Non perturbative flavour-dependent effects due to intrinsic k_T and their impact on the determination of M_W

giuseppe bozzi

in collaboration with
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(arXiv:1807.02101)

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The extraction of physical quantities

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Observables

- accessible via counting experiments: cross sections and asymmetries

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  - M_W at hadron colliders as fitting parameter of a *template fit* procedure

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➡ the result of the fit depends on the hypotheses used to compute the templates (PDFs, scales, non-perturbative, different prescriptions, …)

➡ these hypotheses should be treated as theoretical systematic errors

General template-fit strategy (example: PDF uncertainty)

Bozzi, Rojo, Vicini PRD 83, 113008 (2011)

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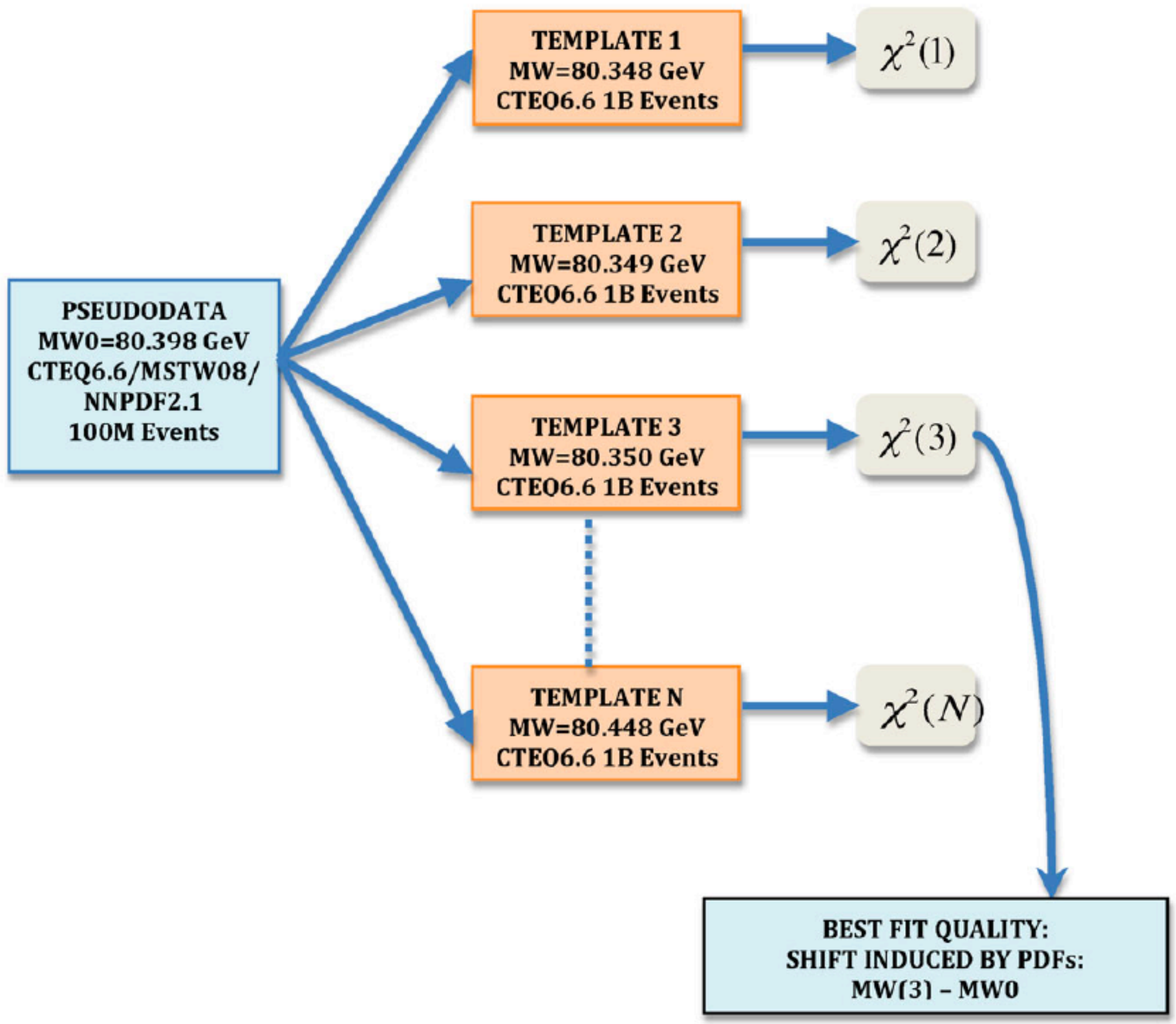
- **pseudodata** with different PDF sets: low-statistics (100M) and fixed M_{W0}
- **templates** with a reference PDF set (CTEQ6.6): high-statistics (1B) and different M_W
- same code used to generate both pseudodata and templates → only effect probed is the PDF one



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ATLAS, EPJC 78, 110 (2018)

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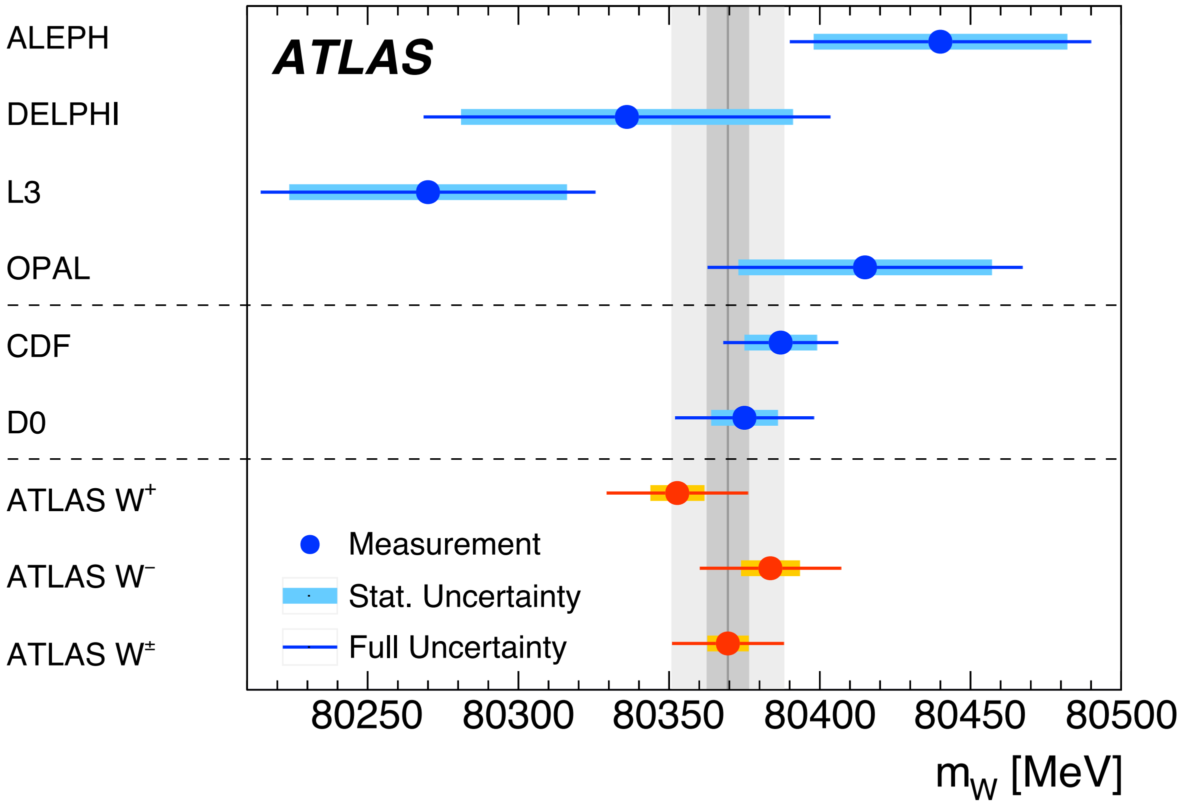

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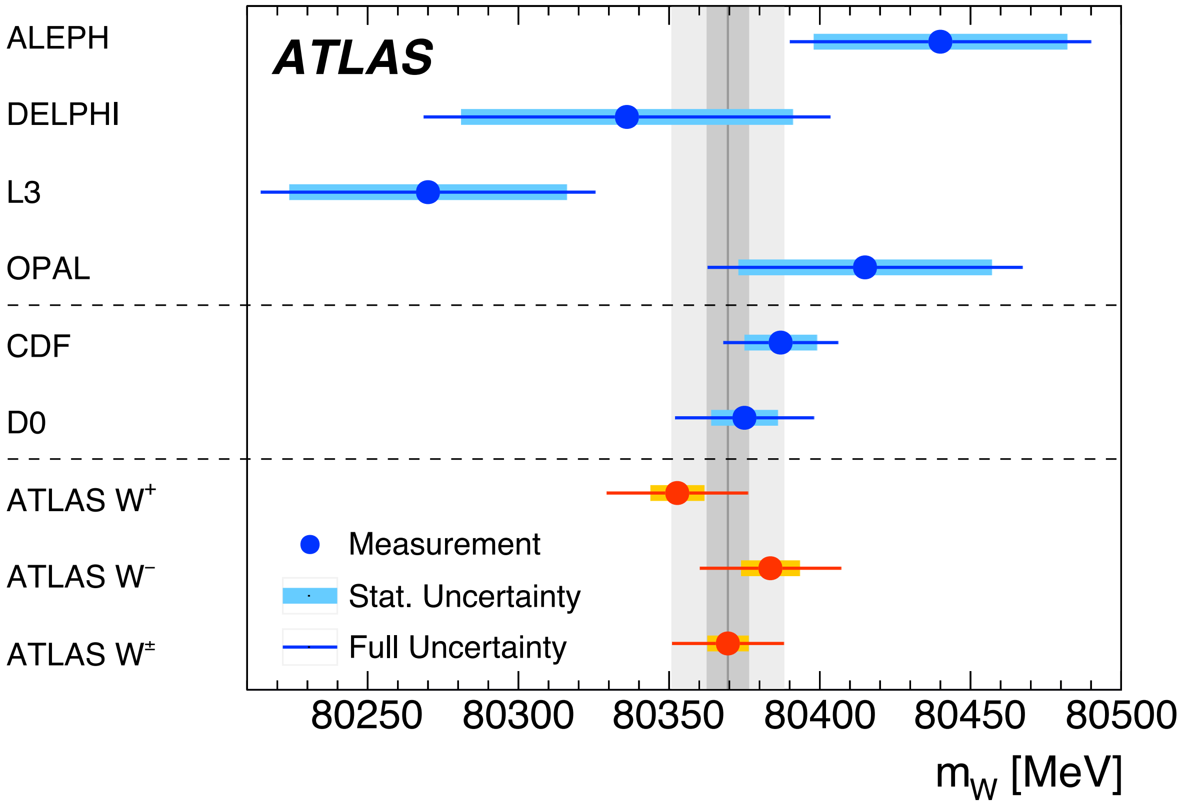

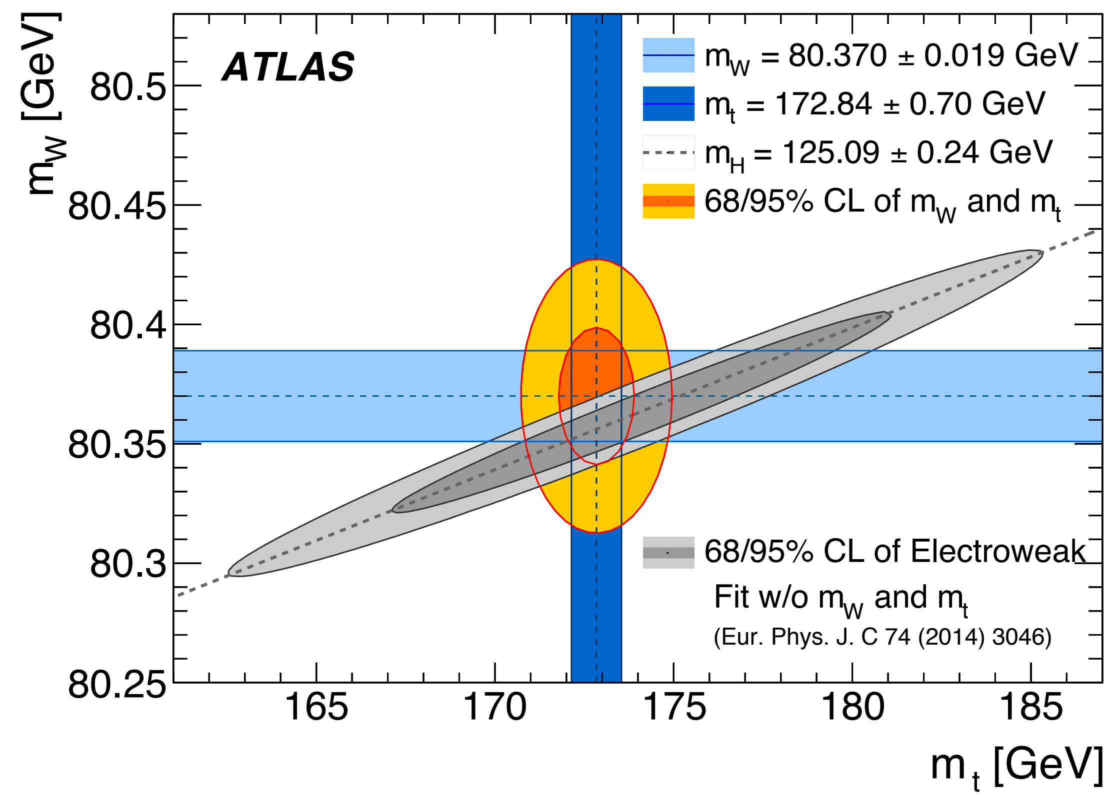

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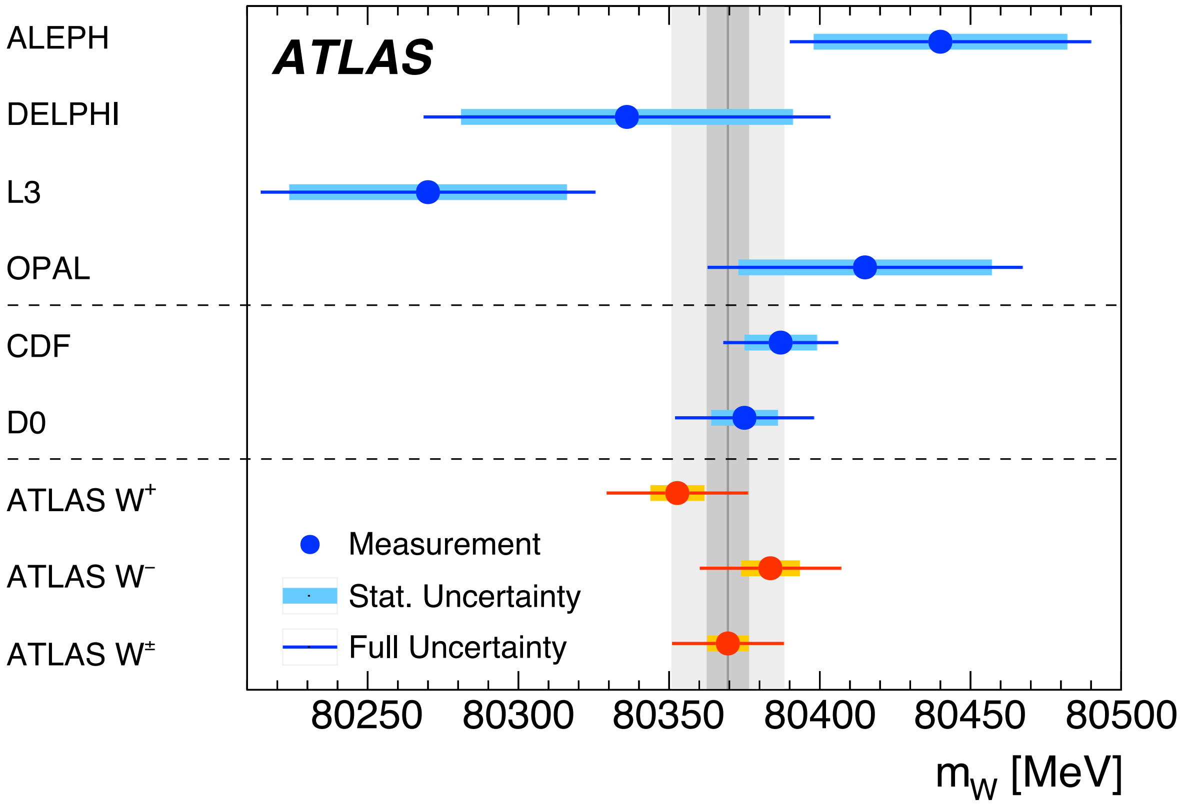

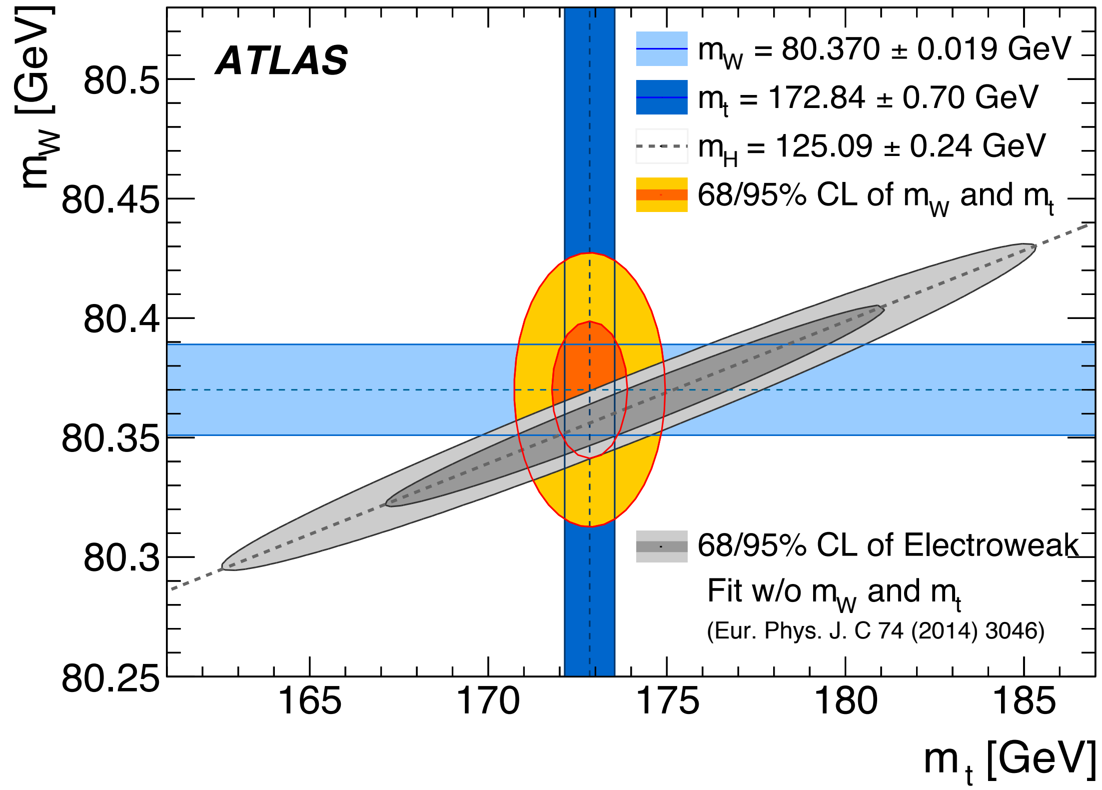

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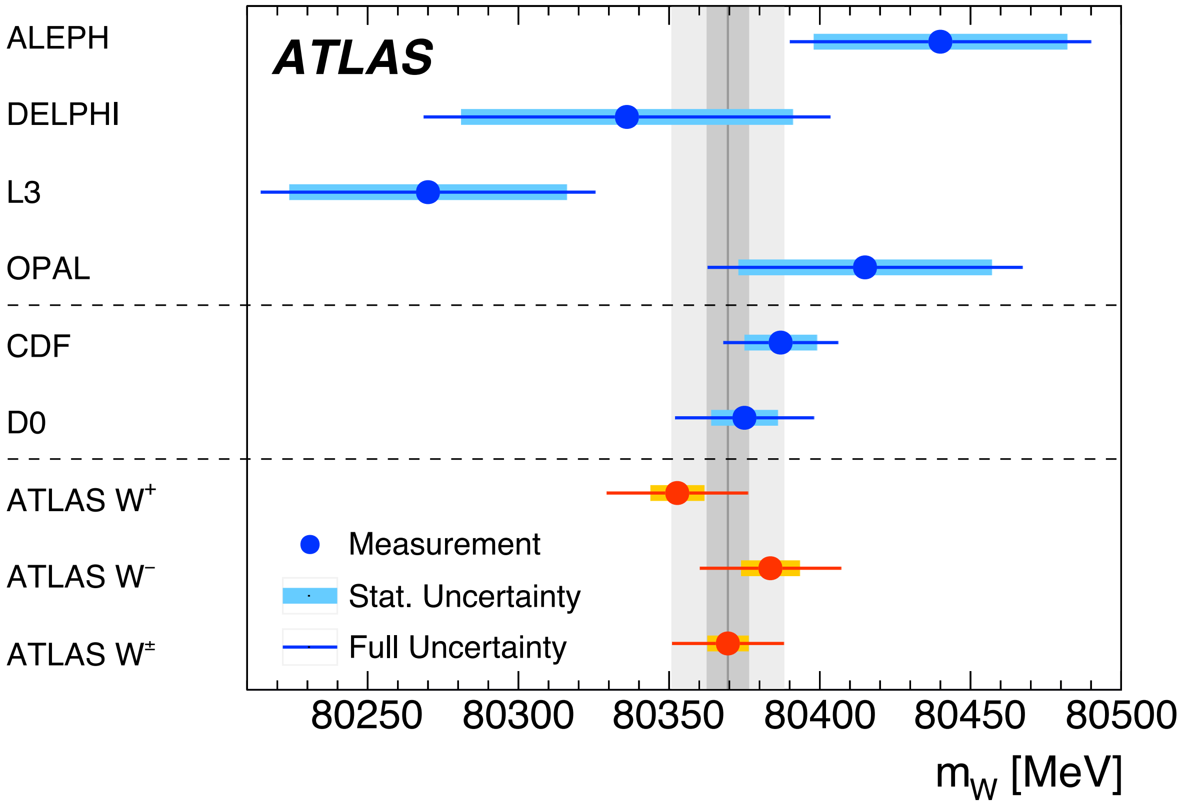

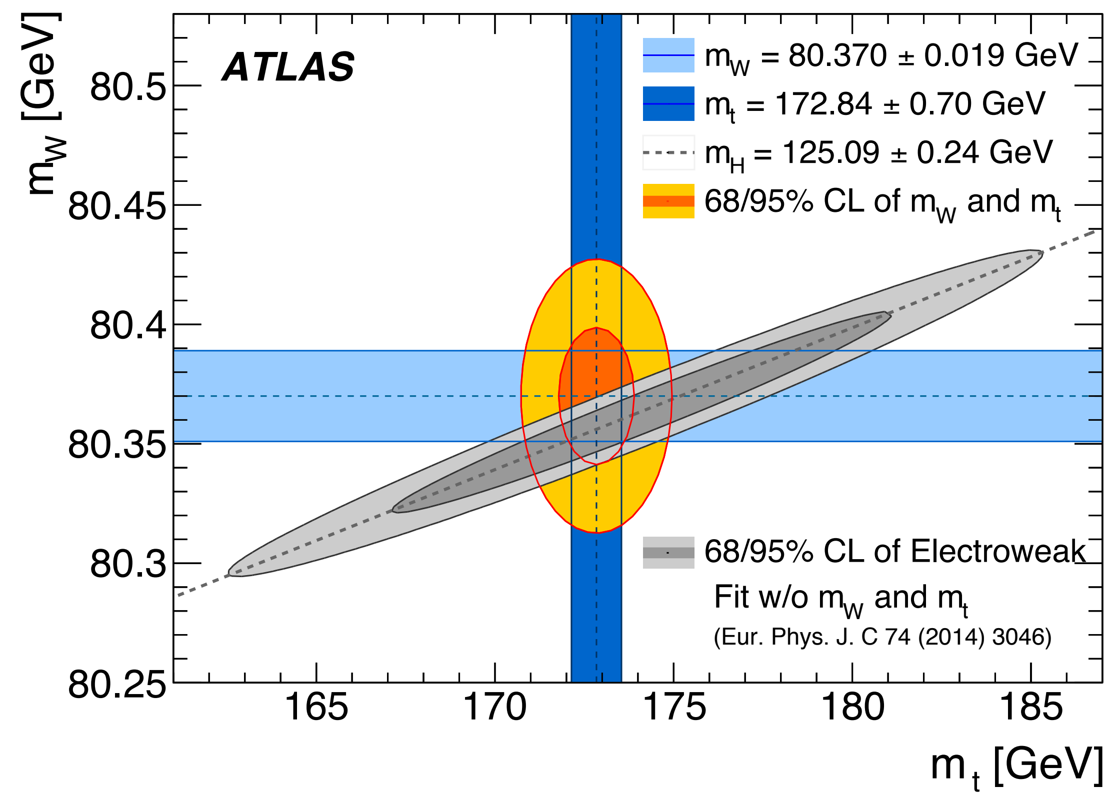

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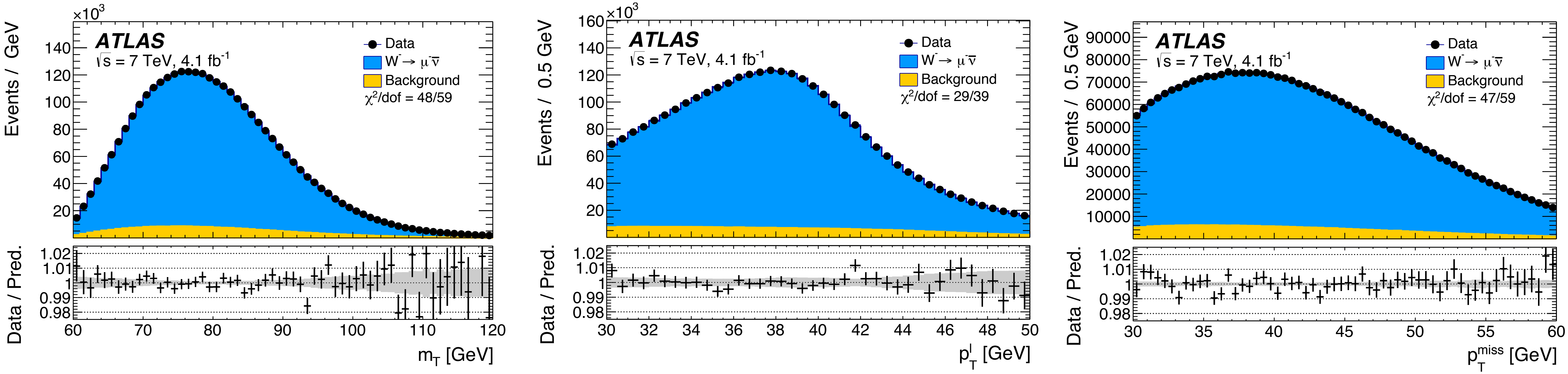

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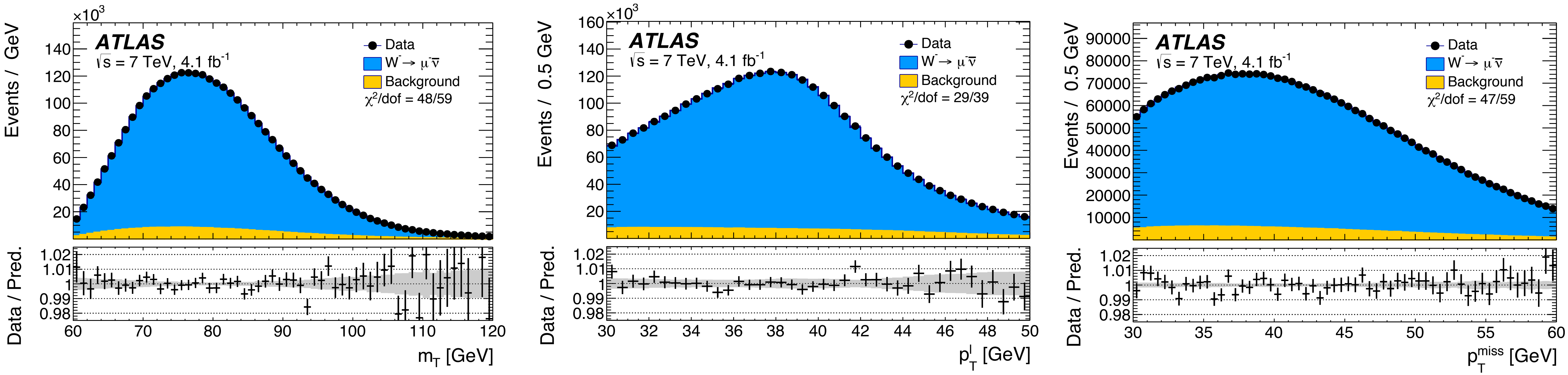

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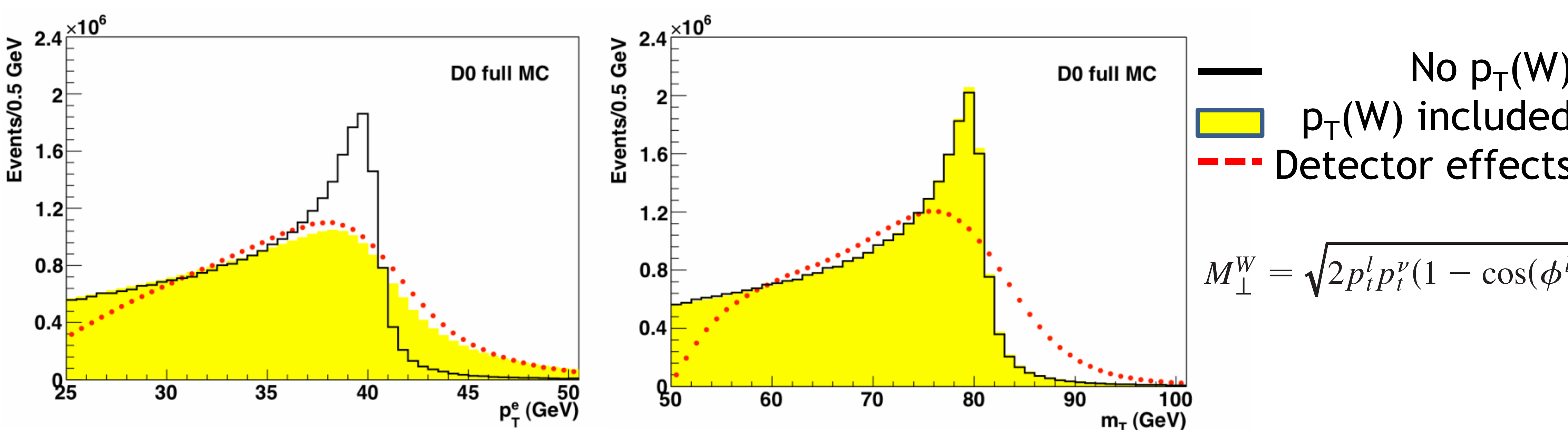

$$M_{\perp}^{W} = \sqrt{2 p_t^l p_t^{\nu} (1 - \cos(\phi^l - \phi^{\nu}))},$$

Transverse mass: important detector smearing effects, weakly sensitive to p_{TW} modelling

Lepton p_T: moderate detector smearing effects, extremely sensitive to p_{TW} modelling

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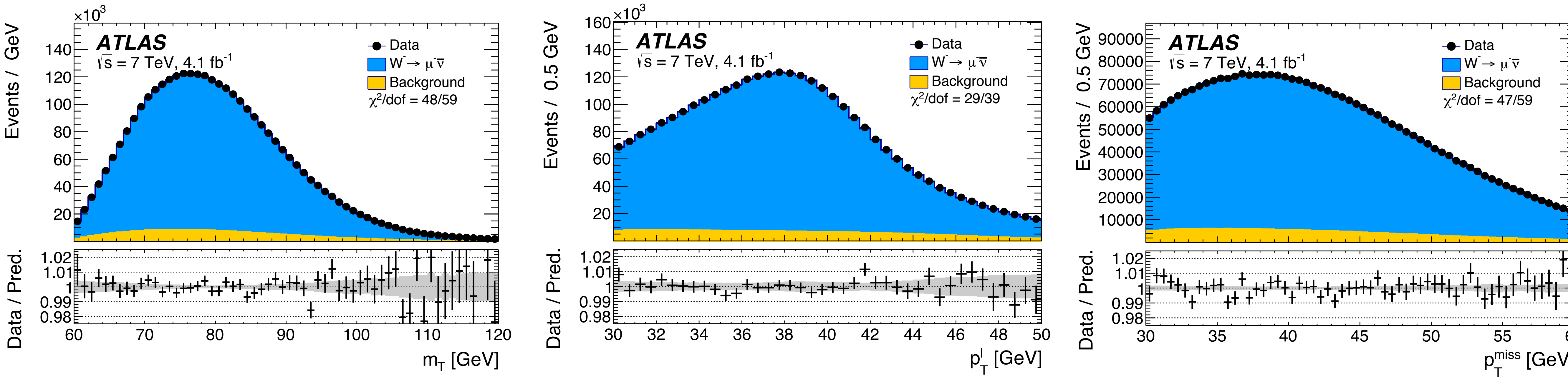

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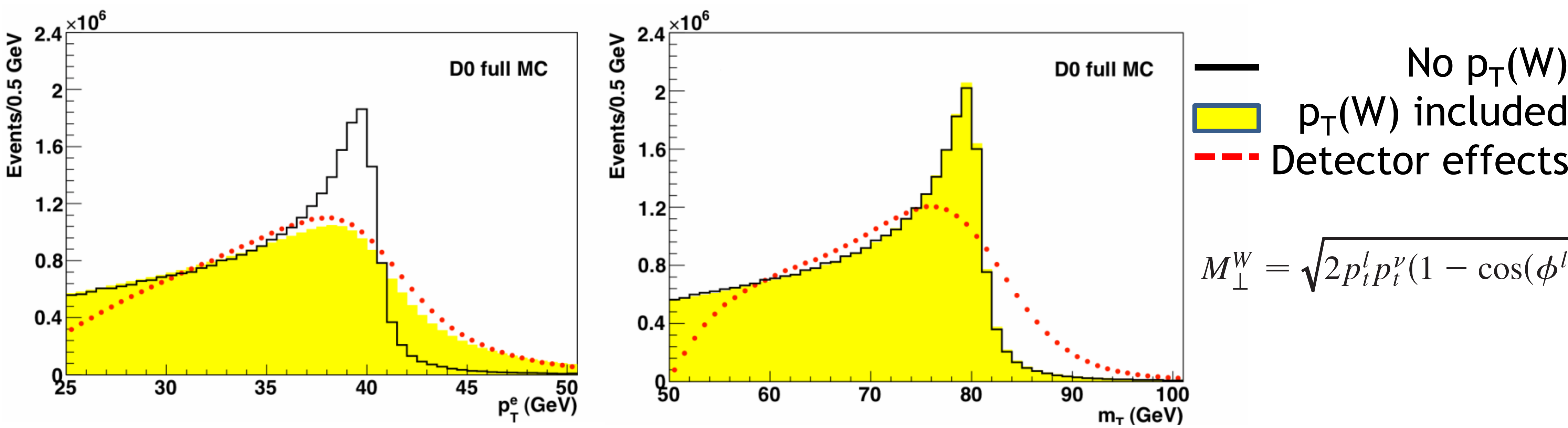

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p_{TW} modelling depends on flavour and all-order treatment of QCD corrections

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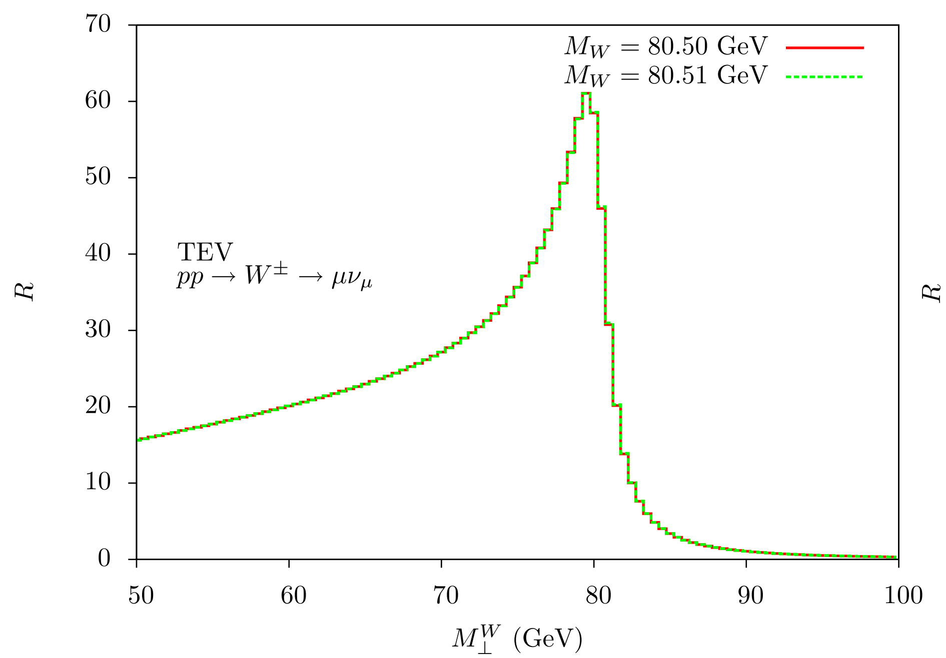

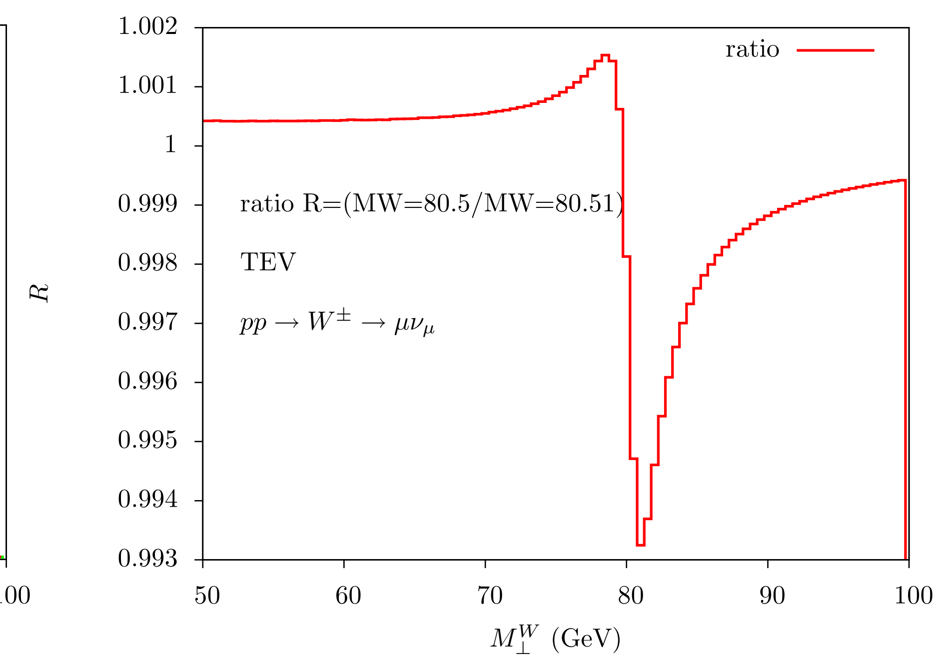

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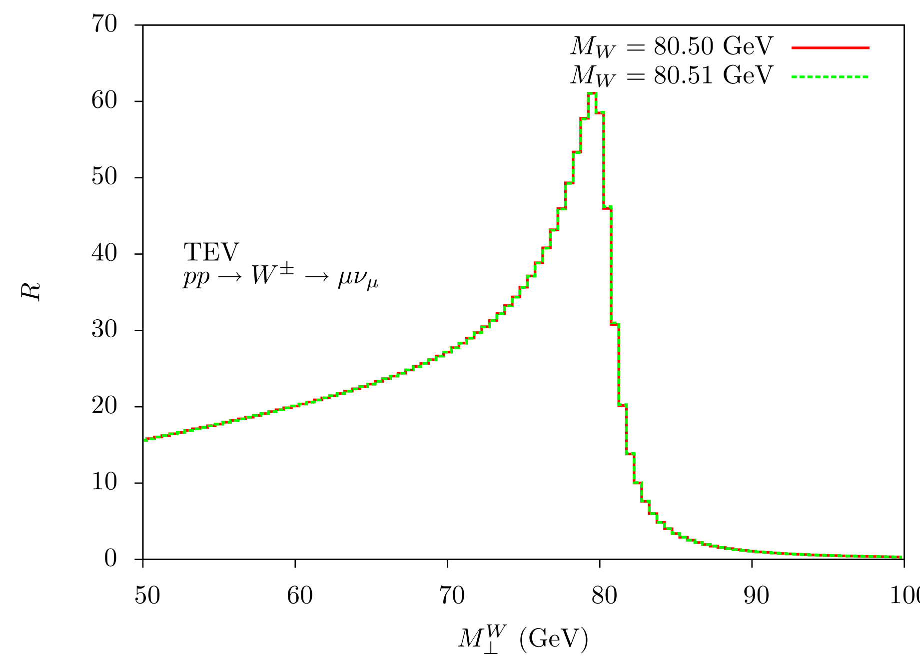
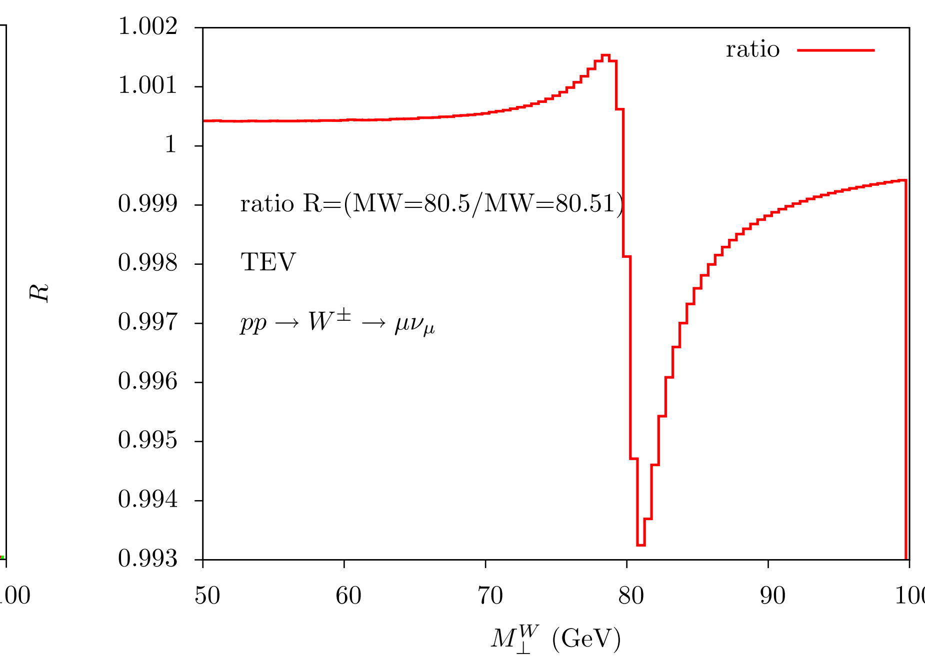
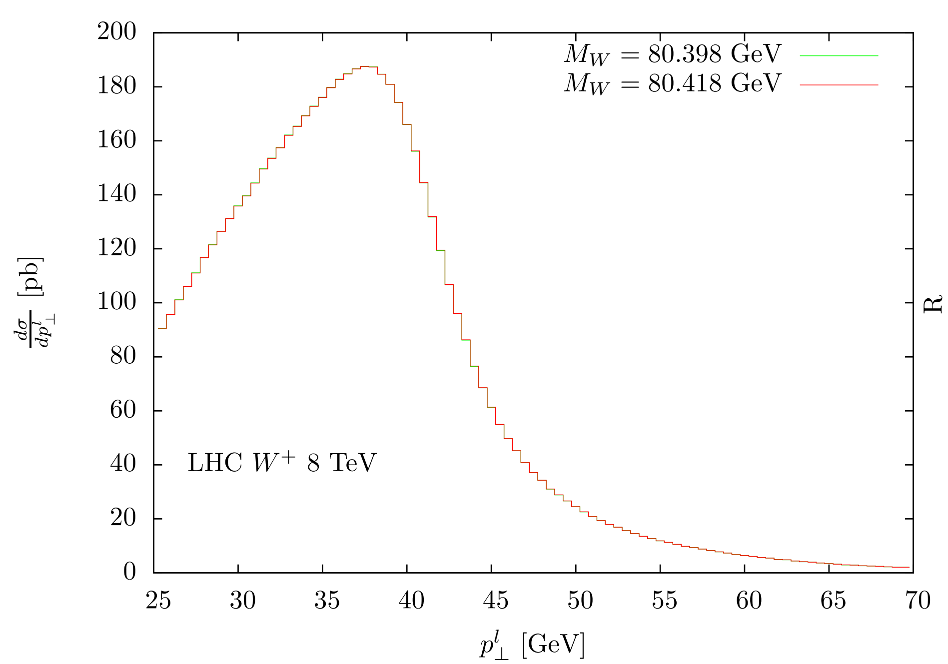
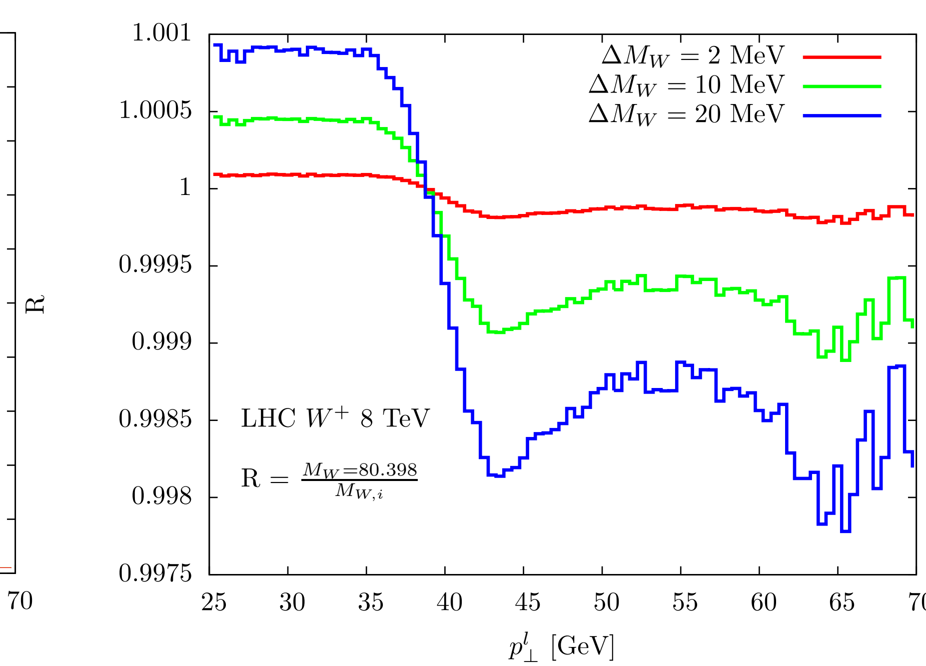




p_{Tl}





Uncertainties on M_W due to p_{TW}

CDF

	m_T fit uncertainties		
Source	$W \to \mu\nu$	$W \to e\nu$	Common
Lepton energy scale	7	10	5
Lepton energy resolution	1	4	0
Lepton efficiency	0	0	0
Lepton tower removal	2	3	2
Recoil scale	5	5	5
Recoil resolution	7	7	7
Backgrounds	3	4	0
PDFs	10	10	10
W boson p_T	3	3	3
Photon radiation	4	4	4
Statistical	16	19	0
Total	23	26	15

	p_T^ℓ fit uncertainties		
Source	$W \to \mu\nu$	$W \to e\nu$	Common
Lepton energy scale	7	10	5
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Lepton efficiency	1	2	0
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Recoil scale	6	6	6
Recoil resolution	5	5	5
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PDFs	9	9	9
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D0

Source	Section	m_T	p_T^e	$\not{E}_T$
Experimental				
Electron Energy Scale	VII C 4	16	17	16
Electron Energy Resolution	VII C 5	2	2	3
Electron Shower Model	V C	4	6	7
Electron Energy Loss	V D	4	4	4
Recoil Model	VII D 3	5	6	14
Electron Efficiencies	VII B 10	1	3	5
Backgrounds	VIII	2	2	2
$\sum$(Experimental)		18	20	24
W Production and Decay Model				
PDF	VI C	11	11	14
QED	VI B	7	7	9
Boson p_T	VI A	2	5	2
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Systematic Uncertainty (Experimental and Model)		22	24	29
W Boson Statistics	IX	13	14	15
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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
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—> *different Gaussian factors for different flavours*

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Flavor and kinematic dependent widths

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Fit to SIDIS/DY/Z data: $g_{evo} \ln\left(\frac{Q^2}{Q_0^2}\right) \in [0.17, 0.39]\ \text{GeV}^2$

[Bacchetta, Del Carro, Pisano, Radici, Signori (2017)]

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Fit to SIDIS/DY/Z data: $g_{evo} \ln\left(\frac{Q^2}{Q_0^2}\right) \in [0.17, 0.39]\ \text{GeV}^2$

[Bacchetta, Del Carro, Pisano, Radici, Signori (2017)]

Choice of NP parameters

$$\frac{d\sigma}{dq_T} \sim \mathrm{FT}\,\exp\{-g_{_{NP}} b_T^2\} \longrightarrow$$ Fit to Z/γ^* Tevatron data: $g_{_{NP}} \sim 0.8\ \mathrm{GeV}^2$

[Guzzi, Nadolsky, Wang (2014)]

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We consider :

- **50 flavour-dependent sets** $\{g^{u_v}_{_{NP}}, g^{d_v}_{_{NP}}, g^{u_s}_{_{NP}}, g^{d_s}_{_{NP}}, g^{s}_{_{NP}}\}$ with $g^a_{_{NP}} \in [0.2, 0.6]\ \mathrm{GeV}^2$
- **1 flavour-independent set** with $g^a_{_{NP}} = 0.4\ \mathrm{GeV}^2$

“Z-equivalent” sets

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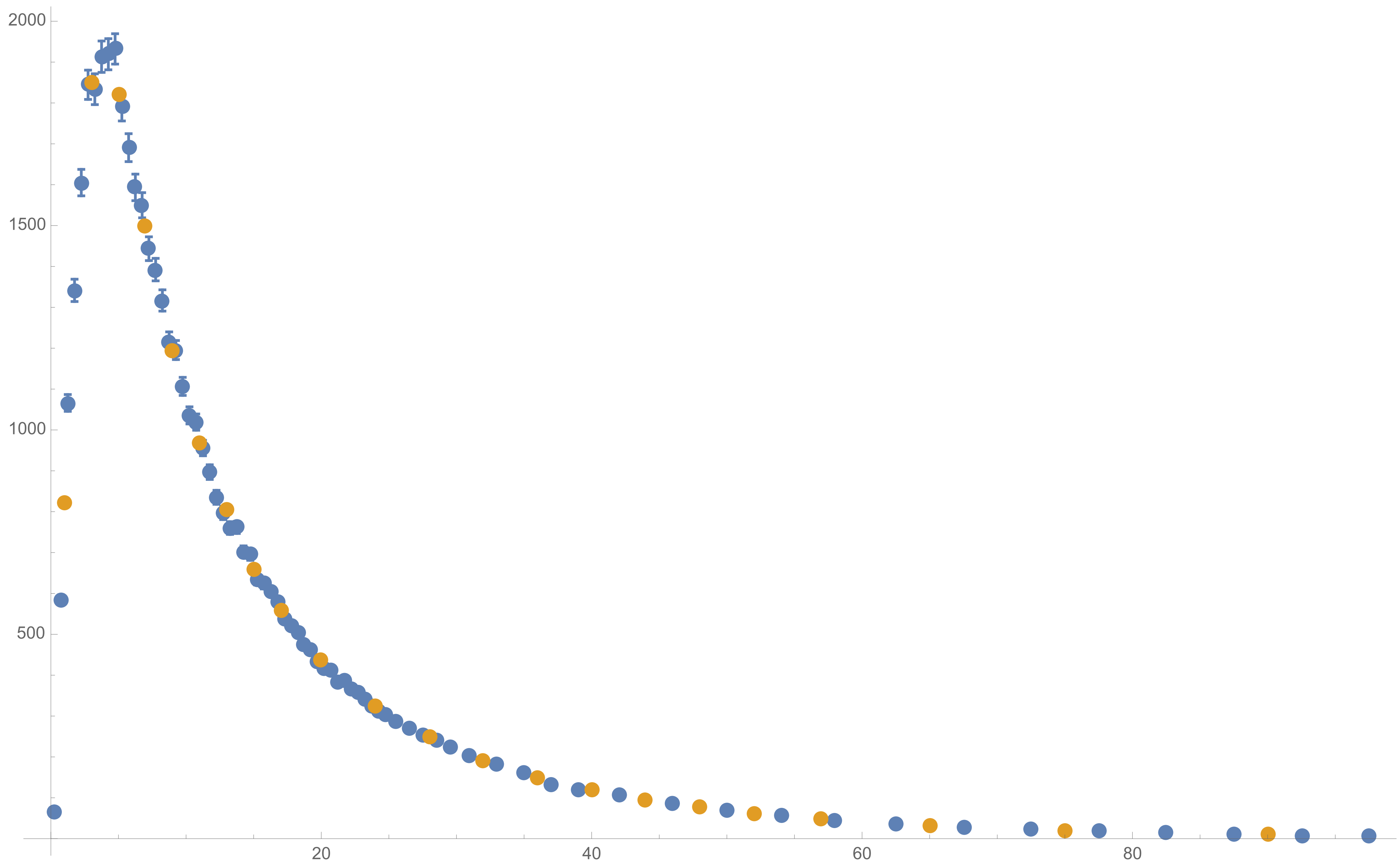

NLL+LO QCD curves obtained through a modified version of the **DYqT** code [Bozzi, Catani, deFlorian, Ferrera, Grazzini (2009,2011)] (Tevatron 1.96 TeV & LHC 7 TeV)

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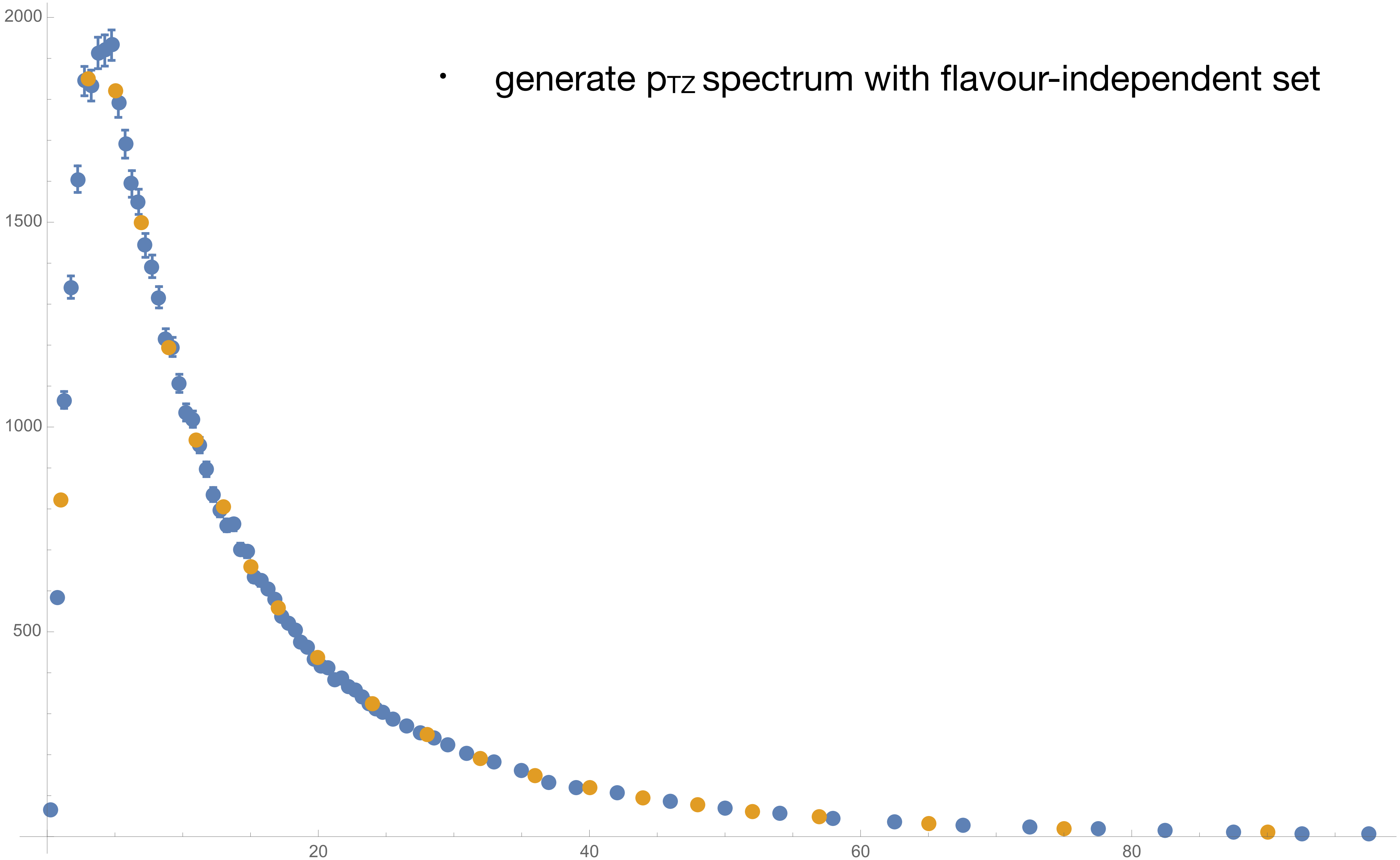

- generate p_{TZ} spectrum with flavour-independent set

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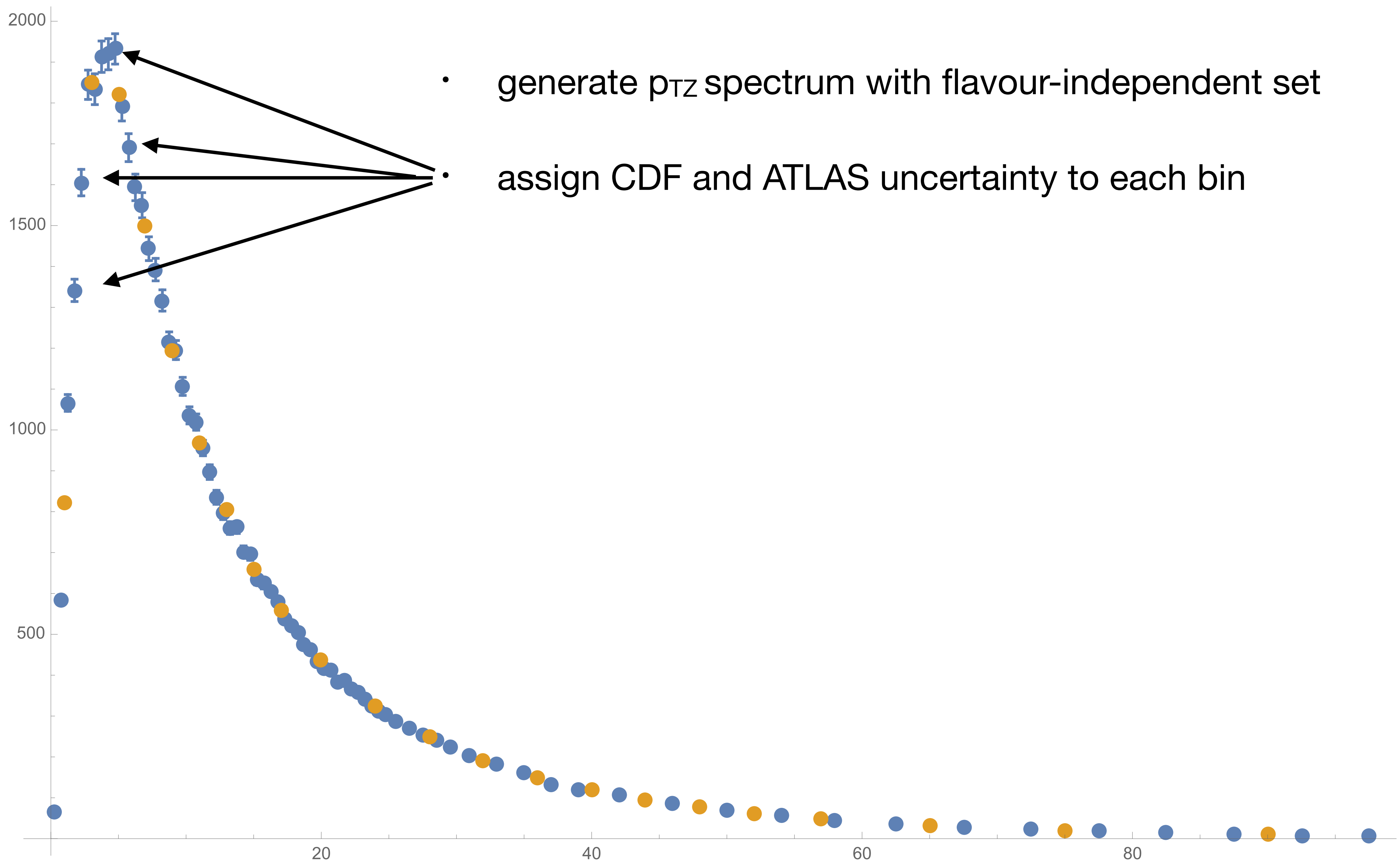

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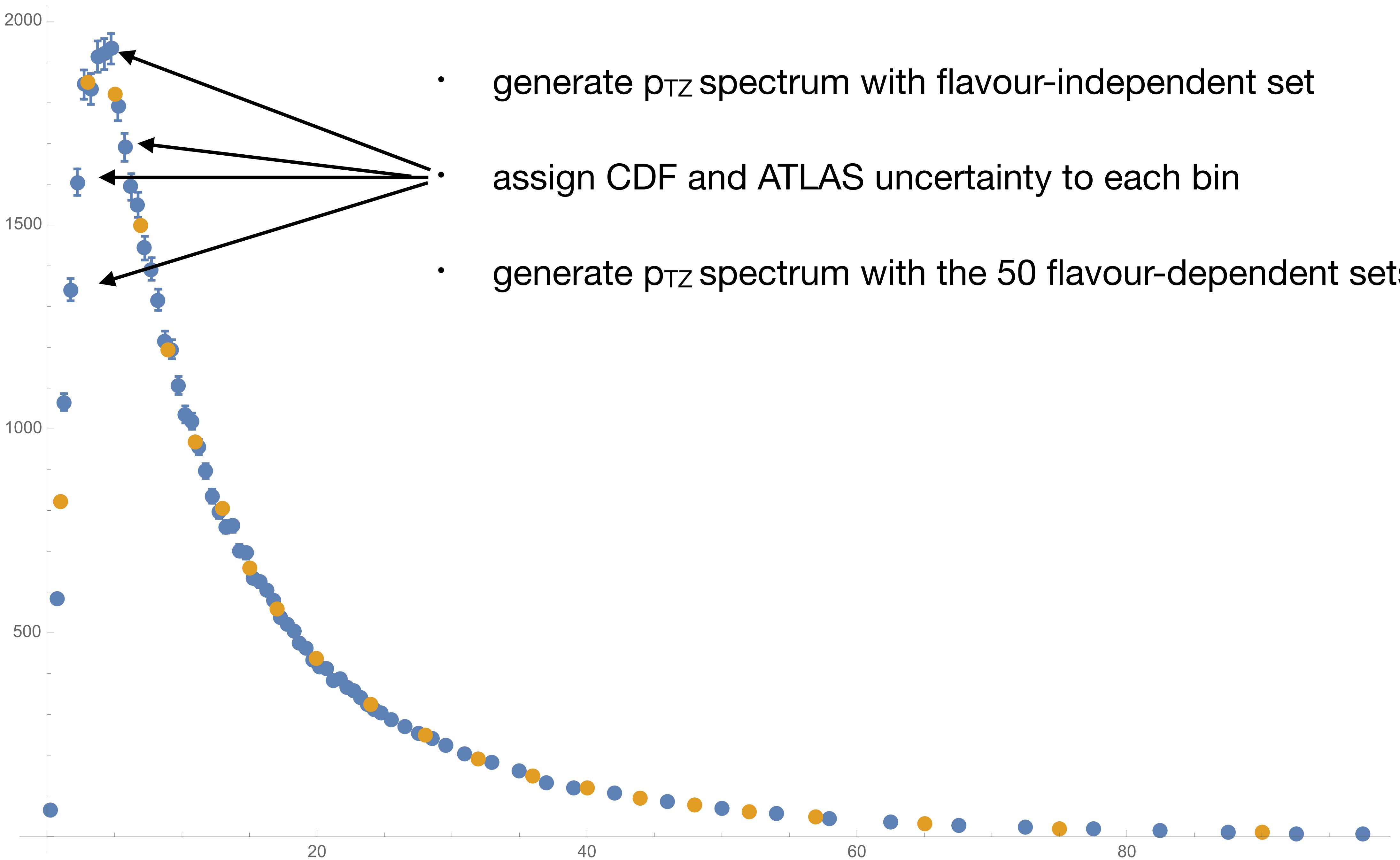

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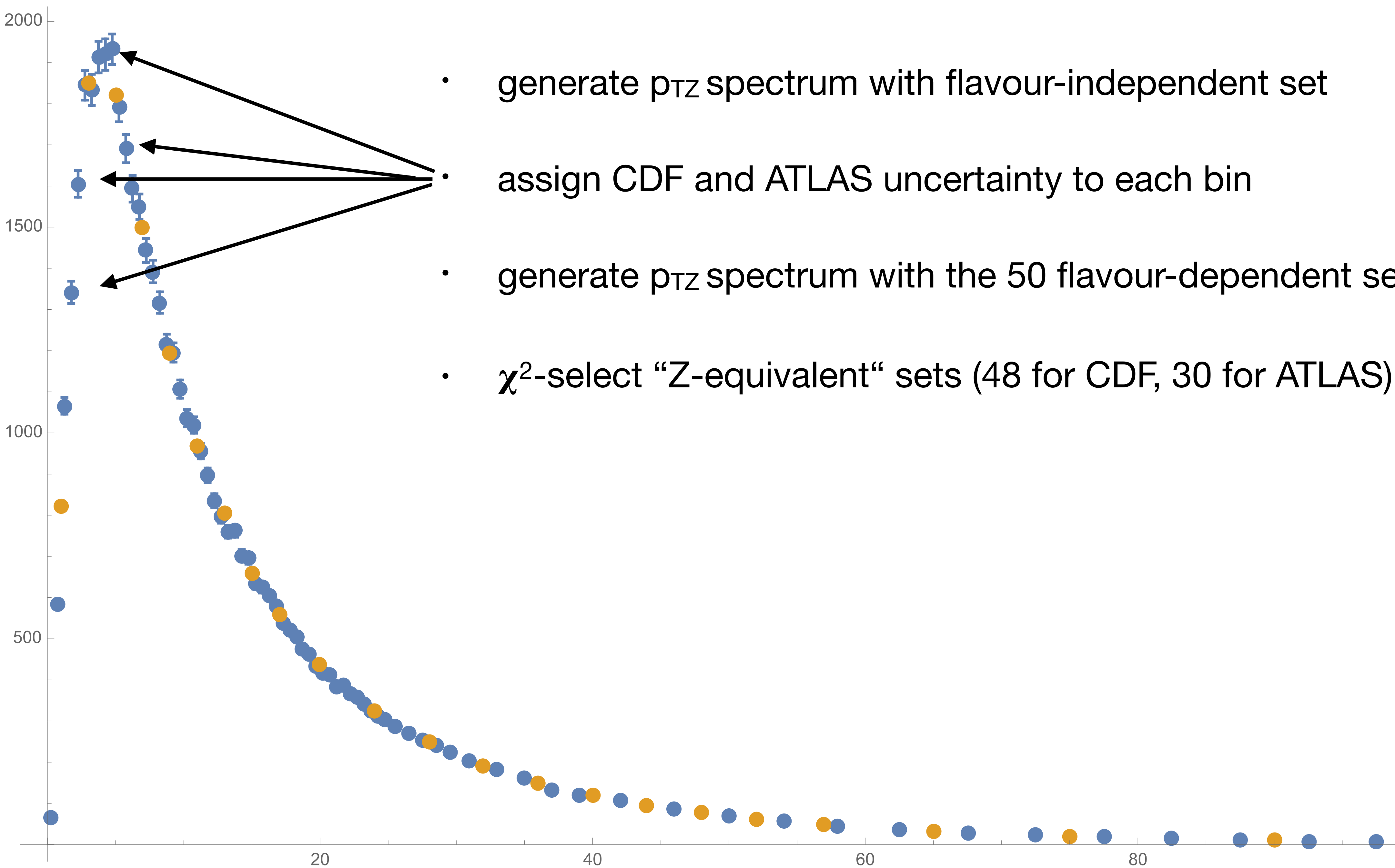

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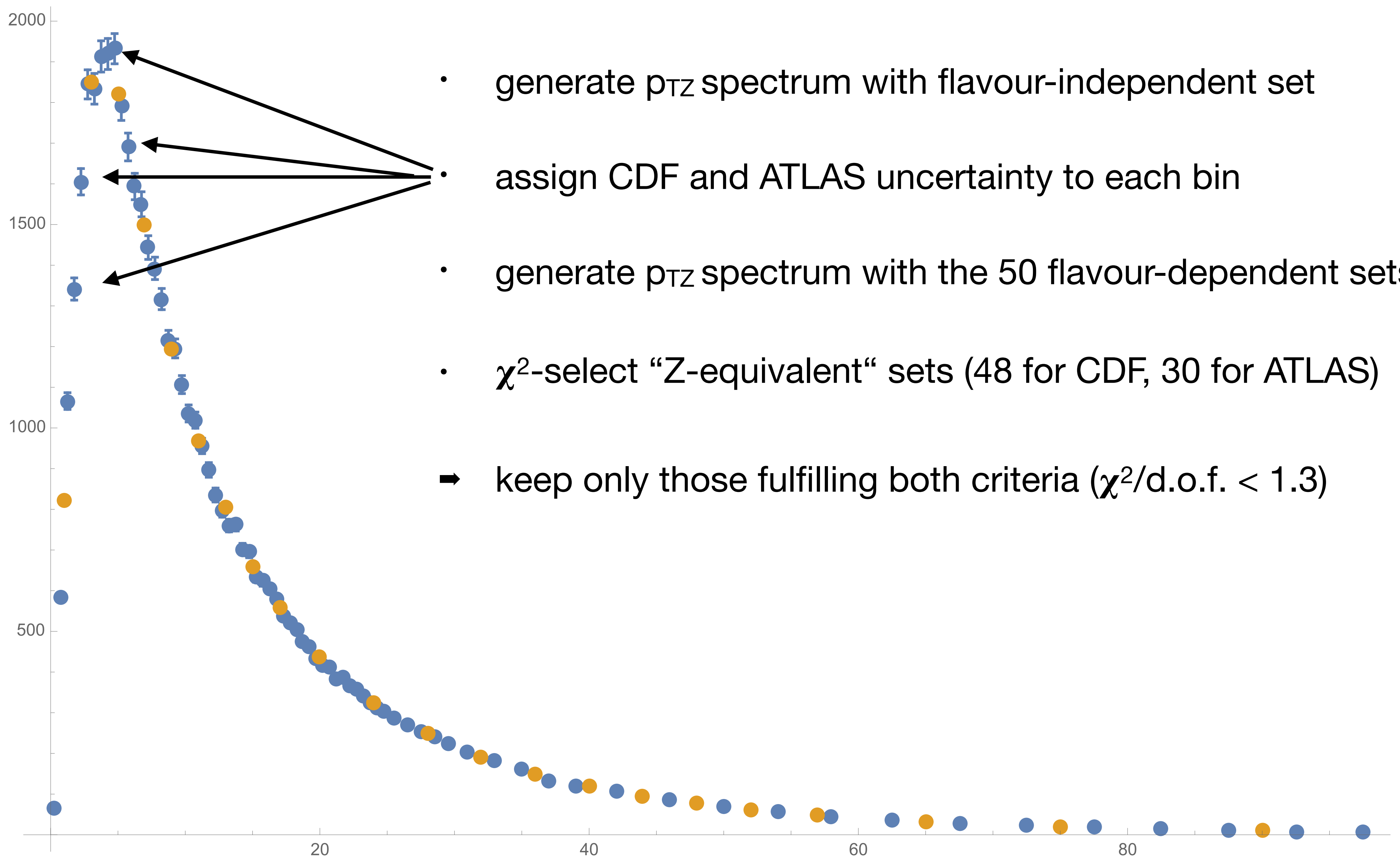

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➡ keep only those fulfilling both criteria (χ^2/d.o.f. < 1.3)

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Impact on the determination of M_W

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

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

Impact on the determination of M_W

- Take the "Z-equivalent" *flavour-dependent* parameter sets and compute *low-statistics* (135M) m_T and p_{Tl} distributions

Set	u_v	d_v	u_s	d_s	s
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Statistical uncertainty: 2.5 MeV

Bacchetta, Bozzi, Radici, Ritzmann, Signori (arXiv:1807.02101)

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- lepton pt: quite important shifts (W^+ set 3: **9 MeV**, envelope: **up to 15 MeV**)

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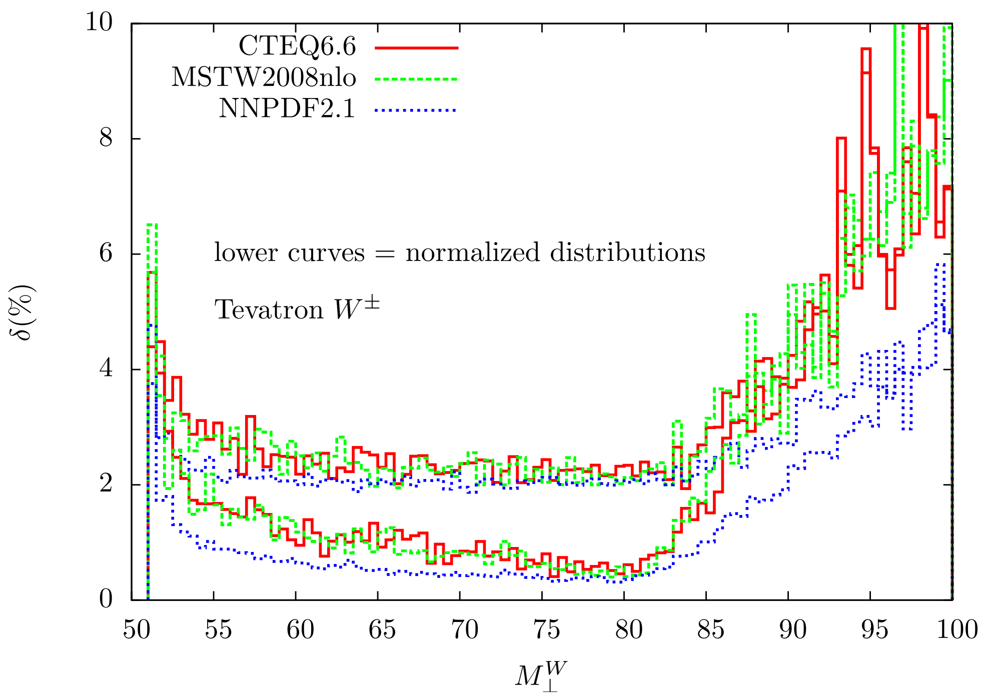
- *Stay tuned for more especially blended flavour papers by your favourite flavorists!*

Backup slides

PDF effect on transverse mass



Bozzi, Rojo, Vicini PRD 83, 113008 (2011)

- Normalised distributions: reduced sensitivity to PDFs
- Ratio of (non-)normalised distributions w.r.t. to central PDF set
- Distributions obtained with **DYNNLO**

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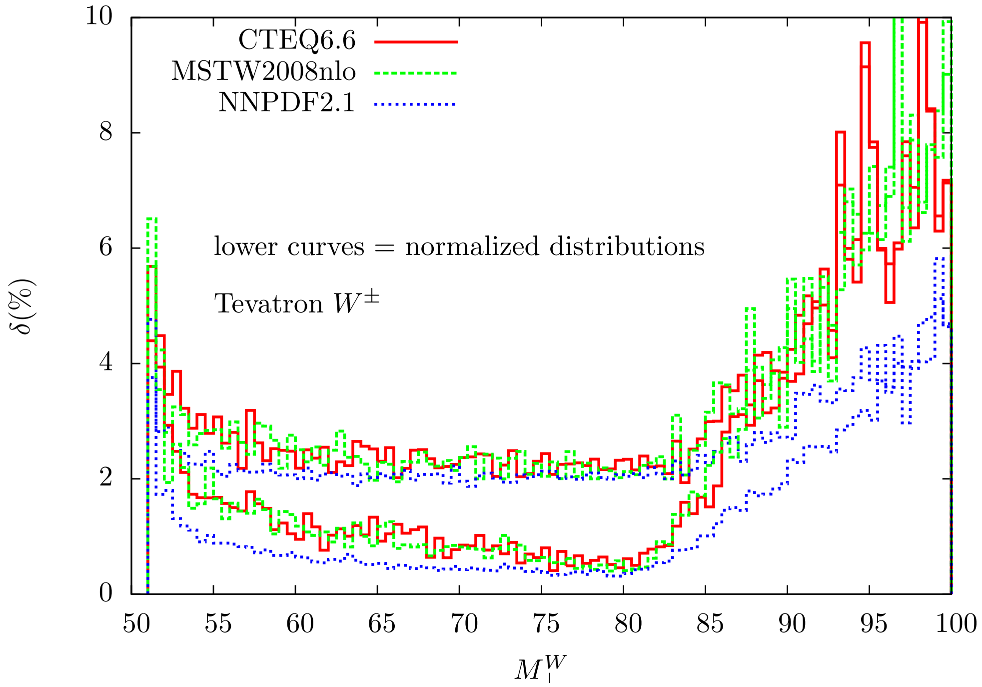

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LHC 7 TeV W^+	80.398 ± 0.004	1.22	80.404 ± 0.005	1.55	80.402 ± 0.003	1.35	8
LHC 7 TeV W^-	80.398 ± 0.004	1.22	80.400 ± 0.004	1.19	80.402 ± 0.004	1.78	6
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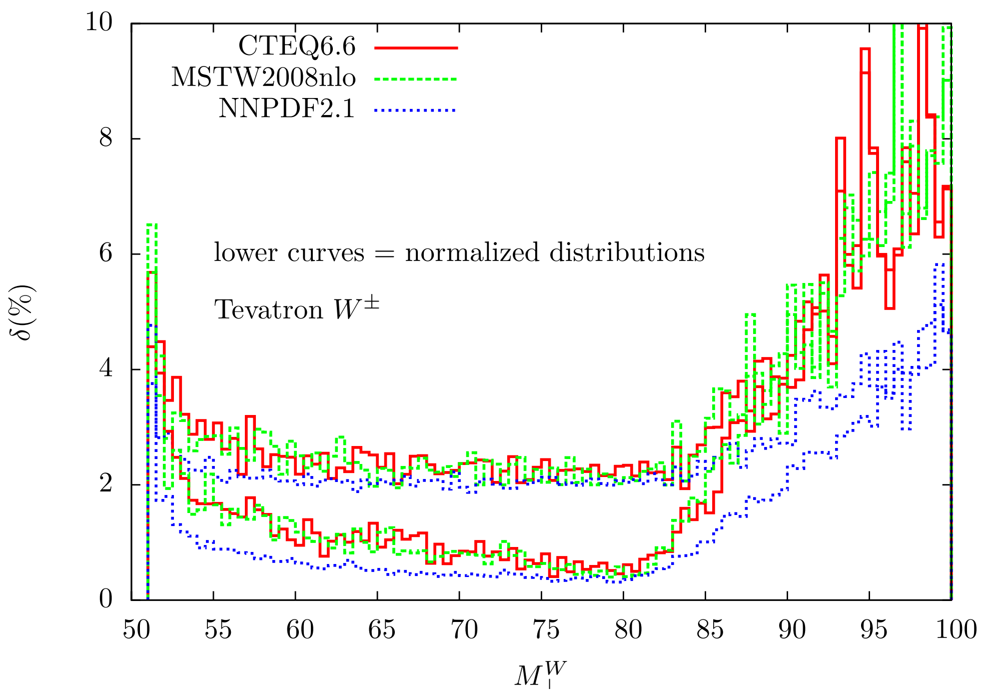

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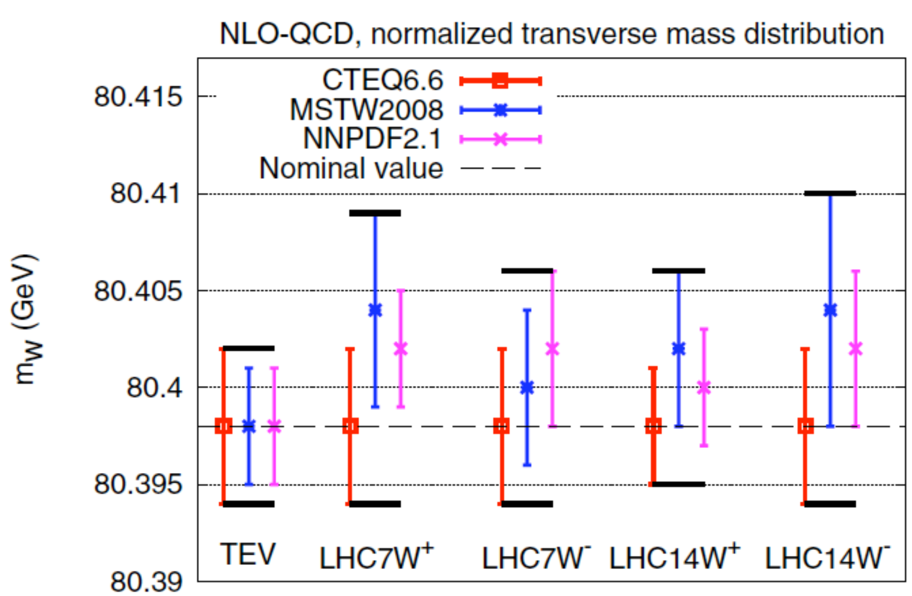

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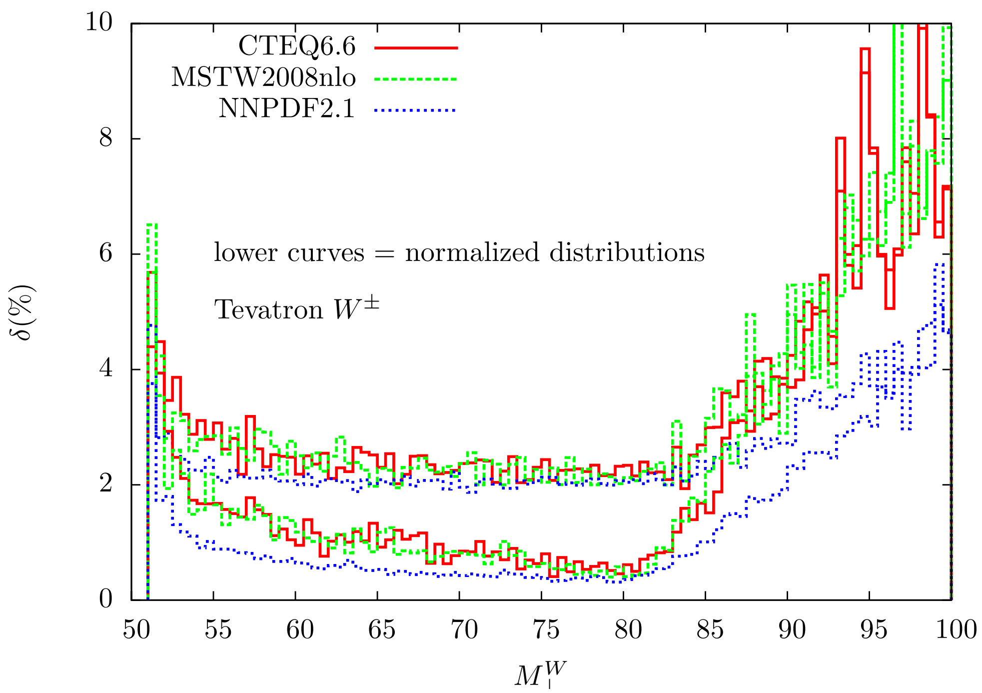

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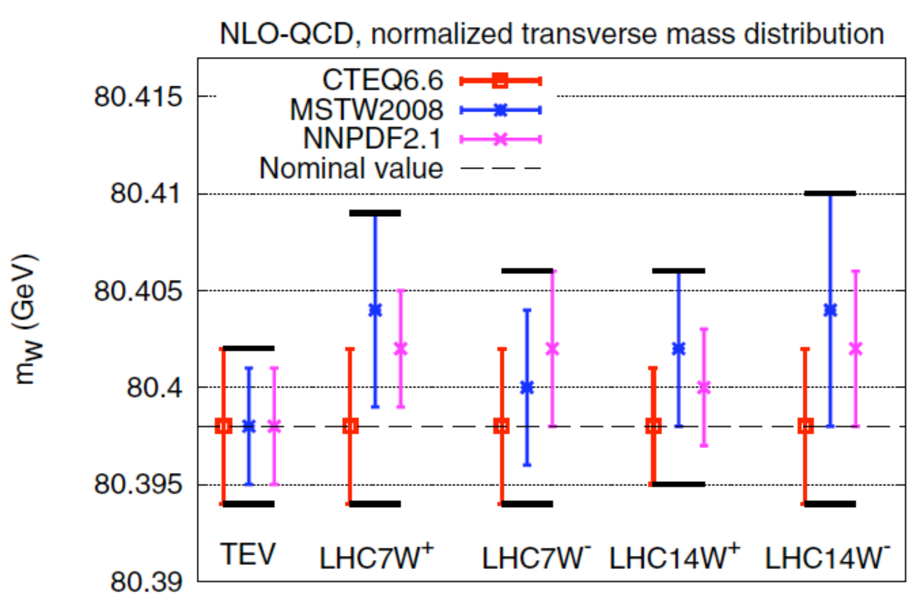
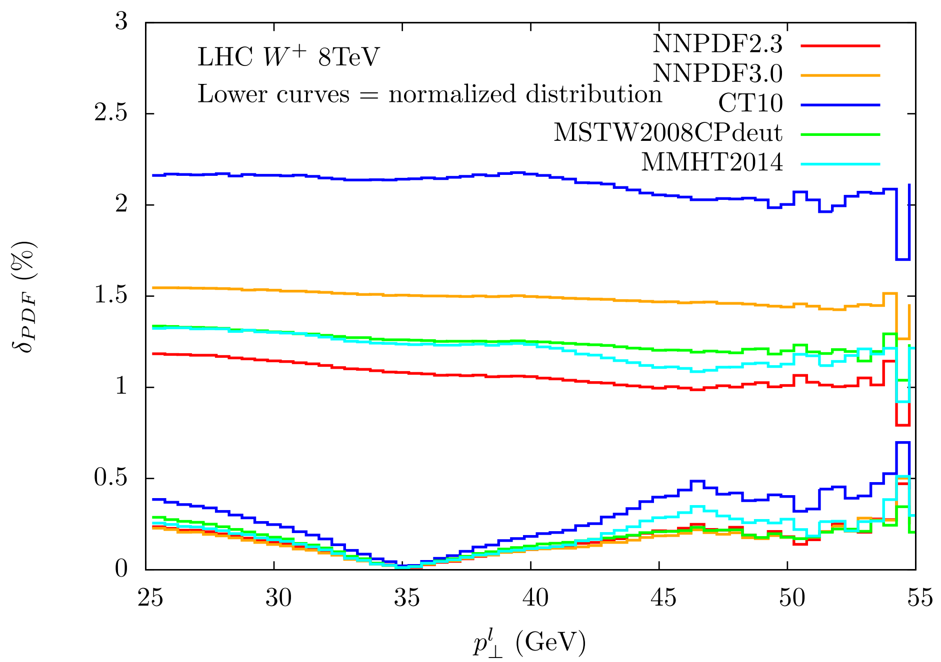


- Accuracy of templates <u>essential</u>: highly demanding computing task!
- For transverse mass distribution, a fixed-order NLO-QCD analysis is sufficient to assess this PDF uncertainty
- PDF error is moderate at the Tevatron but also at the LHC

PDF effect on lepton p_T



Bozzi, Citelli, Vicini PRD 91, 113005 (2015)

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- Distributions obtained with **POWHEG+PYTHIA 6.4**
- PDF uncertainty over relevant p_T range almost flat: O(2%)
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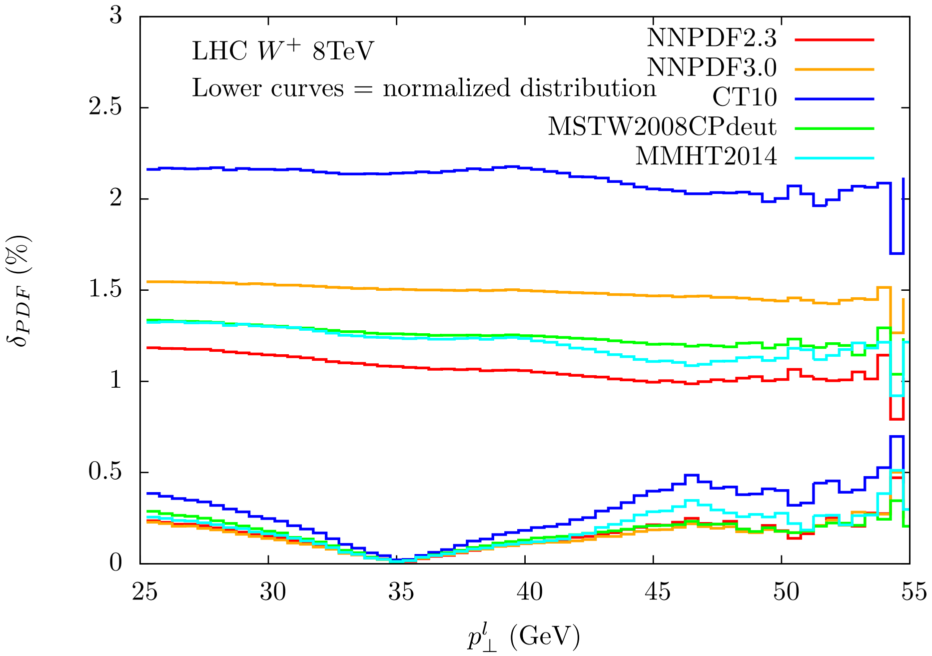

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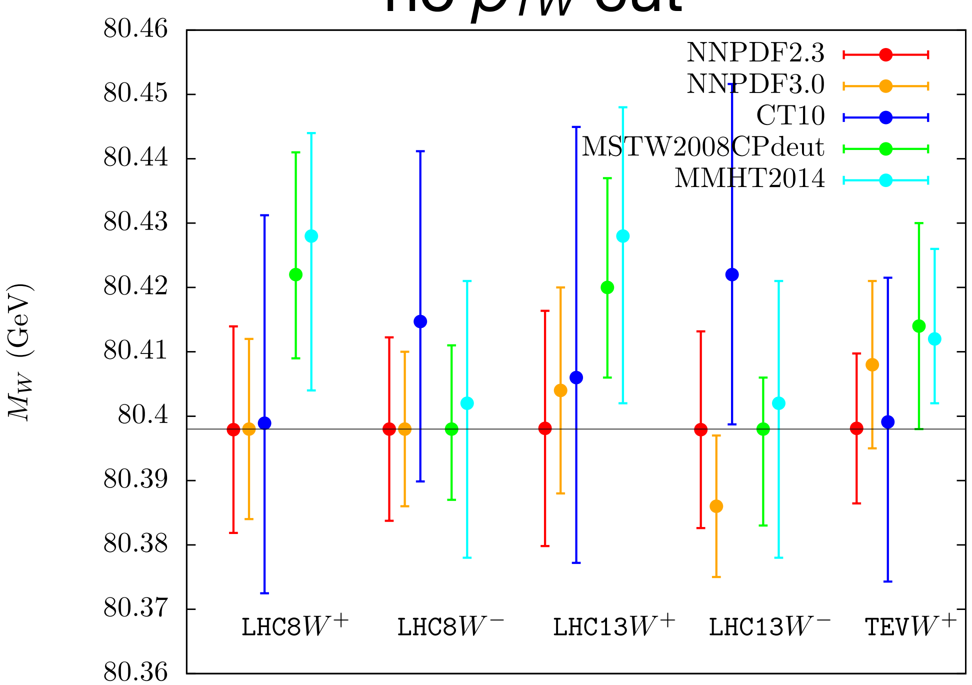
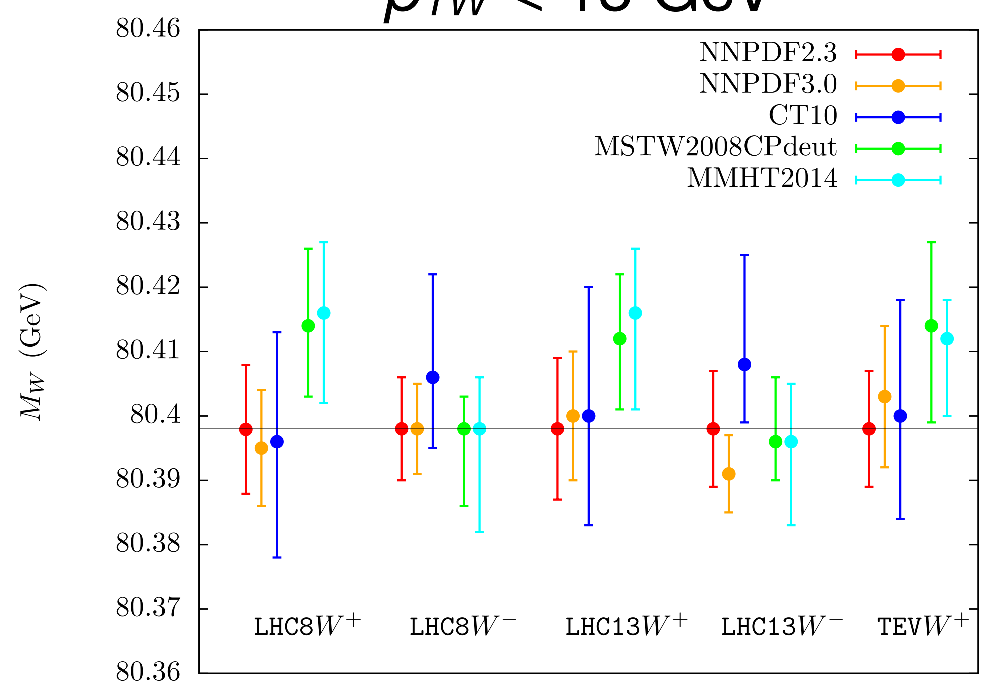
	no $p_\perp^W$ cut		$p_\perp^W < 15$ GeV	
	δ_{PDF} (MeV)	Δ_{sets} (MeV)	δ_{PDF} (MeV)	Δ_{sets} (MeV)
Tevatron 1.96 TeV	27	16	21	15
LHC 8 TeV W^+	33	26	24	18
W^-	29	16	18	8
LHC 13 TeV W^+	34	22	20	14
W^-	34	24	18	12

- Individual PDF sets provide non-pessimistic estimates: $\Delta M_W \sim$ O(10 MeV)
- Global envelope still shows large discrepancies of the central values
- p_{TW} cut is relevant

no p_{TW} cut



p_{TW} < 15 GeV



Acceptance cuts: interesting insights

Bozzi, Citelli, Vicini PRD 91, 113005 (2015)

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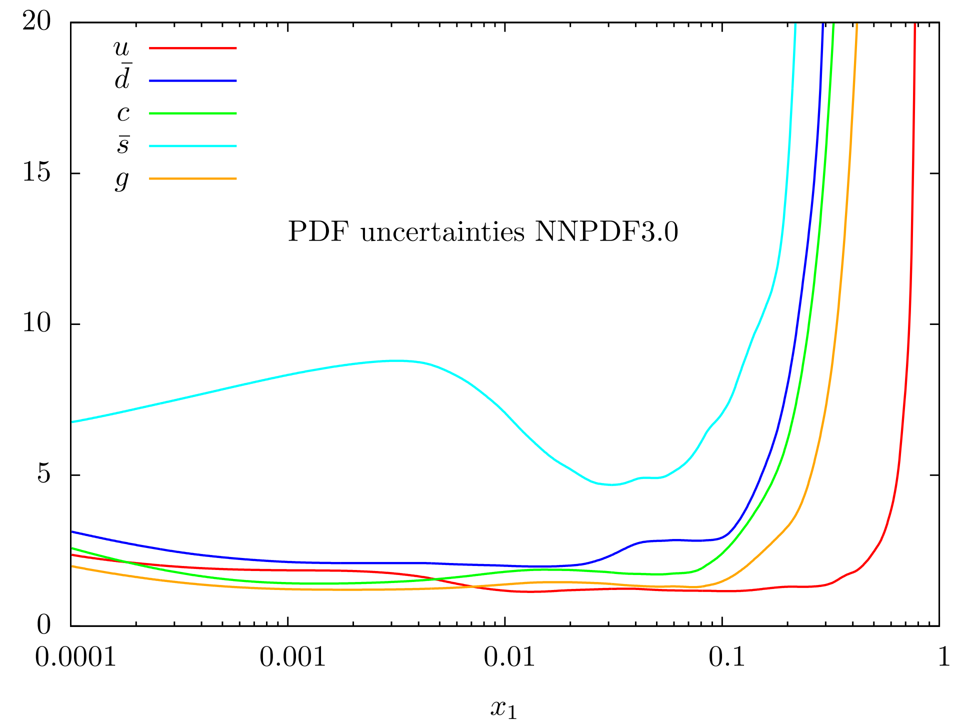

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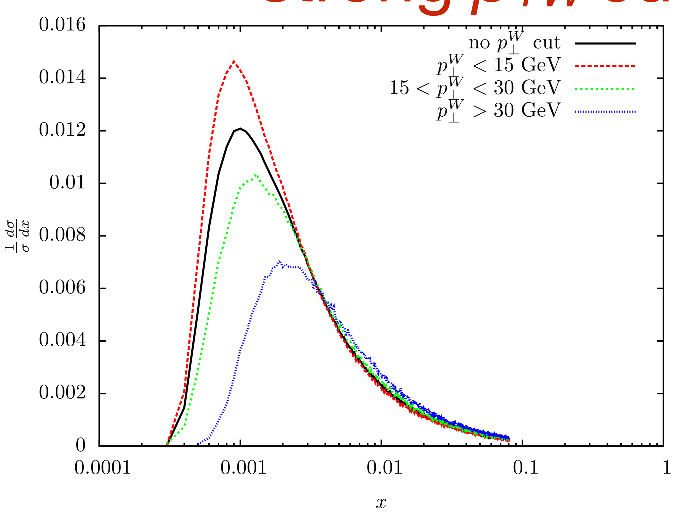

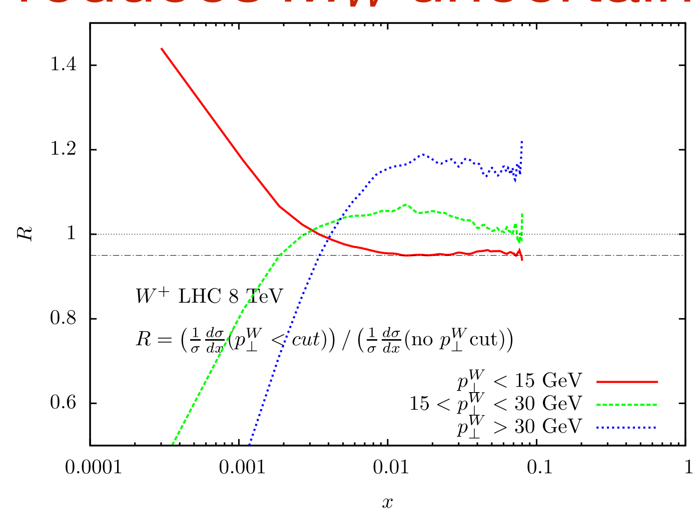

suppression of the large-x region

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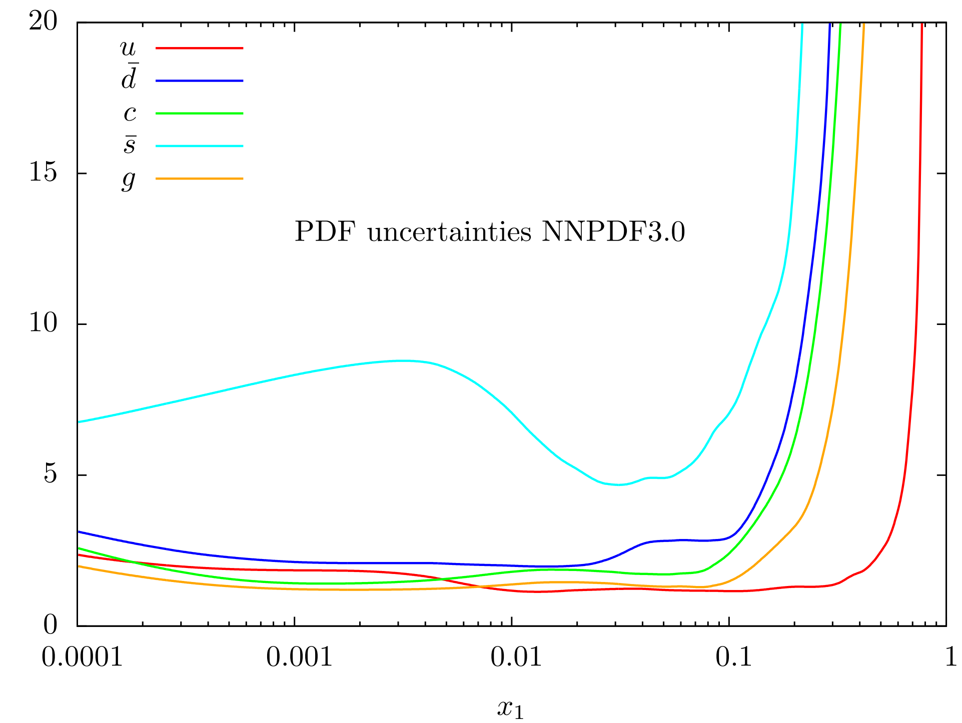

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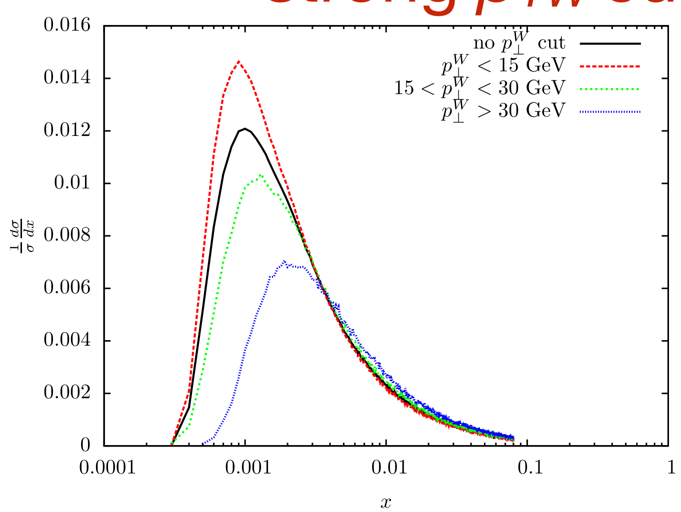

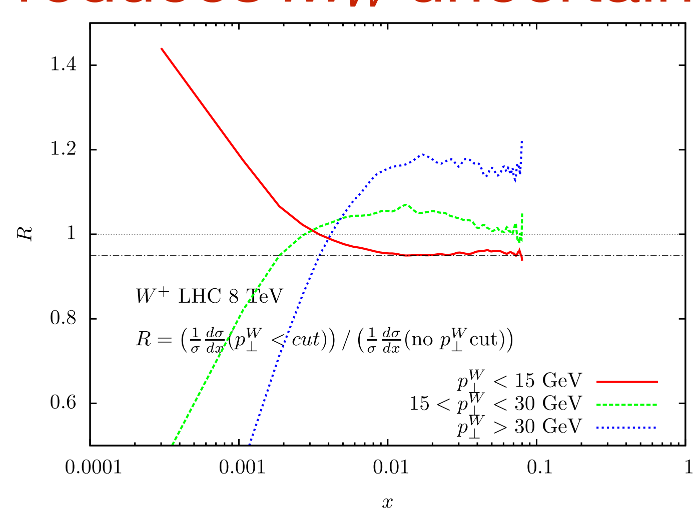

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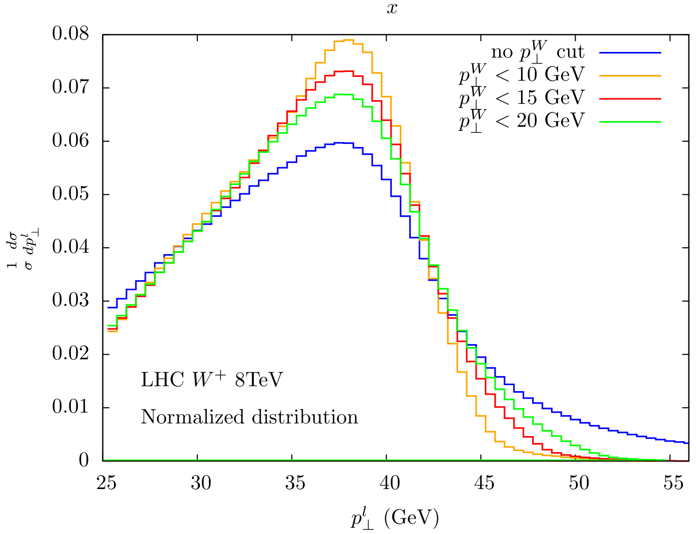

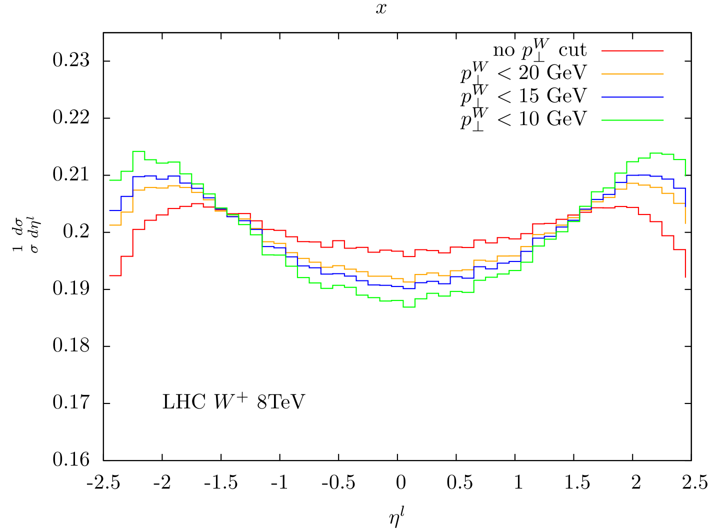

steeper shape of the p_{Tl} distribution

enhancement of high rapidity regions

Acceptance cuts: interesting insights

Bozzi, Citelli, Vicini PRD 91, 113005 (2015)

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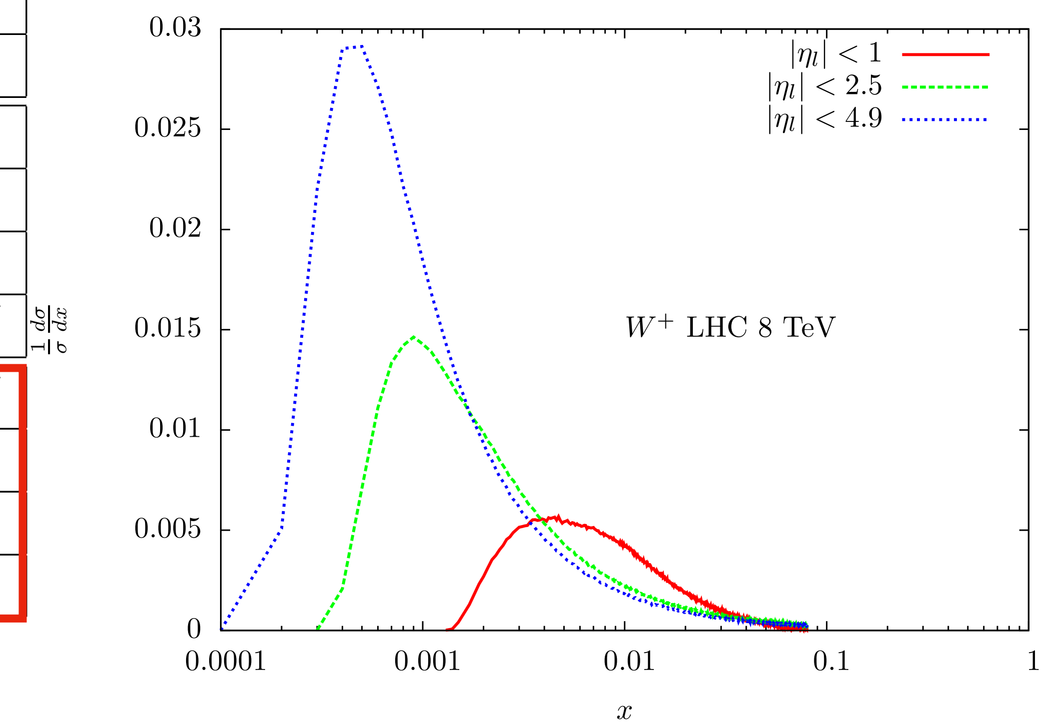

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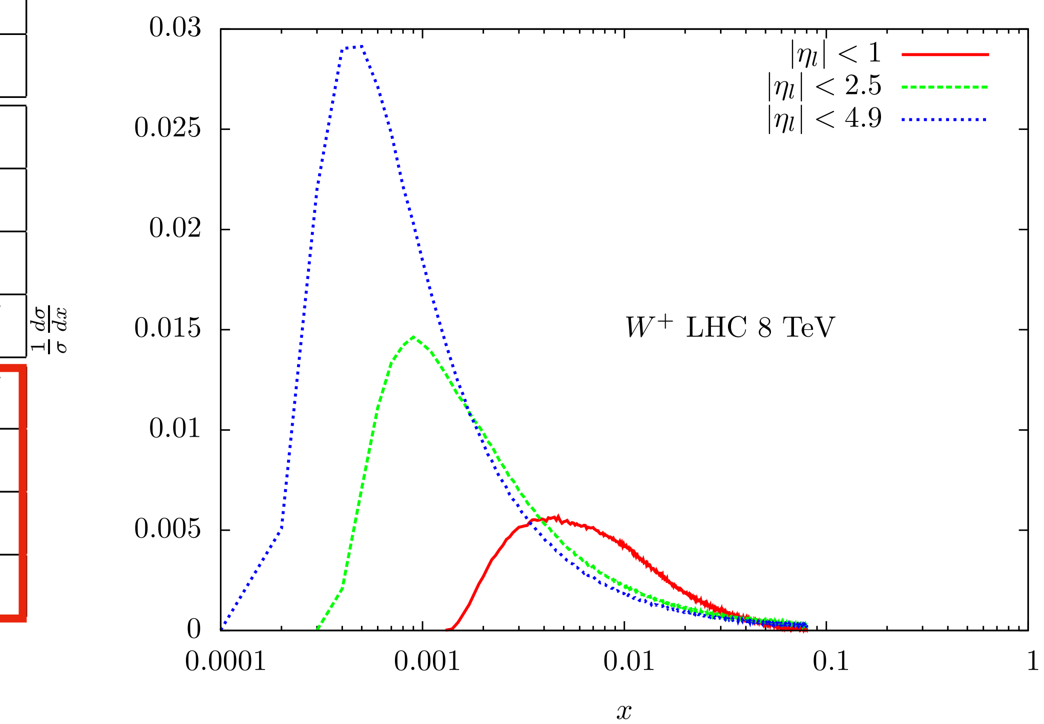

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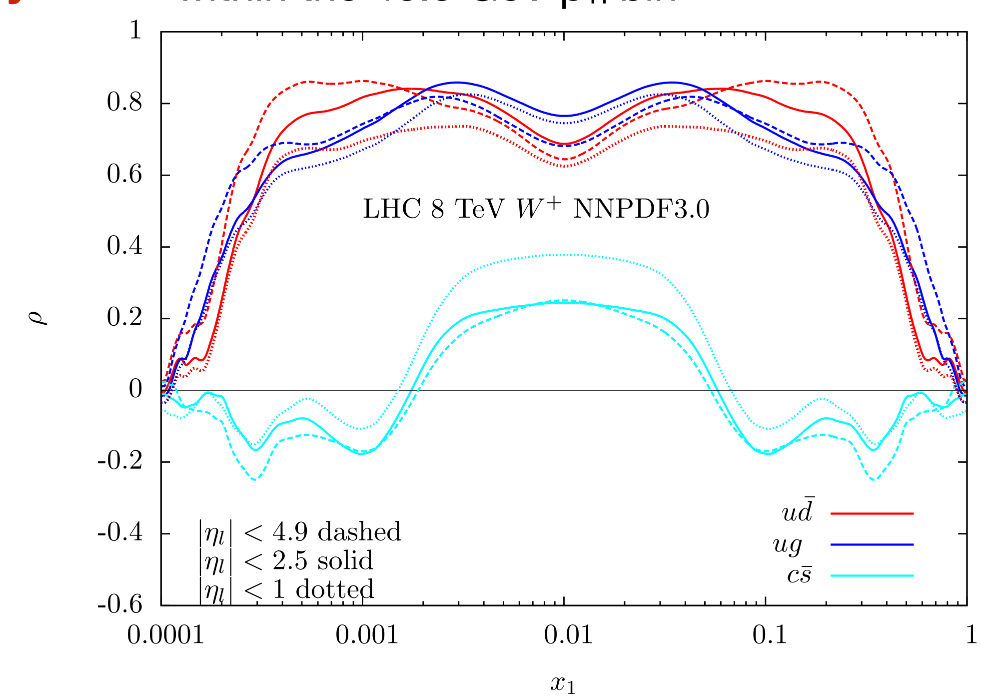
correlation of parton luminosities within the 40.5 GeV p_{Tl} bin



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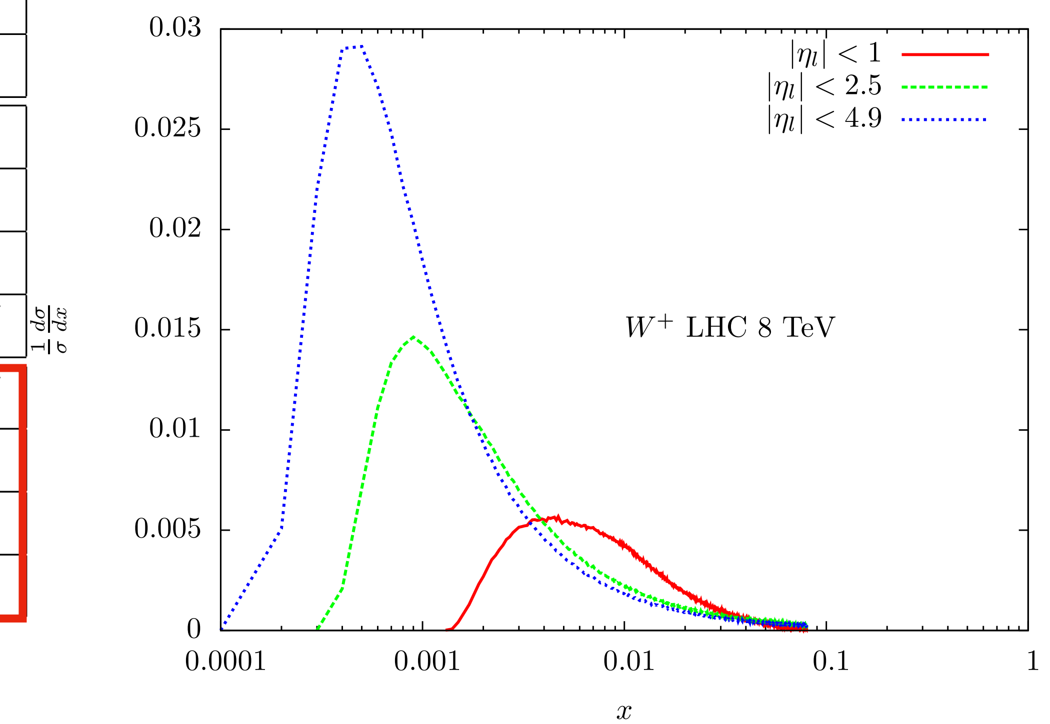

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- PDF sum rules → *non trivial compensations between different rapidity intervals among different flavours*

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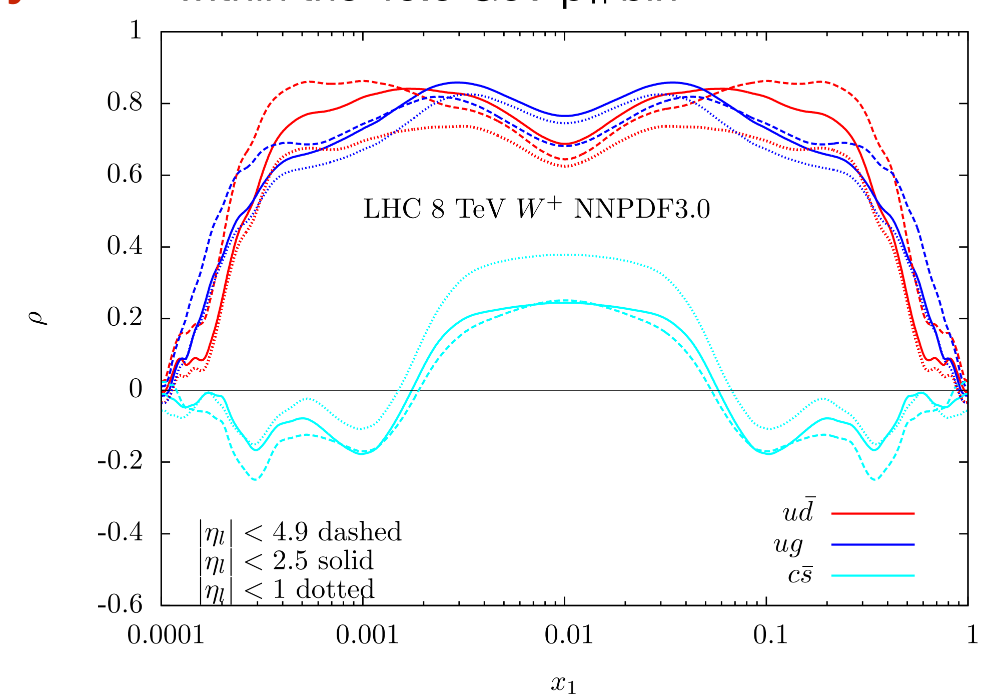

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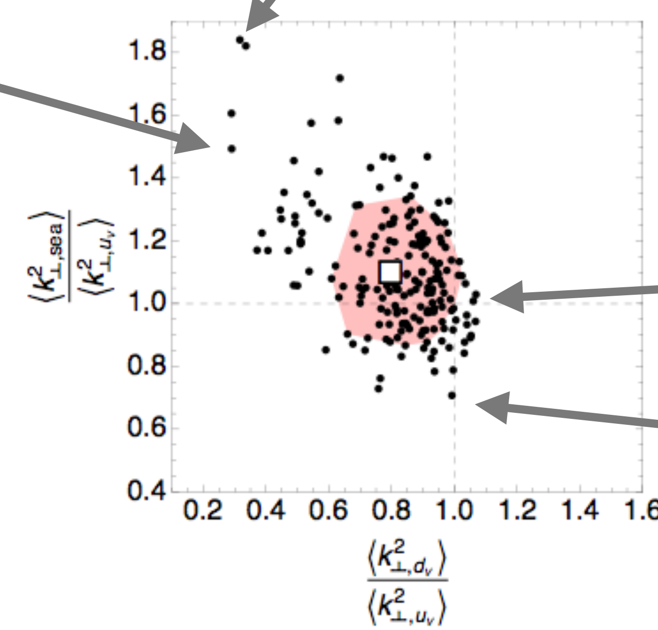
Extraction of parameters from SIDIS

Signori, Bacchetta, Radici, Schnell, JHEP 1311, 194 (2013)

template fit on HERMES data: distribution of parameters

replica 149
χ^2/dof = 1.87

replica 73
χ^2/dof = 1.70



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d_v width < (mostly) u_v width

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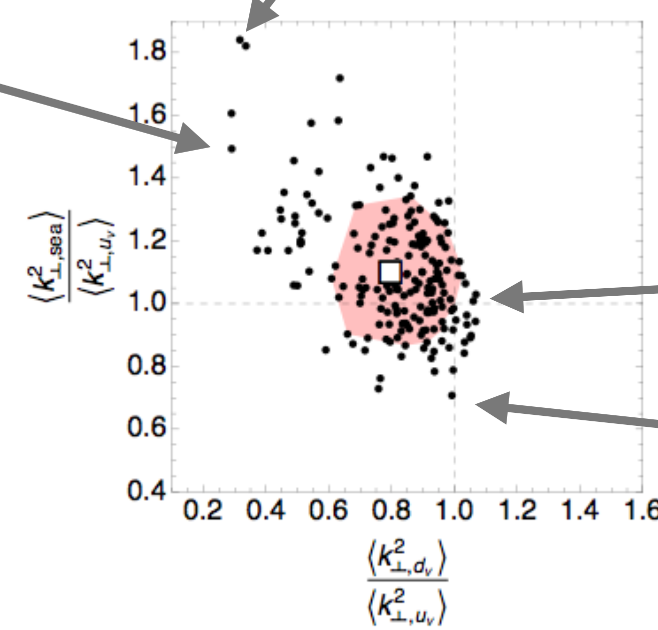

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On average, *sea > u_v > d_v*