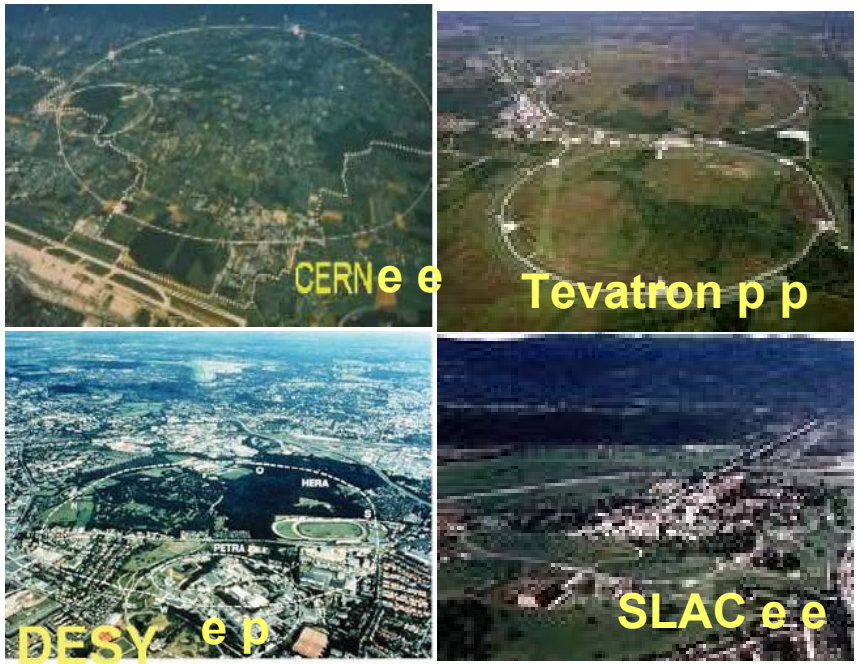
Towards Precision Measurements in the Standard Model Sector in ATLAS

Interplay of detector learning phase and measurements of SM processes as the luminosity is cumulated.

Atlas TDR 1999: under major revision in preparation for 2008

Corinne Goy (CNRS/IN2P3)

Standard Model Measurements @14TeV



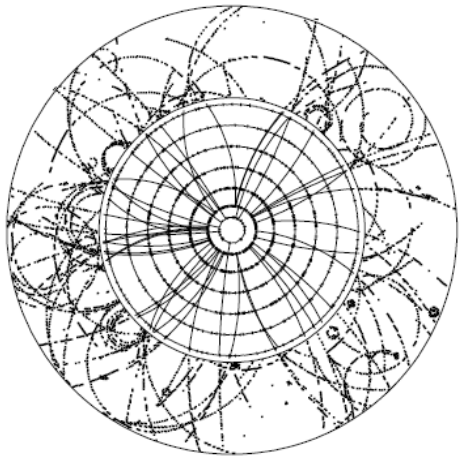
- A fruitful adventure in :
  - insuring the grounds of the Standard Model :
    - $\sin^2(\vartheta_W)$, rad cor, EW cor
  - PDFs
  - detailed knowledge of key ingredients :
    - Z, W, b, Top
    - Production mechanism
    - Branching Ratio

→ Controlled Predictions

- SM @ 14 TeV :
  - New energy domain
  - Precision Top physics
  - SU(2) non-abelian nature : gauge couplings
  - Ultimate(?) precision on M_W

A tool to understand :

- Detector response to muons, electrons, gamma, jets
- Improve/monitor the detector response
  - calibration : $Z \rightarrow e^+e^-$
  - alignment : $Z \rightarrow \mu^+\mu^-$
- Develop sophisticated method
  - b-tagging, missing Et, tau-id, multivariable analysis (NN, pdfs,boosted decision trees etc)



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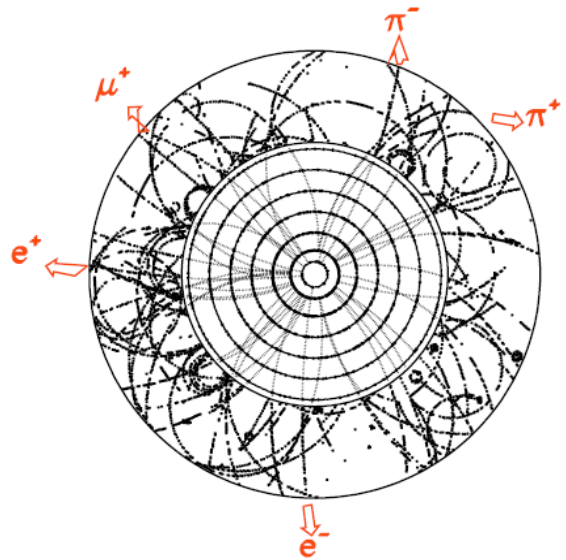
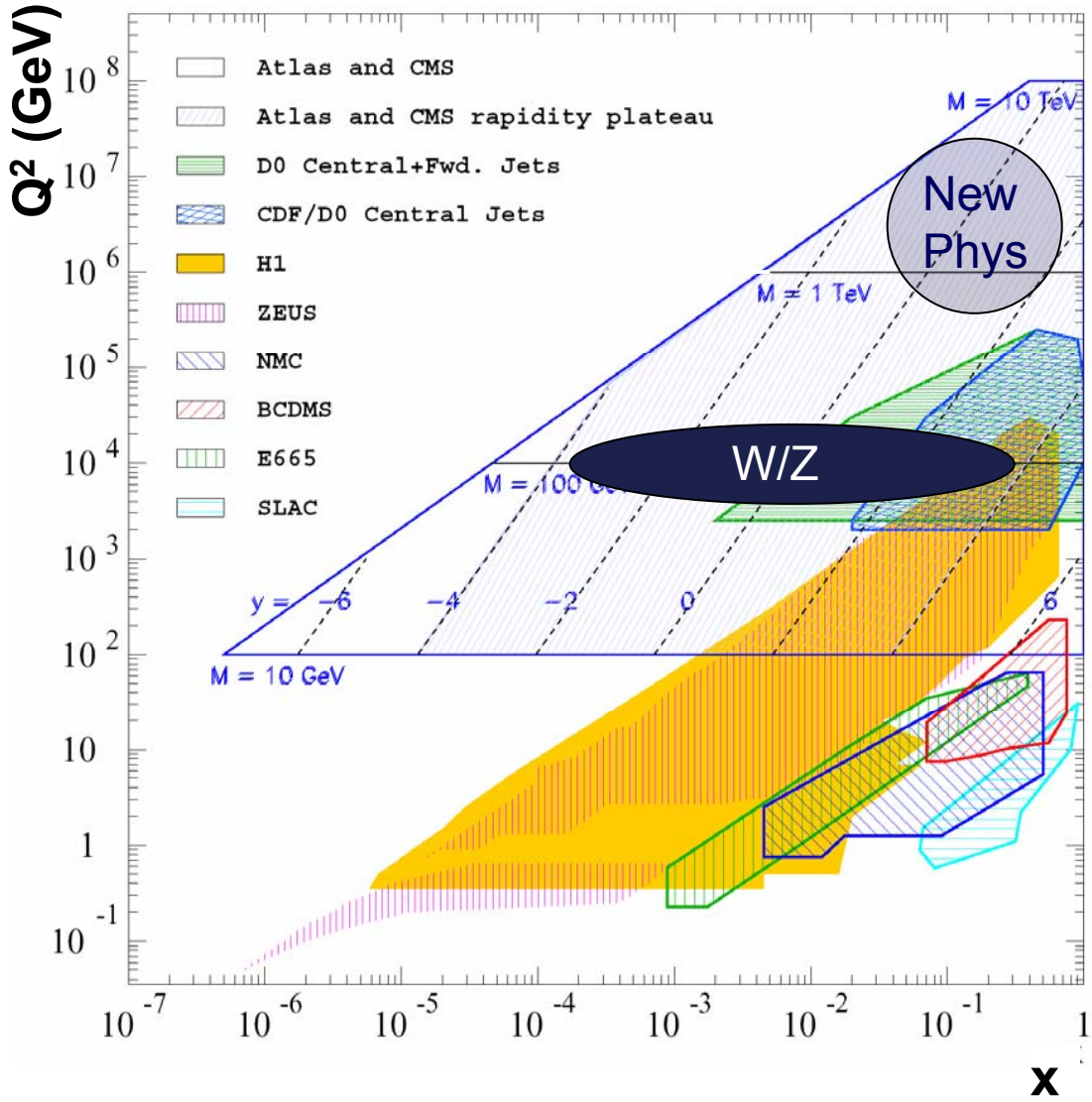
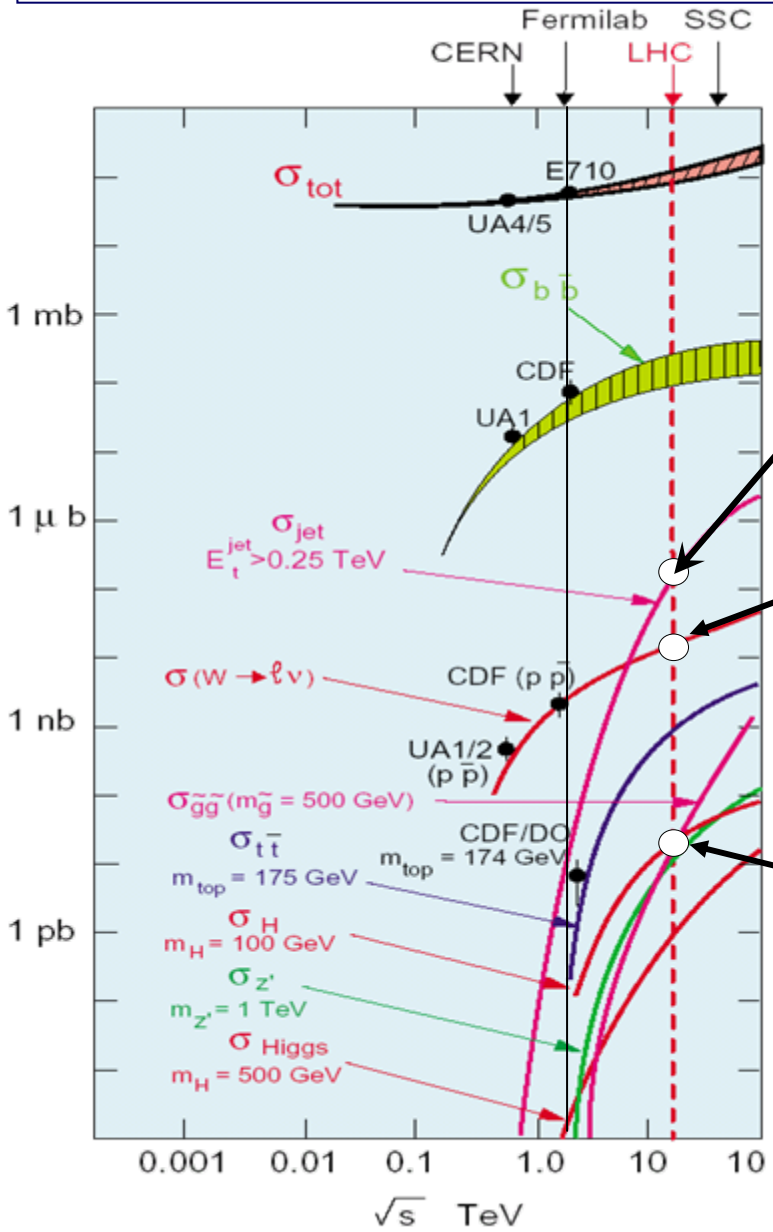


A tool to understand a new Energy Domain

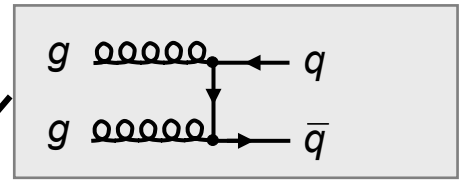
- down to small x
- up to higher Q^2
- PDfs extrapolated



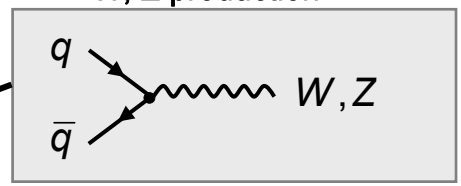
First & Ultimate Background for New Physics



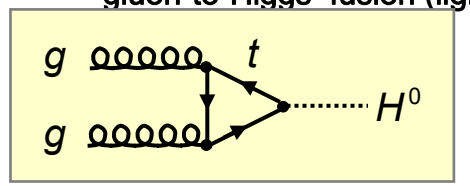
High-p_T QCD jets



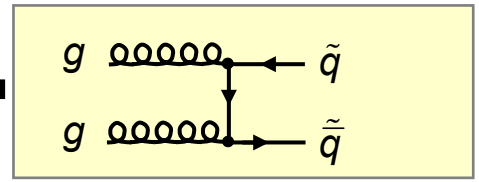
W, *Z* production

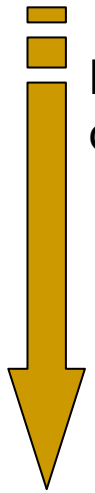


gluon-to-Higgs fusion (light)



squarks, gluinos (*m* ~ 1 TeV)





Physics Signature

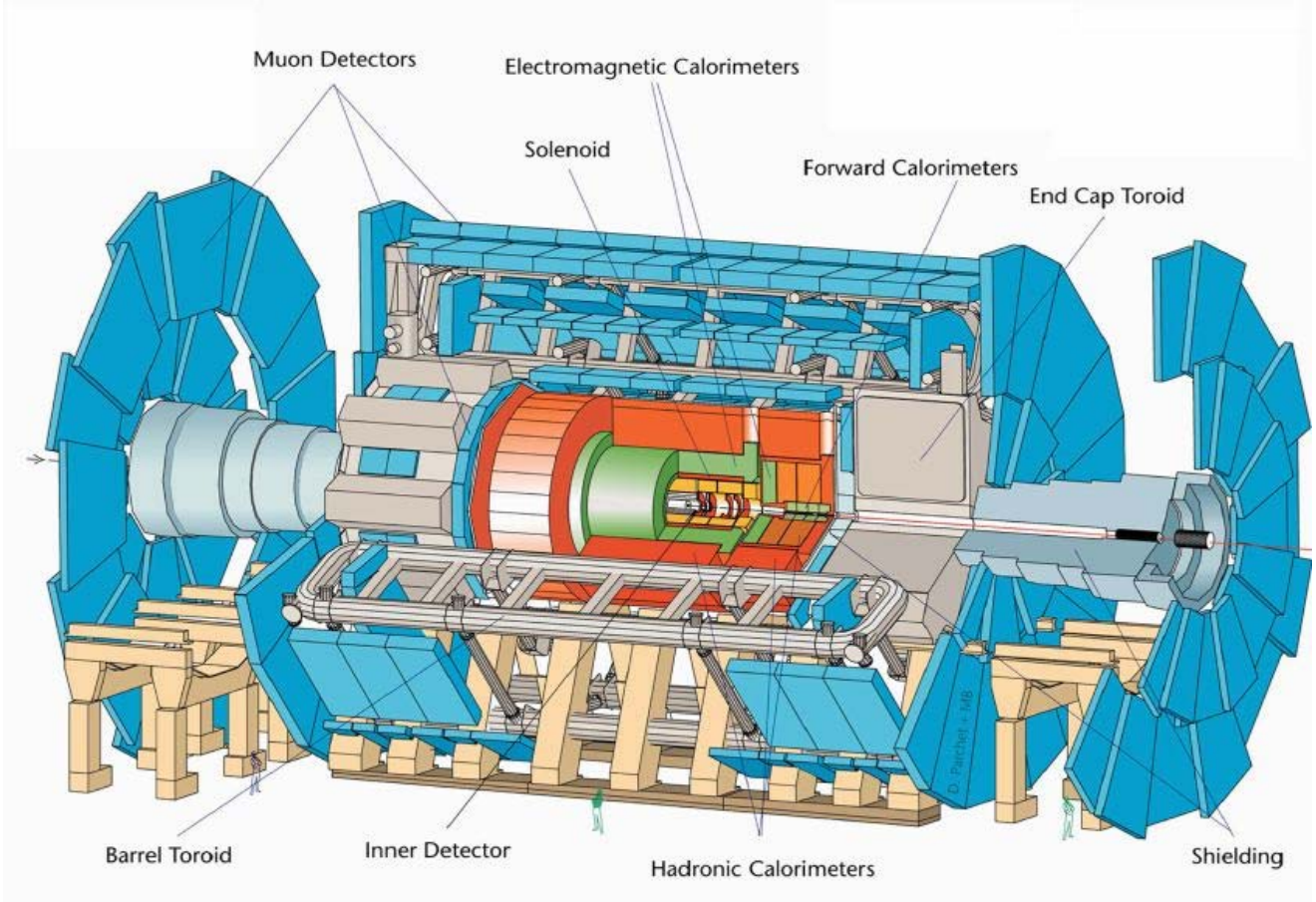
LHC : some numbers

- Startup Conditions /Commissionning (2008 ….)
  - beam crossing: 75ns or less
  - luminosity from 10^{31} to 10^{32}
  - pile-up negligeable

  →O(100 pb^{-1})
- ~ 2009 conditions
  - evolving to nominal conditions
  - crossing angle
  - designed beam crossing: 25ns
  - luminosity: ~10^{33}
  - pile-up

  →O(10 fb^{-1})
- Onwards
  - nominal conditions

ATLAS

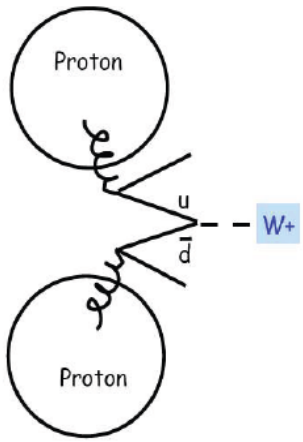


- 2T Solenoid for inner tracker
- Tracker: silicon (pixel + strips) and TRT ($|\eta|<2.5$)
- Sampling calorimetry ($|\eta|<4.9$)
- Toroid system for muons

Z and W production

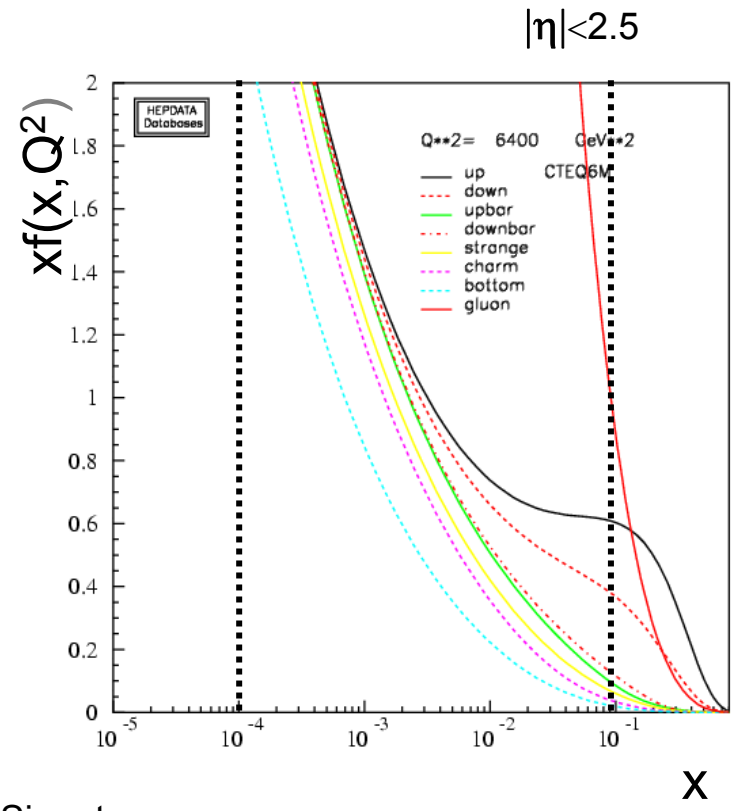
- Expected large production :
  - systematics are rapidly a potential limitation

- Production Mode
  - small x
  - gluon PDF : the least known



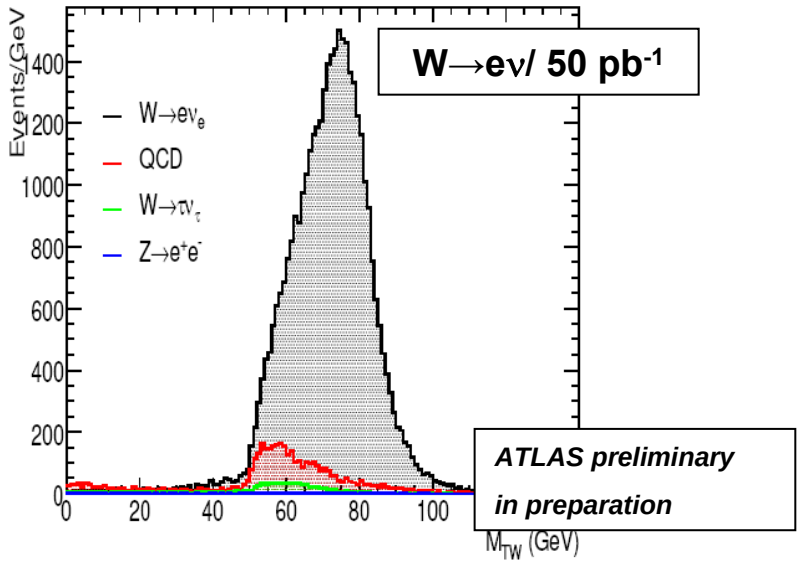
  - NNLO / DGLAP extrapolation at small X

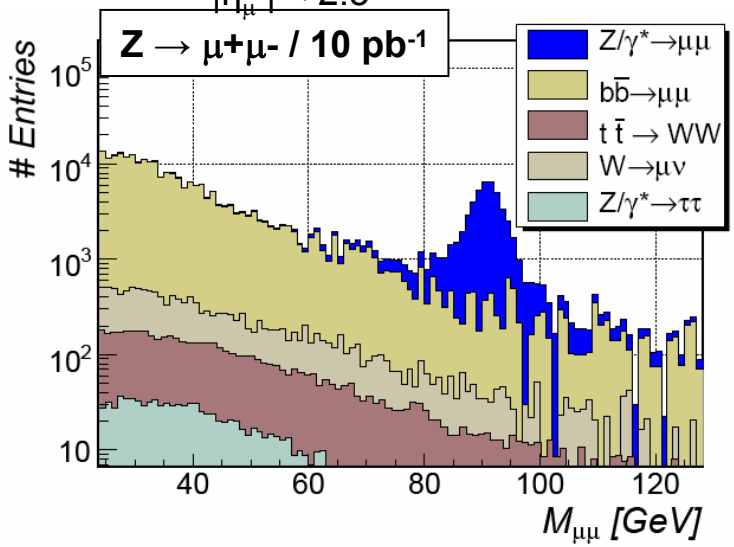
	σ(LO) nb	ε %	Evts/pb^{-1}	Statistical Uncertainty pb^{-1}		
				1 ~week	10	100 ~year
$Z \rightarrow e^+e^-$ $Z \rightarrow \mu^+\mu^-$	1.65	~20	~350	5%	2%	0.5%
$W \rightarrow e\nu$	16.8	~20	~3500	2%	0.5%	0.2%



Some Plots

- Typical W Selection:
  - e-ID
  - $P_t^{l=e,\mu} > 25$ GeV
  - $|\eta_l| < 2.5$
  - $P_t^{\nu} > 25$ GeV
  - no jet with P_t>20 GeV
  - hadronic recoil < 30 GeV
- Typical Z Selection
  - opposite charge Muon Track
  - $P_t^{\mu} > 15$ GeV, 25 GeV
  - Isolation
  - $|\eta_{\mu}| < 2.5$



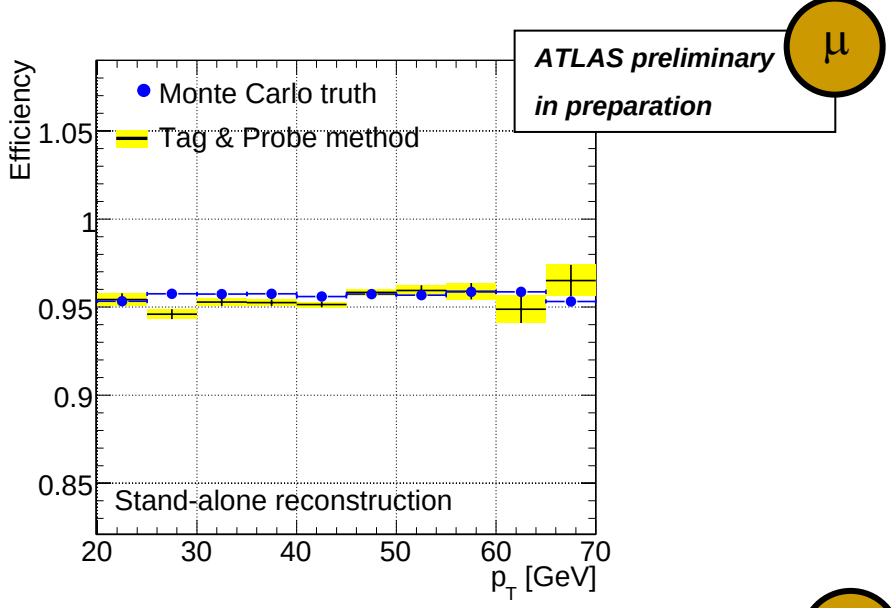


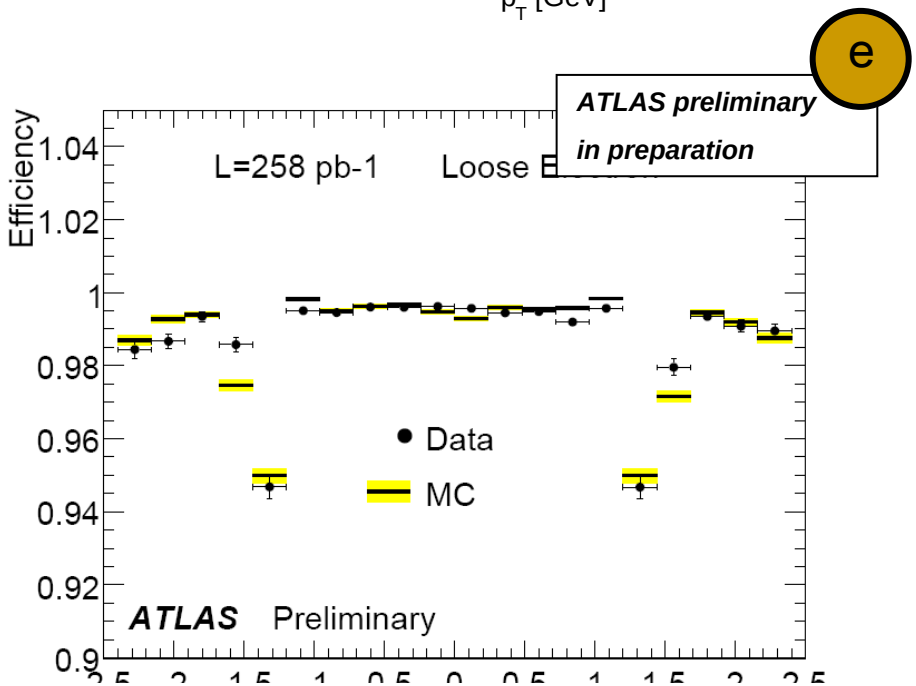
Clean Signal :

- efficiency → PDF
- calibration → Uniformity
- isolation → SUSY events

Tag&Probe efficiency

- Efficiency from Data:
  - $Z \rightarrow e^+e^-$, $Z \rightarrow \mu^+\mu^-$
  - reduced reliance on MC
  - 2 sources of uncertainties
    - statistical
    - background subtraction
    - comparison with MC Truth
- Application:
  - trigger
  - reconstruction
  - selection
- Dominant experimental error:
  - ~ 1% @ 50 pb^{-1} (stat)
  - overlap region

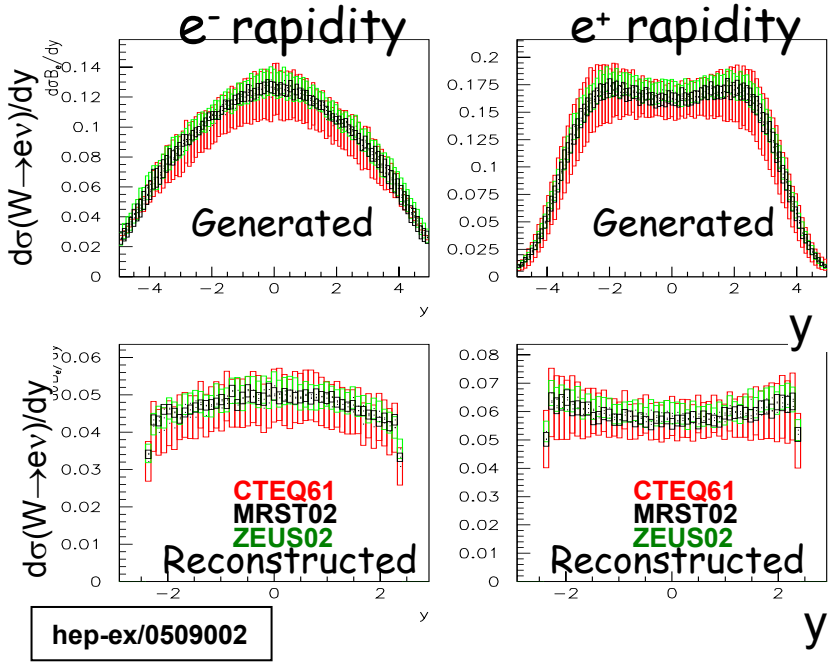


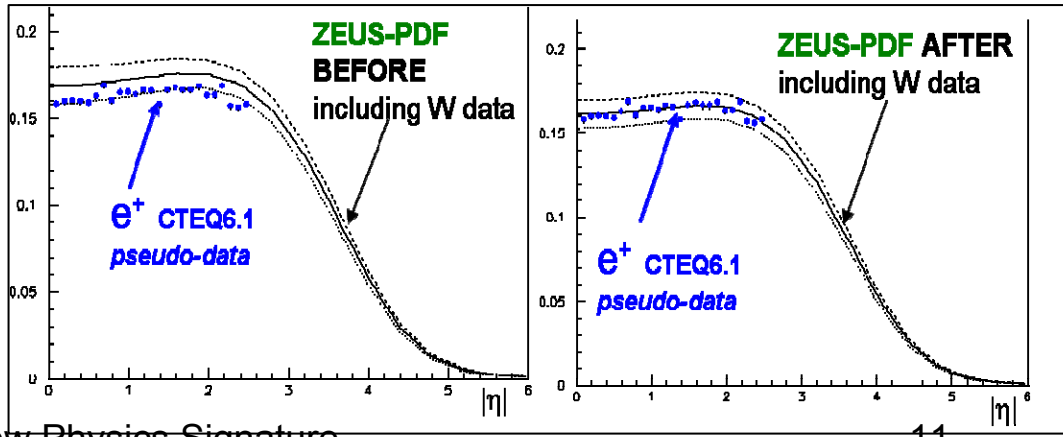


Electron selection efficiency in |η| and Pt bins.

PDFs

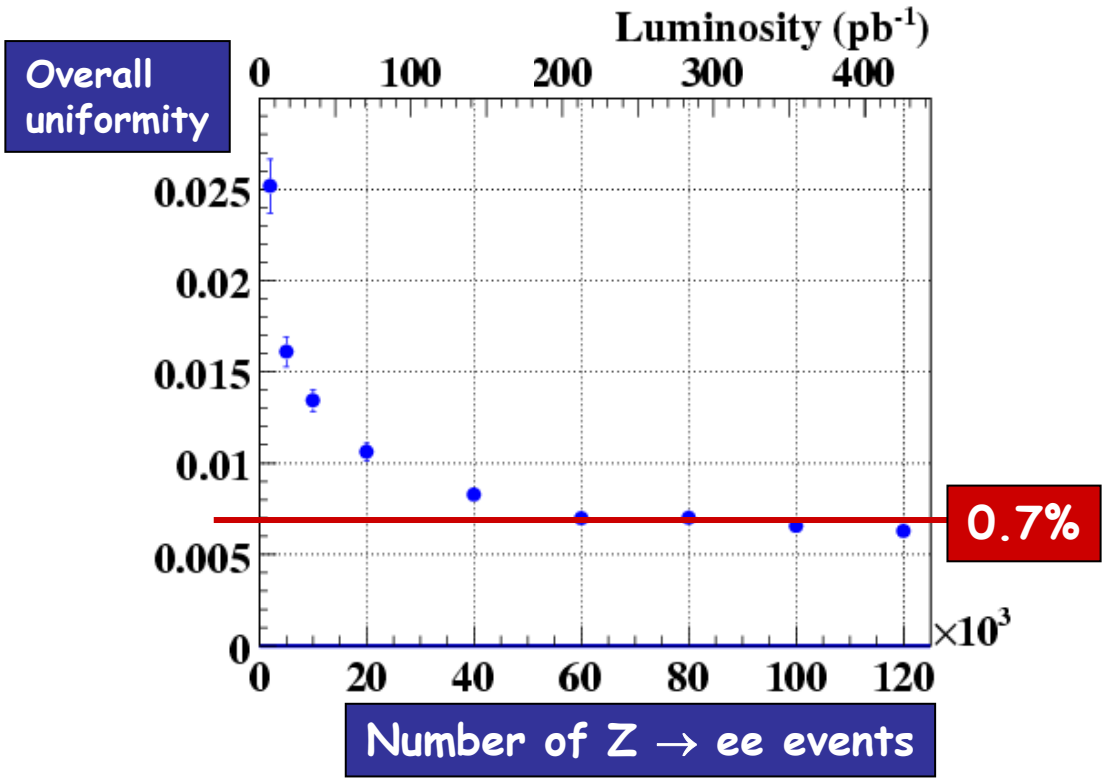
- Sensitivity to PDf not degraded after detector response
  - up to 8% on diff cross-section
- Improvement if experimental systematic error less than 4 %
  - achievable
- Proof of principle :
  - 100 pb^{-1} simulated W data
  - gluons parameter uncertainty reduced by 35% [$xg(x)= x^{-\lambda}$]





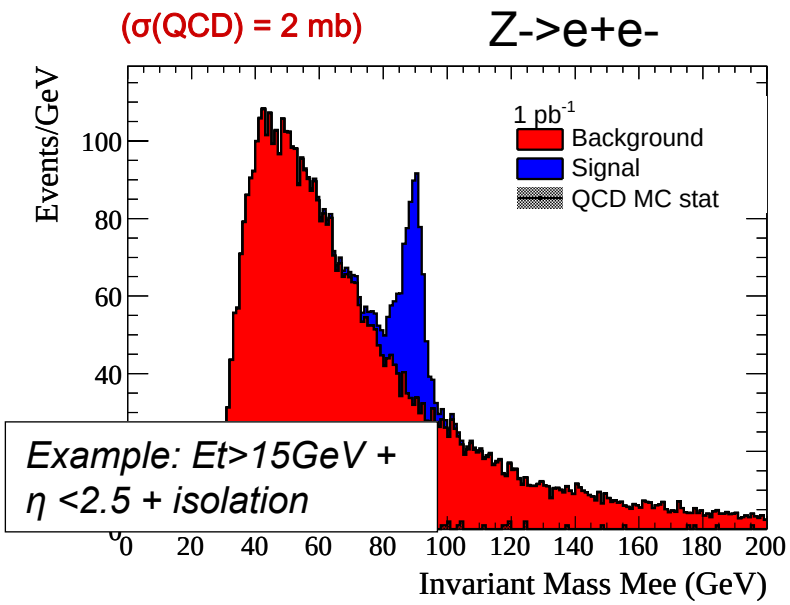
Example: Ecal Calibration/Uniformity

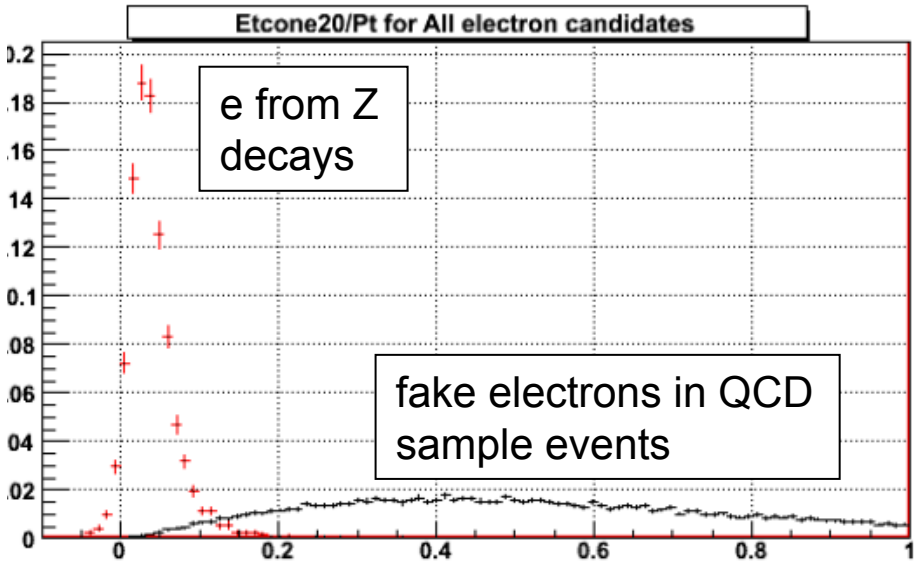
- About a 12-18 months to reach nominal performance



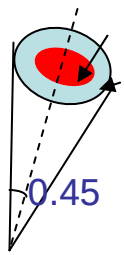
Uniformity necessary for H →γγ

Example: Isolation a powerful tool





Isolation = Econe (blue) /Ecluster(red)
(normalised)



But in real condition control of :

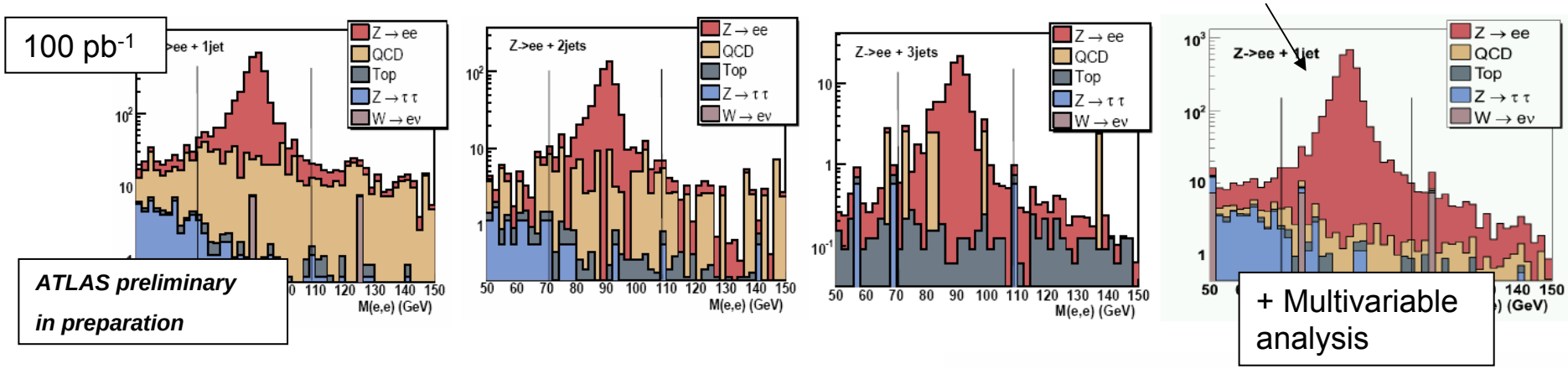
- Electronic Noise
- Physics dependance : Bremstrahlung
- Eta/Phi dependance
- Underlying Events modelling
- Machine Noise / Pile-up

At the end a tool to clean new (other) physics signature:

- Z+jets
- SUSY events

pp -> W/Z + Jets / γ + Jets

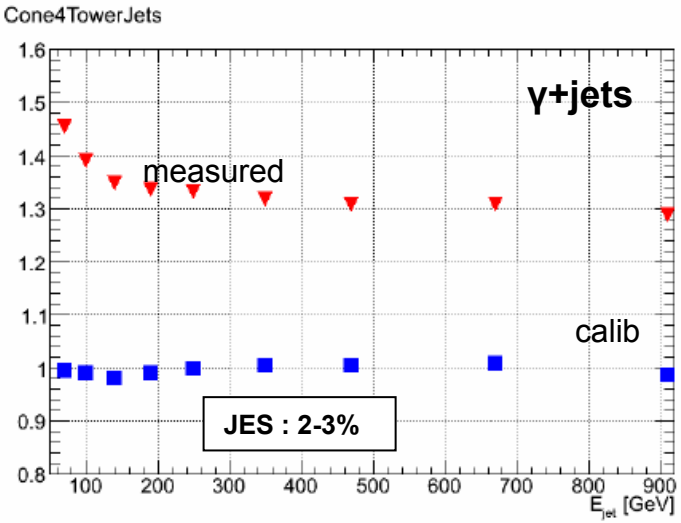
- QCD Studies
- An application of Isolation criteria (trigger/offline) & sophiscated method



•Relevant background for many new particles searches, top physics studies

•First step in reducing jet energy scale uncertainties :

- recoil to Z/γ mass



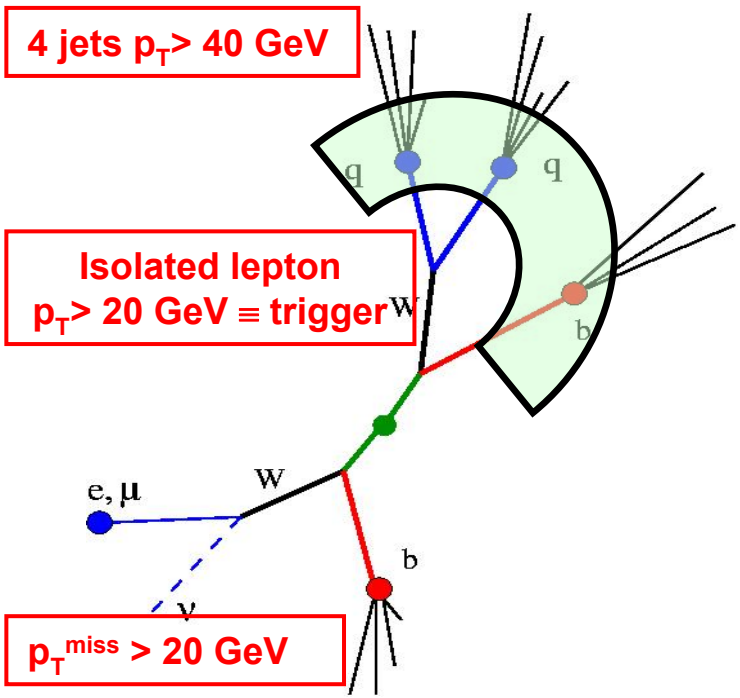
A needless motivation for TOP Physics @LHC

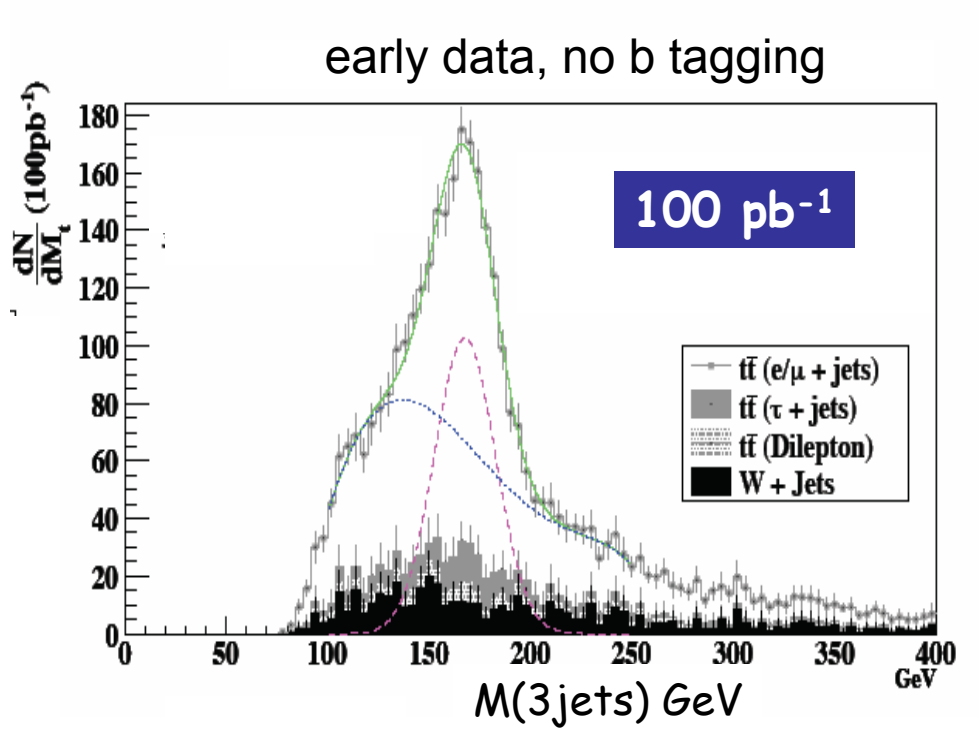
Top in the Standard Model:

The heaviest known particle

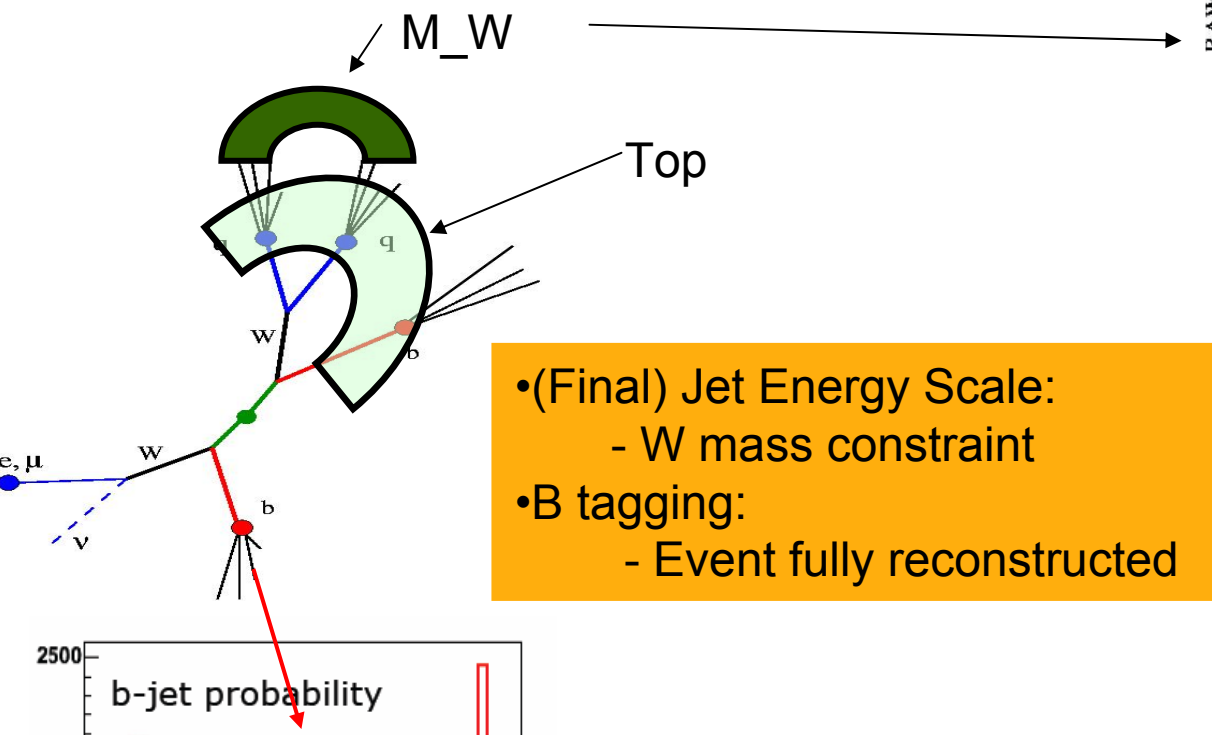
The least known – limited by statistics of Tevatron

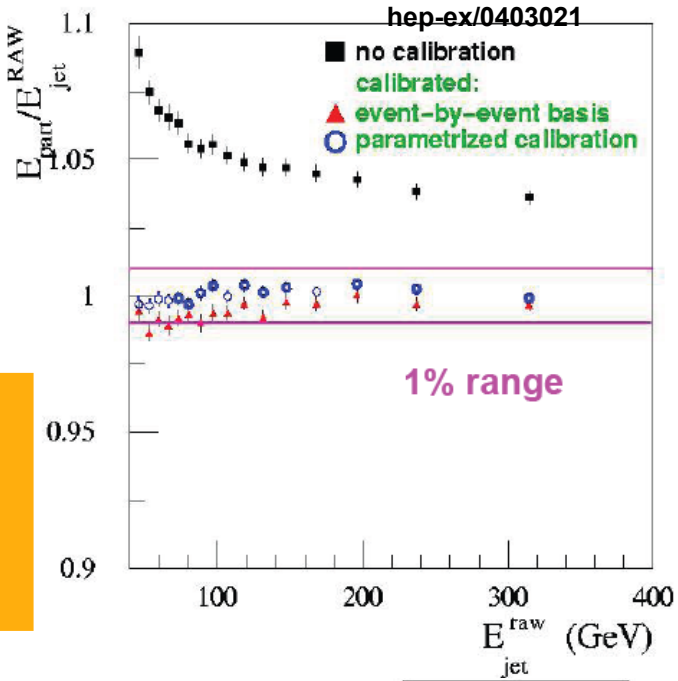
A top factory: 10^6 events per fb^{-1}



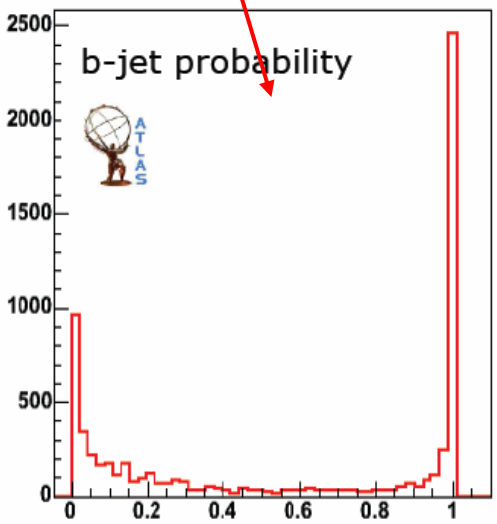


TOP Physics (cont')



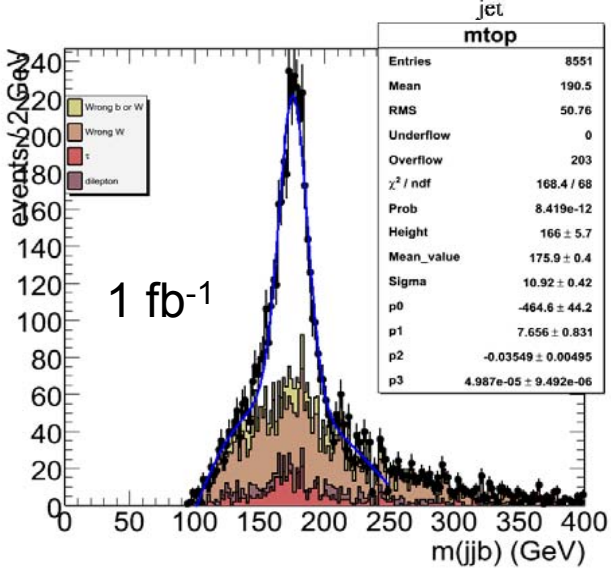


- (Final) Jet Energy Scale:
  - W mass constraint
- B tagging:
  - Event fully reconstructed

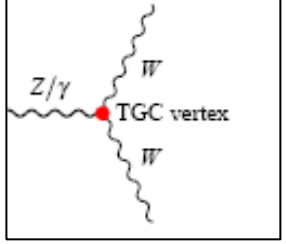


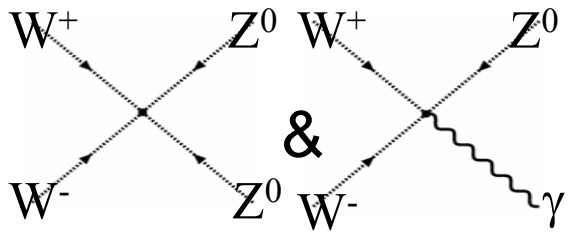
Precision Top Physics:
- mass +/- 1 GeV
(ultimately) seems feasible.
- b jet scale.

LHC New Physics Signature

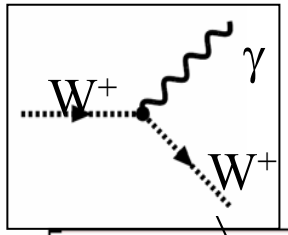


T (and more) GC

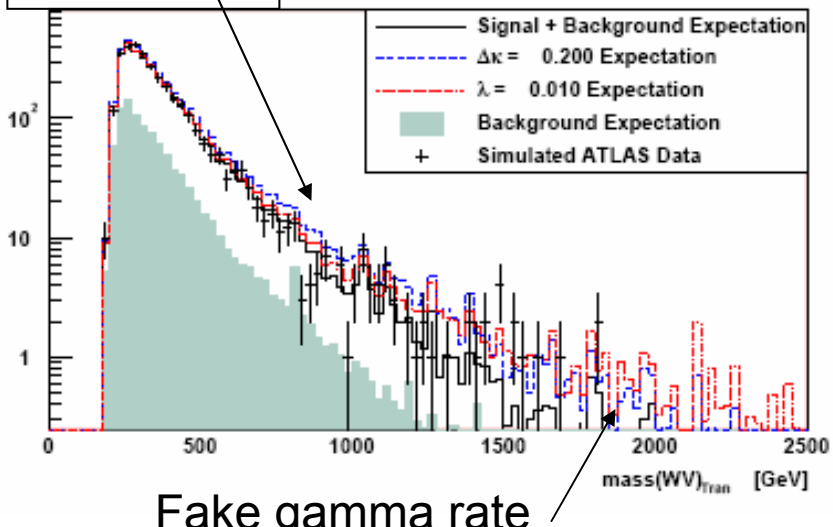




Effective couplings independent of underlying theory



See Detailed Talk by Alan Wilson



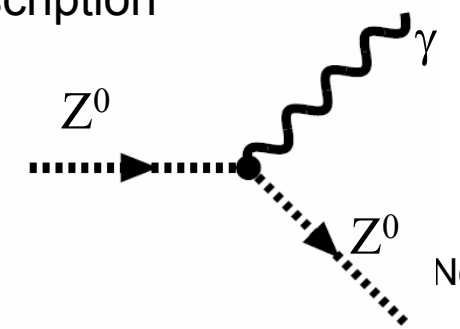
Fake gamma rate

Tails' description

Vertex	Coupling	Present Value (LEP & Tevatron)	Atlas Sensitivity (95% CL, 30 fb^{-1} one experiment)	
WWZ	Δg_1^Z	-0.016 ± 0.022 / 0.019	*-0.003 – 0.016*	Syst limited ~ 30-100fb-1
	λ_Z	-0.088 ± 0.063/0.061	*-0.008 -0.005*	
	$\Delta\kappa_Z$	-0.076 ± 0.061/0.64	*-0.069 – 0.131*	
WWγ	λ_γ	-0.028 ± 0.020/0.021		Stat limited 300 fb-1
	$\Delta\kappa_\gamma$	-0.027 ± 0.044/0.045		

LEPEWWG/TGC/2005-01

ATLAS preliminary in preparation



New

Neutral TGC : 0 in SM

With 100 fb^{-1}: sensitivity to 10^{-3} to 10^{-4}

Tevatron ~ 10^{-1} to 10^{-3} / Weak LEP limit

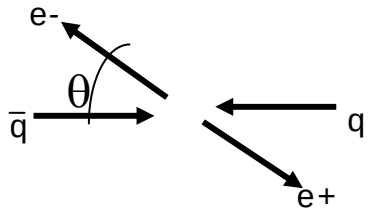
Determination of $\sin^2\theta_W(M_Z^2)$

- Z decay asymmetric :

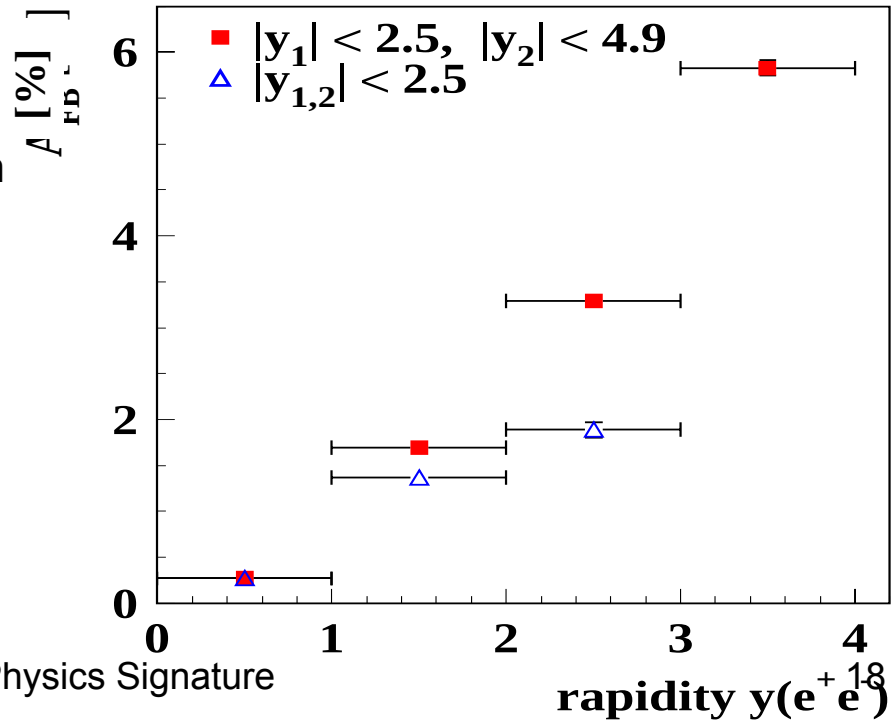
$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta} = \frac{3}{8}N_c[1 + \frac{4}{3}A_{FB}\cos\theta + \cos^2\theta]$$

- $A_{FB} = b\{ a - \sin^2\theta_W(M_Z^2) \}$

a, b calculated to NLO QED and QCD



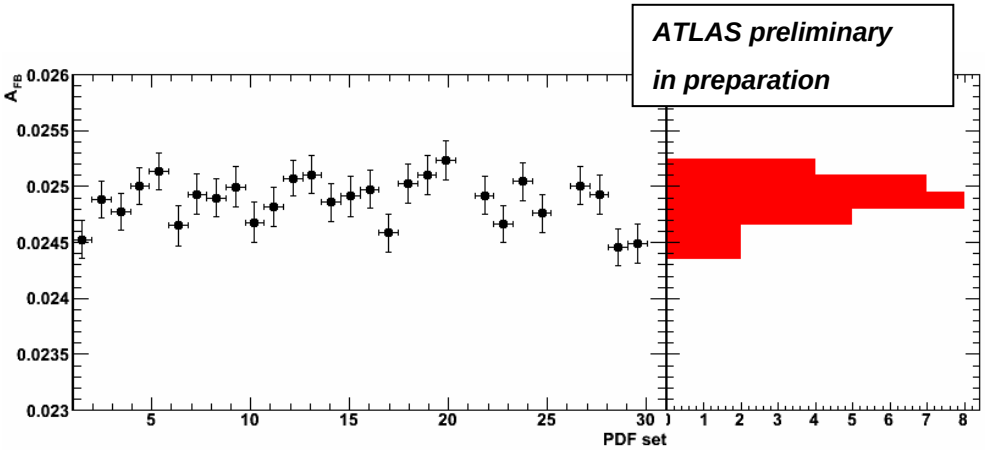
- Selection :
  - at least 1 electron in central region > charge
  - P_T > 20 GeV
  - Mass window M_Z±6 GeV
  - Missing Et cut < 20 GeV



$\sin^2(\vartheta_W)$ (cont')

y cuts – e^+e^- ($|y(Z)| > 1$)	$A_{FB\%}$	ΔAfb stat 100 fb^{-1}
$|y(\ l_{1,2}\ )| < 2.5$	3.0×10^{-4}	4.0×10^{-4}
$|y(\ l_1\ )| < 2.5$ + $|y(\ l_2\ )| < 4.9$	2.3×10^{-4}	1.4×10^{-4}

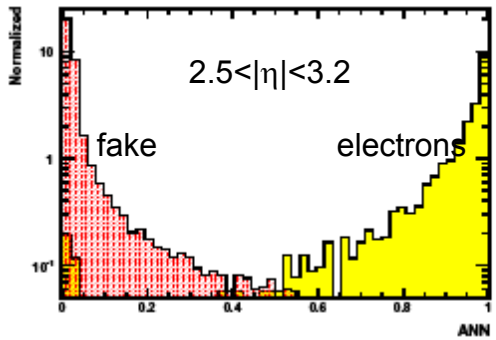
World average error: 1.6×10^{-4}

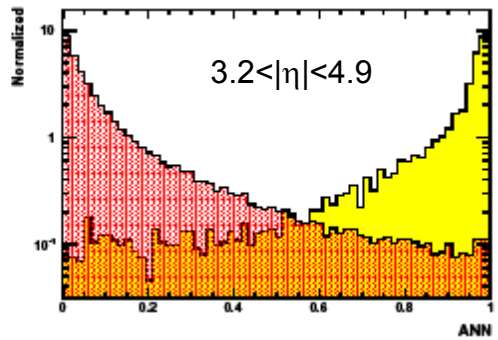


syst = maxValue-minValue= 7.6e-4 (worst case)

- Systematic due to PDF
  - under more complete study
  - effect of Higher Order

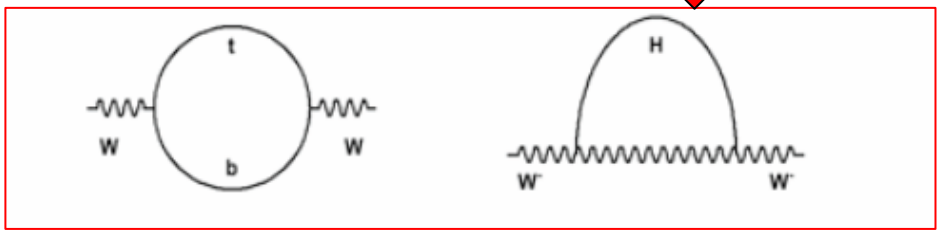
Electron in Forward region :
- etmiss
- new phys signature

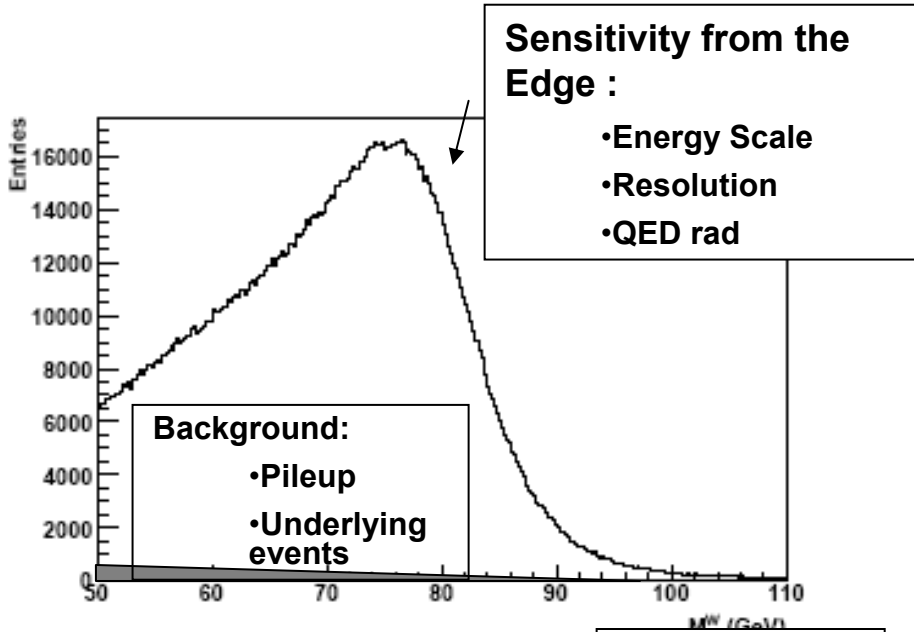


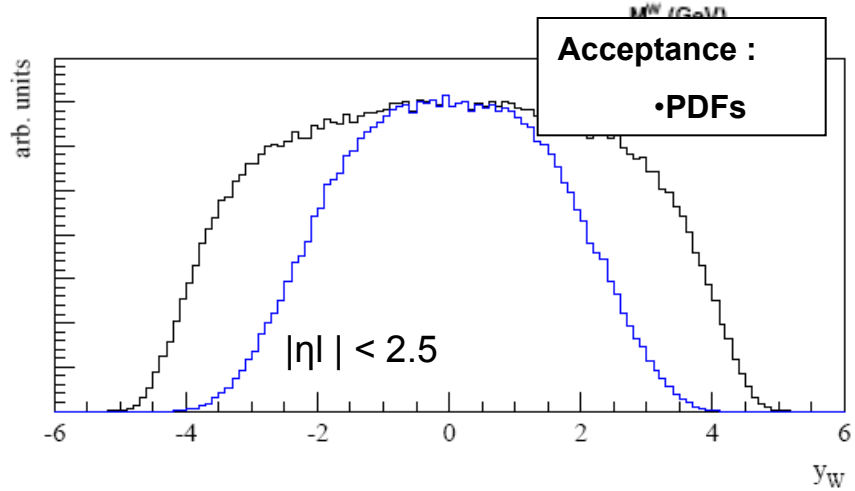


THE precision measurement: M_W

$$m_W^{\,2} = \frac{\pi \alpha_{em}}{\sqrt{2} G_F \sin^2 \theta_W (1 - \Delta r)}$$





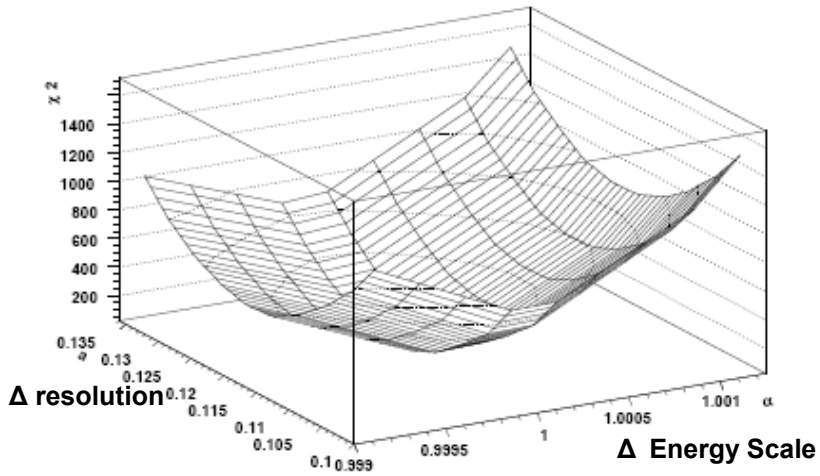


- Current error :
  - CDF Run II : 48 MeV
  - WA : 25 MeV

- Aim : M_W < 15 MeV
- Observables sensitive to M_W
  - Lepton Transverse Momentum
  - **Transverse Mass**

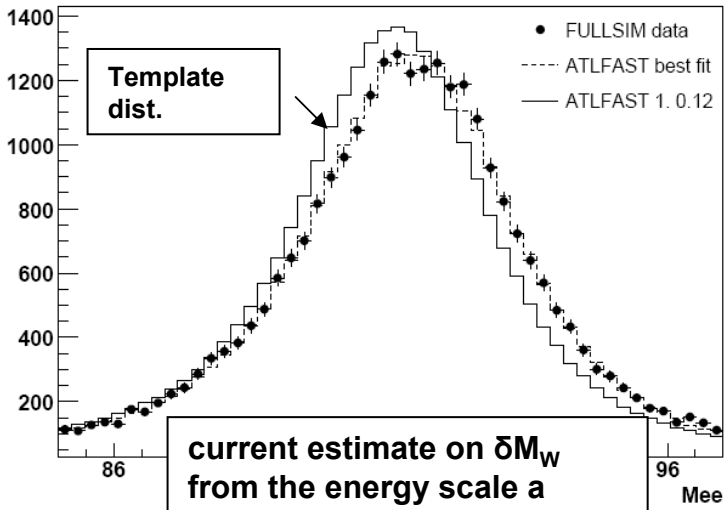
Exemple : Energy Scale

- Systematics controls from the (huge) Z sample:
  - precise Mass (LEP) : 2. 10^{-5}
  - similar production mechanism
  - similar phase space



Channel	$W \to l\nu$	$Z \to ll$
Cross-section (pb)	19800	1870
Lepton η acceptance	0.63	0.51
Trigger & Selection eff.	~ 0.2	~ 0.2
Expected statistics (10 fb^{-1})	4×10^7	3.5×10^6

LEP : ~4.10⁶ Z / exp



- Additional data sets: E/p

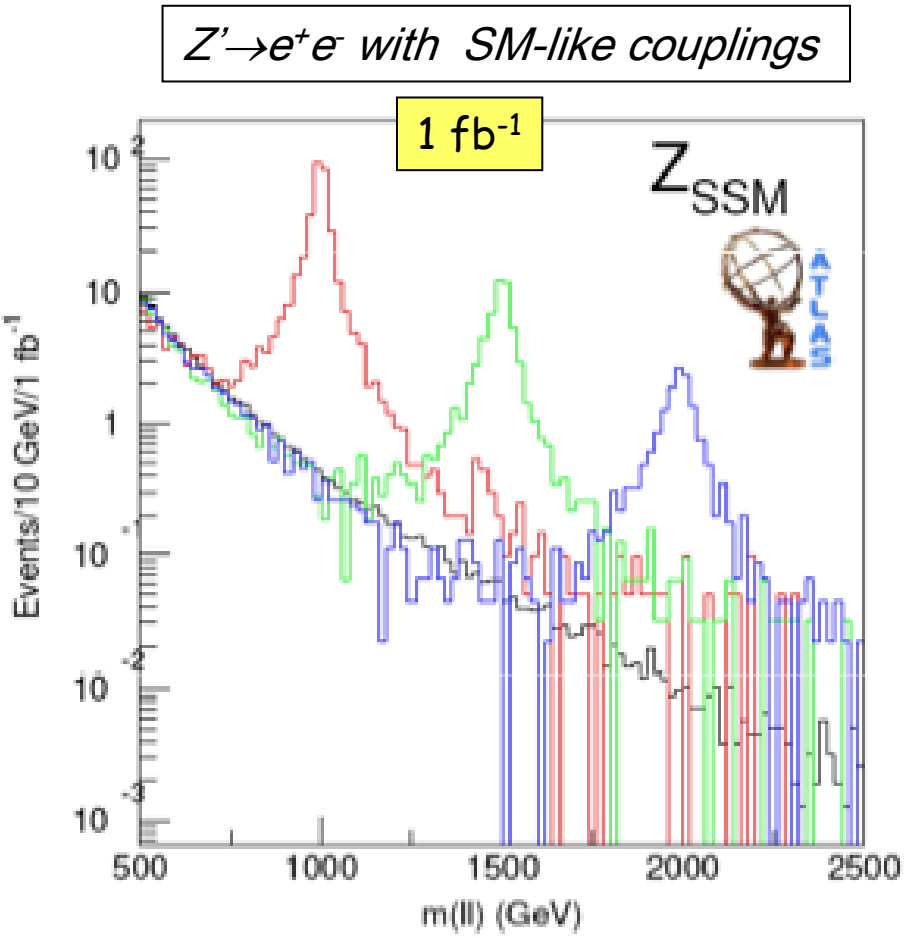
Conclusions : The Ground to New Physics

O(10pb-1)	W/Z	Calibration /Alignment Lepton ID Missing Et Isolation	2008
O(100pb-1)	W/Z + jets Top physics	PDfs B tagging , missing Et “Multi Variables” analysis	
O(1fb-1)	Precision Top Physics TGC	In Situ Final Jets Calibration Full detector understanding	2009
	Solid Grounds for New Physics Should be Established		
O(100fb-1) and more	$\sin^2(\vartheta)$ M_W		

Unless !

Di lepton (electron) spectrum

Mass (TeV)	Nevt (1fb-1)	10 evts
1	~160	~70 pb-1
1.5	~30	~300 pb-1
2	~7	1.5 fb-1



Anyway a lot to learn from SM at the end