ALICE status report

Constantin Loizides (LBNL/EMMI)
on behalf of the ALICE collaboration

116th LHCC meeting
04 Dec 2013

Outline:
- New physics results
- LS1 activities
- Upgrade plans for LS2
Recently submitted papers

• Measurement of charged jet suppression in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV
  - arXiv:1311.0633 (submitted to JHEP)

• Centrality, rapidity and transverse momentum dependence of $J/\psi$ suppression in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV
  - arXiv:1311.0214 (submitted to PLB)

• Two- and three-pion quantum statistics correlations in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV
  - arXiv:1310.7808 (submitted to PRC)
Recently published papers

1) \(K_s^0\) and \(\Lambda\) production in Pb-Pb collisions at \(\sqrt{s_{NN}}=2.76\) TeV, *PRL 111 (2013) 222301*

2) Centrality dependence of the pseudorapidity density distribution for charged particles in Pb-Pb collisions at \(\sqrt{s_{NN}}=2.76\) TeV, *PLB 726 (2013) 610*

3) Charmonium and \(e^+e^-\) pair photoproduction at mid-rapidity in ultraperipheral Pb-Pb collisions at \(\sqrt{s_{NN}}=2.76\) TeV, *EPJC 73 (2013) 2617*

4) Multiplicity dependence of the average transverse momentum in pp, p-Pb and Pb-Pb collisions at the LHC, *PLB 727 (2013) 371*

5) \(J/\psi\) elliptic flow in Pb-Pb collisions at \(\sqrt{s_{NN}}=2.76\) TeV, *PRL 111 (2013) 162301*

6) Centrality determination of Pb-Pb collisions at \(\sqrt{s_{NN}}=2.76\) TeV with ALICE, *PRC 88 (2013) 044909*

7) Centrality dependence of \(\pi,K,p\) production in Pb-Pb collisions at \(\sqrt{s_{NN}}=2.76\) TeV, *PRC 88 (2013) 044910*

8) Long range angular correlations of \(\pi,K,p\) in p-Pb collisions at \(\sqrt{s_{NN}}=5.02\) TeV, *PLB 726 (2013) 164*

9) Performance of the ALICE VZERO system, *JINST 8 (2013) 1001*

10) ... plus 4 more accepted
Recently published papers

1) $K_s^0$ and $\Lambda$ production in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV, 
   *PRL* 111 (2013) 222301

2) Centrality dependence of the pseudorapidity density distribution for charged particles in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV, 
   *PLB* 726 (2013) 610

3) Charmonium and $e^+e^-$ pair photoproduction in ultraperipheral Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV, 
   *EPJC* 73 (2013) 2617

4) Multiplicity dependence of the average transverse momentum in pp, p-Pb and Pb-Pb collisions at the LHC, 
   *PLB* 727 (2013) 371

5) J/$\psi$ elliptic flow in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV, 
   *PRL* 111 (2013) 162301

6) Centrality determination of Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV with ALICE, 
   *PRC* 88 (2013) 044909

7) Centrality dependence of $\pi,K,p$ production in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV, 
   *PRC* 88 (2013) 044910

8) Long range angular correlations of $\pi,K,p$ in p-Pb collisions at $\sqrt{s_{NN}}=5.02$ TeV, 
   *PLB* 726 (2013) 164

9) Performance of the ALICE VZERO system, 
   *JINST* 8 (2013) 1001

10) ... plus 4 more accepted
New preliminary results

1) K* in pp at 2.76 TeV (*)
2) D-meson-hadron angular correlations in pp at 7 TeV (*)
3) $v_2\{SP, |\Delta\eta|>0.8\}$ for $\pi,k,p$ in pp at 7 TeV (*)
4) D-meson rapidity distributions in p-Pb (*)
5) HFE-hadron angular correlations in p-Pb
6) $\pi,K,p$ at high pT in p-Pb
7) Two-particle angular correlation (mini-jets analysis) in p-Pb
8) Balance function in p-Pb
9) $J/\psi \rightarrow \mu\mu$ (forward) vs pT and $<pT>$ of $J/\psi \rightarrow \mu\mu$ (forward) vs multiplicity (*)
10) $J/\psi(2S) \rightarrow \mu\mu$ (forward) in p-Pb
11) $J/\psi \rightarrow ee$ in p-Pb and $J/\psi \rightarrow ee$ vs pT in Pb-Pb
12) $\Phi \rightarrow \mu\mu$ in p-Pb (*)
13) Dijet kT in p-Pb
14) Exclusive $J/\psi$ photoproduction in ultraperipheral p-Pb
15) Azimuthal sensitive HBT in Pb-Pb
16) Hadron-jet coincidence measurements in Pb-Pb

(*) not discussed in the talk
New physics results
Reminder

Local structure of QCD vacuum

Local QCD + initial state/cold nuclear matter

Local QCD + initial state/cold nuclear matter + Quark-Gluon Plasma
Bulk observables in p-Pb
Identified particle ridge $v_2$ and spectra

- Double ridge in high-multiplicity p-Pb
  - Particle type dependent $v_2$ vs $p_T$
    \[ v_n^{i\{2PC\}} = V_n^{h-i}/\sqrt{V_n^{h-h}} \text{ with } V_n^{h-i}\{2PC\} = a_n^{h-i}/a_0^{h-i} \]
Identified particle ridge $v_2$ and spectra

- Double ridge in high-multiplicity p-Pb
  - Particle type dependent $v_2$ vs $p_T$
  - Similar effect also for HF electrons
    - Suggestive of same origin
Double ridge in high-multiplicity p-Pb

- Particle type dependent $v_2$ vs $p_T$
- Characteristic mass splitting and similar $p$-$\pi$ crossing as in Pb-Pb

• In hydro-dynamical models, suggestive of radial flow
Identified particle ridge $v_2$ and spectra

- Double ridge in high-multiplicity p-Pb
  - Particle type dependent $v_2$ vs $p_T$
  - Characteristic mass splitting and similar $p-\pi$ crossing as in Pb-Pb
  - In hydro, suggestive of radial flow
- Spectra similar features as in Pb-Pb
  - Consistent with radial flow picture
  - In pp, also modeled microscopically
Minijet analysis in p-Pb

- Two-particle angular correlations at low $p_T$
  - Statistically study mini-jet production
  - $p_T > 0.7$ GeV/c ($>>\Lambda_{QCD}$ to be insensitive to string breaking)

- Analysis similar to pp (ALICE, JHEP 1309 (2013) 049) except from subtraction of double ridge

- Obtain yields as

\[
\begin{align*}
< N_{\text{trigger}} > &= \frac{N_{\text{trigger}}}{N_{\text{events}}} \\
< N_{\text{assoc, near side}} > &= \sqrt{2\pi} \frac{N_{\text{trigger}}}{N_{\text{events}}} \left( A_1 \cdot \sigma_1 + A_2 \cdot \sigma_2 \right) \\
< N_{\text{assoc, away side}} > &= \sqrt{2\pi} \frac{N_{\text{trigger}}}{N_{\text{events}}} \left( A_3 \cdot \sigma_3 \right)
\end{align*}
\]

Yields extracted by bin-counting after ZYAM and ridge removal or from Gaussian fits as illustrated
In p-Pb, high multiplicity events are not characterized by a higher number of associated particles in jet peak

- No bias on the near-side per trigger yield, except at low multiplicities to softer than average collisions
- Caveat: Different event selection than in pp

Similar findings for away-side (not shown)
Minijet uncorrelated seeds

Define number of uncorrelated seeds:

\[
\langle N_{uncorrelated\ seeds} \rangle = \frac{\langle N_{trigger} \rangle}{\langle N_{trigger\ correlated} \rangle} = \frac{\langle N_{trigger} \rangle}{\langle 1 + N_{assoc,near+away} \rangle}
\]

- In p-Pb, the number of uncorrelated seeds scales with V0A multiplicity
- In Pythia, the number of uncorrelated seeds scale with number of MPI
Minijet uncorrelated seeds

In p-Pb, the number of uncorrelated seeds scales with V0A multiplicity.

In Pythia, the number of uncorrelated seeds scale with number of MPI.

Uncorrelated seeds do not scale with $N_{\text{coll}}$ for low and high multiplicity.

- Consequences for centrality estimation in p-Pb.
Centrality in p-Pb

- Multiplicity fluctuations induce sizeable bias on Mult/Ncoll
- Additional for peripheral collisions
  - Mean impact parameter in NN collisions increases
  - Jet veto by cutting into the NN cross section

For a given centrality, hard processes expect to scale as

$$\left\langle N_{\text{coll}, \text{cent}}^{\text{Glauber}} \right\rangle \left/ \left\langle n_{\text{hard}} \right\rangle_{\text{cent}} \right\rangle \left/ \left\langle n_{\text{hard}} \right\rangle_{\text{pp}} \right\rangle$$

Ongoing discussions between experiments and theorists

(No bias in 0-80% PbPb)
Charge correlations using balance function $BF(\Delta \eta) = \frac{1}{2}(C_{US}(\Delta \eta) - C_{LS}(\Delta \eta))$

- Study system evolution by tracing charge separation in $\Delta \eta$ (and $\Delta \phi$)

- Distribution is narrowing with increasing multiplicity

- Width depends on creation time and degree of collectivity
At low $p_T$, width decreases for increasing multiplicity (while no dependence was found at high $p_T$). Trend similar to Pb-Pb.
Bulk observables in Pb-Pb
Azimuthally sensitive pion femtoscopy

New preliminary

\[ R^2_{\text{long}} (\text{fm}^2) \]

\[ \begin{array}{c|c|c|c|c|c|c}
\text{Pb-Pb, } \sqrt{s_{NN}} = 2.76 \text{ TeV} \\
\hline
0-5\% & 0-10\% & 10-20\% & 20-30\% & 30-40\% & 40-50\% \\
\hline
\end{array} \]

Local co-moving system (LCMS)

\[ \Delta \phi = 0 \]

Rside large
Rout small

q=p_1-p_2
\[ k_T = \left| p_{T,1} + p_{T,2} \right| / 2 \]

Expected dependence of 3D radii in LCMS relative to event plane angle
Femtoscopy using 3-pion cumulants

- 3-pion cumulants
  - Enhances Bose-Einstein (QS) signal
  - Suppresses (2-pion) background

- Measure 3-pion correlations
  \[ C_3(p_1, p_2, p_3) = \frac{N_3(p_1, p_2, p_3)}{N_1(p_1)N_1(p_2)N_1(p_3)} \]

- Remove all 2-pion QS correlations to arrive at 3-pion cumulant \( c_3 \)
  (formula in backup)

- Express correlation \( C_3 \) and cumulant \( c_3 \)
  - vs momentum transfer
    \[ Q_3 = \sqrt{q_{inv,12}^2 + q_{inv,13}^2 + q_{inv,23}^2} \]
  - for triplet momentum
    \[ K_{i,3} = \frac{|p_{T,1} + p_{T,2} + p_{T,3}|}{3} \]

Demonstration of 3-pion cumulant performance for mixed-charge case when projected onto 2-pion momentum space
3-pion mixed-charged correlations

- At low $Q_3$, two- and three-particle correlations ($C_3$) dominated by final state interactions (FSI)
  - Mainly Coulomb interactions
  - Obtain corrections from Therminator
- Use mixed charged correlation to benchmark performance of FSI corrections
- Mixed-charged cumulant ($c_3$) consistent with unity
  - Mixed charged case well understood
  - FSI (Coulomb) corrections work well
  - Small residuals from unity treated as systematic uncertainty for same charge cumulant

New arXiv:1310.7808
3-pion same-charged correlations

- After FSI corrections large same-charged cumulant ($c_3$)
- Genuine 3-pion Bose-Einstein correlations
  - Extract femtoscopic source radii (work in progress)
3-pion to 2-pion ratio $r_3$

- Measure ratio of 3-pion over 2-pion QS correlations

$$r_3(Q_3) = \frac{c_3(Q_3) - 1}{\sqrt{(C_{12}^{QS}(Q_1) - 1)(C_{13}^{QS}(Q_2) - 1)(C_{23}^{QS}(Q_3) - 1)}}$$

- Extract $r_3(Q_3 \to 0) = y$
  - For chaotic particle production, expect $y=2$

- Measure $r_3$ about 1.5σ below chaotic limit (from two types of fits) at low triplet momentum
  - Possible interpretation:
    About 22% ± 12% of low momentum pions are emitted coherently
    - Possible/speculative source:
      Color Glass Condensate formation
Jet quenching

Jet

π, K, p, ...

Freeze Out

Hadron Gas

Chemical Freeze Out

 Mixed Phase?

Beam Rapidity

QGP

Pre-Equilibrium Phase (< τ₀)

parton

Jet

Jet

dN/dy

T

(quenched) jet

A

B

z
Unlike in p-Pb, jets are strongly suppressed, hence jet quenching is a final state effect.
Dijet acoplanarity in p-Pb

Jet $p_{T2}>20$ GeV/c
R=0.4, $|\eta_{lab}|<0.5$
0-20% V0A

Charged jet trigger $p_{T1}$

No indication for $k_T$ broadening, even not in high-multiplicity p-Pb events
(relative to PYTHIA 8, tune 4C, $k=0.7$)

$$k_T = p_{T,\text{ch jet}}^{\text{trigger}} \sin(\Delta \varphi_{\text{dijet}})$$
Hadron-jet correlations in Pb-Pb

- Hadron-jet angular recoil $\Delta \varphi$ distribution consistent with Pythia (embedded in data)
  - No indication for medium induced acoplanarity (at low jet $p_T$)
Hadron-jet correlations in Pb-Pb

New preliminary

- Hadron-jet angular recoil $\Delta \varphi$ distribution consistent with Pythia (embedded in data)
  - No indication for medium induced acoplanarity (at low jet $p_T$)

- Hadron-jet recoil ratio consistent with Pythia
  - No significant energy redistribution within $R=0.5$
Quarkonia

figure from A. Mocsy
Different $p_T$ (and centrality) dependence of $J/\psi$ $R_{AA}$ at LHC and RHIC
J/ψ production in Pb-Pb

As expected in a scenario with $c\bar{c}$ recombination, especially at low $p_T$
J/ψ production versus rapidity in p-Pb

- Suppression at mid- and forward rapidity
  - Consequences for $R_{AA}$: Suggests even stronger recombination
- Consistent with shadowing models (EPS09 NLO) and/or coherent parton energy loss
- Specific CGC calculation disfavored
### J/ψ production versus $p_T$ in p-Pb

**R_{pPb}** close to one
- Little $p_T$ dependence

**R_{pPb}** below one
- More precision needed to see if there is a $p_T$ dependence

**R_{pPb}** below one, in particular at low $p_T$
- Significant $p_T$ dependence
  - Additional constraints on models
$\psi(2S)$ production in p-Pb

- $\psi(2S)$ more suppressed than $J/\psi$
  - Not expected by initial state CNM effects and coherent energy loss
- Stronger relative suppression in backward direction
  - Qualitatively expected from break-up due to comoving system
- But also strong suppression in forward direction
  - Final state effects?
J/ψ photoproduction in pPb

\[ \gamma + p \rightarrow J/\psi + p \]

- Access to gluon distribution in proton target at low x
  - Advantage of p-Pb that photon source is known
  - More results to come from barrel/barrel and barrel/muon
LS1 activities
Main activities for LS1

- Complete TRD (+5 supermodules)
- Install DCal calorimeter (8 supermodules)
- Install one additional PHOS supermodule
- Numerous detector and infra-structure consolidation and restructuring efforts

On track with LS1 schedule, but still a lot of work ahead
DCal installation

- New beams installed inside L3 magnet in June
- C-side plus two 1/3 modules done in October
- PHOS and A-side Dcal SM installation in Sep 2014 (after new PHOS readout is ready)
Detector and services rework

**Muon Tracker LV rework**
- Repaired almost 90 chambers
- Re-solder LV busbar connection in order to fix the occupancy issues
- Tests ongoing for DCS and DAQ

**T0 Rework**
- Production of new QTC modules underway for 25ns beam
- Relocate electronics to C side (C33-34)
- Reduce trigger generation latency (to 430ns) ongoing
- Tuning scheduled for February 2014

**TRD LV rework**
- LV issue: hot connections due to not proper tightening of cables on patch-panel
- Fix: de-install 6 TRD SMs, rework LV distribution and re-install them in LS1
- Completion during this week

**DAQ**
- Pause/recover framework (40% faster)
- New cluster: Global service back June 2014

**HLT**
- New cluster procurement Q4/13 + Q1/13
- Q2/Q3 2014 installation + commissioning
ALICE run-control center (ACR)

29 seats
9 existing desks + 12 new

Redesigned open space to improve efficiency of operation
CERN groups involved at P2 during LS1

• EN-EL:
  – upgrade and consolidation of the UPS network
  – cabling new ACR
  – electrical maintenance and tests
  – installation optical fibers and test
• EN-CV:
  – chilled water upgrade, L3 ventilation upgrade
  – standard maintenance, cleaning cooling towers
  – replacement detector cooling tanks
  – cooling new ACR
• EN-MEF:
  – primary gas supply and gas dewar refurbishment
  – safety coordination
  – cabling and scaffolding coordination
• EN-HE:
  – transport coordination
  – refurbishment of cranes, anti-collision system
  – maintenance lifts and doors
• TE-VSC:
  – removal RB24 beampipe, venting and neon flushing of central beampipe
  – installation of additional gauge in RB24 pipe
• GS-SEE:
  – coordination ACR renovation
  – maintenance of buildings (leaks)
  – new storage building (2014) and removal of barracks
• GS-IS:
  – cleaning
• BE-ABP:
  – survey
• PH-DT:
  – consolidation magnet control and DSS systems
  – maintenance gas systems and gas re-circulation for MTG
• IT-CS:
  – IT network installation and upgrade
  – IT cables new ACR

A special acknowledgment to all CERN groups, for the invaluable support provided to the experiment during 2013 and for their commitments for the rest of LS1
Upgrade plans for LS2
ALICE upgrades for LS2

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

Muon Forward Tracker (MFT)
• new Si tracker
• Improved MUON pointing precision

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

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

TOF, TRD
• Faster readout

New Trigger Detectors (FIT)

(c) by St. Rossegger
ALICE upgrades for LS2

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

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

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

TOF, TRD
- Faster readout

New Trigger Detectors (FIT)

http://cds.cern.ch/record/1603472
ALICE upgrades for LS2

New Inner Tracking System (ITS)
- improved tracking precision
- less material

Time Projection Chamber (TPC)
- new GEM readout chip
- continuous readout
- faster readout

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

TOF, TRD
- Faster readout

New Trigger Detectors (FIT)
### Summary of physics (from ITS TDR)

<table>
<thead>
<tr>
<th>Observable</th>
<th>Current, 0.1 nb$^{-1}$</th>
<th>Upgrade, 10 nb$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$p_T^{\text{min}}$ (GeV/c)</td>
<td>statistical uncertainty</td>
</tr>
<tr>
<td>Heavy Flavour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D meson $R_{AA}$</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>$D_s$ meson $R_{AA}$</td>
<td>4</td>
<td>15%</td>
</tr>
<tr>
<td>D meson from B $R_{AA}$</td>
<td>3</td>
<td>30%</td>
</tr>
<tr>
<td>$J/\psi$ from B $R_{AA}$</td>
<td>1.5</td>
<td>15% (for $p_T$)&lt;br&gt;not accessible</td>
</tr>
<tr>
<td>$B^+$ yield</td>
<td>not accessible</td>
<td>3</td>
</tr>
<tr>
<td>$\Lambda_c$ $R_{AA}$</td>
<td>not accessible</td>
<td>2</td>
</tr>
<tr>
<td>$\Lambda_c/D^0$ ratio</td>
<td>not accessible</td>
<td>2</td>
</tr>
<tr>
<td>$\Lambda_b$ yield</td>
<td>not accessible</td>
<td>7</td>
</tr>
<tr>
<td>D meson $v_2$ ($v_2 = 0.2$)</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>$D_s$ meson $v_2$ ($v_2 = 0.2$)</td>
<td>not accessible</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>D from B $v_2$ ($v_2 = 0.05$)</td>
<td>not accessible</td>
<td>2</td>
</tr>
<tr>
<td>$J/\psi$ from B $v_2$ ($v_2 = 0.05$)</td>
<td>not accessible</td>
<td>1</td>
</tr>
<tr>
<td>$\Lambda_c$ $v_2$ ($v_2 = 0.15$)</td>
<td>not accessible</td>
<td>3</td>
</tr>
<tr>
<td>Dielectrons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature (intermediate mass)</td>
<td>not accessible</td>
<td>10%</td>
</tr>
<tr>
<td>Elliptic flow ($v_2 = 0.1$) [14]</td>
<td>not accessible</td>
<td>10%</td>
</tr>
<tr>
<td>Low-mass spectral function [14]</td>
<td>not accessible</td>
<td>0.3</td>
</tr>
<tr>
<td>Hypermultiplets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^3\Lambda$H yield</td>
<td>2</td>
<td>18%</td>
</tr>
</tbody>
</table>
Summary

• Continue to obtain wide range of measurements in pp, p-Pb and Pb-Pb collisions with the same analysis method
  - Address aspects of initial and final state effects through detailed system comparisons
    • Suppression of inclusive jets and recombination of inclusive J/ψ in Pb-Pb
    • More observables on bulk particle production in p-Pb (not yet conclusive on the origin of the ridge)
  - New measurement on chaoticity from 3-pion cumulants

• Activities ongoing at Point 2 are on track with schedule
• Substantial progress on upgrades for run 3
Identified particle ridge $v_2$ and spectra

- Classical flow (scalar-product) method
  - Low multiplicity p-Pb and minbias pp show no mass ordering
  - High multiplicity p-Pb events exhibit mass ordering

New preliminary

Min-bias pp, 7 TeV
In p-Pb, high multiplicity events are not characterized by a higher number of associated particles on away-side.

- No bias on the near-side per trigger yield, except at low multiplicities to softer than average collisions

Caveat: Different event selection than in pp
Minijet uncorrelated seeds

Define number of uncorrelated seeds:

\[
\langle N_{\text{uncorrelated seeds}} \rangle = \frac{\langle N_{\text{trigger}} \rangle}{\langle N_{\text{trigger correlated}} \rangle} = \frac{\langle N_{\text{trigger}} \rangle}{1 + N_{\text{assoc, near+away}}}
\]

- In p-Pb, the number of uncorrelated seeds scales with V0A multiplicity
- In pp, saturation is reached for highest multiplicity (limited number of MPIs)
  - Caveat: Different event selection than in pp
Charge correlations using balance function

\[ BF(\delta \eta) = \frac{1}{2} \left| C_{US}(\delta \eta) - C_{LS}(\delta \eta) \right| \]

- Study system evolution by tracing charge separation in \( \delta \eta \) (and \( \delta \phi \))
- Width depends on creation time and degree of collectivity

In Pb-Pb width decreases with increasing centrality and constrains models.
3-pion correlation formalism

\[ N_3(p_1, p_2, p_3) = f_1 N_1(p_1) N_1(p_2) N_1(p_3) + f_2 \left[ N_2(p_1, p_2) N_1(p_3) + N_2(p_3, p_1) N_1(p_2) + N_2(p_2, p_3) N_1(p_1) \right] + f_3 K_3(q_{inv,12}, q_{inv,31}, q_{inv,23}) N_3^{QS}(p_1, p_2, p_3), \]

\[ c_3(p_1, p_2, p_3) = 1 + [2N_1(p_1) N_1(p_2) N_1(p_3) - N_2^{QS}(p_1, p_2) N_1(p_3) - N_2^{QS}(p_3, p_1) N_1(p_2) - N_2^{QS}(p_2, p_3) N_1(p_1) + N_3^{QS}(p_1, p_2, p_3)] / N_1(p_1) N_1(p_2) N_1(p_3). \]

\[ r_3(p_1, p_2, p_3) = \frac{c_3(p_1, p_2, p_3) - 1}{\sqrt{(C_2^{QS}(p_1, p_2) - 1)(C_2^{QS}(p_3, p_1) - 1)(C_2^{QS}(p_2, p_3) - 1)}} \]

In Core/Halo picture, given \( \lambda \), the probability of choosing \( N \) particles from the core is \( \lambda^{N/2} \)

- \( f_1 = (1 - \lambda^{1/2}) 3 + 3(1 - \lambda^{1/2}) 2 \lambda^{1/2} - 3(1 - \lambda^{1/2})(1 - \lambda) \)
- \( f_2 = (1 - \lambda^{1/2}) \)
- \( f_3 = \lambda^{3/2} \)
3-pion to 2-pion ratio $r_3$

Chaotic limit

$0-5\%$

$5-10\%$

$10-20\%$

$20-30\%$

$30-40\%$

$40-50\%$

$0.16 < K_{t,3} < 0.3 \text{ GeV/c}$

$0.3 < K_{t,3} < 1.0 \text{ GeV/c}$

ALICE Pb-Pb $\sqrt{s_{NN}} = 2.76 \text{ TeV}$

New arXiv:1310.7808
PHOS readout upgrade tasks

- SRU production Jan 2014
- TRU production planned for first part of 2014
- 1 module re-worked and FEE-DTC tested (global)
- 1 module re-worked and FEE-DTC tested (standalone)
- 2 modules FEEs being re-worked
- Feed-through for R/O (RJ45) in production and for programming JTAG designed
- Minor changes to analysis software
- Infrastructure in P2 designed