The heavy-ion programme of LHCb

Michael Winn
on behalf of the LHCb Collaboration
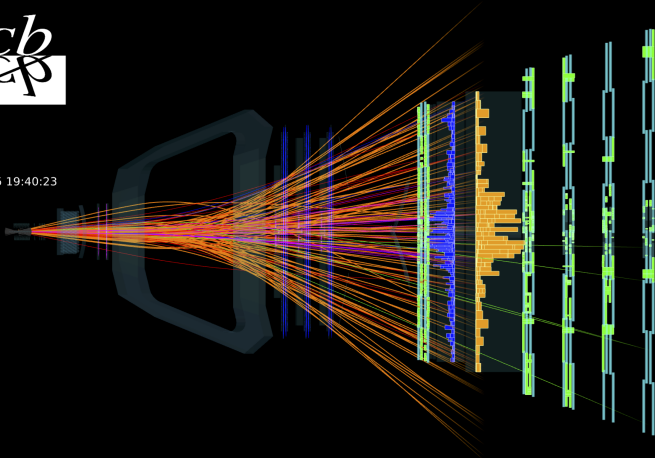
Laboratoire de l'Accélérateur Linéaire, Orsay

erc   LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE   LHCb

GSI, 26.09.2016

Event 1755501
Run 168926
Tue, 01 Dec 2015 19:40:23

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

Outline

# LHCb: a heavy-flavour precision experiment

JINST 3 (2008) S08005.
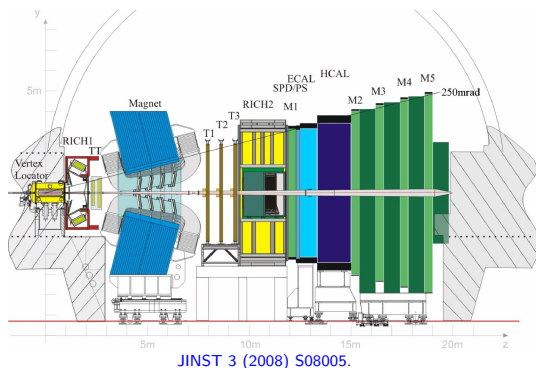
▶ precision tests of the standard model in the flavour sector
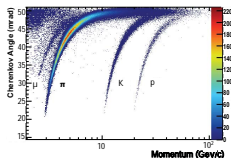
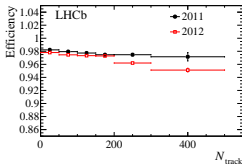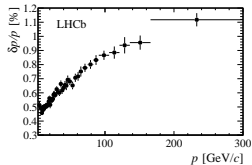Examples: observation of rare $B_S \to \mu^+ \mu^-$ decay together with CMS Nature 522 (2015) 68, most
precise single experiment measurement of the γ angle in the CKM matrix LHCb-CONF-2016-001

▶ first observation of a J/ψ p structure consistent with a
pentaquark state Phys. Rev. Lett. 115 (2015) 072001
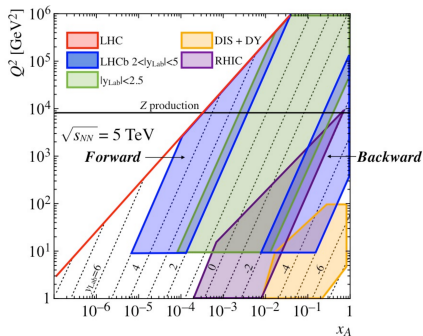
LHCb: a multi-purpose forward detector
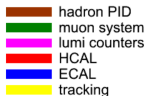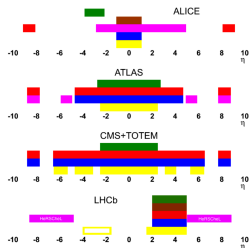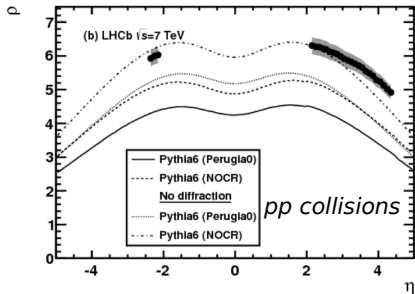

Int. J. Mod. Phys. A 30 1530022.

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

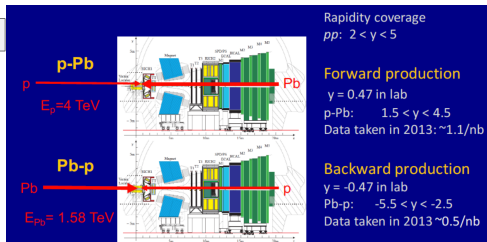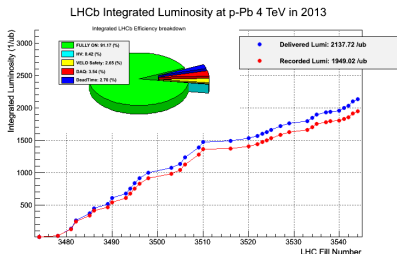# The LHCb detector: its heavy-ion physics case

RHS: Eur. Phys. J. C 72 (2012) 1947 .
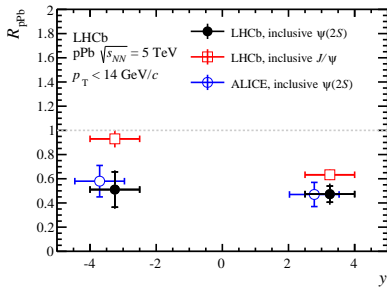
Unique kinematics at the edge of the midrapidity plateau
  ▶ Your observable of choice with this beautiful detector!

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 $\sqrt{s_{NN}} = 5$ TeV

LHCb p–Pb programme: charmonium
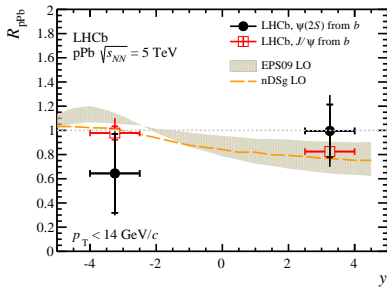

J/ψ: JHEP 02 (2014) 072; ψ(2S): JHEP 1603 (2016) 133.

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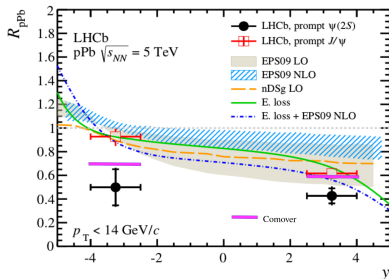
JHEP 02 (2014) 072, JHEP 1603 (2016) 133.

- ▶ result compatible with modifications expected from nuclear PDFs, coherent energy loss model, recent CGC calculations
- ▶ additional suppression for $\psi(2S)$ 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)

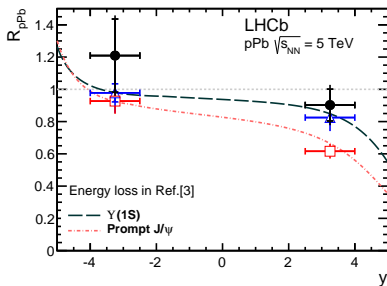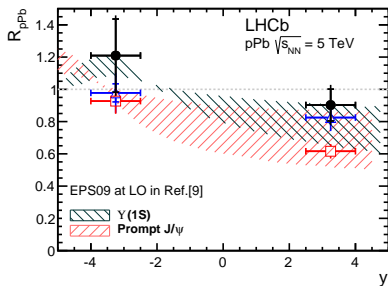# LHCb p–Pb programme: Υ results
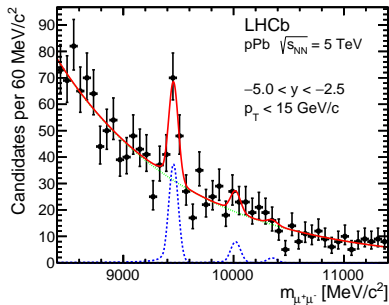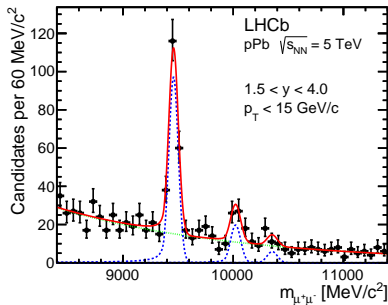
JHEP 07 (2014) 094.

- ► clear separation of Υ states
- ► statistical limitations

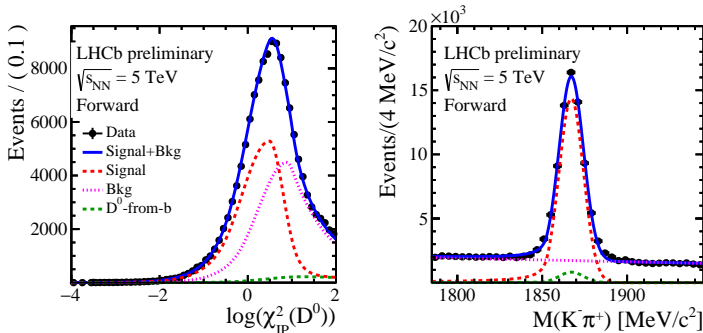# LHCb p–Pb programme: Υ results

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
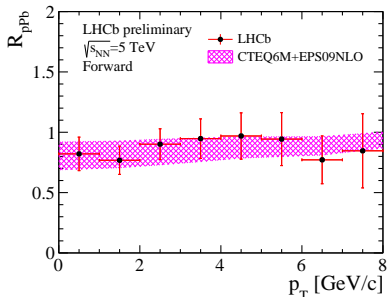
LHCb p–Pb programme: D^0 analysis
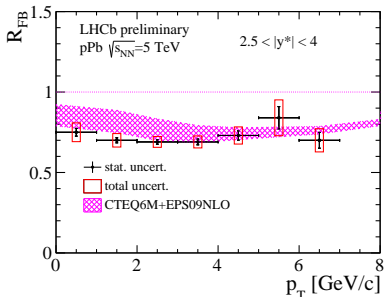

D^0 meson ($p_T < 8$ GeV/c) with $\approx 10\%$ of available statistics at $\sqrt{s_{NN}} = 5.02$ TeV LHCb-CONF-2016-003!

- ▶ 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
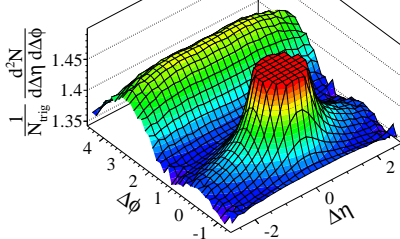
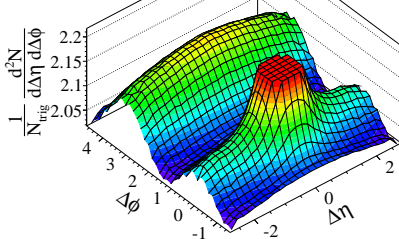# LHCb p–Pb programme: D^0 results

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
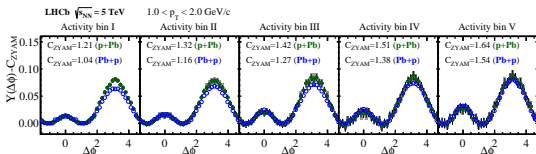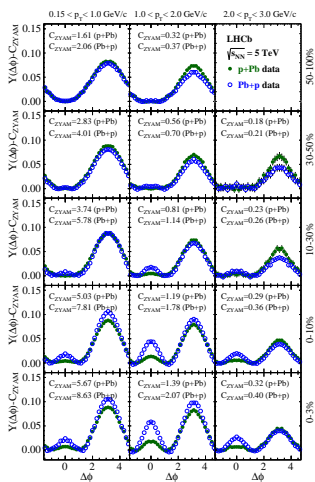
arXiv:1512.00439.

- ▶ 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

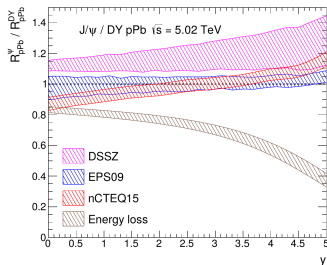- ▶ looking forward to phenomenological models

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
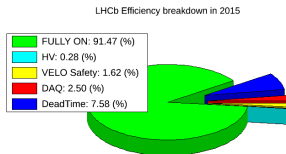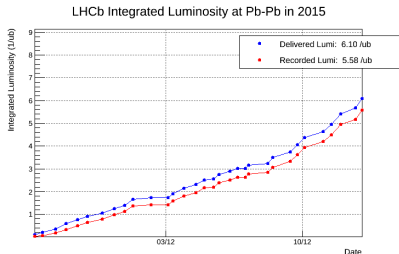nearly 2013 CMS/ATLAS statistics, e.g.:

- ▶ 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

LHCb Integrated Luminosity at Pb-Pb in 2015

Delivered Lumi: 6.10 /ub
Recorded Lumi: 5.58 /ub

LHCb Efficiency breakdown in 2015

FULLY ON: 91.47 (%)
HV: 0.28 (%)
VELO Safety: 1.62 (%)
DAQ: 2.50 (%)
DeadTime: 7.58 (%)

▶ 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
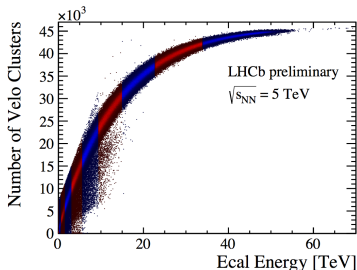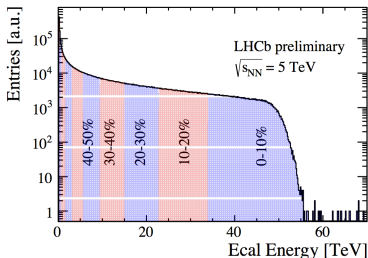
▶ designed for low pile-up pp collisions: running in pp at $\mu \approx 1$

▶ occupancy limitation in Pb–Pb collisions:
current tracking algorithms up to 50% in centrality

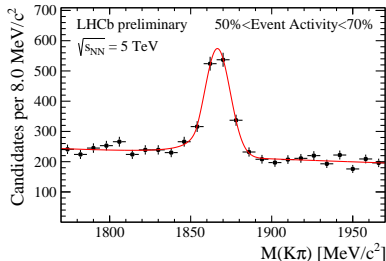# LHCb in Pb–Pb collisions: J/ψ signal
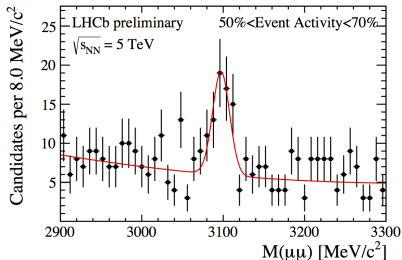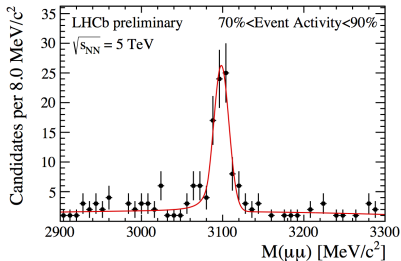
Pb–Pb performance figures: https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015.

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

LHCb in Pb–Pb collisions: D^0 signal
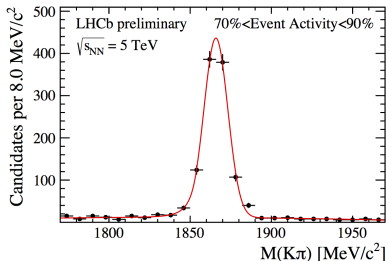
Pb–Pb performance figures: https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015.

► 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.
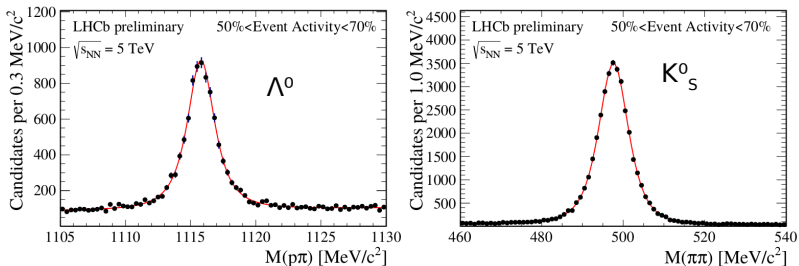
▶ Large strange V^0 samples reconstructed

LHCb in fixed target collisions: a unique opportunity at the LHC
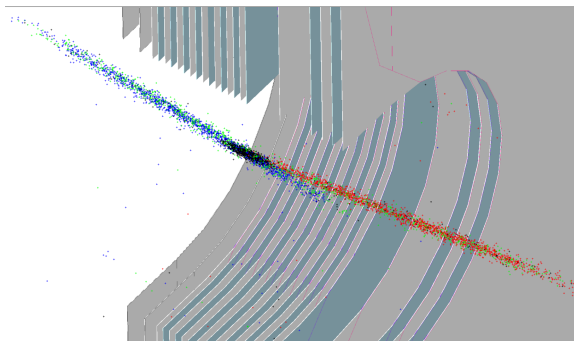
J. Instrum. 9 (2014) P12005.

- ▶ 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

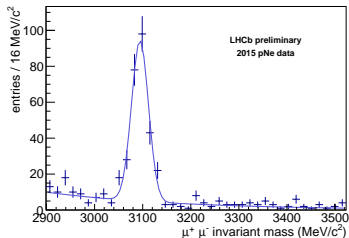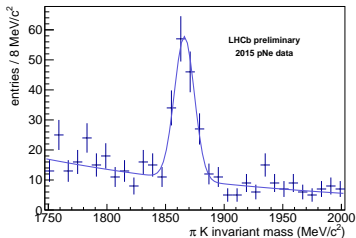# LHCb in fixed target collisions: data samples
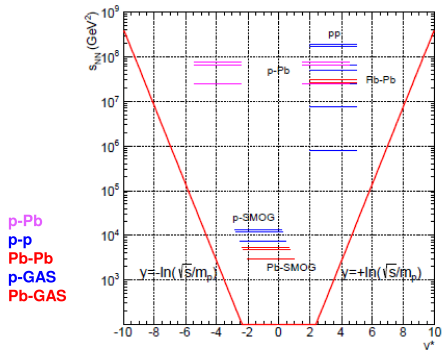
Collisions with proton and Pb beams in the RHIC energy range at midrapidity

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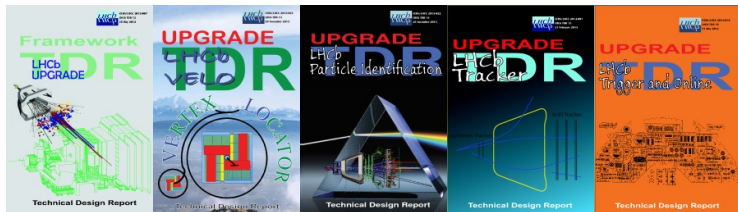
Framework TDR, Velo TDR, PID TDR, Tracker TDR, Trigger & Online TDR

- ▶ 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