
Institute for High Energy Physics
of National Research Centre
"Kurchatov Institute"

# Cosmic-ray muon tomography setup: long-term life of drift tube chambers

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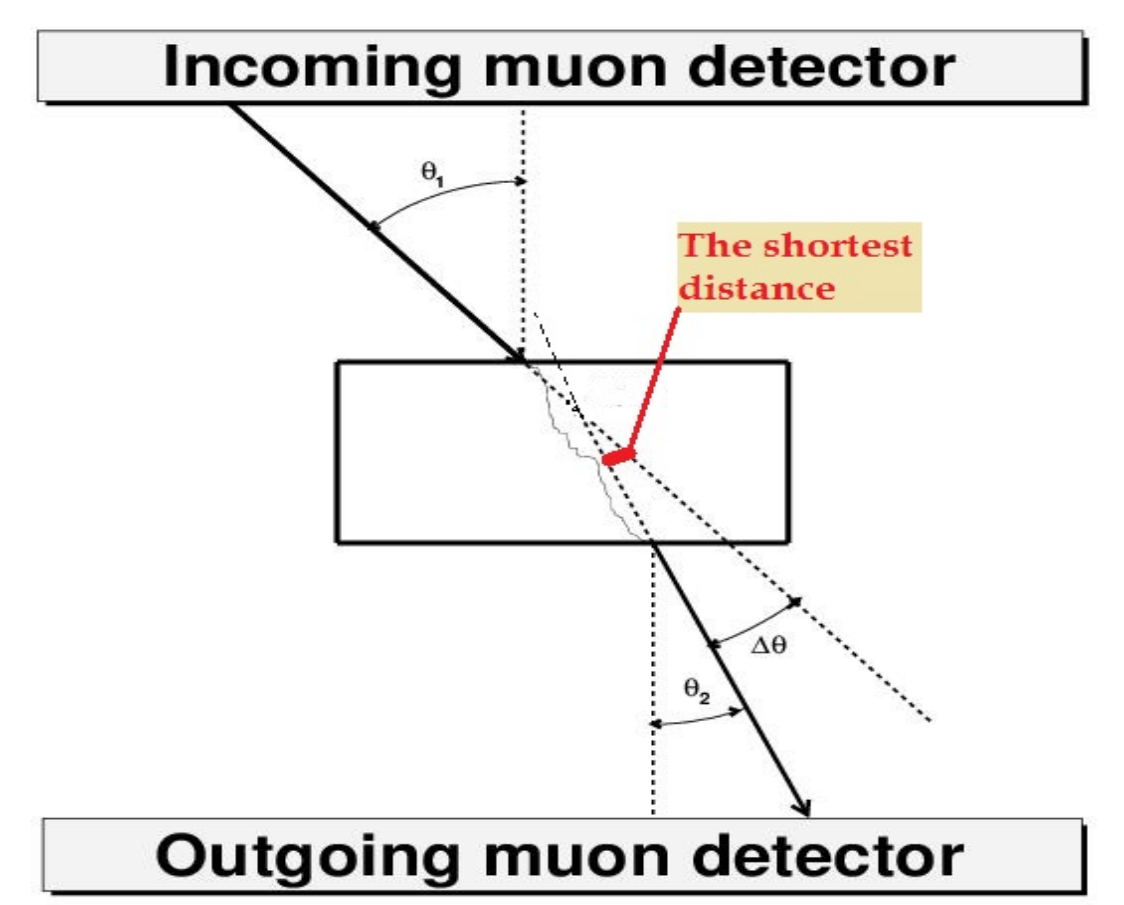
# Cosmic-ray Muon Scattering Tomography (MST)

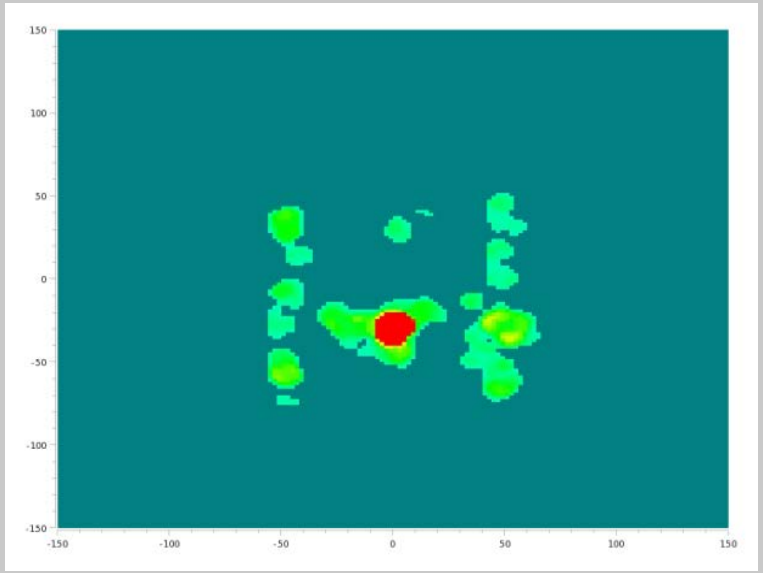


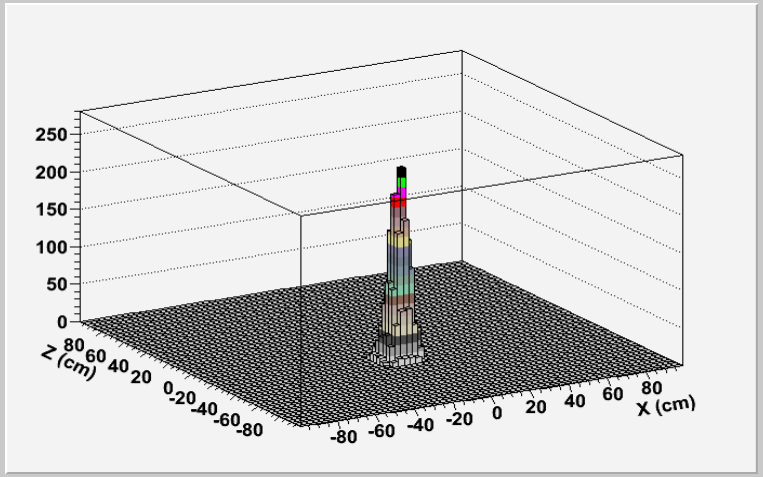

Measurement of muon tracks before and after test object. Multiple Coulomb scattering angle of muons provides information about density (radiation length) of the object.

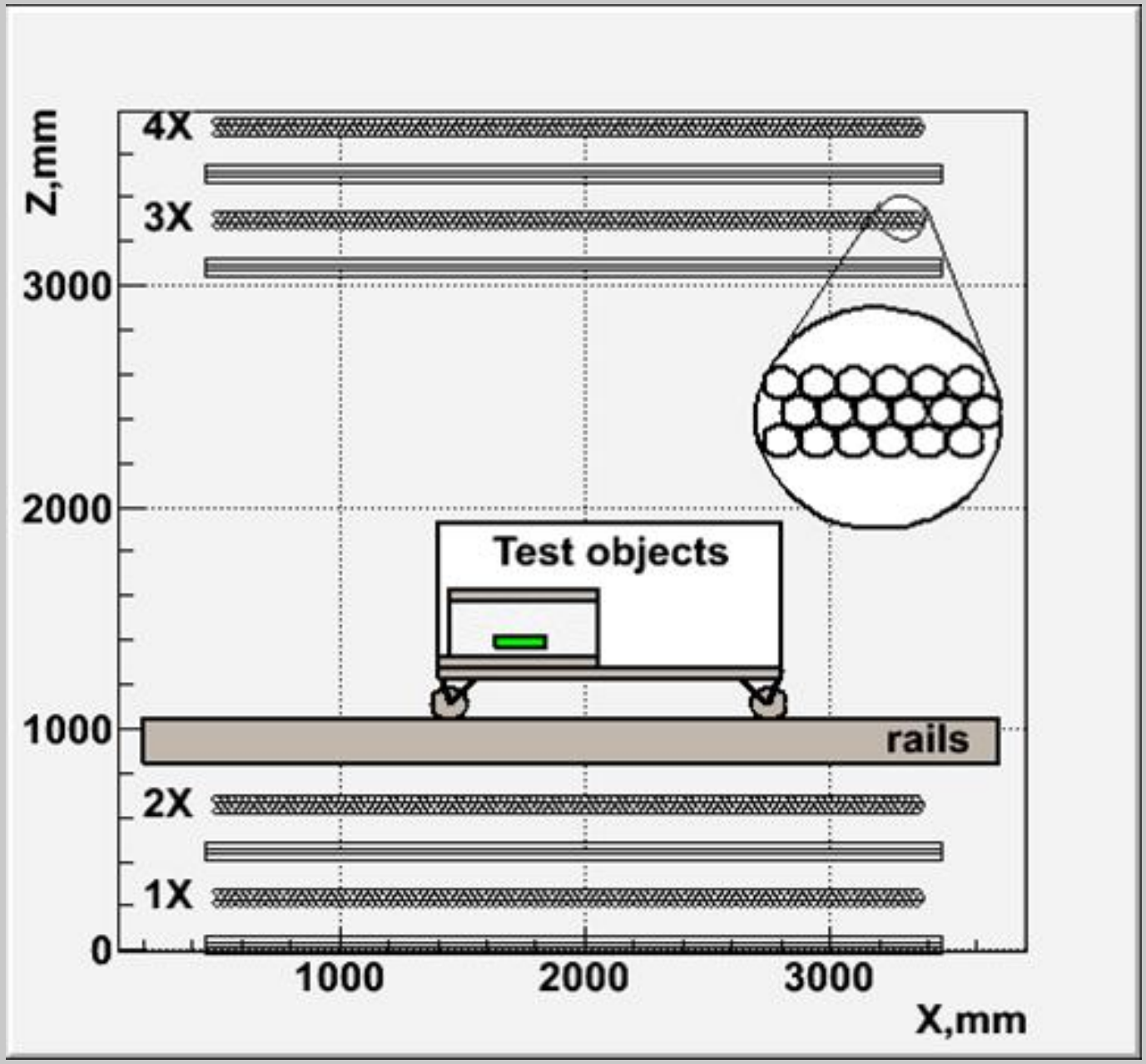
$$\sigma_\theta = \frac{13.6MeV}{\beta pc}\sqrt{\frac{X}{X_0}} \cdot [1 + 0.038log(X/X_0)]$$

For investigation of the cosmic-ray muon Scattering Tomography (MST) concept at NRC "Kurchatov Institute" - IHEP the large-scale setup has been constructed.

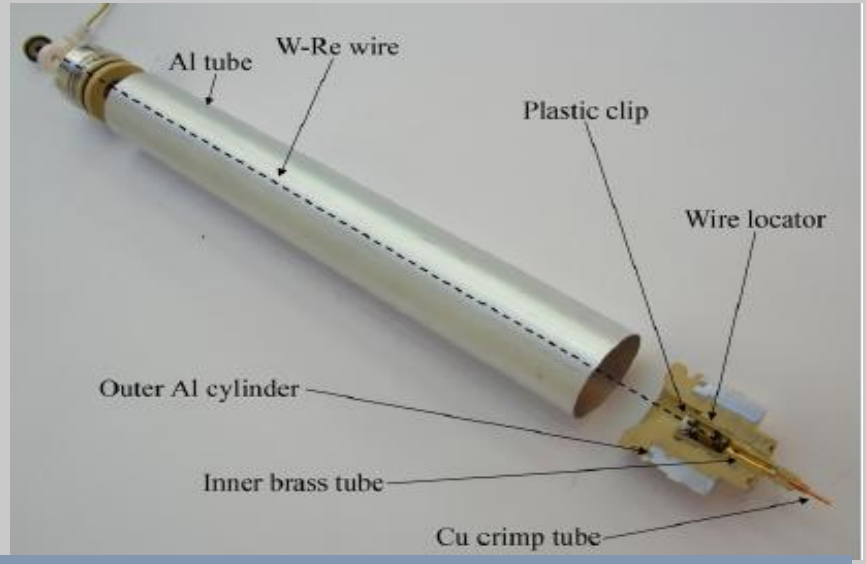
An example:
Lead (Pb) 20×20×20 $cm^3$
Under 30 cm of steel
Exposition time 3 minutes



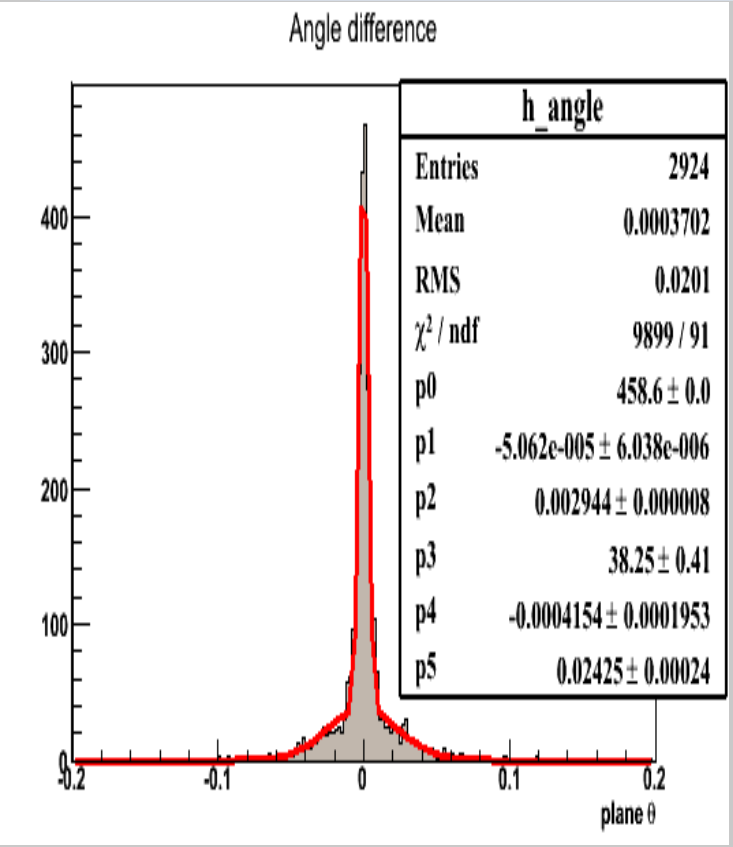


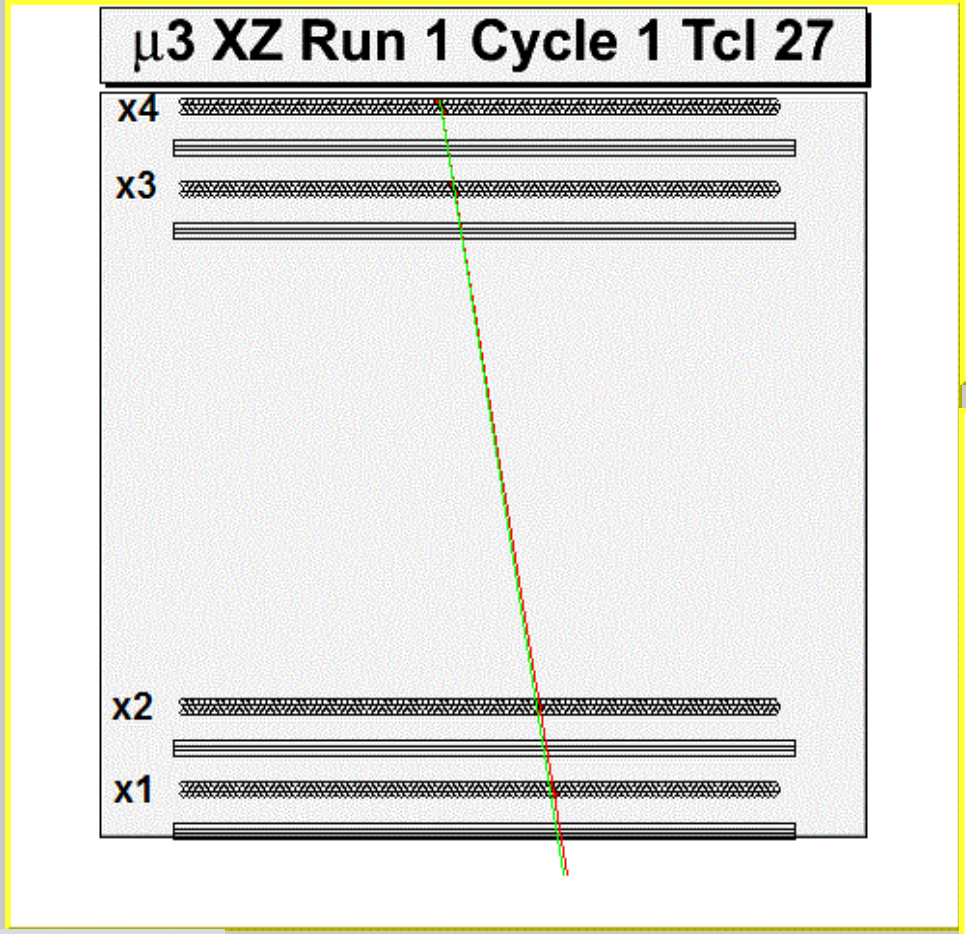

8 planes ( 4 (X & Y)) of drift chambers
Each plane 3×3 $m^2$, 3 layers of drift tubes
Total number of tubes 2304
Drift tube 30 mm aluminium, 0.4 mm wall
The same design as the drift tube of ATLAS muon spectrometer at LHC

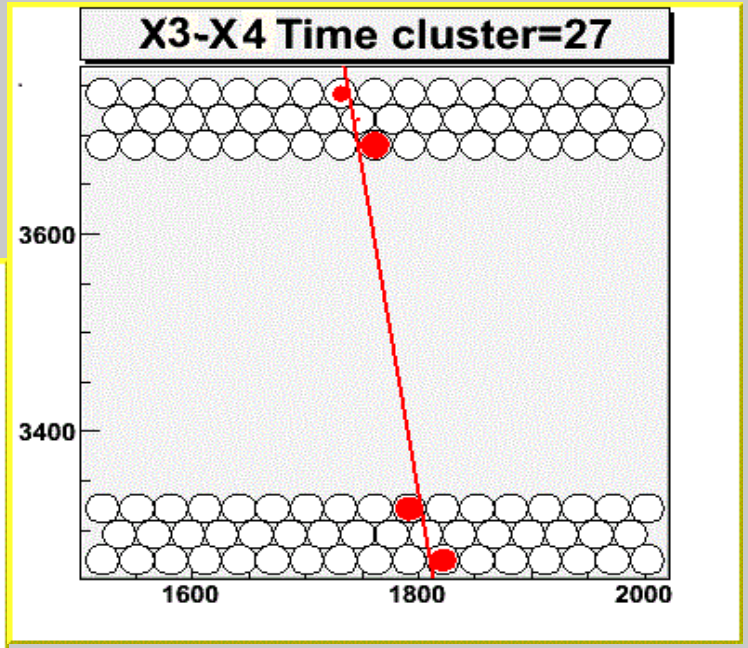


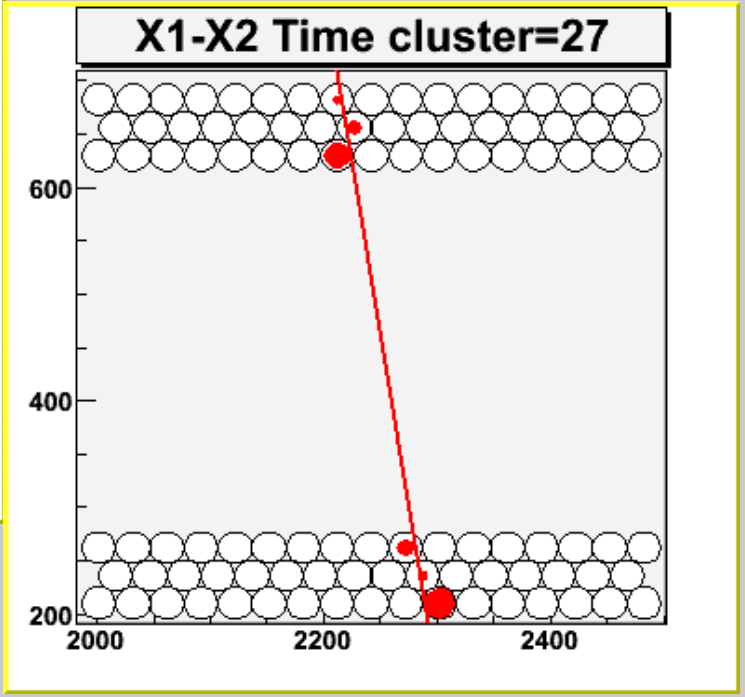

There are not trigger counters!
Only drift chambers are used for track measurements.

Track – tangent line for set of cycles ($R_i$).
Hit radius $R_i$=f(drift time). r(t)-relation common for all tubes. It is non-linear.



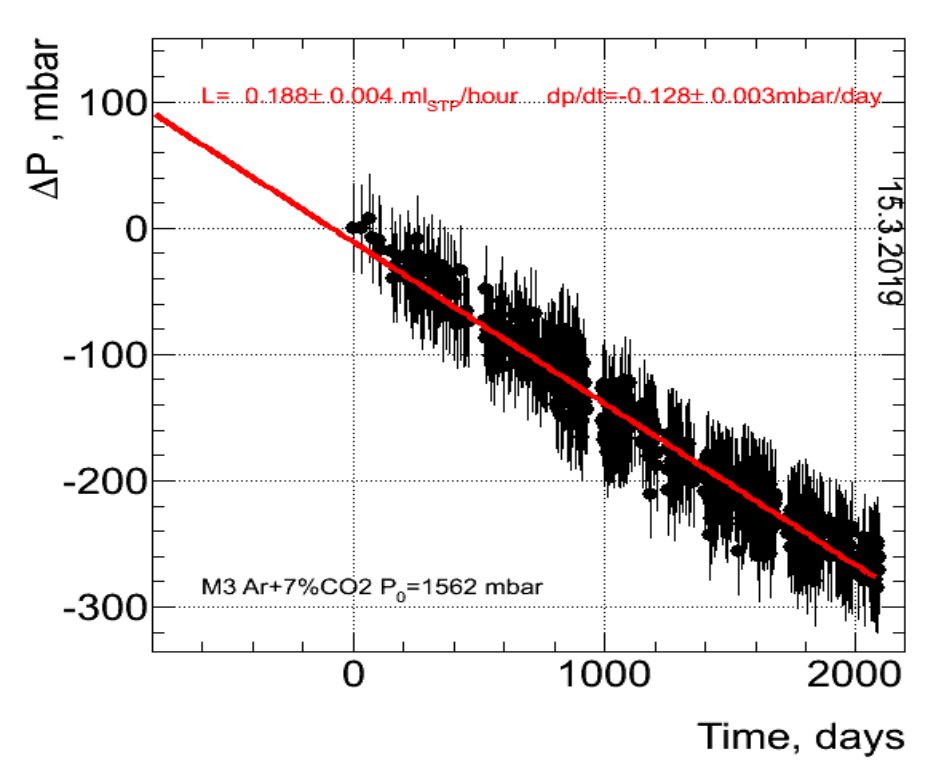



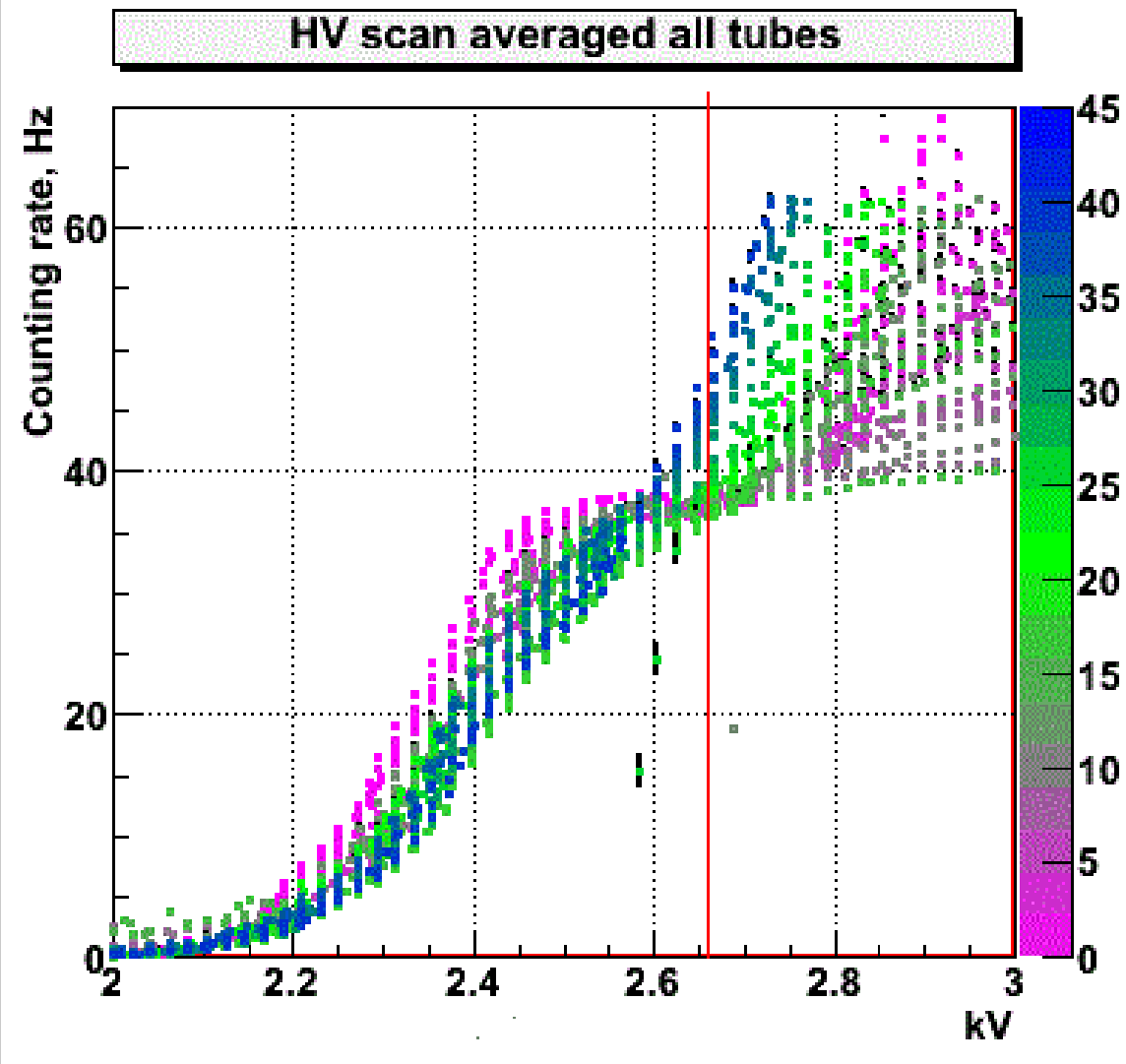

$\sigma(\theta_{up} - \theta_{down})$=1.5-3.0 mrad

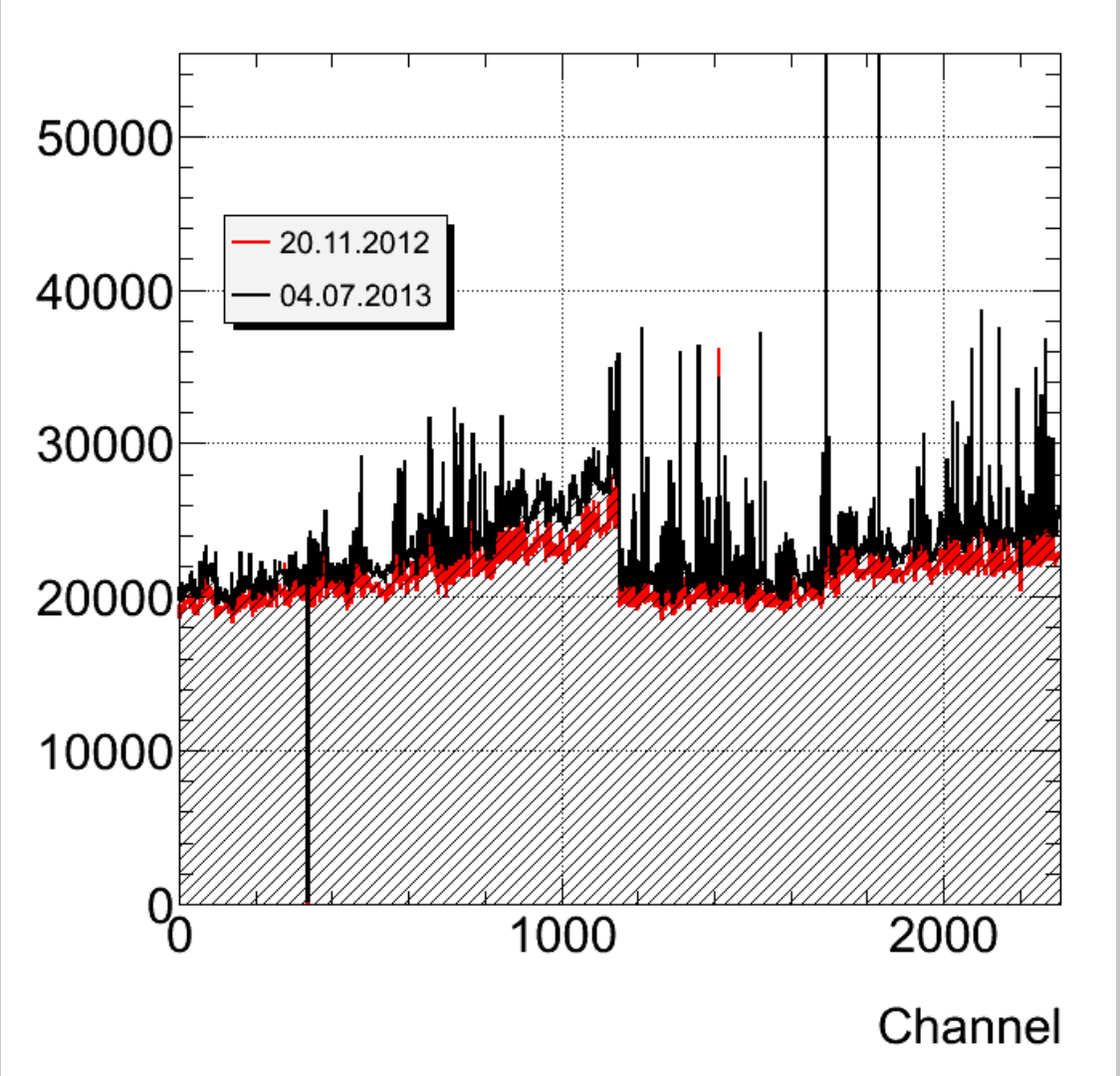
Drift tubes are filled with Ar+7%CO2 gas mixture at ~1.5 bar pressure.
Usually in practice of drift chambers gas mixture is exchanged during operation with rate 0.01-1 volume/day (eg. drift chambers at ATLAS flow is 1 volume/day).
We have filled drift tubes with the gas mixture and they were closed.
The gas mixture was not refreshed since 05 April 2011!



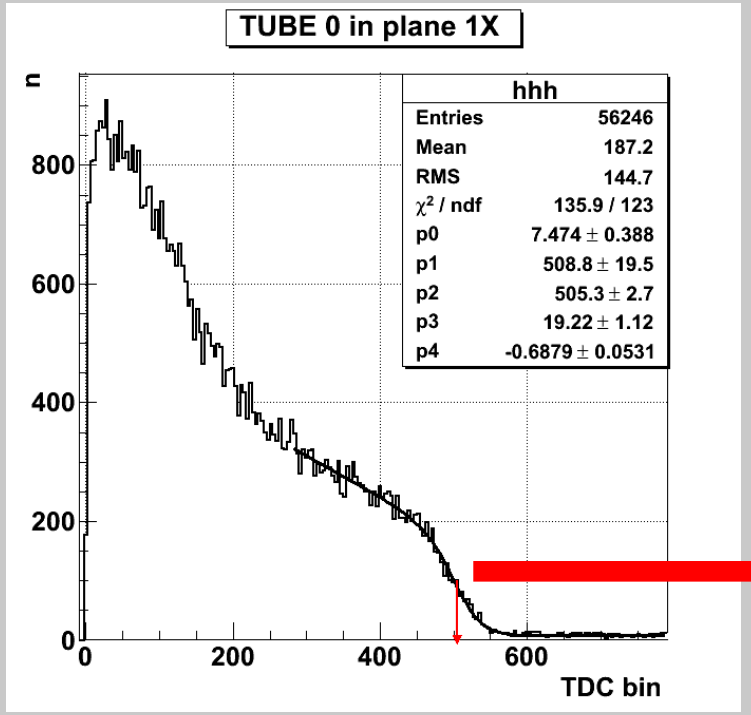

Total volume = 4.7 $m^3$
Drop of pressure (dp/dt, chambers+gas-distribution system) is 0.13 mbar/day
Leak rate 4.6 $\times 10^{-3}$ litres/day

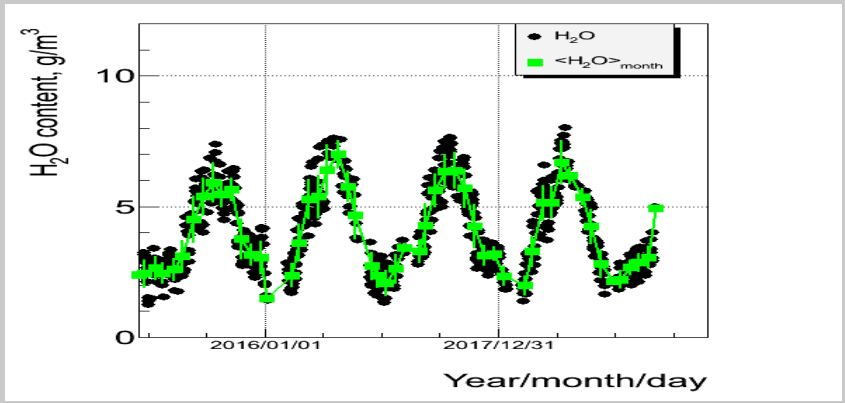
# Counting rate vs. voltage. Decreasing of plateau. Hits per tube.

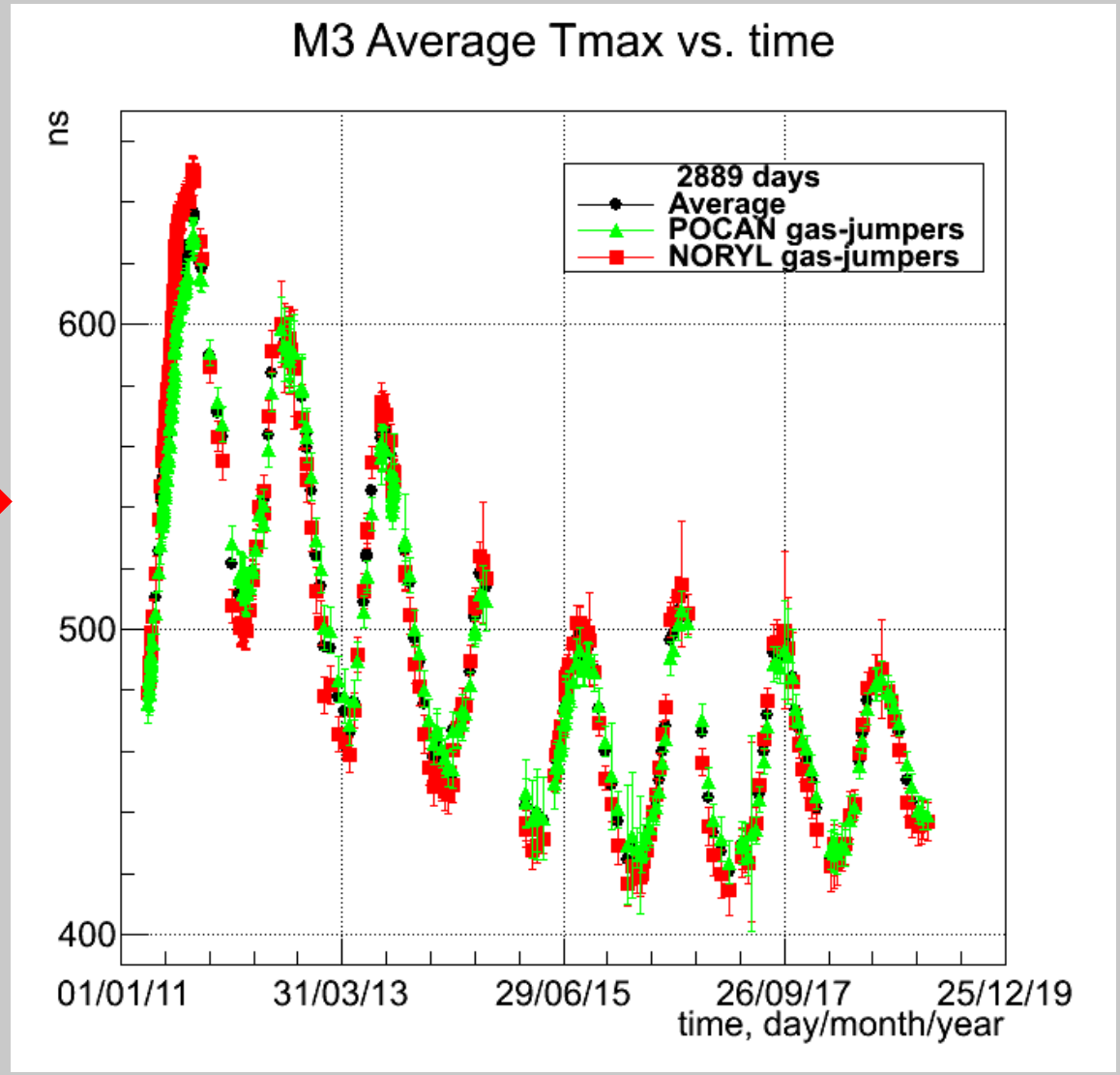


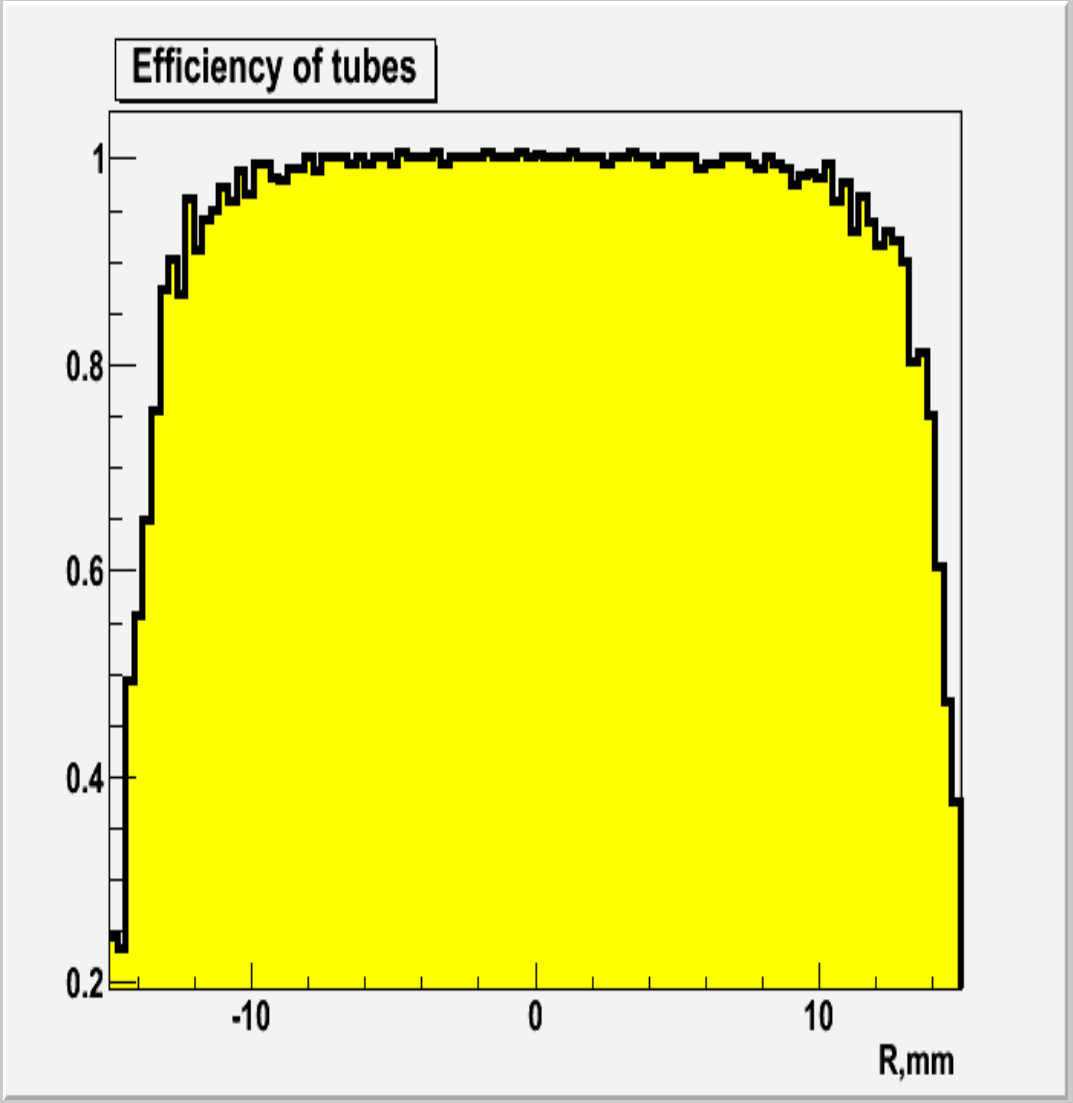
# Maximal drift time corresponds to internal radius of the tube.

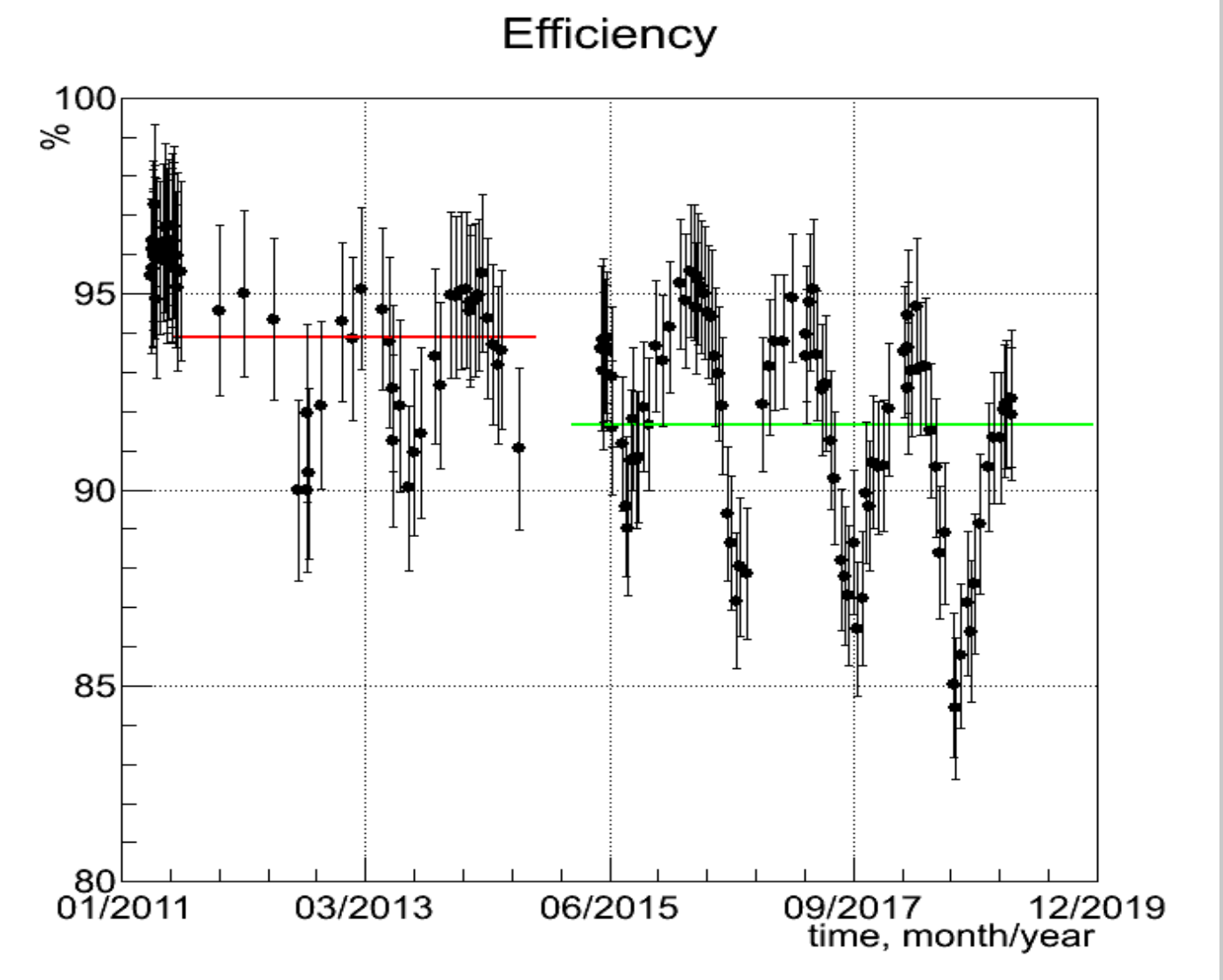


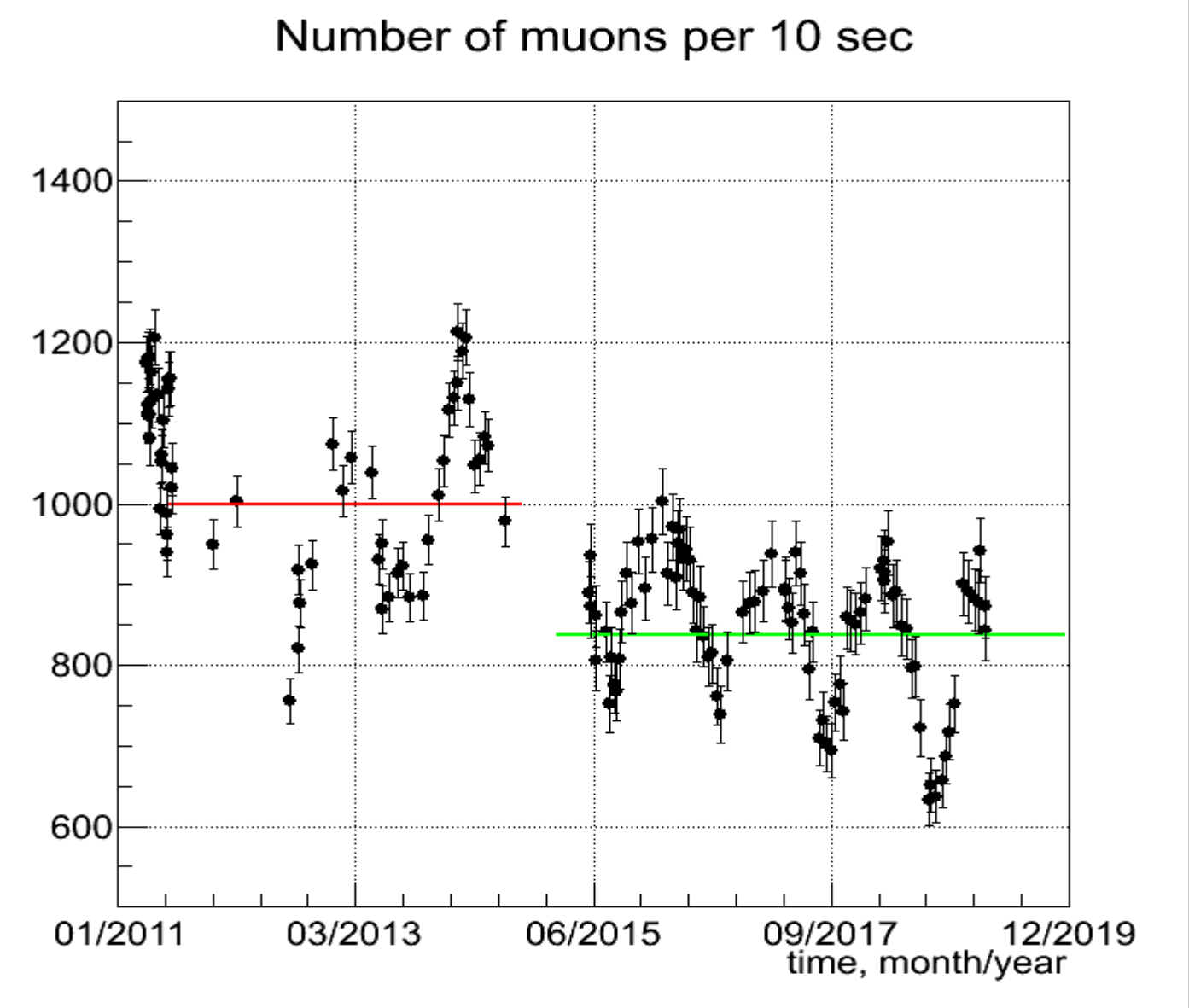



# Efficiency. Layers for control – bottom in 3X an 3Y (excluded from track reconstruction)



# Number of single muons/10 sec

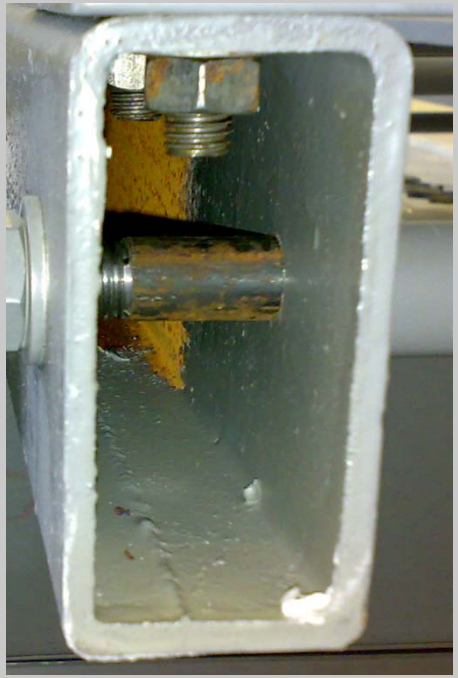


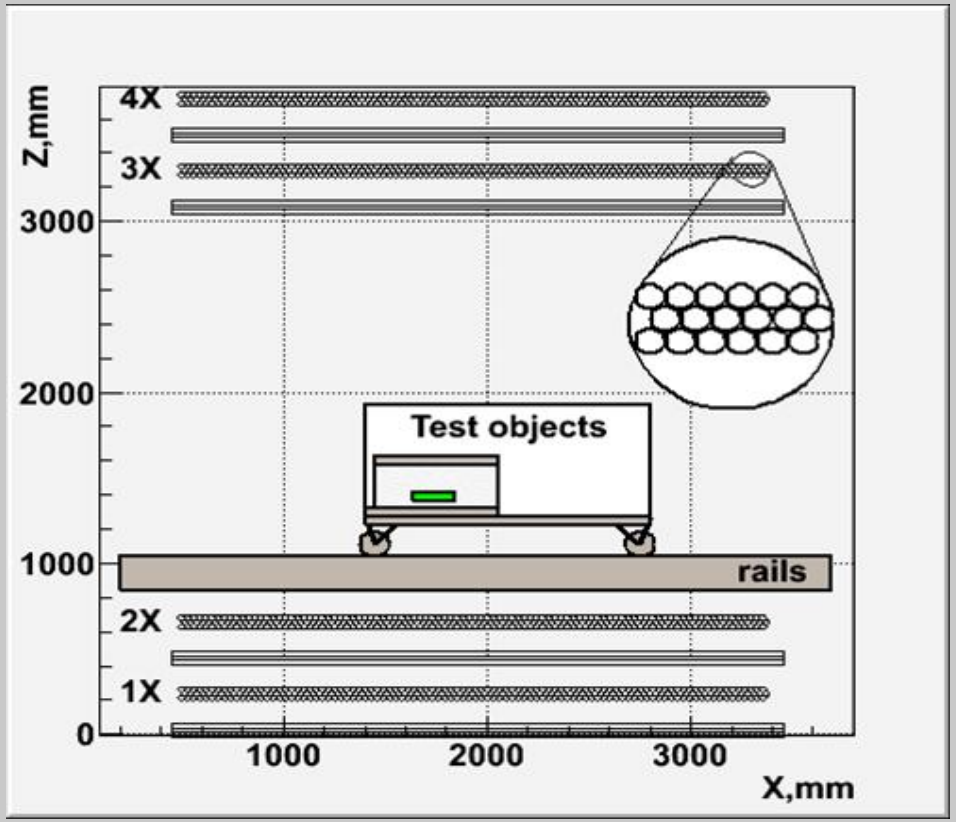

Criteria:
- 19 hits
- Intersection of top and bottom planes
- $\chi^2$ cut

Track reconstruction different of ones used for tomography

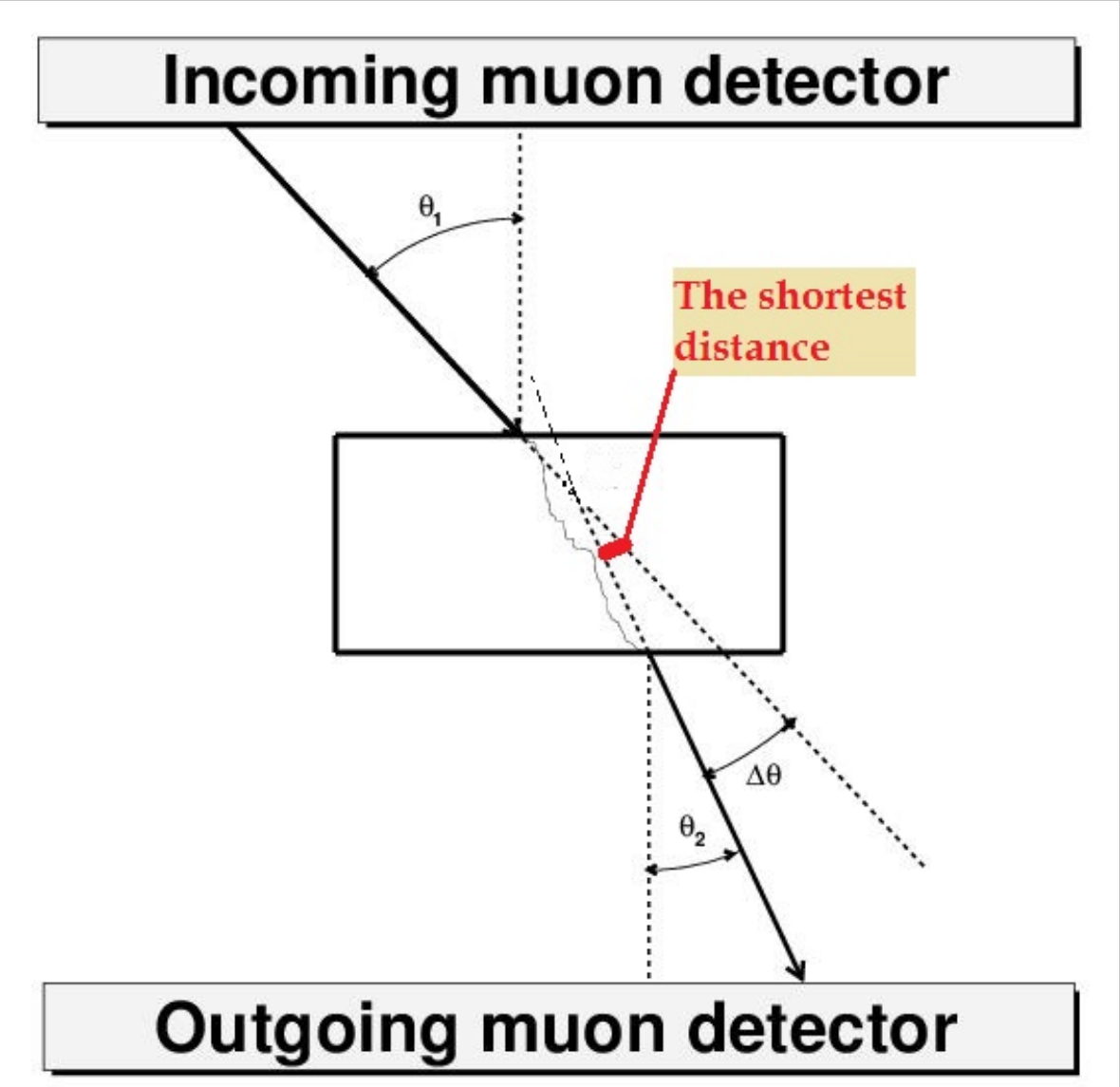
Drift chambers are working after 8 years since moment of the gas mixture filling.

What we can say about tomography? Many different scenes were investigated. But lucky for us, heavy objects, 2 rails are always present. Each rail is made of two steel beams rectangular hollow section 100×50×5 $mm^3$, welded at short side.





# The simplest analysis – Point Of the Closest Aproach (POCA)




POCA – the middle of the shortest distance between tracks.

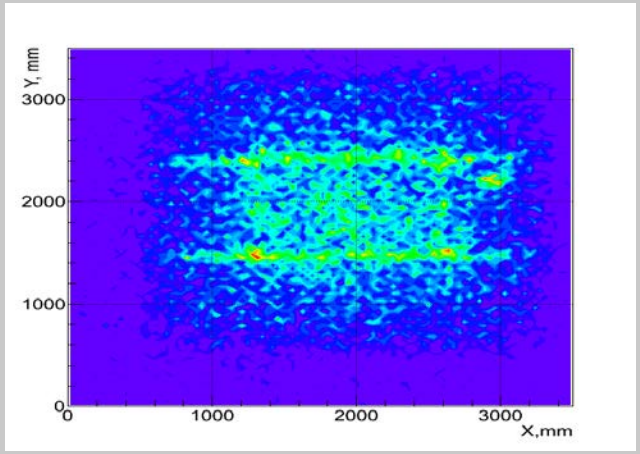
Analysis without density calculations – only 3D-histogram of the points.

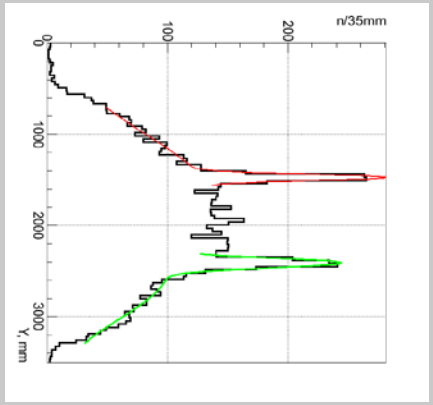
Selected tracks:

with scatter angle $\Delta\theta > 4$ mrad.

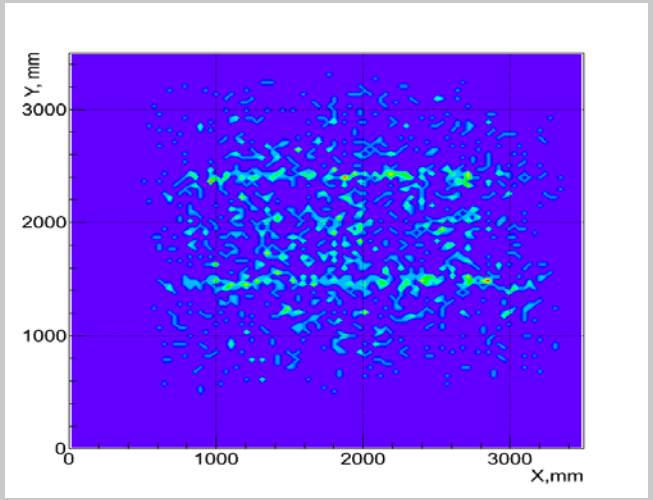
Visualization: slice in Z and projection of the slice on the Y-axis, perpendicular to rails

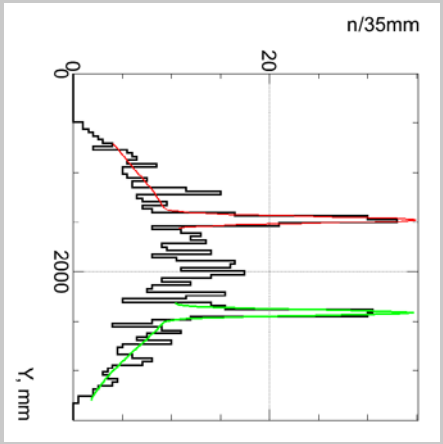
# Exposition time 28 minutes. POCA



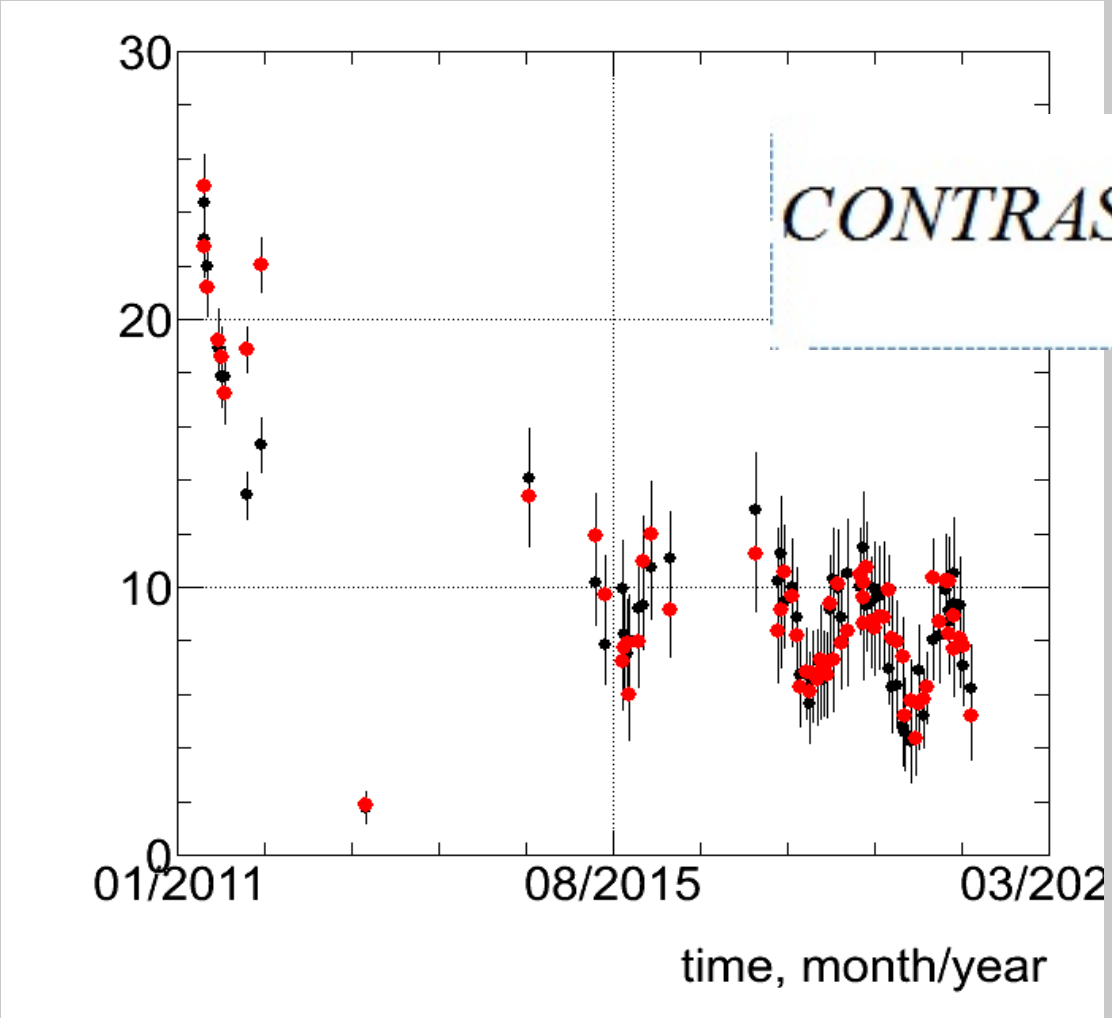




11 April 2011 8 days




08 May 2019 2966 days




$$CONTRAST = \frac{N\_signal}{\sqrt{(N\_signal + N\_bcgr)}}$$

# Conclusion

Drift tube chambers filled with Ar+7%$CO_2$ gas mixture are successfully used for cosmic-ray muon track detection at muon scattering tomography setup. Once filled with the gas mixture they are working without refresh of the gas more than 8 years keeping the average tube efficiency at the level of 92%. Contrast tomography image of rectangular hollow section steel beams are seen as well.

# Thanks for your attention