Highlights and Accomplishments in 2016

Constantin Loizides (LBNL) for the ALICE collaboration

16 Dec 2016, Council meeting
2 LHC Run-2 datasets

- Versatile and challenging trigger mix
- Extremely stable operations
  - Thanks to CERN accelerator teams
  - ALICE efficiency > 90%

Datasets taken end of 2015 and 2016 are 7-8x larger than those from Run-1
3 Performance (from fast muon/calo reco)

\( p-Pb, 5.02 \, \text{TeV} \)

\[ M_{\mu\mu} \text{ (GeV/c}^2) \]

\( p-Pb, 8.16 \, \text{TeV} \)

\[ M_{\mu\mu} \text{ (GeV/c}^2) \]

\( Pb-p, 8.16 \, \text{TeV} \)

\[ M_{\mu\mu} \text{ (GeV/c}^2) \]
4 TPC space-charge distortion calibration

- Large space point distortions in Run2 located in edges of a few inner chambers (visible eg. in DCA distributions)
- Implemented time-dependent calibration scheme using inner (ITS) and outer (TRD+TOF) detectors
- Scheme originally foreseen for RUN3

Example: Hypertriton production (roughly have of 2015 Pb-Pb statistics)

Intense effort over ~12 months resulted in effective calibration scheme!
5 Bayesian PID

- Generalized approach for usage of combined PID of various detectors
  - Standard approach “nSigma-cuts”
- Proof-of-concept for D-mesons

![Graph showing the comparison between n_σ PID and Bayesian PID for different mass distributions.]

- Allows access to probes with worse S/B
  - Λ_c → pK^−π^+ and c.c.
6 Scientific approach

Local structure of QCD vacuum

Local QCD + initial state/cold nuclear matter

Local QCD + initial state/cold nuclear matter + Quark-Gluon Plasma
7 Initial and final anisotropy

Temperature profiles in transverse plane from hydrodynamical calculation (H. Niemi)

Initial spatial anisotropy
Eccentricity

\[ \epsilon_n e^{-in\varphi_n} \]

KSS bound
\[ \frac{\eta}{s} > \frac{1}{4\pi} \sim 0.08 \]

Momentum space anisotropy
Flow

\[ \nu_n = \langle \cos \left( 2\varphi - 2\psi_n \right) \rangle \]
Latest “flow” results

Wealth of new data for precision comparisons with hydro calculations and extraction of $\langle \eta/s \rangle$
9 Correlation of anisotropic harmonics

- Measure relation between $v_m$ and $v_n$ via “Symmetric 2-harmonic 4-particle Correlations”
  $$SC(m, n) = \langle v_m^2 v_n^2 \rangle - \langle v_m^2 \rangle \langle v_n^2 \rangle$$

- If $SC(m,n) \neq 0 \rightarrow$ (anti)-correlation

- Insensitive to
  - Non-flow effects
  - Inter-correlations of various symmetry plane angles

SC measurements are sensitive to the temperature dependence of $\eta/s$ and initial conditions
10 Jet quenching

Search for effects in data:

\[ R_{AA} = \frac{dN_{AA}/dp_T}{N_{coll} dN_{pp}/dp_T} \]

Compared to pp (vacuum) parton evolution in QGP affected by presence of many color charges which induce collisional and radiative energy loss:

→ Expected to change the inner structure, angular distribution and rate of jets

\[ \Delta E_{\text{loss}}(g) > \Delta E_{\text{loss}}(q) > \Delta E_{\text{loss}}(Q) \]

(color factor) (dead-cone effect)

Compared to pp (vacuum) parton evolution in QGP affected by presence of many color charges which induce collisional and radiative energy loss:
11 Jets via two particle correlations

- Neutral pions as trigger particles
  - Measure associated charged hadron per-trigger yield $J = Y - B$
  - Compare to pp on near-side and away-side via

$$I_{AA} = \frac{\int J_{AA} d\Delta \Phi}{\int J_{pp} d\Delta \Phi}$$
Per-trigger yield modification

- Neutral pions as trigger particles
  - Measure associated charged hadron per-trigger yield J=Y-B
  - Compare to pp on near-side and away-side via
    \[ I_{AA} = \frac{\int J_{AA} d\Delta\Phi}{\int J_{pp} d\Delta\Phi} \]
- Enhancement at low \( p_T \), and suppression on away-side for high \( p_T \)
  - Suppression well described by parton-energy loss calculations
  - Enhancement in AMPT from jet-medium interactions
    (but predicts suppression NS at high \( p_T \))
13 Jet shapes: jet mass

New result for Hard Probes conference; to be submitted soon

Interactions between jet and QGP cause changes in the jet structure

Expect relation between jet mass and virtuality of the partons, sensitive to the mechanism for energy loss
**14 Heavy-quark energy loss**

\[ R_{AA} = \frac{dN_{AA}/dp_T}{N_{coll}dN_{pp}/dp_T} \]

via the measurement of decay electrons from charm and beauty hadrons

**Strong suppression of electrons originating from heavy-flavor decays observed in central Pb-Pb collisions, unlike in p-Pb.**

**Constrain theoretical models (with D-meson \( R_{PbPb} \) & elliptic flow)**

\( \rightarrow \) Extraction of heavy-quark transport coefficients
Strangeness enhancement

- Values in pp (and p-Pb) reach those from Pb-Pb
- Grand-canonical statistical description works well in Pb-Pb
  - Same mechanism in smaller system?
  - String hadronization models do not describe the data
- Follow-up studies at 13 TeV ongoing
16 Charmonia

Debye screening of $Q\bar{Q}$ potential at large $T$
17 Charmonia

Increase of J/psi yield in particular at low $p_T$ (consistent with regeneration calculation)
18 ALICE upgrade program (for Run 3) ...

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

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

MUON ARM
- continuous readout electronics

New Central Trigger Processor (CTP)

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

TOF, TRD, ZDC
- Faster readout

New Trigger Detectors (FIT)

→ technical design reports in CDS
ALPIDE sensor ready for production

- 1024 pixel columns
- 1.3x10^5 pixels/cm
- Spatial resolution
- Max particle rate: 100 MHz / cm^2
- Fake-hit rate: < 10^{-10} pixel / event
- Power: ~ 300 nW /pixel

First final-design TPC OROC assembly at NIPNE Bucharest

- SAMPA MPW2 chips being tested to confirm TPC specs
- First FEC Rev0 prototypes being tested
- Preproduction almost completed (2 IROC + 2 OROC)
- Comprehensive tests in lab and beam
- Start of mass production in 2017
20 Summary

- Extremely successful data taking
  - Thanks to the over-performing LHC
- TPC SCD calibration in production
- Numerous physics results
  - For all, see http://aliceinfo.cern.ch/ArtSubmission/submitted
  - Many more in the pipeline, stay tuned
- Ambitious upgrade in full swing
21 Extra
TPC Space point distortions

- Large space point distortions in Run2 (eg. in DCA distributions)
  - Charge originating from edges of a few inner chambers
  - Due to drifting columns of ions
  - Prop. to interaction rate

- Time dependent calibration as foreseen for Run3
  - Use inner (ITS) and outer (TRD+TOF) detectors
  - 3D distortion vector for each TPC voxel
  - Smoothed parameterization used as correction in reco
23 Upsilon regeneration?

Expected from sequential melting would be lower $R_{AA}$ at higher energy, however the opposite trend is seen (even if not a large effect considering uncertainties). Do we see (re)-generation in QGP or at phase boundary even for Upsilon?
Four pion correlation (Pb-Pb)

- Discrepancy of quantum optics calculation with measured 4-pion correlation
- Possible explanations
  - Quantum coherence
    - $G=33\% \pm 9\%$
    - Fails to explain 3-pion correlation
    - Present also at high $kT$
  - Coulomb repulsion
    - Asymptotic limit used
    - If genuine multibody relevant, deviations up to 20% can explain effect
Jet-like dihadron correlation

Asymmetry of near side jet peak: broader in $\eta$ than in $\varphi$

→ Possibly due to coupling to longitudinal flow; interplay between hard and soft physics
**ALICE upgrade program**

- **Motivation:** Focus on high-precision measurements of rare probes at low $p_T$
  - can not be selected with hardware trigger
  - need to record large sample of events
- **Target:** Pb-Pb recorded luminosity: $\geq 10\text{ nb}^{-1}$
  - gain in statistics: factor 100 for selected probes!
  - plus pp and pA data
- **Strategy:**
  - read out all Pb-Pb interactions at a maximum rate of 50 kHz with a minimum-bias trigger or continuously (TPC)
  - perform online data reduction
New ITS layout

12.5 G-pixel camera (~10 m²)

7-layer barrel geometry based on CMOS Pixel Sensors
- r coverage: 23 – 400 mm
- $\eta$ coverage: $|\eta| \leq 1.22$ for tracks from 90% most luminous region

3 Inner Barrel layers (IB)
4 Outer Barrel layers (OB)

Material /layer: 0.3% $X_0$ (IB), 1% $X_0$ (OB)

Design Requirements
Event Readout Rate
Pb-Pb: 100 kHz
pp: > 400 kHz
ALPIDE sensor ready for production

1024 pixel columns
512 rows

Bias, Data Buffering, Interface

1.3x10^5 pixels/cm^2 O(30x30x30 \mu m^3)
Spatial resolution: \( \sim 5 \mu m \) (3-D)
Max particle rate: 100 MHz / cm^2
Fake-hit rate: < 10^{-10} pixel / event
Power: \( \sim 300 \) nW /pixel

Detection Efficiency & Fake Hit Rate

Sensitivity Limit

-10 Pixels masked

V_{BB} = 3V

3/NIEL, 1.7e+13 1MeV n/cm^2
29 The ALICE detector

Central Barrel Tracking, PID $|\eta| < 0.9$

Muon Arm $-4 < \eta < -2.5$

EM/DCal $|\eta| < 0.7$, $\Delta \phi \approx 1/2$