ATLAS Top Physics overview

From early data to precision measurements

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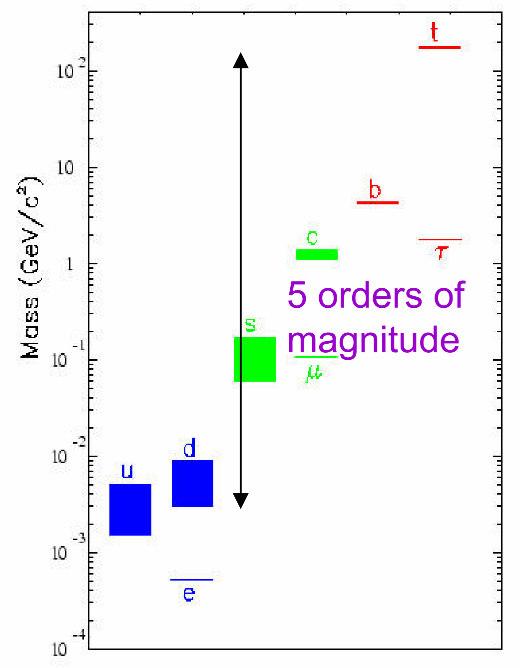
NIKHEF

Motivations for top quark physics

- **Special role in the EW sector and in QCD**
  - Heaviest elementary particle known → Yukawa coupling close to 1.0
  - Top and W masses constrain the Higgs mass
- ➔ **A tool to probe symmetry breaking in SM**

- **Special role in various SM extensions through EWSB**
  - New physics often preferentially coupled to top
  - New particles can produce / decay to tops

➔ **A sensitive probe to new physics**



- **Special interest even if it is just a «normal» quark**

➔ **A major source of background** for many searches

➔ **A tool to understand/calibrate the detector**, all sub-detectors involved

Top properties scorecard

We still know little about the top quark, limited by Tevatron statistics

Mass	precision <2%
Electric charge ⅔	-4/3 excluded @ 94% C.L. (preliminary)
Spin ½	not really tested – spin correlations
Isospin ½	not really tested
BR to b quark ~ 100%	at 20% level in 3 generations case
V – A decay	at 20% level
FCNC	probed at the 10% level
Top width	?? First observe single top !
Yukawa coupling	??

- ➔ This leaves plenty of room for **new physics** in top production and decay
- ➔ Tevatron run II starts to incise probe the top quark sector
- ➔ The LHC will open a new opportunity for **precision measurements**

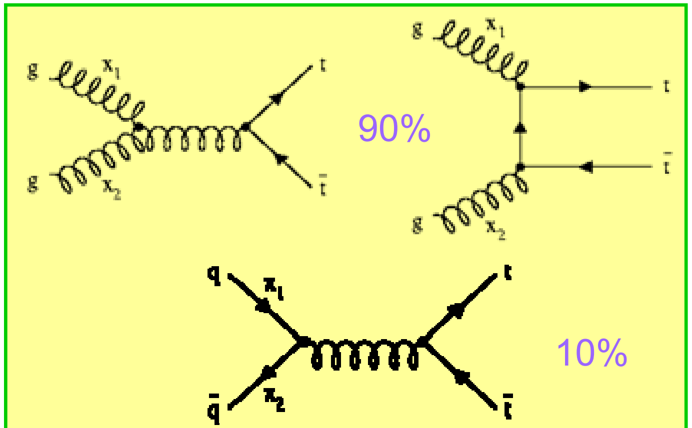
Utilizing ttbar events

LHC: σ ~ 830±100 pb

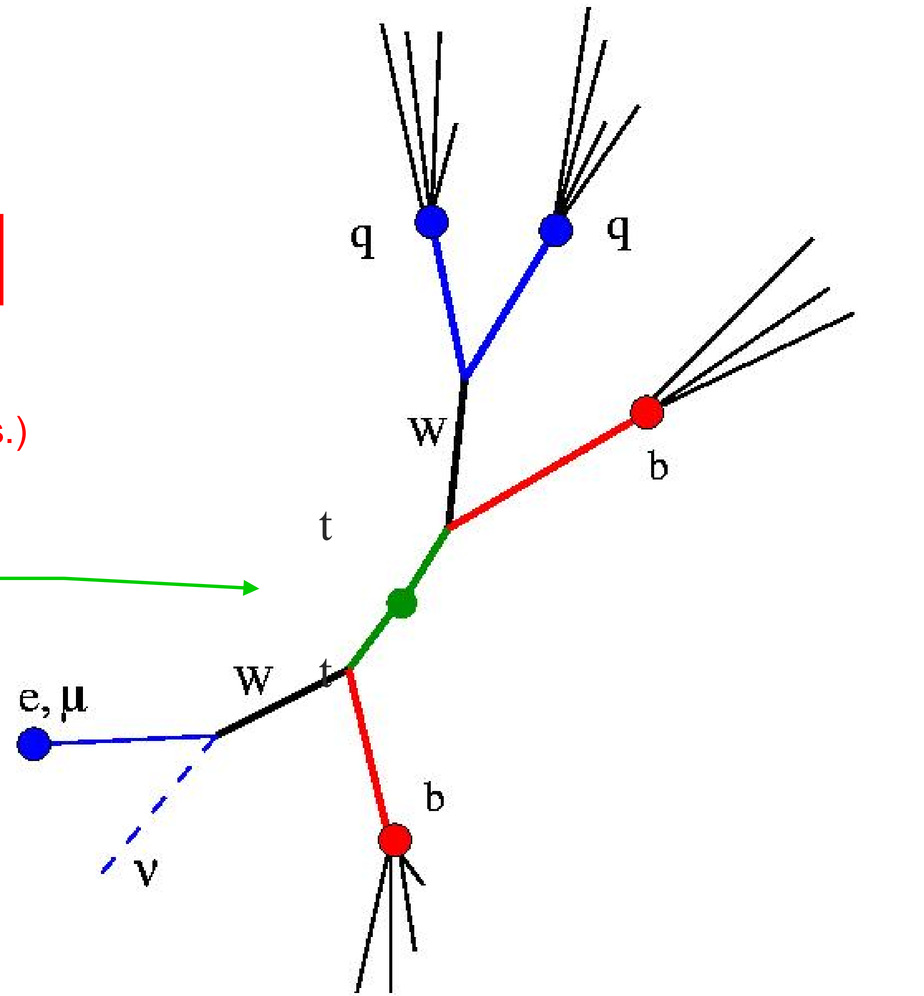
$t\bar{t}$ final states (LHC,10 fb^{-1})

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

→ **Golden channel** (early physics, precision meas.)

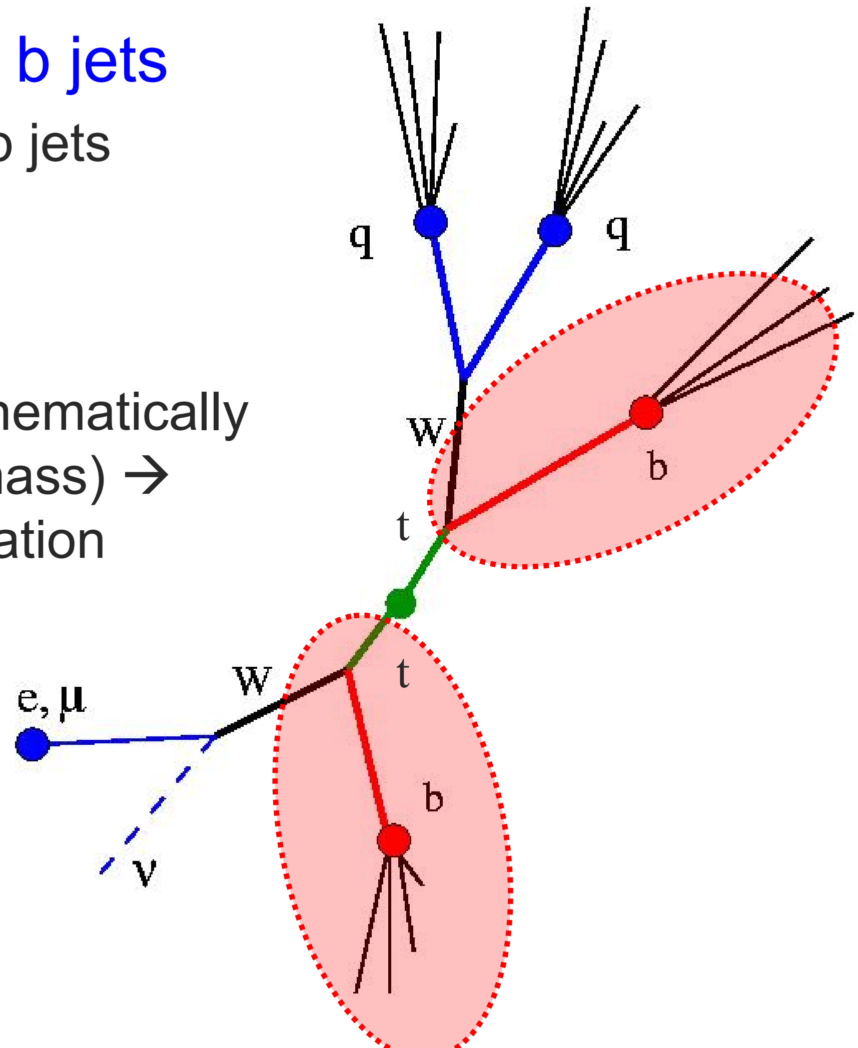


$$\hat{s} = s x_1 x_2 \quad ; \quad x_1 x_2 \sim 10^{-3}$$



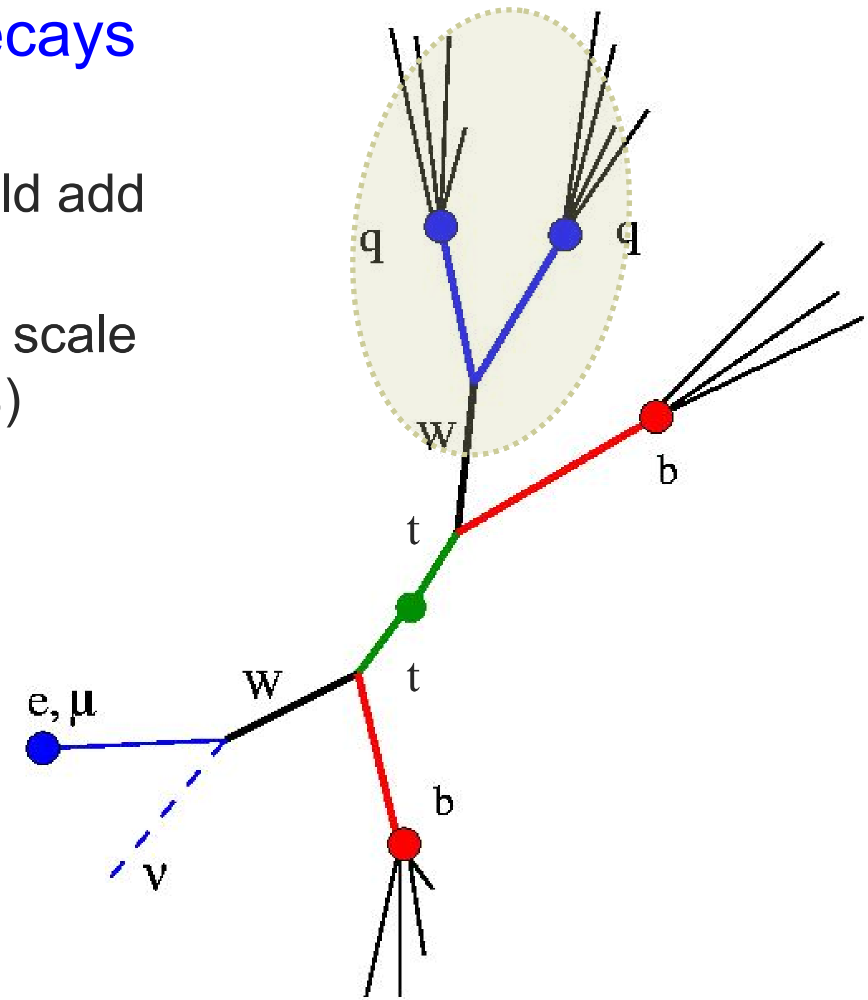
Utilizing ttbar events

- Abundant clean source of b jets
  - 2 out of 4 jets in event are b jets ➔ ~50% a priori purity (need to be careful with extra ISR/FSR jets)
  - Remaining 2 jets can be kinematically identified (should form W mass) → possibility for further purification



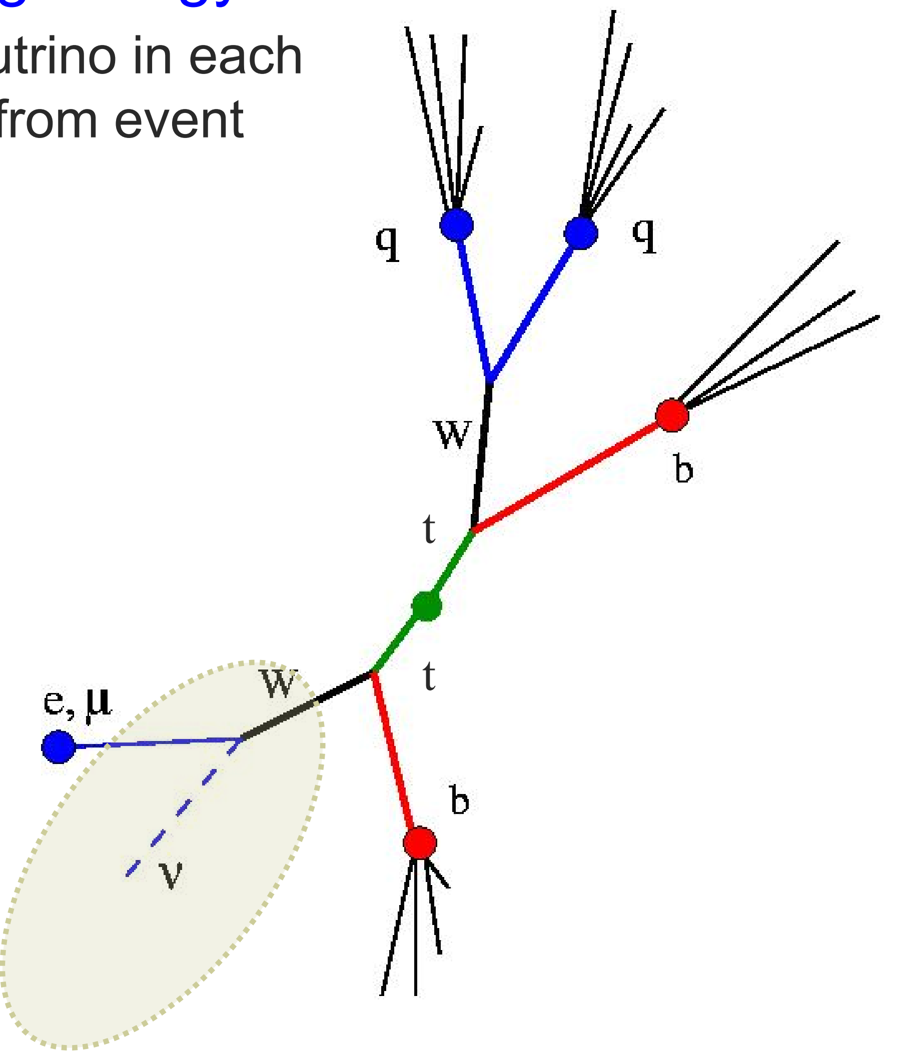
Utilizing ttbar events

- Abundant source of W decays into light jets
  - Invariant mass of jets should add up to well known W mass
  - Suitable for light jet energy scale calibration (target prec. 1%)
  - If (limited) b-tagging is available, W jet assignment combinatorics greatly reduced



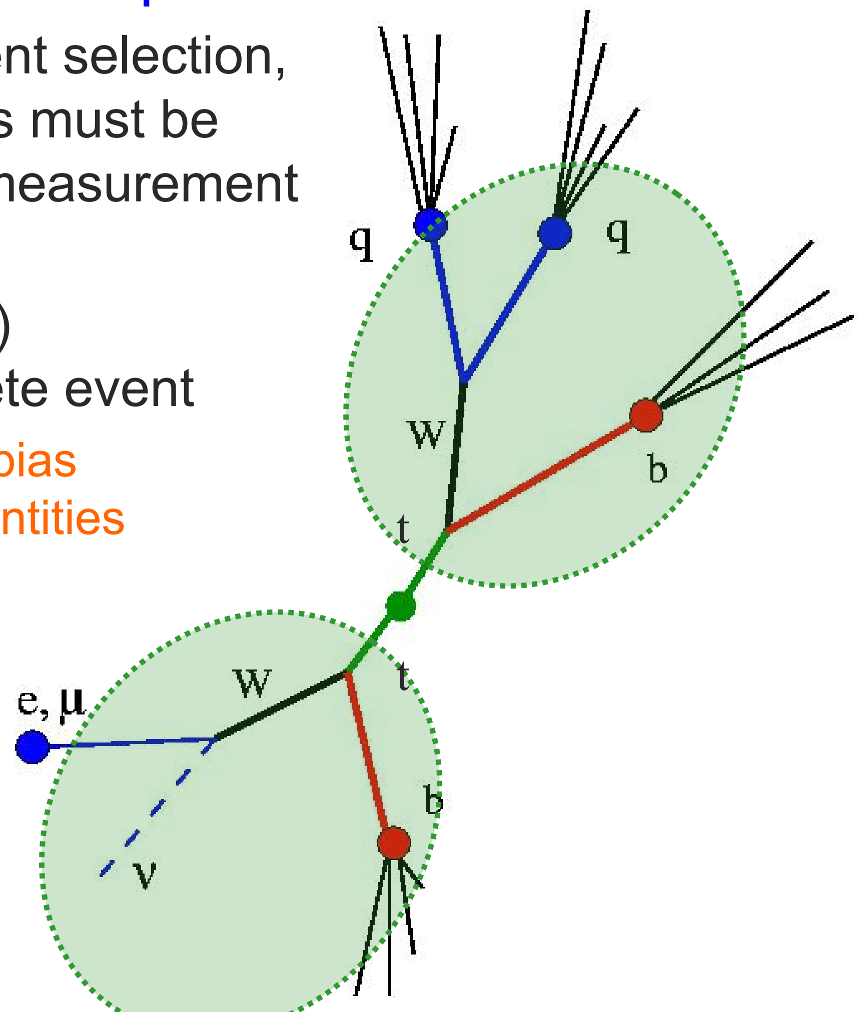
Utilizing ttbar events

- Known amount of missing energy
  - 4-momentum of single neutrino in each event can be constrained from event kinematics
    - Inputs in calculation: m(top) from Tevatron, b-jet energy scale and lepton energy scale
    - Calibration of missing energy relevant for ***all*** (R parity conserved) SUSY and most exotics!



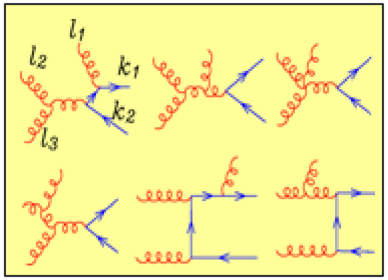
Utilizing ttbar events

- Two ways to reconstruct the top mass
  - Initially mostly useful in event selection, as energy scale calibrations must be understood before quality measurement can be made
  - Ultimately determine m(top) from kinematic fit to complete event
    - Needs understanding of bias and resolutions of all quantities
    - ***Not a day 1 topic***



Status of top event generators

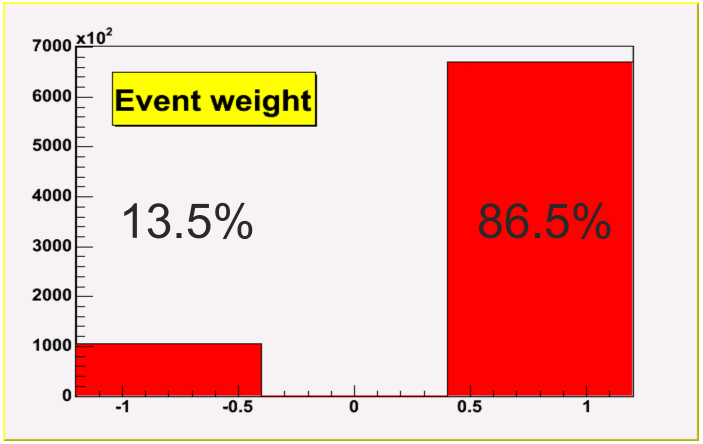
- Leading Order MC:
  - Pythia & Herwig : full standalone MC
  - TopRex (include spin effects – interfaced to Pythia)
  - AcerMC (include spin effects – interfaced to Pythia)
  - AlpGen (include additional ME hard jets)



- NLO QCD calculations implemented in MC
  - MC@NLO – interfaced to Herwig shower and fragmentation
  - ttbar process (among others) available
  - Recently single top processes included (s- and t-channel)

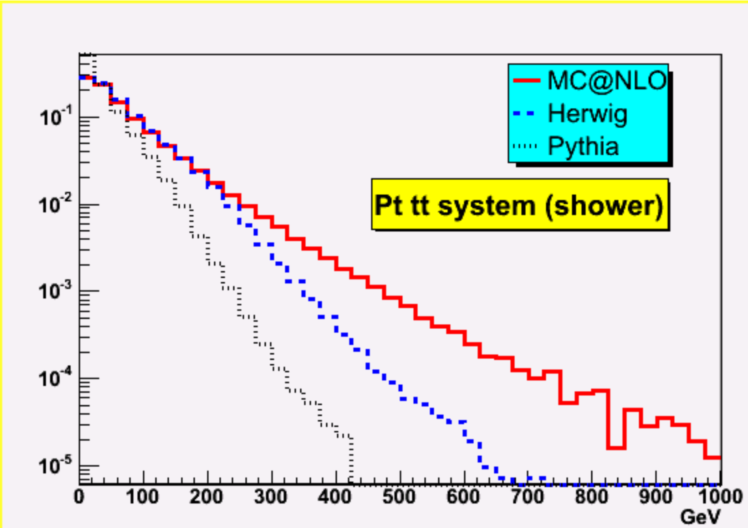
→ **This is theoretical improvement**

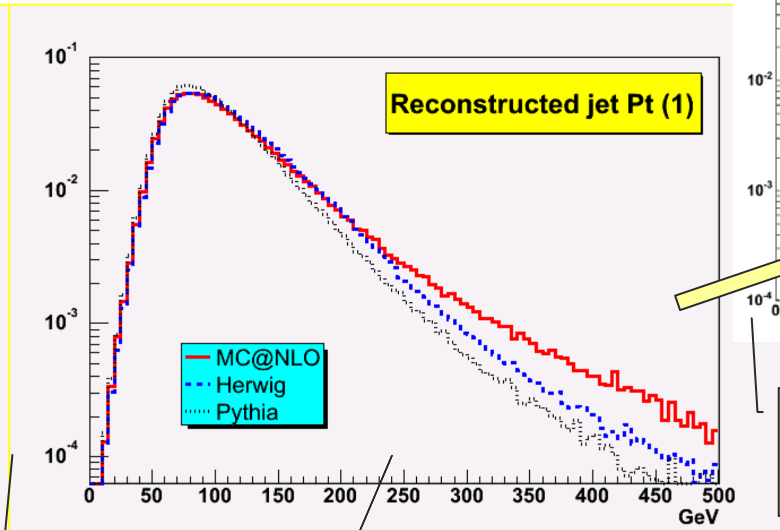
- Validation done for this generator
- Widely used in Atlas now
  - Introduction of events with 'negative weight'

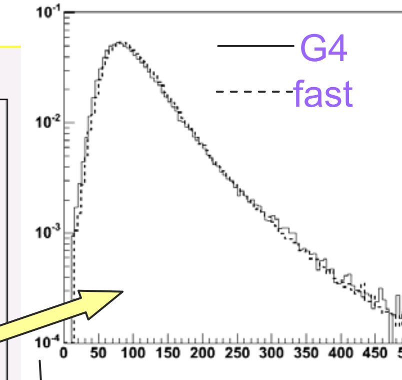


Generators: MC@NLO, Herwig, Pythia

Examples of MC validation (fast simulation detector response)







Geant4 vs fast simulation

PT(tt system)

PT system balanced by ISR & FSR

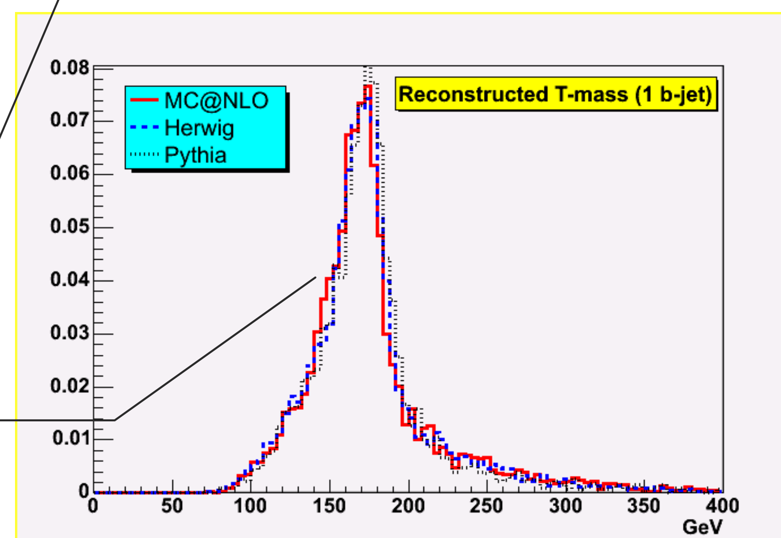
- Herwig & MCatNLO agree at low PT,
- At large PT MCatNLO 'harder'
- PYTHIA completely off

Jet PT

Jet with highest PT

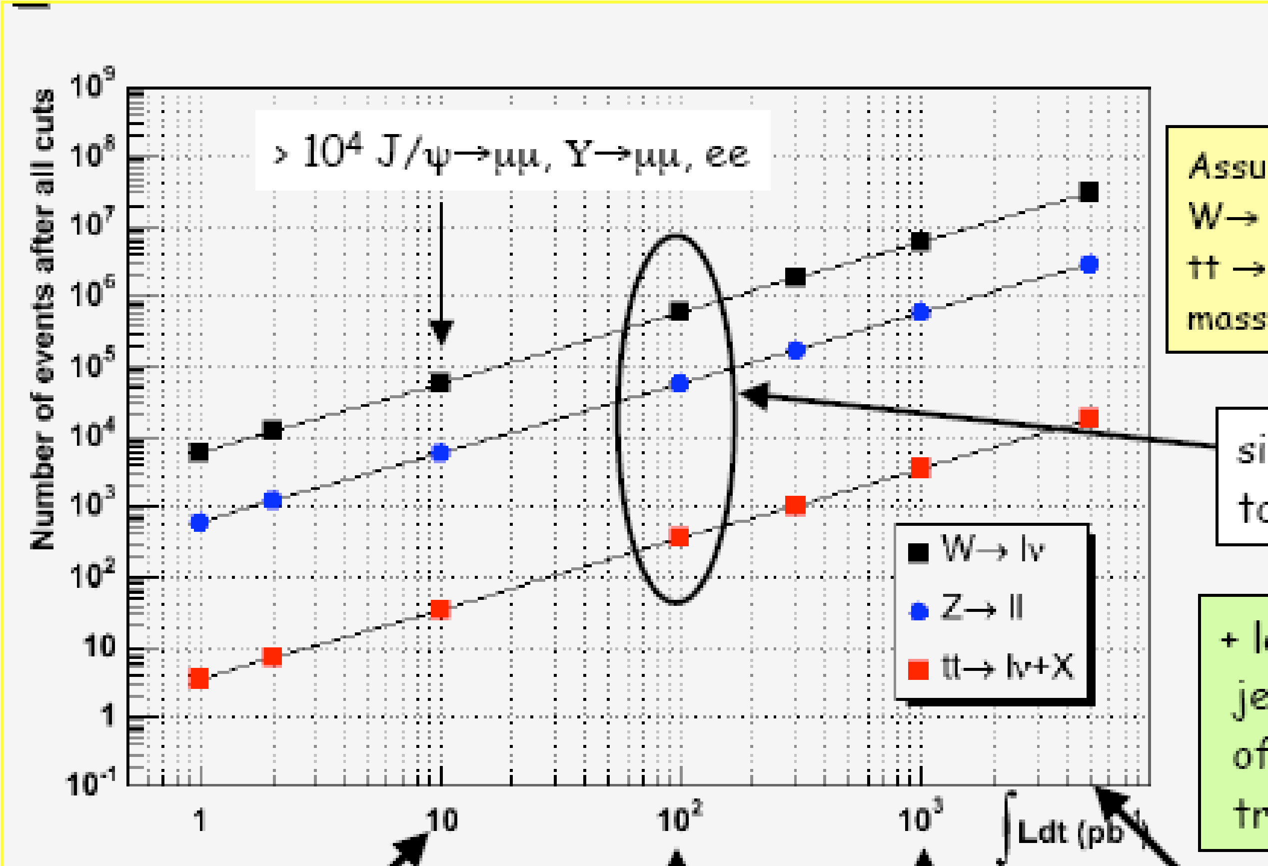
Top mass

Standard reconstruction using 1 b-tagged jet



How many events in ATLAS at the beginning ?

F.Gianotti, T+P week Mar06



l ≡ e or μ

Assumed selection efficiency:
W→ lν, Z→ ll : 20%
tt → lν+X : 1.5% (no b-tag, inside mass bin)

similar statistics to CDF, D0 today

+ lots of minimum-bias and jets (10^7 events in 2 weeks of data taking if 20% of trigger bandwidth allocated)

10 pb^{-1} ≡ 1 month at 10^{30} + < 2 weeks at 10^{31}, ε=50%

100 pb^{-1} ≡ few days at 10^{32} , ε=50%

1 fb^{-1} ≡ 6 month at 10^{32}, ε=50%

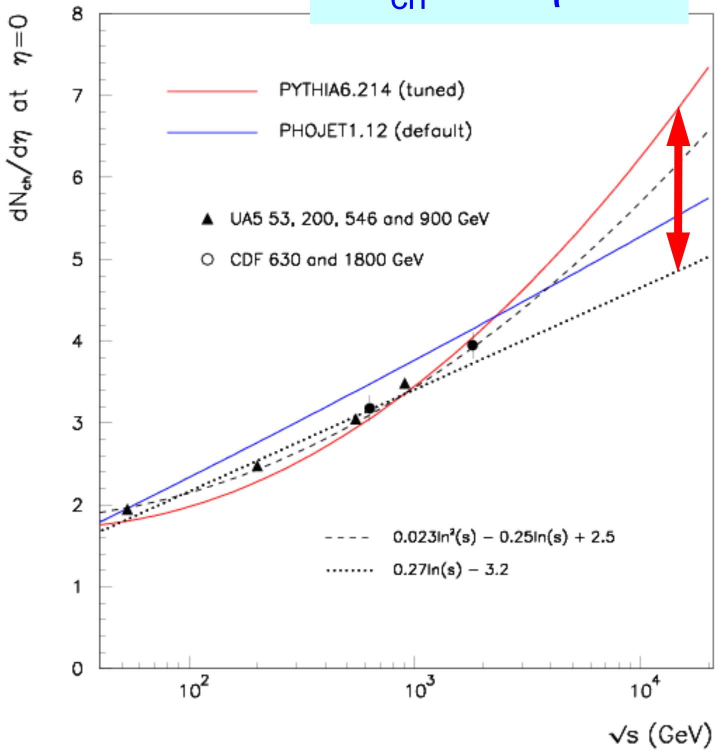
5 fb^{-1} ≡ 3 month at 10^{32} + 3 month at 10^{33}, ε=50%

→ end 2007 ?

→ end 2008 ?

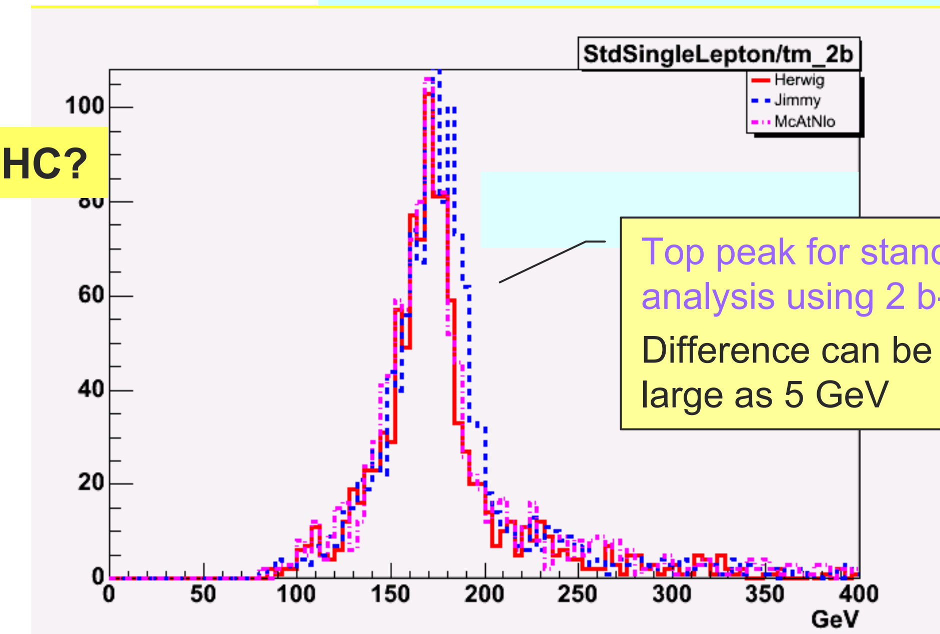
UE / min-bias determination

$\langle n_{ch} \rangle$ at $\eta = 0$



LHC?

M_{top} for various UE models



Top peak for standard analysis using 2 b-tags

Difference can be as large as 5 GeV

- Extremely difficult to predict the magnitude of the UE at LHC
  - Will have to learn much more from Tevatron before startup
  - Energy dependence of dN/dη ?

→ **Really need data to check data on UE – Only few thousand events required**

Pessimistic scen: b-tagging & JES

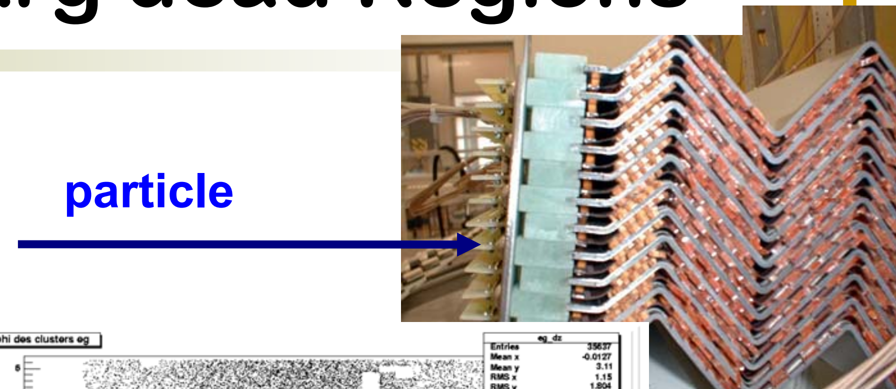
- Using early top-sample for calibration
  - B-tagging
    - Identify jets originating from b quarks from their topology
    - Select a pure t-tbar sample with tight kinematical cuts
    - Compare 0 vs 1 vs 2 b-tagged jets in top events
    - ***Can expect the b-tagging efficiency different in data from MC***
  - Jet energy scale calibration
    - Relate energy of reconstructed jet to energy of parton
    - Dependent of flavor of initial quark → need to measure separately for b jets
    - ***Observation of hadronic W for calibrating JES***

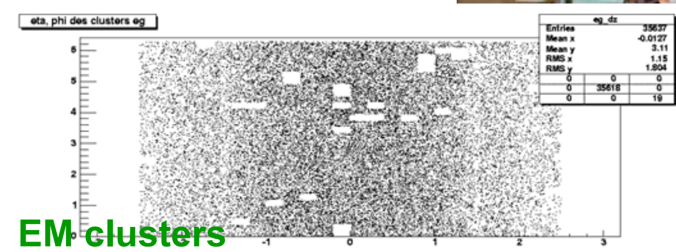
- In most pessimistic scenario b-tag is absent at start

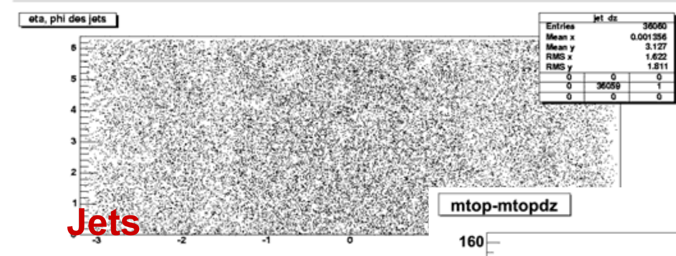
Can we observe the top without b-tagging?

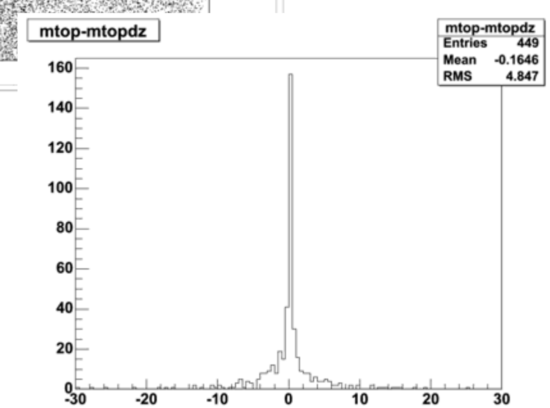
Pessimistic scen: LArg dead Regions

- Argon gap (width ~ 4 mm) is split in two half gaps by the electrode
  - ~ 33 / 1024 sectors where we may be unable to set the HV on one half gap → multiply energy by 2 to recover
- Simulated 100 000 tt events (~ 1.5 days at LHC at low L)
- If 33 weak HV sectors die (very pessimistic) effects on the top mass measurement, after a crude recalibration, are:
  - Loss of signal: < 8 %
  - Displacement of the peak of the mass distribution: -0.2 GeV









m_{top}(without) – m_{top}(with)

Top analysis w/o b-tag

- First apply selection cuts

Missing	$E_T > 20$ GeV	Selection efficiency = 5.3%
1 lepton	$P_T > 20$ GeV	
4 jets(R=0.4)	$P_T > 40$ GeV	

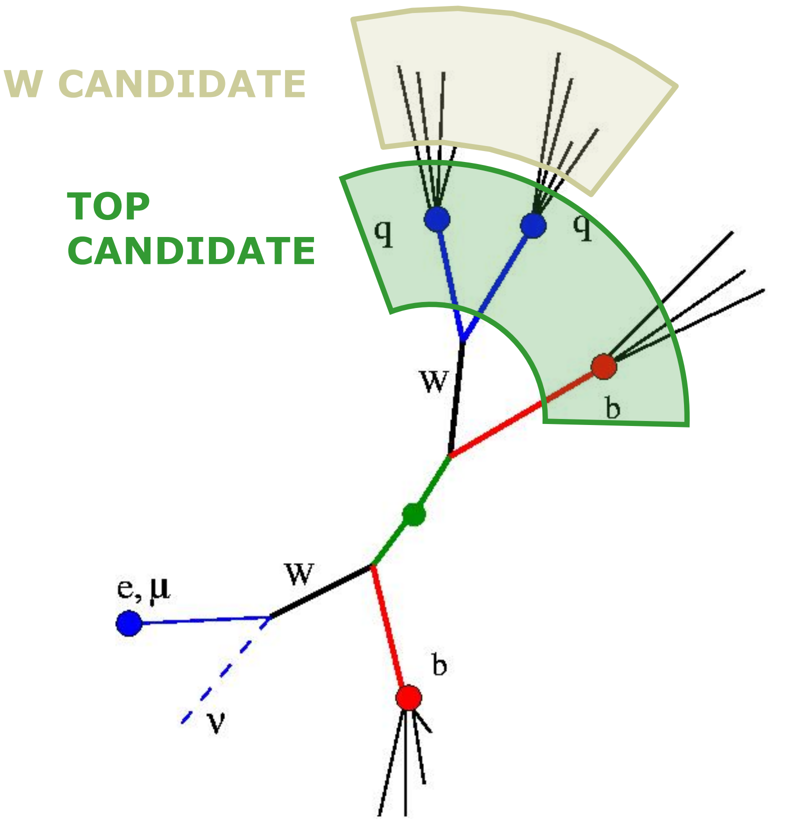
- Assign jets to W, top decays

1 Hadronic top:

Three jets with highest vector-sum pT as the decay products of the top

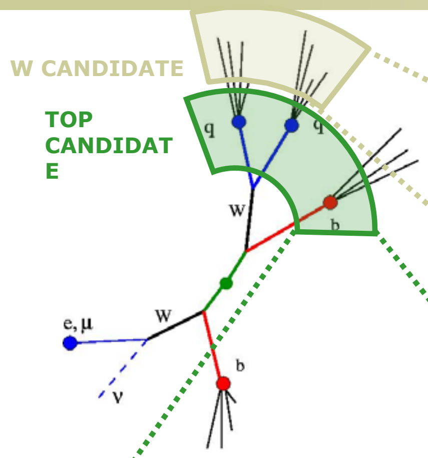
2 W boson:

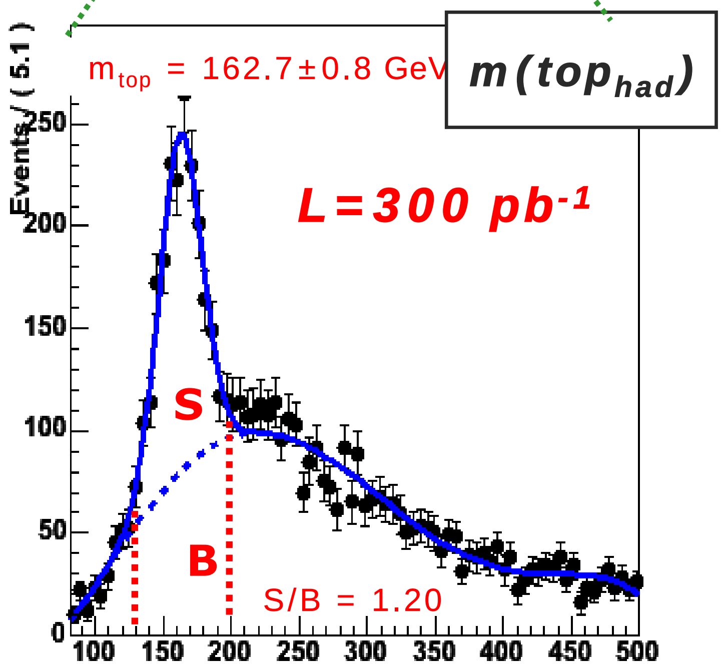
Two jets in hadronic top with highest momentum in reconstructed jjj C.M. frame.

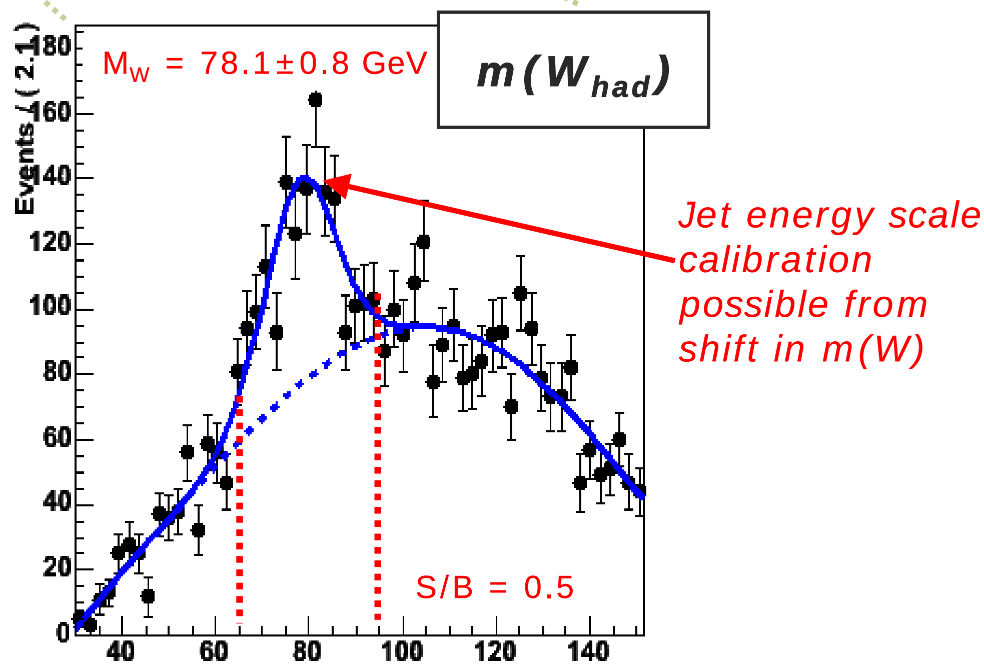


Signal-only distributions

- Clear top, W mass peaks visible
- Combinatorial background
  - Easier to get top assignment right than to get W assignment right
- Masses shifted somewhat low
  - Effect of (imperfect) energy calibration

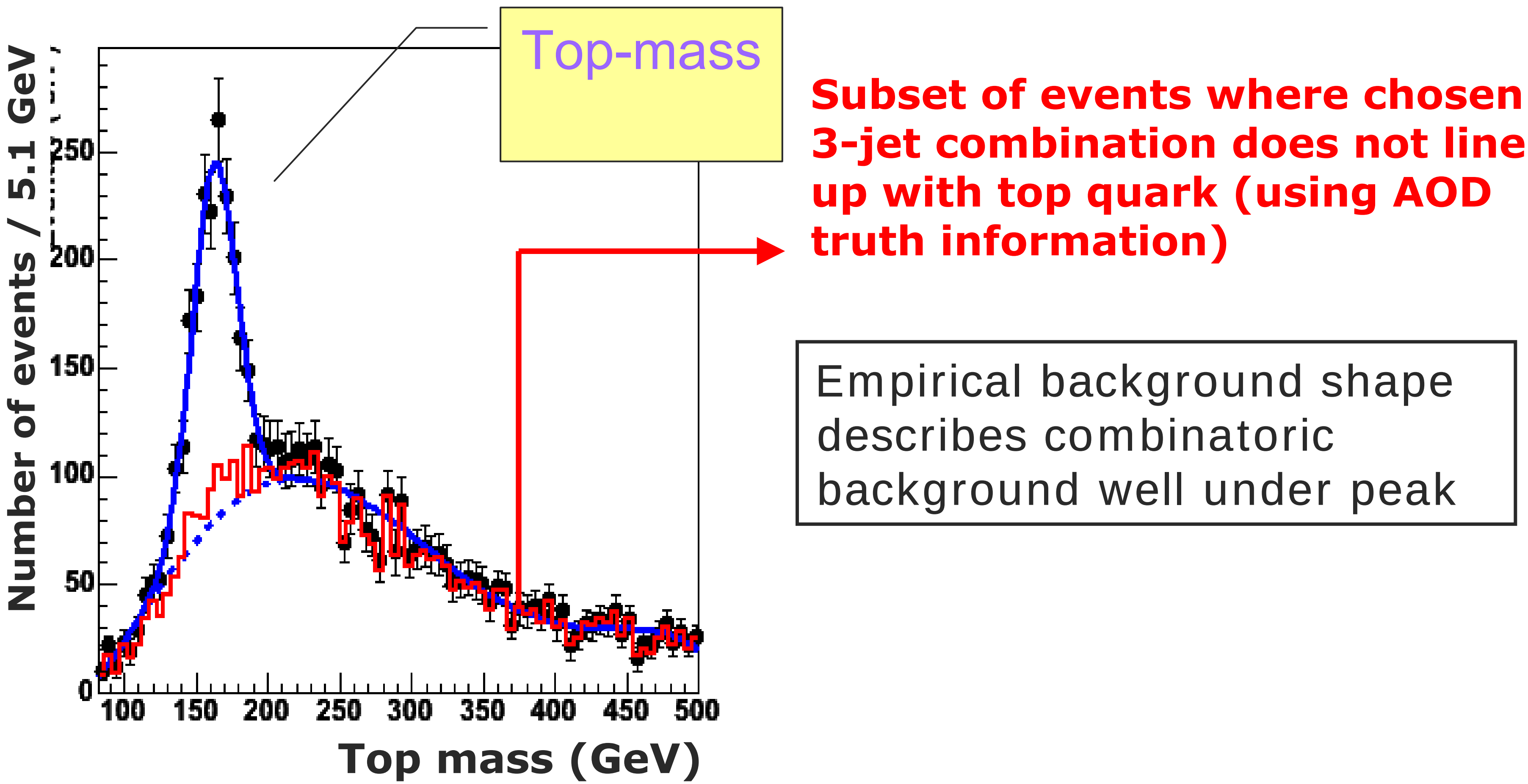






Consistency checks

Check behaviour combinatorics using MC@NLO signal Monte Carlo



Empirical background shape describes combinatoric background well under peak

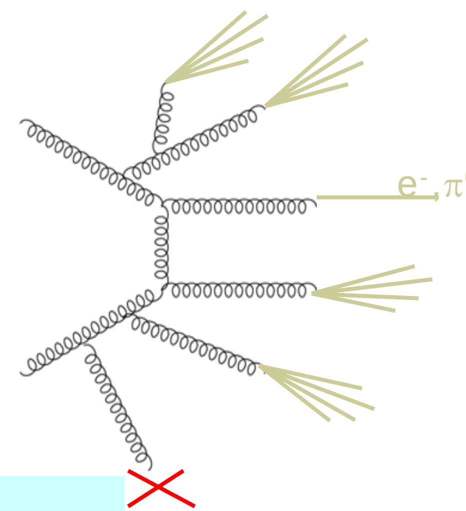
Estimating background

- **Top physics background**
  - Mistags or fake tags
  - Non-W (QCD)
  - W+jets, Wbbar, Wccbar
  - Wc
  - WW,WZ,ZZ
  - Z $\rightarrow$ tt
  - Single top
- **QCD background**
  - Not possible to realistically generate
    - Crucially depends on Atlas' capabilities to separate π/e to 10^{-5}
  - Background *has* to be obtained from data itself

Largest background is W+4 jet.

This background cannot be simulated by Pythia or Herwig shower process. Dedicated generator needed: e.g. AlpGen. Large uncertainties in rate

Ultimately, get this rate from data itself. For example, measure Z+4 jets rate in data, and determine ratio (Z+4 jets)/(W+4 jets) from MC



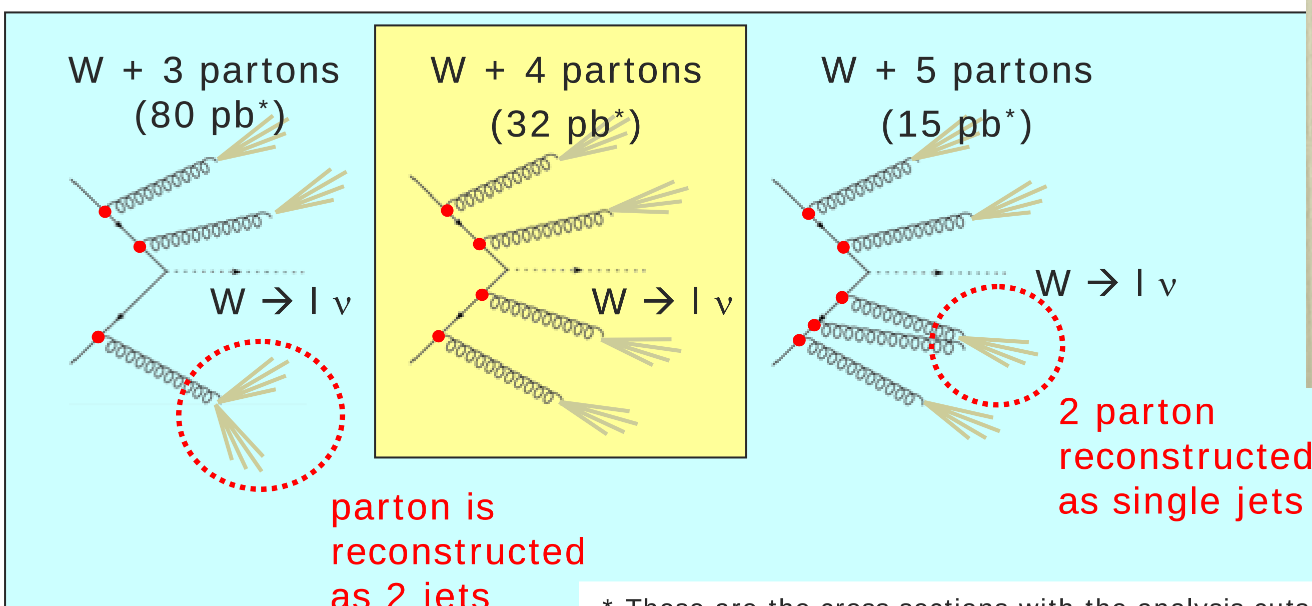
Need to

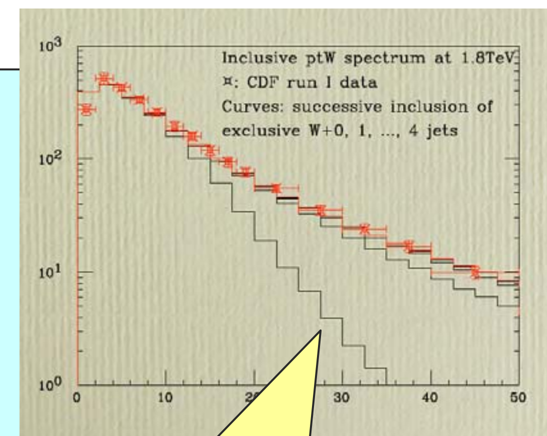
Minimise most poorly estimated backgrounds (at expense of statistics?)

Estimate remaining backgrounds from combination of data and MC;

Estimate W+jets bckgrnd

- So far, W+4 partons ME available (Alpgen)
  - Only using W + 4 *partons* now, but W + 3,5 *partons* may also result in W + 4 *jet* final state due to splitting/merging
  - CSC data sets W+njets are being produced ~ now
  - MLM matching prescription to explicit elimination of double counting.
  - So far: pessimistic approach and scaled 4-partons by factor two

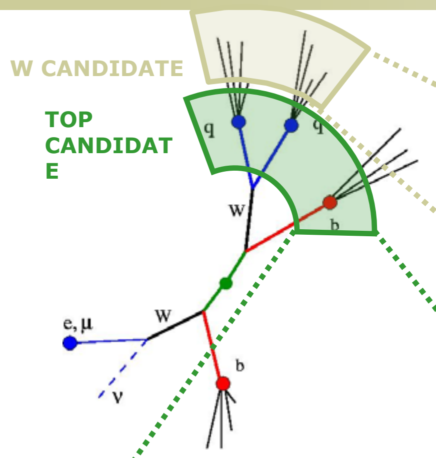




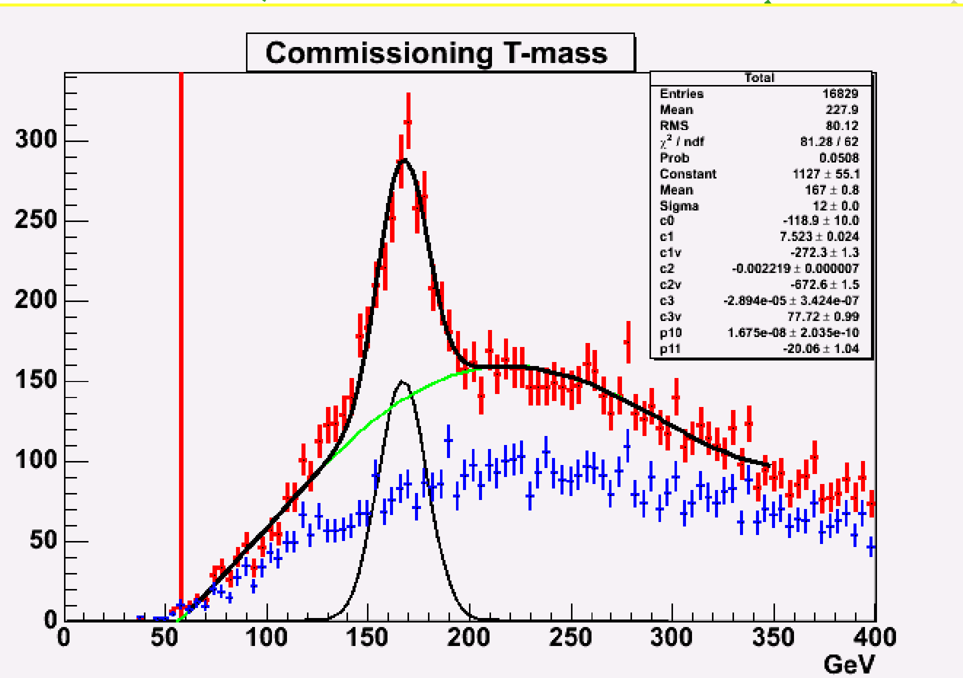
AlpGen v2.03: in progress
Convincing at Tevatron
e.g. PT spectrum W

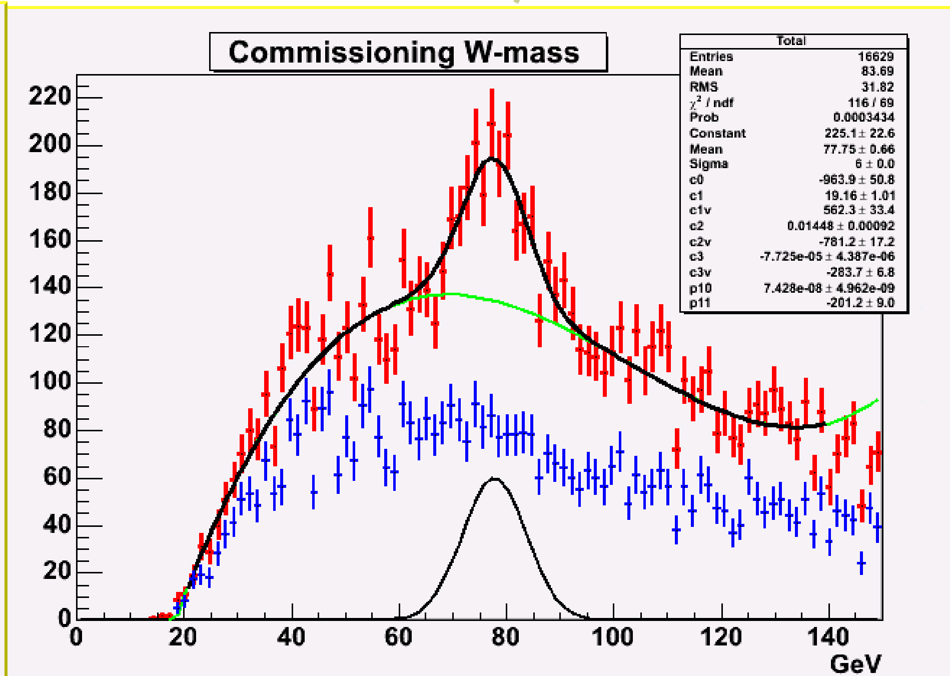
* These are the cross sections with the analysis cuts on lepton and jet pT applied at the truth level

Signal + Wjets background



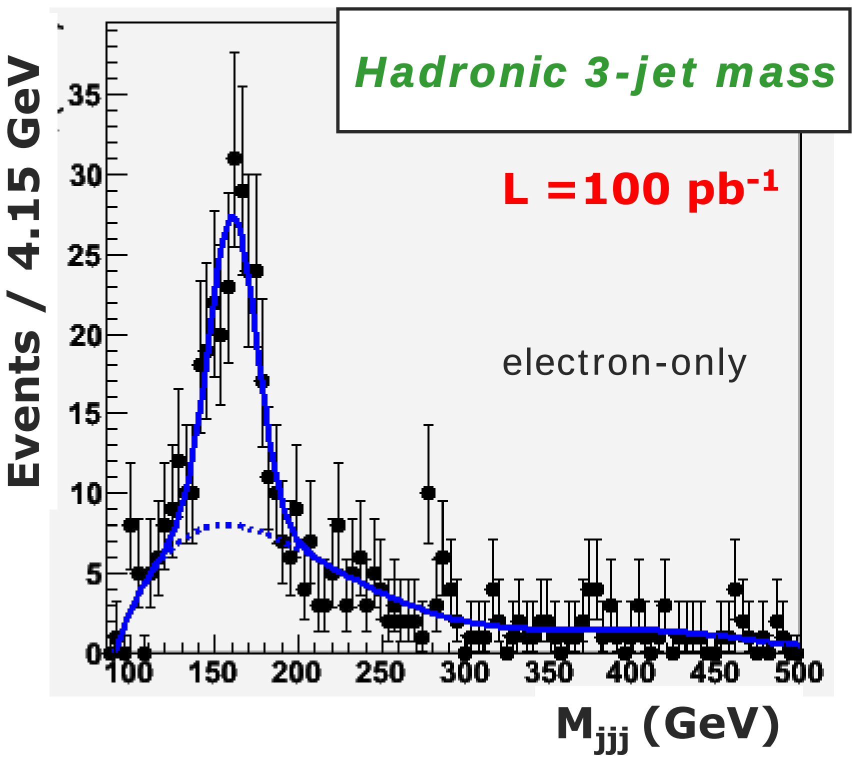
- Plots now include W+jets background
  - Background level roughly triples
  - Signal still well visible
  - Caveat: bkg. cross section quite uncertain

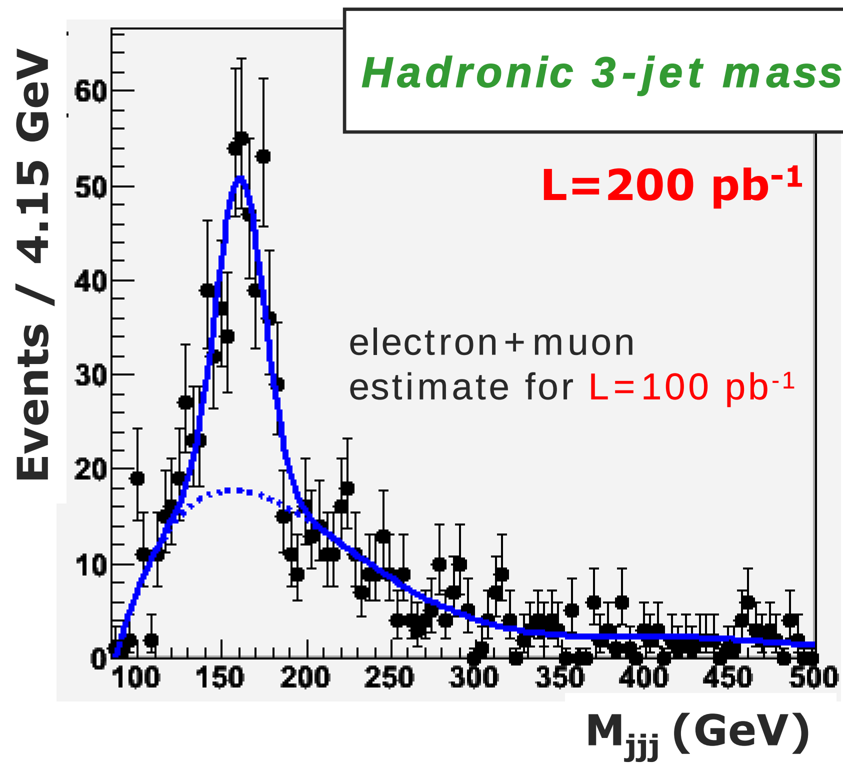




Results for 100-200 pb^{-1} (with cut on W mass)

- Distribution of 3-jet invariant mass after a cut on the mass of the reconstructed W-boson: 70 < Mjj < 90 GeV





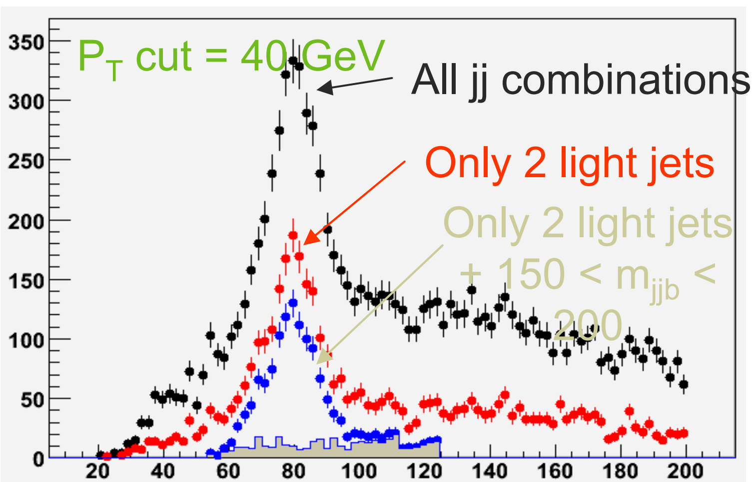
Exploiting ttbar for JES calibration

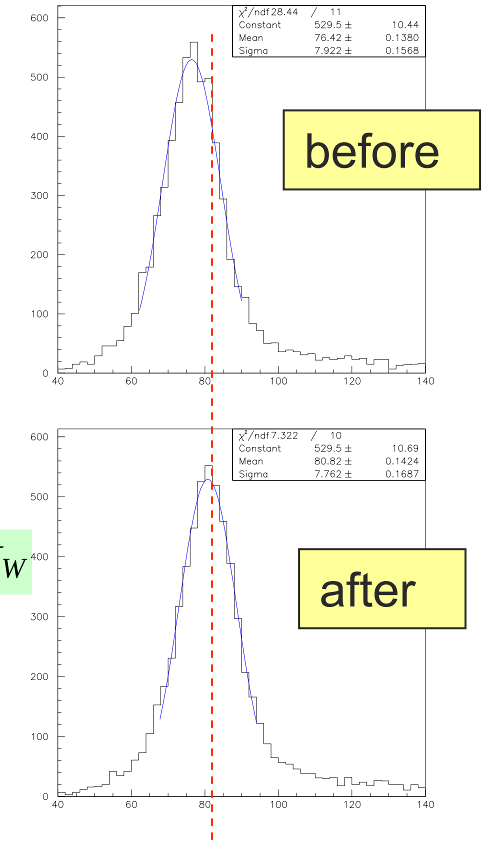
- Use the W mass constraint to set the JES
  - Rescale jet E and angles to parton energy
    $\alpha = E_{parton} / E_{jet}$

$$\chi^2 = \left(\frac{m_{jj} - M_W}{\sigma_W}\right)^2 + \sum_{1,2}^{X=E,\eta,\phi} \left[\frac{X_i - \alpha_E^i X_i}{\sigma_X}\right]^2$$

$$M_W^{PDG} = \sqrt{\alpha_1 \alpha_2} M_W \quad with \quad \alpha_i = \frac{E_i^{part}}{E_i^{jet}}$$

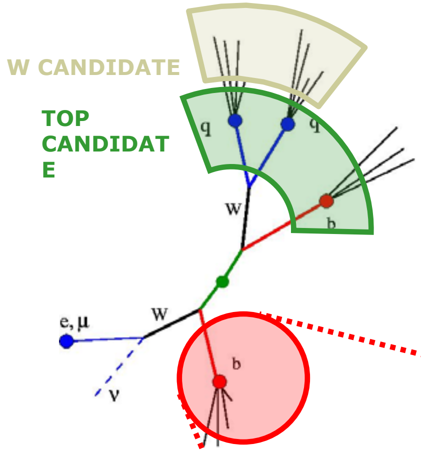
$$M_{jj} = \sqrt{2 E_{j1} E_{j2} (1 - \cos\theta_{j1j2})} = M_W$$





- Active area, new ideas, in cooperation with Jet/ETMiss
  - Newly developed ‘template’ method
  - But LOTS of space for improvement here (using top)

Exploiting ttbar as b-jet sample

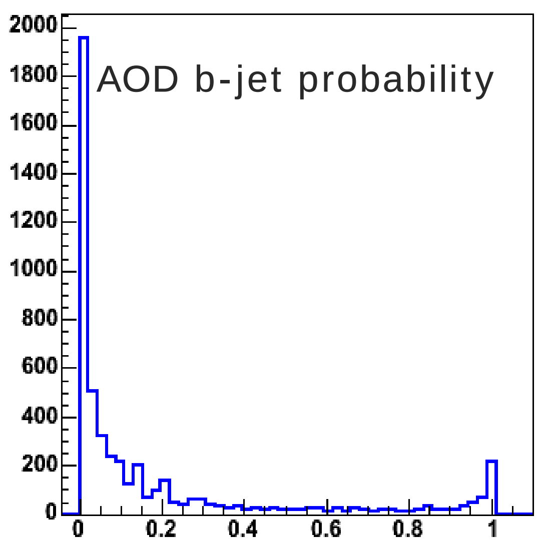


- Simple demonstration use of ttbar sample to provide *b* enriched jet sample
  - Cut on $m(W_{had})$ and $m(top_{had})$ masses
  - Look at b-jet prob for 4^{th} jet (must be b-jet if all assignments are correct)

W+jets (background)

'random jet',

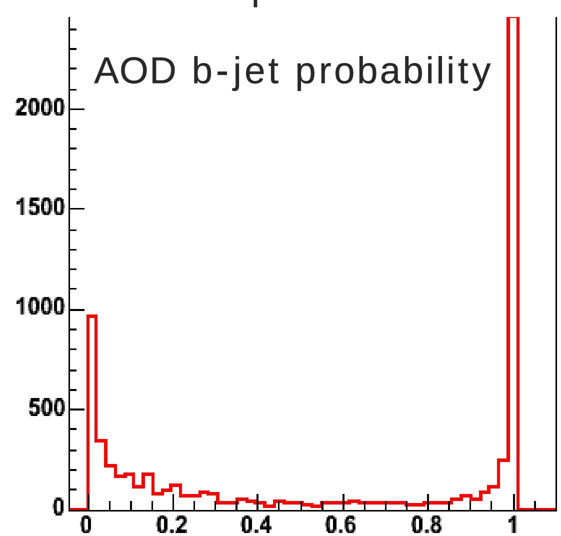
no b enhancement expected



ttbar (signal)

'always b jet if all jet assignment are OK'

b enrichment expected and observed

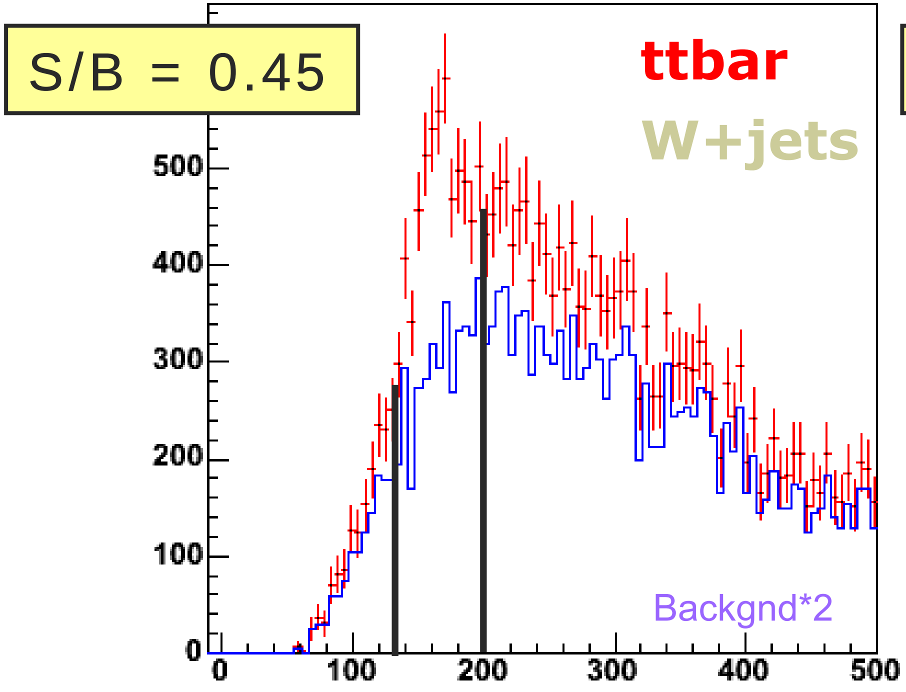


Clear enhancement observed!

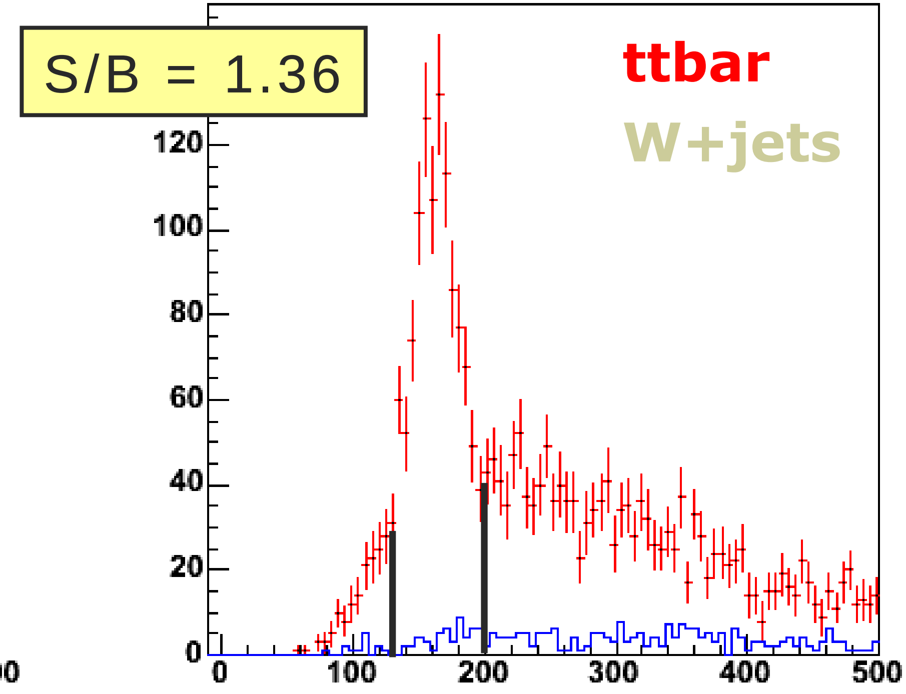
Use b-tag of 4th jet

Use b-tag of 4th jet to clean up hadronic top

Standard analysis (for comparison)



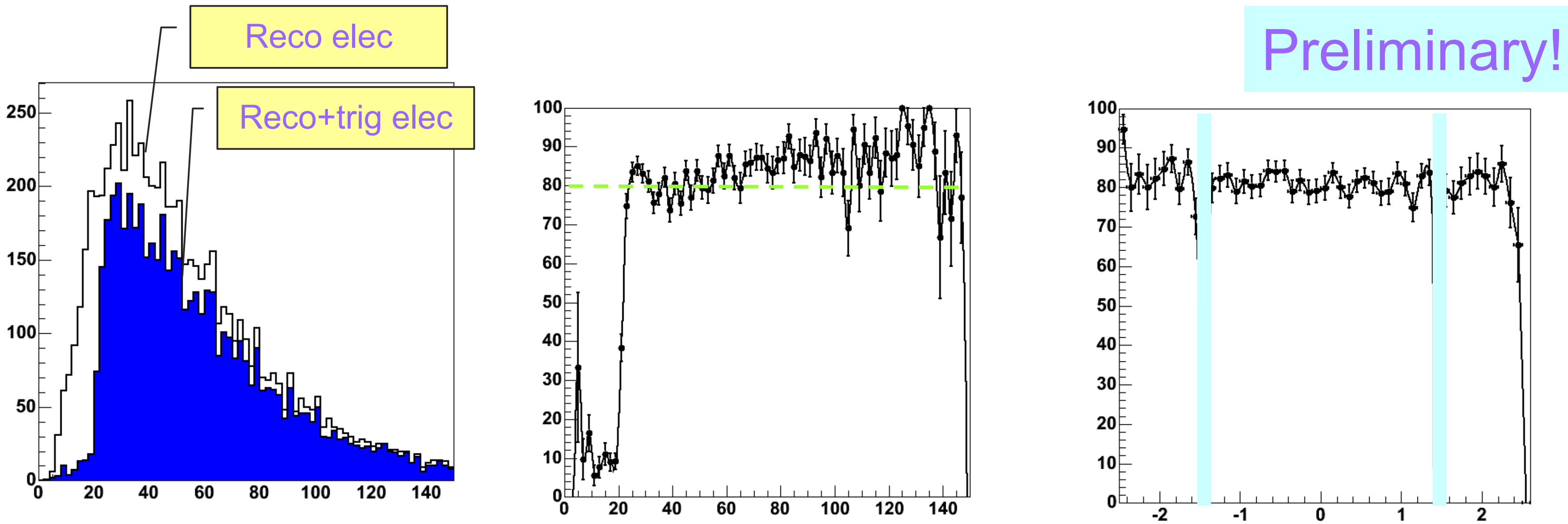
Cut on b signal probability > 0.90 on 4th jet



Effectively background is killed, combinatorics left

Effect of trigger – 1st steps

- Study started with e/γ trigger
  - Triggering through 2E15i, E25i, E60 channels
- Preliminary trigger efficiency as function of lepton p_T
  - Includes effects of 'untriggerable' events due to cracks etc…
  - Work in progress; important topic for CSC samples



Electron pT (GeV) E/γ trig eff (pT) E/γ trig eff (η)

M_{top} and σ_{top} during commissioning

Inputs

- Single lepton trigger efficiency
- Lepton identification efficiency
- Integrated luminosity
  - At startup around 10-20%.
  - Ultimate precision < 5%
- Eventually:
  - B-tagging efficiency
  - Jet scales

Summary:

Understand the interplay between using the top signal as tool to improve the understanding of the detector (b-tagging, jet E scale, ID, etc..) and top precision measurements.

Can reconstruct top and W signal after ~ one week of data taking *without using b tagging*

What we can provide

- Top enriched samples
- Estimate of a light jet energy scale
- Estimate of the b-tagging efficiency
- Estimate of M_{top} and σ_{top}
  - ~20% accuracies. First physics measurements?

ToDo list (among others):

- Complete background (MLM matching, W+bjets…)
- Full trigger information, exploiting redundancy
- Apply JES corrections
- Influence of jet algorithms
- Repeat study with realistic alignment and condition simulation (CSC)

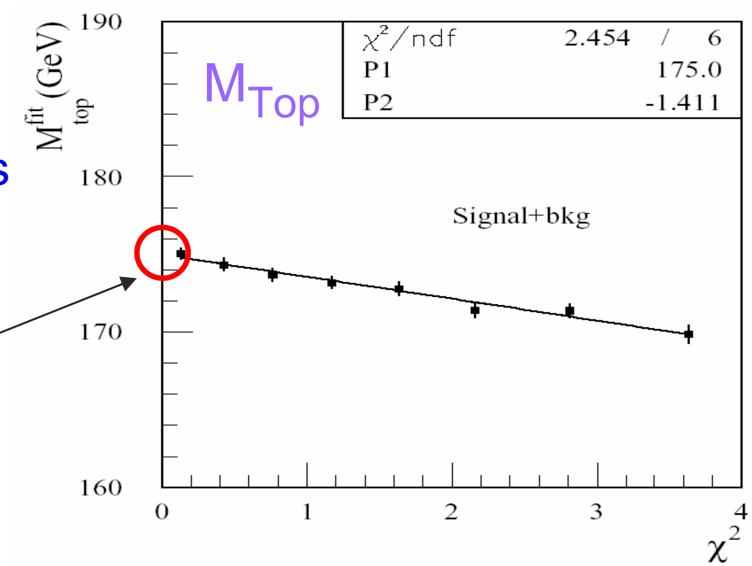
Ultimate top mass

- **Measurement method (semileptonic)**
  - Kinematic fit event by event using t and $\bar{t}$ sides

    $M_{jj} = M_{l\nu} = M_W$ and $M_{jjb} = M_{l\nu b} = M_t^{fit}$

    ➔ (M_t^{fit}, χ^2) by slices of χ^2

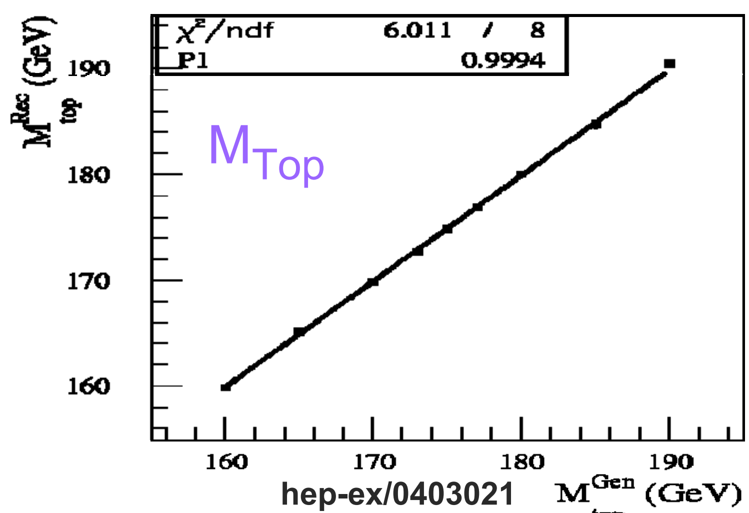
    ➔ top mass estimator: $m_t = M_t^{fit}(\chi^2=0)$
  - This selects well reconstructed b-jets



- **Results**

- m_t linear with generated top mass, flat in PT

Statistical error with 10 fb^{-1}: ~ 0.1 GeV



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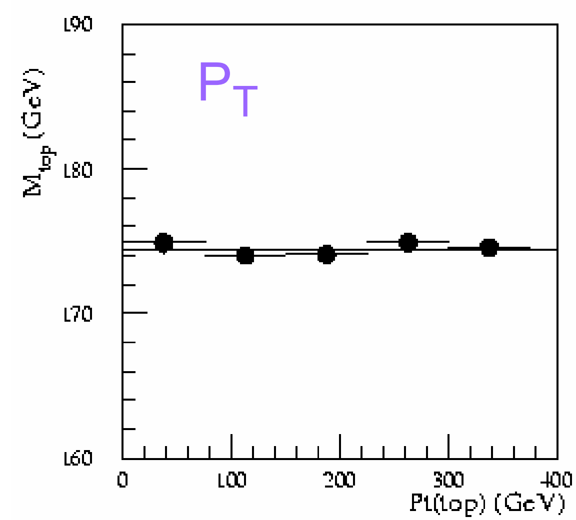


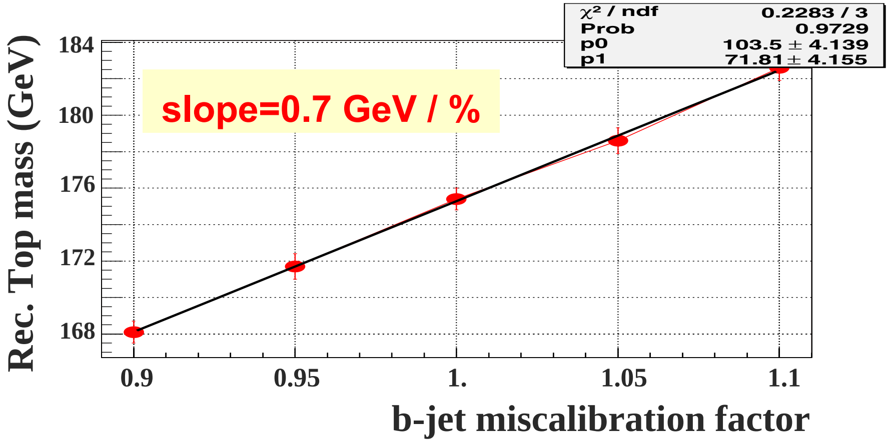
Ultimate top mass (systematics)

▪ Systematic errors on m_t (GeV) in semileptonic channel

Source	Error 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

hep-ex/0403021

- Systematics from b-jet scale (full simulation):



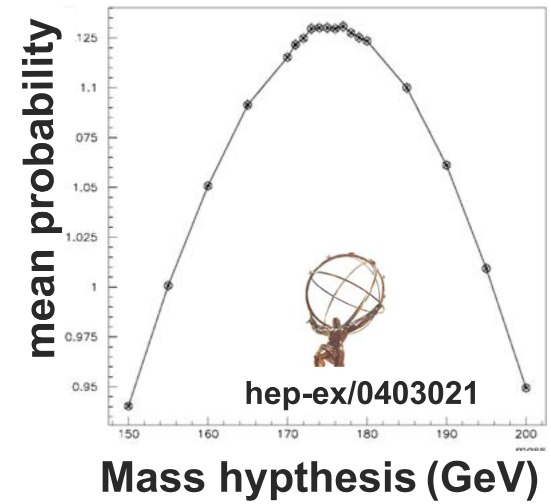
- Other methods (invariant 3 jet jjb mass, large p_T events, ...) give larger systematic but will allow reliable cross-checks

➔ A ~1 GeV accuracy on M_t seems achievable with 10 fb^{-1} at ATLAS

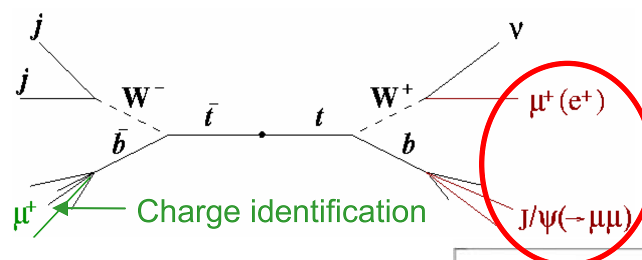
Ultimate top mass (alternatives)

- **Dileptonic (10 fb^{-1})**
  - Need to reconstruct full $t\bar{t}$ event to assess the 2 ν momenta ➔ 6 equations ($\Sigma p_T=0$, $M_{l\nu}=$ ***M_W***, $M_{l\nu b}=$ ***M_t***)
  - Assume m_t and compute solution probability event by event using MC kinematic distributions
  - Choose m_t with highest mean probability on all events
  - Systematic uncertainty: ~2 GeV (PDF + b-frag.)

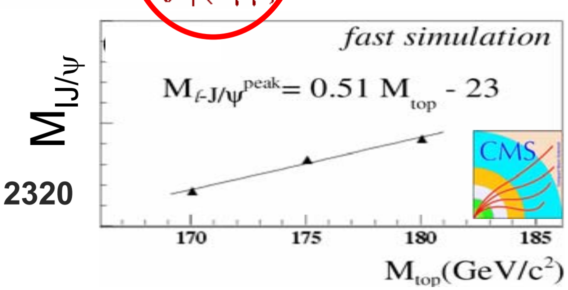
Input top mass=175 GeV



- **Final states with J/ψ (100 fb^{-1})**
  - Correlation between $M_{lJ/\psi}$ and m_t
  - Low statistics: ~1000 evts/100 fb^{-1}
  - No systematics on b-jet scale !
  - Systematic uncertainty: ~1 GeV (b-frag.)



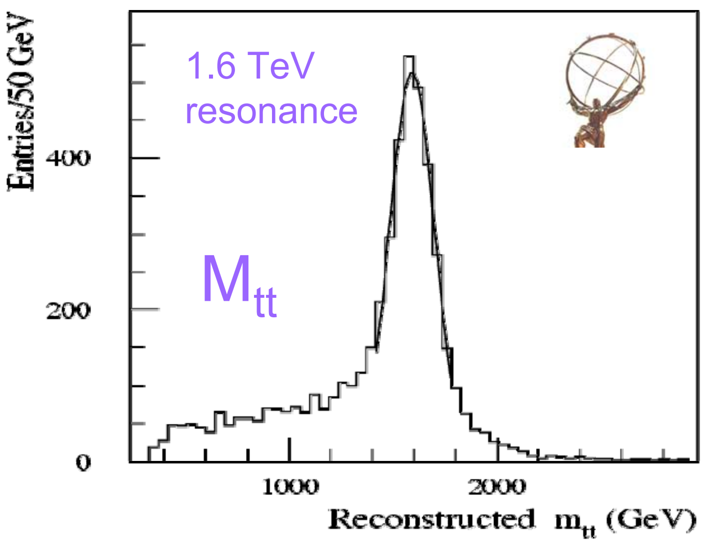
hep-ph/9912320

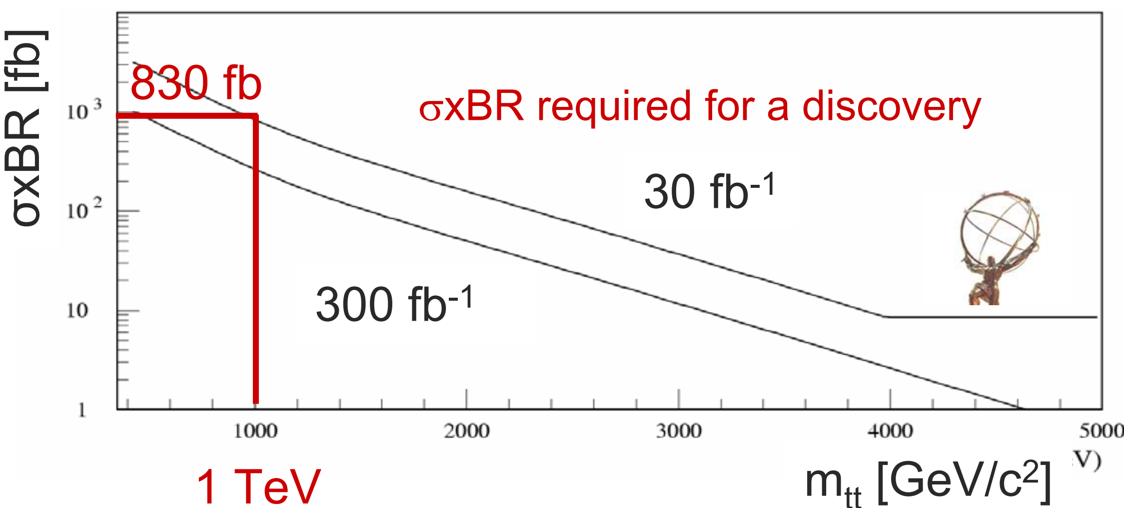


Search for resonances

- Many theoretical models include the existence of resonances decaying to top-topbar
  - SM Higgs (but BR smaller with respect to the WW and ZZ decays)
  - MSSM Higgs (H/A, if $m_H, m_A > 2m_t$, $BR(H/A \to tt) \approx 1$ for $\tan\beta \approx 1$)
  - Technicolor Models, strong ElectroWeak Symmetry Breaking, Topcolor, "colorons" production, […]

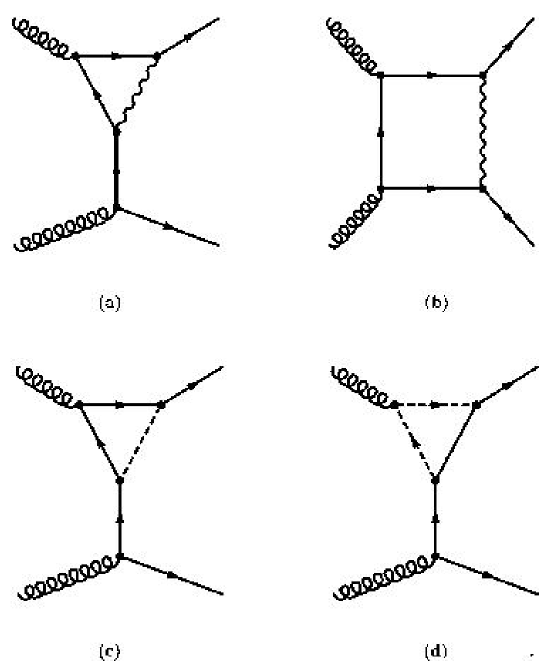
- Study of a resonance X once known σ_X, Γ_X and $BR(X \to tt)$
  - Reconstruction efficiency for semileptonic channel:
    - 20% m_{tt}=400 GeV
    - 15% m_{tt}=2 TeV



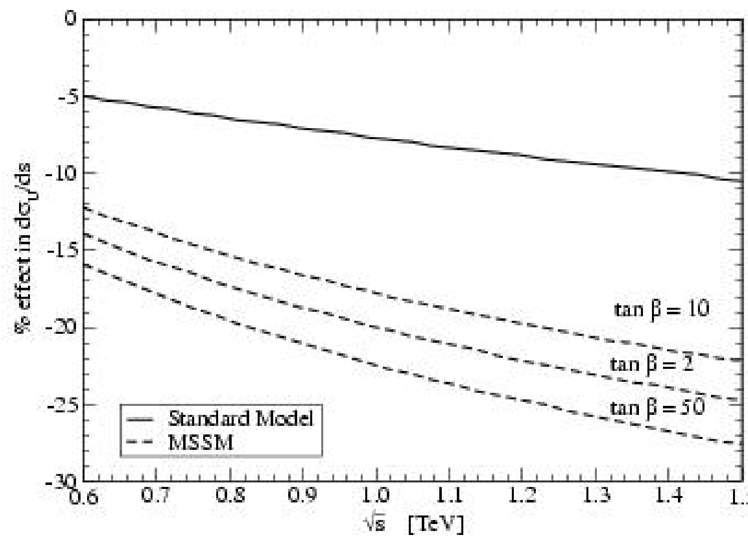


Implicit new physics..

- E.g. SUSY particles modify ttg vertex, investigate M_{tt}:
  - All SuSY masses ≤ $M_{SuSY} \equiv M \cong 400$ GeV, "SuSY Yukawa" might be visible in higher order corrections



Diagrams for SuSy corrections to gg →ttbar



Modified Mtt distribution for various tanb

- Can be measured with ~20% precision using $10fb^{-1}$ data
- QCD NLO effects estimated with MC@NLO

Confirmation of SUSY?

Couplings and decays

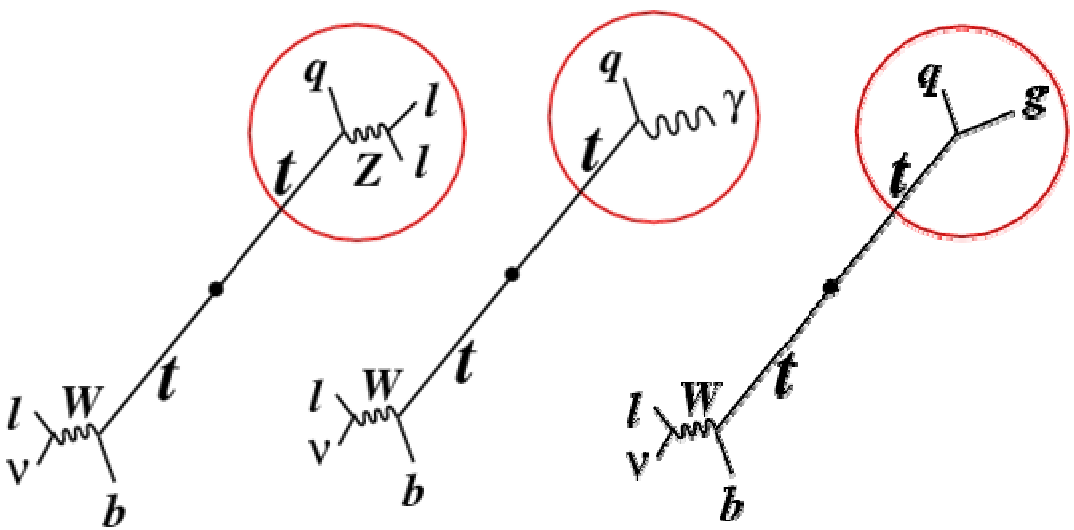
- Does the top quark behaves as expected in the SM?
  - Yukawa coupling to Higgs from ttbarH events
  - Electric charge
  - Top spin polarization
  - CP violation
- According to the SM:
  - $Br(t \rightarrow Wb) \approx 99.9\%$, $Br(t \rightarrow Ws) \approx 0.1\%$, $Br(t \rightarrow Wd) \approx 0.01\%$
    (difficult to measure)
- Can probe $t \rightarrow W$[non-b] by measuring ratio of double b-tag to single b-tag
  - Statistics more than sufficient to be sensitive to SM expectation for $Br(t \rightarrow W + s/d)$
  - need excellent understanding of b-tagging efficiency/purity

Top quark FCNC decay

- GIM suppressed in the SM
- Higher BR in some SM extensions (2-Higgs doublet, SUSY, exotic fermions)

	BR in SM	2HDM	MSSM	$\not{R}$ SUSY	QS
$t \rightarrow qZ$	~10^{-14}	~10^{-7}	~10^{-6}	~10^{-5}	~10^{-4}
$t \rightarrow q\gamma$	~10^{-14}	~10^{-6}	~10^{-6}	~10^{-6}	~10^{-9}
$t \rightarrow qg$	~10^{-12}	~10^{-4}	~10^{-5}	~10^{-4}	~10^{-7}

- 3 channels studied:



Preselection

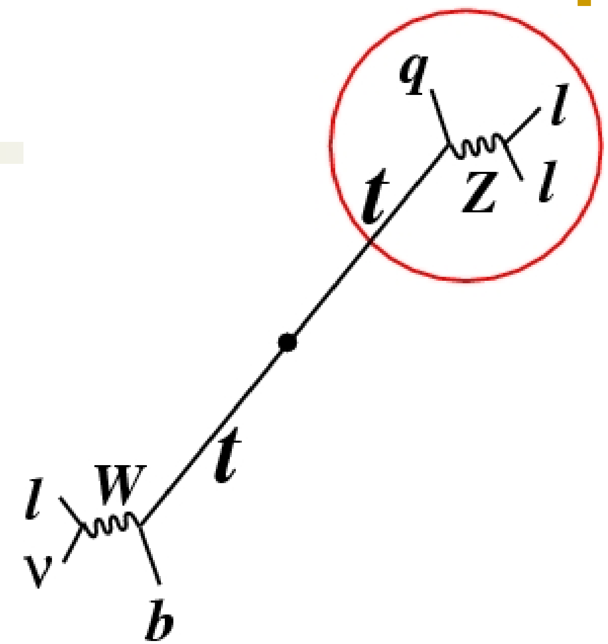
≥ 1 lepton (pT > 25 GeV and |h| < 2.5)

≥ 2 jets (pT > 20 GeV and |h| < 2.5)

Only 1 b-tagged jet

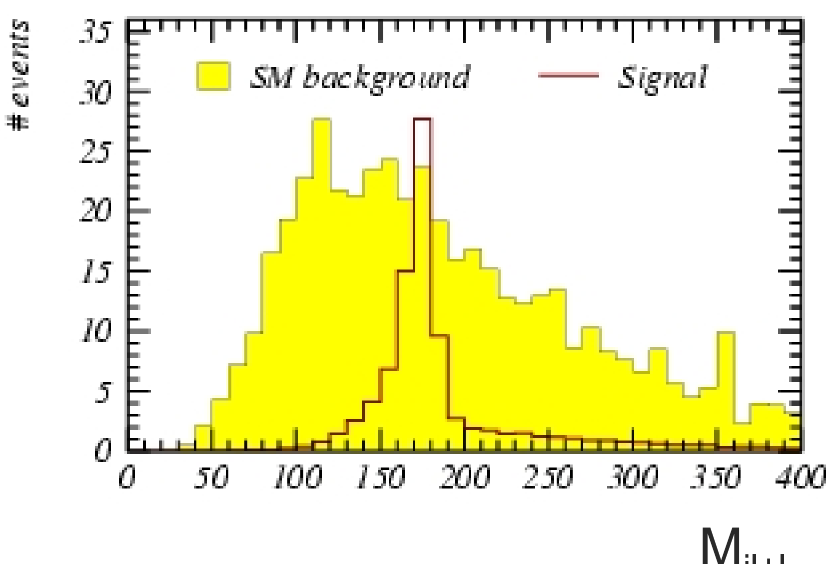
ETmiss > 20 GeV

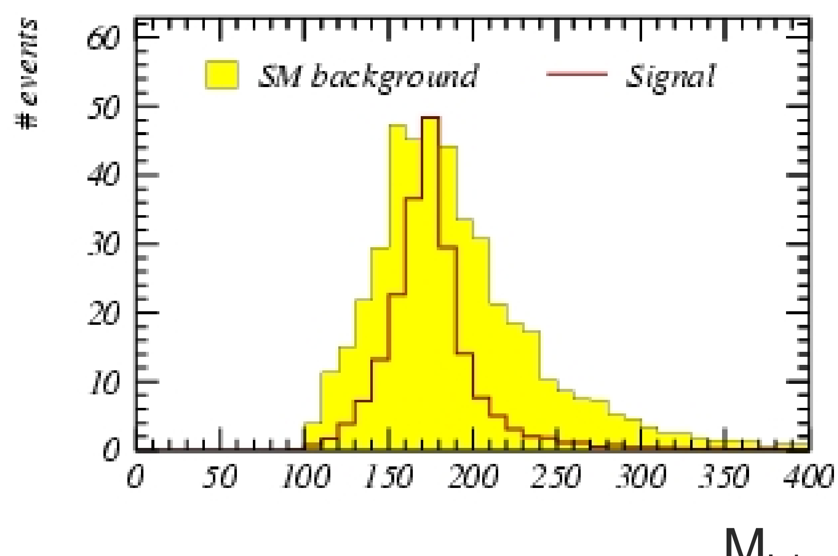
FCNC: $t \to qZ$



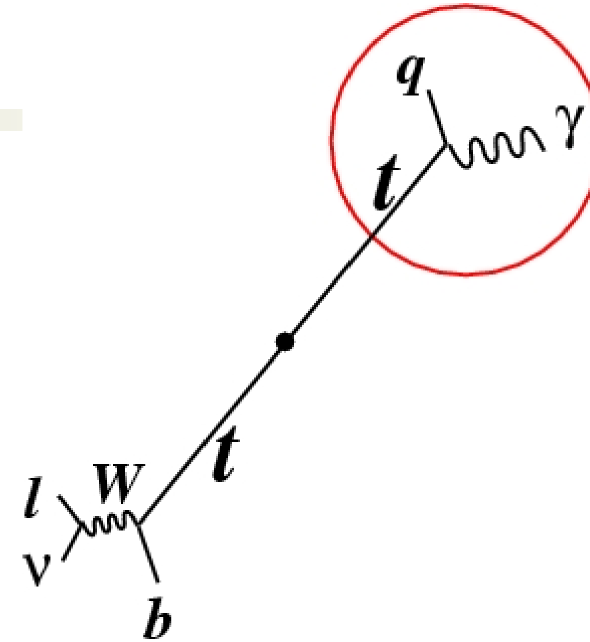
- Specific criteria:
  - ≥ 3 leptons
    - **PTl2,l3 > 10 GeV and |h|<2.5**
    - **2 leptons same flavour and opposite charge**
    - **PTj1 > 30 GeV**
- 453.8 backgnd evts, ε x BR = 0.23%

L = 10 fb^{-1}



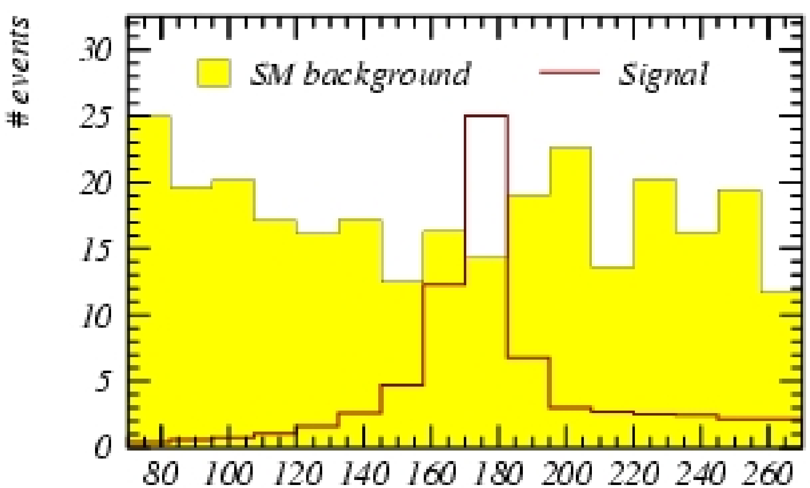


FCNC: $t \rightarrow q\gamma$

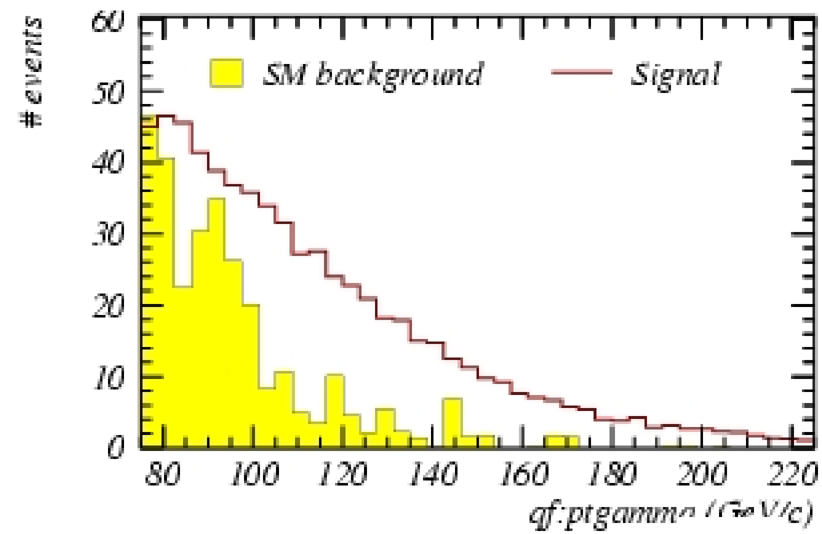


- Specific criteria:
  - 1 photon
    - **PT > 75 GeV and |η|<2.5**
  - 20 GeV < mγj < 270 GeV
  - < 3 leptons
- 290.7 backgnd evts, ε x BR = 1,88%

L = 10 fb^{-1}

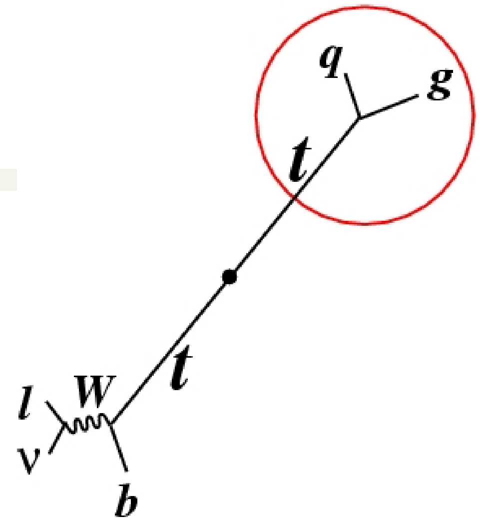


$M_{\gamma j}$



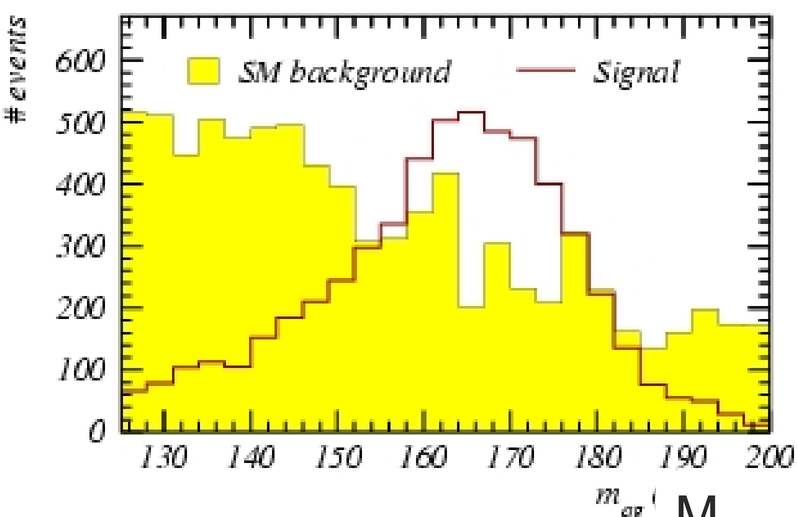
$P_{T\gamma}$

FCNC: $t \to qg$

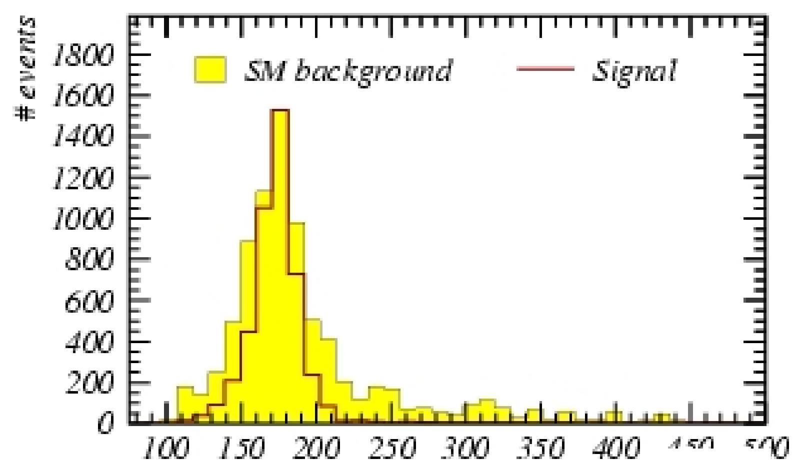


- Specific criteria:
  - Only one lepton
  - No γ with $P_T > 5$ GeV
  - $E_{vis} > 300$ GeV
  - 3 jets **($P_{T1} > 40$ GeV, $P_{T2,3} > 20$ GeV and $|h| < 2.5$)**
  - **$P_{Tg} > 75$ GeV**
  - **$125 < mgq < 200$ GeV**
- 8166.1 backgnd evts, ε x BR = 0,39%

L = 10 fb^{-1}



M_{gq}



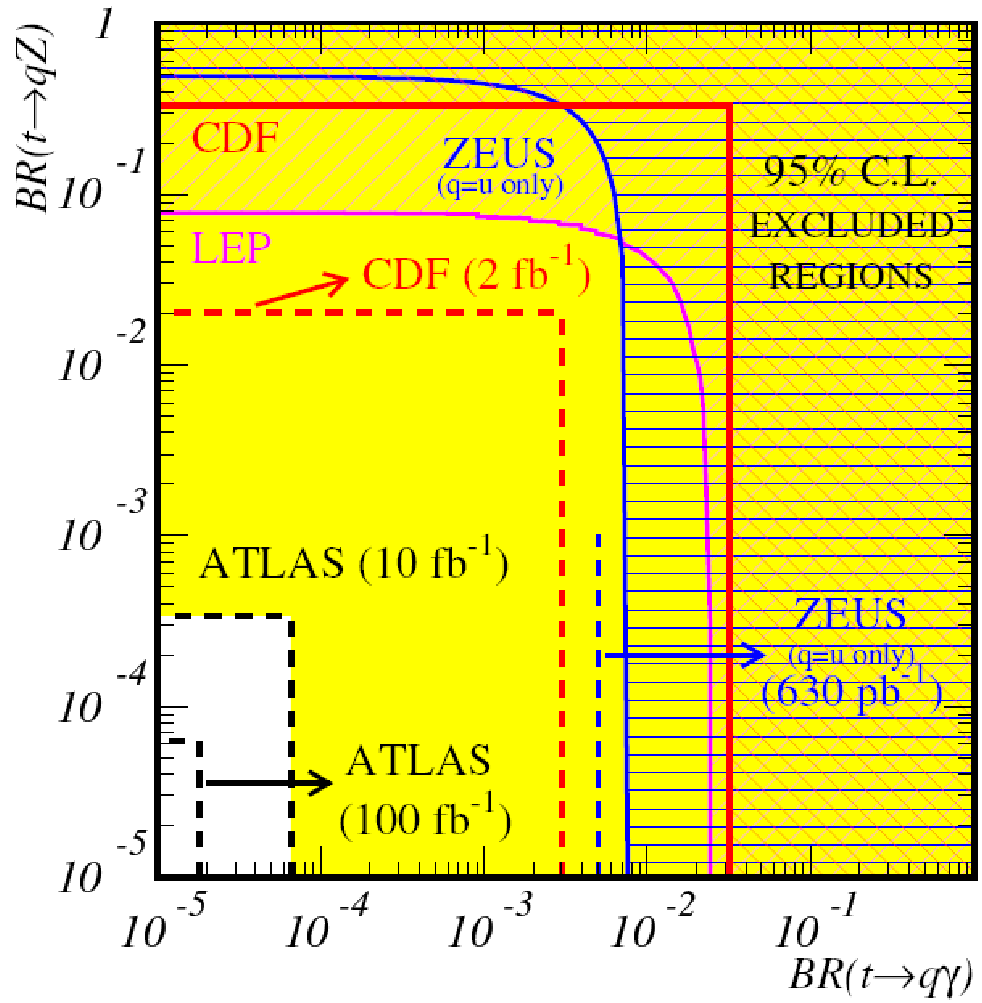
$M_{l\nu b}$

FCNC: Results

- BR 5σ sensitivity:

L(fb-1)	t→qZ	t→qγ	t→qg
10	5.1×10^{-4}	1.2×10^{-4}	4.6×10^{-3}
100	1.6×10^{-4}	3.8×10^{-5}	1.4×10^{-3}

- Results statistically limited
  - Combination of CMS & Atlas will improve the limits
- Sensitivity at the level of SuSy and Quark singlet models



W polarization in top decay

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

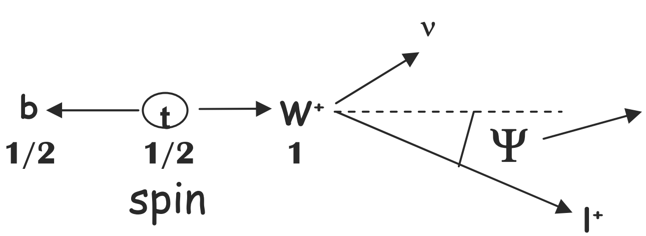
	Longitudinal W^+ (F_0)	**Left-handed W^+ (F_L)**	**Right-handed W^+ (F_R)**
Standard Model (M_{top}=175 GeV) NLO	**0.703** $\left(=\frac{M_t^2}{M_t^2+2M_W^2}\right)$ 0.695	**0.297** $\left(=\frac{2M_W^2}{M_t^2+2M_W^2}\right)$ 0.304	**0.000** 0.001

Sensitive to EWSB (← F_0)

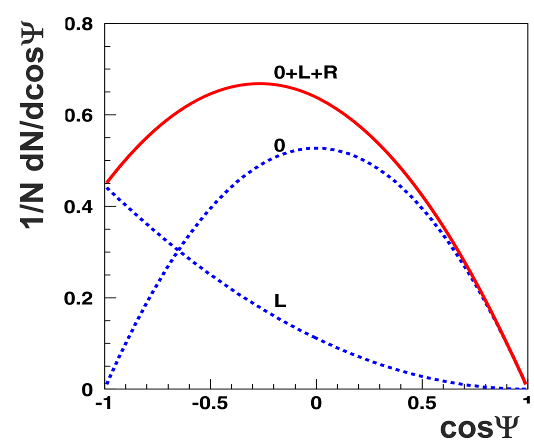
Test of V-A structure (← F_R)

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

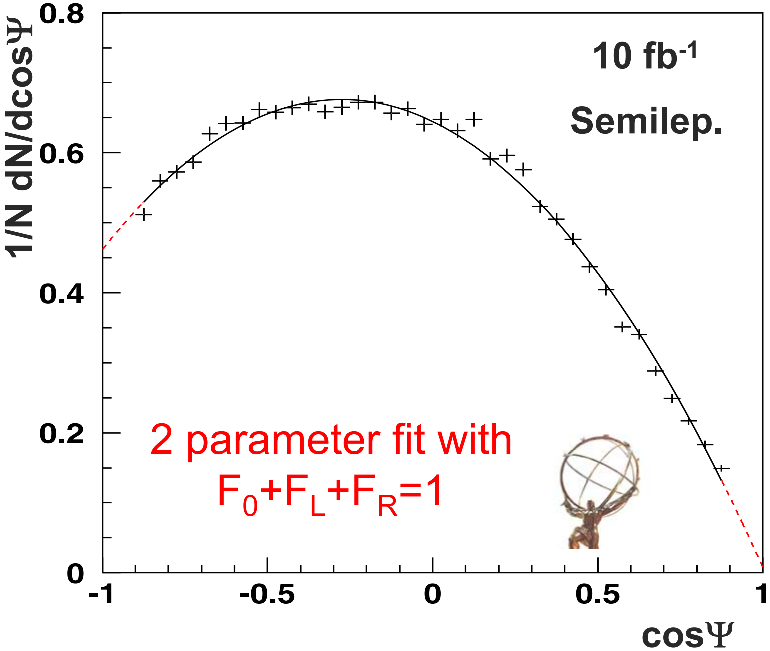
$$\frac{1}{N}\frac{dN}{d\cos\Psi}=\frac{3}{2}\left[F_0\cdot\left(\frac{\sin\Psi}{\sqrt{2}}\right)^2+F_L\cdot\left(\frac{1-\cos\Psi}{2}\right)^2+F_R\cdot\left(\frac{1+\cos\Psi}{2}\right)^2\right]$$



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



W polarization in top decay



Combined results of semilep+dilep

	SM (M_t=175 GeV)	Error (±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

hep-ex/0508061

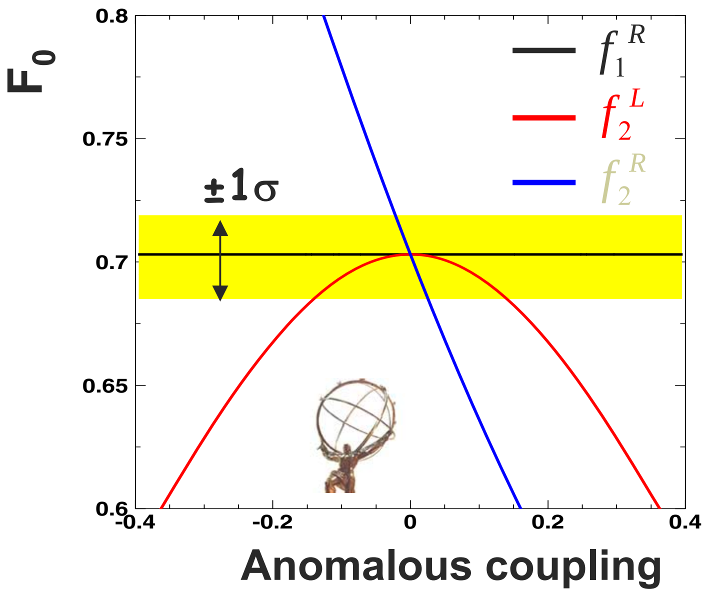
- Systematics dominated by b-jet scale, top mass and final state radiation (FSR)
- With 10 fb^{-1}, can measure F_0 with a ~2% accuracy and F_R with a precision ~1%
- Tevatron expectations (2 fb^{-1}): $\delta F_0^{stat}/F^0$~12% and $\delta F_R^{stat}/F^R$~3%

W polarization in top decay

- **From W polarization, deduce sensitivity to tWb anomalous couplings**
  ➔ 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

tt spin correlation

In SM with $M_{top} \approx 175$ GeV, $\Gamma(t) \approx 1.4$ GeV » Λ_{QCD}

Top decays before hadronization, and so can study the decay of 'bare quark'

Substantial ttbar spin correlations predicted in pair production

$$\frac{1}{N}\frac{dN}{d\cos\theta_i} = \frac{1}{2}(1 + S\alpha_i \cos\theta_i)$$

angle between daughter and top spin axis **s**

spin analyzing power

	W	b	l⁺,d,s	v,u,c	lej*
α (NLO)	0.40	-0.40	1.	-0.31	0.47

* lej = least energetic jet in top rest frame

- Measurement of tt spin *correlation* (NP **B690** (2004) 81)

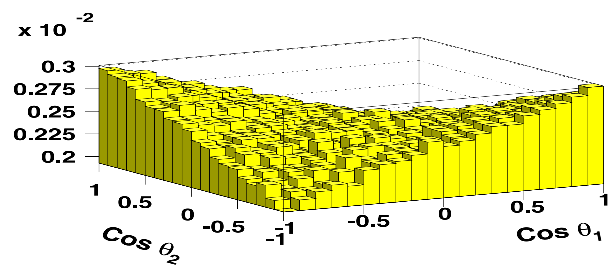
$$\frac{1}{N}\frac{d^2N}{d(\cos\theta_1)d(\cos\theta_2)} = \frac{1}{4}(1 - C\cos\theta_1\cos\theta_2)$$

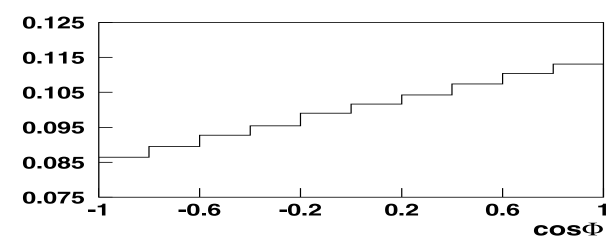
$C \rightarrow A \cdot \alpha_1 \cdot \alpha_2$

$$\frac{1}{N}\frac{dN}{d\cos\Phi} = \frac{1}{2}(1 - D\cos\Phi)$$

$D \rightarrow A_D \cdot \alpha_1 \cdot \alpha_2$

Φ → angle btwn spin analyzers direction in the t($\bar{t}$) rest frame





tt spin correlation

- **Test the top production …**

  t and $\bar{t}$ are not polarized in $t\bar{t}$ pairs, but their spins are correlated

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

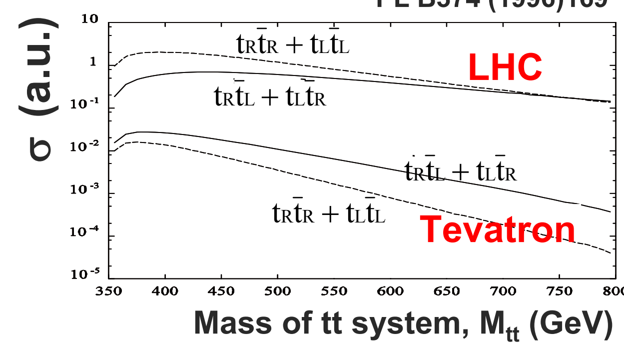
=0.33 → (M_{tt}<550 GeV) → **A=0.42**

$$A_D = A_X + A_Y + A_Z$$

=-0.24 → **A_D=-0.29**

top spin ≠ 1/2, anomalous couplings, t→H^+b

PL B374 (1996)169



- **… measuring angular distribution of daughter particles in top rest frame**

Semilep. + dilep. (10 fb^{-1})

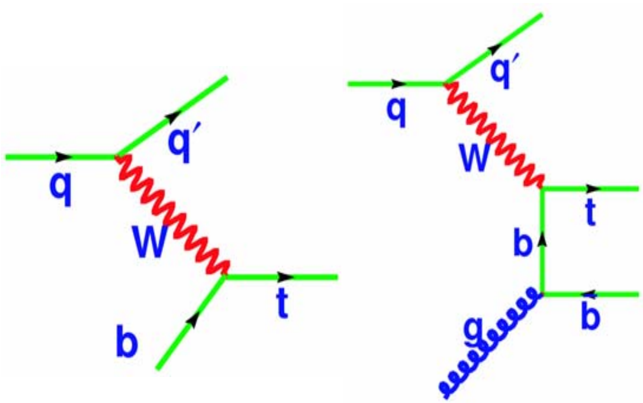
	SM	Error (±stat ±syst)
A	0.42	± 0.014 ± 0.023
A_D	-0.29	± 0.008 ± 0.010

hep-ex/0508061

- Syst. dominated by b-JES, top mass and FSR
- ~4% precision on spin correlation parameters
- Tevatron expectations (2 fb^{-1}): $\delta A^{stat}/A$~40%

Single top production

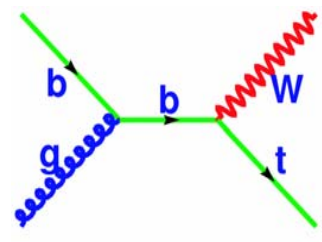
Three production mechanisms:



Wg fusion: 245±27 pb

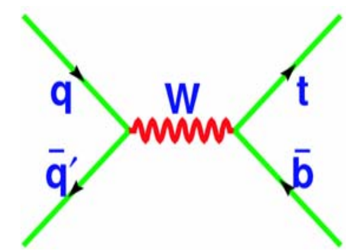
(t-channel)

S.Willenbrock *et al.*, Phys.Rev.D56, 5919



Wt: $62.2^{+16.6}_{-3.7}$ pb

A.Belyaev, E.Boos, Phys.Rev.D63, 034012



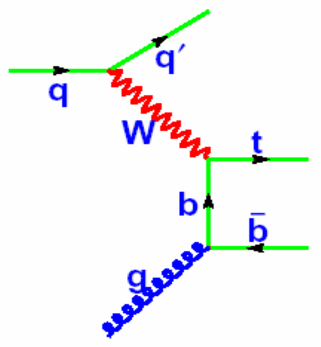
W* 10.2±0.7 pb

(s-channel)

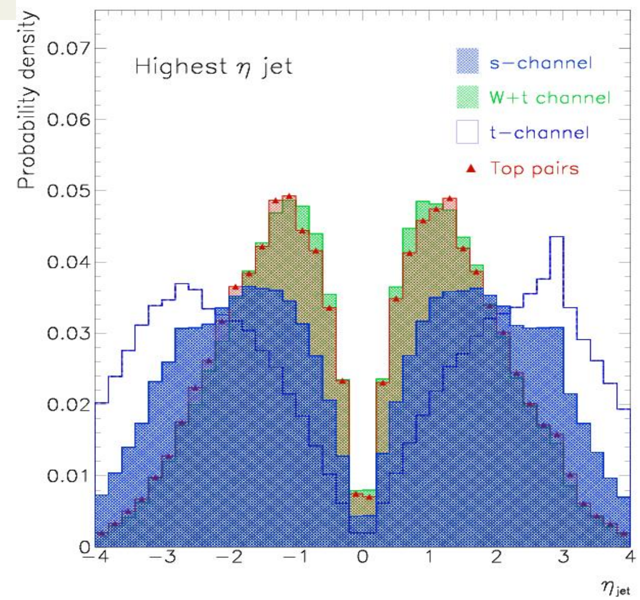
M.Smith *et al.*, Phys.Rev.D54, 6696

- Never observed so far
- Directly related to $|V_{tb}|$
- Sensitivity to new physics: FCNC (t-ch.), new gauge bosons or KK excitations (s-ch.), $H^{\pm}\rightarrow tb$ …
- Background to tt, WH→lνbb, some SUSY and BSM final states
- Possibility to study top properties (mass, polarization, charge) with very little reconstruction ambiguities
- Together they provide complementary informations on Wtb coupling, since they probe it for $q^2<0$, $q^2>0$, $q^2=0$

t-channel single top



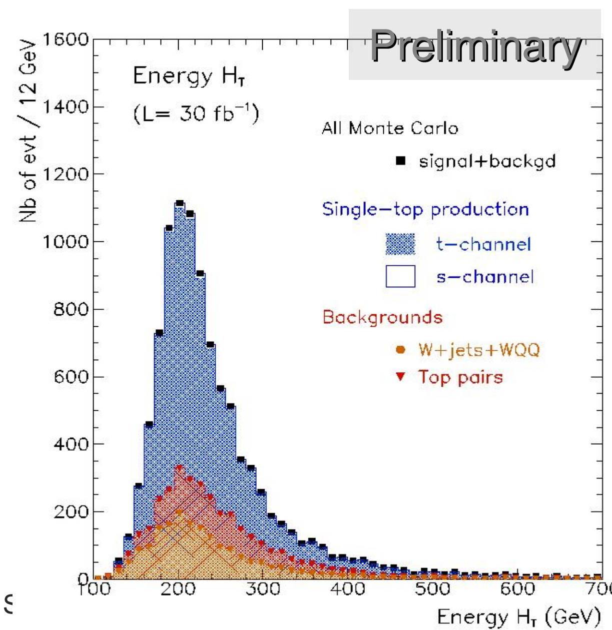
- Most characteristic feature: the "recoil" light quark.
- The additional b quark is often unobservable due to low P_T.



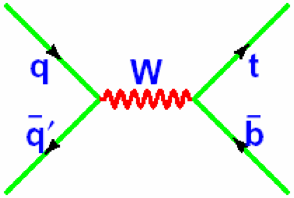
- **Selection**
  - Exactly 2 high-P_T jets: 1 high P_T central b-jet
    1 forward light jet $|\eta|>2.5$
  - Reconstruct Top using the central b-jet and the ν solution giving minimum $|m_{l\nu b} - m_t^{gen}|$
  - Resolution better than 25 GeV on M_{top}
  - Window in H_T or M_{top}

- **Performance :**
  - Efficiency $\varepsilon \approx 1.3\%$, $N(30fb^{-1}) \sim 7{,}000$ events
  - Main backgrounds : W+jets , ttbar
  - Main systematics (lumi excepted):
    b-tag efficiency & mistag rates, JES

S/B ~ 3
$\sqrt{(S+B)}/S \sim 1.4\%$ @ 30 fb^{-1}



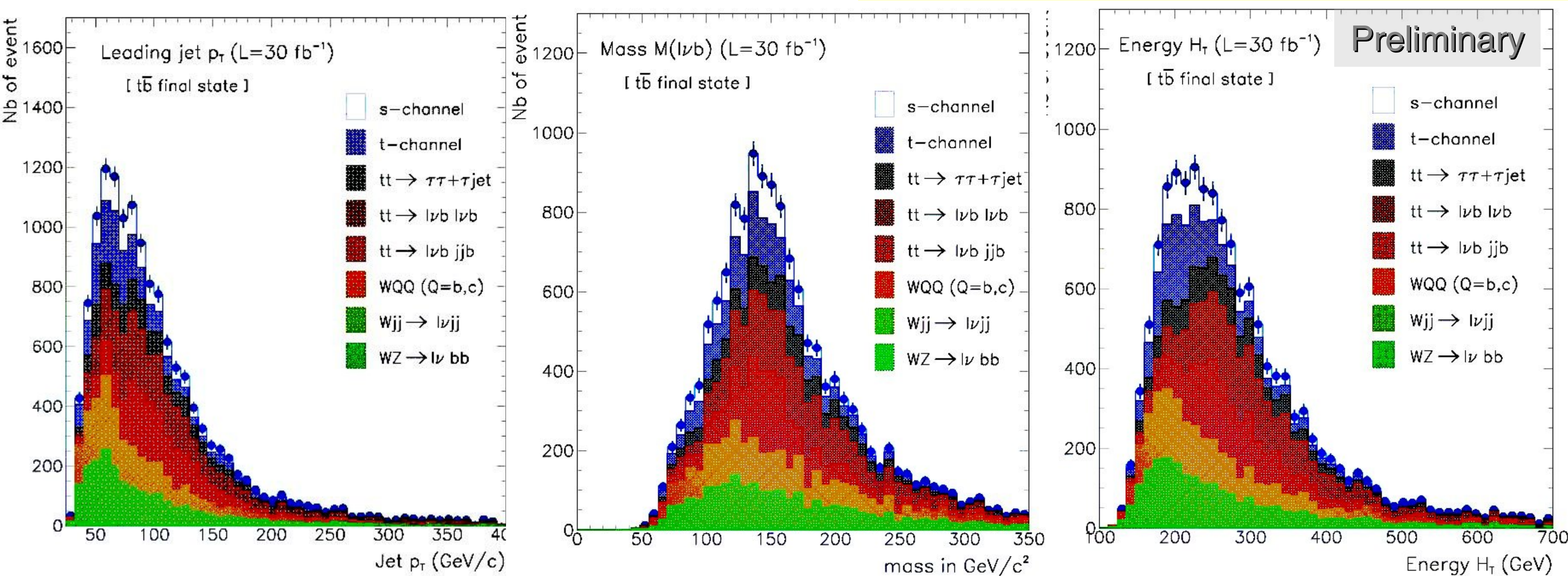
s-channel single top



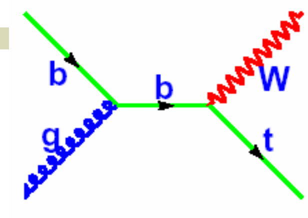
In principle more difficult than t-channel:

- Smaller cross section (1/25)
- No the extra forward jet
- t-channel itself is background

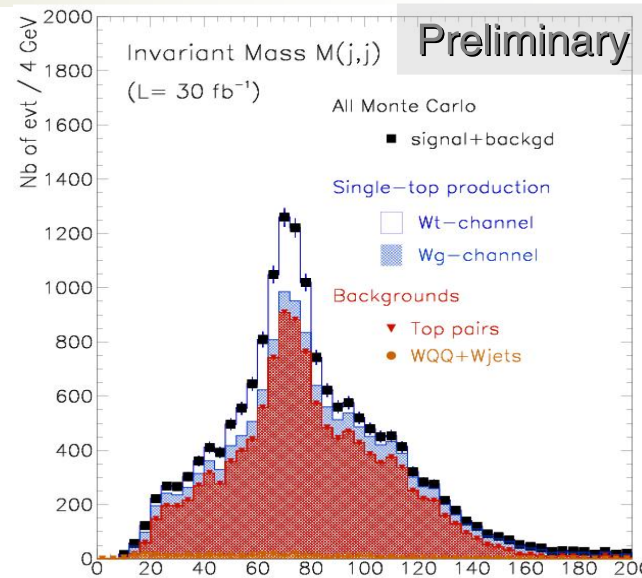
- Selection :
  - Exactly 2 central high-P_T jets, both identified as b-tagged jets
  - Reconstruct Top w/ highest-P_t lνb combination
  - Window in H_T or M_{top}



Wt production in single top



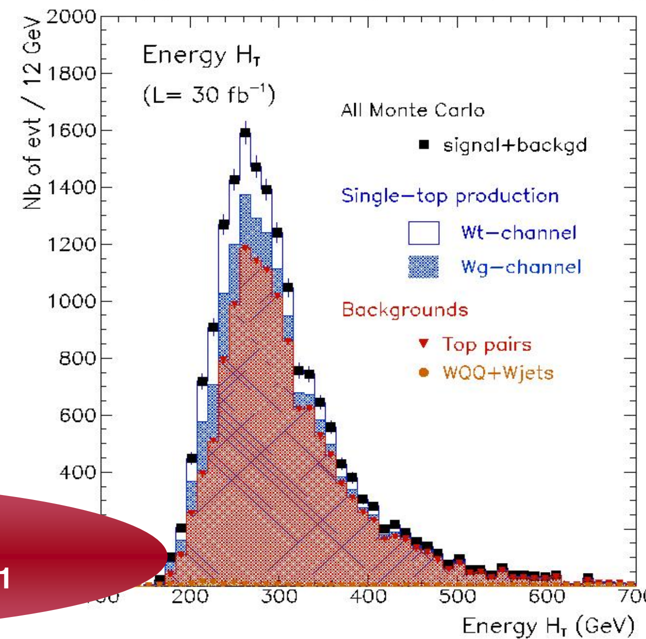
- Background to gb→$H^{\pm}t$
- Difficult channel:
  - signal is overwhelmed by ttbar background (ttbar with a b-jet outside acceptance is a perfect Wt fake)
- Also not trivial to define what the signal is
  - (at NLO: entangled with ttbar diagrams!)



- Selection :
  - At least 3 high-p_T jets :
    w/ only 1 high P_T central b-tagged jet
  - Reconstruct a W→ jj: 60 <m_{jj} < 90 GeV/c^2
  - Reconstruct leptonic Top : minimum $|m_{l\nu b}-m_t|$
  - Window in H_T or M_{top}
- Performance :
  - efficiency ε ≈ 0.90%, N(30fb^{-1}) ~ 4,700 events
  - Main background : ttbar, t-channel
  - Main systematics (lumi excepted):
    b-tag efficiency & mistag, JES

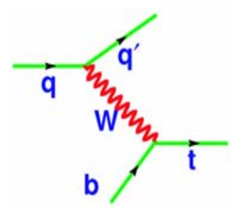
S/B ~ 1/7

$\sqrt{(S+B)}/S$ ~ 4% @ 30 fb^{-1}



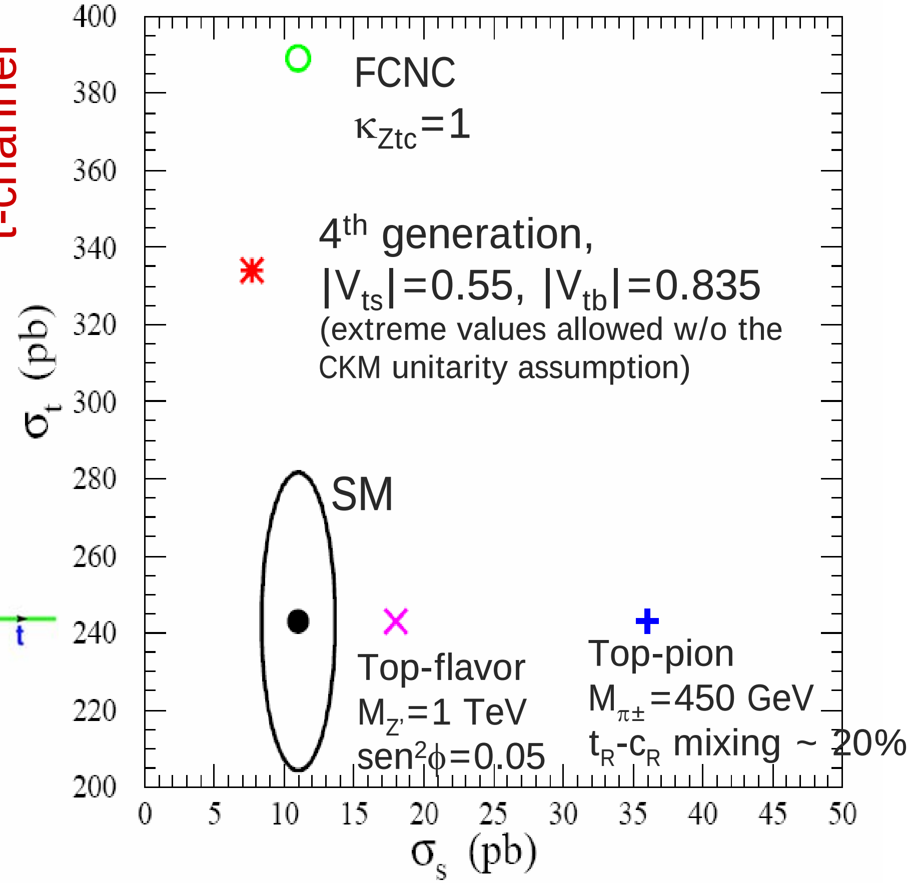
Single top and New Physics

- Single top physics provides a new test ground for the Standard Model and a possible window on new physics
- Precision physics in this sector will be possible at LHC
- One of the three production modes, Wt, will be measurable at LHC for the first time
- Studies of QCD NLO effects started
  - Using MC@NLO
  - Awaiting full simulations

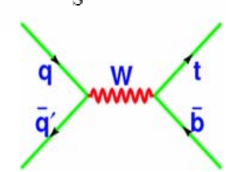


T.Tait, C.-P.Yuan, Phys.Rev. D63 (2001) 0140018

t-channel



s-channel



Conclusions

LHC is top factory

$\sigma(tt)\sim830 \pm 100\ pb^{-1}$

10^7 events in first year

- Top quarks for commissioning the detectors
  - Top peak should be visible with eyes closed
- Precise determination M_{top} is waiting…
  - Challenge to get $\delta M_{top} \sim 1$ GeV
- Confirmation that top-quark is SM particle
  - Measure V_{tb}, charge, CP, spin, decays
  - Single top production
- Today's signal, tomorrow's background
  - Top quarks as main background for many new physics channels
  - New physics decaying into, or associated with tt-bar

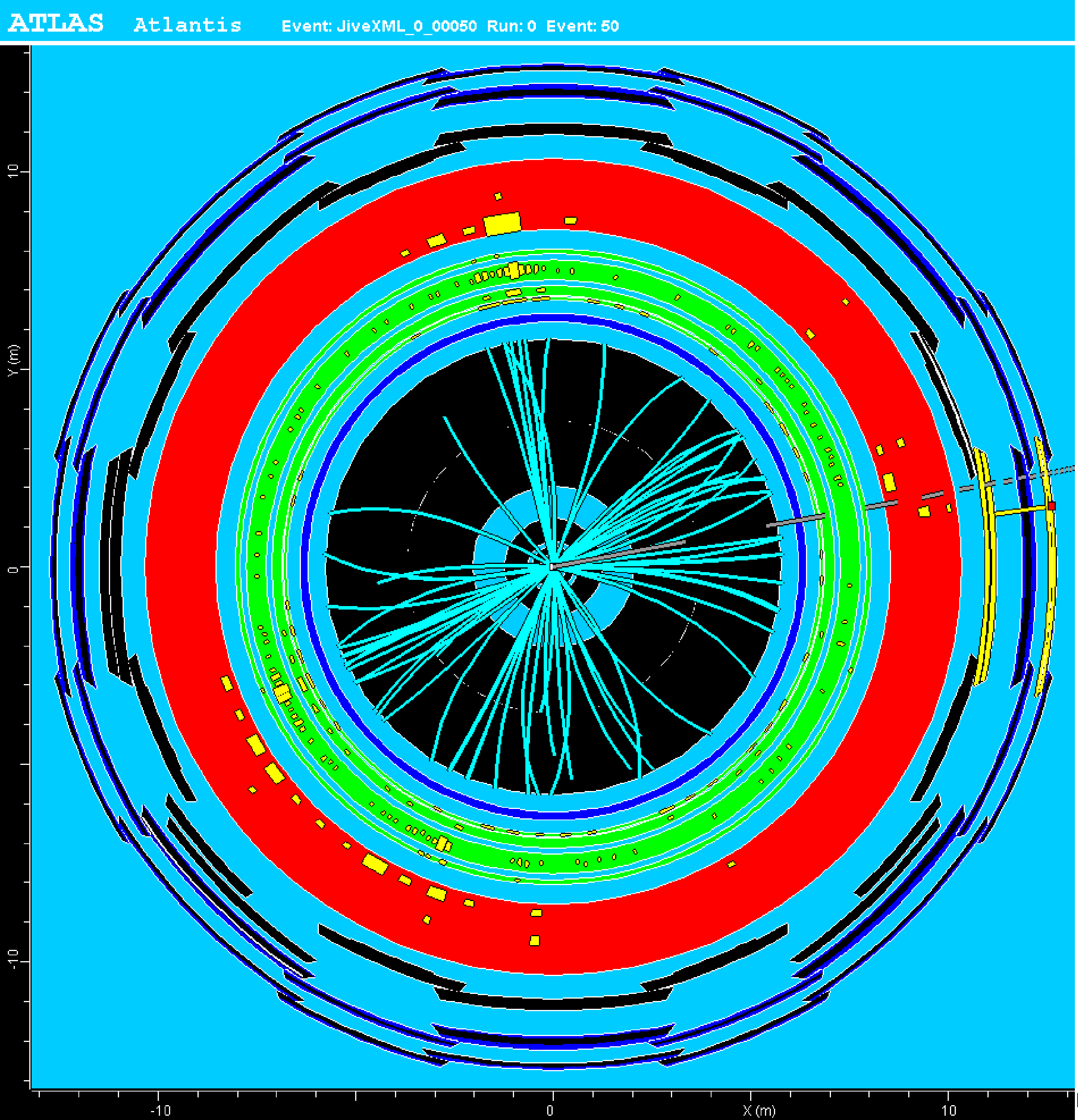
Thanks to I van Vulpen, F Hubaut, D. Pallin, A. Lucotte, M. Cobal, J. Schwindling, W Verkerke

Preparations for 2007

- Physics readiness
  - Atlas will produce “physics readiness review” rapports
  - Based on 100 pb^{-1} and 10 fb^{-1} of data
  - Small documents, papers, for all performance and physics groups, foreseen by the end of this year
  - Finished by end of 2006, based on CSC data
  - Volunteers will be needed!
- Building confidence
  - Data-taking startup program started with notably Standard Model and QCD groups
  - Plan being developed for basic distributions, e.g. jet and lepton spectra
- Trigger
  - Trigger awareness with upcoming CSC data
  - We HAVE to be aware of trigger
  - Utilizing trigger redundancies in top events
    - Determine efficiencies

Opportunities

- Top physics working group is (still) relatively small
  - Upto today mainly concentrated on clean signal
  - Effort for top as calibration only started
- Realism in top analyses
  - Missing close connections to performance groups.
    - E-gamma, b-tagging, tracking, jets
    - Lots of room to contribute here
    - Will take off in coming period I hope!
  - CSC data sets become available soon
    - Please join the validation efforts
    - We have a MC set with top pT>500 GeV. Who looks at this?
- Give feedback in top meetings @ CERN
  - Frequency ok?



CSC Top event

MC samples for top

- CSC data
  - http://jarguin.home.cern.ch/jarguin/dc3requests_sm.html
  - Ttbar:
    - Set on "Only Fully hadronic" and set on "Only non fully hadronic"
    - MC@NLO and AcerMC
  - Single top
    - AcerMC for channels separately

Work to do in the top group

- Validation on MC samples

Generator studies and Monte Carlo validation

Comparison ttbar generators

Pythia, Herwig and MC@NLO: ***NIKHEF (S. Bentvelsen)*** This study is presented in earlier top meetings and written up as part of the Atlas note ATL–PHYS–PUB–2005–024

Comparison generators TopReX with AcerMC

◊ ***ttbar*** production : ***Marseille*** Preparation for DC3 (B.Resende)
◊ ***single–top*** production : ***LPSC Grenoble*** Preparation for DC3 (A.Lleres, A.Lucotte)
◊ Link to MC Validation Page

Evaluation W+n jets background

NIKHEF (I. van Vulpen and W. Verkerke) this is presented in earlier top meetings. Also interest from Joey Huston.

Reconstructing top without b–tagging

Udine (M Cobal) and ***NIKHEF (S. Bentvelsen, I. van Vulpen and W Verkerke)***. A note on fast simulation has been produced.

Tools, systematics and contact with performance groups, trigger

Calibration of jets using W–boson

A lot of work has been done to calibrate the linearity of the calorimeter using hadronic decays from the W of the top decay. ***Clermont Ferront (D. Pallin, E. cogneras, P.O. Defay), Saclay(A.I Etienvre, J.P. Meyer,J. Schwindling)***

Electron performance

Marseille

Muon performance

??

Jet finding

Cone sizes, iterative clustering, high Pt big cones, effect of jet algorithms ***Wuppertal (M. Sandhoff)***.

Tagging of b–jets using tops

Displaced vertices, soft lepton tags. So far the top group has been *using* the b–tagging. Can we improve on estimating and optimizing the b–tagging using zero or single b–tags in ttbar? ***Wuppertal (G. Gorfine), CERN (contact R Hawkings)***

Initial and final state radiation

Upto now the systematics have been estimated turning the ISR and FSR in Pythia on and off respectively, and take some percentage of the observed difference. A more detailed and realistic estimate for this uncertainty needs to be performed. ***Not covered***

Trigger issues

Manchester (T. Wengler, S. Head), CERN (A. Krasznahorkay) triggering complete events

The mass of the Top–quark (high precision)

Generator studies
- First comparisons between Pythia and MCatNLO? done by ***Saclay***

Top mass in semi–leptonic channel
- ***CLERMONT (D. Pallin, E. cogneras, P.O. Defay), Saclay(A.I Etienvre, J.P. Meyer,J. Schwindling),Tufts(K. Sliwa)***

Top mass with High Pt semi–leptonic sample
- TBD

Top mass in fully hadronic channel
- TBD

Top mass in di–lepton channel
- ***LPNHE Paris(F. Derue, D. Lacour, I. Nikolic–Audit, M. Ridel, S. Trincaz–Duvoid), Prague (V. Simak),Tufts (S. Todorova, K. Sliwa)***

Top mass using the mean b decay length
- ***Birmingham (Dimitrios Typaldos)***

Top mass using lepton's Pt
- ***Athens (N. Giokaris, A Antonaki)***

Top mass from total cross section
- ***CERN (contact R Hawkings)***

Tools and contact with performance groups, trigger

Calorimeter uniformity and performance

A study assuming pessimistically that part of the EM calorimeter does not respond is performed by ***Saclay***.

Electron performance

LPNHE Paris

Trigger

Birmingham (A Watson, J Thomas) calorimeter trigger. ***Manchester (T. Wengler, S. Head), CERN (A. Krasznahorkay)*** triggering complete events – See also commissioning.

Tagging of b–jets

LPNHE Paris for soft electron b–tag, ***CERN for vertex and perhaps soft muon b–tag***, see also commissioning.

- Concerning the talk, it would be brilliant if you could
  - give us a general overview over ATLAS-top
  - indicate what needs to be done in terms of top/general ATLAS analysis
    and calibration ... MC ... infrastructure, validation of background estimation methods, measurements of trigger efficiencies, determination of object resolutions ... all using data methods.
    Is there some ATLAS-wide plan/coordination of such projects (although each quantity probably needs to be reevaluated for the different analyses) ?
  - point out which `infrastructure' topics are uncovered or would welcome help
  - point out which physics analysis MC studies are uncovered, would welcome help or might be interesting to start.