Top physics studies in Atlas

E. Monnier
on behalf of the Atlas collaboration

- Introduction
- Top mass measurement
- Commissioning
- Coupling
- Single top
- Spin correlations…
- Conclusion

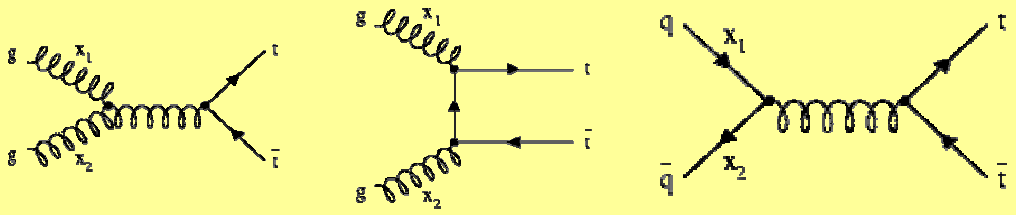
Top production

Low lumi = 10 fb^{-1}/y

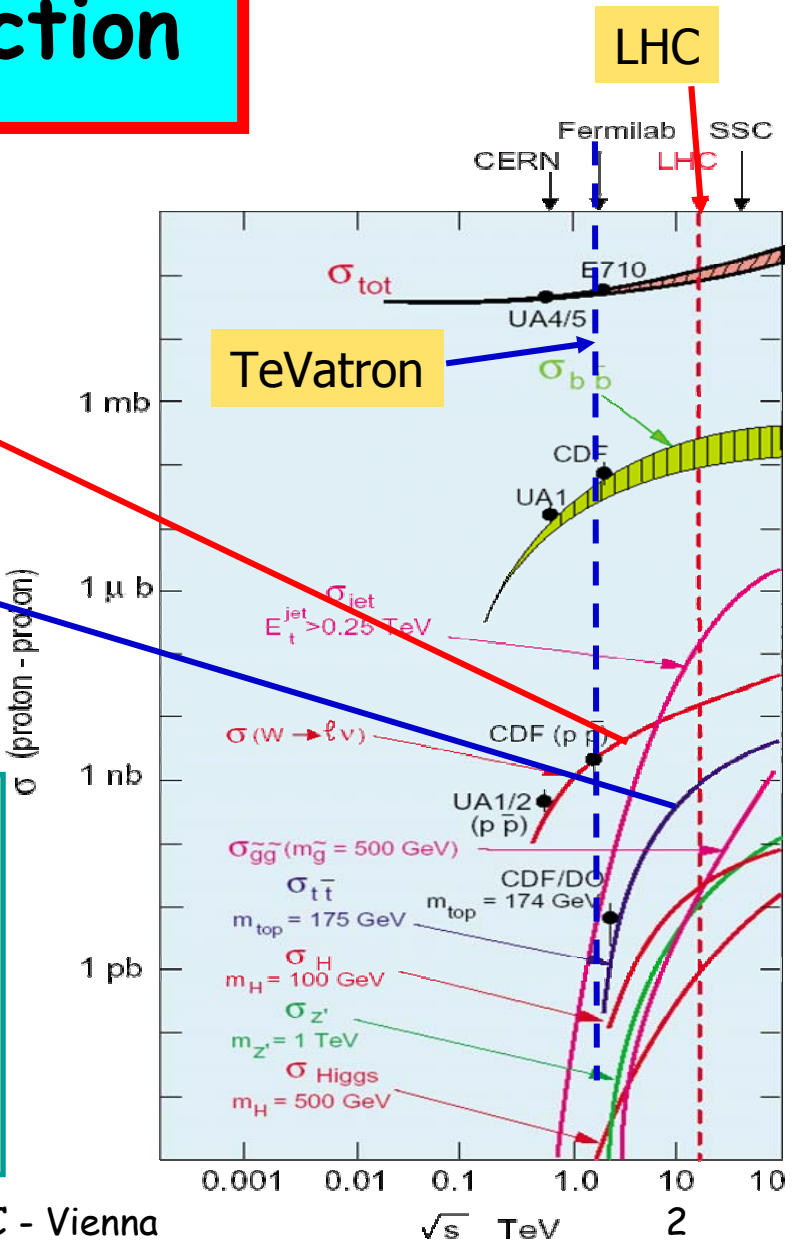
Process	σ(pb)	N/s	N/year	Total collected before start of LHC
W→ lν	3×10^4	30	10^8	10^4 LEP / 10^7 FNAL
Z→ ee	1.5×10^3	1.5	10^7	10^7 LEP
tt	830	1	10^7	10^4 Tevatron
bb	5×10^8	10^6	10^{13}	10^9 Belle/BaBar ?

→ LHC top factory !

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



~90% gg (Opposite @ FNAL) ~10% qq



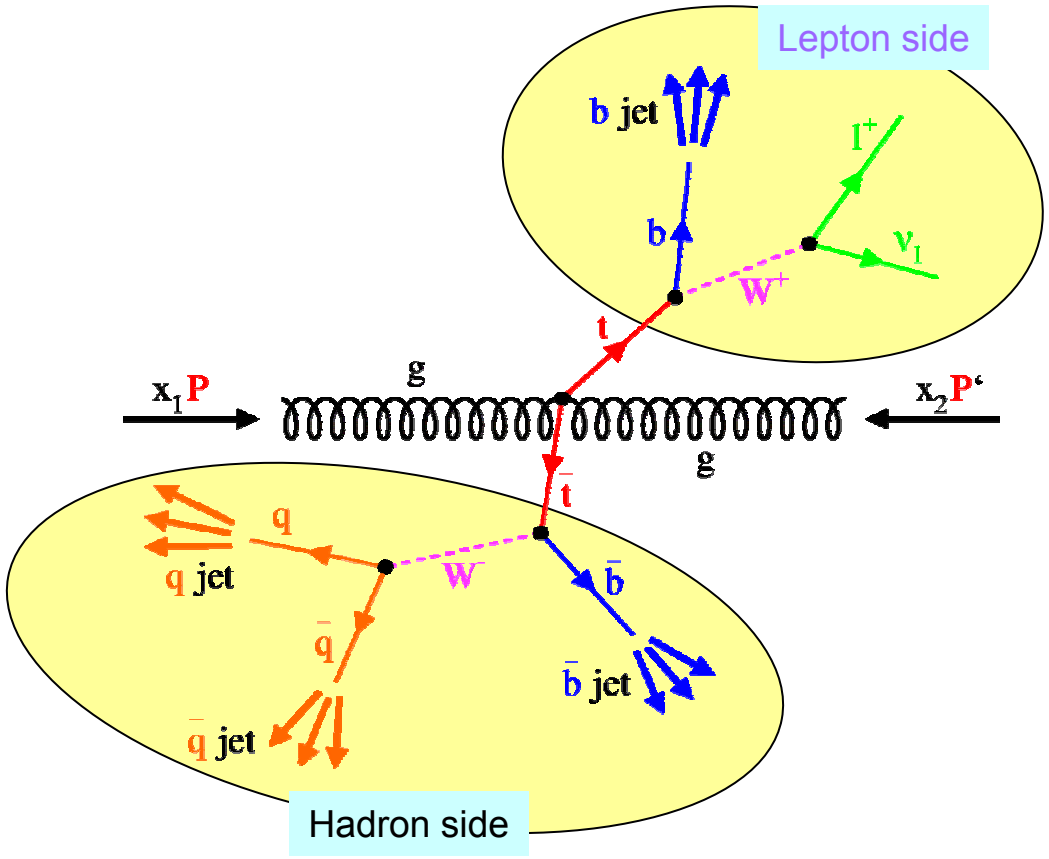
Interest to study top quarks

- Mass is a fundamental parameter of the SM
- 178 ± 4 GeV → heaviest known particle
- Life time 10^{-24}s → decay before hadronization
- Abundant

→ Detailed top properties probe SM and beyond

- New heavy particles produce top quarks
- Background for beyond the SM physics
- Detector calibration

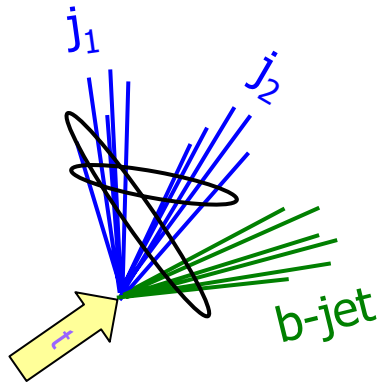
Top Decays



- Dileptons 5%
- Semi-leptonic 30%
- Hadronic 45%
- Tau+X 21%

Top mass: Semi-leptonic case

SN-ATLAS-2004-040



- Isolated lepton PT>20 GeV
- ETmiss>20 GeV
- 4 jets with PT>40 GeV $\Delta R=0.4$
- >1 b-jet ($\varepsilon_b \approx 60\%$, $r_{uds} \approx 10^{-2}$, $r_c \approx 10^{-1}$)

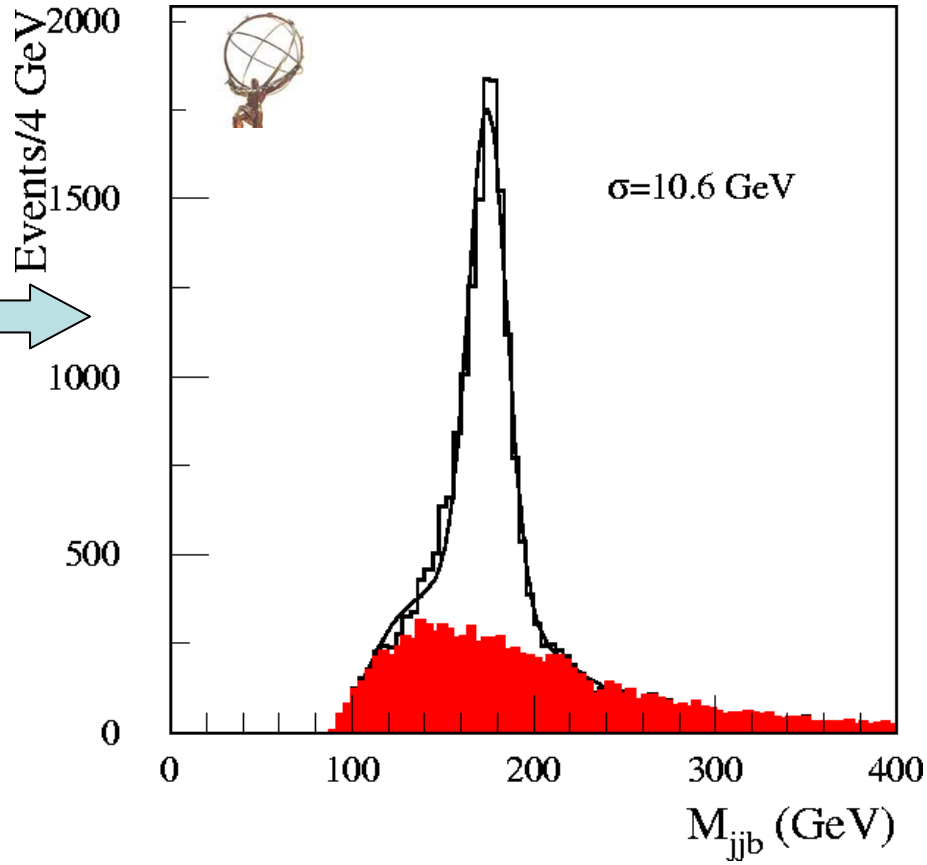
Hadron side:

- Require $|M_W - M_{jj}| < 20$ GeV
- light jet calibrated with M_W

Lepton side:

- $|m_{lvb} - \langle m_{jjb} \rangle| < 35$ GeV
- Kinematic fit with M_W constraint

- 70% purity and 1.2% efficiency
- Background (<2%):
- W/Z+jets, WW/ZZ/WZ…

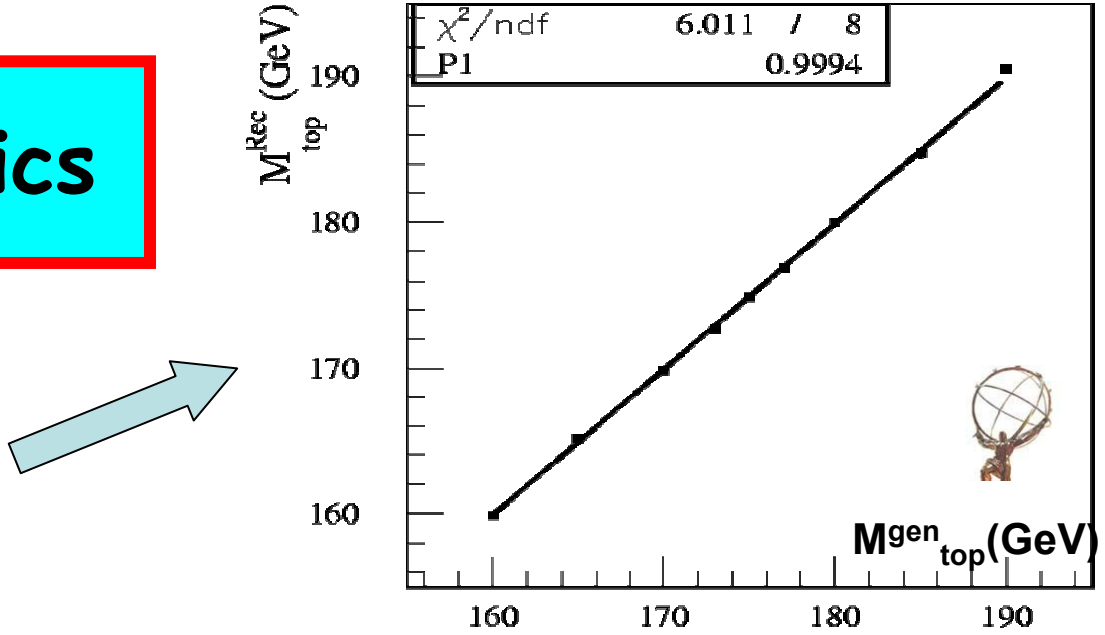


Mass systematics

- **Fit method work:**
  linear with input M_{top}
  independent of top P_T
- **Biggest uncertainties:**
  Jet energy calibration
  FSR: 'out of cone' give large variations in mass
  B-fragmentation
- **Detailed simulation underway (DC2)**

Challenge:

δMtop at 1GeV after 1 LHC year ?

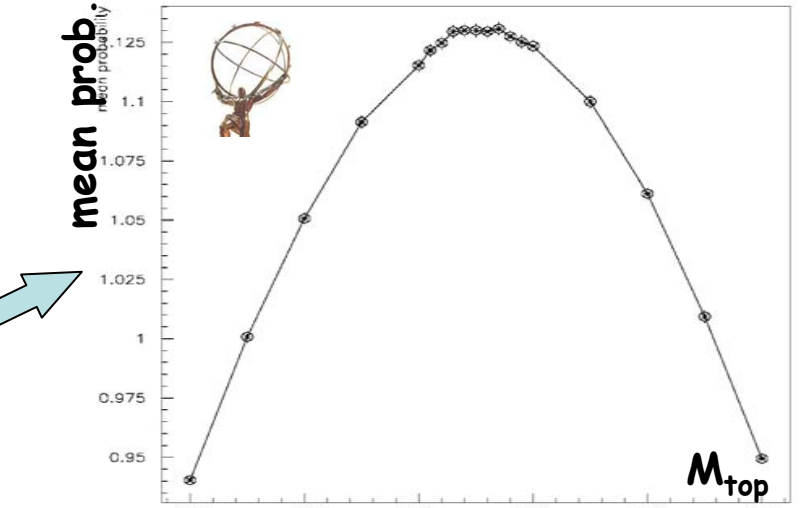


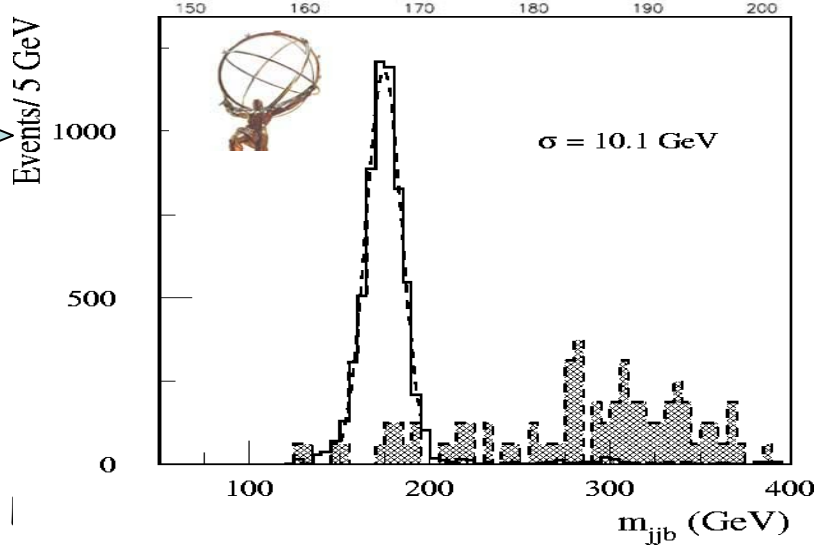
Source of uncertainty	Hadronic δM_{top} (GeV)	Fitted δM_{top}(GeV)
Light jet scale	0.2	0.2
b-jet scale	0.7	0.7
b-quark fragm	0.1	0.1
ISR	0.1	0.1
FSR	1.0	0.5
Comb bkg	0.1	0.1
Total	1.3	0.9
Stat	0.1	0.1

Alternative methods

All have different systematics but similar values up to 3 GeV

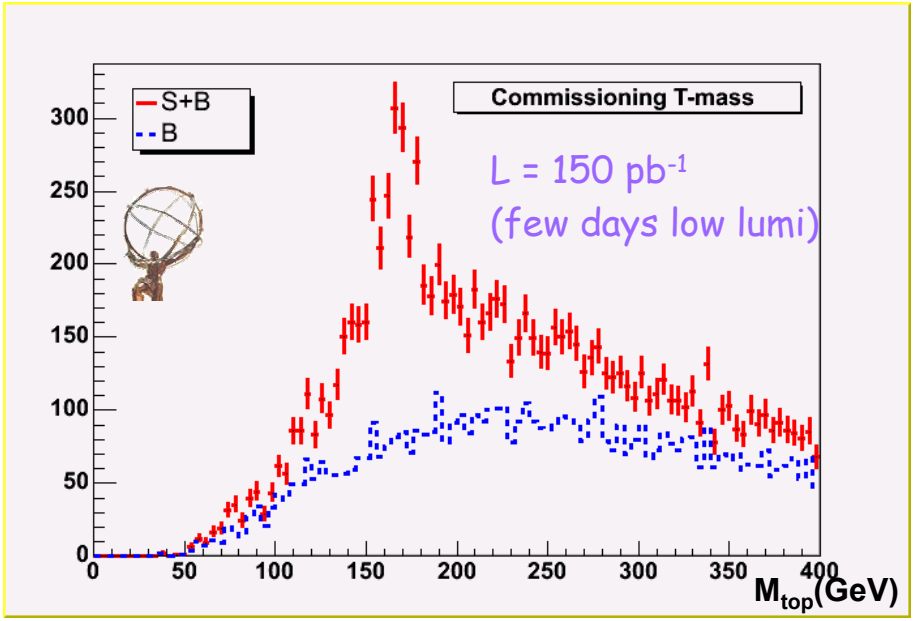
- High P_T semi-leptonic
  (>200GeV and large $\Delta R>0.8$ and hemisphere separation)
- Dilepton mass extraction
  (fit procedure with various input M_{top})(80000evt/y S/B=10)
- All Hadronic events
  Difficult jet environement
  $P_T>200$GeV, S/B=18
- Semi-leptonic + J/ψ at high lumi





Commissioning

- Commissioning phase:
  - No b-tagging
  - No jet calibration
  - Good lepton id
- Semi-leptonic evts selection
- jet calib with W → jj
- Signal + background at initial phase of LHC

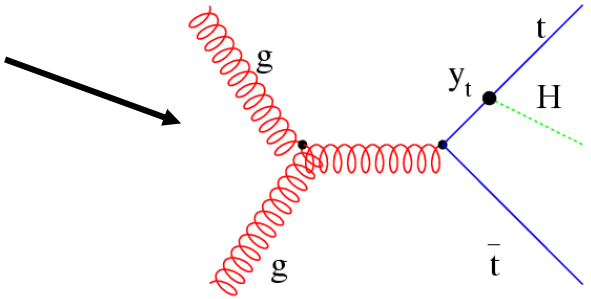


→ Top peak visible, minimal selection and reco (3-7 GeV)

+ isolated High pT leptons
+ B-tagging and Bjet studies
+ $\Delta\sigma_{stat}$ ~ 2% (1 week)

Other Top quark properties

- Does the top quark behaves as expected in the SM?
- Yukawa coupling to Higgs from ttbarH events
- Electric charge
- Top spin polarization
- CP violation



- Br(t $\rightarrow$Wb) $\approx$ 99.9%, Br(t $\rightarrow$ Ws) $\approx$ 0.1%, Br(t $\rightarrow$ Wd) $\approx$ 0.01%

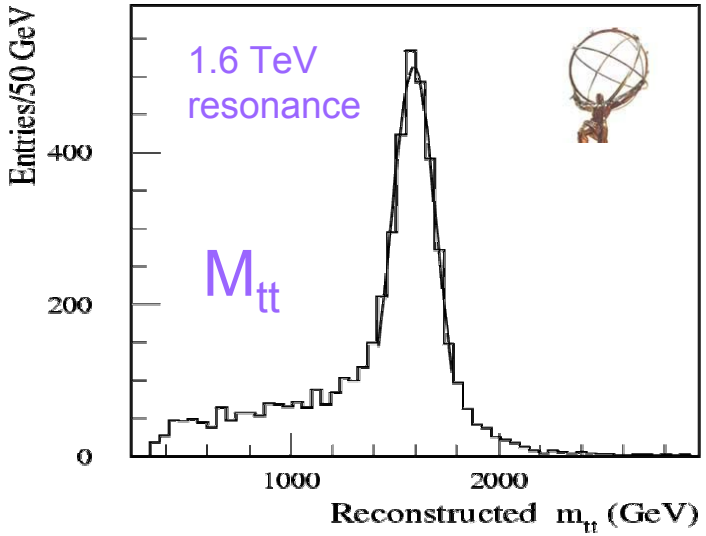
(difficult to measure, need excellent understanding of b-tagging)

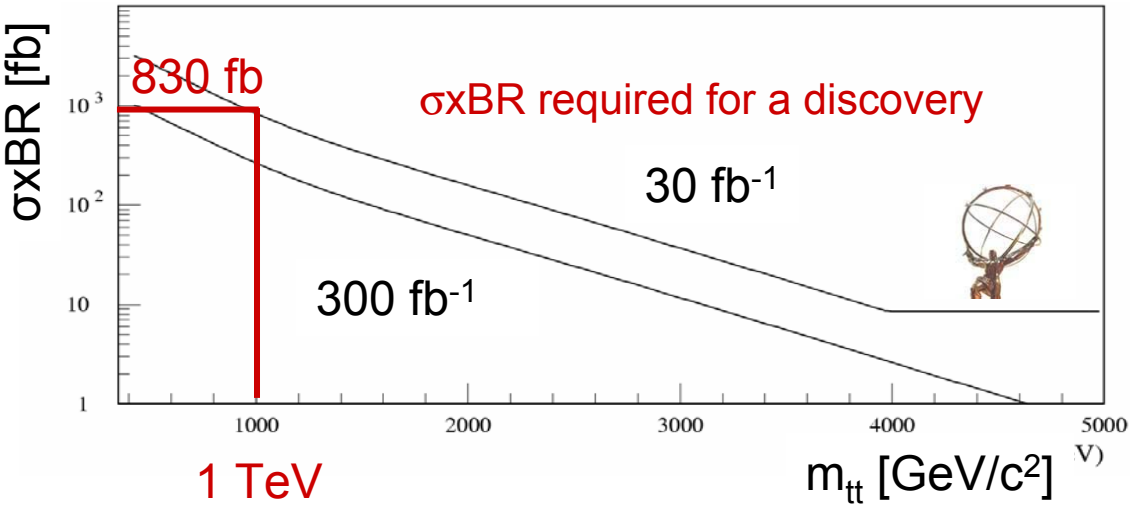
- Many decays outside SM $\rightarrow$ anomalous coupling with clear signature
- FCNC decays highly supressed (Br<10^{-13}-10^{-10}) and 10^{-3} to 10^{-5} sensitivity…

Search for resonances

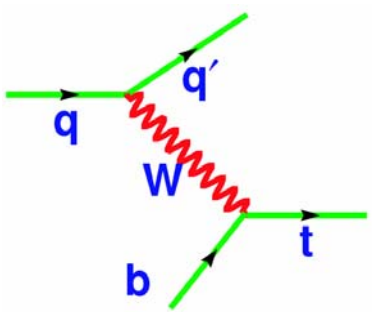
- Many models have resonances decaying in tt:
  - SM Higgs (BR smaller with respect to the WW and ZZ decays)
  - MSSM Higgs (H/A, if mH,mA>2mt, BR(H/A→tt)≈1 for tanβ≈1)
  - Technicolor Models, strong ElectroWeak Symmetry Breaking…
- Study of X if σ_X, Γ_X and BR(X→tt) predicted

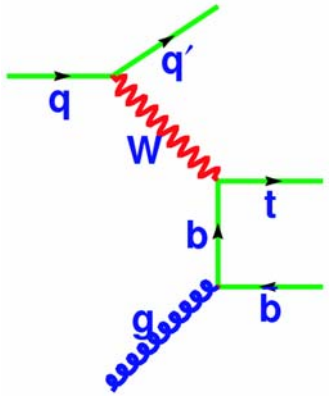
  Efficiency for semi-leptonic evts: 20% m_{tt}=400GeV – 15% m_{tt}=2TeV





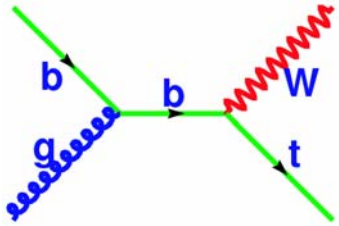
Single Top production





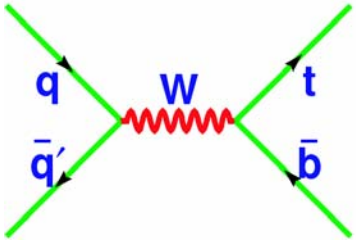
Wg Fusion 245±27 pb

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

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

- Vtb measurement to % level with 30 fb^{-1}
- Independent mass measurement
- Top spin polarization
- Probe for FCNC
- Background are tt, wbb, wjj

Top spin correlations

- Since no hadronisation: daughter keep spin info
- Study in semi-leptonic and di-leptonic

Spin analyser:

Leptonic: lepton

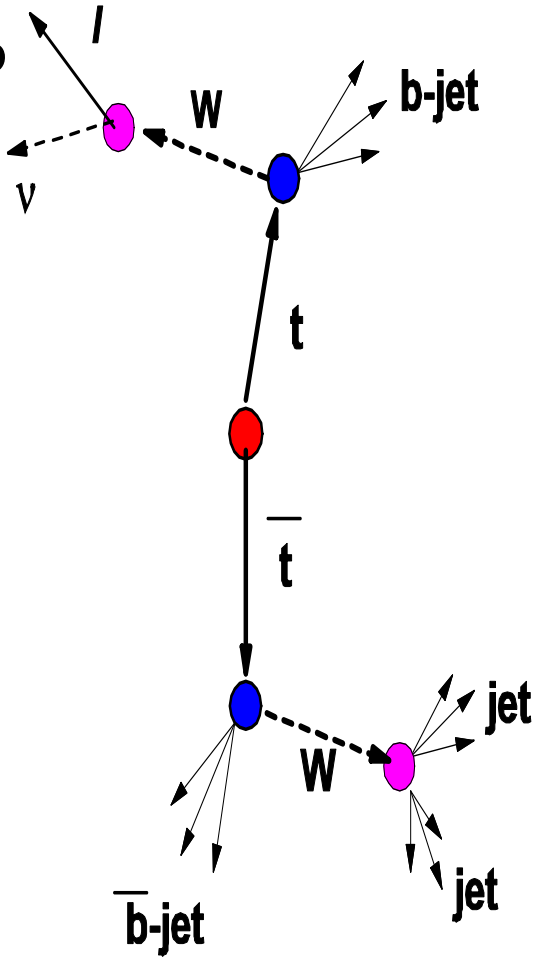
Hadronic: (W, b) or least energetic jet (lej)

Interesting angles:

· Θ_1 (Θ_2) : angle between chosen spin axis and spin analyzer direction in the t(t) rest frame.

Spin axis is t(t) direction in the parton c.m.s. (helicity basis)

· φ : angle between spin analyzers direction in the t(t) rest frame



Spin correlation variables

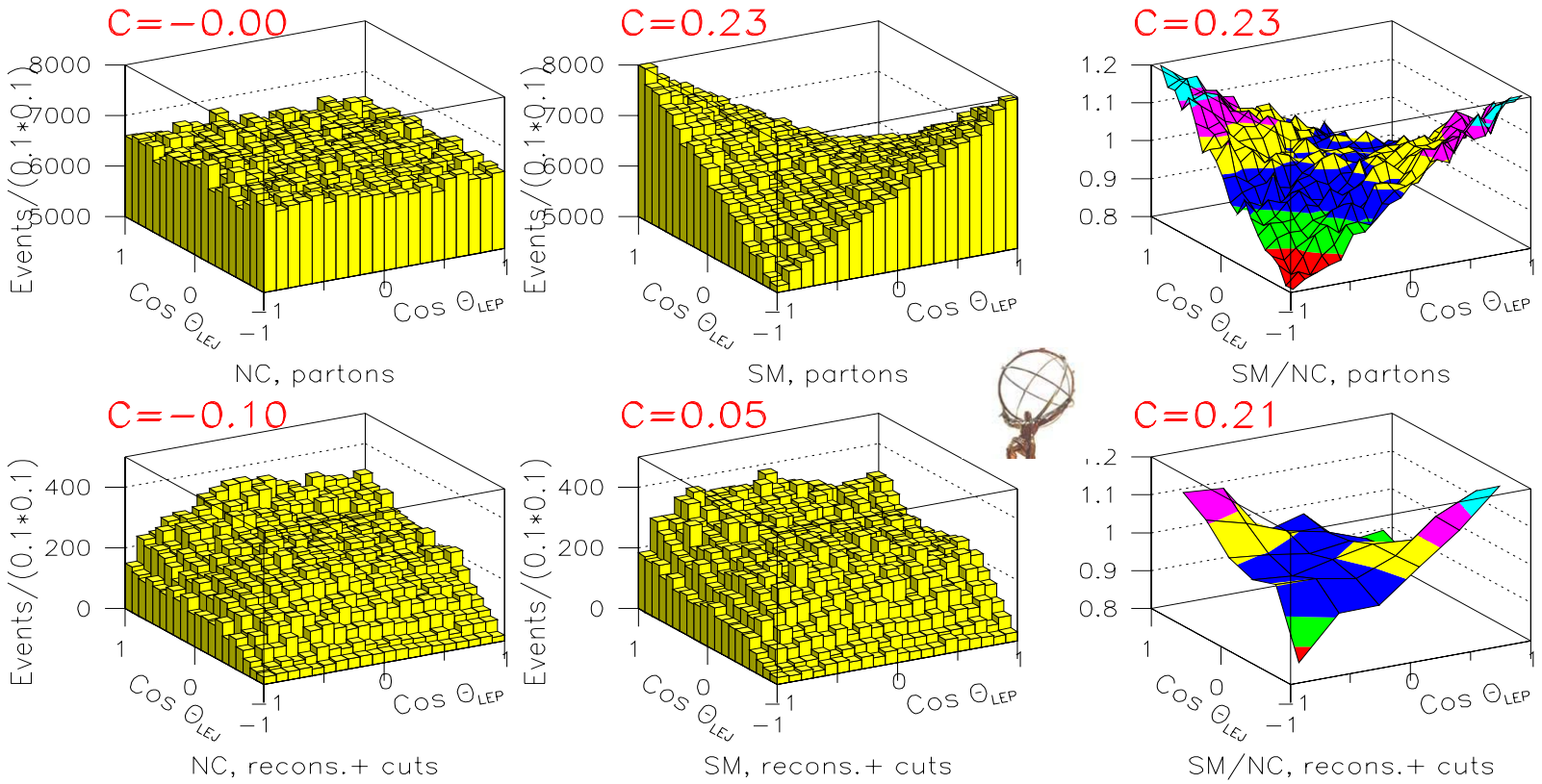
$$\frac{1}{N}\frac{d^2N}{d(\cos\theta_1)d(\cos\theta_2)} = \frac{1}{4}(1 - C\cos\theta_1\cos\theta_2) \qquad \frac{1}{N}\frac{dN}{d\cos\varphi} = \frac{1}{2}(1 - D\cos\varphi)$$

Unbiased estimator of C : $-9 < \cos\theta_1 \cos\theta_2 > = 0.16$ or (0.23 if Mtt cut)

Unbiased estimator of D : $-3 < \cos\varphi > = -0.11$ or (-0.16 if Mtt cut)

- TopReX 4.05 (SM): LO spin correlation simulation
- Pythia 6.221 (NC): hadronisation, fragmentation and decays with CTEQ5L structure function, ISR-FSR
- AlpGen: used for W+jets background
- Tauola+Photos 2.6: t decay and radiative corrections
- Atlfast 2.60: ATLAS fast simulation and reconstruction

C extraction



Results for S + B (± stat. ±syst errors) : 80500 S, S/B=15

- **C(lej) = 0.21 ± 0.015 ± 0.04 = ~ 5 σ from 0**
- **D(lej) = -0.12 ± 0.01 ± 0.02 = ~ 5 σ from 0**

Spin correlation efficiency

- Semi-leptonic analysis probe SM at 5 σ after 1 year at low lumi.
- Di-leptonic analysis complementary and similar power
- Single top can bring additional infos

- Polarization probe the "bare quark" so sensitivity to new physics such as extra dimension…

See M. Arai poster for ex.

Conclusion

- LHC top quark factory
- Many precise studies of top quark properties
- Goal measure m_t to 1 GeV seams achievable

- Probe the SM and window on new physic beyond SM
- First physics in Atlas will come from top quark analysis which then will become a background…

- But lots of work still to be ready
- MC tuning, full simulation, effect of real detector on studies (dead channels, …)