PANDA Muon System

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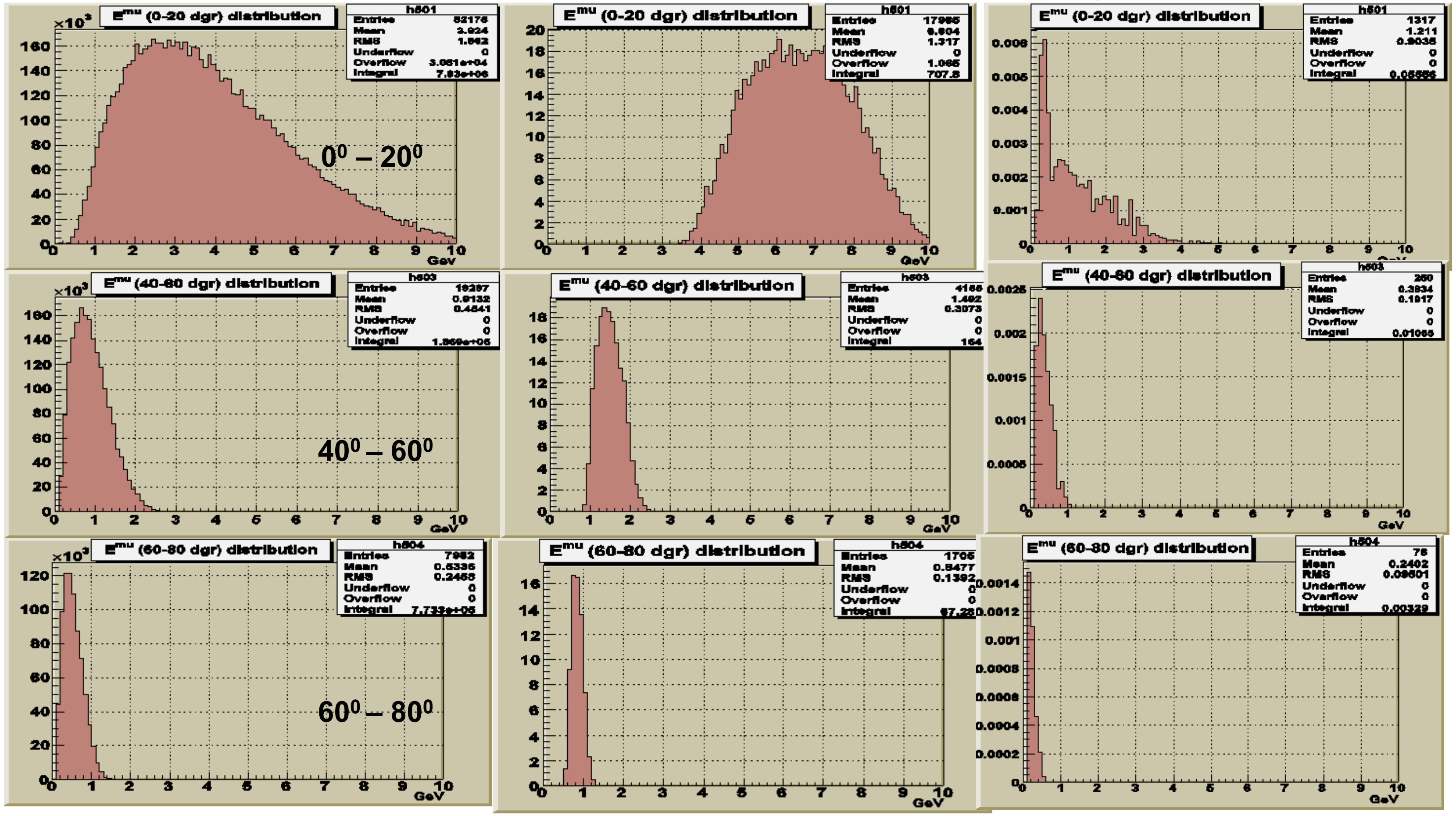
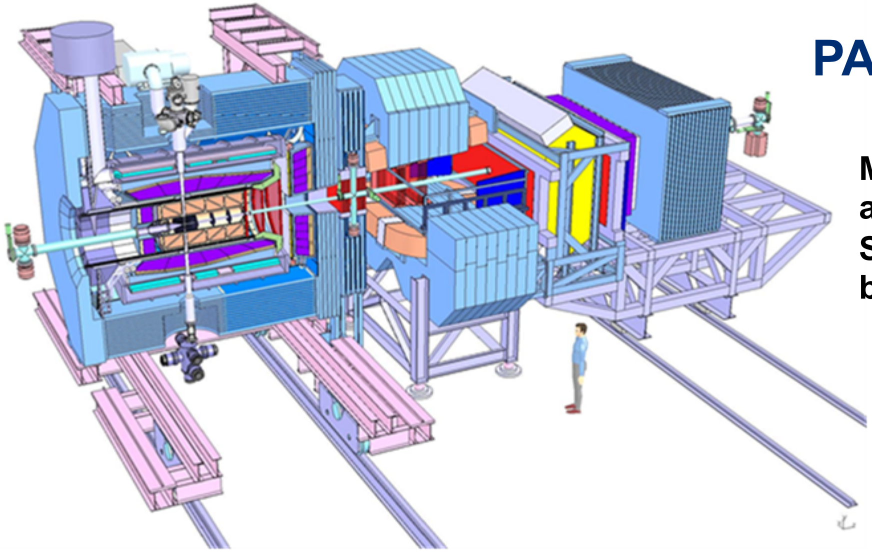
The muons are important probe for J/Ψ decays, semi-leptonic D-meson decays and the Drell-Yan process. As a benchmark process for Muon system (Range system) optimization we use Drell-Yan process because his muon pairs have maximal energy spread which covers the spectra of other processes of interest with muons in the final states, like those originating from J/Ψ and D-mesons.

Di - muon production | **J/Ψ** production | **D - meson** production (non-direct)





PANDA setup

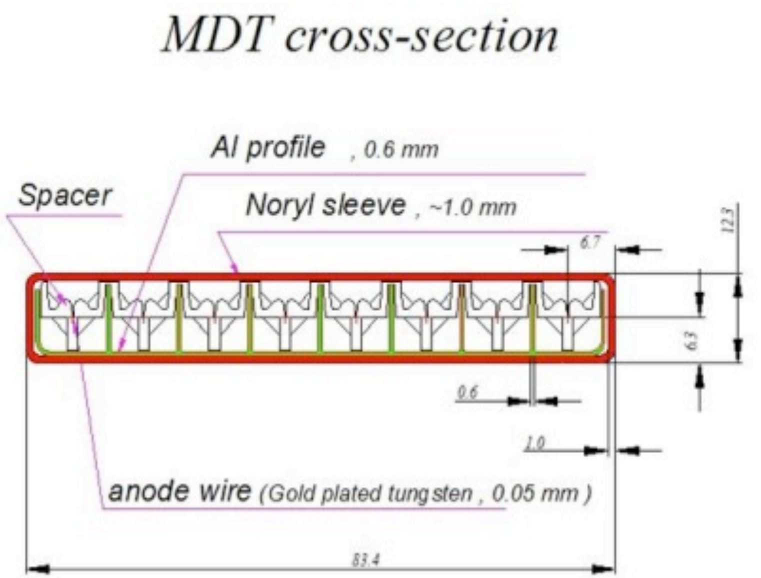
Muon system as a Range System(RS) structure which is aimed for identifying of low/high-momentum (Target Spectrometer/Forward Spectrometer) of primary muons and background contamination from pions and decaing muons.

Keeping in mind the specific dependence of muon energy on the polar angle at PANDA kinematics we arrive to the current muon system layout: MDT layer/absorber plate sandwich. The Range System will consist of fine segmentation yoke as a hadrons absorber interleaved by layers of Mini-Drift Tubes (MDT)

The Mini-Drift Tubes (MDT) were proposed as detectors to PANDA Collaboration by JINR/Dubna group as optimal choice for the muon system. The motivation includes:

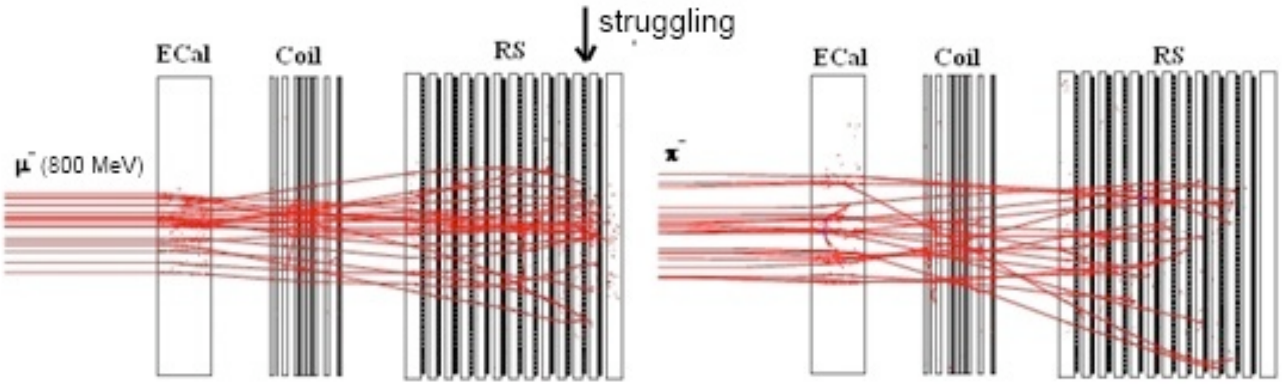
- features of detector comprising: good spatial resolution, simplicity and flexibility of design, small ageing;
- performance of MDT's in muon systems which is proven in the big experiments like D0 at FNAL (6300 detectors, 50000 r/o channels) and COMPASS at CERN (1500 detectors, 12000 r/o channels);

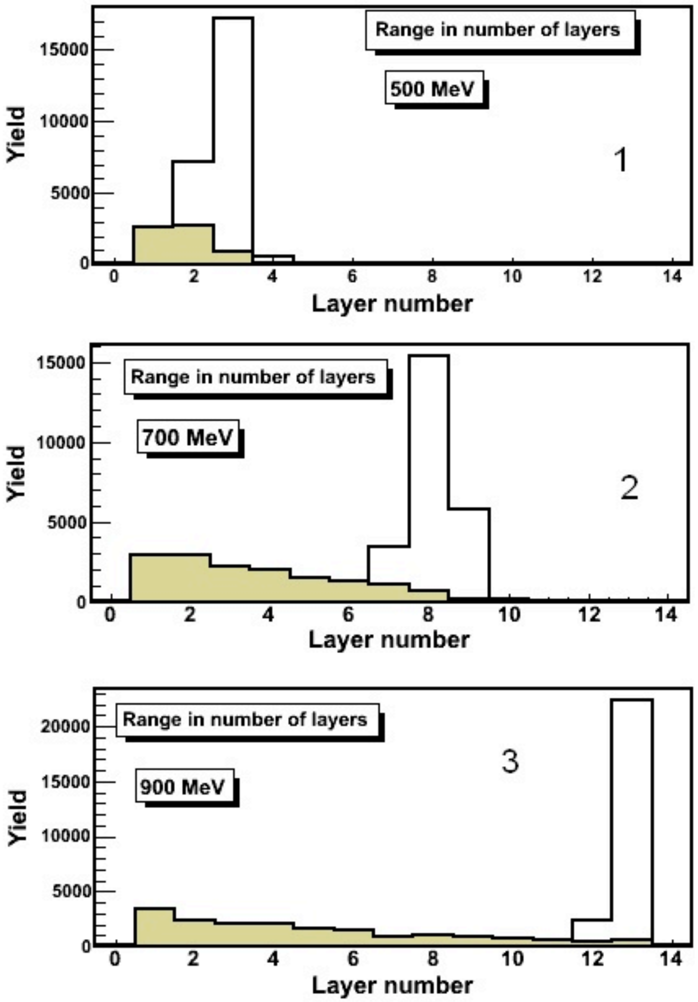
The MDT detector is the development of Iarocci tubes (streamer tubes) but uses proportional mode of operation instead of streamer and replaces the plastic cathode by the metallic one. The MDT detector comprises the following parts: metallic cathode - aluminum extruded comb-like profile and stainless steel cover (not shown on this figure) anode wire and plastic envelop for gas tightness.



Target Spectrometer: Barrel

Detailed study of the RS response on muon/pion beams has been done by simulating of passage of particles through the RS prototype layout made on the Monte Carlo (MC) approach.

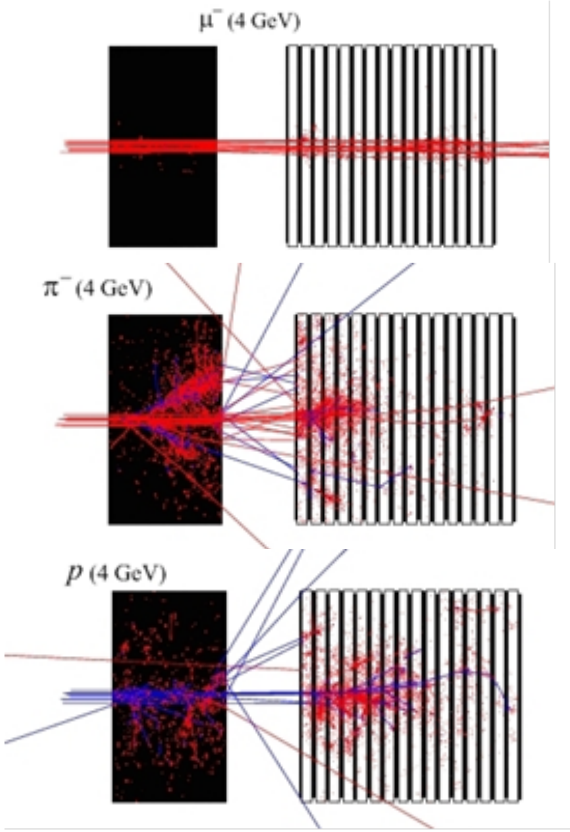




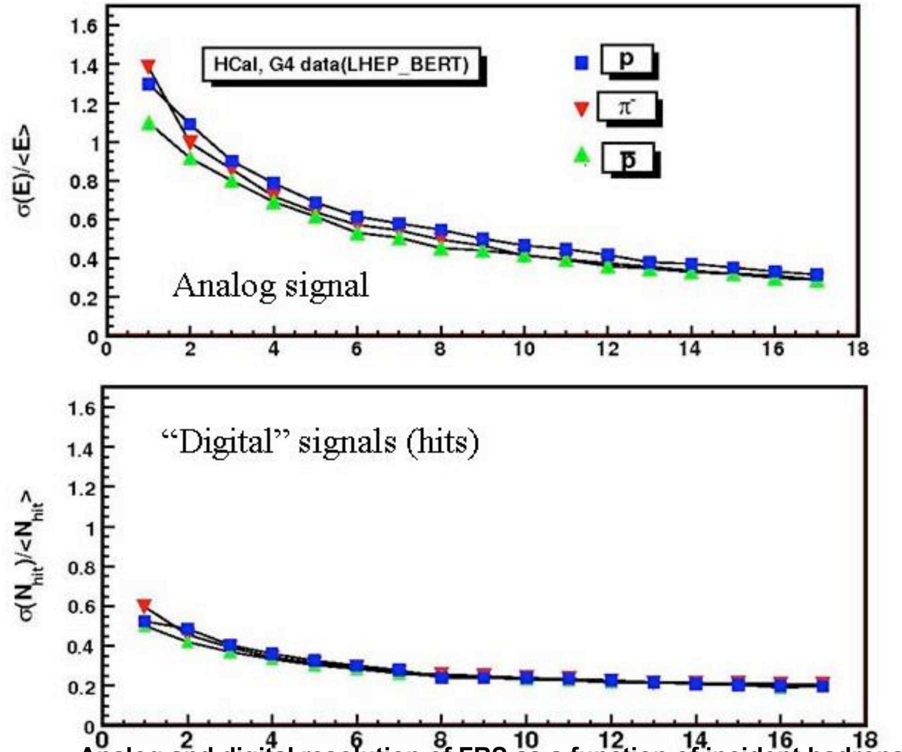
RS prototype for PANDA muon system

The dynamical energy range depends only from the number of layers of sampling calorimeter. We come to the most important future of RS: the muons can be distinguished from hadrons by the range in sampling calorimeter.

Forward Spectrometer: Forward Range System

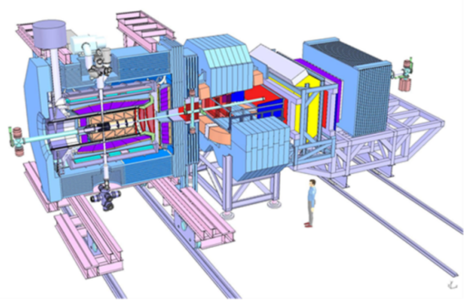


At high energies hadron mostly produces a hadronic shower whereas a muon has a sample of "straight" line spoiled by the multiple scattering. This situation is true for the Forward Spectrometer where particles enter with relatively high energies.

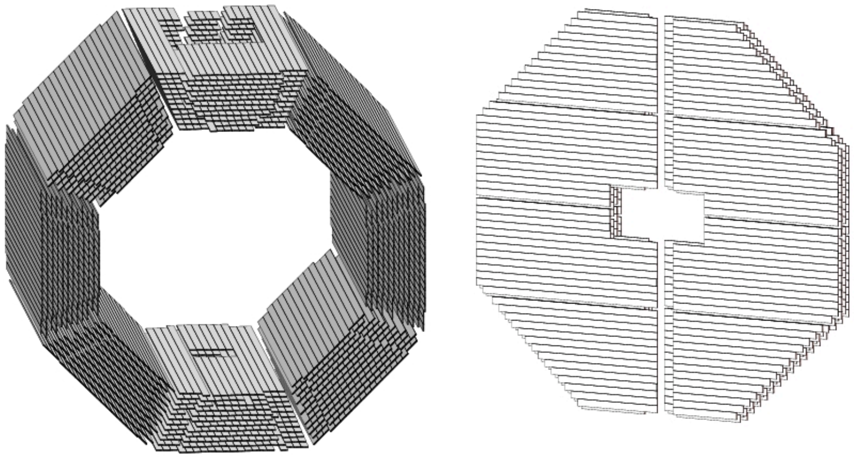


Analog and digital resolution of FRS as a function of incident hadrons with different energies.

The important feature of RS due to its laminated structure is possibility to be used also as a sampling hadron calorimeter. This is important for the Forward Spectrometer at the very end of the PANDA setup where the energies of coming particles are maximal (up to 10 GeV). The MC study performed with corresponding RS structure (16 layers, each 6 cm thick) has shown that energy resolution for hadrons is acceptable. This study also demonstrates that digital r/o of information (wire hits only) provides much better energy resolution than the analog one, when total charge deposition is measured . Above obvious physical meaning that promises a great saving in the cost of front end electronics.



Overview of Muon system in Pandaroot setup



<u>Muon system in Pandaroot :</u>

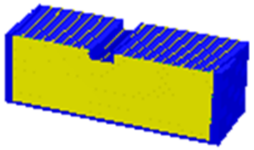
Barrel: 12 layers inside the yoke + "zero" bi-layer;

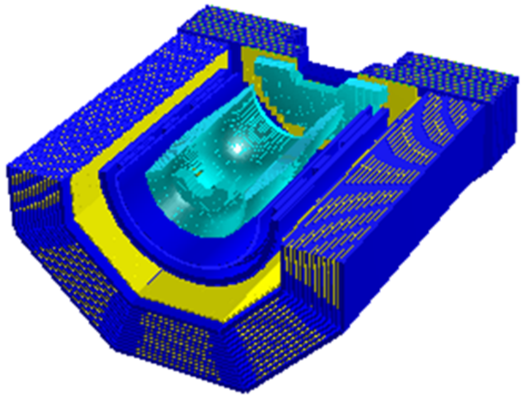
Endcap: 5 layers + "zero" bi-layer;

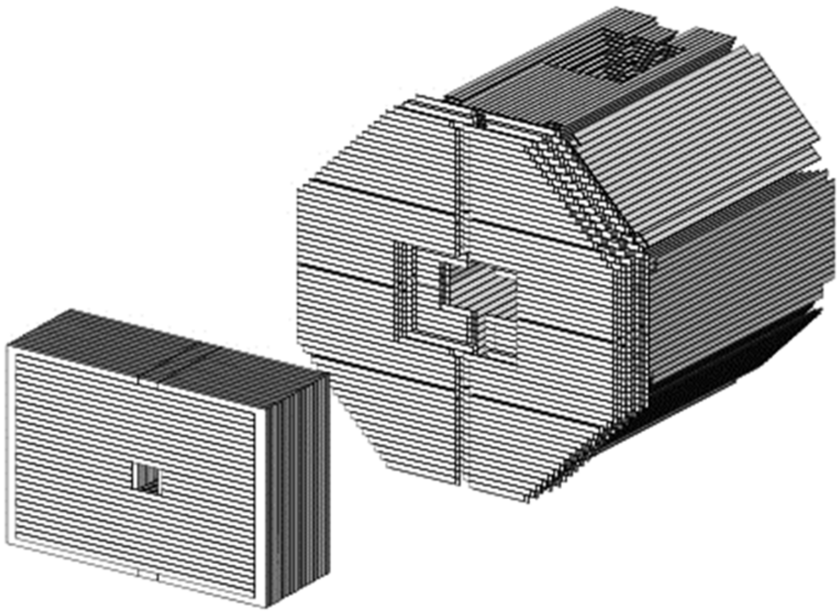
Muon Filter: 4 layers;

Forward Range System: 16 layers + "zero" bi-layer.

Target Spectrometer (barrel&endcap):	muon_TS_barrel_v3.root
Muon Filter:	muon_MF.root
Forward Range System:	muon_FS.root







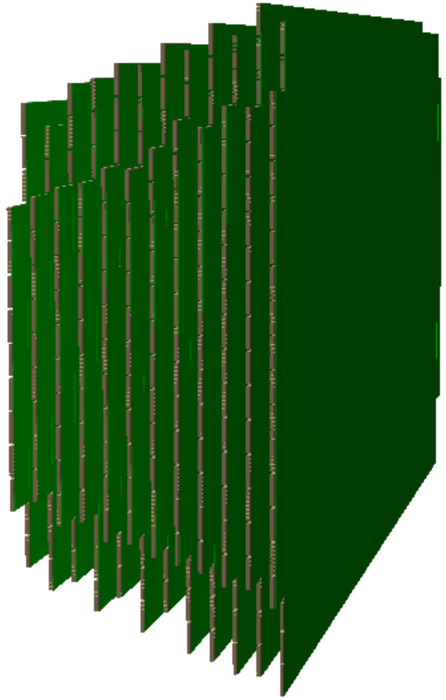
The geometry description of strips (barrel) in PANDAroot.

Strips in Pandaroot:

The MDT design permits also to use it as two-coordinate detector by readout of induced signal on external sample of electrodes (strips or pads).

G10 strip board + copper strips with 1 cm pitch.

Barrel (12+2 layers): ~37K strips ↔ 2135 MDTs.

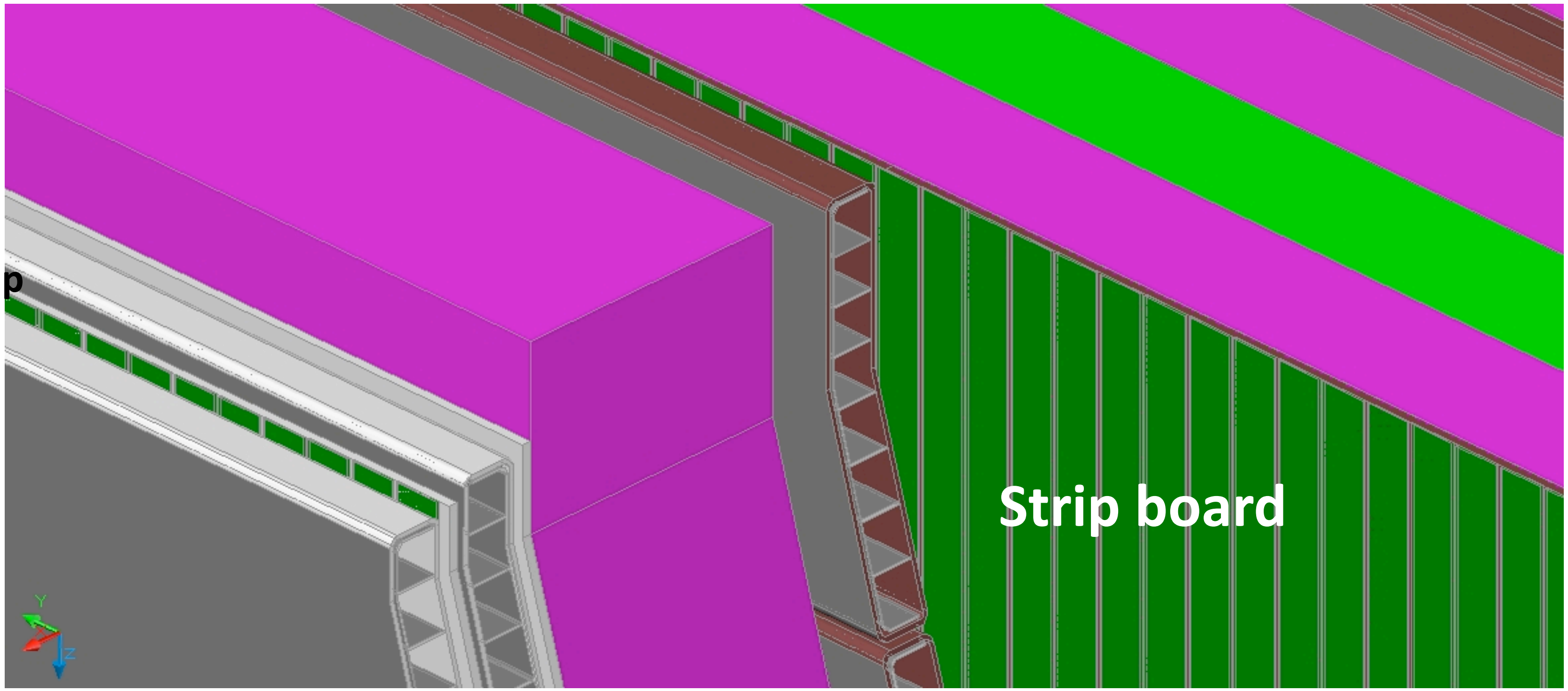


Barrel octant (MDTs + strips)

MDT layer **Fe 3cm**

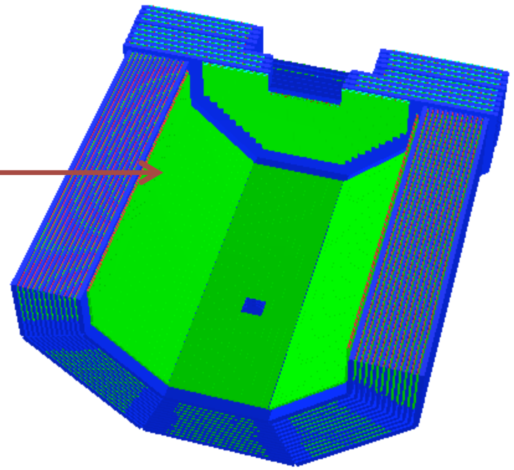
Fe 6 cm

“Zero” bi-layer+ double sided strip board



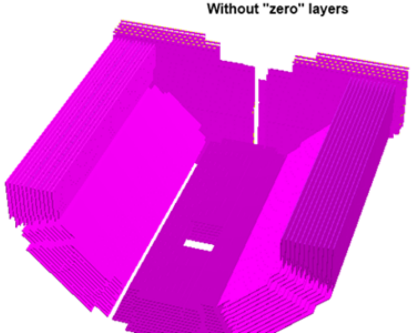
Geometry acceptance study of muon system in Pandaroot by measuring μ^- registration efficiency.

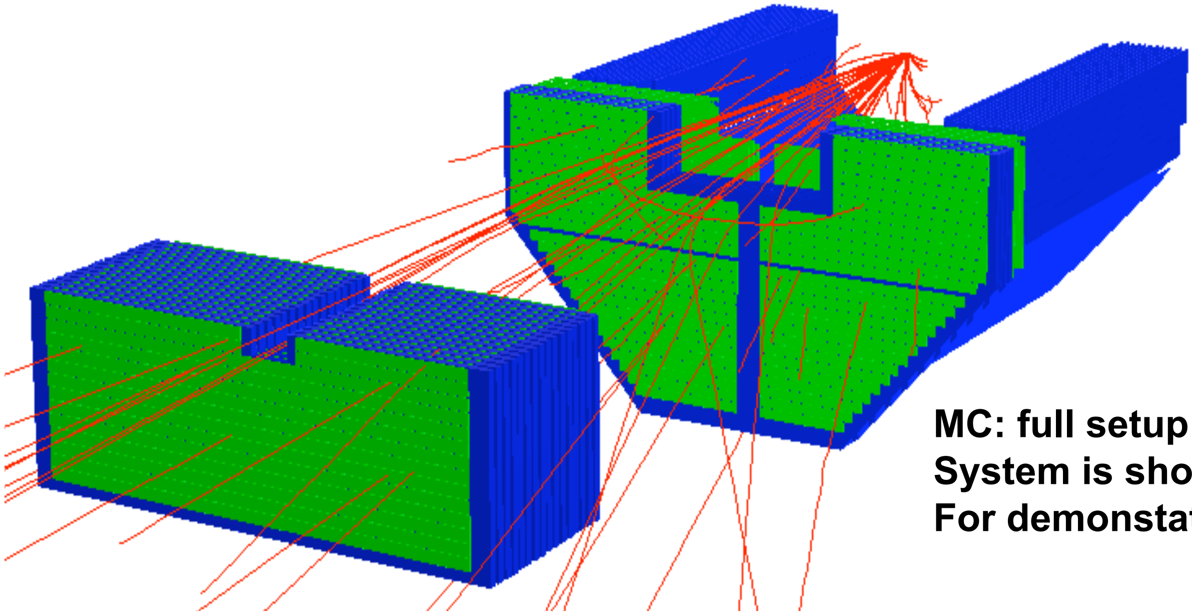
Event generator: PndBoxGenerator.
μ^- (1÷12)GeV/c with step 1 GeV/c ,
uniform distribution over ($\theta=0^0\div140^0$, $\varphi=0^0\div360^0$),
full PANDA setup, with field (solenoid & dipole).
Option: with/without "zero" bi-layers in Barrel&Endcap.



selection criterion for μ^- registration in muon system:
at least one hit in Muon System.
No hit -> missing event.

Layout of PANDA muon system (barrel&endcap) without yoke
Without "zero" layers





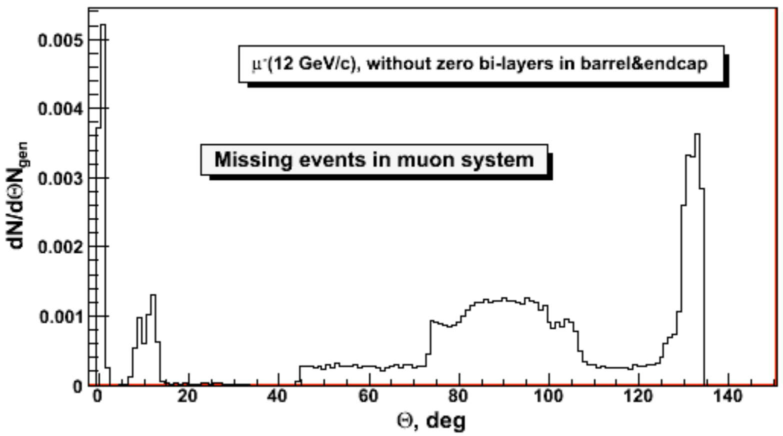
MC: full setup calculation. The only Muon System is shown.
For demonstation: 80 μ^- in one event.

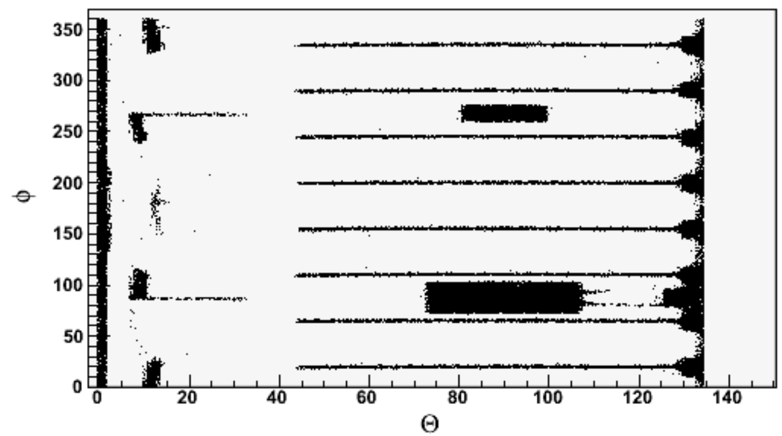
μ^-@12 GeV/c

Inefficiency vs polar angle

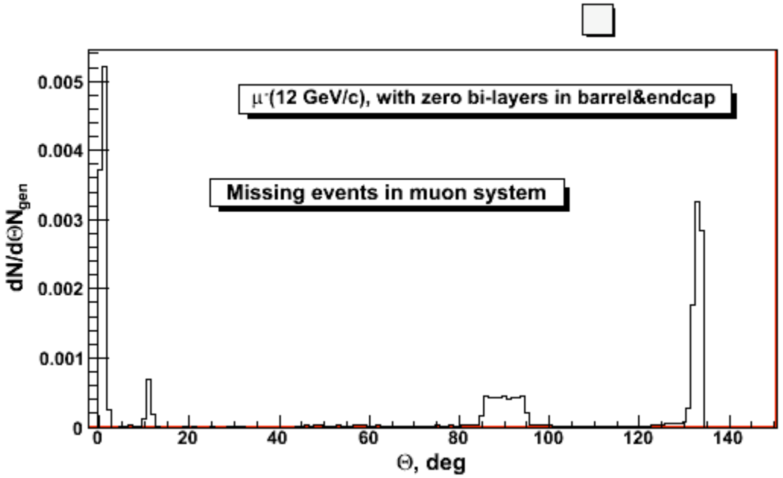
Inefficiency (θ,φ) scatter plot

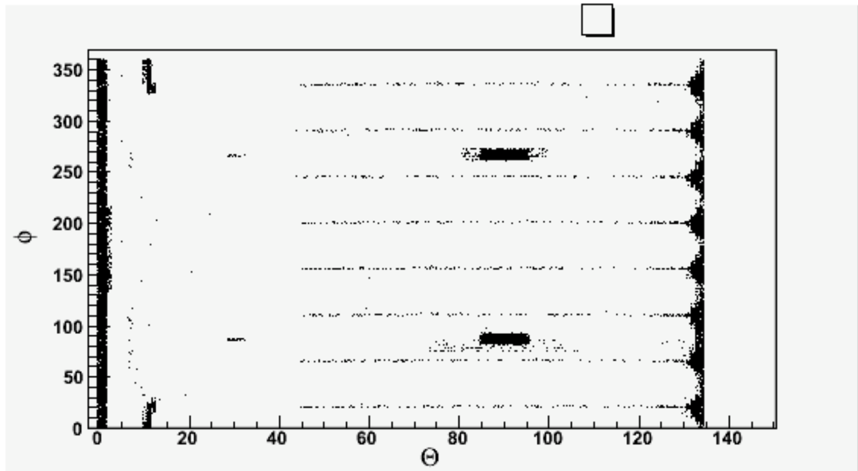
"Zero" layer
OFF





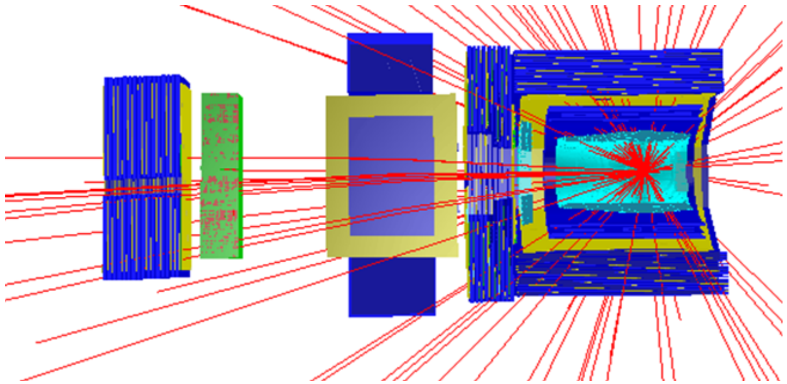
"Zero" layer
ON





"Negative" picture of lost muons

1) Missing events as a function of polar angle of generated muons (left row) without/with "zero" layers .
2) Missing events as a function of polar and azimuthal angles of generated muons (right row) without/with "zero" layers .

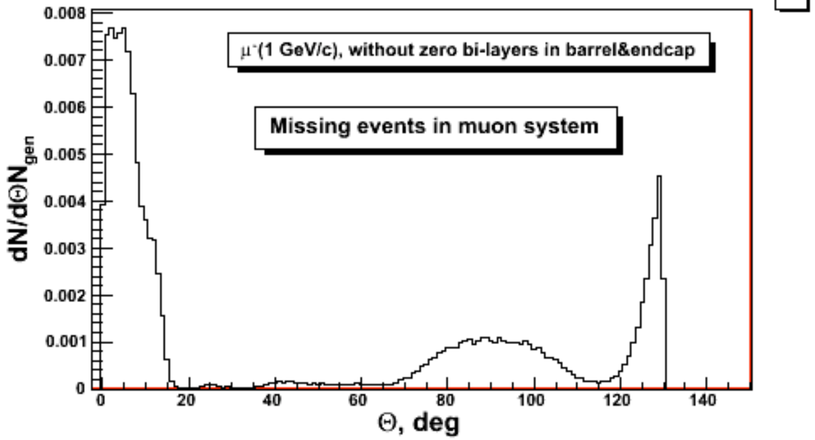


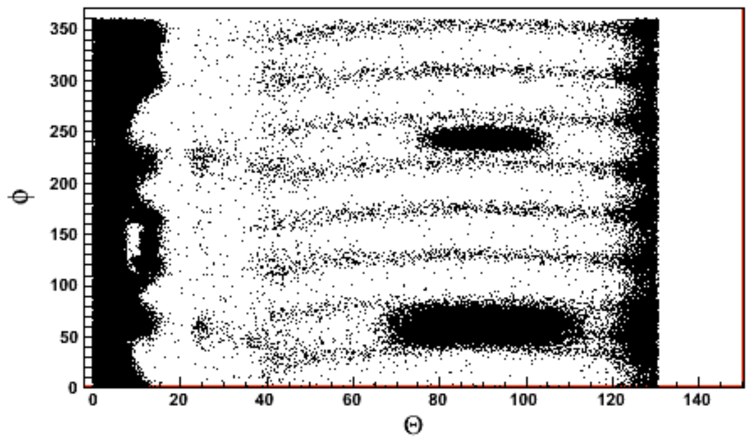
μ^-@1 GeV/c

Inefficiency vs polar angle

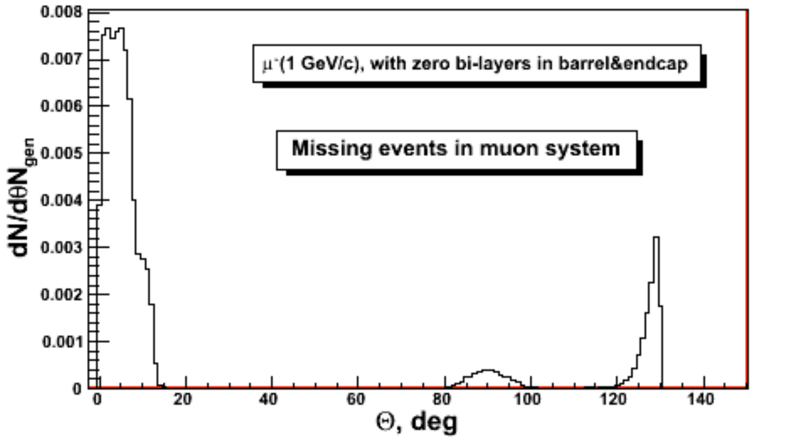
Inefficiency (θ,φ) scatter plot

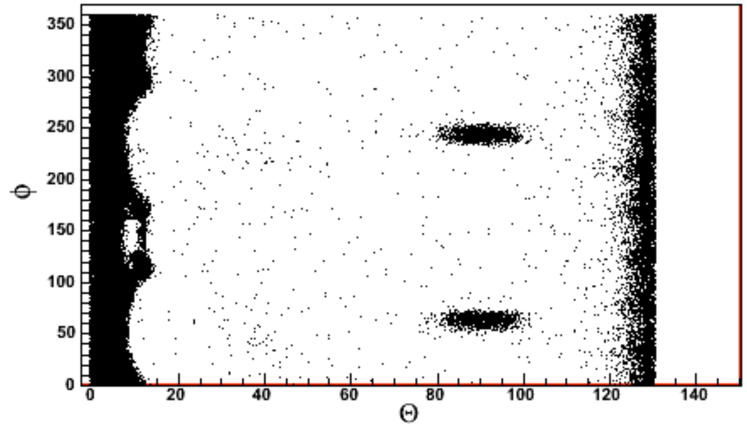
"Zero" layer
OFF



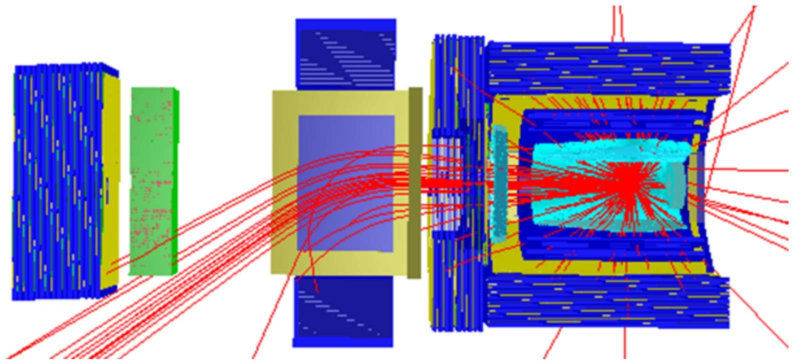


"Zero" layer
ON

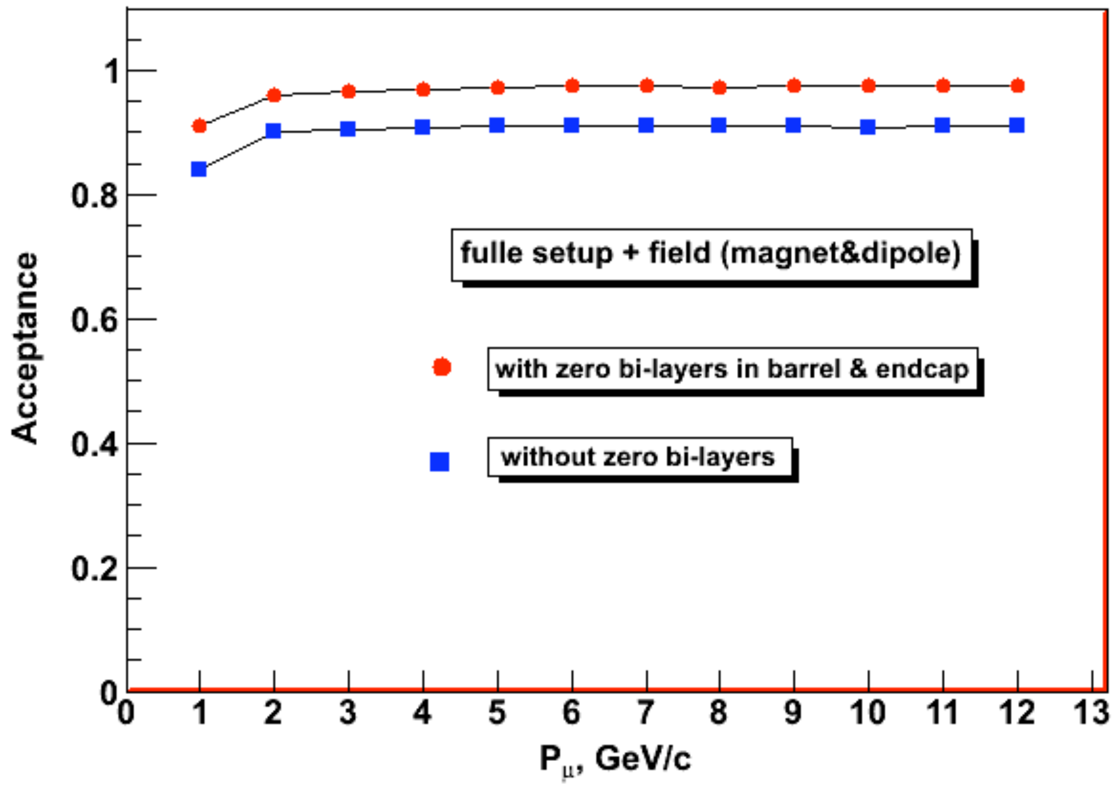




"Negative" picture of lost muons



Geometry efficiency (acceptance) of PANDA muon system

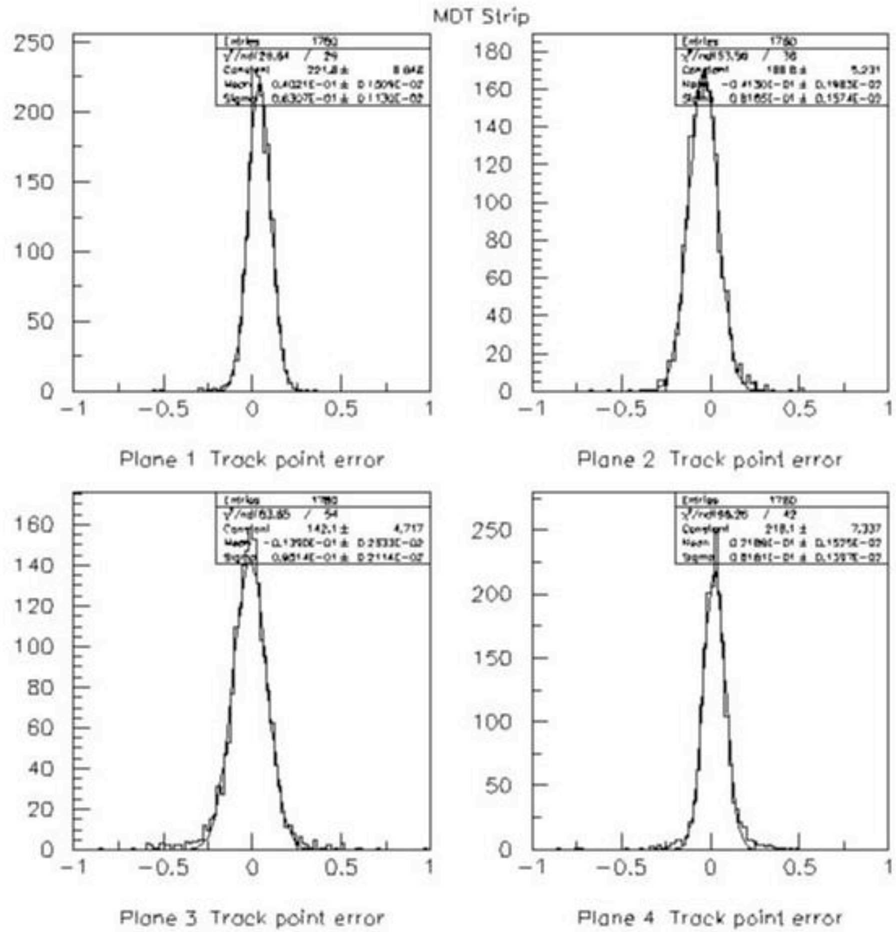


The calculated efficiencies are: 91% (at 1GeV) and 98% with "zero" layers
81% (at 1GeV) and 87% without "zero" layers.

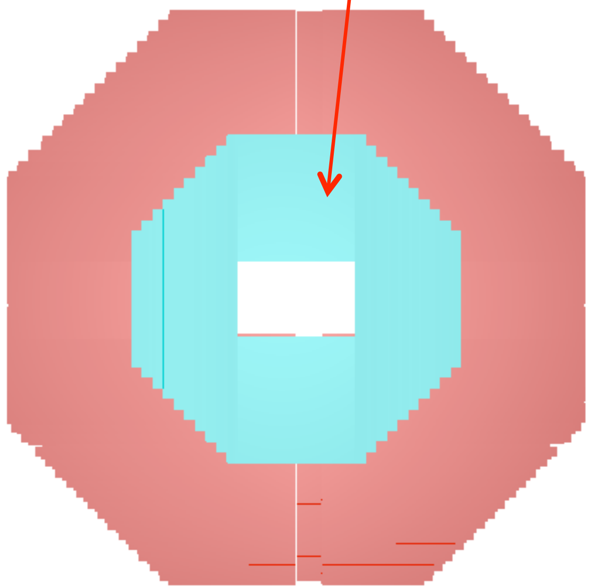
Technical Design Report for the PANDA Muon System (draft #1)
XXXVI PANDA Collaboration (GSI, March 14–18, 2011).

Backup

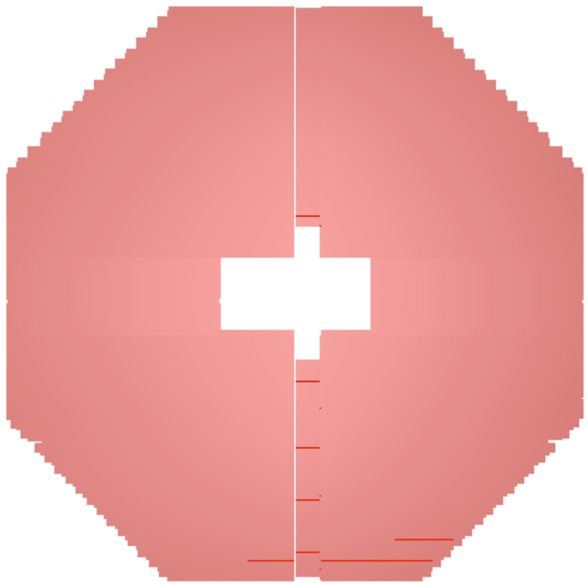
R&D works conducted at JINR/DLNP test stand has demonstrated the possibility to readout the second coordinate through registration of small (smaller than typical cathode pulse) induced pulse on the system of external pickup strips perpendicular to the MDT wires. In this case the setup was small enough: 4 planes of 40 cm long MDT's and only 8 cm long strips (1 cm wide). This lab experiment has demonstrated two important things: first, principal feasibility to readout a second coordinate from MDT and, second, possibility to use standard amplifier Ampl-8.3 in two cascades without oscillations. The coordinate accuracy preliminary achieved with small strips in this small setup by the centre of pulse "gravity" measurement is around 0.5 mm r.m.s. (fig.9), which is comparable with typical coordinate accuracy for MDT wires in drift mode – 0.4-0.5 mm r.m.s. for comparable size detectors.



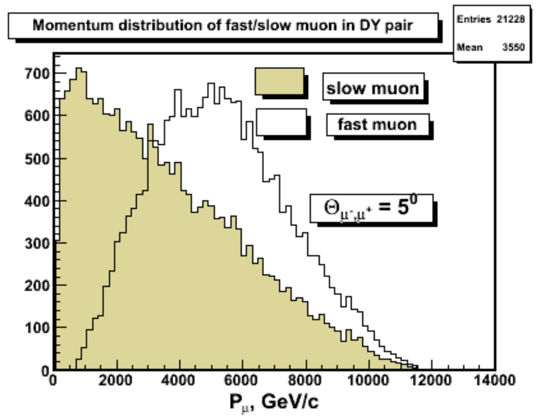
“Zero” bi-layer: two layers of MDTs (44/layer), shifted by 5mm each other, hole 460x920 mm, max tube size 1620 mm.

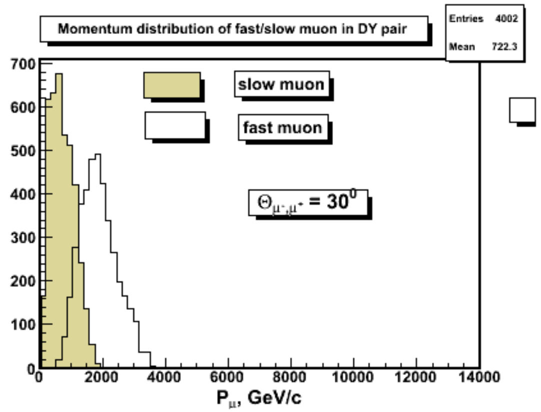


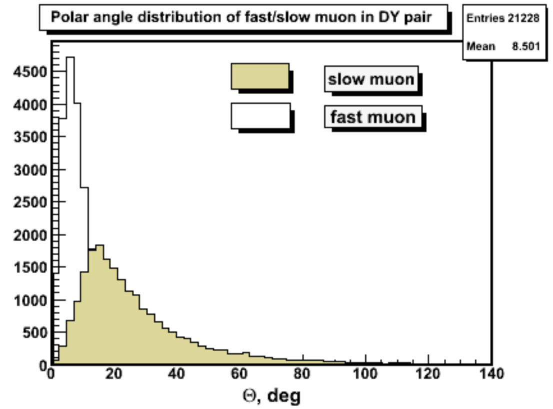
(X-Y) view of Endcap&MF with “zero”

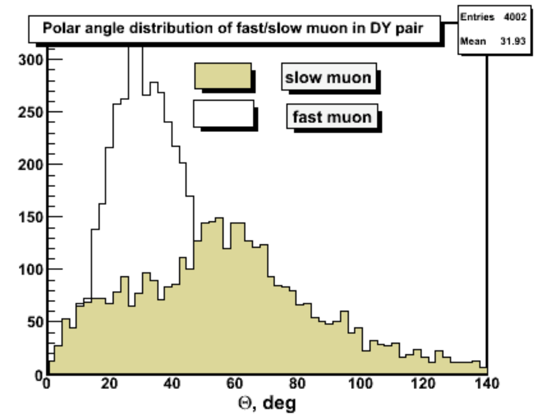


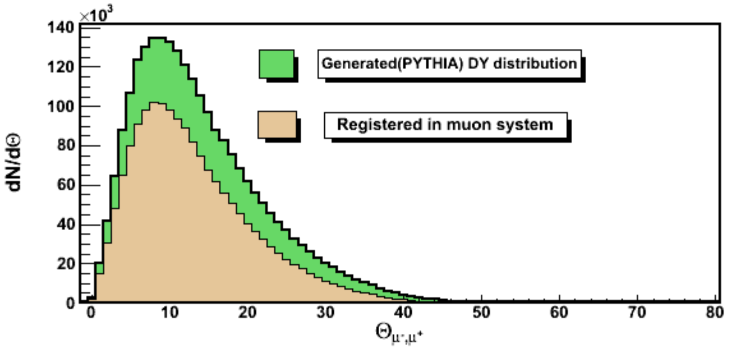
(X-Y) view of Endcap&MF without “zero”

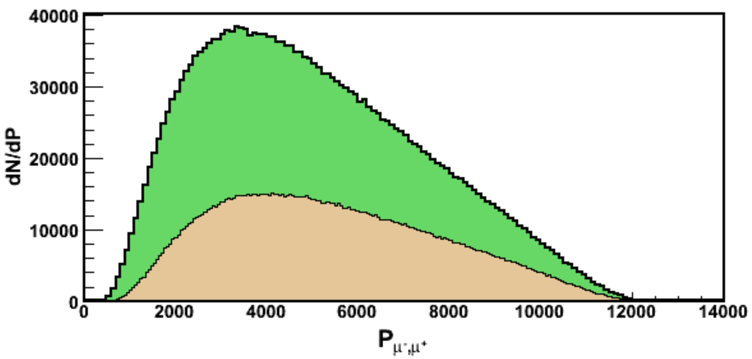

Momentum distribution of fast/slow muon in DY pair
Entries 21228
Mean 3550
slow muon
fast muon
$\Theta_{\mu^-,\mu^+} = 5^0$
P_μ, GeV/c


Momentum distribution of fast/slow muon in DY pair
Entries 4002
Mean 722.3
slow muon
fast muon
$\Theta_{\mu^-,\mu^+} = 30^0$
P_μ, GeV/c

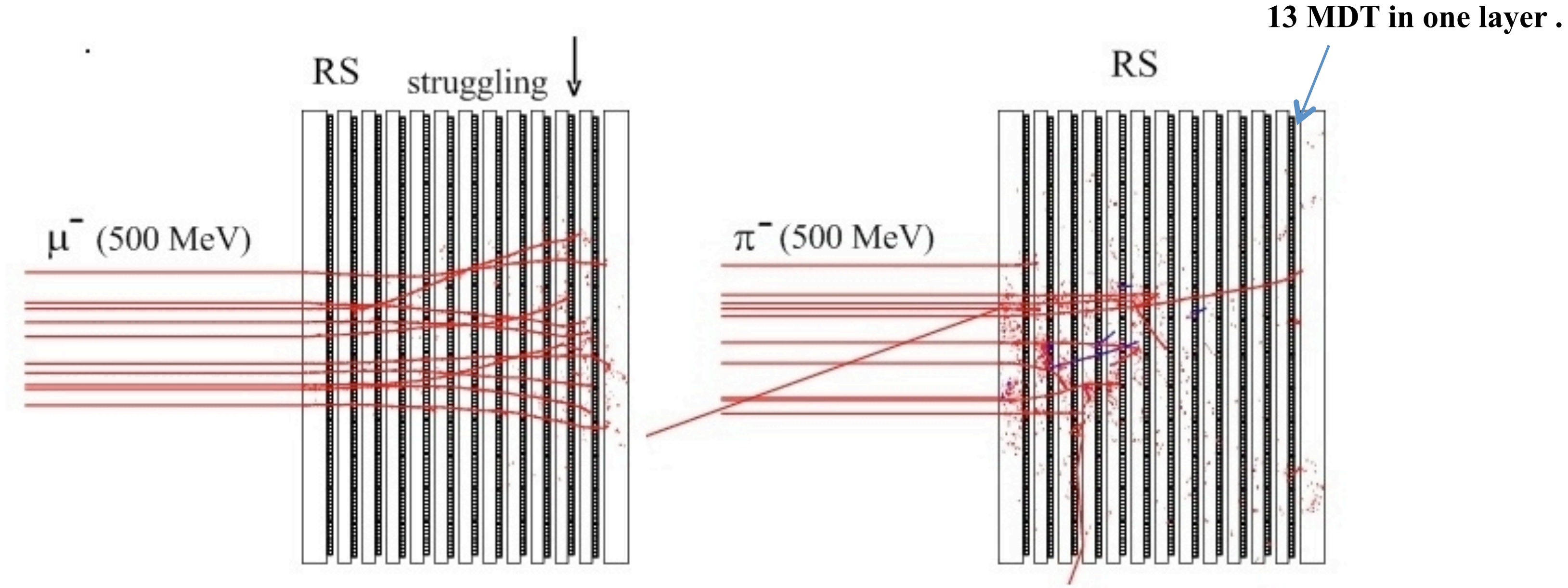

Polar angle distribution of fast/slow muon in DY pair
Entries 21228
Mean 8.501
slow muon
fast muon
Θ, deg


Polar angle distribution of fast/slow muon in DY pair
Entries 4002
Mean 31.93
slow muon
fast muon
Θ, deg


$\times 10^3$
Generated(PYTHIA) DY distribution
Registered in muon system
dN/dΘ
Θ_{μ^-,μ^+}


dN/dP
P_{μ^-,μ^+}

October – December 2009:
RS for PANDA TS simulations:
- RS response to hadron/lepton beams;
- Muon detection efficiency and background contamination

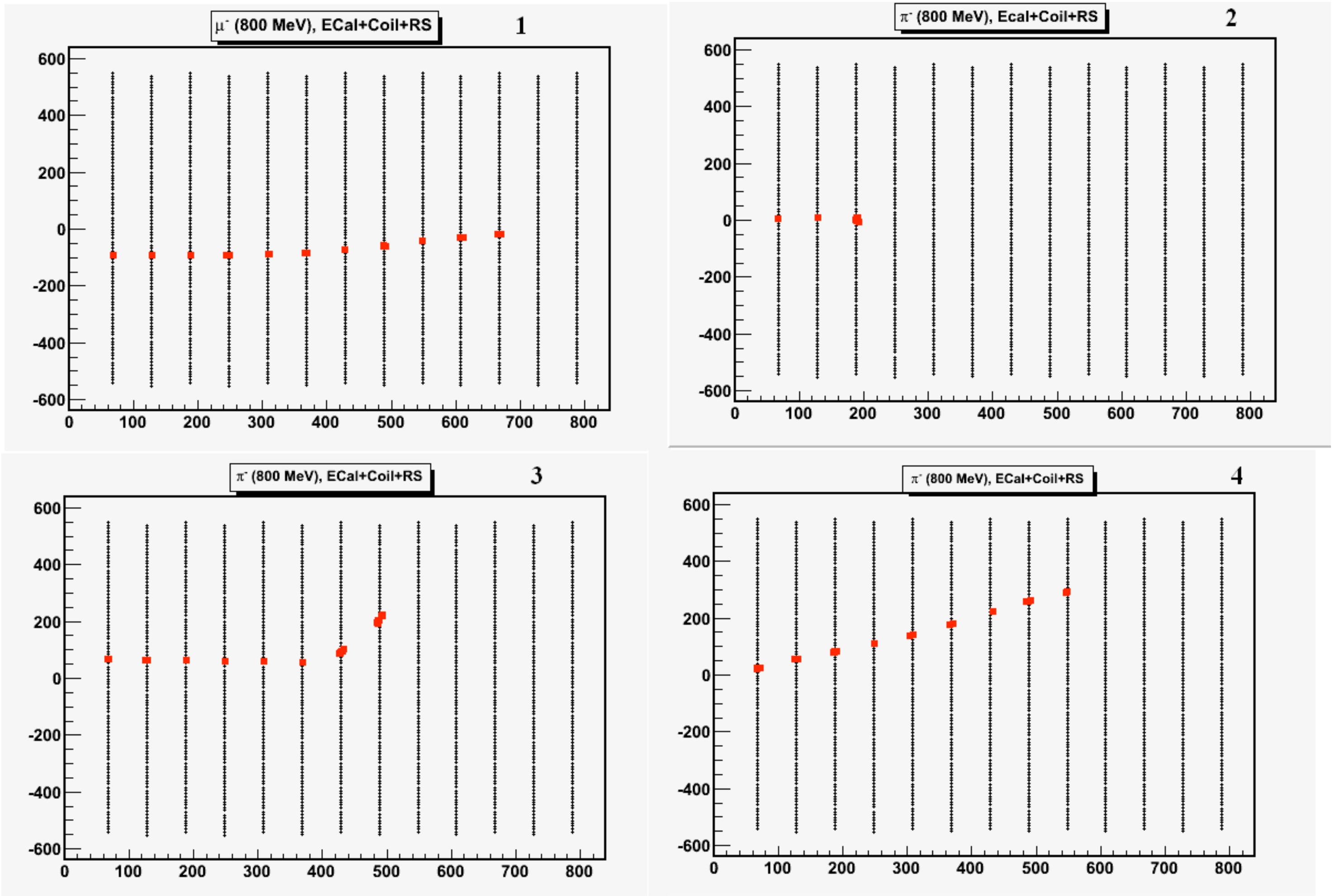


Response of RS to muons and pions at kinetic energy of 500 MeV.

October – December 2009:

RS for PANDA TS simulations:

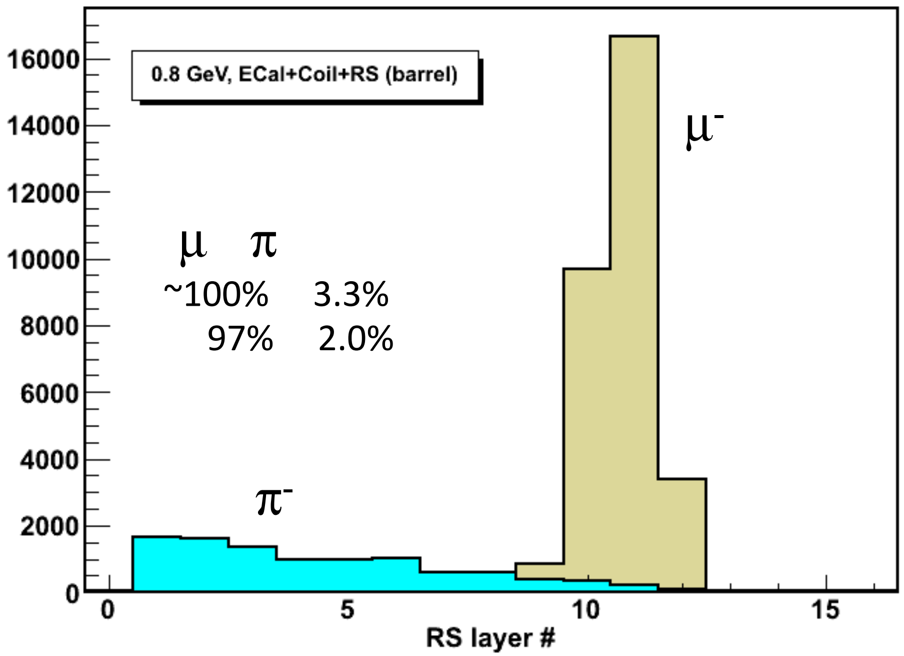
- RS response to hadron/lepton beams;
- Muon detection efficiency and background contamination

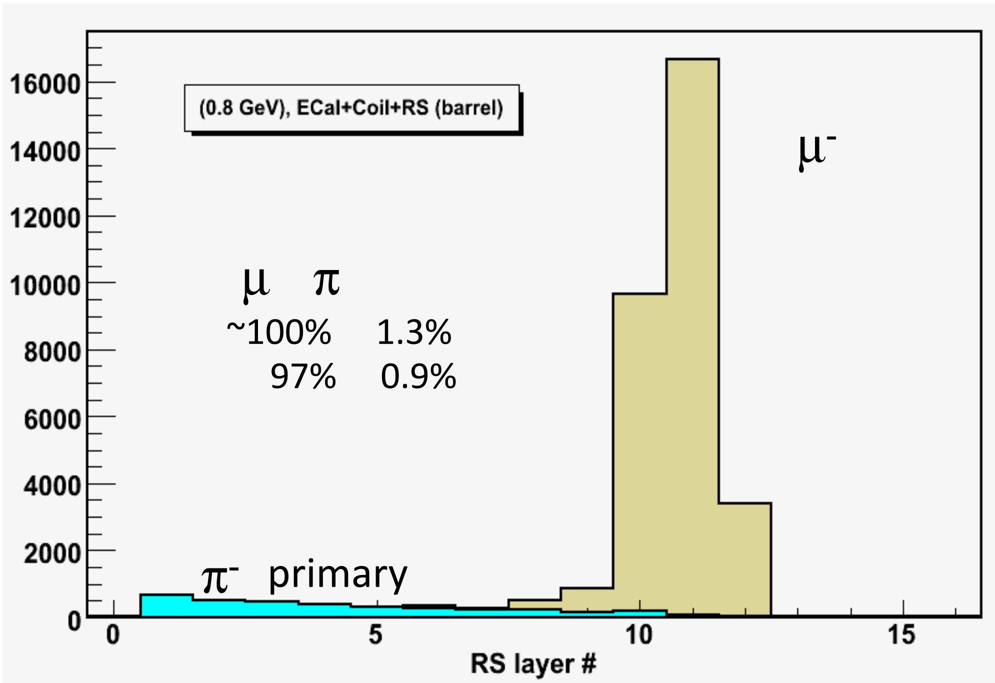


Typical hit pattern in RS for muon case (1) and pion cases (2-4).

(4) the pions passing through the RS at same depth without giving a shower or the muons from the pion decay (or cascade muons) are giving the same range in RS

π/μ separation in RS at 800 MeV





Superposition of distributions of particle ranges in RS for the case of pion and muon beams with initial kinetic energies. Distributions of particle ranges (in number of layers) for muon and pion (dashed) cases at initial beam energies of 800 MeV.

There are three sources of muon background given the same (muon-like) signal in RS:

1) pions transversing the passive material and iron absorber by energy losses process only;

2) cascade muons from pions giving a shower in passive material or iron absorber;

3) muons from pion decay (in flight) before electromagnetic calorimeter.

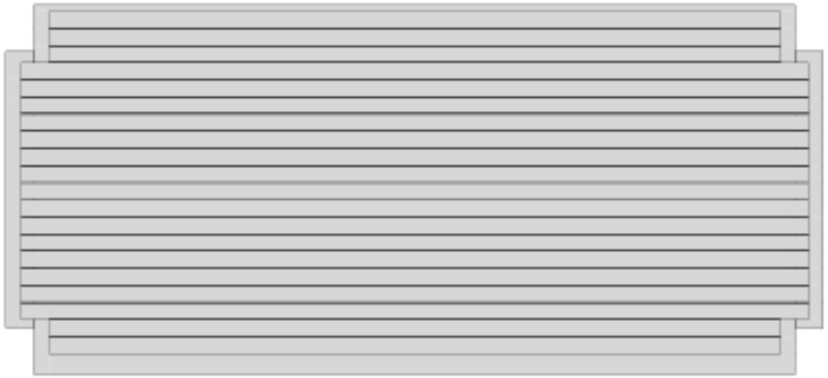
the more problematic source of background to the "true" muons produced closer to the production vertex

Short report: October – December 2009.

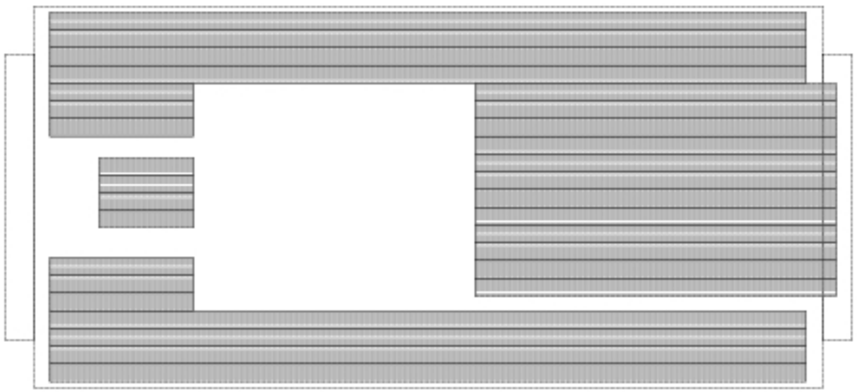
A GEANT4 based the RS for PANDA Target Spectrometer (TS) simulations.

RS design in Target Spectrometer.

- Detailed layout design of RS in Target Spectrometer;
- RS geometry file preparation for Pandaroot framework;

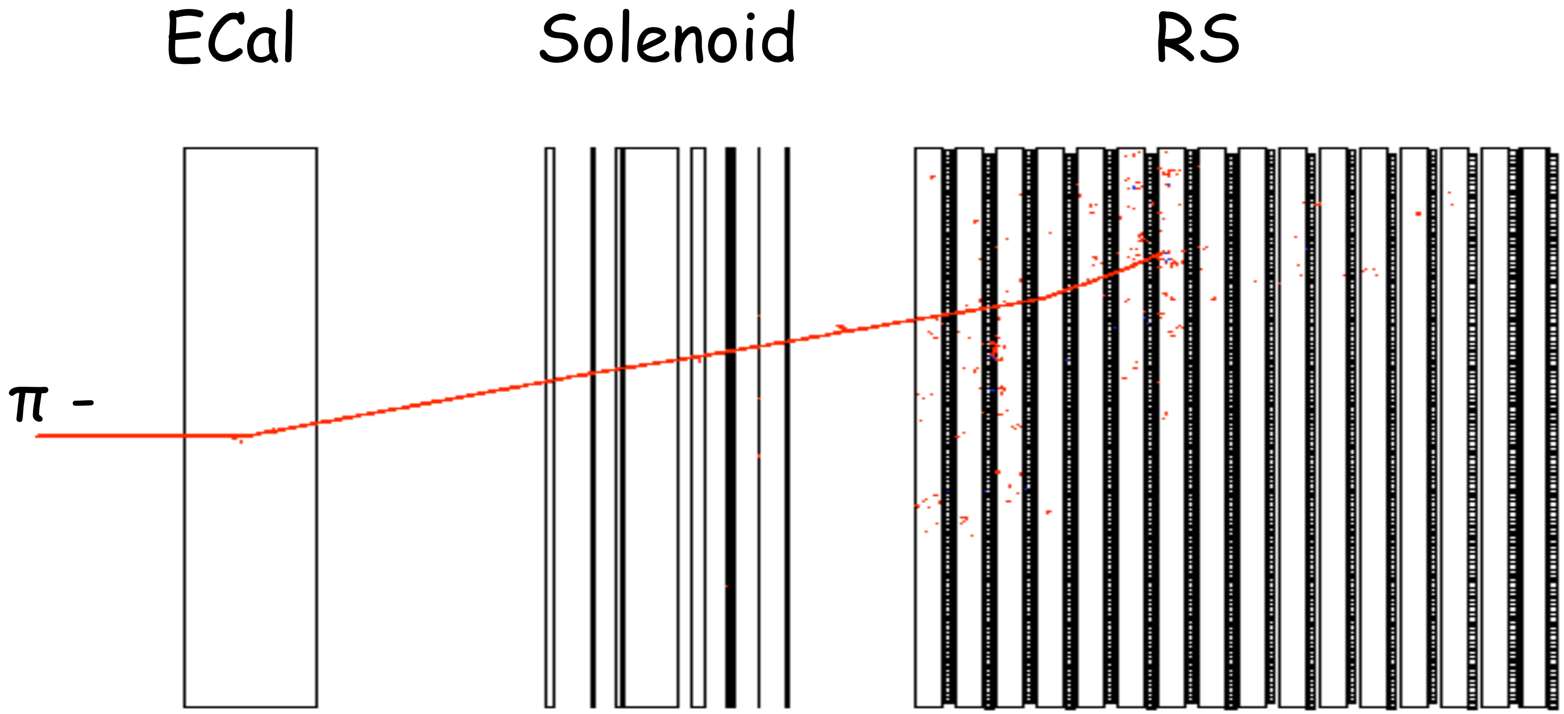


MDTs in PANDAroot for TS barrel side module, layer#12

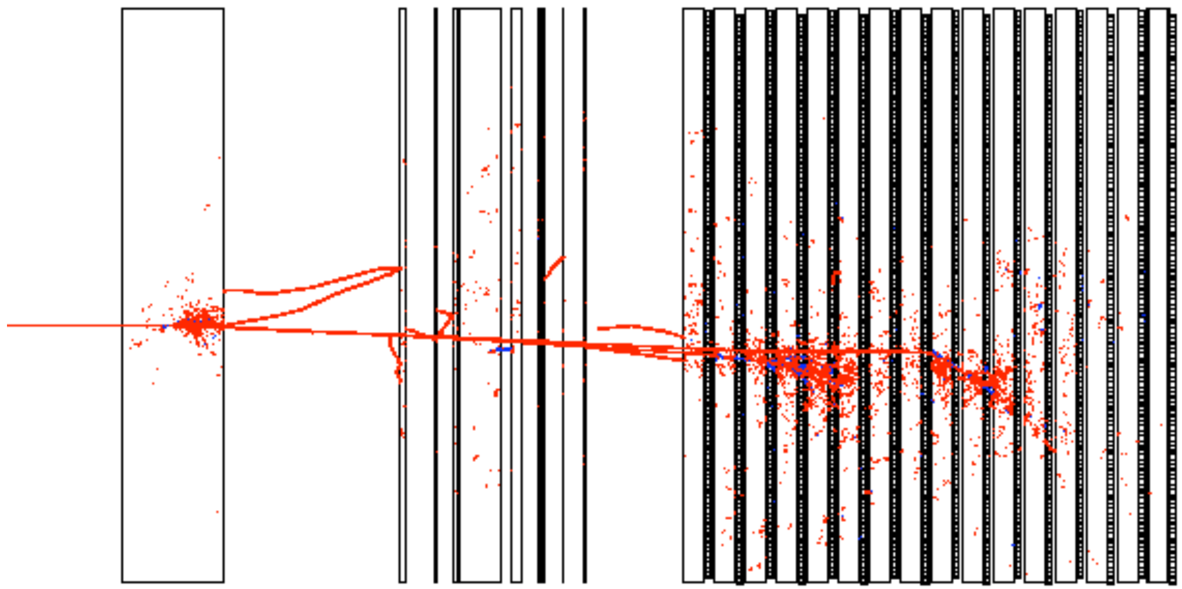


MDTs in PANDAroot for TS barrel top module, layer#12 (with target hole)

1 GeV pion shower



10 GeV pion shower



50 GeV pion shower