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THE TOMOGRAPH BASED ON DRIFT TUBE TRACK CHAMBERS FOR MUON REGISTRATION

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Introduction

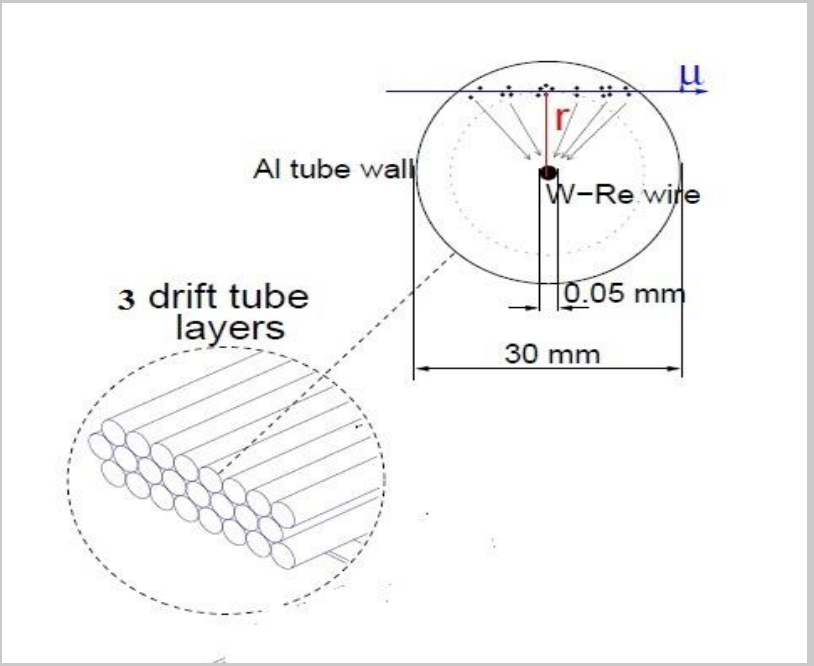
Drift chamber is the only cost effective way for charged particle tracking at large (~ 10 - 1000 m^2) areas .

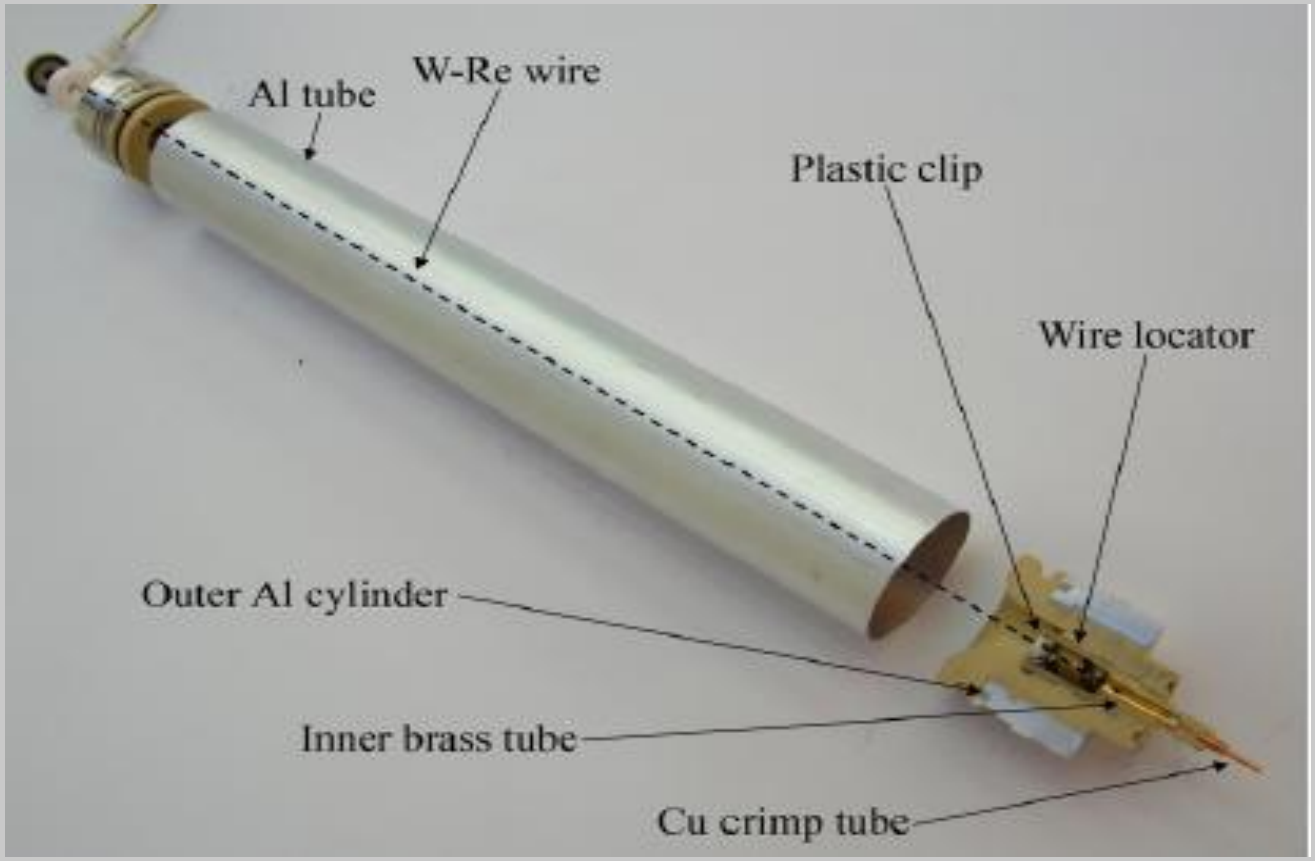
NRC “Kurchatov institute” – IHEP has developed and constructed 254 big drift tube track chambers which are successfully used now in the ATLAS detector at LHC. More than 30 similar chambers have been assembled for the experiments at 70 GeV accelerator in Protvino.

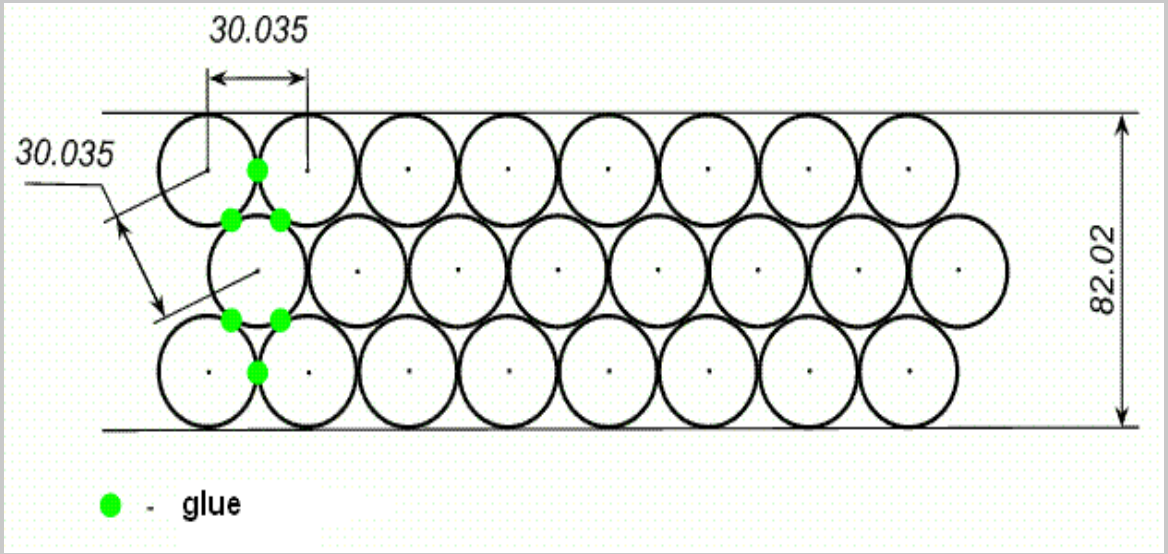
On the basis of these chambers we in NRC “Kurchatov institute” – IHEP have manufactured and successfully tested the Cosmic-ray Muon Scattering Tomograph (MST). Its some performance characteristics will be presented below.

Drift chambers of ATLAS

For the ATLAS muon spectrometer, Protvino has designed and constructed 76000 drift tubes with OD 30 mm and length up to 6.3 m. The chambers have trapezoidal shape and consist of two multi-layers separated by 364 (316) mm.

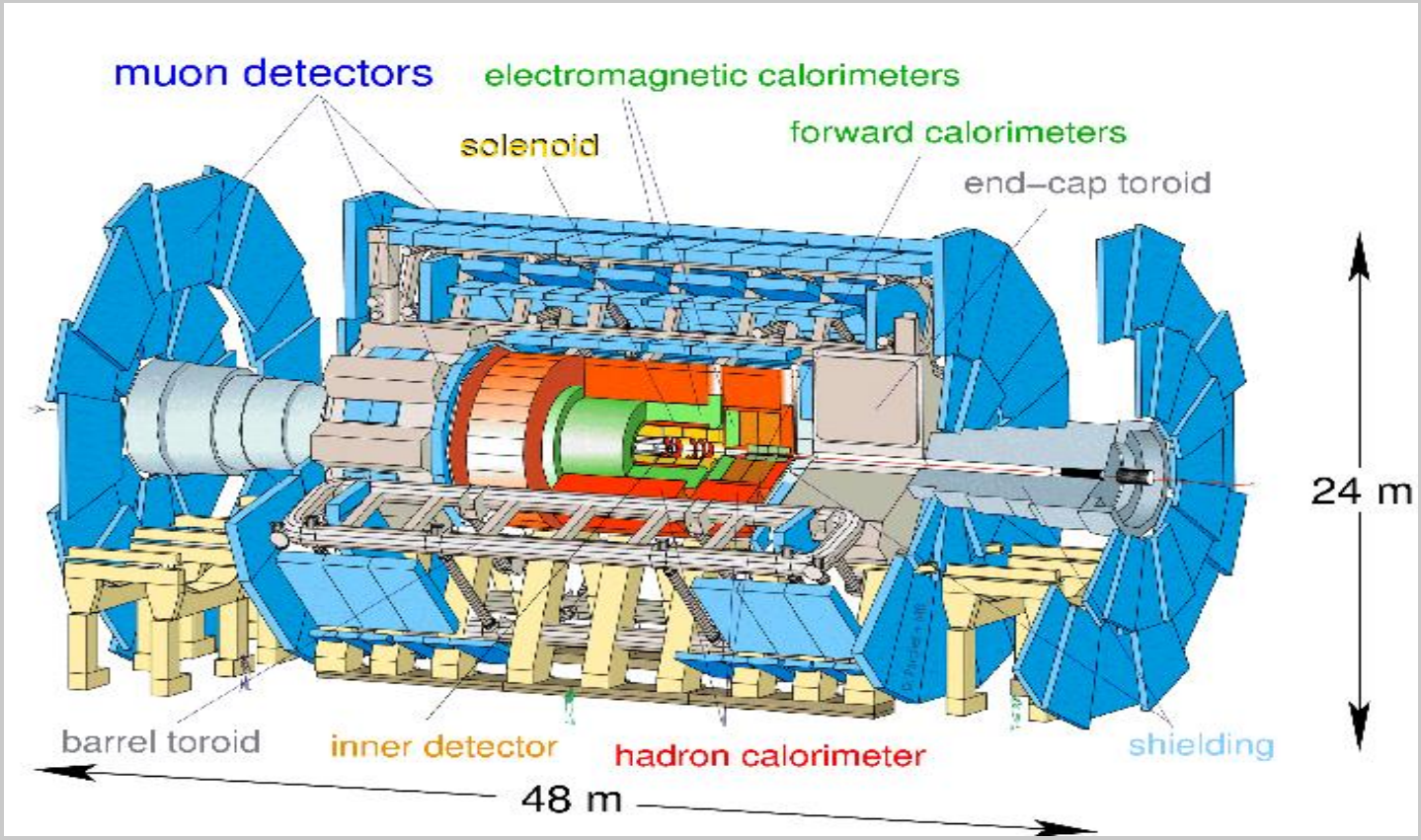






Drift chambers of ATLAS

254 drift chambers (22% of total at ATLAS) have been assembled in Protvino. They are located at end-caps of the ATLAS muon spectrometer.



Drift chambers of ATLAS End-cap

1170 chambers 356 K tubes

At RUN2 fraction of dead DTs: 0.26%

Chamber sizes:
from 0.5m x 1m to 2 m x 6.3m

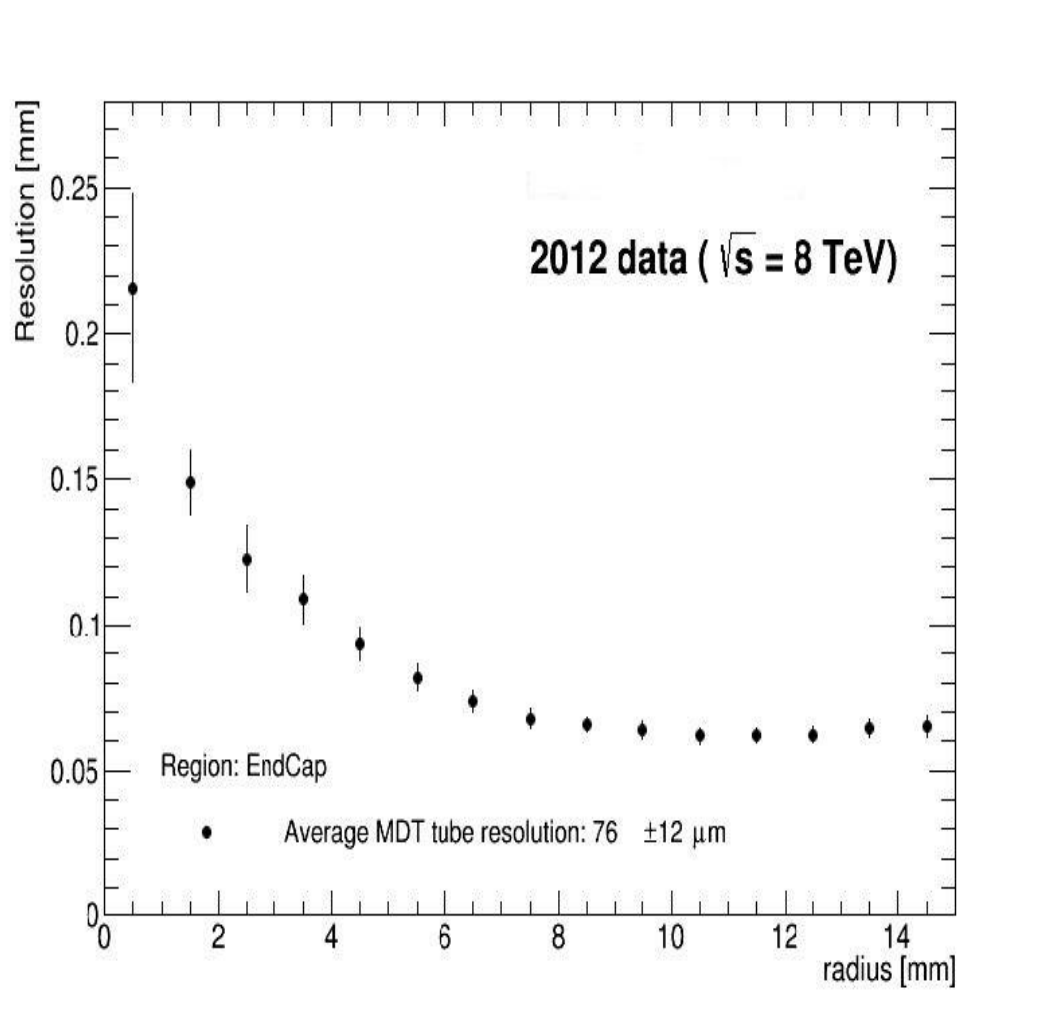
Total area: ~ 5000 m^2

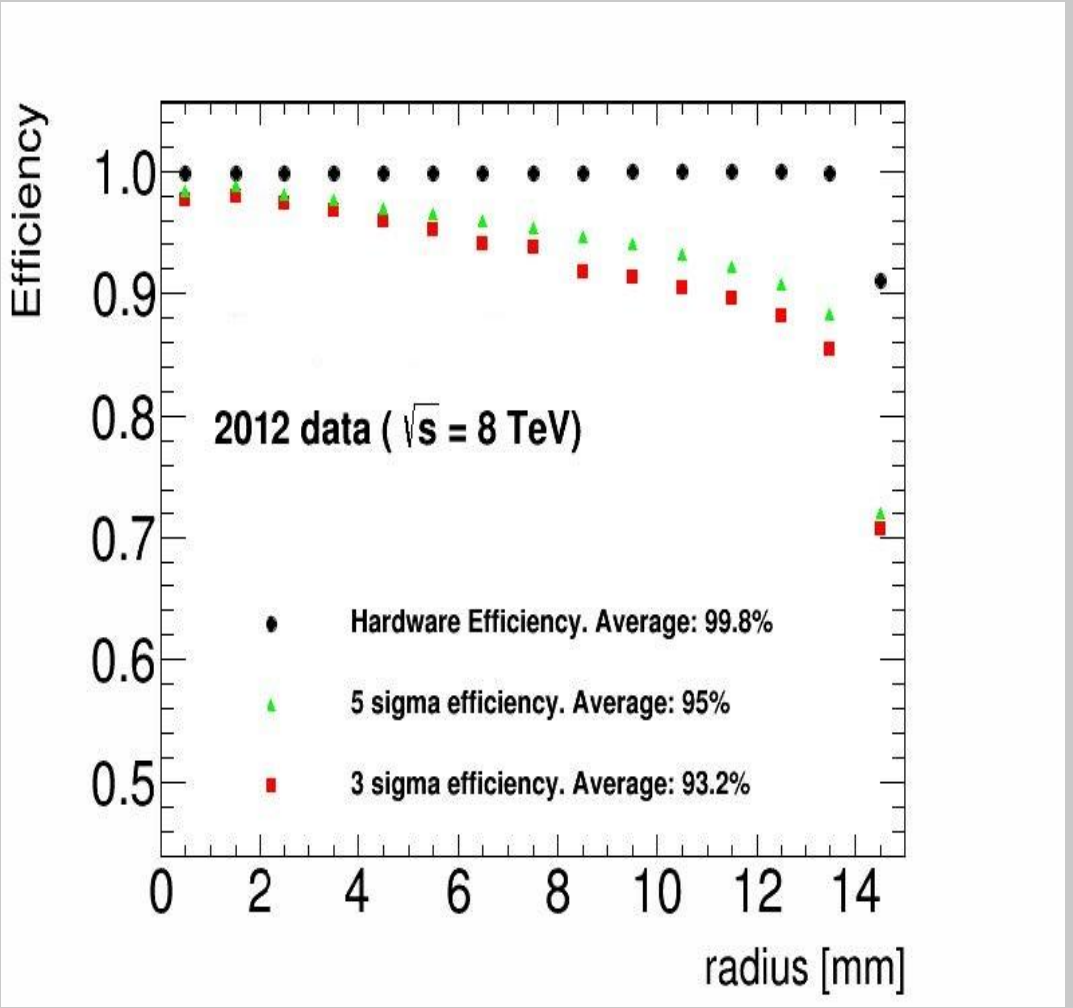
Wire position accuracy: 20 mkm

Gas mixture: Ar-CO_2 (93-7) 3 bar
+ ~ 0.0001% H_2O

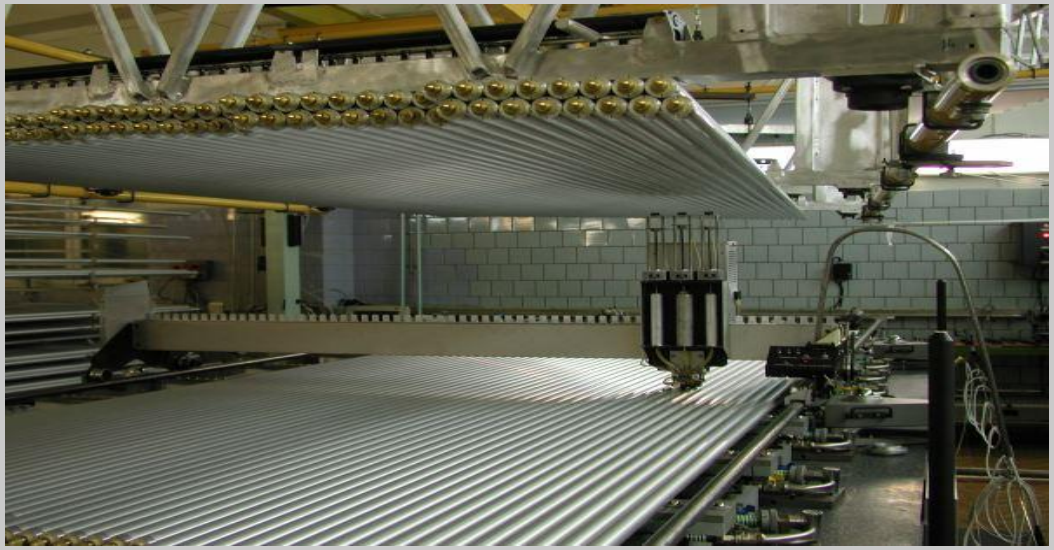
Average chamber resolution: 80 mkm

Drift chambers of ATLAS: resolution and efficiency

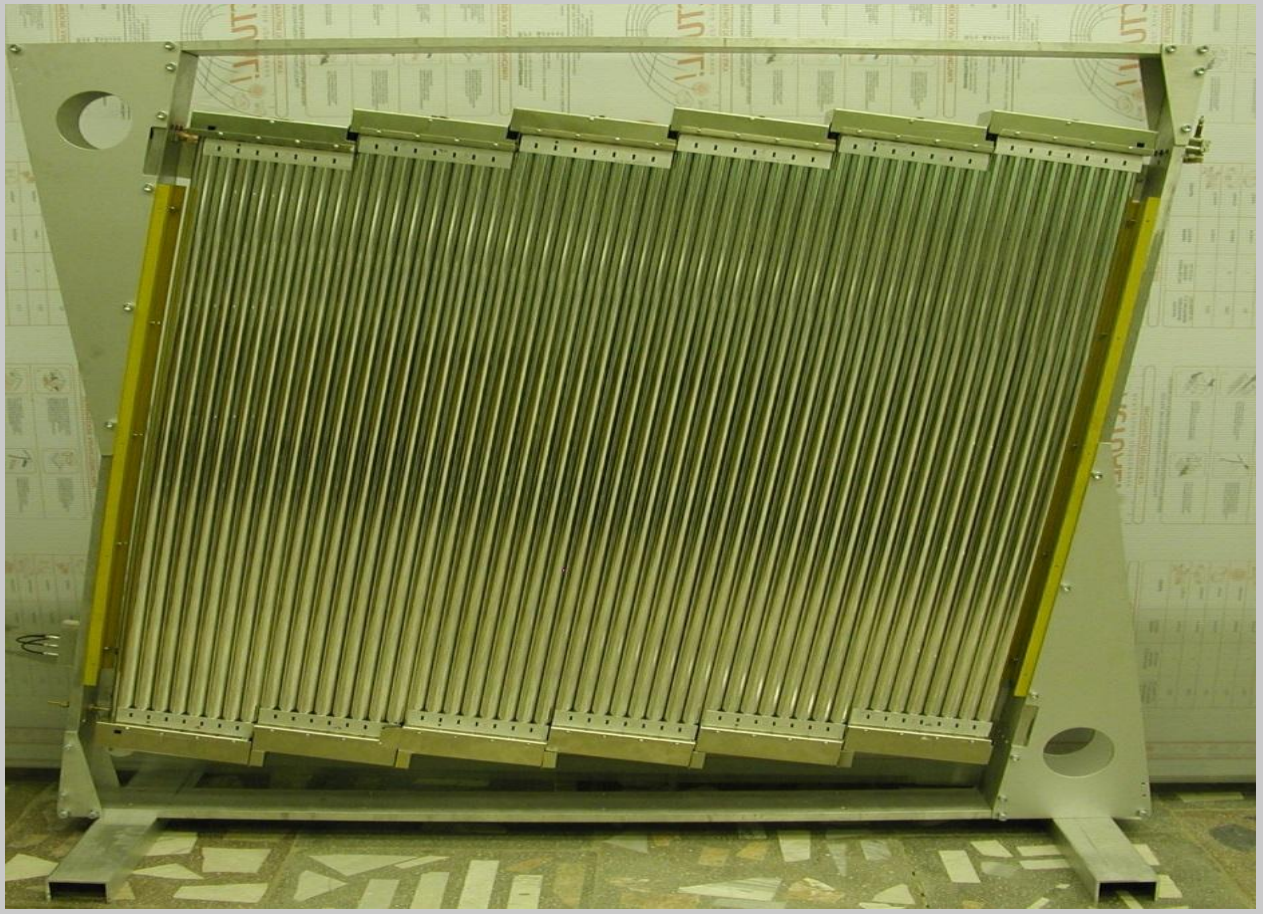




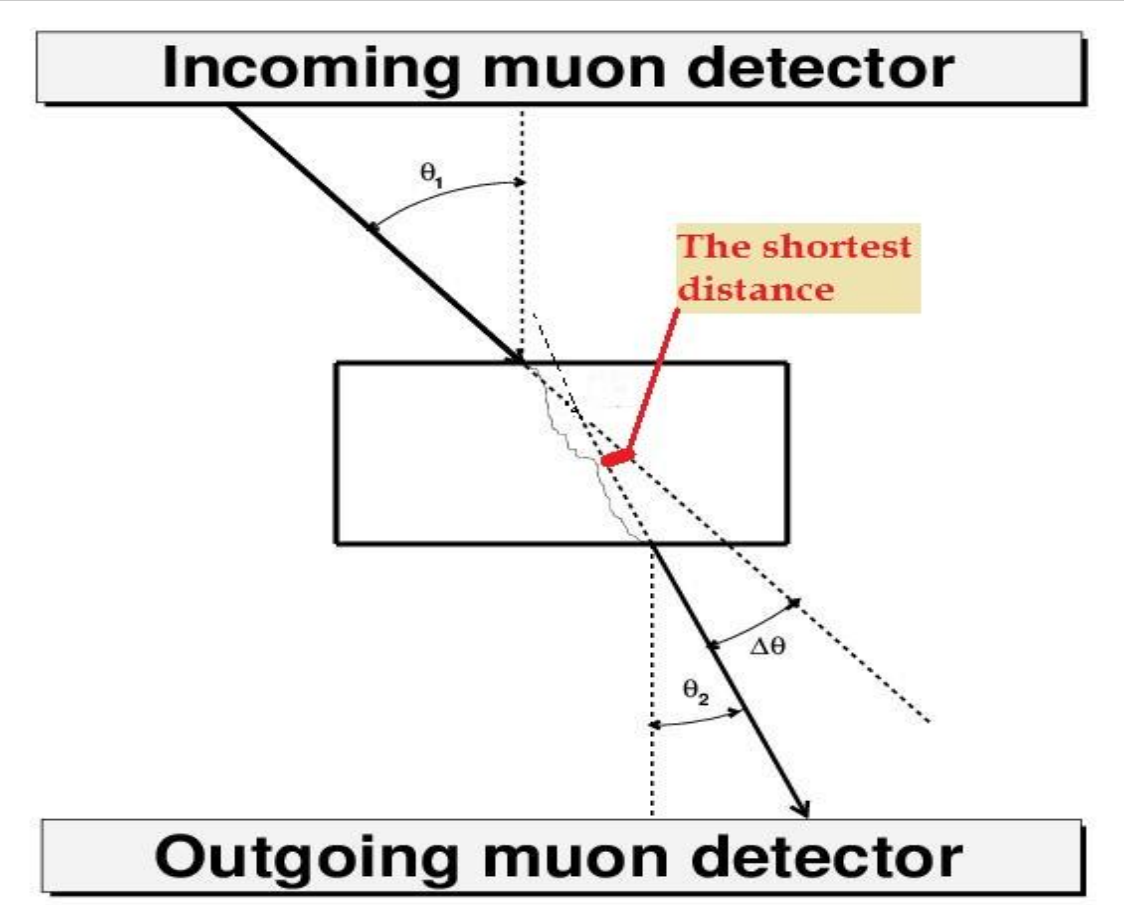
Assembling of the ATLAS chambers in Protvino



3-layer chambers (more than 30 pcs) consisting of drift tubes of ATLAS-like design have been manufactured for the experiments at 70 GeV Protvino accelerator.
Chamber sizes: from 0.8x1.0 to 2.5x2.5 м^2



Cosmic-ray Muon Scattering Tomography (MST)

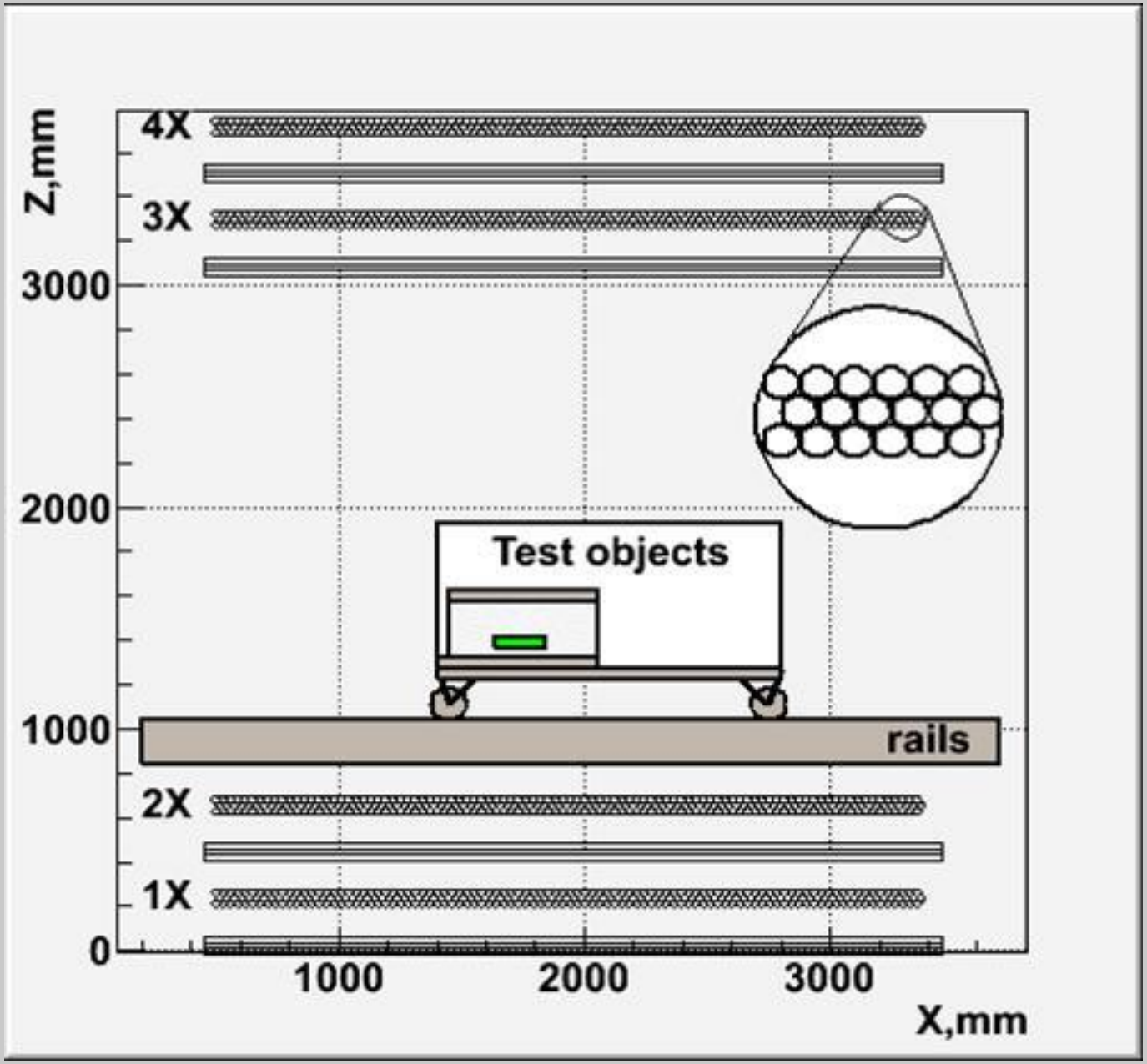


Measurement of muon track before and after test object. Multiple Coulomb scattering angle of muons provides information about density of the object.

$$\sigma_\theta = \frac{13.6MeV}{\beta pc}\sqrt{\frac{X}{X_0}} \cdot [1 + 0.038log(X/X_0)]$$

The simplest analysis mode – Point Of the Closest Approach (POCA) – histogramming of the POCA points at 3D

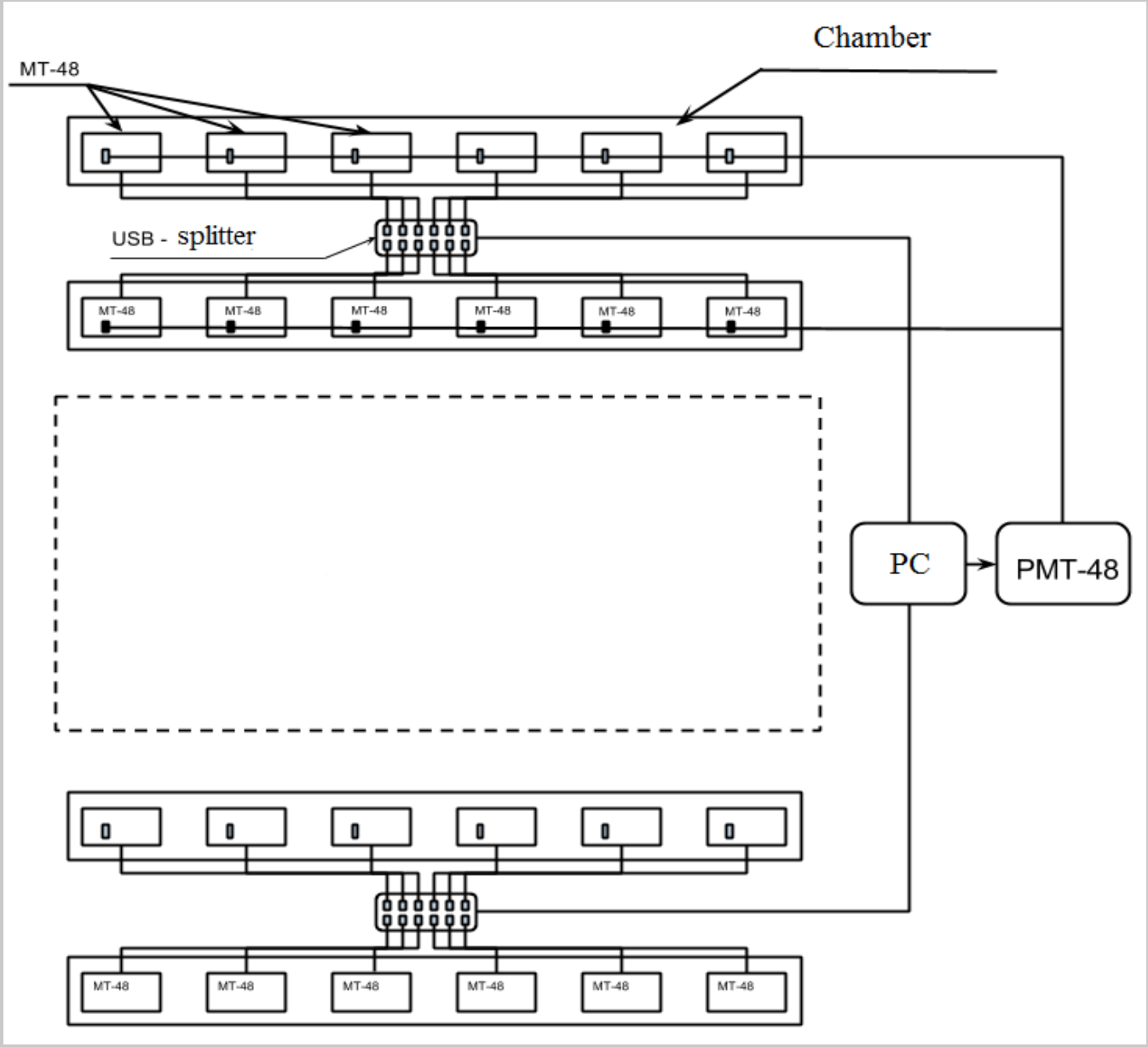
For the MST concept investigation, a large-scale setup has been constructed at NRC "Kurchatov Institute" - IHEP



8 planes (4 (X & Y)) of drift chambers
Each plane 3×3 m^2, 3 layers of DTs
Total number of DTs: 2304
DTs: 30 mm alum., 0.4 mm wall thickness
The same design as the ATLAS DTs

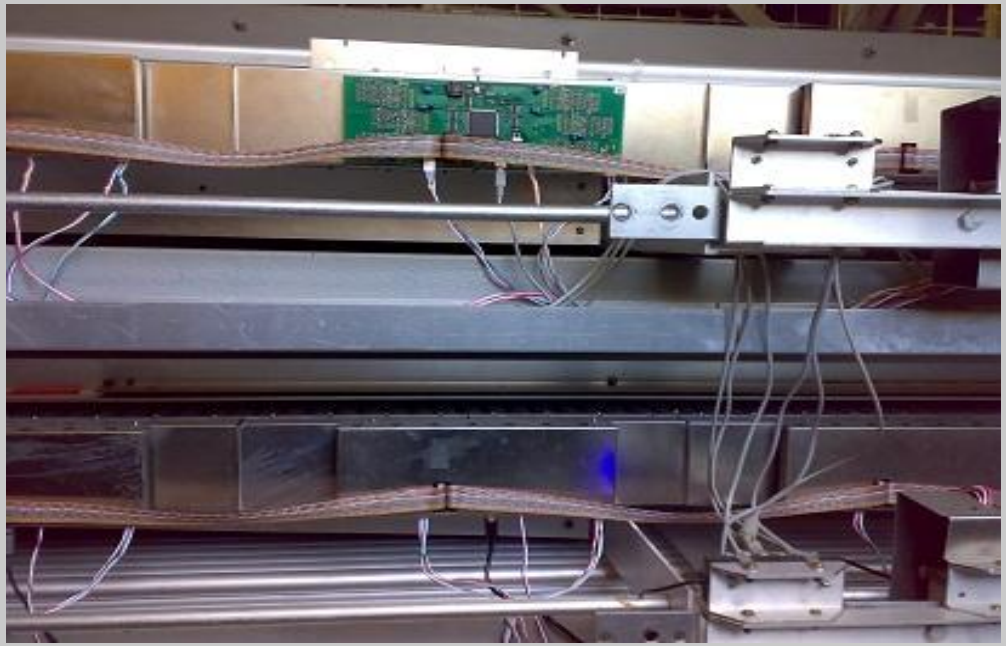
There are no trigger counters!
Only drift chambers are used for track measurements.

Cosmic muon tracks are measured independently by top and bottom DT chamber blocks. Schematically each chamber block looks like traditional muon hodoscope, widely used at cosmic ray investigations.

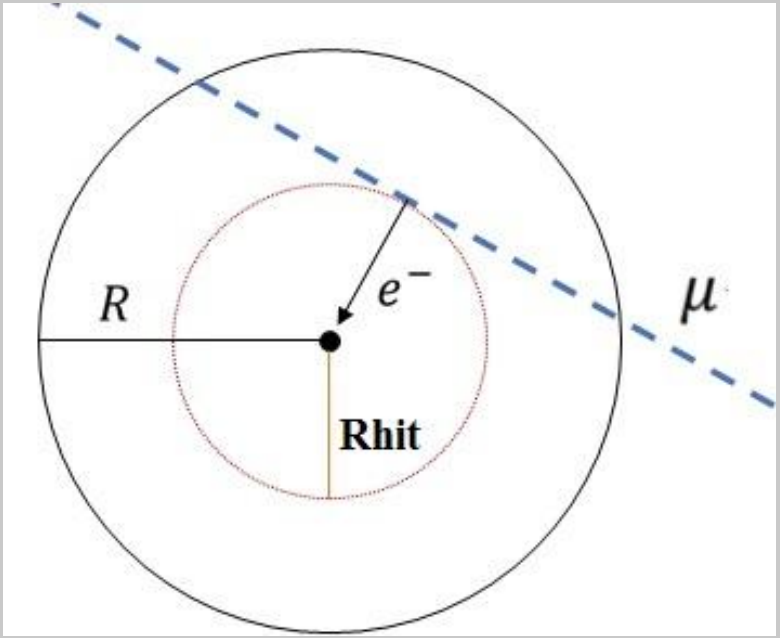


←DAQ scheme for one projection.

On-chamber elx. includes amplifiers and TDC.
One board serves 48 tubes.
TDC are based on FPGA.
Triggerless mode.
All signals from DTs are stored in TDC buffer during fixed period ~(100 μsec, variable); then data from the buffer are transferred to PC through USB (dead time of DAQ is 15%) .

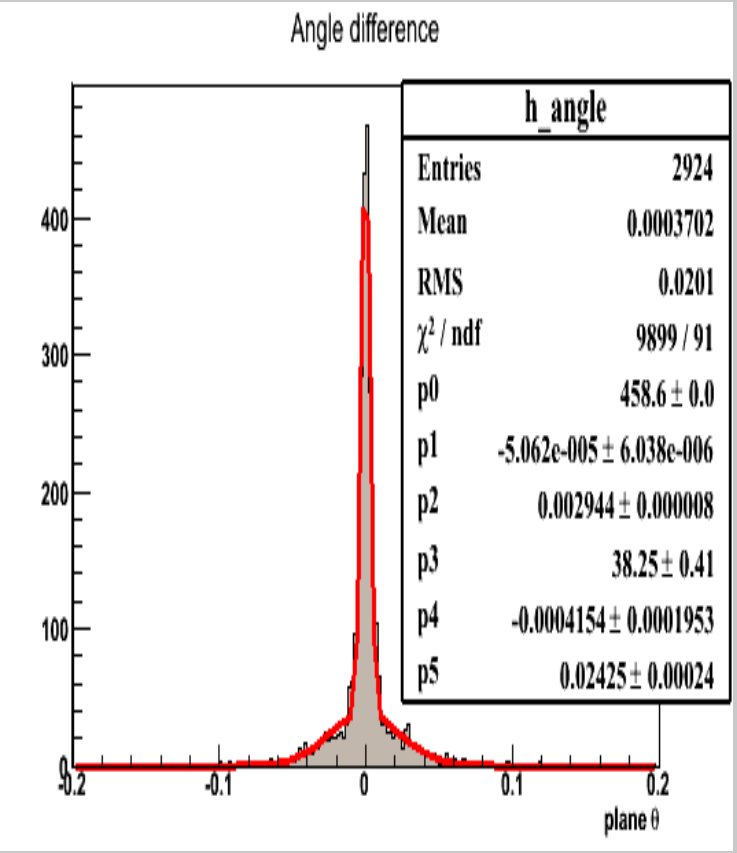


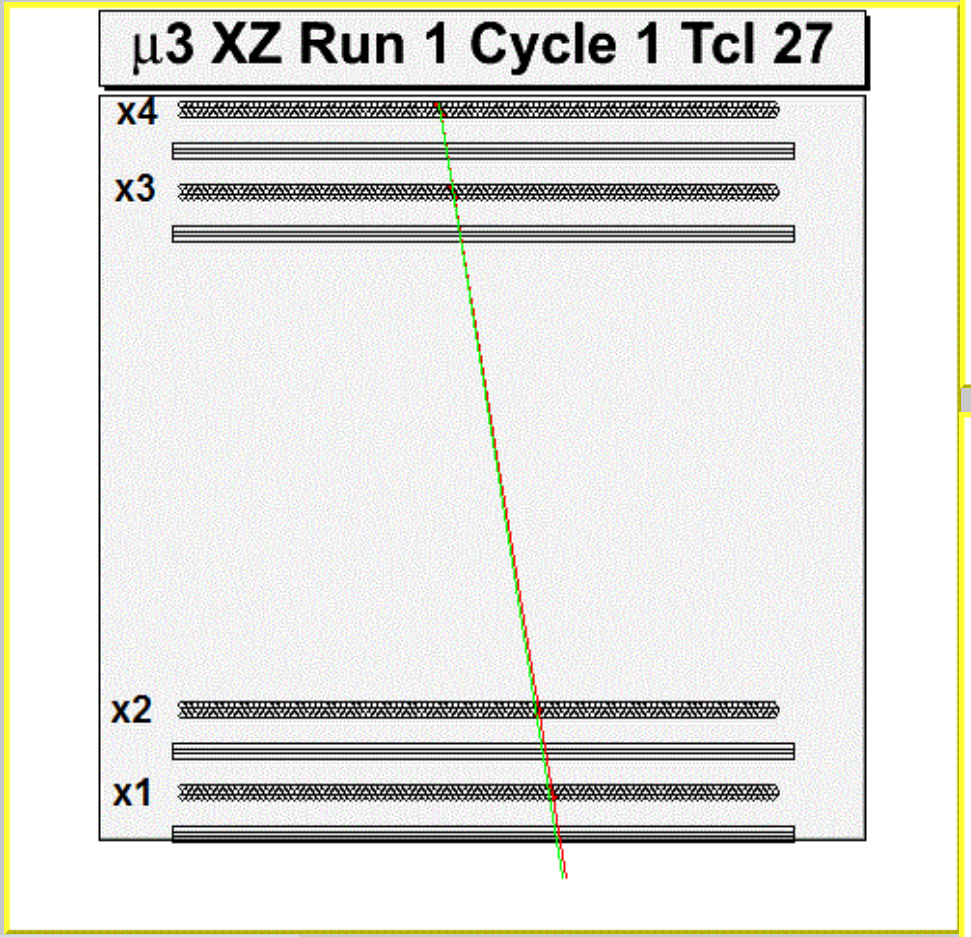
Drift tubes are filled with Ar-CO_2 (93-7) 1.5 bar, no continious flow, ones filled and closed. Working voltage: 2.5-2.6 kV. Rhit=r(t).

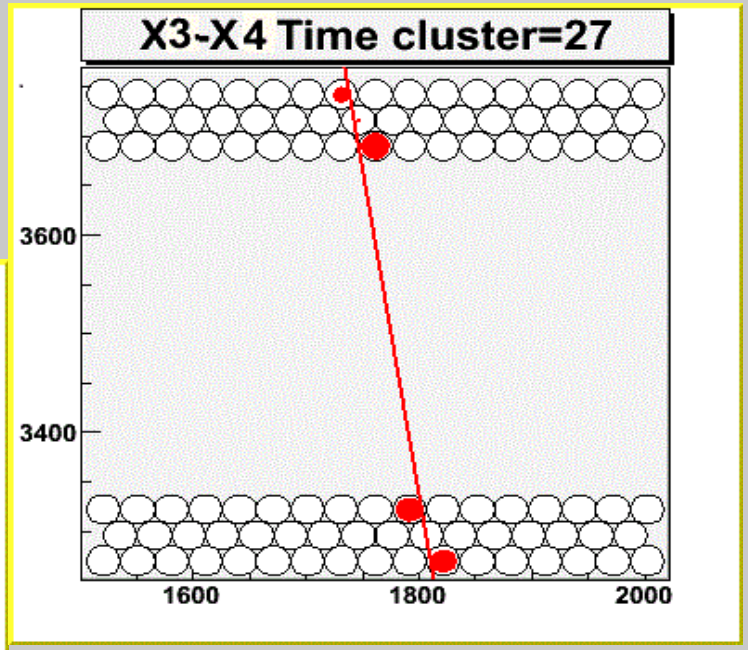


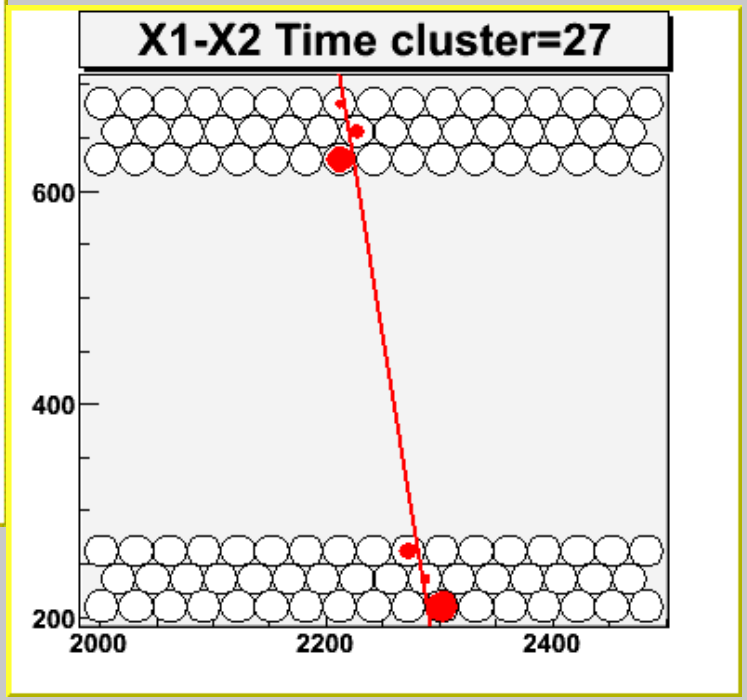
Relation r(t) continuously is re-freshed by special autocalibration procedure.
Tracks are reconstructed as a common tangent line for set of cycles with radius = Rhit.
Soft-ware was developed for unambiguous measurement of a single cosmic-ray track in top and bottom sets of chambers. Multi-track events are detected but not included into scattering analysis.

Track: tangent line for set of cycles (R_i).
Hit radius R_i=f(drift time) - not linear.
r(t)-relation common for all tubes



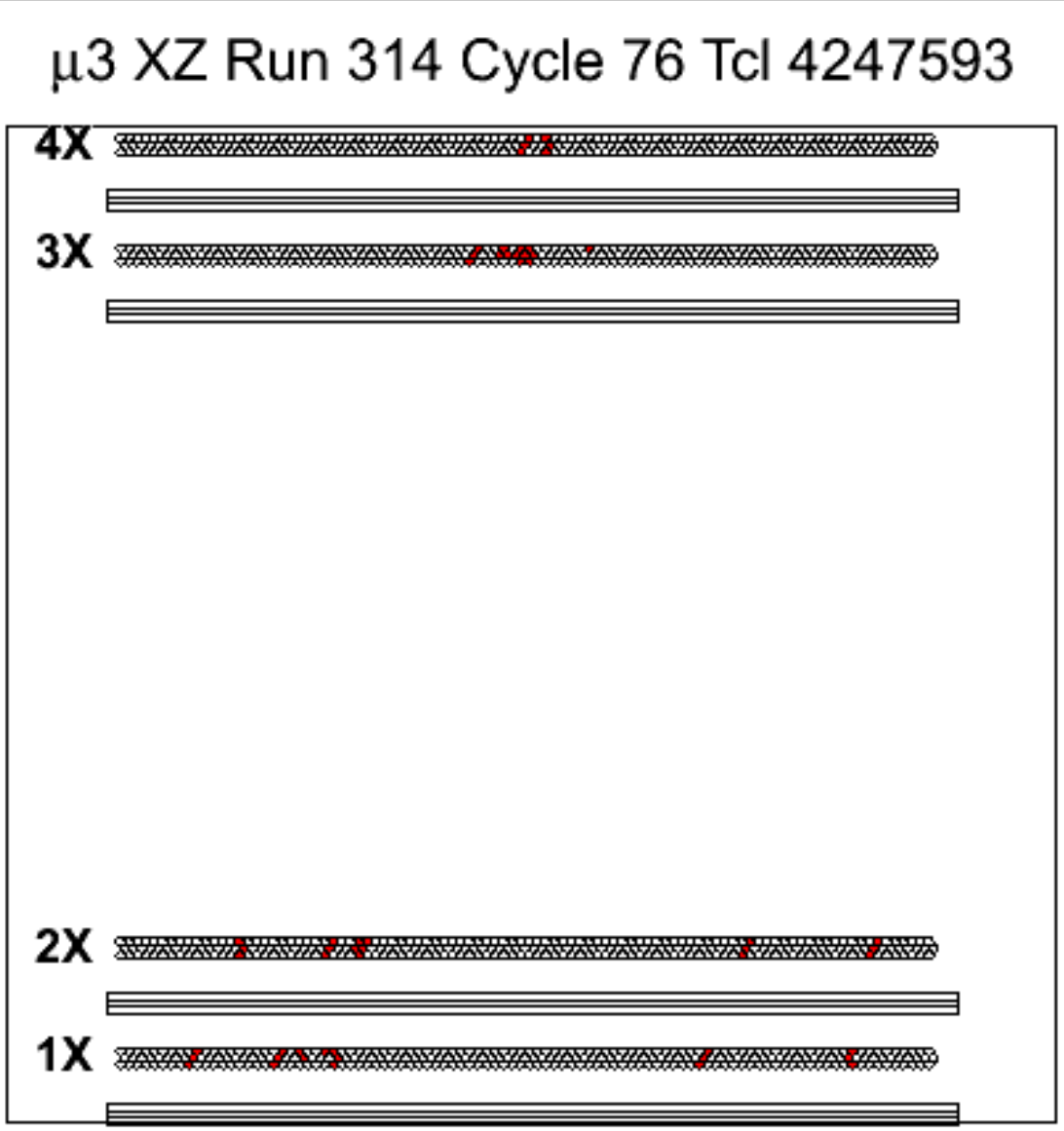


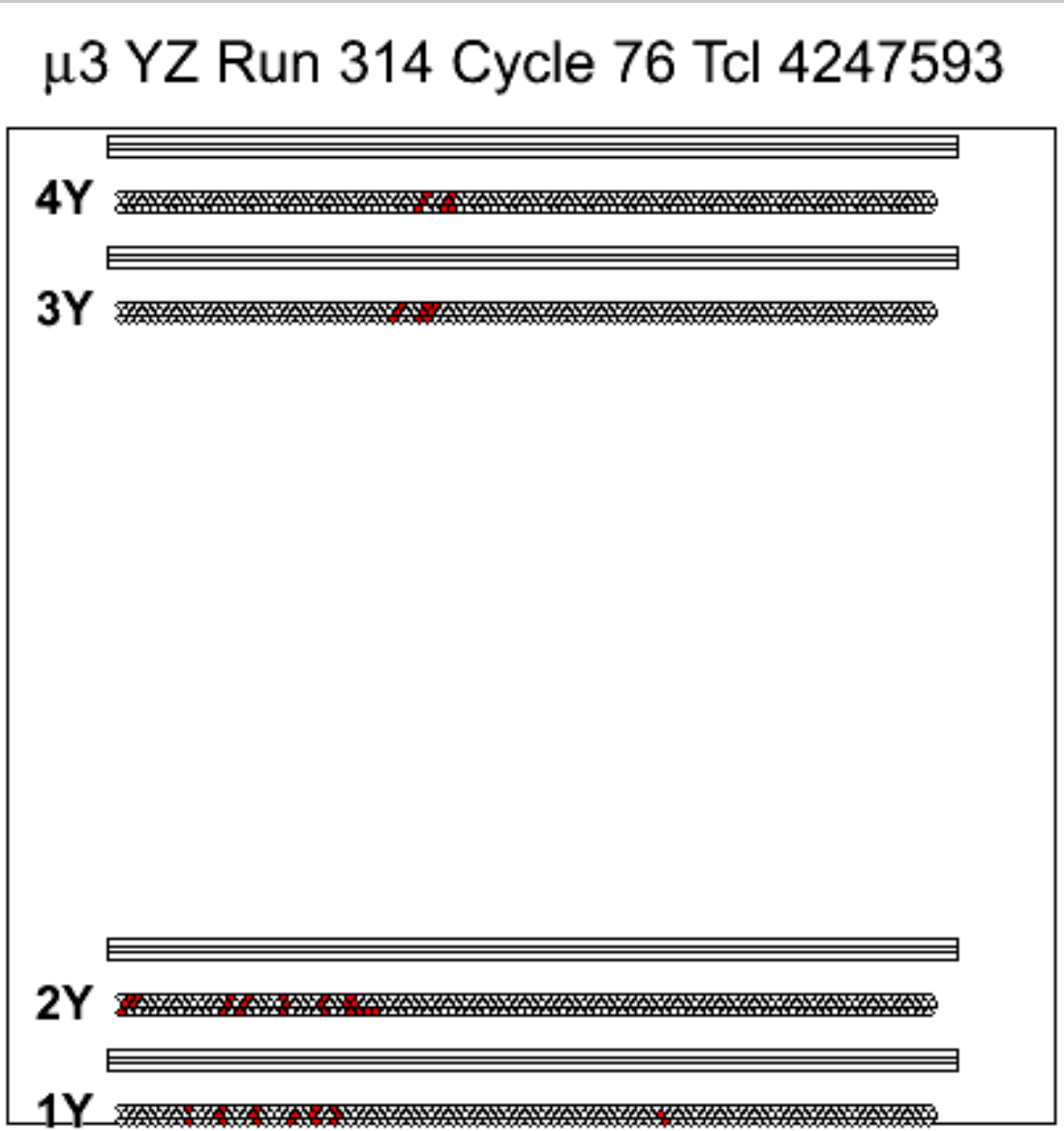




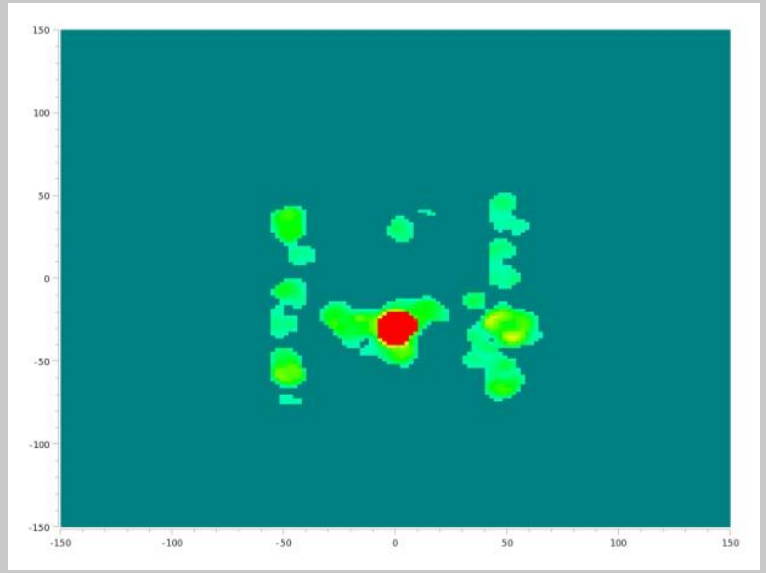
$$\sigma(\theta_{up} - \theta_{down}) = 1.5 - 3.0 \text{ mrad}$$

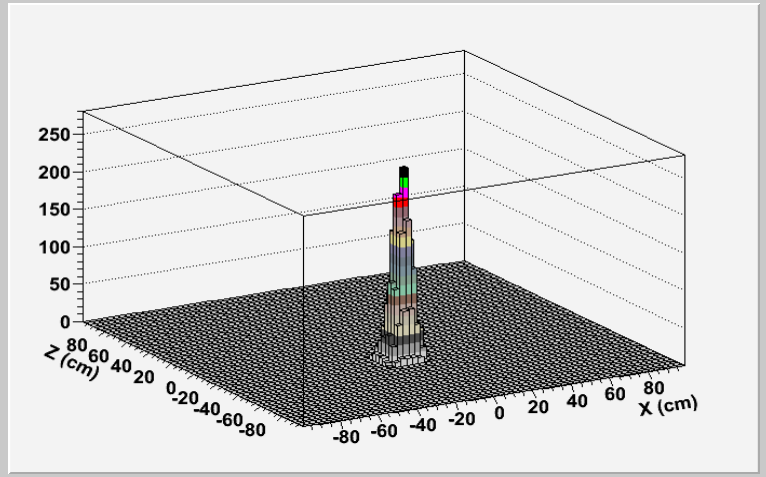
Example of event with group of cosmic-ray tracks.



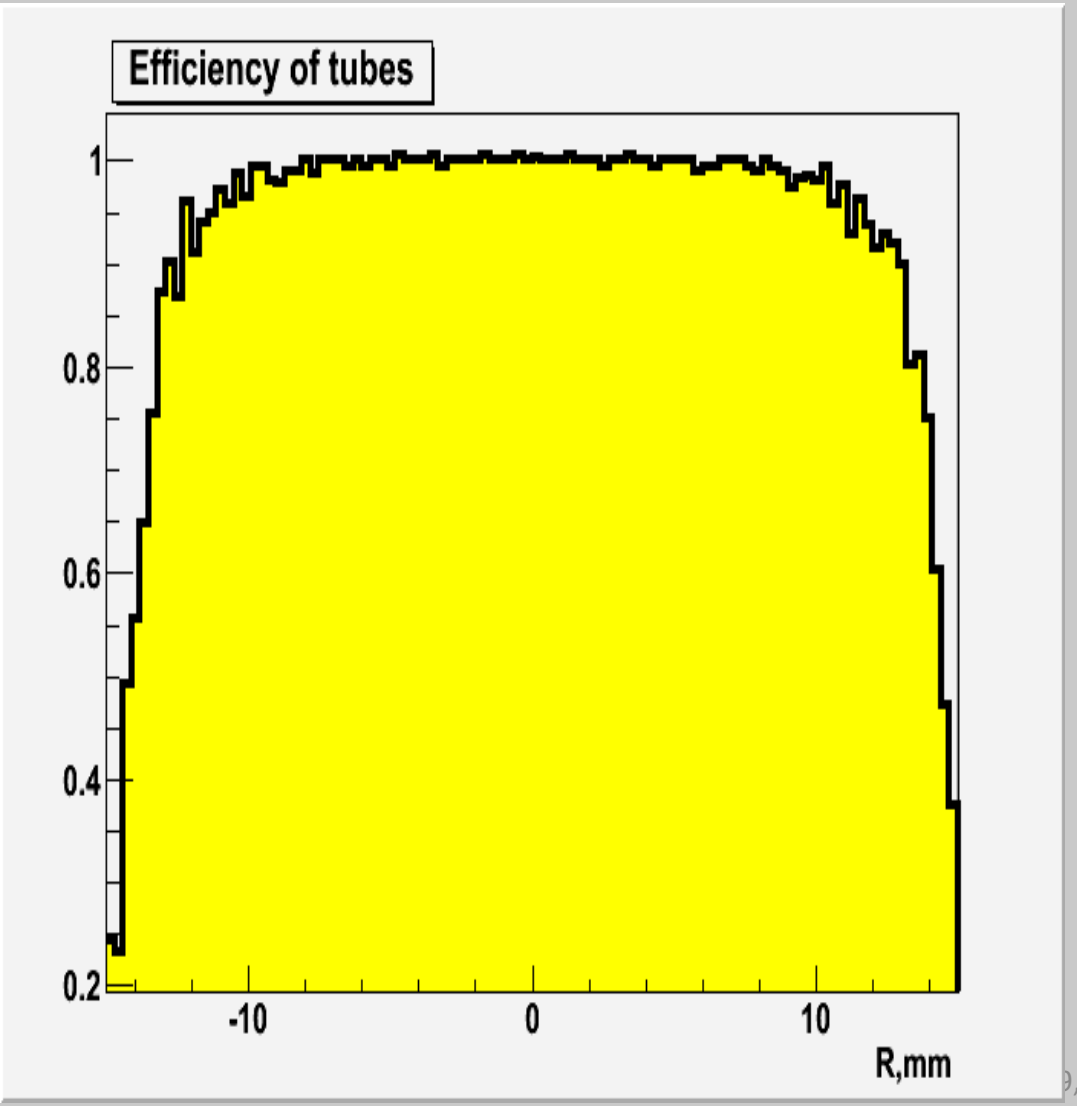


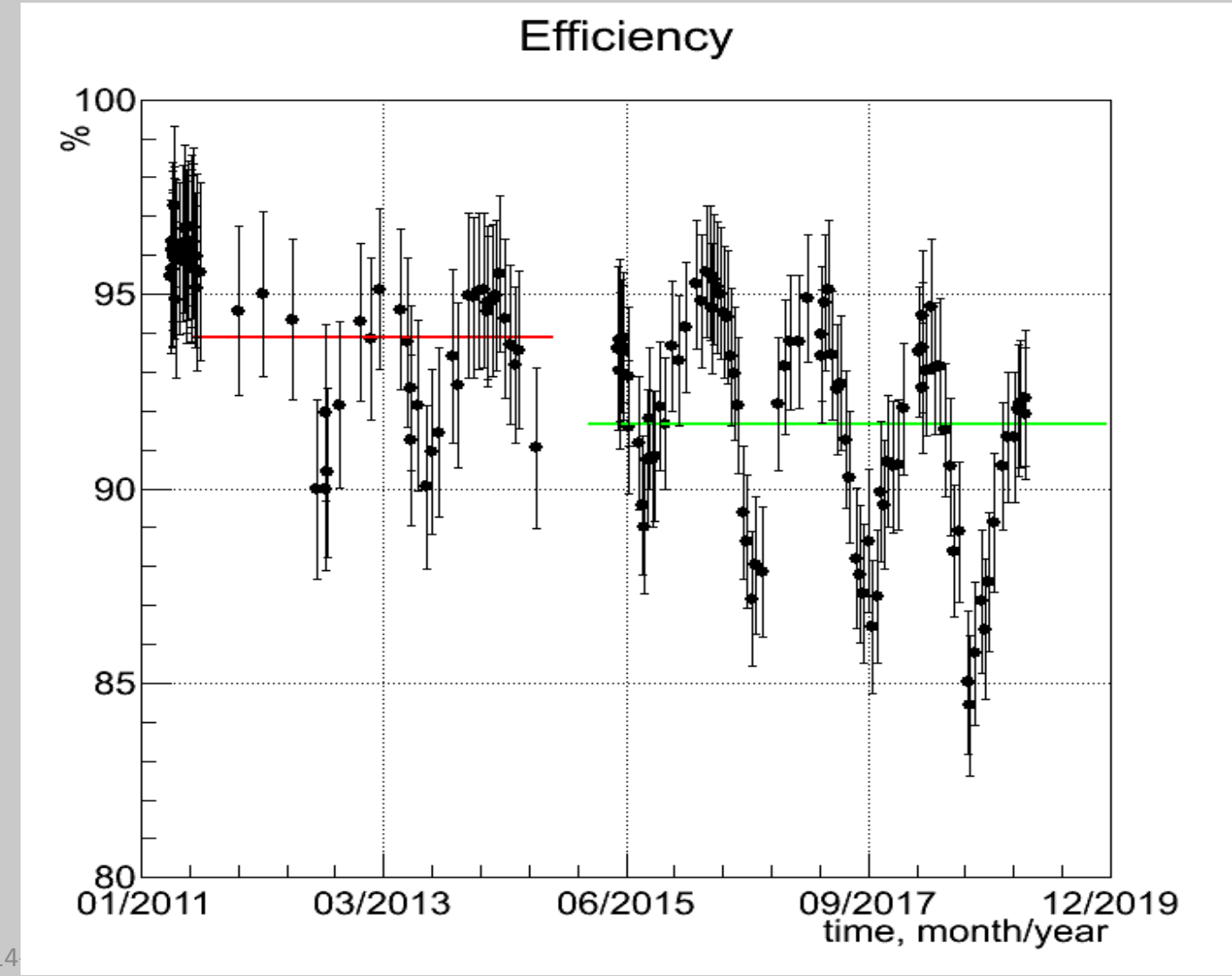
An example of heavy object detection
Lead 20×20×20 cm^3 under 30 cm of steel
Exposition time 3 minutes



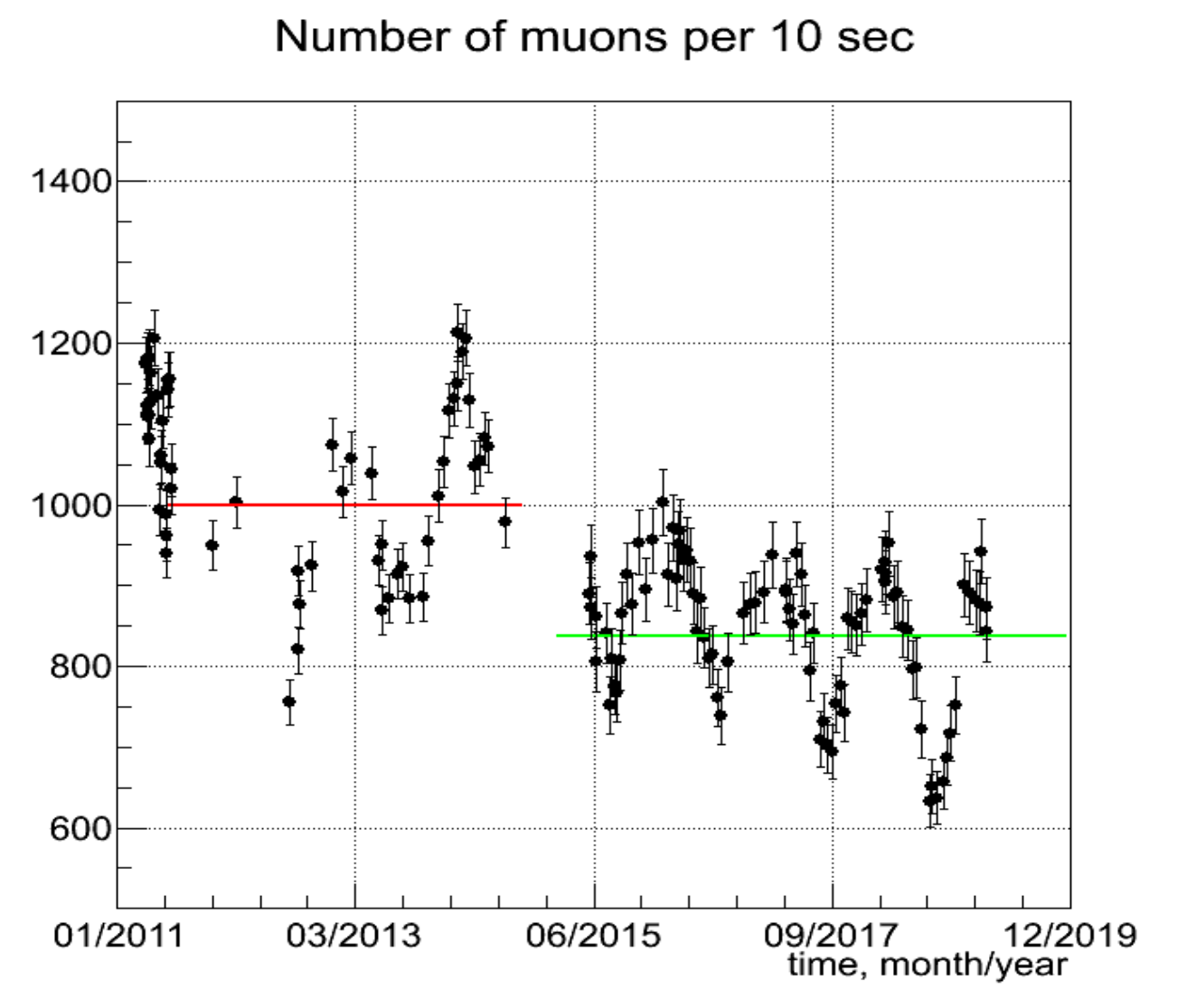


DT efficiency. (In figures below – averaged for the bottom layers in 3X and 3Y)





Number of single muons/10 sec



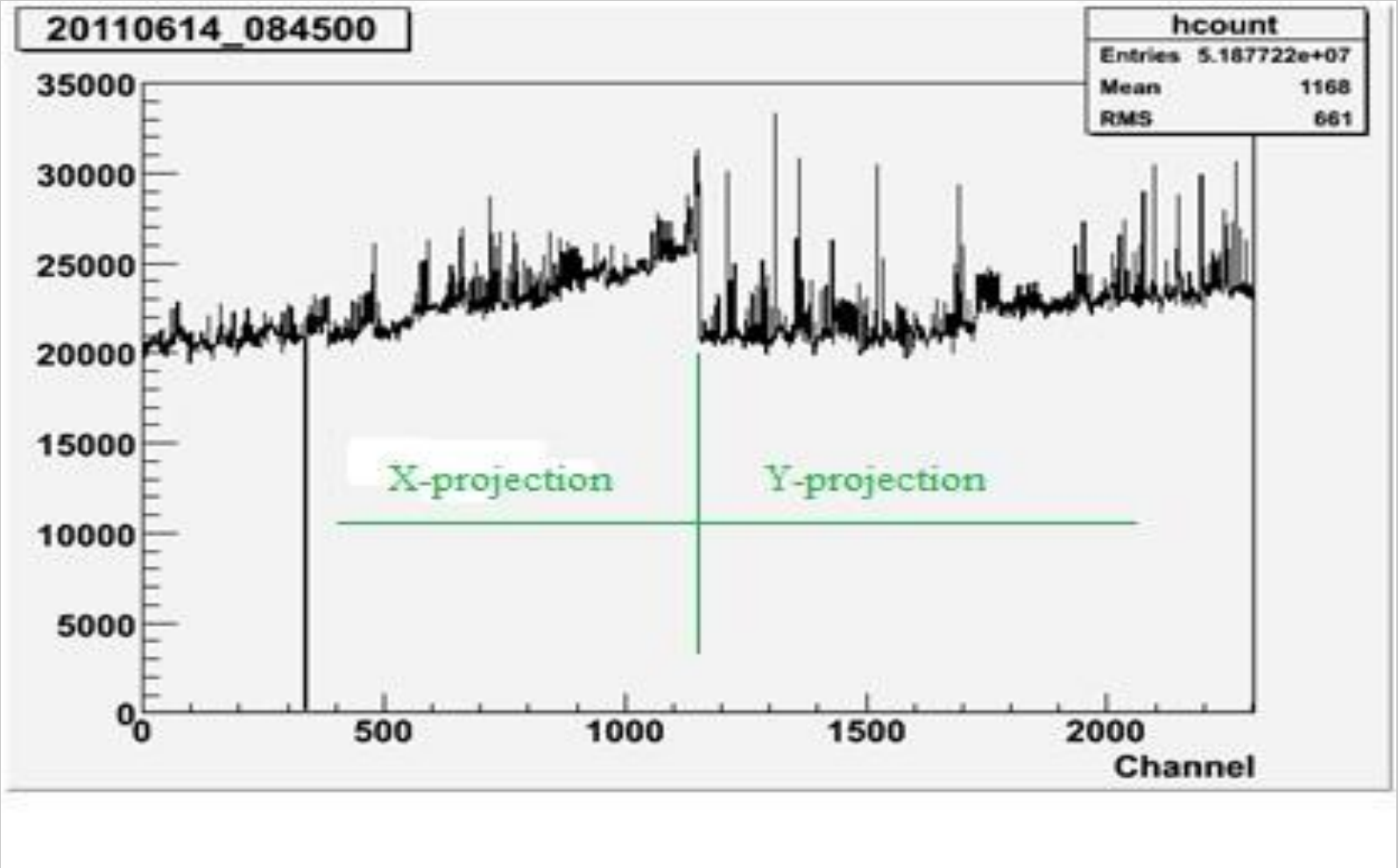
Criteria:
- 19 hits
- Intersection of top and bottom planes
- χ^2 cut

Track reconstruction different of one used for tomography.

Two lines – separate fits for different DAQ and elx.

Detection of all natural radiation (cosmics+environmental) *(just exercises)*

1-st step: Counting of all hits of all individual DTs during first 15 minutes of each hour

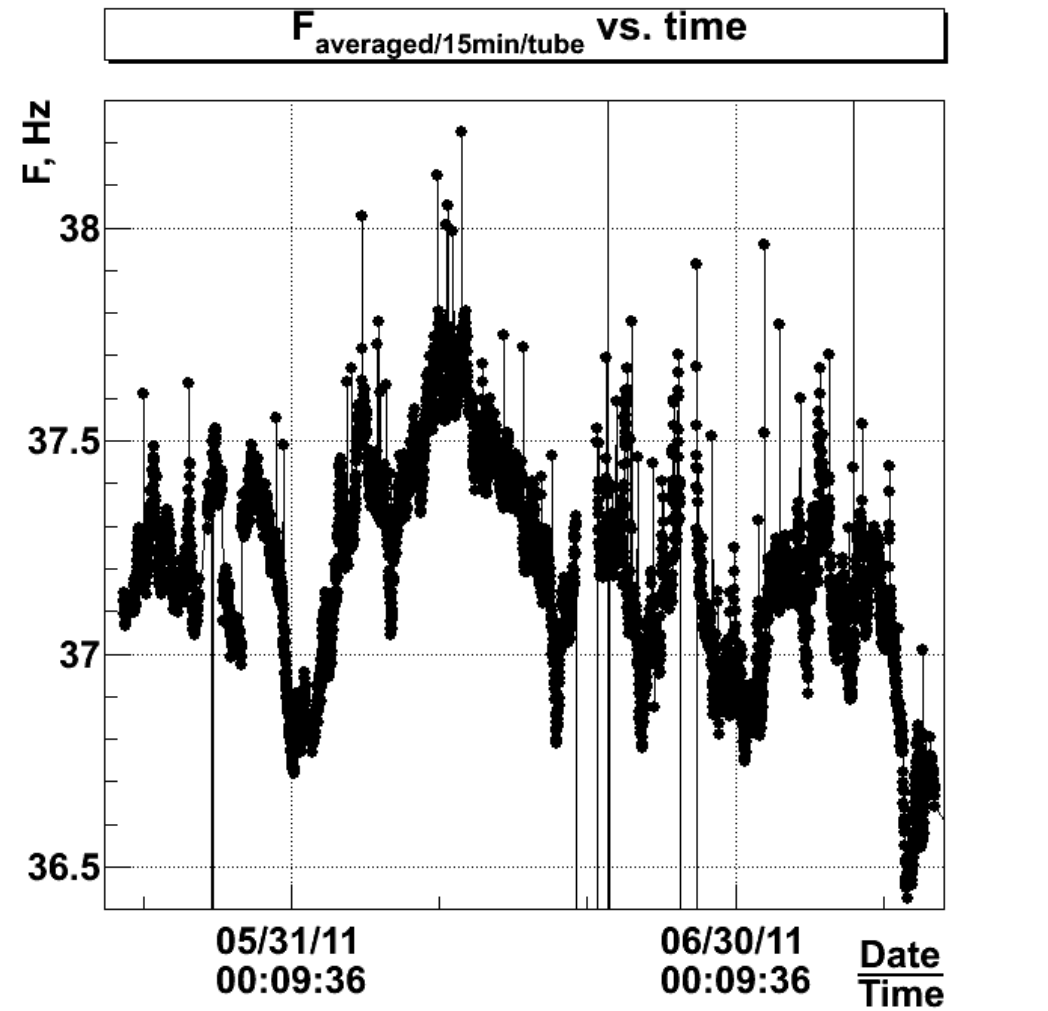


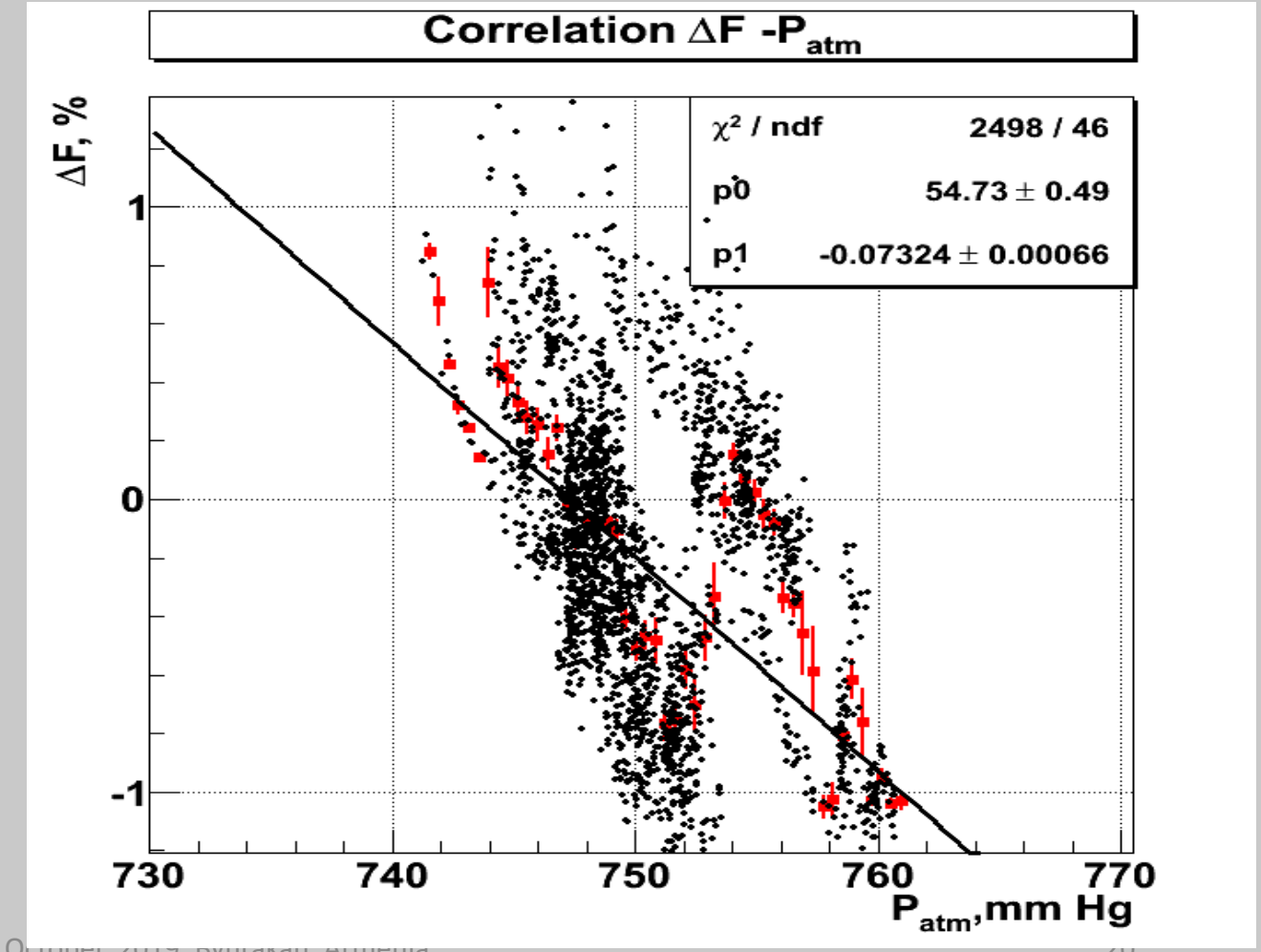
Detection of all natural radiation (cosmic+environmental) (2)

2-d step: calculation of the averaged (all DTs) counting rate (F)

Left fig. - average frequency as a function of time (2 months)

Right fig. - correlation F - Patm





Conclusion

Large area drift tube track chambers like ones used in Protvino MST are robust, sensitive detectors for cosmic ray tracks registration. And not so expensive!

Protvino MST (which in fact is a couple of muon hodoscopes) made of 30 mm DTs; it can measure single cosmic ray tracks with angle resolution about 1.5mrad. The angle resolution can be improved by increasing the separation between the chambers in the registering blocks.

Single drift tube efficiency is 92-95%, spatial resolution is as good as 150 mkm.

Two-track separation is limited with the tube radius, in our case it is 15 mm.

The tubes are filled with safe and cheap gas mixture Ar-CO2 and can work many years without gas refreshing.

The chambers are equipped with compact on-chamber electronics connected with PC through USB port.

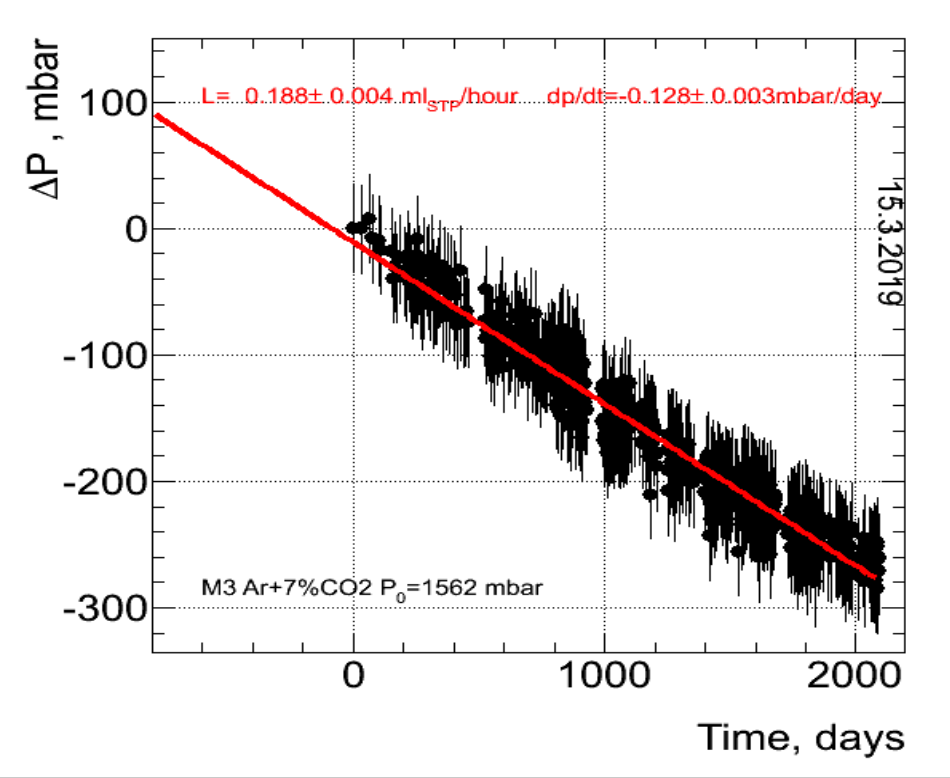
Cosmic ray tracks can be continuously measured (dead time of DAQ is 15%).

Multiple tracks and all natural radiation are also detectable.

Thanks for your attention

Back-up slides

DTs were filled with Ar+7%CO_2 gas mixture at ~1.5 bar pressure.
Usually in practice of drift chambers gas mixture is exchanged during operation with rate 0.01-1 volume/day (e.g. ATLAS gas flow rate is 1volume/day).
We have filled DTs with the gas mixture and closed.
The gas mixture was not refreshed since 05 April 2011!



Total volume = 4.7 m^3
Drop of pressure (dp/dt, chambers+gas-distribution system) is ~0.13 mbar/day
Leak rate 4.56 $\times 10^{-3}$ litre/day