Heavy-flavor tagging and intrinsic bottom at the EIC

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HF and Jets WG meeting
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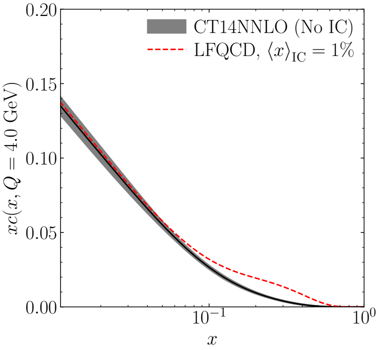
Extrinsic and intrinsic charm

Most PDF fits assume heavy quarks in the proton are generated perturbatively above $Q^2 \sim m_c^2$, but "intrinsic" heavy quarks are also possible.



JHEP 02 (2018) 059

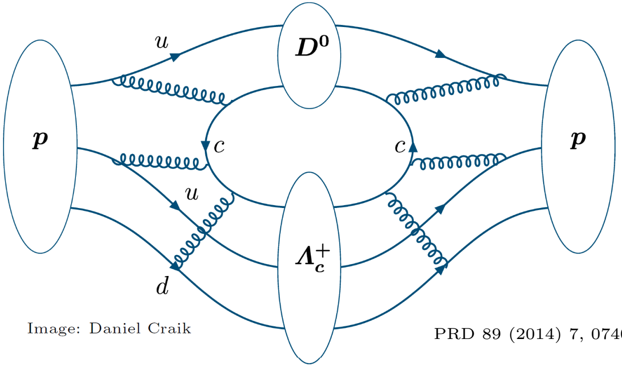


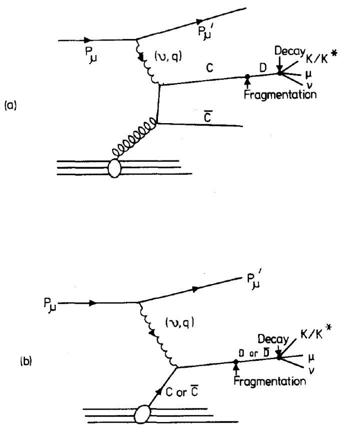
Image: Daniel Craik

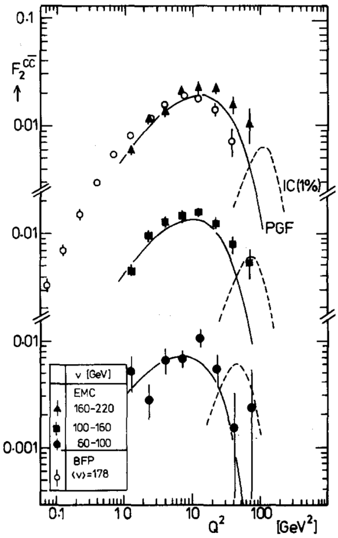
PRD 89 (2014) 7, 074008

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.

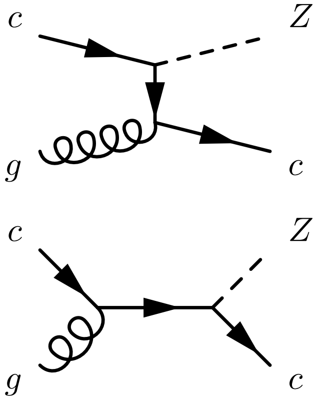
EMC $F_2^{c\bar{c}}$ data (Nucl. Phys. B 213, 31-64)

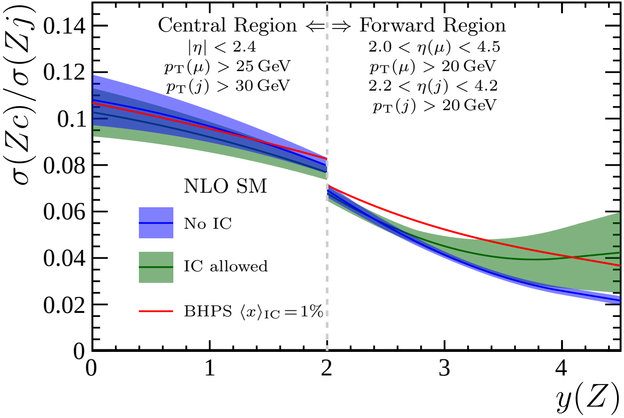




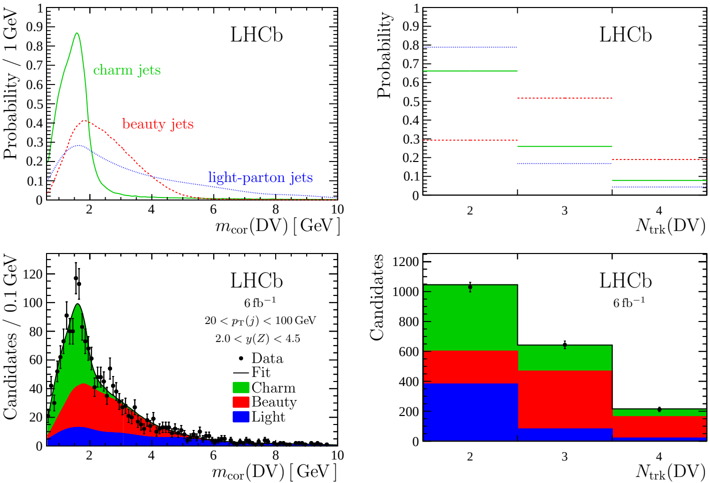
- First evidence for IC
- Still the only high-x DIS charm data
- Typically omitted from global PDF fits

$Z + c$ directly probes the charm PDF (PRD 93, 074008 (2016))



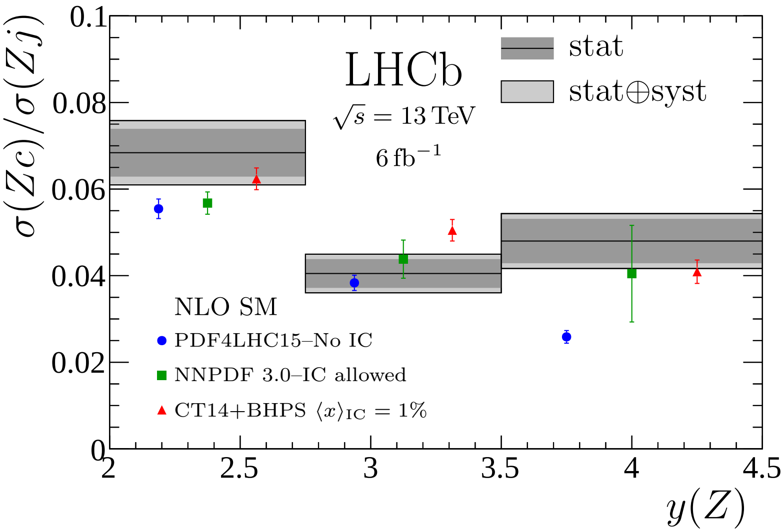


LHCb identifies charm jets using displaced vertices (JINST 17 P02028 (2022))



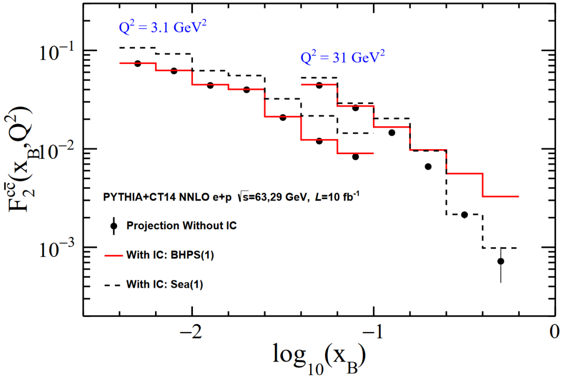
$$m_{\rm cor} = \sqrt{m({\rm DV})^2 + p_\perp({\rm DV})^2} + p_\perp({\rm DV})$$

LHCb results suggest valence-like IC (PRL 128 (2022) 082001)

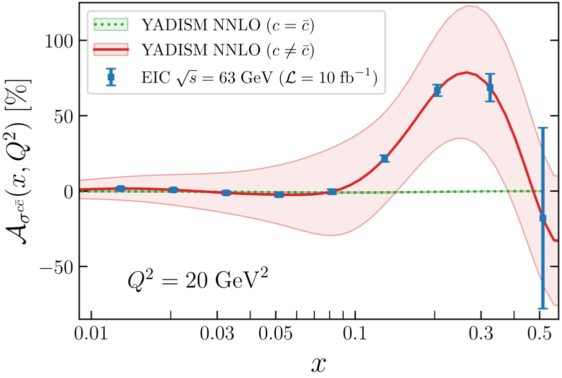


The EIC will be able to see percent-level intrinsic charm

PRD 104, no.5, 054002

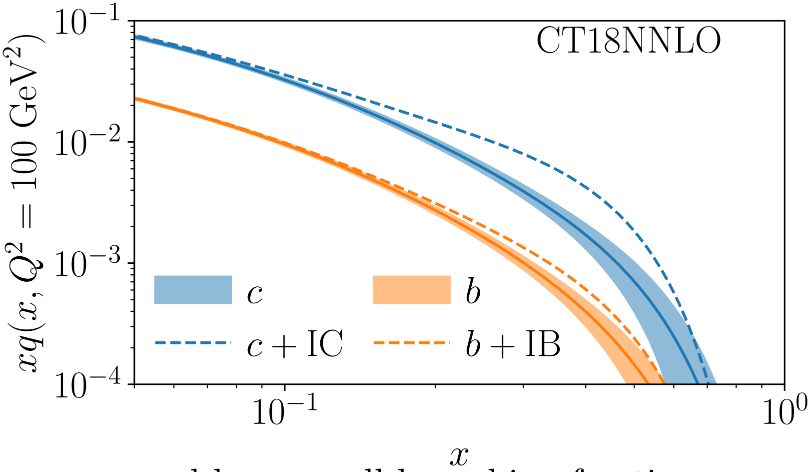


arXiv:2311.00743



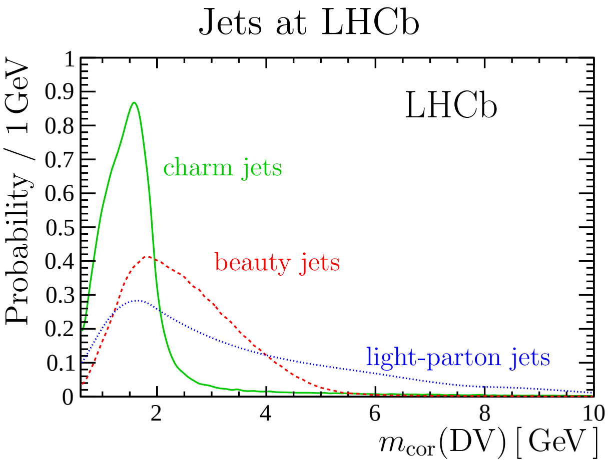
Intrinsic bottom is much more difficult

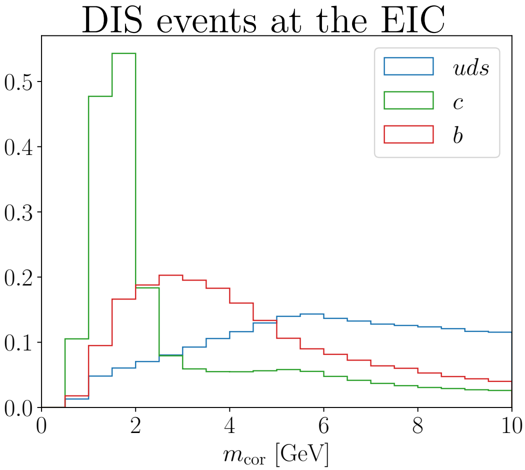
$$\mathrm{IB} \sim \frac{m_c^2}{m_b^2} \times \mathrm{IC}$$
$$\sim 0.1 \times \mathrm{IC}$$



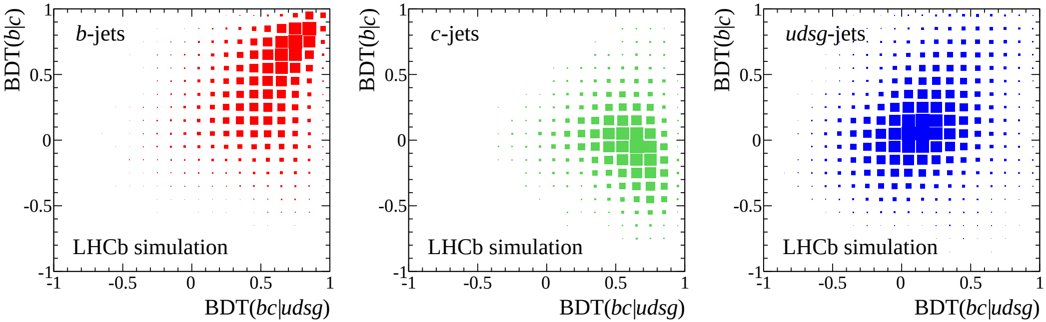
Bottom hadrons are rare and have small branching fractions.

The LHCb topological jet tagging strategy applied to the EIC





Tagging with BDTs



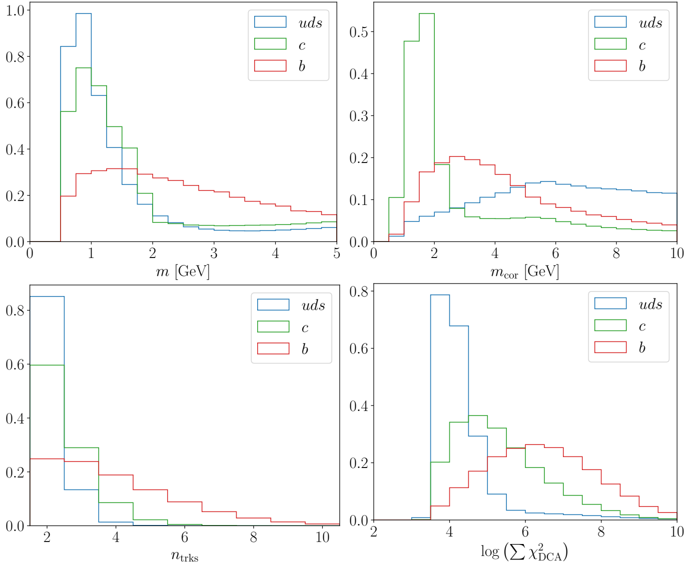
JINST 10 (2015) P06013

LHCb identifies heavy-flavor jets using the properties of secondary vertices in the jet, reaching $\sim 60\%$ tagging efficiency for bottom and $\sim 25\%$ for charm.

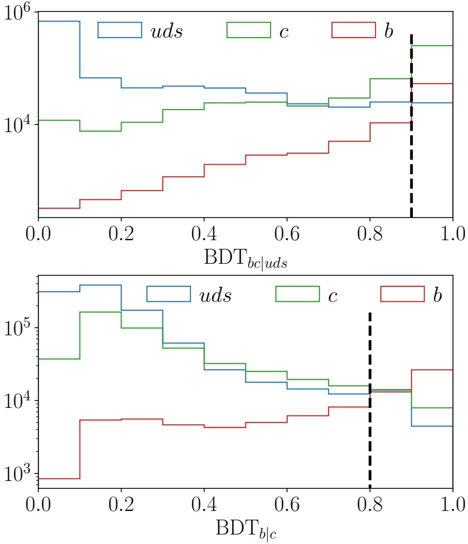
The strategy

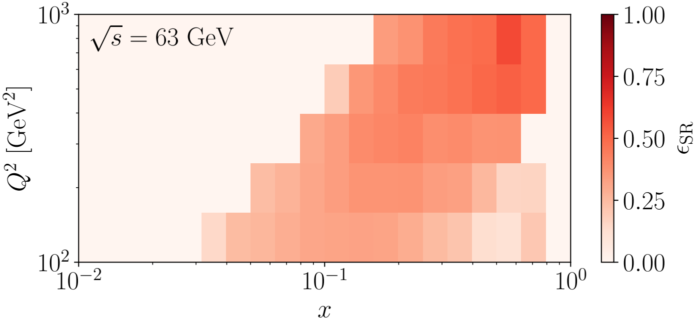
- Generate EIC events with Pythia
- Smear charged particle momentum and positions according to the anticipated detector performance in the EIC Yellow Report.
- Build 2-track from displaced tracks based on distance of closest approach. Build n-track vertices by combining vertices that share tracks.
- Train bc-vs.-uds and b-vs.-c BDTs.
- Use the estimated tagging performance to study sensitivity to intrinsic bottom

Discriminating variables



An EIC detector can efficiently tag b events (arXiv:2402.11344)

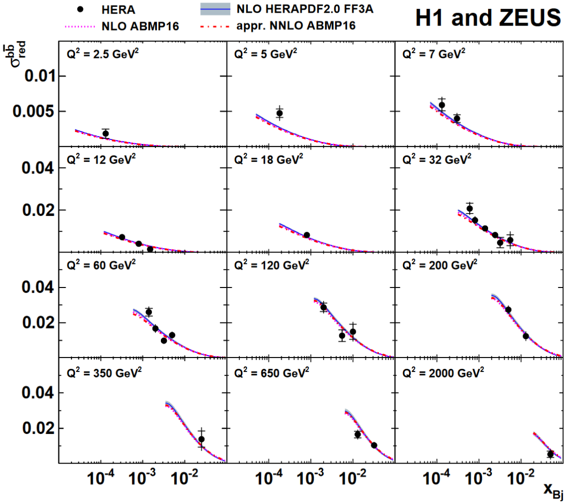




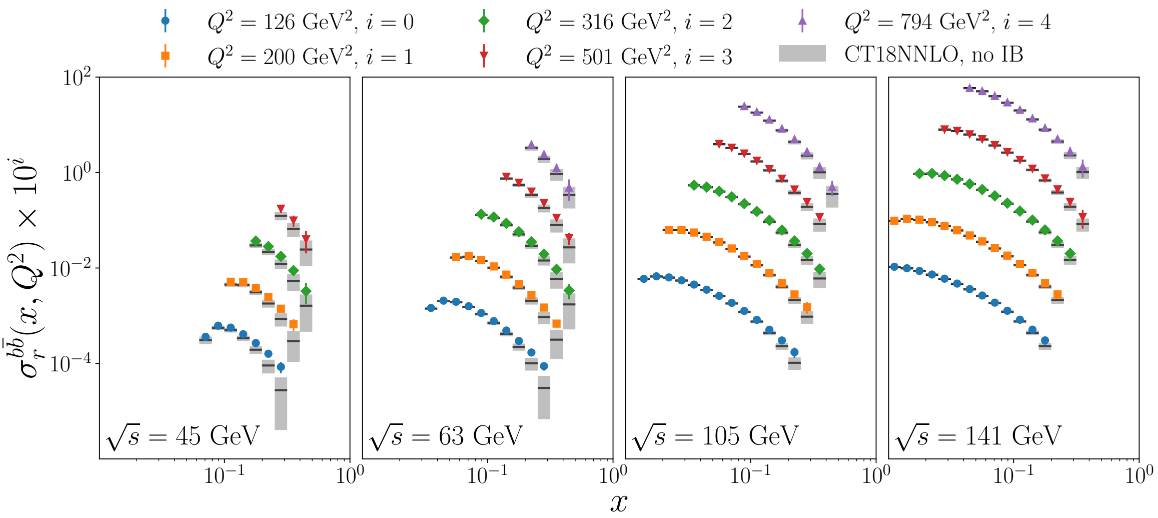
Successfully tags up to 60% of b events.

HERA experiments measured $F_2^{b\bar{b}}$ at low x (EPJC 78 (2018) 6, 473)

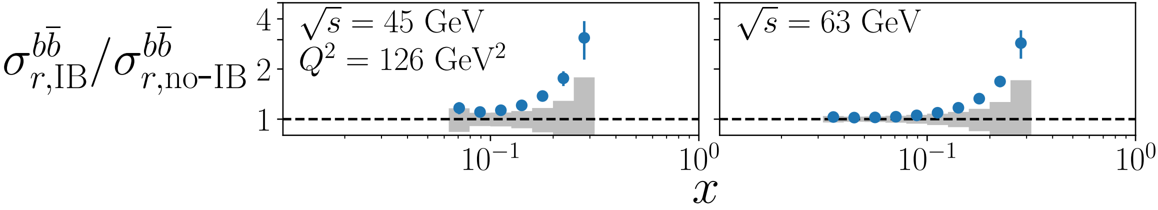
- Used topological heavy-flavor tagging
- $\sqrt{s} = 320$ GeV $\rightarrow$ smaller x than the EIC
- Small data sample compared to EIC



The EIC can precisely study b-hadron production (arXiv:2402.11344)



The EIC could be sensitive to intrinsic bottom (arXiv:2402.11344)



Using topological jet tagging from the LHC, the EIC has the potential to discover intrinsic bottom quarks.

Final thoughts

Absent IB, a precise measurement of $F_2^{b\bar{b}}$ is extremely valuable

- b-quark mass
- Heavy-flavor structure function evolution

Topological tagging has many applications

- Charm production
- Heavy-flavor angular correlations
- Jet tagging

Thank you!

Backup