ALICE status and early physics prospects

Jean-Pierre Revol
The 9th ICFA seminar
Stanford Linear Accelerator Center
October 28-31, 2008
The ALICE Collaboration

1187 Members
(63% from CERN MS)

109 Institutes

31 Countries

140 MCHF Investment cost
(+ ‘free’ L3 magnet & cavern)

A brief history of ALICE
1990-1996: Design
1992-2002: R&D
2000-2010: Construction
2002-2007: Installation
2008 - : Commissioning

Revol/Oct. 28, 2008
Size: 16 x 26 meters
Weight: 10,000 tons
Det. + Syst: 18 + 5

PID; Low $P_T$ sensitivity
Low B field (0.5T)
Limited solid angle
**Completed:**
ITS, TPC, TOF, HMPID, FMD, T0, V0, ZDC, Muon arm, Acorde, Trigger, DCS, ECS, 40% DAQ/HLT

**Partially installed:**
1/5 PHOS
4/18 TRD
9/48 PMD

**Not yet installeds:**
0/6 EMCAL
DAQ integration tests and cosmic muon runs in December 2007 (2 weeks) and Feb./Mar 2008 (3 weeks); continuous running from May 2008 to October 12:
- 5 million muons in TPC (ACORDE trigger); 50000 pixel triggers

First LHC activity – injection tests:
- June: TI2 dump, August: TED (very high particle fluxes, 10 to 1000 particles/cm², September 10: first circulating beams, (timing and background studies)

320 TB recorded to tape in total
First performance results at Point 2:

- Excellent noise performance ($\sigma \sim 800$ e)
- dE/dx resolution $\leq 6\%$ (gain calibration with Kr$^{83}$) (goal: $\sim 5.5\%$)
- $p_t$ resolution (TPC only) $\leq 10\% @ 10$ GeV w/o calib. (goal: $\sim 5\% @ 10$ GeV)

5,000,000 cosmic events from June 2008, simple Kr calibration
Inner Tracking System
~ 10 m² Si detectors, 6 layers
Pixels, Drift, double sided Strips
3.9 cm < r < 43 cm

Unique level-zero trigger with local intelligence (fast OR)

Radii: 4, 7, 15, 24, 39, and 44 cm
Total material budget of 7%\(X_0\) (normal incidence)
Beam pipe radius 2.98 cm
- ITS contributing to robust tracking from 30 MeV to 100 GeV
  - Low soleniodal field (0.2-0.5 T)
  - Small material budget: ~ 10% $X_0$ from vertex to end of TPC ($r = 2.6$ m)
  - Long lever arm (BL$^2$: Alice ~ CMS > Atlas!)

- SPD Alignment:
  - Impact resolution $\sigma \approx 56 \mu m$
  - Misalignment < 10 $\mu m$!!

- Momentum resolution
  - ~ 5% @ 100 GeV

- Transverse momentum resolution (%)
  - TPC
  - ITS+TPC
  - ITS+TPC+TRD

- Momentum resolution
  - ~ 5% @ 100 GeV
- **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!
High Momentum PID

~ 11 m² prox. focusing RICH detector
CsI photo-cathode, MWPC chambers
PID up to 3 ($\pi/K$) – 5 (K/p) GeV

Installation: September ’06

Revol/Oct. 28, 2008
PHOton Spectrometer

- Status: 3/5 constructed
  - 2 more modules to be constructed
  - funding stretched to 2010
  - only 1 installed & commissioned

- ~ 8 m² PbWO₄ crystals, r ~ 5m
- 18 k channels, 20X₀ APD R/O high resolution & granularity

Module 1 installed mid '08

Revol/Oct. 28, 2008
10 Cathod Strip Chambers tracking planes, 90 m², 1.1 M FEE
4 RPC trigger planes, 120 m², 20 k FEE
Dipole 0.7 T, 3 Tm  Acceptance 2.4 < η < 4
σ(M): 70 MeV (J/Ψ) – 100 MeV(Y)
Muon Arm status

Muon tracking: ~ 70% commissioned
Muon trigger: fully operational

A rare ‘horizontal’ cosmic, pointing to the IP
3564 bunch crossings
Use LHC commissioning (low luminosity) to study large cross-section phenomena (strong interaction), non-elastic pp collisions.

QCD is an excellent description of the strong interaction at large $Q^2$, where asymptotic freedom is ideal for perturbative methods to work, but QCD needs to be also understood at low $Q^2$ (soft phenomena), in the non-perturbative regime, which dominates low $p_T$ particle production.

- LHC should bring non-perturbative phenomena to relatively large $Q_s^2 \sim 1 \text{ GeV}^2$, large enough to be studied directly;
- This expected new regime in proton-proton collisions is of course very relevant to the understanding of heavy ion collisions (pp energy densities overlapping with RHIC HI densities).
As lower $x$ ($\sim Q^2/s$) values are reached, both parton density and parton transverse size increase, there must be a scale (at $q^2 < Q_s^2$) where partons overlap. When this happens, the increase in the number of small $x$ partons becomes limited by gluon fusion ($gg \rightarrow g$).

(Kharzeev $Q_s^2 \sim 0.7$ GeV$^2$), where the effect must be visible

(BRAHMS in Au-Au, forward region: $Q_s^2 \sim A^{1/3}$)
p_T distributions and multiplicities of charged particles, in the low momentum range where the bulk of particle production occurs, **will constitutes the initial ALICE physics, with/without PID.** Hopefully more than Monte Carlo tuning.
- **Study of the extreme energy densities, where parton overlap is maximum**
- **Pixel Fast OR Trigger (level0)**
  - Trigger on number of fired chips (per layer), or more sophisticated, using correlations with FPGAs
- **No topology bias in trigger:**
  - Topology studies
  - Comparison with Heavy Ions

*Optimization of pixel trigger thresholds to reach multiplicities > 10-20 x average*

**Sector:** 4 (outer) + 2 (inner) staves

**Half-Stave:** 10 chips

**SPD:** 10 sectors (1200 chips)
Can gluons carry baryon number? (Rossi, Veneziano String Junction model)

\[ \pi^- + p \rightarrow \Omega^- + K^+ + 2K^0 \]


At LHC huge rapidity interval between incoming protons \( (y_p = \pm 9.6) \) and central rapidity. Veneziano’s model would result in substantial net baryon production in central rapidity region.

HERA point plotted at rapidity 9.6 - 7.4 = 2.2

 Ideal for ALICE
ALICE physics with pp

- Taking ‘comparison data’ for the heavy ion program
  - eg: $J/\psi$ & $\Upsilon$ suppression in AA requires measuring $J/\psi$ & $\Upsilon$ production in pp
- Survey and characterization of typical (‘Minimum Bias’) events
  - Detailed measurements of particle composition, strangeness, charm, baryon, etc.
  - Specific QCD measurements for which ALICE is particularly well suited (charm & beauty production at low $p_T$)
ALICE was ready for first physics in September 2008. We will take full advantage of the long shutdown to complete some of the installation, improve integration (access), and for maintenance and small repairs.

We have learned a lot from first circulating beams. First data confirm that performance of the tracker and of PID detectors, in some cases even a bit better than expected.

ALICE has an ambitious proton-proton programme, which is the best preparation for future heavy ion physics.
First 5 years: exploitation of present ALICE detector:

- Continuous running with **p-p** (comparison data and some genuine pp physics: charm, baryon, high multiplicity, etc.)
- 1 yr (10^6s) **Pb-Pb** at low Luminosity (initially \( \sim 1/20^{th} \) design, i.e. \( L \sim 5 \times 10^{25} \text{cm}^{-2}\text{s}^{-1} \))
- 1-2 yrs **Pb-Pb** at nominal \( L \sim 10^{27} \), targeting integrated \( L \sim 0.5-1 \text{nb}^{-1} \): \( \langle L \rangle \sim \frac{1}{3} \text{ or } \frac{1}{2} L_{\text{max}} \) depending on sharing among exper.
- 1 yr **p-A** (initial state interaction effects); 1 yr **low mass A-A** (system size dependence)

Following 5 years:

- Lower energies (energy dependence, thresholds, pp@5.5 TeV); Additional AA and pA combinations; Increased PbPb statistics.

Detector upgrade:

- 2010-2011 Decision on upgrade.
- 2013-15 Inst. of upgraded detectors (depending on LHC schedule)