Measurements of Drell-Yan Processes at LHCb

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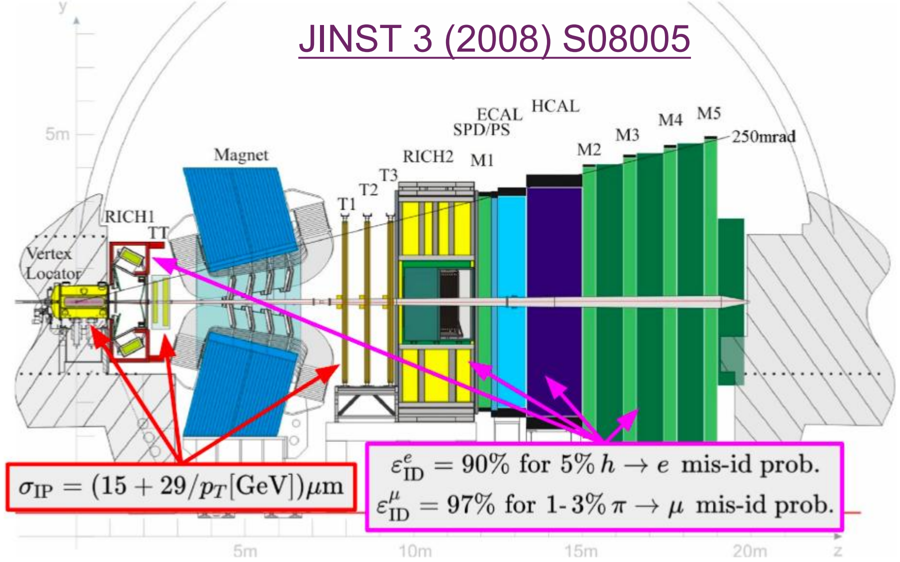
General information on the LHCb experiment

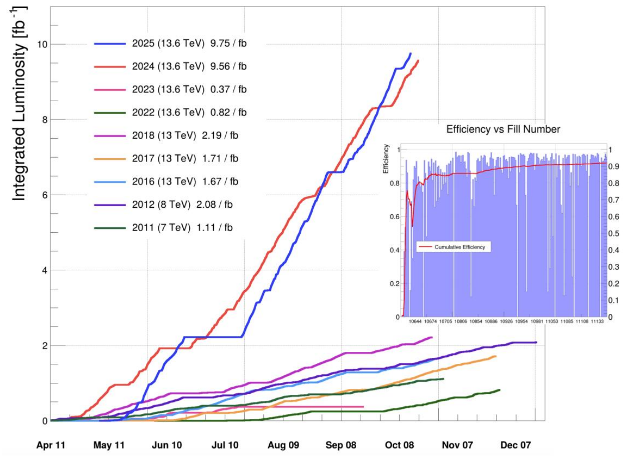
- Small angle spectrometer, covering the forward region, $2 < \eta < 5$
- Momentum resolution is ~1%
- Trigger efficiencies
  - ~90% for dimuon channels in Run2
  - nearly 100% in Run 3 due to the fully software-based trigger system

Integrated luminosity

- 2011: 1.0 fb-1
- 2012: 2.0 fb-1
- 2015: 0.30 fb-1
- 2016: 1.6 fb-1
- 2017: 1.7 fb-1
- 2018: 2.1 fb-1

20 fb-1 collected in Run 3

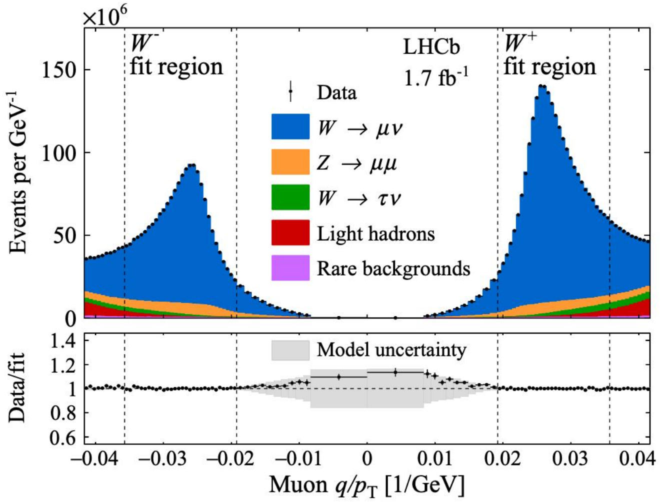


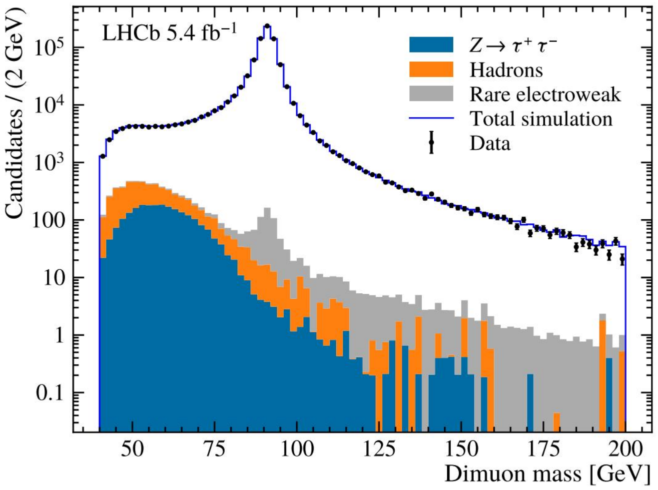


Drell-Yan process at LHCb

- In LHCb, Drell–Yan measurements **usually refer to the $\boldsymbol{\mu}$ channel**
  - muon reconstruction and momentum measurement are very precise
  - high purity
- High p_{T} (EW scale) electrons are limited by E-Cal cell saturation, not allowing for precision reconstruction of electronic modes of gauge boson decays
  - the E-Cal saturates at $E_{\mathrm{T}} \approx 10$ GeV per channel

$N_{\mathrm{bkg}}/N_{\mathrm{sig}} \sim 2\%$





So far

full shopping list

- $Z \to e^+e^-$ production cross-section measurement at 7 and 8 TeV [1]: y^Z, ϕ^*
- $Z \to \mu^+\mu^-$ production cross-section measurement at 5.02, 7, 8 and 13 TeV [2]
    - the 13 TeV paper reports $p_\mathrm{T}^Z - y^Z$ double differential cross-section
- Inclusive low mas Drell-Yan production measurement at 7 TeV [3]: y^Z, M
- $Z \to \mu^+\mu^-$ angular coefficient measurement at 13 TeV [4], p_T^Z, y^Z
    - A_2 values in low p_T region (<20 GeV) at different mass regions
- The effective weak mixing angle measurement with Run1 and Run2 dataset [5]
- Z-boson mass measurement with 2016 dataset [6]
- W-boson mass measurement with 2016 dataset [7]
- W-boson cross-section measurement at 5.02 TeV, 7TeV and 8TeV [8]

[1] JHEP 01 (2013) 111, JHEP 05 (2015) 109

[2] JHEP 08 (2015) 039, JHEP 01 (2016) 155, JHEP 07 (2022) 26, JHEP 02 (2024) 070

[3] LHCb-CONF-2012-013 [4] Phys. Rev. Lett. 129 (2022) 091801

[5] JHEP 11 (2015) 190, JHEP 12 (2024) 026 [6] arXiv:2505.15582 [7] JHEP 01 (2022) 036

[8] arXiv:2509.18817, JHEP 12 (2014) 079, JHEP 01 (2016) 155

Cross section measurement

- The measured quantity is the cross-section defined from the muon kinematics after QED radiation
- The reported results include an additional correction for QED final-state radiation (except for the W xsec measurement at 5.02 TeV)
- The FSR correctionis evaluated either as
  - the average of the values determined using Herwig++ and Pythia 8 (and Photos)
  - or the difference between ResBos predictions with and without the implementation of PHOTOS
    - the mean correction is ~2% for muons and 5% for electrons
    - the strongest variation is seen as a function of p_{T}^{Z}, where the correction varies over the distribution by about 10%

fiducial region:

$p_{\mathrm{T}}^{l} > 20$ GeV ($28 < p_{\mathrm{T}}^{l} < 52$ GeV for W)

$2.0\ (2.2) < \eta^{l} < 4.5\ (4.4)$

$60 < M_{ll}$ (Z) < 120 GeV

From $W \to \mu\nu$ cross section to m_W measurement

- Fit $d\sigma/dp_{\mathrm{T}}^{\mu}$ with a semi-arbitrary model to extract m_W
  - inputs: 24 $d\sigma/dp_{\mathrm{T}}^{\mu}$ values (without FSR correction) and one 24×24 covariance matrix
  - fit can be performed with any model
- External analysts can use the cross section result to perform their own extraction of m_W using different theoretical predictions

arXiv: 2509.18817

Table 2: Results of the differential cross-section fits, where the first and second uncertainties are statistical and systematic, respectively.

Interval in p_{T} [GeV]	$\mathrm{d}\sigma/\mathrm{d}p_{\mathrm{T}}$ [pb/GeV] $W^+ \to \mu^+\nu_\mu$	$W^- \to \mu^-\overline{\nu}_\mu$
28–30	$11.93 \pm 0.44 \pm 0.36$	$14.81 \pm 0.47 \pm 0.35$
30–32	$14.36 \pm 0.46 \pm 0.29$	$15.70 \pm 0.48 \pm 0.26$
32–34	$17.66 \pm 0.48 \pm 0.31$	$15.59 \pm 0.48 \pm 0.24$
34–36	$18.87 \pm 0.51 \pm 0.31$	$16.09 \pm 0.48 \pm 0.29$
36–38	$22.73 \pm 0.56 \pm 0.36$	$16.53 \pm 0.49 \pm 0.24$
38–40	$23.50 \pm 0.58 \pm 0.31$	$14.57 \pm 0.48 \pm 0.32$
40–42	$17.16 \pm 0.53 \pm 0.31$	$10.26 \pm 0.42 \pm 0.24$
42–44	$10.45 \pm 0.43 \pm 0.30$	$6.13 \pm 0.35 \pm 0.18$
44–46	$6.01 \pm 0.35 \pm 0.17$	$3.28 \pm 0.28 \pm 0.23$
46–48	$3.46 \pm 0.30 \pm 0.14$	$2.41 \pm 0.24 \pm 0.14$
48–50	$2.59 \pm 0.26 \pm 0.13$	$1.65 \pm 0.22 \pm 0.15$
50–52	$1.75 \pm 0.21 \pm 0.14$	$1.42 \pm 0.18 \pm 0.11$

Appendix

A Total covariance matrix

The total covariance matrix (statistical + systematic) used to fit m_W, as demonstrated in Sec. 7, is given in Listing 1.

Listing 1: Full 24×24 covariance matrix of the measurement.

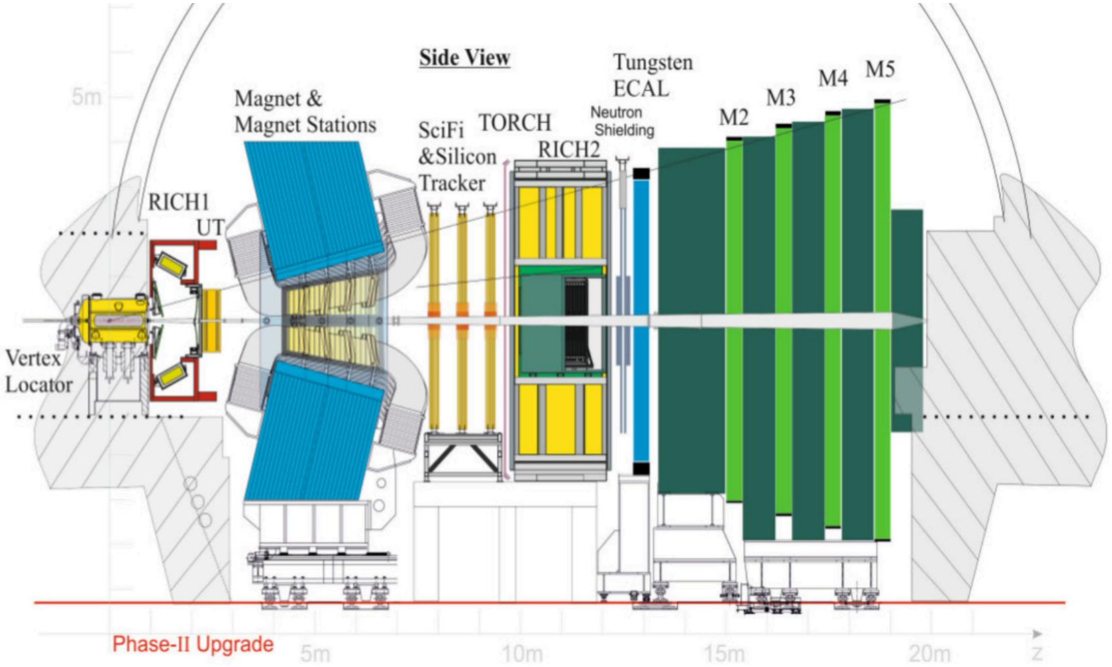
```
Row 1: 0.3192, -0.0252, 0.0287, 0.0302, 0.0696, 0.0258, 0.0048,
   -0.0028, -0.0022, 0.0057, 0.0089, -0.0050, 0.0644, 0.0592, 0.0113,
   0.0273, 0.0114, 0.0369, 0.0145, 0.0241, 0.0085, 0.0113, 0.0022,
   0.0114
Row 2: -0.0252, 0.2915, 0.0282, 0.0816, 0.0403, 0.0529, 0.0213,
   -0.0106, 0.0045, -0.0002, 0.0015, 0.0020, -0.0114, 0.0001, 0.0381,
   0.0029, 0.0381, 0.0154, 0.0314, 0.0140, 0.0197, -0.0010, 0.0031,
   0.0040
```

The LHCb upgrade II detector

$\mathcal{L} = 1.5\times10^{34}\,\mathrm{cm^{-2}s^{-1}}$
$\mathcal{L}_{int} = 300\ \mathrm{fb^{-1}}$
$\mu \approx 40$

- Upgrade II E-Cal is expected to allow similar reconstruction precision of high-p_{T} electrons as current muon reconstruction
- Availability of electronic channels at the EW scale, along with a significant increase in luminosity will allow some considerable future studies at LHCb

LHCb-TDR-023



LHC Run Year	Integrated luminosity fb^{-1}		
$\mathrm{cm}^{-1}\mathrm{s}^{-1}$	1.0×10^{34}	1.5×10^{34}	2.0×10^{34}
Run 1-4	50	50	50
LS4	–	–	–
Run 5 Year 1	21	25	26
Run 5 Year 2	43	50	51
Run 5 Year 3	43	50	51
LS5	–	–	–
Run 6 Year 1	43	50	51
Run 6 Year 2	43	50	51
Run 6 Year 3	43	50	51
Total	284	325	331