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Experimental Overview: Electroweak Measurements and Direct Searches

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LHCb Implications Workshop: 21/10/22

Introduction

- When we find new physics, we expect a coherent pattern in multiple areas of research.
- From me today: LHCb studies that complement Heavy Flavour in two key areas:
    1. Electroweak measurements – measurements with electroweak bosons
        a. Probing QCD modelling
        b. Probing the consistency of the EW theory, providing a very precise test of the Standard Model (which, of course, relies on fine control of QCD).
    2. Direct Searches – direct observation key to a claim of new physics
        a. LHCb measurements currently targeting Long-Lived Particles (low mass, short lifetime)
        b. A strong programme studying dark photons

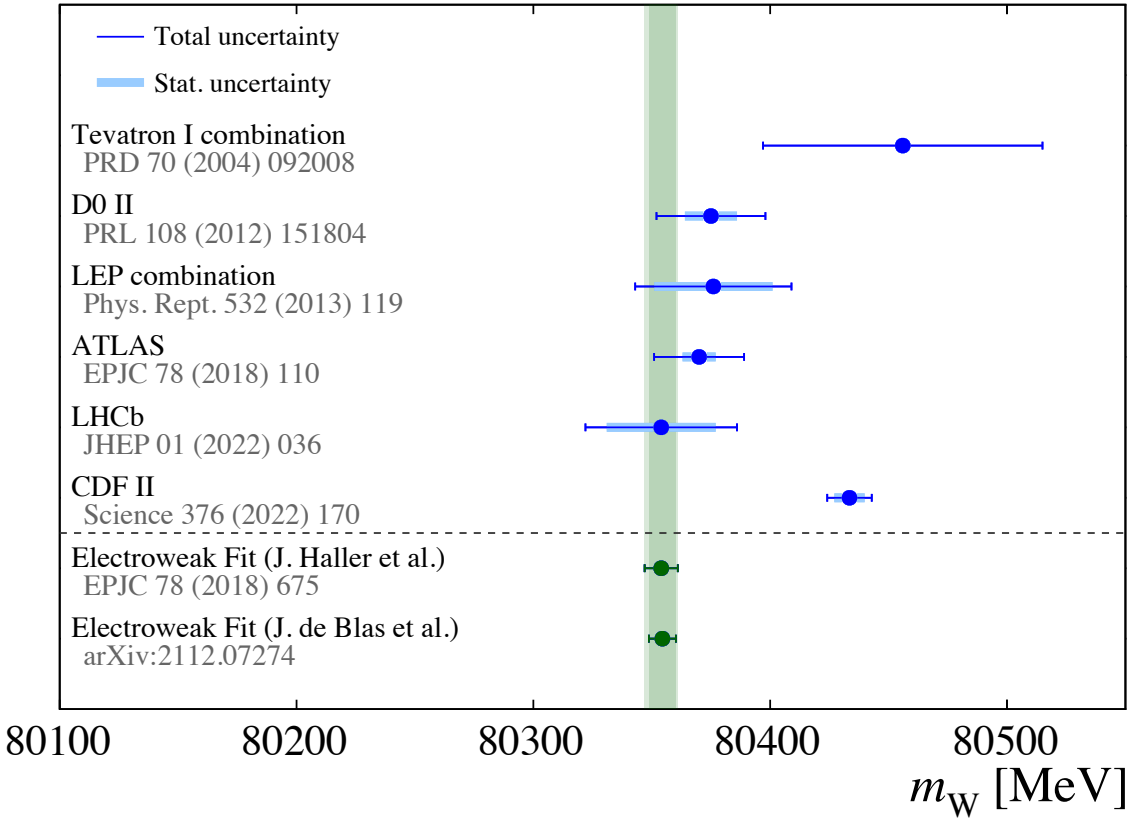
+ more (of course)!

- Direct searches and EW measurements at LHCb can be found here (pp) and here (HI).

Over the last year!

- New CDF measurement of the W boson mass with stunning precision.
  - In significant tension with a consistent picture of EW physics (7σ)
  - Also in tension with naïve combination of other W mass measurements including LHCb (4σ)
- Detailed study needed over next 5-10 years to understand this physics.
  - LHCb has a clear role to play here

(see Ross Hunter talk)



NNPDF, Nature 608 (2022) 483

Implications!

16:45

The charm of the proton: using forward Z+c production to study intrinsic charm at LHCb

Speaker: Daniel Charles Craik (Massachusetts Inst. of Technology (US))

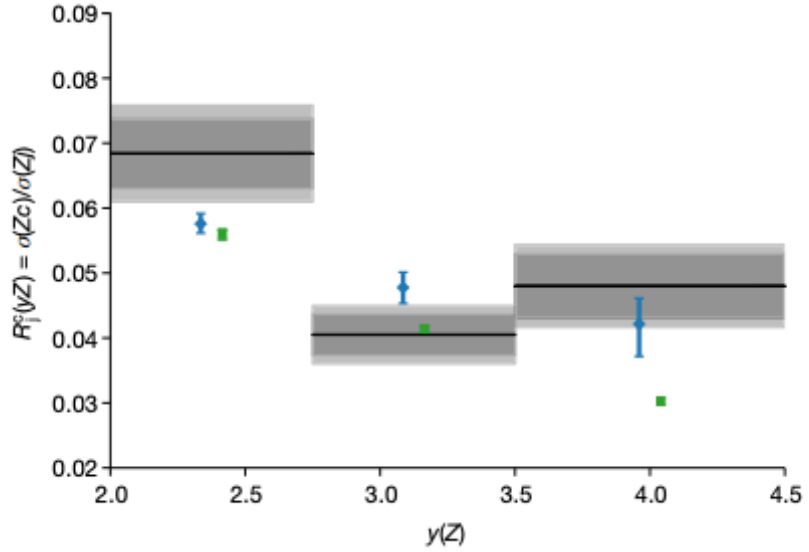
20211021_dcraik_i...

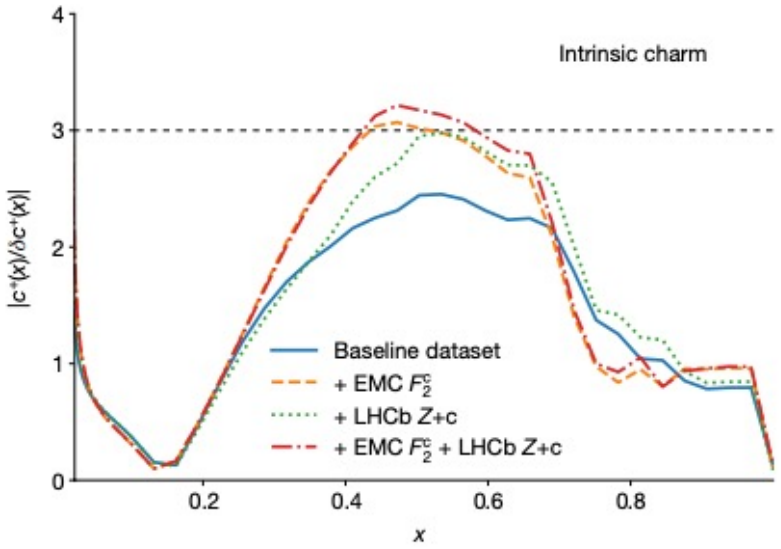
A talk at LHCb
Implications WS in 2021

Its implication…

Article

Evidence for intrinsic charm quarks in the proton





Recent LHCb Results

- A rich series of recent measurements

… in pp

TITLE	DOCUMENT NUMBER	JOURNAL	SUBMITTED ON
Multidifferential study of identified charged hadron distributions in Z-tagged jets in proton-proton collisions at $\sqrt{s}$ =13 TeV	PAPER-2022-013 arXiv:2208.11691 [PDF]	PRD Lett	24 Aug 2022
First measurement of $Z \to \mu^+\mu^-$ angular coefficients in the forward region of pp collisions at $\sqrt{s} = 13$ TeV	PAPER-2021-048 arXiv:2203.01602 [PDF]	Phys. Rev. Lett. 129 (2022) 091801	03 Mar 2022
Precision measurement of forward Z boson production in proton-proton collisions at $\sqrt{s} = 13$ TeV	PAPER-2021-037 arXiv:2112.07458 [PDF]	JHEP 07 (2022) 26	14 Dec 2021
Search for massive long-lived particles decaying semileptonically at $\sqrt{s} = 13$ TeV	PAPER-2021-028 arXiv:2110.07293 [PDF]	Eur. Phys. J. C82 (2022) 373	14 Oct 2021
Study of Z bosons produced in association with charm in the forward region	PAPER-2021-029 arXiv:2109.08084 [PDF]	Phys. Rev. Lett. 128 (2022) 082001	16 Sep 2021
Measurement of the W boson mass	PAPER-2021-024 arXiv:2109.01113 [PDF]	JHEP 01 (2022) 036	02 Sep 2021

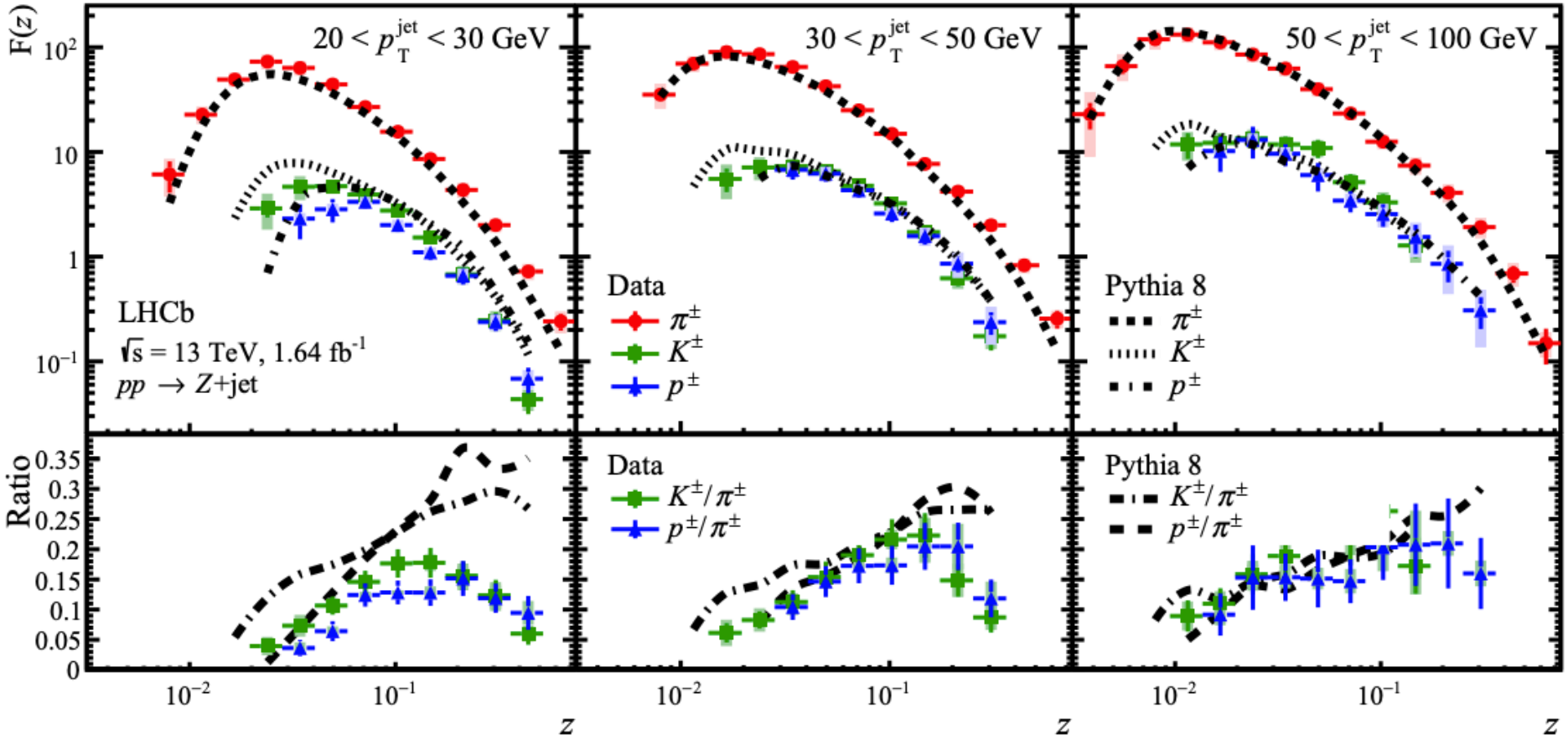
Recent LHCb Results

- A rich series of recent measurements

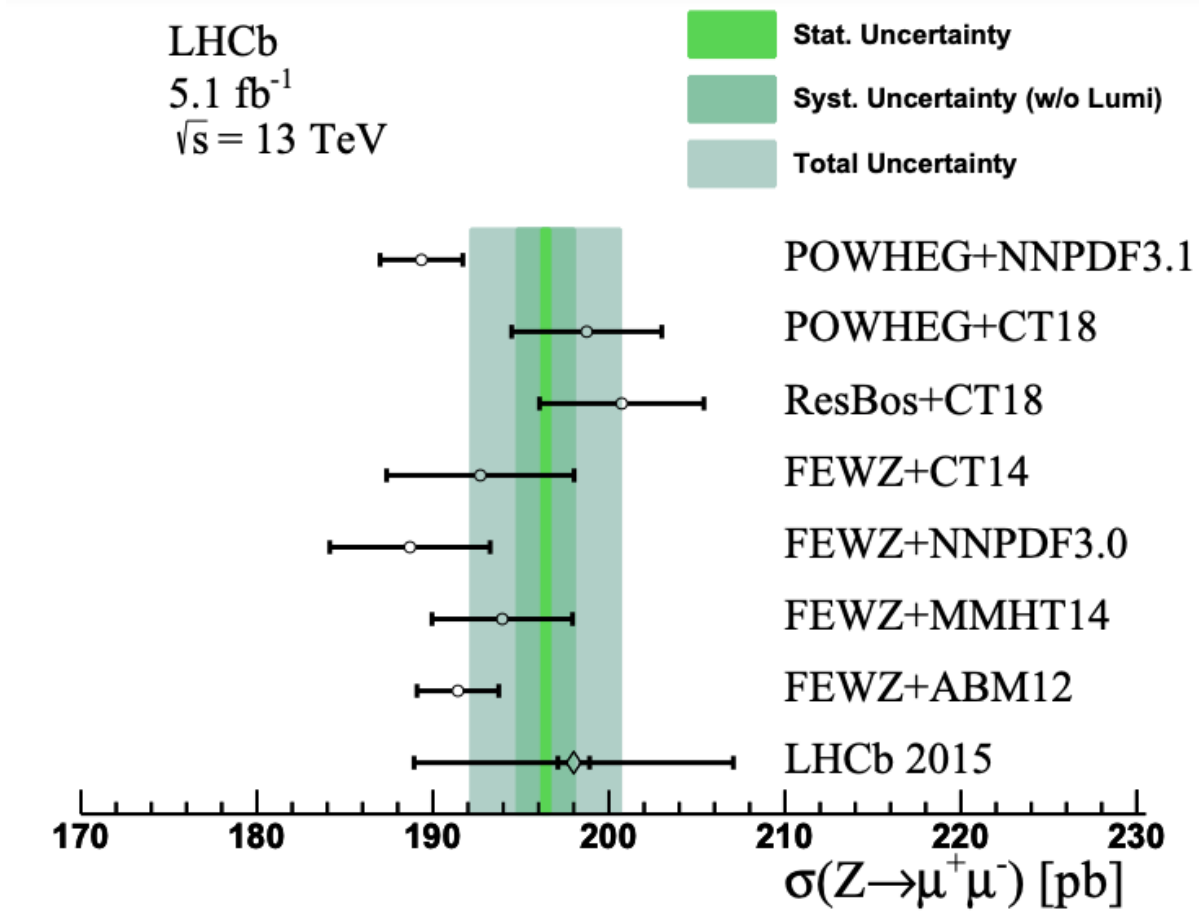
… and in HI

TITLE	DOCUMENT NUMBER	JOURNAL	SUBMITTED ON
Study of coherent charmonium production in ultra-peripheral lead-lead collisions	PAPER-2022-012 arXiv:2206.08221 [PDF]	JHEP	16 Jun 2022
Measurement of the Z boson production cross-section in proton-lead collisions at $\sqrt{s_{NN}} = 8.16\text{TeV}$	PAPER-2022-009 arXiv:2205.10213 [PDF]	JHEP	20 May 2022
Measurement of antiproton production from antihyperon decays in pHe collisions at $\sqrt{s_{NN}} = 110$ GeV	PAPER-2022-006 arXiv:2205.09009 [PDF]	EPJC	18 May 2022
Measurement of the prompt D^0 nuclear modification factor in pPb collisions at $\sqrt{s_{NN}} = 8.16$ TeV	PAPER-2022-007 arXiv:2205.03936 [PDF]	PRL	08 May 2022
Evidence for modification of b quark hadronization in high-multiplicity pp collisions at $\sqrt{s} = 13$ TeV	PAPER-2022-001 arXiv:2204.13042 [PDF]	PRL	27 Apr 2022
Nuclear modification factor of neutral pions in the forward and backward regions in pPb collisions	PAPER-2021-053 arXiv:2204.10608 [PDF]	PRL	22 Apr 2022

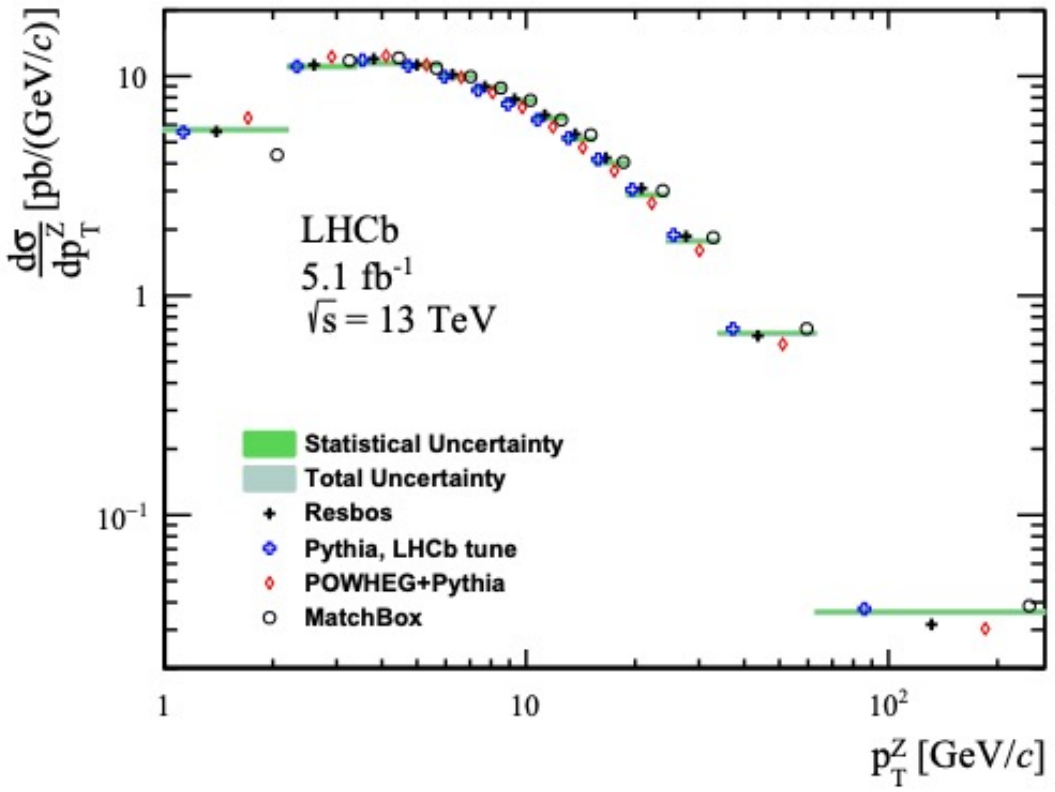
Probing QCD in Jet Fragmentation



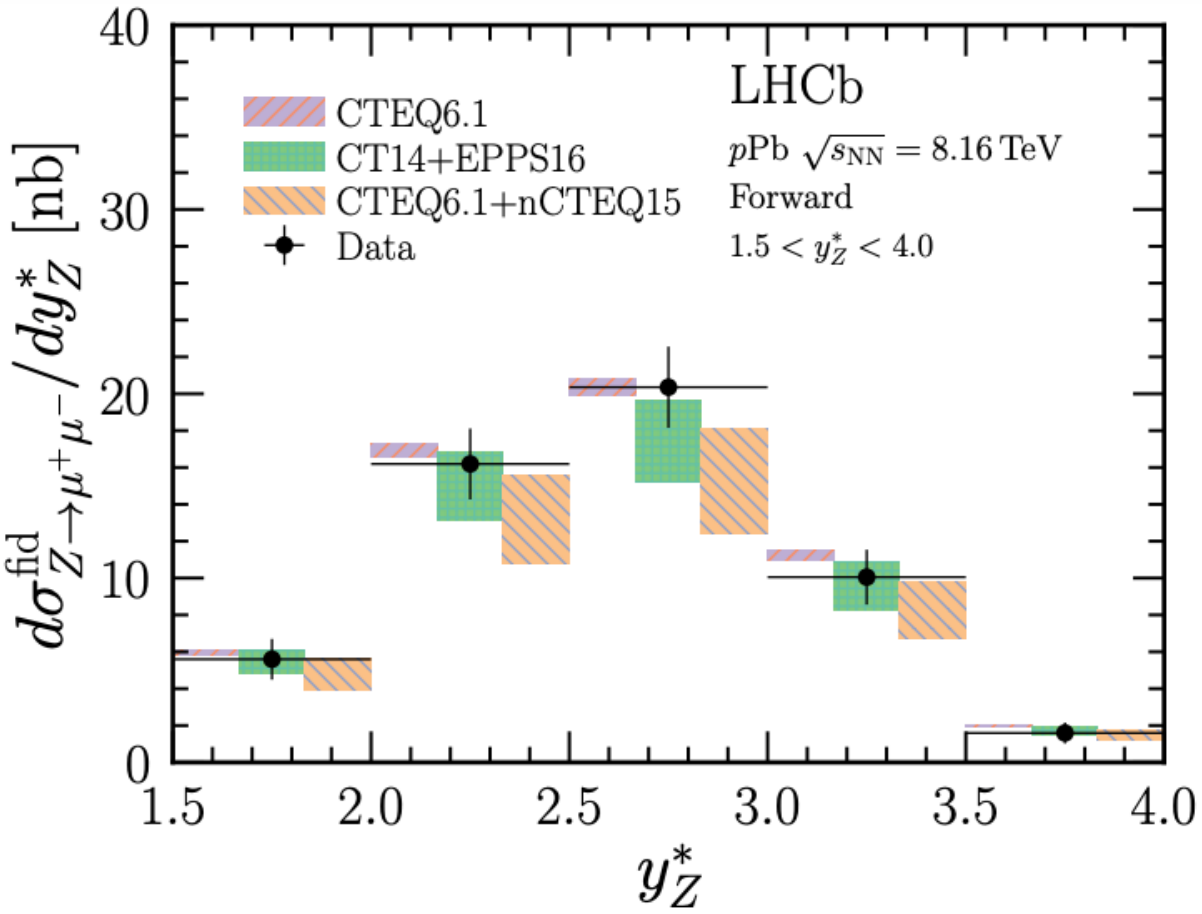
Probing QCD in EW production in pp

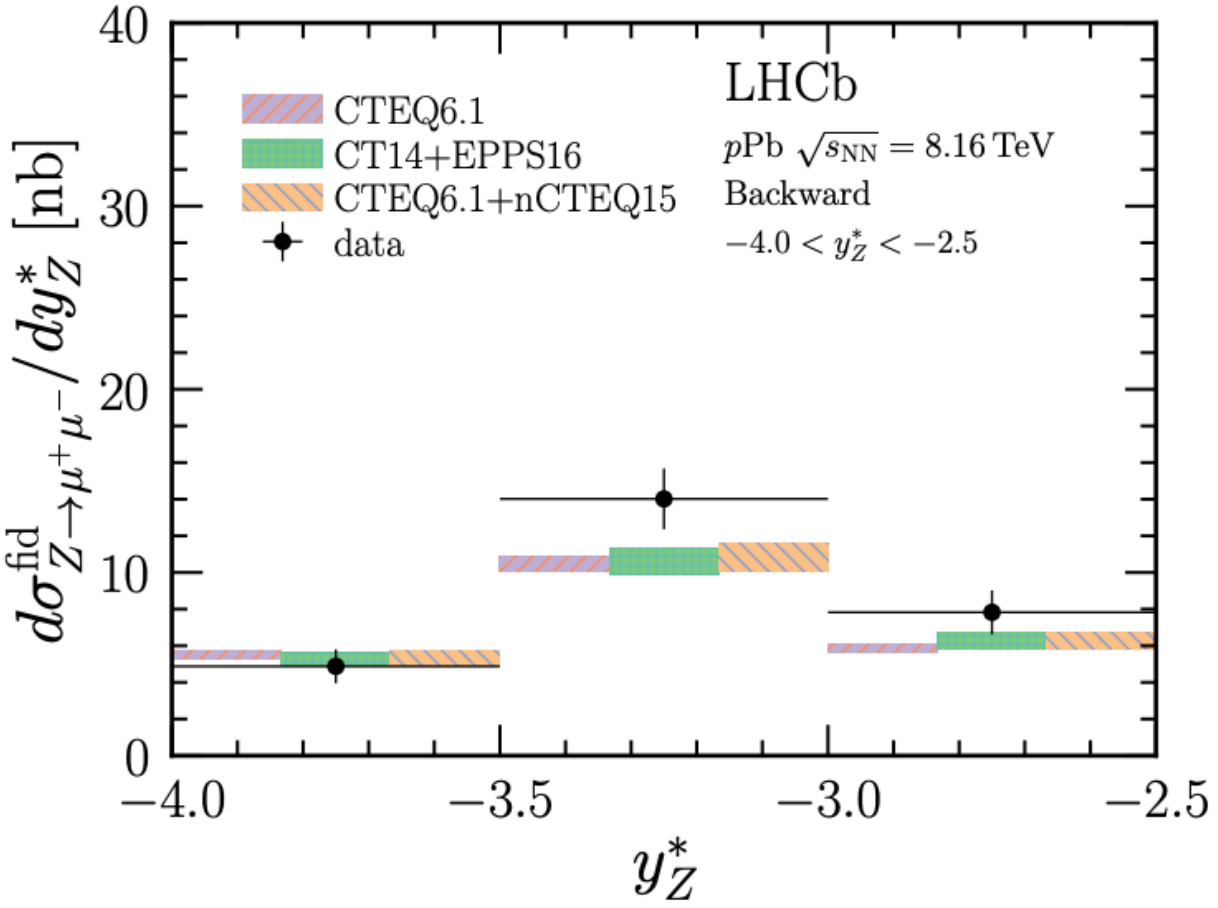


Measurement is double-differential in y, pT and y, ϕ^*



Probing QCD in EW production in p-Pb and Pb-p

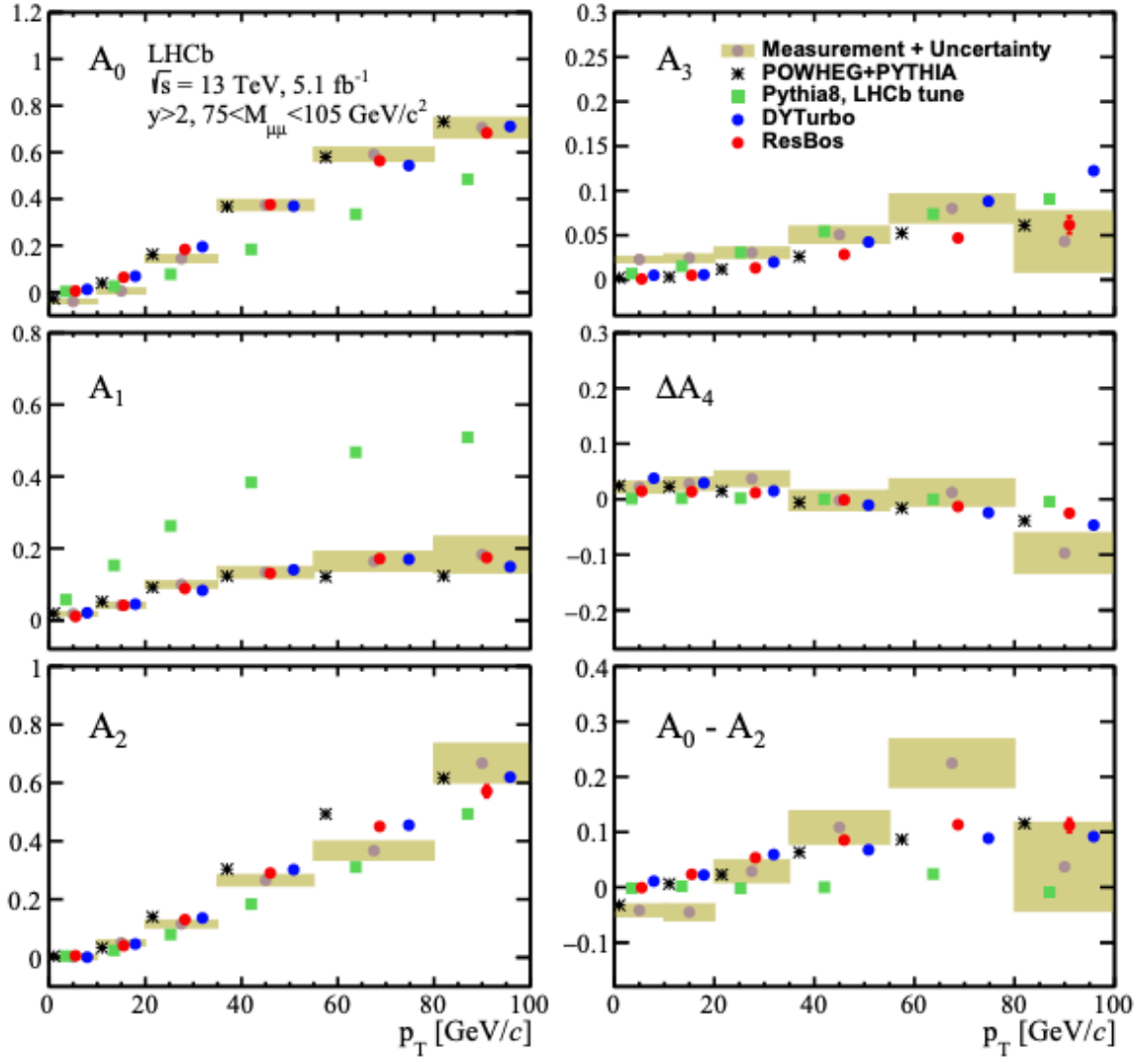




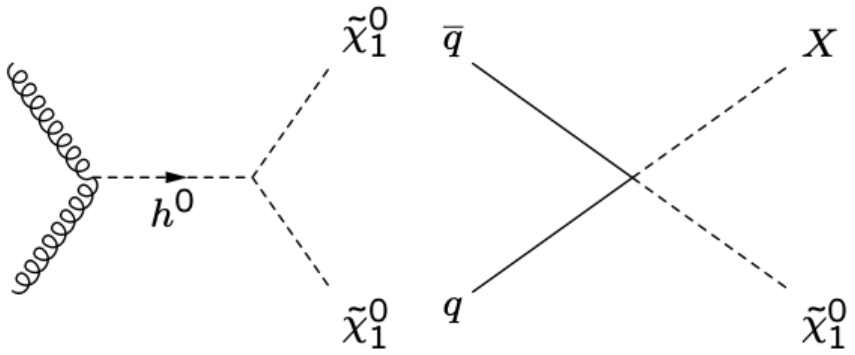
Probing EW and QCD in EW Decay

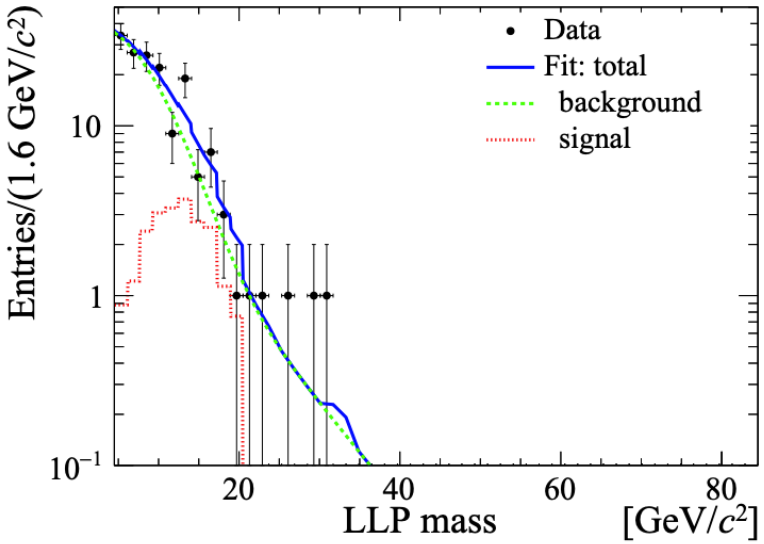
Measure Angular Coefficients as a function of pT and y.

$$\frac{\mathrm{d}\sigma}{\mathrm{d}p_{\mathrm{T}}^{W}\,\mathrm{d}y\mathrm{d}M\,\mathrm{d}\cos\theta\mathrm{d}\phi} = \frac{3}{16\pi}\frac{\mathrm{d}\sigma^{\mathrm{unpol.}}}{\mathrm{d}p_{\mathrm{T}}^{V}\mathrm{d}y\mathrm{d}M}$$
$$\{(1+\cos^2\theta) + A_0\frac{1}{2}(1-3\cos^2\theta) + A_1\sin 2\theta\cos\phi$$
$$+ A_2\frac{1}{2}\sin^2\theta\cos 2\phi + A_3\sin\theta\cos\phi + A_4\cos\theta$$
$$+ A_5\sin^2\theta\sin 2\phi + A_6\sin 2\theta\sin\phi + A_7\sin\theta\sin\phi\}$$



Direct Search for LLP decaying semileptonically





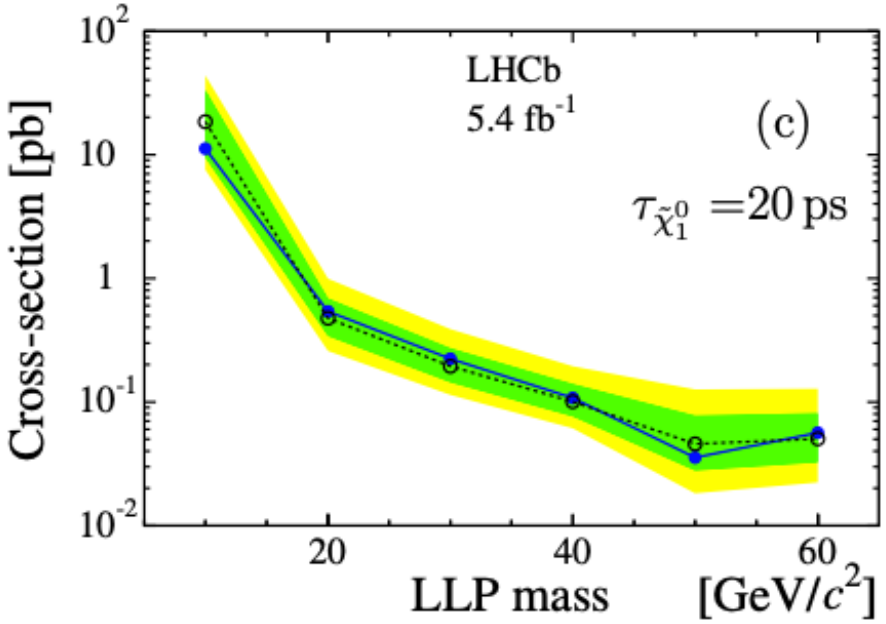
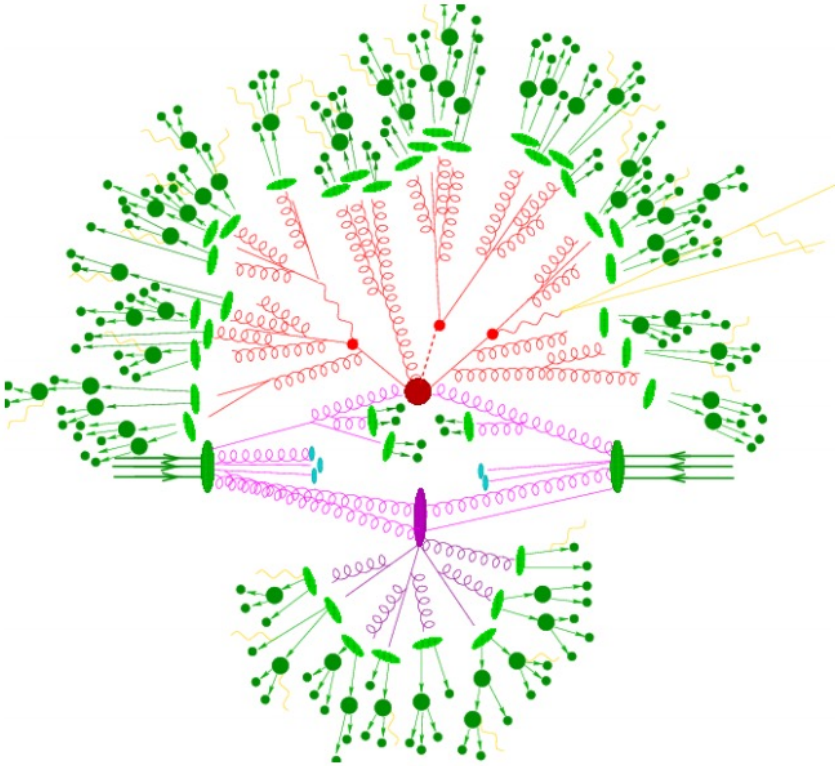


Image from SHERPA collab.

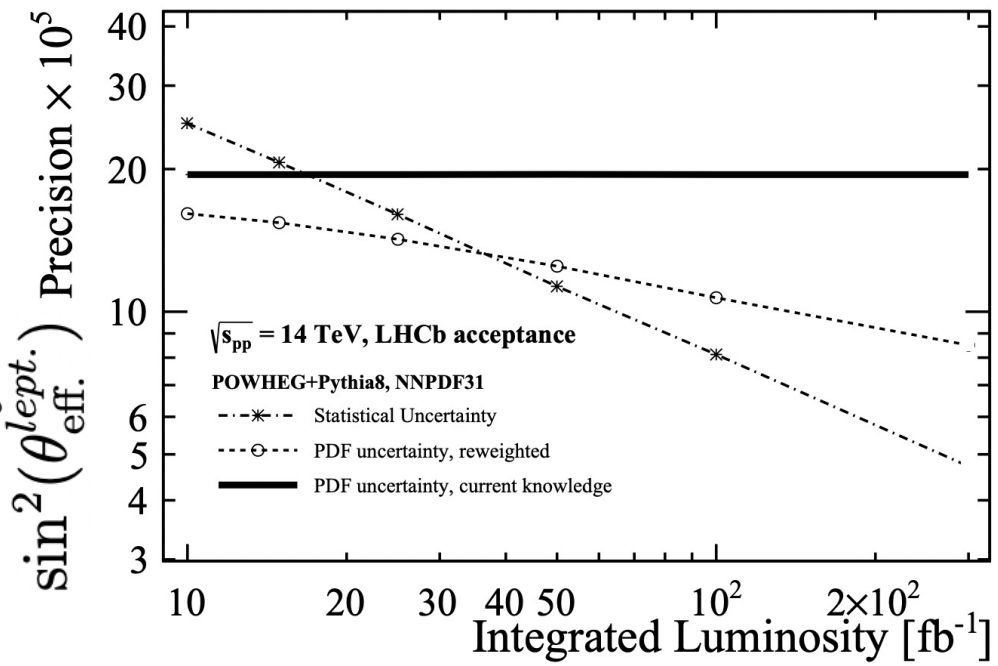
What more can you expect from us (soon)?

- QCD
  - Studies of PDFs via W boson charge asymmetries
  - Studies of Jet production @ LHCb (e.g. Z+jet in Run 3)
  - Studies of Jet fragmentation for different flavour jets
  - And much more!



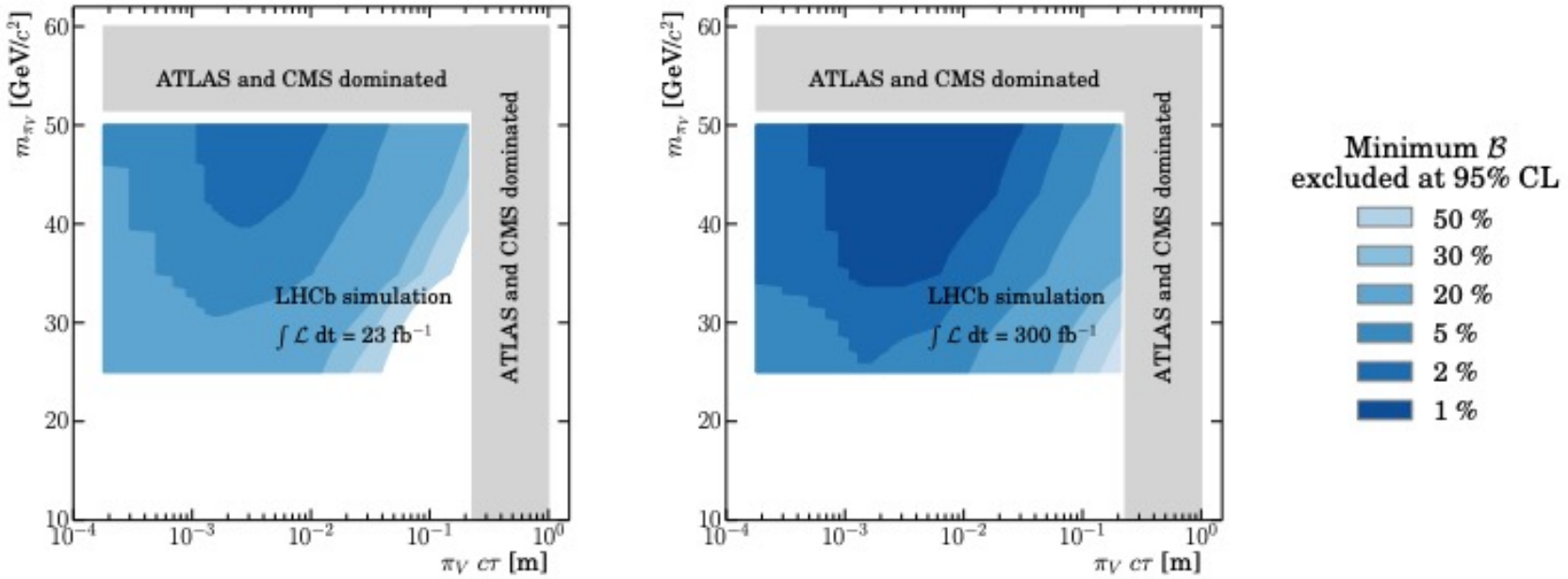
What more can you expect from us (soon)?

- Precision Electroweak measurements
  - Weak mixing angle with full Run 2 dataset
  - W boson mass with full Run 2 dataset
  - Test of lepton universality with $W \to \tau\nu$ decays
- Run 3 data will let us go further in all these areas.



What more can you expect from us (soon)?

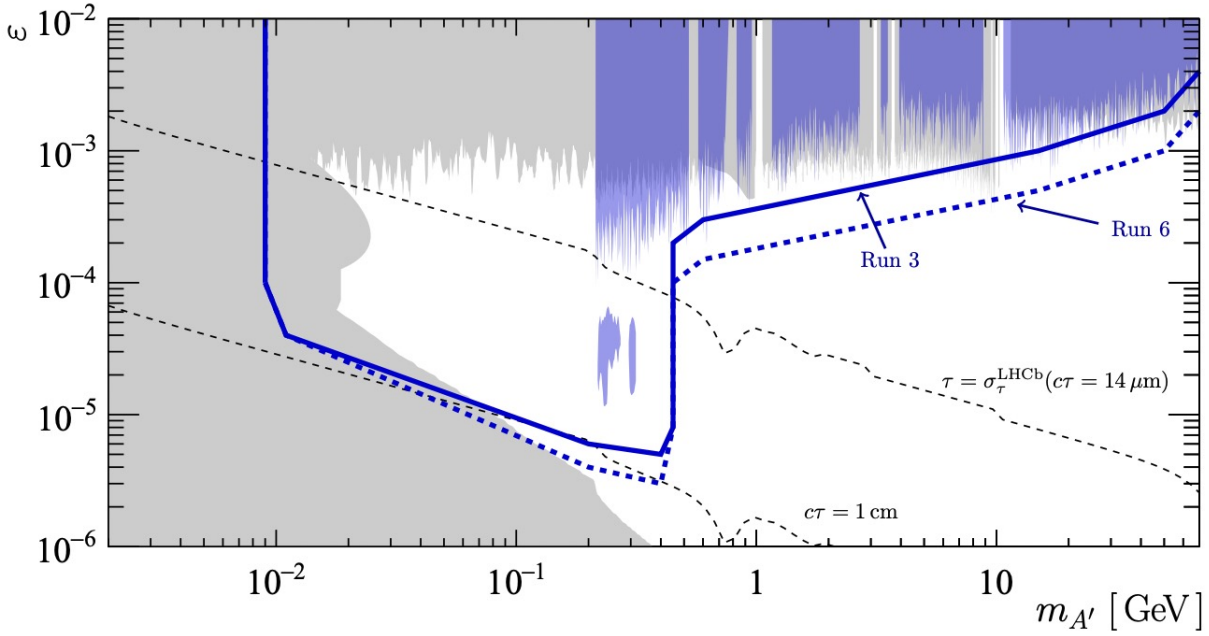
- Direct Searches – Long Lived Particles
  - Targeting low mass, short lifetime
  - Using jet substructure information to enhance sensitivity.



Ilten, Thaler, Williams and Xue, PRD 92 (2015) 115017
Craik, Ilten, Johnson, Williams, arxiv:2203.07048

What more can you expect from us (soon)?

- Direct Searches – Dark Photons
  - Existing limits for prompt and displaced dark photons with m > 200 MeV
  - Trigger strategy in Run 3 allows new opportunities to detect low mass dark photons via $D^* \rightarrow D^0 A'(\rightarrow ee)$



Summary

- A rich programme of EW measurements and Direct Searches at LHCb.
  - Clear complementarity to those possible at other experiments!
  - But also complementary to the studies in HF.

- Significant implications from these measurements historically, and expect implications from those shown today!

- Have shown selected recent results, and some potential opportunities in coming months/years.

- More detail to come in following talks!

Backups

Gori *et al.*, arxiv:2209.04671