# 桶部量能器软件进展

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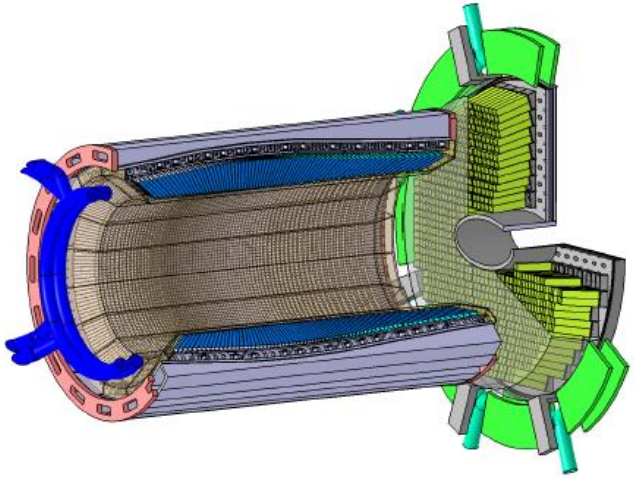


PANDA实验中方协调会
2018年12月17日

Institute of High Energy Physics
Chinese Academy of Sciences

# 报告内容

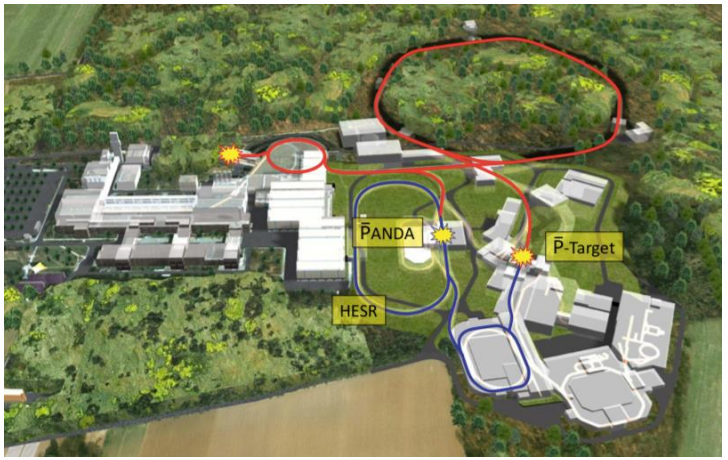
- **PANDA实验介绍**
- **工作进展**
  - 前端物质的构建
  - 更新PANDAROOT
- **总结和展望**

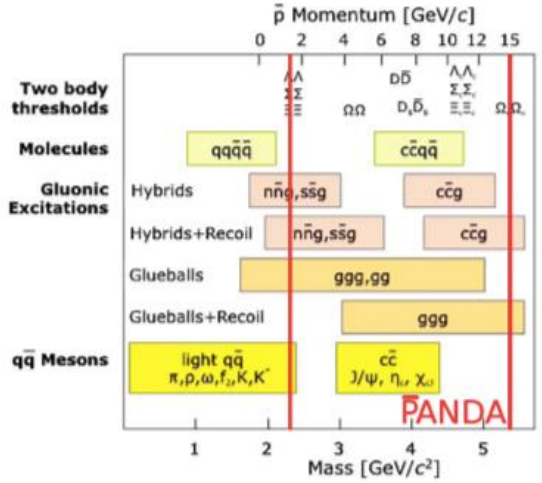
# The PANDA experiment

- **PANDA at FAIR**
  - Located at slow ramping synchrotron storage ring for internal target (HESR)
  - Cooled pbar beam

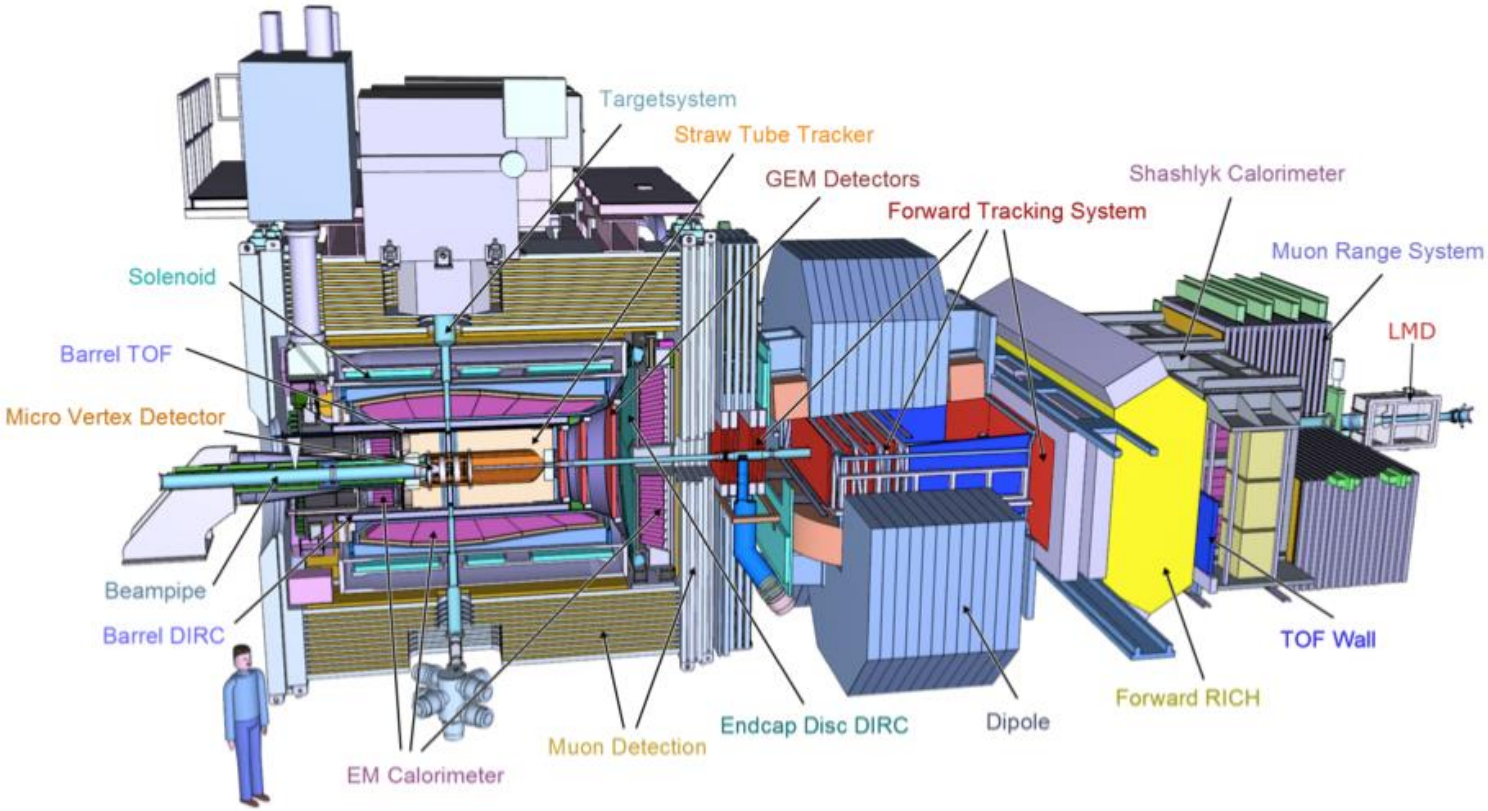
- **PANDA experiment**
  - ppbar annihilation, fixed hydrogen target
  - pbar momenta: 1.5-15 GeV/c

  - Strong interaction studies
    - Hadron spectroscopy
    - Proton structure
    - Mesons in nuclei
    - Hypernuclei
    - …

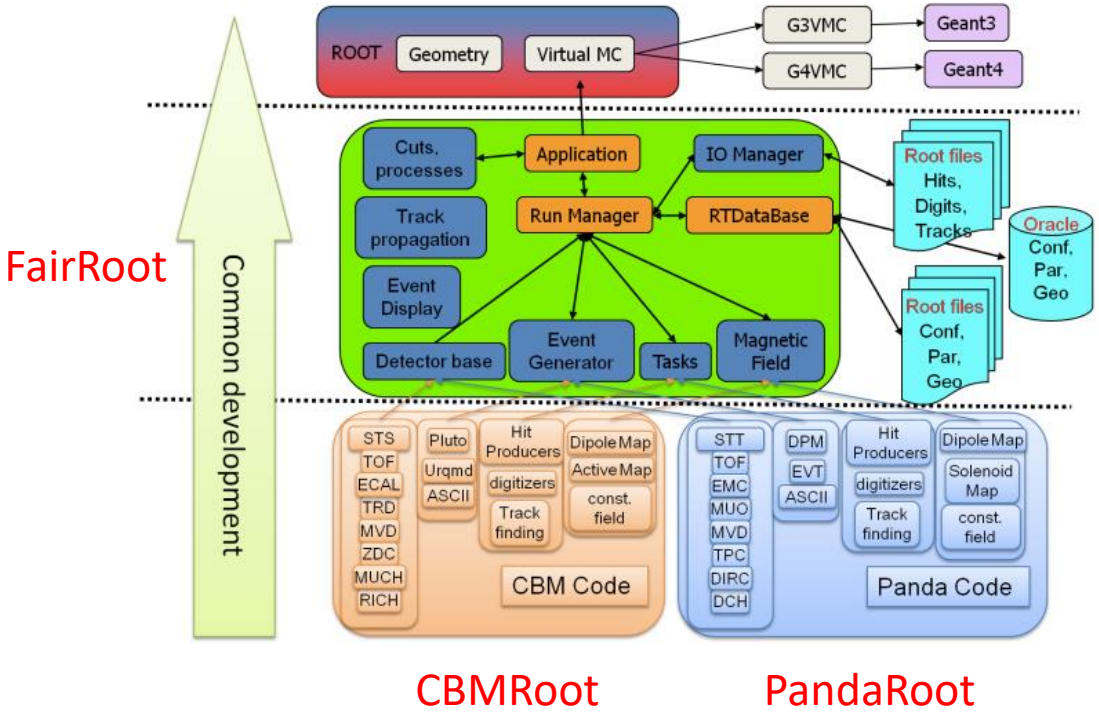


# The detectors

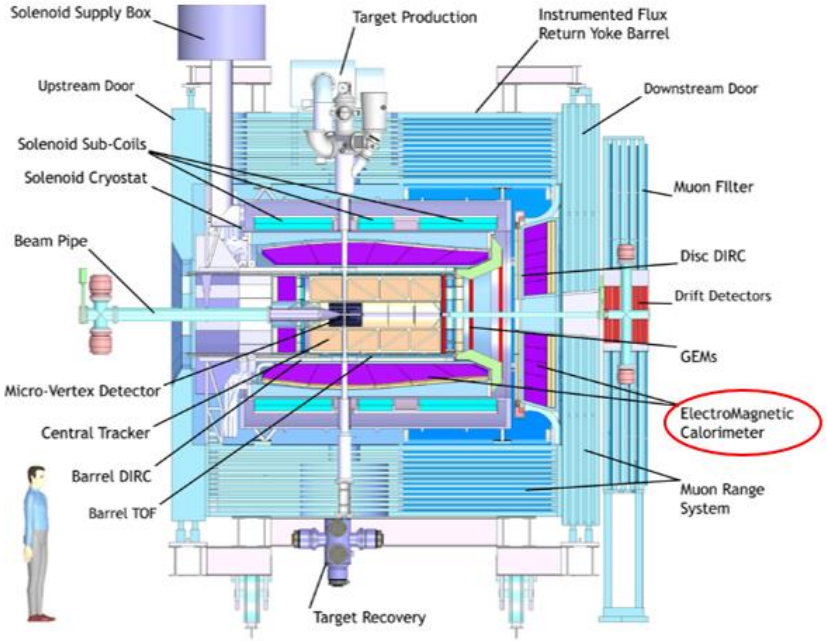


# The software framework




- ✓ Based on ROOT and Virtual MC
- ✓ FairRoot: manages the general infrastructure with simulation and tasks
- ✓ PandaRoot: the implementation of the PANDA detector simulation and reconstruction code inside the FairRoot framework

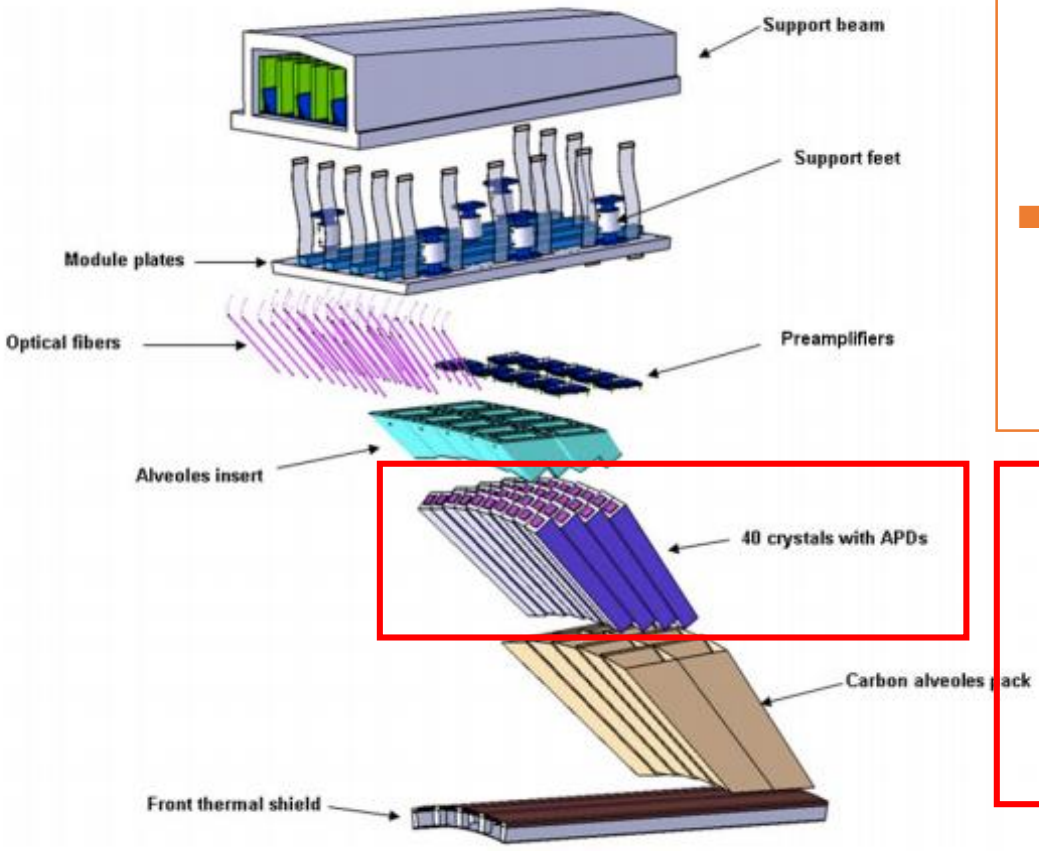
# The barrel EMC



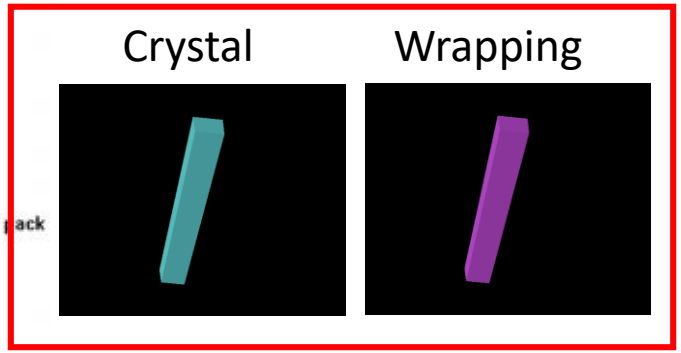

**Status of barrel EMC's geometry description**

- ✓ Last update: 2009 by Spataro
  - ✓ Only crystals
  - ✓ # of crystals, parameters of crystals are out of date
- ✓ Need to do
  - ✓ Update detailed geometry
  - ✓ Using ROOT geometry class

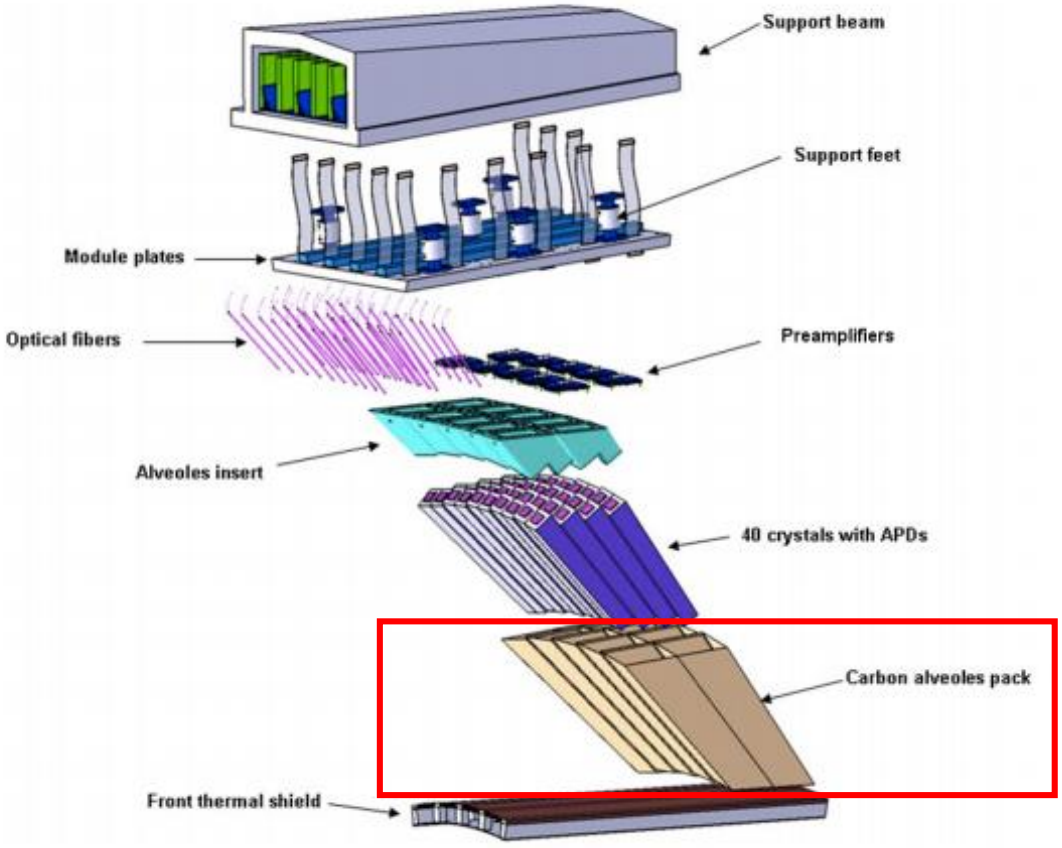
# Geometry updates



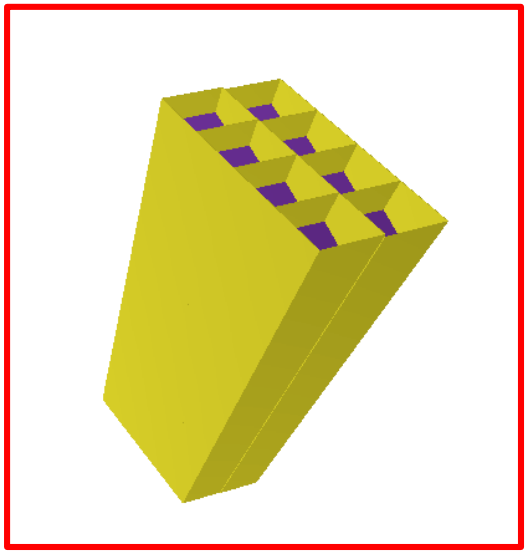

- The geometry updates were based on an old version of geometry in 2009 (only crystals).
- Until the last meeting, we have:
  - updated all crystals
  - newly added wrappings



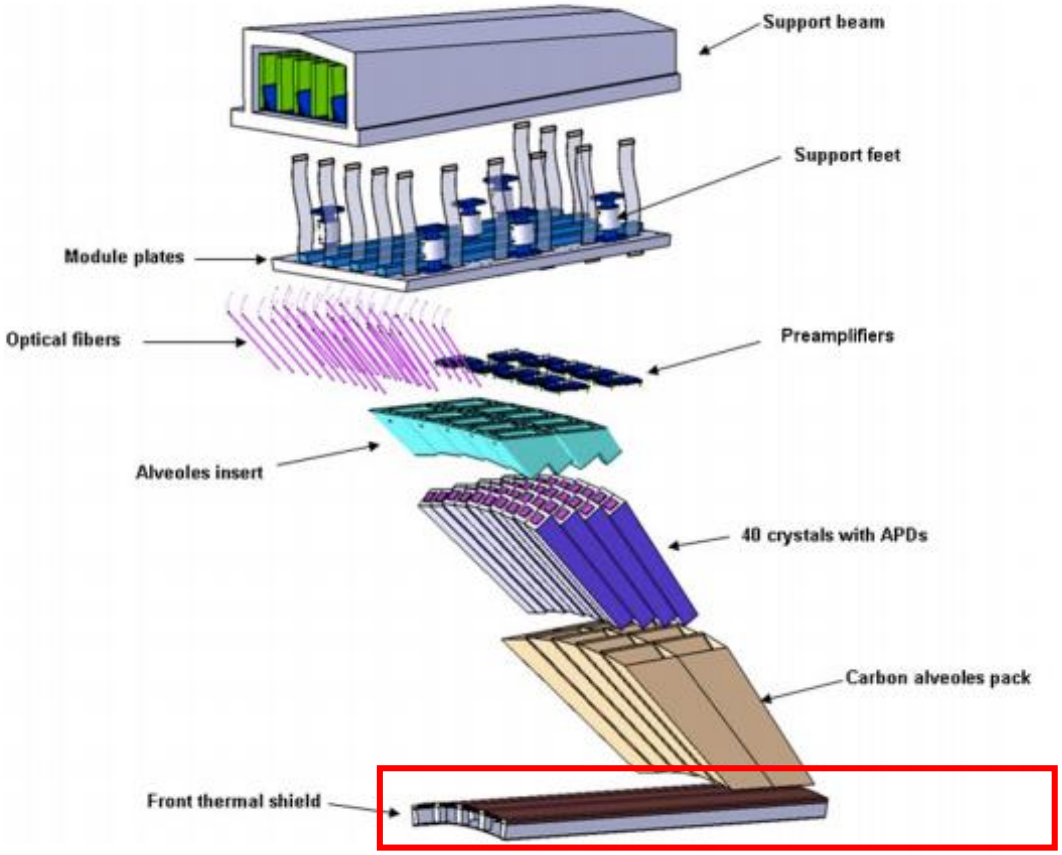
# Geometry updates




- We also have added:
  - Carbon alveoles

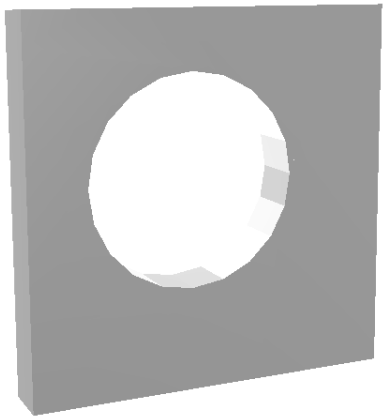


# Geometry updates

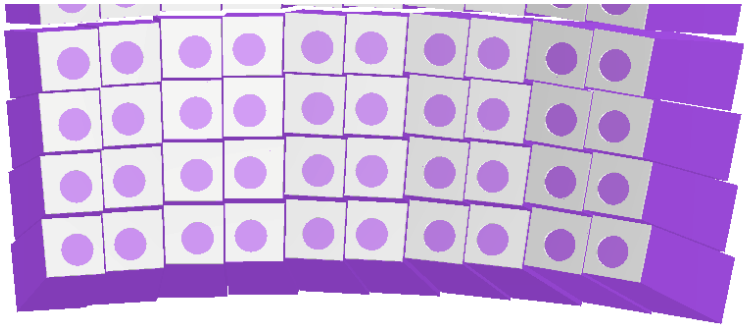


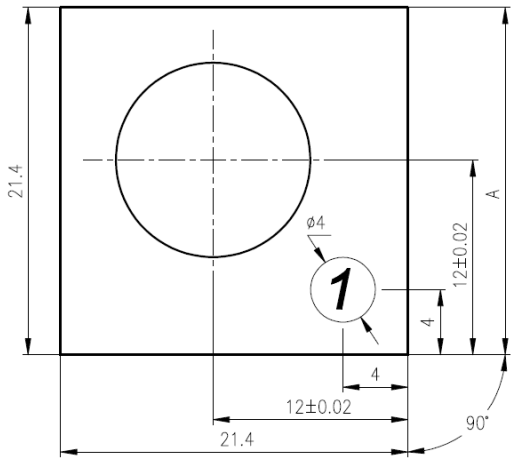

- We continue the geometry implementation for the front-end materials, including:
  - Front insert
  - Temperature insulation
  - Aluminum plate

# Front insert



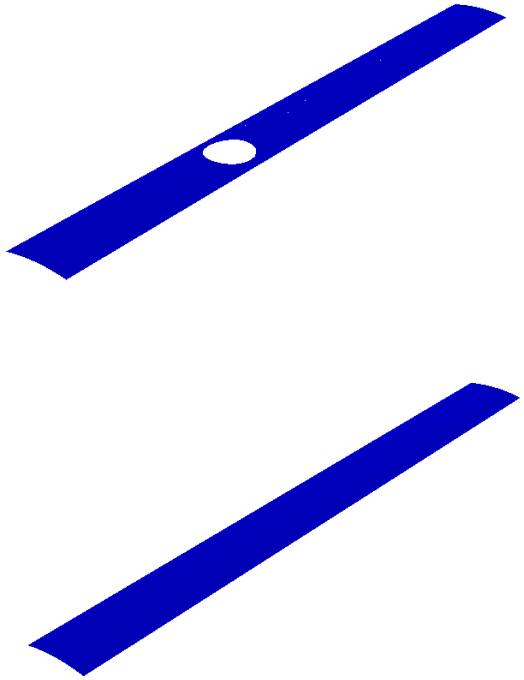
Front inserts are placed in front of the crystals





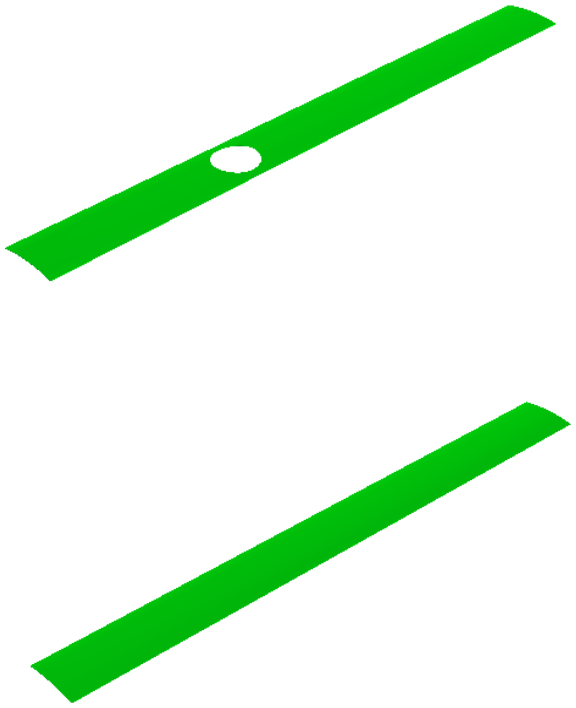

- ✓ Shape:
  - ✓ Cuboid with a hole
  - ✓ ~3 mm thickness in average
- ✓ Material: ABS plastic
  - ✓ Elements: C, H, N (molecule – 15:17:1)
  - ✓ Density: 1.07 g/cm$^3$

# Temperature insulation



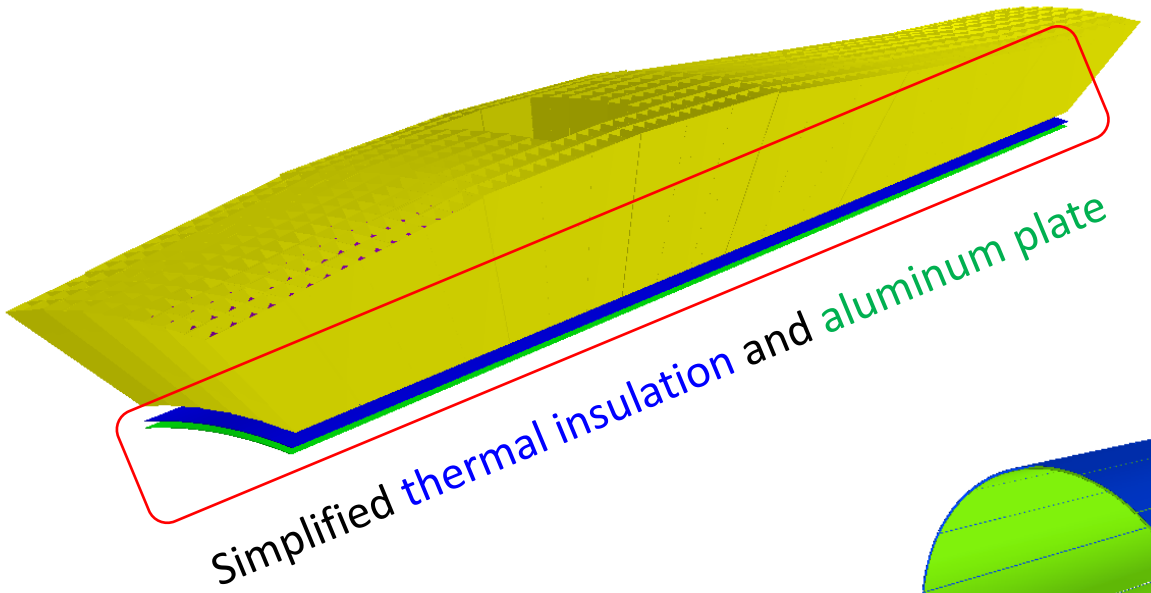
- ✓ Shape:
  - ✓ Tube segment
  - ✓ Thickness: 1 mm
- ✓ Material: vakuVIP Heat 360 (Polyurethane 聚亚安酯)
  - ✓ Elements: C, H, N, O (molecule – 25: 42: 2 : 6)
  - ✓ Density: 0.225 g/cm$^3$

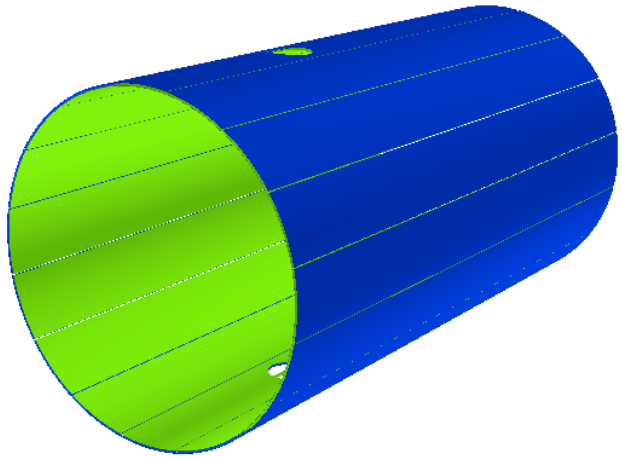
# Aluminum plate



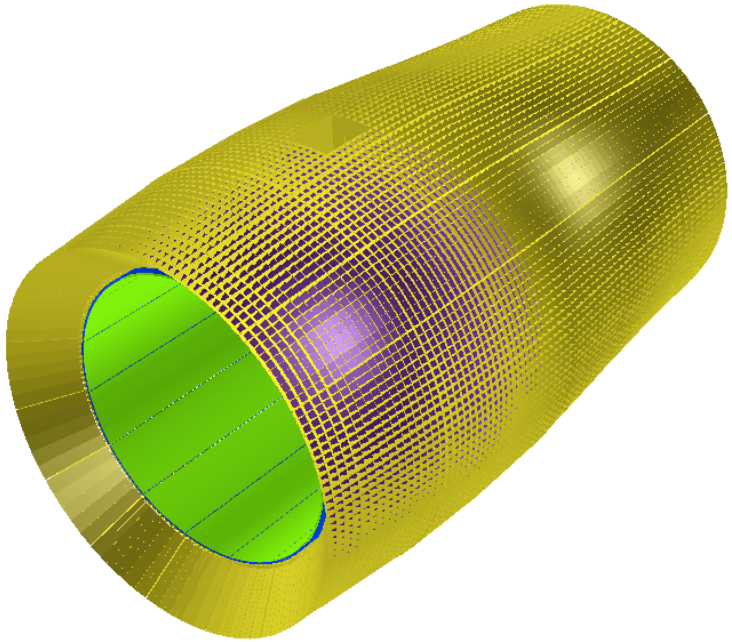
- ✓ Shape:
  - ✓ Tube segment
  - ✓ Thickness: 1 mm
- ✓ Material:
  - ✓ Element: aluminum
  - ✓ Density: 2.7 g/cm$^3$

# Simplified vacuum insulation panel

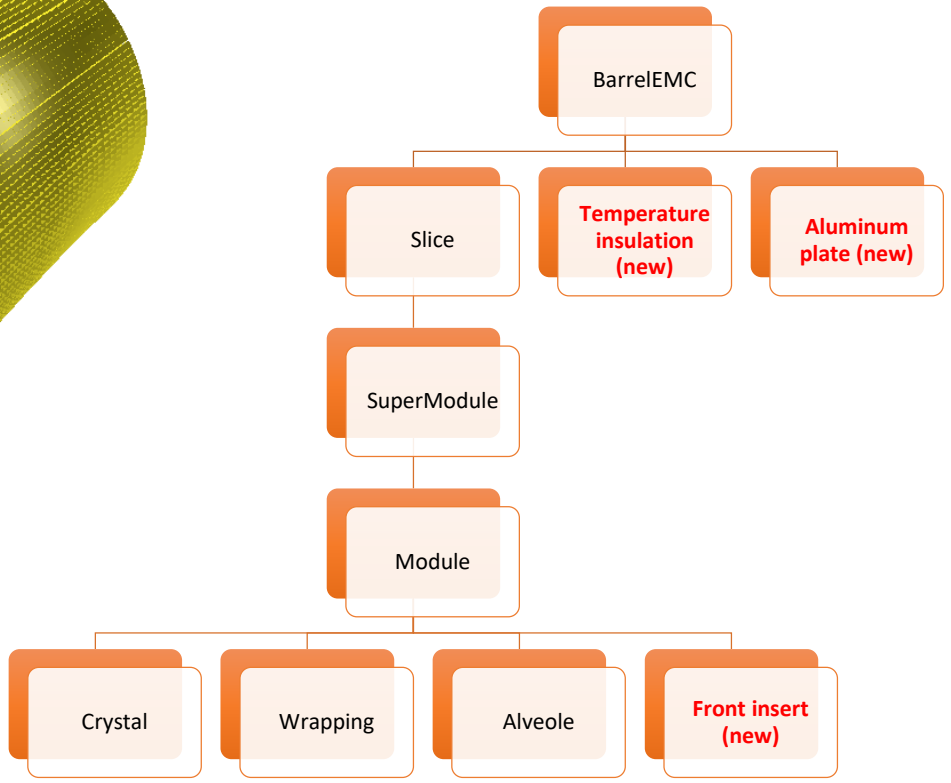


# The updated geometry



Volumes hierarchy

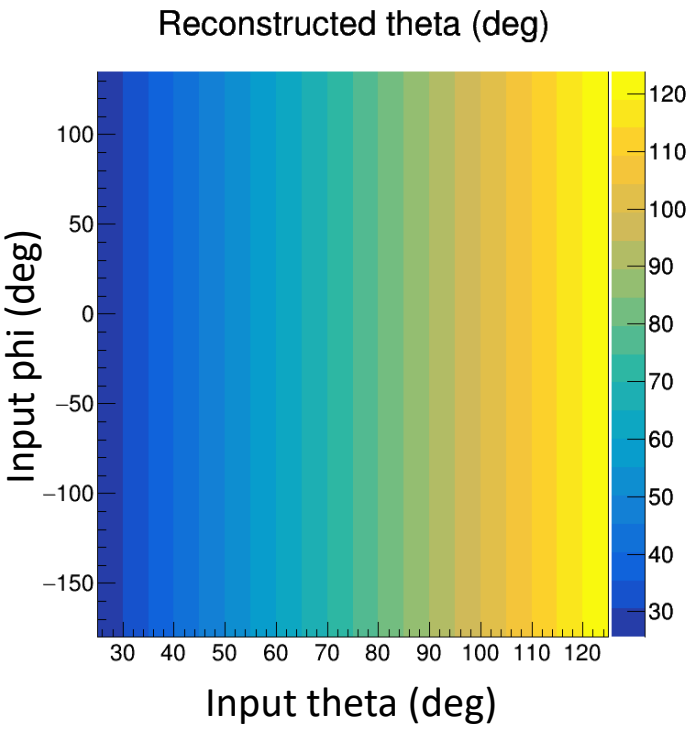


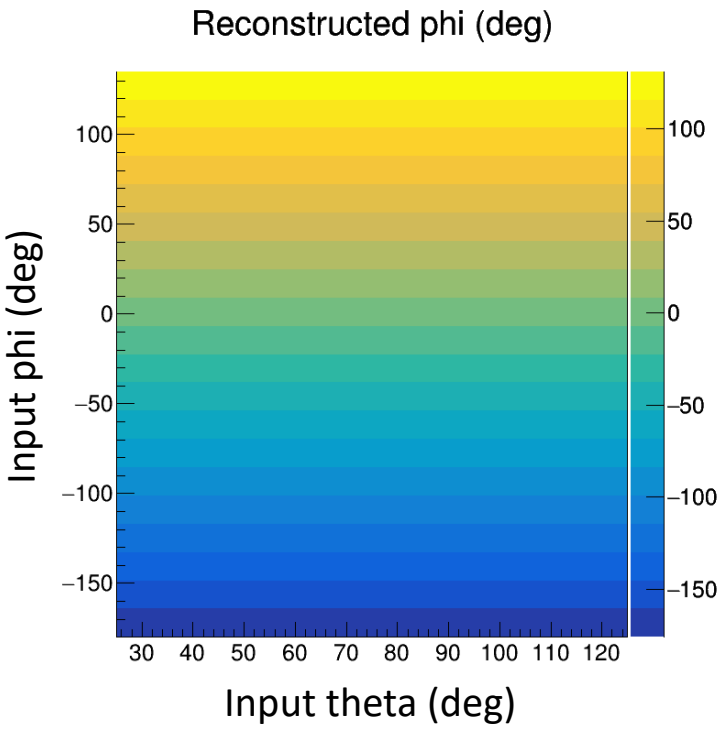
# Material summary

| Part | Material | Elements | Density ($g/cm^3$) |
|---|---|---|---|
| Crystal | PWO | Pb, W, O (molecule - 1:1:4) | 8.29 |
| Wrapping (new) | VM2000 | C, H (molecule - 2:4) | 0.9 |
| Alveole | Prepreg | C, H, Cl, O (frac. mass - 0.846:0.088:0.028:0.038) | 1.8 |
| Front insert (new) | ABS | C, H, N (molecule - 15:17:1) | 1.07 |
| Temperature insulation (new) | Polyurethane | C, H, N, O (molecule - 25: 42: 2 : 6) | 0.225 |
| Aluminum plate | Aluminum | Al | 2.7 |

# Check I – Photon position

- ✓ Generate 1 GeV photon with different input $\theta$s and $\phi$s, check the reconstructed directions.
- ✓ The plots show consistent input/output, which means the crystals' indices are correctly put in simulation



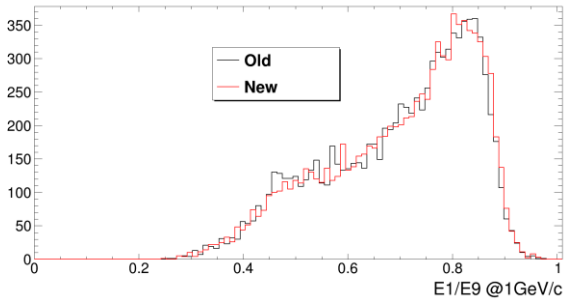



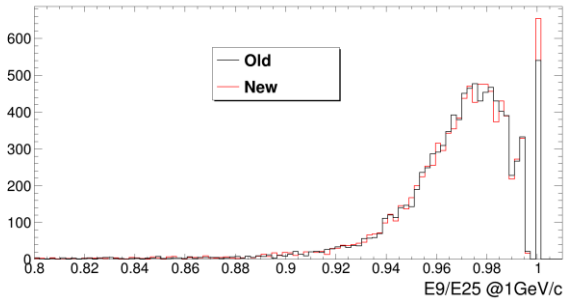
# Check II – Photon energy/moment

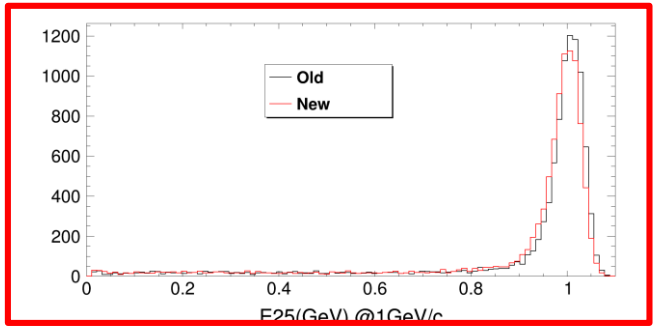
- **Some variables**
  - E1, E9, E25:
    - the energy deposited in the central crystal, the 3*3 crystal array, 5*5 crystal array containing the central crystal and the first innermost ring
  - Lateral moment:
    - $\frac{\Sigma_{i=3}^{n} E_i r_i^2}{\Sigma_{i=3}^{n} E_i r_i^2 + E_1 r_0^2 + E_2 r_0^2}$,
    - where n is the number of crystals associated to the shower, $E_i$ is the deposited energy in the i-th crystal with $E_1 \geq E_2 \geq \cdots \geq E_n$, $r_i$ is the lateral distance between the central and the i-th crystal, and $r_0$ is the average distance between two crystals.
  - Zernike moments $Z_{20}$, $Z_{53}$:
    - A set of Zernike moments which describe the energy distribution within a cluster by radial and angular dependent polynomials

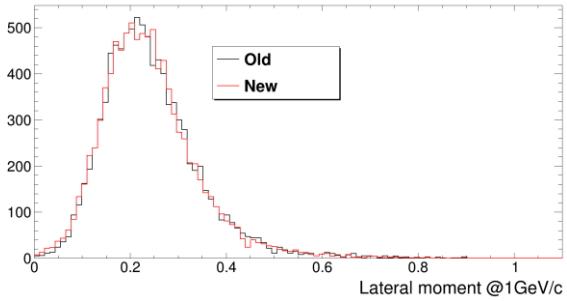
# Check II – Photon energy/moment

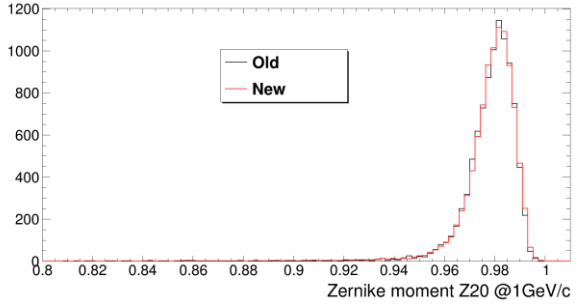
- ✓ Compare energy/moment distributions between the new and old geometries for 1 GeV photon
- ✓ Most distributions are similar, except for the E25. Mean value of E25 in the new geometry is slightly smaller than the old one. This is reasonable as in the new geometry more materials are imposed.

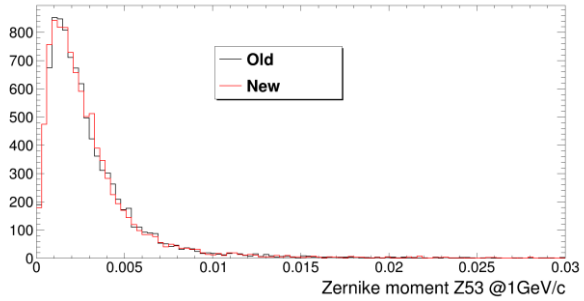


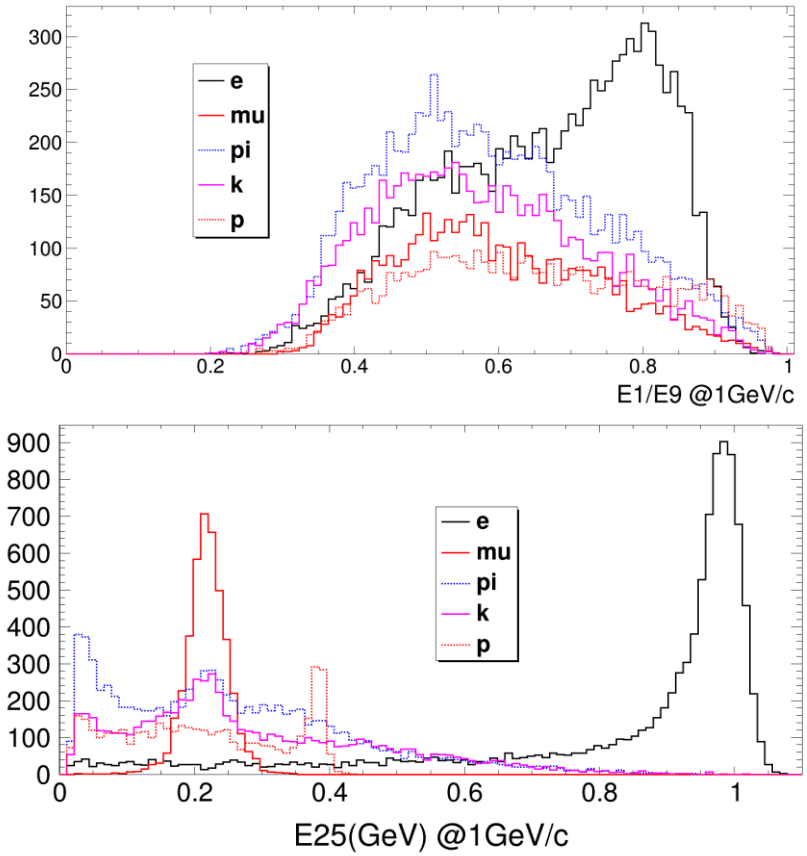



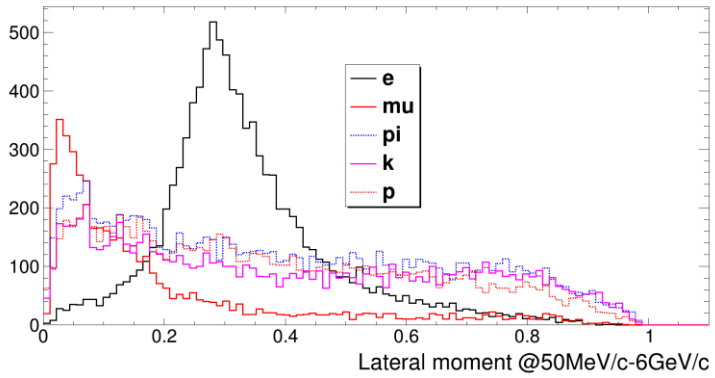



# Check III – Charged particles

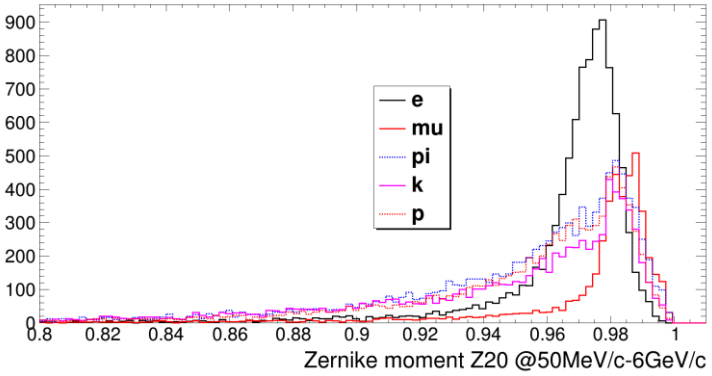


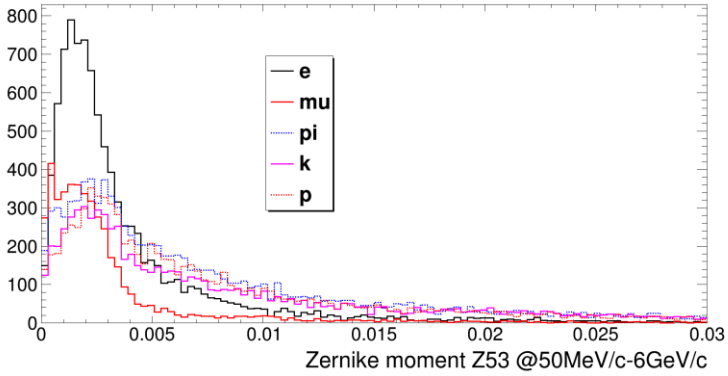

- ✓ Besides photon detection, EMC is also a powerful detector for electron identification.
- ✓ Generate e/mu/pi/K/p @ 1 GeV
- ✓ If we look at E25, for example, electrons can be well separated to other particles.

# Check III – Charged particles




- ✓ Generate e/mu/pi/K/p within the momentum range of 0.05 – 6 GeV
- ✓ All distributions are reasonable



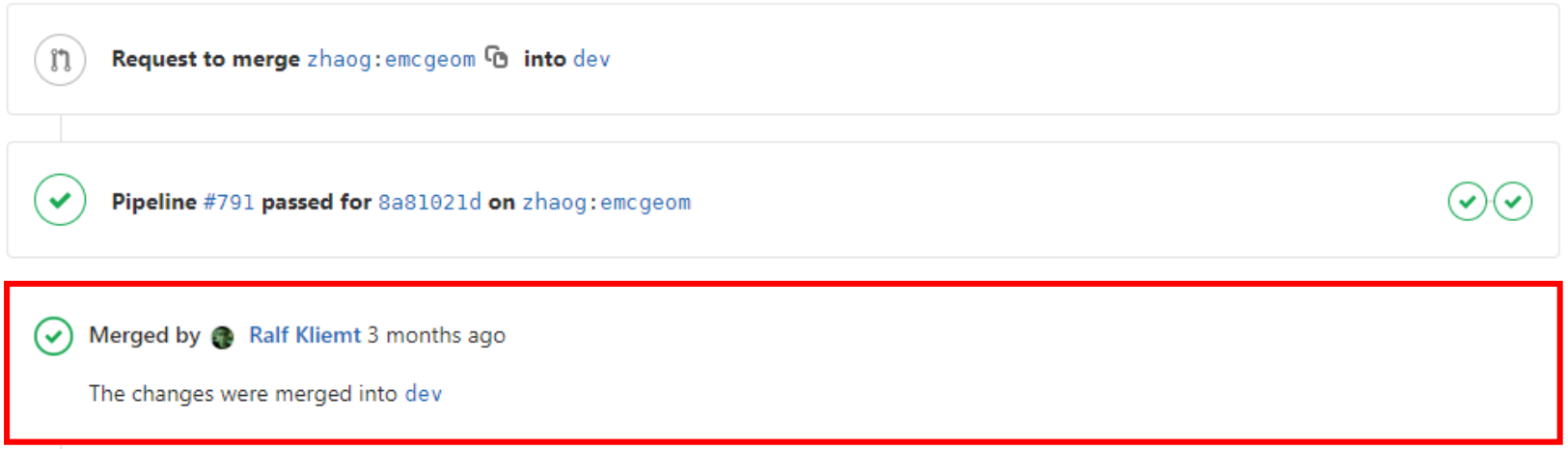
# Code update summary

- PndEmc: Update the logic to handle the new ROOT file
  - SetGeometryVersion()
  - ConstructRootGeometry()
  - ProcessHits()
- PndEmcMapper: Update the map of detector ID to tci (PndEmcTwoCoordIndex)
  - New class PndEmcMapperGeo12Root
- PndEmcStructure: Update the map of tci to xtal (PndEmcXtal)
  - Crystal_name_analysis()

# Merge request #91

## Update the barrel EMC geometry

The barrel EMC geometry is updated. We have updated all the crystals and the front-end materials. The new geometry is set to be the default version in PndEmc.cxx, which means users will use the new geometry if he/she runs SetGeometryVersion(1) in the simulation macro. Three materials (VM 2000, ABS and Polyurethane) are added in pnd_medio.geo.




Merged to the main dev branch

# Merge request #100

## Remove PndEmcMapper initializations

Remove the unneeded initialization of the PndEmcMapper in PndEmcApdHitProducer.cxx and PndEmcWaveformToDigi.cxx

**Request to merge** zhaog:emcgeom2 **into** dev

**Pipeline** #866 **passed for** 106555c9 **on** zhaog:emcgeom2

Merged by Ralf Kliemt 2 months ago

The changes were merged into dev

You can remove source branch now Remove Source Branch

Merged to the main dev branch

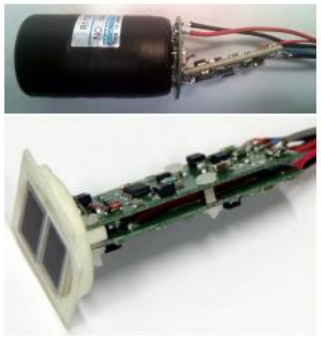
# Summary for the barrel geometry update

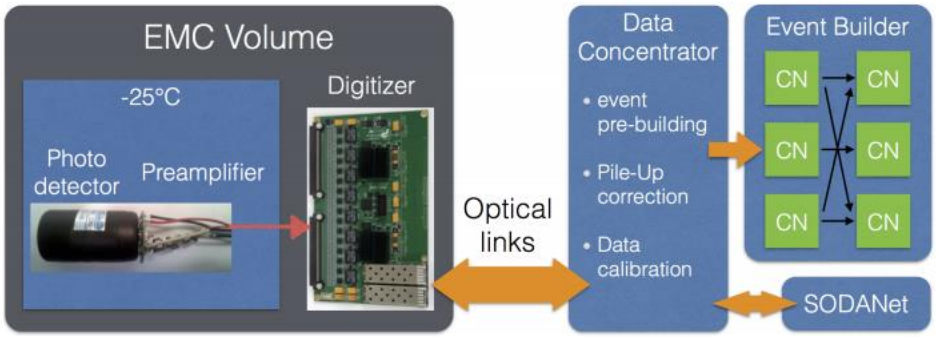
- **Have Updated the front-end geometries and materials for the barrel EMC**
- **Have looked at some of the position/energy distributions with the updated geometry. More detailed checks/studies will be done.**
- **Our branch has already been merged to the main developing branch and will be published in the next release**

# Outlook for the digitization

- **EMC readout systems**
  - Barrel and backward endcap:
    two APDs per crystal, readout w/ APFEL ASIC (GSI)
  - Forward endcap: two APDs or one VPTT per crystal

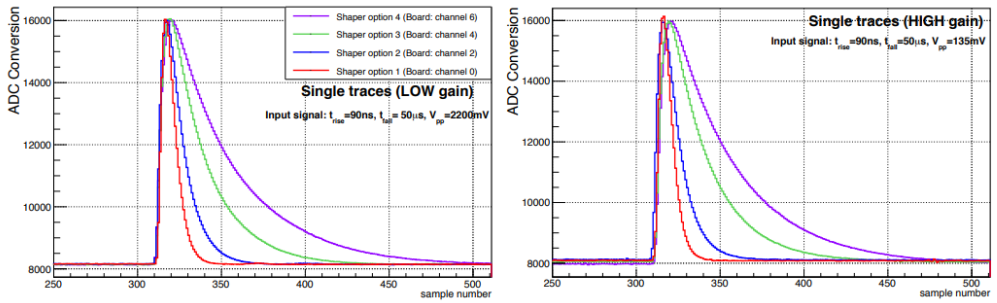
  → All photodetectors read out w/ low-noise preamplifiers (U Basel)
  - Different preamplifier gains to accommodate for differences in photodetector gains:
    - APDs: 0.1 V/pC
    - VPTTs: 0.7...0.89 V/pC

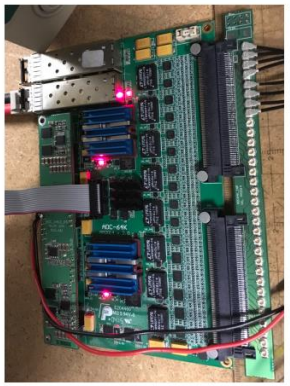




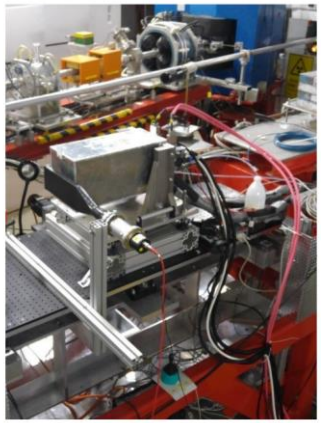
# Experimental samples

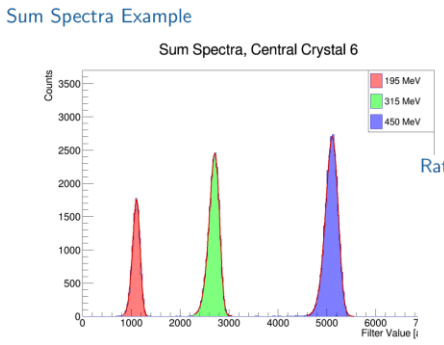
- **SADC and shaper tests for the forward endcap EMC (Bochum U)**

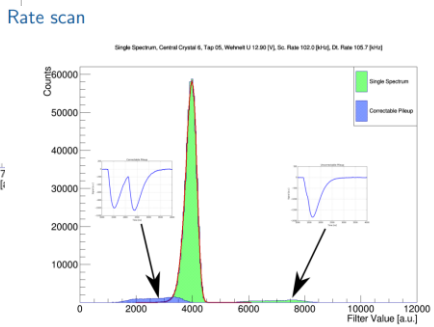


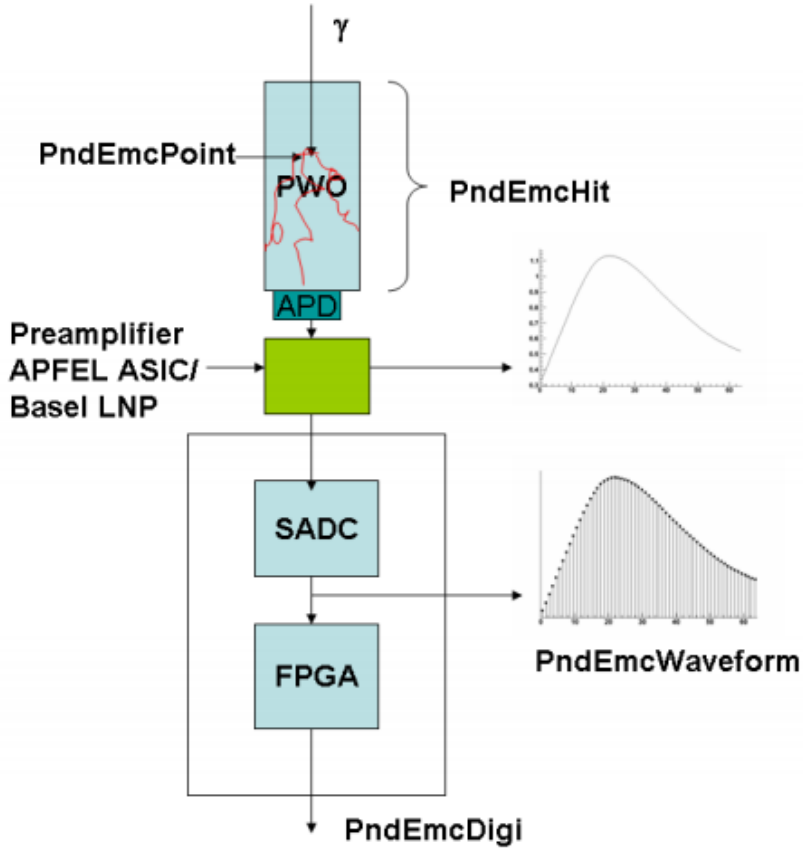
- **Digital signal processing for the APFEL ASIC (Mainz U)**





# Digitization in pandaroot




Part of digitization parameters

[PndEmcDigiPar]
EnergyHitThreshold:Double_t 0.000001
NBits:Int_t 16
DetectedPhotonsPerMeV:Double_t 500
DetectedPhotonsPerMeV_PMT:Double_t 21
SensitiveAreaAPD:Double_t 200
SensitiveAreaVPT:Double_t 200
EmcClusterPosMethod:Text_t lilo
QuantumEfficiencyAPD:Double_t 0.7
QuantumEfficiencyVPT:Double_t 0.22
QuantumEfficiencyPMT:Double_t 0.24
ExcessNoiseFactorAPD:Double_t 1.7
ExcessNoiseFactorPMT:Double_t 1.3
ExcessNoiseFactorVPT:Double_t 2.2
Incoherent_elec_noise_width_GeV_APD:Double_t 1.5e-3
experiment
Incoherent_elec_noise_width_GeV_VPT:Double_t 1.5e-3
EnergyRange:Double_t 15
EnergyRangeBW:Double_t 3
FirstSamplePhase:Double_t 0
Number_of_samples_in_waveform:Int_t 120
Number_of_samples_in_waveform_pmt:Int_t 60
Number_of_samples_in_waveform_fwd:Int_t 60
ASIC_Shaping_int_time:Double_t 70e-9
PMT_Shaping_int_time:Double_t 5e-9
PMT_Shaping_diff_time:Double_t 20e-9

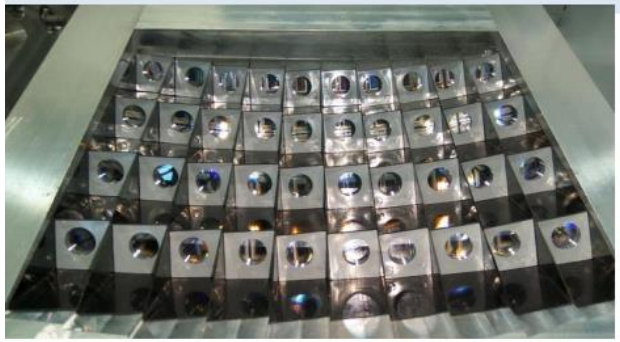
# Plan for digitization

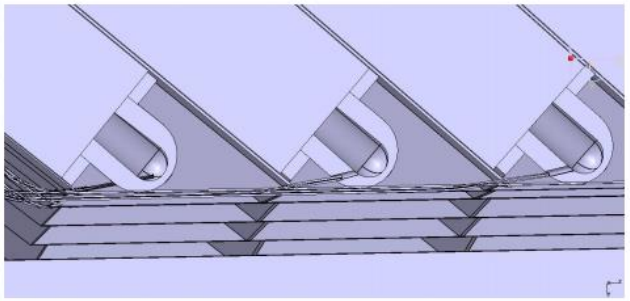
- To update the digitization according to the latest electronics design in simulation
- For now, we are reading code and documents in order to understand the digitization in detail
- We have also started to communicate with the electronics experts. We plan to ask for the hardware performance parameters and experimental samples.

# Backup

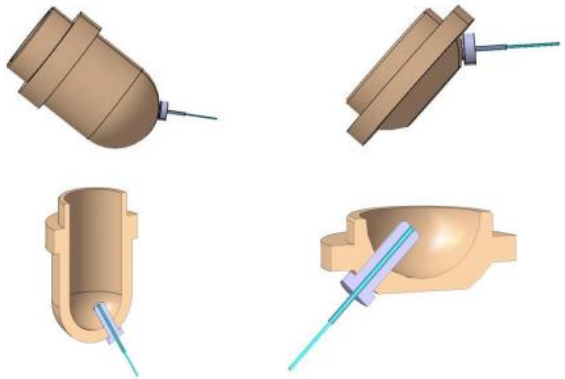
## Light Pulser Fiber Coupling

14





- Different length for different positions
- Prototypes will be ordered next week
- Inside coating with high reflective material
- Different coatings will be tested:
  - Titanium dioxide
  - Barium sulfate
  - Aluminium
  - ….



06.12.2016 PANDA collaboration meeting – Darmstadt -Markus Moritz- Justus-Liebig-Universität Gießen

# Some variable definitions

The neural network inputs are the EMC cluster energy and the following six shower-shape variables:

- The lateral moment LAT of the shower energy deposition [14] defined as LAT $= \sum_{i=3}^{n} E_i r_i^2 / (E_1 r_0^2 + E_2 r_0^2 + \sum_{i=3}^{n} E_i r_i^2)$ where the $n$ crystals in the EMC cluster are ranked in order of deposited energy ($E_i$) , $r_0 = 5$ cm is the average distance between crystal centers, and $r_i$ is the radial distance of crystal $i$ from the cluster center.

- The second radial moment of the shower energy deposition, defined as $\sum_i E_i r_i^2$ where $r_i$ is the radial distance of crystal $i$ from the cluster center.

- The energy sum of a $3 \times 3$ block of crystals, centered on the single crystal with the most energy, divided by the larger $5 \times 5$ block, also centered in the same way.

- The energy of the most energetic crystal in the cluster divided by the energy sum of the $3 \times 3$ crystal block with the most energetic crystal in the center.

- The Zernike moments [15] $A_{2,0}$ and $A_{4,2}$ defined below.

The Zernike moment $A_{n,m}$ is defined as

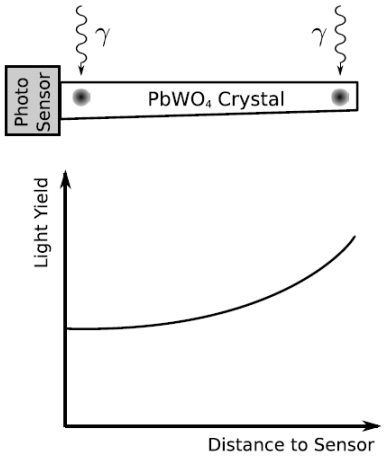
$$A_{n,m} = \left| \sum_i \frac{E_i}{E_{\text{tot}}} f_{n,m}(r_i/R_0)\, e^{im\phi_i} \right|$$

with

$$f_{2,0}(x) = 2x^2 - 1 \qquad \text{and} \qquad f_{4,2}(x) = 4x^4 - 3x^2$$

where $r_i$ and $\phi_i$ are the radial and angular separation of crystal $i$ with respect to the cluster center, $E_{\text{tot}}$ is the total cluster energy, and $R_0$ is a cutoff radius of 15 cm.

# Non-uniformity of light collection




For tapered parallelepipedal crystals, light yield at the rear end sensor distributed non-uniform due to the interplay of absorption and focusing effect.

From Bremer Daniel's thesis

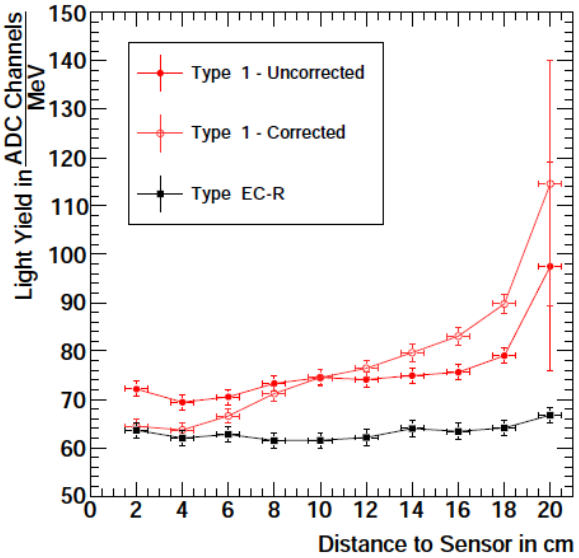
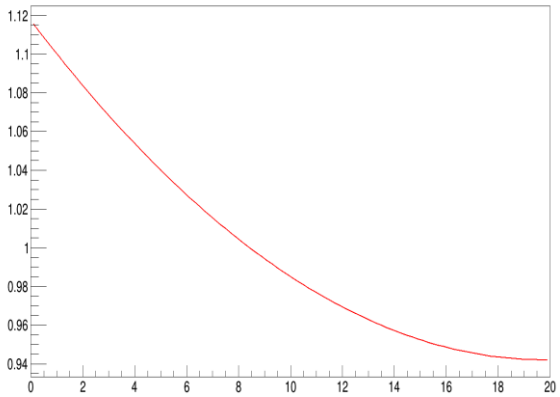



Figure 2.33: Position dependent response to minimum ionising cosmic muons at −25 °C for PWO-II crystals in type 1 and EC-R geometry. For the tapered shape, additionally the LY corrected for the most probable MIP energy deposition (see Tab. 1.3) for the corresponding pathlength $e(z)$ is shown.

# Non-uniformity of light collection (II)

Non-uniform function




Distance to front end (cm)

Non-uniform function in pandaroot for a typical crystal:

$$1.117356 + x \times (-0.01767657 + 4.456127 \times 10^{-4} x)$$

- ✓ By enabling the non-uniformity correction, the reconstructed energy becomes larger
- ✓ Need to further study the reconstruction/calibration