Highlights from the LHCb experiment

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on behalf of the LHCb Collaboration

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May 14, 2018
LHCb: unique & beautiful detector for heavy-ions

- fully instrumented forward spectrometer
- low-$\rho_T$ capability
- excellent particle identification
- precision vertex reconstruction & tracking
LHCb heavy-ion collider mode: a wealth of data

<table>
<thead>
<tr>
<th>year</th>
<th>$\sqrt{s_{NN}}$</th>
<th>pPb/PbPb</th>
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<tr>
<td>2013</td>
<td>5.02 TeV</td>
<td>2015</td>
<td>5.02 TeV</td>
<td>2016</td>
<td>8.16 TeV</td>
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<td></td>
<td>1.6 nb$^{-1}$</td>
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<td>10 $\mu$b$^{-1}$</td>
<td>34 nb$^{-1}$</td>
<td>0.4 $\mu$b$^{-1}$</td>
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</table>

- fast detector
  - full inelastic luminosity in PbPb and XeXe
  - full rate in $pPb/Pb$ in HLT

- tracking 50-100 % centrality in PbPb
- data full of peaks and phenomena to explore

Just the tip of the iceberg!
The initial state & collectivity: important questions

- initial state and its fluctuations: required for quantitative QCD matter studies
- focus of LHCb at this Quark Matter
- entangled with the quest for limits of fluid dynamics paradigm

LHCb: frontier experiment in phase space

Thanks to boost, resolution, low-$p_T$ reach and fast read-out

- disentangle initial state from other phenomena
- constrain initial state
- sensitive to physics of the saturation scale
Collective phenomena with LHCb: unique forward acceptance

- dilute-dense limit at forward rapidity in \( pp \) and \( pPb \)
- backward vs forward
  \( \approx \) same behaviour at same multiplicity
- \( pPb/PbPb \) collisions: starting point for \( pp \) and PbPb analyses
First femtoscopy at forward rapidity at LHC in $pp$ collisions at 7 TeV

- Increase of one-dimensional source size $R$
- Decrease of chaoticity $\lambda$
- Qualitatively consistent with findings at midrapidity
- Starting point for studies in other collision systems

Bartosz Małecki, Wednesday 14:40
Prompt $J/\psi$ production in $p$Pb collisions at 8.16 TeV: precision nuclear modification

▶ nuclear PDFs & CGC accounting for observations
▶ assuming no other effect:
  constraining nPDFs in unexplored area at low-$x$

Shanzhen Chen, Tuesday 12:50

PLB 774 (2017) 159.
$D^0$ production in $pPb$ collisions at 5.02 TeV: precision data

▶ nuclear PDFs & CGC accounting for observation
▶ assuming no other effect:
  constraining nPDFs in unexplored area at low-$x$

Jiayin Sun, Wednesday 14:40
$\Lambda_c$ production in $p$Pb collisions at 5.02 TeV: test of charm fragmentation

▶ input for hadronisation phenomenology and in comparison with other collision systems
▶ hadronisation pattern of $c\bar{c}$ similar to model tuned to $pp$

Jiayin Sun, Wednesday 14:40
Non-prompt $J/\psi$ production in $p$Pb collisions at 8.16 TeV: precision data on beauty

- first precise $b$-production measurement in $p$Pb down to 0 $p_T$
- crucial input for PbPb phenomenology

Shanzhen Chen, Tuesday 12:50
Photons in $p$Pb collisions: probe of saturation

- clean probe of initial state: search for gluon saturation signature in unique LHCb acceptance
- effort using reconstruction with conversions ongoing

Thomas Boettcher, Tuesday 11:10, Poster, Cesar Da Silva
Ultra-peripheral PbPb collisions at 5.02 TeV: first \( J/\psi \) results

- LHCb well suited for exclusive production studies: resolution, PID and very forward detector HerSChel

- \( J/\psi \) production: access to squared nuclear gluon distribution low-\( x \): \( 10^{-2} < x < 10^{-5} \)
- starting point for further UPC measurements

Albert Bursche, Monday 17:30
LHCb fixed-target set-up: unique opportunity

$\sqrt{s_{NN}} = 69 - 110 \text{ GeV}$

backward rapidity hemisphere in centre-of-mass system
LHCb fixed-target data:
a full programme of collision systems

▶ $pA$ collisions: high statistics recorded suitable for charm in three collision systems
$pHe$ collisions at 4.0 TeV beam energy: 7.6 nb$^{-1}$ of data!
Soft particle production in $p$He fixed target collisions: precise cross sections

▶ powerful PID down to low-$p_T$ for antiprotons: input for cosmic ray community

▶ cross sections in $p$He 6.5 TeV beam energy underestimated by EPOS-LHC

▶ proves capability for primary particle spectra

LHCb-CONF-2017-002.
Charm production in fixed-target collisions: unique constraints

- sensitive to nuclear modification of parton distribution function & intrinsic charm
$D^0$ and $J/\psi$ production in $p$He fixed target: first cross sections

- Unique constraints on intrinsic charm with $p$He: no strong indication observed
- Starting point for future ion-ion collisions: open charm & charmonium down to 0 $p_T$ at $\sqrt{s_{NN}} = 69$ GeV

Shanzhen Chen, Tuesday 12:50
### LHCb upgrades: unique opportunities

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- **Phase I:** \( \rightarrow \approx 5 \times L_{\text{inst}}(\text{Run II}) \)
  - extent ion-ion capabilities
  - increase \( pA \) luminosity for low-\( x \) sector
- **Phase II in design phase:** \( \approx 50 \times L_{\text{inst}}(\text{Run II}) \)
  - dream detector for heavy-ion physics
LHCb detector upgrades phase I

- replace full tracker for 5 times higher pile-up in $pp$
- inspect 30 MHz rate in software trigger in $pp$
- magnet stations for low-$p_T$ tracks & TOF for low momentum PID in consideration for Phase I consolidation or Phase II
LHCb fixed target upgrade phase I: higher luminosity & more targets

- storage cell upstream: allow also for non-noble gas targets
- target with 10-100 × larger instant. luminosity per unit length
LHCb Upgrade Phase II

Expression of Interest submitted last year: design phase

Flavour physics precision experiment at pile-up 50 in $pp$: dream detector for heavy-flavour heavy-ion studies and more

physics case: document in preparation including heavy-ions & low-$x$ case

Conclusions

Heavy-ion collisions in collider and in fixed-target mode

▶ precise and unique constraints on nuclear modifications in proton-nucleus collisions at low-\(x\) & high-\(x\)

▶ potential for light-flavour, correlations & more barely touched scratching only surface with available data & data to come

▶ upgrades suited to overcome limitations in ion-ion collisions

▶ unique studies at low-\(p_T\) in heavy-flavours & far beyond

Unique opportunity for the study of strongly interacting matter in the lab!
Scratching only surface with available data!
LHCb at Quark Matter 2018
Initial state physics and approach to equilibrium

► Albert Bursche, Monday 17:30: Charmonium production in ultra-peripheral heavy-ion collisions at LHCb
► Thomas Boettcher, Tuesday 11:10: Prompt photon production in \( pPb \) collisions at \( \sqrt{s_{NN}} = 5 \) TeV
► Poster, Cesar Da Silva: Search for gluon saturation at small Bjorken-\( x \) with the LHCb detector

Quarkonia

► Shanzhen Chen, Tuesday 12:50: Heavy Flavour production measurements in proton-lead and fixed target collisions at LHCb

Open heavy flavour

► Jiayin Sun, Wednesday 14:40: Production of open charm and beauty states in \( pPb \) collisions with LHCb

Correlations and fluctuations

► Bartosz Małecki, Wednesday 14:40: Bose-Einstein correlations and \( b\bar{b} \) correlations in \( pp \) collisions with LHCb