Two examples of PDF impact on EW applications

- Nathalie Besson, Florent Chevallier, Maarten Boonekamp (Saclay) + Fred Olness (plots and discussions). Studies done within ATLAS SM group

- W-mass
  - Current PDF uncertainty and goal to be achieved
  - Impact of Z events
  - Caveats : flavour asymmetries

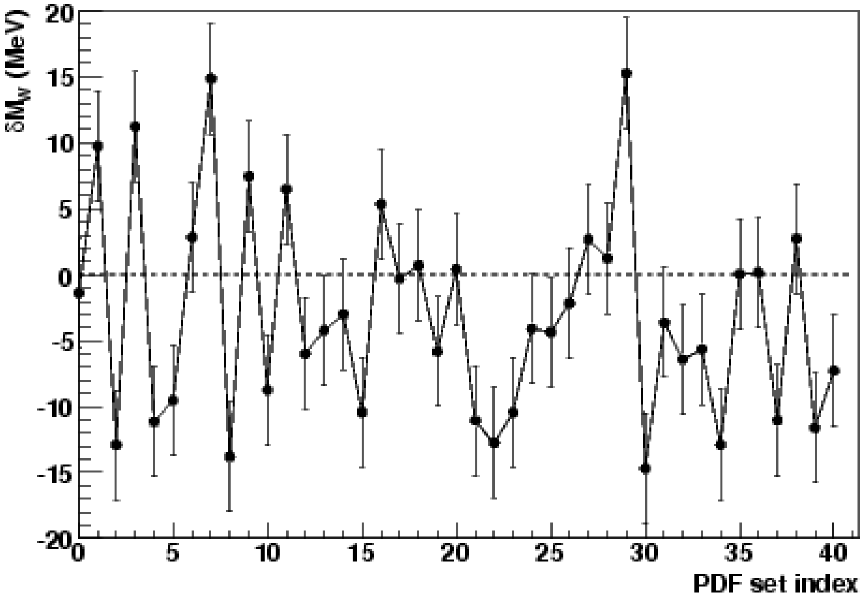
- High-mass Drell-Yan spectrum
  - extension of “LEP-2” precision measurements of ee --> ff
    - consider everything with $M > M_Z$ as a window to new physics
  - Constraints using the “SM-certified” range $m \leq MZ$
  - Caveats : Q^2-evolution of pdf uncertainties ?

- PDF reweighting

- Summary

MW (1)

- Propagation of PDF uncertainties on the W-mass measurement - CTEQ6.1



- Quadratic sum yields δM_W ~ 25 MeV (M_T-based)
- Source : distortions of the rapidity-distribution
- Goal : ~ MeV, since other systematics all seem to shrink to this level (ATLAS-COM-2007-047, to be published)

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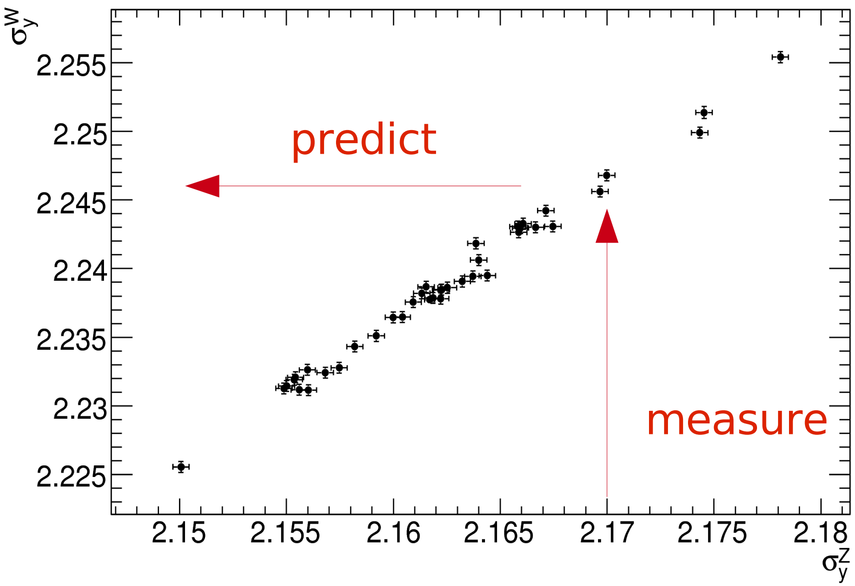
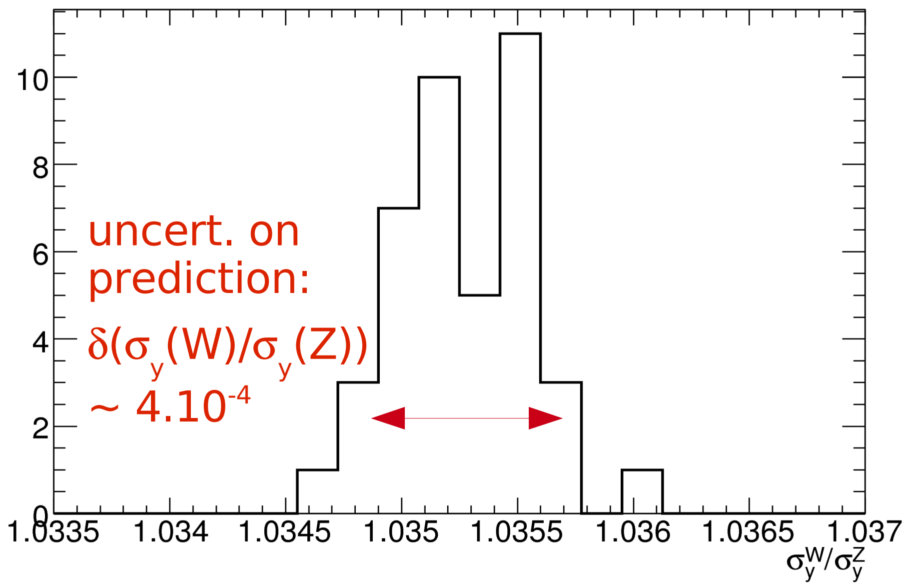
MW (2)

- Improvement from $d\sigma/dy(Z)$: W (~$u\bar{d}+\bar{u}d$) and Z (~$u\bar{u}+d\bar{d}$) should be correlated under PDF variations
  - Measure : σ_y = spread of the y-distribution (RMS or any other estimate)





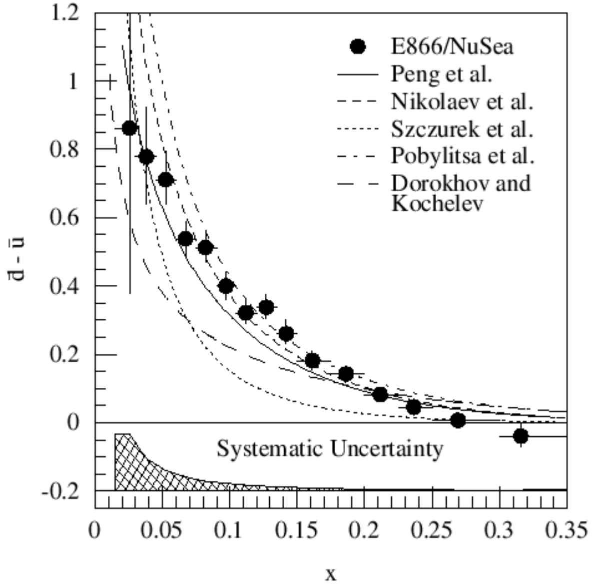
- Anticipate : $\delta\sigma_y(Z)$ *= 1/30 (from measurement)

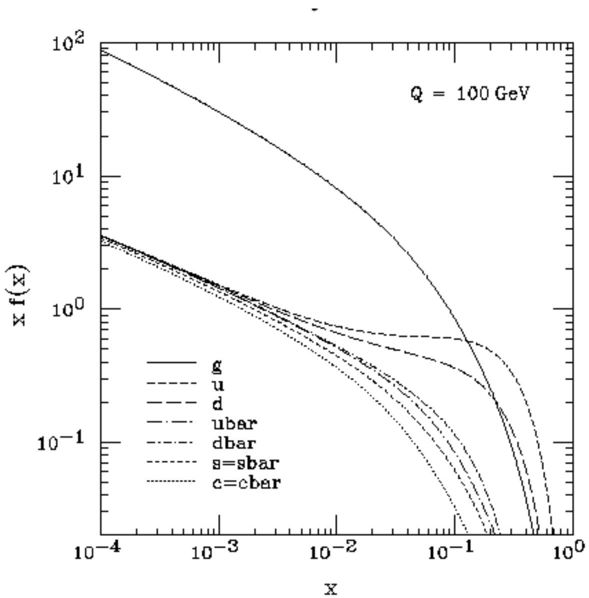
  $\Rightarrow$ $\delta\sigma_y(W)$ *= ~1/20, because of the small decorrelation.
- So OK??

MW (3)

- Caveats : CTEQ6.1 assumes sea flavour symmetry, and fixed strangeness. This is enouh to enforce the correlation seen on previous slide. Validity of these assumptions?

- discussion : ubar/dbar. Releasing ubar==dbar implies a decorrelation of order $(u-d)x(\bar{u}-\bar{d})/(u\bar{u}+d\bar{d})$. Size of this factor?

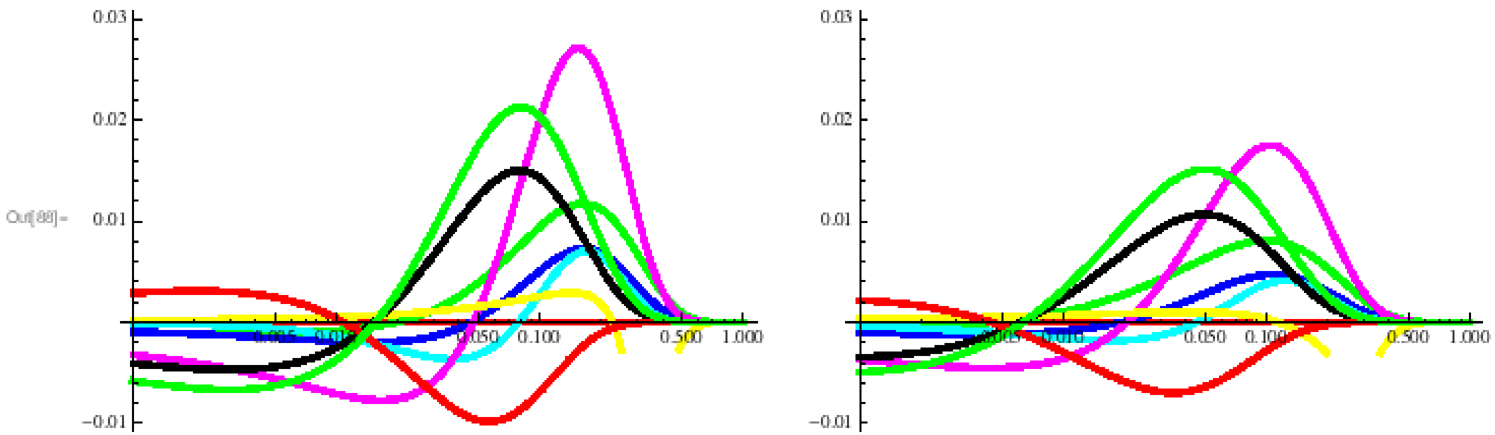




- --> ~ 10^{-4}. So smaller than the current decorrelation (right plot, previous slide)

MW (4)

- discussion : s / s̄. Effect of releasing s == s̄?
- below : (s-s̄) vs. x; Q=1.3 (l) and Q=100 (r) ; thanks F.Olness

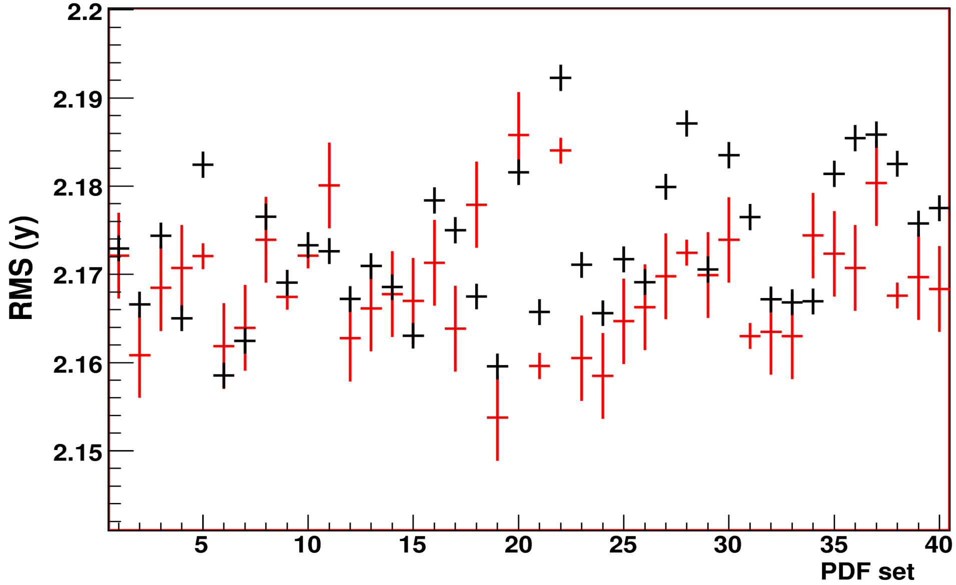


- relative assymmetry (s-s̄)/(s+s̄) ~ 10^{-3} (also exploiting previous plot)
- And s-induced W production ~25% of d-induced W production

- → Effect of order 2-3 . 10^{-4}, again smaller than the default decorrelation. TBC!!

PDF reweighting

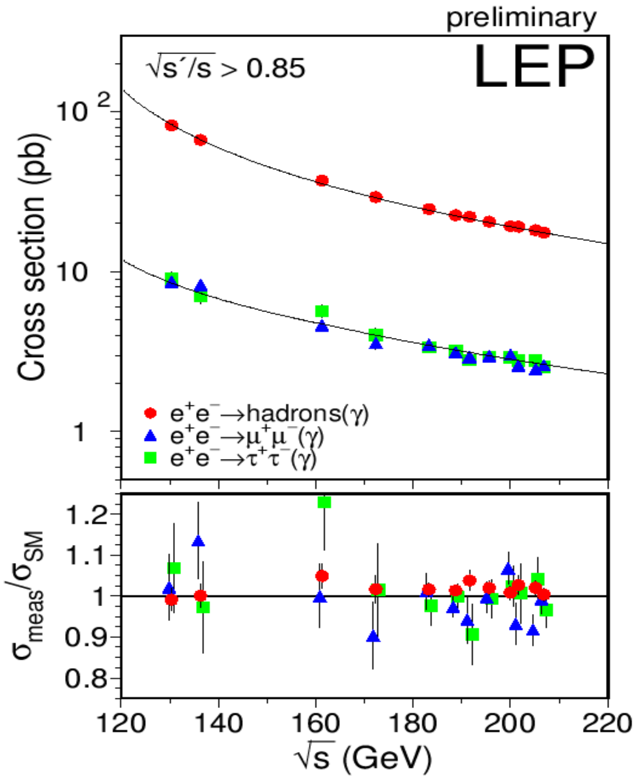
- unavoidable for high-statistics applications
  - M_W : data ~ 10^7 events; templates ~ 10^9 events; x 40 PDF sets ??
- widely-used approximation : hard vertex reweighting (ignores parton shower)
- Comparisons of $\sigma_y(Z)$, as obtained from full generation vs. reweighting:



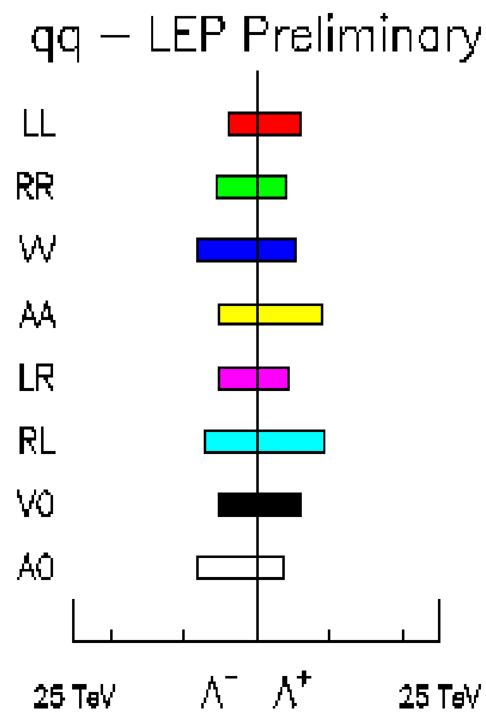
- Not too bad, but clearly imperfect (pull RMS ~ 1.4). Can we do better?

Drell-Yan (1)

- Precision measurement above the Z. Cf. LEP2 :
  - ~30 measurements, precision ~1-5%



⇒

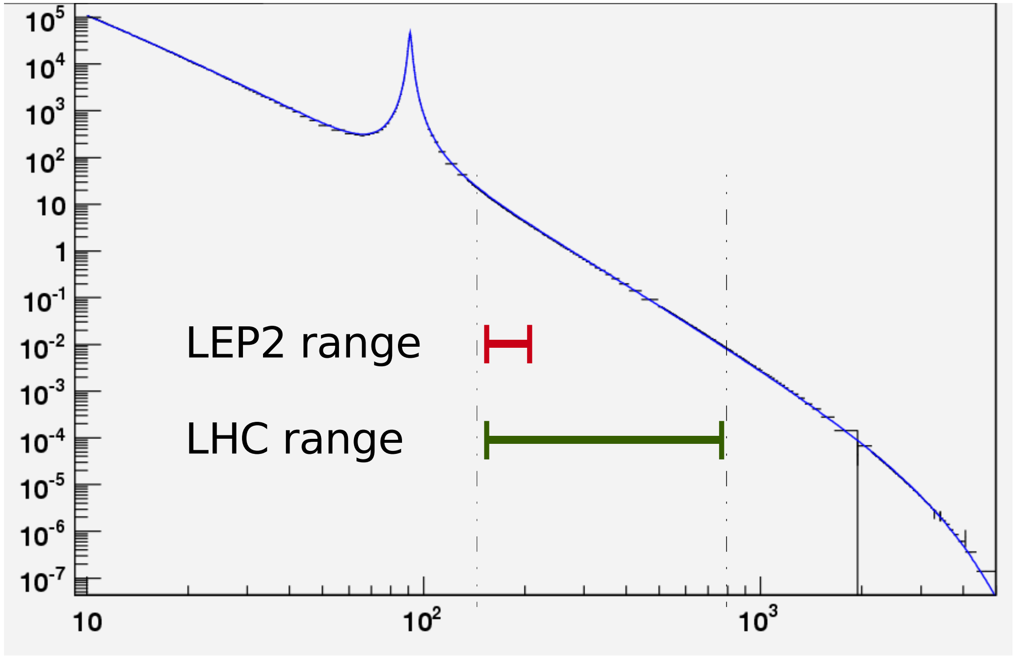


Drell-Yan (2)

- We can do better at the LHC!

Di-lepton
mass spectrum.

And we have the W!

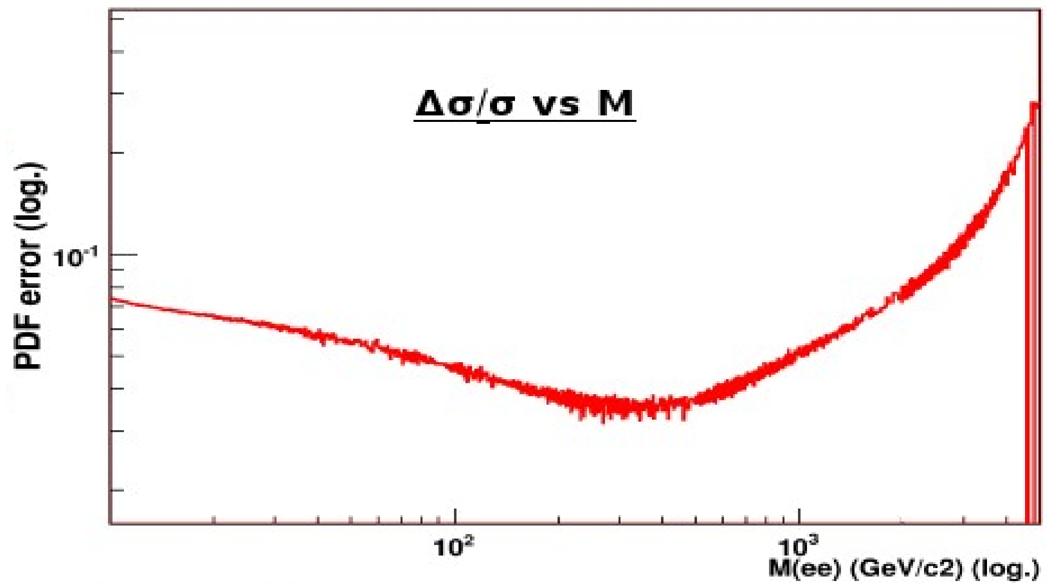


- ...provided we have 1% precision on the high-mass predictions (== precision of the powerful LEP2 measurements)

Drell-Yan (3)

- Current uncertainty:

  ~4-5% for
  100 GeV < M < 1 TeV



- → gain a factor ~5. To do this, relate:
  - $\sigma(m, y=0) \sim f^2(x, m)$ (at m [low-mass], **measure**)
  - $\sigma(m_z, y\neq 0) \sim f(X, m_z) \times f(x, m_z)$ (at M_z, **measure**)
  - $\sigma(M, y=0) \sim f^2(X, M)$ (at M [high-mass], **predict**)

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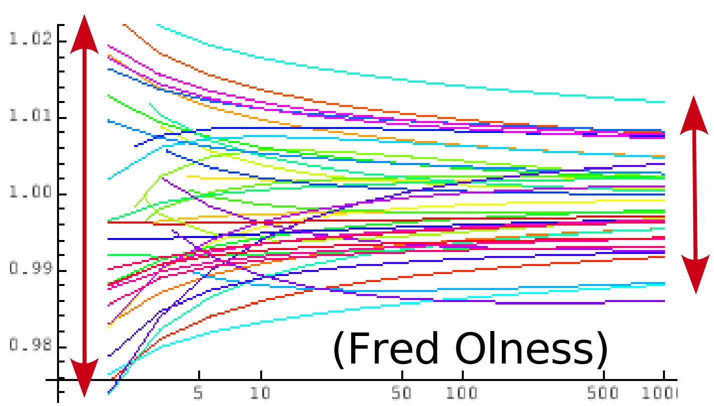
Drell-Yan(4)

- Specifically, one obtains, if $m = m_Z\, e^{-y}$, $M = m_Z\, e^{y}$

predict → $$\frac{\delta\sigma(M,0)}{\sigma(M,0)} = \alpha_2 \left(2\frac{\delta\sigma(m_Z,y)}{\sigma(m_Z,y)} + \alpha_1 \frac{\delta\sigma(m,0)}{\sigma(m,0)} \right)$$ ← **measure**

  - PDF uncertainties, i.e $\delta f/f$ at given (x,Q^2), are traded against $\delta\sigma/\sigma$ which are direct measurement results
  - hard cross-sections carry small uncertainty (<1%, cf. FEWZ)
  - α_1, α_2 account for Q^2-dependence of the PDF uncertainty, well known ?!

$\delta u/u(x,Q_1)$



$\delta u/u(x,Q_2)$

$$\alpha(x,\Delta Q) = \frac{\delta u/u\ (x,Q_1)}{\delta u/u\ (x,Q_2)}$$

Drell-Yan (5)

- So we have a partial by-pass of global PDF fits here as well. Not for ultimate precision, but useful for fast feed-back within the experiments
- In this case : “calibration”and “target” process couple to the ~same flavour combination over the whole mass range, so no uncertainties from flavour asymmetries
- we still need to know and qualify the α's

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Summary

- We have ways to estimate PDF impact on EW measurements, and how they will evolve with LHC measurements. This obviously does not replace global QCD fits

- Drell-Yan (neutral and charged) have very strong sensitivity to PDFs (my guess : the strongest at the LHC) so we need to be prepared

- Questions:

  - PDF sets (incl. uncertainty sets) with relaxed symmetry assumptions would be of great use, both to quantify and to define strategies to overcome these issues

  - Need to quantify the Q^2-evolution uncertainty, separately from the PDF uncertainty at Q_0 itself

  - The simple hard-vertex PDF reweighing has limitations. Working with large samples, a complete reweighting procedure (hard vertex + parton shower) would save enormous amounts of computing. Possible?