Searching for intrinsic charm with LHCb

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on behalf of the LHCb collaboration

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Extrinsic and intrinsic charm

Most PDF fits assume heavy quarks in the proton are generated perturbatively, but non-perturbative "intrinsic" heavy quarks are also possible.

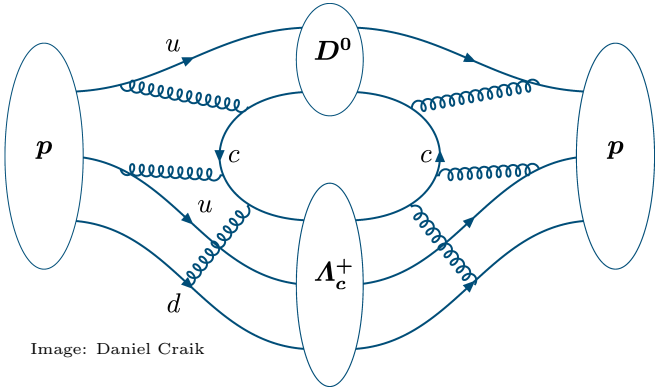
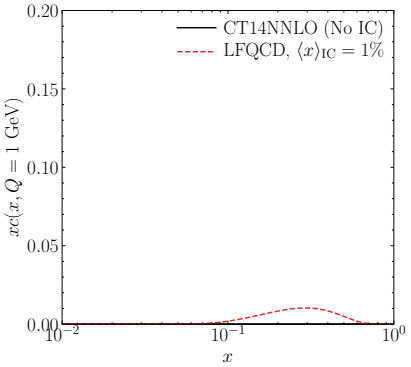


Image: Daniel Craik



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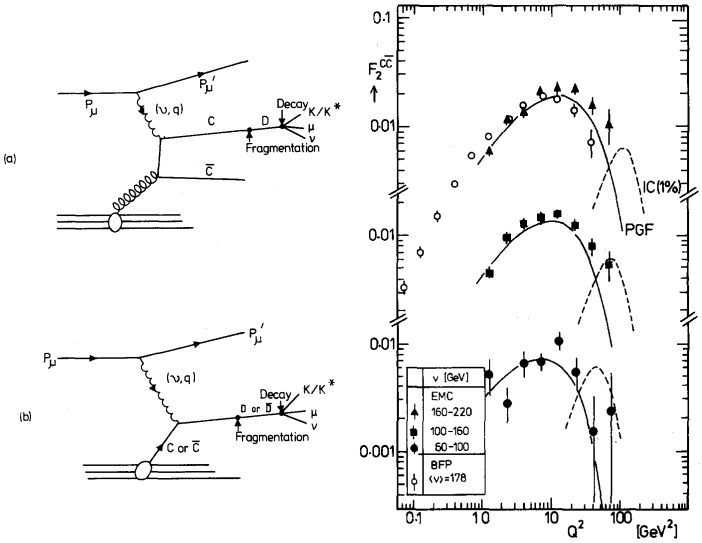
Intrinsic charm predicted by Light-Front QCD (LFQCD): PLB 93 (1980) 451-455

Heavy charm quarks carry most of the proton momentum → valence-like bump.

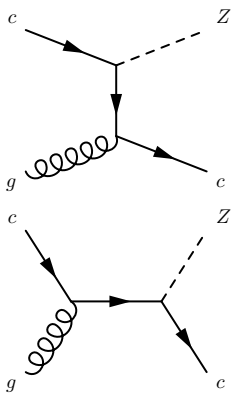
Evidence for intrinsic charm: EMC $F_2^{c\bar{c}}$ data (Nucl. Phys. B **213**, 31–64)

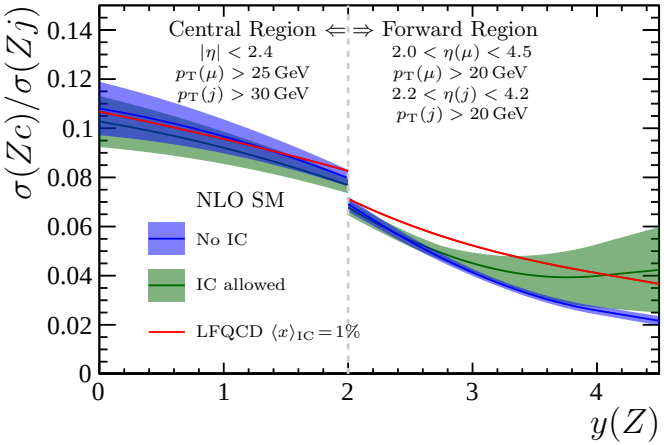


- First experimental evidence for intrinsic charm
- Fixed target DIS: $Q \lesssim 10$ GeV
- Interpretation has been controversial. See Adv. High Energy Phys. **2015**, 231547 for a review
- Typically omitted from global PDF fits

Looking for Intrinsic Charm with $Z + c$ (PRD 93, 074008 (2016))

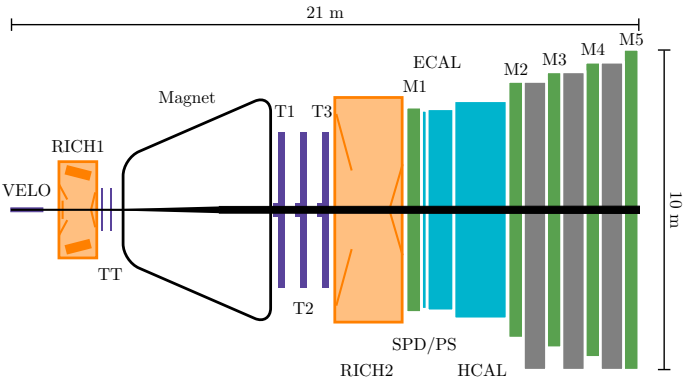
At leading order, $Z + c$ occurs via $gc \to Zc$. In the forward region (high $y(Z)$), this probes the valence region where intrinsic charm is expected.



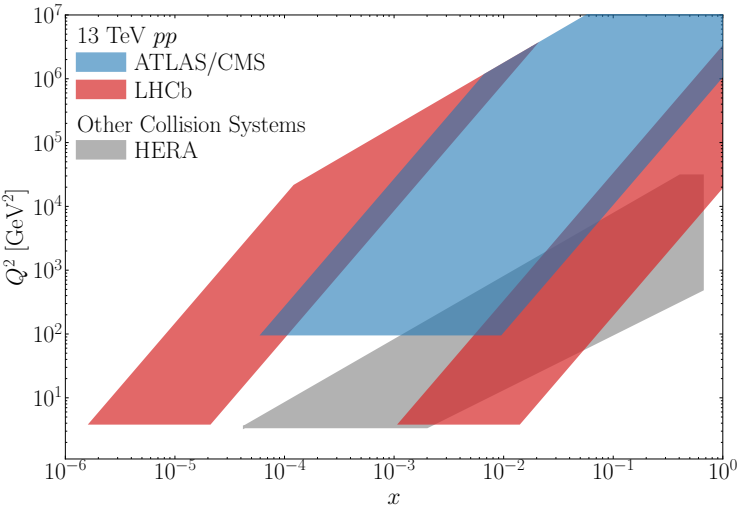


The LHCb detector (Int. J. Mod. Phys. A 30, 1530022 (2015))

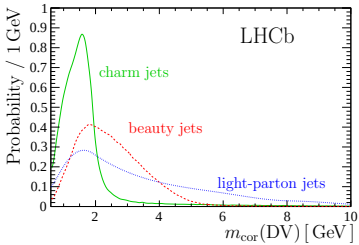
- Forward spectrometer: $2 < \eta < 5$
- **tracking**, **calorimetry**, **RICH**, **muon** systems
- Excellent vertex resolution ($10 - 50$ μm in x and y)
- Track $\sigma(p)/p \sim 0.5 - 1.0\%$
- Fixed-target mode with the SMOG system

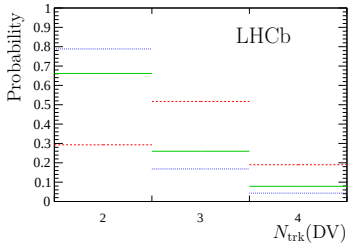


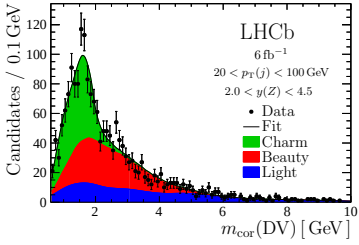
Studying PDFs with LHCb

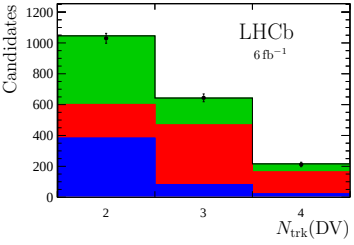


Identifying charm jets with the LHCb detector (JINST 17 P02028 (2022))







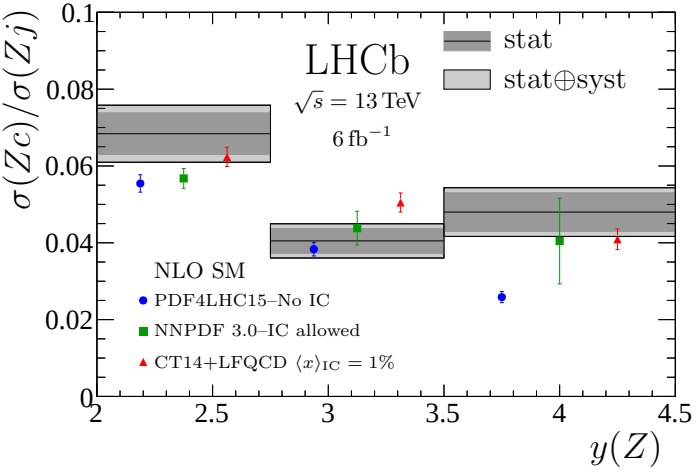


- LHCb has excellent momentum and vertex position resolution
- Identify jets using displaced vertices (DVs)
- Charm jets tagged with an efficiency of $\epsilon = (24.0 \pm 0.6 \pm 1.4)\%$

$$m_{\rm cor} = \sqrt{m({\rm DV})^2 + p_\perp({\rm DV})^2} + p_\perp({\rm DV})$$

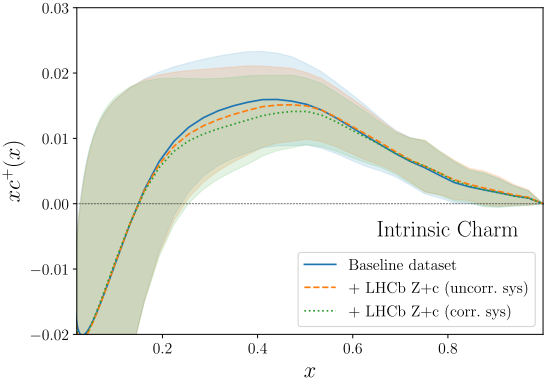
LHCb Results (PRL 128 (2022) 8, 082001)

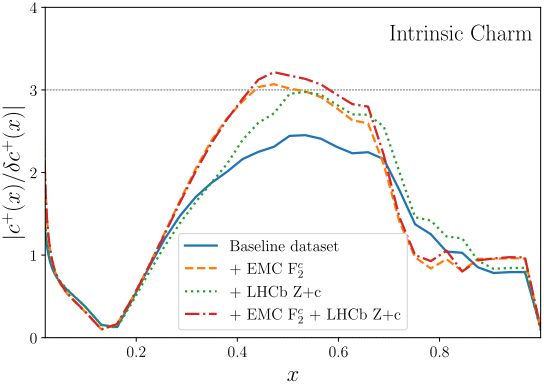
Results disagree with no-IC predictions at forward $y(Z)$ and are consistent with valence-like IC.



Implications: Evidence for intrinsic charm in the proton (Nature **608**, no.7923, 483-487)

NNPDF analysis finds LHCb $Z + c$ and EMC $F_2^{c\bar{c}}$ data both favor IC at about 3σ.





LHCb could make a definitive observation in Run 3 and differentiate between IC models.
Close to answering a question almost as old as QCD itself!

Thank you!