CPV detector of the ALICE experiment

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Introduction

Charge Particle Veto 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:

<table>
<thead>
<tr>
<th>State</th>
<th>Safety matrix</th>
<th>LV/HV</th>
<th>Run type</th>
<th>When</th>
</tr>
</thead>
<tbody>
<tr>
<td>READY</td>
<td>NOT_SAFE</td>
<td>LV on, HV=2212V</td>
<td>PHYSICS</td>
<td>stable beam, cosmic</td>
</tr>
<tr>
<td>STBY_CONFIGURED</td>
<td>SAFE</td>
<td>LV on, HV=1000V</td>
<td>TECHNICAL, PEDESTAL</td>
<td>normal injection, beam tuning</td>
</tr>
<tr>
<td>STANDBY</td>
<td>SUPERSAFE</td>
<td>LV on, HV off</td>
<td>TECHNICAL</td>
<td>harmful injection</td>
</tr>
<tr>
<td>OFF</td>
<td>SUPERSAFE</td>
<td>LV off, HV off</td>
<td>none</td>
<td>L3 magnet ramp</td>
</tr>
</tbody>
</table>
Detector control system: safety

- CPV DCS is hosted on a single computer, it’s more than 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.

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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.
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% CO₂), 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 -> CO₂ 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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