A light tracker based on scintillating fibers with SiPM readout

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on behalf of the Bari group

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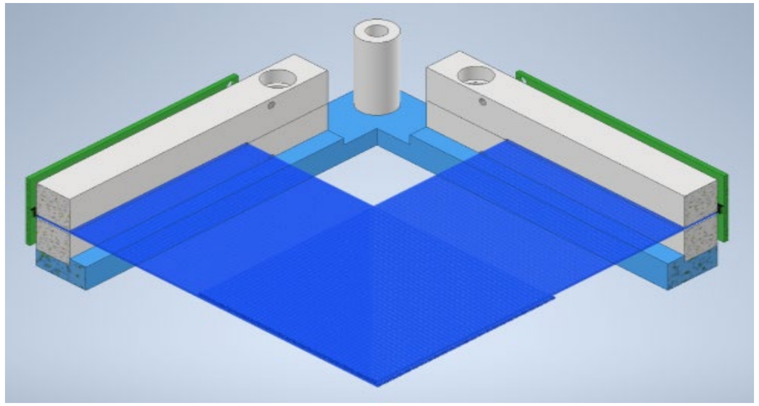
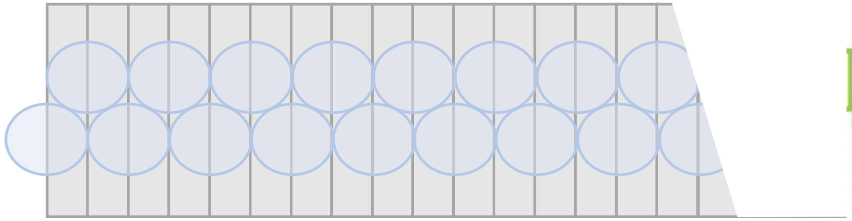
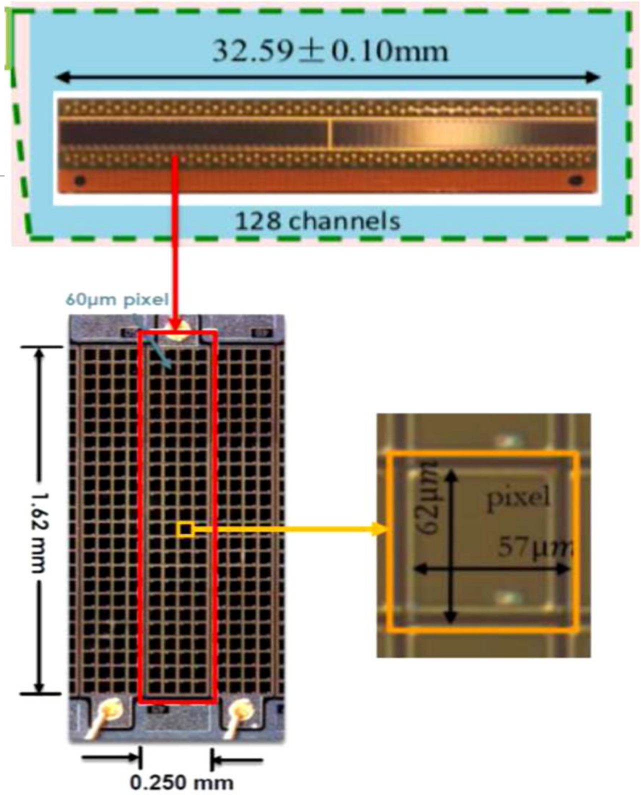
Introduction

- We are developing a large area tracker based on scintillating fibers read-out by SiPM arrays
  - High segmentation
  - Reduced material budget
  - Self-triggering capabilities
- Application: new generation of space-borne cosmic-ray and gamma-ray detectors
  - Detection of sub-GeV gamma rays requires precise reconstruction of electron-positron pairs produced in pair conversions and of Compton-scattered electrons
- Thanks to the recent developments on SiPMs, trackers based on long SciFi now represent a valuable alternative option to silicon detectors
  - No strip-to-strip wire bonding needed
  - Spatial resolution $< 100\ \mu m$
  - Time resolution ≈ 100 ps
  - Tested up to $6\times10^{11}\ n_{eq}/cm^2$ total neutron fluence
  - Non-planar geometries can also be easily implemented

Module concept





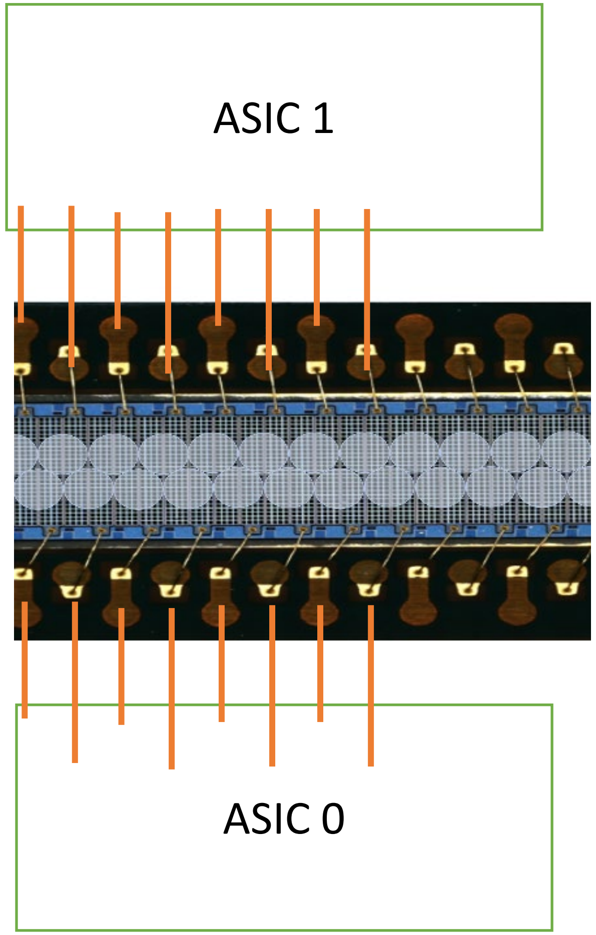


Hamamatsu S13552 128 channels SiPM array.

- X-Y module consisting of two staggered layers of fibers in each view readout by SiPM arrays at their ends
  - 500 μm diameter round fibers
  - 250 μm SiPM strip pitch
    - Photons from each fiber are shared between two SiPMs
- A charged particle crossing a plane will release an energy deposit in at least a pair of adjacent fibers in the top and bottom layers
  - Scintillation photons will be then collected by at least a pair of adjacent SiPM strips

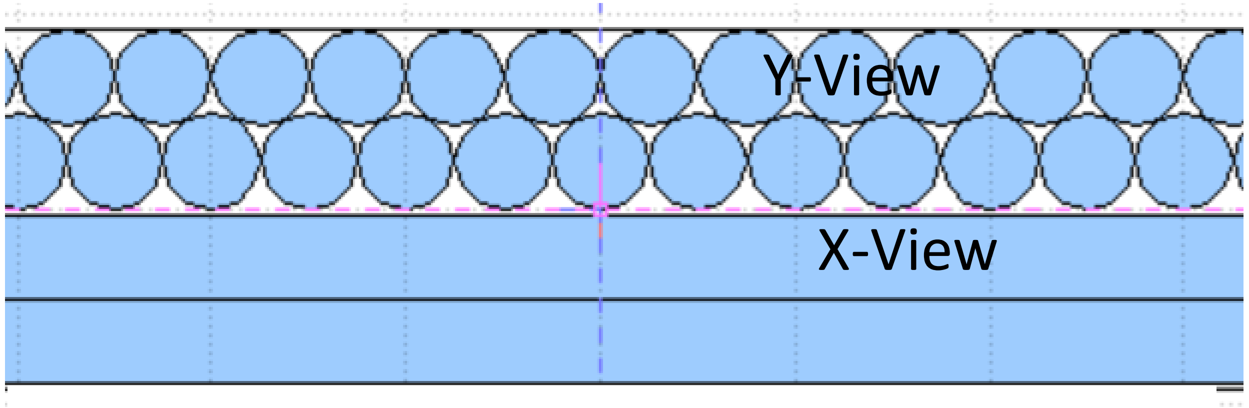
Prototype front-end and read-out electronics

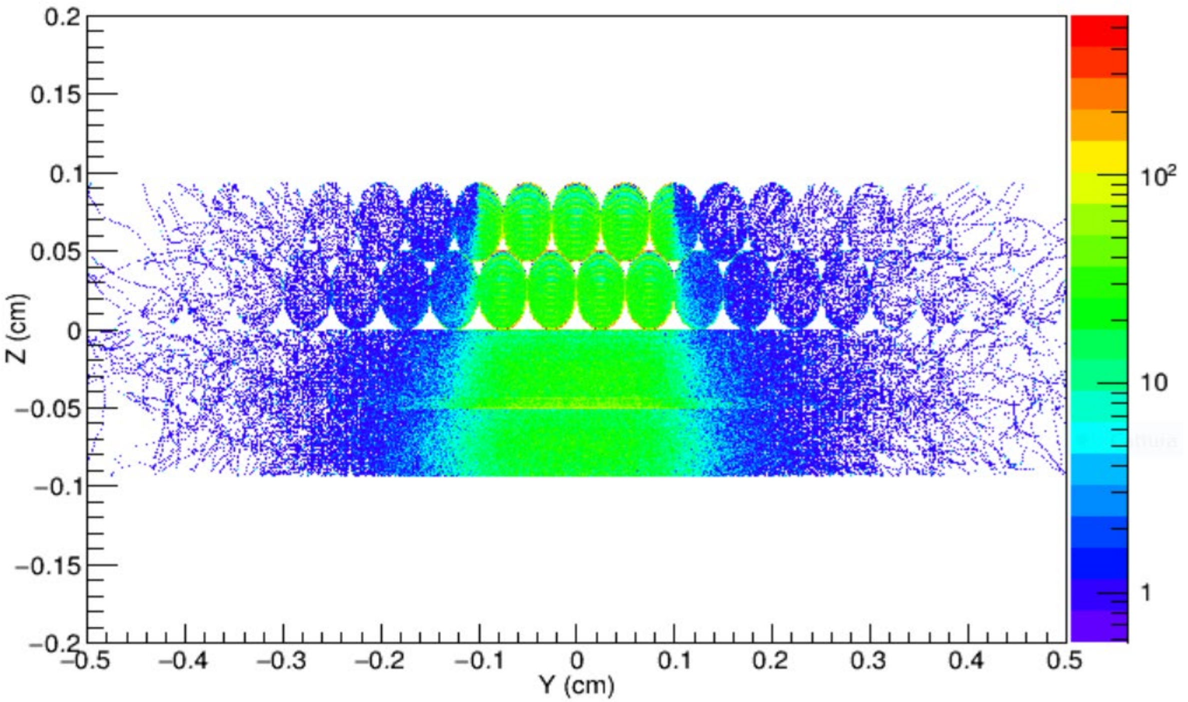
- SiPM signals read-out with 32-channel PETIROC2A ASIC
- Even and odd SiPM strips are connected to two different FE ASICs
- The light produced in a fiber is expected to be shared between a pair of adjacent SiPM channels, and consequently a signal is expected from both ASICs
- The trigger configuration in each plane requires a signal from both ASICs
- A trigger threshold of a few photoelectrons should suppress fake triggers due to SiPM dark noise while keeping a high trigger efficiency



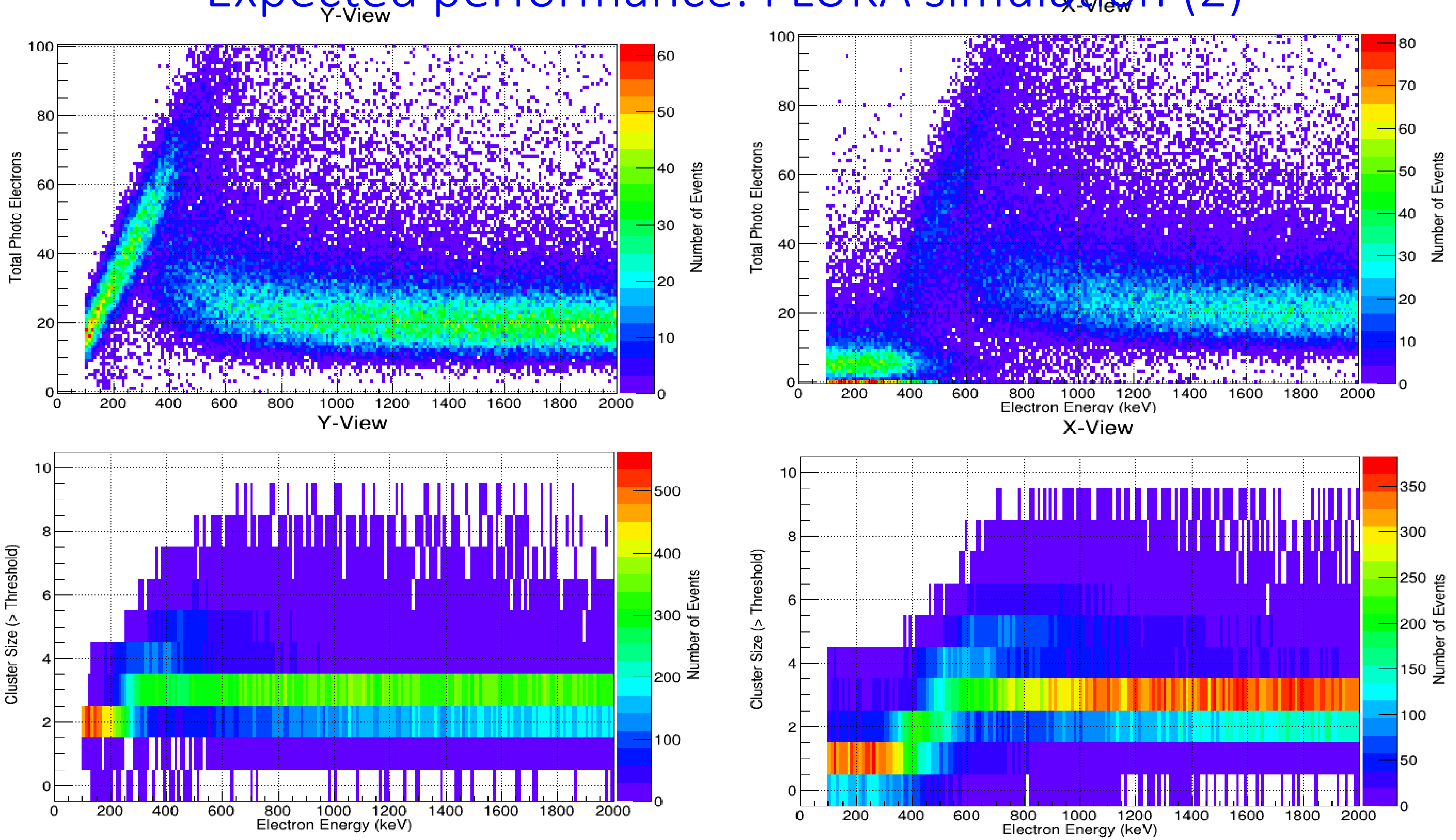
Expected performance: FLUKA simulation (1)

- X-Y module:
  - Two staggered layers/view
  - 500 μm diameter fiber
- Fiber Yield: 8 ph/keV
- Fiber Trapping Efficiency = 5.4%
- SiPM PDE = 0.4
- SiPM strip threshold = 3 pe
- On-axis electrons 100 keV – 2 MeV



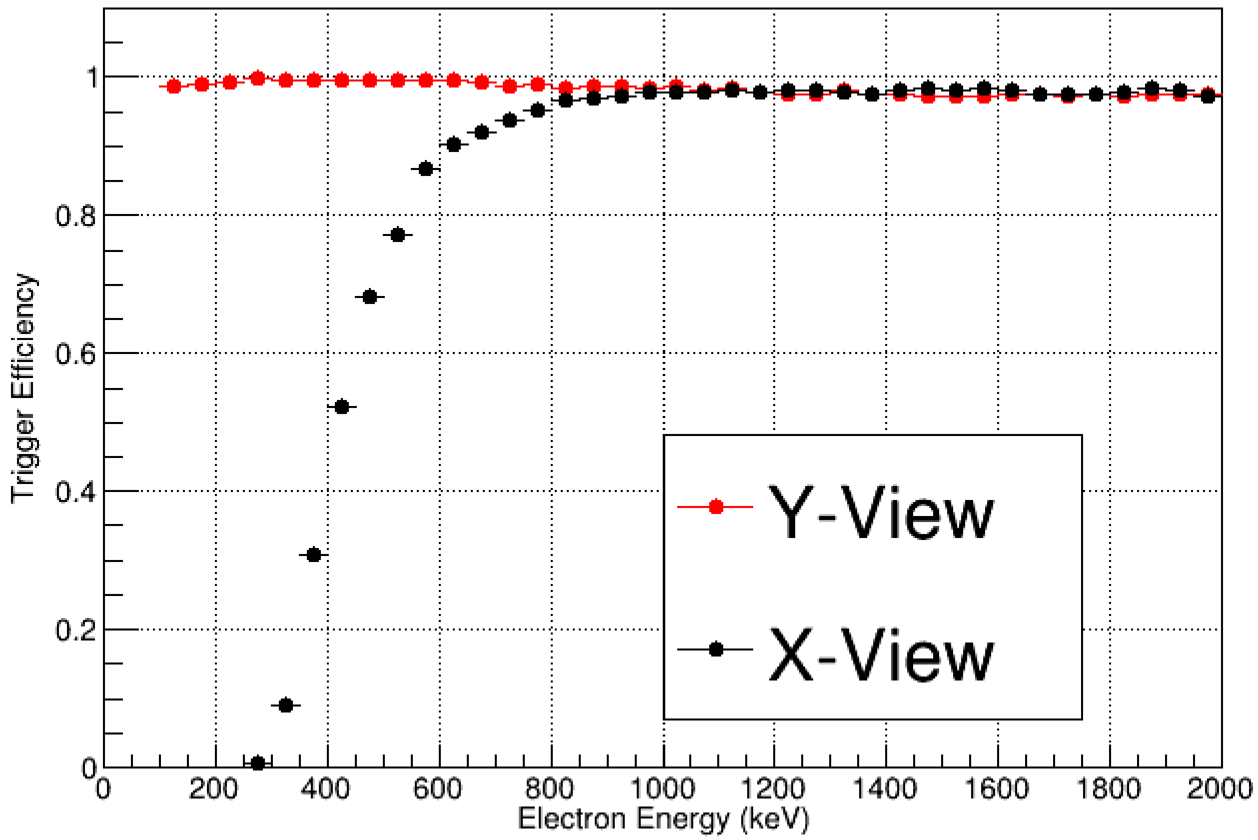


Expected performance: FLUKA simulation (2)



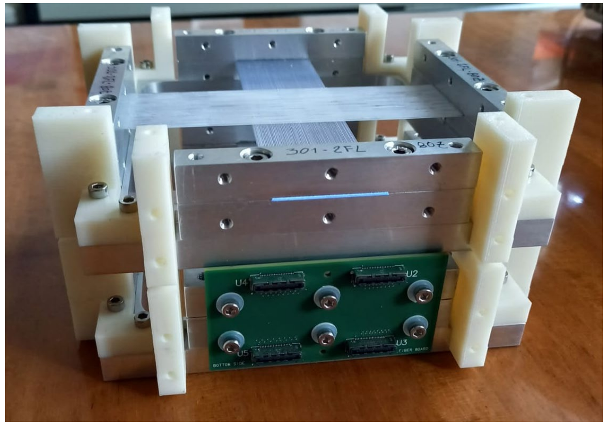
Expected performance: FLUKA simulation (3)

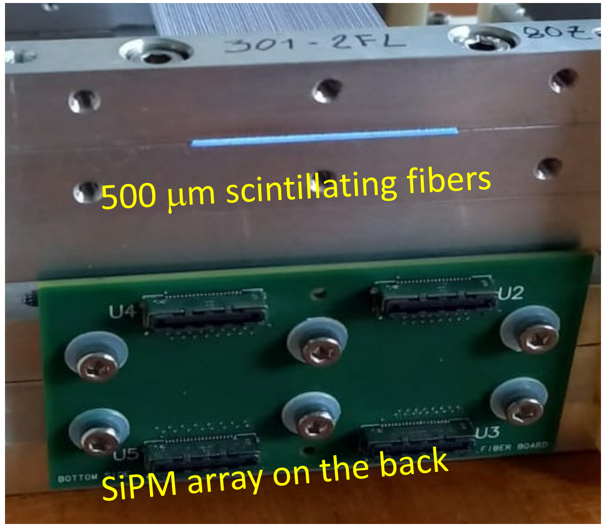
Trigger: any pairs of adjacent strips with at least 3 p.e. each

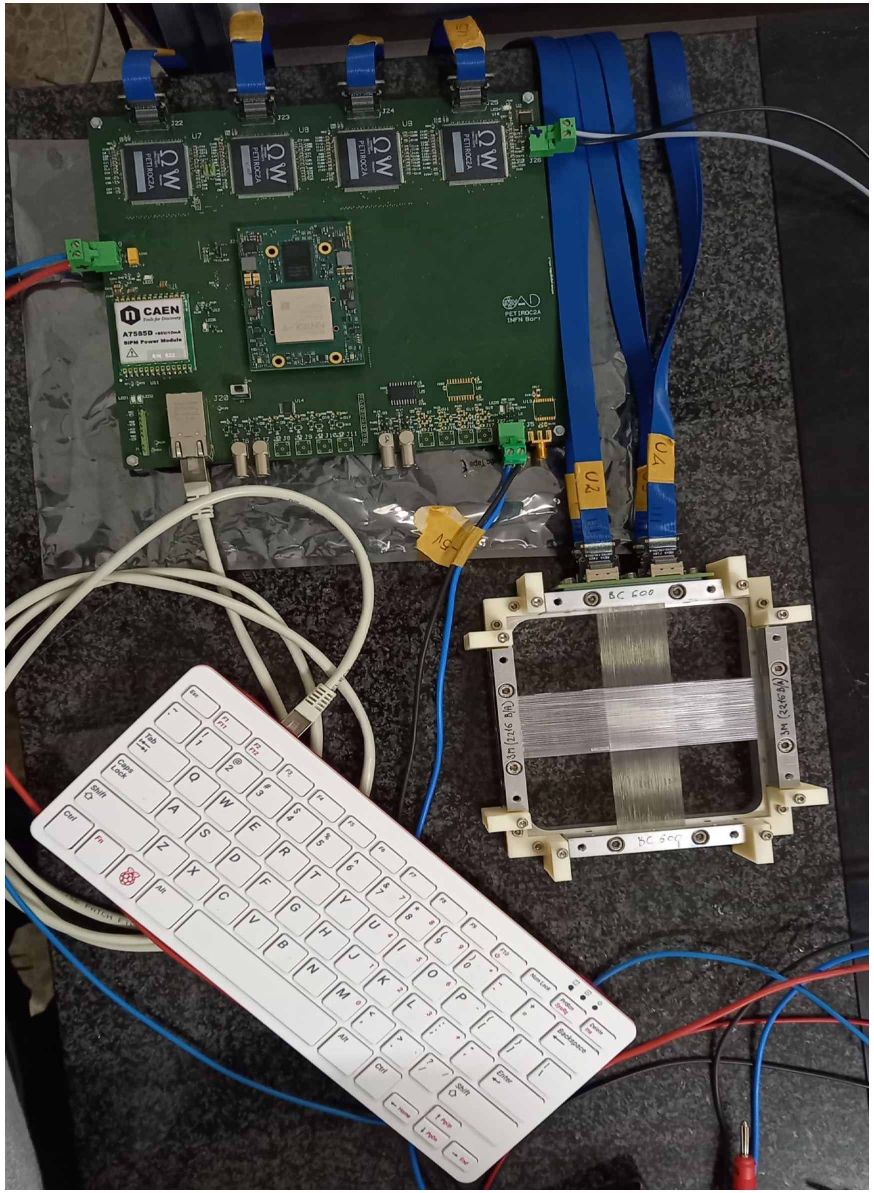


Fiber tracker prototype

- X-Y module with 500 μm diameter Saint Gobain fibers BCF12 double cladding
  - Fiber length 14 cm
- SiPM: Hamamatsu S13552
  - 128-channels
  - 250 μm strip pitch
  - OV=4-5 Volt
- Read-out board
  - 4 Petiroc 2A ASICs
  - CAEN A7585D SiPM voltage module
  - Kintex-7 FPGA module
- DAQ based on the Raspberry Pi4

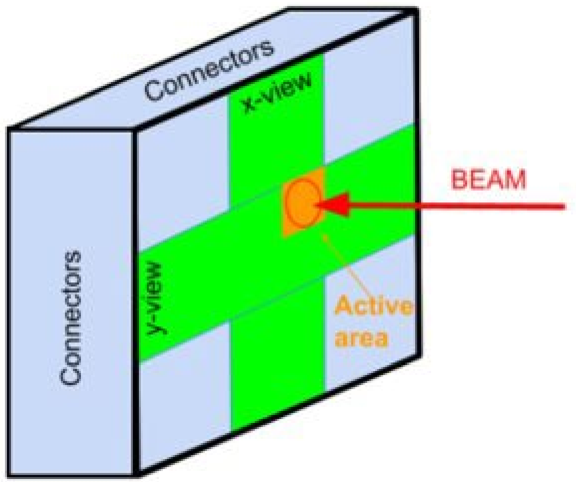


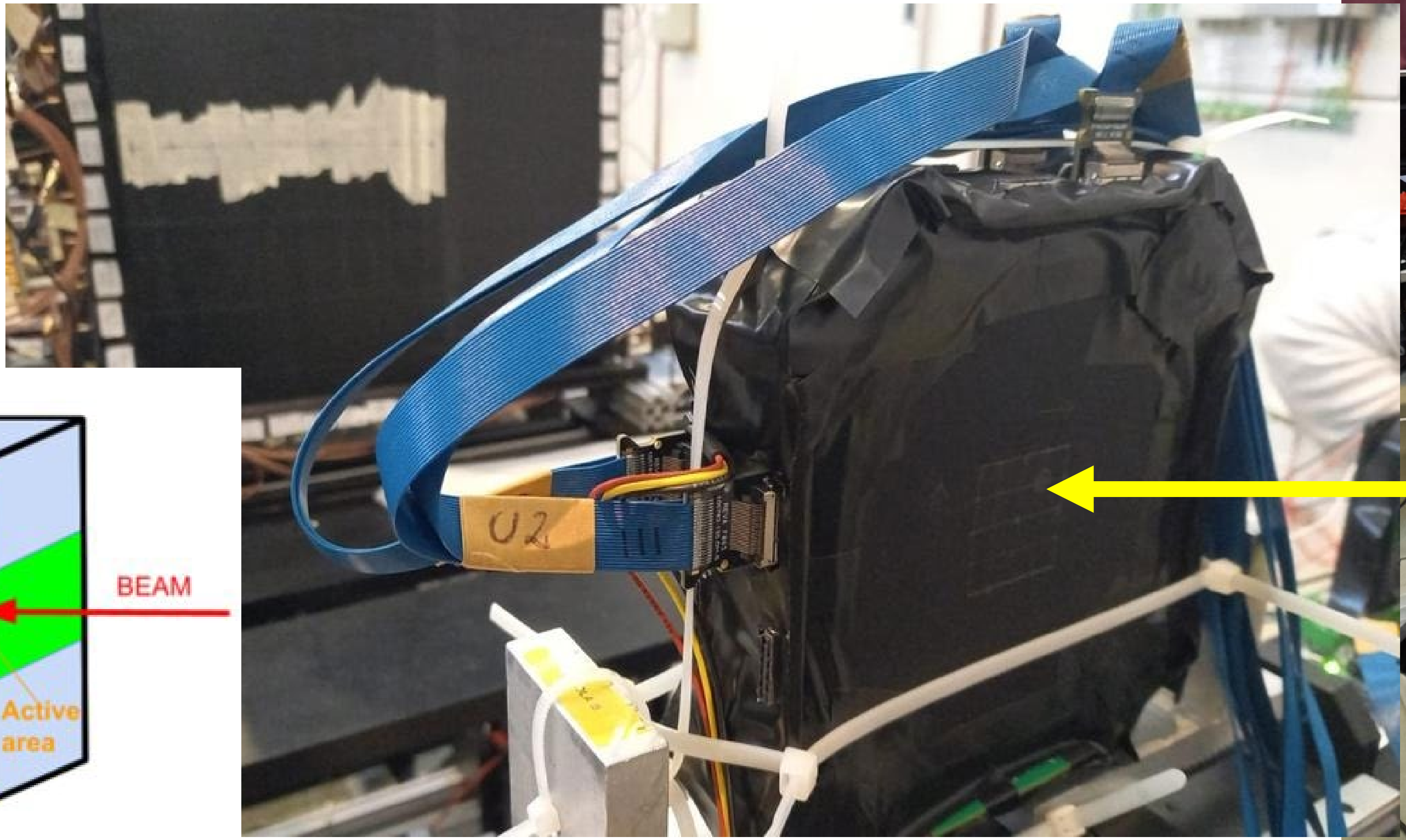


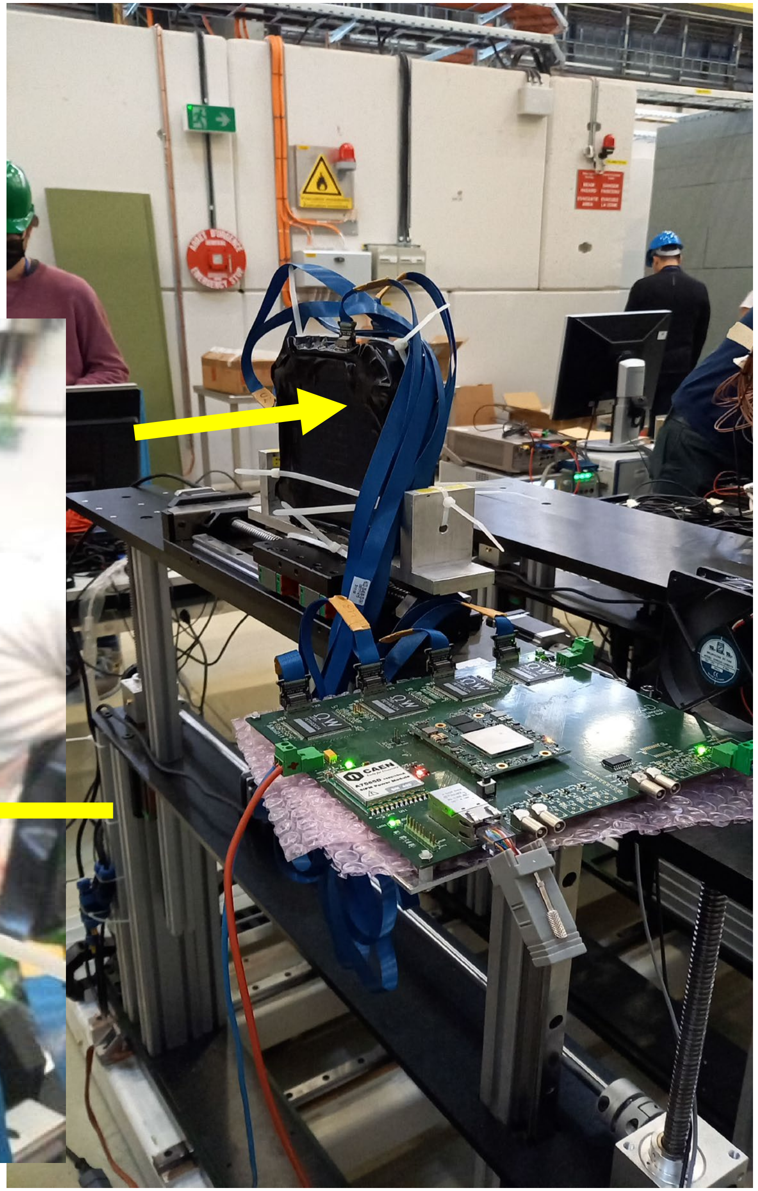


CERN T9-PS beam test 2021 (BT21)

- Two Petiroc 2A ASICs for each view
  - About 1.6 cm x 1.6 cm active fibers



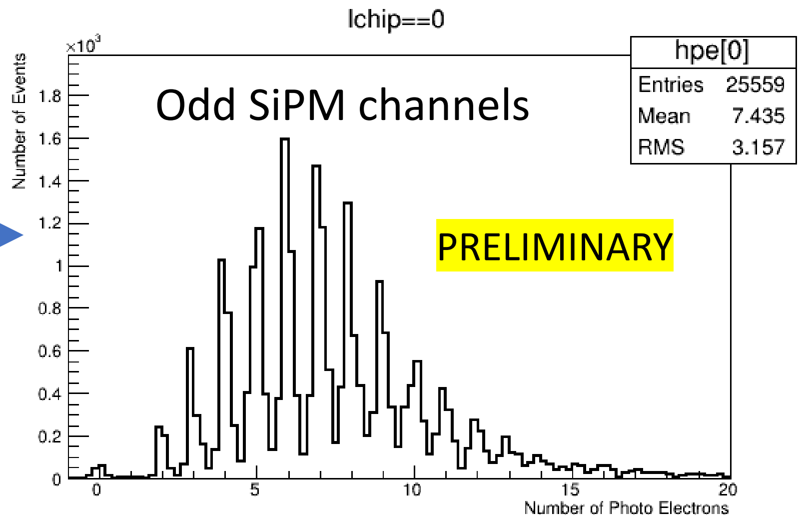


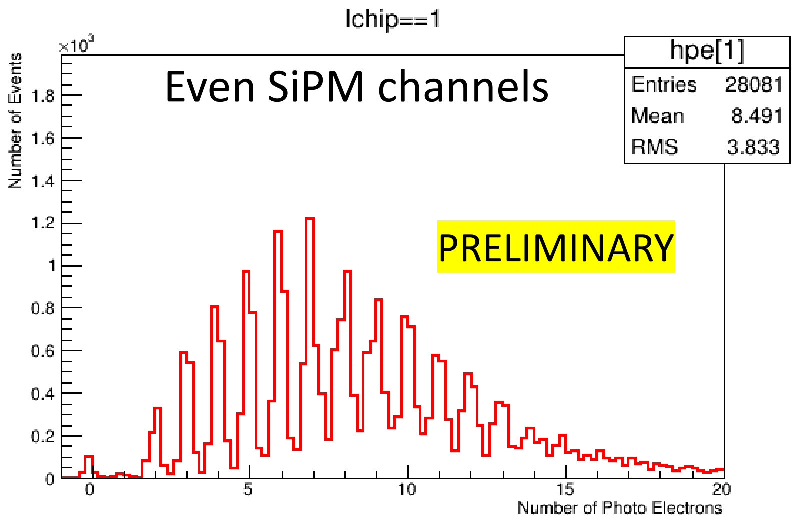


Preliminary BT21 results (1)

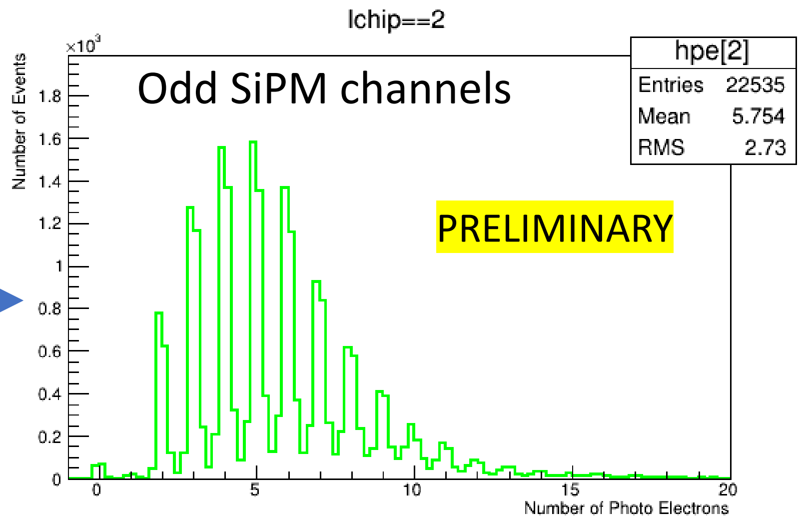
OV = 4.5Volt

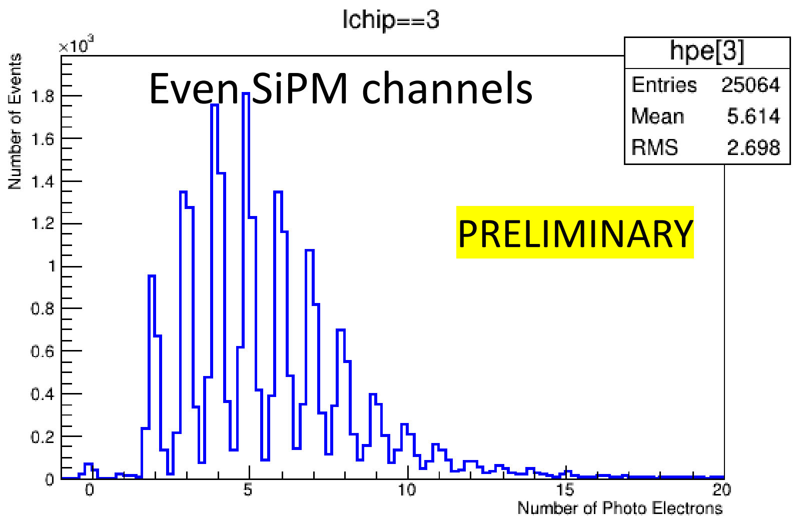
Horizontal View





Vertical View





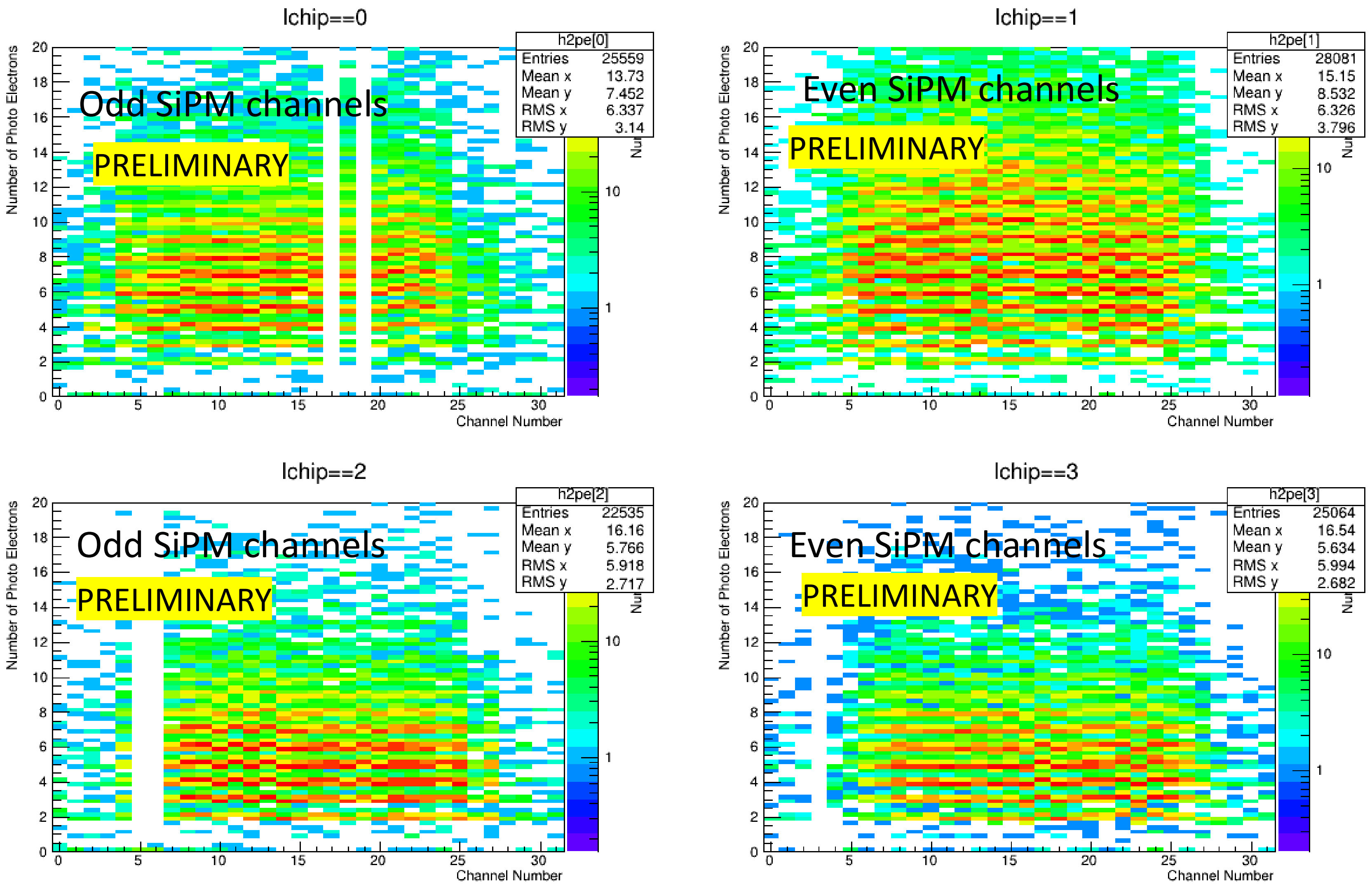
Preliminary BT21 results (2)

OV = 4.5Volt

Horizontal View

External Trigger:
1 cm x 1 cm plastic scintillators

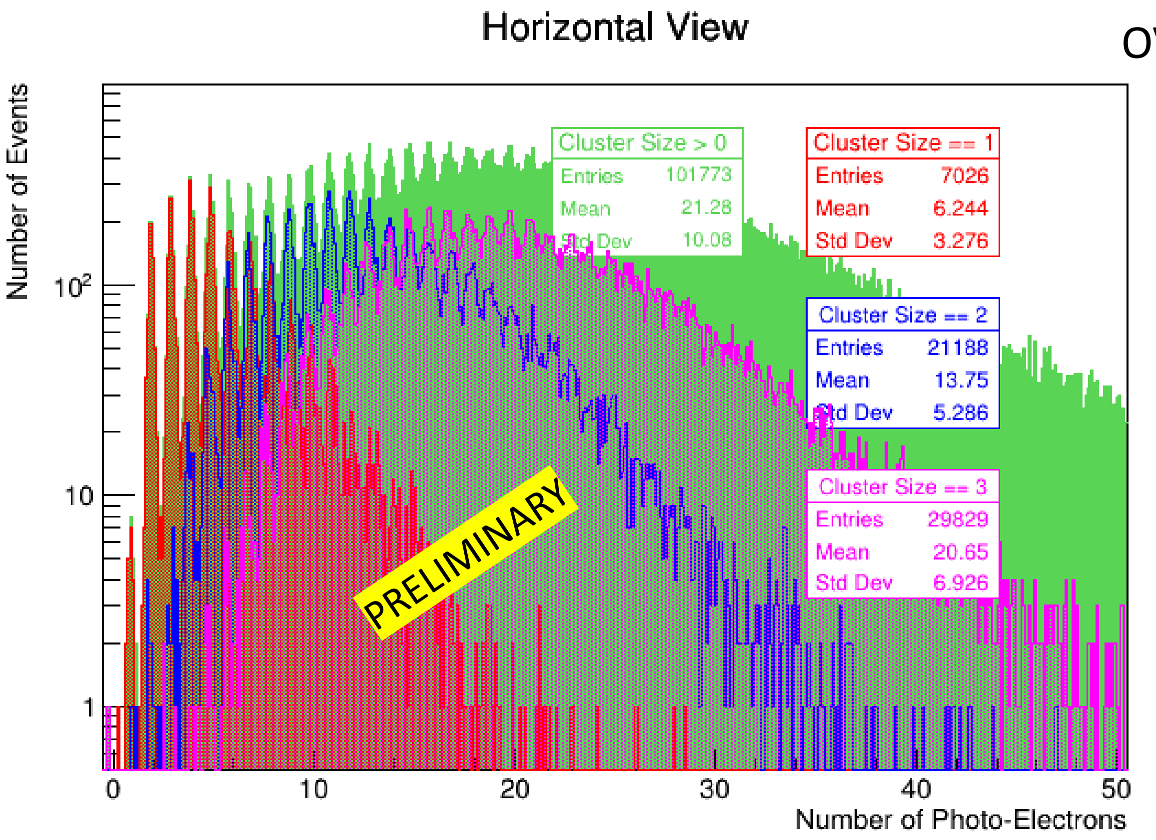
Vertical View

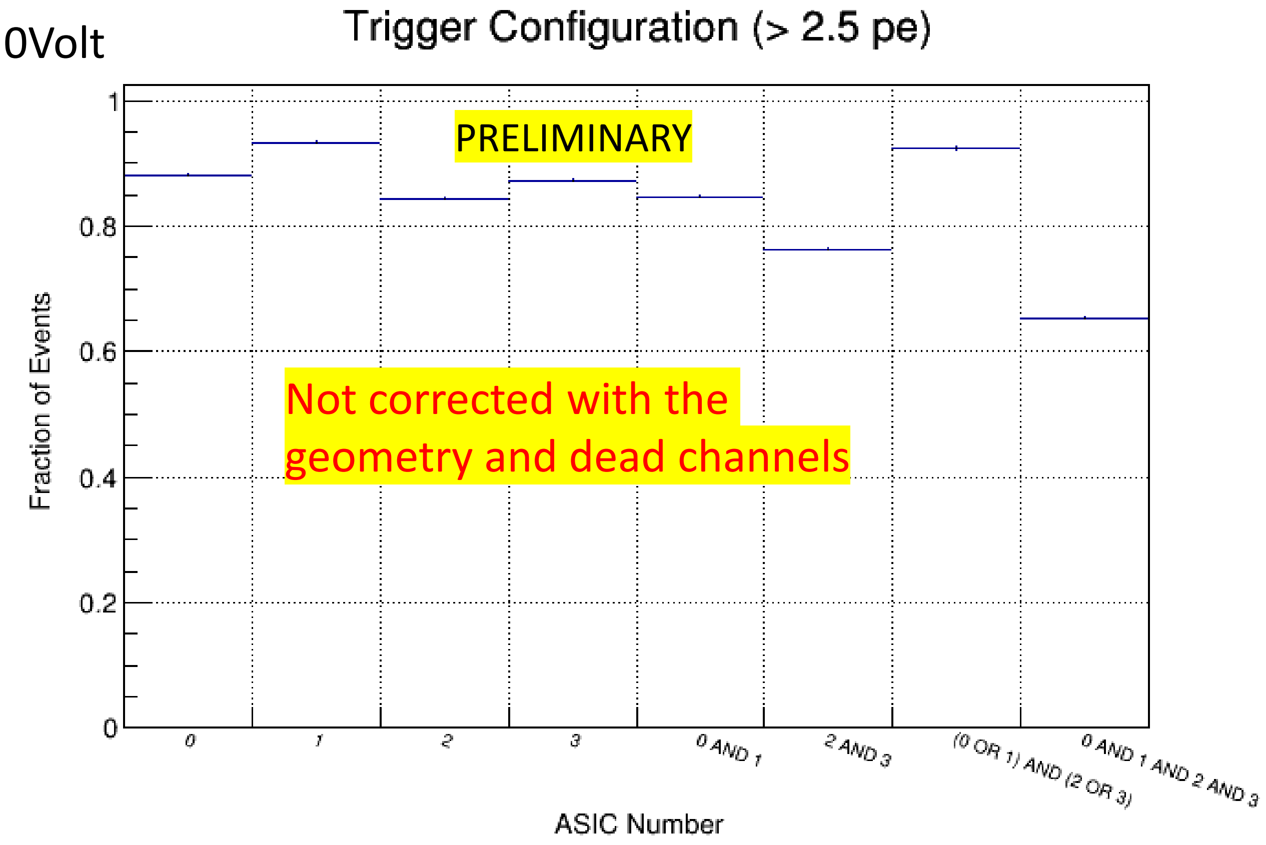


Preliminary BT21 results (3)

- Less photoelectrons than expected
- Too many events with single strip clusters

OV = 6.0Volt





Conclusions and outlook

- Saint Gobain BCF fibers give a lower light yield than expected
  - Already seen by other groups
- Further tests planned with Kuraray fibers