The heavy-ion programme of LHCb

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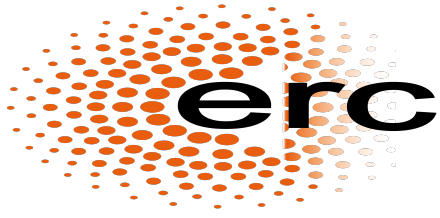
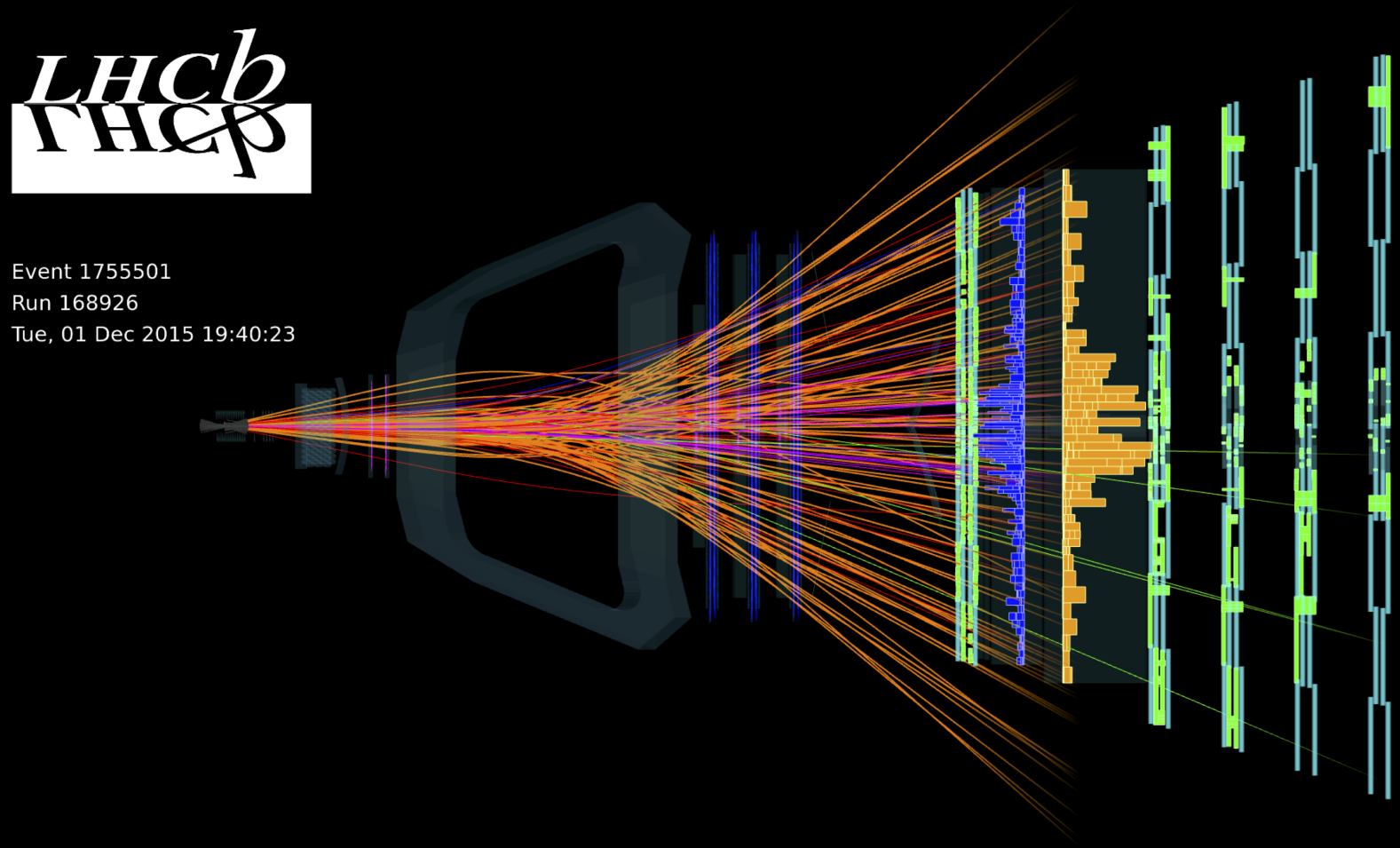


International School of Nuclear Physics
ERICE, September 23, 2016



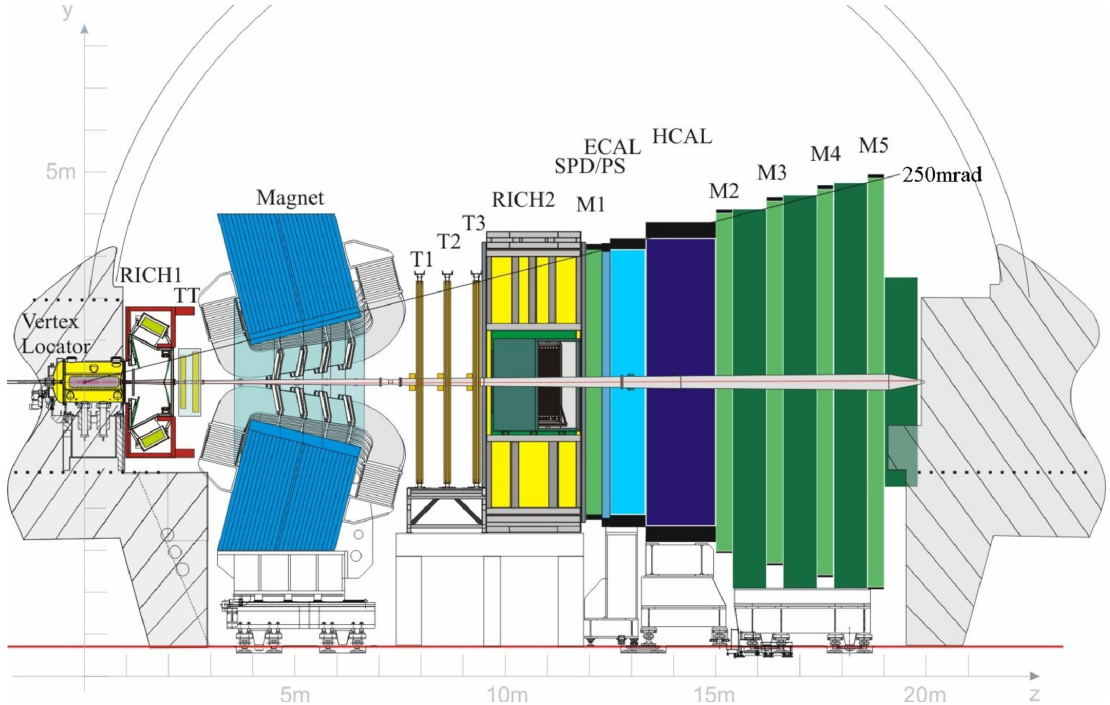
Pb–Pb event display with 1130 reconstructed tracks and a J/ψ candidate

LHCb Pb–Pb performance figures: https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015

Outline

1. LHCb detector: overview and heavy-ion case
2. p–Pb collisions: results and outlook
3. Pb–Pb collisions: first glimpse on data
4. fixed target collisions: the unique case at the LHC
5. Outlook and Conclusions

LHCb: a heavy-flavour precision experiment



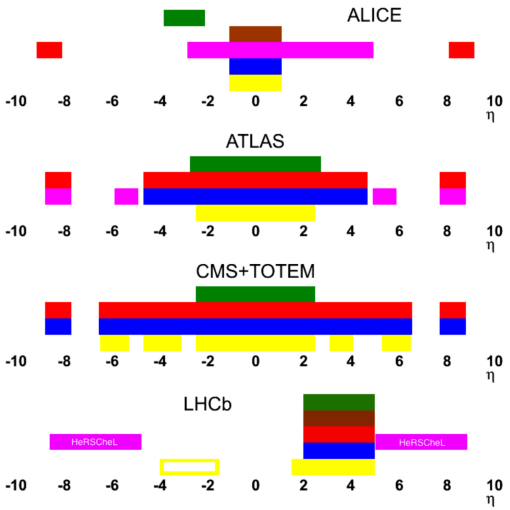
JINST 3 (2008) S08005.

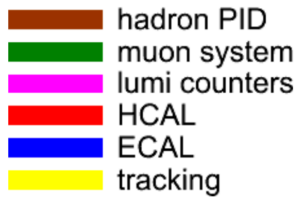
- precision tests of the standard model in the flavour sector

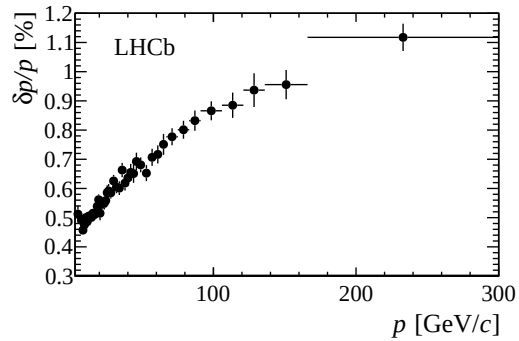
  Examples: observation of rare $B_S \to \mu^+\mu^-$ decay together with CMS Nature 522 (2015) 68, most precise single experiment measurement of the γ angle in the CKM matrix LHCb-CONF-2016-001

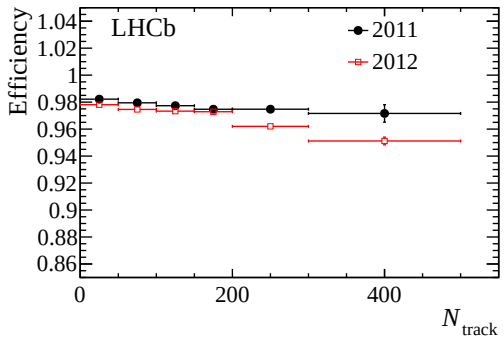
- first observation of a J/ψ p resonant state consistent with a pentaquark state Phys. Rev. Lett. 115 (2015) 072001

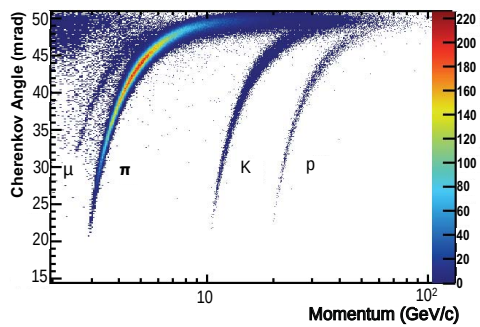
LHCb: a multi-purpose forward detector









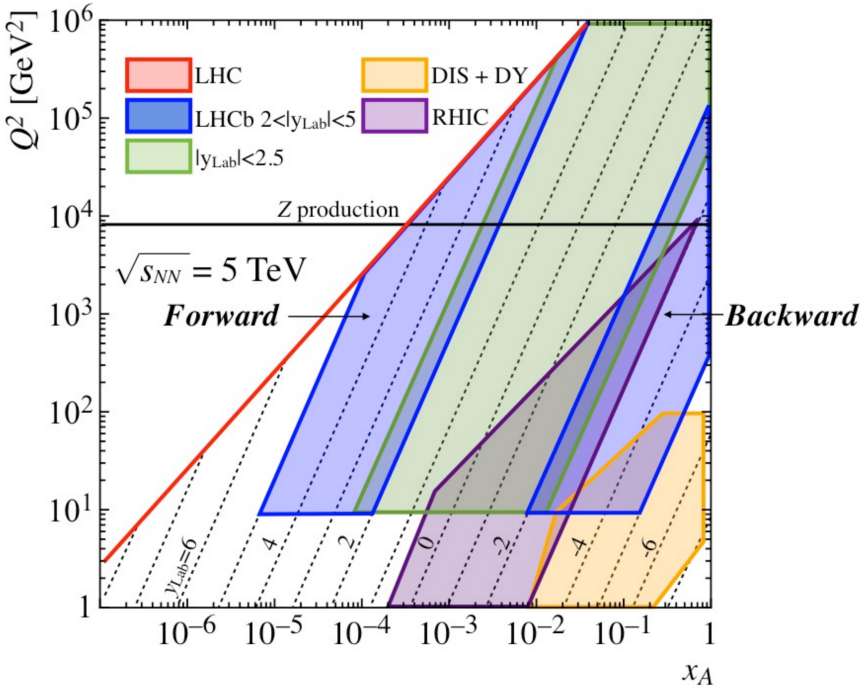


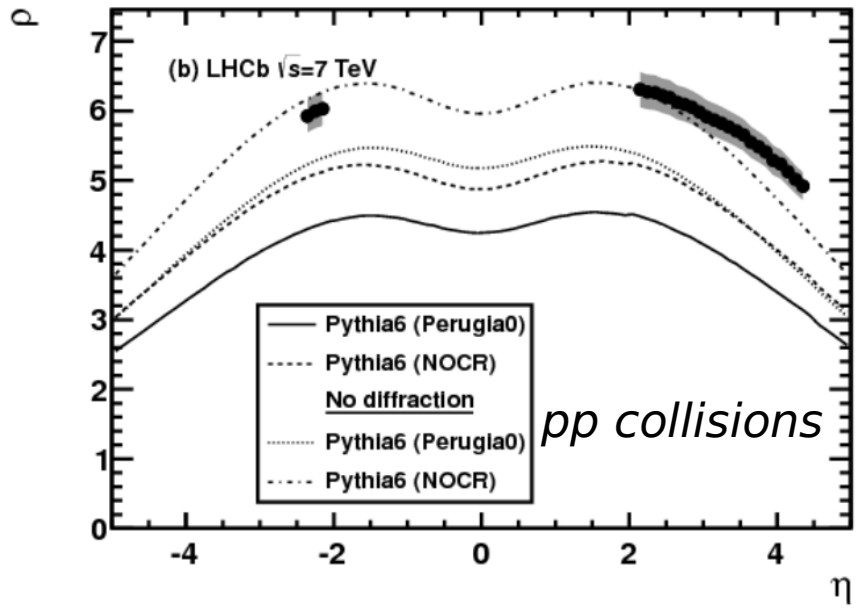
Int. J. Mod. Phys. A 30 1530022.

Fast forward spectrometer complementing other LHC experiments

- momentum resolution below 1% and hadron ID in large momentum range
- topological ID of charm and beauty hadrons down to 0 p_T
- hardware trigger inspecting all bunch crossing at 40 MHz in pp

The LHCb detector: its heavy-ion physics case



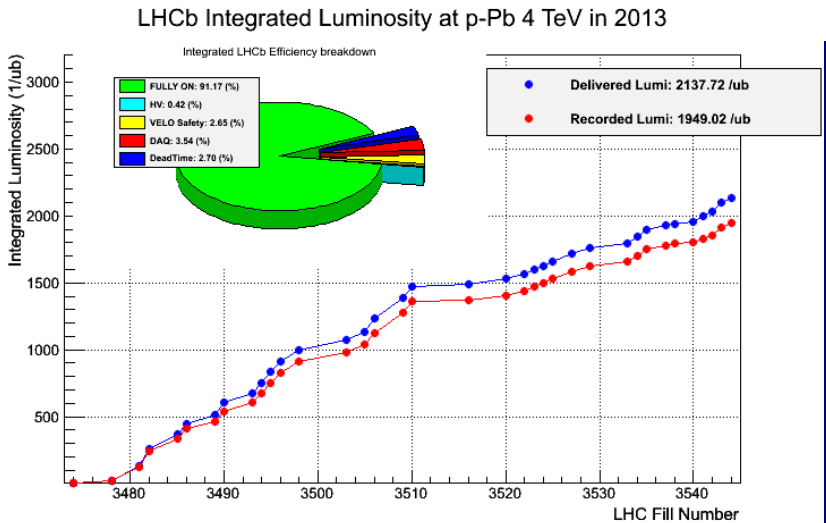


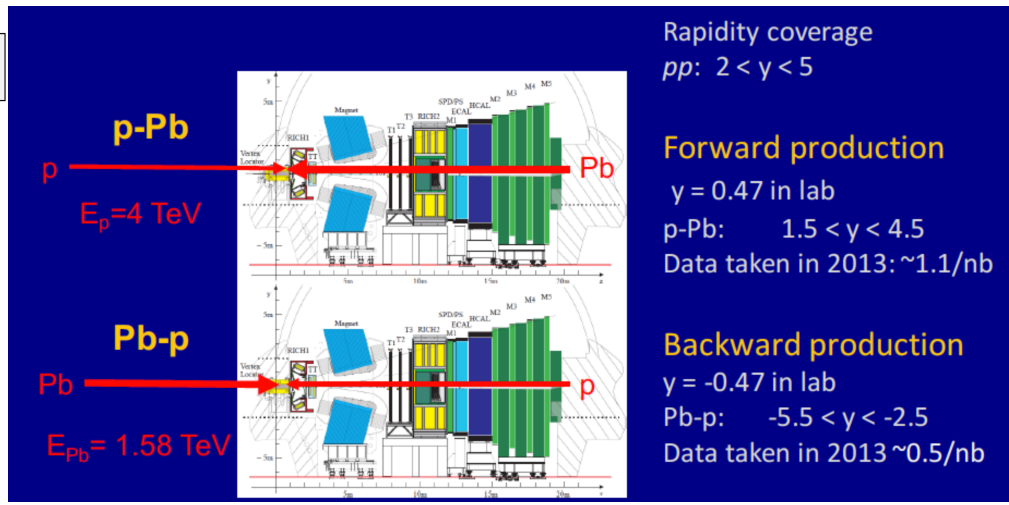
RHS: Eur. Phys. J. C 72 (2012) 1947 .

Unique kinematics at the edge of the midrapidity plateau

- Your observable of choice with this beautiful detector!

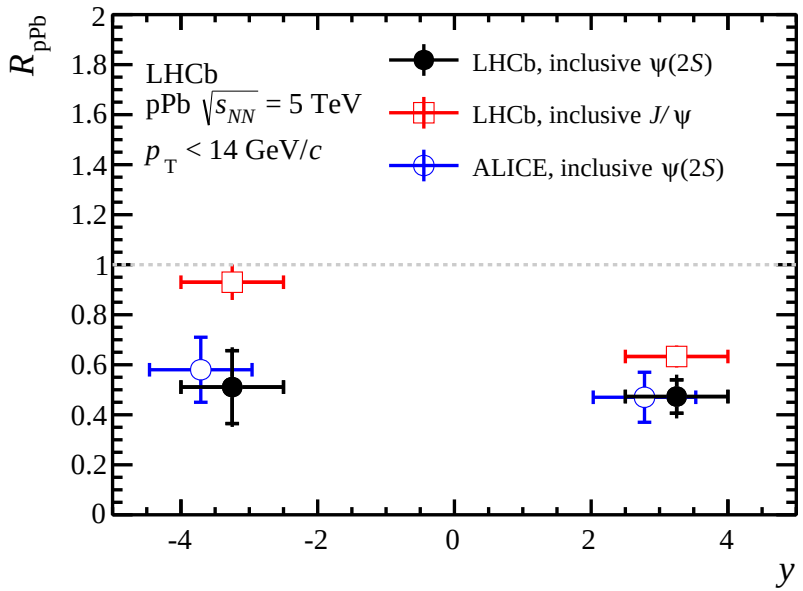
LHCb p–Pb programme: 2013 run





- first data taking with Pb beams for LHCb
- smooth detector operation
- 1.1 nb^{-1} at forward and 0.5 nb^{-1} backward rapidity collected at $\sqrt{s_{\text{NN}}} = 5$ TeV

LHCb p–Pb programme: charmonium

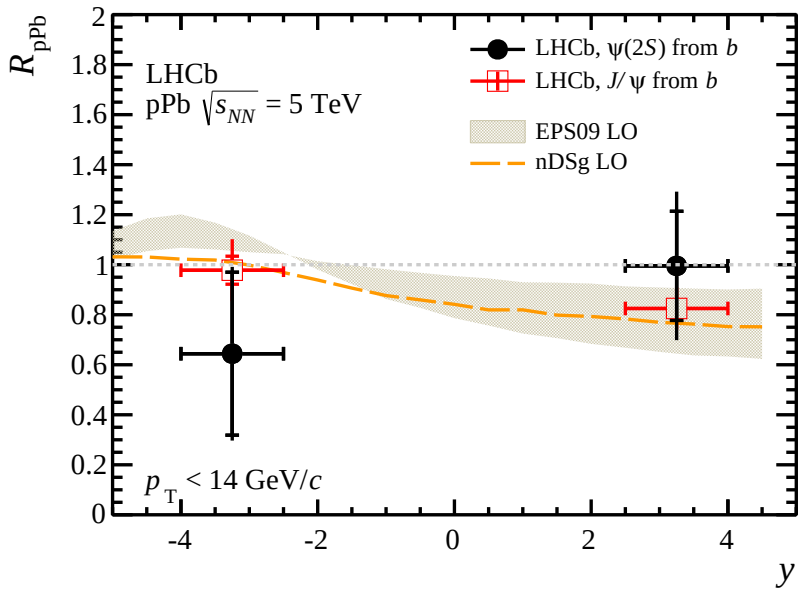


J/ψ: JHEP 02 (2014) 072; ψ(2S): JHEP 1603 (2016) 133.

Charmonium results with $\approx$ 10%(20%) at backward (forward) of luminosity of ALICE muon arm:

- similar precision for inclusive measurement thanks to better resolution
- separation prompt and B-feeddown down to 0 p_T: unique at the LHC

LHCb p–Pb programme: non-prompt charmonium results

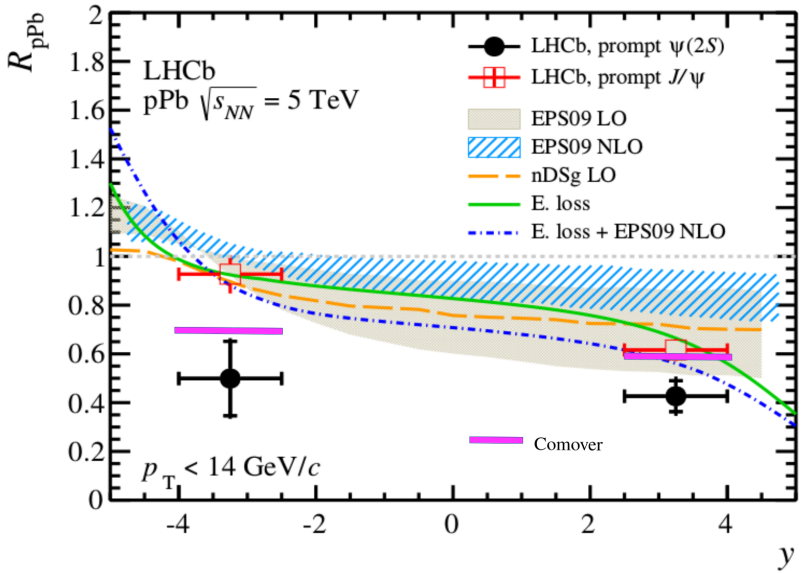


JHEP 02 (2014) 072, JHEP 1603 (2016) 133.

Capability to separate prompt and non-prompt component down to 0 p_T: constraints on low-p_T B production

- result compatible with modifications expected from nuclear PDFs
- no discrimination between parameterisation due to statistical limitations

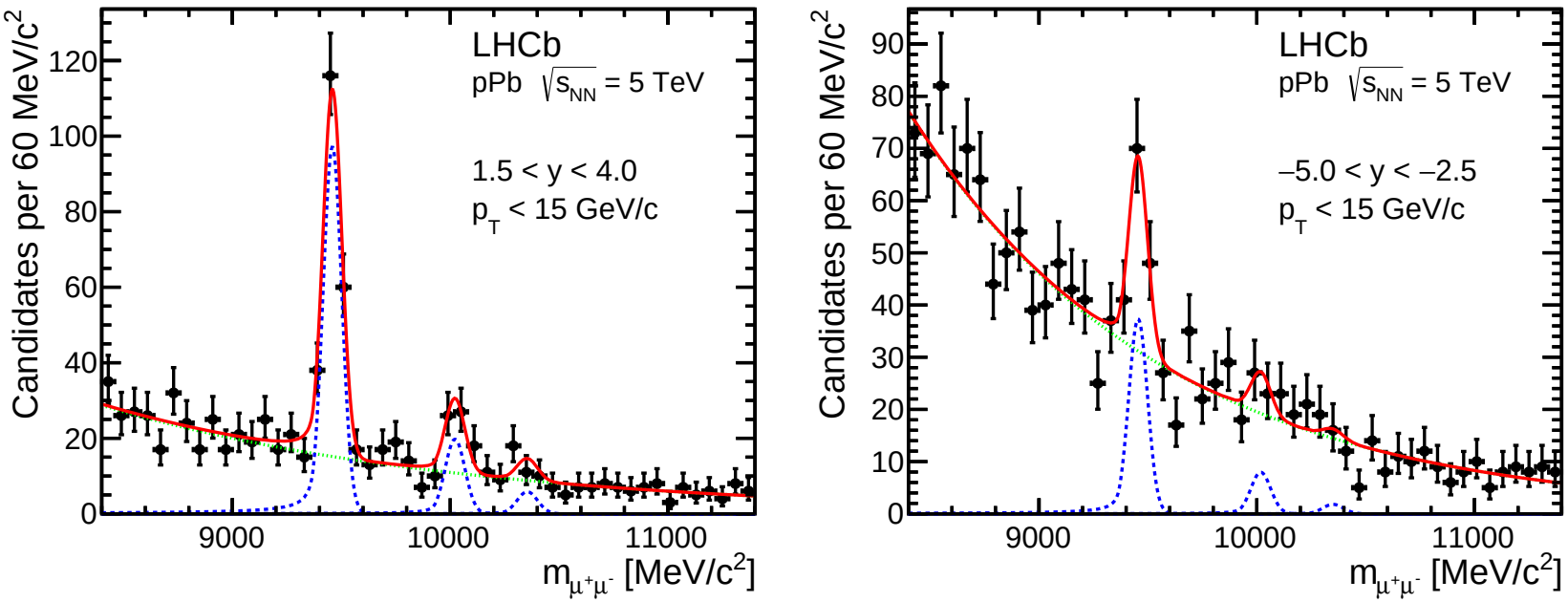
LHCb p–Pb programme: prompt charmonium results



JHEP 02 (2014) 072, JHEP 1603 (2016) 133.

- result compatible with modifications expected from nuclear PDFs, coherent energy loss model, recent CGC calculations
- additional suppression for ψ(2S) not explained by nuclear PDFs nor by coherent energy loss
- comover model shows observed additional suppression
- data also described with HRG+QGP ansatz by Du & Rapp Nucl.Phys. A 943 (2015)

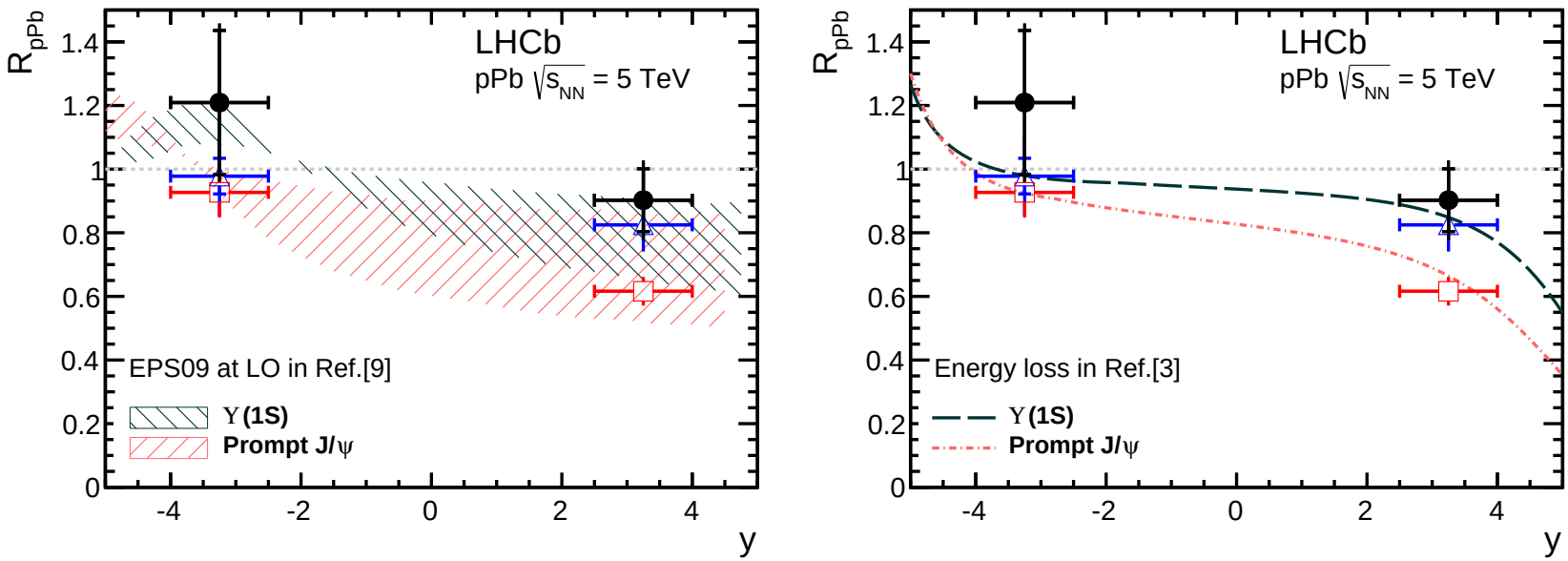
LHCb p–Pb programme: Υ results



JHEP 07 (2014) 094.

- clear separation of Υ states
- statistical limitations

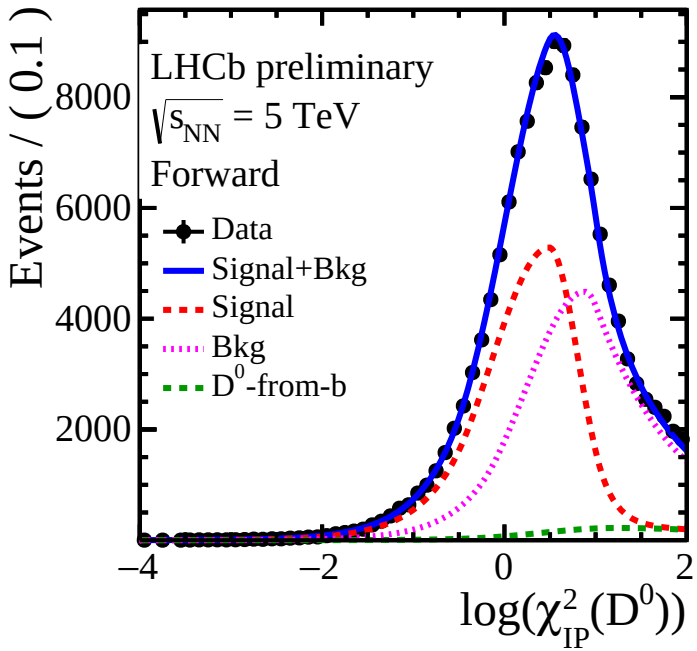
LHCb p–Pb programme: Υ results

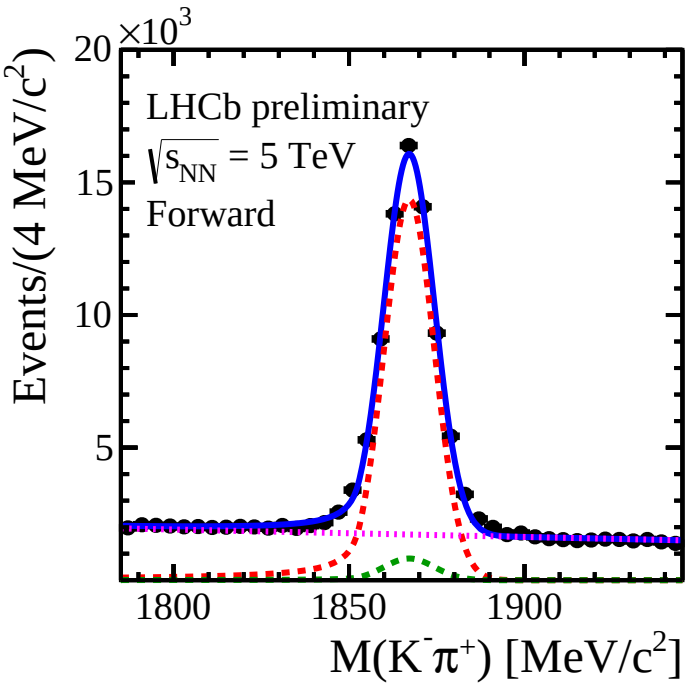


prompt J/ψ,J/ψ from B,Υ(1S), JHEP 07 (2014) 094.

- results compatible with modifications expected from nuclear PDFs and from coherent energy loss model
- within uncertainties compatible modification of open and hidden beauty

LHCb p–Pb programme: D^0 analysis

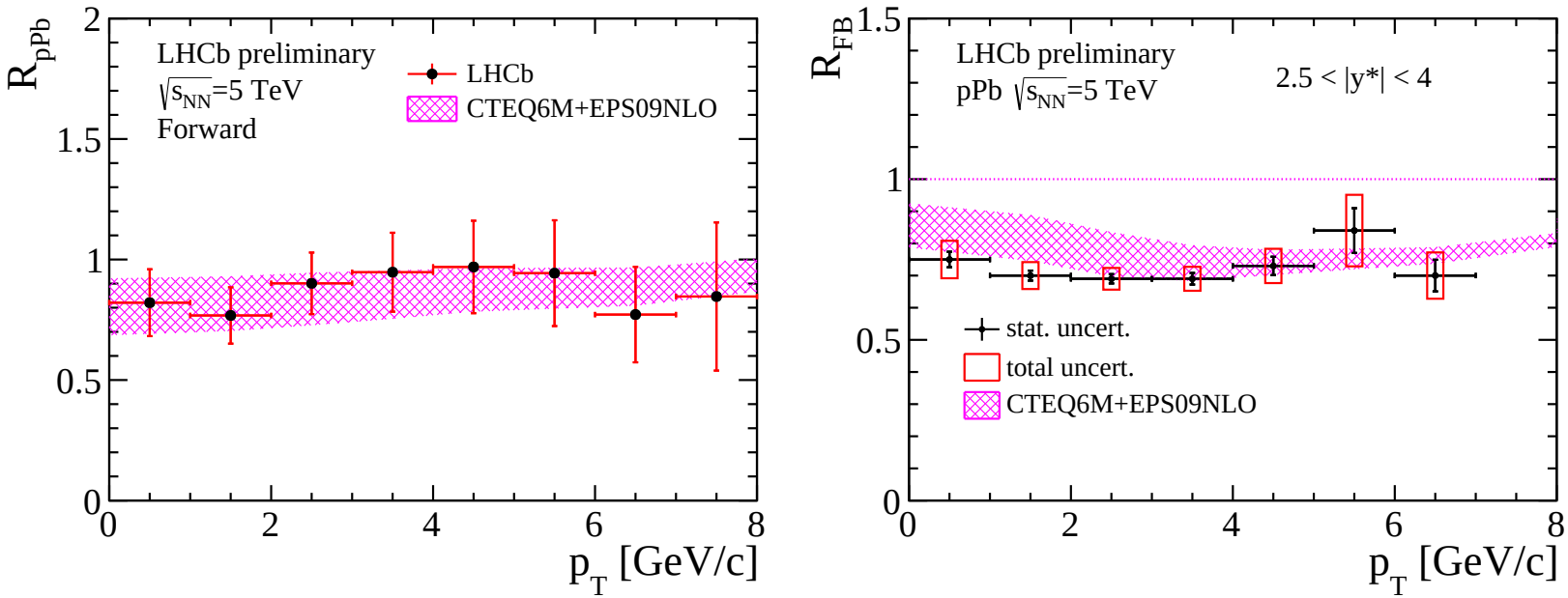




D^0 meson ($p_T < 8$ GeV/c) with $\approx$ 10% of available statistics at $\sqrt{s_{NN}} = 5.02$ TeV LHCb-CONF-2016-003!

- unique measurement at the LHC: open charm down to 0 p_T with high precision
- large statistics sample available
- separation of B feed-down from prompt production by impact parameter of D-meson

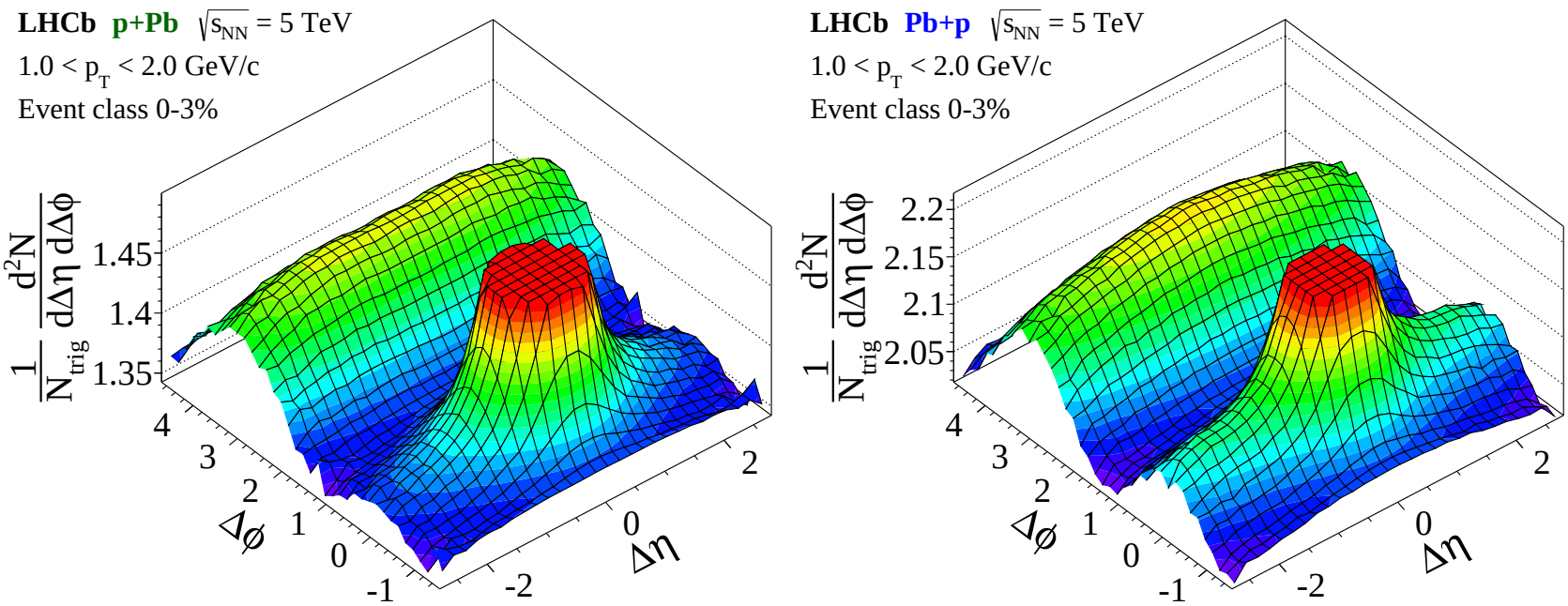
LHCb p–Pb programme: D^0 results



LHCb-CONF-2016-003.

- observed nuclear modification compatible with EPS09 parametrisation
- forward-backward ratio more precise than theory thanks to cancellation of uncertainties
- stay tuned for full statistics result with pp reference from data!

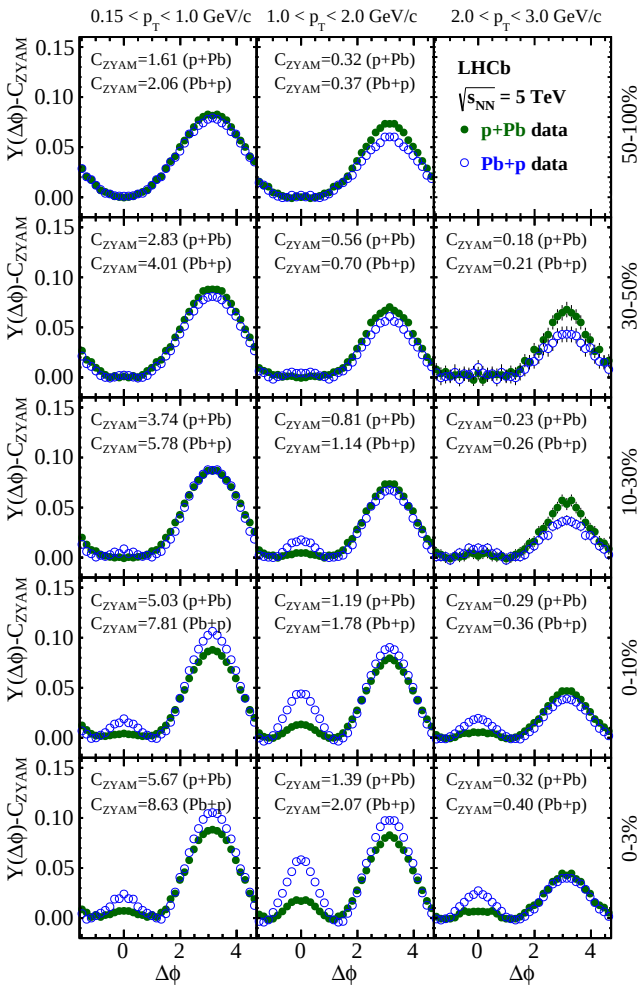
LHCb p–Pb programme: Di-hadron correlations

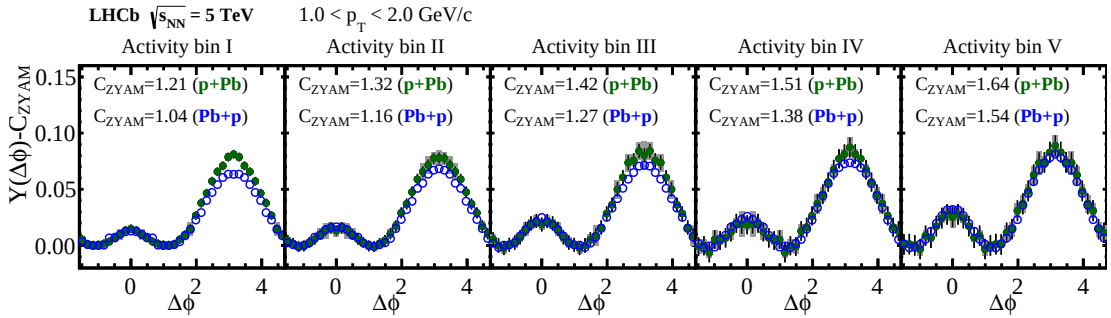


arXiv:1512.00439.

- unique forward acceptance with full tracking
- qualitative agreement with mid-rapidity findings by ALICE, ATLAS and CMS in high multiplicity events
- significant difference between lead and proton fragmentation side, when comparing same fraction of events based on multiplicity in experimental acceptance $2.0 < \eta < 4.9$

LHCb p–Pb programme: Di-hadron correlations





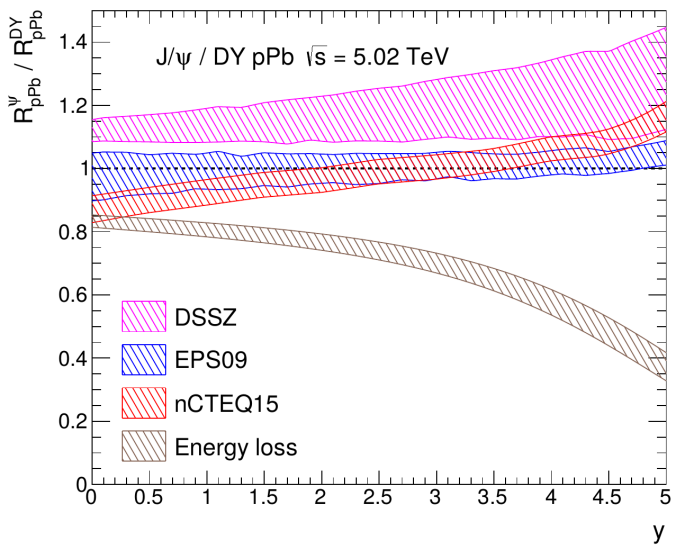
arXiv:1512.00439.

- increase of near-side correlation towards larger multiplicities and lower p_T after pedestal subtraction
- results at forward and backward rapidity at same estimated overall multiplicity: similar results of correlation strength after pedestal subtraction
- looking forward to phenomenological models

LHCb p–Pb programme: 2016 run

request 10 nb^{-1} per beam direction at 8 TeV:
Hadron PID and precision tracking/vertexing down to low-p_T with nearly 2013 CMS/ATLAS statistics, e.g.:

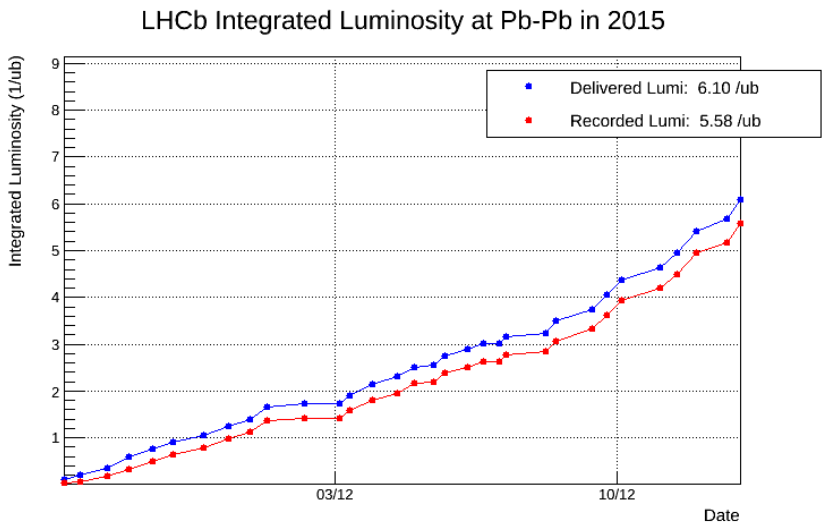
- ψ(2S) results with J/ψ 2013 precision
- W,Z and Drell-Yan at lower masses:
  theoretical clean constraints for nuclear PDFs/saturation down to low x

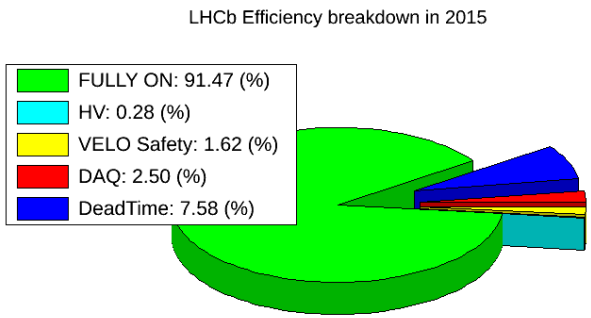


understand dominant nuclear modification of quarkonium in p–A collisions

Fig. taken from arXiv:1512.01794 [hep-ph].

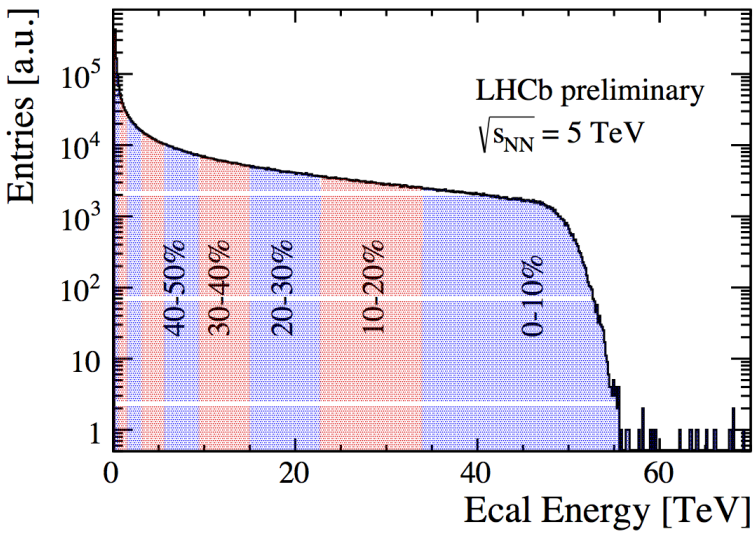
LHCb in Pb–Pb collisions: 2015 run

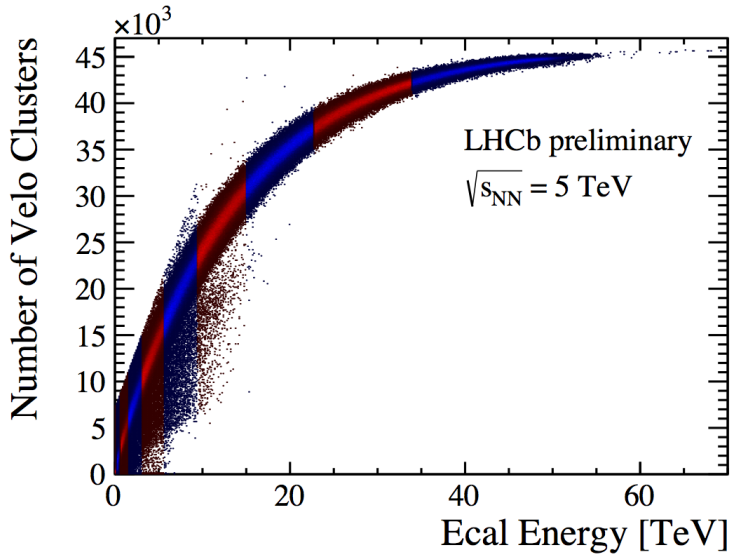




- first data taking in most challenging environment for LHCb
- smooth detector operation
- about 50 million minimum bias collisions collected

LHCb in Pb–Pb collisions: centrality reach

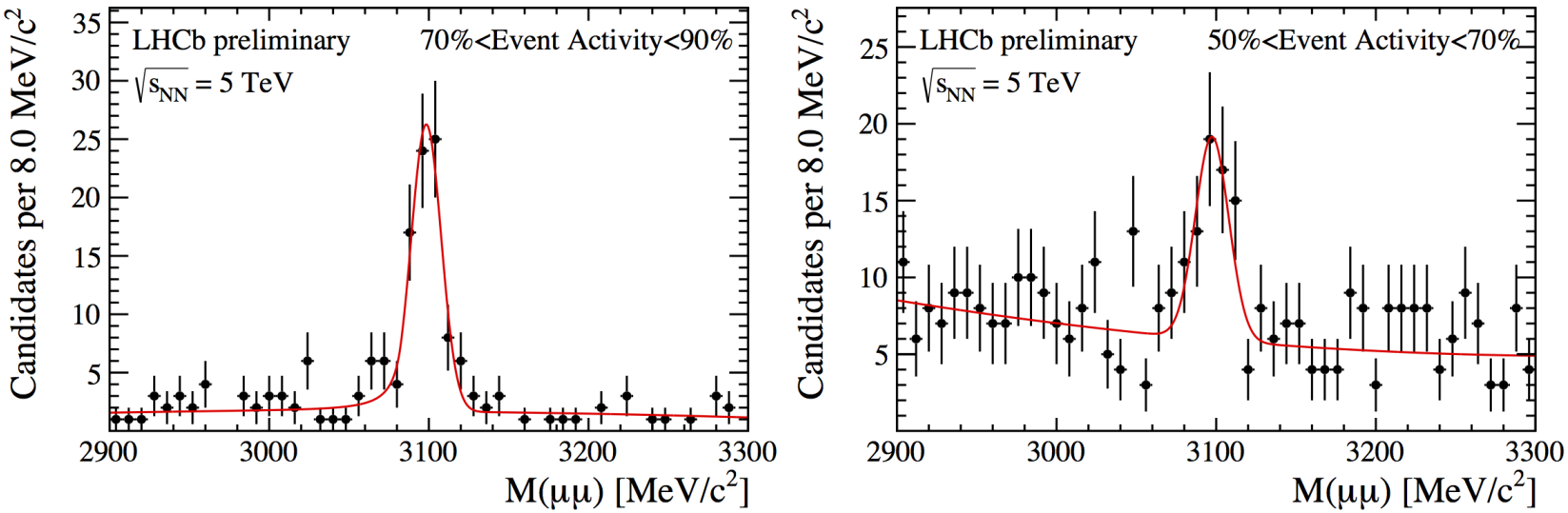




Pb–Pb performance figures: https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015

- designed for low pile-up pp collisions: running in pp at $\mu \approx 1$
- occupancy limitation in Pb–Pb collisions:
  current tracking algorithms up to 50% in centrality

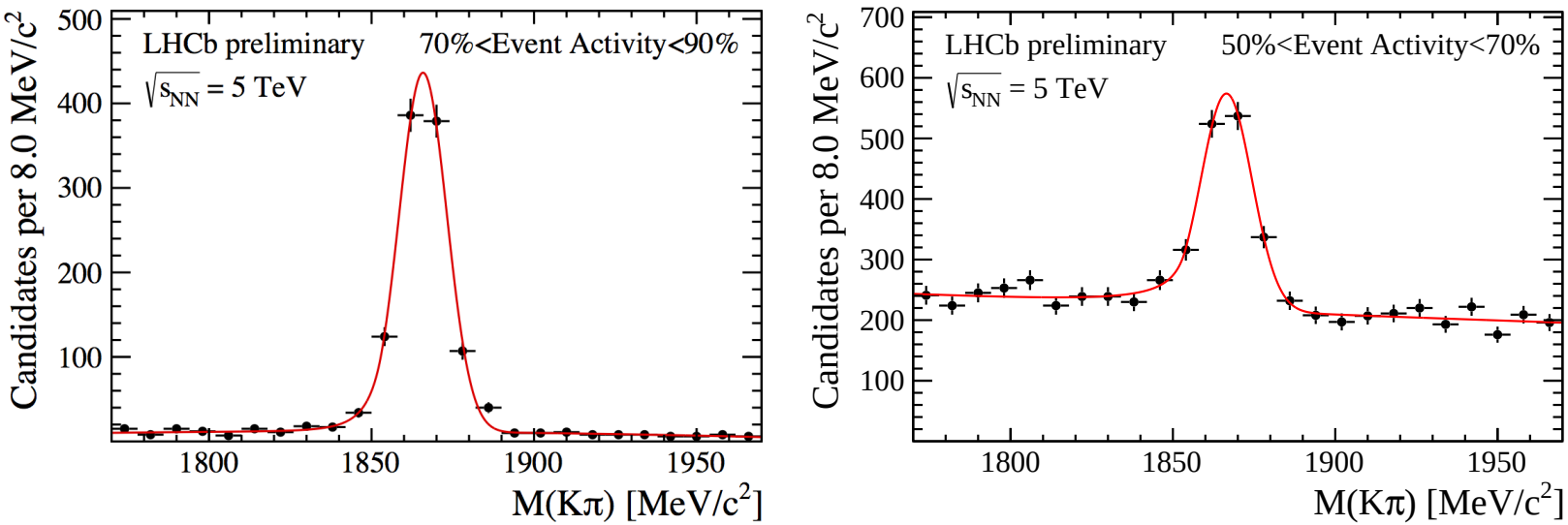
LHCb in Pb–Pb collisions: J/ψ signal



Pb–Pb performance figures: https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015.

- clear signal up to edge of occupancy limit thanks to similar resolutions as in pp collisions

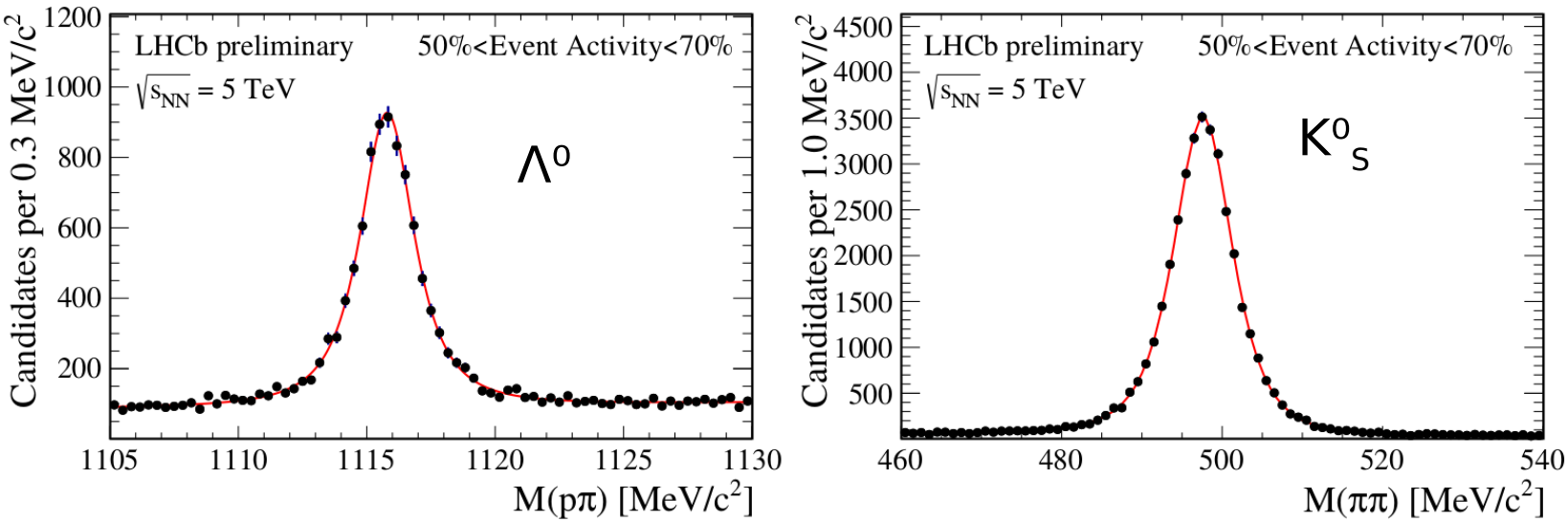
LHCb in Pb–Pb collisions: D^0 signal



Pb–Pb performance figures: https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015.

- clear signal up to edge of occupancy limit thanks to similar resolutions as in pp collisions

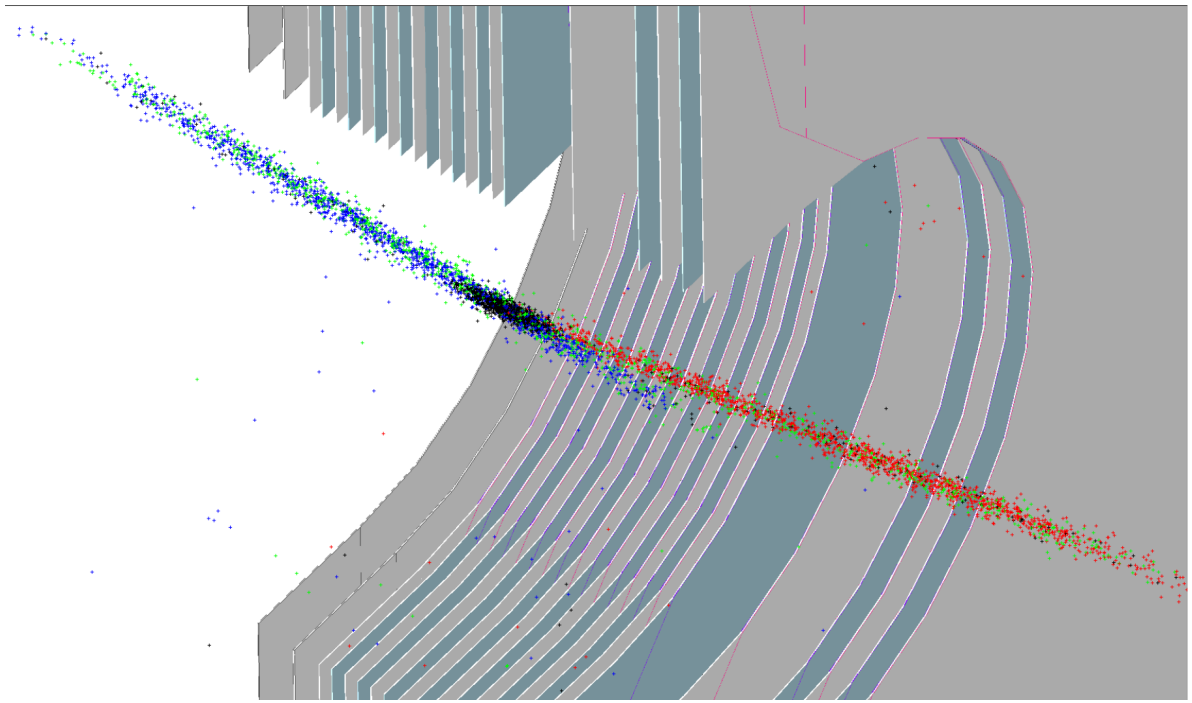
LHCb in Pb–Pb collisions: strangeness



Pb–Pb performance figures: https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015.

- Large strange V^0 samples reconstructed

LHCb in fixed target collisions: a unique opportunity at the LHC

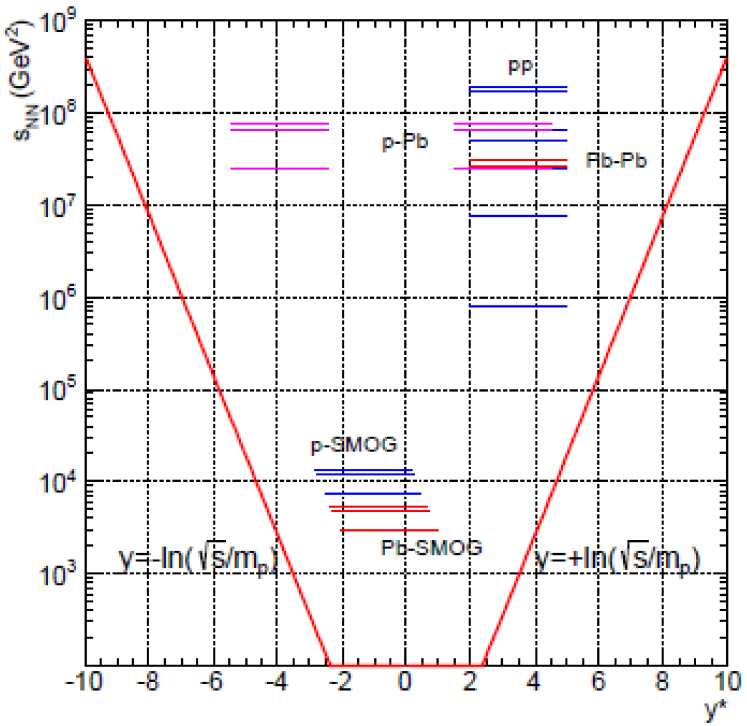


J. Instrum. 9 (2014) P12005.

- noble gas injected in interaction region:
  improve luminosity measurement by beam imaging
- vacuum increased by two orders of magnitude: $O(10^{-7})$ mbar
- can be used for fixed target physics with proton and Pb beams

LHCb in fixed target collisions: data samples

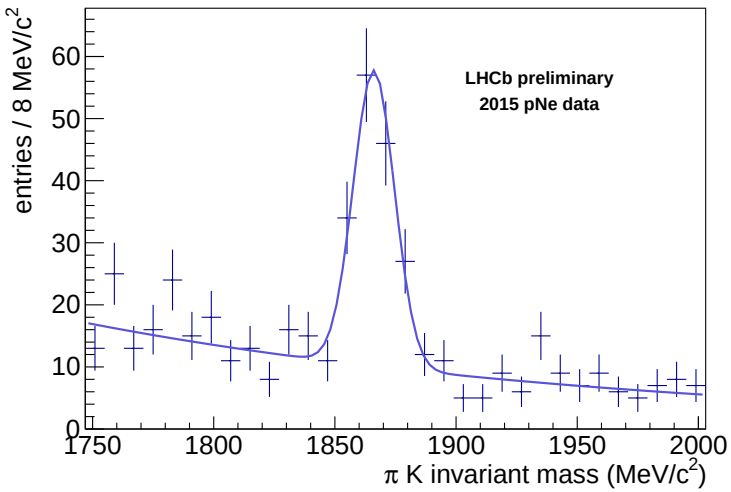
p-Pb
p-p
Pb-Pb
p-GAS
Pb-GAS

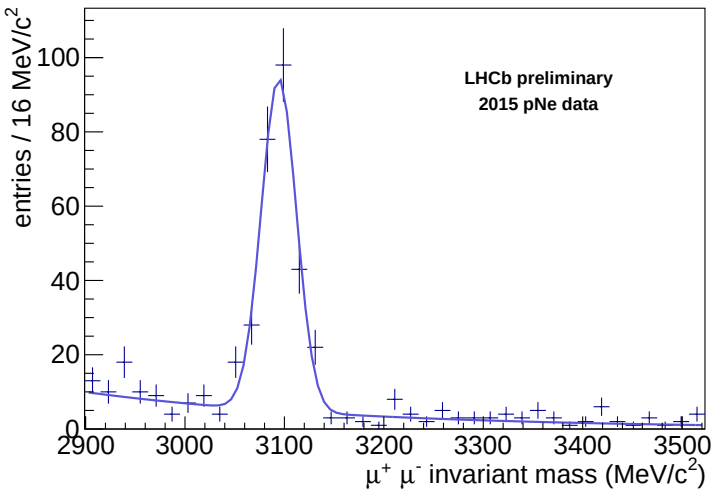


Collisions with proton and Pb beams in the RHIC energy range at midrapidity

- p–He at 110.4 GeV
- p–Ne at 86.6 GeV and 110.4 GeV
- p–Ar at 110.4 GeV and 69 GeV
- Pb–Ne at 55 GeV
- Pb–Ar at 69 GeV

LHCb in fixed target collisions: charm signals in p–Ne data

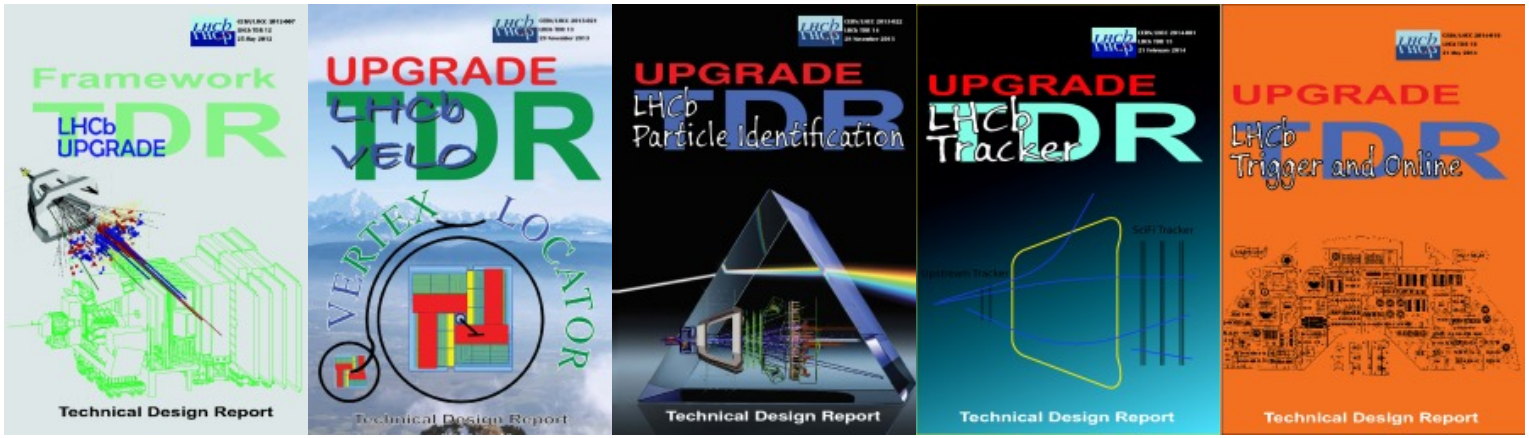




performance figures at $\sqrt{s_{NN}} = 110$ GeV: https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015.

- pp performance preserved
- main challenges: contaminations and luminosity determination
- stay tuned!

The LHCb upgrade and heavy-ion physics



Framework TDR,Velo TDR, PID TDR,Tracker TDR,Trigger & Online TDR

- LHCb detector upgrade in 2019/2020
- run at $L_{inst} = 2 \times 10^{33}$ cm^{-2} s^{-1}:
  on average 5.2 visible pp collisions per bunch crossing
- process full pp input rate in HLT without hardware trigger
- tracker fully replaced: increased granularity
- silicon vertex locator from strip to pixel detector
- improved Pb–Pb centrality reach

Conclusions

LHCb designed as a heavy-flavour precision experiment takes off in heavy-ion collisions:

- unique potential in many sectors of heavy-ion physics at forward rapidity, where data are scarce and precious
- first measurements in p–A collisions with high impact
- fascinating opportunities with large data samples in all collision systems both in collider and in fixed-target mode
- upgrade promises to boost LHCb in Pb–Pb collisions