ATLAS Physics Potential I

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ATLAS Physics Potential:

- Standard Model
- Higgs & Susy
- BSM: Susy & Exotics

Introduction (1)

- **LHC: pp collisions at $\sqrt{s}$=14 TeV every 25 ns in 2007**
- **2 phases: $10^{33}cm^{-1}s^{-2}$ (initial), $10^{34}cm^{-1}s^{-2}$ (design)**

❑ **High statistics at initial luminosity (10 fb^{-1})**

- Hard cuts to select clean events
- Few pile-up events

❑ **Systematics dominant for precision physics**

- MC reliability to reproduce data (physics + detector performance)
- Can be reduced with numerous control samples, experience from Tevatron

Process	σ (nb)	Evts/year (10 fb^{-1})
Minimum Bias	10^8	~10^{15}
Inclus. jets*	100	~ 10^9
$b\bar{b}$	5 10^5	~ 10^{12}
$W \rightarrow e\nu$	15	~ 10^8
$Z \rightarrow e^+ e^-$	1.5	~ 10^7
$t\bar{t}$	0.8	~ 10^7
Dibosons	0.2	~ 10^6

* p_T>200GeV

Which physics the first year(s) ?

Expected event rates at production in ATLAS at L = 10^{33} cm^{-2} s^{-1}

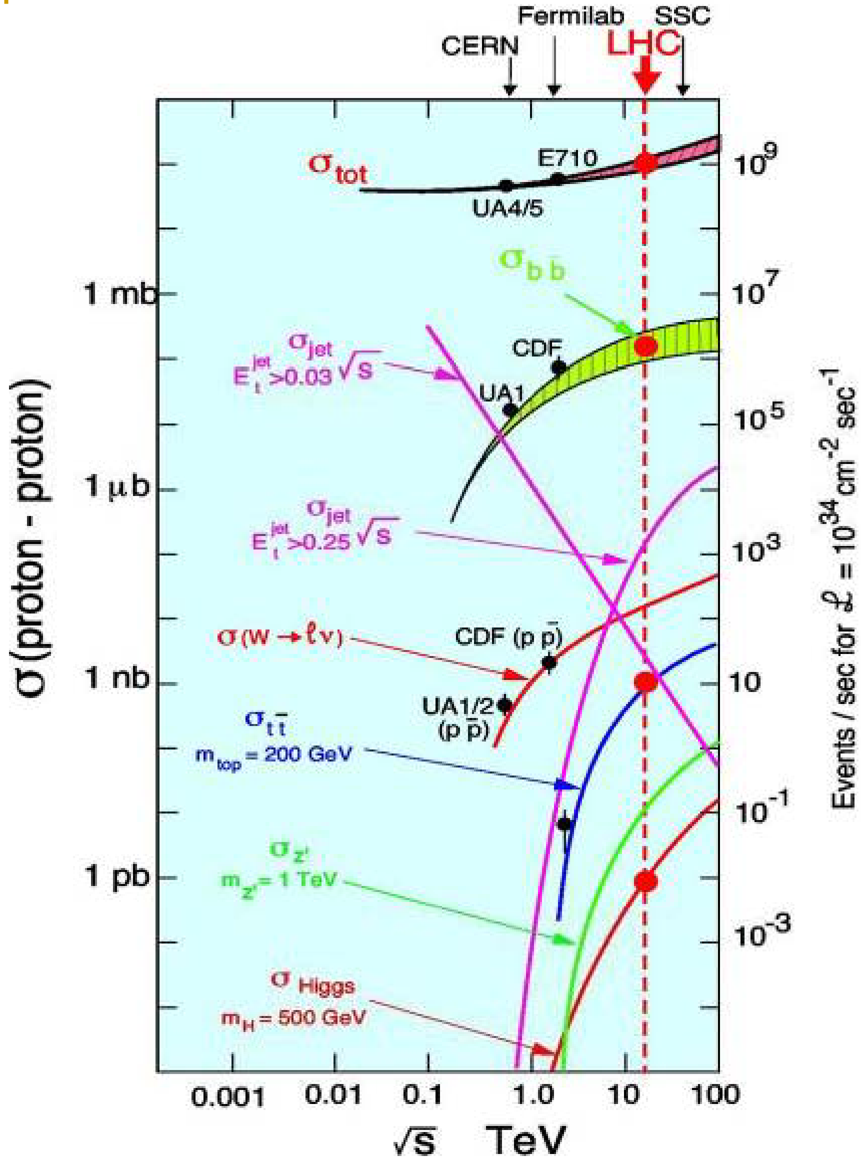
Process	Events/s	Events for 10 fb^{-1}	<u>Total</u> statistics <u>collected</u> at previous machines by '07
$W \to e\nu$	15	10^8	10^4 LEP / 10^7 Tevatron
$Z \to ee$	1.5	10^7	10^7 LEP
$t\bar{t}$	1	10^7	10^4 Tevatron
$b\bar{b}$	10^6	$10^{12} - 10^{13}$	10^9 Belle/BaBar ?
H m=130 GeV	0.02	10^5	?
$\tilde{g}\tilde{g}$ m= 1 TeV	0.001	10^4	---
Black holes m > 3 TeV (M_D=3 TeV, n=4)	0.0001	10^3	---

Already in first year, <u>large statistics</u> expected from:

-- known SM processes $\to$ <u>understand detector</u> and physics at $\sqrt{s}$ = 14 TeV

-- several New Physics scenarios

Cross Sections and Production Rates



Rates for L = 10^{34} cm^{-2} s^{-1}: (LHC)

• **Inelastic proton-proton reactions:**	**10^9 / s**
• **bb pairs**	**5 10^6 / s**
• **tt pairs**	**8 / s**
• **W → e ν**	**150 / s**
• **Z → e e**	**15 / s**
• **Higgs (150 GeV)**	**0.2 / s**
• **Gluino, Squarks (1 TeV)**	**0.03 / s**

LHC is a factory for:
top-quarks, b-quarks, W, Z, ……. Higgs, ……

(The challenge: you have to detect them !)

Introduction (2)

- **Goals of precision physics:**
  - Improve current SM measurements to provide stringent consistency tests of the underlying theory
  - Control W, Z and top to properly estimate the background for physics beyond the SM
  - Use W, Z and top to calibrate the detector, measure the luminosity...

- **Crucial parameters for precision physics:**
  - Lepton E, p scale
  - Jet energy scale

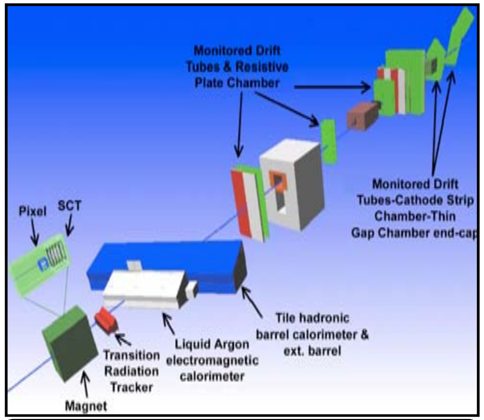
  } <u>Detector</u>: start with inputs from module test beams, improve with in situ calibration

  - b-tagging
  - Angular coverage

  } <u>Detector</u>: in situ calibration

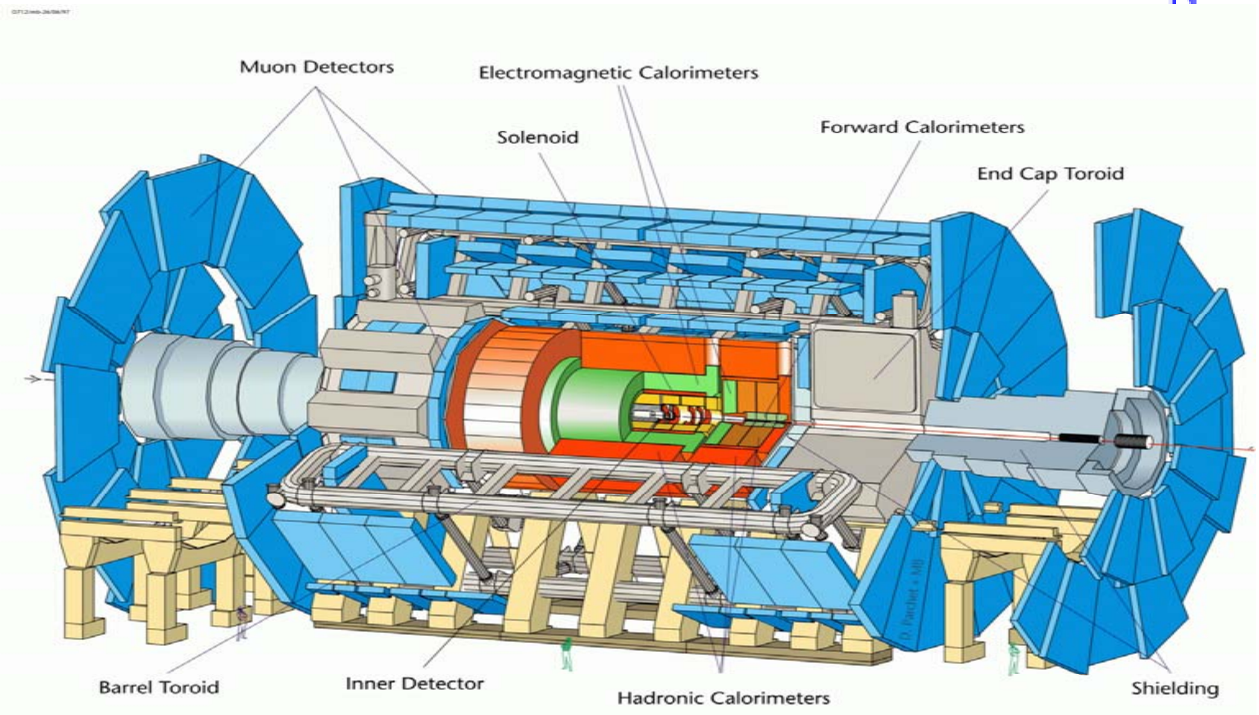
  - Luminosity

  } <u>LHC</u> (± 5 % ?)



2004 Combined test beam: Complete ATLAS barrel slice

ATLAS detector (1)



❑ General
- L ~ 44 m, ∅ ~ 22 m
- 7000 tons
- 2000 persons

❑ Inner Detector (tracker)
- Si pixels & strips +TRT
- 2 T magnetic field
- Coverage $|\eta|< 2.5$

❑ Calorimetry
- Liquid Argon EM up to $|\eta|< 3.2$
- Hadronic (Tile, LAr, forward) to $|\eta|< 4.9$

❑ Muon Spectrometer
- Air-core toroidal system
- Coverage $|\eta| < 2.7$

GOALS

For $|\eta|< 2.5$ (precision region):
- Lepton E,p scale: 0.02% precision
- Jet energy scale: 1% precision
- b-tagging: $\varepsilon_b \approx 60\%$, $r_{uds} \approx 100$, $r_c \approx 10$

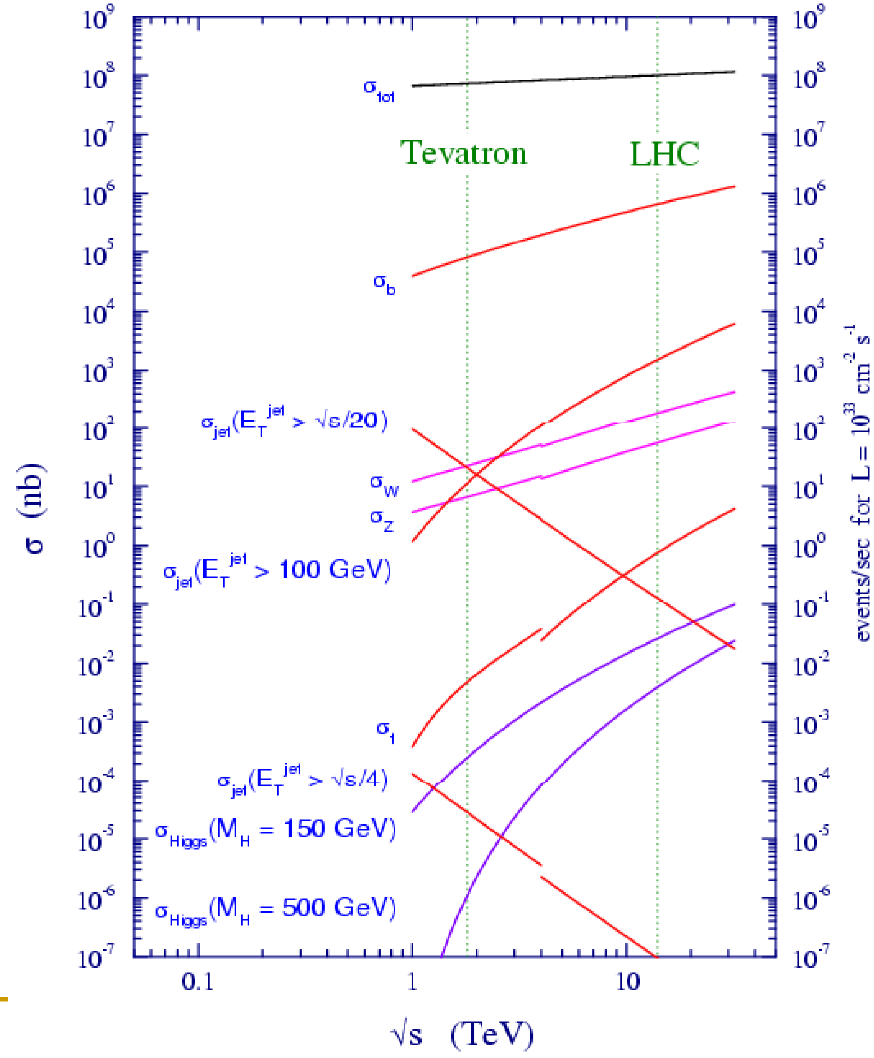
Importance of (nonpert.) QCD at LHC: PDFs

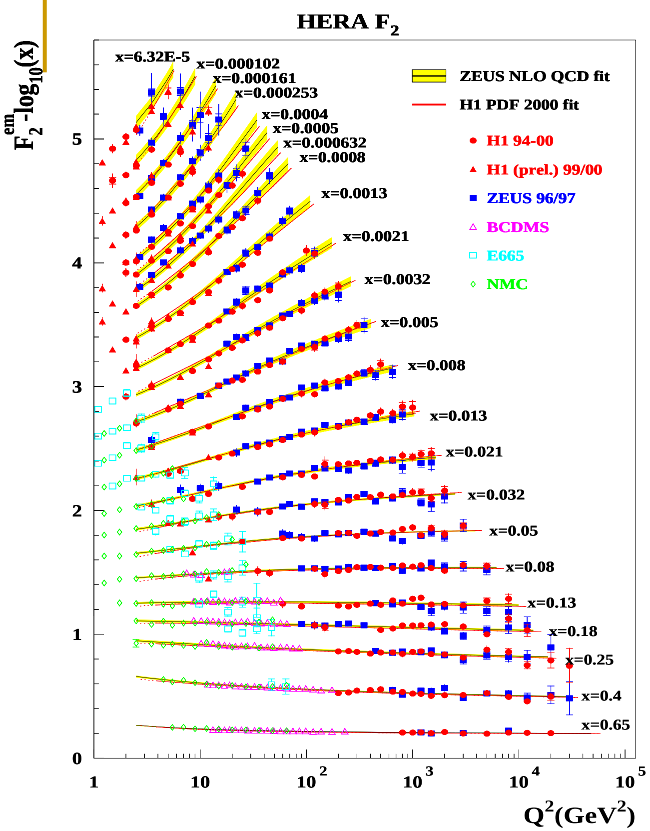
- At a hadron collider, cross sections are a convolution of the partonic cross section with the PDFs.

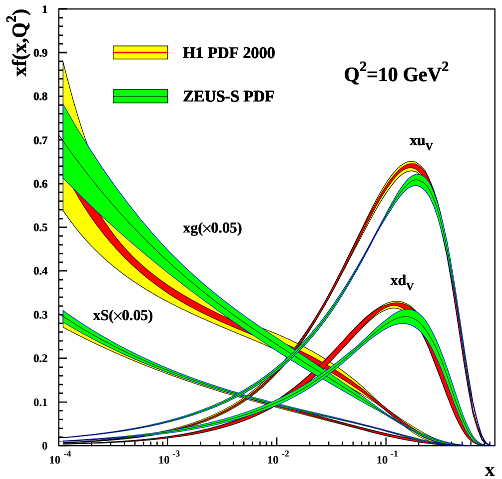
$$
\begin{aligned}
\sigma_X &= \sum_{a,b} \int_0^1 dx_1 dx_2\, f_a(x_1, \mu_F^2)\, f_b(x_2, \mu_F^2) \\
&\times\; \hat{\sigma}_{ab\to X}\left(x_1, x_2, \{p_i^\mu\}; \alpha_S(\mu_R^2), \alpha(\mu_R^2), \frac{Q^2}{\mu_R^2}, \frac{Q^2}{\mu_F^2}\right)
\end{aligned}
$$

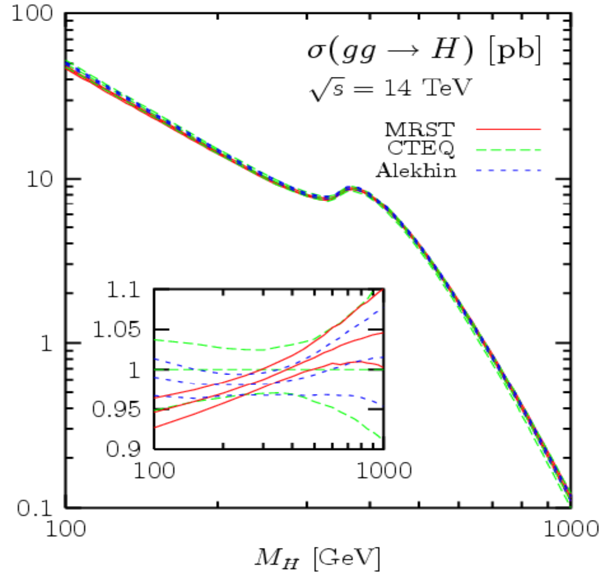
- PDFs are vital for calculating rates of any new physics, for example: Higgs, Extra-Dimensions etc.

- PDFs vital for Standard Model physics, which will also be backgrounds to any new physics.









- The **x** dependence of $f(x,Q^2)$ is determined by fits to data, the Q^2 dependence is determined by the DGLAP equations.
- Fits and evaluation of uncertainties performed by CTEQ, MRST, ZEUS etc.

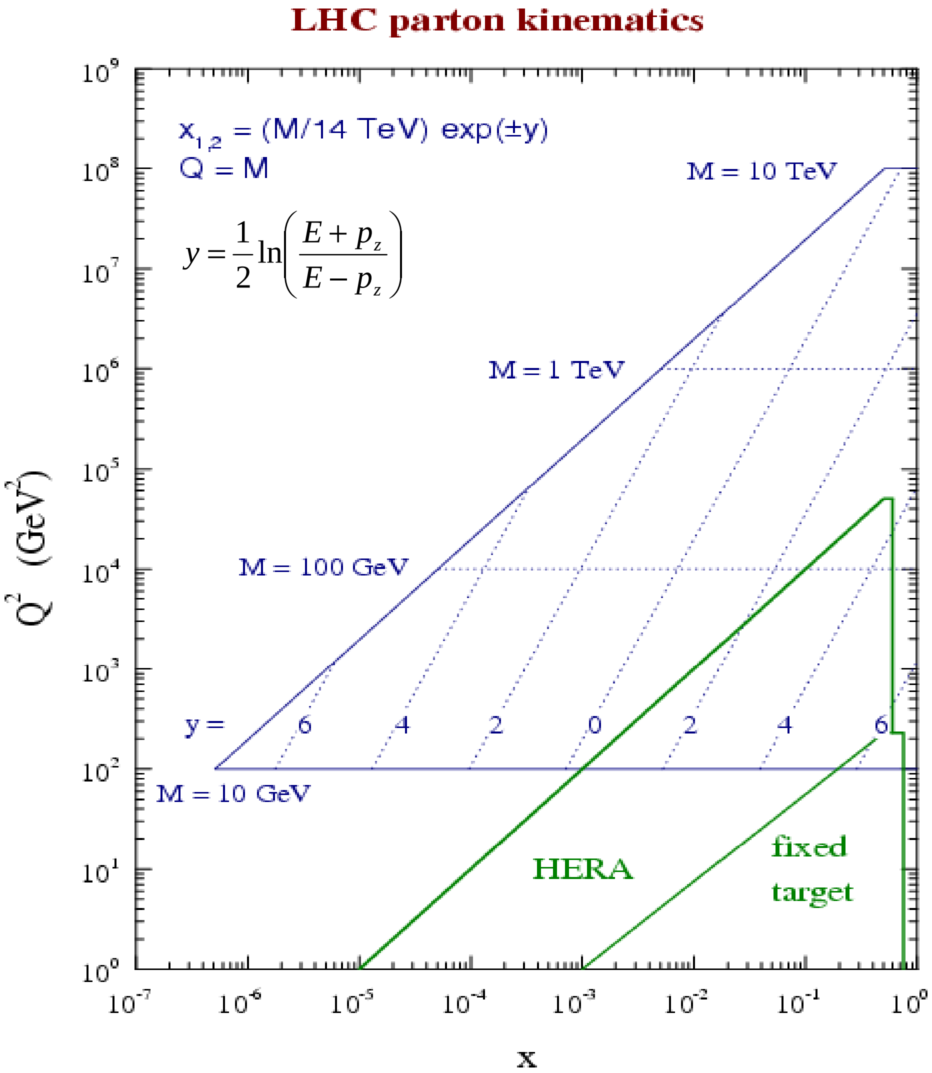
- Simple spread of existing PDFs gives up to 10% uncertainty on prediction of Higgs cross section.

Parton kinematics at the LHC

- The kinematic regime at the LHC is much broader than currently explored.

- At the EW scale (ie **W** and **Z** masses) theoretical predictions for the LHC are dominated by **low-x gluon** uncertainty
  - → Is NLO (or NNLO) DGLAP sufficient at small x ?

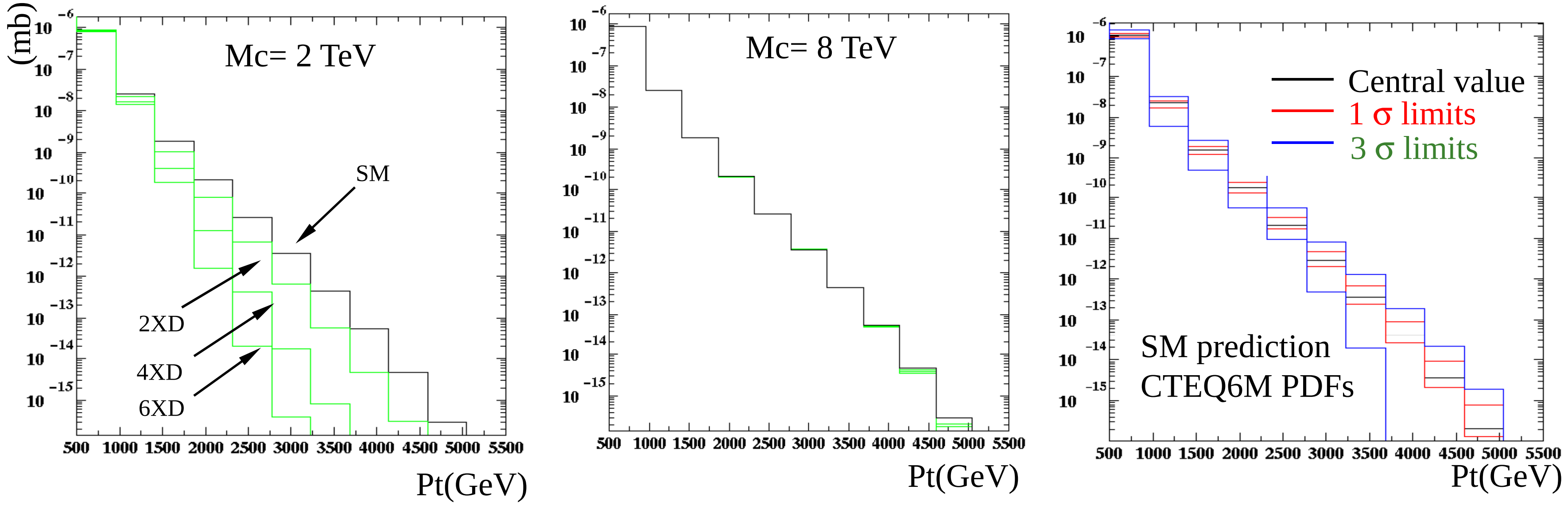
- At the TeV scale, uncertainties in cross section predictions for new physics are dominated by **high-x gluon** uncertainty
  - → not sufficiently constrained, as we shall now see



Impact of PDF uncertainty on new physics

Example: **<u>Extra Dimensions</u>** (S.Ferrag, hep-ph/0407303)

- Extra-dimensions affect the di-jet cross section through the running of αs. Parameterised by number of extra dimensions D and compactification scale Mc.



- PDF uncertainties reduce sensitivity to compactification scale from ~5 TeV to 2 TeV
- High-x gluon dominates high-Et jet cross section.

Constraining PDFs at LHC

- Several studies on ATLAS looking at reducing PDF uncertainties, especially gluon distributions, for example:

<u>Leading order processes.</u>

1) Inclusive jet production: $qg \to qg \to jets, \quad gg \to gg \to jets$

2) W^{+-} production: $u\bar{d} \to W^+ \to e^+\nu, \quad d\bar{u} \to W^- \to e^-\bar{\nu}$

3) Direct γ production: $gq \to \gamma q \to \gamma + jet, \quad q\bar{q} \to \gamma g \to \gamma + jet$

4) Z + b-jet: $gb \to Zb \to \mu^+\mu^- + bjet$

- Other channels are being studied, eg Drell Yan, but not presented today.

1) Jet cross sections

$$qg \to qg, \quad gg \to gg$$

- Because jet cross sections are sensitive to new physics, especially at high-Et, need to understand and hopefully constrain high-x gluon PDFs.

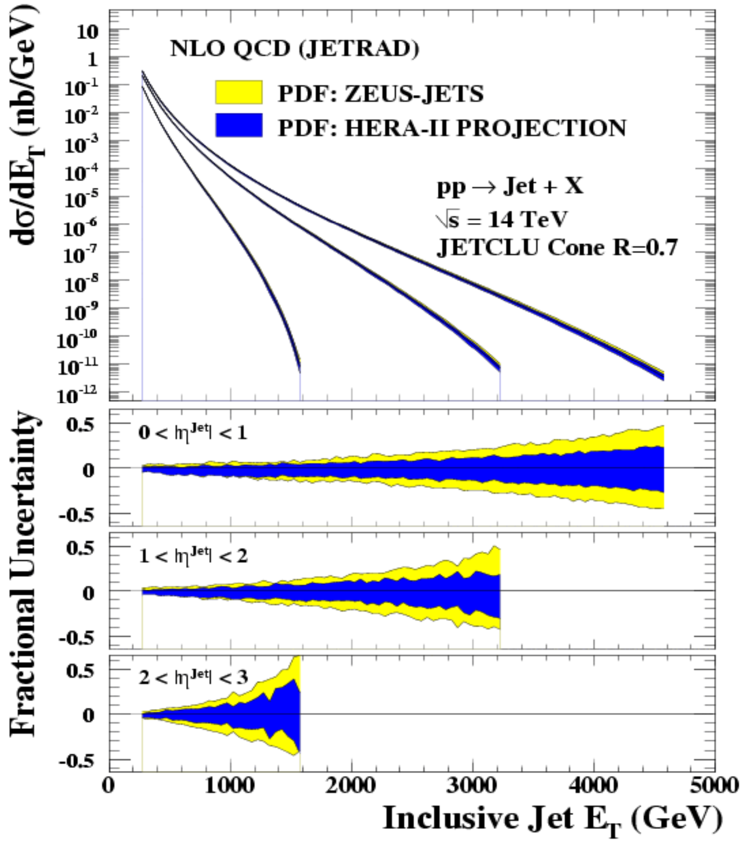
- HERA-II will constrain further the gluon PDFs, especially at high-x. Projections for 2007 suggest a ~20% PDF error on high-Et jets is achievable. (C.Gwenlan, Oxford.)

Can the LHC improve on this?

- Theoretical uncertainties include **renormalisation** and **factorisation** scale errors. Early studies at NLO suggest **~15%** for 1 TeV jets. (D.Clements, Glasgow.)

- Experimental uncertainties, eg the **jet energy scale**, are currently being studied: expected to be significant!

High-E_T inclusive jets at the LHC



2) W^{+-} production

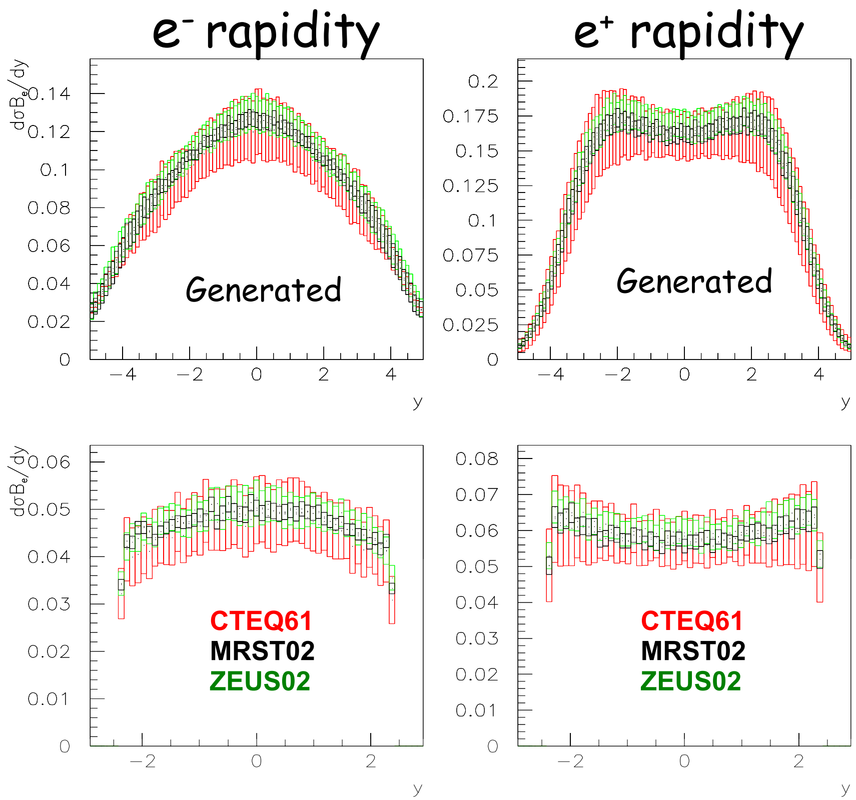
$$u\bar{d} \to W^{+} \to e^{+}\nu$$

$$d\bar{u} \to W^{-} \to e^{-}\bar{\nu}$$

- **W bosons** produced copiously at LHC (experimental uncertainty dominated by systematics).
  - → Clean signal (background ~ 1%)
  - → Theoretical uncertainties dominated by gluon PDFs

- Impact of PDF errors on **W->eν** rapidity distributions investigated using HERWIG event generator with NLO corrections. (A.Cooper-Sarkar, A.Tricoli, Oxford Univ.)

- PDF uncertainties only slightly degraded after passing through **detector simulation** with cuts. →



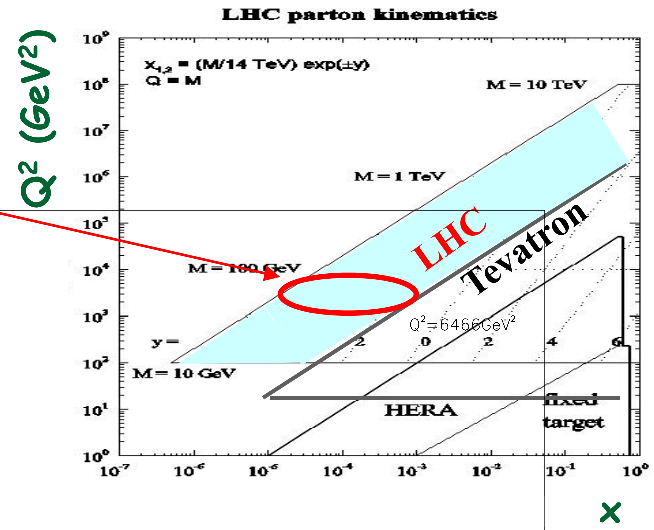
At y=0 the total PDF uncertainty is:
~ ±5.2% from ZEUS-S
~ ±3.6% from MRST01E
~ ±8.7% from CTEQ6.1M
ZEUS-S to MRST01E difference ~5%
ZEUS-S to CTEQ6.1 difference~3.5%

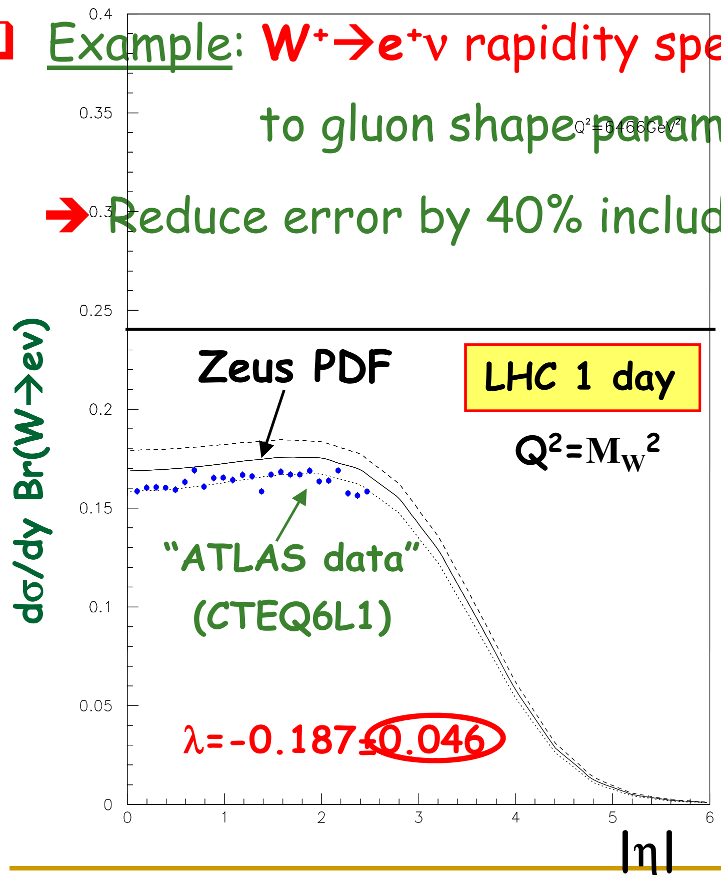
Goal is experimental systematic error < 5%

Constraining PDF

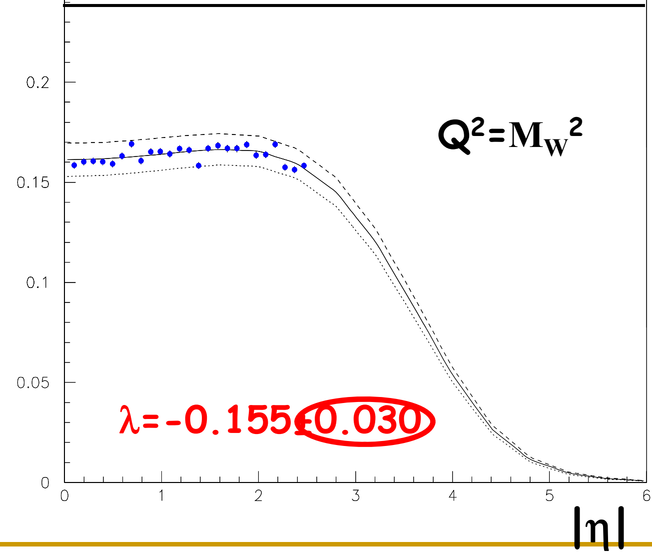
- Use W to probe low-x gluon PDF at $Q^2 = M_W^2$
- Example: $W^+ \rightarrow e^+\nu$ rapidity spectrum is sensitive to gluon shape parameter λ $(xg(x)=x^{-\lambda})$

➔ Reduce error by 40% including "ATLAS data"





Include "ATLAS data" in global PDF fits

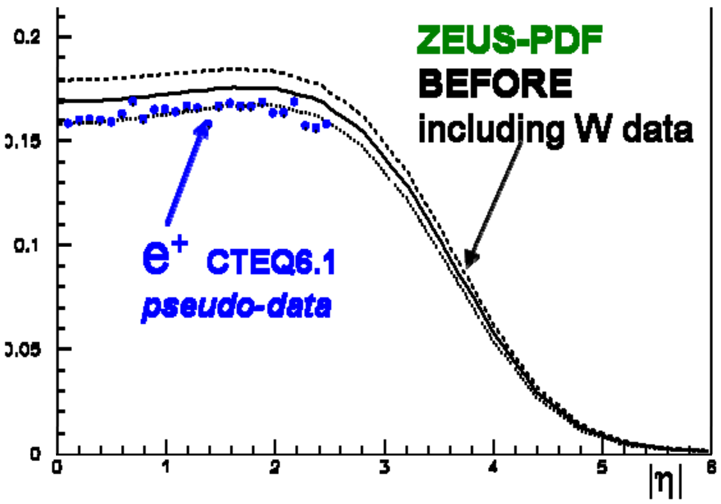


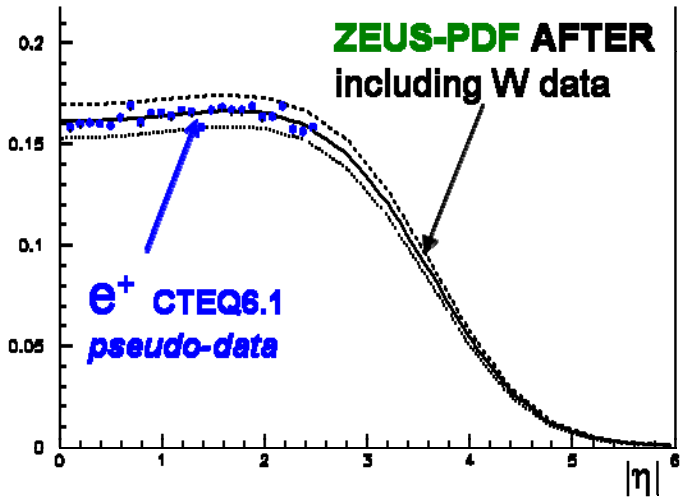
2) W^{+-} production (continued)

- Investigate PDF constraining potential of ATLAS. What is effect of including ATLAS W rapidity "pseudo-data" into global PDF fits.

How much can we reduce PDF errors?

- Created 1M "data" sample, generated using **CTEQ6.1 PDF** and simulate ATLAS detector response using ATLFAST. Correct back to generator level using **ZEUS-S PDF** and use this "*pseudo-data*" in a global **ZEUS-S PDF fit**. Central value of **ZEUS-S PDF** prediction shifts and uncertainty is reduced:





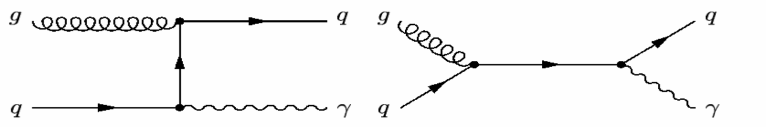
low-x gluon shape parameter λ: $xg(x) \sim x^{-\lambda}$:

BEFORE $\lambda = -0.199 \pm 0.046$
AFTER $\lambda = -0.181 \pm 0.030$

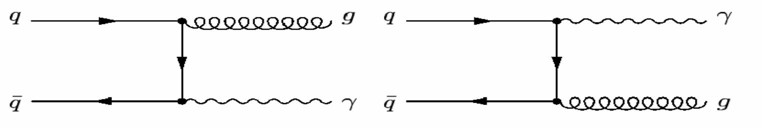
35% error reduction

3) Direct γ production

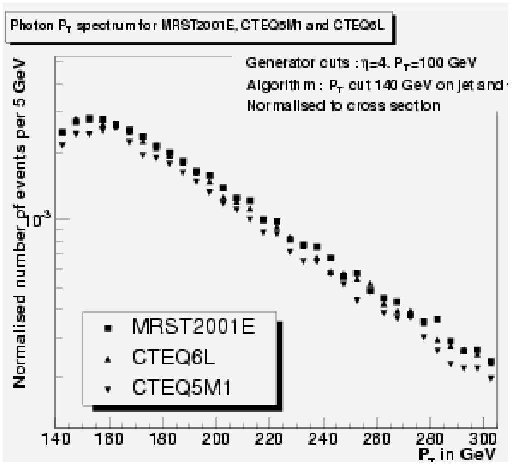
Compton
~90%

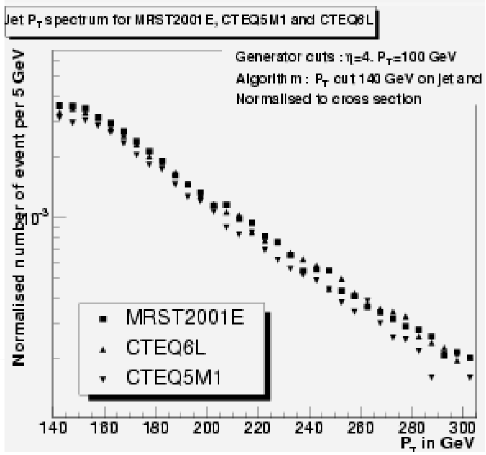


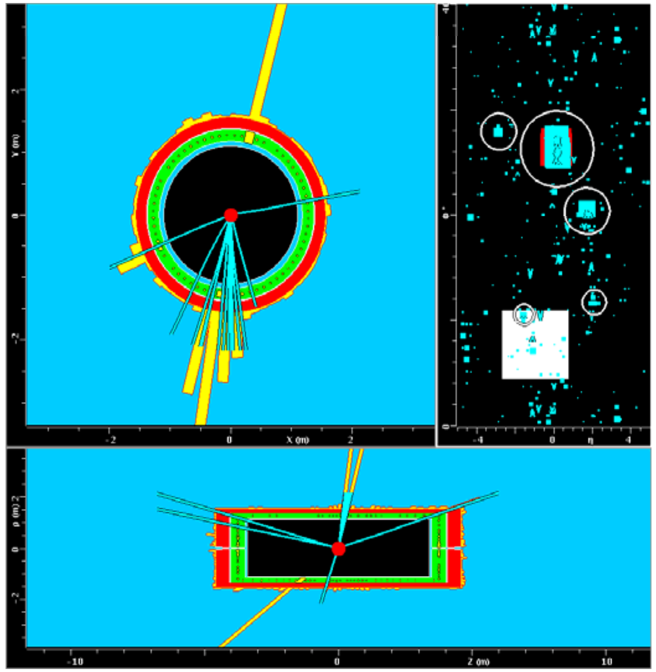
Annihilation
~10%



Typical Jet + γ event.
Jet and photon are back to back

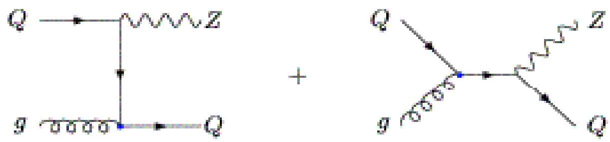






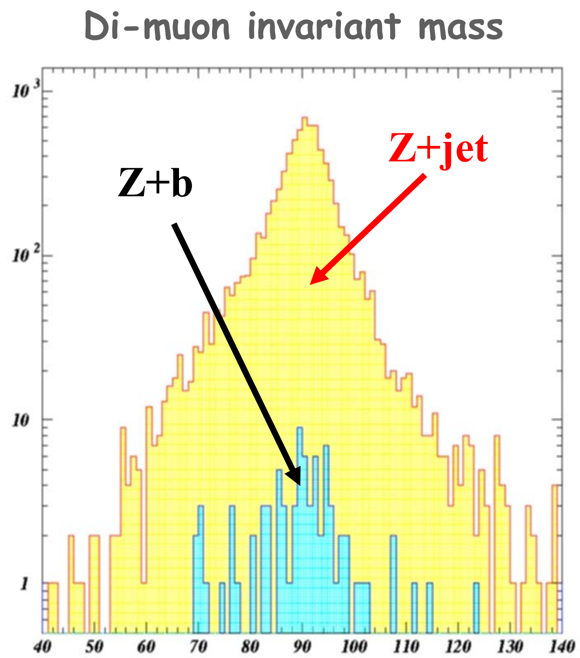
- Photon couples only to quarks, so potential good signal for studying underlying parton dynamics.
- Differences observed between different PDF's on *jet* and γ p_T distributions (I.Hollins, Birmingham.)
- Studies ongoing to evaluate experimental uncertainties (photon identification, fake photon rejection, backgrounds etc.)

4) Z + b-jets



- **<u>Motivation</u>:**

1) Sensitive to b content of proton *(J.Campbell et al. Phys.Rev.D69:074021,2004)*
   → **PDF differences in total Z+b cross section 5% → 10%** ***(CTEQ, MRST, Alehkin)***
2) Background to Higgs searches *(J.Campbell et al. Phys.Rev.D67:095002,2003)*
3) bb→Z is ~5% of Z production at LHC.
   → **Knowing σ_Z to about 1% requires a b-PDF precision of the order of 20%**



- **<u>Z→$\mu^+\mu^-$ channel</u>** (S.Diglio et al., Rome-Tre)
  - → Full detector reconstruction.
  - → Two isolated muons (Pt > 20 GeV/c, opposite charge, inv. mass close to Mz)

- Inclusive b-tagging of jet:
  - → Z+ b selection efficiency ~15%; purity ~53%

- Z+b measurements will be possible with high statistics and good purity of selected events, but systematics must be controlled.

PDF Summary

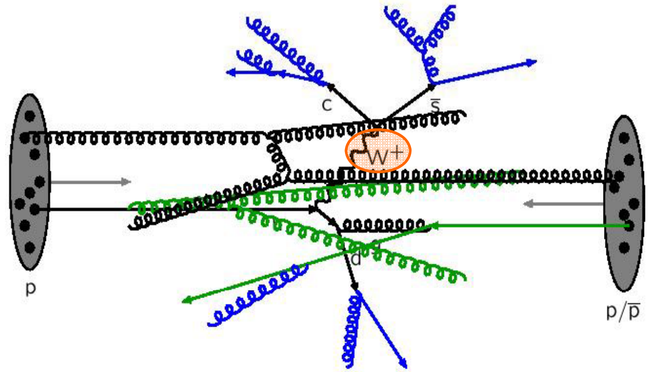
- Precision Parton Distribution Functions are crucial for new physics discoveries at LHC:
  - → **PDF uncertainties can compromise discovery potential**
- At LHC we are not limited by statistic but by **systematic uncertainties**
- To discriminate between conventional PDF sets we need to reach **high experimental accuracy** (~ few%)
  - → **LHC experiments working hard to understand better and improve the detector performances to determine and reduce systematic errors.**
- Standard Model processes like **Direct Photon, Z and W productions** are good processes to **constrain PDF's** at LHC
  - → **LHC should be able to constrain further PDF's, especially the gluon**
- From now to the LHC start up, 2007, our PDF knowledge should improve
  - → **HERA-II: substantial increase in luminosity, possibilities for new measurements**
    - → **Projection: significant improvement to high-x PDF uncertainties (impact on new physics searches)**

Minimum Bias – what is this?

- Essentially all physics at LHC are connected to the interactions of quarks and gluons (small & large transferred momentum).
  - Hard processes (high-pT): well described by perturbative QCD
  - Soft interactions (low-pT): require non-perturbative phenomenological models

Strong coupling constant, $\alpha_s(Q^2)$, saturation effects,…

- **Minimum-bias** and the **underlying event** are dominated by **"soft"** partonic interactions.

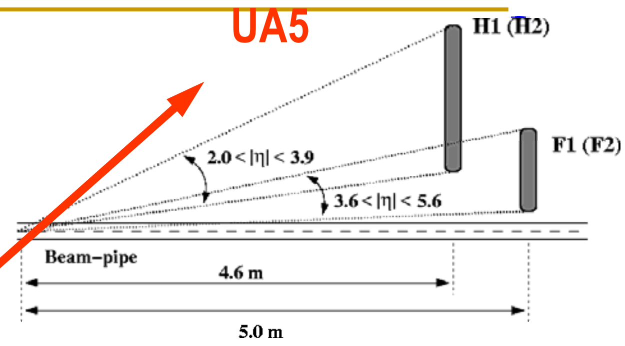


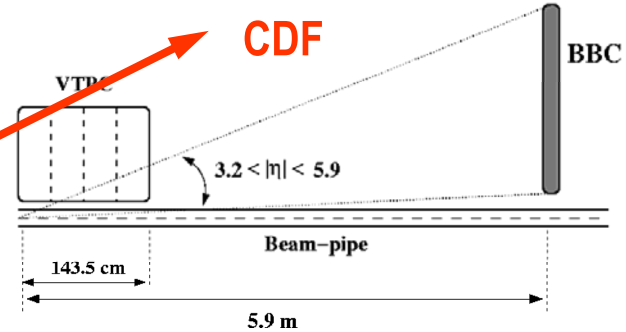
- Why should we be interested?
  - Physics: improve our understanding of QCD effects, total cross-section, saturation, jet cross-sections, mass reconstructions,…
  - Experiments : occupancy, pile-up, backgrounds,…

Minimum-bias events

- A **minimum-bias event** is what one would see with a totally inclusive trigger.
- On average, it has low transverse energy, low multiplicity. Many can be diffractive (single and double).

- **Experimental definition**: depends on the experiment's **trigger**!
- "Minimum bias" is usually associated to **non-single-diffractive events** (NSD), e.g. ISR, UA5, E735, CDF,..





$$\sigma_{tot} = \sigma_{elas} + \sigma_{s.dif} + \underbrace{\sigma_{d.dif} + \sigma_{n.dif}}$$

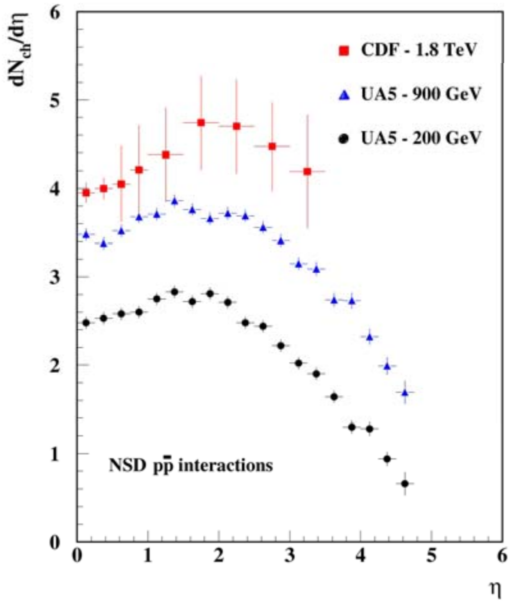
$\sigma_{tot} \sim$ **102 - 118 mb**
(PYTHIA) (PHOJET)

$\sigma_{NSD} \sim$ **65 - 73mb**
(PYTHIA) (PHOJET)

- At the LHC, studies on minimum-bias **should be done early on**, at low luminosity to remove the effect of overlapping proton-proton collisions!

Minimum bias data:

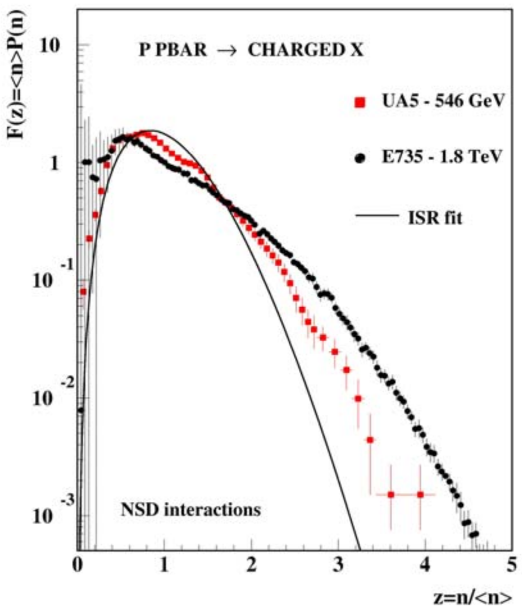
Multiplicity information: $\langle n_{ch} \rangle$, $dN/d\eta$, KNO, FB, etc.

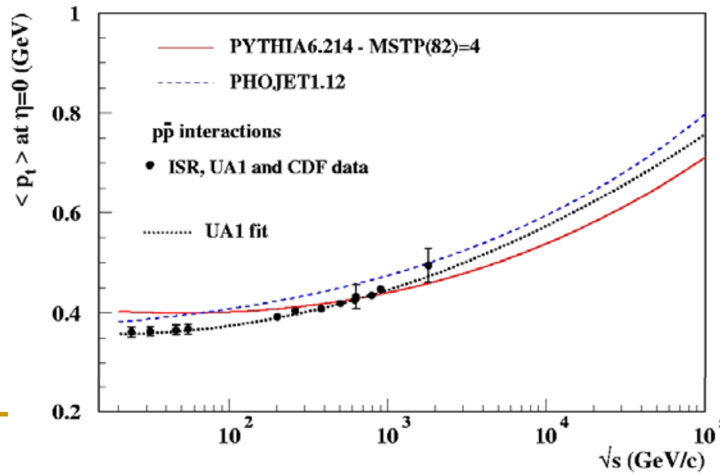


Set π^0, K^0_s and Λ^0 stable

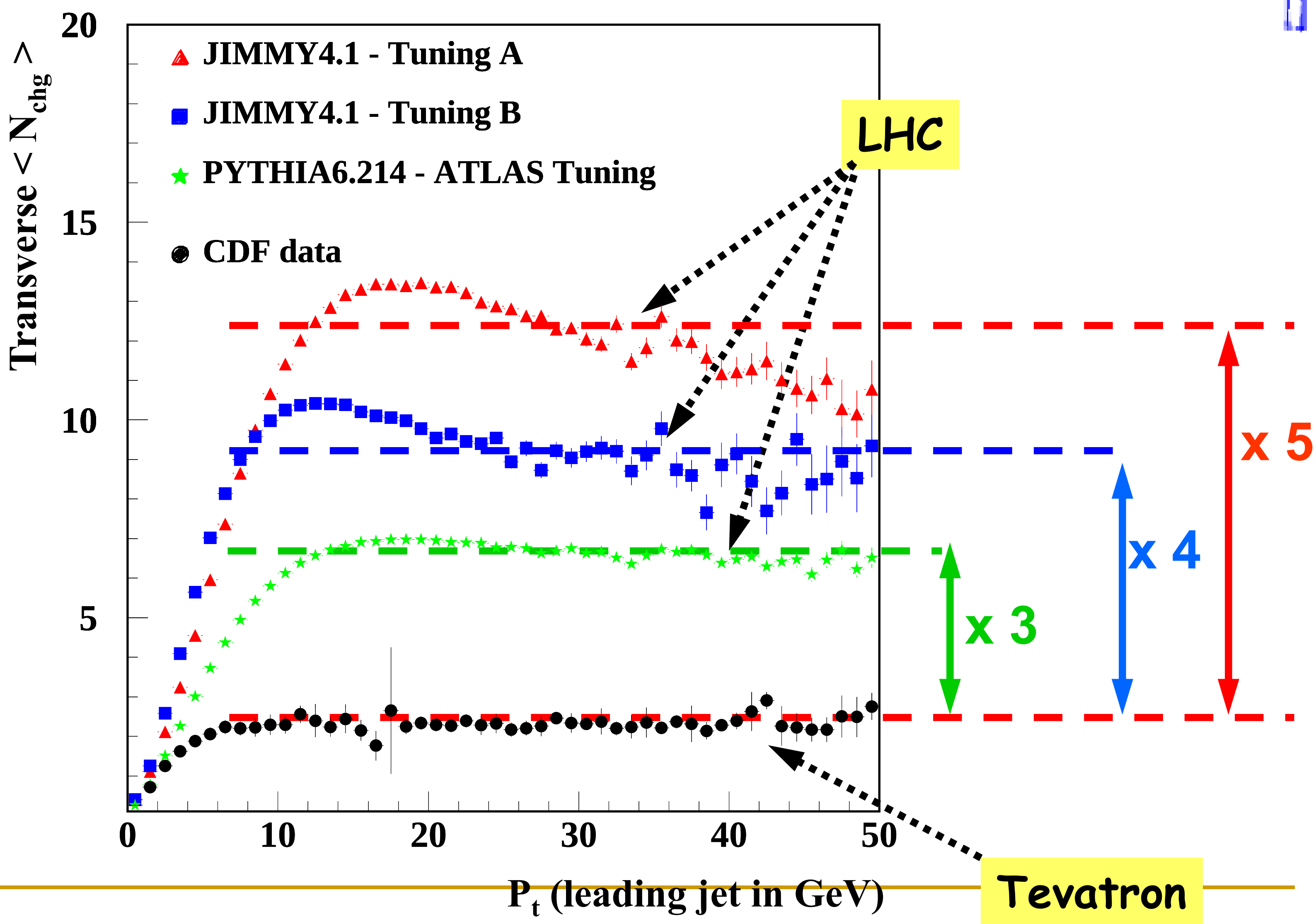
Experiment	Colliding beams
CERN – ISR	pp at $\sqrt{s}$ = 30.4, 44.5, 52.6 and 62.2 GeV
UA5 – SPS	$p\bar{p}$ at $\sqrt{s}$ = 200, 546 and 900GeV
CDF - Tevatron E735 - Tevatron	$p\bar{p}$ at $\sqrt{s}$ = 1.8TeV

- Data samples are (usually) corrected for detector effects (p_T cuts, limited η range, etc.)

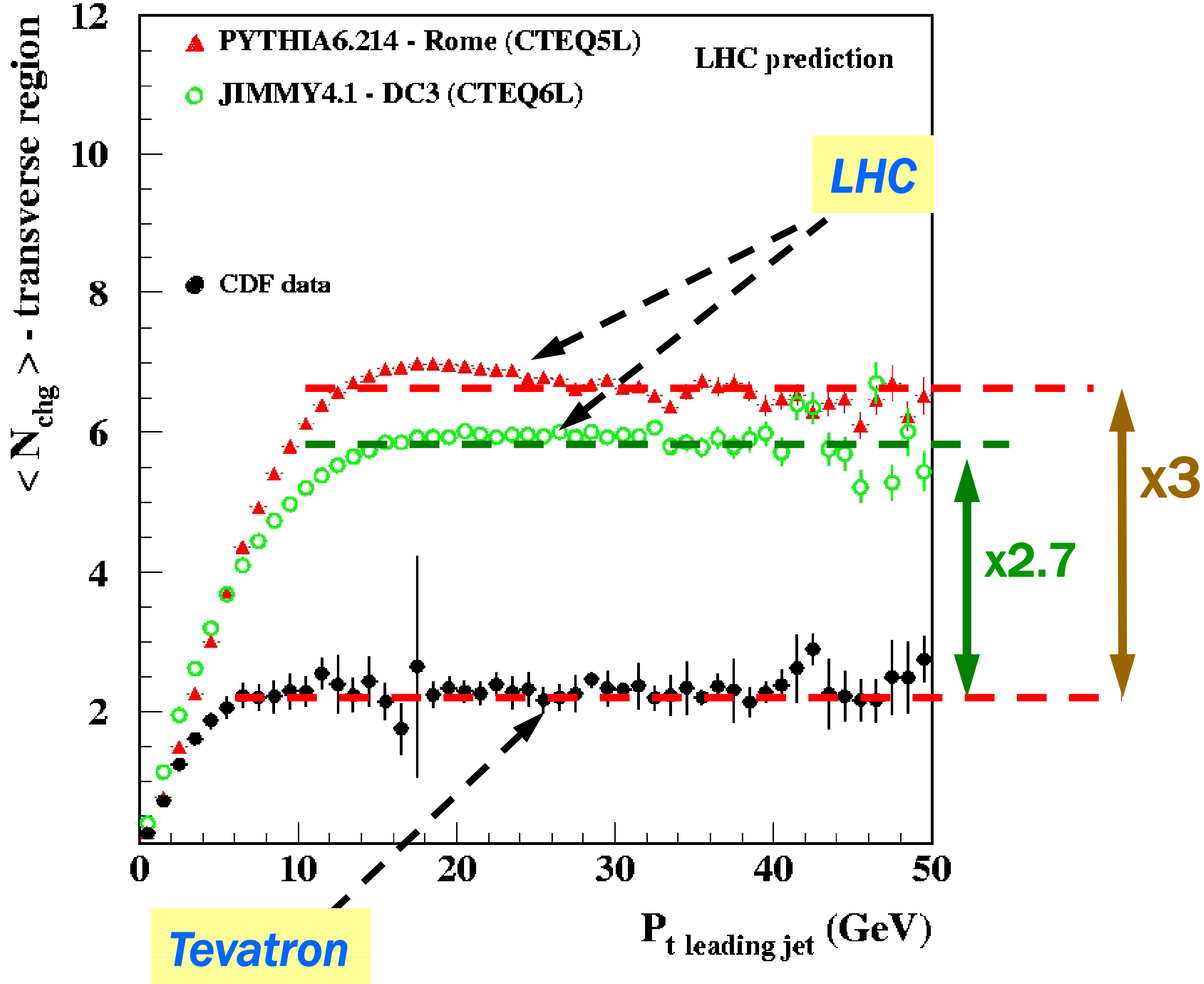




LHC predictions: JIMMY4.1 Tunings A and B vs. PYTHIA6.214 – ATLAS Tuning (DC2)



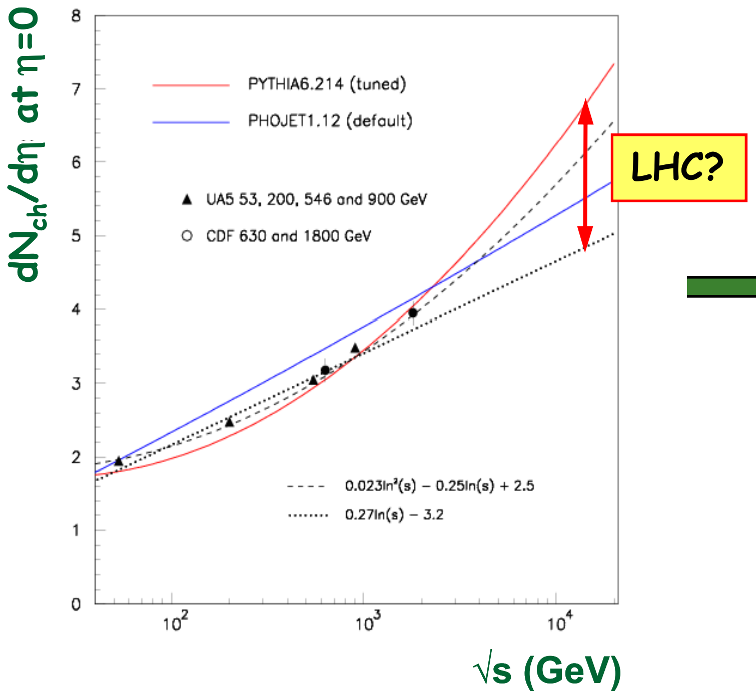
Min. Bias tuning: Jimmy in CSC

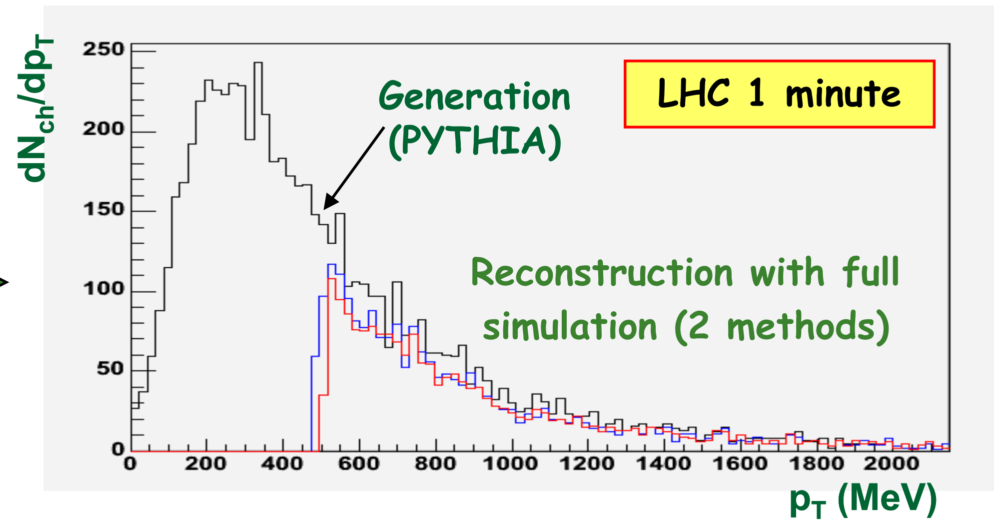


Energy dependent PTJIM generates UE predictions similar to the ones generated by PYTHIA; the difference used to be a factor two!

Minimum bias tuning on data

- **Need to control this QCD process!** (Ex.: Number of charged tracks, N_{ch})





- Check MC with data during commissionning
- Limited to ~500 MeV by track efficiency

Difficult to predict LHC minimum bias

Take special runs with lower central magnetic field to reach p_T~200 MeV

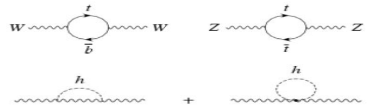
W mass (1)

- M_W is a fundamental SM parameter linked to the top, Higgs masses and $\sin\theta_W$. In the "on shell" scheme:

$$M_W = \sqrt{\frac{\pi\alpha_{EM}}{G_F\sqrt{2}}} \times \frac{1}{\sin\theta_W \sqrt{1-\Delta r}}$$

radiative correction ~4%

$f(M_t^2, \ln M_H)$



- Current precision on M_W direct measurement:

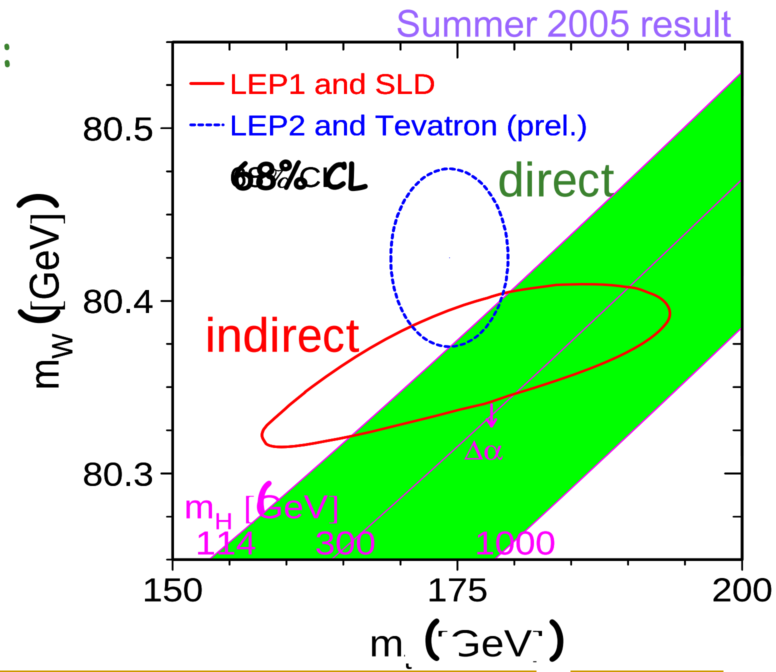
LEP2 + Tevatron ➔ ΔM_W ~ 35 MeV

- For equal contribution to M_H uncertainty:

$$\Delta M_W \approx 0.7\times10^{-2}\,\Delta M_t$$

ΔM_t < 2 GeV ➔ ΔM_W < 15 MeV

Challenging but needed for consistency checks with direct M_H measurement



W mass (2)

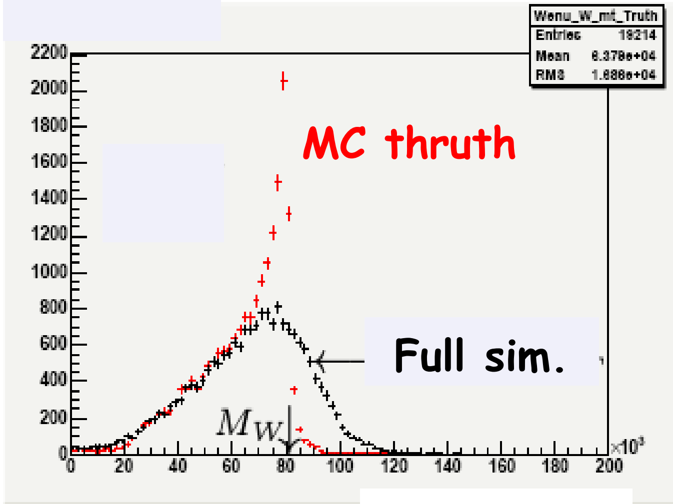
Measurement method:

$$M_T^W = \sqrt{2\, p_T^l\, p_T^\nu (1 - \cos \Delta\phi_{l\nu})}$$

Estimated with W recoil

- Isolated lepton P_T>25 GeV
- E_T^{miss}>25 GeV
- No high pt jet E_T<20 GeV
- W recoil < 20 GeV

➔ 30M evts/10 fb^{-1}



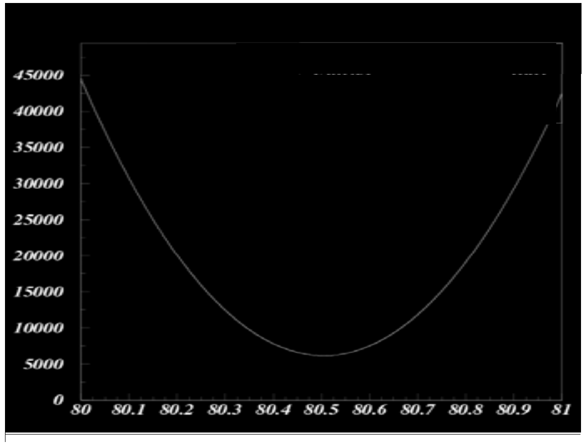
M_T^W (MeV)

➔ Sensitivity to M_W through falling edge

➔ Compare data with Z^0 tuned MC samples where input M_W varies in [80-81] GeV by 1 MeV steps

➔ Minimize χ^2(data-MC): 2 MeV statistical precision

χ^2 (data-MC)



Input M_W (GeV)

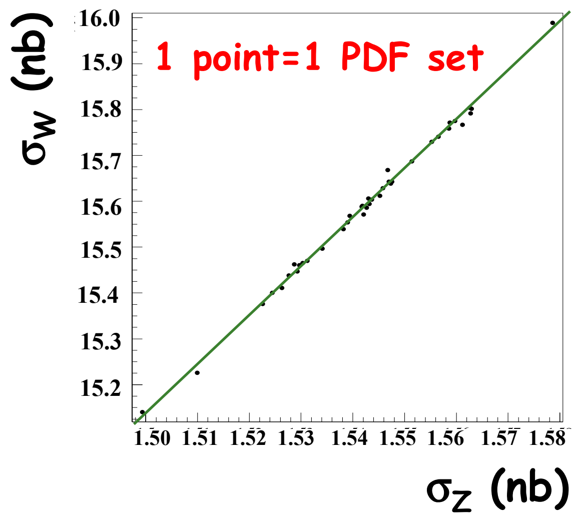
W mass (3)

❑ **Systematics errors on M_W (MeV) from <u>experiment</u> and *theory***

Source	CDF, runIb PRD64,052001	ATLAS 10 fb^{-1}	Comments
Lepton E,p scale	75	15*	B at 0.1%, align. 1μm, tracker material to 1%
PDF	15	10*	
Rad. decays	11	<10	Improved theory calc.
W width	10	7	$\Delta\Gamma_W$=30 MeV (Run II)
Recoil model	37	5*	Scales with Z stat
p_T^W	15	5*	Use p_T^Z as reference
Background	5	5	
E resolution	25	5*	
Pile-up, UE	-	??*	Measured in Z events
Stat⊕syst	113	< 25	W→e ν
TOTAL	89	< 20	W→e ν + W→μ ν

* Z reduce syst. on M_W

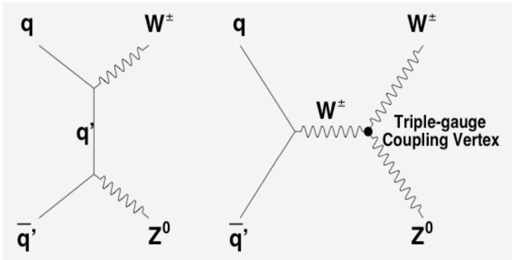
Ex.: Correlation between Z and W cross-section



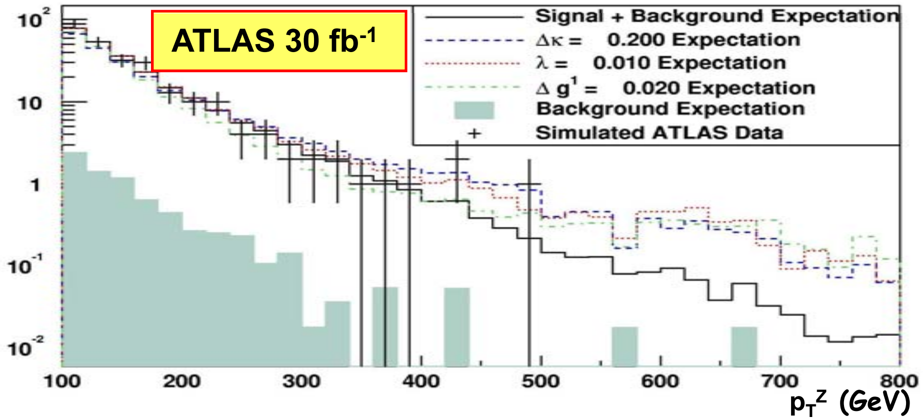
→ deduce W kinematics from Z

Triple gauge couplings (1)

- **Self interaction between 3 gauge bosons ➔ Triple Gauge Coupling (TGC)**
  - direct test of non-Abelian structure of the SM
  - SM TGC ($WW\gamma$, WWZ) beautifully confirmed at LEP
  - ➔ Modification of gauge-boson pair production



- **Most favorable observable at LHC**
  - p_T^V ($V=Z, \gamma$)
  - ➔ Sensitivity to new physics: few events in high p_T^V tail



NLO studies with selection tuned for Z/W leptonic decay: maximum likelihood on p_T^V ➔ sensitivity to anomalous TGC

Triple gauge couplings (2)

- **SM allowed charged TGC in WZ, Wγ with 30 fb^{-1}**
  - ≥1000 WZ (Wγ) selected with S/B = 17 (2)
  - **5** parameters for anomalous contributions (=0 in SM) scale with $\sqrt{\hat{s}}$ for g_1^Z, κ_s and $\hat{s}$ for λ_s
  - Measurements still dominated by statistics, but improve LEP/Tevatron results by ~2-10

	ATLAS 95% CL (±stat ±syst)
Δg_1^Z	± 0.010 ± 0.006
$\Delta\kappa_Z$	± 0.12 ± 0.02
λ_Z	± 0.007 ± 0.003
$\Delta\kappa_\gamma$	± 0.07 ± 0.01
λ_γ	± 0.003 ± 0.001

- **SM forbidden neutral TGC in ZZ, Zγ with 100 fb^{-1}**
  - **12** parameters, scales with $\hat{s}^{3/2}$ or $\hat{s}^{5/2}$
  - Measurements completely dominated by statistics, but improve LEP/Tevatron limits by ~10^3-10^5

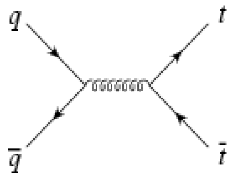
	ATLAS 95% CL stat
$f_{4,5}^{Z,\gamma}$	$7\ 10^{-4}$
$h_{1,3}^{Z,\gamma}$	$3\ 10^{-4}$
$h_{2,4}^{Z,\gamma}$	$7\ 10^{-7}$

- **Quartic Gauge boson Coupling in Wγγ can be probed with 100 fb^{-1}**

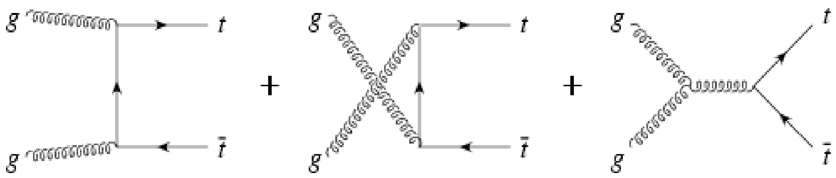
Top production and decay at LHC

Strong Interaction → $t\bar{t}$

LHC
σ ~833 pb
10% $q\bar{q}$, 90% gg

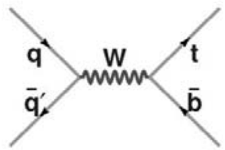


Tevatron
σ ~7 pb
85% $q\bar{q}$, 15% gg

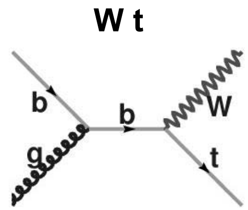


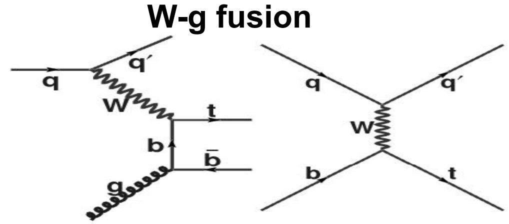
Weak Interaction → single top*

LHC
σ ~300 pb
75%Wg, 20%Wt



Tevatron
σ ~3 pb
65%Wg, 30%Wt





*not observed yet !

BR ($t \rightarrow Wb$) ~ 100 % in SM and no top hadronisation

$W \rightarrow e\nu, \mu\nu$

$t\bar{t}$ final states (LHC,10 fb^{-1})

- Full hadronic (3.7M) : 6 jets
- Semileptonic (2.5M) : l + ν + 4jets
- Dileptonic (0.4M) : 2l + 2ν + 2jets

Single top final states (LHC, 10 fb^{-1})

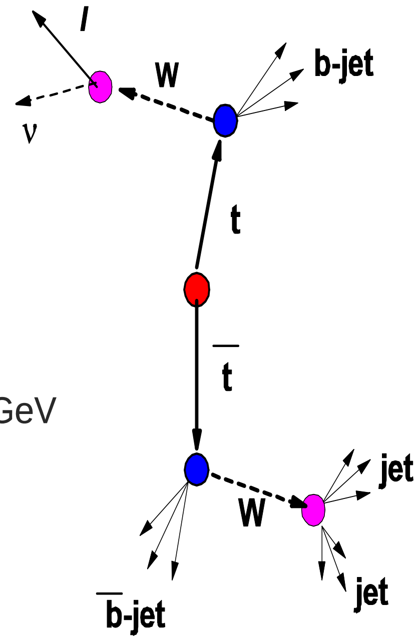
- W-g (0.5M) : l + ν + 2jets
- Wt (0.2M) : l + ν + 3jets
- W* (0.02M) : l + ν + 2jets

$t\bar{t}$ event selection

❑ Selection cuts

- High statistics ➔ well reconstructed high p_T particles
- Rely on expected b-tagging performances

➔ non $t\bar{t}$ background (W+jets, $b\bar{b}$, ...) negligeable



Semileptonic

- Isolated lepton P_T>20 GeV
- E_T^{miss}>20 GeV
- 4 jets with p_T>40 GeV (ΔR=0.4)
- **2 b-tagged jets**

- **ε(sig) ~ 3%, 80k events / 10 fb^{-1}**
- **S/B~12 ($t\bar{t}\to\tau$+X, other negligeable)**

Dileptonic

- 2 opposite charged lepton P_T>20 GeV
- E_T^{miss}>40 GeV
- **2 b-tagged jets** with p_T>20 GeV

- **ε(sig) ~ 6%, 20k events / 10 fb^{-1}**
- **S/B~6 ($t\bar{t}\to\tau$+X, other neg.)**

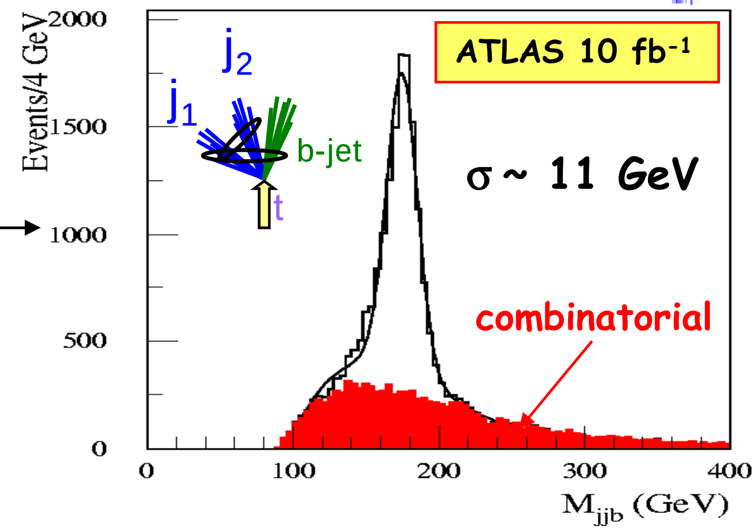
❑ Apply this selection for top mass, W polarization, $t\bar{t}$ spin correlation studies

Top mass with semileptonic events (1)

❑ Reconstruction of the full $t\bar{t}$ event

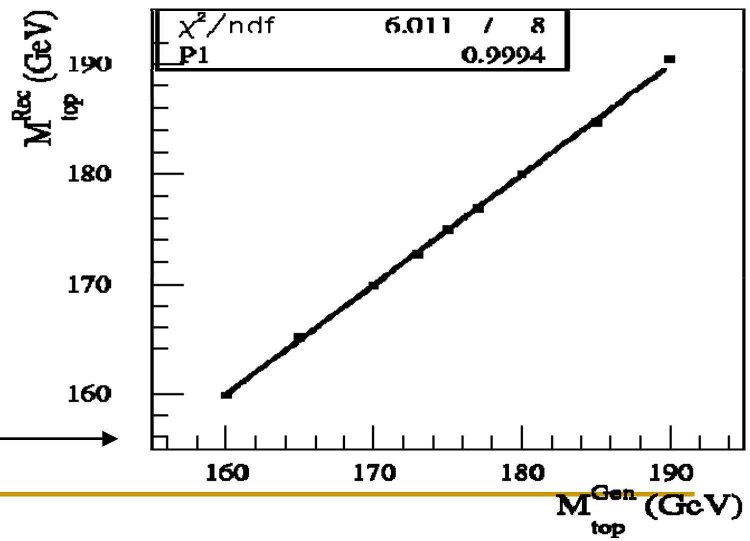
- Use W→jj to calibrate light jet scale
- Reconstruct t→jjb side: M_{jjb} in ± 35 GeV
- Reconstruct t→lνb side using M_W constraint

ε(sig)~ 1%, 20k events / 10 fb^{-1}, top purity = 70%



❑ Kinematic fit

- Select well recons. b-jets, low FSR events
- Constraint event by event:
  $M_{jj} = M_{l\nu} = M_W$ and $M_{jjb} = M_{l\nu b} = M_t^{fit}$
  ➔ (χ^2, M_t^{fit}) ➔ top mass estimator (m_t)
- m_t linear with input top mass in ~0.1 GeV

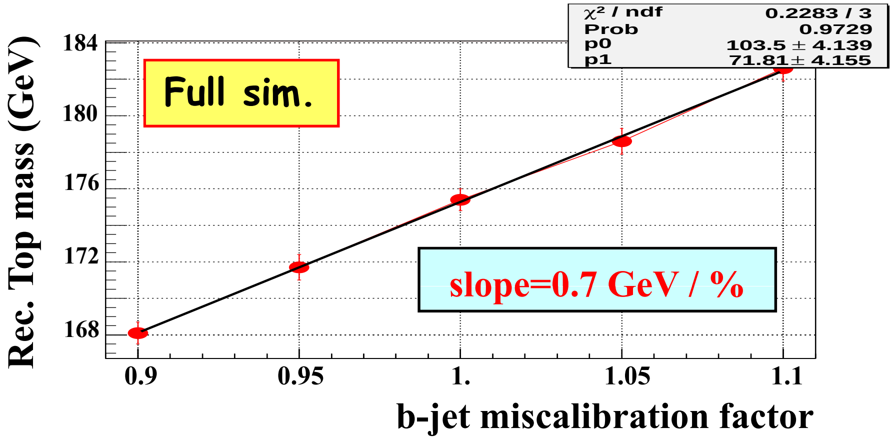


Top mass with semileptonic events (2)

❑ Systematics errors on m_t (GeV)

Source	ATLAS 10 fb^{-1}
b-jet scale (±1%)	0.7
Final State Radiation	0.5
Light jet scale (±1%)	0.2
b-quark fragmentation	0.1
Initial State Radiation	0.1
Combinatorial bkg	0.1
TOTAL: Stat ⊕ Syst	0.9

- Systematics from b-jet scale:



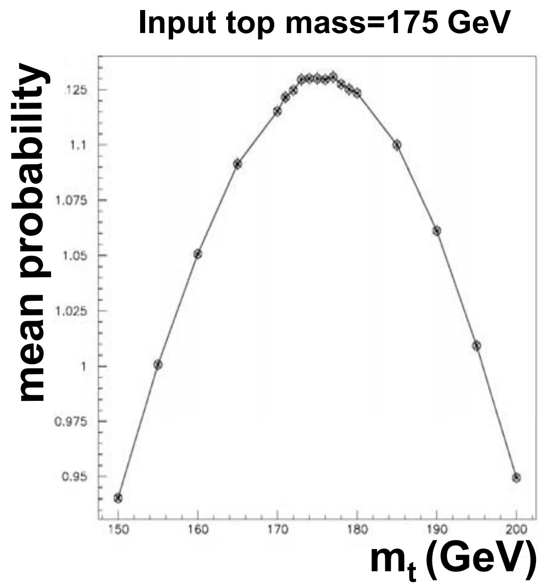
- Other methods (invariant 3 jet jjb mass, large pT events, ...) gives higher systematics but will allow reliable cross-checks

❑ **ATLAS can measure M_t at ~1 GeV in semileptonic events to be compared with Tevatron expectations (2 fb^{-1}) ~2 GeV**

Top mass with other channels

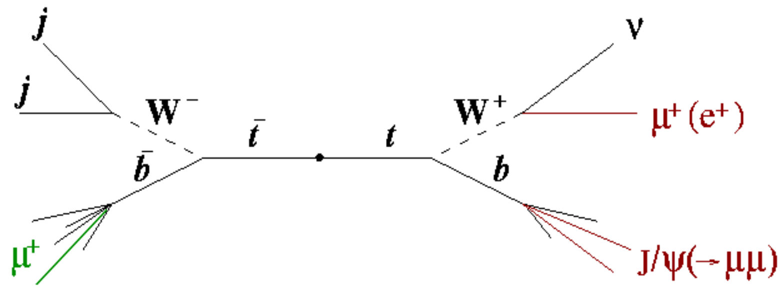
❑ Dileptonic (10 fb^{-1})

- Need to reconstruct full $t\bar{t}$ event to assess the 2 ν momenta ➔ 6 equations (Σp_T=0, $M_{l\nu}= M_W$, $M_{l\nu b}= M_t$)
- Event/event: assume m_t and compute the solution probability (using kinematics & topology)
- All evts: choose m_t with highest mean probability
- Systematic uncertainties: ~2 GeV (PDF + b-frag.)



❑ Final states with J/ψ (100 fb^{-1})

- Correlation between $M_{lJ/\psi}$ and m_t
- No systematics on b-jet scale !
- ~1000 evts/100 fb^{-1} ➔ ΔM_t ~1 GeV



Day one: can we see the top?

We will have a non perfect detector:
Let's apply a simple selection

W =2 jets maximising p_T W in jjj rest frame

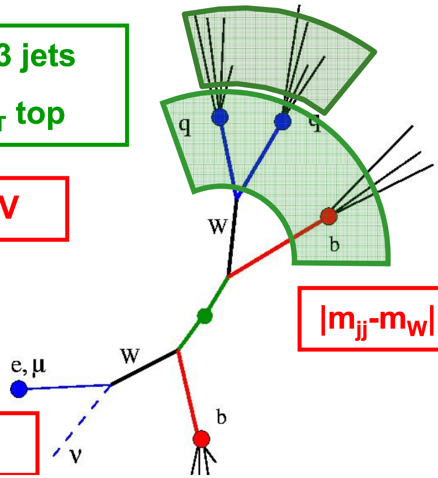
Hadronic top=3 jets maximising p_T top

4 jets p_T> 40 GeV

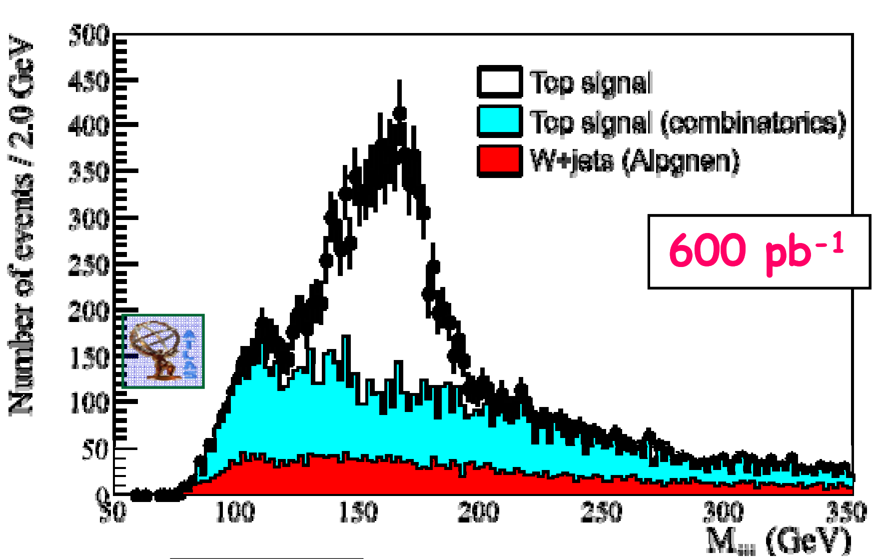
Isolated lepton p_T> 20 GeV

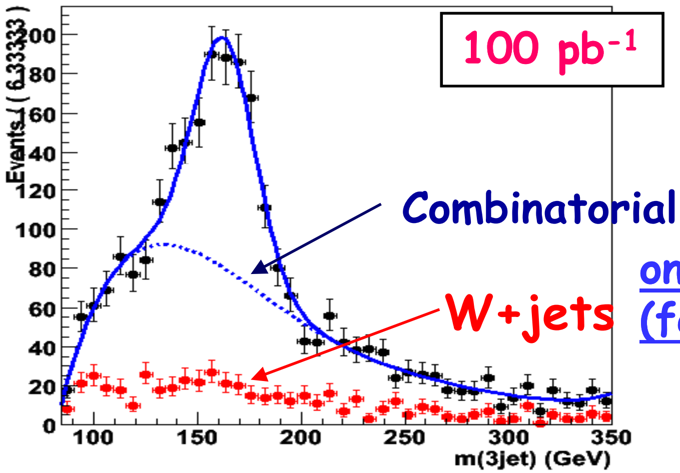
E_T^{miss} > 20 GeV

$|m_{jj}-m_W|$ < 20 GeV

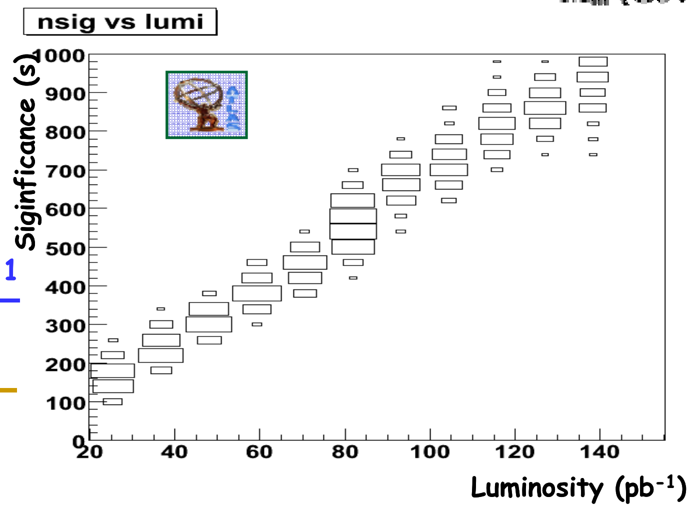


- No b-tag
- relaxing cut on 4th jet: p_T>20 GeV:





only with 100 pb^{-1}
(few days)



W polarization in top decay (1)

❑ **Test the top decay** (in fully reconstructed $t\bar{t}$) **with W polarization ...**

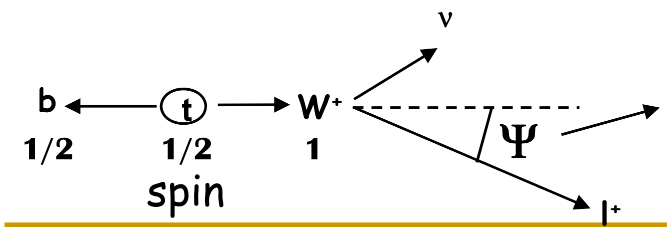
	Longitudinal W^+ (F_0)	Left-handed W^+ (F_L)	Right-handed W^+ (F_R)
Standard Model (M_{top}=175 GeV) NLO	0.703 $\left(= \frac{M_t^2}{M_t^2 + 2M_W^2}\right)$ 0.695	0.297 $\left(= \frac{2M_W^2}{M_t^2 + 2M_W^2}\right)$ 0.304	0.000 0.001

Sensitive to EWSB

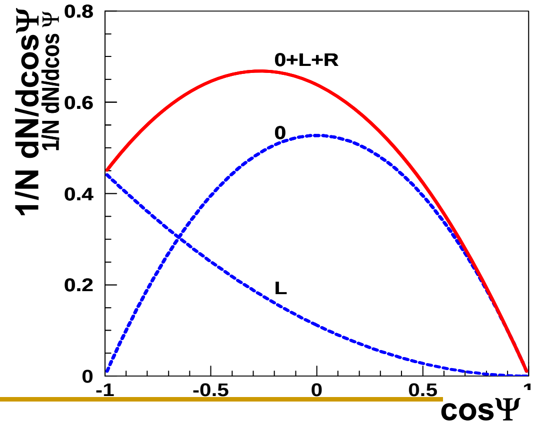
Test of V-A structure

❑ **...measured through angular distribution of charged lepton in W rest frame**

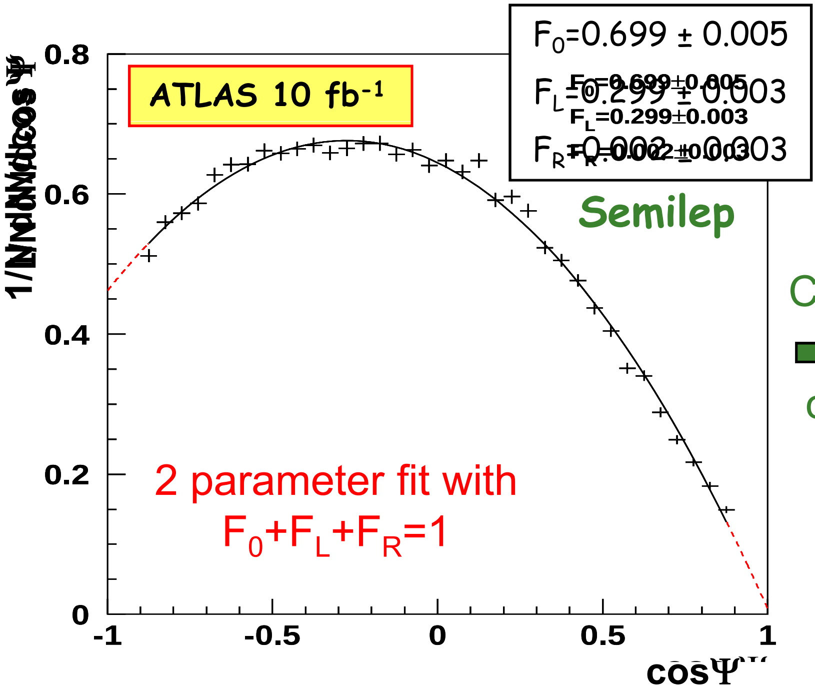
$$\frac{1}{N}\frac{dN}{d\cos\Psi} = \frac{3}{2}\left[\boxed{F_0}\cdot\left(\frac{\sin\Psi}{\sqrt{2}}\right)^2 + \boxed{F_L}\cdot\left(\frac{1-\cos\Psi}{2}\right)^2 + \boxed{F_R}\cdot\left(\frac{1+\cos\Psi}{2}\right)^2\right]$$



Angle between:
- lepton in W rest frame and
- W in top rest frame



W polarization in top decay (2)



Combined results of semilep+dilep

	SM (M_t=175 GeV)	ATLAS (±stat ±syst)
F_0	0.703	± 0.004 ± 0.015
F_L	0.297	± 0.003 ± 0.024
F_R	0.000	± 0.003 ± 0.012

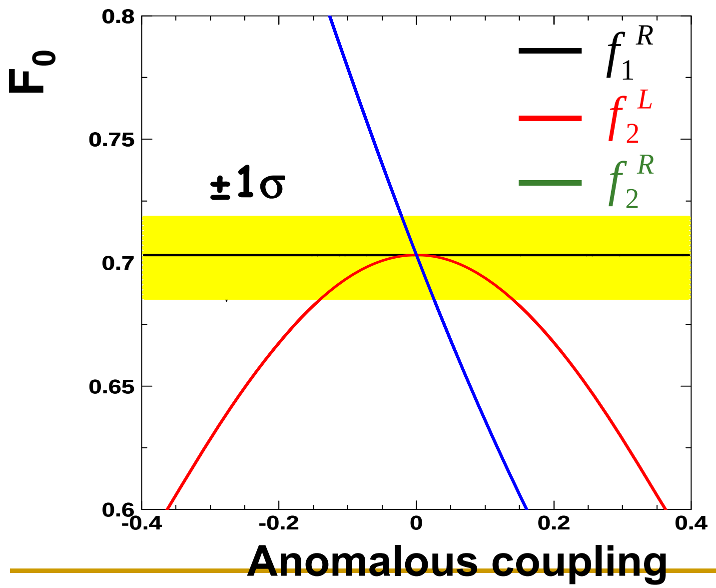
- Systematics dominated by b-jet scale, input top mass and FSR
- ATLAS (10 fb^{-1}) can measure F_0~2% accuracy and F_R with a precision ~1%
- Tevatron expectations (2 fb^{-1}): δF_0^{stat}~0.09 and δF_R^{stat}~0.03

Anomalous tWb couplings

- From W polarization, deduce sensitivity to anomalous tWb couplings in a model independent approach, i.e. effective Lagrangian

$$L = \frac{g}{\sqrt{2}} W_\mu b \gamma^\mu (f_1^L P_L + f_1^R P_R) t - \frac{g}{\sqrt{2}\Lambda} \partial_\nu W_\mu b \sigma^{\mu\nu} (f_2^L P_L + f_2^R P_R) t + h.c.$$

$P_{R/L} = \frac{1}{2}(1 \pm \gamma_5)$ and 4 couplings (in SM LO $f_1^L = V_{tb} \approx 1,\ f_1^R = f_2^L = f_2^R = 0$)



- **2σ limit (stat⊕syst) on f_2^R = 0.04**
- **3 times better than indirect limits (B-factories, LEP)**
- **Less sensitive to f_1^R and f_2^L already severely constrained by B-factories**

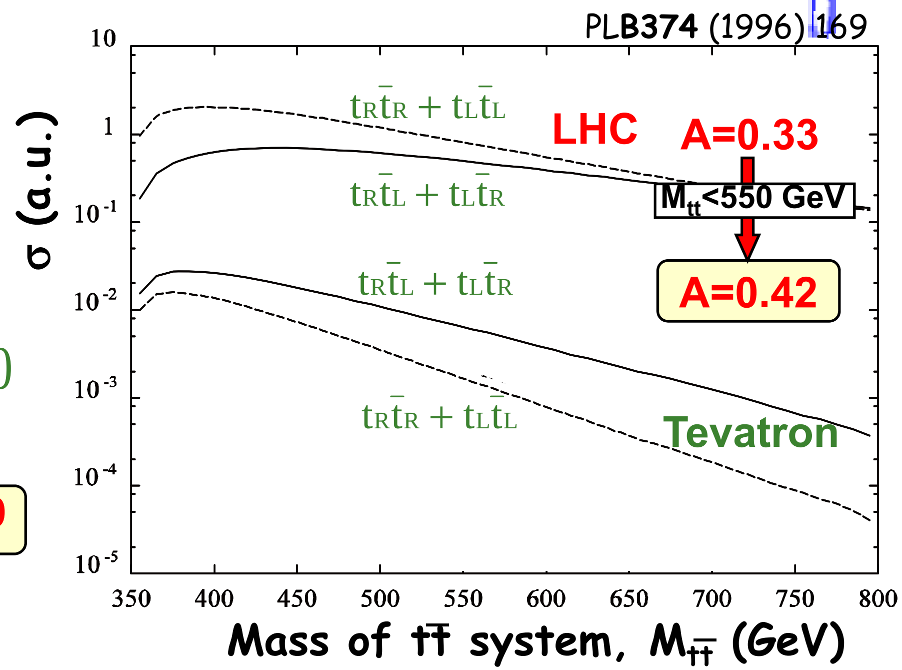
$t\bar{t}$ spin correlation

- **Test the top production …**
  - t and $\bar{t}$ not polarised in $t\bar{t}$ pairs, but
  - correlations between spins of t and $\bar{t}$

$$A = \frac{\sigma(t_L\bar{t}_L) + \sigma(t_R\bar{t}_R) - \sigma(t_L\bar{t}_R) - \sigma(t_R\bar{t}_L)}{\sigma(t_L\bar{t}_L) + \sigma(t_R\bar{t}_R) + \sigma(t_L\bar{t}_R) + (t_R\bar{t}_L)} \neq 0$$

$$A_D = A_X + A_Y + A_Z$$

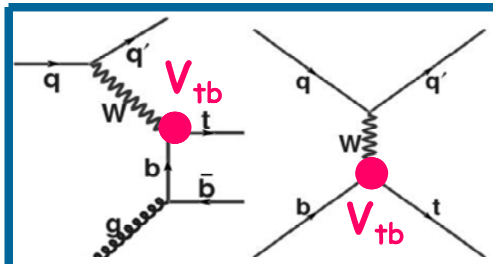
A_D=-0.24 → **A_D=-0.29**



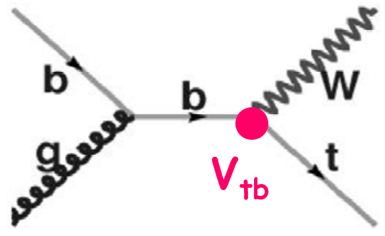
- **… by measuring angular distributions of daughter particles in top rest frames**
  - ATLAS (10 fb^{-1}) semilep+dilep ➔ **A ±0.014±0.023, A_D ±0.008±0.010 (±stat±syst)**
  - Tevatron expectations (2 fb^{-1}): $\delta A^{stat}/A \sim 40\%$
  - Sensitivity to new physics: top spin ≠ 1/2, anomalous coupling, $t \to H^+ b$

EW single top

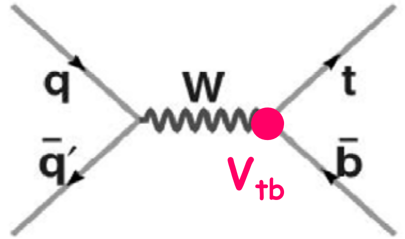
Three different Processes (never observed yet)



t-channel



Wt-channel



W* (s-channel)

$\sigma \sim 250$ pb | $\sigma \sim 70$pb | $\sigma \sim 10$ pb

Powerfull Probe of V_{tb} ($\delta V_{tb}/V_{tb}$~few% @ LHC)

Theoretical uncertainties: [PRD 70 (2004) 114012, PL B524 2002 283-288]

- Quark-gluon luminosity inside b-quark (PDF)
- Renormalization scale (μ)
- top mass (Δm_{top}=4.3GeV $\rightarrow$ σ(W*) changed by 3%)

Probe New Physics Differently: ex. FCNC affects more t-channel
[PRD63 (2001) 014018] ex. W′ affects more s-channel

EW single top (1)

❑ Selection

- Compare to $t\bar{t}$ statistics and S/B lower:
  - ➔ Likelihood based on N(jet), N(b-jet), $H_T = \Sigma p_T(\text{jet})$, $M_{l\nu b}$
  - ➔ Need 30 fb^{-1} (especially W*)
- Main background: tt, W+jets, ...

Selected Signal (S) and Background (B) after 30 fb^{-1}

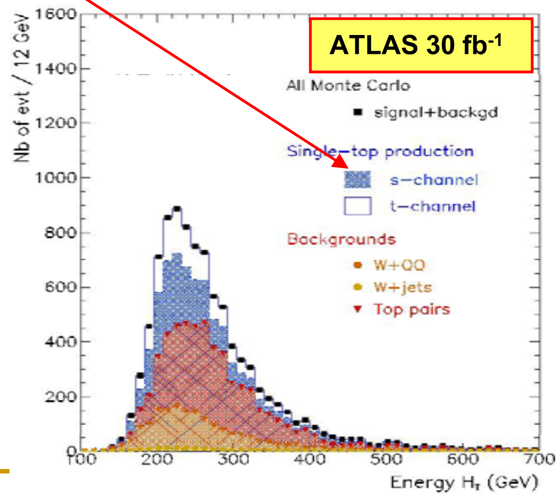
Process (W→lν)	S	B	√(S+B)/S
W-g	7k	2k	1 %
Wt	5k	35k	4 %
W*	1k	5k	6 %

❑ Cross-section (σ) measurement

- Theory uncertainty from ±4% (W*) to ±8% (W-g)
- Relative **statistical** error on σ estimated with √(S+B)/S for all 3 processes separately: 1%-6%

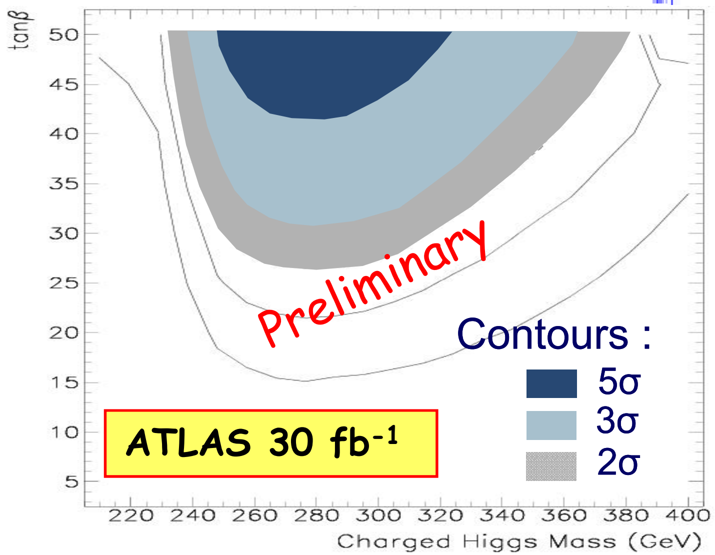
➔ Stat⊕theory errors ~7-8% per process (no syst.)

➔ Need to control background level with LHC data



EW single top (2)

- **Sensitivity to new physics in W***
  - Presence of $H^{+} \rightarrow tb$ decay (2HDM model) increases the cross-section
  - Sensitivity for high tanβ and M_H>200 GeV
  - Complementary to direct search



- **Direct access to CKM Matrix element V_{tb}**
  - $\sigma \propto |V_{tb}|^2$ ➔ **stat**. error from 0.5% (Wg) to 3% (W*)
  - Stat⊕theory errors ~3-4% for each process (no systematics)
  - Sensitivity to new physics by combining results with W polarization in $t\bar{t}$
- **Single top are highly polarized**
  - **Statistical** precision on top polarization of ~2% after 10 fb^{-1}

Flavor Changing Neutal Current

- **SM FCNC in top decays are highly suppressed (Br < 10^{-13}-10^{-10})**
  - Some models beyond SM can give HUGE enhancements (Br up to 10^{-5})
  - FCNC can be detected through top decay ($t\bar{t}$, single top)
  - Likelihood to separate signal from background (mainly $t\bar{t}$)

- **ATLAS 5σ sensitivity / 95% CL to FCNC branching ratio in $t\bar{t}$**

Process	95% CL in 2005	ATLAS 5σ (10 fb^{-1})	ATLAS 95% CL (10 fb^{-1})
$t \to Zq$	~ 0.1	$5\ 10^{-4}$	$3\ 10^{-4}$
$t \to \gamma q$	0.003	$1\ 10^{-4}$	$7\ 10^{-5}$
$t \to gq$	0.3	$5\ 10^{-3}$	$1\ 10^{-3}$

Reconstruct $t \to Zq \to (l^+l^-)j$

Huge QCD background

➔ ATLAS improve current limits by ~10^2-10^3, far from SM reach

Standard Model Summary

- Atlas has a lot to do in performing detailed measurements of the Standard Model predictions.
  - One must not forget that that these processes are the backgrounds for any kind of new physics search.
  - The improvements in SM parameter estimations lead to enhanced precision in indirect New Physics measurements.
  - A lot of topics not covered in this talk (like e.g. B-physics measurements, heavy ions etc.) which are however rather active fields at ATLAS.