Measurement of the Z boson mass with the LHCb detector

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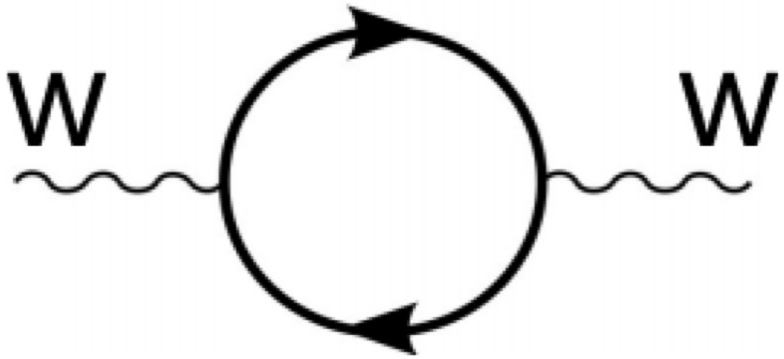
Prospects of a Z measurement

- m_z is an important fundamental parameter in the Standard Model

- Predictions at higher precision require loop corrections
  - Depends on top mass, Higgs mass, etc..



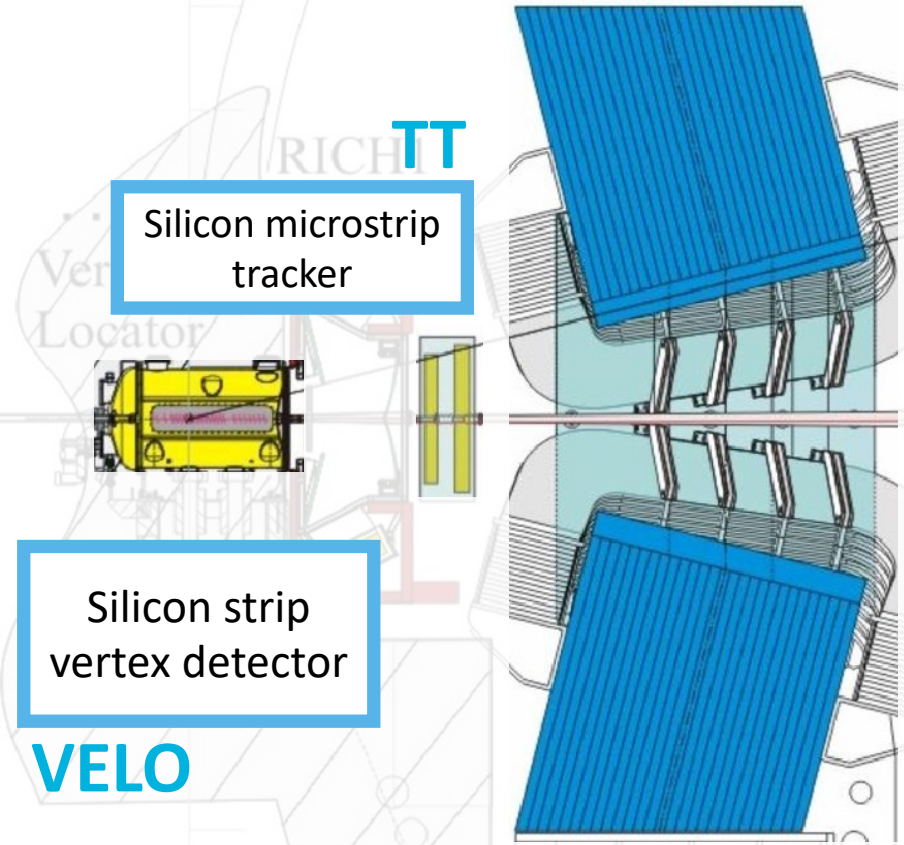
Indirect $m_z = 91204.7 \pm \mathbf{8.8}$ MeV

Phys. Rev. D 106 (2022) 033003

- ***LHCb*** has measured m_W, and $\sin^2\theta_W$…, can we measure m_Z?

LHCb's Run II detector

Int J Mod Phys A 30 (2015), 1530022



VELO

Silicon strip vertex detector

TT

Silicon microstrip tracker

T Stations

Inner tracker: silicon strips
Outer trackers: straw drift tubes

Dipole magnet

4 Tm (vertical)
Polarity switchable

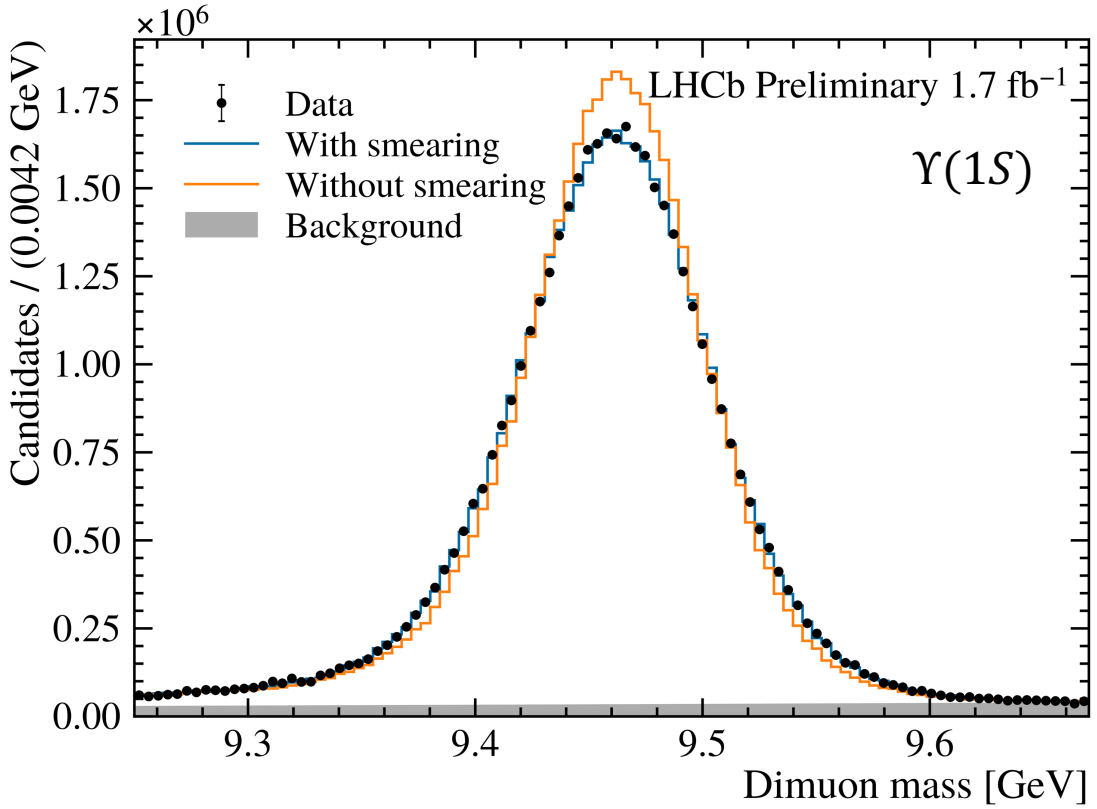
Tracking ranges
ATLAS / CMS: $|\eta| < 2.5$
LHCb: $2 < \eta < 5$

Detector Response

Differences between data and simulation are of the form

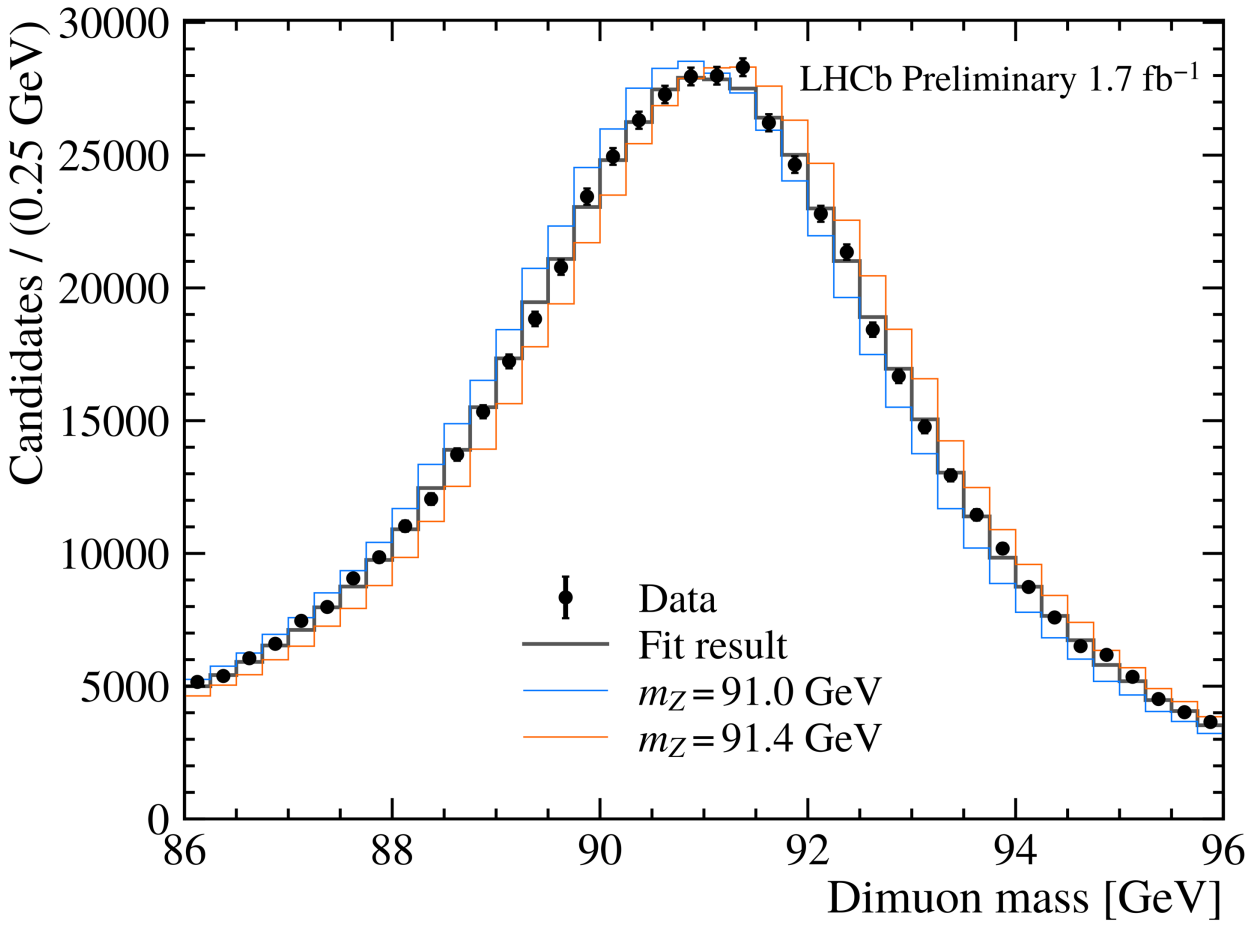
$$p^{\pm} \rightarrow (1 + \alpha + \frac{\beta}{p^{\pm}} \mp \delta p^{\pm})(1 + a\mathcal{R}_1\sigma_1)(1 + b\mathcal{R}_2\sigma_2 p^{\pm})p^{\pm}$$

$$\mathcal{R} \sim \mathcal{N}(0,1)$$



Source	Size [MeV]
Detector material description	2.6
Calibration samples	2.0
Smearing fit	1.8
Mass of the $\Upsilon(1S)$	1.5
Curvature Biases	0.7
QED corrections for $\Upsilon(1S)$	0.6
Momentum calibration uncertainty	**4.1**

Z mass Fit



Chi squared

44.2/37

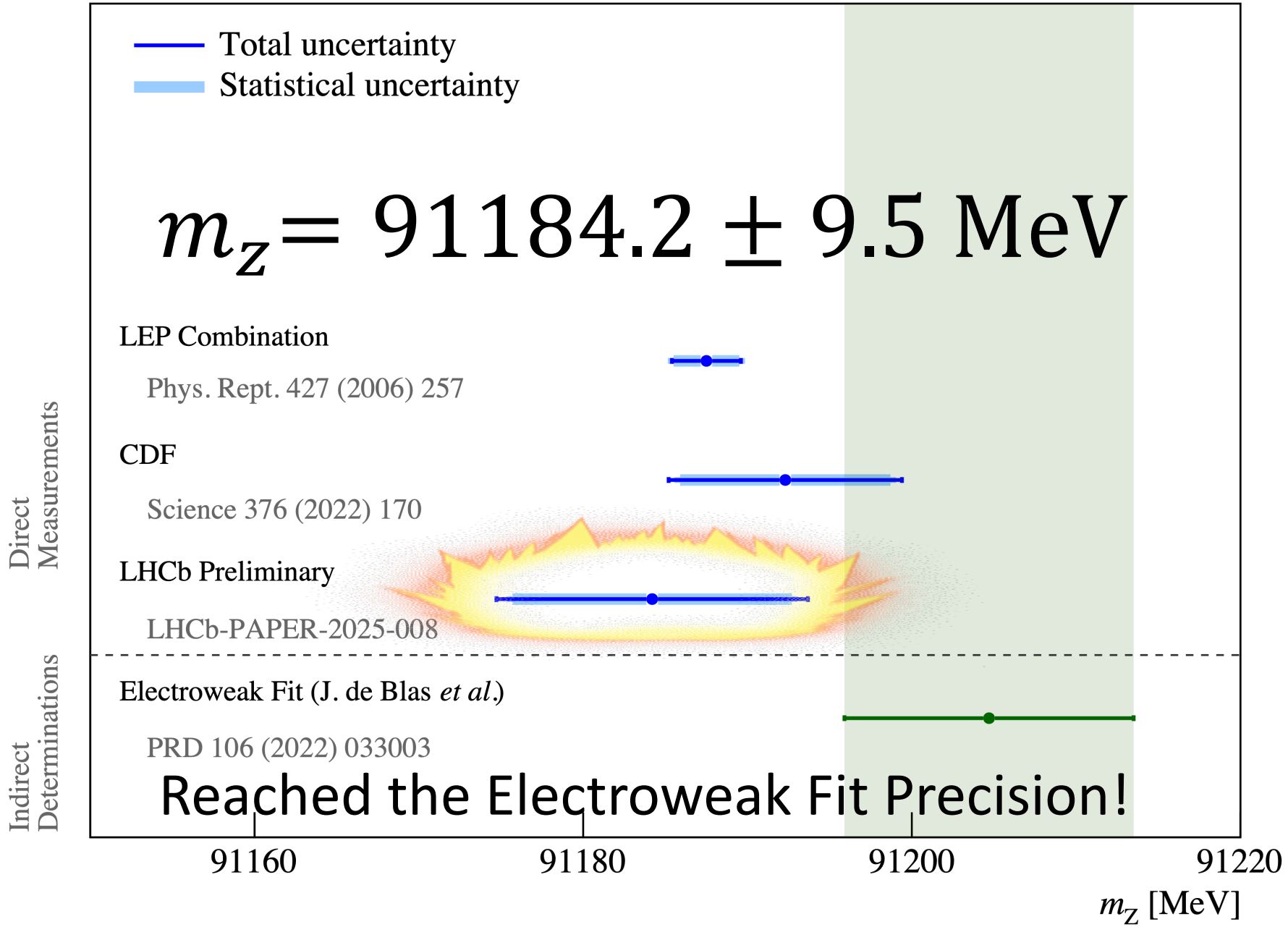
Z mass

91xxx ± 8.5 MeV

- Binned Chi squared fit
- m_z varied by reweighting to generator level events
- From a version of POWHEG with QED predictions at NLO [Eur. Phys. J. C 73 (2013) 6]

Source	Size [MeV]
Momentum calibration	4.1
Signal QED corrections	0.8
Parton distribution functions	0.7
Detection Efficiency	0.1
Statistical uncertainty	8.5
Total	**9.5**

Result


Total uncertainty
Statistical uncertainty
$m_z = 91184.2 \pm 9.5$ MeV
LEP Combination
Phys. Rept. 427 (2006) 257
CDF
Science 376 (2022) 170
LHCb Preliminary
LHCb-PAPER-2025-008
Direct Measurements
Electroweak Fit (J. de Blas *et al.*)
PRD 106 (2022) 033003
Indirect Determinations
Reached the Electroweak Fit Precision!
91160
91180
91200
91220
m_Z [MeV]

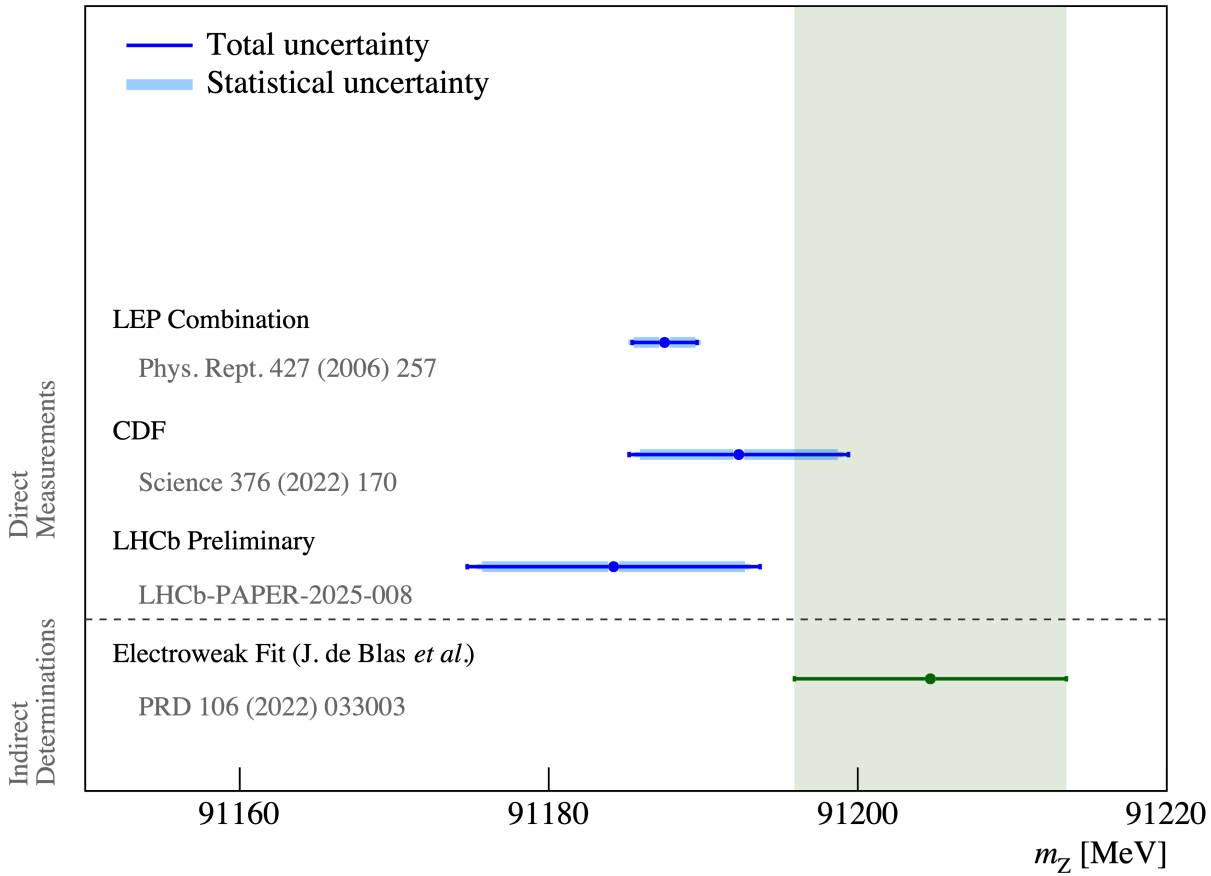
Summary

- m_Z measurable at ***LHCb***!

$$m_Z = 91184.2 \pm 9.5 \text{ MeV}$$

- Results consistent with SM and previous measurements

- First dedicated measurement at the LHC



Backup

The momentum response

$$\mathcal{R} \sim \mathcal{N}(0,1)$$

$$p^{\pm} \rightarrow \left(1 + \alpha + \frac{\beta}{p^{\pm}} \mp \delta p^{\pm}\right)\left(1 + a\mathcal{R}_1\sigma_1\right)\left(1 + b\mathcal{R}_2\sigma_2 p^{\pm}\right)p^{\pm}$$

Bias terms

Smearing terms

Momentum Scale
(time/direction dependent)

Detector Misalignment

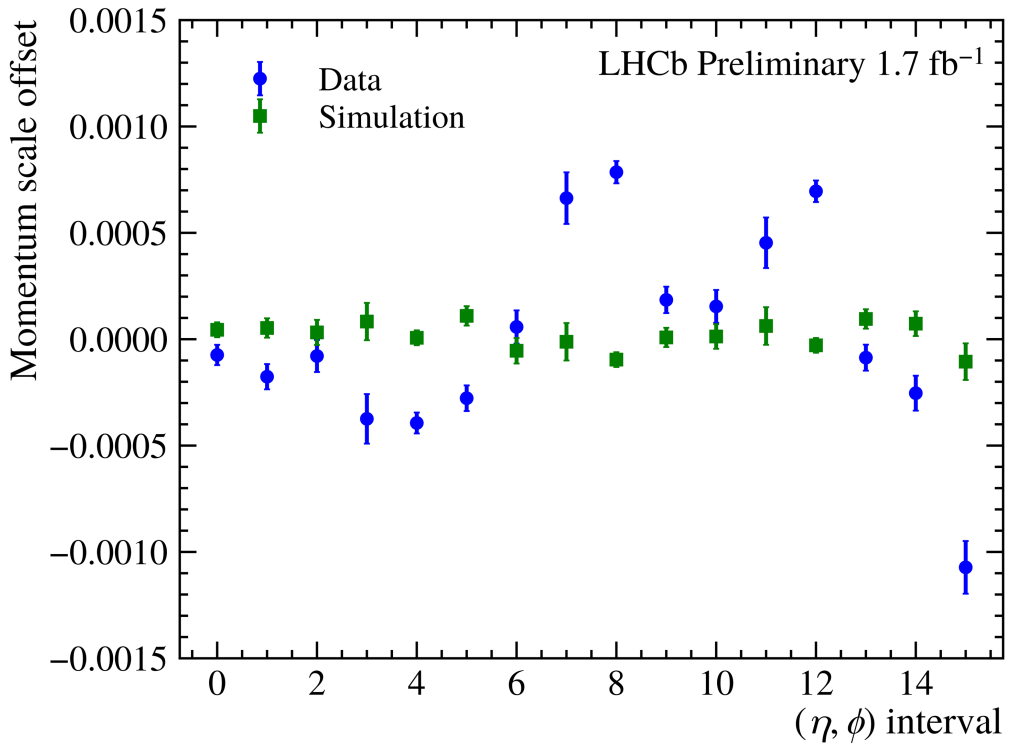
Detector resolution

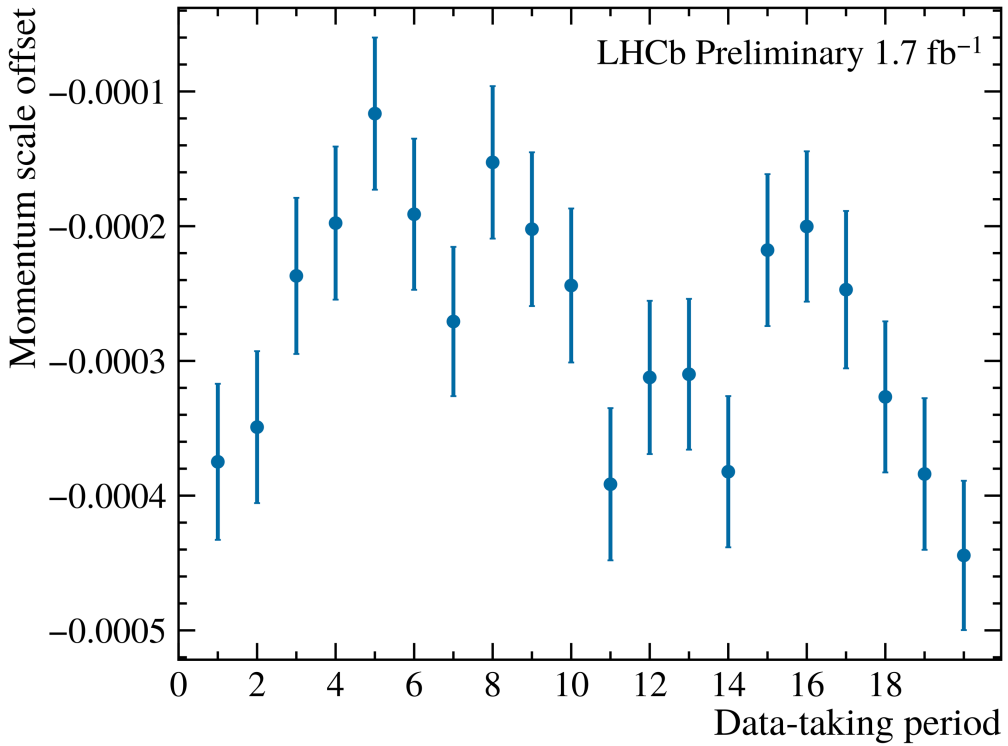
Energy Loss

Material scattering

$$a(\eta) = \begin{cases} 1, & \eta < 3.3 \\ 1.5, & \eta \geq 3.3 \end{cases} \qquad b(\eta) = \frac{1}{\cosh \eta}$$

Supplementary plots





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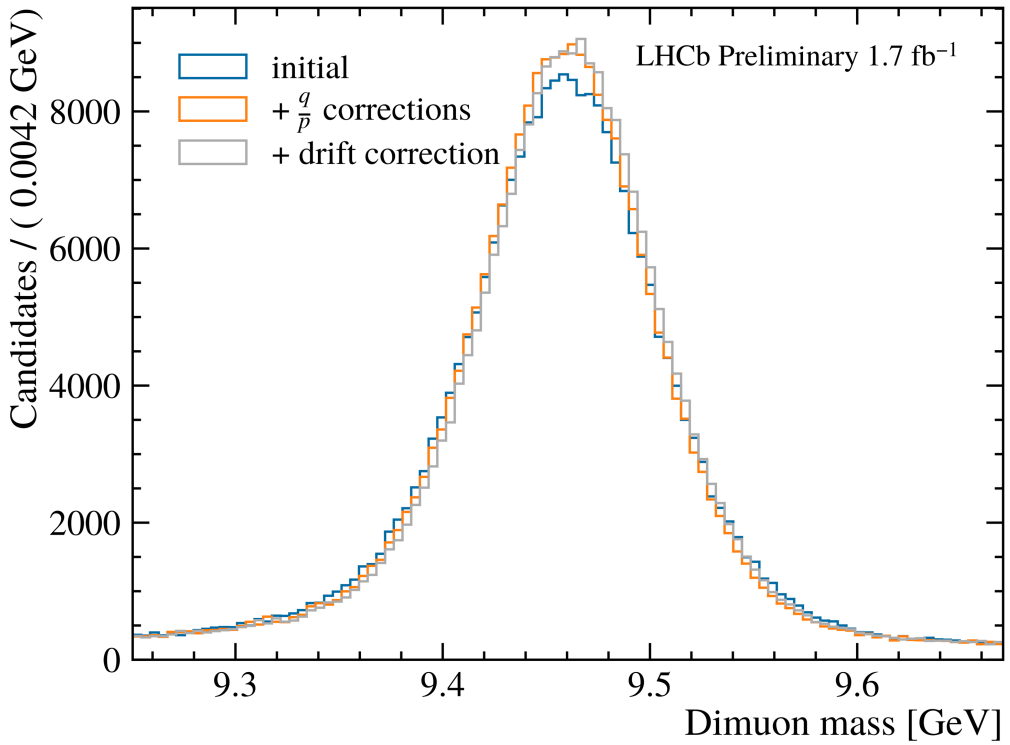

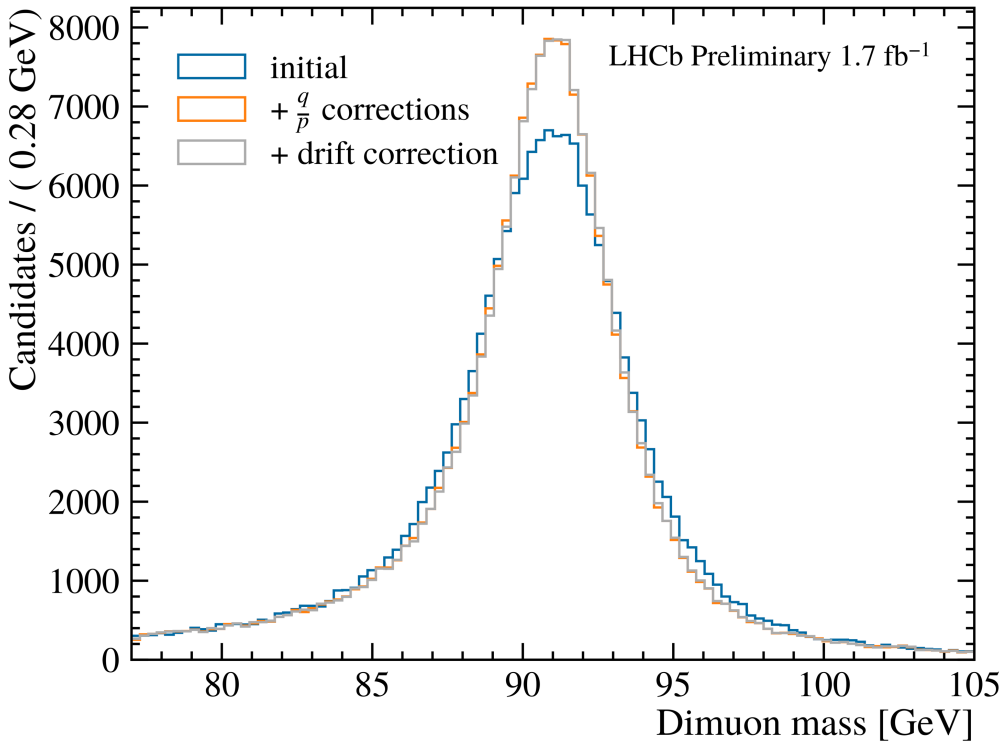

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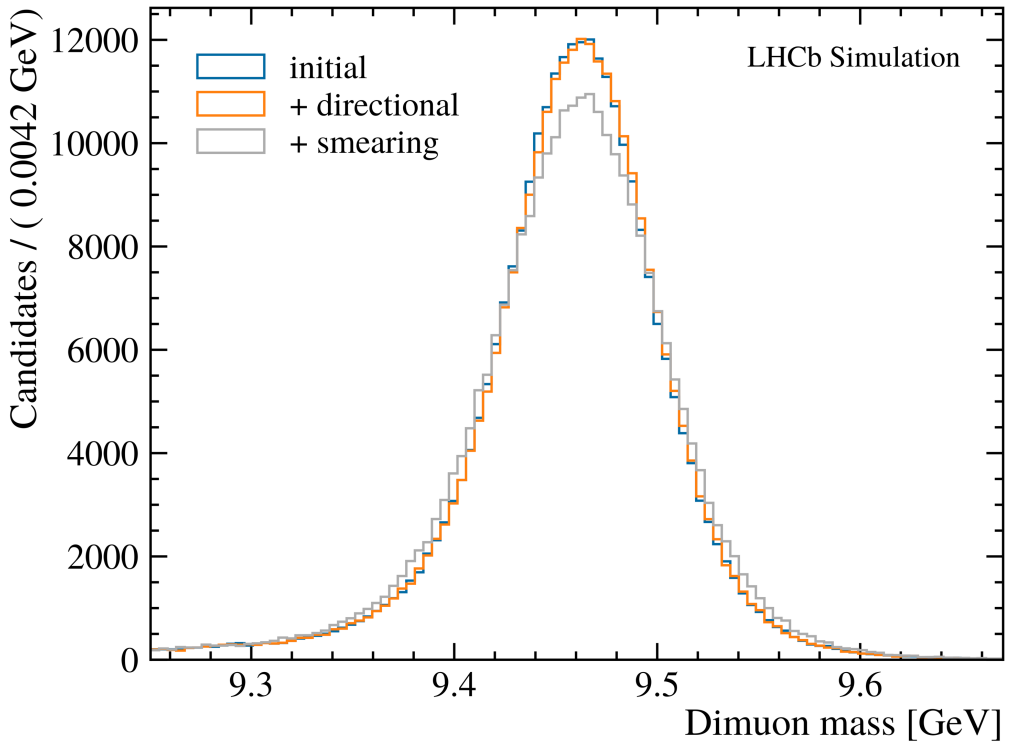

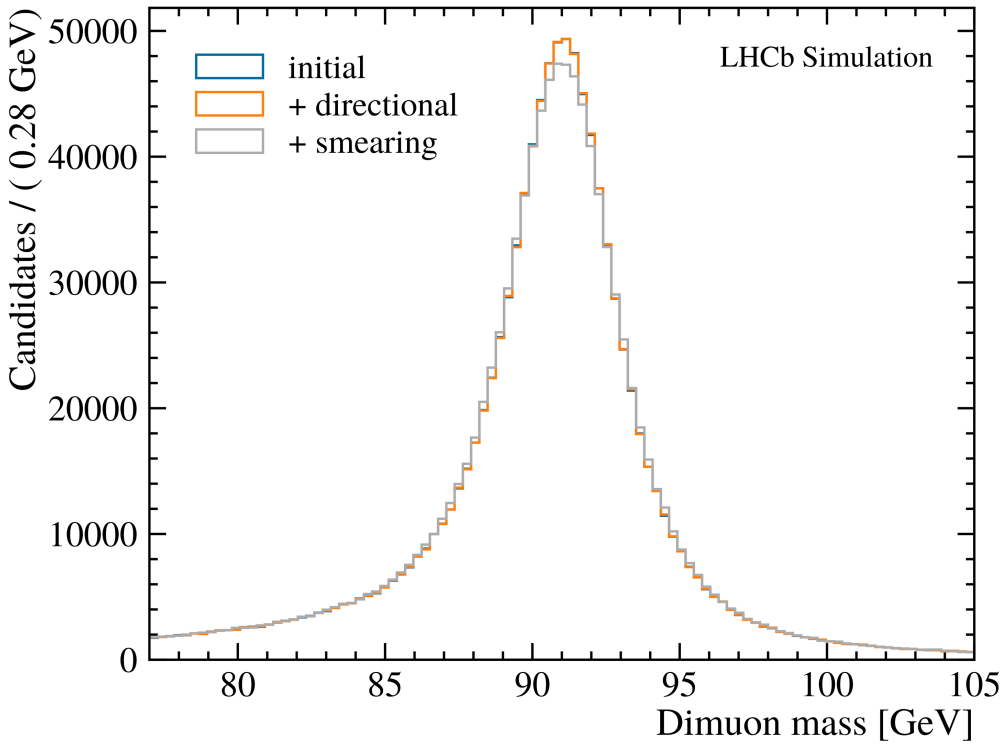

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