ATLAS Status and Highlights

103rd LHCC Open Meeting
23 September 2010

Tom LeCompte/Argonne National Laboratory

On Behalf of the ATLAS Collaboration

Outline

- Detector Operation and Performance
- A subset of ATLAS' physics program
  - Soft QCD
  - W/Z Production
  - Direct Photons
  - Jets
  - Dimuons & B Physics
  - Top
  - Searches

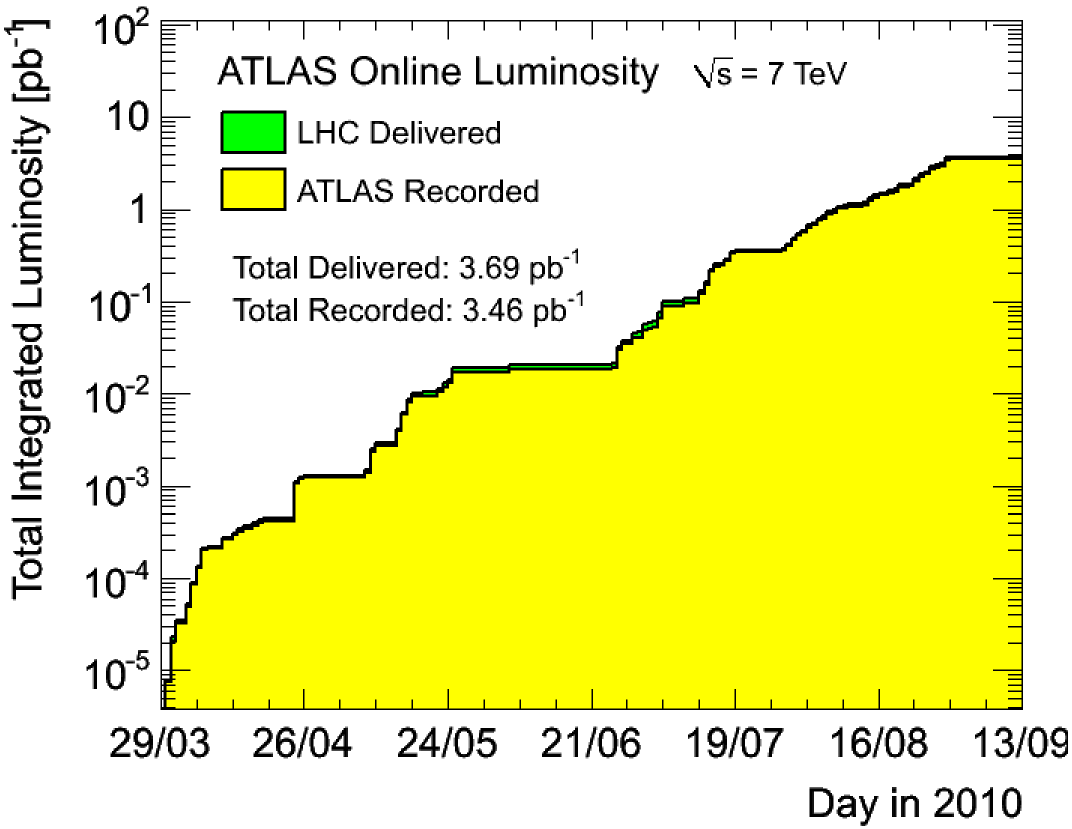
Many more **new results** can be found on the ATLAS physics page, linked from http://atlas.web.cern.ch/Atlas/

ATLAS' strategy - detailed ongoing work to lay the foundation for solid physics measurements

Integrated Luminosity

Peak luminosity in ATLAS
$\mathcal{L} \sim 1.0 \times 10^{31}\ cm^{-2}\ s^{-1}$

Luminosity detectors calibrated with van der Meer scans. Luminosity known today to 11% (error dominated by knowledge of beam currents)



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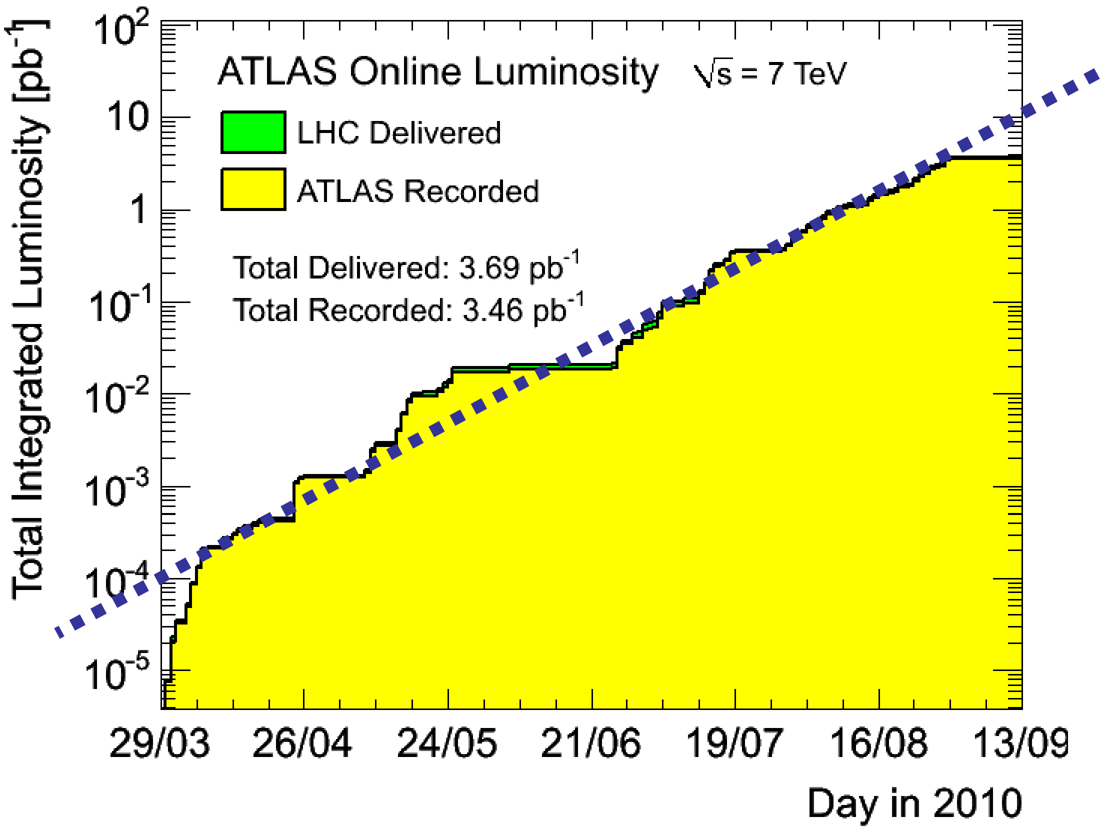
Integrated luminosity doubling time: about 10 days



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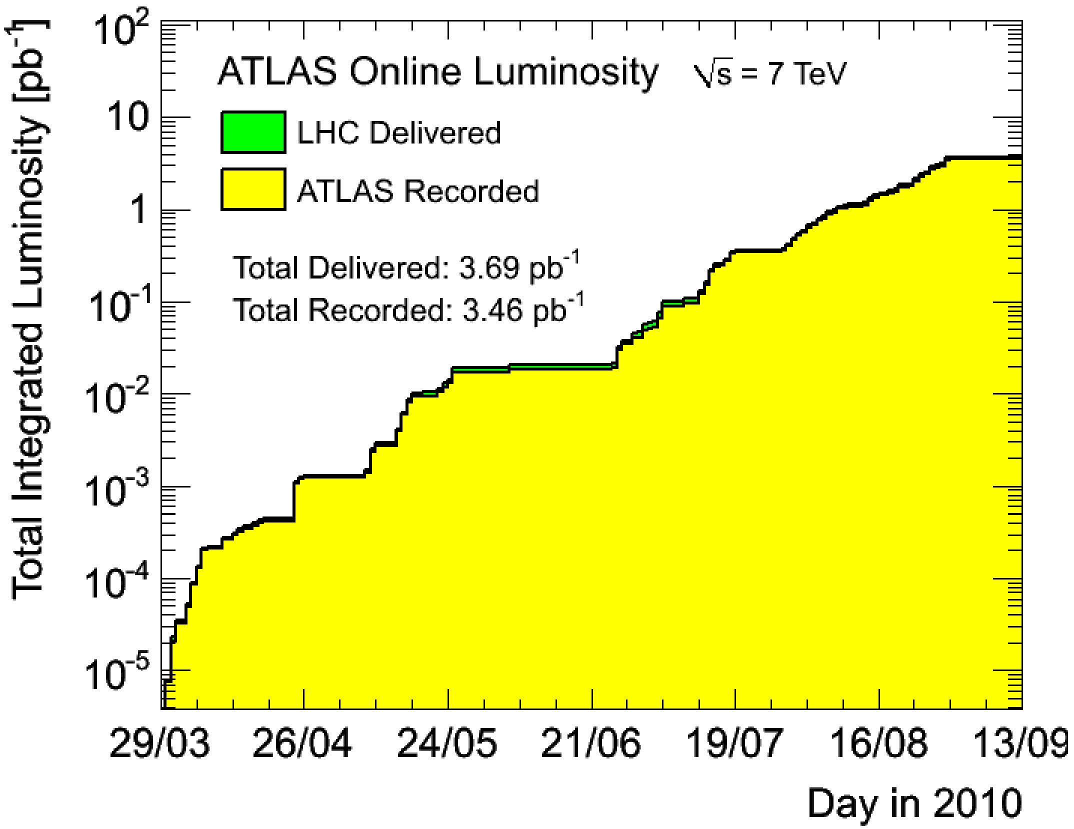


Overall data taking efficiency (with full detector on): ~ 94%

Many of the results presented here are based on the full data sample recorded up to the last technical stop/machine development period.

Status of ATLAS

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.3%
SCT Silicon Strips	6.3 M	99.2%
TRT Transition Radiation Tracker	350 k	97.1%
LAr EM Calorimeter	170 k	98.1%
Tile calorimeter	9800	96.9%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo trigger	7160	99.9%
LVL1 Muon RPC trigger	370 k	99.5%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.5%
RPC Barrel Muon Chambers	370 k	97.0%
TGC Endcap Muon Chambers	320 k	98.6%

All subdetectors have operational fractions in the upper 90's.

n.b. we are tightening the definition of "operational" – e.g. a TRT wire now needs to be at least 60% efficient to be counted as operational.

Good Quality Data Fraction

Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	TGC	CSC
96.7	97.5	100	93.8	98.8	99.0	99.7	98.6	98.5	98.6	98.5

Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams at $\sqrt{s}$=7 TeV between March 30th and August 30th (in %)

Few percent inefficiencies EM calorimeter due to occassional trips & sporadic noise bursts

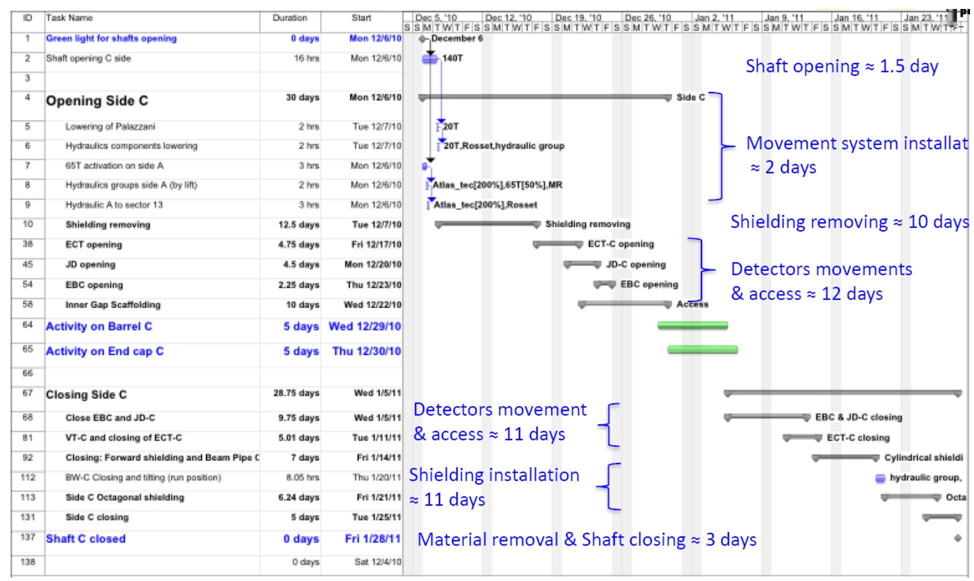
Small inefficiencies in Silicon and Muon detectors due to time to ramp up HV after stable beams are declared.

We are learning how to recover from (or at least mitigate) these operational issues and are continually improving – e.g. recovering from noise bursts

General Operation Issues

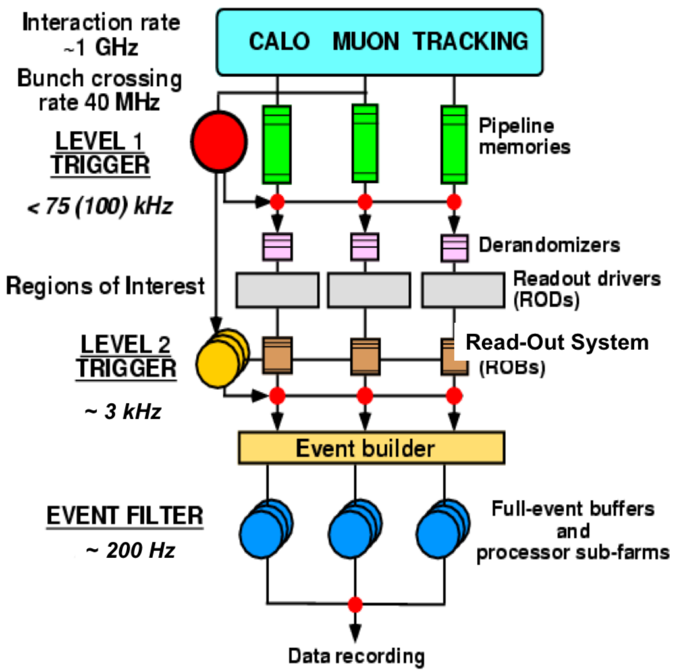
- CSC Readout – continues to improve, no longer limits our readout speed
- LAr OTx – 24 failures (rate ~1/month). Confined to units with a narrow-width pulse
- SCT/Pixel Optical links – few failures per week (in USA15: can be replaced quickly). Spares on order.
- Magnet/Cryo – recent intervention to fix the filter clogging problem.
- Calorimeter LVPS – some will be replaced over the winter shutdown

- We are developing a detailed plan for the winter shutdown
  - Open one side of the detector (baseline is C side) for work on
    - Liquid Argon Calorimeters
    - Tile Calorimeters
  - Much preventative maintenance on cryogenics, HVAC, safety systems, etc.
- We will do as much as we can in the time we have
  - Access is not easy!

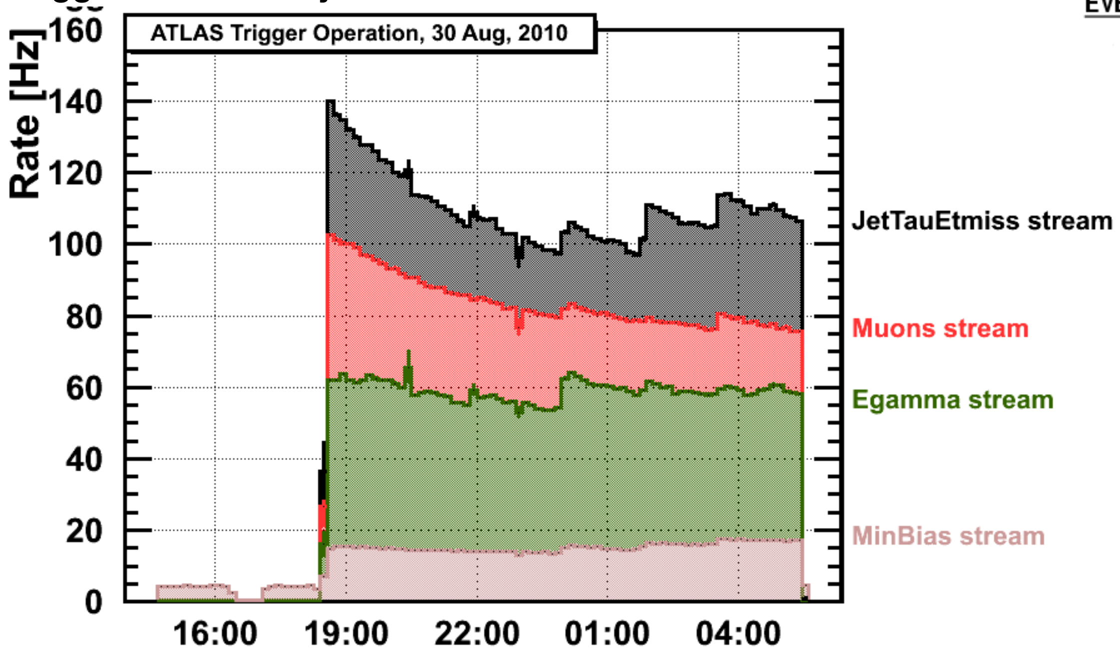


Trigger

- ATLAS has a three level trigger
- **All three levels are now actively selecting events**
  - Of course, we still have monitoring triggers where the trigger tags events



Trigger rates of major streams



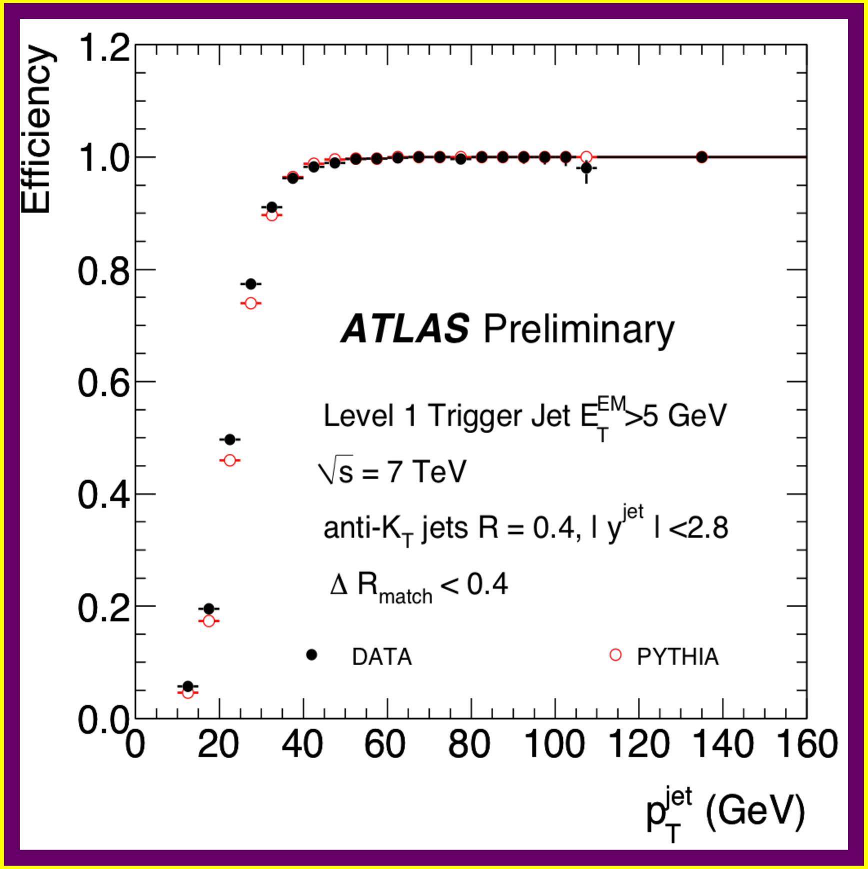
Prescales are adjusted throughout the fill to hold the output rate around 300 Hz.

This is set by our offline capacity.

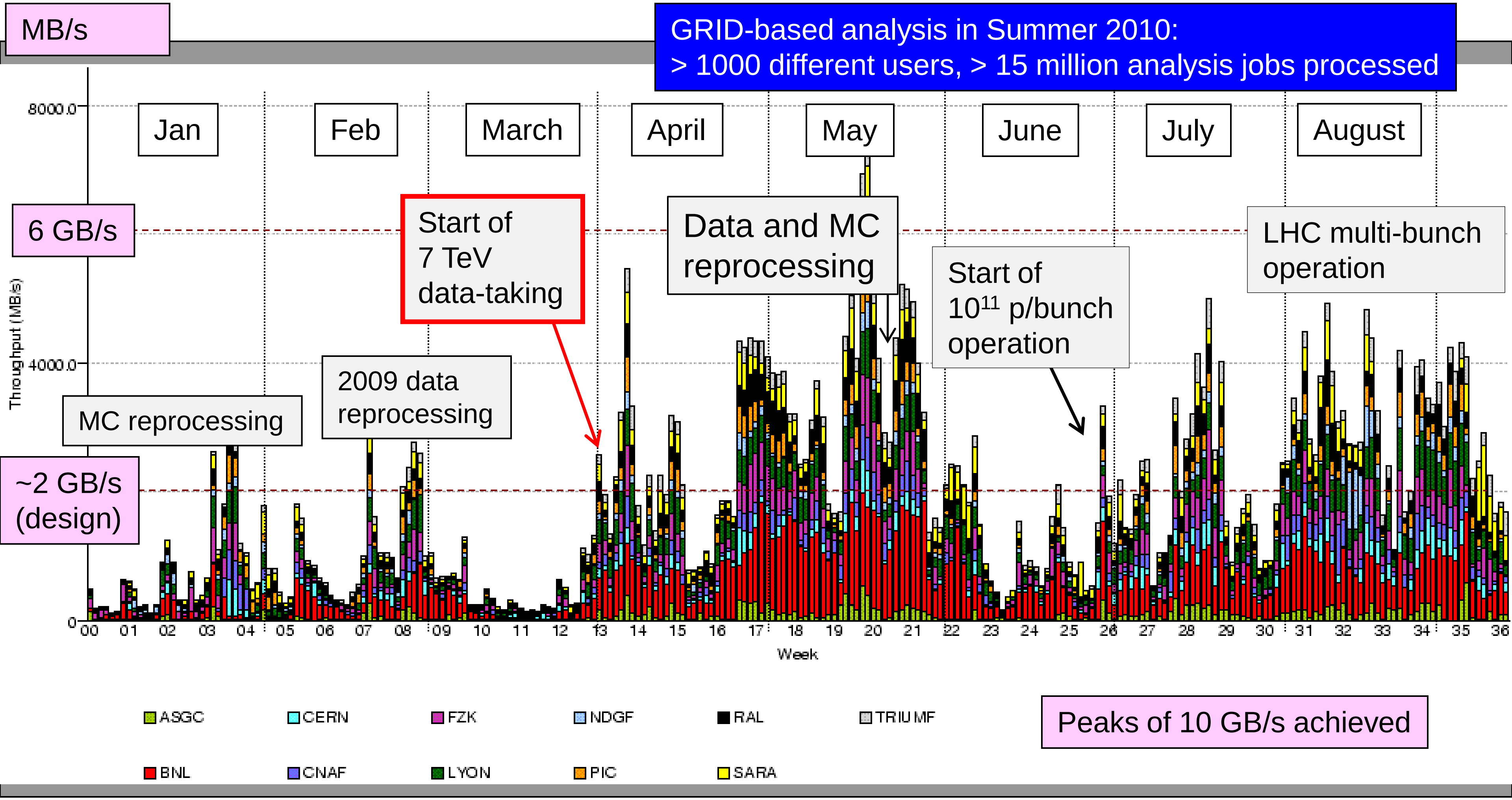
Trigger & Physics

- The trigger menu is evolving with luminosity. The 10^{31} menu has three primary components
  - The 10^{32} menu as a subset
  - Lower p_T muon triggers (to enhance the B-physics program)
  - Triggering objects with lower p_T /looser cuts to study trigger performance.

Example of performance: LVL1 jet trigger efficiency for the lowest threshold (J5)



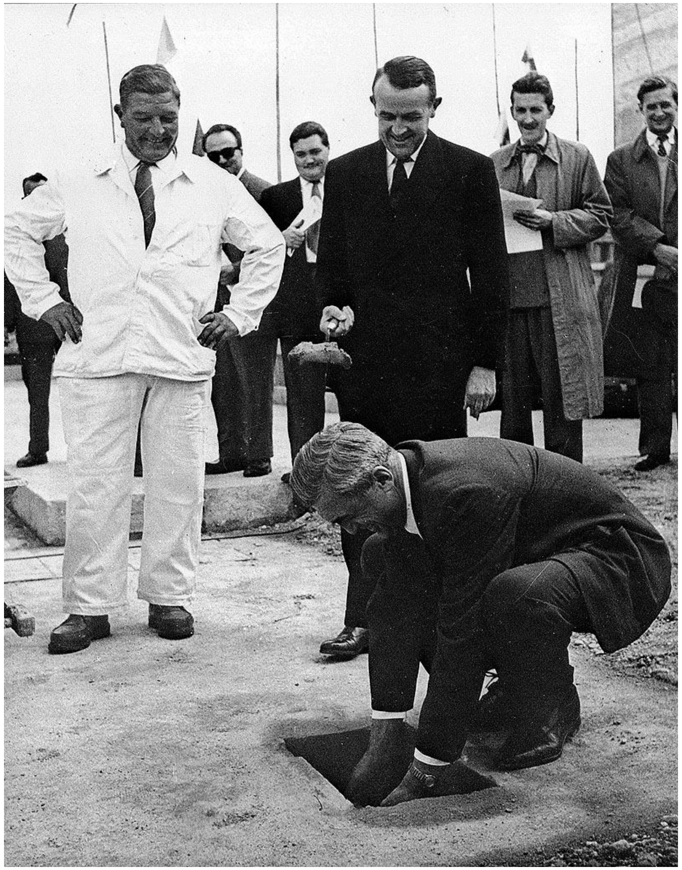
ATLAS Worldwide Grid Computing



The excellent grid performance was critical in showing the full data sample at ICHEP: data taken as late as Monday was shown in the Friday parallel sessions.

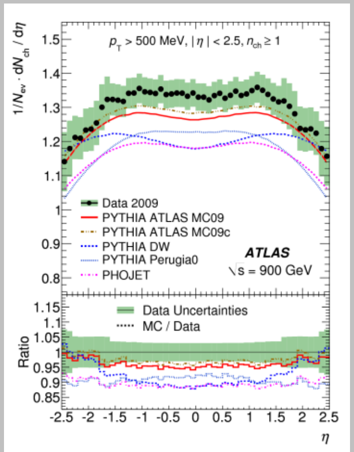
SM Physics – Laying the Foundation

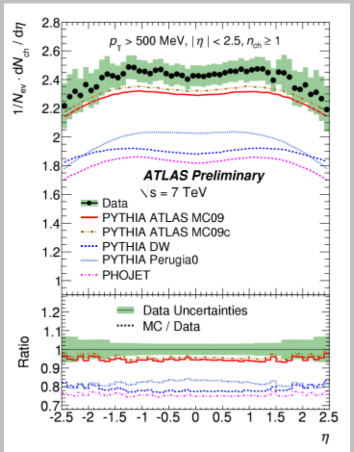
Standard Model Physics is important in its own right, but also is the base upon which we build our searches for new particles and phenomena.



Soft QCD I – Minimum Bias

Last time, we showed the minimum bias measurements at 900 GeV and 7 TeV.





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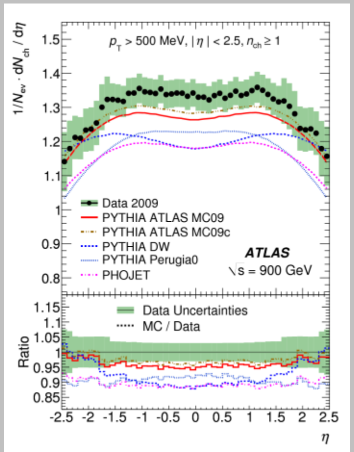
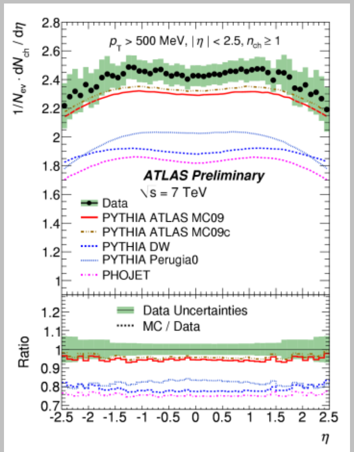
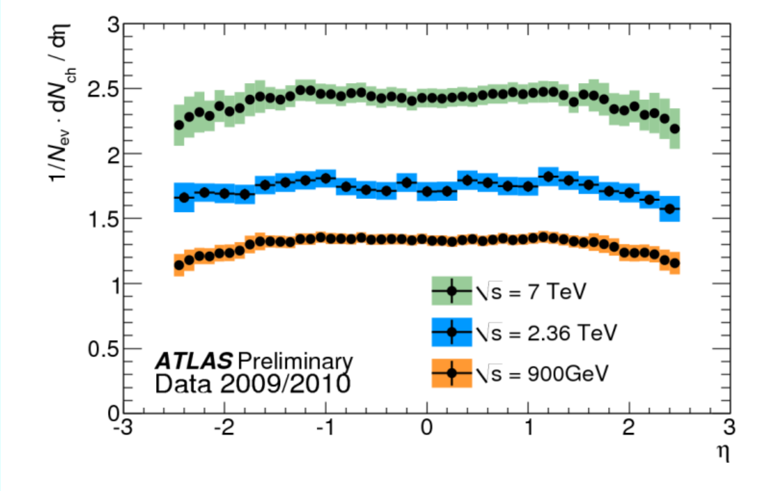




We have since added 2.36 TeV…



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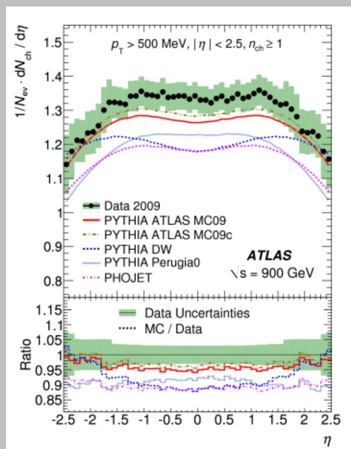

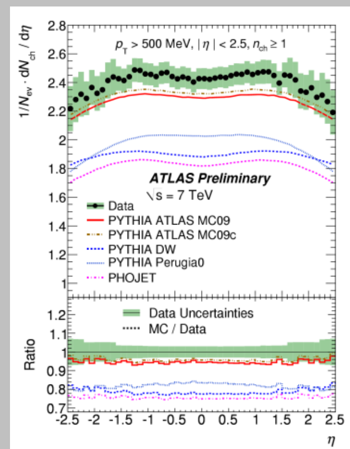

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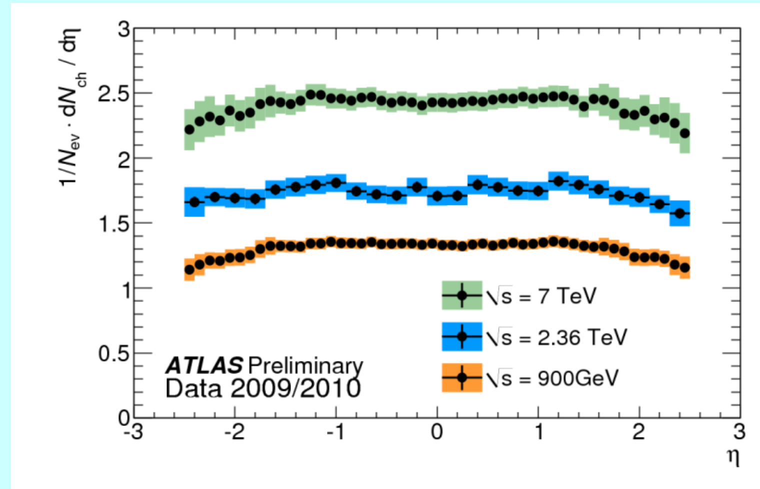
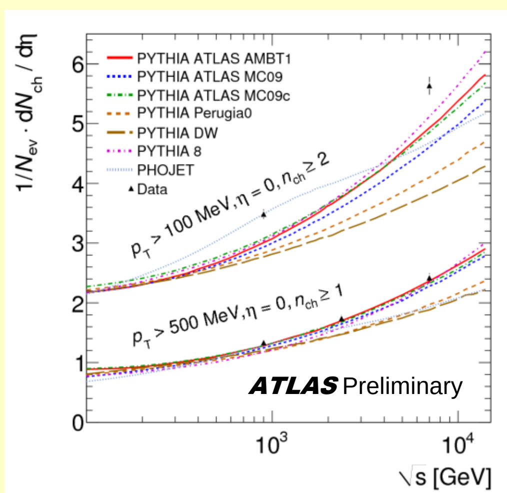


…lowered the track p_T cut…



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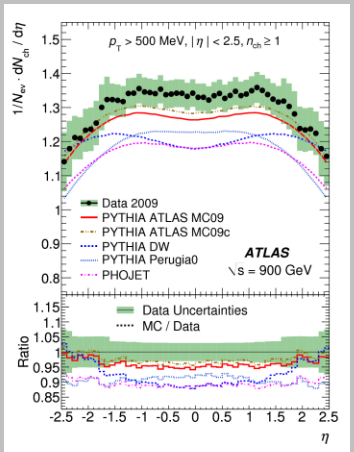

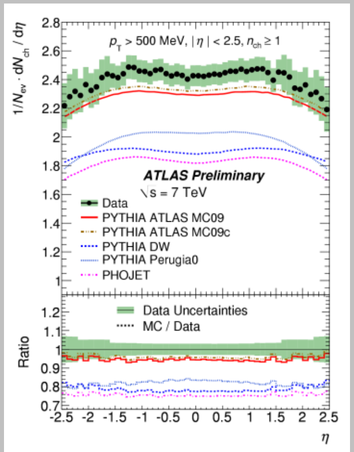

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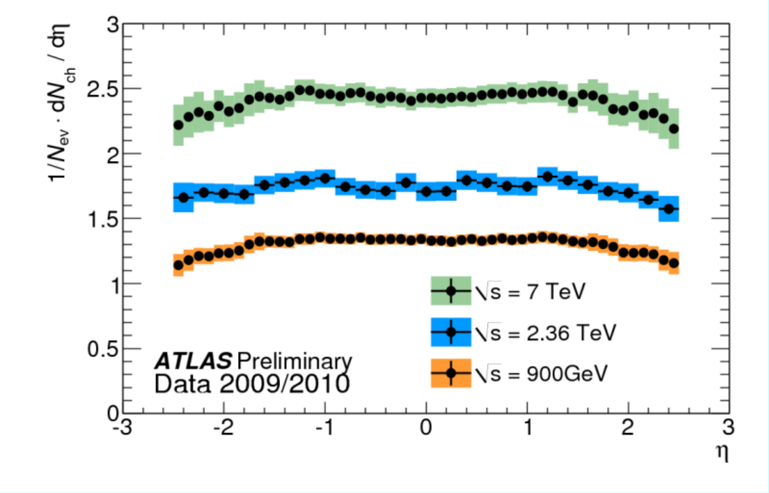

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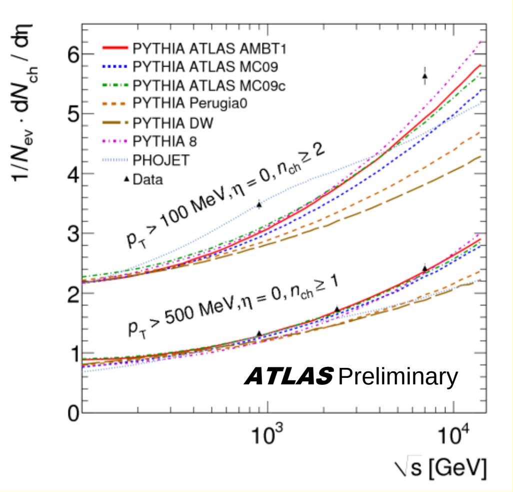
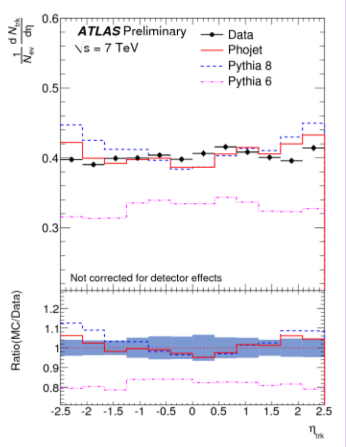
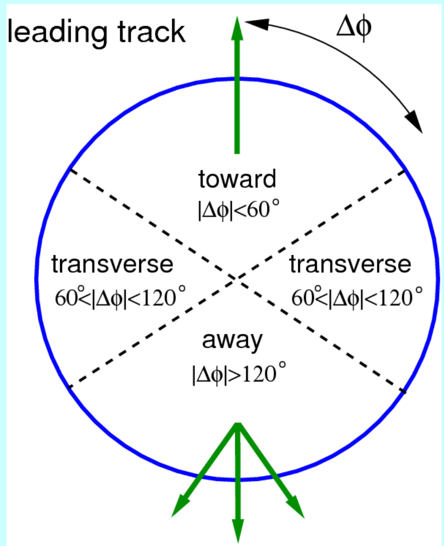


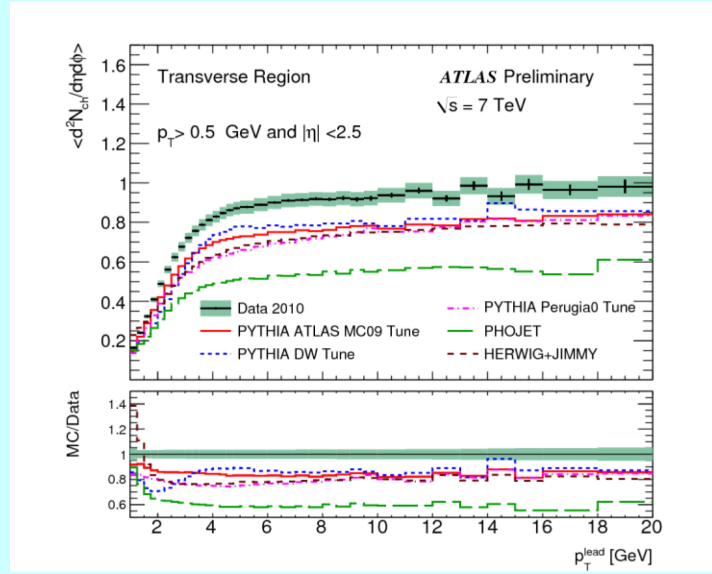


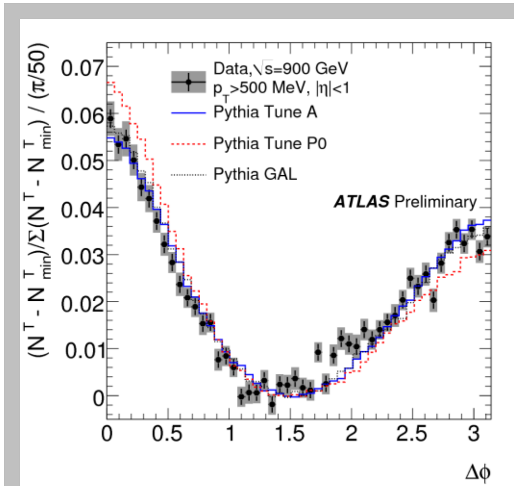
…and studied a diffraction-enhanced sample.

Soft QCD II – Angular Distributions

Underlying event: properties of tracks in selected regions relative to the leading track





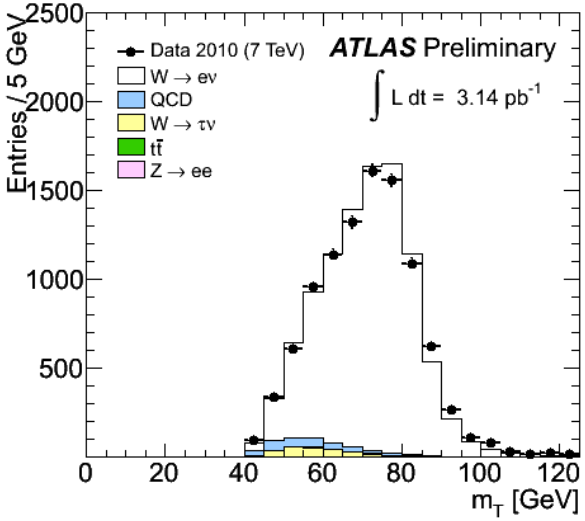


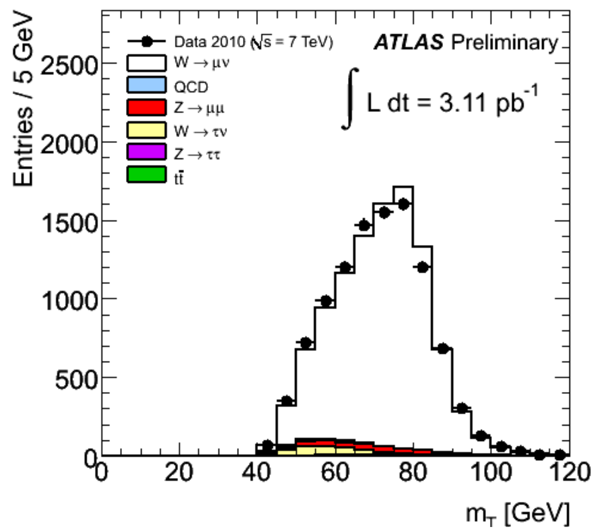
Angular difference (Δφ) between leading track and other tracks in the event.

(A more "continuous" version of the above measurement)

- Overall ATLAS strategy for soft QCD : report what we measure
  - Corrected for detector effects, of course
- Instead of (e.g.) correcting for diffraction, we have released measurements of diffraction-enhanced and diffraction-suppressed samples.

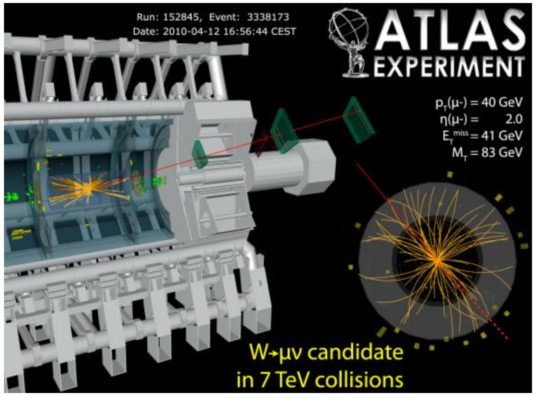
Electroweak Bosons

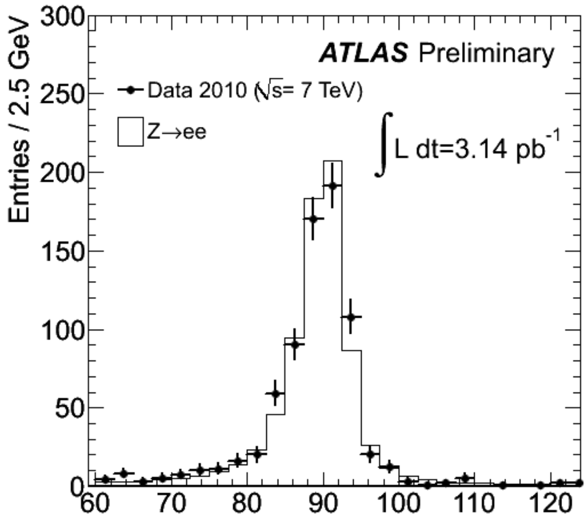


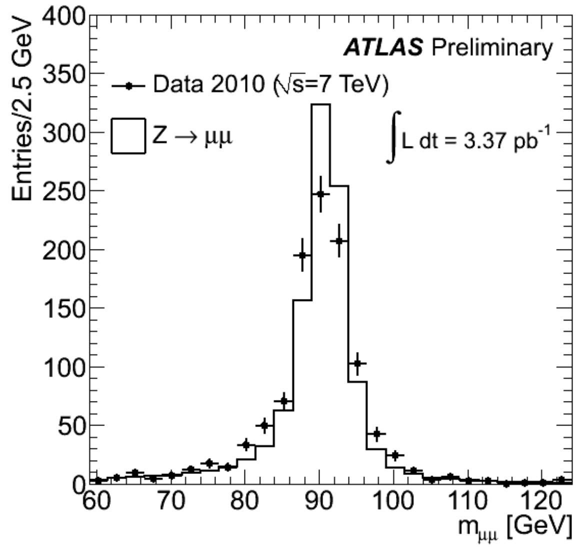


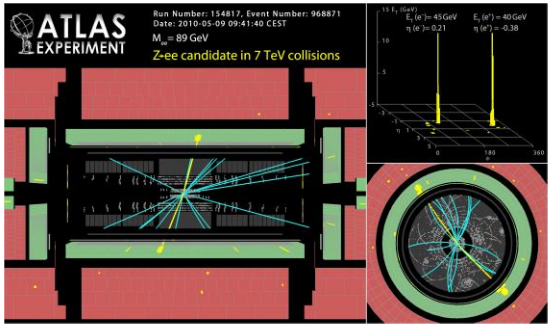
ATLAS has collected ~10^4 W's and ~10^3 Z's per channel.

Yield is between Tevatron 1A and 1B datasets.)



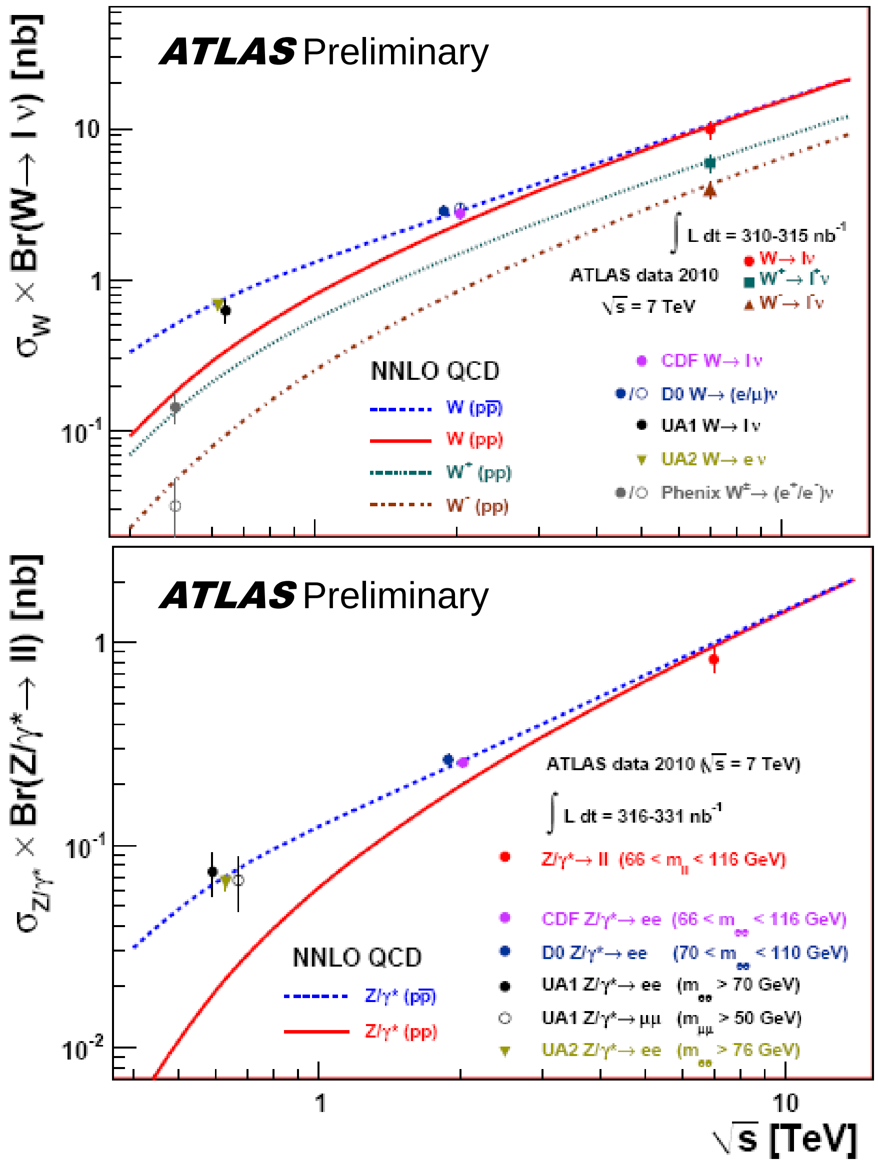






Based on 3+ pb^{-1} of data.

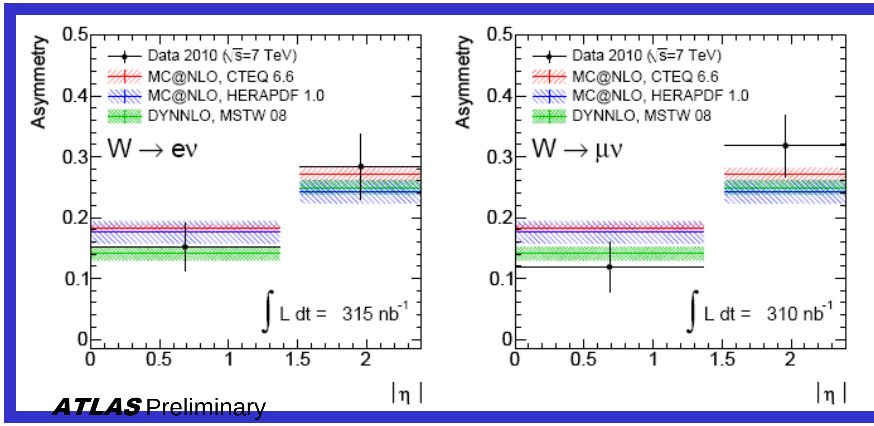
W/Z Cross-Sections



σ (W→ lν) = 9.96 ± 0.23 (stat) ± 0.50 (syst) ± 1.10 (lumi) nb

σ (γ*/Z→ ll) = 0.83 ± 0.06 (stat) ± 0.04 (syst) ± 0.09 (lumi) nb

n.b. largest uncertainty is the luminosity.

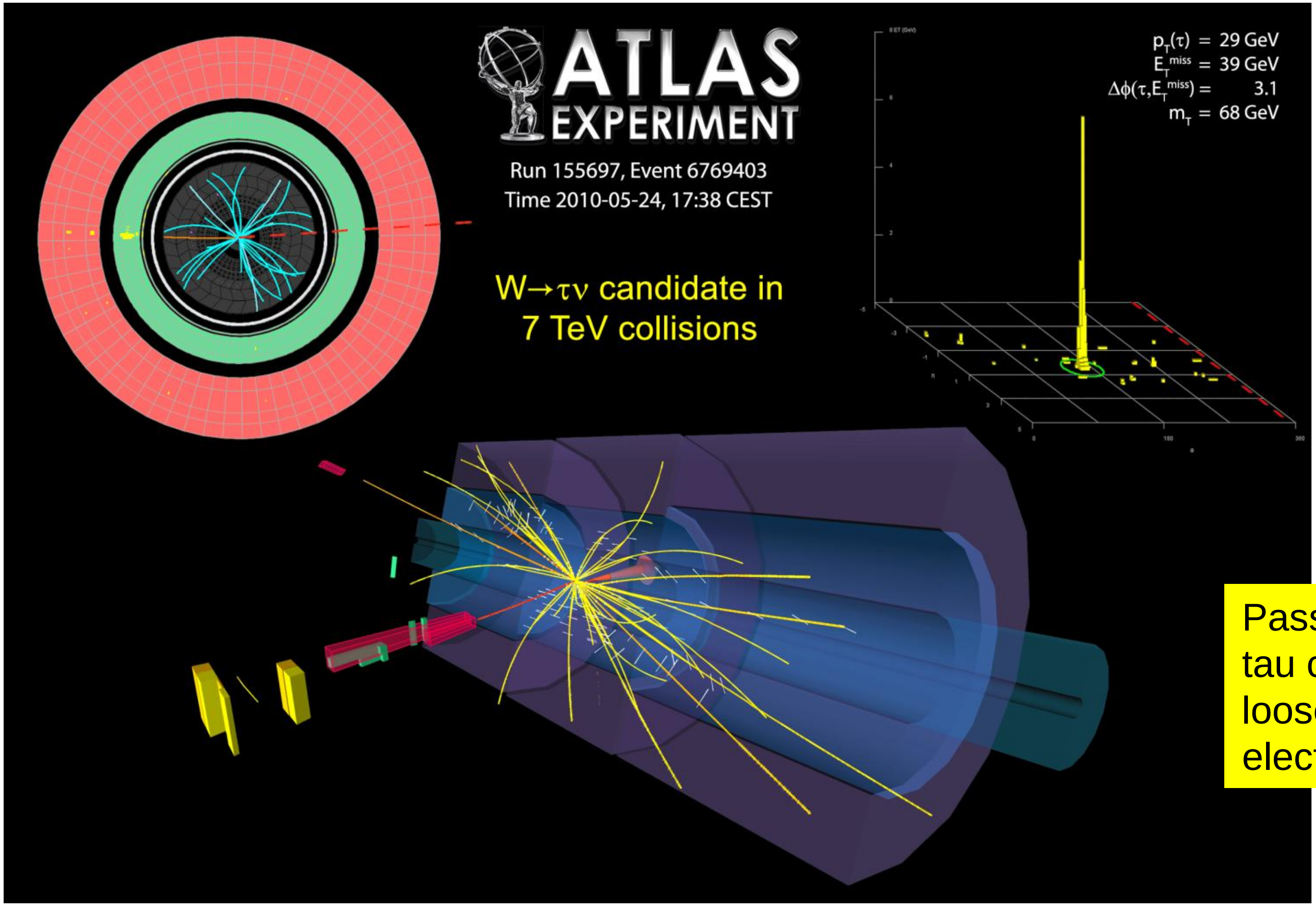


$$A = \frac{\sigma(W \to l^+\nu) - \sigma(W \to l^-\nu)}{\sigma(W \to l^+\nu) + \sigma(W \to l^-\nu)} \neq 0$$

ATLAS measurement:
A = 0.200 ± 0.022 (stat) ± 0.006 (syst)

Based on 300 nb-1 of data.

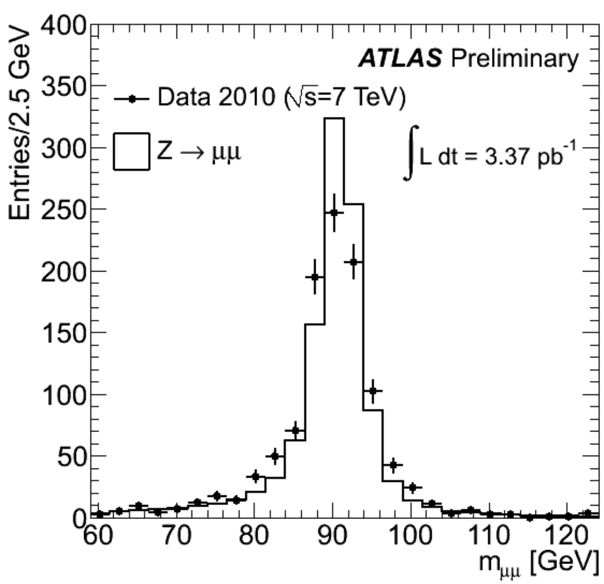
And Even Some Candidate W to Tau Nu Events

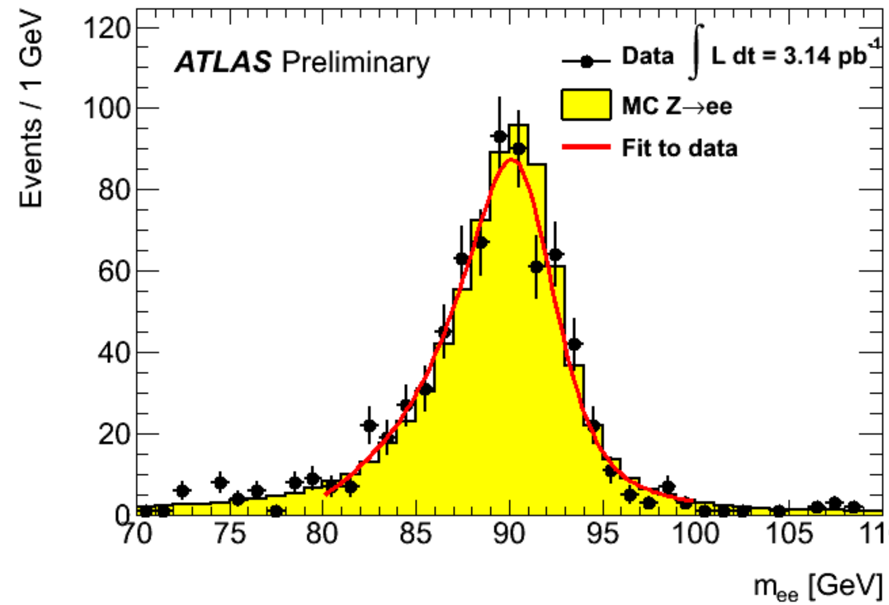


Passes tightest tau cuts; fails loosest electron cuts.

This channel has substantially more background, so it's more difficult to tell event-by-event if a given event is a real tau or background.

Improving Lepton Resolution





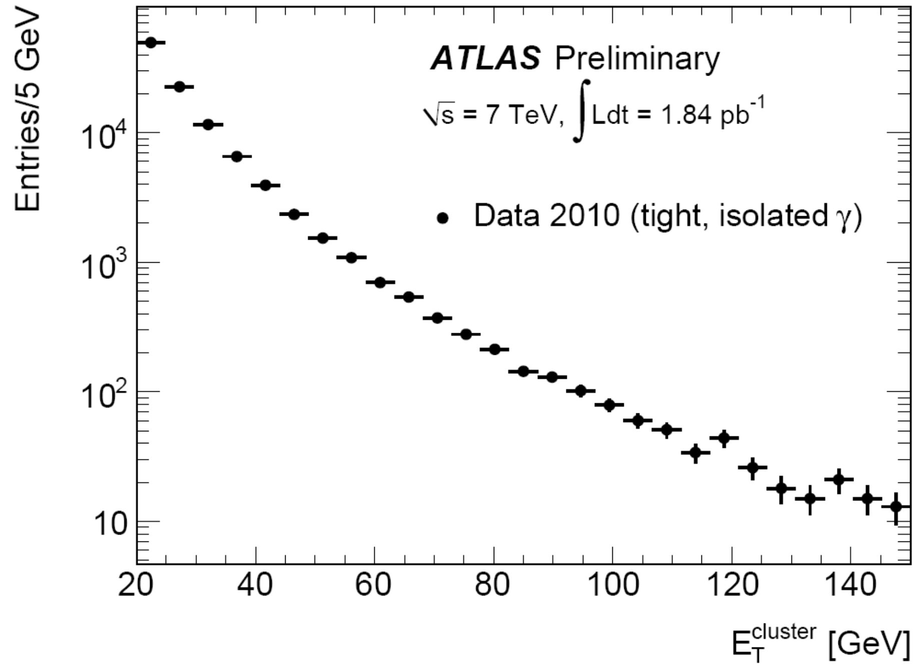
- Resolution already quite good
- Campaign in progress to improve – focusing on alignment
  - Already improvements (e.g. CSC)
  - Special toroid-off runs play a key role here.

- Mass peak used to inter-calibrate absolute E-scale in 10 regions of the EM calorimeter (corrections within ~ 3%)
- Experimental mass resolution: 1.59 ± 0.04 GeV
  - (MC: 1.40 ± 0.01 GeV)

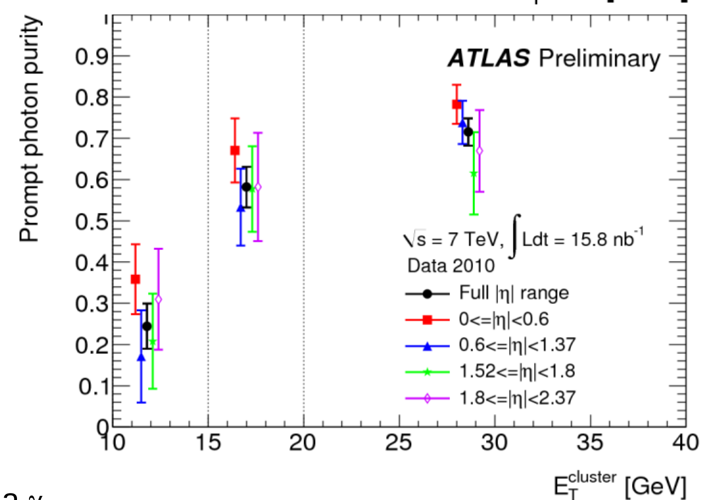
The “Electro” of Electroweak – Direct Photons

- In principle, prompt photons are an excellent probe of the gluon density.
- Today, the major global fits avoid them:
  - A very large (2-3 GeV) intrinsic k_T is needed to fit the data.
- This is less of an issue here:
  - At the LHC, the same x_T is probed with p_T's 3.5 larger than the Tevatron
  - We operate at a typical p_T where a few GeV of intrinsic k_T doesn't matter as much.

The LHC kinematics helps here.

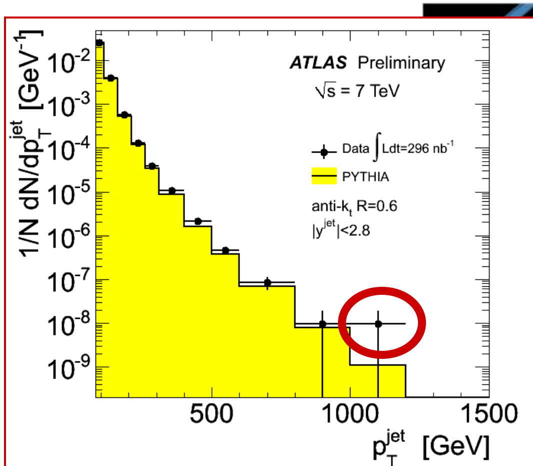


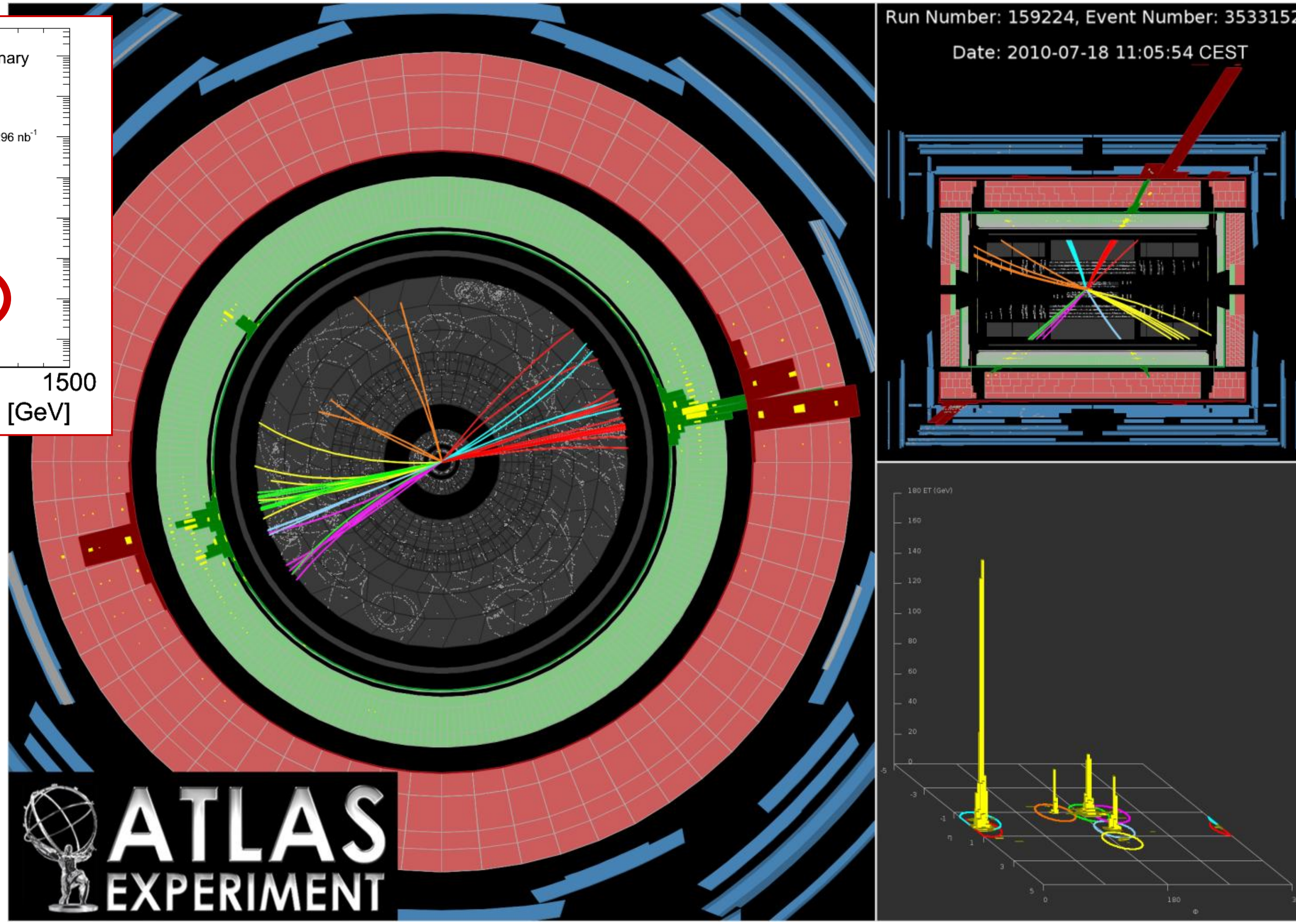
Photon purity measured almost entirely from data (small MC) corrections.



Beyond QCD, these are useful to set or check the JES via γ-jet balancing.

Jets at ATLAS

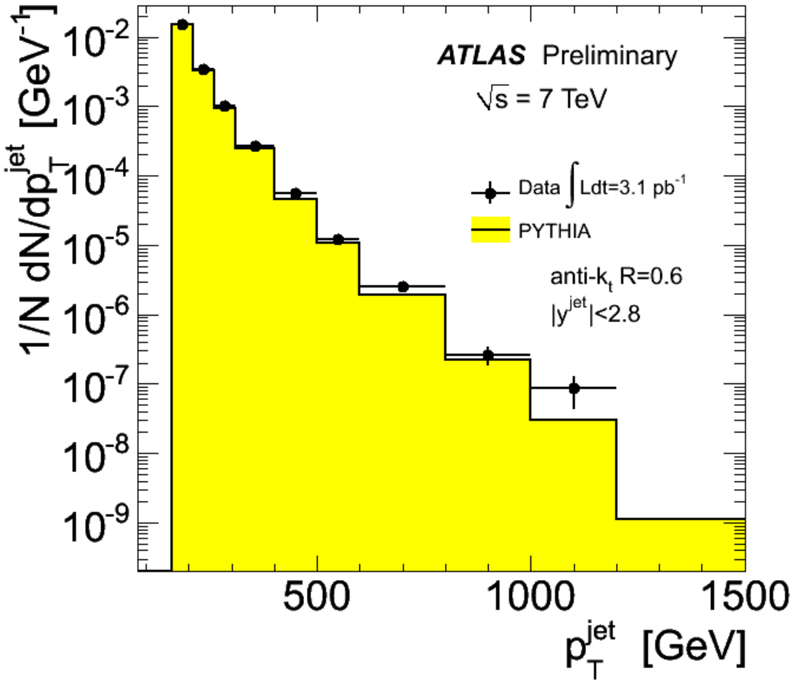




p_T (j_1)= 1.12 TeV
p_T (j_2)= 480 GeV
p_T (j_3)= 155 GeV
p_T (j_4)= 95 GeV

Inclusive Jet Measurements

As you can see, ATLAS is collecting TeV-scale jets.



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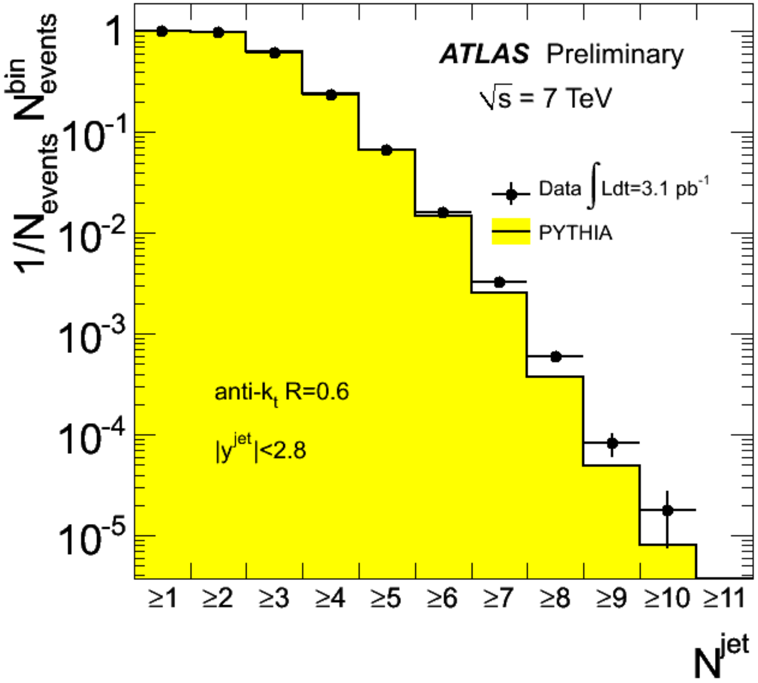
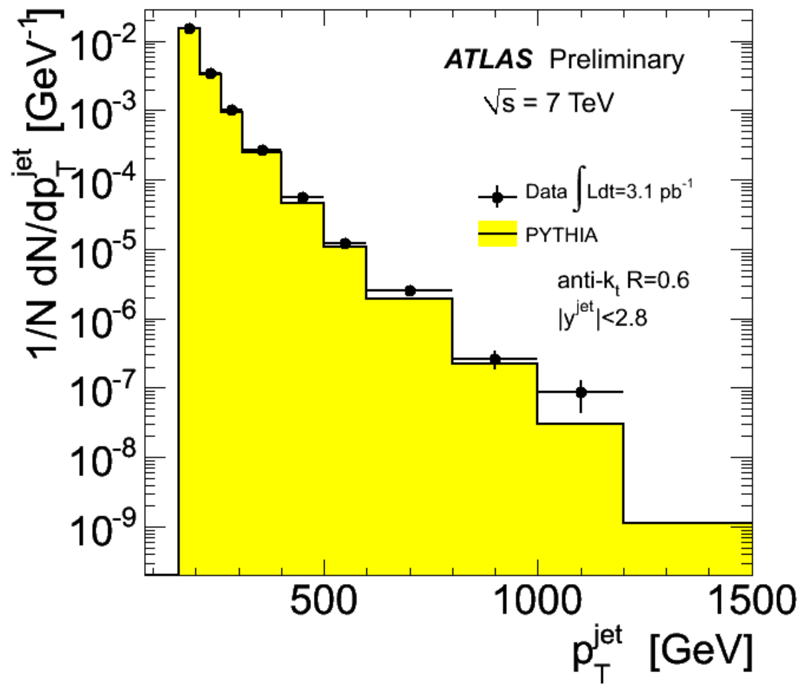
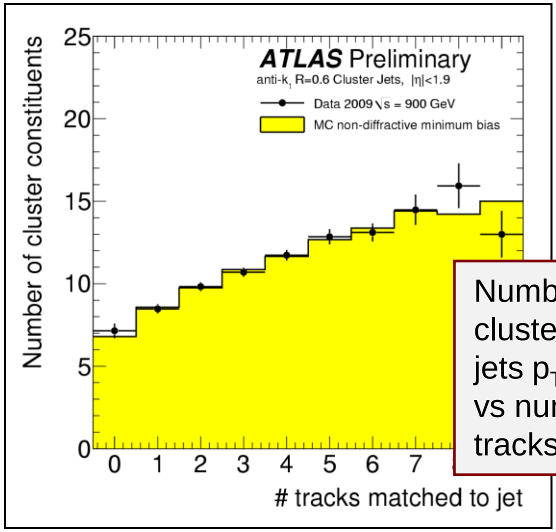




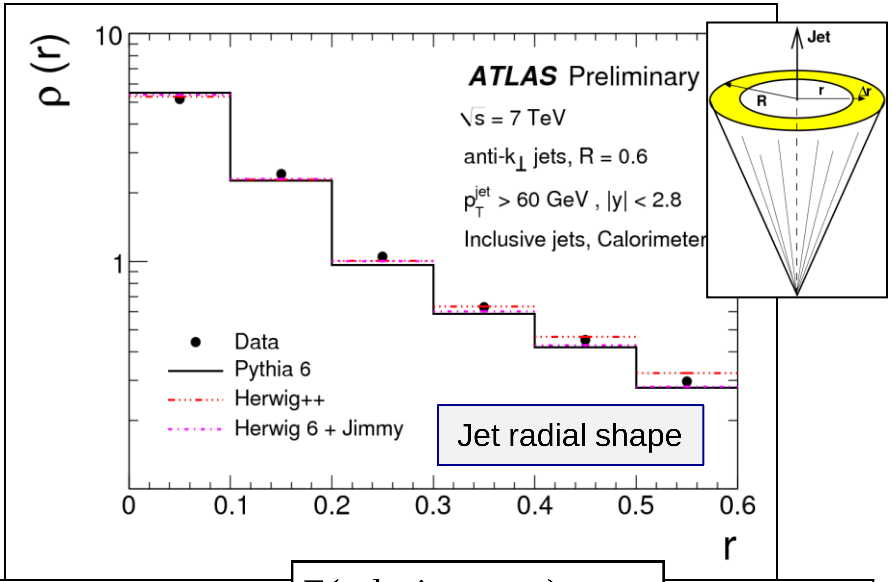
Shape comparisons between data and Pythia (distributions normalized to unity)
It's good but (more than) a little mysterious that Pythia does as well as it does.

Leading jet: p_T > 160 GeV
Other jets: p_T > 30 GeV

Looking at Jets in (Much) More Detail

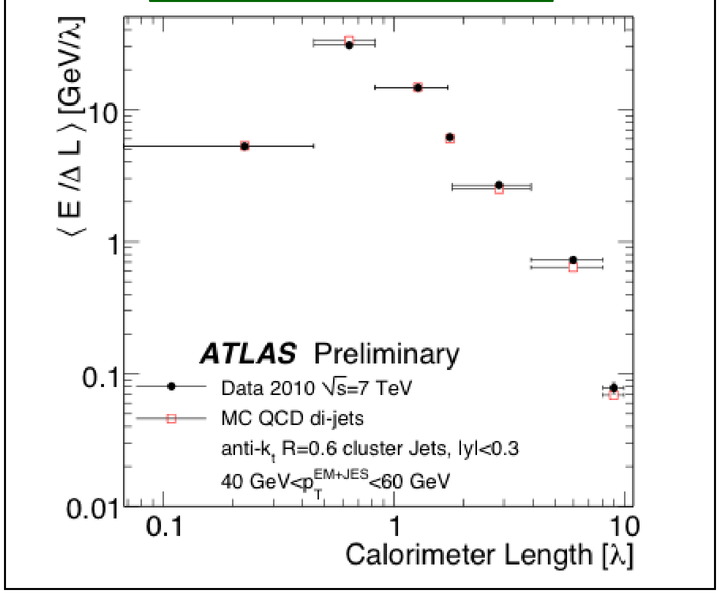


Number of clusters in jets p_T>7 GeV vs number of tracks

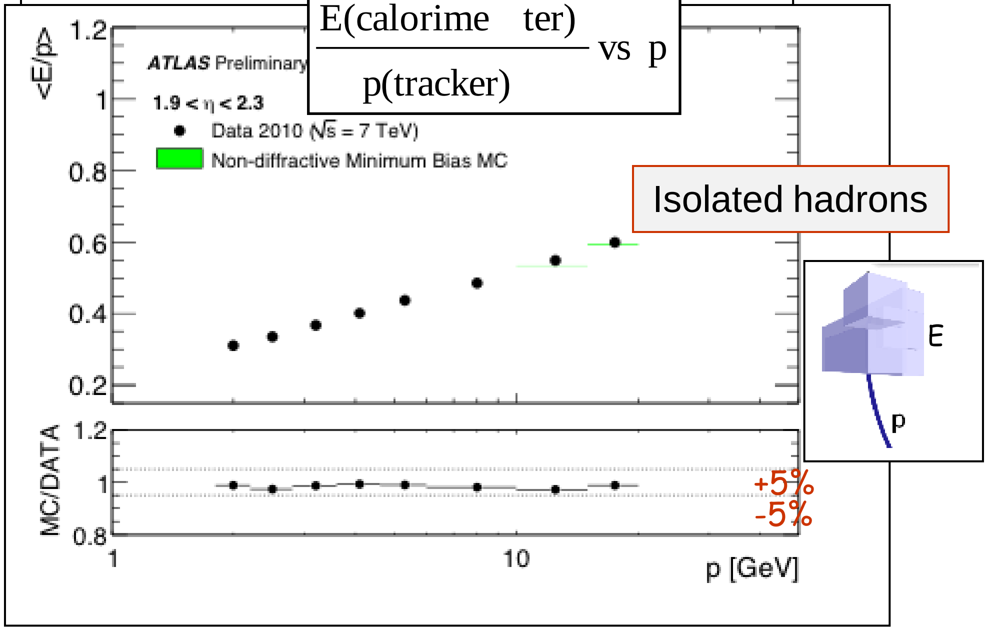


Jet radial shape

Longitudinal jet profile



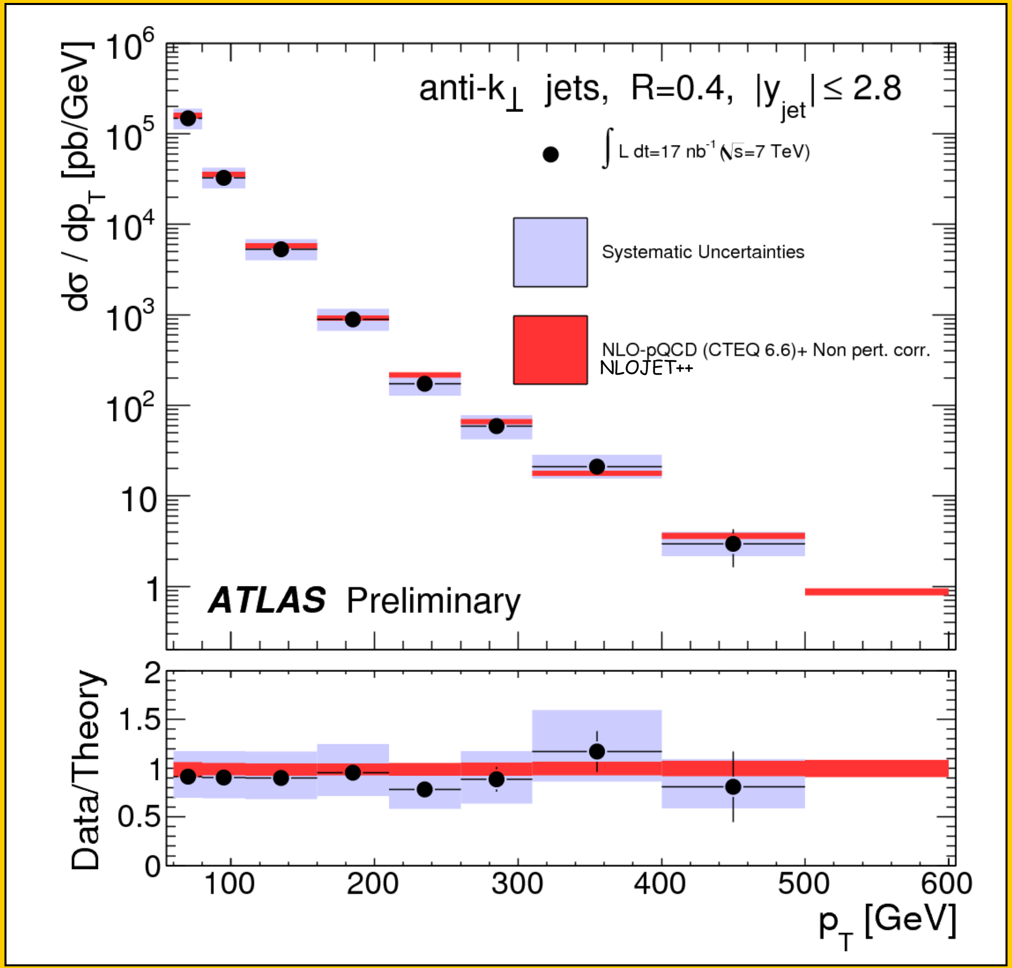
$$\frac{E(\text{calorimeter})}{p(\text{tracker})} \text{ vs } p$$



Isolated hadrons

Inclusive Jet Cross Section

- Observed jets corrected to particle-level using parton-shower MC (Pythia, Herwig)
  - justified by detailed comparison studies and good agreement with data
- NLO QCD comparison after corrections for hadronization and underlying event
- Theoretical uncertainty: ~20% (up to 40% at large |y|) from variation of PDF, α_s, scale
- Experimental uncertainty: ~30-40% dominated by Jet Energy scale (known to ~7%)
  - Luminosity (11%) not included

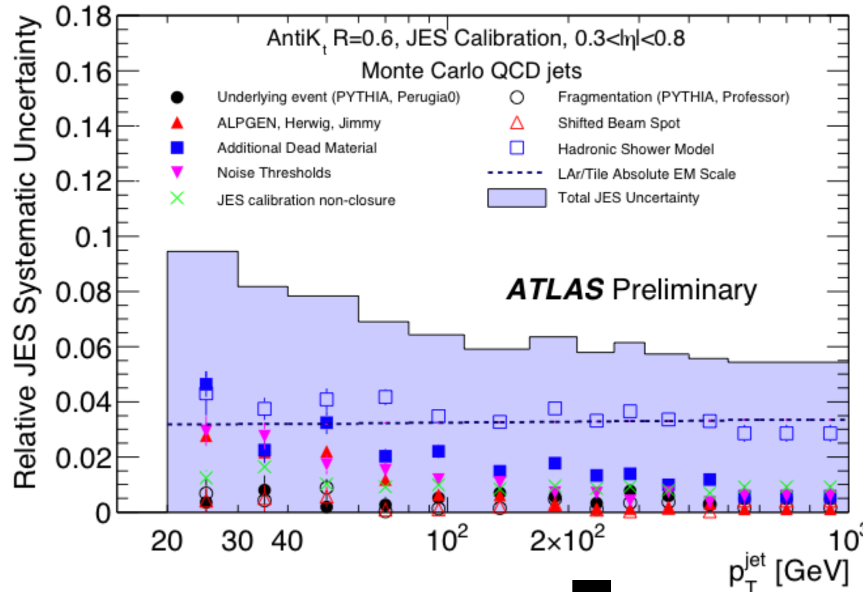


Good agreement with QCD over 5 orders of magnitude

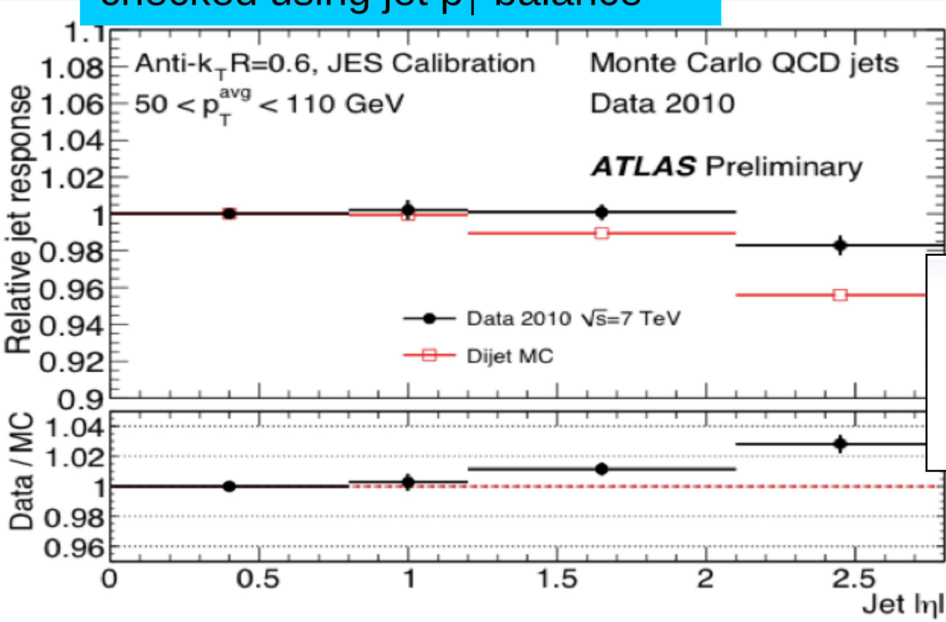
JES Uncertainty

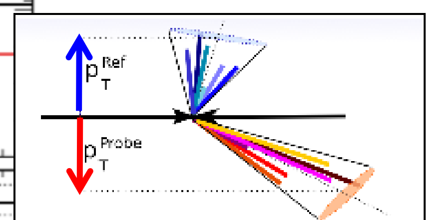
Jet momenta corrected (for calorimeter non-compensation, material, etc.) using η/p_T-dependent calibration factors derived from MC (need a few pb^{-1} for in-situ gamma/jet)

- ❑ Builds on detailed foundation work to understand main ingredients by comparing MC/data (see two slides back)
- ❑ Many sources of systematic uncertainties studied in detail



Inter-calibration central-forward checked using jet p_T-balance





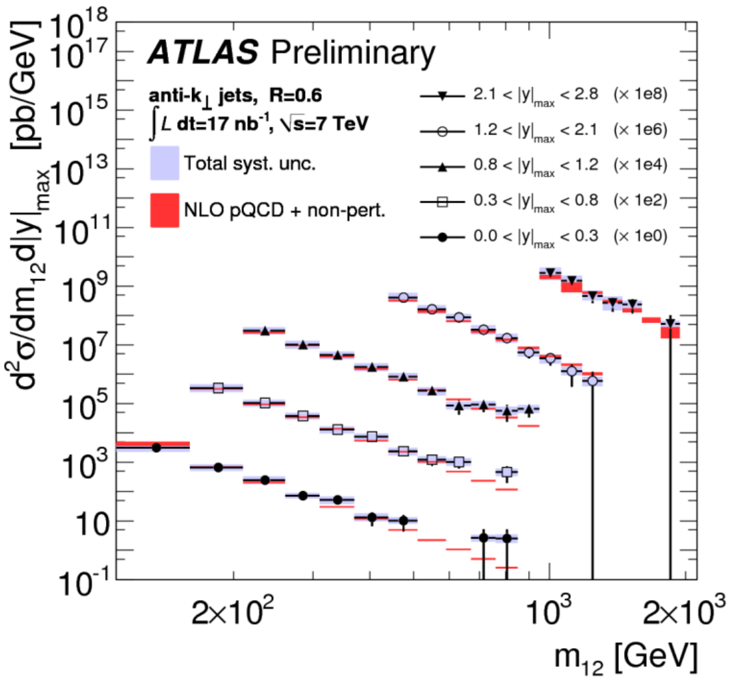
(|η| > 2.8)

Today JES known to : ~ 7%

Ultimate goal: ~1%

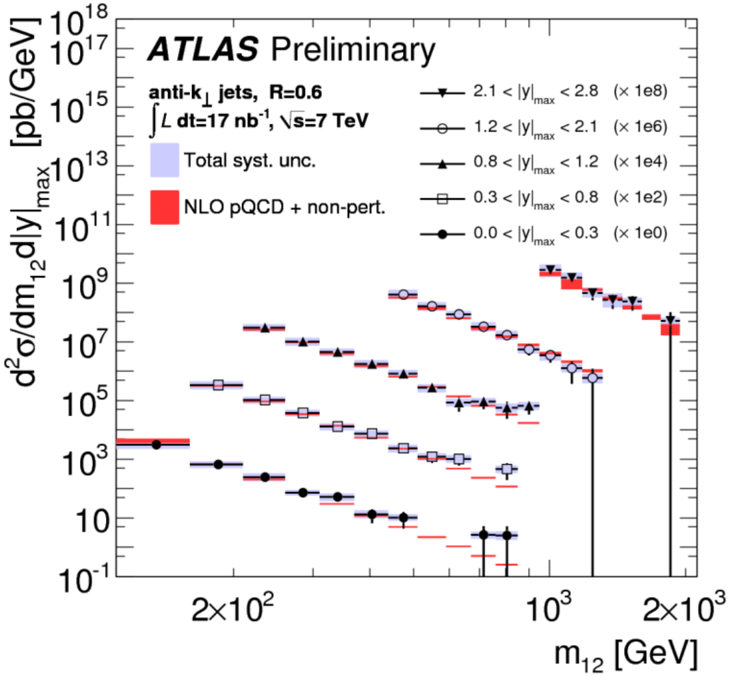
Other Jet Measurements

Di-jet cross-section vs mass

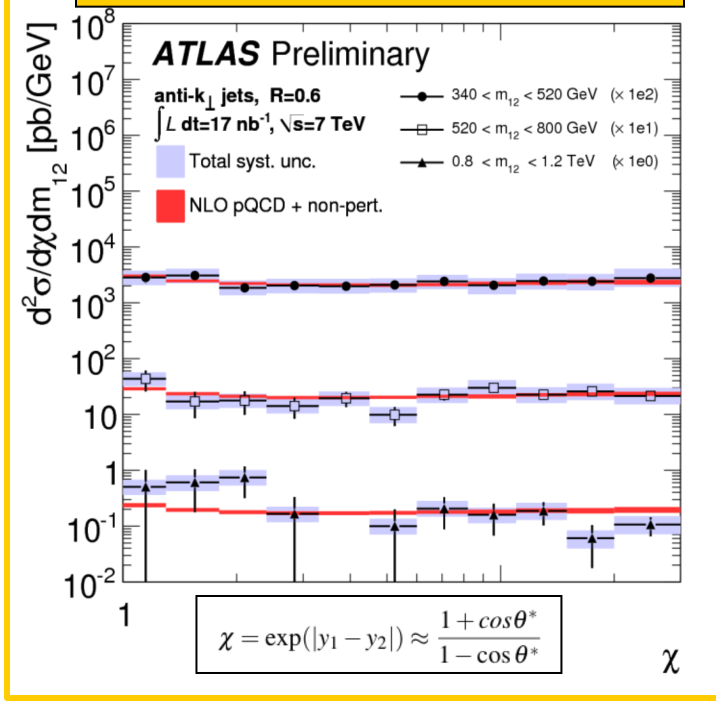


Other Jet Measurements

Di-jet cross-section vs mass

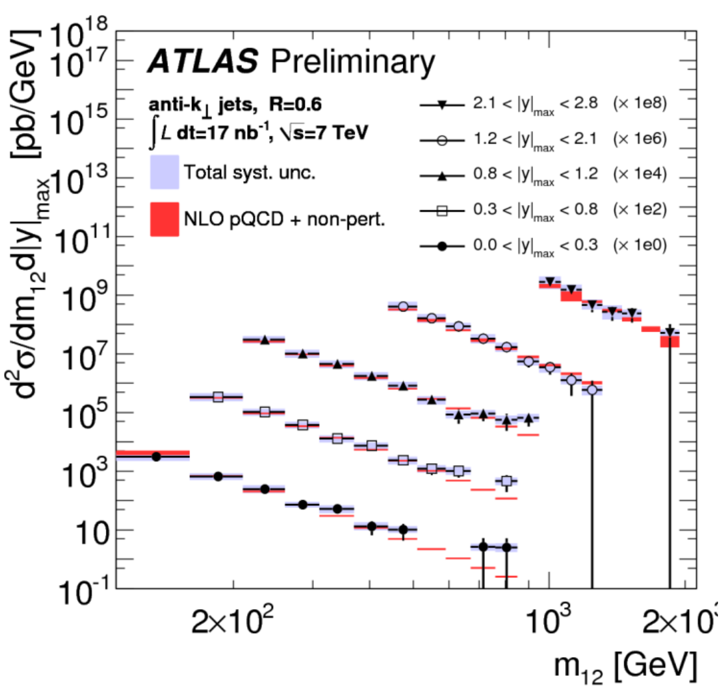


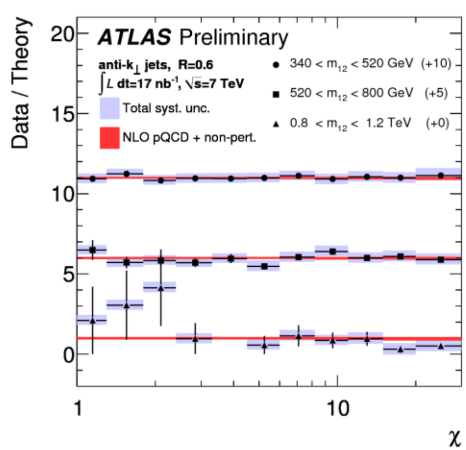
Di-jet cross-section vs angle



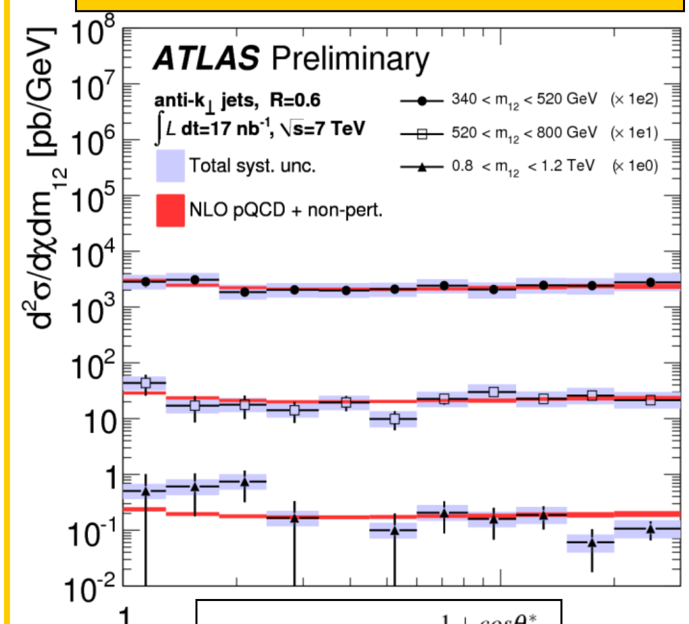
Other Jet Measurements

Di-jet cross-section vs mass





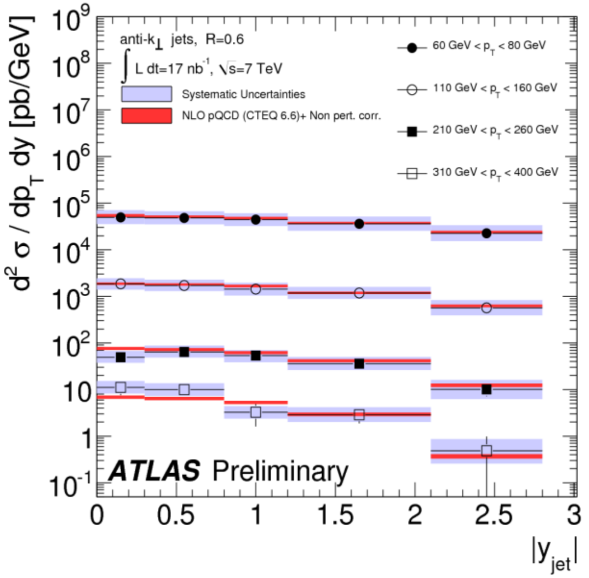
Di-jet cross-section vs angle



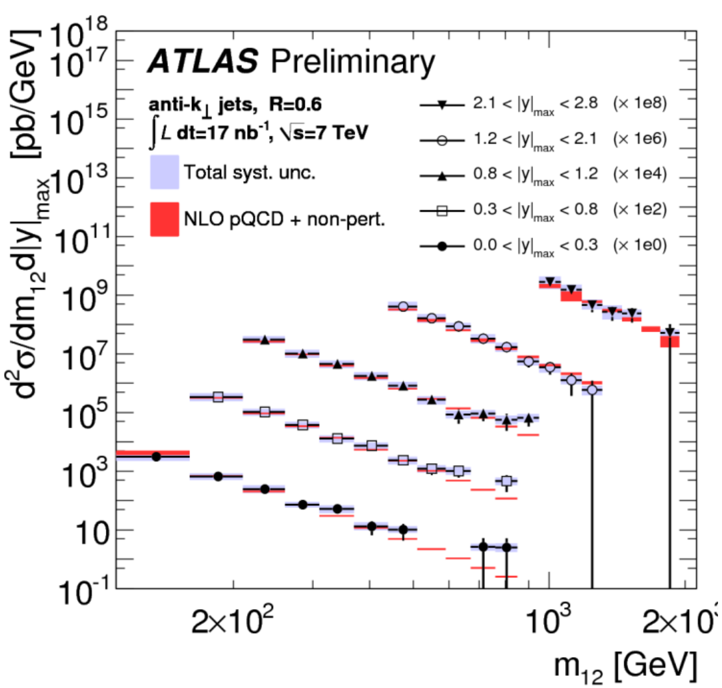
$$\chi = \exp(|y_1 - y_2|) \approx \frac{1+\cos\theta^*}{1-\cos\theta^*}$$

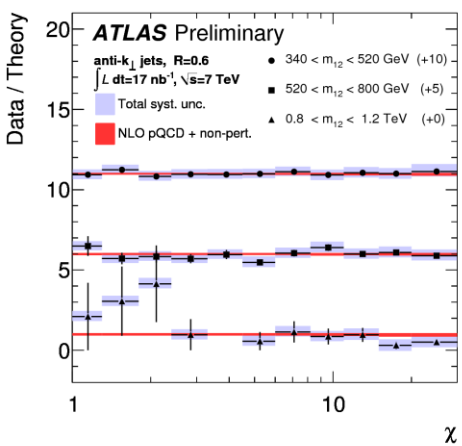
χ

Other Jet Measurements

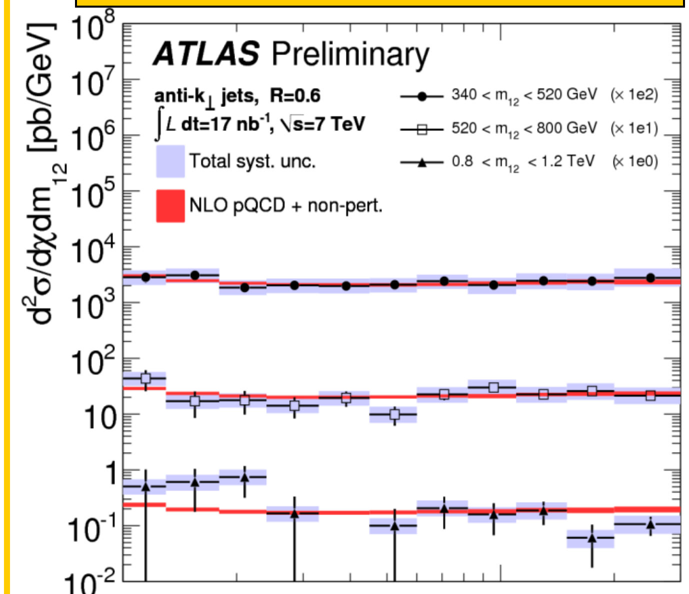


Di-jet cross-section vs mass



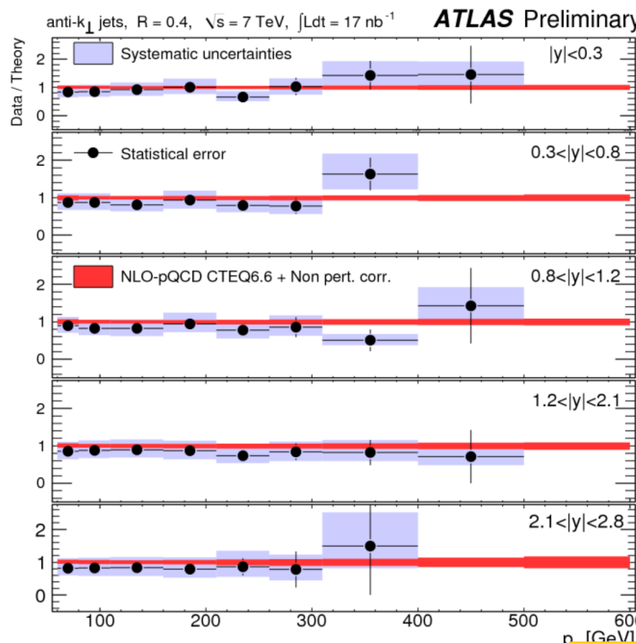


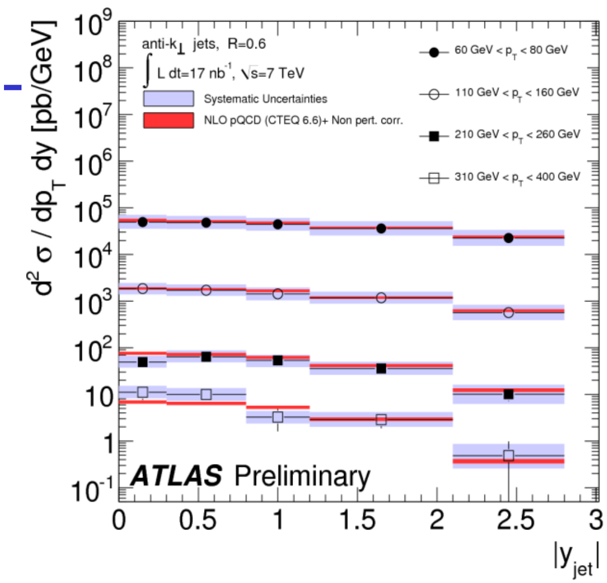
Di-jet cross-section vs angle



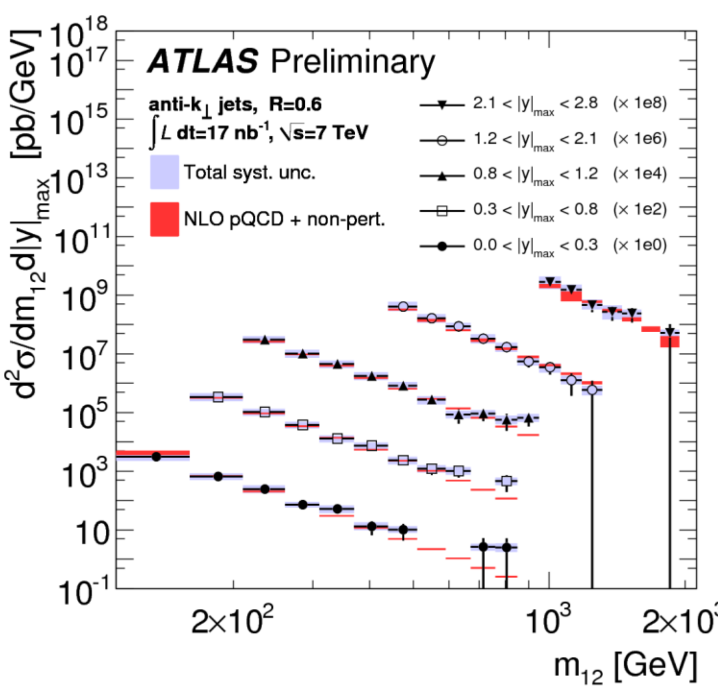
$$\chi = \exp(|y_1 - y_2|) \approx \frac{1+\cos\theta^*}{1-\cos\theta^*}$$

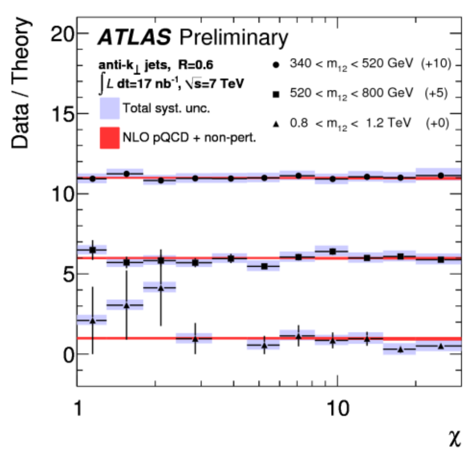
Other Jet Measu



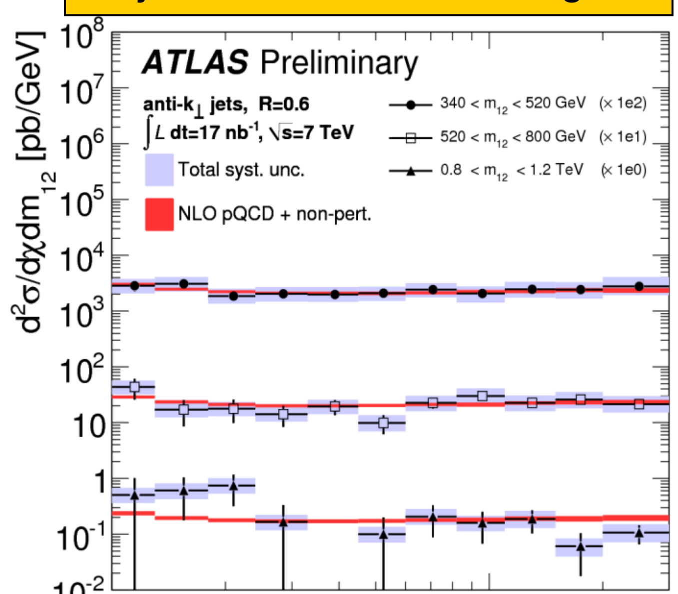


Di-jet cross-section vs mass



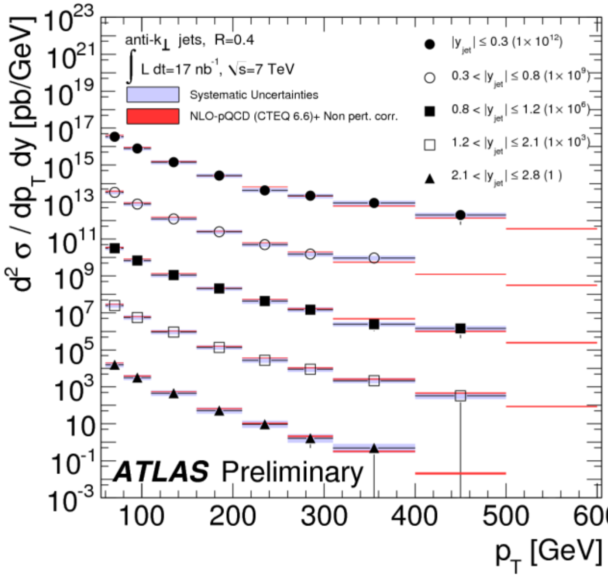


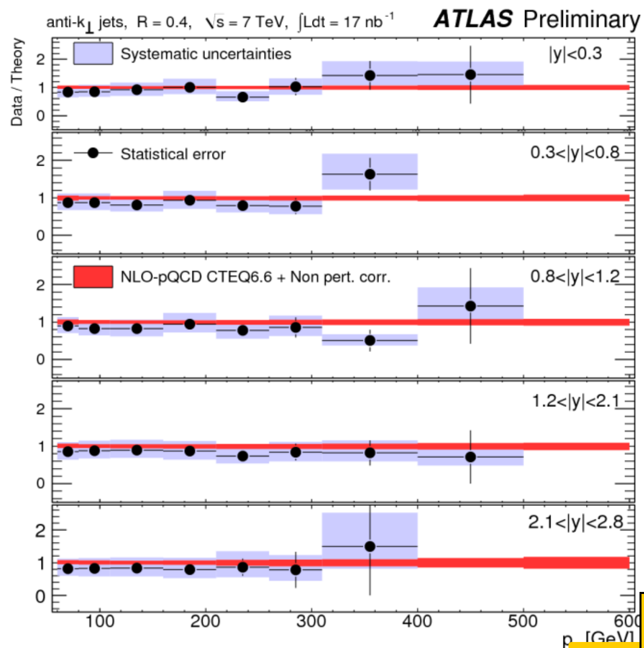
Di-jet cross-section vs angle

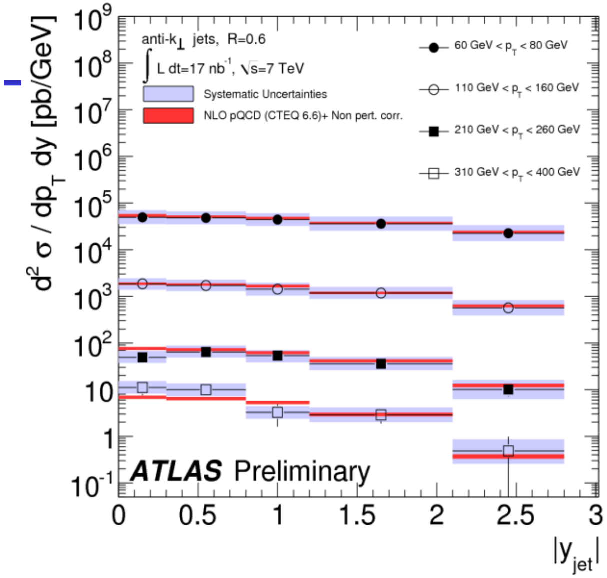


$$\chi = \exp(|y_1 - y_2|) \approx \frac{1+cos\theta^*}{1-\cos\theta^*}$$

χ

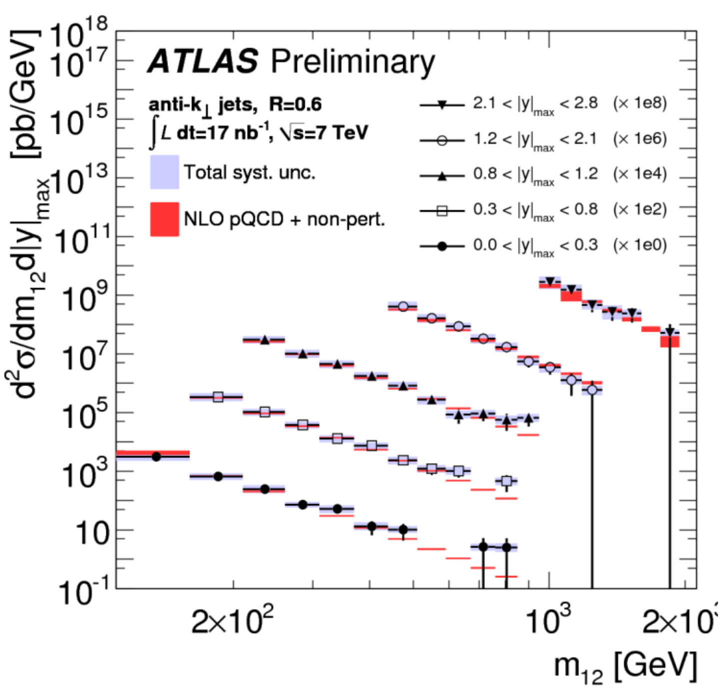


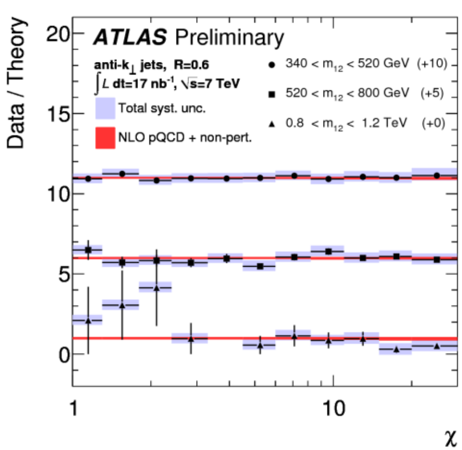


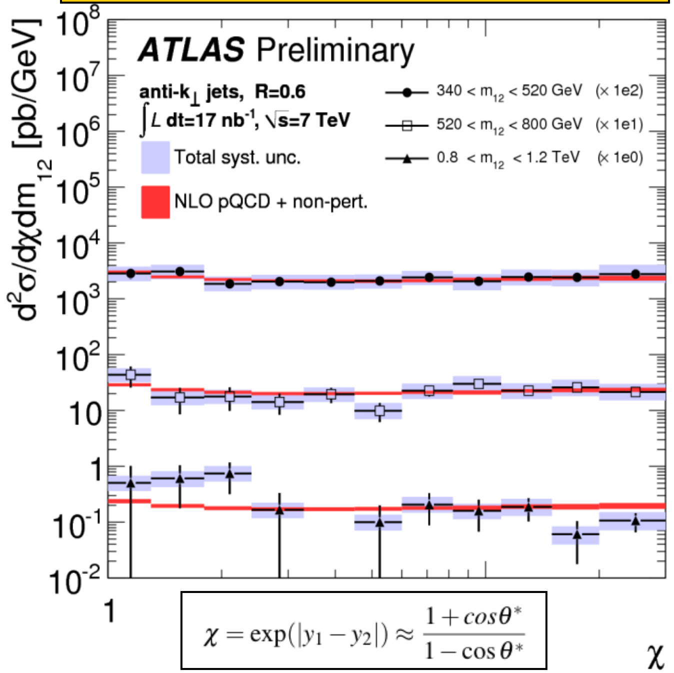


Di-jet cross-section vs mass

Di-jet cross-section vs angle

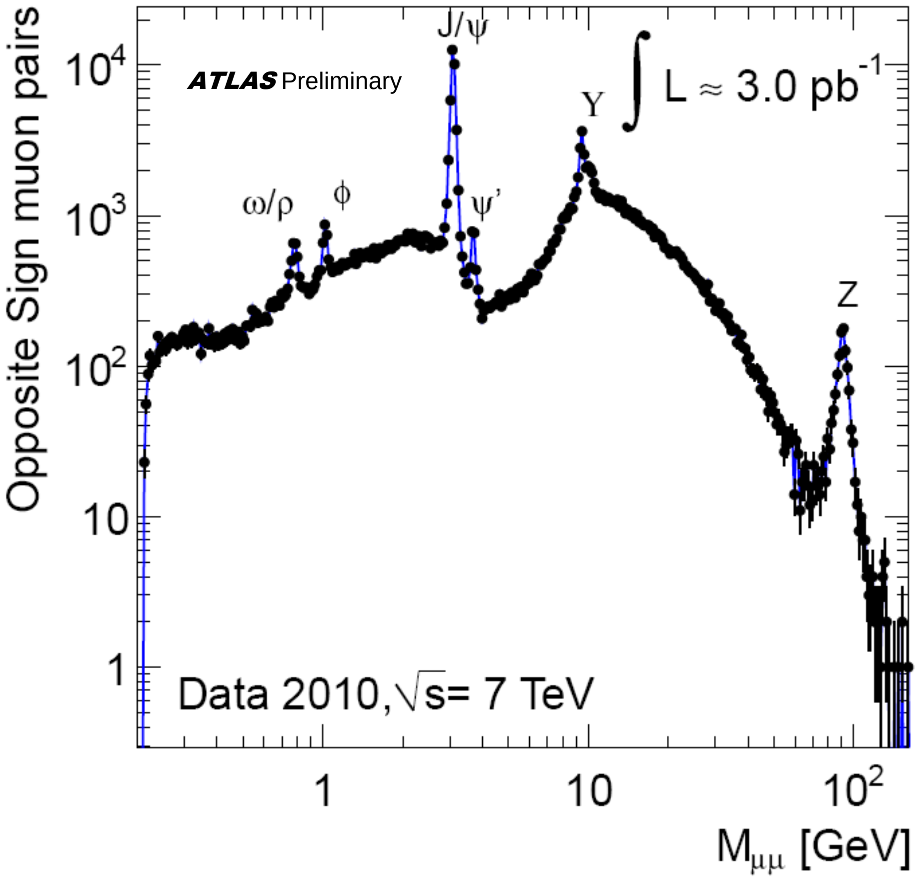






$$\chi = \exp(|y_1 - y_2|) \approx \frac{1+\cos\theta^*}{1-\cos\theta^*}$$

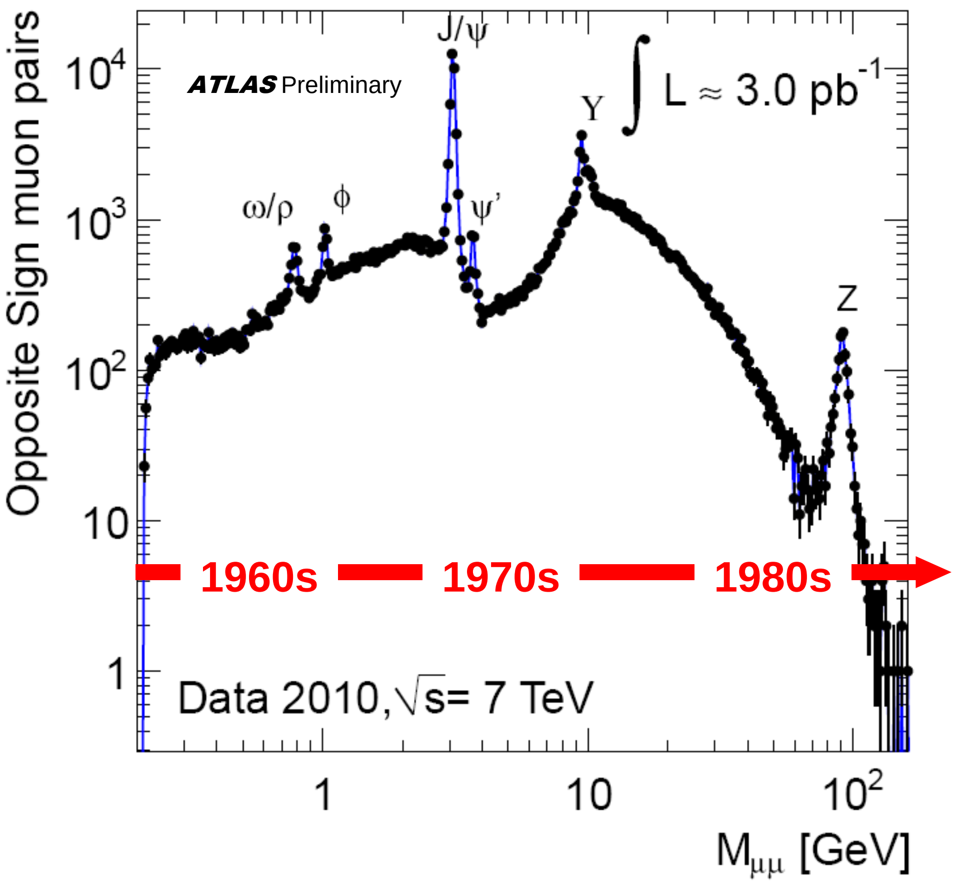
Dimuon Resonances (+ the Z)



Simple analysis:

- ❑ LVL1 muon trigger with p_T ~ 6 GeV threshold
- ❑ 2 opposite-sign primary muons reconstructed by combining tracker and muon spectrometer

Dimuon Resonances (+ the Z)



Simple analysis:

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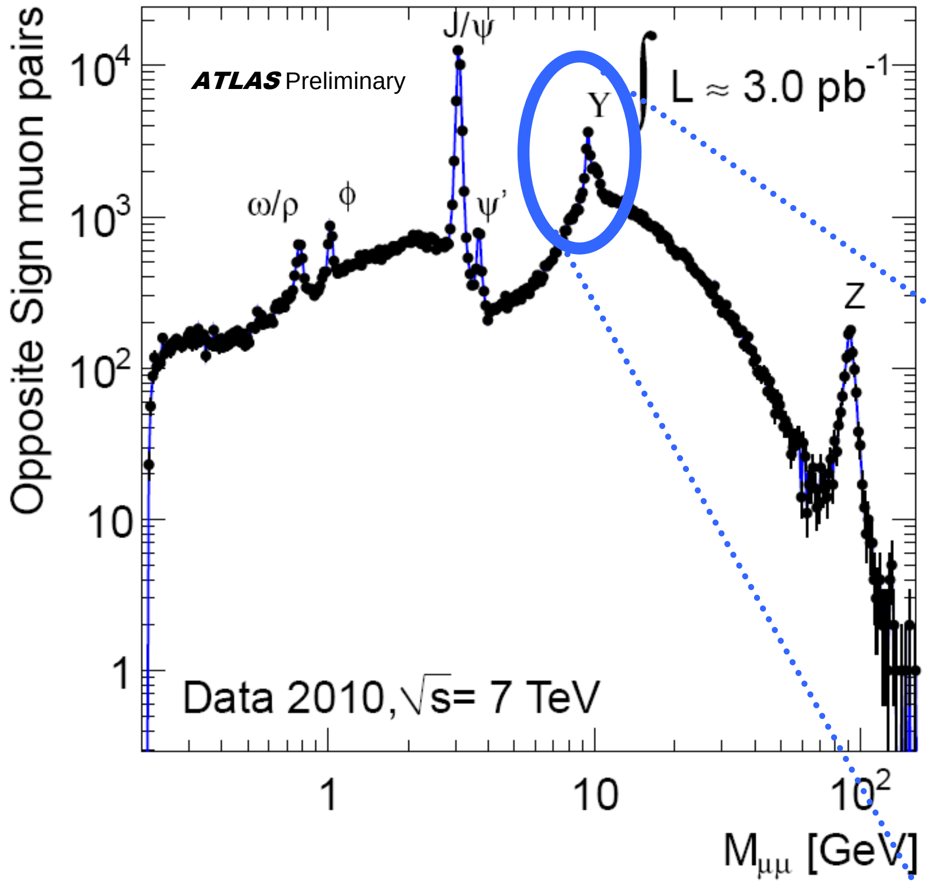
Dimuon Resonances (+ the Z)



Simple analysis:
- ❑ LVL1 muon trigger with p_T ~ 6 GeV threshold
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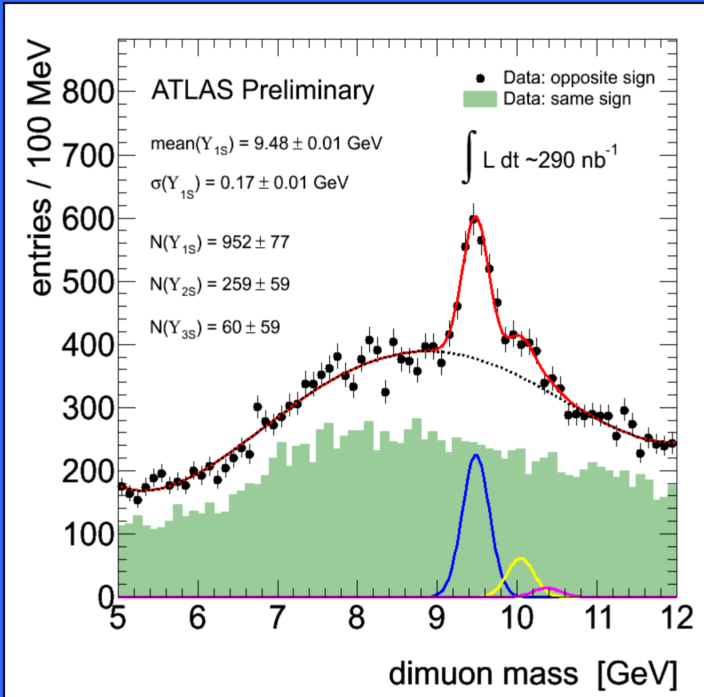
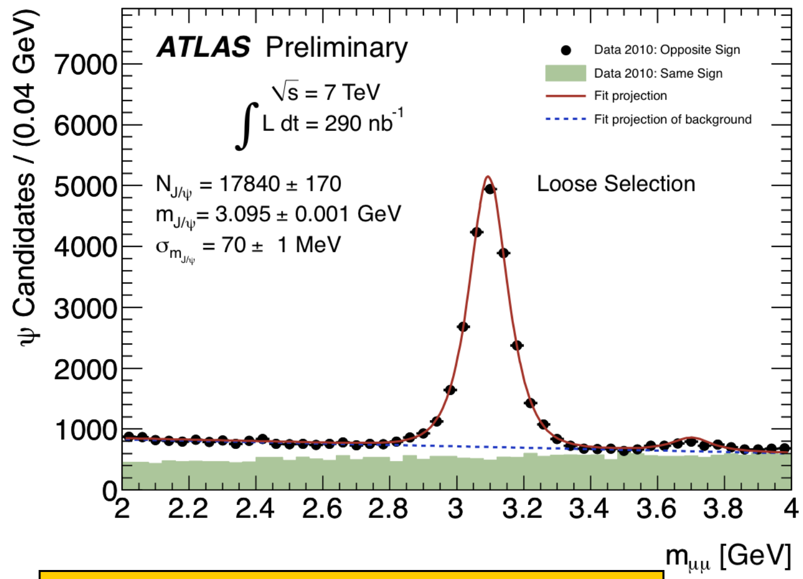


- ❑ Looser selection: includes also muons made of Inner Detector tracks + Muon Spectrometer segments
- ❑ Distances between resonances fixed to PDG values; Υ(2S), Υ(3S) resolutions fixed to Υ(1S) resolution

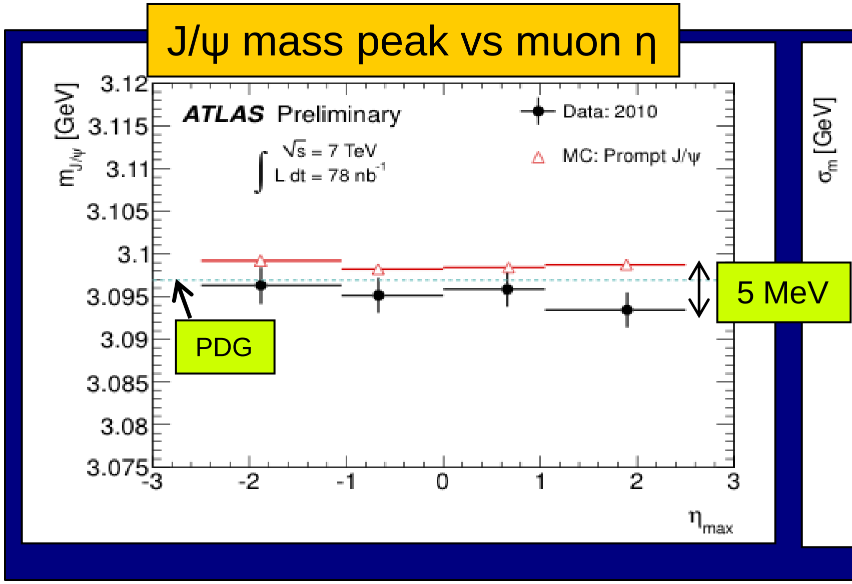
J/ψ in the Dimuon Channel

J/ψ reconstruction uses the muon spectrometer to identify ID tracks that are muons from which we form combinations.

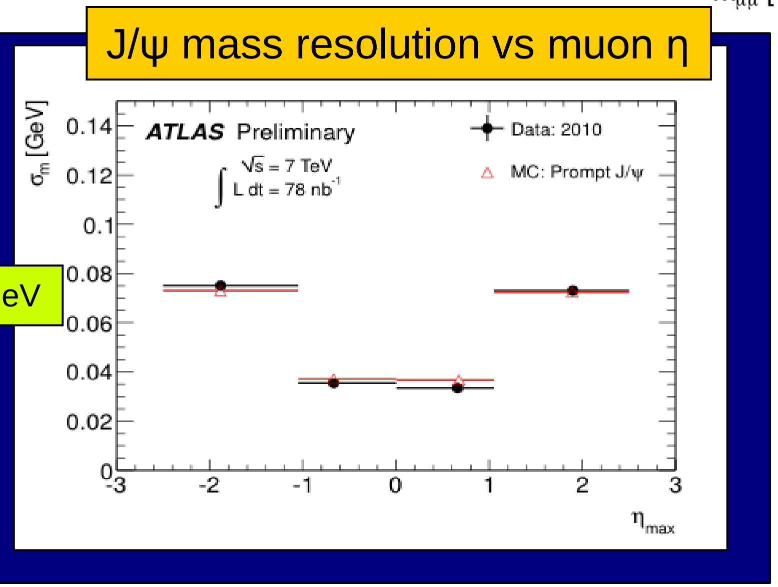
From J/ψ mass peak and resolution reconstructed in the Inner Detector: absolute momentum scale known to ~ 0.2% and momentum resolution to ~2 % in the ~few GeV region



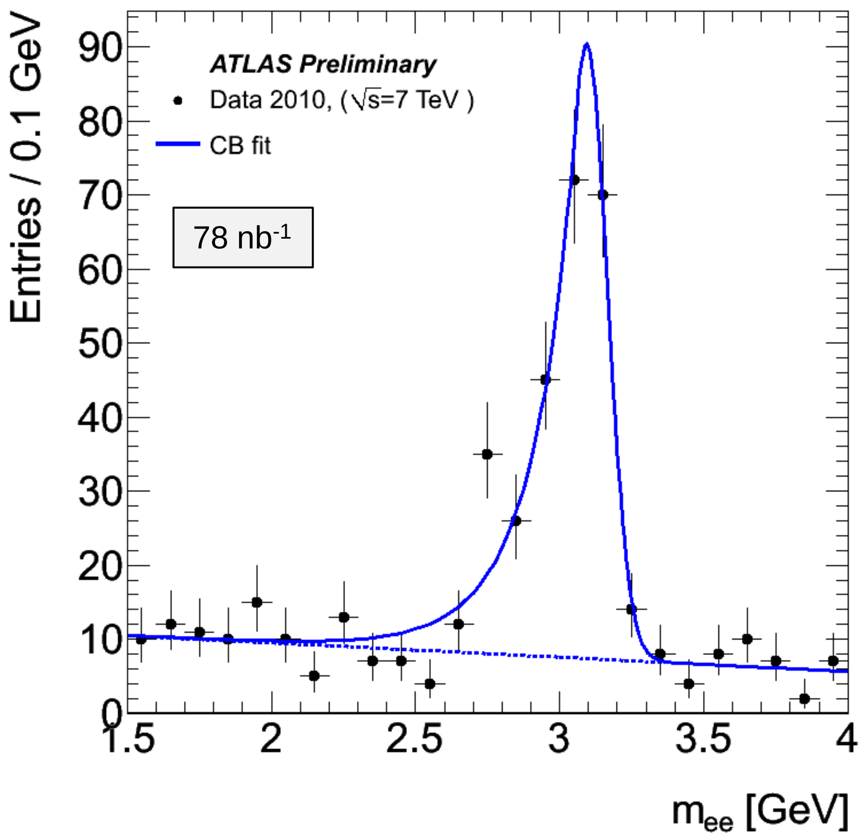
J/ψ mass peak vs muon η



J/ψ mass resolution vs muon η



J/ψ into electrons

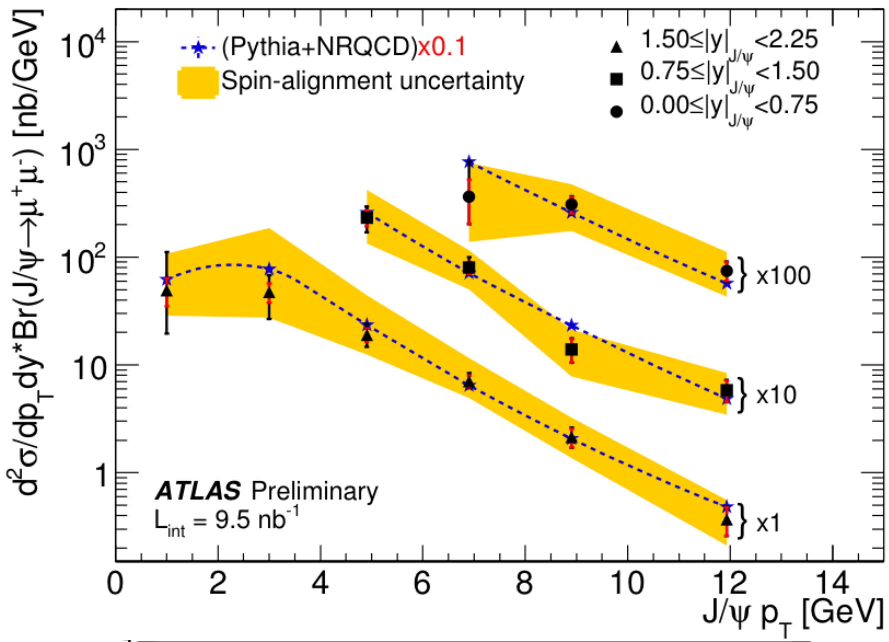


Signal	: 222 ± 11 events
Background	: 28 ± 2 events
Mass peak	: 3.09± 0.01 GeV
Mass resolution	: 0.07 ± 0.01 GeV

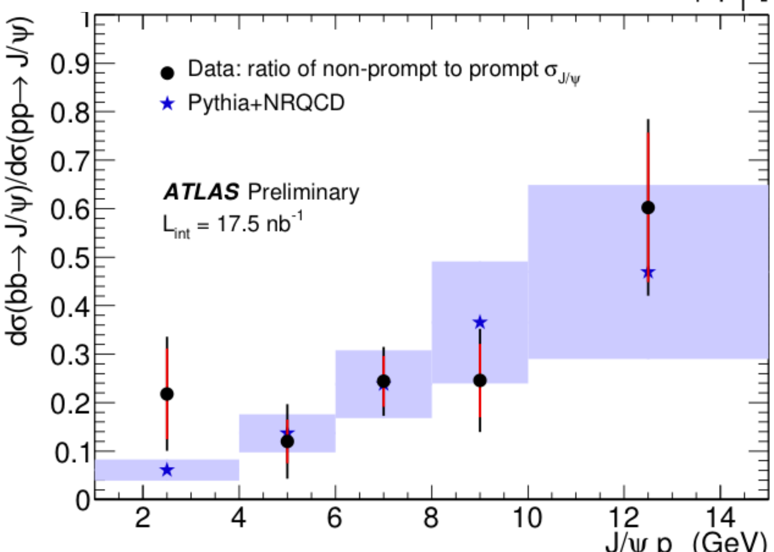
Requirements:

- 2 EM clusters matched to tracks
- p_T ($e^{\pm}$ tracks) > 4, 2 GeV
- track quality, calo shower shapes
- key handle: large transition radiation in TRT
- invariant mass from track parameters after Brem recovery (GSF)

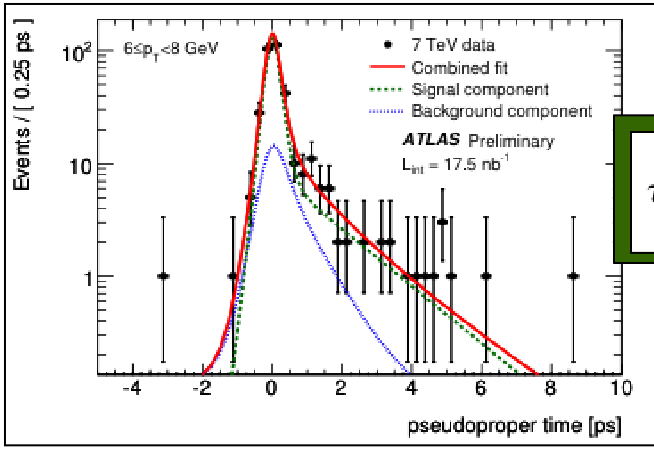
J/ψ Production



- ❑ Measured over |y (J/ψ)|<2.25, down to p_T (J/ψ)~ 1 GeV in forward region (p larger → higher acceptance)
- ❑ Pythia (Color Octet Model): good agreement in shape
- ❑ Uncertainty dominated by (unknown) spin-alignment



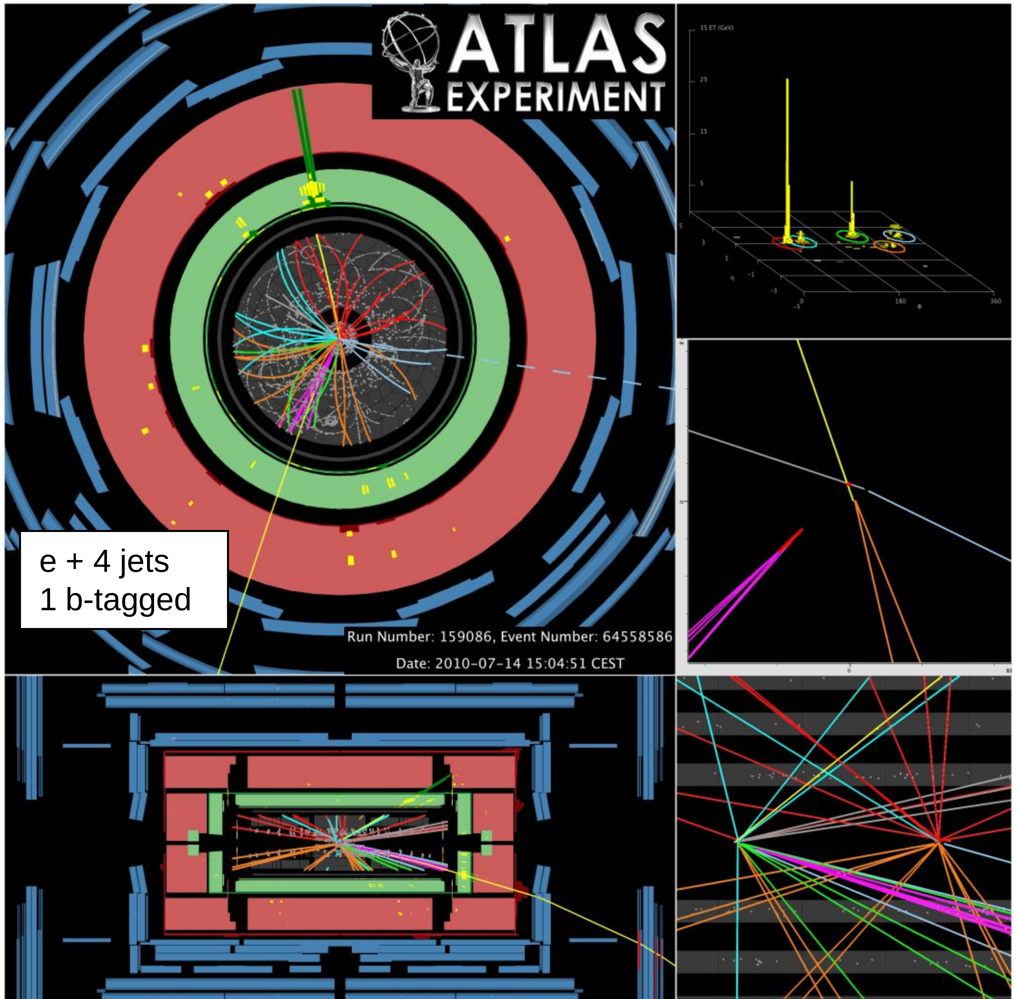
- ❑ From fit of proper decay time in inclusive J/ψ sample.
- ❑ Many uncertainties cancel in the ratio

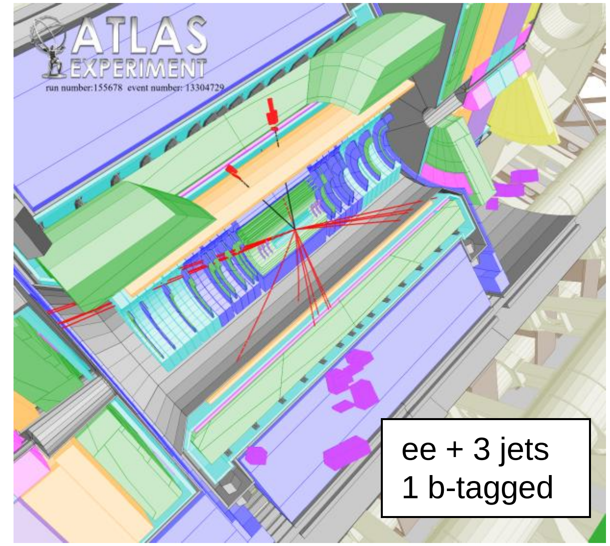


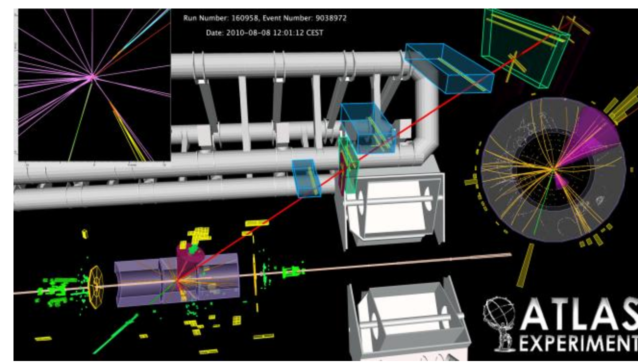
$$\tau = \frac{L_{xy}\, m(J/\psi)}{p_T(J/\psi)}$$

Top Quarks

- Towards the end of May we started recording events like this







eμ + 3 jets
1 b-tagged

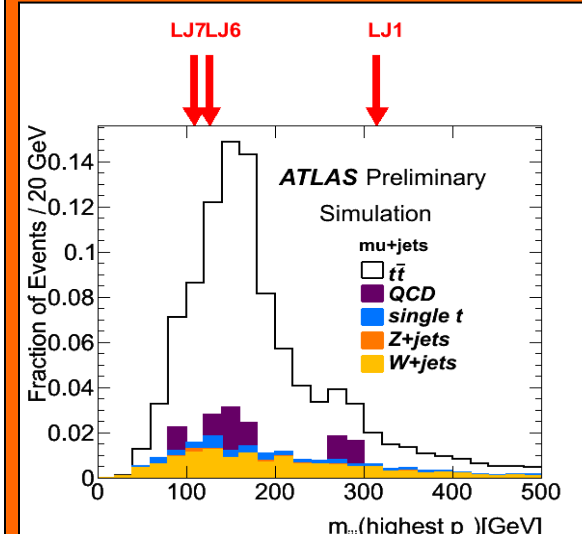
By ICHEP, We Had Nine Candidates

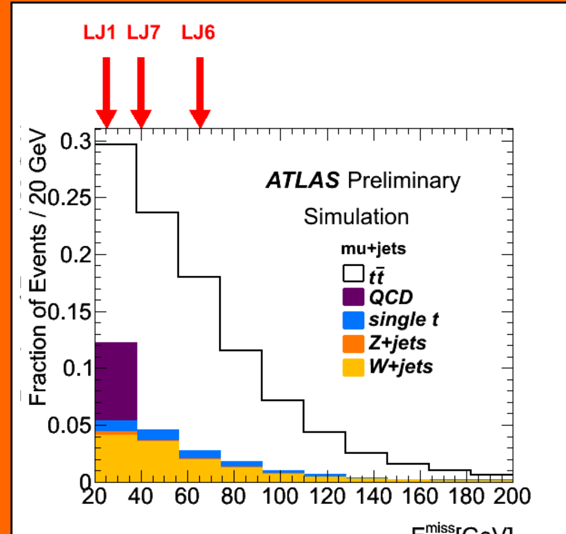
2 dilepton

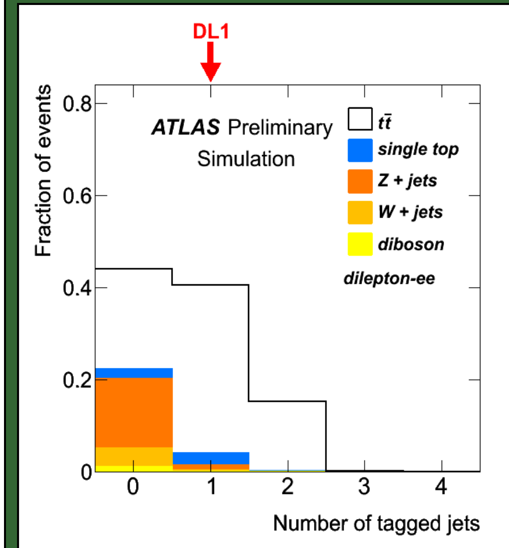
ID	Run number	Event number	Channel	p_T^{lep} (GeV)	E_T^{miss} (GeV)	H_T (GeV)	#jets $p_T > 20$ GeV	#b-tagged jets
DL1	155678	13304729	ee	55.2/40.6	42.4	271	3	1
DL2	158582	27400066	$e\mu$	22.7/47.8	76.9	196	3	1

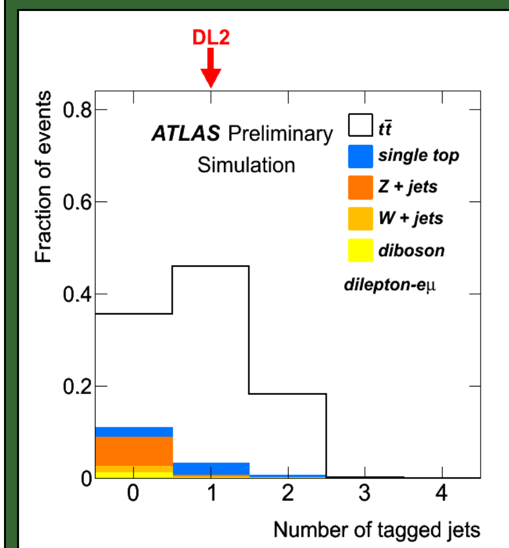
7 lepton + jets

ID	Run number	Event number	Channel	p_T^{lep} (GeV)	E_T^{miss} (GeV)	m_T (GeV)	m_{jjj} (GeV)	#jets $p_T > 20$ GeV	#b-tagged jets
LJ1	158801	4645054	μ+jets	42.9	25.1	59.3	314	7	1
LJ2	158975	21437359	e+jets	41.4	89.3	68.7	106	4	1
LJ3	159086	12916278	e+jets	26.2	46.1	62.6	94	4	1
LJ4	159086	60469005	e+jets	39.1	66.7	102	231	4	1
LJ5	159086	64558586	e+jets	79.3	43.4	86.7	122	4	1
LJ6	159224	13396261	μ+jets	29.4	65.4	64.1	126	5	1
LJ7	159224	13560451	μ+jets	78.7	40.0	83.7	108	4	1









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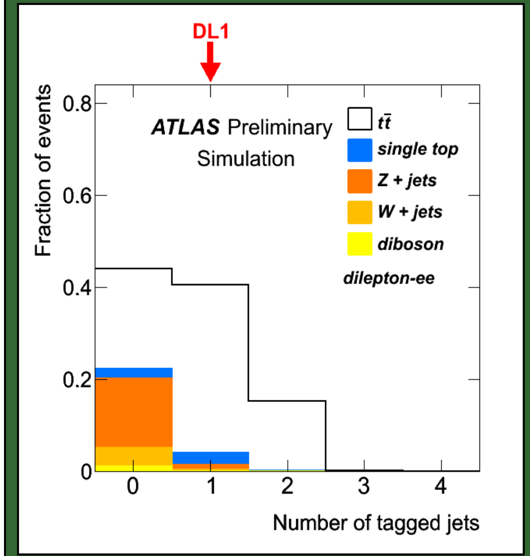
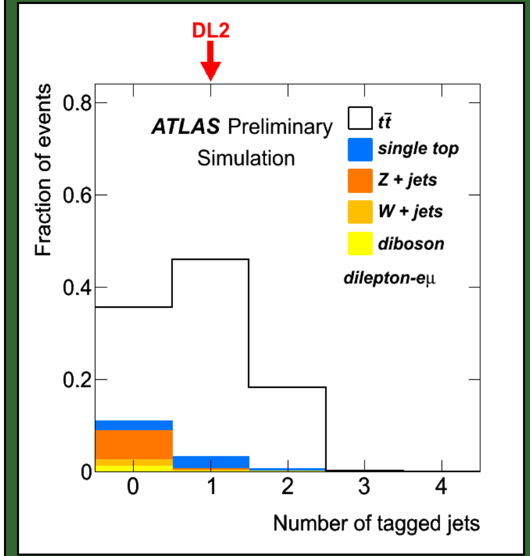
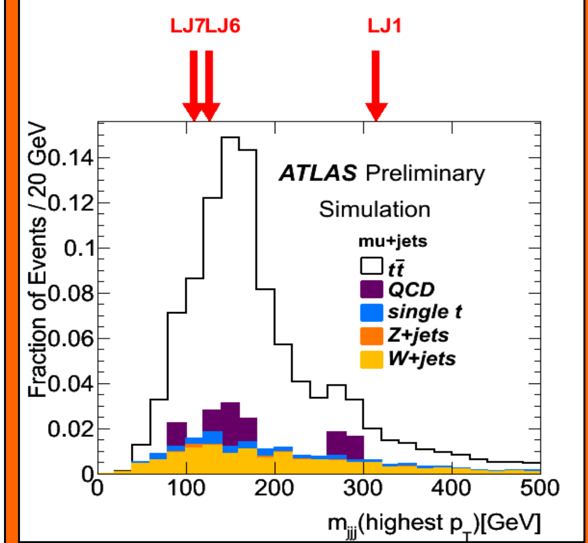
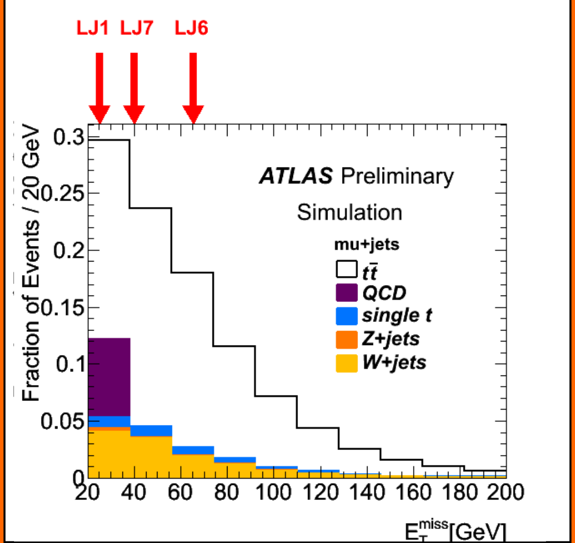
By ICHEP, We Had Nine Candidates

- Some of these events look a lot like signal
  - For example, both dilepton events
- Some of these events look more like background
  - For example, LJ1, a μ+jets event
- Quantifying the background is the obvious next step.
  - After b-tagging, the backgrounds are dominated by real heavy flavor. Need several pb^{-1} to produce a data-driven background estimate.









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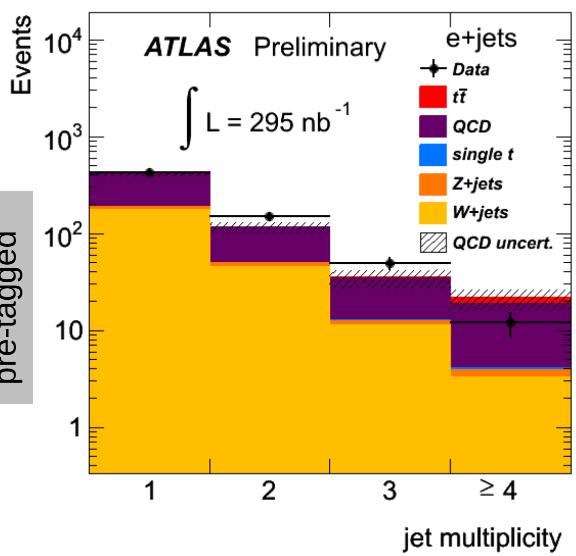
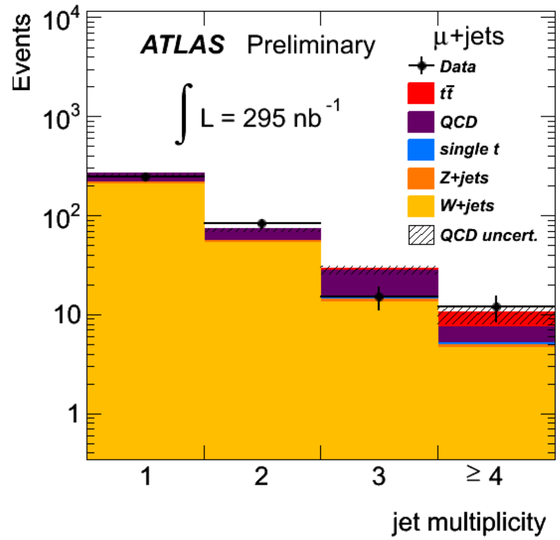
Backgrounds to Top

pre-tagged



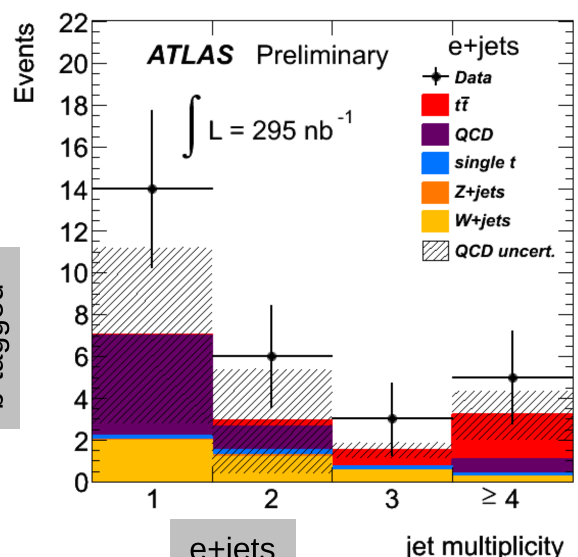


The QCD background here is data-driven (these plots use the matrix method).

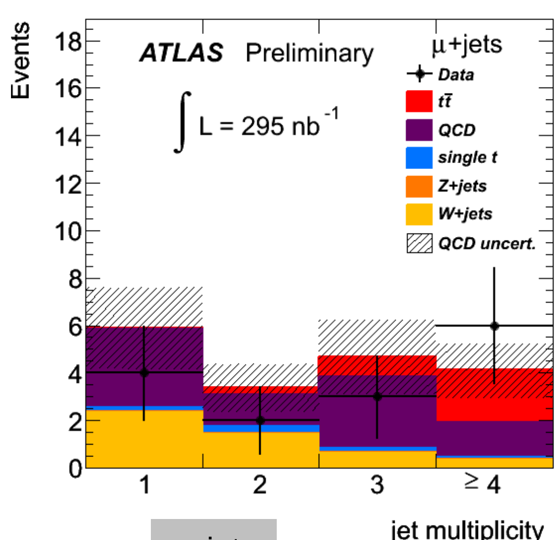
The single top and W/Z+jets backgrounds are taken from Monte Carlo: MC@NLO and ALPGEN

In parallel, we are using the 3 pb^{-1} of data taken so far to quantify the backgrounds

b-tagged

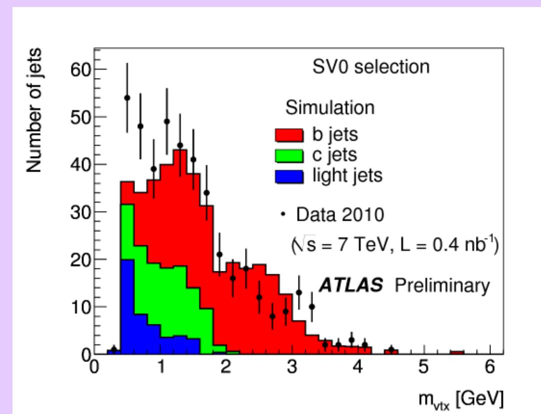


e+jets

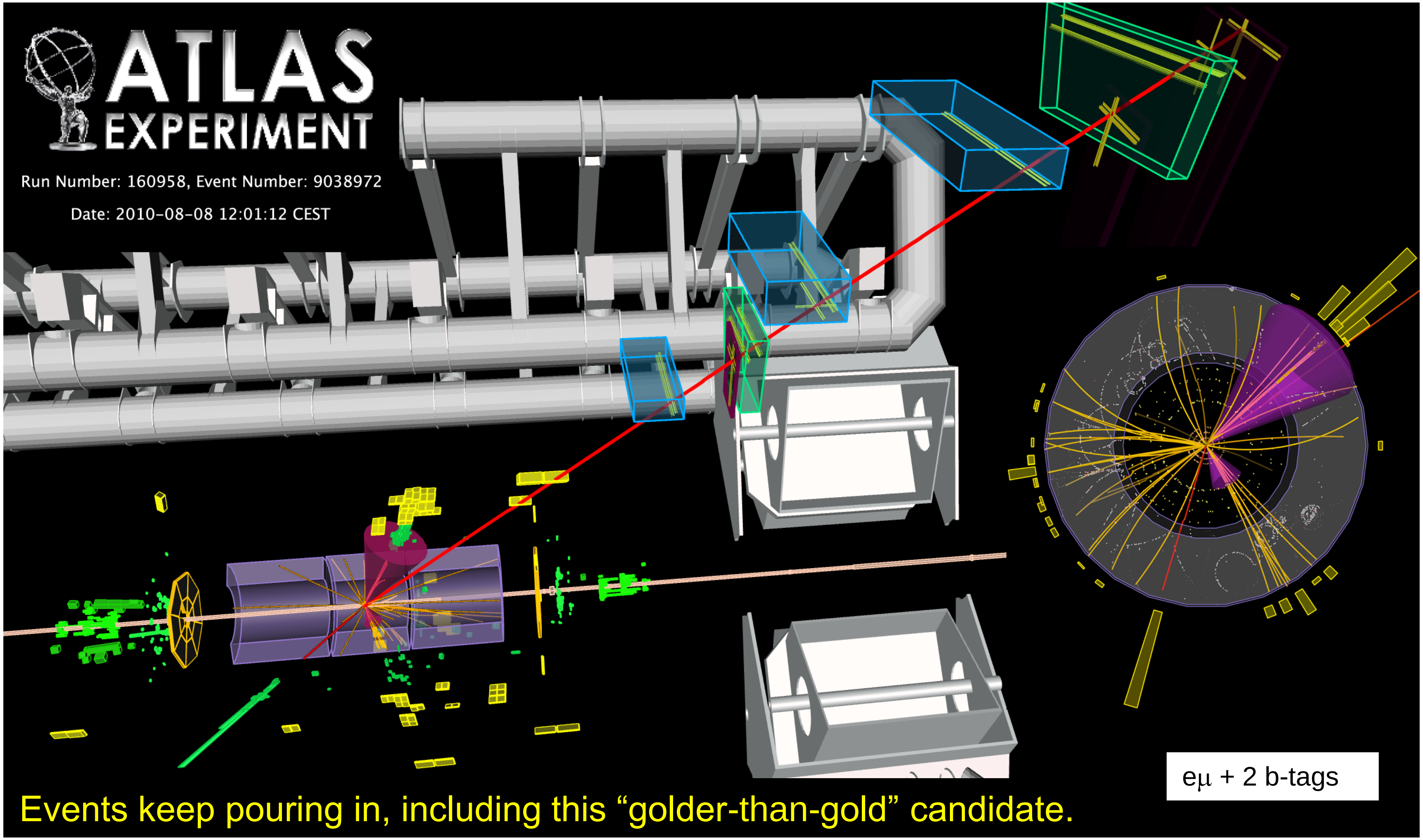


μ+jets

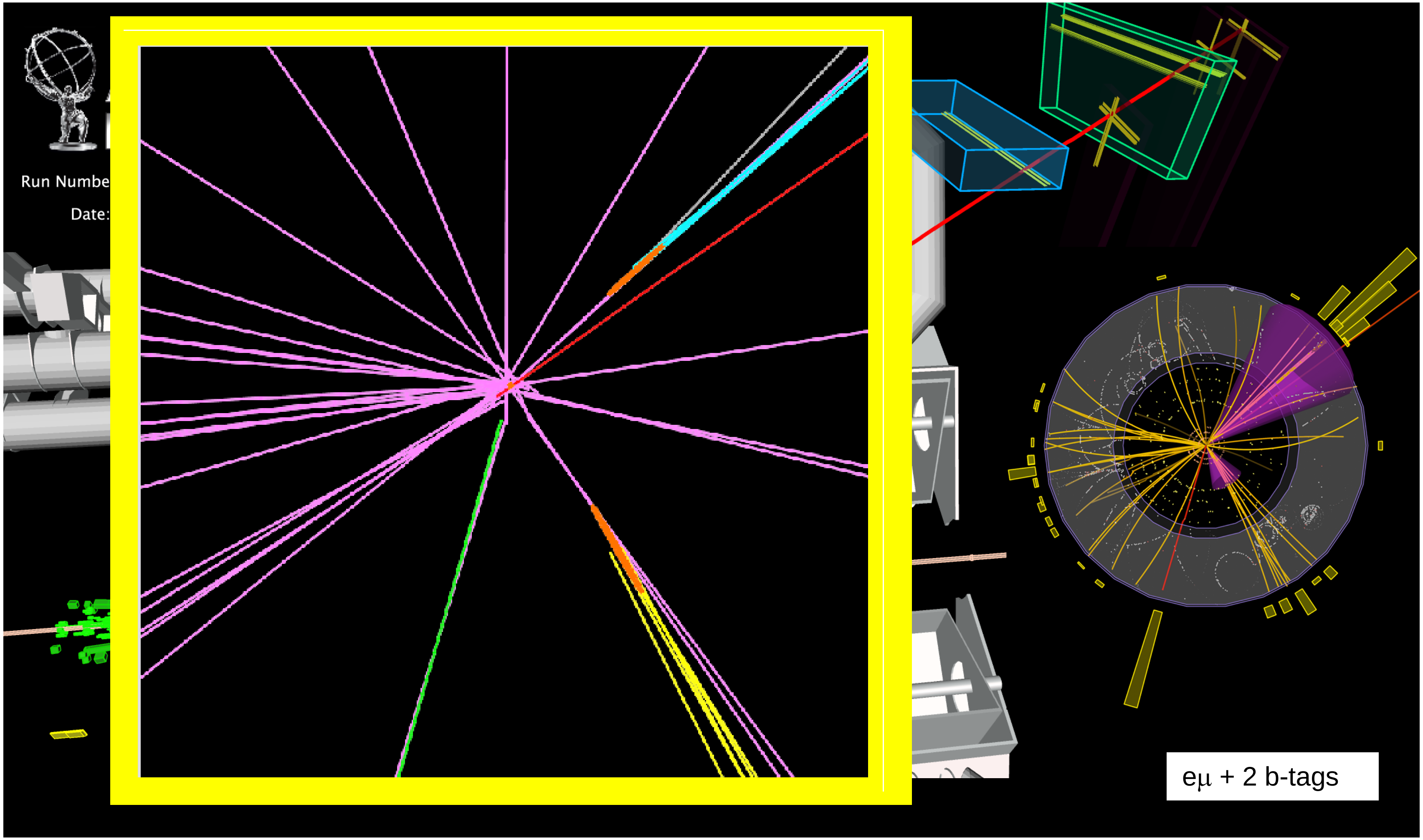
Jets are b-tagged by the SV0 algorithm.



More on Top Quarks

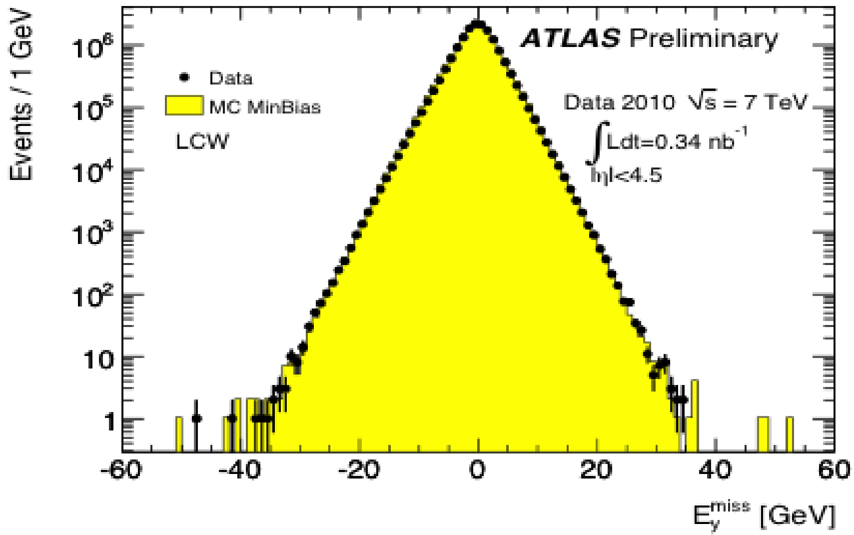


More on Top Quarks



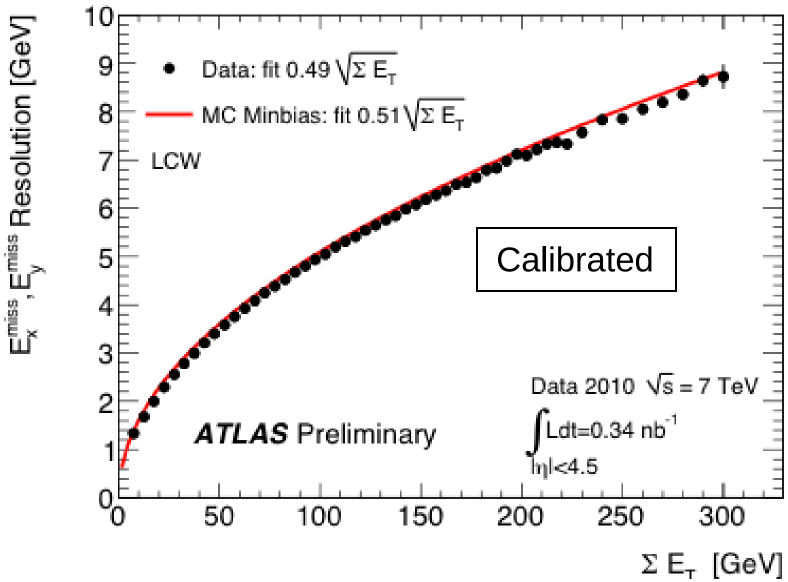
Close-up of the b-tags.

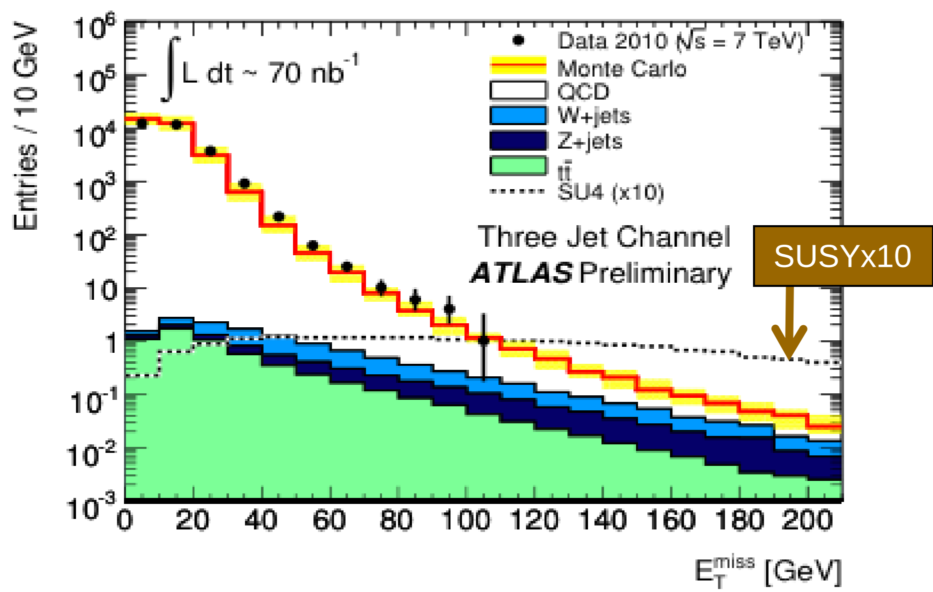
Missing Transverse Energy



Start with the basic missing ET distributions…

…and apply it in (e.g.) SUSY searches: events with ≥ 3 high-pT jets

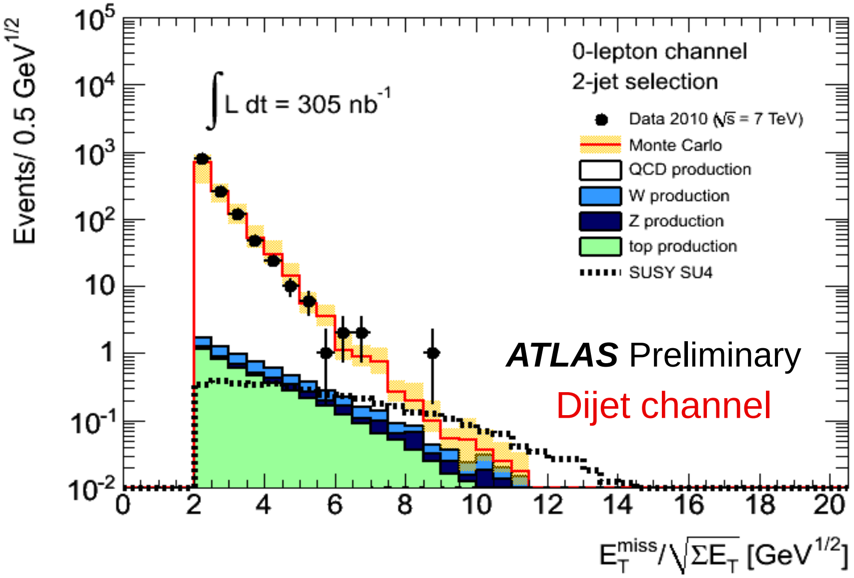




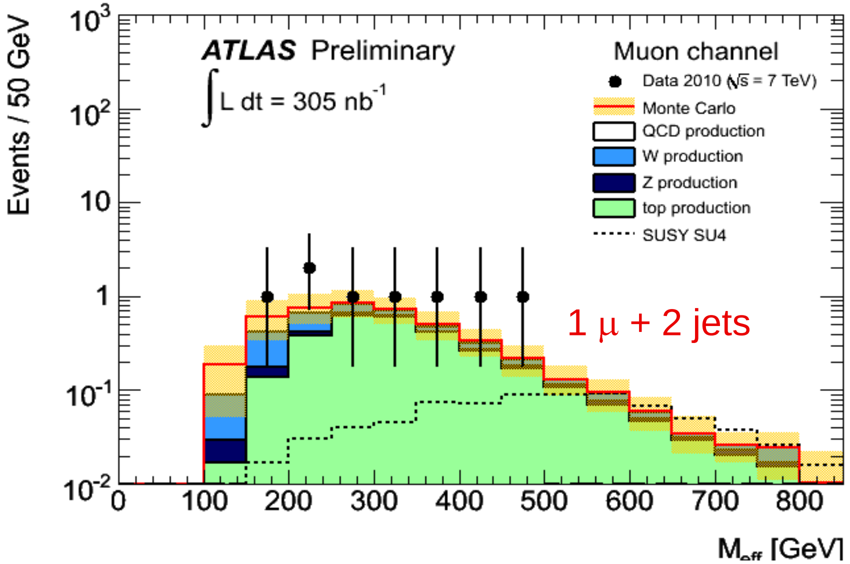
Searches

SUSY Search in b-jets + Missing E_T

- Secondary vertex b-tagging algorithm:
  - Decay length significance: $L/\sigma > 6$
  - $\varepsilon_{b\text{-tagging}} \sim 50\%$
- Event selection (305 nb^{-1}):
  - channels: "≥2-j (70,30)", "≥1 lep (20) + 2 j (30,30)"
  - $E_{Tmiss}/\sqrt{\Sigma E_T} > 2\ \sqrt{GeV}$, at least one b-jet



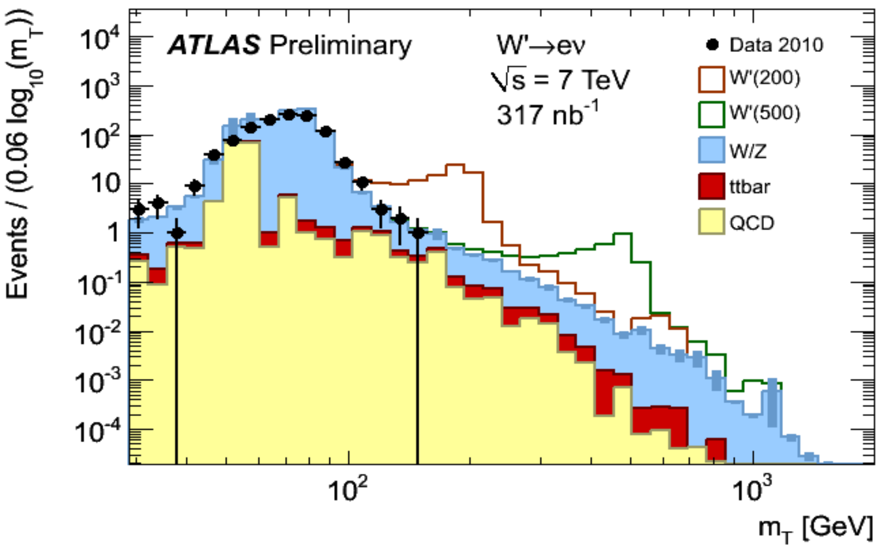
- Two things to take away from these plots:
  - The data are consistent with background
  - SUSY is not on this plot with the "x10" any more: a sign our sensitivity is getting close to where it needs to be to make a discovery..

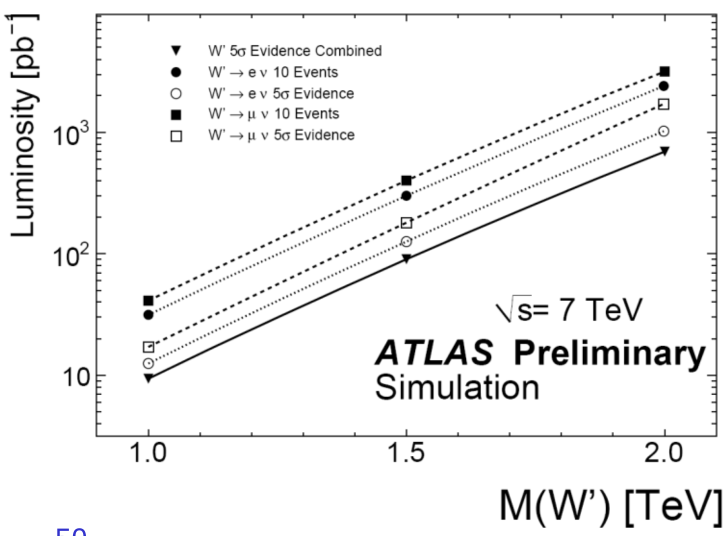


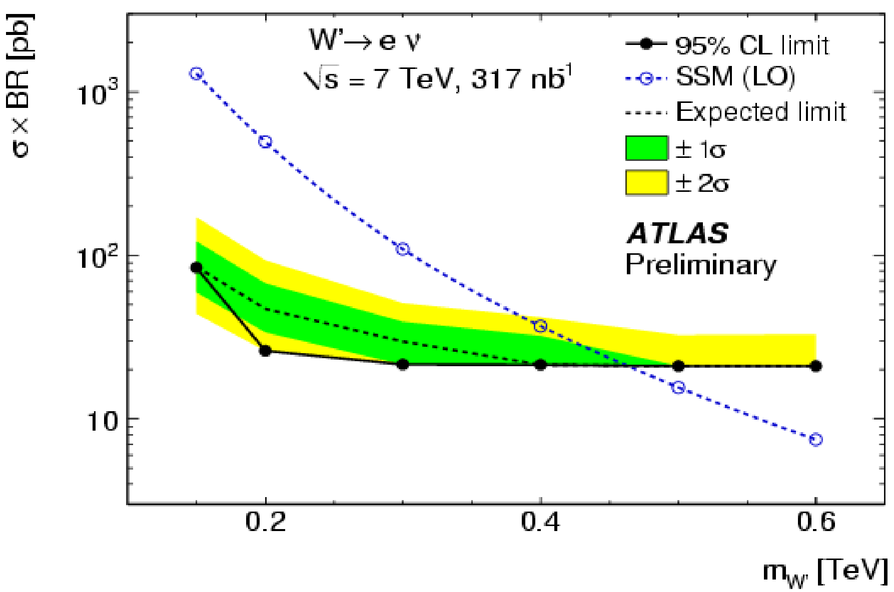
Status of W' Search (example: electron channel)

- Analysis uses 317 nb-1 of data
- Data consistent with SM predictions
- Current limit that can be set (electrons): 465 GeV
  - Present Tevatron limit is 1 TeV
- Current results support estimates from previous MC sensitivity studies
  - Extend sensitivity around 5 pb^{-1}
  - Discovery potential at 10-20 pb^{-1}

electron channel



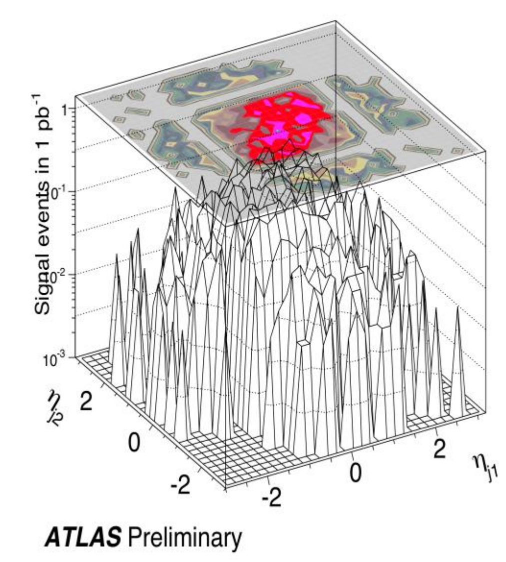




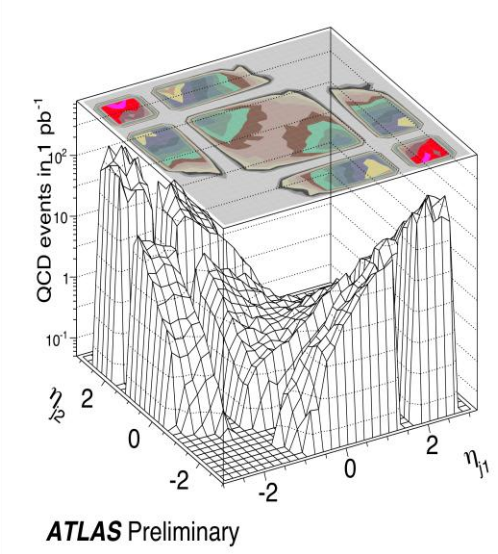
Dijet Resonance Search

- Select events where the jet p_T is on the trigger plateau
  - $p_T(j_1) > 80$ GeV
  - $p_T(j_2) > 30$ GeV
- Cut on $|\Delta\eta| < 1.3$
  - Favors s-channel over t-channel (QCD) production
- Search m(jj) spectrum for features
  - Six tests (tail hunter, bump hunter…)
- If consistent with a smooth background, set a limit.
  - An excited quark (q*) is our benchmark model
  - Previous limit: m(q*) excluded below 870 GeV

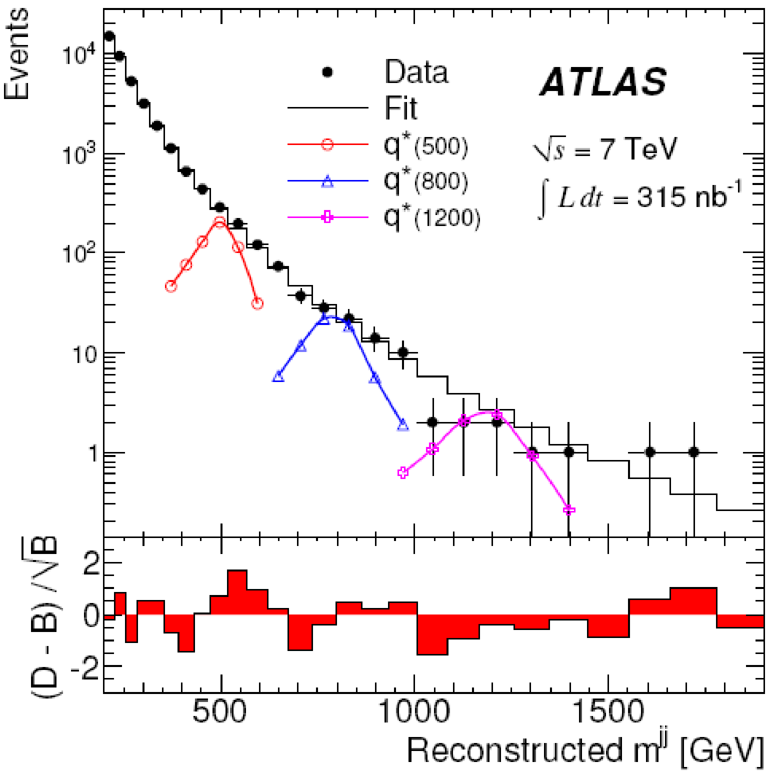
q*
(m = 1 TeV)

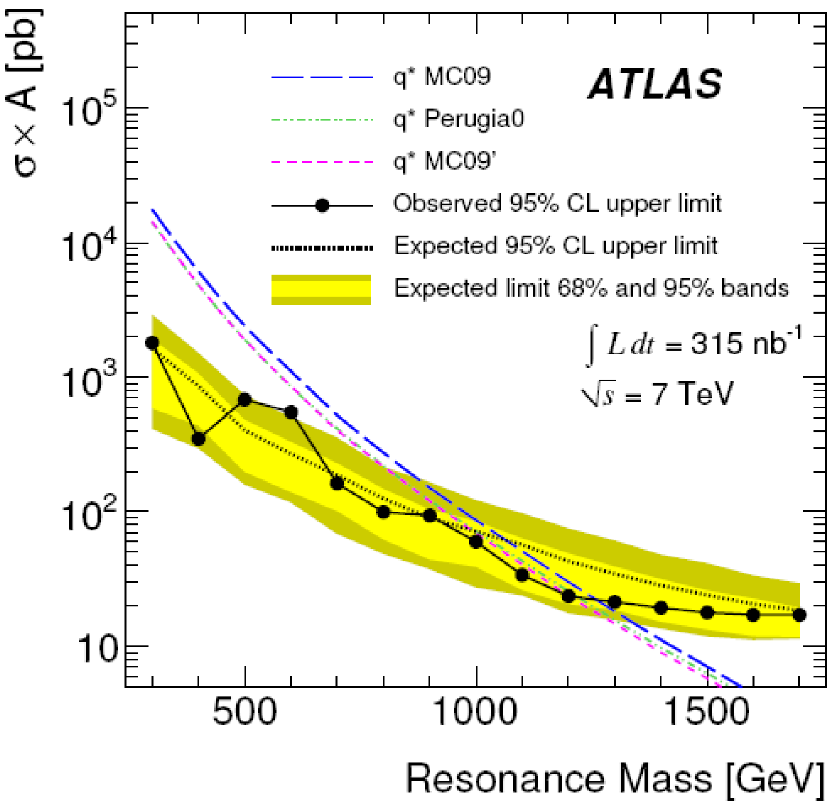


QCD,
875 <m^{jj}< 1020 GeV



Dijet Resonance Search: Outcome



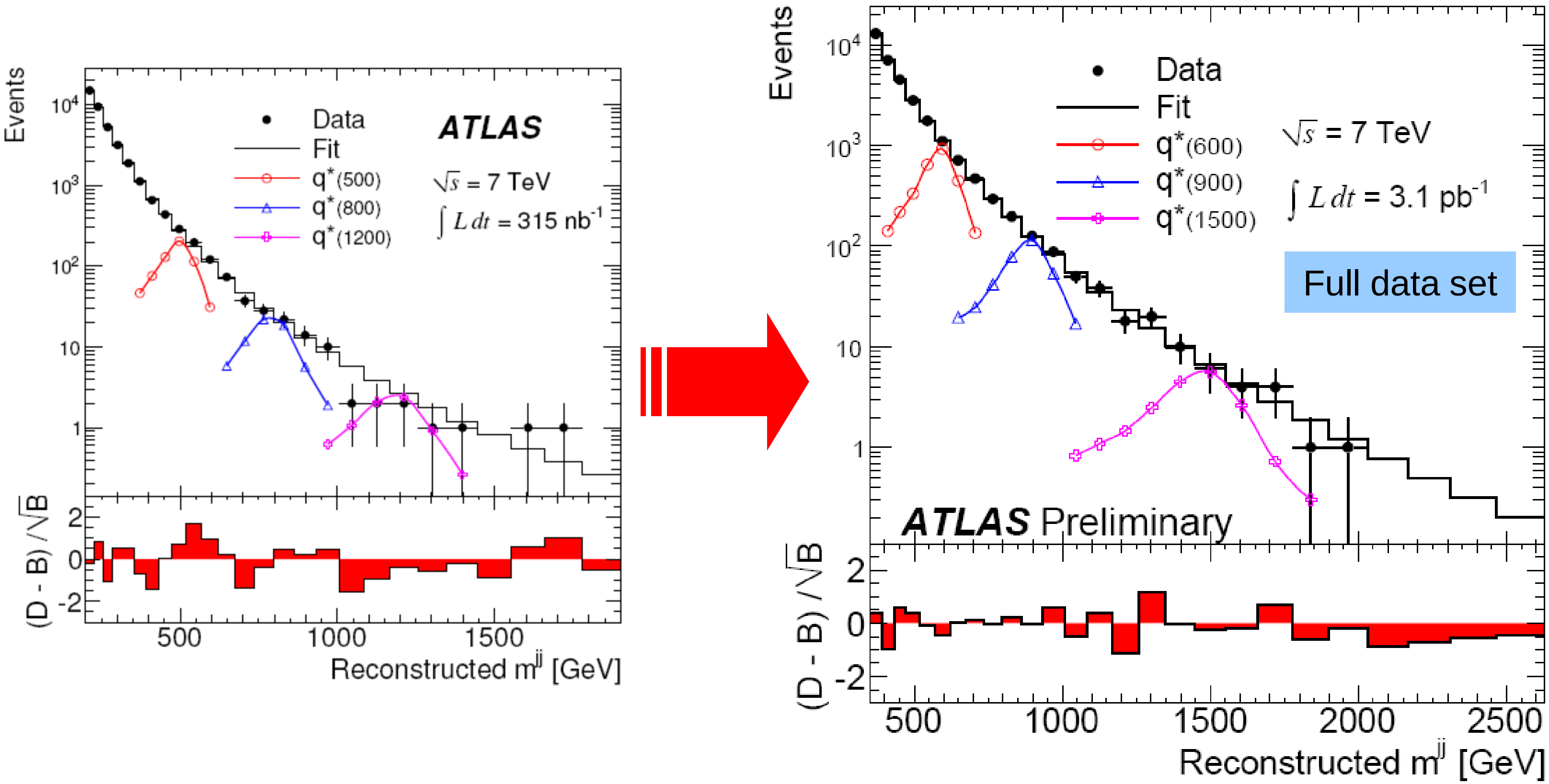


- No evidence of a bump
- Set limit at m(q*) > **1.26 TeV** (expected limit 1.06 TeV)

This data was collected until Monday 19 July, and shown at ICHEP on Friday afternoon.

Accepted for publication in PRL
arXiv:1008.2461

Dijet Resonance Search Update



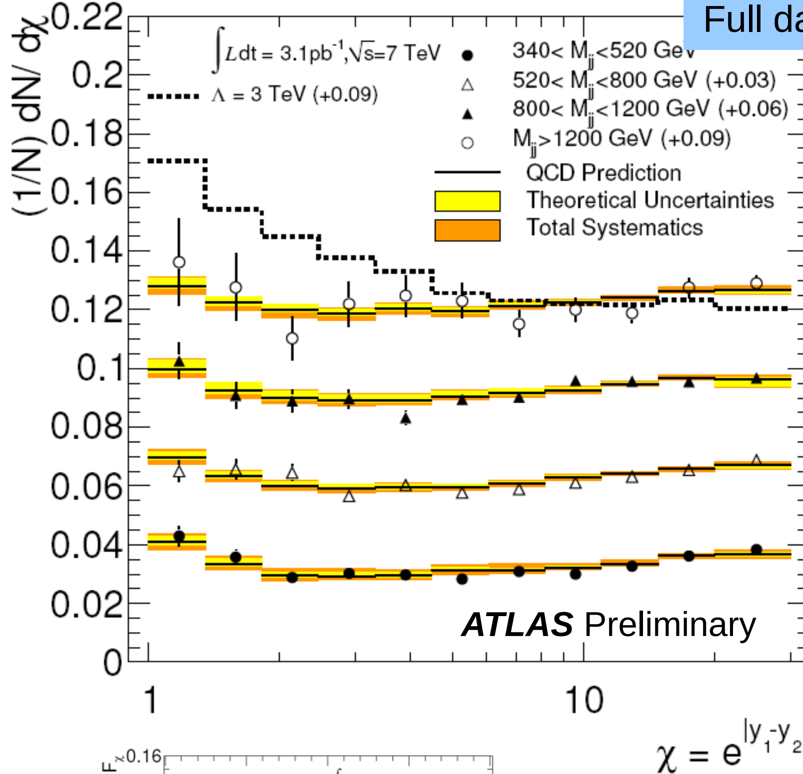
- With 10x as much data the expected limit moves from 1.06 TeV to 1.51 TeV and the observed limit moves from 1.26 TeV to **1.53 TeV**.
  - We raised the jet requirement to $p_T(j_1) > 150$ GeV to match the evolving trigger.

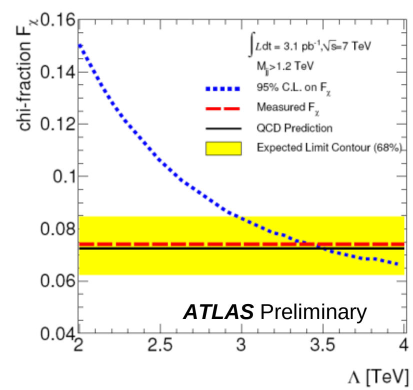
Search With Angular Distributions

- Angular distributions are sensitive to s-channel vs. t-channel (QCD) production of dijets
  - The variable χ is convenient – it's flat for Rutherford scattering, and almost flat for QCD
  - s-channel exchange peaks at low χ.
- We require (depending on mass bin)
  - $p_T(j_1) > 80$-150 GeV (trigger)
  - $p_T(j_2) > 30$ GeV (reconstruction)
  - $|y_1 + y_2| < 1.5$
  - $|y_1 - y_2| < 4.9$

  } Makes acceptance in χ relatively flat.
- No significant deviation from QCD is observed
  - Expressed as our benchmark, a contact interaction Λ, this works out to $\Lambda > 3.4$ TeV (at 95%), with an expected sensitivity of 3.5 TeV
  - Previous best limit is from D0, $\Lambda > 2.8$ TeV

Full data set





$\Lambda_{qqqq} > 3.4$ TeV

Summary

- ATLAS is operating very well
  - We have things to watch
  - We are planning on opening one side over the winter shutdown
- We are starting to realize the scientific potential of the LHC
  - ATLAS has a rich program of standard model physics
    - Precise measurements of W/Z, jets, photons, W/Z+jets, soft QCD
    - These are the foundation for searches for BSM physics
  - Important benchmark searches like W',Z', SUSY, etc. are underway
    - Using all our objects: jets, Missing E_T,muons, electrons, photons, b-tagging…
  - We are exploring uncharted territory at the TeV scale
    - The first LHC search paper has been accepted by PRL. It extends limits for new physics beyond previous experiments: m(q*) > 1.26 TeV (now **1.53 TeV**)
    - We now have a second measurement probing beyond previous experiments: Λ_{qqqq} > **3.4 TeV**
- We are very grateful to the LHC team for making this possible

See ATLAS results page for more details.