Selected Topics in ATLAS (France) and Specific Requests/Questions to Theorists

Marumi Kado (LAL)

Overview of ATLAS France

	Lumi.	FP	QCD	EW	HF	Top	Higgs	SUSY	Exotics	HI
CPPM Marseille						✓	✓			
IRFU Saclay CEA		✓			✓	✓	✓		✓	
LAL Orsay	✓		✓	✓			✓	✓		
LAPP Annecy		✓	✓	✓			✓	✓		
LPC Clermont						✓				
LPNHE Paris			✓			✓	✓			
LPSC Grenoble						✓	✓		✓	

Lumi. : Luminosity (Alpha)

FP : Forward Physics (Diffractive)

QCD : Standard Model (QCD)

EW : Standard Model (EW)

Top : Standard Model (Top)

HF : Heavy Flavour physics

HI : Heavy Ion physics

ATLAS (France) Analyses Priorities

"… the consequences of interpreting possible discrepancies as new physics are too important for us to blindly rely on our FAITH in the goodness of the available tools."

→ Experimentalist's interpretation : Do not trust our predictions!

→ Holds for precision measurements too…

"An extensive and coherent campaign of MC testing , validation and tuning at the LHC will therefore be required."

→ Need guidance from the authors of the tools

→ Validation and tuning among MCs and w/ TeVatron data

→ Preparing data driven methods is a priority in ATLAS and therefore also in ATLAS France

"Its precise definition will probably happen only once the data are available, and the first comparisons will give us an idea of how far off we are and which areas require closer scrutiny."

→ But of course need to be careful not to tune out NP

→ Awaiting for the data we should prepare ourselves as best we can…

"The burden, and the merit, of a discovery should and will only rest on the experiments themselves !

M. L. Mangano, Eur. Phys. J. C **59**, 373 (2009)

Outline

Disclaimers :

1.- Concentrate mostly on standard topics : QCD, EW, Top and Higgs.

- *Beyond the standard model topics are the object of a EuroGDR TeraScale.*
- *FP in ATLAS has been studied in close connection with theorists.*
- *HF, HI : Also strong interactions with theorists.*

2.- Even in these general topics only a few cases will be highlighted
(mostly those in which ATLAS France is highly involved)

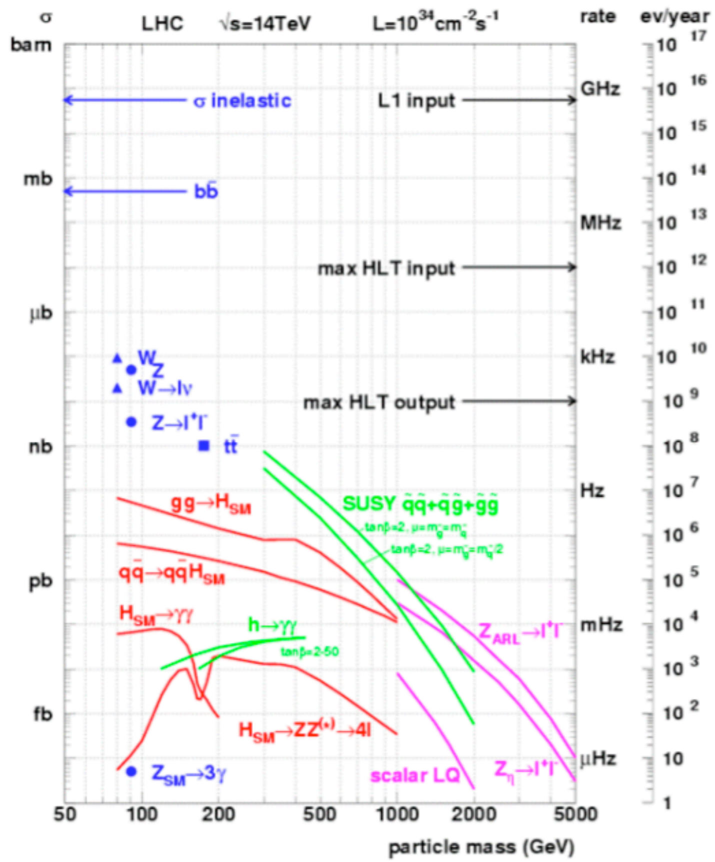
I.- The Main ATLAS Tools

II.- QCD Measurements

III.- EW Measurements

IV.- Top Quark

V.- Higgs Boson



The Main ATLAS Tools

MC Generators and Cross Sections

The ATLAS CSC* exercise

Opportunity to reappraise TDR (1999) results

G. Aad et al, arXiv:0901.0512 [hep-ex]
(1852 pages)

- Improved detector simulation :
  - More precise material description
  - Improved geometry, w/ simulation of misalignments
  - Geant 4
  - Accurate trigger simulation
- Improved Monte Carlo generators :
  - NLO event generators
  - N(N)LO/NLL parton level generators
  - Improved PDFs
  - Parton shower / Matrix element matching
- Data driven methods :
  - Estimate of efficiencies and fake rates
  - Estimate of specific backgrounds

*CSC : Computing System Commissioning

Main Monte Carlo Generators Used in ATLAS

Generator	Version	Hadronization	Processes	Features
PYTHIA	6.4	own	Most Processes	
HERWIG	6.5	own	SUSY signals	
Sherpa	1.011	own	W,Z+jets and VBF Higgs	CKKW matching
AcerMC	3.4	Pythia/Herwig	tt,single top, ttbb, Zbb	Comb. w/ MC@NLO*
ALPGEN	2.13	Herwig/Jimmy	W, Z & tt+jets, VBF Higgs**	MLM Matching
MC@NLO	3.3	Herwig/Jimmy	Inclusive W,Z and Higgs	NLO+PS
MadGraph	4.15	Pythia	Multiple bosons + jets	Ampl. Gen.
Charybdis	1.003	Pythia	μ-Black Holes	
CompHEP	-	Pythia	Exotics	Ampl. Gen.
TopRex	4.11	Pythia	Top prod. (w/ FCNC)	Addition to PYTHIA
WINHAC/HORACE	1.21	Pythia	W hadro-production	QED/EW corr.

PHOTOS : for photon radiation by charged leptons.

TAUOLA : for τ decays.

*AcerMC was combined with MC@NLO for instance in the ttH channel where the overlap of MC@NLO tt events w/ gluon splitting to bb were removed to avoid overlap with AcerMC.

**Also vector diboson production

Main Parton Level Cross Sections

Generator	Hard Scat.	Soft Treat.	Processes
FEWZ	NNLO	FO	Most W and Z inclusive
MCFM	NLO	FO	W, Z, H, WW, ZZ, and ZZ (excl. & incl.)
ResBos	NLO	NLL	Higgs Gluon Fusion, $\gamma\gamma$, inclusive Z
DiPhox	NLO	FO	$\gamma\gamma$ inclusive, single/double frag
JetPhox	NLO	FO	γ–jet inclusive/fragmentation
NLOJet++	NLO	FO	Jet Production
HiGlu	NLO	FO	HiggsGluon Fusion
VV2H	NLO	FO	Higgs VBF
V2HV	NLO	FO	WH, ZH
HQQ	LO	FO	ttH
Prospino	NLO	FO	SUSY
Whizard*	LO	FO	WW scattering

*Interfaced with O'Mega (Optimized Matrix Element GenerAtor)

HDecay : Higgs decays (partly NLO)

Mostly NLO (for consistency w/ backgrounds) mostly FO

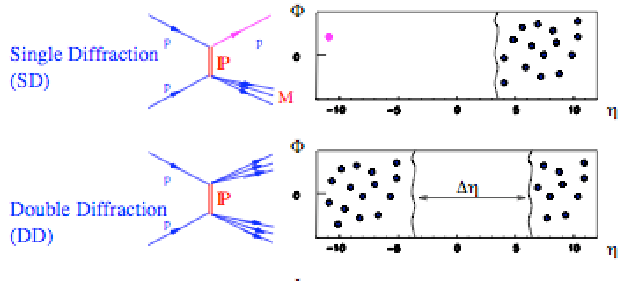
QCD Measurements

Mininum Bias and Underlying Event, Jet Cross Sections, Prompt Photons

Minimum Bias and Underlying Event

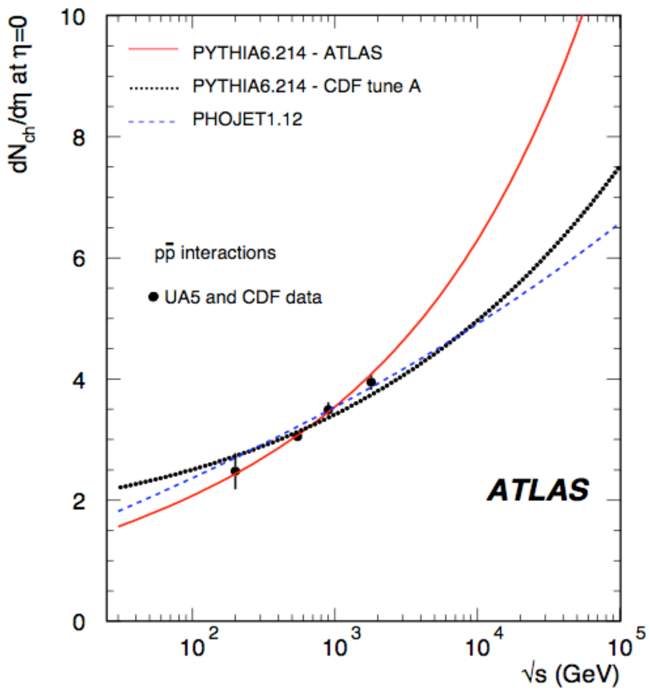
Minimum bias events are defined as inelastic with the least bias possible :

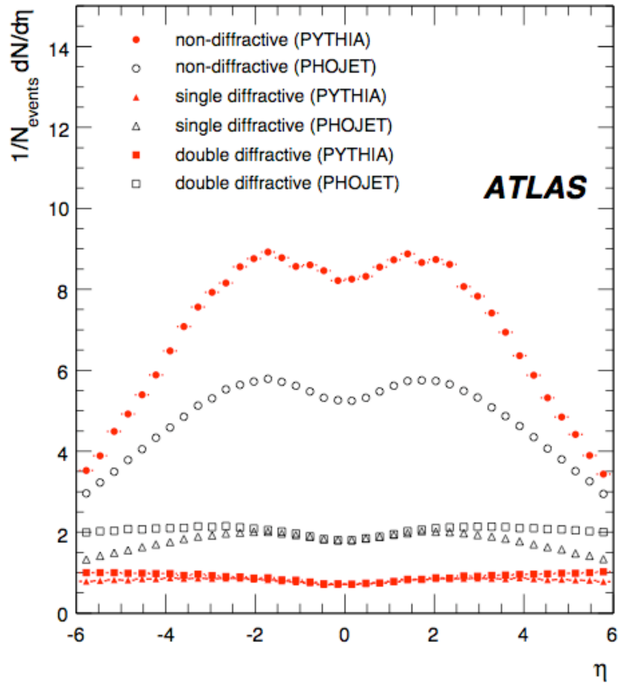
- Historically : Non Single Diffractive (firing backward & forward MB)
- Could include Double Diffractive using improved random triggers



Very important to understand/tune underlying event

Two generators are compared in ATLAS : PYTHIA and PHOJET





Predictions are quite different : Large systematic due to the relative amounts of SD, DD and Non-Difractive

Jetology in ATLAS

ATLAS general concerns

Aside Infrared and collinear safety :
underlying event and noise safety

Default jets in ATLAS :

ATLAS Cone (IC-SM) more recently w/ MidPoint and k_T

Algorithm	Main parameter	Clients
Seeded fixed cone	$R_{\rm cone} = 0.4$	$W \to jj$ in $t\bar{t}$, SUSY
(seed $p_T > 1$ GeV)	$R_{\rm cone} = 0.7$	inclusive jet cross-section, $Z' \to jj$
k_T	$R = 0.4$	$W \to jj$ in $t\bar{t}$, SUSY
	$R = 0.6$	inclusive jet cross-section, $Z' \to jj$

Most widely used : ATLAS cone   Not infrared safe!

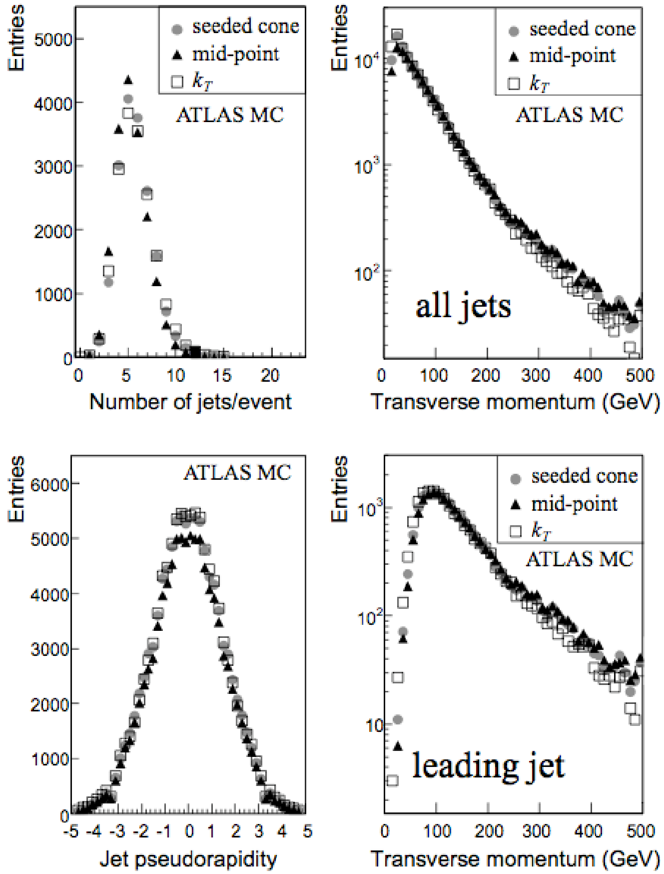
FastJet (M. Cacciari, G. Salam, G. Soyez) package interfaced with ATLAS software including :

- SIScone (Seedless IR Safe Cone)

New default ← - Anti-k_T

- Cambridge-Aachen …

Small differences appear for high P_T jets (in ttbb events)



General guidance for the choice of jet algorithm : Try them all !

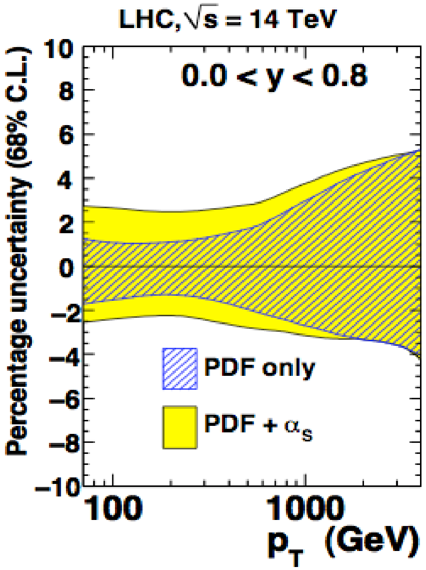
Jet Cross Sections and SUSY searches

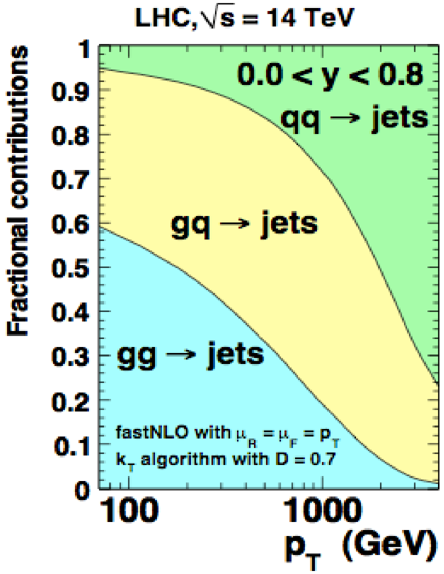
Jet cross section studies in ATLAS done using NLOjet++ (Z. Nagy) based on :

S. Catani and M. H. Seymour, Nucl. Phys. B **485**, 291 (1997)

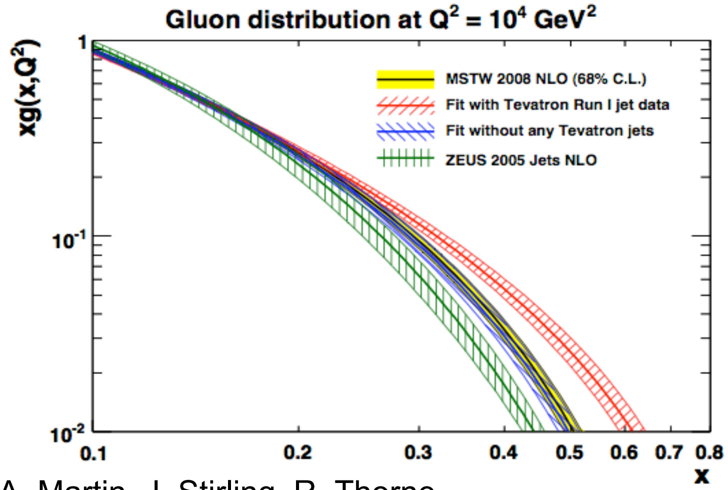
Uncertainties at high P_T are dominated by PDF error…

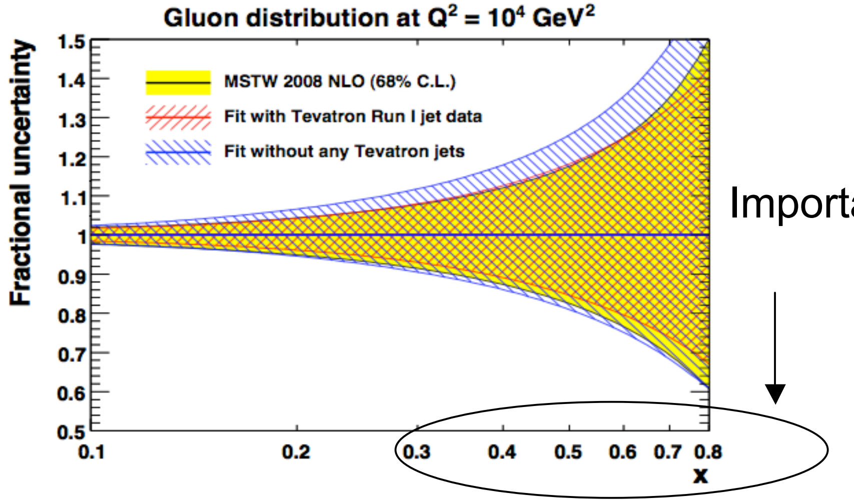
Where in some cases searches for SUSY are most sensitive.





As an example, the use or not of the TeVatron jet data (Run I) changes substantially the picture at large x…





Important but difficult region

A. Martin, J. Stirling, R. Thorne

Apart from PDF (in particular that of the gluon) : NNLO jet cross sections ?

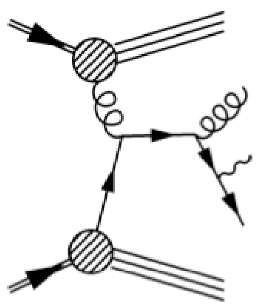
S. Weinzierl (HEP-PH 0606301v1)

Prompt Photons

- Very important for Jet Energy scale calibration
- Classic tool to constrain the gluon PDF through gq→γq

Of particular interest for the Higgs production in general... also large background in the H→γγ

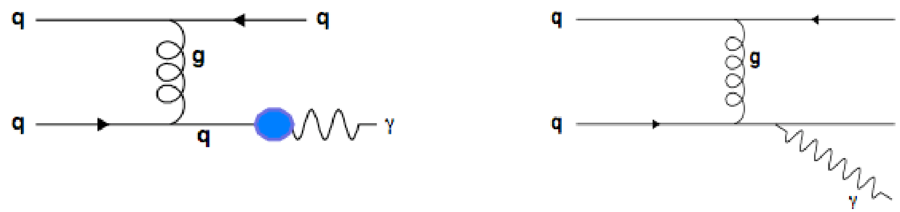
The intricate question : treatment/control of the fragmentation processes ?



Direct and fragmentation modelled at NLO (FO) by JetPhox

S. Catani, M. Fontannaz, J.-P. Guillet and E. Pilon, JHEP **0205**, 028 (2002)

Complete treatment to match collinear part to the

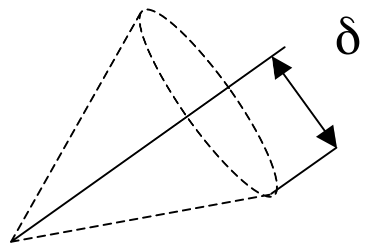


How to match the parton level isolation implemented in JetPhox with the data isolation criteria ?

Checked with PYTHIA (differences at the 15% level)

Use the fragmentation-less IR safe cone definition by S. Frixione?

$$E_{tot}(\delta) \leq \mathcal{K}\, \delta^2$$

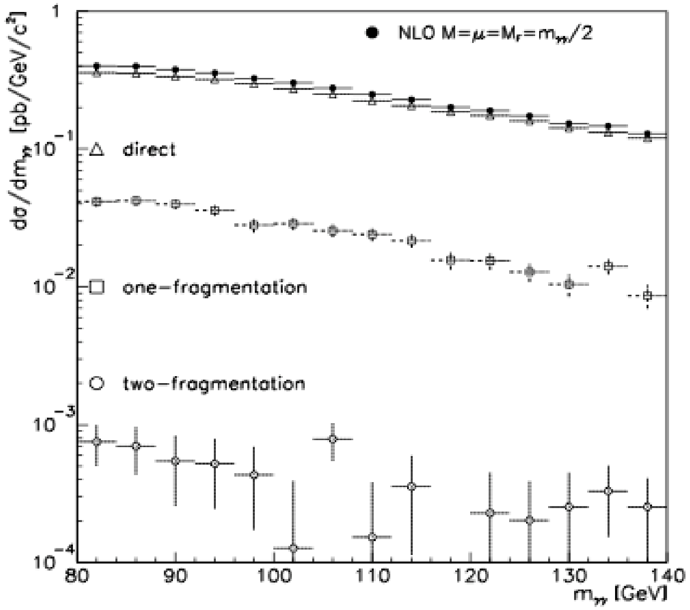


Infrared safe but not noise safe…

To fully answer this question experimentally : need a complete fragmentation generator w/ PS

Di-photons

Primordial background for the $H \rightarrow \gamma\gamma$ search



Binoth, Guillet, Pilon and Werlen Phys. Rev. D 63 (2001)

- Pythia and ALPGEN generators
- DiPhox and ResBos for NLO cross sections
- DiPhox for the fragmentation (introduces a scale M_f)

Total cross section varies very little with M_f

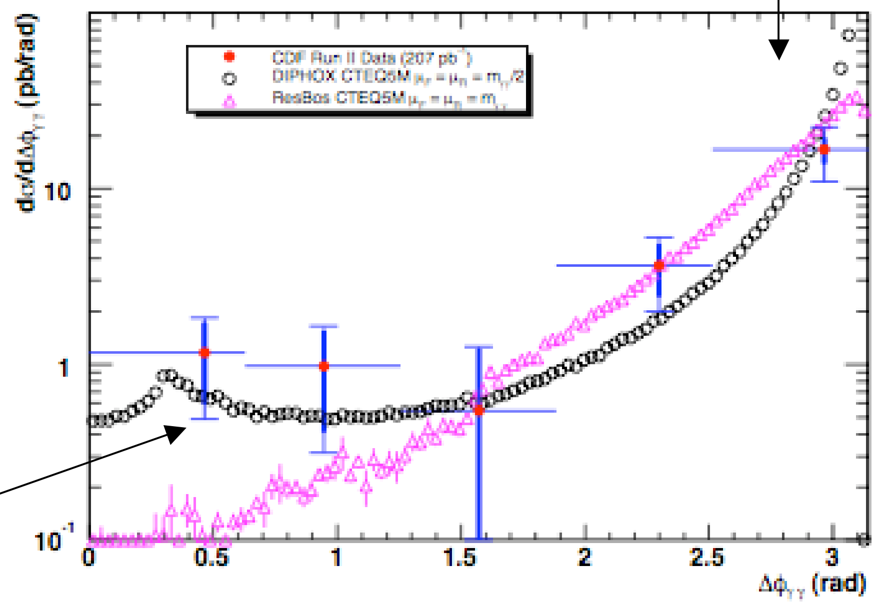
Relative amount of fragmentation varies much more

How to choose the fragmentation scale ?

How to control the fragmentation process ?

Divergence of all Processes

$(\Delta\phi = \pi)$ **CDF Run II preliminary**



Could it shed light on the fragmentation contribution ?

Divergence of Fragmentation Processes

$(\Delta\phi = 0)$

EW Measurements

W, Z Cross Sections, W Mass

Specific Standard Model Measurements

The W and Z cross sections

Acceptance error on W and Z cross section (CSC) : (Dominant error excluding luminosity)

From a comparison of PYTHIA, Herwig and MC@NLO…

2.5% (resp. 3.2%) variation for W and Z

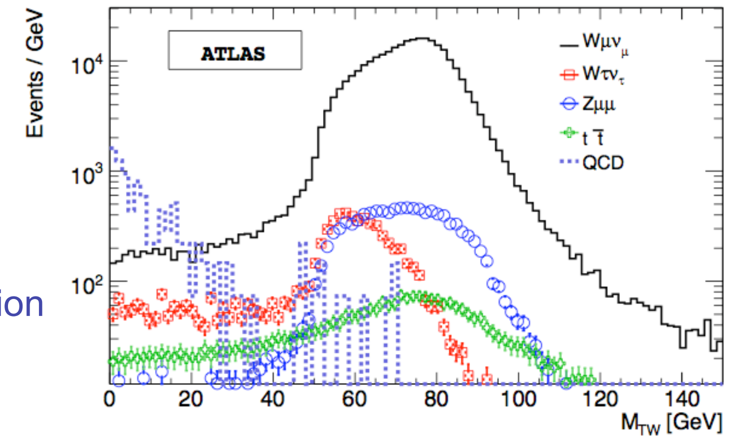
To estimate the systematic error :

- ISR (10%)
- Primordial k_T (2%)
- Underlying Event (1%)
- γ-radiation (Photos) (2%)

Take 20% of these numbers

(Guess ?)-timate of the precision of the model.

- CTEQ 6.5 PDF uncertainty sets (1%)



Process	$N(\times 10^5)$	$B(\times 10^5)$	$A\times\varepsilon$	$\delta A/A$	$\delta\varepsilon/\varepsilon$	σ (pb)
$W\to e\nu$	45.34 ± 0.02	1.22 ± 0.41	0.215	0.023	0.004	$20520\pm\ 9\pm516$
$W\to\mu\nu$	60.08 ± 0.02	4.02 ± 0.05	0.273	0.023	0.004	$20535\pm\ 7\pm480$
$Z\to ee$	5.42 ± 0.01	0.46 ± 0.02	0.246	0.023	0.007	$2016\pm\ 4\pm\ 49$
$Z\to\mu\mu$	5.14 ± 0.01	0.02 ± 0.001	0.254	0.023	0.007	$2016\pm\ 4\pm\ 49$

Typical error (w/o lumi) : 2.5%

Theory uncertainty from scale dependence : ~1-2%

K.~Melnikov and F.~Petriello, Phys. Rev. D **74** (2006)   N. E. Adam, V. Halyo, S. A. Yost and W. Zhu, JHEP **0809**, 133 (2008)

Good tool to constrain PDFs ! …

… second look at one detail in the theory error : μ_F and μ_R dependence

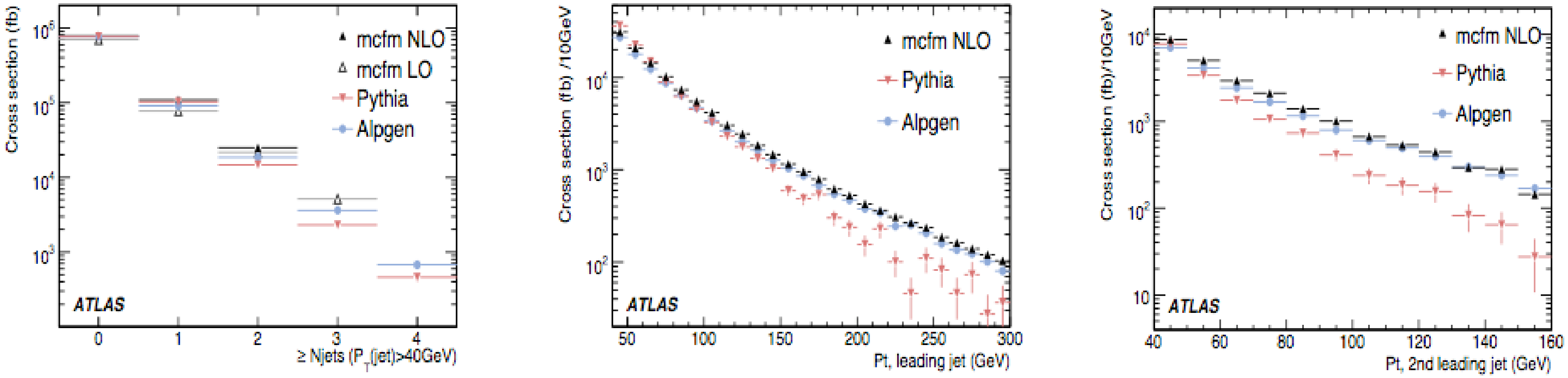
1-2% until μ_F and μ_R varied independently, yielding a much larger uncertainty ~4-5% !

How should μ_F and μ_R scales be varied ?

The exclusive W/Z+jets cross sections :

- Interesting checks of pertubative QCD
- Important background for many analyses
- Interesting check of the ME/PS matching

Comparison between PYTHIA, ALPGEN (MLM) and MCFM (NLO) :



Some NLO/LO differences, but good jet p_T spectrum

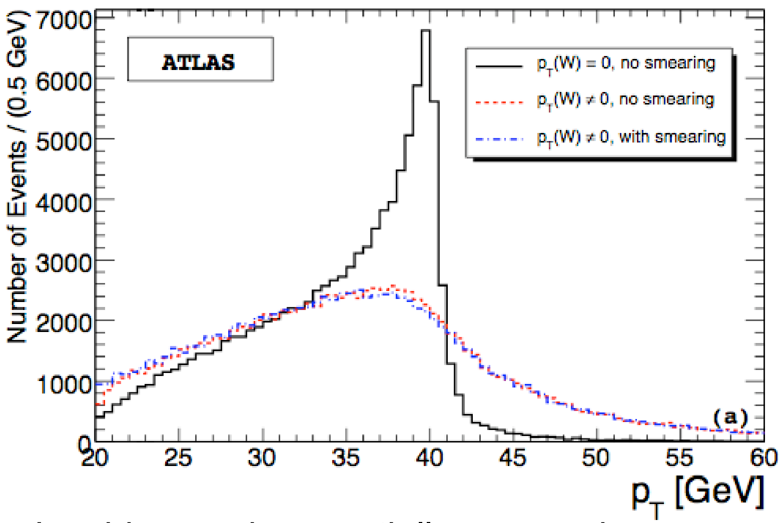
The W Mass Measurement

Measurement precision of the Z mass at LEP : Δm_z = 0.002% …

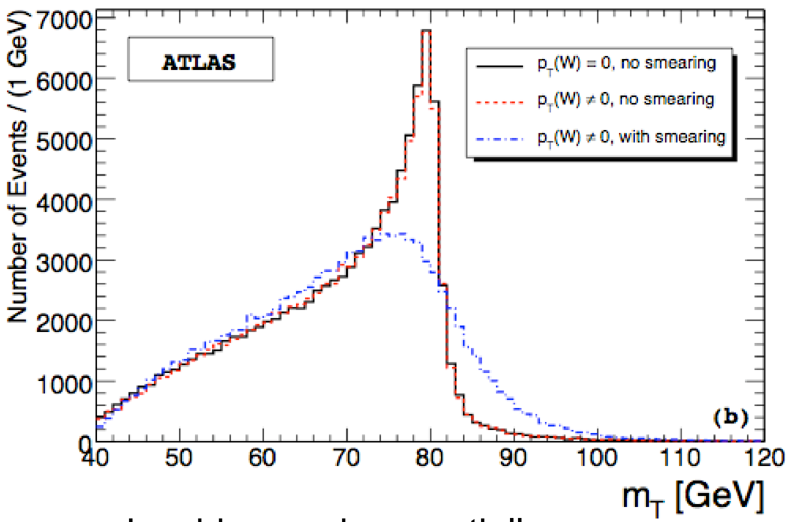
… foreseen precision on the W mass at LHC : Δm_W = 0.01%

Tremendous endeavour ! Not only experimental…

Historically in hadron colliders three ways to measure the W mass… (Omitting the MET)



Jacobian peak essentially smeared by the W transverse momentum



Jacobian peak essentially smeared by detector resolution

- The advantage of the lepton p_T is that it is much less sensitive to the recoil
- The advantage of the transverse mass is that it is much less sensitive to the p_T of the W

W mass measurement uncertainties (transverse mass) :

Source	Effect	$\partial m_W / \partial_{rel}\alpha$ (MeV/%)	$\delta_{rel}\alpha$ (%)	δm_W (MeV)
Prod. Model	W width	3.2	0.4	1.3
	y^W distribution	–	–	1
	p_T^W distribution	–	–	1
	QED radiation	–	–	<1 (*)
Lepton measurement	Scale & lin.	800	0.005	4
	Resolution	1	1.0	1
	Efficiency	–	–	4.5 (e) ; <1 (μ)
Recoil measurement	Scale	-200	–	–
	Resolution	-25	–	–
	Combined	–	–	5 (**)
Backgrounds	$W \to \tau\nu$	0.11	2.5	1.5
	$Z \to \ell(\ell)$	-0.01	2.8	0.2
	$Z \to \tau\tau$	0.01	4.5	0.1
	Jet events	0.04	10	0.4
Pile-up and U.E				<1 (e); $\sim 0(\mu)$
Beam crossing angle				<0.1
Total (m_T^W)				~8 (e); 7(μ)

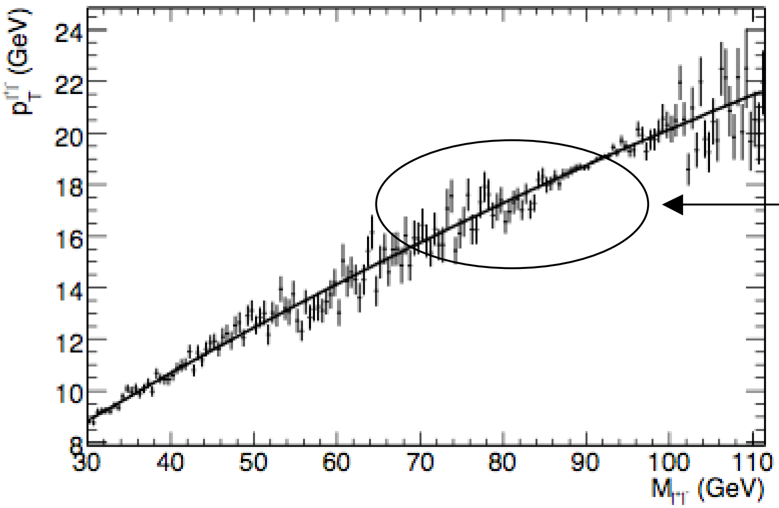
Z to W extrapolation

→ (3 MeV for the p_T lepton)

→ Very large impact (800 MeV/c²)

Extrapolated from LEP Z mass

Extrapolated from TeVatron (absent in p_T lepton)



The W mass range is covered by the Z mass and Drell-Yan

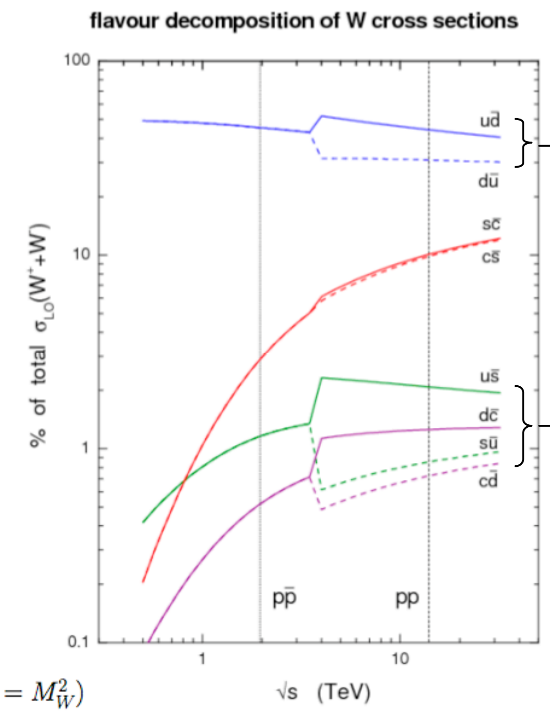
Is this sufficient ?

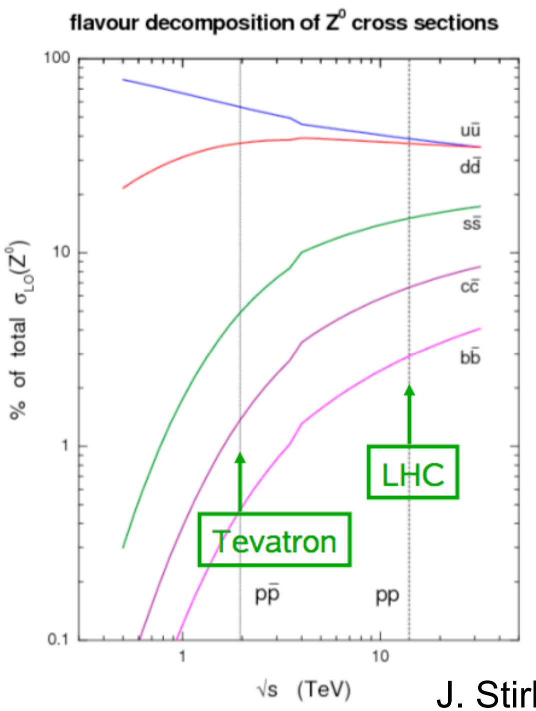
- The W and Z have rather different annihilation production modes…

-The valence quarks important
(but well constrained by Z)

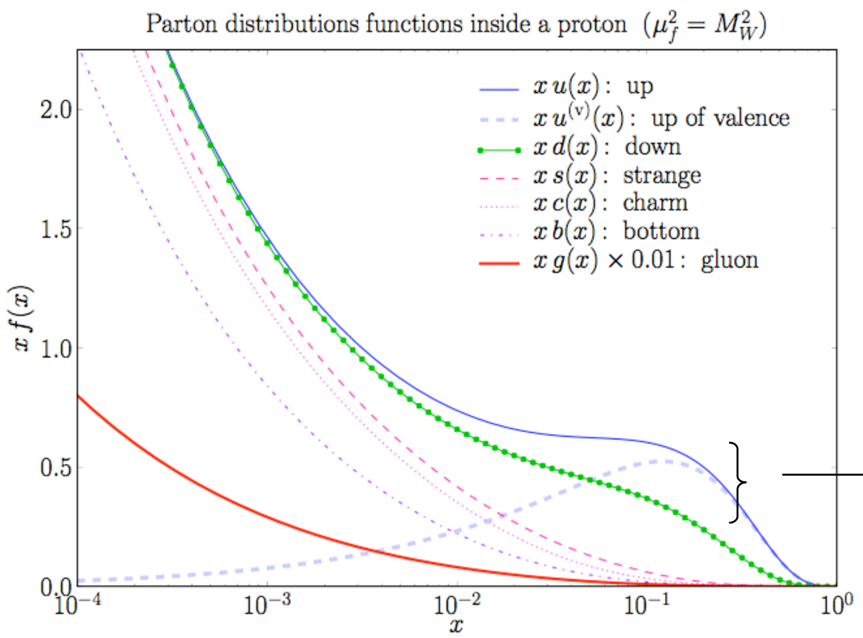
- s and c contribute to 30% in W production !

- b quark contribution is of course suppressed for the W





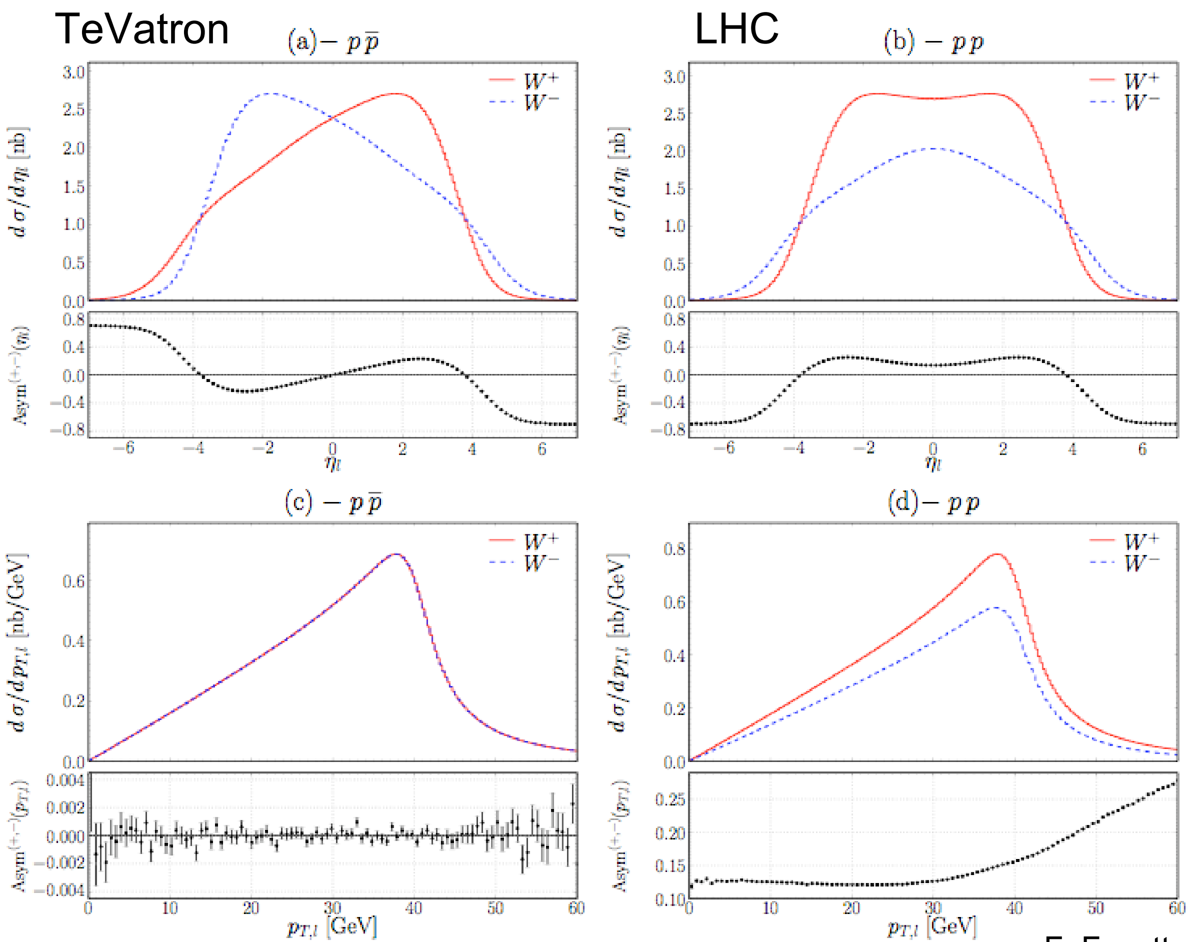
J. Stirling



Effect of the valence quarks asymmetry

Induces a sizeable difference between W^+ and W^- production…

… enhanced by the effect of W helicity in the decay…



F. Fayette

Large impact on the lepton P_T measurement, smaller but not negligible on the transverse mass…

- Need excellent constraints on the valence quark PDFs and their asymmetry

- Need excellent constraints on the s, c (and b) quark PDFs, perhaps releasing constraints such as :

$$s = \bar{s} = \frac{\kappa}{2}(\bar{u} + \bar{d}) \quad \text{with} \quad \kappa = 0.4 - 0.5$$

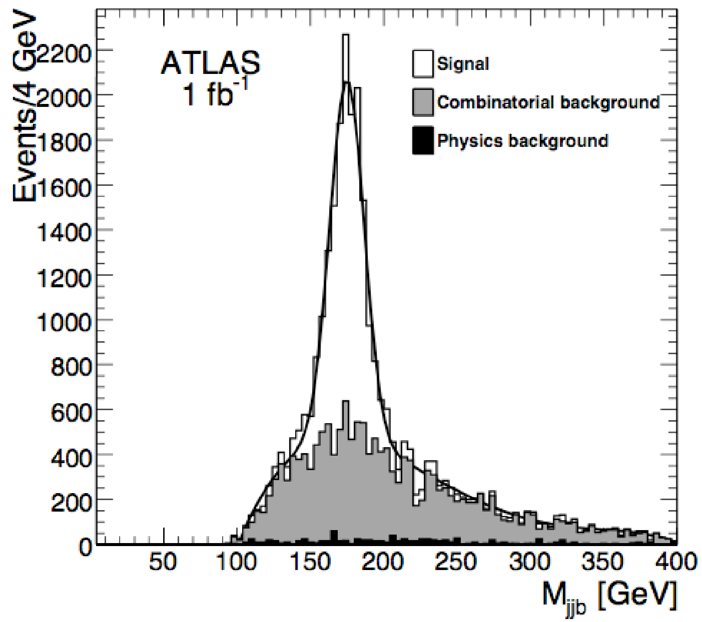
Top Quark Physics

Top Mass and Single Top Wt

Top Quark Physics

The Top Mass Measurement

Top quark pairs will be produced in very large amounts at LHC. However improving on the TeVatron mass measurement will not be an easy task…



Main systematic uncertainties :

-b-Jet Energy Scale : Mostly an experimental problem…

How could exclusive b-decays be useful?

- Effect of ISR/FSR : using AcerMC with different PS configurations

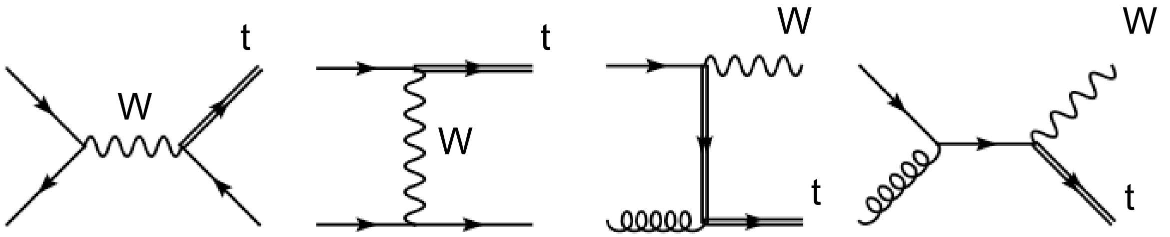
Systematic uncertainty	χ^2 minimization method	geometric method
Light jet energy scale	0.2 GeV/%	0.2 GeV/%
b jet energy scale	0.7 GeV/%	0.7 GeV/%
ISR/FSR	$\simeq$ 0.3 GeV	$\simeq$ 0.4 GeV
b quark fragmentation	$\lesssim$ 0.1 GeV	$\lesssim$ 0.1 GeV
Background	negligible	negligible
Method	0.1 to 0.2 GeV	0.1 to 0.2 GeV

} Light JES ~ 1% ($1fb^{-1}$)

How to best control b-JES and FSR ?

Top mass inherently ambiguous by amount $\propto \Lambda_{QCD}$ said to be ~100MeV/c^2, correct ?

Single top and Measuring Wtb



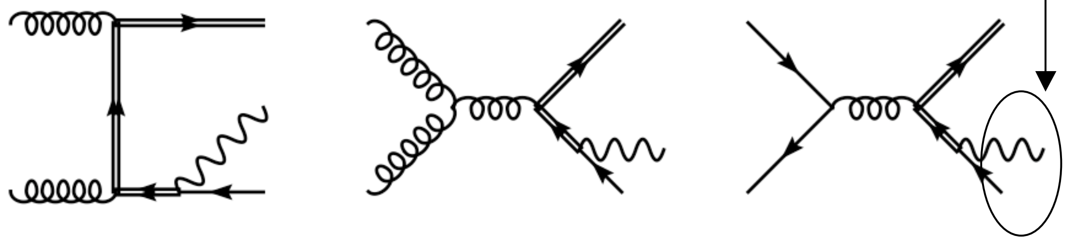
s-channel t-channel

Observed at the TeVatron

Wt production ~20% at LHC

NLO correction to Wt huge !

Ambiguity when $\sim m_{top}$



Ambiguity between NLO Wt and tt with subsequent decay of a top

Theory provided a set of cuts to minimize the interference between Wt and tt…

C. D. White, S. Frixione, E. Laenen and F. Maltoni HEP-PH 0908.0631

Should enable us to measure Wt…

… needs to be validated with a complete analysis in ATLAS

Higgs Physics

Cross Sections, $H \to \gamma\gamma$, $H \to bb$ and Miscelaneous

Higgs Physics

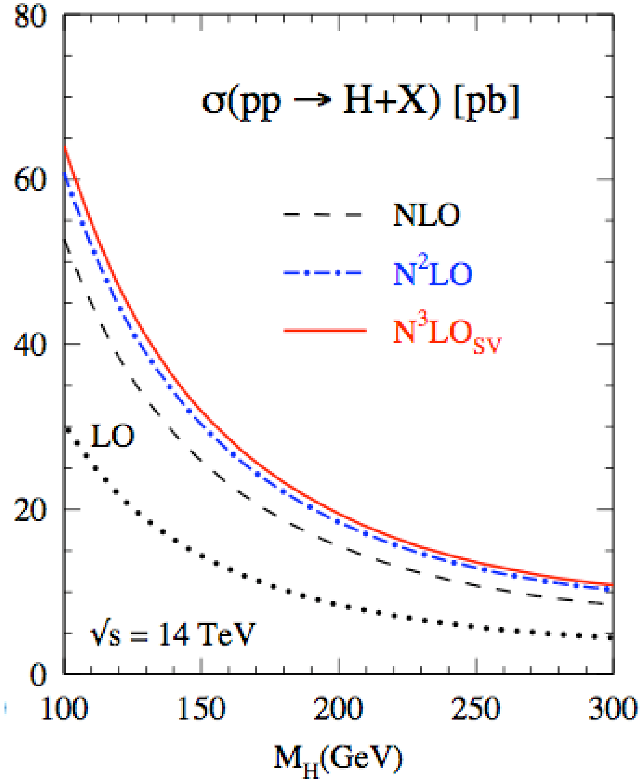
Cross Section Prediction

- NNLO cross sections

FO
- FEHiP (Anastasiou, Melnikov, Petriello)
- HNNLO (Catani, Grazini)

- Soft N^3LO contribution (Moch, Vogt)
- NNLL + NLO HqT (Bozzi, Catani, de Florian, Grazini)
- Two loop EW corrections
  (Aglietti, Bonciani, Degrassi, Vincini, Maltoni, Actis, Passarino,Sturm, Uccirati, Gambino)

Very large k-factors!



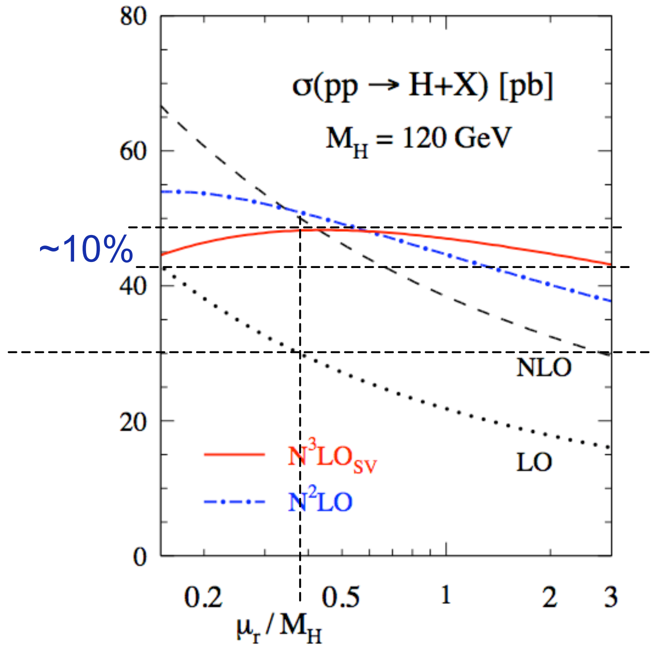
Uncertainties on the total cross section (scale variation)

$\delta\sigma_{PDF} \sim 2\%$

Variation with scale is not monotonic

Need to vary scale by more than $m_H/2$ to cover the following order

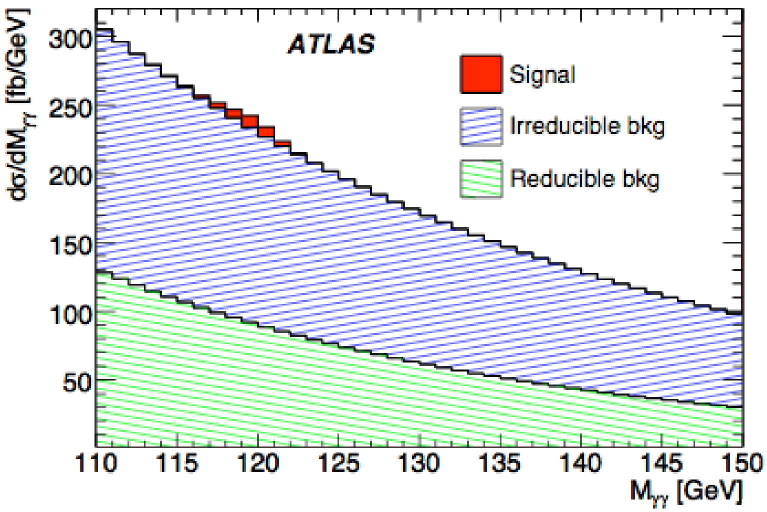
Why does the LO vary as much as the NLO ?



None of these features were used for the CSC notes

For consistency w/ bkg only NLO cross sections were used (HiGlu Spira)

The H→γγ Channel



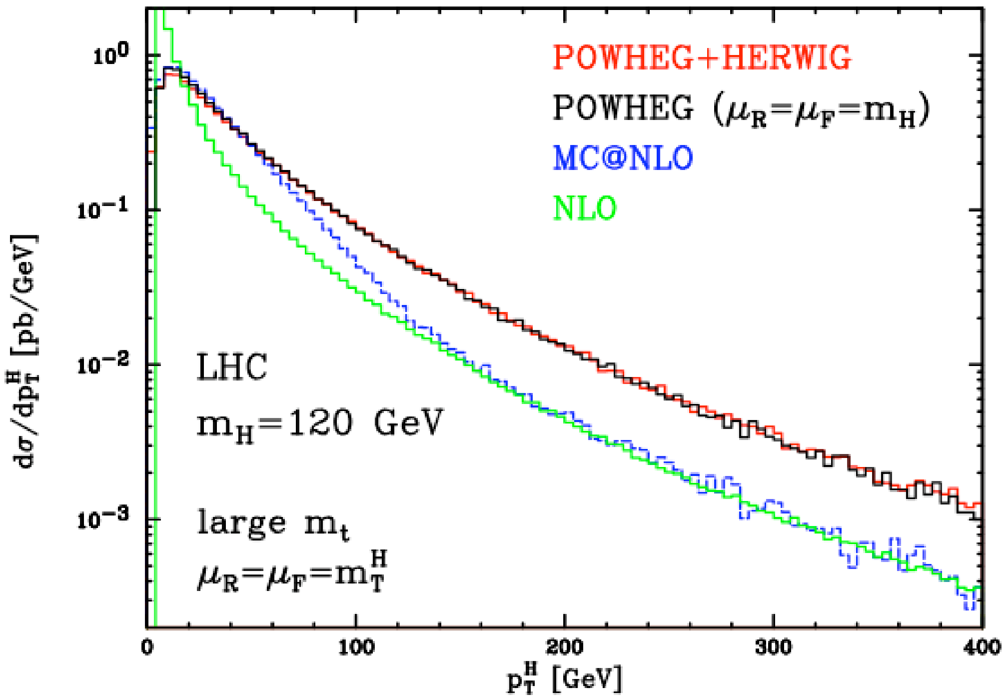
In the inclusive channel : s/b ~ 2.6%

The signal significance for 10pb^{-1} is 2.3σ

Improve the statistical power with discriminating variables : $p_T^{\gamma\gamma}$ and cos θ*

Estimated $p_T^{\gamma\gamma}$ distribution with resBos and MC@NLO

The POWHEG method (Frixione, Nason, Oleari) yields very different results…



How well is the $p_T^{\gamma\gamma}$ simulated ?

How to control these variables for the signal ?

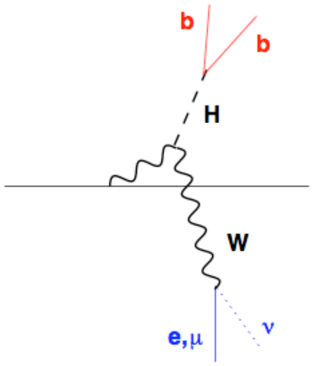
The H→bb Channels

- The ttH associated production channel :

  - Very challenging 6 jet topology and intricate tt+2jets and ttbb backgrounds
  - Control samples are not easy to select
  - Seemed promissing (2σ with 30 pb^{-1}) but disapeared completely with systematics
  - Experimentally one could try multivariate techniques, or to improve b-tagging
  - On the theory side : - Could spin correlations in top decays help ?
    - How to best predict ttjj and ttbb ?

- The VH associated production revisited :
  - Idea : - Use high p_T Higgs to improve acceptance and reduce bkg.
    - The Higgs would be a single jet, then investigate the jet structure

P_T> 200 GeV/c



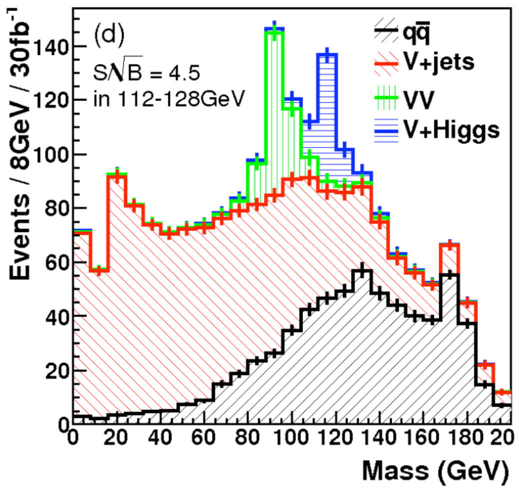
- No significant loss in Mass resolution
- Z→νν is possible : 3 channels

Preliminary significance in ATLAS

4.5σ with 30 fb^{-1}

New discovery channel ?

Butterworth, Davison, Salam, Rubin

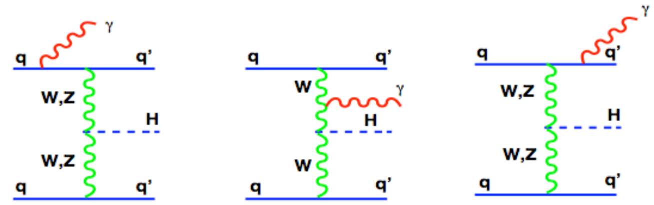


- Yet another promissing channel VBF with an additional photon :

- Idea :

-Reduction of the irreducible background due to a destructive interference

-The extra photon will improve trigger efficiency

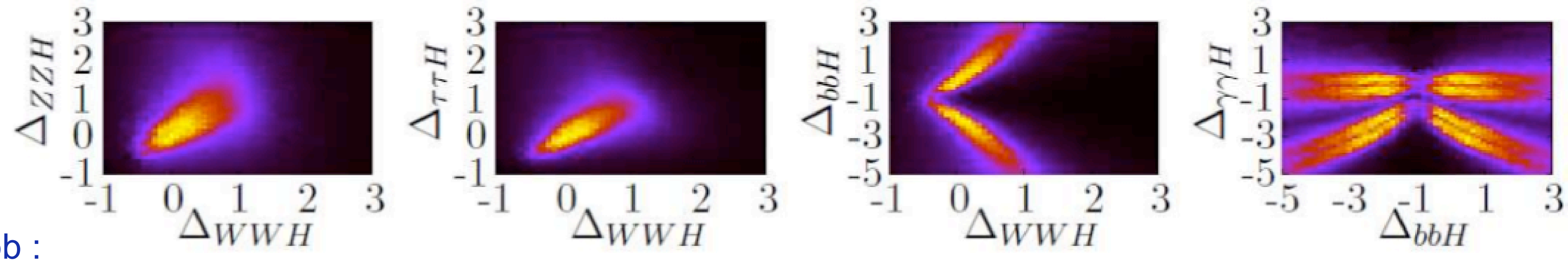


Interesting : About 3σ at 100 fb^{-1} and m_H = 120 GeV/c^2 studies are underway in ATLAS

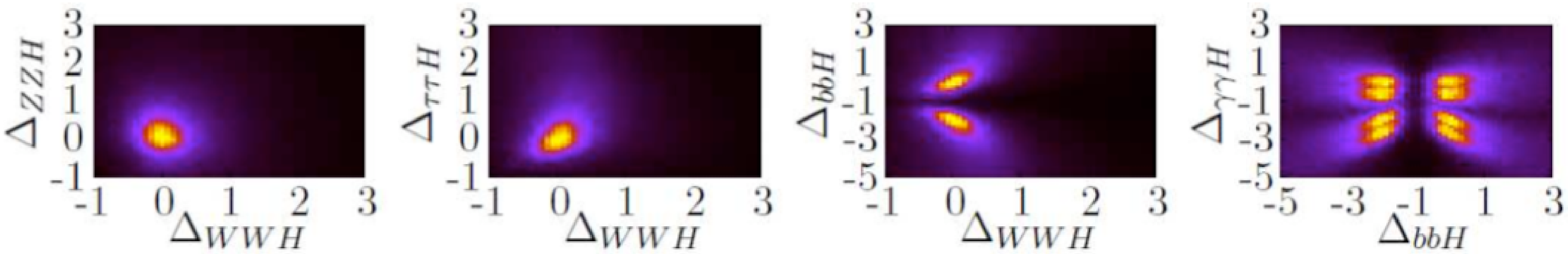
E. Gabrielli, F. Maltoni, B. Mele, M. Moretti, F. Piccinini and R. Pittau, Nucl. Phys. B **781**, 64 (2007)

- Why is the bb Higgs decay so important ?

Precision on the couplings without the Hbb :



With Hbb :



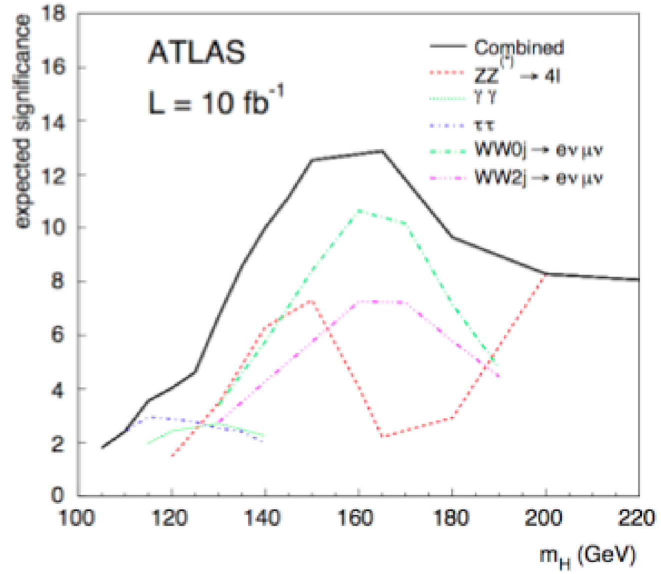
R. Lafaye, T. Plehn, M. Rauch, D. Zerwas and M. Duhrssen, HEP-PH 0904.3866

Without Hbb the error on the couplings increase by ~100%

Higgs Miscellaneous Questions

- The VBF $H \rightarrow \gamma\gamma$ channel :
  - For the associated production : need a thorough estimate of $tt\gamma\gamma$ background
  - Large differences are observed in leading π^0 fragmentation (PYTHIA/HERWIG,jj,γj), control ?
- The VBF $H \rightarrow \tau\tau$ channel :
  - Implementation of the signal in MC@NLO or POWHEG
  - How to control jet veto and tagging efficiencies ?
  - Ways to isolate the color-singlet Z production ?
- The $H \rightarrow WW$ chanel :
  - Good simulation of backgrounds is necessary (not trivial to control backgrounds)
  - $gg \rightarrow WW$ (box is 35% of the background) NLO ?
  - What about W+3-jets and tt+2-jets at NLO ?

Reappraised (CSC) combined
Higgs sensitivity



Conclusions

Numerous tools available have not yet been thoroughly tested in ATLAS, *e.g.* :

- Sherpa/CKKW in various topolgies, need to validate PS and PS/ME Matching (W+jets)
- POWHEG available processes need to be validated
- AcerMC vs MC@NLO validation of ttbar and single top…

Need guidance in the interpretation/use of model parameters :

- Scales : Renormalisation, Factorisation, Resummation, Fragmentation, Matching…
- Jet algorithms, lepton/photon isolation definition
- Intrinsic k_T, General MC tuning parameters
- How to match leading partons to reconstructed jets ?

General needs :

- BSM and more specifically SUSY corrections to most processes
- NLO or even NNLO for numerous background processes
- Develop generator with combining photon fragmentation and PS
- Release constraints on PDFs (even if *a priori* unphysical)
- A complete NLL PS ? …