Overview of the calorimetry performance of ALICE at the LHC

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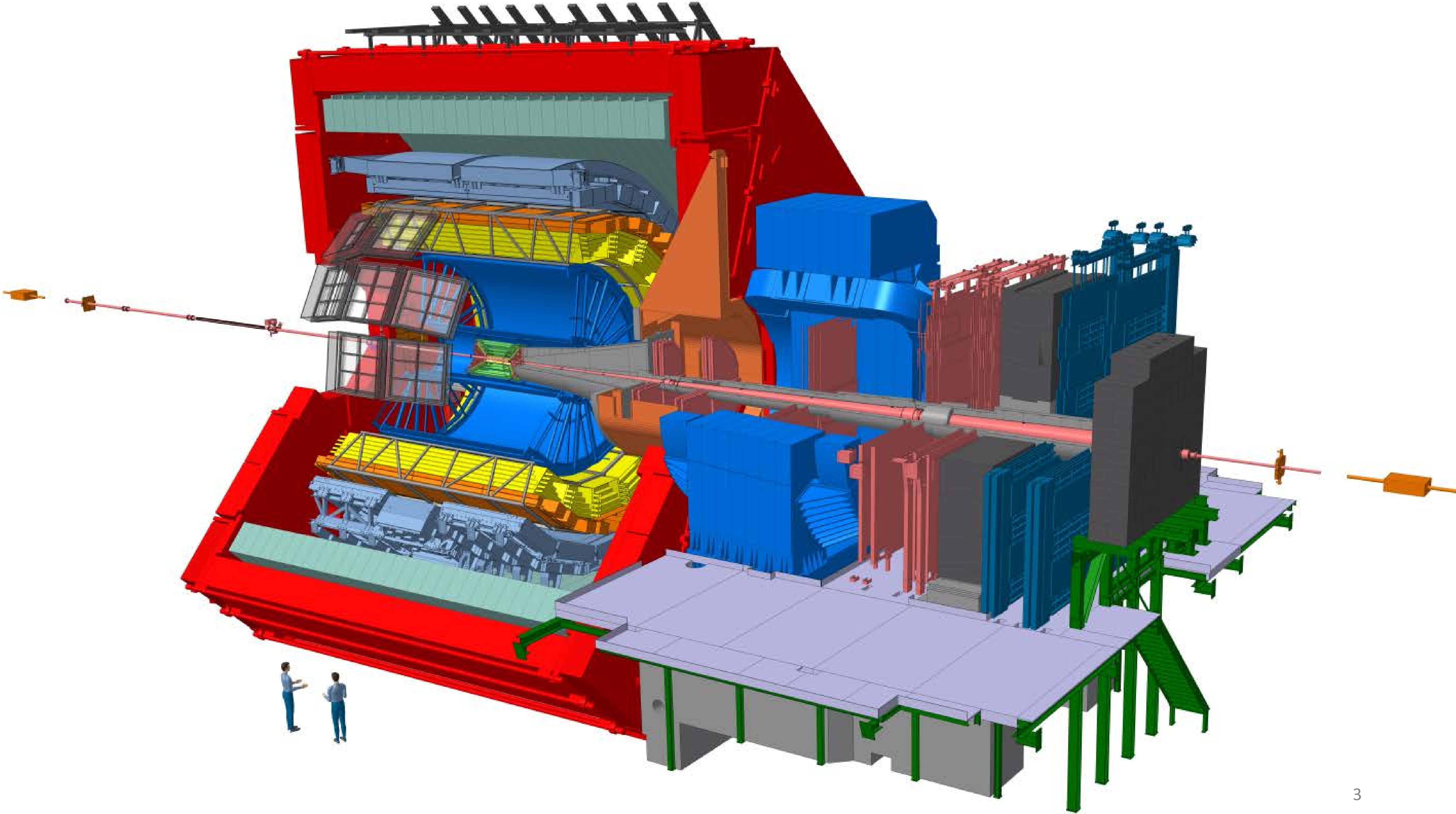
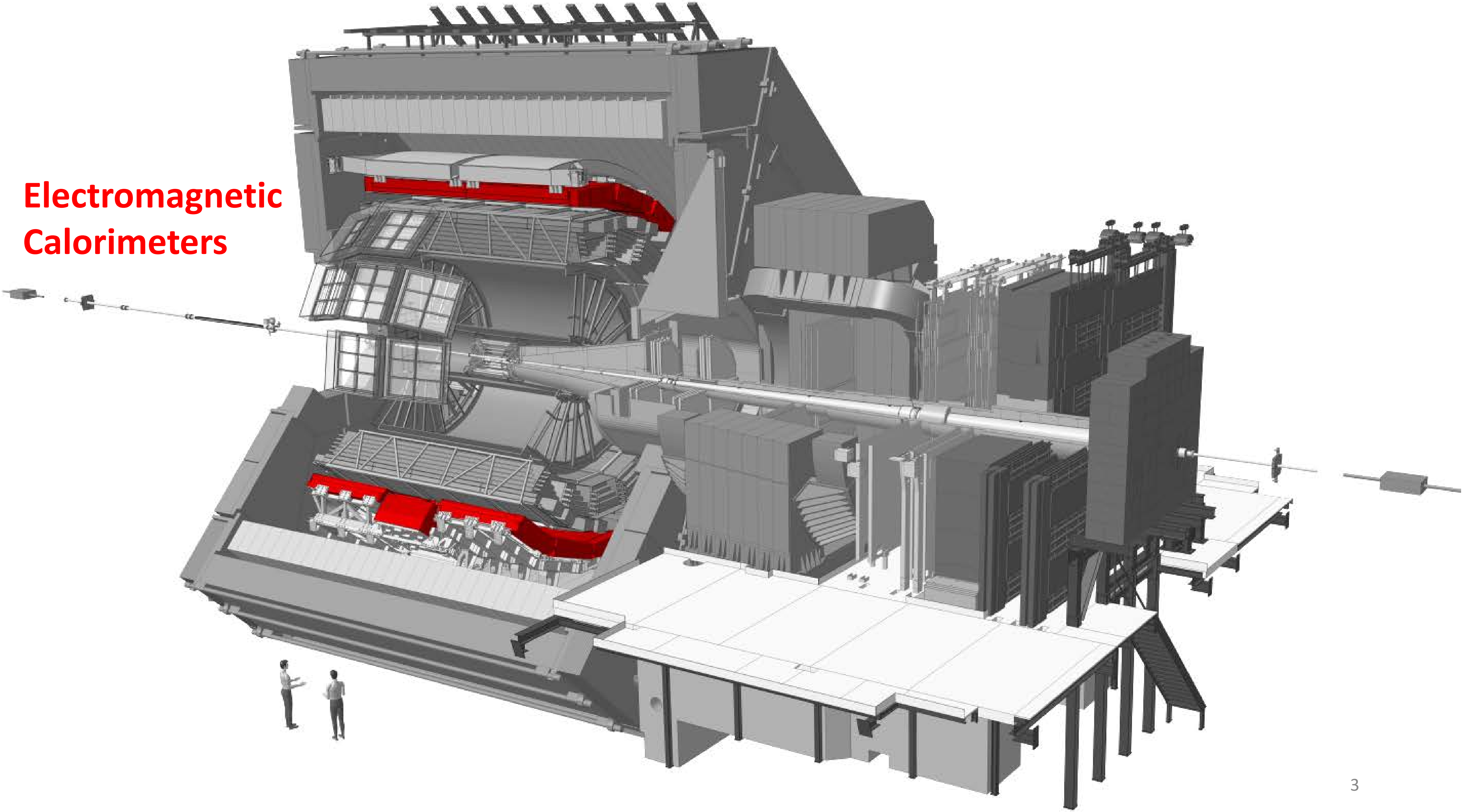
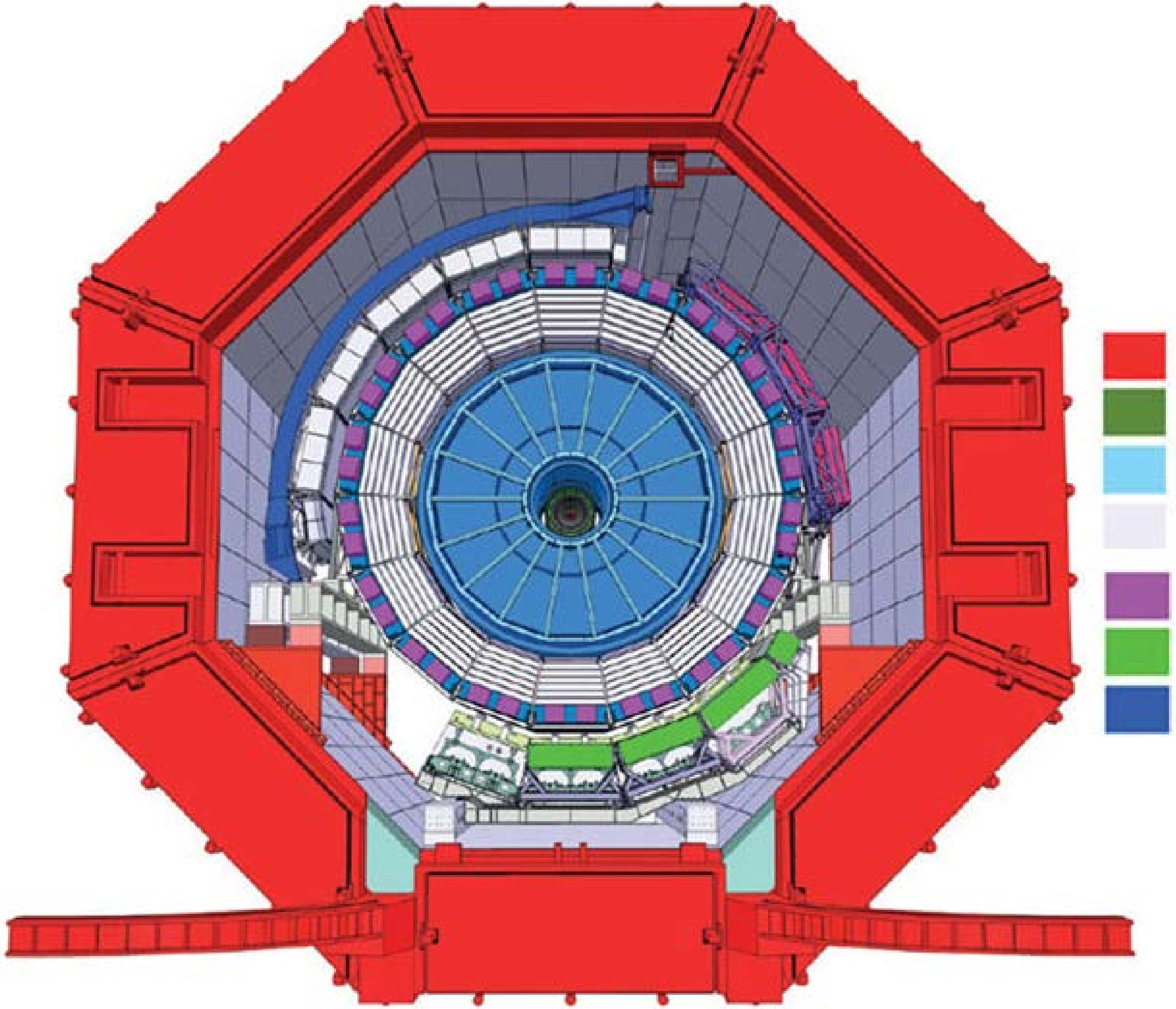
18Th International Conference on Calorimetry in Particle Physics, Eugene, Oregon



Electromagnetic Calorimeters





$B = 0.5\ T$

🟥 solenoid magnet (surrounds)

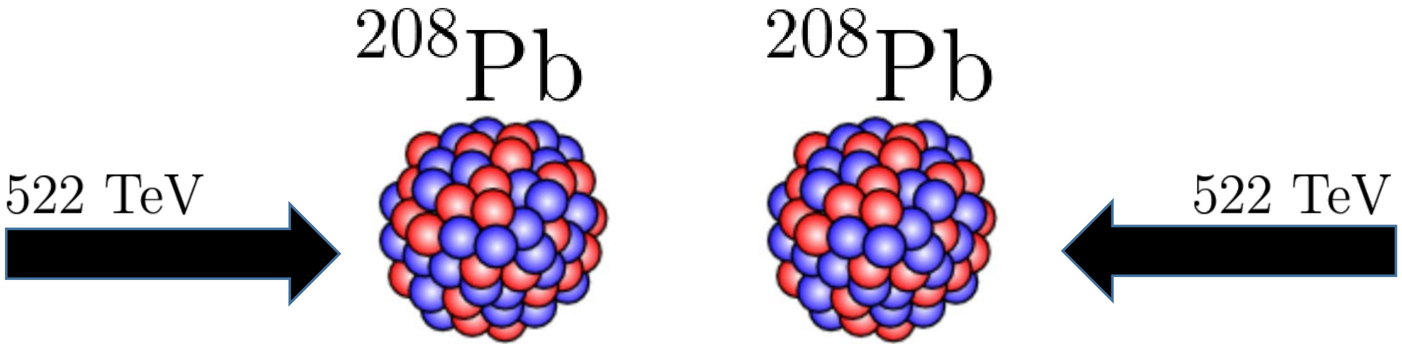
🟩 ITS (small ring, centre)
🟦 TPC (“spoked wheel”)
tracking

⬜ TRD (“stripes”)
🟪 TOF
Particle ID

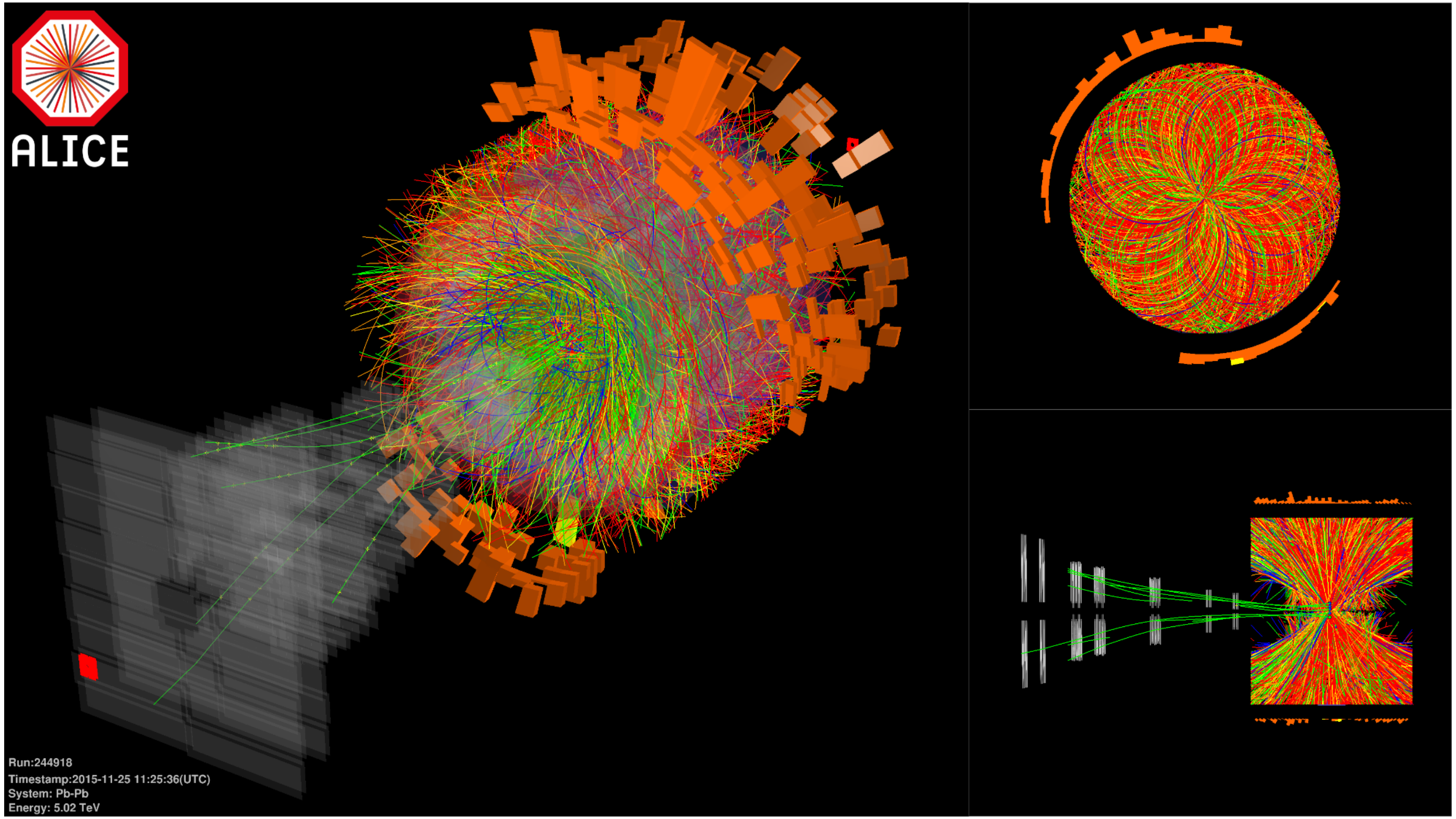
🟩 DCAL
🟦 EMCAL

EM Calorimeters

EMCAL installed in 2011
DCAL installed in 2015

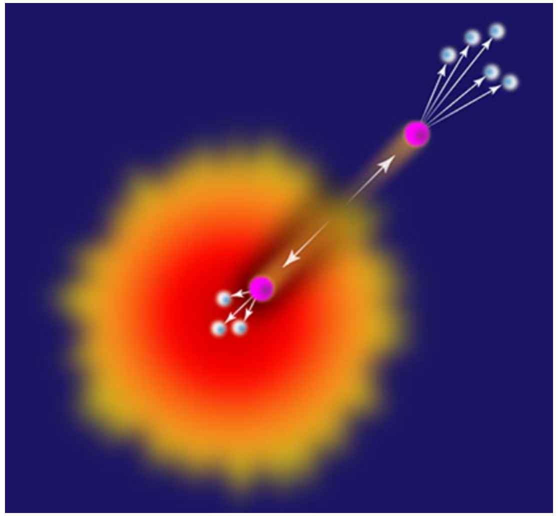


Average CM energy of pairs of colliding nucleons = 5.02 TeV

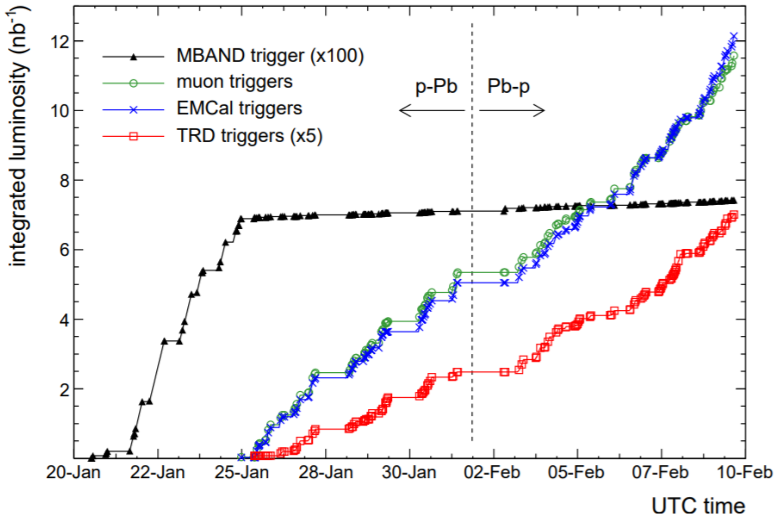


Why calorimeters in ALICE?

- Jets, photons and electrons (c and b) are prime “probes” to study the quark-gluon plasma

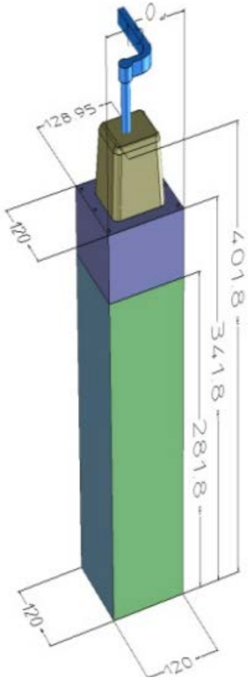


- Calorimeter are used for triggering and to measure these probes.
  (main program of ALICE focuses on minimum bias data)

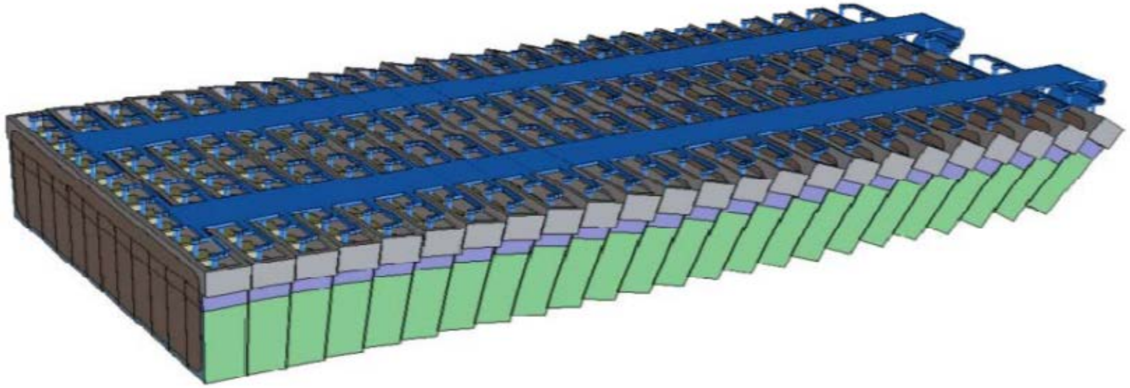


EMCAL,
Pb/Sc sampling calorimeter
Shashlik layout

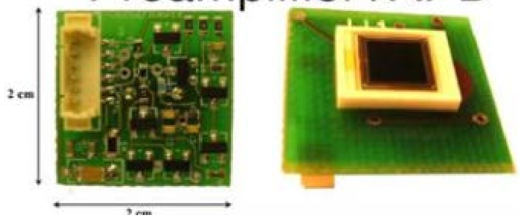
Module (2x2 towers)

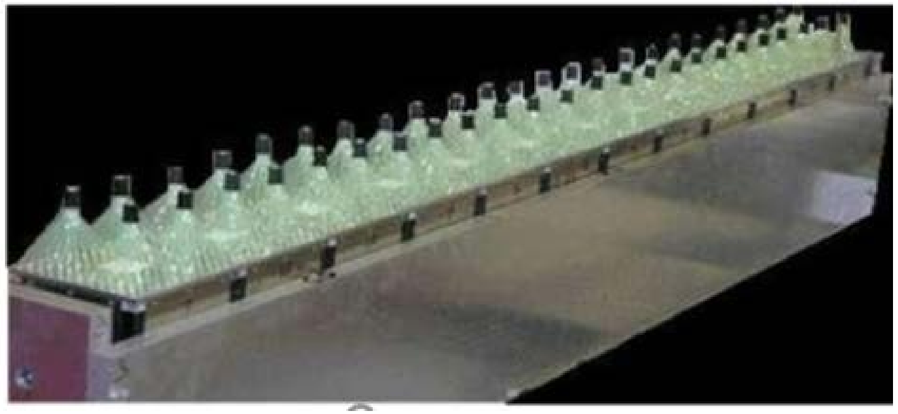


Supermodule



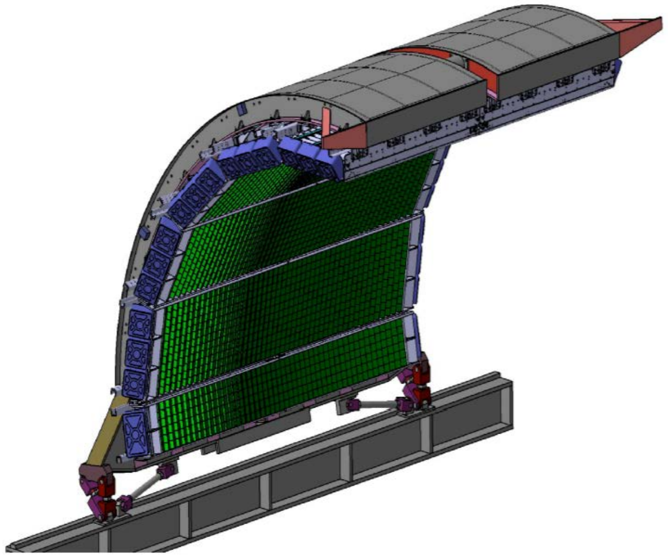
Preamplifier+APD

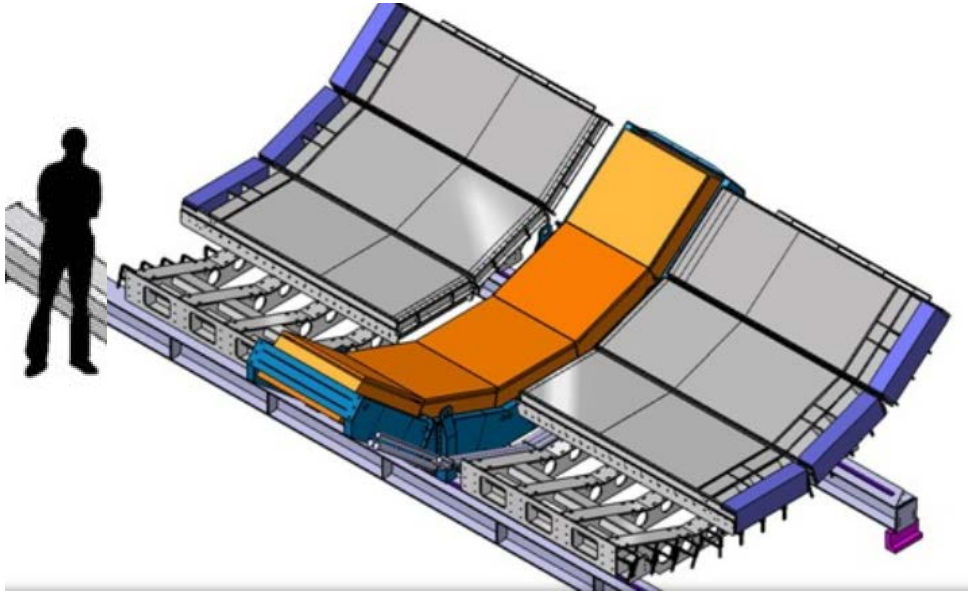




- 12 supermodules
  - 24 strips in η
  - 12 (or 6) modules in φ
- 12672 elementary sensors (towers)
  - 77 alternating layers of
    - 1.44 mm Pb (1% Sb)
    - 1.76 mm polystirene scintillator
  - $\Delta\eta \times \Delta\phi = 0.014 \times 0.014$

Geometry





EMCal Coverage:

$|\eta| < 0.7$
$80° < \varphi < 187°$

DCal Coverage:

$0.22 < |\eta| < 0.7$
$260° < \varphi < 320°$
&
$|\eta| < 0.7$
$320° < \varphi < 327°$

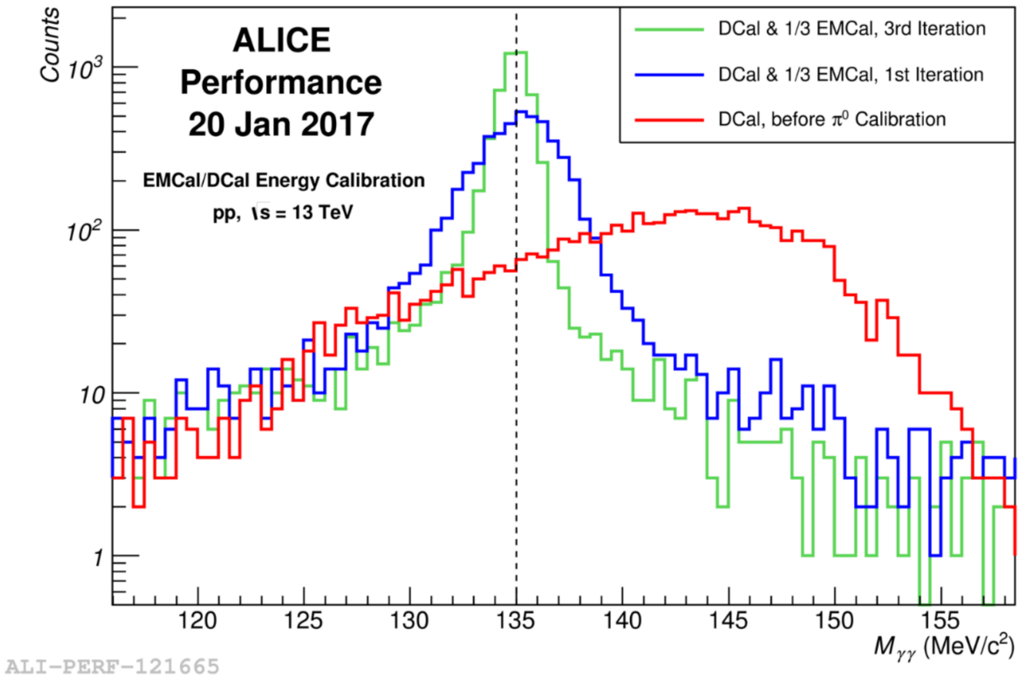
*EMCAL and DCAL technology is the same

Resolution

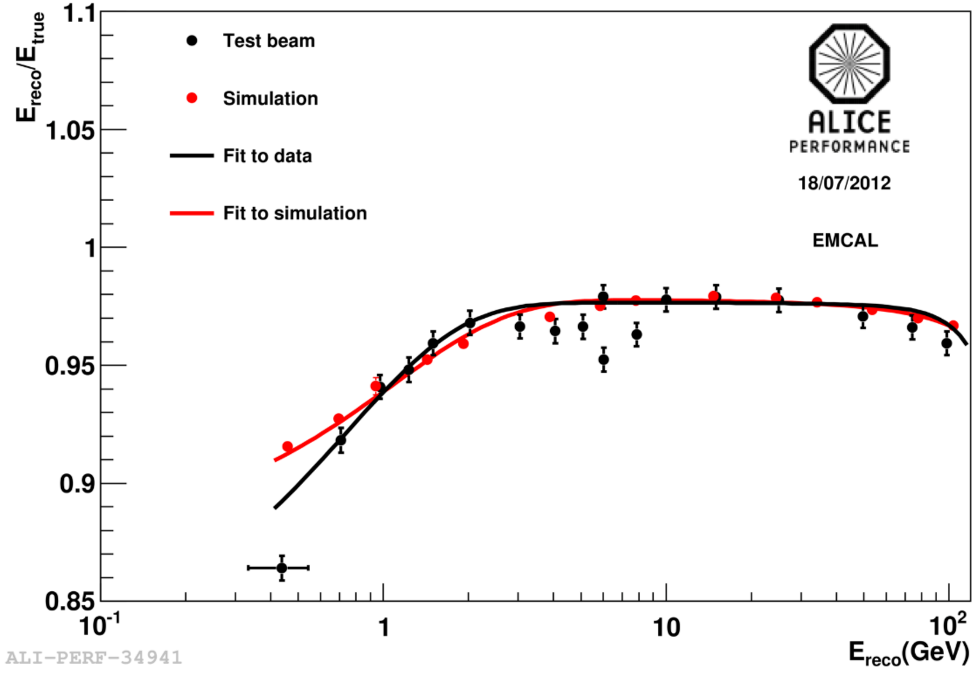
$$\frac{\sigma_E}{E}(\%) = \sqrt{\left(\frac{11.3}{E}\right)^2 + \frac{1.7^2}{E} + 4.8^2}$$

Energy calibration and linearity

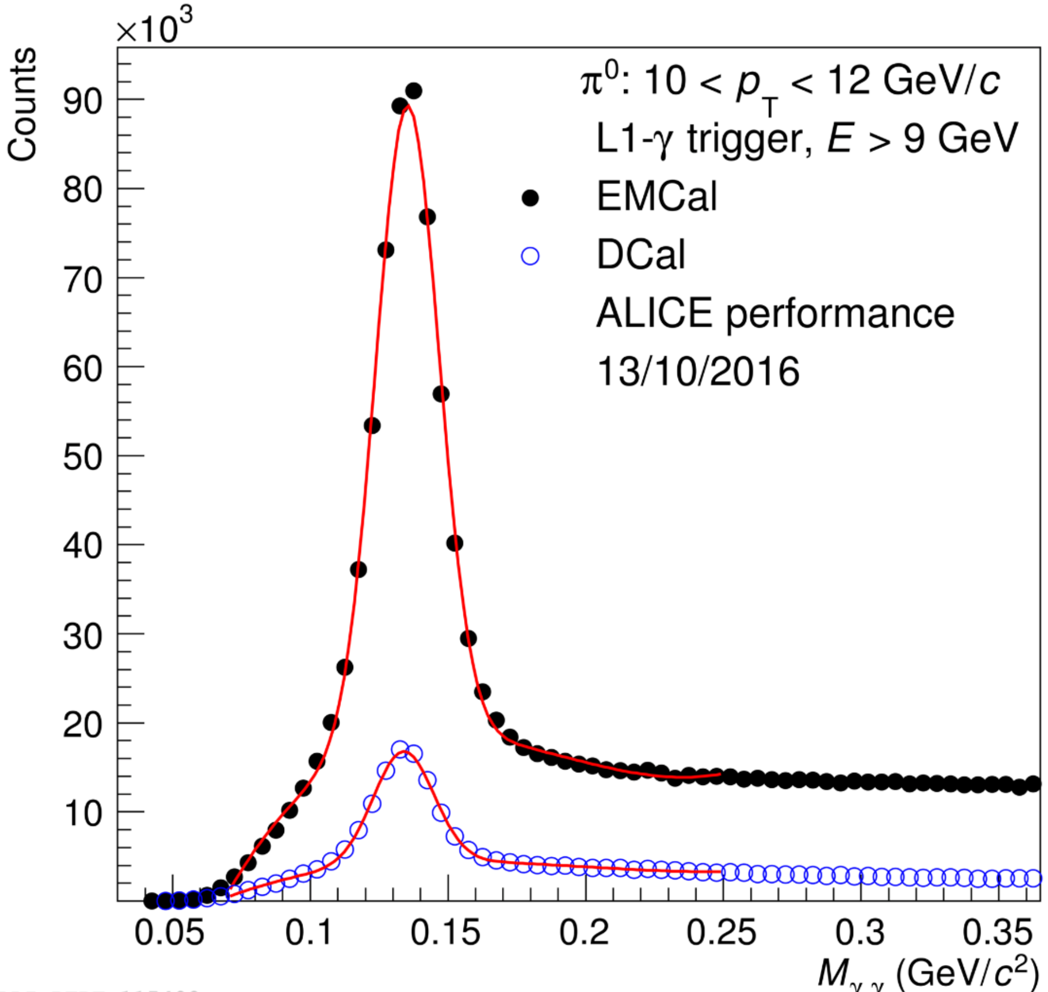
After adjusting gain of each channel, we calibrated each channel with iterative procedure based on the pi0 peak.



Linearity from test beam data, well described by simulation



Pi0 and eta peaks after calibration



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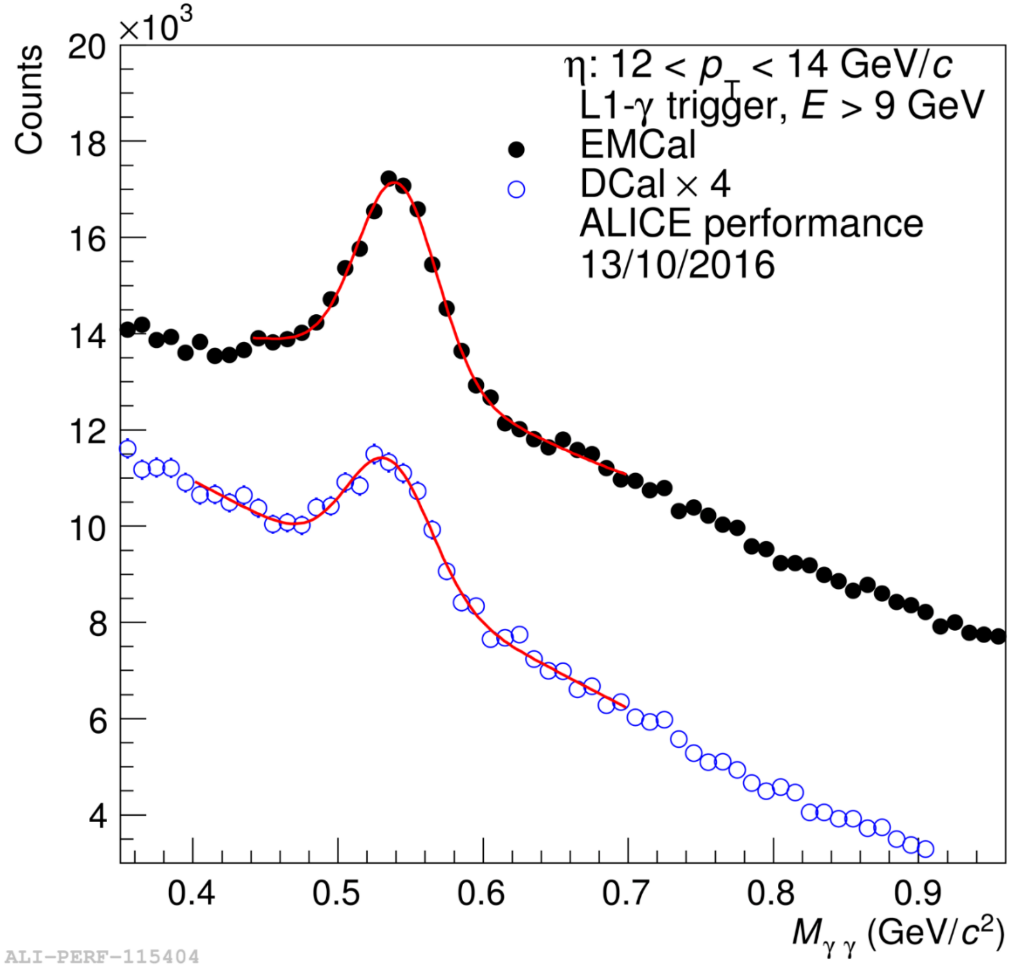

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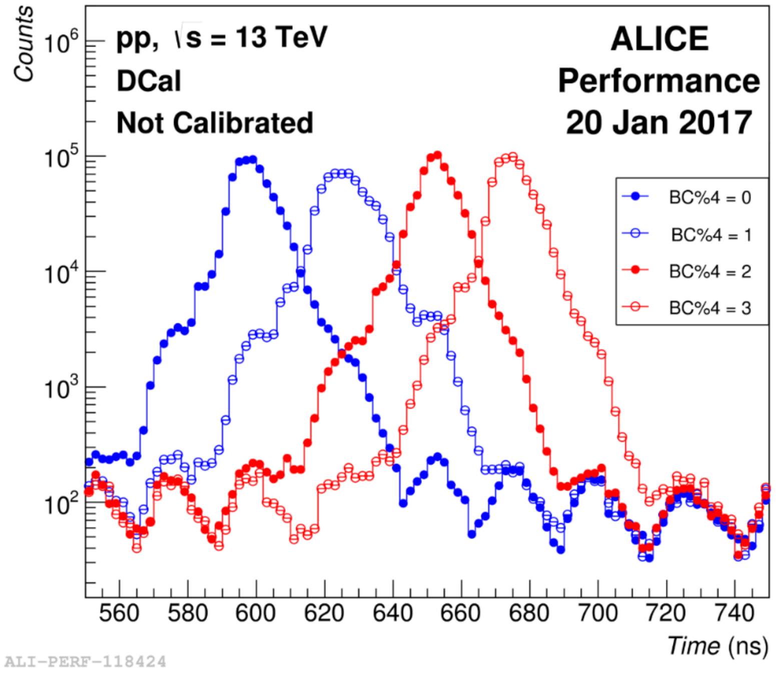
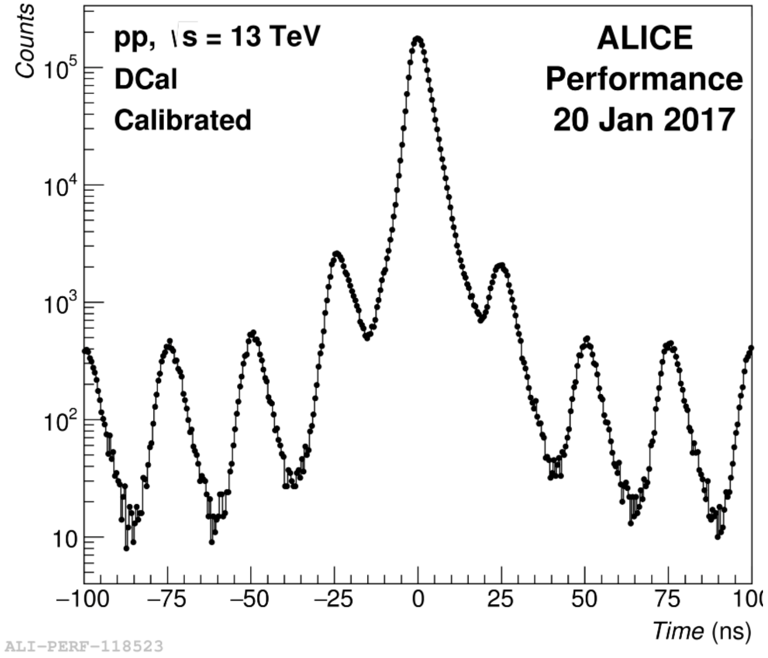
Time calibration

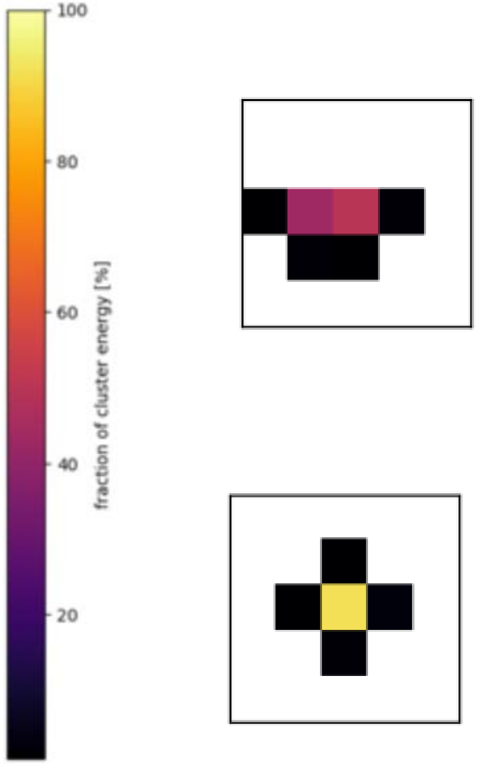
- Iterative procedure to yield appropriate cell-by-cell time offset.
  Depends on bunch-crossing number due to 100 ns (4 bunch crossings) shaping time

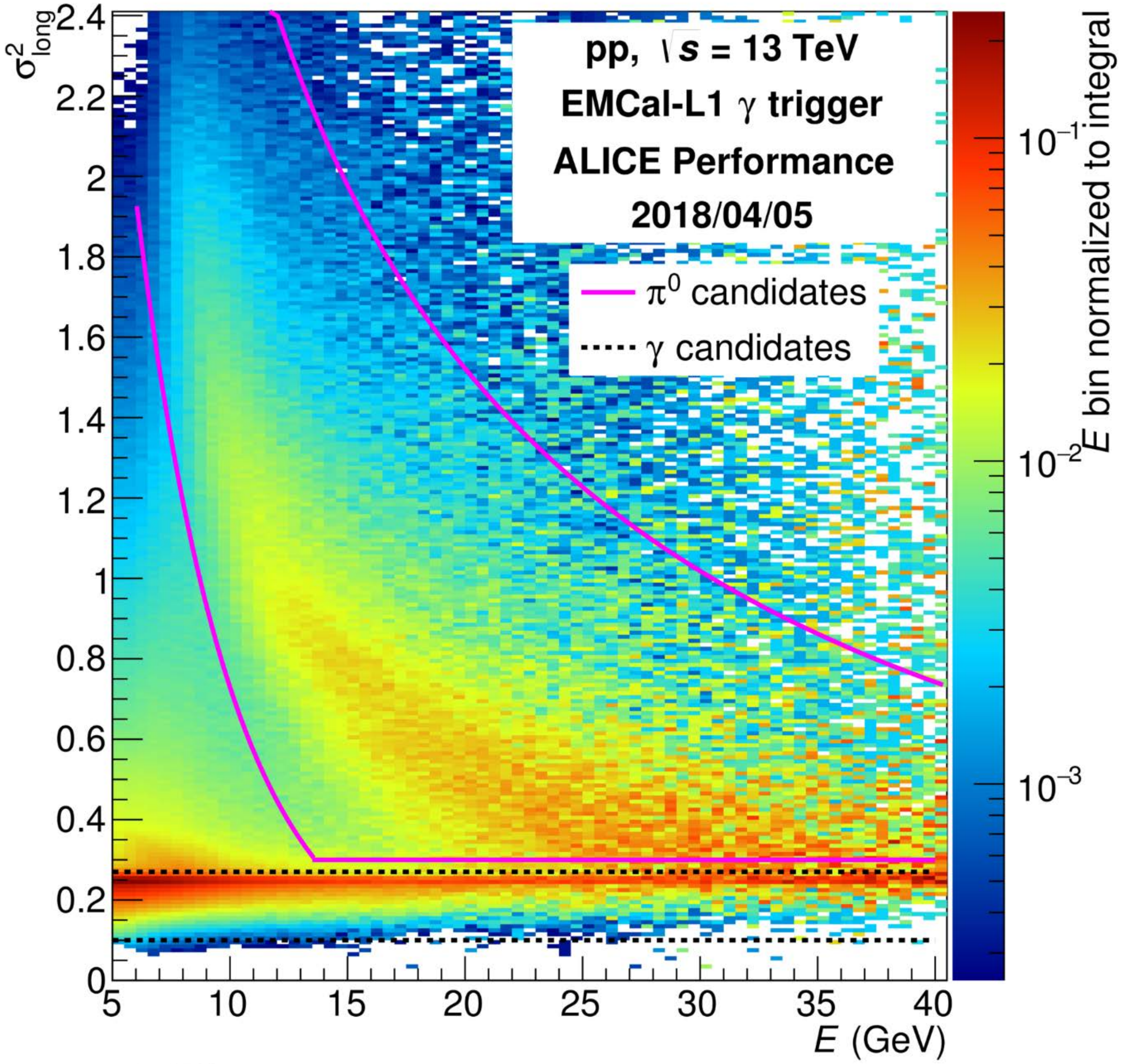
- After calibration, out-of-time pileup peaks are visible.





Shower shape for photon/pi0 separation





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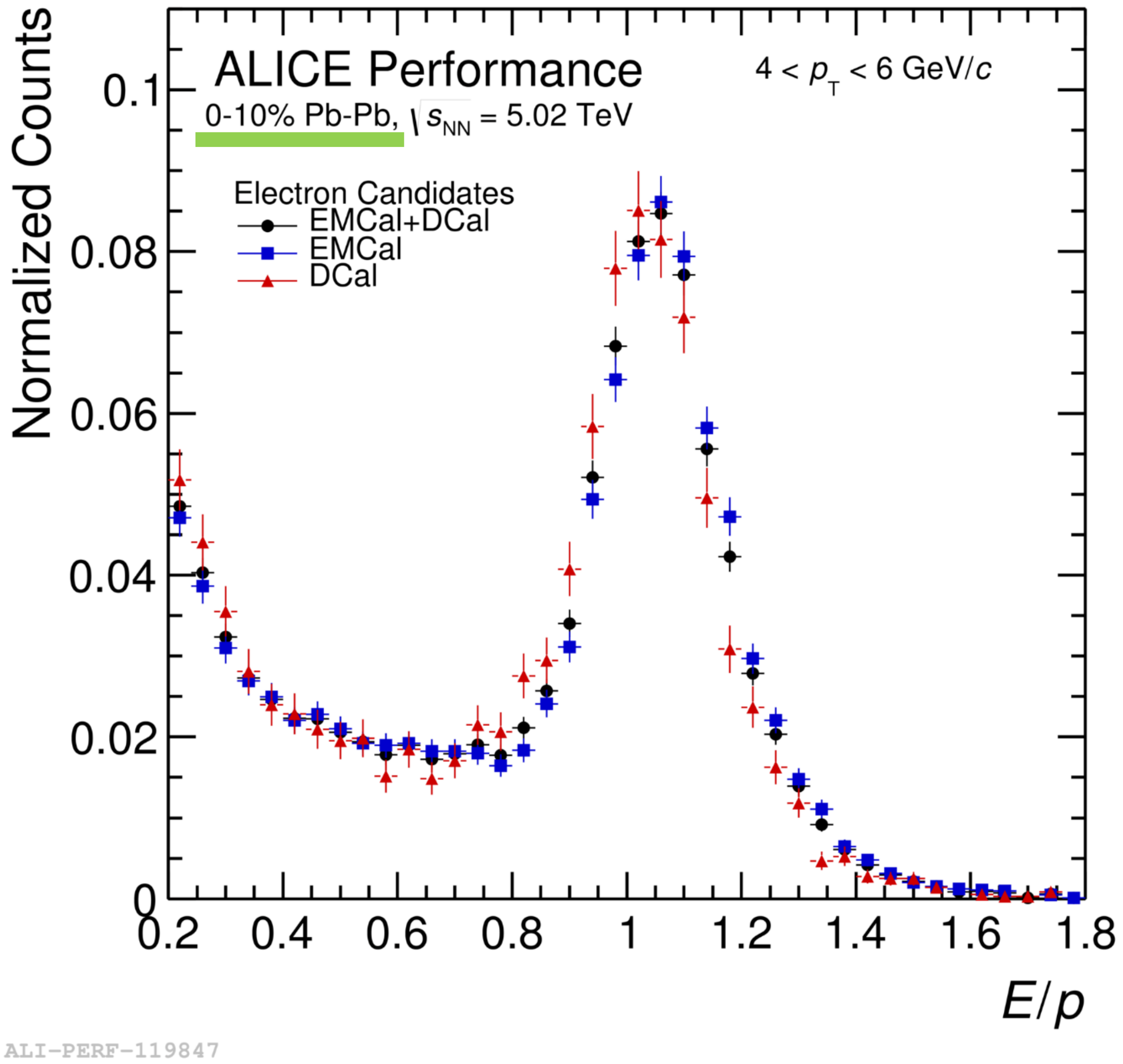
Good discrimination in momentum range of interest to ALICE

Electron identification



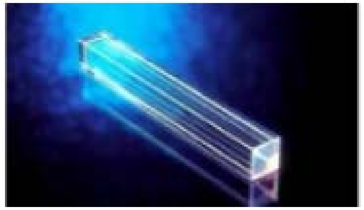
- Electron ID matching tracks and calorimeter clusters, with dE/dx selection from Time-Projection Chamber
- Rather clean electron peak, even in more central nuclear collisions

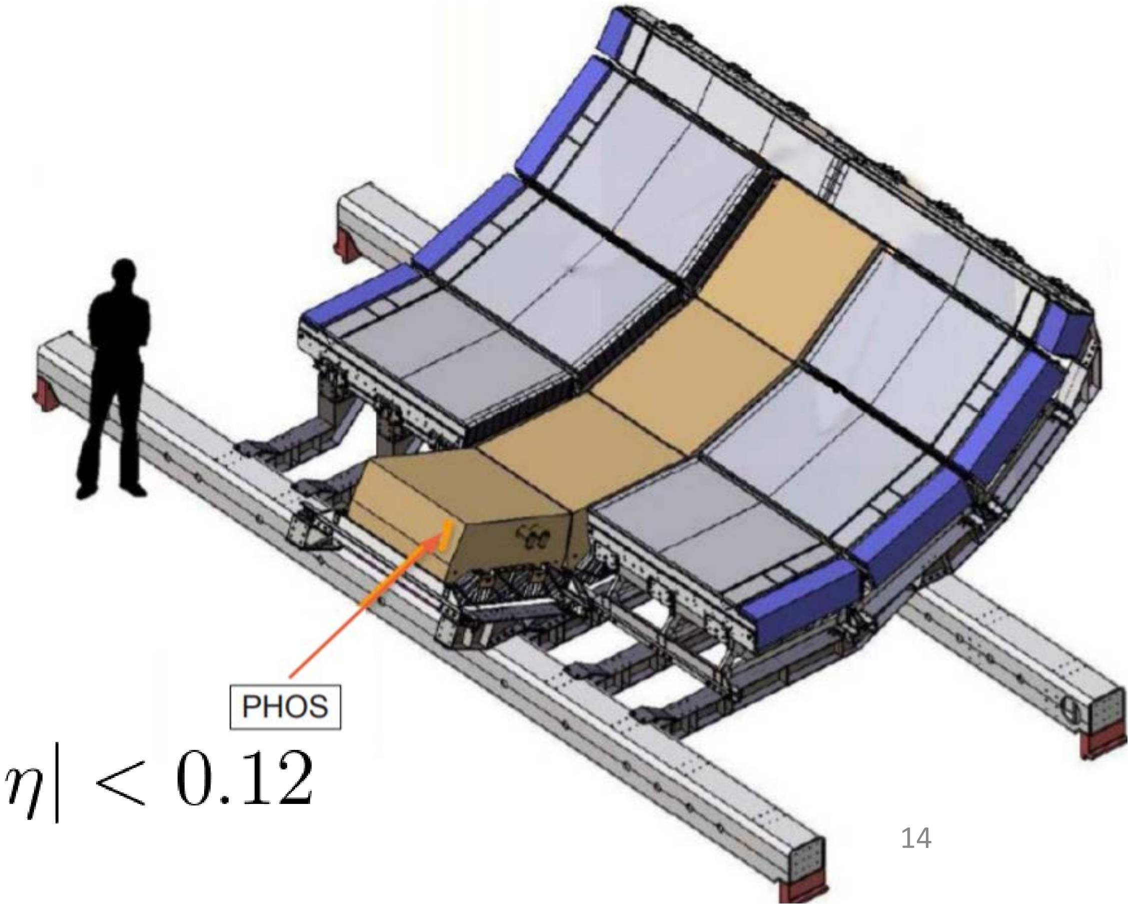
PHOS,
PbW04 crystal calorimeter

Module

Supermodule

$$\frac{\sigma_E}{E}(\%) = \sqrt{\left(\frac{1.3}{E}\right)^2 + \frac{1.3^2}{E} + 1.12^2}$$





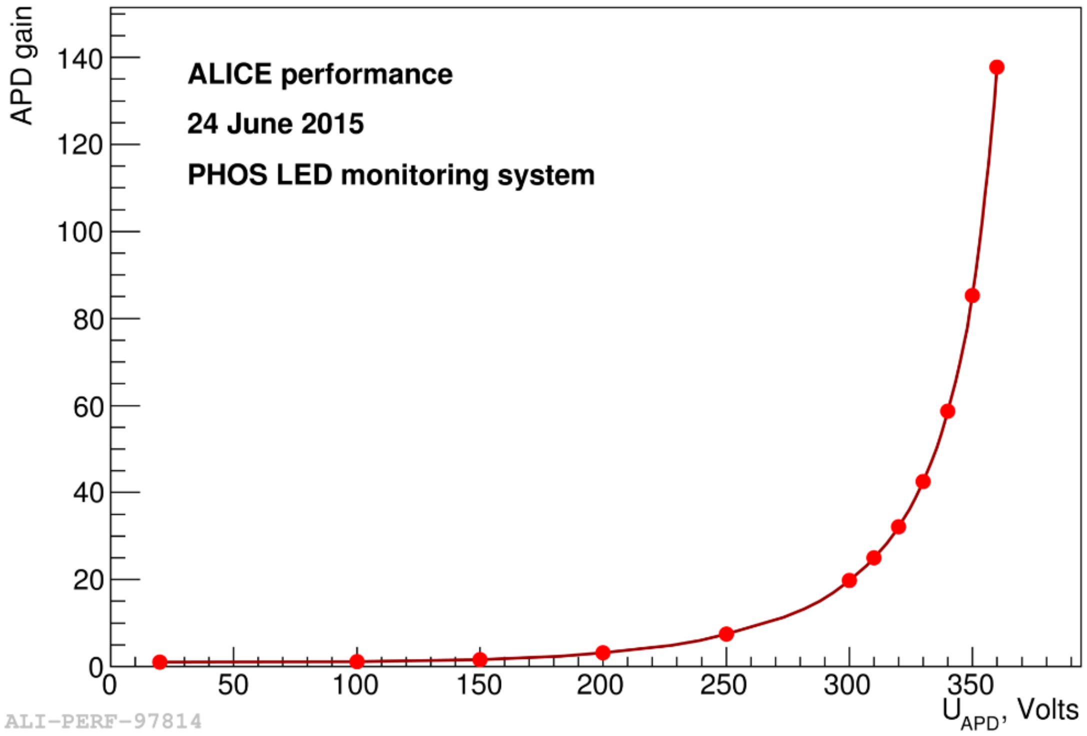
Avalanche photo-diode readout

$$\Delta\eta \times \Delta\phi = 0.004\times0.004$$

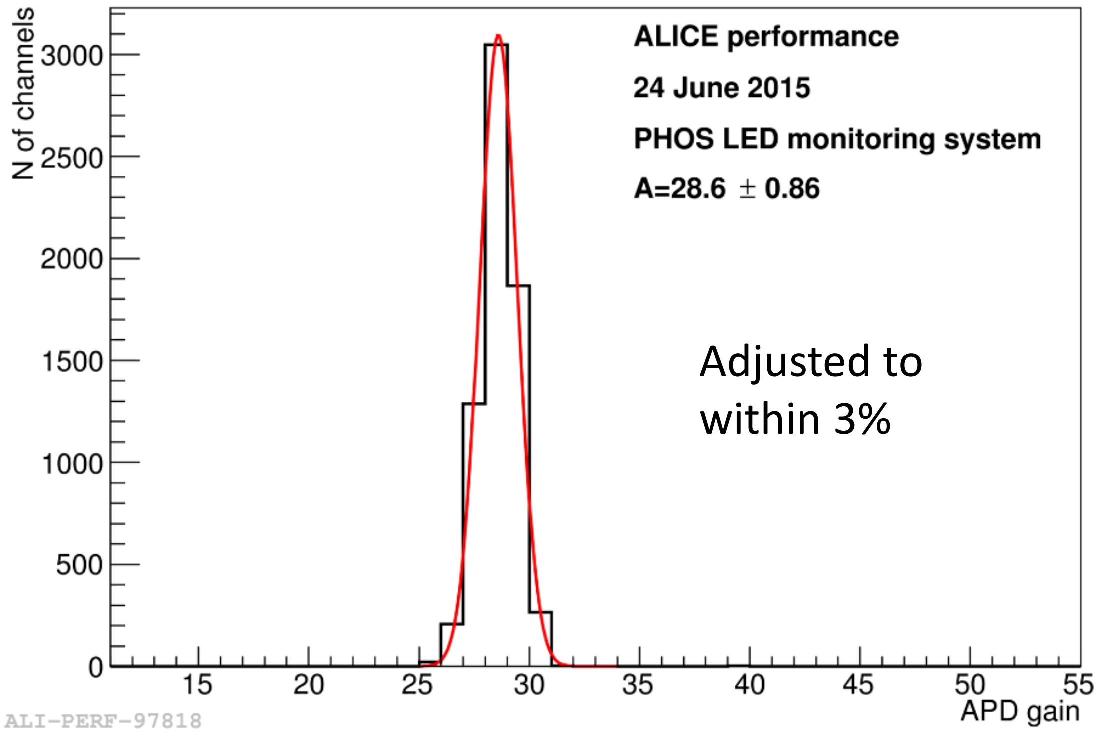
$$|\eta| < 0.12$$

PHOS LED *in-situ* calibration

Tune V to get same APD gain for each cell



Gain after cell-by-cell tuning

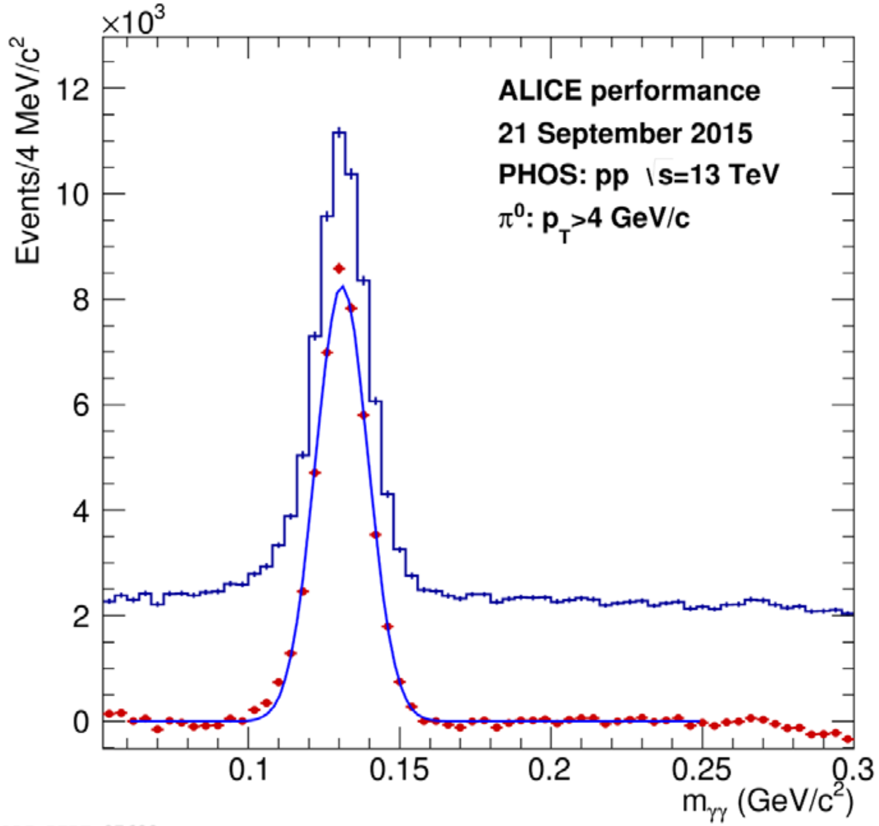


Adjusted to within 3%

PHOS energy calibration, second stage

- After APD gain adjustments, each cell is calibrated with an iterative procedure based on neutral pion mass

- Mass and width of pi0 peak well described by simulation



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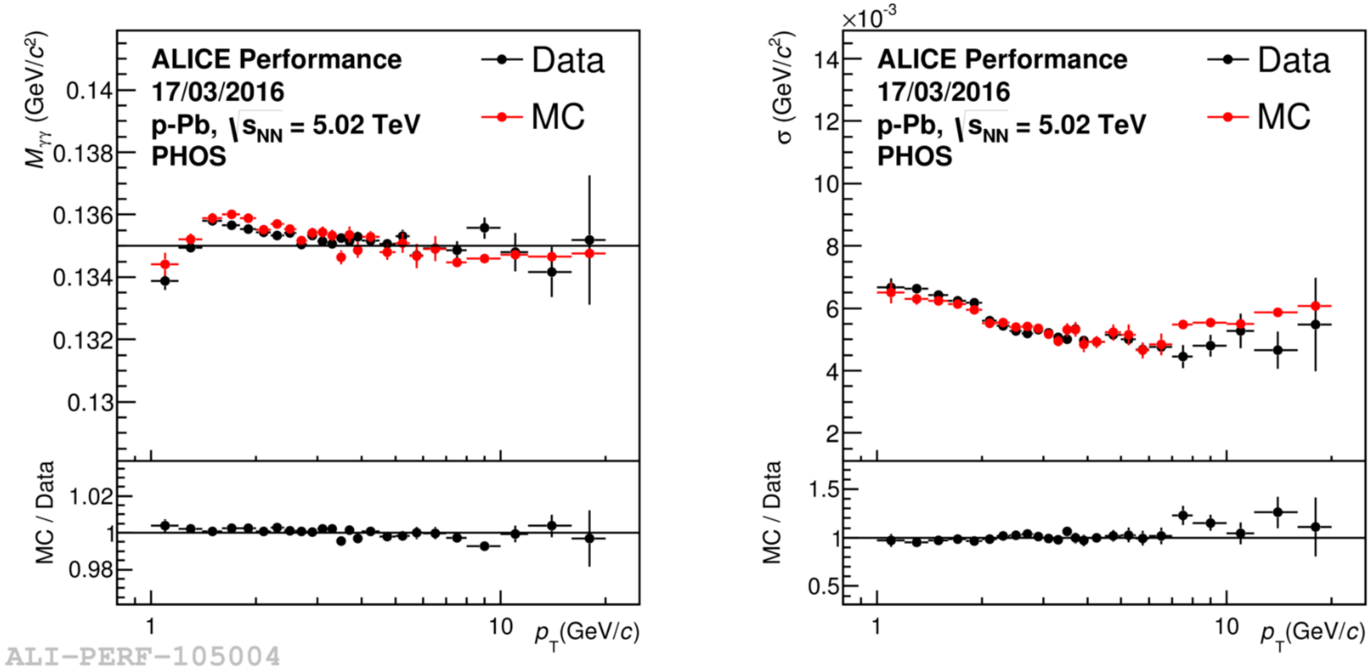

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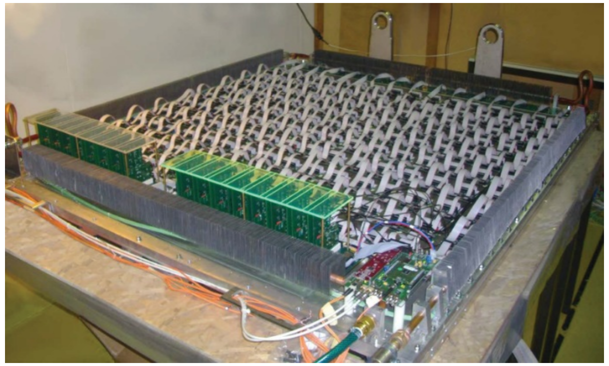
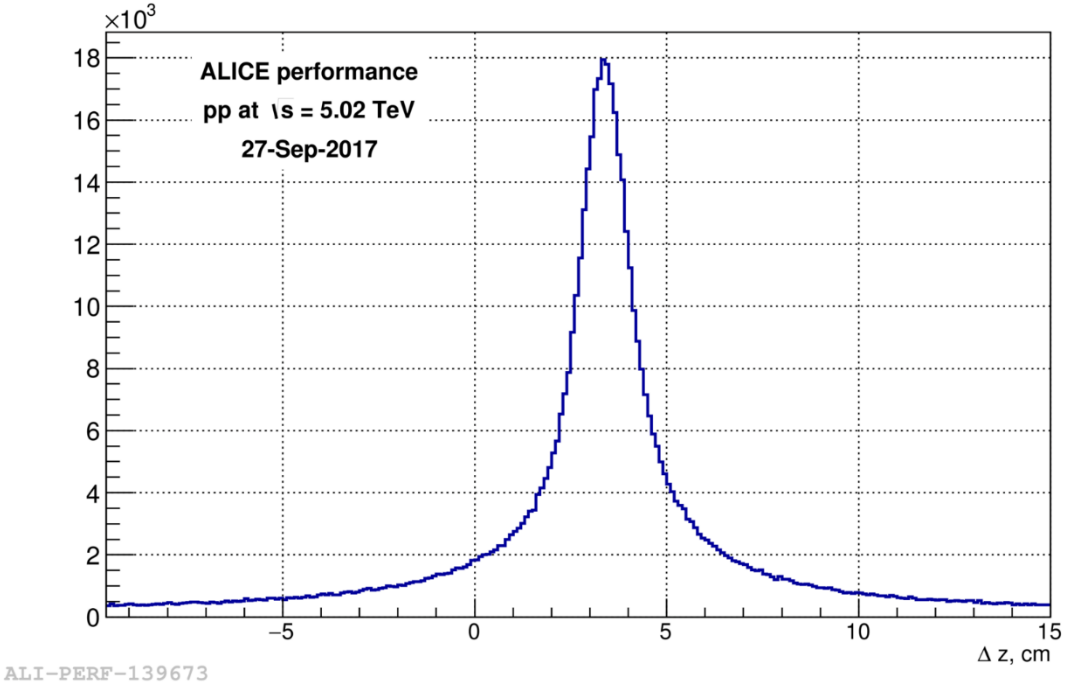
Charged-Particle Veto (CPV) detector

multi-wire proportional chamber with cathode readout
12 cm above PHOS surface

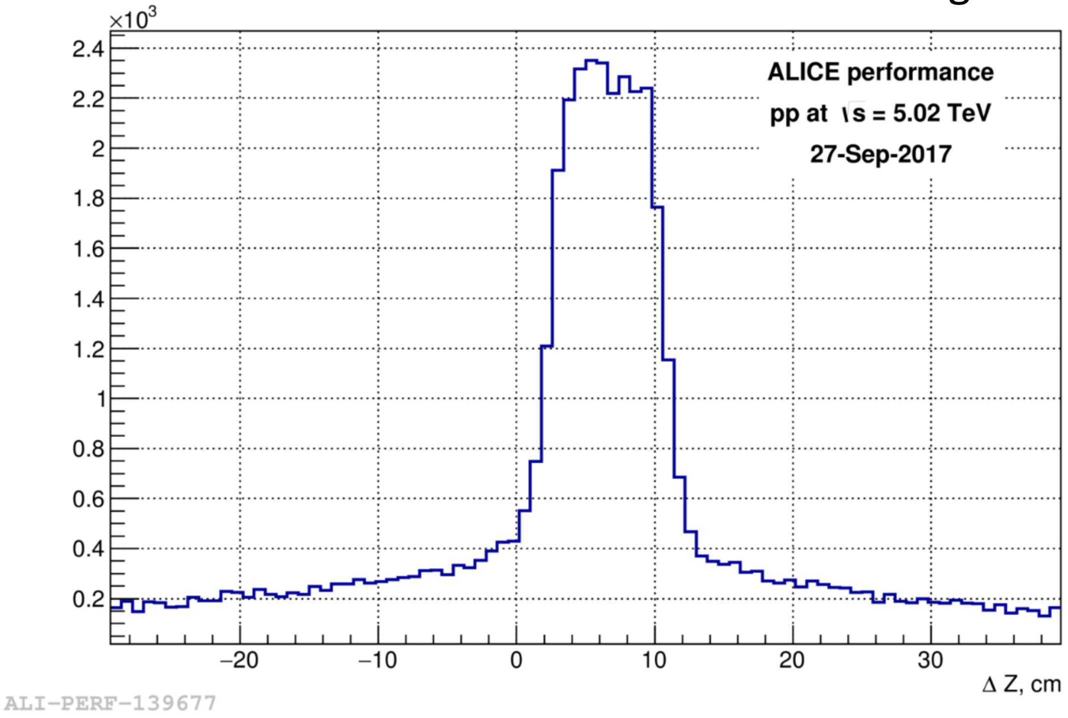


Distance between track and CPV cluster



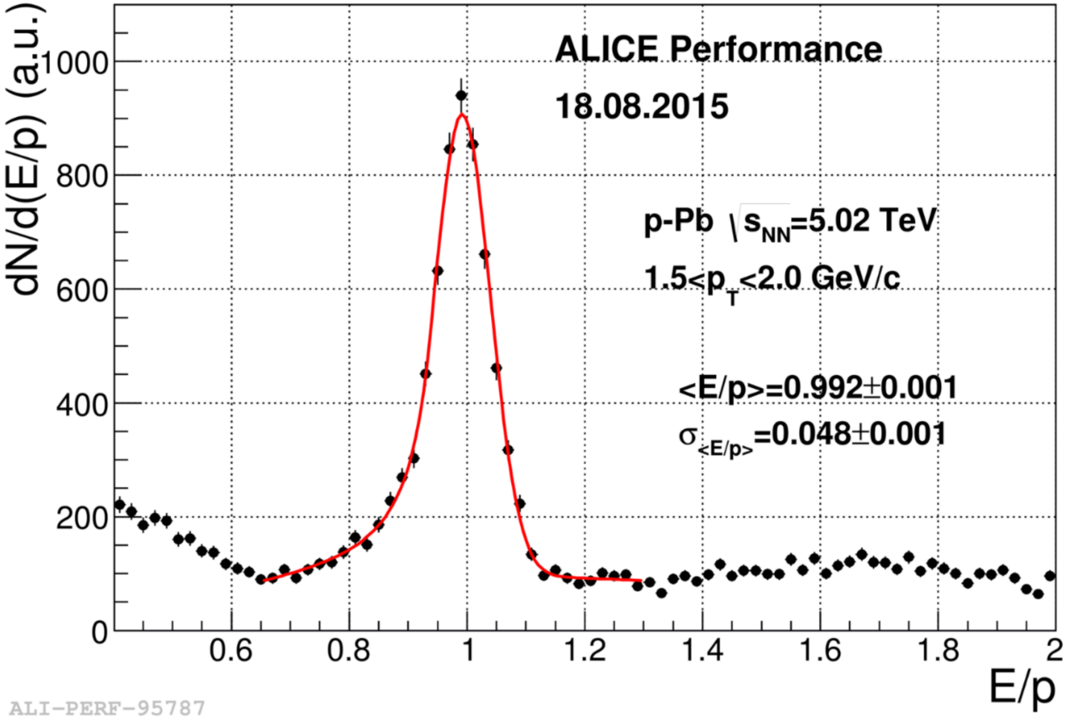
Resolution ~ 7.6 mm
Bias is due to misalignment

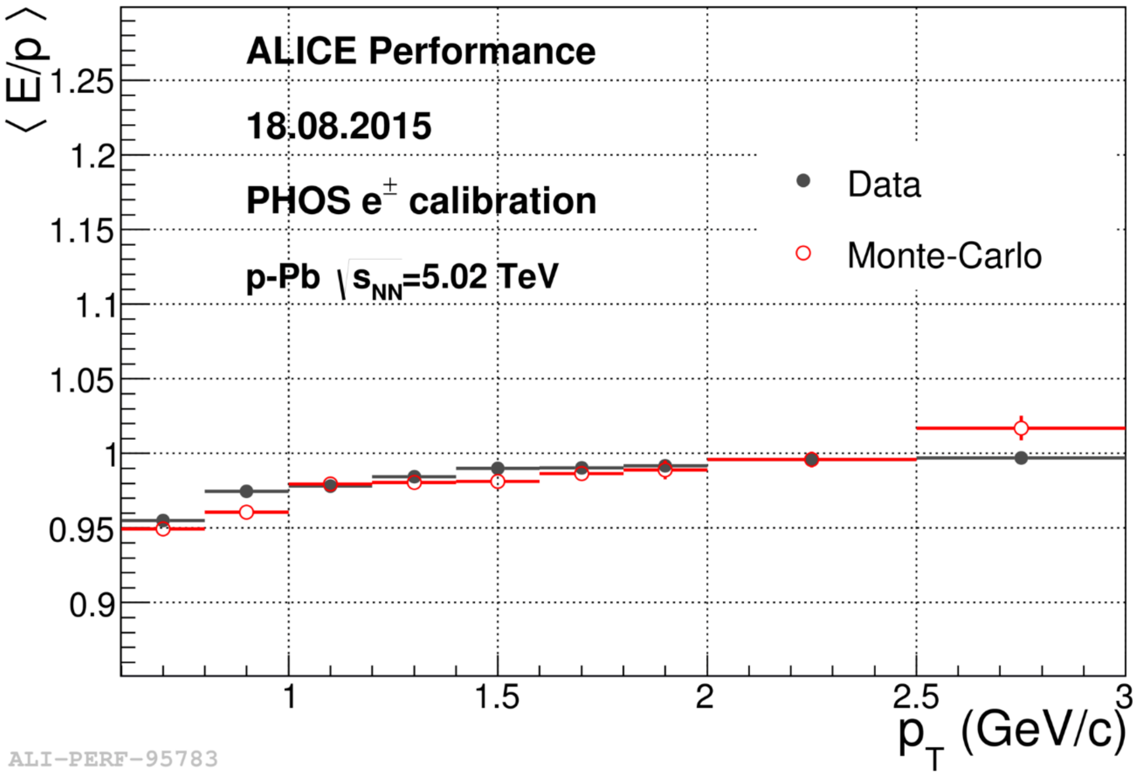
PHOS cluster and CPV cluster matching



Improves purity of photon selection

Electron performance with PHOS

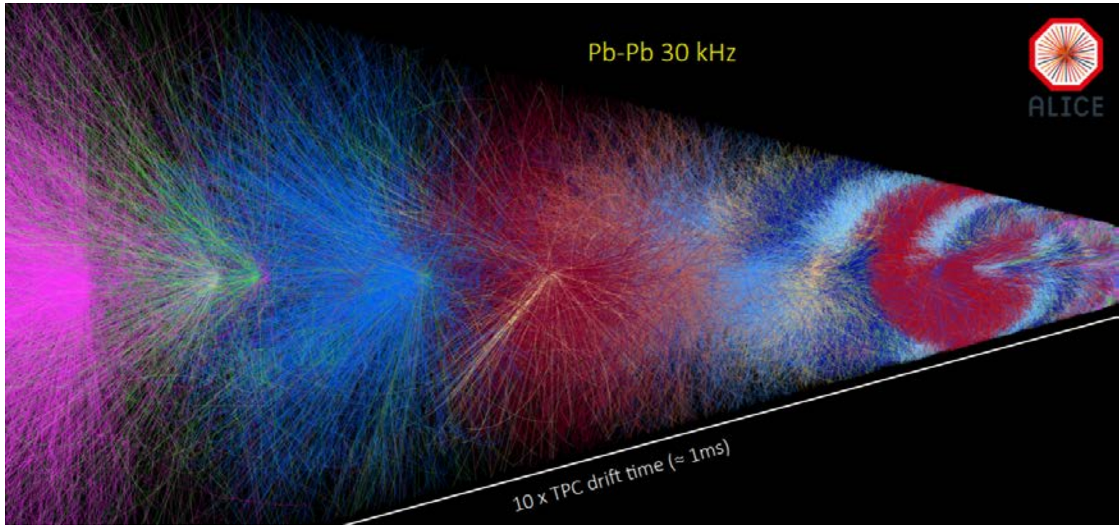


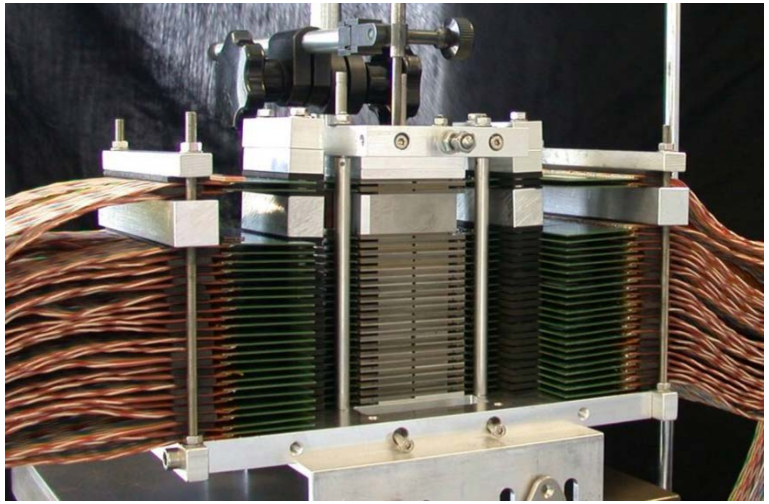


- Good electron performance in low momentum range, which is interesting for the ALICE physics program (thermal sources)
- Well described by simulation.

Upgrades

- New Online-Offline infrastructure will merge DAQ, HLT and Offline for Run 3. Includes EMCAL using readout electronics to cope with higher rates (Run 3)
- Two more modules of Charged-Particle Veto detector for PHOS. (Run 3)
- New active silicon-tungsten calorimeter, 30x30 μm^2 pitch CMOS technology at 3.2 <η < 5.3





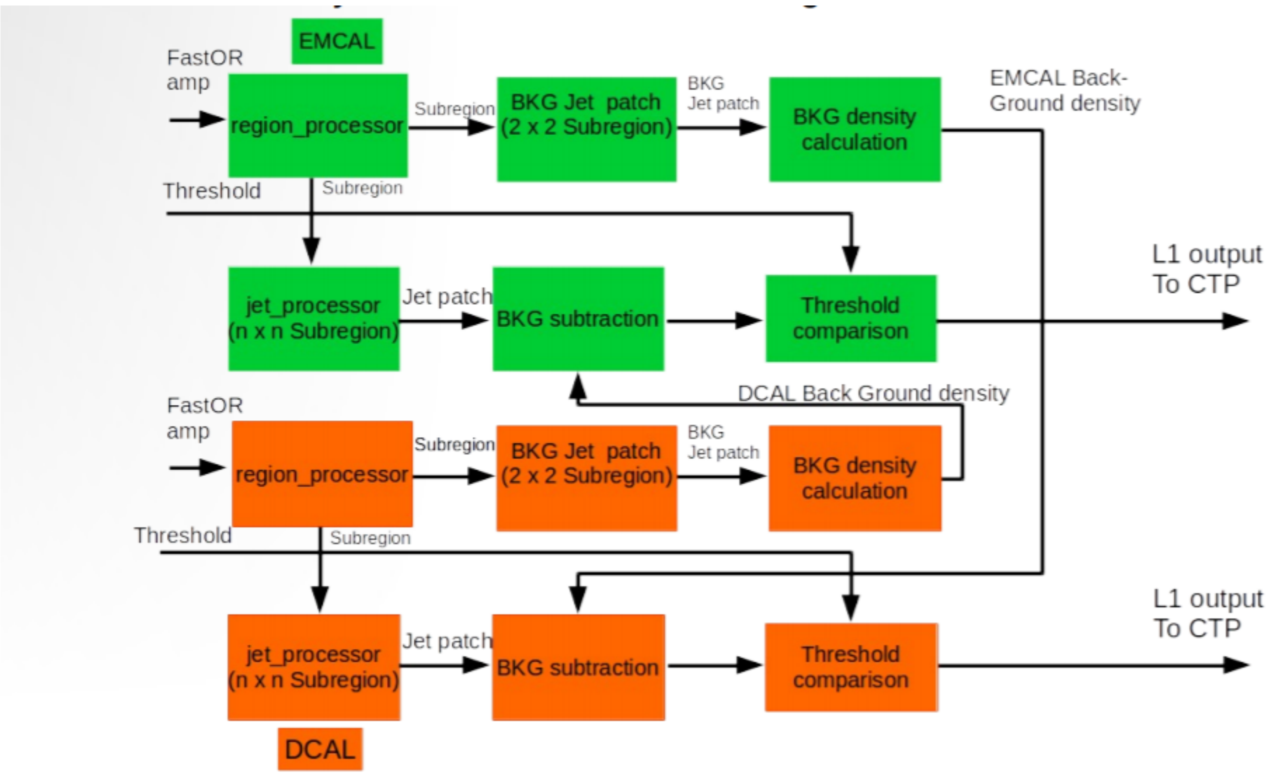
Conclusions

- ALICE experiment will use a combination of high-granularity small-acceptance PbWO4 crystal calorimeter and larger-acceptance PbSc-sampling calorimeter to enhance the performance of key physics measurements.
- Future upgrades will focus on increases in the readout rate, dedicated charged-particle veto detectors and state-of-the-art forward-calorimeter

Thank you!

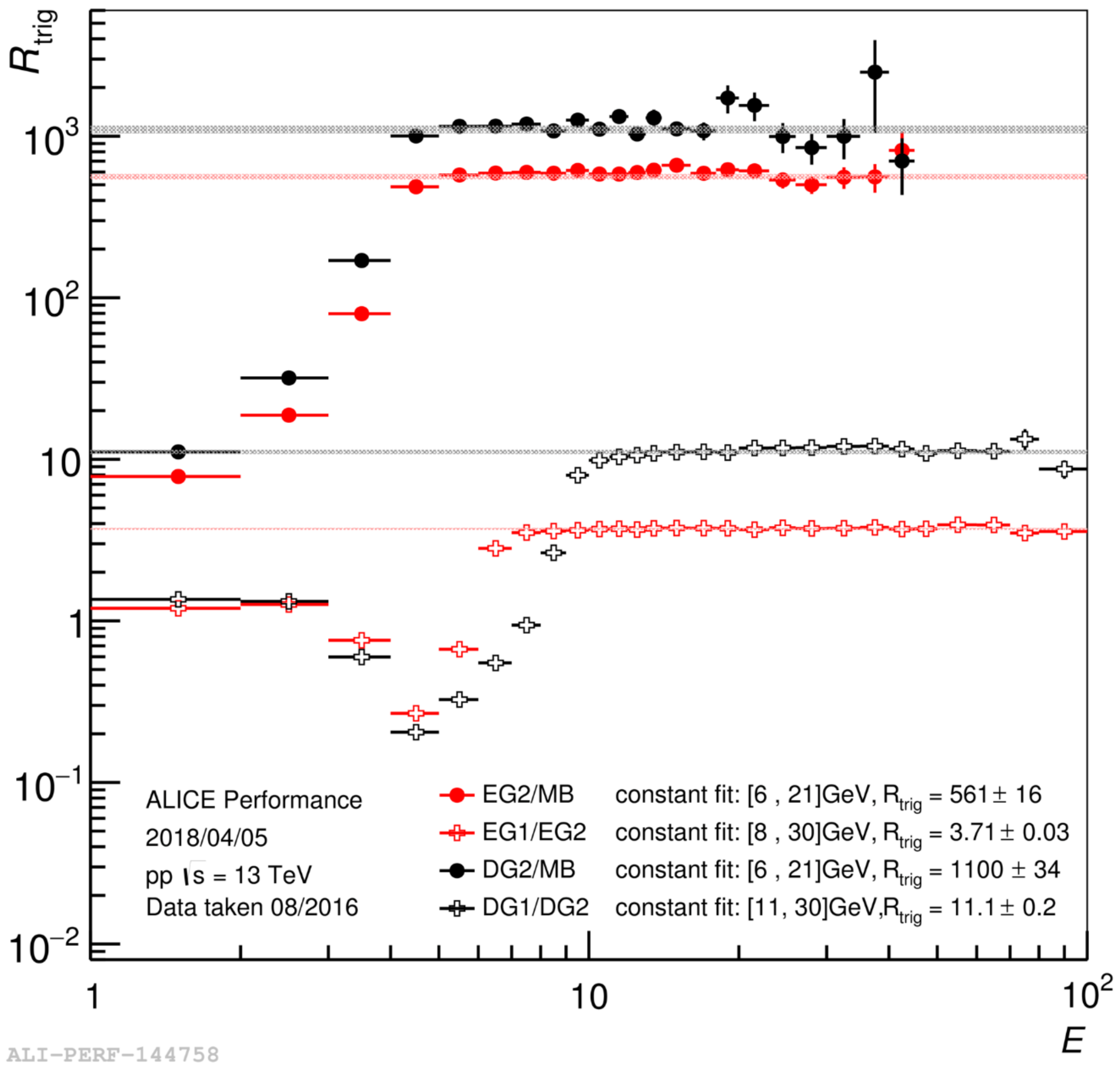
Backup

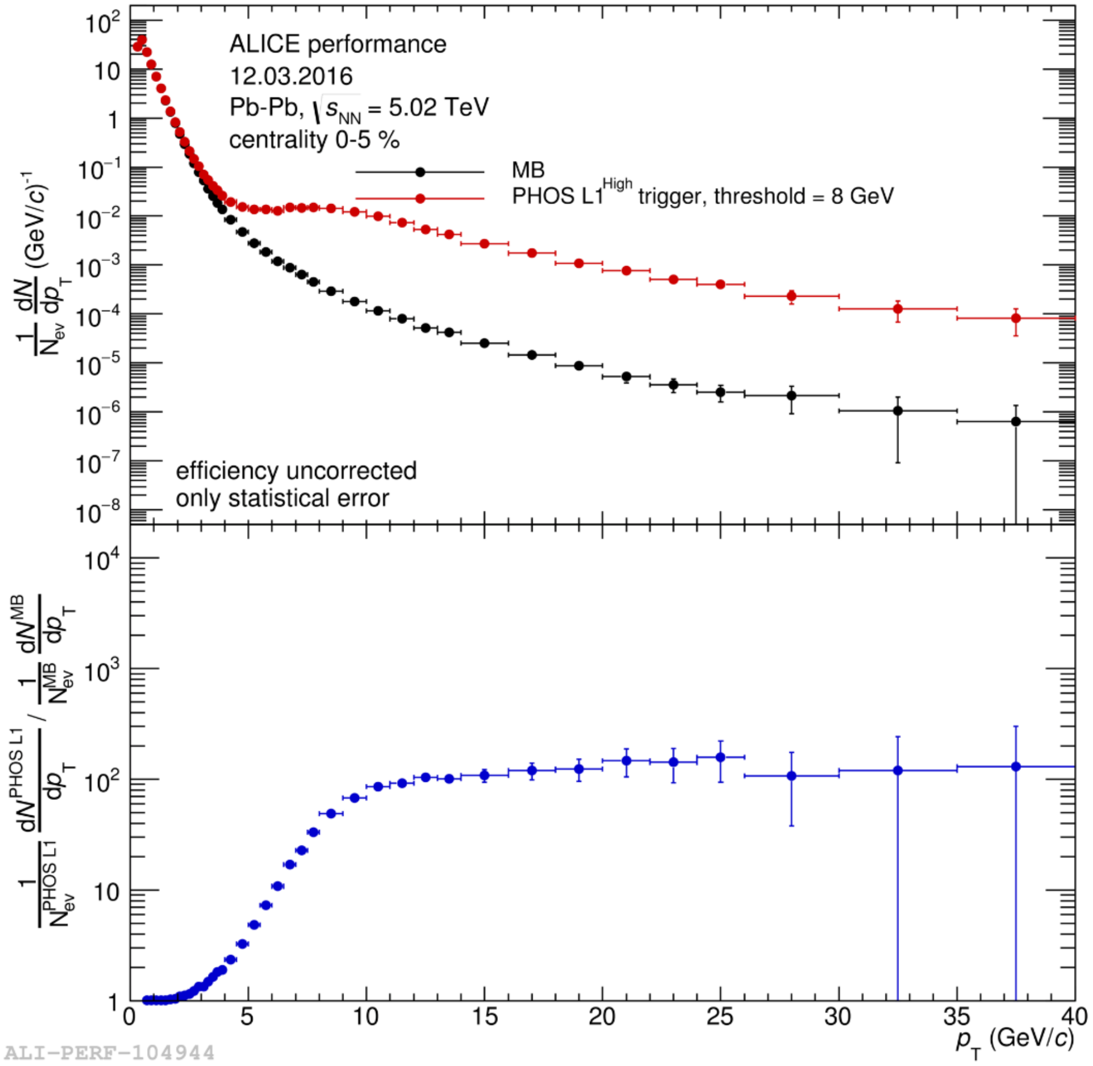
L1 jet trigger (bkg subtraction)



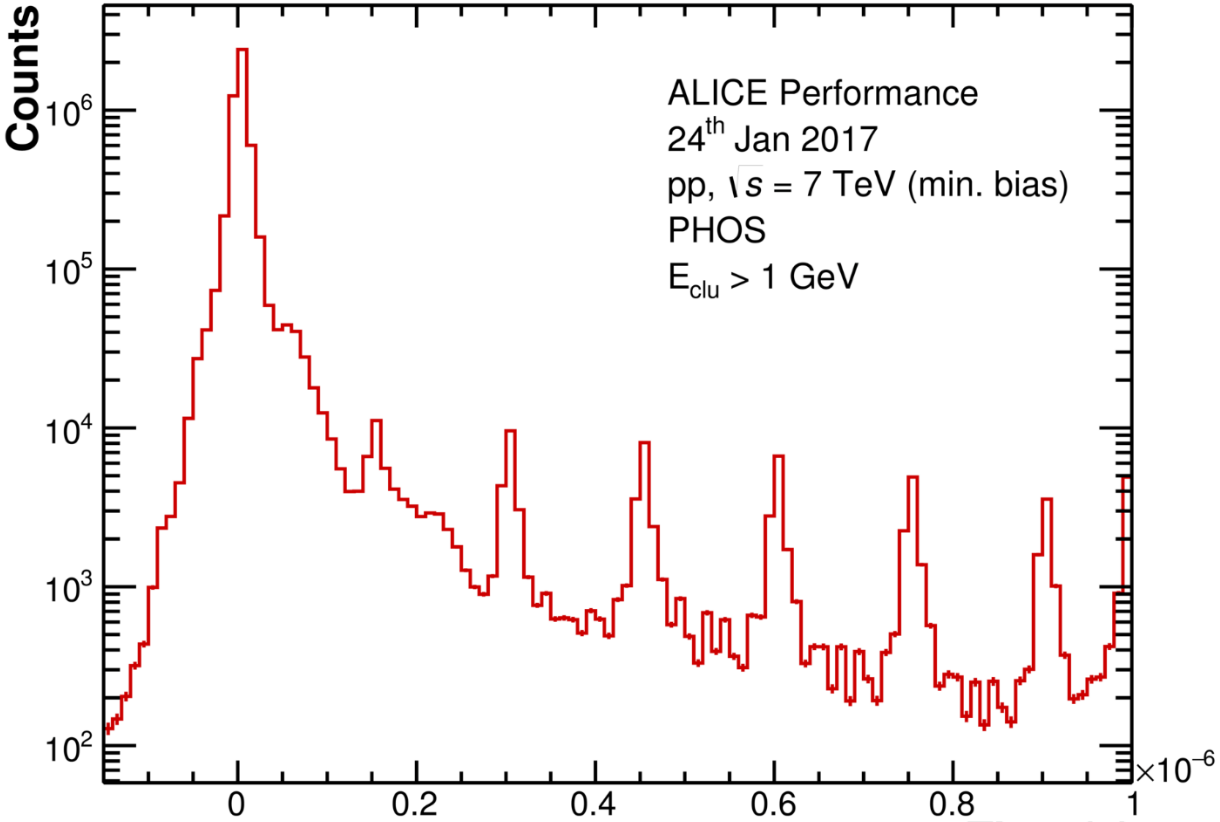
- Run1: event by event threshold calculation by using V0 multiplicity
- Run2: event by event background subtraction by using background energy that is estimated by opposite side calorimeter

Trigger performance in pp and PbPb





Time resolution using PHOS



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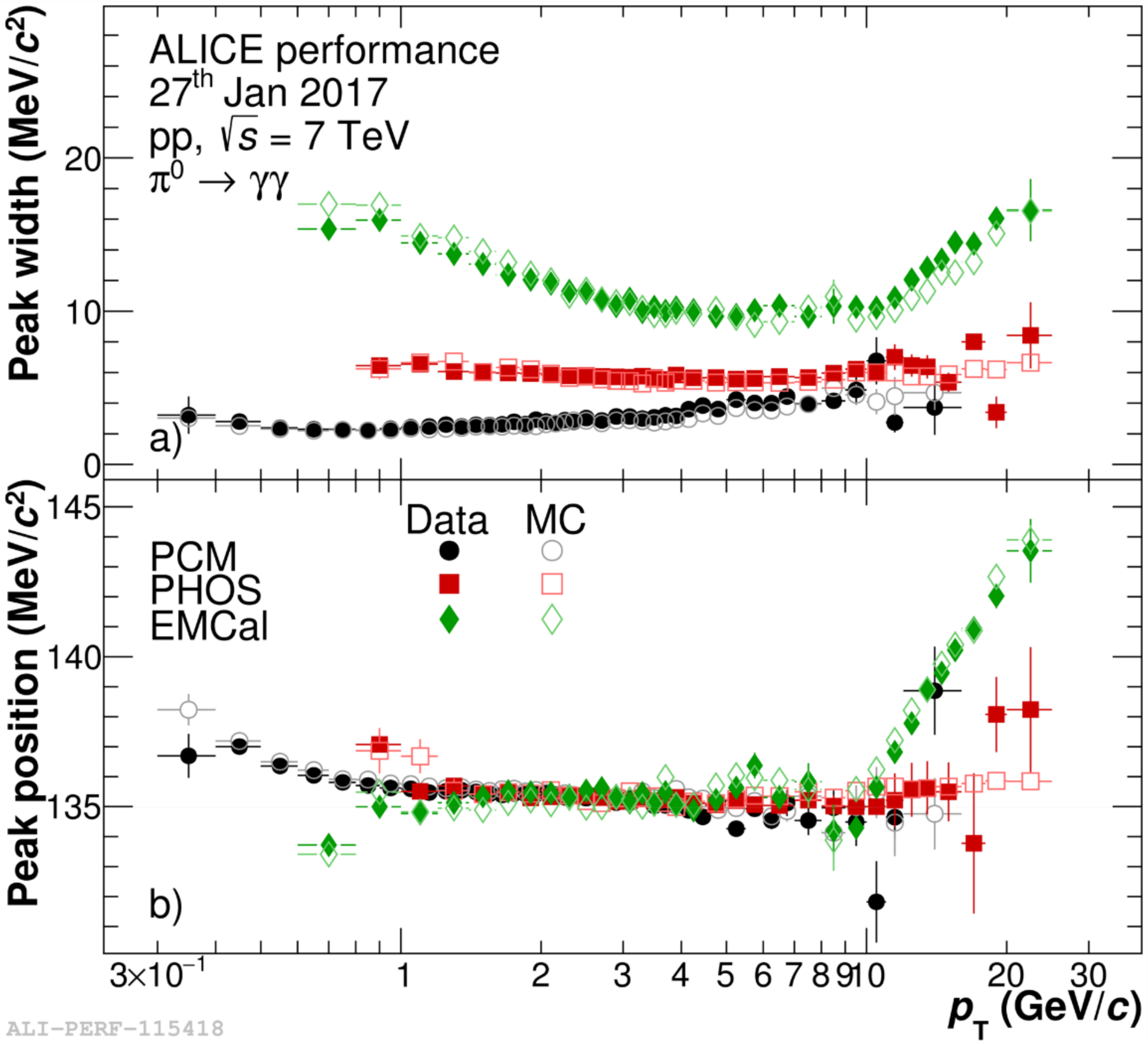
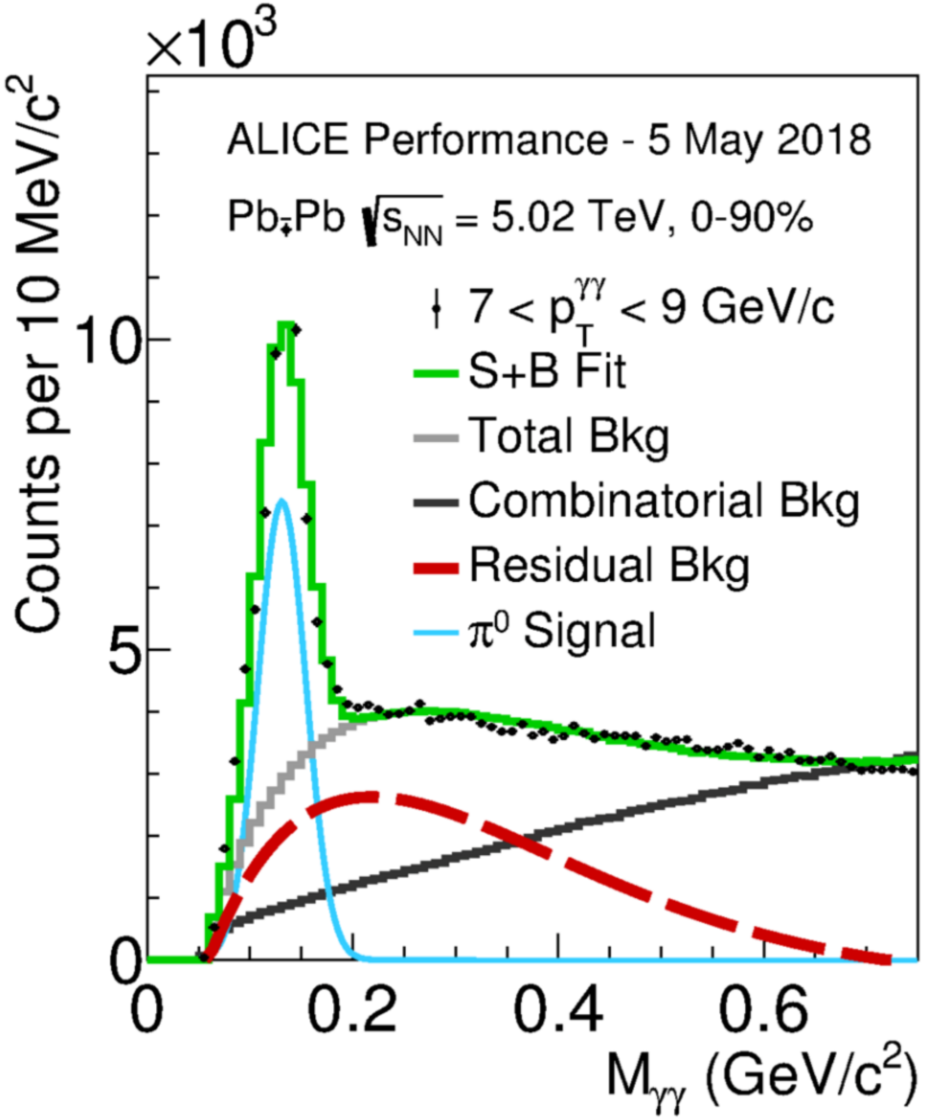
Neutral pion reconstruction



- PHOS: Its better energy resolution and granularity show a rather flat *p*T dependence on mass and peak, but limited *p*T reach due to small acceptance
- EMCAL: Its larger acceptance enables measurements at higher *p*T, but suffers from pi0 merging.
- Simulation describes the data well.

Pion reconstruction in Pb-Pb collisions



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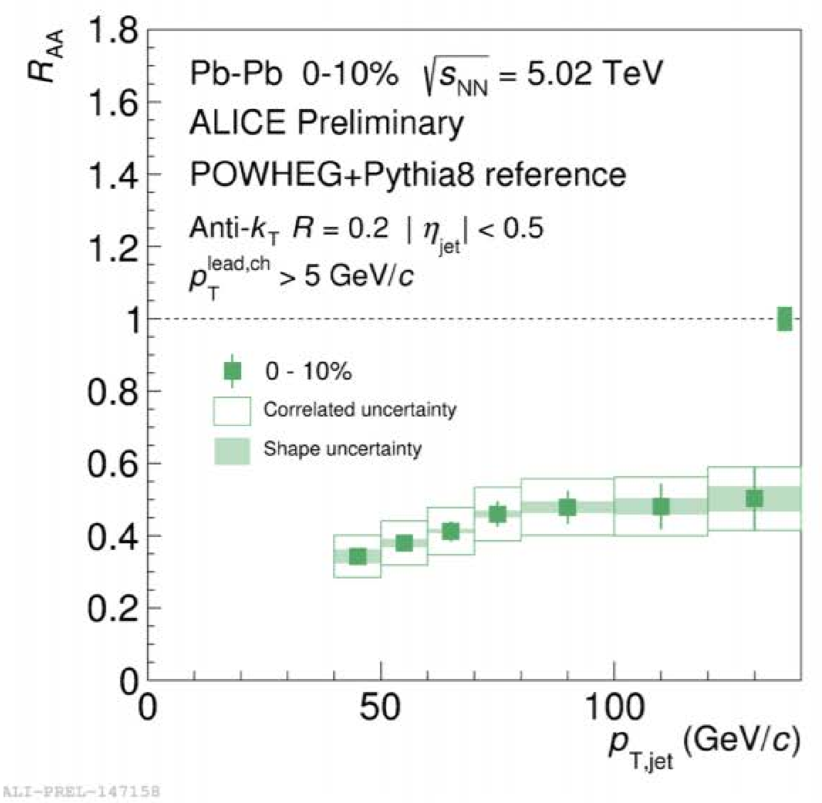
- ALICE physics program relies on pi0 not only for calibration, but also for as proxies for jets

Jet suppression

R = 0.2



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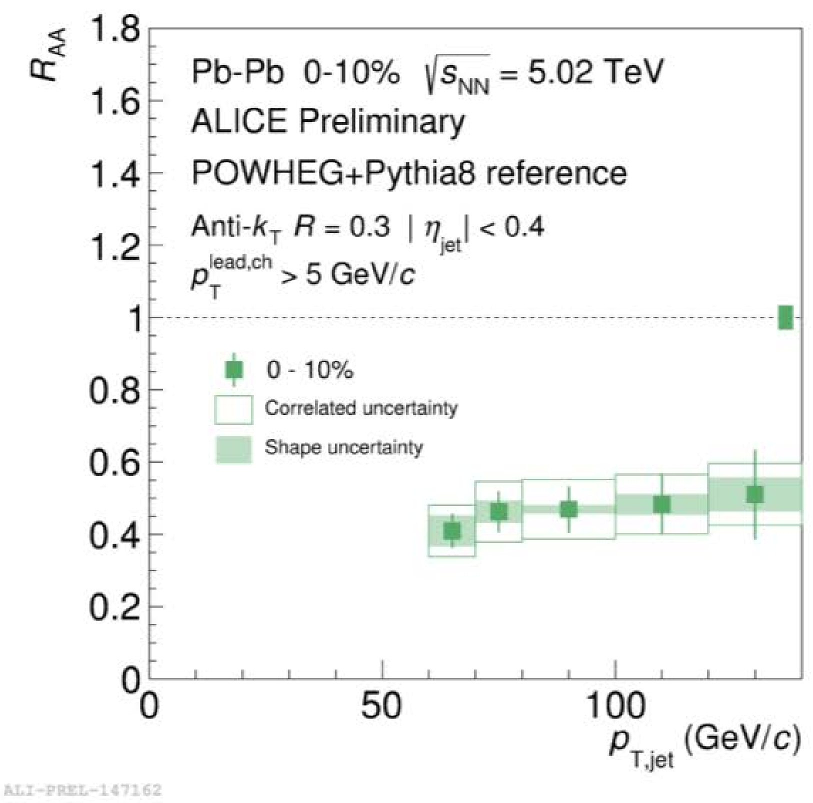
R = 0.3



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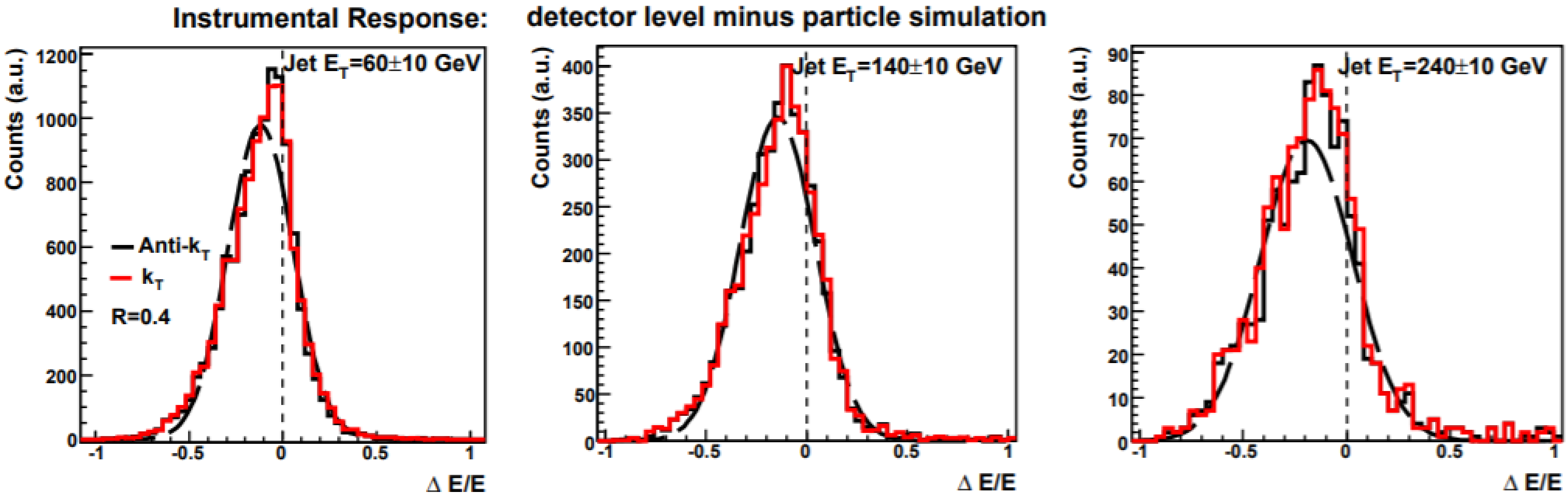

Figure 5.1: Instrumental effects on jet reconstruction, for jets from 5.5 TeV p–p collisions in the EMCal acceptance. ΔE is the event-wise difference between jets reconstructed on the Detector minus Particle level, for selected intervals in Particle level jet energy E. Algorithms are FastJet k_T and anti-k_T $R = 0.4$. Solid curve is Gaussian function fit to anti-k_T distribution.