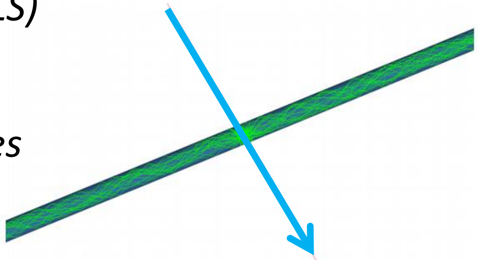
Geant4 optical photon process

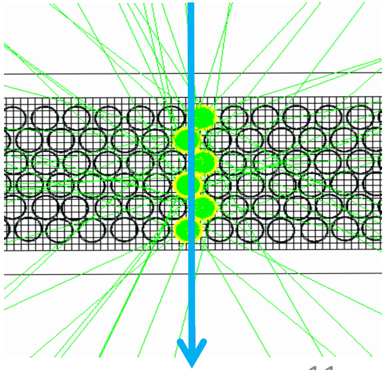
➢ **Generation of photons**

Cerenkov effect, Scintillation, Wavelength shift(WLS)

➢ **Tracking of Photons**

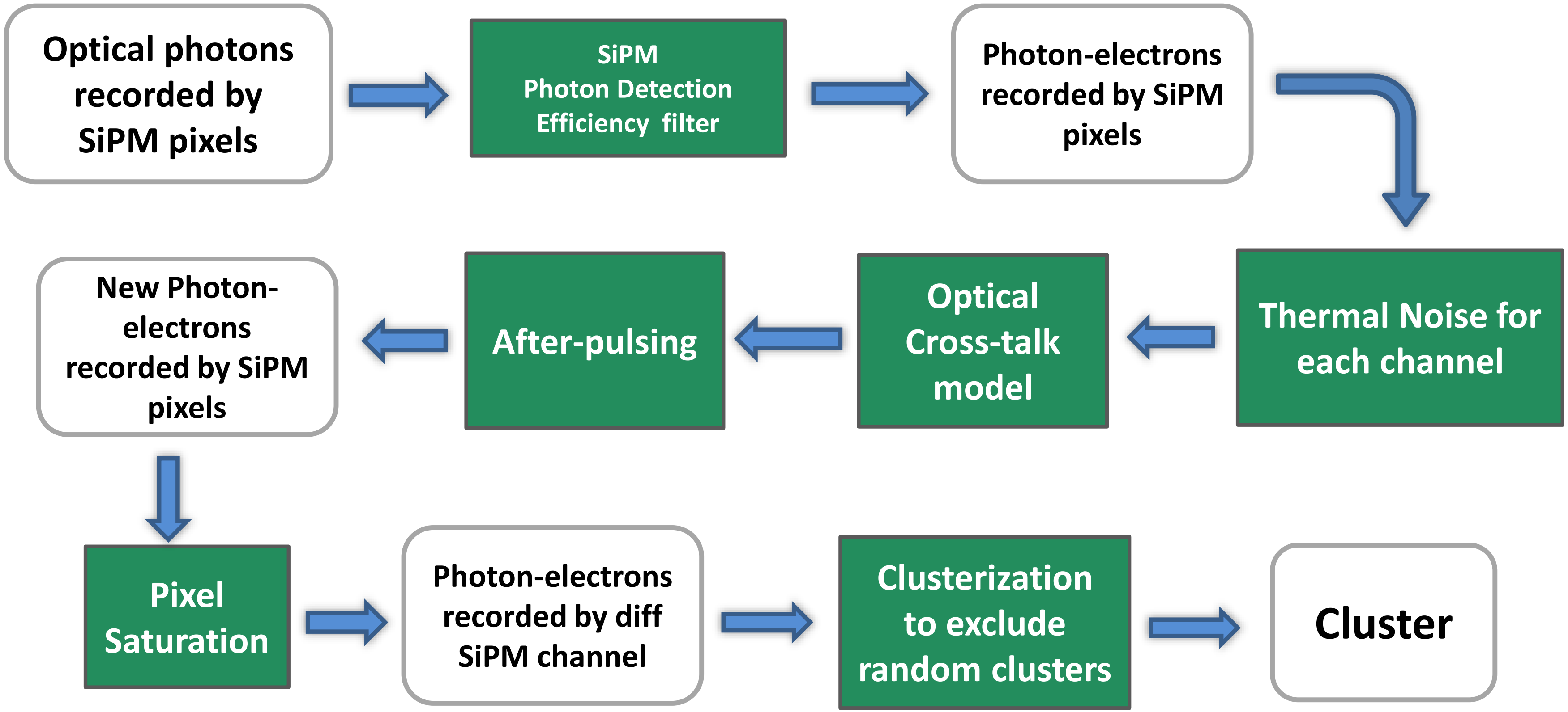
- *Refraction and reflection at medium boundaries*
- *Absorption*
- *Rayleigh scattering*





All parameters above should be provided by a input data file.

DIGI Flow: from optical photons to cluster



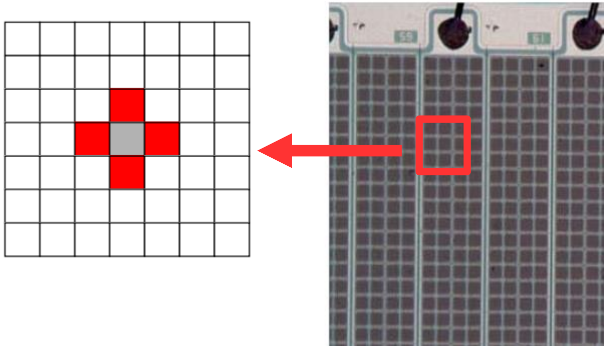
Thermal noise and after-pulsing ~ Poisson distribution

Optical cross-talk(CT) model

Assuming:

- Any triggered pixel can induce CT in 4 neighboring pixels;
- Same probability ***p*** of CT for any individual neighbor;
- Binomial distribution

$$P(s) = \binom{n}{s} p^s (1-p)^{n-s}$$

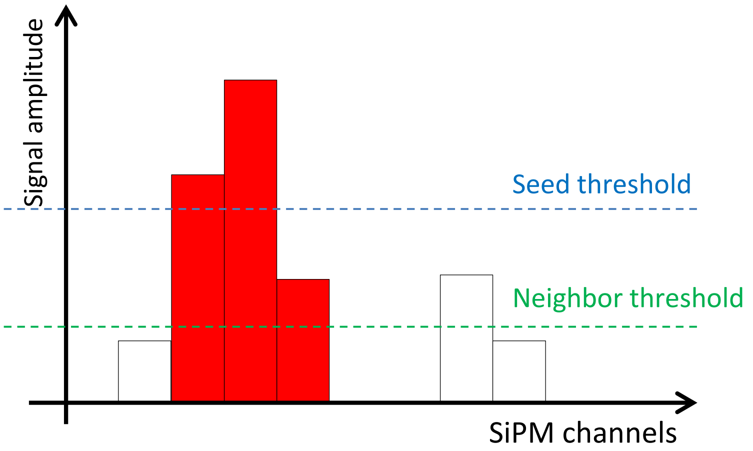


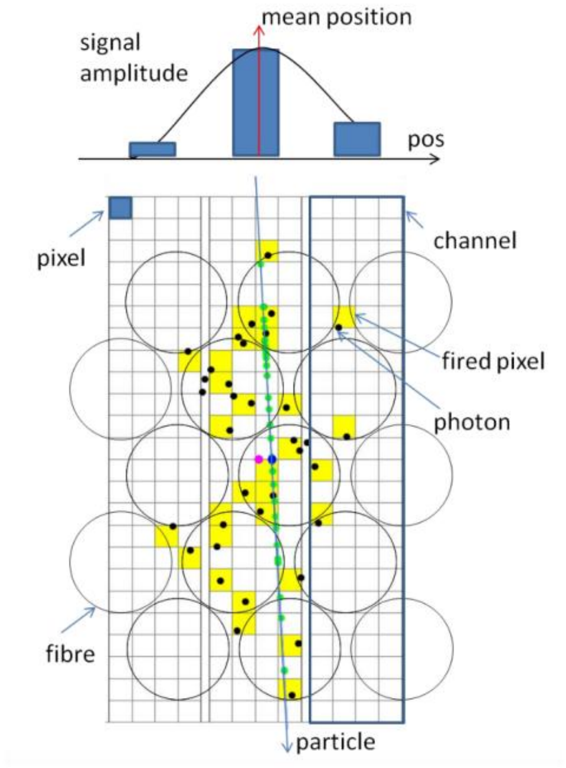
If measured CT probability is ε, $1 - \varepsilon = (1-p)^n$

L. Gallego, et al., Journal of Instrumentation 8 (05) (2013) P05010

Cluster Algorithm

- Scan through the array to select channels with signal above ***seed threshold***
- Accept neighbor channels on the left and right if they have signal above ***neighbor threshold***





Part 3: Beamtest Simulation

Configuration

Particle Source

Type: proton

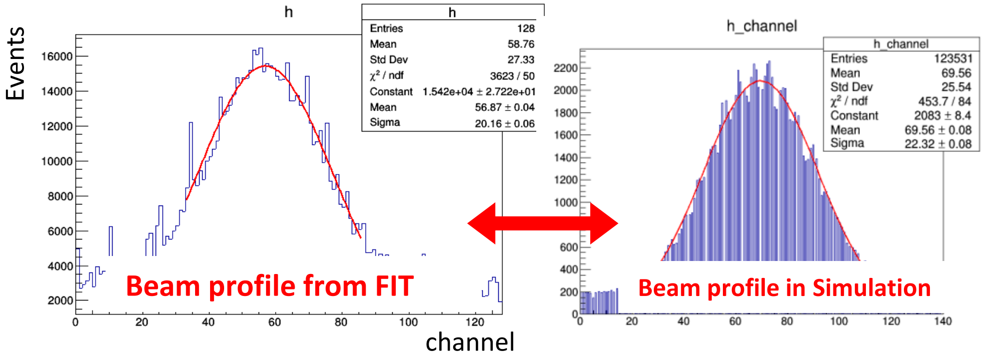
Energy: 100GeV

2D-Gauss Spot, sigma 0.5cm

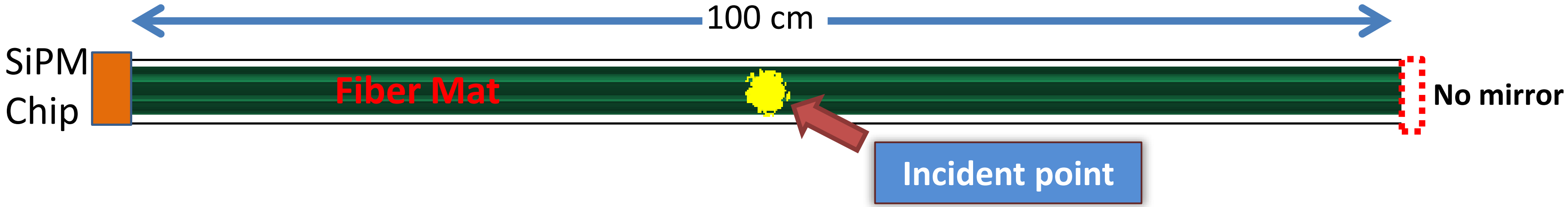
Perpendicularly

Incident position: center of mat

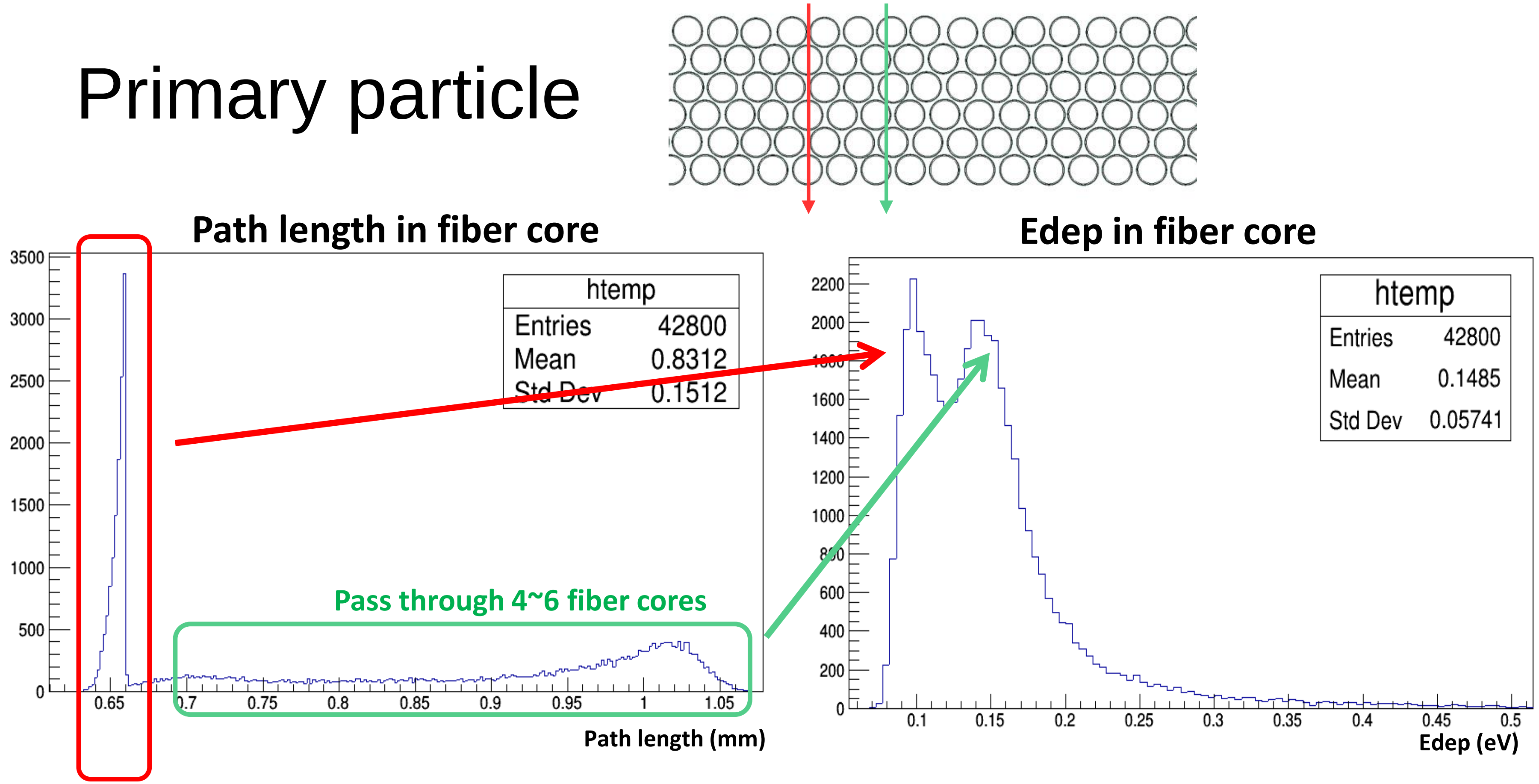
Events: 42800



The 100 cm long module has been installed together with the 5 AMS ladders of the telescope.

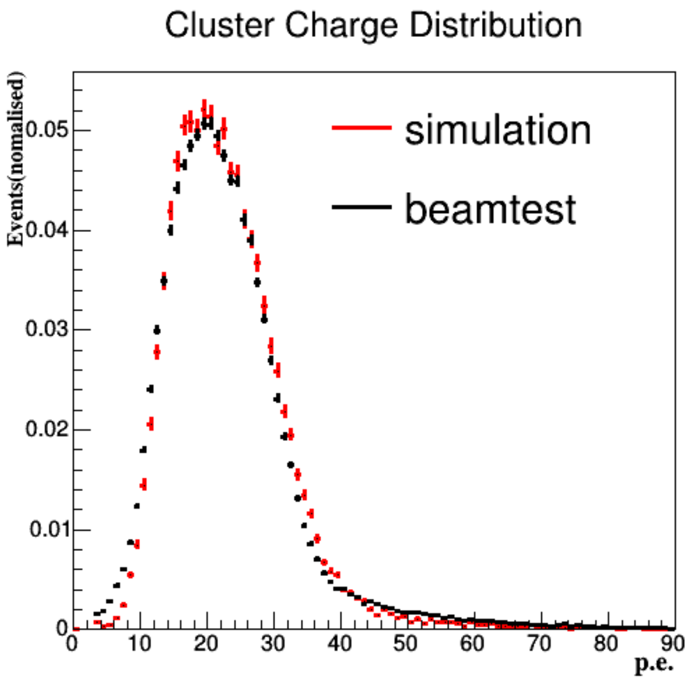


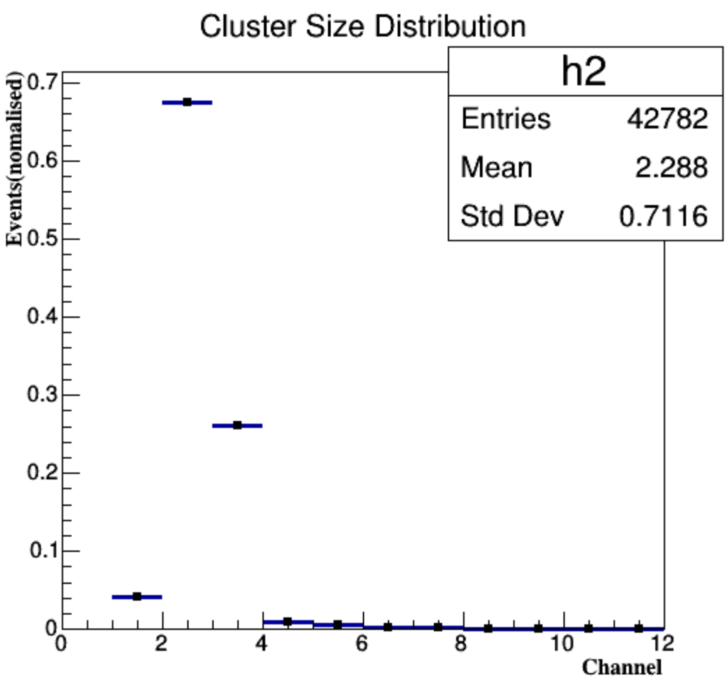
Primary particle



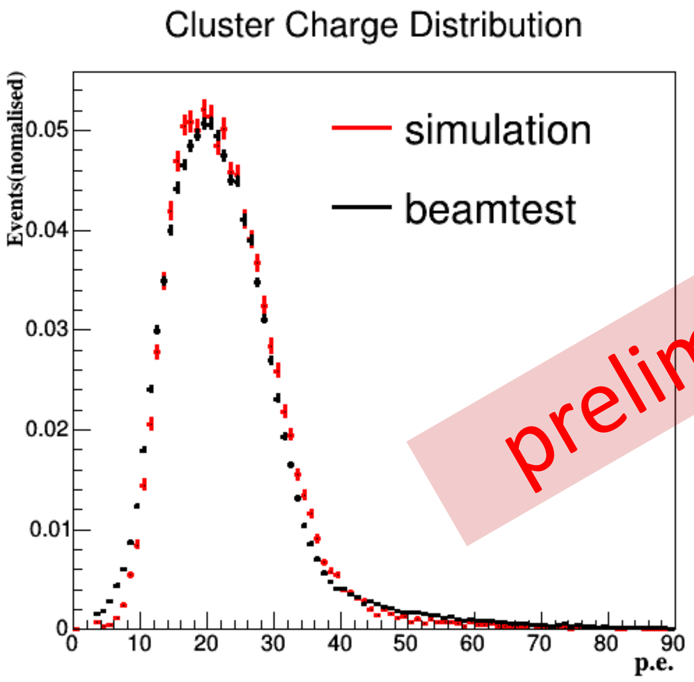
Peak at 0.66mm (3 x fiber core diameter ~0.22mm)

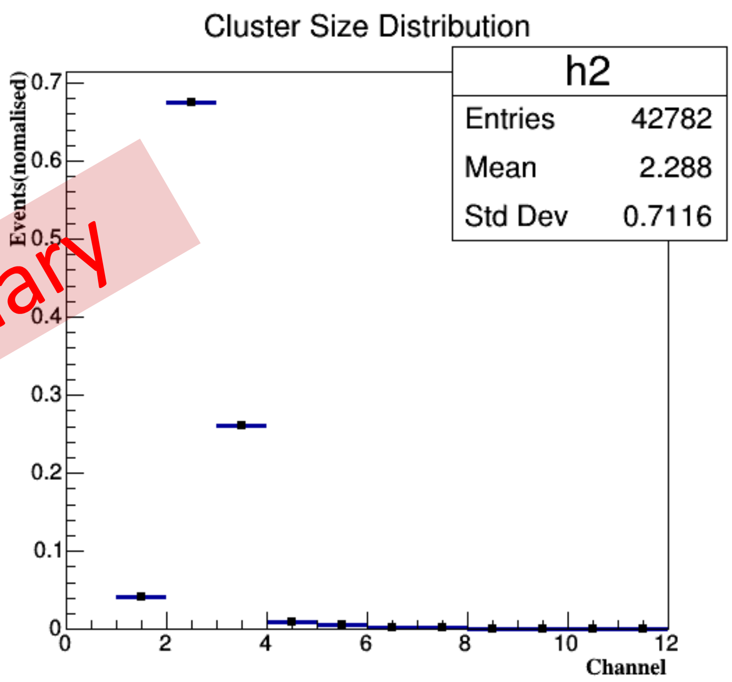
Comparison with beamtest





Comparison with beamtest





Conclusion and Further Plan

The optical simulation program is developed, the digitization is still ongoing.

- Many parameters should be tuned to match beamtest.
- Hit efficiency, position resolution and cluster size
- Fast simulation will be developed