Development of New Beam Position Detectors for the NA61/SHINE experiment

Author: Marta Urbaniak

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Nuclear Physics Group
Institute of Physics University of Silesia

mail: marta.urbaniak@us.edu.pl

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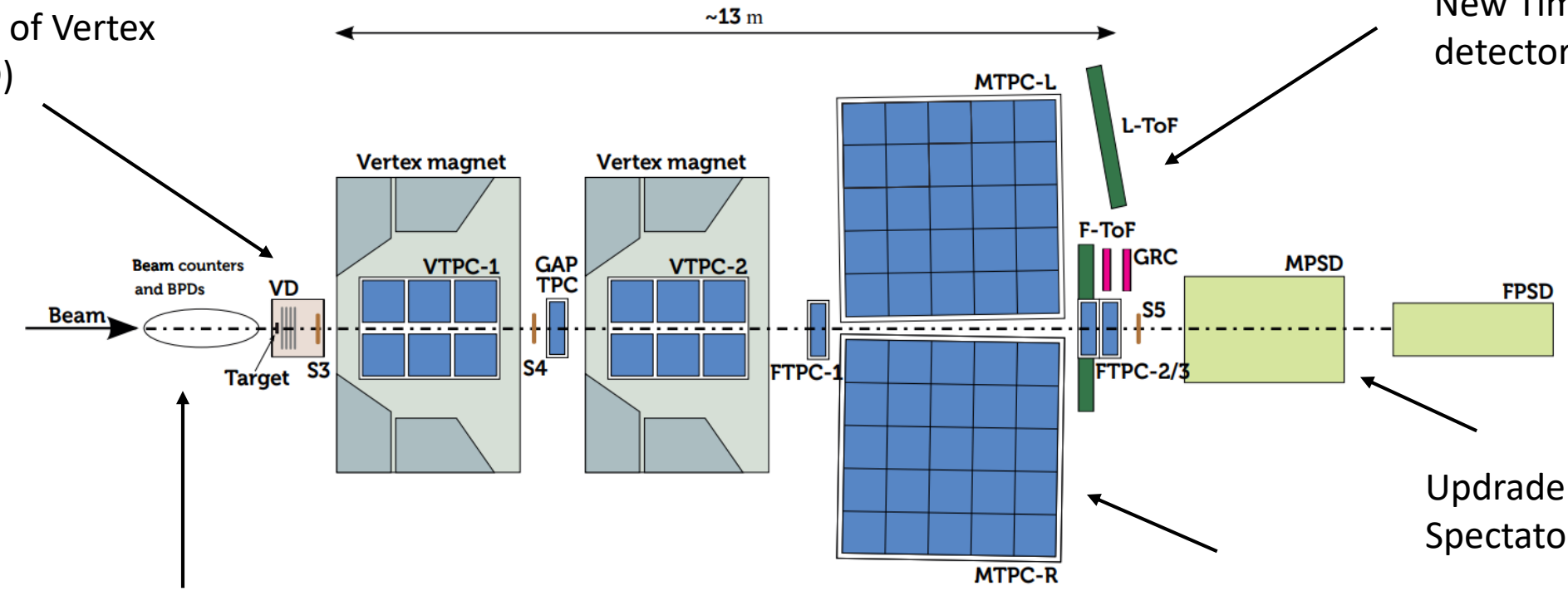
NA61/SHINE is a fixed-target experiment located at CERN Super Proton Synchrotron (SPS)[1]

The open charm measurements required upgrades of the NA61/SHINE detector system.

Construction of Vertex Detector (VD)



New Time-of-Flight detectors

New Beam Postion Detectors

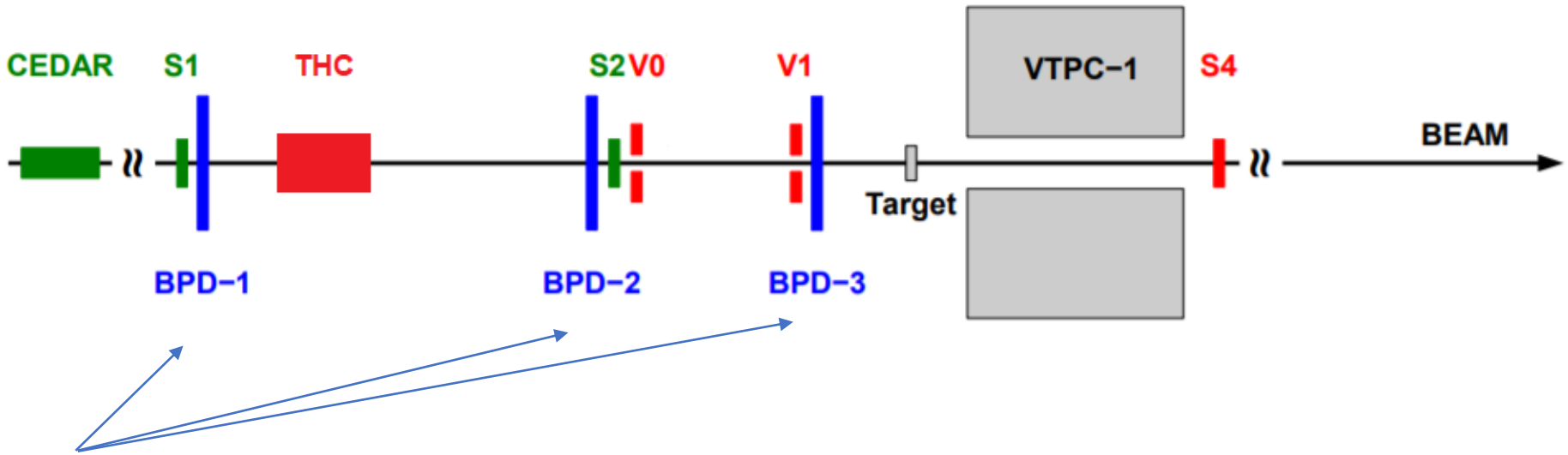
New trigger and data acquisition system

Updrade of Projectile Spectator Detector

Replacment of the TPC read-out electronics - to increase the data taking rate to about 1kHz.

An array of beam detectors provide:

- timing reference,
- charge measurement,
- position measurement of the incoming beam particles,
- are part of the trigger system.

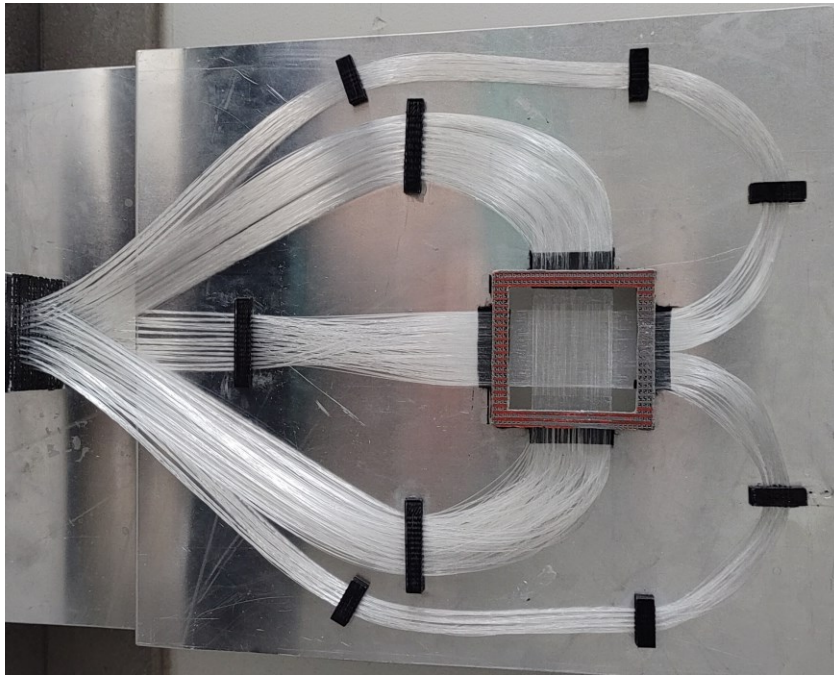


Beam postion detectors - replacement with a new one is caused by:

- need to increase the detection efficiency for beams with high Z,
- the requirements of the new fast TDAQ system.

New Beam Position Detector (BPD) must meet several requirements:

- should work efficiently with proton and lead beams, with beam intensity on the level of 100 kHz,
- the detector's material on the beamline should be minimized,
- should be able to determine the position in XY plane of each beam particle with maximum possible accuracy,
- should operate in vacum.

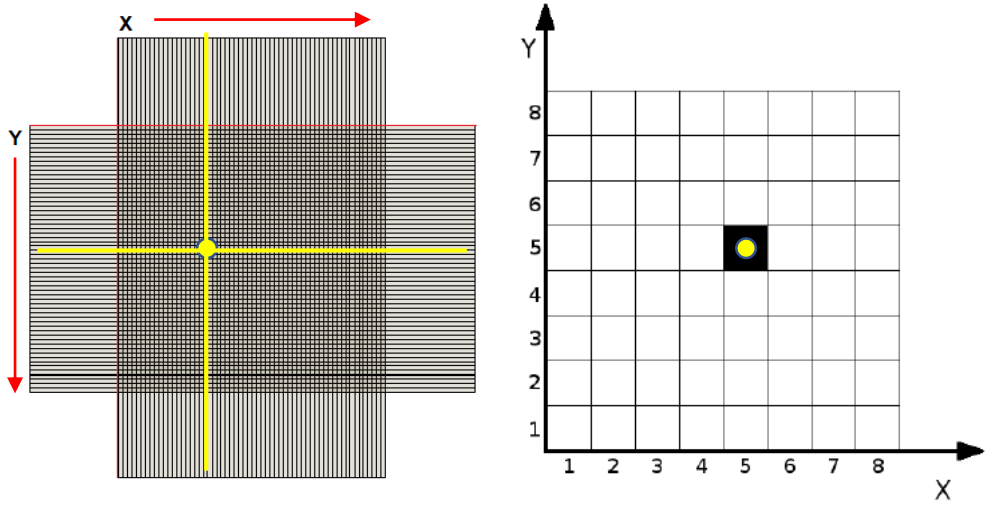


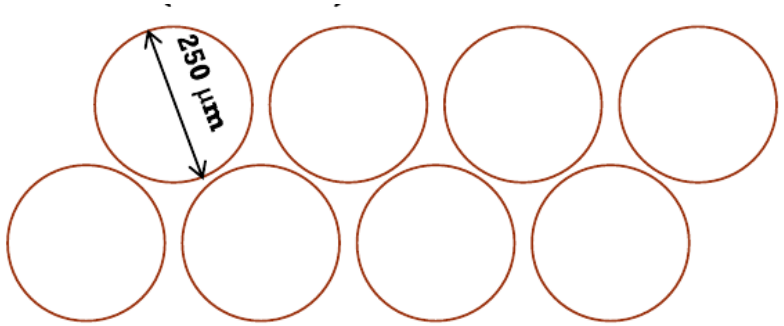
Two types of detectors have been manufactured and are currently being tested:

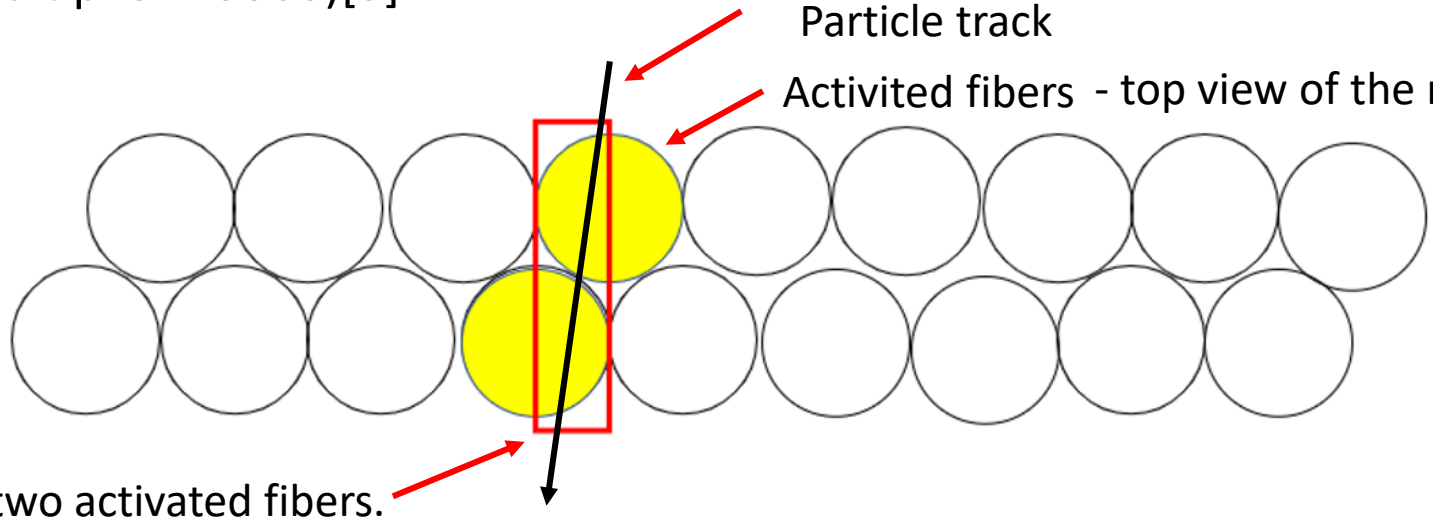
- **scintillating fibers detector (ScFi)**
- **single-sided silicon strip detector (SSD)**

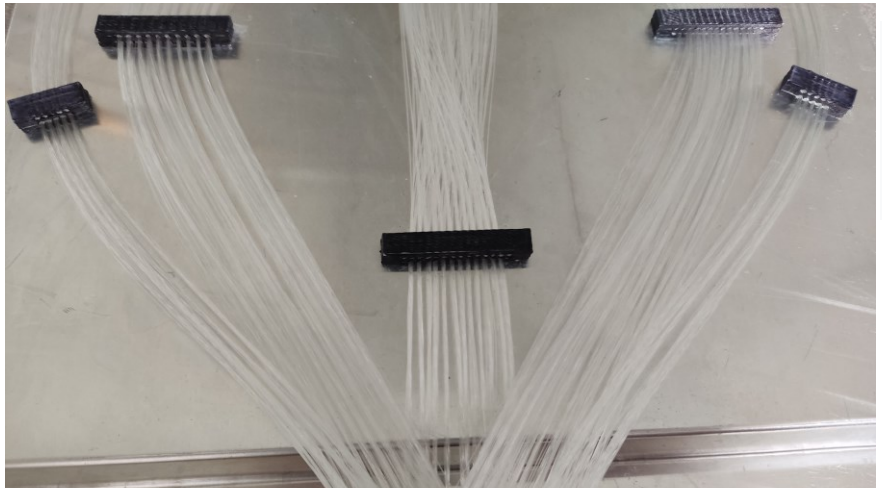
Scintillating fiber detector

- It consist of two ribbons arranged perpendicular to each other, to describe position in XY plane.
- Each ribbon is made of two layers of scintillating fibers (BCF-60)[2].
- Layers are shifted relative to each other by 125 µm.
- End of every ribbon is connected with phto-multiplier (multianode photomultiplier H9500)[3].

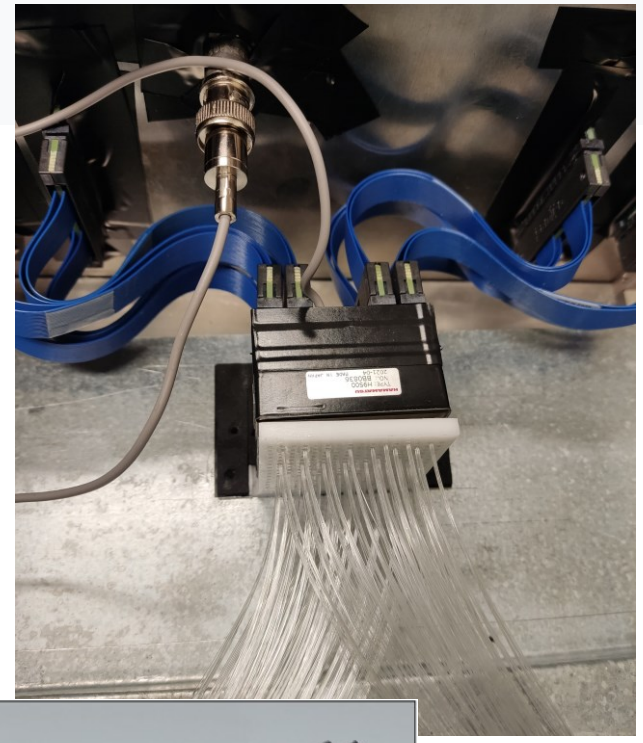




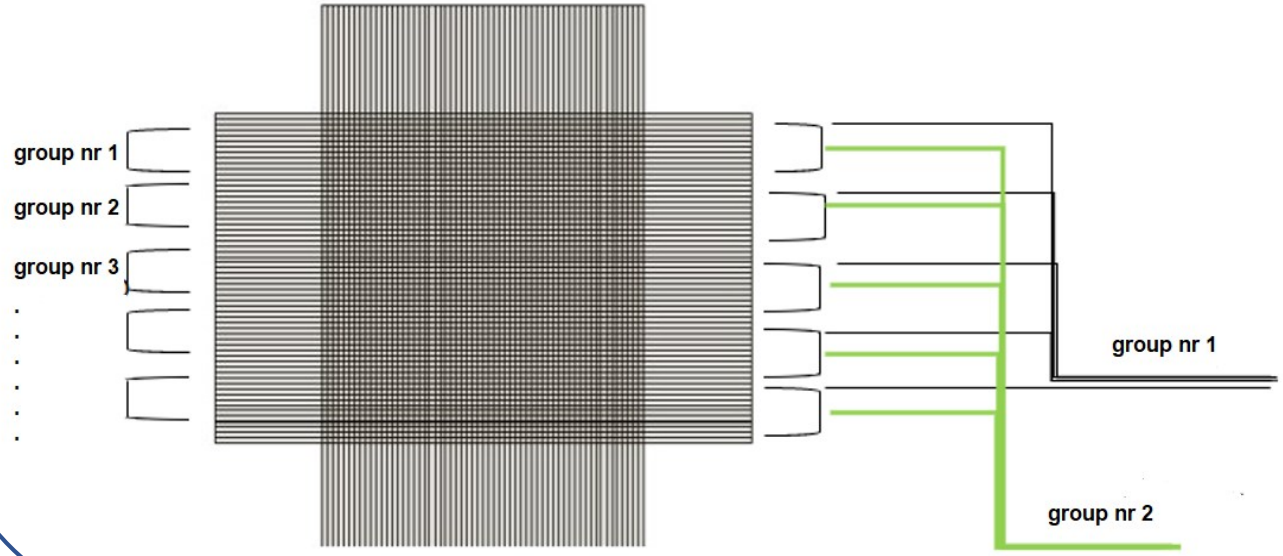


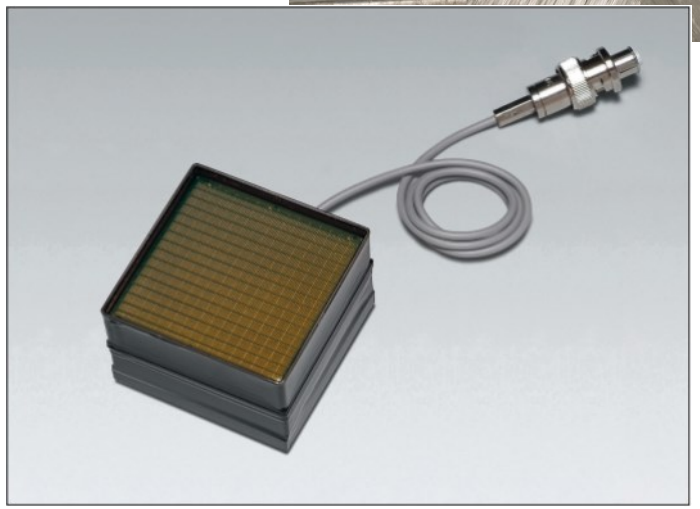


- **Special matrix** connecting groups of optical fibers with photomultiplier pixels was designed



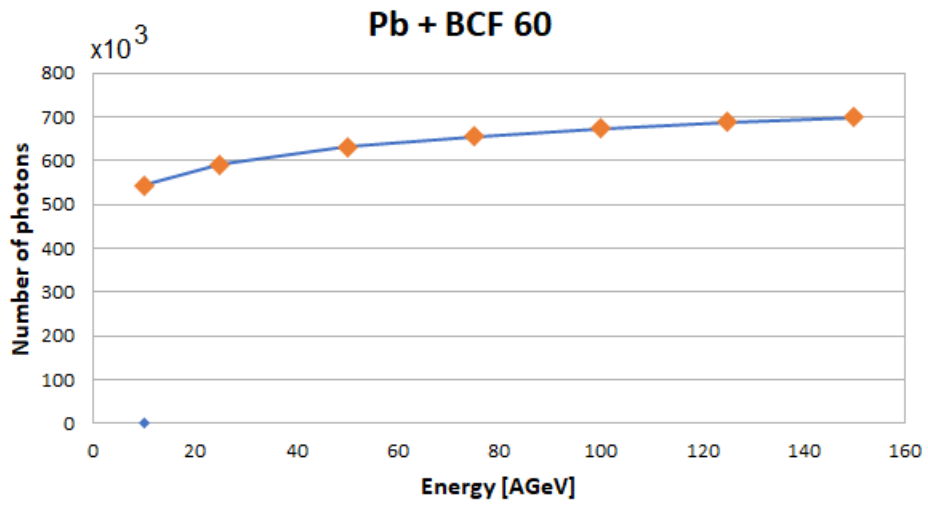
- The **grouping of fibers** method is implemented. This allow to reduce numer of channels.

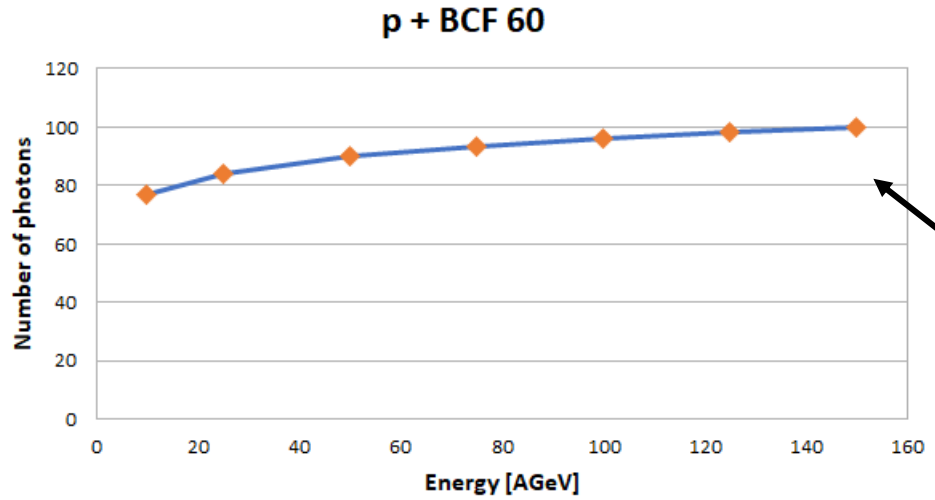




Simulations:

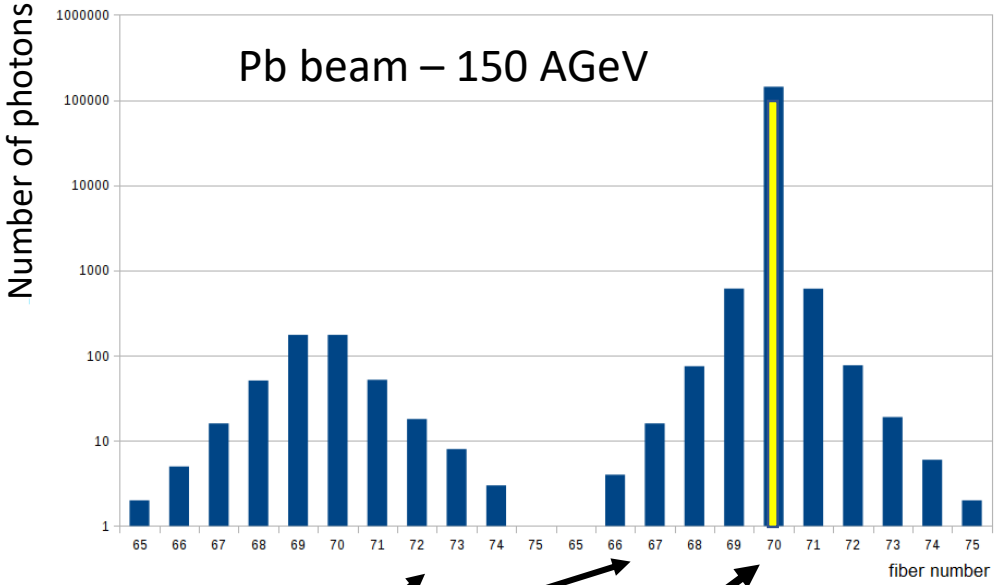
Amount of light at the end of the fiber after the passage of protons and lead nuclei





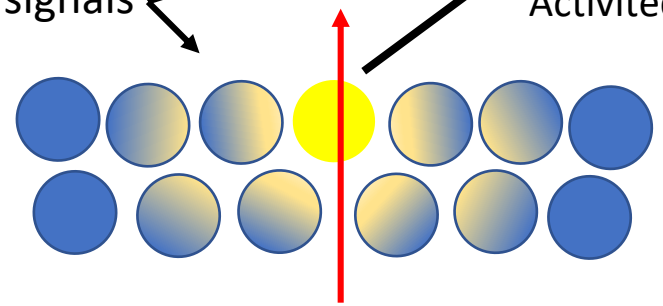
for proton we need high amplification

Cross-talk beetewen fibers



Cross-talk light signals

Activited fiber light signal



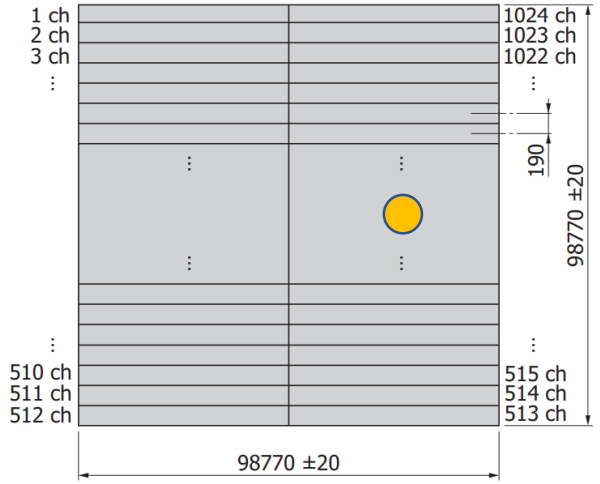
Particle track

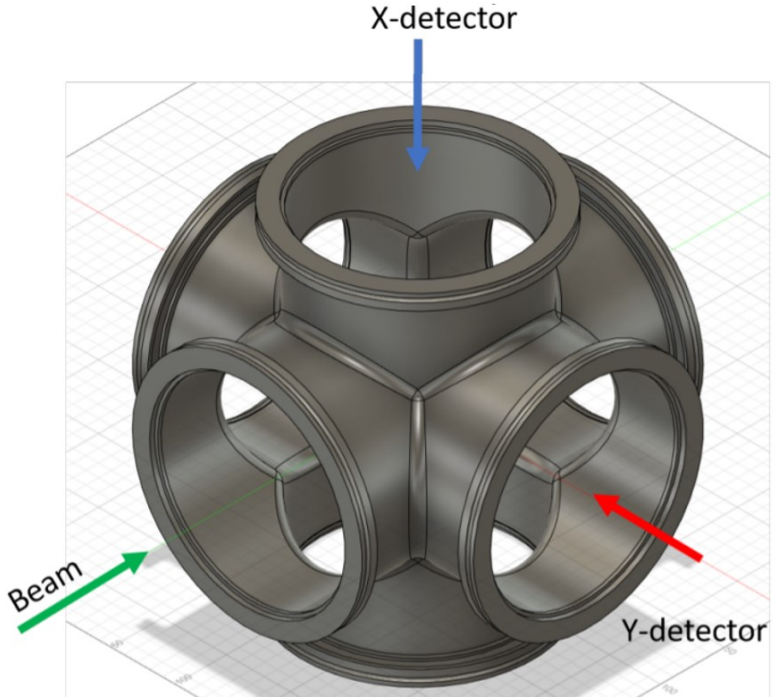
Silicon strip detector

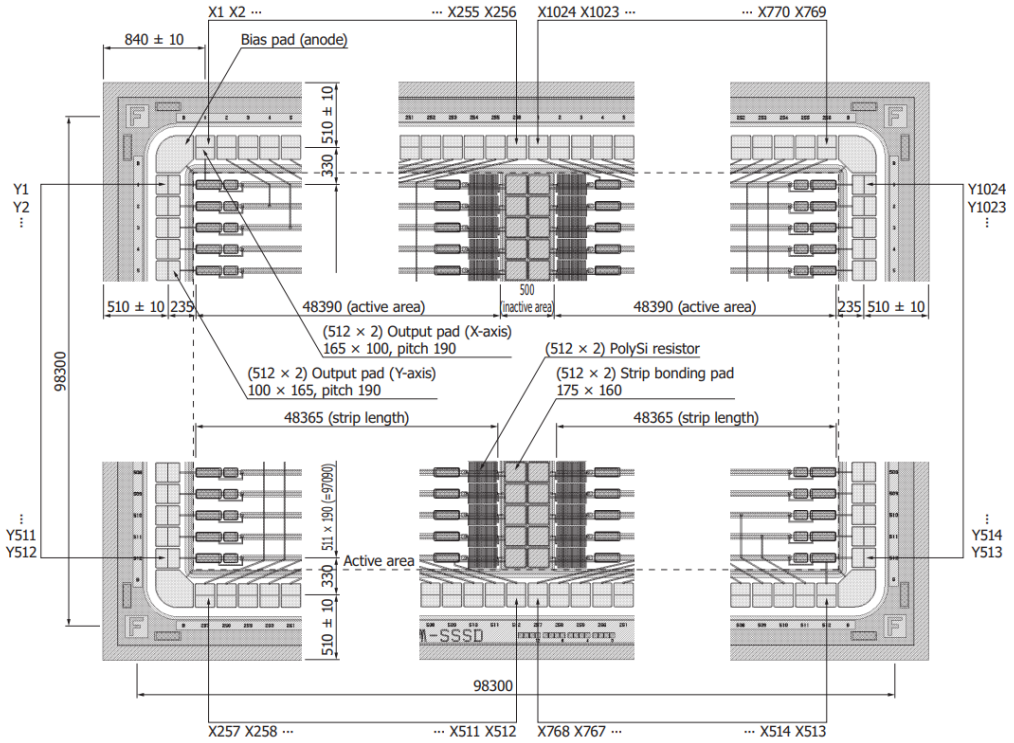
Single-sided SSD for high energy particle position detection:

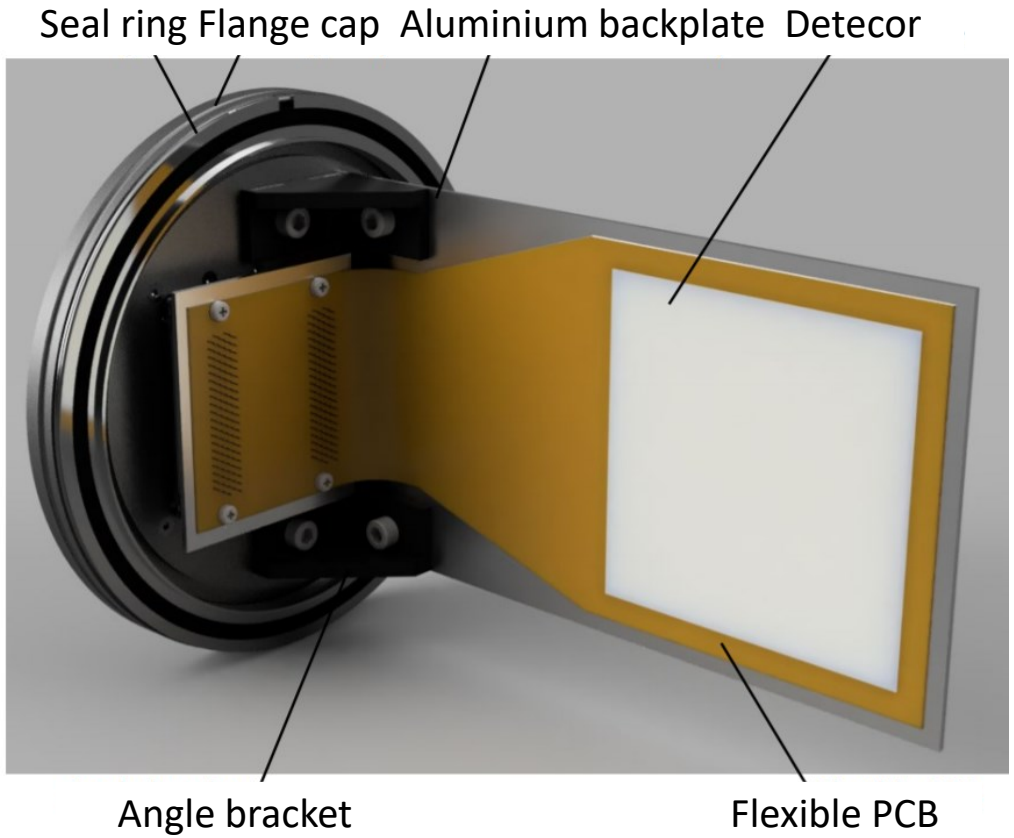
- Hamamatsu S13804[3]
- 1024 strips (channels)
- Strip width - 80 µm
- high radiation hardness
- only the 200 inner ones are used
- for each BPD a 6-way vacum fitting will be used

Dimensional outline in µm.







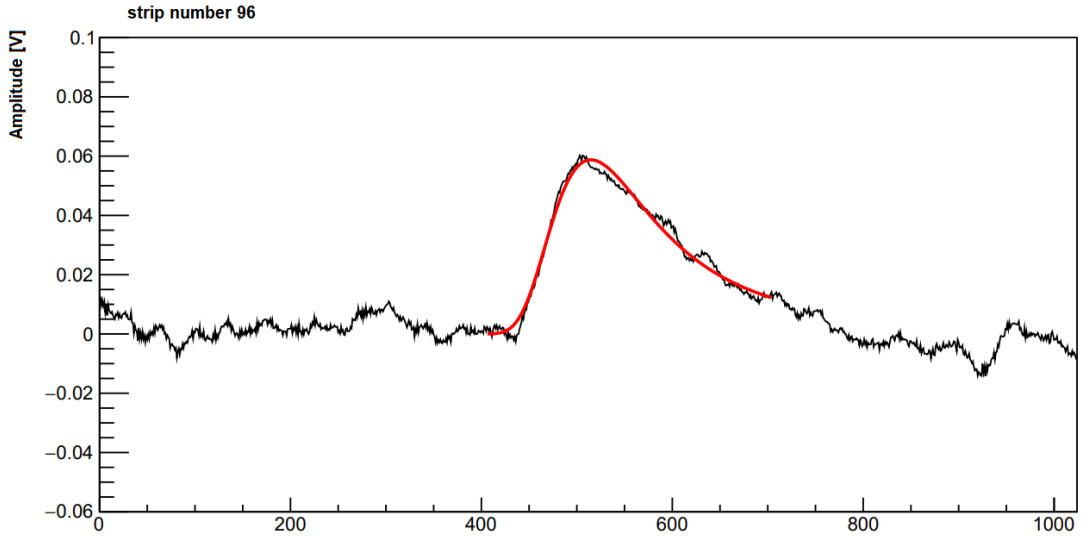


Mechanical design

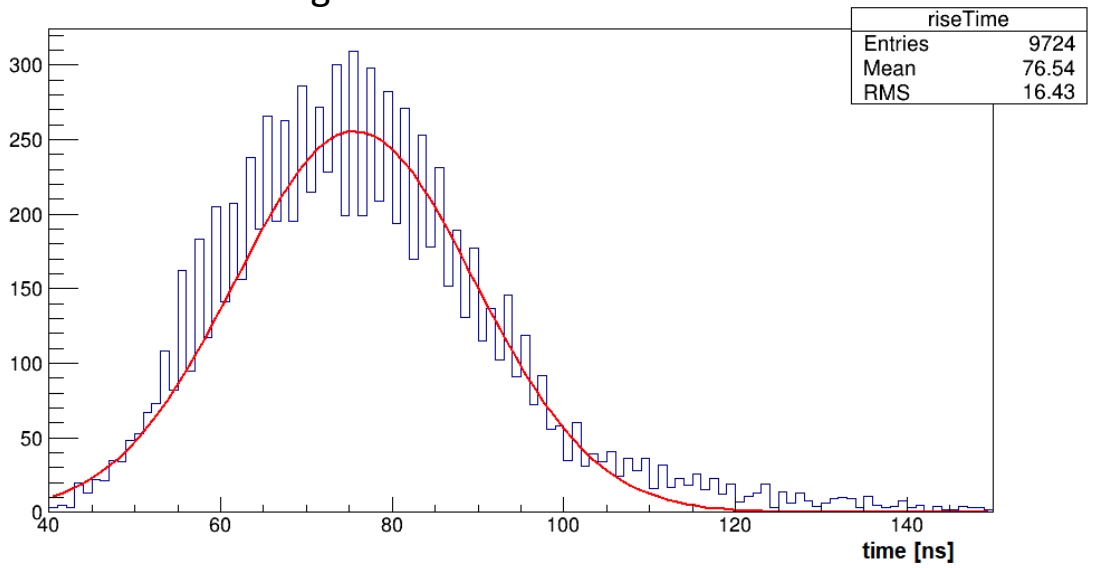
Electronics design

- A discrete amplifier with off-the-shelf components was been designed and manufactured
- Amplifier has been fitted with scale-changing circuitry to operate at both heavy ion beams and proton beams

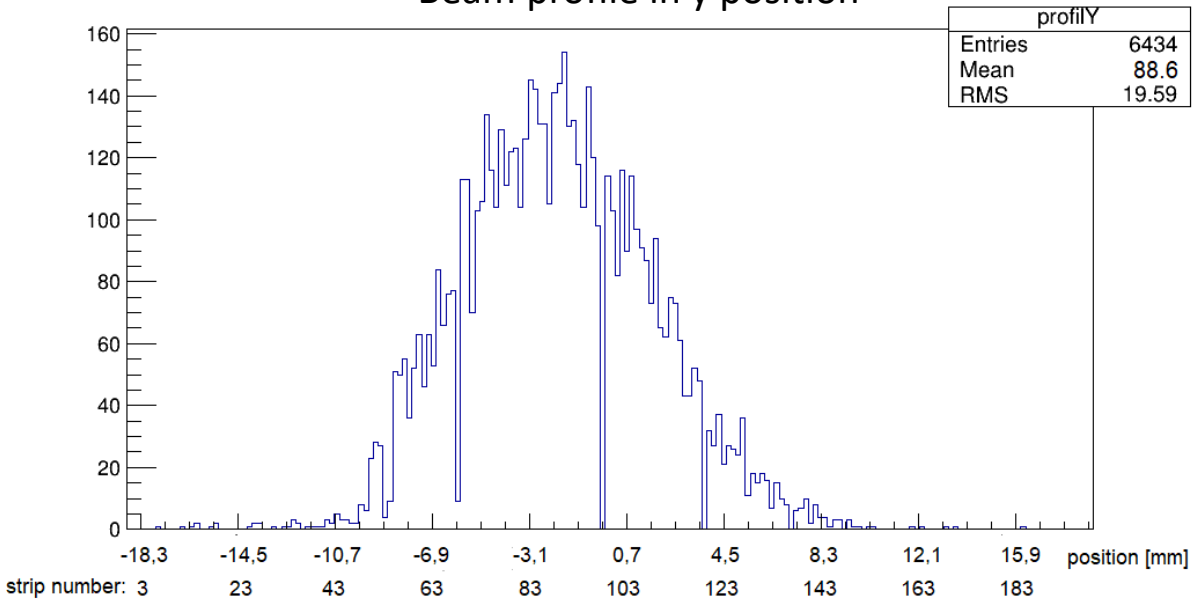
Silicon strip detector test results on 30 GeV/c proton beam:



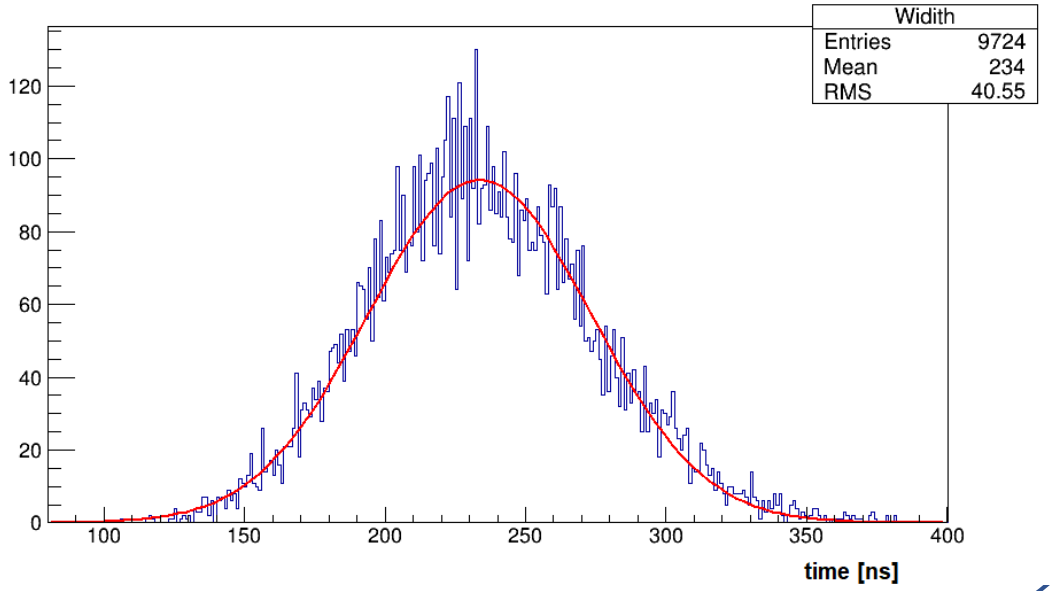
Signals rise time distributions



Beam profile in y position



Signals width distributions



Summary:

- Two types of detectors have been manufactured and are currently being tested.
  - **Scintillating fiber detector**
  - **Si strip detector**
- A new electronics was been designed and manufactured for Si strip detector.
- Estimated spacial resolution is in on the level of 100 µm.
- Low signal-to-noise ratio during proton beam tests showed the need for additional work on signal amplification and noise reduction.
- Next tests will be carried out on the lead beam.

References:

[1] Abgrall N et al. (NA61/SHINE Collaboration) 2014 JINST 9 P06005 (Preprint physics.ins-det/14014699)
[2] URL https://www.crystals.saint-gobain.com/products/organic-scintillation-materials
[3] URL https://www.hamamatsu.com/eu/en/product/type/S13804/index.html