Range (muon) System Status and Plans for 2024

G.Alexeev, SPD Collaboration meeting, Almaty 21.05.2024

- **Main results and current activities (after SPD Collaboration meeting, Oct. 2023):**

- Conclusion of the Agreement between JINR and (Institute of Physics + Integral, Minsk) on production of the first portion of Ampl-8.53 amplifiers
- Full commissioning of the RS prototype (MDT detectors, analog and digital front-end electronics, DAQ) at Nuclotron test beam area, and initial data collection with cosmic
- Calculation of magnetic forces influence on the Range System (magnet yoke)
- First test of Cherenkov counter with modified optical system on cosmic
- Preparation for testing the “final” digital FEE unit with DAQ L1 concentrator
- Preparations for deployment of equipment for MDTs mass production
- Participation in development of PID algorithms for pion-to-muon separation

- **Plans for the rest of 2024**
- **Conclusion**

Range System prototype at Nuclotron test beam area in cosmic tests position (vertical)

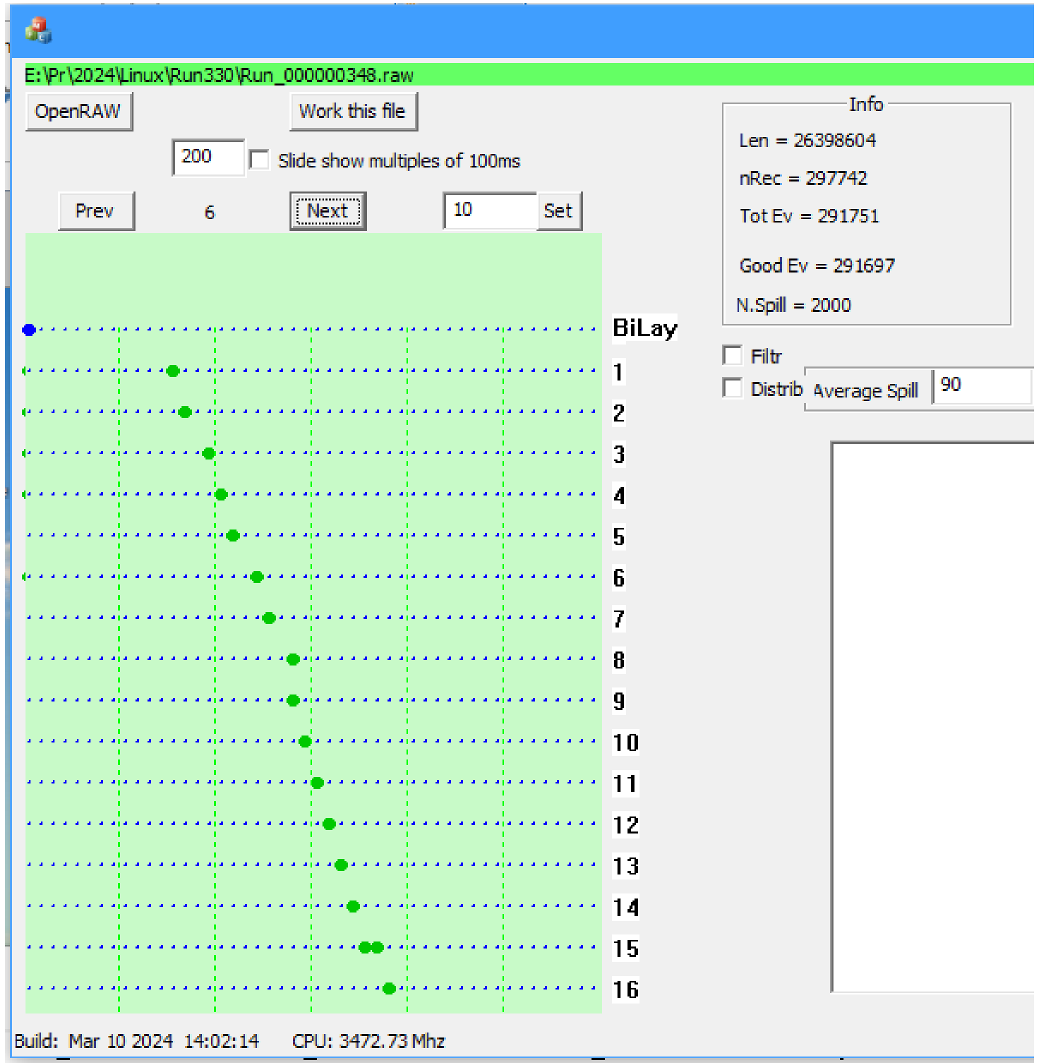
On-line/DAQ comp

2 VME/6U crates: digital FEE units MFDM-192 and DAQ crate

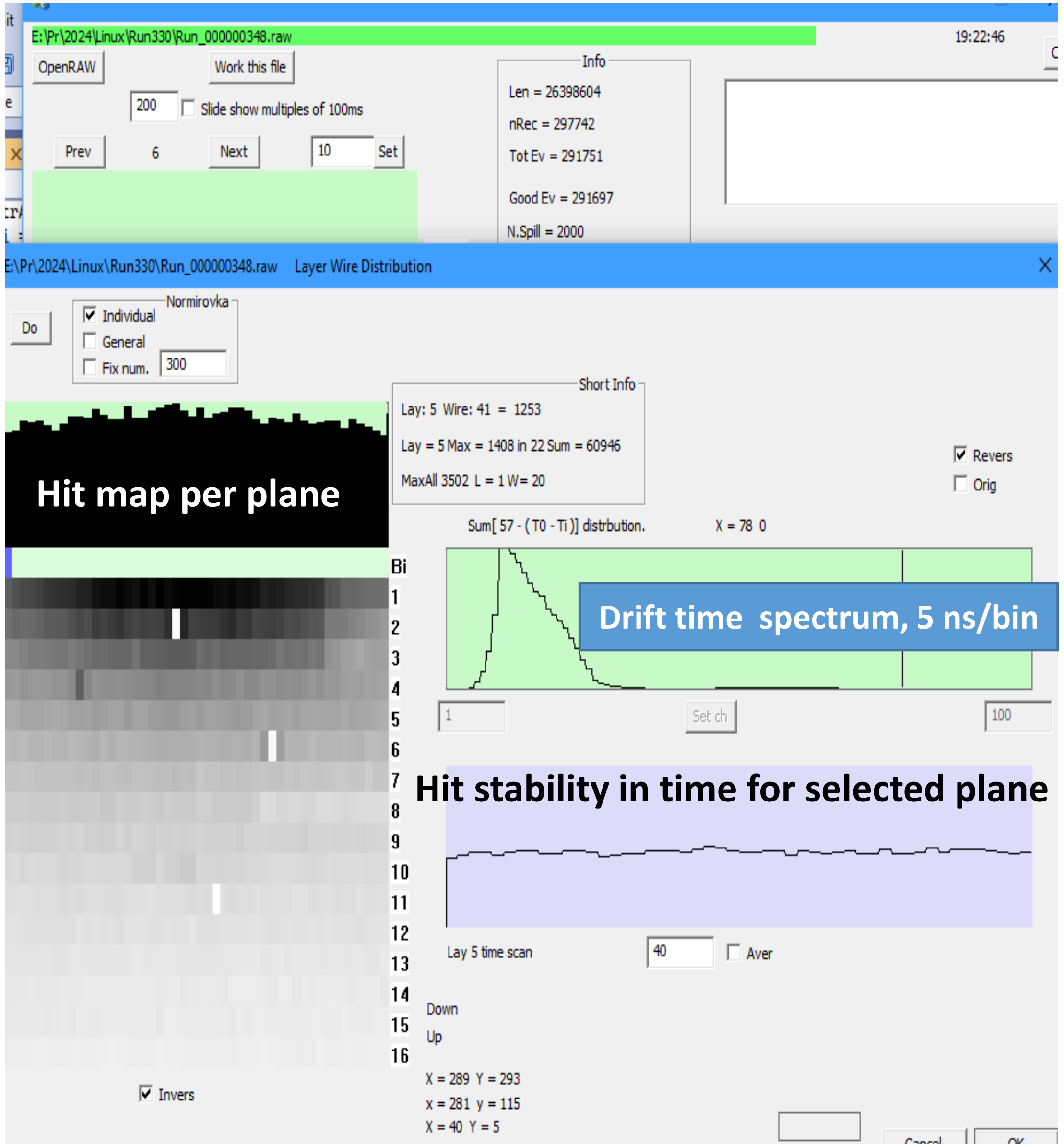
2 scint.counters 2x50x50 cm3 as trigger

RS Proto (1.5 ton): 16 layers, 6 MDTs per layer (48 wires per plane) -> **768 channels**

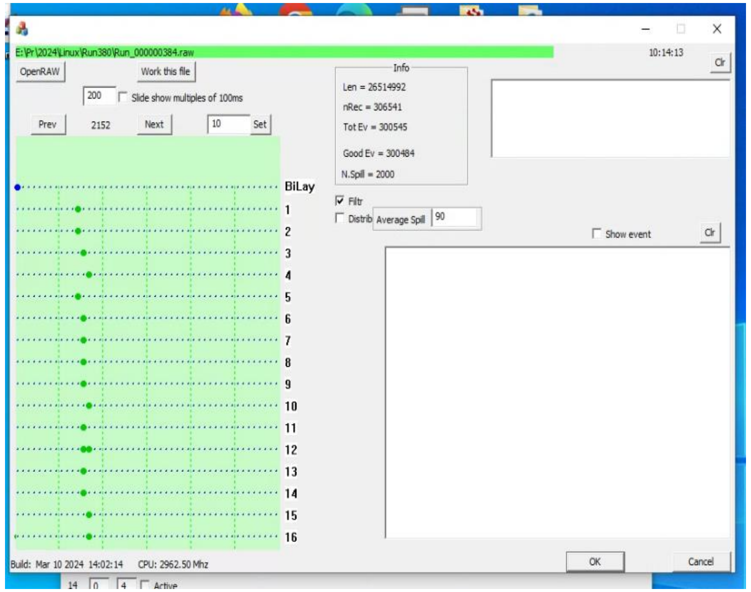
On-line event display for monitoring of data taking – possibility to view the events/tracks and corresponding statistics and distributions (hit maps, drift time spectra, stability in time)

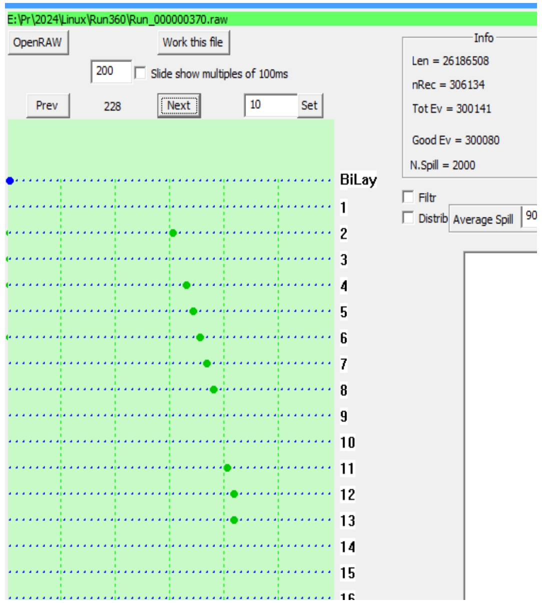


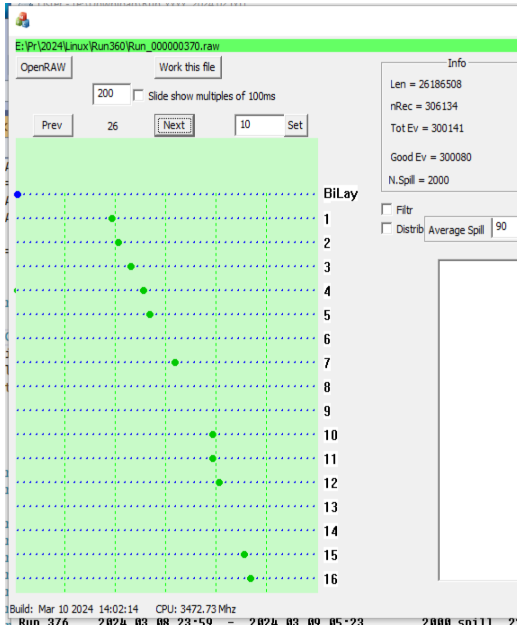
Run_345	2024.03.02_23:57	-	2024.03.03_05:19	2000 spill		
Run_346	2024.03.03_08:55	-	2024.03.03_13:02	1539 spill	2250v	
Run_347	2024.03.03_13:04	-	2024.03.03_18:30	2000 spill	2300v	
Run_348	2024.03.03_18:40	-	2024.03.04_00:04	2000 spill	2350v	

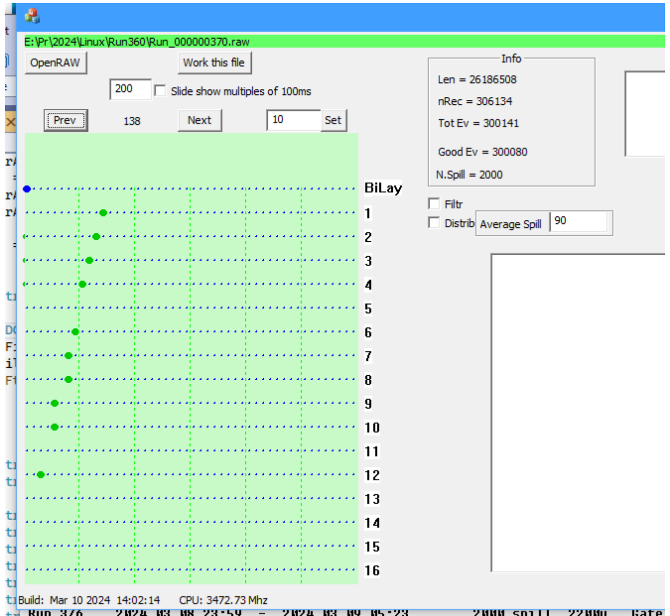


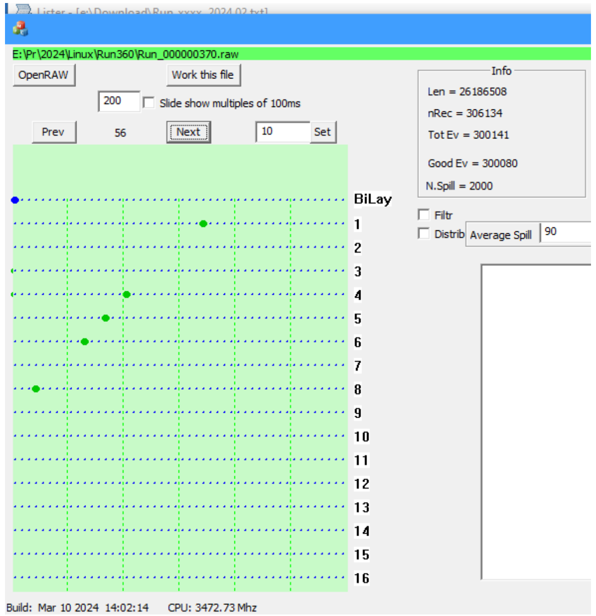
Examples of cosmic events





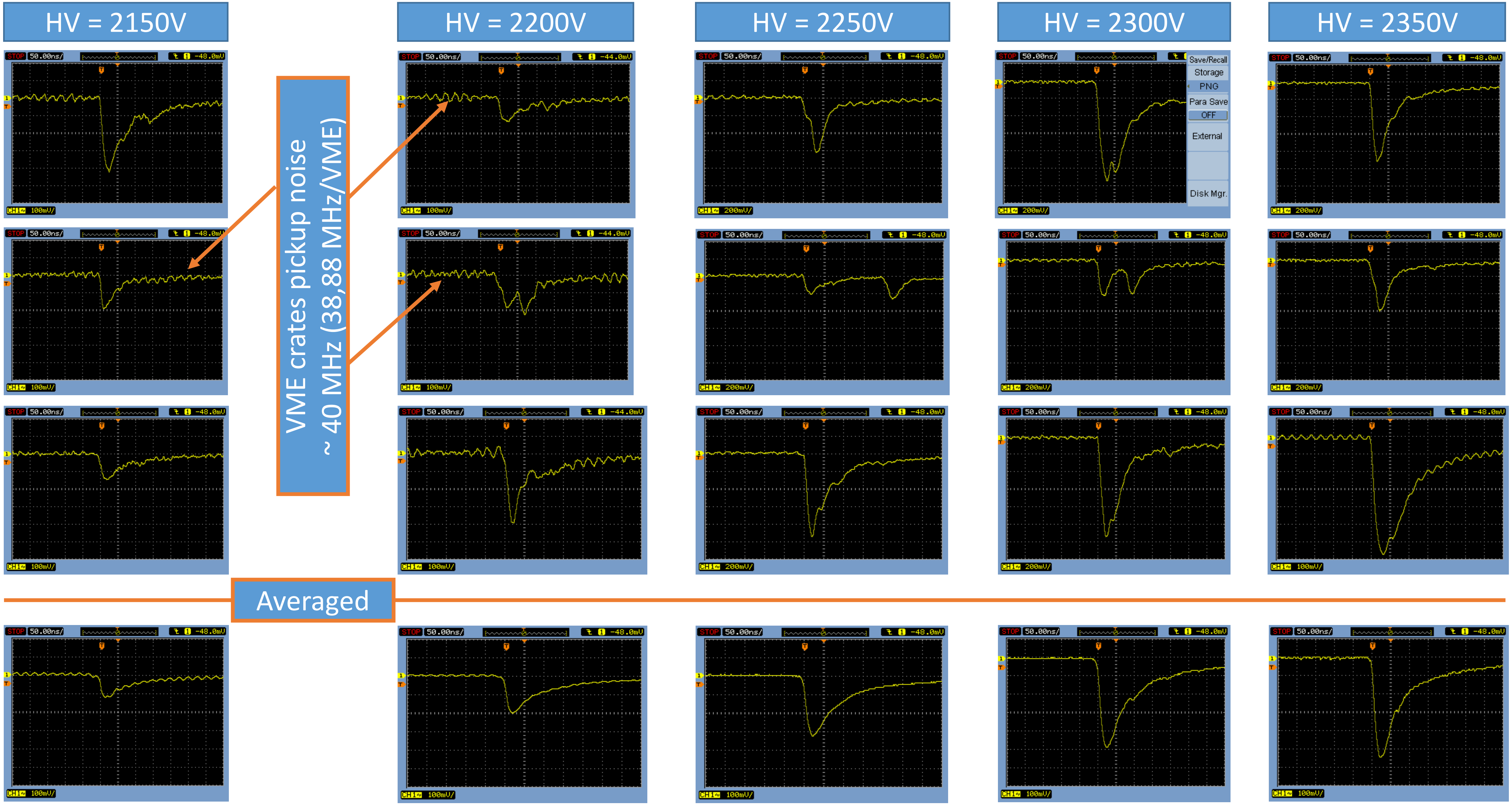






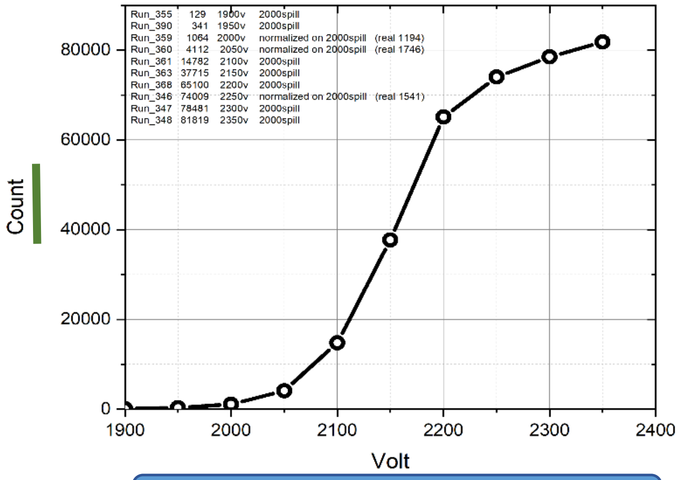
- * RS prototype was tested with 1 μA threshold
- * Gas mixture Ar : CO_2 = 70:30
- * Voltage range : 1,9 – 2,35 kV
- * Statistics of events ~ 10**6

Signals of MDTs @ different HV

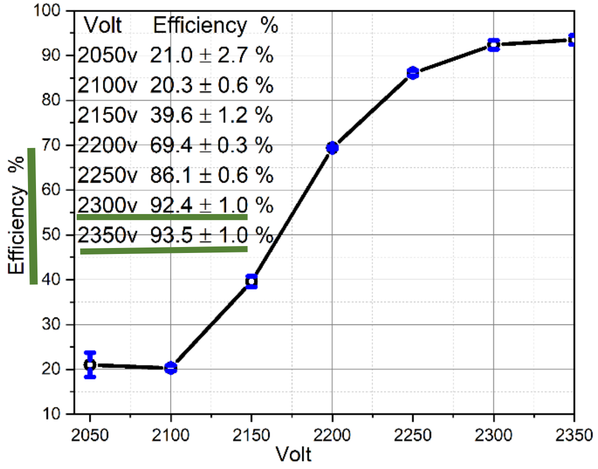


Characteristics of RS prototype

Counting characteristic



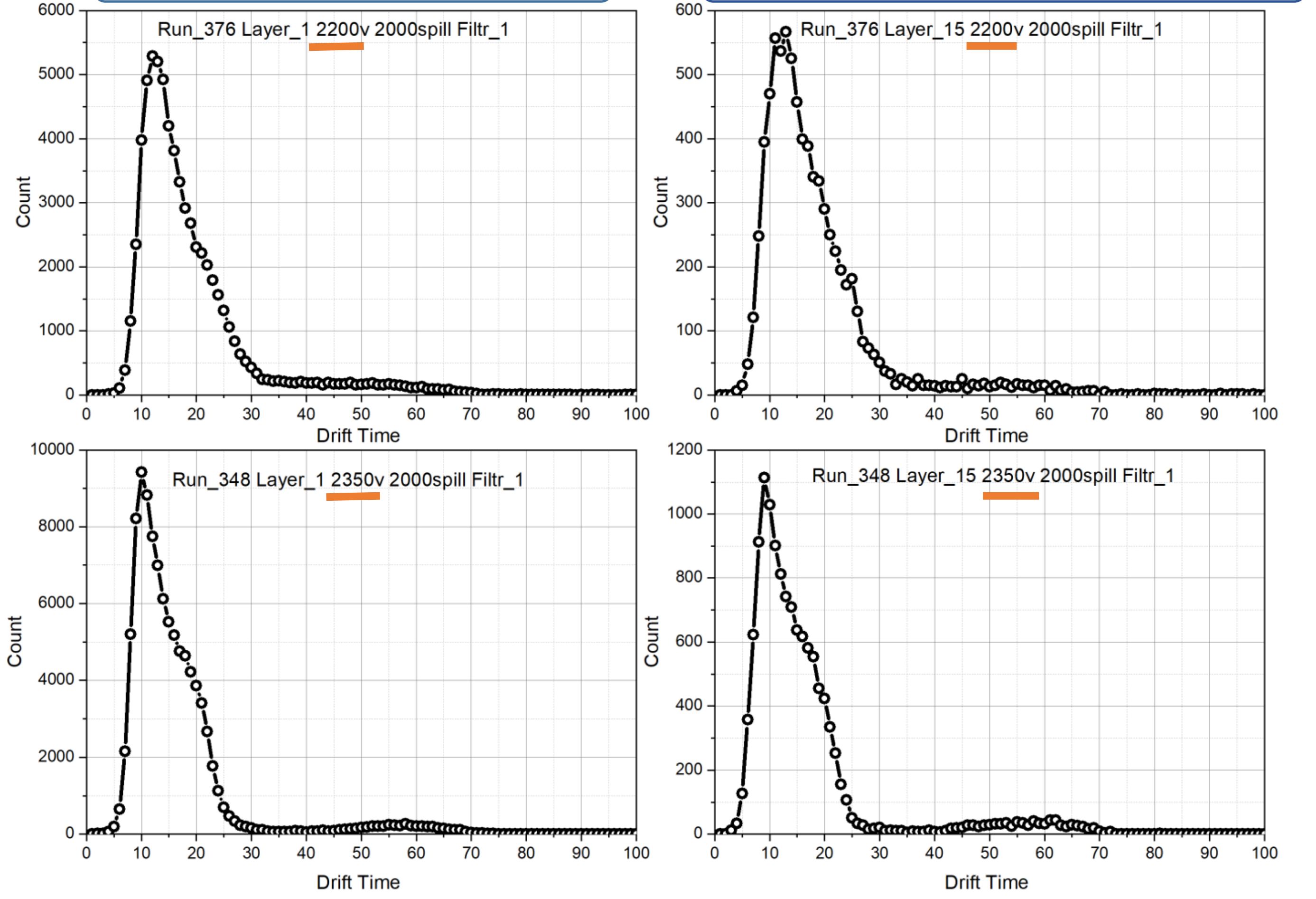
<efficiency> per plane



Drift time spectra, 5 nsec/bin

Wide angle tracks, 1st plane

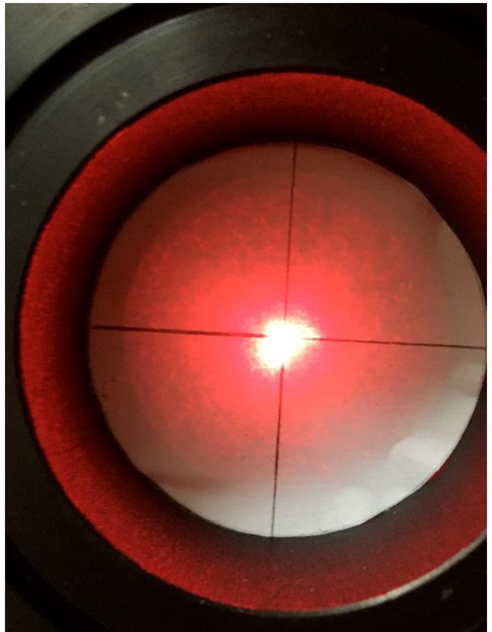
'Perpendicular' tracks, 16th plane



Cherenkov counter -> optical system upgrade



- **Improvement of light reflection with mirror-grade aluminum foil**
- **Replacement of flat mirror on quasi-parabolic for better focusing on photomultiplier**
- **Final adjustment of optical system**



Flat versus quasi-parabolic Cherenkov mirrors

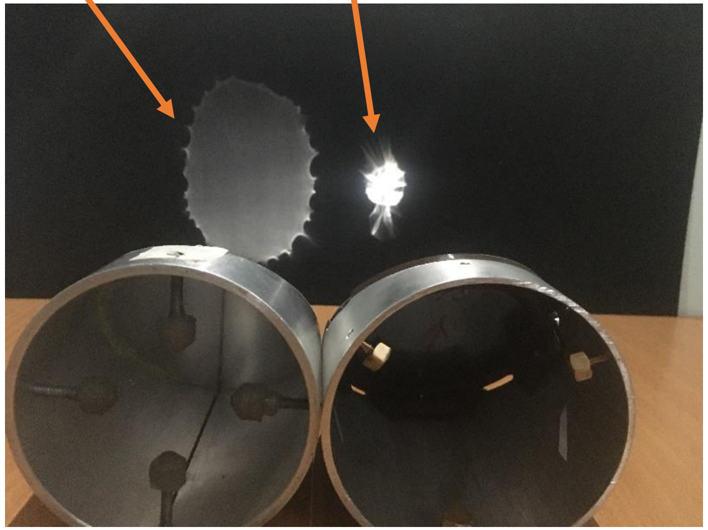
Flat

Quasi-parabolic

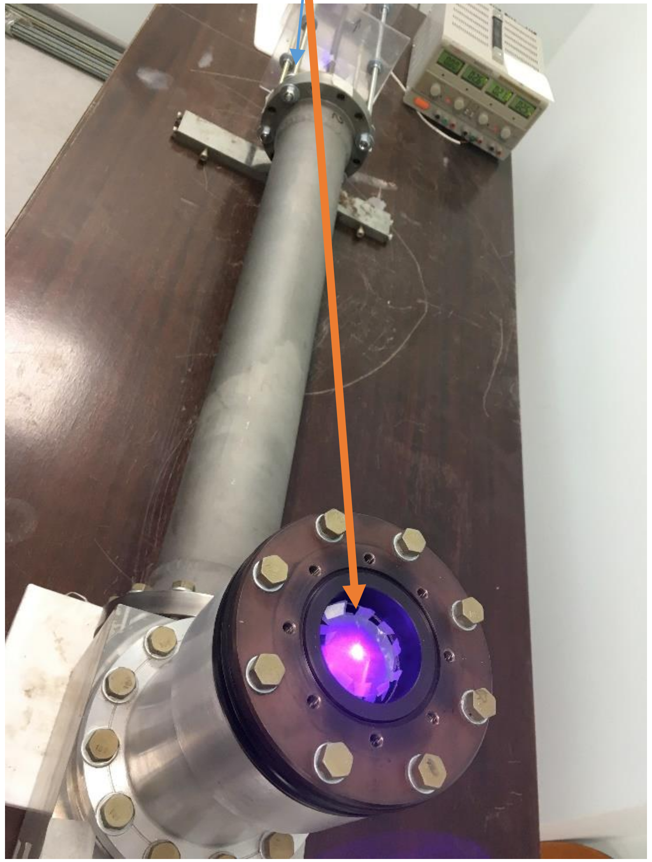
Wide-angle light beam

Quasi – parabolic mirror permits focusing of slightly diverged Cherenkov light at the threshold of formation (few mrad) on photocathode of photomultiplier, thus increasing signal amplitude by minimizing reflections from the inner surface of the counter

Reflected wide-angle beam by flat and quasi-parabolic mirrors

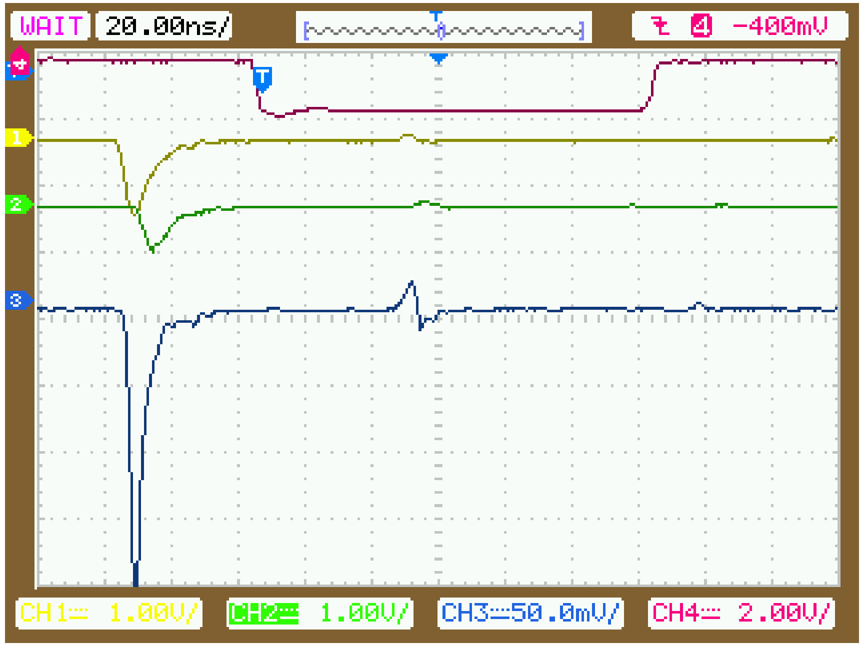


Final adjustment of optics with light focused in the middle of quartz glass window



Cosmic test stand for Cherenkov counter

(data taken up to 30 atm, to be continued up to 50+ (CO2 at saturation), was factory tested/certified up to 86 atm)



Trigger:
S1*S2*Č triple coincidence

S1 signal

S2 signal

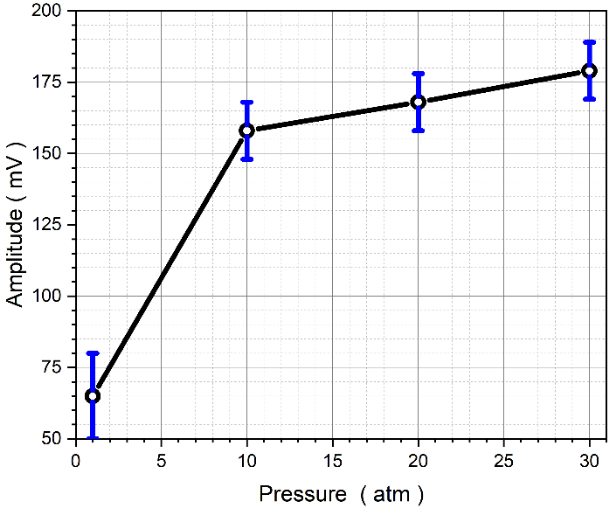
Č signal

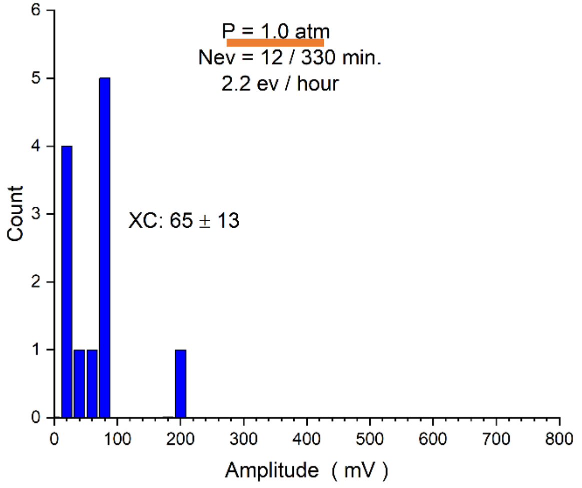
Cherenkov counter

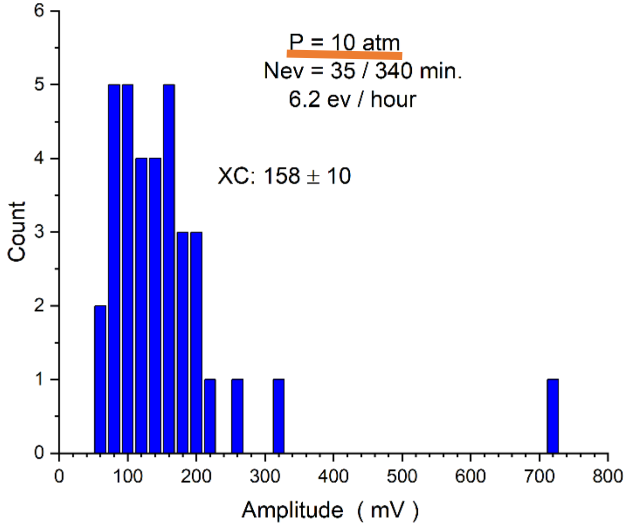
Amplitude of analog signal from Cherenkov counter was written by trigger signal one by one to flash card memory of digital oscilloscope

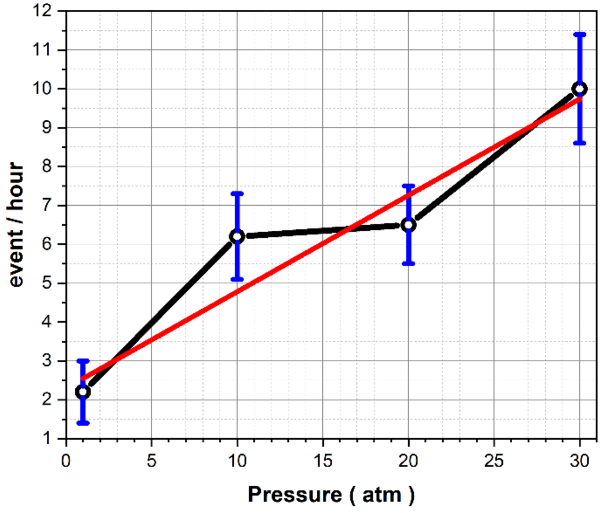
Initial results of testing Cherenkov counter on cosmic (up to 30 atm)

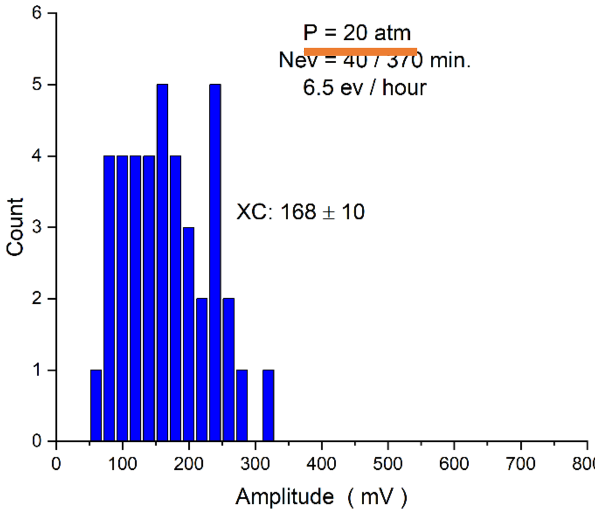
Aplitude spectra

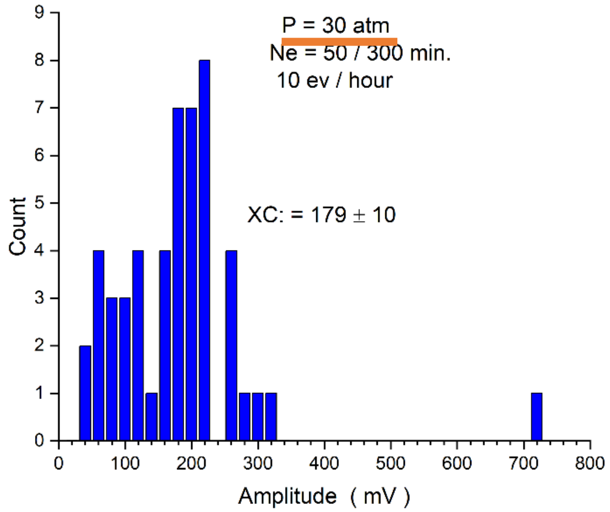












Plans for the rest of 2024

- Monitoring of contract execution on Ampl-8.53 chips by Integral
- Simulation of 3D Range System model with inclusion of magnetic forces (Barrel and End Caps). Final optimization of RS conceptual mechanical design.
- Preparations for deployment of equipment for MDTs mass production
- Participation in tests of digital FDM-192 units with L1/DAQ prototype (step forward final DAQ design)
- Treatment of the RS prototype data collected in first cosmic run (track efficiency vs incident angle)
- Tests of Cherenkov counter on cosmic (higher statistics and pressure) and electron beam at DLNP linac
- Development of strip readout technology (analog cards and strip boards)
- Detailing of 5 year planning for RS construction (preliminary)
- Participation in development of PID algorithms for pion-to-muon separation

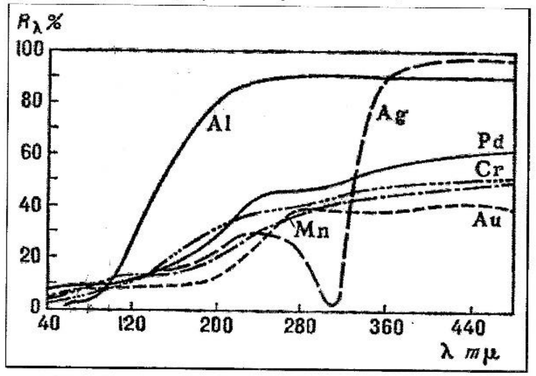
CONCLUSION

- Range System at present does not have visible principle technical challenges
- Still we have a lot to do for development of final technologies (mostly for strip readout)
- Main worry now is slow progress for deployment of MDTs production workshop

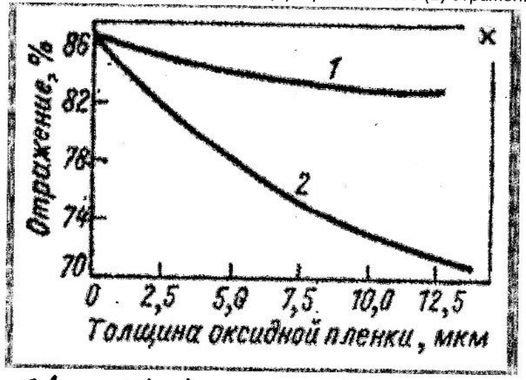
Backup slides

Input information on optimization of Cherenkov counter

Reflection factor
Коэфф. отражения

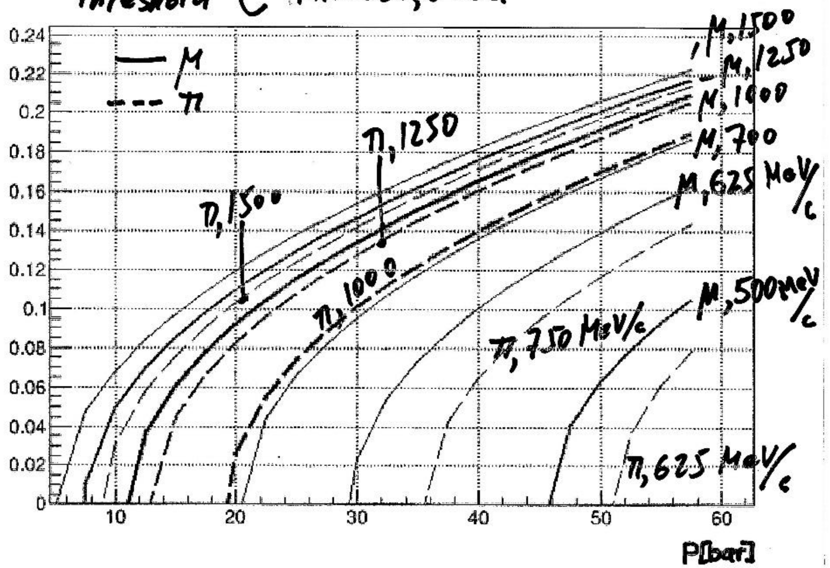


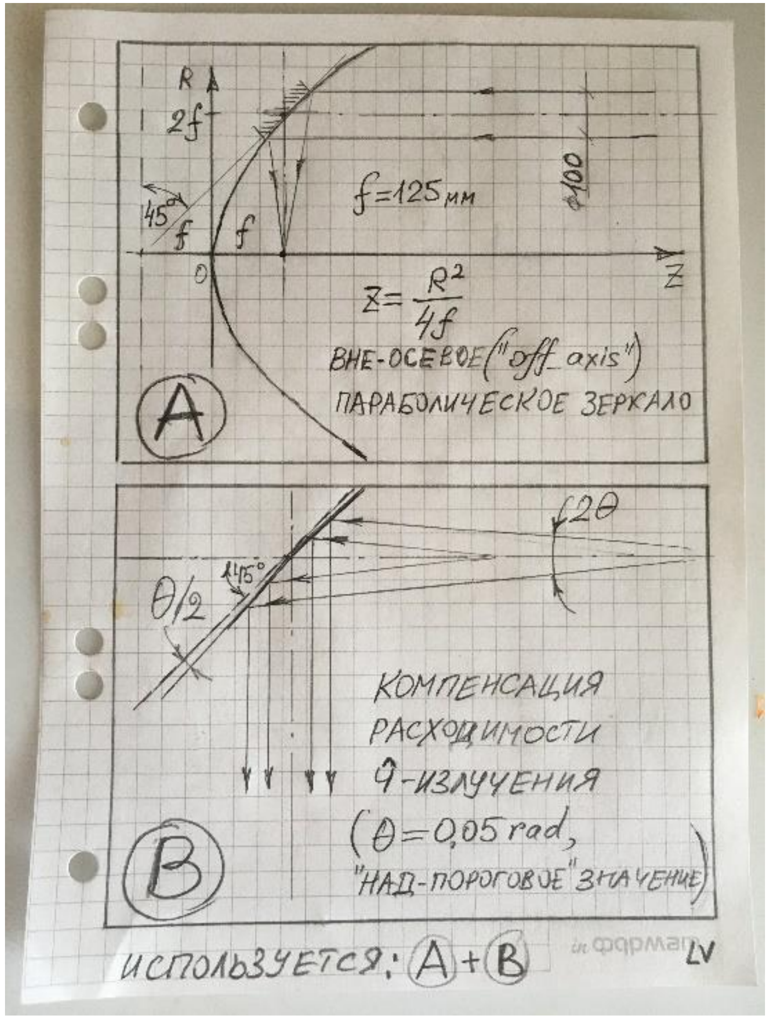
ALU: degradation of mirror(1) & diffuse(2) reflection
Алюминий: деградация зеркального (1) и рассеянного (2) отражений



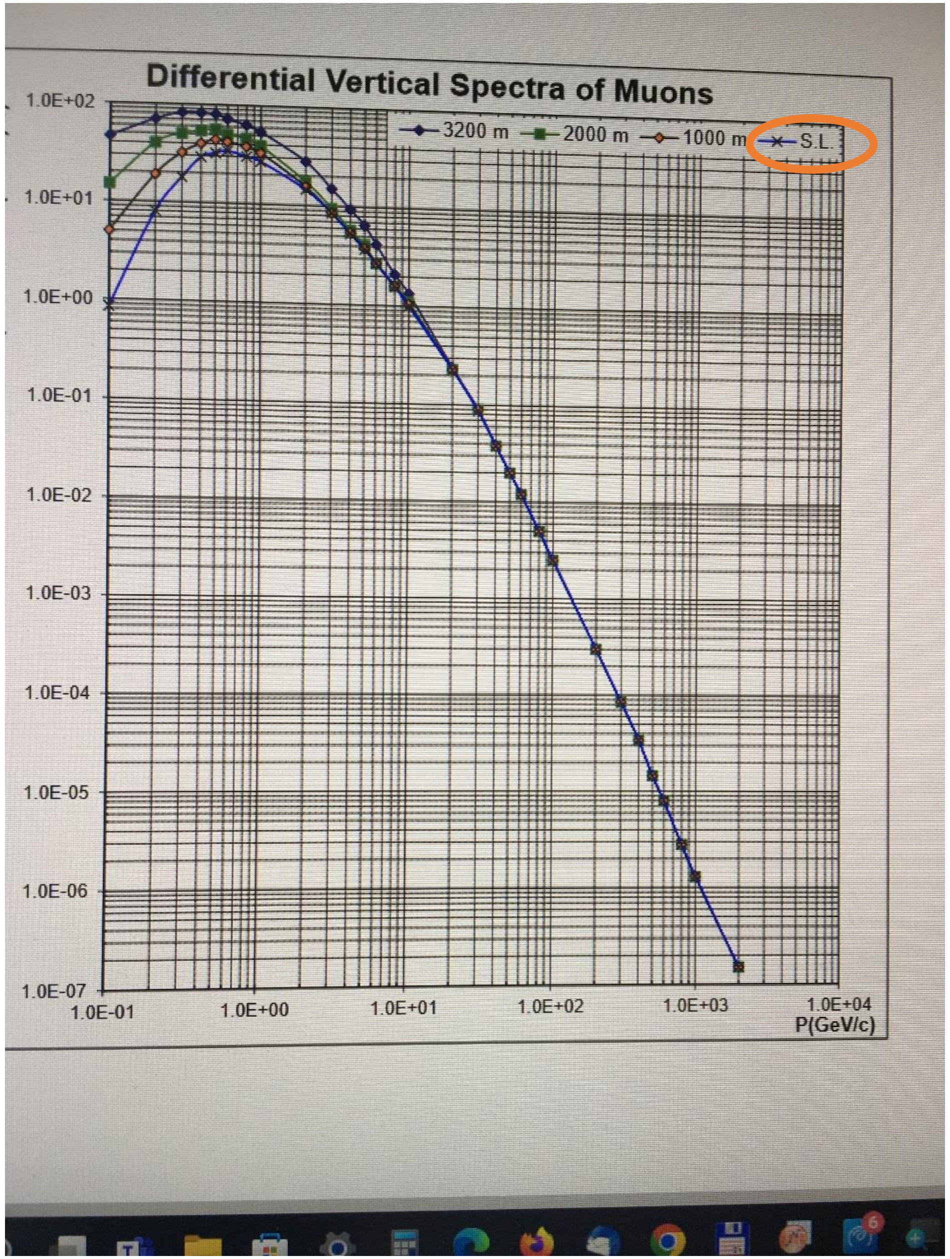
Oxide Film Thickness, μm

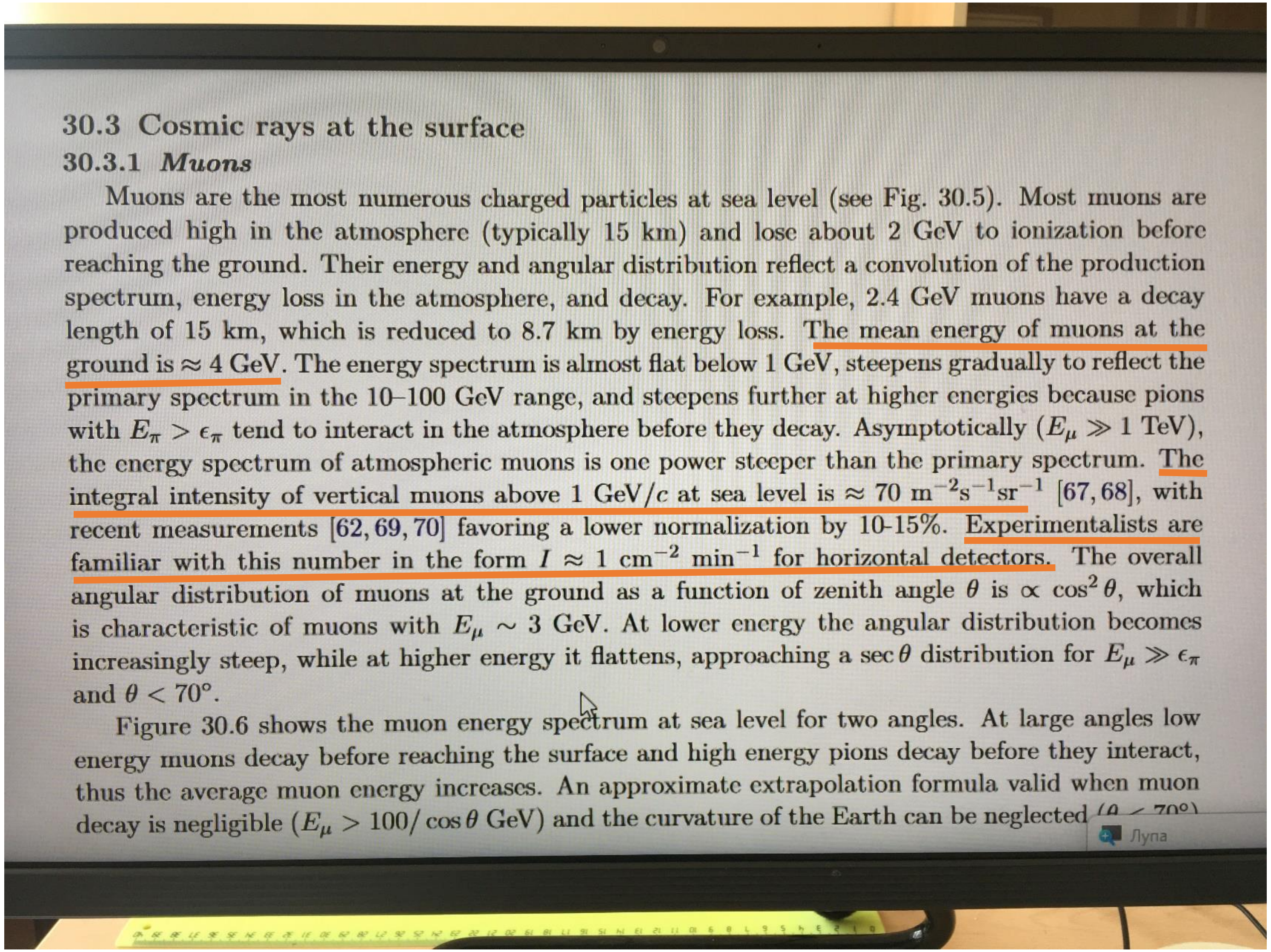
Threshold Č ANGLES, t=20°C





Usefull information on cosmic muons





30.3 Cosmic rays at the surface

30.3.1 *Muons*

Muons are the most numerous charged particles at sea level (see Fig. 30.5). Most muons are produced high in the atmosphere (typically 15 km) and lose about 2 GeV to ionization before reaching the ground. Their energy and angular distribution reflect a convolution of the production spectrum, energy loss in the atmosphere, and decay. For example, 2.4 GeV muons have a decay length of 15 km, which is reduced to 8.7 km by energy loss. The mean energy of muons at the ground is ≈ 4 GeV. The energy spectrum is almost flat below 1 GeV, steepens gradually to reflect the primary spectrum in the 10–100 GeV range, and steepens further at higher energies because pions with $E_\pi > \epsilon_\pi$ tend to interact in the atmosphere before they decay. Asymptotically ($E_\mu \gg 1$ TeV), the energy spectrum of atmospheric muons is one power steeper than the primary spectrum. The integral intensity of vertical muons above 1 GeV/c at sea level is $\approx 70\ \mathrm{m^{-2}s^{-1}sr^{-1}}$ [67, 68], with recent measurements [62, 69, 70] favoring a lower normalization by 10-15%. Experimentalists are familiar with this number in the form $I \approx 1\ \mathrm{cm^{-2}\ min^{-1}}$ for horizontal detectors. The overall angular distribution of muons at the ground as a function of zenith angle θ is $\propto \cos^2\theta$, which is characteristic of muons with $E_\mu \sim 3$ GeV. At lower energy the angular distribution becomes increasingly steep, while at higher energy it flattens, approaching a $\sec\theta$ distribution for $E_\mu \gg \epsilon_\pi$ and $\theta < 70°$.

Figure 30.6 shows the muon energy spectrum at sea level for two angles. At large angles low energy muons decay before reaching the surface and high energy pions decay before they interact, thus the average muon energy increases. An approximate extrapolation formula valid when muon decay is negligible ($E_\mu > 100/\cos\theta$ GeV) and the curvature of the Earth can be neglected ($\theta < 70°$)