National Research Center «Kurchatov Institute»

Institute for High Energy Physics named by A.A.Logunov of NRC «Kurchatov Institute»

Performance of the ALICE charged-particle veto detector in pp-collisions at √s = 13 TeV

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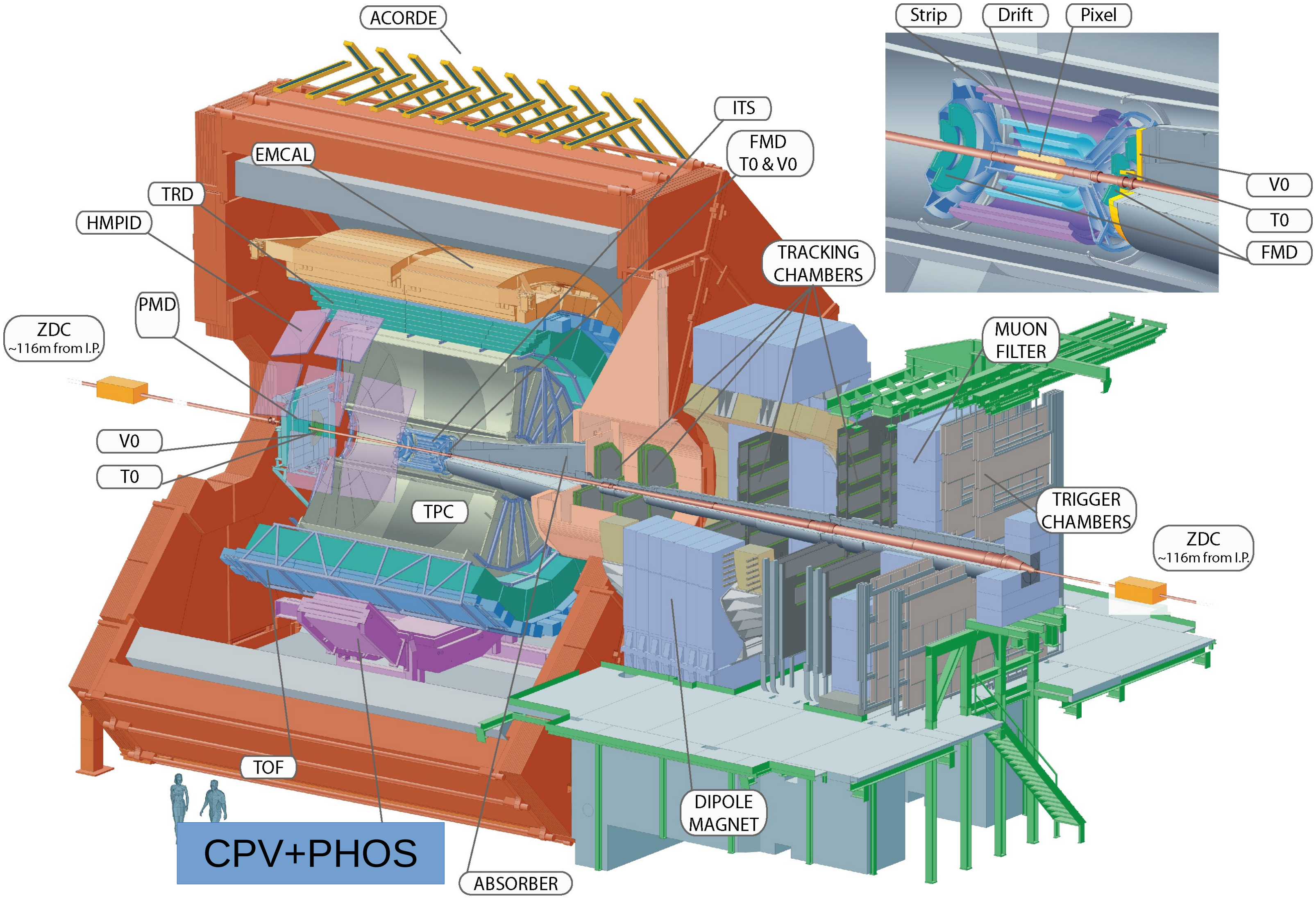
Introduction

- One of the tasks of ALICE is to study photons emitted directly from pp or Pb–Pb collisions, so-called direct photons.
- ALICE is equipped with a high-precision photon spectrometer PHOS, and there are 3 methods to identify neutral clusters in it:
  - Use the shower shape of PHOS clusters to discriminate between electromagnetic and hadronic showers.
  - Use the cluster timing in PHOS to discriminate between fast (photons, electrons) and slow particles (heavier hadrons).
  - Use the **CPV** detector to match PHOS clusters and charged-particle tracks.
- **C**harged-**P**article **V**eto detector – multi-wire proportional chamber with cathode pad readout positioned in front of PHOS. Its main purpose is to improve neutral-clusters identification with PHOS by detecting charged leptons and hadrons.

Introduction (2)

Charged-**P**article **V**eto detector (CPV) – multi-wire proportional chamber with cathode pad readout positioned in front of PHOS. Its main purpose is to improve neutral-clusters identification with PHOS by detecting charged leptons and hadrons.



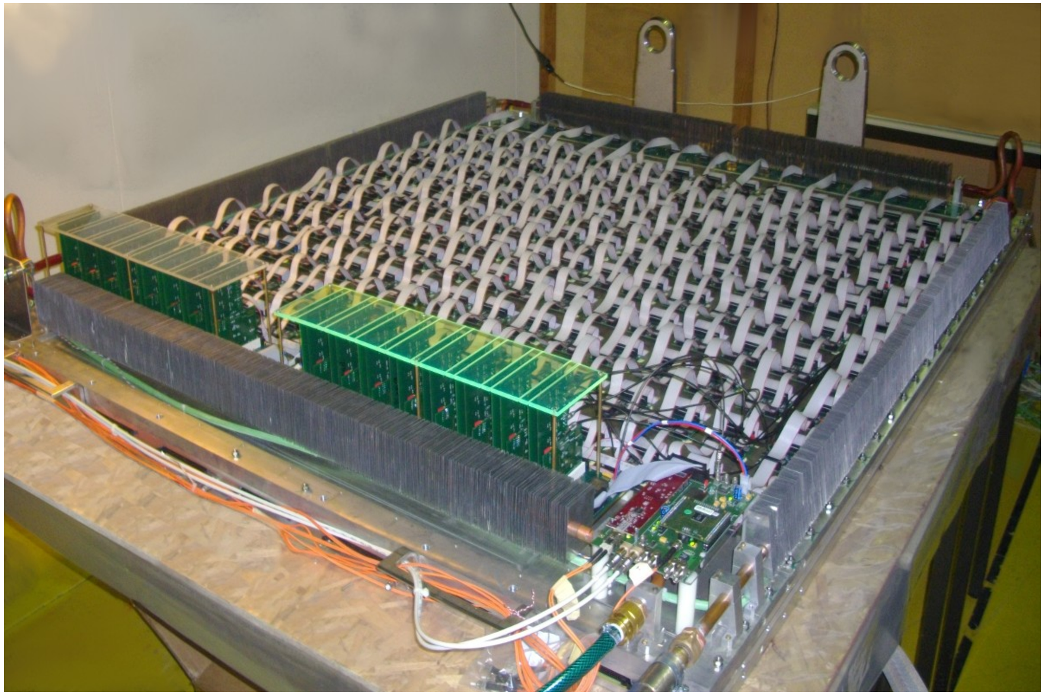
Main characteristics

- Sensitive volume size: 140 x 123 x 1.4 cm^3
- Wire pitch – 5.6 mm
- Wire diameter (W+Re) – 28 μm
- Number of anode wires – 258
- Wire tension – 100 g
- Anode-cathode distance – 7 mm
- Pad size – 10 x 21 mm^2
- Transverse segmentation – 128x60 pads
- Number of channels with charge-sensitive amplifiers and digitization – 7680
- Gas mixture – Ar(80%)+CO_2(20%) ← optimized during 2016
  - Gas humidifier (0.1% H_2O) ← installed in 2018 for HV stability during high-luminosity runs
- Nominal anode HV – 2.2 kV ← tuned during Pb-Pb 2015 run
- Material budget – 5% X_0
- Designed coordinate resolution 5.6/√12 = ~1.6 mm

Readout

Electronics of 1 CPV module consists of:

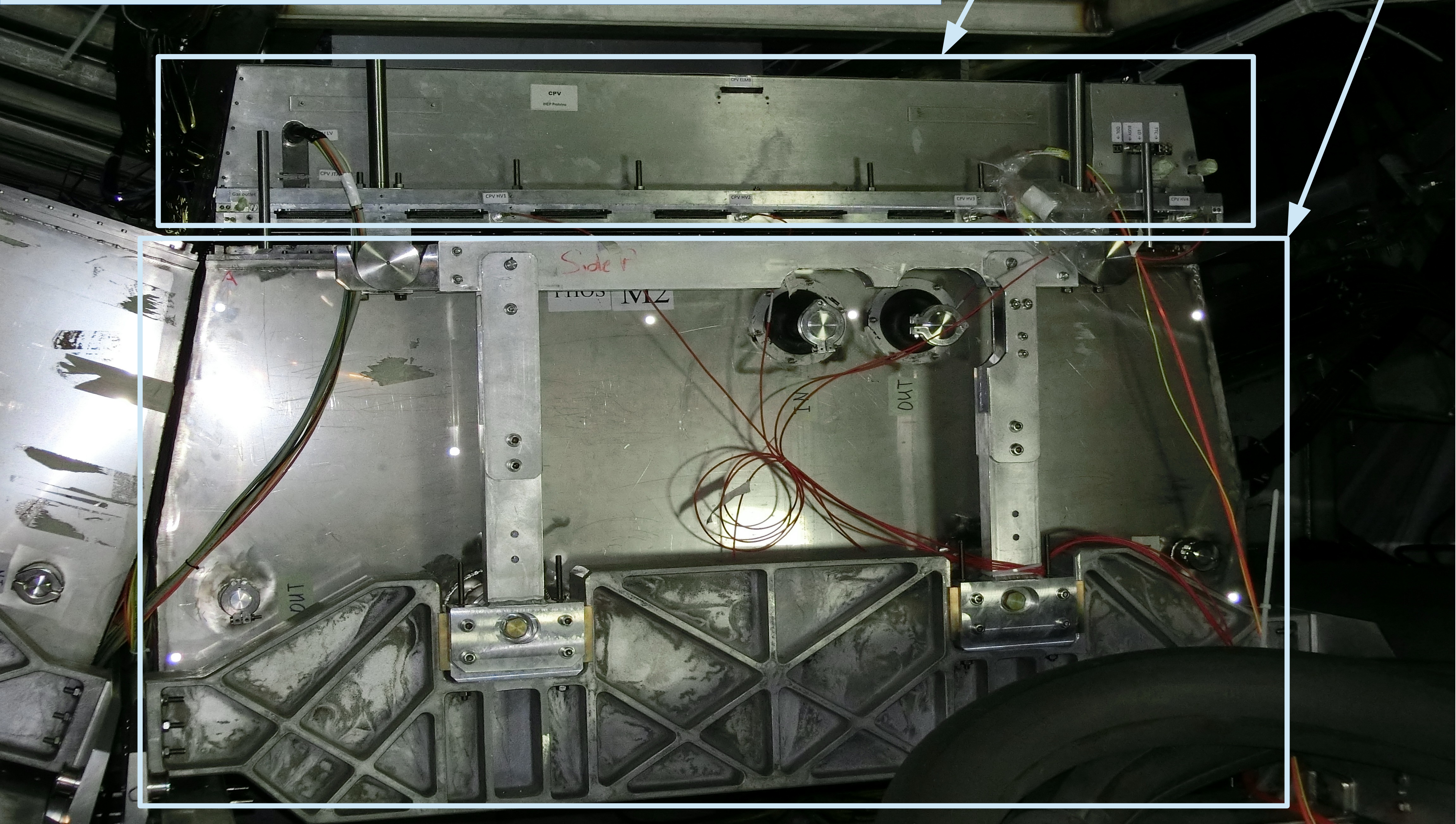
- **160 3gassiplex cards – 48-channels charge-sensitive amplifiers with signal multiplexing**
- **32 Dilogic cards – 5 ADC (12 bits), each ADC for multiplexed readout of 48 channels**
- **16 Column Controllers – readout controllers for 2 Dilogic cards each**
- **2 Segment cards – motherboard for 8 Column Controllers and 16 Dilogic cards**



- **1 RCB card – optical DAQ interface (1 DDL) and optical(TTC)+LVDS(L0+busy) trigger interface**
- **Readout time in Run2: ~200μs (physics runs) – ~1800μs (fully occupied module)**

CPV@ALICE cavern

- 1 CPV module was installed in 2014 during LHC LS1
- It is participating in data taking in 2015-2018 (LHC Run2)

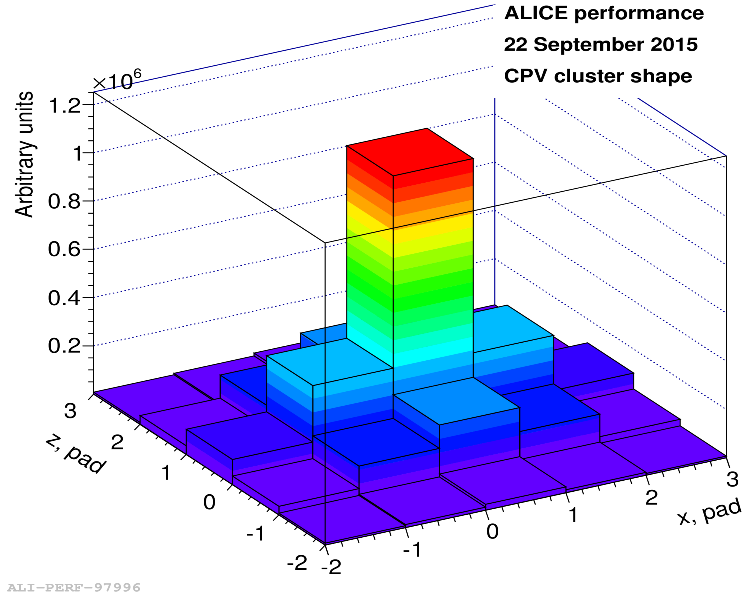


Performance study

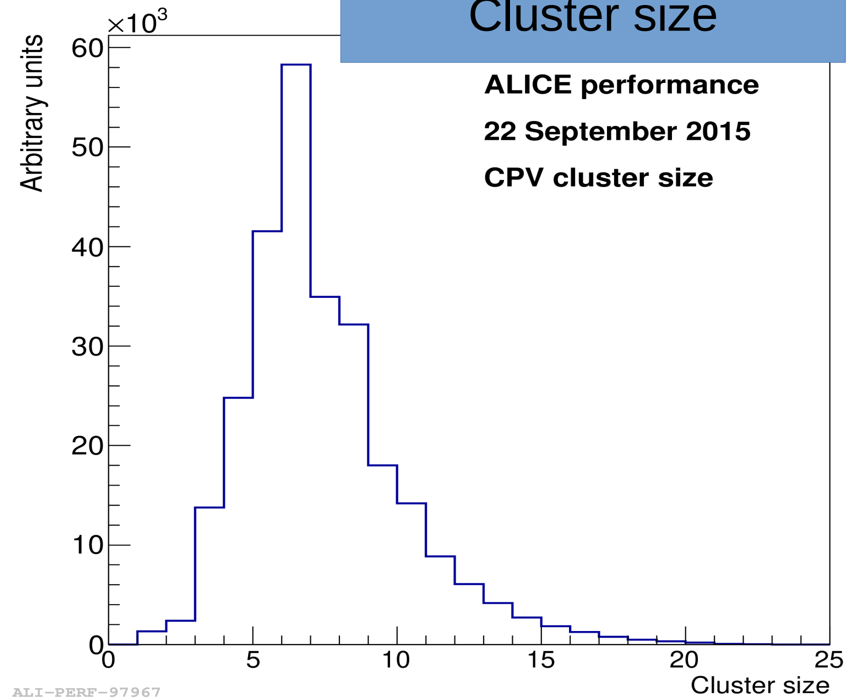
- CPV performance was studied using pp collisions at $\sqrt{s}$ = 13 TeV collected by ALICE in 2016-2017:
  - Signal study – optimization of selection criteria for charged-particles candidates;
  - Efficiency study – one needs to be sure that efficiency for charged-particle registration is close to 100%;
  - Physics performance study – do we improve signal/background ratio for neutral particles detected by PHOS?

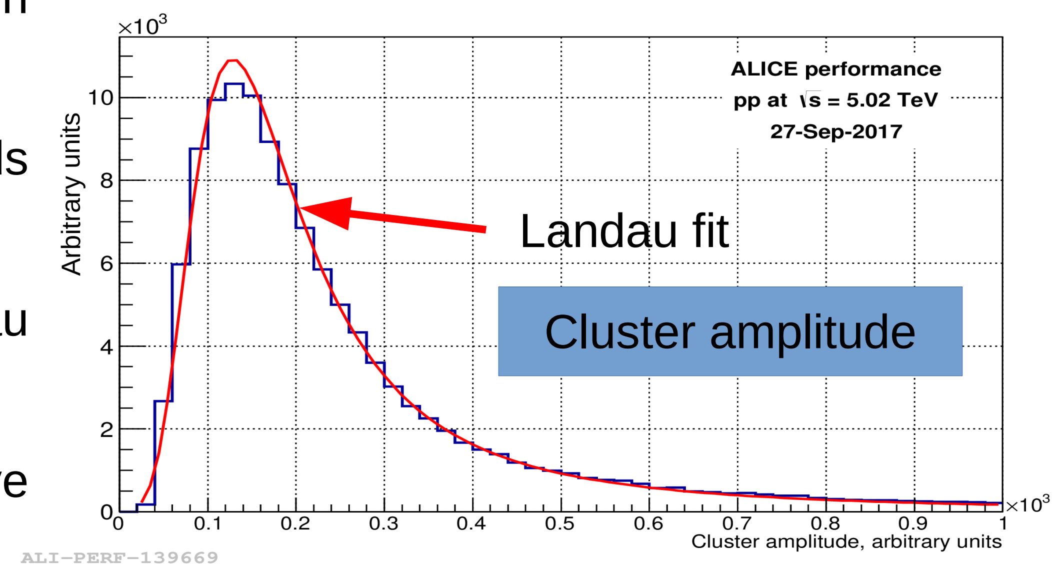
Signals in CPV

Cluster shape



Cluster size





Cluster amplitude

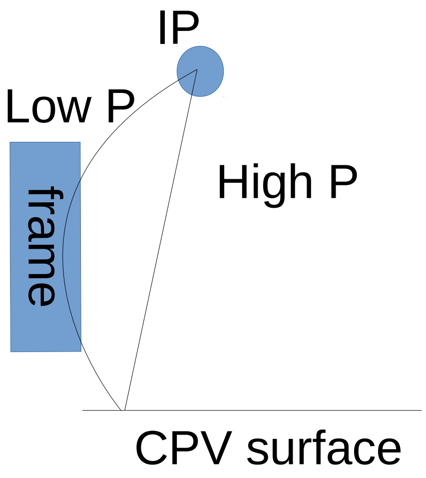
- Charged particle causes ionization in electric field of the chamber which induces charge in a segmented cathode-pad plane;
- Signal is reconstructed as a cluster of pads with induced charge;
- Total cluster amplitude follows Landau distribution;
- Cluster size is large enough to achieve designed coordinate resolution (3 mm).

Efficiency for charged-particle registration

- Efficiency of CPV is calculated as a probability of charged tracks penetrating the CPV, to produce a cluster in CPV:
  - track matches PHOS cluster → total number of tracks traversing the CPV (N_{tot});
  - track matches PHOS and CPV clusters → number of registered CPV tracks (N_{reg});

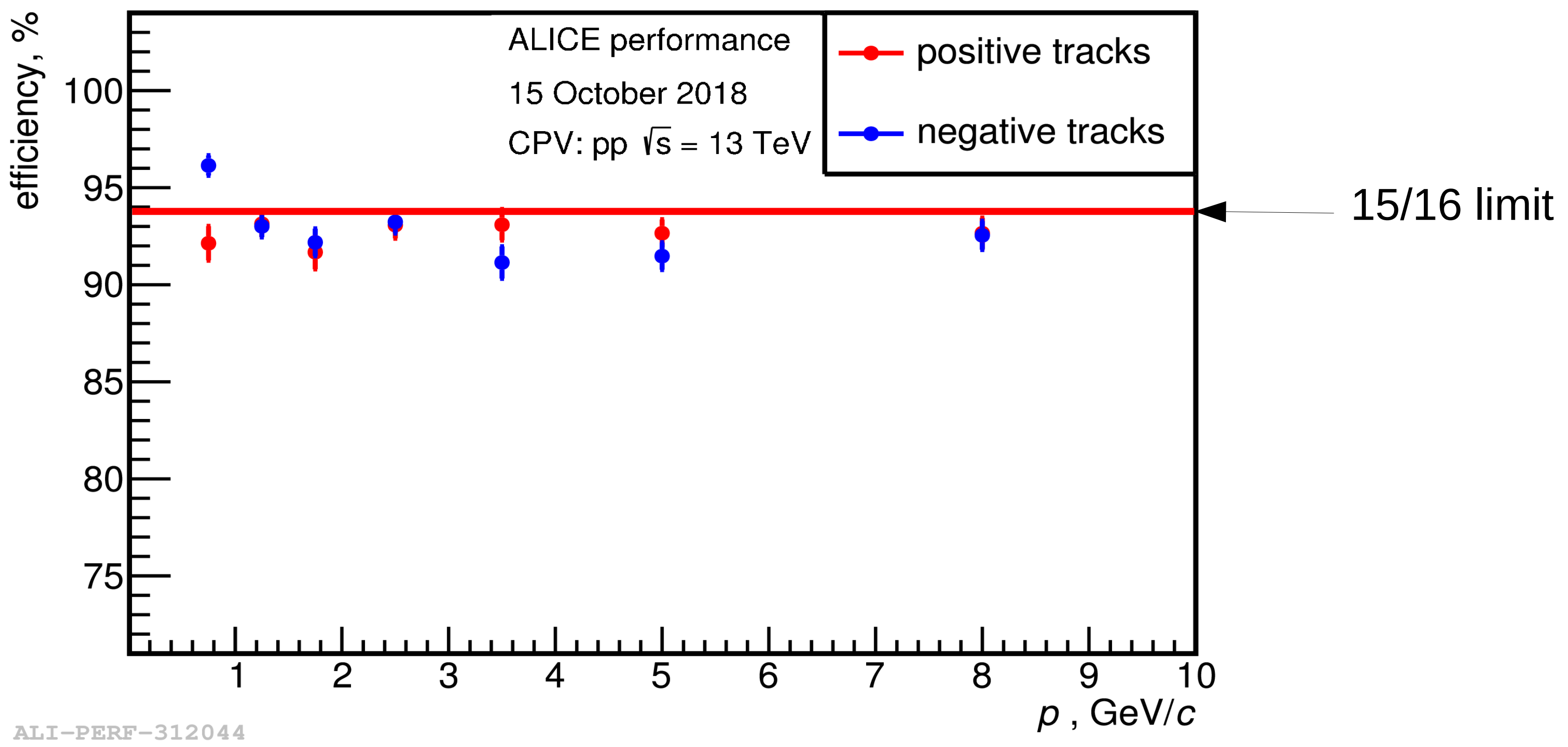
$$\varepsilon = \frac{N_{reg}}{N_{tot}}$$

- 1/16 of the FEE cards is faulty and excluded from data taking, hence, efficiency of the module is limited by 15/16 (~94%).
- Particles with different momenta, which hit the same point at the CPV surface, travel along different trajectories:
  - Low-momentum tracks have significant curvature so they can interact with ALICE supporting frame;
  - High-momentum tracks are almost straight such effects are therefore less pronounced;
  - Efficiency is studied as a function of track momentum.



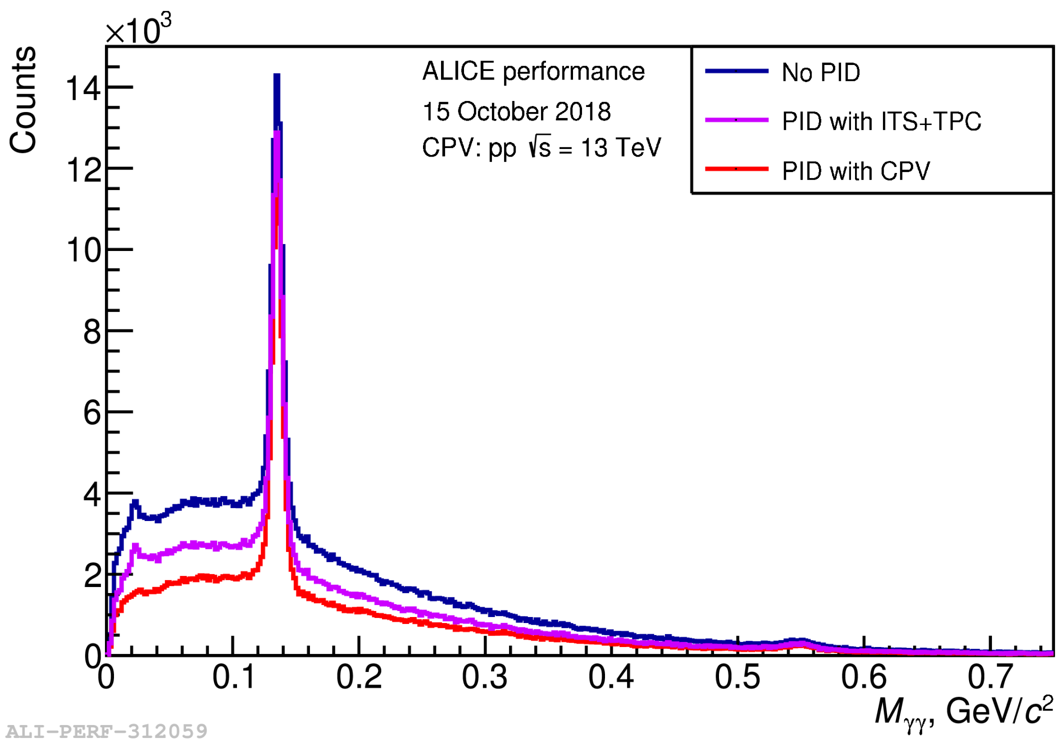
Efficiency for charged-particle registration (2)

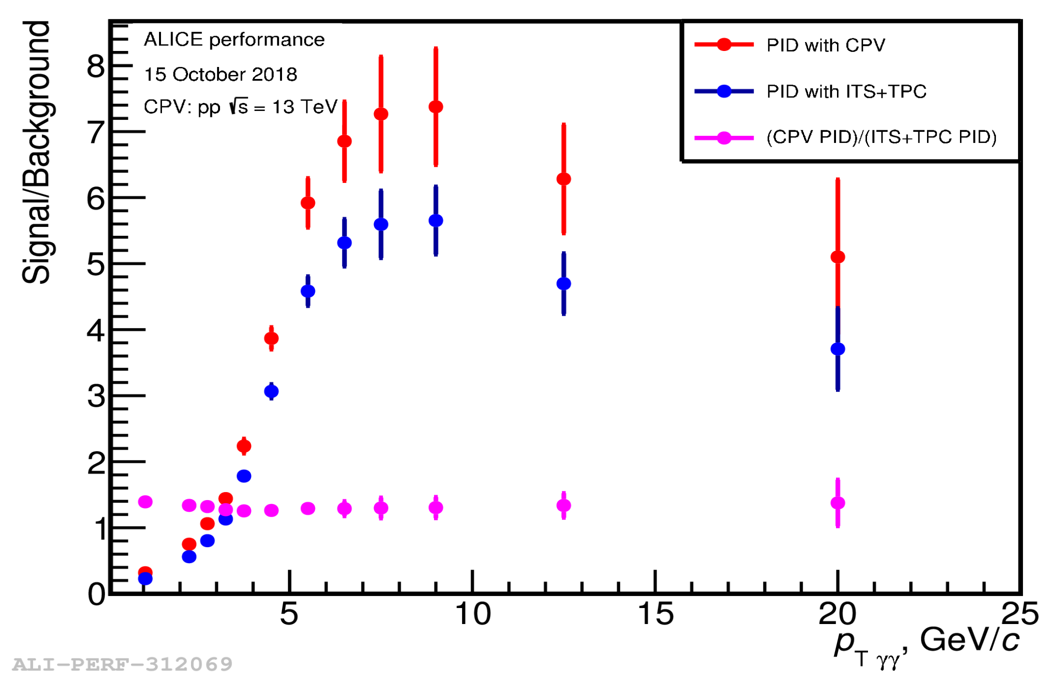
- Efficiency is close to its geometrical acceptance 15/16 (94%);
- For edge effects, when track hits CPV module close to borders of sensitive volume, the registration efficiency is decreased by ~1-2%;
- Obtained efficiency is almost independent from track momentum variation.



Improvement of signal/background (S/B) ratio in PHOS

- Performance of CPV in terms of background suppression is studied by comparing signal/background ratio for $\pi^0 \rightarrow 2\gamma$ decays detected by PHOS;
- PHOS clusters can also be identified using the ALICE central tracking system. However, charged tracks created at radii beyond 1.8 m (late photon conversion of strange hadron decays) cannot be reconstructed, but do create a background in PHOS. CPV helps to eliminate such background.
- CPV improves S/B ratio by factor 1.2 – 1.4 comparing to tracking system identification;
- π^0 loss due to identification with CPV is at the level of 6%;





Conclusion

- One module of CPV is successfully participating in ALICE data taking of LHC Run2 period;
- Settings of the detector (HV, gas mixture) were optimized during that period ;
- CPV detection efficiency for charged tracks is 93%/(15/16) = 99%;
- CPV improves signal/background ratio for $\pi^0 \rightarrow 2\gamma$ decays by factor 1.2 – 1.4 comparing to tracking system identification; small rejection of signal events (~6%) is observed.

Plans

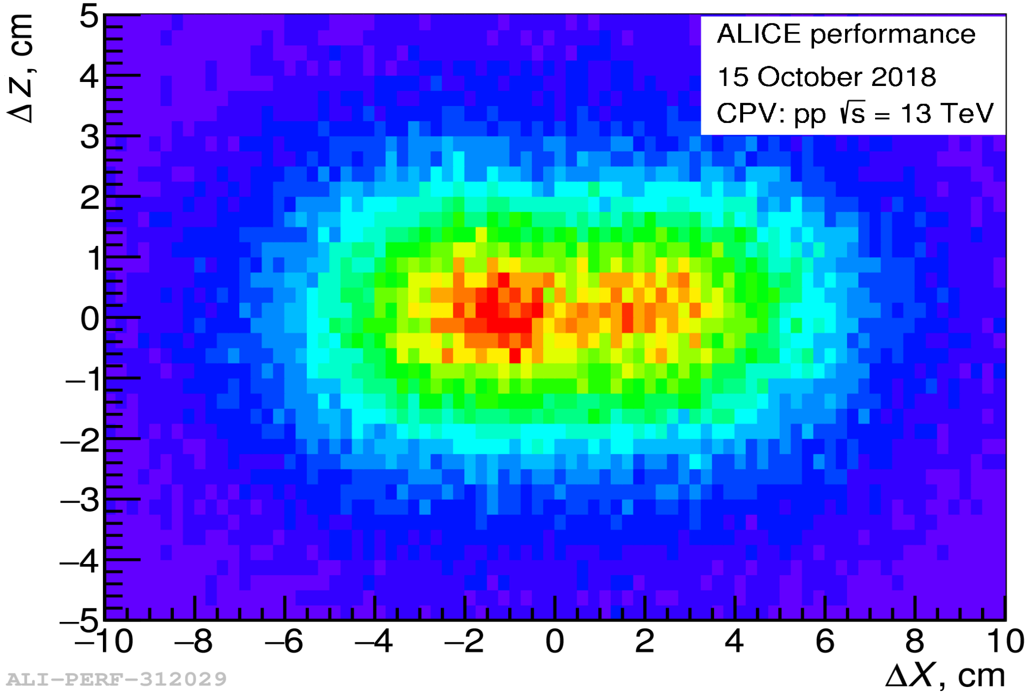
- 2 new modules were built and delivered to CERN; to be installed in the ALICE cavern during LHC Long Shutdown 2;
- FEE is a subject for upgrade: new prototypes are developed to handle 50 kHz readout rate (currently only 5 kHz at max).

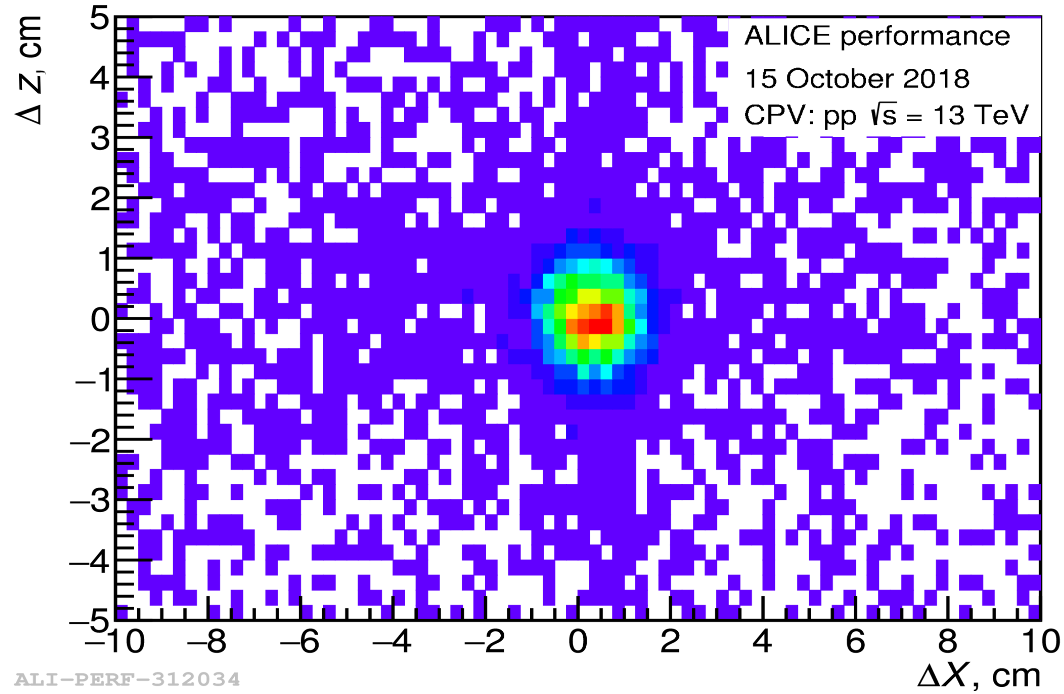
Backup
Cluster matching: PHOS-tracks

Correlation between track projections and PHOS clusters:

- Two peaks correspond to positive and negative tracks;
- The peaks are fitted by Gauss distribution in different momentum ranges;
- Matching criteria: $|(\Delta X,\Delta Z) - \mu_{(\Delta X,\Delta Z)}| < 1.1\ \sigma$

- Same procedure for matching CPV clusters and track projections but:
- Matching criteria: $|(\Delta X,\Delta Z) - \mu_{(\Delta X,\Delta Z)}| < 2.5\ \sigma$





Backup
Cluster matching: PHOS-CPV

- Correlation between PHOS and CPV clusters which originates from the same track