

INTRODUCTION

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CHALLENGES FOR PRECISION PHYSICS AT THE LHC

LPNHE, Paris

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The 2010 edition:

The EW physics focused on W and Z bosons

... for three reasons

Timing: of the order of 10^7 W and 10^6 Z bosons decaying into leptons are expected to be recorded at the LHC by the end of the year 2011 ($L \sim 1 \text{ fb}^{-1}$) a comparable samples to those which will be accumulated the Tevatron experiments ... and to LEP (10^6 Z events)

Discriminating power : the SM fails badly at the classical level (e.g . M_W - 22σ discrepancy $\sin^2(\theta_w)$ - 150σ discrepancy,...) a perfect testing ground of any QFT-based extension of the SM ... for example, a real possibility of rejecting the SM Higgs boson before it is not discovered....

Tool calibration : W and Z bosons will be our principal tools to investigate experimentally the EW symmetry breaking mechanism

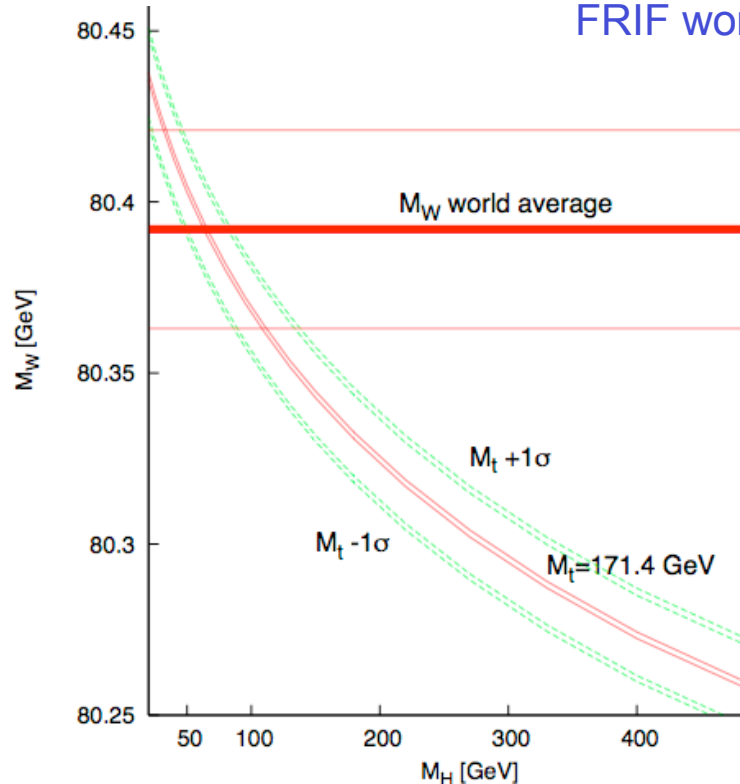
Challenges for Precision Physics at the LHC

What is “precision physics” ?

What is a “precision measurement” ?

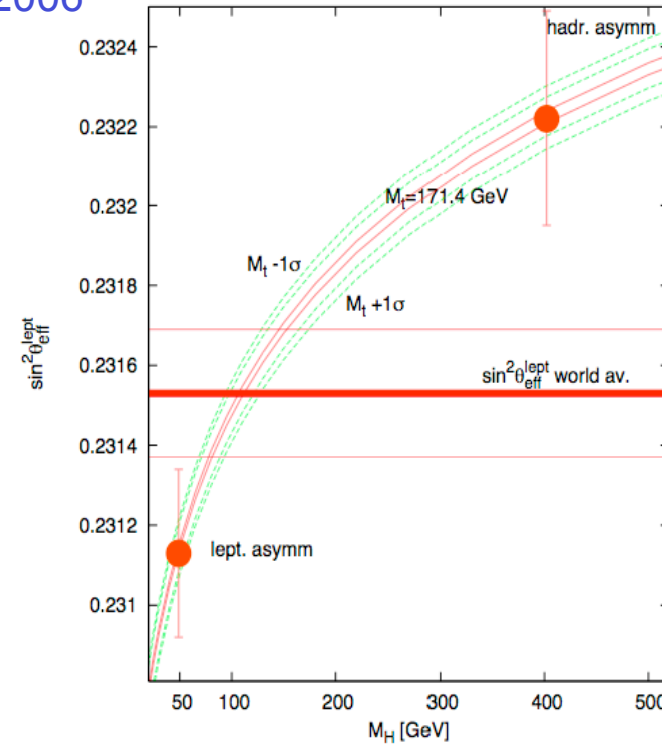
Two examples:

FRIF workshop 2006



Present precision: ~ 20 MeV

Precision measurement:
 $\Delta M_W < 20$ MeV



Present discrepancy ~ 0.001

Precision measurement:
 $\Delta \sin^2(\theta_w) < 0.001$

Precision (EW) physics

...at a hadronic collider!

Ultimate criterion:

Interpretation of the measurement results in the framework of the EW theory must be, as much as possible, independent of any theoretical, phenomenological and modelling approximations used in the analysis (in particular, robust with respect to all the modelling aspects of the effective partonic beams and their “QCD-noise”)

... two paths in this directions will be explored at this workshop

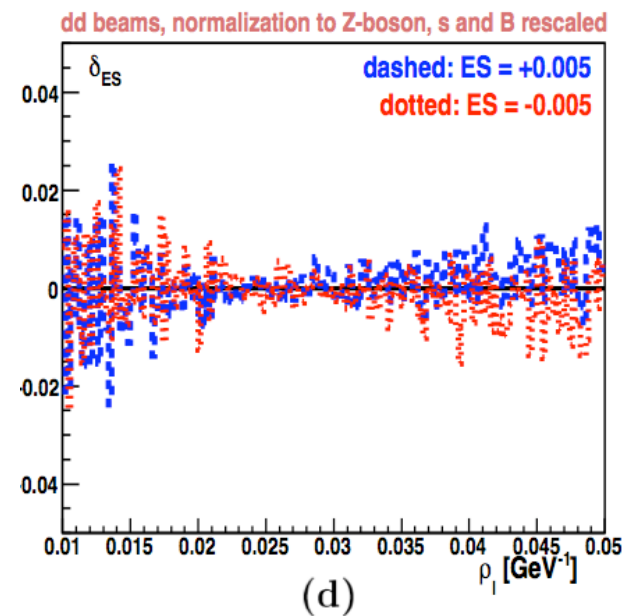
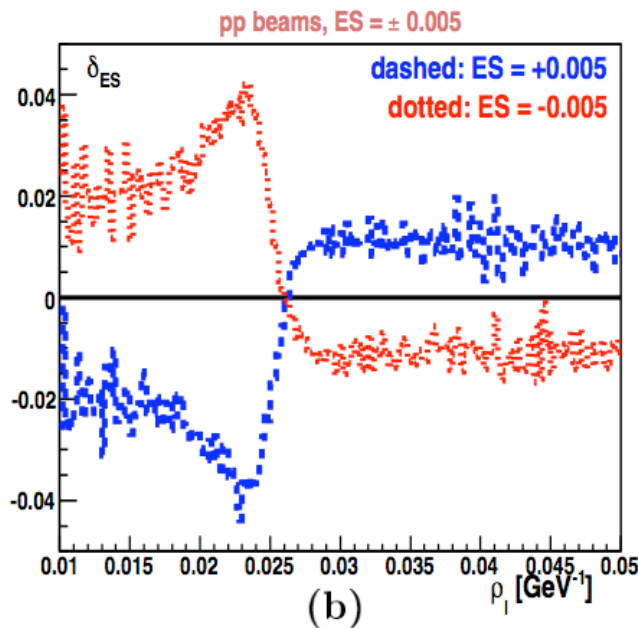
1. Canonical measurement techniques based on the state of art analysis tools (main emphasis on the development of high-precision Monte-Carlo generator(s) which include both the QCD and the EW effects).
2. Dedicated observables and dedicated measurement procedures (strategies) capable to drastically reduce the impact of: (1) the detector imperfection, and (2) the modelling approximation on the measurement precision.

... two examples

Impact of the lepton energy scale bias: $E_{\text{true}} = E_{\text{meas}}(1 \pm ES)$

$$\delta_{ES} = \frac{d\sigma/d\rho_l(ES \pm) - d\sigma/d\rho_l(ES)}{d\sigma/d\rho_l(ES)}, \quad \rho_l = 1/p_{t,l}$$

Reduction of biases by a factor of ~ 20 !



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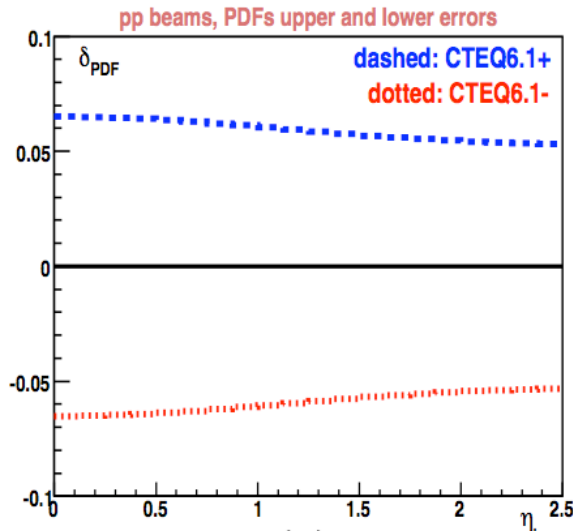
Standard measurement procedure

Dedicated observable
and dedicated measurement
procedure

Impact of the PDF uncertainties

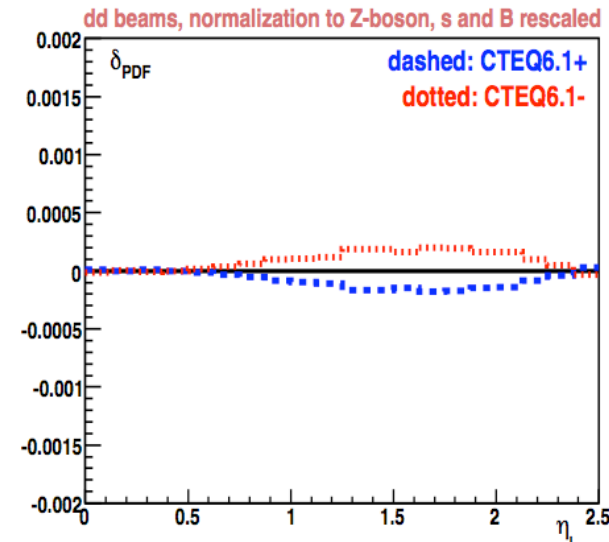
$$\delta_{PDF} = \frac{d\sigma/d\eta_l(CTEQ6.1\pm) - d\sigma/d\eta_l(CTEQ6.1)}{d\sigma/d\eta_l(CTEQ6.1)}$$

Reduction of biases by a factor of ~ 200 !



*Eur.Phys.J.C*51:607-617,2007

Standard measurement procedure



Dedicated observable
and dedicated measurement
procedure

Challenges for precision physics at the LHC

1. The LHC physics programme is and will be optimized to explore the high energy and the high luminosity frontier of Particle Physics (the precision frontier is bound to be explored parasitically - at least for the next couple of years)
2. It will be hard to implement new, non-standard measurement strategies within the present “modus operandi” of the LHC experiments.
3. The LEP and Tevatron experiments did an excellent job...
...it will be very hard to improve their measurement(s) accuracy
4. We have to achieve an unprecedented level of understanding of the detector performance, introduce new calibration methods, develop new MC tools
...and/or develop (and implement!) new measurement strategies - to join the competition...

If the same Monte-Carlo tools and the same measurement procedures are used at the Tevatron and at the LHC, and no LHC-specific effort is undertaken, the precision of the W mass and of the other parameters of the Electroweak Standard Model, will not be improved at the LHC - no matter what level of the understanding of the detector performance will eventually be achieved....

Why?

Challenges for precision physics at the LHC

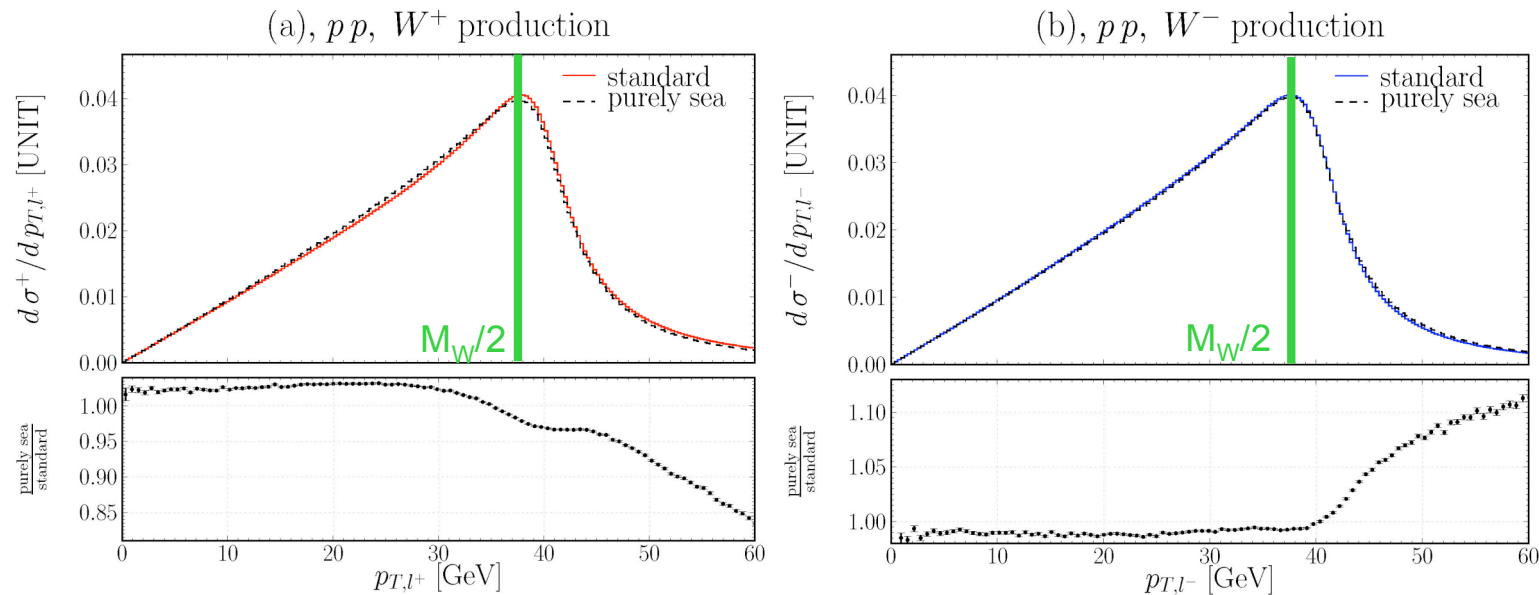
At the LHC we collide pp not $p\bar{p}$ like at the Tevatron

Symmetry relations not at work! (need to understand the charge and polarization asymmetries in W and Z production (valence/sea separation))

Collisions at much higher energy! (need to understand heavy flavours with much better precision)

W and Z bosons are produced at the LHC by the low-x partons!
(need to understand precisely not only the x dependence of their distributions but also the x- and flavour dependent k_T distributions)

Example 1: Valence quarks and W mass measurement

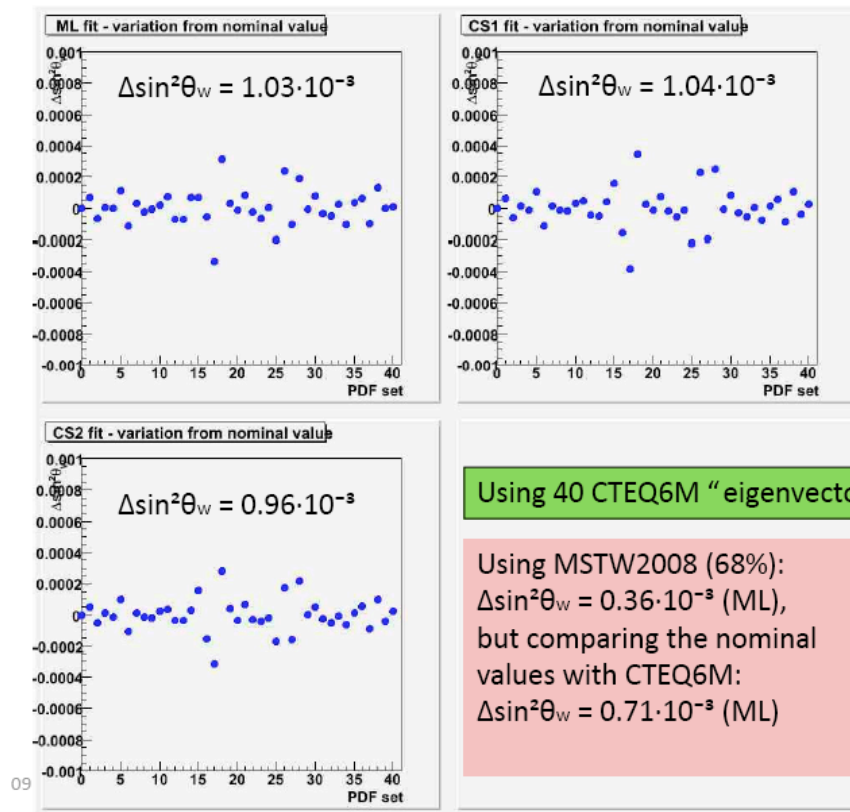


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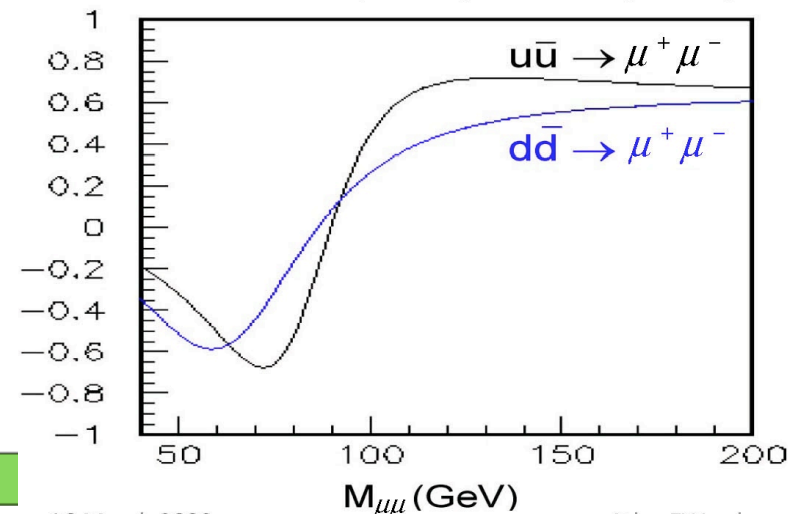
(M_W biases at the level of ~ 400 MeV
...at the Tevatron 0 MeV)

Example2: Valence quarks and $\sin^2(\theta_W)$ measurement

PDF Systematics



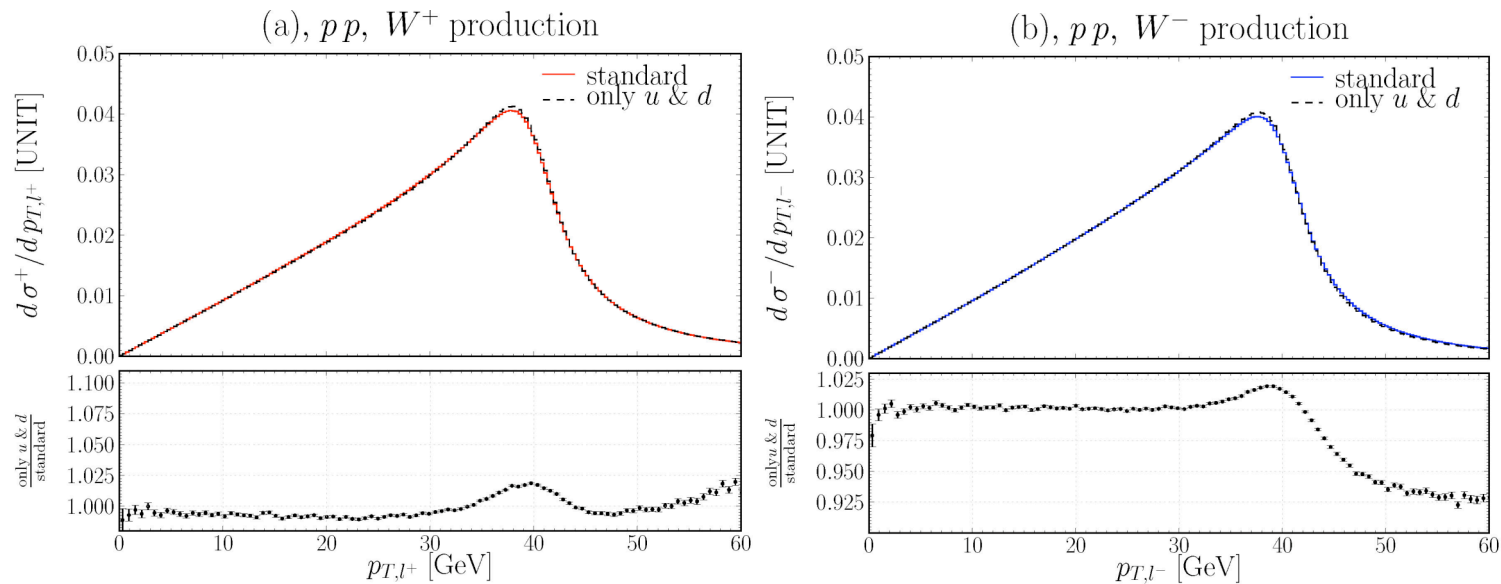
$$A_{FB} = \frac{3}{4} \frac{-2q_q a_q a_\ell \operatorname{Re}(\chi) + 2v_q a_q 2v_\ell a_\ell |\chi|^2}{q_q^2 - 2q_q v_q v_\ell \operatorname{Re}(\chi) + (v_q^2 + a_q^2)(v_\ell^2 + a_\ell^2) |\chi|^2}$$



- The total error on $\sin^2 \theta_W$ is limited by the PDF uncertainties.
- Without better knowledge of PDF, the error will not be below 0.001.

G. Bella

Example3: Heavy flavours in W mass measurement

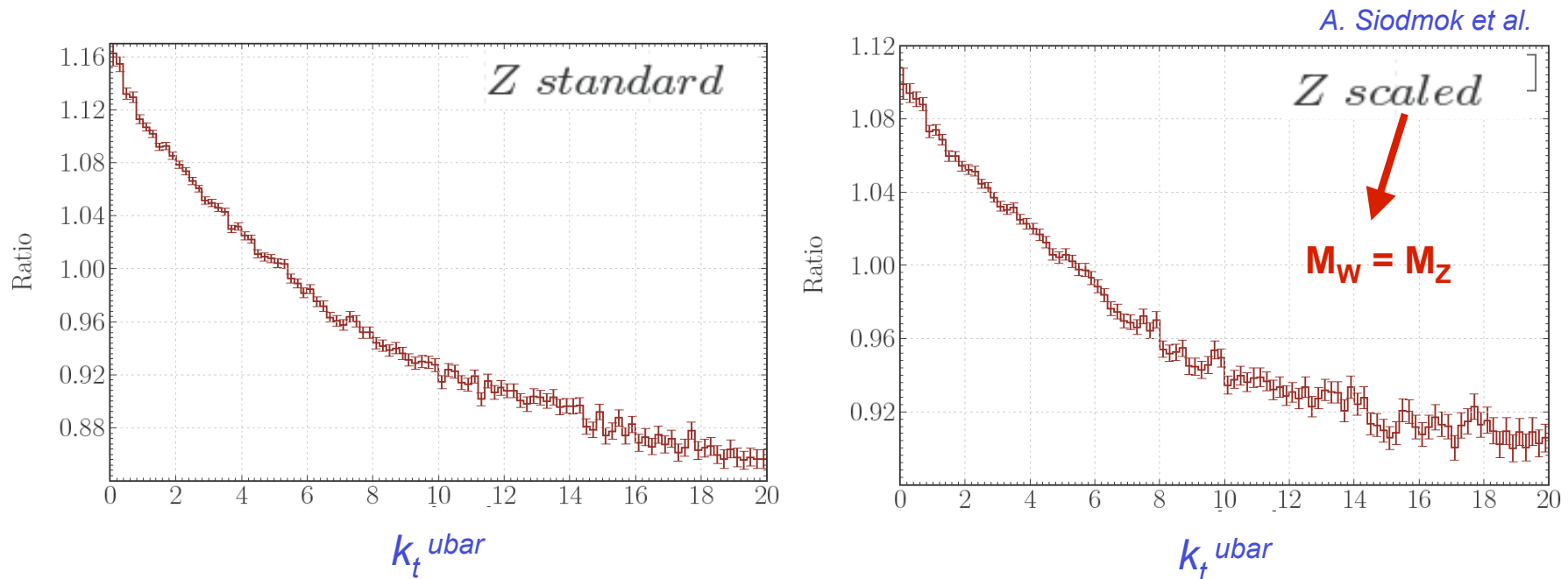


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(M_W biases at the level of ~ 150 MeV
...at the Tevatron < 30 MeV)

Example4: The need to understand the x and flavour dependent distribution of the quark transverse momentum

Look at the ratio of transverse momentum distributions of u_{bar} quarks producing W and Z bosons:



- The momentum distribution of the “matching parton” (the one needed to create W- and Z-bosons) is the dominant source of the biases in the relative transverse momentum distribution of the W and Z bosons!!!
- Note: $u^{(v)} \neq d^{(v)}$ for the proton beam !

Workshop program

- **Wednesday - introductory talks**
(status of the LHC experiments, theoretical and historical context of the precision EW physics at the LHC)
- **Thursday - present status**
(Tevatron W/Z results, present understanding of W and Z boson production, understanding of partonic beams, Monte-Carlo tools - present status and outlook)
- **Friday - perspectives**
(LHC experiment's views, the role of the “LHC-precision-support” programme, experimental control of partonic beams at the LHC, “standard candles” - discussions)
- **Saturday - concluding talks**

We are looking forward to
stimulating talks,
pertinent questions
and
illuminating discussions