126\textsuperscript{th} LHCC session: ALICE status report

Friederike Bock
for the ALICE collaboration

Lawrence Berkeley National Laboratory Berkeley,
Physikalisches Institut Universität Heidelberg

May 24\textsuperscript{th}/25\textsuperscript{th} 2016
<table>
<thead>
<tr>
<th>Small Systems</th>
<th>Centrality dependence of $\psi(2S)$ suppression in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, arXiv:1603.02816</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measurement of azimuthal correlations of D mesons and charged particles in pp collisions at $\sqrt{s} = 7$ TeV and p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, arXiv:1605.06963</td>
</tr>
<tr>
<td></td>
<td>D-meson production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV and in pp collisions at $\sqrt{s} = 7$ TeV, arXiv:1605.07569</td>
</tr>
<tr>
<td>Large Systems</td>
<td>Measurement of transverse energy at midrapidity in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, arXiv:1603.04775</td>
</tr>
<tr>
<td></td>
<td>Correlated event-by-event fluctuations of flow harmonics in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, arXiv:1604.07663</td>
</tr>
<tr>
<td></td>
<td>Pseudorapidity dependence of the anisotropic flow of charged particles in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, arXiv:1605.02035</td>
</tr>
<tr>
<td>SMALL SYSTEMS</td>
<td>Production of $K^*(892)^0$ and $\phi(1020)$ in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, \textit{arXiv:1601.07868, accepted by EPJC}</td>
</tr>
<tr>
<td>Multi-strange baryon production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, \textit{arXiv:1512.06104, accepted by PLB}</td>
<td></td>
</tr>
<tr>
<td>Centrality dependence of charged jet production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, \textit{arXiv:1603.03402, accepted by EPJC}</td>
<td></td>
</tr>
</tbody>
</table>

| LARGE SYSTEMS | Centrality Dependence of the Charged-Particle Multiplicity Density at Midrapidity in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, \textit{arXiv:1512.06104, accepted by PRL} |
| Multipion Bose-Einstein correlations in pp, p-Pb, and Pb-Pb collisions at the LHC, \textit{arXiv:1512.08902, accepted by PRC} |
| Charge-dependent flow and the search for the Chiral Magnetic Wave in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, \textit{arXiv:1512.05739, accepted by PRC} |
| Measurement of an excess in the yield of J/psi at very low pt in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, \textit{arXiv:1509.08802, accepted by PRL} |
| Differential studies of inclusive J/ψ and $\psi(2S)$ production at forward rapidity in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, \textit{arXiv:1506.08804, accepted by JHEP} |
### SMALL SYSTEMS

Inclusive quarkonium production at forward rapidity in pp collisions at $\sqrt{s} = 8$ TeV,  
*arXiv: 1509.08258, EPJ C76 (2016) no.4, 184*

Forward-central two-particle correlations in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV,  
*arXiv:1506.08032, PLB 753(2016) 126-139*

### LARGE SYSTEMS

Production of light nuclei and anti-nuclei in pp and Pb–Pb collisions at LHC energies,  
*arXiv:1506.08951, PRC 93 (2015) 024917*

Centrality dependence of the nuclear modification factor of charged pions, kaons, and protons in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV,  
*arXiv:1506.07287, PRC 93 (2016) 034913*

Measurement of $D_{s}^{+}$ production and nuclear modification factor in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV,  
*arXiv:1509.07287, JHEP 1603 (2016) 082*

Transverse momentum dependence of D-meson production in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV,  
*arXiv:1509.06888, JHEP 1603 (2016) 081*

Event shape engineering for inclusive spectra and elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV,  
*arXiv:1507.06194, PRC 93 (2016) 034916*

Anisotropic flow of charged particles in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV  
*arXiv:1602.01119, PRL 116 (2016) 132302*
SMALL SYSTEMS (pp & p-Pb) & HARD PROBES
Bayesian Particle Identification in ALICE

- Generalized approach for usage of full PID information in ALICE
  - Standard approach cuts in $n\sigma$ to expected for each detector & species

F. Bock (LBL Berkeley & PI Heidelberg)
Bayesian Particle Identification in ALICE

- Generalized approach for usage of full PID information in ALICE
- Proof of Concept: D-meson extraction
  - Trade-off between purity/higher dependence on MC ⇒ higher purity ideal for correlation analysis
  - Increase in S/B with respect to standard approach particularly at low $p_T$
  - Currently only TPC and TOF included in analysis, other PID detectors to come

arXiv:1602.01392
Bayesian Particle Identification in ALICE

- Generalized approach for usage of full PID information in ALICE
- Proof of Concept: D-meson extraction
  - Trade-off between purity/higher dependence on MC
    ⇒ higher purity ideal for correlation analysis
  - Increase in S/B with respect to standard approach particularly at low $p_T$
  - Currently only TPC and TOF included in analysis, other PID detectors to come
- Access to even rarer probes: $\Lambda_C \rightarrow pK\pi$

arXiv:1602.01392
D-h correlations in pp & p-Pb

- First measurement of D-h correlation functions at the LHC
- Provides information on:
  - Charm production & fragmentation process
  - Implementation of underlying event and help tuning MC generators
- Similar correlations functions for pp & p-Pb
  ⇒ The current measurements shows no evidence for a possible $v_2$ in min bias p-Pb collisions
  ⇒ Looking forward to p-Pb run this year

arXiv:1605.06963
D-h correlations in pp & p-Pb

- First measurement of D-h correlation functions at the LHC
- Provides information on:
  - Charm production & fragmentation process
  - Implementation of underlying event and help tuning MC generators
- Similar correlations functions for pp & p-Pb
  - The current measurements shows no evidence for a possible \( \nu_2 \) in min bias p-Pb collisions
  - Looking forward to p-Pb run this year

arXiv:1605.06963
D-mesons at low $p_T$ in pp & pPb

- First $D^0$ measurement by ALICE to $p_T = 0$
- Reconstruction w/o secondary vertex provides a more precise result at $p_T < 2$ GeV/c as separation between primary and secondary vertex at low $p_T$ is smaller
  - Different systematics between the two methods
  - Smaller contribution from feed-down from B-mesons

arXiv:1605.07569
D-mesons at low $p_T$ in pp & pPb

- First $D^0$ measurement by ALICE to $p_T = 0$
- Reconstruction w/o secondary vertex provides a more precise result at $p_T < 2$ GeV/$c$ as separation between primary and secondary vertex at low $p_T$ is smaller
- $c\bar{c}$ cross sections for pp $\sqrt{s} = 7$ TeV & p-Pb $\sqrt{s_{NN}} = 5.02$ TeV at mid rapidity determined with improved systematics

$$\sigma^{c\bar{c}}_{pp, 7\text{TeV}} = 8.18 \pm 0.67(\text{stat}) \pm 1.62(\text{syst}) \pm 2.4(\text{extr}) \pm 0.29(\text{lum}) \pm 0.36(\text{FF}) \text{ mb}$$

$$R^{\text{prompt } D^0}_{p-Pb, 5.02\text{TeV}} = 0.89 \pm 0.11(\text{stat}) \pm 0.13(\text{syst}) \pm 0.18 \text{ measured for } -0.96 < y_{\text{cms}} < 0.04, p_T > 0$$

arXiv:1605.07569
Decreased $\psi(2S)$ w.r.t $J/\psi$ for central p-Pb collisions

⇒ Stronger at backward $y$
⇒ Cancellation of shadowing effects in double ratio
⇒ Hint for final state effects

$\psi(2S)$ suppression in p-Pb vs. event activity

arXiv:1603.02816
Decreased $\psi(2S)$ w.r.t $J/\psi$ for central p-Pb collisions

$\Rightarrow$ Stronger at backward $y$
$\Rightarrow$ Cancellation of shadowing effects in double ratio
$\Rightarrow$ Hint for final state effects

Different suppression pattern vs event activity for $J/\psi$ and $\psi(2S)$

$\Rightarrow$ Shadowing could reproduce $J/\psi$ results
$\Rightarrow$ Points to final state effects

$$Q_{pA} = \frac{1}{N_{\text{evt}}} \frac{dN_{pA}}{dp_T} \frac{1}{\langle N_{\text{Glauber}} \rangle} \frac{dN_{pp}}{dp_T}$$

arXiv:1603.02816
Jet production in p-Pb vs. event activity

- Nuclear modification factor $Q_{pPb} \sim 1$ in all centrality classes
  - Cold matter effects: shadowing and nuclear PDFs &
  - Hot matter effects: energy loss are small for high $p_T$ probes

- Measurements of full jet (ATLAS) and charged jet production at midrapidity fully consistent

- Ratio of jet production cross sections with $R=0.2$ and 0.4 in different centrality fully consistent with pPb min bias ratio and pp 7TeV
  - No significant broadening of the jet seen at midrapidity

arXiv:1603.03402
LARGE SYSTEM (Pb–Pb)

&

GLOBAL EVENT PROPERTIES
Transverse energy $E_T$ vs. cent

- $\langle dE_T/d\eta \rangle / \langle dN_{ch}/d\eta \rangle$ flat vs. $\langle N_{part} \rangle$
- $\langle dE_T/d\eta \rangle / \langle dN_{ch}/d\eta \rangle$ rises much stronger than expected from extrapolation of low energy experiments
- Bjorken estimate for volume averaged energy density $\epsilon$

$$\epsilon \tau_0 = \frac{1}{Ac} J \left( \frac{dE_T}{d\eta} \right)$$

assuming (conservatively) $\tau_0 = 1$ fm/c:

⇒ Energy density ranges from 1.6 to 12.3 GeV/fm$^3$
⇒ Core densities of up to 21 GeV/fm$^3$

arXiv:1603.04775
LARGE SYSTEM (Pb–Pb) & ANISOTROPIC FLOW

Alver, Roland (arXiv:1003.0194)
Anisotropic flow $v_n(\eta)$

- Extended longitudinal scaling observed by PHOBOS in Au-Au collisions holds up to LHC energy.
- None of the harmonics show clear centrality dependence in the shape of $v_n(\eta)$ within uncertainties.
- Small decrease of $v_3/v_2$ at high $|\eta|$ \(\Rightarrow\) viscous effects suppressing higher harmonics.
- Small increase of $v_4/v_2^2$ at high $|\eta|$ \(\Rightarrow\) Relatively larger contribution from $v_2$ at larger $|\eta|$.
- $v_n/(dN/d\eta)$ vs $\eta$ flat for all centralities, except $v_2$.
  \(\Rightarrow\) $v_3$ & $v_4$ largely driven by local particle density in fixed centrality window.

arXiv:1605.02035
Anisotropic flow $v_n(\eta)$

- Extended longitudinal scaling observed by PHOBOS in Au-Au collisions holds up to LHC energy.
- None of the harmonics show clear centrality dependence in the shape of $v_n(\eta)$ within uncertainties.
- Small decrease of $v_3/v_2$ at high $|\eta|$ \(\Rightarrow\) viscous effects suppressing higher harmonics.
- Small increase of $v_4/v_2^2$ at high $|\eta|$ \(\Rightarrow\) Relatively larger contribution from $v_2$ at larger $|\eta|$.
- $v_n/(dN/d\eta)$ vs $\eta$ flat for all centralities, except $v_2$ \(\Rightarrow\) $v_3$ & $v_4$ largely driven by local particle density in fixed centrality window.

arXiv:1605.02035
Event-by-Event fluctuations of flow harmonics

- Study correlation between $v_m$ and $v_n$ via Symmetric 2-harmonic 4-particle Cumulants
  \[
  SC(m, n) = \langle v_m^2 v_n^2 \rangle - \langle v_m^2 \rangle \langle v_n^2 \rangle
  \]
  insensitive to:
  - Inter-correlations of various symmetry planes & non flow effects
- Normalized $SC(m, n)/\langle v_m^2 \rangle \langle v_n^2 \rangle$ can be used to constrain temperature dependence of $\eta/s$ ($SC(4,2)$) and initial conditions ($SC(3,2)$)
- Anisotropies in central collisions mainly arise from fluctuations
  \[\Rightarrow\] Discriminate between different initial conditions using both $SC(3,2)$ & $SC(4,2)$ in central events

**arXiv:1604.07663**
Overview of 2016 Operations

& News from RUN 2
Overview of 2016 Operations

& News from RUN 2
Overview of 2016 Operations

TED shots

Quite Beam

1st Event @Stable Beam

& News from RUN 2
Overview of 2016 Operations

TED shots

Quite Beam

1st Event @Stable Beam

All Detectors Joined

News from RUN 2

F. Bock (LBL Berkeley & PI Heidelberg)
### Commissioning & Startup in 2016

#### TPC RCU2 commissioning finished in time for stable beam

#### Shots on TED (21\textsuperscript{st} - 22\textsuperscript{nd} March) used for initial trigger alignment

#### Finalized trigger alignment during quite beam period
Running Strategy for pp 2016

Default strategy

- $\mu$: $\sim 1\%$
- Interaction rate: up to V0AND $\sim 300$ kHz ($L=5\text{Hz}/\mu\text{b}$) with 2500 colliding bunches
- Lifetime: $\sim 50\%$ in central barrel, $\sim 80\%$ in muon arm
- Foreseen integrated luminosity: $7.5\text{pb}^{-1}$ in central barrel, $12\ \text{pb}^{-1}$ in muon arm

Trigger menu:

- Central barrel:
  - Minimum bias: 300 Hz (target $\sim 900\text{M}$), $B=0.2\text{T}$: $\sim 150\text{M}$
  - High multiplicity trigger: 80 Hz (target $\sim 250\text{M}$)
  - CALO (EMCAL/DCAL/PHOS) gamma and jet triggers: 60 Hz
  - Double-gap diffractive trigger: 30-50 Hz (downscaled)
  - ACORDE cosmic 4-fold coincidence interleaved with beam: $<1$ Hz

- MUON arm:
  - Single muon low and high $p_T$: 10-20 Hz (downscaled) and 130 Hz
  - Dimuon low $p_T$: 30 Hz
Early Running in pp 2016

**Ramp up scenario**

- 3 b/beam (isolated bunches): → Global OR, $\mu=5\%$, IR=1kHz
- 12-48 b/beam: MB (VBAND) data taking with trains at $\mu=5\%$
- 72-600 b/beam: MB data with B=0.2T
- 72-1700 b/beam: MB+RARE data taking: keep constant $\mu$ 1% and gradually increase IR

### Quite Beams

- Only Calorimeters & trigger detectors (ITS, V0, AD, T0)
- Mainly for trigger alignment

### Trigger setup for vdM

- ATLAS+CMS+LHCb vdM: GlobalOR data taking with ZDC, $\mu=0.1-1\%$
- ALICE vdM: standard vdM scan setup (ADAND, VBAND, 0TVX)

### Trigger setup after ramp up

- IR=300kHz (or @IR=100kHz)
- Muon cluster decoupled (~80% lifetime))
- Central cluster: MB(300Hz) + HM(80Hz) + CALO(60Hz) + DG(tests) + TRD

---

**Table:**

<table>
<thead>
<tr>
<th>Week</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mo</td>
<td>14</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>Tu</td>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>We</td>
<td>18</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Th</td>
<td>19</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Fr</td>
<td>20</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Sa</td>
<td>21</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Su</td>
<td>22</td>
<td>25</td>
<td>26</td>
</tr>
</tbody>
</table>

**Legend:**

- Quite Beams
- Stable Beams
- Recovery
- B=0.2T Run
- VdM
- TS1
- MD 1
- Injector TS (8 hours)
- 1st May
- Intensity ramp-up Scrubbing as required
- beta* 2.5 km dev.
- May Day comp
ALICE Performance 2016

Special periods:

- 75M global OR triggers (V0 | AD | SPD) with isolated bunches
- 54M minimum bias triggers with reduced solenoid field B=0.2T (to be continued)
- 10M minimum bias at $\mu < 0.002$ with ZDC during ATLAS/CMS/LHCb vdB
TPC Distortion Corrections

- Correction extraction procedure well established (was foreseen for RUN3)
  - New calibration allows to correct for up \( \sim 10 \) cm distortions
  - Distortions fluctuations remain, accounted by increasing errors of affected clusters

- Study of distortions scaling with IR (caused major delay in starting the production)
  - Scaling is not precise enough to reliably extrapolate corrections from one run to another (in analysis grade production)
  - Very useful in initial reconstruction for calibration

- Pb-Pb 2015 production status
  - Low luminosity: finished in middle of May
  - High luminosity: running

TPC track DCA@vertex (convolution of \( p_T \) and angular resolution)

Uncorrected Corrected

\( p_T > 2 \text{ GeV}/c \)
Van der Meer Scans in IP2

- $\beta^* = 19$ m
- Detectors: T0, V0, ITS, AD0
- Taking data with half crossing angle = $+160 \mu$rad external in shadow of ATLAS and CMS vdM scan
- Successful scan within $\sim 3.5$ h
- Data taking efficiency 93%
The Future: ALICE Upgrade Program

New Inner Tracking System (ITS)
- improved pointing precision
- less material → thinnest tracker at the LHC

Muon Forward Tracker (MFT)
- new Si tracker
- Improved $\mu$ pointing precision

MUON ARM
- continuous readout electronics

Time Projection Chamber (TPC)
- new GEM technology for readout chambers
- continuous readout
- faster readout electronics

New Central Trigger Processor (CTP)

Data Acquisition (DAQ)/High Level Trigger (HLT)
- new architecture
- on line tracking & data compression
- 50kHz Pbb event rate

TOF, TRD, ZDC
- Faster readout

New Trigger Detectors (FIT)

(c) by St. Rossegger
Upgrade Progress: New ITS

η coverage: 
$|\eta| \leq 1.5$

r coverage: 
22 – 400 mm

7 layers of MAPS

$\langle X/X_0 \rangle = 0.3\%$

Total weight: 1.4 g

12.5 G-pixel camera
(10 m$^2$)

η coverage: 
$|\eta| \leq 1.5$

r coverage: 
22 – 400 mm

7 layers of MAPS

$\langle X/X_0 \rangle = 0.3\%$

Total weight: 1.4 g

12.5 G-pixel camera
(10 m$^2$)
Inner Barrel
Production:
31 units produced

Outer Barrel
Production:
Spaceframe
21 units 1.4m (OL) produced
14 units 1m (ML) produced

Coldplate
23 units 1.5m (OL) produced
9 units 1m (ML) produced
ITS Module & Stave Prototypes

Semi-automatic Module Assembly Machine

- Factory Acceptance Test successful (IBS Precision Mechanics – Netherlands)
- 1st Delivery to CERN: May 2016, 5 more to come during the remainder of the year

Outer Barrel HIC, pixel chip side

- Successful construction of detector modules
- Noise thresholds as for single chip
- Successful ITS stave engineering design review (May 3-4 2016)

Outer Barrel HIC, FPC side

Inner Barrel Stave
TPC Upgrade with GEMs

World Largest TPC ALICE key tracking and PID instrument 500 million pixels

To operate at the 50 kHz rate
⇒ no gating grid
⇒ need to minimize Ion Back Flow to keep space charge distortions at a tolerable level
Replace wire-chambers with quadruple-GEMs
- 100 m² single-mask foils
- Limit Ion Back Flow into drift volume
- Maintain excellent dE/dx resolution

New readout electronics
Keep all other subsystems

GEM and ROC EDR in November 2015
MoU sent to FA
Final decision on readout scheme taken
Preparing for Series Production

GEM QA: HD optical and gain scanning

- Pre-production campaign ongoing (2 IROC + 2 OROC)
- QA and production procedures being established
- Start of mass production after PRR in August 2016
New TPC Readout Scheme

Use direct readout mode of SAMPA without zero suppression and move signal processing functionality to CRU

⇒ Reduce complexity of SAMPA and FEC
⇒ Increase flexibility of signal treatment in CRU

Reduce SAMPA ADC sampling frequency from 10 MHz to 5 MHz

⇒ Reduce raw data volume by factor 2
⇒ No significant performance loss

FEC schematic

For 5 MHz
Summary

- **6 paper submitted**, 9 accepted and 8 published
- Exploiting new techniques and the full detector capabilities
- New insights from hard probes in pp & p-Pb collisions from RUN1 data
  - Hint for final state effects in central p-Pb collisions from $\psi(2S)$ production
  - Looking forward to high statistics Run 2 data for these probes and other statistics hungry analyses!
- TPC distortions for RUN2 under control, data reconstruction ongoing
- Successful start up of pp 2016 data taking campaign
- Some key upgrade milestones have been passed, the ALICE upgrade is proceeding according to schedule