The production of Single top quark in ATLAS (LPSC & SDU collaboration)

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Outline

1/ Motivation for Single-top Physics at the LHC

2/ Strategy and Cross-section measurements of single-top processes in ATLAS

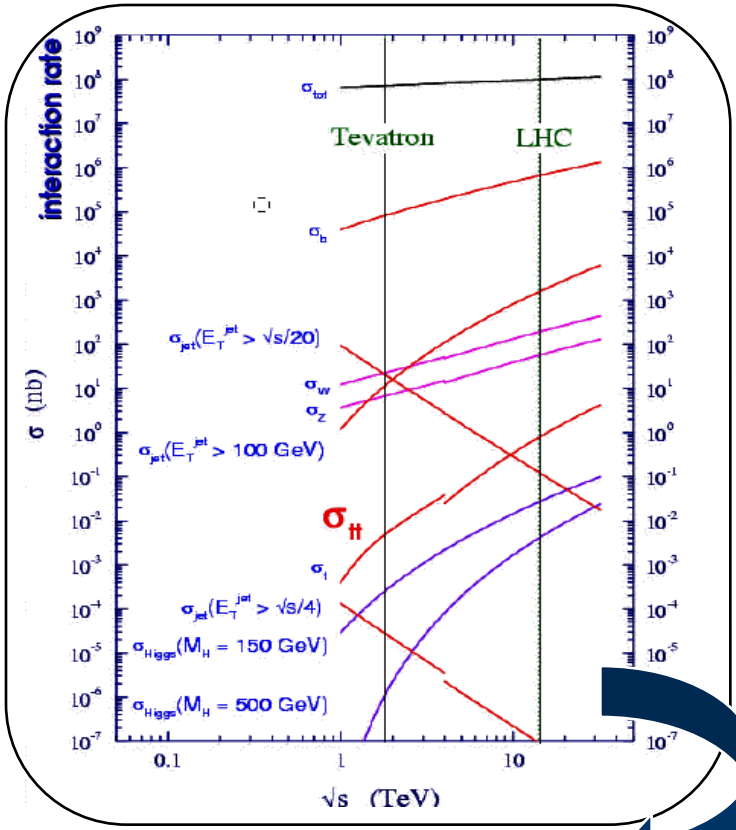
- Past measurements of three single-top channels
- Activities with data-like data (TopMix) in ATLAS

3/ Implications on technical aspects in ATLAS

- Validation of Monte Carlo generators (NLO, LO)
- Validation and tests of parton density functions
- Production of Derived Physics Data for analyses

4/ Summary

Top Physics Context at the Tevatron

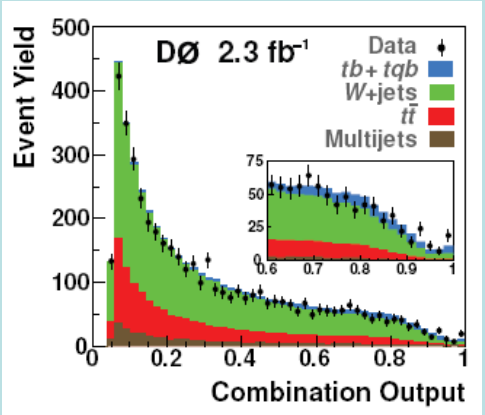


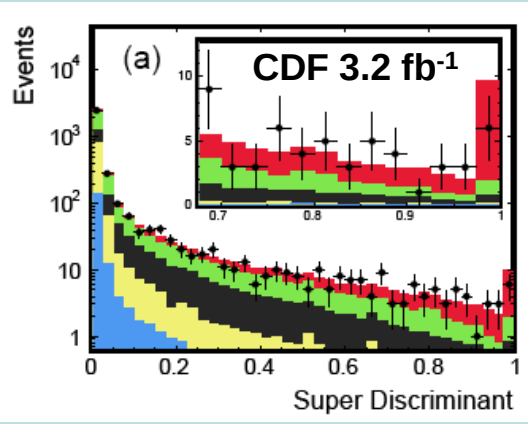
Top Quark Selection

~10 pairs a day (before selection)
~500 pairs selected so far
~few single-top
S/B lower than the LHC : W+jets

Top Quark @ TeVatron …

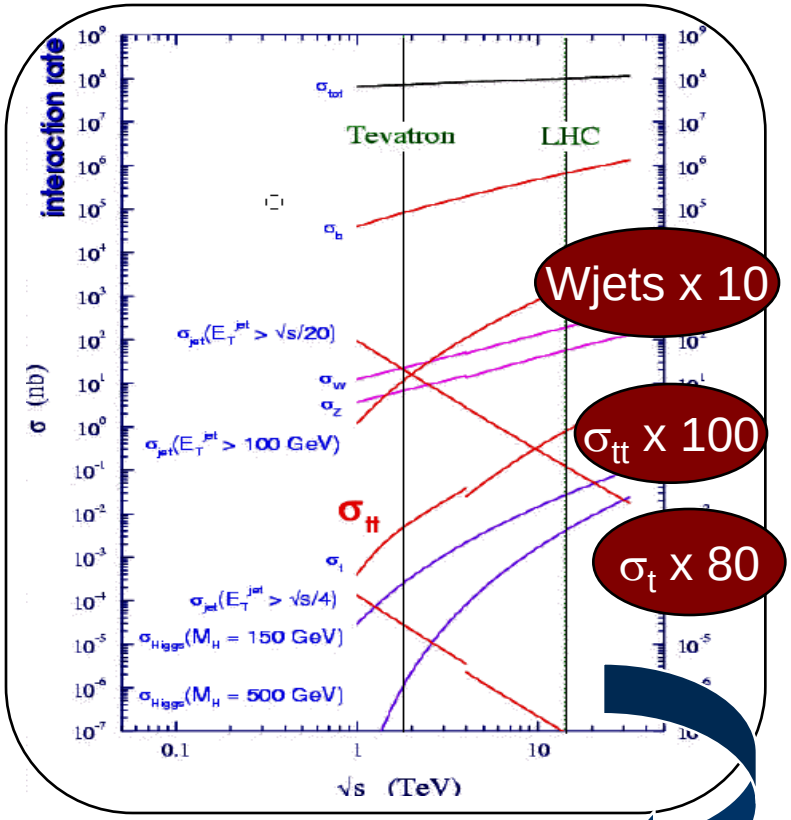
Besides the discovery…
Stringent test of QCD and the EW sector
– Top mass is known at <1% level
– QCD production mechanism at ~12%
– V-A couplings and W polarization at ~20%
– CKM matrix |Vtb| > 0.78 @ 95% CL





And the discovery of the single-top (s+t) !!!

…and at the LHC



Top as a Tool

Commissioning with early data:
- in situ JES determination
- b-tagging performance calibration
- Missing ET

Top as a precision test of SM

Mass, cross-section, properties analyses
- Measurements in all channels
- Theoretically limited very early

Systematics limited analyses early
- Data driven analyses
- Use of MVA techniques mandatory

Top Quark Selection

Nominal luminosity of $L=10^{33}$:

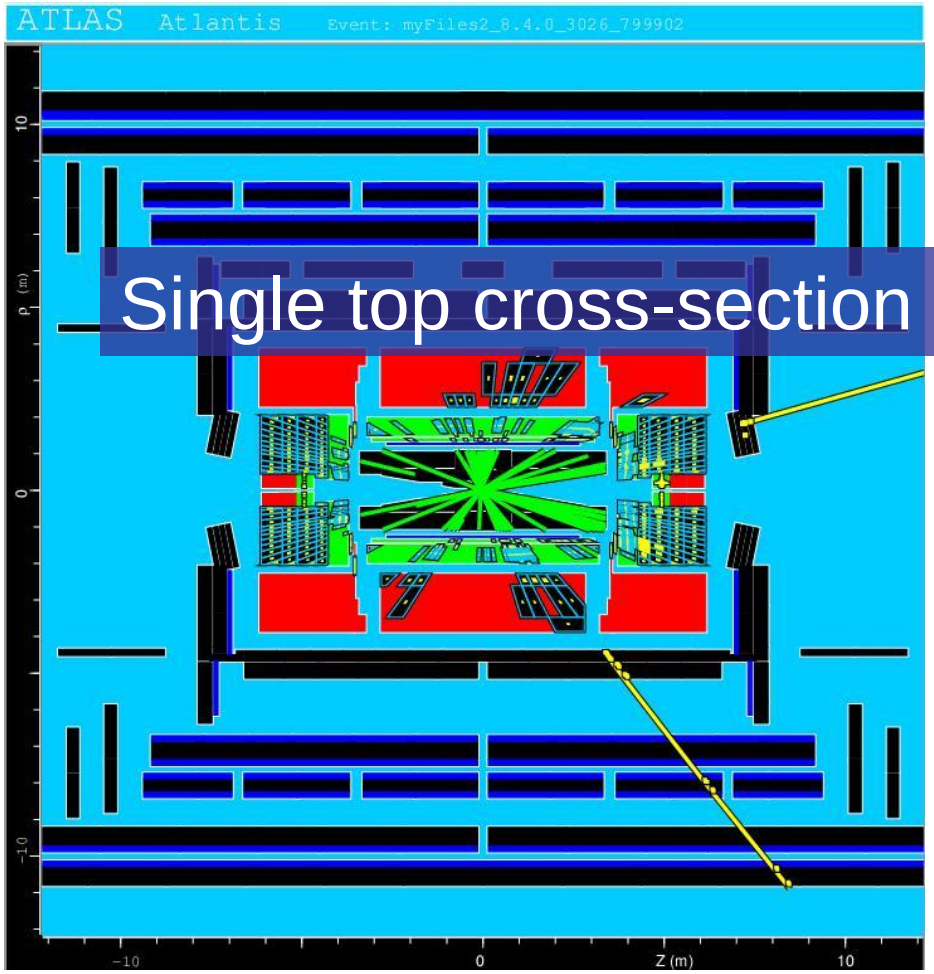
~1000 selected pairs a day

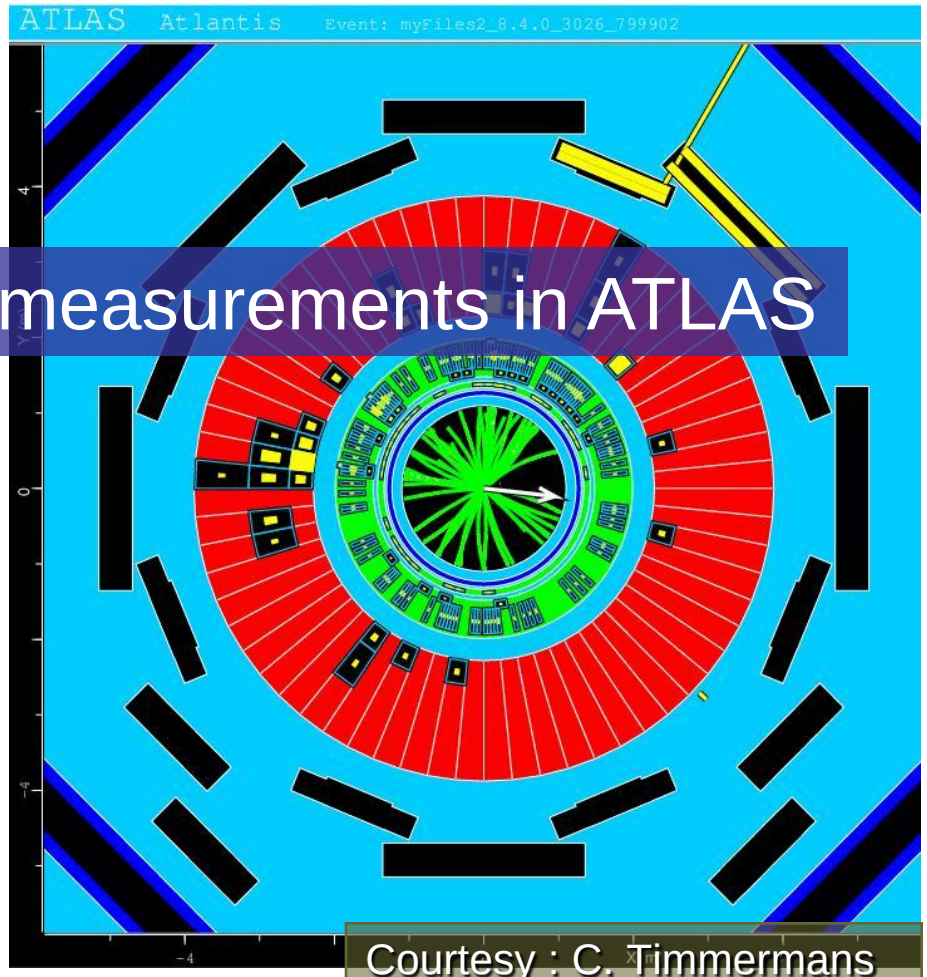
~a few 10 single-top a day

S/B more favorable than TeVatron

Top as a probe to new Physics

In production or decays :
- High mass resonance
- Anomalous couplings
- Top and charged Higgs
- Top and SUSY

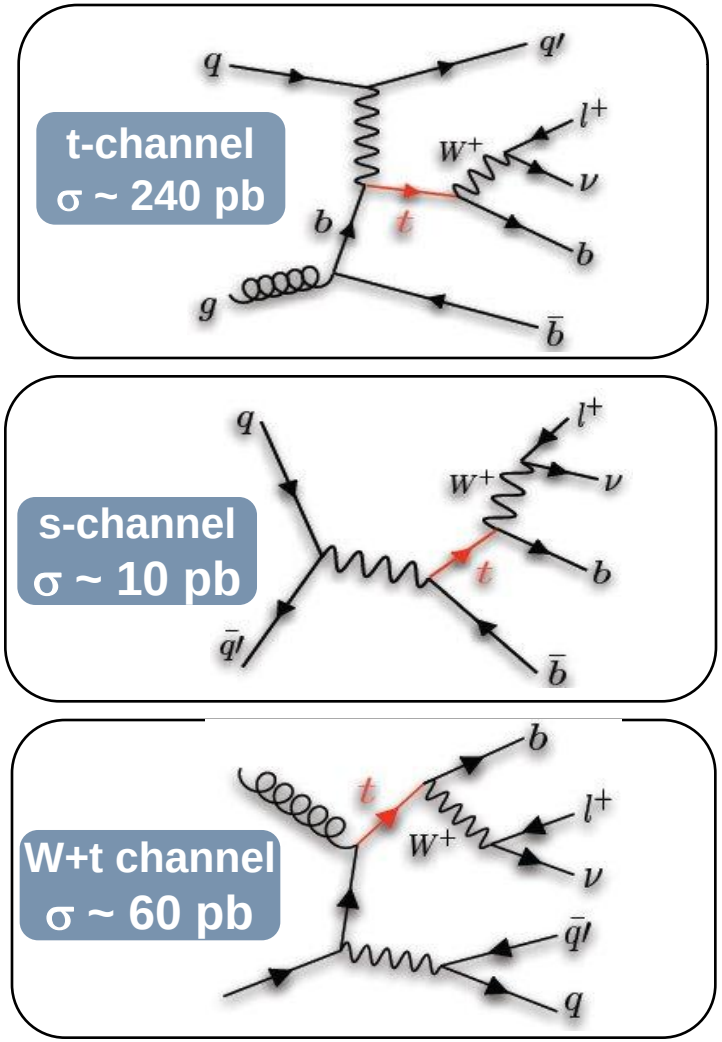




Single top cross-section measurements in ATLAS

Courtesy : C. Timmermans

Why Single-top measurement at the LHC ?



Properties of the Wtb vertex :

- Determination of σ(pp→tX), Γ(t→Wb)
- Direct determination of |Vtb|
- Test of V-A, top polarization

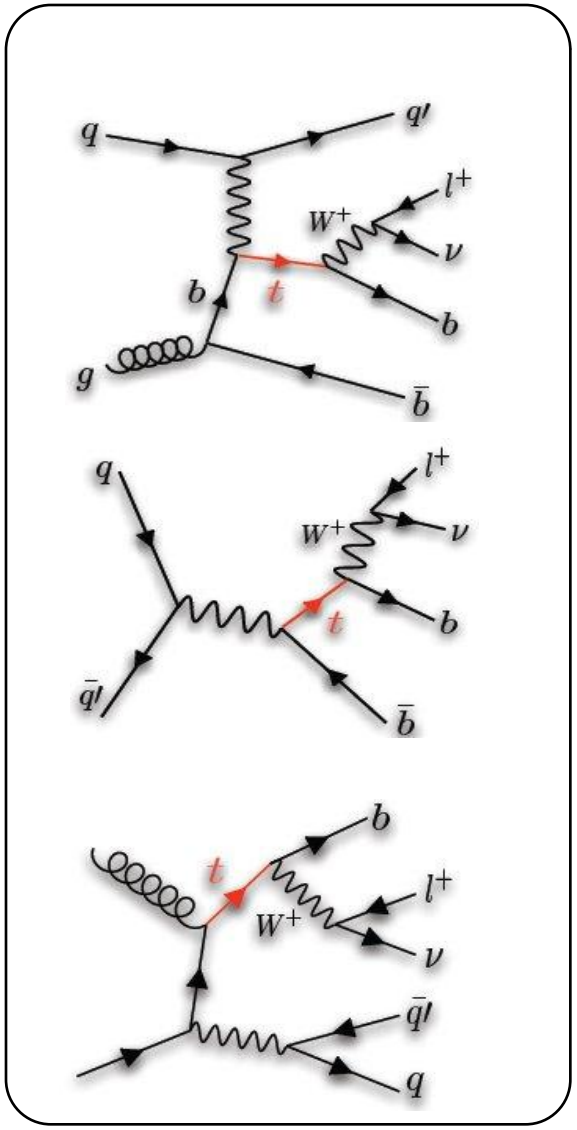
Probe to new physics :

- Anomalous couplings, FCNC
- Extra gauge-bosons W' (GUT, KK)
- Extra Higgs boson (2HDM)

Single-top is one of the main background to …

- … Higgs physics with jets…

Single-top in ATLAS : strategy



Common pre-selection

Inclusive lepton trigger ~80% efficiency

– at least one isolated high p_T lepton

– at least two jets

– at least one b-tagged jet

– missing ET

All single-top analyses are

– Background dominated w/ S/B ~few %

– Systematics on background dominate !

→ Use of data driven techniques mandatory

→ Necessity to enhance purity : use of MVA !

Analyses Strategy

MVA vs CutBased selections

Cross-section extraction using $\sigma = D\text{-}B/\varepsilon L$

Selection optimization:

– Cuts on MVA outputs that minimize systematics

– Use of toy MC to generate D,B as Poisson and D,B, ε for all sources of systematics

Single-top at the LHC : t-channel

Event Selection

Exactly 2 high-p_T jets:

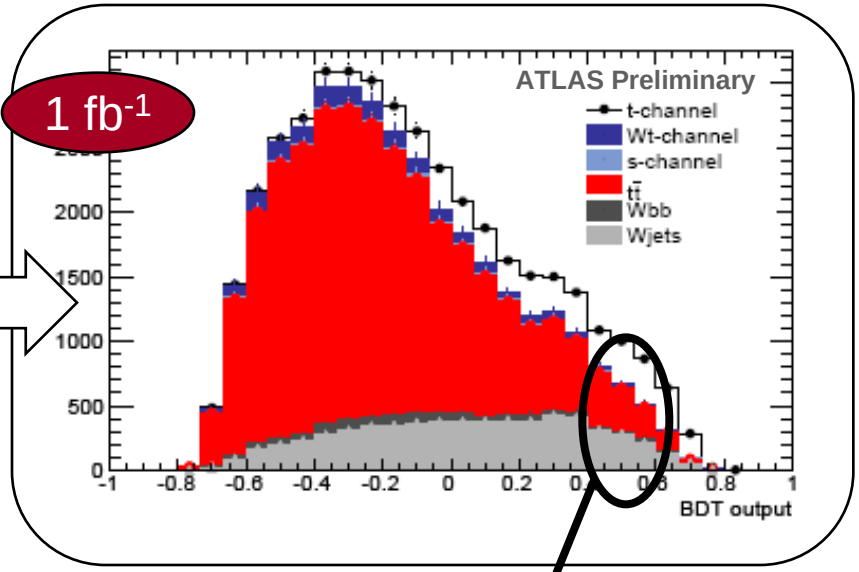
- 1 high pT central b-jet
- 1 forward light jet |η|>2.5

BDT analysis

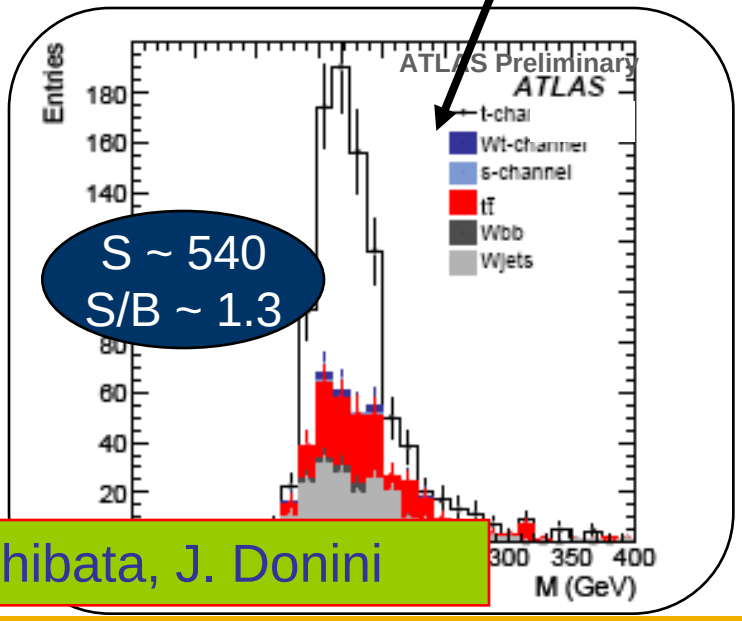
– 6 variables not (too) sensitive to JE

– Optimization vs top pair

Signal : ε ≈ 1-2% N ~ 500 evts



Systematics @ 1 fb^{-1}	δσ/σ
Luminosity	8.8%
Jet energy scale	9.9%
B-tagging	6.6%
Backgrounds (MC)	8.2%
ISR/FSR + PDF …	9.9%
MC statistics	7.9%
Total SYSTEMATIC	**22.4%**
Total STATISTICAL	**5.7%**



A. Shibata, J. Donini

Single-top at the LHC : W+t channel

B. Clement

W+t channel selection

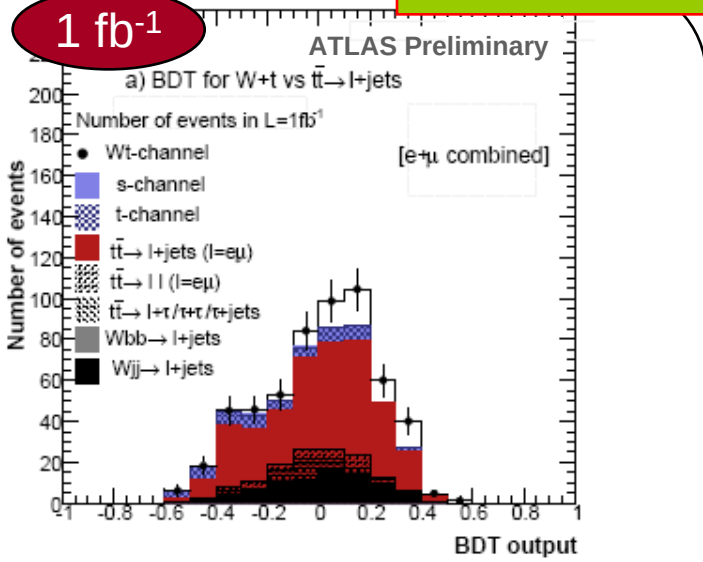
–2 high-p_T untagged-jets reconstruct W→ jj

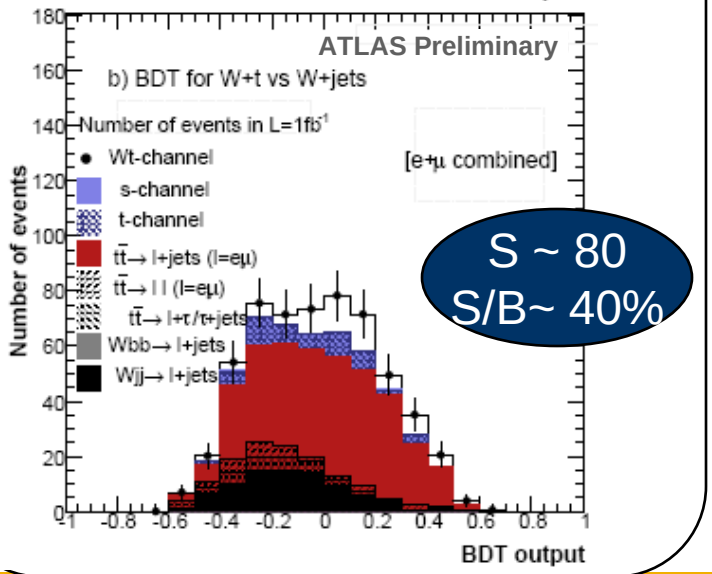
– Veto of a 2nd b-tagged jet

Boosted Decision Trees:

– Set of 4 BDTs vs specific bkgds

– Set of BDTs for 2/3/4 jet final states





Systematics @ 10 fb^{-1}	δσ/σ
Luminosity	7.9%
B-tagging	6.6%
Jet energy scale	2.0%
Backgrounds (MC)	9.6%
ISR/FSR+ PDF +b frag	13.3%
Lepton ID, trigger	6%
Total SYSTEMATIC	**19.4%**
Total STATISTICAL	**6.6%**

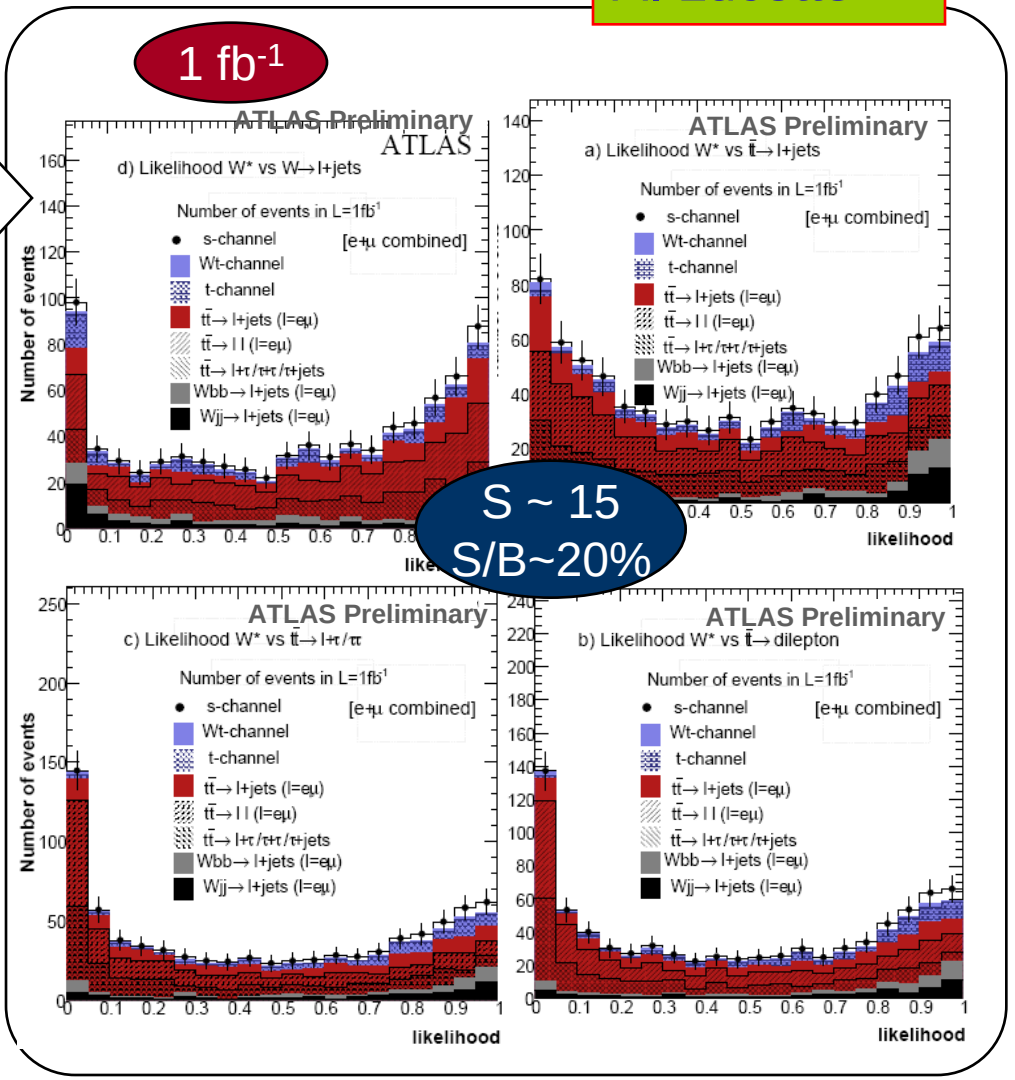
Single-top at the LHC : s-channel

s-channel selection
– 2 high-pT b-jets
– Veto of a 3rd jet
Likelihood functions:
– 5 likelihoods vs specific bkgds
– Choice of ~indpt variables

Systematics @ 10 fb^{-1}	δσ/σ
Luminosity	18%
B-tagging	25%
Jet energy scale	8%
Backgrounds (MC)	16%
ISR/FSR+ PDF +b frag	30%
Lepton ID, trigger	6%
Total SYSTEMATIC	48%
Total STATISTICAL	20%

A. Lucotte

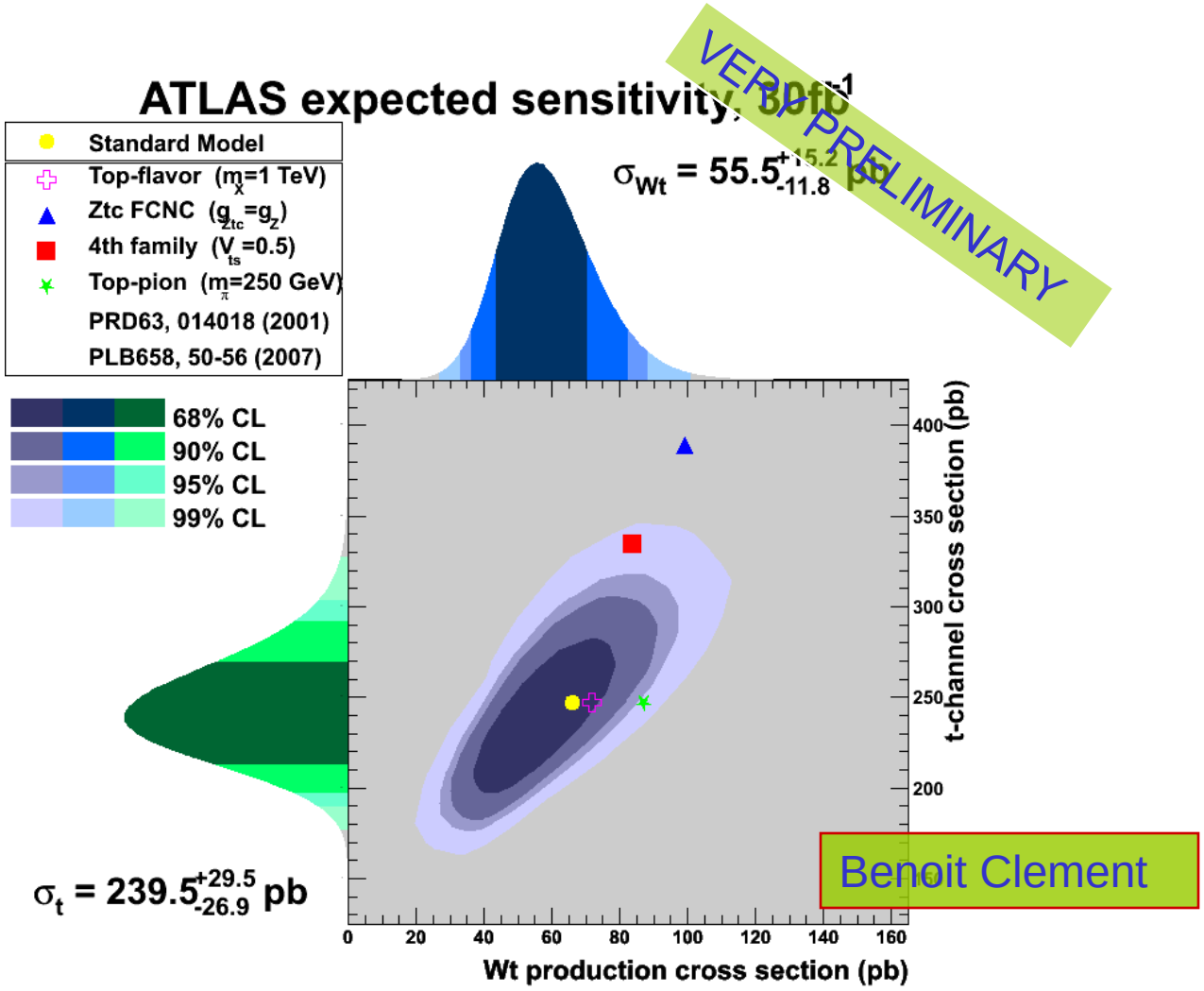
1 fb^{-1}



S ~ 15
S/B~20%

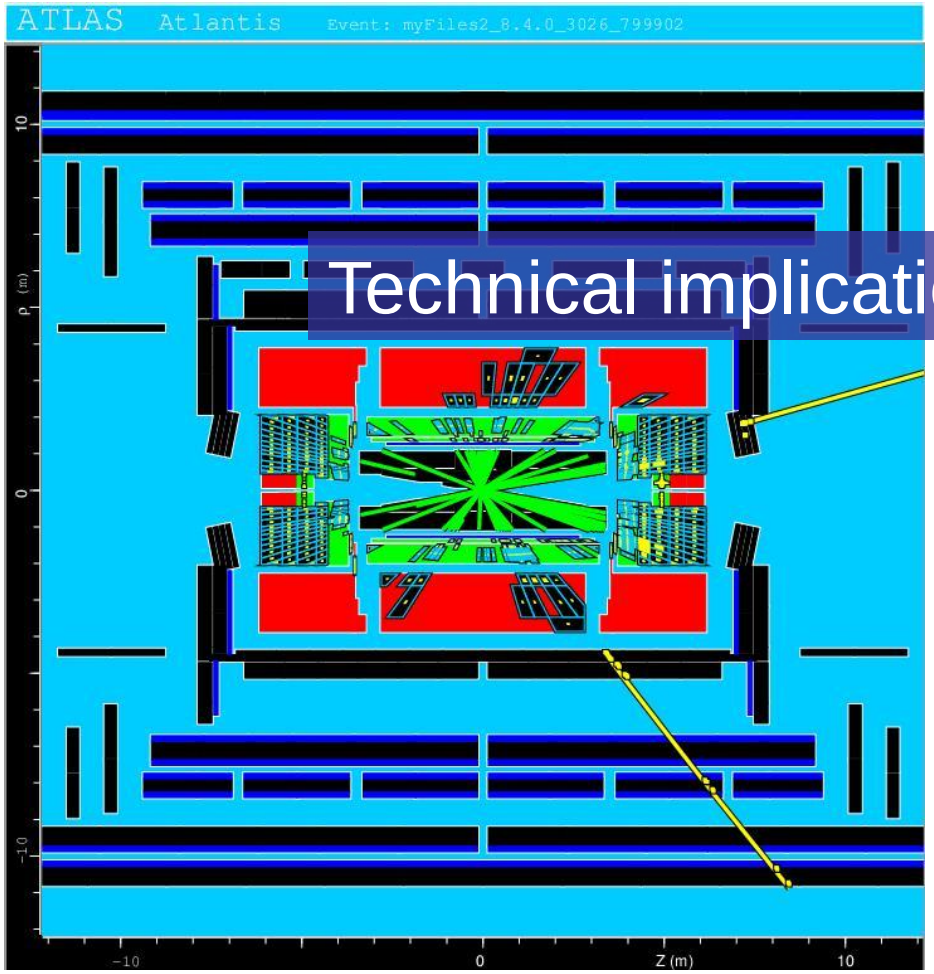
Combination of single-top analyses

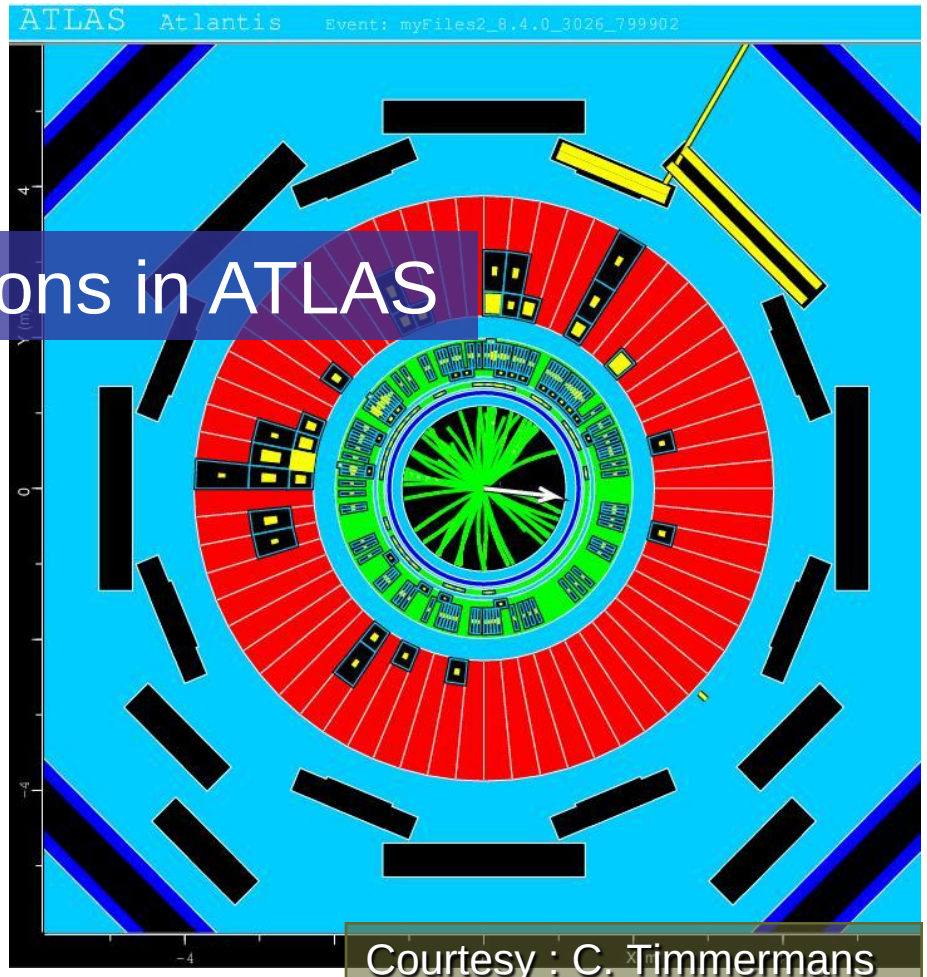
- **Simultaneous fit of the three single-top cross-sections**



Benoit Clement

Technical implications in ATLAS





Courtesy : C. Timmermans

Monte Carlo Generator Validation

- **Event selection**
  - Lepton: N=1, pT>30GeV
  - Jet: N ≥2, pT>30GeV
- **AcerMC vs MC@NLO: Herwig**
  - s: agreed well
  - t: MC@NLO → low jet multiplicity
- **Herwig vs Pythia: AcerMC**
  - s: agreed well
  - t: Herwig → low Njet, more forward jet
- **AcerMC+Pythia vs MC@NLO+Herwig**
  - s: no significance difference
  - t: MC@NLO+Herwig → low Njet, hard forward jet

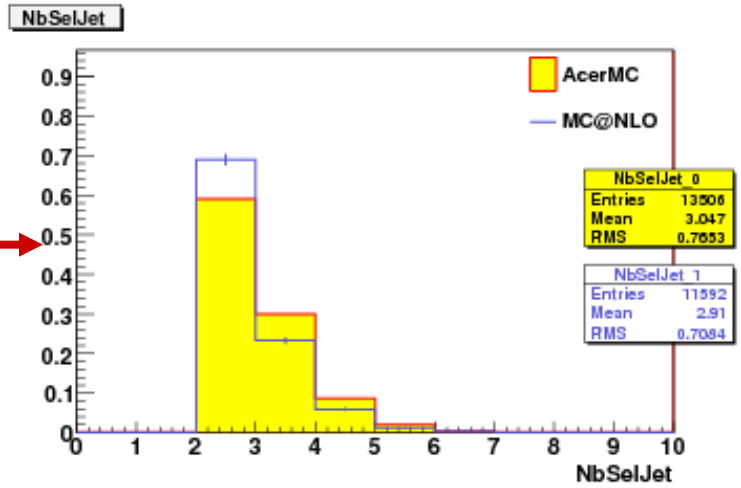


Figure 4: N selected jets

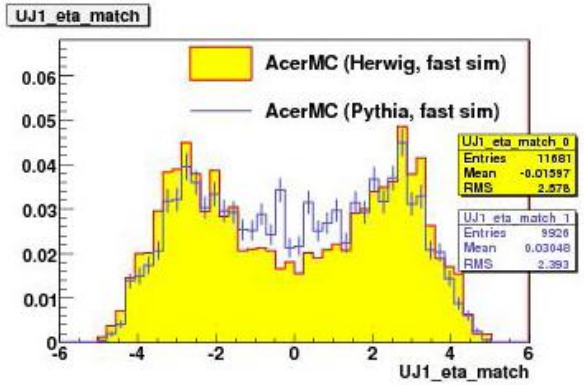


Figure 17: untagged-jet1 η

Julien Donini, Cunfeng Feng, Arnaud Lucotte

Tests of Parton Density Function

- **New CTEQ66**
- **Change: CTEQ6->CTEQ6.6**
  - X-sections of processes with light quark scattering at $x \sim 10^{-2}$ higher.
  - X-sections of processes induced by high x gluon are few percent lower.
  - Uncertainty reduced from 5% to 3.5% due to inclusion of HERA data.
  - 44(40) eigenvectors used in CTEQ6.6 (6)
- **MC@NLO34**
  - Ecm=10TeV
  - Mtop=172.5GeV

Cross section for PDF central value (Cunfeng Feng)

Channel	CTEQ6M[pb]	CTEQ66[pb]	Change [%]
t channel	133.9	132.5	-1.05
s channel	7.019	7.133	+1.62
Wt channel	38.25	37.12	-2.95

Impact of Parton Density Function on σ

Errors associated with central value are calculated with CTEQ master formula

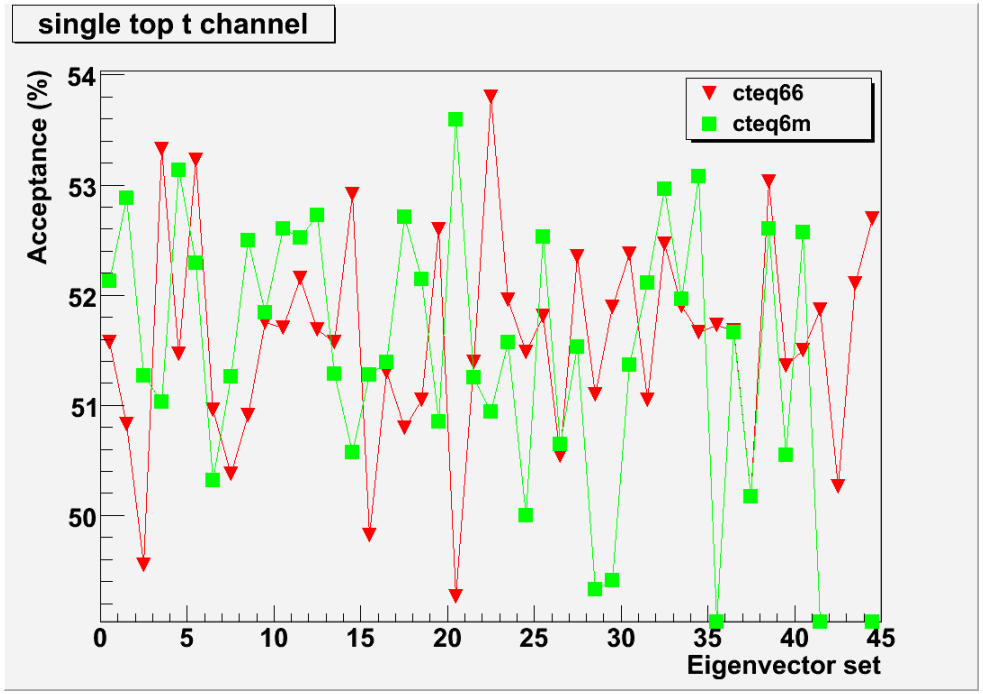
$$\Delta X^{+}_{\max} = \sqrt{\sum_{i=1}^{n} [\max(X_i^{+} - X_0, X_i^{-} - X_0, 0)]^2}$$

$$\Delta X^{-}_{\max} = \sqrt{\sum_{i=1}^{n} [\max(X_0 - X_i^{+}, X_0 - X_i^{-}, 0)]^2}$$

Asymmetry

channel		+Δσ[pb]	-Δσ[pb]	Max(Δσ/σ) ×100
t	CTEQ6	1.56	2.19	1.64
	CTEQ66	1.84	1.88	1.42
s	CTEQ6	0.25	0.28	4.04
	CTEQ66	0.21	0.23	3.17
Wt	CTEQ6	2.00	2.01	5.24
	CTEQ66	1.89	1.87	5.09

Cross section Uncertainty decrease a little for CTEQ66



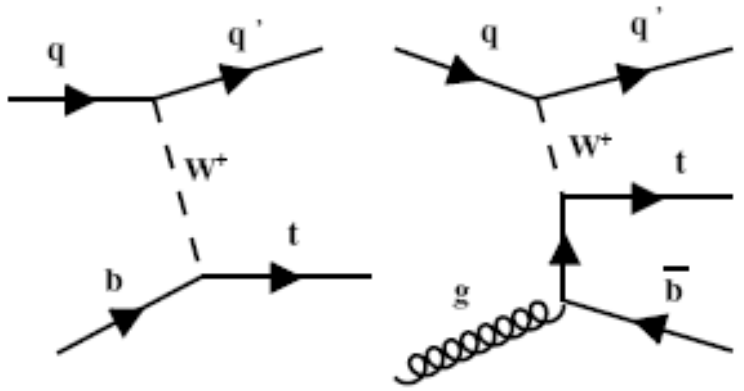
No significant different CTEQ6 & CTEQ66 for t channel.

Cunfeng Feng

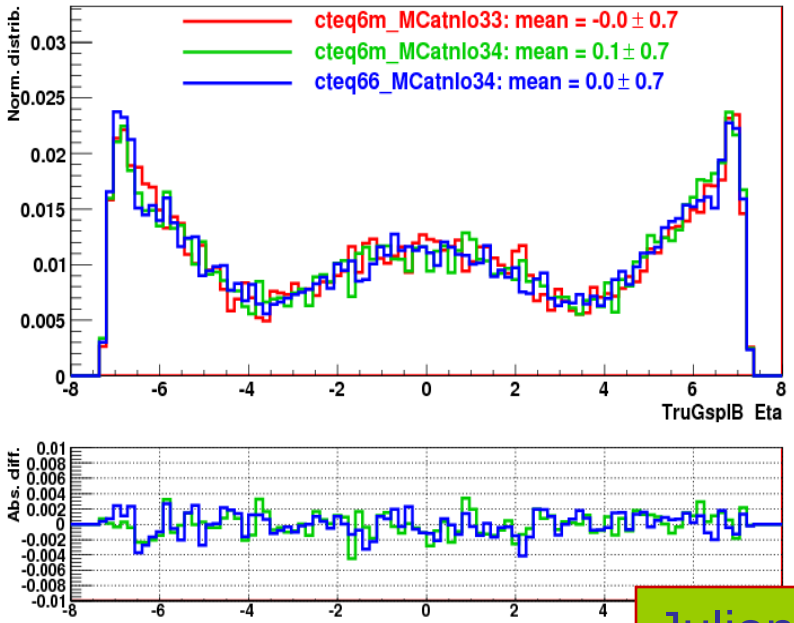
Monte Carlo Validation : eg. of t-channel

Compared at parton level for t channel

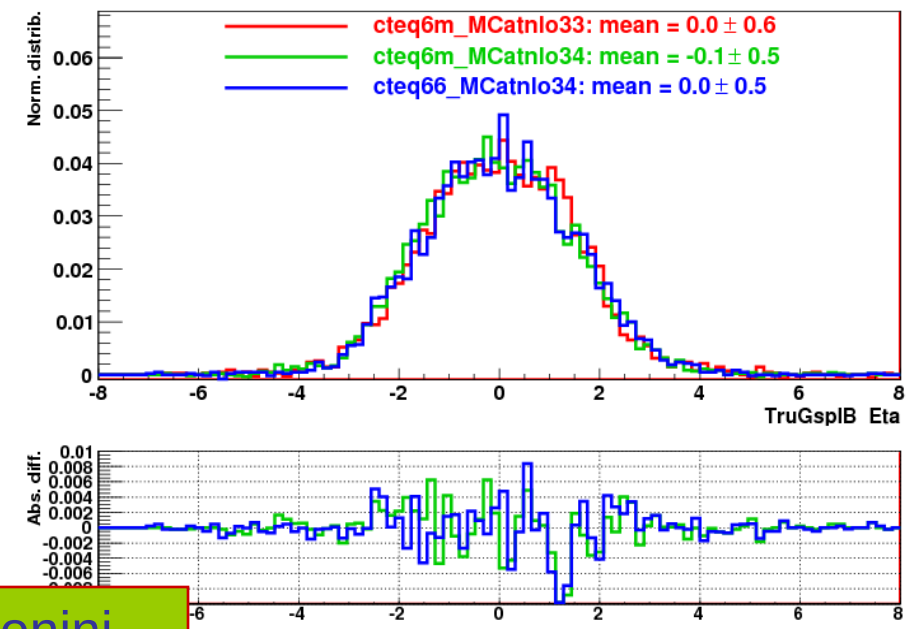
- agreed well for PDF CTEQ6m and CTEQ66 central value.



η: b-quark from proton PDF



η: b-quark from gluon splitting



Julien Donini

Ntuple production in ATLAS

- **Central production of ntuples**
  - Aim for small size, single top specific data format.
  - Developed by LPSC/CNRS ATLAS single top team
  - Produce flat ntuple by skimming, thinning, slimming ATLAS reconstruction data
  - This ntuple format is official and used by the ATLAS Top group

Julien Donini, Arnaud Lucotte, Annick Lleres, Jin Wang

Summary

An exciting Top physics Program :

- "Rediscovery of top", calibration, ..
- Top as a probe to New physics

Single top one of the major top physics field

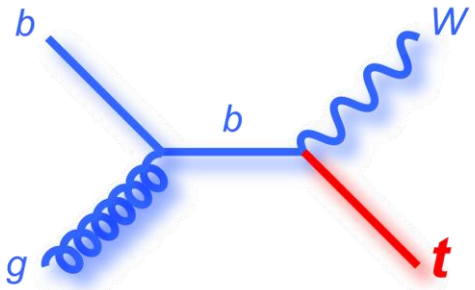
- Discovery of individual single-top processes at the Tevatron is imminent
- LHC will have to do precision measurements …
- …so that searches to New Physics can be made

- **Collaboration LPSC + SDU is fruitful :**
  - Physics aspects: transfer of expertise, analysis techniques…
  - Technical aspects: Monte Carlo Validation, Production of ATLAS Derived Physics Data for analyses

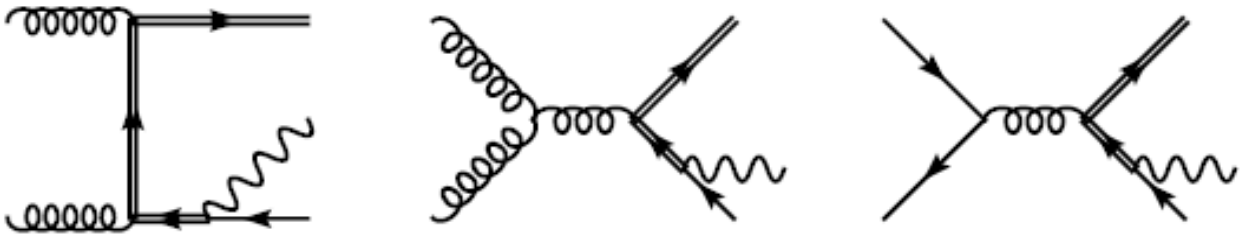
Thanks !

Backup

Wt channel with MC@NLO



- **Single top associated production**
  - LO: gb → W+t
  - NLO:
    - ttbar resonances can appear, also contribution to Wt production
      - gg, qq->Wtb



    - σ_{Wt} get a huge correction! Due to contamination from tT
  - Two approaches for defining Wt
    - Diagram remova (DR)l: tT removed at amplitude level
    - Diagram subtraction (DS): tT removed at x-section level
    - Results from DR and DS agree well (arXiv: 0805.3067v1)

MC@NLO for MC08 single top

- **New run-number defined for single top MC 08**

channel	t channel			s channel		
	t->b e nu	t->b mu nu	t->b tau nu	t->b e nu	t->b mu nu	t->b tau nu
Run No.	108340	108341	108342	108343	108344	108345

- **Main parameter:**
  - top: mass=172.5GeV; width=1.7GeV
  - W: mass= 80.403GeV; width=2.141GeV
  - PDF set: CTEQ6m (10000)
- **Full simulation is ready**

- **Single top MC plan in 2009**
  - MC@NLO34: W+t channel was included
  - LHAPDF: CTEQ6.6 released
  - Validation sample has been produced

Results of t channel cross section

- **Sequential Cut Analysis**

N signal and BG evts (1 fb^{-1})

process	N(1 fb^{-1})	
ST t-ch	AcerMC	MC@NLO
	1479.2 + 57.5	2138.1 + 71.8
ST s-ch	27.1 ± 1.4	
ST Wt-ch	125.0 ± 8.6	
$t\bar{t}$	3051.3 ± 67.5	
Wbb	76.0 ± 8.6	
W+jets	894.7 ± 30.3	
Total Bgd	4174.0 ± 75.0	
S/B	0.35	0.51

Uncertainty on signal x-section

Source of uncertainty	$\Delta\sigma/\sigma(\%)$	
	AcerMC	MC@NLO
Poisson	5.1 %	3.9%
Stat	6.3 %	5.5%
JES	23.2%	21.2%
BTag	28.7%	21.4%
XSerr	23.6%	17.2%
ISR/FSR	6.4 %	6.0%
PDF	12.1%	9.2%
LeptonID	3.8 %	3.0%
Trigger	3.8 %	3.0%
Lum	18.9%	15.1%
Total	51.4%	41.1%

MC@NLO: small improvement in x-section uncertainty due to larger amount of signal (+45%).

Results of t channel cross section

- **Multivariate Analysis**

N signal and BG evts (1 fb^{-1})

process	N(1 fb^{-1})	
ST t-ch	AcerMC	MC@NLO
	621.0 ± 36.5	991.7 ± 59.9
ST s-ch	2.6 ± 0.4	
ST Wt-ch	10.8 ± 2.5	
$t\bar{t}$	235.0 ± 18.6	
Wbb	5.8 ± 2.4	
W+jets	123.5 ± 10.4	
Total Bgd	377.7 ± 21.7	
S/B	1.64	2.63

Uncertainty on signal x-section

Source of uncertainty	$\Delta\sigma/\sigma(\%)$	
	AcerMC	MC@NLO
Poisson	5.1%	3.7%
Stat	6.8%	6.4%
JES	1.4%	9.7%
BTag	7.6%	7.4%
XSerr	5.4%	3.4%
ISR/FSR	6.0%	5.6%
PDF	3.6%	2.7%
LeptonID	1.6%	1.4%
Trigger	1.6%	1.4%
Lum	8.0%	6.9%
Total	17.3%	18.2%

MC@NLO: no improvement despite 60% increase of signal. JES syst becomes dominant due to different jet multiplicity.