Top Mass and Properties at the LHC

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on behalf of the ATLAS & CMS collaborations

Outline

Motivation & Context

LHC as a Top Pair Factory

– Cross-section measurement

– Mass measurement

– W polarization

LHC as a Single-top Factory

– Cross-section measurement

Conclusion

From the TeVatron to the LHC…

Top Quark @ TeVatron …

Stringent tets of QCD and the EW sector

- Top quark mass is known at ~1% level (~2 GeV)
- QCD production mechanism tested at ~12% level
- V-A couplings and W polarization known at ~20%
- CKM matrix $|V_{tb}| > 0.68$ @ 95% CL
- Electroweak production (single-top) evidence @ 3.4σ …

Top Quark @ LHC : precision measurements…

Consistency checks of SM Higgs

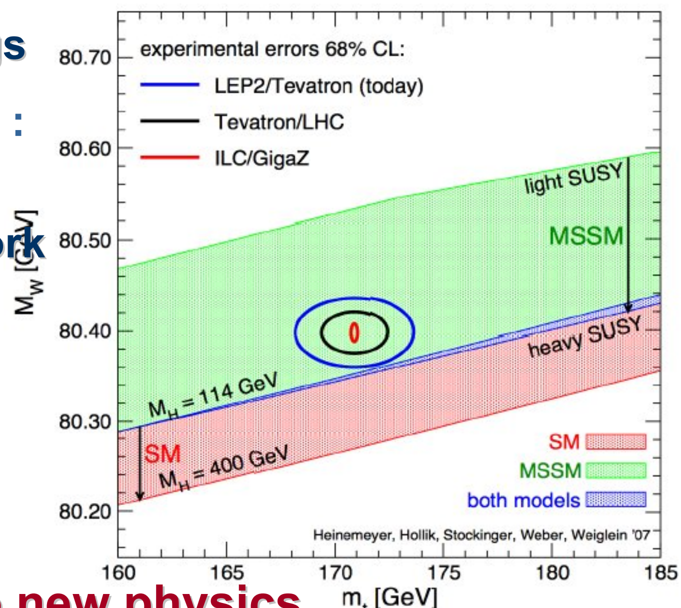
- Equal contributions to χ^2 :

$$\Delta m_W \approx 0.7\% \, \Delta m_t$$

… or ID the underlying framework

$$m_h^2 = m_Z^2 + \frac{3 G_F m_t^4}{\pi^2 \sqrt{2}} \ln \frac{M_t^2}{m_t^2}$$

s-top mass



Top quark @ LHC : … a probe to new physics

Searches for new (heavy) particles

- Flavor/mass dependent couplings
- Extra bosons : W' (GUT, KK)
- Charged Higgs Boson H^+

Technicolor : strong interaction @ TeV

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Top Quark @ LHC : precision measurements…

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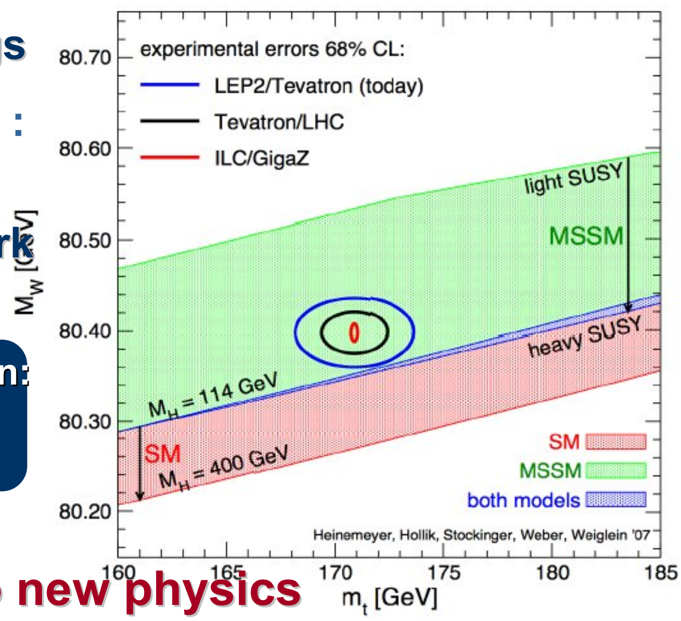
…or ID the underlying framework

Need accuracy better than:
Δm_W~15 MeV/c²
Δm_t ~ 1GeV/c²



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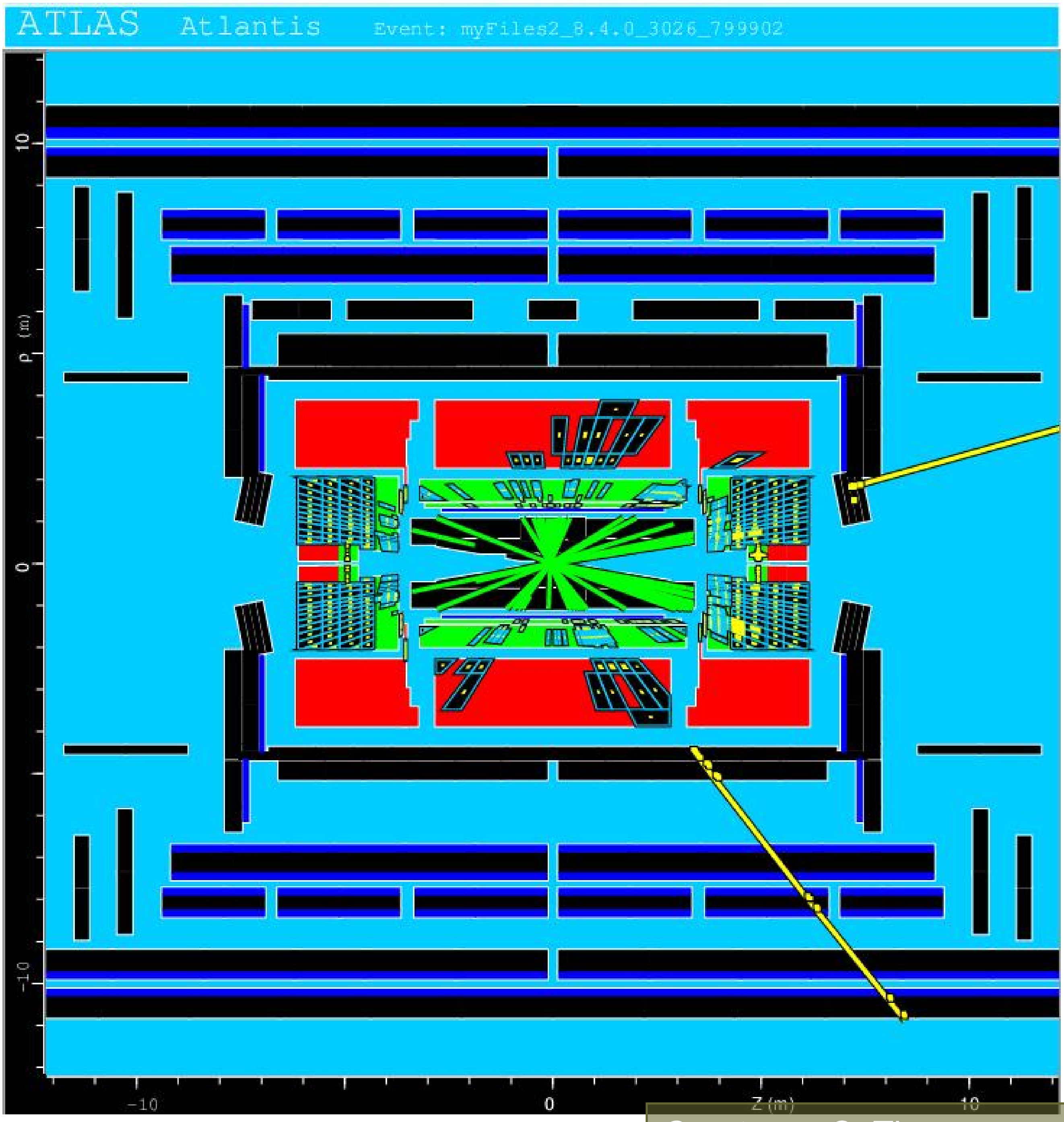
LHC as a Top Pair Factory…



Courtesy : C. Timmermans

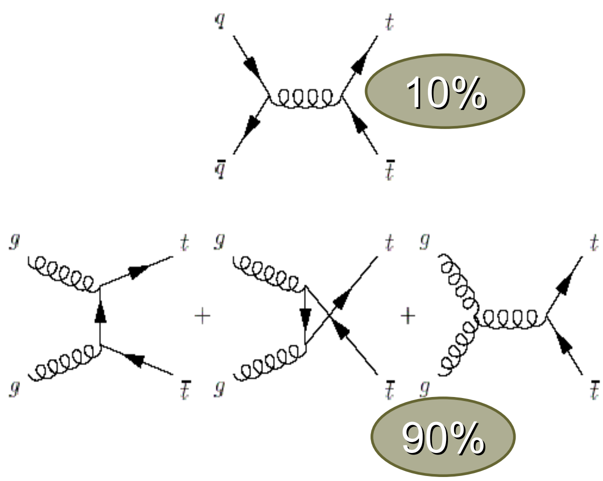
Top Pair Production & Decays @ LHC

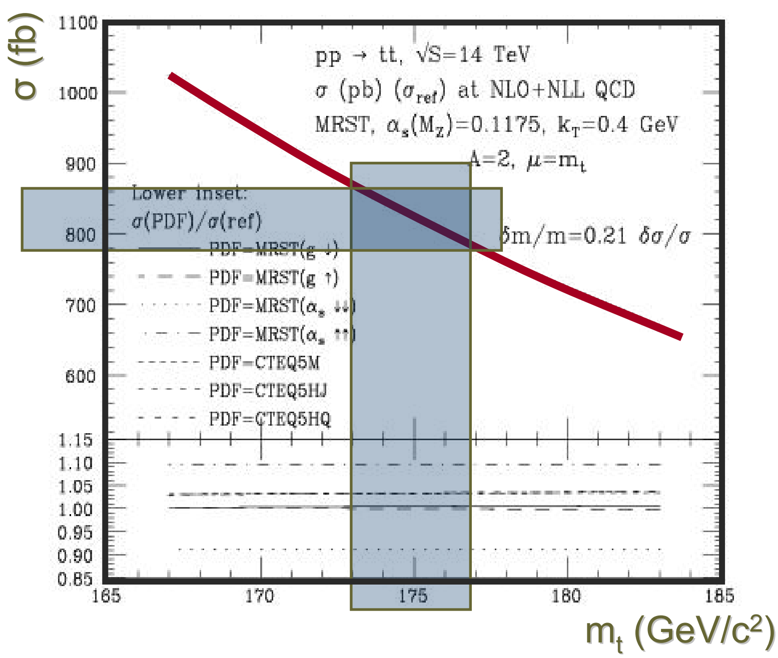
Top pair production

SM Total cross-section

NLO calculations σ_{tt} = 835 pb ± $10\%_{pdf}$ ± 6% $_{\mu\text{-scale}}$

- Production via gluon-fusion (90%) and quark anihilation
- Dependence in Top Mass : $\delta\sigma_{tt}/\sigma_{tt} \approx 5 \times \delta m_t/m_t$





Event yields @ 1 fb^{-1}

Standard Model: BR(t→W+b) ≈ 1

	BR	N_{evt} (1 fb^{-1})
tt → (lv)b (jj)b	30%	250,000
tt→(lv)b(lv)b	5%	40,000
tt→(jj)b (jj)b	44%	370,000

"lepton+jets"

"di-lepton"

"full-hadronic"

Top Pair in the "lepton+jets" channel : comissionning analyses

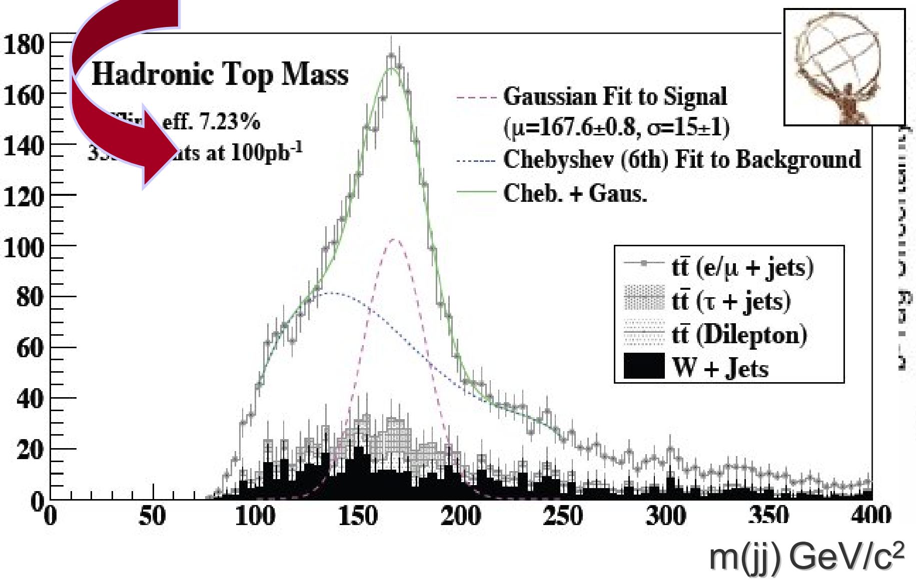
Comissionning analyses with 100 pb^{-1}

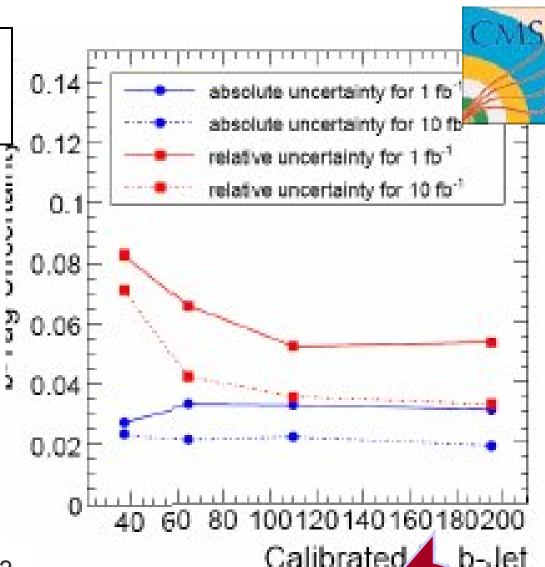
Both experiments use top pair as commissioning analyses

Select a leptonic top (to tag the event)

- L1+HLT trigger (μ,e) ~ 80%
- 1 high-p_T lepton > 20 GeV/c
- at least 3 high-p_T jets > 40 GeV/c
- 1 high-p_T jets > 20 GeV/c

Reconstruct the "hadronic top":





- Determine the light Jet energy scale from W→ jj :
  - Calibration with template histograms
  - → stat error ~0.5% w/ 1 fb^{-1}
- Study of missing ET resolution
- b-tagging commissioning
  - b-tag efficiency → relative accuracy of 6% w/ 1 fb^{-1}
  - Rejection rates from W→ jj

Top Mass using "lepton+jets" : Top quark reconstruction

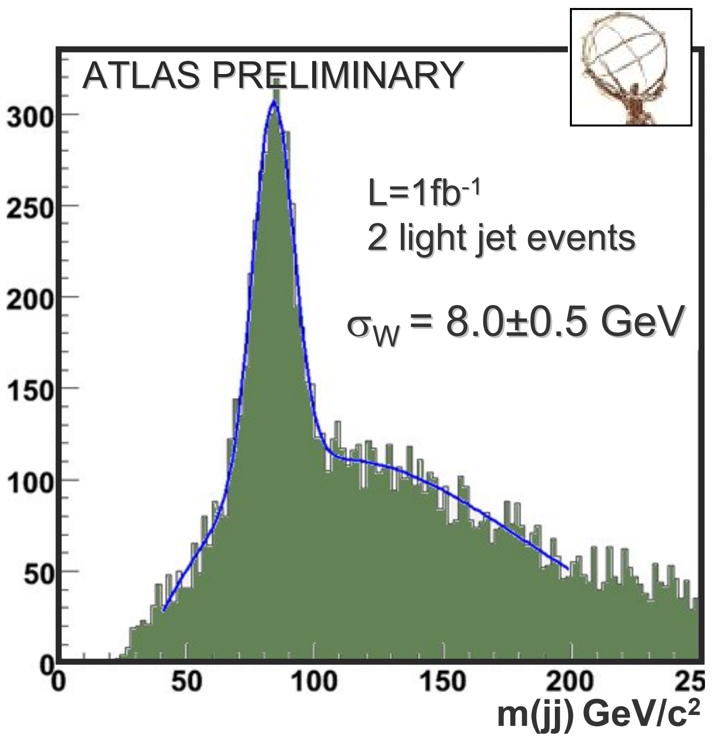
W boson reconstruction & re-scaling

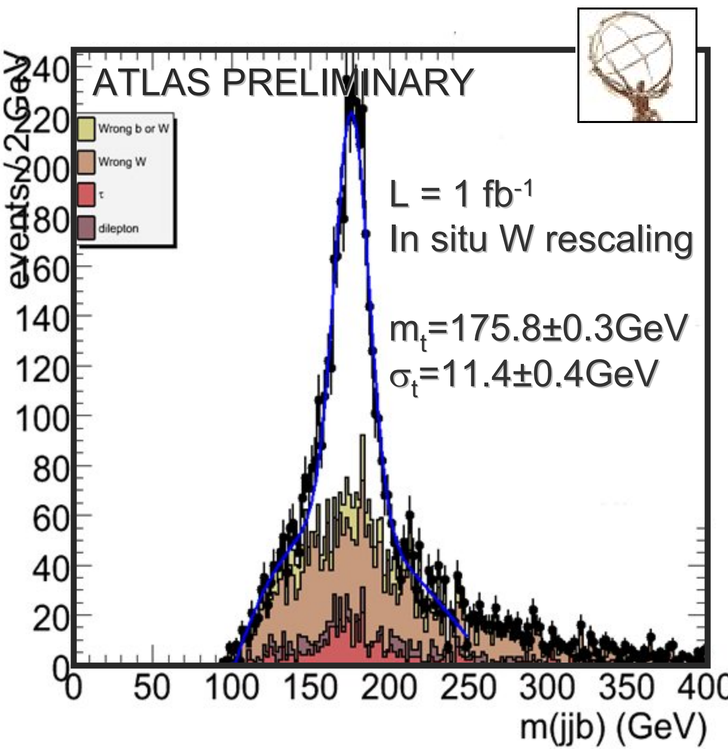
Light jet association W → jj

Select (jj)-pair such: $|m_{jj} - m_W| \leq 3\ \sigma_W$

Event-by-event rescaling

Minimization of: $$\chi^2 = \frac{\left(M_{jj}(\alpha_1,\alpha 2) - M_W\right)^2}{\Gamma_W^2} + \left(\frac{E_{j1}(1-\alpha_1)}{\sigma_{j1}}\right)^2 + \left(\frac{E_{j2}(1-\alpha_2)}{\sigma_{j2}}\right)^2$$





Top quark reconstruction

Association of hadronic W and b-jet :

Combination leading to the highest p_T^{top}

or that maximizes $\Delta R(l,b)$ / minimizes $\Delta R(b, W \rightarrow jj)$

→ Top Purity : 70% w/ efficiency : 1.2%

Top Mass using "lepton+jets" : systematic uncertainties

Top mass performance

Event yields : ~6,800 per 1 fb^{-1}

Mass resolution :

$\sigma \approx 11$ GeV/c^2 (14 before calibration)

Statistical error ~0.05 GeV with 10 fb^{-1}

Main uncertainties	δm_t(GeV)	δm_t(GeV)
light jet energy sc.(1%)	0.2	0.2
b-jet energy scale(1%)	0.7	0.7
Initial State Radiation	0.1	0.1
Final State Radiation	1.0	≤ 0.5
b-quark fragmentation	0.1	0.1
Combinatorial backgd	0.1	0.1
Total SYSTEMATIC	**1.3**	**0.9**
Total STATISTICAL	**0.05**	**0.12**

Improvements :

Use of a kinematic fit on the entire tt event

→ reconstruct hadronic / leptonic top

Use of Mass constraints (evt by evt):

$m_{jj} = m_W$ & $m_{l\nu} = m_W$, $m_{jjb} = m_{l\nu b}$

→ Select lower (χ^2,m_t^{fit}) to reduce contamination from badly reconstructed b-jets (FSR)

Top Mass using "lepton+jets" : systematic uncertainties

Top mass performance

Topological selection

Build Probability for the evt to be a "l+jets"

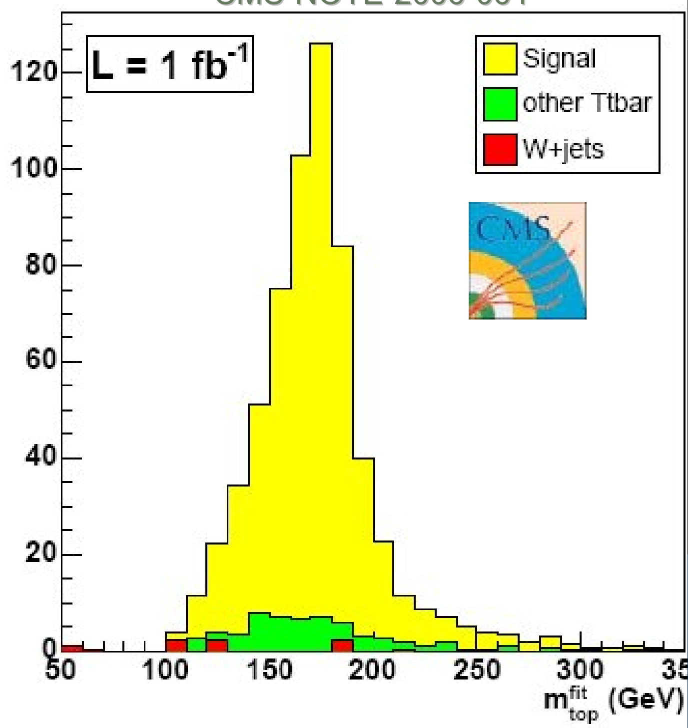
→ light jets from W, b-jet combination…

Mass resolution :

Top width similar to ATLAS (w/ kinematic fit)

Statistical error ~0.05 GeV with 10 fb^{-1}

CMS-NOTE-2006-064



Uncertainties in 10 fb^{-1}	δm_t(GeV)
b-tag efficiency (5%)	0.20
Jets energy scale	0.15
Heavy jet enegy scale	0.98
Pile up (30% On-Off)	0.23
Underlying Event	0.50
Gluon Radiation(Λ,Q^2)	0.27
b-quark fragmentation	0.40
Parton Density Funct.	0.10
Backgrounds	0.25
Total SYSTEMATIC	**1.27**
Total STATISTICS	**0.36**

Use of Ideogram techniques (CMS)

Quantify relative compatibility of the kinematics w/ m_{top}

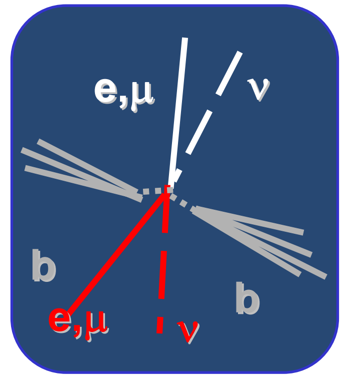
→ χ^2 from m_{top} vs m_{top}^{fit}

→ Build Probability from χ^2 , given the evt kinematics

Top Pair in the di-lepton channel : Event Selection

Event Selection

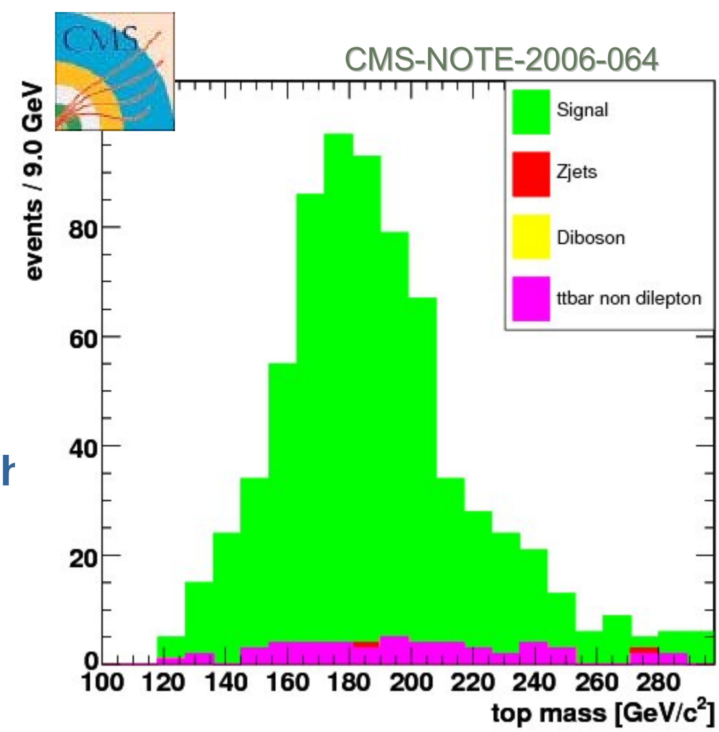
- **Triggering L1+HLT**
  - Lepton trigger $\varepsilon \sim 80\%$
- **Two high p_T leptons**
  - Isolated, opposite signs
  - Veto on Z-mass peak
- **At least two high p_T jets**
  - two b-tagged jets
- **Missing Transverse Energy**



Event kinematic reconstruction

- **Six constraints**
  - $m_{l\nu}=m_{W1}$ and $m_{l\nu}=m_{W2}$
  - $m_{l\nu b}=m_{t2}$ and $m_{l\nu b}=m_{t2}$
  - $\Sigma\, p_T = 0$
- **Six unknowns**
  - Solve for m_{top} hypothesis
  - → Weight each solution
- **Top mass Determination**
  - Preferred solution's weigh
  - Window on m_{top}

$N_{evt}(1fb^{-1}) = 660$
$\varepsilon_{sel} = 1.2\%$
$S/B \sim 12. / 1$



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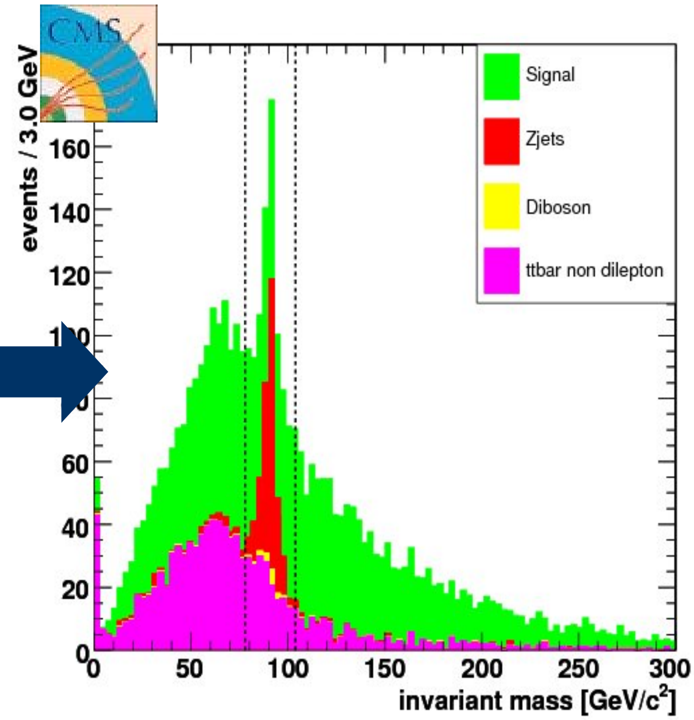

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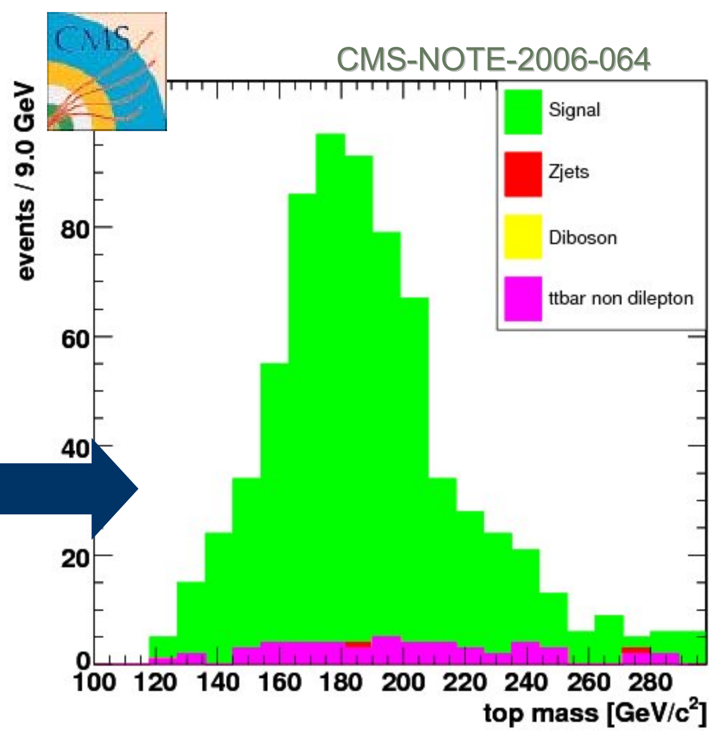
  - $\Sigma\, p_T = 0$
- Six unknowns
  - Solve for m_{top} hypothesis
  - → Weight each solution
- Top mass Determination
  - Highest weight
  - → Window on m(jjb)

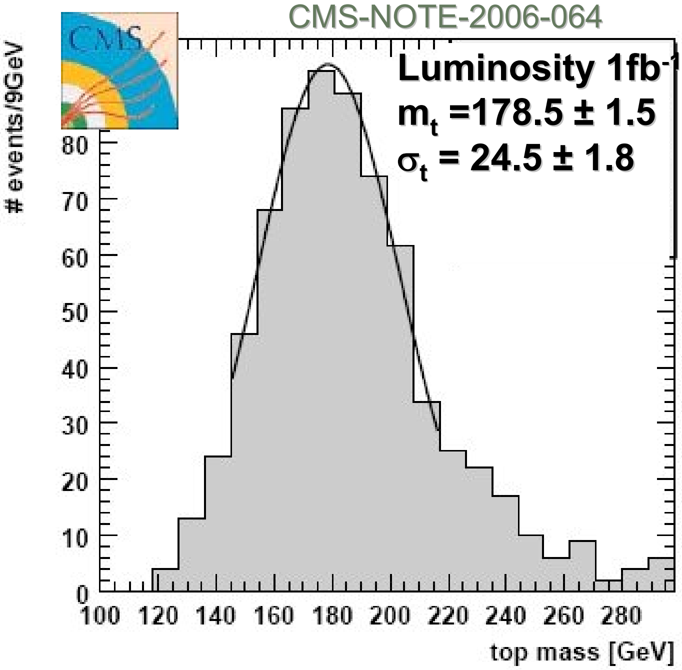
$N_{evt}(1fb^{-1}) = 660$
$\varepsilon_{sel} = 1.2\%$
S/B ~ 12. / 1



Top Pair in the di-lepton channel : $\sigma(tt)$ measurement

Cross-sections Measurements

- **Di-lepton kinematic reconstruction**
  - Preferred solution's weight
  - → Window on m_{top}



Uncertainties in 10 fb^{-1}	$\Delta\sigma/\sigma$
b-tag efficiency (5%)	3.8%
Jets energy scale (3%)	3.6%
Lepton reconstruction	1.6%
Missing E_T	1.1%
Pile up (30% On-Off)	3.6%
Underlying Event	4.1%
Gluon Radiation(Λ,Q^2)	2.5%
b-quark fragmentation	5.1%
Parton Density Function	5.2%
Luminosity	3%
Total SYSTEMATIC	11%
Total STATISTICS	0.9%

Systematics

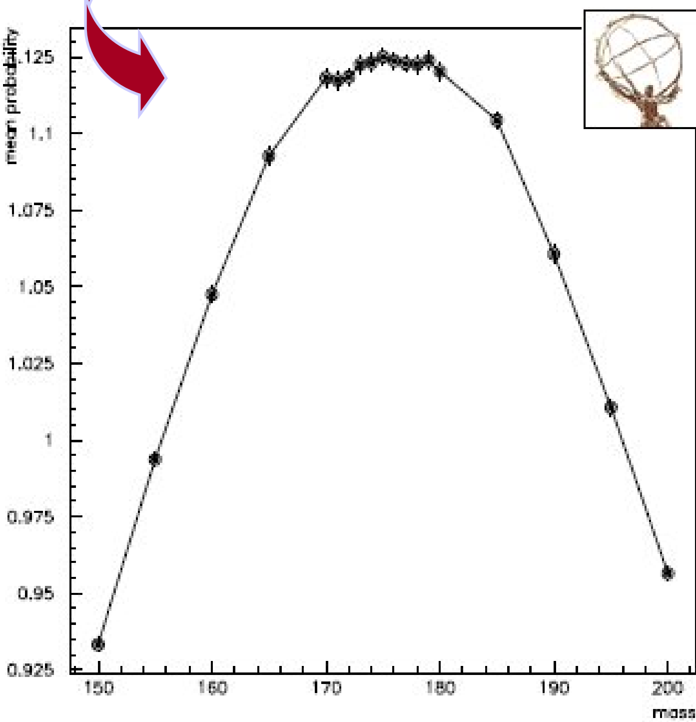
- **Measurement dominated by systematics from the beginning..**
- **Modeling are dominant effects:**
  - PDF, gluon radiation, pile-up+UE,…
- **Experimental biases :**
  - b-tagging and JES, should be improved with calib. data

Top Pair in the di-lepton channel : m_{top} measurement

Top Mass Determination

Extraction of Top mass

- Kinematic reconstruction as f(m_{top})
- → fit of the "preferred" top mass



Uncertainties in 10 fb^{-1}	δm_t
b-jet energy scale (1%)	0.6
b-quark fragmentation	0.7
ISR / FSR modelisation	0.6
Parton Distr. function	1.2
Total SYSTEMATIC	1.6
STATISTICS & method	0.3

Systematic uncertainties

Strong dependence upon theory

- Parton distribution function
- Gluon Radiation (Λ_{QCD},Q^2)
- b-quark fragmentation

Jet Energy scale

- ~0.6 GeV per 1% miscalibration

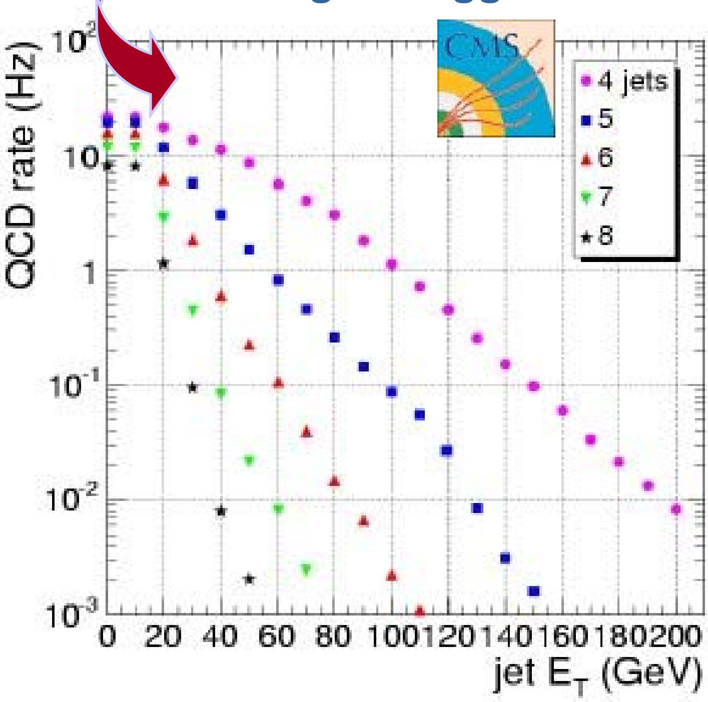
Top Pair in the "full hadronic" channel : Event Selection

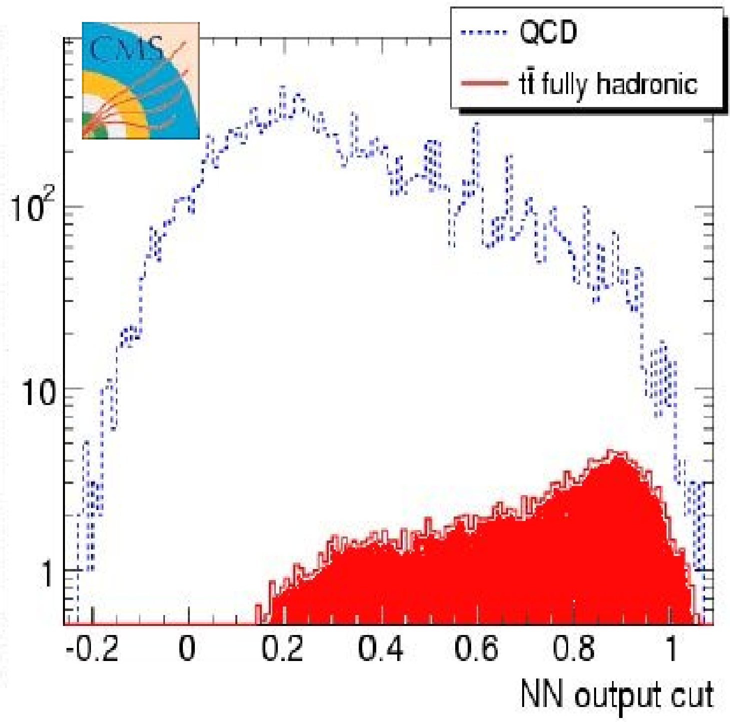
Triggers

Specific triggers designed:

L1/HLT multi-jet triggers + HLT b-tagged jet trigger

➔ Signal trigger ε ~ 15-20% vs rates ~ 20 Hz





Event Pre-selection & classification

Use of Event shape variables + Jet energies

→ Neural Net

Yields @ 1 fb^{-1}	ε(%)	S/B	S/√S+B
trigger HLT jet + b-tag	16.8	1/300	11.1
Event : $6 \leq N_{jet} \leq 8$	15.5	1/225	12.4
Neural Net	4.0	1/10	28.5
1-b tag	3.8	1/7	32.6
2-b tag	2.7	1/3	37.2

Top Pair in the "full hadronic" channel : σ(tt) measurement

Cross-section measurements

Full hadronic events selected by a NN

→ Cut on on Neural Net

Uncertainties in 1 fb^{-1}	$\Delta\sigma/\sigma$
Jets energy scale (3%)	11.2%
High Level Trigger	5.0%
b-tag efficiency (5%)	2.0%
Pile up (30% On-Off)	10.0%
Gluon Radiation (Λ_{QCD},Q^2)	7.9%
Underlying Event	4.1%
Parton Density Functions	4.2%
b-quark fragmentation	1.9%
Background level	5.0%
Luminosity	5%
Total SYSTEMATIC	20%
Total STATISTICS	3.0%

Systematic uncertainties

Experimental biases dominate :

JES, trigger efficiency, b-tagging efficiency

Modeling biases

Pile-up+UE, should be tuned with data

PDF, IS/FS radiations

Backgrounds shape & levels

Top Pair in the "full hadronic" channel : m_{top} measurement

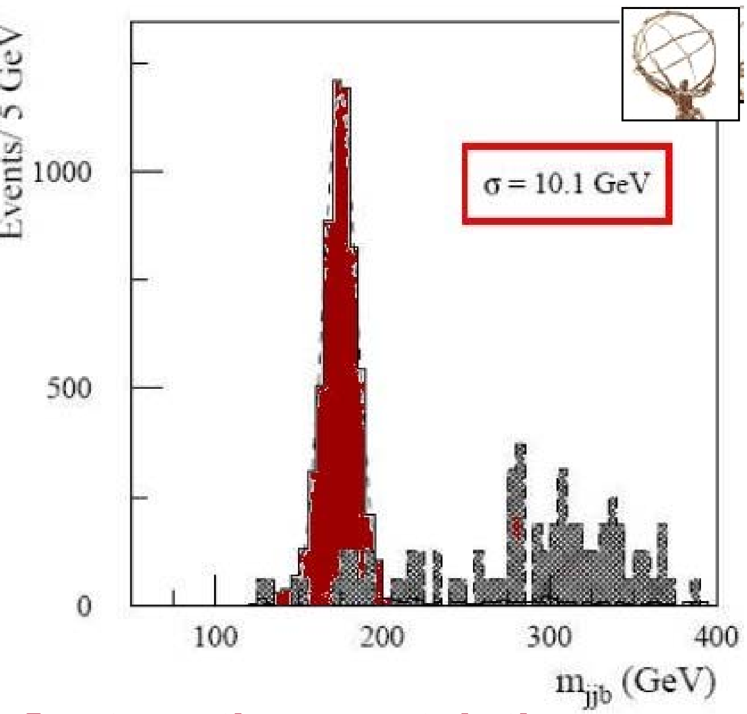
Top Mass Determination

Jet Combination :

- Jet energy variables (H_T, E_T^b, ΔRjj..)
- Kinematic fit to W→ jj (χ^2_W) and t→ Wb (χ^2_t)

Event yields :

- For events with $p_T^{top} \geq 200$ GeV/c & $130 < |m_{jjb}| < 200$
- → Signal ~ 3,300 events in S/B ~ 18/1 in $10 fb^{-1}$
- → Resolution $\sigma \approx 13$ GeV/c



hep-ex/0403021

Uncertainties @ 10 fb^{-1}	δm_t
light jet energy (1%)	0.8
b-jet energy (1%)	0.7
Initial State Radiation	0.4
Final State Radiation	2.8
b-quark fragmentation	0.3
Background	0.4
Total SYSTEMATIC	**3.1**
Total STATISTICAL	**0.2**

Systematic uncertainties

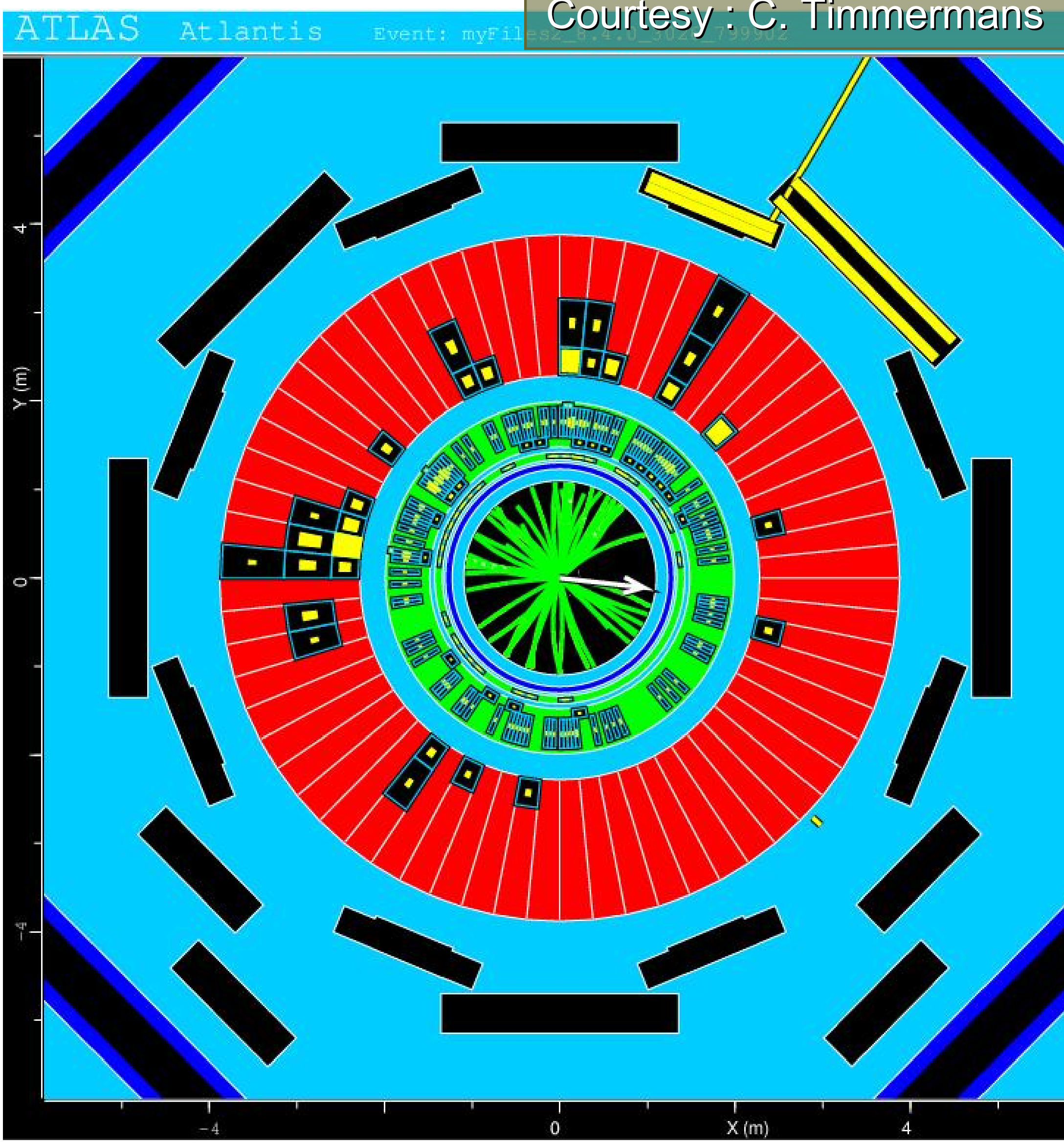
Light-jet and b-jet energy scales dominate:

- Need 1% level to reach ~3 GeV/c^2

Modeling effects

- Dominated by gluon radiation, background

LHC as a Single-Top Factory



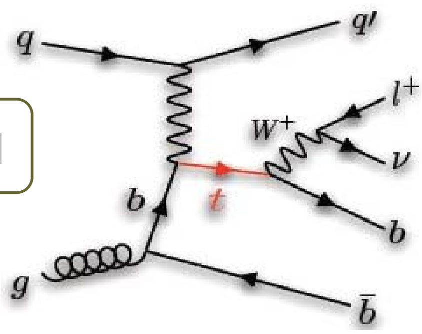
Courtesy : C. Timmermans

Single Top cross-section : Production @ LHC

Production at the LHC

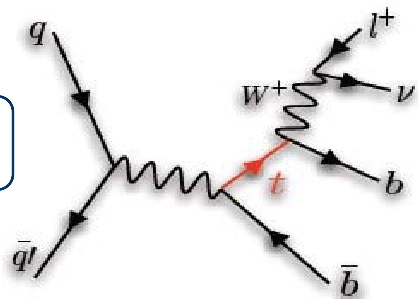
All 3 contributing mechanisms in SM

t-channel



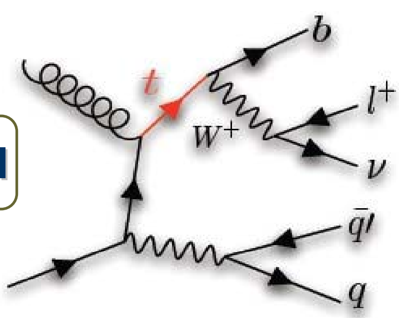
σ = 246.6±10 pb (NLO) (1)
- dominant source of single top
- N(1 fb^{-1}) ~ 80,000 in W→ e/μ,ν

s-channel



σ = 10.65±0.65 pb (NLO) (1)
- smallest source of single top
- N(1 fb^{-1}) ~ 3,000 in W→ e/μ ν

W+t channel



σ = 62.10±0.03 pb (NLO) (2)
- source of single top
- N(1 fb^{-1}) ~ 18,000 in W→ e/μ ν

Phenomenology

Cross-section uncertainties

$\Delta\sigma/\sigma_{theo}$ ~ 4 to 6% (renorm. scale, pdf, input m_{top})

Main backgrounds @ LHC

Top pair events (was W+jets @ TeVatron)

(1) Z. Sullivan, Phys. Rev D70 (2004) 114012
(2)Campbell et al., hep-ph/0506289

Single-top t-channel

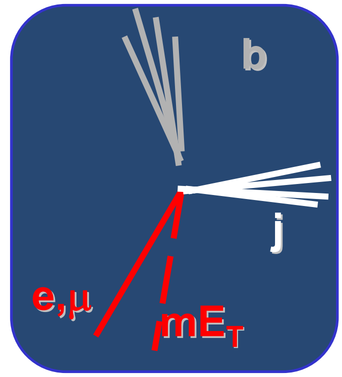
Event Selection

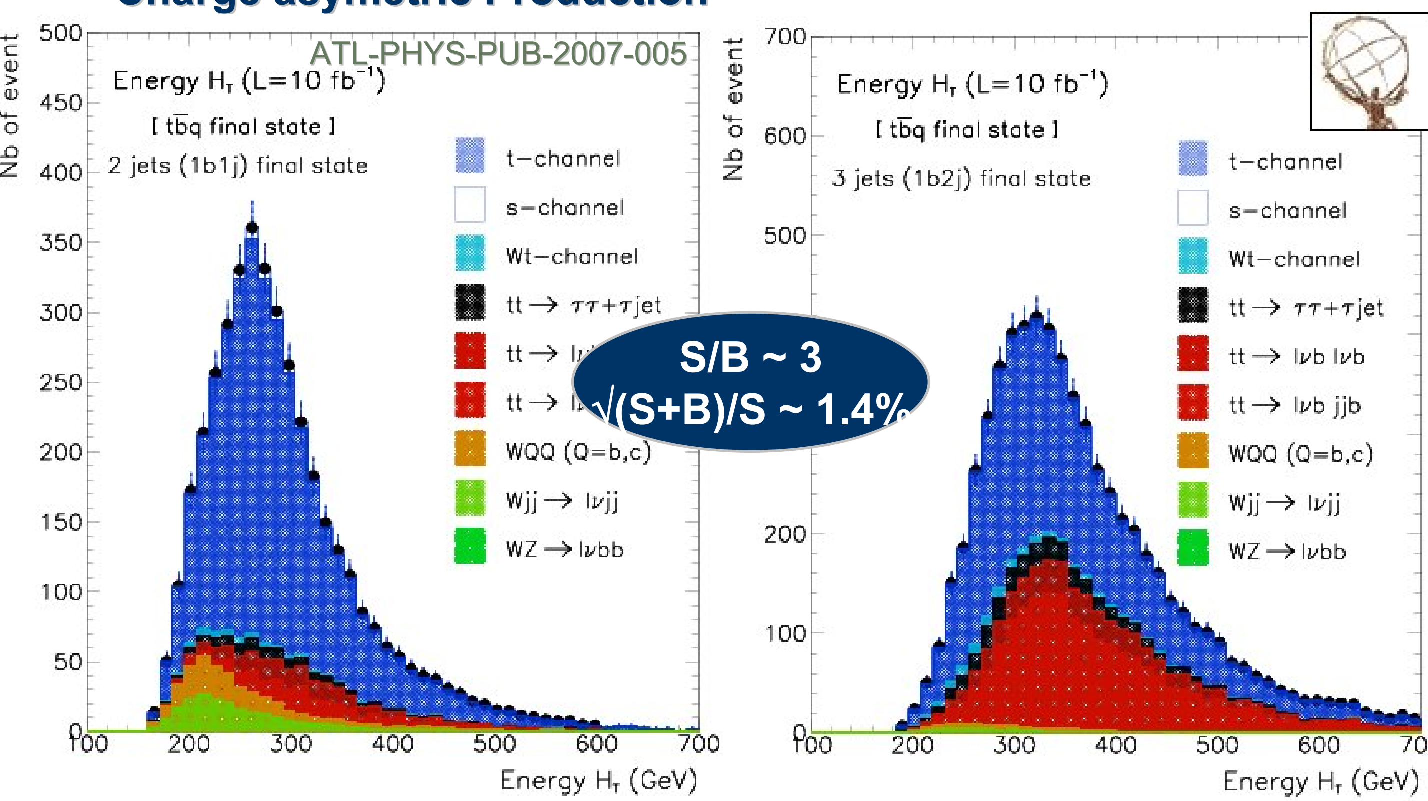
Exactly 2 high-p_T jets:

- **1 high p_T central b-jet**
- **1 forward light jet $|\eta|>2.5$**

Window in H_T or M_{tot}

Charge asymetric Production





S/B ~ 3

$\sqrt{(S+B)}/S$ ~ 1.4%

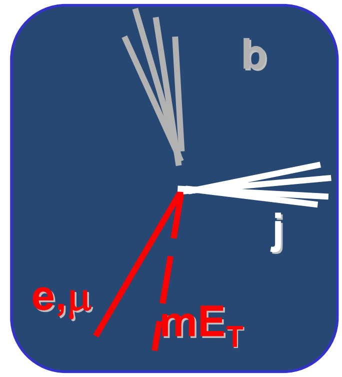
Performance

Signal : $\varepsilon \approx$ 1-2% and N(1fb^{-1}) ~ 7,000 events

Backgrounds : W+jets , top pair

Systematics: $\Delta\sigma/\sigma = 1.3\%_{stat} \pm 11\%_{exp} \pm 6\%_{bckgd} \pm 5\%_{lumi}$ @ 10fb^{-1}

t-channel cross-section



Event Selection

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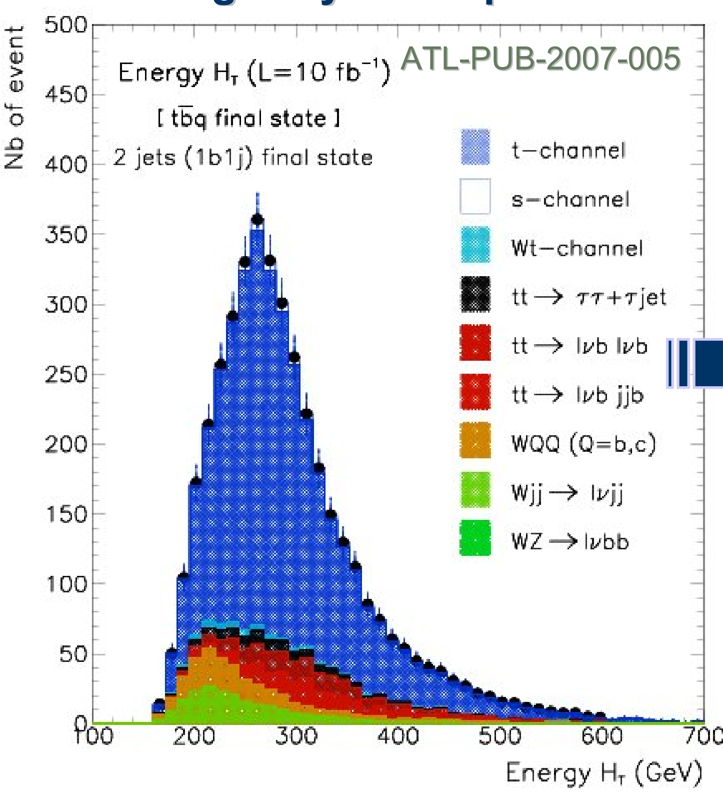
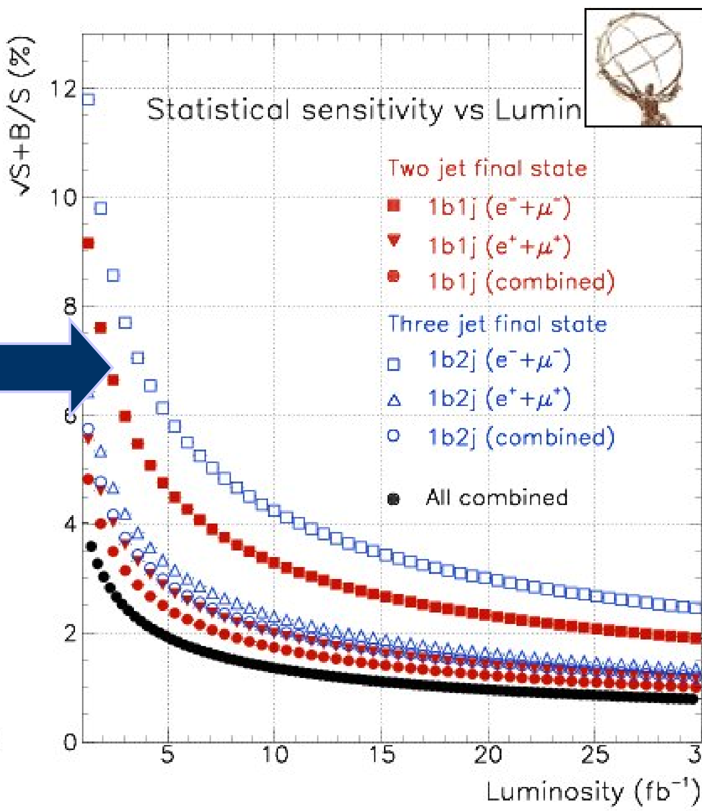
Window in H_T or M_{tot}

Charge asymetric production





Performance

Signal : $\varepsilon \approx$ 1-2% and N(1fb^{-1}) ~ 7,000 events

Backgrounds : W+jets , top pair

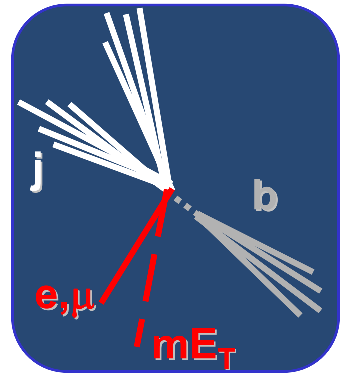
Systematics: $\Delta\sigma/\sigma = 1.5\%_{stat} \pm 11\%_{exp} \pm 6\%_{bckgd} \pm 5\%_{lumi}$ @ 10fb^{-1}

ISR/FSR
b-tag
JES

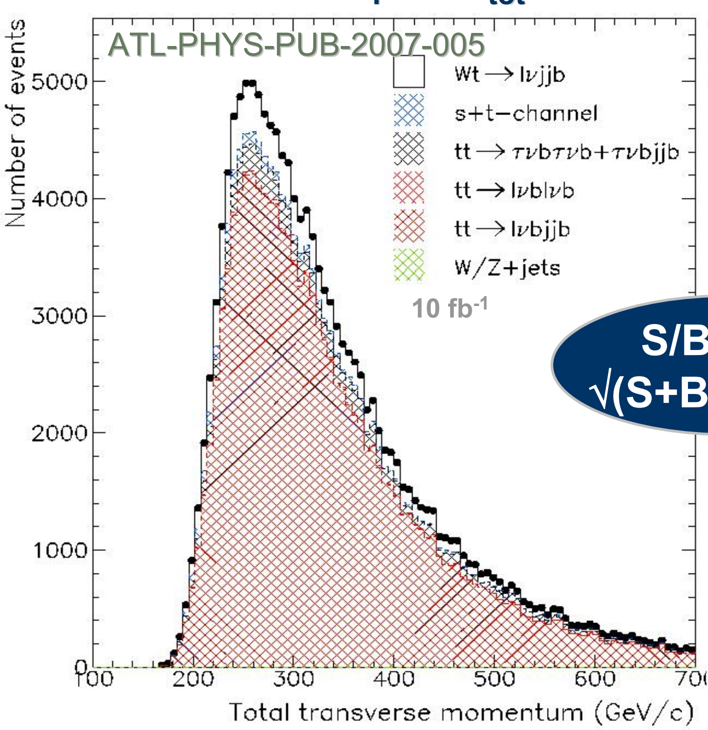
uncertainty in bckgd:
ttbar estimate

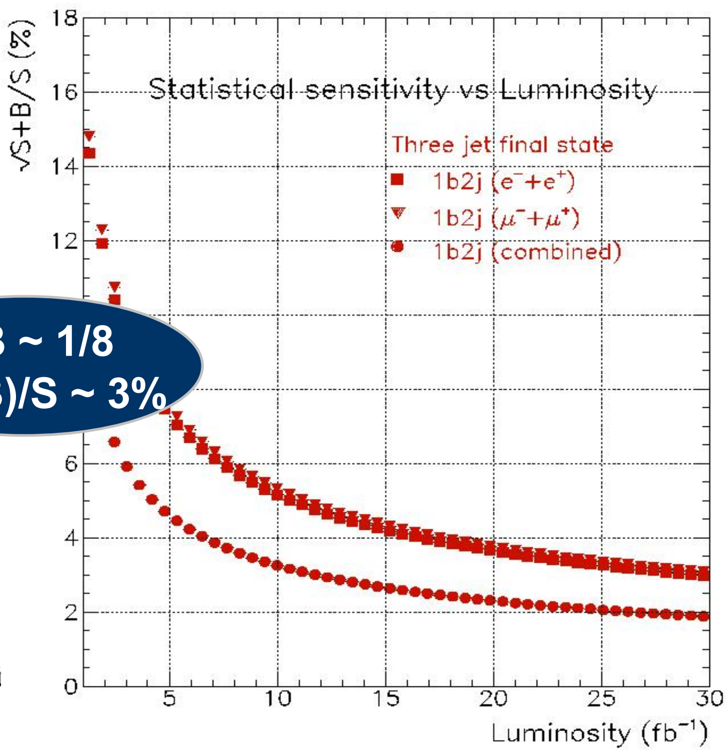
W+t channel cross-section

Event Selection



- **Exactly 3 high-p_T jets**
  - **1 high p_T central b-jet**
  - **→ 2nd b jet veto (loose b-tag)**
- **Reconstruct a W→ jj**
- **Reconstruct a t → lνb**
- **Window in H_T or M_{tot}**





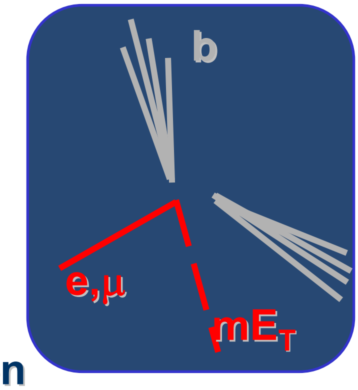
S/B ~ 1/8
√(S+B)/S ~ 3%

Performance

- **Signal ε ≈ 5-7% and N(10fb^{-1}) ~ 13,000 events**
- **Backgrounds : top pair, t-channel**
- **Systematics: $\Delta\sigma/\sigma = 3\%_{stat} \pm 11\%_{exp} \pm 9\%_{bckgd} \pm 5\%_{lumi}$ @ 10fb^{-1}**

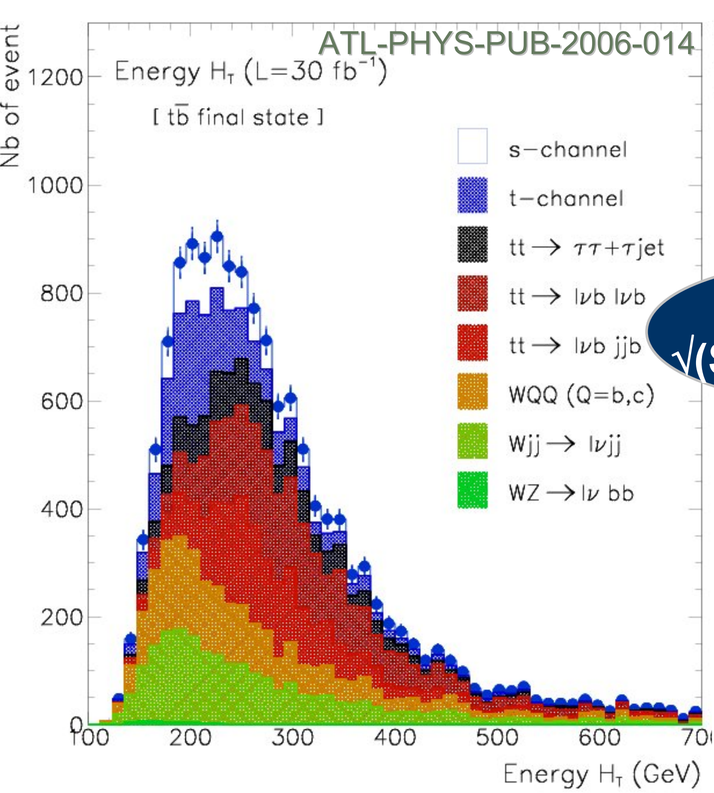
ISR/FSR
b-tag
JES

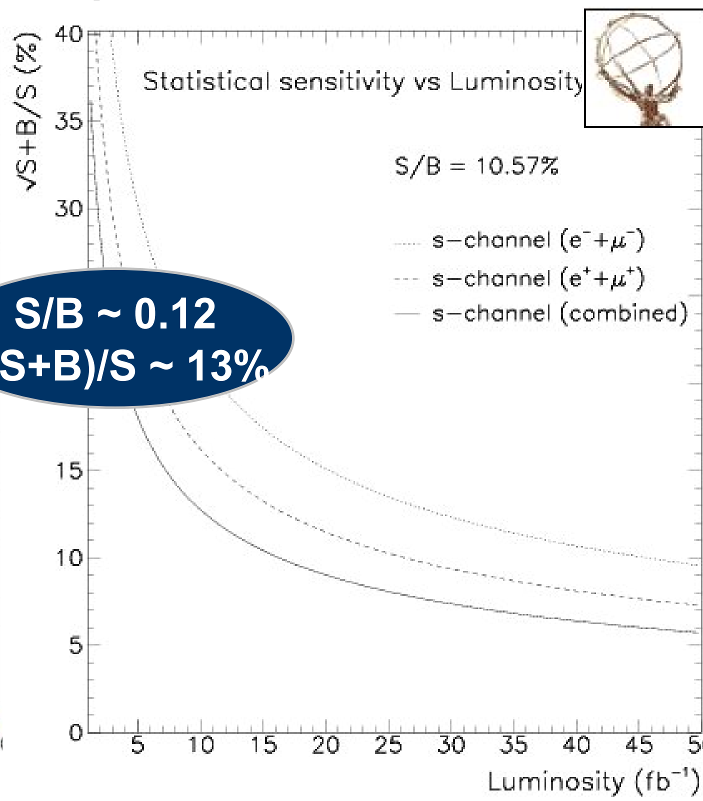
s-channel cross-section



Event selection

- 1 high p_T lepton (2^{nd} lepton veto)
- Missing E_T
- 2 high-p_T b-jets, veto of a 3^{rd} jet
- Window on H_T and on $M_{l\nu b}$
- Separate charge tb tbb asymetric production





S/B ~ 0.12
√(S+B)/S ~ 13%

Performance

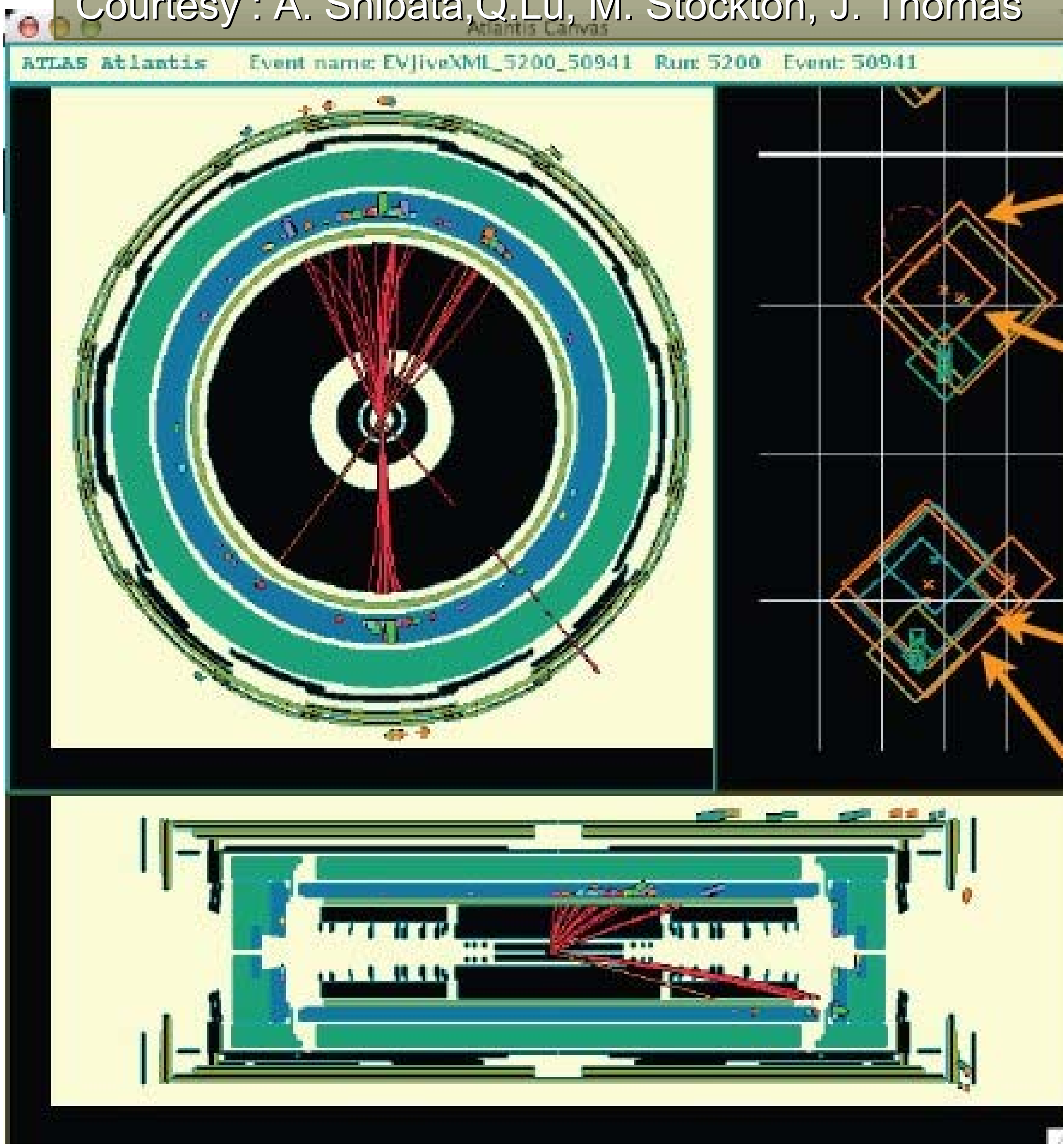
- Signal ε ≈ 1-2% , N(10fb^{-1}) ~ 400 events
- Systematics: $\Delta\sigma/\sigma = 13\%_{stat} \pm 12\%_{exp} \pm 11\%_{bckgd} \pm 5\%_{lumi}$ @ 10fb^{-1}

ISR/FSR
b-tag
JES

Uncertainty in bckgd:
ttbar, W+jets, Wg

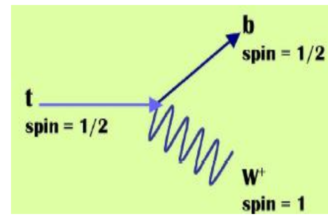
Polarization in top events

Courtesy : A. Shibata,Q.Lu, M. Stockton, J. Thomas



W polarization measurement in top decays

Polarization of W in top decays

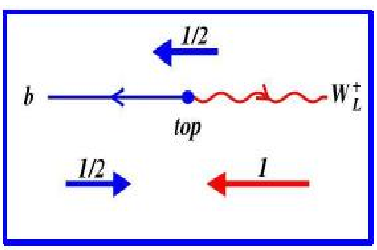
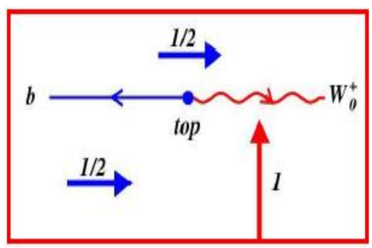
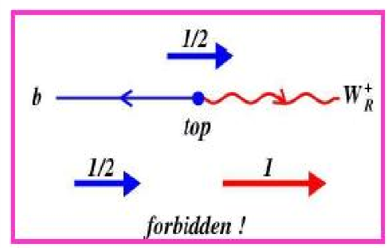


V-A current $\frac{-ig}{2\sqrt{2}}\bar{t}\gamma^{\mu}(1-\gamma^{5})V_{tb}bW_{\mu}$

Measurement Principle

Use the lepton decays of W boson as spin analyzor

→ Angle between l^{+} and W^{+} direction ("top at rest" frame)

"Left handed": F_L	"Longitudinal" F_0	"Right handed" F_R
		
Standard Model: $F_L=2m_W^2/(m_t^2+2m_W^2)$ = 0.297	Standard Model: $F_0=m_t^2/(m_t^2+2m_W^2)$ = 0.703	Standard Model: F_R= 0.00 (forbidden) (m_b=0 approx.)

Observable:

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

W polarization measurement in top decays

Polarization of W in top decays

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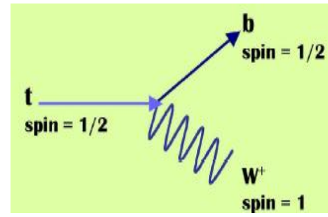

Measurement Principle

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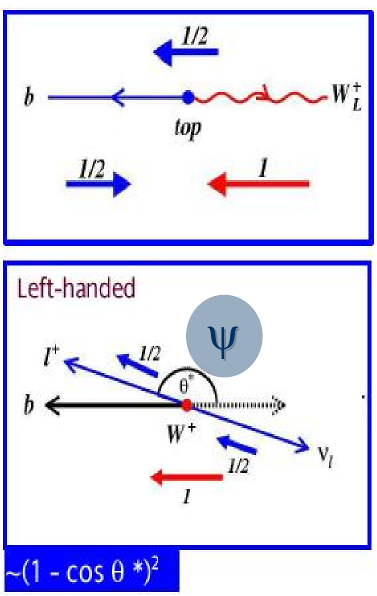	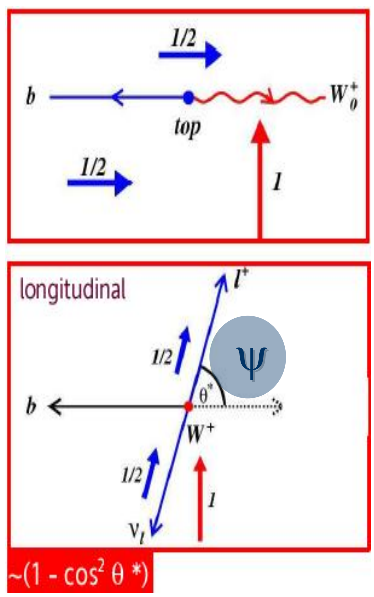	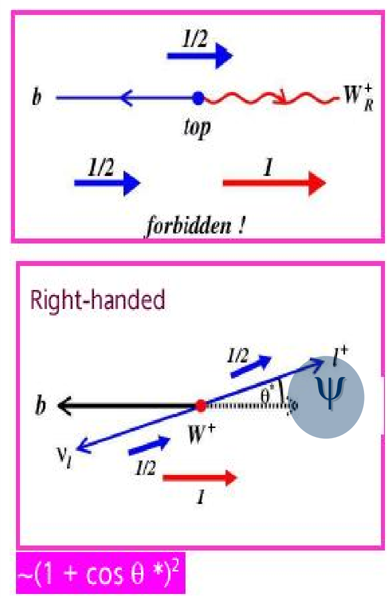

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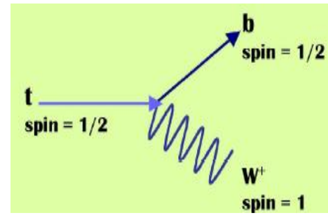

Measurement Principle

Use the lepton decays of W boson as spin analyzor

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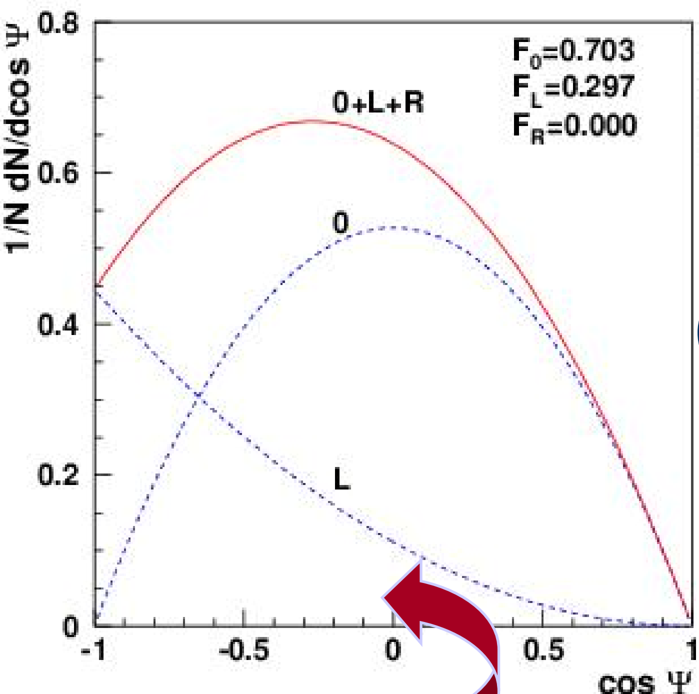
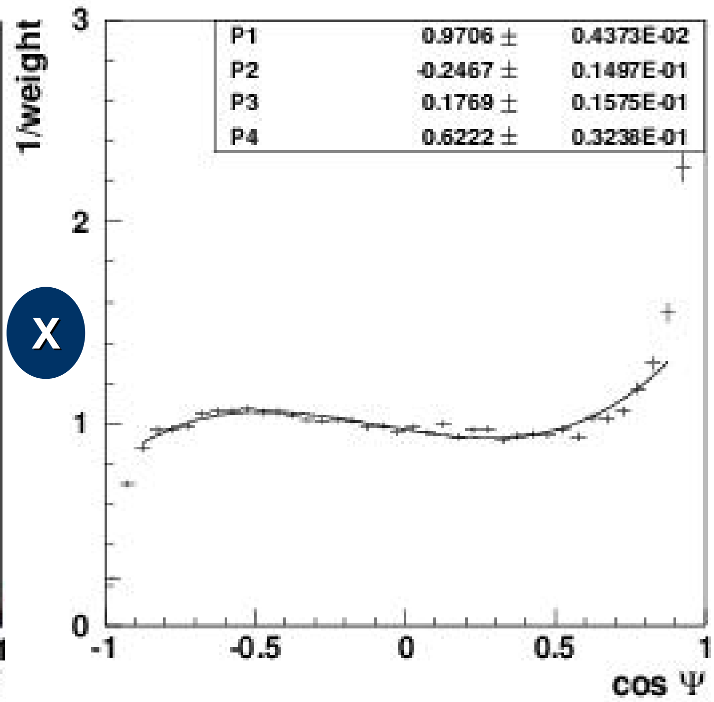


X



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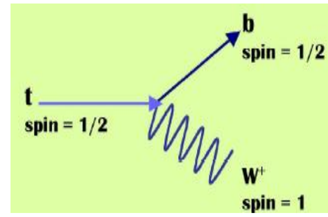
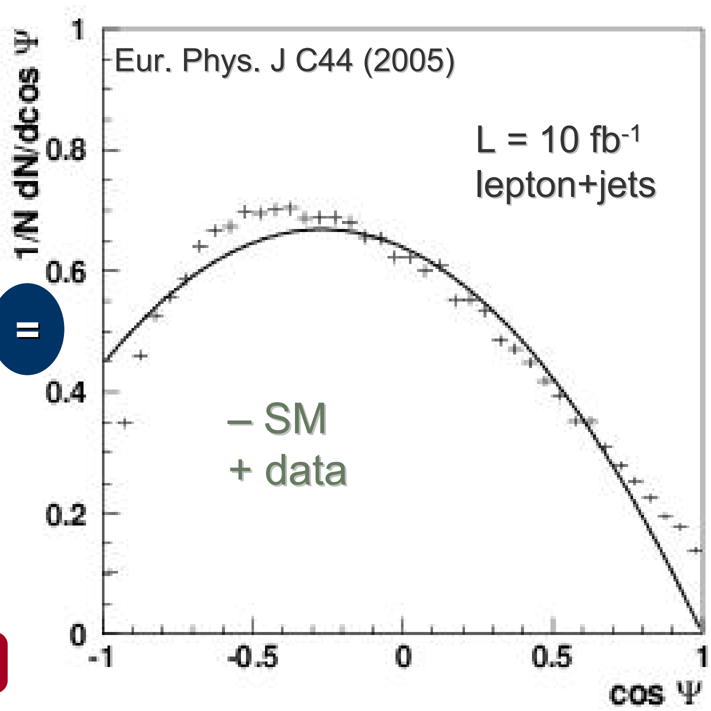


Measurement Principle

- Use the lepton decays of W boson as spin analyzor
- → Angle between l^+ and W^+ direction ("top at rest" frame)

Source of uncertainty	Semileptonic channel		
	F_L	F_0	F_R
Generation			
Q-scale	0.000	0.001	0.001
Structure function	0.003	0.003	0.004
ISR	0.001	0.002	0.001
FSR	0.009	0.007	0.002
b-fragmentation	0.001	0.002	0.001
Hadronization scheme	0.010	0.016	0.006
Reconstruction			
b-tagging (5%)	0.006	0.006	0.000
b-jet miscalibration (3%)	0.011	0.005	0.005
Input top mass (2 GeV)	0.015	0.011	0.004
Others			
S/B scale (10%)	0.000	0.000	0.000
Pile-up (2.3 events)	0.005	0.002	0.006
TOTAL	0.024	0.023	0.012

=



Systematic uncertainties

- **Systematics are dominant**
- **b-jet energy scale, b-tagging efficiency**
  - Input top mass, FSR modeling
  - Pile-up+underlying event

Sensitivity to anomalous couplings

Sensitivity to anomalous couplings

In models beyond the SM

New particles affecting the Wtb couplings

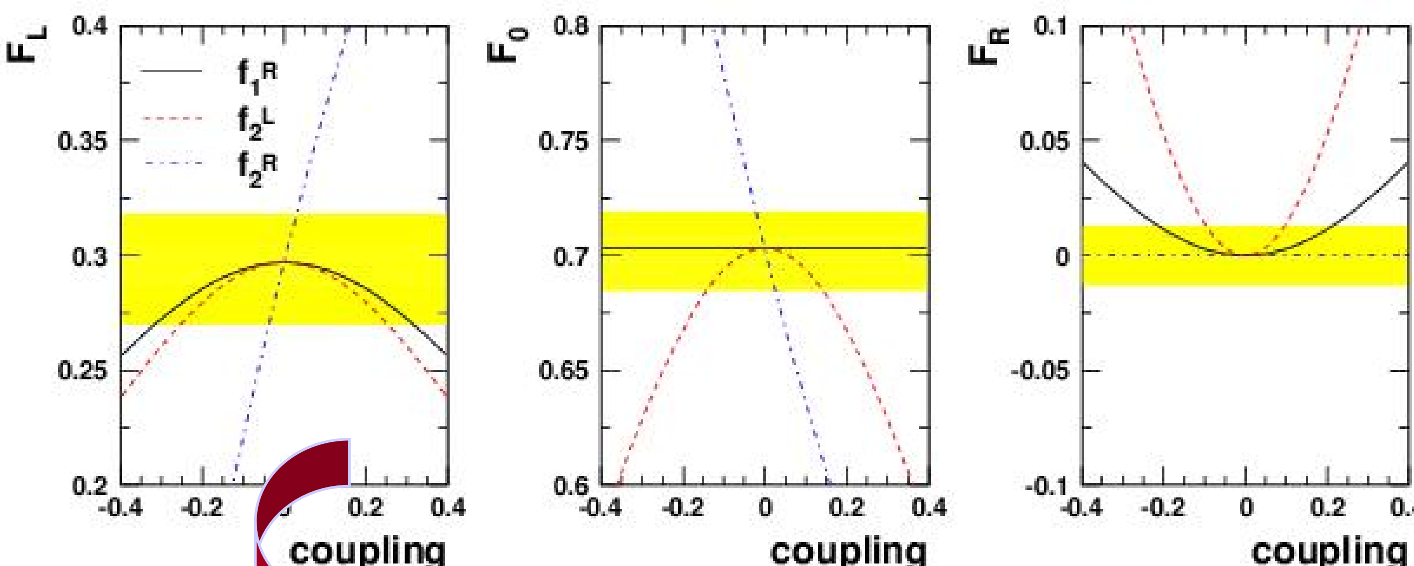
Model Independent approach

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

→ four couplings : f_1^L, f_1^R, f_2^L et f_2^R

(in the MS: $f_1^L = V_{tb} \cong 1$, $f_1^R = f_2^L = f_2^R = 0$)

Results



	f_1^R	f_2^L	f_2^R
$t\bar{t}$, LHC (10 fb^{-1}) (Stat.+ Syst.)	0.30	0.13	0.04
$t\bar{t}$, Tevatron (2 fb^{-1}) (Stat. only)	0.5	0.3	0.3
single top, LHC (100 fb^{-1}) (Stat.+ 5% Syst.)	0.06	0.07	0.13
$b \to s\gamma, sl^+l^-$, B-factories (indirect)	0.004	0.005	0.4

Sensitivity to anomalous couplings

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Results

Sensitivity to anomalous couplings

	f_1^R	f_2^L	f_2^R
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Conclusion & perspectives

LHC as a "top pair factory"

- **More than 300k recorded events a year :**
  - Use top pair for commissionning analyses
  - Measurements will be early systematics limited
- **Top mass measurements:**
  - TeVatron results will be difficult to match…
  - Although an uncertainty of ~1 GeV/c^2 seems achievable
  - …provided 1% level calibration of (b)-jet energy scale
  - …and the optimization of m_t determination technique
- **Cross-section measurements:**
  - Errors should match soon the theoretical uncertainties
  - Should provide a test of QCD at ~6% level
- **W polarization measurements**
  - Precision at ~1-2% level
  - Top spin correlation asymmetry to ~4%
  - High sensitivity to anomalous couplings

LHC as "single-top" factory

- **More than 80k recorded events a year**
  - Systematics limited measurements ~ 10%
- **Cross-section measurements**
  - Should lead to V_{tb} at ~5% level
  - Will be sensitivie to anomalous couplings, FCNC
  - Will probe to new extra boson W', $H^{\pm}$ (2HDM)
  - → Will need to use data to model ttbar/W+jet background

Thanks to…

Many thanks to :

Pamela Ferrari,
Jorgen D'hondt,
Anne-Isabelle Etienvre,
Jerome Schwindling,
Javier Cuevas,
Akira Shibata

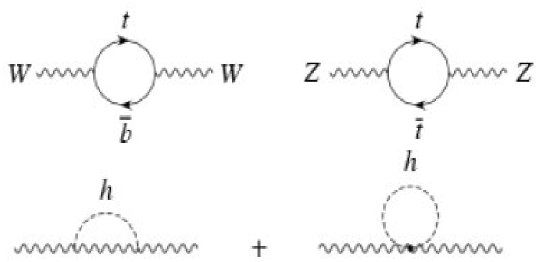
BACKUP

Top Mass measurement : motivations at the LHC

Precision measurements in the EW sector

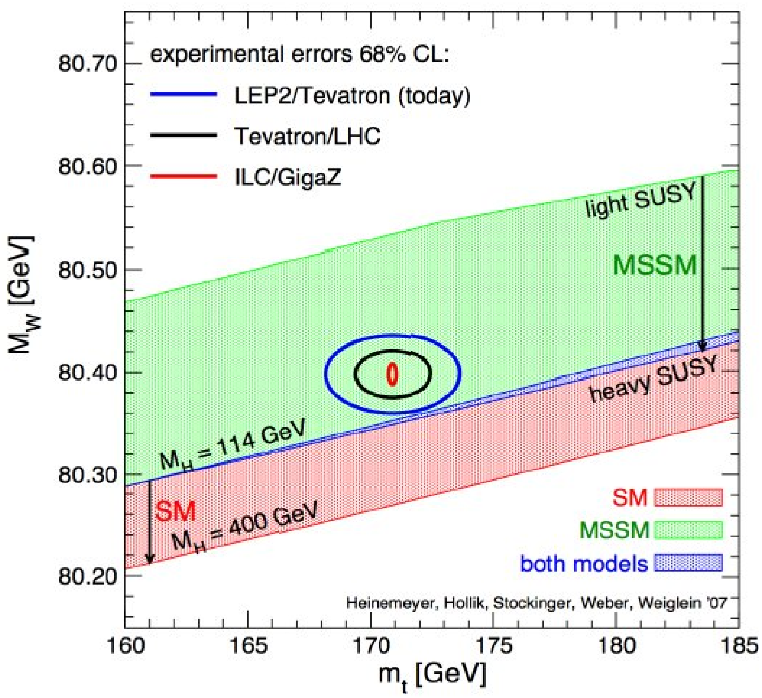
Boson masses relation:

$$M_W^2\left(1-\frac{M_W^2}{M_Z^2}\right)=\frac{\pi\alpha}{\sqrt{2}G_\mu}\frac{1}{1-\Delta r}$$



$$(\Delta r)_{top}\approx-\frac{3}{8}\frac{Gm_t^2}{\sqrt{2}\pi^2}\frac{1}{\tan^2\theta_W}$$

$$(\Delta r)_{Higgs}\approx\frac{11}{24}\frac{GM_Z^2\cos^2\theta_W}{\sqrt{2}\pi^2}\log\frac{m_H^2}{M_Z^2}$$



Present Measurements :

- Limit to Higgs Mass
  m_H < 144 GeV/c^2 (95%CL)
- Do not indicate any clear departure from SM (yet)
- Equal weight to χ^2 from :
  $\Delta m_W \approx 0.7\% \, \Delta m_t$

15 MeV/c^2 → 2 GeV/c^2

LHC prospects

Consistency checks with direct m_H measurements…

→ MSSM (1-loop): $m_h^2 = m_Z^2 + \frac{3G_F m_t^4}{\pi^2\sqrt{2}} \ln\left(\frac{M_t^2}{m_t^2}\right)$ ← s-top mass

hep-ph/0303092

Top Mass measurement : motivations at the LHC

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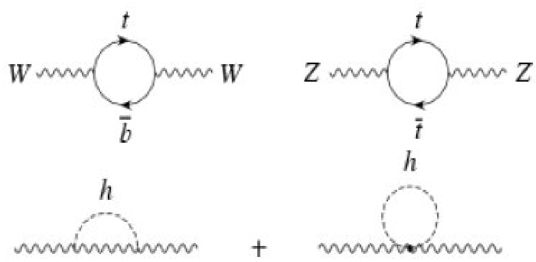

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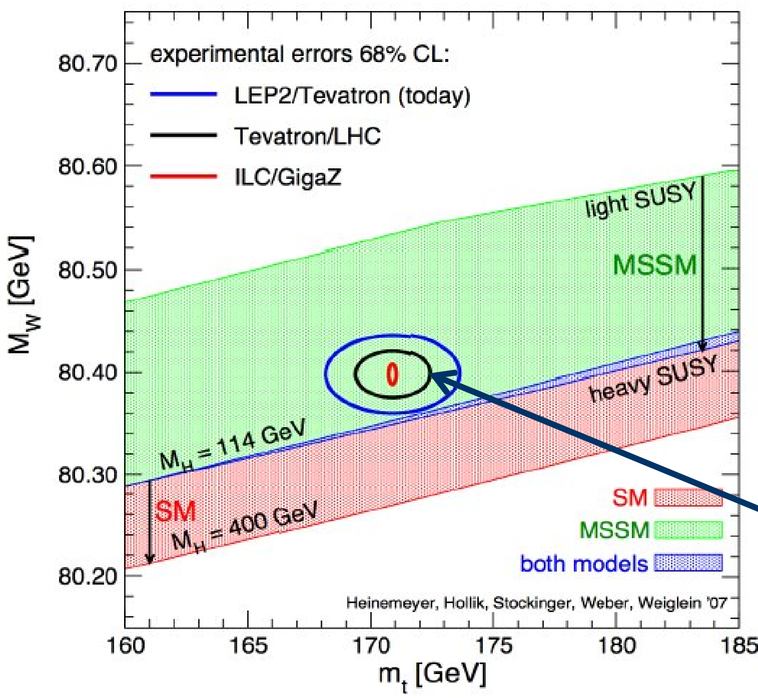


Present Measurements :

→ constraint Higgs Mass

$m_H < 285$ GeV/c^2 (95%CL)

→ do not indicate any clear departure from SM (yet)

→ equal weight to χ^2 from :

$\Delta m_W \approx 0.7\% \, \Delta m_t$

Δm_t=1 GeV/c^2
Δm_W=15 MeV/c^2

LHC prospects

Consistency checks with direct m_H measurements

Determination of the underlying framework requires :

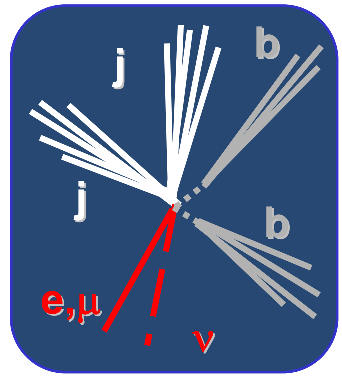
→ $\Delta m_W \approx 15$ MeV/c^2 vs $\Delta m_t \approx 1$ GeV/c^2

Top Mass in the "lepton+jets" channel : Event Selection

Event Selection

Select a leptonic top (to tag the event)

- L1+HLT trigger (μ,e) ~ 80%
- 1 high-p_T lepton (trigger)
- high missing Energy
- at least 4 high-p_T jets
- at least 1 high-p_T b-tagged jet



Reconstruct the "hadronic top"

- Classify events / b-tags
  - → 2 samples : 2 b-tag (1 btag)
- W-boson reconstruction from jj
  - → in-situ light jet re-calibration
- Top quark reconstruction from jjb

m(jj) GeV/c^2

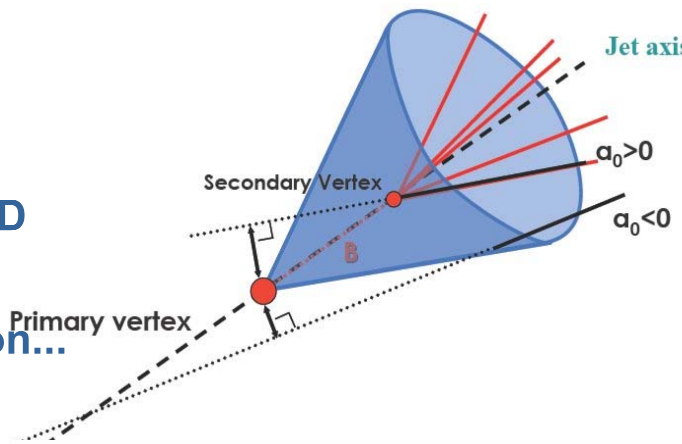
Top Mass using "lepton+jets" : b-tagged jet

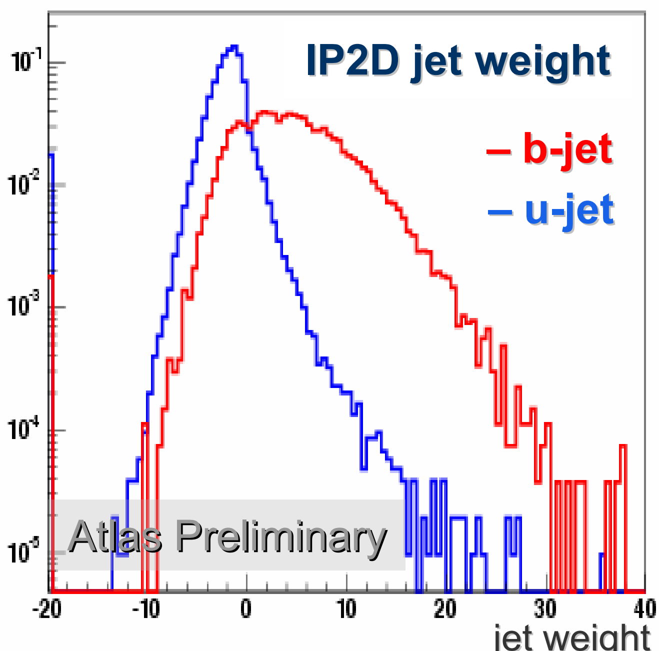
b-tagging algorithms

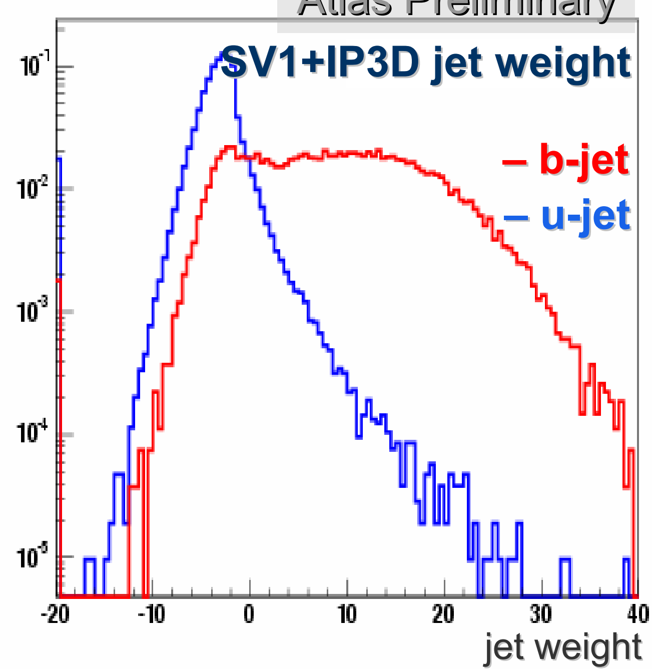
Several taggers

- Soft lepton tag
- Impact parameter 2D/3D
- Secondary Vertex
  - Mass, charged fraction...
- Lifetime tag ...

→ Combined likelihood/weight







Performance

- Typical results on top pair events :

	R_u (50%)	R_u(60%)
IP2D	160	55
IP3D	230	85
SV1+IP3D	500	185

- Ongoing studies:

→ Geant-3 vs Geant-4

→ underlying event

→ jet algorithm

Top Mass using “lepton+jets” : b-tagged jet

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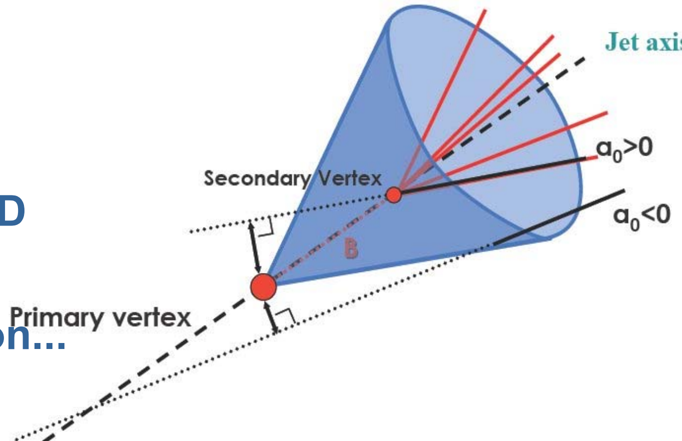

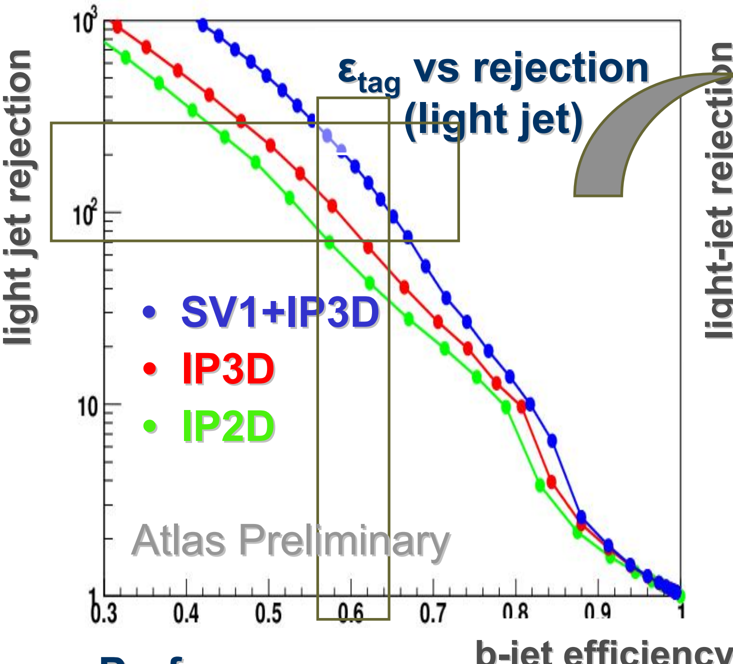

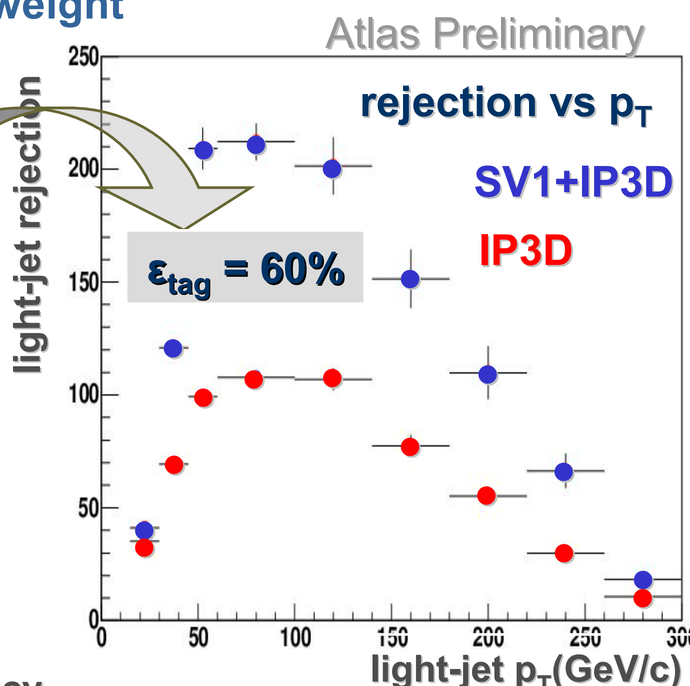

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- → underlying event
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IP2D	160	55
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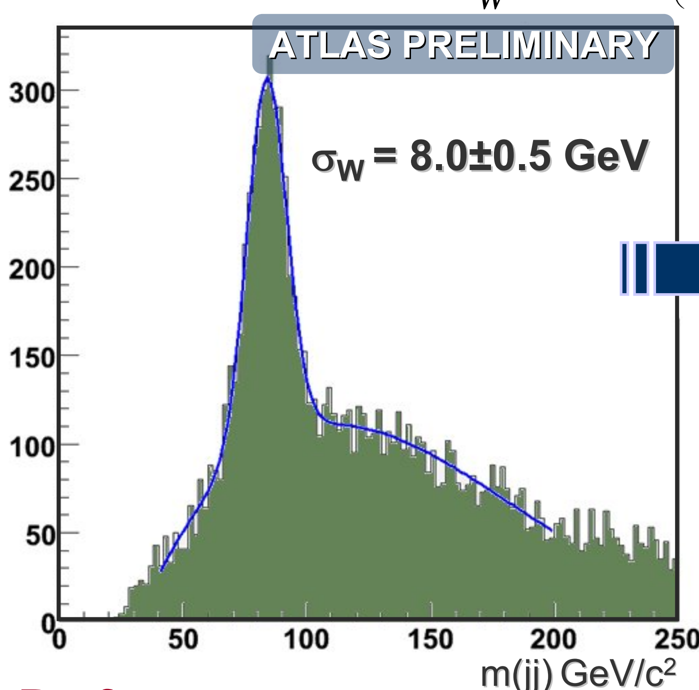
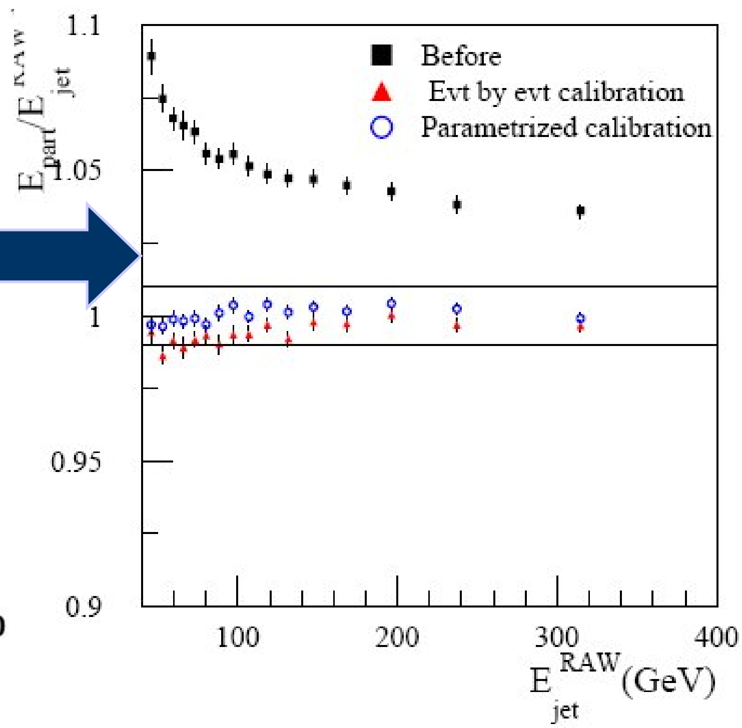
Top Mass using "lepton+jets" : light jet in situ re-scaling

In situ jet energy scale rescaling

- **Jet association W → jj**
  - Select (jj)-pair such: $|m_{jj} - m_W| \leq 3\ \sigma_W$
- **Event by event rescaling of the 2 light jets**
  - Minimization of:

$$\chi^2 = \frac{\left(M_{jj}(\alpha_1, \alpha 2) - M_W\right)^2}{\Gamma_W^2} + \left(\frac{E_{j1}(1-\alpha_1)}{\sigma_{j1}}\right)^2 + \left(\frac{E_{j2}(1-\alpha_2)}{\sigma_{j2}}\right)^2$$





Performance

- **Improvement of the purity**
- **Improvement on energy resolution**
  - Top width : 14 GeV → 11 GeV
  - Reduce sensitivity to JES to 0.2 GeV per % (light jets)

Top Mass using “lepton+jets” : Light jet calibration w/ templates

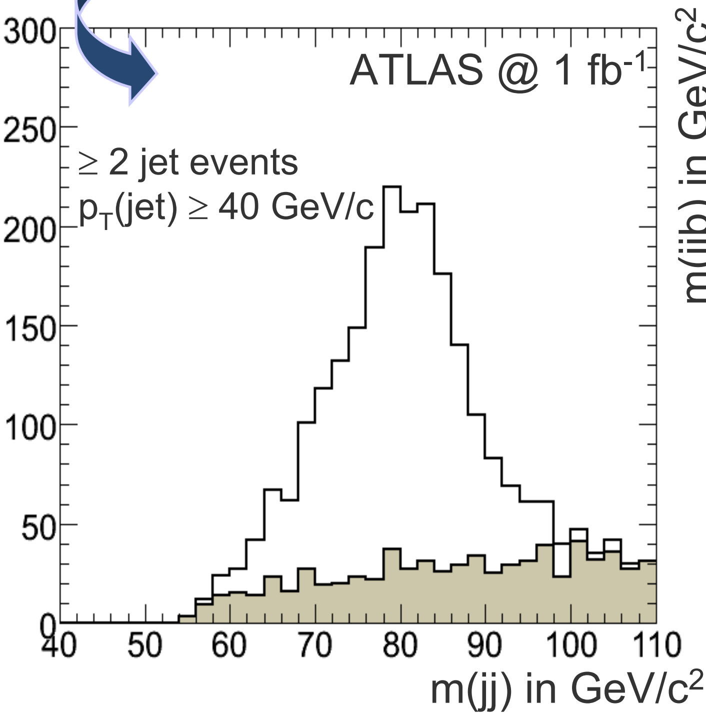
Light jet calibration with template method

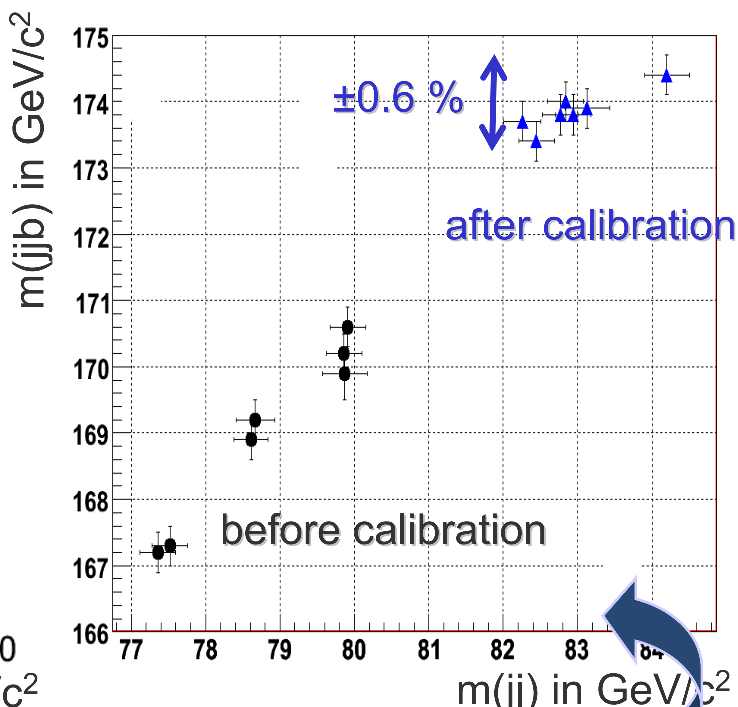
Smear quark 4-momentum:

- Consider only pairs with 150 < mjjb < 200 GeV
- Energy & angle resolution, energy correlation

Fitting procedure

- Generate a set of template histograms w/ α and β
- Fit each template histogram to m_{jj} in the data → best χ^2





Performance

Improve top mass resolution : 14 → 11.4 GeV/c²

- reduce statistical error : 0.5% with 1 fb^{-1}
- reduce dependence in JES : 0.6% miscalibration

Top Mass in the “di-lepton” channel (ATLAS)

Procedure

(1) Selection & yield @ 10 fb^{-1}

- 2 high-p_T leptons
- high missing Energy
- 2 high-p_T jets
  - → 80,000 evts & S/B ~ 10

(2) Reconstruct fully tt event :

- Assess neutrino’s momenta
  - → 6 eqs ($\Sigma p_T=0, M_{l\nu}=m_W, M_{l\nu b}=m_t$)
  - → ε ~ 97% w/ Purity ≈ 73%

(3) Top mass determination :

- Evt/evt: m_t → solve system → weight (using kinematics & topology)
- All evts: mean weight per m_t
  - → $m_t^{fit} = m_t$ w/ highest <weight>

Performance with 10 fb^{-1}

Mass resolution :

- $\sigma \approx 13$ GeV/c^2

Systematics :

- Choice of PDF
- b-jet energy-scale

V. Simak et al.

	δm_t
b-jet energy scale (1%)	0.6
b-quark fragmentation	0.7
ISR / FSR modelisation	0.6
Parton Distr. function	1.2
Total SYSTEMATIC	1.6
STATISTICS & method	0.3

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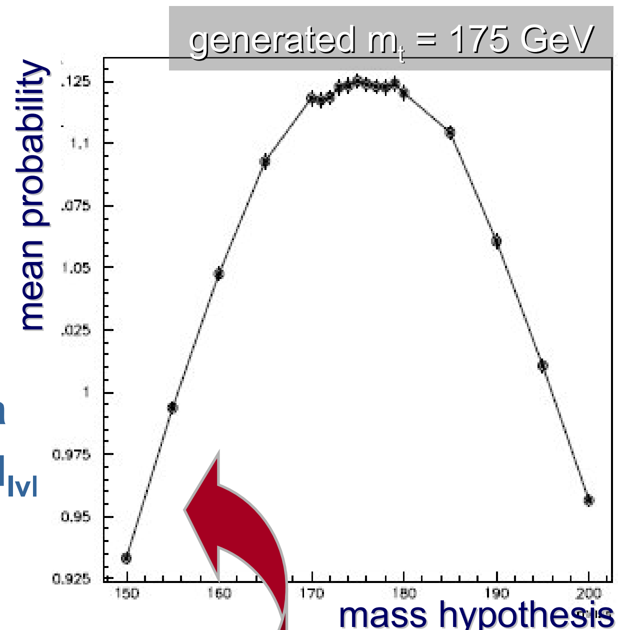

Performance with 10 fb^{-1}

Mass resolution :
- $\sigma \approx 13$ GeV/c^2

Systematics :
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V. Simak et al.

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ISR / FSR modelisation	0.6
Parton Distr. function	1.2
Total SYSTEMATIC	1.6
STATISTICS & method	0.3

Top pair production : cross-section measurement

Cross-section measurement

Strategy :

- Same pre-selection as for m_t measurements

Performance :

- Uncertainty $\delta\sigma^{stat}$ ~negl.
- Systematics dominated :
  machine : $\Delta L/L \sim 5\%$
  b-tagging ε & mistag rates
  ISR/FSR, pdf, Jet energy scale

Atlas Preliminary

	N_{event} @ 10^{33}	$\Delta\sigma/\sigma^{stat}$
1 month	70,000	0.4%
1 year	300,000	0.2%

Interpretations

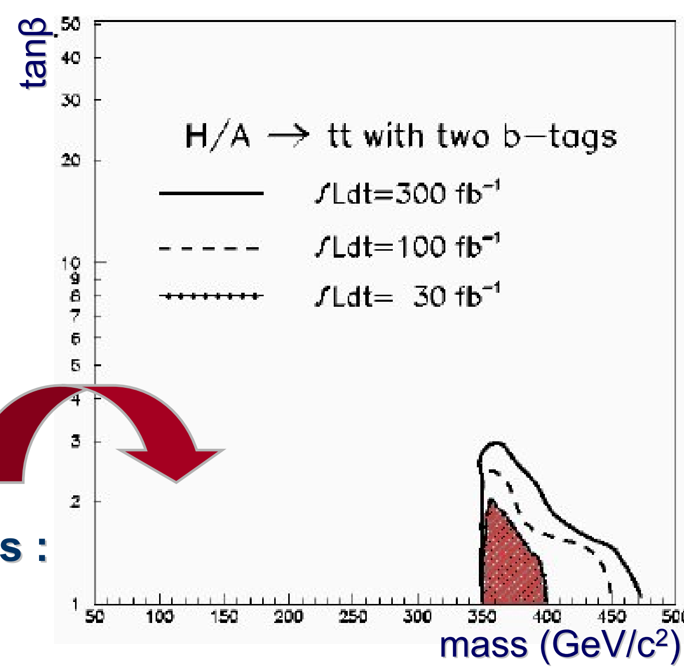
Test of QCD :

(m_t,σ_{tt}) measurements
→ $\Delta\sigma/\sigma \sim 6\%$

$\Delta\sigma_{tt}/\sigma_{tt}^{theo} = 10\%$
→ $\Delta m_t \sim 3$ GeV/c²

Sensitivity of $d\sigma_{tt}/dM_{tt}$:

High mass resonance
→ for eg. H/A→tt



Sensitivity of σ_{tt} to New Physics :

- SUSY EW corr. < 4%
- SUSY QCD corr. < 10%

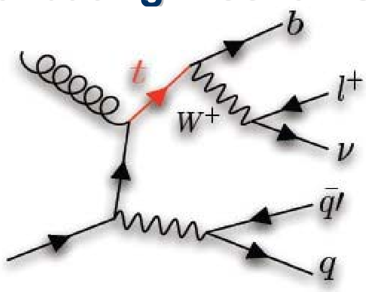
→ Consistency check with direct evidence ?

Single Top cross-section : Production @ LHC

Production at the LHC

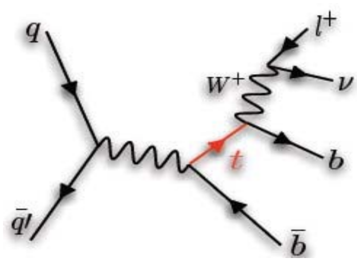
All 3 contributing mechanisms in SM

t-channel



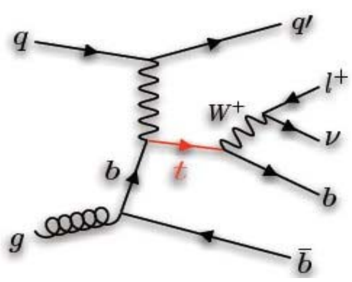
t-channel : σ ~ 250 pb
- dominant source of single top
- N(1 fb^{-1}) ~ 80,000 in W→ e/μ,ν

S-channel



s-channel : σ ~ 10 pb
- smallest source of single top
- N(1 fb^{-1}) ~ 3,000 in W→ e/μ ν

W+t channel



Wt-channel : σ ~ 60 pb
- source of single top
- N(1 fb^{-1}) ~ 18,000 in W→ e/μ ν

Motivations

Direct determination of $|V_{tb}|$, top width

Test of V-A, top polarization (100% polarized)

Sensitivity to anomalous couplings, FCNC

Sensitivity to extra W' (GUT, KK modes)

Sensitivity to $H^{\pm}$ bosons (2HDM)

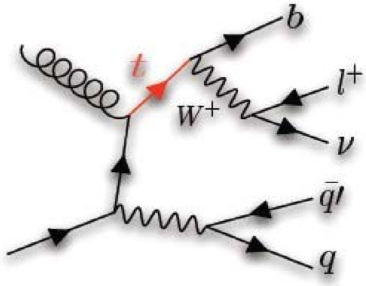
… and one of the main backgrounds to Higgs searches

Single Top cross-section : Production @ LHC

Production at the LHC

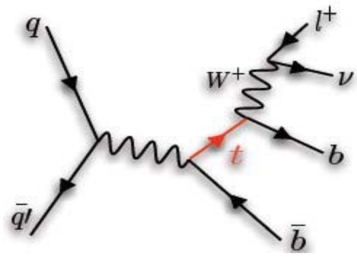
All 3 contributing mechanisms in SM

t-channel



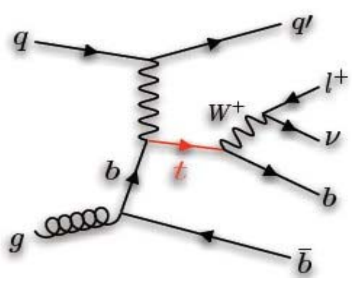
σ = 246.6±10 pb (NLO) (1)
- dominant source of single top
- N(1 fb^{-1}) ~ 80,000 in W→ e/μ,ν

S-channel



σ = 10.65±0.65 pb (NLO) (1)
- smallest source of single top
- N(1 fb^{-1}) ~ 3,000 in W→ e/μ ν

W+t channel



σ = 62.10±0.03 pb (NLO) (2)
- source of single top
- N(1 fb^{-1}) ~ 18,000 in W→ e/μ ν

Cross-section & uncertainties

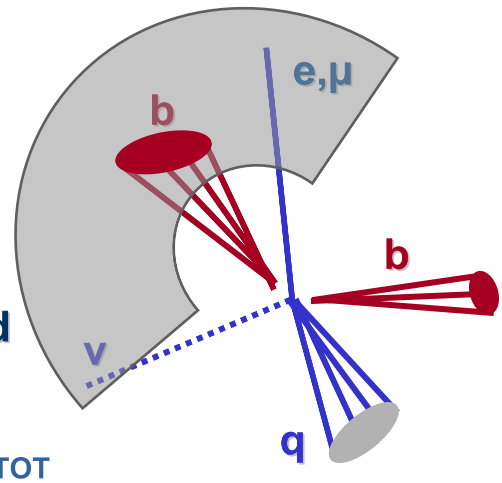
Channel	σ(pb)	Uncertainties		
		PDF	μ-scale	Δm_{top}
W-g	246.6 ± 8.7	4%	3%	1%
W+t	60 ± 15	10%	?	1%
W*	10.6 ± 0.7	4%	2%	3%

(1) Z. Sullivan, Phys. Rev D70 (2004) 114012
(2)Campbell et al., hep-ph/0506289

Single Top : Event Selection

Procedure

(1) Select and tag event
- 1 high-p_T lepton
- high missing Energy
- at least 2 high-p_T jets
- at least 1 high-p_T b-tagged jet



(2) Discriminate vs non-top background
- Reconstruct a Top mass $M_{l\nu b}$
- Use event shape & high H_T or M_{TOT}

(3) Discriminate vs top backgrounds
- Number of b-jets
- Event topology

	σ x BR (pb)
Wg → (lν)b qb	54.2
Wt → (jj) (lν)b	17.8
W* → (lν)b b	2.2
W+jets → lν+jets	3,850
W+QQ → lν+QQ	66.7
WZ → lν+jets	3.4
WW → lν + jets	17.1
tt → (lν)b (lν)b	38.2
tt → (lν)b (jj)b	242.8

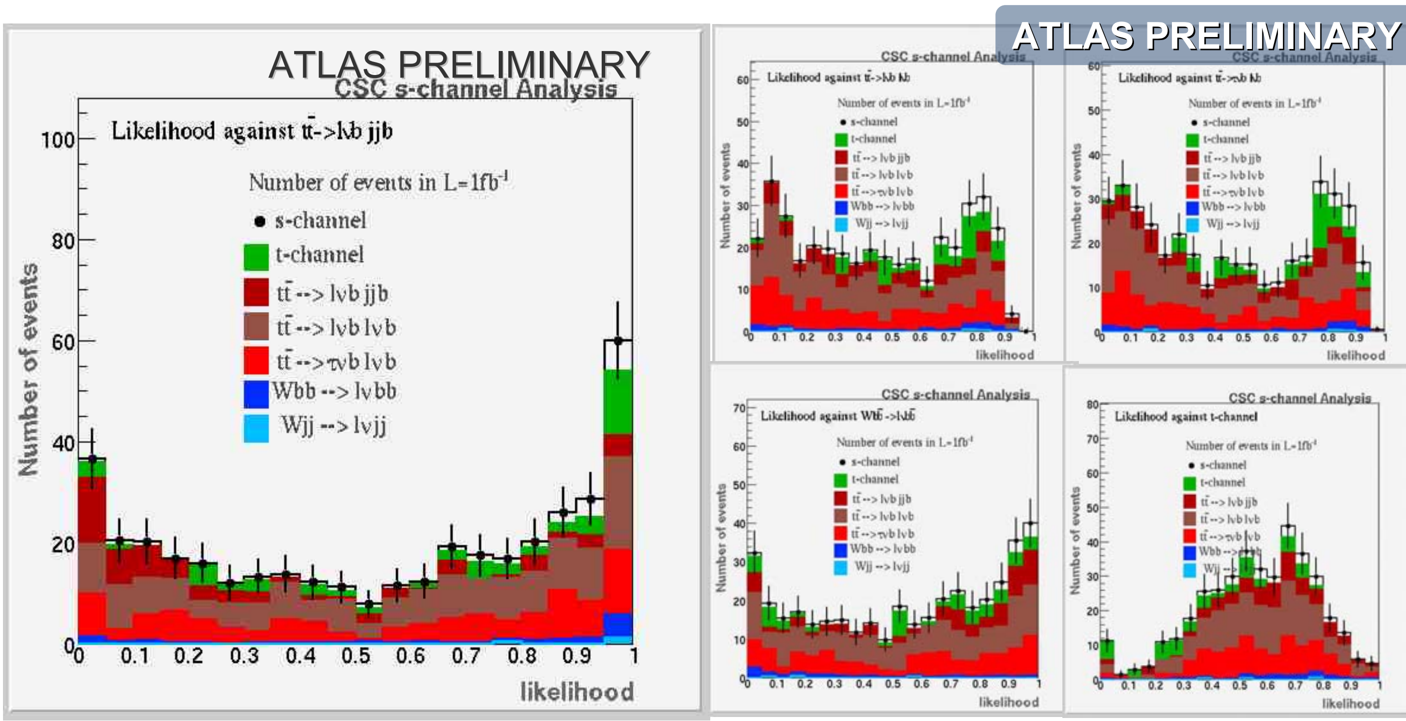
Main backgrounds :
- ttbar : ~ 1/100 , Δtheo~10%
- W+jets : ~ 1/2000, Δtheo~ ??

→ Use of DATA !

Single-top : summary

Measurements

- **Single-top analyses are delicate**
  - Mostly because of the top pair background !
- **Single-top analyses require specific tools**
  - loose b-tag, MVA …
  - → measurements will be systematics limited (bckgd +exp)



Strategies for early data in progress…

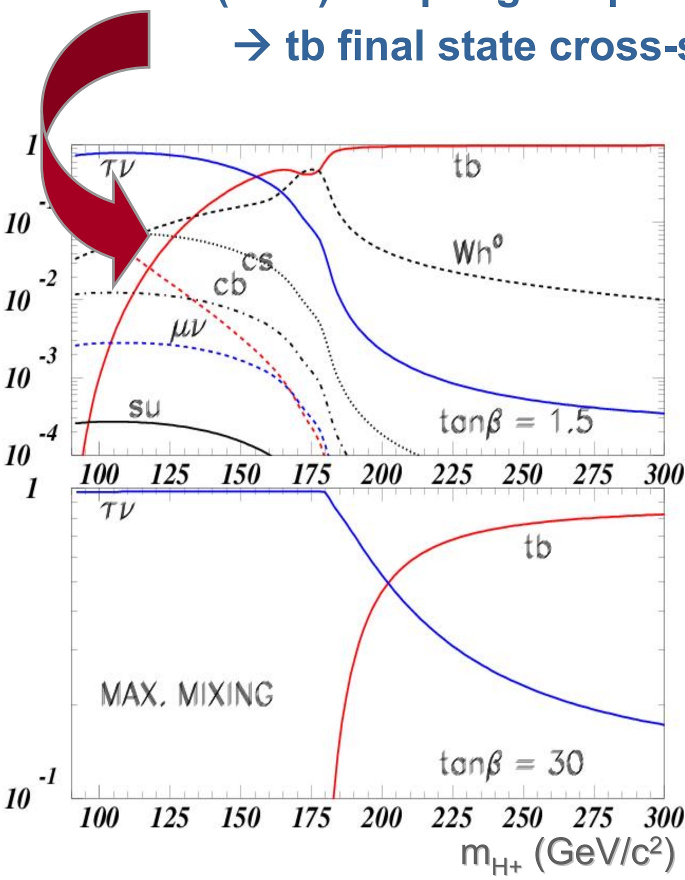
- **Understand backgrounds with data**
  - Trigger turn on's
  - B-tagging weight and pdf's
  - → MC shape & normalization
- **Use likelihood's combination "a la Dzero"**
  - Devoted to specific backgrounds

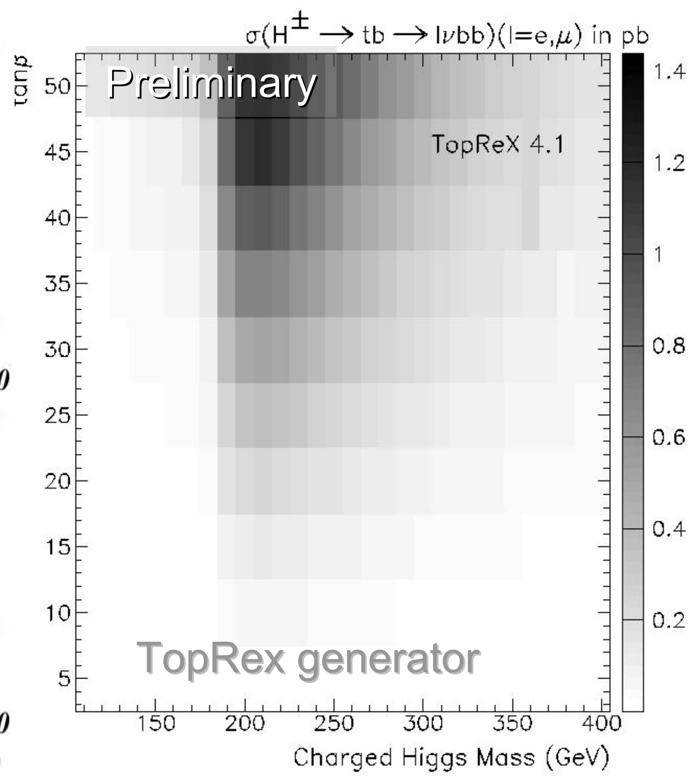
s-channel with 30 fb^{-1} : Why is it so interesting ?

Charged Higgs & single-top

Production mode in 2 HDM :

- 5 higgs: 3 neutral (A,h,H) + 2 charged ($H^{\pm}$)
- Mass spectrum predicted in MSSM
- ($H^{+}tb$) couplings depends on $m_{H\pm}$ and tan β
  → tb final state cross-sections are modified by an H^{+}





Event Selection :

- Use same analysis as developed for the s-channel
  → efficiency increases with m_{H+}
- Systematics limited measurements
- Only standard sequential analysis so far

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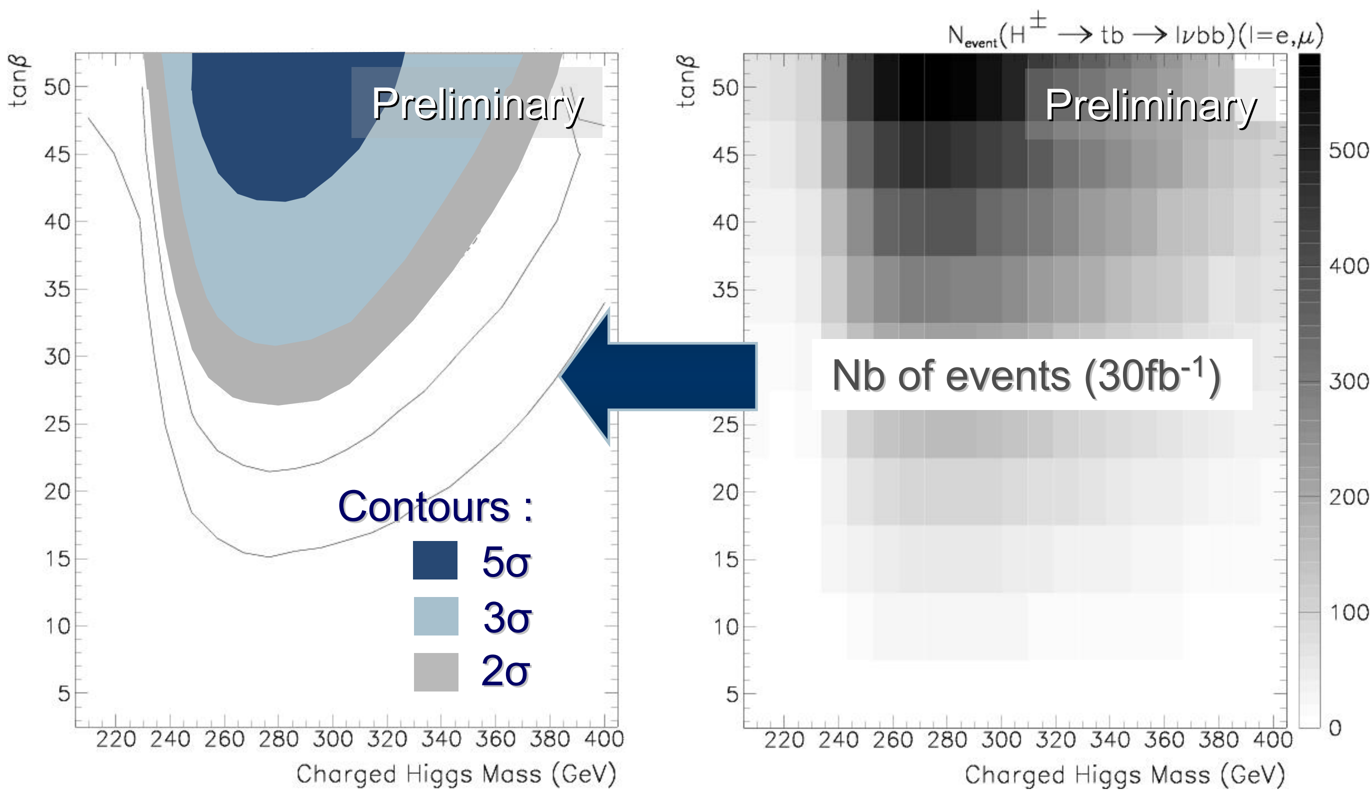

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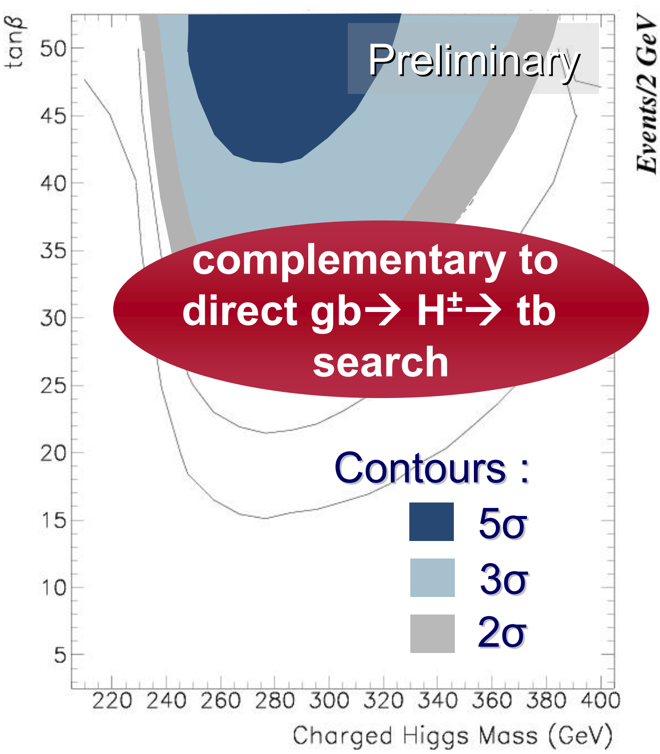

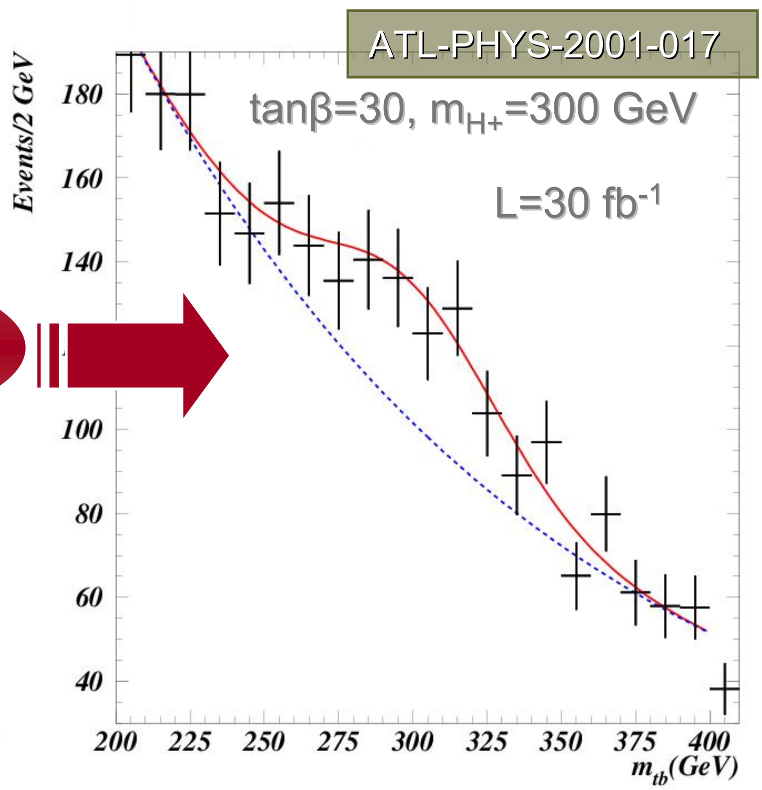

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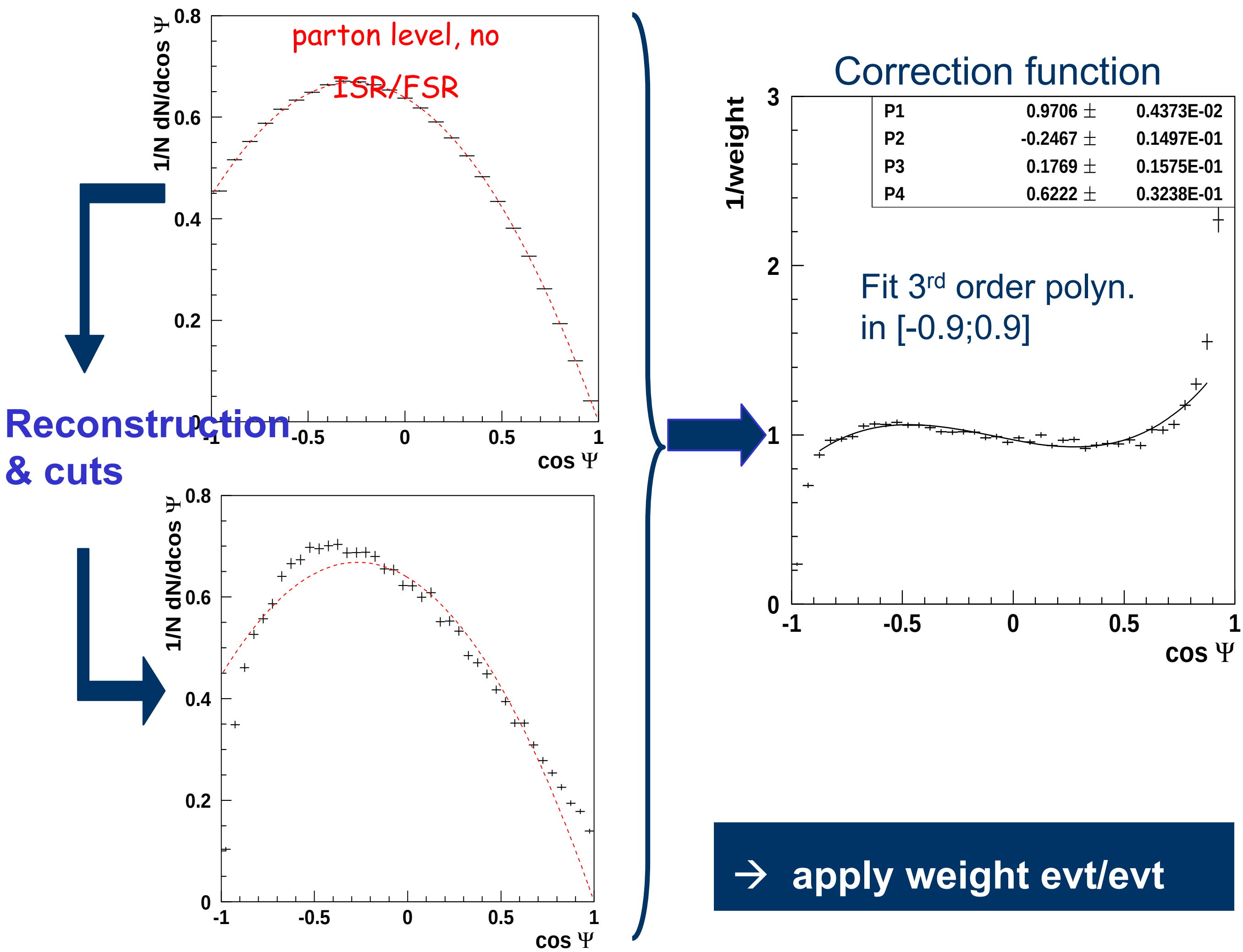
  - → efficiency increases with m_{H+}
- Systematics limited measurements
- Only standard sequential analysis so far

Mesure de polarisation du boson W : méthode

Selection & correction

Reconstruction & selection distort distributions

→ Correction function evaluate on an independent sample



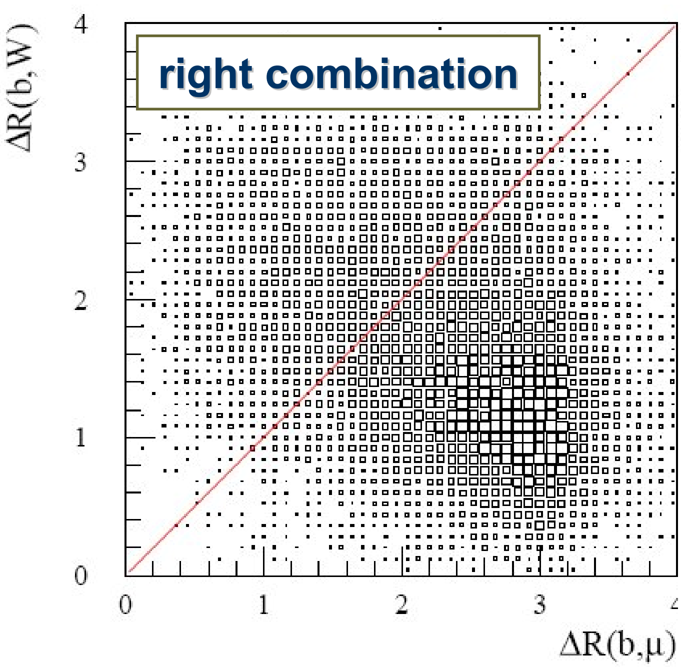
→ **apply weight evt/evt**

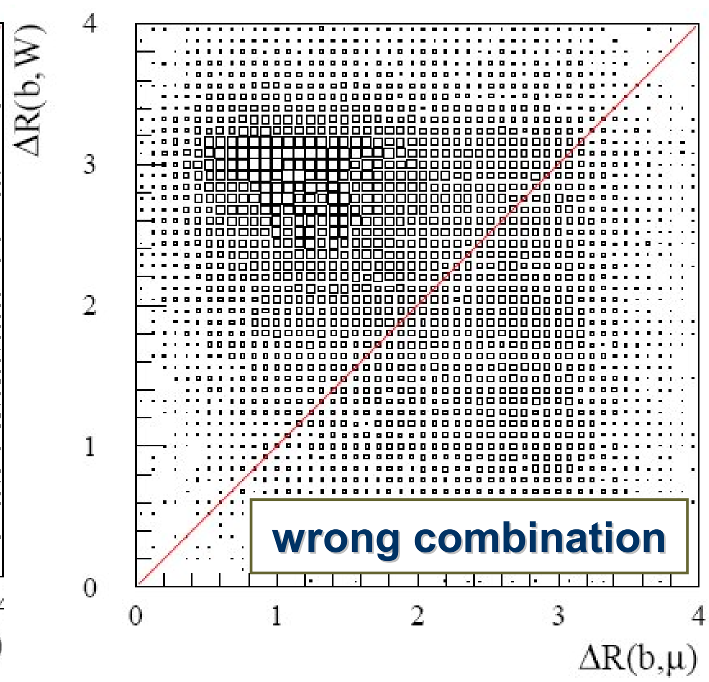
Top Quark Mass measurement :
Top Quark reconstruction

Top Quark reconstruction

Association of hadronic W and b-jet :

- Combination leading to the highest p_T^{top}
  or that maximizes $\Delta R(l,b)$ / minimizes $\Delta R(b,W \rightarrow jj)$
  → right (jjb) combination in ~ 80% cases





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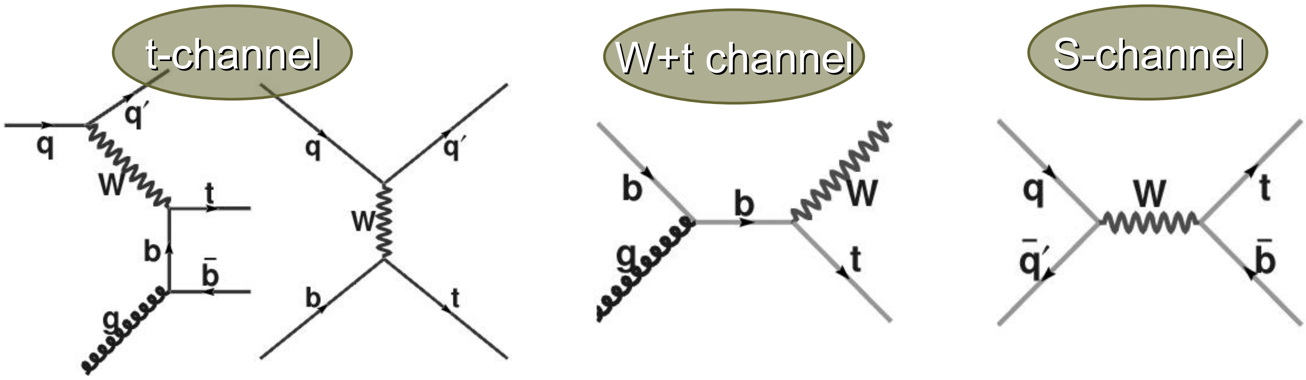
Production at the LHC

All 3 contributing mechanisms in SM



Theoretical prediction

NLO/NLL available for W* and W-g only

→ affect significantely σ as well as p_T(jet), H_T etc …

hep-ph/0408049

Channel	σ(pb)	Uncertainties		
		PDF	μ-scale	Δm_{top}
W-g	246.6 ± 8.7	4%	3%	1%
W+t	60 ± 15	10%	?	1%
W*	10.6 ± 0.7	4%	2%	3%

Theoretical uncertainties:

Quark-gluon luminosity --choice of the (b) PDF

Renormalization scale μ

Δm_{top} (175 to 178 GeV → σ(W*) down by 6%)