Outline

- Introduction
- New physics results
- Run2 operation and performance
- Special runs: beam gas and heavy ion collisions
- LHCb upgrade
- Conclusion
LHCb is a dedicated heavy flavor physics experiment at the LHC.

Its primary goal is to look for indirect evidence of new physics in CP violation and rare decays of beauty and charm hadrons.

Excellent performance:
- tracking efficiency >96%
- decay time resolution ~45 fs
- momentum resolution 0.5-1.0%
- kaon ID efficiency ~95%
- muon ID efficiency: ~97%
Physics publication

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- **37 published papers in 2015**
- New from last LHCC:
  - 12 Submitted
  - 14 Published
- Still a lot results with the Run1 data in the pipeline
New papers

- **PAPER-2015-051** Angular analysis of the $B^0_d \rightarrow K^0 \mu^+\mu^-$ decay. To be submitted to JHEP
- **PAPER-2015-043** First observation of the decay $D^0 \rightarrow K^-\pi^+\mu^+\mu^-$ in the $\rho^0-\omega$ region of the dimuon mass spectrum. Submitted to Phys. Lett. B; arXiv:1510.08367
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- **CONF-2015-005** Study of $\psi(2S)$ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}}=5$ TeV; Presented at last LHCC
Latest News


2 December 2015: A mysterious ridge effect.

The LHCb collaboration has submitted today a paper reporting the study of correlations in particle production in proton(p)-lead(Pb) ion collisions at the LHC. The plots (see below) showing the angular distribution of these correlations show features similar to a "ridge" in a mountain landscape. Therefore physicists name this kind of analysis a study of "ridge effect".

Two sets of data were taken: p-lead and lead-p, where in the second case the direction of the proton and lead ion beams were reversed. This allowed the LHCb detector, recording the particles only on one side of the interaction point, to make measurements in the case of proton beam pointing towards the LHCb detector as well as in the opposite case of lead beam pointing to it.

The idea of analysis is simple. LHCb physicists plotted differences $\Delta$ between production angle of particle pairs both in angle $\theta$ along the direction of incoming proton or lead beams, and in angle $\phi$ around this direction. The difference in angle $\theta$ is plotted as the difference of a related variable, pseudo-rapidity $\eta$, where $\eta=-\ln(\tan(\theta/2))$. In this way the plot bin sizes closer to the beam direction are expanded.

This result was presented at last LHCC
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Angular analysis of the $B^0_d \rightarrow K^{*0} \mu^+\mu^-$ decay
Angular analysis of the $B^0_d \rightarrow K^{*0}\mu^+\mu^-$ decay

- Flavour-changing neutral current $b \rightarrow s$ via loop (or box) in SM
- Rate and angular observables can be affected by presence of virtual new particles (if there are any)
- Full angular analysis of the $B^0_d \rightarrow K^{*0}\mu^+\mu^-$ decay
  - System fully described by $q^2$ and three angles $\Omega=(\cos\theta_l, \cos\theta_k, \phi)$
Angular analysis of the $B^0_d \rightarrow K^{*0}\mu^+\mu^-$ decay

- Differential decay rate
  \[
  \frac{d^4\Gamma[B^0 \rightarrow K^{*0}\mu^+\mu^-]}{dq^2 d\Omega} = \frac{9}{32\pi} \sum_j I_j(q^2) f_j(\tilde{\Omega})
  \]
  \[
  \frac{d^4\Gamma[B^0 \rightarrow K^{*0}\mu^+\mu^-]}{dq^2 d\Omega} = \frac{9}{32\pi} \sum_j \bar{I}_j(q^2) f_j(\tilde{\Omega})
  \]

- $I_j$ are $q^2$-dependent angular observables
- $q^2$-dependent CP averages $S_j$ and CP asymmetries $A_j$ defined as [arxiv:0811.1214]
  \[
  S_j = \frac{(I_j + \bar{I}_j)}{\left(\frac{d\Gamma}{dq^2} + \frac{d\bar{\Gamma}}{dq^2}\right)}
  \]
  \[
  A_j = \frac{(I_j - \bar{I}_j)}{\left(\frac{d\Gamma}{dq^2} + \frac{d\bar{\Gamma}}{dq^2}\right)}
  \]

- CP-averaged observables
  - the forward-backward asymmetry of the dimuon system
    \[
    A_{FB} = \frac{3}{4} S_{6s}
    \]
  - the longitudinal polarisation fraction of the $K^{*0}$
    \[
    F_L = S_{1c}
    \]
  - “Optimized-theoretical clean” observables [arxiv:1303.5794]
    \[
    P'_{4,5} = S_{4,5}/\sqrt{F_L(1 - F_L)}
    \]
Angular analysis of the $B^0_d \rightarrow K^{*0} \mu^+\mu^-$ decay

- Update of [LHCb-CONF-2015-002]
- Inclusion of the scalar S-wave component in $K\pi$ system in angular analysis
- Three analysis methods with different strengths
- **Fit full angular distribution** \(\rightarrow\) complete set observables and correlations
  - Fit performed in bins of $q^2 \sim 2$ GeV\(^2/c^4\)
  - $B^0$ and $\bar{B}^0$ separately
- Yield: $624 \pm 30$ in $q^2 \in [1.1,6]$ GeV\(^2/c^4\) in $L = 3$ fb\(^{-1}\)

All CP asymmetries consistent with zero
All observables consistent with SM except $S_5$
Angular analysis of the $B^0_d \rightarrow K^{*0} \mu^+\mu^-$ decay

Tension from 1 fb$^{-1}$ analysis remains.
Now split over two bins of $2.8\sigma$ and $3.0 \sigma$ (q$^2$ bins [4.0, 6.0] GeV$^2$ and [6.0, 8.0] GeV$^2$) when comparing to [DHMV, JHEP 12 (2014) 125].
Angular analysis of the $B^0_d \to K^{*0} \mu^+\mu^-$ decay

**Method of moments**

**Amplitude fit**
- Modelling the $q^2$ dependence of the amplitudes $\Rightarrow$ fit for zero-crossing points [JHEP06(2015)084]
Angular analysis of the $B^0_d \rightarrow K^{*0}\mu^+\mu^-$ decay

- Perform $\chi^2$ fit of measured: $F_L$, $A_{FB}$, $S_{3..9}$ to extract Re(C9) fixing all other Wilson coefficients to their SM value
- Use EOS software package [JHEP07(2010)098] to test compatibility with SM.
- Float a generic vector coupling a.k.a. Wilson Coefficient Re(C9)

$\Delta \text{Re}(C9) = -1.04\pm0.25$

- Best fit to data is $3.4\sigma$ from the SM prediction of [Eur. Phys. J. C74 (2014) 2897]
- Caused by a contribution from a new non-SM particle or by unexpectedly large hadronic effect, underestimated in SM predictions [Altmannshofer, Straub, EPJC 75 382 (2015) and others]
Search for the lepton-flavour violating decay $D^0 \rightarrow e^\pm \mu^\mp$
Search for the lepton-flavour violating decay $D^0 \rightarrow e^\pm \mu^\mp$

- The decay $D^0 \rightarrow e^\pm \mu^\mp$ is a forbidden decay, in which lepton flavour is not conserved.
- The decay is predicted with $\mathcal{B}$ of $\mathcal{O}(10^{-6})$ in several models BSM
  - e.g. SUSY with R-parity violation and leptoquark model
- Candidate signal events are selected using the decay $D^{\ast+} \rightarrow D^0 \pi^+$ and the measurements are normalized to $D^{\ast+} \rightarrow D^0(\rightarrow K^- \pi^+)\pi^+$ decays
- Most dangerous background mis-ID $D^0 \rightarrow \pi^- \pi^+$ reconstructed as $e^+ \mu^-$
Search for the lepton-flavour violating decay $D^0 \rightarrow e^\pm \mu^\mp$

- No signal observed in 3 fb$^{-1}$
- Set world best limit $\mathcal{B}(D^0 \rightarrow e^\pm \mu^\mp) < 1.3 \times 10^{-8}$ at 90% CL
- Improving by an order of magnitude on previous limits
- Result further constrains products of couplings in SUSY models with R-parity violation and constrains the parameter space in some leptoquark models.
Model-independent measurement of mixing parameters in $D^0 \rightarrow K^0_S \pi^+ \pi^-$ decays
Model-independent measurement of mixing parameters in $D^0 \to K^0 S \pi^+ \pi^-$ decays

- Different superposition of amplitudes at each point in phase-space
- Interfering amplitudes enhance the sensitivity to mixing
- Requires a challenging time-dependent Dalitz plot analysis
  - Dalitz plane divided in 16 bins with constant strong phase difference
  - Model-independent approach
  - Constrain hadronic parameters ($T_i, c_i, s_i$) to values measured by the CLEO experiment [PRD 82 (2010) 112006]

- Time dependent decay rate:

\[
P_{D^0} = e^{-\Gamma t} \left[ T_i - \Gamma t \sqrt{T_i T_{-i}} \left( y c_i + x s_i \right) \right]
\]
Model-independent measurement of mixing parameters in $D^0 \rightarrow K^0_S \pi^+ \pi^-$ decays

- Integrated luminosity of 1 fb$^{-1}$ (only 2011 data)
- Yield: 178k with a purity of 97.4%
- Flavour tagging provided by $D^{*+} \rightarrow D^0 \pi^+$
- Simultaneous fit to all Dalitz bins
  - Separate signal from background by $\Delta m - m(D^0)$ fit
  - Determine the time evolution by two dimensional fits of $D^0$ decay time and $\ln(\chi^2_{IP})$ to distinguish charm prompt and $D^*$ from $B \rightarrow D^*X$ decays
Model-independent measurement of mixing parameters in $D^0 \rightarrow K^0_S \pi^+ \pi^-$ decays

- First model-independent measurement of $x$ and $y$
  
  $x = (0.86 \pm 0.53 \pm 0.17) \times 10^{-2}$
  
  $y = (0.03 \pm 0.46 \pm 0.13) \times 10^{-2}$

- Compatible with current HFAG world averages (but not yet competitive) with other experiments

- ~10x more signal yield in the other 2 fb$^{-1}$ collected in Run1 thanks to improved trigger

- Signal yield in 2015 equivalent to the full sample collected in Run1

Courtesy M Gersabeck
Measurement of the forward $W$ and $Z$ boson production in $pp$ collisions at $\sqrt{s}=8$ TeV
Measurement of the forward $W$ and $Z$ boson production in $pp$ collisions at $\sqrt{s}=8$ TeV

- Cross-sections and ratios can be used to test the SM.
- Parton density functions parameterised as functions of $x$ and $Q^2$.
- Two distinct regions low- and high-$x$ covered due to forward acceptance $2 < \eta < 4.5$.
  - High-$x$ well known HERA, Tevatron.
  - Low-$x$ unexplored.
- Potential to improve constraints on parton density function at low Bjorken-$x$ values down to $10^{-4}$.
Measurement of the forward W and Z boson production in pp collisions at $\sqrt{s}=8$ TeV

- **Data sample:**
  - 2 fb$^{-1}$ collected in 2012
  - ~140k Z candidates with purity of (99.3±0.2)%
  - ~1.7M W$^+$ and W$^-$ candidates with purity of 79.3% (78.0%) for W$^+$ (W$^-$)

- **Fiducial region**
  - $P_{\mu T} > 20$ GeV/c and 2<|$\eta_\mu$|<4.5
  - For Z: 60<$M_{\mu\mu}$< 120 GeV/c$^2$

- **Cross section measured**
  - For W in bin of muon $\eta$
  - For Z in bin of boson y, $p_T$ and $\phi^*$
Measurement of the forward W and Z boson production in pp collisions at $\sqrt{s}=8$ TeV

Cross sections

Cross section ratios

Very good agreement with theory
Measurement of the forward $W$ and $Z$ boson production in $pp$ collisions at $\sqrt{s}=8$ TeV

Ratios at different $\sqrt{s}$

Double ratio at different $\sqrt{s}$

Maximum deviation of double ratio is 2 $\sigma$

These measurements could potentially improve the determination of the parton density functions in this region
Next results…

- Lots more results still to come from Run1 and Run2 data
- Upcoming new results:
  - New Lepton flavour universality tests
  - New measurements of $\gamma$
  - W and Z production at 13 TeV
  - First results from PbPb and beam-gas data
  - More exotic spectroscopy
  - CP violation and mixing measurements in charm
  - ...
Run2 operation and performance
Run 2 data taking: pp collisions

Early measurement with 50 ns beam

Special run for commissioning after LS

EM during intensity ramp-up with 25 ns beam

Core physics program with 25 ns beam

Big thanks to the LHC!!
New strategy in Run 2

- Buffer all events to disk before running 2\textsuperscript{nd} software level trigger (HLT2)
- Perform calibration and alignment of the full tracking sub-detectors in real-time
  - same constants in the trigger and offline reconstruction
- Last trigger level runs the same offline reconstruction
- Some analyses performed directly on the trigger output
  - Storing only selected candidates to reduce event size
Real-time alignment and calibration

Calibration

RICH

OT time

CALO

Alignment

VELO

RICH mirrors

Tracker

Muon
Real-time alignment

Alignment

Automatically evaluated and updated

Run as stability monitoring
Real-time alignment

- Alignment of the full tracking system, about **1700** elements
- Run automatically for each fill
- Update of the constants only when needed
- Time required $\sim$ **7 minutes** for each task
- Alignment updates in Run2:
  - each 2/3 fills for the VELO
  - after each magnet polarity switch for the tracker
  - no update required, as expected, for the Muon chambers

Evaluated automatically for each fill and updated if needed
Real-time calibration

Calibration

- RICH
- OT time
- CALO

automatically evaluated and updated
Real-time calibration

Calibration

RICH  OT time  CALO

Stability of cherenkov angle resolution

σΔθ = 0.67 mrad

LED average over 456 cells in the very central part of ECAL

2012: no correction
2015: applied new π0 calibration
applied new LED corrections

Calib. runs  EM  25 ns
Performance
Trigger performance in Run 2

- Improvement of the trigger efficiency thanks to e.g.
  - Run the same offline reconstruction in HLT2
  - Having the detector fully calibrated and aligned
  - Using PID selection in the trigger

Efficiency of the HLT2 inclusive beauty trigger as a function of B $p_T$

- Efficiency for $B^+ \rightarrow D^0 \pi^+$ is ~75%
- Efficiency for $B^+ \rightarrow D^0 \pi^+$ is >90%

Tracking Performance of Run 2 data

- Same offline performance as in Run1 directly in HLT2

IP resolution

```
LHCb VELO Preliminary
2012 Data: $\sigma = 11.6 + 23.4/p_T$
2015 25 ns Data: $\sigma = 11.8 + 23.7/p_T$
```

Track efficiency
PID Performance of Run 2 data

- Similar performance as in Run1

Kaon identification efficiency and pion misidentification rate

PID Performance of Run 2 data

- Similar performance as in Run1
  Pion misidentification efficiency vs Kaon identification efficiency
Turbo stream

- Some analyses performed directly on the trigger output
- Storing only selected candidates to reduce event size → Save ~90% of space
- Analysis with large yields: possible to reduce the pre-scaling of all the channels that were trigger output rate constrained

Trigger output (12.5 kHz)

 Turbo stream
2.5 kHz: ~5kB per event → 12.5 Mb/s output rate

Full stream
10 kHz: ~70kB per event → 700 Mb/s output rate

Offline reconstruction

User analysis
Turbo stream

- Some analyses performed directly on the trigger output
- Storing only selected candidates to reduce event size \(\Rightarrow\) Save \(\sim90\%\) of space
- Analysis with large yields: possible to reduce the pre-scaling of all the channels that were trigger output rate constrained

The first 2 papers, few weeks after data taking, on cross section measurements on Run2 data used the Turbo stream output data.
Presented at September’s LHCC

Measurements of prompt charm production cross-sections in \(pp\) collisions at \(\sqrt{s} = 13\) TeV

Measurement of forward \(J/\psi\) production cross-sections in \(pp\) collisions at \(\sqrt{s} = 13\) TeV
Special runs: beam gas and heavy ion collisions
Beam gas collisions

- System to inject gas in the VELO region
- Used for luminosity measurements by Beam Gas Imaging Method
  - Alternative to Van der Meer Scan method
  - The combination of the two techniques 1.1% in Run1: best precision for LHC experiments
    \[ \text{JINST 9(2014) 12, P12005} \]

➡️ Allowing the LHCb experiment
to do also fixed target physics, unique opportunity at LHC!
Beam-gas collisions

- Exploiting the SMOG system with different noble gases: Ar, He, Ne
- Physics motivations:
  - Input to the understanding of nucleus-nucleus collisions
  - Sensitive probes of nuclear structure
  - Measurement of $\sigma(p\text{He} \to \overline{p}X)$. The largest uncertainty in the AMS results showing antiproton excess is due to the theoretical precision of the production $\sigma(p\text{He} \to \overline{p}X)$ [AMS-02 Coll., CERN 15.04.2015]
  - Probe quark gluon plasma (QGP)
  - Reference sample for heavy ion collisions

<table>
<thead>
<tr>
<th></th>
<th>$\sqrt{s}$</th>
<th>Date in 2015</th>
<th>Data sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>pNe</td>
<td>110.4GeV</td>
<td>25-26 Aug.</td>
<td>2 fills (~13h)</td>
</tr>
<tr>
<td>pHe</td>
<td>110.4GeV</td>
<td>8 Sept.</td>
<td>1 fill (~8 h)</td>
</tr>
<tr>
<td>pAr</td>
<td>110.4GeV</td>
<td>15-18 Oct.</td>
<td>7 fills (~29 h)</td>
</tr>
</tbody>
</table>
PbPb collisions

- LHCb is participating in Pb-Pb collision runs
- Unique fully instrumented experiment in the forward region
- Physics motivations:
  - Probe colour screening and quark gluon plasma (QGP) temperature through sequential melting of quarkonium states
  - Structure of nucleons, hadronisation, central exclusive production, …
  - Focus on peripheral collisions in Pb-Pb, with a centrality up to 50%

<table>
<thead>
<tr>
<th>Date</th>
<th>Data sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>PbPb</td>
<td>25 Nov.-.....</td>
</tr>
<tr>
<td>PbAr</td>
<td>27 Nov.-.....</td>
</tr>
</tbody>
</table>

Data taking ongoing
PbPb collisions

Event 250756
Run 168821
Sun, 29 Nov 2015 21:13:03
LS2 LHCb Upgrade
LHCb upgrade

40MHz readout of all sub-detectors and data processed with software triggers

**Upstream Tracker based on silicon strip technology**

**RICH:**
- New PMTs & readout electronics
- Downstream Tracker: New stations based on SciFi technology

**CALO:** reduced PMT gain and new electronics

**VELO:**
- New pixel detector

**Muon:**
- More shielding and upgraded readout electronics
The upgrade project is progressing well.

Many important Engineering Design Reviews since June.

Sub-detector projects are now moving to the construction phase.

Procurement is already started or about to start.

First Production Readiness Reviews expected for Q1 2016.
LHCb upgrade

- High-level view with components and data processed with software triggers

**VELO:**
- Microchannel cooling substrate prototype
- New pixel detector

**RICH:**
- New PMTs & readout electronics

**CALO:**
- Reduced PMT gain and new electronics

**Downstream Tracker:**
- New stations based on SciFi technology

**Muon:**
- More shielding and upgraded readout electronics
LHCb upgrade

40MHz readout of all sub-detectors and data processed with software triggers

**RICH:**
- New PMTs & readout electronics
- Photon detection module test on test beam
- RICH photon detection module test on test beam
- CALO: reduced PMT gain and new electronics
- Downstream Tracker: New stations based on SciFi technology
- Muon: More shielding and upgraded readout electronics
- Upstream Tracker based on silicon strip technology
- RICH photon detection module test on test beam
LHCb upgrade

40MHz readout of all sub-detectors and data processed with software triggers

RICH:
- New PMTs & readout electronics
- & readout electronics

Muon:
- More shielding
- and upgraded readout electronics

Downstream Tracker:
- New stations based on SciFi technology

VELO:
- New pixel detector

UT sensor connected to Beetle readout for the testbeam

Prototype scintillating fibre mats ready for panel assembly

Upstream Tracker based on silicon strip technology

UT sensor connected to Beetle readout for the testbeam

Prototype scintillating fibre mats ready for panel assembly

Upstream Tracker based on silicon strip technology

VELO:
- New pixel detector

RICH:
- New PMTs & readout electronics

More shielding and upgraded readout electronics

Downstream Tracker:
- New stations based on SciFi technology
Conclusion
Conclusion

- Wide physics programme with many results in the pipeline
  - New measurements of $\gamma$, CPV and mixing in the charm sector, lepton flavour universality tests, spectroscopy, $W$ and $Z$ production…

- Enriched programme in Run2 by the study of
  - beam-gas (Ar, He, Ne) collisions
  - lead ion collisions on Pb-Pb runs

- Major change in the Run2 strategy:
  - Automatic alignment and calibrations in real-time
  - Running the same offline reconstruction in 2nd level trigger
  - Dedicated Turbo stream to analyse the output of the trigger without offline reprocessing

→ Fully commissioned and operational
→ First 2 analyses from the trigger output published few weeks after the data taking

- Detector performance is similar to Run1, with the great advantage to profit from this in the second level software trigger.

- Upgrade work is progressing well
Backup
Real-time OT calibration

- Global time offset related to the synchronization between the OT time and the collision time

- A shift of 0.5 ns leads to tracking inefficiency of ~2.5‰

Evaluated automatically for each run and updated if needed.
Real-time Calorimeter calibration

- The LED measurements to compensate the ageing of the PMTs for ECAL and HCAL automatically performed and update each fill.
- Method based on detector occupancy is under commissioning.
- Absolute calibration
  - ECAL: $\pi^0$ calibration evaluated each 2 months.
  - HCAL: Cs source scan evaluated at each TS.

LED average over 456 cells in the very central part of ECAL.

2012: no correction
2015: applied new $\pi^0$ calibration
applied new LED corrections.
Measurement of the forward W and Z boson production in pp collisions at √s=8 TeV

**Data sample:**
- 2 fb⁻¹ collected in 2012
- ~140k Z candidates with purity of (99.3±0.2)%
- ~1.7M W⁺ and W⁻ candidates with purity of 79.3% (78.0%) for W⁺ (W⁻)

**Fiducial region**
- Pµ_T > 20 GeV/c and 2<η_µ<4.5
- For Z: 60<M_µµ< 120 GeV/c²

**Cross section measured**
- For W in bin of muon η
- For Z in bin of boson y, p_T and φ*

**Cross sections**

\[
\sigma_{Z\rightarrow\mu\mu} = 95.0\pm0.3^{\text{stat}}\pm0.7^{\text{syst}}\pm1.1^{\text{beam en.}}\pm1.1^{\text{lumi}}\text{pb}
\]

\[
\sigma_{W^+\rightarrow\mu^+\nu} = 1094.1\pm2.1^{\text{stat}}\pm7.1^{\text{syst}}\pm10.9^{\text{beam en.}}\pm12.7^{\text{lumi}}\text{pb}
\]

\[
\sigma_{W^-\rightarrow\mu^+\bar{\nu}} = 819.4\pm1.9^{\text{stat}}\pm5.1^{\text{syst}}\pm7.1^{\text{beam en.}}\pm9.5^{\text{lumi}}\text{pb}
\]

**Cross section ratios**

\[
R_{W^+Z} = \frac{\sigma_{W^+\rightarrow\mu^+\mu^-}}{\sigma_{Z\rightarrow\mu^+\mu^-}} = 11.52\pm0.04^{\text{stat}}\pm0.06^{\text{syst}}\pm0.02^{\text{beam en.}}
\]

\[
R_{W^-Z} = \frac{\sigma_{W^-\rightarrow\mu^+\nu}}{\sigma_{Z\rightarrow\mu^+\mu^-}} = 8.63\pm0.03^{\text{stat}}\pm0.04^{\text{syst}}\pm0.03^{\text{beam en.}}
\]

\[
R_{W^\pm} = \frac{\sigma_{W^\rightarrow\mu^+\bar{\nu}}}{\sigma_{W^+\rightarrow\mu^+\nu}} = 1.335\pm0.004^{\text{stat}}\pm0.005^{\text{syst}}\pm0.002^{\text{beam en.}}
\]
Angular analysis of the $B^0_d \rightarrow K^{*0}\mu^+\mu^-$ decay

- Yield: $624\pm30$ in the region $q^2 \in [1.1,6]$ GeV$^2$/c$^4$ in $L = 3$ fb$^{-1}$
- Fit angular distribution in bins of $\sim 2$ GeV$^2$/c$^4$ to determine the CP averaged observables and CP asymmetries ($B^0$ and $B^0$bar separately)
Measurements of long-range near-side angular correlations in $\sqrt{s_{NN}}=5$ TeV proton-lead collisions in the forward region.

Presented at last LHCC

Conservation of momentum so corresponding far side ridge

Study $\Delta \eta$ and $\Delta \phi$ in pPb collisions to probe collective effects

Isolated structure dominates at (0,0) due to fragmentation around the initial parton

In large events, strong interactions with the media cause near-side ridge