Electron beam test of the MPD electromagnetic calorimeter on the «Pakhra» synchrotron

V.A. Baskov [1]***, S.A. Bulychjov*** [2]***, Yu.F. Krechetov***[3]***, V.V. Kulikov***[2]***,***
I.A. Mamonov [1]***, M.A. Martemianov*** [2]***, A.Yu. Semenov*** [3]***,***
I.A. Semenova[3]***, I.A. Tyapkin***[3]

[1] *Lebedev Physical Institute – Moscow, Russia*
[2] *NRC "Kurchatov Institute" – ITEP, Moscow, Russia*
[3] *Joint Institute for Nuclear Research, Dubna, Russia*

Vth International Conference on Particle Physics and Astrophysics,
MEPhI, 5 – 9 October 2020

****Supported by RFBR Grant №18-02-40079***

NICA and MPD (Multi-Purpose Detector)

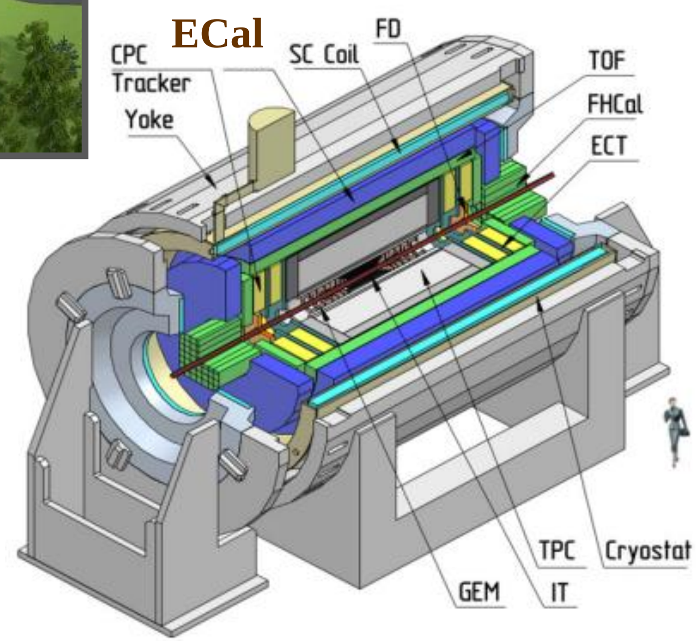
✓ Initial beam NICA collider parameters :

$$\sqrt{S_{NN}} = \mathbf{7 \div 11\ GeV}$$

Ions : $\mathbf{Au^{197}/Bi^{209} + Au^{197}/Bi^{209}}$

$$L \sim \mathbf{10^{27} cm^{-2}\ c^{-1}}$$

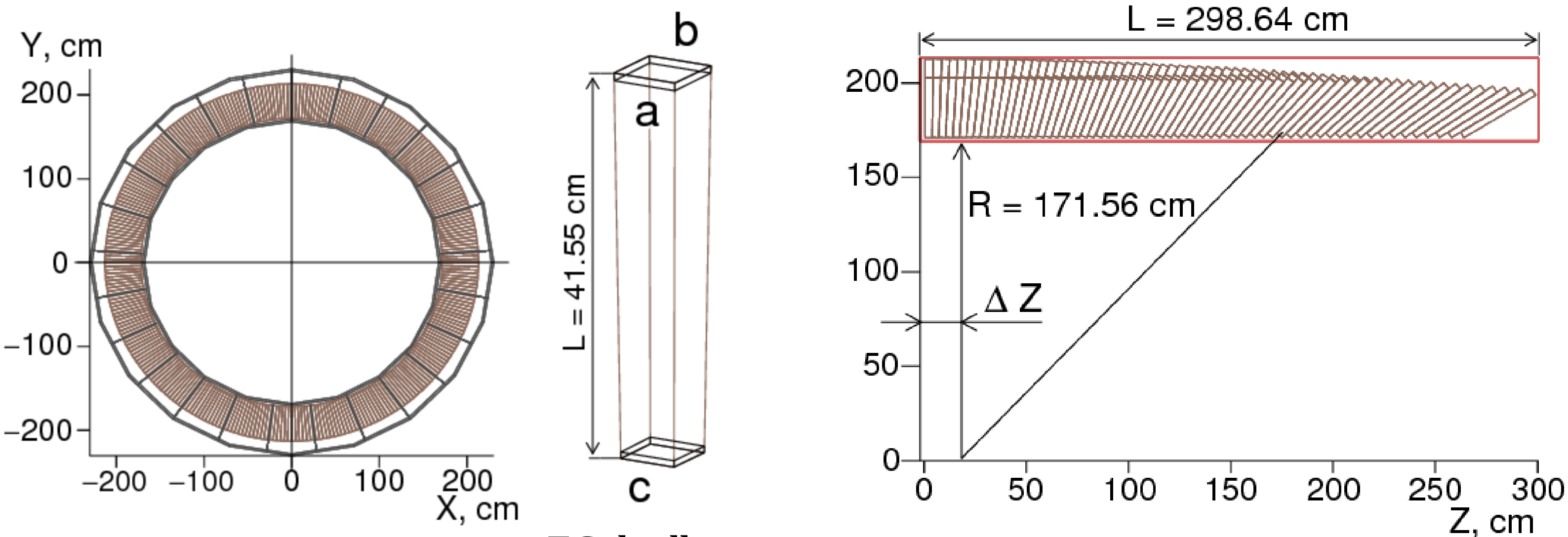
✓ Now collider building and MPD hall are ready



✓ MPD first stage : construction and installation of the superconducting magnet, ECal, TOF, TPC, ZDC

✓ All components of the MPD first stage detector are in production stage, commissioning expected for next year

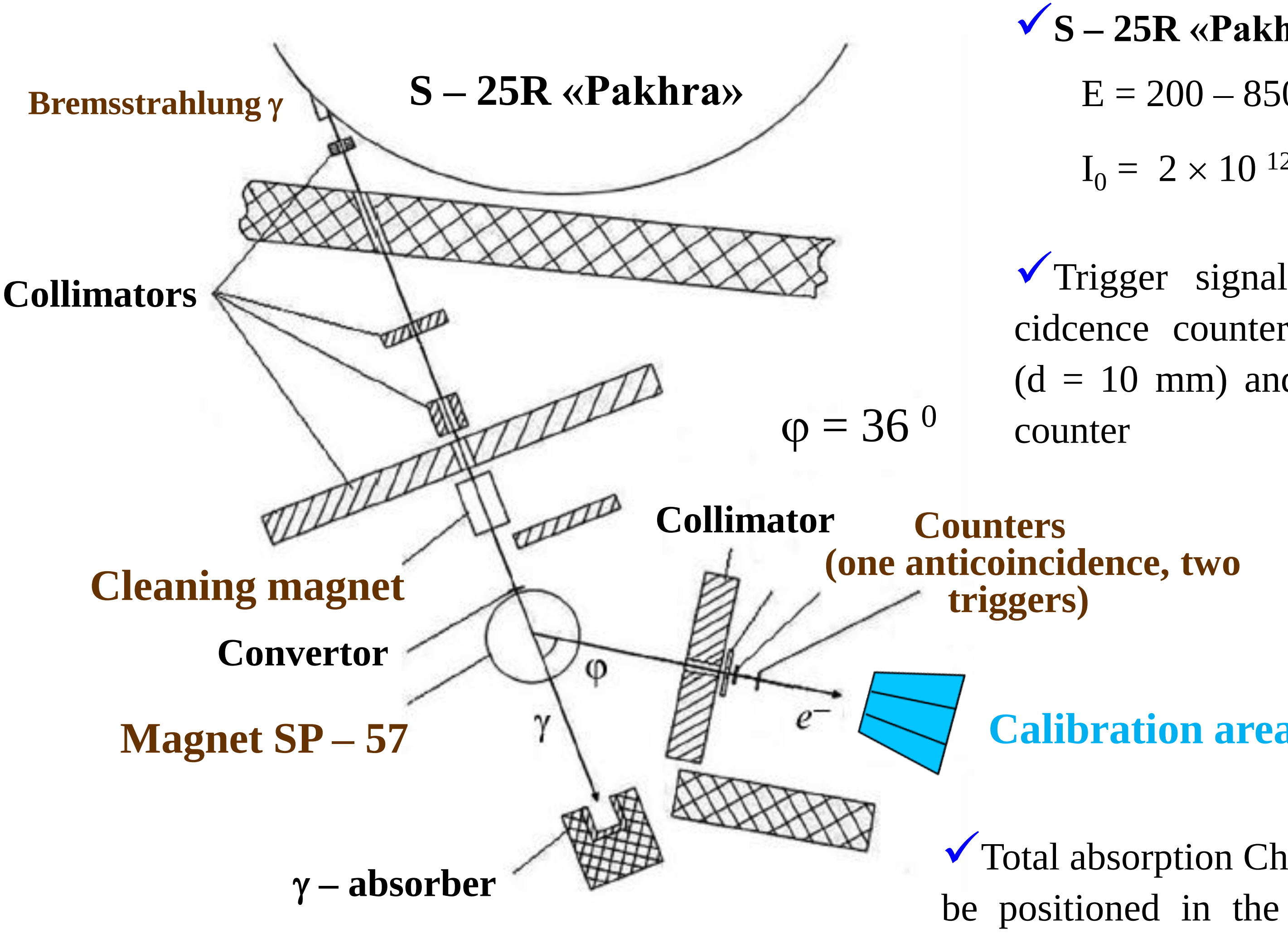
ECal construction



ECal cell - tower

- ECal geometry is close to projective, that means all cells are oriented to the NICA collider beams crossing area. ECal consists from 2400 modules of different types
- Each module consists from 16th cells (towers) fixed by the special gule (N towers = 38 400)
- Tower calorimeter has a sampling structure consisting of active medium (scintillator, width = 1.5 mm) and absorber (lead, width = 0.3 mm). Total number of such layers in cell is equal to 210.
- The shapes of the towers are approximately truncated pyramids with base of 4×4 cm^2, more accurately described by a set of trapezoids (milling angle = 0.9^0 along Z and 1.2^0 in XY – plane)

Electron beam at S-25R «Pakhra» of the LPI



✓**S – 25R «Pakhra»** parameters **:**

E = 200 – 850 MeV

I_0 = 2×10^{12} e^- / second

✓Trigger signal : one anticoincidcence counter with inner hole (d = 10 mm) and two scintillation counter

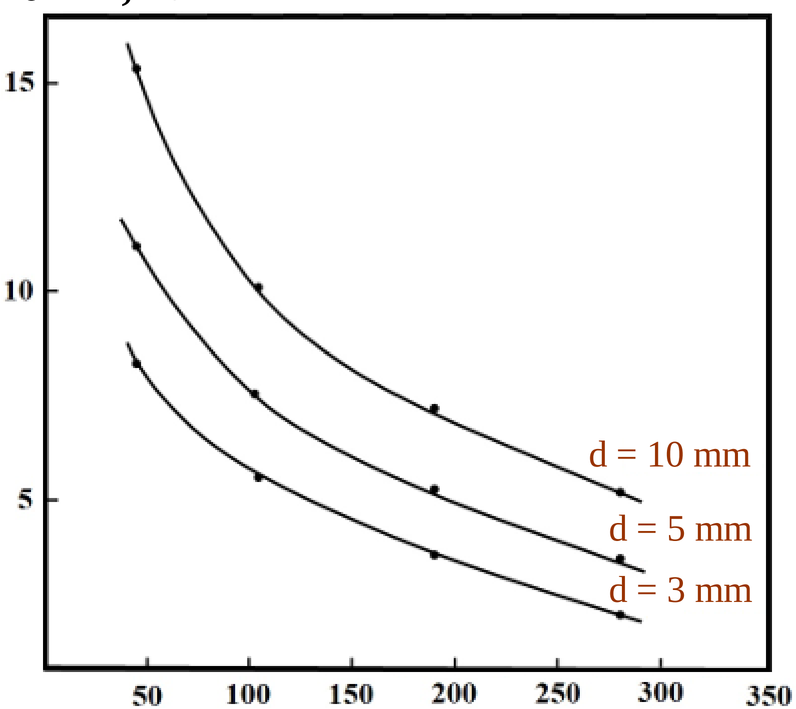
✓Total absorption Cherenkov counter can be positioned in the calibration area to define electron energy

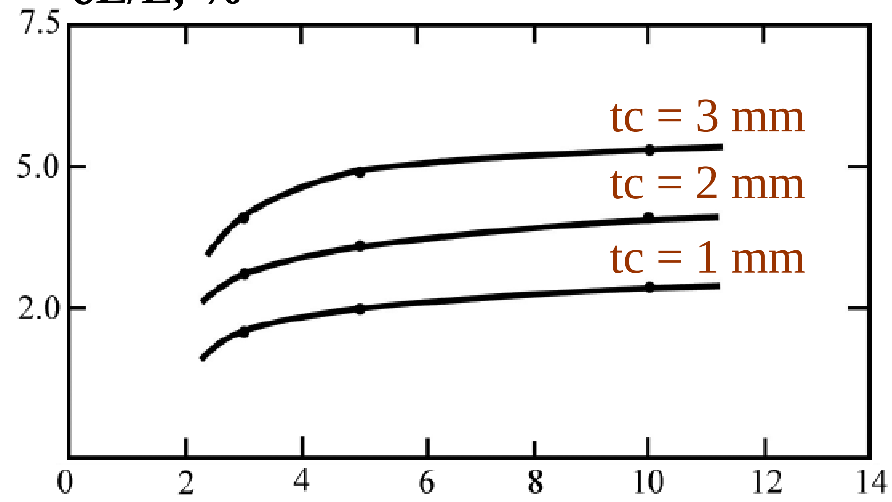
Calibration electron beam resolution

✓ Beam energy resolution depends from collimator diameter (d) and convertor thickness (tc)

✓ Electron beam was optimized at d = 5mm and tc = 1 mm with intensity :

$I_0 \sim 20 \div 50\ e^- /\ second$





Calibration beam energies

Beam energy, MeV	Energy resolution , %
30	13.8
54	11.0
98	7.5
150	6.3
196	5.4
293	3.4

Cosmic ray generator (muons)

✓ Parameterization of the cosmic ray spectra (atmospheric muons) obtained from experimental data and covers wide energy range

✓ Cosmic ray flux at sea level has $\cos^{N-1}$ dependence, where N – power of the energy distribution [P. Shukla, Int.J.Mod.Phys. A33 (2018) no.30, 1850175]

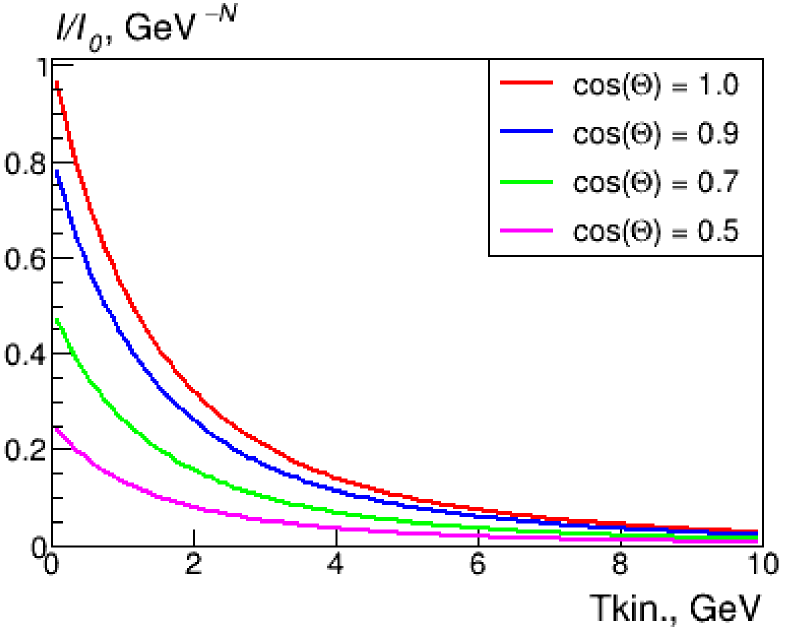
$$I / I_0 = (E_0 + E)^{-N} \times \cos^{N-1}\Theta / (1 + E / 854);$$
$$E_0 = 4.29, N = 3.01$$

✓ cos Θ – zenith angle, E – energy;

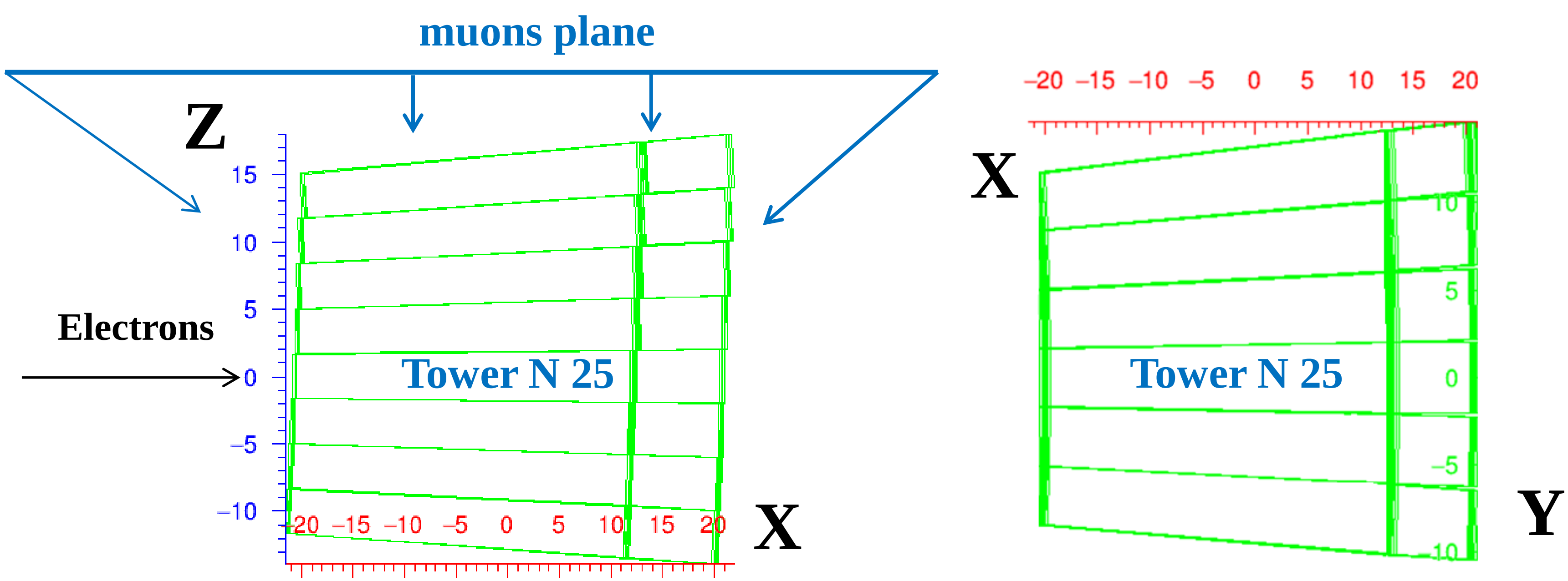
this formula is valid for muons, not for proton part

✓ Generator was developed in the framework of MpdRoot, where muons are produced as function of energy (0 – 10 GeV) and zenith angle

Cosmic muons energy spectra



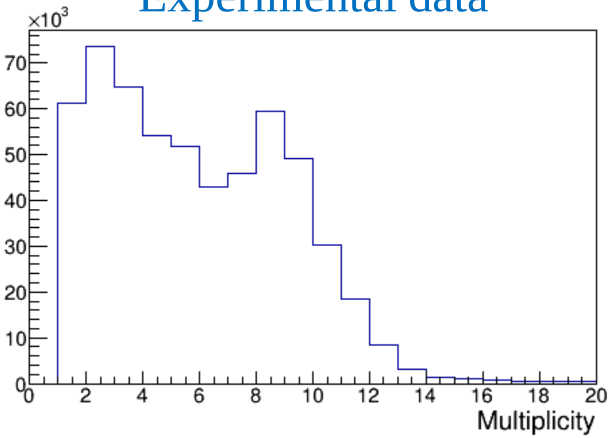
MC muons production



- ✓ Geometry of one module of the first type (emcModule0) is extracted from file emc_v3.root directly to add in the mpdroot frame (only this detector)
- ✓ Three module were joined to the assembly (48 towers, 6 in YZ) × 8 in XZ), as for experimental data
- ✓ Comic muons are generated from large plane at Z_0 = 20 cm in all directions, selected only particles passing detector area

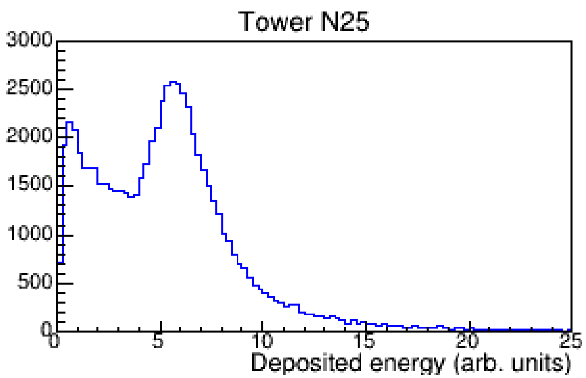
Different methods to cosmic muon selection

Experimental data

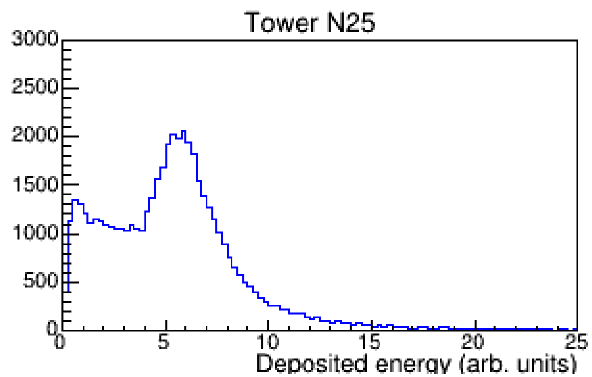


✓ Multiplicity of the module assembly is large number (until 15 tower / one muon). It’s a good way to collect a large statistics during short time

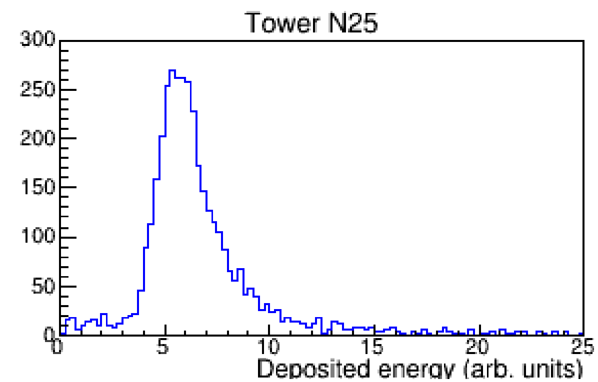
✓ For better presentation, it’s useful to add scale coefficient = 10^{-3}



✓ Method 1: all events, low energy part can simply describe by expo-nential function; use this method for further analysis

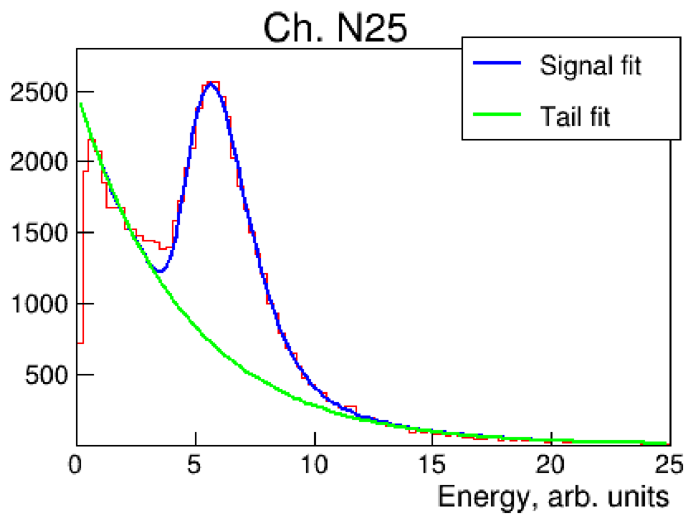


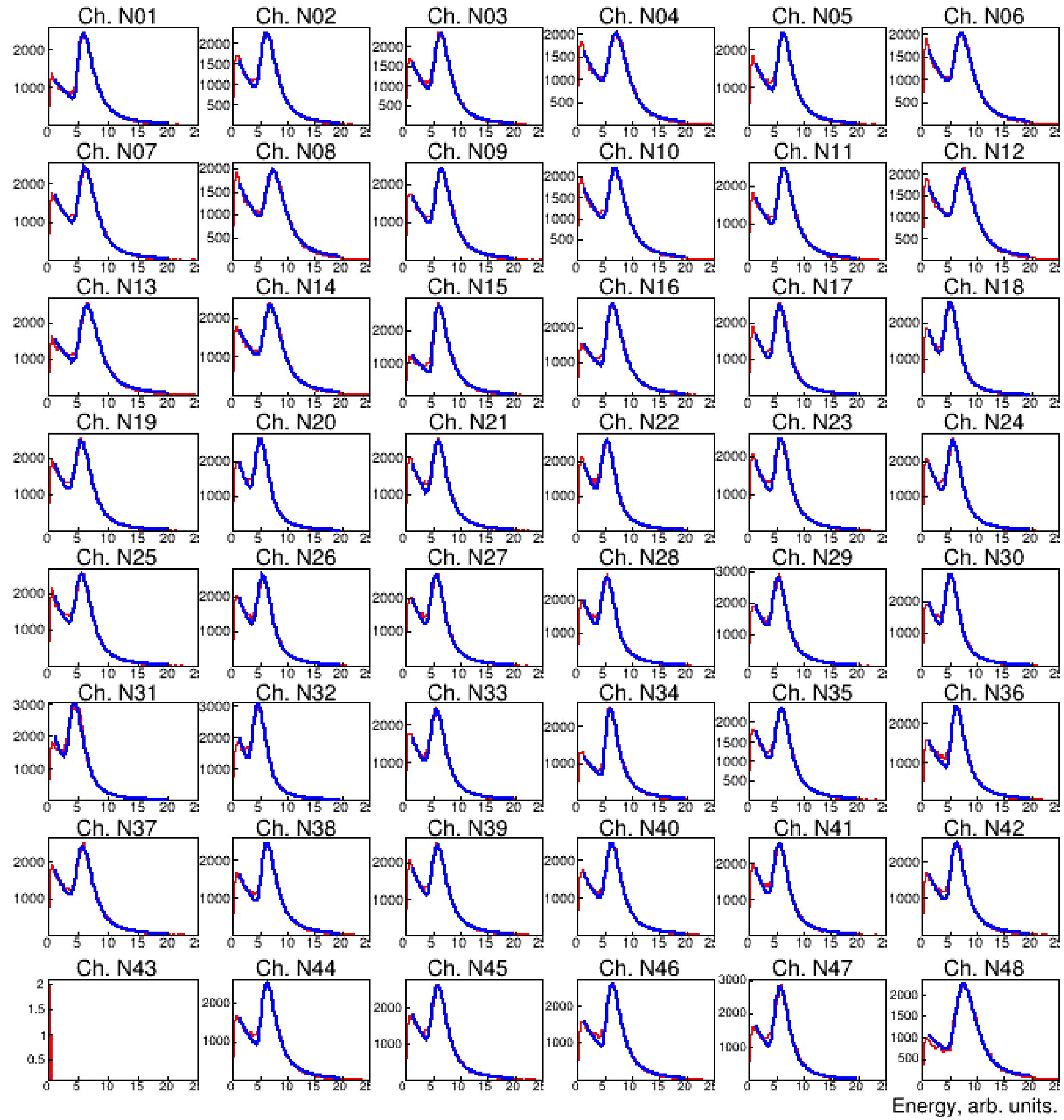
✓ Method 2: multiplicity > 7, less statistics, but tail still exists



✓ Method 3: two (upper and lower towers in line give a trigger), tail is eliminated, but statistics – 7 times less

Energy spectra fit

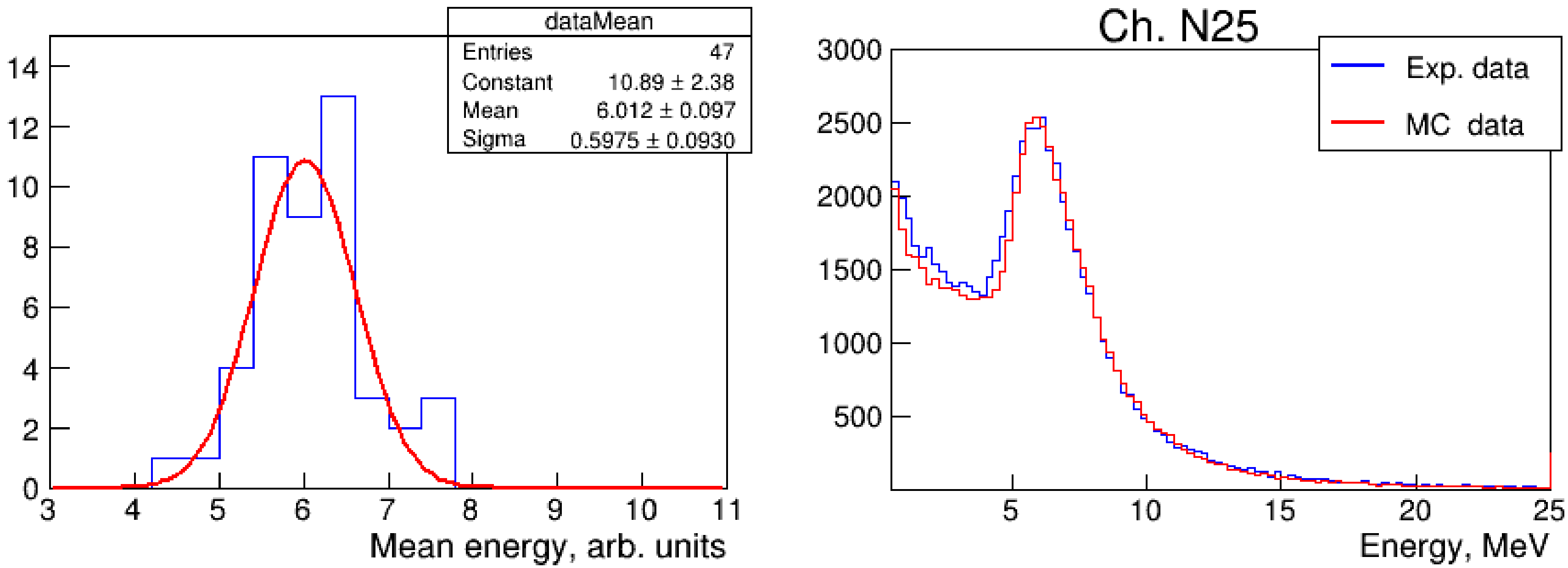




- ✓ Clear peak from muons can be a reliable tool for calibration
- ✓ Fit is a sum of two functions (signal and exponential tail)
- ✓ Signal fitting function :

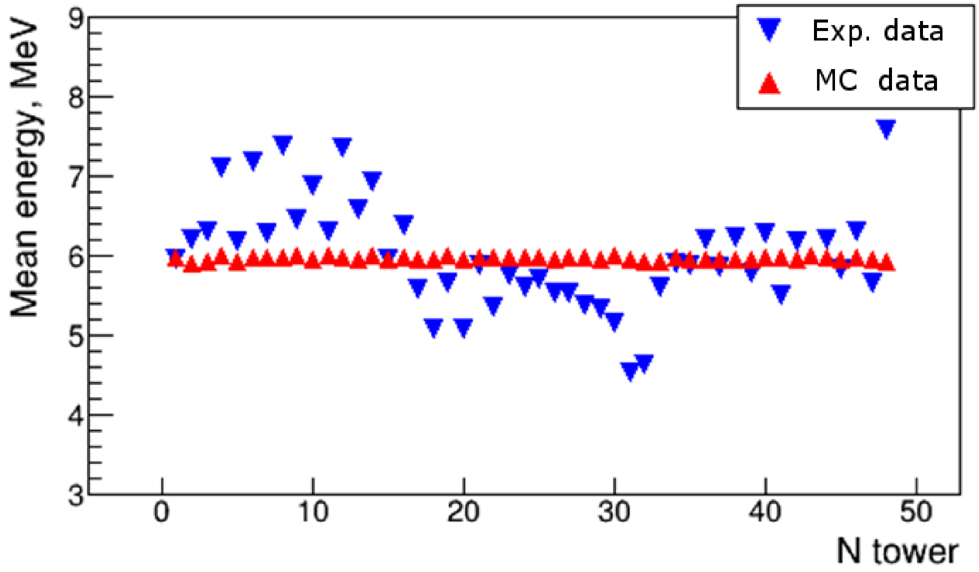
$$\sim (x - x_0)^{\alpha} / x^{\beta}$$

MC and experimental data comparison

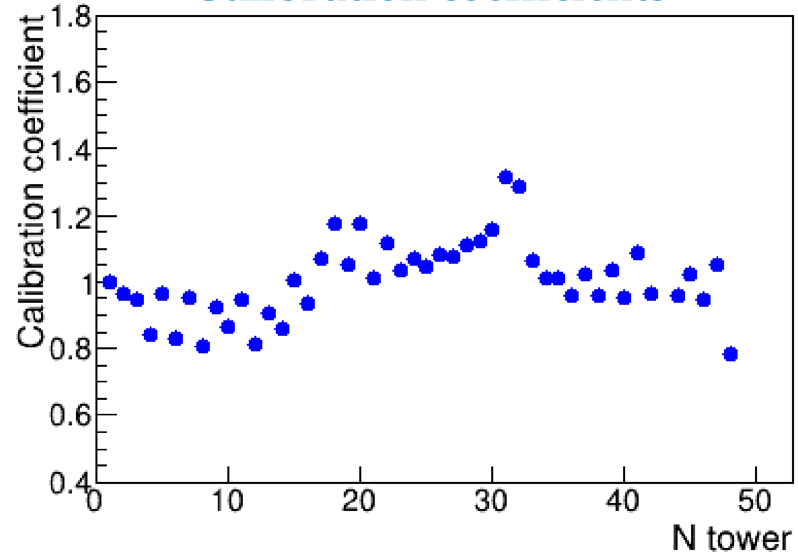


- ✓ Experimental and MC data are in a good agreement
- ✓ MC peak is stable for all 48 towers and equal to 5.95 MeV
- ✓ Experimental data are varied for different modules (each 16 towers)
- ✓ Experimental mean value (peak position) is 6.01 (first tower, arb. units) and comparison with MC gives conversion factor ~ 0.99 MeV

Results of the calibration

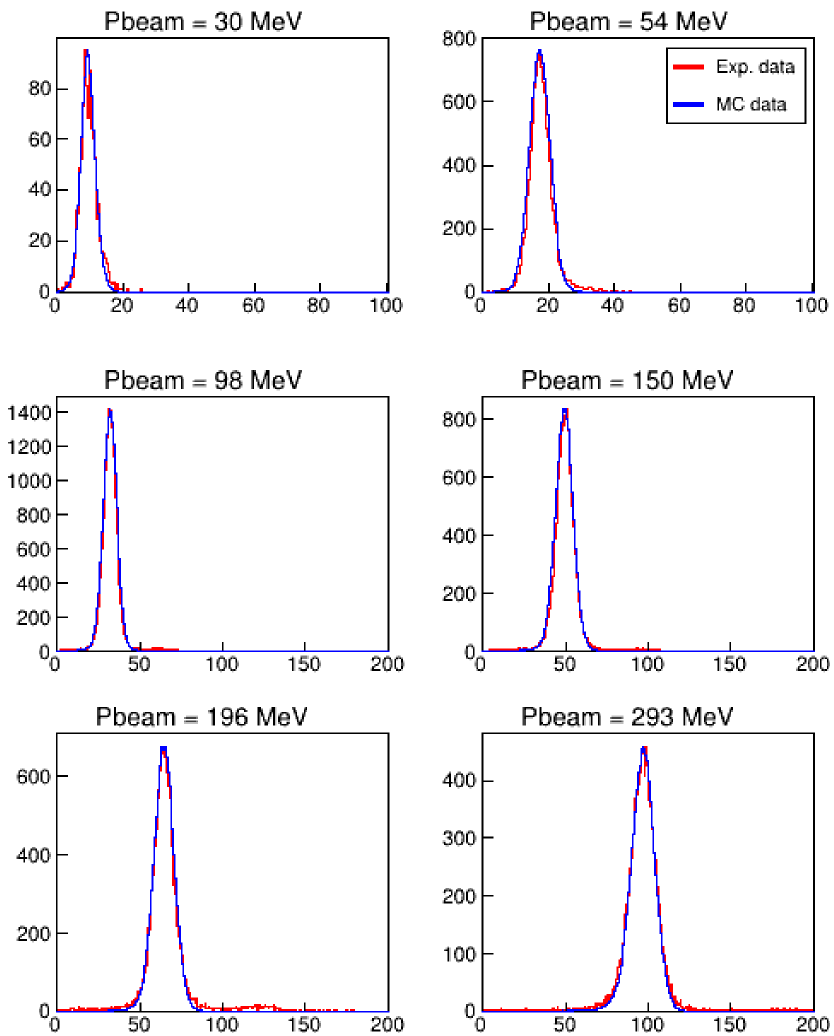


Calibration coefficients

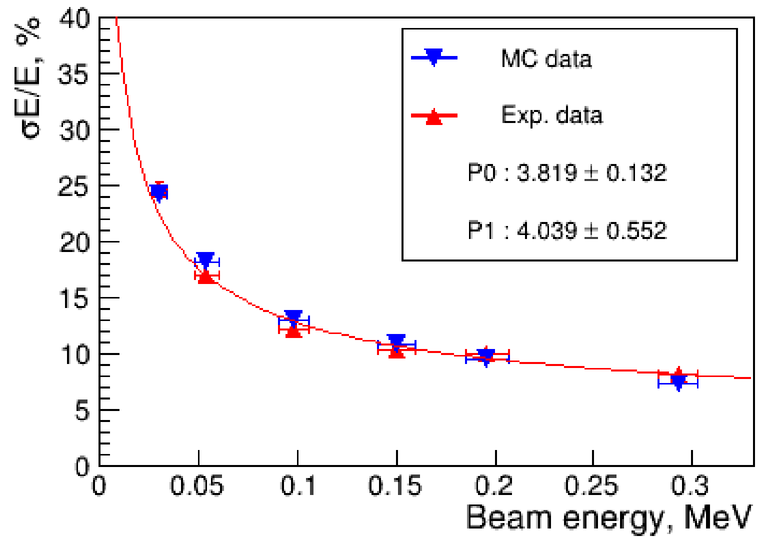


- ✓ Good method to perform a quality control of each produced tower/module
- ✓ Independence of the MC peak position from its number demonstrates a reliability of this calibration method
- ✓ It doesn’t take a significant time to be done (one day/night is enough to test module)
- ✓ Calibration coefficients are defined concerning mean value, the fluctuation of this calibration coefficient ~ 10 %
- ✓ This calibration is used for further analysis to obtain electron energy

Electron beam (MC and experimental data)



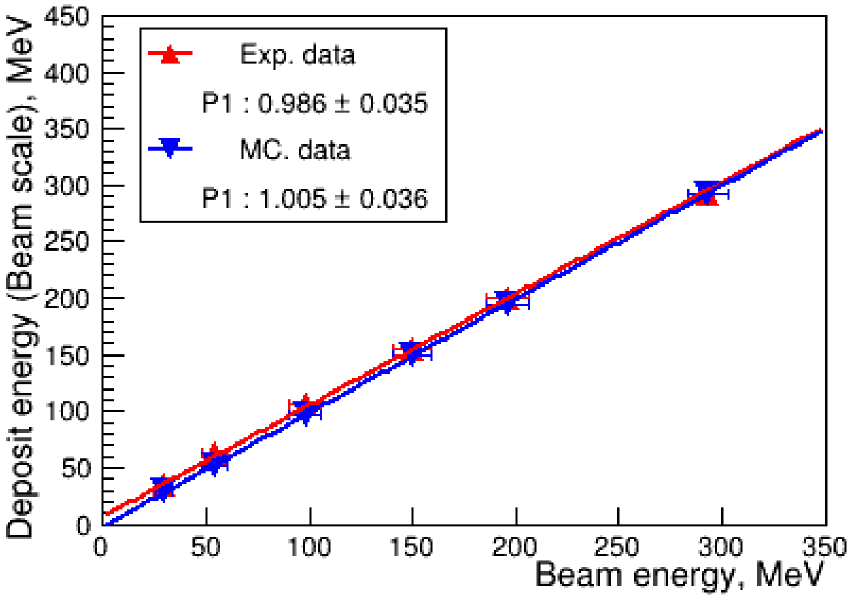
Deposited energy, MeV



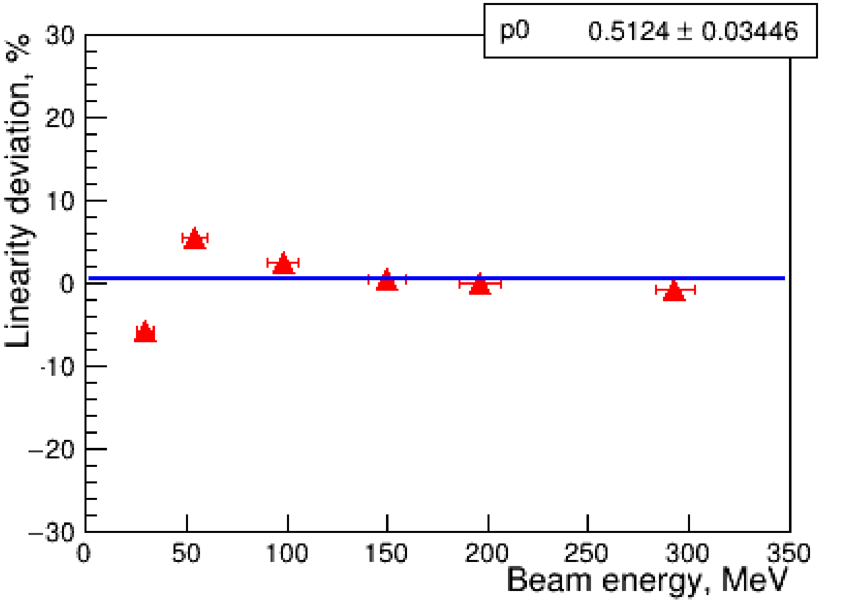
- ✓ Module assembly was measured at 6 electron beam energies
- ✓ Deposit energy is defined by all towers
- ✓ All towers are calibrating by cosmic data
- ✓ Energy resolution is calculated with electron beam spread
- ✓ MC and experimental data are in a good agreement within ~ 5÷ 6 %

Calorimeter linearity

ECal linearity



Deviation from linearity



✓ Calorimeter linearity is estimated with respect to the largest beam energy (293 MeV)

✓ Linearity is observed well for MC data, but for experimental data there is a deviation and scale coefficient is less than unity

✓ Some reasons of that are clear :

1) Uncertainty of the beam energy (~ 10 % of beam energy at 54 MeV)

2) In general, light loss in tower fibers, this effect is larger for low energy electromagnetic shower

Conclusion and future plans

- ✓ A significant number of the modules (~ 250) are in the process of production on the factory «Tensor» at Dubna (Russia)
- ✓The extracted electron beam at S – 25R «Pakhra» (LPI, Troitsk division) with energies until 500 – 600 MeV will be launched to study characteristics and calibration of the produced calorimeter modules. Addition calibration area is prepared for shifters during the calibration of equipment and detectors.
- ✓Calibration of the new produced modules will be carried out on cosmics to perform test quality procedure, and limited number of modules – on electron LPI beam to measure a preliminary calibration characteristics
- ✓ MC simulation and test strategy are ready. MC and experimental data demonstrate a good agreement, but need some adjustments
- ✓ This work is supported by the *RFBR Grant №18-02-40079*