First Physics in ATLAS
(including electroweak and top)

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On behalf of the ATLAS collaboration

Outline :

- Early data : minimum bias / underlying event / SM candles
- Early top physics & prospects for the top mass

(W mass prospects & TGCs not covered here, not early measurements)

DIS april 07 - München   EW and BSM Session

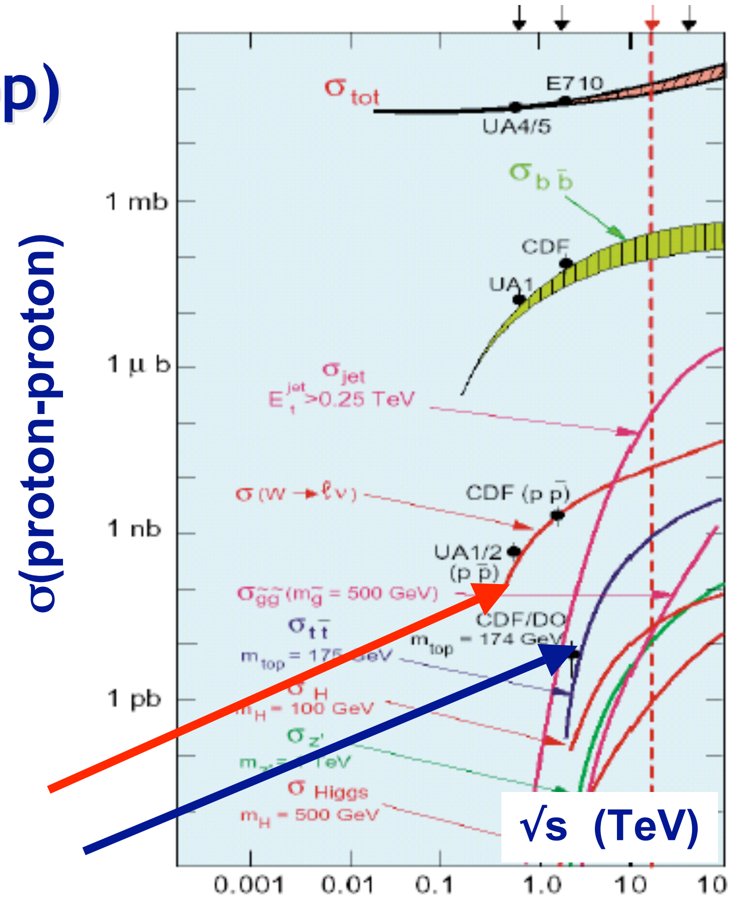
Physics motivation (electroweak & top)

The LHC is a top, W and Z factory :

$\sigma(W \to l\nu)$ ~ 15 nb 10^7 evts / 1 fb^{-1} (low lumi)
$\sigma(Z \to ll)$ ~ 1.5 nb 10^6 evts / 1 fb^{-1}
$\sigma(t\bar{t})$ ~ 0.8 nb 10^6 evts / 1 fb^{-1}

→ large samples to study systematic effects, perform precision measurements and search for rare processes !

$\sigma(W \to l\nu)$ @ LHC x 10 Tevatron
$\sigma(t\bar{t})$ @ LHC x 100 Tevatron

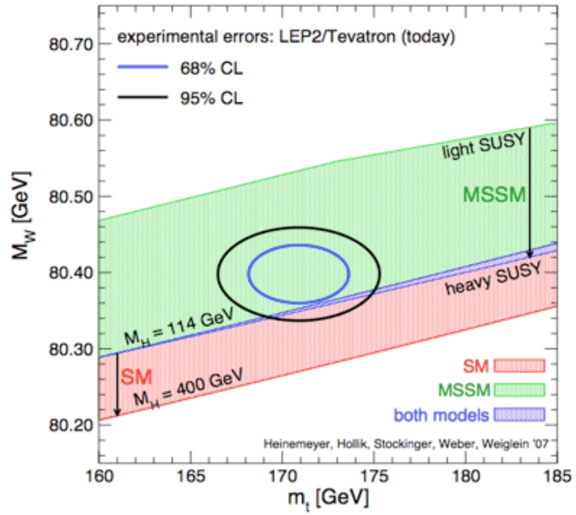


The top and W masses are crucial parameters of the SM : allow to constrain the mass of the Higgs boson.

For equal contribution to the M_H uncertainty :

$\Delta M_W = 0.7 \times 10^{-2}\ \Delta M_{top}$

$\Delta M_{top} < 2$ GeV → $\Delta M_W < 15$ MeV

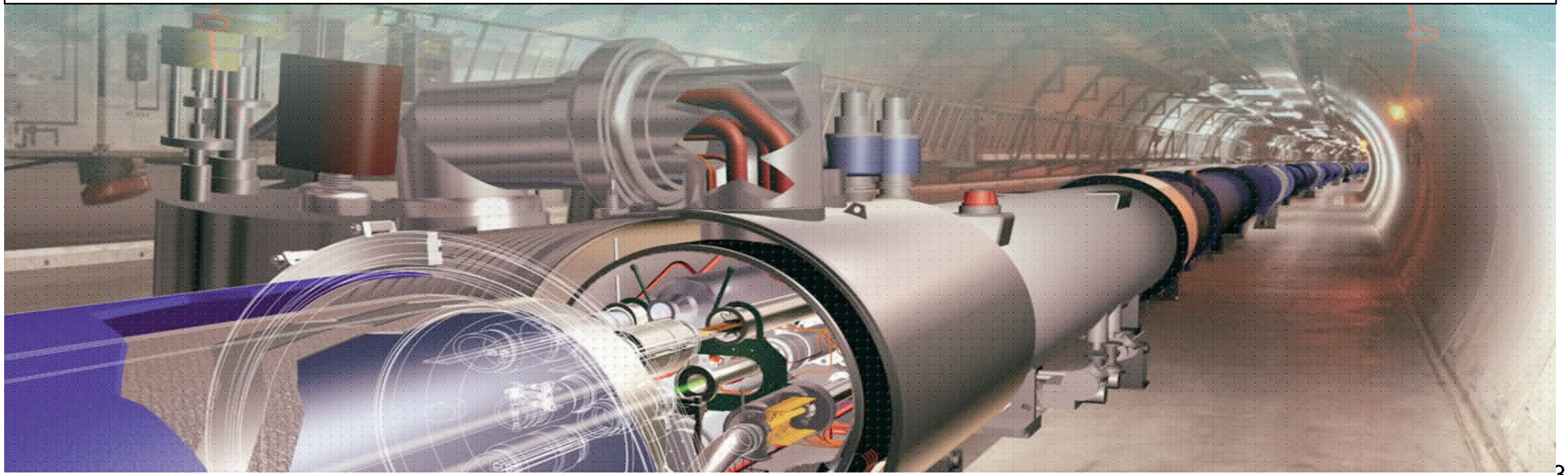


LHC possible startup scenario

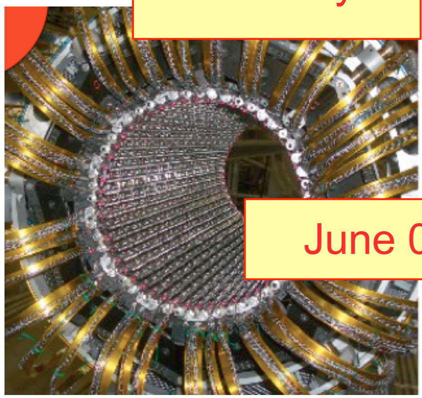
- End 2007 - early 2008 (??) :
  - single beam operations @ 450 GeV
  - pp collisions @ $\sqrt{s}$ =900 GeV L= 10^{29} $cm^{-2}.s^{-1}$

- Summer 2008 : pp collisions @ $\sqrt{s}$ = 14 TeV
  - Until 2009 : L = 5.10^{30} - 1.10^{33} $cm^{-2}.s^{-1}$
  - After 2009 : L = 10^{34} $cm^{-2}.s^{-1}$, bunch spacing = 25 ns

Integrated luminosity end 2008 : 0.5 to 1 fb^{-1} ?

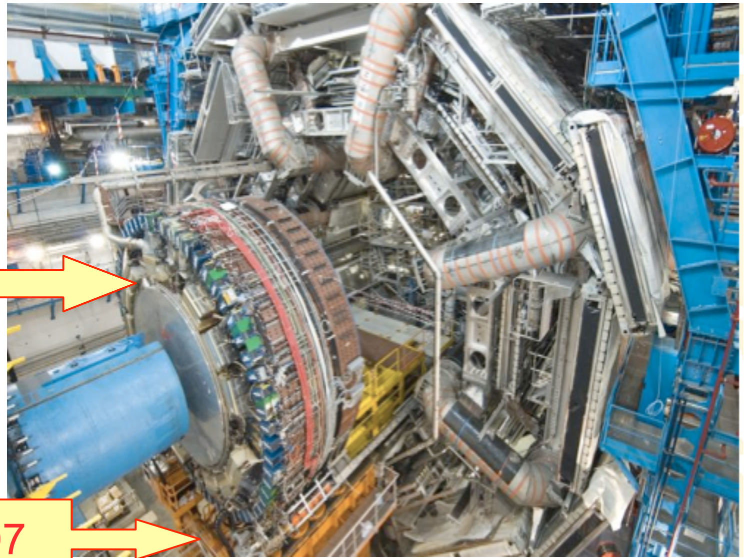


The ATLAS detector in early days



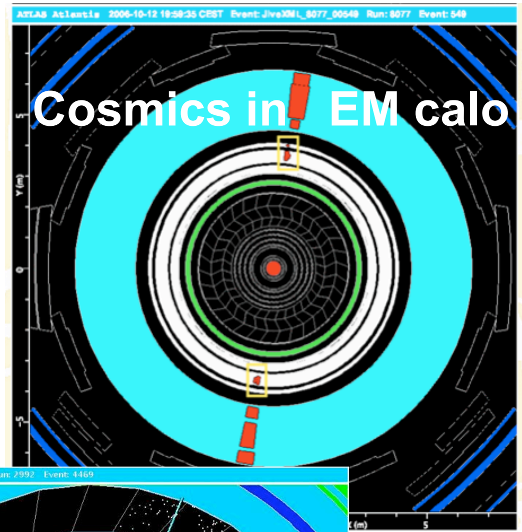
Major steps remaining :

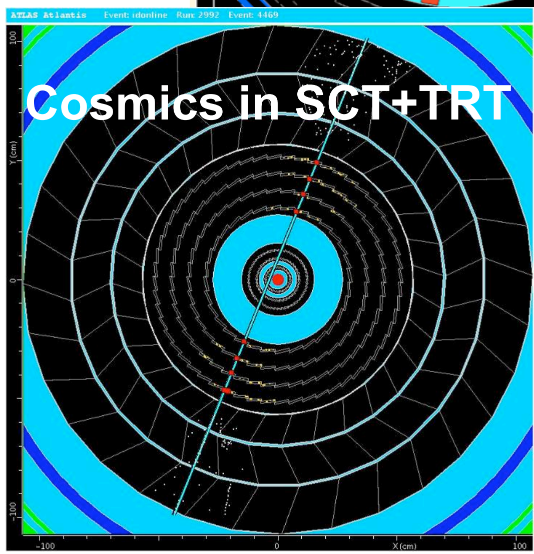
Inner-detector endcap / pixel / endcap toroid installation



June / July 07

June 07



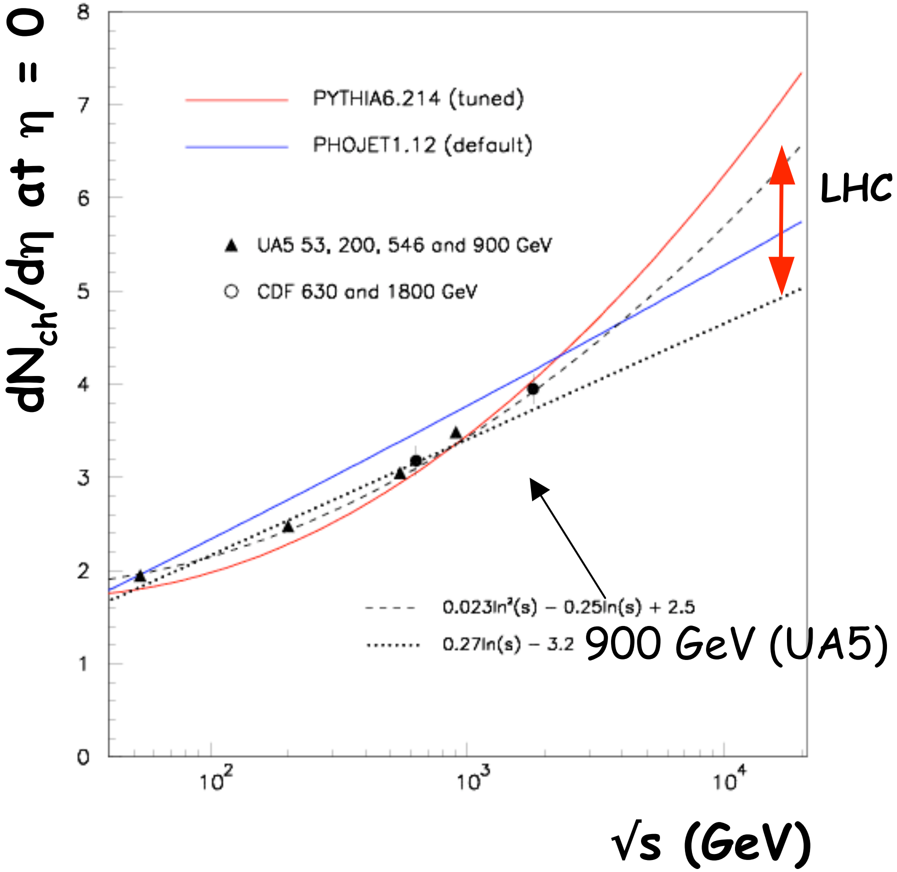


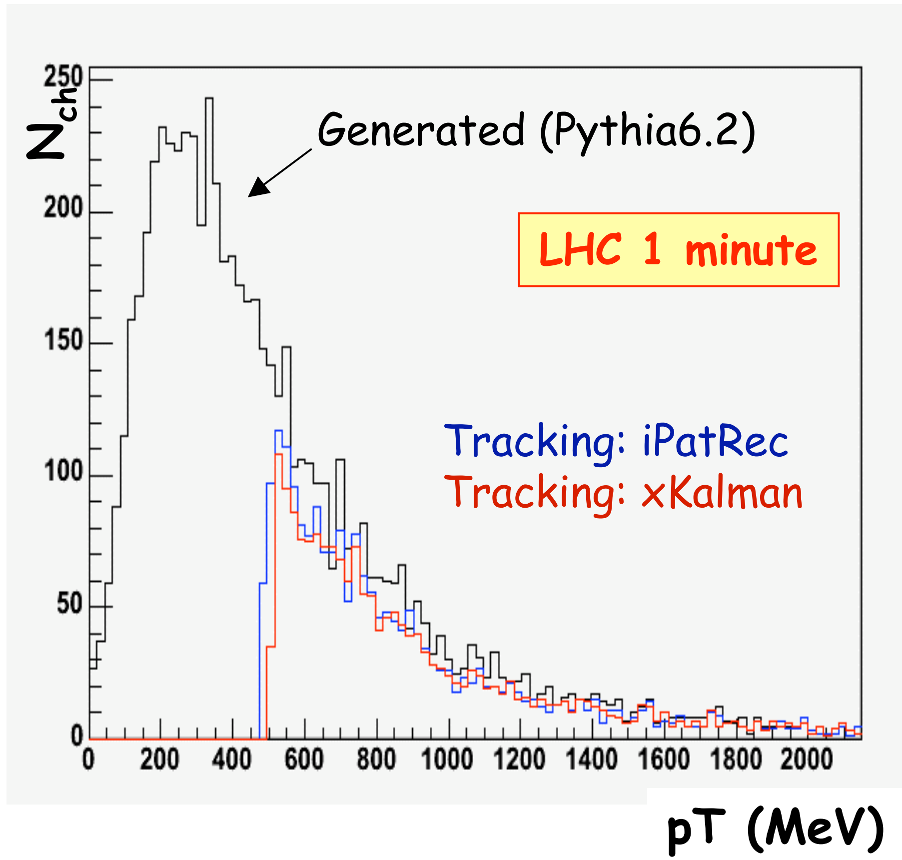
→ ATLAS on a tight schedule to operate almost complete fall 2007

Expected detector performance on day one:
- ECAL uniformity : ~1%
- e/γ scale : 1-2 %
- HCAL uniformity : ~2-3%
- Jet scale <10%
- Expected alignement of 20-200 μm in R-φ

Minimum bias (@ √s = 900 GeV and 14 TeV)

→ Large uncertainties in the predicted particle multiplicities @ √s = 14 TeV





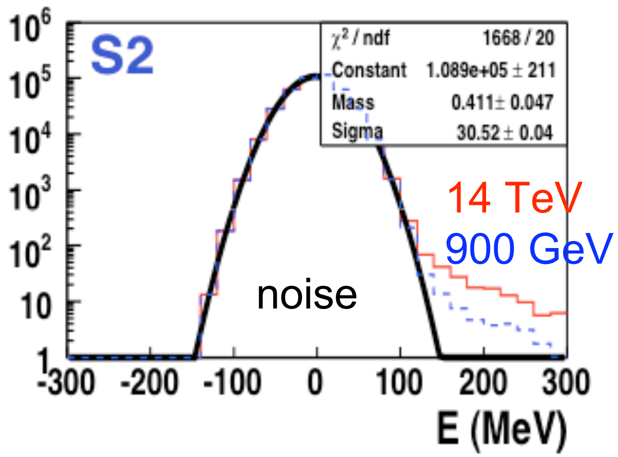
- Expected LHC inelastic cross-section : 70 mb ?
- Control the charged particle multiplicities $dN_{ch}/d\eta$ & dN_{ch}/dp_T
- Track reconstruction straightforward above 500 MeV only (cut-off at ~ 400 MeV)
- Reconstruct track segments in pixels down to ~100 MeV ?

Use minimum bias @ √s = 900 GeV and 14 TeV

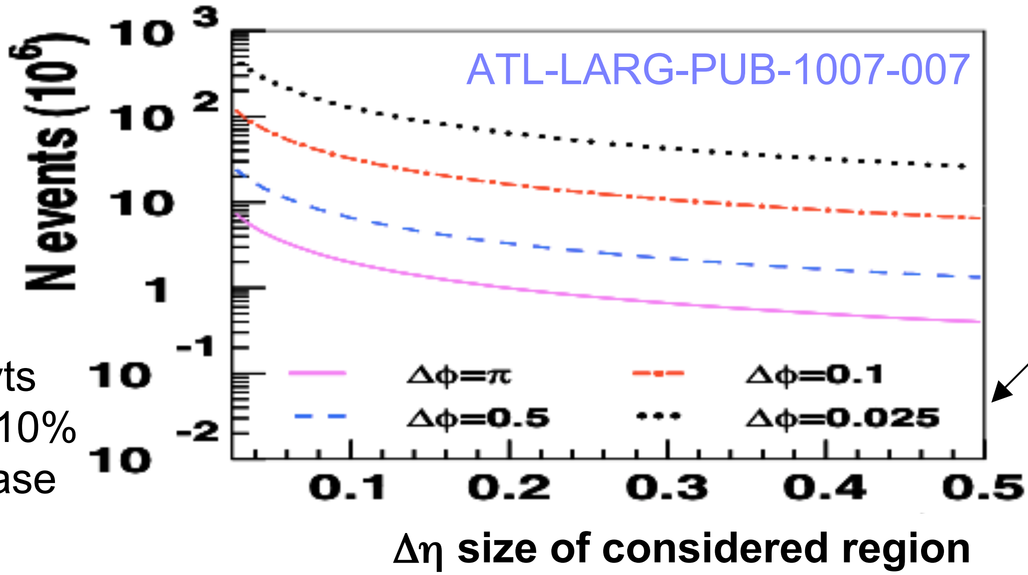
Ex. : commissionning of the electromagnetic calorimeter :

- Map of all EM calo cells in ~1 day :
  → dead cells, HV failures …

Monitoring of energy depostion
in one cell of 2nd. sampling →



- Energy flow in second sampling (mainly low energy non converting photons) sensitive to tracker material vs φ
  → excess of 10% of X_0 in ΔηxΔφ visible with ~2 weeks of data



(EM calo uniformity, expected to be better than 1% - from test beam experience)*

Δϕ size of considered region

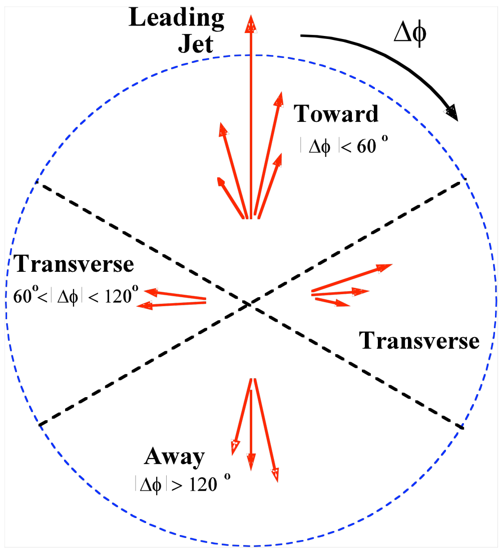
Number of evts to observe a 10% relative increase in X_0

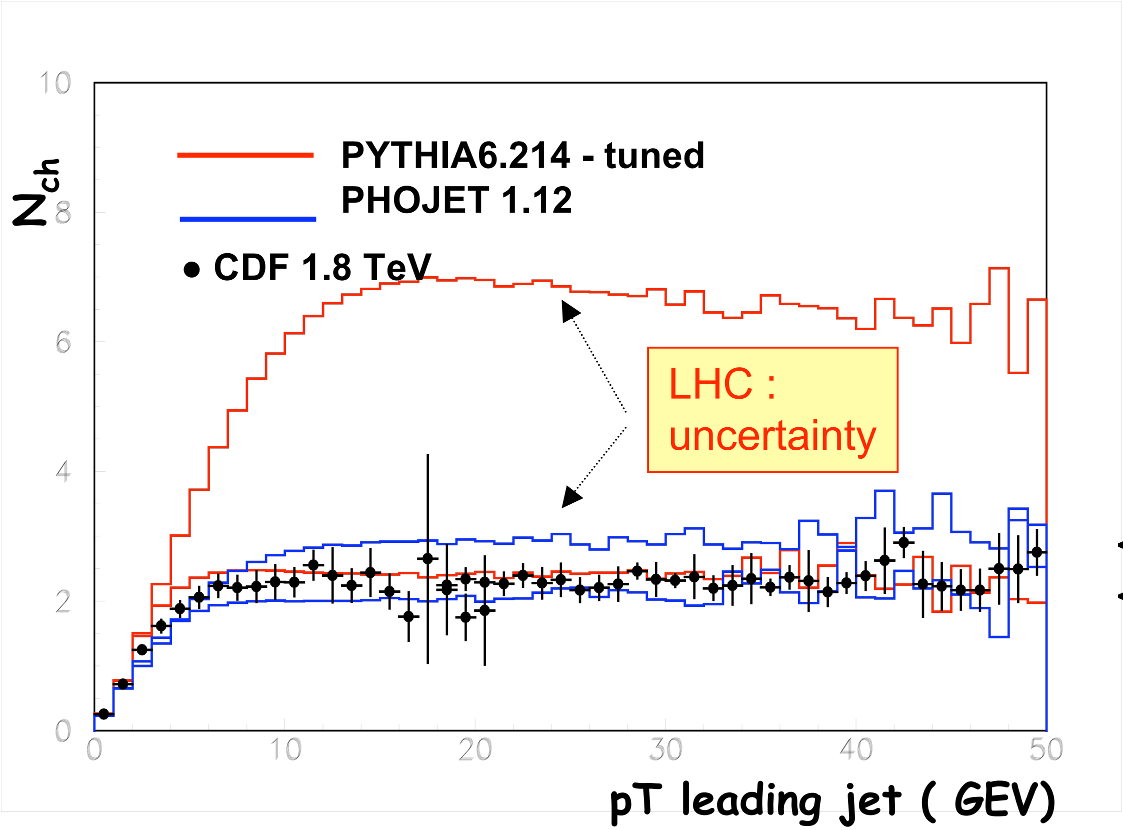
Underlying event in dijet production ($\sqrt{s}$ = 14 TeV)

Underlying event also uncertain at LHC :

- Depends on : multiple interactions, PDFs, gluon radiation
- Important ingredient for :
  Isolation of jets and leptons, energy flow, jet tagging …

Measure underlying event through flow of charged particles in region transverse to the jets (p_T>0.5 GeV $|\eta|$<1.)





← Compare plateaus in early runs
← ~20 M events needed to reach p_T ~ 30 GeV

Select the Standard Model candles

Low luminosity runs (L=0.5 10^{30} - 10^{33} $cm^{-2}.s^{-1}$) will allow to trigger early on on large samples of SM candles :

- $Z \rightarrow ll$
- $W \rightarrow l\nu$

$\rightarrow$ l = e/μ but also τ (hadronic τ + E_t^{miss} trigger)

A few analyzes topics :

- Energy and momentum scale calibration from $Z \rightarrow ll$ (l = e/μ)
- E_T^{miss} calibration from $W \rightarrow l\nu$
- Understand W+jets and Z+jets : important background for $t\bar{t}$ and SuSy !
- Measure the $W \rightarrow \tau\nu$ cross section : validation of τ-id needed for Higgs and SuSy searches !

LVL1 Menu	$2x10^{33} cm^{-2} s^{-1}$
MU20	0.8
2MU6	0.2
E25i	12.0
2E15i	4.0
J200	0.2
3J90	0.2
4J65	0.2
J60+xE60	0.4
TAU25+xE30	2.0
MU10+EM15i	0.1
Others	5.0
Total rate (kHz)	**~ 25**

(preliminary ...)

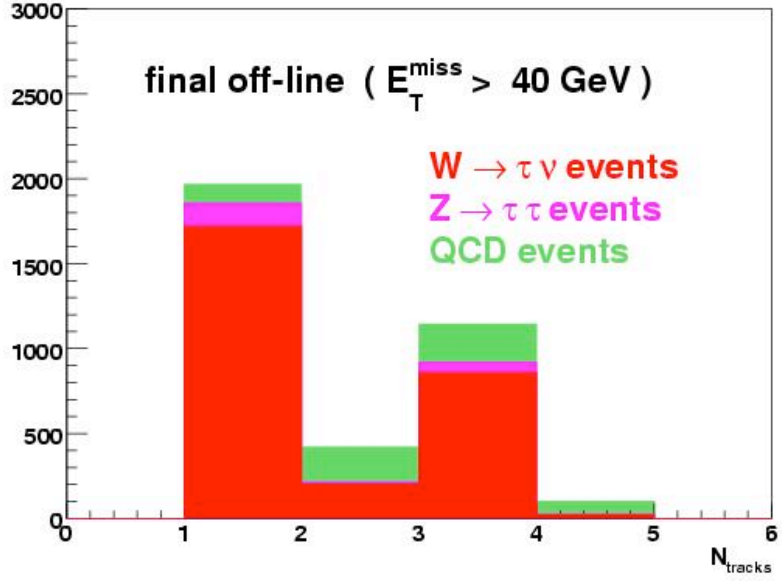
Prospects for W→τν

Aim is to extract a W→τν signal early on with an integrated luminosity of 100 pb^{-1} .

LHC : signal x 10 and multi-jet background x 100 with respect to Tevatron : E_T^{miss} cut needed .

→ Implement a hadronic τ + E_T^{miss} trigger and profit from low-luminosity operation to trigger at lowest possible E_T thresholds (20-30 GeV), raise E_T^{miss} cut as luminosity goes up.

Events for 100 pb^{-1} (preliminary)



Signal evidence through N_{track} spectrum

Event rates assuming eff ~ 80% for τ trigger, ~ 50% for τ reco/id →

Expected rates for 100 pb^{-1}	W → τν, τ →hadron	W → eν	Z → ττ, 1τ →hadron
σ.B (pb)	11200	17300	1500
τ30i + xE35	~ 15 000	~ 250 000	~ 1300
τ20i + xE25	~ 60 000	~ 560 000	~ 3500

Select $Z \to b\bar{b}$ @ $L = 2.\ 10^{33}\ cm^{-2}.s^{-1}$?

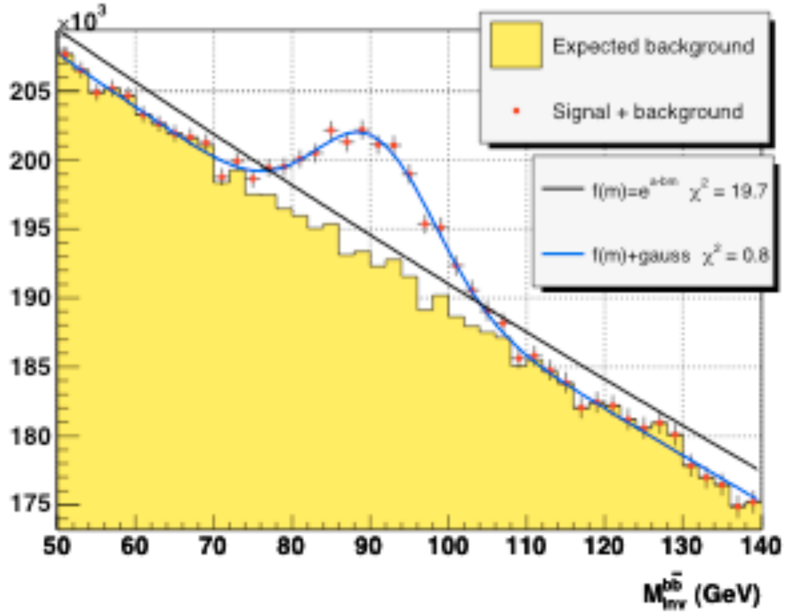
ATL-PHYS-PUB-2006-006

Crucial for measuring the b jet energy scale.

Offline strategy : Select Z + jet → $b\bar{b}$ + jet events instead of Z → $b\bar{b}$:

→ main selected background : gluon splitting at low $M_{b\bar{b}}$
→ allows to raise the p_T thresholds on b jets w/o cutting away the background low mass side band
→ higher S/B thanks to higher $p_T(b)$ thresholds

30 fb^{-1}



Trigger strategy :
(not (yet ?) in official trigger menu)

Implement at LVL1 : 1j120, 2j10 (expected rate ~ 5 kHz)

Use impact parameters / b-tagging at LVL2 to keep the multi-jet background low (expected rate ~100 Hz)

$|\eta| < 2.5$
p_T(leading jet)>190 GeV (not b-tagged)
2 b-jets p_T>40 GeV

$S/\sqrt{B}$ ~20 $80 < M_{b\bar{b}} < 100$ GeV

Early top studies : 100 pb^{-1}

Focus on semileptonic channel :

BR ($t\bar{t} \to WbW\bar{b} \to (l\nu b)(\bar{b}jj)$) ~30 %
Easy to trigger thanks to isolated lepton (e or μ)
Clean topology : t and $\bar{t}$ central and back-to-back

Typical event selection:

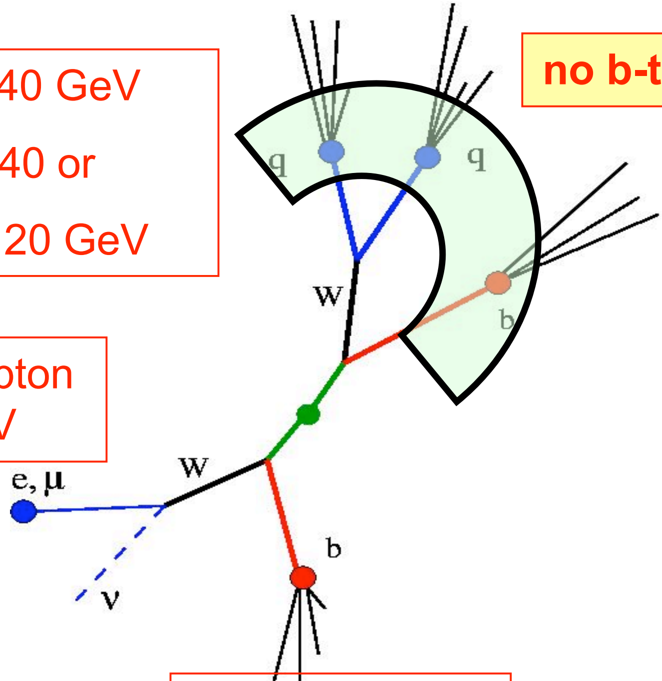
3 jets p_T >40 GeV

4th jet p_T >40 or 20 GeV

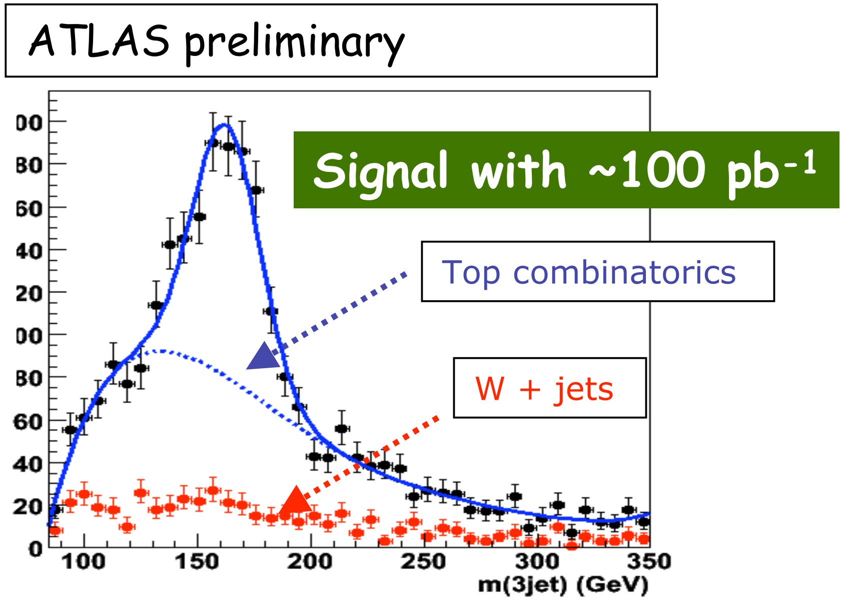
Isolated lepton pT>20 GeV

E_T^{miss} > 20 GeV

no b-tag !



Compute invariant mass of 3 jets with highest Σp_T :



If 2 b-jets requested :
BKG <2% : mainly W/Z+jets, WW, WZ, ZZ
Efficiency 1-2%

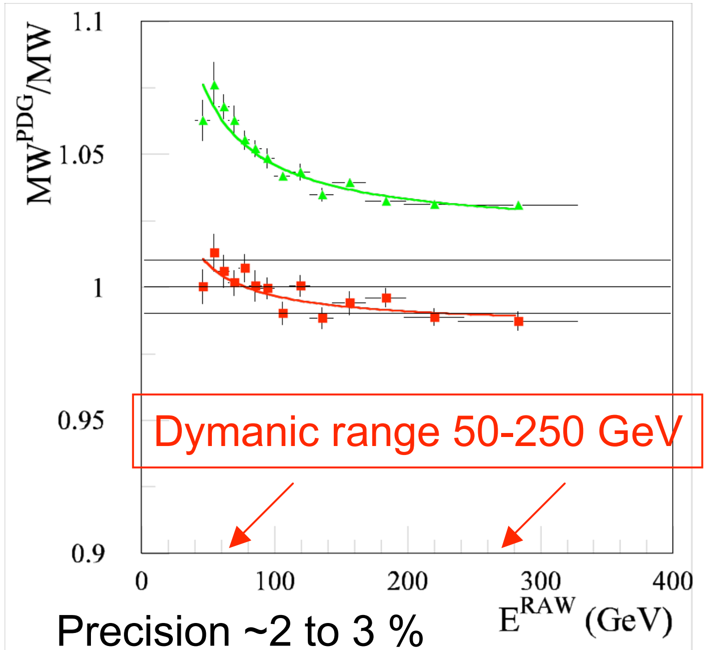
Exploiting the semileptonic $t\bar{t}$ signal

Extract the light jet energy scale (target <1%) :

1) Compute the W mass out of the 2 jets in hadronic top with highest momenta (jjj C.M. frame) : purity ~ 80% (2 b-tagged jets)

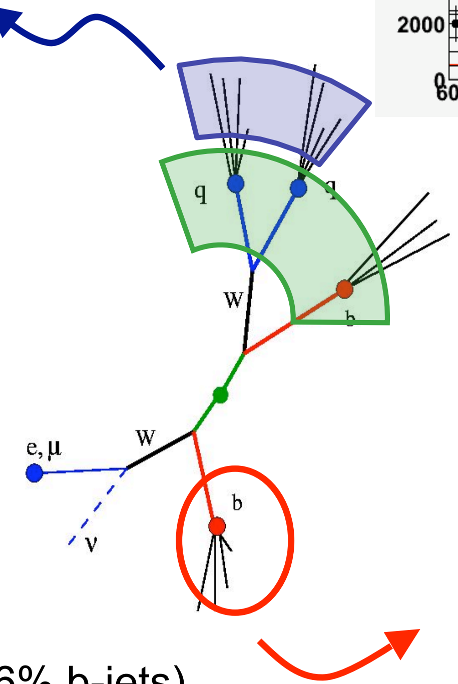
Invariant mass should add up to 80.4 GeV.

$$\begin{cases} M_{jj} = \sqrt{2E_{j1}E_{j2}(1-\cos\vartheta_{j1j2})} \\ E_j \to \alpha E_j \quad M_{jj} \sim M_W = 80.4\,GeV \end{cases}$$

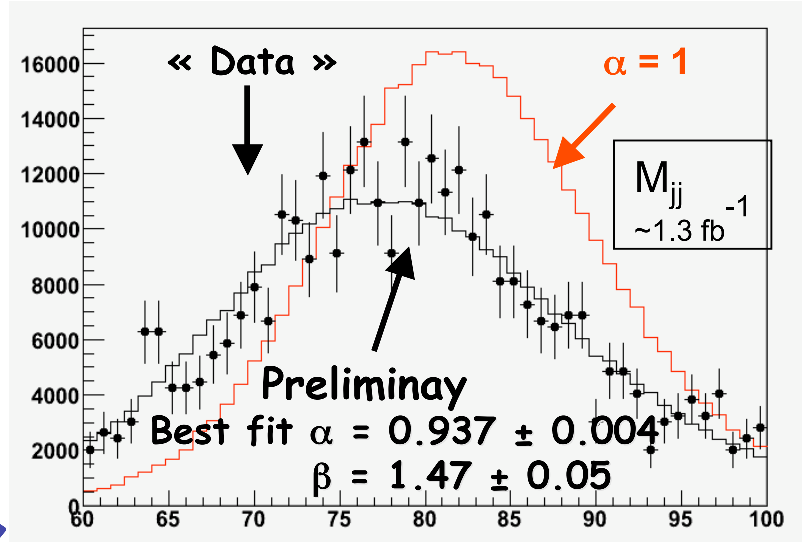


Precision ~2 to 3 %

Alternative pT balance in Z/γ + jet (6% b-jets)



2) Fit template histograms with different E scales α and relative E resolutions β



b-tagging studies :

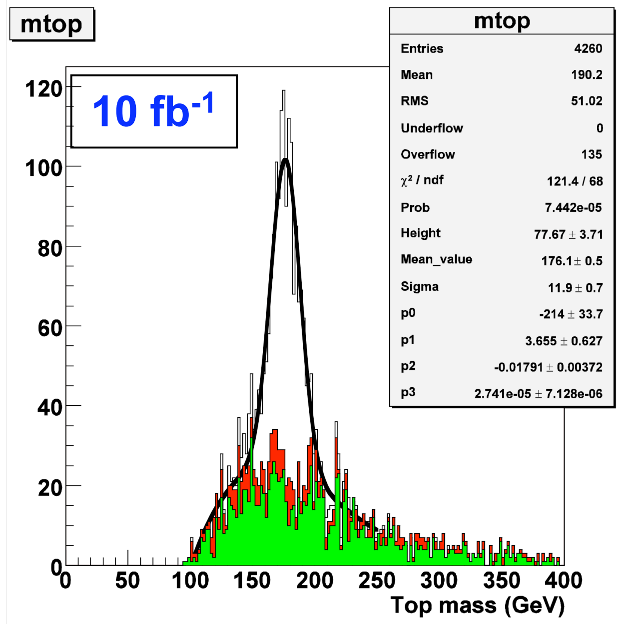
→ Cut on W_{had} and top_{had} masses to create an enriched tt sample out of the semileptonic selection

→ Look at the b-jet tagging probability & jet-energy scale for the jet on the lepton side : main systematics ISR/FSR

Top mass with semileptonic events : 2 strategies

Reconstruction of the hadronic W and top :

- W_{jj} used to calibrate the light jet scale
- require $|M_W - 80.4| < 2 \times \sigma(M_W)$ & 2 b-jets
- Choose b-jet that maximizes p_T top
- ε=1.1%, top purity = 69 %



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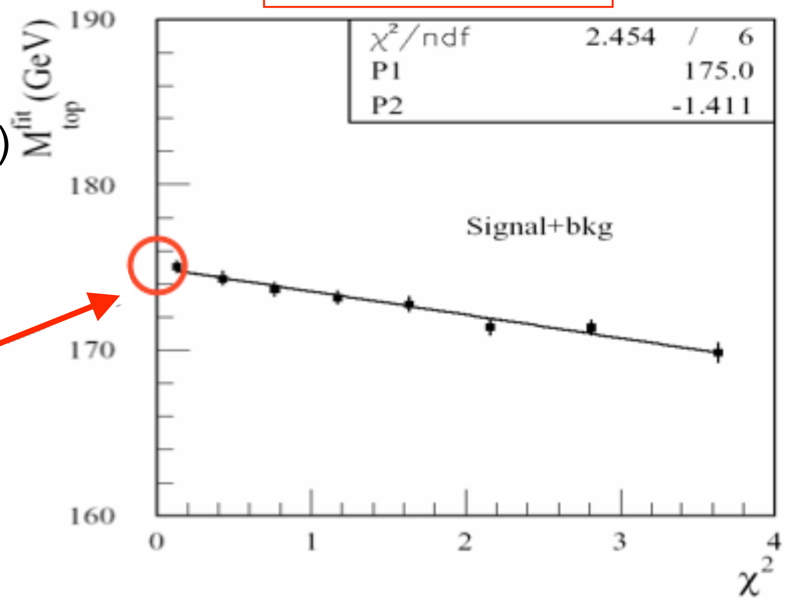
Kinematic fit

- Constraint event by event :
  $M_{jj}=M_{l\nu}=M_W$ and $M_{jjb}=M_{lb} = M_t^{fit}$
  (2 $p_z(\nu)$ envisaged + leptons and jets resolutions)

- Fit M_t^{fit} by slices of χ^2
- Top purity ~ 80% : χ^2 <4

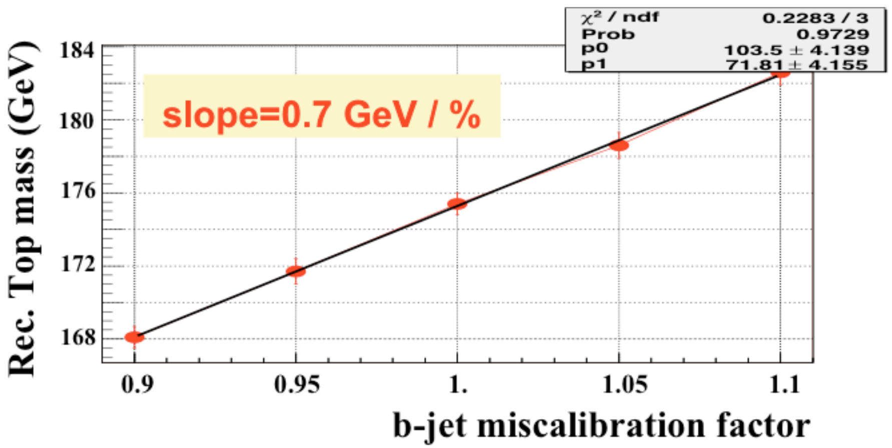
- Top mass m(top) = M_t^{fit} (χ^2 = 0)



Top mass with semileptonic events : uncertainties

Source of uncertainty	Systematic on m(top) ATLAS 10 fb^{-1} kinematic fit	/ hadronic top
b-jet scale (±1%)	0.7	0.7
light-jet scale (±1%)	0.2	0.2
Final state radiation	0.5	1.
b-quark fragmentation	0.1	0.1
Initial state radiation	0.1	0.1
Combinatorial bkg	0.1	0.1
Total syst	0.9	1.3
Statistical error	0.1	0.05

← Main systematics : b-jet scale



→ Δm(top) ~1 GeV achievable with 10 fb^{-1}

Other channels :

- Full leptonic channel : clean channel but 2 neutrinos (6 equations) : Δm(top) ~ 2 GeV (10 fb^{-1})
- Full hadronic channel : significant QCD background : Δm(top) ~ 3 GeV (10 fb^{-1})
- Semileptonic with b →J/ $\psi \to \mu\mu$: 1 K evts / 100 fb^{-1} (high lumi) : Δm(top) ~ 1 GeV (small impact of b-jet scale but small statistics)

Summary

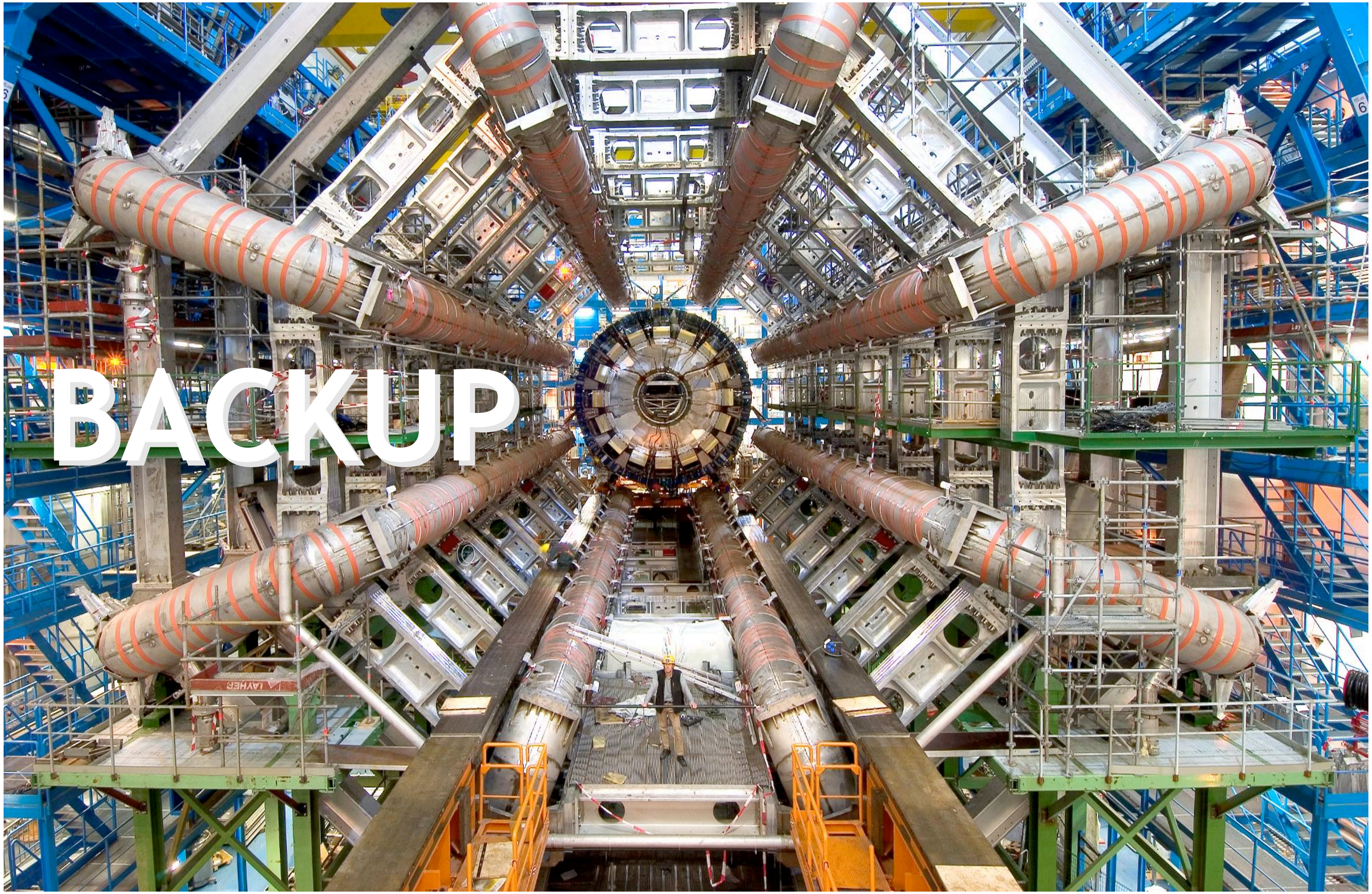
- ATLAS on tight schedule to operate almost complete in fall 2007

- First measurements : particle multiplicities in minimum bias events and underlying event. Use minimum bias to commission the detector (inner detector material in front of calorimeter + inner detector alignement) in $\sqrt{s}$ = 900 GeV and 14 TeV runs.

- Extract W / Z / top basic measurements with 100 pb^{-1} to 1 fb^{-1} of luminosity.
- Look at $W \rightarrow l\nu$ and $Z \rightarrow ll$: large statistics to understand early on the detector performance (leptons, E_T^{miss}) and to check the MC/data agreement.
- Look at W/Z + jet production including heavy flavours ⇔ important background for SuSy.
- Look at initial top samples to calibrate b-tagging, jet-energy scale (light and heavy).

- Precision measurements (top mass, W mass, triple gauge couplings …) need time !

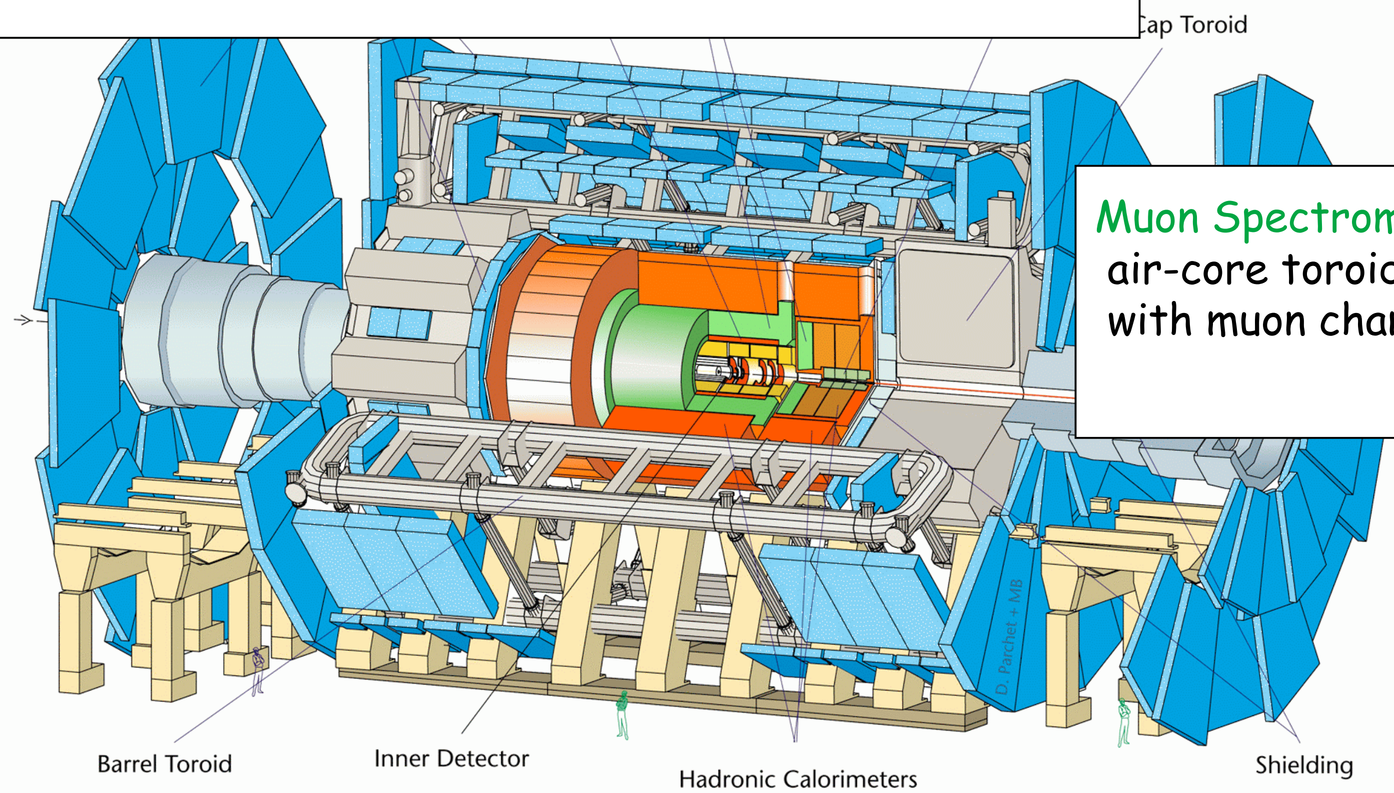
(First QCD measurements not covered here : see talk by D. Clements «Expectations for Inclusive Jet Cross-sections with Early data in ATLAS» Heavy flavour and QCD session)*


BACKUP

The ATLAS detector

Length : ~45 m
Radius : ~12 m
Weight : ~ 7000 tons
Electronic channels : ~ 10^8
~ 3000 km of cables

Tracking ($|\eta|<2.5$, B=2T) :
-- Si pixels and strips
-- Transition Radiation Detector (e/π separation)

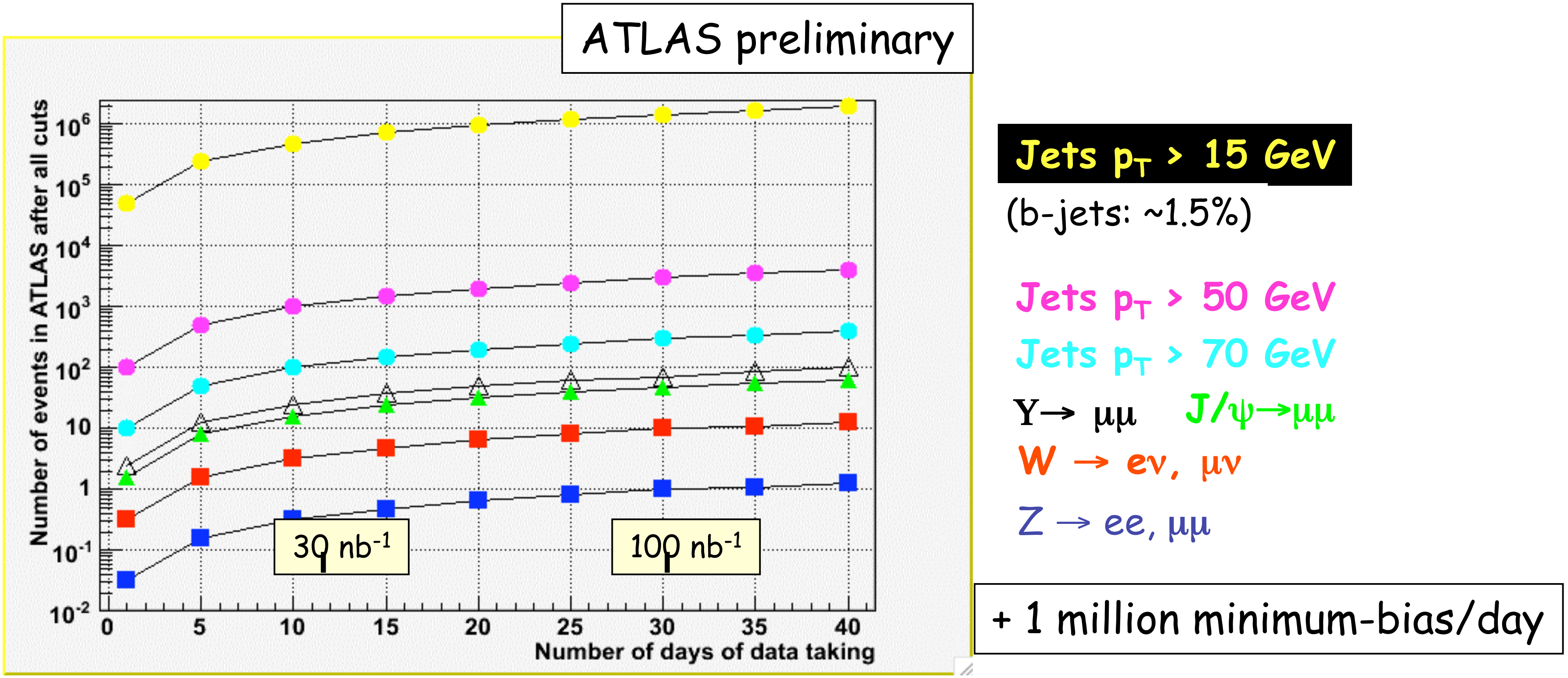


Muon Spectrometer ($|\eta|<2.7$) :
air-core toroids (B=0.5T)
with muon chambers

Calorimetry ($|\eta|<5$) :
-- EM : Pb-LAr with Accordion shape
-- HAD: Fe/scintillator (central), Cu/W-LAr (fwd)

Expected event rates : √s = 900 GeV operation

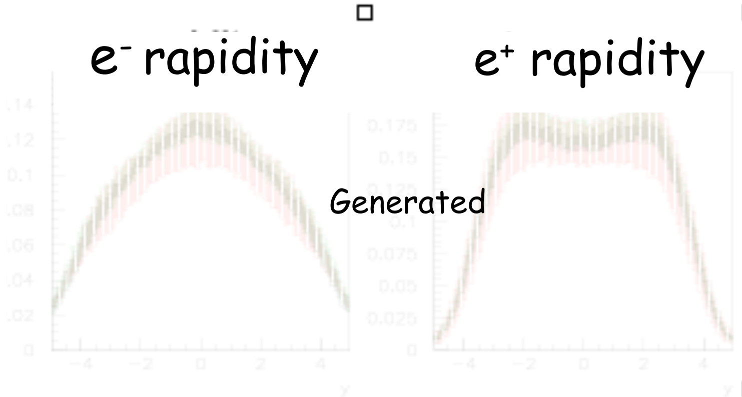
- Observe a few Υ→ll, J/ψ ??
- Mainly minimum bias !



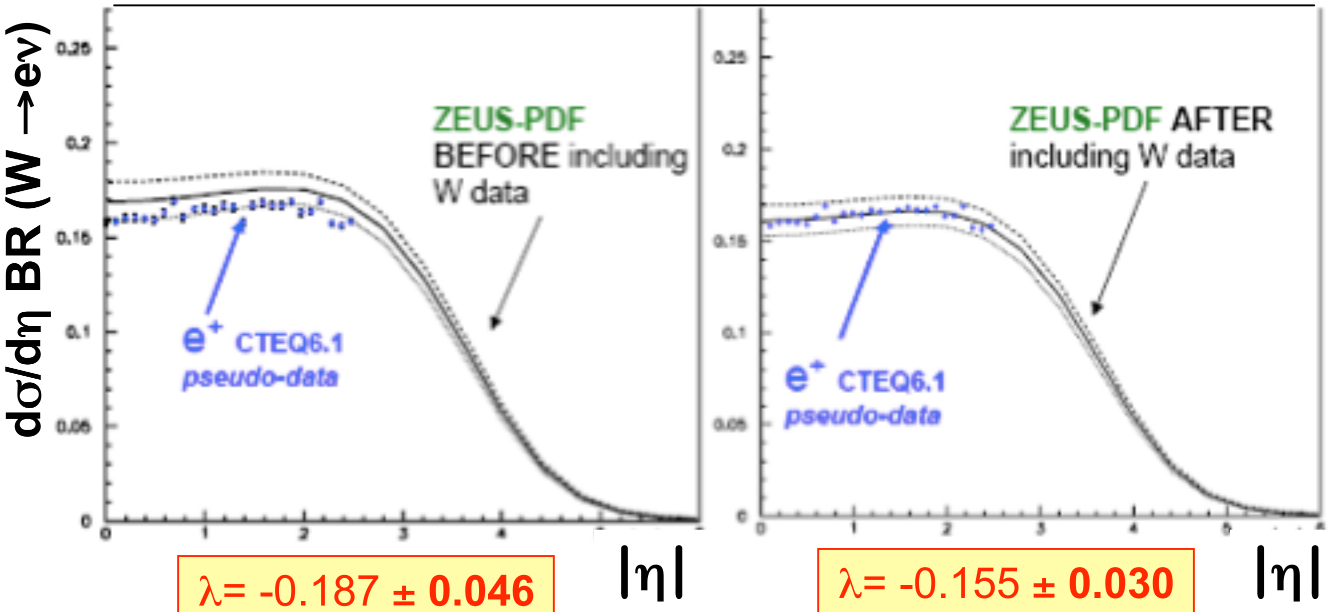
- 30 % data taking efficiency included (machine + detector)
- Trigger and analysis efficiencies included

W production study (~200 pb^{-1})

- $W \rightarrow l\nu$ rapidity is sensitive to the gluon shape parameter λ, $xg(x)= x^{-\lambda}$
- Use W to probe the low-x gluon PDF at $Q^2= M^2_W$ ($x < 10^{-2}$)



- Improve error on λ by ~40% by including ATLAS data in PDF fits



λ= -0.187 ± **0.046**

λ= -0.155 ± **0.030**

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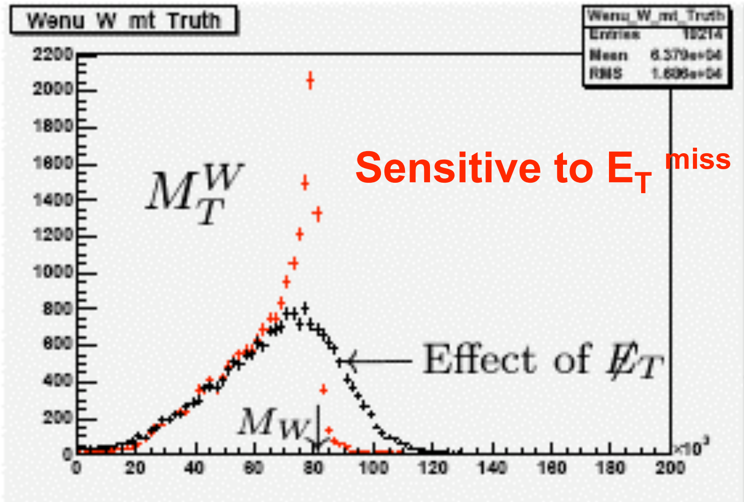
→ Improvements also from analysis of Z distributions,
at higher x jets and direct photons will play the prominent role

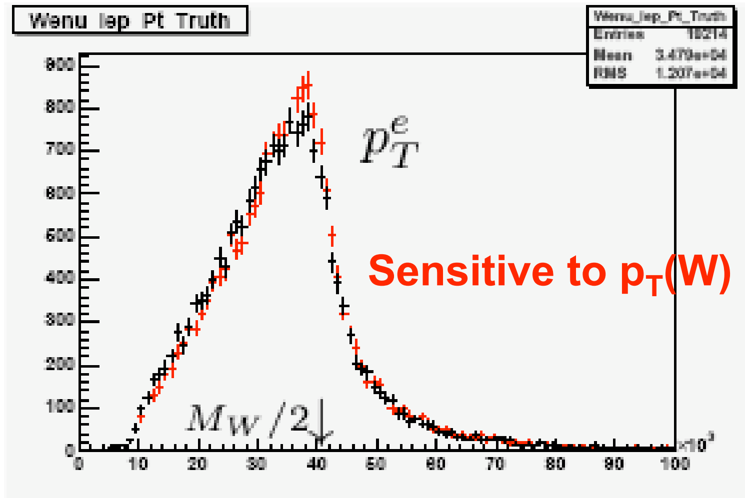
W mass : method

- 10 fb^{-1} : ~30 M of events

} Iso. lepton p_T>25 GeV, no jet with pT>30 GeV
E_T^{miss}>25 GeV

- Two main observables :
  Transverse mass $M_T^W = \sqrt{2 p_T^l p_T^\nu (1 - \cos \Delta\varphi_{l\nu})}$ Lepton momentum : p_T(l)





- Predict the M_T(W) and p_T(l) distributions using following ingredients :
  - lepton energy scale and resolution, linearity, reconstruction efficiency
  - W dynamics : rapidity, transverse momentum, polarization, final state radiation

- Compare templates with data → perform χ^2 minimization
  (statistical uncertainty ~2 MeV)

W mass : systematics (W→eν channel) (I)

Source	Estimate on M_W	Tool
Lepton energy scale & resolution	~3 MeV	Z→ee
Lepton reco efficiency	~8 MeV	Z→ee
Lepton resolution	<1 MeV	Z→ee
PDF's	~1 MeV	Rapidity in Z→ee
Background in M_T(W) or p_T(l) (mainly W→τν ~1-2 % & Z→ll ~ 1-2 %)	~1 MeV	Known acceptances and shapes from each background
QCD corrections	~2 MeV	
QED FSR	< 10 MeV	to be studied further

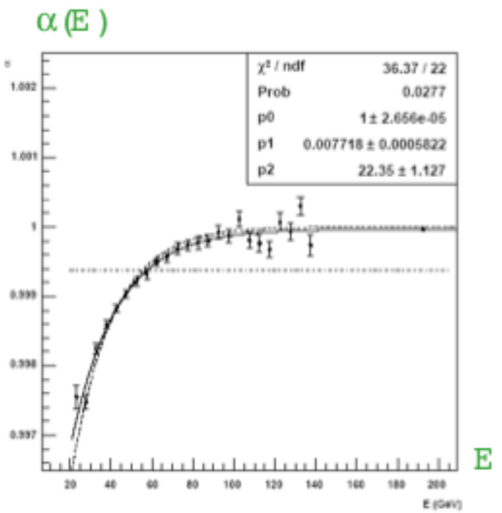
} Main envisaged tool : Z→ee

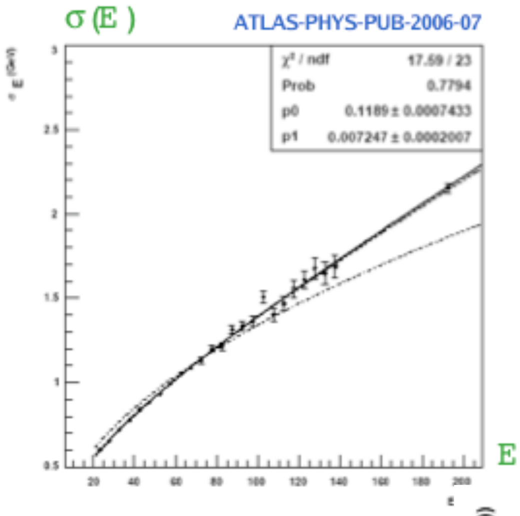
→ Additional systematics ~5 MeV : recoil (if using) M_T(W) - p_T (W) if using p_T(l)
→ Uncertainty on lepton reconstruction efficiency significant in W→eν channel (less important for W→μν ~2% (stable efficiencies in dynamic range))

W mass : systematics (II)

Ex : use Z→ee to constrain the lepton energy scale and resolution

- Divide Z→ee depending on lepton momenta in (i,j) bins
- Fit mass scale and resolution using templates
- Use least squares to get the lepton energy scale α(E) and resolution σ(E)

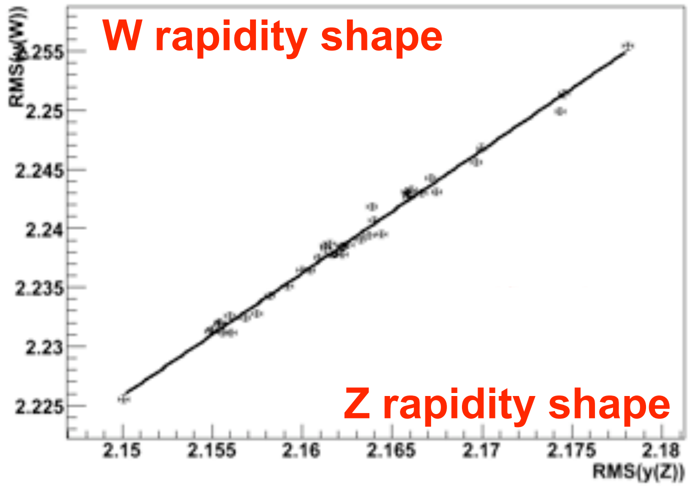




← Binning in energy improves extrapolation from Z to W

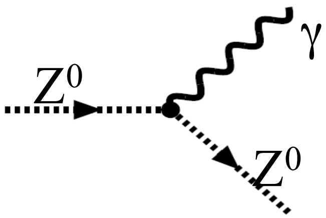
Ex : use Z→ee to constrain the PDF's

- W and Z rapidity shapes related →
- Expect that Z rapidity uncertainty divided by ~20 (10 fb-1)
- PDF uncertainty & W rapidity in turn better constrained

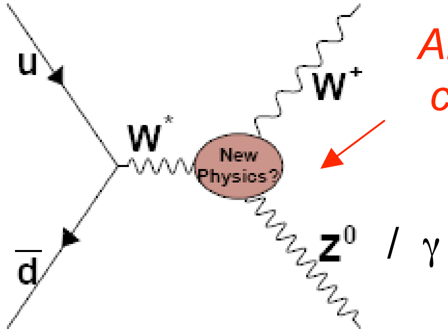


Triple gauge couplings (TGC's)

- Triple gauge couplings WWγ and WWZ allowed by SM & observed at LEP
- Any observation of a neutral TGC or anomalous charged TGC is a sign of new physics :



(ex : neutral forbiden TGC)



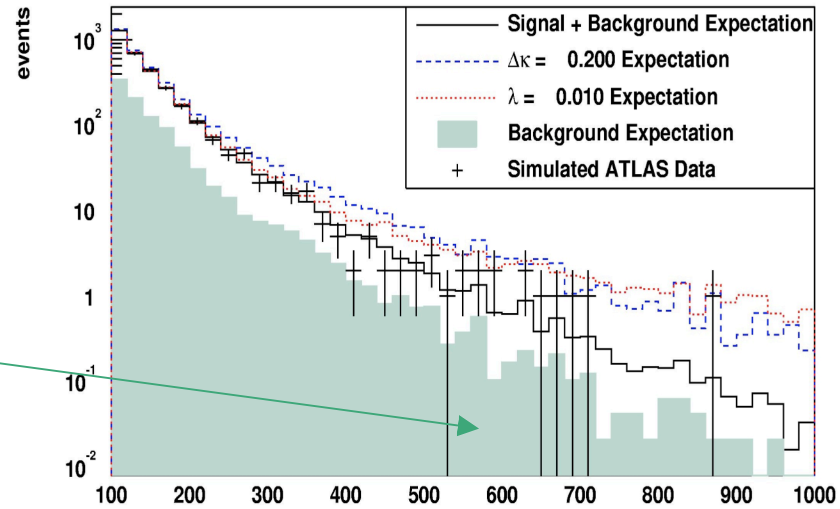
Anomalous charged couplings ?

- Anomalous couplings in WWγ WWZ ?
  Main observable at LHC :high pT Z's or γ 's

  Early running :
  reco of Z's and W's easy
  γ efficiency and jet fake rate more challenging

  30 fb^{-1}:
  few background events in tail !

  Measurements dominated by statistics
  anomalous charged TGC's : ~factor 2-10 better than LEP/Tevatron
  neutral TGC's : ~factor 100 better than Tevatron (100 fb^{-1})



$p_T(V)$ V=(Z,γ)