NICA Days 2019

MPD electromagnetic calorimeter simulation

Yu.F. Krechetov[1], V.V. Kulikov[2], <u>M.A. Martemianov</u>[2], M.A. Matsyuk[2], A.Yu. Semenov[1], I.A. Semenova[1], I.A. Tyapkin[1]

[1] *Joint Institute for Nuclear Research, Dubna, Russia*

[2] *NRC "Kurchatov Institute" – ITEP, Moscow, Russia*

WARSAW UNIVERSITY OF TECHNOLOGY, POLAND

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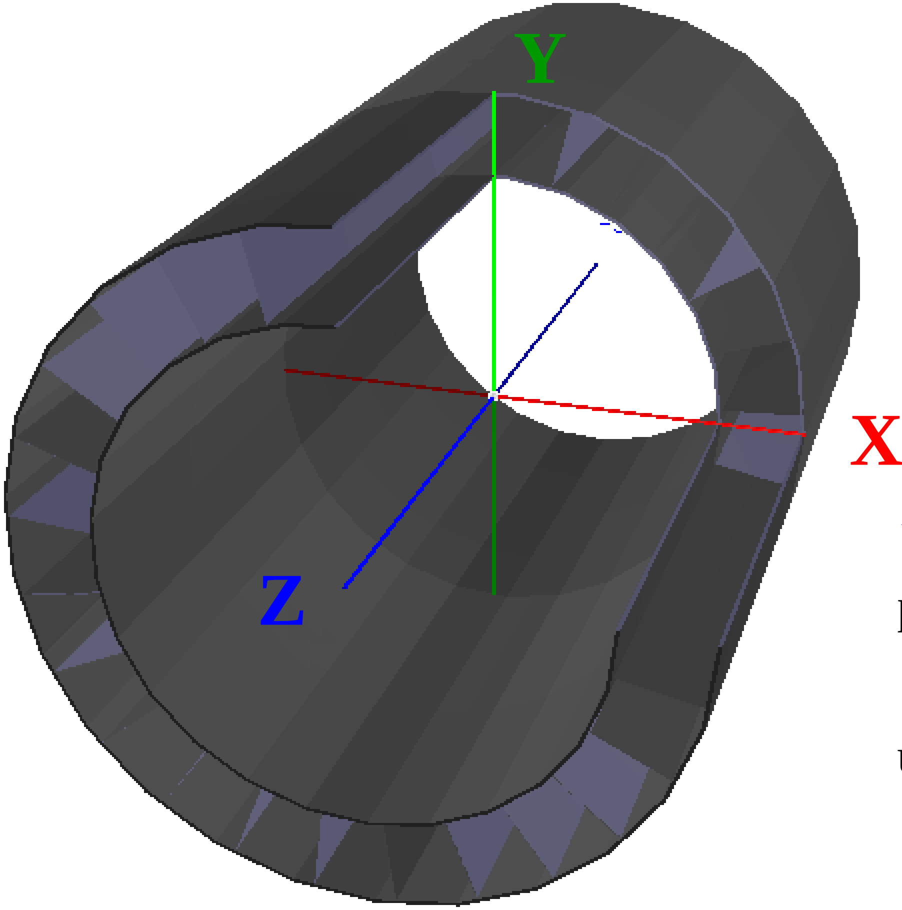
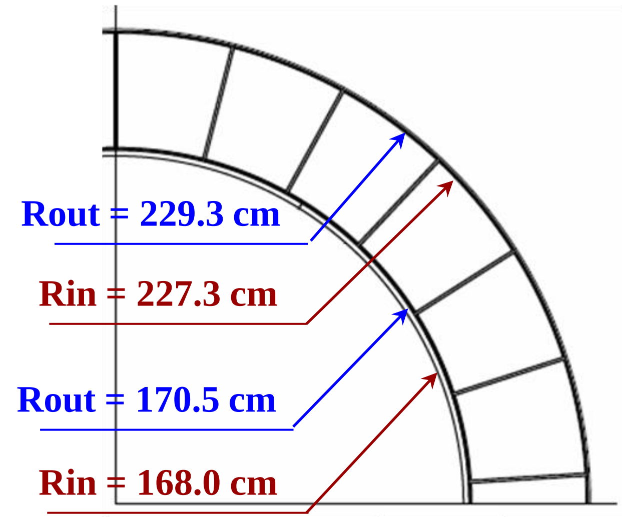
New geometry of the ECal

- Recently, the full design of the ECal / MPD structure and its power supporting frame made of carbon fiber was almost completed
- Last modifications proposed by the VBLHEP design department led to significant changes of the calorimeter structure
- This report gives a brief description of the new ECal geometry, the modification of simulation procedure and the current basic parameters of the calorimeter
- Current ECal geometry simulation is based on the standard software of the MPD detector: MpdRoot and FairSoft
- ECal geometry is stored in the ROOT – file (~mpdroot/geometry/emc_v3.root)
- New calorimeter geometry has a lot of different elements ($\sim 19 \times 10^{6}$) and includes power frame, supporting baskets for calorimeter modules, modules combined from ECal towers, specific tower of the different types, and tower structure till Pb and scintillation plates
- New physical parameters of the ECal characterizing last geometry version will be also presented in report

MPD power frame





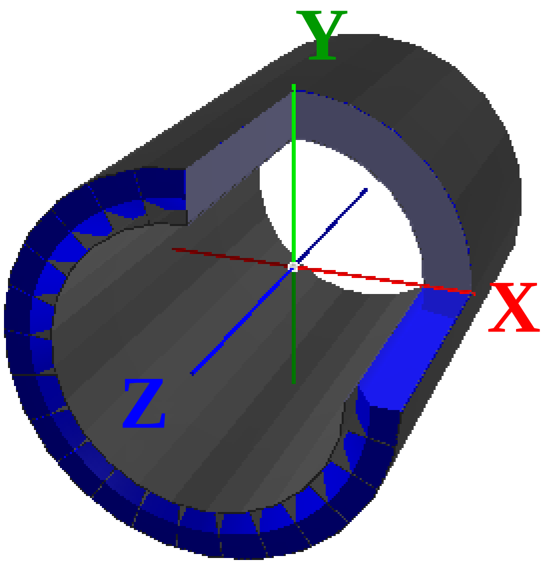
- ✓ Power frame supports ECal and TOF parts
- ✓ Material – carbon composite. For MC used mixture (graphite + epoxy) :

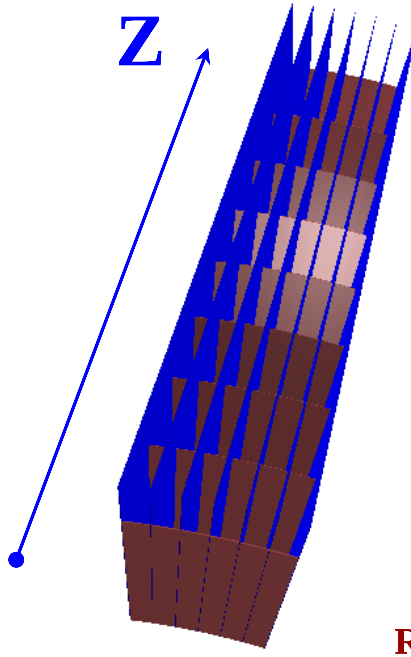
  H (7.4 %) + C (80.9 %) + O (11.7%)

  $\rho = 1.38\ \text{g/cm}^3,\ X_0 = 30.4$ cm

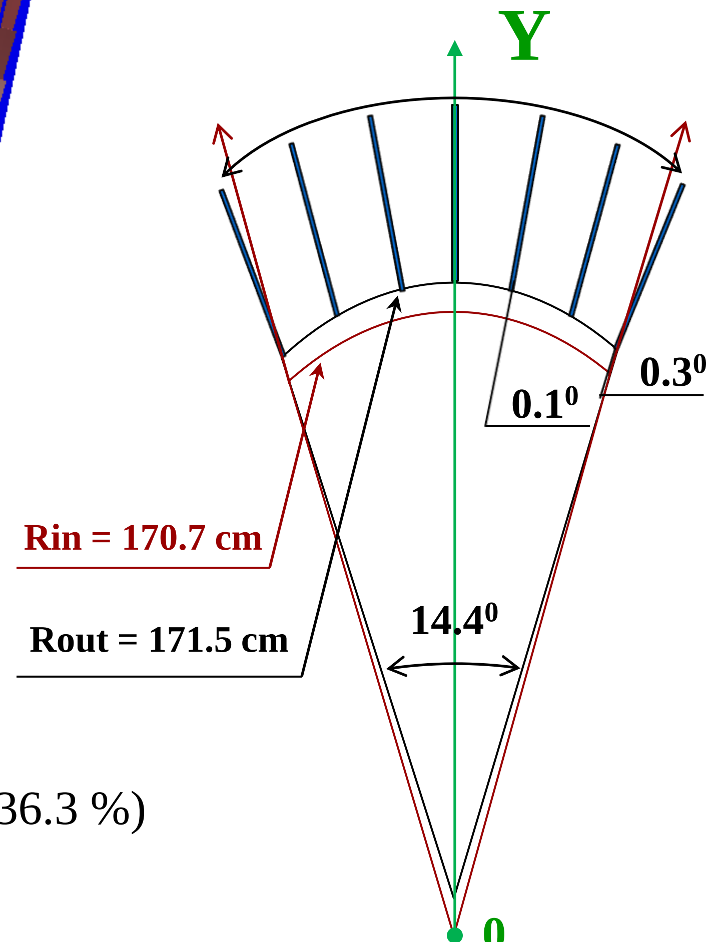
- ✓ Low radial edge gives 8.2 % X_0 before ECal
- ✓ Power frame consists from 25 transverse and two radial edges

Baskets for ECal modules





Container XY – scheme

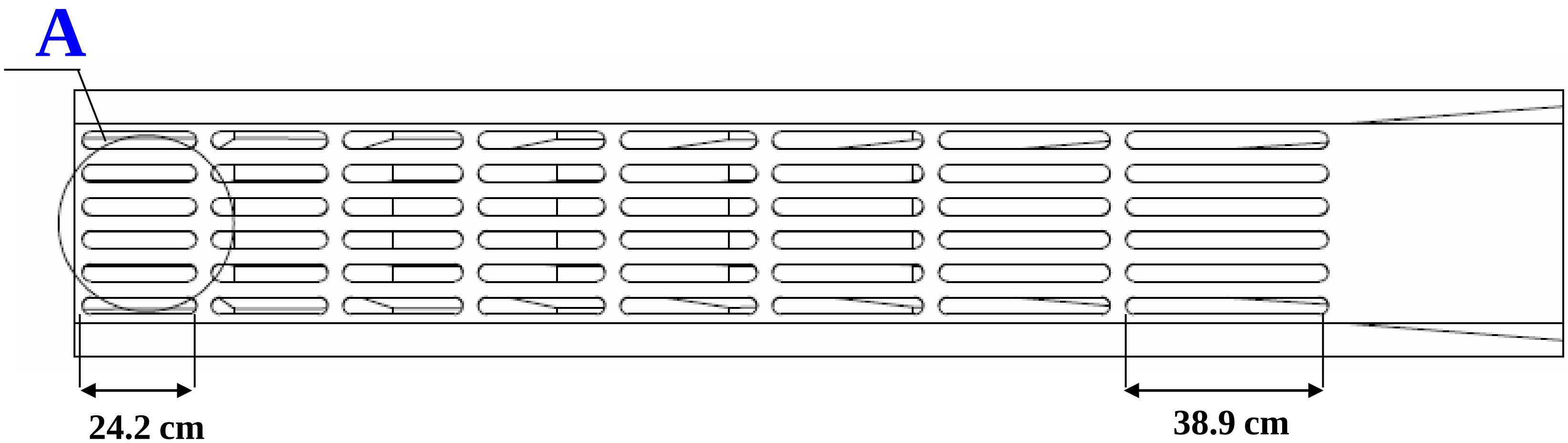


- 25×2 baskets move inside power frame
- Material – fiberglass :

  H (5.8 %) + C (43.1 %) + Si (14.8 %) + O (36.3 %)

  ρ = 1.9 g/cm^3, X_0 = 18.4 cm
- Total weight of one container ~ 1200 kg (empty container weight ~ 60 kg)

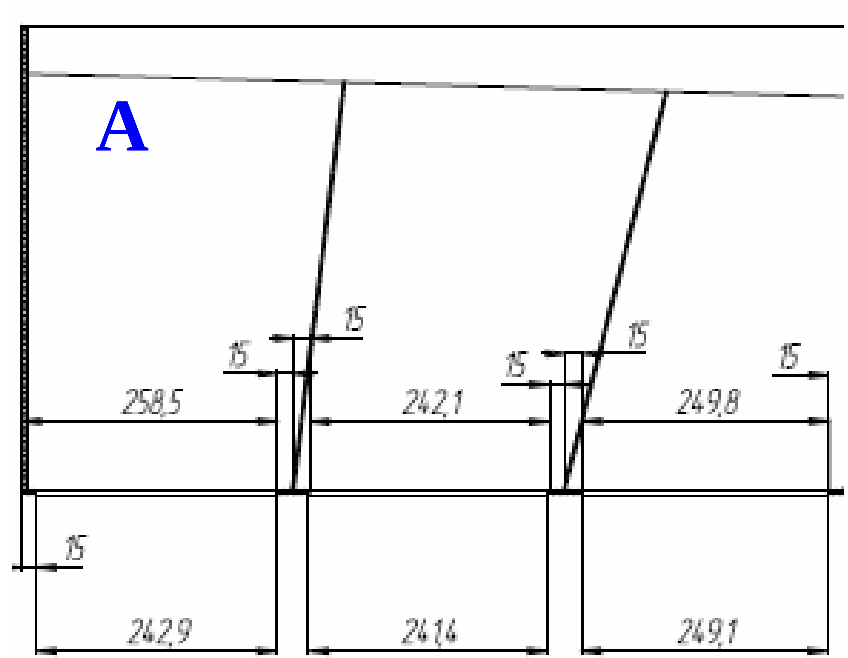
Lower container wall



✓ Lower radial edge of container has a lattice structure to prevent background production (radial width = 0.5 cm)

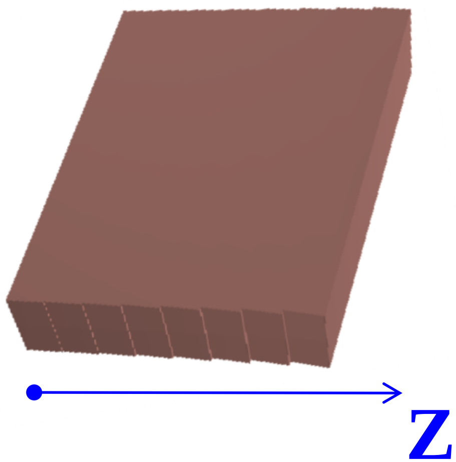
✓ Lattice has a non-periodic hole size along OZ – axis, grid width is constant (3.0 cm)

✓ Non-periodic hole size duplicates tower projection on OZ – axis

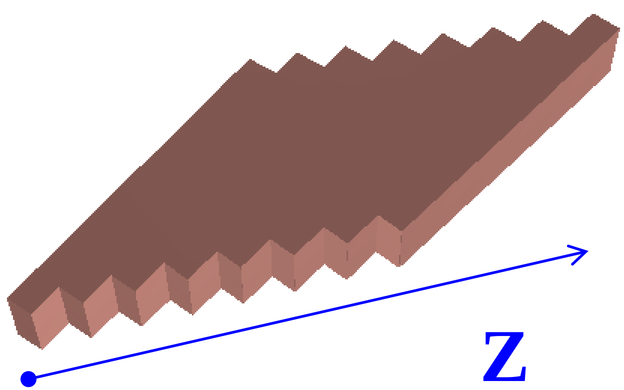


ECal module

First module in row



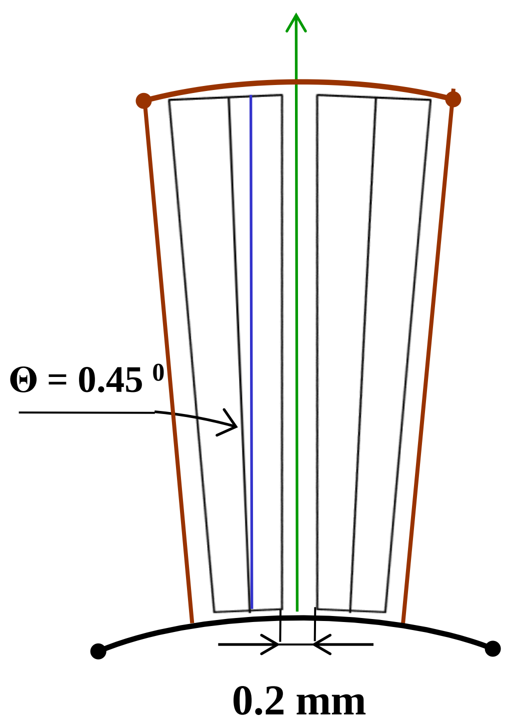
Last module in row



- Towers are merging into modules by special glue, which is included in the ECal geometry. Glue is a Ti – epoxy mixture :

$$H\ (4.9\ \%) + C\ (46.1\ \%) + Ti\ (16.5\ \%) + O\ (32.5\ \%)$$

$$\rho = 1.2\ g/cm^3,\ X_0 = 26.51\ cm$$



- Each basket has 6×8 modules
- Modules are constructing from 2×8 towers of different types
- Eight modules with different shapes have been approved
- In the GEANT4 geometry such shape can be describe by the polygon volume, which has 50 cross sections and repeated a shape of eight towers

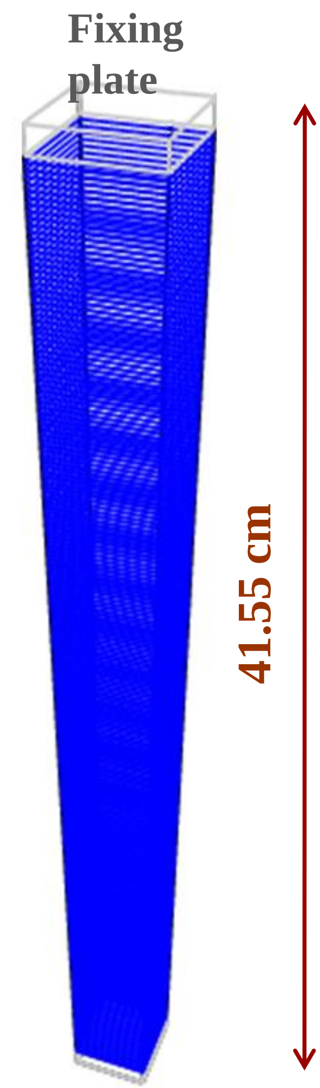
ECal tower

- ✓ Total number of towers : 38400
- ✓Each tower has 210 lead (h = 0.3 mm) and scintillation plates (FscScint – C_9H_{10}, h = 1.5 mm)
- ✓ Each lead plate is coating of the $Ti2O_2$ paint (h = 0.05 mm) with parameters:

$$H\ (2.9\ \%) + C\ (17.2\ \%) + Ti\ (41.1\ \%) + O\ (38.9\ \%)$$

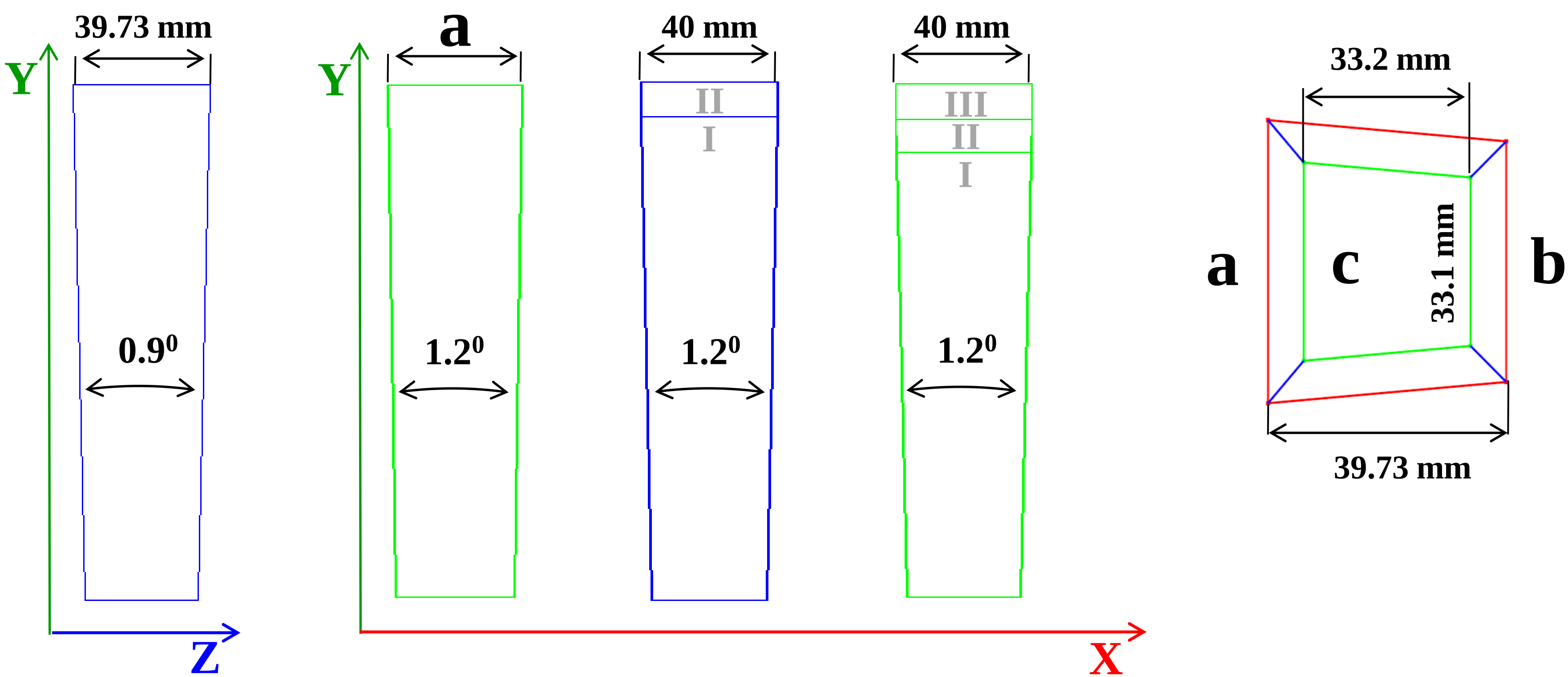
$$\rho = 1.18\ g/cm^3,\ X_0 = 20.49\ cm$$

- ✓Tower is fixed by two plates on top and bottom (Kapton, h = 8 mm, $N_2C_{22}H_{10}O_5$, $\rho = 1.42\ g/cm^3$, $X_0 = 28.4$ cm)
- ✓ Tower shape can be described by the GEANT4 class TGeoArb8 – arbitrary trapezoid with 2×4 vertices at two parallel planes perpendicular to central axis
- ✓ Sensitive volume in MpdRoot is a scintillation plate
- ✓ Towers give a main contribution to number of the GEANT4 elements; total number of nodes ~ 16×10^6



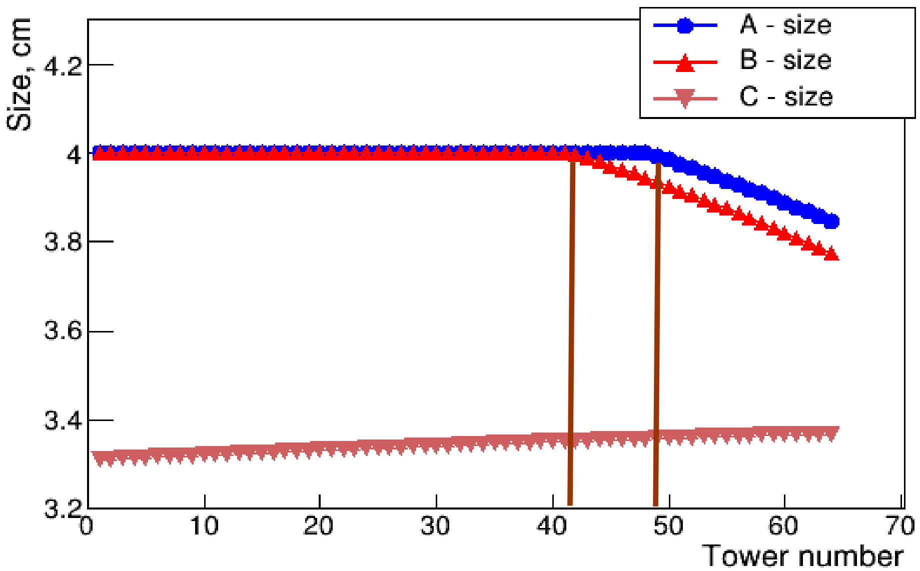
ECal tower types

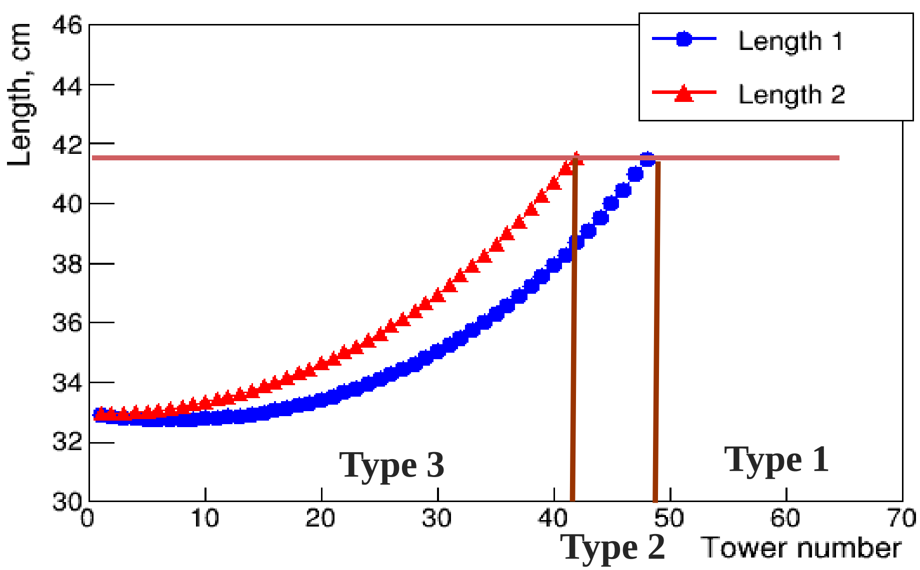
Type 1 : one trapezoid | Type 2 : two trapezoids | Type 3 : three trapezoids



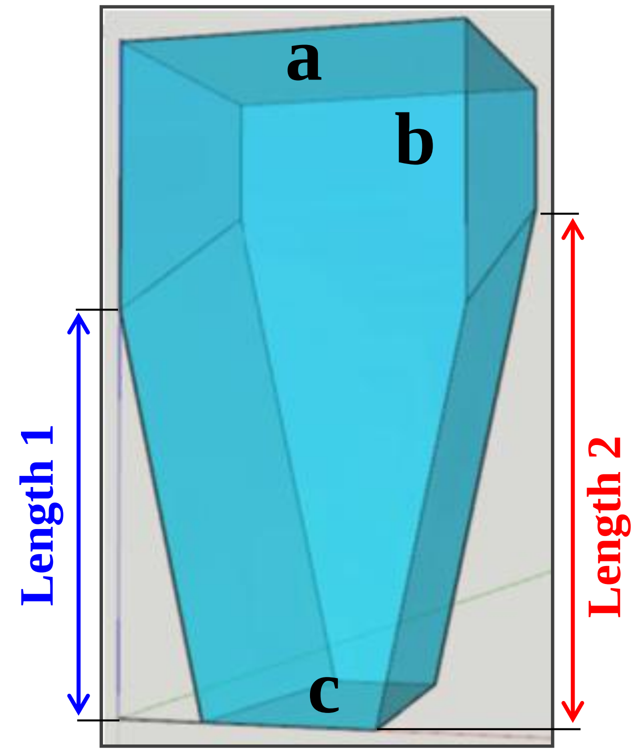
- ECal geometry has 64 trapezoids with different sizes (**a**, **b**, **c**) positioning along Z – axis
- As a result of the module milling, three types of tower shapes were selected
- For Type 2 and Type 3 we use compound volume, consisting from 2 and 3 trapezoids

Tower parameters



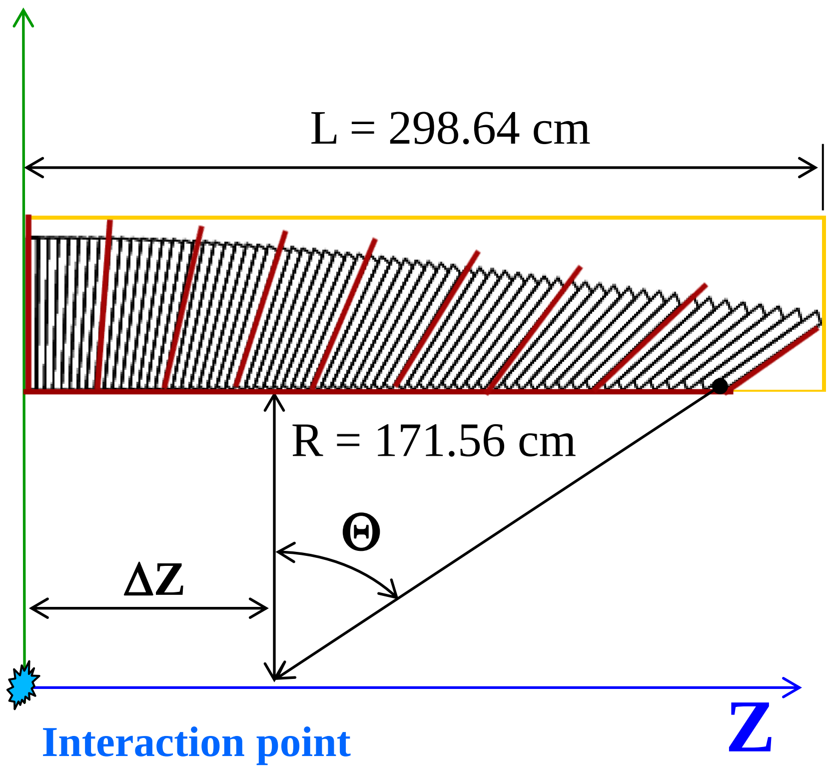


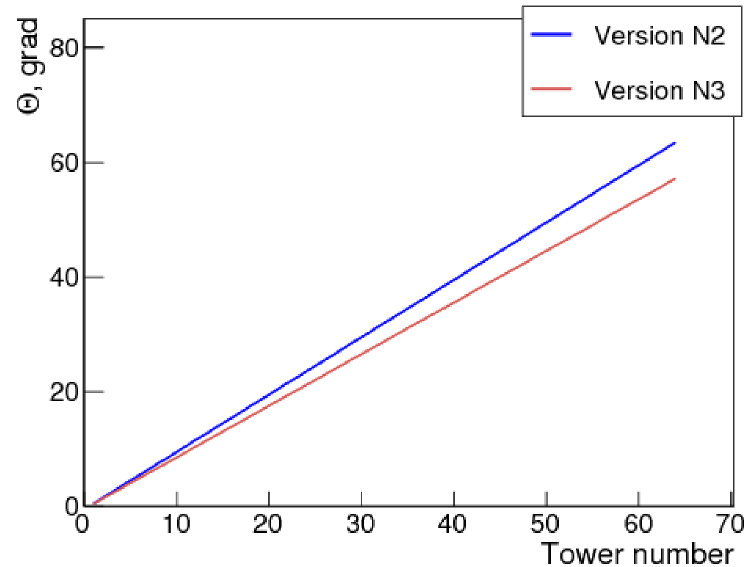
Tower: Type 3

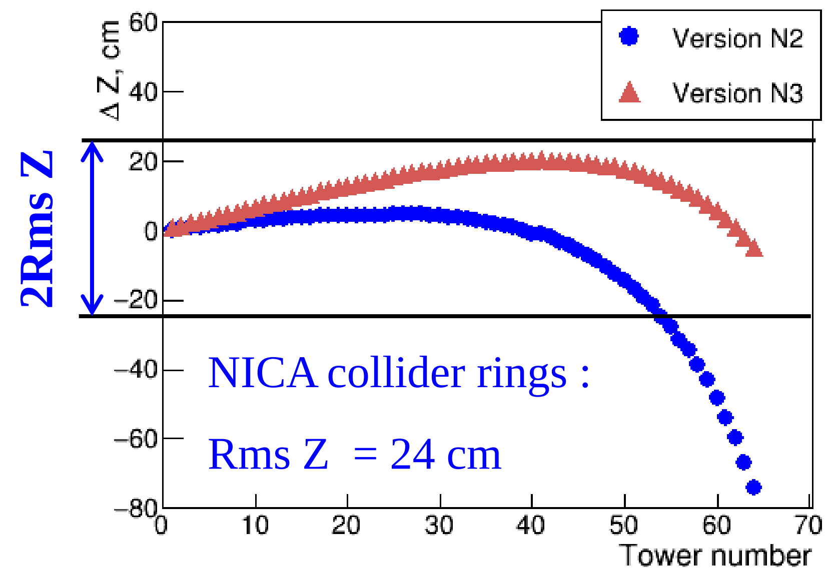


- ✓ A, B and C parameters are calculated precisely on a basis of two milling angles
- ✓ Three trapezoids : towers 1 ÷ 41; two trapezoids : towers 42 ÷ 48; one trapezoid : towers 49 ÷ 64

Tower Z – position

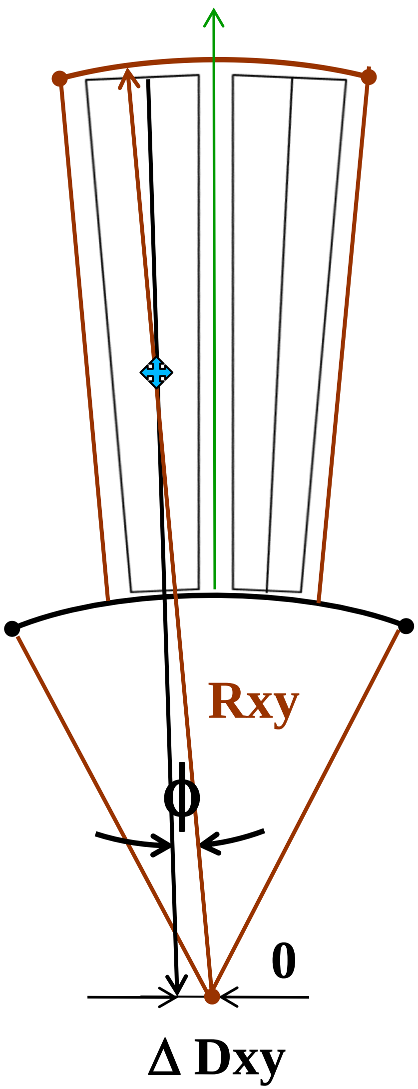


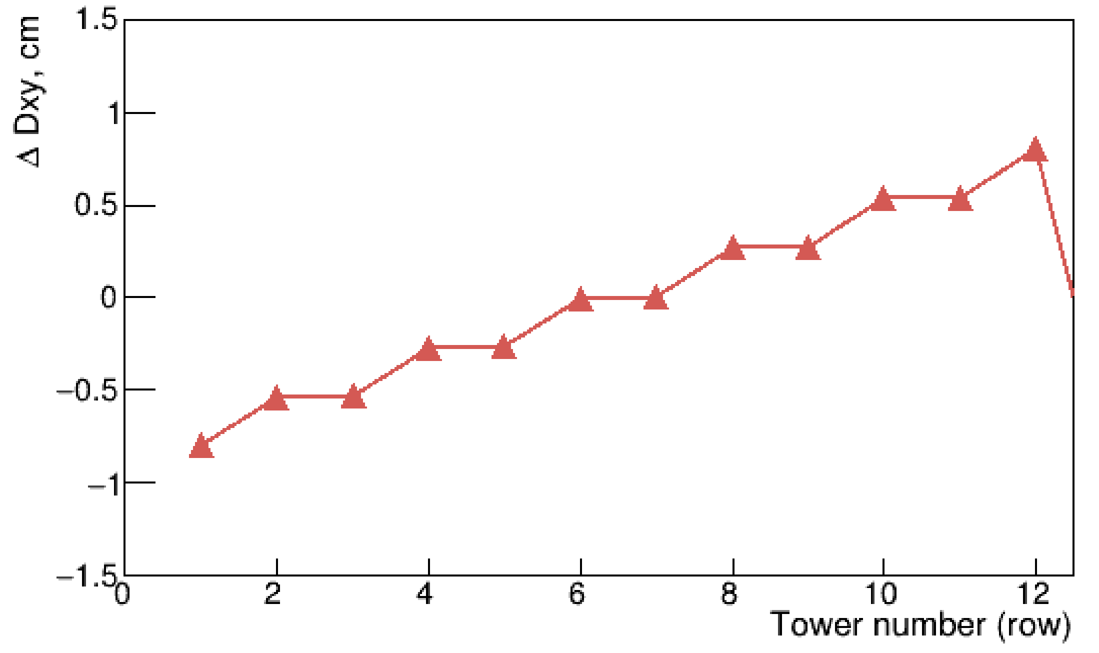




- ✓ Each container has 8 modules
- ✓ Modules is combined from 2×8 towers
- ✓ 64 different towers are placed along Z – axis at different Θ - angles

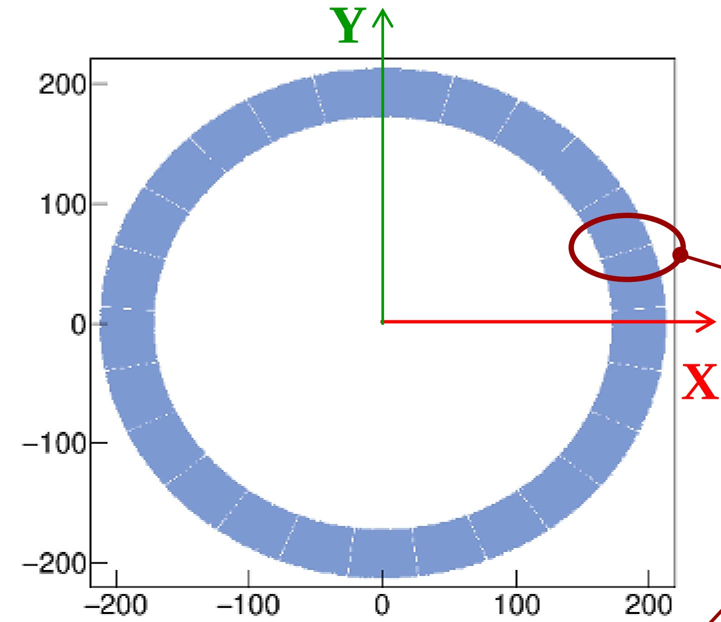
Tower XY - position

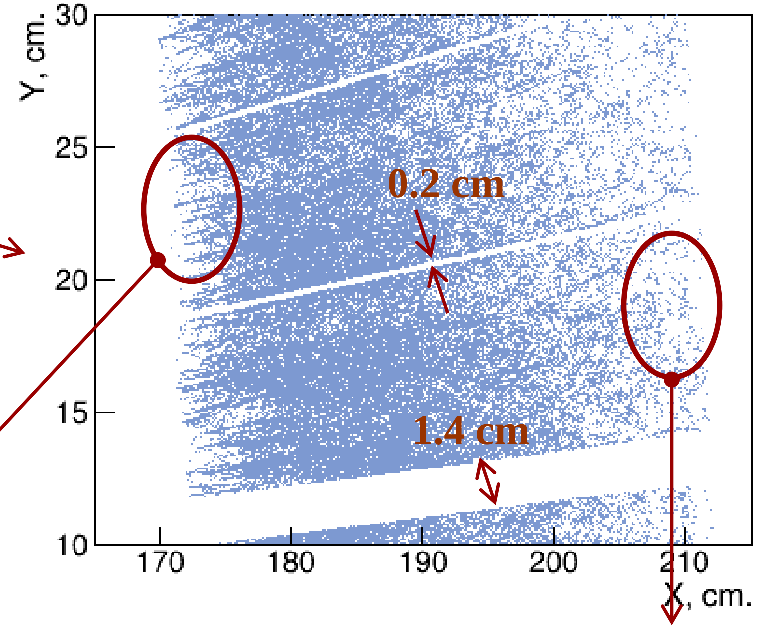


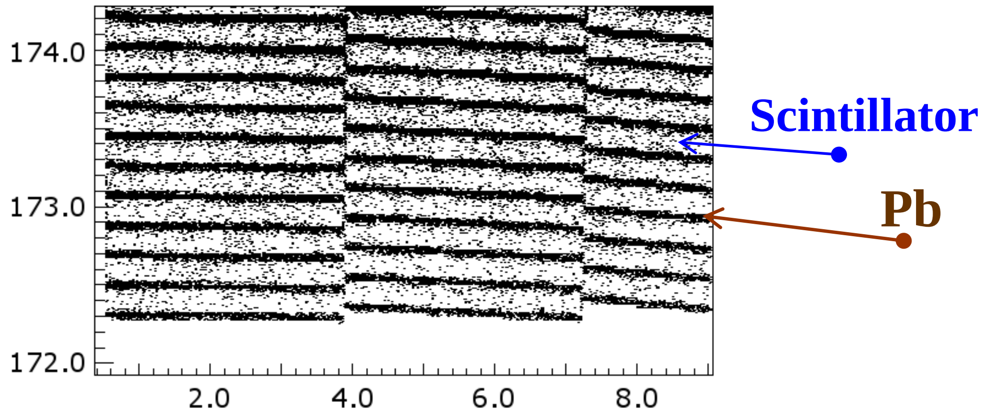


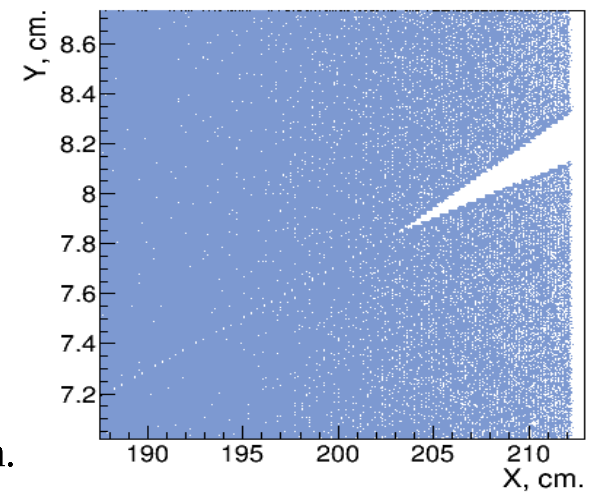
- Generally, the ECal geometry was planned to be a projective, but small asymmetry for towers position in XY plane is presented
- Displacement of towers in XY plane can be estimated by formula **:** Δ Dxy = $\phi \times$ Rxy (Rxy – radius of the tower center)
- This effect is related to a special milling of towers and different edges of the supporting structure

Geometry check with MC points





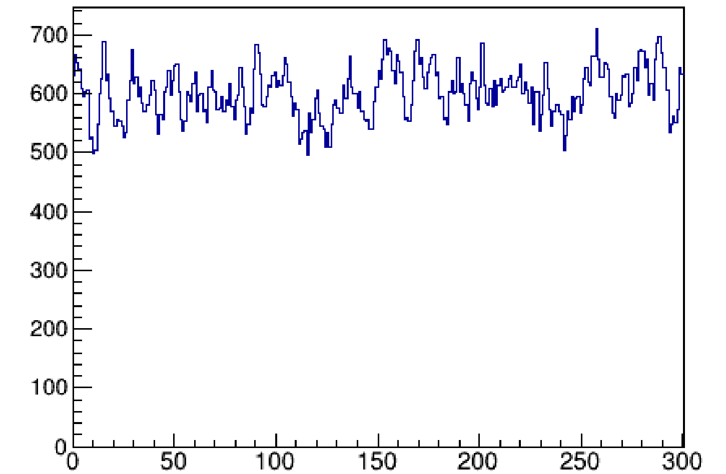




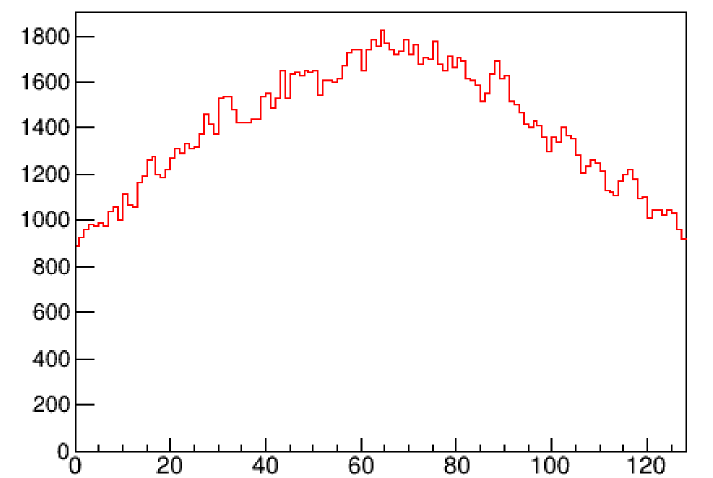
✓ Check overlaps on a level of **10** $^{-5}$ cm.

Hit and cluster creation

- To create hits in ECal we use a class MpdHitCreation
- Each hit is defined by three numbers (number of basket, number of hit in XY – plane, counterclockwise enumeration from 0 to 300, and number of hit along Z – axis, or 0 - 63 at Z < 0 area; 64 - 127 at Z > 0)
- Hit is a sum of all MC points in the tower scintillator; coordinate of each hit is defined in the center of tower
- Our software determines hit due to geometrical parameters extracted from ECal ROOT – file. It's important to do, since ROOT function FindNode gives the wrong solution at the level of 2-3 %
- Cluster algorithm is based on the merging neighboring hits close hits into cluster starting from initial hit with maximal energy deposition
- All cluster parameters are also energy weighted



Number of hit, XY plane



Number of hit, Z axis

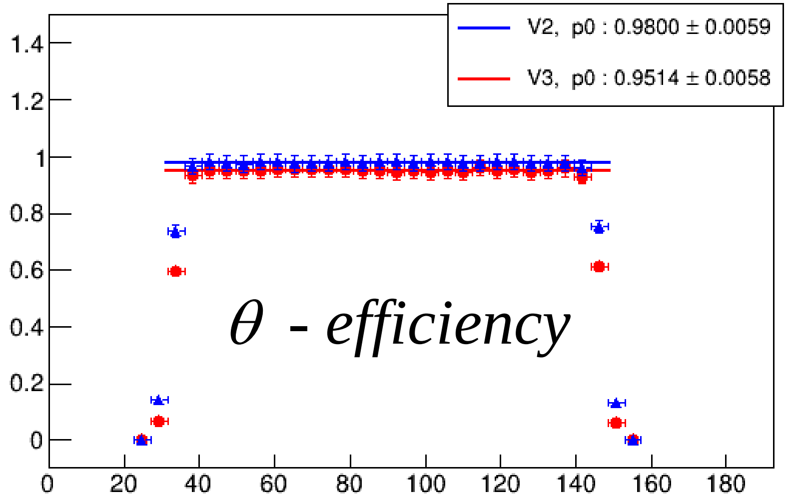
Version 2 and 3 comparison

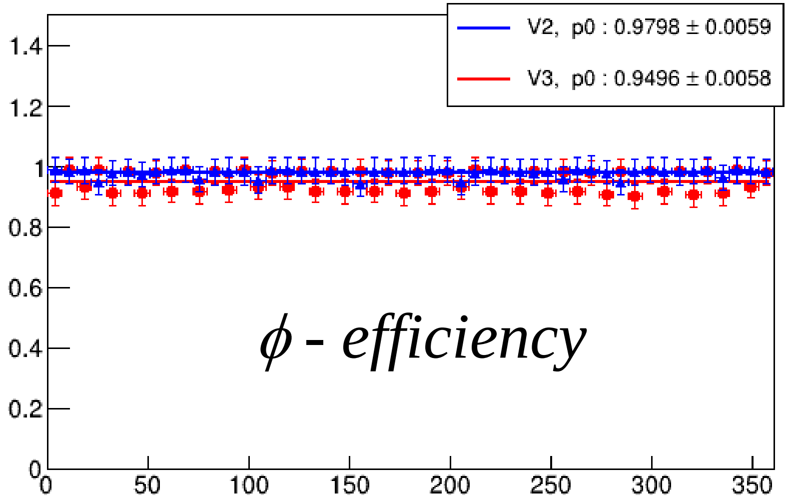
ECal parameters	Version 2	Version 3
Number of nodes	$\sim 19 \times 10^{6}$	$\sim 16 \times 10^{6}$
ECal total weight* (tons)	~ 60	~ 65
Power Frame	No	Yes
Baskets	2×8 (no material)	2×25 (fiberglass)
Number of modules in basket	No	6×8
Tower radius in space (cm)	172	171.56
Total number of towers	43008	38400
Tower length (cm)	43.095	41.55
Number of tower types	64	64
Number of tower shapes	1	1÷3
Number of layers per tower	221	210

* Weight of the detector estimated in the ROOT – frame

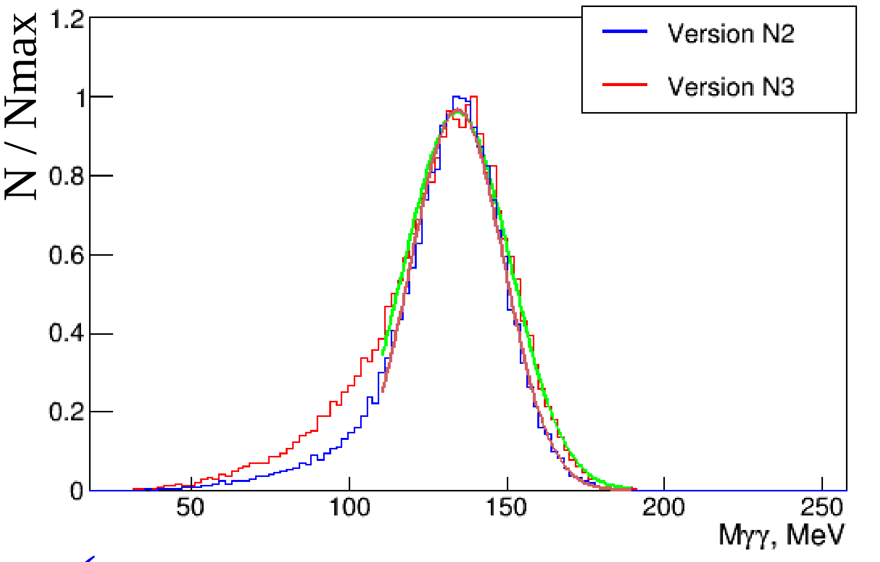
New physics ECal parameters

✓ ECal geometry efficiency, Eγ = 1.0 GeV





✓ π^0 invariant mass , p (π^0) = 0.2 GeV



✓ New ECal geometry efficiency goes down, but not significantly in comparison to the previous

✓ π^0 – invariant mass demonstrates a small enlargement in width and more essential increase of the low energy tail due to new design features (more detailed – report of V. Kulikov, ITEP)

Conclusion

1. Quasi-spherical ROOT - geometry of ECal was done for MpdRoot software. It consists from 16×10^6 elements and includes power frame, 25 baskets, specific ECal modules, which combined from 2×8 towers. New geometry was proposed by the VBLHEP Design Department including special materials for different ECal parts.

2. New geometry is stored in the emc_v3.root file. The quality of the ECal geometry was tested in the ROOT frame for overlaps on the level of 10^{-5} cm.

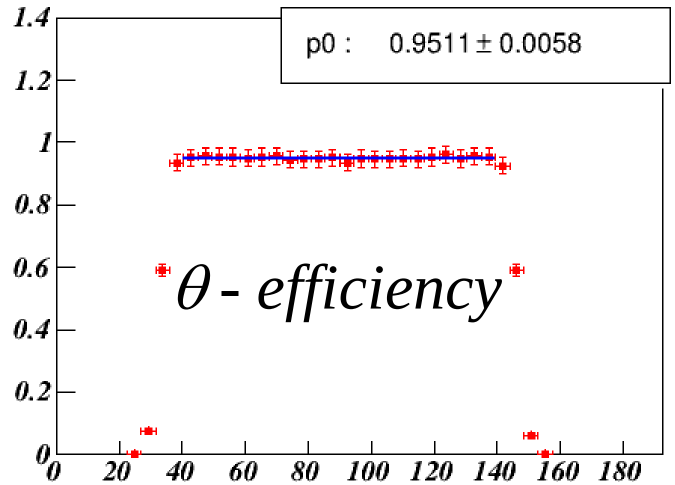
3. Two MpdRoot classes (MpdHitCreation and MpdClusterCreation) gives us a possibility to estimate the physical parameters of calorimeter. MpdHitCreation is used a geometrical prediction based directly on the current version to create hit. Other software part to produce a cluster is working only for low multiplicity and should be updated.

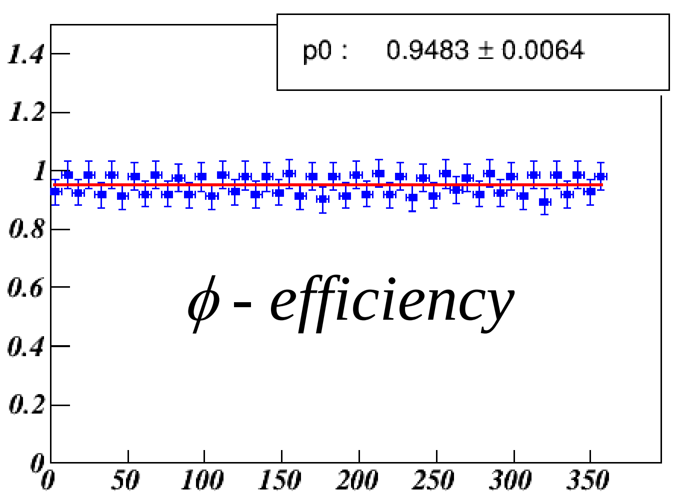
4. In case of the geometry completeness, ROOT file will be transferred to git.jinr.ru. Next efforts should focus on optimal way to create the ECal cluster both for neutral and charged particles. Any ideas to separate hadronic and electromagnetic showers will be tested

Thank You

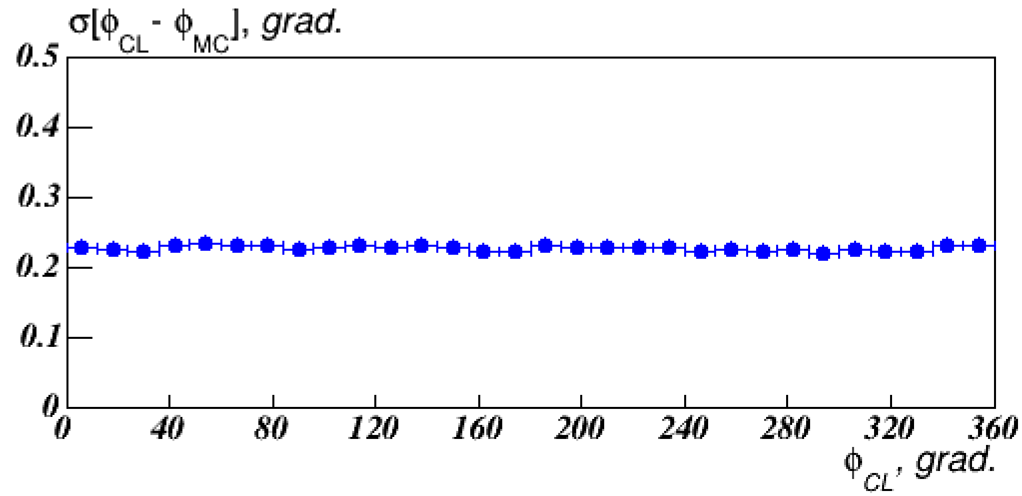
Geometry acceptance

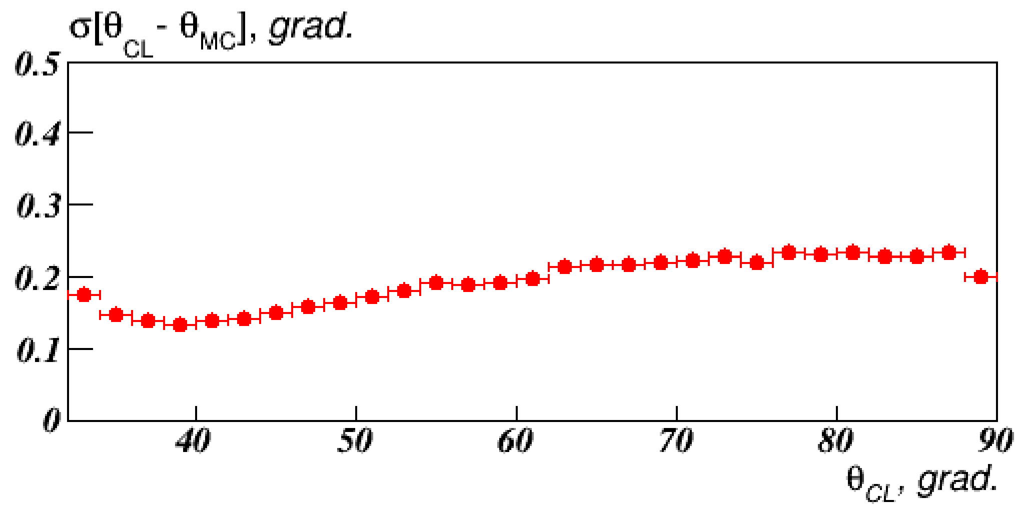
- ✓ ECal geometry efficiency at Eγ = 1.0 GeV



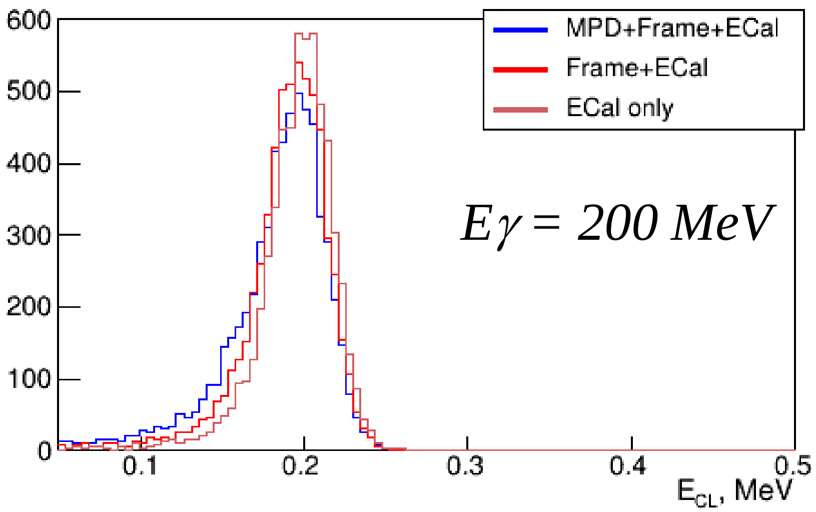


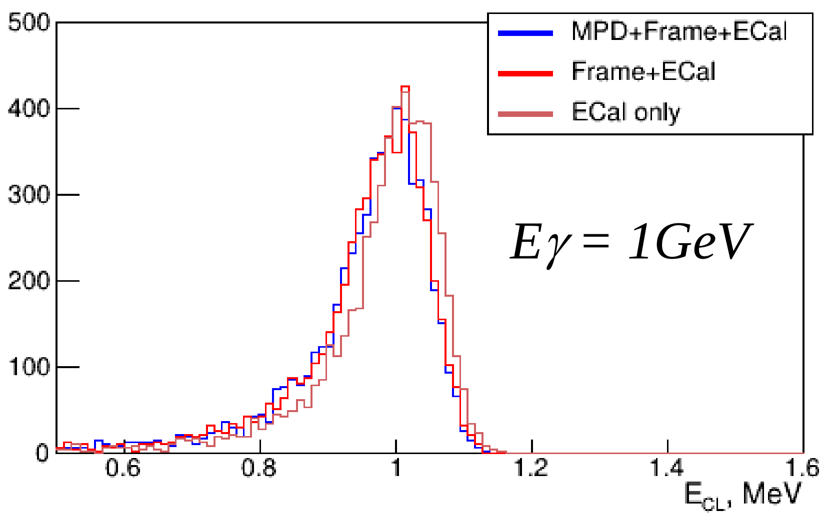
- ✓ Angular resolution of the ECal cluster by angles ϕ and Θ at Eγ = 1.0 GeV

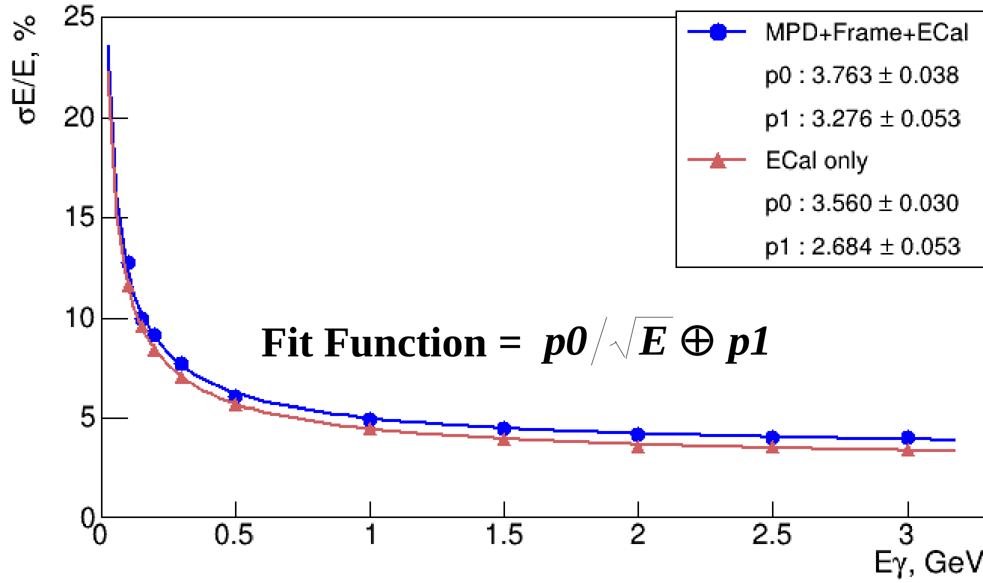




Energy resolution

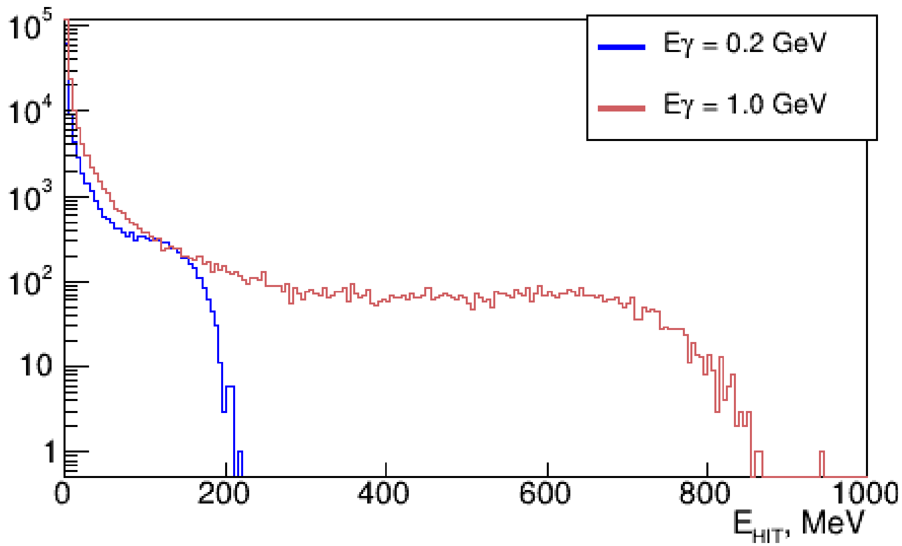


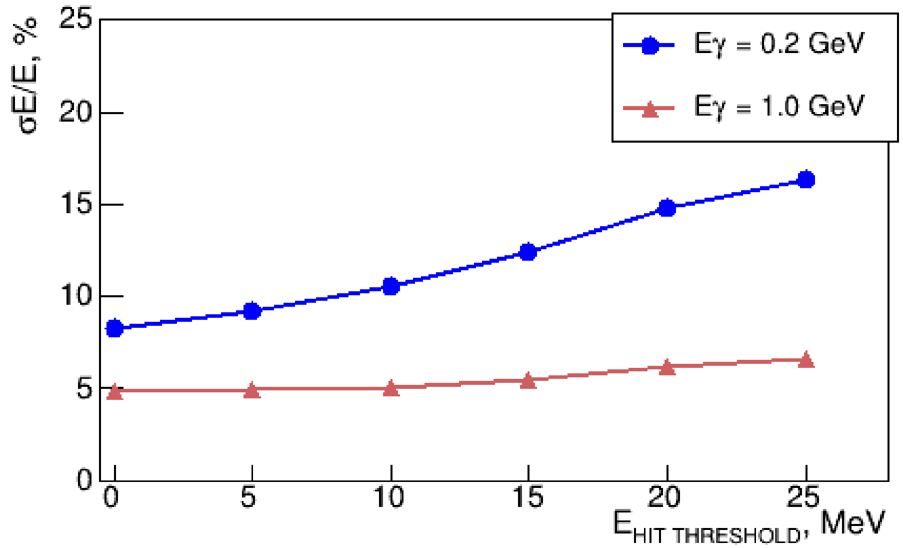




- ✓ Energy resolution is defined for two cases : MPD (TPC and TOF) + Power Frame + ECal and ECal only
- ✓ Contribution of the Power Frame is not significant
- ✓ MPD deterctor parts are slightly corrupted the energy resolution of ECal

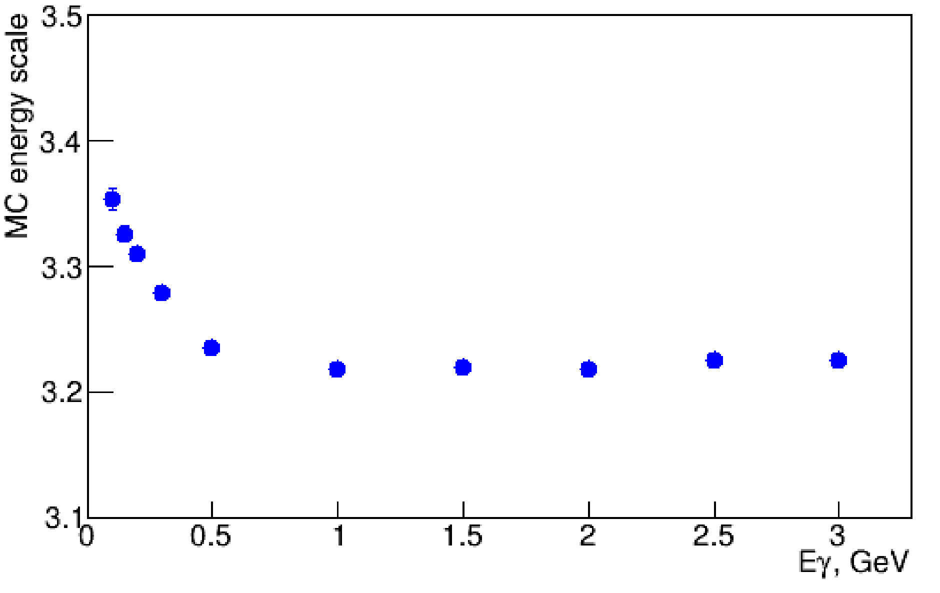
Energy threshold





- ✓ Right slide – energy deposit of γ's in ECal tower (hit) at different energies (Eγ = 0.2, 1.0 GeV)
- ✓ Left slide – energy resolution of the cluster vs hit thershold at different Eγ
- ✓ Threshold growing for a hit leads to an increase in the energy resolution
- ✓ This effect is more sufficient for γ's with low energies

MC energy scale



π^0 selection in ECal

- NICA collider rings :

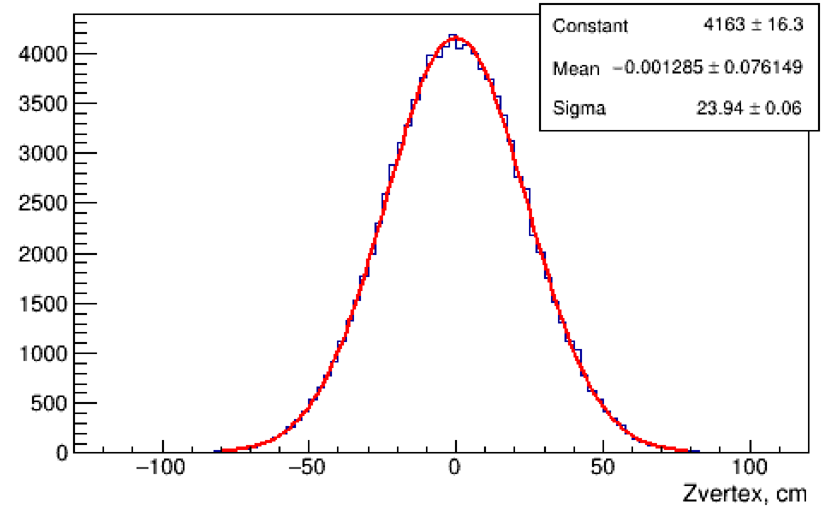
  Rms Z (bunch length ~ 60 cm) : 24 cm

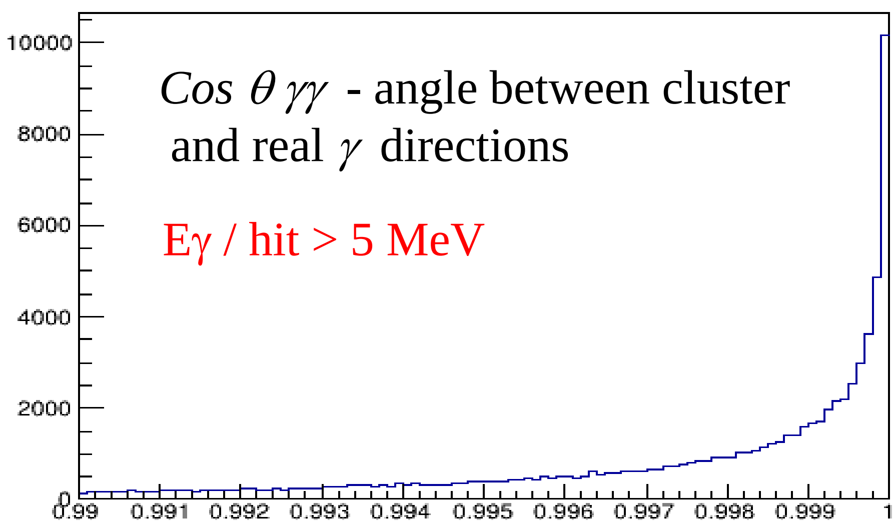
- Rms X = Rms Y ~ 0.0 cm

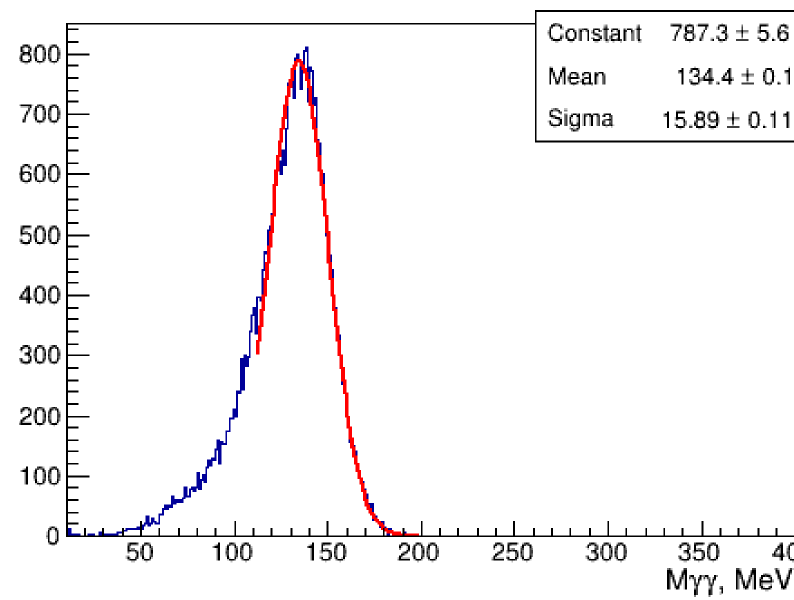
- Gaussian smearing of π^0 vertex along Z - axis

  $\sigma M_{\gamma\gamma} / M_{\gamma\gamma}$ ~ 10.6 % (definitre vertex)

  $\sigma M_{\gamma\gamma} / M_{\gamma\gamma}$ ~ 11.8 % (vertex smearing)



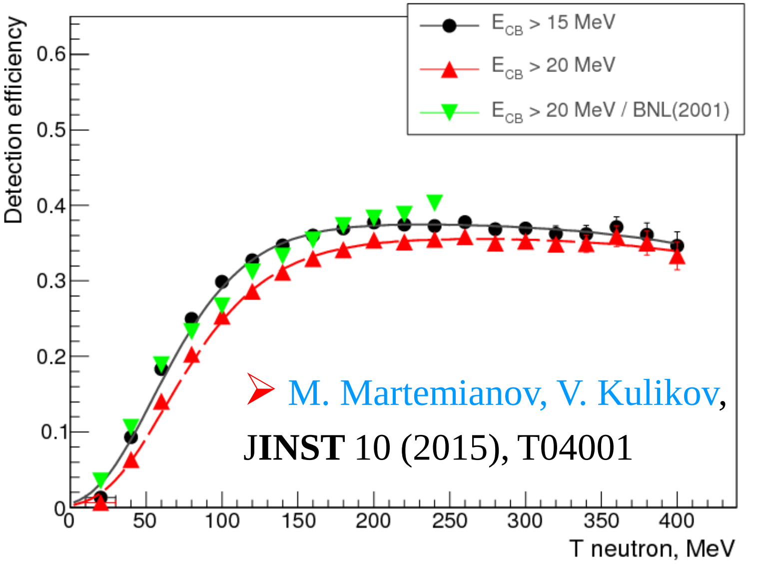




Neutron registration by ECal

- ✓CB calorimeter at Mainz (A2 experiment) installed on the MAMI photon facility
- ✓CB : NaI crystals, length of 40.7 cm
- ✓ Neutron efficiency obtained in the A2 experimental data close to MPD / ECal simulation
- ✓ So, neutrons gives a significant background to the neutral component
- ✓EM shower has a compact time in ECal and many cells are fired; hadronic shower has a big time difference between energy depositions in the early and late stages
- ✓An effective way to separate neutrons from light particles and photons will be investigated
- ✓ Possible way to separate photos and neutrons is a correct investigation of time shapes

Detection efficiency at CB / A2



MC detection efficiency at MPD/ECal