8th Collaboration Meeting of the BM@N Experiment at the NICA Facility

Status of the ECAL

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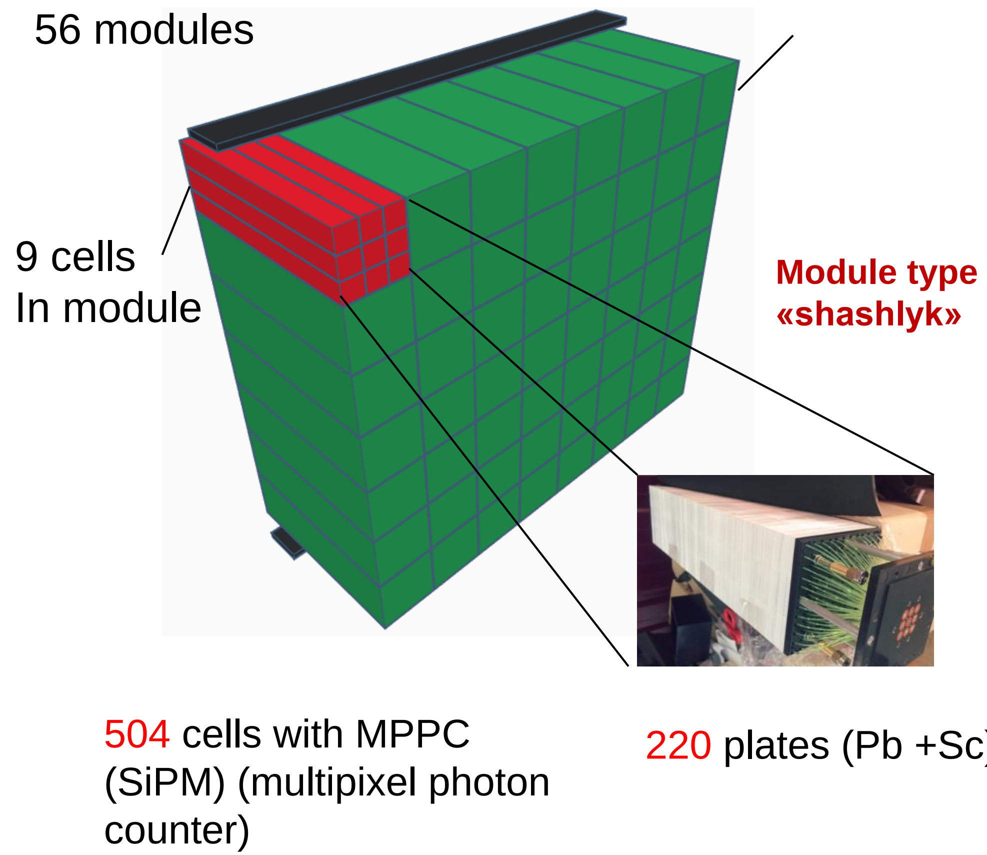
Ocrober 03 2021

ECAL BM@N

ECAL is formed from lead-scintillation modules "Shashlyk"-type in the wall size of 8x7 modules (96x84 cm2). The total number of active cells in one ECAL wall is 504. The 441 cells of one wall were used in the experimental run 2018. Modules for the second wall have been prepared and will be operated in 2021.

The «Shashlyk» module is a lead-scintillator sandwich which read out by means of wavelength shifting fibers .

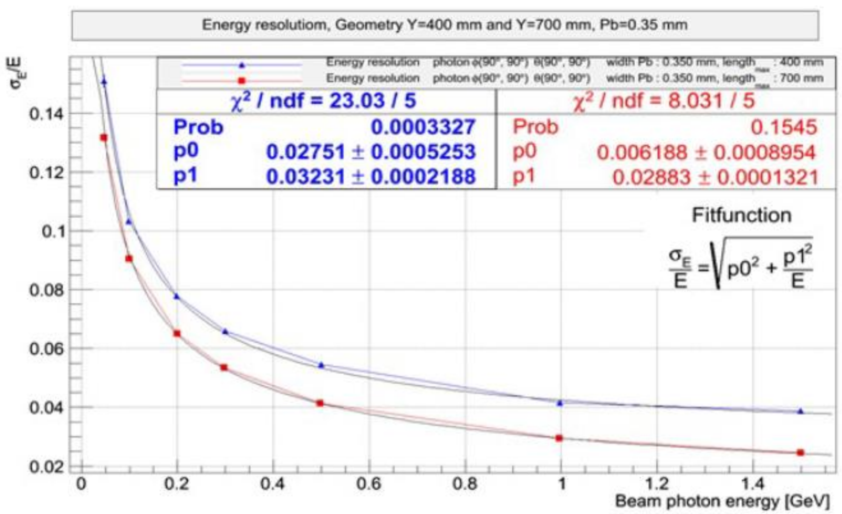


ECal key parameters

MPD NICA Technical Design Report of the Electromagnetic calorimeter (ECal)
(http://mpd.jinr.ru/wp-content/uploads/2019/01/TDR_ECAL_v3.6_2019.pdf)

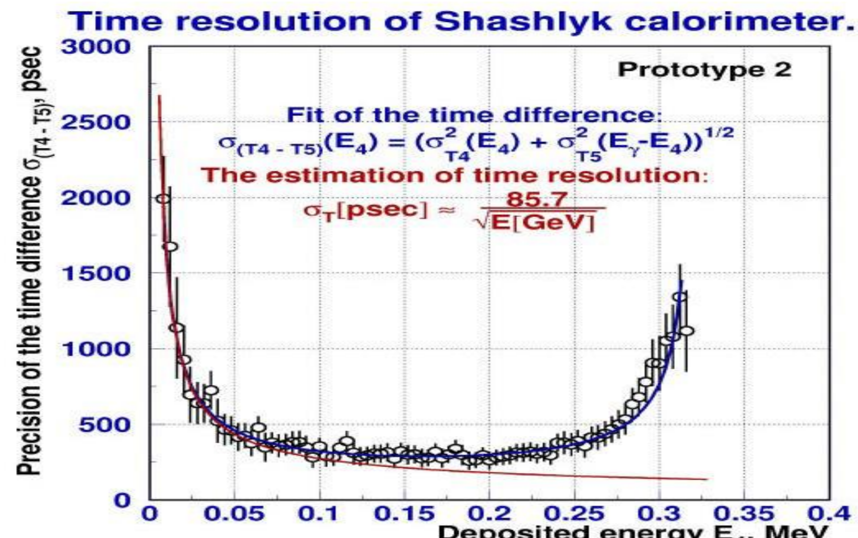
Energy resolutions of the calorimeter with lengths of the modules – 400mm (blue line).

$$\mathbf{dE} = \frac{3.2}{\sqrt{E(GeV)}} \oplus 2.7 \quad (\%)$$



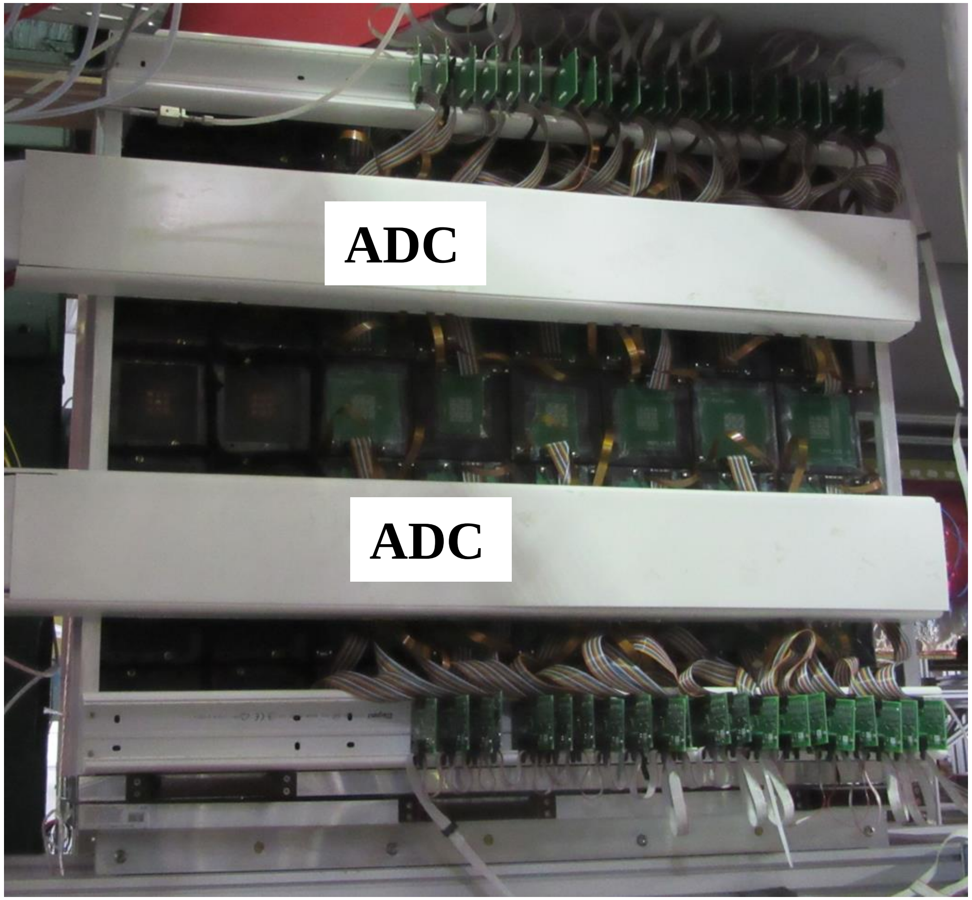
Time resolution of the "Shashlyk" type calorimeter

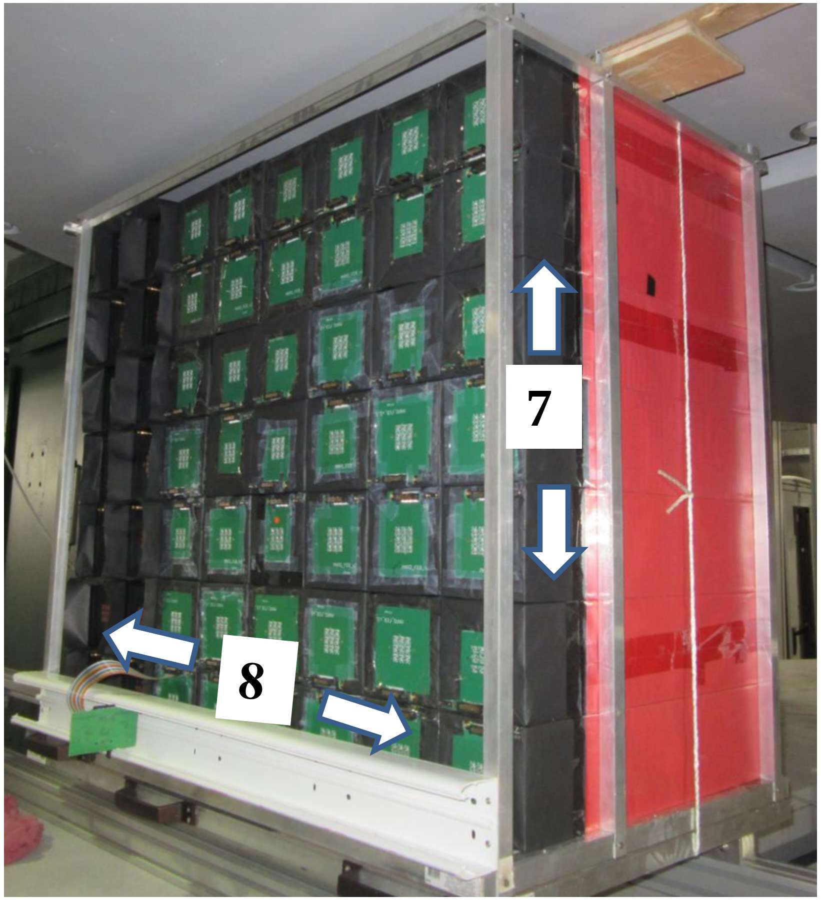
$$\sigma_t = \frac{85.7}{\sqrt{E(GeV)}} \quad (ps)$$



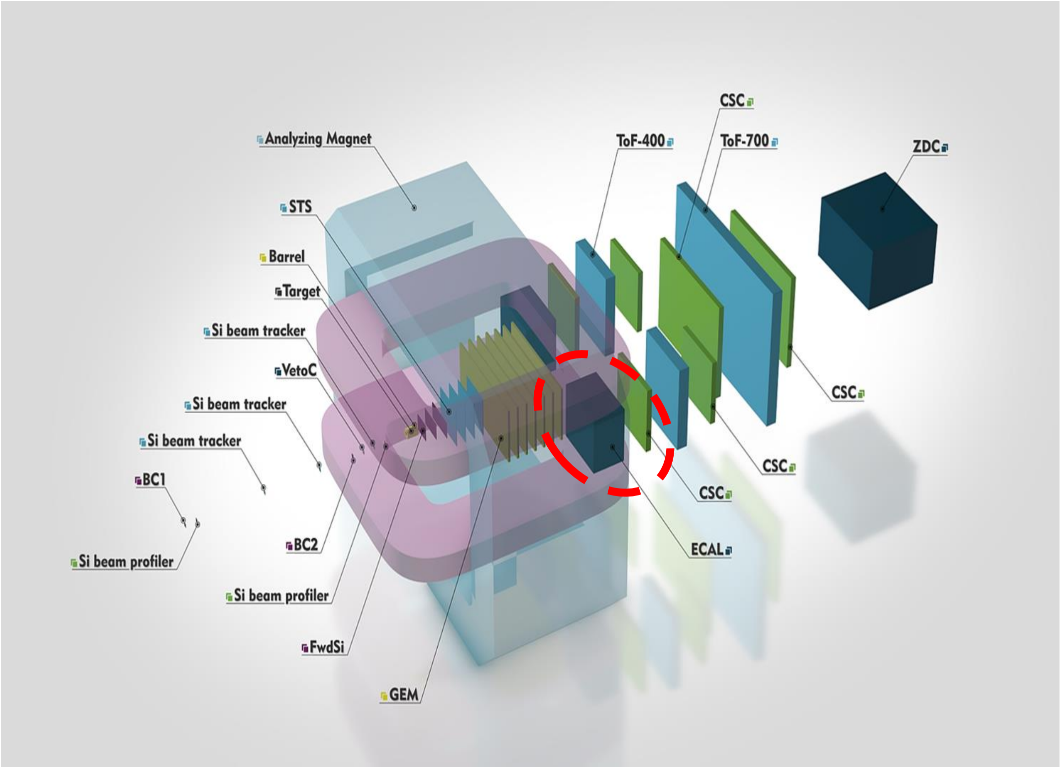
The ECAL location in the magnet (Run 7)

The ECAL detector was assembled from 56 modules stacked in a wall of 8x7 modules. The front-end electronics are located directly behind the detectors. (SiPM power supply and ADC)

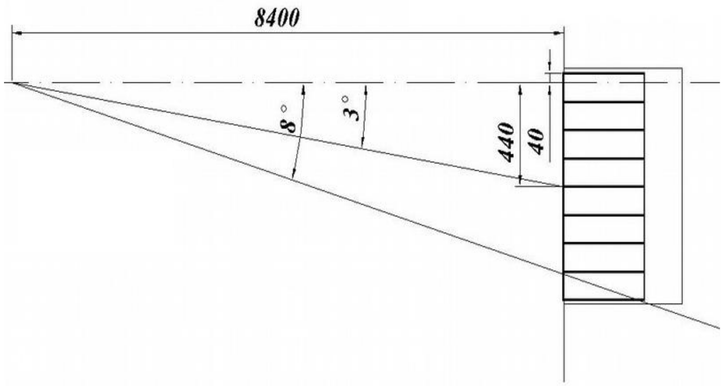




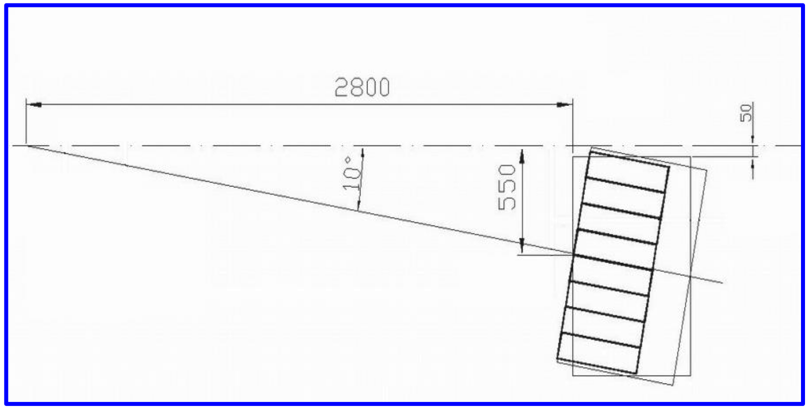
The ECAL location in the BM@N setup and positions in run 7.



Position 1, Run 7 (SRC) ECAL calibration runs C 3.17 AGeV → Pb, run ids 3503-3511, ~2 M ev.



Position 4, Run 7 (BMN) ECAL data analysis Kr 2.6 AGeV → Sn, run ids 4921-4966, ~5.7 M ev.



- **2018 year ECAL setup (run 7)**
  - **one swall 7x7 modules, 441 cells**
- New ECAL setup
  - two Walls of 8x7 modules, 1008 cells

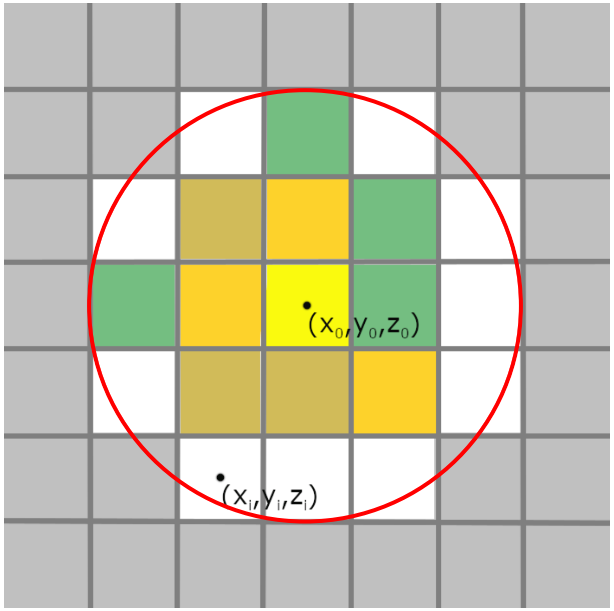
ECAL data analysis

Petr Alekseev on behalf of BMN ECAL group

6th Collaboration Meeting of the BM@N Experiment at the NICA Facility
JINR
October 26–27, 2020

Cluster parameters

- Minimal cell energy is 30 MeV, other cells are ignored
- Cluster radius is 10 cm (21 cells of 5x5 area)
- Cluster parameters are:
  - energy
  - center gravity
  - weighted average time (t_{wa})
  - time spread (t_{sp})
  - normalized moment (M_{norm})

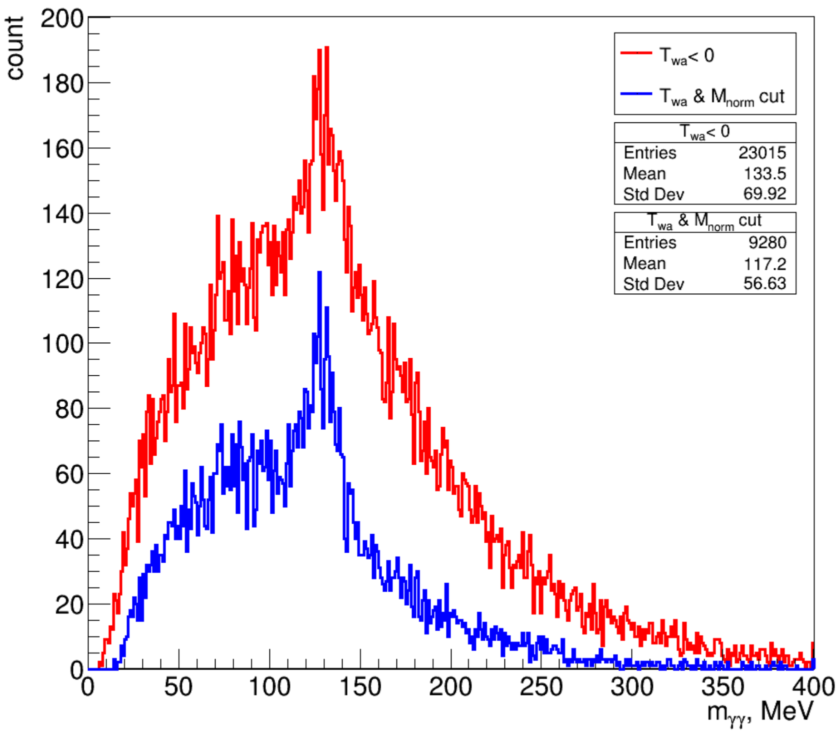


$$t_{wa} = \frac{\sum E_i \cdot t_i}{\sum E_i} \qquad t_{sp} = \frac{\sum E_i \cdot (t_i - t_0)^2}{\sum E_i}$$

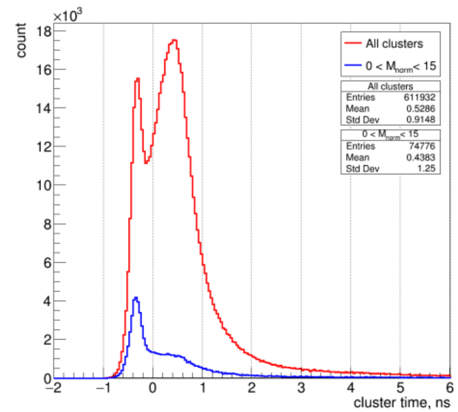
$$M_{norm} = \frac{\sum E_i \times ((x_i - x_0)^2 + (y_i - y_0)^2 + (z_i - z_0)^2)}{\sum E_i}$$

Simulation:
GEANT4, DCMQGSM KrSn 2.36AGeV, ~2M ev

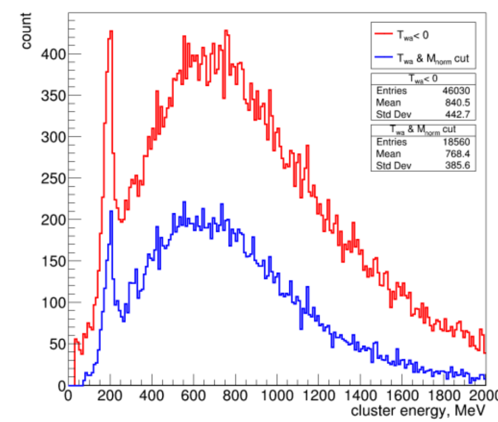
Effective mass spectrum



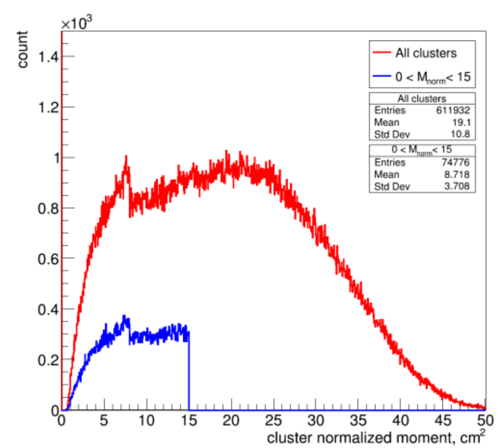
Cluster time



Cluster energy



Normalized moment



t_{wa} < 0

M_{norm} < 15

N_{cells} > 1

$E_{cluster}$ no cut

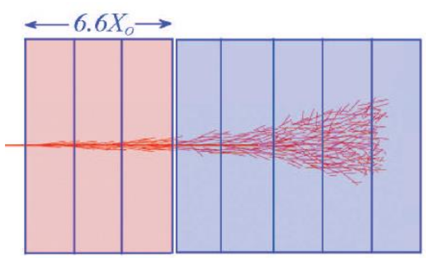
Normalized moment

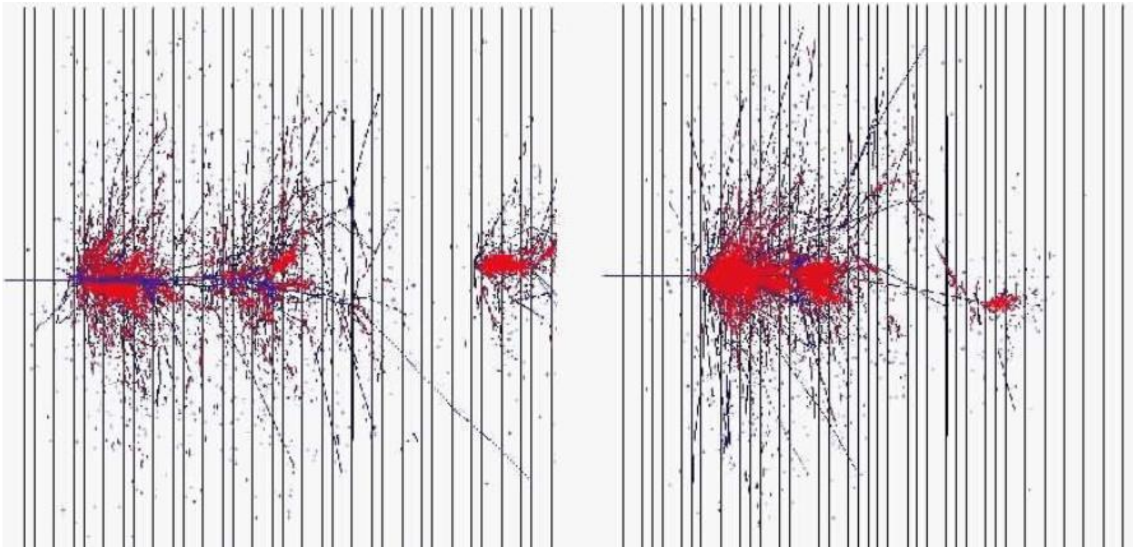
$$M_{norm} = \frac{\sum E_i \times ((x_i - x_0)^2 + (y_i - y_0)^2 + (z_i - z_0)^2)}{\sum E_i}$$

Electromagnetic shower

Hadron shower

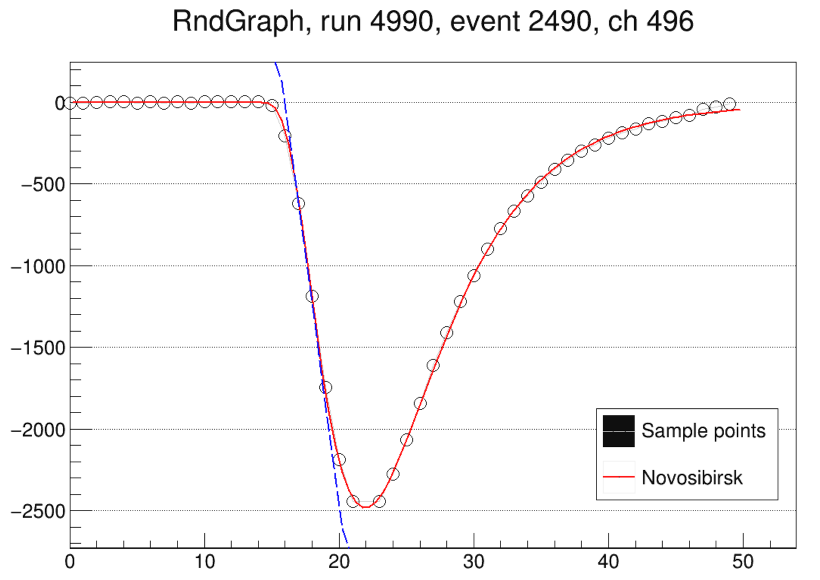
HELIOS





ECAL signal raw to digi conversion

1. Pedestal - mean of slices 0..7
2. Novosibirsk fit
3. Peak amplitude $\mathbf{A}_{\mathbf{peak}}$ and time $\mathbf{T}_{\mathbf{peak}}$
4. Cell start time $\mathbf{T}_{\mathbf{cell}}$
5. Amplitude **A** - mean of T_0...T_0+20 slices
6. Get coords from geometry file



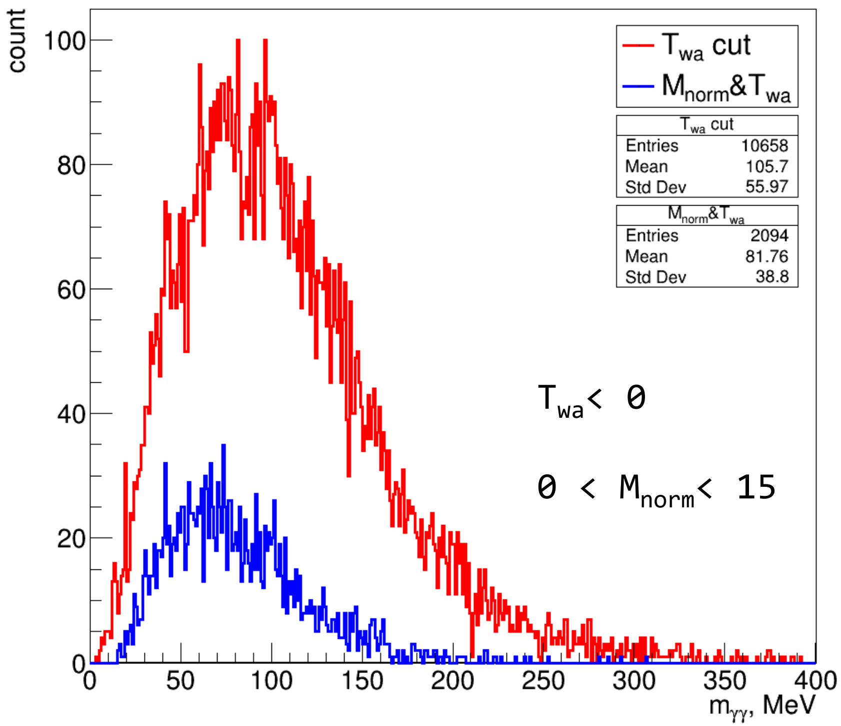
Novosibirsk function:

$$f(x) = e^{-\frac{\ln^2 q_y}{2\Lambda^2}+\Lambda^2}, \quad q_y = 1 + \frac{\Lambda(x - x_0)}{\sigma} \times \frac{\sinh\left(\Lambda\sqrt{\ln 4}\right)}{\Lambda\sqrt{\ln 4}}$$

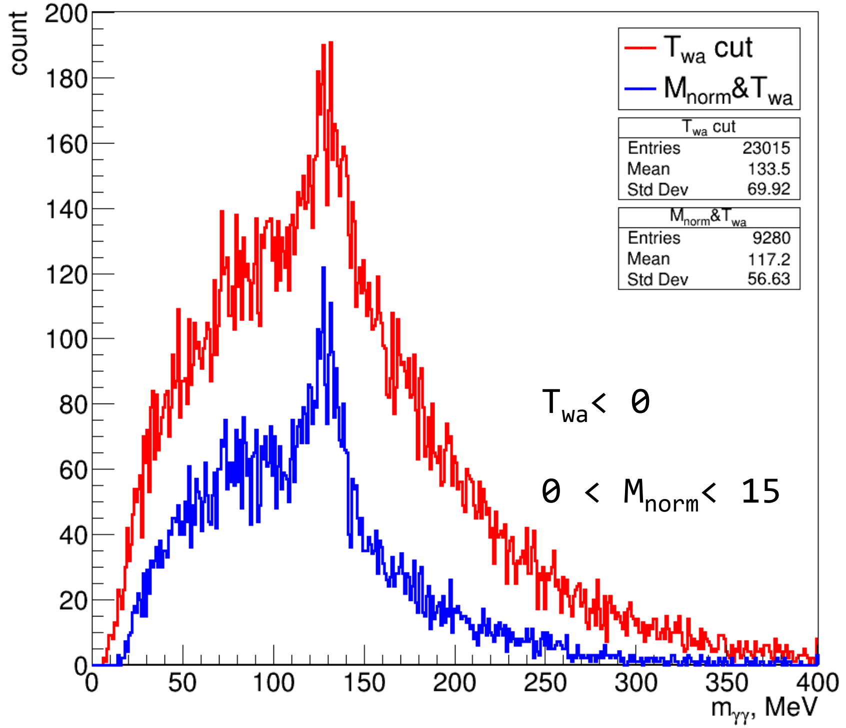
Experimental data:

Effective mass spectra with cuts KrSn 2.36AGeV

Exp. data. **-1.5 cm < Z_{vertex}< 0 cm**



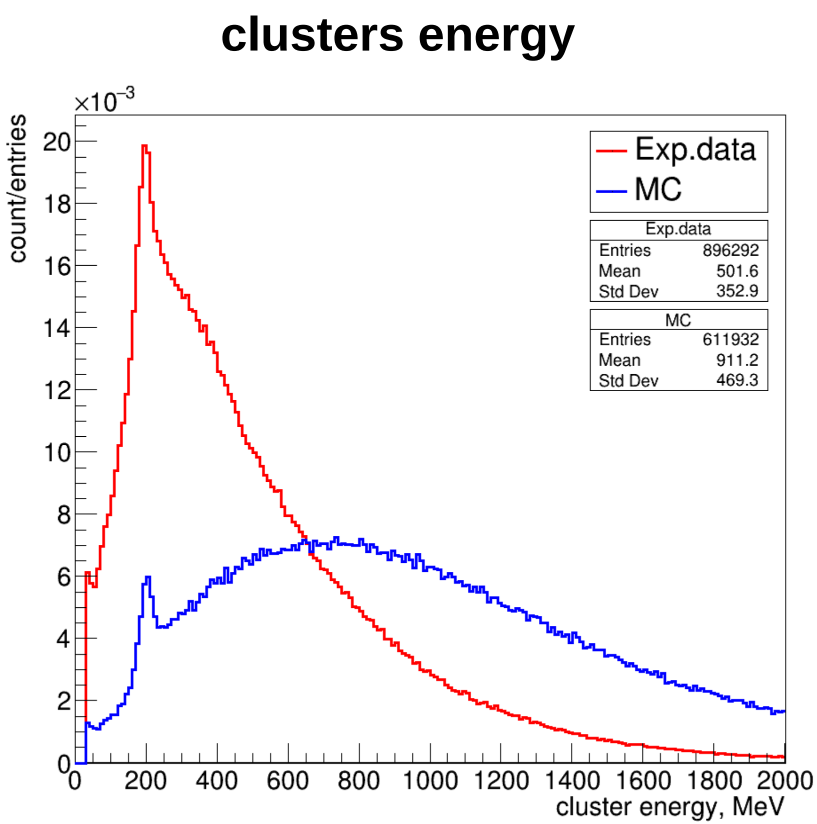
Monte-Carlo simulation.

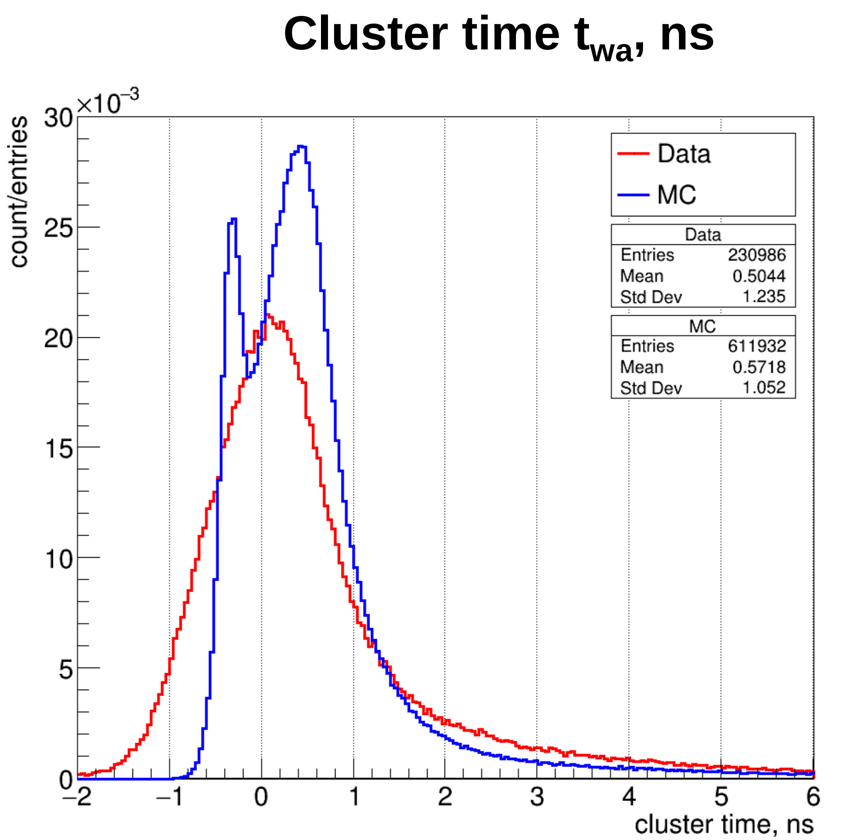


Why the big discrepancy?

Investigation of problem points in the processing of experimental data.

- **Mean cluster energy**
- **Time resolution of ECAL**



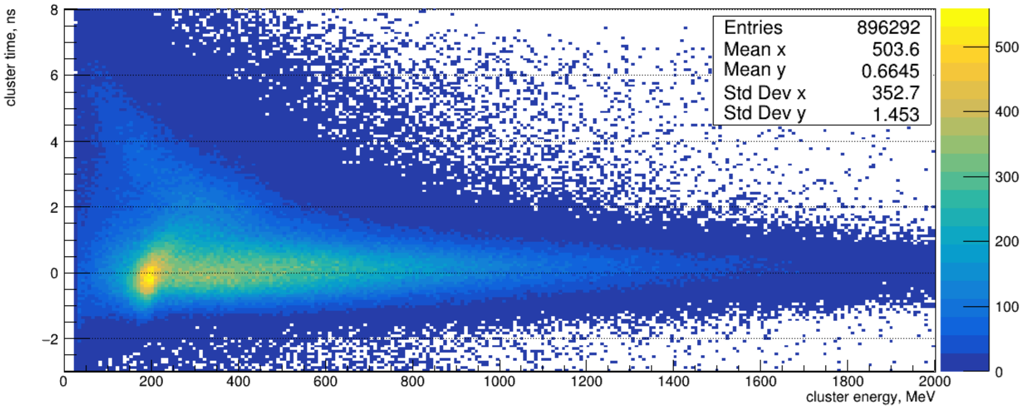


Add vertex information into analysis

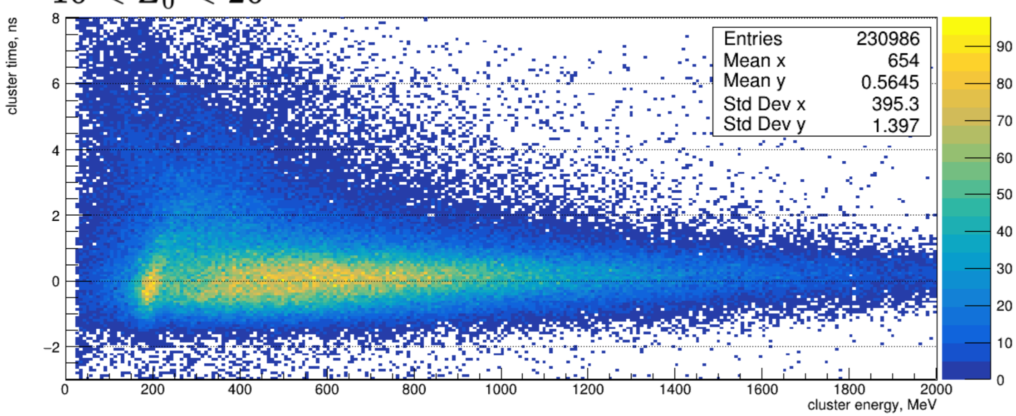
ECAL cluster time vs energy (experiment)

Kr 2.6 AGeV→ Sn (2.57), runs 4921...4966, ~5.7M events

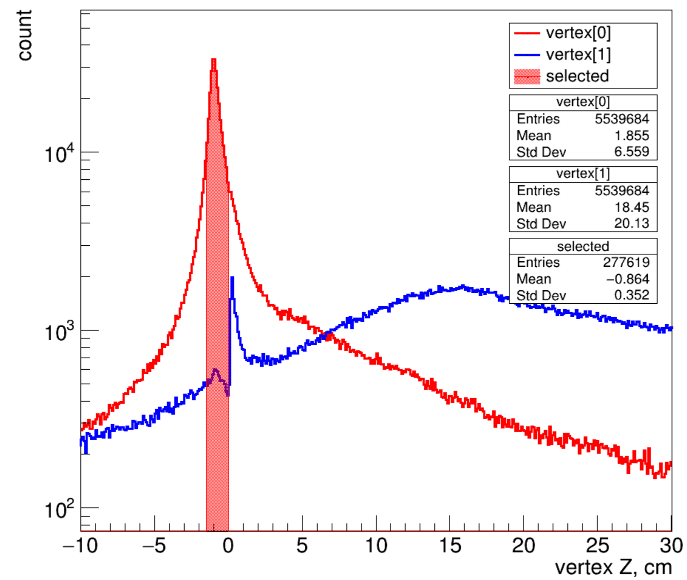
No cut



$-10 < Z_0 < 20$

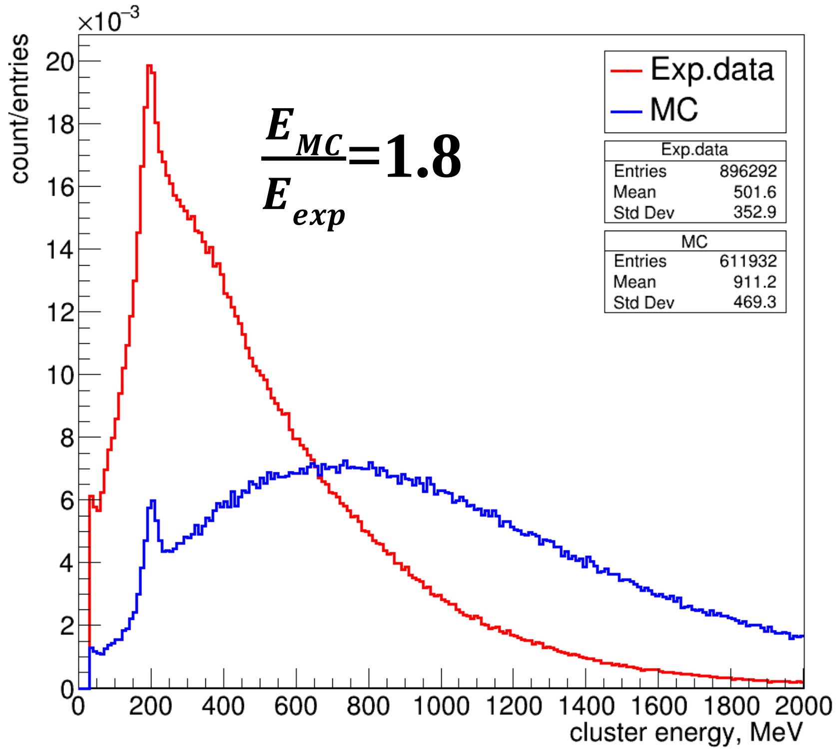


All clusters involved into effective mass calculation

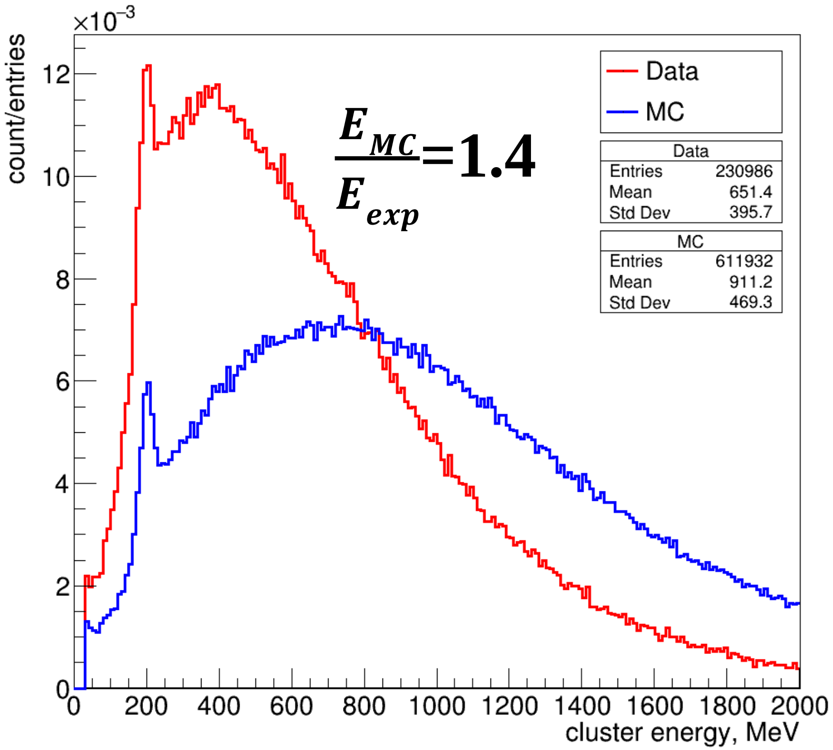


Events selected that has primary vertex found in the range (using run_reco_bmn.C)

ECAL clusters energy spectra with vertex cut.



Experimental data spectrum of all clusters involved into effective mass calculation



Events selected that has primary vertex found

The vertex information significantly improves the ratio of MC and experimental data, but does not fully explain.

The proposed source of the background is particles from secondary interactions.

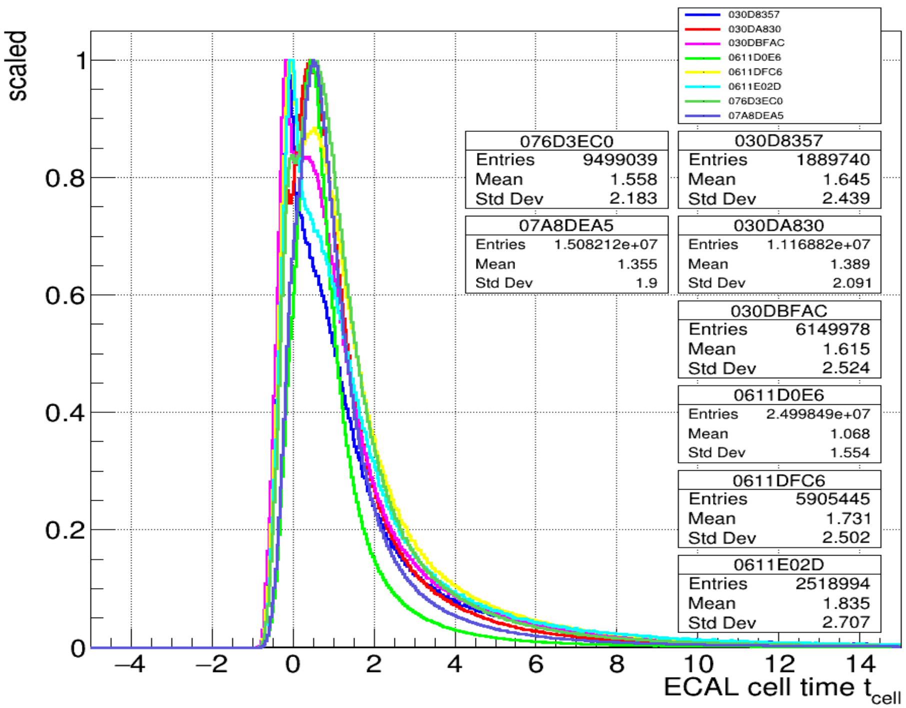
It is planned to:

- **perform MC modeling with detailed geometry of the GEM chambers.**
- **add into analysis beam type information**

Analysis of ECAL time resolution.

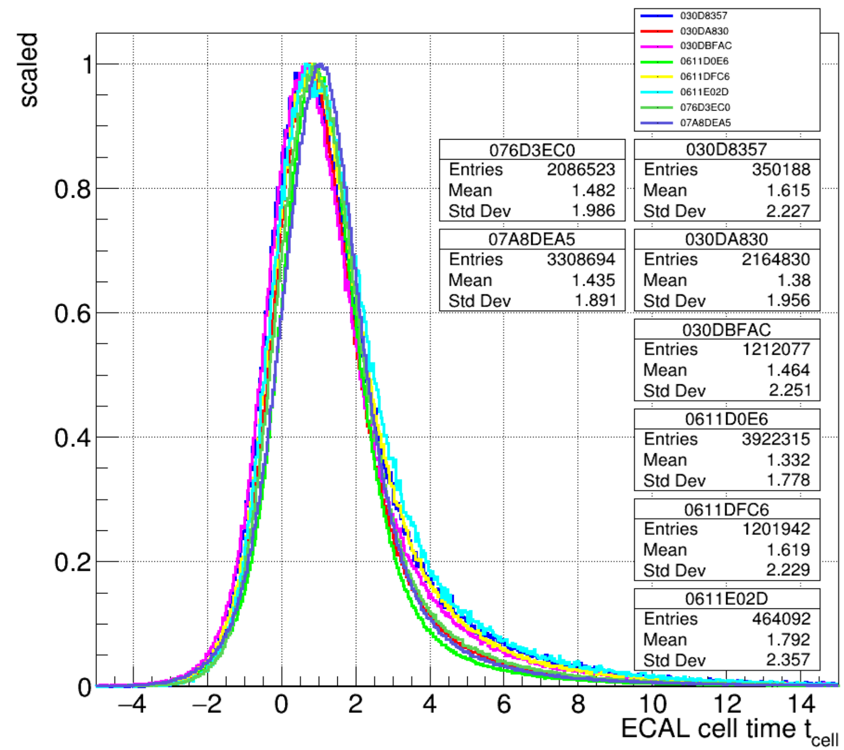
MC estimation of the experimental time resolution.

The estimation of the time resolution was performed by the method of “ time distortion” of the MS calculations. Cells time distortion in MC was set to match the width of the experimental distribution.



MC KrSn 2.36AGeV mb

No distortion (original state)

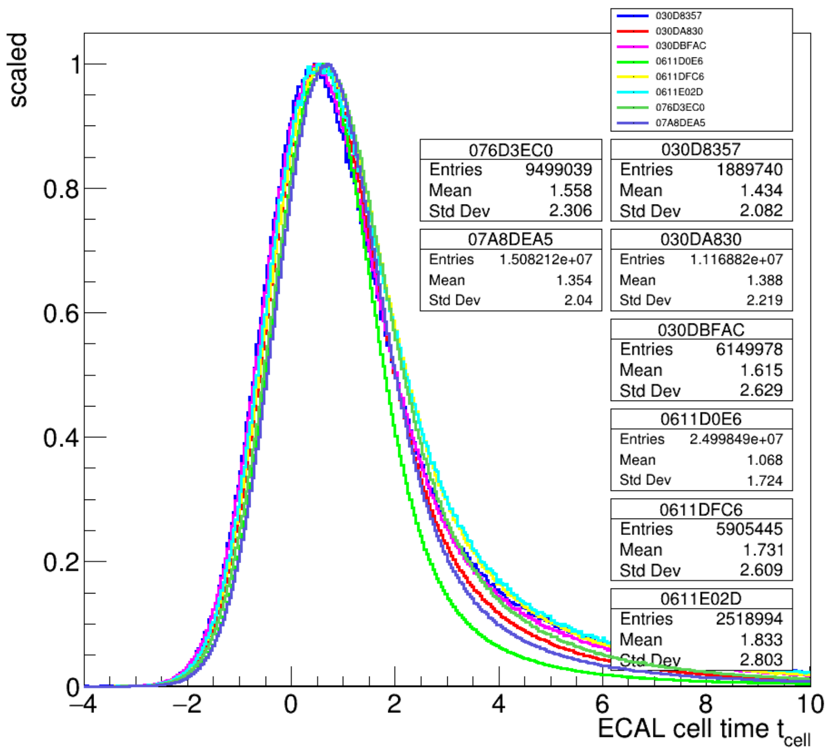


Exp.data KrSn

Time shifted to match MC on the half height of the rising edge

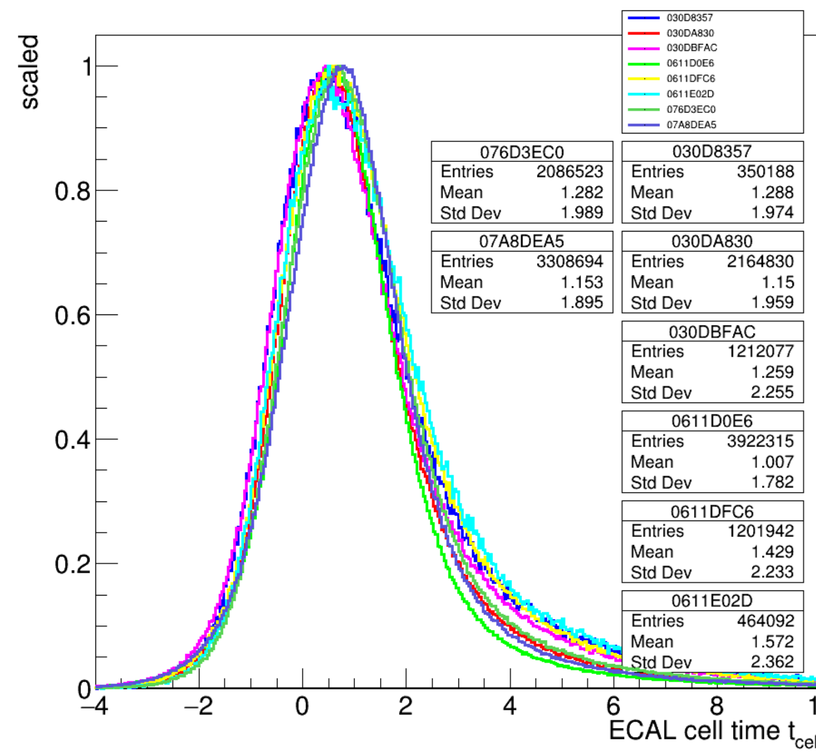
MC estimation of the experimental time resolution.

The best agreement between the MS calculations and the experimental data was obtained for σ_t=750 ps.



MC KrSn 2.36AGeV mb

Time distortion (σ = 0.75 ns)

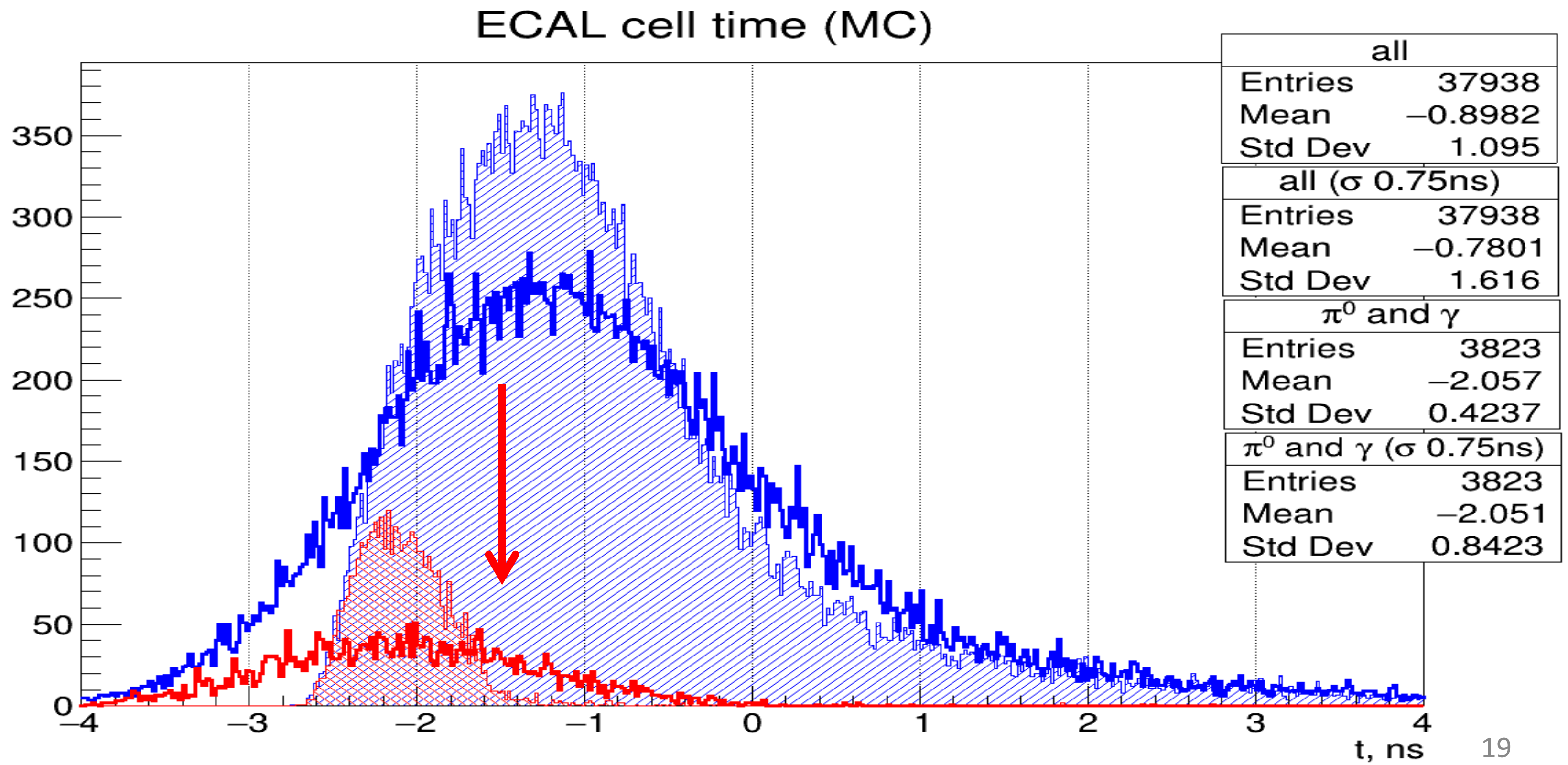


Exp.data KrSn

Time shifted to match MC on the half height of the rising edge

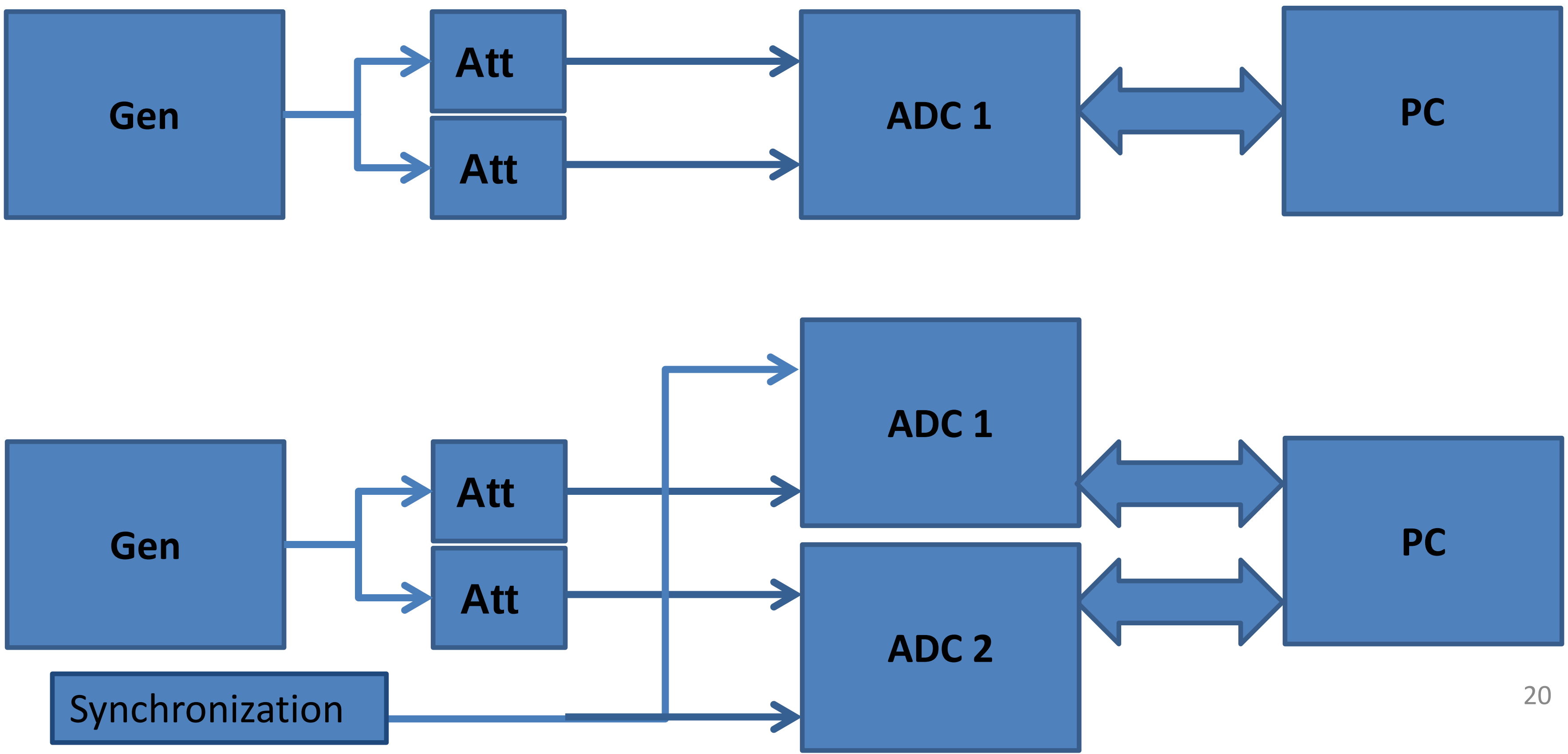
Estimation of the time resolution for the event selection criteria.

The criteria for clusters selection based on the time of arrival of the signal is determined by the time of delay of the background particles relative to the gamma quanta. The shaded areas correspond to the gamma (red) and neutron (blue) detection times without distortion. They are offset by 1 ns. This is enough to suppress the background by an order of magnitude. A time spread of 0.75 ns (bright red and blue line) devalues the time analysis.

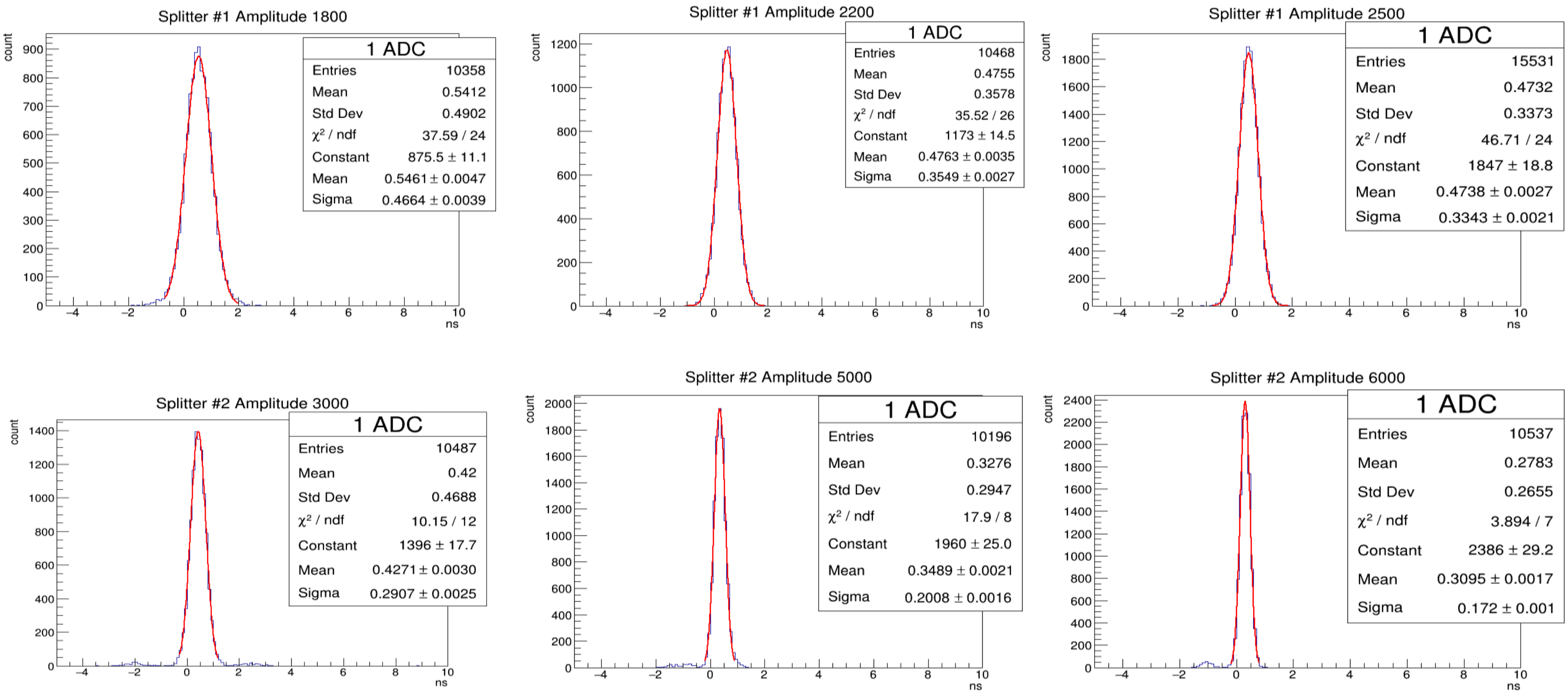


Source of the time distortion for experimental data.

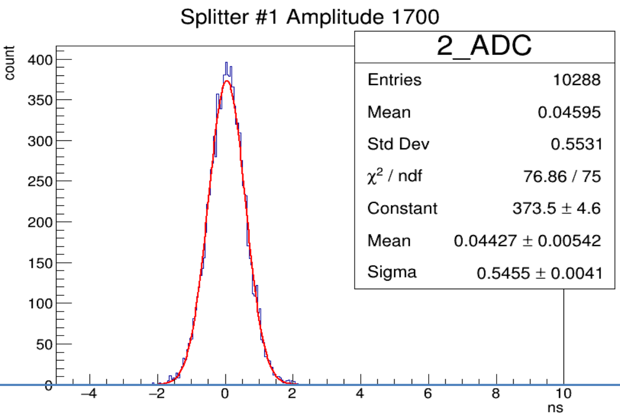
The time resolution of the ADC was investigated by measuring the time difference between the two ADC channels. The times were measured both for a single ADC and for two ADCs synchronized from an external source. For a single ADC, the time resolution has good agreement with the TDR data. The time resolution of paired ADCs is significantly wider and significantly bifurcates at amplitudes of 5000.

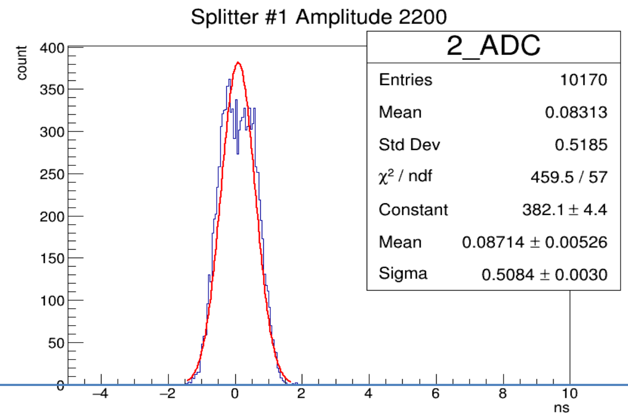


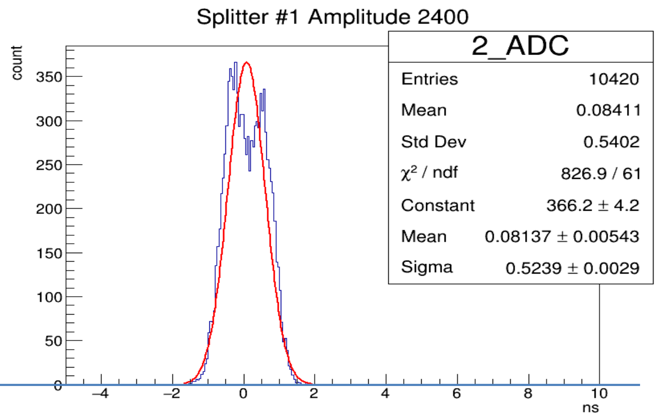
Time difference between the two channels in single ADC

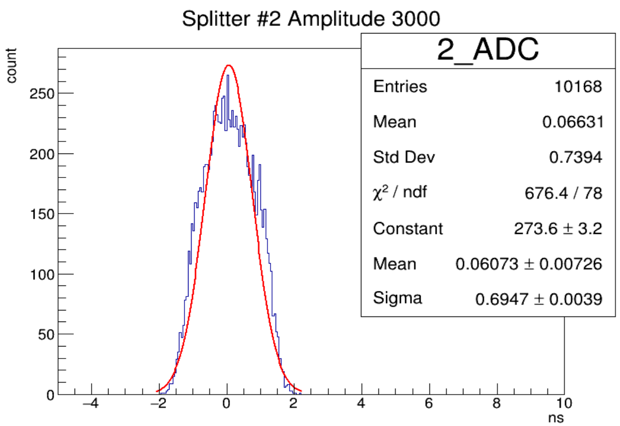


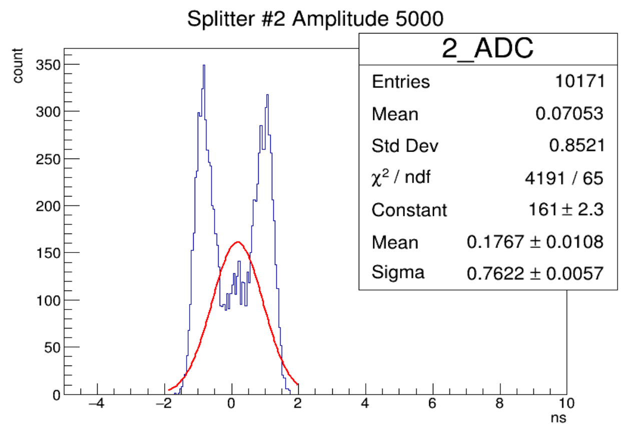
Time difference between two channels in two ADCs



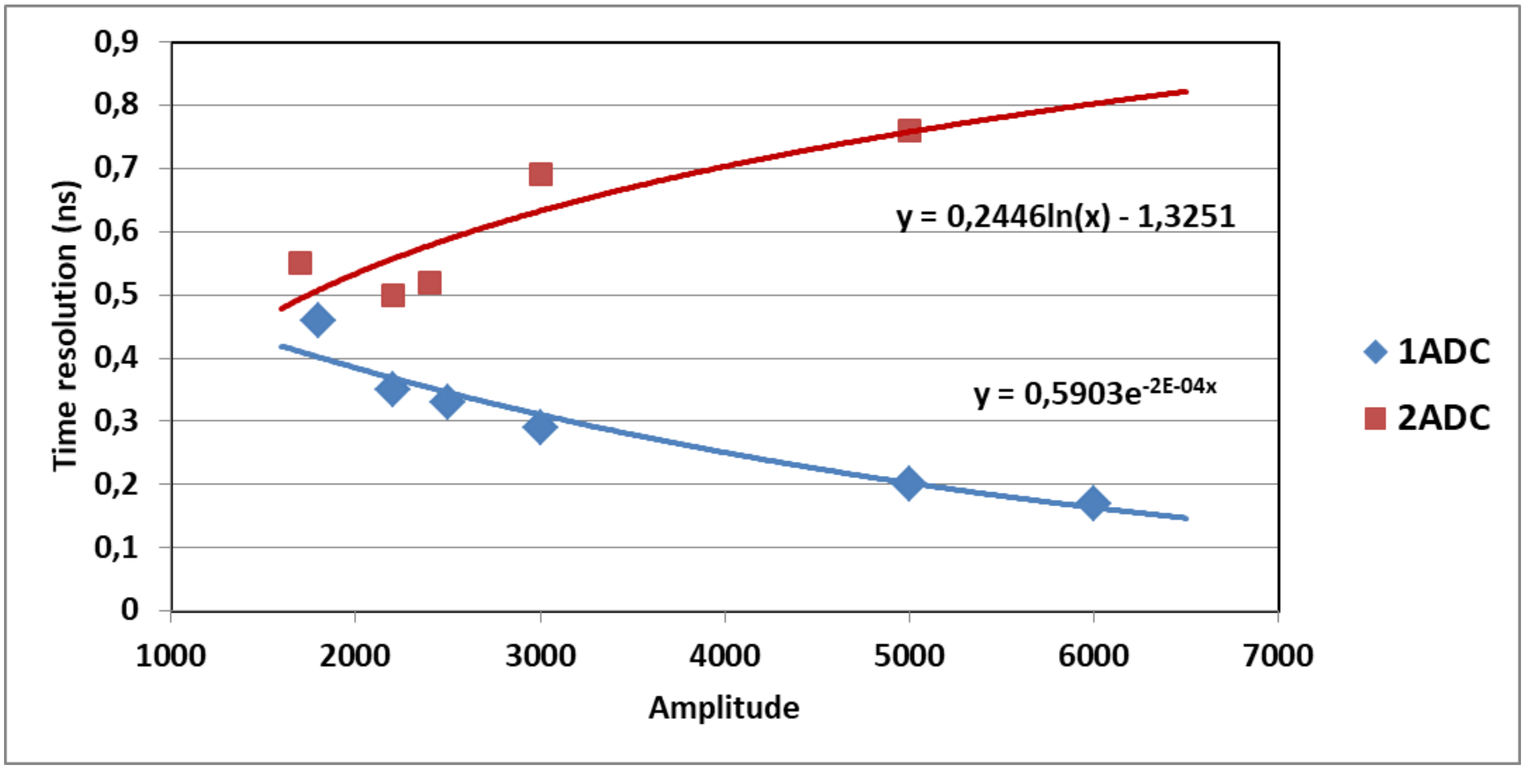








For a single ADC, the time resolution has good agreement with the TDR data. The time resolution of paired ADCs is significantly wider and sensitive bifurcates at amplitudes of 5000.



The proposed source of the time distortion is external start of ADCs.

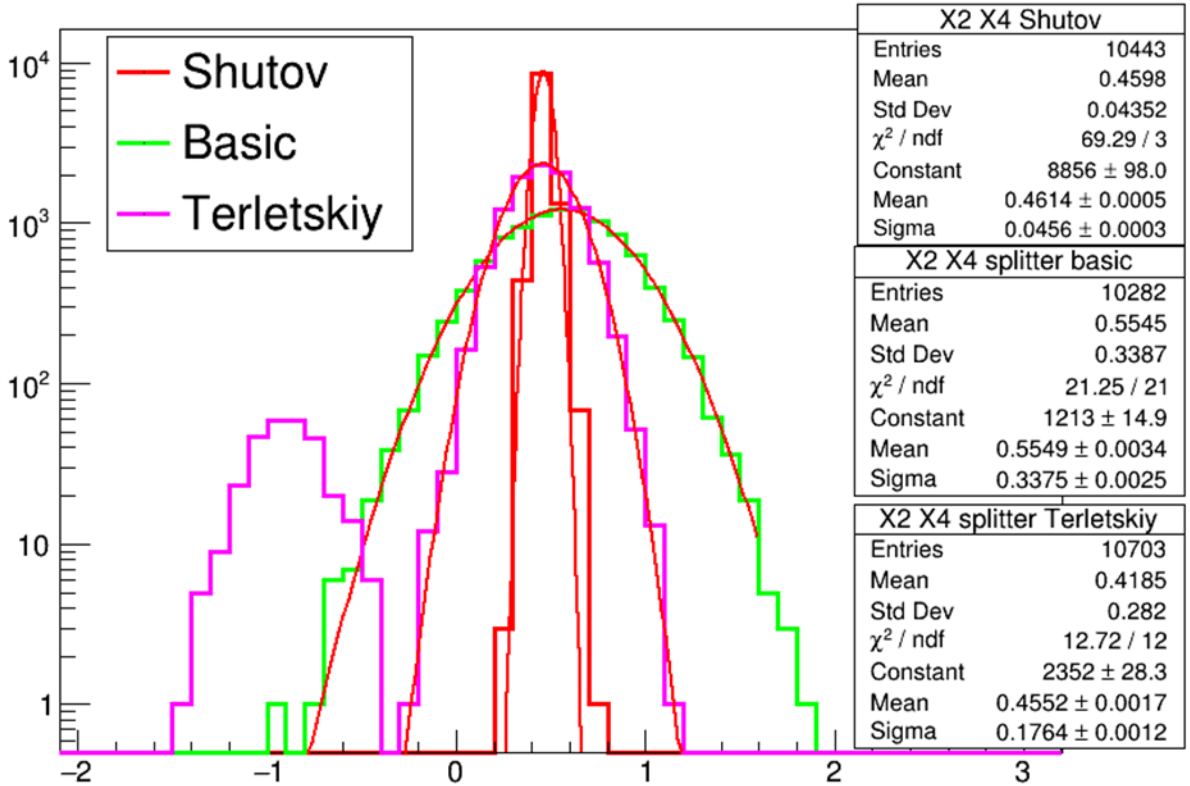
Unfortunately, it is not possible to correct the information from run 7.

Possible solutions for run 8 are

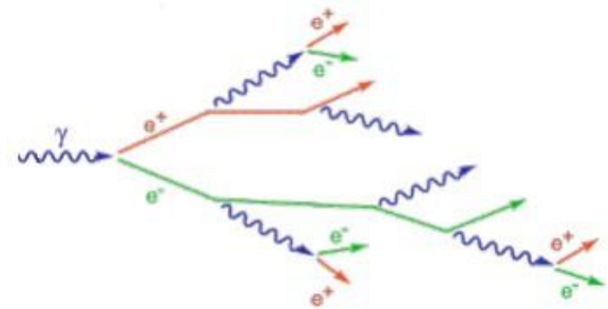
- **to use the 64th free ADC input for synchronization**
- **make changes to the ADC synchronization system.**

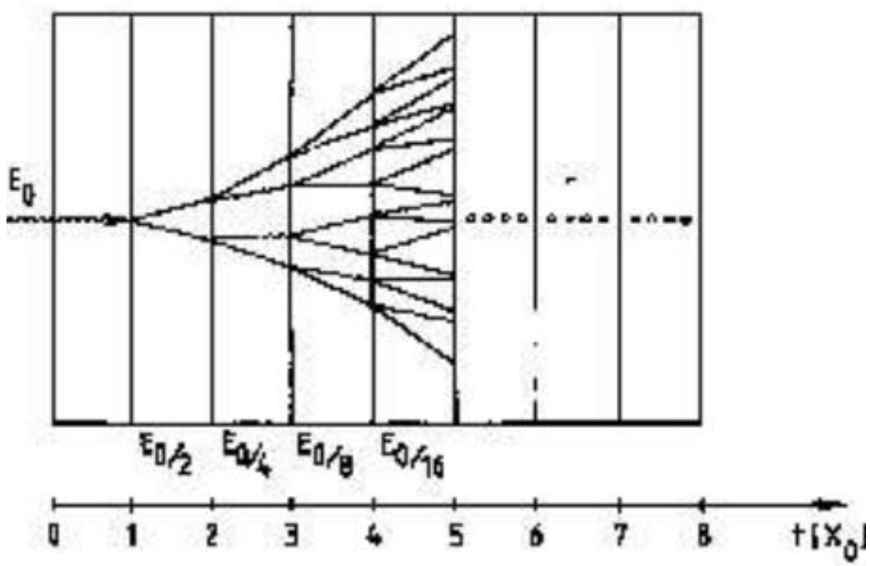
This item was completed in the summer of this year.

The time spread of the signal in the ADC was reduced to 50 ps.

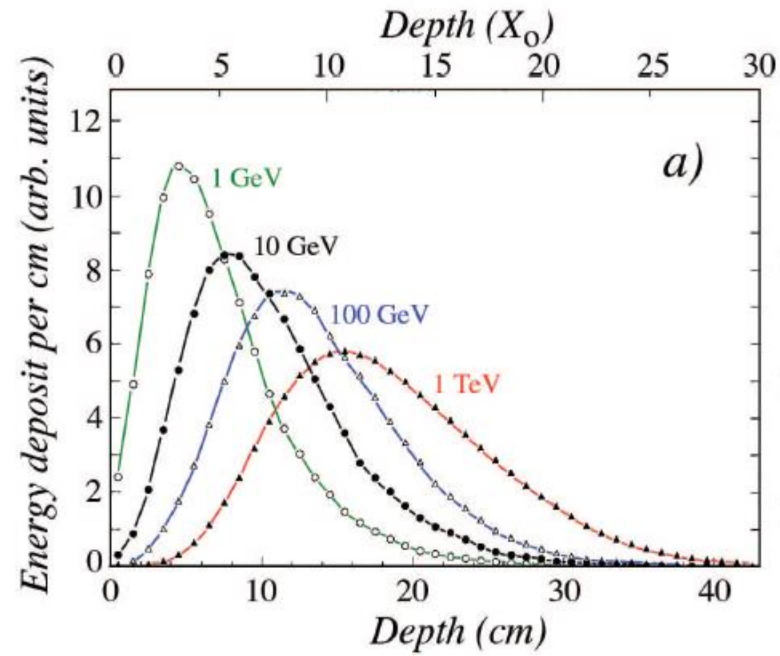


A global problem is the spatial distribution of the electromagnetic shower along the detector. This leads to a significant time shift of the recorded signal depending on the initial energy.





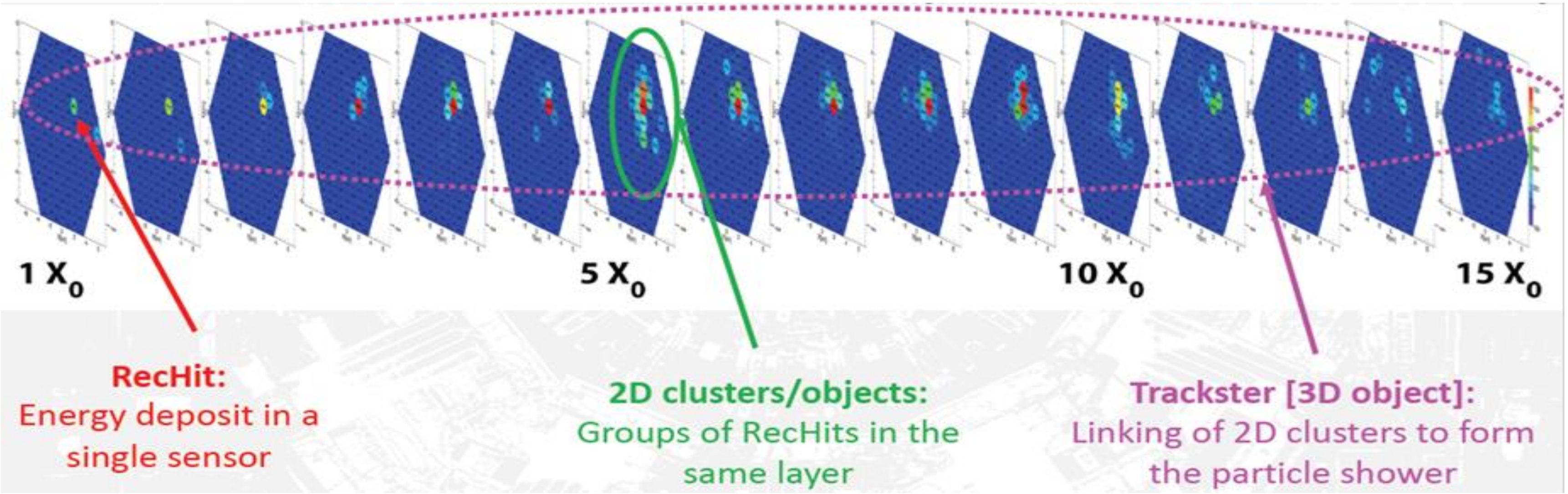
$$N(t) = 2^t \qquad E(t)/\ particle = E_0 \cdot 2^{-t}$$



A modern approach to solving the problem of the time distortion of a shower is the registration of time and amplitude from each layer of the detector.

Project HGCAL CMS

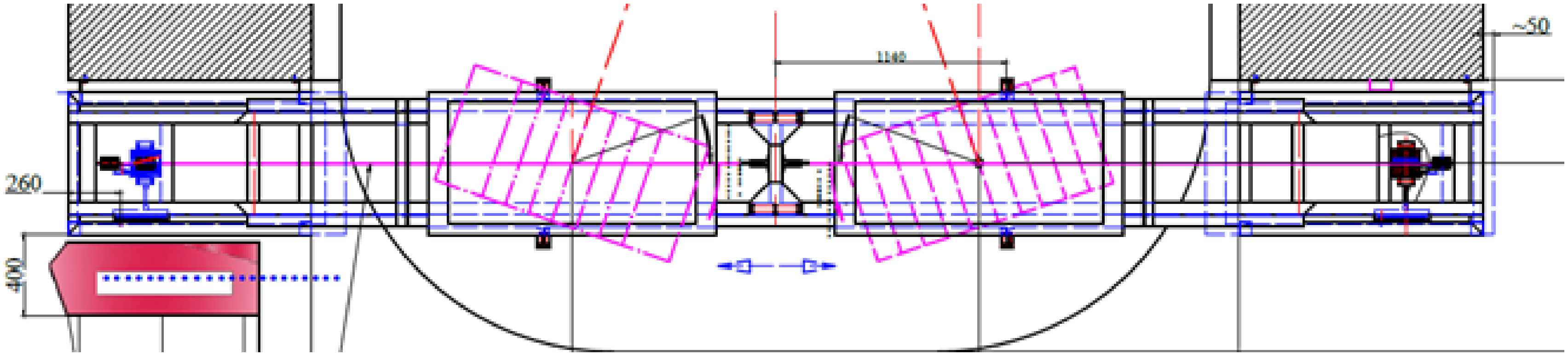
- **A modular reconstruction framework designed to fully exploit HGCAL potential**
  - **Goal: process the energy deposited by particles on HGCAL [RecHits] and return particles and probabilities**



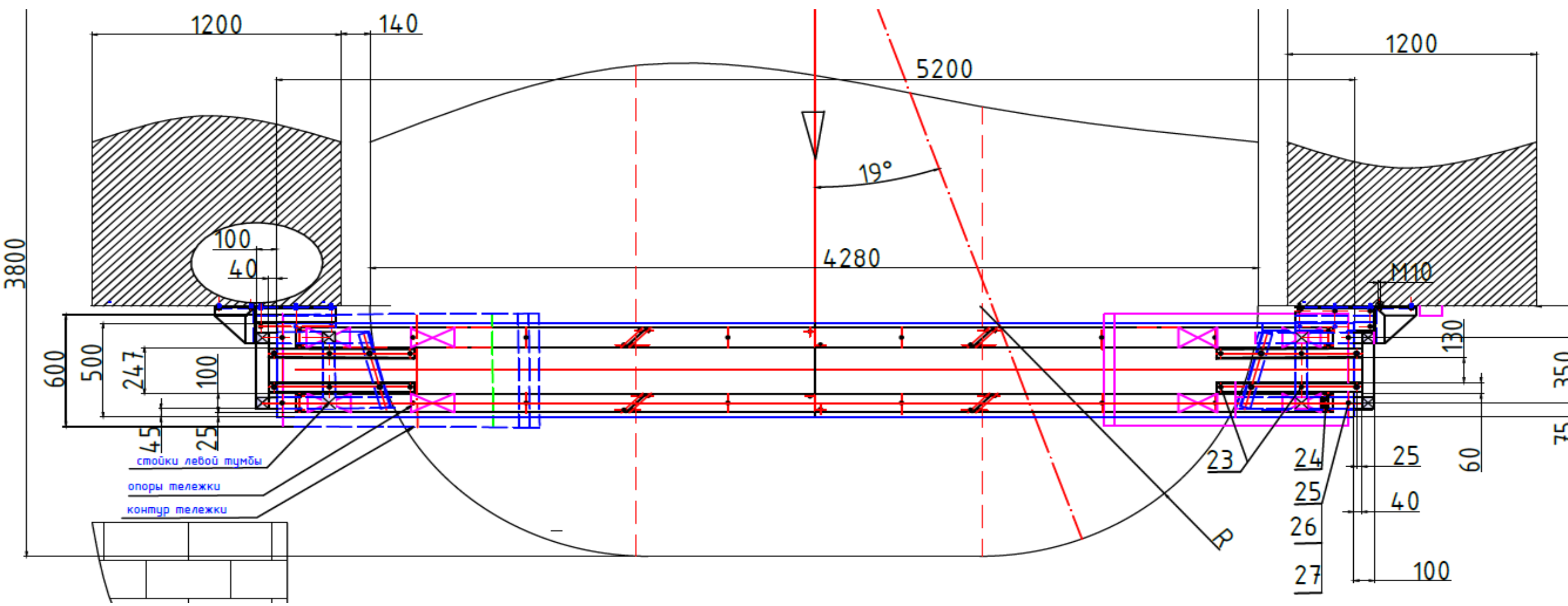
Preparation for RUN 8

Operation regimes for ECAL

Close to beam



RUN 8 position out of SRC aperture

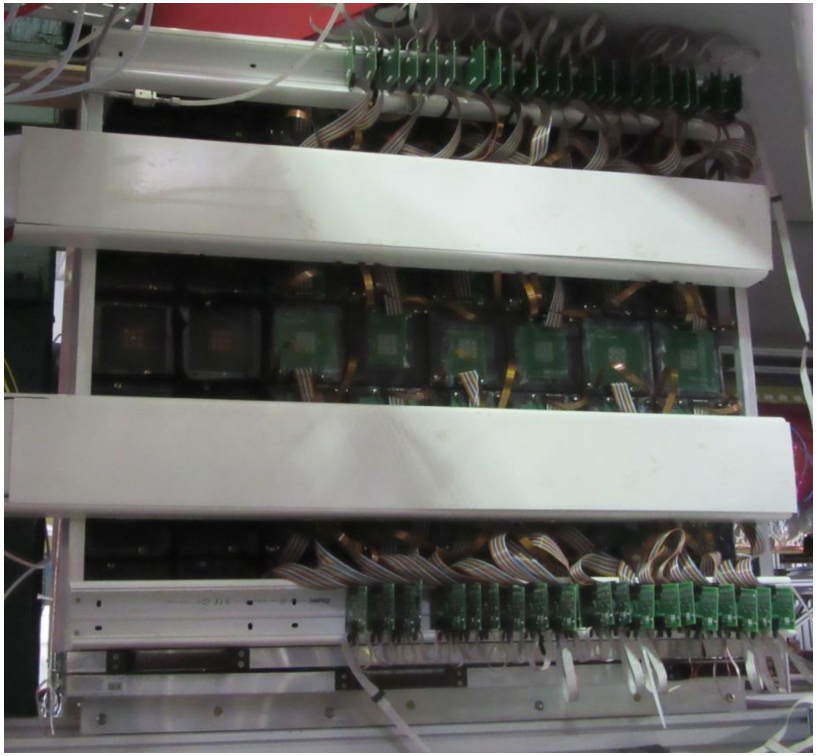


New mechanics for the two-arm calorimeter is ready.

The ADC and modules for the two arms ECAL have been prepared.

The non standard modules from the right arm of the ECAL were checked and prepared for replacement.

Tested modules for the left arm of the ECAL.



Right arm

Left arm

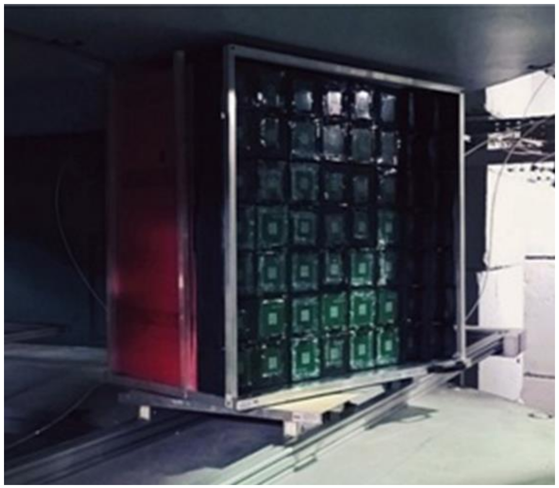
ECAL assembling time-table will be prepared in connection to GEM chambers and magnetic measurement.

Thank for your attention!

BACKUP

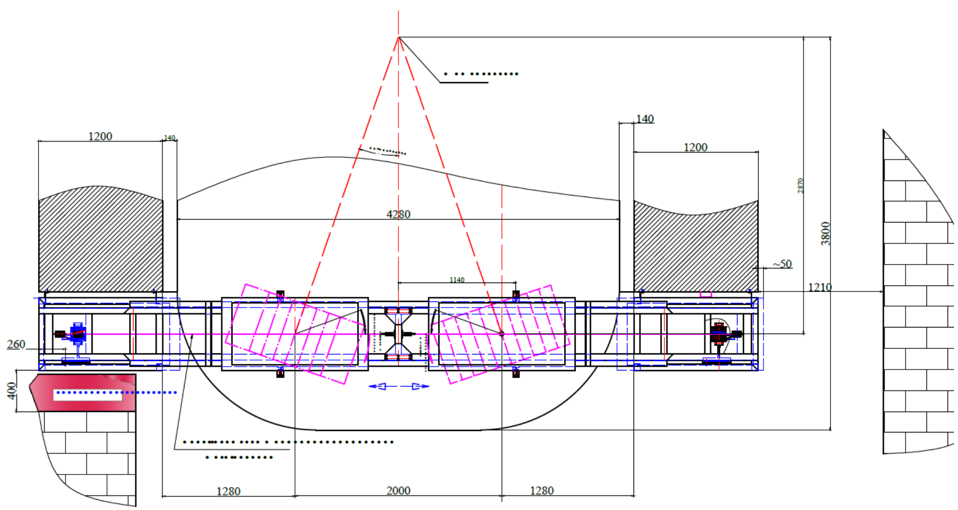
ECAL two arms installation (status 2020).

- main effort was add ECAL data analysis considering signal time parameters
- assembled of two racks for ECAL in the magnet
- performed tests array of modules for second arm of the ECAL

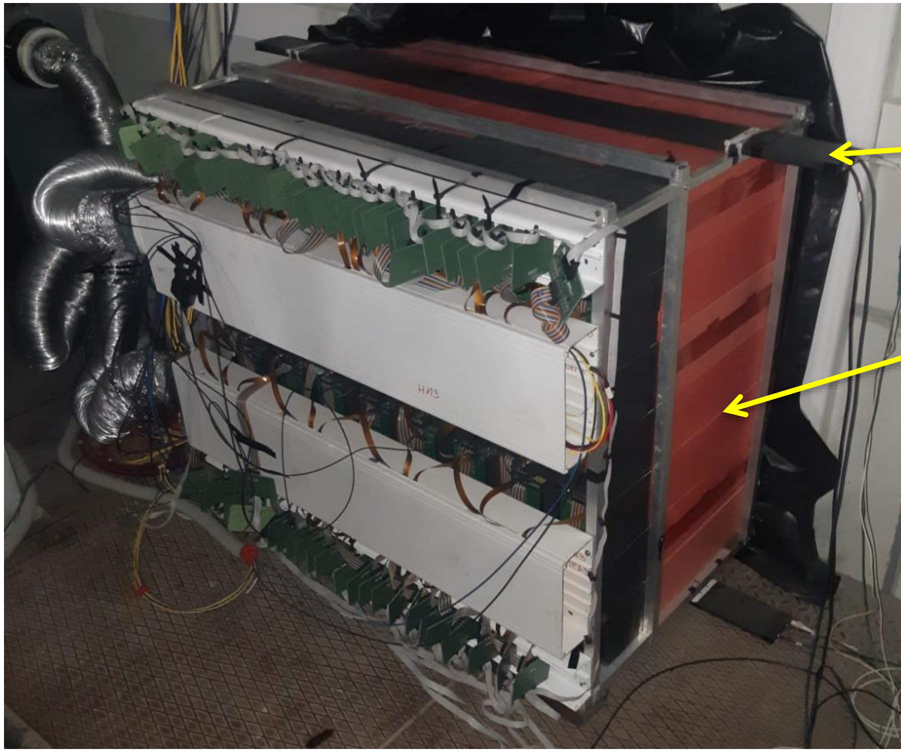


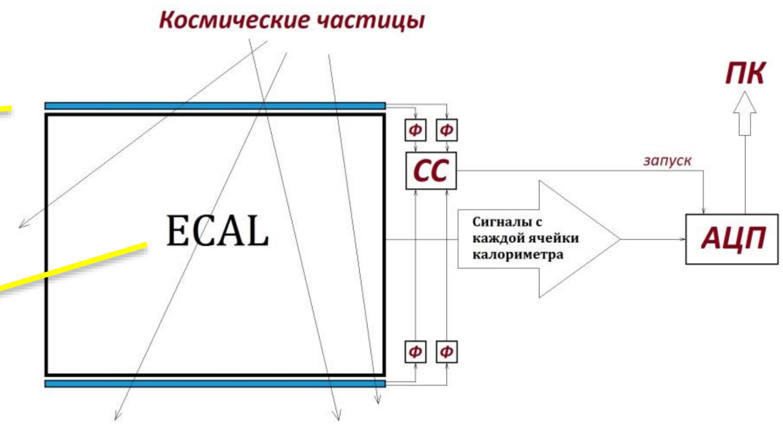
Location of Ecal in the magnet SP-41

New racks for ECAL



The test of the modules for second arm of ECAL





The modules was tested using monitors in three position. Each positions gives attenuated amplitude and allowed to calculate quality of the module.

The decay coefficients for tested modules.