ATLAS results on Heavy Particles: b top BSM

Workshop on Heavy Particles at the LHC

January 5th - 7th 2011

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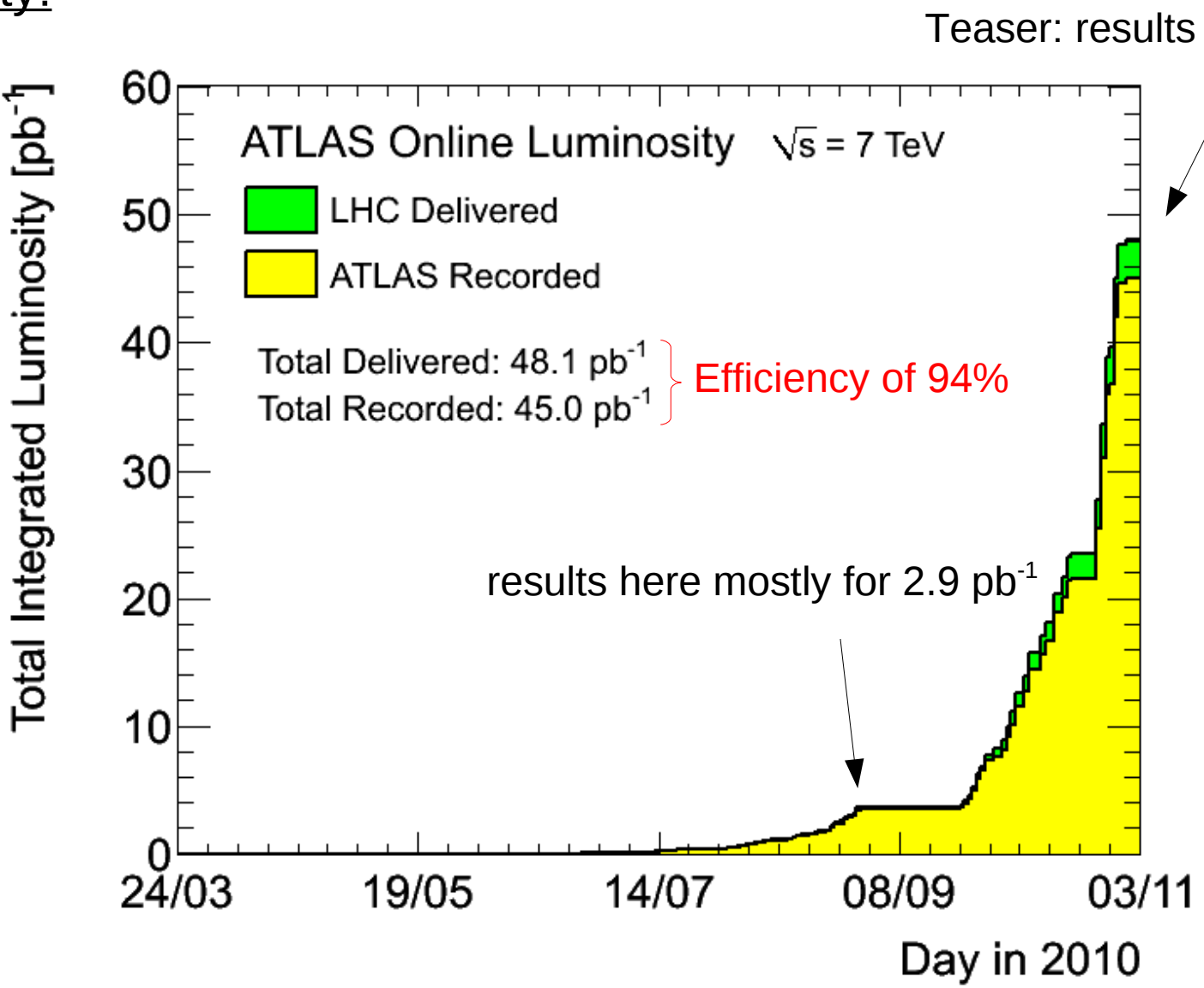
for the ATLAS collaboration

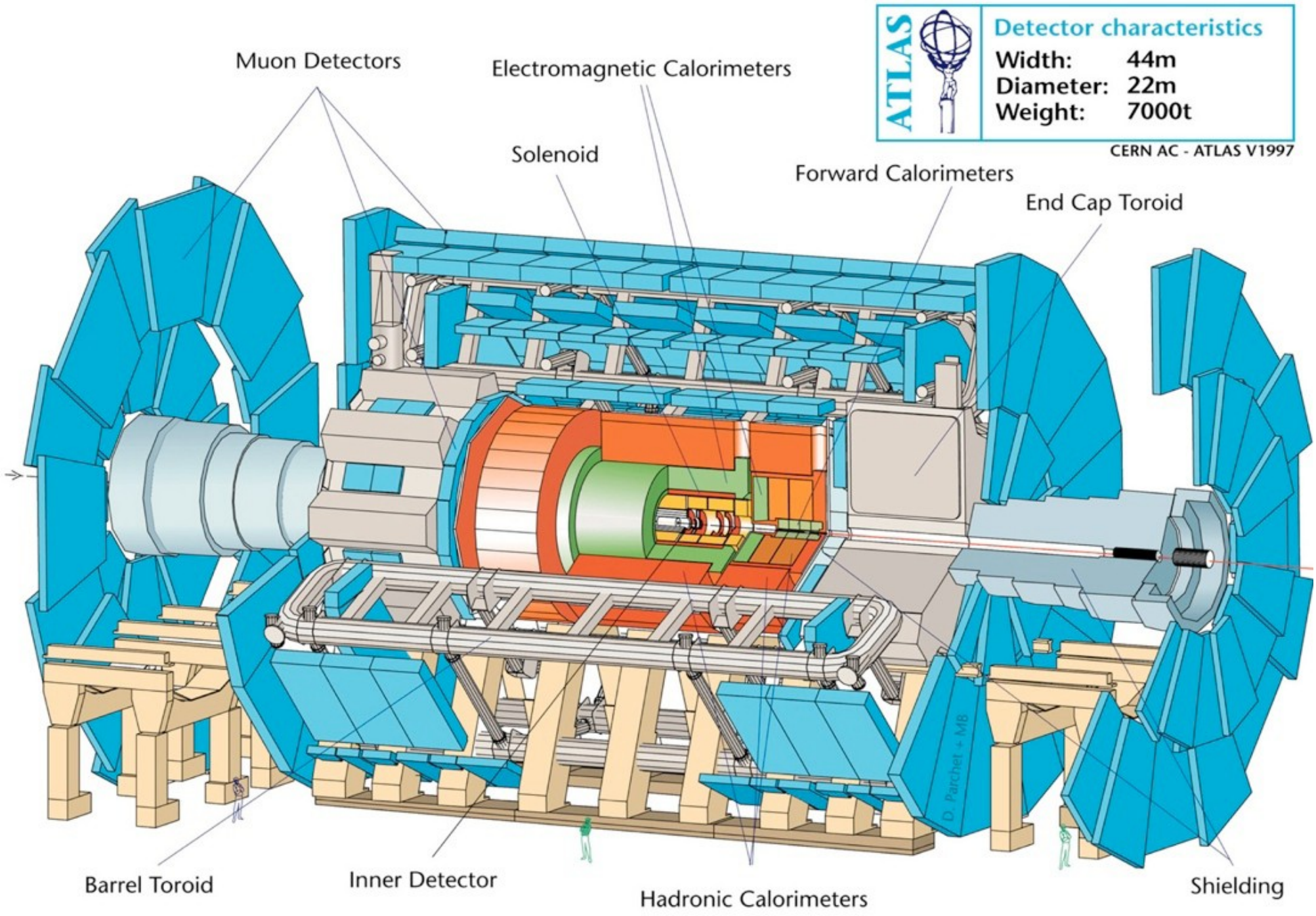
LHC/ATLAS performance ◦ b highlights ◦ top cross section ◦ BSM ◦ Summary/Outlook

Luminosity:



Peak luminosity $2.1 \cdot 10^{32}$ $cm^{-2}s^{-1}$

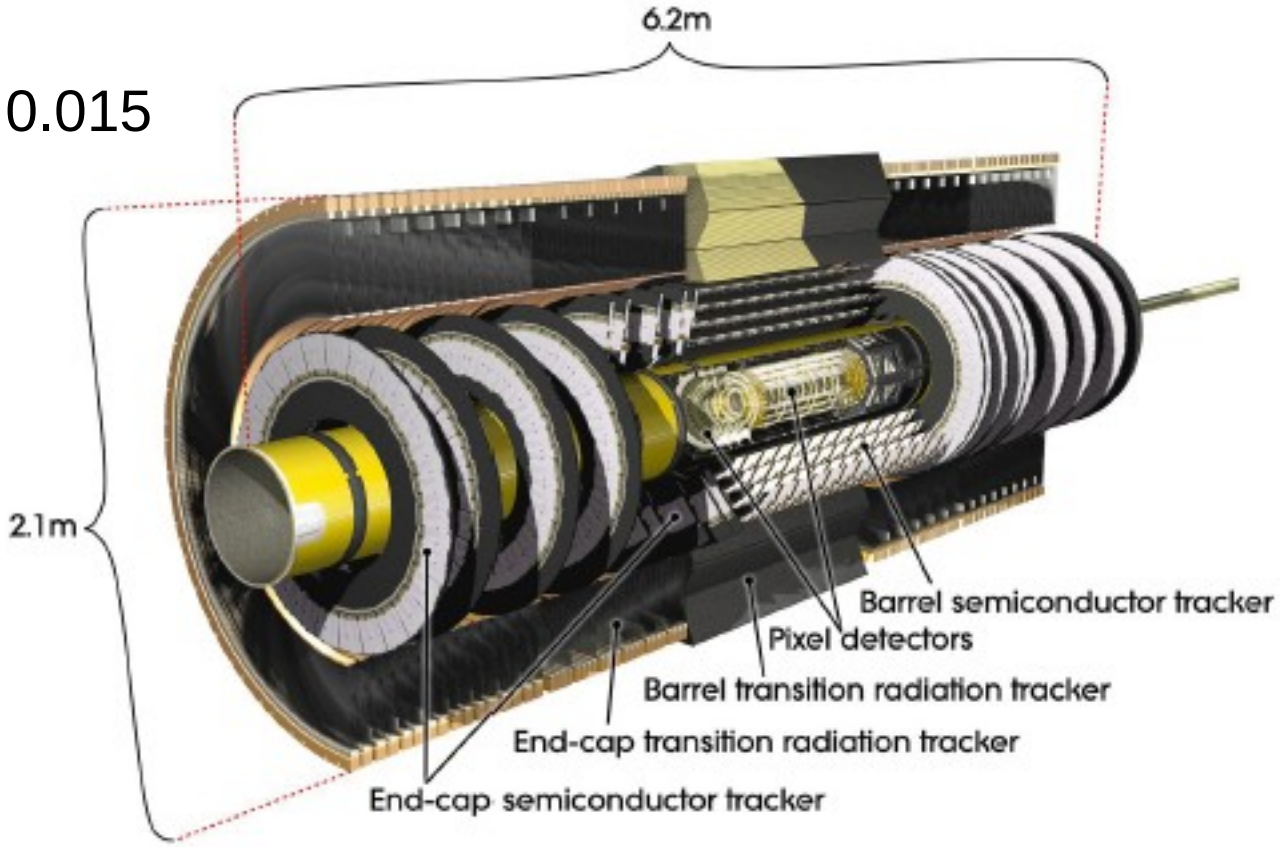
Luminosity uncertainty 11%


ATLAS
Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC - ATLAS V1997
Muon Detectors
Electromagnetic Calorimeters
Solenoid
Forward Calorimeters
End Cap Toroid
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding
D. Parchet + MB

Inner detector:

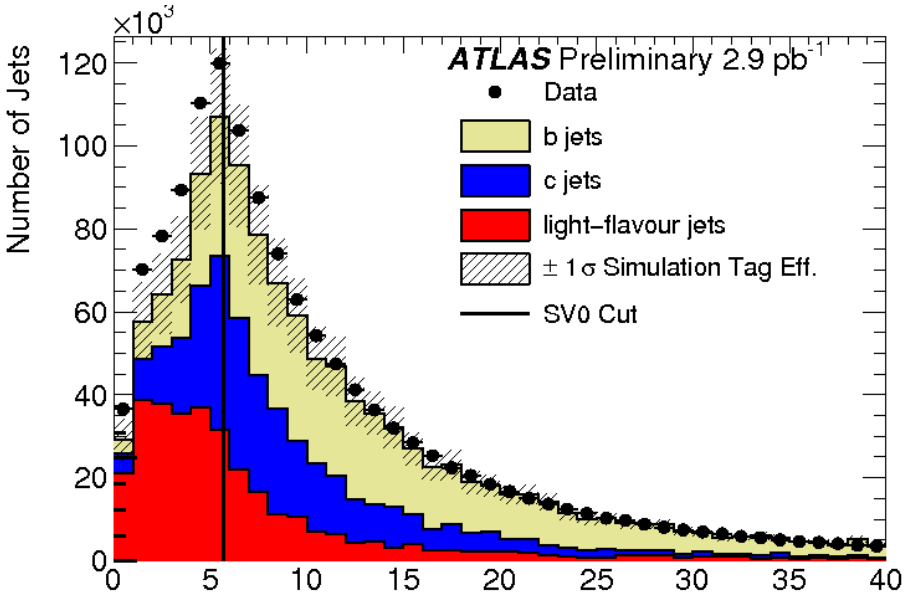
- Silicon Pixel detector
- Silicon Strip detector
- Transition Radiation detector
- Coverage up to $|\eta| < 2.5$
- p_T resolution:
  $\sigma/p_T \sim 3.4 \cdot 10^{-4}\, p_T + 0.015$

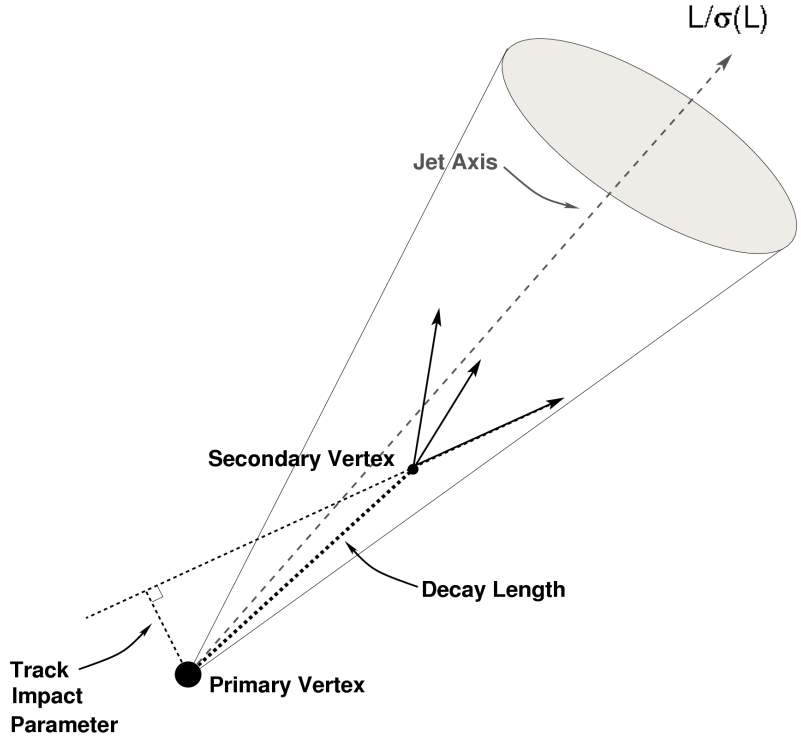
- Allows precision measurement of tracks (e.g., for b-physics)
- Allows b-tagging with a d0 (impact parameter) resolution of 10 μm (e.g., for top)



b-tagging:

- SV0 tagger: search for secondary vertex and calculate decay length (significance)
- Operating point chosen to be 50% efficient in sim. ttbar events
- Measured in data:
  - (40 – 60)% efficient rising with p_T ($25 < p_T$ [GeV] < 85)
  - Mistag rate (0.2 – 1)% increasing with p_T ($20 < p_T$ [GeV] < 150)
- Used for top, alternative taggers exist

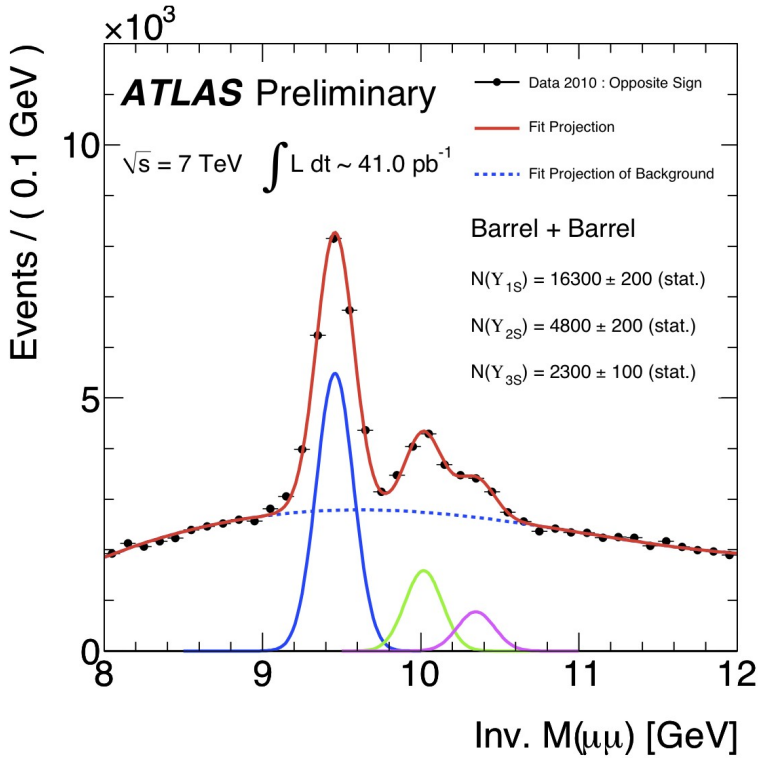


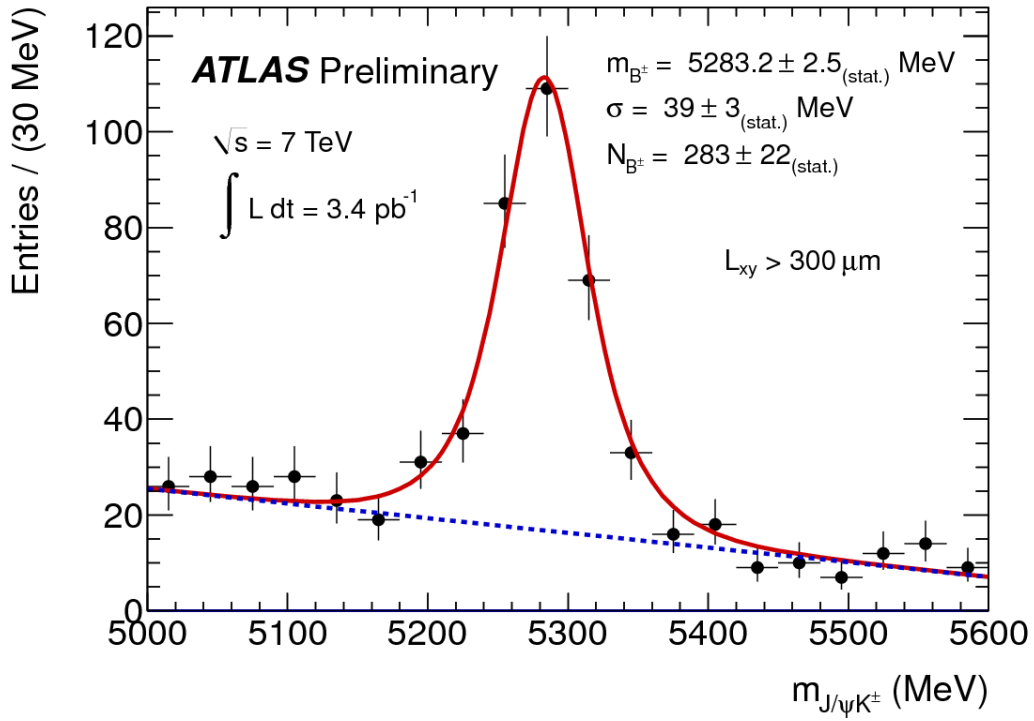


ATLAS-CONF-2010-099

Highlights:

- Observation of bbar resonances
- Observation of $B^{\pm} \rightarrow J/\Psi\, K^{\pm}\,(J/\Psi \rightarrow \mu^{+}\mu^{-})$





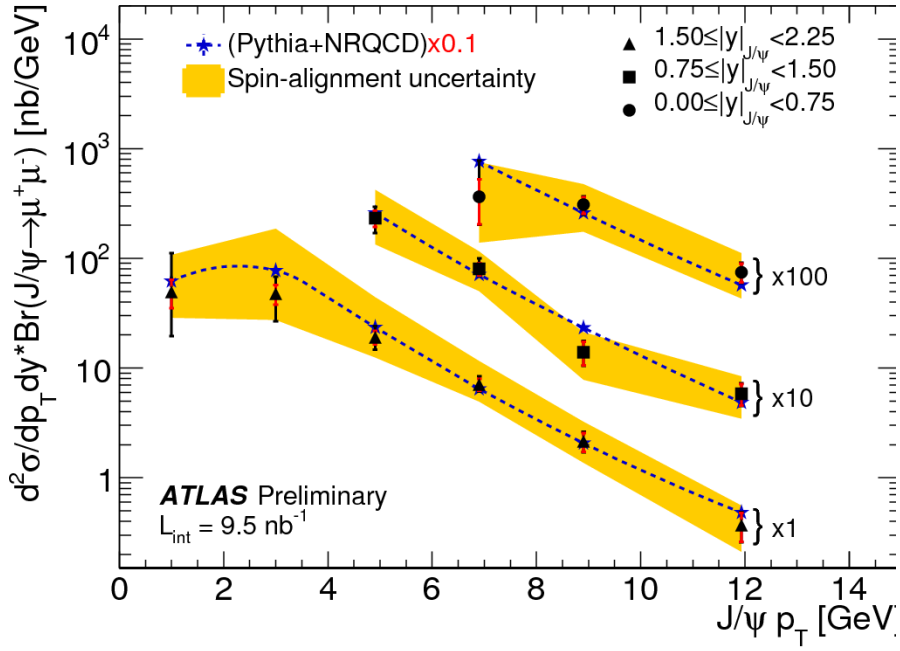
ATLAS-CONF-2010-098
ATLAS-CONF-2010-078

Calibration tool for inner detector and flavor tagging

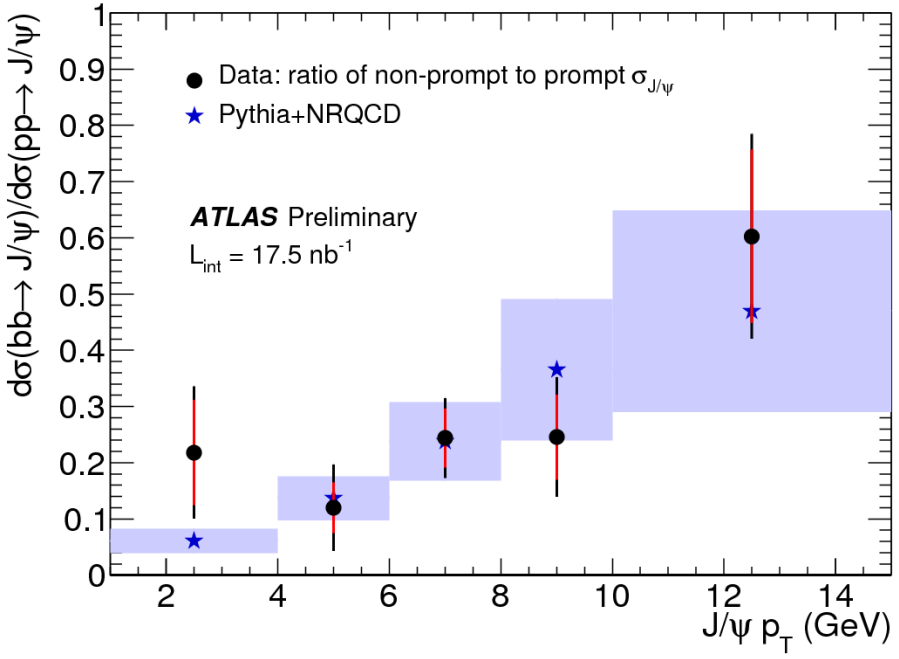
Highlights:

- Measurement of J/Ψ → $\mu^+\mu^-$ differential cross-section in η, p_T
- Measurement of the non-prompt-to-prompt J/Ψ cross-section

$$\mathcal{R} \equiv \frac{d\sigma(pp \to b\bar{b}X \to J/\psi\, X')}{d\sigma(pp \to J/\psi\, X'')_{\text{prompt}}}$$



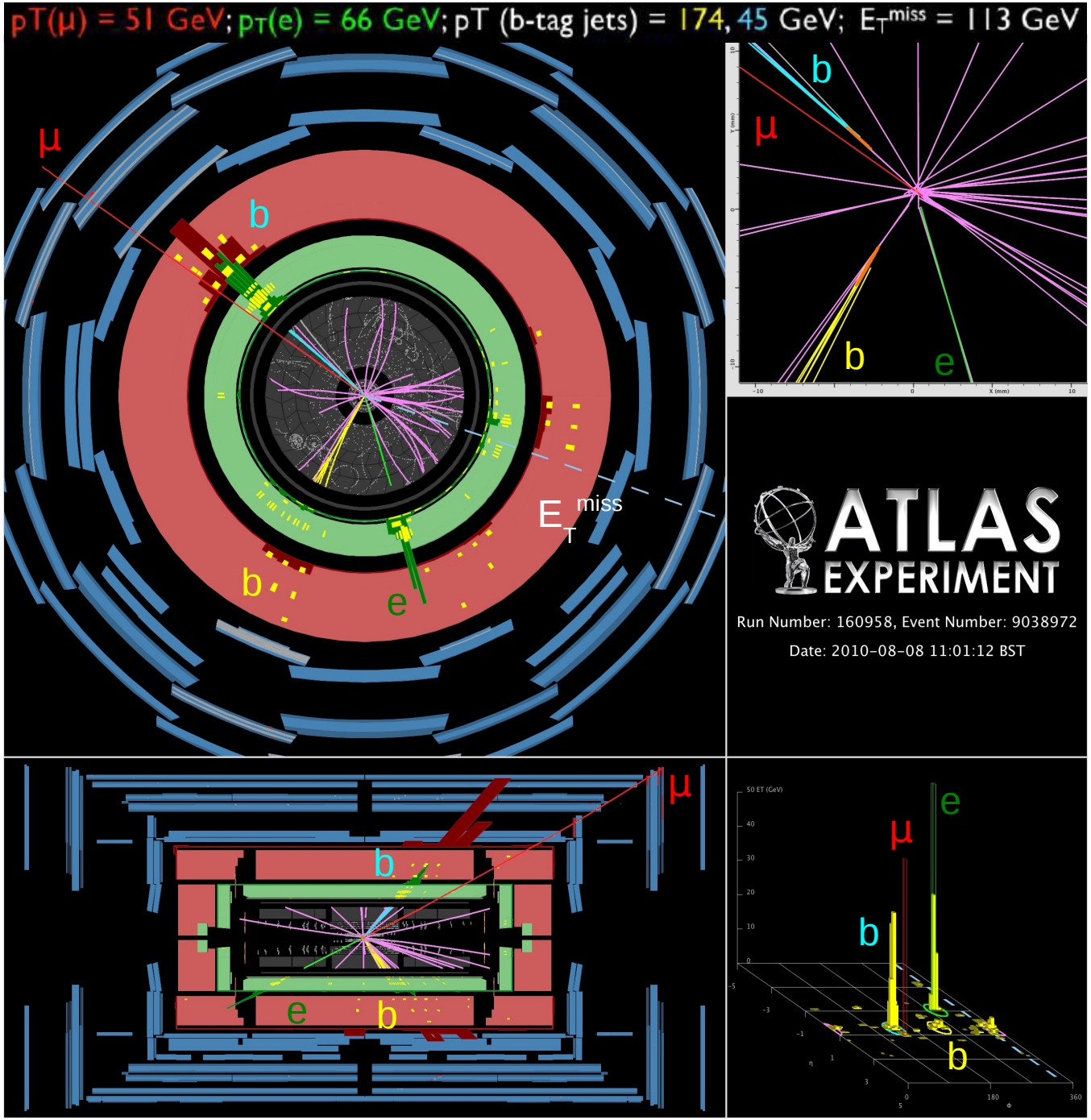
- Shape in agreement
- MC normalization 10 times higher than data



- Normalization cancels out
- Good agreement between data and MC prediction

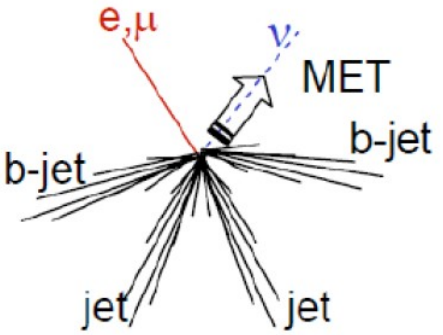
ATLAS-CONF-2010-062

A top quark event candidate

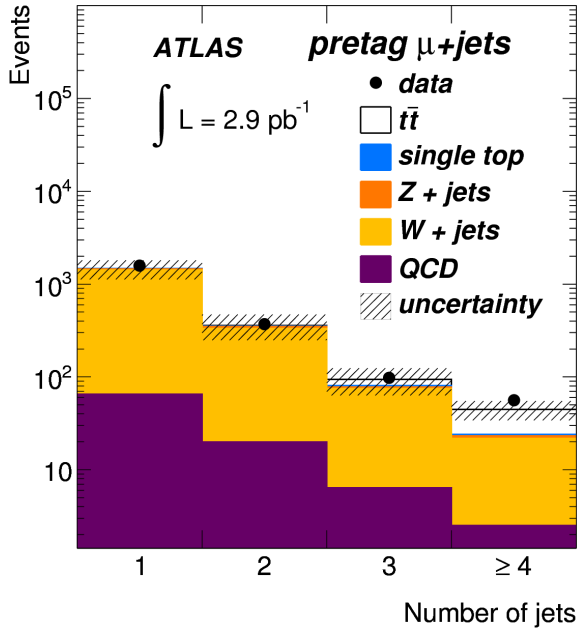


Single lepton channel:

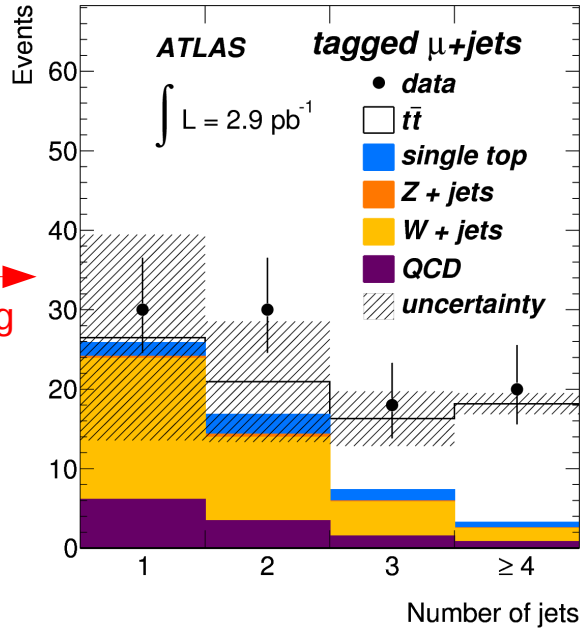
arXiv:1012.1792



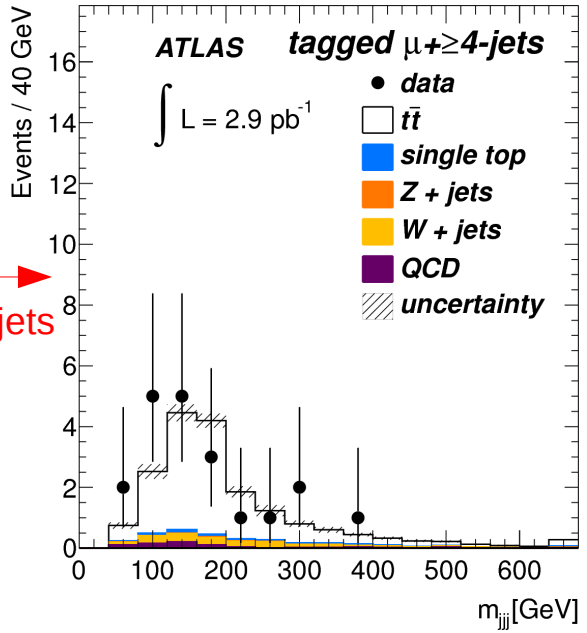
- Event selection:
  - Assure detector readiness, data quality and collision event
  - Single lepton trigger fired
  - Exactly one isol. lepton with p_T > 20 GeV and |η|<2.5 matching the HLT object
  - E_T^{miss} > 20 GeV
  - E_T^{miss} + $m_T(W)$ > 60 GeV
  - ≥ 4 jets with p_T > 25 GeV and |η|<2.5
  - 1 b-tag



b-tag



≥4 jets



arXiv:1012.1792

Single lepton channel:

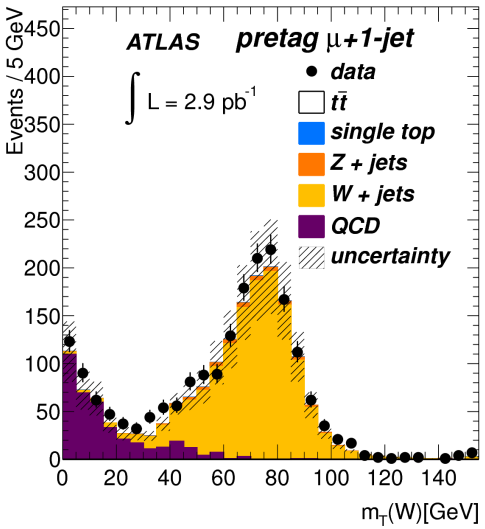
- Background sources:
  - QCD multijet events with 'fake' or 'non-prompt' leptons and mis-measured E_T^{miss}
  - W+jets (same signature)
  - Z+jets (small)
  - Single top (small)
- Background estimate:
  - No precise determination of QCD and W+jets at LHC
  - QCD: Matrix Method
  - W+jets: Extrapolation using Berends-Giele scaling
  - Small contributions from MC

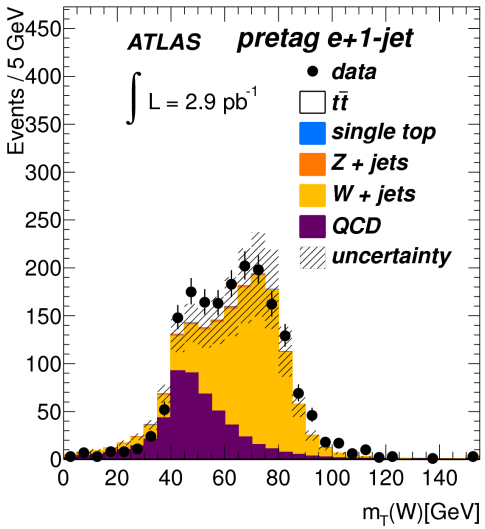
Matrix method:

- Solve system of equations :

$$N^{\text{loose}} = N^{\text{loose}}_{\text{real}} + N^{\text{loose}}_{\text{fake}},$$
$$N^{\text{std}} = rN^{\text{loose}}_{\text{real}} + fN^{\text{loose}}_{\text{fake}}$$

- Loose: no isolation (first pixel layer) requirement for mu (e)
- *r* from Z→ll sample
- *f* from QCD-enhanced region





arXiv:1012.1792

Single lepton channel:

- Event yield:

	e+jets	μ+jets	combined
Observed	17	20	37
Total est. background	7.5 ± 3.1	4.7 ± 1.7	12.2 ± 3.9
$t\bar{t}$	$9.5 \pm 4.1 \pm 3.1$	$15.3 \pm 4.4 \pm 1.7$	$24.8 \pm 6.1 \pm 3.9$

- Cross-section: Cut and count

Method	e+jets	μ+jets	e/μ +jets combined
Counting $\sigma_{t\bar{t}}$ [pb]	$105 \pm 46\ ^{+45}_{-40}$	$168 \pm 49\ ^{+46}_{-38}$	$142 \pm 34\ ^{+50}_{-31}$

- Largest Systematics
  - QCD normalization
  - b-tagging (HF fraction)
  - Jet energy scale 6-10% for different η and p_T
  - W+jets normalization
- Additional checks:
  - Pile-up due to increased instantaneous luminosity

37 ttbar candidate events observed

12.2±3.9 background events expected

arXiv:1012.1792

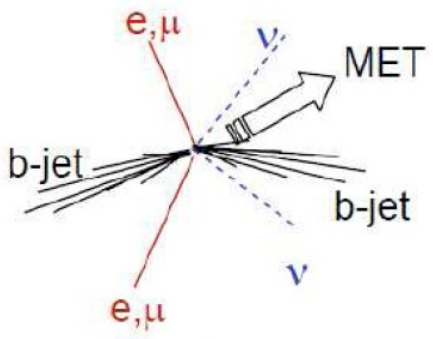
Single lepton channel:

- Systematics:

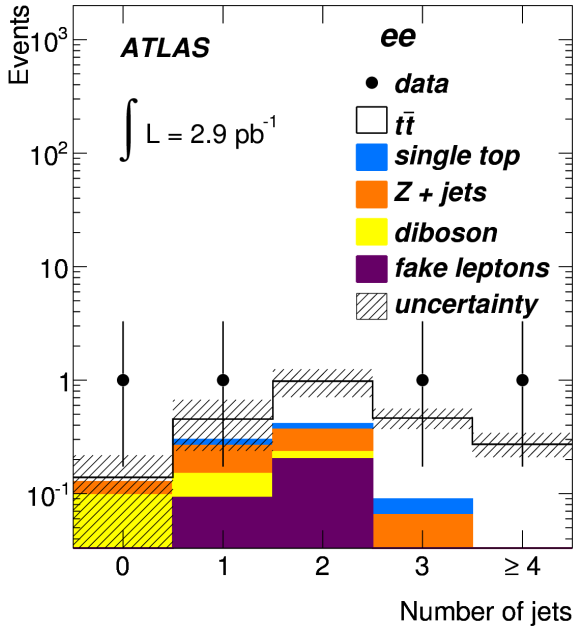
	Relative cross-section uncertainty [%]	
Source	e+jets	μ+jets
Statistical uncertainty	±43	±29
Object selection		
Lepton reconstruction, identification, trigger	±3	±2
Jet energy reconstruction	±13	±11
b-tagging	-10 / +15	-10 / +14
Background rates		
QCD normalisation	±30	±2
W+jets normalisation	±11	±11
Other backgrounds normalisation	±1	±1
Signal simulation		
Initial/final state radiation	-6 / +13	±8
Parton distribution functions	±2	±2
Parton shower and hadronisation	±1	±3
Next-to-leading-order generator	±4	±6
Integrated luminosity	-11 / +14	-10 / +13
Total systematic uncertainty	-38 / +43	-23 / +27
Statistical + systematic uncertainty	-58 / +61	-37 / +40

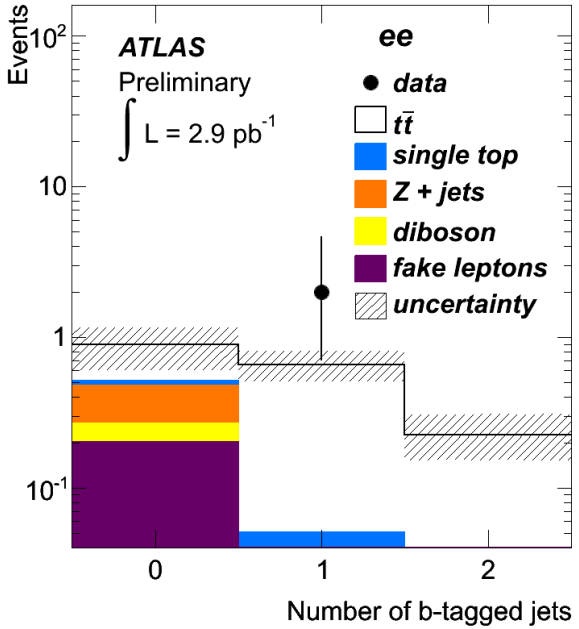
arXiv:1012.1792

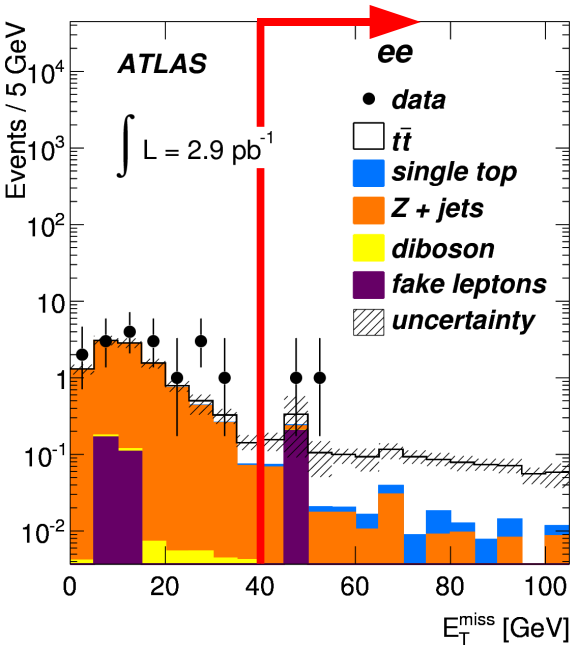
Dilepton channel:



- Event selection:
  - ≥ 2 OS isol. leptons (ee, μμ, eμ) with p_T > 20 GeV and |η|<2.5
  - One lepton matches HLT
  - ≥ 2 jet(s) with p_T > 20 GeV and |η|<2.5
  - Cosmic veto
  - Z-mass veto: $|m_{ll} - m_Z| > 5$ (10) GeV for ee (μμ)
  - E_T^{miss} > 40 (30) GeV for ee (μμ)
  - H_T > 150 GeV for eμ







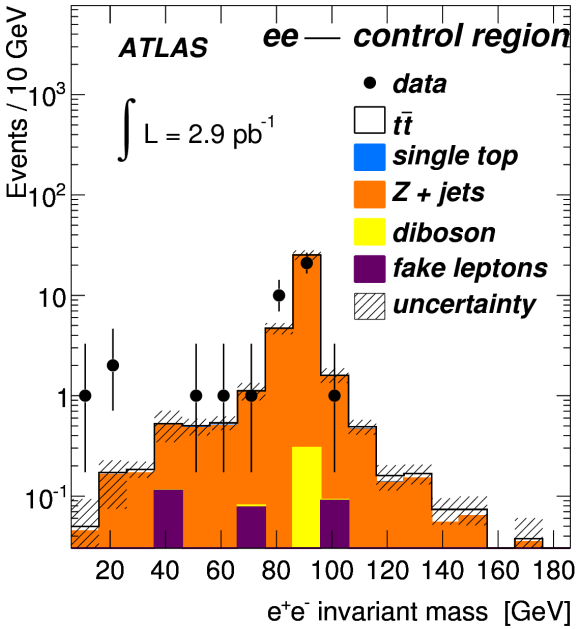
arXiv:1012.1792

Dilepton channel:

- Background sources:
  - Z+jets for ee and μμ (extrapolated)
  - W+jets with ‘fake’ lepton
  - QCD multijet events (small)
  - Single top
  - Di-bosons
- Matrix method:
  - Solve system of equations:

$$\begin{bmatrix} N_{TT} \\ N_{TL} \\ N_{LT} \\ N_{LL} \end{bmatrix} = \begin{bmatrix} rr & rf & fr & ff \\ r(1-r) & r(1-f) & f(1-r) & f(1-f) \\ (1-r)r & (1-r)f & (1-f)r & (1-f)f \\ (1-r)(1-r) & (1-r)(1-f) & (1-f)(1-r) & (1-f)(1-f) \end{bmatrix} \begin{bmatrix} N_{RR} \\ N_{RF} \\ N_{FR} \\ N_{FF} \end{bmatrix}$$

  - Loose: no isolation (E/p) requirement for mu (e)
  - r from Z→ll sample
  - f from QCD-enhanced region



arXiv:1012.1792

Dilepton channel:

9 ttbar candidate events observed

4.82±0.65 background events expected

- Sample composition:

	ee	$\mu\mu$	$e\mu$
Z+jets (DD)	0.25 ± 0.18	0.67 ± 0.38	-
$Z(\rightarrow \tau\tau)$+jets (MC)	0.07 ± 0.04	0.14 ± 0.07	0.13 ± 0.06
Non-Z leptons (DD)	0.16 ± 0.18	-0.08 ± 0.07	0.47 ± 0.28
Single top (MC)	0.08 ± 0.02	0.07 ± 0.03	0.22 ± 0.04
Dibosons (MC)	0.04 ± 0.02	0.07 ± 0.03	0.15 ± 0.05
Total (non $t\bar{t}$)	0.60 ± 0.27	0.88 ± 0.40	0.97 ± 0.30
$t\bar{t}$(MC)	1.19 ± 0.19	1.87 ± 0.26	3.85 ± 0.51
Total expected	1.79 ± 0.38	2.75 ± 0.55	4.82 ± 0.65
Observed	2	3	4

- Cross-section estimate: Cut and count

- Preliminary result:

Channel	$\sigma_{t\bar{t}}$ [pb]
ee	$193\ ^{+243}_{-152}\ ^{+84}_{-48}$
$\mu\mu$	$185\ ^{+184}_{-124}\ ^{+56}_{-47}$
$e\mu$	$129\ ^{+100}_{-72}\ ^{+32}_{-18}$
Combined	$151\ ^{+78}_{-62}\ ^{+37}_{-24}$

arXiv:1012.1792

Dilepton channel:

- Systematics:

	Relative cross-section uncertainty [%]		
Source	*ee*	*μμ*	*eμ*
Statistical uncertainty	-79 / +126	-67 / +100	-56 / +77
Object selection			
Lepton reconstruction, identification, trigger	-2 / +11	-4 / +3	-1 / +3
Jet energy reconstruction	-7 / +13	-14 / +9	-3 / +5
Background rates			
Fake leptons	-31 / +24	-4 / +1	-15 / +8
Z+jets	-12 / +4	-19 / +5	-2 / +1
Monte-Carlo simulation statistics	-5 / +3	-3 / +4	± 2
Theoretical cross-sections	± 3	-5 / +4	± 3
Signal simulation			
Initial/final state radiation	-4 / +5	-2 / +3	-2 / +3
Parton distribution functions	-2 / +1	-2 / +3	-2 / +3
Parton shower and hadronisation	-9 / +14	-6 / +9	± 3
Next-to-leading order generator	-8 / +11	-11 / +13	-3 / +4
Integrated luminosity	-11 / +16	-11 / +16	-12 / +14
Total systematic uncertainty	-25 / +44	-25 / +30	-14 / +25
Statistical + systematic uncertainty	-83 / +134	-72 / +104	-57 / +81

arXiv:1012.1792

Cross-section combination:

- Use binned profile Likelihood fit to estimate combined cross-section
- Number of expected events:

$$N^{exp}(\sigma_{t\bar{t}}, \alpha_j) = L \cdot \epsilon_{t\bar{t}}(\alpha_j) \cdot \sigma_{t\bar{t}} + \sum_{bkg} L \cdot \epsilon_{bkg}(\alpha_j) \cdot \sigma_{bkg}(\alpha_j) + N_{DD}(\alpha_j)$$

(signal) (bkg from MC) (bkg from data)

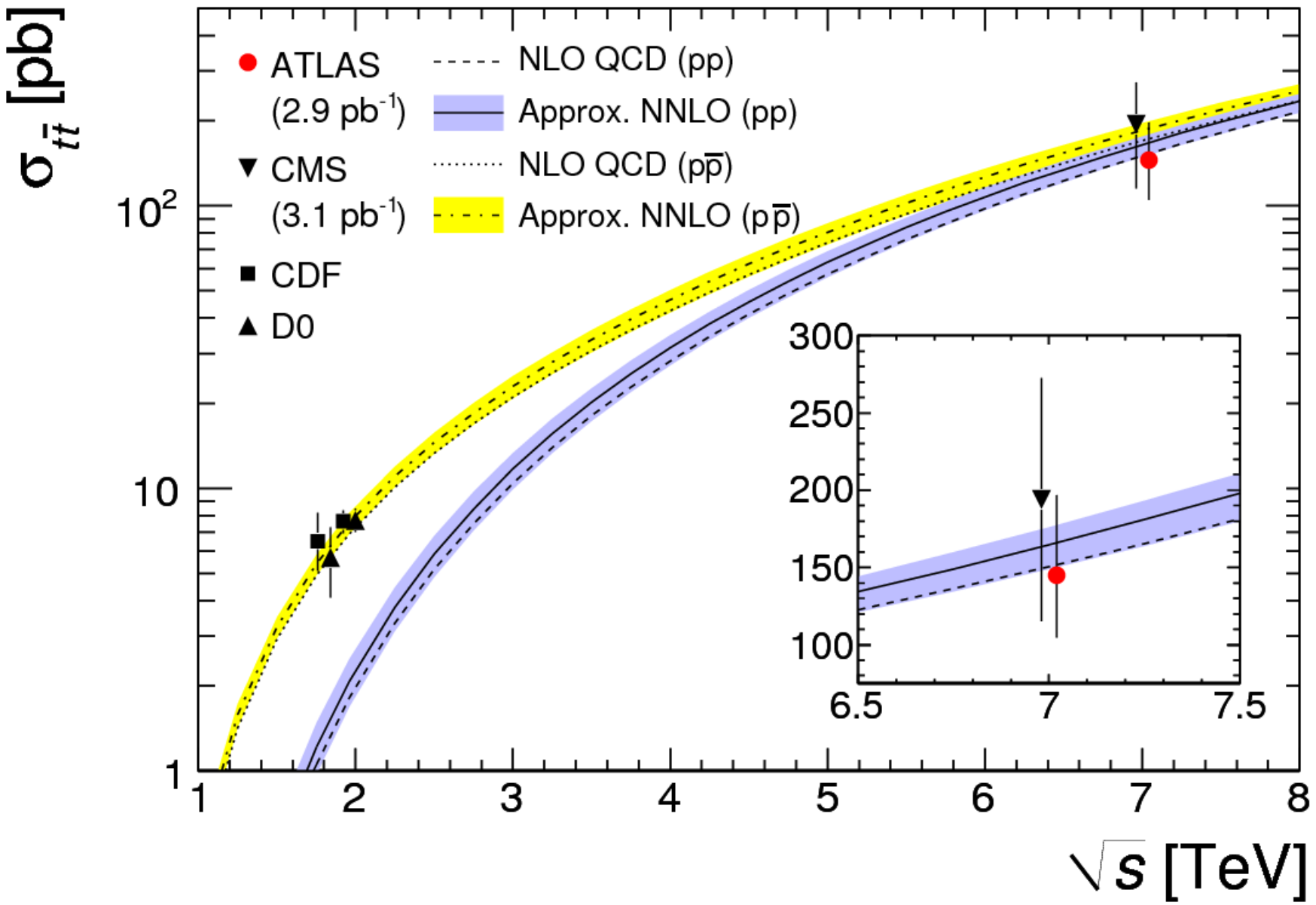
- Likelihood:

$$\mathcal{L}(\sigma_{t\bar{t}}, L, \alpha_j) = \text{Poisson}\left(N^{obs} \mid N^{exp}(\sigma_{t\bar{t}}, \alpha_j)\right) \times \text{Gauss}(L_0|L, \delta_L) \times \prod_{j \in \text{syst}} \Gamma_j(\alpha_j)$$

- Gaussians and Gamma-distributions for systematics α_j
- Luminosity uncertainty: 11%

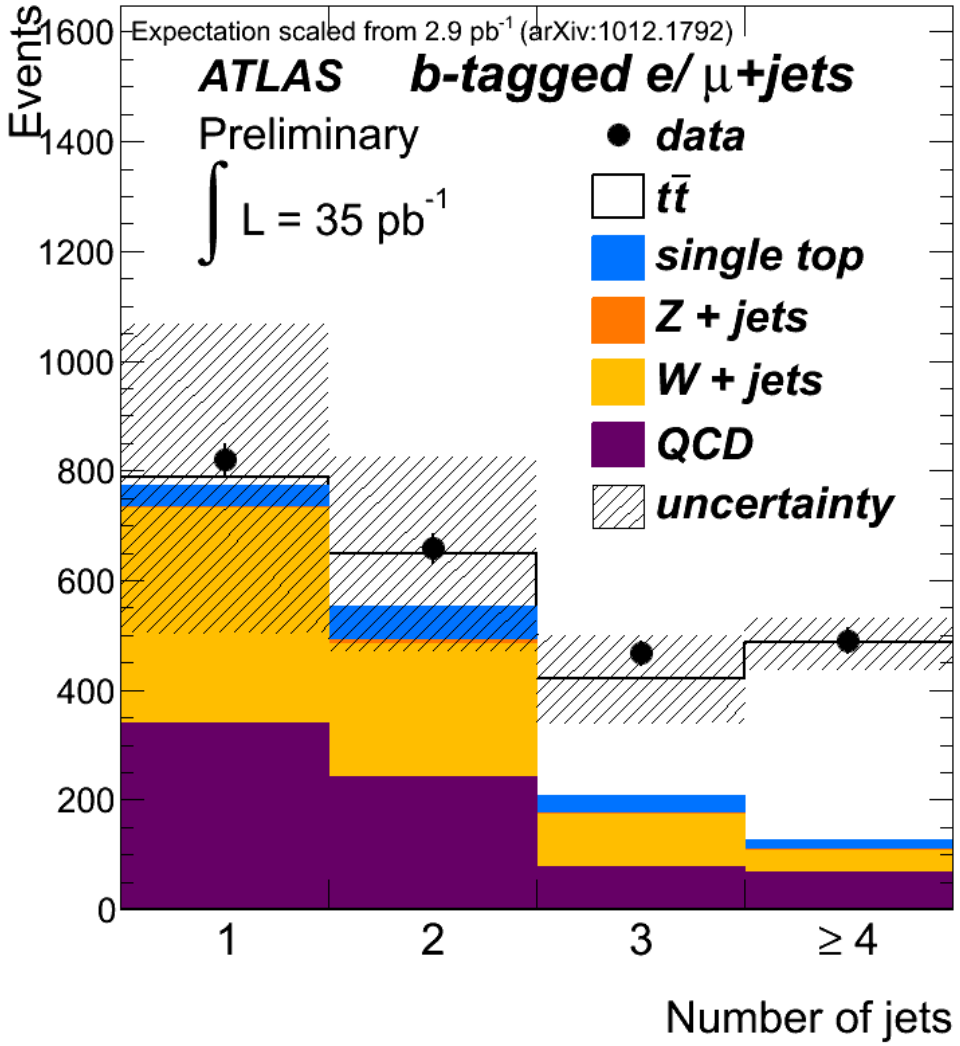
	Cross-section [pb]	Signal significance [σ]
Single lepton channels	$142 \pm 34\ ^{+50}_{-31}$	4.0
Dilepton channels	$151\ ^{+78}_{-62}\ ^{+37}_{-24}$	2.8
All channels	$145 \pm 31\ ^{+42}_{-27}$	4.8

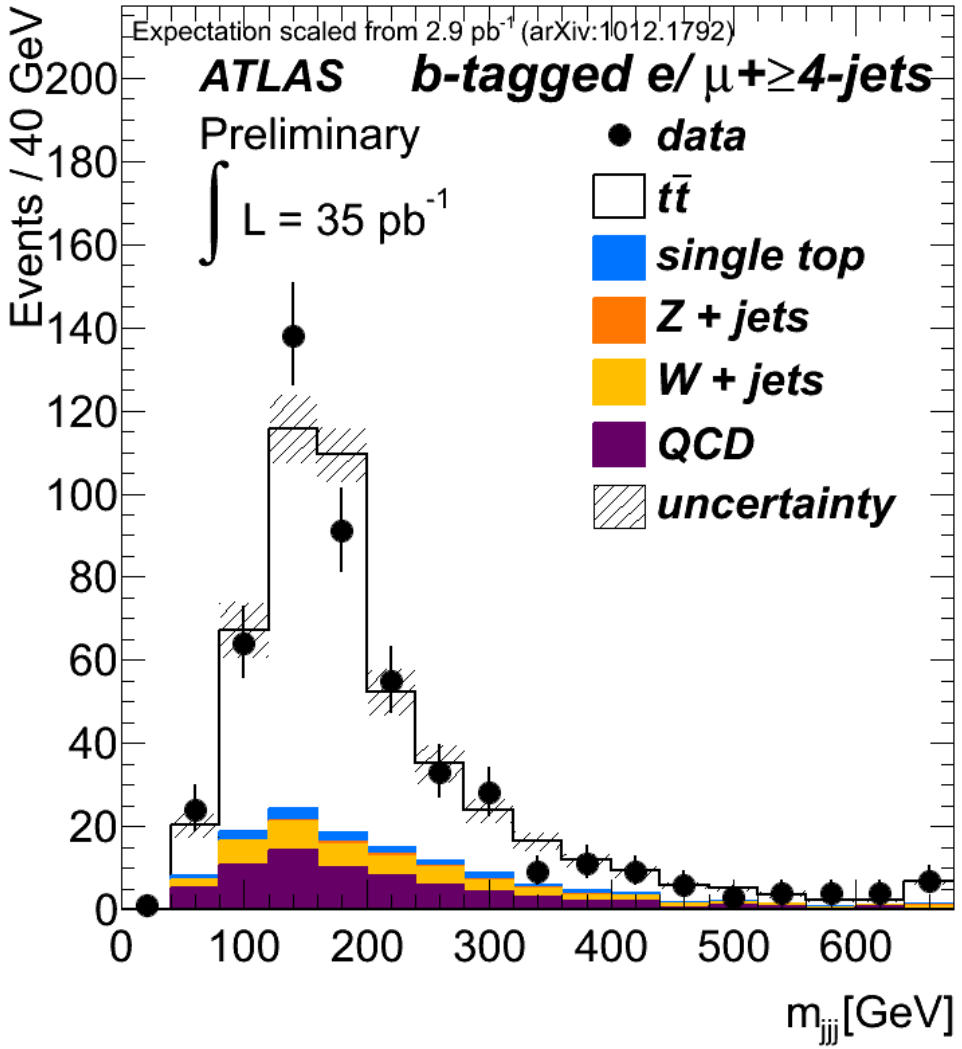
arXiv:1012.1792



M. Aliev, H. Lacker, U. Langenfeld, S. Moch, P. Uwer, and M. Wiedermann, HATHOR HAdronic Top and Heavy quarks crOss section calculatoR, arXiv:1007.1327 [hep-ph].

arXiv:1012.1792


Expectation scaled from 2.9 pb^{-1} (arXiv:1012.1792)
ATLAS b-tagged e/ μ+jets
Preliminary
∫ L = 35 pb^{-1}
data
tt̄
single top
Z + jets
W + jets
QCD
uncertainty
Events
Number of jets

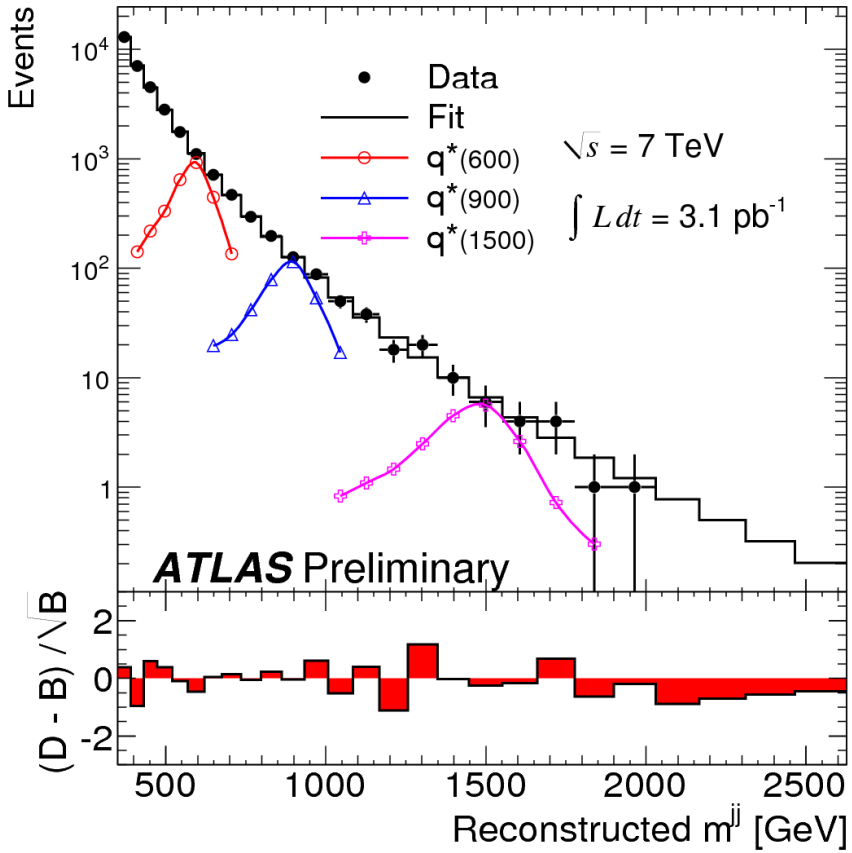

Expectation scaled from 2.9 pb^{-1} (arXiv:1012.1792)
ATLAS b-tagged e/ μ+≥4-jets
Preliminary
∫ L = 35 pb^{-1}
data
tt̄
single top
Z + jets
W + jets
QCD
uncertainty
Events / 40 GeV
m$_{jjj}$[GeV]

Searches in di-jets spectra:

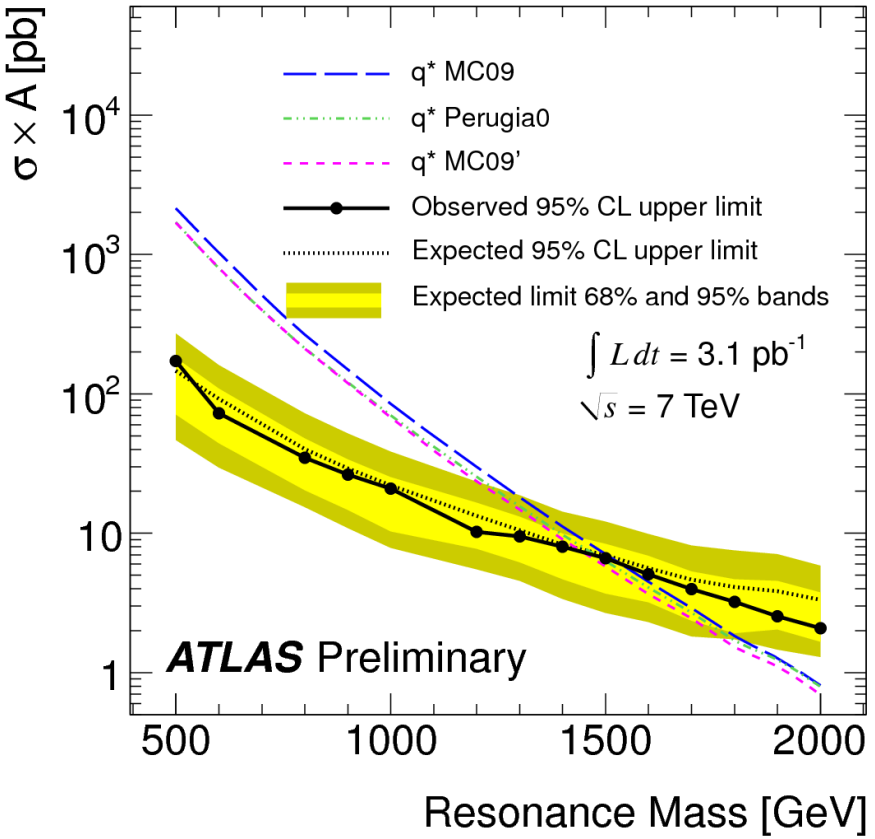
- Model independent searches for massive particles in di-jet invariant mass spectra (resonances)
- Excludes excited quarks in region 0.50 < m [TeV] < 1.53

SUSY:

- No surprises so far with a sub-set of the data available
- Expect to surpass Tevatron limit on squarks and gluinos with the current data set



PRL 105, 161801 (2010) (315 nb^{-1})
ATLAS-CONF-2010-093 (3.1 pb^{-1})



Summary:

- Observation of b-Hadrons shows ATLAS' very good tracking performance
- Top quark signal established in single and dilepton channels using 3 pb^{-1}, submitted to journal and available on arxiv:1012.1972
- Initial ATLAS top cross-section measurement in agreement with predictions and CMS:

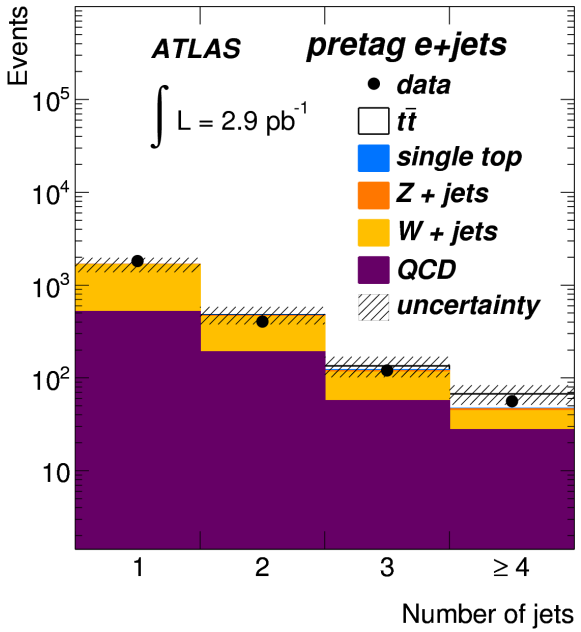
$$\sigma(pp \rightarrow ttbar) = 145 \pm 31^{+42}_{-27}\ pb$$

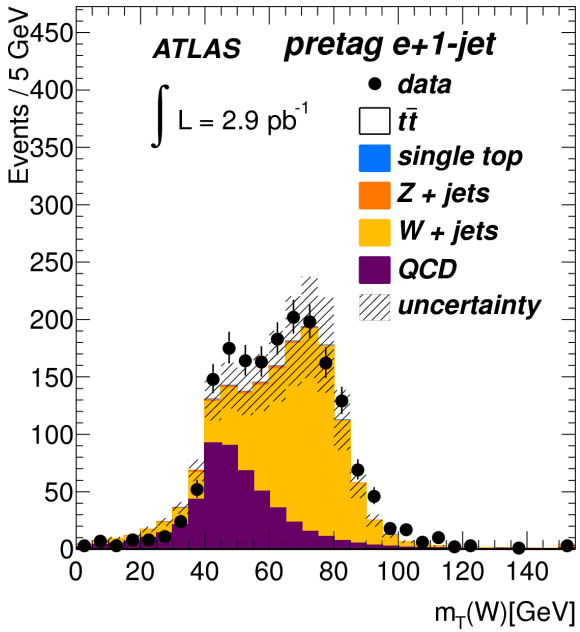
- Larger data set with 35 pb^{-1} being analyzed
- Searches for resonances in di-jet events exceed current Tevatron limits using a small fraction of available data (3.1 pb^{-1})
- Results also in SUSY sector expected
- Outlook: LHC is expected to collect ~1 fb^{-1} in 2011, maybe with 8 TeV
- Run might be prolonged for 2012 and ~5 fb^{-1} (Chamonix)

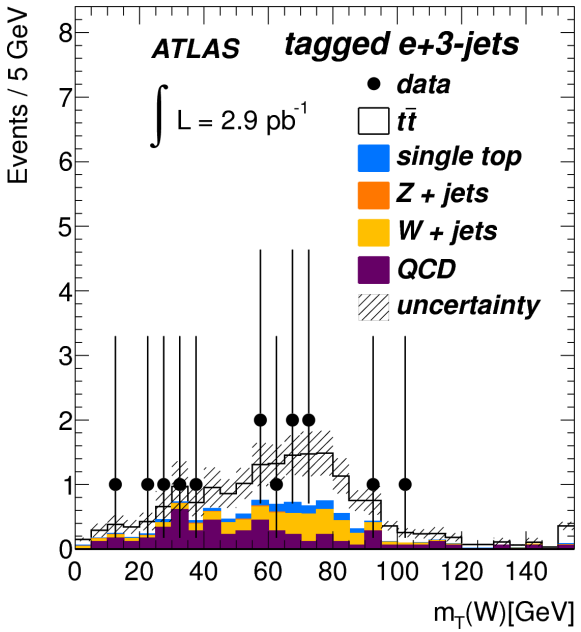
Monte Carlo Samples:

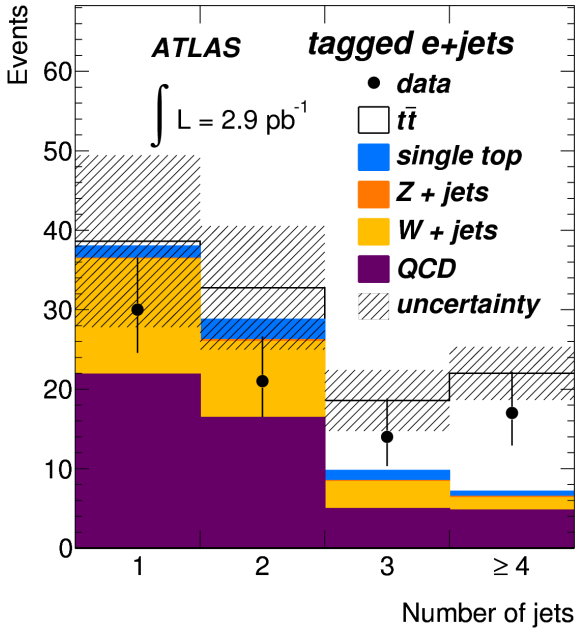
- Ttbar: MC@NLO v3.41 with CTEQ66 assuming m_{top}=172.5 GeV
  cross-section normalized to 164.6 pb to match from $NNLO_{approx}$ calc.
- W/Z bosons: ALPGEN v2.13 with CTEQL1
  cross-sections multiplied by 1.22 to match NNLO calc.
- Z boson: PHYTHIA in region $10 < m_{ll}$ [GeV] < 40
- Separate samples with bbar and ccbar in the final state at ME level
- Single top: MC@NLO v3.41 with ‘diagram removal scheme’
- Hadronization done with HERWIG
- Underlying event done with JIMMY

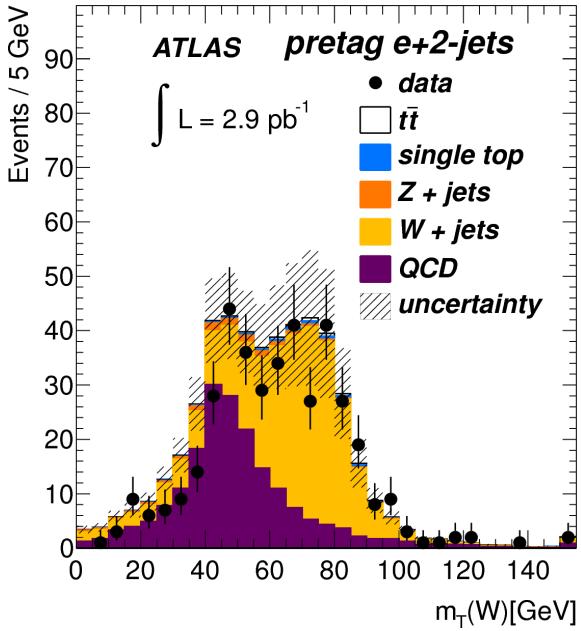
Appendix: single electron channel

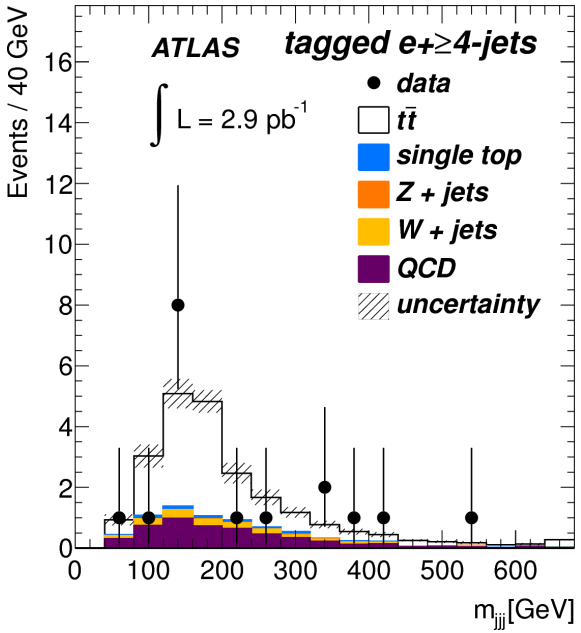






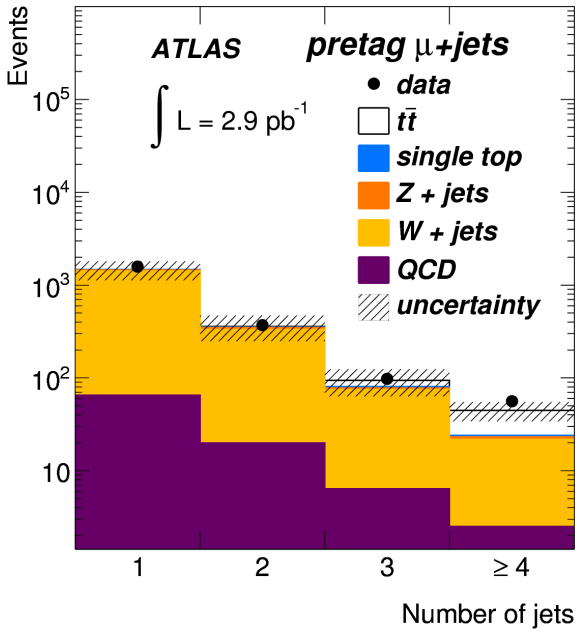


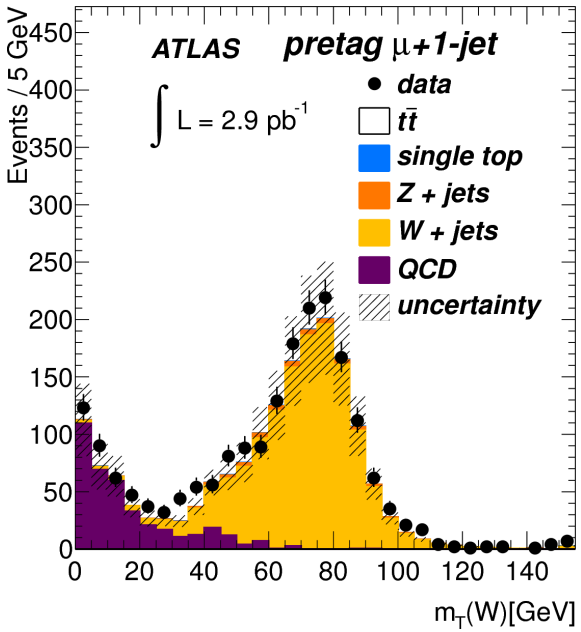


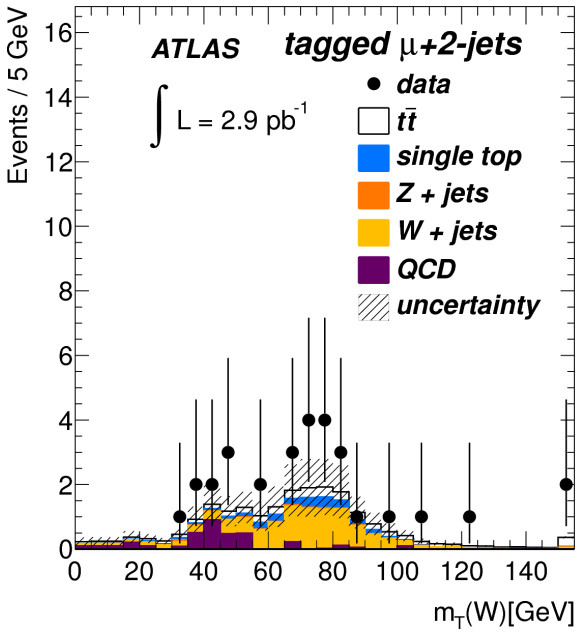


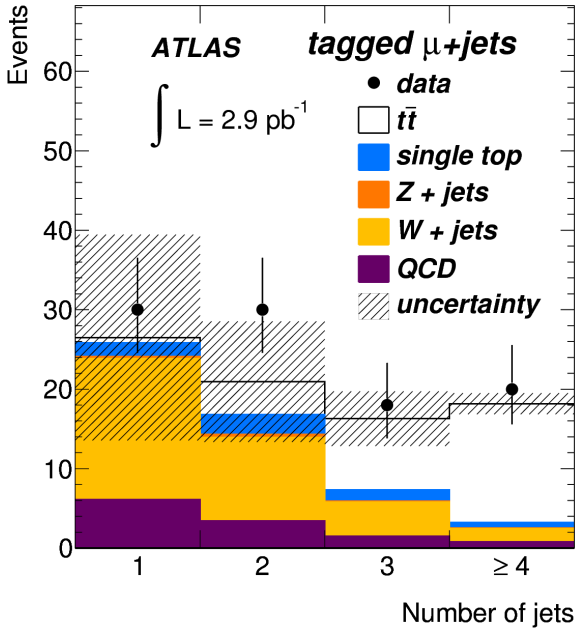
arXiv:1012.1792

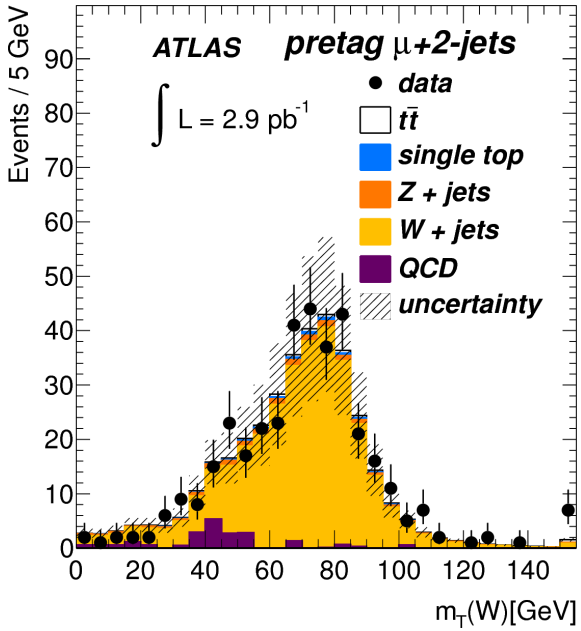
Appendix: single muon channel

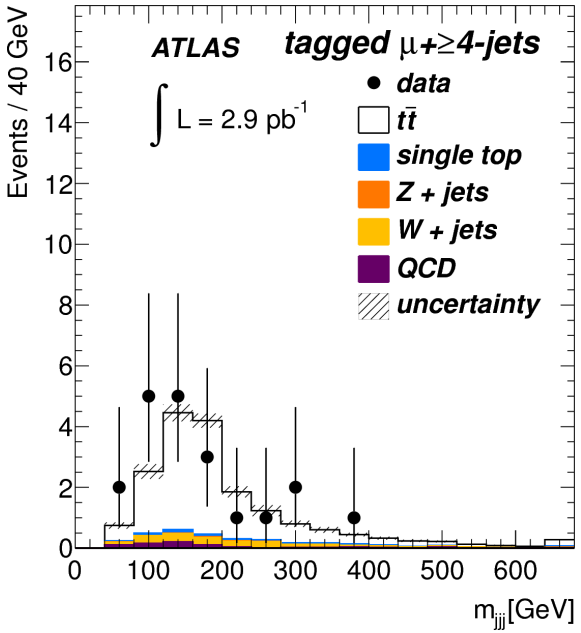




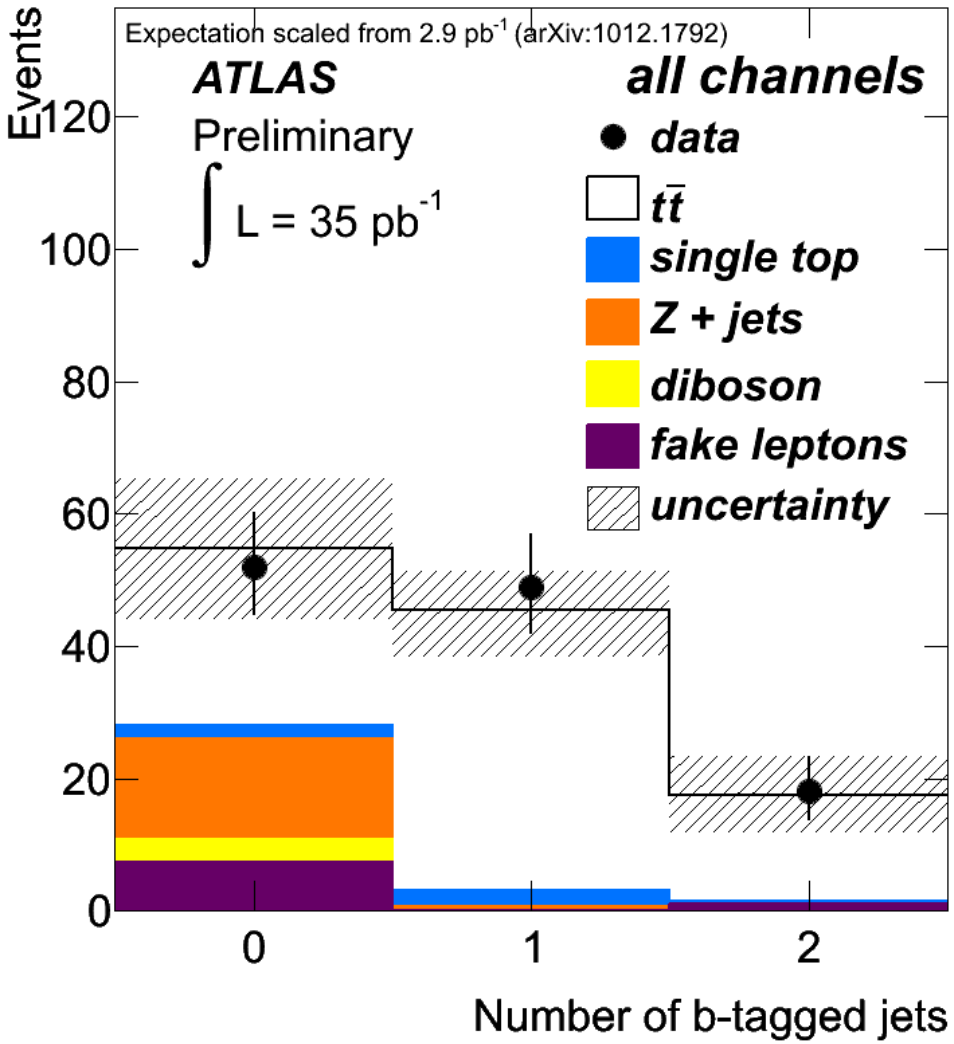






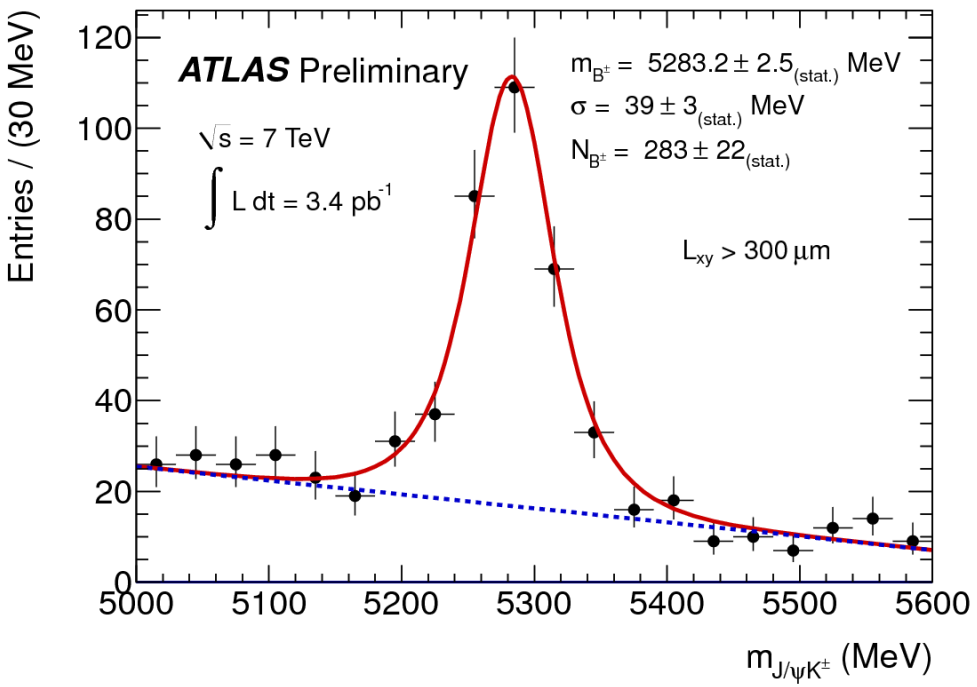


arXiv:1012.1792


Expectation scaled from 2.9 pb-1 (arXiv:1012.1792)
ATLAS
Preliminary
∫ L = 35 pb-1
all channels
data
tt̄
single top
Z + jets
diboson
fake leptons
uncertainty
Events
120
100
80
60
40
20
0
0
1
2
Number of b-tagged jets

Observation of $B^{\pm}$:

- Channel:
  $B^{\pm} \rightarrow J/\Psi\ K^{\pm}$ (BR~0.1%)
  with $J/\Psi \rightarrow \mu^{+}\mu^{-}$ (BR~6%)
- Calibration tool for inner detector and flavor tagging
- Event selection:
  - Proper collision event with at least three tracks
  - At least two oppositely charged muons ($p_T > 1$ GeV, $|\eta|<2.7$)
  - J/Ψ candidate:
    - Tracks fit one common vertex
    - $p_T(\mu) > 4$ (2.5) GeV
    - Invariant mass in window $2915 < m_{\mu+\mu-}$ [GeV] < 3275



- $B^{\pm}$ candidate:
  - Additional track fit to vertex
  - $p_T > 10$ GeV for three-track obj.
- Perform unbinned Likelihood fit

	m_B, MeV	σ_m, MeV	N_{sig}	N_{bkg}	S
$B^{\pm}$	5283.2 ± 2.5	39 ± 3	283 ± 22	131 ± 13	1.09 ± 0.07
B^{+}	5282.6 ± 3.6	40 ± 4	138 ± 15	70 ± 11	1.12 ± 0.11
B^{-}	5283.7 ± 3.3	39 ± 4	146 ± 15	61 ± 8	1.06 ± 0.10
MC	5281.8 ± 0.2	39.8 ± 0.2			1.100 ± 0.003

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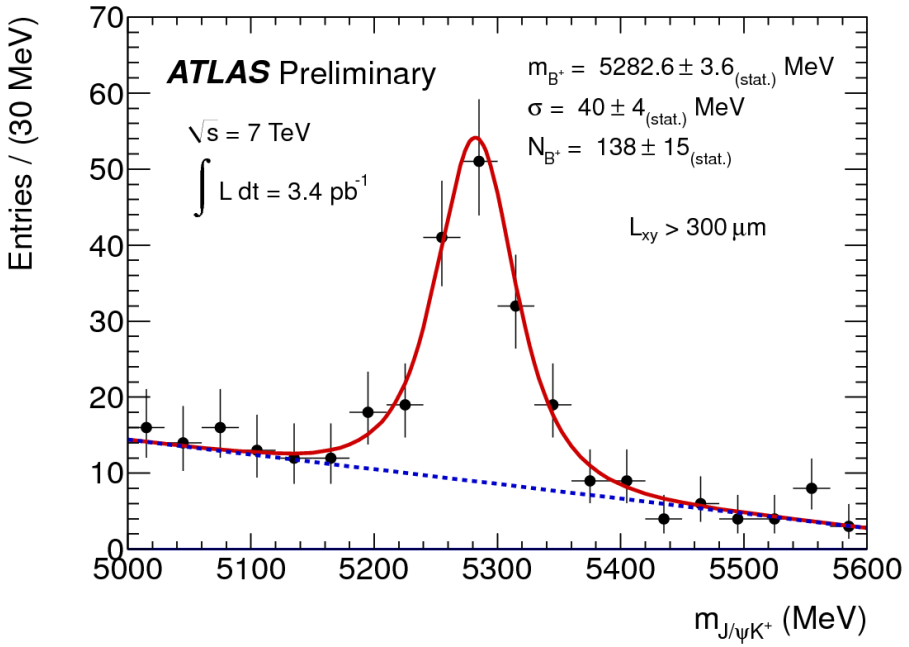

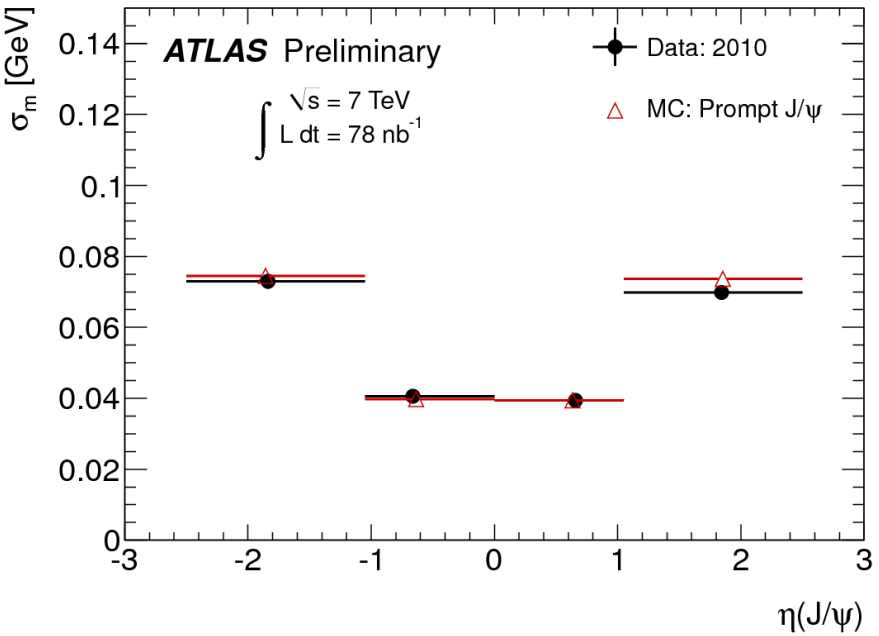

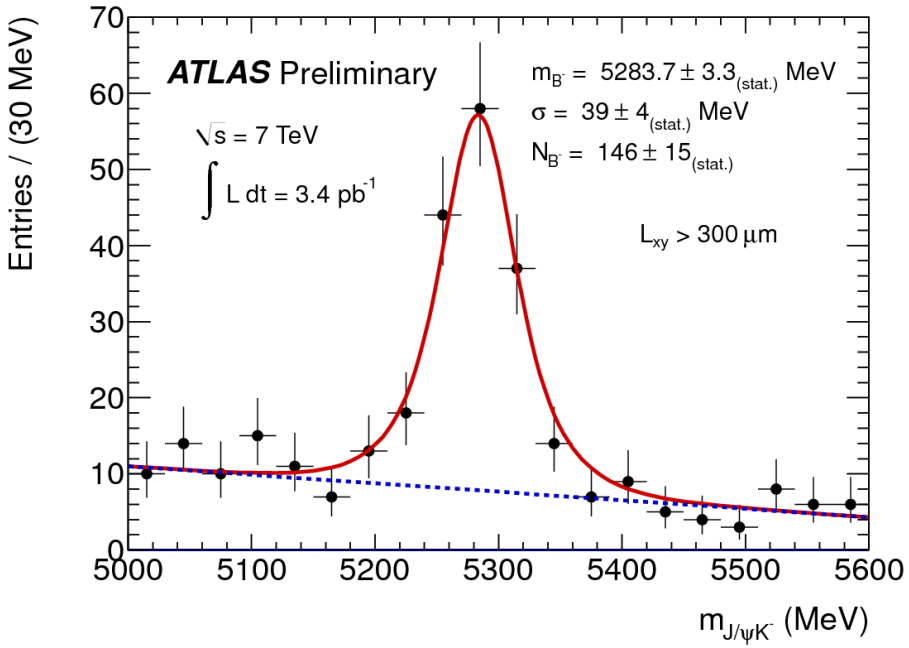

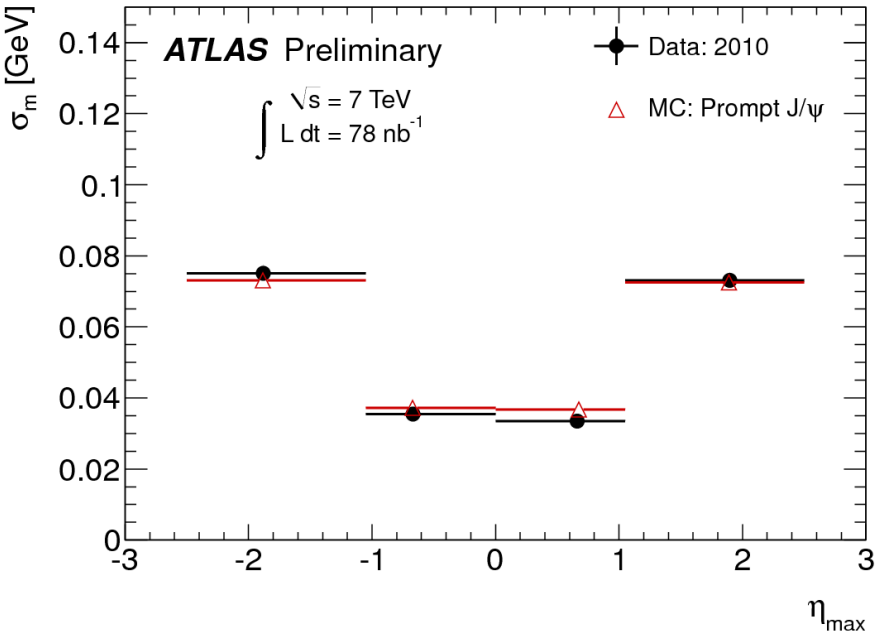

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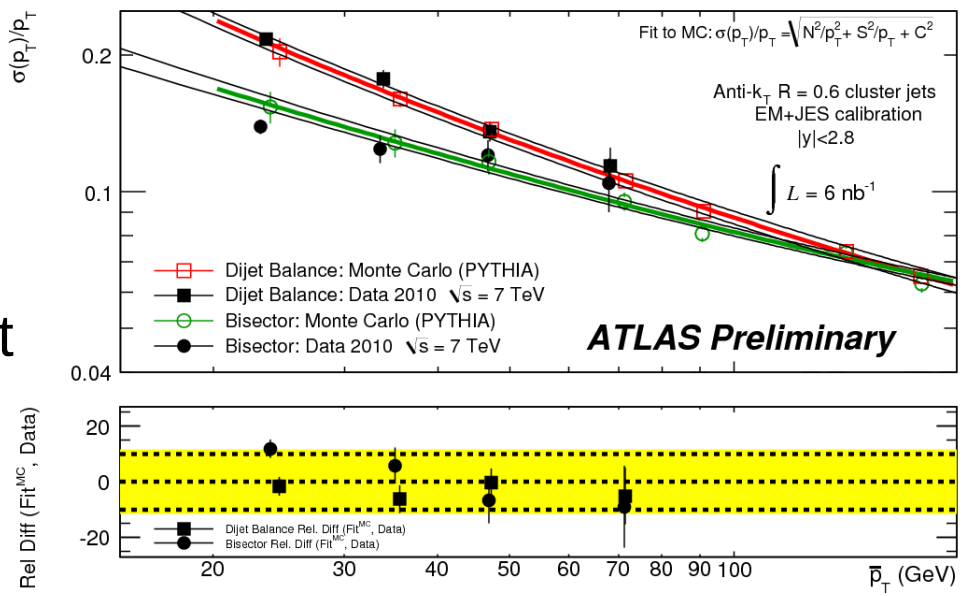
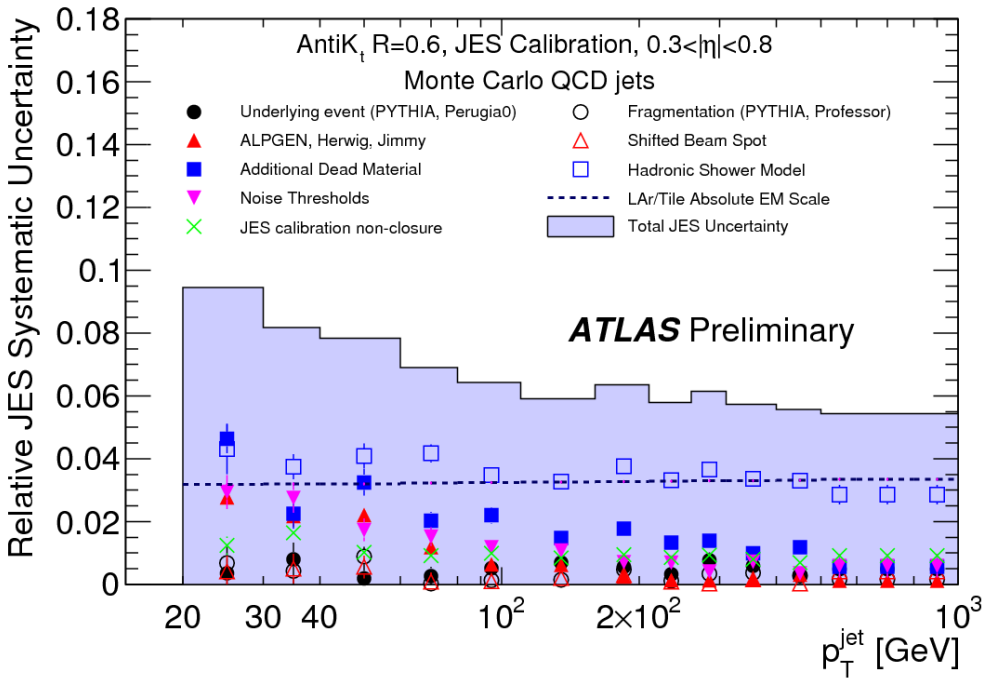
Jets in ATLAS:

- Use Anti-kT algorithm with R=0.4 on topological clusters
- Calibration based on EM-scale objects using p_T and η-dependent scale factors from simulation





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ATLAS-CONF-2010-056