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A Search for a Light Charged Higgs Boson Decaying to $c\bar{s}$

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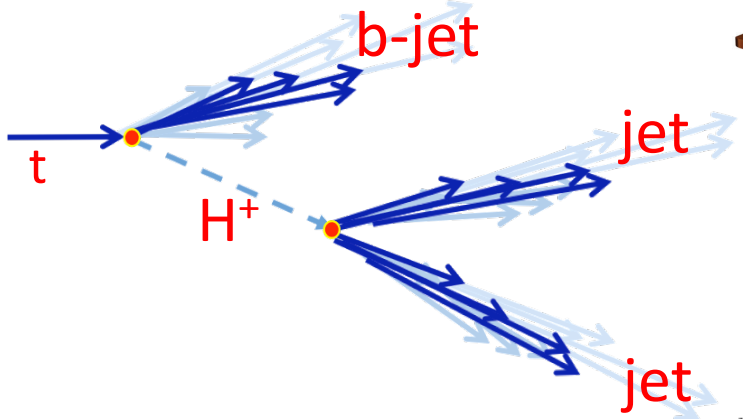
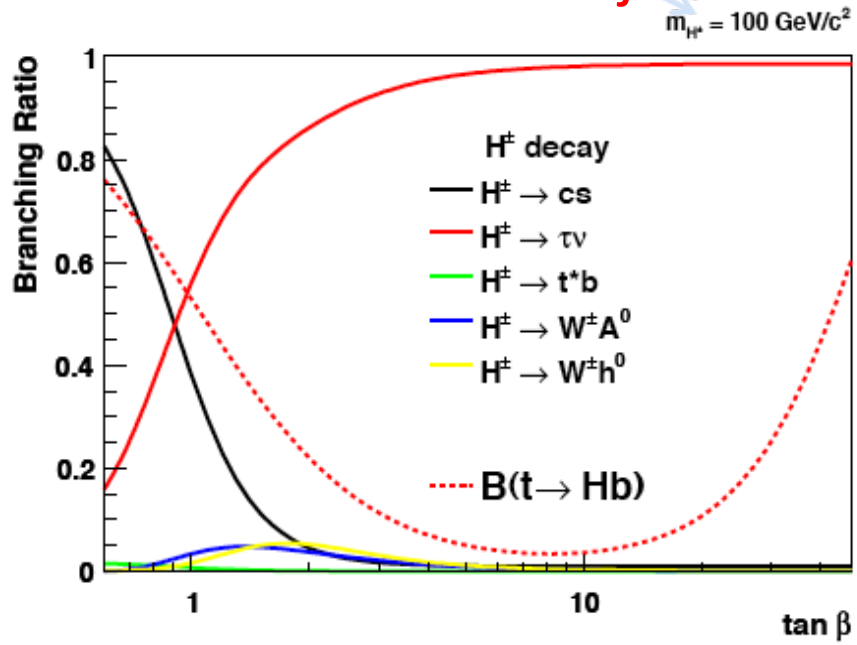
ATLAS Collaboration

Charged Higgs

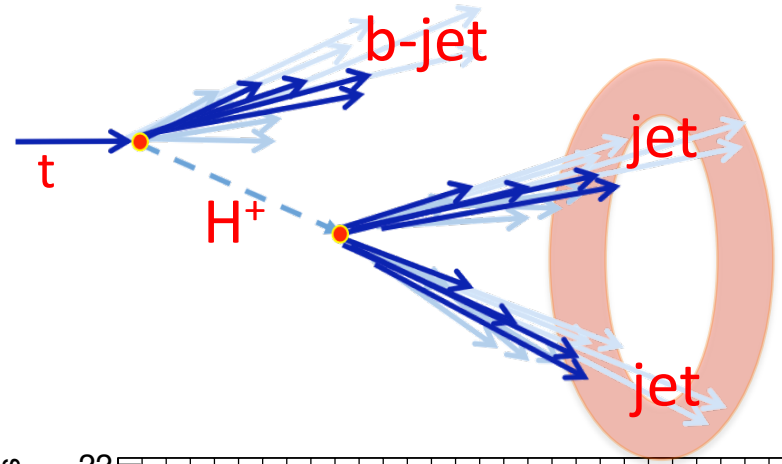
- Two Higgs Doublet Model for electro-weak symmetry breaking beyond the Standard Model:
  - H^0, h^0, A^0, $H^{\pm}$
- Direct production of charged Higgs at the LHC is relatively small (0.1~0.01pb)
- But a charged Higgs from top quark decays eg. in the MSSM
  - Huge top production
  - Tevatron limits on BR(t->H+b) ≈ 10-20% (Depending on M_{H+})
  - Focus on $H^+ \rightarrow cs$ at low tanβ
  - Complementary to τν channel which is dominant at high tanβ

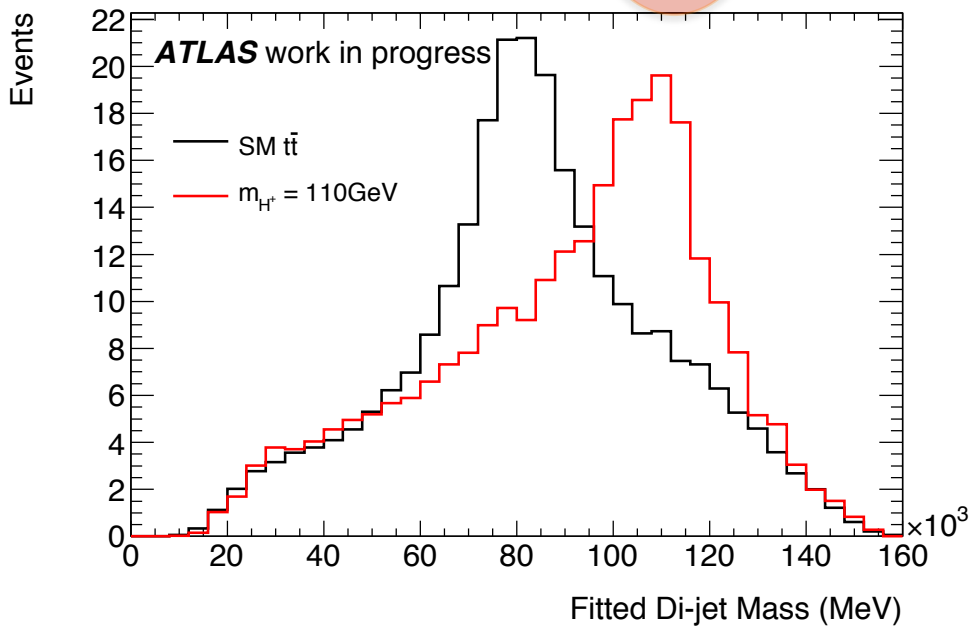




The Analysis in Brief

- Search for $H^+ \rightarrow cs$ from top decays
- Look for second peak in W di-jet mass distribution
- Semi-leptonic events:
  - lepton (e/μ)
  - Neutrino (E_T^{miss})
  - 4 jets
  - 2 b-jets
- Use a kinematic χ^2 fitter to fully reconstruct the ttbar events
- In doing so we improve the di-jet mass resolution and increase the separation power

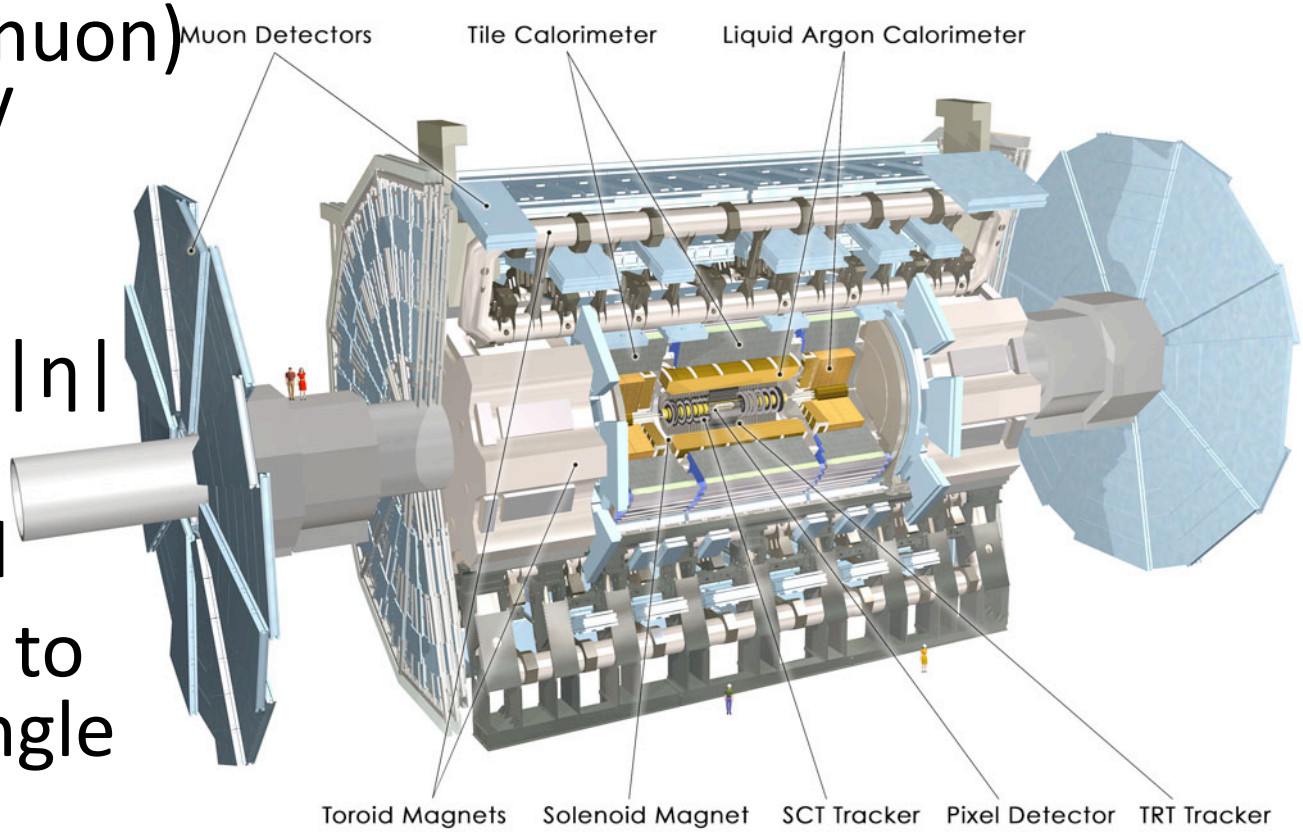




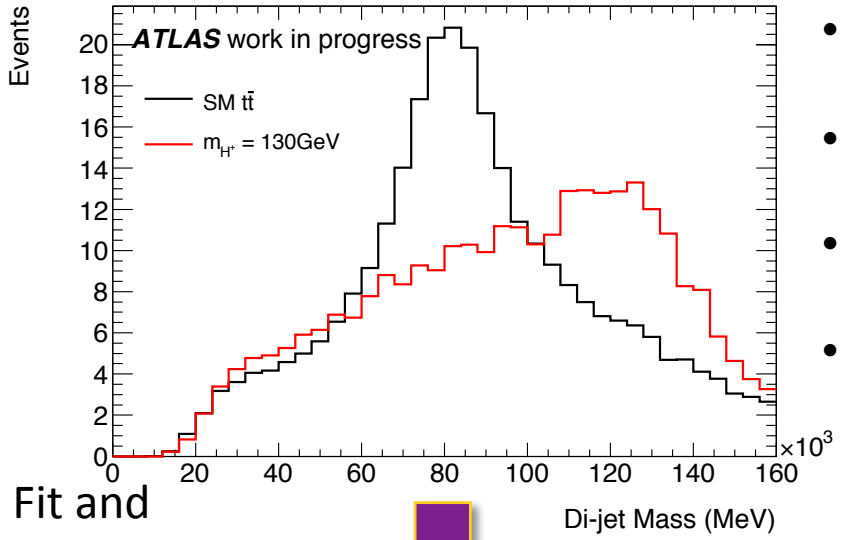
Object Selection

- Exactly one muon || electron p_T>20GeV
- MET>20GeV (muon) || MET>35GeV (electron)
- ≥4 jets with E_T>25GeV and |η| <2.5
- ≥1 jet b-tagged
- Event required to pass high p_T single lepton trigger

The analysis uses all of the main ATLAS sub-detectors

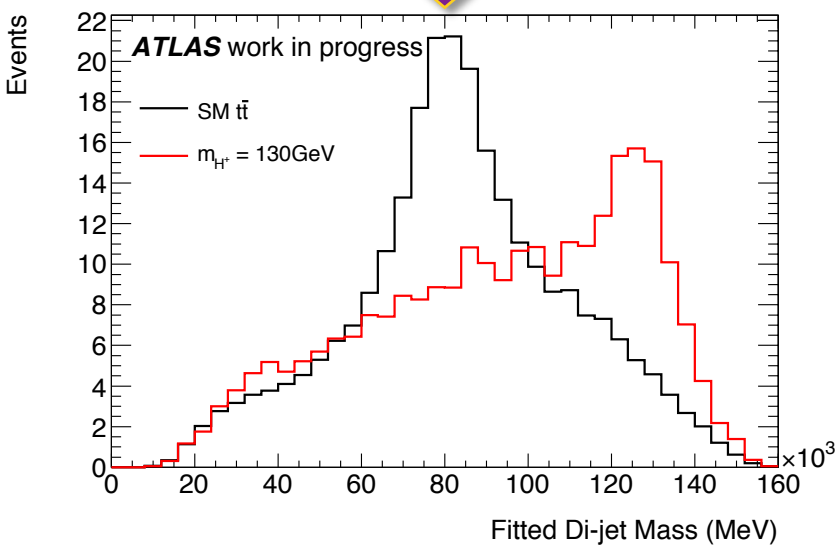


χ2 Fitter



Fit and

χ2<20 cut



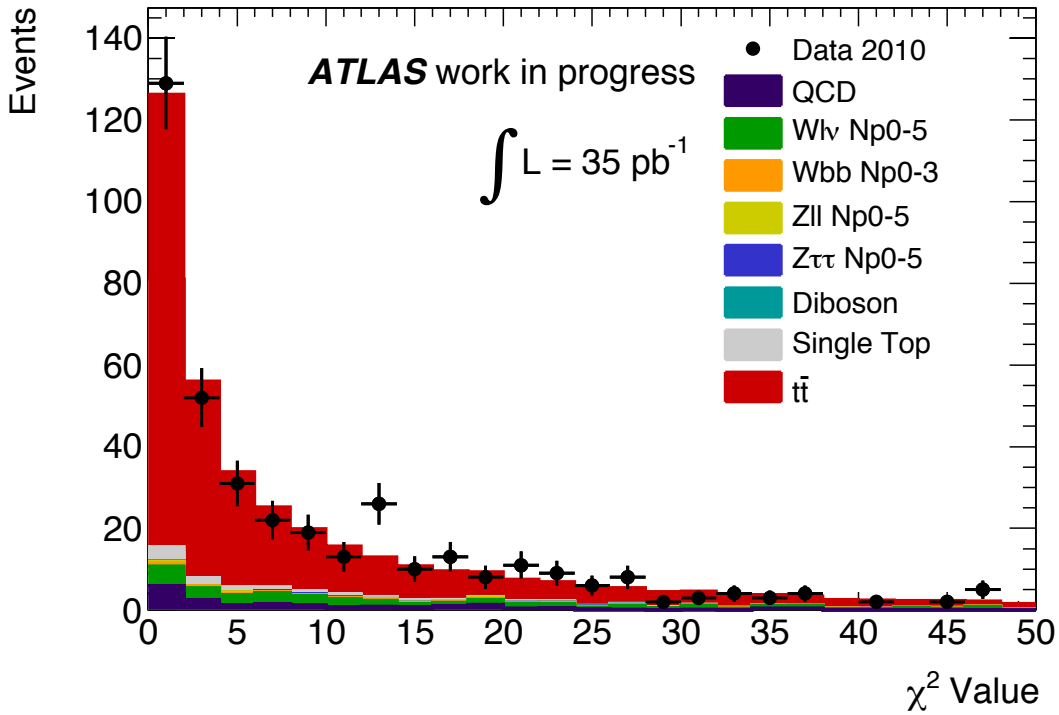
- Reconstruct the whole ttbar event using a χ^2 fitter
- Allow measured p_T values to vary within their uncertainties
- Remove badly reconstructed top events including background using χ^2 value
- Fitted di-jet mass distributions with a $\chi^2 < 20$ cut are used as signal and background templates

$$\chi^2 = \sum_{i=l,4jets} \frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i^2} + \sum_{j=x,y} \frac{(p_j^{UE,fit} - p_j^{UE,meas})^2}{\sigma_{UE}^2} + \sum_{k=jjb,blv} \frac{(M_k - M_{top})^2}{\sigma_{top}^2} + \frac{(M_{l\nu} - M_W)^2}{\sigma_W^2}.$$

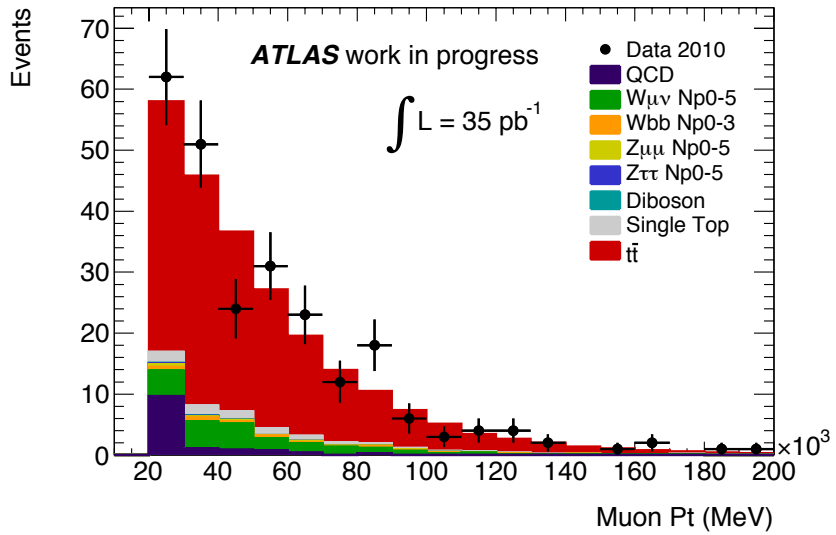
Event Yields

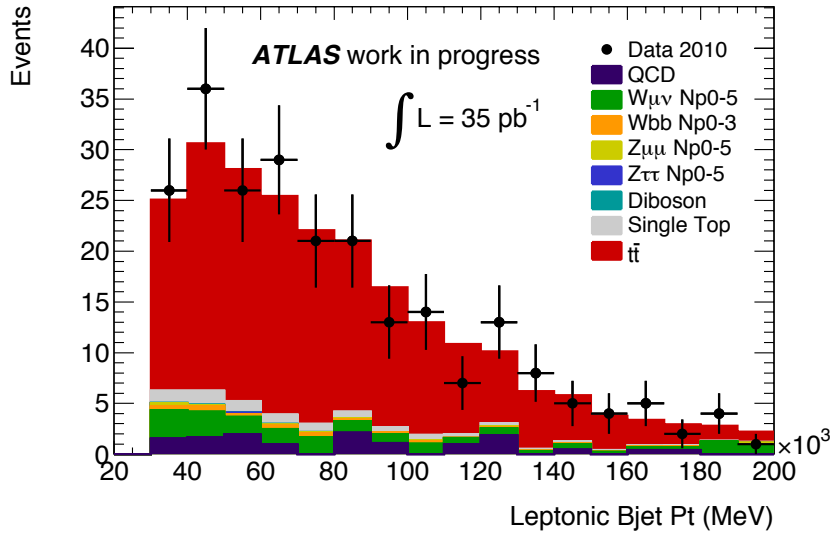
- Observe good agreement with the data from standard model MC and data driven backgrounds after all cuts
- χ^2 output for both channels combined in good agreement with the data

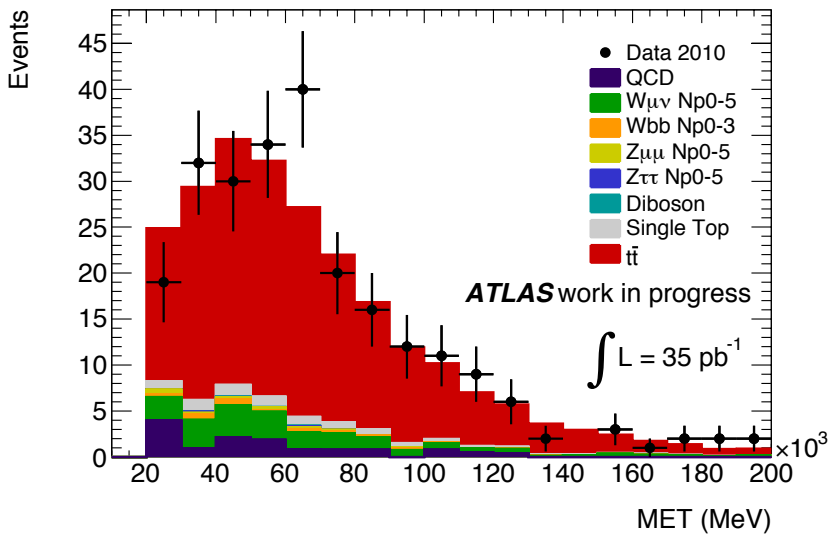
Channel	Muon	Electron
ttbar	156	108
W+jets	16	9
QCD multi-jet	11	6
Other	8	5
SM Total	191	129
Data 2010 ($35pb^{-1}$)	193	130

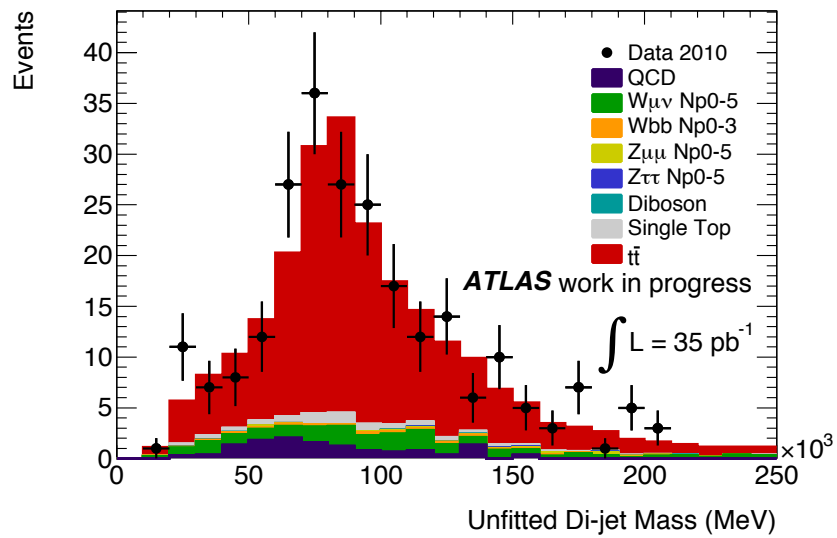


Data Validation : Muon

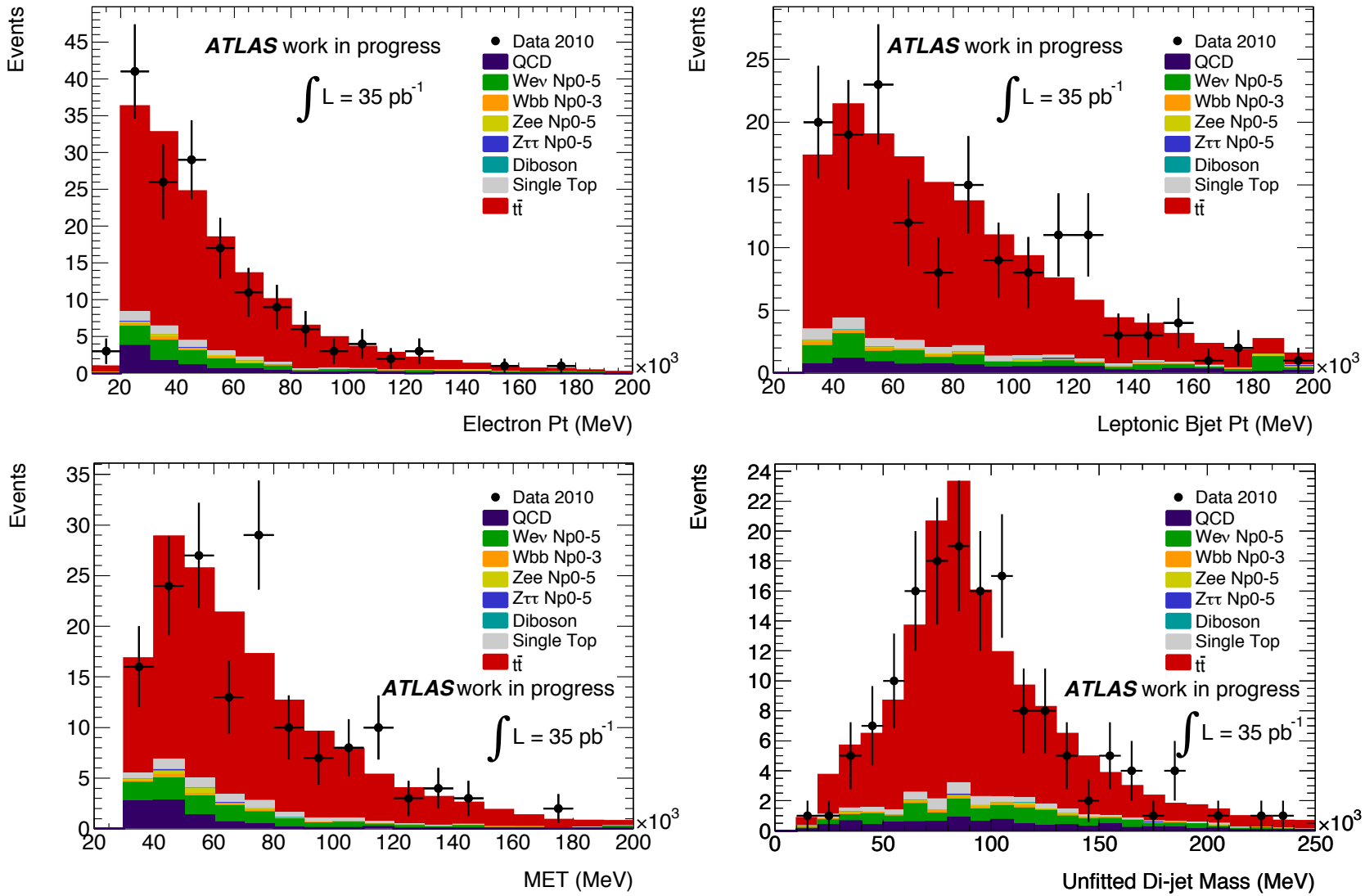








Data Validation : Electron



BR(t->H$^+$b) Limits: Likelihood

- We define a likelihood function where
  - n_i observed events in each bin
  - ν_i is the expected number of events in each bin

$$L(\mathcal{B},\alpha) = \prod_i Pois(n_i|\nu_i) \prod_j N(\alpha_j)$$

$$\nu_i = 2\mathcal{B}(1-\mathcal{B})A^{-1}n_i^s\sigma_{1i}(\alpha) + (1-\mathcal{B})^2 n_i^{t\bar{t}}\sigma_{2i}(\alpha) + n_i^b\sigma_{3i}(\alpha)$$

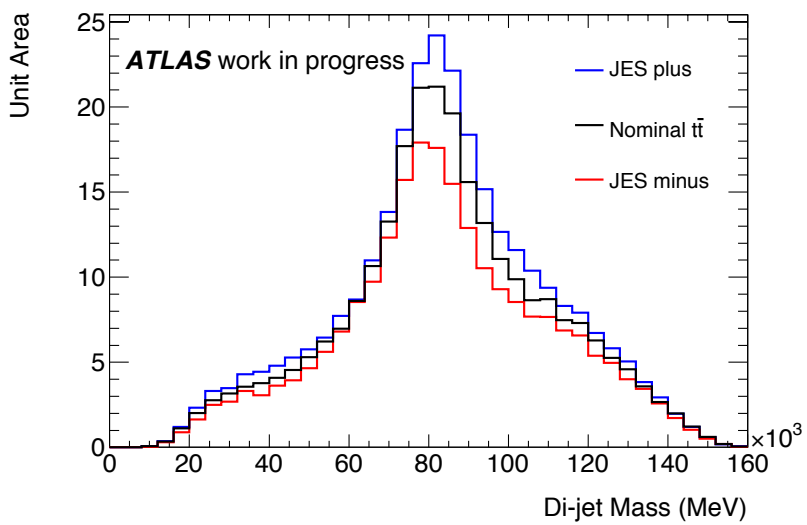
- Increases signal contribution as the BR(t->H$^+$b) increases
- Decreases the standard model contribution as the BR(t->H$^+$b) increases
- Independent of signal BR

Systematics

- Systematic uncertainties are included via the σ_{mi} nuisance parameters
- They are constrained in the LH via the α_j gaussian terms
- For each systematic we define a ±1σ distribution

$$\sigma_{mi}(\alpha) = \prod_j I(\alpha_j; \sigma^+_{mij}, \sigma^-_{mij})$$

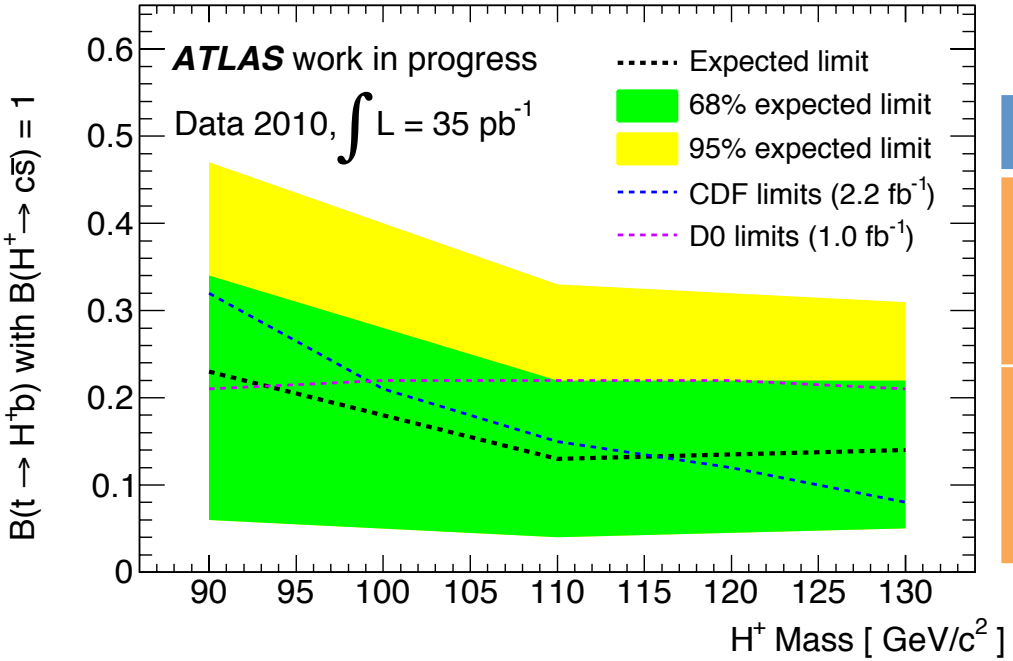
$$I(\alpha; x^+, x^-) = \begin{cases} 1 + \alpha x^+ & \text{if } \alpha > 0 \\ 1 & \text{if } \alpha = 0 \\ 1 - \alpha x^- & \text{if } \alpha < 0 \end{cases}$$



Systematic	Definition ±1σ
Jet energy scale	± 4%∗ (|η| < 3.2), ± 10%∗ (|η| > 3.2)
Jet energy resolution	± 5%∗ (|η| < 0.8), ± 10%∗ (|η| > 0.8)
b-tagging scale	8%∗
MC generator	MC@NLO vs POWHEG
Parton shower	HERWIG vs PYTHIA
ISR/FSR	ACER: up vs down
Luminosity	±3.4%
Electron reconstruction & identification	1.6%
Muon reconstruction & identification	0.2%
Electron trigger	0.2%
Muon trigger	0.5%
$t\bar{t}$ cross section	+7%, −9%
Non-$t\bar{t}$ backgrounds	background nomalization, ±20%

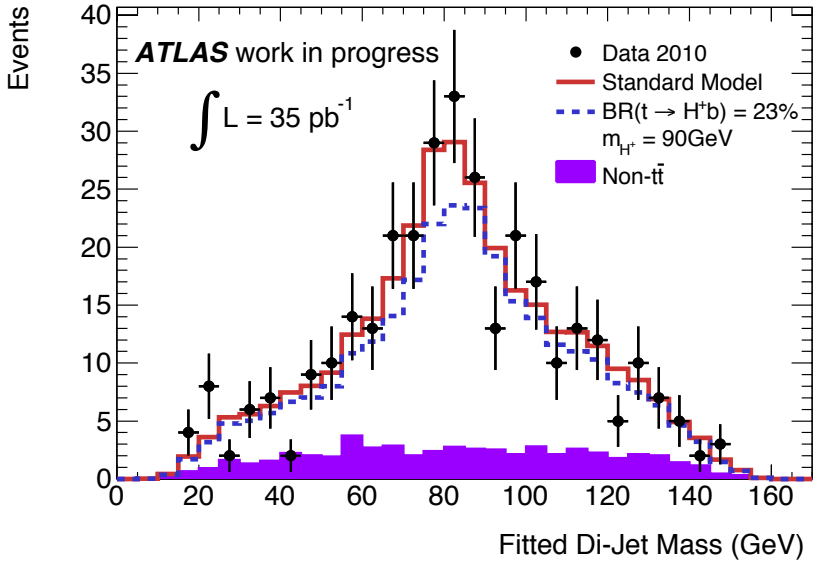
Expected Limits

- We assume no evidence of a charged Higgs
- Limits have been produced of the form CL_{s+b} with a power constraint
- We set an expected upper limit on the BR(t->H^+b) from the results of 1000 pseudo experiments
  - Pseudo data created from SM templates with BR(t->H^+b) = 0
- The -2σ band is removed as per the power constrained limit prescription

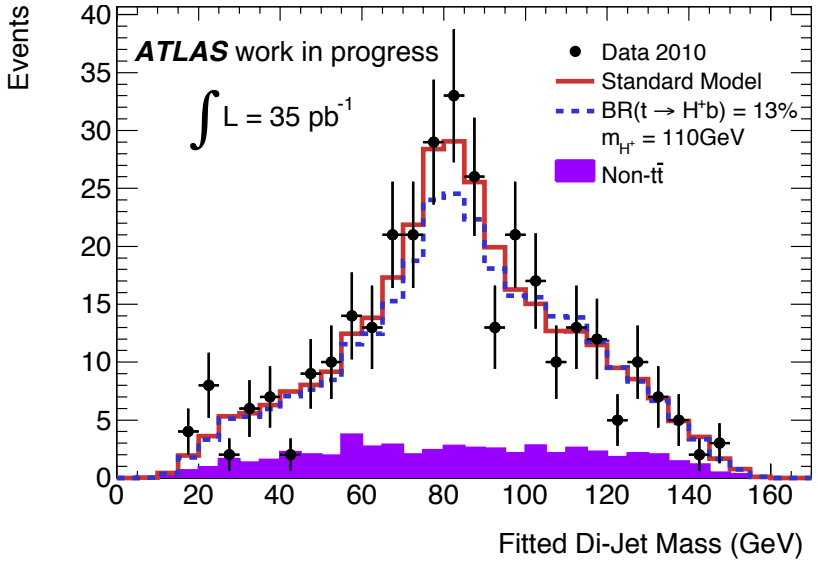


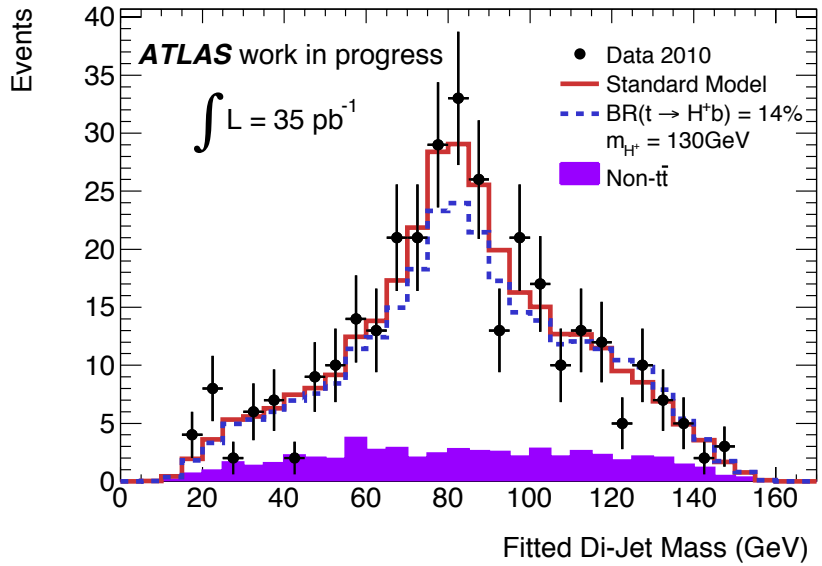
m_{H+}(GeV)	90	110	130
Expected upper limit BR(t->H^+b) stat. only	16%	11%	9%
Expected upper limit BR(t->H^+b) stat.+syst	23%	13%	14%

Expected Results



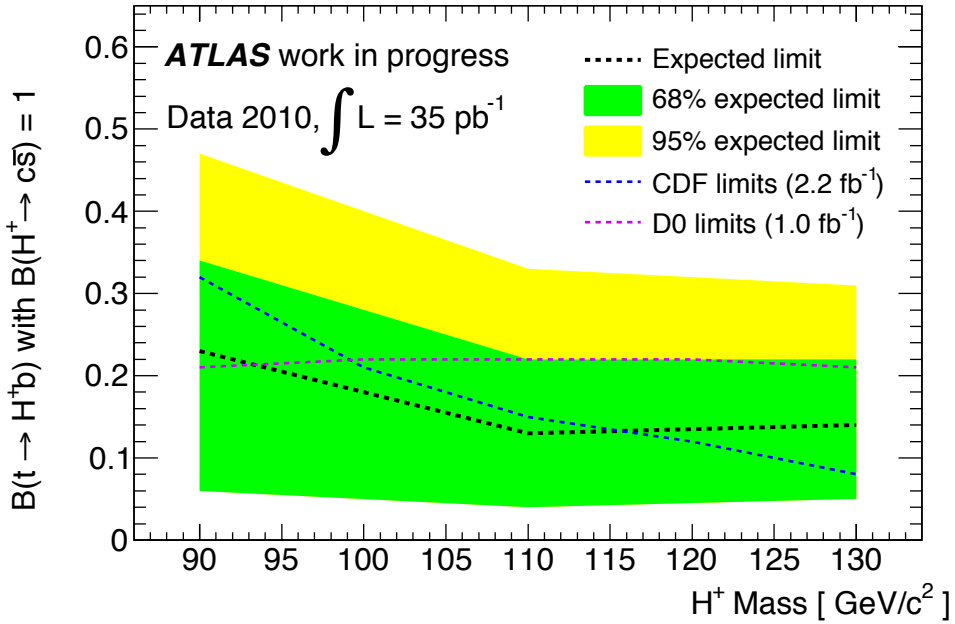
- In the data sample of 35pb^{-1} we observe 323 events in data after all cuts
- We observe the data to be consistent with SM expectations
- We have set expected limits at three mass points 90, 110 and 130GeV with 1000 pseudo experiments





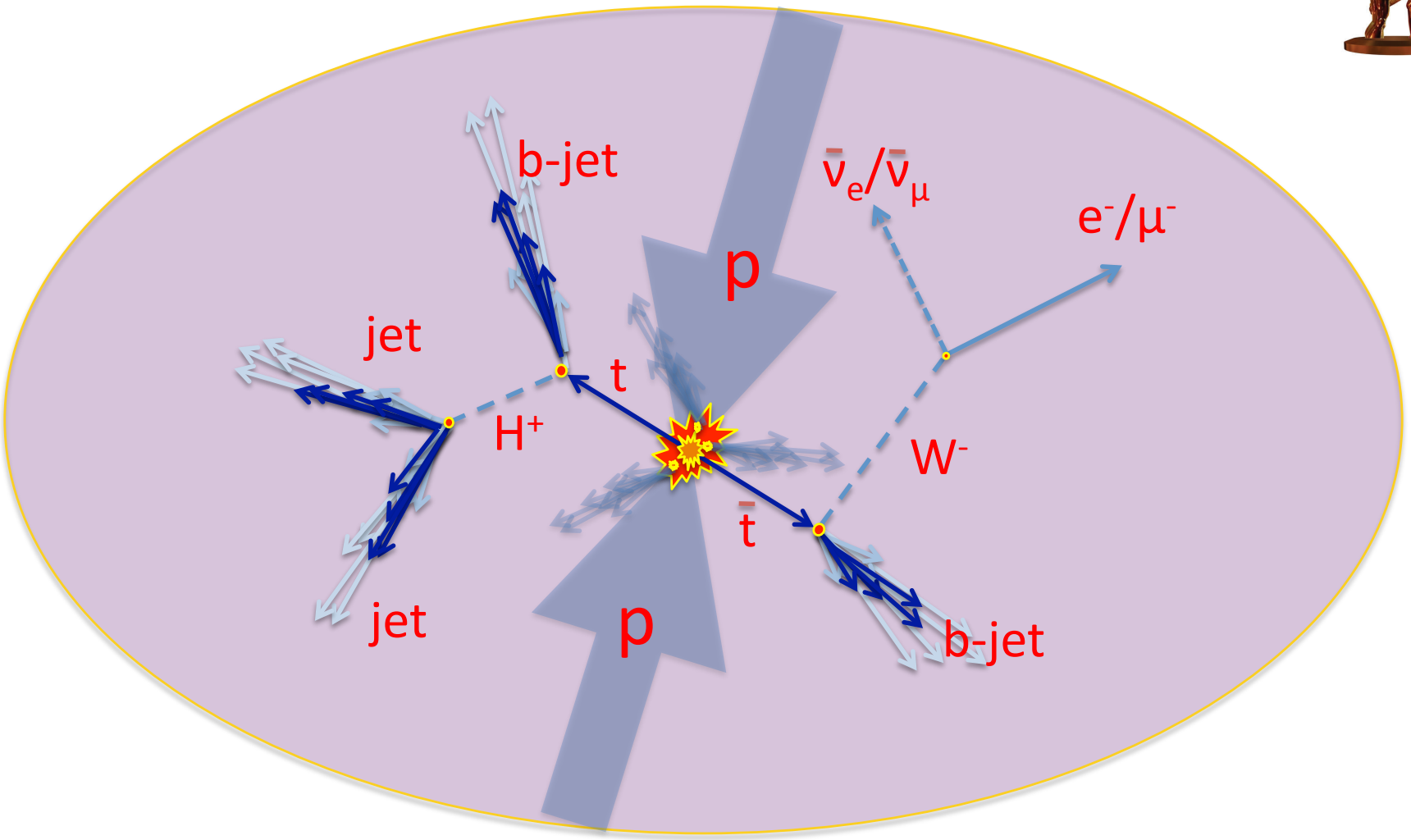
Summary

- We search for a non-SM scalar charged Higgs boson in semi-leptonic ttbar decays
- Search for a secondary peak in the di-jet mass peak corresponding to the decay $t \to H^+ b$ at various m_{H+}
- Produced a set of expected upper limits on the BR($t \to H^+ b$) with 95% CL
- Expect to be competitive with existing Tevatron limits
- Observed limits will arrive shortly….
- Watch this space!!!



m_{H+}(GeV)	Expected 95% limit BR($t \to H^+ b$)
90	23%
110	13%
130	14%

BACKUP



Trigger

- Following the Top group's trigger MC and Data
- Muon
  - MC : EF_mu13_tight
  - Data :
    - E4-F : EF_mu10_MSonly
    - G1-G5 : EF_mu13
    - Since G6 : EF_mu13_tight Electron
- Electron
  - MC : EF_e15_medium
  - Data :
    - Since E4: EF_e15_medium

Previous Pub Notes

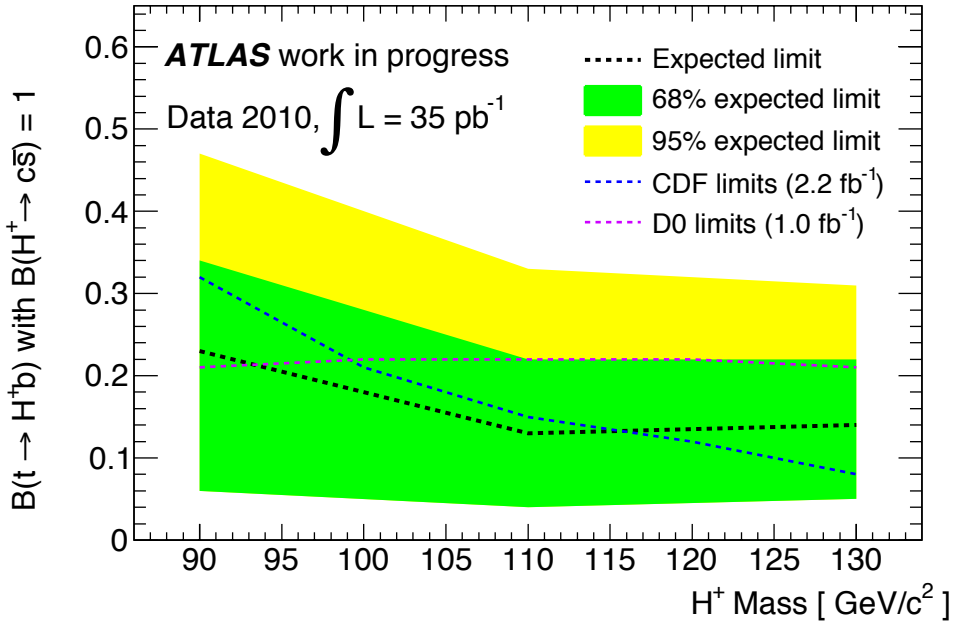
- These notes follow the same analysis but with two b-tags
- ATLAS-PHYS-PUB-2010-009
  - 7TeV expected results
- ATLAS-PHYS-PUB-2010-006
  - 10TeV expected results

Full Event Cuts

- Full cuts are as follows;
  - Exactly one electron p_T>20GeV || exactly one muon p_T>20GeV
  - MET>20GeV (muon) || MET>35GeV (electron)
  - M_t(W)+MET>60GeV (muon) || M_t(W)>25GeV (electron)
  - ≥4 jets with E_T>25GeV and |η|<2.5
  - ≥1 jet tagged with SVO>5.85
  - Reject events with loose bad jets p_T>20GeV
  - Require primary vertex with #tracks>4
  - Event required to pass high pT single lepton trigger (and lepton to dR match trigger)
- Also apply lepton ID, trigger efficiency and b-tagging scale factors

95% CL_{s+b} PCLimits

- Limits have been produced of the form CL_{s+b} with a power constraint
  - Do not allow observed limit to go below -1σ band (16% power constrained limit)
- Calculated on a test statistic q_B based on a profile likelihood ratio



$$q_{\mathcal{B}} = \begin{cases} -2\ln\frac{L(\mathcal{B},\hat{\hat{\alpha}}(\mathcal{B}))}{L(0,\hat{\hat{\alpha}}(0))} & \text{if } \hat{\mathcal{B}} < 0 \\ -2\ln\frac{L(\mathcal{B},\hat{\hat{\alpha}}(\mathcal{B}))}{L(\hat{\mathcal{B}},\hat{\alpha})} & \text{if } 0 < \hat{\mathcal{B}} < \mathcal{B} \\ 0 & \text{if } \hat{\mathcal{B}} > \mathcal{B} \end{cases}$$