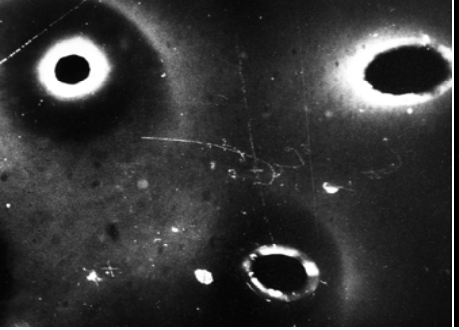
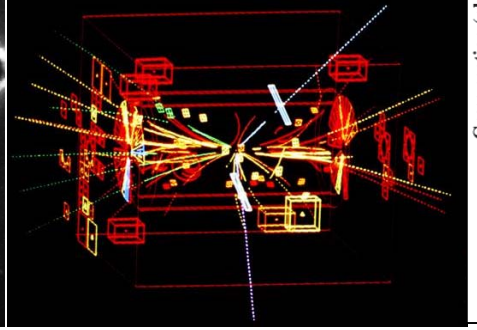
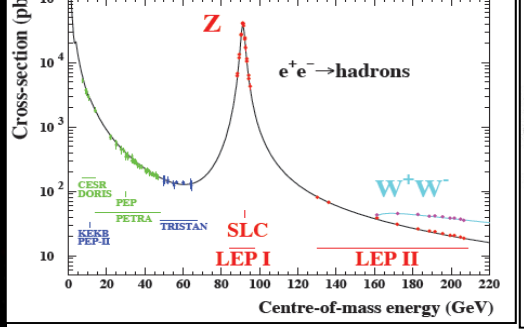


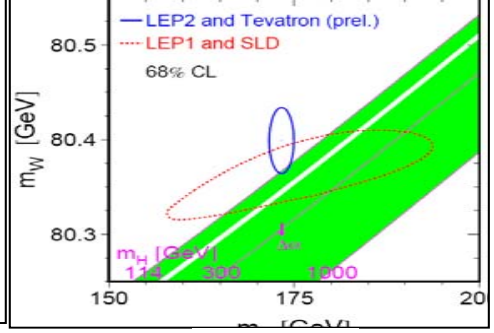
Neutral current ;1973



W & Z discovery; 1983



Z line shape; 90's



M_W ;00's

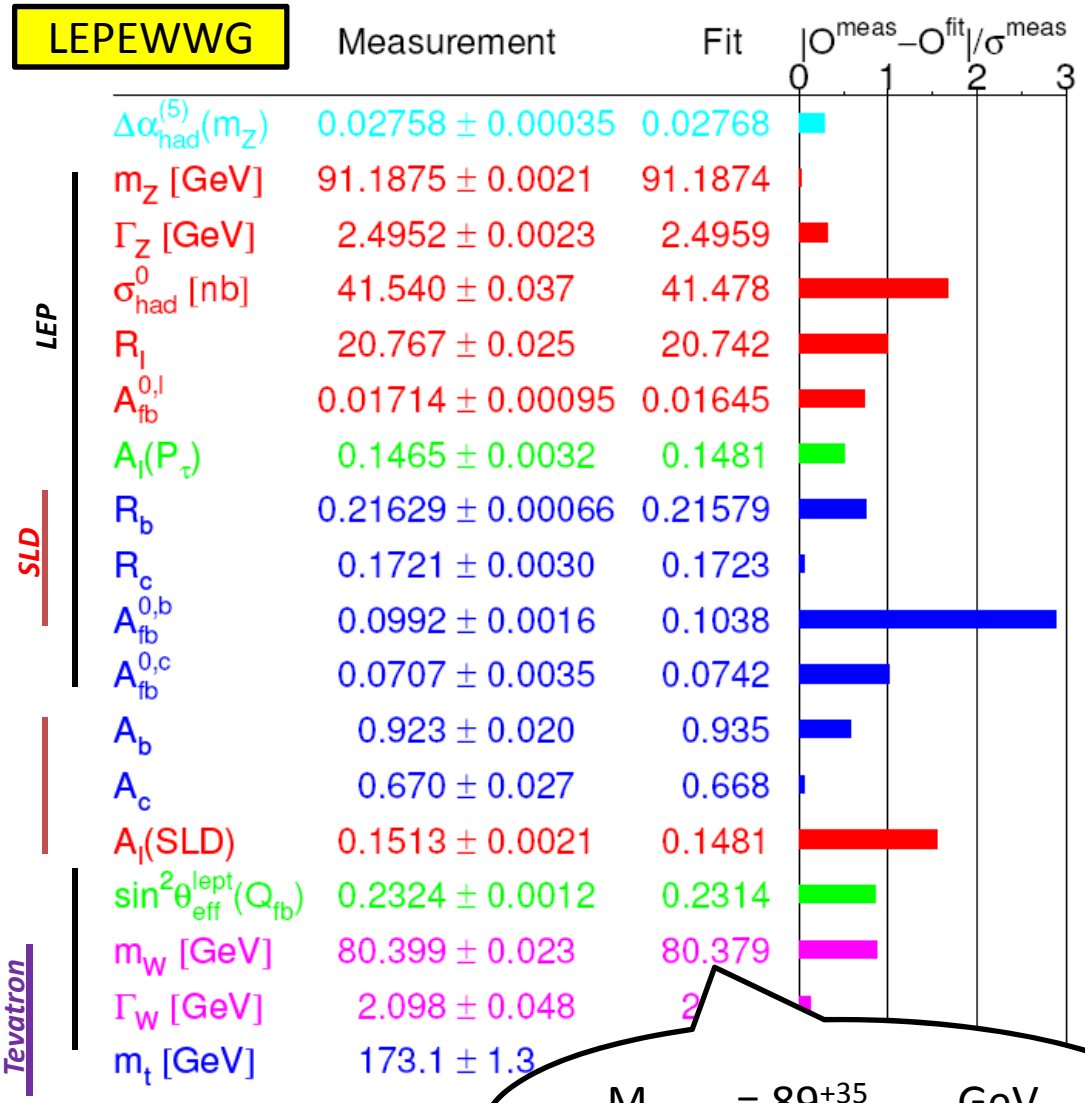
Electroweak Physics in ATLAS

From W/Z observations to the Higgs Mass

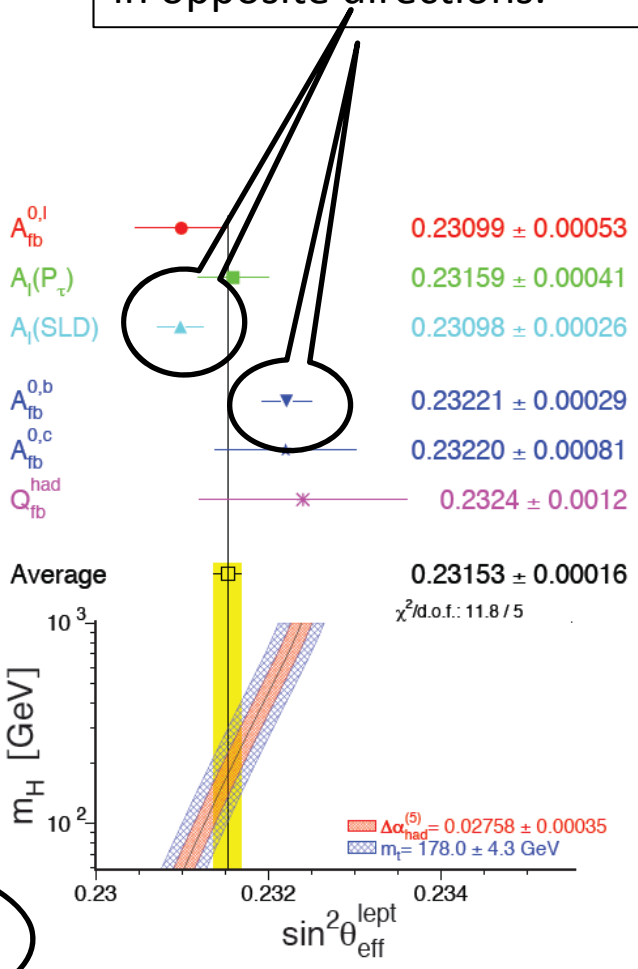
New Data from the Energy Frontier – Aspen 2011

Corinne Goy – LAPP Annecy CNRS/IN2P3

The legacy from LEP, SLD & Tevatron



The 2 most precise measurements drive the fit in opposite directions.



$M_{Higgs} = 89^{+35}_{-26}$ GeV
~ 30% uncertainty

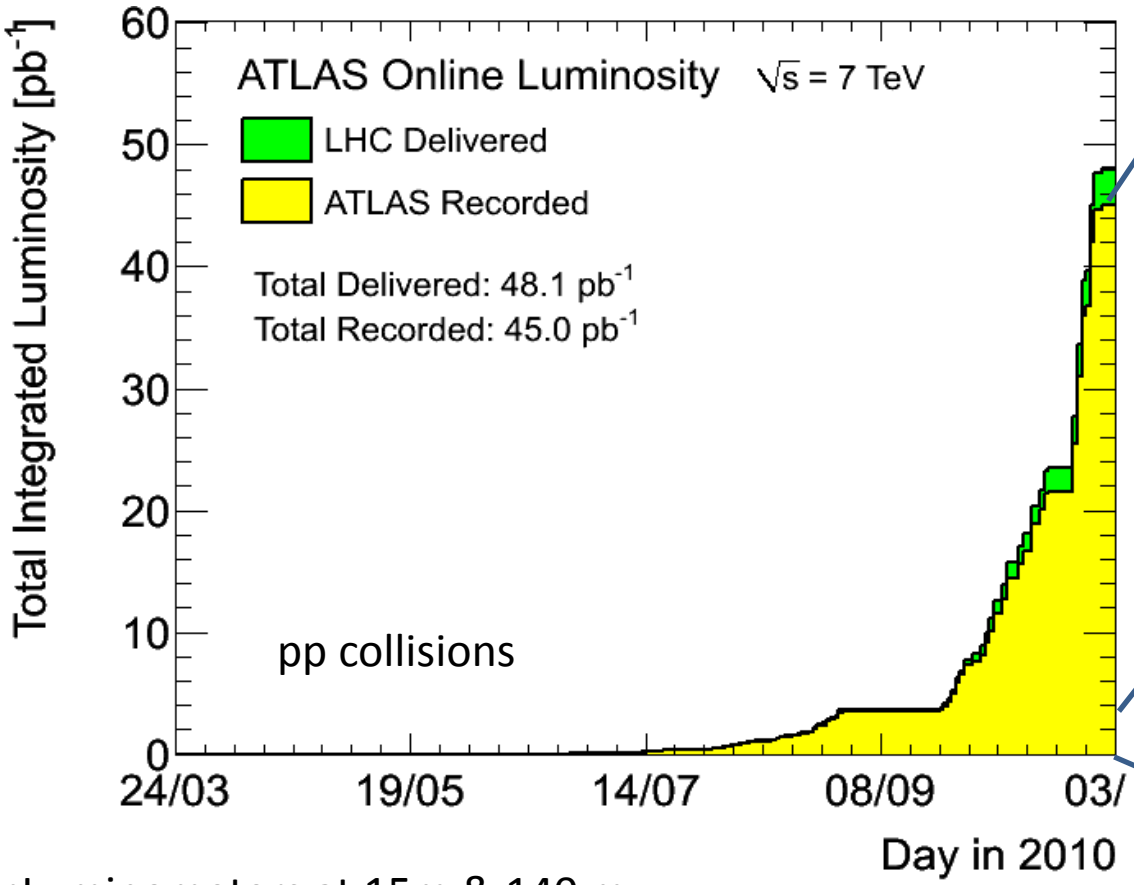
Electroweak Physics with ATLAS

- The breaking mechanism :
  - (Discovery of the Higgs boson)
  - Indirect effects:
    - M_w is a central issue.
    - $Sin^2\Theta_W$
- The gauge sector :
  - Triple Gauge Couplings

> $10\ fb^{-1}$

- **First focus on current data :**
  - **$L = 45\ pb^{-1}$ at $\sqrt{S} = 7$ TeV**

Luminosity / √S = 7 TeV



- Luminometers at 15m & 140 m
- Absolute normalization from Van Der Meer scans
- Current precision on Luminosity : 11%
  - → One of the dominant systematic today
- Aim : 2 to 3%
  - 2011 : new detector at 240m → absolute L

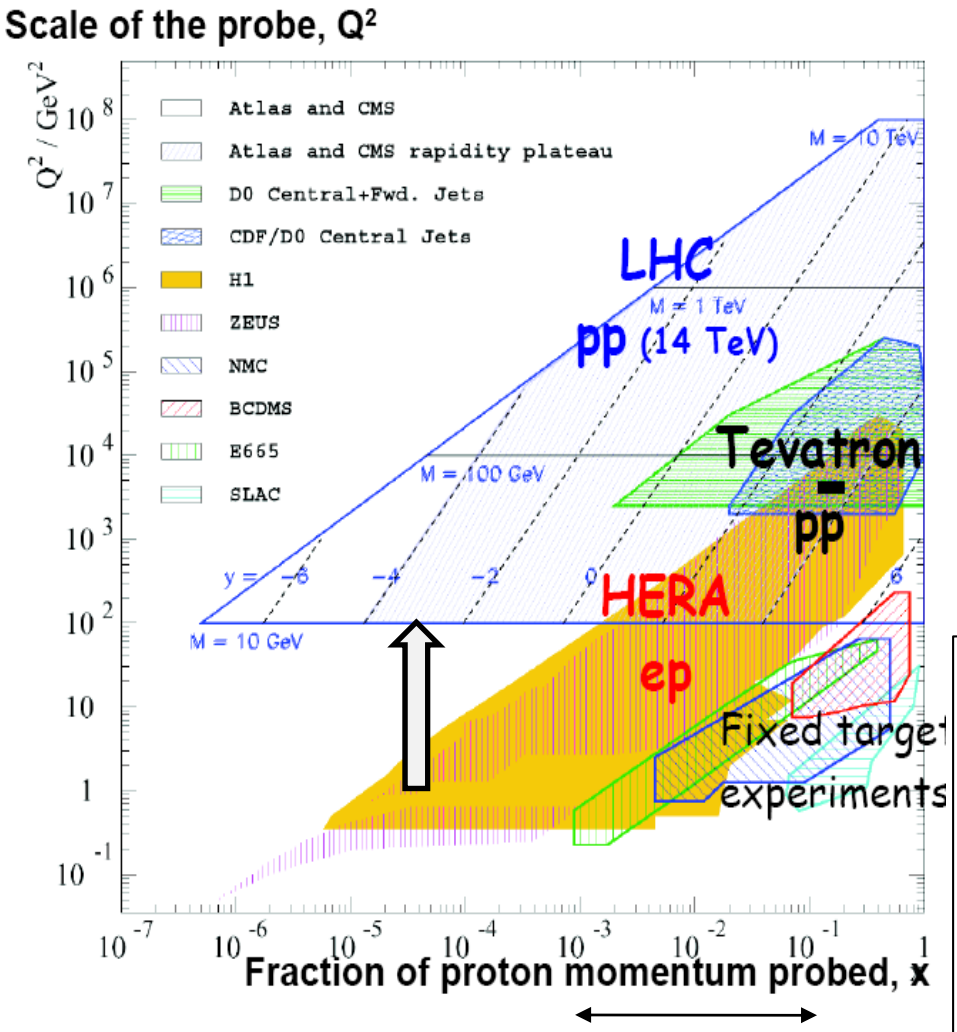
- Differential cross-sections
  - dσ/dPt , dσ/dη
- Di bosons :
  - Wγ, Zγ, WW
- W+/W- asymmetry

- W + jets
- Z + jets

- Observation :
  - W →τν
- W/ Z inclusive cross section:
  - W → e/μ ν
  - Z →ee, μμ

arXiv:1101.2185 Sub to EJPC

The Life at LHC: PDFs



- Low x
- PDFs
  - Extrapolated from Hera data to higher Q^2
  - Well known in $[10^{-3},10^{-1}]$ range
  - Less well measured:
    - Gluon , s-quark
  - Larger uncertainties at very high and very low x

E.g : 3-4 % uncertainty on W/Z production.

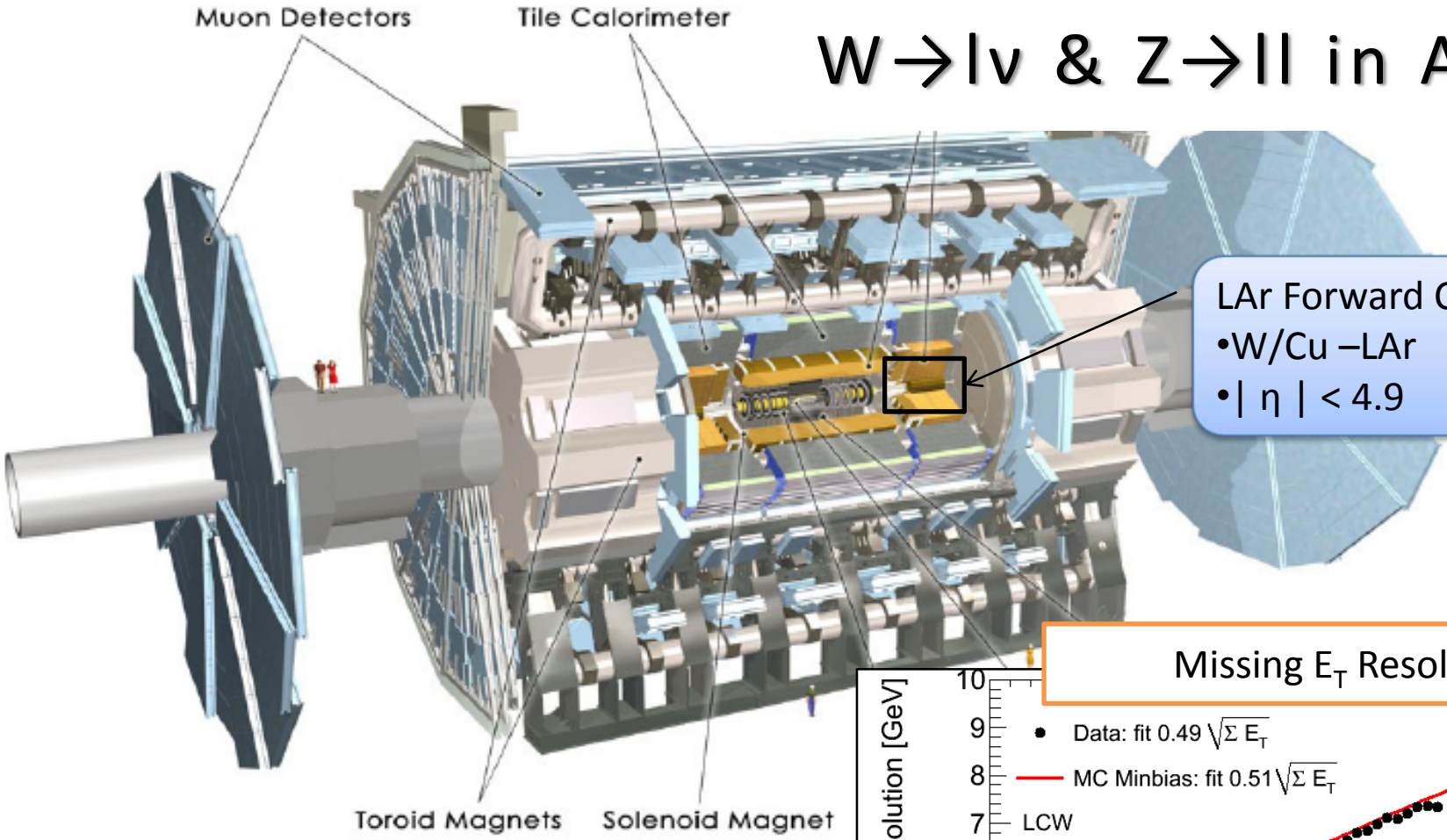
•Largest source of uncertainty once δLum improved.

•SM measurements ↔PDFs

- W asymmetry
- $d\sigma_{W/Z}/d\eta$
- W + c/b jets ?

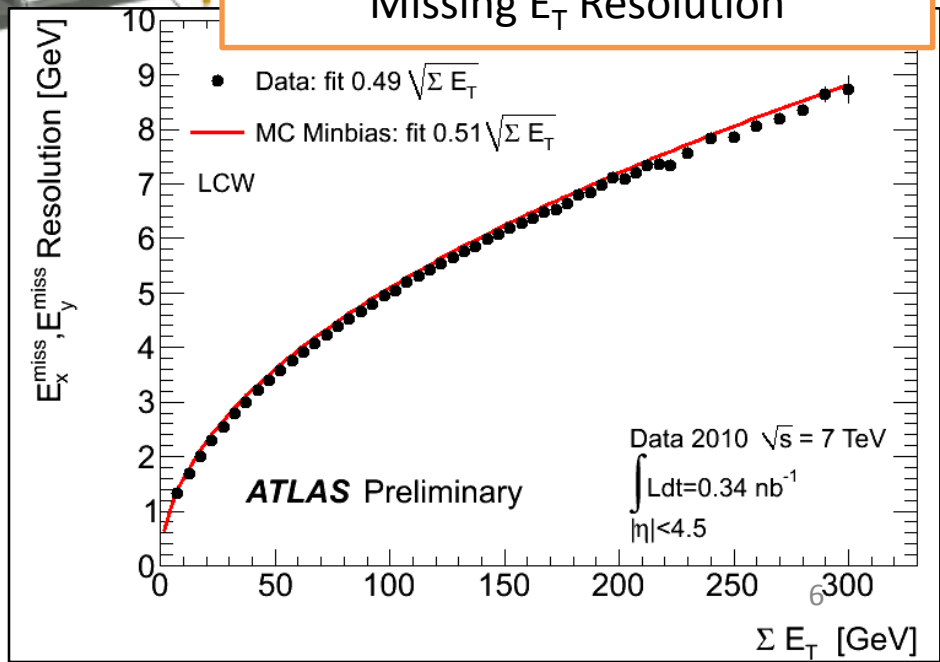
(NB: HERA data not fully exploited yet)

W→lν & Z→ll in ATLAS



LAr Forward Calorimeter:
- W/Cu –LAr
- $|\eta| < 4.9$

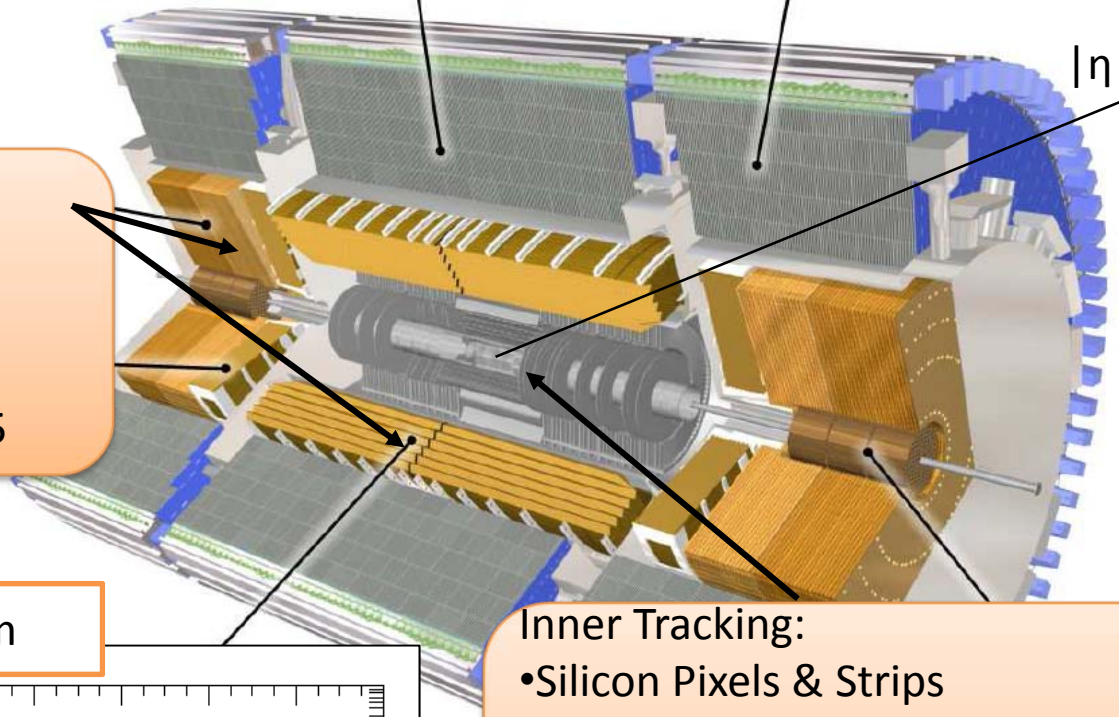
Missing E_T Resolution



Instrumented down to $|\eta| \sim 4.9$ thanks to the Forward Calorimeter :
→ Missing Energy
→ Forward e-ID

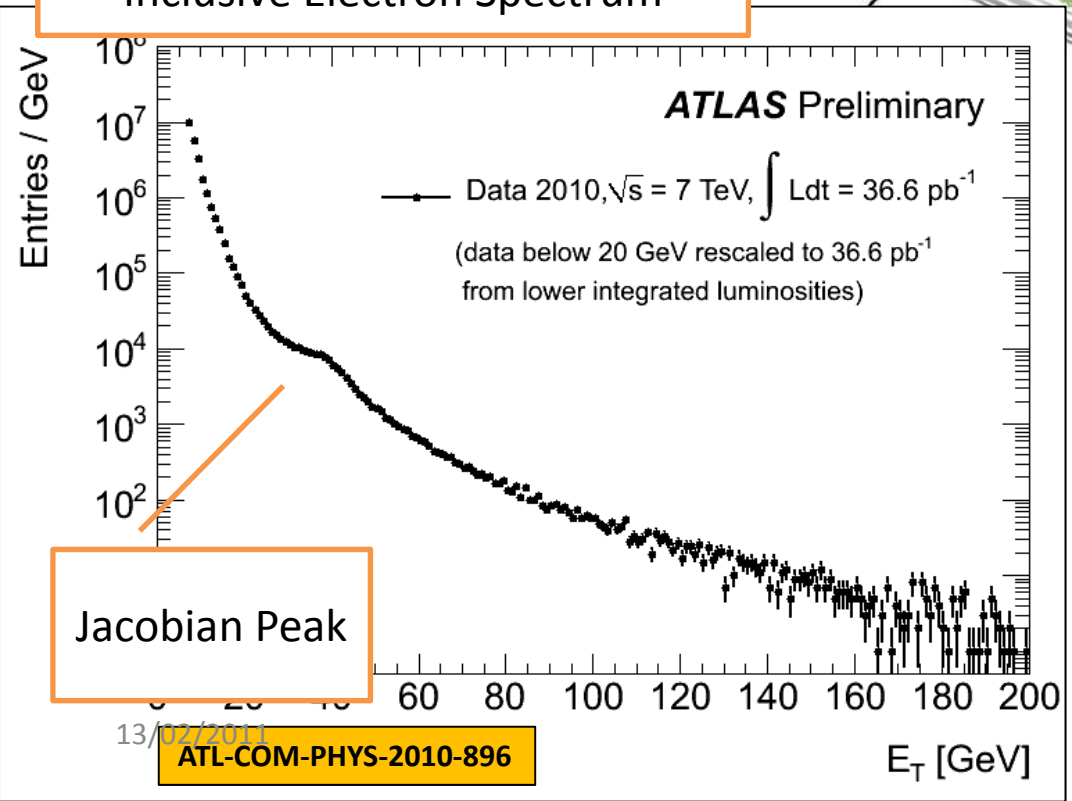
Electrons

EM Calorimeter:
- Pb – LAr
- 10%/√E
- $|\eta| < 3.2$
- Barrel/Endcap trans $|\eta|$ ~1,5



Inner Tracking:
- Silicon Pixels & Strips
  - Tracking + Vertexing
- TRT
  - Tracking + e-ID
- B_{sol} = 2T
- $|\eta| < 2.5$

Inclusive Electron Spectrum



W/Z

Energy Resolution :

$10\%/\sqrt{E} + 0.7\%$ $(\eta = 0)$

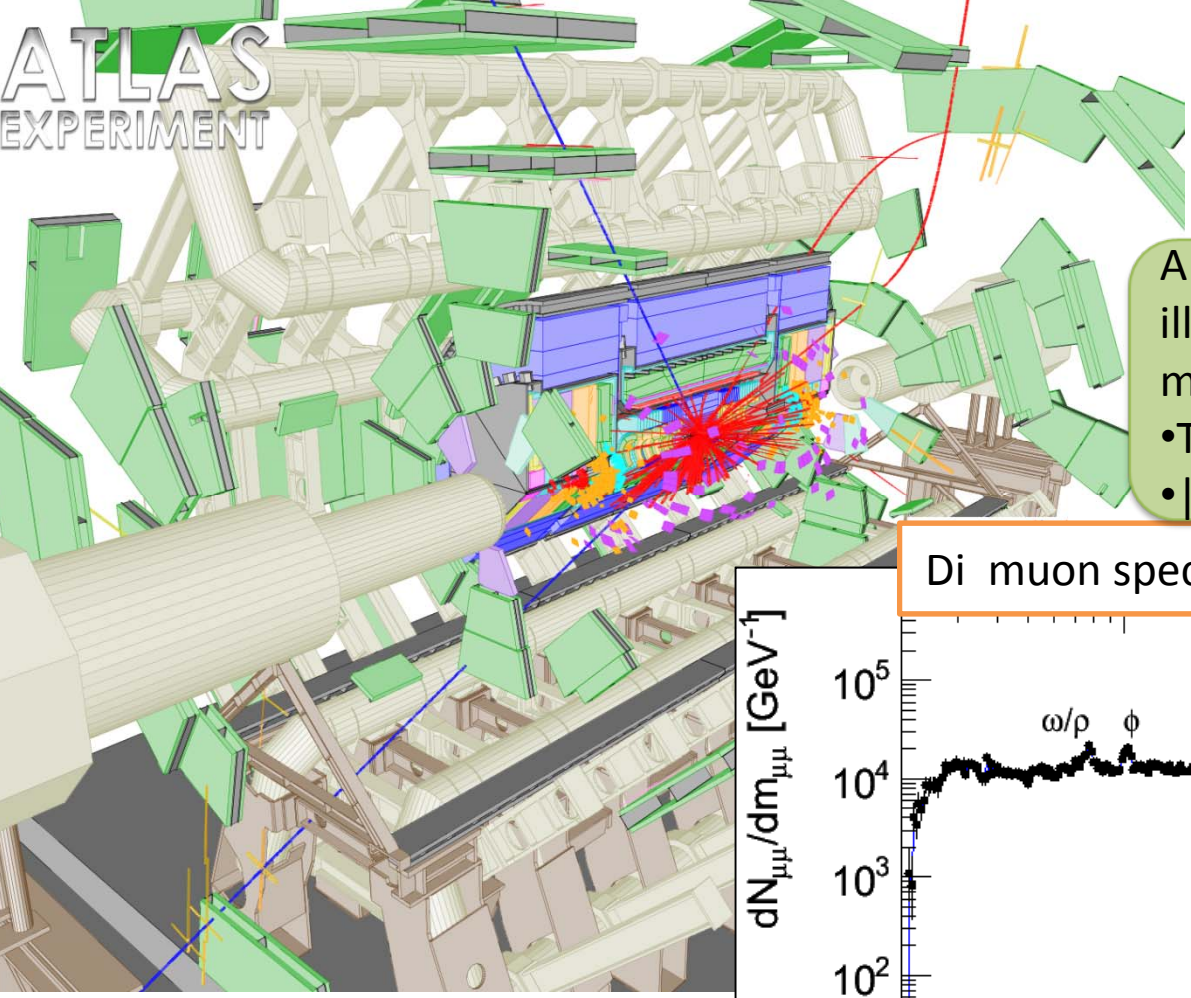
$|\eta| < 2.5$

Typical e-ID Efficiency :

Z : 95%

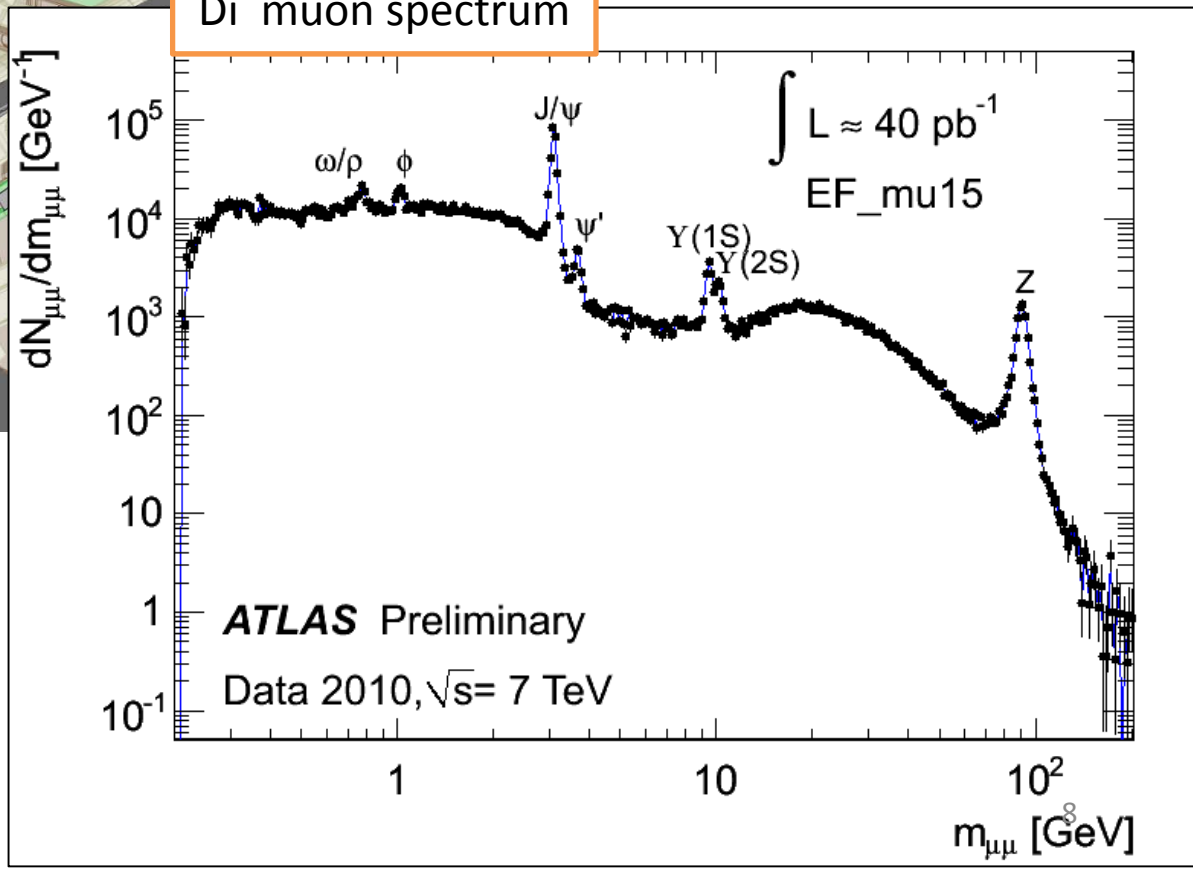
W: 75 %

Muons



A Heavy Ion collision event illuminating the structure of the muon spectrometer in green:
- Toroidal Magnet Bl = 2 Tm to 8 Tm
- $|\eta| < 2.7$

Di muon spectrum



W/Z

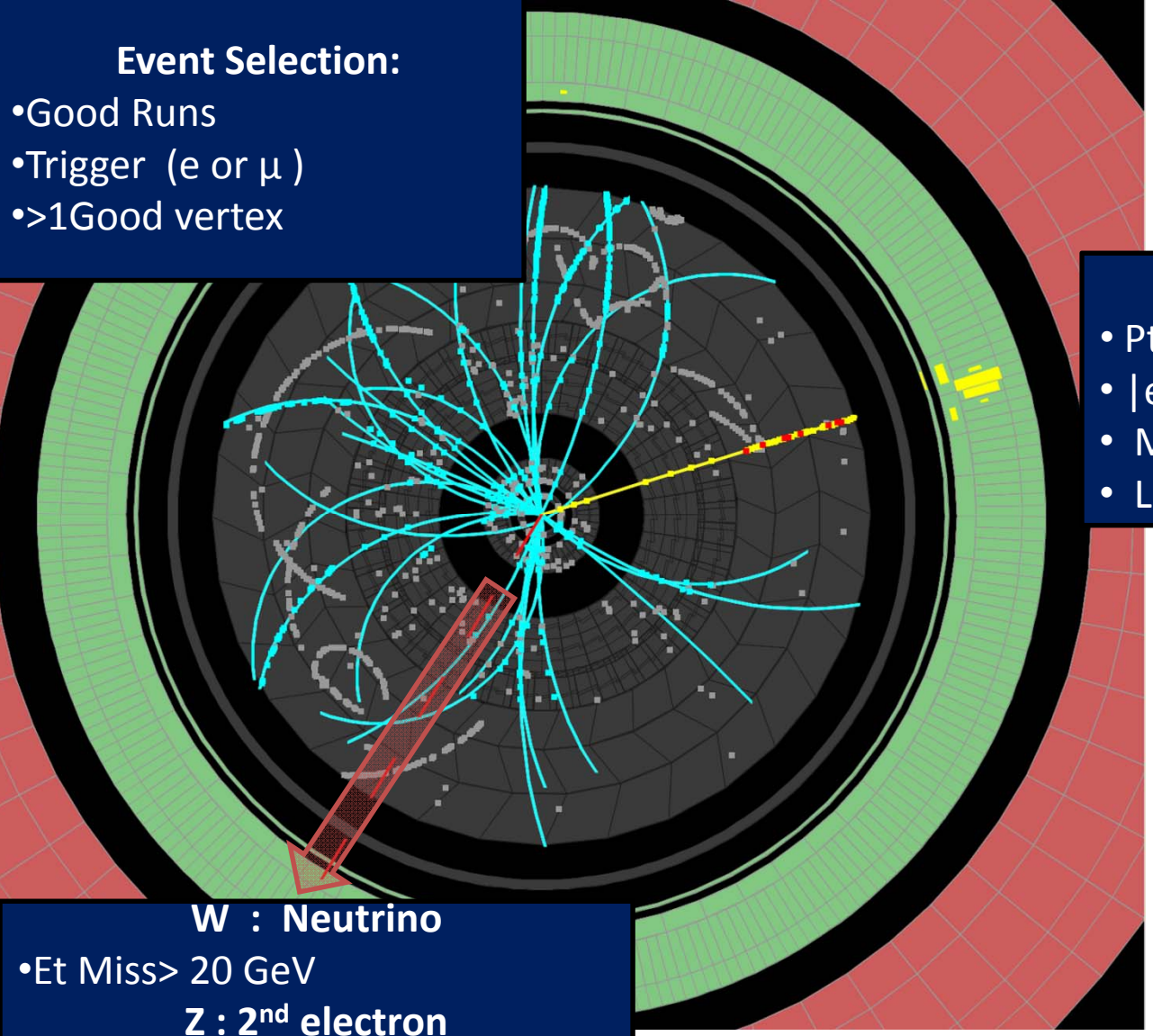
Resolution: < 10%

$|\eta| < 2.4$

Typical μ-ID Efficiency :89%

W & Z Selection

Event Selection:
- Good Runs
- Trigger (e or μ)
- >1Good vertex



1st Lepton Selection :
- Pt > 20 GeV
- |eta| < 2.47
- Muon Isolation
- Loose to Tight criteria

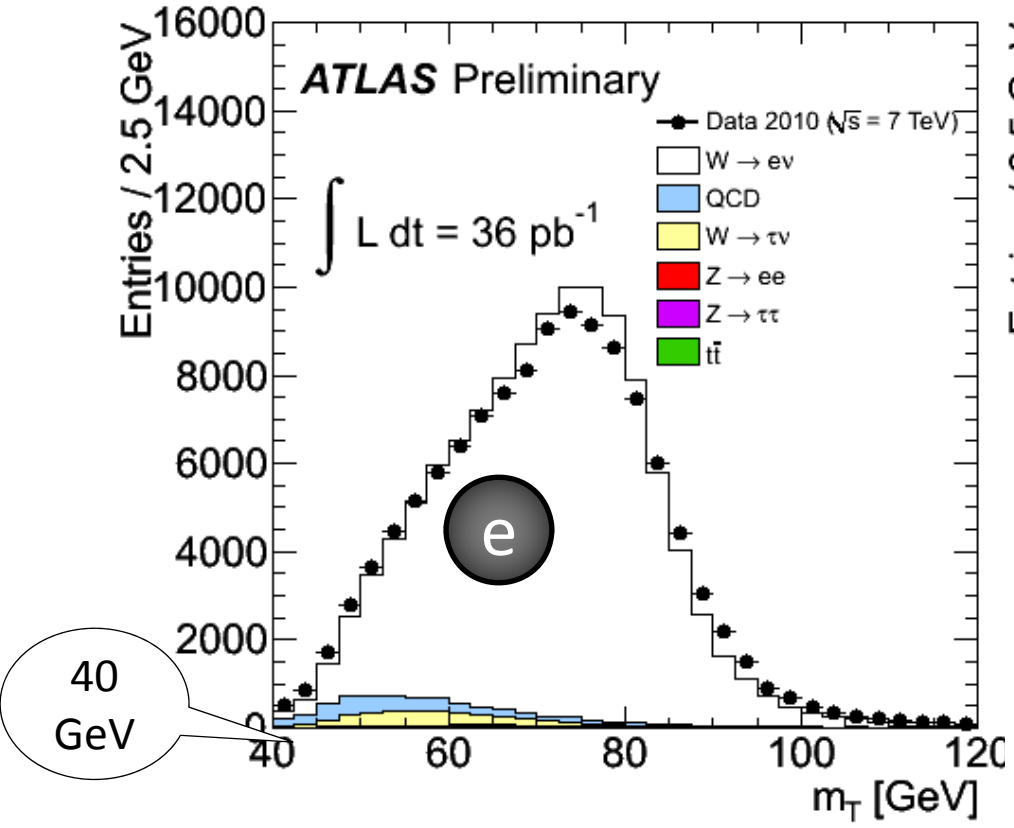
W : Neutrino
- Et Miss> 20 GeV

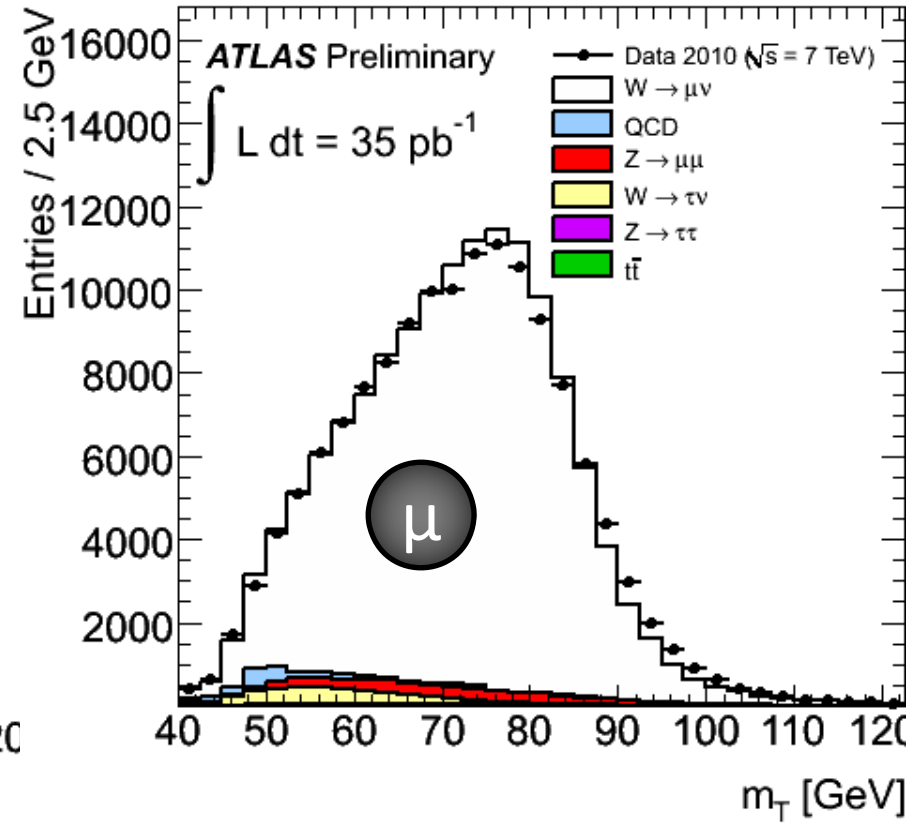
Z : 2nd electron
- Pt > 20 GeV
- |Eta | < 2.47
- Loose to Tight criteria
- (Isolation)

+ Jets
+ 2nd boson (γ,W,Z)

Inclusive W production

Full available statistics





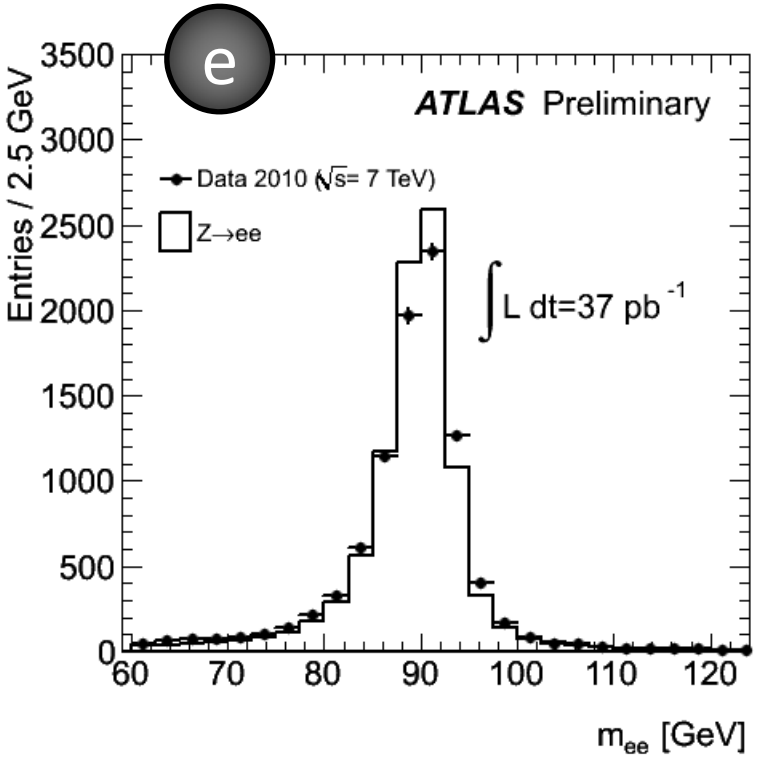
Total background : 6%

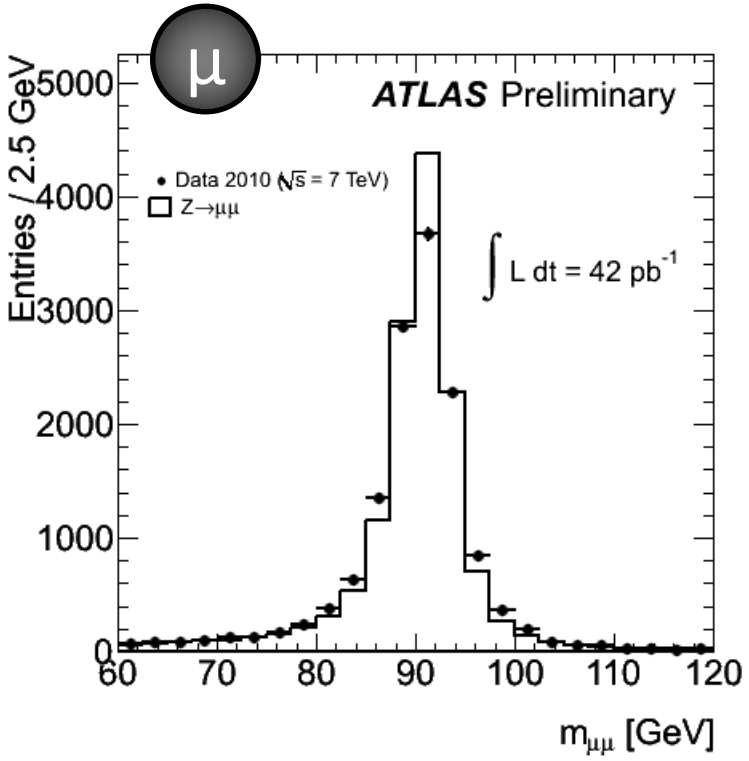
- QCD – fake electron (evaluated by data driven method)
- W →τν

- ~8%
- Z→μμ
- W→τν

Inclusive Z production

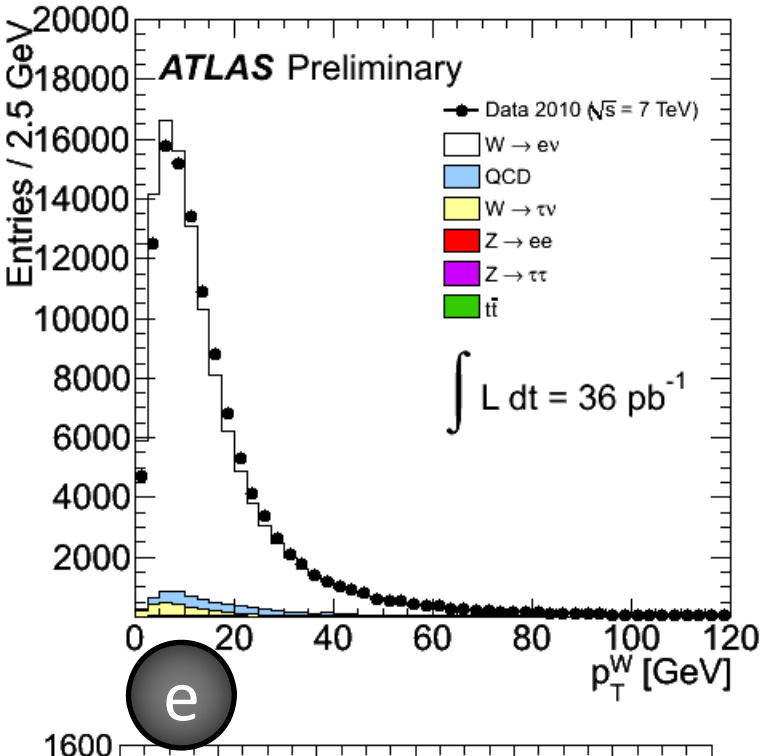
Full available statistics



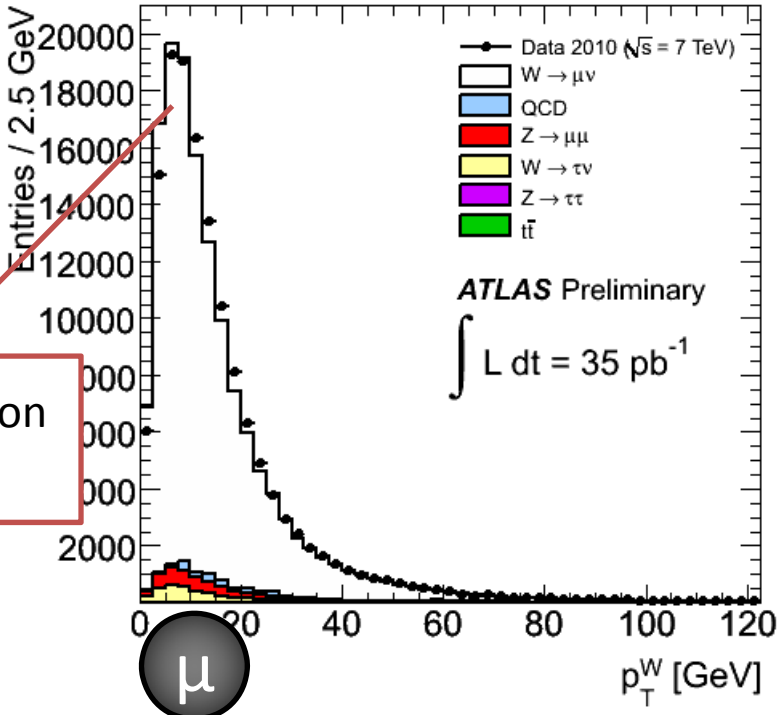


No visible background in linear scale

P_T W,Z

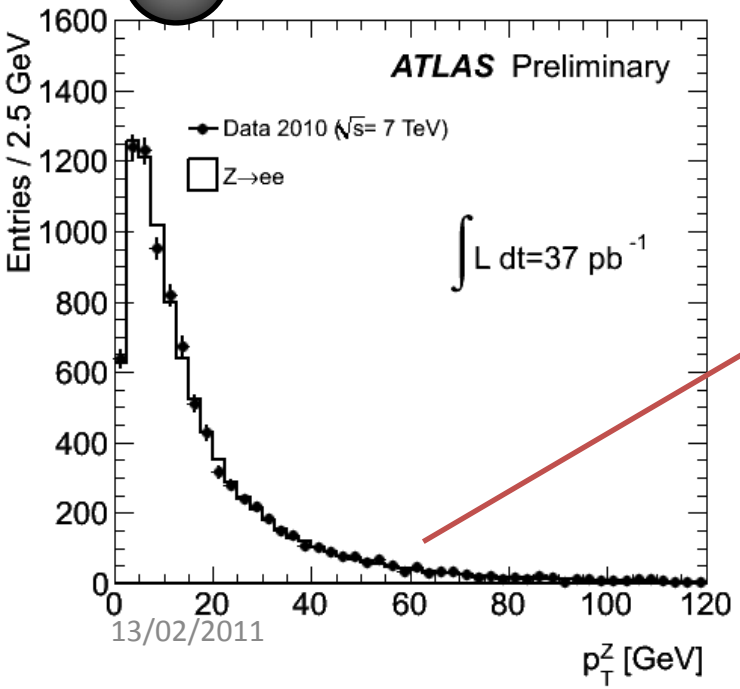


e

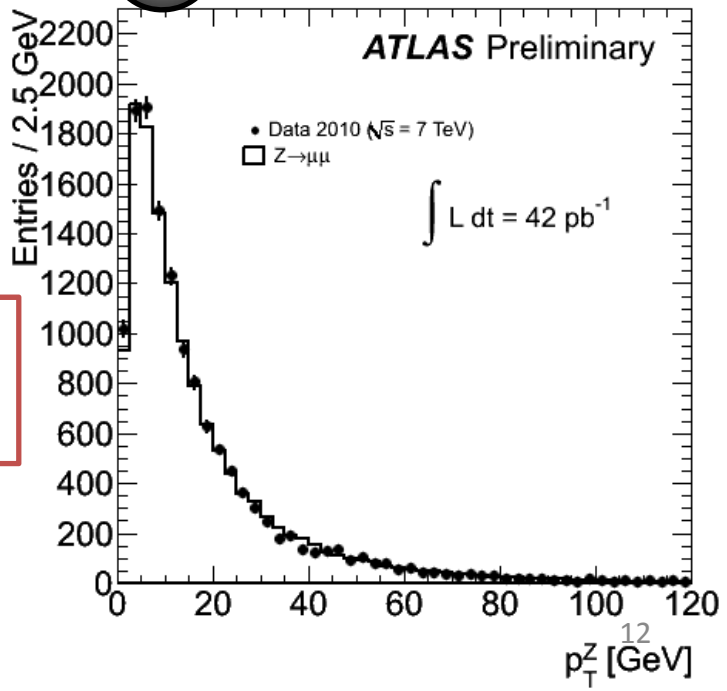


μ

Low Pt : QCD non pertubative



High Pt : pQCD



Cross-Section determination (300 nb^{-1})

$$\sigma = \frac{N_{cand} - \sum_{EW,QCD} N_{bkg}}{ACL}$$

- Geometrical acceptance
- Only dependent upon model
- A = 0.457 to 0.486
- δA_W : 3%
- δA_Z : 4%

Before QED final state radiation : Born Cross-Section

- Includes all experimental effects (Trig,Id,Rec)
- No theoretical dependence

%	W	Z
e	7.0	9.4
μ	4.0	5.5

$$\sigma_{fid} = \frac{N_{cand} - \sum_{EW,QCD} N_{bkg}}{CL}$$

Integrated Luminosity

δL: 11%

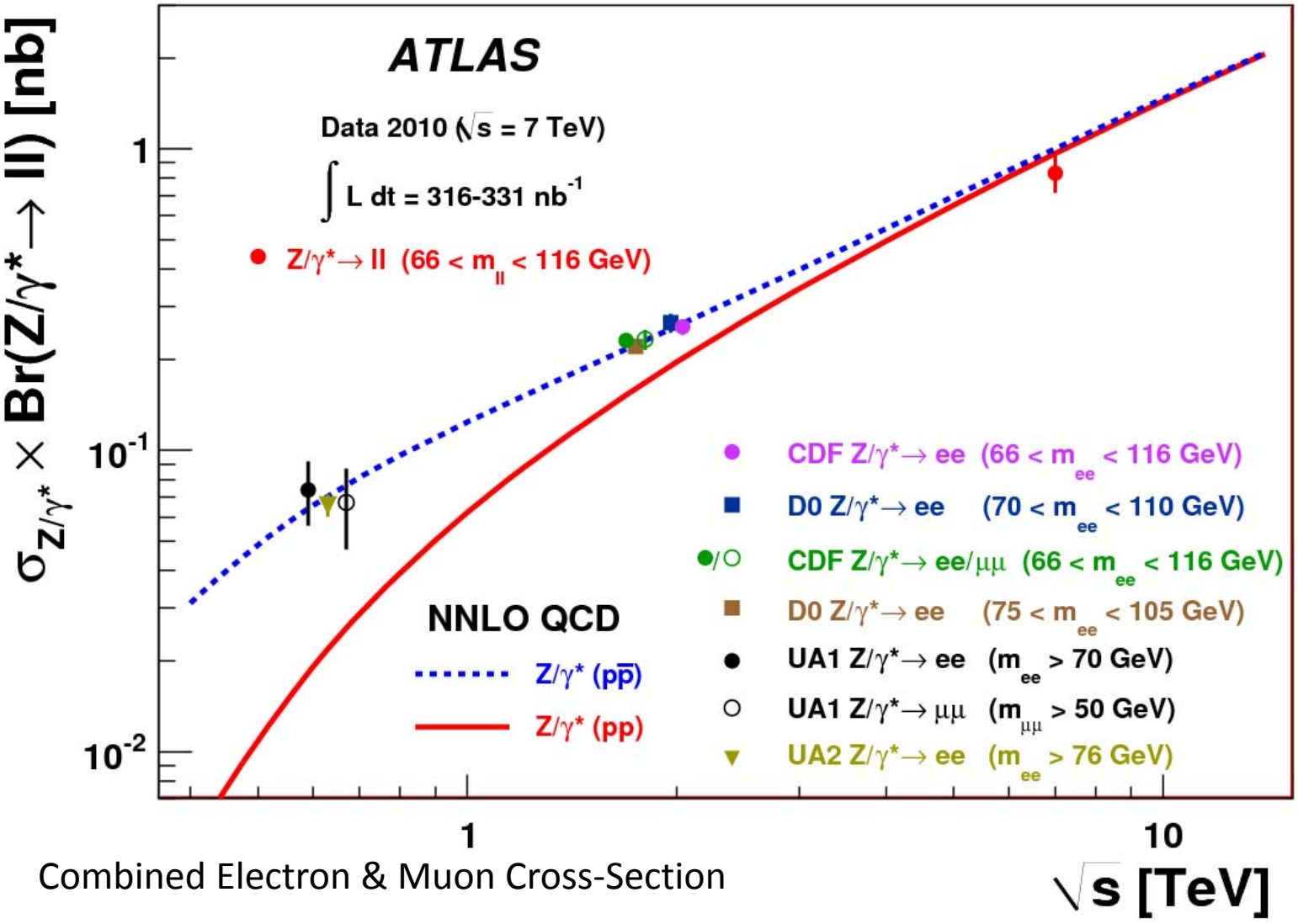
e- channel	$\delta C_W/C_W$ (%)	Comments
Trigger	<0.2	
Material effect, reconstruction and identification	5.6	Stat + Syst error on T&P **(→ ~2%)**
Energy scale and resolution	3.3	Energy Scale known to 3% **(→0.5%)**
E_T^{Miss} scale and resolution	2.0	Calorimeters energy scale
Problematic region in calo	1.4	**Most of them repaired during shutdown**
Pile up	0.5	
Charge Mis ID	0.3	
FSR modeling	0.3	
Theoretical uncertainty (PDFs)	0.3	

μ channel	$\delta C_W/C_W$ (%)	Comments
Trigger	1.9	Stat +Syst uncertainty on the Scale Factor
Reconstruction efficiency	2.5	Stat +Syst uncertainty on the Scale Factor
Momentum scale	1.2	
Momentum resolution	0.2	
E_T^{Miss} scale and resolution	2.0	Calorimeters energy scale
Isolation efficiency	1.0	
Theoretical uncertainty (PDFs)	0.3	

σ_{Z/γ^*}

σ_{Z/γ^*} = 0.82 ±0.06 ±0.05 ±0.09 nb
NNLO: 0.96 ± 0.05 nb

JHEP12 (2010) 060



Combined Electron & Muon Cross-Section

σ_W

σ_W = 9.96 0.23 0.50 1.1 nb
NNLO : 10.46 (0.52) nb

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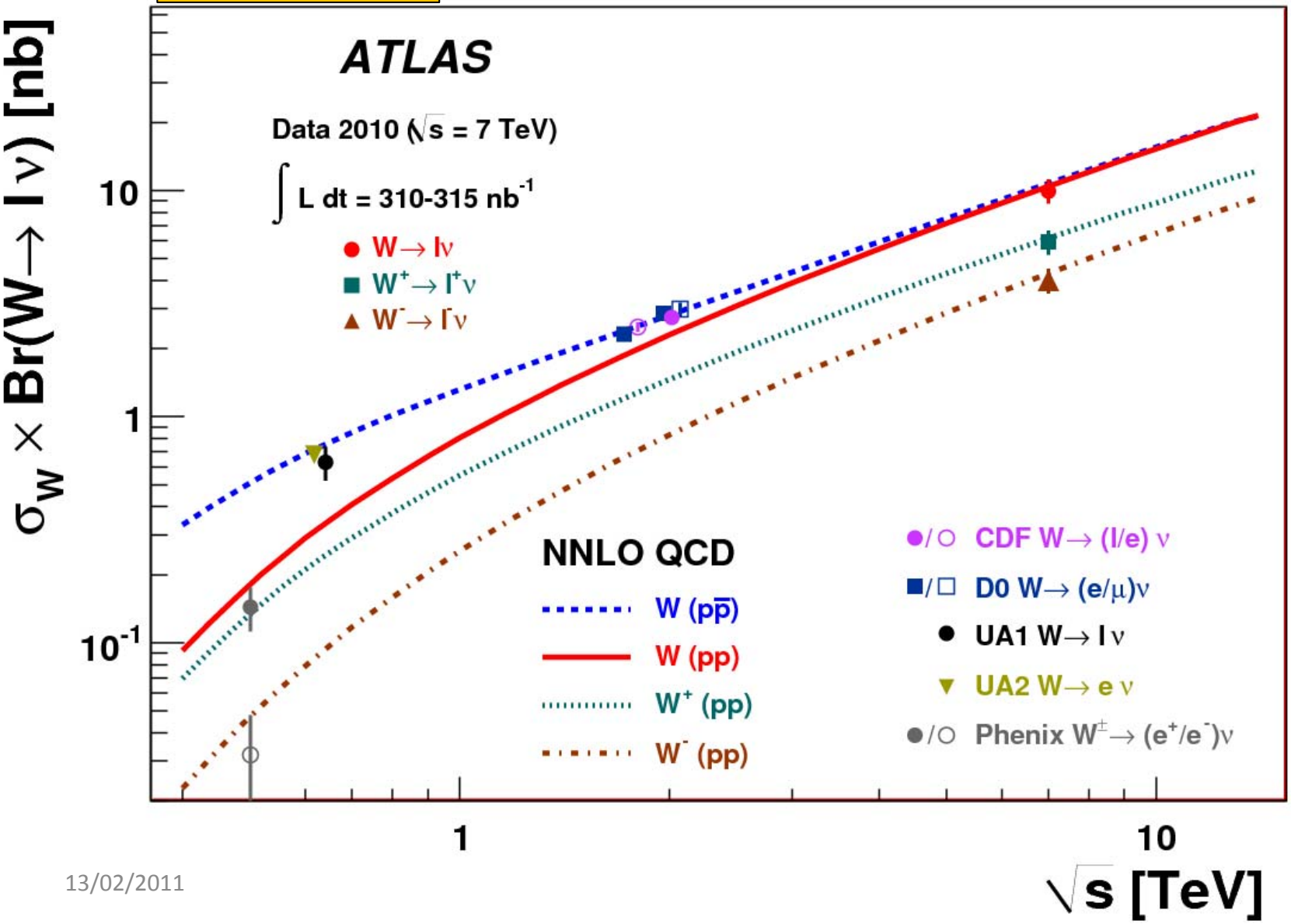
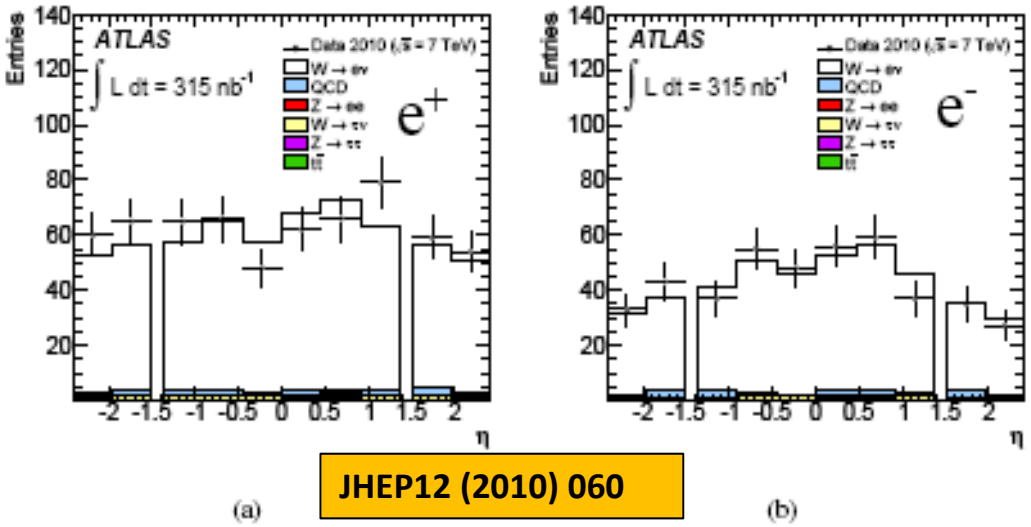


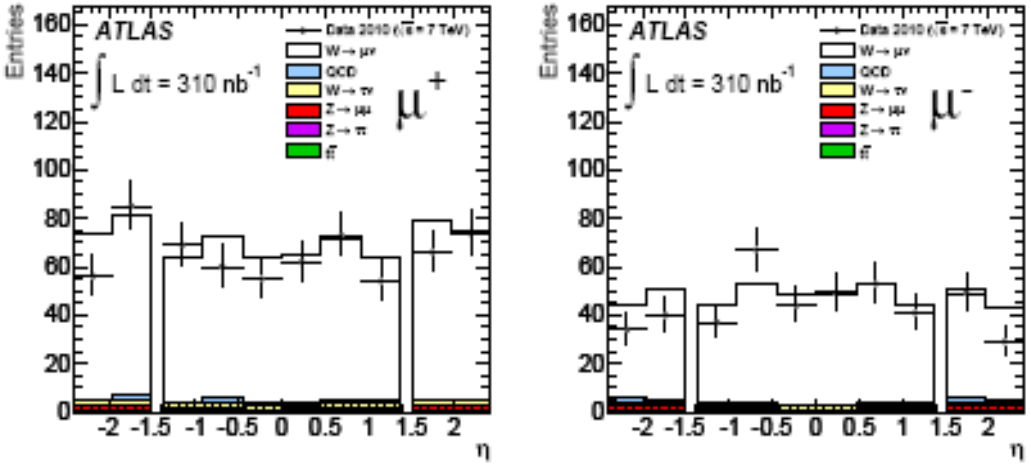
W Charge Asymmetry (300 nb^{-1})

$$A_l = \frac{\sigma^{fid}_{W^+} - \sigma^{fid}_{W^-}}{\sigma^{fid}_{W^+} + \sigma^{fid}_{W^-}}$$

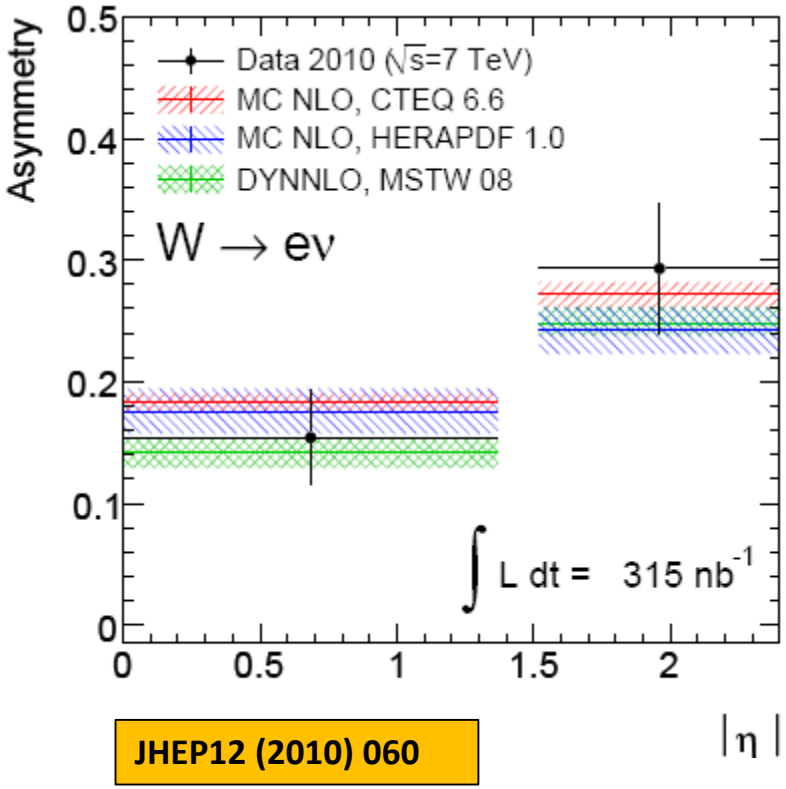
- A ≠ 0 because more u quarks than d quark in proton:
  → sensitivity to valence quark PDFs.
- δLum contracts in the ratio.
- Dependence in $|\eta_l|$

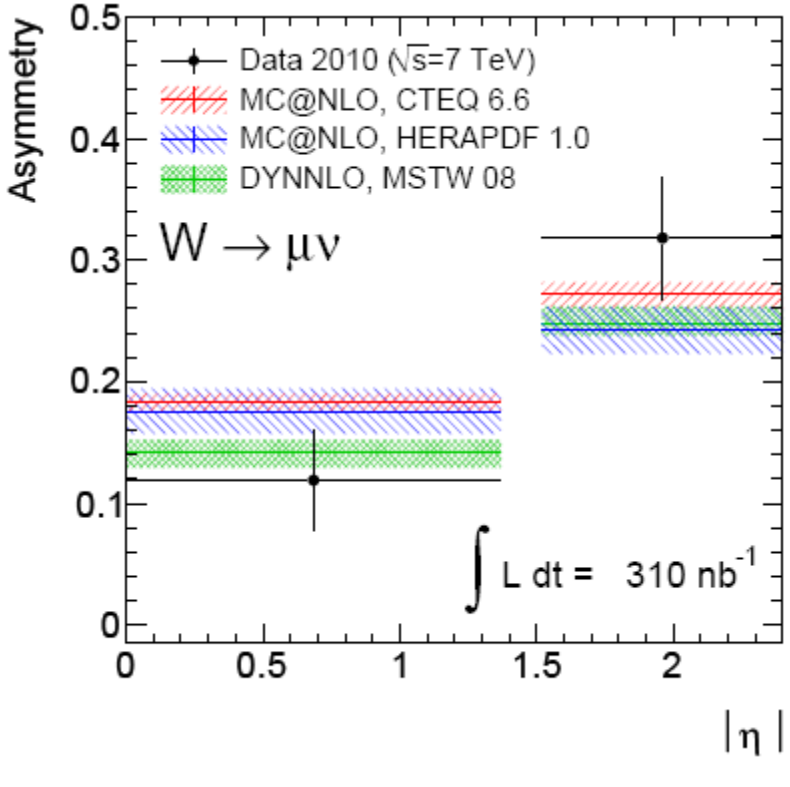


JHEP12 (2010) 060



W Charge Asymmetry (300 nb^{-1})





JHEP12 (2010) 060

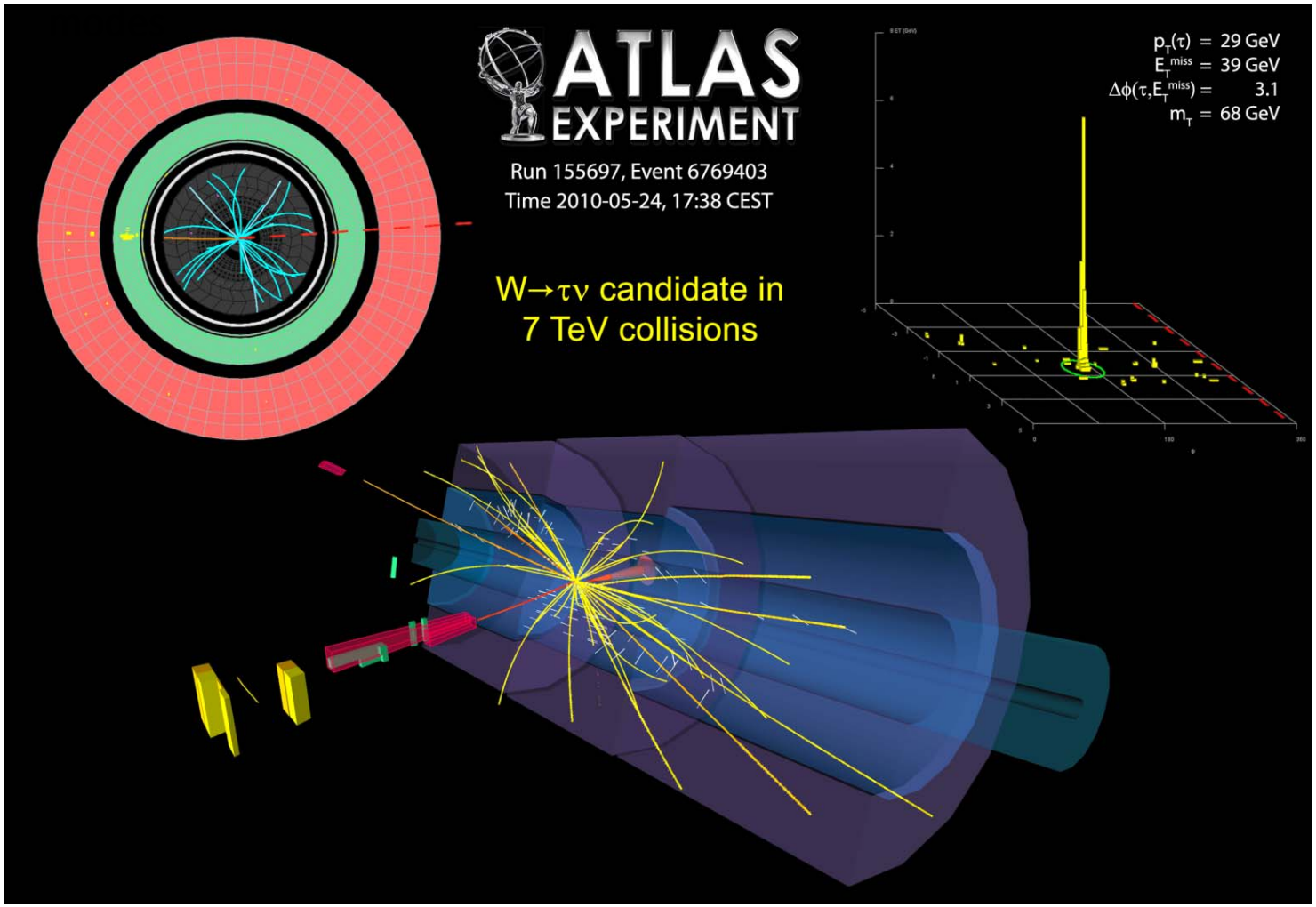
No stringent constraints with 300 nb^{-1}

→ But some sensitivity with the full available statistics (to be published soon)

Next steps: differential cross-sections $d\sigma_W / d\eta_l$

Observation of $W \rightarrow \tau_h \nu$ ($546\ nb^{-1}$)

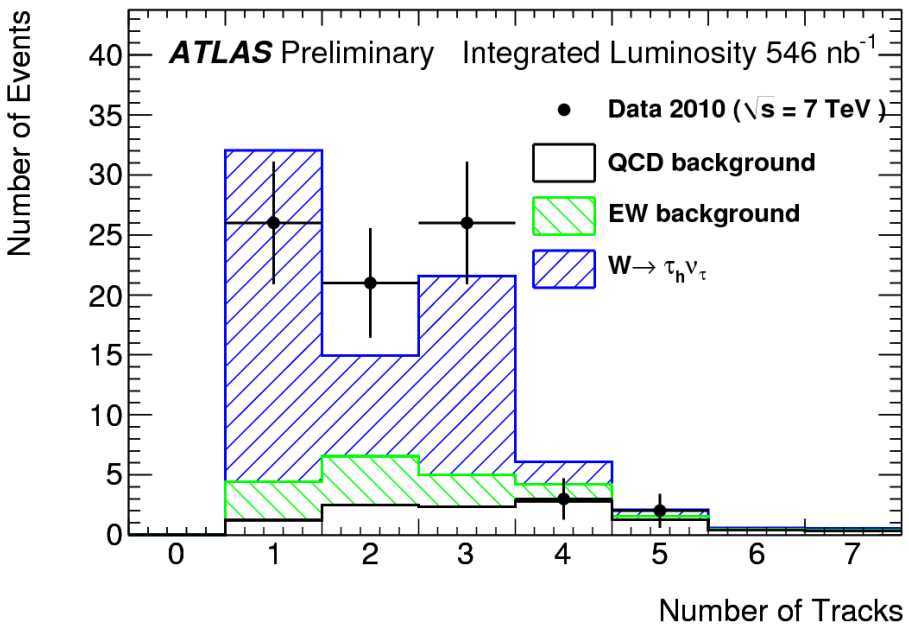
τ's Identified in their hadronic decay

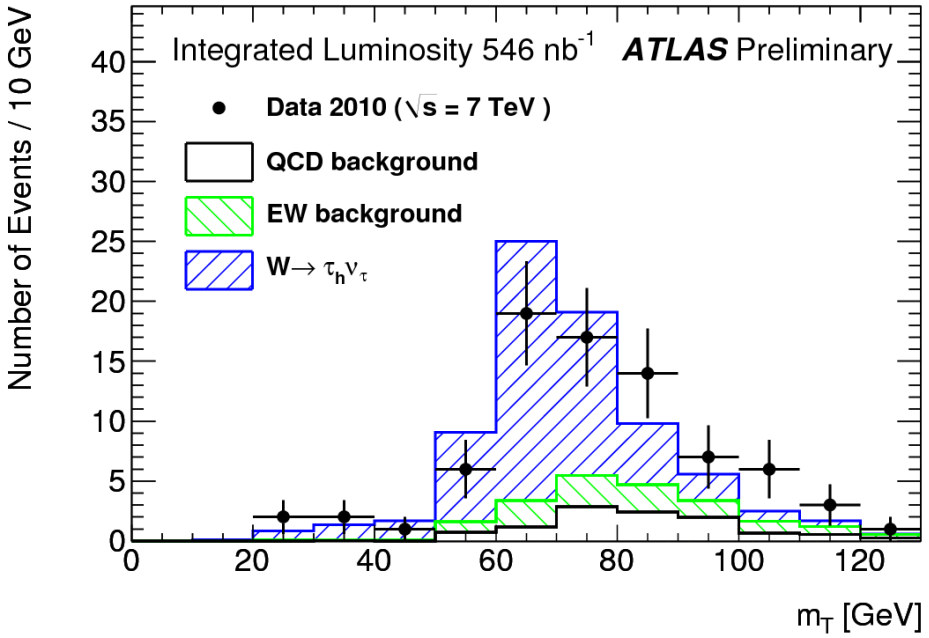


Cross-section measurement feasible with the current statistics.

Observation of W $\rightarrow \tau_h \nu$ (cont')

ATLAS-CONF-2010-097





- N_{signal} = 55.1 ± 10.5 (stat) ± 5.2 (syst)
- QCD background estimated from data
- EW : W→μν, eν, τν(→lν) and Z →ττ

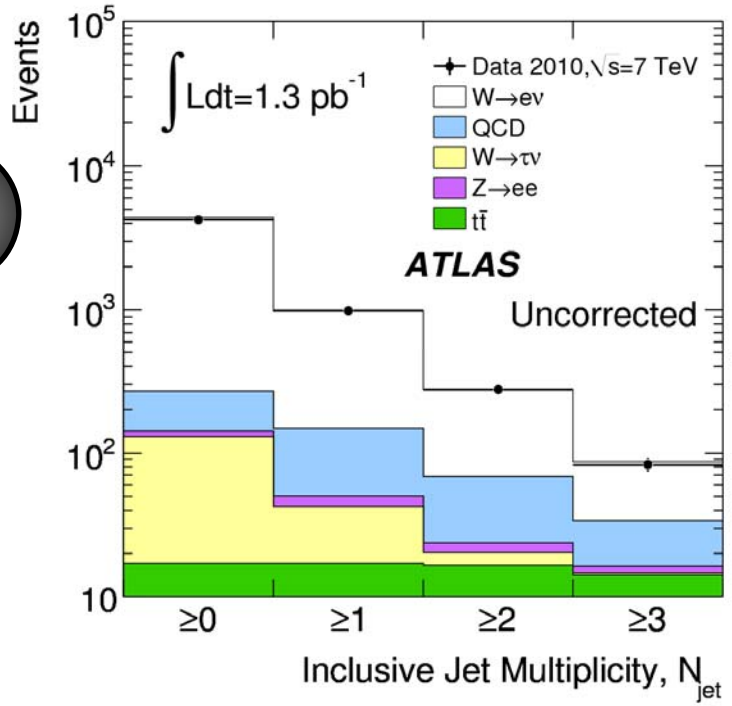
W(or Z) + jets (1.3pb^{-1})

- Test of pQCD
- Important background to top physics , new physics

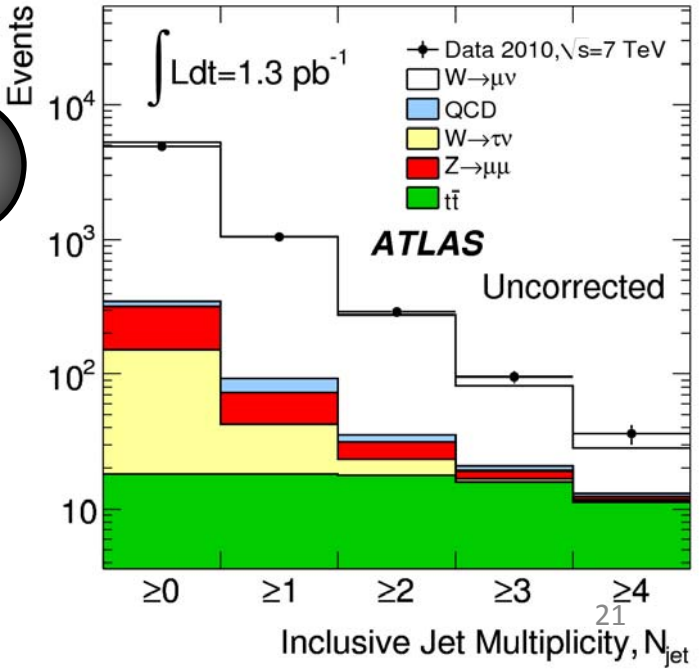
- If jets from c/b quarks

  →Flavor PDFs !

e

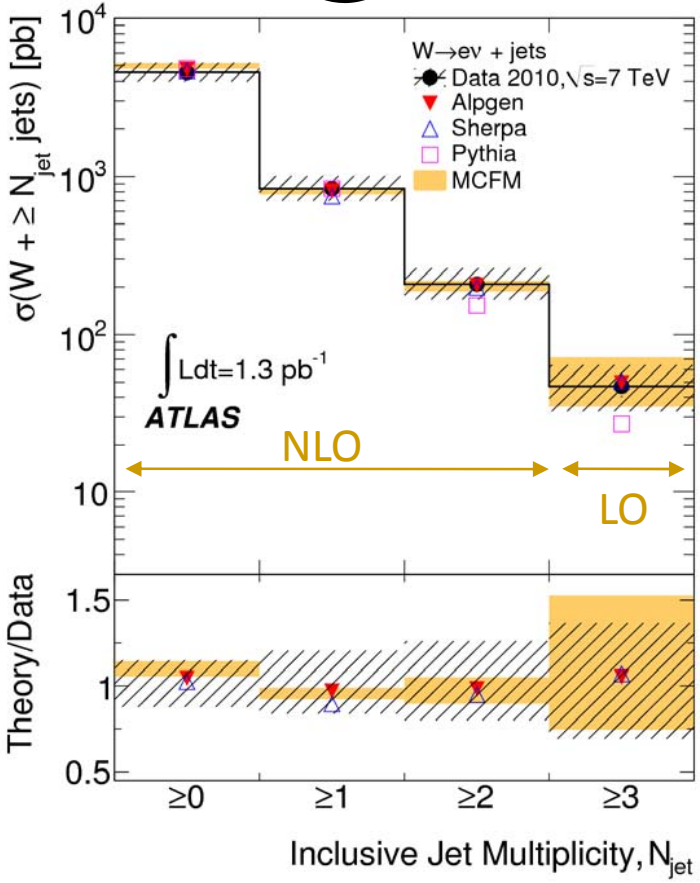


μ



$\sigma_{W + jets}$

e



Systematics:

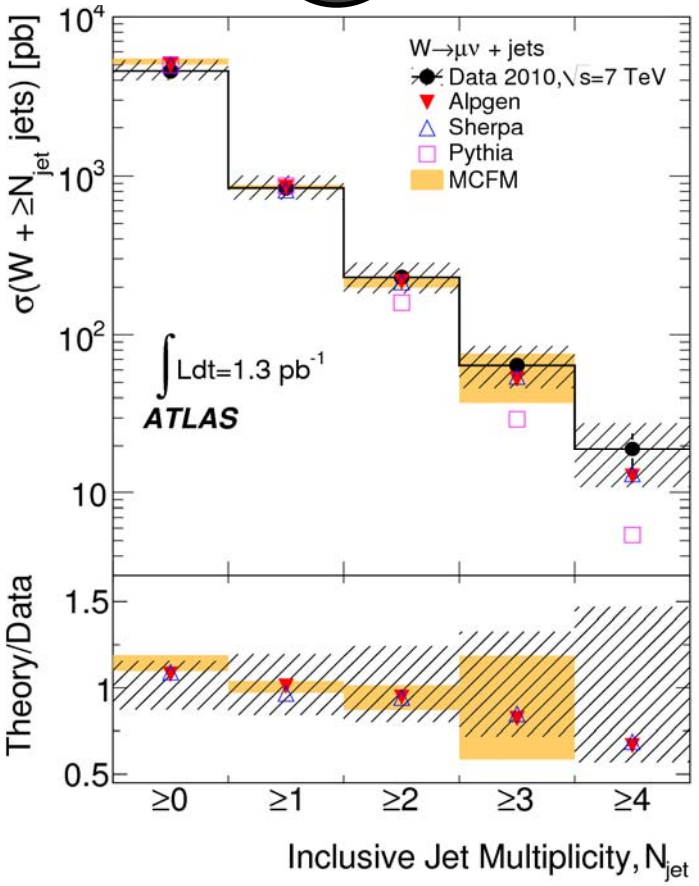
- Jet Energy Scale
- Luminosity
- Lepton ID

MCFM : NLO
(corrected for QED FSR and soft QCD)

Pythia : LO

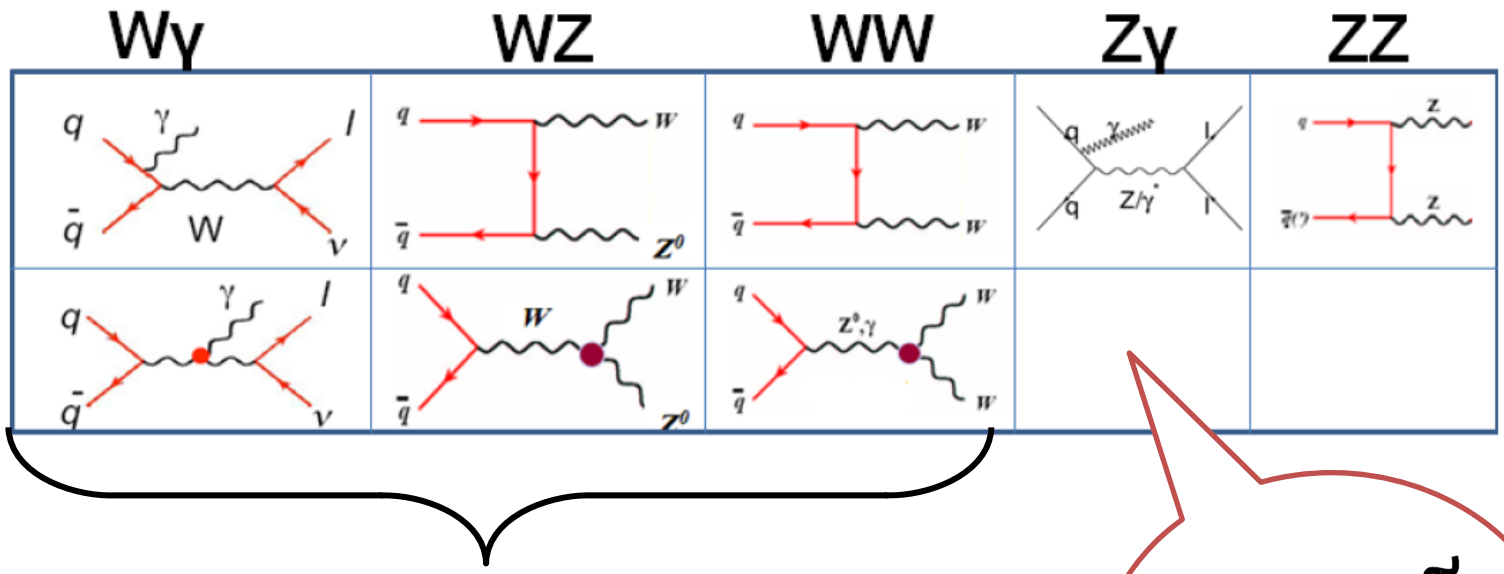
Alpen/Sherpa: LL

μ

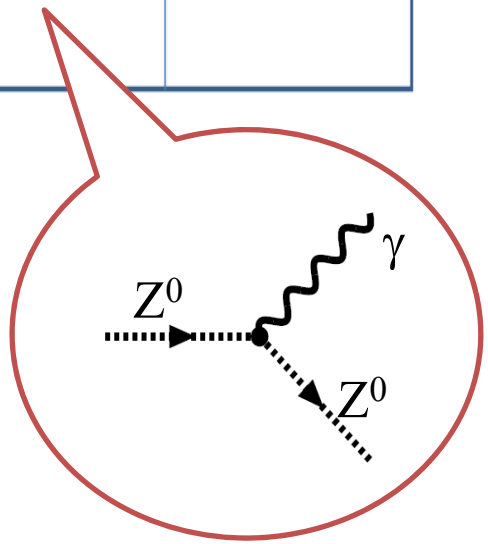


arXiv:1012.5382, Sub to Phys. Lett. B

Di-bosons final states



SU(2) : Triple Gauge Coupling

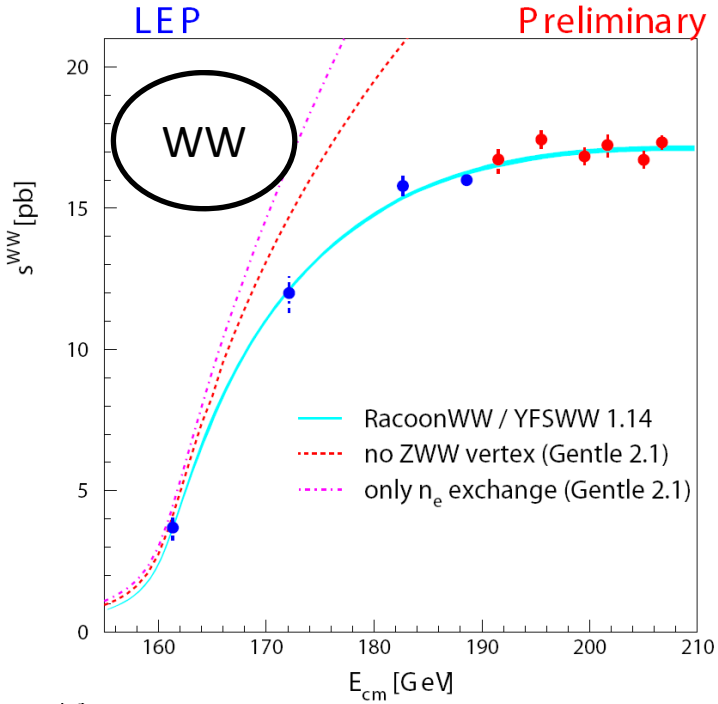


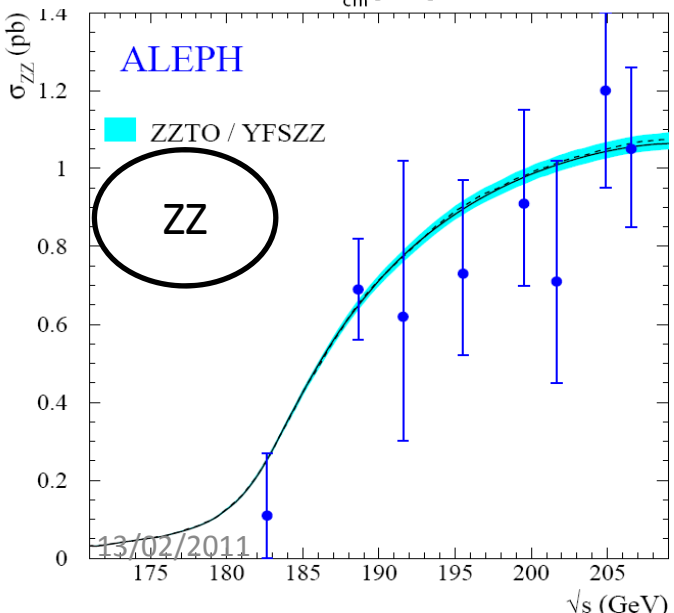
Or anomalous couplings !

Xsection(pb)	@7 TeV
Wγ (> 15 GeV)	188
Zγ	91
WW	46
WZ	18
ZZ	6

L ~ 45 pb^{-1}

The legacy from LEP & Tevatron

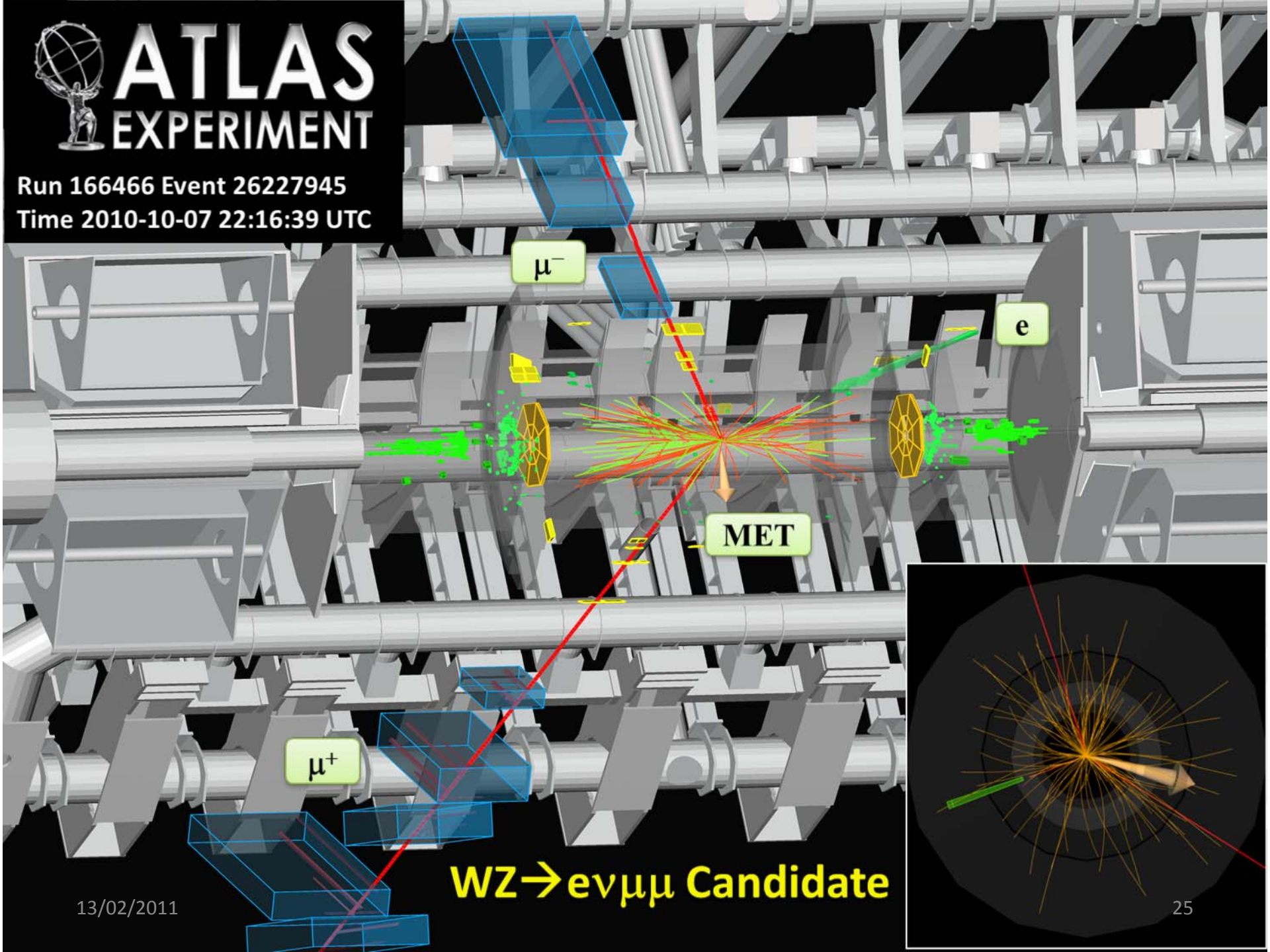




→First test of the SU(2) gauge structure
ZWW + γWW simultaneously

	CDF (pb)	D0 (pb)
WW	12.1 ± 0.9	11.5 ± 2.2
WZ	4.1 ± 0.7	3.9 ± 1.1
ZZ	1.7 ± 1.2	1.6 ± 0.65
Zg	4.6 ± 0.5	4.96 ± 0.42
Wg	18.0 ± 2.8	14.8 ± 2.1

Compilation by H Yang, Ann Arbor 2010


ATLAS
EXPERIMENT
Run 166466 Event 26227945
Time 2010-10-07 22:16:39 UTC
μ⁻
e
MET
μ⁺
WZ→eνμμ Candidate

Perspectives

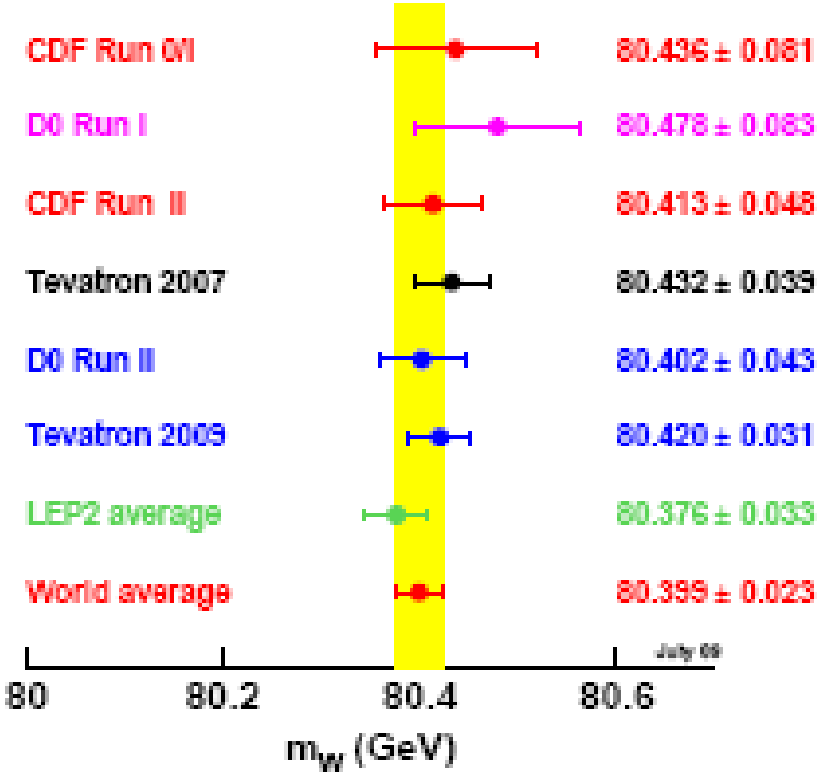
- **45 pb^{-1} (Spring 2011)**
  - **First measurement of Wγ, Zγ and WW**

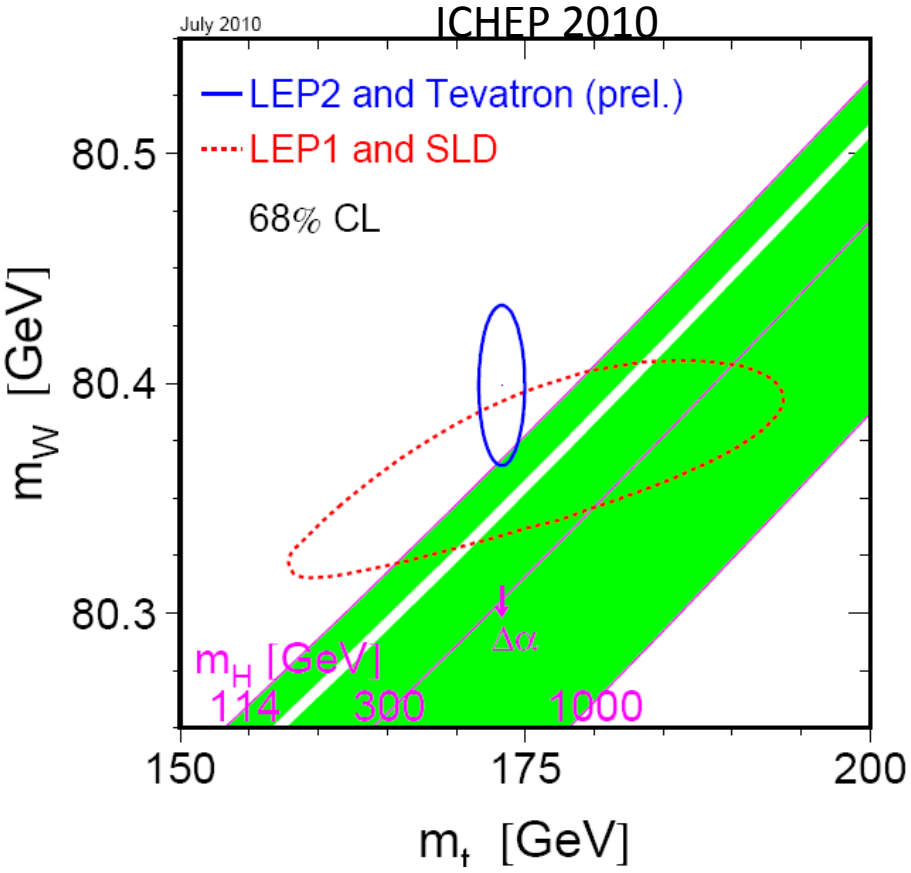
- 1fb^{-1} (End of 2011)
  - Cross section measurement of Wγ, Zγ, WW, WZ & ZZ
  - Sensitivity to TGCs
    - WZ : a factor ~2
    - ZZ : an order of magnitude

Expected better sensitivity than Tevatron

- 100fb^{-1} (End of ?)
  - WW & ZZ polarisation studies

The challenge : $\delta M_W < 10$ MeV



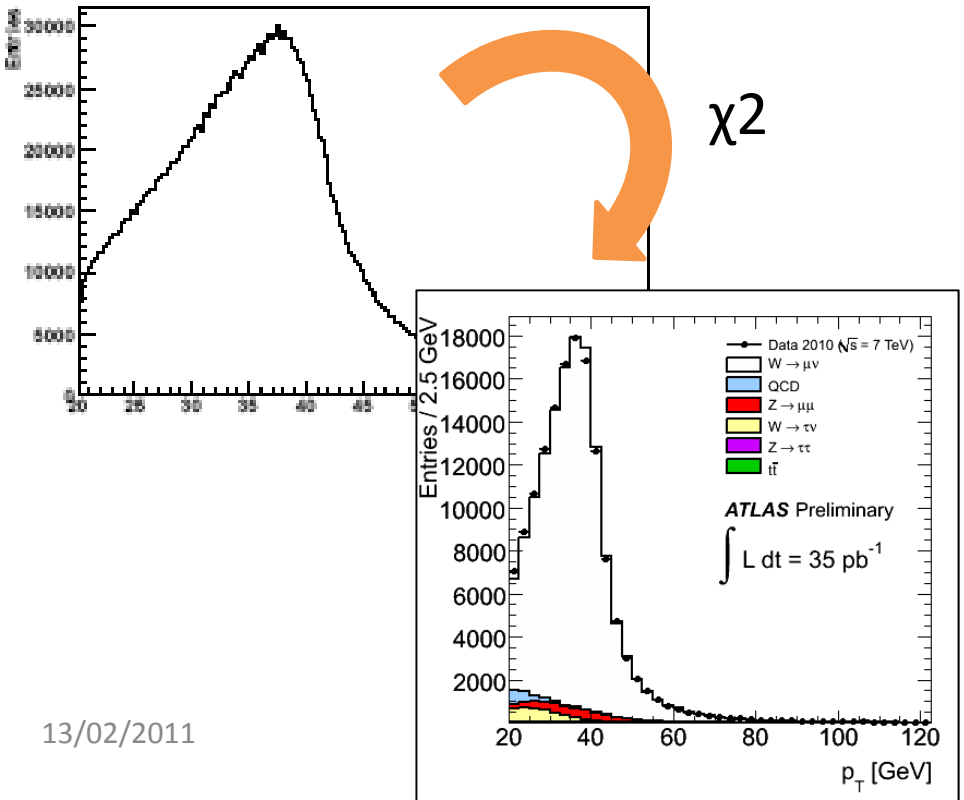


ICHEP 2010 :
δM_W : 23 MeV
δM_{Top} : 1.1 GeV

A Template Method

MC Template = f(Mw) :

- P_T^{lep} or M_T^W
- Edge sensitive to Mw
- Distorted by detector effects
  - E resolution, linearity, tails
  - Lepton efficiency & acceptance

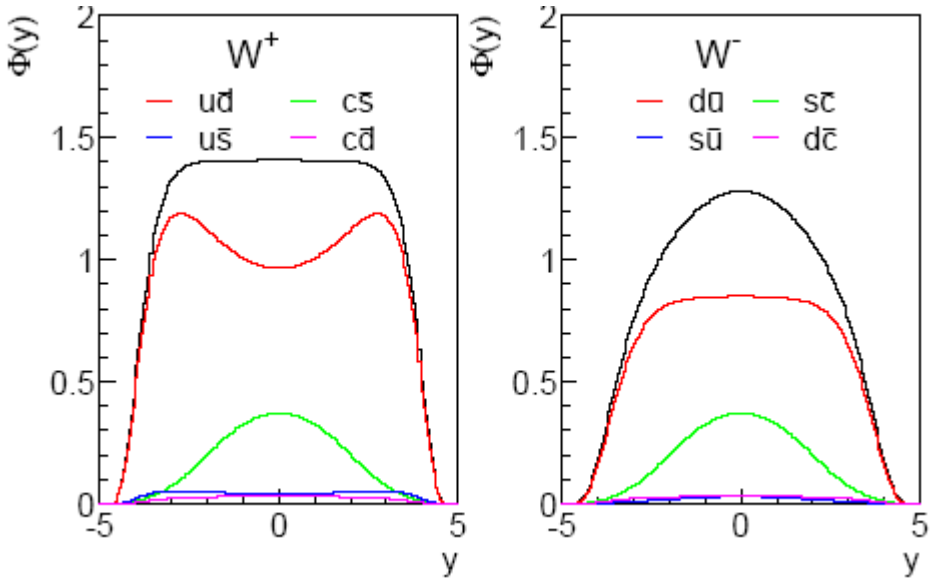


- 10 fb^{-1} → 2 MeV stat. error
- How well can we predict the MC templates ?
- Large statistics of Z bosons:
  - ~2.5 10^6 per flavour
  - M_z constraint : 2.3 10^{-5}

→Energy Scale & Resolution
→Lepton efficiency

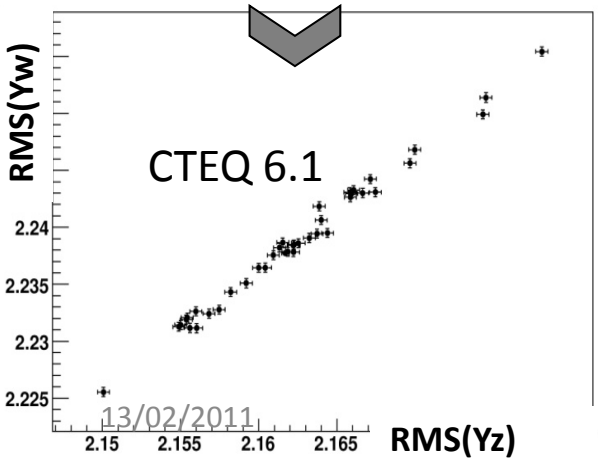
- Experimental effects under control at the level of δM_W < 7 MeV

The role of PDFs

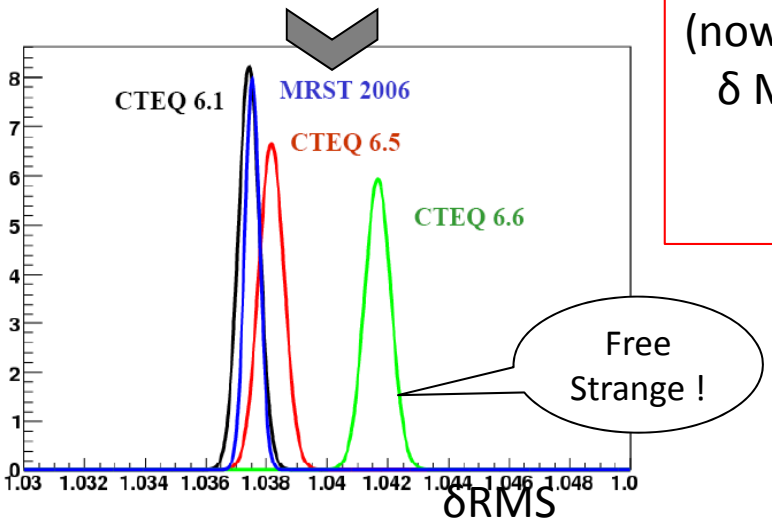


The lepton spectrum is sensitive to the W rapidity driven by the initial quarks' flavor.

The PDF uncertainty on Y_W well controlled by the measurement of Y_Z



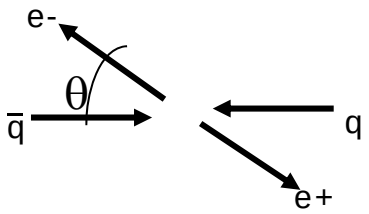
A non negligible strange quark contribution



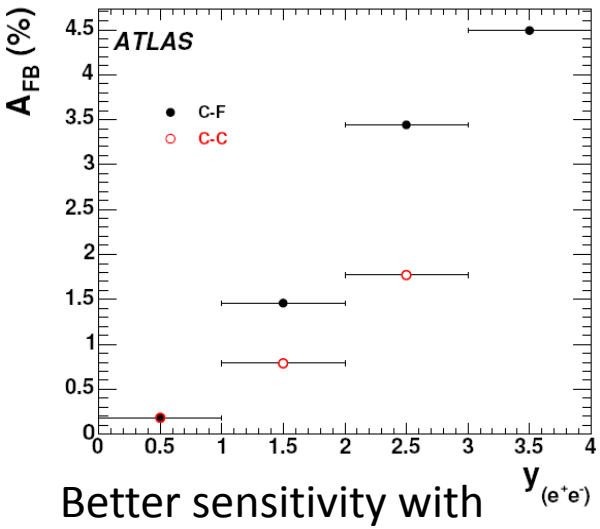
arXiv:0901.0512 CERN-OPEN 2008-020

Expectation with L ~ 35 pb^{-1} (now):

δ Mw = 110 (Stat)
114 (Syst)
25 (PDFs)



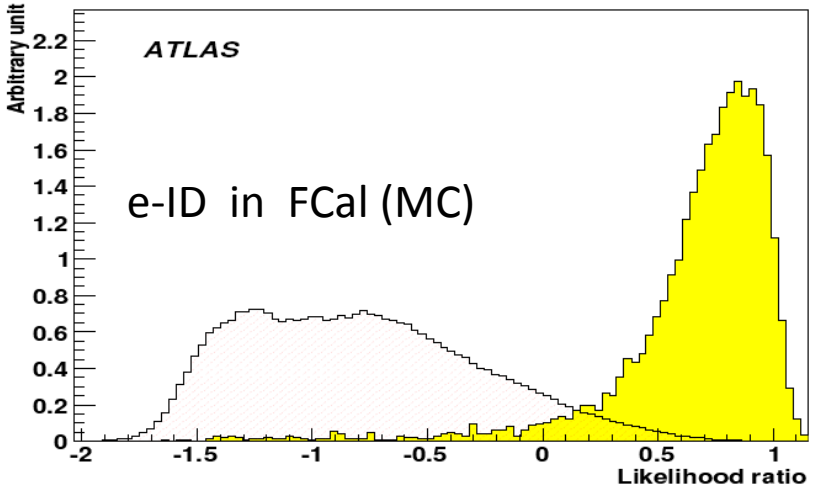
$$A_{FB} = \sigma_F - \sigma_B / \sigma_F + \sigma_B$$

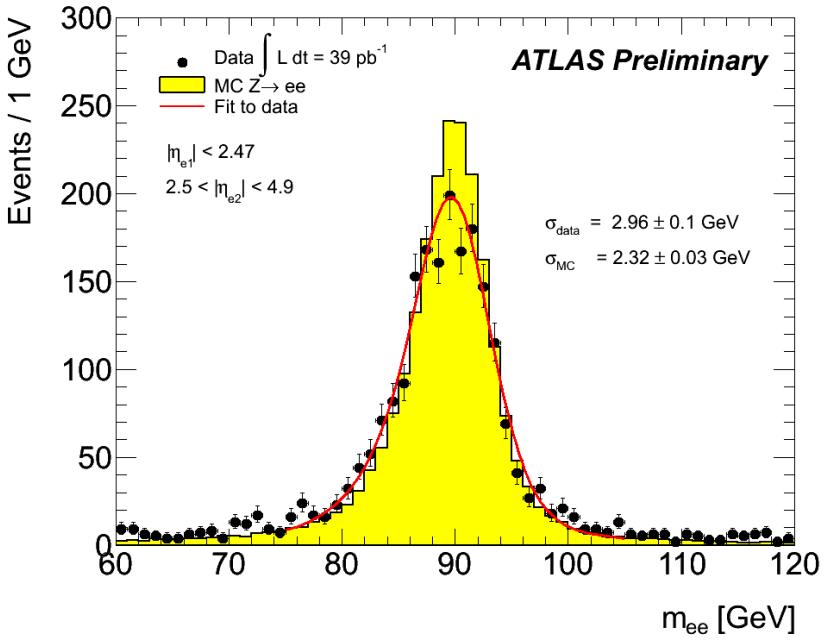


- L = 100 fb^{-1}
- Provide a determination of **$\sin^2 \Theta_W$** :
  - A_{FB}^{eff} = b (a - $\sin^2\theta_W$) at the Z pole *(a, b depends upon PDFs)*

Better sensitivity with forward Z (electrons)

1 forward electron (|η|<4.9) , 1 central electron (charge)





$\delta \sin^2\Theta_W$ = 1.5 (stat) + 0.3 (syst) + 2.4 (PDFs) 10^{-4}

arXiv:0901.0512 CERNOPEN 2008-020

Conclusions

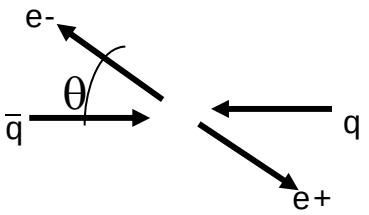
- Current ATLAS performance is very encouraging
- **2010** - Electroweak measurements at LHC are just starting:
  - Observations and first cross-sections measurements ($\sqrt{S}$ = 7 TeV)
    - W→ lν , W +jets, Z → ll
  - Development of methods, tools (T&P , calibration) to control systematic and to use optimally the detector
- **Projection**
  - **2011** : 1 fb^{-1}
    - Differential cross-sections ↔ new constraints on PDFs
    - First interesting results on TGCs
    - First significant Top mass measurement
  - **2012-2013** : ~ 10fb^{-1}
    - First significant M_W measurement
    - TGCs
  - **100 fb^{-1}** : the bulk of precision EW
    - $\sin^2 \Theta_W$
    - TGCs
    - ZZ & WW polarisation

18 % uncertainty on M_{Higgs} !

References

- JINST 3 S08003 (2008) *The ATLAS Collaboration*
- JHEP12 (2010) 060 *The ATLAS Collaboration*
- arXiv:0901.0512 CERN-OPEN 2008 – 020 *The ATLAS Collaboration*
- Eur. Phys J C57 (2008) *N Besson et al.*
- ATLAS-CONF-2010-097
- ATL-COM-PHYS-2010-896
- arXiv:1012.5382 Sub to Phys. Lett. B *The ATLAS Collaboration*

$$A_{FB} = \sigma_F - \sigma_B / \sigma_F + \sigma_B$$



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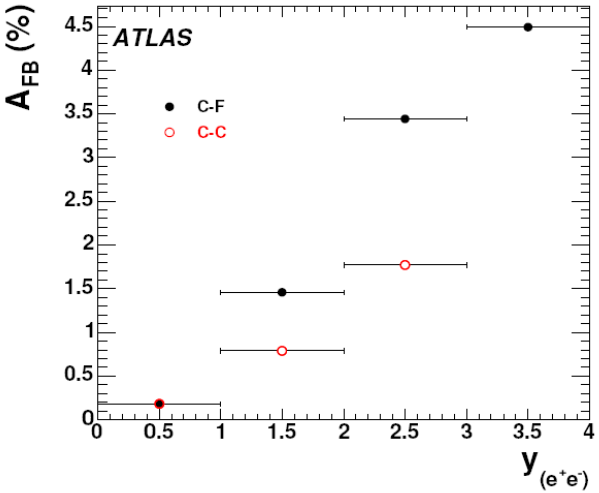
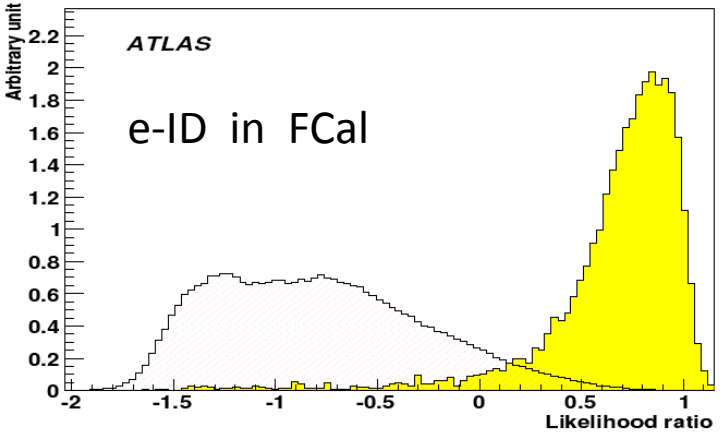
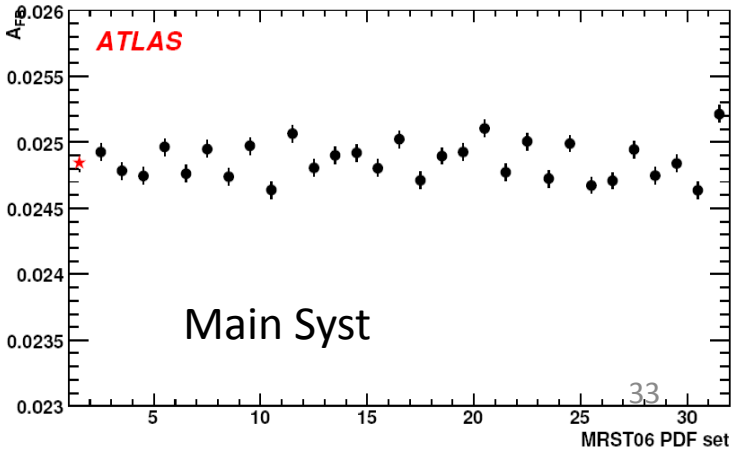
Better sensitivity with forward Z (electrons)



1 forward electron
1 central electron (charge)





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arXiv:0901.0512 CERNOPEN 2008-020

M_{Top}

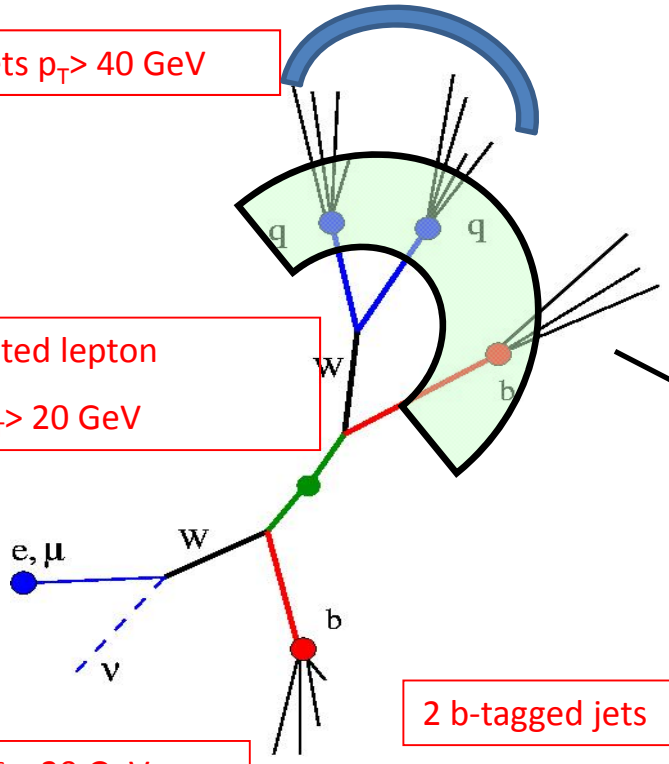
M_W as a constraint

4 jets p_T> 40 GeV

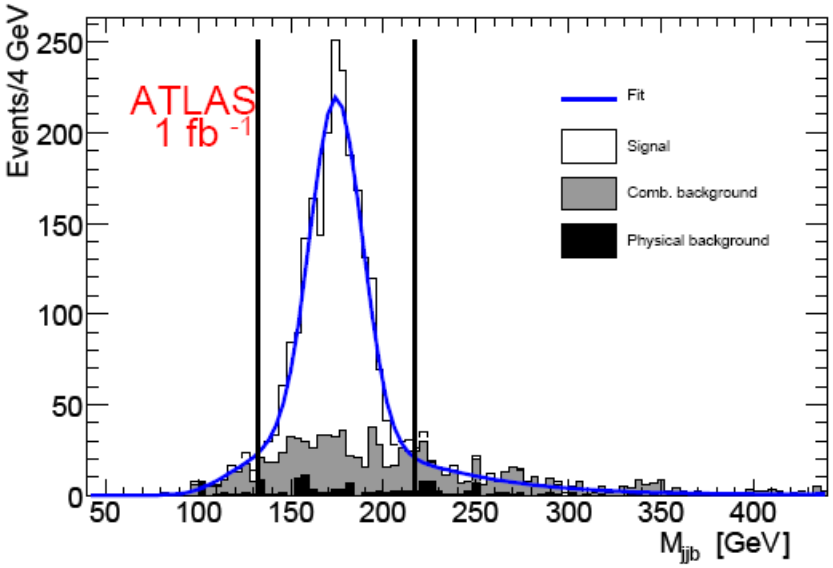
Isolated lepton

p_T> 20 GeV

E_T^{miss} > 20 GeV



2 b-tagged jets



1 fb $^{-1}$

- Stat Error : < 0.4 GeV
- b-jet energy scale :

5% : δM_{Top} = 3.5 GeV

1% : δM_{Top} = 1 GeV

arXiv:0901.0512 CERNOPEN 2008-020