

# pA collisions in fixed-target mode at LHCb



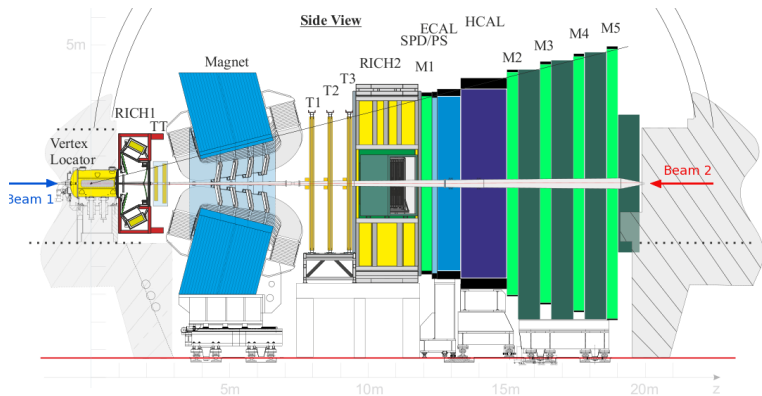
Jihyun Bhom  
On behalf of the LHCb collaboration



International Conference of High Energy Physics  
7 July 2018

# LHCb Detector

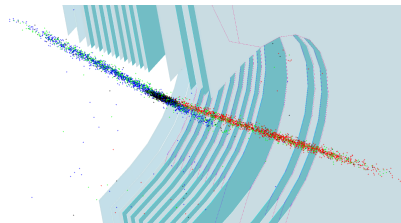
- ⇒ Fully instrumented forward spectrometer,  $2 < \eta < 5$ .
- ⇒ Excellent particle identification (PID).
- ⇒ Precision vertex reconstruction and tracking.
- ⇒ Fixed target capability via gas injection (SMOG).
- ⇒ Successful data taking in heavy-ion collisions.



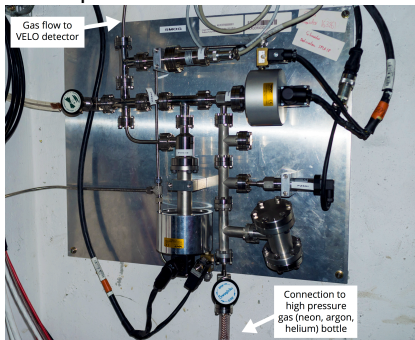
[2014 JINST 9 P12005]

# The Fixed Target data taking (SMOG)

⇒ SMOG: System for Measuring the Overlap with Gas



As the beam passes through LHCb, interactions with gas allow the experiment to measure the full beam profile. In this diagram, neon gas, beam 1 (blue) and beam 2 (red) are measured by the surrounding VELO detector.  
<https://cds.cern.ch/journal/CERNBulletin/2015/47>

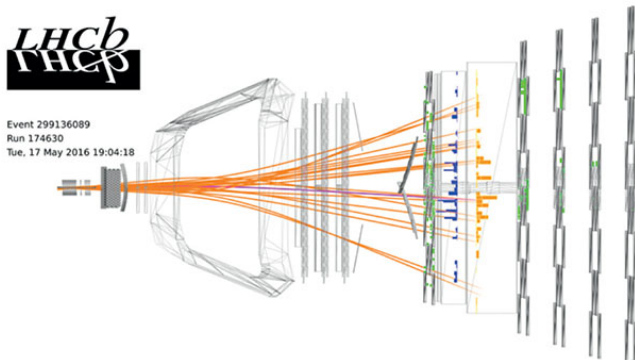


The gas injection system installed near the VELO detector at LHCb.

# Introduction of fixed target mode with LHCb

p-Gas and Pb-Gas data taking.

<http://cerncourier.com/cws/article/cern/68420>

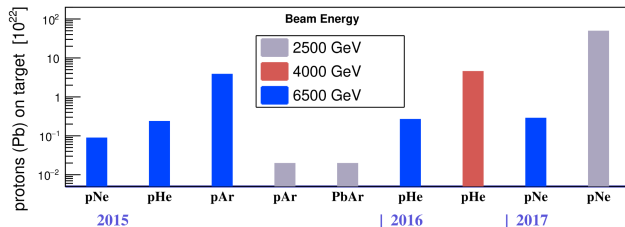


Event simulation in pHe

⇒ A fully reconstructed proton–helium collision event in the LHCb detector, with the particle identified as an antiproton.



# Running modes and plan



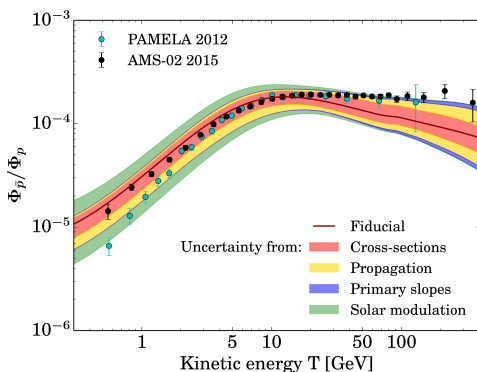
Element	He	Ne	Ar
A	4	20	40

⇒ In this talk;

- pHe  $\sqrt{s_{NN}} = 110$  GeV

- pAr  $\sqrt{s_{NN}} = 110$  GeV and pHe  $\sqrt{s_{NN}} = 86.6$  GeV.

# Motivation of soft particle production

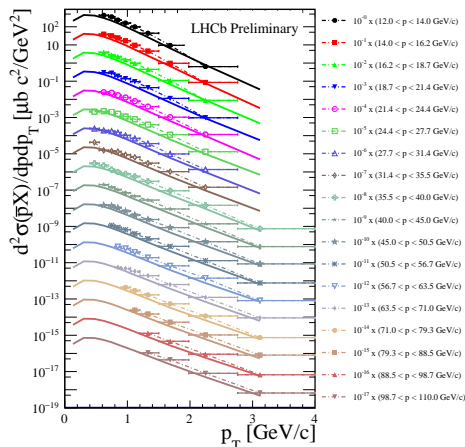


The combined total uncertainty on the predicted secondary  $\bar{p}/p$  ratio [CONF-2017-002]

⇒ Interesting link with cosmic ray physics

- The AMS (ISS) experiment measures antiproton production.
- Observed excess may be due to dark matter candidates annihilation
- Predictions for  $\bar{p}/p$  currently limited by uncertainties on  $\bar{p}$  production in pHe
- LHCb has measured  $\bar{p}$  cross-section in pHe  $\sqrt{s_{NN}} = 110$  GeV.

# Soft particle production in pHe fixed target collisions



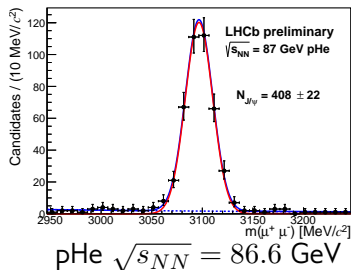
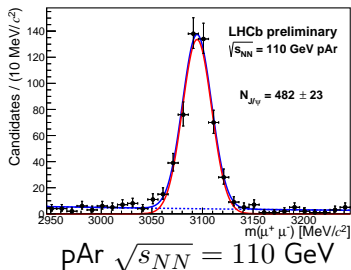
$\bar{p}$  cross-section measurement. The data points show the double differential cross-section as a function of  $p_T$ . The solid curves show the EPOS LHC [arXiv:1708.05184].

$\Rightarrow$  Cross sections in pHe 110 GeV TeV beam energy underestimated by EPOS-LHC:

– total inelastic cross-section  
 $\sigma_{inel}^{LHCb}(\text{pHe } \sqrt{s_{NN}} = 110 \text{ GeV}) = (140 \pm 10) \text{ mb}$ .

# $J/\psi$ Production in pAr and pHe

[LHCb-CONF-2017-001]



$\Rightarrow J/\psi \rightarrow \mu^- \mu^+$

$\Rightarrow$  Mass distributions with the fit functions compared.

The black points are the data, the red line the signal, the dashed blue line the background, and the solid blue the sum of background and signal.

# $J/\psi$ and $c\bar{c}$ cross section as functions of the centre-of-mass energy

[LHCb-PAPER-2018-23]

- $J/\psi$  and  $c\bar{c}$  in pHe total cross-sections per target nucleon, in the full phase-space, are found to be:

$$\sigma_{J/\psi}^{86.8\text{GeV}} = 1225.6 \pm 62.0(\text{stat.}) \pm 81.6(\text{syst.}) \text{ nb/nucleon}$$

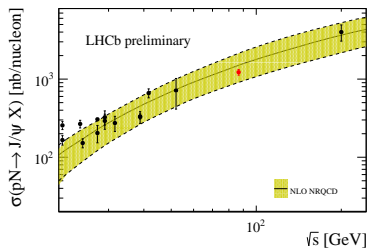
$$\sigma_{D^0}^{86.8\text{GeV}} = 156.0 \pm 4.6(\text{stat.}) \pm 12.3(\text{syst.}) \mu\text{b/nucleon}$$

- Scaling  $D^0$  cross-section with the global fragmentation ratio,  $f(c \rightarrow D^0) = 0.542 \pm 0.024$ , production cross section can be obtained:

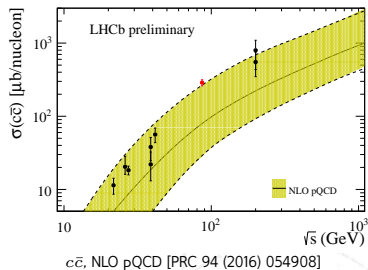
$$\sigma_{c\bar{c}}^{86.8\text{GeV}} = 287.8 \pm 8.5(\text{stat.}) \pm 25.7(\text{syst.}) \mu\text{b/nucleon}$$

# $J/\psi$ and $c\bar{c}$ cross section as functions of the centre-of-mass energy

[LHCb-PAPER-2018-23]



Fit results as a function of the LHC-energy for the  $J/\psi$   
NLO NRQCD [PLB 638 (2006) 202]

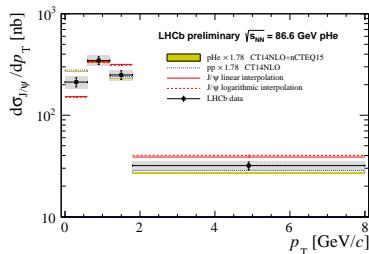
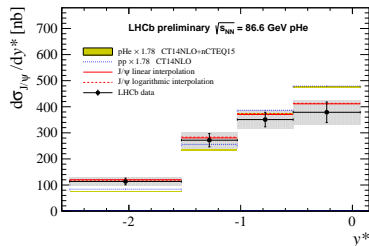


$c\bar{c}$ , NLO pQCD [PRC 94 (2016) 054908]

⇒ Red points correspond to the results presented here.

# $J/\psi$ differential cross section at pHe $\sqrt{s_{NN}} = 86.6$ GeV

[LHCb-PAPER-2018-023]



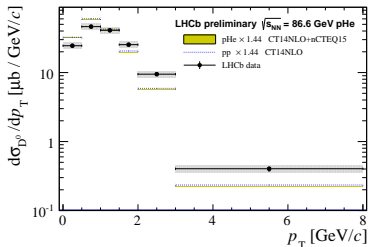
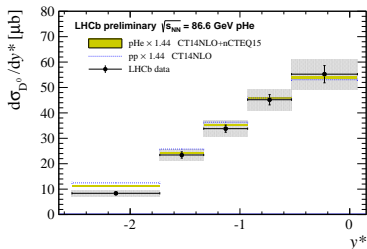
⇒ HELAG-ONIA [EPJC 77:1 (2017)] predictions for pp (blue line) and pHe (yellow box) overlaid with measurement.

⇒ Plain and dashed red lines: phenomenological parametrization [PRL 109 (2012) 122301, PRD 83 (2011) 114036].

⇒ Reasonable agreement with theoretical expectations.

# $D^0$ differential cross section at pHe $\sqrt{s_{NN}} = 86.6$ GeV

[LHCb-PAPER-2018-023]

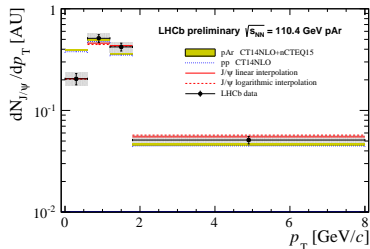
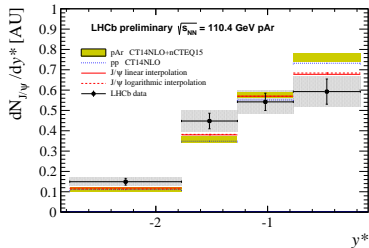


- ⇒ HELAG-ONIA [EPJ C 77:1 (2017)] predictions for pp (blue line) and pHe (yellow box) overlaid with measurement.
- ⇒ No strong intrinsic charm contribution is observed.
- ⇒ Reasonable agreement with theoretical expectations.



# $J/\psi$ differential yields at pAr $\sqrt{s_{NN}} = 110$ GeV

[LHCb-PAPER-2018-023]



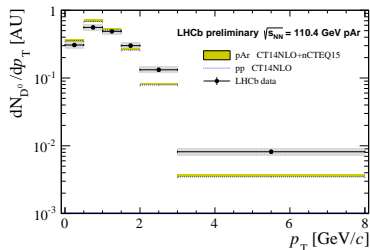
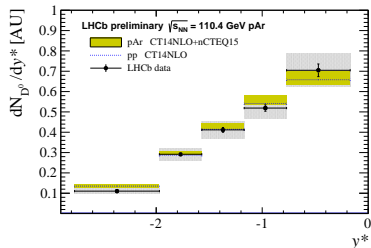
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⇒ Reasonable agreement with theoretical expectation.

# $D^0$ differential yields at pAr $\sqrt{s_{NN}} = 110$ GeV

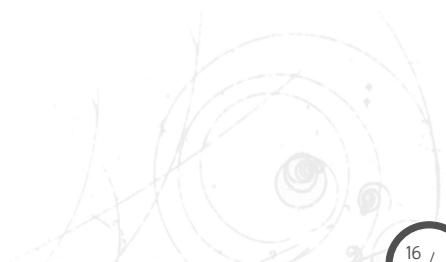
[LHCb-PAPER-2018-023]



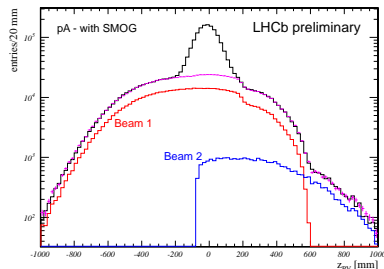
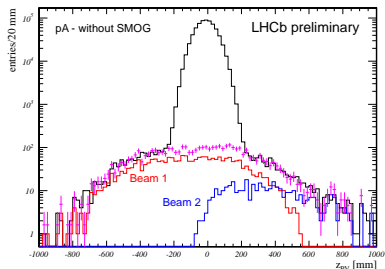
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- ⇒ No strong intrinsic charm contribution is observed.
- ⇒ Reasonable agreement with theoretical expectation.

# Summary

- ⇒  $\bar{p}$  cross-section measurement in pHe  $\sqrt{s_{NN}} = 110$  GeV.
- ⇒ Measure  $J/\psi$  in pAr  $\sqrt{s_{NN}} = 110$  GeV and pHe  $\sqrt{s_{NN}} = 86.6$  GeV.
  - No strong intrinsic charm contribution is observed within experimental uncertainties.
- ⇒ Fixed-target program in LHCb successfully measure a heavy-flavor cross-section.
- ⇒ More results in pipeline.
  
- ⇒ For more results tune in for LHCb talks:
  - Shanzhen Chen: *Quarkonia production in pPb with LHCb*
  - Benjamin Audurier: *Production of open charm and beauty states in pPb with LHCb*
  - Jihyun Bhom: *Photon production and correlations in pp and pPb with LHCb*



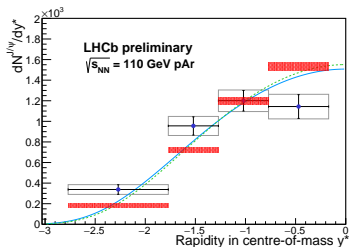
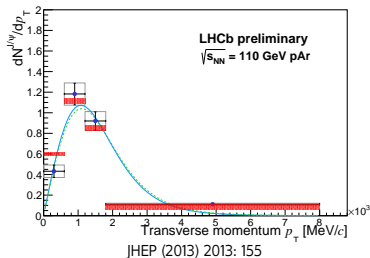
# Fixed Target Interaction Properties



- ⇒ Distribution of the  $z_{PV}$  positions of reconstructed primary vertices in pPb collisions without (left) and with (right) activated SMOG system. The distributions for only beam 1 (proton) and beam 2 (lead) are shown in red and blue, respectively. The magenta points are the weighted sums of the two, with weights adjusted to reproduce the integrals over the pPb distributions for  $|z_{PV}| > 300\text{mm}$ .
- ⇒ Beam-Beam / Beam-Gas interactions can be separated from the filling scheme a Fixed target collisions can be isolated from regular collisions in collider mode. No need for dedicated physics runs.
- ⇒ SMOG increases the beam gas rate by two order of magnitudes  
Gas pressure (  $1.5 \times 10^{-7}$  mbar ) 2 order of magnitude larger than vacuum pressure.

# $J/\psi$ Production in pAr vs PYTHIA

[LHCb-CONF-2017-001]



⇒  $J/\psi \rightarrow \mu^- \mu^+$  differential corrected yields.

⇒ Red boxes correspond to Pythia. Blue and green curves correspond to two phenomenological parametrizations based on JHEP (2013) 2013: 155. The data points indicate the centres of the bins.