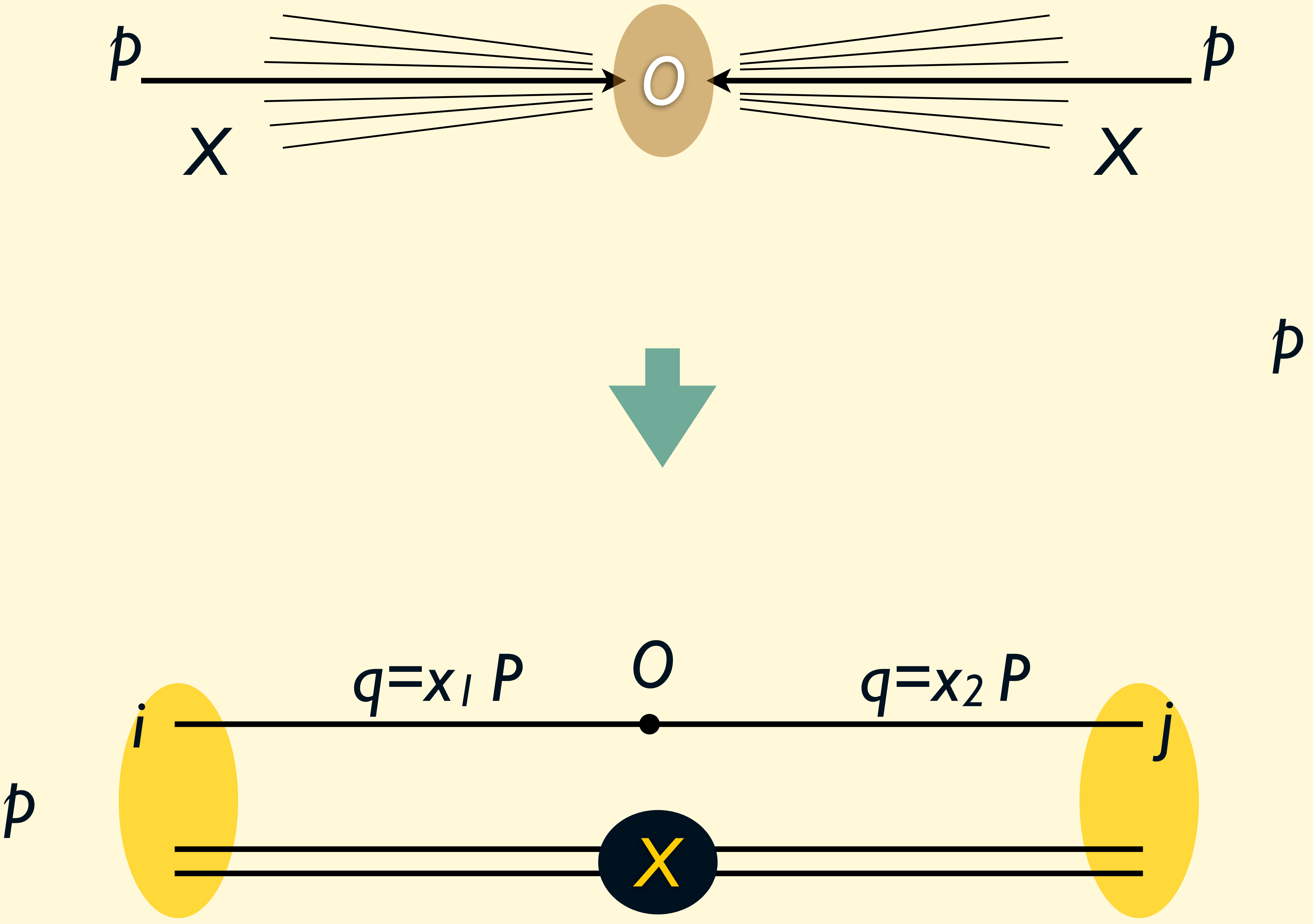
Motivations and precision targets for an accurate luminosity determination

LHC Lumidays
CERN
Jan 13-14 2011

Michelangelo L. Mangano
CERN PH-TH



i,j=u,d,s,c,b, gluon

cross section for
the elementary
process ij→O,
function of M_O, g_{ijO}

strength of the
coupling between
i,j and O

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mass of O

N of partons of type “i”, “j”,
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← **exp**

← **this meeting**

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The obvious target of a programme of precision measurements is to bring the accuracy of all elements in the above relation to the same level

The target is driven by the level of accuracy of the available, required inputs

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Example 1 ("indirect" luminosity measurement)

$$\text{Luminosity} = \frac{N_{events}(O)}{\sigma(pp \to O)}$$

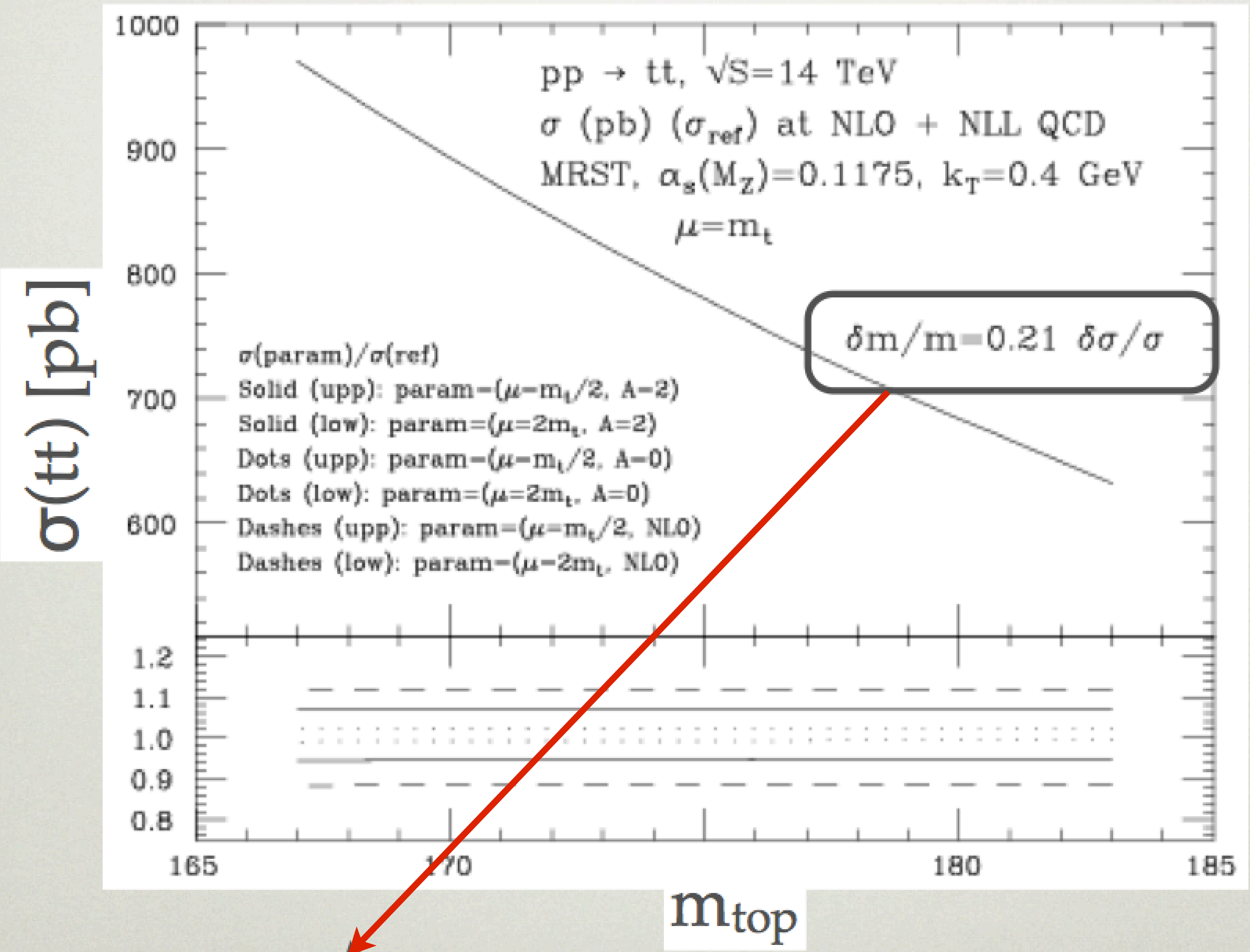
← *addressed by exptl talks of this morning*

← *addressed by V.Khoze talk*

Assumes as input the precise knowledge of the cross section for a given final state *O*, and a correspondingly accurate measurement of event rates

Examples include *O=anything*, *O*=$pp\mu^+\mu^-$, *O*=$pp\gamma$

Example II (indirect top mass measurement)



$\Delta\sigma/\sigma = \pm 5\% \Leftrightarrow \Delta m/m = \pm 1\% \lesssim 2$ GeV, comparable to Δm_{direct}

Theory and PDF syst, today:

$$\sigma(pp \to t\bar{t})[14\ \text{TeV}, m_t = 171\ \text{GeV}] = 908\text{pb}\ \times (1 \pm 9\%_{\hat{\sigma}} \pm 3\%_{PDF})$$

Expected theory accuracy, in ~2yrs (after completion of NNLO, HERA2/LHC PDFs, etc): ± 3-5% $_{\sigma+PDF}$

Example III (W and Z production, and determination of PDFs)

will be measured to sub-% level

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known to 2%, most accurately known elementary cross section at the LHC

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$$\Rightarrow \quad \sigma(f_i\, f_j) \sim 2\% \oplus \sigma(\text{lum})$$

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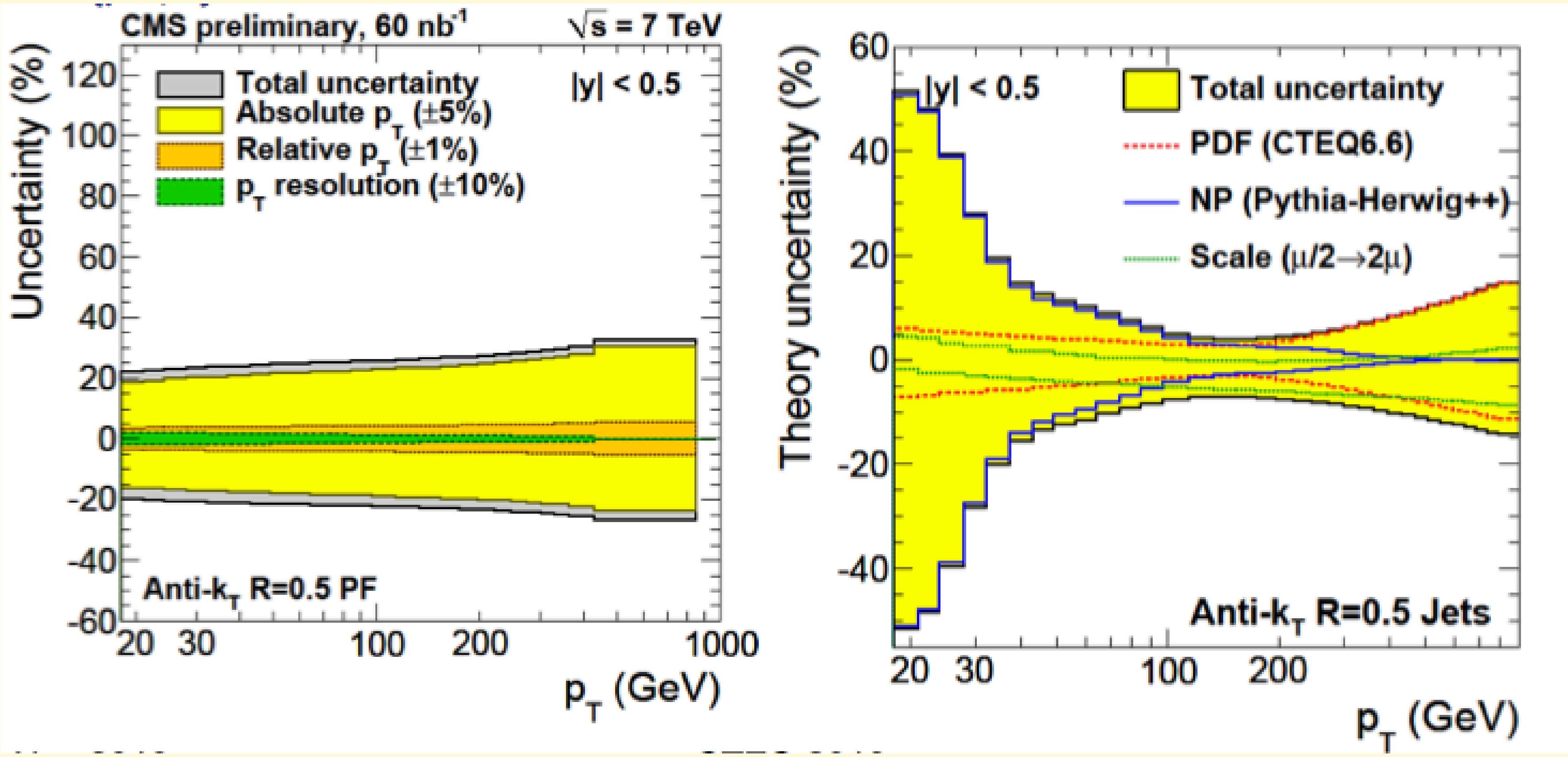
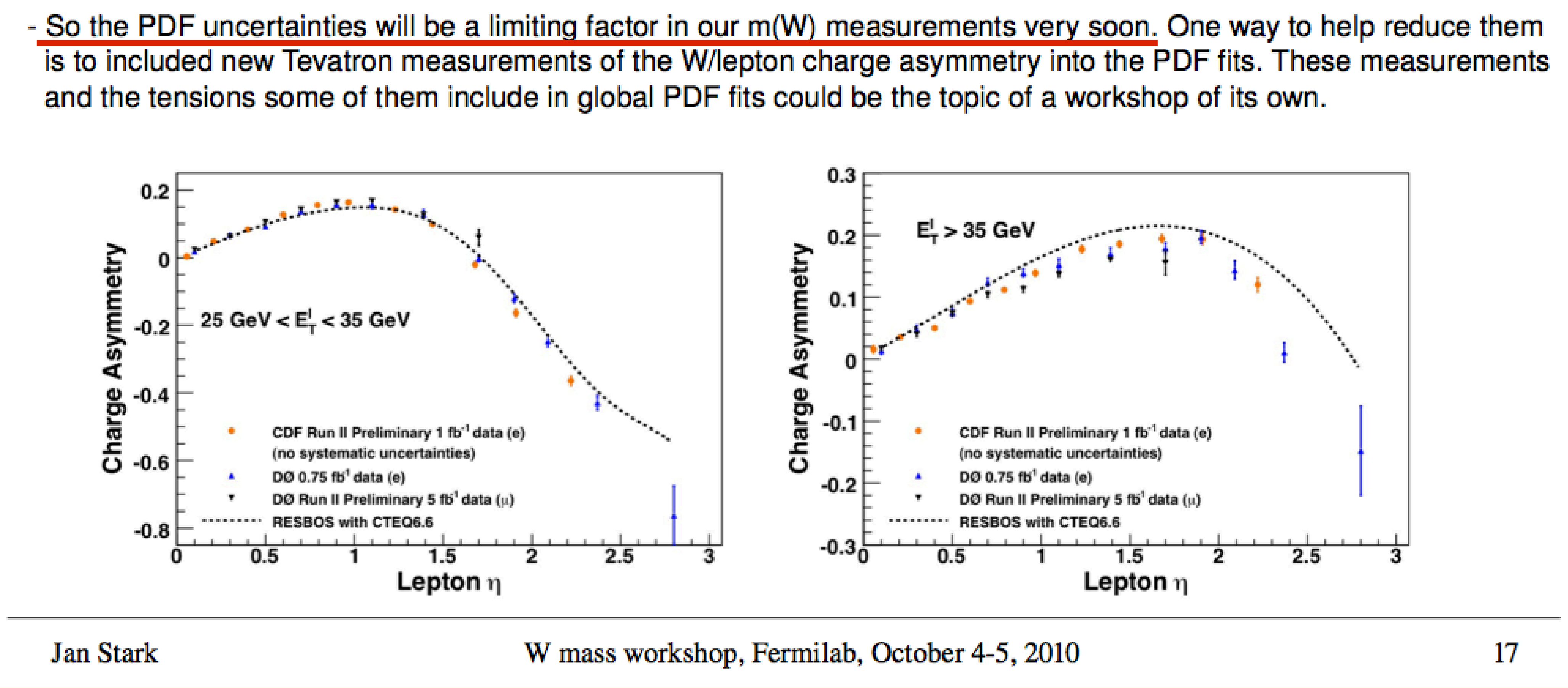
± 2%

PDF impact on jet cross sections



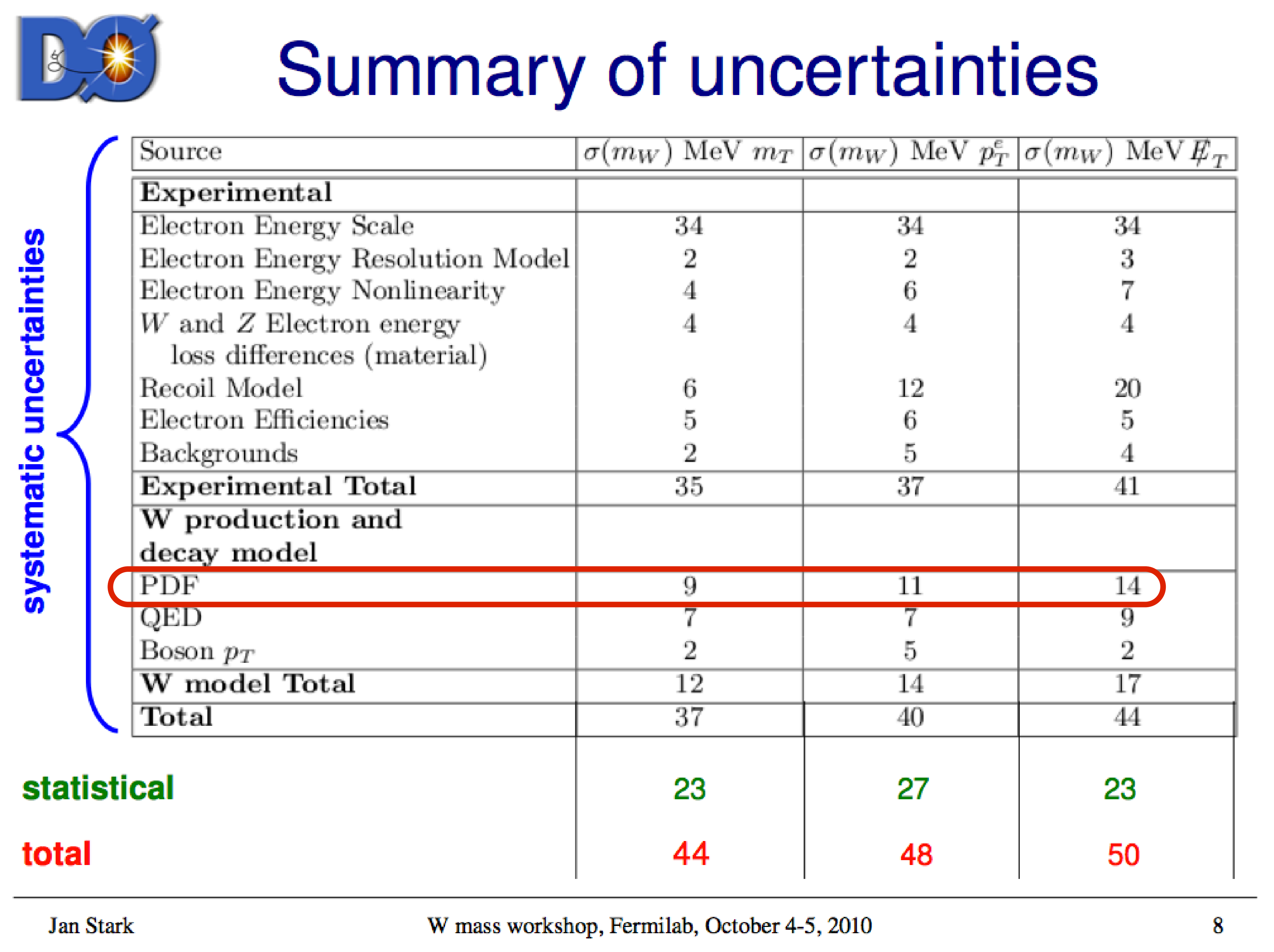
PDF will be dominant source of theoretical systematics at large E_T

PDF impact on W mass measurement



- So the PDF uncertainties will be a limiting factor in our m(W) measurements very soon. One way to help reduce them is to included new Tevatron measurements of the W/lepton charge asymmetry into the PDF fits. These measurements and the tensions some of them include in global PDF fits could be the topic of a workshop of its own.

Jan Stark W mass workshop, Fermilab, October 4-5, 2010 17



Summary of uncertainties

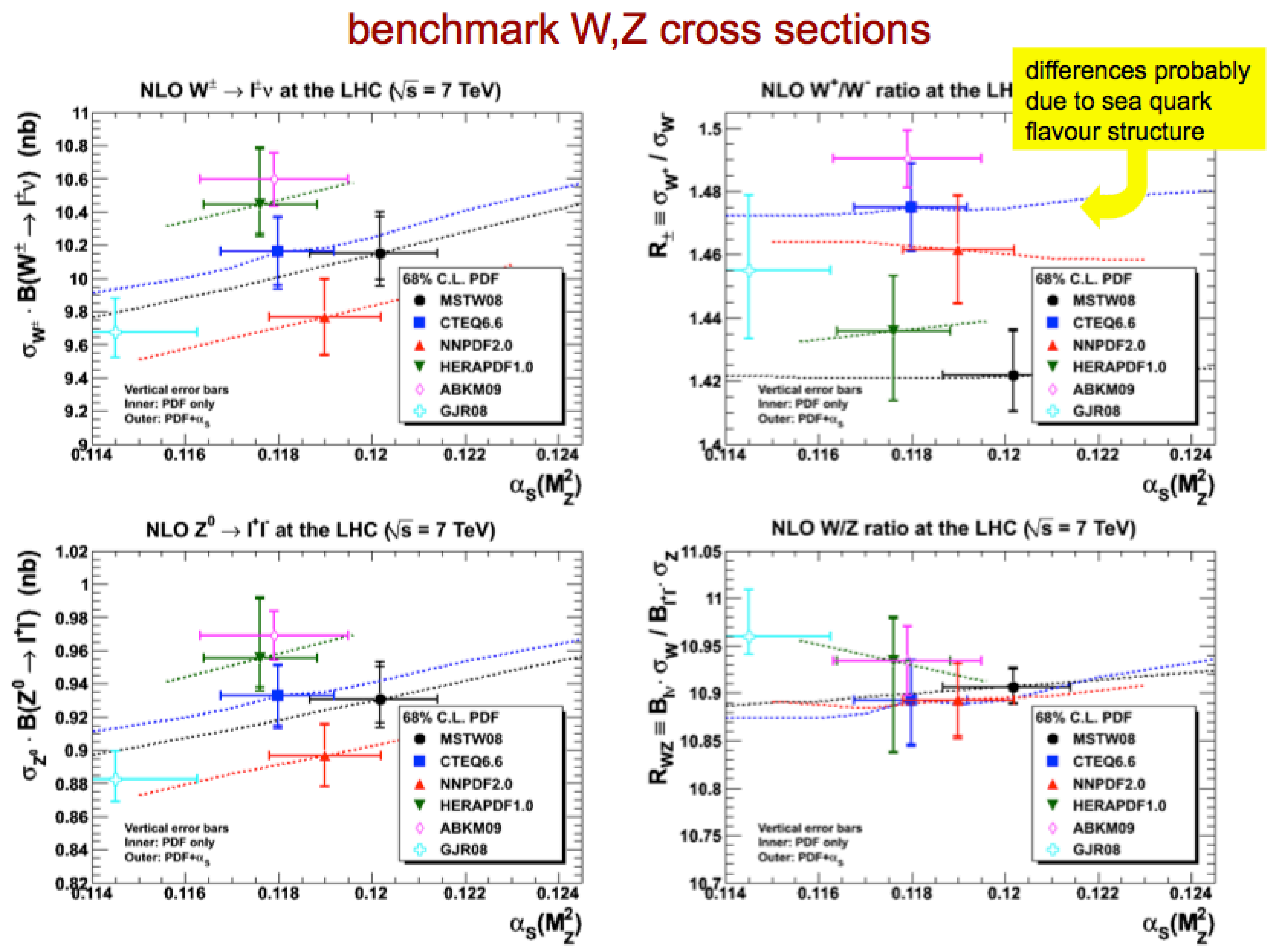
systematic uncertainties

Source	$\sigma(m_W)$ MeV m_T	$\sigma(m_W)$ MeV p_T^e	$\sigma(m_W)$ MeV $\not{E}_T$
Experimental			
Electron Energy Scale	34	34	34
Electron Energy Resolution Model	2	2	3
Electron Energy Nonlinearity	4	6	7
W and Z Electron energy loss differences (material)	4	4	4
Recoil Model	6	12	20
Electron Efficiencies	5	6	5
Backgrounds	2	5	4
Experimental Total	35	37	41
W production and decay model			
PDF	9	11	14
QED	7	7	9
Boson p_T	2	5	2
W model Total	12	14	17
Total	37	40	44
statistical	23	27	23
total	44	48	50

Jan Stark W mass workshop, Fermilab, October 4-5, 2010 8

The PDF uncertainty impact on the W mass measurement is even bigger at the LHC (see e.g. W.Krasny et al, CERN–PH–EP/2010-007)

From G. Watt, and W.J. Stirling talk at Trento Workshop "LHC at the LHC"



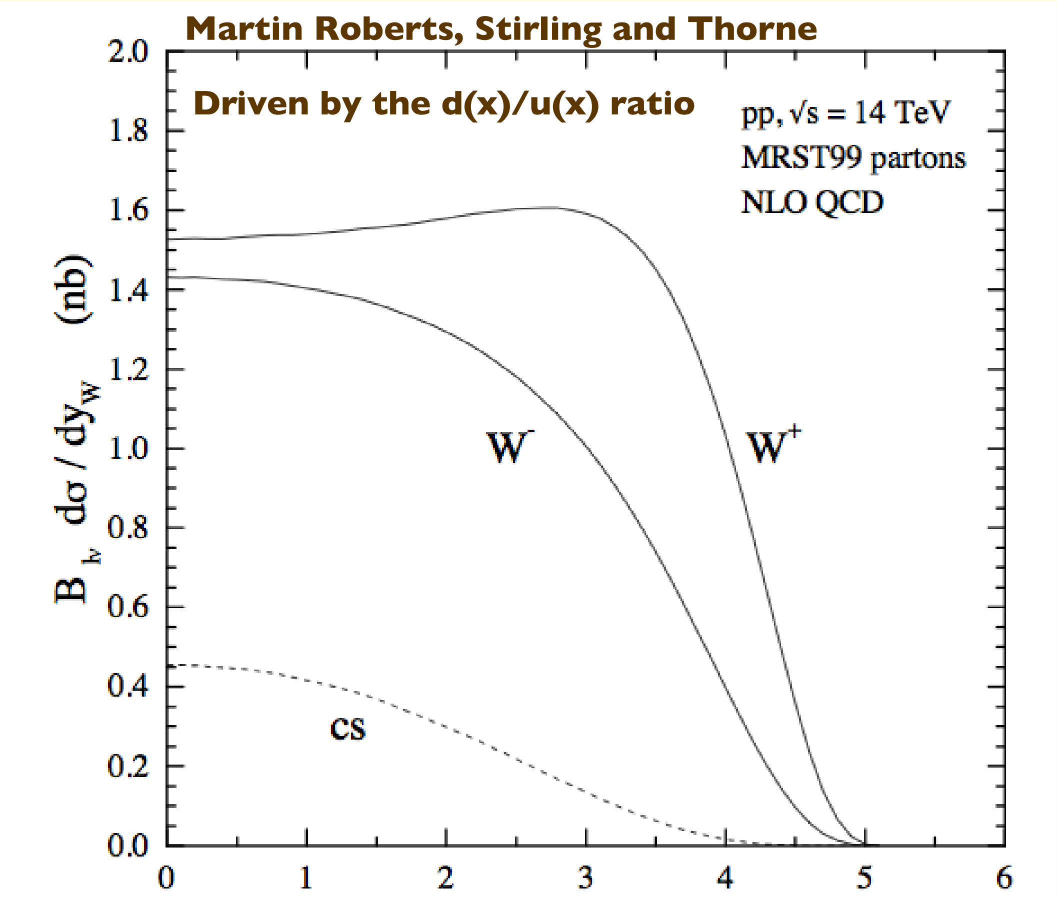
benchmark W,Z cross sections

differences probably due to sea quark flavour structure

Current level of PDF systematics on W and Z cross section predictions: ~ ±5%

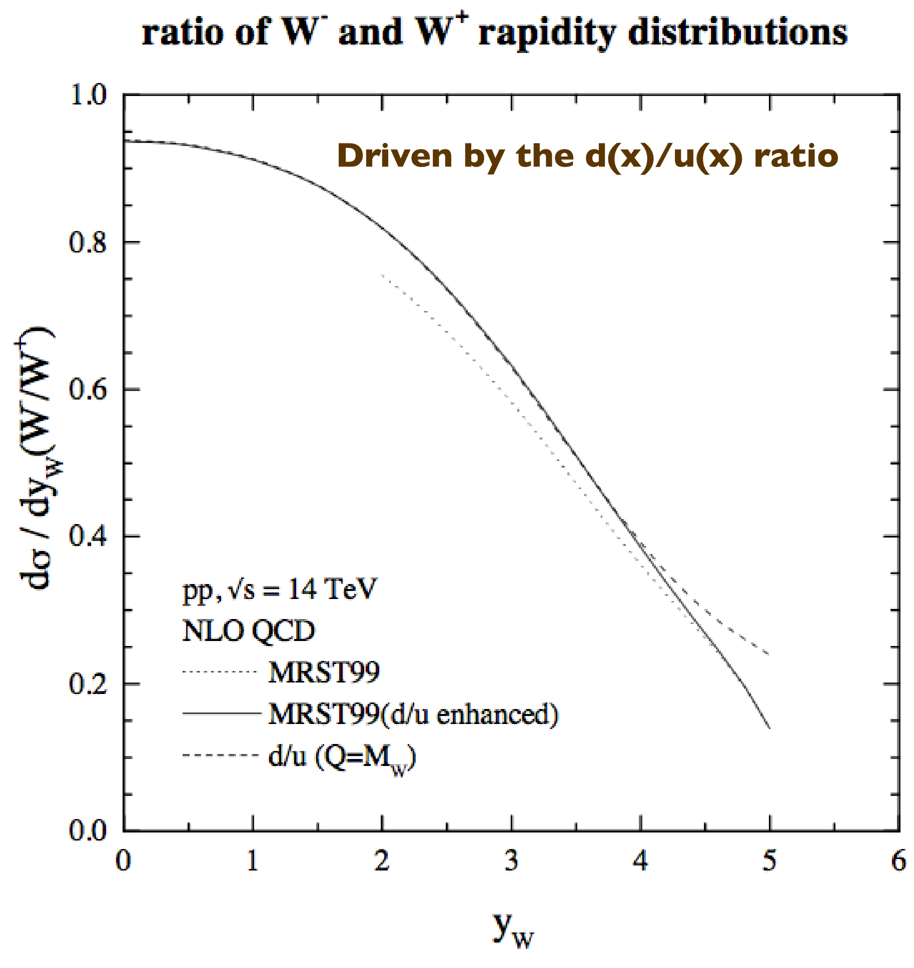
⇒ a luminosity measurement better than 5% would allow to make progress

Shapes as alternative PDF probes: W+ / W– production asymmetries



Martin Roberts, Stirling and Thorne

Driven by the d(x)/u(x) ratio



ratio of W^- and W^+ rapidity distributions

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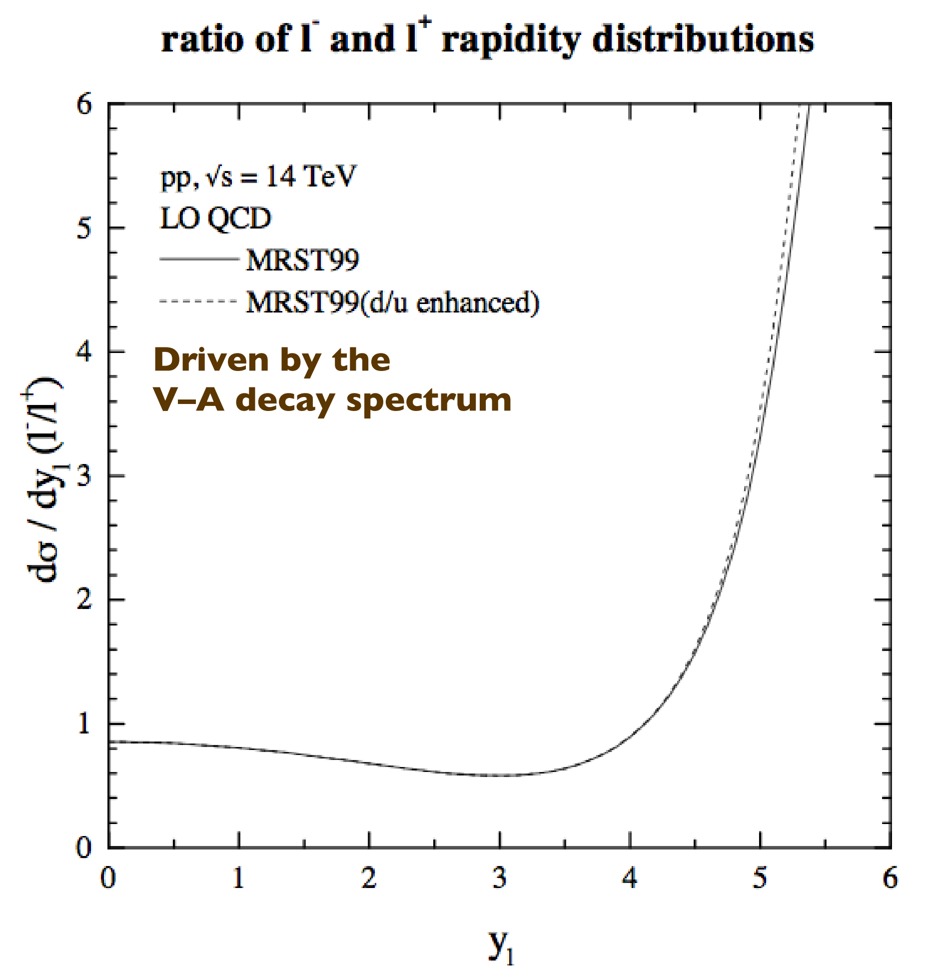


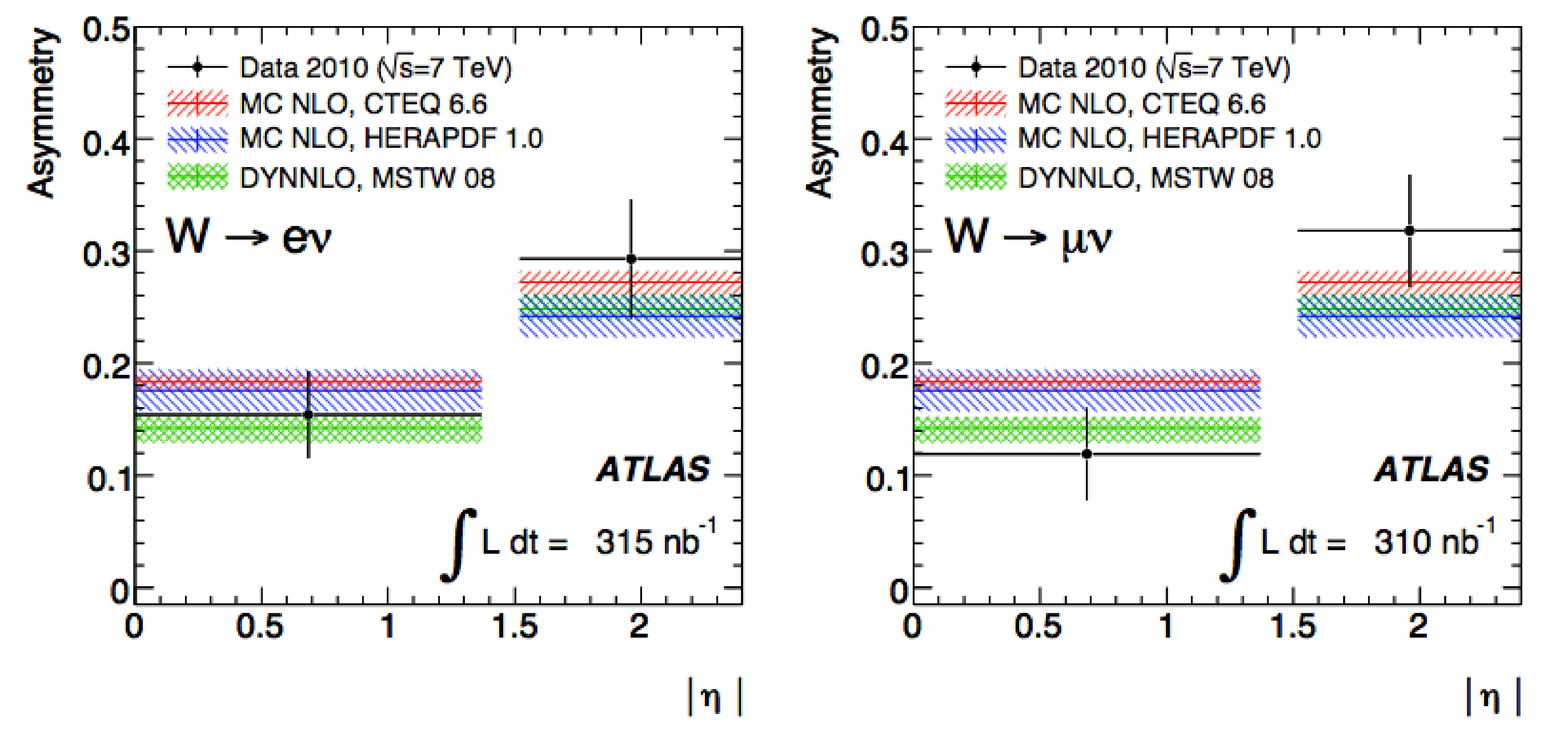
ratio of l^- and l^+ rapidity distributions

Driven by the V–A decay spectrum

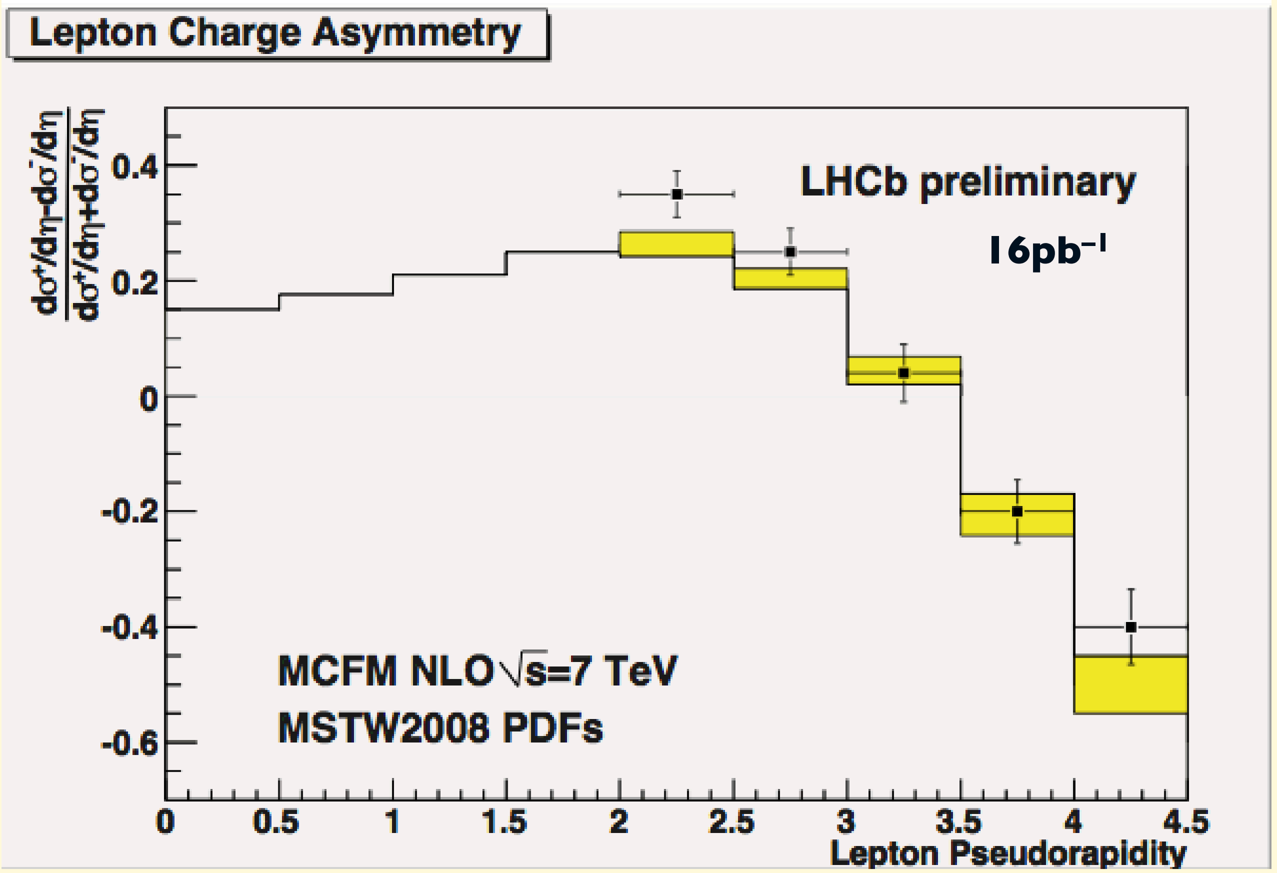
Lepton charge asymmetry at the LHC

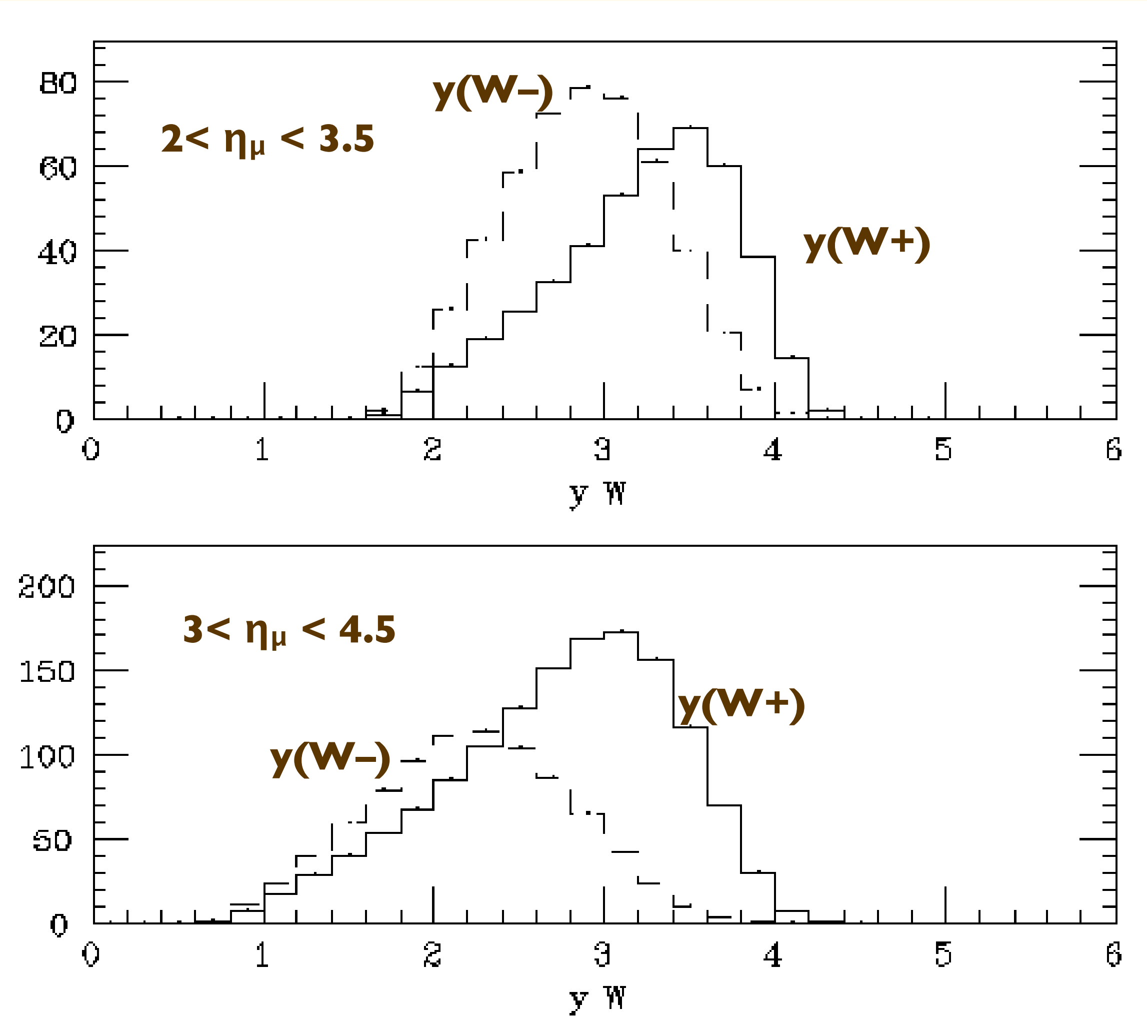
$$A_\ell = \frac{\sigma^{\text{fid}}_{W^+} - \sigma^{\text{fid}}_{W^-}}{\sigma^{\text{fid}}_{W^+} + \sigma^{\text{fid}}_{W^-}}$$

320 nb^{-1}, http://arxiv.org/abs/1010.2130



EW boson production in the forward region, LHCb



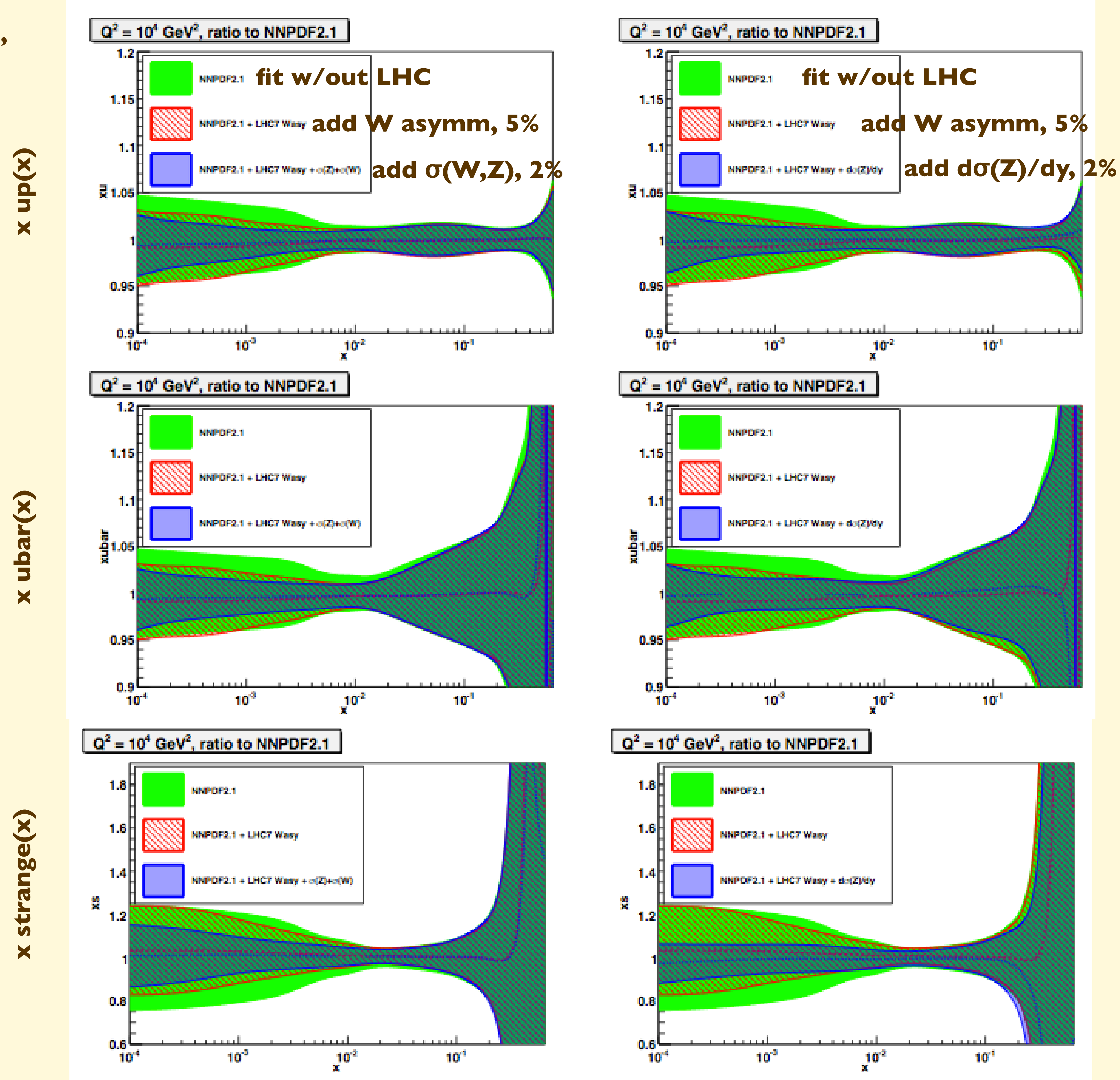


W → μν, charge asymmetry

Examples of impact of W and Z cross sections and asymmmetries

S. Forte and J. Rojo, private communication. See also http://arXiv.org/abs/1101.1300

For these plots, lepton acceptance within η<2.5



fit w/out LHC

add W asymm, 5%

add σ(W,Z), 2%

fit w/out LHC

add W asymm, 5%

add dσ(Z)/dy, 2%

NB The inclusion of the LHCb acceptance would lead to improvements also for x~O(0.1)

Examples of correlations between PDFs and W and Z cross sections

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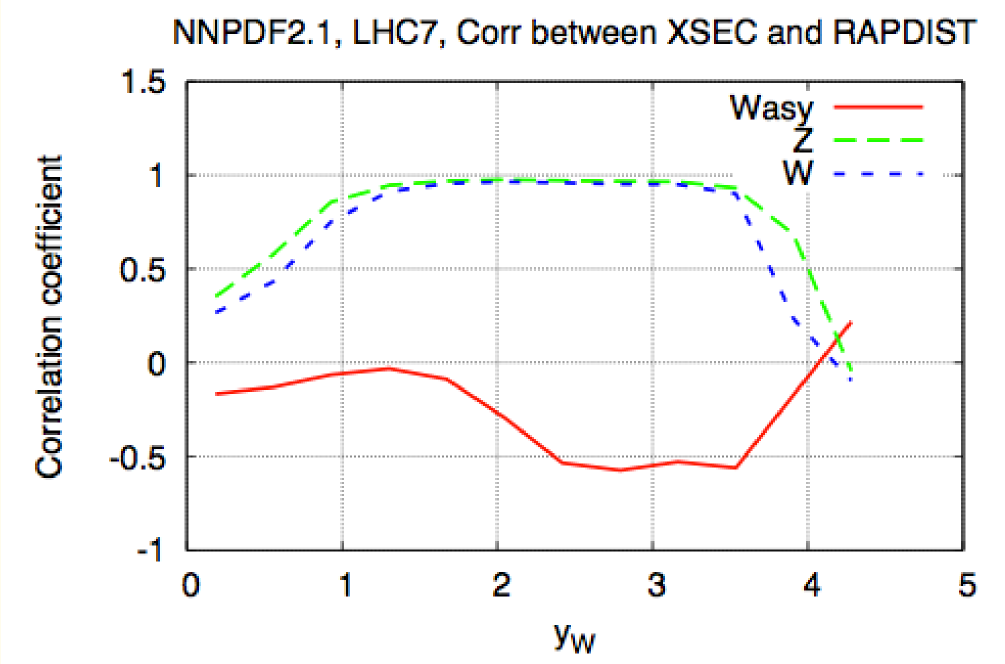

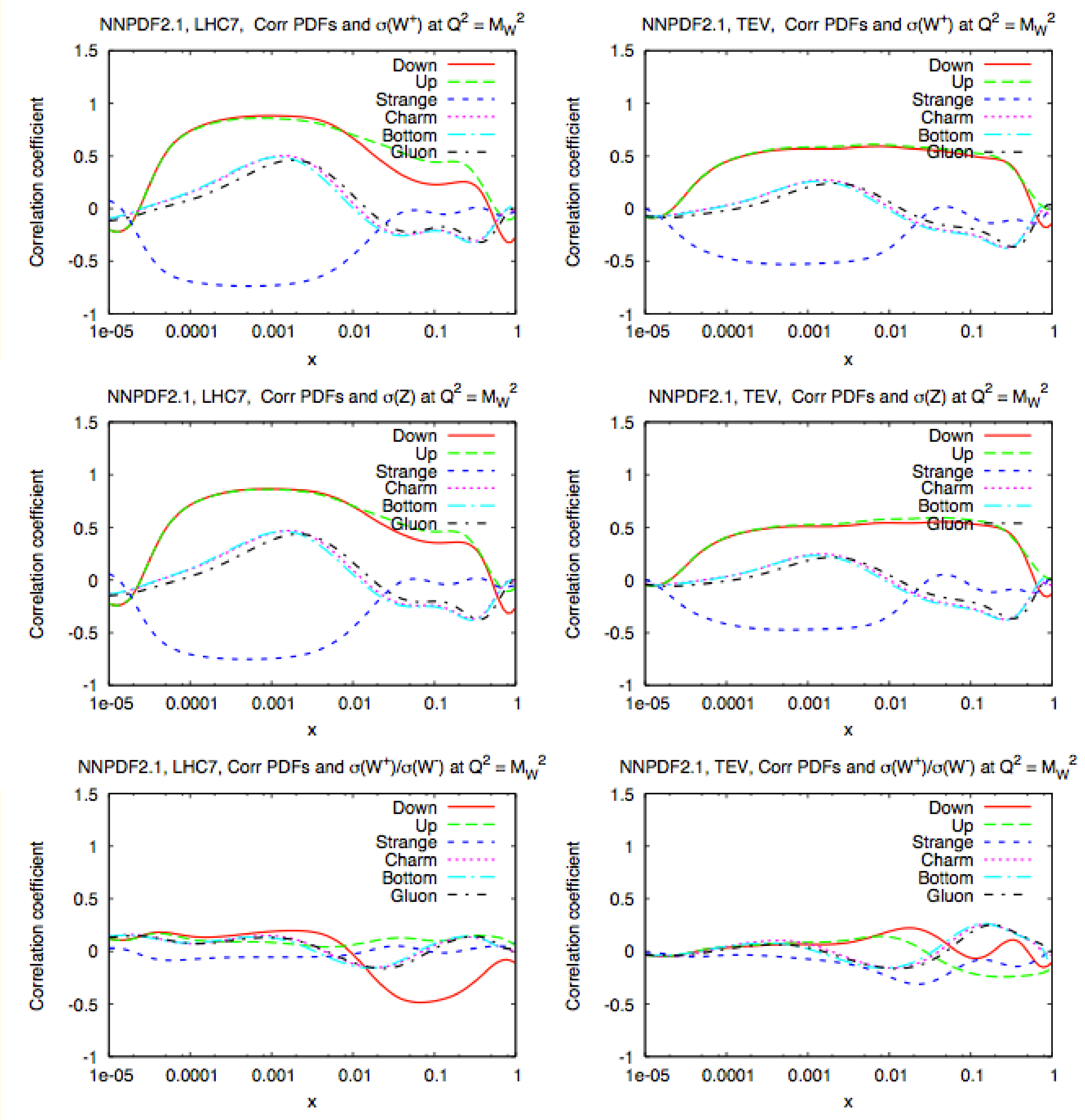

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- Thus **2%** sets a natural **benchmark scale for the target precision** of the luminosity measurement at the LHC
- A complete assessment of the consequences of O(2-5%) measurements of W and Z production properties is under way (*).
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(*) many dedicated activities are starting. See e.g.

- the recent Paris Workshop on *Precision challenges at the LHC,* http://www.lpthe.jussieu.fr/~kbenakli/FRIF2010/

- LHC EW WG, first mtg April 4-5 2011, http://indico.cern.ch/conferenceDisplay.py?confId=118357