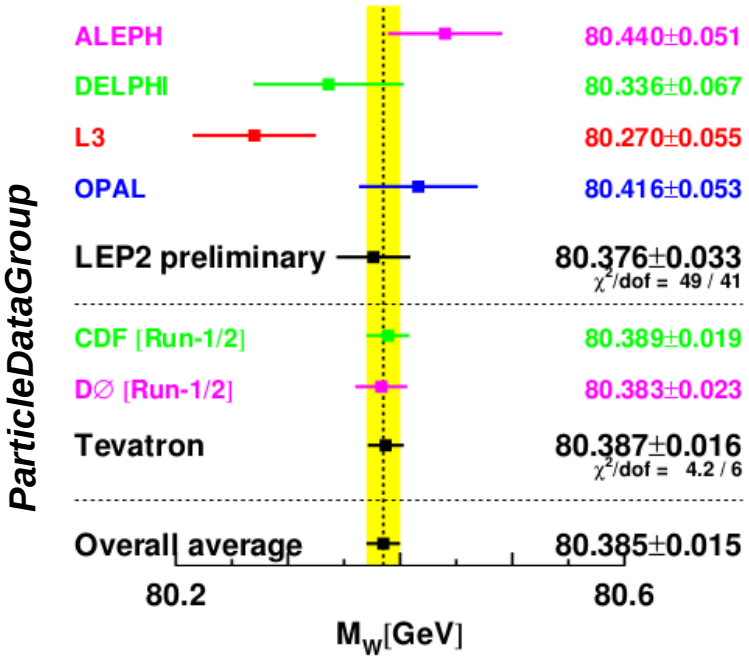
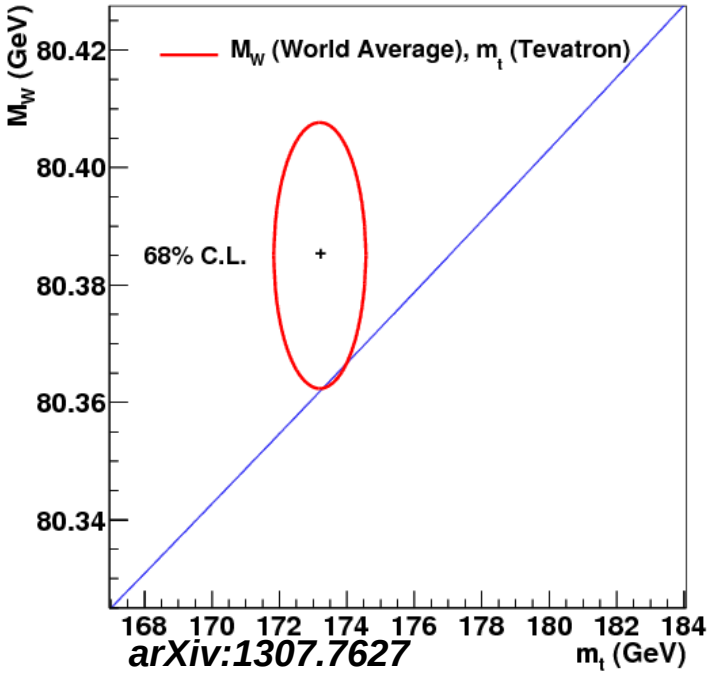
HANNA Rémie
ED 517 – Université Paris-Sud

Thesis subject : Measuring the W-mass with the ATLAS detector.



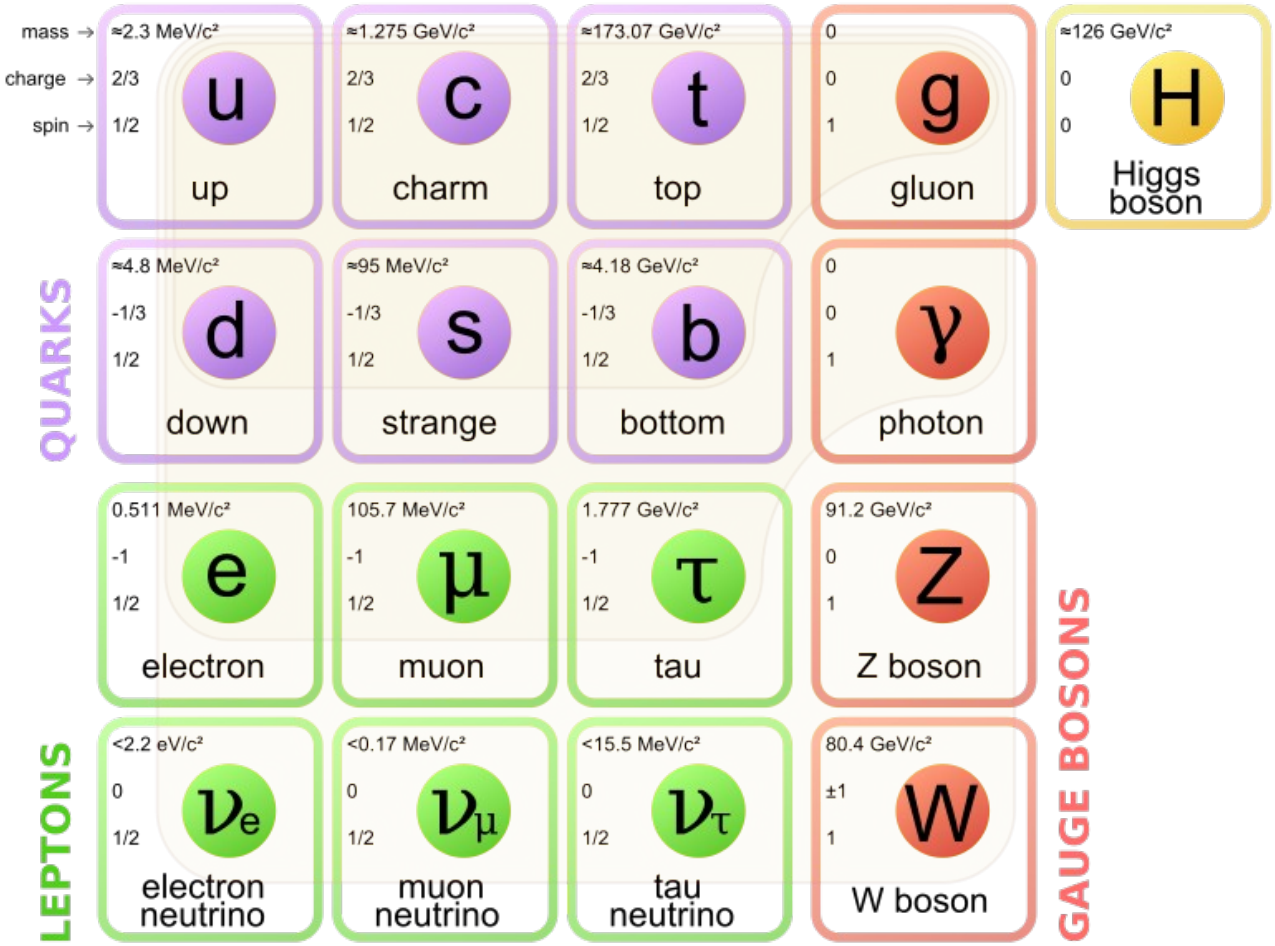


Goal : Improve the precision on the M_W (~x2)

SUMMARY :

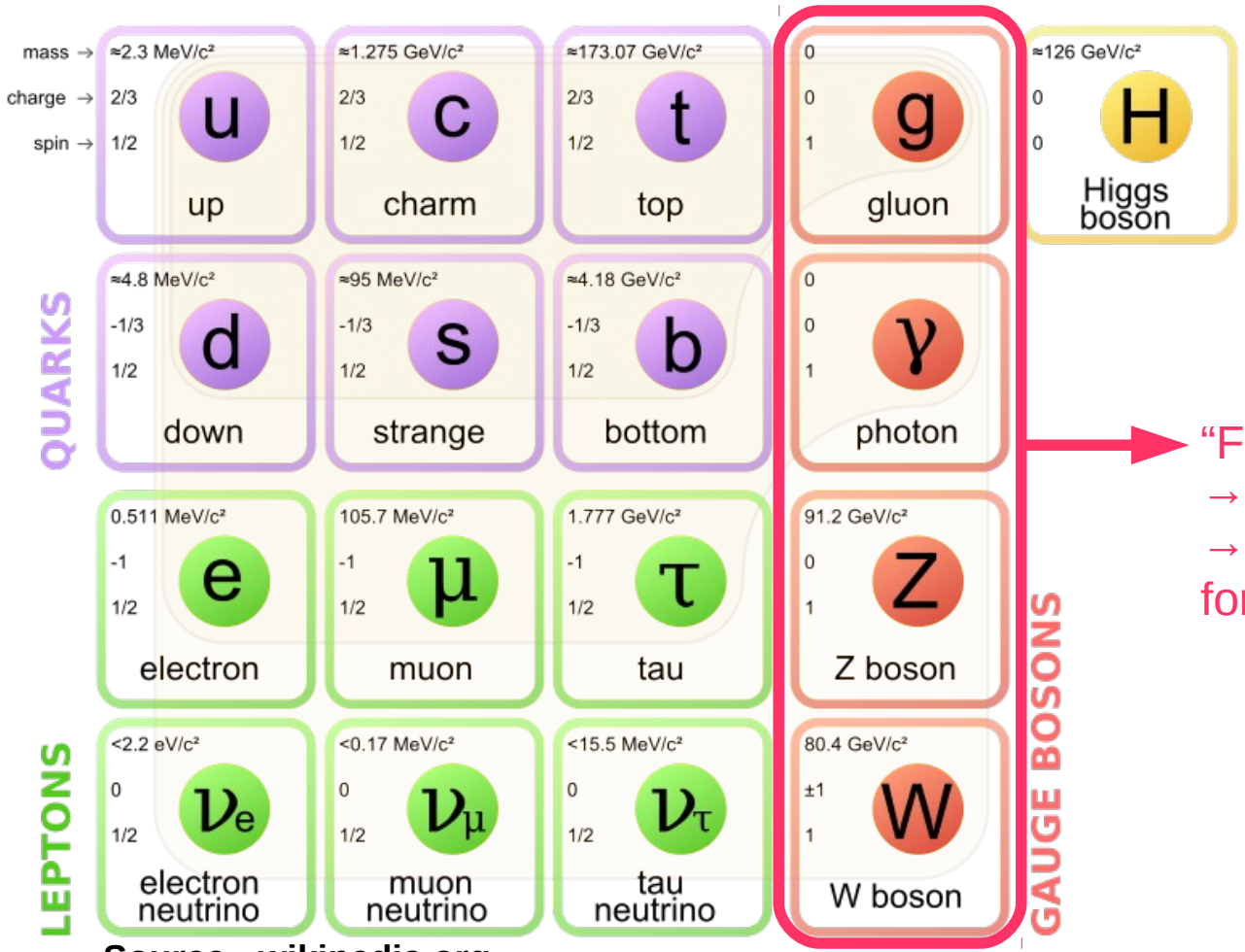
I. Standard Model – W and Z bosons
II. The ATLAS detector
III. Sources of uncertainty
IV. Using Z-p_T
V. Propagating to M_Z and M_W

I. Standard Model – W and Z bosons



Source : wikipedia.org

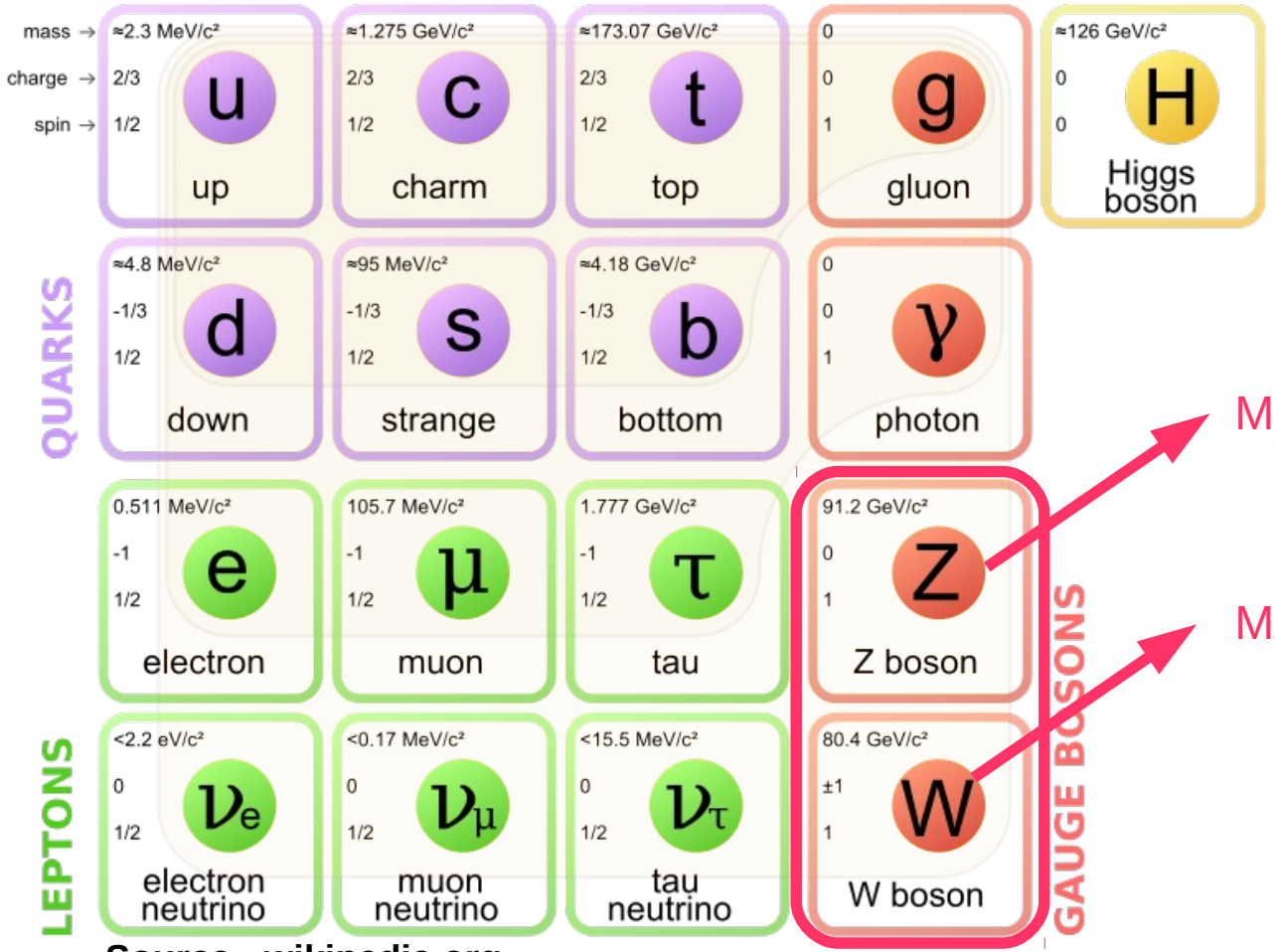
I. Standard Model – W and Z bosons



"Force carriers"
→ g : Strong force
→ γ – W/Z : Electroweak force

Source : wikipedia.org

I. Standard Model – W and Z bosons



$M_Z = 91.1876 \pm 0.0021$ GeV

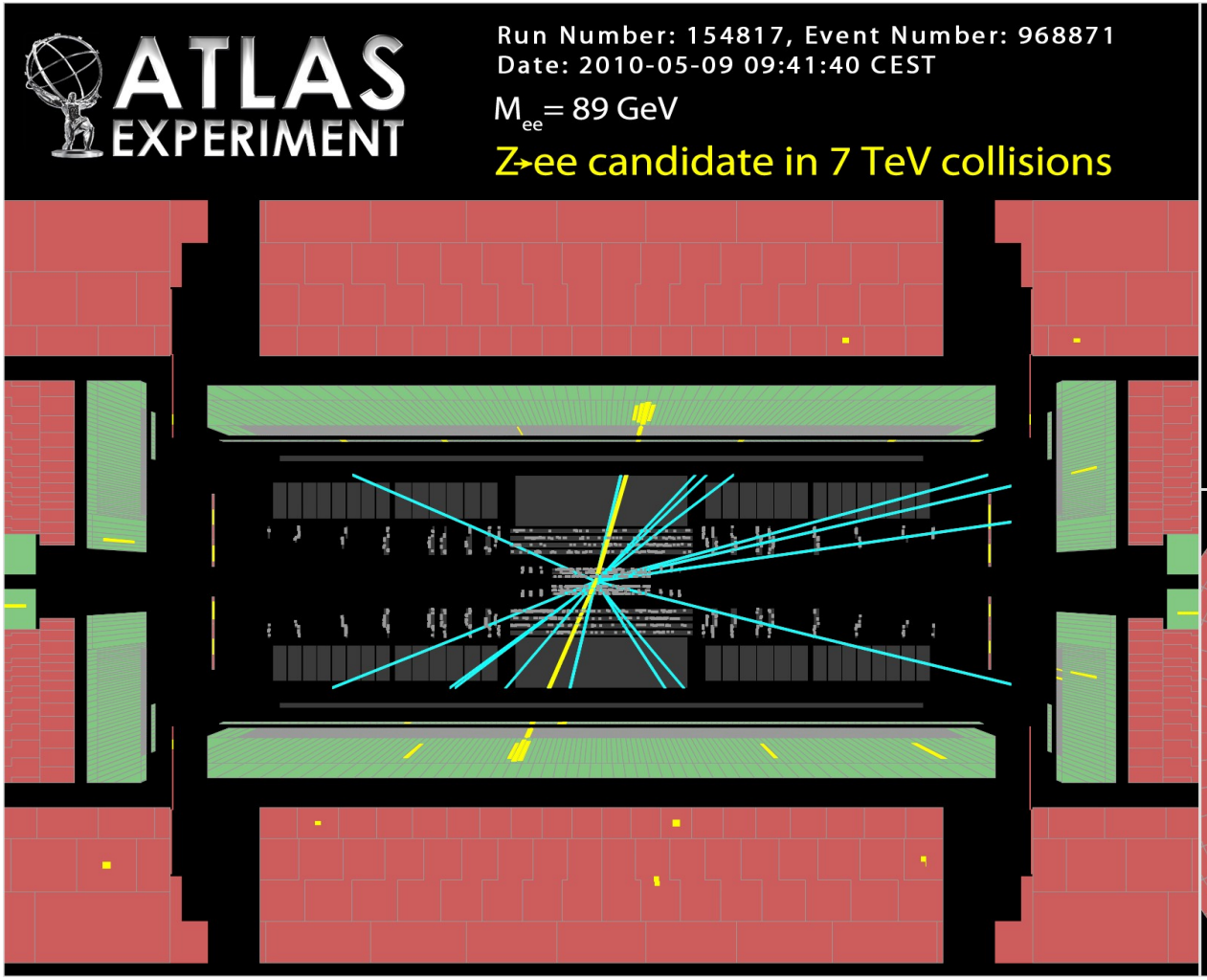
$Z \rightarrow l^+ + l^-$

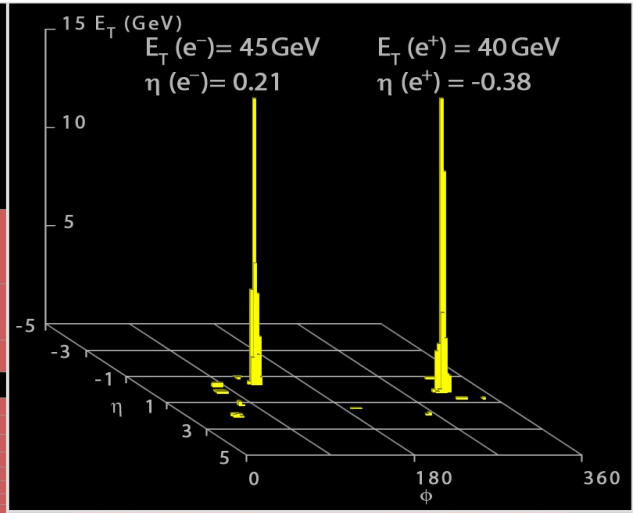
$M_W = 80.385 \pm 0.015$ GeV

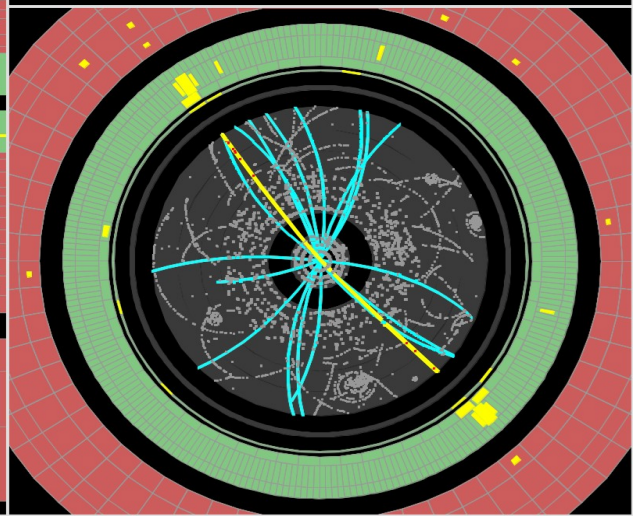
$W^{+/-} \rightarrow l^{+/-} + \nu_l$

Source : wikipedia.org

II. The ATLAS detector







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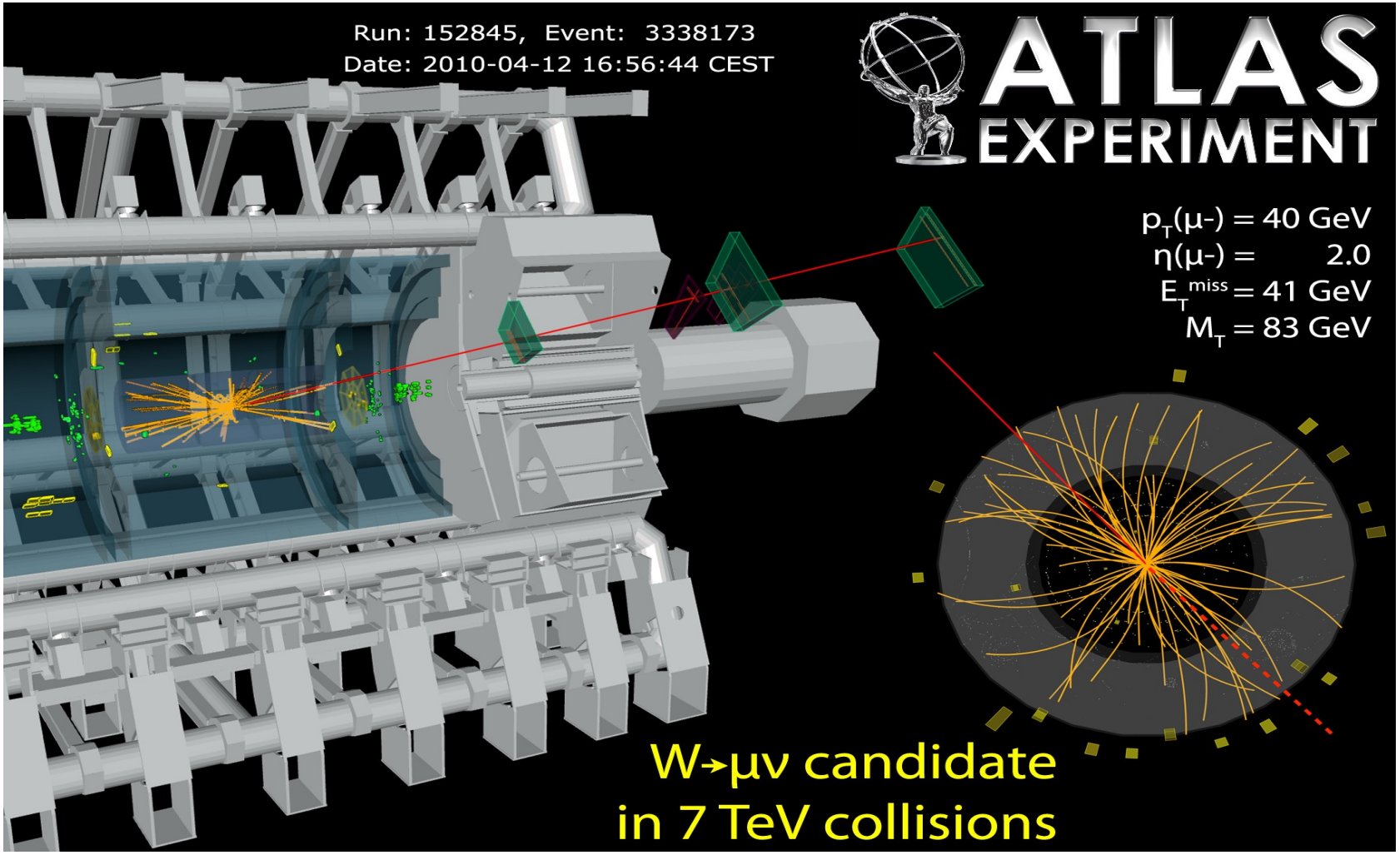
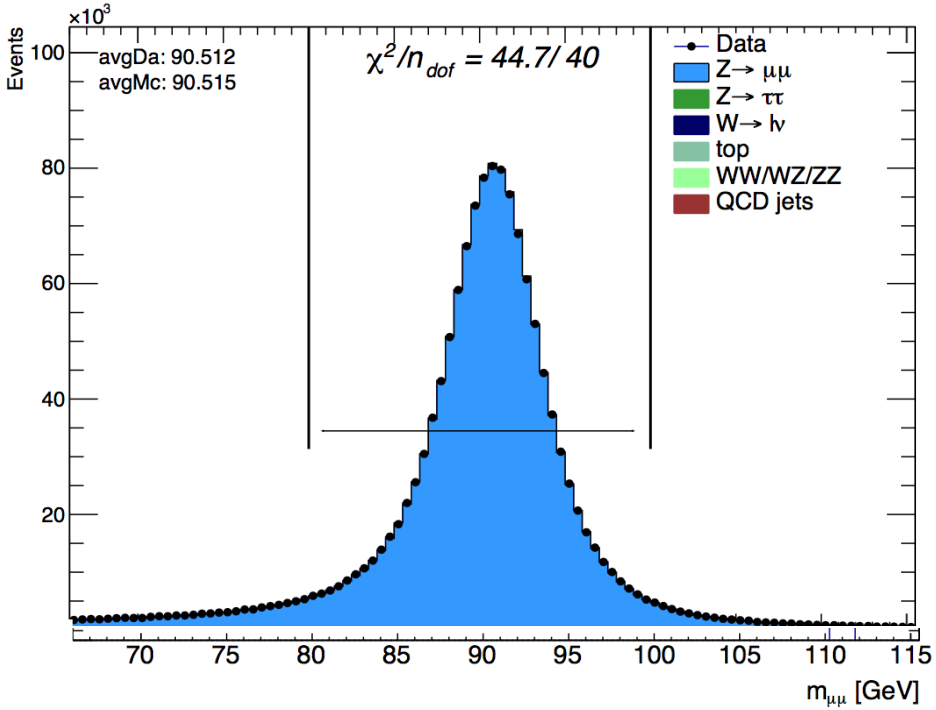
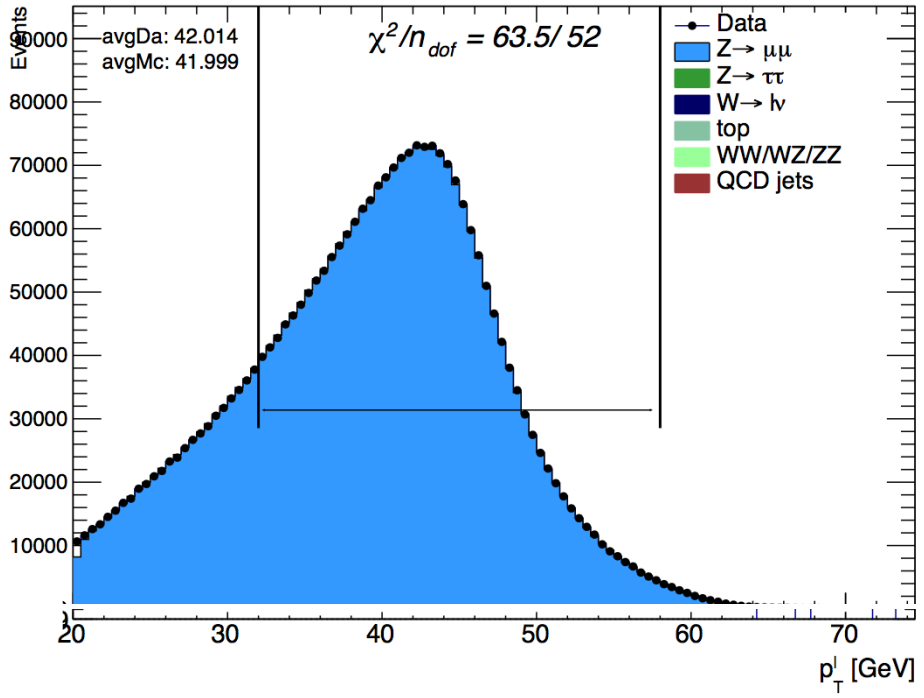


III. Sources of uncertainty





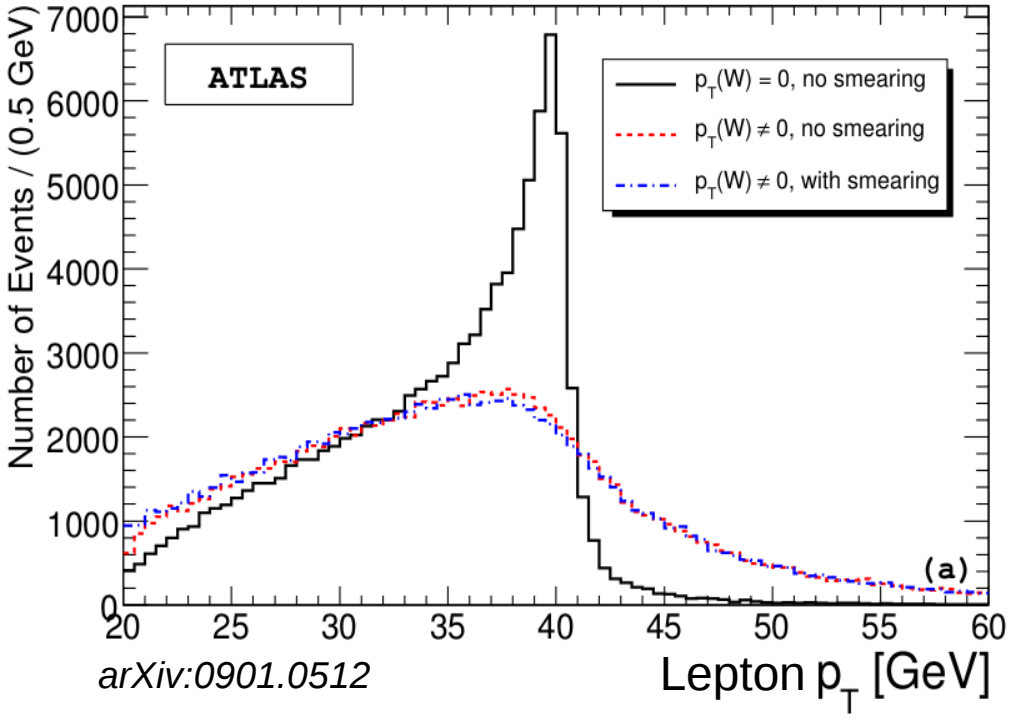
The invariant mass of the Z (left) was precisely measured in LEP, it can be used as a calibration reference for electrons and muons.
The lepton p_T (right) is sensitive to the boson's mass, as well as other effects (physics modeling,...) → Important to be well modeled.

III. Sources of uncertainty

Source	Uncertainty from CDF (MeV)	Expectation in LHC (MeV)
Lepton energy scale and resolution	7	~ 2
Recoil energy scale and resolution	6	~ 2
Lepton removal from recoil	2	~ 2
Backgrounds	3	~ 2
Experimental subtotal	**10**	**~ 4**
Parton distribution functions	10	~ 20
QED radiation	4	4
$p_T(W)$ model	5	**?**
Production subtotal	**12**	**?**
Total systematic uncertainty	15	?
W-boson statistics	12	< 2
Total uncertainty	**19**	**?**

Uncertainties of the CDF (2012) M_W measurement (middle column, taken from *arXiv:1307.7627v2*). The column on the right shows the expectations in LHC.

III. Sources of uncertainty



Sharp peak for lepton p_T if boson $p_T = 0$.

It is critical to describe the boson p_T as well as possible, since it smears the Jacobian edge of the lepton pT.

III. Sources of uncertainty

→ W-p_T spectrum needs to be modeled accurately as it is an important source of systematic uncertainty on the W-mass.

→ W-p_T and Z-p_T involve the same QCD radiation effects.

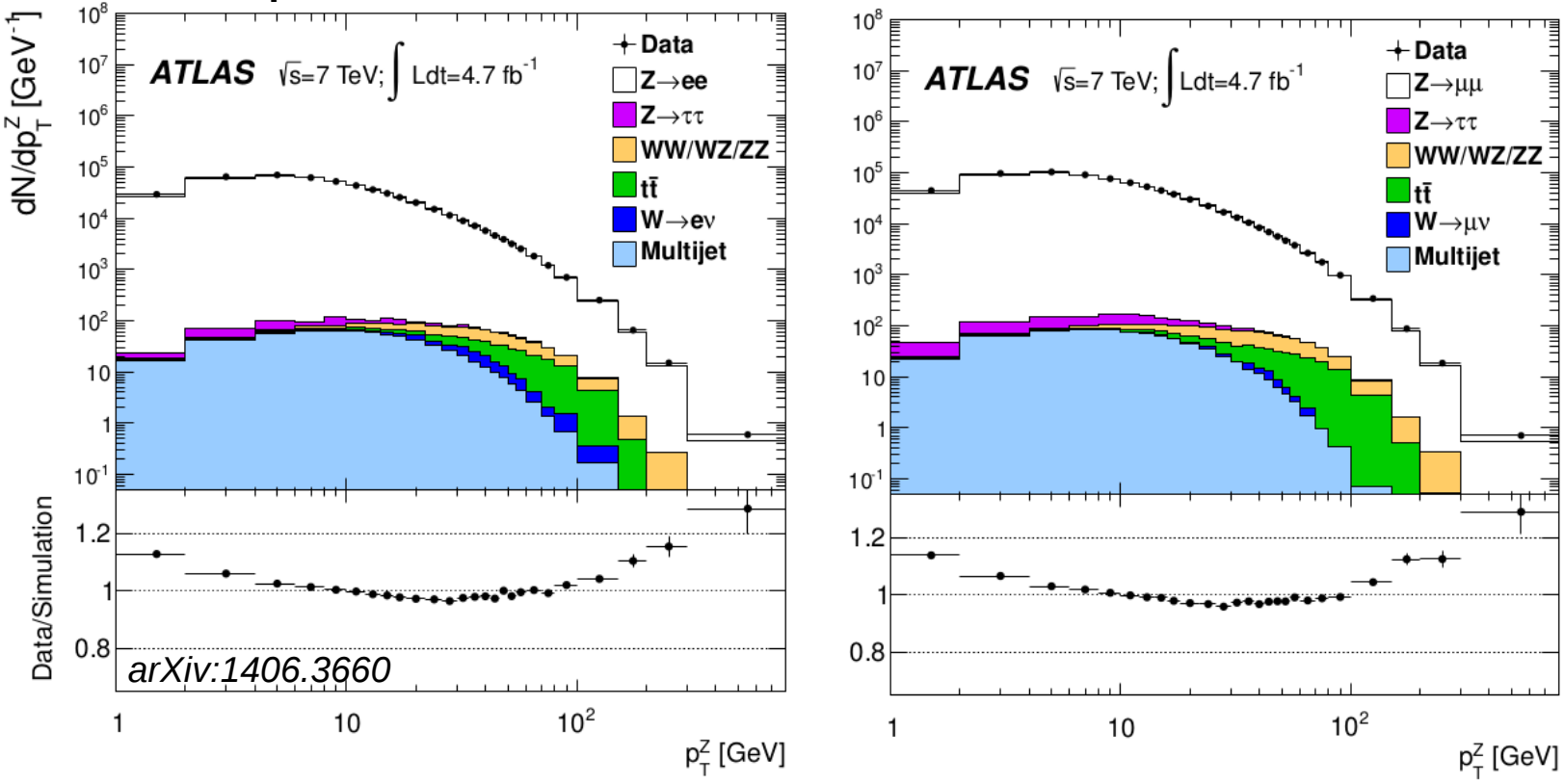
→ However, Z-p_T is more precisely measured.

→ Tune Parton Shower parameters on Z-p_T data and use on W-p_T.

→ Evaluate systematic uncertainty on W-mass

IV. Using Z-p_T :

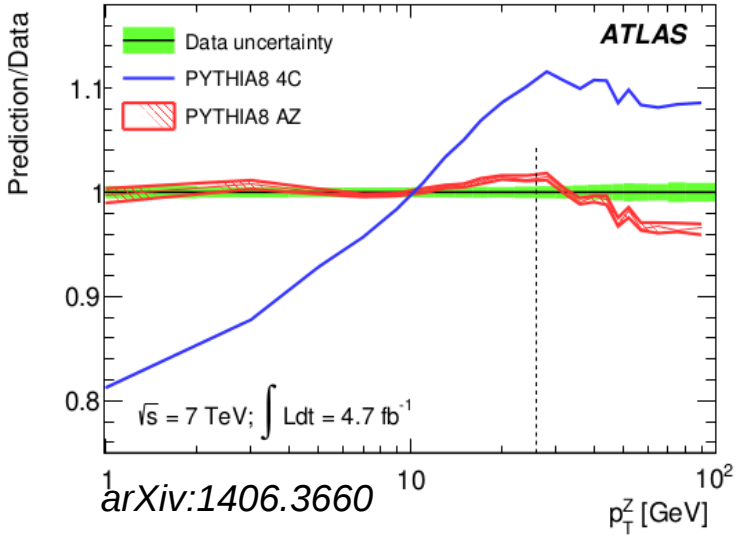
a) p_T



p_T^Z measurements in the electronic (left) and muonic (right) channel. Ratios wrt. Simulation.

IV. Using Z-p_T :

b) Tuning



Comparison of the Pythia8 generator with the old (blue) and new (red) tunes to the p_T^Z data. One “central” set of parameters is defined, as well as 3 others, representing different variations around the central values.

V. Propagating to M_Z and M_W :

a) The Procedure

→ Make tuned variations of simulated data (1 central tune + 3 variations)

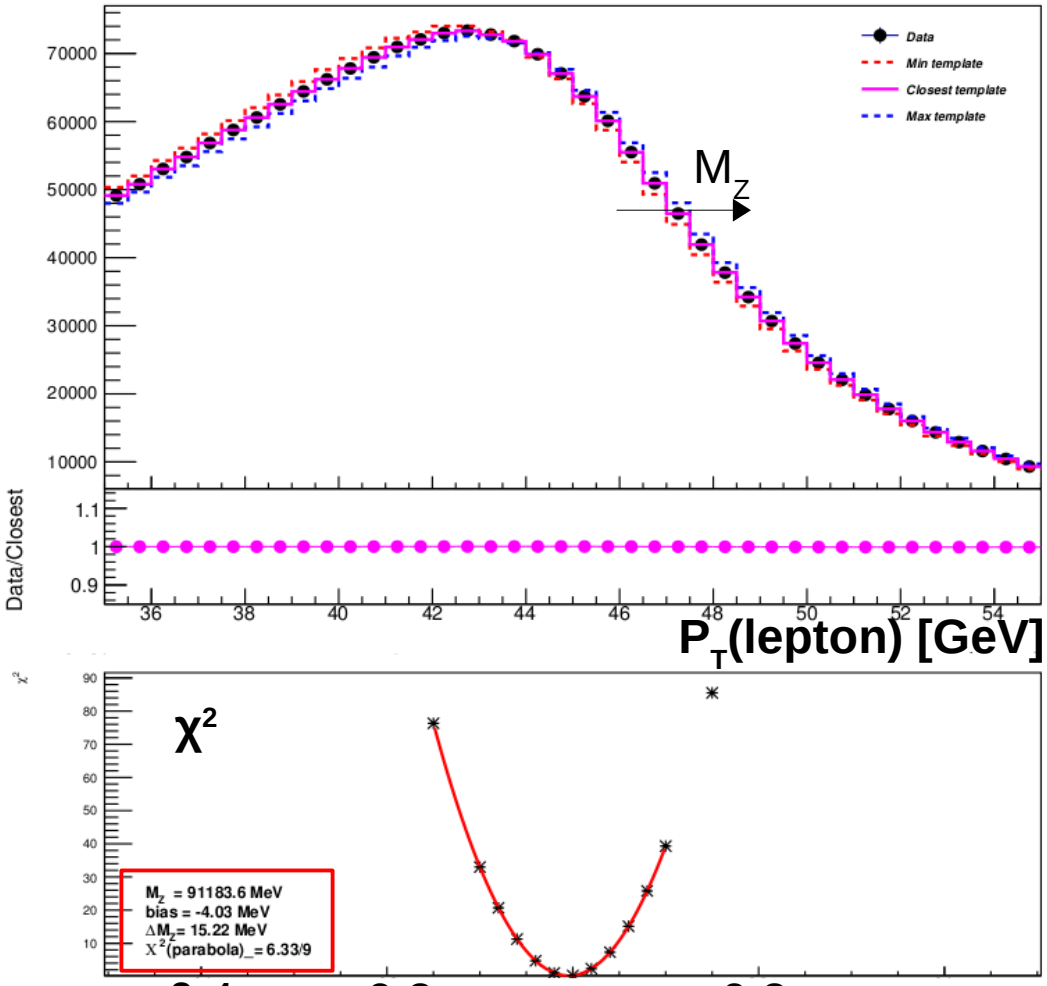
→ Reweight the Z-p_T distributions from simulated samples to these variations (~20M Z-events, sqrt(s) = 7 TeV)

→ Make mass templates out of the central tune, ie. vary the mass within small steps : +/- 0.02, 0.04, …, 0.5 %

→ Make « pseudo-data » out of the 3 variations

→ Fit pseudo-data with different templates, find the closest one and extract preliminary systematics

V. Propagating to M_z and M_w : b) The Fitting Method



Top :
Lepton transverse momentum distribution in Z → μμ :
Reference : M_z = 91187.6 MeV

- PsD
- template closest to PsD
- min. template (M_z – 0.5%)
- max. template (M_z + 0.5%)

Bottom :
χ^2 between shifted and reference masses, as a function of the mass shift.
We extract the bias between the reference and the closest template.

V. Propagating to M_Z and M_W : c) Results

→ At this point of the study, and from the precision on the Z-p_T study, we expect an uncertainty of 3-4 MeV on the W-p_T measurement.

→ The most important contribution to the systematics comes from the parton distributions in the proton (there's an ongoing study on this topic).

→ Next : perform the same study on 8 TeV W-events (~75M events) and extract the final systematics.