CPV detector of the ALICE experiment

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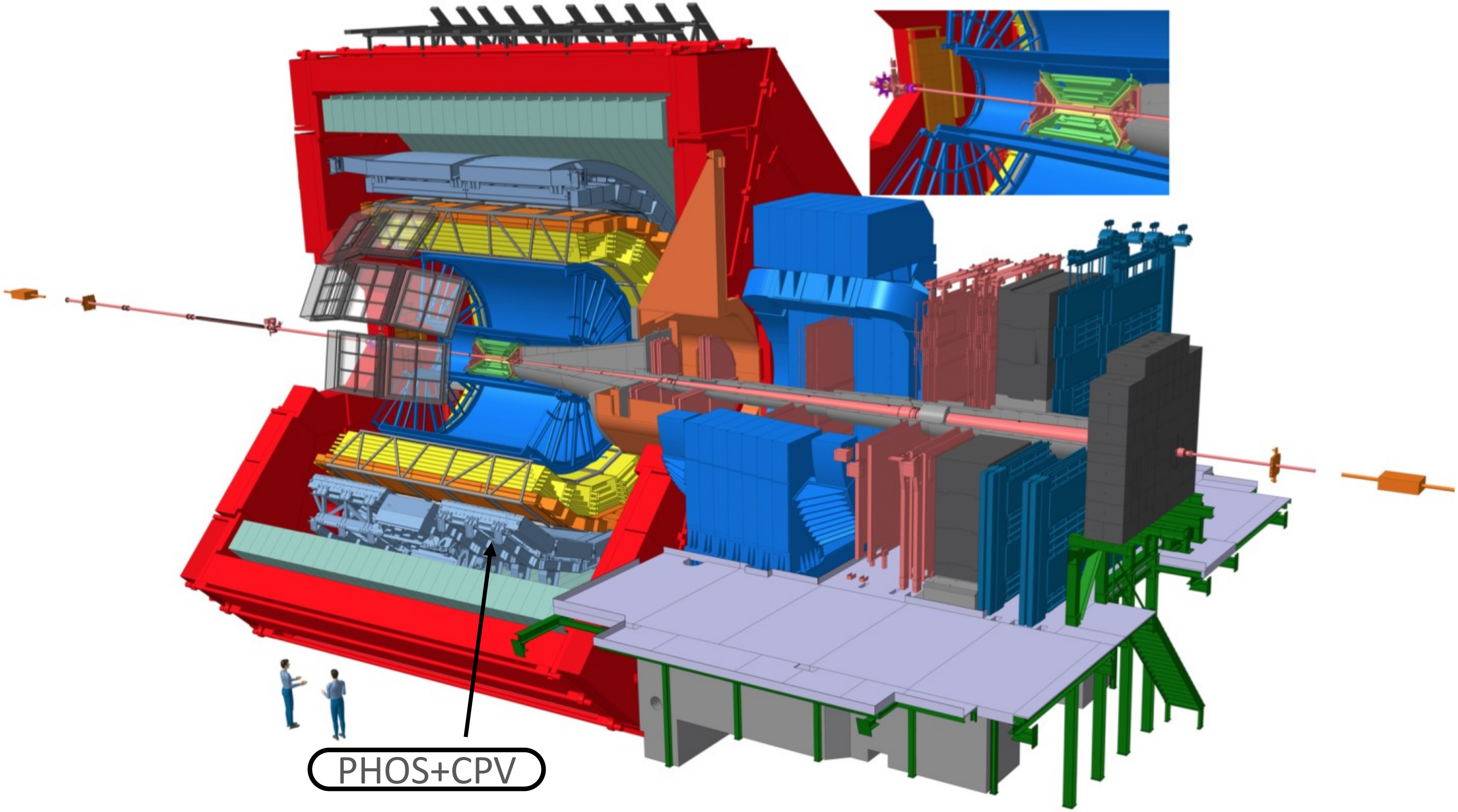
Introduction

Charge **P**article **V**eto detector (CPV) is multi-wire proportional chamber with cathode pad readout placed on the top of photon spectrometer PHOS to suppress charged-particle background of the photon sample detected in PHOS. Its main purpose is to improve neutral clusters identification in PHOS.



Physics motivation for CPV

- One of the tasks of ALICE is to study photons emitted directly from pp or PbPb collision, so-called “direct photons”.
- ALICE is equipped by a high-precision photon spectrometer PHOS, consisting of 12544 $PbWO_4$ crystals each one of size 2.2x2.2x18 cm.
- Signal of thermal photon radiation from hot QCD matter produced in AA collisions is expected to be observed in area $1<p_T<4$ GeV/c as a small excess over photons from hadron decays.
- Photon identification is an important task for decreasing systematical errors in the direct photon spectra.

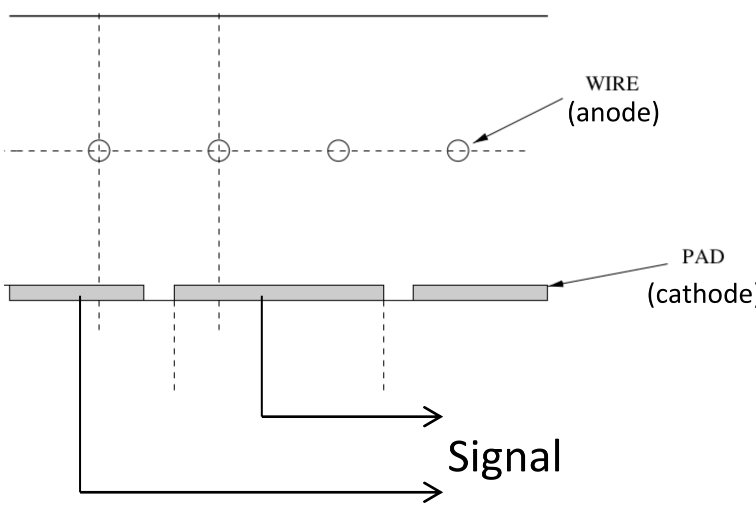
There are 3 methods of photon identification in ALICE:

- Shower shape of PHOS cluster -> discriminate electromagnetic and hadronic shower
- Cluster timing in PHOS -> discriminate fast particles (photons, electrons) from slow particles (heavier hadrons).
- Anti-matching of PHOS clusters and charged-particle tracks -> discriminate neutral clusters PHOS (photons) and charged clusters (electrons, charged hadrons). This is the CPV task.

Construction

- CPV is a proportional chamber with cathode pad readout.
- Charged track passes through the CPV ionizing the gas mixture. Ions induce charge on the segmented cathode, which is detected by the readout electronics.
- Track coordinate is reconstructed from a cluster of induced charge distribution

- CPV measures charged track hits in (x,y) plane with resolution 0.7-1 mm
- CPV is positioned at 12 cm above the PHOS crystal surface, thus cluster matching in PHOS and CPV will be used for photon identification.
  - -- PHOS and CPV cluster matching means that PHOS cluster is produced by charged particle.
  - -- No matching of PHOS and CPV means that PHOS cluster is produced by neutral particle.
- Induced charge in each pad is measured by individual front-end channel with charged-sensitive amplifier.
- One CPV module was installed above one PHOS module before Run2.



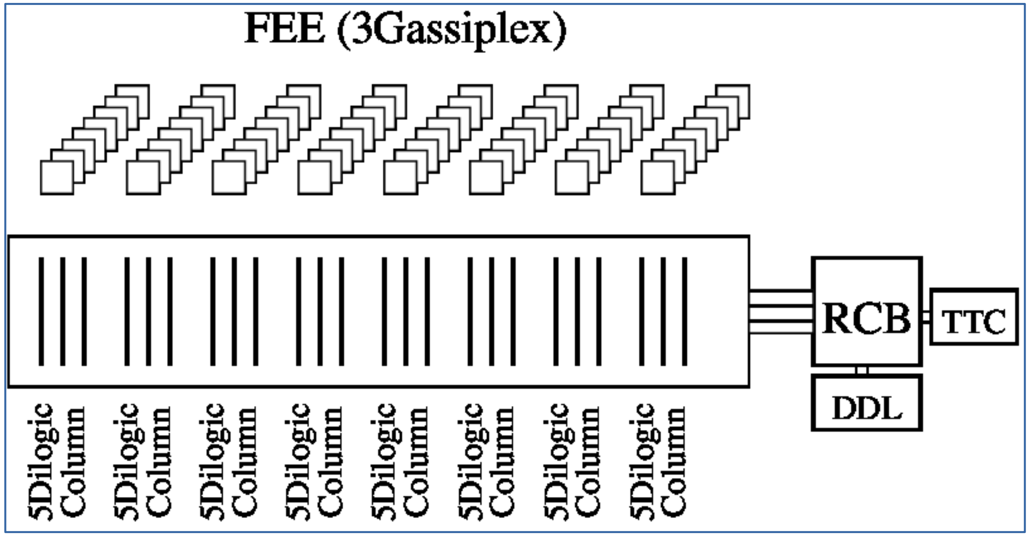
Main characteristics

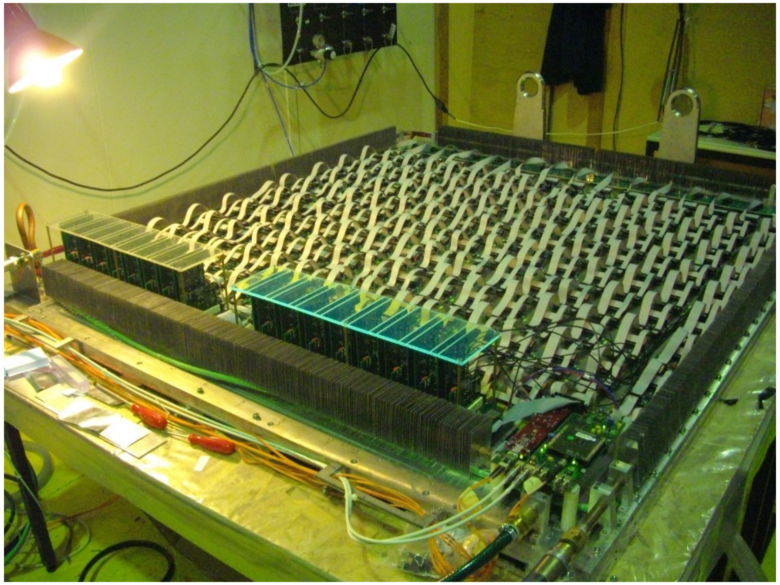
- Sensitive volume size: 140 x 123 x 1.4 cm^3
- Wire pitch – 5.6 mm
- Wire diameter – 28 μm
- Number of sensitive wires – 258
- Wire tension – 100 g
- Anode-cathode spacing – 7 mm
- Pad size – 21 x 10 mm^2
- Transverse segmentation: 128x60 pads
- Number of channels with charge-sensitive amplifiers – 7680
- Gas mixture – Ar(80%)+CO_2(20%)
- Nominal anode HV – 2.2 kV (+)
- Material budget – 5% X_0
- Designed coordinate resolution ≈1 mm

Readout

1 CPV module electronics consists of:

- 160 3Gassiplex cards – 48-channels charge-sensitive amplifiers
- 32 Dilogic cards – 5 ADC (12 bits) with sparse readout, each for multiplex readout of 48 channels
- 16 Column Controllers – readout controllers for 2 Dilogic cards each
- 2 Segment cards – readout controllers for 8 CC each
- 1 RCB card – optical DAQ interface (1 DDL) and optical(TTC)+ LVDS (L0+busy) trigger interface
- Readout time in Run2:
  - ≈ 200μs (low-multiplicity events)
  - ≈ 1800μs (fully occupied module)
- Data readout rate: 5 kHz in pp and 4 kHz in PbPb collisions





Detector control system

- DCS has the following hardware: 1 low voltage (LV) and 1 high voltage (HV) power supplies, temperature sensors inside the CPV, water valve with sensor for cooling and gas conditions monitoring tools. The latter is provided by the ALICE gas service.
- Software is CERN-wide standard: Siemens WinCC system of slow control+JCOP framework, written by the CERN team.
- Complex software is behind the simple setup. DCS tasks are:
  - correctly switch the detector states using the FSM
  - ensure safe work during the physics runs, using different automatic check and procedures
  - fix all failures without stopping the physics run, if possible

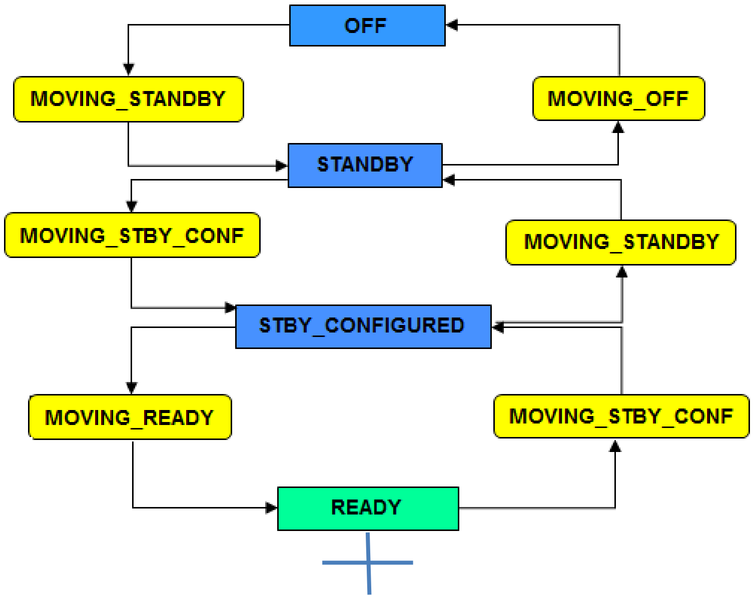
The possible states of the detector are the following:

State	Safety matrix	LV/HV	Run type	When
READY	NOT_SAFE	LV on, HV=2212V	PHYSICS	stable beam, cosmic
STBY_CONFIGURED	SAFE	LV on, HV=1000V	TECHNICAL, PEDESTAL	normal injection, beam tuning
STANDBY	SUPERSAFE	LV on, HV off	TECHNICAL	harmful injection
OFF	SUPERSAFE	LV off, HV off	none	L3 magnet ramp

Detector control system: safety

- CPV DCS is hosted on a single computer, it’s more then enough to control everything.
- All the finite states of the detector are set up according to the central DCS team’s requirements.
- CPV as a wire chamber can be easily damaged by the incorrect run conditions.
- Low voltage powers up readout electronics , high voltage creates electric field in the proportional chamber. HV can be switched on only when LV is on.
- There are a lot of checks happening during the transition between the main states to ensure the correct conditions at all times. This can slow all the procedures a bit because devices can’t react instantly on the changes, but CPV can be switched on relatively fast: <1 min from off to ready.

FSM (finite state machine) scheme

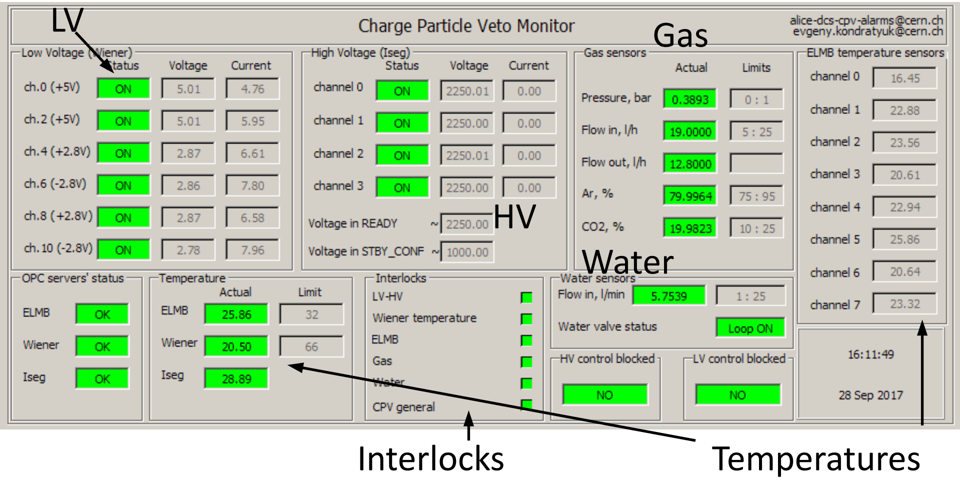


Unusual states: error, mixed, etc.

Detector control system: safety

- The DCS has a number of safety scripts (software interlocks), which monitor state of the detector and save it from damage in case of any accident, because operator can’t watch it all the time.
  - LV-HV interlock – Low voltage powers up readout electronics , high voltage powers up wires. HV without LV can burn the electronics, so we need to prevent this. Happened several times for the past years because of global power blackouts.
  - Temperature interlock – if it’s too hot inside the CPV, it will be switched off – never happened, cooling works fine. Power supplies also have sensors.
  - Water and gas interlocks – concentration, flow and pressure must be in pre-set limits.
- In case of trip the corresponding HV channel is switched off without breaking the global run. Run is paused while the channel is switching off (≈ 15sec).
- Notifications about hardware failures and software interlocks are distributed via the ALICE alarm panel and via e-mails

DCS panel for online monitoring



Operational issues

- Different electronics' glitches:
  - Missing columns → when one of column controllers doesn't work correctly, 1/16 of the detector is out of data taking
  - High busy time and large event size → some noisy channels may overcome the pedestal threshold. More signals from pads require more time for electronics to process them.
  - "Single event upset" → particle interacts with electronics
  - Noise in single 3gassiplex card → makes all of channels under a single card noisy
  - "Start of run" signal is not received
- All problems with electronics are rare and can be solved with "power cycle" procedure: switch off/on electronics, takes ≈ 20 seconds.

- High voltage trips → discharge inside the gas volume, between wire and pads. Can be detected as a high current in the HV power supply or at the data quality plots online.

- CPV Participation in Runs since 1.09.2015: **98.4%**

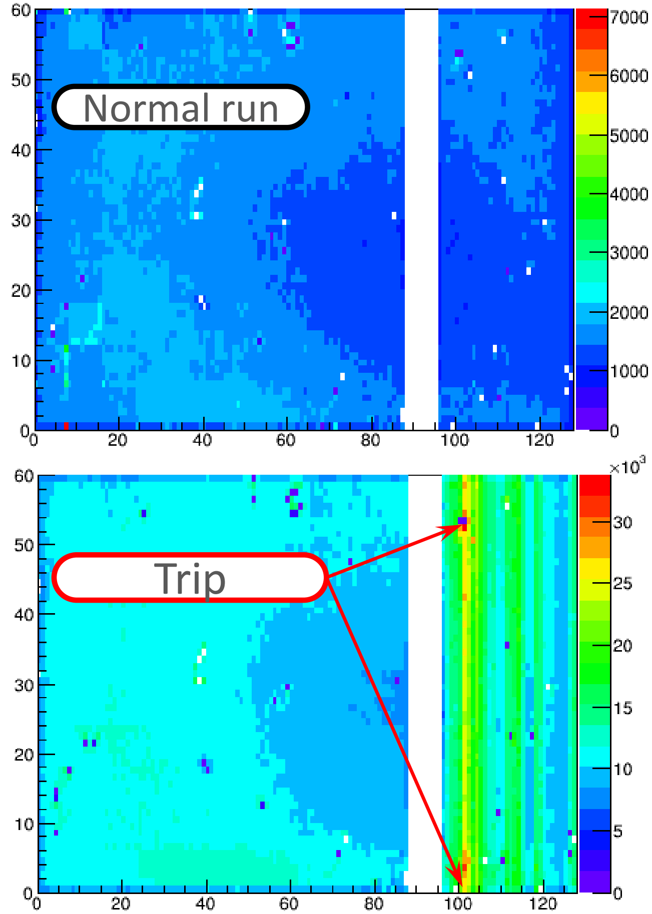
HV trips at high-luminosity and recovery

- HV trips are observed in runs with high particle flux: Pb-Pb, high-luminosity p-Pb and pp collisions.
- This first experience of CPV operation with collisions forced us to look for optimal detector conditions: nominal HV (2212V), gas relative concentration (83% Ar + 17% CO_2), gas flow (13.4 l/h).
- At the end of Pb-Pb run 2015, optimal conditions were found until the high luminosity pp-collisions at 700 kHz
- Stripes in the right part of the module, along the wires

- We had trips in pp runs at high luminosity 700 kHz, gas mixture is being attuned to fix this -> CO_2 percentage is increased up to 20%.

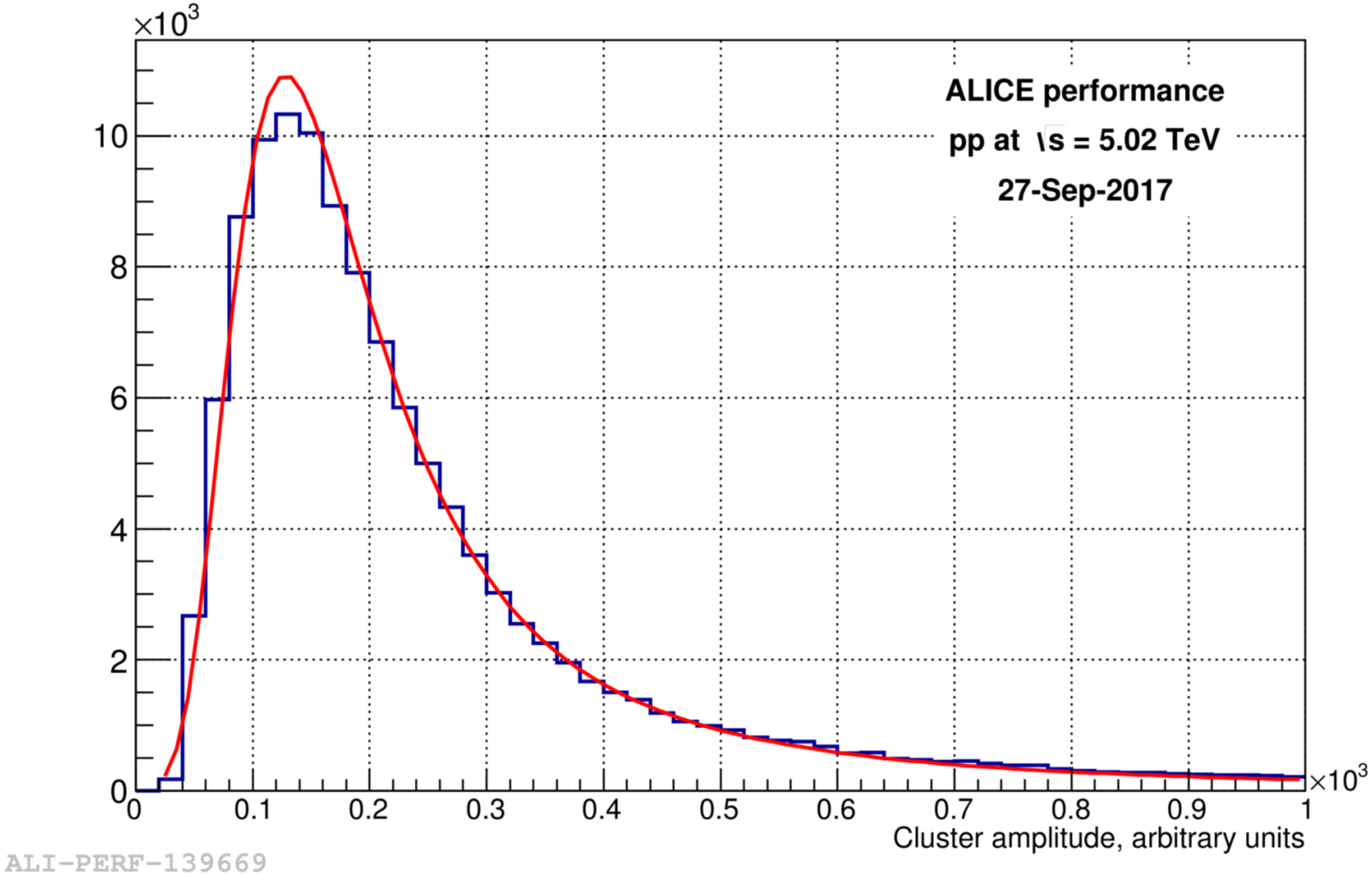
Map of CPV, each rectangle represents a single pad.

Color indicates total amplitude of signals, in arbitrary units.



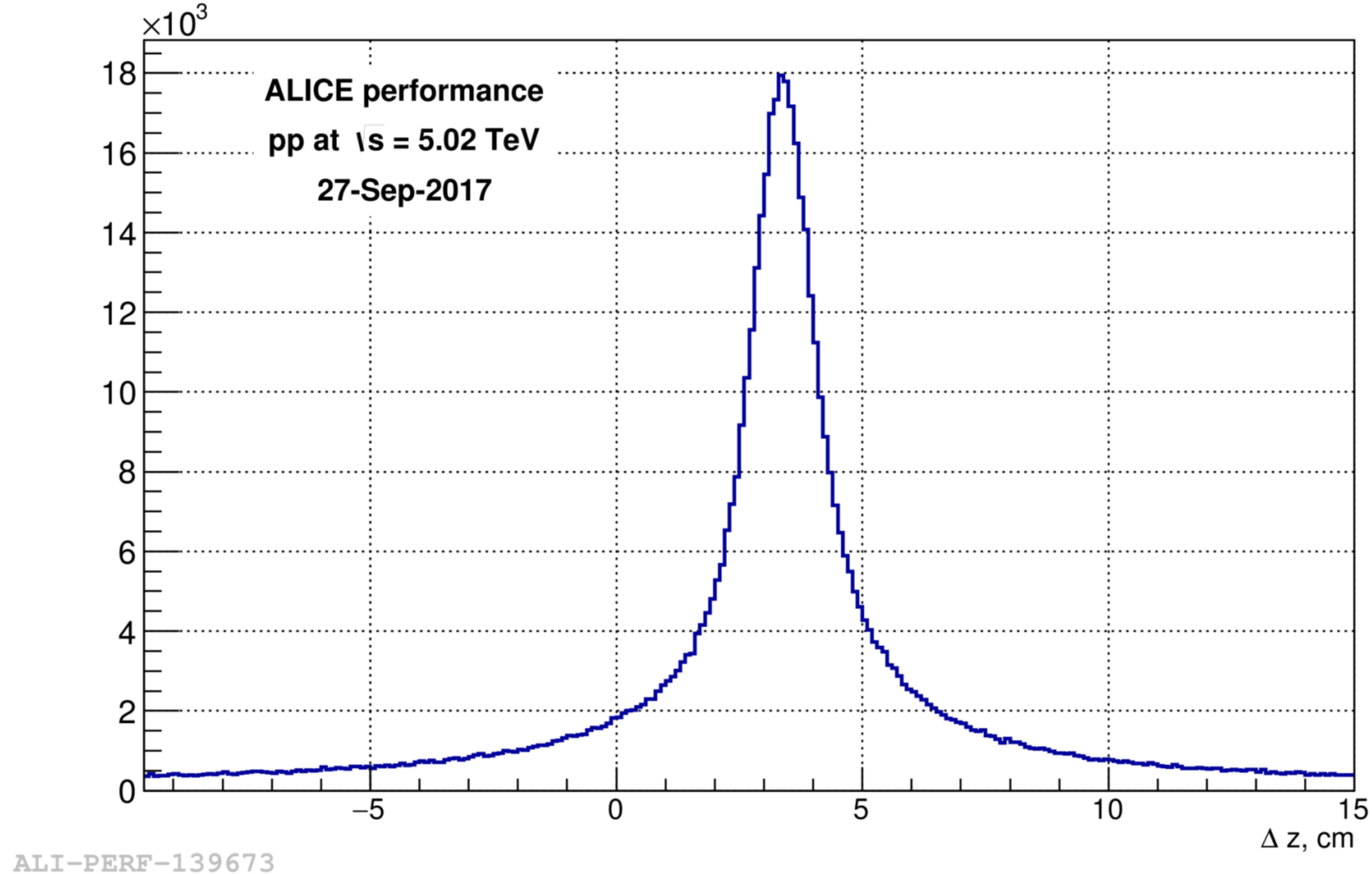
Performance

- Amplitude spectrum of CPV clusters matched with charged tracks reconstructed in central tracking system in pp collisions at 5.02 TeV.
- CPV cluster has 3 and more pads. Measured induced charge is defined by ionization energy loss of charge particles punching the CPV which is well described by Landau distribution (red curve)



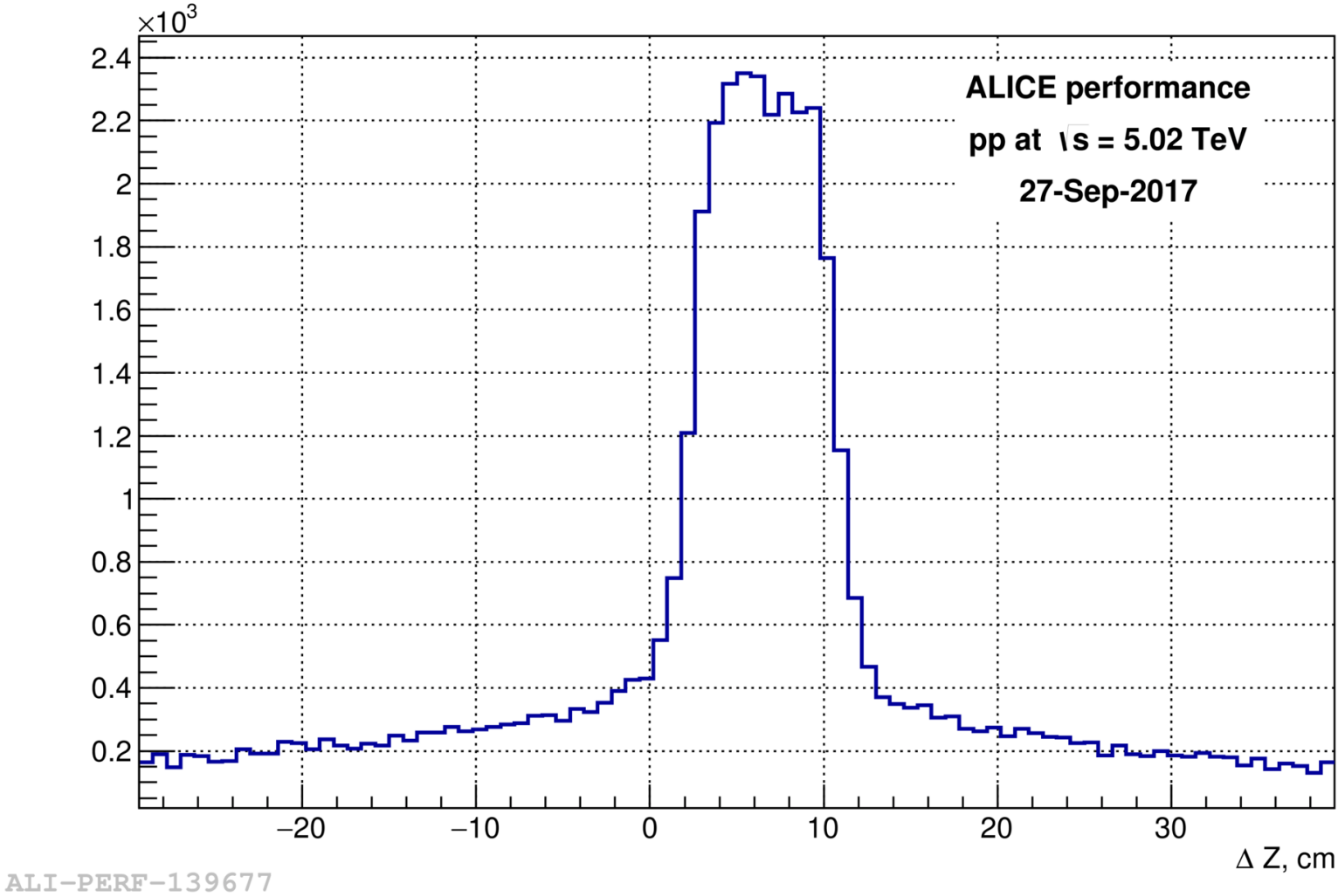
Performance

- Matching distance along z axis between the CPV cluster and projection of the global track to the CPV surface. Analysis of pp at 5.02 TeV.
- Main peak on the distribution corresponds to clusters produced by reconstructed charged tracks, while background is clusters uncorrelated with global tracks.
- The peak position is displaced at 3.3 cm which is explained by the CPV misalignment with respect to the central tracking system.



Performance

- Matching distance along z axis between the CPV cluster and PHOS clusters at energy 1<E<2 GeV. Analysis of pp at 5.02 TeV.
- Main peak on the distribution corresponds to PHOS clusters produced by charged tracks which also generated a CPV cluster, while background is PHOS and CPV uncorrelated clusters.
- Photon is identified as cluster outside the width of this main peak or as cluster without a track.



Conclusion

- One module of the Charge Particle Veto for PHOS spectrometer is produced and installed successfully.
- It was fully integrated into ALICE DCS and ECS.
- Its performance is tested in the laboratory and during data taking.
- Clusters of CPV, PHOS and TPC tracks are correlated.
- We are looking forward first direct photons measurements in PbPb collisions during Run2 of the LHC as CPV provides such abilities to reject charged particle hits from PHOS.

Plans

- Production and installation of another 2 modules is planned during LHC LS2 (2018-2020).
- FEE will be modified for the purposes of HL-LHC. CPV will be suitable for high collision rates.
- Increase of acceptance and data taking speed will greatly extend amount of collected data for direct photons measurement in Run3 of the LHC.

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