Monte-Carlo simulations of the Straw Tracker performance in SPD setup

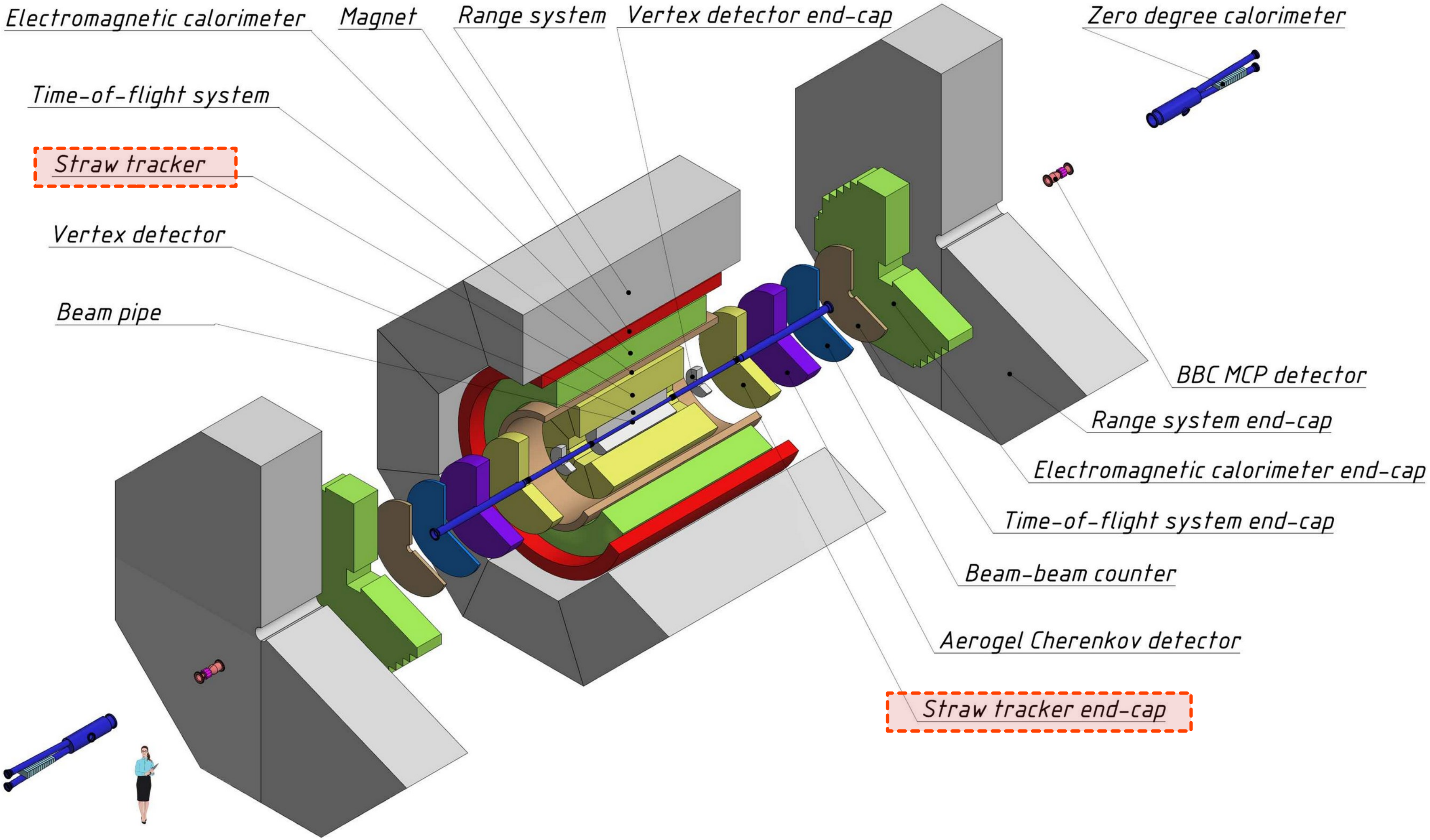
Ruslan Akhunzyanov

Joint Institute for Nuclear Research

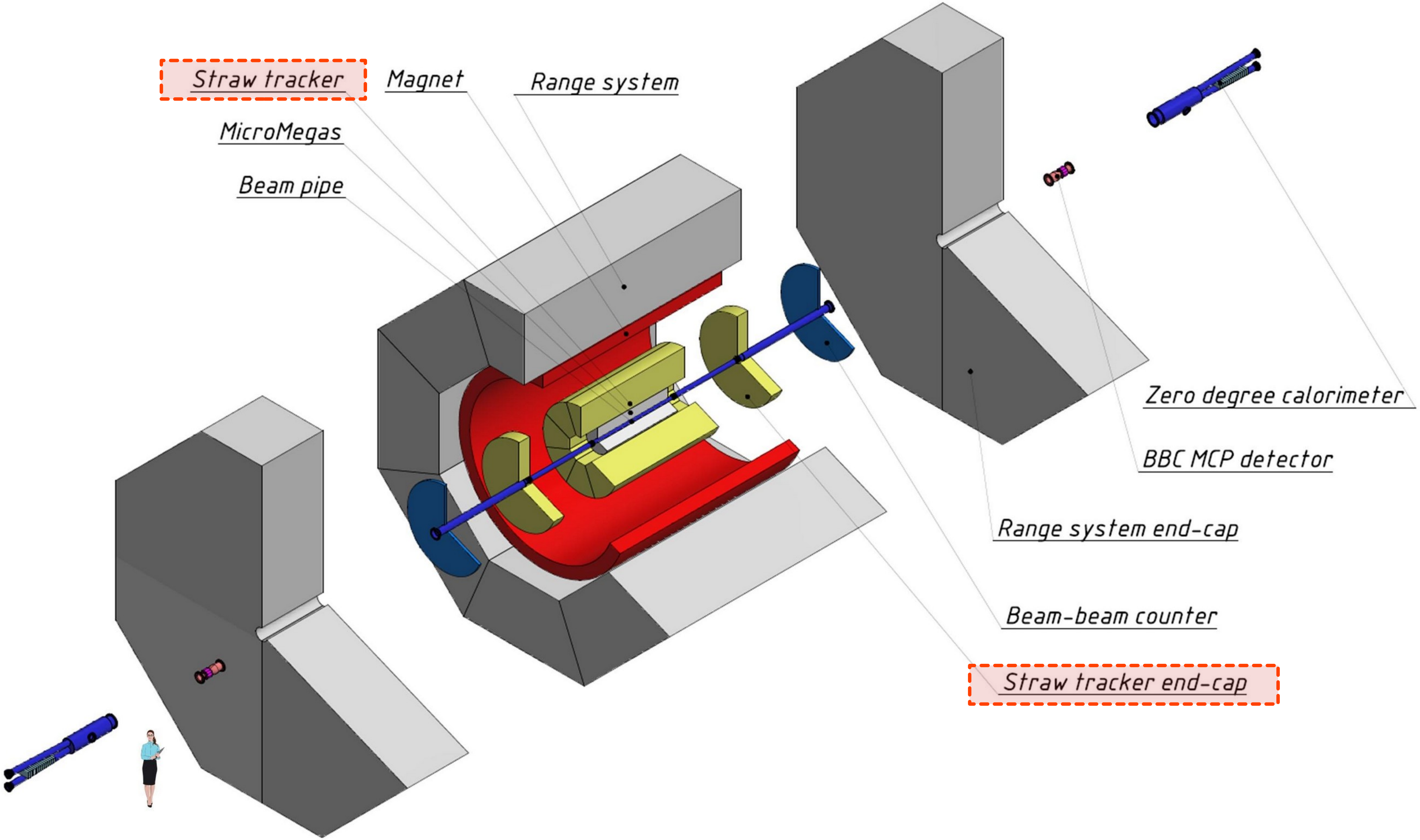
XXXI Annual International Seminar
Nonlinear Phenomena in Complex Systems

Minsk, 2024

Schematic view of the complete SPD setup



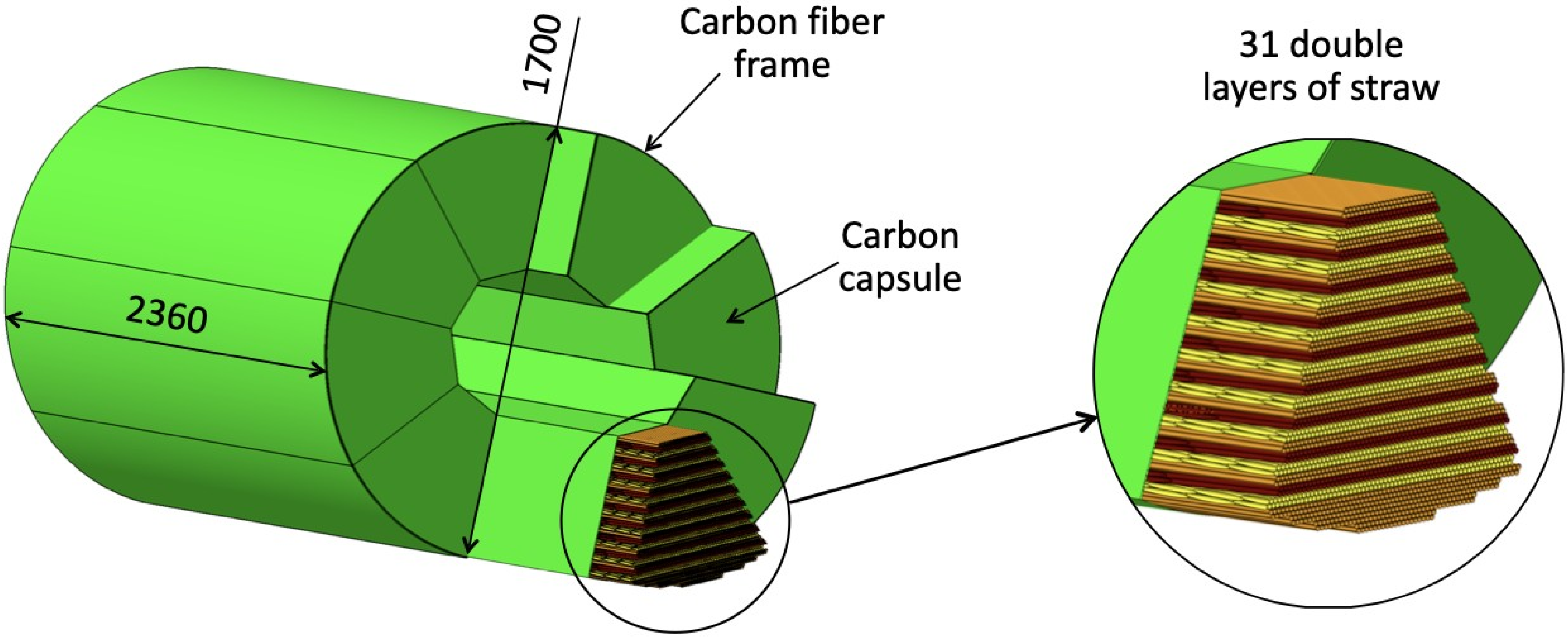
Schematic view of the SPD setup at the first stage



Purpose of the straw tracker

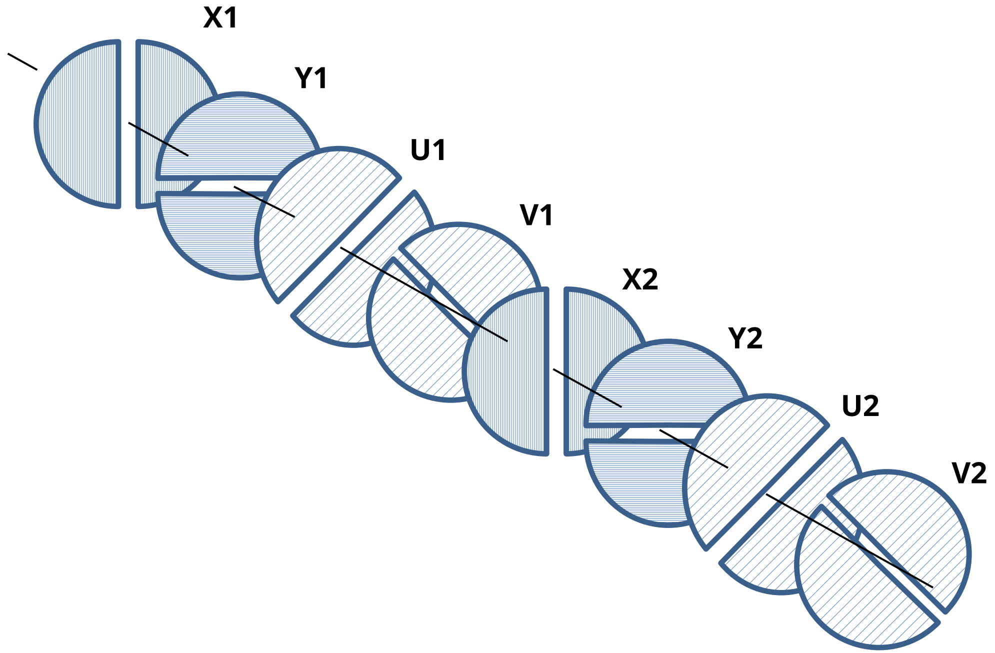
- To reconstruct tracks of charged primary and secondary particles with high efficiency.
- To measure their momenta with high precision, based on a track curvature in a magnetic field.
- To contribute to charged particle identification via energy deposition (*dE/dx*) measurements.

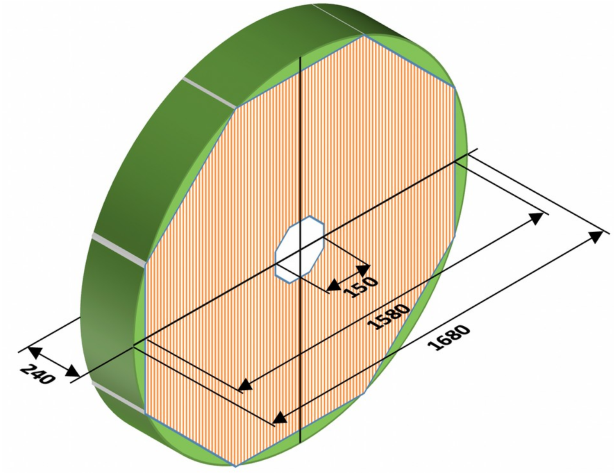
Straw Tracker (barrel part)



The barrel part of the straw tracker is subdivided azimuthally in 8 modules, with 31 double layers of straw tubes each.
Orientations of straw tubes are alternately in Z, U, and V directions. The Z axis is along beam axis. The angle between U, V and Z axes is ± 3°. Straw diameter is 9.8 mm. Spatial resolution is ~ 150-200 μm.

Straw Tracker (endcap part)

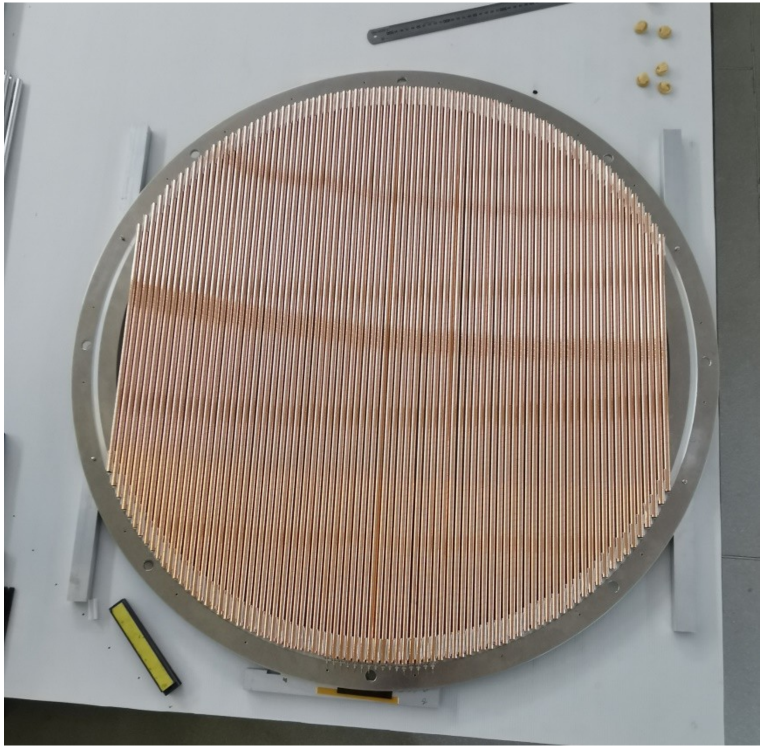




Common view and main dimensions

Each endcap consists of 8 coordinate planes with angles that are multiple of 45°.

Straw endcap prototype

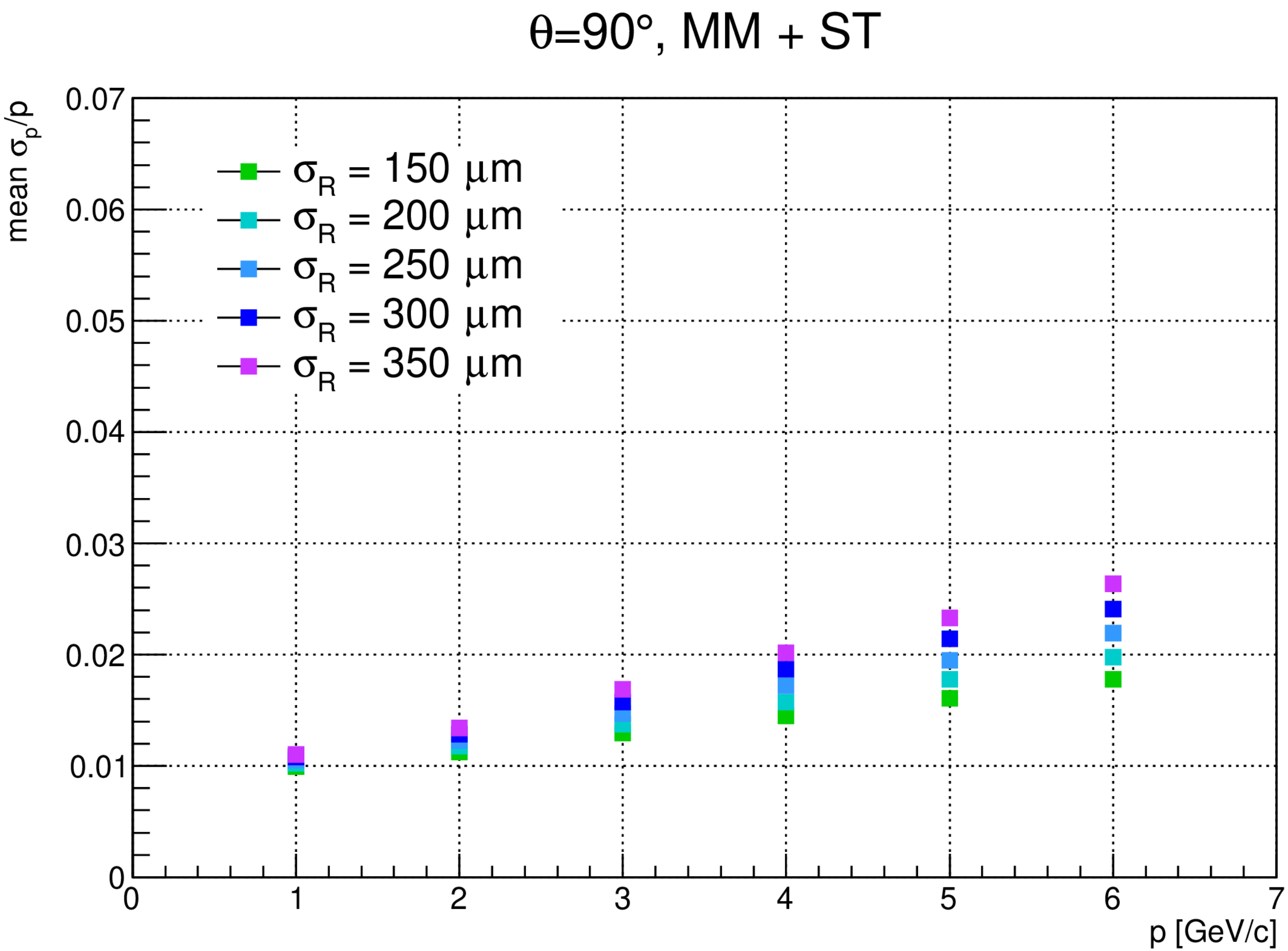


1 meter prototype made in JINR to test the assembly technology

SpdRoot

- SpdRoot (https://git.jinr.ru/nica/spdroot) is currently the main package for Monte-Carlo simulations for the SPD project.
- Based on FairRoot / FairSoft framework.
- It includes:
  - Flexible geometry description (in ROOT format)
  - Primary event generators (Pythia8, FTF, isotropic, etc.)
  - Geant4 as a toolkit for the simulation of the passage of particles through matter
  - Hit producing (in simplified form; work is going on more realistic hit simulation)
  - Track reconstruction. Genfit2 package is used for track fitting.

Mean momentum resolution σ_p/p

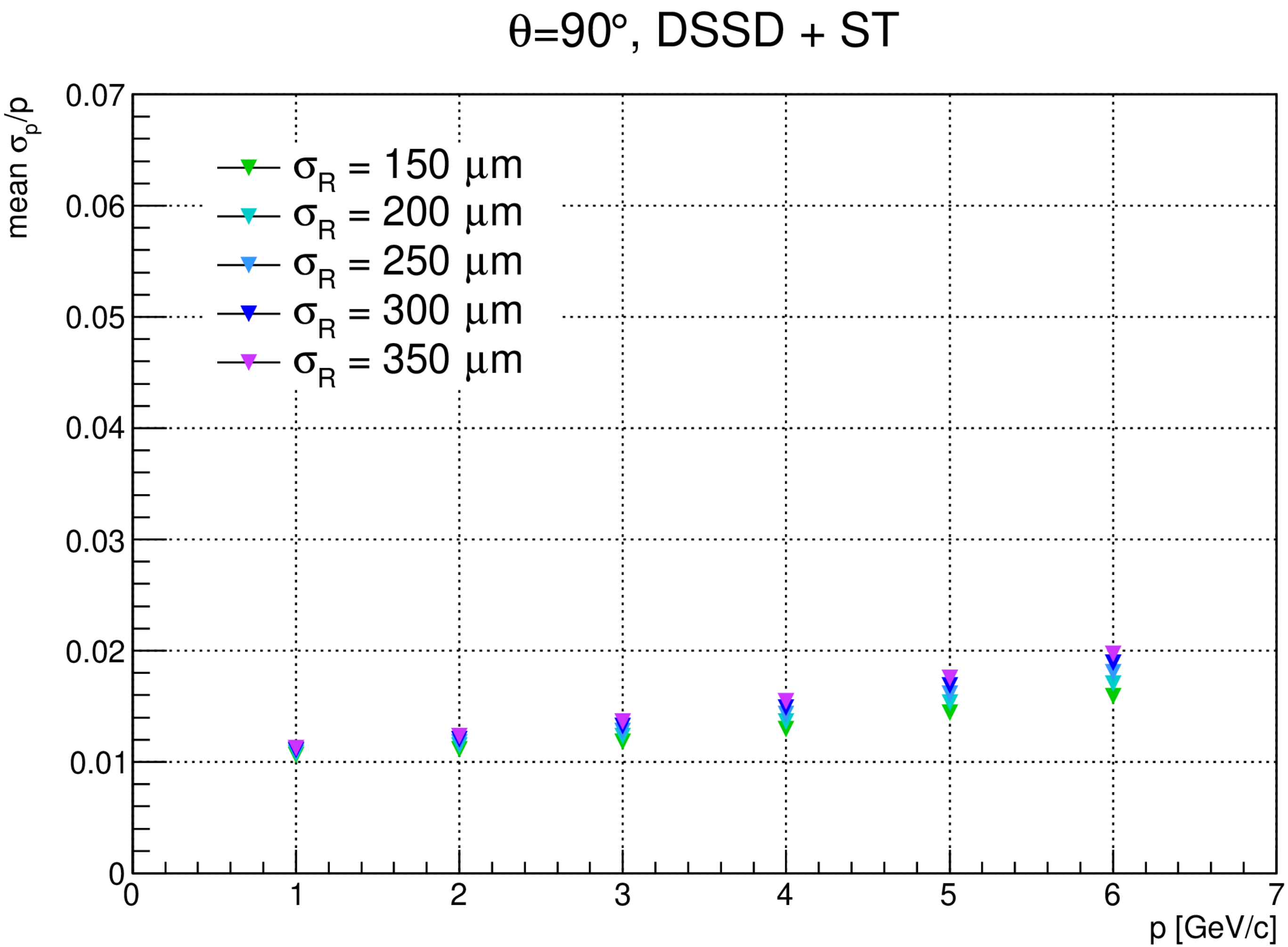


Straw Tracker:
31×2 layers
σ_R on plot

Micromegas:
1 superlayer
(with 3 sublayers)
σ_u = 800 μm
σ_v = 90 μm

(u || z, v ⊥ z)

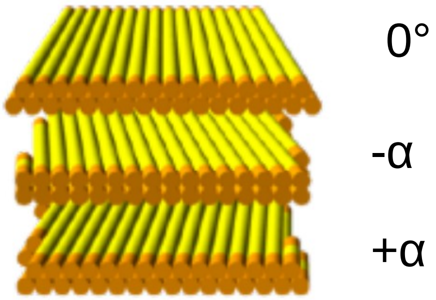
Mean momentum resolution σ_p/p

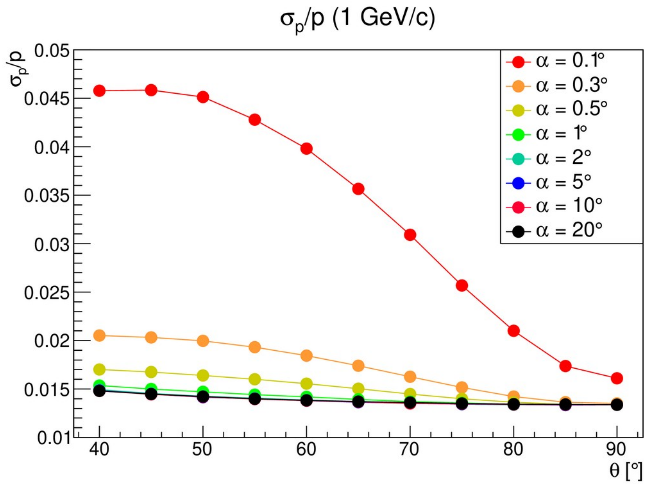


Straw Tracker:
31×2 layers
σ_R on plot

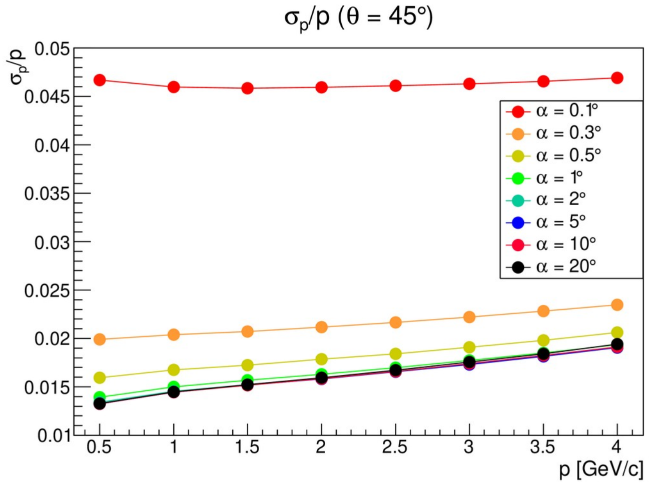
Silicon Vertex Detector (Double-Sided Silicon Detector): 3 layers
σ_u = 81.3 μm
σ_v = 27.4 μm
(u || z, v ⊥ z)

MC simulations for determining straw tube angle





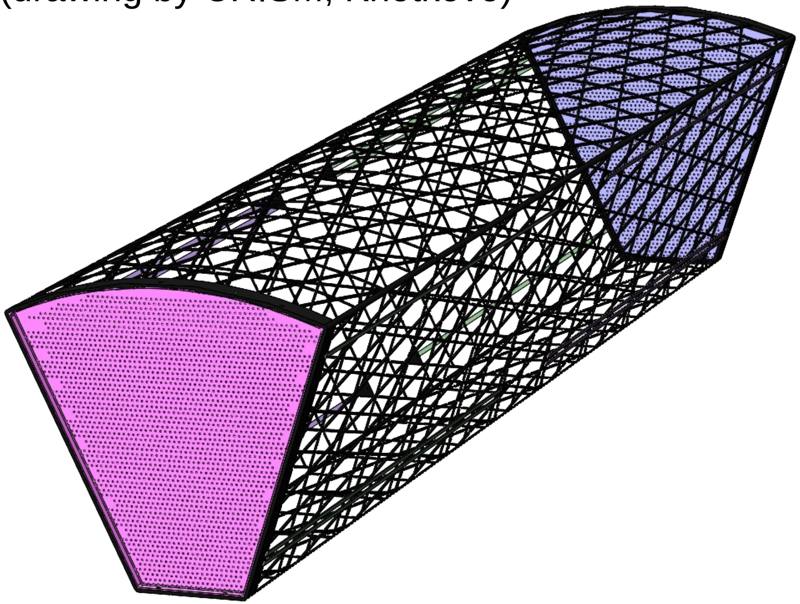
- Dependence of momentum resolution of the straw tracker on straw orientation angle (α) was studied for different values of momentum and polar angle.
- Momentum resolution almost does not change for values of α ≥ 2°.



(straw tracker only)

Power frame of the straw detector

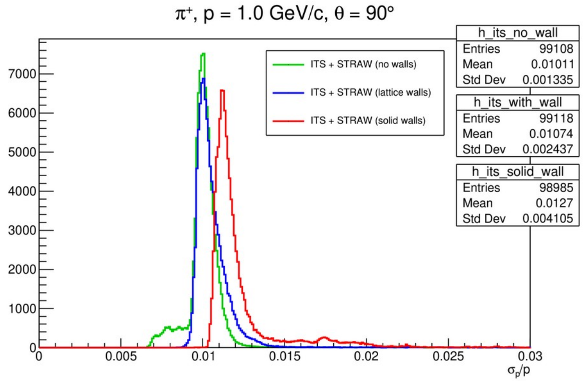
Power frame of one module
(drawing by CRISM, Khotkovo)



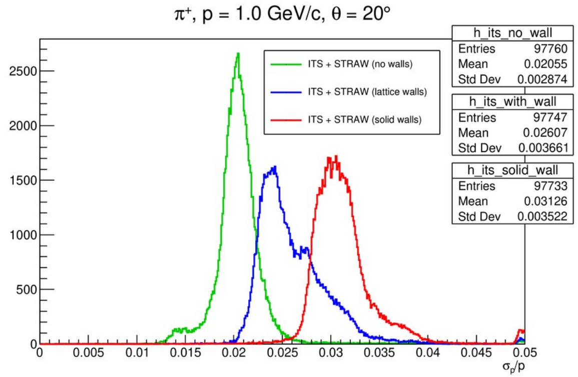
Parameters for simulation:
material: carbon fiber
thickness = 4 mm
thickness of front/back walls = 20 mm

Momentum resolution σ_p/p for simulations without and with power frame

$\theta = 90°$:



$\theta = 20°$:



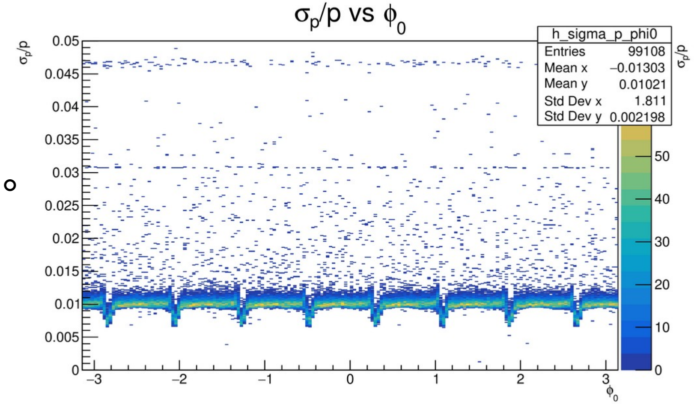
Impact of straw detector frame on momentum resolution

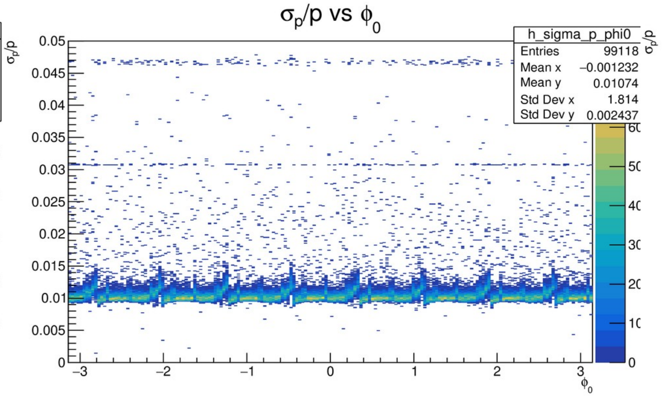
NO WALLS

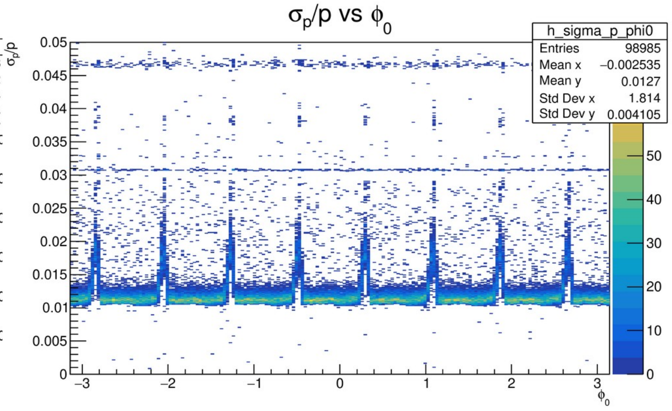
LATTICE WALLS

SOLID WALLS

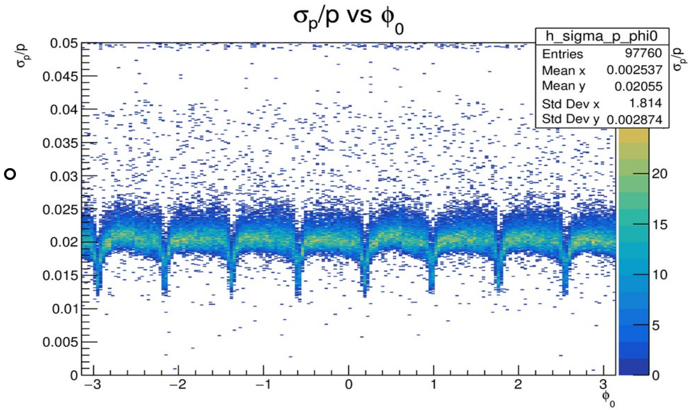
θ = 90°

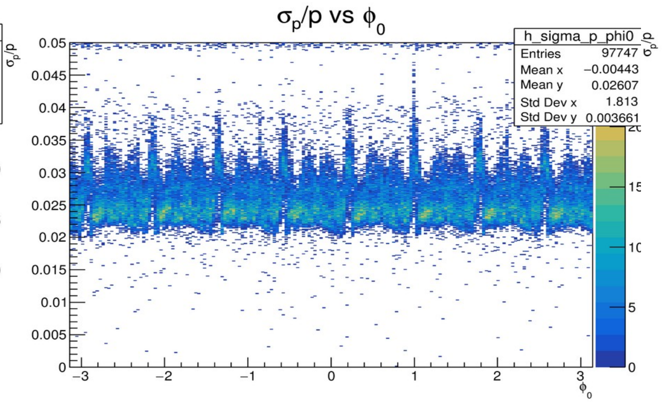


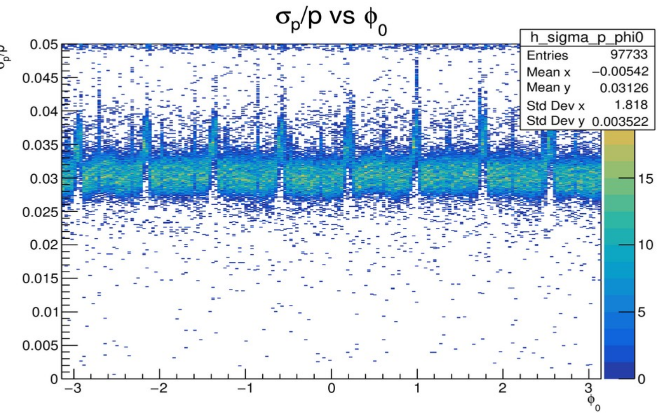




θ = 20°

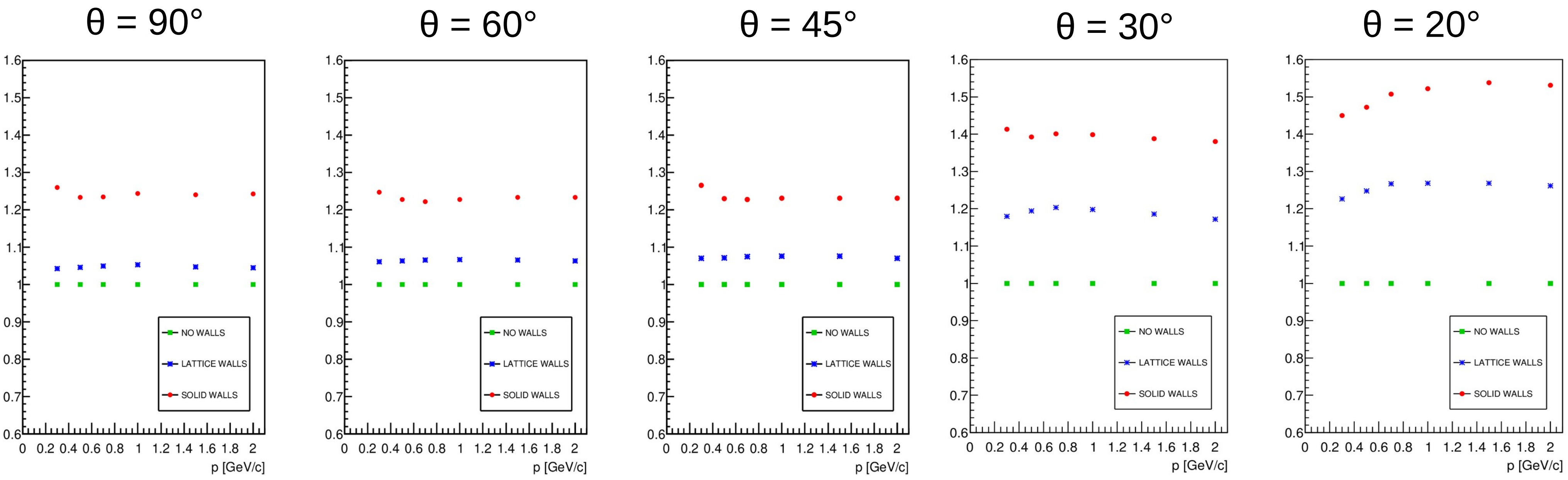






Impact of straw detector frame on momentum resolution

Relative increase of mean σ_p/p



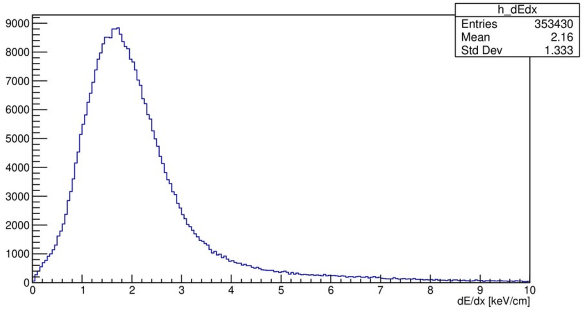
Particle identification via dE/dx method

- Energy loss of a particle crossing a certain amount of material depends on its velocity, which makes it possible to distinguish between particles of different masses and the same momentum.

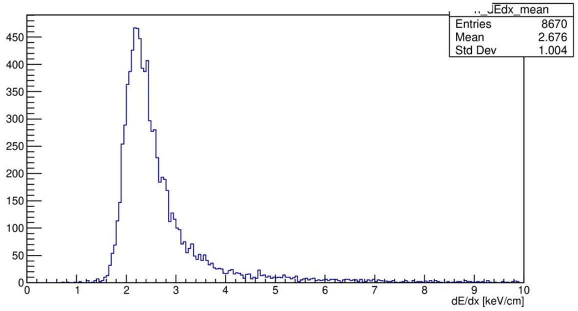
- However, energy losses in individual tube have large fluctuations following Landau distribution, with large “tail”.

- That’s why, a truncated mean approach is applied, where for each track a certain fraction (35%) of highest dE/dx measurements are discarded, and mean of the rest is calculated.

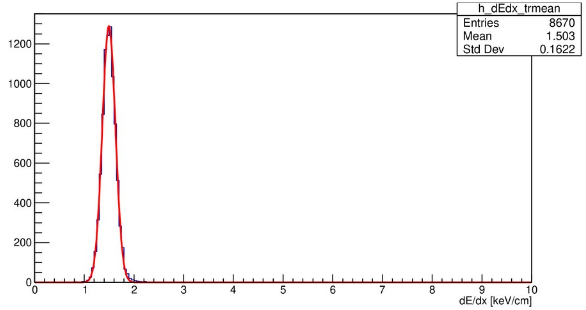
d*E*/d*x* in one hit



Mean d*E*/d*x* of track



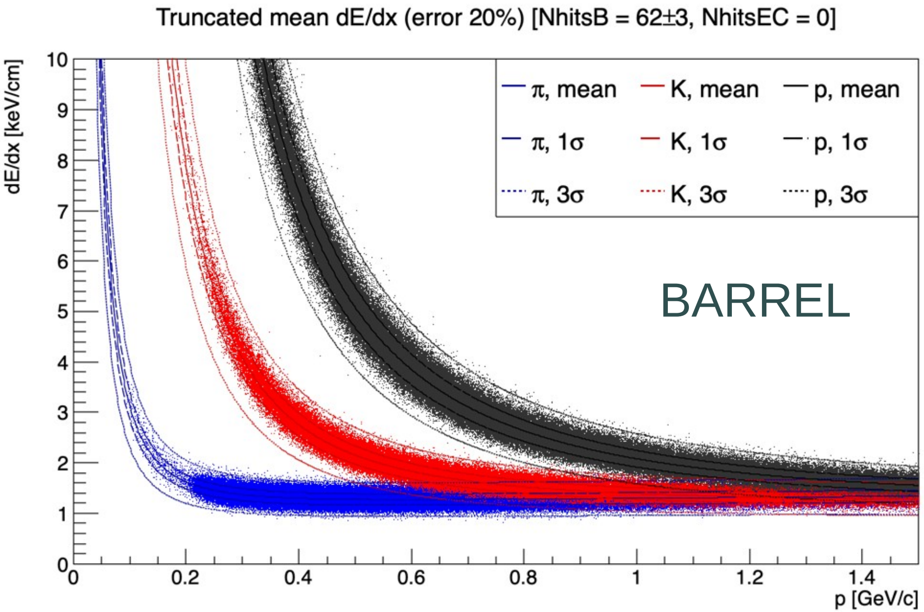
Truncated mean d*E*/d*x* of track

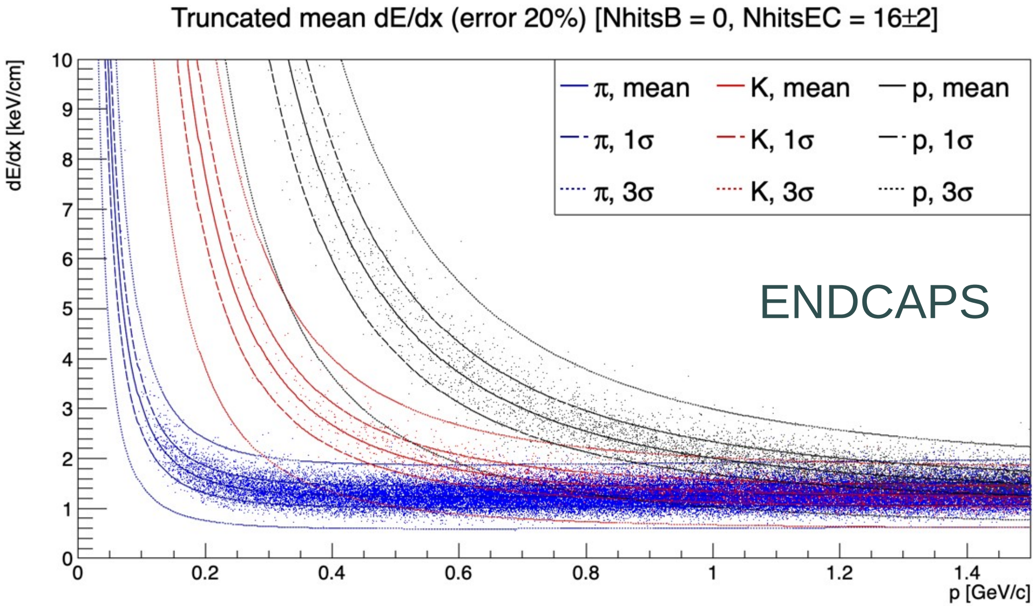


(example distributions for pions with p = 0.3 GeV/c)

Particle identification via dE/dx method

Truncated mean dE/dx distributions

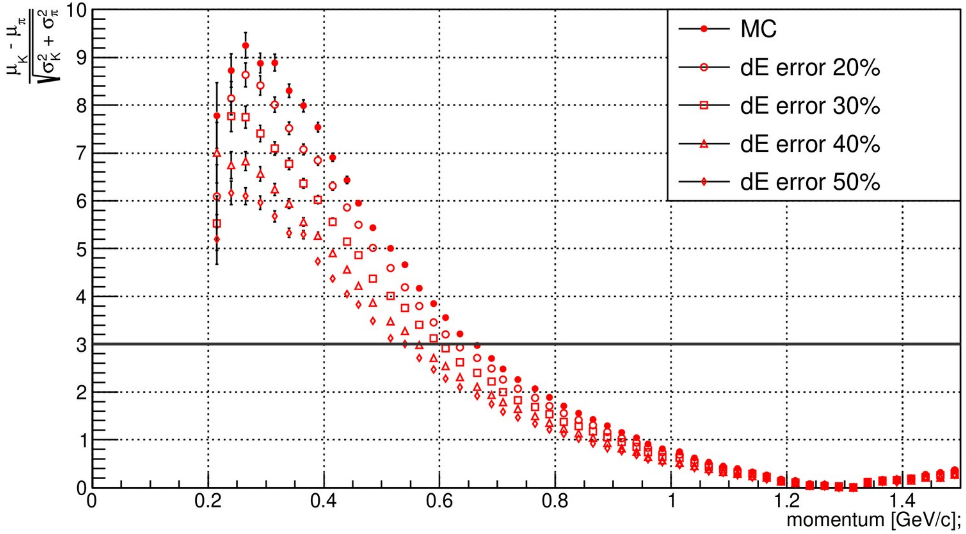




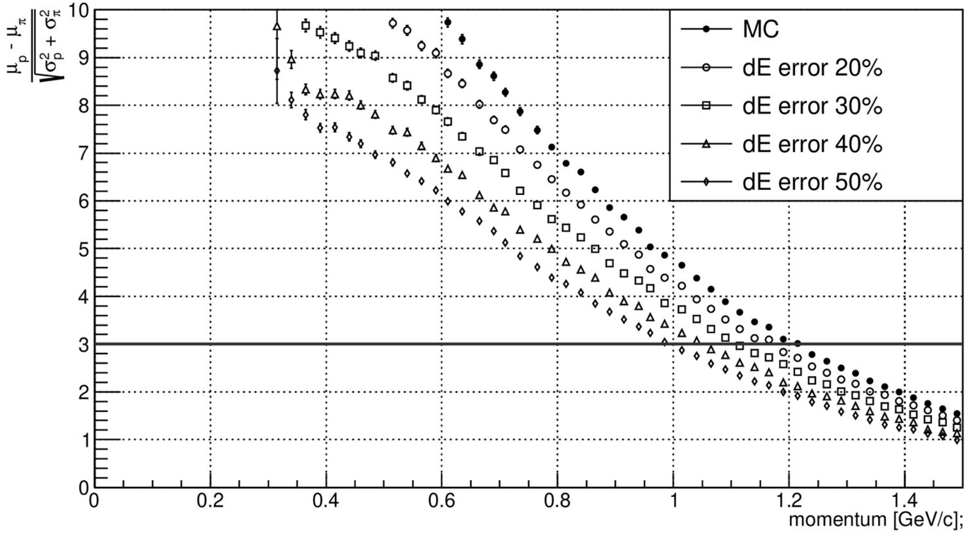
- Additional 20% error of dE was introduced to account for gas gain fluctuations.

Particle identification via dE/dx method

Pions vs kaons separation



Pions vs protons separation



Assuming energy loss measurement error ≈ 20%, for particles passing through the barrel (Nhits ≈ 62), pions can be separated from kaons at the level of 3σ for momenta up to 0.63 GeV/c, pions from protons - for momenta up to 1.17 GeV/c.

Summary

- Straw tracker is the main tracking detector of the SPD setup.
- Estimated momentum resolution σ_p/p of the tracking system of SPD is from 1% to 2.5%.
- Several Monte-Carlo simulations were performed to estimate influence of various factors on its performance:
  - Dependence of momentum resolution on straw tube angle in U and V layers was studied. It was found that any angle $\geq 2°$ is acceptable since momentum resolution almost does not depend on it in this region.
  - Impact of the power frame on momentum resolution was estimated. It is small for tracks crossing barrel through the sides (factor ~1.05) and moderate for tracks crossing it through the ends (factor ~1.2).
- It was also shown that straw tracker can contribute to particle identification at small momenta ($\leq$0.6 GeV/c for π/K separation, $\leq$ 1.1 GeV/c for π/p separation). This capability is important for the first stage of SPD, when no other PID detector is included in the setup.