Heavy-flavour production in fixed-target mode with LHCb

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Abstract

The LHCb detector has the unique capability to study collisions of the LHC beams on fixed targets. Internal gas targets of helium, neon and argon have been used so far to collect samples corresponding to integrated luminosities up to 0.1 pb^{-1}. An upgraded target, allowing a wider choice of target gas species and an increase in the gas density by up to two orders of magnitude, is planned to be installed for the LHC Run 3. Results on open and hidden charm production measurements in the case of proton-argon and proton-helium collisions are presented as well as fixed-target prospects. These measurements can provide crucial constraints on cold nuclear matter effects and nPDF at large x. In addition, production measurements of anti-protons are of great interest for cosmic-ray physics [PRL 121, 222001].

The LHCb Detector

- The LHCb detector is a single-arm spectrometer in the forward direction covering the pseudo-rapidity range $2 < \eta < 5$.
- Very high precision tracking system, vertex locator (VELO), and particle identification.
- LHCb has a System for Measuring the Overlap with Gas (SMOG) which gives the unique possibility to inject gas into the VELO, turning LHCb into a fixed-target experiment.

Fixed-target operation

- **A schematic view**

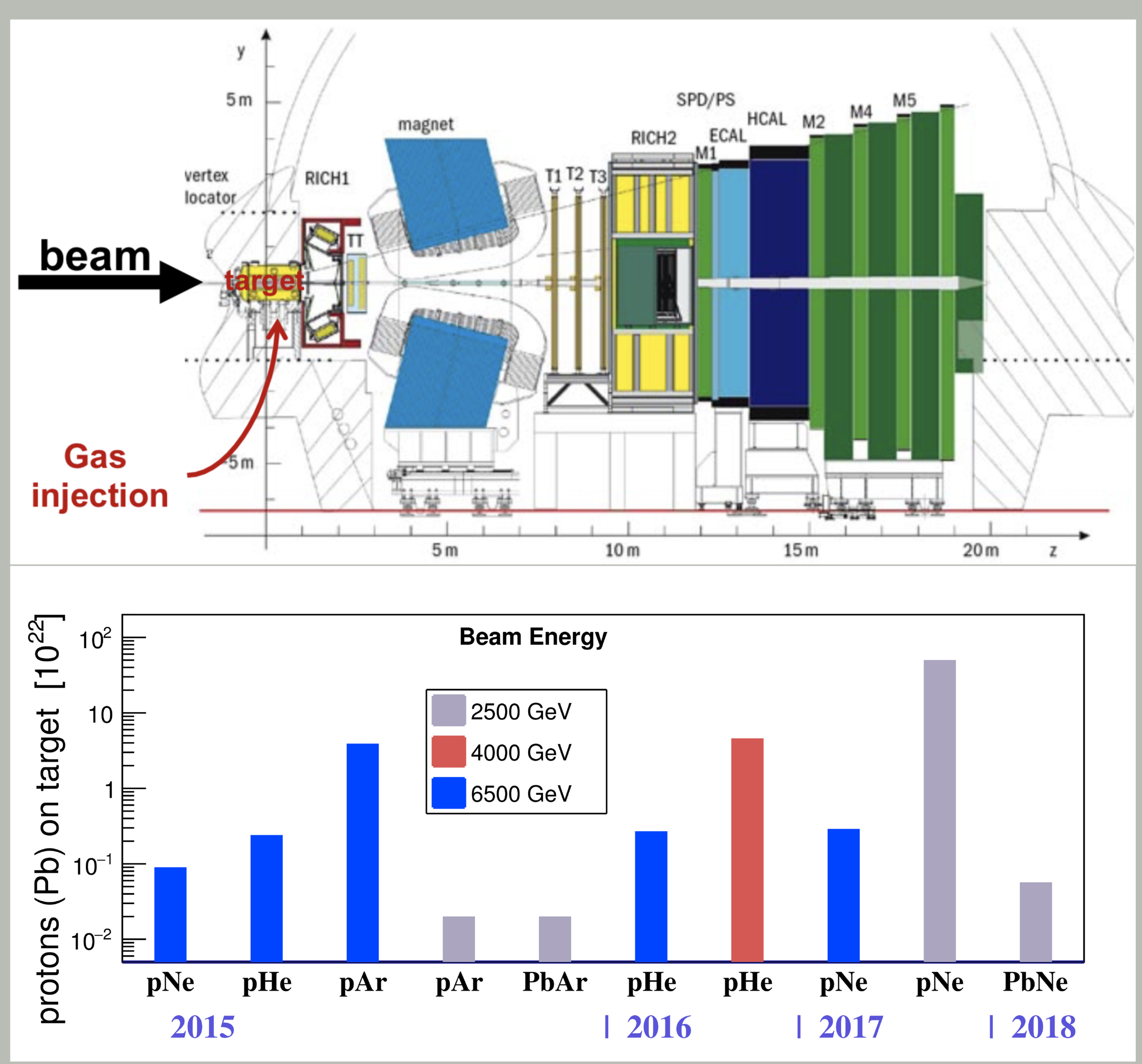

Figure 1: Schematic view of the LHCb detector (top), showing the corresponding sub-detectors. Also, the region where gas is injected as a target inside the VELO is pointed out. Different fixed-target collision systems (bottom) with the respective beam energies and estimated projectiles (protons or lead nuclei) on target.

- Fixed-target data recorded since 2015.
- Gas species used are so far limited to noble gasses (He, Ne, Ar).
- The centre of mass energy ranges from $\sqrt{s_{NN}} = 68.8 - 110$ GeV.
- Covers gap between CERN SPS (~ 20 GeV) and RHIC (~ 200 GeV).
- The covered rapidity is shifted $\Rightarrow$ at $\sqrt{s_{NN}} = 110$ GeV, $y^* = y_{lab} - 4.77$ and thus the range covered is $-2.77 < y^* < 0.23$.
- Thanks to the rapidity shift it is possible to probe the high Bjorken-x region in the target nucleon ($x \simeq \frac{2m_c}{\sqrt{s_{NN}}} \exp(-y^*)$).

Charm production in p-A collisions: Data taking conditions

- p beams against Ar ($\sqrt{s_{NN}} = 110.4$ GeV) and He ($\sqrt{s_{NN}} = 86.6$ GeV).
- Only recorded data when bunches of the detector-going beam cross the IP and nothing from the other side.
- Reconstructed vertex position restricted to $-200 < z_{PV} < 200$ mm.

Charm production in p-A collisions: Results

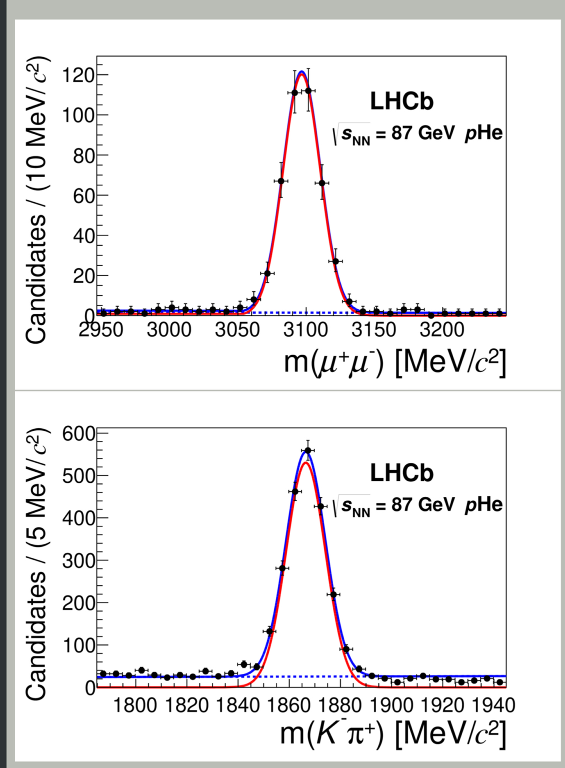

Figure 2: pHe measured yields.

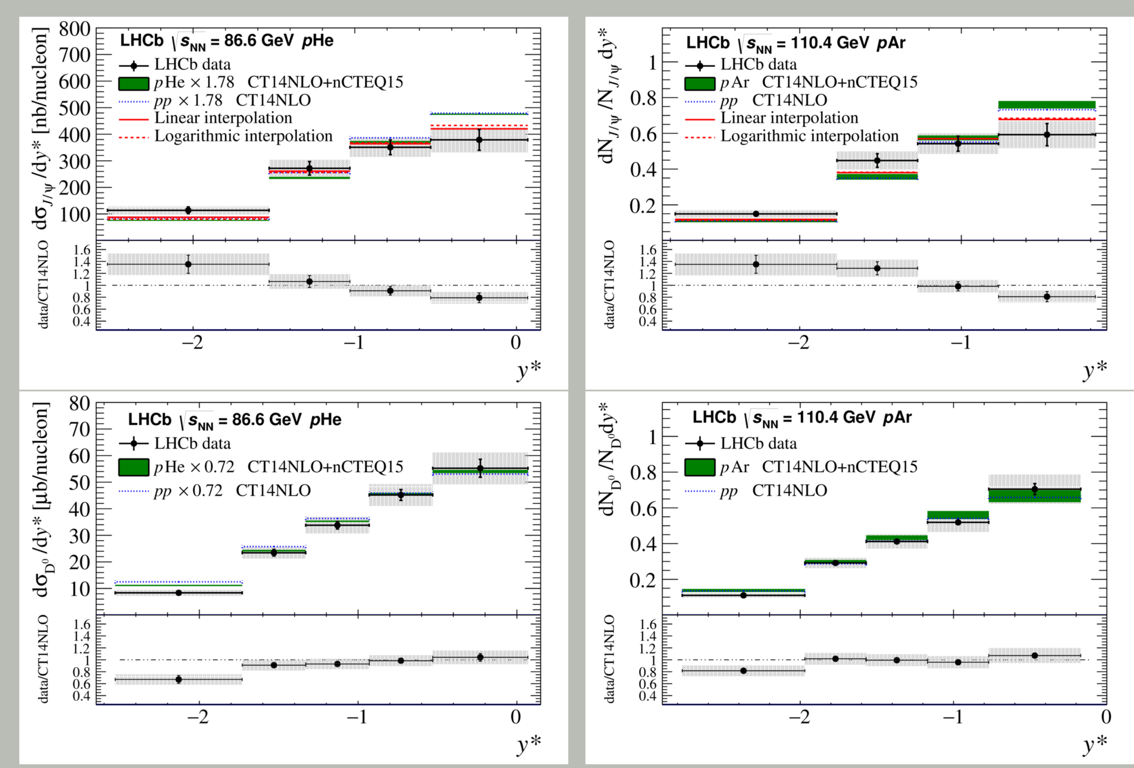

Figure 3: Cross sections and yields in y^* bins in pHe and pAr.

- The luminosity information was only available for pHe.
- The total cross-sections:

$$\sigma_{J/\psi} = 1225.6 \pm 100.7\, \mathrm{nb/nucleon}$$
$$\sigma_{D^0} = 156.0 \pm 13.1\, \mu\mathrm{b/nucleon}$$
$$\sigma_{c\bar{c}} = 144 \pm 13\, \mu\mathrm{b/nucleon}$$

- The first rapidity bin in the D^0 cross section plot corresponds roughly to the Bjorken-x region $x \in [0.17, 0.37]$, where intrinsic charm would contribute.
- The data point falls below the theoretical prediction from HELAC-ONIA, there is no conclusive evidence of a strong intrinsic charm contribution to the nucleon. [Phys. Rev. Lett. 122, 132002]

SMOG2: The upgraded fixed-target set up

- Storage cell consisting of a 20 cm long tube with 1 cm diameter.
- Target volume displaced from IP, located at $z \in [-500, -300]$ mm.
- More gas species could be used (H_2, D_2 and heavier nobles gasses).
- Expected luminosity increase of factor 100.

[LHCB-TDR-020]

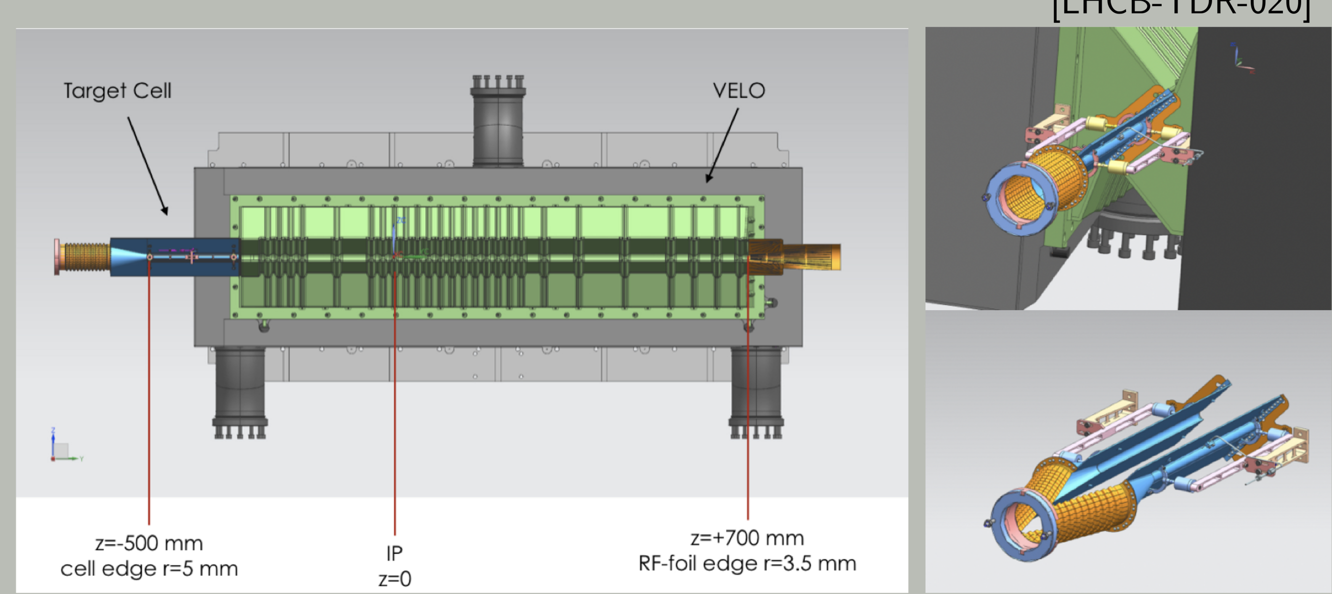

Figure 4: SMOG2 storage cell layout.

Conclusions

- The fixed-target set up of LHCb has already rendered promising results and has proven that it can make remarkable contributions to the field.
- No evidence for strong intrinsic charm has been seen.
- SMOG2 will drastically improve the fixed-target programme of LHCb, regarding luminosity, running conditions, and broader choice of a target, expanding significantly the physics reach of LHCb.