ALICE highlights

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LHC Physics Colloquium
Open Session of the CERN Council
18th December 2015
ALICE Collaboration

37 countries, 151 institutes, 1550 members
Heavy-ion collisions

nuclear matter under extreme conditions
high temperature and energy-density
expected to undergo a phase-transition
hadronic matter
\[ \downarrow \]
Quark-Gluon Plasma (QGP)

study the phase diagram and the properties of hot QCD matter
The ALICE detector

a dedicated heavy-ion experiment at the LHC

designed to cope with

**very high multiplicities**

\( dN_{\text{ch}}/d\eta \leq 8000 \)

3D tracking with TPC

**low-\( p_T \) tracking**

moderate \( B = 0.5 \) T

thin materials

uses all known **PID** techniques

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A few selected recent results from LHC Run-1 and Run-2
CPT invariance in nuclear systems

precision measurement of nuclei mass with time-of-flight

$$(m/z)^2_{\text{TOF}} = (p/z)^2 \left[ (t_{\text{TOF}}/L)^2 - 1/c^2 \right]$$

makes use of heavy-ion collisions as an efficient source of nuclei and anti-nuclei combined with high-precision tracking and identification capabilities of ALICE
CPT invariance in nuclear systems

\[
(m/z)^2_{\text{TOF}} = \left( \frac{p}{z} \right)^2 \left[ \left( \frac{t_{\text{TOF}}}{L} \right)^2 - \frac{1}{c^2} \right]
\]

measuring mass differences rather than absolute values
\[\rightarrow \text{reduced uncertainties}\]
momentum, time-of-flight, track length

these results are
the highest precision direct measurement of the mass difference of nuclei/anti-nuclei
improved by one to two orders of magnitude wrt. previous measurements
(dating back to 1965 and 1971)
Strangeness enhancement

Hyperon-to-pion ratio

(c) \( \frac{\Xi}{\pi} \)

\( \frac{\Omega}{\pi} \)

\( 10^{-3} \)

\( 10^{-4} \)

ALICE Pb-Pb at 2.76 TeV
ALICE pp at 7 TeV
ALICE pp at 900 GeV
STAR Au-Au, pp at 200 GeV
ALICE Pb-Pb at 2.76 TeV
ALICE pp at 7 TeV
STAR Au-Au, pp at 200 GeV

Clear increase of strangeness production from minimum bias pp to central Pb-Pb collisions

One of the first proposed QGP signatures
Rafelski & Müller, PRL 48 (1982) 1066
Strangeness enhancement

also measured in pp and p-Pb collisions as a function of charged-particle multiplicity

first observation of enhanced production of strange particles in pp and p-Pb collisions

ratios to pions reach values measured in Pb-Pb collisions

PYTHIA cannot reproduce the data
Charged particles in pp@13 TeV

pseudorapidity dependence

\[
\langle dN_{\text{ch}}/d\eta \rangle
\]

measured in INEL events and in events with at least one charged particle in \(|\eta| < 1\)

agreement with CMS results for INEL class

charged-particle multiplicity density

at mid-rapidity, \(|\eta| < 0.5\)

5.31 ± 0.18 \hspace{1em} (INEL)

6.46 ± 0.19 \hspace{1em} (INEL>0)
Charged particles in pp@13 TeV

transverse-momentum dependence

\[ \frac{1}{N_{ev}} \frac{d^2N}{dp_T^2 d\eta} (\text{GeV}/c^2) \]

\[ \eta \mid < 0.8 \]

**MC / Data**

\[ 0.5 - 1.5 \]

\[ 0.5 - 10 \]

**Ratio to 7 TeV**

\[ 1.2 - 2.2 \]

\[ 10^{-1} - 10^{-7} \]

ALICE, pp, \( \sqrt{s} = 13 \) TeV, INEL>0
charged particles, \( \mid \eta \mid < 0.8 \)

\[ p_T \text{ distribution measured} \]

for events with at least one
charged particle in \( \mid \eta \mid < 1 \)

\[ 0.15 < p_T < 20 \text{ GeV}/c \]

\[ \mid \eta \mid < 0.8 \]

\[ \text{spectrum significantly harder than at } \sqrt{s} = 7 \text{ TeV} \]

\[ \text{crucial measurements to tune} \]

Monte Carlo models

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*arXiv:1509.08734 [nucl-ex]*
Charged particles in pp@13 TeV

evolution of $p_T$ spectra with multiplicity

ALICE, pp, $\sqrt{s} = 13$ TeV, charged particles, $|\eta| < 0.8$

Data, $\langle N_{ch}^{acc} \rangle = 6.7$, $\langle N_{ch} \rangle = 9.4$ ($p_T > 0.15$ GeV/c)

- $1 \leq N_{ch}^{acc} < \langle N_{ch}^{acc} \rangle$
- $\langle N_{ch}^{acc} \rangle \leq N_{ch}^{acc} < 2\langle N_{ch}^{acc} \rangle$
- $N_{ch}^{acc} \geq 2\langle N_{ch}^{acc} \rangle$

ratio of spectra to the inclusive sample
measured in three intervals of multiplicity
low / intermediate / high

general features are reproduced
by the models
but not in all details
Charged particles in Pb-Pb@5.02 TeV

centre-of-mass energy dependence

charged-particle multiplicity density at mid-rapidity, $|\eta| < 0.5$

reaches a value of $1943 \pm 56$
in most central collisions

much stronger $\sqrt{s}$ dependence than pp

2.4x larger charged-particle multiplicity than p-Pb at same energy

scaled by the average number of participating nucleon pairs $\langle N_{\text{part}} \rangle / 2$
ALICE continues to produce exciting physics results.

Pb-Pb collisions \( \sqrt{s_{\text{NN}}} = 5.02 \text{ TeV} \)