Heavy-Flavour production in fixed-target mode with LHCb

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On behalf of the LHCb collaboration

European Physical Society Conference on High Energy Physics

The LHCb detector

❖Forward single arm spectrometer.

❖Designed to study heavy flavour physics in *pp* collisions.

❖Only LHC experiment fully instrumented in the region $2 < \eta < 5$.

❖Some nice features:

✤Excellent vertex, IP and decay time resolution thanks to VELO.

$\Rightarrow \sigma(\text{IP}) \approx 20\,\mu\text{m}$.

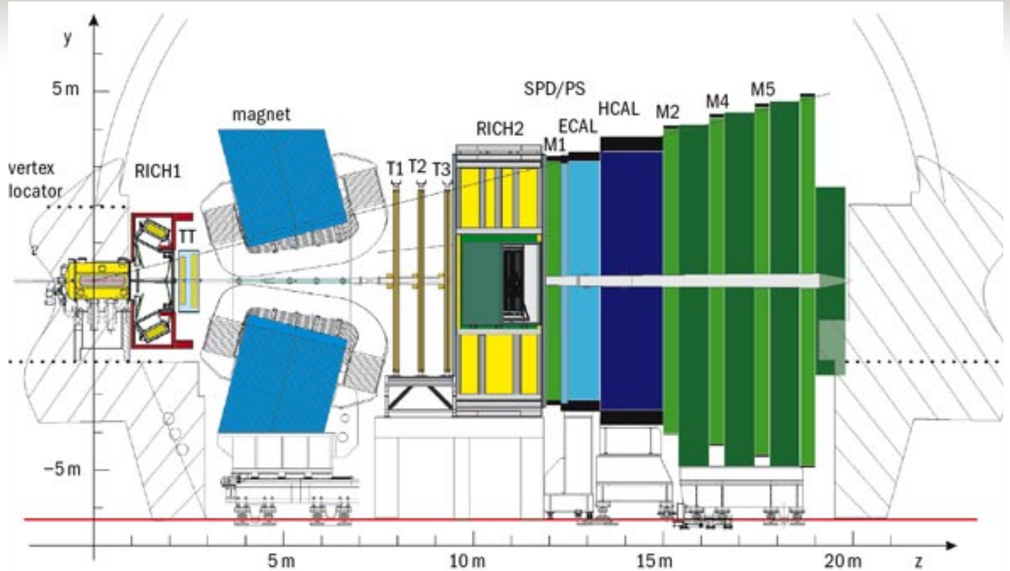
✤Very good momentum resolution.

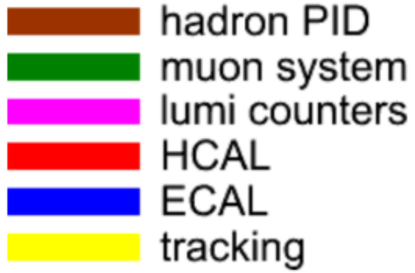
$\Rightarrow \delta p/p \approx 0.5 - 1.0\,\%$ for $0 < p < 200$ GeV/c.

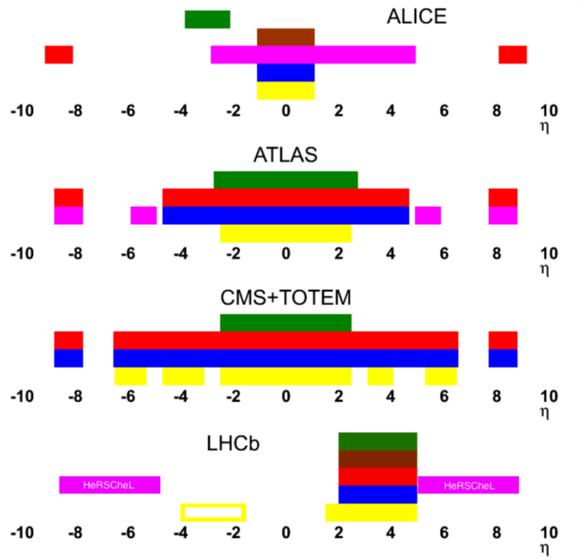
✤Particle identification.

$\Rightarrow \varepsilon_{K\to K} \approx 95\,\%$ for $\varepsilon_{\pi\to K} \approx 5\,\%$ up to 100 GeV/c.
$\Rightarrow \varepsilon_{\mu\to\mu} \approx 97\,\%$ for $\varepsilon_{\pi\to\mu} \approx 1 - 3\,\%$.

❖LHCb can also operate in *p*-Pb and Pb-Pb collisions.

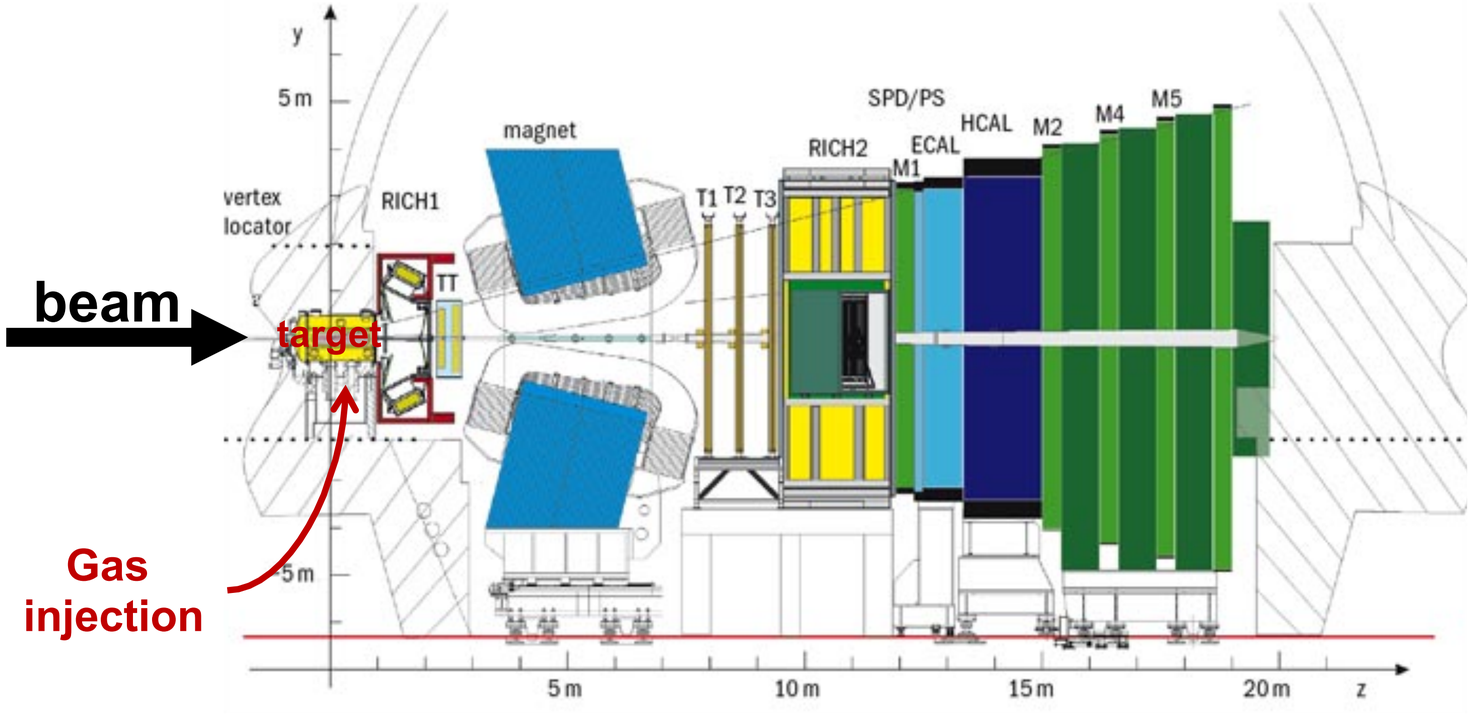






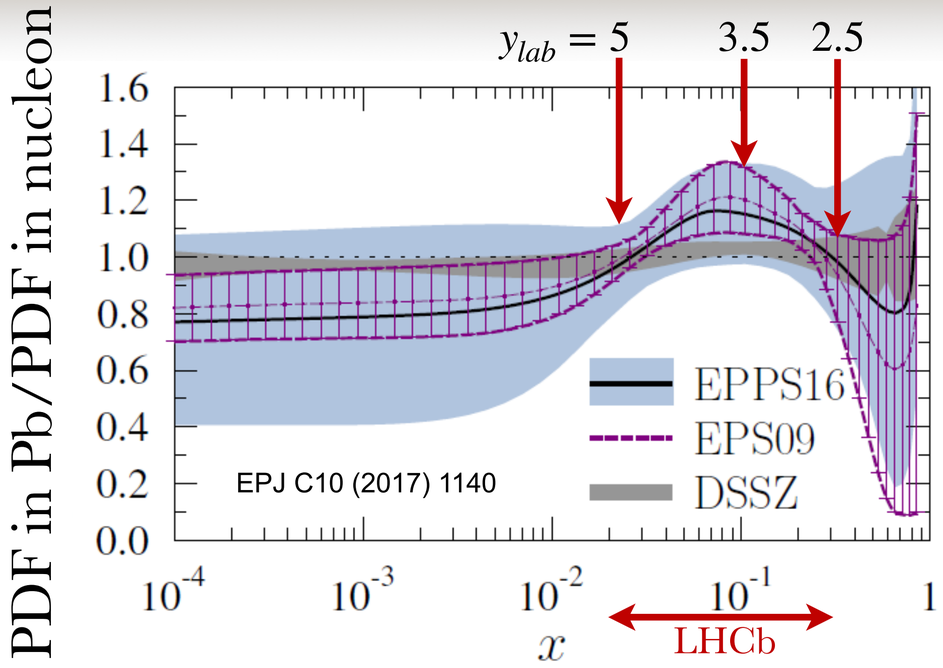
The LHCb detector

Fixed-target operation



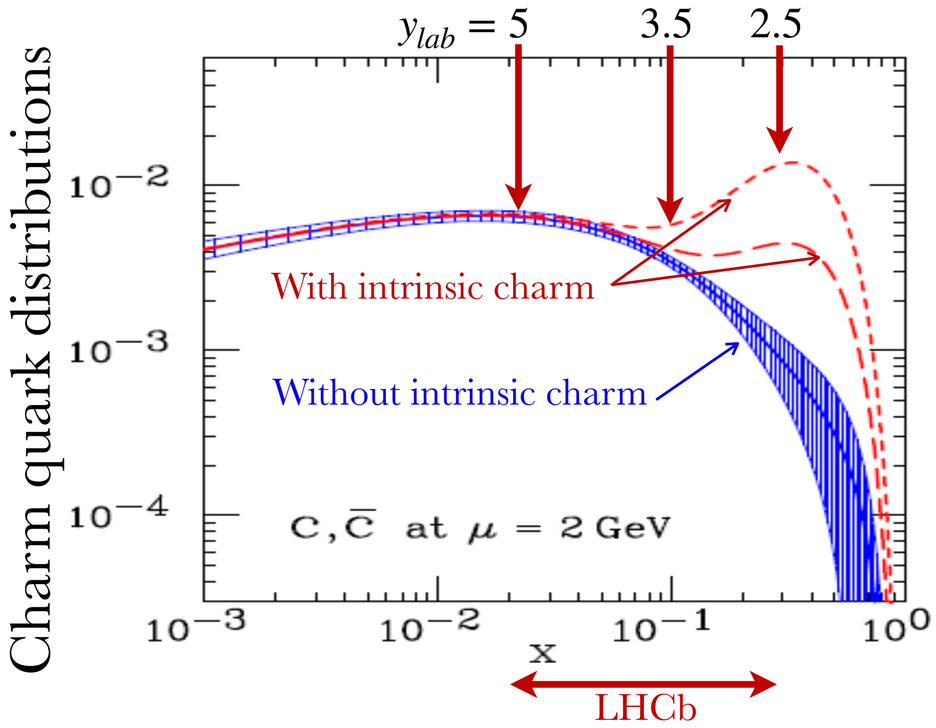
- Unique feature at LHC.
- Inject noble gas into the VELO tank (interaction region).
- Gas target for *p*-gas and Pb-gas collisions.
- So far have been used: He, Ne and Ar.
- Typical pressure $\sim 2 \times 10^{-7}$ mbar (about two orders of magnitude higher than nominal pressure).

Charm in fixed-target p-A and Pb-A collisions



❖**Nucleus-nucleus collisions** ($\sqrt{s_{NN}} = 69$ GeV): 2.5 TeV Pb beam on fixed target.

- No regeneration of charmonium ($\sigma^{FT}_{c\bar{c}} \approx \frac{1}{100}\sigma^{LHC}_{c\bar{c}}$).
- Probe the Quark Gluon Plasma (QGP) phase transition via colour screening.
- LHCb allows for new opportunities for charm: $J/\psi, \psi', \chi_c, D^0, D^{+/-}, D^*, \Lambda_c$, ...

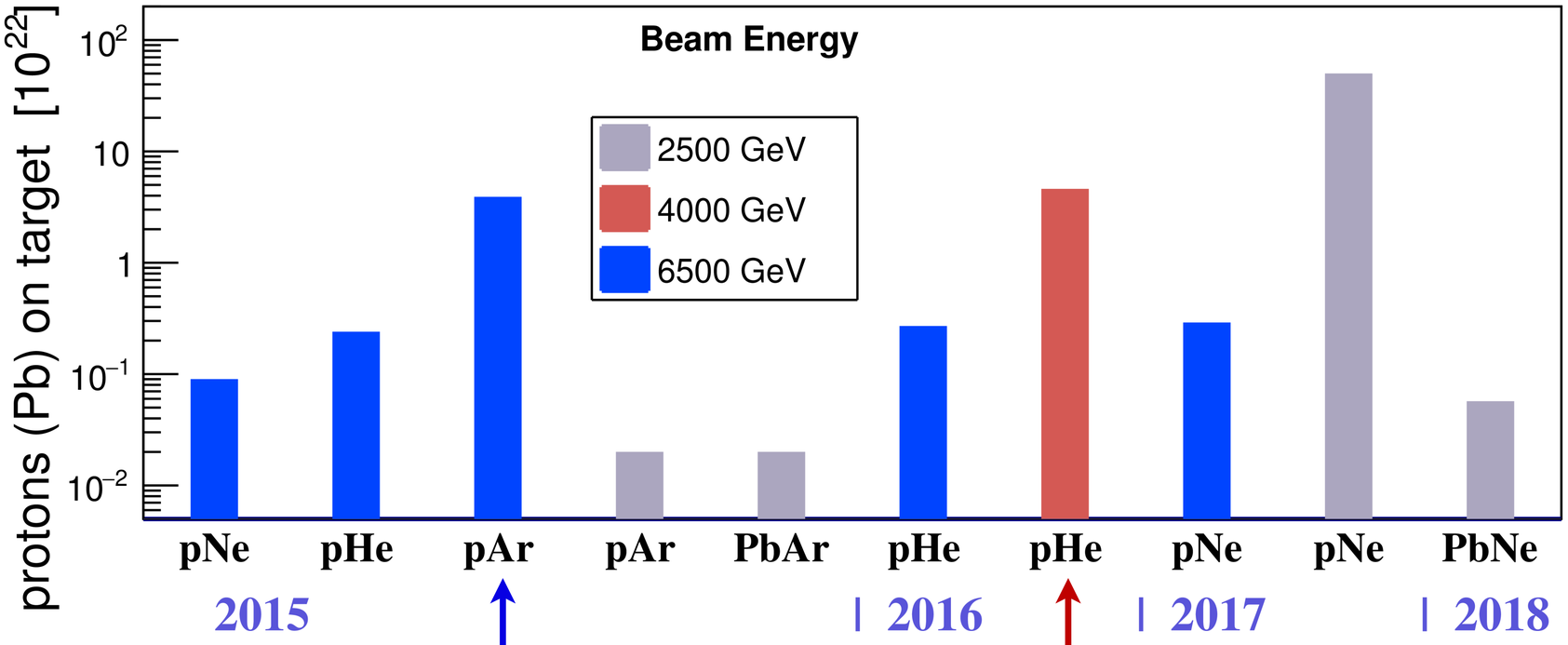


❖**Proton-nucleus collisions.**

- Baseline for the nucleus-nucleus collisions, study of nuclear PDF, and other effects.
- At LHCb, 3 units of rapidity coverage, at large Bjorken-x in the target (x_2).
  - Access the nPDF anti-shadowing region and intrinsic charm content in the nucleon

Fixed-targets so far

Data samples: two datasets in this presentation.



$\sqrt{s_{NN}} = 110$ GeV proton-Ar collisions

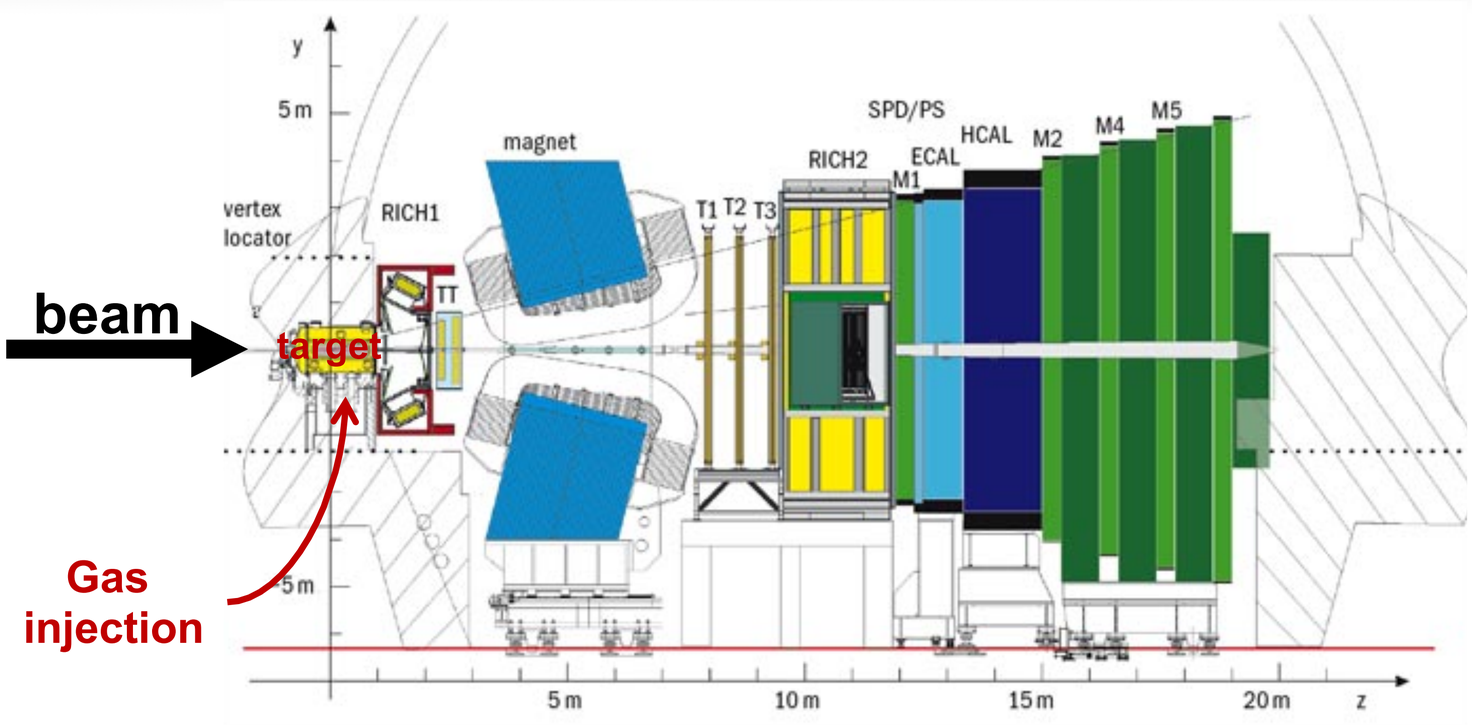
$\sim 4 \times 10^{22}$ protons on target

$\sqrt{s_{NN}} = 86.6$ GeV proton-He collisions

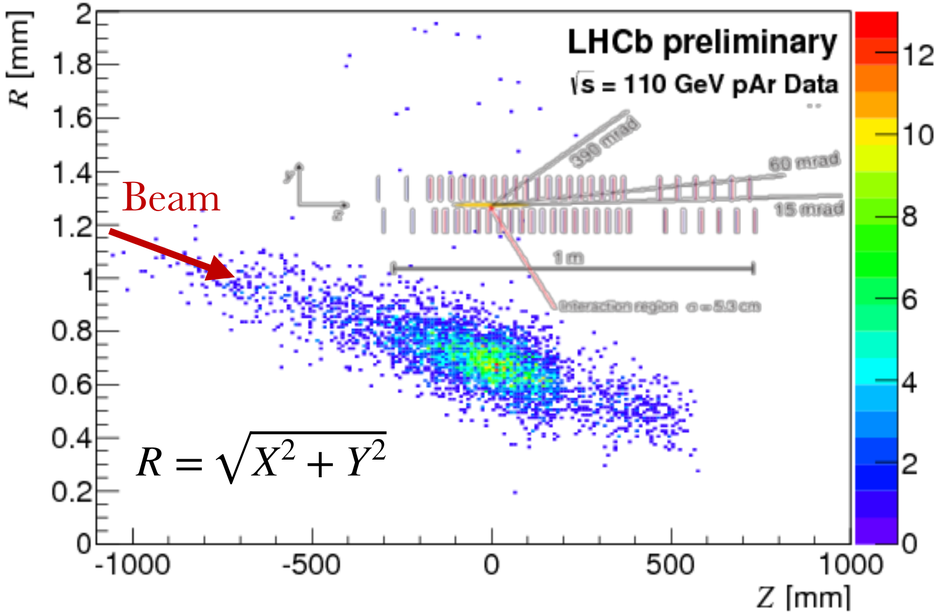
$\sim 4 \times 10^{22}$ protons on target

$\mathscr{L}_{pHe} = 7.6 \pm 0.5$ nb^{-1}

Charm production in p-A collisions



(R, Z) position of primary vertex



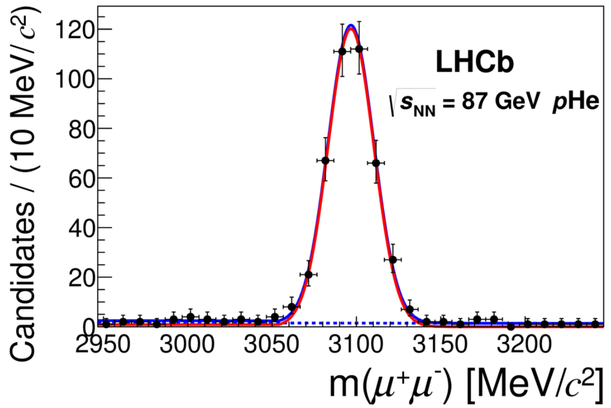
❖Select events with only Beam 1 at the interaction point.

❖Select only events within the VELO $\Rightarrow Z_{vertex} \in [-200,200]$ mm.

Charm production in p-A collisions

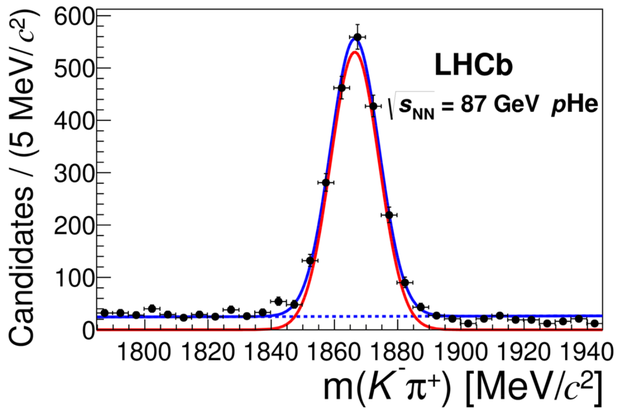
❖$J/\psi \to \mu^+\mu^-$ and $D^0 \to K^\mp\pi^\pm$ inclusive cross sections in p-He at $\sqrt{s_{NN}} = 86.6$ GeV.

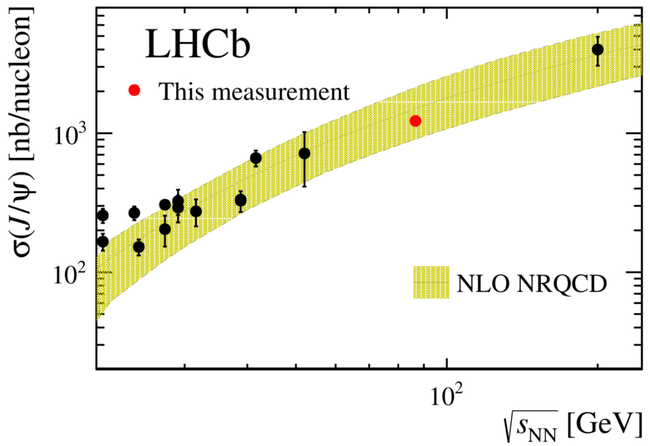
Phys. Rev. Lett. 122, 132002



❖J/ψ measurement.

- $\sigma_{J/\psi} = 1225.6 \pm 100.7$ nb/nucleon.
- LHCb result in good agreement with other measurements.



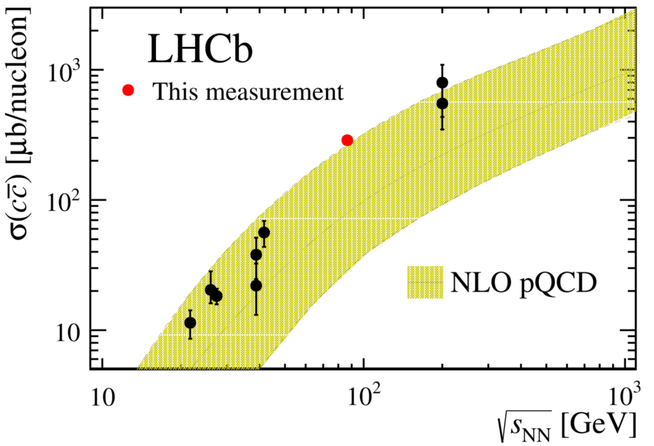


❖D^0 measurement.

- $\sigma_{D^0} = 156.0 \pm 13.1\,\mu$b/nucleon.

With fraction ($c \to D^0$) = 0.542 ± 0.024:

- $\sigma_{c\bar{c}} = 287.8 \pm 24.2 \pm 6.9\,\mu$b/nucleon.
- LHCb result in reasonable agreement with NLO pQCD predictions and other measurements.



Charm production in p-A collisions

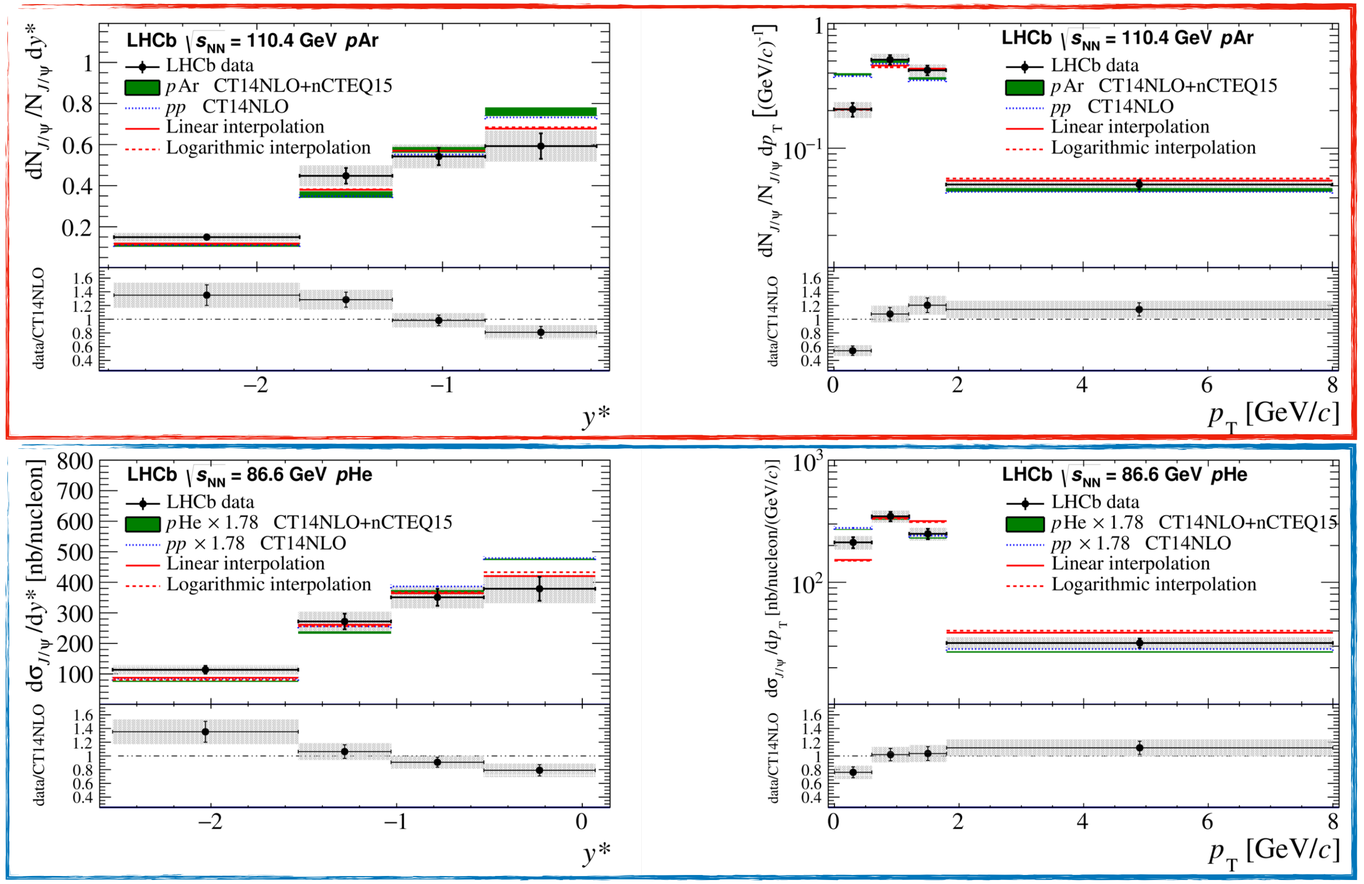
❖J/ψ differential yields in p-Ar and cross sections in p-He.

Phys. Rev. Lett. 122, 132002

- Plain and dashed red lines are phenomenological parametrisation: JHEP 05 (2013) 155
- HELAC-ONIA predictions for p-p (blue lines) and p-A (green boxes): EPJC(2017) 77:1

✤p-Ar yields at $\sqrt{s_{NN}} = 110$ GeV.

✤p-He cross sections at $\sqrt{s_{NN}} = 86.6$ GeV.



- HELAC-ONIA underestimates the J/ψ cross section on p-He by a factor 1.78.
- Good shape agreement with the predictions.

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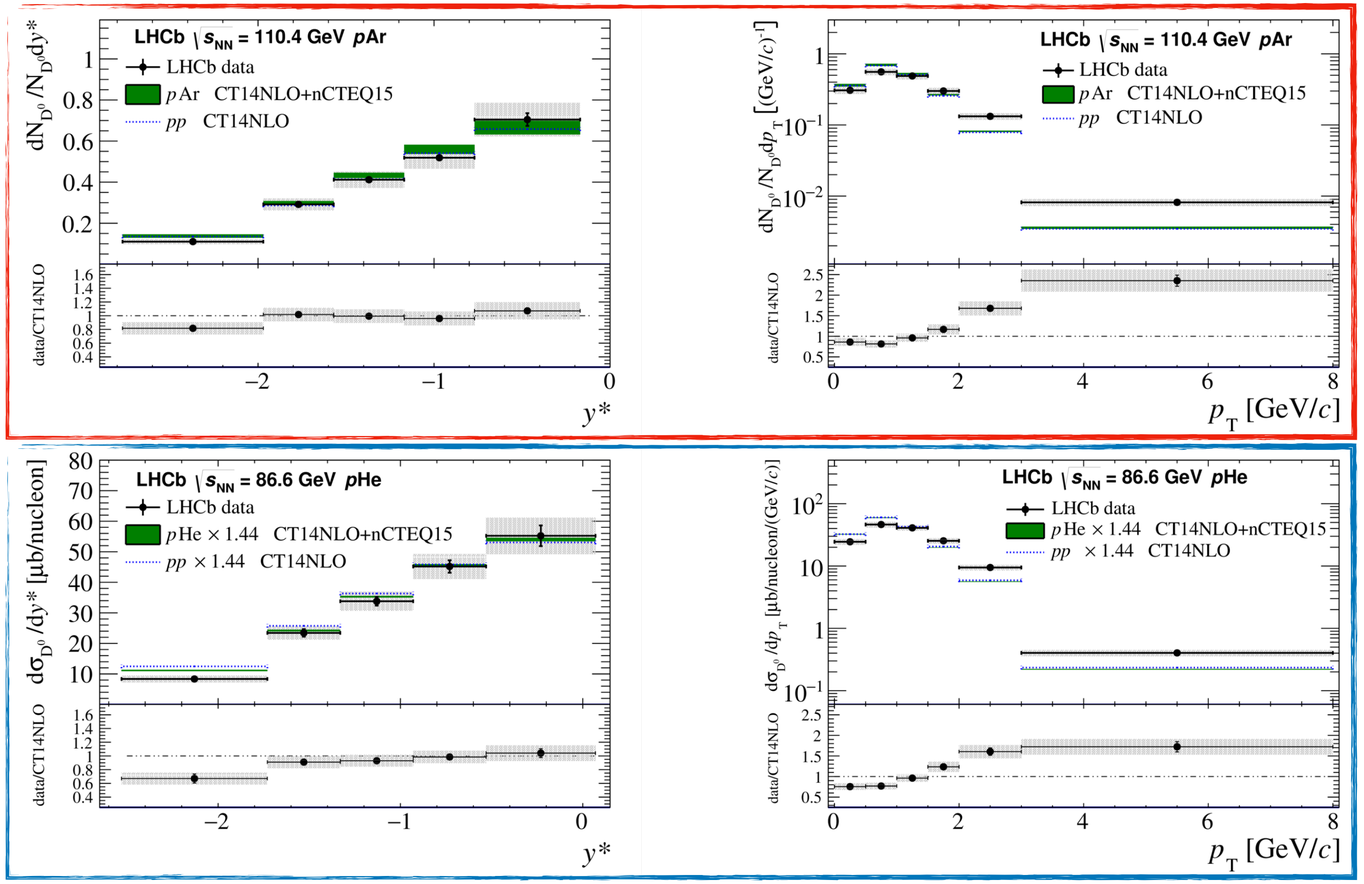
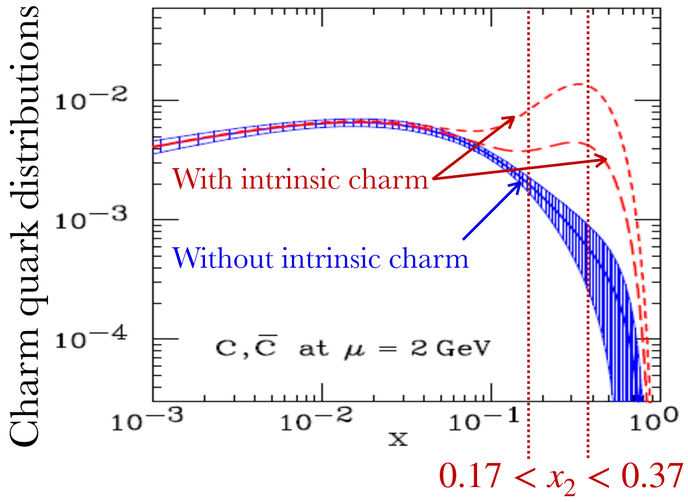
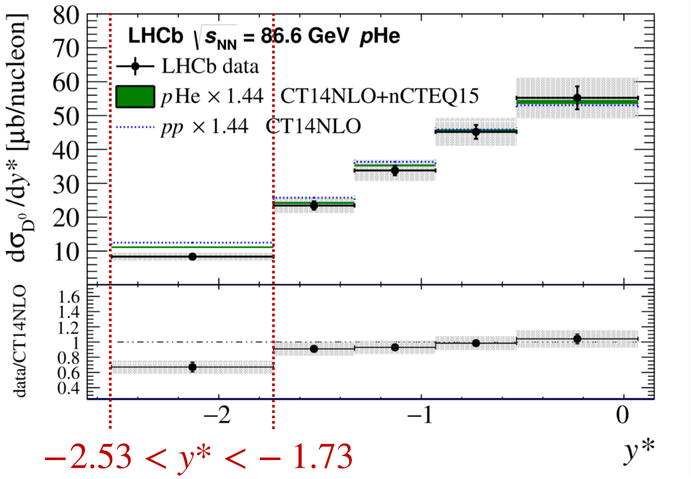


- HELAC-ONIA underestimates the D^0 cross section on p-He by a factor 1.44.
- Good rapidity shape agreement with the predictions.

Charm production in p-A collisions

Phys. Rev. Lett. 122, 132002





❖D^0 cross sections from p-He at $\sqrt{s_{NN}} = 86.6$ GeV and intrinsic charm

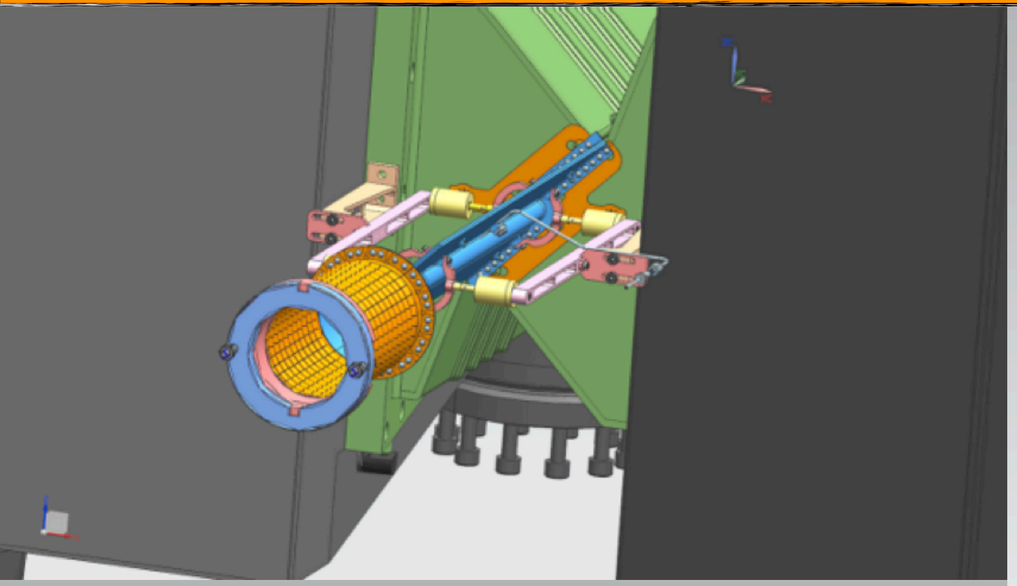
- HELAC-ONIA predictions for p-p (blue lines) and p-A (green boxes): EPJC(2017) 77:1
- With $x_2 \approx \frac{2m_c}{\sqrt{s_{NN}}}\exp(-y^*)$ we have: $y^* \in [-1.73, -2.53] \Leftrightarrow x_2 \in [0.17, 0.37]$

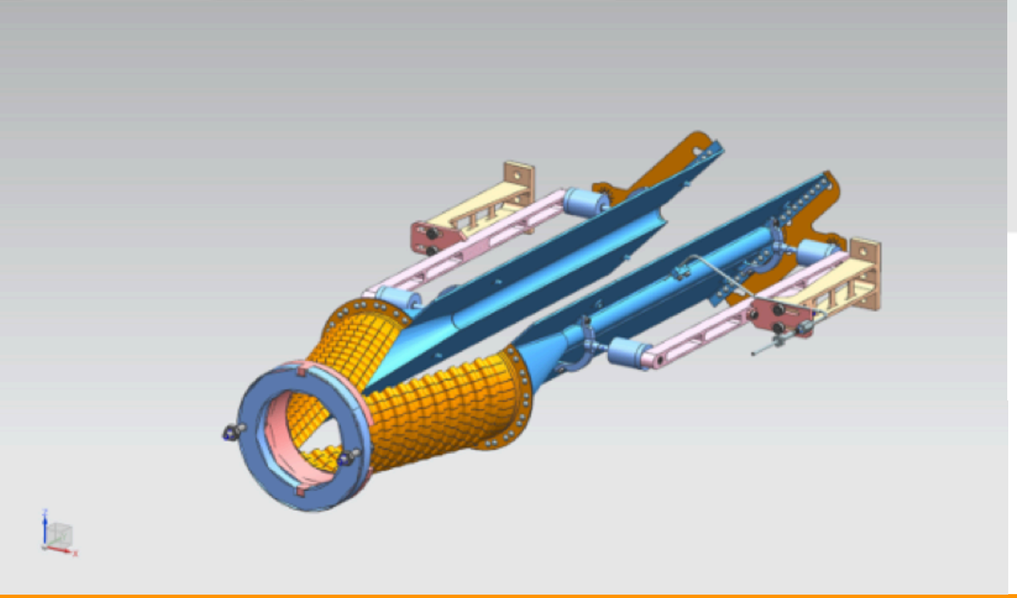
❖HELAC-ONIA does not contain intrinsic charm contribution.

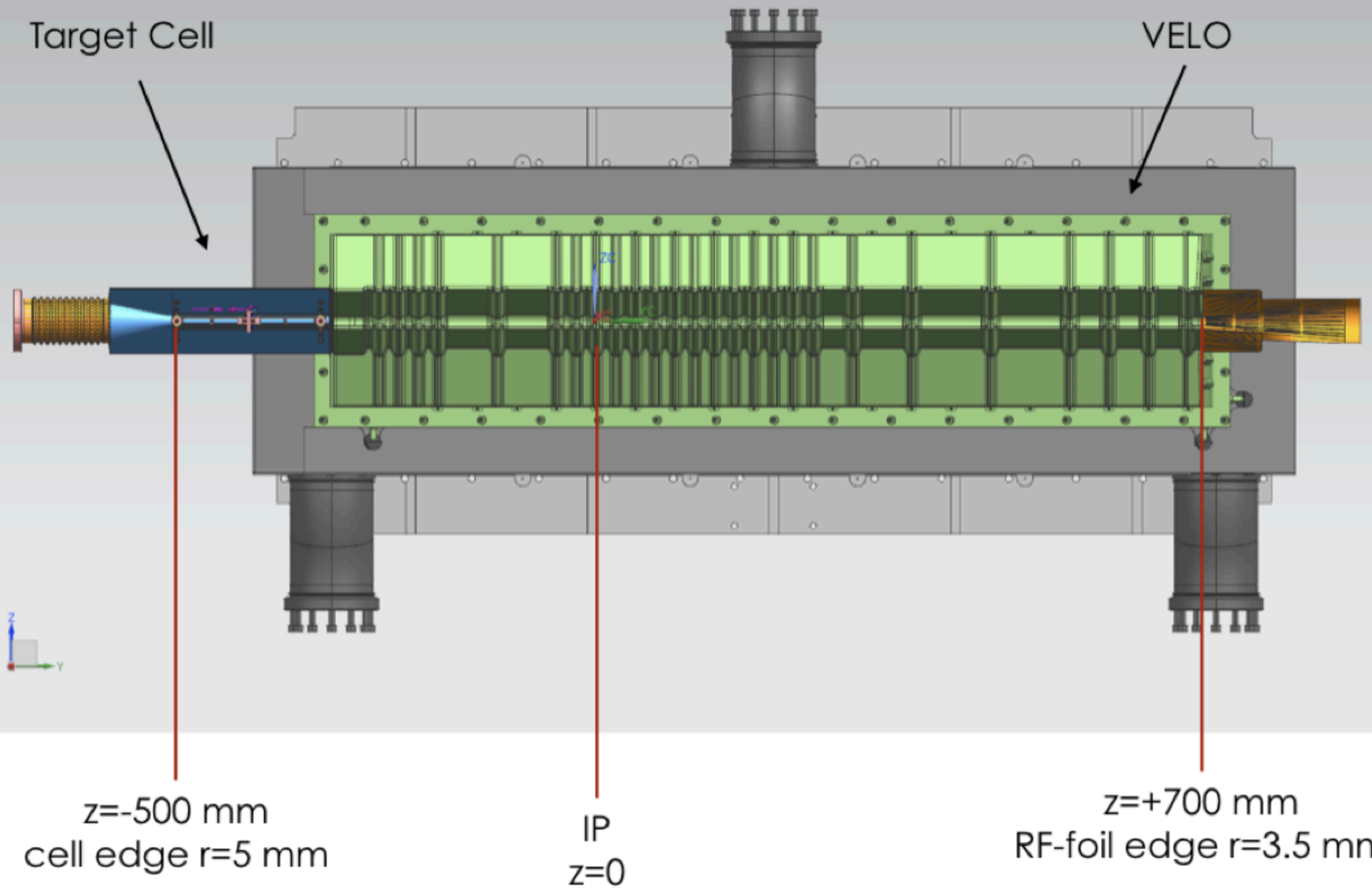
❖For the moment, **no evidence** of strong valence-like intrinsic charm contributions.

SMOG2

The SMOG2 set up







Storage cell for the target gas

SMOG2 Technical Design Report

The SMOG2 set up

❖Storage cell to be installed upstream of the vertex detector (between −500 and −300 mm from IP).

❖Increase target gas density by a factor ~ 100.

❖No spatial overlap between FT operation and *p*-*p* collisions.

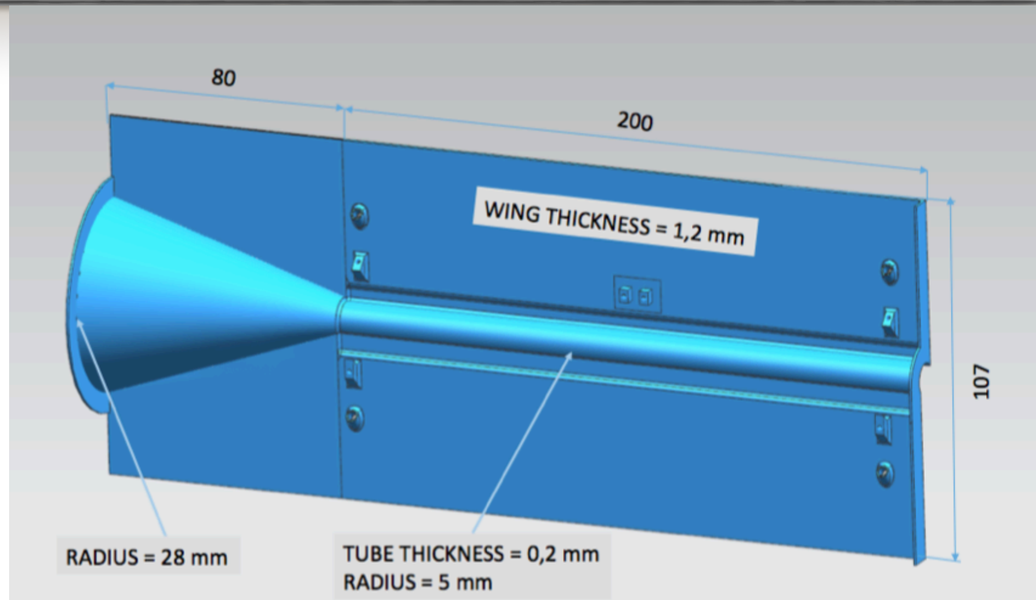
➡ Reduced background and possible parallel running.

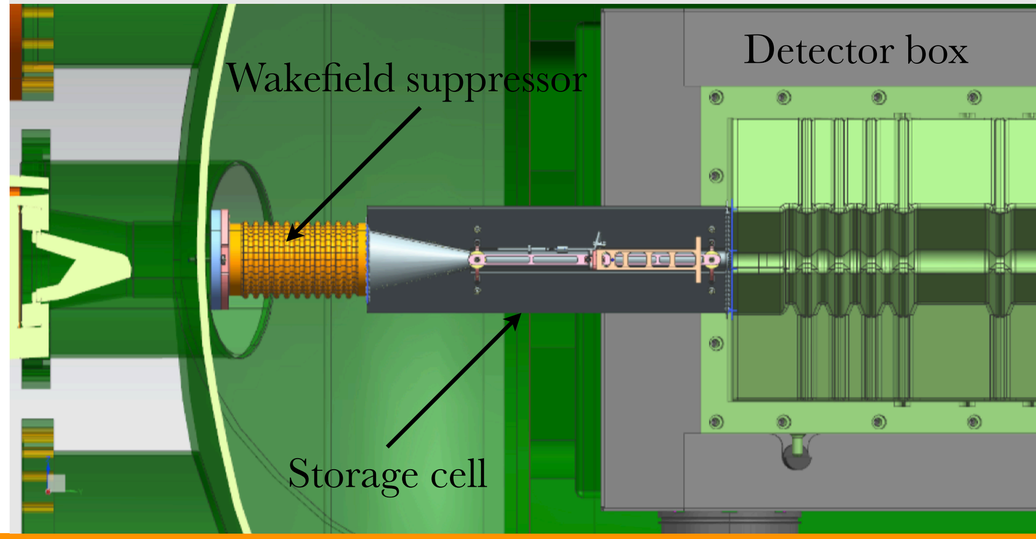
❖More sophisticated gas feed set up.

❖More gas species could be injected: H, D, O, N, He, Ne, Ar, Kr, Xe. (SMOG: He, Ne, Ar)

❖Installation to begin in November 2019.

❖Data taking in 2021 for LHC Run 3.



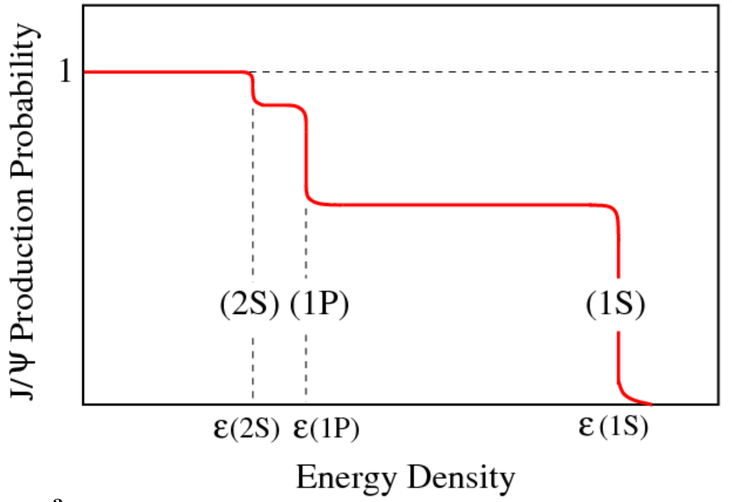


The SMOG2 prospects

LHCb-PUB-2018-015

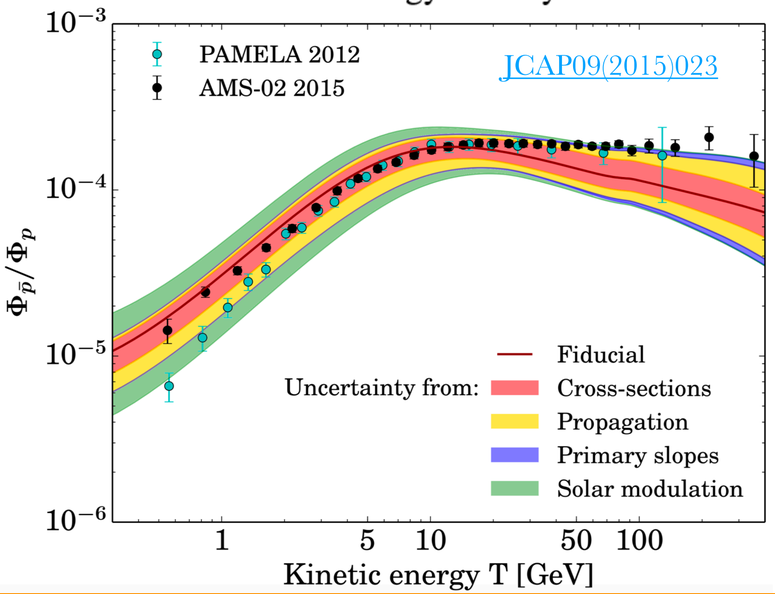
❖Hadron Physics:

- ✤New measurements of charm production with increased statistical power.
- ✤Include excited charmonia states, relevant for the study of suppression via colour screening.
- ✤Possibility to measure prompt beauty production with the increased luminosity.



❖Cosmic Rays:

- ✤Antiproton/proton ratio known with great precision from cosmic rays.
- ✤Interstellar medium dominated primarily by He and H. ⇒ SMOG2 could replicate these systems.
- ✤In the 10-100 GeV region, cross sections dominate the uncertainty of the predictions.
- ✤SMOG2 could provide higher precision on cross sections measurements ($\sigma_{\bar{p}}$ on p-He and p-H).
- ✤See yesterday's dedicated talk here.



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- ✤SMOG2 would allow to probe the quark and gluon PDFs at high Bjorken-x, where experimental data is scarce.

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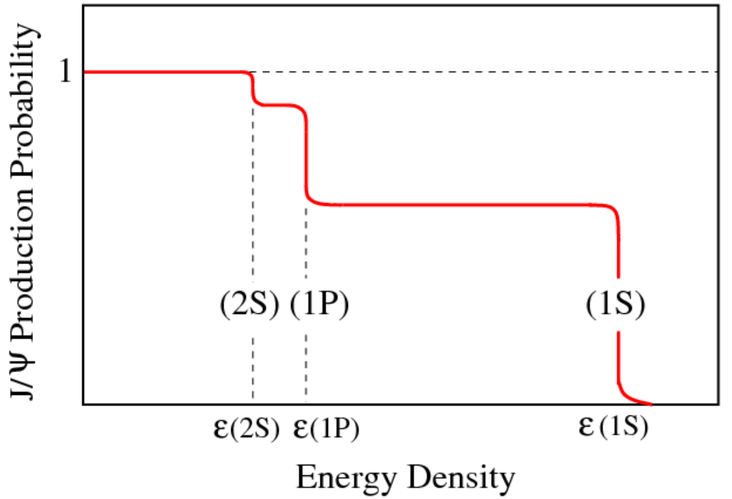

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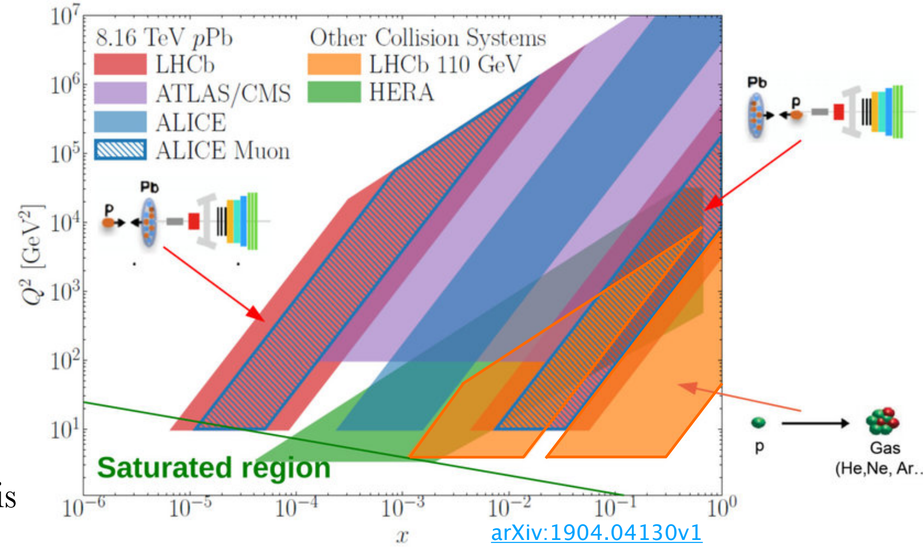

Conclusions

❖LHCb is the only LHC experiment capable of running in both collider and fixed-target modes.

❖LHCb has unique capabilities for heavy-flavour measurements at LHC.

❖Fixed-target programme has delivered J/ψ and D^0 cross sections and yields measurements:

- In $\sqrt{s_{NN}}$ = 110 GeV p-Ar collisions.
- In $\sqrt{s_{NN}}$ = 86.6 GeV p-He collisions.
- No evidence for strong intrinsic charm contribution.
- Other analyses ongoing (p-Ne and Pb-Ne at $\sqrt{s_{NN}}$ = 69 GeV).

❖The SMOG2 upgrade, to be installed at the end of 2019, will enhance performance and allow more ambitious measurements with LHCb in fixed-target mode.

Thank You!