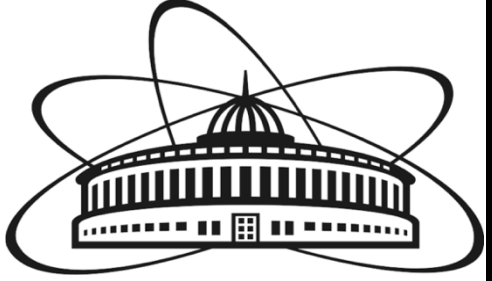


PANDA Muon System

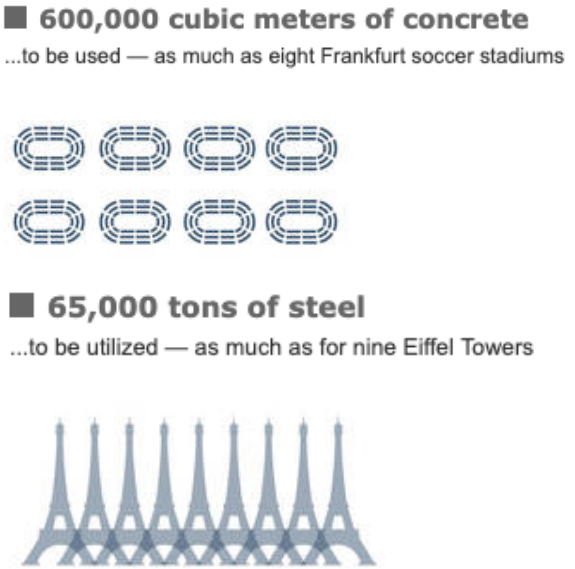
Alexander Verkheev

DLNP, JINR

4 June 2019

Outline

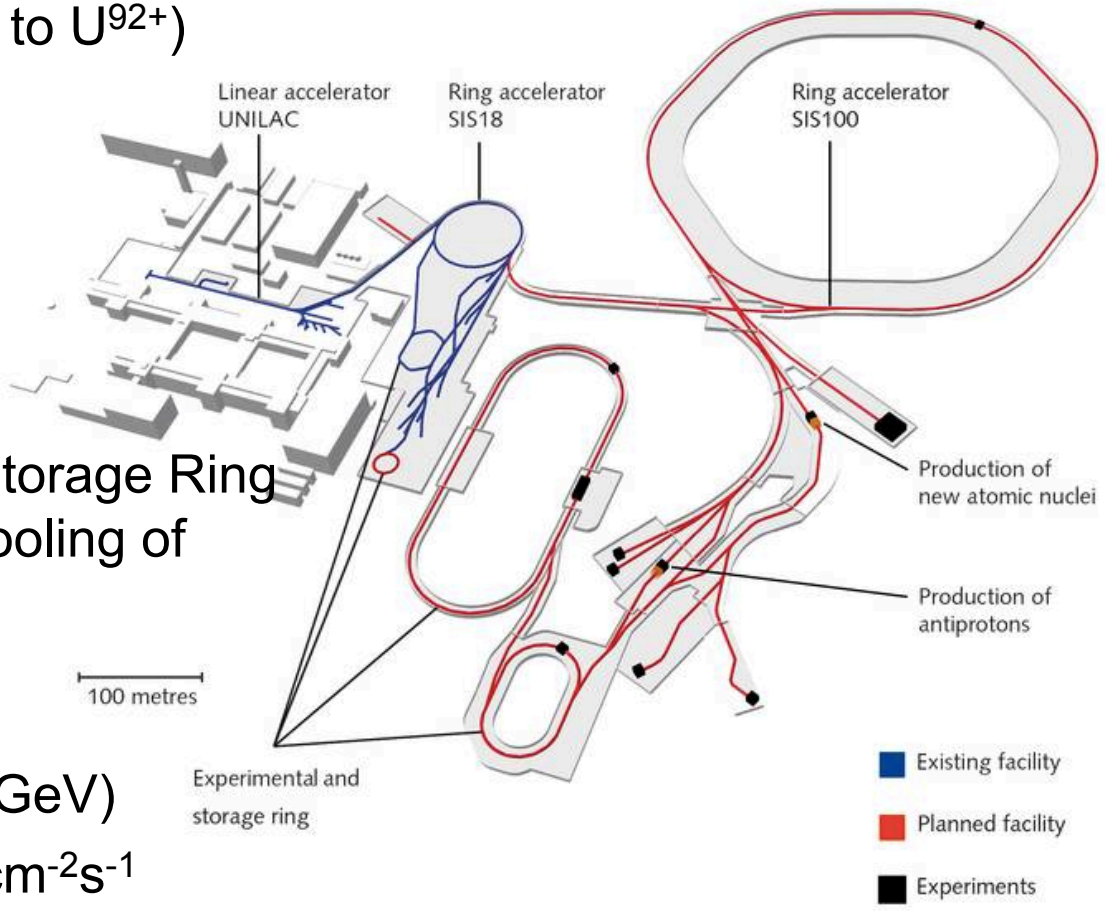
- FAIR & PANDA Experiment
- Muon System Detector
- Panda Muon System Prototype at CERN
- Geometry modeling of Muon System
- Results of the Muon System Prototype test beams



Facility for Antiproton and Ion Research in Europe

Primary beams:
p and heavy ion beams (up to U^{92+})

Secondary beams:
pbar, radioactive beams

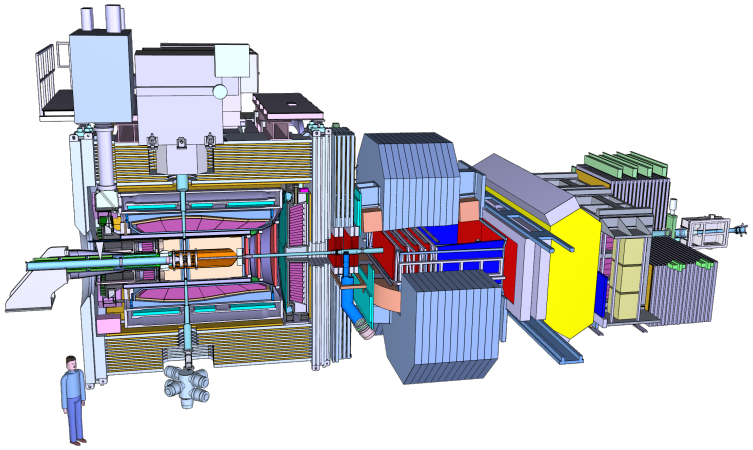


PANDA @ FAIR:

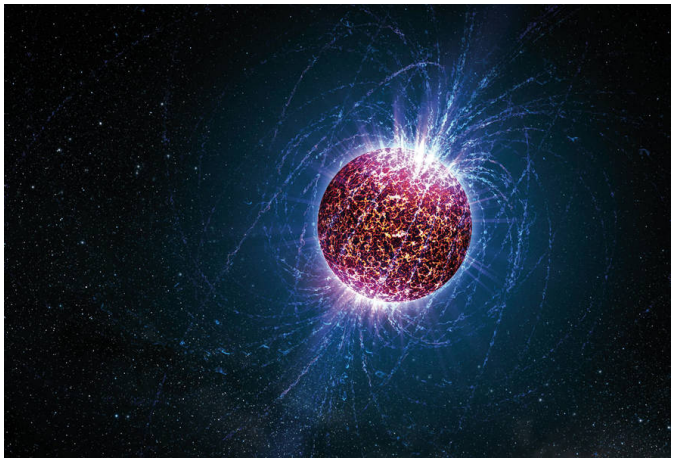
- located at High Energy Storage Ring
- stochastic and elecron cooling of ppbar beam
- ppbar, pbarA collisions
  p = 1.5 – 15 GeV/c ,
  (√s from 2.25 up to 5.46 GeV)
- Luminosity up to $2 \cdot 10^{32}$ $cm^{-2}s^{-1}$

4 Pillars of FAIR

PANDA — Antimatter research



CBM — Inside a neutron star



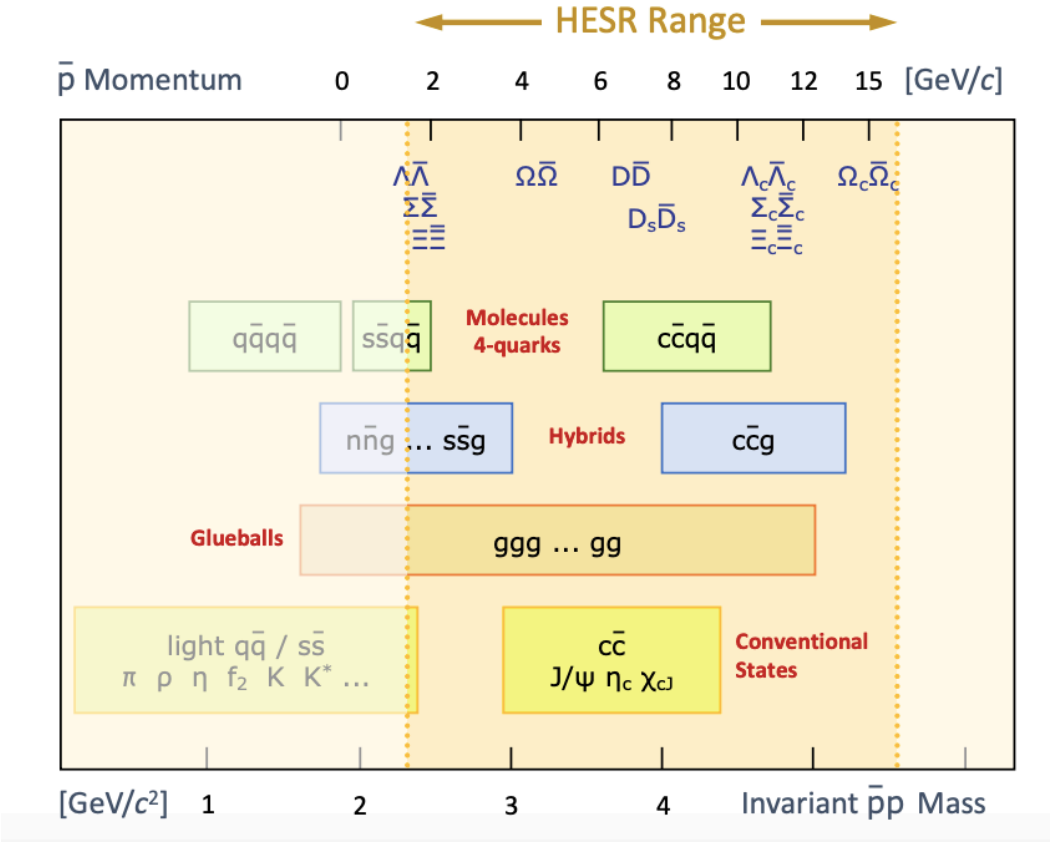
NUSTAR — Stars and nuclei

APPA — From atoms and planets to cancer therapy

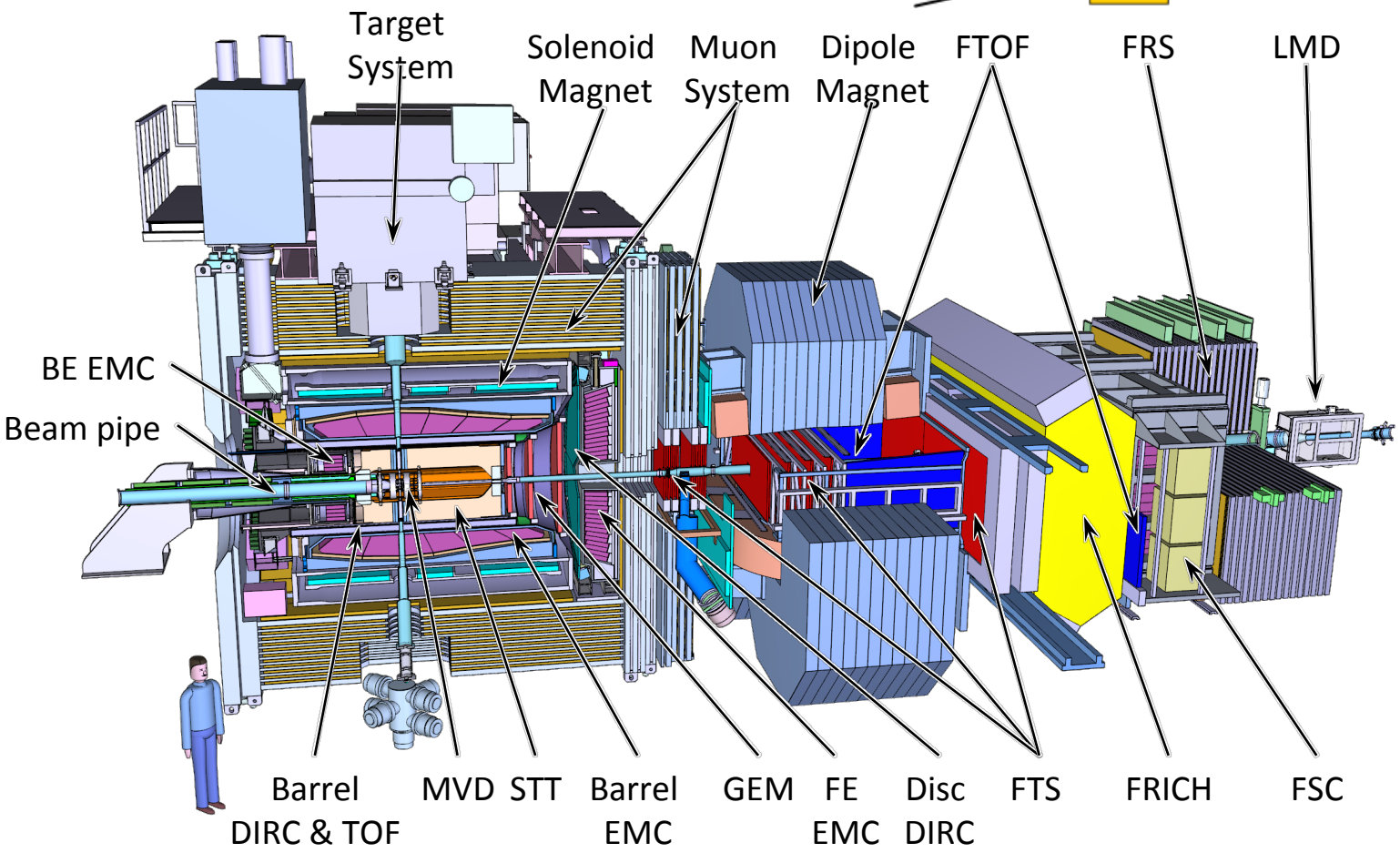
PANDA Research Program

Topics of research:

- hadron spectroscopy (XYZ, exotic QCD states)
- nucleon structure (GPD, Drell-Yan, formfactors)
- strange and charm physics
- hypernuclear physics with anti-proton beams.

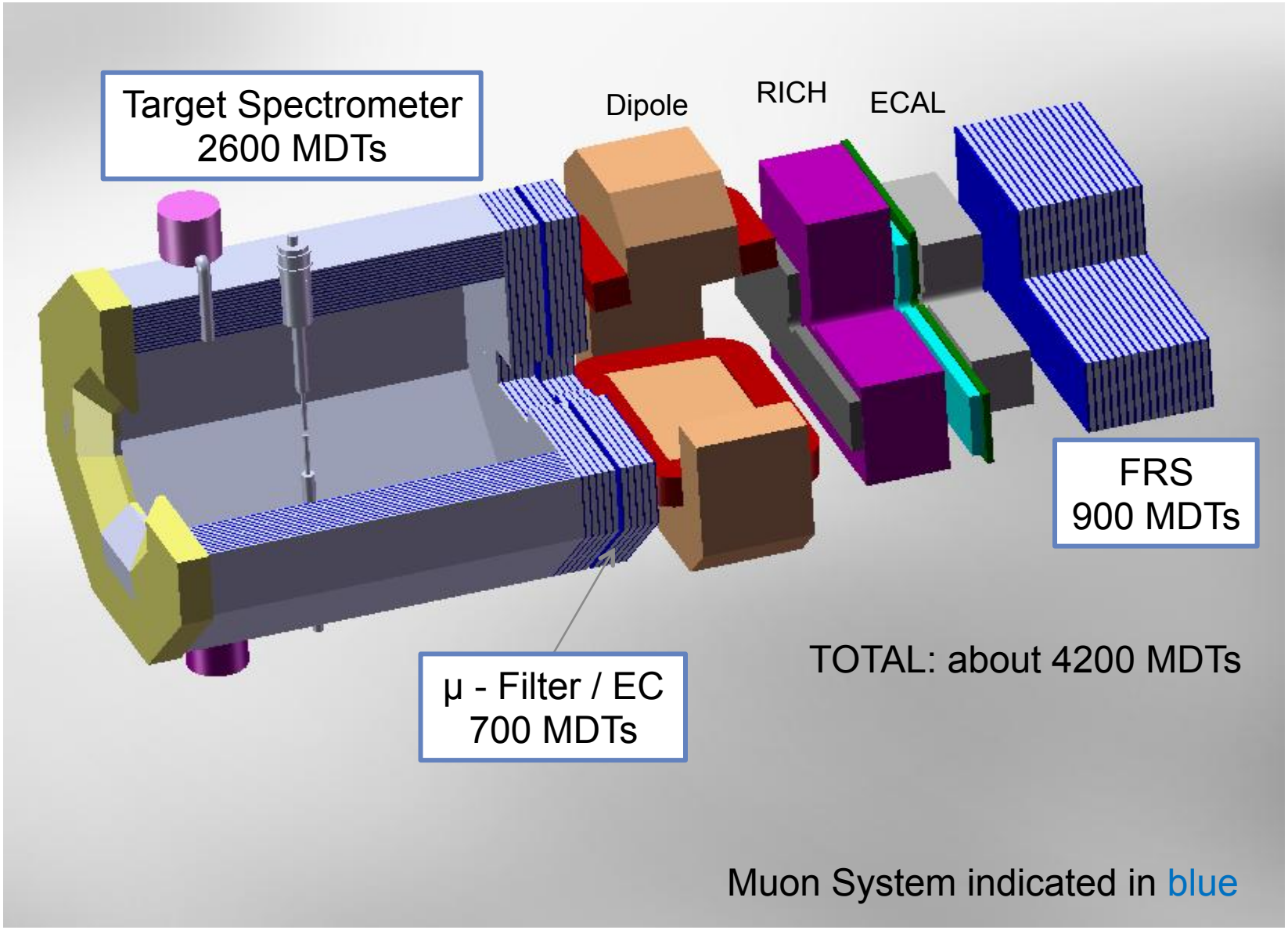


PANDA Detector



- Nearly 4π solid angle for large acceptance
- Tracking : ~50 μm vertex resolution
- Different PID techniques for π±, K±, e±, μ±, γ identification
- Good momentum resolution ~ 1%

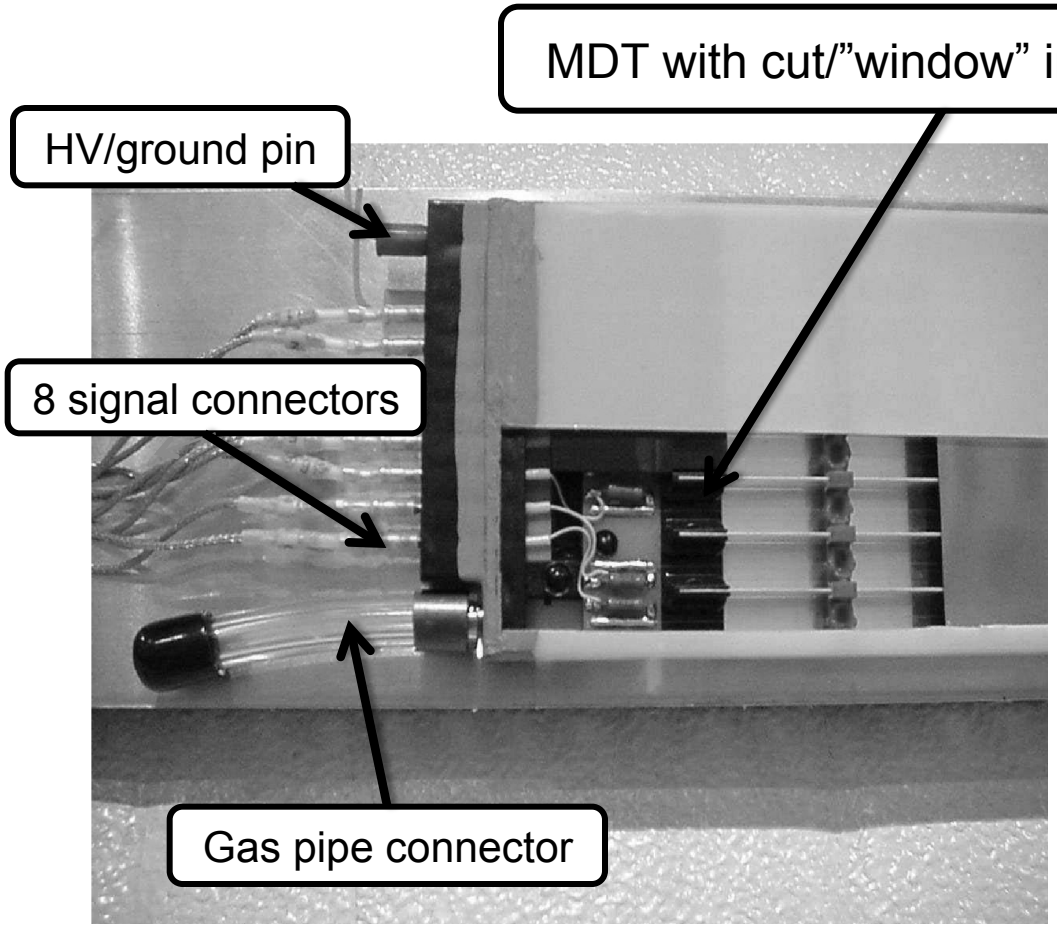
PANDA Muon System

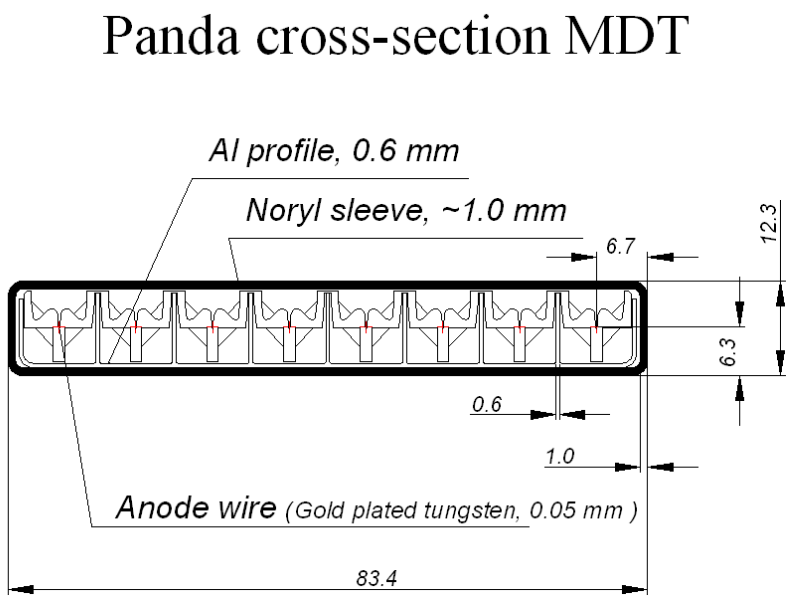


Muon System as PID

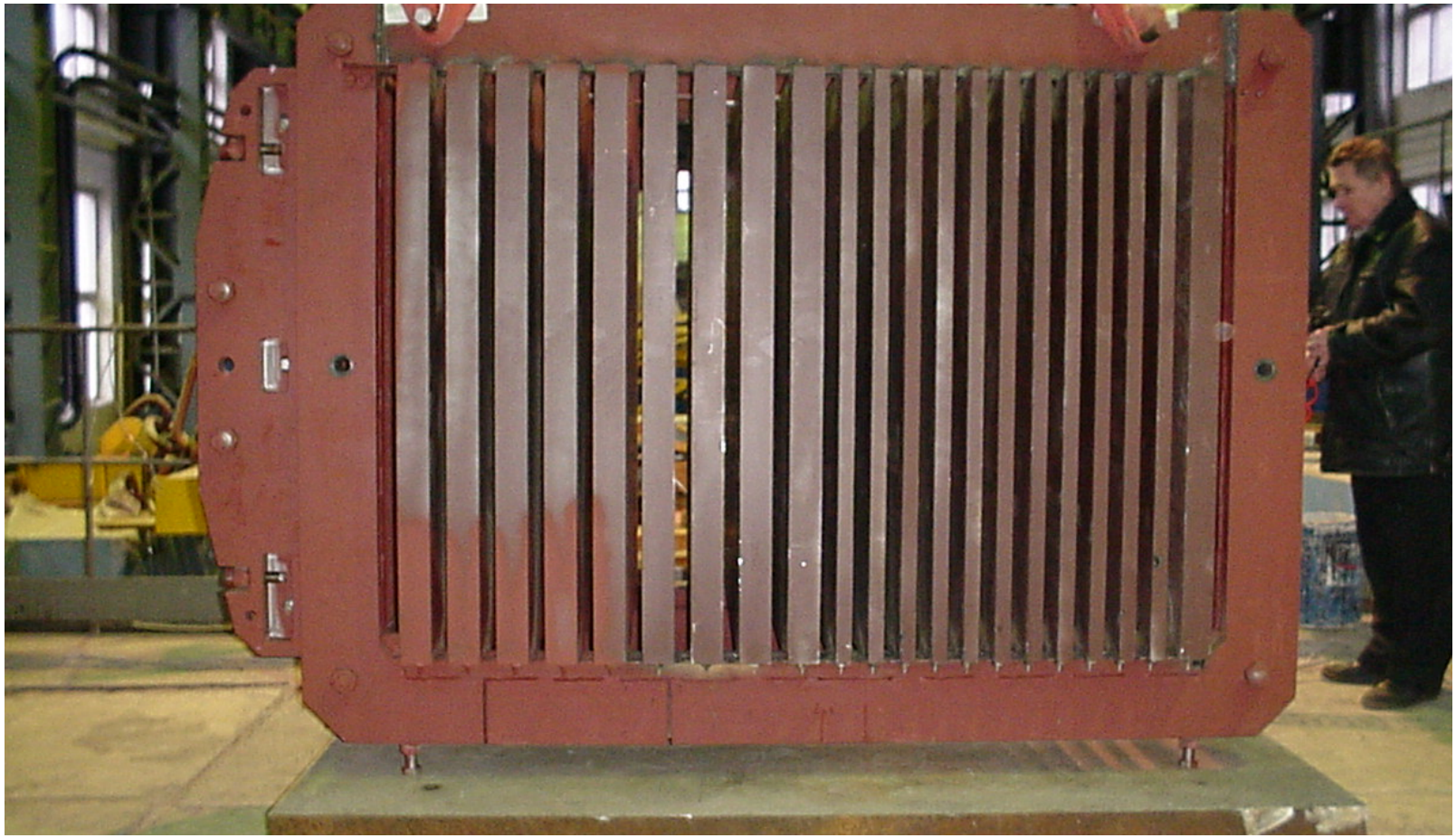
- PANDA Muon System, based on the range system technique, is a good PID system for muon-to-hadron separation.
- It works in full energy range of secondary particles at PANDA (0.5 ÷ 10 GeV).
- It resolves muons and hadrons with ~ 100% efficiency (zero hadron contamination) above ~ 1 GeV by obviously different response pattern.
- Separation of muons vs pions (the main rival) below 1 GeV is less efficient and requires test beam measurements for calibration.
- Range system will used as a coarse hadron calorimeter – > very important for neutron registration (the only system in PANDA)!

Mini-Drift Tube (MDT) Detector as Basis for the Muon System





Range System Prototype @ CERN



The absorber structure in horizontal position

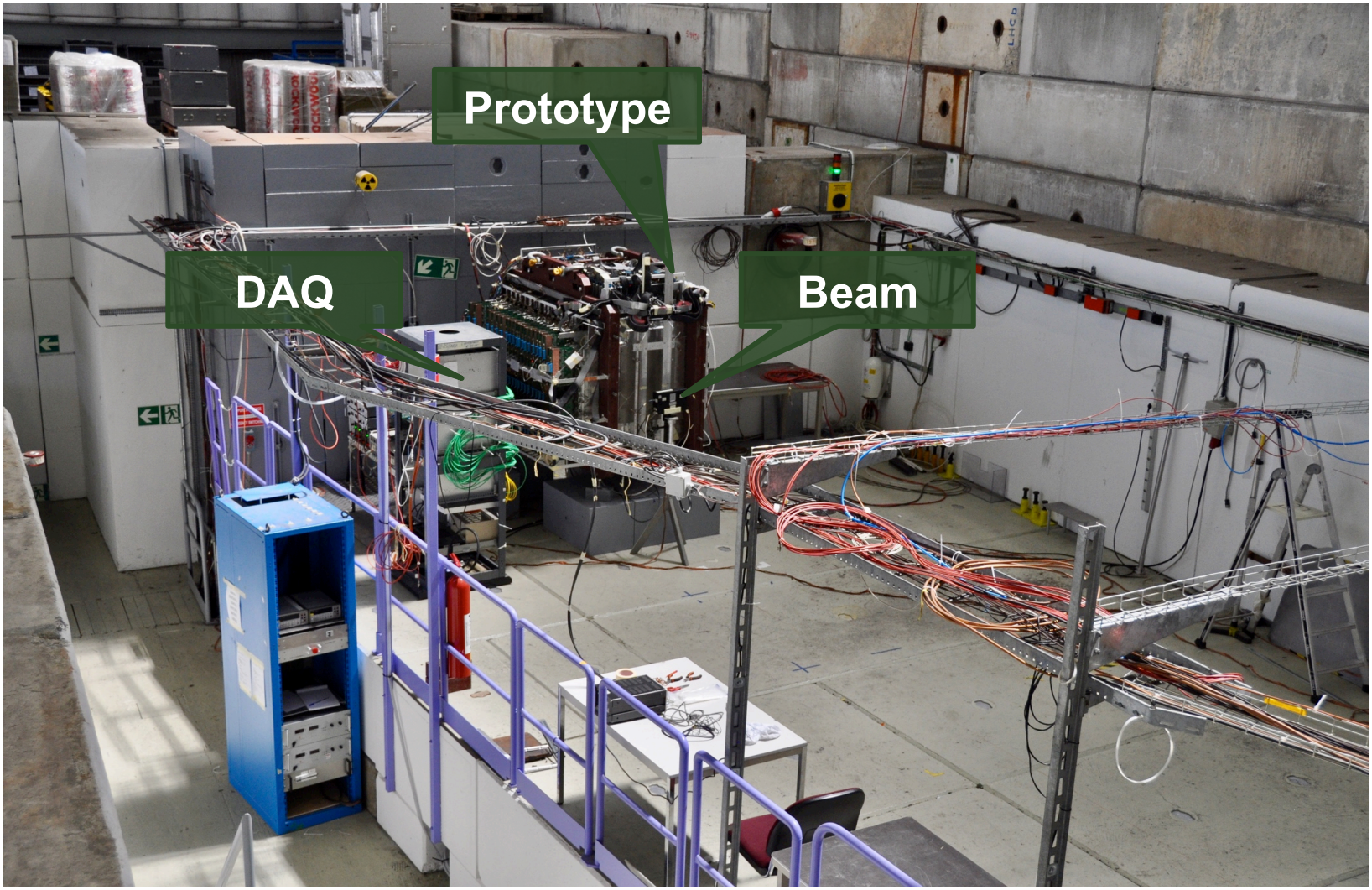
Main Tasks of Range System Prototype Study @ CERN

- Calibration of the system's response to the different particles and energies.
- Test of algorithms for μ/π separation
- Tune digitization algorithm
- Technical issues

Range System:

- absorber plates;
- detecting layers of MDTs;
- strips between the plates;
- "zero" bi-layers.

PANDA Muon System Prototype @ PS/T9/CERN Beam Line



PANDA Muon System Prototype Status

Test beam runs in 2017-2018

Calibration of the Prototype using
μ, π, p and n of different (+/-) momentum

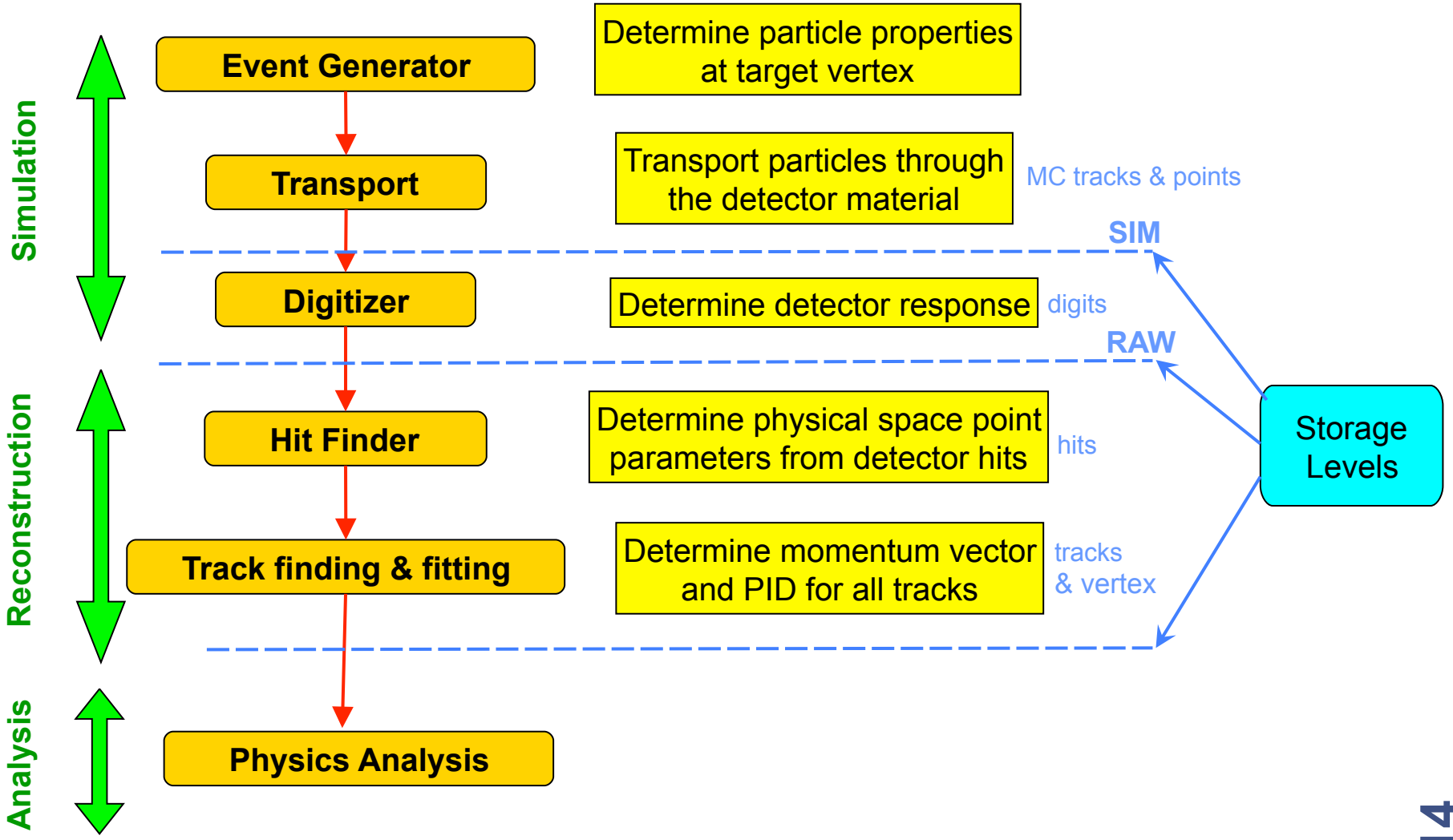
2 years of PS shutdown and T9 beam line area renovation (since 2019)

Prototype is relocated to COMPAS area

Cosmic tests in 2019

New high pressure Čerenkov counter (60 atm) is ready and will be install in spring 2021 (π/μ rejection up to 1.5-2.0 GeV/c)

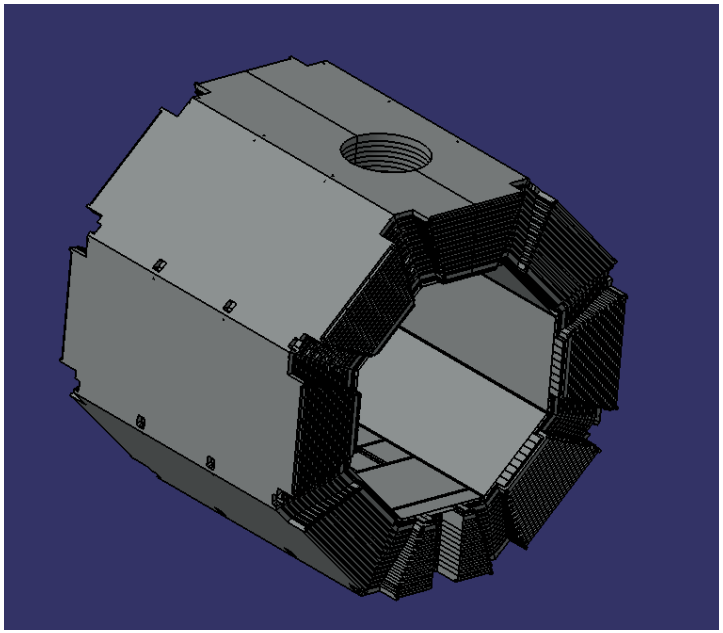
Simulation and analysis steps of experiments

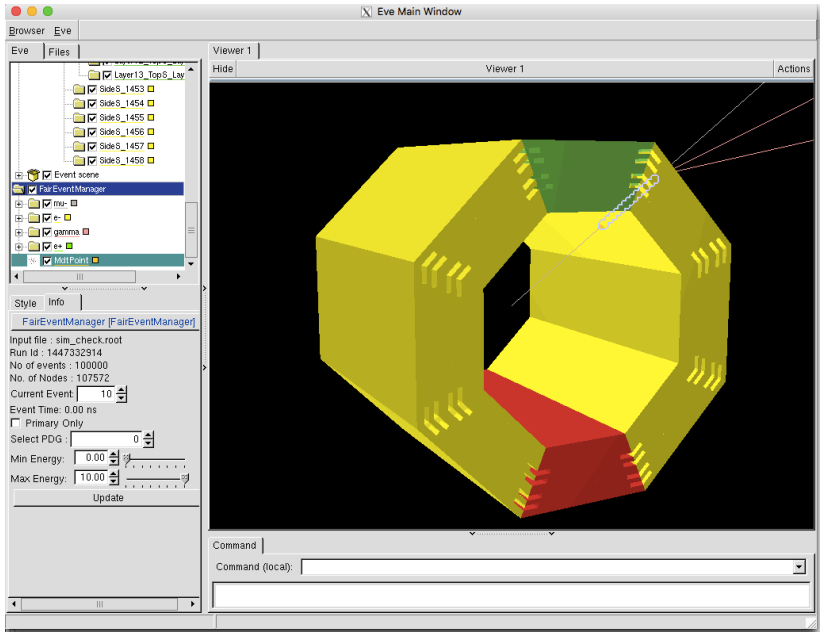


CAD and ROOT Models of Muon System (Barrel part)

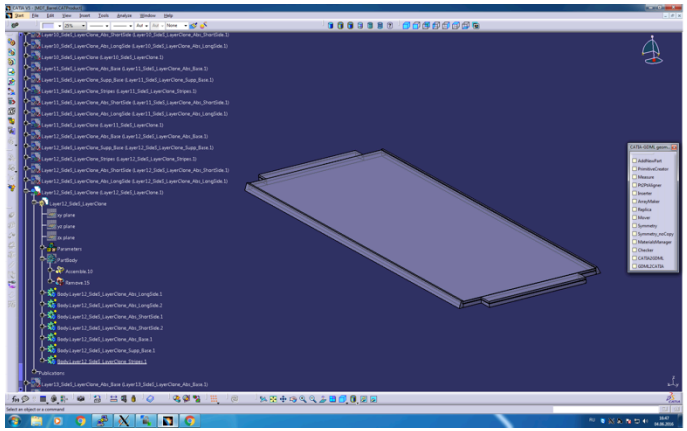
It is important to have the model of the Muon System in PandaRoot software for full MC simulation of PANDA setup.

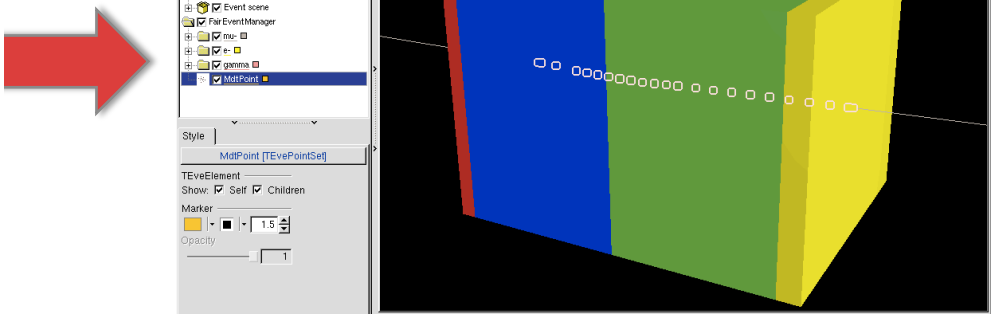
Transfer of the detector geometry from Computer-Aided Design (CAD) systems to particle transport Monte Carlo codes like GEANT4 and ROOT is always an issue due to geometry description incompatibility.





CAD and ROOT Models of Muon System (Prototype)

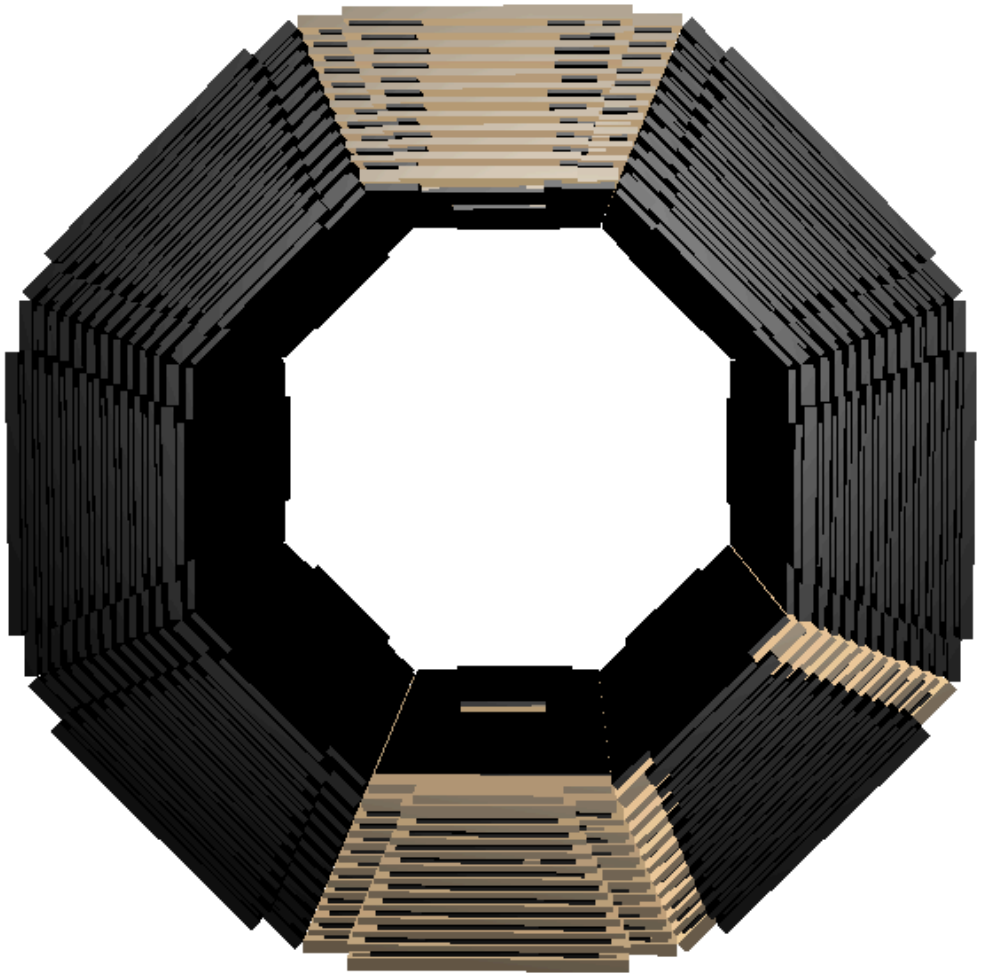




Detector geometry in CAD systems

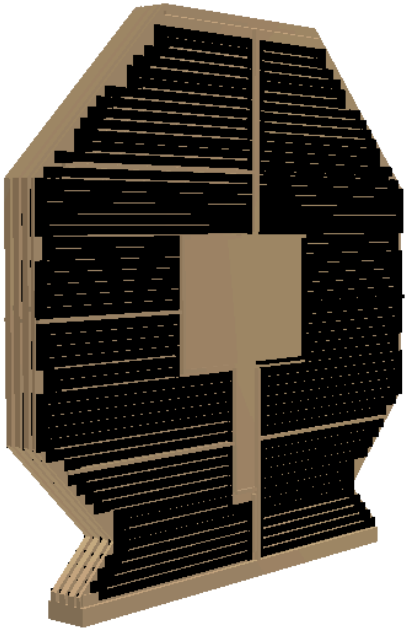
Physical model - particle transport Monte Carlo codes (ROOT)

Models of Muon System

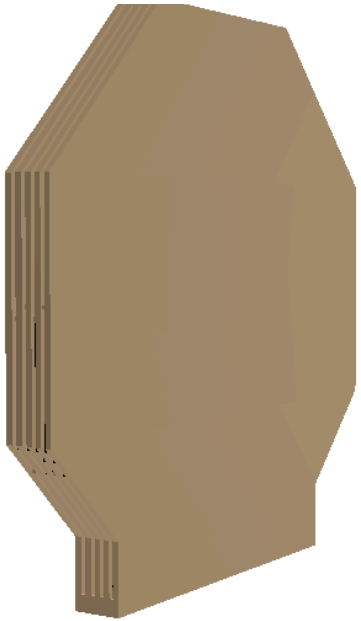


Barrel part

MF

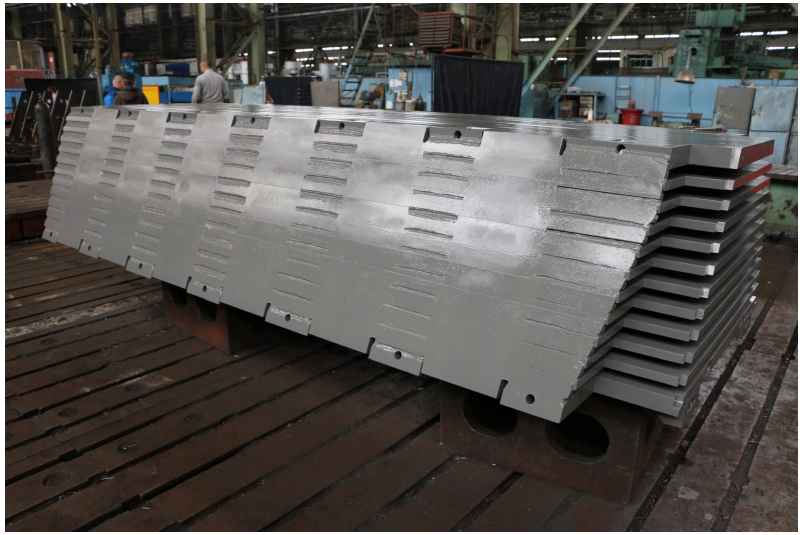


EC

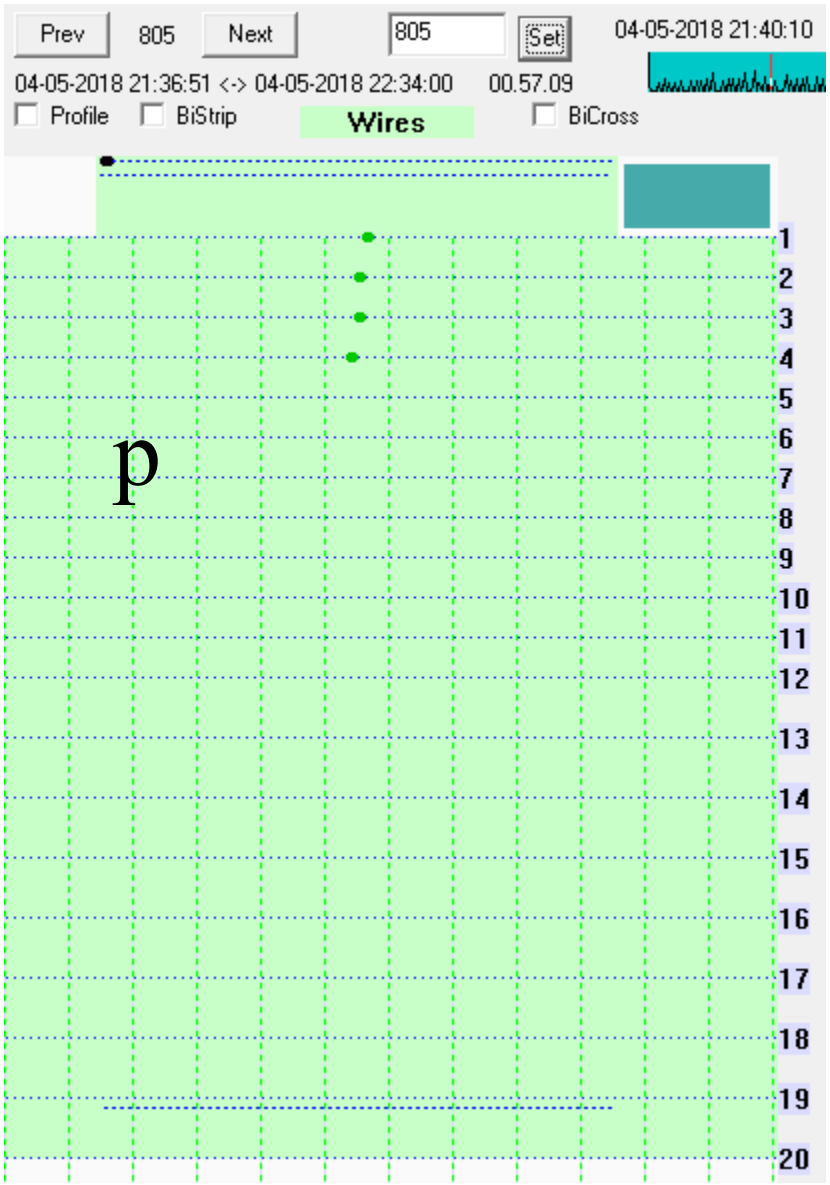


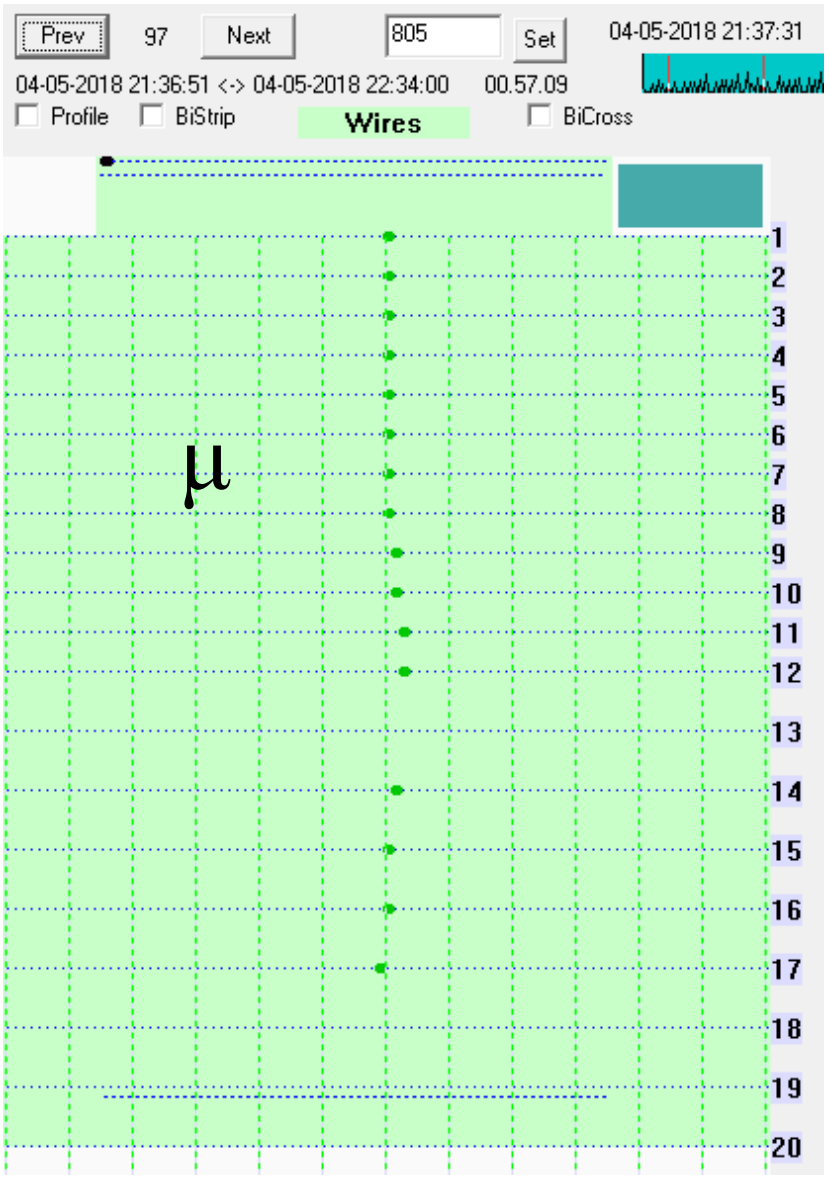
Geometry Status

1) The first octant of the PANDA Solenoid Magnet Yoke is completed in Novosibirsk in August 2018
2) Geometrical model of Muon System is changed significantly (ex. size of installation, number of detecting layers)
3) New Barrel, MF, EC Muon System physical models are ready for integration to PandaRoot.
4) Model for FRS will be updated after discussions with BINP colleagues and developing of 3D final mechanical models.

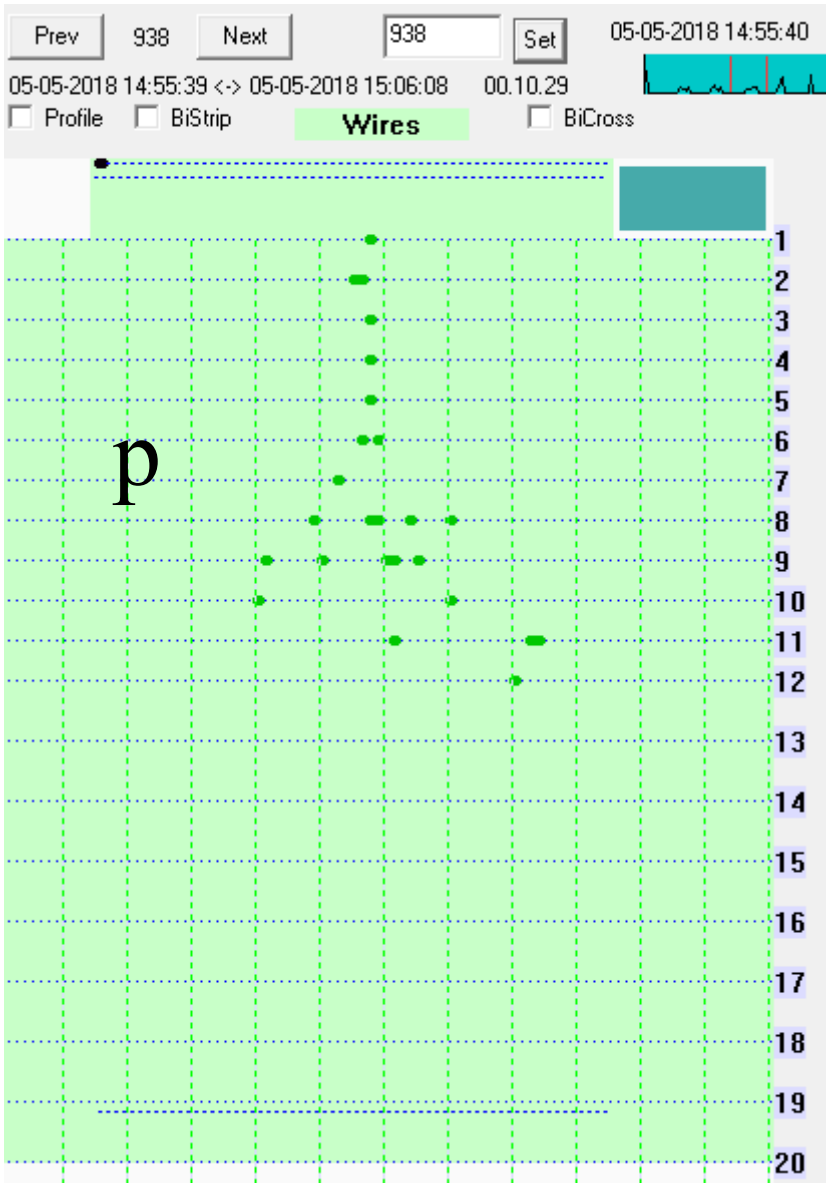


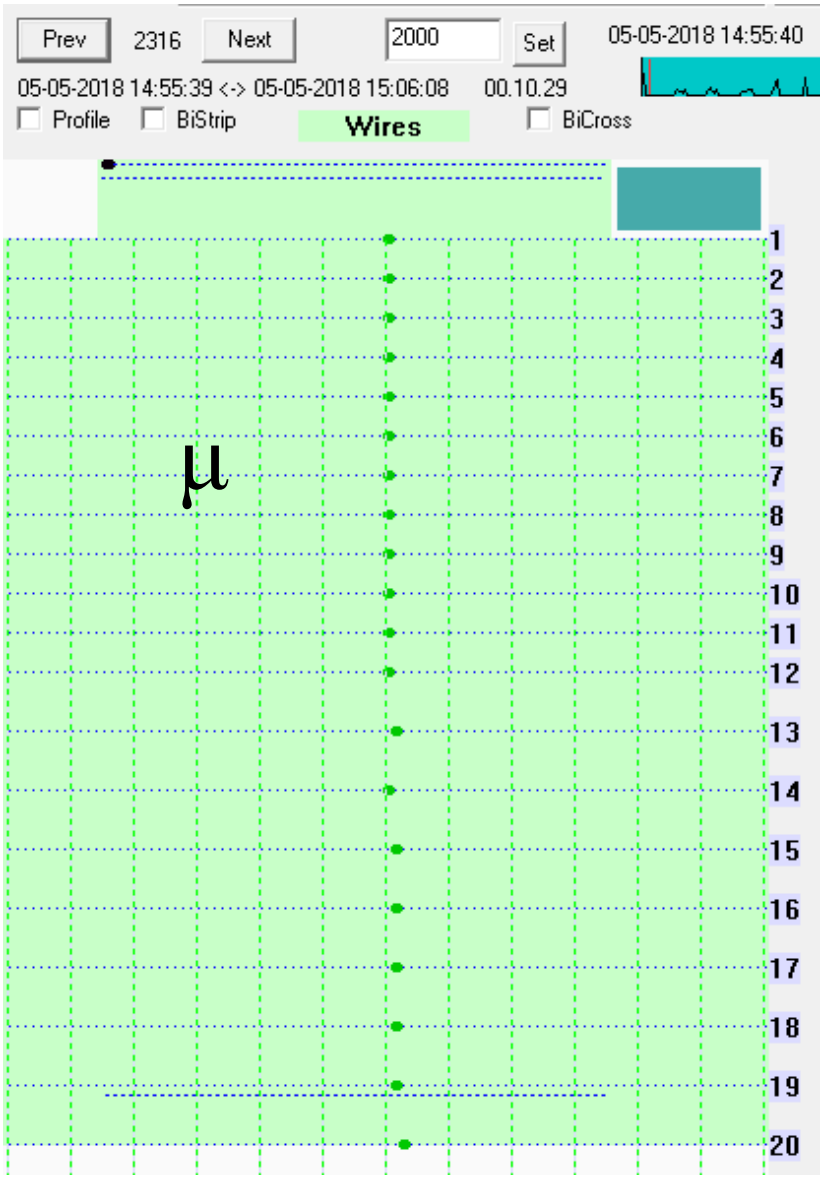
Event Examples (Run 822, P = 1 GeV/c)



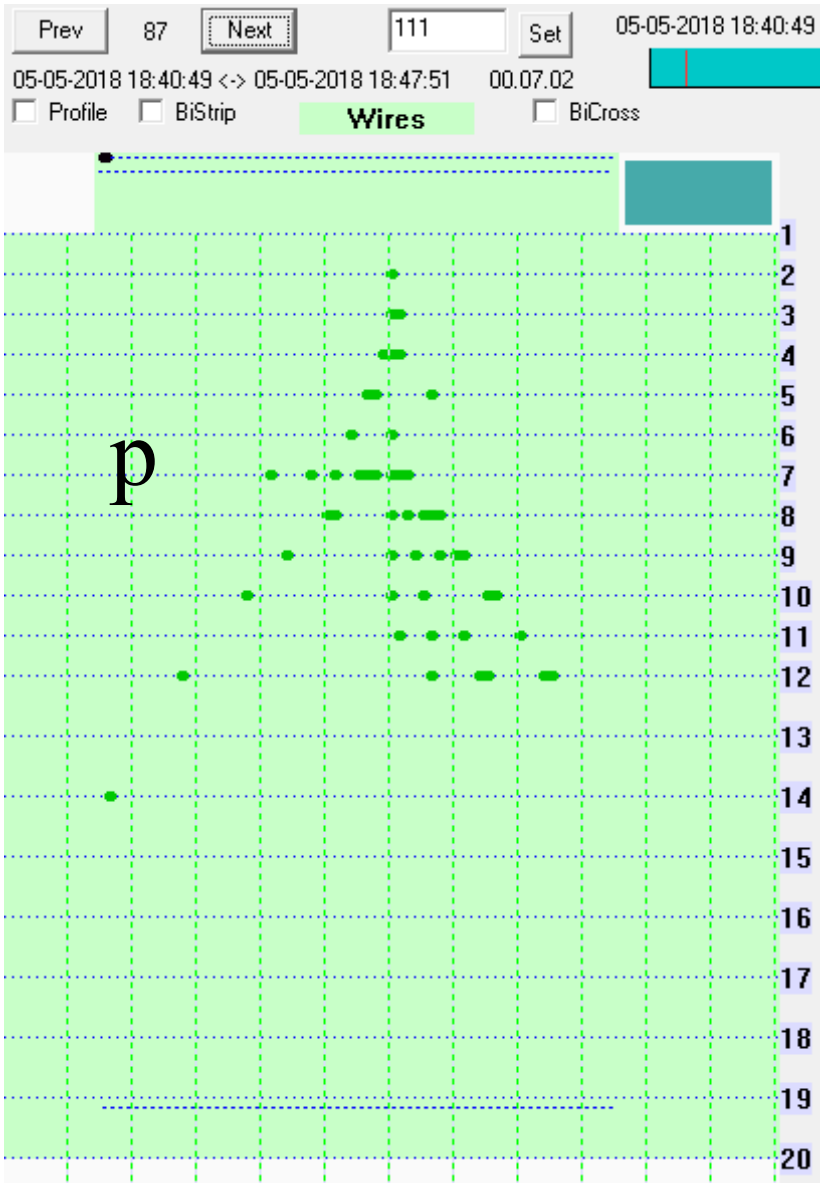


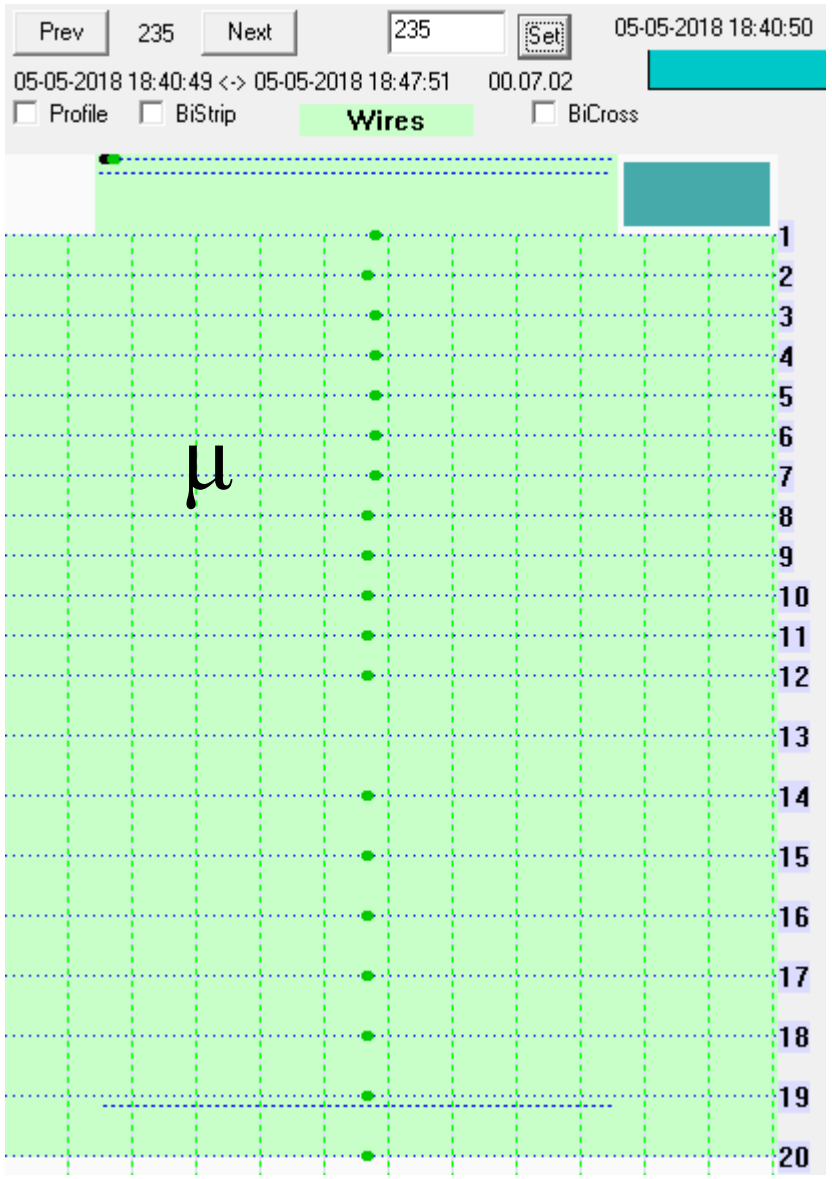
Event Examples (Run 829, P = 5 GeV/c)





Event Examples (Run 835, P = 10 GeV/c)



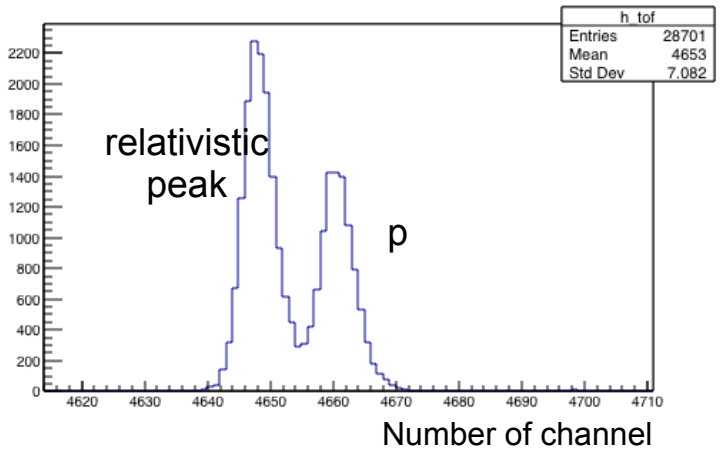


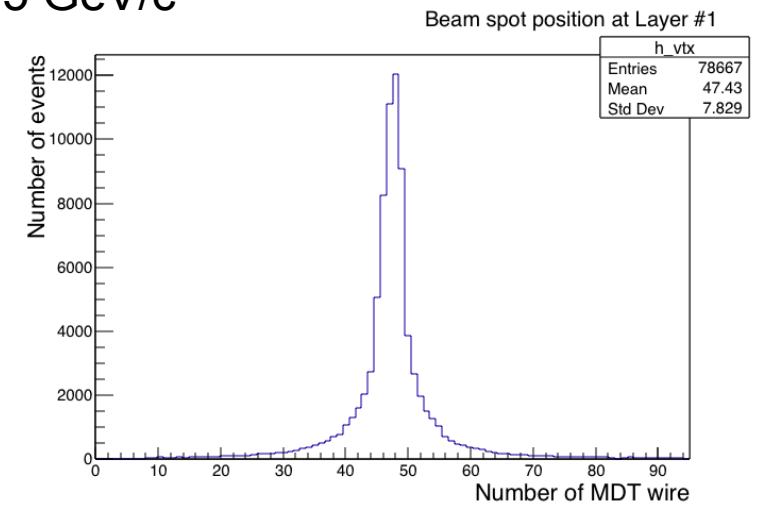
Selection Criteria for protons and antiprotons

For calorimetry we estimate the energy of protons (antiprotons) by measuring the number of hits in an event.

1) Two scintillation counters of the TOF system (up to 5 GeV/c)
2) Čerenkov counters (> 5 GeV/c)
   Čer(A): 2 bar of CO_2 <-> reject e/π/μ
3) Beam entrance spot

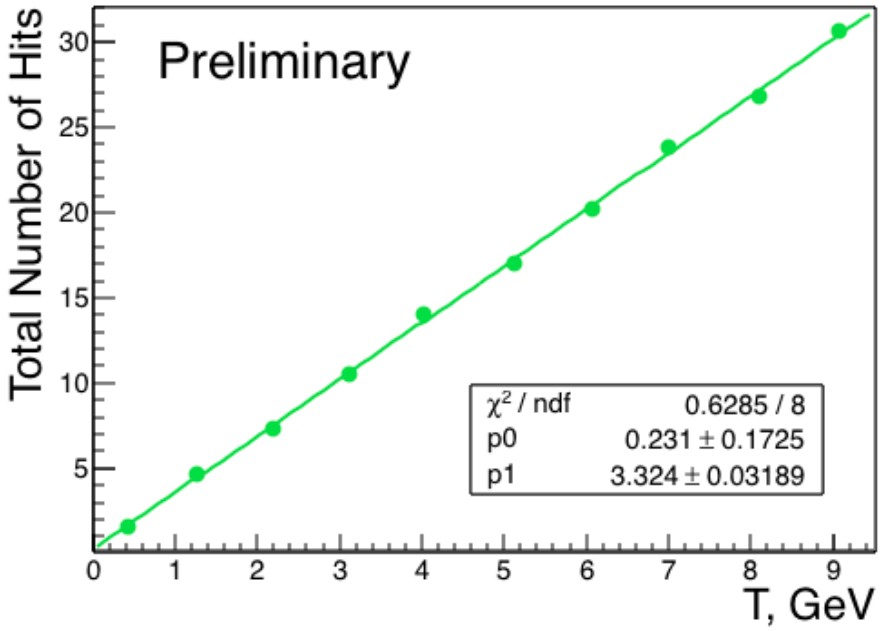
Run 829, P = 5 GeV/c

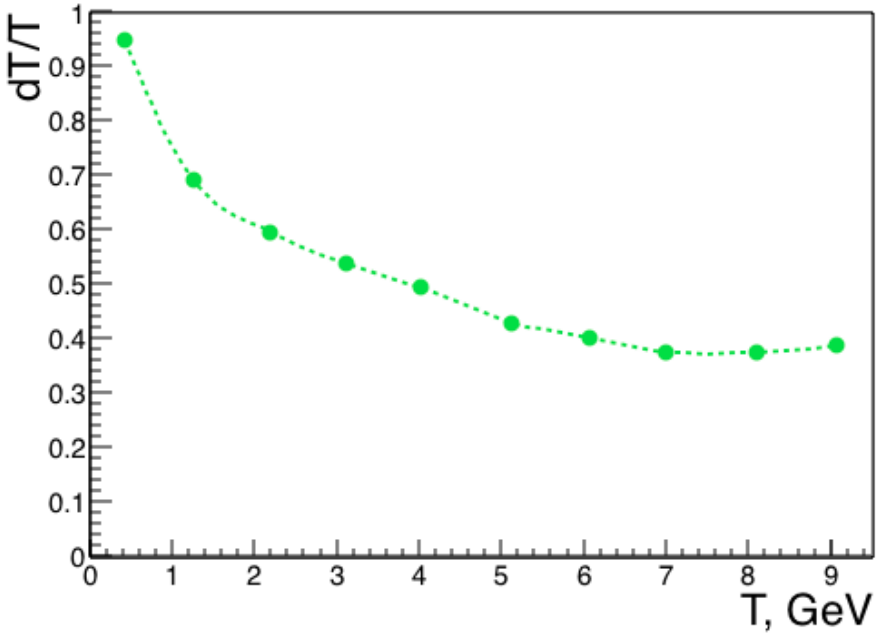




Calorimetry for protons: PANDA FRS Structure

Various combination of layers can be used to represent different parts of Muon Range System.

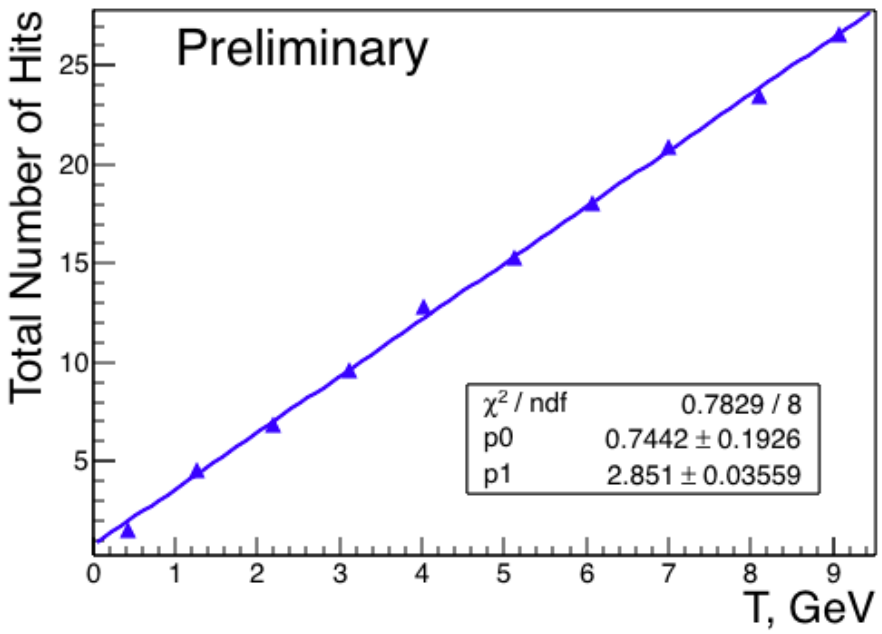


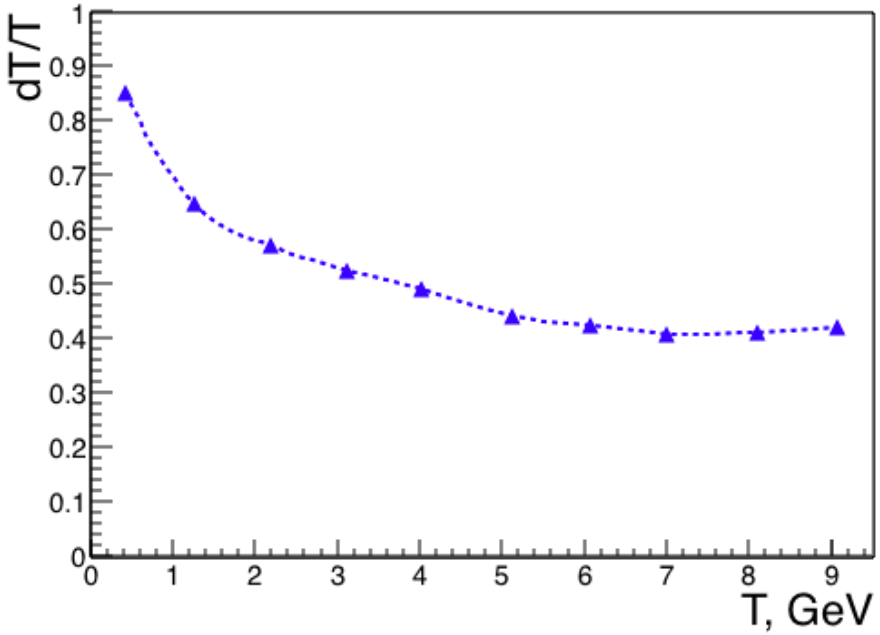


Sampling: 60 mm / Fe

Nuclear interaction length $\lambda_I \approx 5.2$

Calorimetry for protons: PANDA MF+EC Structure

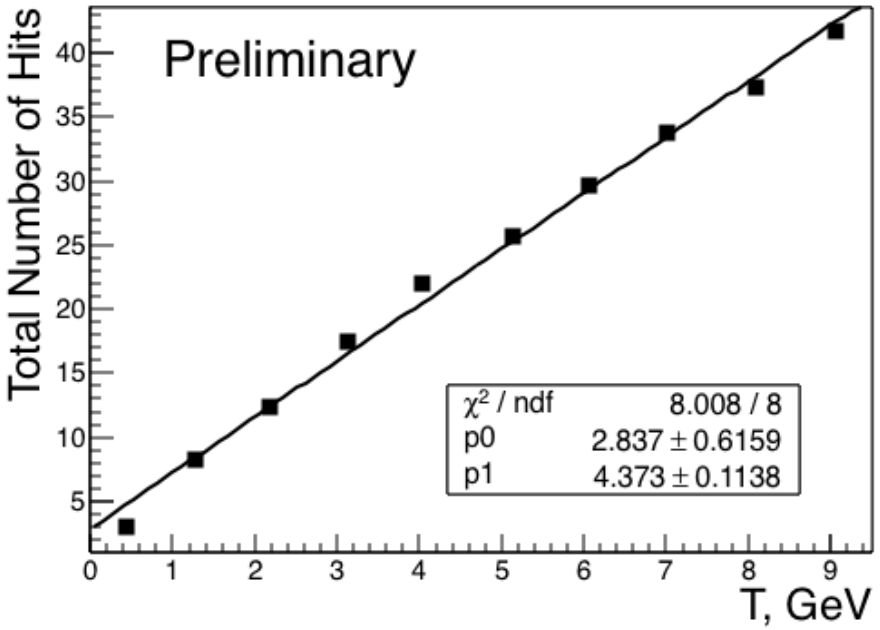


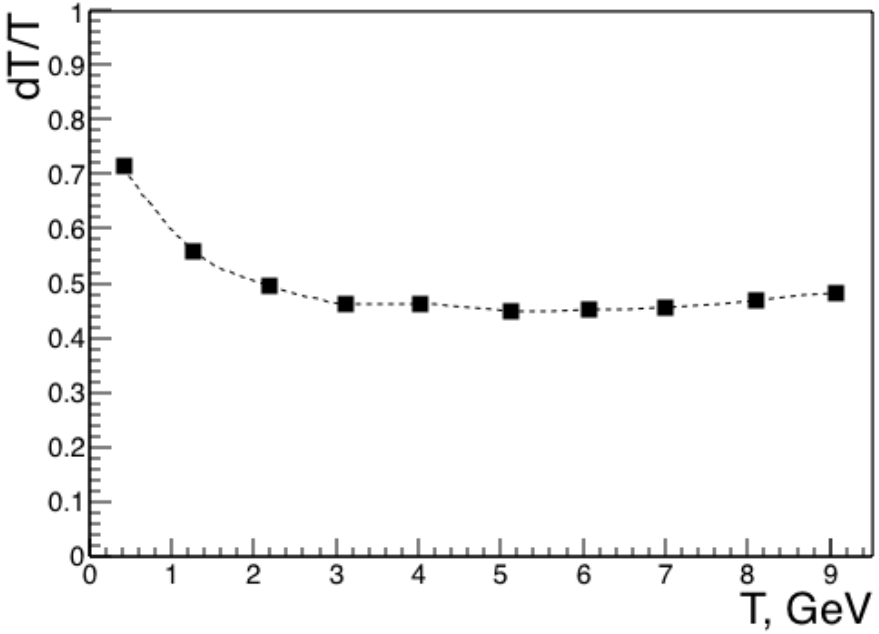


Sampling: 60 mm / Fe

Nuclear interaction length $\lambda_I \approx 3.4$

Calorimetry for protons: PANDA Barrel Structure

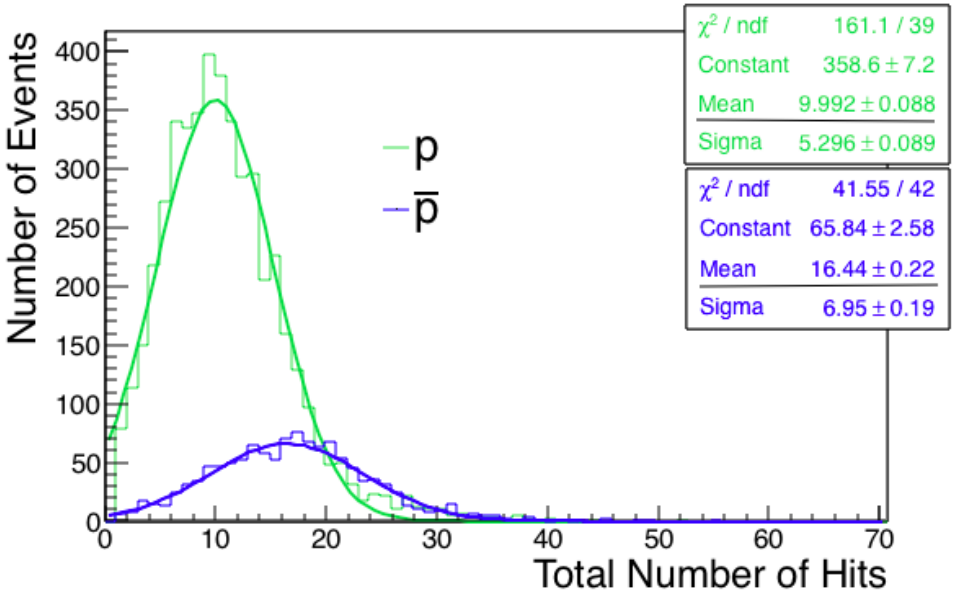


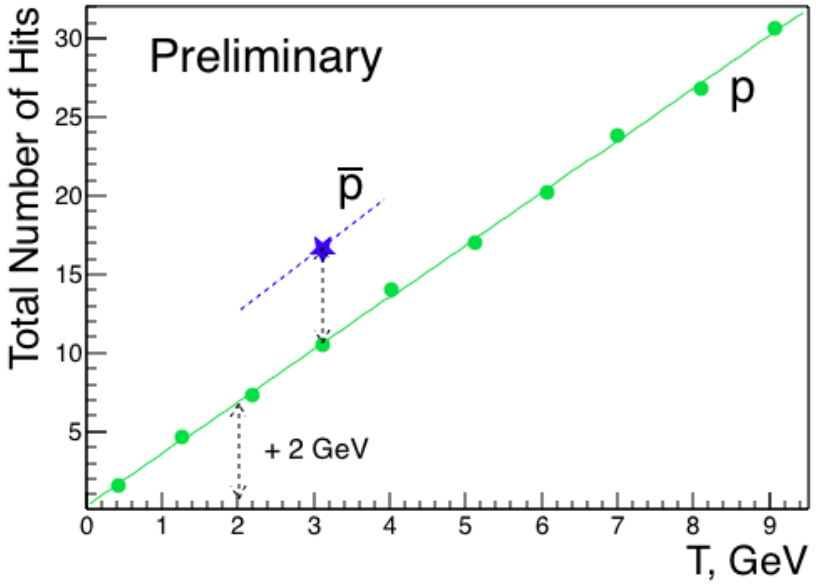


Sampling: 30 mm / Fe

Nuclear interaction length $\lambda_I \approx 2.3$

Protons vs Antiprotons

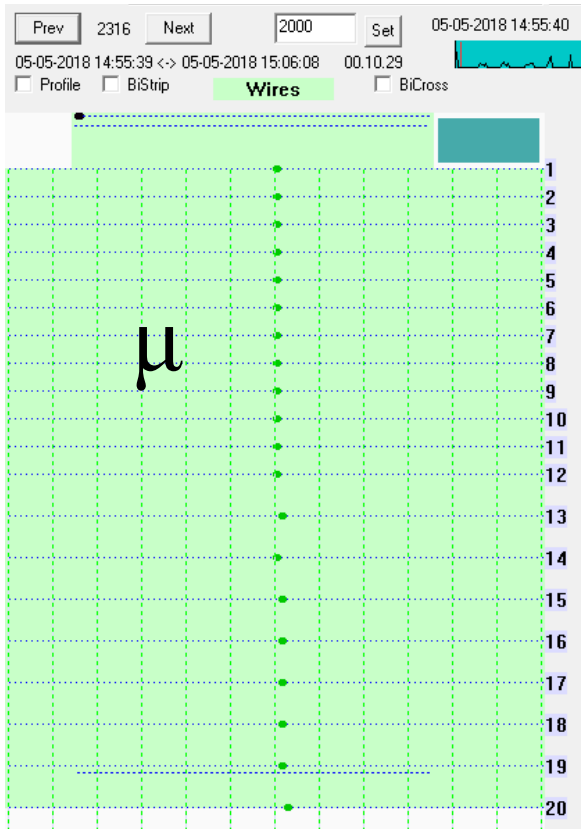




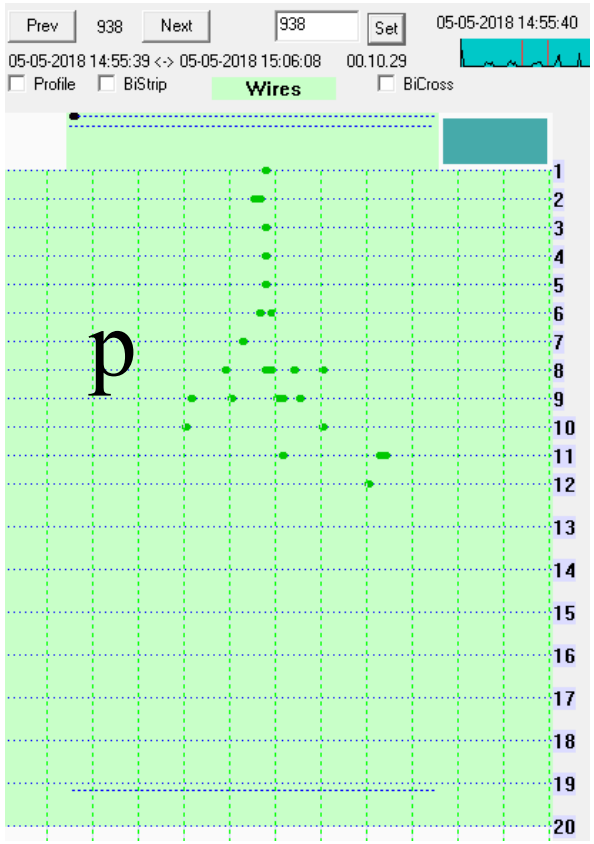
PANDA FRS Structure, T = 3.1 GeV (P = 4 GeV/c)

Event Examples (P = 5 GeV/c)

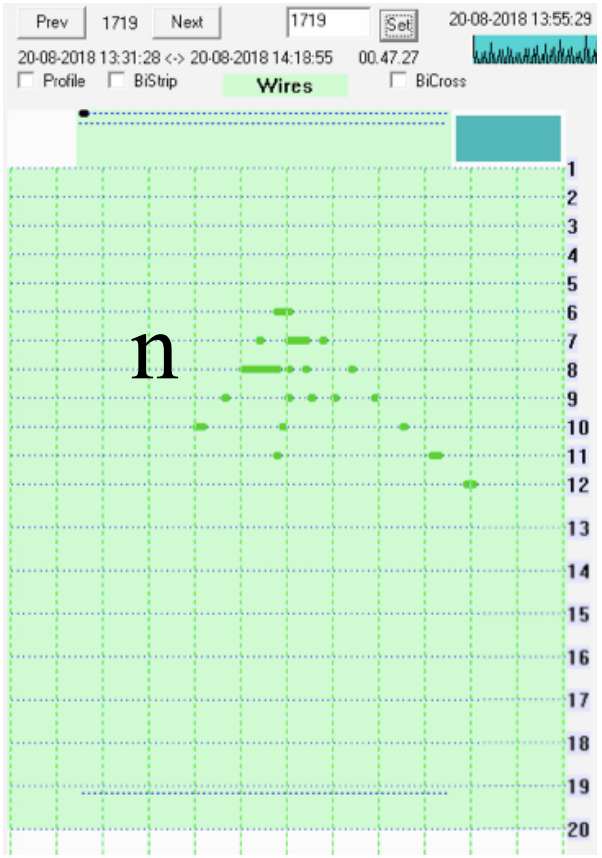
Range System will also be used as a coarse hadron calorimeter – > very important for neutron registration (the only system in PANDA)!



Run 829



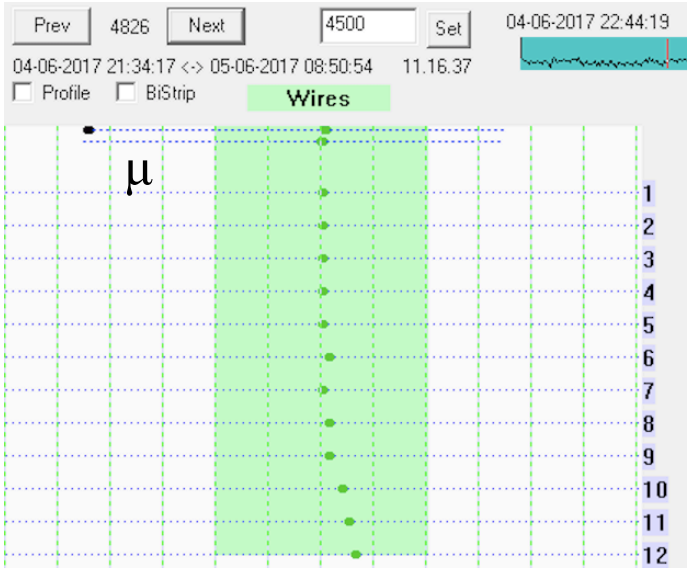
Run 829

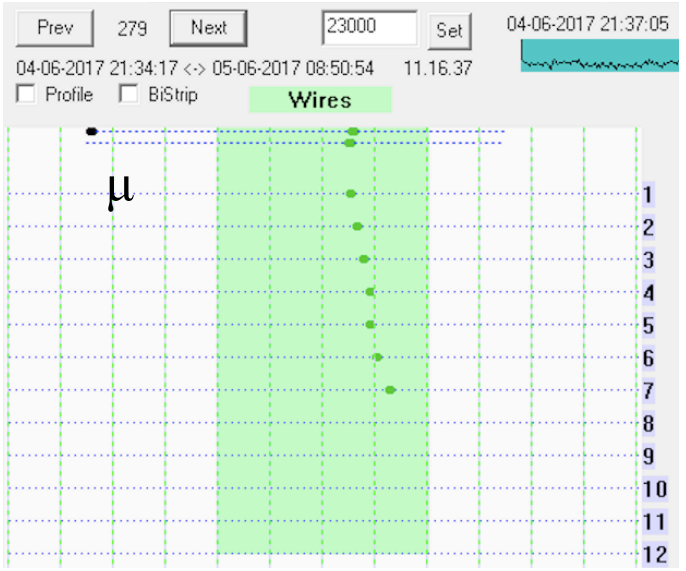


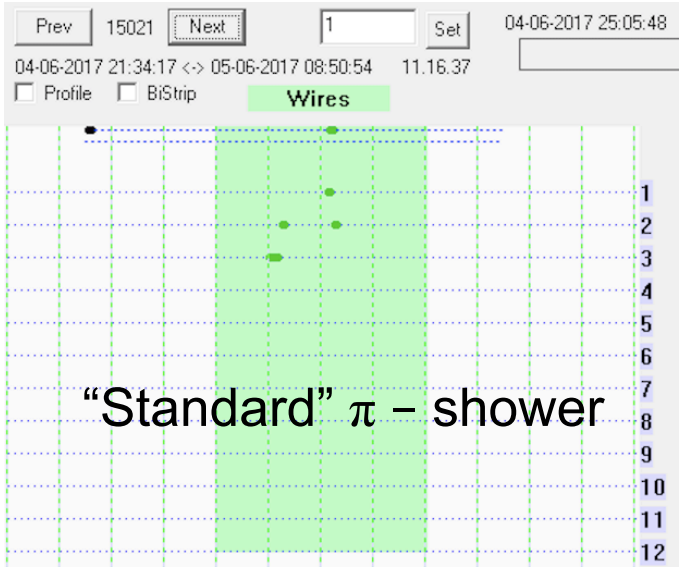
Run 951

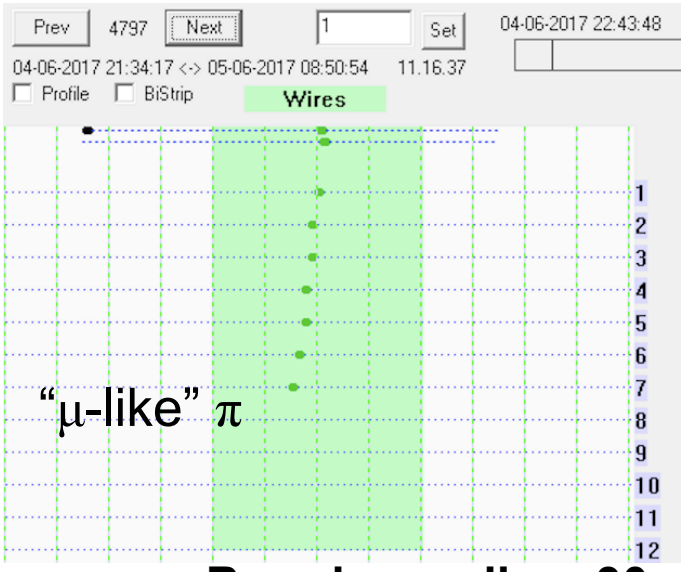
Prototype Data (μ vs π)

Run 605
P = 0.5 GeV/c



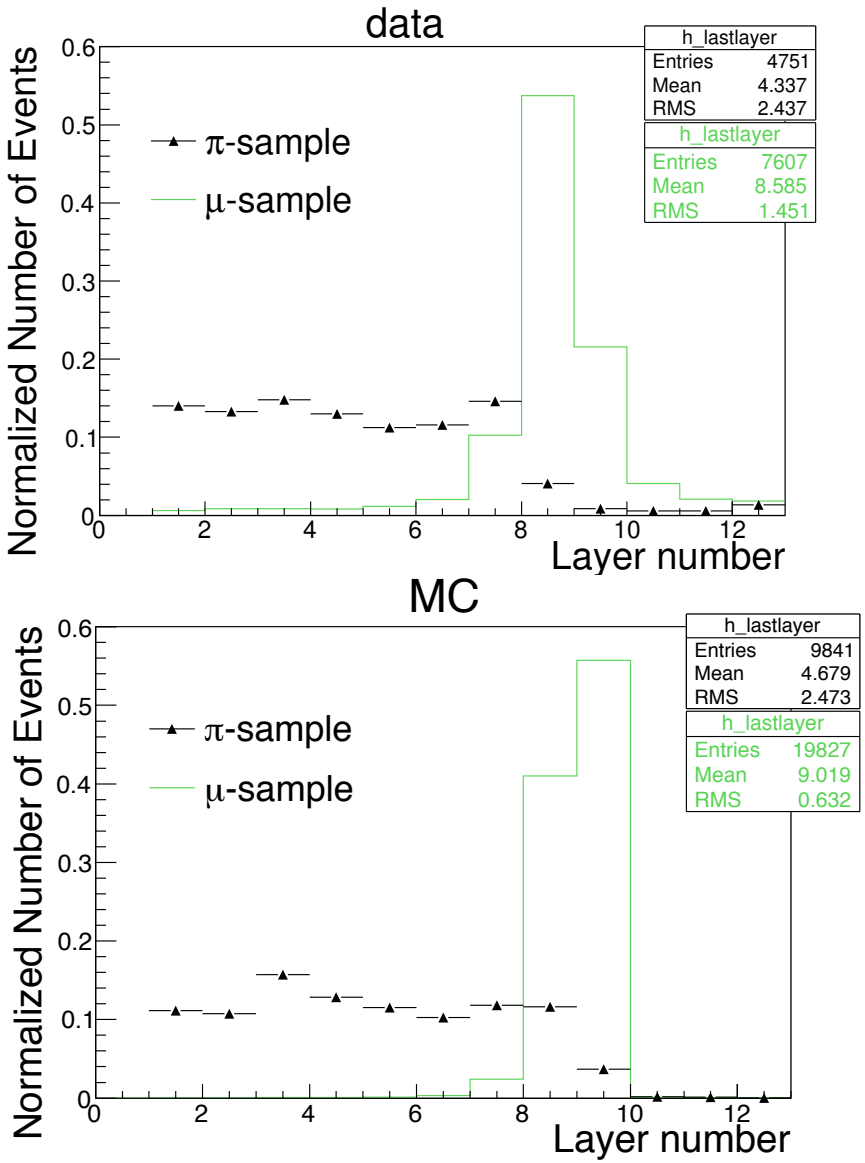






Barrel sampling, 30 mm

Preliminary Test Beam Results



EPJ WoC, Volume 177 (2018) 04001

Run 605, autumn 2017
P = 0.5 GeV/c

Selection -> after layer #7:
22% - pion contamination and
93% - muon efficiency

FairBoxGenerator, PandaRoot
P = 0.5 GeV/c

Selection -> after layer #7:
27% - pion contamination and
99% - muon efficiency

Barrel sampling, 30 mm

Summary and Plans

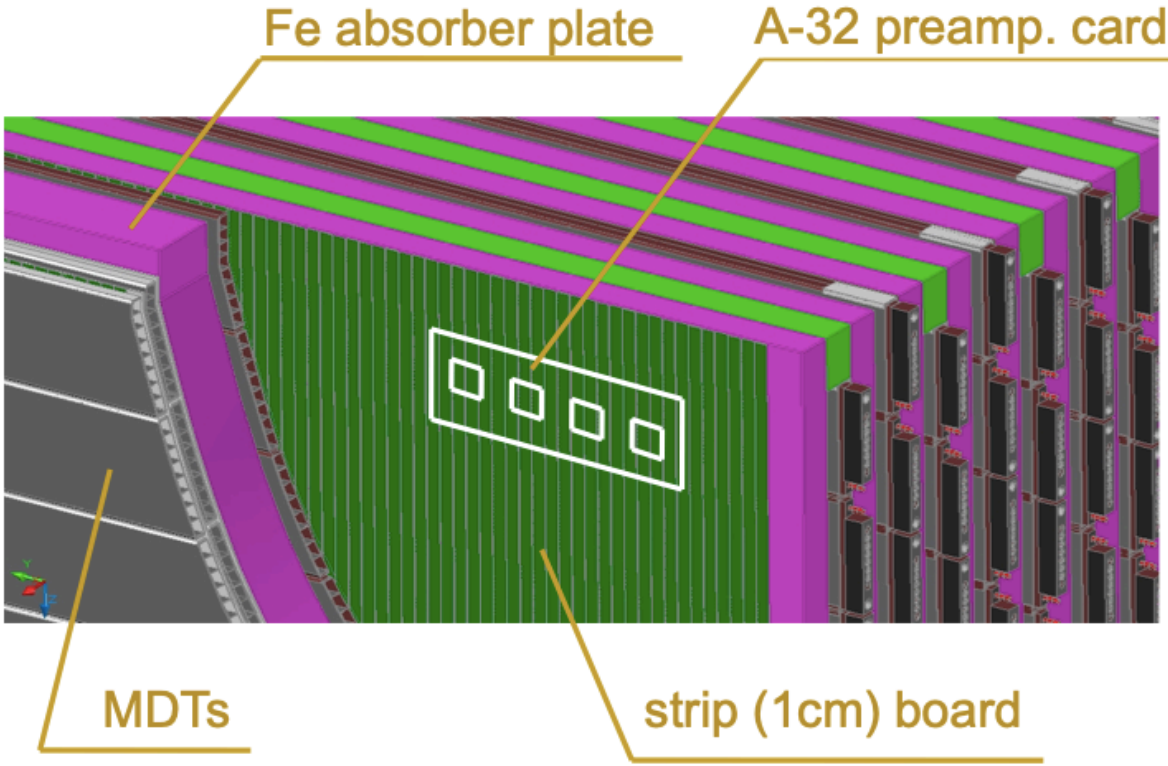
- Preliminary calorimetry of PANDA Muon System Prototype for protons and antiprotons is performed with test beam data.
- Processing of pionic data is in progress
- Identification of neutrons is demonstrated.

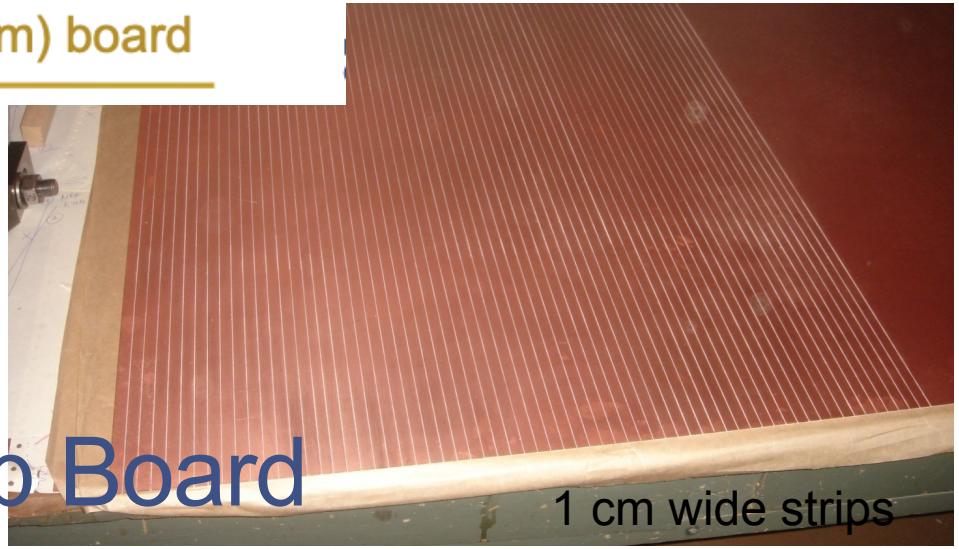
Plans:

- Finalizing 3D mechanical model of FRS Muon System (detector geometry).
- Transferring the detector geometry from CAD system to particle transport Monte Carlo code like (ROOT).
- Digitization / pattern recognition of hadrons and muons using test beam data 2017-2018.
- Cosmic tests at CERN (2019-2021).

Backup Slides

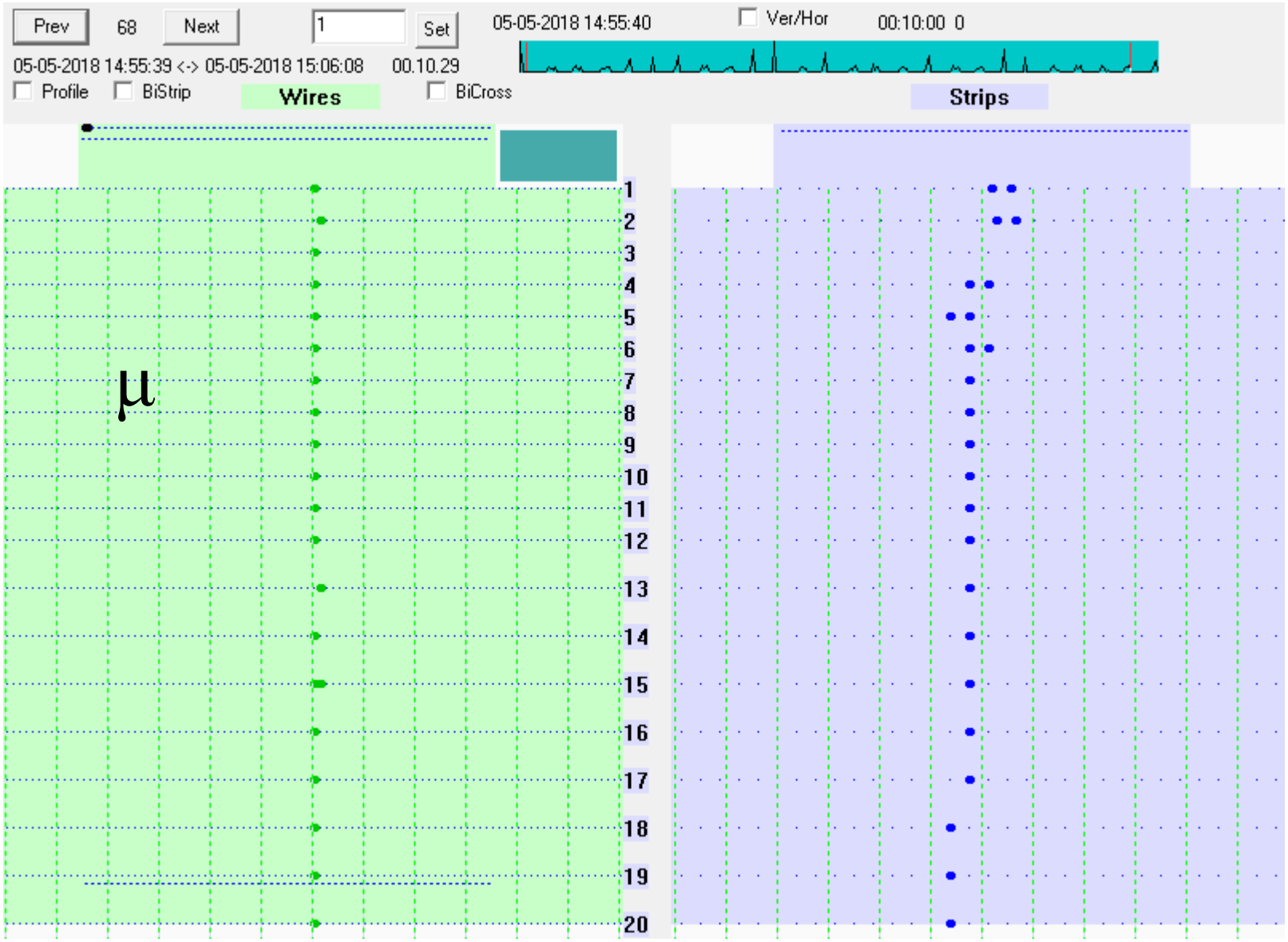
Strip R/O from RS Prototype



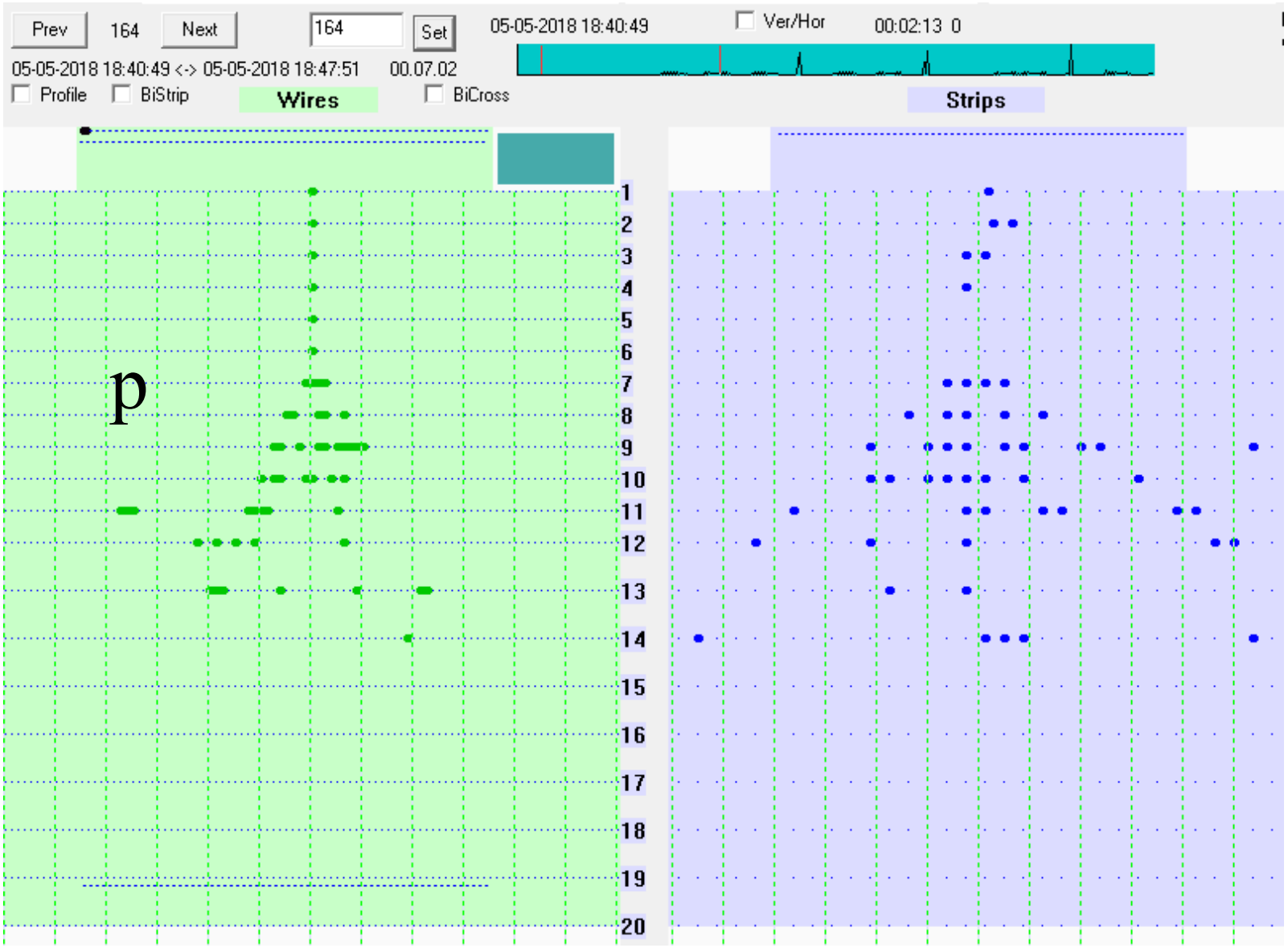


G10 Fiberglass Strip Board

Event Examples (Run 829, P = 5 GeV/c)



Event Examples (Run 835, P = 10 GeV/c)



Estimated maximum flux in beam @ T9