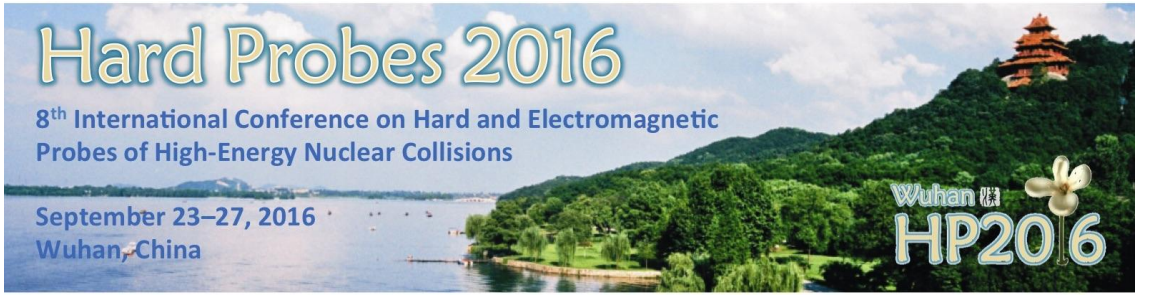
D^0 meson production in pPb and PbPb collisions at $\sqrt{S_{\mathrm{NN}}}$ = 5 TeV with LHCb

Xianglei Zhu (Tsinghua University)
on behalf of the LHCb collaboration



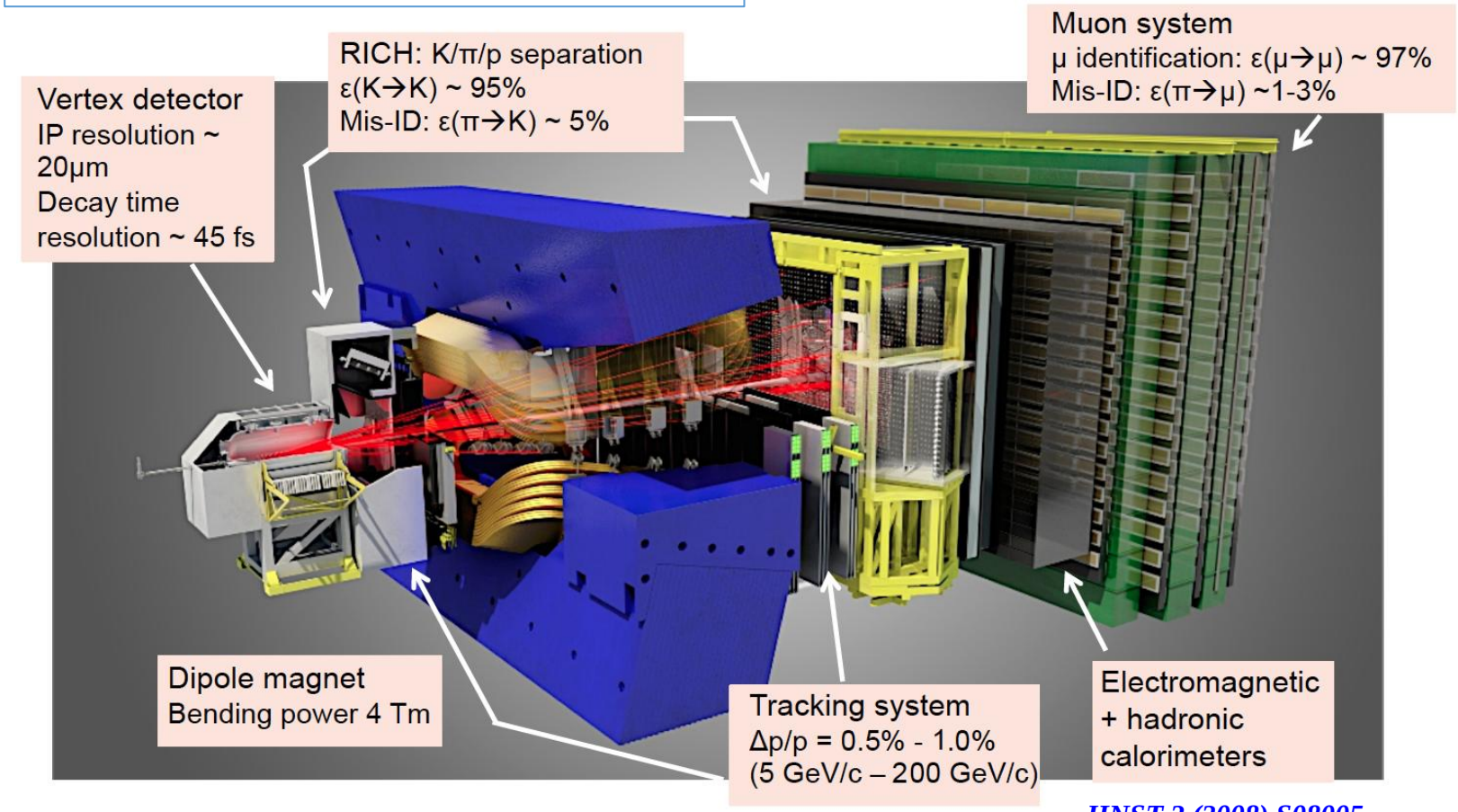
Outline

- The LHCb detector
- pPb data taking and physics motivation
- Prompt D^0 production in pPb collisions
- Prospects of D^0 measurement in PbPb and fixed-target collisions
- Summary

The LHCb detector

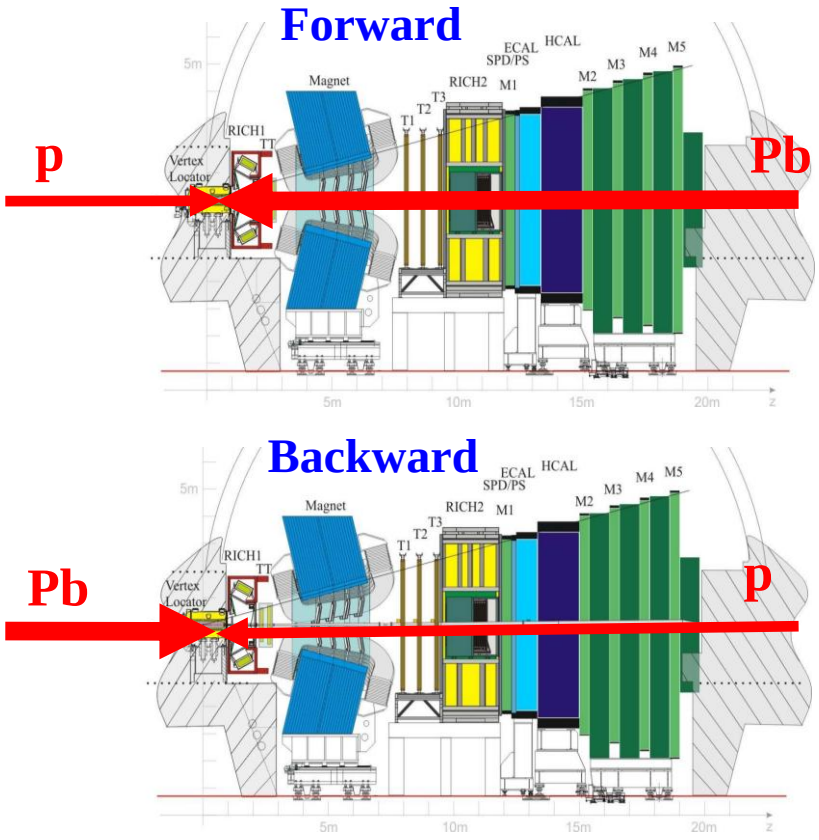
A single arm **general purpose detector** at **forward** rapidity !

pseudorapidity acceptance $2 < \eta < 5$



JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022

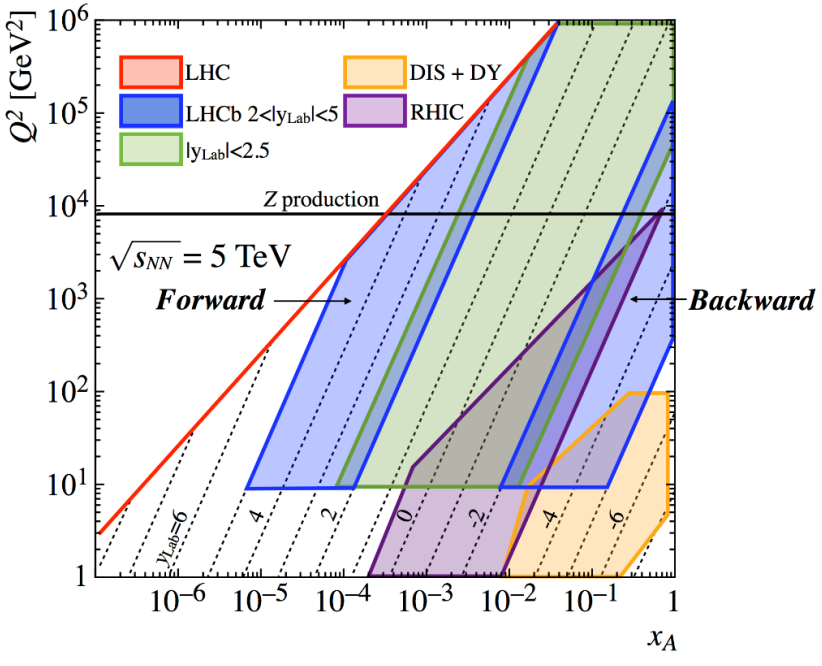
pPb data taking in 2013



- Asymmetric collision energy
  - $E_p = 4$ TeV
  - $E_{\mathrm{Pb}} = 1.58$ TeV per nucleon
  - $\sqrt{S_{\mathrm{NN}}} = 5$ TeV
  - $y_{\mathrm{cms}} = \pm 0.465$, nucleon-nucleon cms
- Rapidity coverage
  - Rapidity in nucleon-nucleon cms, y^*
  - **Forward (pPb)**: $1.5 < y^* < 4.0$
  - **Backward (Pbp)**: $-5.0 < y^* < -2.5$
  - Common coverage: $2.5 < |y^*| < 4.0$
- Integrated luminosity
  - Forward (pPb): 1.1 nb^{-1}
  - Backward (Pbp): 0.5 nb^{-1}
  - **Only 1/10 data used for the preliminary prompt D^0 analysis !**

pPb open charm physics

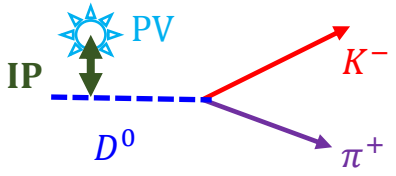
- Open charm states are sensitive probe to the QGP properties in AA collisions
- However, **cold nuclear matter effect** should be quantified in detail first
  - Nuclear parton distribution function
  - Initial stage radiation or energy loss due to soft collisions
  - Final stage hadronic rescatterings
- With the pPb data, LHCb can play important role in understanding cold nuclear matter effect, thanks to its unique capability
  - Open charm measurement down to zero p_T at forward rapidity
  - Separation of prompt and secondary open charm (from b decay)



Prompt D^0 measurement in pPb

- Reconstructed through $D^0 \to K^-\pi^+$ decays
- Simultaneous 2D fit to D^0 mass and impact parameter (IP)

→ Extraction of prompt D^0 yields down to zero-p_T



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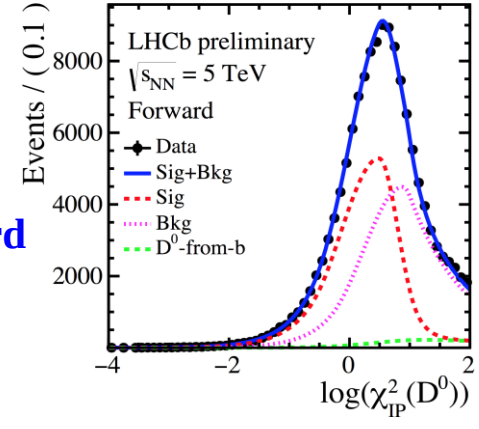
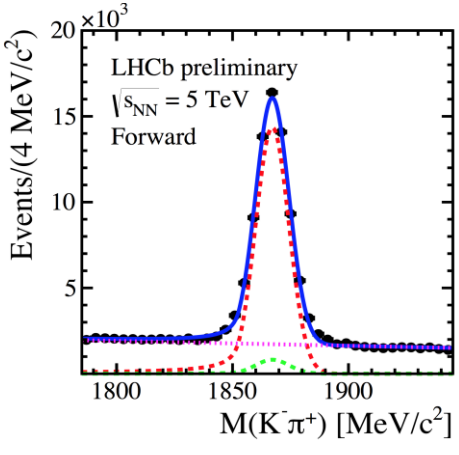
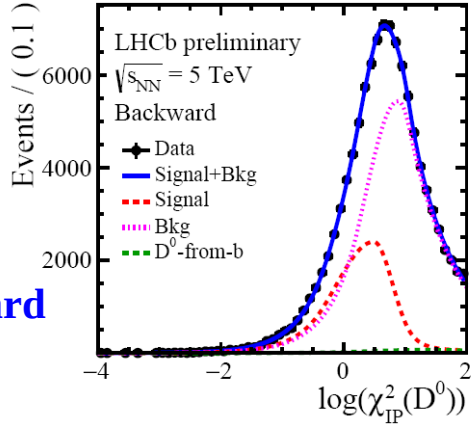
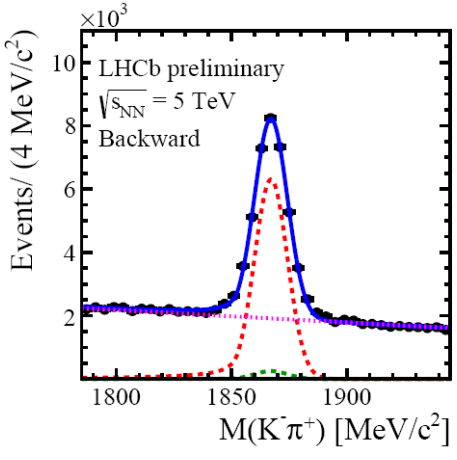
Forward





Backward





Mass distribution:
Signal: Crystal Ball
Background: linear function

IP distribution:
Prompt Signal: from simulation
D^0 from b: from simulation
Background: shape from sidebands

Prompt D^0 total cross-sections in pPb

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Forward:

$$\sigma_{\text{forward}}(p_{\text{T}} < 8\,\text{GeV}/c, 1.5 < |y^*| < 4.0) = 237 \pm 1 \pm 15\,\text{mb},$$

$$\sigma_{\text{forward}}(p_{\text{T}} < 8\,\text{GeV}/c, 2.5 < |y^*| < 4.0) = 124 \pm 1 \pm 8\,\text{mb}.$$

Backward:

$$\sigma_{\text{backward}}(p_{\text{T}} < 8\,\text{GeV}/c, 2.5 < |y^*| < 5.0) = 259 \pm 3 \pm 19\,\text{mb},$$

$$\sigma_{\text{backward}}(p_{\text{T}} < 8\,\text{GeV}/c, 2.5 < |y^*| < 4.0) = 174 \pm 2 \pm 13\,\text{mb}.$$

Source	Relative uncertainty (%)	
	forward	backward
Correlated between bins		
Signal extraction	0.4	0.4
Tracking	3.6	5.5
PID efficiency	1.1–20	1.4–15
Luminosity	1.9	2.1
$\mathcal{B}(D^0 \to K^+\pi^-)$	1.0	1.0
Uncorrelated between bins		
MC Sample size	1.4–6.5	1.4–8.3
Statistical uncertainty	1.5–16	2.2–24

Prompt D^0 double differential cross-section in pPb

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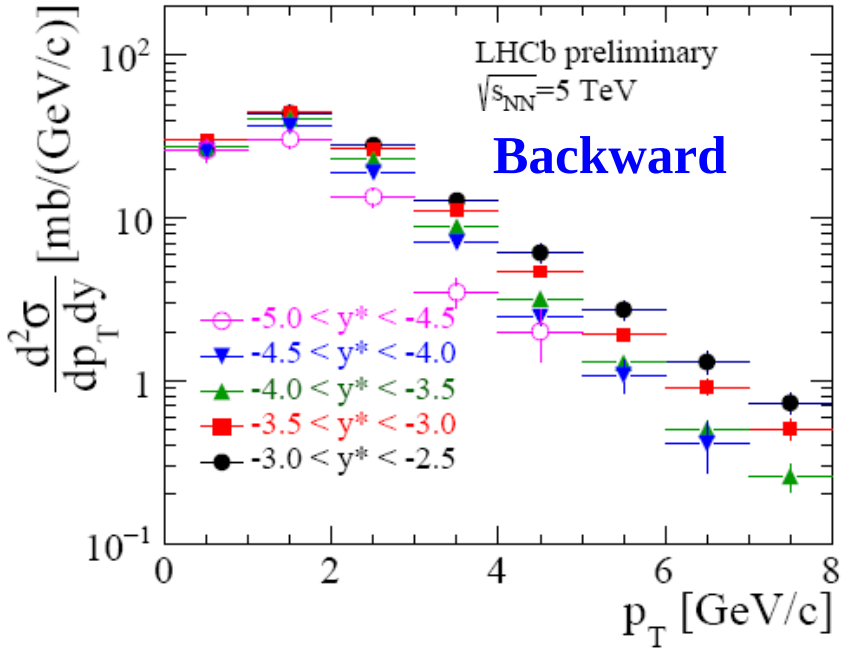

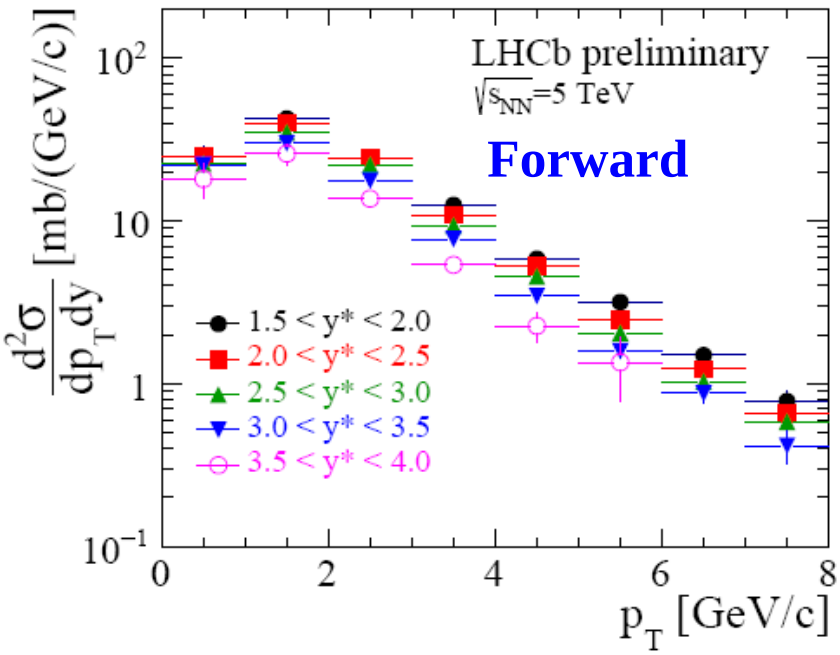

Backward:
$-5.0 < y^* < -2.5$
$p_T < 8$ GeV/c

Forward:
$1.5 < y^* < 4.0$
$p_T < 8$ GeV/c

Prompt D^0 differential cross-section in pPb

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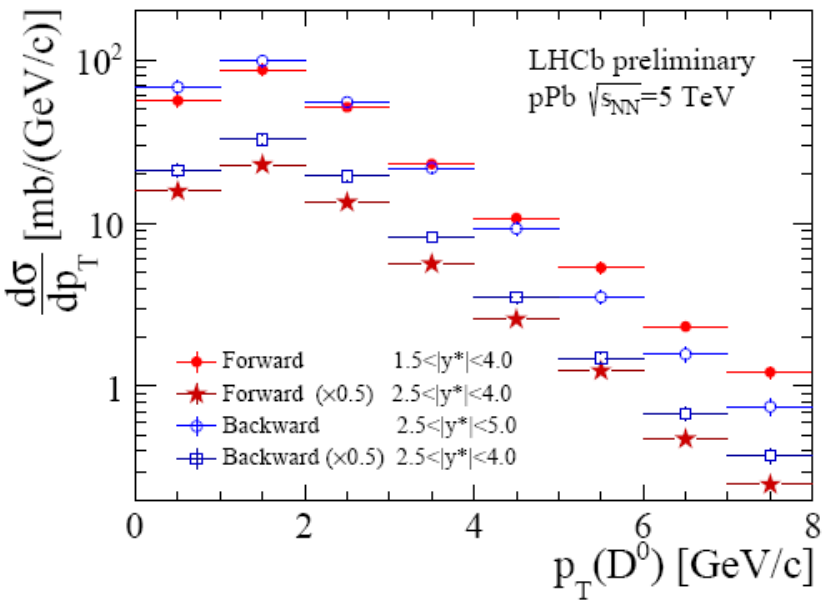
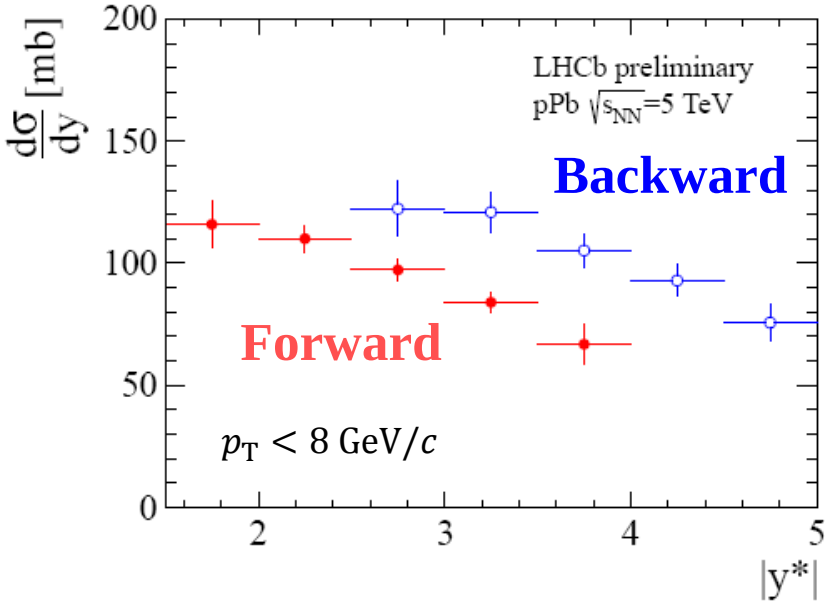
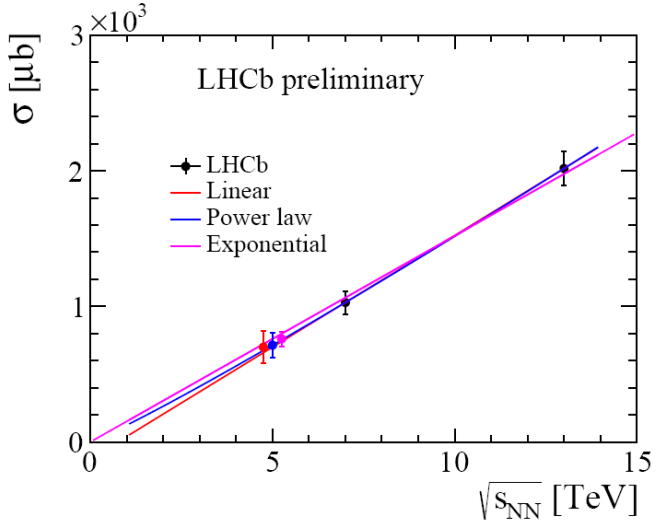




Sizable forward-backward asymmetry

Prompt D^0 nuclear modification factor in pPb

- $R_{p\mathrm{Pb}}(y^*, p_T) = \frac{1}{A} \times \frac{\sigma_{p\mathrm{Pb}}(y^*, p_T, \sqrt{s_{NN}})}{\sigma_{pp}(y^*, p_T, \sqrt{s_{NN}})}$, A=208 ***LHCb-CONF-2016-003***
- Prompt D^0 cross-section in pp collisions at $\sqrt{s} = 5$ TeV was extrapolated using LHCb measurements at 7 and 13 TeV ***Nucl. Phys. B871 (2013) 1; JHEP 03 (2016) 159, Erratum-ibid 09 (2016) 013***



$$\sigma(\sqrt{s}) = \begin{cases} p_1(\sqrt{s})^{p_0} & \text{power law,} \\ p_1 + p_0\sqrt{s} & \text{linear,} \\ p_1(1-\exp(-\sqrt{s}/p_0)) & \text{exponential.} \end{cases}$$

CAUTION: Preliminary R_{pPb} uses extrapolated pp cross-sections for reference! will be updated soon with the measured pp values!

Extrapolated: $\sigma_{pp}(p_T < 8\ \mathrm{GeV}/c, 2.5 < |y^*| < 4.0)$ = **713** $\pm$ 95(LHCb) $\pm$ 47 (fit model) μb

- Prompt D^0 in pp at $\sqrt{s} = 5$ TeV was measured recently! ***LHCb-PAPER-2016-042***

Measured: $\sigma_{pp}(p_T < 8\ \mathrm{GeV}/c, 2.5 < |y^*| < 4.0)$ = **943** $\pm$ 2 $\pm$ 49 μb

Prompt D^0 nuclear modification factor in pPb

- Extrapolated pp data at $\sqrt{s} = 5$ TeV for reference

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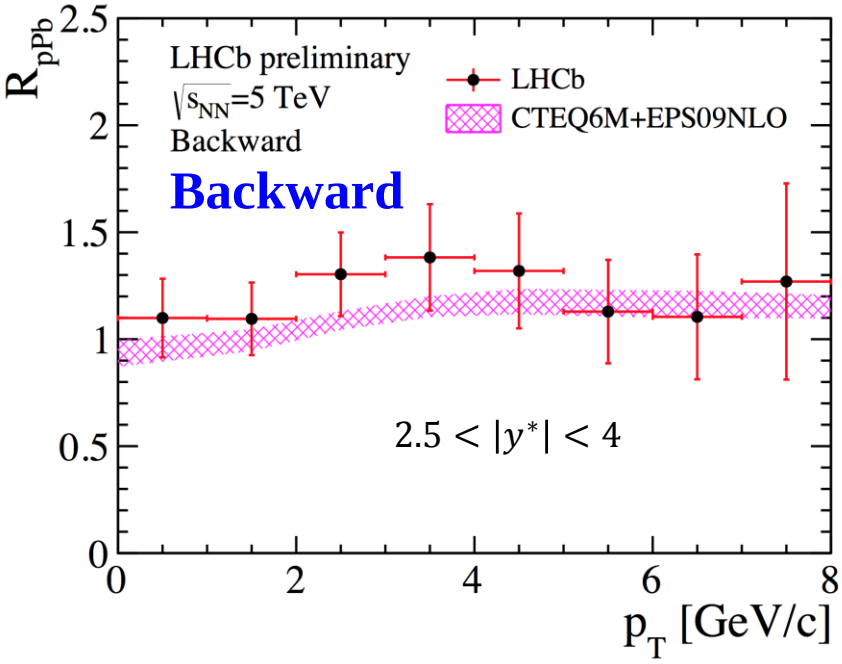
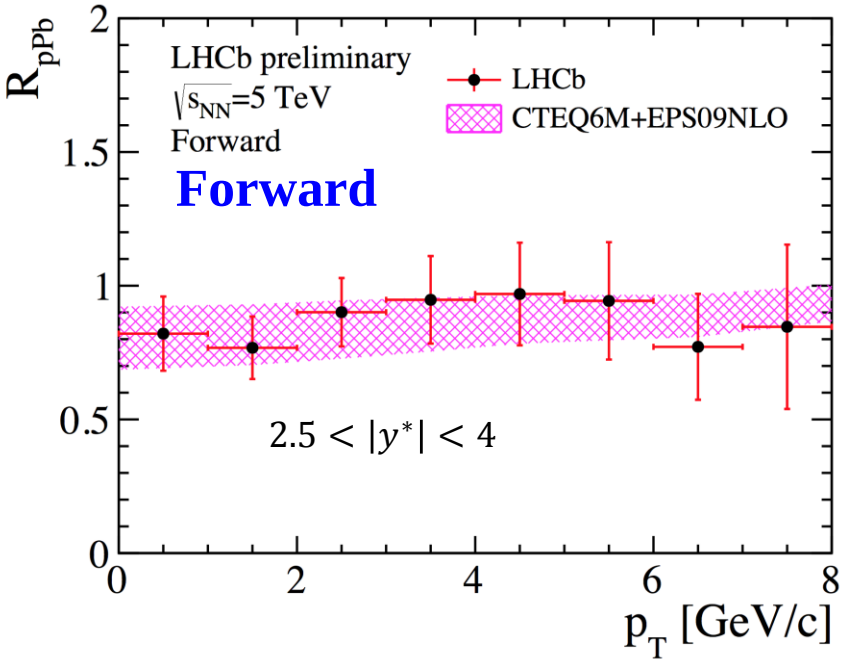
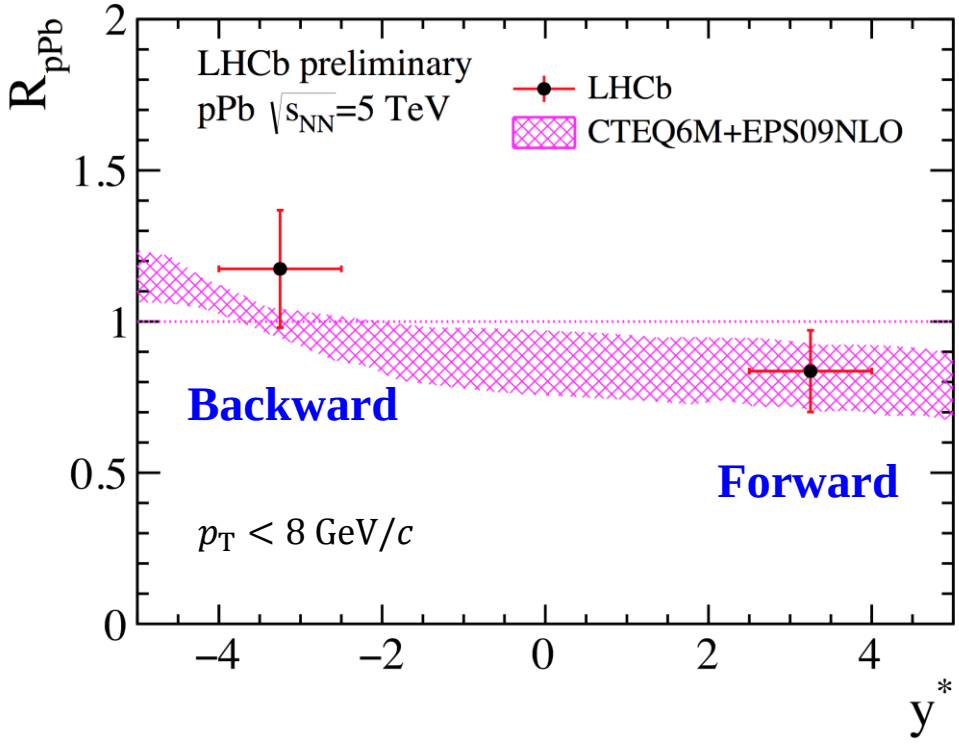




MNR with CTEQ6M+EPS09NLO: ***Nucl. Phys. B373 (1992) 295, JHEP 10 (2003) 046, JHEP 04 (2009) 065***

Prompt D^0 nuclear modification factor in pPb



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- Extrapolated pp data at $\sqrt{s} = 5$ TeV for reference
- Nuclear modification factor smaller at forward rapidity
- Measurements consistent with theoretical predictions

MNR with CTEQ6M+EPS09NLO: ***Nucl. Phys. B373 (1992) 295, JHEP 10 (2003) 046, JHEP 04 (2009) 065***

Prompt D^0 forward-backward asymmetry in pPb

- $R_{\mathrm{FB}}(|y^*|, p_T) = \dfrac{\sigma_{p\mathrm{Pb}}(+|y^*|, p_{T,\sqrt{s_{NN}}})}{\sigma_{\mathrm{Pb}p}(-|y^*|, p_{T,\sqrt{s_{NN}}})}$

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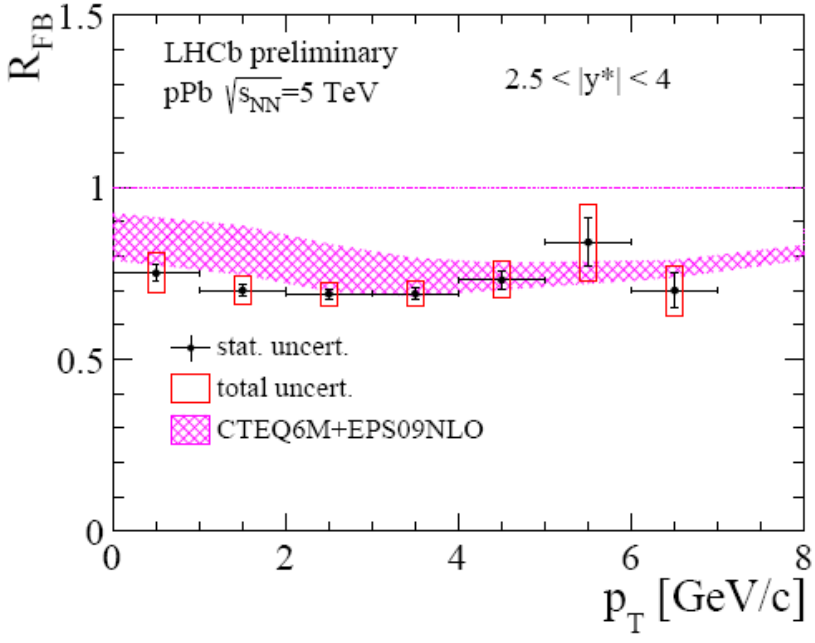
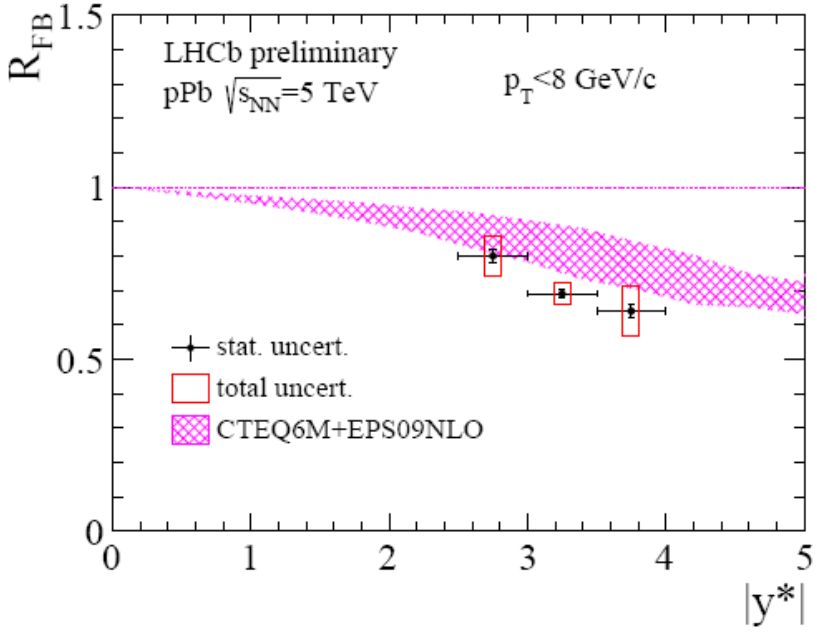




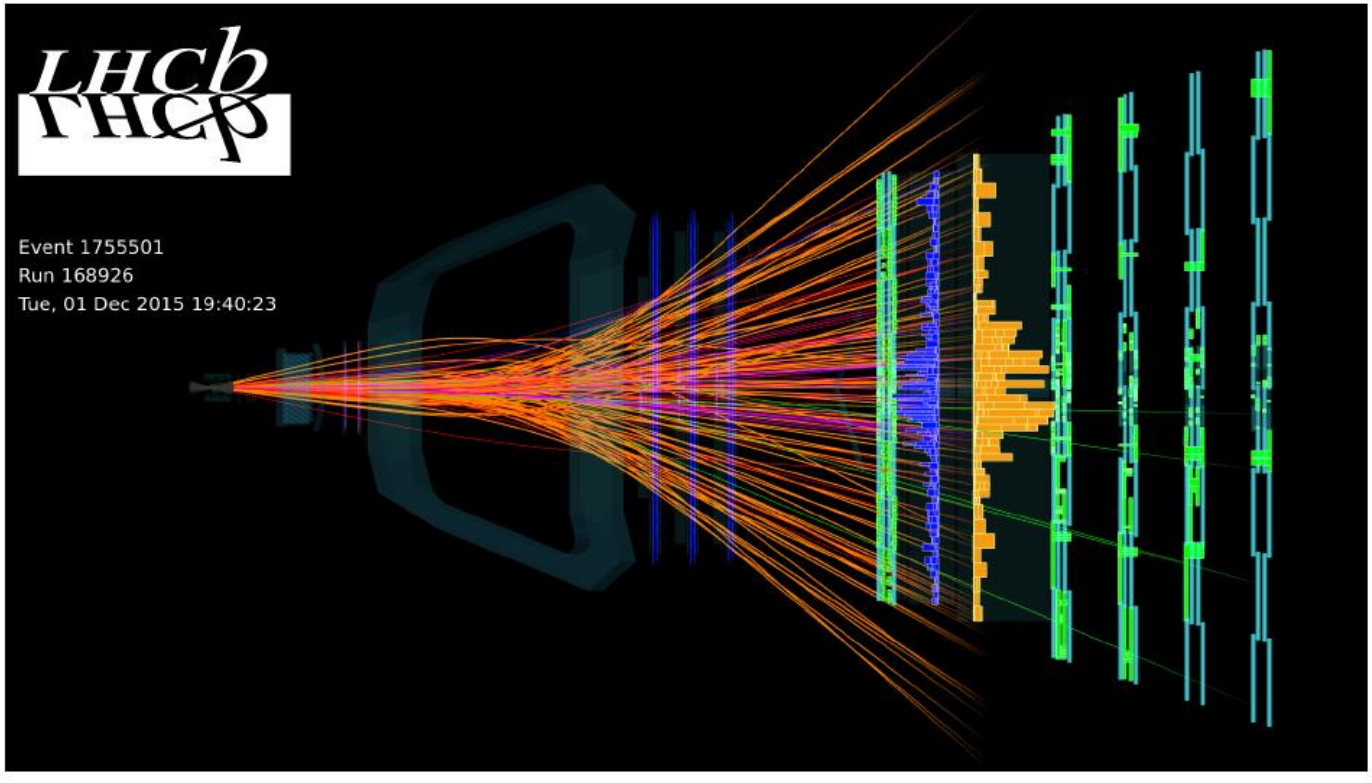
- No need for pp reference, systematic uncertainty largely cancels
- Significant forward-backward asymmetry observed

MNR with CTEQ6M+EPS09NLO: ***Nucl. Phys. B373 (1992) 295, JHEP 10 (2003) 046, JHEP 04 (2009) 065***

PbPb data taking in 2015

- LHCb first participated in PbPb run in December 2015
- 24 colliding bunches, integrated luminosity L = 3 - 5 μb^{-1}
- Minimum bias trigger

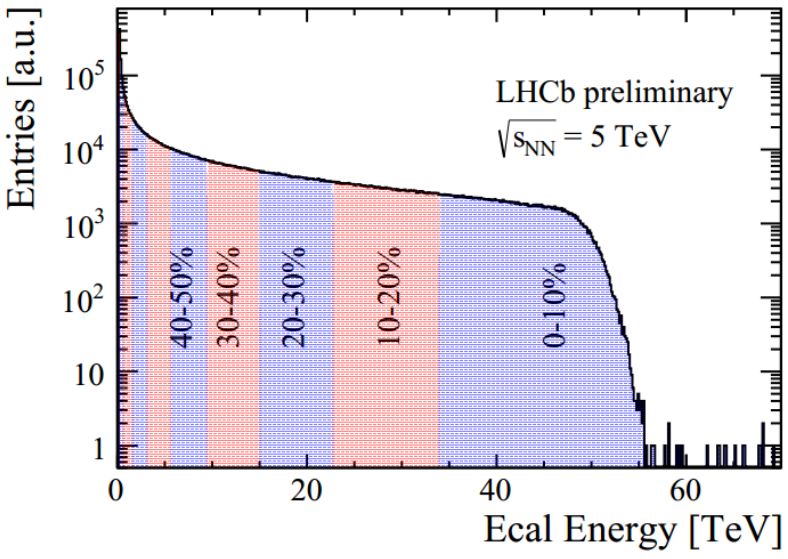
https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015

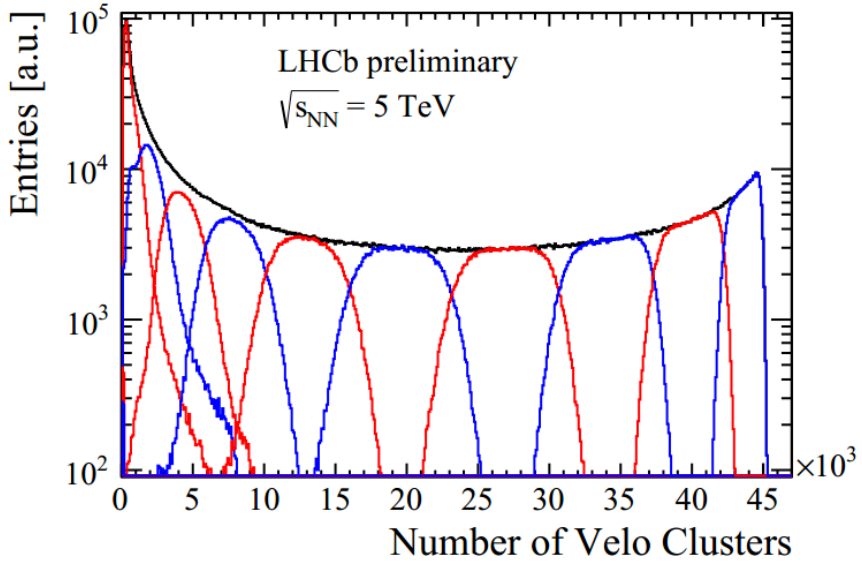


A PbPb event with 1130 reconstructed tracks and a J/ψ candidate

Centrality definition in PbPb

- Energy deposition in ECAL/HCAL are used to define collision centrality
  - Not saturated even for most central collisions
  - Minimal correlation with particle production measurements
  - Tracking may be possible up to ~15k VELO hits (**100% - 50% centrality**)

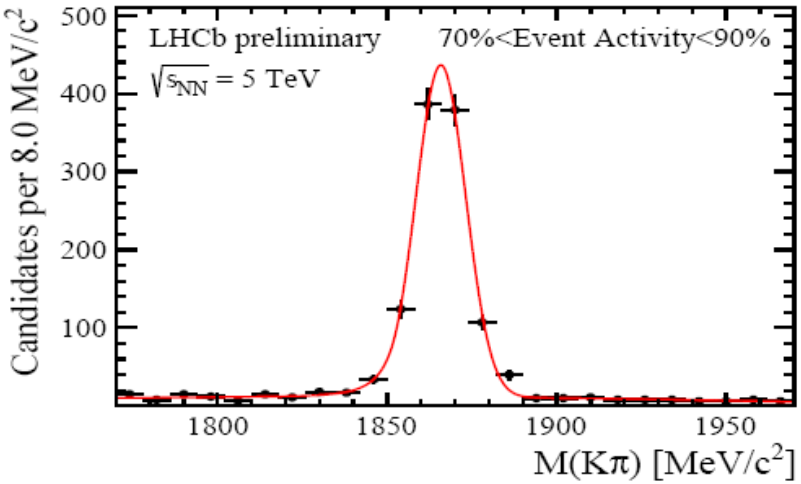


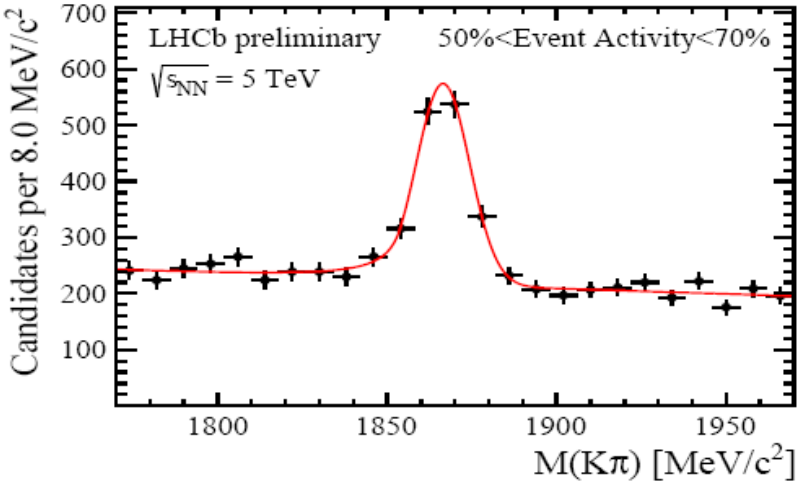


https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015

D^0 in PbPb (a first look)

Reconstructed through $D^0 \to K^-\pi^+ + CC$ decays

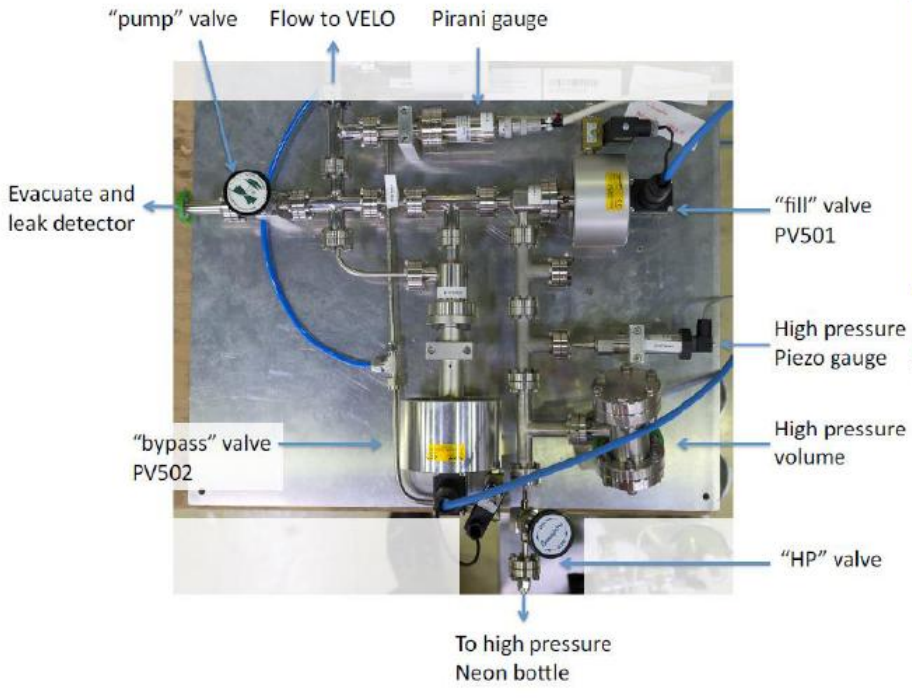




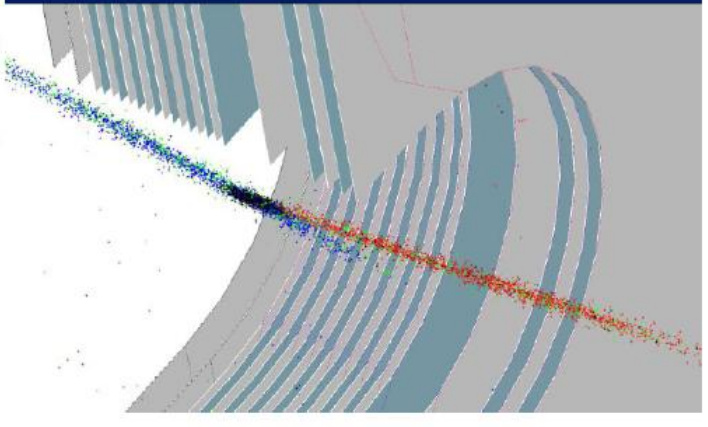
https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015

Fixed-target experiment with LHCb

SMOG: System for Measuring Overlap with Gas ***JINST 9 (2014) P12005***



- injection of gas into interaction region
- very simple robust system
- used for a precise luminosity determination

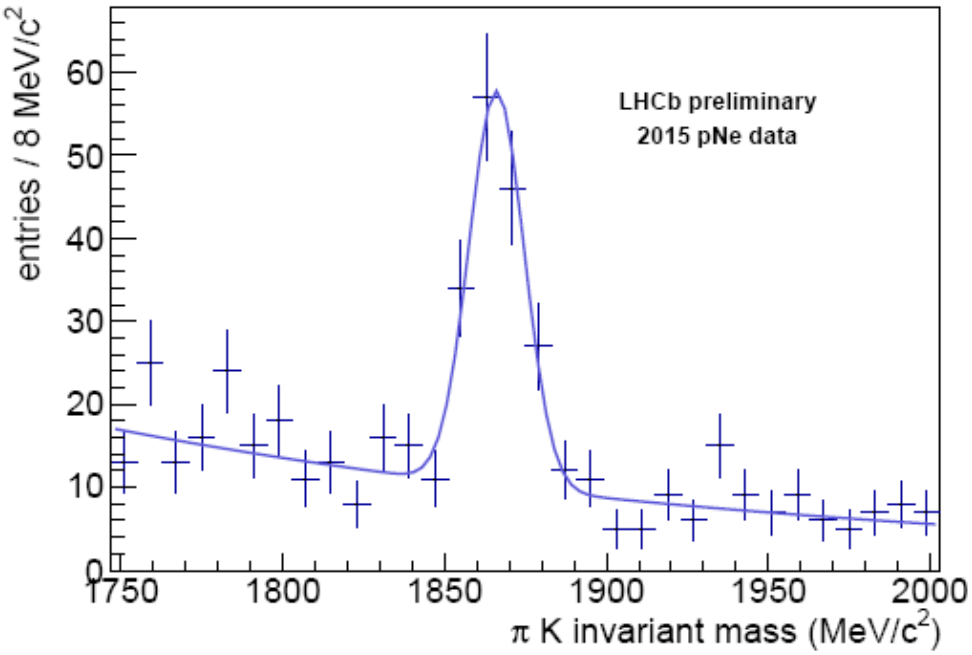


- Inject noble gases (He, Ne, Ar) into the LHCb vertex detector
- fixed-target physics in pA and PbA configuration, **covering mid-rapidity!**

Bridge the gap from SPS to LHC in a single experiment!

D^0 in fixed-target collisions (a first look)

pNe collisions at $\sqrt{s_{\mathrm{NN}}}$ = 110 GeV，~12 hours data taking in 2015



https://twiki.cern.ch/twiki/bin/view/LHCb/LHCbPlots2015

Summary

- Prompt D^0 in $\sqrt{s_{\mathrm{NN}}}$ = 5 TeV pPb collisions
  - Preliminary results on cross-sections, nuclear modification factor, and forward-backward ratio obtained with 1/10 data
  - Sizable forward-backward asymmetry observed, consistent with theoretical predictions
  - Analysis to be updated including full pPb statistics and $\sqrt{s} = 5$ TeV pp data as reference
- D^0 in $\sqrt{s_{\mathrm{NN}}}$ = 5 TeV PbPb collisions
  - Clear D^0 signals, analysis on-going, results expected up to centralities around 50%
- D^0 in fixed-target collisions
  - Clear D^0 signals, development of methods to exploit the data
- **Outlook**
  - Systematic prompt open charm ($D^+, D^{*+}, D_S^+, \Lambda_c$) analysis in $\sqrt{s_{\mathrm{NN}}}$ = 5 TeV pPb collisions
  - New pPb data taking at $\sqrt{s_{\mathrm{NN}}}$ = 8 TeV (high statistics) in 2016
  - Additional fixed-target data taking runs

Thanks and stay tuned!