114th LHCC Meeting: ALICE Status Report

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144th LHCC Open Session
June 12th-13th
OUTLINE

1. New Physics Results (since last LHCC)
2. Detector Status
3. Status of the Upgrade R&D
HEAVY-ION PHYSICS

With heavy-ion collisions we can study a new state of matter which is expected to be present in the earliest moments of the big-bang.

The Quark Gluon Plasma (QGP)
**HEAVY-ION PHYSICS**

With heavy-ion collisions we can study a new state of matter which is expected to be present in the earliest moments of the big-bang.

The Quark Gluon Plasma (QGP)

**Particle & Jet Spectra**
freeze-out temperature, energy density, transport coefficients...

**Particle Correlations**
- **Flow**: equation of state, shear viscosity...
- **Femtoscopy**: freeze-out size (Radius~7 fm)...
NEW PAPERS

Recently Submitted:
“J/ψ elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV” -- arXiv: 1303.5880
“D meson elliptic flow in non-central Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV” -- arXiv: 1305.2707
“Mid-rapidity anti-baryon to baryon ratios in pp collisions at $\sqrt{s} = 0.9, 2.76$ and $7$ TeV measured by ALICE” -- arXiv: 1305.1562
“Centrality dependence of the pseudorapidity density distribution for charged particles in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV” -- arXiv: 1304.0347
“Charmonium and e+e- pair photoproduction at mid-rapidity in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV” -- arXiv: 1305.1467

Recently Published:
“Charge correlations using the balance function in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV”
-- PLB 723, 267
“Measurement of the inclusive differential jet cross section for pp collisions at $\sqrt{s_{NN}} = 2.76$ TeV”
-- PLB 722, 262
“Net-charge fluctuations in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV”
-- PRL 110, 152301
“Measurement of electrons from beauty hadron decays in pp collisions at $\sqrt{s} = 7$ TeV”
-- PLB 721, 13
Non-central heavy-ion collisions create an almond shaped region. We expect an increased production of particles In-plane ($v_2 > 0$) due to hydrodynamic expansion in the medium. $v_2$ is sensitive to the equation of state and shear viscosity of the medium.
D Meson Elliptic Flow

- $v_2$ is sensitive to the Eq. of state and shear viscosity of the medium.

D meson strongly interacting with the medium.

Does that mean it flows too?

Prompt $D^0, D^+, D^{**}$ average.
D meson $v_2$ suggests collective expansion.
J/ψ Elliptic Flow

- $v_2$ is sensitive to the Eq. of state and shear viscosity of the medium.

New Result

J/ψ meson strongly interacting with the medium.

Does that mean it flows too?

J/ψ $v_2$ suggests collective expansion.
Nuclear Modification Factor

Compare particle production rates in heavy-ion collisions (AA) to those in pp.

- Quarks/gluons loose energy while traversing the hot medium in heavy-ion collisions.
- Reduced particle production in heavy-ion collisions compared to N-binary scaled pp reference.
- $R_{AA}$ is sensitive to the transport coefficients of the medium.
$\Upsilon(1S \text{ and } 2S)$

Differential Cross-Section in $pp$

ALICE and LHCb Results Consistent.
\( \Upsilon(1S) \) Nuclear Modification Factor

- One Signature of the QGP is the suppression of Quarkonium production.
- \( R_{AA} \) is sensitive to the transport coefficients of the medium.

\[
R_{AA}(p_T, y) = \frac{d^2 N_{AA} / dyd p_T}{\langle N_{coll} \rangle \times d^2 N_{pp} / dyd p_T}
\]

Clear suppression below unity!
Despite different rapidity intervals, ALICE & CMS results consistent.
\( \phi \) meson in pp 2.76 TeV

\( \phi \) spectra in pp 2.76 TeV provides a direct baseline for \( \phi \) spectra in Pb-Pb 2.76 TeV.
The $\phi$ meson $R_{AA}$

- $R_{AA}$ is sensitive to the transport coefficients of the medium.

$$R_{AA}(p_T, y) = \frac{\frac{d^2N_{AA}}{dydp_T}}{\langle N_{coll} \rangle \times \frac{d^2N_{pp}}{dydp_T}}$$

$\phi$ meson production is suppressed in Pb-Pb. Suppression is somewhat less than charged hadrons.
Ultra-Peripheral Collisions

Nuclei do not overlap. Instead, they interact through a photon exchange.

Photonuclear interactions $\rightarrow J/\psi$ production
-- presented at the last LHCC

Two-photon interactions $\rightarrow e^+ e^-$ production
-- Sensitive to the strong fields within the nucleus.
Ultra-Peripheral Collisions

\[ \text{Pb+Pb} \rightarrow \text{Pb+Pb} + \gamma\gamma \]

Two-photon production rate in fair agreement with STARLIGHT prediction. Although the photon coupling is large, \( Z\sqrt{\alpha} \), higher order corrections do not appear important.
Collective expansion in p-Pb?

The $\Delta \eta \Delta \varphi$ di-hadron correlation is formed with a trigger and associated particle in $p_T$ intervals ($p_{T,\text{assoc}} < p_{T,\text{trig}}$)

- A double ridge was seen in p-Pb collisions.
- If this is caused by flow, it should be seen in spectra as well.

PLB, 719, 29
Light Flavor Spectra in p-Pb
Comparison to Hydrodynamic Expectation

Prediction from Bozek Model (PRC 85, 014911):
- Initial conditions from Glauber Monte Carlo
- E-by-E (3+1)-D viscous hydrodynamic expansion
- Statistical hadronization at freeze-out (Cooper-Frye).

Comparison done for Similar $dN_{ch}/d\eta$.

The Hydrodynamic model reasonably describes only the proton spectra.
Clear evolution with multiplicity in p-Pb.
Mid-pT: ratio increases
Low-pT: corresponding depletion
This is reminiscent of nucleus-nucleus phenomenology
...generally understood in terms of collective flow or recombination.
J/ψ in p-Pb Collisions

J/ψ → μ⁺μ⁻
Reconstructed in the forward Muon arm

\( Y_{J/\psi}^{pPb} = \frac{N_{J/\psi}}{(A \times \varepsilon) N_{MB}} \)

\( R_{FB} = \frac{Y_{J/\psi}^{Forward}}{Y_{J/\psi}^{Backward}} \)
J/ψ in p-Pb Collisions

Reference for understanding dissociation in a hot medium:
Knowledge of J/ψ behavior in p-Pb is fundamental to disentangle genuine QGP from cold nuclear matter effects in Pb-Pb.

Nuclear shadowing alone can largely explain the data. Energy loss scenarios can also describe the data.
Main release of preliminary figures for the upcoming summer conferences is scheduled for next month.
ALICE DETECTOR STATUS
ALICE plans for LS1

- Complete TRD detector (+5 super-modules)
- Install Di-jet Calorimeter (6 full + 2*1/3 super modules)
  - 1 New PHOS super-module
Recent Consolidation Work

TRD HV & LV,
- TRD 17 removed and shipped to Muenster to fix HV instabilities.
- TRD 7 LV rework started
- TRD 8,10,11 repair ongoing

MCH LV,
- Almost 90 chambers (slats) being repaired (re-solder LV bus-bar connection) to fix occupancy problems.
ALICE UPGRADES
Beyond the current ALICE and into the next ALICE

Detailed characterization of the Quark–Gluon–Plasma
(Non-exhaustive list. The upgrade opens many more opportunities!)

• Measurement of heavy-flavor transport parameters
  – Diffusion coefficient (QGP eq. of state, $\eta/s$) $\rightarrow$ HF azimuthal anisotropy and $R_{AA}$
• Measurement of low-mass and low-$p_t$ di-electrons
  – Chiral symmetry restoration $\rightarrow$ $\rho$ spectral function
  – $\gamma$ production from QGP (temp.) $\rightarrow$ low-mass di-lepton continuum
• $J/\psi$, $\psi'$, and $\chi_c$ states down to zero $p_t$
  – statistical hadronization vs. dissociation/recombination scenario
• Jets
  – Heavy-flavor tagged jets (gluon vs. quark induced jets and charm fragmentation)

○ The upgrade plans entails:
  • Run ALICE at 50 kHz with $O^2$ project (currently 500 Hz max, MB)
  • New, high-resolution, low-material ITS
  • Upgrade of TPC with replacement of MWPCs with GEMs and new R/O electronics.
  • Many other upgrades as well...

○ It targets 2018/19 (LHC 2\textsuperscript{nd} Long Shutdown). ~18 months to complete
New ITS (silicon tracker)

Inner Barrel (IB): 3 layers pixels
Outer Barrel: 4 layers pixels
First layer: ~22 mm from IP
Material thickness (IB): 0.3% $X_0$
Pixels pitch: ~20 μm
Total surface: ~10 m²

Detector module (Stave) consists of:
- Carbon fibber mechanical support
- Cooling unit
- Polyimide cable
- Silicon chips (CMOS sensors)

3x Impact parameter resolution
Dramatic improvement of tracking at low $p_T$

Flex-cable bus
Mechanical structure
Bump bonding
Pixel modules

CDR – Sep 2012
TDR submission fall 2013
TPC Upgrade with GEMs

Replacement of wire-chambers with GEM-chambers
- 100 m² single-mask foils
- Limit Ion-Back-Flow into drift volume
- Maintain excellent dE/dx resolution

New readout electronics
Keep all other subsystems

Extensive R&D and simulations ongoing through 2012 and 2013
Production schedule: 2014 to 2017

Replace wire chambers With triple-GEM chambers

TDR preparation for Sep 2013
SUMMARY

5 papers have been submitted since the last LHCC

New Physics Results:

Elliptic Flow:
- J/ψ and D meson elliptic flow have been measured.
- Results suggest collectivity of heavy flavor mesons in Pb-Pb collisions.

Nuclear-Modification Factor:
- Υ(1S), J/ψ, and φ R_{AA} and R_{FB} have been measured.
- All yields are suppressed as compared to N-binary scaled pp expectation.
- J/ψ suppression in p-Pb can largely be explained by nuclear shadowing. Models including energy loss can also explain the data.

Spectra:
- Λ, K^{0}_{s}, Υ(1S), Υ(2S) and φ spectra have been measured.
- Some hints of collectivity seen in the p-Pb spectra, however still inconclusive.
- Two-photon production in Ultra-Peripheral Pb-Pb collisions has been measured and are consistent with STARLIGHT expectation.
SUPPORTING SLIDES
Beyond the ALICE approved physics program

Detailed characterization of the Quark–Gluon–Plasma
(not exhaustive; the upgrade opens many more opportunities!)

• Measurement of heavy-flavor transport parameters
  – Diffusion coefficient (QGP eq. of state, $\eta/s$) $\rightarrow$ HF azimuthal anisotropy and $R_{AA}$
  – In-medium thermalization and hadronization $\rightarrow$ HF baryons and mesons
  – Mass dependence of energy loss $\rightarrow$ HF $R_{AA}$

• Measurement of low-mass and low-$p_t$ di-electrons
  – Chiral symmetry restoration $\rightarrow$ $\rho$ spectral function
  – $\gamma$ production from QGP (temp.) $\rightarrow$ low-mass di-lepton continuum
  – Space-time evolution of the QGP $\rightarrow$ radial and elliptic flow of emitted radiation

• $J/\psi$, $\psi'$, and $\chi_c$ states down to zero $p_t$
  – statistical hadronization vs. dissociation/recombination scenario
  – transition between low and high transverse momenta
  – density dependence – central vs. forward production

• Jets
  – Heavy-flavor tagged jets (gluon vs. quark induced jets and charm fragmentation)
  – Particle identified fragmentation functions (influence of medium on fragmentations)
  – $\gamma$–jet correlations (radiated energy recovery at very low momenta)

• Nuclear states
  – mass–4 and –5 (anti–)hypernuclei
  – search for H–dibaryon, $\Lambda n$ bound states, etc.
ALICE Upgrade Strategy

- Run ALICE at 50 kHz (i.e. $L = 6 \times 10^{27} \text{ cm}^{-1} \text{s}^{-1}$), with a minimum bias (pipeline) readout (max readout with present ALICE set-up 500 Hz)
  
  ➔ Gain factor of 100 in statistics over current program: x 10 integrated luminosity, 1 nb$^{-1}$ → 10 nb$^{-1}$, x 10 via pipelined readout allowing inspection of all collisions, namely inspect $O(10^{10})$ central collisions instead of $O(10^8)$

- Improve vertexing and tracking at low $p_T$ ➔ NEW ITS

- The upgrade plans entails building
  - New, high-resolution, low-material ITS
  - Upgrade of TPC with replacement of MWPCs with GEMs and new R/O electronics.
  - Upgrade of readout electronics of: TRD, TOF and Muon Spectrometer
  - Upgrade of the forward trigger detectors and ZDC
  - Upgrade of the online systems
  - Upgrade of the offline reconstruction and analysis framework and code

- It targets 2018/19 (LHC 2nd Long Shutdown)
Timeline for Upgrades

- 2012 Sept  Lol and ITS CDR approved by LHCC
- 2013 June  Lol extension (MFT)
- 2013 Fall  TDR for ITS, TPC, Readout and Trigger
- 2014 Fall  TDR for Online, Computing, Offline
- 2012–2014 Complete R&D
- 2014–2017 Procurement/Fabrication
- 2016–2017 Integration, pre-commissioning
- 2017–2018 Installation, commissioning
- 2019–2020 Full deployment of DAQ/HLT

**Installation:** need 18 months.
**O² (Online–Offline upgrade project)**

**System Requirements**
- Sample full 50kHz Pb–Pb interaction rate (currently ~500Hz)
- ~1.1 TByte/s detector readout
- ~20 GByte/s to mass storage
- Classical trigger/event filter approach not efficient
- Massive data volume reduction by online calibration, (partial) reconstruction and compression.
- Store only reconstruction results, discard raw data

**O² system: combined effort of the DAQ, HLT and Offline projects**
- Common R&D effort performed in a dozen Computing Working Groups (CWGs) about: architecture, tools & procedure, data–flow, reconstruction, calibration, physics simulation, computing platforms, etc

**TDR preparation for Sep 2014**
**Outer Stave**
layer 3, 4, 5, 6

**Inner Stave**
layer 0, 1, 2

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~270mm

~1500 mm

~1475mm

~843mm

~270mm

Modules 2x7 chip
Pixel chip – R&D with TowerJazz technology

What has been established so far

- Adequate radiation hardness
- Good charge collection (_detection) efficiency for pixel \(~20\mu m \times 20\mu m\)

R&D will continue till end 2014, with the following objectives

- **Improve signal/noise ratio**
  - Optimization of charge-collection diode
  - Increase resistivity and thickness of epi-layer
  - apply large reverse-bias voltage \(\Rightarrow\) lower capacitance, smaller cluster size

- **Study different front-end circuit and readout architectures**
  - Reduce power consumption
  - Reduce integration/readout time

- **Circuit/layout optimization for high yield and stitching**

\(\Rightarrow\) Submission in Mar 2013: Engineering Run (full reticle \(~7\text{ cm}^2\))
Reduce material budget: $X/X_0$ /layer:

$\sim 1.14\% \Rightarrow \sim 0.3\%$ (for inner layers)

Mean $X/X_0 = 0.282\%$
Irradiated samples
Explorer-0 @ DESY March 2013

- 13%
- 14%
Light Flavor Spectra in p-Pb

Hydrodynamic inspired Global blast-wave fits can reasonably well describe the spectra,...however it also works to some extent in Pythia where there is no collective flow.

\[ \langle \beta_T \rangle = \text{radial flow velocity} \]

\[ T_{fo} = \text{freeze-out temperature} \]
$\langle p_T \rangle$ versus Multiplicity

$p$-$Pb \quad s_{NN} = 5.02$ TeV

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

$dN_{ch}/d\eta$

$\langle p_T \rangle$ increases with multiplicity for all particle species
Baryon To Anti-Baryon Ratios
Baryon To Anti-Baryon Ratios