W mass: a theory overview

giuseppe bozzi
University and INFN, Cagliari

Istituto Nazionale di Fisica Nucleare
Sezione di Cagliari

STVDIORVM VNIVERSITAS CARALITANA

The W boson in the electroweak sector

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- EW sector uniquely determined by fixing 3 parameters (g, g', v) in terms of 3 exp. inputs

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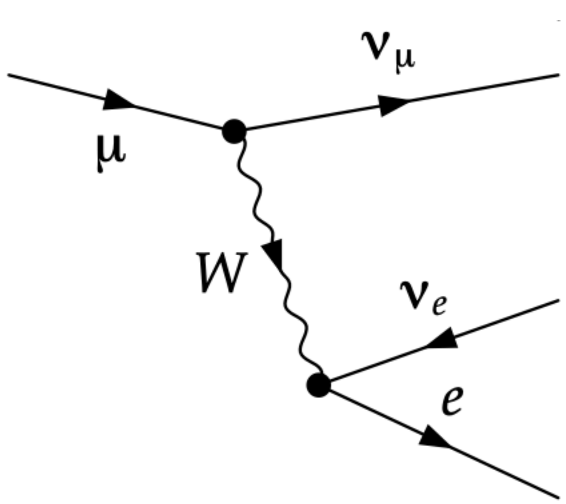
- Well-known $m_W - m_Z$ interdependence:
matching of muon decay width within Fermi model and in the full SM



$$m_W^2\left(1 - \frac{m_W^2}{m_Z^2}\right) = \frac{\pi\alpha}{G_\mu\sqrt{2}}$$

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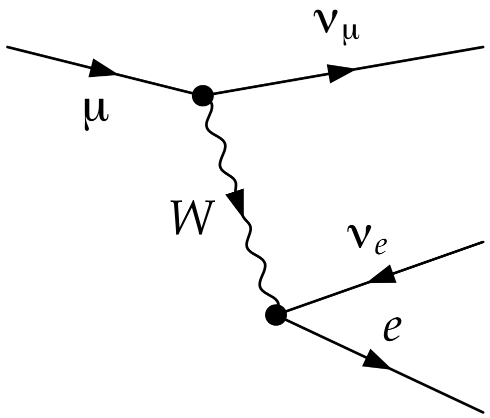
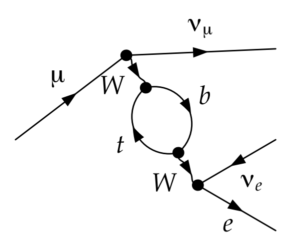
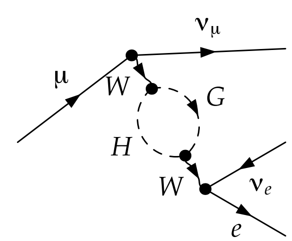
Tree level

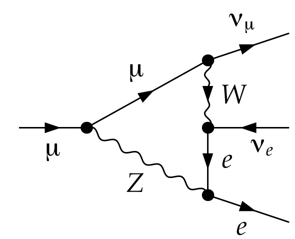


1-loop

+







+ full 2-loop + partial 3- and 4-loop

+ ...

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$\Delta m_W = \mathcal{O}(0.5 \text{ GeV})$

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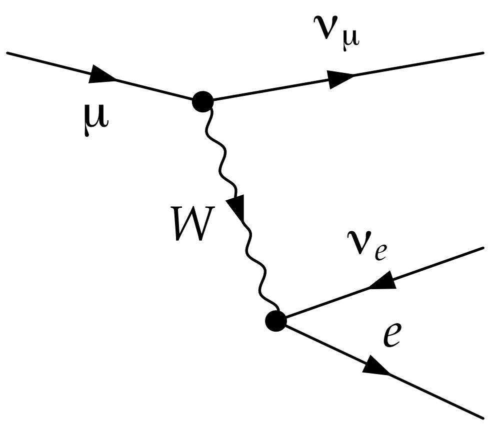

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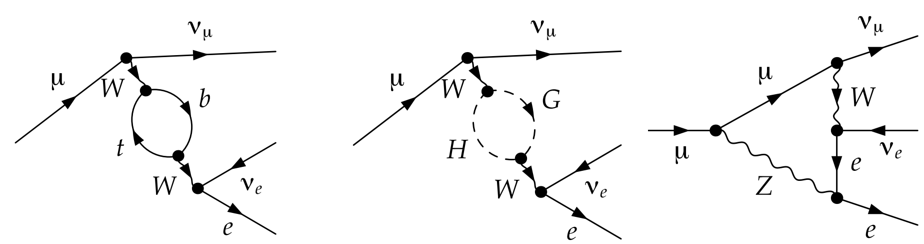

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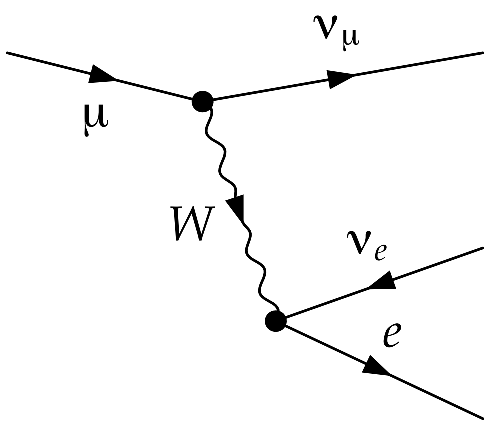

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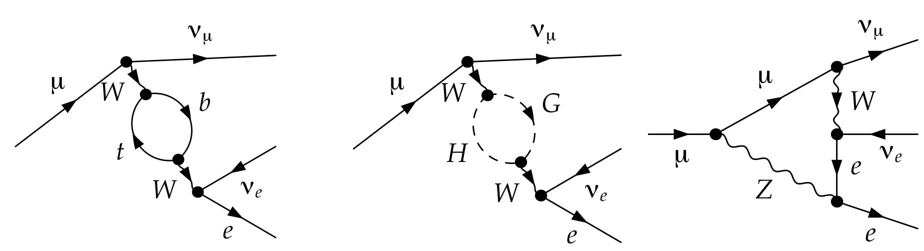

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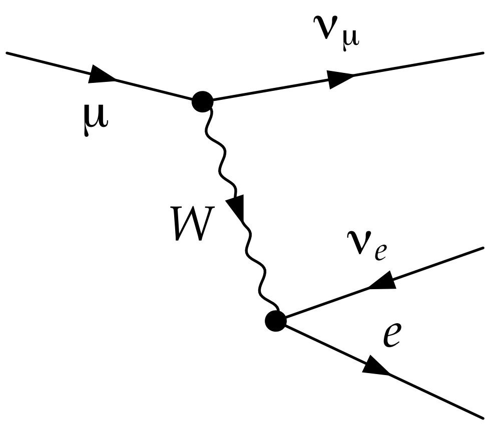

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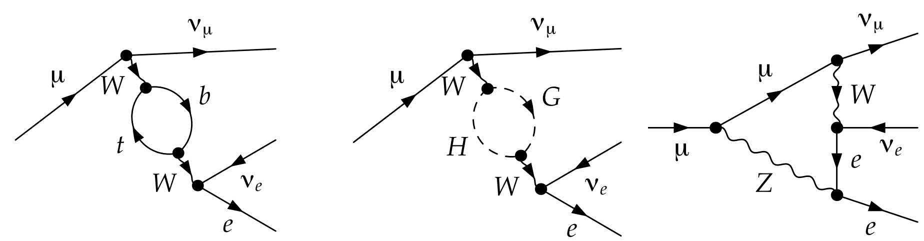

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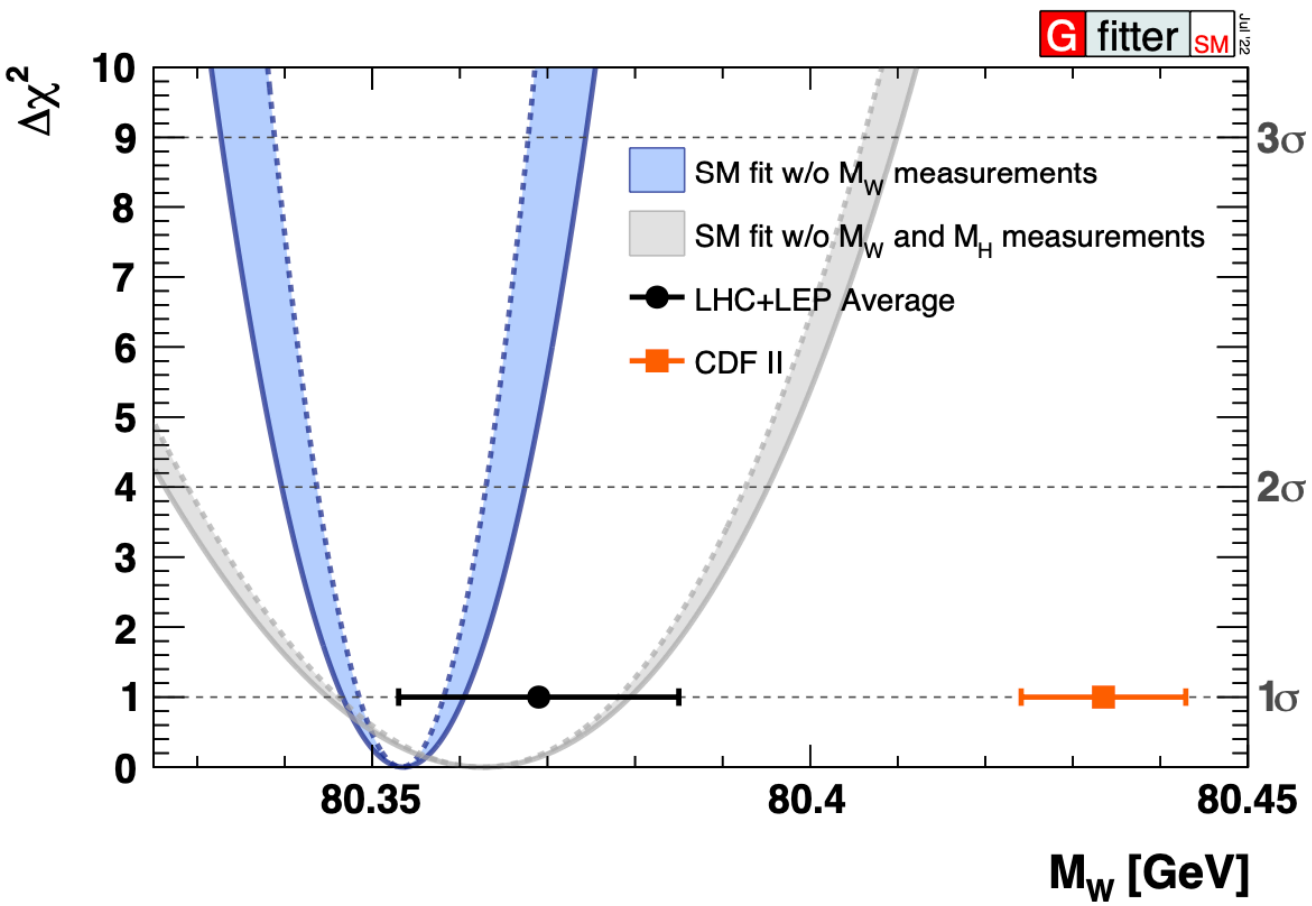

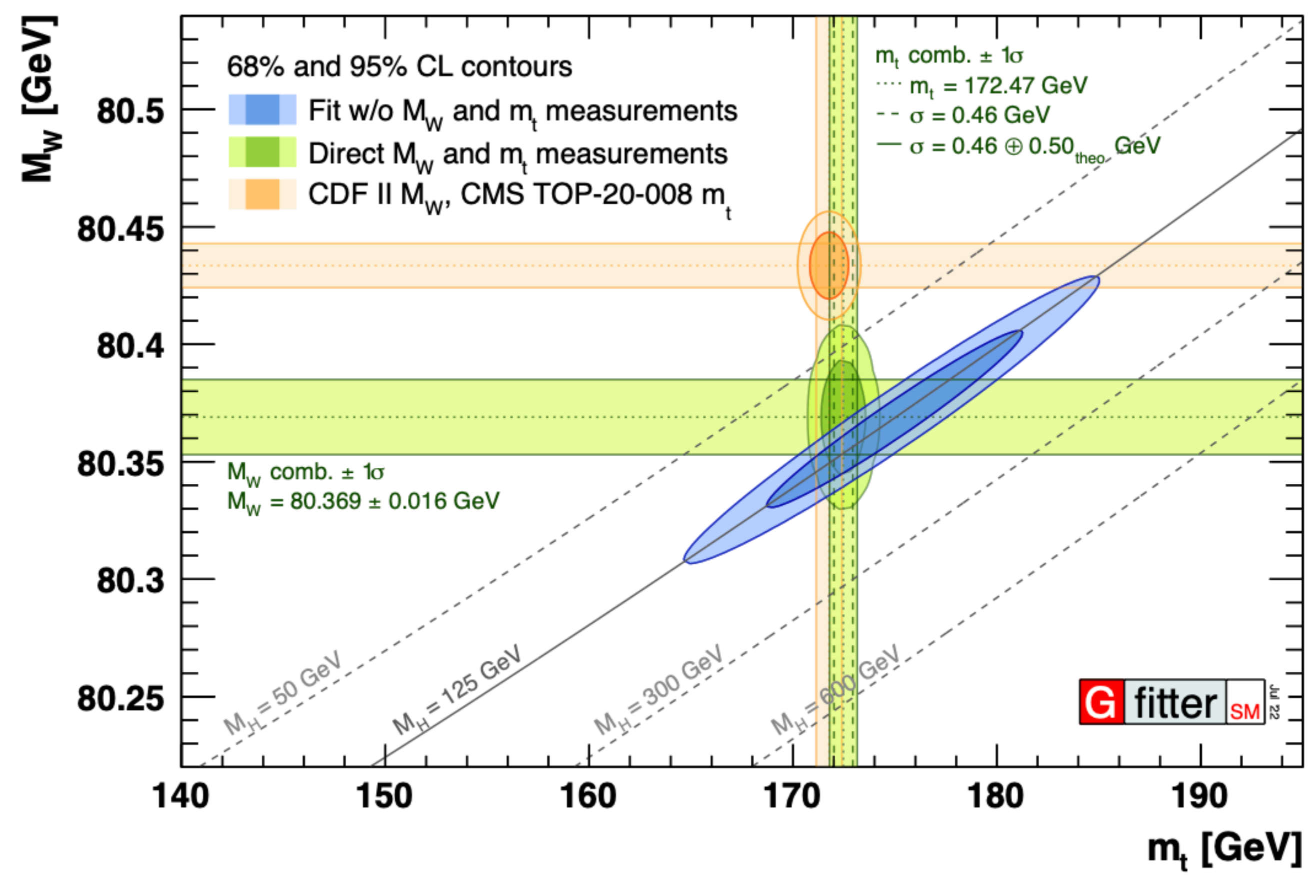

Indirect determination

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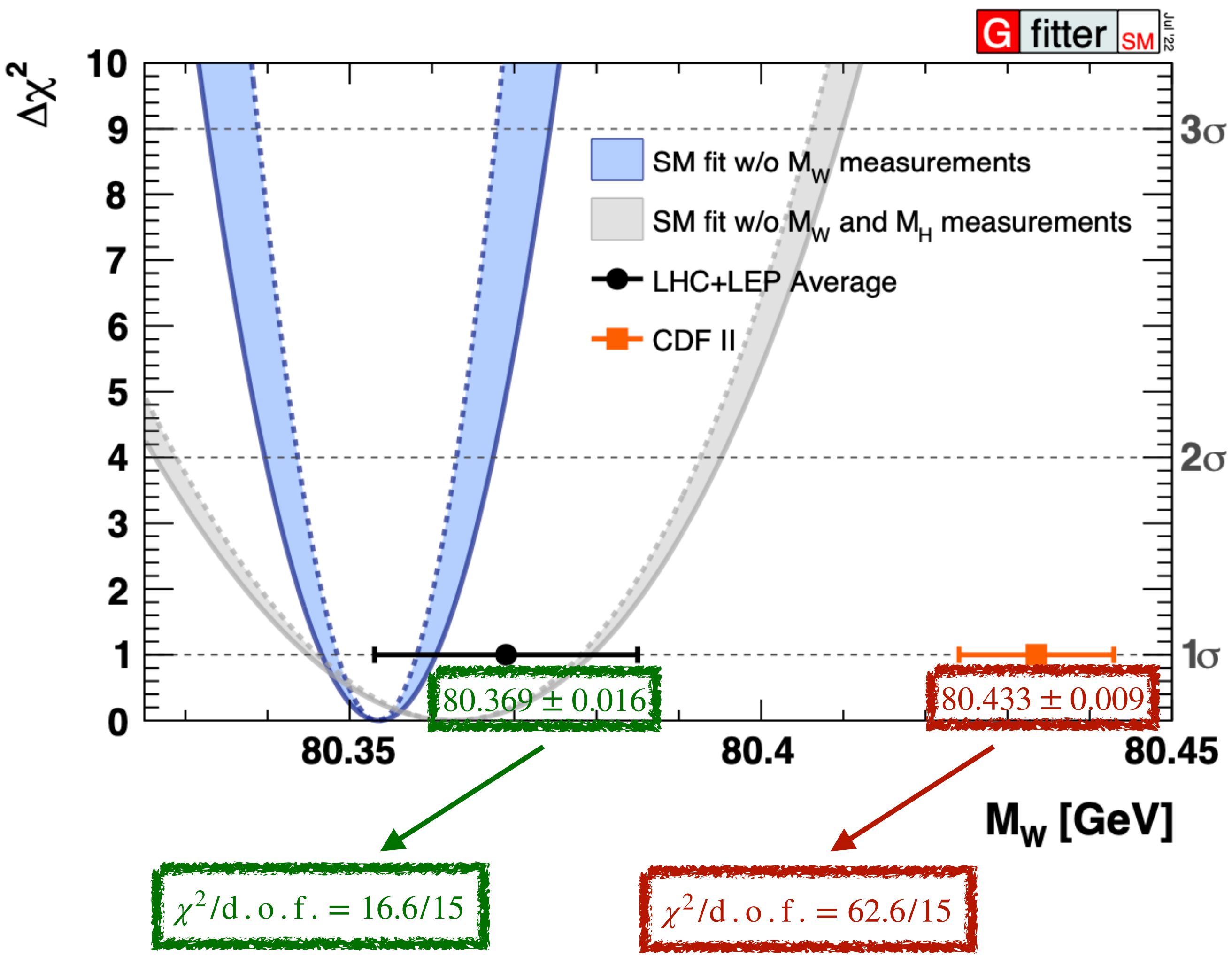

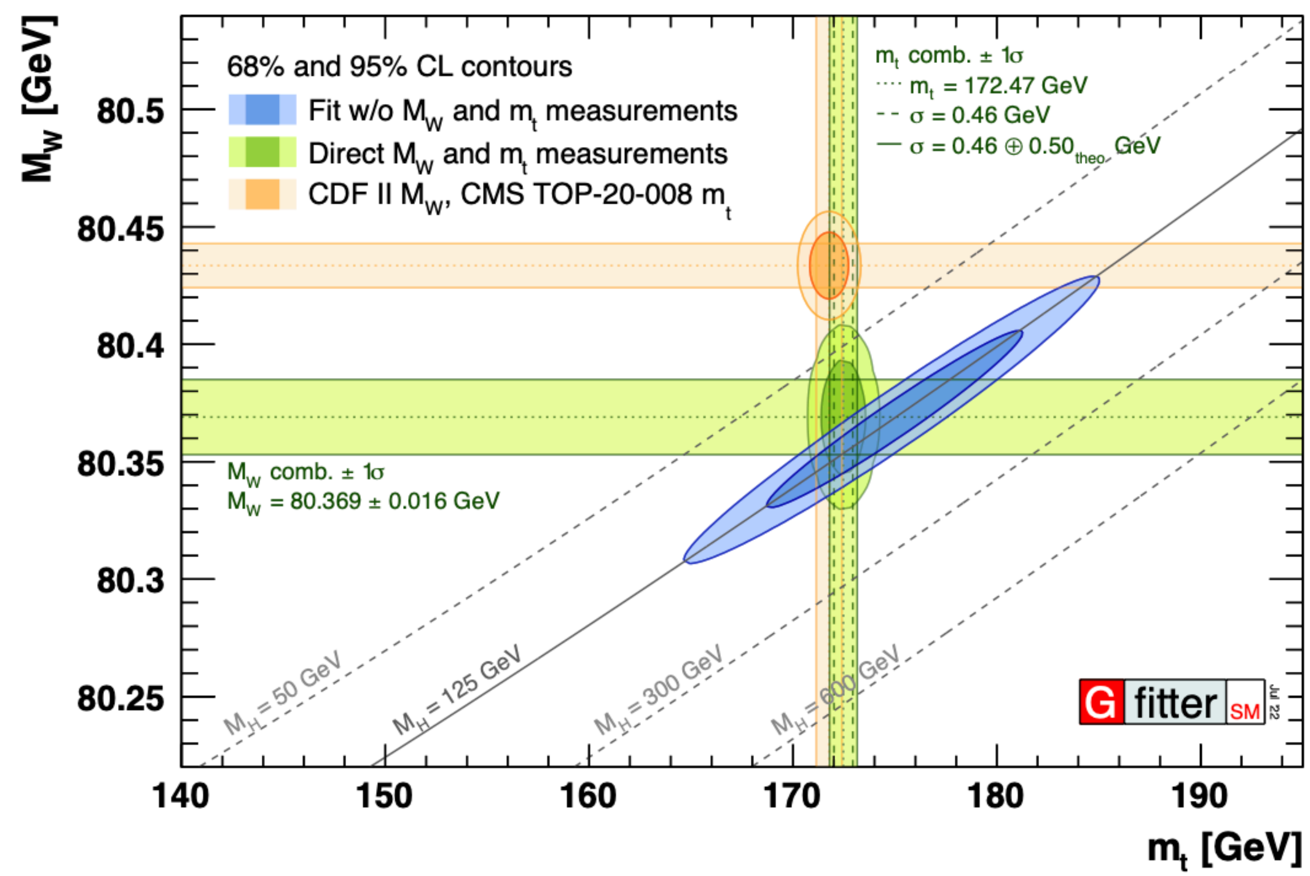

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- Measurement performed in leptonic decays only (overwhelming multi-jet bkg)
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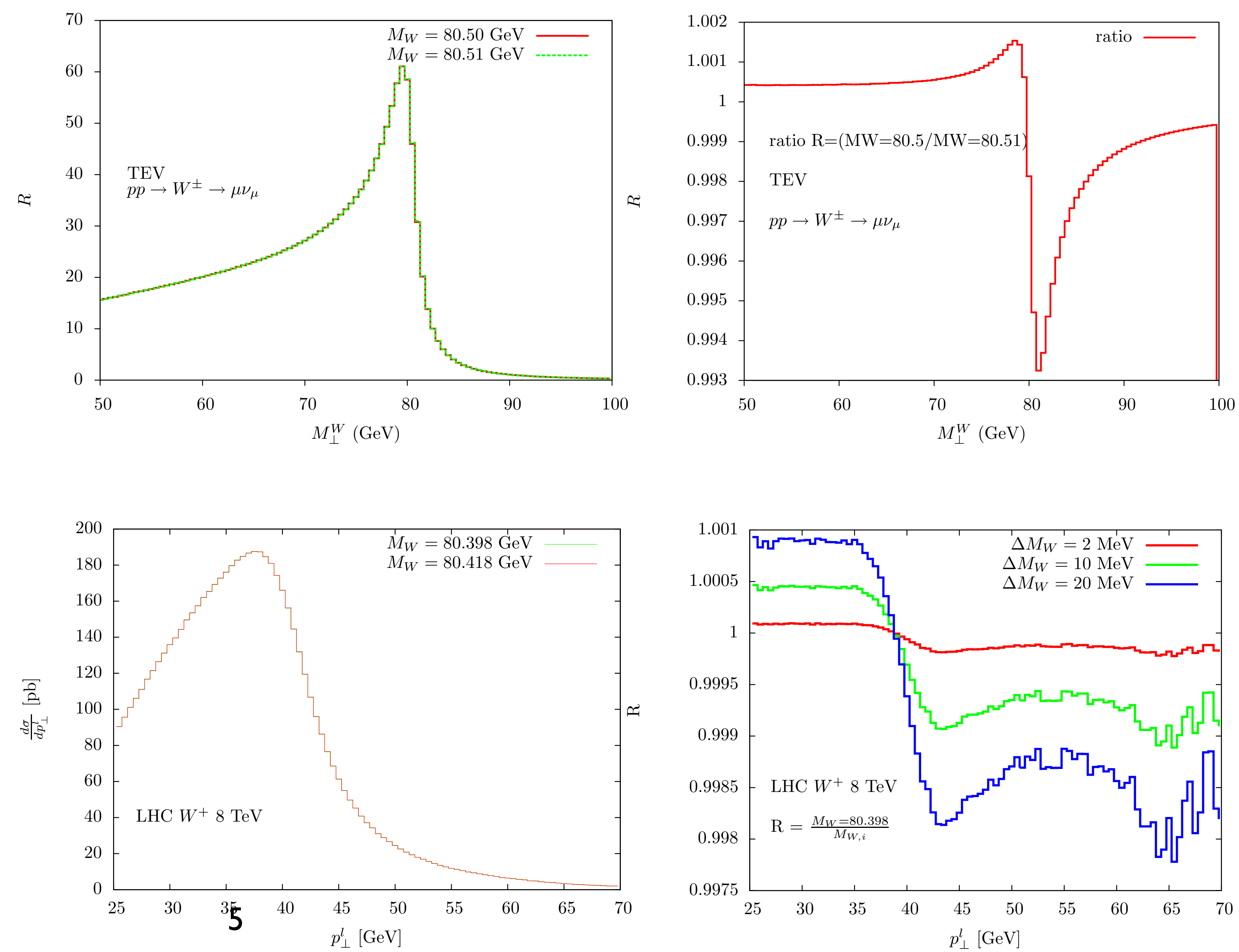

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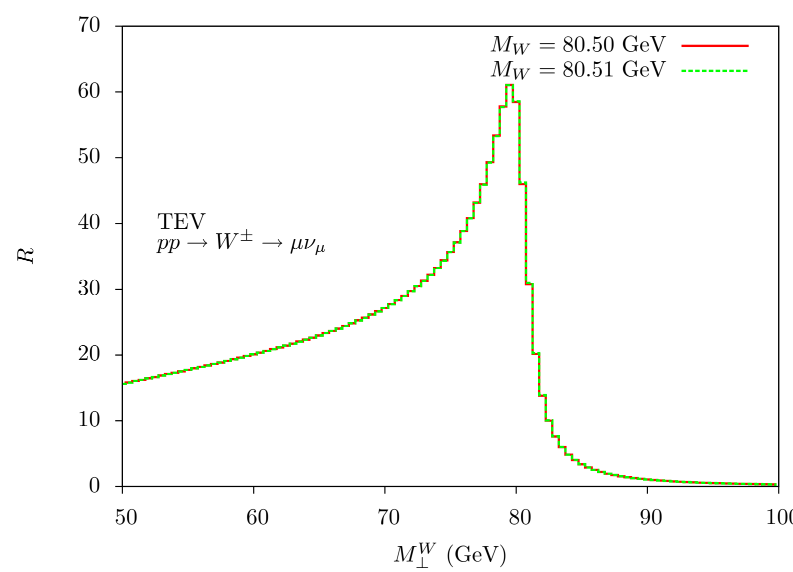

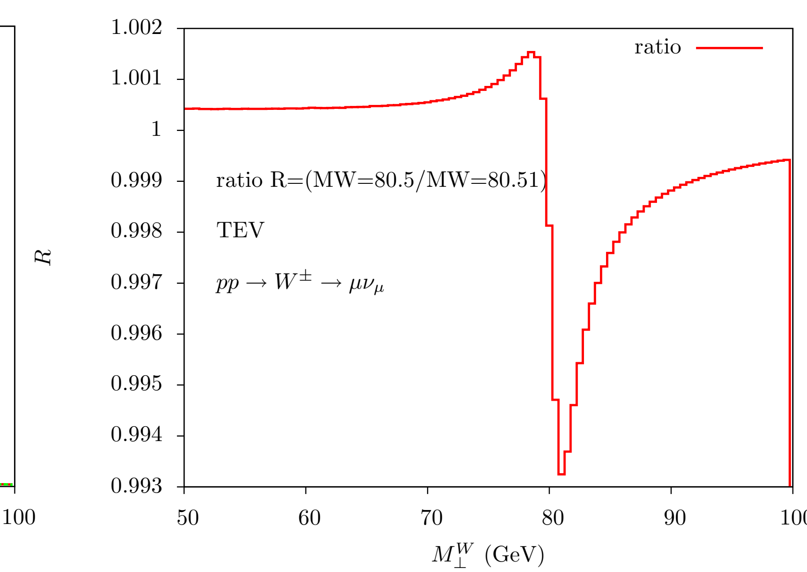

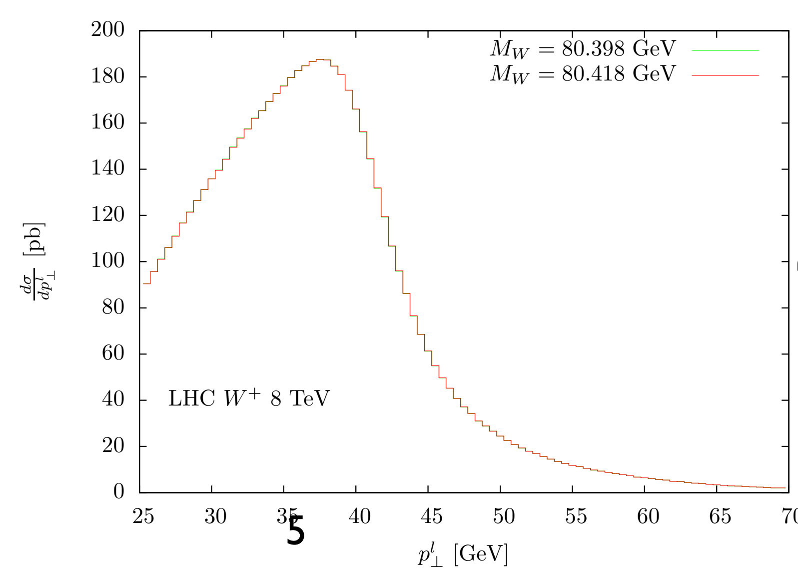

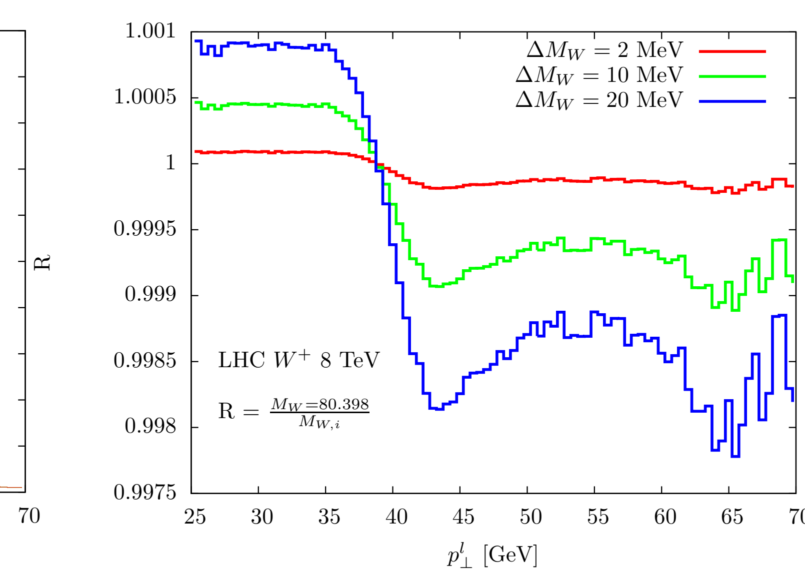

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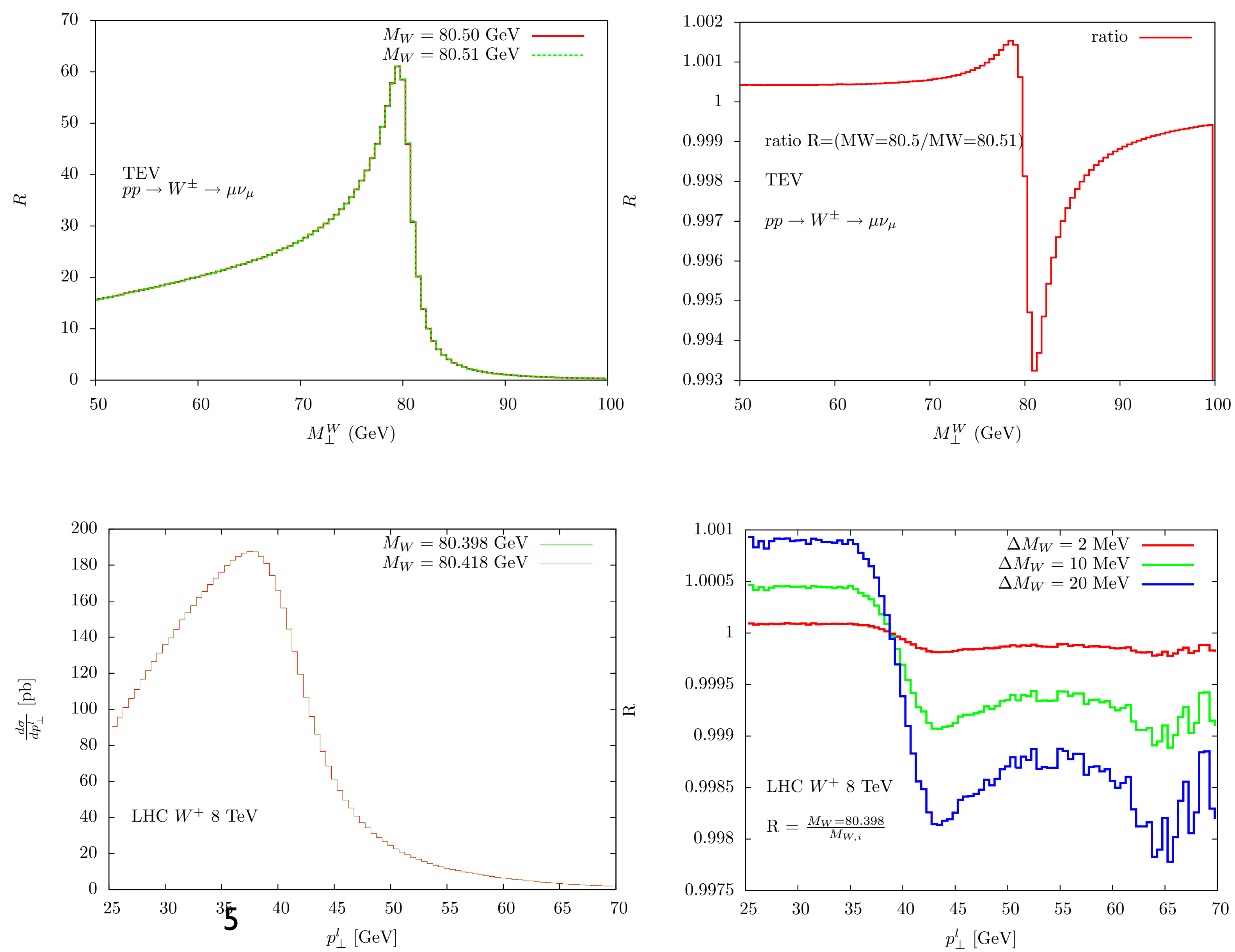

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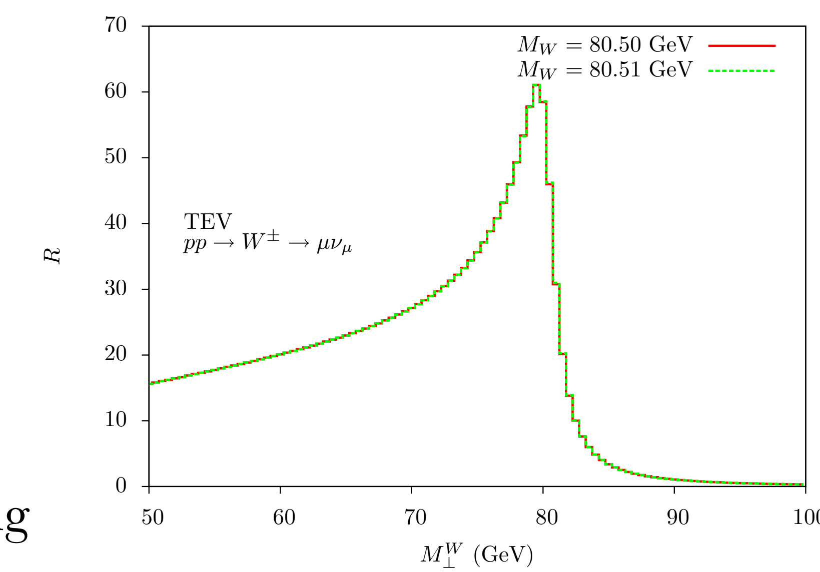

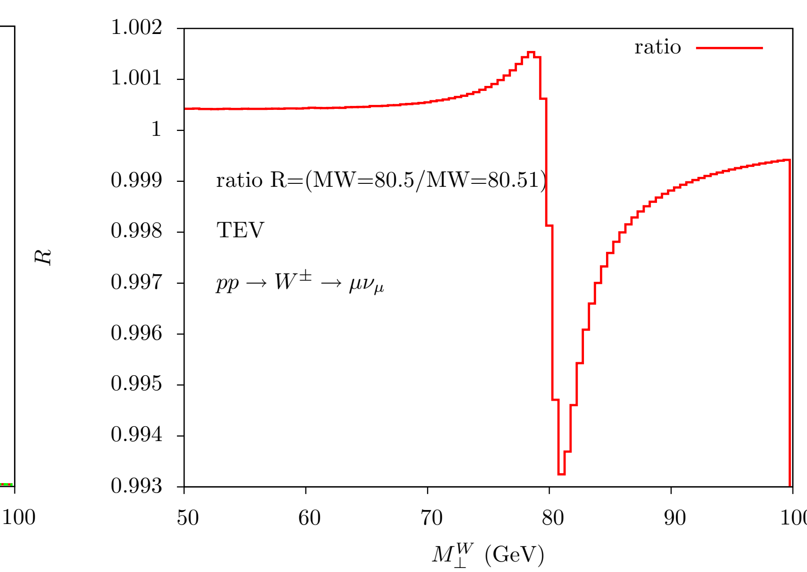

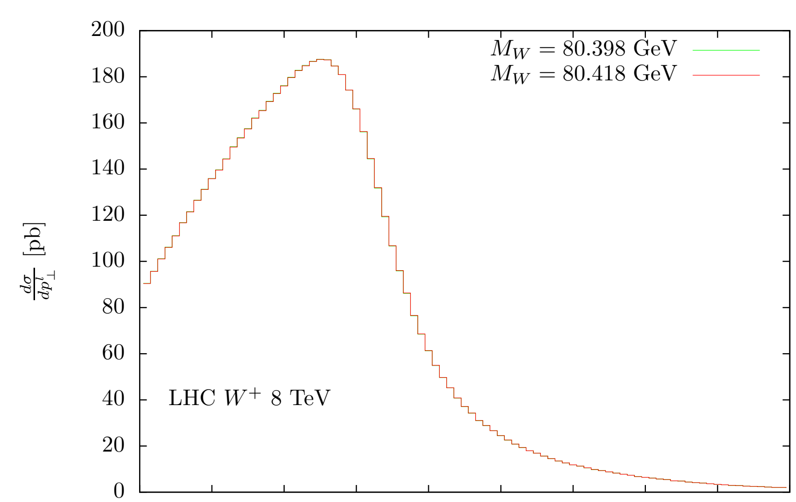

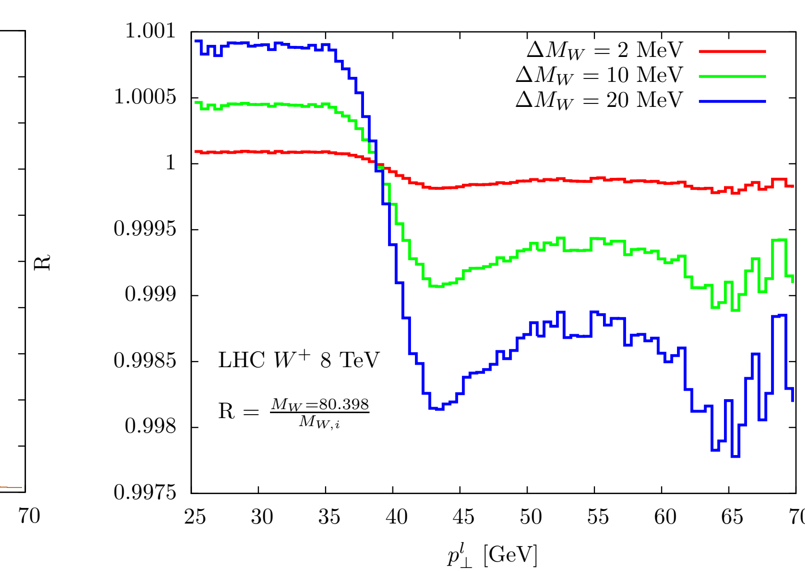

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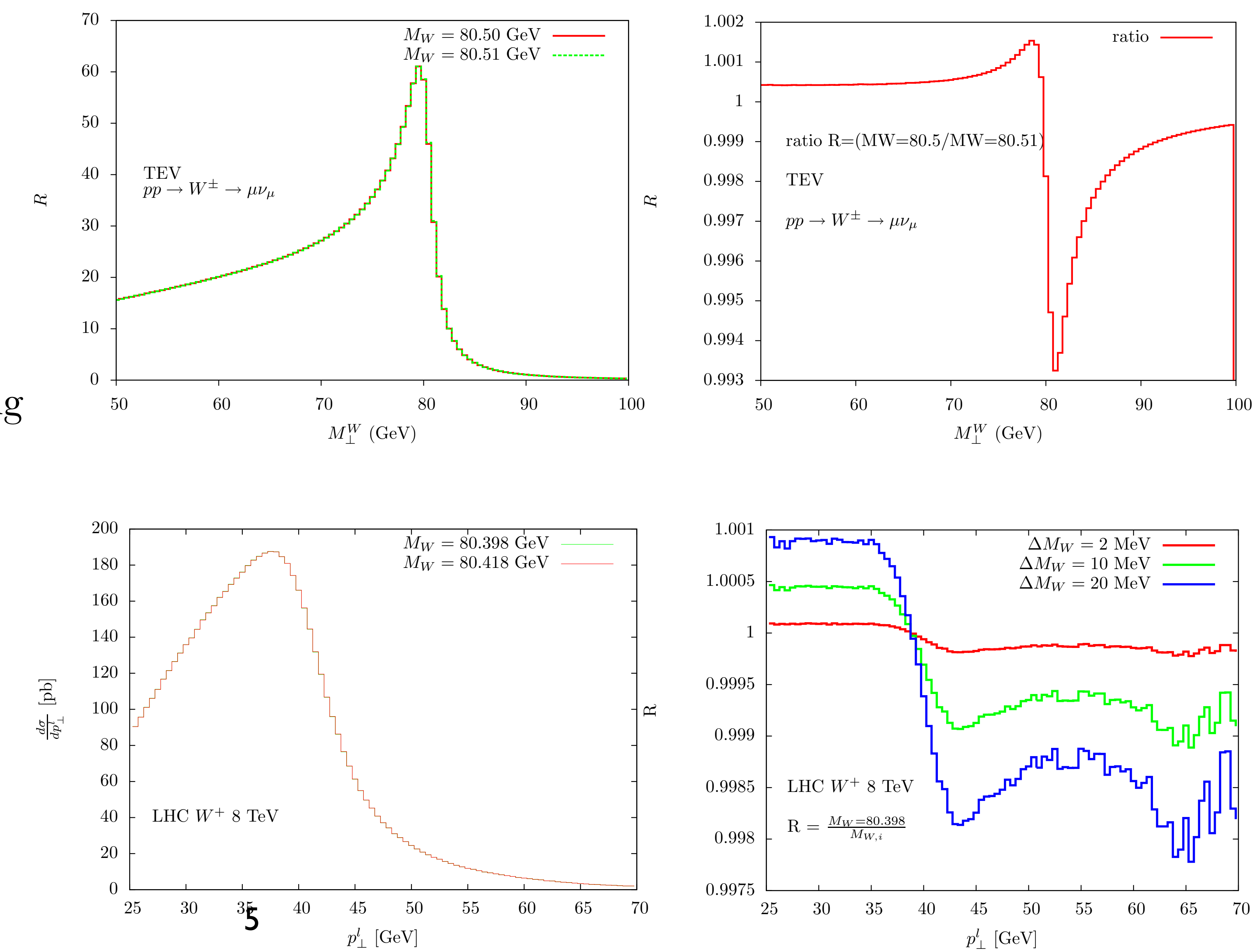

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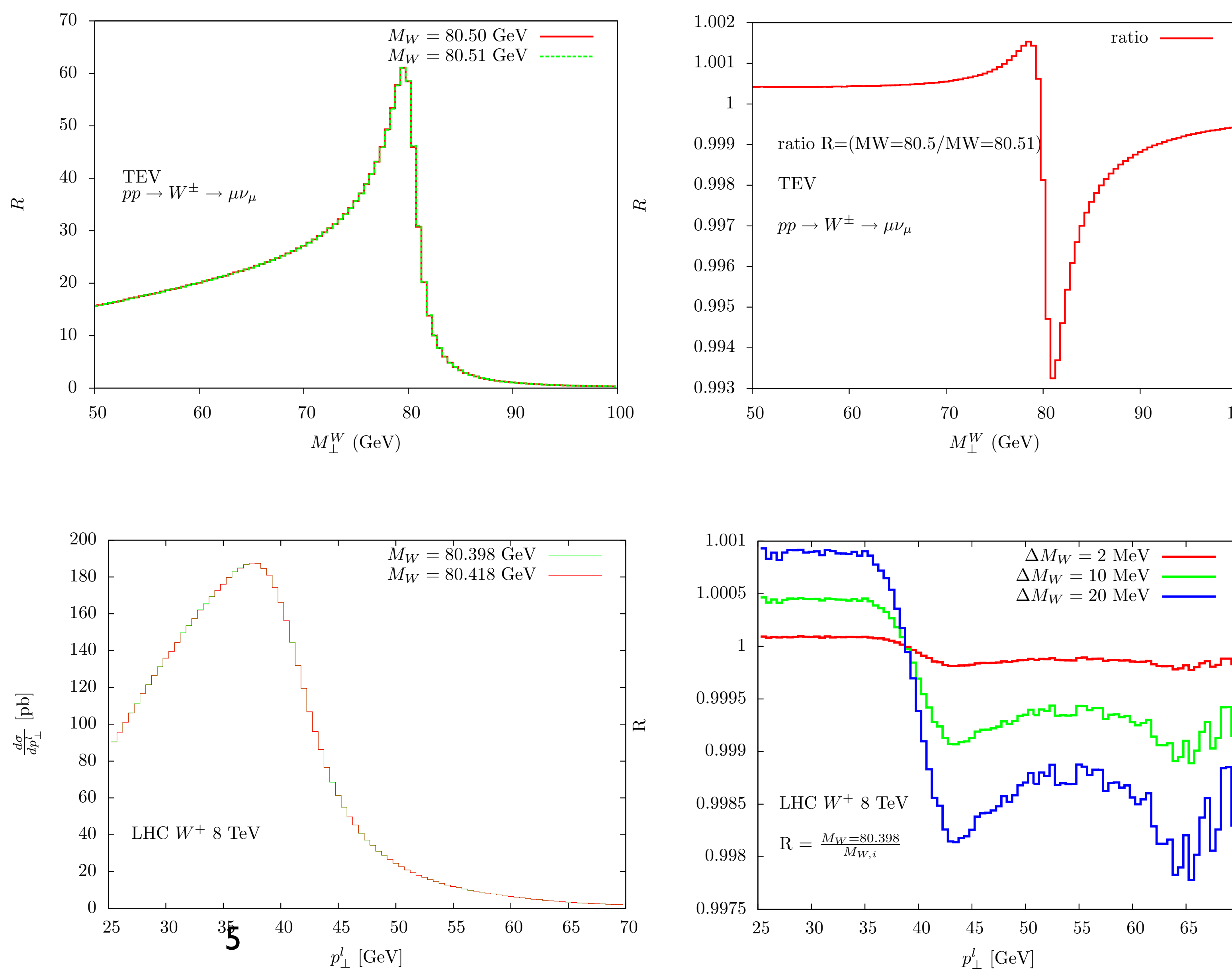

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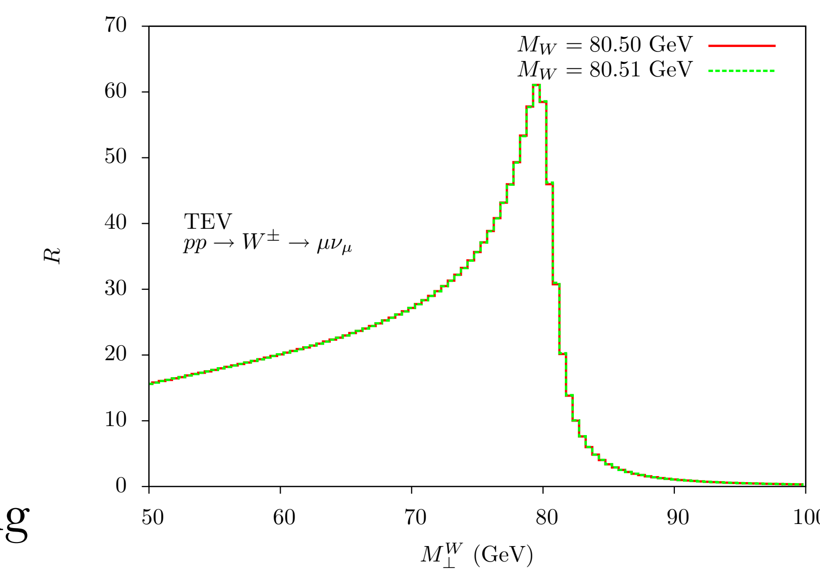

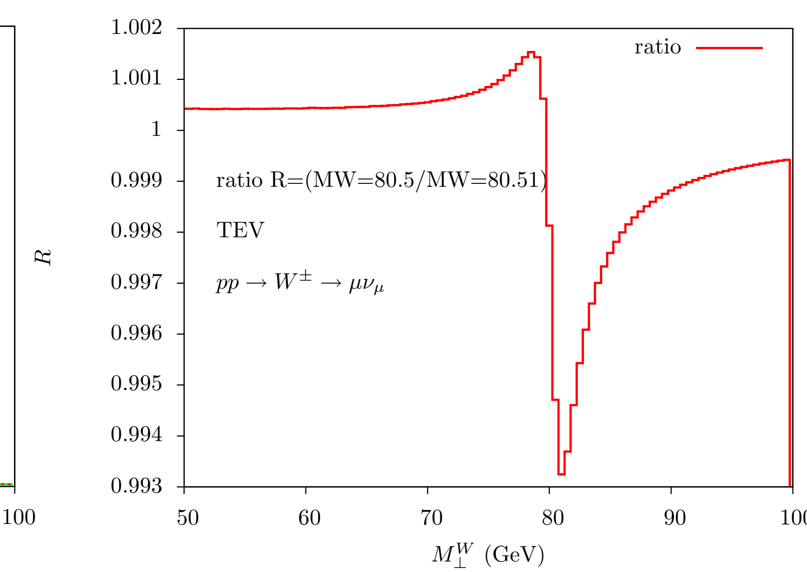

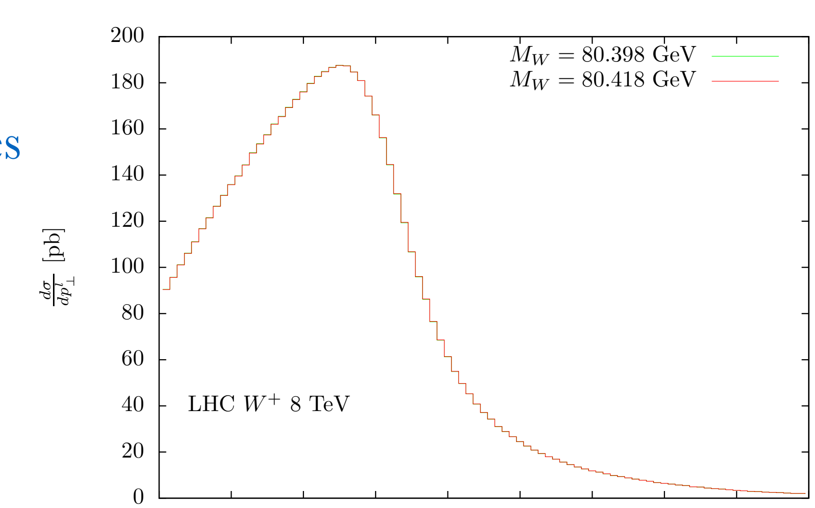

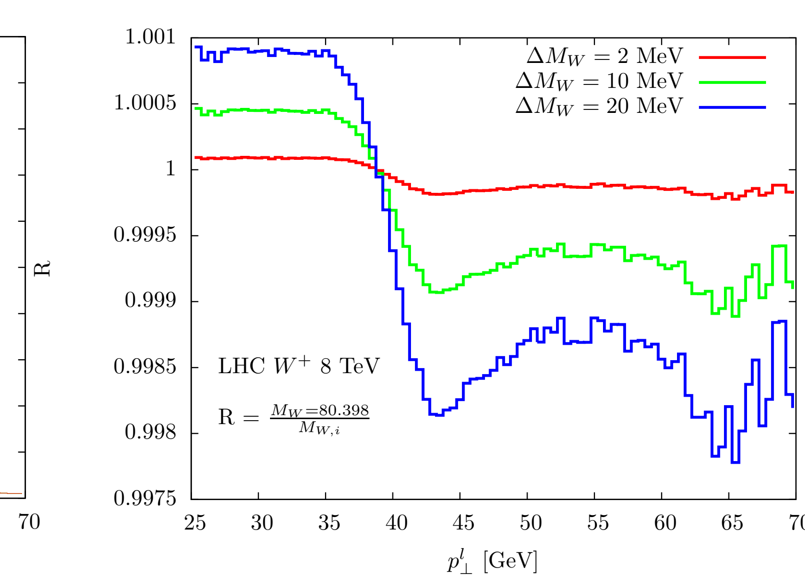

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determination at 10^{-4} level requires control of the shape at permille level

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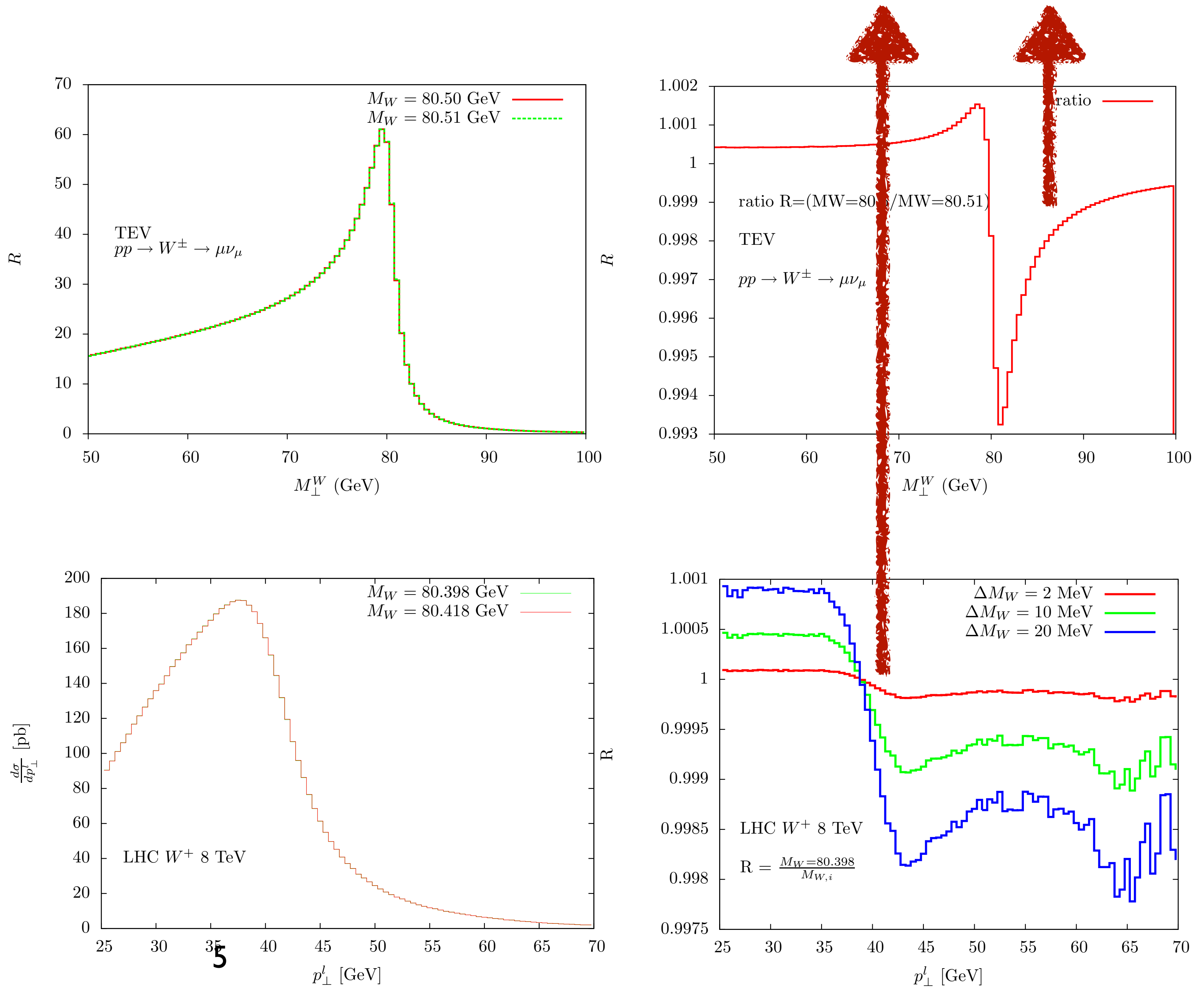

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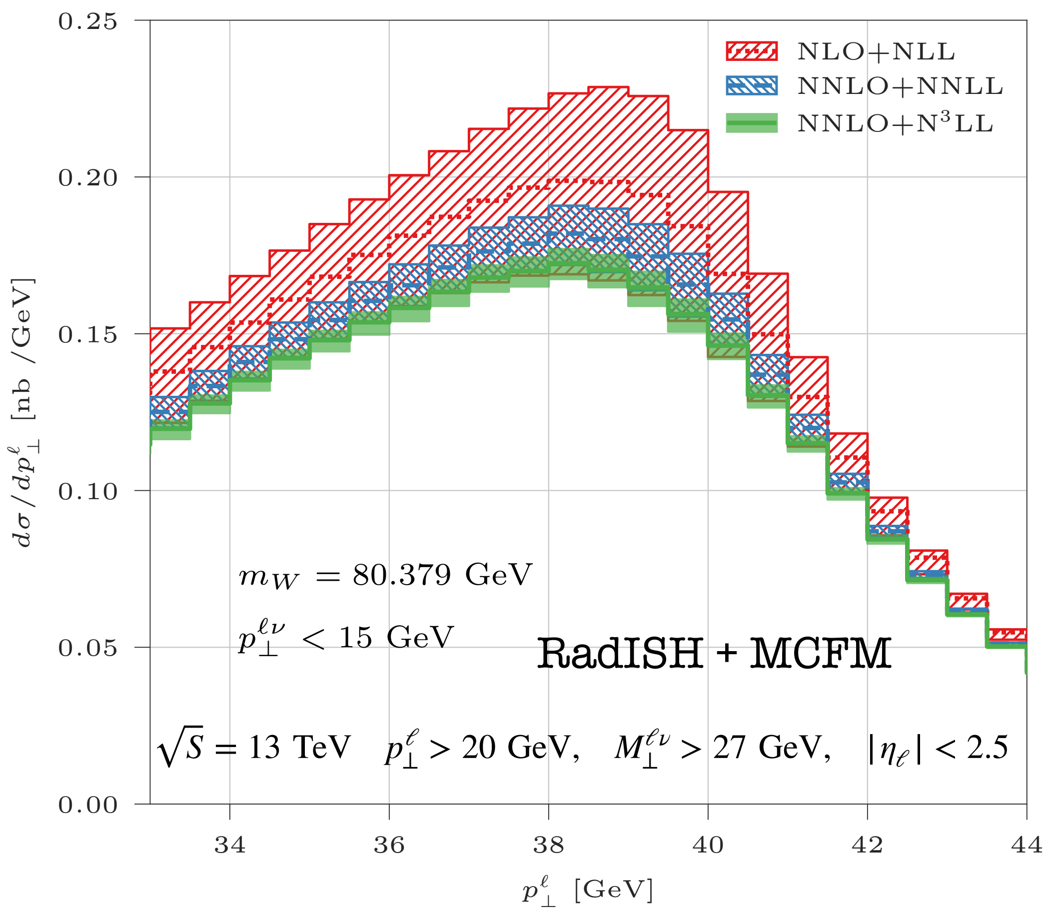

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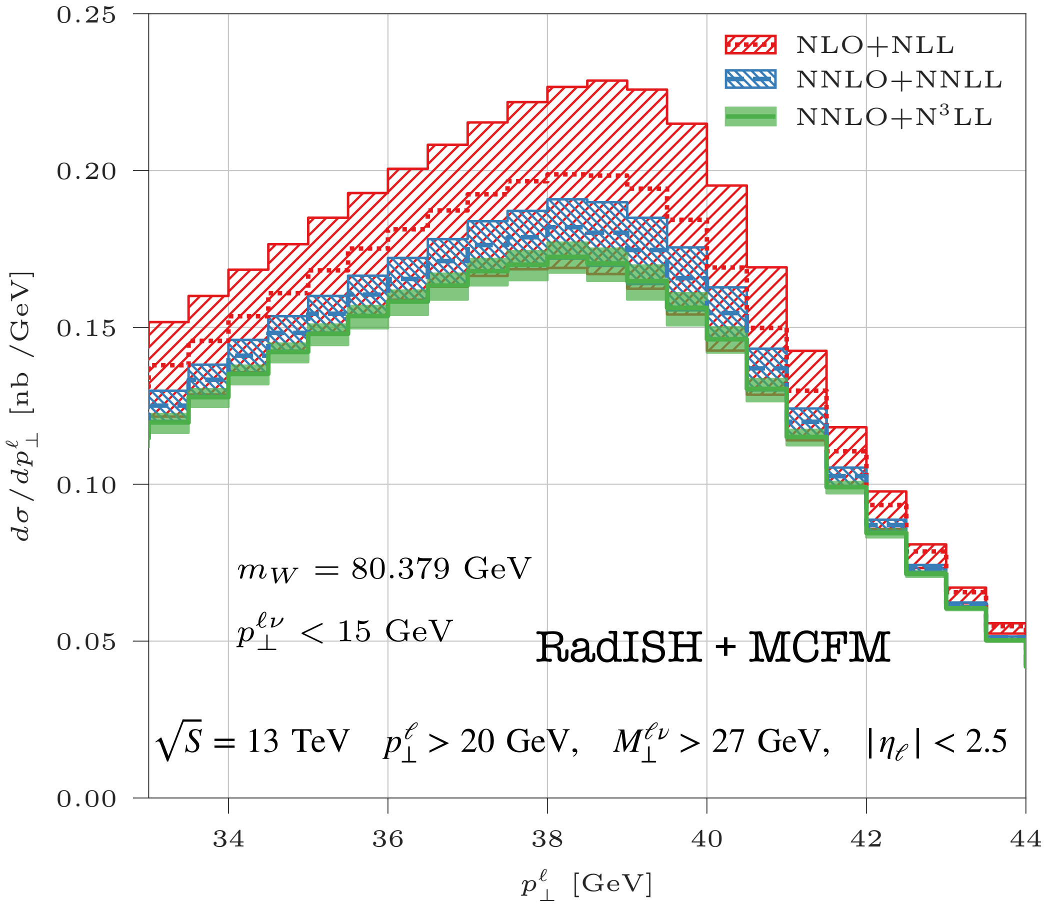

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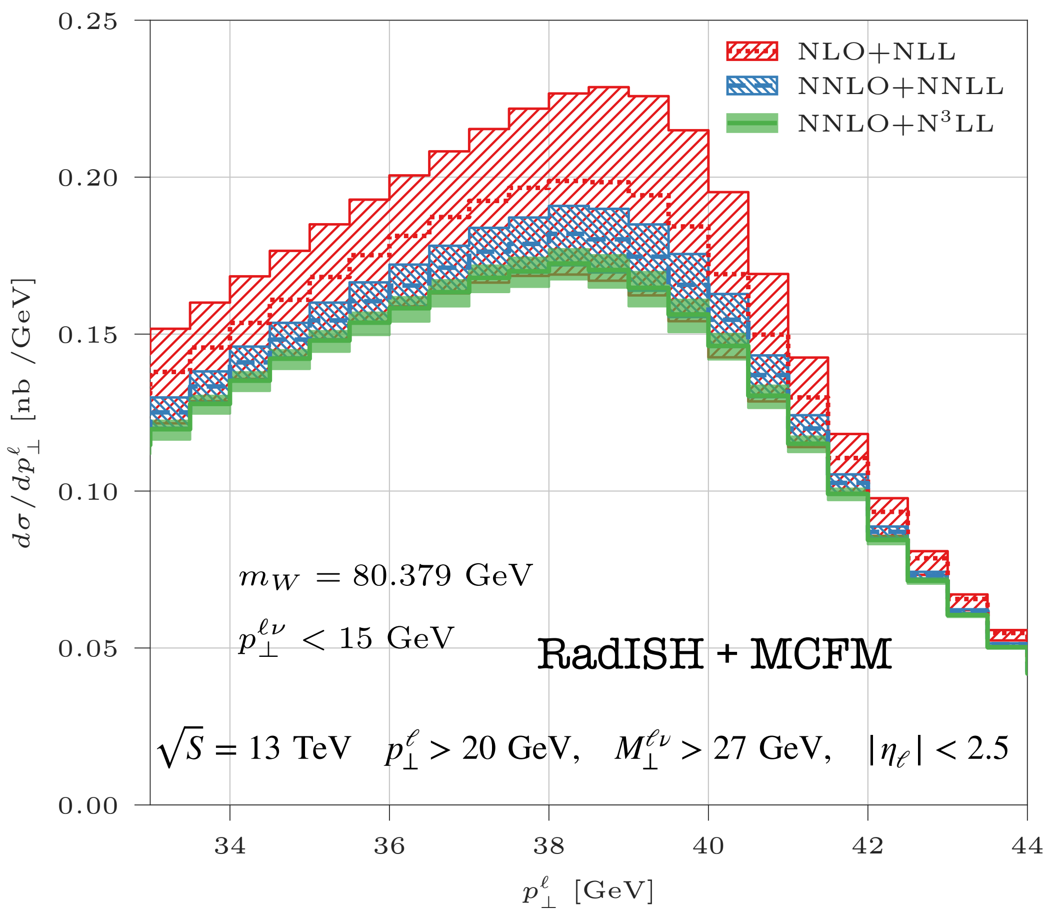

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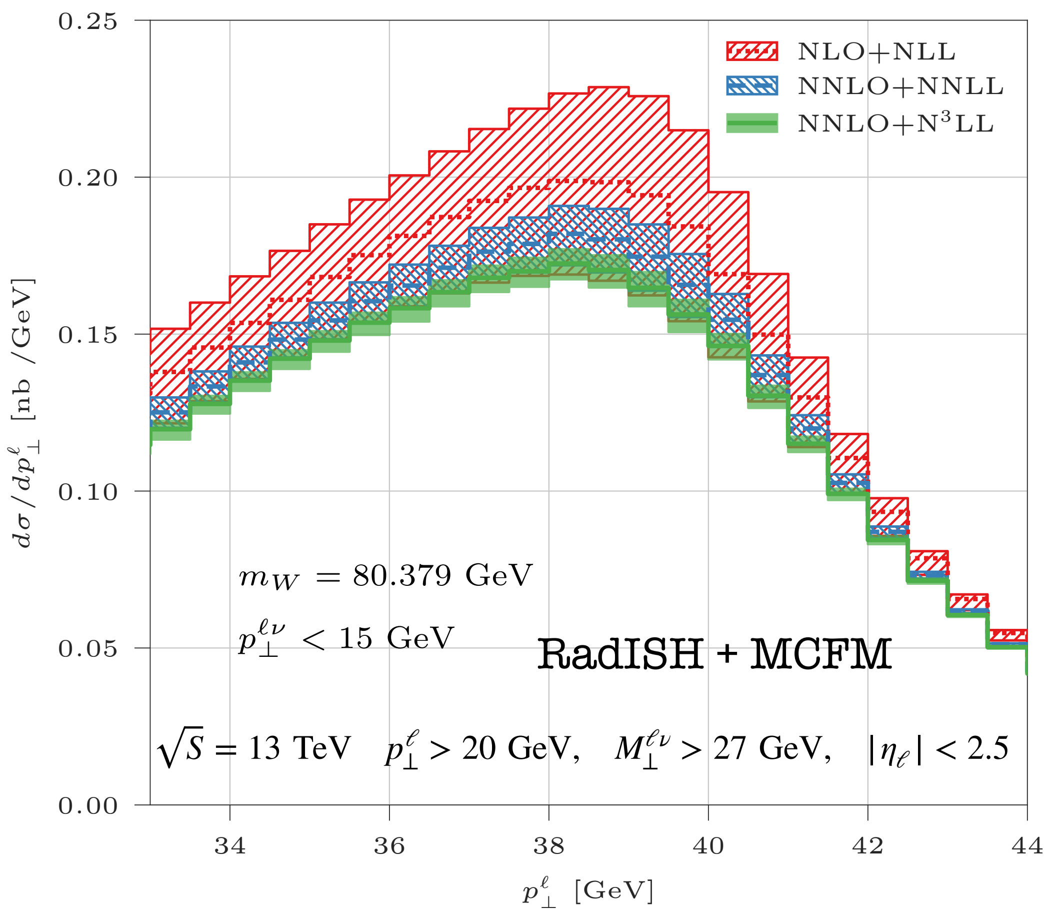

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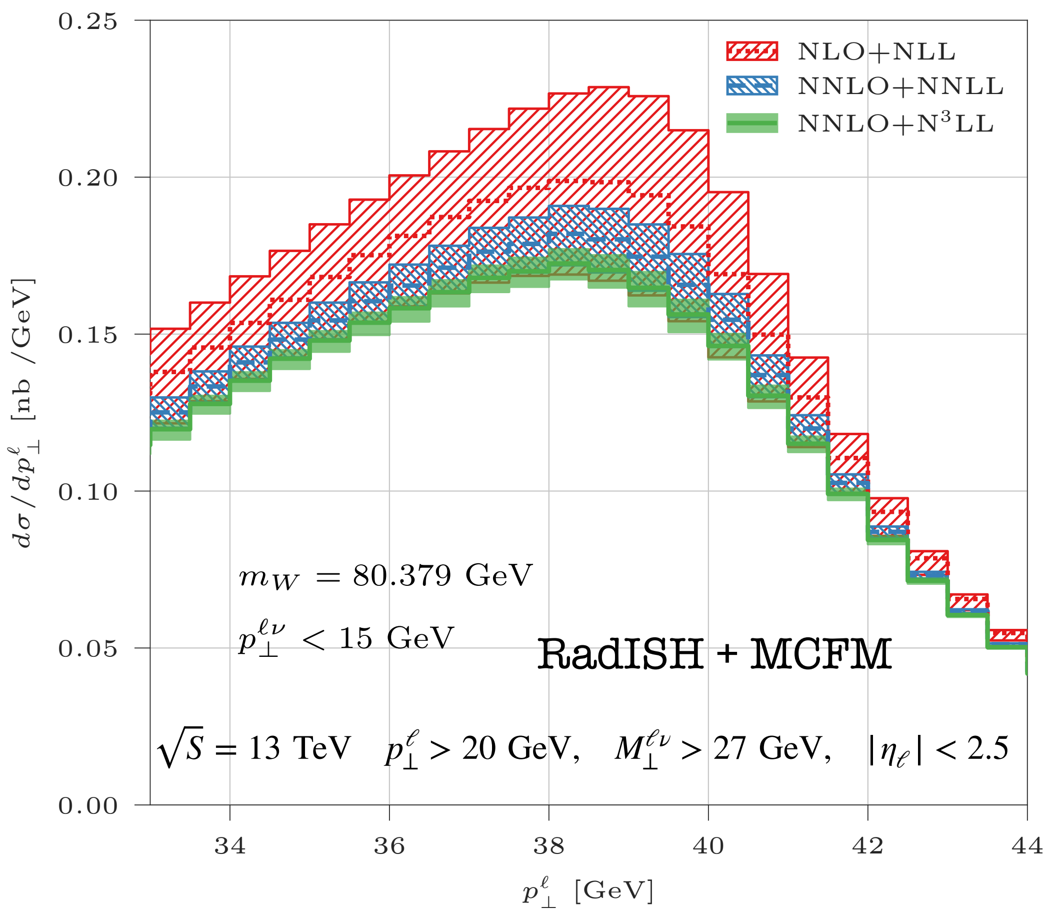

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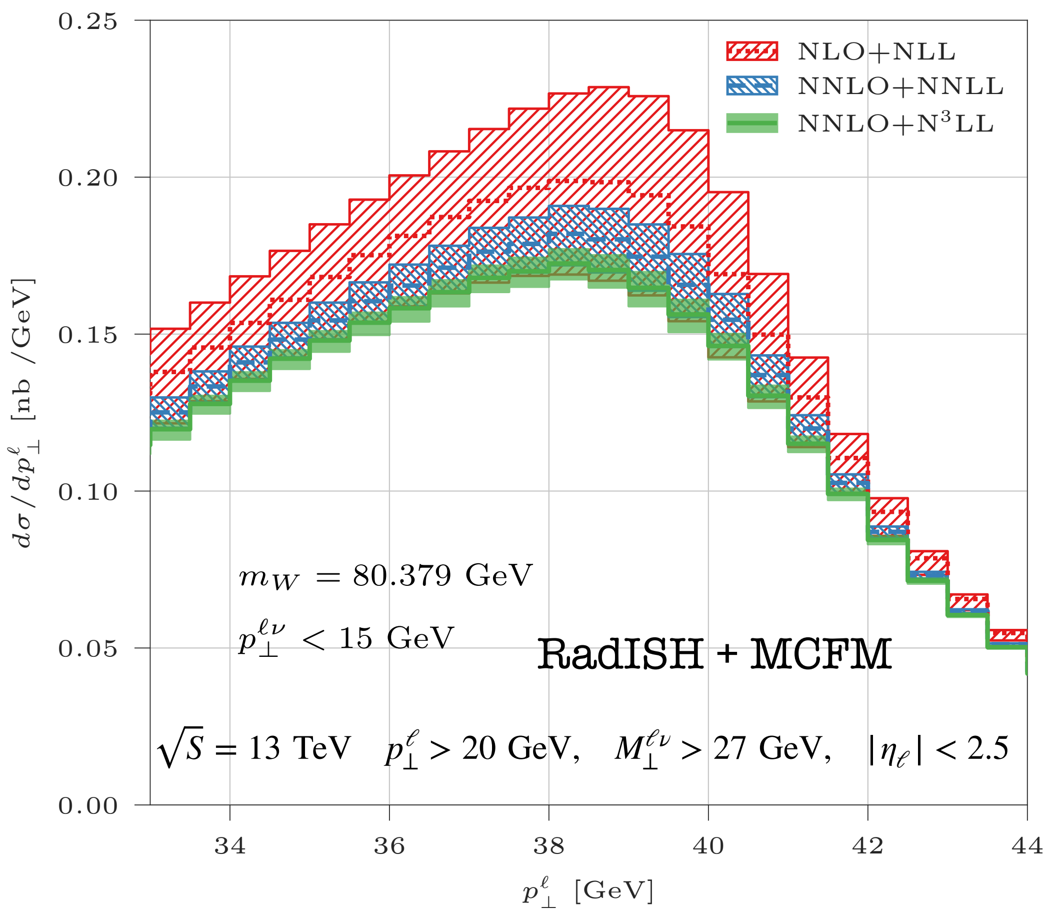

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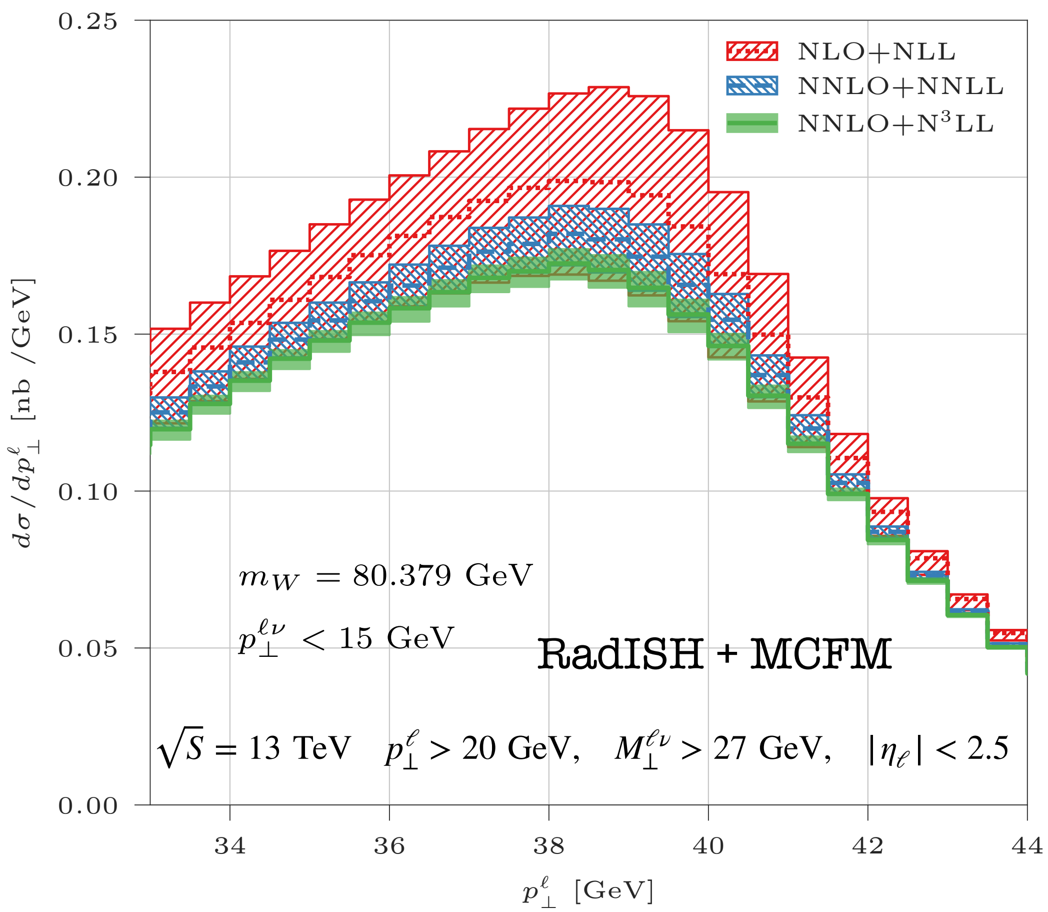

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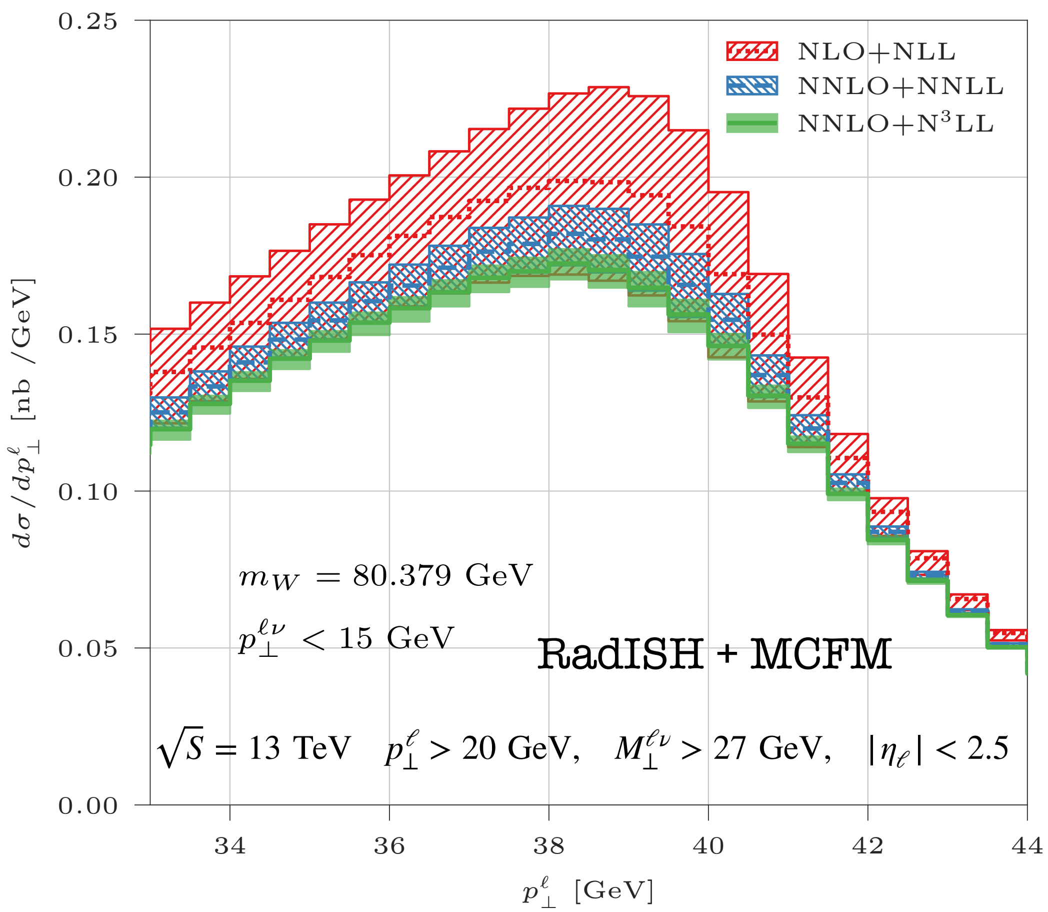
Perturbative uncertainties



- QCD scale variation
  - set of equally good templates
  - $\mathcal{O}(1\%)$ width → 10x larger than required!
- Non-statistical nature of Th Sys → not included in χ^2 covariance matrix
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➡ data-driven approach: MC tuned to NCDY data (typically for single QCD scale choice) and used to prepare CCDY templates

- Comments on data-driven approach
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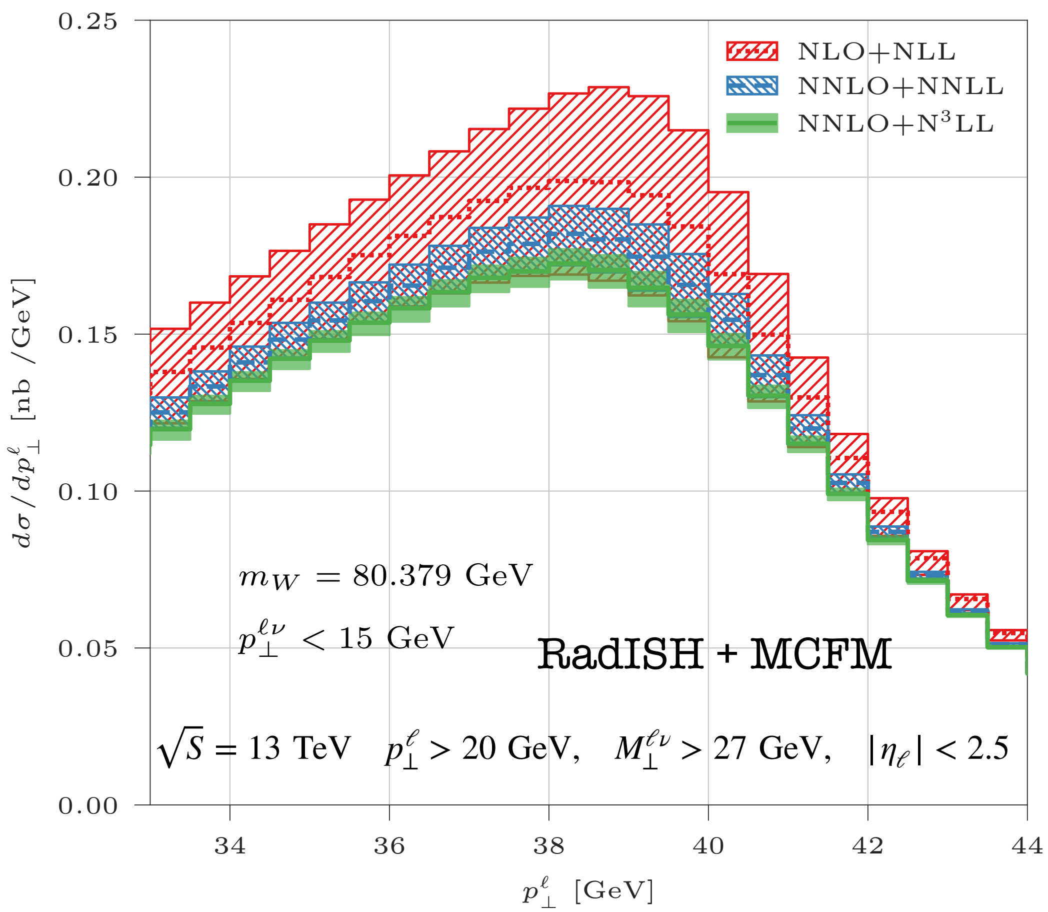

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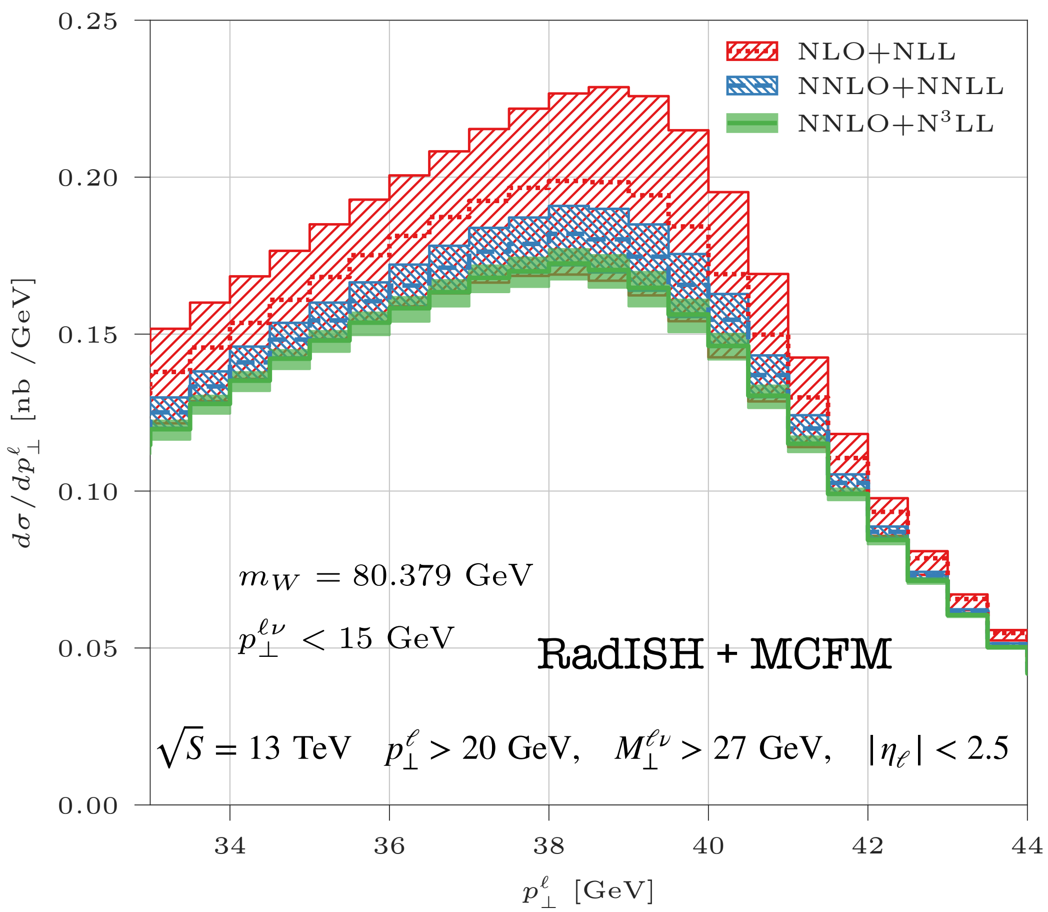

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  - fitted value not necessarily the SM lagrangian parameter

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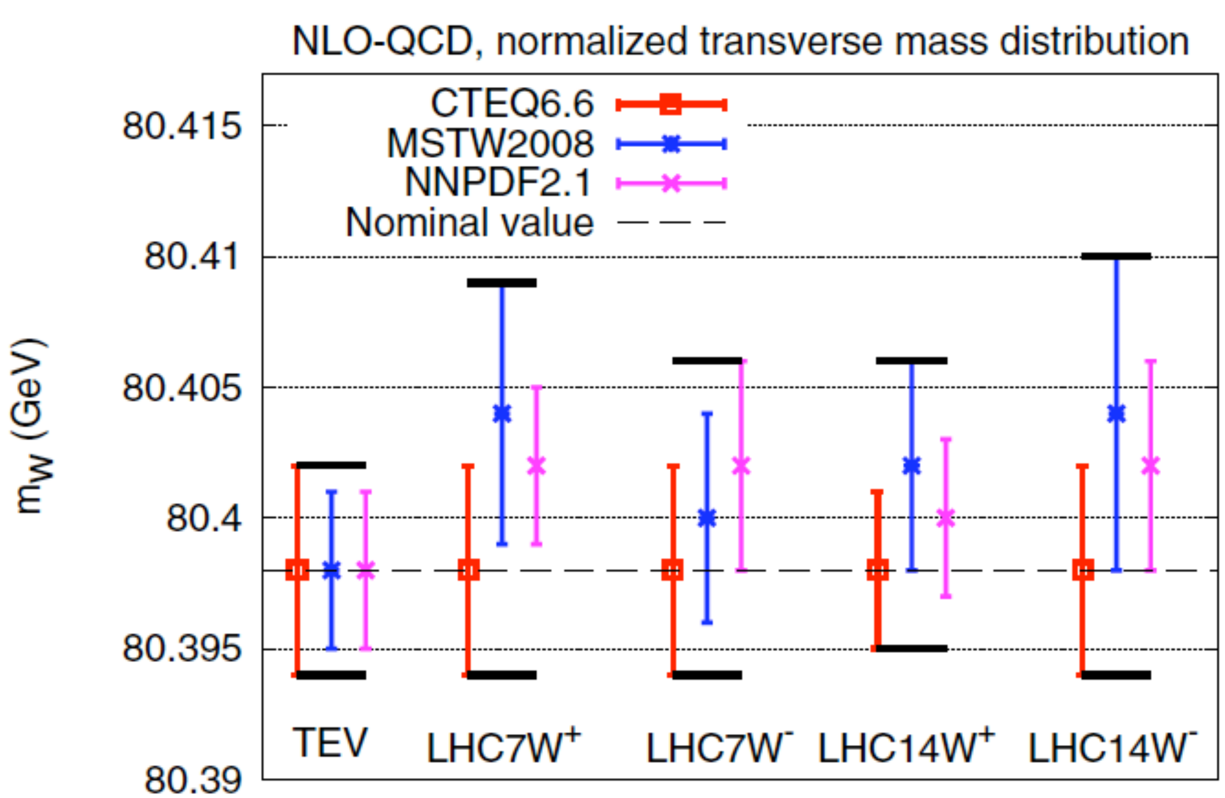

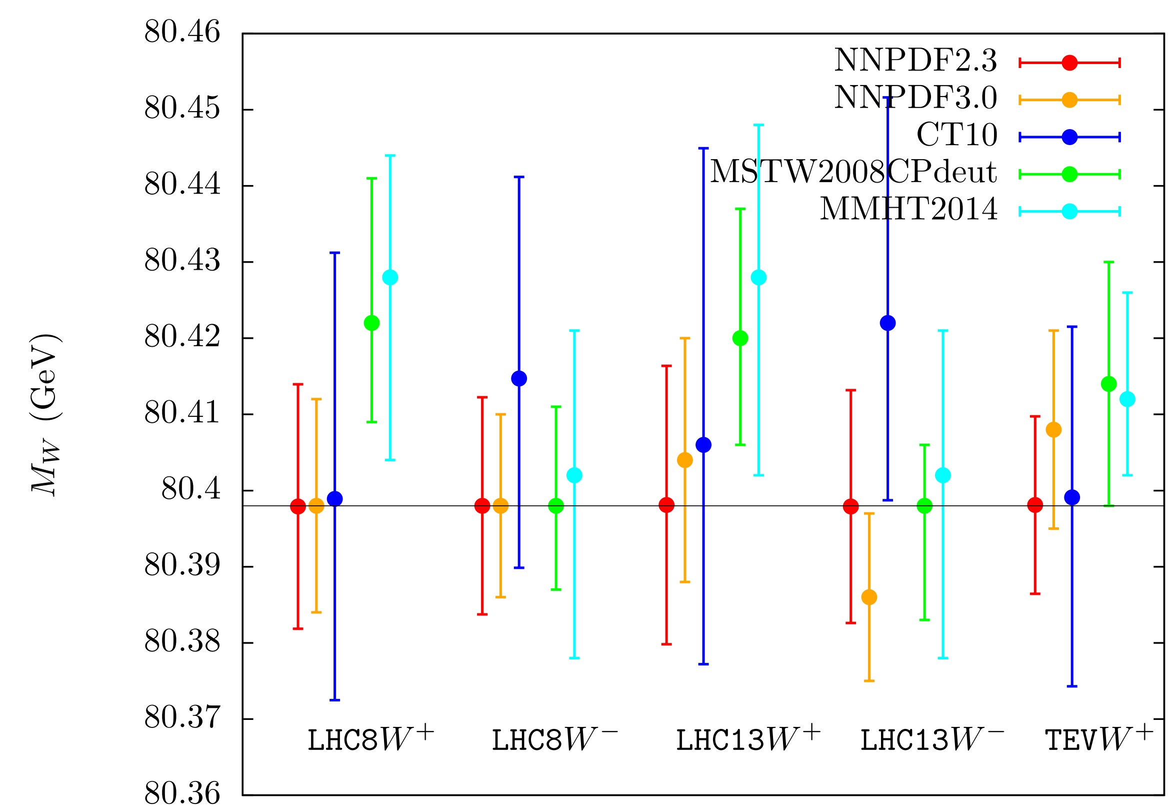

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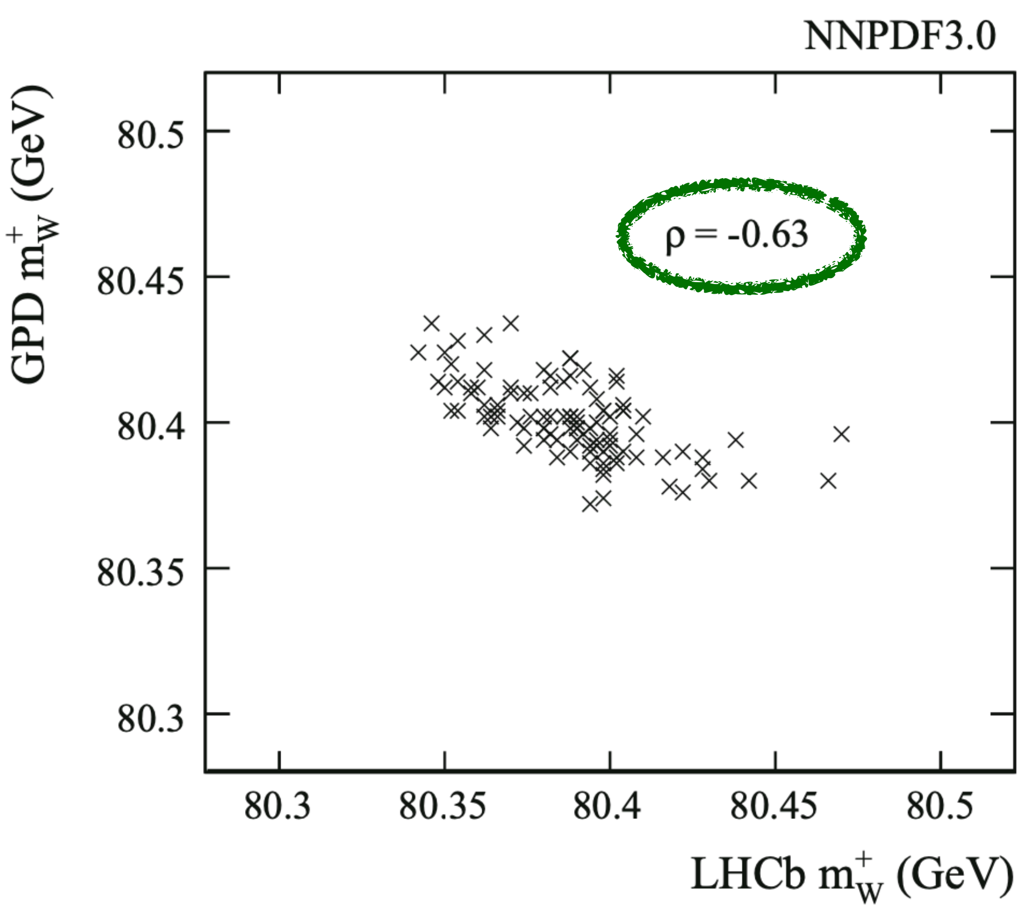

Fitted m_W in ATLAS/CMS vs. LHCb

PDFs	Experiments	δ_{PDF}
PDF4LHC(2-sets)	$2 \times$ GPD	10.5
PDF4LHC(2-sets)	$2 \times$ GPD + LHCb	7.7
PDF4LHC(3-sets)	$2 \times$ GPD	16.9
PDF4LHC(3-sets)	$2 \times$ GPD + LHCb	12.7
NNPDF30	$2 \times$ GPD	5.2
NNPDF30	$2 \times$ GPD + LHCb	3.6
MMHT2014	$2 \times$ GPD	9.2
MMHT2014	$2 \times$ GPD + LHCb	4.6
CT10	$2 \times$ GPD	11.6
CT10	$2 \times$ GPD + LHCb	6.3

Considerable reduction of PDF uncertainty when combining measurements!

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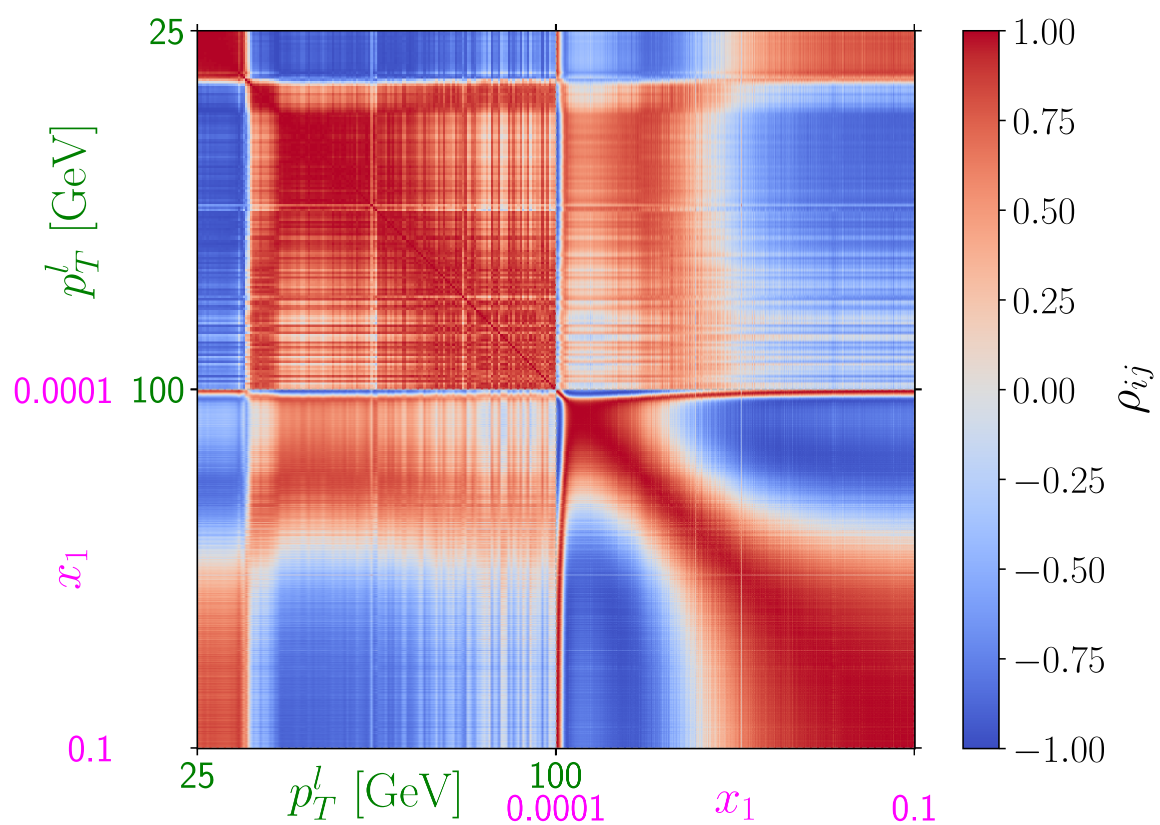

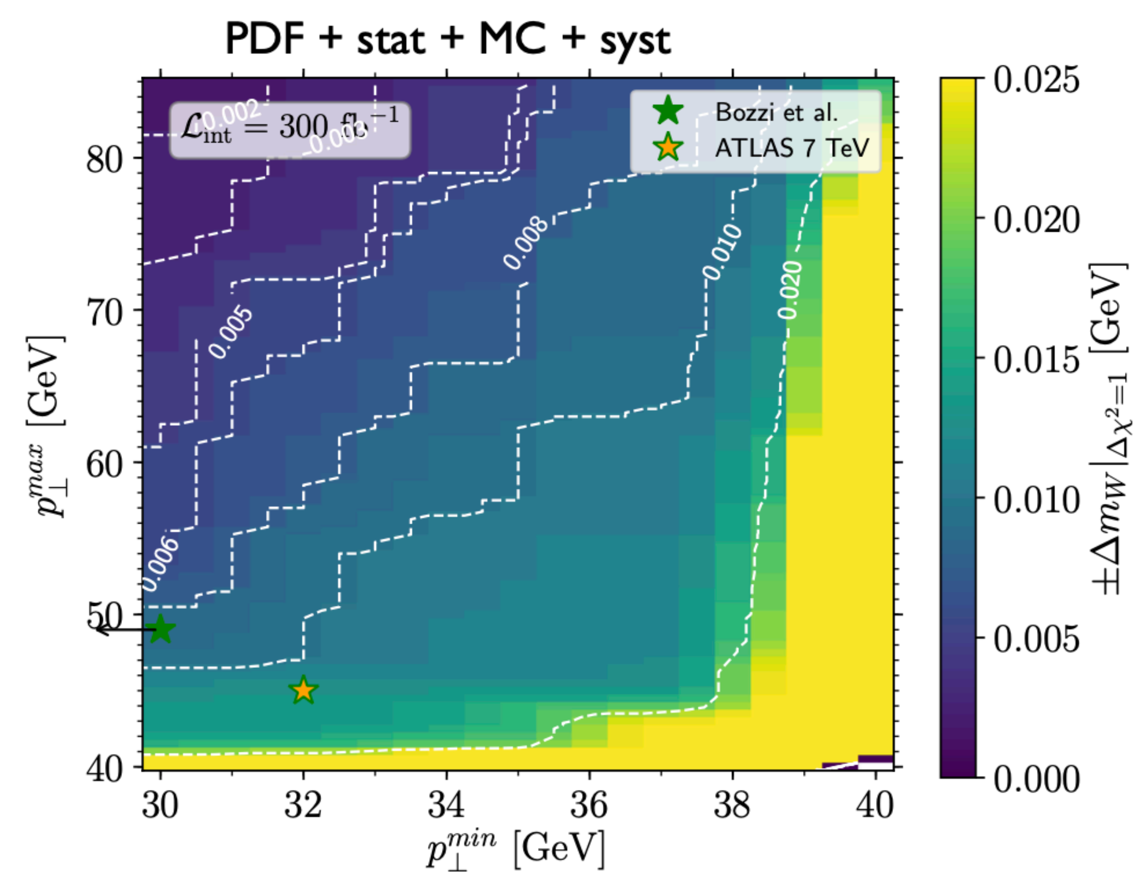

scan over fitting windows

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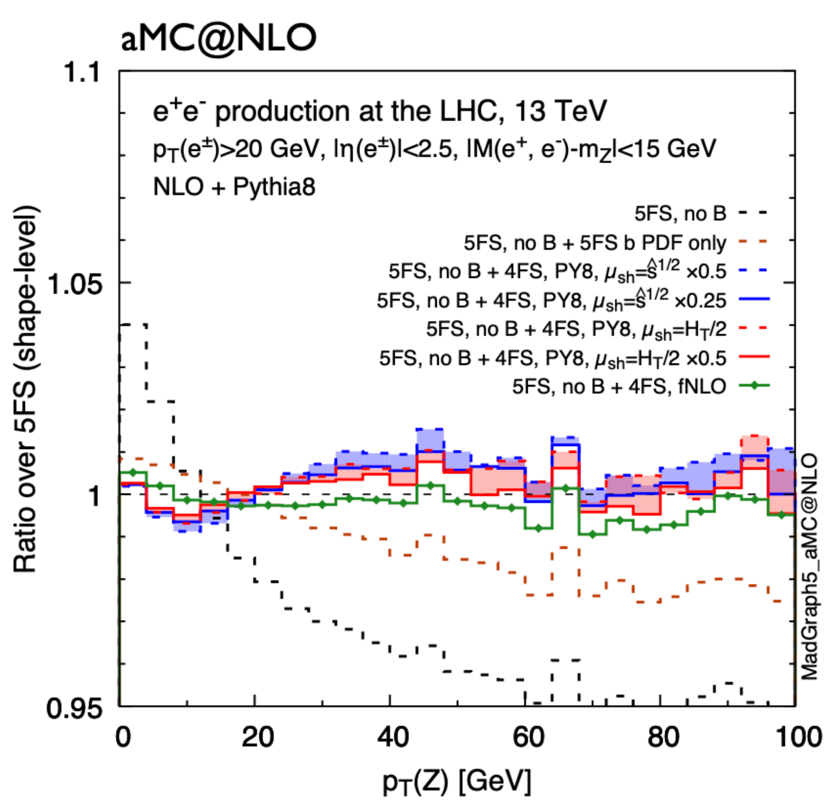

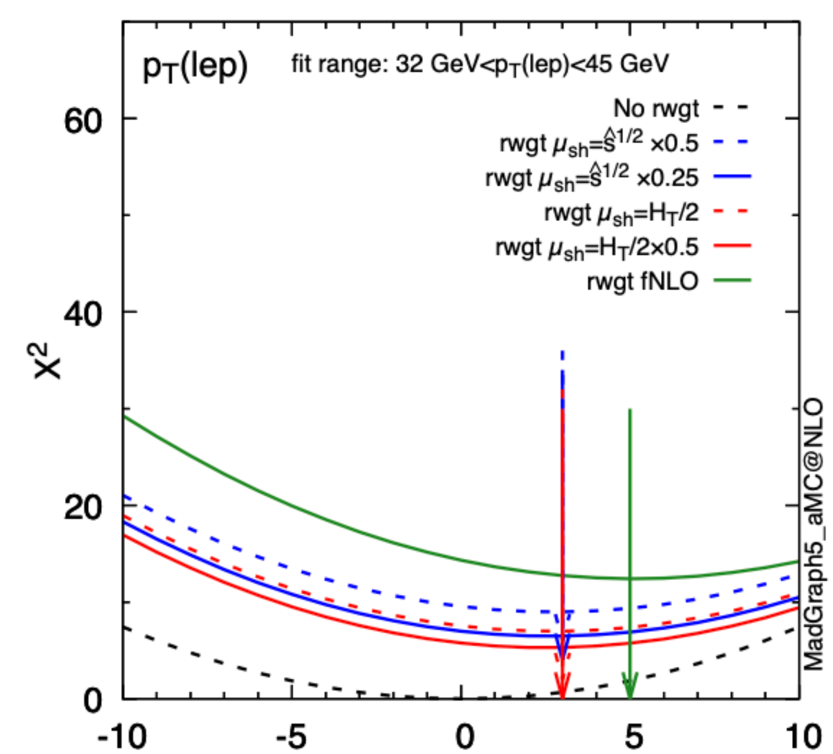

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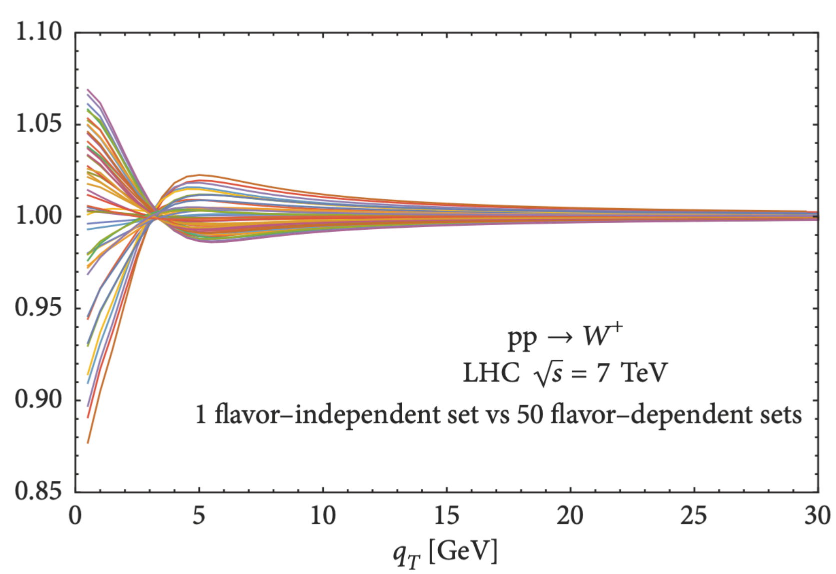
- Intrinsic-k_T
  - impact of flavour-dependence comparable to PDF variations
    [Bacchetta,Bozzi,Radici,Ritzmann,Signori PLB 788 (2019) + Bozzi,Signori AHEP 2526897 (2019)]



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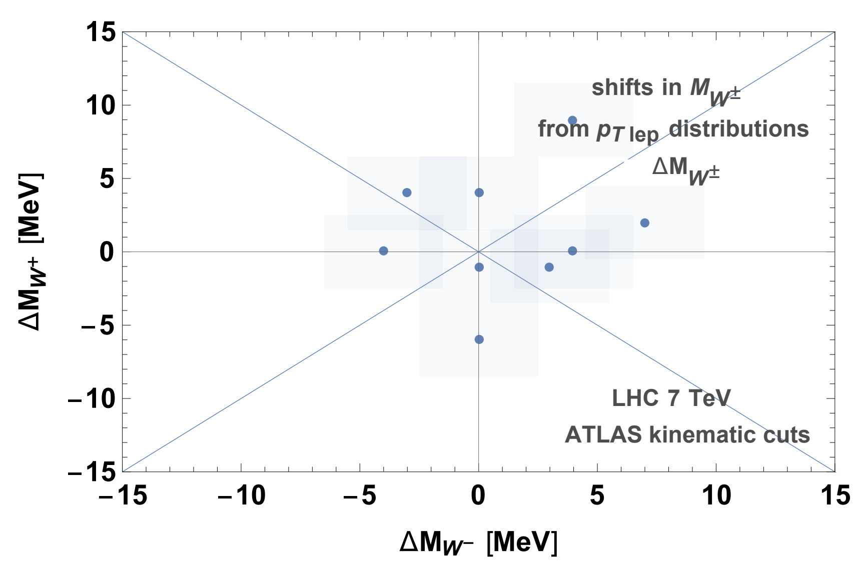
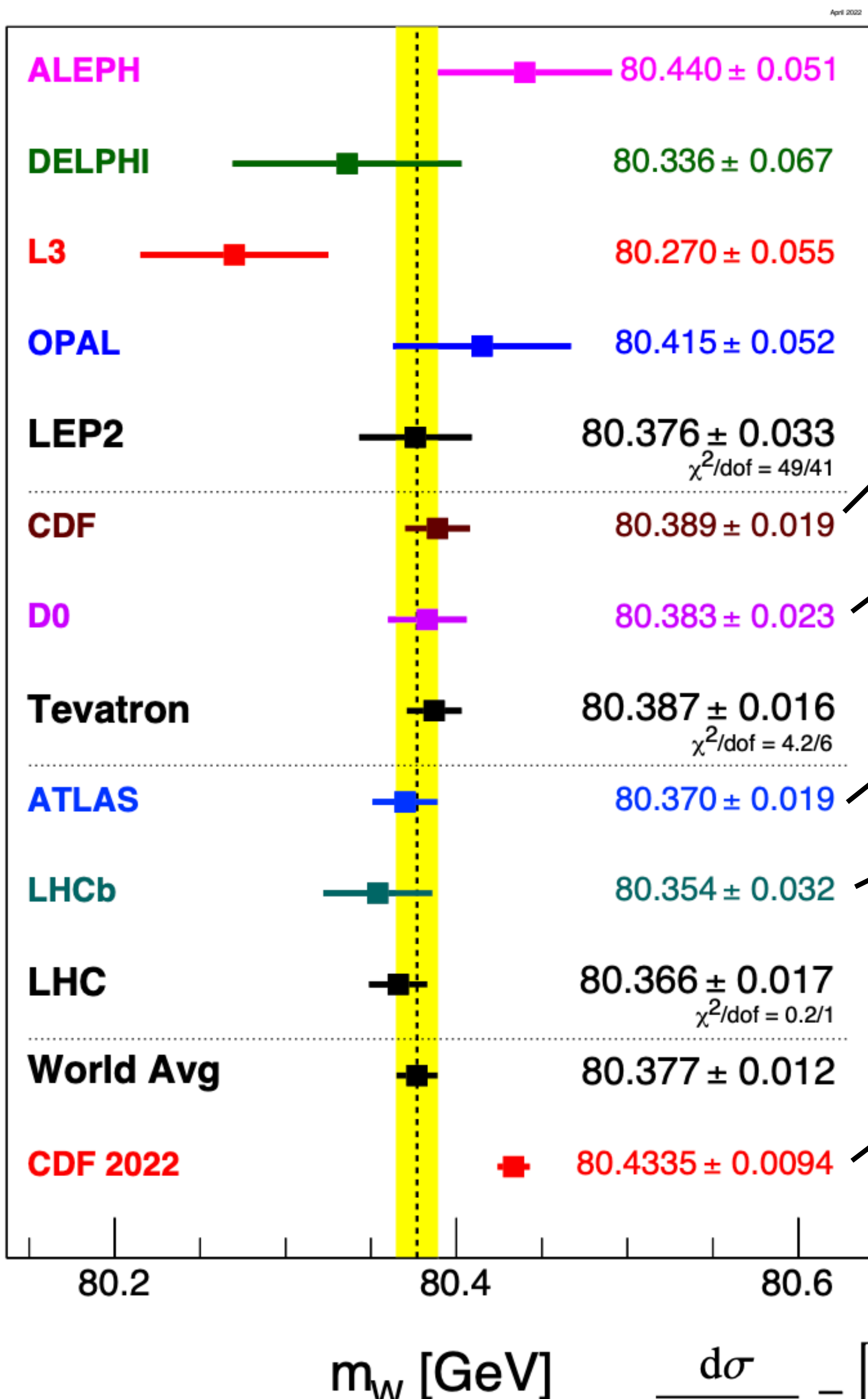


Experimental measurements



CDF I : ±12 (**stat**) ±10 (**exp syst**) ±7 (**model**) ±10 (**PDF**)

D0: ±13 (**stat**) ±18 (**exp syst**) ±9 (**model**) ±11 (**PDF**)

ATLAS: ±7 (**stat**) ±11 (**exp syst**) ±14 (**model**) ±8 (**PDF**)

LHCb: ±23 (**stat**) ±10 (**exp syst**) ±17 (**model**) ±9 (**PDF**)

CDF II : ±6 (**stat**) ±5 (**exp syst**) ±3 (**model**) ±4 (**PDF**)

very different methods to estimate modelling and PDF uncertainties

$$\frac{d\sigma}{dp_1\,dp_2} = \left[\frac{d\sigma(m)}{dm}\right]\left[\frac{d\sigma(y)}{dy}\right]\left[\frac{d\sigma(p_T,y)}{dp_T\,dy}\left(\frac{d\sigma(y)}{dy}\right)^{-1}\right]\left[(1+\cos^2\theta)+\sum_{i=0}^{7}A_i(p_T,y)P_i(\cos\theta,\phi)\right]$$

Experimental measurements

D0

	m_T	p_T^e	$\not{E}_T$	
PDF	11	11	14	→ 68% CL template fit CTEQ6.1
QED	7	7	9	→ comparison Wgrad/Zgrad vs. Photos
Boson p_T	2	5	2	→ NP fit on Z data

CDF

	m_T	p_T^e	$\not{E}_T$	
p_T^Z model	0.7	2.3	0.9	→ NP fit on Z data
p_T^W/p_T^Z model	0.8	2.3	0.9	→ propagation of μ_R, μ_F, μ_{res} scale variation
Parton distributions	3.9	3.9	3.9	→ CTEQ6.6 vs. ABMP16, CJ15, CT18, MMHT2014, NNPDF3.1

LHCb

Parton distribution functions	9	→ average of 3 separate fits: CT18, MSHT20, NNPDF3.1
Theory (excl. PDFs) total	17	
Transverse momentum model	11	→ spread of Powheg+Pythia/Herwig, DYTurbo, Pythia/Herwig
Angular coefficients	10	→ μ_R, μ_F scale variation
QED FSR model	7	→ comparison of Herwig, Pythia, Photos

ATLAS

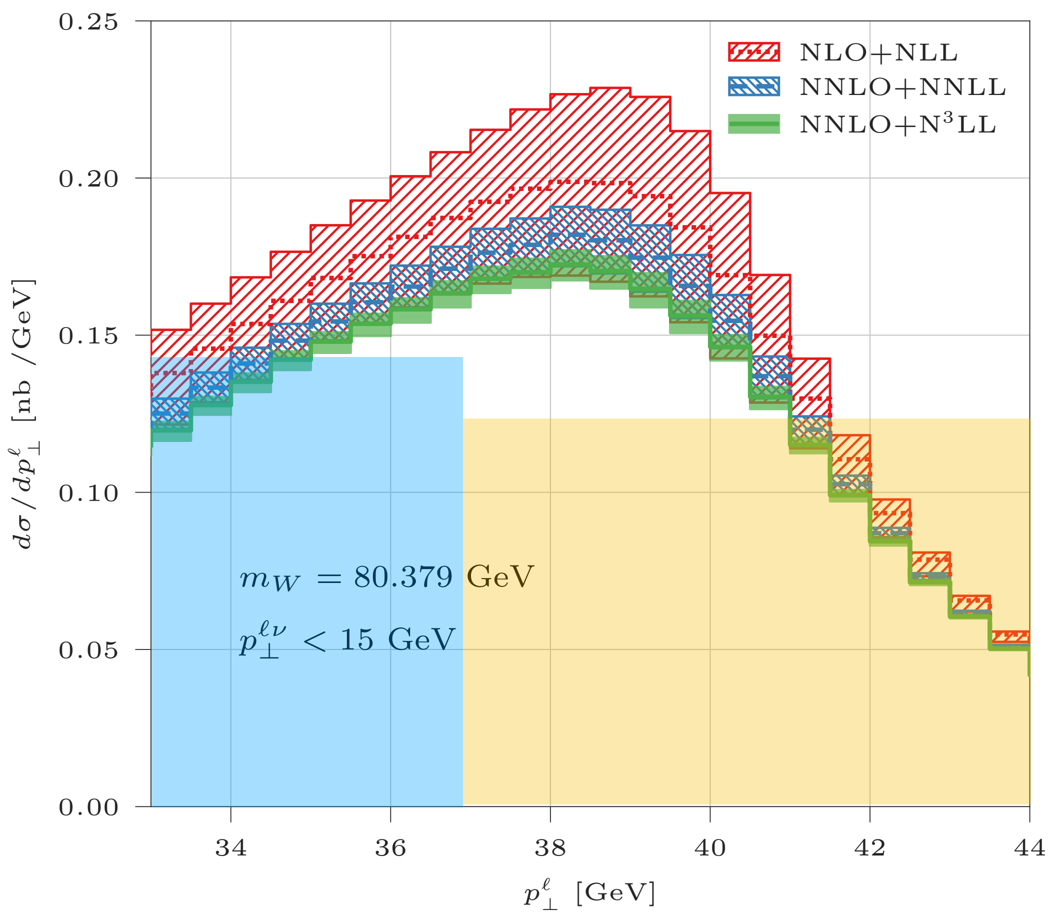
W-boson charge	W^+		W^-		Combined		
Kinematic distribution	p_T^ℓ	m_T	p_T^ℓ	m_T	p_T^ℓ	m_T	
δm_W [MeV]							
Fixed-order PDF uncertainty	13.1	14.9	12.0	14.2	8.0	8.7	Hessian on CT10 + quadrature with MMHT2014 and CT14
AZ tune	3.0	3.4	3.0	3.4	3.0	3.4	propagation of Pythia parameter uncertainty
Charm-quark mass	1.2	1.5	1.2	1.5	1.2	1.5	variation of m_c
Parton shower μ_F with heavy-flavour decorrelation	5.0	6.9	5.0	6.9	5.0	6.9	μ_F variation: simultaneous (independent) for u,d,s (c,b)
Parton shower PDF uncertainty	3.6	4.0	2.6	2.4	1.0	1.6	variation of LO PDF sets for Parton Shower
Angular coefficients	5.8	5.3	5.8	5.3	5.8	5.3	propagation of Z data uncertainty
Total	15.9	18.1	14.8	17.2	11.6	12.9	

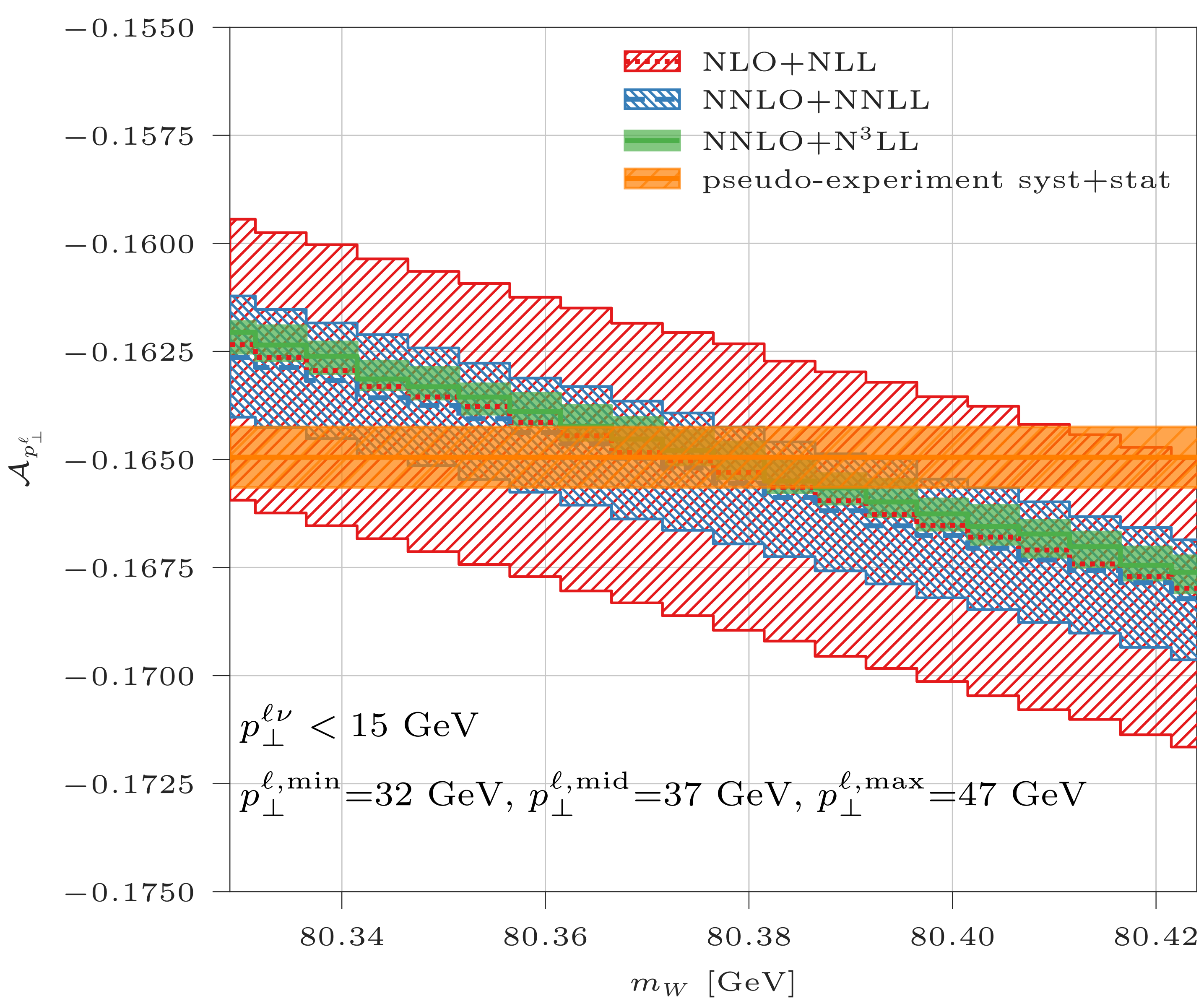
Future prospects

- New Observables: asymmetry around the p_T^ℓ jacobian peak [Rottoli, Torrielli, Vicini - EPJC 83 (2023)]

$$L_{p_\perp^\ell} \equiv \int_{p_\perp^{\ell,\mathrm{min}}}^{p_\perp^{\ell,\mathrm{mid}}} dp_\perp^\ell \frac{d\sigma}{dp_\perp^\ell}, \qquad U_{p_\perp^\ell} \equiv \int_{p_\perp^{\ell,\mathrm{mid}}}^{p_\perp^{\ell,\mathrm{max}}} dp_\perp^\ell \frac{d\sigma}{dp_\perp^\ell}$$

$$\mathcal{A}_{p_\perp^\ell}(p_\perp^{\ell,\mathrm{min}}, p_\perp^{\ell,\mathrm{mid}}, p_\perp^{\ell,\mathrm{max}}) \equiv \frac{L_{p_\perp^\ell} - U_{p_\perp^\ell}}{L_{p_\perp^\ell} + U_{p_\perp^\ell}}$$





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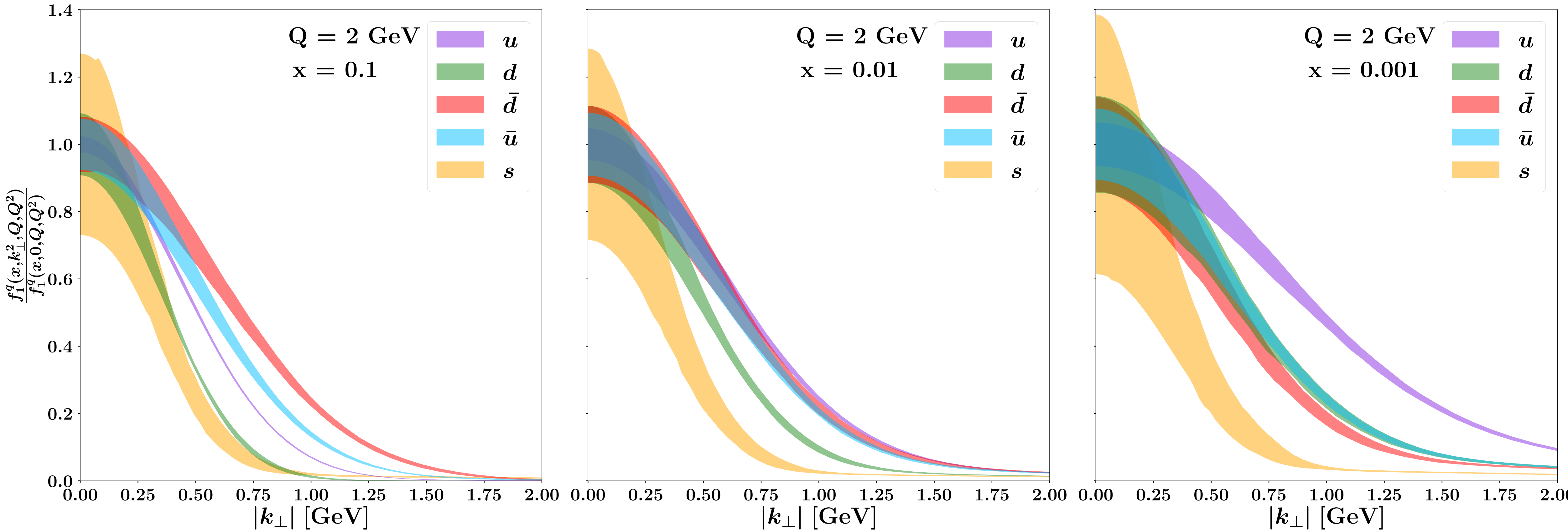

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- Dedicated effort: [https://twiki.cern.ch/twiki/bin/view/LHCPhysics/THuncertainties]

Ongoing studies on the assessment of theoretical uncertainties in the precision determination of SM parameters

The following studies are currently ongoing, the active people involved (coordinators) are indicated in each case.

Modelling of non-perturbative corrections in extraction of α_s

Main coordinators
Bacchetta, Bertone, Bozzi, Camarda
Description
Assessment of the impact of the choice of the non-perturbative model in the α_s extraction

State of the art predictions for of ptW/ptZ ratio

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[TBA]
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Thank you!

Backup

The electroweak fit

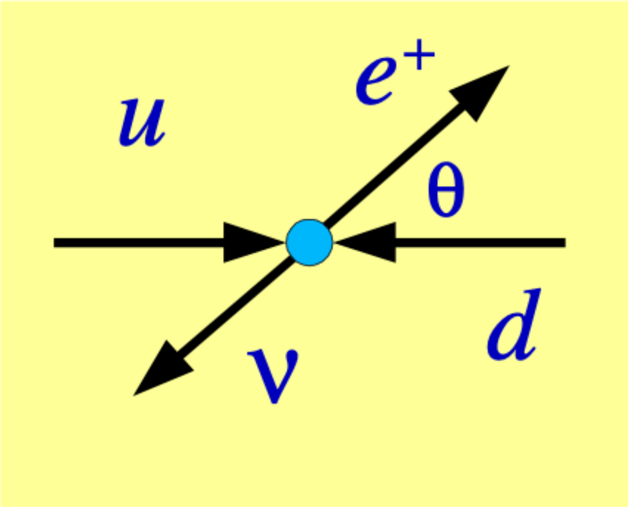
$$\text{Pull} = \frac{\text{Value} - \text{SM}}{\sigma_{\text{value}}}$$

Quantity	Value	Standard Model	Pull
m_t [GeV]	172.83 ± 0.59	173.13 ± 0.56	-0.5
M_H [GeV]	125.30 ± 0.13	125.30 ± 0.13	0.0
Γ_H [MeV]	$3.2^{+2.4}_{-1.7}$	4.12 ± 0.05	-0.4
M_W [GeV]	80.387 ± 0.016 **Tevatron**	80.360 ± 0.006	1.7
	80.376 ± 0.033 **LEP2**		0.5
	80.366 ± 0.017 **LHC**		0.4
Γ_W [GeV]	2.046 ± 0.049	2.089 ± 0.001	-0.9
	2.195 ± 0.083		1.3
$\mathcal{B}(W \to \text{hadrons})$	0.6736 ± 0.0018	0.6751 ± 0.0001	-0.8
$g_V^{\nu e}$	-0.040 ± 0.015	-0.0397 ± 0.0001	0.0
$g_A^{\nu e}$	-0.507 ± 0.014	-0.5064	0.0
$Q_W(e)$	-0.0403 ± 0.0053	-0.0473 ± 0.0002	1.3
$Q_W(p)$	0.0719 ± 0.0045	0.0709 ± 0.0002	0.2
$Q_W(\text{Cs})$	-72.82 ± 0.42	-73.24 ± 0.01	1.0
$Q_W(\text{Tl})$	-116.4 ± 3.6	-116.90 ± 0.02	0.1
$\hat{s}_Z^2(\text{eDIS})$	0.2299 ± 0.0043	0.23122 ± 0.00004	-0.3
τ_τ [fs]	290.75 ± 0.36	288.90 ± 2.24	0.8
$\frac{1}{2}(g_\mu - 2 - \frac{\alpha}{\pi})$	$(4510.88 \pm 0.60) \times 10^{-9}$	$(4508.61 \pm 0.03) \times 10^{-9}$	3.8

(PDG 2022 **before** CDF II)

Observables and techniques for m_W

$$u+\overline{d}\rightarrow W^{+}\rightarrow e^{+}\nu$$



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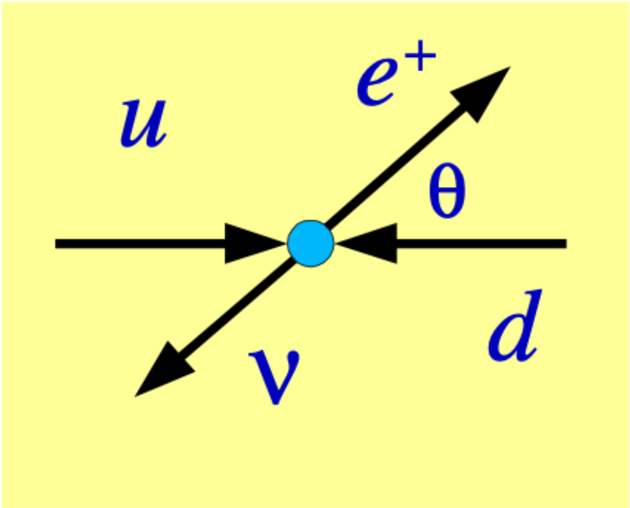

m_W extracted from the study of the shape of m_T, p_T^l, p_T^ν

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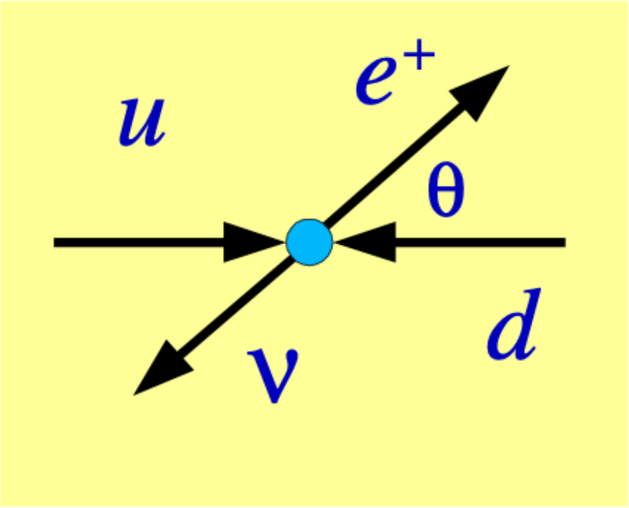

m_W extracted from the study of the shape of m_T, p_T^l, p_T^ν

transverse mass

$$m_T^2 = (|\vec{p}_T^{\,l}| + |\vec{p}_T^{\,\nu}|)^2 - (\vec{p}_T^{\,l} + \vec{p}_T^{\,\nu})^2$$

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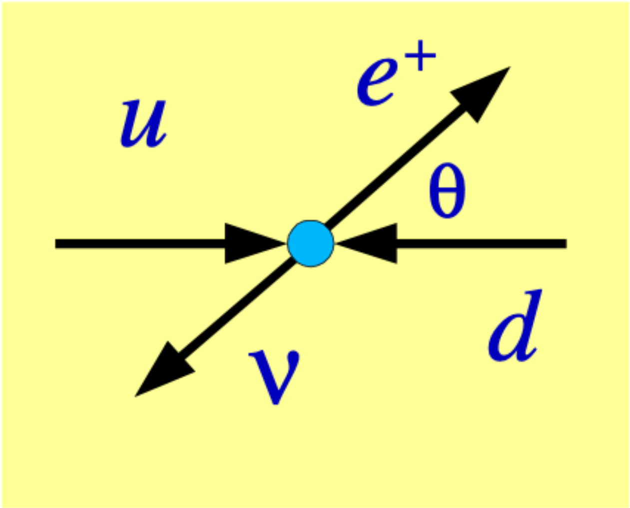

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endpoint at $m_T = m$ (invariant mass)

$$m^2 = (|\vec{p}^{\,l}| + |\vec{p}^{\,\nu}|)^2 - (\vec{p}^{\,l} + \vec{p}^{\,\nu})^2$$

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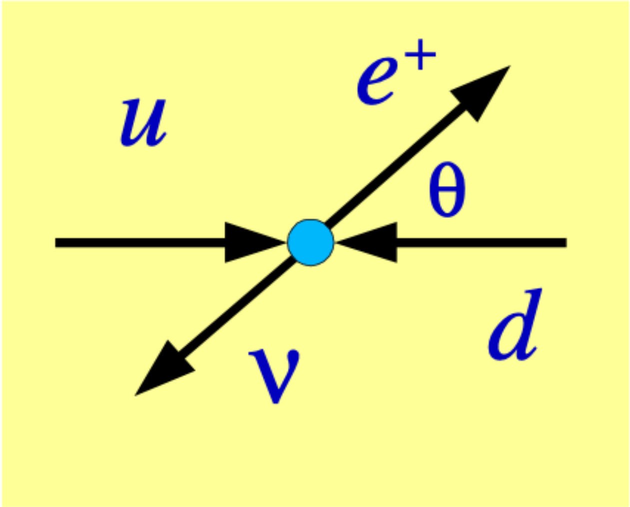

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endpoint at $m_T = m$ (invariant mass)

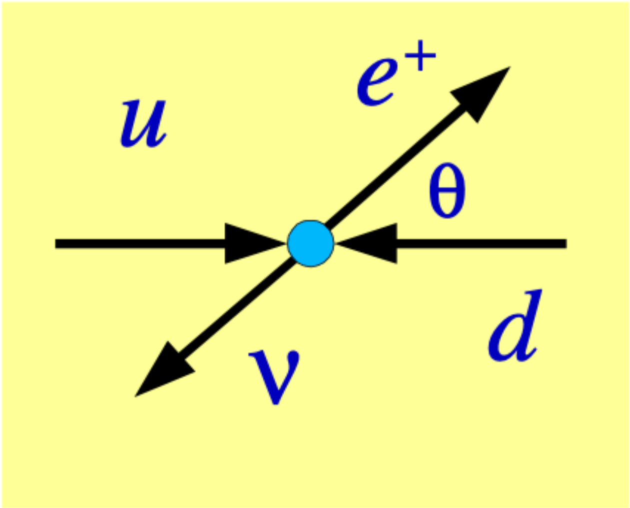
$$m^2 = (|\vec{p}^l| + |\vec{p}^\nu|)^2 - (\vec{p}^l + \vec{p}^\nu)^2$$

also expressed as

$$m_T = \sqrt{2|\vec{p}_T^l||\vec{p}_T^\nu|(1-\cos\Delta\phi)}$$

Observables and techniques for m_W

$$u + \bar{d} \to W^+ \to e^+ \nu$$



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also expressed as

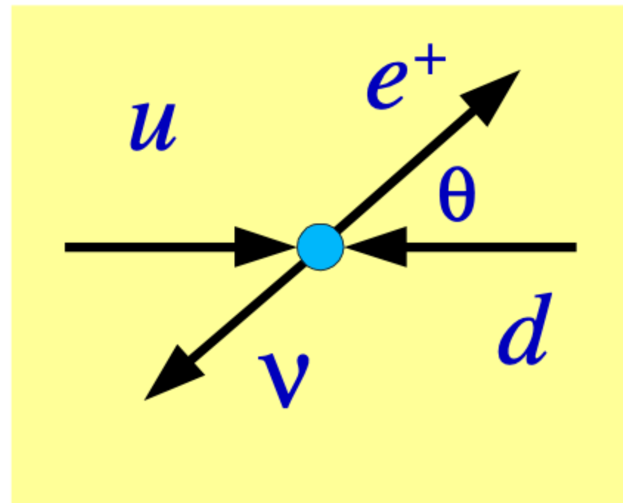
$$m_T = \sqrt{2|\vec{p}_T^{\,l}||\vec{p}_T^{\,\nu}|(1 - \cos\Delta\phi)}$$

lepton p_T

sharp **Jacobian peak** at $p_T^l \sim m_W/2$

Observables and techniques for m_W

$$u+\bar{d}\to W^{+}\to e^{+}\nu$$



m_W extracted from the study of the shape of m_T, p_T^l, p_T^ν

transverse mass

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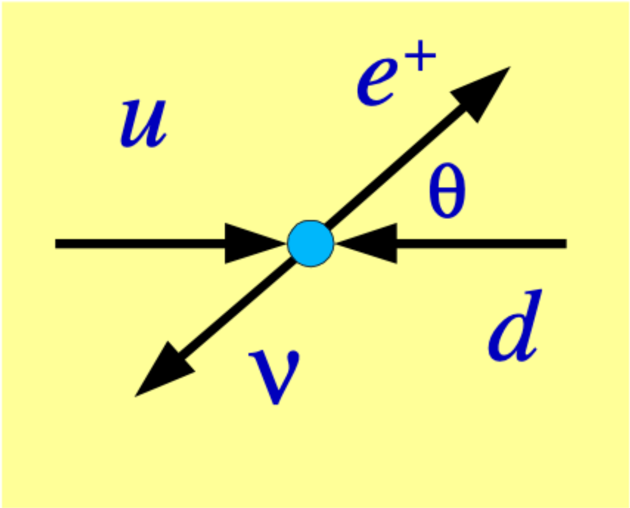

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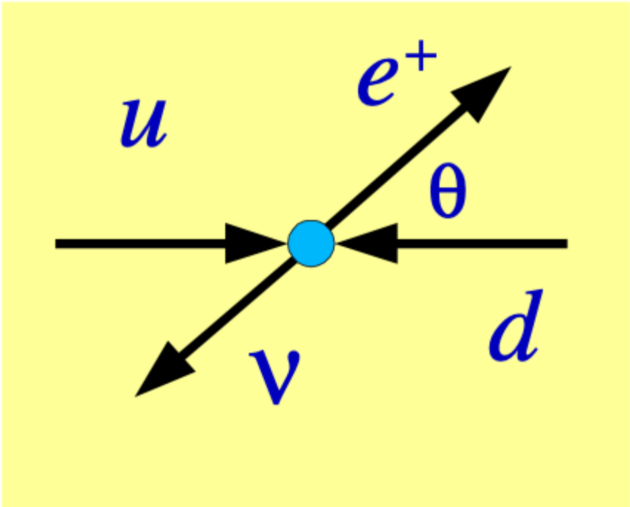

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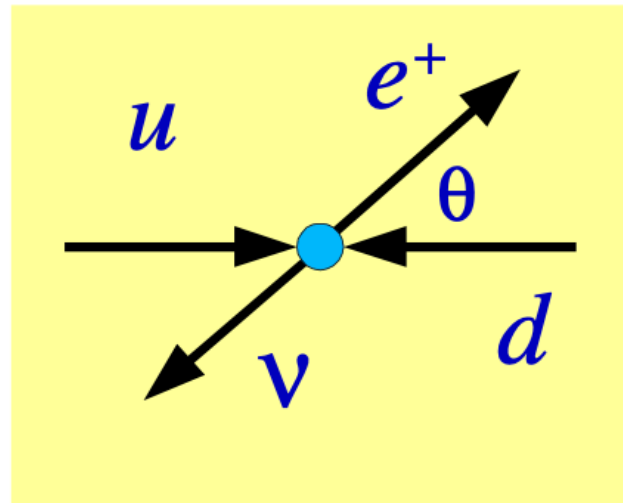

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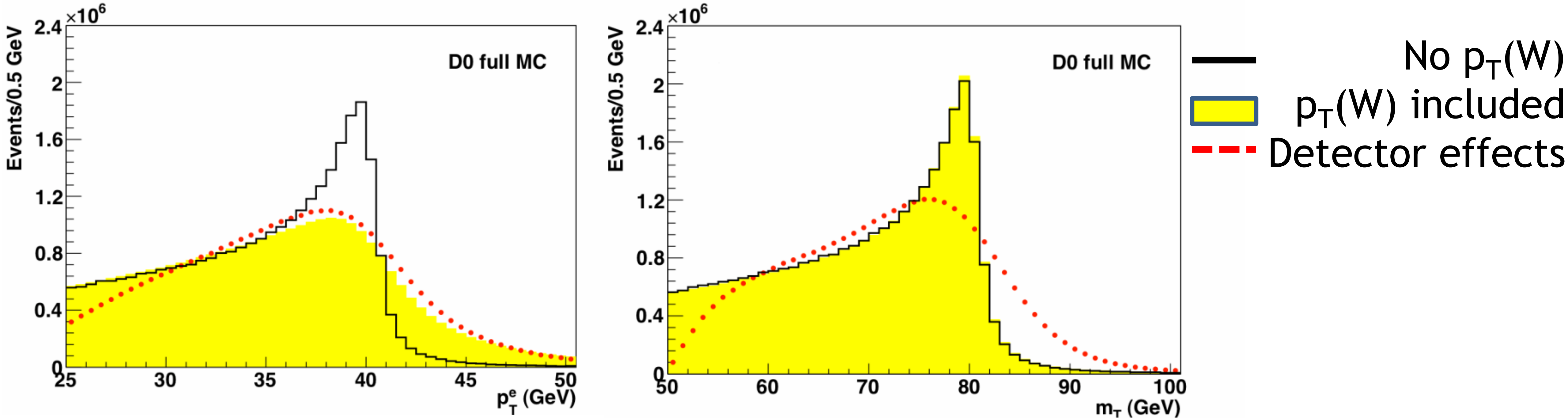
very different dependence on p_T^W and, ultimately, on hadronic uncertainties

Observables and techniques for m_W



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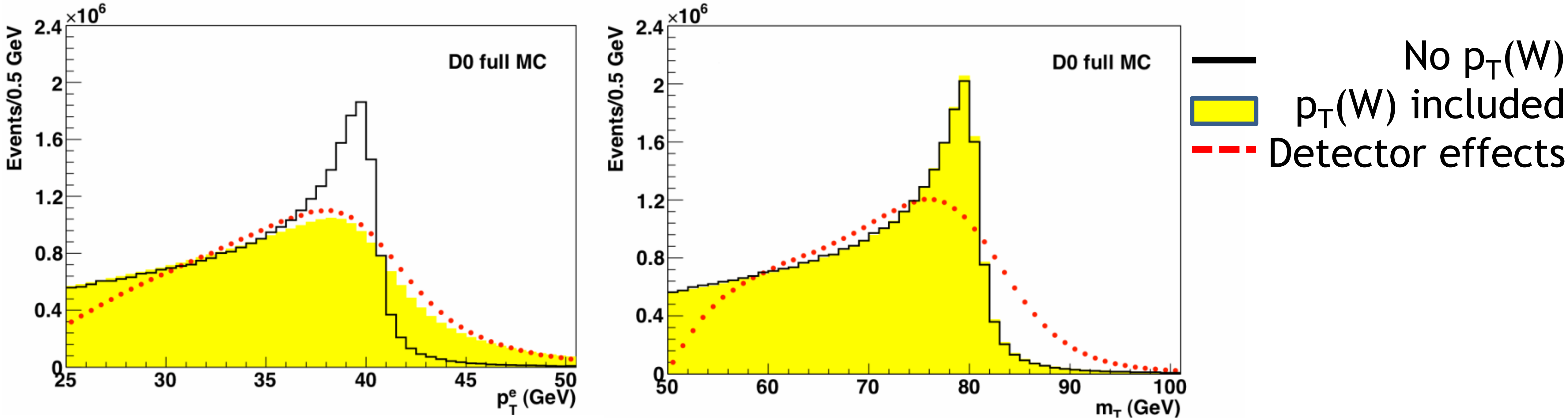
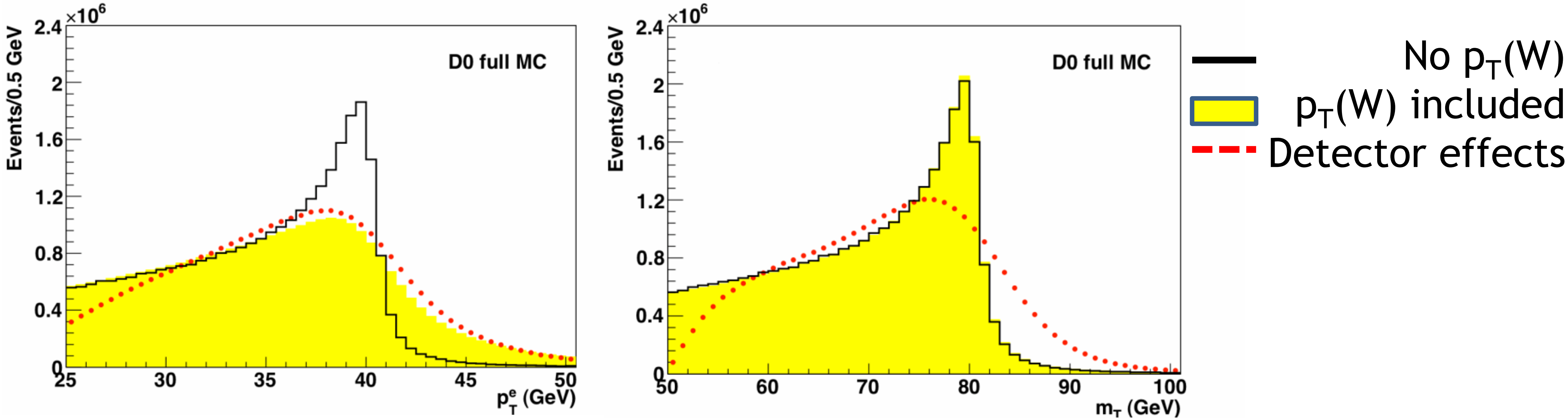


Lepton p_T: **moderate** detector smearing effects, **high** sensitivity to p_{TW} modelling

Observables and techniques for m_W



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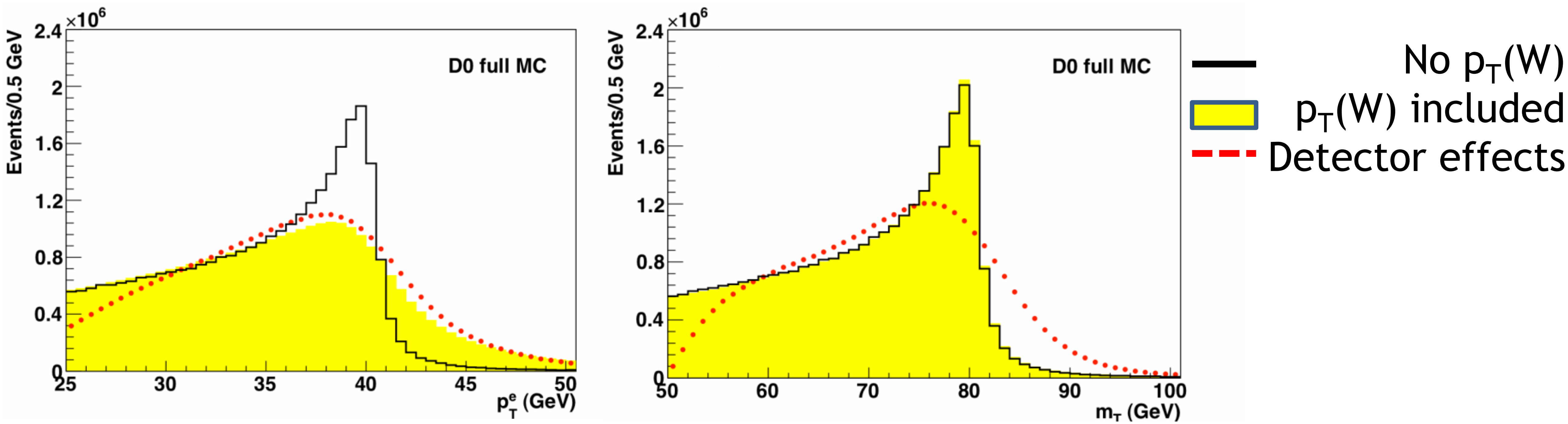

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p_{TW} modelling depends on intrinsic-k_T and all-order treatment of QCD corrections

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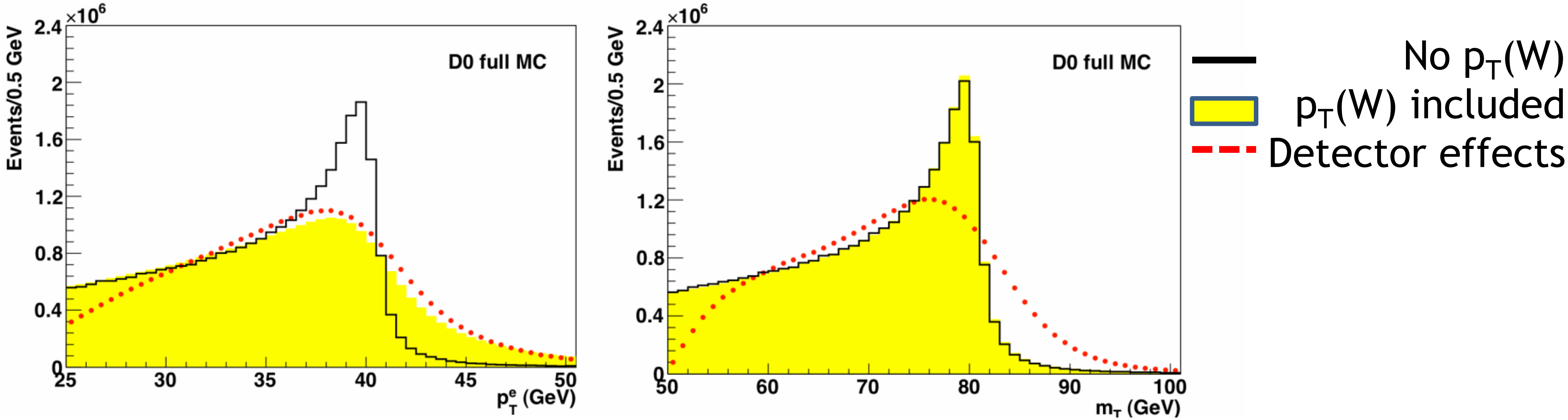

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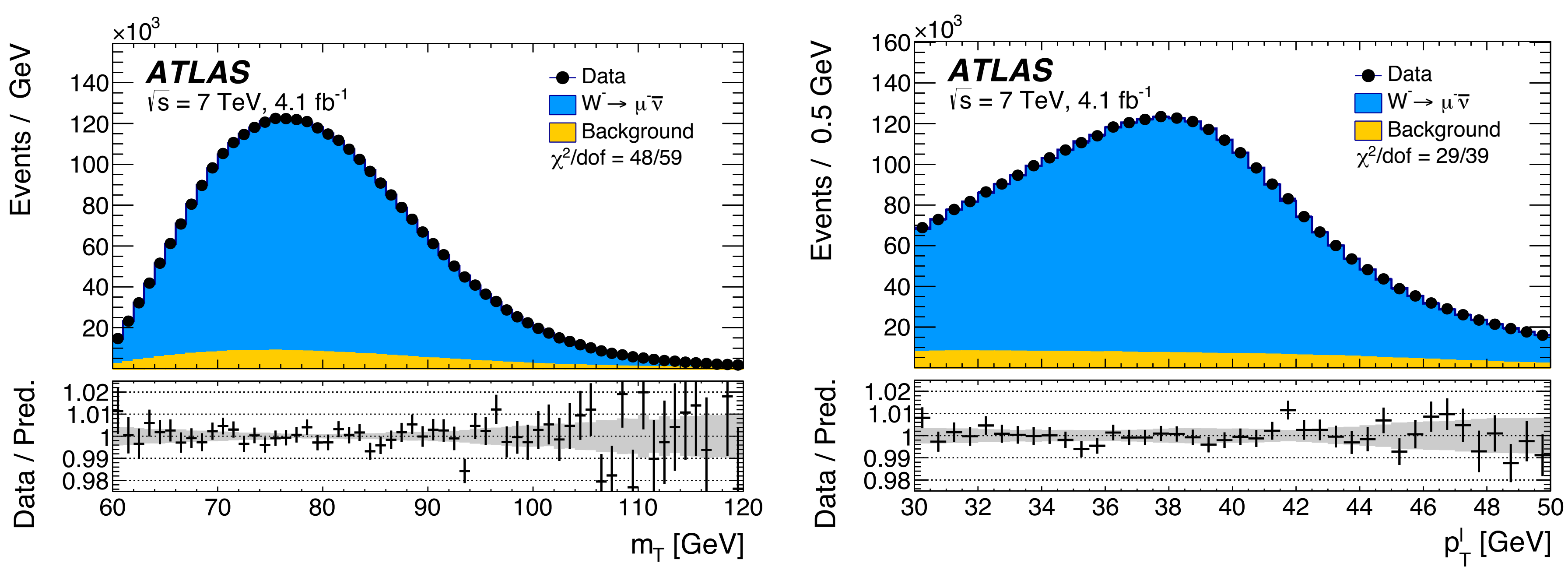

ATLAS

ATLAS

- default samples for predictions: **POWHEG + PYTHIA 8**
- **reweighing** to include higher-order effects

$$\frac{\mathrm{d}\sigma}{\mathrm{d}p_1\,\mathrm{d}p_2} = \left[\frac{\mathrm{d}\sigma(m)}{\mathrm{d}m}\right]\left[\frac{\mathrm{d}\sigma(y)}{\mathrm{d}y}\right]\left[\frac{\mathrm{d}\sigma(p_\mathrm{T},y)}{\mathrm{d}p_\mathrm{T}\,\mathrm{d}y}\left(\frac{\mathrm{d}\sigma(y)}{\mathrm{d}y}\right)^{-1}\right]\left[(1+\cos^2\theta)+\sum_{i=0}^{7}A_i(p_\mathrm{T},y)P_i(\cos\theta,\phi)\right]$$

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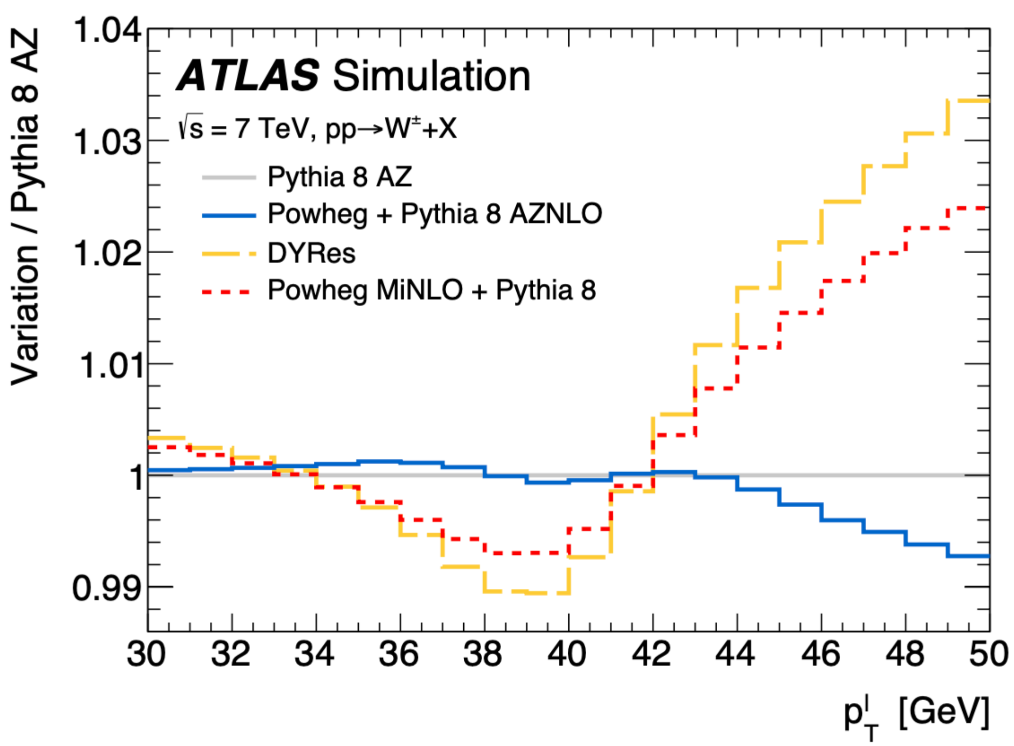

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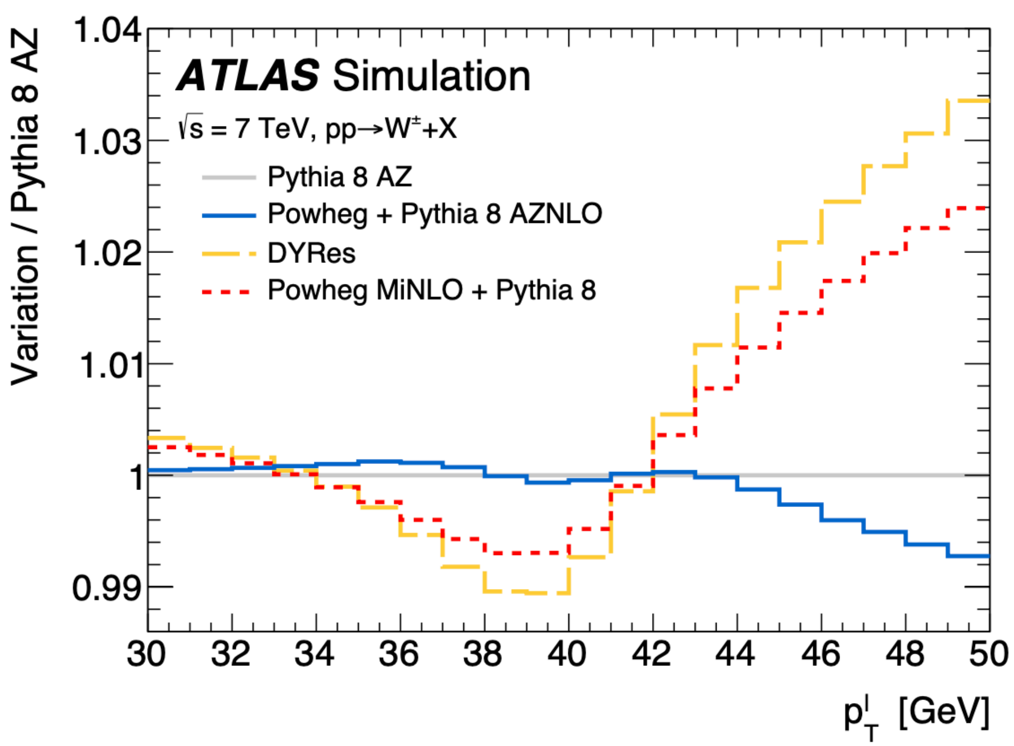
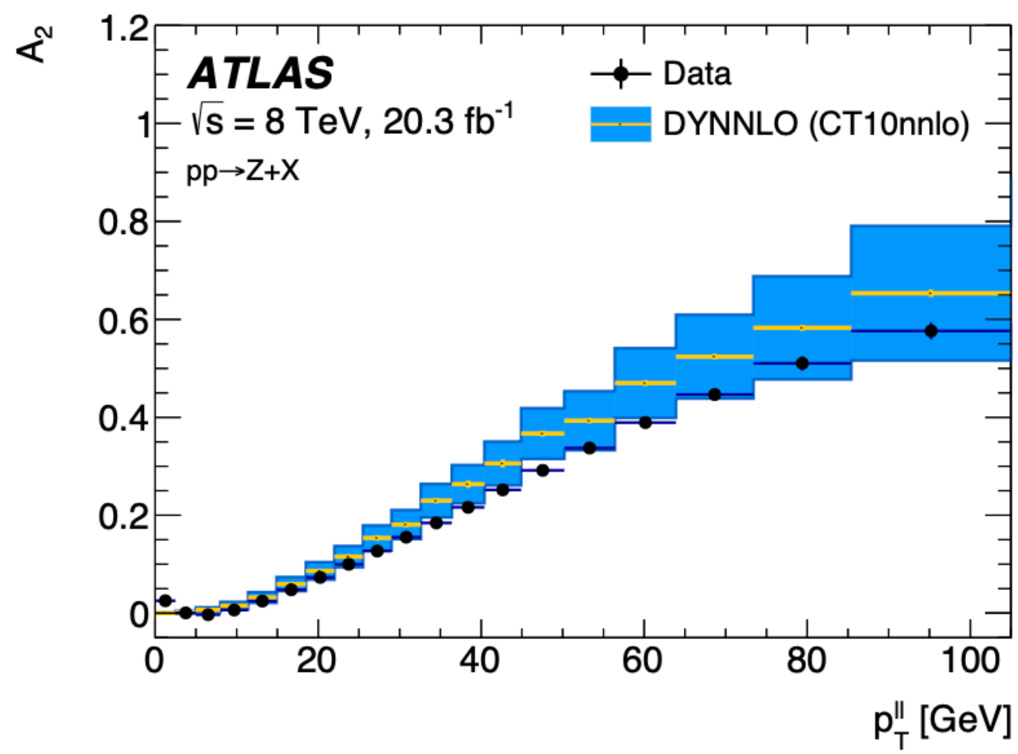
- A_i **: DYNNLO** ($\mathcal{O}(\alpha_s^2)$) [large deviations for A_2 → ***additional source of uncertainty***]





ATLAS

ATLAS

W-boson charge	W^+		W^-		Combined	
Kinematic distribution	p_T^ℓ	m_T	p_T^ℓ	m_T	p_T^ℓ	m_T
δm_W [MeV]						
Fixed-order PDF uncertainty	13.1	14.9	12.0	14.2	8.0	8.7
AZ tune	3.0	3.4	3.0	3.4	3.0	3.4
Charm-quark mass	1.2	1.5	1.2	1.5	1.2	1.5
Parton shower μ_F with heavy-flavour decorrelation	5.0	6.9	5.0	6.9	5.0	6.9
Parton shower PDF uncertainty	3.6	4.0	2.6	2.4	1.0	1.6
Angular coefficients	5.8	5.3	5.8	5.3	5.8	5.3
Total	15.9	18.1	14.8	17.2	11.6	12.9

ATLAS

- **Fixed-order PDF uncertainty: Hessian method on CT10nnlo**
  - simultaneous variation of $d\sigma/dy$ and A_i → 12.0-14.0 MeV
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- **Angular coefficients:**
  - propagation of Z-data uncertainty used to measure A_i
  - + quadrature with propagation of A_2 data-theory mismatch → **(5.8, 5.3) MeV**

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Charm-quark mass	1.2	1.5	1.2	1.5	1.2	1.5
Parton shower μ_F with heavy-flavour decorrelation	5.0	6.9	5.0	6.9	5.0	6.9
Parton shower PDF uncertainty	3.6	4.0	2.6	2.4	1.0	1.6
Angular coefficients	5.8	5.3	5.8	5.3	5.8	5.3
Total	15.9	18.1	14.8	17.2	11.6	12.9

ATLAS

- **Fixed-order PDF uncertainty: Hessian method on CT10nnlo**
  - simultaneous variation of $d\sigma/dy$ and $A_i \rightarrow$ 12.0-14.0 MeV
  - + anti-correlation between W^+ and $W^- \rightarrow$ 7.4 MeV
  - + quadrature with MMHT2014 and CT14 → **(8.0, 8.7) MeV**
- **Scale variation on** $d\sigma/dy$ **(DYNNLO): negligible (0.1% - 0.3%)**
- **AZ tune:** propagation of k_T, α_s, p_{T0} uncertainties → **(3.0, 3.4) MeV [*flavour blind*]**
- **Charm mass:** 1.5 ± 0.5 GeV → **(1.2, 1.5) MeV** (m_b variation → negligible)
- **PS** μ_F**:** variation of $\mu_F^2 = p_{T0}^2 + p_T^2$ simultaneously for $q = u, d, s$, independently for $c\bar{c}, b\bar{b} \rightarrow Z,\ c\bar{d}, c\bar{s} \rightarrow W$ → **(5.0, 6.9) MeV [*30 MeV if correlated btw flavours but uncorrelated W,Z prod.*]**
- **PS PDF:** variation of LO sets
  - largest spread among CTEQ6L1, CT14LO, NNPDF2.3LO, MMHT2014LO → 3.8-2.5 MeV
  - + anti-correlation between W^+ and $W^- \rightarrow$ **(1.0, 1.6) MeV**
- **Angular coefficients:**
  - propagation of Z-data uncertainty used to measure A_i
  - + quadrature with propagation of A_2 data-theory mismatch → **(5.8, 5.3) MeV**
- **Data-driven check** (based on p_{TW}/p_{TZ}) among Pythia/POWHEG+Pythia/DYRes
  - **DYRes** include $(\mu_{res}, \mu_F, \mu_R)$ variations → would induce $\Delta M_W \sim 60$ MeV → ***not considered***

ATLAS

W-boson charge	W^+		W^-		Combined	
Kinematic distribution	p_T^ℓ	m_T	p_T^ℓ	m_T	p_T^ℓ	m_T
δm_W [MeV]						
Fixed-order PDF uncertainty	13.1	14.9	12.0	14.2	8.0	8.7
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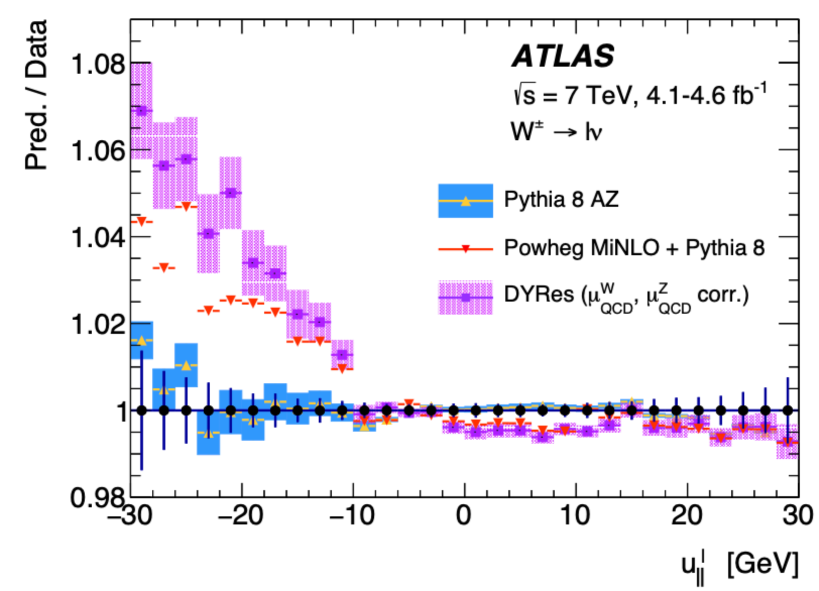

LHCb

LHCb

Parton distribution functions	9
Theory (excl. PDFs) total	17
Transverse momentum model	11
Angular coefficients	10
QED FSR model	7
Additional electroweak corrections	5

LHCb

- **codes considered for predictions:**
  - Pythia, Herwig, POWHEG+Pythia, POWHEG+Herwig, DYTurbo

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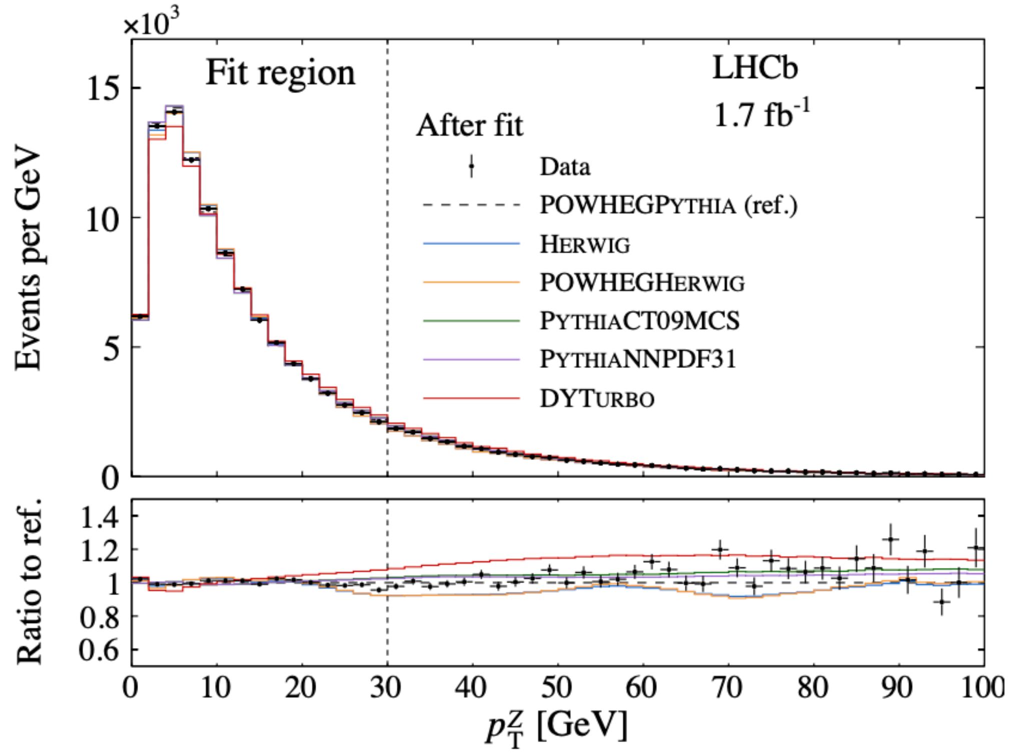
- $d\sigma/dp_T$ **:** tune of NP parameters to p_{TZ} data → best description: POWHEG+Pythia
  - default samples for predictions: **POWHEG+Pythia 8**
  - spread from alternative descriptions → **11 MeV**



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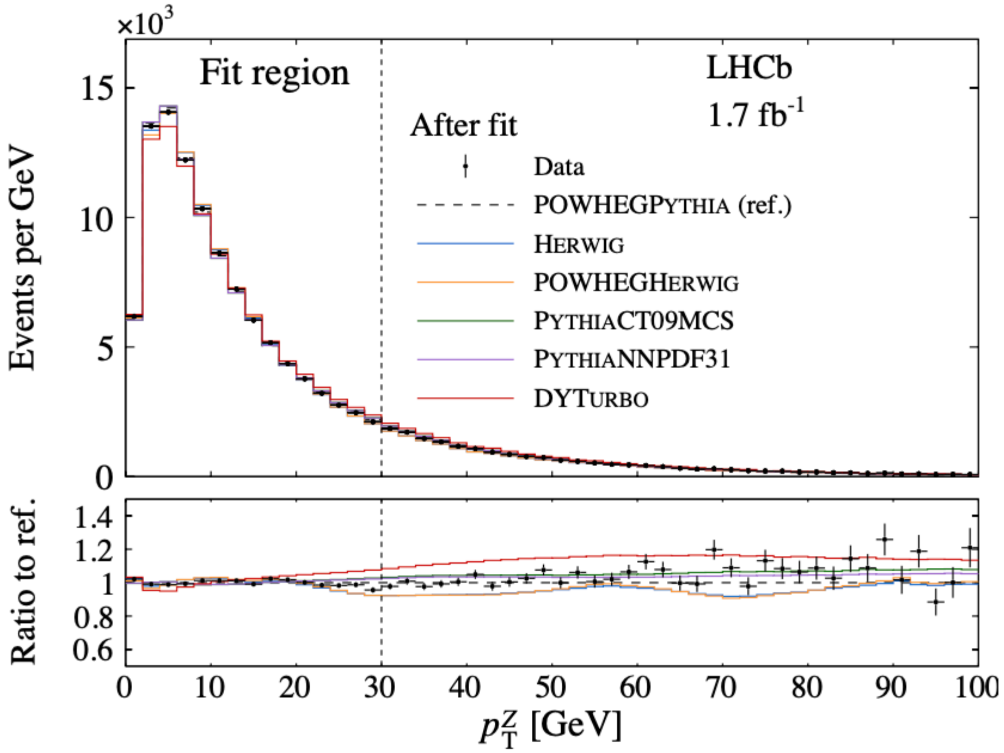
- A_i **: DYTurbo** ($\mathcal{O}(\alpha_s^2)$) **scale variation** (instead of DYNNLO, because negligible sensitivity to A_0, A_2)
  - A_3 main source of uncertainty → **10 MeV**



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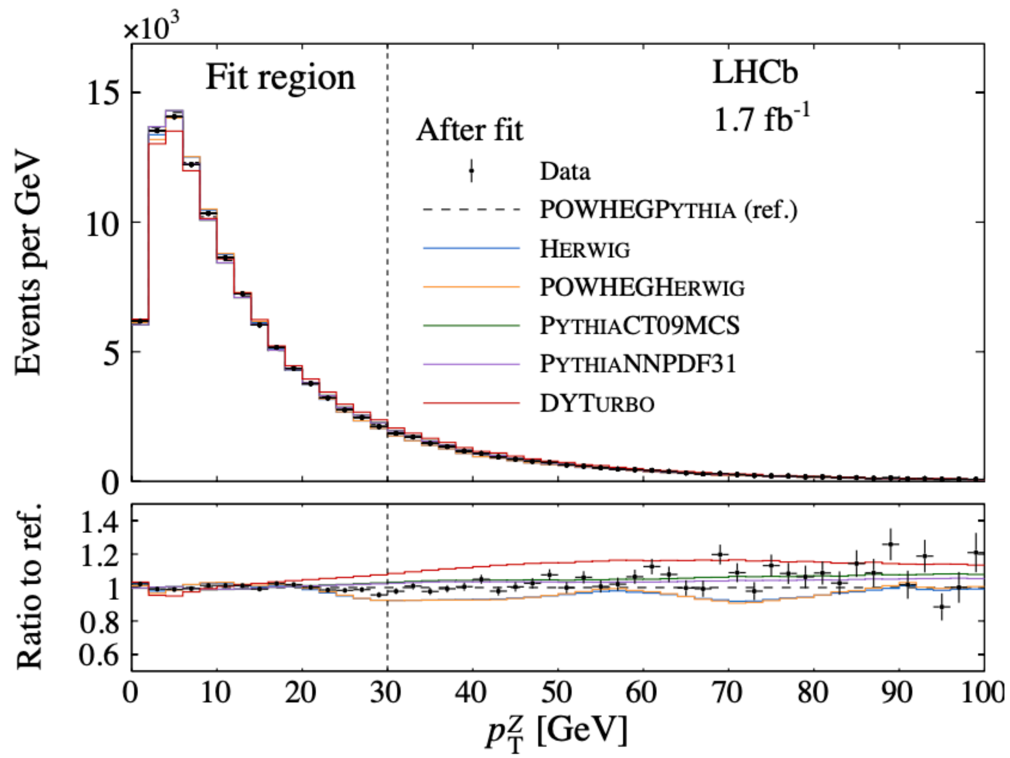
- **PDF:** separate fits
  - NNPDF3.1 (8.3 MeV replica + 2.4 α_s variation → 8.6 MeV)
  - CT18 (11.5 MeV Hessian + 1.4 α_s variation → 11.6 MeV)
  - MSHT20 (6.5 MeV Hessian + 2.1 α_s variation → 6.8 MeV)
  - assumption: fully correlated uncertainties → **arithmetic average: 9 MeV**



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D0

D0

	m_T	p_T^e	$\not{E}_T$
PDF	11	11	14
QED	7	7	9
Boson p_T	2	5	2

D0

- default samples for predictions: **RESBOS(1)@NNLL (CTEQ6Mnlo)**

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  - weak sensitivity to $g_1, g_3 \rightarrow$ propagate g_2 uncertainty $\rightarrow$ **(2,5,2) MeV for** $(m_T, p_{T\ell}, p_{T\nu})$

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  - weak sensitivity to g_1, g_3 → propagate g_2 uncertainty → **(2,5,2) MeV for** $(m_T, p_{T\ell}, p_{T\nu})$
- **PDF: Pythia with CTEQ6.1 LO (40 error sets)**
  - template fit 68% C.L. → **(11,11,14) MeV for** $(m_T, p_{T\ell}, p_{T\nu})$

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CDF II

CDF

	m_T	p_T^e	$\not{E}_T$
p_T^Z model	0.7	2.3	0.9
p_T^W/p_T^Z model	0.8	2.3	0.9
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  - use BLNY fitted values (2003) for g_1, g_3
  - fit g_2 on Z data ($\Delta g_2 = 0.007\,\mathrm{GeV}^2$)
  - $\Delta g_3 = 0.03$ from BLNY fit equivalent to an additional $\Delta g_2 = 0.007\,\mathrm{GeV}^2$ in terms of ΔM_W
  - propagate g_2, g_3 uncertainty → (0.5,2.2,0.5) MeV for $(m_T, p_{T\ell}, p_{T\nu})$
  - α_s tuning to Z data → (1.0,3.2,1.2) MeV for $(m_T, p_{T\ell}, p_{T\nu})$
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- **PDF:** pseudodata generated with ABMP16, CJ15, CT18, MMHT2014, NNPDF3.1 (NLO & NNLO)
  - single PDF uncertainty: 25 symmetric NNPDF3.1(NNLO) eigenvectors → **3.9 MeV**
  - all other NNLO sets within uncertainty band of NNPDF3.1
  - shift between NNPDF3.1 and CTEQ6m → **(3.3,3.6,3.0) MeV for** $(m_T, p_{T\ell}, p_{T\nu})$

CDF

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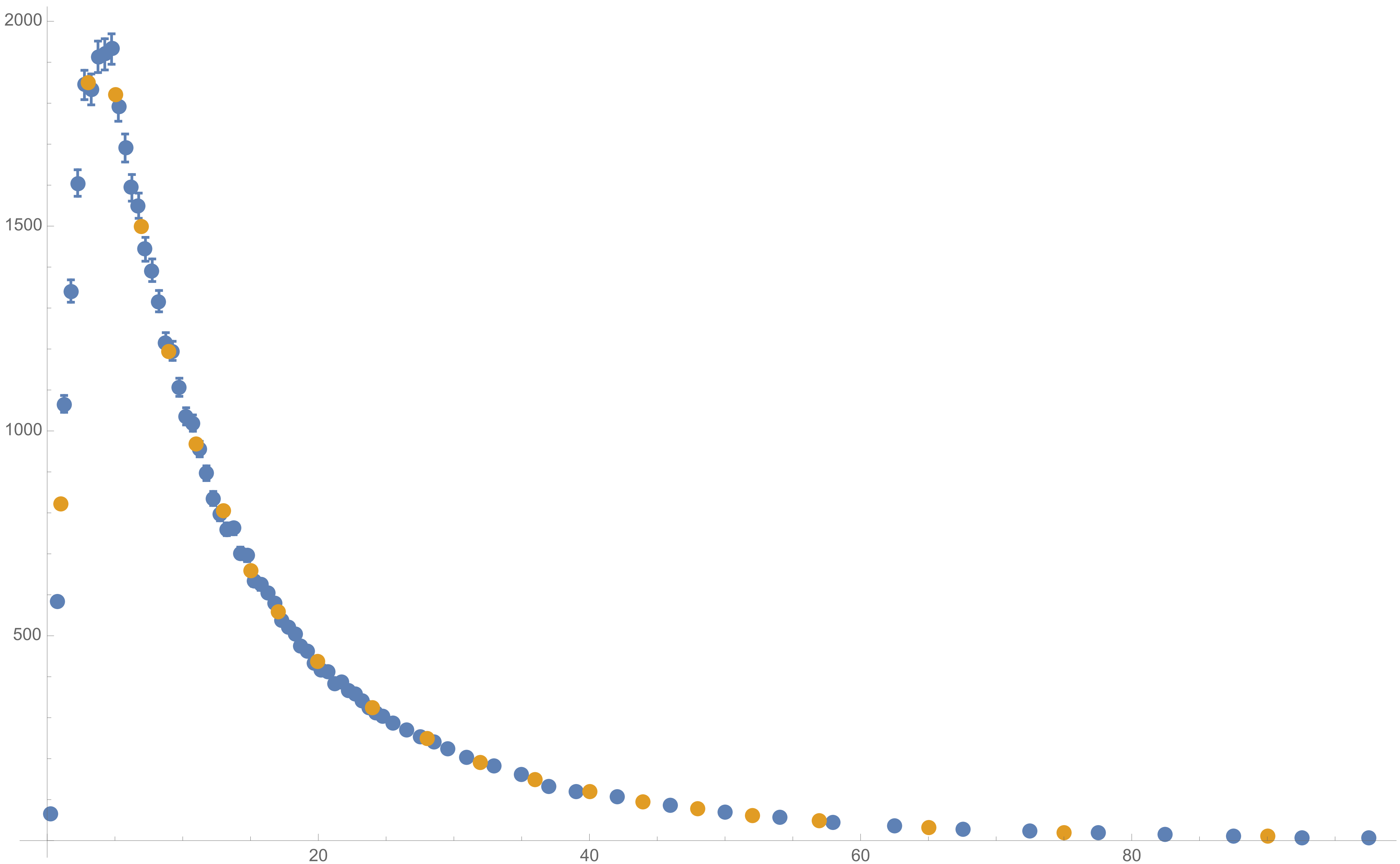
“Z-equivalent” sets

Bacchetta, Bozzi, Radici, Ritzmann, Signori
PLB 788, 542 (2019)

“Z-equivalent” sets



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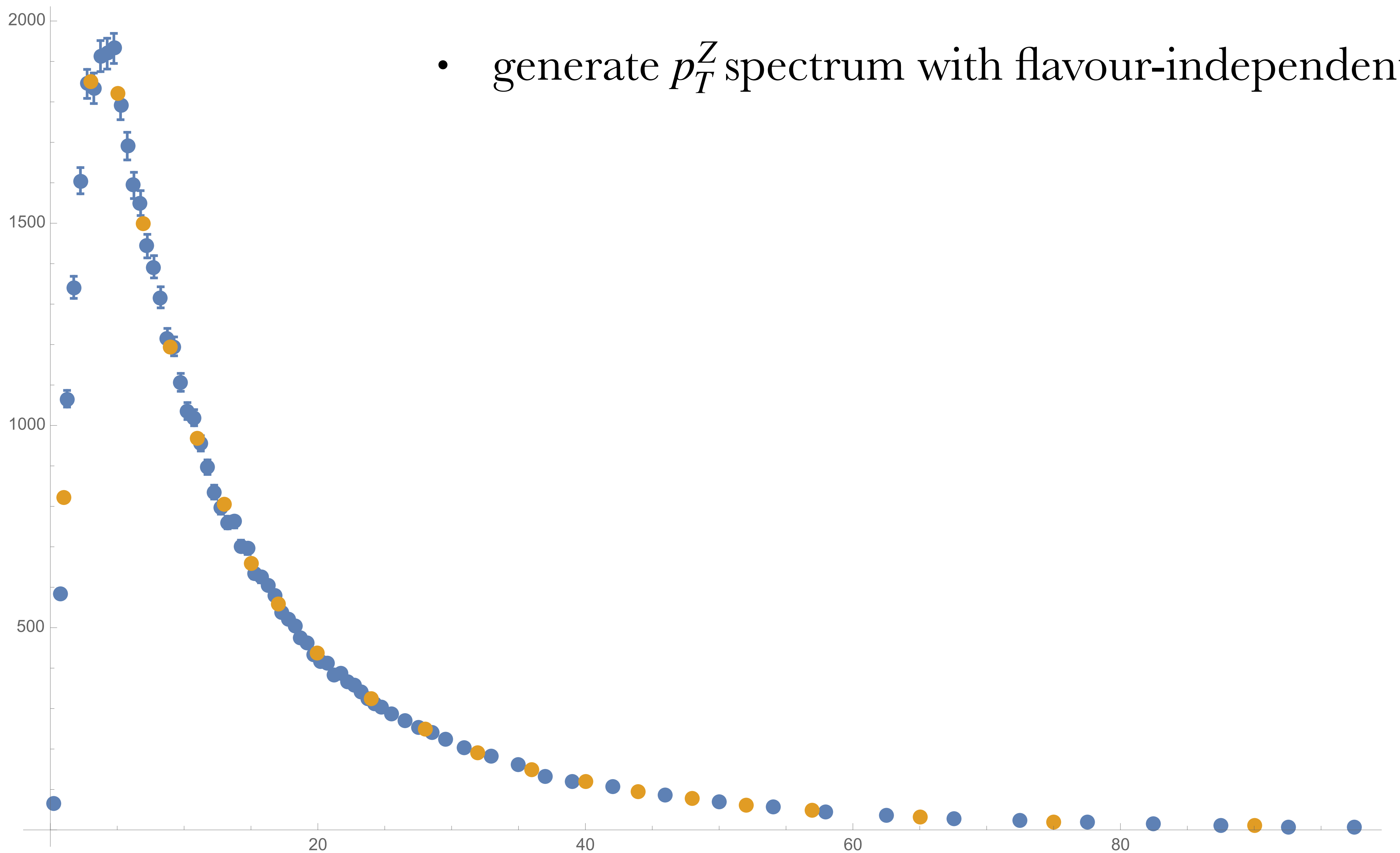

- generate p_T^Z spectrum with flavour-independent set

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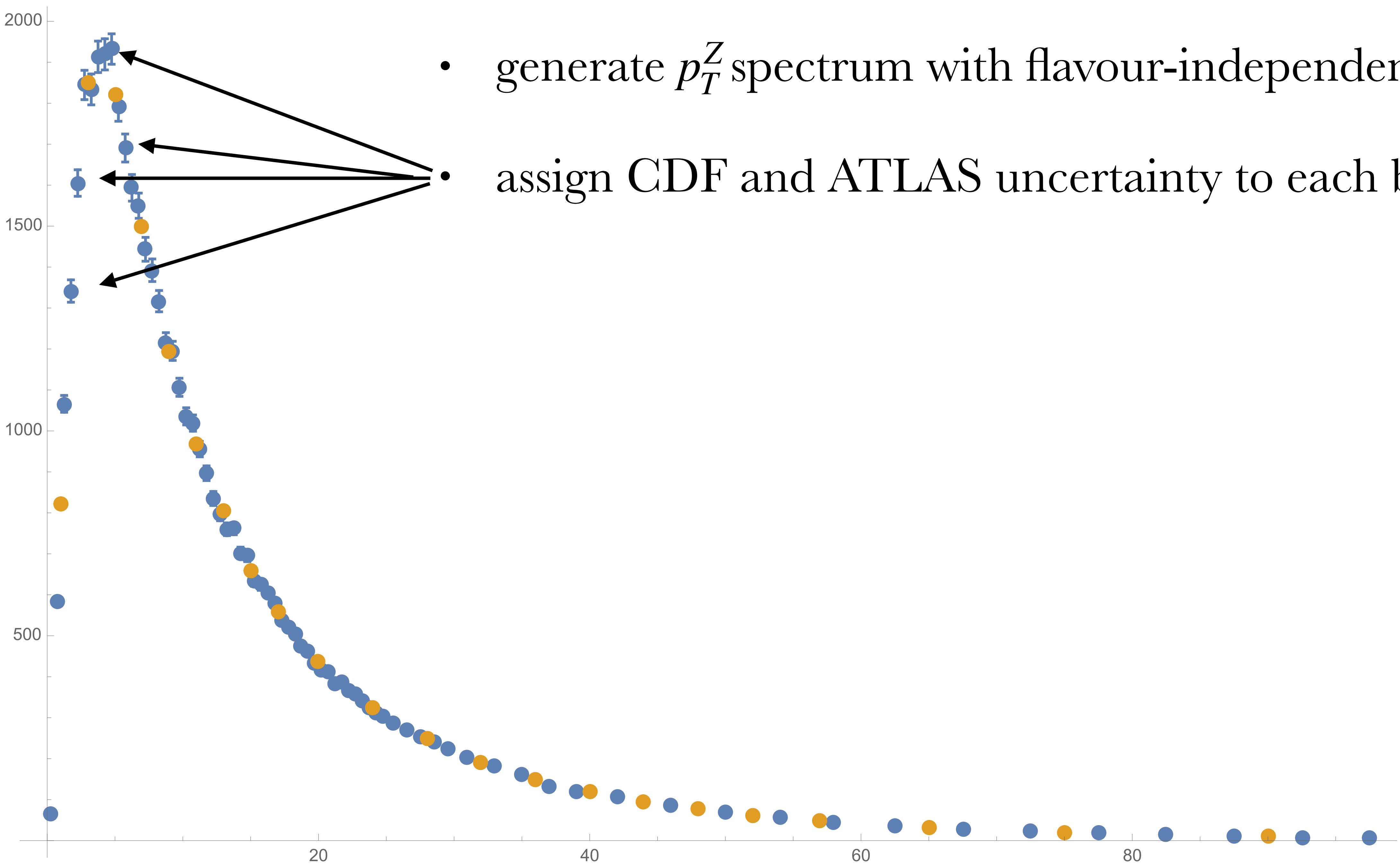

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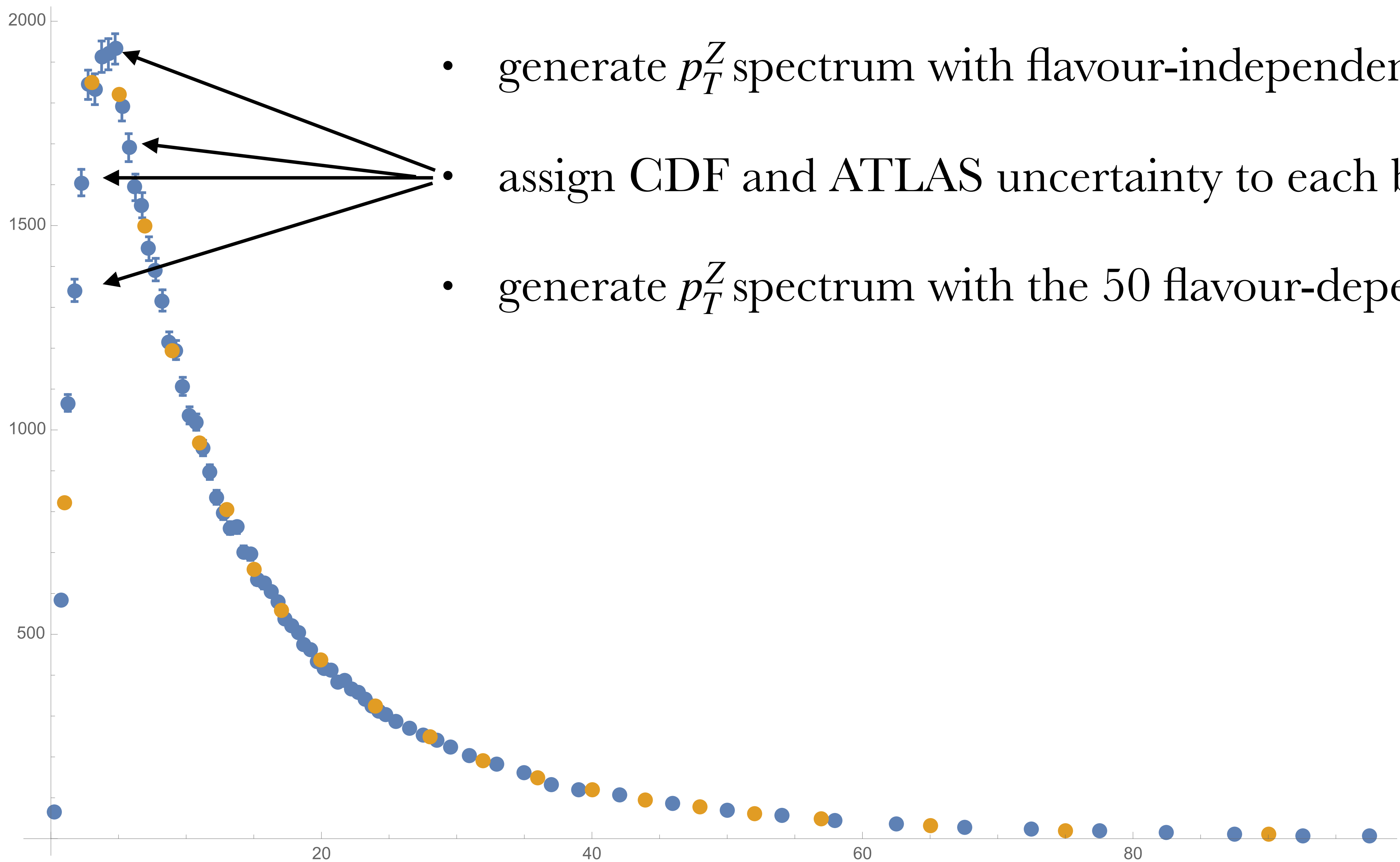

- generate p_T^Z spectrum with flavour-independent set
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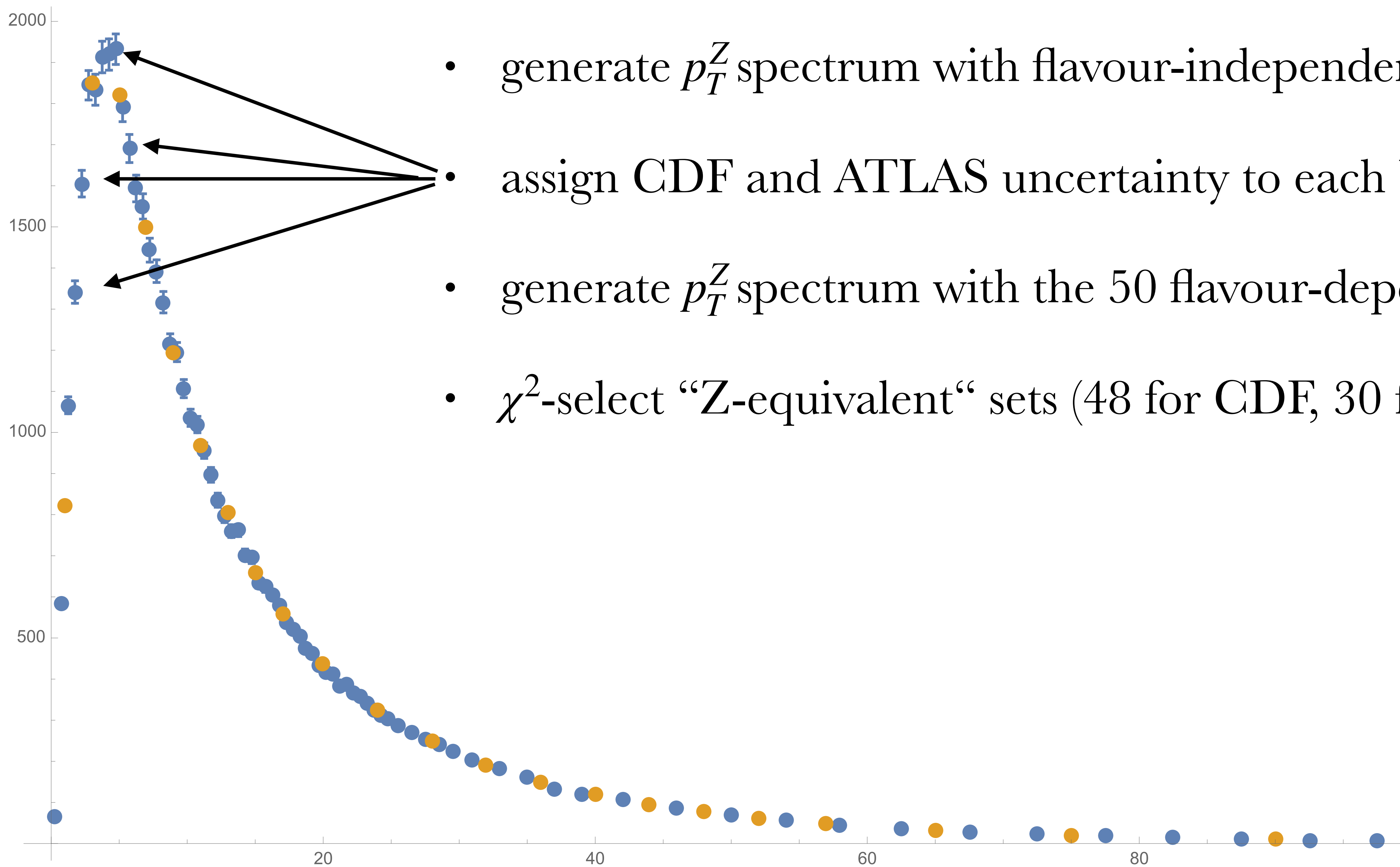

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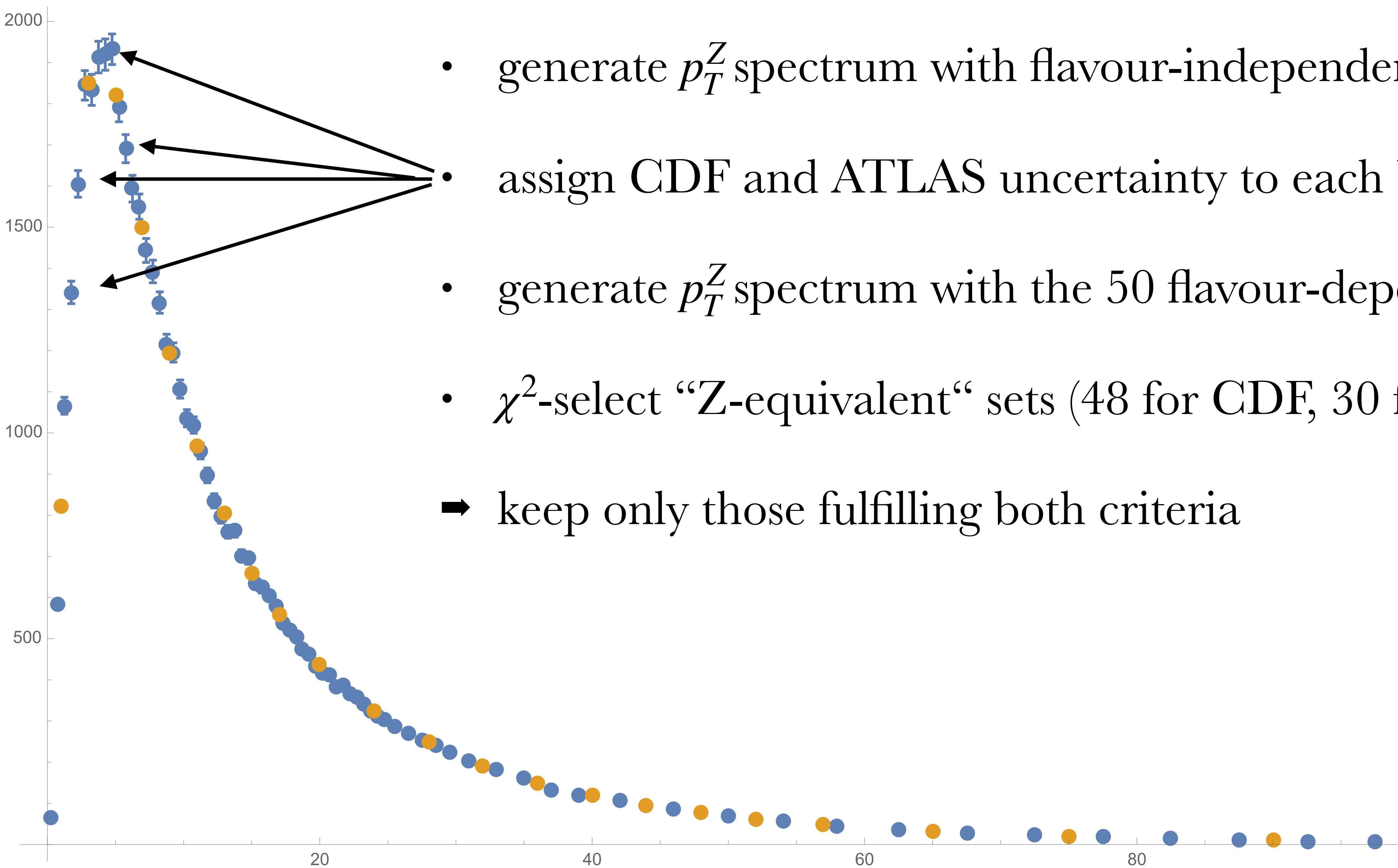

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➡ keep only those fulfilling both criteria

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Impact on m_W

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Impact on m_W

- Take the "Z-equivalent" *flavour-dependent* parameter sets and compute *low-statistics* (135M) m_T, p_T^l, p_T^ν distributions

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- **perform the template fit procedure and compute the shifts induced by flavour effects**

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	ΔM_{W+}			ΔM_{W-}		
Set	m_T	$p_{T\ell}$	$p_{T\nu}$	m_T	$p_{T\ell}$	$p_{T\nu}$
1	0	-1	-2	-2	3	-3
2	0	-6	0	-2	0	-5
3	-1	9	0	-2	4	-10
4	0	0	-2	-2	-4	-10
5	0	4	1	-1	-3	-6
6	1	0	2	-1	4	-4
7	2	-1	2	-1	0	-8
8	0	2	8	1	7	8
9	0	4	-3	-1	0	7

TABLE I: ATLAS 7 TeV

	ΔM_{W+}			ΔM_{W-}		
Set	m_T	$p_{T\ell}$	$p_{T\nu}$	m_T	$p_{T\ell}$	$p_{T\nu}$
1	-1	-5	7	-1	-3	8
2	-1	-15	6	0	5	10
3	-1	1	8	-1	-7	5
4	-1	-15	6	0	-4	5
5	-1	-4	6	-1	-7	5
6	-1	-5	7	0	2	9
7	-1	-15	6	-1	-6	5
8	-1	0	8	0	3	10
9	-1	-7	7	0	4	10

TABLE II: LHCb 13 TeV

Set	u_v	d_v	u_s	d_s	s
1	0.34	0.26	0.46	0.59	0.32
2	0.34	0.46	0.56	0.32	0.51
3	0.55	0.34	0.33	0.55	0.30
4	0.53	0.49	0.37	0.22	0.52
5	0.42	0.38	0.29	0.57	0.27
6	0.40	0.52	0.46	0.54	0.21
7	0.22	0.21	0.40	0.46	0.49
8	0.53	0.31	0.59	0.54	0.33
9	0.46	0.46	0.58	0.40	0.28

Statistical uncertainty: 2.5 MeV

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Impact on m_W

- Take the "Z-equivalent" *flavour-dependent* parameter sets and compute *low-statistics* (135M) m_T, p_T^l, p_T^ν distributions

  ➡ **pseudodata**

- Take the *flavour-independent* parameter set and compute *high-statistics* (750M) m_T, p_T^l, p_T^ν distributions for 30 different values of M_W

  ➡ **templates**

- **perform the template fit procedure and compute the shifts induced by flavour effects**

- transverse mass: zero or few MeV shifts, generally favouring lower values for W- (preferred by EW fit)

	ΔM_{W+}			ΔM_{W-}		
Set	m_T	$p_{T\ell}$	$p_{T\nu}$	m_T	$p_{T\ell}$	$p_{T\nu}$
1	0	-1	-2	-2	3	-3
2	0	-6	0	-2	0	-5
3	-1	9	0	-2	4	-10
4	0	0	-2	-2	-4	-10
5	0	4	1	-1	-3	-6
6	1	0	2	-1	4	-4
7	2	-1	2	-1	0	-8
8	0	2	8	1	7	8
9	0	4	-3	-1	0	7

TABLE I: ATLAS 7 TeV

	ΔM_{W+}			ΔM_{W-}		
Set	m_T	$p_{T\ell}$	$p_{T\nu}$	m_T	$p_{T\ell}$	$p_{T\nu}$
1	-1	-5	7	-1	-3	8
2	-1	-15	6	0	5	10
3	-1	1	8	-1	-7	5
4	-1	-15	6	0	-4	5
5	-1	-4	6	-1	-7	5
6	-1	-5	7	0	2	9
7	-1	-15	6	-1	-6	5
8	-1	0	8	0	3	10
9	-1	-7	7	0	4	10

TABLE II: LHCb 13 TeV

Set	u_v	d_v	u_s	d_s	s
1	0.34	0.26	0.46	0.59	0.32
2	0.34	0.46	0.56	0.32	0.51
3	0.55	0.34	0.33	0.55	0.30
4	0.53	0.49	0.37	0.22	0.52
5	0.42	0.38	0.29	0.57	0.27
6	0.40	0.52	0.46	0.54	0.21
7	0.22	0.21	0.40	0.46	0.49
8	0.53	0.31	0.59	0.54	0.33
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- lepton pt: quite important shifts (envelope **up to 15 MeV**)

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1	0	-1	-2	-2	3	-3
2	0	-6	0	-2	0	-5
3	-1	9	0	-2	4	-10
4	0	0	-2	-2	-4	-10
5	0	4	1	-1	-3	-6
6	1	0	2	-1	4	-4
7	2	-1	2	-1	0	-8
8	0	2	8	1	7	8
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2	-1	-15	6	0	5	10
3	-1	1	8	-1	-7	5
4	-1	-15	6	0	-4	5
5	-1	-4	6	-1	-7	5
6	-1	-5	7	0	2	9
7	-1	-15	6	-1	-6	5
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- lepton pt: quite important shifts (envelope **up to 15 MeV**)

- neutrino pt: same order of magnitude (or bigger) as lepton pt

	ΔM_{W+}			ΔM_{W-}		
Set	m_T	$p_{T\ell}$	$p_{T\nu}$	m_T	$p_{T\ell}$	$p_{T\nu}$
1	0	-1	-2	-2	3	-3
2	0	-6	0	-2	0	-5
3	-1	9	0	-2	4	-10
4	0	0	-2	-2	-4	-10
5	0	4	1	-1	-3	-6
6	1	0	2	-1	4	-4
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2	-1	-15	6	0	5	10
3	-1	1	8	-1	-7	5
4	-1	-15	6	0	-4	5
5	-1	-4	6	-1	-7	5
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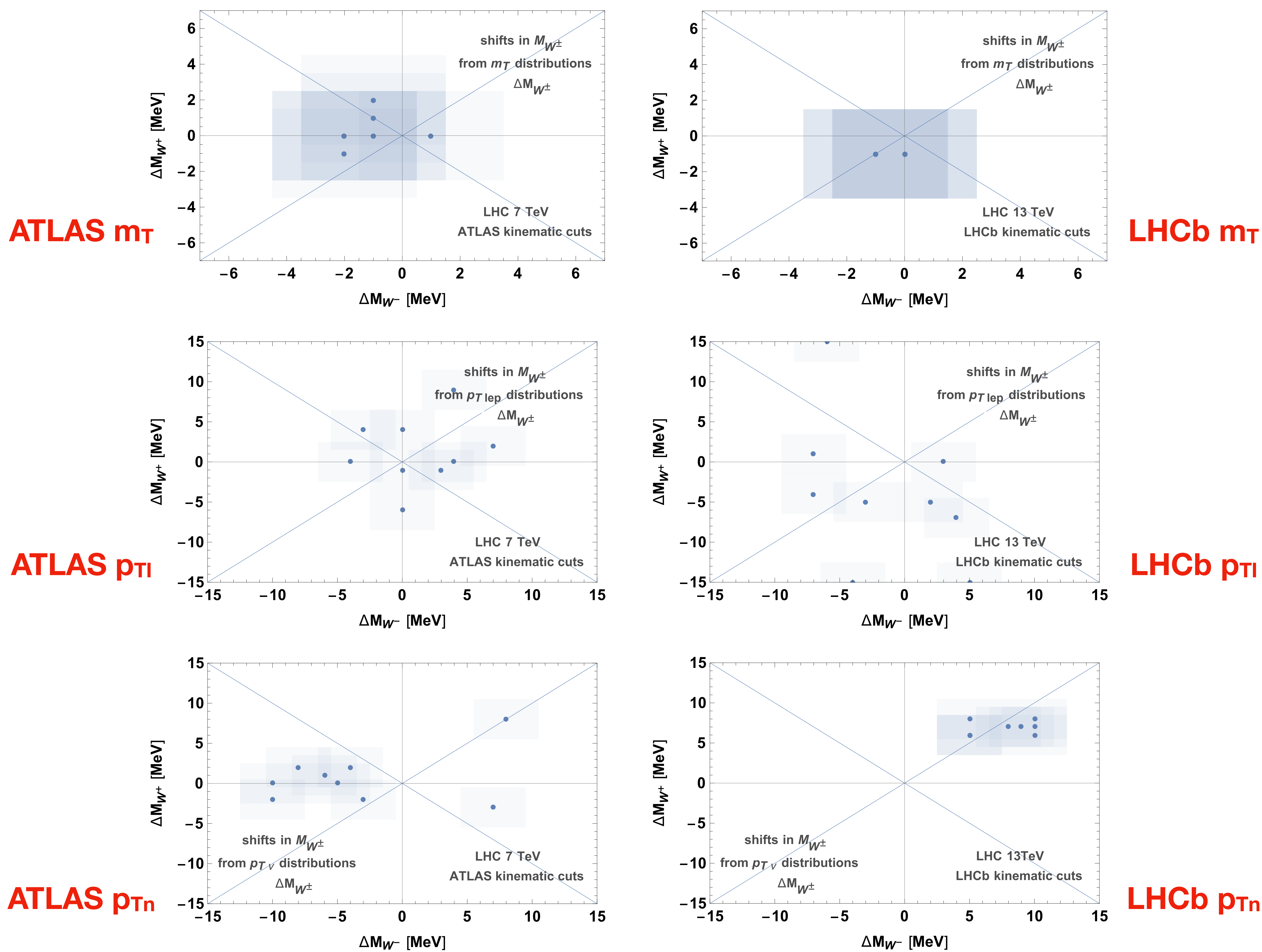

ATLAS mT
LHCb mT
ATLAS pTl
LHCb pTl
ATLAS pTn
LHCb pTn
shifts in $M_{W^\pm}$
from m_T distributions
$\Delta M_{W^\pm}$
shifts in $M_{W^\pm}$
from $p_{T\,lep}$ distributions
$\Delta M_{W^\pm}$
shifts in $M_{W^\pm}$
from $p_{T\,\nu}$ distributions
$\Delta M_{W^\pm}$
LHC 7 TeV
ATLAS kinematic cuts
LHC 13 TeV
LHCb kinematic cuts
LHC 13TeV
ΔM_{W^+} [MeV]
ΔM_{W^-} [MeV]