LXXIV International conference Nucleus-2024: Fundamental problems and applications

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SILICON PIXEL SENSORS FOR DETERMINATION OF CHARACTERISTICS OF PROTON BEAMS IN THE ENERGY RANGE 100 – 1000 MeV FOR THEIR USE IN TRACKING DETECTORS

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Outline

Motivation

Experimental setup

Measurement of beams characteristics

Studying the materials properties on proton beams

Conclusions

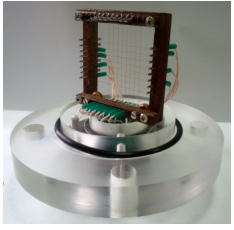
Motivation
Beam diagnostic methods

The important role of beam diagnostic systems:

- Fundamental physics on ion beams.
- Applied problems in radiation materials science, nuclear physics technologies.
- Nuclear medicine.

Commonly used detector systems:

- Fluorescent screens.
- Radiochromic film.
- Secondary emission monitors.

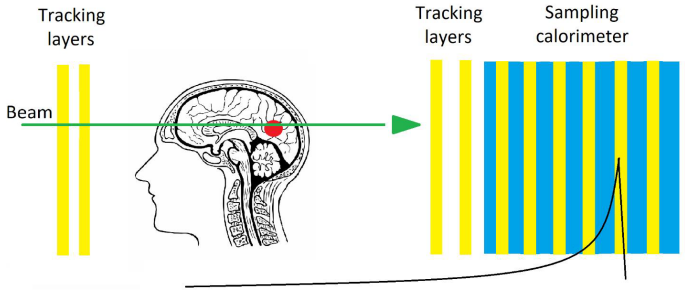


Multi-wire beam monitoring system developed in Educational Laboratory of Nuclear Processes.

Proton tomography is a promising tool for treatment planning in hadron therapy.

More details: see Vladimir Zherebchevsky report on Friday

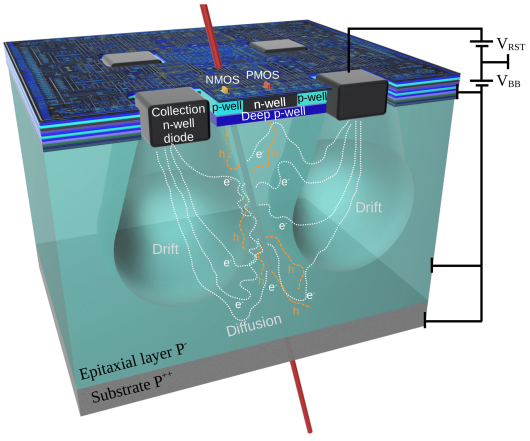
The importance of precise measurement of properties of beam after patient.



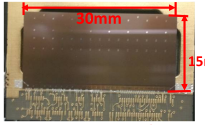
Credits: Erygin Ilya, SPbU

Experimental setup

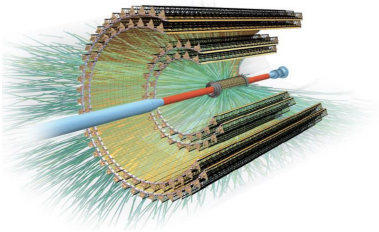
Silicon pixel sensors



Structure of a pixel detector.



512 × 1024 sensitive pixels

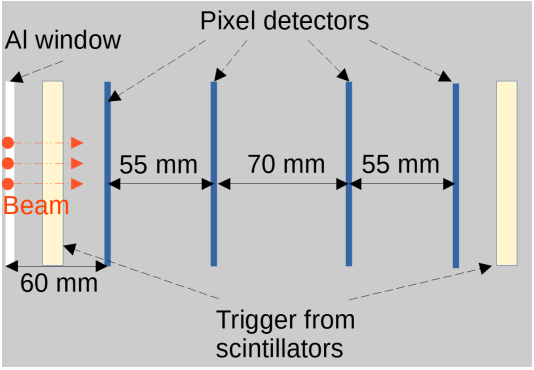


ALICE Inner Tracking System (Run 3)

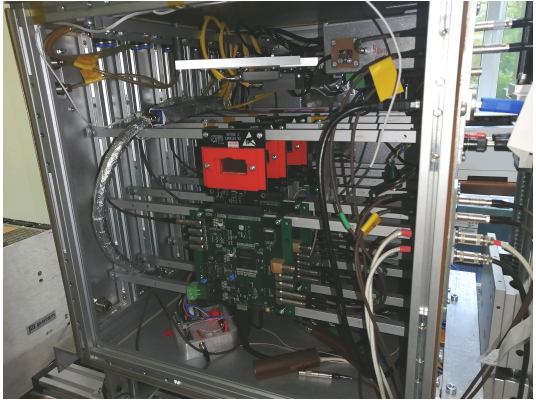
B Abelev et al and (The ALICE Collaboration) 2014 J. Phys. G: Nucl. Part. Phys. 41 087002.

Experimental setup

Telescope of silicon pixel detectors



Scheme of experimental setup.



Detectors inside the experimental setup.

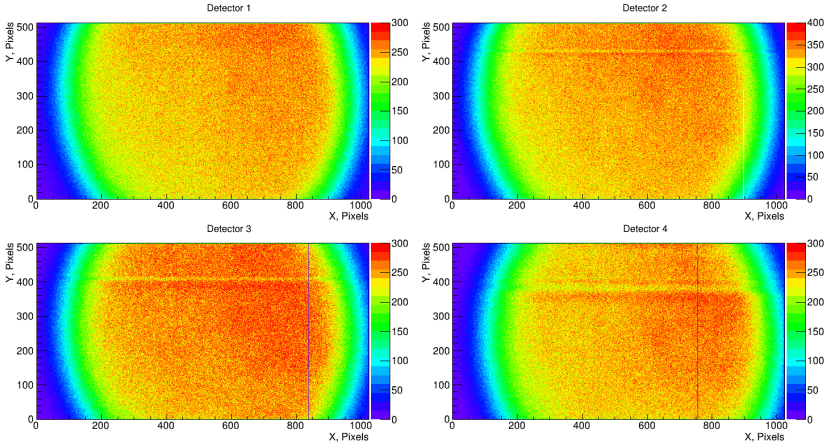
Experimental setup

Placement of the detector system on the beam

Telescope with detectors was used on the Synchrocyclotron "SC 1000"(NRC "Kurchatov Institute"PNPI) proton beam.

Measurement of beams characteristics

Raw hits

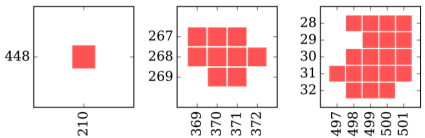


1 GeV proton beam spot on MAPS detectors

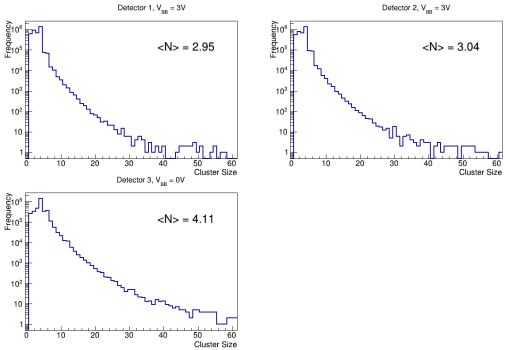
Measurement of beams characteristics

Clusters of hits

Each proton generates a charge, distributed in space, which leads to the actuation of several pixels. They are combined into clusters. The center of mass of pixels is used as input parameter in next analysis.

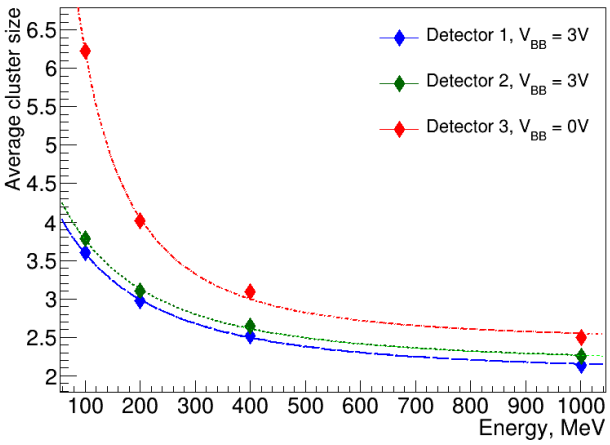


Cluster sizes distribution for 200 MeV protons:



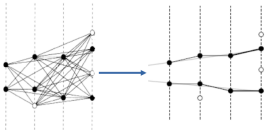
Measurement of beams characteristics

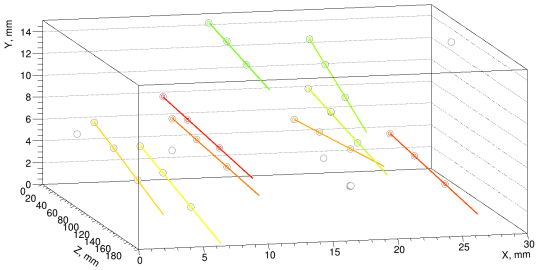
Cluster sizes



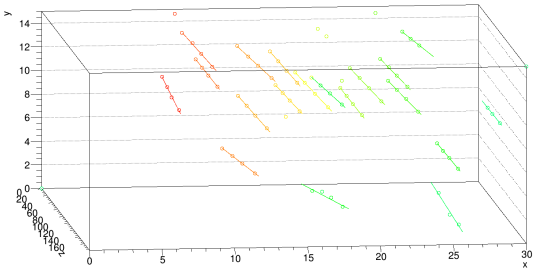
- Dependence of the cluster size on energy.
- May be used as additional information for calorimetry in proton tomography.

Track finding algorithm via Cellular Automaton:





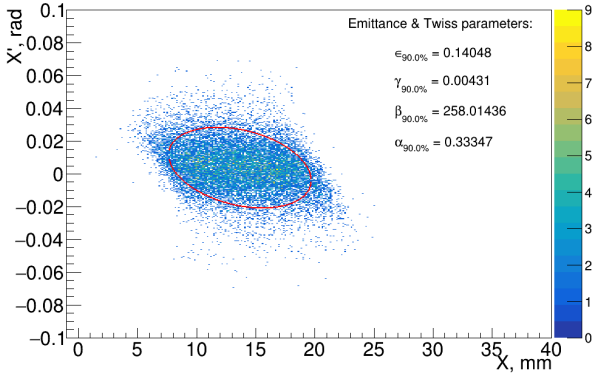
Reconstruction of tracks for 200 MeV protons.



Reconstruction of tracks for 1 GeV protons.

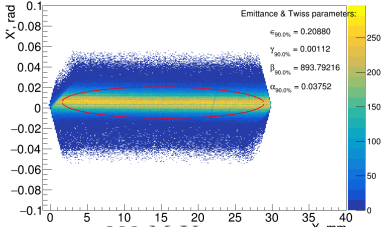
Measurement of beams characteristics

Using the reconstructed tracks, one can measure slope of each proton relative to the beam axis. Thus, the phase space of the beam, transverse emittance and the Twiss parameters can be obtained.

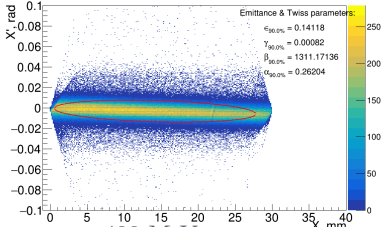


Phase space of 100 MeV protons (after collimator) along X axis.

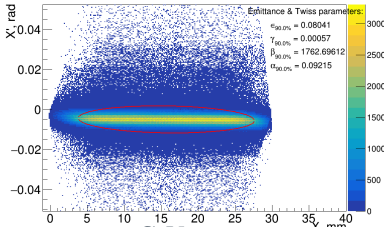
Measurement of beams properties



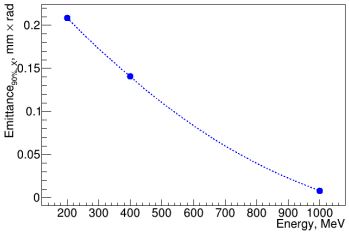
200 MeV protons.



400 MeV protons.

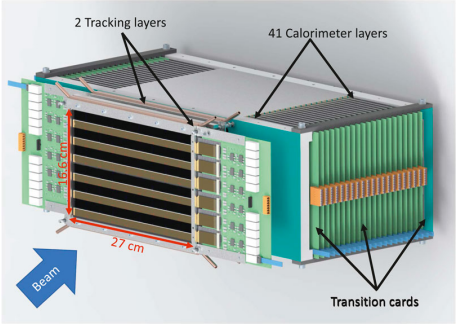


1 GeV protons.



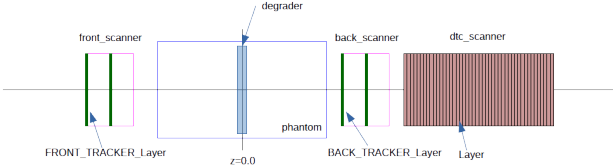
Digital tracking calorimeter prototype by Bergen pCT collaboration.

J. Alme et al, Front. Phys. Sec. Med. Phys. and Imag. 2020; 8, 20.



The track calorimeter consists of layers of pixel detectors and aluminium absorbers.

Schematic view of conception of a SPbU Digital tracking calorimeter.

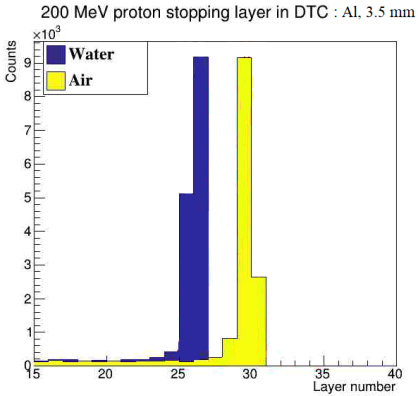


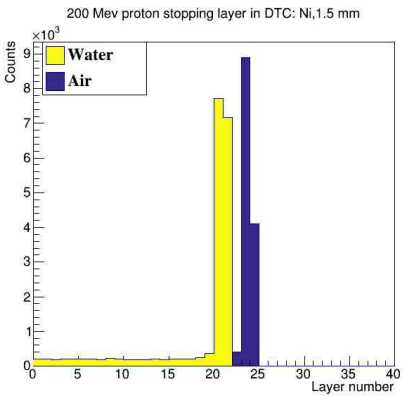
- Additional tracker (front scanner) in front of the patient.
- Optimisation of geometrical and material parameters.

Studying the materials properties on proton beams

MC simulation of calorimiter with different absorbers

Geant4 simulations shown that new materials, such as Ni, could be perspective for usage as absorber. The advantage is decreasing of layers number (as well as detectors).



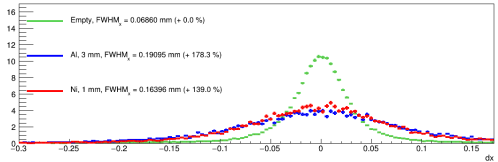


Will spatial resolution worsen?

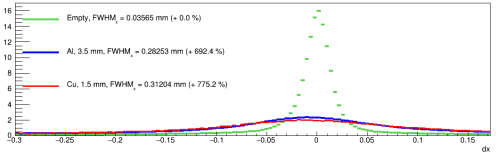
Studying the materials properties on proton beams

Experimental studying of the absorber materials

By deviations of cluster centers from reconstructed straight lines (dx, dy) one can estimate spatial resolution. Absorbers may decrease the resolution.



100 MeV protons.



200 MeV protons.

Conclusions

Beam's characteristics was succesfully determinated using Silicon Pixel Sensors.
Experimental setup described abowe is highly accurate due to good spatial resolution.

Materials that are promising for the development of a proton tomograph have been studied.

The future plans include determination of the beam characteristics for lower energies. Also additional materials research will be held.

Thanks for the attention!