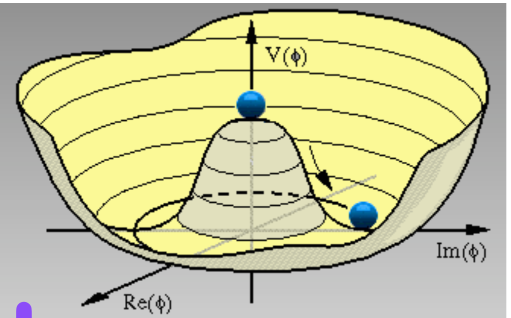


ATLAS discovery prospects for a light charged Higgs, $H^+ \rightarrow c\bar{s}$

Un-ki Yang

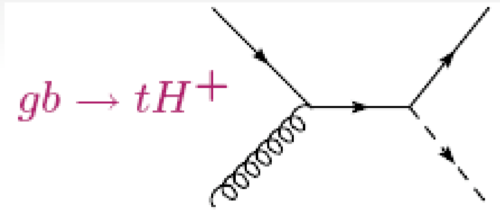
The University of Manchester

for the ATLAS collaboration

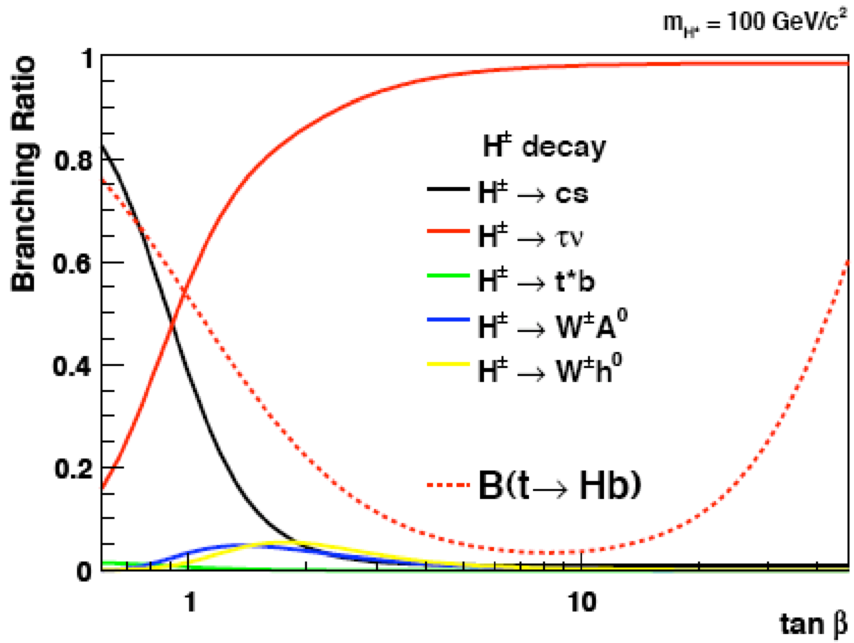
The 3rd Int. Workshop on Charged Higgs Discovery at Uppsala, Sep. 27-30, 2010

Charged Higgs, H^+ production

- Two Higgs Doublet Model for electro-weak symmetry breaking beyond the Standard Model:
  - H^0, h^0, A^0, $H^{\pm}$
- Direct production of charged Higgs at LHC is relatively small (0.1~0.01pb)



- But charged Higgs from top quark decays in MSSM
  - Huge top production
  - Focus on $H^+ \rightarrow c\bar{s}$ at low tanβ
  - Clean signature

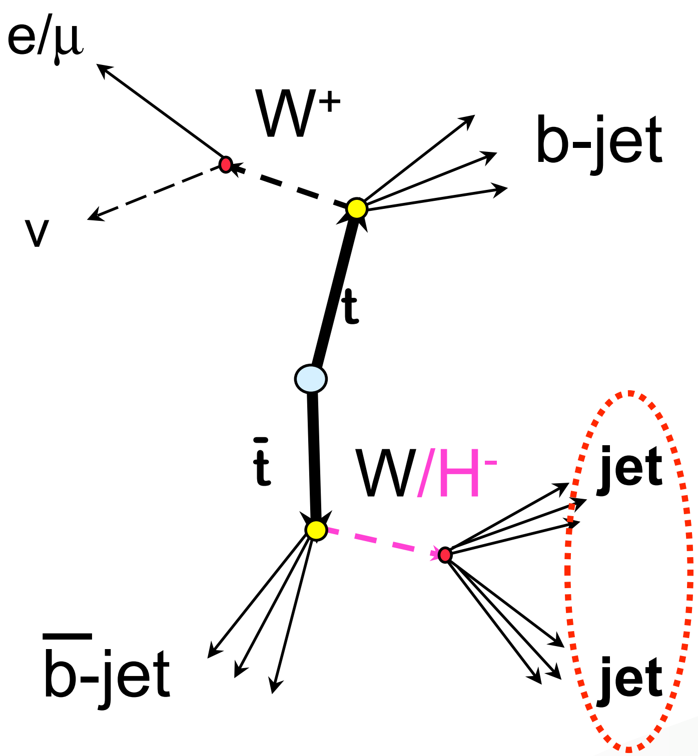


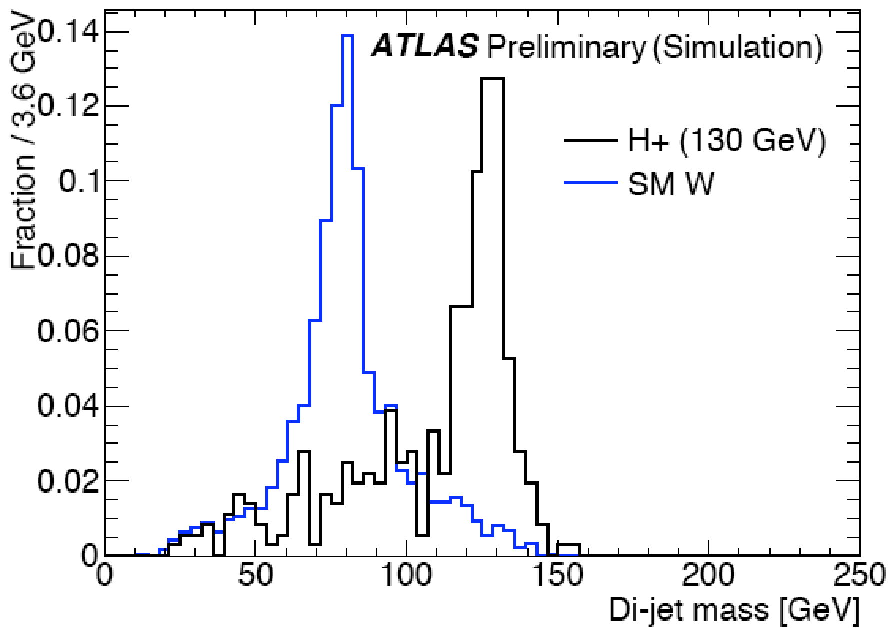
Direct Search for H^+ from top decays

- Search for $H^+ \rightarrow c\bar{s}$ from top decays at low tanβ (MSSM), and any generic charged Bosons (decay into two jets);

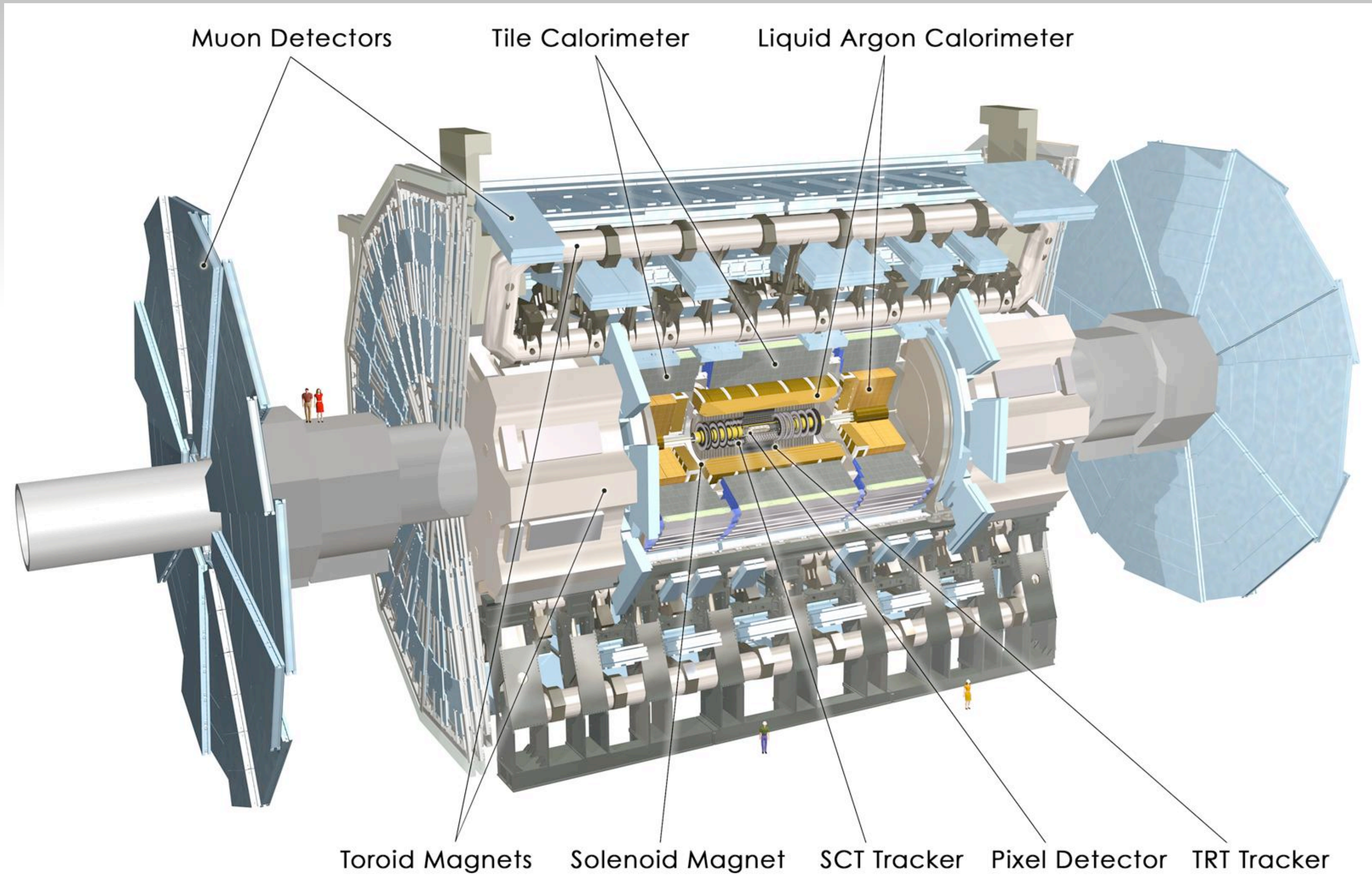
  a second bump in W mass distribution

- Semi-leptonic events: lepton (e/μ) + 4 jets with 2 b-jets





The ATLAS Detector



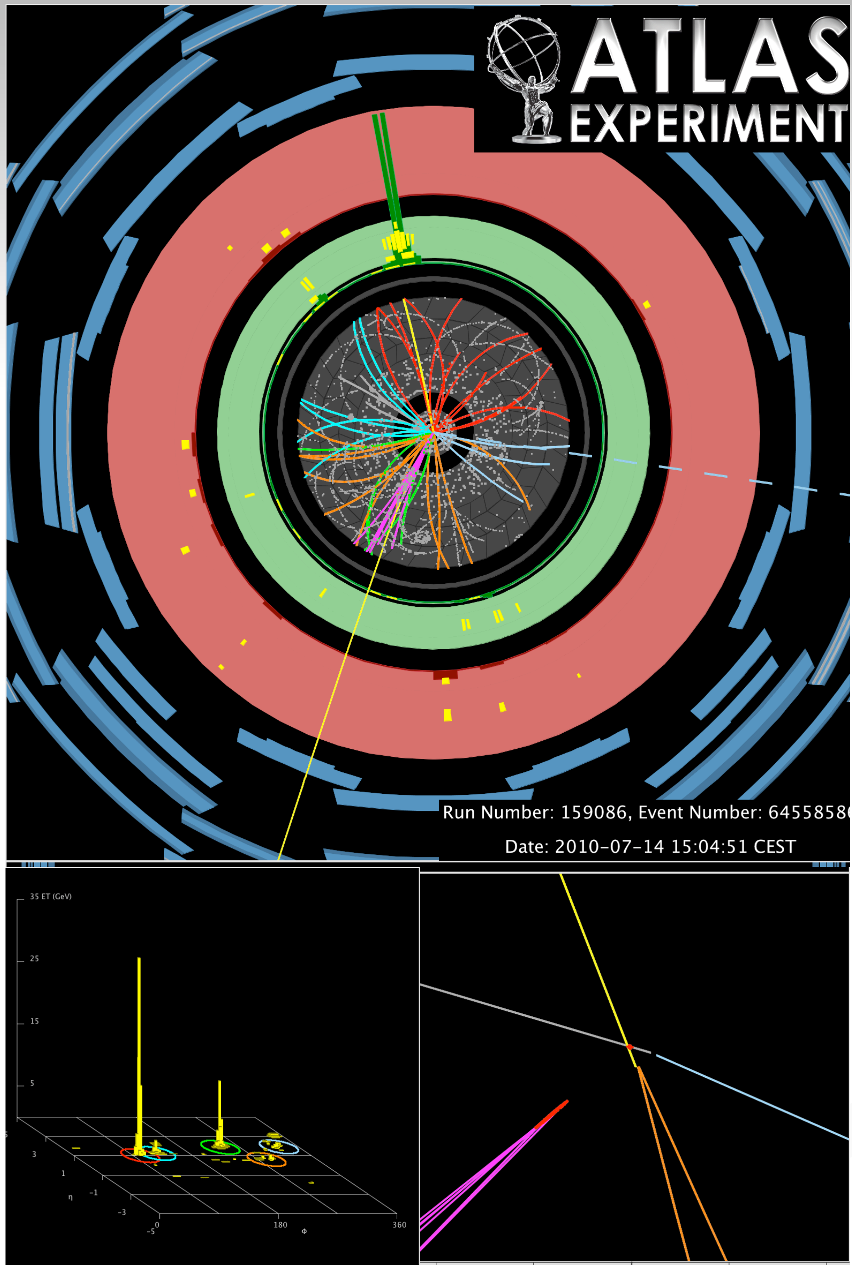
EM cal: LAr/Pb, $\sigma/E \sim 10\%/\sqrt{E}$

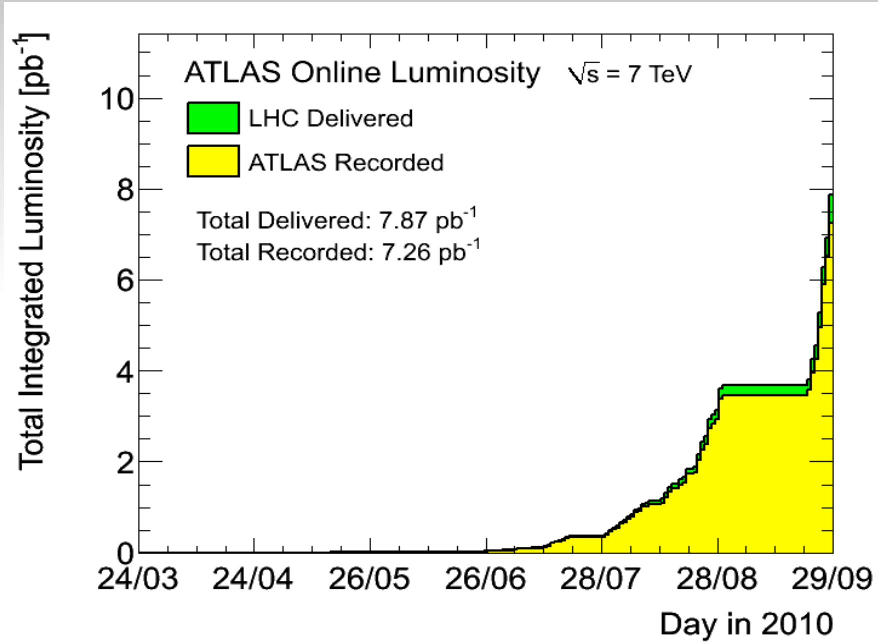
Had cal: Scint./Fe, $\sigma/E \sim 50\%/\sqrt{E}$

Tracking: $\Delta p_t/p_t \leq 0.05\%\, p_T \oplus 1\%$

muon spectrometer (η < 2.7):
$\Delta p/p$ < 10% up to 1 TeV

Top productions at the ATLAS

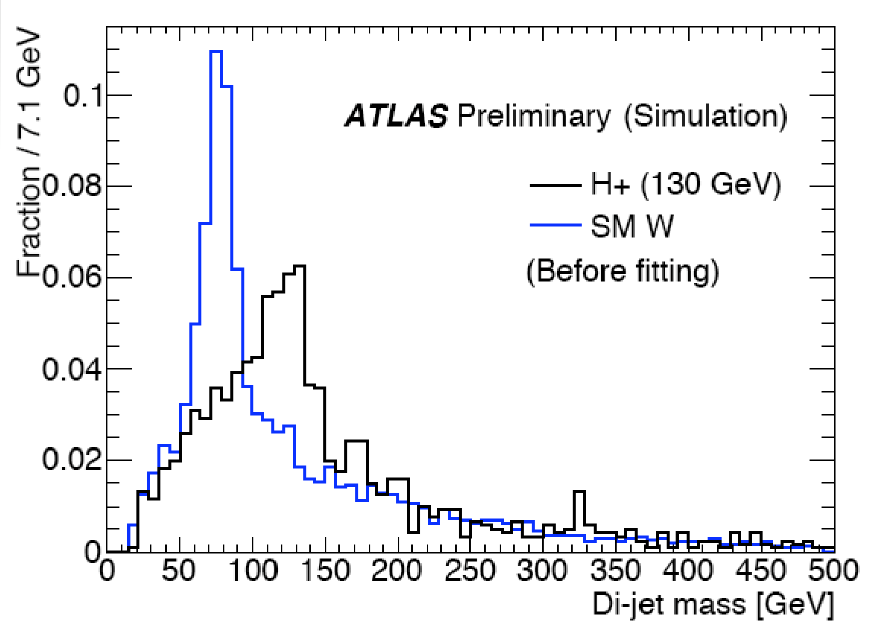




- **Talk: expected sensitivity on H^+ searches using early data**
  - **200 pb^{-1} at 10 TeV**
  - **1 fb^{-1} at 7 TeV**

Di-jet mass for H^+ signal

- Event selection cuts:
  - 1 lepton (e,μ) pt > 20 GeV
  - MET > 20 GeV
  - At least, 4 jets Et > 20 GeV
  - 2 of the leading 4 jets have b-tag based on the 3D impact parameter
  - Dominant bkgd: SM ttbar (non-ttbar: only 5%)



Reconstructed mass using two un-tagged jets

- How can we improve a di-jet mass resolution?

Improved Di-jet Mass using Kinematic Fitter

- Reconstruct whole ttbar event using kinematic χ^2 fitter
  - Constrain the masses of W(e/μ), two top quarks to be the PDG values
  - Fit the the pt of lepton, 4 leading jets within uncertainties

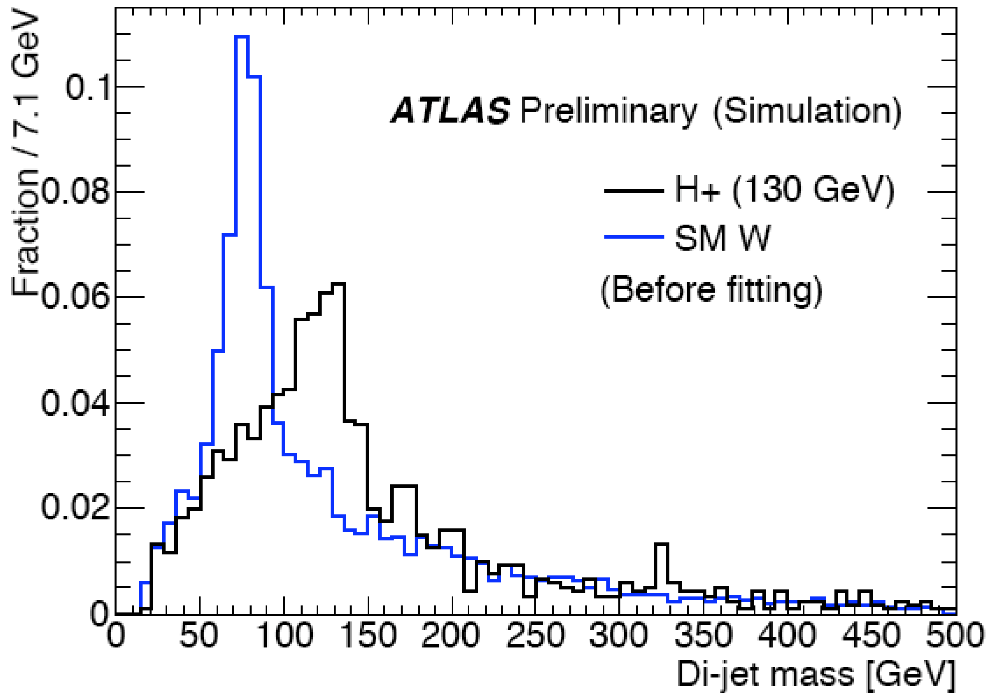
$$\chi^2 = \sum_{\substack{i=lepton,\\ 4\ jets}} \frac{\left(p_T^{i,fit} - p_T^{i,meas}\right)^2}{\sigma_i^2} + \sum_{j=x,y} \frac{\left(p_j^{UE,fit} - p_j^{UE,meas}\right)^2}{\sigma_{UE}^2} + \sum_{\substack{k=jjb,\\ l\nu b}} \frac{\left(M_k - M_{top}\right)^2}{\Gamma_{top}^2} + \frac{\left(M_{l\nu} - M_W\right)^2}{\Gamma_W^2}$$

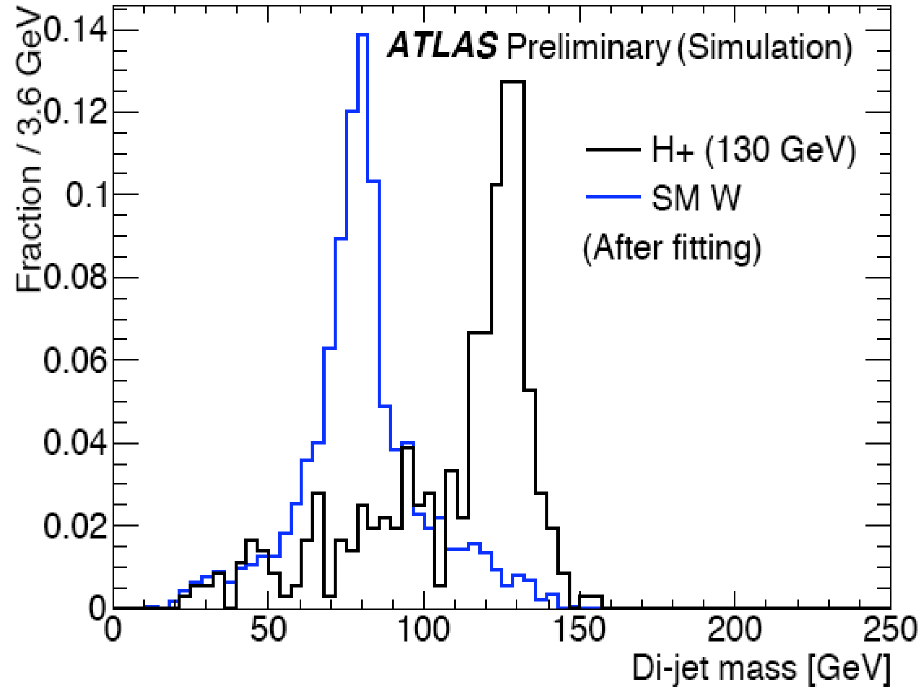
$$Pt(jet) = Fit \bullet TS\_corr \bullet Jet\_corr \bullet Pt(raw)$$

- For 2 b-tagged events:
  - Which b-jet belongs to top (or anti-top) quark?
    assignment is made with the choice of the lowest χ^2
  - But the events with χ^2>10 are removed (backgrounds or poorly reconstructed events)
  - Additional cut: Mjjb(top: unfitted)>195 GeV

Improved Di-jet Mass using Kinematic Fitter

- Reconstruct whole ttbar event using kinematic χ^2 fitter





- $\chi^2 < 10$ cut eff:
  43 % for ttbar
  19 % for W+jets

Expected Events for 200pb^{-1} at 10 TeV

Process	No Cuts (N events)	Lepton (%)	MET (%)	4 jets (%)	2 btags (%)	Trigger (%)	X^2 < 10 (%)	Mtop < 195 GeV
H+ (90 GeV)	4757	0.39	0.90	0.62	0.25	0.88	0.37	0.84 (72)
H+ (110 GeV)	4757	0.39	0.90	0.62	0.22	0.88	0.40	0.85 (70)
H+ (130 GeV)	4757	0.39	0.90	0.61	0.18	0.88	0.35	0.86 (48)
H+ (150 GeV)	4757	0.40	0.89	0.56	0.12	0.88	0.31	0.84 (27)
SM ttbar no all had	43680	0.39	0.91	0.51	0.27	0.88	0.43	0.86 (683)
Single Top	11792	0.41	0.89	0.17	0.20	0.88	0.24	0.80 (24)
W + jets	55220	0.37	0.86	0.33	0.01	0.89	0.19	0.75 (6)

- For signal, we take $B(t \rightarrow H^+b) = 0.1$ with $B(H^+ \rightarrow c\bar{s}) = 1$, closed to the current Tevatron limits
- Dominant background SM ttbar (95%)
- W+jets and QCD backgrounds:
  - flat di-jet mass distributions
  - less than 3% of the total backgrounds

Extract Signals

- Use a binned maximum likelihood fit to the di-jet mass dist.

$$LH = \prod \frac{\nu_i^{n_i} \times e^{-\nu_i}}{n_i!} \otimes G(N_{bkg}, \sigma_{Nbkg})$$

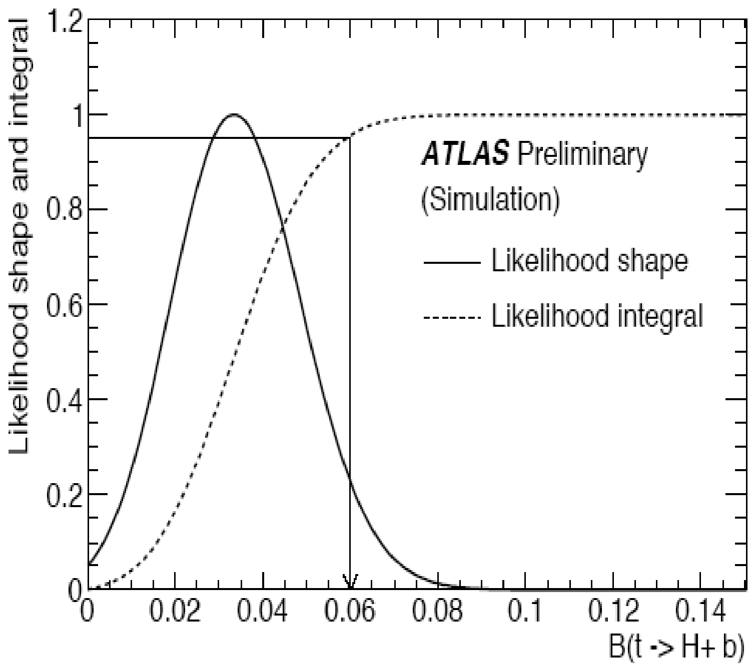
- Three fit parameters:
  - *B*(t → H⁺b)
  - Total N_{tt} (all normalization uncertainties absorbed)
  - N_{bkg} (non-ttbar bkgds): Gaussian constraint from independent measurement with δσ=30%

$$\nu_i(\text{expected}) = 2N_{t\bar{t}}B(1-B)A_{H^+}P_i^{H^+}B(W \to l\nu)$$
$$+ N_{t\bar{t}}(1-B)^2 A_W P_i^W B(W \to l\nu)\big(2 - B(W \to l\nu)\big)$$
$$+ N_{bkg}P_i^{bkgd}$$

n_i (observed events in bin i)

Sensitivity: Upper Limit on $B(t\rightarrow H^+b)$

- Assume no signal, we obtain 95% CL upper limit on $B(t\rightarrow H^+b)$ using set of 1000 pseudo-experiments (PEs)
- For each PE
  - Fit 3 parameters using the LH
  - Scan LH from $B(t\text{->}H^+b)$ = 0 to 1 with fitted values of N_{tt} and N_{bkg} to obtain 95% CL upper limit on $B(t\text{->}H^+b)$
- 95% CL on $B(t\rightarrow H^+b)$:
  - Take the mean value of the PEs results: no difference using the median value



Systematics

- Systematic in extracted limits
  - Acceptance and di-jet mass distributions
  - Effect due to overall normalization is negligible

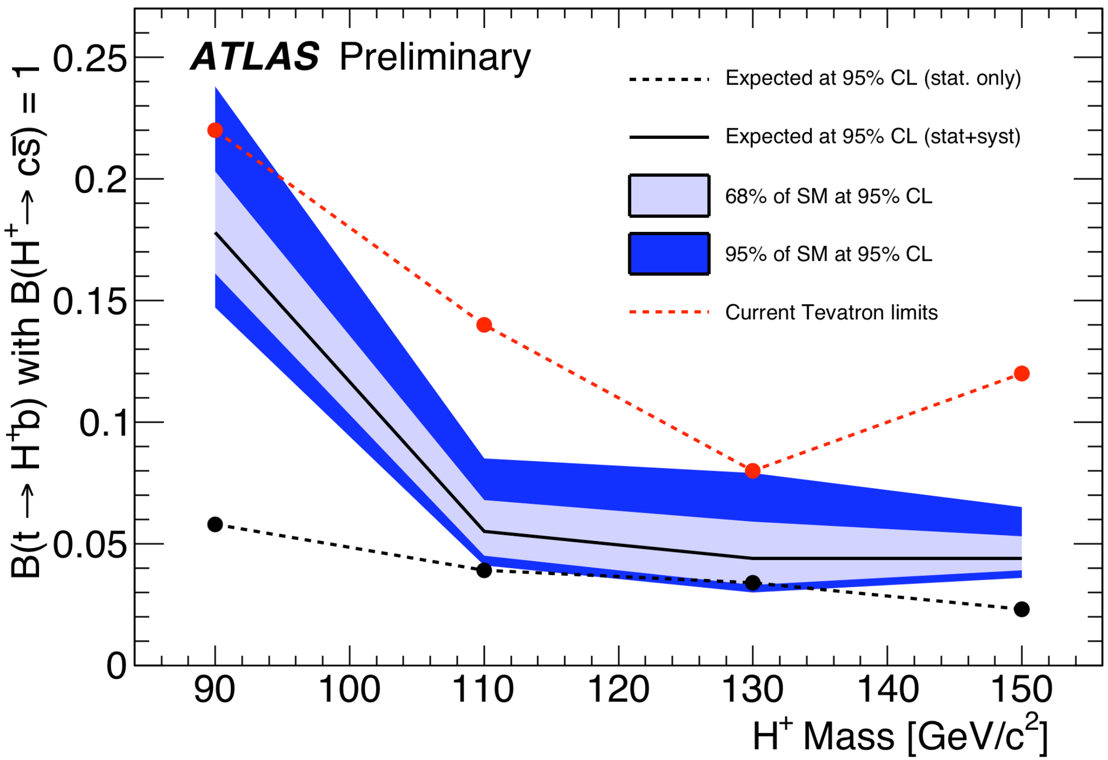
Systematic	Δ(B): 90 GeV	Δ(B): 130 GeV
Jet Energy Resolution	6.7%	0.7%
Jet Energy Scale (7% |ε|<3.2, 15% else)	0.9% (*5.8%)	0.1%
MC Generator (MCNLO vs AcerMC)	1.8%	0.6%
ISR/FSR	5.5%	0.5%
b-jet Energy Scale	3.3%	0.8%
Lepton Energy Scale	0.2%	0.1%
Combination	**9.4%**	**1.3%**

*: no recalib.

- JES recalibration using peak position in the di-jet mass dist.
  - Recalibration applied to all jets (Et>20 GeV)
  - Extra 3% uncertainty for b-jet energy
- See Simonetta Gentile's talk

Expected Limits at 10 TeV with 200pb^{-1}

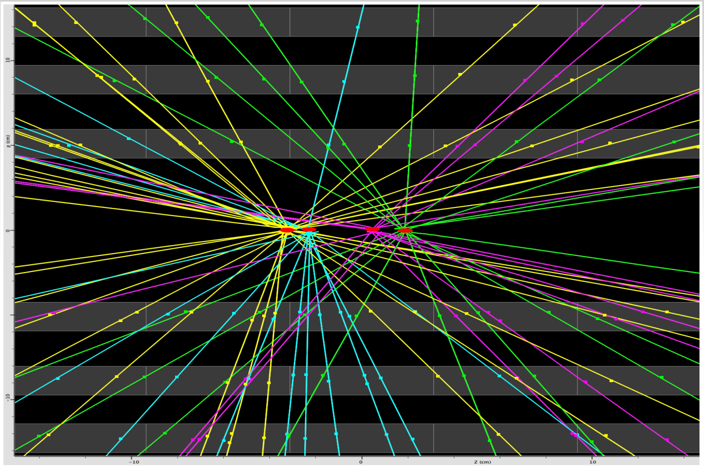
- For final limits including systematics;
  - Convolute LH with a Gaussian whose width describes the combination of all systematics

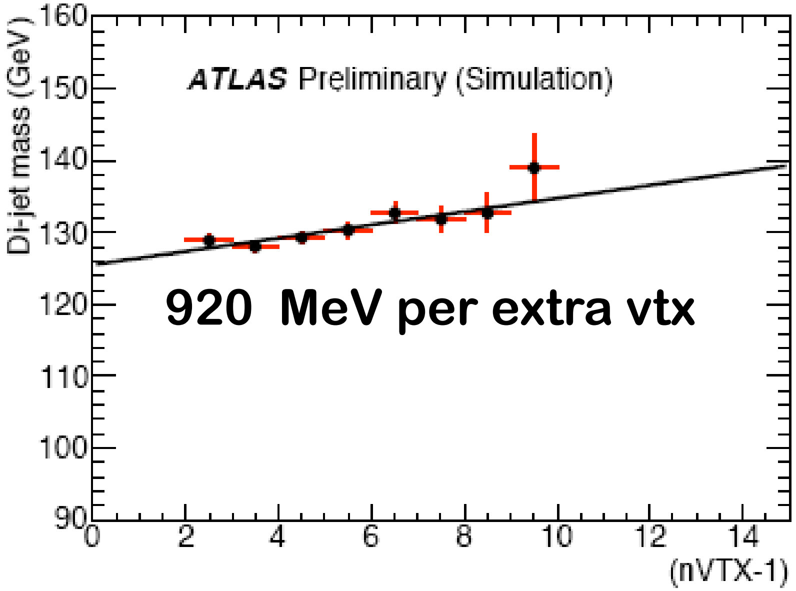


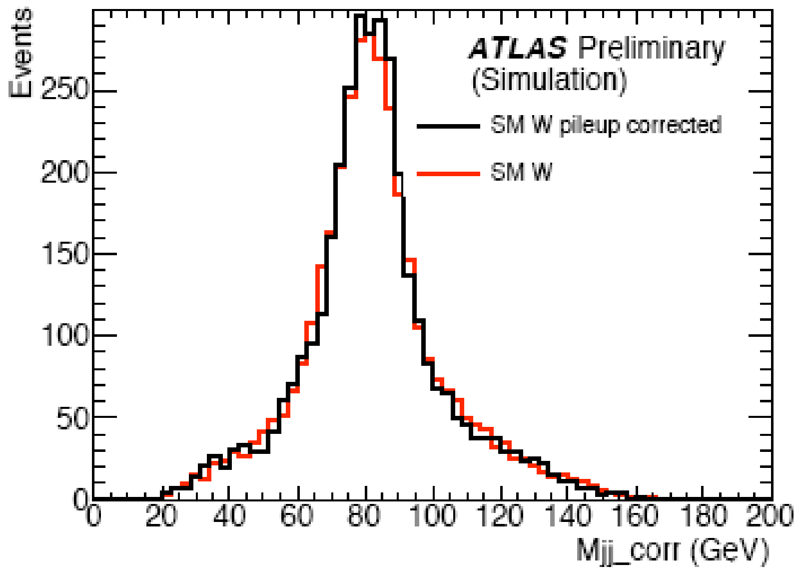
ATL-PHYS-PUB-2010-006

Pileup Effect

- **Pileup for lum 10^{32}, 450ns bunch spacing**







Pileup Effect

- **Efficiencies**

Process	cut efficiency (%) 1 lepton	E_T^{miss}	4 jets	2 b-tags	trigger
SM $t\bar{t}$, no pileup	0.390	0.906	0.507	0.270	0.883
SM $t\bar{t}$, pileup	0.385	0.907	0.628	0.256	0.873
SM $t\bar{t}$, pileup+recal	0.389	0.905	0.540	0.263	0.860
H^+ 90 GeV, no pileup	0.395	0.897	0.624	0.254	0.882
H^+ 90 GeV, pileup	0.389	0.898	0.718	0.232	0.860
H^+ 90 GeV, pileup+recal	0.389	0.898	0.645	0.236	0.863

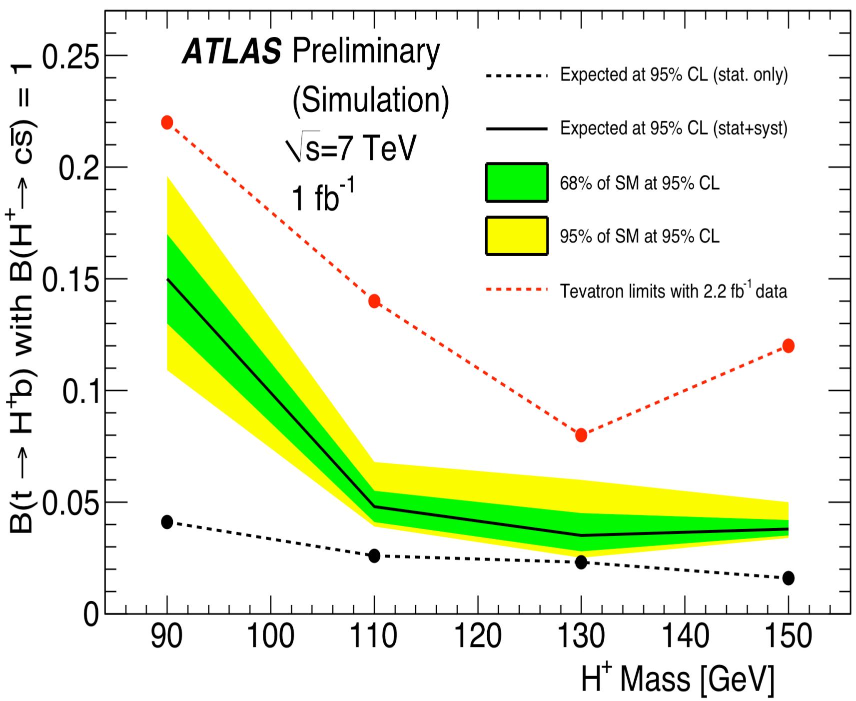
- **Limits**

	limits (with pileup)	limits (no pileup)
90	20.8%	17.8%
130	4.5%	4.4%

- Effect of the pileup is found to be between 3% and <0.3% as the charged Higgs mass increases from 90 to 130 GeV

Projected Limits at 7 TeV with 1fb^{-1}

- Slightly higher acceptances at 7 TeV (than 10 TeV) are used: SM ttbar(4%), signal(5-7%), more centralized jets, lepton within $|\eta|<2.5$
- The same dijet mass distributions for 7 TeV and 10 TeV are used for signal and SM ttbar: same at the generator level



M(H$^+$) [GeV]	Teva tron	10 TeV 200 pb^{-1}	7 TeV 1 fb^{-1}
90	22%	17.8%	15.0%
110	14%	5.5%	4.8%
130	8%	4.4%	3.5%
150	12%	4.3%	3.8%

ATL-PHYS-PUB-2010-009

Comparison of the sensitivities

M(H^+) [GeV]	B($t \rightarrow H^+ b$):	
	CDF @ 1.9 TeV 2.2 fb^{-1} (150 top evts)	ATLAS @7 TeV 1 fb^{-1} (14k top evts)
90	22% (17: stat.)	15.0%(5.8)
110	13%(10)	4.8%(3.9)
130	10%(9)	3.5%(3.4)
150	9%(8)	3.8%(2.3)

Summary & Discussions

- Search for a light charged Higgs boson in ATLAS is quite promising:
  - 1fb^{-1} data at 7 TeV & 200 pb^{-1} data at 10 TeV
  - a factor of 2~3 improvement compared to the Tevatron limits
- However, this promise wouldn't be free, it does require a lot of dedicated coherent works with Jet, top, and Higgs groups
  - Jet energy scale, resolution, and pileup etc
  - Lepton IDs, ttbar acceptance in semi-leptonic etc
  - W+jets, QCD bkgds etc
- With real data in our hand (7 pb^{-1} now, 1 fb^{-1} in near future), we can deliver our promise!!!

  \- many systematic checks are possible with real data -