ALICE Commissioning: Getting ready for Physics

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Moriond QCD and High Energy Interactions
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Outline

• Introduction to ALICE
• ALICE Commissioning in 2007-09.
• Status and some selected results:
  1) ITS,
  2) TPC,
  3) ACORDE,
  4) ‘Outer’ Central Detectors: TRD, TOF, HMPID, PHOS, EMCAL,
  5) Muon Spectrometer,
  6) ‘Forward Detectors’: FMD, T0, V0, ZDC, PMD.
• Status of Trigger, HLT, DCS, DAQ.
• Summary & Outlook.
ALICE is the dedicated heavy ion experiment at LHC:

- Study Pb-Pb collisions at 5.5 TeV per nucleon pair.
- Study the physics of strongly interacting matter at extreme energy densities (formation of quark-gluon plasma).
- Carry out detailed studies of the hadrons, electrons, muons and photons produced in the collisions.
- High multiplicities ⇒ high granularity;
- low momenta ⇒ low material budget.
- Chose TPC as main tracking detector (slow as compared to other LHC experiments).

ALICE will also study p-p collisions at 14 (10) TeV:

- For comparison with Pb-Pb collisions and
- in physics areas where Alice complements the other LHC experiments.
Size: 16 x 26 meters
Weight: 10,000 tons
Detectors: 18
ALICE commissioning in 2007-09

1st global run  
10-21 Dec

2nd global run  
4 Feb-9 Mar

3rd global run  
5 May – 20 Oct

First particles from machine  
15 Jun

Injection tests  
8 Aug, 24 Aug

1st Circulating beam  
10 Sep

Installation & Commissioning

24/7 operation

Installation & Upgrade
1) **ITS: Inner Tracking System**

- 3 different silicon detector technologies (2 layers each):

<table>
<thead>
<tr>
<th>Detector</th>
<th>Technology</th>
<th>Acceptance ((\eta, \phi))</th>
<th>Radial position ((m))</th>
<th>N. of channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPD</td>
<td>Pixel</td>
<td>(\pm 2 \ (\pm 1.4), 2\pi)</td>
<td>0.039, 0.076</td>
<td>9.8 M</td>
</tr>
<tr>
<td>SDD</td>
<td>Drift</td>
<td>(\pm 0.9, 2\pi)</td>
<td>0.15, 0.239</td>
<td>133000</td>
</tr>
<tr>
<td>SSD</td>
<td>Strip</td>
<td>(\pm 0.97, 2\pi)</td>
<td>0.38, 0.43</td>
<td>2.6 M</td>
</tr>
</tbody>
</table>

- **Fully installed and commissioned.**

- 'Pixel trigger' :
  - Fast-OR of 1200 SPD chips; available for Level 0;
  - Different programmable algorithms: High multiplicity, minimum-bias, cosmics, ...
  - ALICE is the only LHC experiment including the vertex detector in the first trigger decision from startup.

- **Operational.**
Lowering the ITS into the Cavern
(March 2007)
ITS Alignment (1)

Silicon Pixel Detector (SPD):
- ~10M channels
- 240 sensitive vol. (60 ladders)

Silicon Drift Detector (SDD):
- ~133k channels
- 260 sensitive vol. (36 ladders)

Silicon Strip Detector (SSD):
- ~2.6M channels
- 1698 sensitive vol. (72 ladders)

**ITS total: 2.2k alignable sensitive volumes → 13k degrees of freedom**

- Alignment using tracks and Millepede program in a hierarchical approach
- ~50k cosmic µ for alignment collected since end of May, using Pixel trigger
ITS Alignment (2)

Preliminary results for SPD (Pixels):

- Track-to-track (top vs bottom) distance in transv. plane

  \[ \sigma = 55 \mu m \] (vs 40 \( \mu m \) in simul. without misalignment)

- Track-to-“extra clusters” distance in transv. plane

  \[ \sigma = 21 \mu m \] (vs 15 \( \mu m \) in simul. without misalignment)

- These results indicate a residual misalignment of < 10 \( \mu m \), after realignment with cosmics.
- This is to be compared to a detector position resolution of 12 \( \mu m \) in \( r_\phi \).
• Event from very first injection tests in August 2008.
• Self-triggering with the Pixel Trigger.
• In general ITS, V0 and FMD (and often Muon) were on during injection tests.
First Interaction in ALICE

- Collision of beam-halo particle with SPD.
2) **TPC: Time Projection Chamber**

- The largest TPC ever;
- Optimized for \( dN/d\eta \approx 8000 \);
- \( L=5 \text{ m}, \ \phi = 5 \text{ m}, \ 88 \text{ m}^3 \);  
- Material (\( \eta=0 \)): 3\% \( X_0 \);
- Drift gas: Ne/CO\(_2\)/N\(_2\) (86/9.5/4.5\%) + \sim 1 \text{ppm} \ O_2 ;
- Drift time: 92 \ \mu s;
- \sim 570 \ 000 \ \text{pads} \  
  (\Rightarrow \sim 570 \ \text{Mio pixels}),
- Highly integrated digital electronics (ALTRO chip);
- Laser calibration system;
- **Installed and commissioned.**
Installation of the ALICE TPC

- Field Cage Assembly: 2002-04
- Readout Chamber Installation: 2005
- Electronics Installation: 2006
- Installation in cavern: 2007
- Commissioning/Calibration: 2007-09
Moving the TPC over the ITS
(September 2007)
TPC Calibration

- TPC was running continuously May-October 2008.
- 60 million events (Cosmic, krypton and laser) recorded.
- First round of calibrations completed.

Transverse momentum resolution, $B=0.5 \ T$

- Resolution at 10 GeV:
  - Measured: 6.0%
  - Design: 4.5%

Particle identification via $dE/dx$

- Resolution:
  - Measured: 5.7%
  - Design: 5.5%

Performance close to design value, TPC ready for collisions
3) ACORDE: Alice COsmic Ray Experiment

- Provides cosmic ray trigger.
- 60 modules with two plastic scintillator paddles with $190 \times 19.5 \text{ cm}^2$ effective area.
- Cosmic $\mu$ ($E \geq 10 \text{ GeV}$) reach ACORDE at $\leq \sim 5\text{Hz/m}^2$.
- Multi-$\mu$ events at $\leq 0.1 \text{ Hz/m}^2$.
- Operational.
4) ‘Outer’ Central Detectors (1)

- **TRD**: Transition Radiation Detector.
  - Drift chambers filled with Xe, CO₂; ~1 180 000 pads;
  - $|\eta|<0.9$, $\Delta\varphi=2\pi$, $R\geq 295\text{cm}$;
  - *Electron ID* for $1<p<10$ GeV/c; *trigger* on high momentum particles.
  - 20% now installed & commissioned.
    Up to 45% for 2009 run.

- **TOF**: Time Of Flight detector.
  - MRPCs (a revolution in TOF PID!); ~160 000 pads;
  - System resolution: <100 ps;
  - $|\eta|<0.9$, $\Delta\varphi=2\pi$, $R\geq 370\text{cm}$;
  - *Particle ID* ($\pi/K$ up to 2.5 GeV/c, $p/K$ up to 5 GeV/c), *timing and triggering*.
  - Fully installed & commissioned.
4) ‘Outer’ Central Detectors (2)

- **HMPID**: High Momentum Particle ID.
  - Proximity focused RICH, 7 modules, ~16 100 pads;
  - Acceptance: \(|\eta|<0.6; \Delta\phi=58\text{deg}; R\geq450\text{cm};\)
  - *Particle ID* (\(\pi^\pm/K^\pm\) for 1<\(p<3\) GeV/c, p for 2<\(p<5\) GeV/c).
  - Fully installed and commissioned.

- **PHOS**: PHOton Spectrometer.
  - \(\text{PbO}_4\text{W}-\) crystal calorimeter, 5 modules; ~18 000 crystals; APD read out;
  - Acceptance: \(|\eta|<0.12; \Delta\phi=100\text{deg.}; R\geq460\text{cm};\)
  - *Particle ID* (\(\gamma,\pi^0,\eta\)) up to 10 GeV/c, possibly higher momenta; Level 0 *trigger*;
  - Will be partially installed for 2009 Run.
4) ‘Outer’ Central Detectors (3)

- **EMCAL**: ElectroMagnetic CALorimeter.
  - Pb-Scintillators; 12 modules; ~13,000 projective towers in ‘Shashlik’ geometry; APD read out.
  - Acceptance: $|\eta|<0.7$; $\Delta\phi=107\text{ deg.}; R \geq 430\text{ cm}$;
  - Project approved in December 2007. 8% to be installed in March 2009. Possibly 25% for 2009 Run.
Planned Status for Central Detectors for 2009 Run
5) Muon Spectrometer

- Fully installed & commissioned.

• Acceptance on single $\mu$:
  - $p > 4$GeV/c;
  - $-0.4 < \eta < -2.5$.

• Tracking:
  - 5 tracking stations; two planes each.
  - Cathode pad chambers; 60$\mu$m space resolution.

• Triggering:
  - 2 Trigger stations; two planes each.
  - RPC technology; avalanche or limited streamer mode.
Partial view of Muon chambers
A Rare Horizontal Particle
6) ‘Forward Detectors’ (1)

- **FMD**: Forward Multiplicity Detector
  - 3 planes of Si-pad detectors;
  - *Charged particle multiplicities and elliptic flow*;
  - Acceptance: $-3.4<\eta<-1.7; 1.7<\eta<5.03$.
  - Fully installed for 2009 Run.

- **T0**:
  - 2 arrays of 12 PMTs with quartz radiators;
  - *Time reference* for TOF (30 ps resolution) and *vertex measurement*.
  - Fully installed for 2009 Run.

- **V0**:
  - 2 arrays of 32 scintillator tiles (600ps resolution);
  - Level 0 *centrality trigger & luminosity monitor, beam-gas rejection*.
  - Fully installed for 2009 Run.
6) ‘Forward Detectors’ (2)

- **ZDC**: Zero Degree Calorimeter.
  - 2 neutron and 2 proton calorimeters at +/-116 m;
  - *Measure spectators*;
  - *Fully installed for 2009 Run*.

- **PMD**: Photon Multiplicity Detector.
  - Pre-shower detector;
    ~220 000 channels;
  - *Measure photon multiplicities*;
  - Acceptance: 2.3<\(\eta<3.7\).
  - *Fully installed for 2009 Run*.
Trigger, DAQ, DCS, HLT

• **CTP**: **C**entral **T**rigger **P**rocessor.
  • Hierarchy of three levels (L0, L1, L2).
  • Operational.

• **DAQ**: **D**ata **A**c**Q**uisition.
  • Data rate adequate for p-p collisions: Up to 400 MB/s sustained, 1.3GB/s for short periods.
  • 1.2 GB/s sustained data rate planned for LHC luminosity increase.
  • 2.5 PB/year.
  • Operational.

• **HLT**: **H**igh-**L**evel **T**rigger.
  • Currently 1,000 processors; scalable to 20,000.
  • Data pre-processing and compression; trigger decisions.
  • Operational.

• **DCS**: **D**etector **C**ontrol **S**ystem.
  • Operational.
• ALICE is the general purpose *Heavy ion experiment* at LHC.
• Now reality after 15 years of planning and construction.
• At start-up ALICE will have
  • *full hadron and muon capabilities*.
  • *partial electron and photon capabilities*.
• 3 commissioning runs (calibration data taking) in 2007/08.
• *Current shutdown is used for repairs, upgrades and further installations*.
• Next commissioning run scheduled for summer 2009 until first beams.
• ALICE will be ready for taking first p-p collisions and we eagerly await Pb-Pb collisions at the end of the upcoming run!
Backup slides
ALICE offers:

- Particle ID for $100 \text{ MeV}/c < p < 100 \text{ GeV}/c$;
- Precision tracking for $100 \text{ MeV}/c < p < 100 \text{ GeV}/c$;
- Excellent determination of secondary vertices;
- Low material thickness;
- Low magnetic field;
- Measurement of hadrons, leptons and photons at mid-rapidity and
- muons at forward rapidity.
Particle ID in ALICE

- **Stable hadrons** ($\pi$, $K$, $p$):
  - $dE/dx$ in silicon (ITS) and gas (TPC) + Time-of-Flight (TOF) + Cerenkov (HMPID)
- **Leptons** ($e$, $\mu$):
  - Transition radiation (TRD), Muon spectrometer
- **Photons**, $\eta, \pi^0$
  - E.m calorimeters (PHOS, EMCAL)
- **Decay topology** ($K^0$, $K^+$, $K^-$, $\Lambda$, $D^+$, ..), secondary vertices ($c$, $b$)

Alice uses ~ all known techniques!

**PID**
from ~100 MeV
to above 50 GeV
- $^{83}\text{Kr}$ isotopes released into the gas.
- Relative resolution of main peak: $\sim$5%.
- Pad to pad calibration.
Temperature homogeneity in TPC

Requirement: $\sigma < 0.1$ K

Achieved by actively stabilizing 50 cooling loops using information from 500 temperature sensors (36 inside gas volume).

Further improvements down to 80 mK in progress.

$\sigma = 99$ mK
Pixel Trigger (1)

- Pixel chip prompt fast-OR.
  - Active if at least one pixel hit in the chip matrix.
  - 10 chips each per optical link, transmitted at 10MHz.
  - Different programmable algorithms: High multiplicity, minimum-bias, cosmics, ...
Pixel Trigger (2)

To DAQ

Optical splitters

Fast-OR extraction

Processing

Pixel Trigger electronics

120 G-Link

1200 bits @ 10 MHz

350 ns

200 ns

225 ns

25 ns

800 ns
ITS-TPC Alignment

Cosmic muon in TPC and ITS
ALICE Commissioning in 2007/08: Data taking activity

Cumulated amount of data readout from detectors

~350 TB recorded to tape in total

Global runs