First Results from the ALICE Experiment at the LHC

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ISVHECRI 2010, Fermilab
The ALICE Experiment

- One of the 4 large experiments at CERN LHC
- Dedicated to heavy-ion physics
- Very good capabilities for p+p

~ 1000 scientists  
  (63% CERN member states)  
~ 100 institutions  
~ 30 countries
Central Detectors:
- Inner Tracking System
- Time Projection Chamber
- Time-of-Flight
- Transition Radiation Detector

Spectrometers:
- High Momentum PID (RICH)
- Photon Multiplicity
- Forward Multiplicity
- Muon Spectrometer

Calorimeters:
- EM Calorimeter
- Photon Spectrometer (PHOS)
- Zero Degree Calorimeter
ALICE – installation status

- ITS, TPC, TOF, HMPID, MUON, V0, T0, FMD, PMD, ZDC (100%)
- TRD* (7/18)
- EMCAL* (4/12)
- PHOS (3/5)

*upgrade to the original setup

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6 Layers, three technologies

- Silicon Pixels (SPD) 0.2 m², 9.8 M channels, starting at r = 3.9 cm
- Silicon Drift (SSD) 1.3 m², 133 k channels
- Silicon Strip (SSD) 4.75 m², 2.6 M channels

Material Budget ~ 1% $X/X_0$ per layer

L_{outer} = 97.6 cm
R_{outer} = 43.6 cm

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ITS alignment

alignment with cosmic tracks

SPD alignment:

- $\sigma_{r\phi} \approx 14 \mu m$
- impact parameter resolution $\sigma \sim 50 \mu m$
- misalignment $< 10 \mu m$

\[ \rightarrow \text{close to design values} \]

alignment with pp data ongoing

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Time Projection Chamber TPC

- Central electrode (100 kV)
- 85 m³ NeCO₂N₂ (90/10/5)
- 557,568 readout channels
- 92 µs maximum drift time
- 10 bit ADC at 10 MHz

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momentum resolution (from matching of two segments of cosmic track)

\[ \Delta p_T / p_T \approx 7\% \text{ at } 10 \text{ GeV/c} \]

ALICE performance work in progress

\[ \mu = 497.3 \pm 0.07 \text{ MeV} \]
\[ \sigma = 5.2 \pm 0.08 \text{ MeV} \]

PDG: 497.6 MeV

- \( \rightarrow \) present \( p_T \) resolution
- 7\% at 10 GeV/c
- below 1\% at \( p_T < 1 \text{ GeV/c} \)
- confirmed by \( K^0_s \) measurements

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TPC $dE/dx$

TPC $dE/dx$ resolution:
5.5% (= design value!)

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First collision on Nov. 23 2009

- only SPD + trigger detectors
- $B = 0$
- 284 events in 43 mins
First LHC physics paper Nov. 28 2009

→ first LHC physics paper submitted on Nov. 28 2009

ALICE Collaboration
First results

• Multiplicity distributions and $dN_{ch}/d\eta$ at 0.9, 2.36 and 7 TeV


• $dN/dp_T$ and $<p_T>$ vs $n_{ch}$ at 0.9 TeV

• antibaryon to baryon ratio at 0.9 and 7 TeV
$dN_{ch}/d\eta$ – comparison to experiments

Good agreement with UA5 (INEL and NSD at 900 GeV) and CMS (NSD at 900 GeV and 2.36 TeV)

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\[ \text{dN}_{\text{ch}}/\text{d}\eta \text{ – comparison to models} \]

- PYTHIA D6T and Perugia-0 don’t match at any energy
- Pythia ATLAS-CSC and PHOJET reasonably close at 0.9 and 2.36 TeV
- only ATLAS-CSC close at 7 TeV
dN_{ch}/d\eta – energy dependence

Increase in dN_{ch}/d\eta in |\eta| < 1 for INEL > 0
arXiv:1004.3514

<table>
<thead>
<tr>
<th>\sqrt{s}</th>
<th>ALICE (%)</th>
<th>MCs (%)</th>
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<tbody>
<tr>
<td>0.9 \rightarrow 2.36 TeV</td>
<td>23.3 ± 0.4 _0.7^{+1.1}</td>
<td>15 – 18</td>
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<tr>
<td>0.9 \rightarrow 7 TeV</td>
<td>57.6 ± 0.4 _1.8^{+3.6}</td>
<td>33 – 48</td>
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significantly larger increase from 0.9 to 7 TeV than in MCs
multiplicity distributions at 0.9 and 2.36 TeV

consistent with UA5 at 0.9 TeV

fits with single Negative Binomial Distributions (NBD) work well in limited $\eta$-regions

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multiplicity distributions at 2.36 and 7 TeV

7 TeV: INEL>0

\( \sqrt{s} = 7 \text{ TeV (x 100)} \)

\( \sqrt{s} = 2.36 \text{ TeV (x 10)} \)

\( \sqrt{s} = 0.9 \text{ TeV (x 1)} \)

7 TeV: NBD fit deviates slightly at the highest multiplicities

ALICE
INEL>0
|\( \eta \) | < 1

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Fit by function to allow extrapolation to $p_T=0$:

$$\frac{1}{p_T} \frac{d^2 N_{ch}}{d\eta dp_T} \propto \frac{p_T}{m_T} \left(1 + \frac{p_T}{p_{T,0}}\right)^{-n}$$
• good agreement at $p_T < 1$ GeV/c
• ALICE spectrum harder at higher $p_T$

• UA1 sees higher yield at low $p_T$
ALICE sees larger $<p_T>$ than other experiments with larger $\eta$ acceptance at 900 GeV

- similar trend also observed
  - at Tevatron
  - in $\eta$ bins of CMS data
  - in PYTHIA

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dN_{ch}/dp_T – comparison to MC

- PYTHIA D6T and Perugia0 describe shape reasonably well but fail in the yield
- PHOJET and ATLAS-CSC are off

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\[ \langle p_T \rangle \text{ vs multiplicity} \]

Fits of
\[ \frac{1}{p_T} \frac{d^2 N_{ch}}{d \eta d p_T} \propto \frac{p_T}{m_T} \left(1 + \frac{p_T}{p_{T,0}}\right)^{-n} \]

in bins of multiplicity

ALICE, pp, INEL
\( \sqrt{s} = 900 \text{ GeV}, |\eta| < 0.8 \)

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ALICE Preliminary
\[ \langle p_T \rangle \text{ vs multiplicity} \]

\[ \sqrt{s} = 900 \text{ GeV}, \ |\eta| < 0.8 \]

\( p_T > 500 \text{ MeV/c}: \)
weighted average over data points 0.5\(<p_T<4 \text{ GeV/c} \)

\( p_T > 150 \text{ MeV/c}: \)
weighted average over data points 0.15\(<p_T<4 \text{ GeV/c} \)

\( p_T >0: \)
weighted average over data points 0.15\(<p_T<4 \text{ GeV/c}, \) combined with result from fit at \( p_T<0.15 \text{ GeV/c} \)

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<pT> vs multiplicity

ALICE, pp, INEL
\( \sqrt{s} = 900 \text{ GeV}, |\eta| < 0.8 \)

\( \langle p_T \rangle \) (GeV/c)

ALICE Preliminary

from measured to true multiplicity (employing MC)
\(<p_T> \) vs multiplicity – comparison to MC

• \( p_T > 500 \text{ MeV/c} \):
  PYTHIA Perugia0 gives good description of the data

• \( p_T > 150 \text{ MeV/c} \):
  all models fail
  (Perugia0 is still best)
antiproton to proton ratio

- data well described by PYTHIA tunes
identified charged particles

**charged hadron ID in ALICE:**

- dE/dx in ITS and TPC
- TOF
- HMPID
neutral strange particles at 900 GeV

\[ \Lambda \rightarrow p\pi \]

\[ \bar{\Lambda} \rightarrow \bar{p}\pi \]

\[ K^0_s \rightarrow \pi\pi \]

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neutral strange particles at 7 TeV

\[ \Xi \rightarrow \Lambda + \pi \]

2010 data
\[ p+p \text{ at } \sqrt{s} = 7 \text{ TeV} \]

Gaussian+Pol1 Fit:
- \( \chi^2/\text{ndf} = 98.97/40 \)
- \( M_{\Xi} = 1.3214 \pm 0.0000 \text{ GeV/c}^2 \)
- \( \sigma_{\Xi} = 2.0 \pm 0.0 \text{ MeV/c}^2 \)

\[ \Omega \rightarrow \Lambda + K \]

2010 data
\[ p+p \text{ at } \sqrt{s} = 7 \text{ TeV} \]

Gaussian+Pol1 Fit:
- \( \chi^2/\text{ndf} = 43.71/45 \)
- \( M_{\Omega} = 1.6722 \pm 0.0003 \text{ GeV/c}^2 \)
- \( \sigma_{\Omega} = 2.7 \pm 0.3 \text{ MeV/c}^2 \)

\[ \phi \rightarrow K+K \]

\[ K^* \rightarrow K+\pi \]

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γ reconstruction from conversions

π⁰ candidate in 900 GeV data

- γ conversions reconstructed from V⁰ topology and electron PID from TPC dE/dx

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γ reconstruction from conversions

distribution of γ conversion points (7 TeV)

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\( \gamma \) reconstruction from conversions

\[ \pi^0 \rightarrow \gamma \gamma \rightarrow e^+e^- \]
• two EM calorimeters:  
EMCAL (Pb-Scint)  
PHOS (PWO)  

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charmed mesons

\[ D^0 \rightarrow K^- \pi^+ \]

**Significance (2 \( \sigma \))** 12.8 \( \pm \) 1.3

\[ S (2 \sigma) 677 \pm 67 \]
\[ B (2 \sigma) 2134 \pm 30 \]

Mean = 1.866 \( \pm \) 0.002

Sigma = 0.019 \( \pm \) 0.002

\[ D^+ \rightarrow K^- \pi^+ \pi^+ \]

**Mean** 1.870 \( \pm \) 0.002
**Sigma** 0.017 \( \pm \) 0.002

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$J/\psi \rightarrow e^+ e^-$

- electron PID from TPC $dE/dx$
$J/\psi \rightarrow \mu^+ \mu^-$

Forward Muon Spectrometer:
- fully installed
- alignment not yet finalized

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outlook for 2010

• expect \( \sim 10^9 \) min bias pp events at 7 TeV

identified charged particle spectra
\( \pi^0, \eta \)
\( J/\psi \)
c and b production
inclusive electrons
reconstructed jets
jet correlations, underlying event
b-tagged jets
high multiplicity events
...

• hope to get pp at 2.75 TeV

Looking forward to Pb-Pb at 2.75 TeV!

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backup
ALICE Detectors & Acceptance

**central barrel** -0.9 < η < 0.9
- $\Delta\phi = 2\pi$ tracking, PID (TPC/ITS/ToF)
- single arm RICH (HMPID)
- single arm e.m. cal (PHOS)
- electron id (TRD)
- EM calorimeter arms (EMCal + DCal)

**forward muon arm** -4 < η < -2.4
- absorber, 3 T-m dipole magnet
- 10 tracking + 4 trigger chambers

**multiplicity detectors** -5.4 < η < 3
- including photon counting in PMD

**trigger & timing detectors**
- 6 Zero Degree Calorimeters
  - T0: ring of quartz window PMT's
  - V0: ring of scint. Paddles

$$\eta = -\frac{1}{2} \ln (\tan \frac{\theta}{2})$$