

# 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*



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# Standard Model Measurements @14TeV

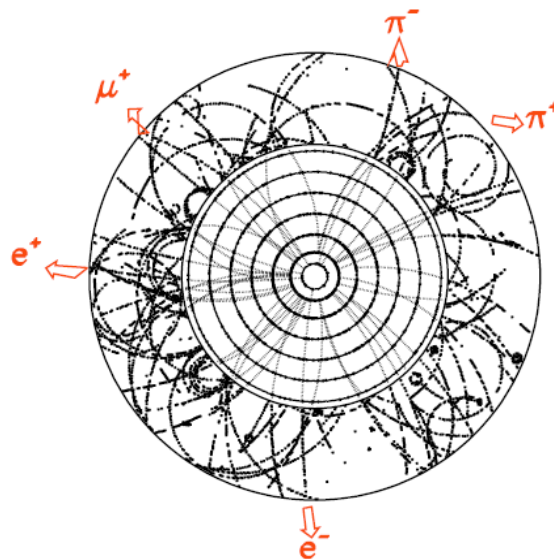
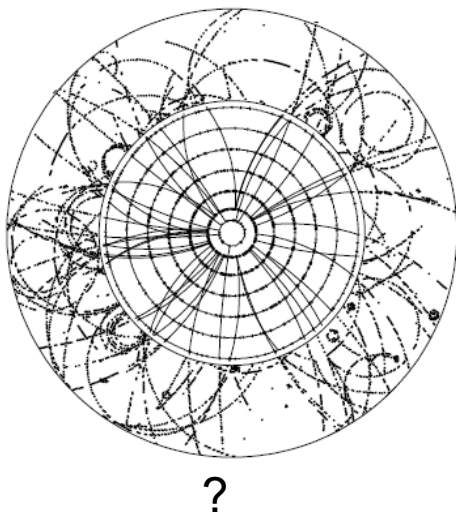


- A fruitful adventure in :
    - insuring the grounds of the Standard Model :
      - $\sin^2(\vartheta_W)$ , rad cor, EW cor
    - PDFs
    - detailed knowledge of key ingredients :
      - Z, W, b, Top
      - Production mechanism
      - Branching Ratio
- Controlled Predictions

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

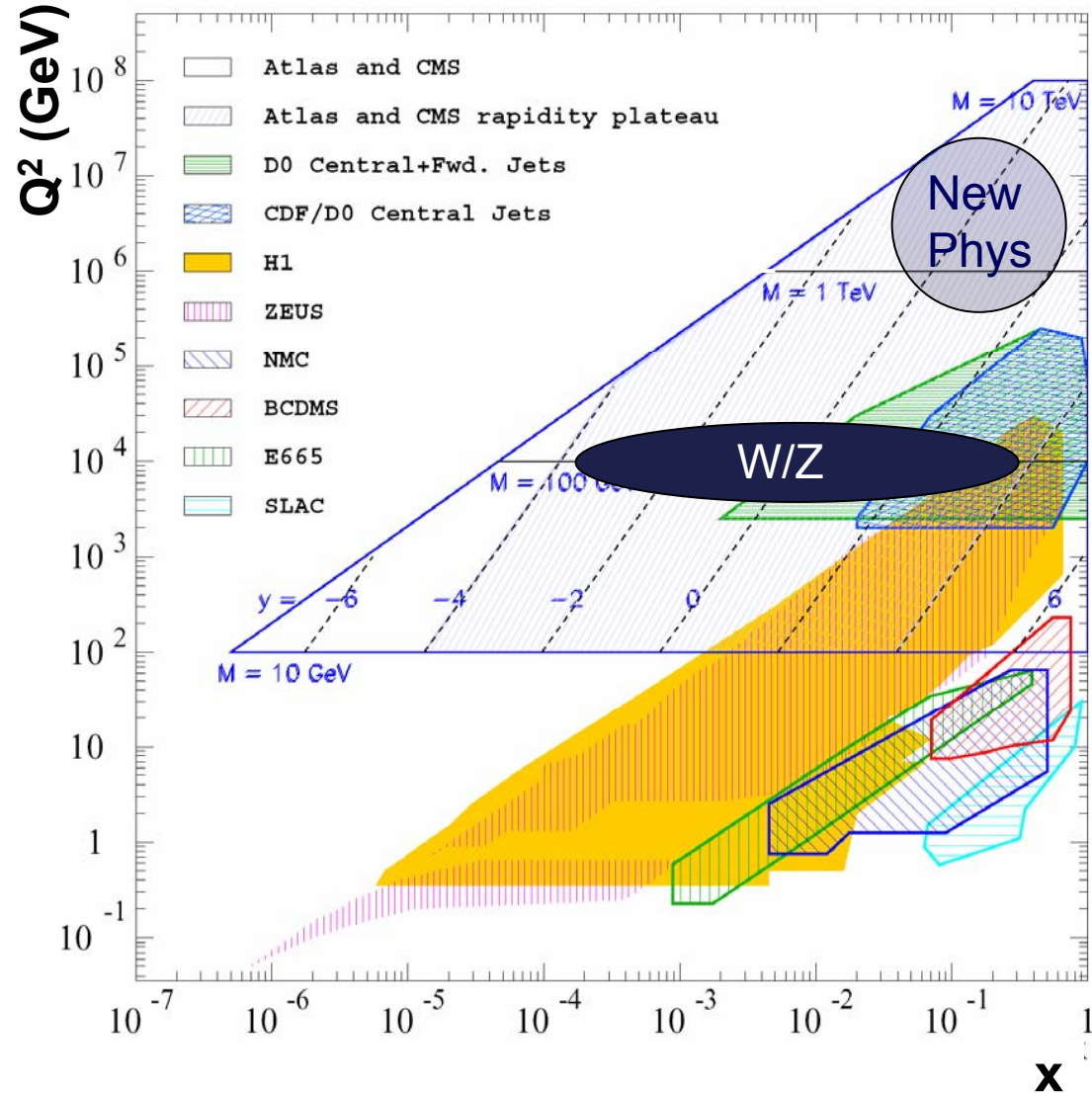
## A tool to understand :

- 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  $E_t$ , tau-id, multivariable analysis (NN, pdfs, boosted decision trees etc)

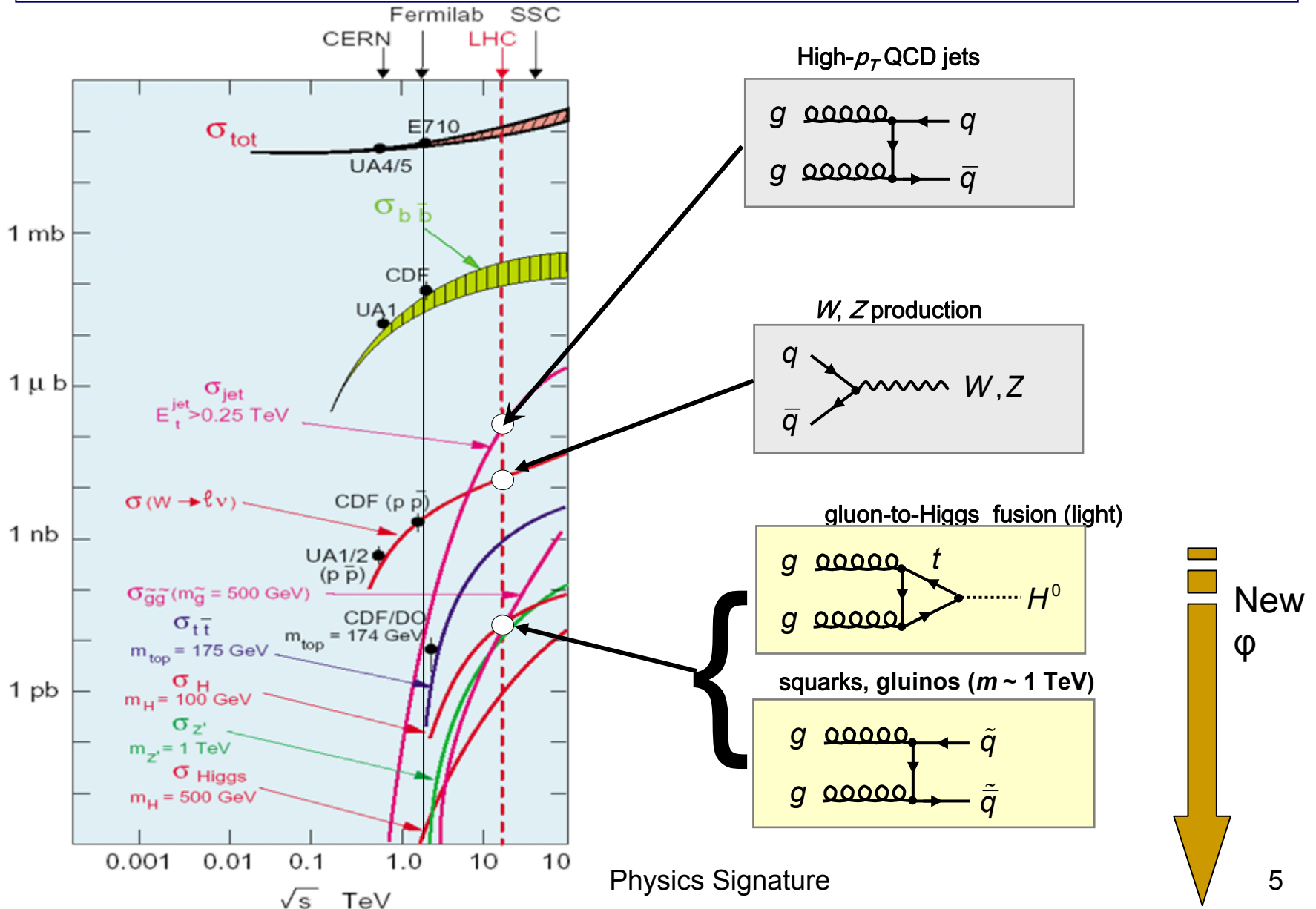


# A tool to understand a new Energy Domain

- down to small  $x$
- up to higher  $Q^2$
- PDFs extrapolated



# First & Ultimate Background for New Physics



# LHC : some numbers

- Startup Conditions /Commissioning (2008 ....)

- beam crossing: 75ns or less

- luminosity from  $10^{31}$  to  $10^{32}$

- pile-up negligible

#bun

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→O(100 pb<sup>-1</sup>)

- ~ 2009 conditions

- evolving to nominal conditions

- crossing angle

- designed beam crossing: 25ns

- luminosity:  $\sim 10^{33}$

- pile-up

|  | Beam 1  | Beam 2  |                           |                          |
|--|---------|---------|---------------------------|--------------------------|
|  | 43      | 43      | →O(100 pb <sup>-1</sup> ) |                          |
|  | 0.41e12 | 1.73e12 |                           |                          |
|  | 121     | 140     |                           |                          |
|  | ATLAS   | ALICE   | CMS                       | LHC-B                    |
|  | 7.32    | 6.23    | 7.13                      | 5.21                     |
|  | 0.78    | 0.68    | 0.78                      | 0.52                     |
|  | 0.70    | 0.52    | 0.90                      | 0.43                     |
|  | 0.45    | 0.82    | 0.50                      | →O(10 fb <sup>-1</sup> ) |

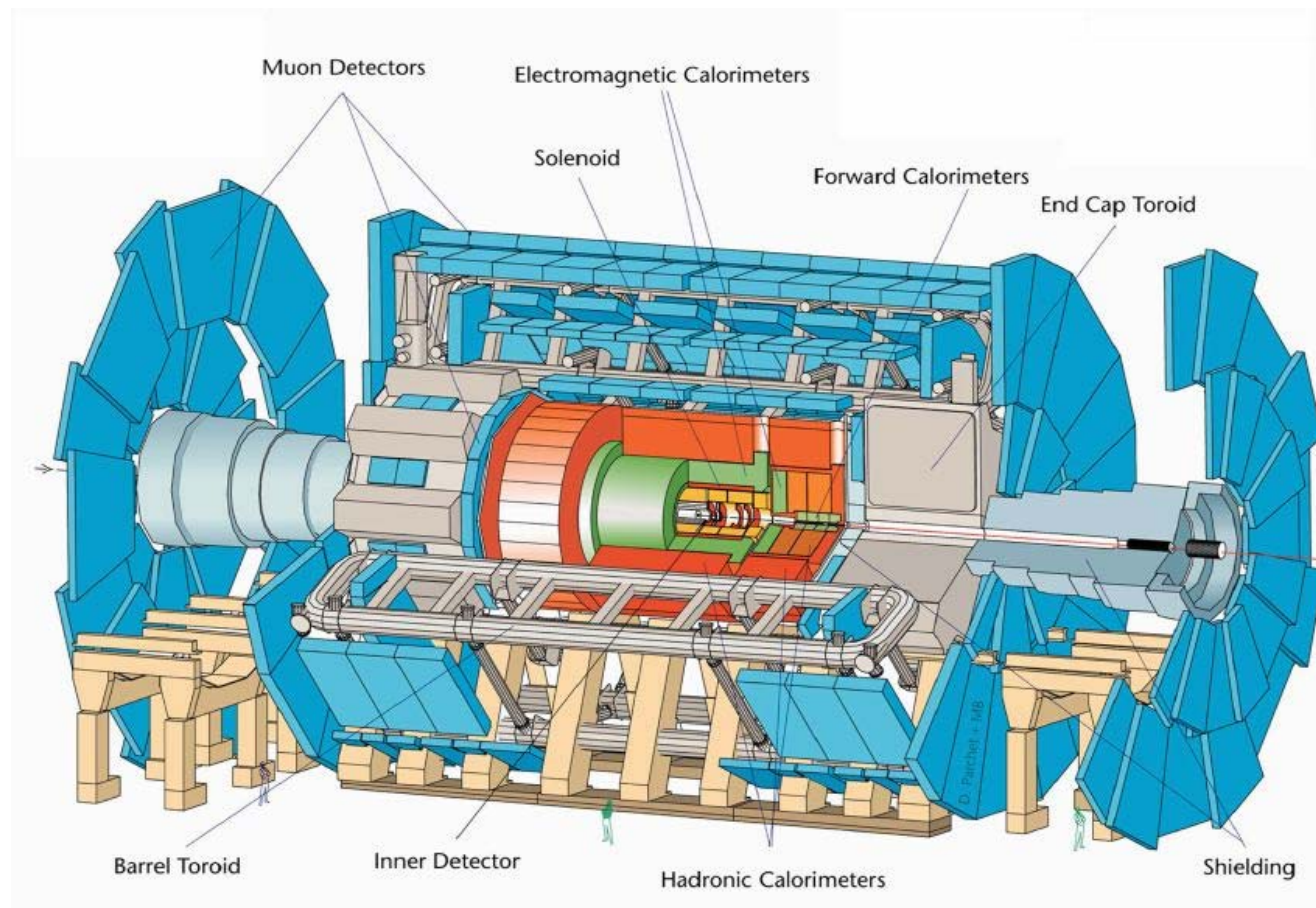
- Onwards

- nominal conditions

Separation Scan in IR1/Atlas



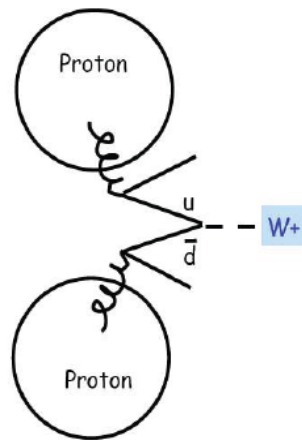
# ATLAS



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

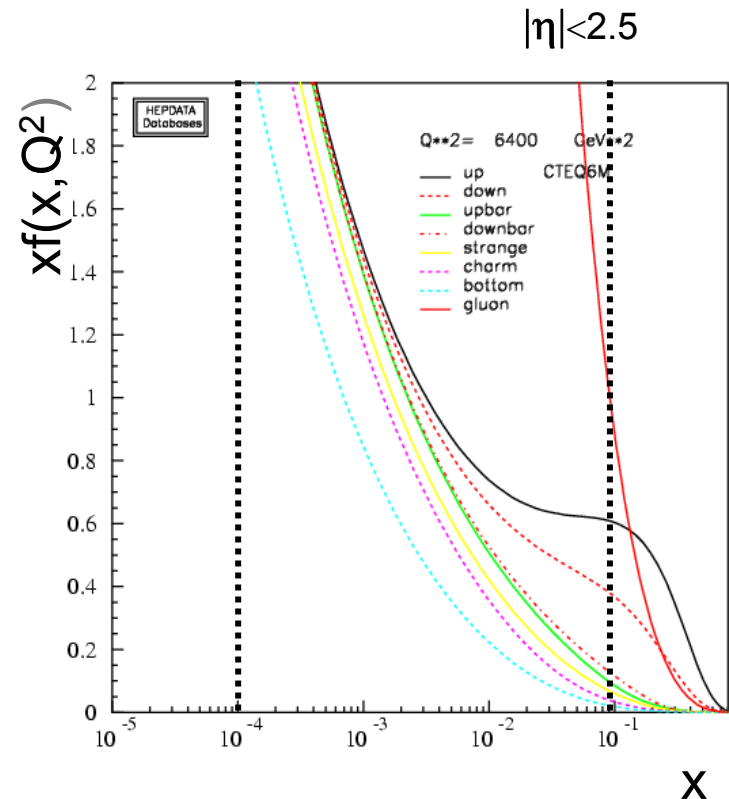
# Z and W production

- Expected large production :
  - systematics are rapidly a potential limitation
- Production Mode
  - small x
  - gluon PDF : the least known



- NNLO / DGLAP extrapolation at small X

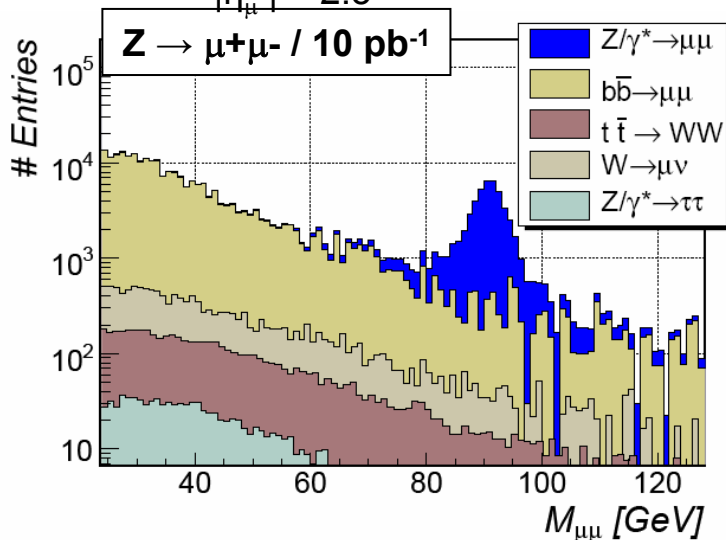
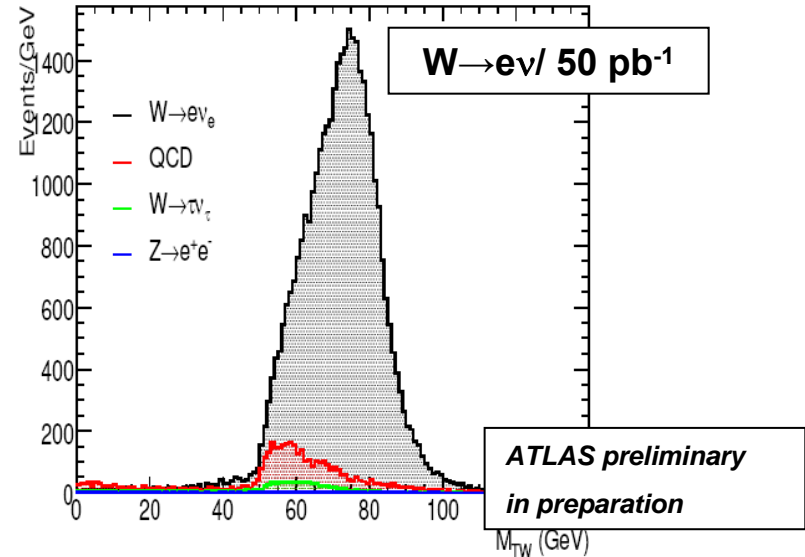
|  | $\sigma(\text{LO})$<br>nb | $\epsilon \%$ | Evts/pb <sup>-1</sup> | Statistical Uncertainty<br>pb <sup>-1</sup> |      |              |
|--|---------------------------|---------------|-----------------------|---|------|--------------|
|  |                           |               |                       | 1<br>~week                                  | 10   | 100<br>~year |
| $Z \rightarrow e^+e^-$<br>$Z \rightarrow \mu^+\mu^-$ | 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
  - $P_t^{l=e,\mu} > 25 \text{ GeV}$
  - $|\eta_l| < 2.5$
  - $P_t^{\nu} > 25 \text{ GeV}$
  - no jet with  $P_t > 20 \text{ GeV}$
  - hadronic recoil  $< 30 \text{ GeV}$
- Typical Z Selection
  - opposite charge Muon Track
  - $P_t^{\mu} > 15 \text{ GeV}, 25 \text{ GeV}$
  - Isolation
  - $|\eta_{\mu}| < 2.5$

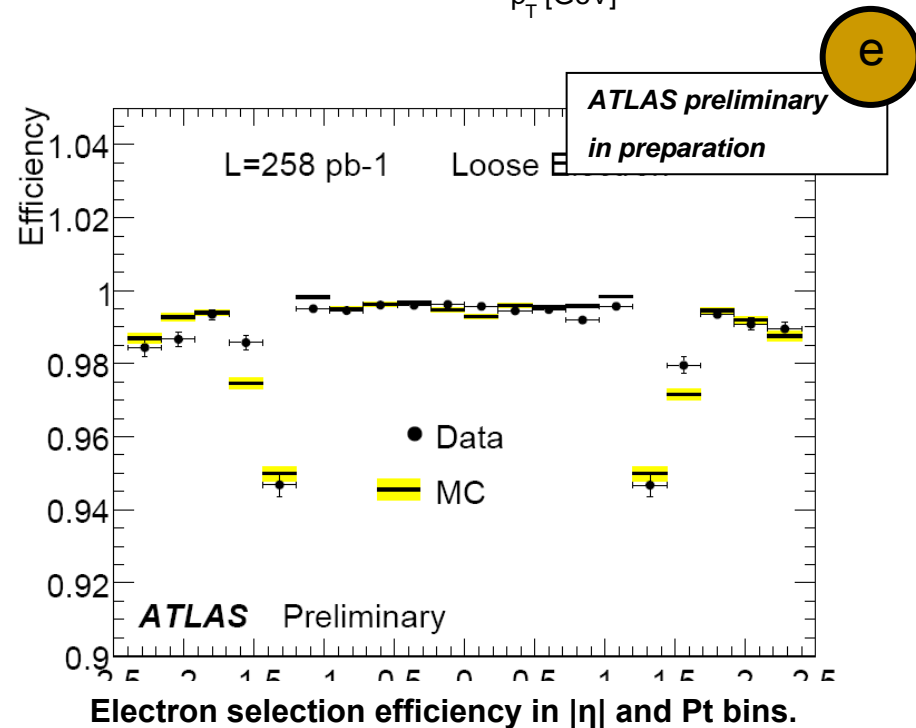
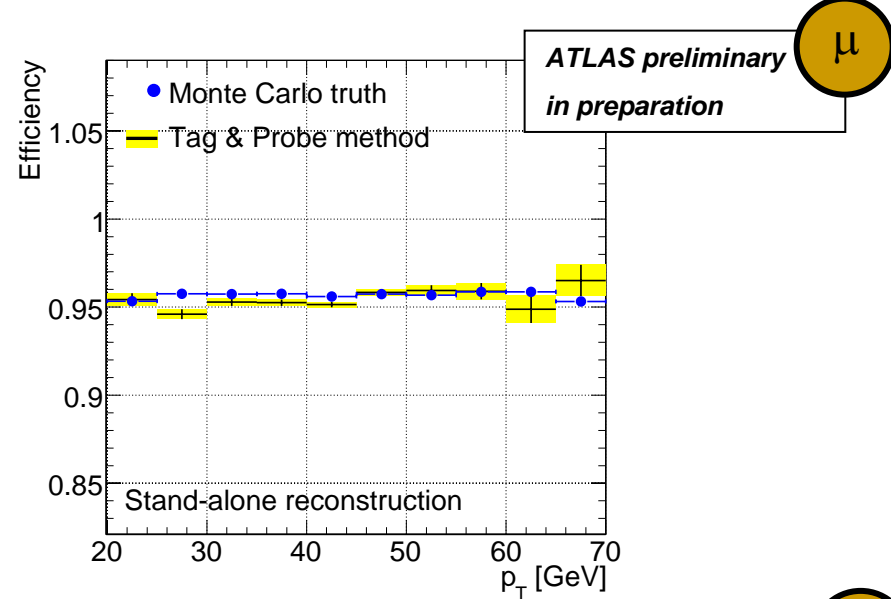


## Clean Signal :

- efficiency  $\rightarrow$  PDF
- calibration  $\rightarrow$  Uniformity
- isolation  $\rightarrow$  SUSY events

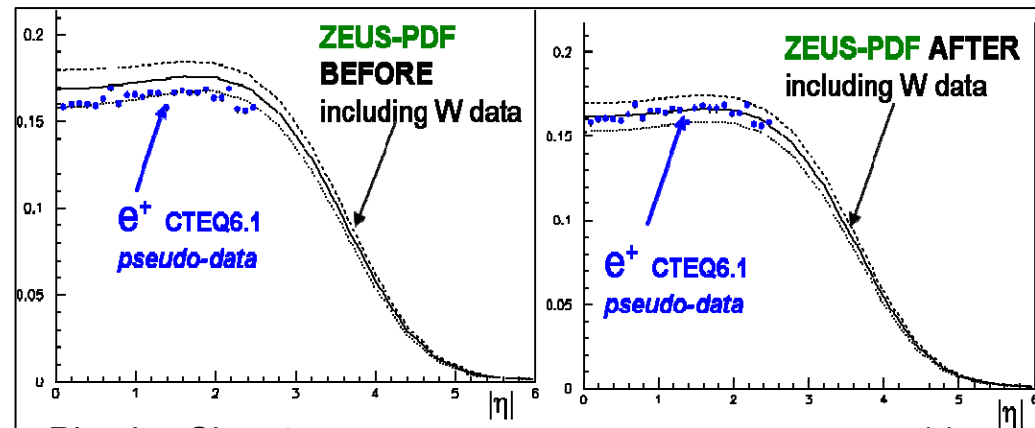
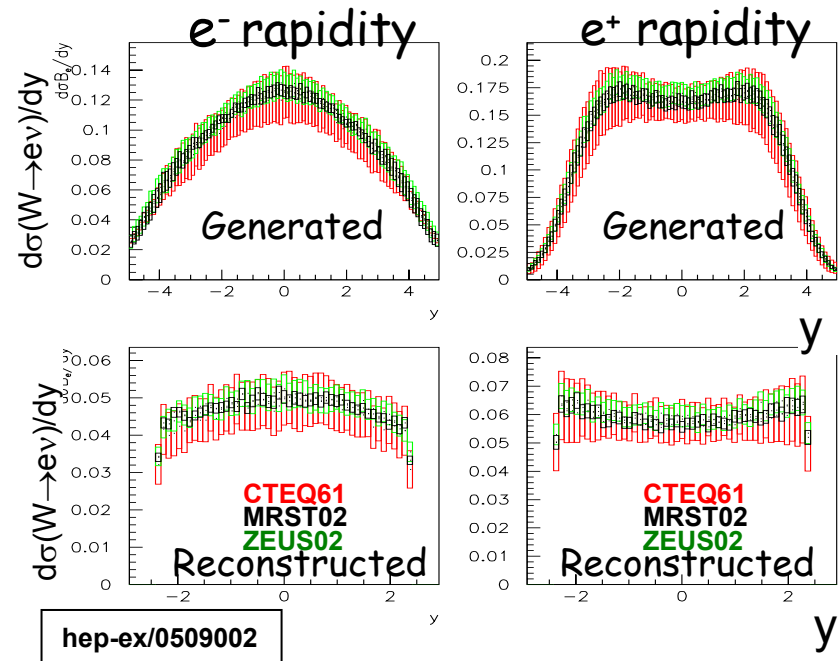
# Tag&Probe efficiency

- 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:
  - $\sim 1\%$  @  $50 \text{ pb}^{-1}$  (stat)
  - overlap region



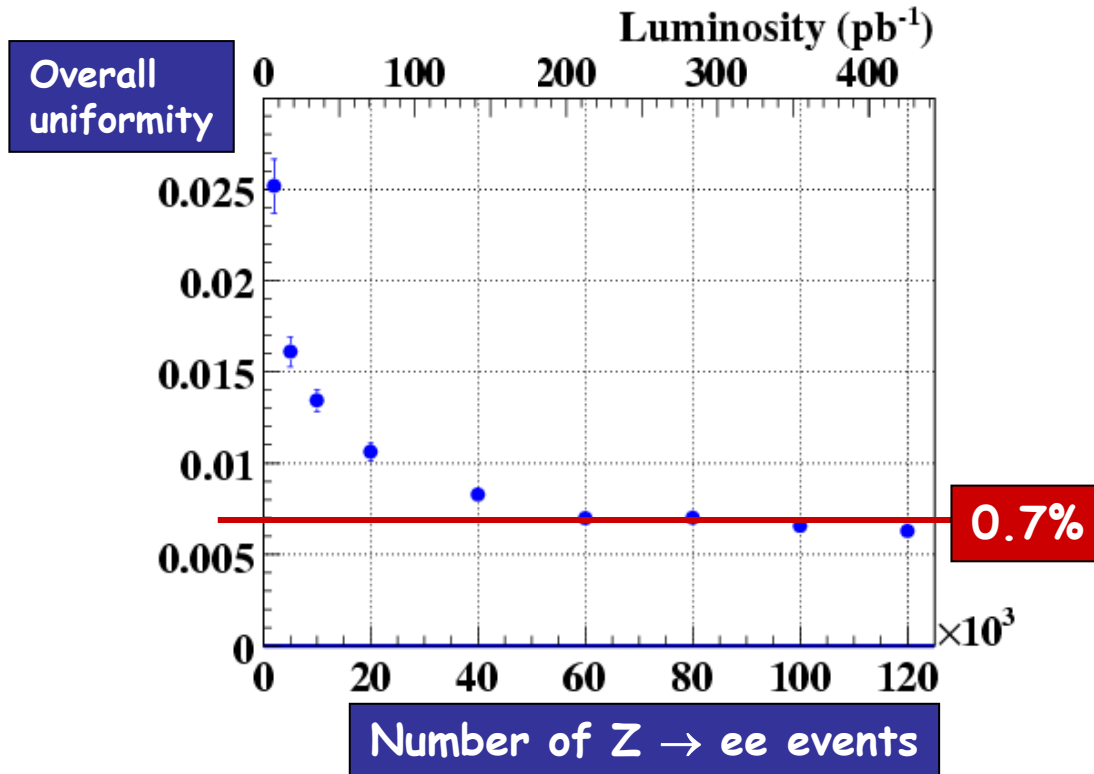
# PDFs

- 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<sup>-1</sup> 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

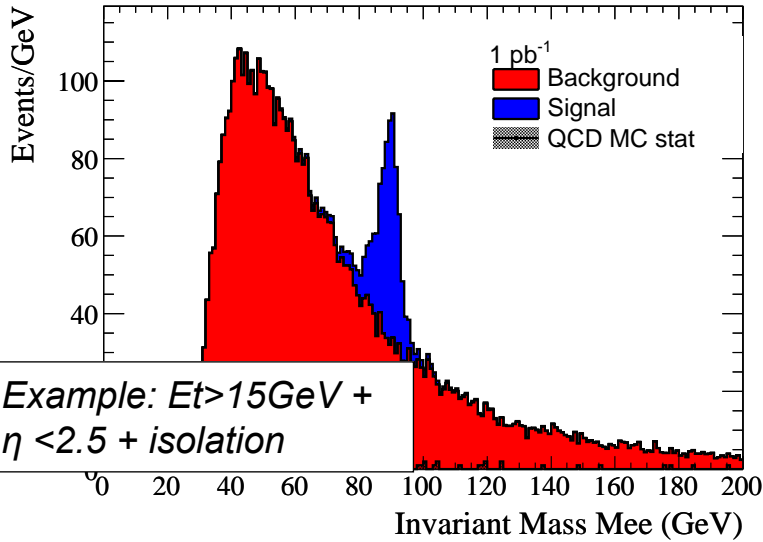


Uniformity necessary for  
 $H \rightarrow \gamma\gamma$

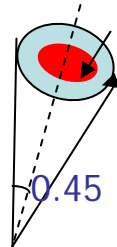
# Example: Isolation a powerful tool

$(\sigma(\text{QCD}) = 2 \text{ mb})$

$Z \rightarrow e^+e^-$



Example:  $E_t > 15 \text{ GeV} + \eta < 2.5 + \text{isolation}$

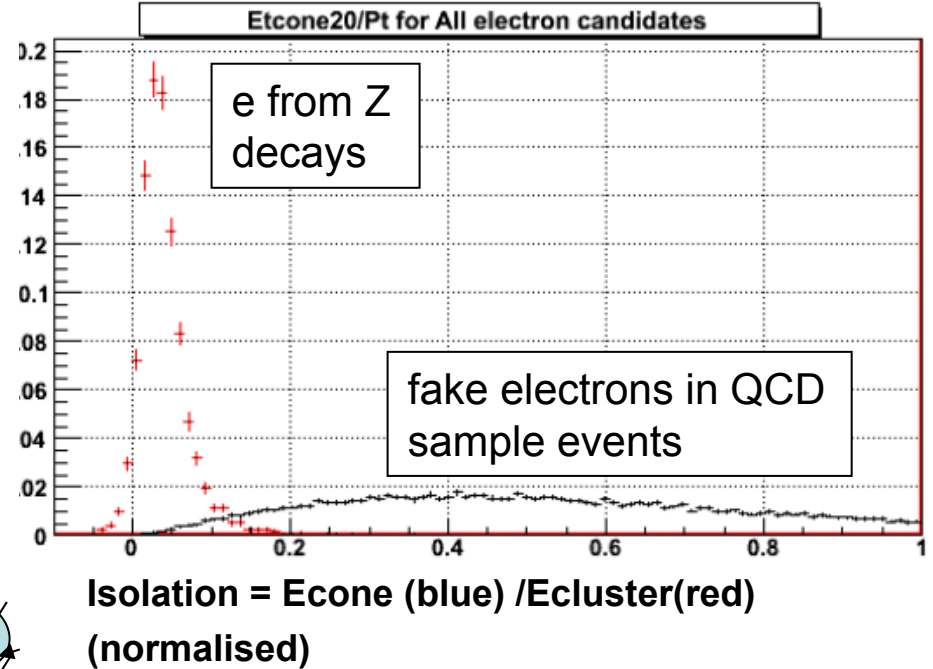


But in real condition control of :

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

5-11/01/2008

LHC New Physics Signature



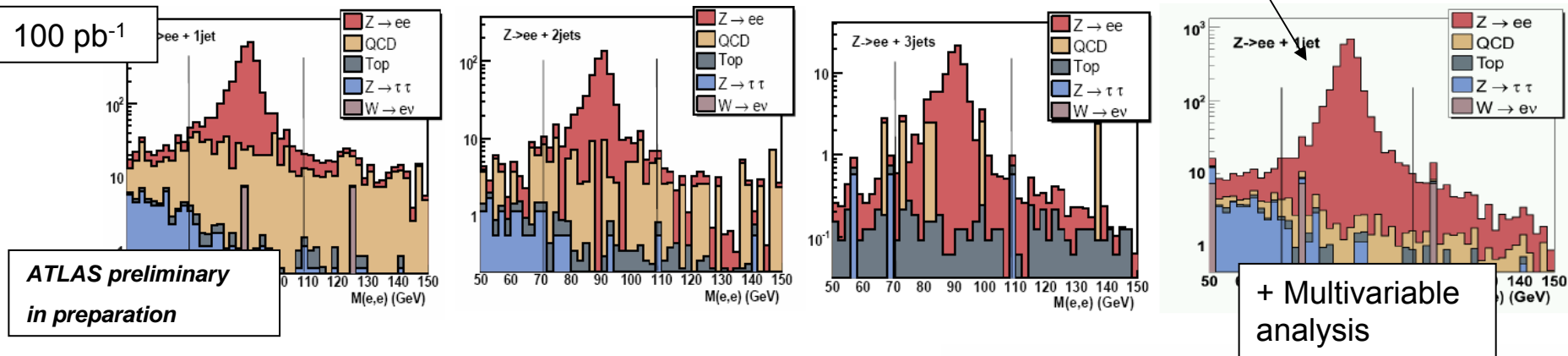
At the end a tool to clean new (other) physics signature:

- Z+jets
- SUSY events

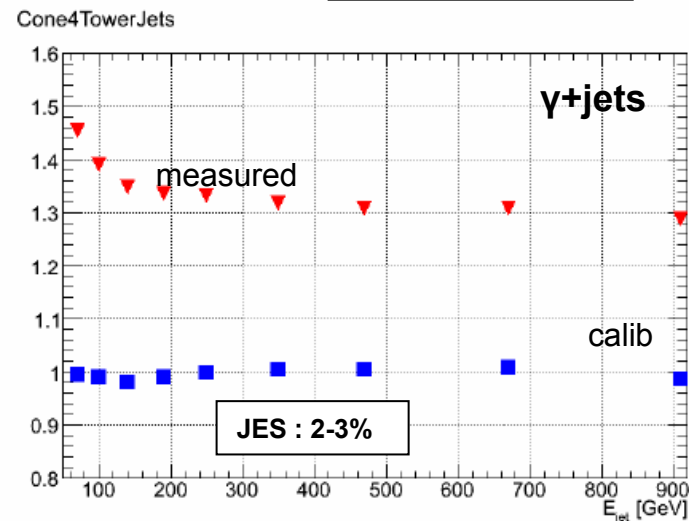
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# pp -> W/Z + Jets / $\gamma$ + Jets

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



- Relevant background for many new particles searches, top physics studies
- First step in reducing jet energy scale uncertainties :  
- recoil to Z/ $\gamma$  mass





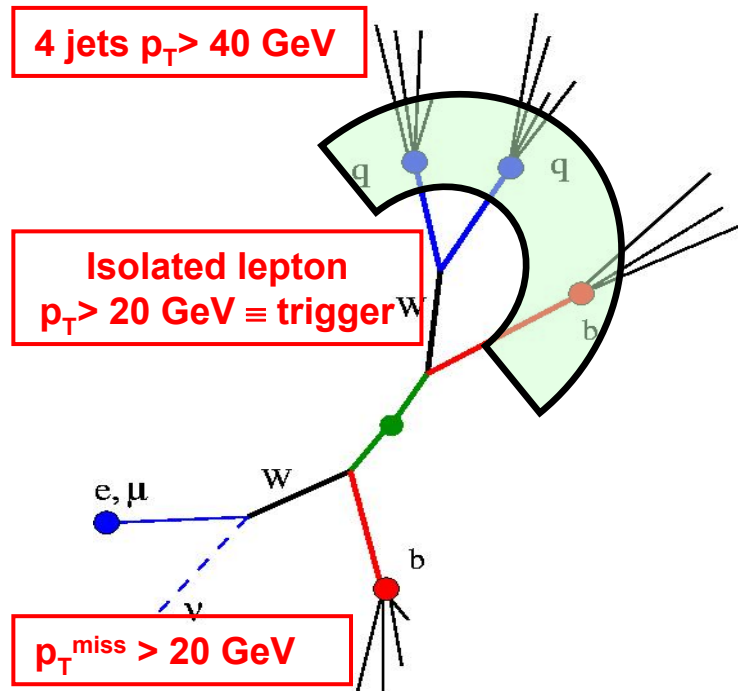
# A needless motivation for TOP Physics @LHC

Top in the Standard Model:

The heaviest known particle

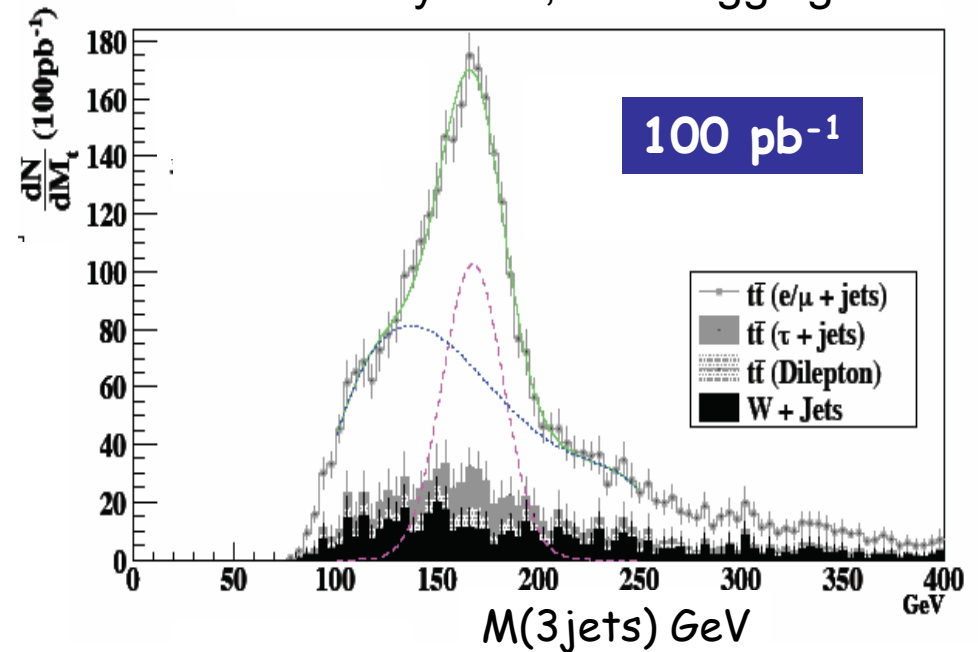
The least known – limited by statistics of Tevatron

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



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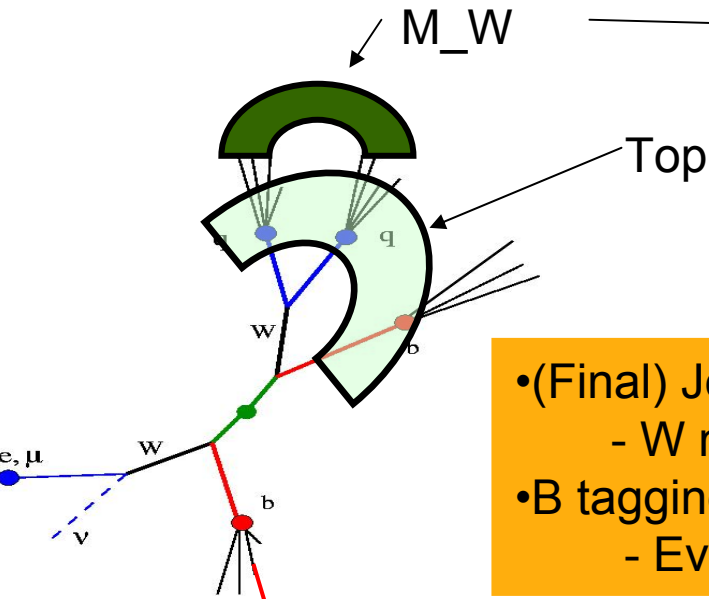
early data, no b tagging



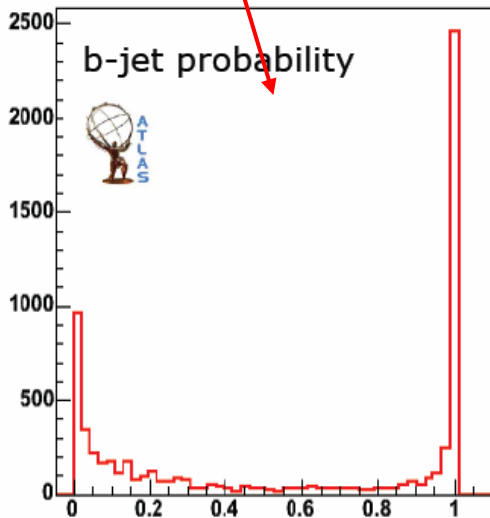
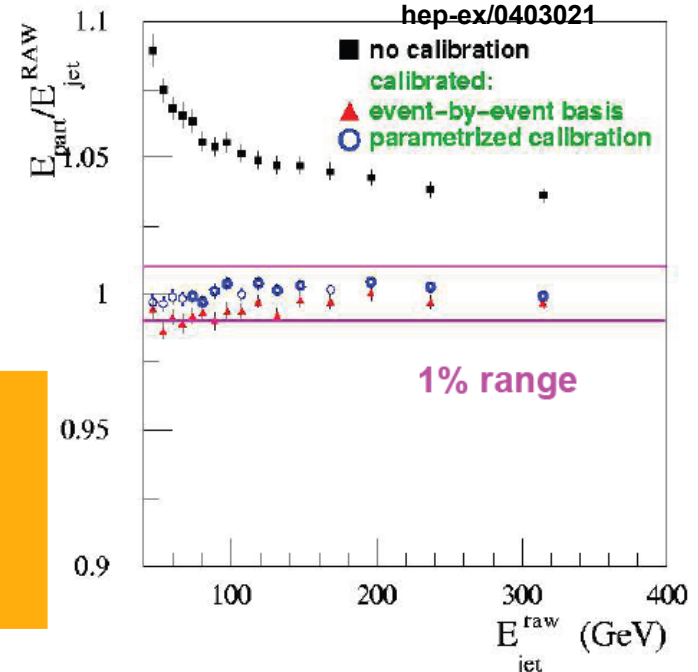
LHC New Physics Signature

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# TOP Physics (cont')

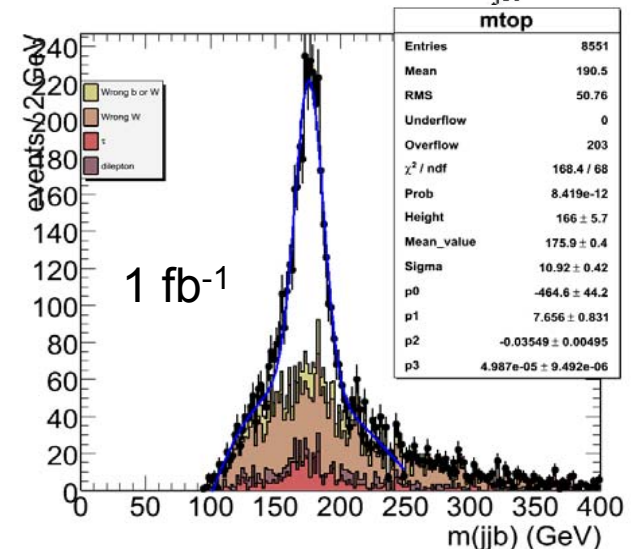


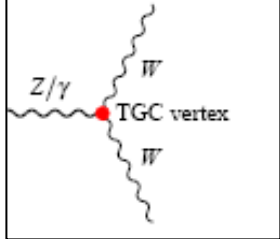
- (Final) Jet Energy Scale:
  - W mass constraint
- B tagging:
  - Event fully reconstructed



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

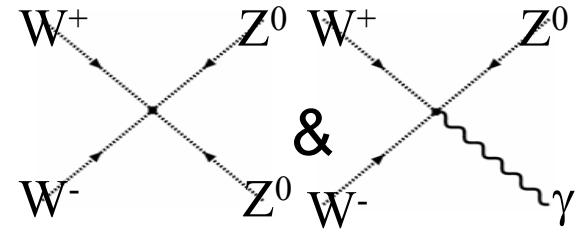
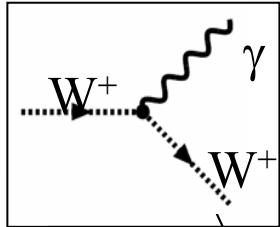
LHC New Physics Signature



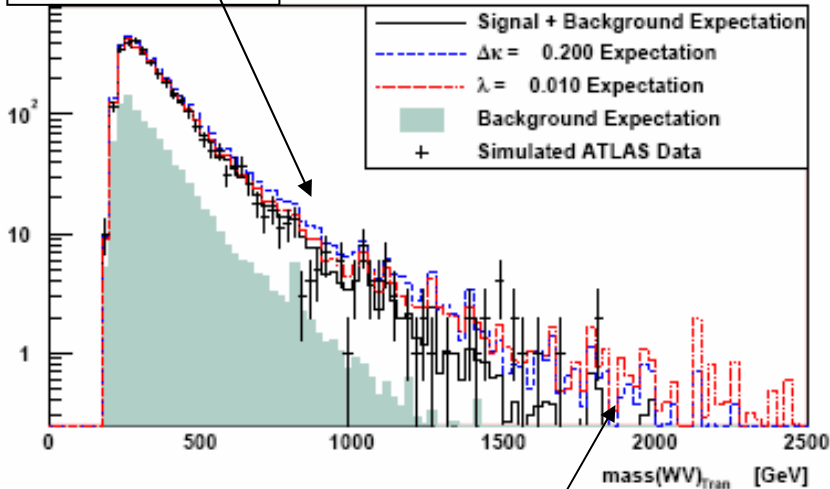


# T (and more) GC

Effective couplings independent of underlying theory

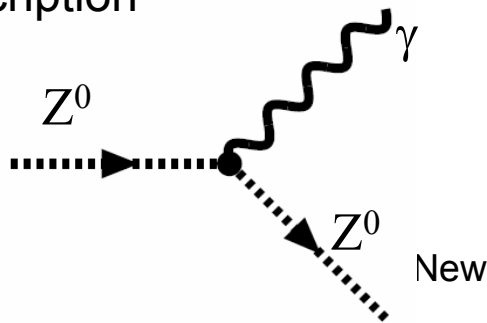


See Detailed Talk by Alan Wilson



Fake gamma rate

Tails' description



5-11/01/2008

| Vertex      | Coupling              | Present Value (LEP & Tevatron) | Atlas Sensitivity (95% CL, 30 fb <sup>-1</sup> one experiment) |                                       |
|-------------|-----------------------|--------------------------------|--|---------------------------------------|
| WWZ         | $\Delta g_1^Z$        | $-0.016 \pm 0.022 / 0.019$     | $-0.003 - 0.016$   | Syst limited ~ 30-100fb <sup>-1</sup> |
|             | $\lambda_Z$           | $-0.088 \pm 0.063/0.061$       | $-0.008 - 0.005$   |                                       |
|             | $\Delta\kappa_Z$      | $-0.076 \pm 0.061/0.64$        | $-0.069 - 0.131$   |                                       |
| WW $\gamma$ | $\lambda_\gamma$      | $-0.028 \pm 0.020/0.021$       |  | Stat limited 300 fb <sup>-1</sup>     |
|             | $\Delta\kappa_\gamma$ | $-0.027 \pm 0.044/0.045$       |  |                                       |

LEPEWWG/TGC/2005-01

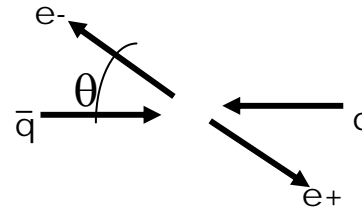
ATLAS preliminary in preparation

Neutral TGC : 0 in SM  
 With 100 fb<sup>-1</sup>: sensitivity to 10<sup>-3</sup> to 10<sup>-4</sup>  
 Tevatron ~ 10<sup>-1</sup> to 10<sup>-3</sup> / Weak LEP limit

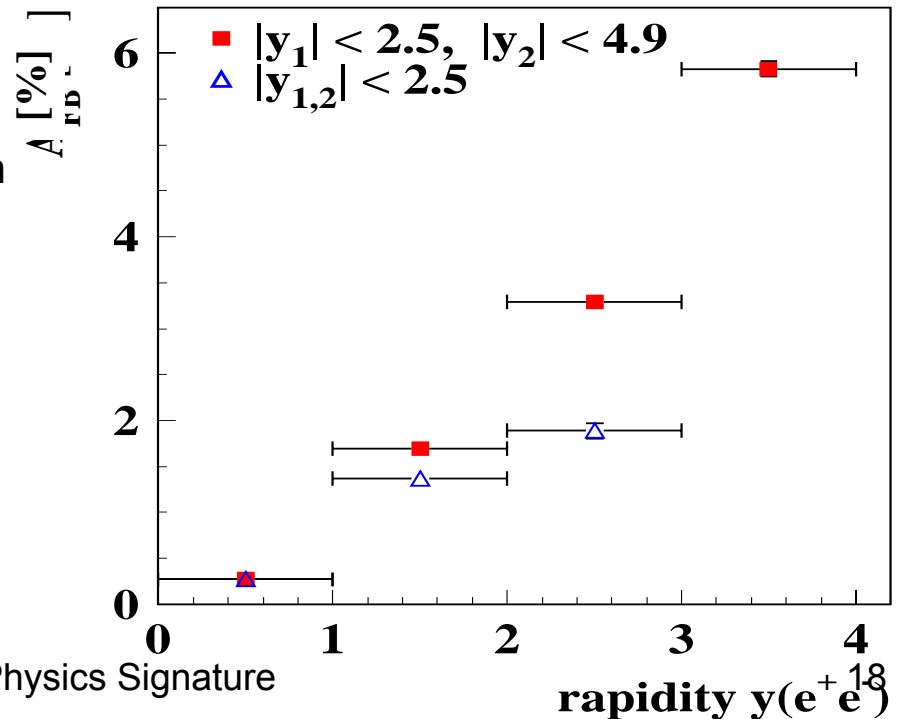
# Determination of $\sin^2\theta_W(M_Z^2)$

- Z decay asymmetric : 
$$\frac{1}{\sigma} \frac{d\sigma}{d\cos\theta} = \frac{3}{8} N_c \left[ 1 + \frac{4}{3} A_{FB} \cos\theta + \cos^2\theta \right]$$

- $A_{FB} = b \{ a - \sin^2\theta_W(M_Z^2) \}$   
 $a, b$  calculated to NLO QED and QCD



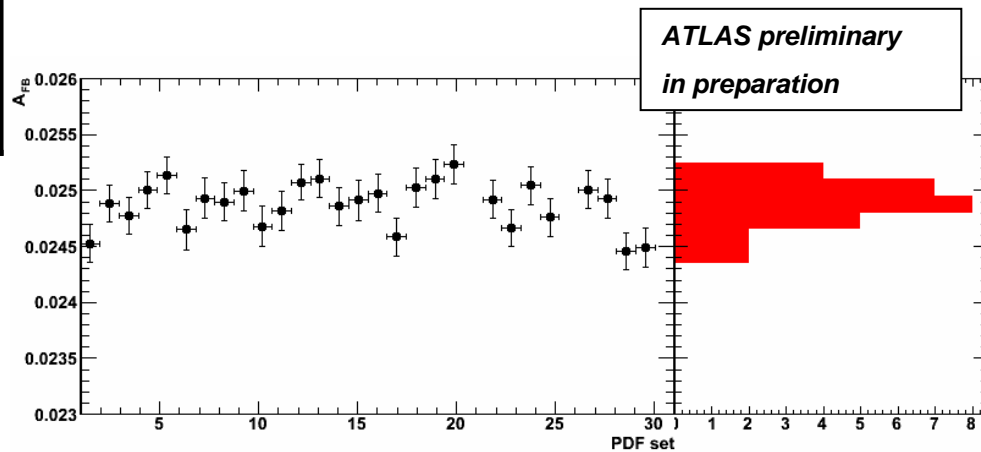
- Selection :
  - at least 1 electron in central region > charge
  - $P_T > 20$  GeV
  - Mass window  $M_Z \pm 6$  GeV
  - Missing  $E_t$  cut  $< 20$  GeV



# sin<sup>2</sup>(θ<sub>W</sub>) (cont')

| y cuts – e <sup>+</sup> e <sup>-</sup><br>( y(Z)  > 1)    | A <sub>FB%</sub>       | ΔA <sub>fb</sub> stat<br>100 fb <sup>-1</sup> |
|---|------------------------|---|
| y(l <sub>1,2</sub> )  < 2.5                               | 3.0 × 10 <sup>-4</sup> | 4.0 × 10 <sup>-4</sup>                        |
| y(l <sub>1</sub> )  < 2.5 +<br> y(l <sub>2</sub> )  < 4.9 | 2.3 × 10 <sup>-4</sup> | 1.4 × 10 <sup>-4</sup>                        |

World average error: 1.6x10<sup>-4</sup>

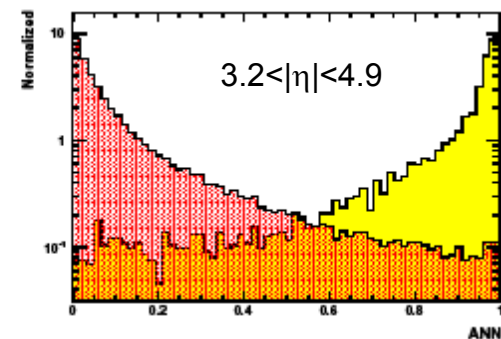
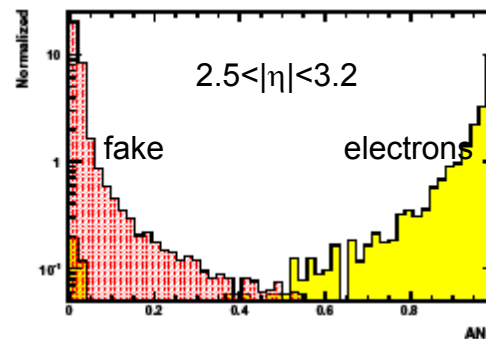


syst = maxValue-minValue = 7.6e-4 (worst case)

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

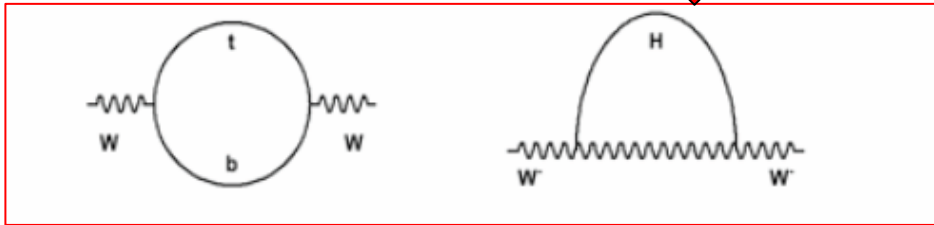
Electron in Forward region :

- etmiss
- new phys signature

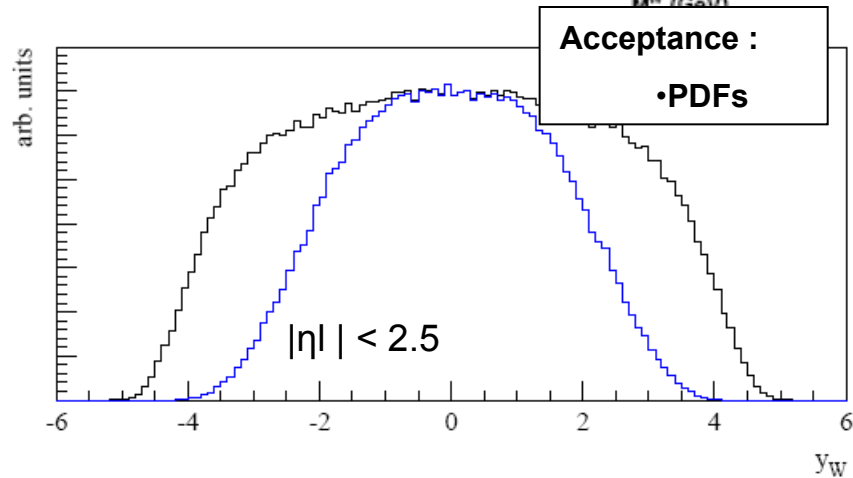
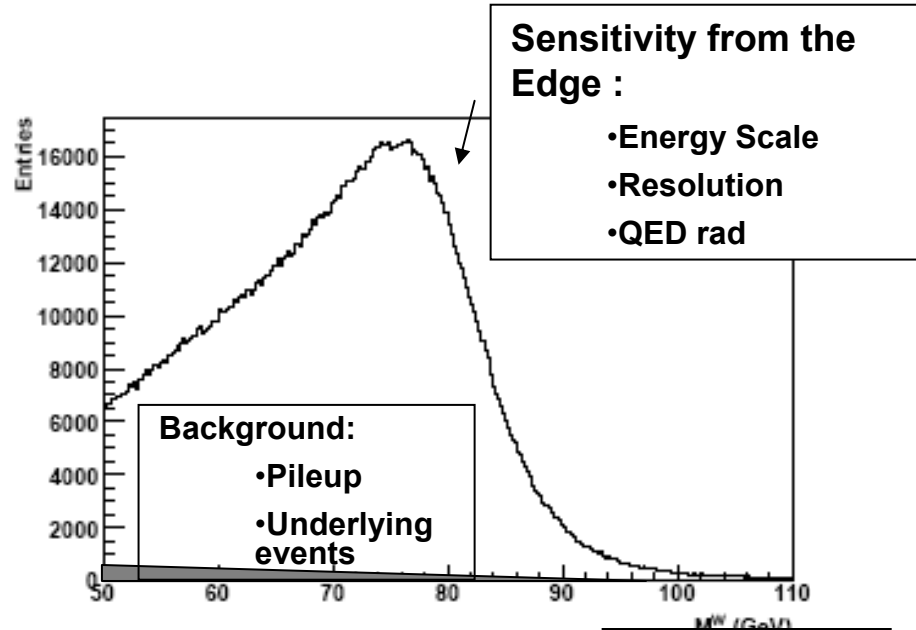


# THE precision measurement: $M_W$

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



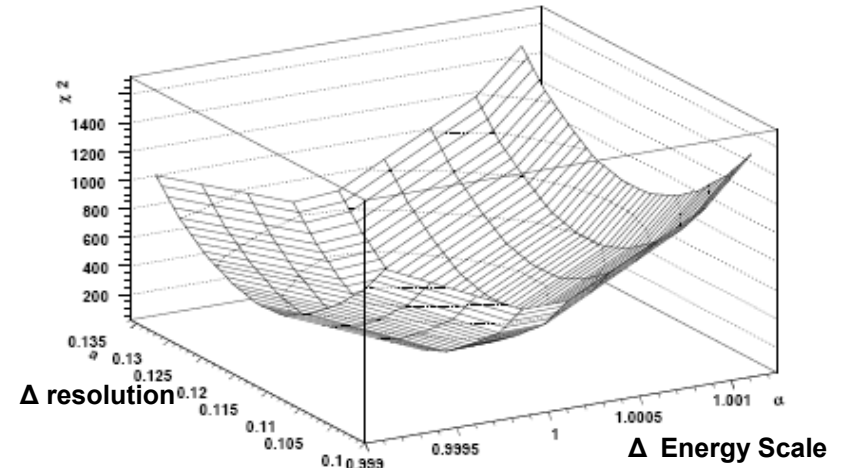
- Current error :
  - CDF Run II : 48 MeV
  - WA : 25 MeV
- Aim :  $M_W < 15$  MeV
- Observables sensitive to  $M_W$ 
  - Lepton Transverse Momentum
  - **Transverse Mass**





# Exemple : Energy Scale

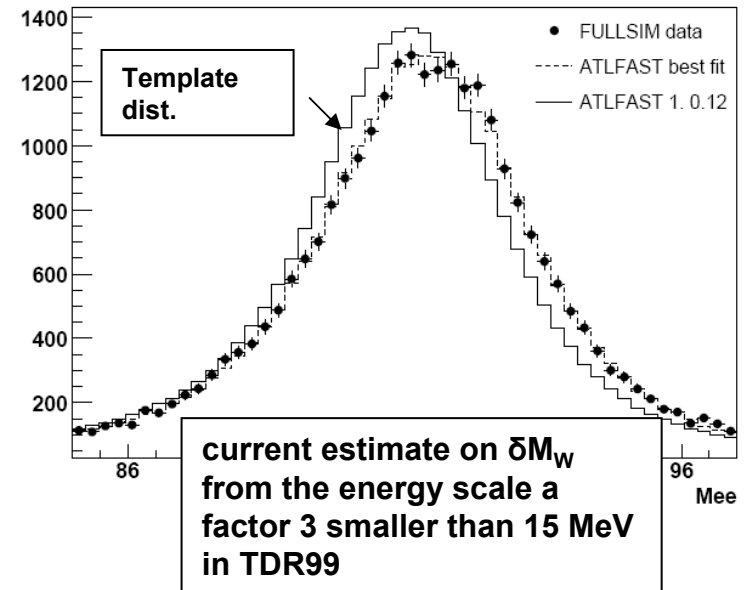
- Systematics controls from the (huge) Z sample:
  - precise Mass (LEP) :  $2 \cdot 10^{-5}$
  - similar production mechanism
  - similar phase space



| Channel                                      | $W \rightarrow l\nu$ | $Z \rightarrow ll$ |
|--|----------------------|--------------------|
| Cross-section (pb)                           | 19800                | 1870               |
| Lepton $\eta$ acceptance                     | 0.63                 | 0.51               |
| Trigger & Selection eff.                     | $\sim 0.2$           | $\sim 0.2$         |
| Expected statistics ( $10 \text{ fb}^{-1}$ ) | $4 \times 10^7$      | $3.5 \times 10^6$  |

LEP :  $\sim 4 \cdot 10^6$  Z / exp

- Additional data sets: E/p



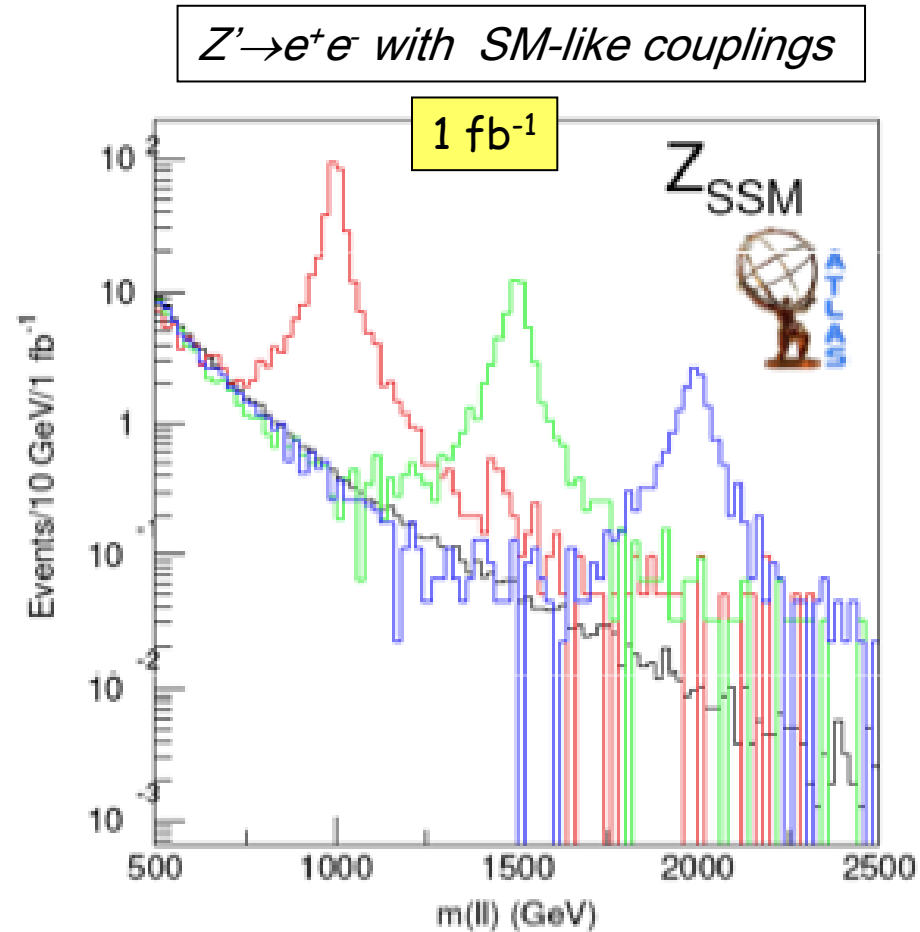
# Conclusions : The Ground to New Physics

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

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

