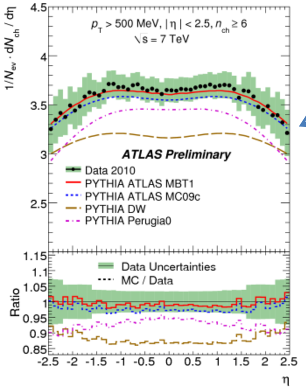
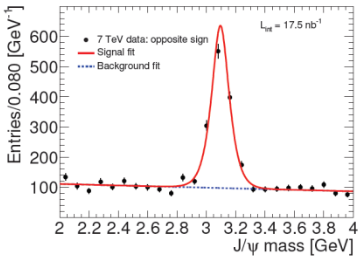
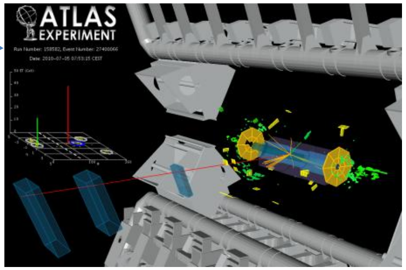
First Results from ATLAS on QCD, Quarkonia and Heavy-flavour Physics in p-p collisions at 7TeV

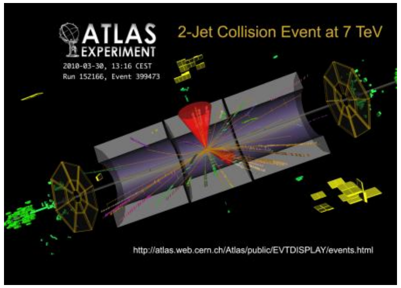
Julie Kirk, RAL
On behalf of the ATLAS Collaboration

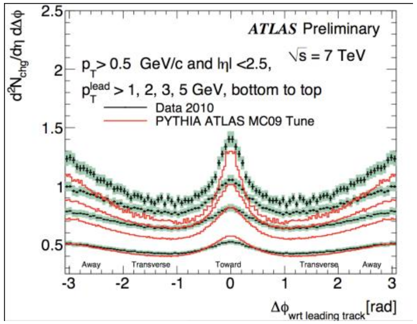
- Charged particle multiplicities
- Underlying event
- Jets
- Quarkonia
- ttbar events









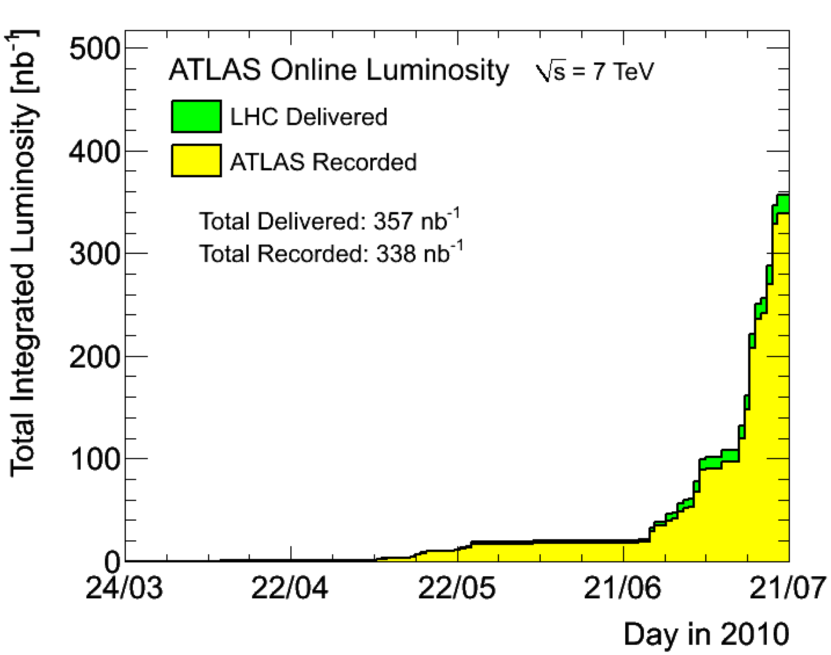


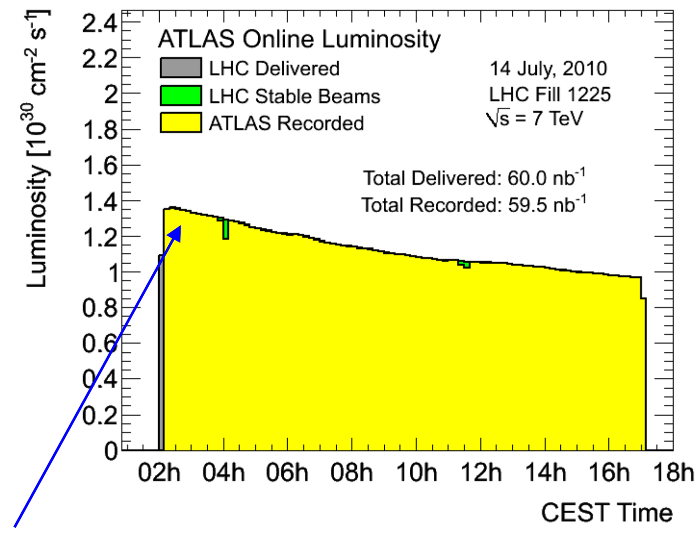
Introduction

A very exciting few months :

- ❑ November 2009 - First physics at 900 GeV.
- ❑ End of 2009 - ATLAS recorded 12 μb^{-1} (plus a few hours at 2.36 GeV)
- ❑ Since 30th March 2010: LHC running at 7 TeV

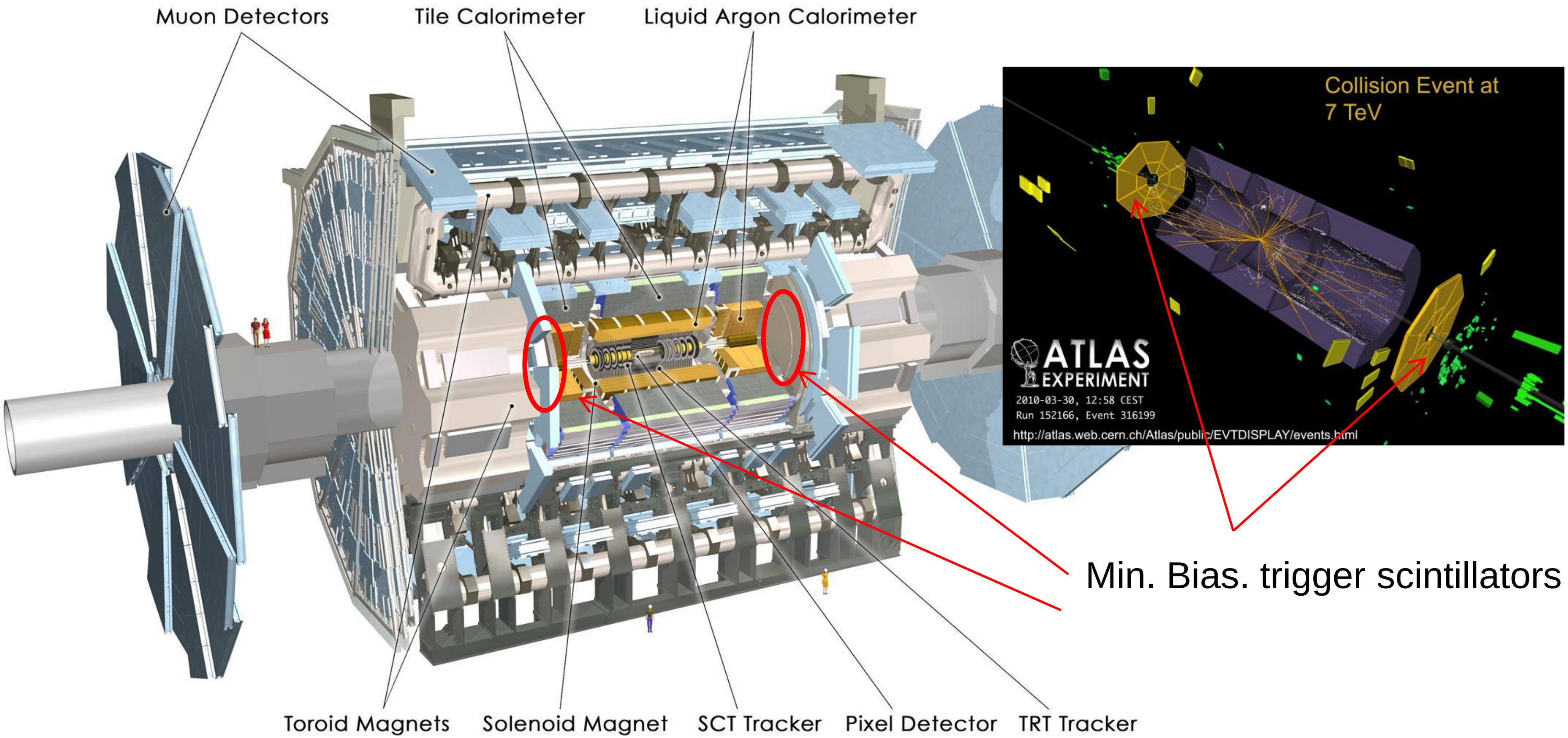
Many physics results now being produced – can only give a flavour of results here.
For the details please see other ATLAS talks at this conference!!





Peak luminosity : 1.6 x 10^{30} cm^{-2}s^{-1}
Data-taking efficiency : 95%

ATLAS Detector



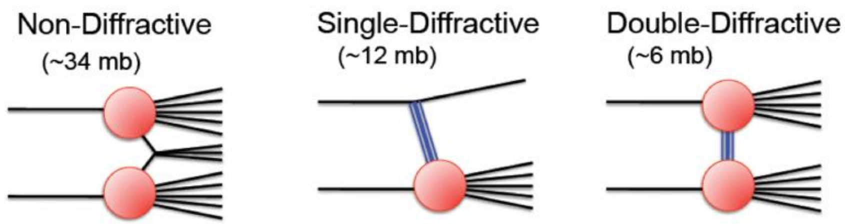
Much work done already to understand detector and trigger performance: see previous talks

J. Baines - Performance of the ATLAS Trigger
A. Limosani – Commissioning and performance of the ATLAS inner detector
J. Fleckner – Performance of track and vertex reconstruction and b-tagging studies
P. Pralavorio – Commissioning and performance of the ATLAS Calorimeter Systems
A. Morley – Material studies with Photon Conversions and Energy Flow at the ATLAS Experiment
A. Schwartzman – Performance of Jet, Missing Transverse Energy and Tau Reconstruction with ATLAS
M. Woudstra – Performance of the ATLAS muon spectrometer and of muon identification

All allows us to start doing physics

Charged Particle Multiplicities

For details see talks by Alison Lister (Track 8 17:20 22nd July) and Emily Nurse (Track 3, 12:05 24th July)



Study inclusive charged particle multiplicities:
- Can be used to tune MC models and study components of cross-section

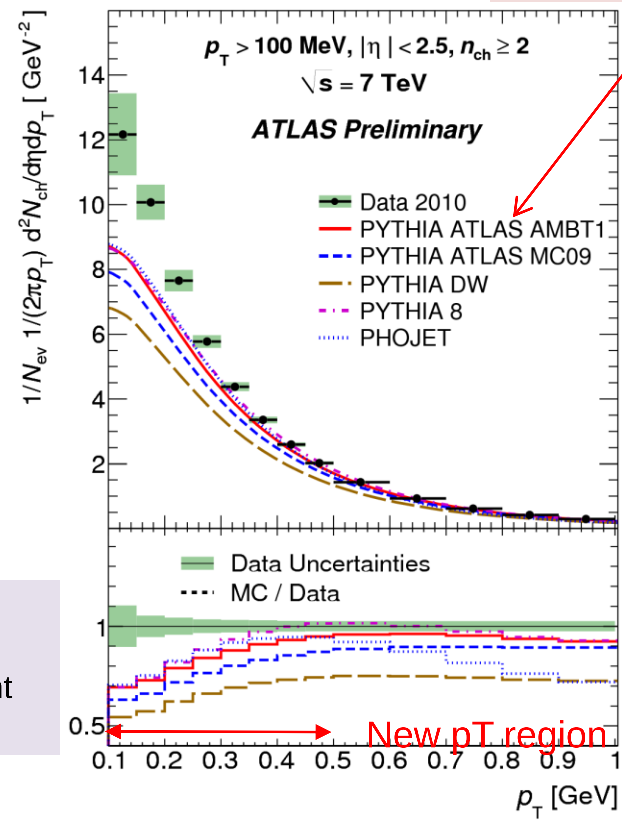
New MC tune to diffractive limited ATLAS dataset

Observables:

N_{ch} = total number of charged particles
N_{ev} = number of events
N_{ch}= number of charged particles in an event

$$\frac{1}{N_{ev}}\cdot\frac{dN_{ch}}{d\eta} \qquad \frac{1}{N_{ev}}\cdot\frac{dN_{ev}}{dn_{ch}} \qquad \frac{1}{N_{ev}}\cdot\frac{1}{2\pi P_T}\cdot\frac{d^2N_{ch}}{d\eta dp_T} \qquad \langle p_T\rangle \text{ vs } n_{ch}$$

ATLAS uses a single arm MBTS (min bias scintillator) trigger
→ no subtraction of SD component
→ minimal model dependence
→ measurement in kinematic region defined at hadron level by cuts on p_T, η, n_{ch}



- Analysis extended to lower momentum region (p_T>100MeV, n_{ch}≥2)
- Luminosity – 190 μb^{-1} (10 M events)
- Data-MC agreement is worse at low p_T – larger diffractive component which was not used in MC tune.

• Data
| Statistical uncertainty
Statistical + systematic in quadrature

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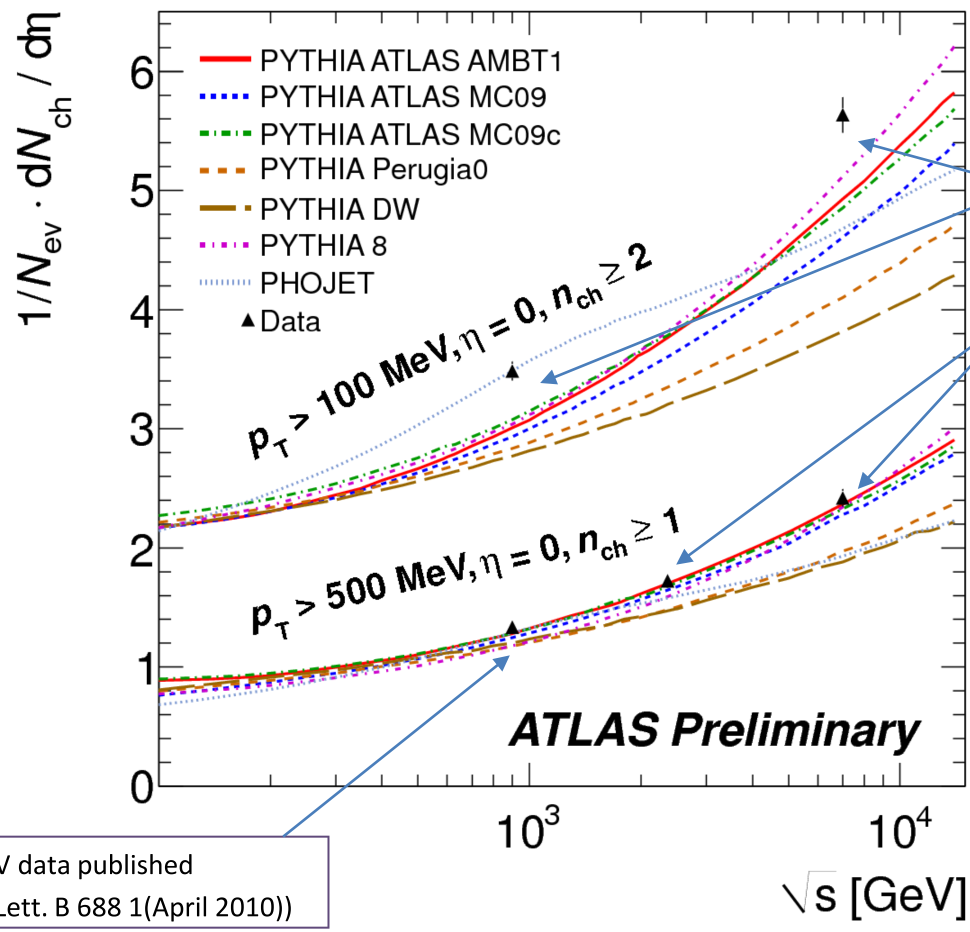
ATLAS-CONF-2010-047

Charged Particle Multiplicities

Summarise all results:



New results including lower pT region

Repeat published analysis at:
2.36 TeV and 7 TeV

2 fills with SCT at standby
- analysed using special track reconstruction
- see Alison's talk

900 GeV data published
(Phys. Lett. B 688 1(April 2010))

<u>dn/dη (@ η= 0) :</u>

p_T>100 MeV
7 TeV: 5.635 0.002(stat.) 0.149(syst.)
0.9 TeV: 3.486 0.008(stat.) 0.077(syst.)

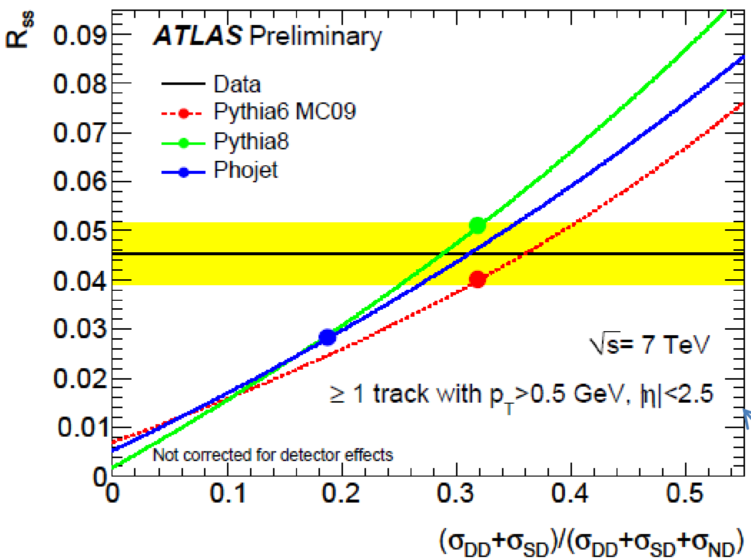
p_T>500 MeV
7 TeV: 2.418 0.004(stat.) 0.076(syst.)
2.36 TeV: 1.739 0.019(stat.) 0.058(syst.)
0.9 TeV: 1.333 0.003(stat.) 0.040(syst.)

Diffractive enhanced sample

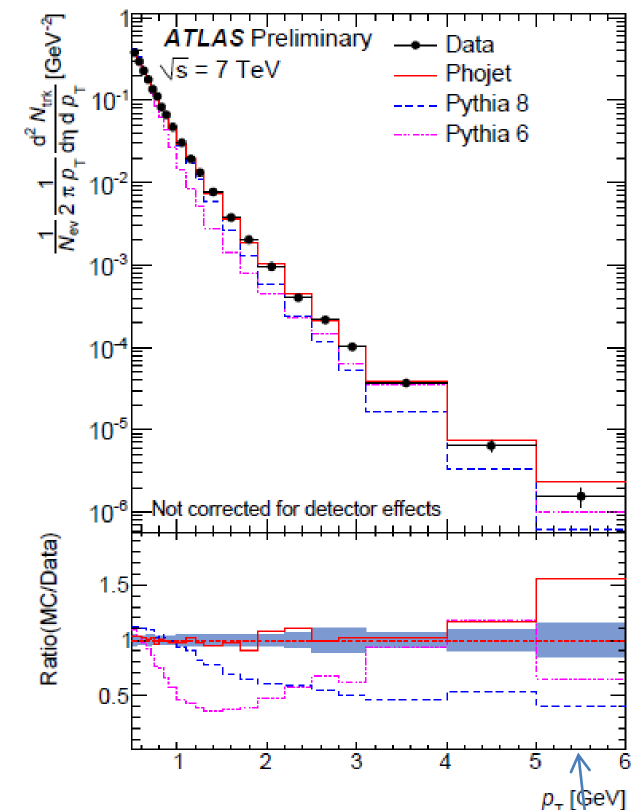
NB. Not yet corrected for detector effects

Probe diffractive part of cross-section:
Min. Bias Scintillator - require activity on one-side of detector ONLY

R_{ss} = Events with ONLY 1 side/ Events with EITHER side
= (4.52 0.02 (stat) 0.61 (syst)) %



Generator	R_{ss}^{1-trk} (%)
Pythia 6	4.01
Pythia 8	5.11
Phojet	2.83



- Pythia 6 and 8 describe rate of diffractive events well
- Phojet best description of track distributions

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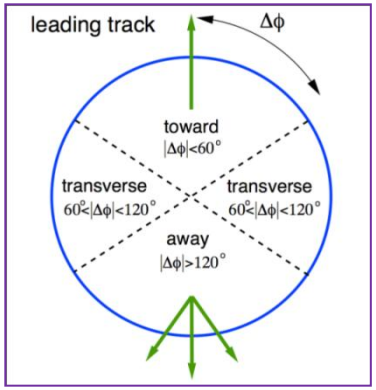
Underlying event

For details see talk by E. Nurse
(Track 3, 12:05 24th July)

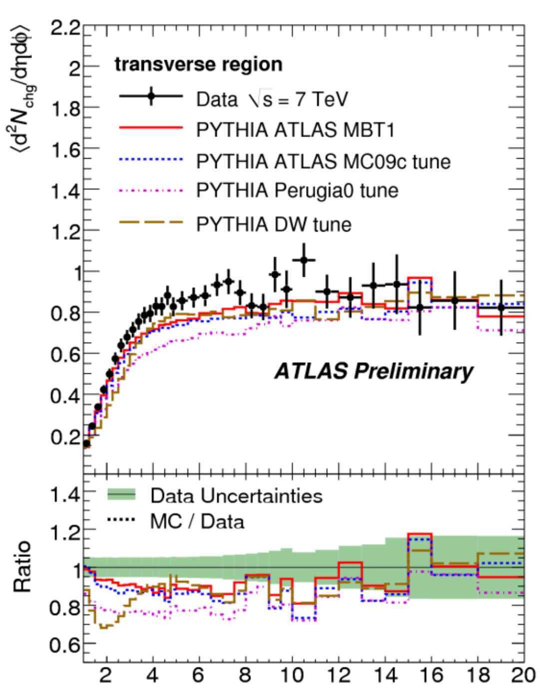


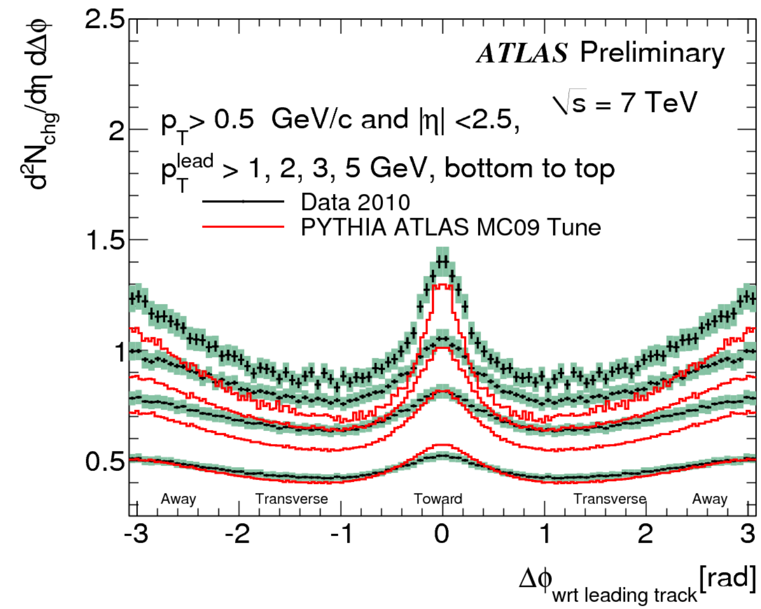
Underlying Event (UE) = everything EXCEPT the hard scattering.
Similar to Min Bias analysis but look at topology of event.
Leading track = highest p_T.
Transverse region most sensitive to UE

Distributions are fully corrected for detector effects

Charged particle density

- MC all underestimate activity in plateau region by ~10-15%
- also at 900 GeV





Emergence of jet-like structure as p_T^{lead} inc.

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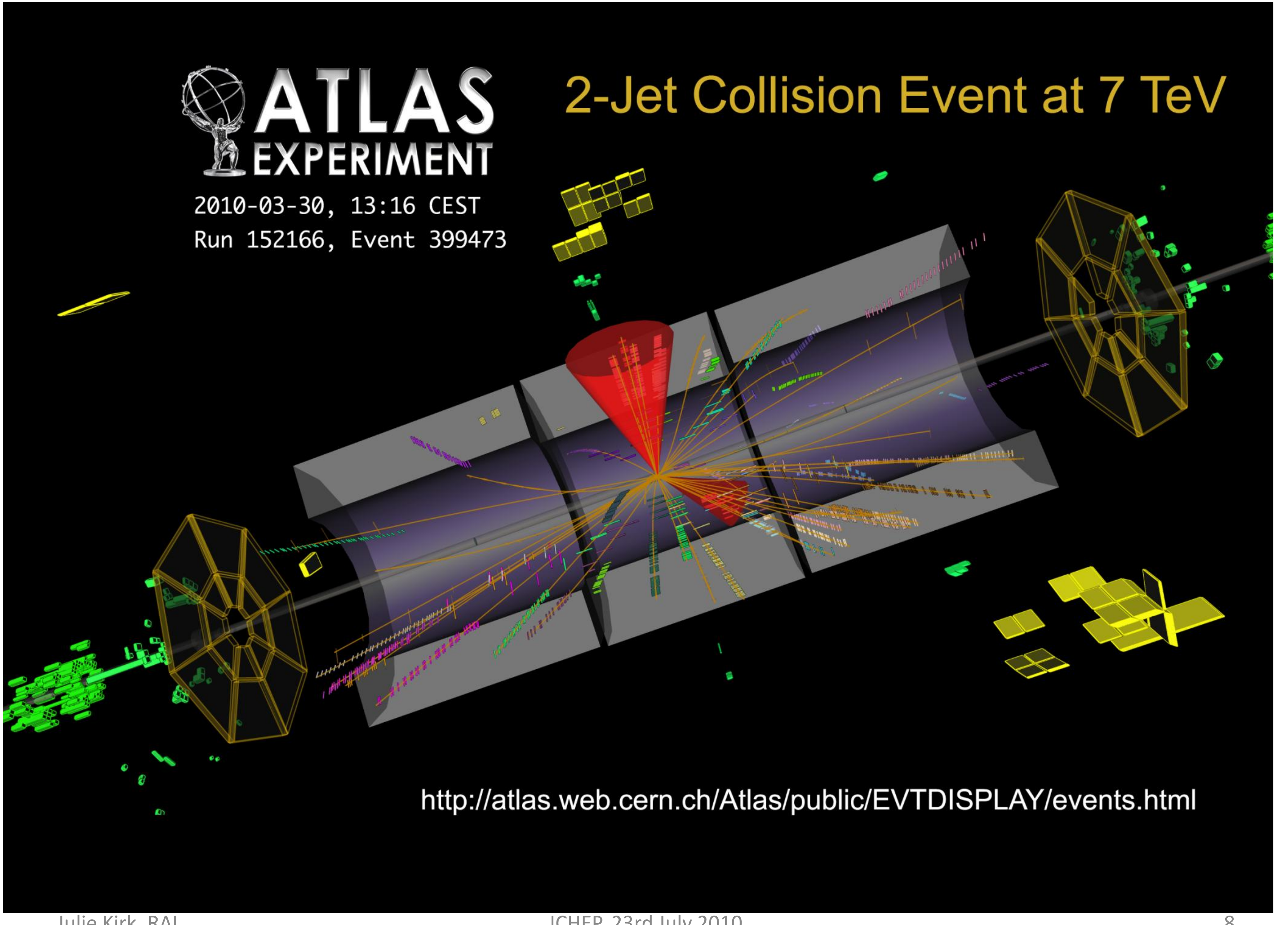
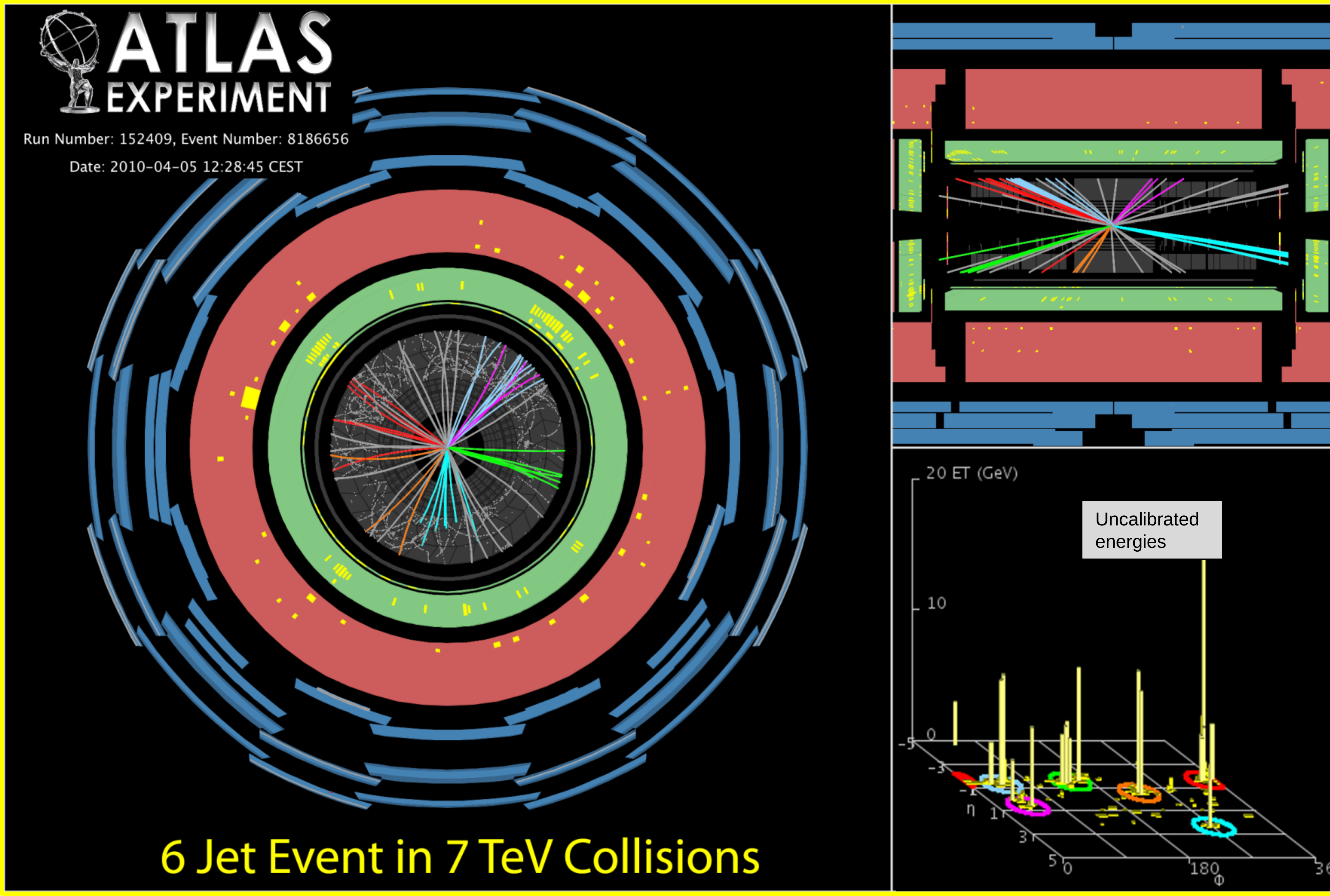

ATLAS
EXPERIMENT
2-Jet Collision Event at 7 TeV
2010-03-30, 13:16 CEST
Run 152166, Event 399473
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

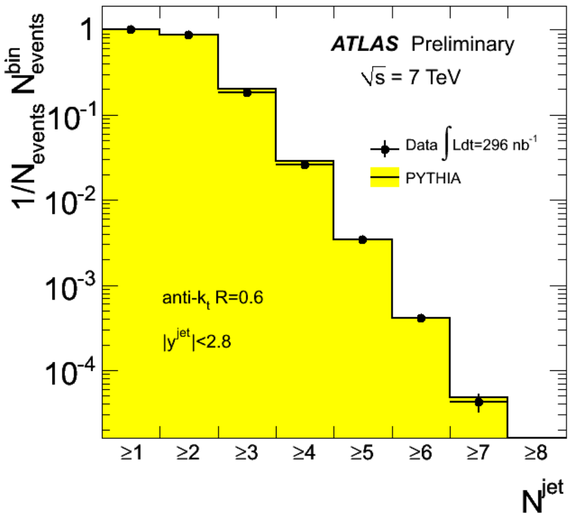


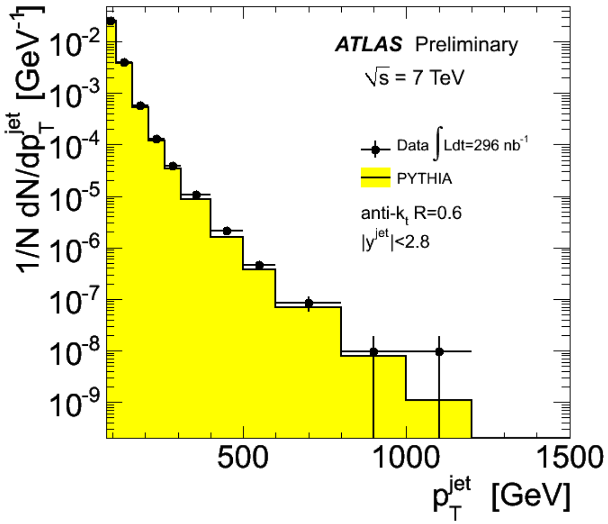
(Jet p_T: 30-70 GeV)

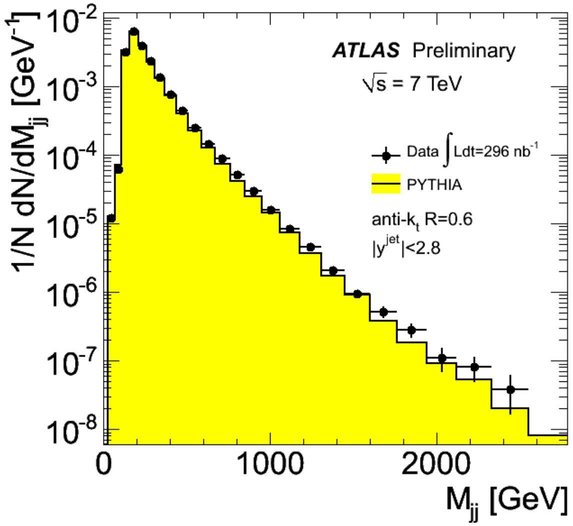
Observation of energetic jets

Anti-k_T jet algorithm (R=0.6) using calorimeter clusters.
p_T(jet) > 80 GeV

Compare to Pythia MC09 tune : LO matrix element + parton shower







Di-jets with M_{jj} up to >2TeV
(pT(jet1) > 80 GeV , pT(jet2) > 40 GeV)

(Statistical uncertainty only - systematic uncertainty on jet energy scale ~7%)

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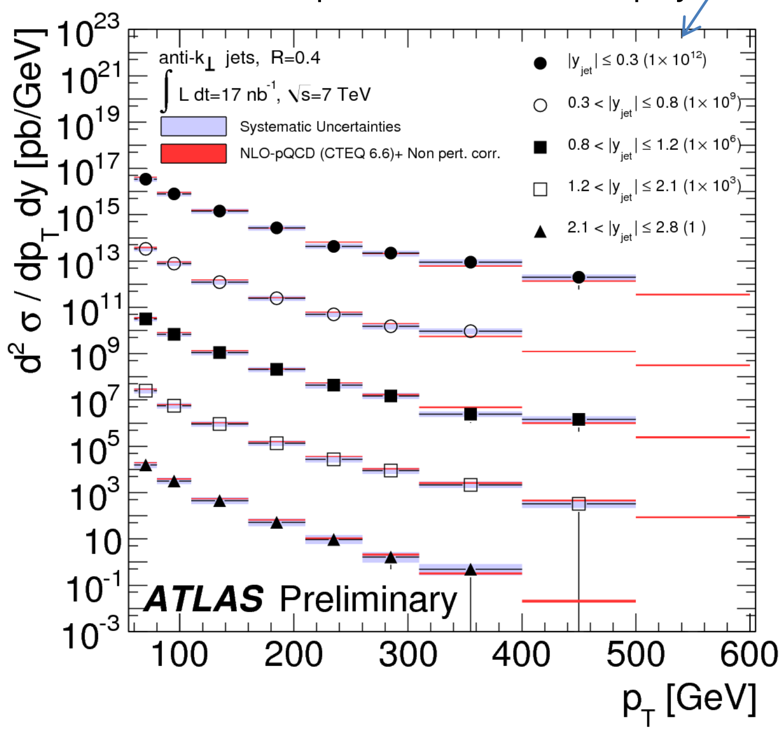
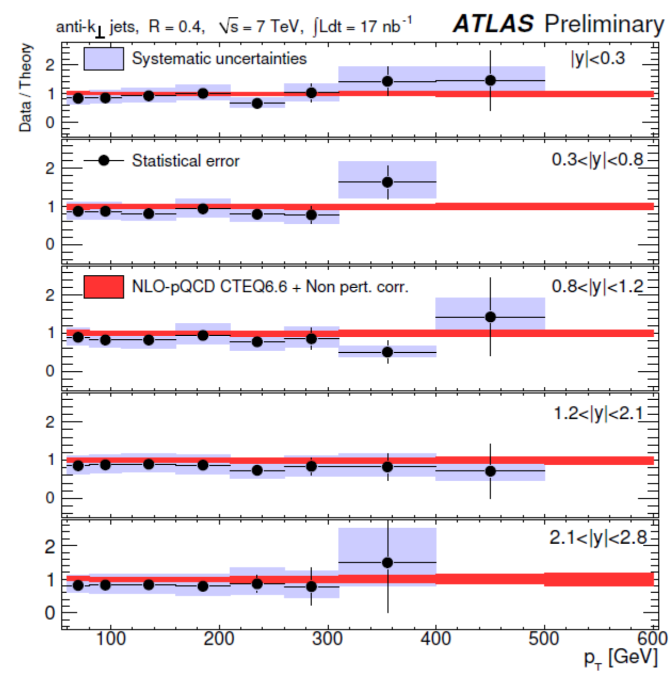
Jet production

For details see talk by T. Carli
(Track 3, 15:00 24th July)

Jet production cross-sections for R=0.4,0.6, p_T(jet)>60 GeV
Theory: NLO perturbative calculations with non-perturbative corrections

Cross-sections in different rapidity bins
Note multiplication factors for display:

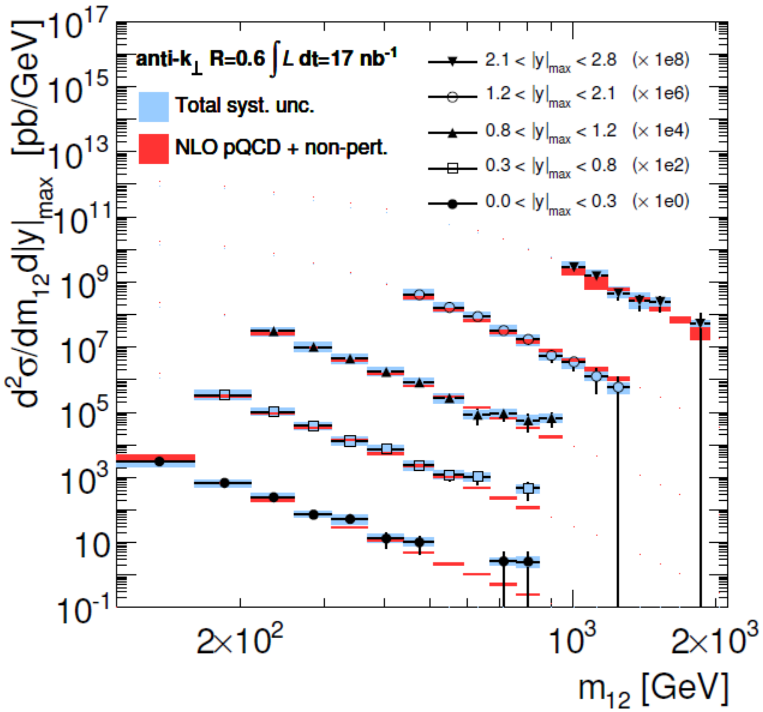


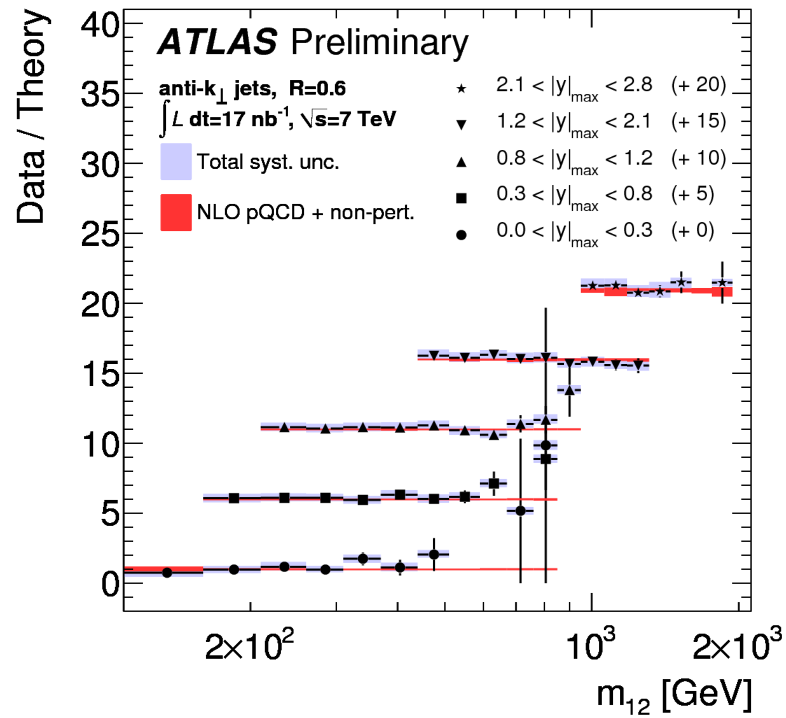


Systematic uncertainty dominated by Jet Energy Scale (~7% for central jets , <9% over full p_T and y region)
11% uncertainty due to luminosity measurement is not shown

Di-jet production

Di-jet production cross-sections for R=0.4,0.6, p_T(jet1)>60 GeV, p_T(jet2)>30 GeV





Good agreement between data and MC in both single and di-jet cross-sections

Track jets

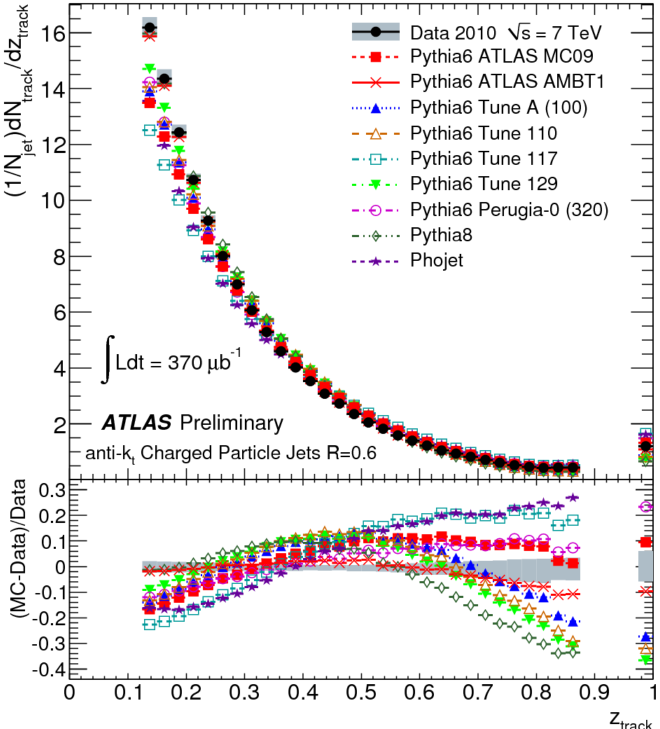
For details see poster by S. Zenz

Track jets – charged particle jet cross-section (p_T>500MeV)
Anti-k_T jets with R=0.4,0.6
Complimentary to calorimeter based measurement:
- Independent systematic uncertainties
- Can go to low momentum (min. bias trigger so no jet pT cut at trigger) – emergence of jets from soft collisions

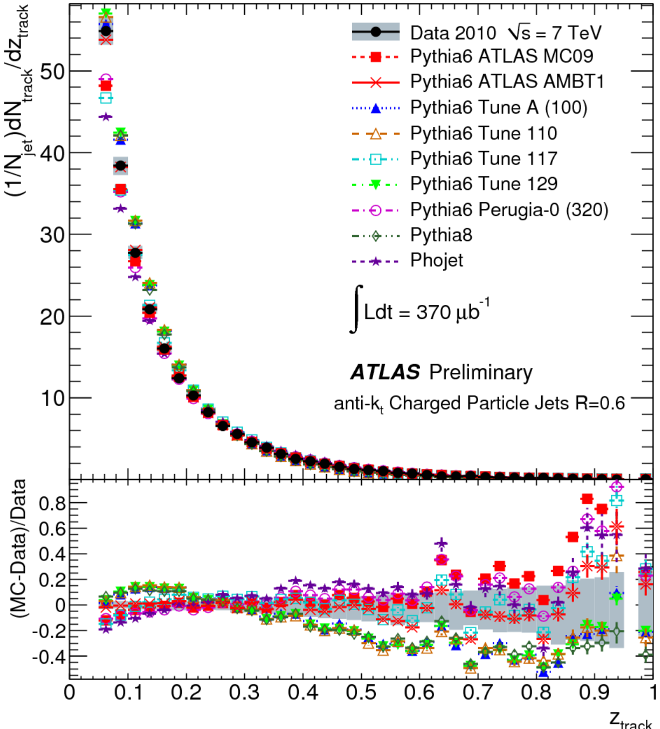
Measure Jet p_T and corrected fragmentation distribution f(z)

(*z* is defined to be the momentum of a charged particle in a jet along the jet's axis, divided by the momentum of the charged particle jet)

Unfolded z (p_T 4-6 GeV)



Unfolded z (p_T 15-24 GeV)



Shape of fragmentation best described by ATLAS AMBT1 tune for pT 10-24GeV.
For p_T<10GeV fragmentation not well described by any tune

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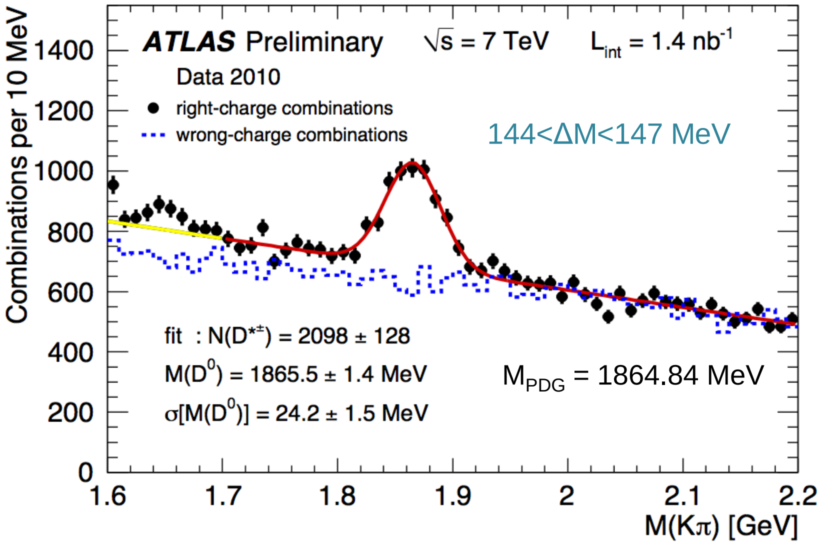
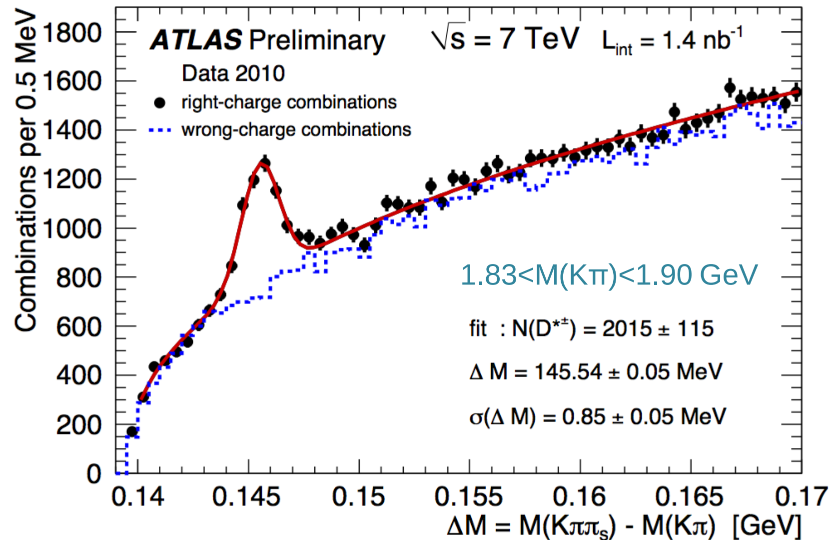
$D^{(*)}$ Mesons

For details see talk by L. Gladilin (Track 8, 12:00 22nd July)

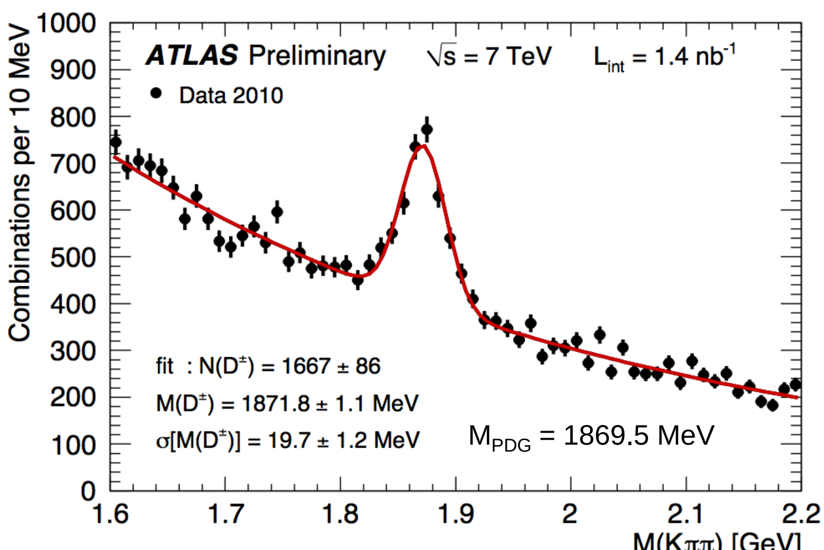
$D^0 \to K^- \pi^+$



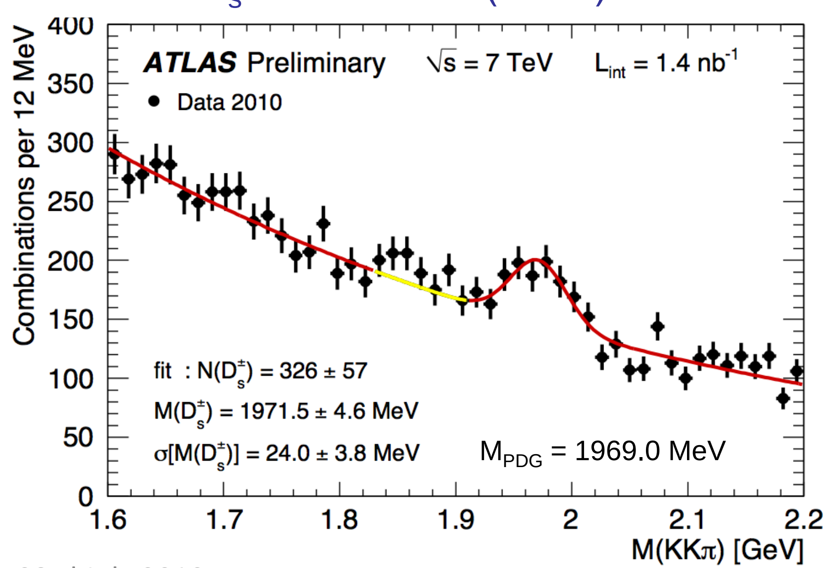
$D^{*+} \to D^0 \pi_s^+ \to (K^- \pi^+) \pi_s^+$ (π_s^+ = soft pion)



$D^+ \to K^- \pi^+ \pi^+$



$D_s^+ \to \Phi \pi^+ \to (K^+ K^-) \pi^+$



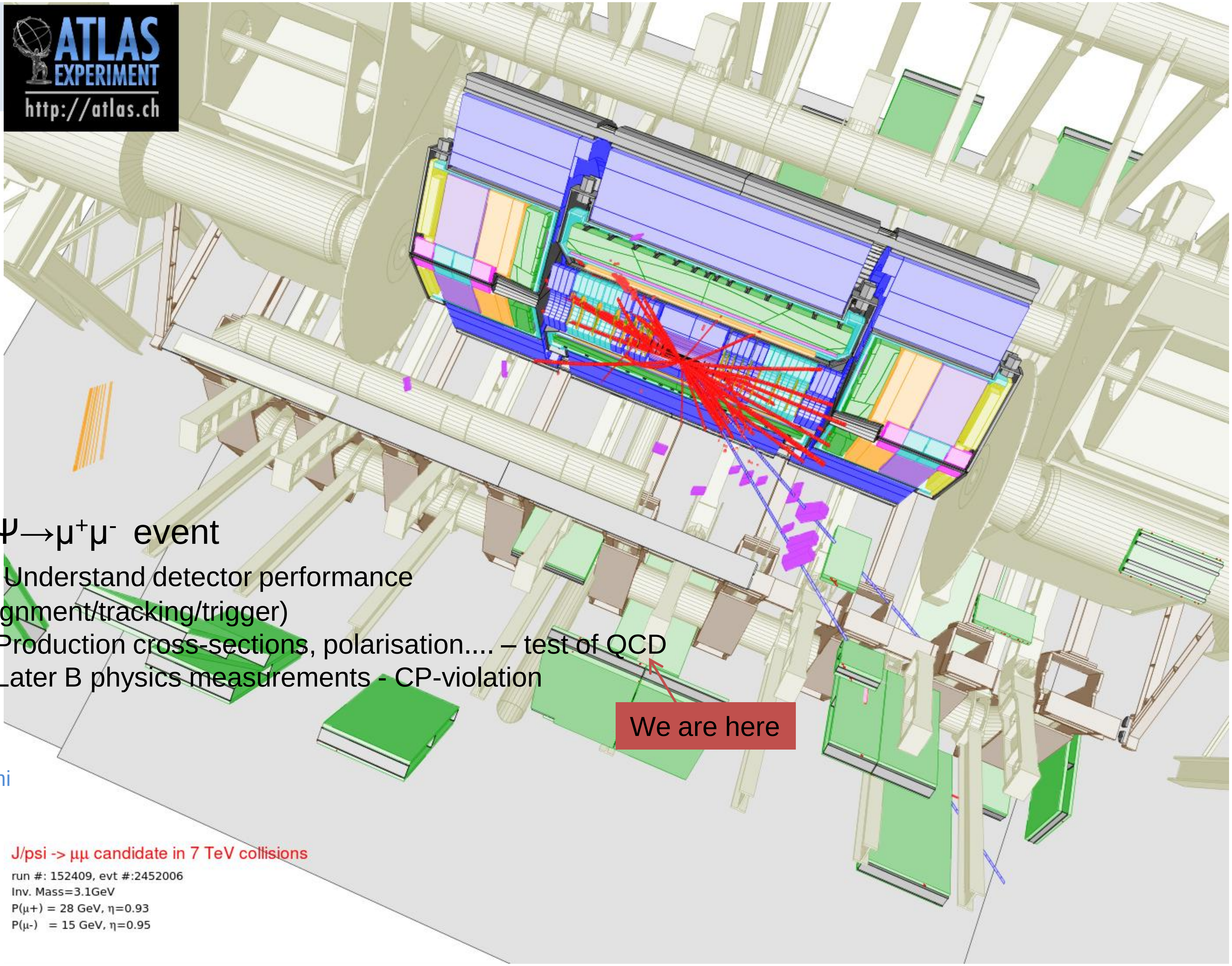
Clean signals and fit masses in reasonable agreement with PDG

$J/\Psi \rightarrow \mu^+\mu^-$ event

- ❑ Understand detector performance (alignment/tracking/trigger)
- ❑ Production cross-sections, polarisation.... – test of QCD
- ❑ Later B physics measurements - CP-violation

We are here

↓ Inc. Lumi

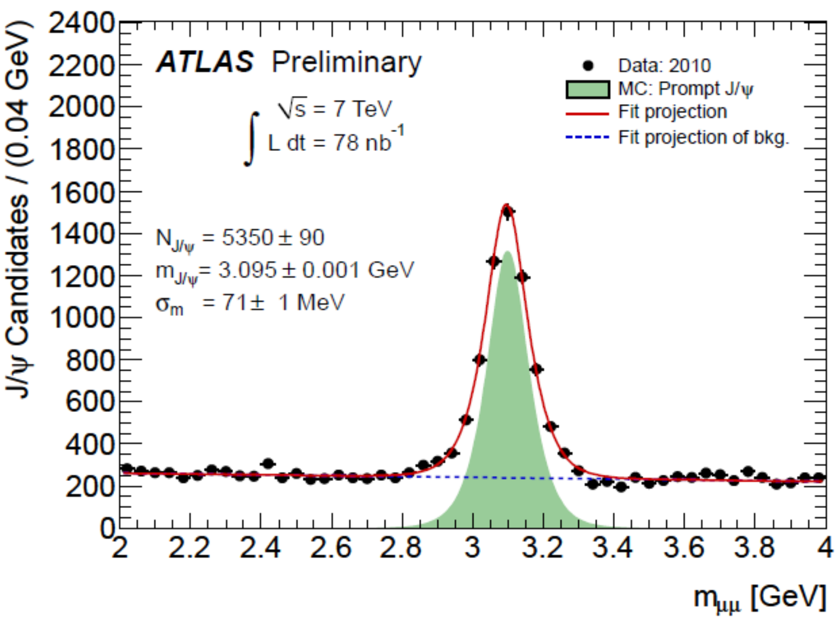


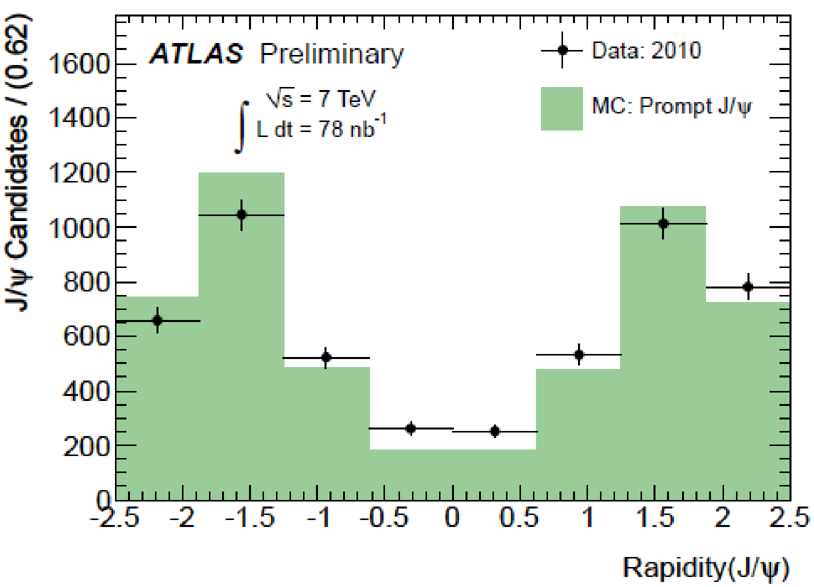
$J/\psi \rightarrow \mu^+\mu^-$

For details see talks by
A. Korn, A. Nelson
(Track 6, 16:34, 16:47 24th July)

First observation of $J/\psi \rightarrow \mu^+\mu^-$
Loose selection cuts:

- ❑ Min Bias trigger → sensitive to $p_T(\mu)$ ~1GeV
- ❑ 2 opposite sign muons
- ❑ Fit to common vertex.





Kinematic distributions agree with MC expectation

Fraction of J/ψ→μ⁺μ⁻ from B decays

In the fraction:

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

many factors cancel (efficiency, acceptance) making this an attractive "early data" measurement.

Discriminating variable pseudo proper-time:

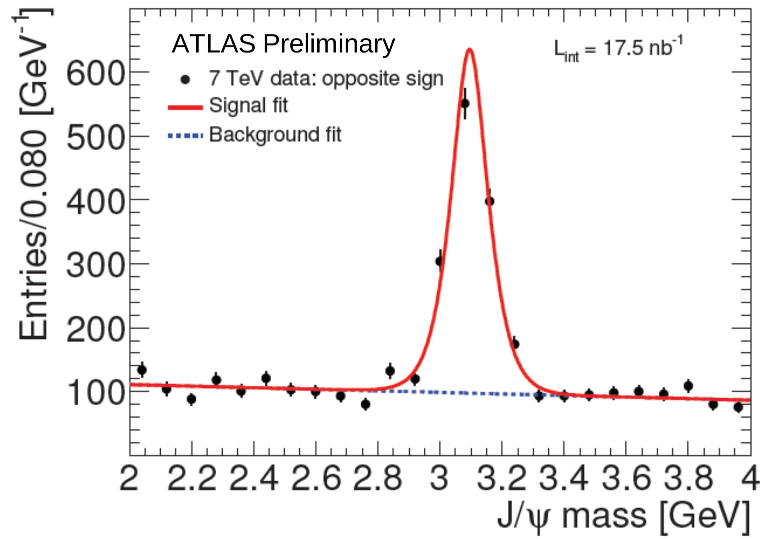
$$\tau = \frac{L_{xy}\, m(J/\psi)}{p_T(J/\psi)}$$

xy displacement of candidate from PV (L_{xy})

Invariant mass of candidate ($m(J/\psi)$)

p_T of candidate ($p_T(J/\psi)$)

Mass and lifetime distributions fitted simultaneously using unbinned maximum likelihood fit.



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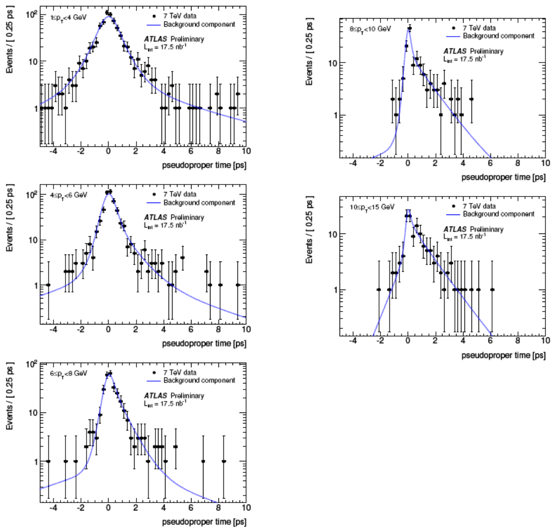
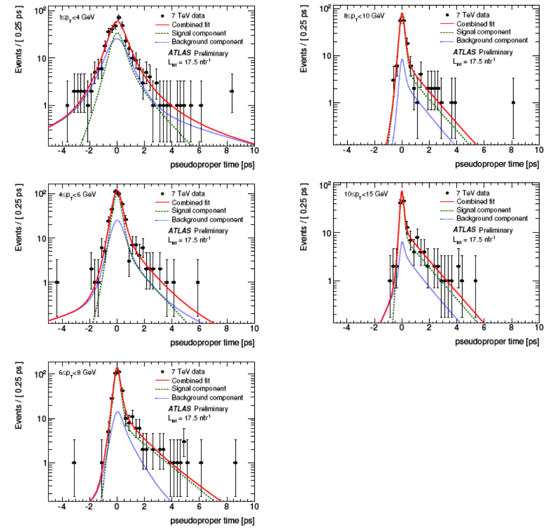
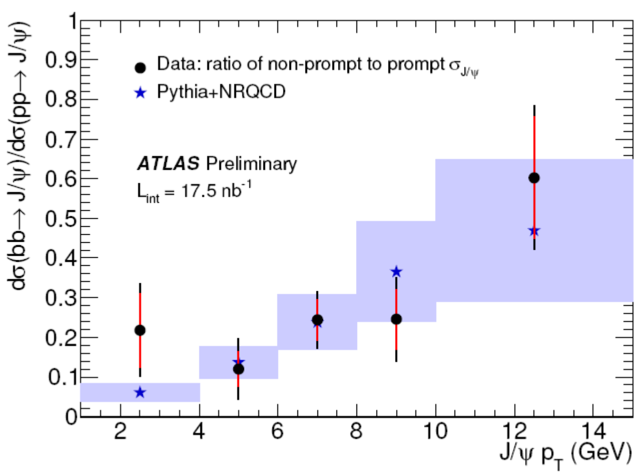
Fraction of $J/\psi \rightarrow \mu^+\mu^-$ from B decays



Fit to
• sidebands to get shape for background
• then to signal region.





Good data/MC agreement for $p_T(J/\psi)$ up to 15 GeV

J/ψ→μ+μ- differential cross-section

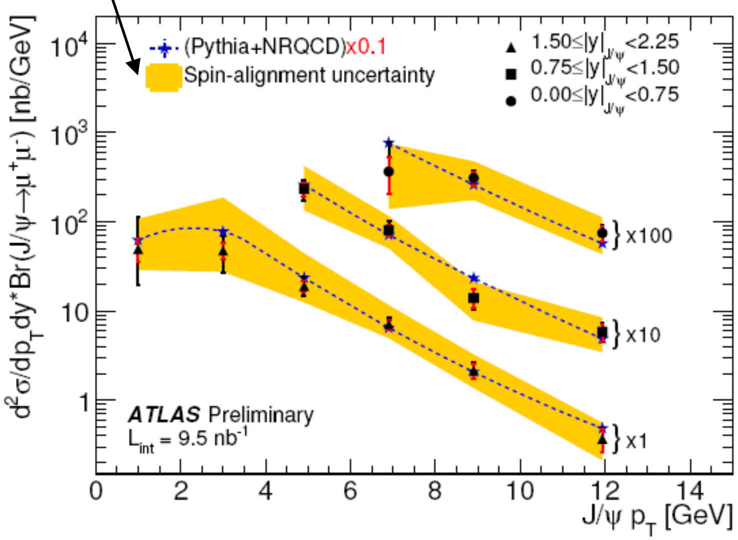
Use unbinned maximum likelihood fit.
Event weight:

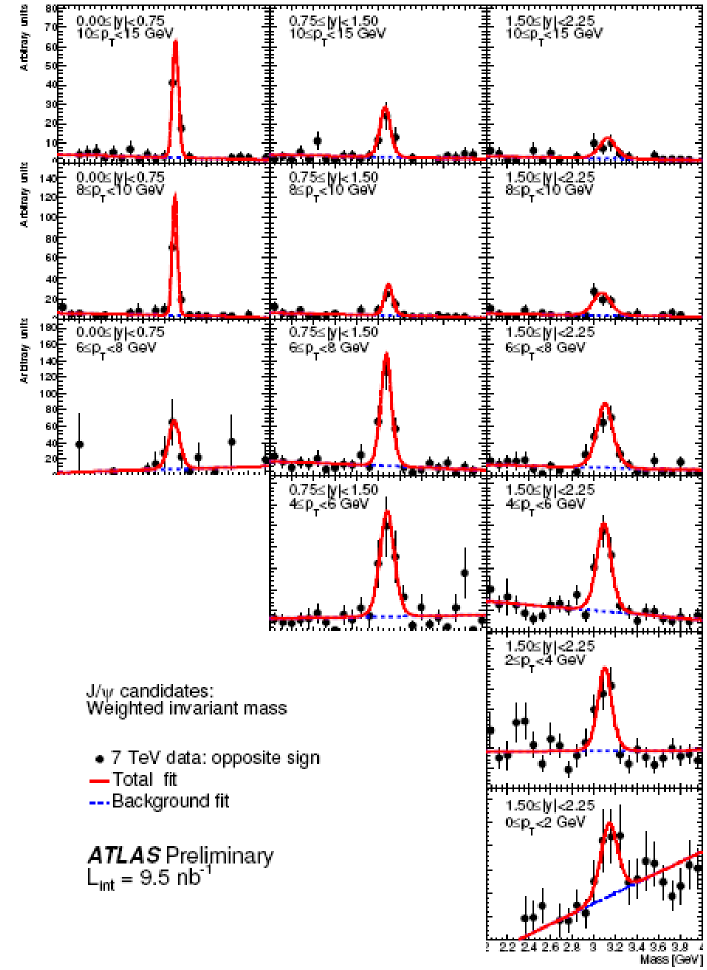
$$w^{-1} = \mathcal{A}(p_T, y, \lambda_i) \times \mathcal{E}_\mu(\vec{p}_1) \times \mathcal{E}_\mu(\vec{p}_2) \times \mathcal{E}_{\rm trig}(\vec{p}_1, \vec{p}_2)$$

Detector acceptance (from generator level MC – dependence on spin alignment of J/ψ is taken as a systematic)

Reconstruction efficiency (from fully simulated MC – will eventually use tag-and-probe methods)

Trigger efficiency (from data)





MC-data shape agree – MC normalisation is higher than data

J/ψ→e⁺e⁻

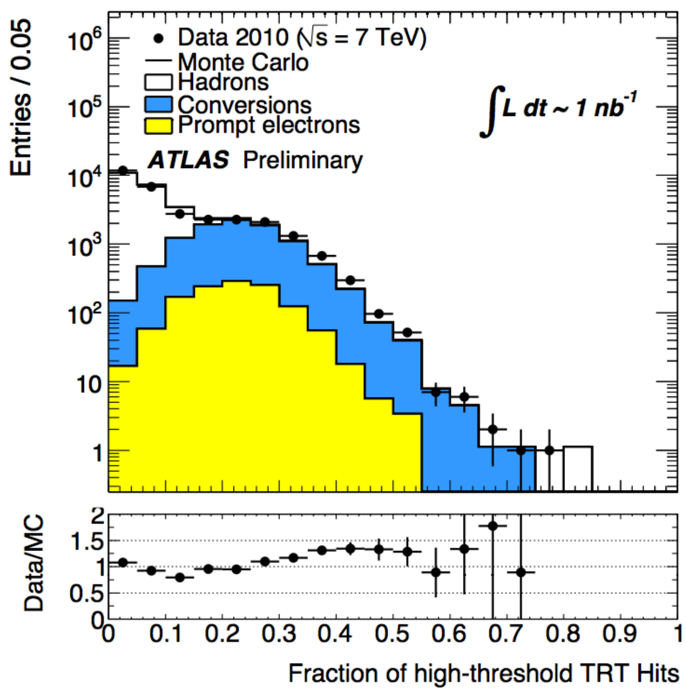
For details see talk by S. Snyder
(Track 1, 15:00 22nd July)

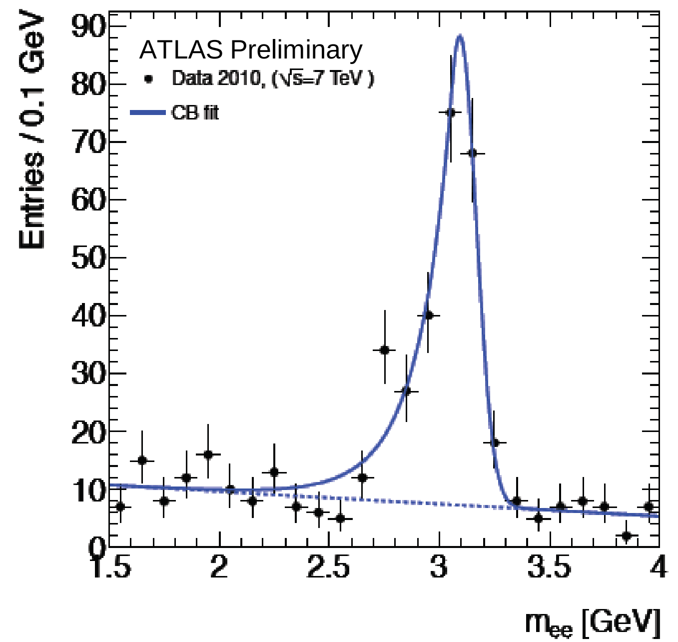
More difficult – large background, small signal and bremsstrahlung of electrons
– important source of low p_T electrons to understand electron ID and trigger

Selection:
- 2 electrons with p_T>2,4 GeV
- Track quality and shower shapes
- high threshold hits in TRT

Mass from tracks - GSF
mean = 3.09 +/- 0.01
sigma = 0.07 +/- 0.01
signal = 222 +/- 11
bkg = 28 +/- 2

Corrected for bremsstrahlung

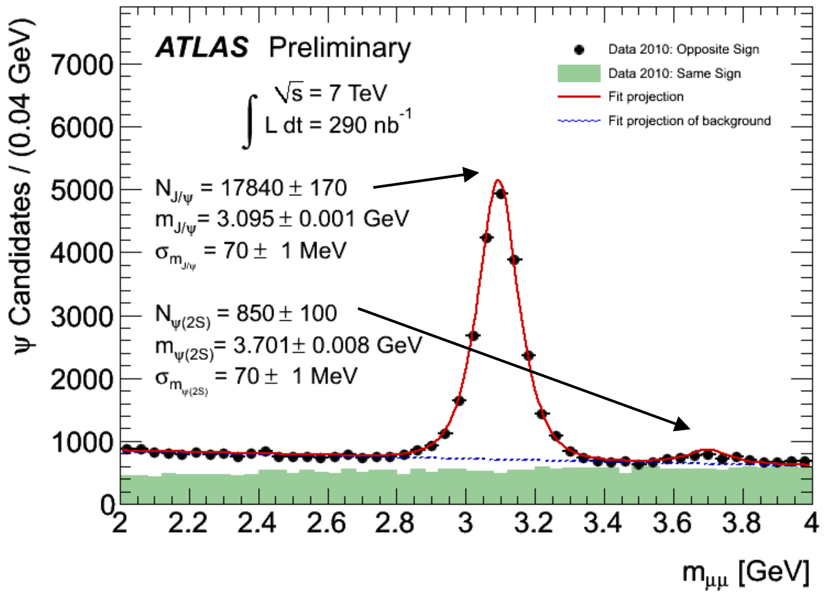




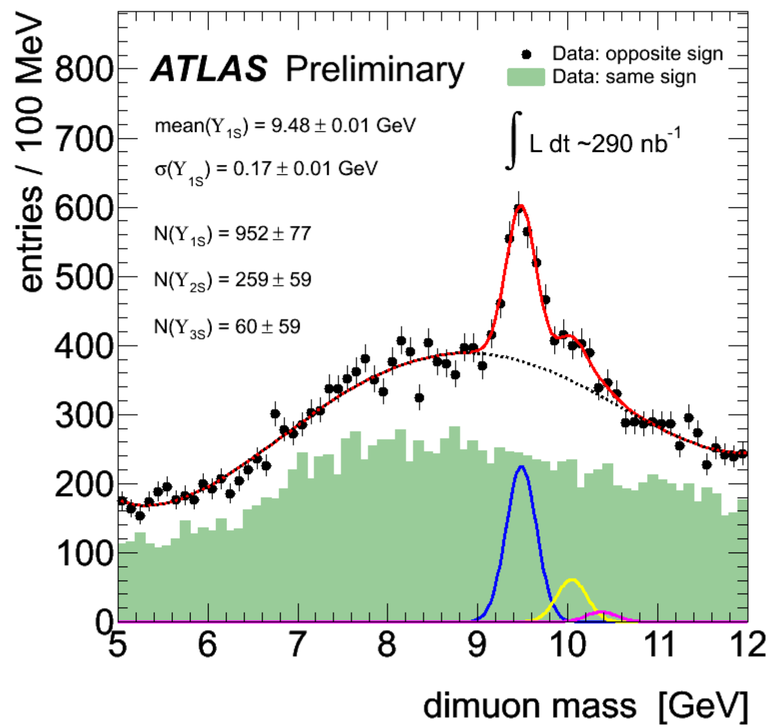
Signal from fit integration from 1.5 to 4 GeV
Bkg from fit integration from -3σ to +2σ

Observation of ψ(2s) and ϒ

ψ(2s) selection as for J/ψ (slide 16)



$p_T(\mu_1)$ > 4 GeV
$p_T(\mu_2)$ > 2.5 GeV



First candidate ttbar events

For details see talk by A. Lucotte (Track 2, 12:10 23rd July)

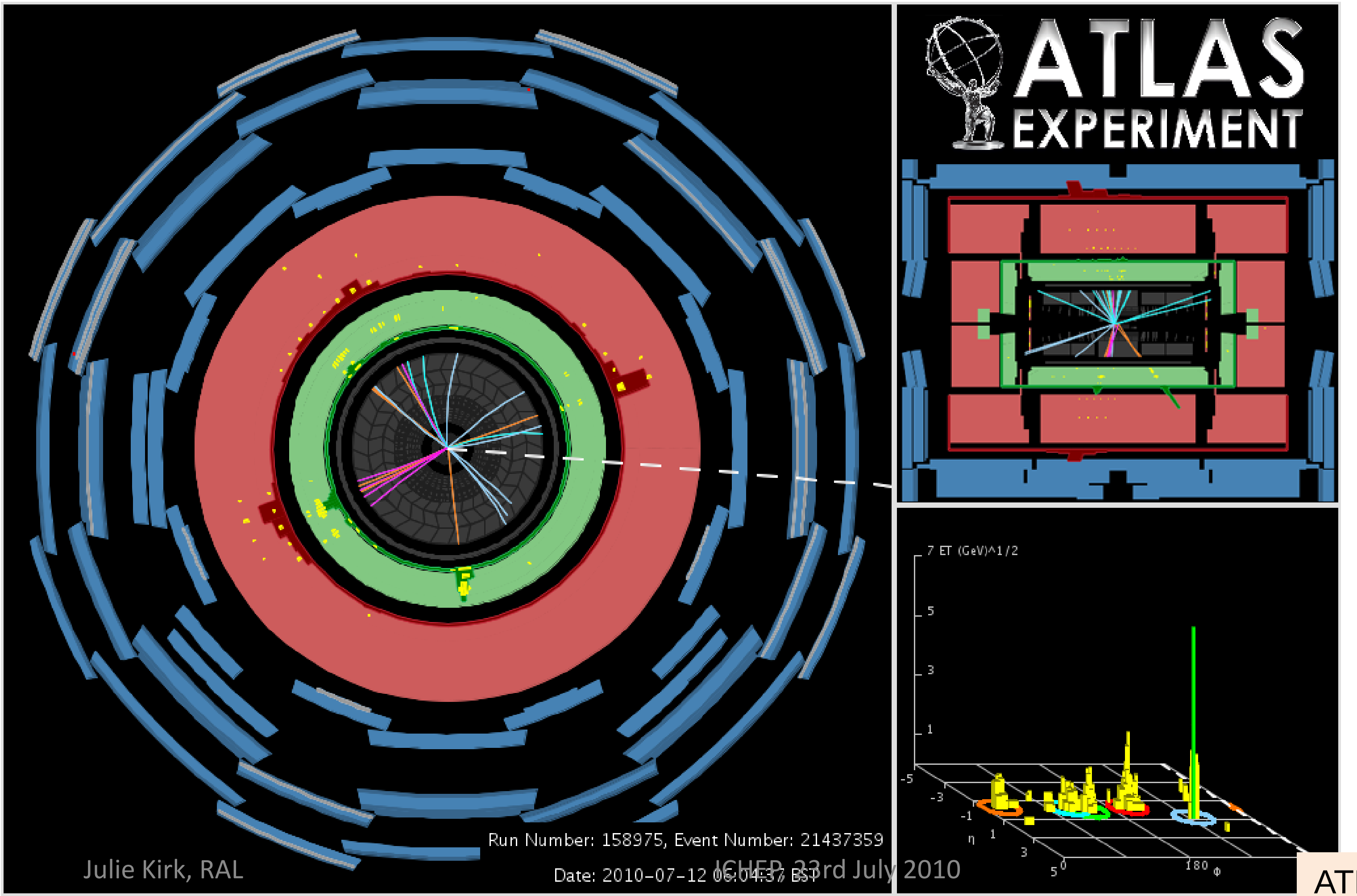
Analysed 280 nb-1

Lepton+jets: 7 candidate events (4e, 3 μ)

Di-lepton + jets : 2 candidate events (1 ee, 1 eμ)

Candidate event ttbar → 'e + jets'

- Electron p_T=41.4 GeV, MET=90.6 GeV → M_T= 68.2 GeV
- Four jets with p_T>20 GeV
- One b-tagged jet



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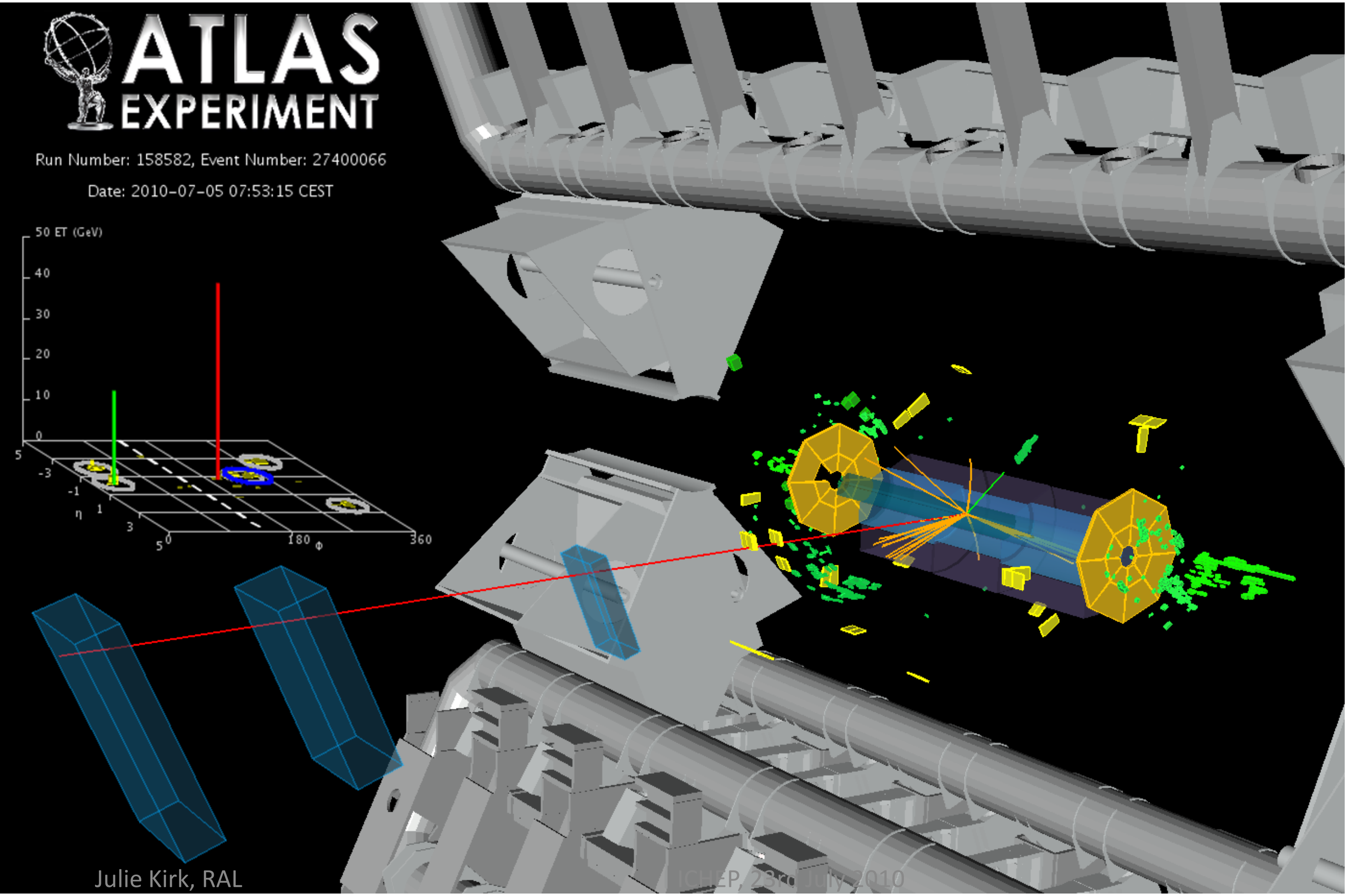
Candidate event ttbar → e-μ + jets

- Electron p_T=22.7 GeV, Muon p_T=47.8 GeV, MET=90.6 GeV
- Three jets with p_T>20 GeV
- One b-tagged jet



Summary

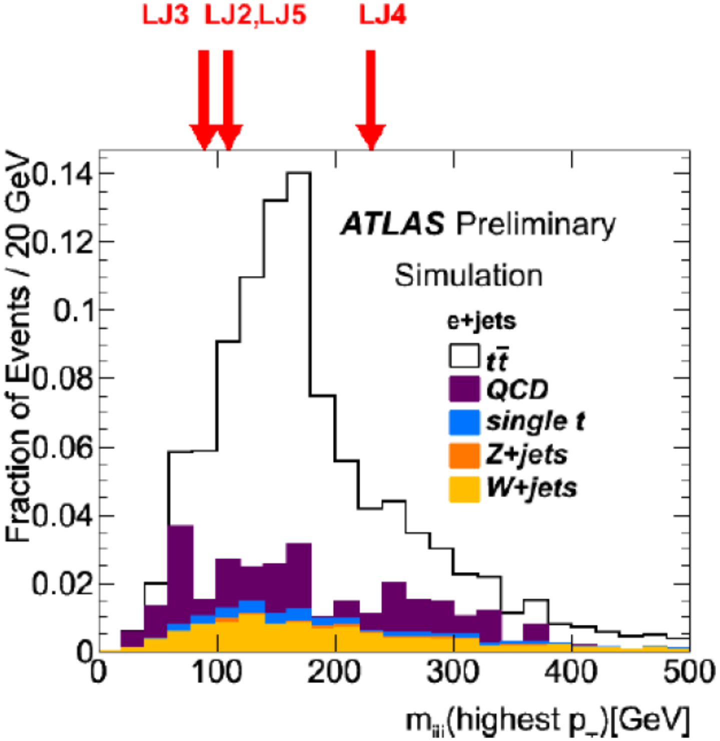
- ATLAS producing many new physics results
  - LHC luminosity increasing all the time so we can expect many more in the near future
- Studies of minimum bias events and underlying event well underway.
  - Tuning of MC to high energy data started
- Jet studies started :
  - first measurement of jet production cross-sections
  - good agreement with data
- Heavy flavour physics getting underway
  - $J/\Psi \rightarrow \mu^+\mu^-$ production cross-section
  - Fraction of $J/\Psi \rightarrow \mu^+\mu^-$ from B decays
  - Observation of $\Upsilon \rightarrow \mu^+\mu^-$ and $\psi(2s) \rightarrow \mu^+\mu^-$
  - First candidate ttbar events

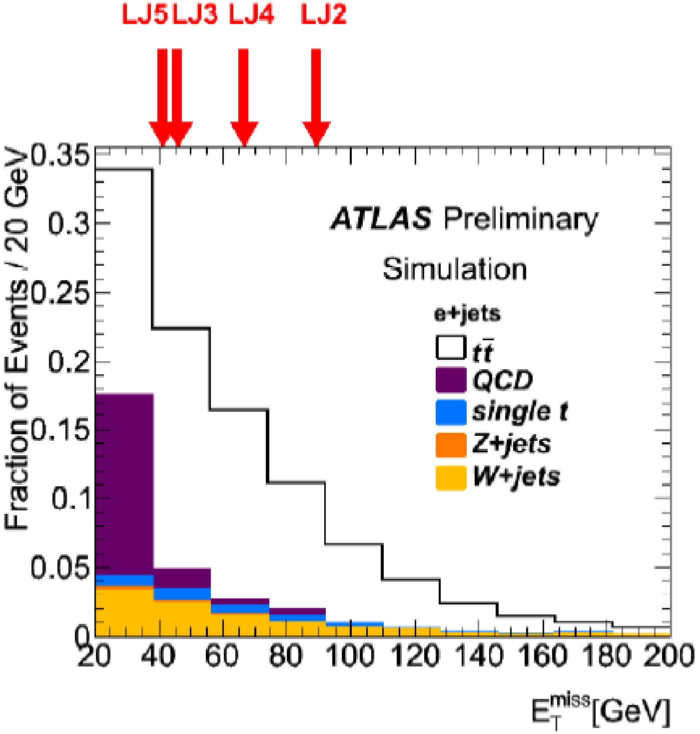
- Looking to the future:
  - expect more detailed quarkonia results soon for QCD studies
  - top quark observation
  - New Physics

⋮

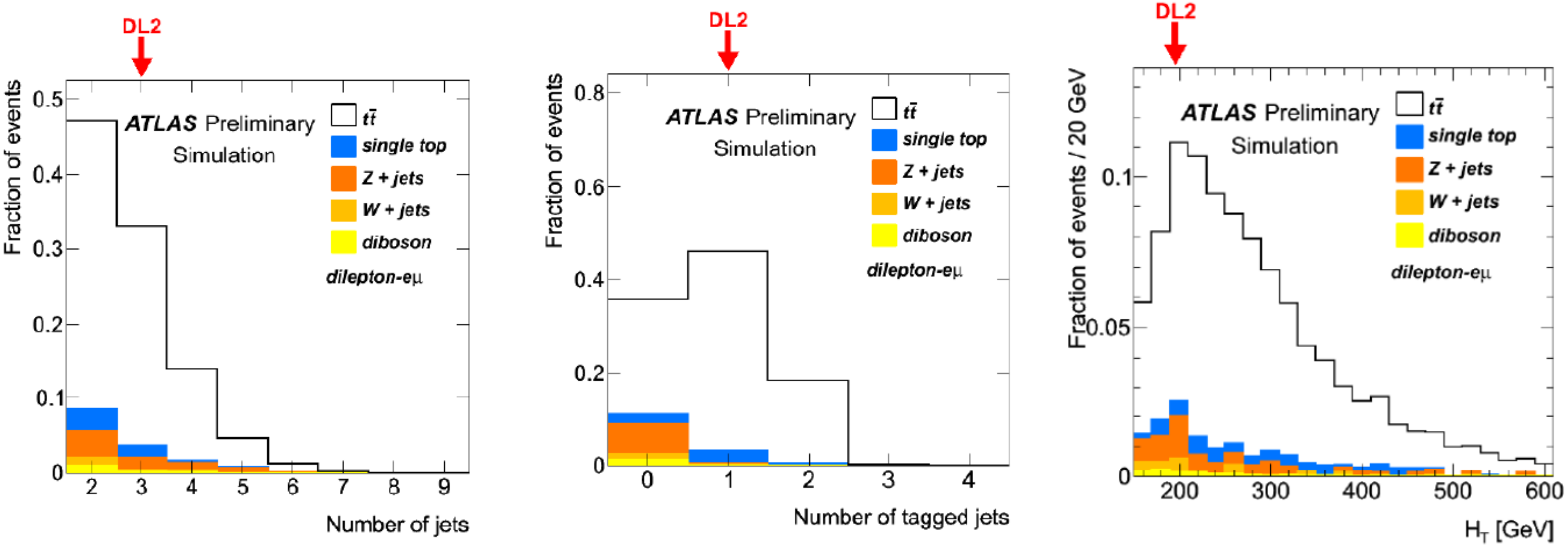
Backup

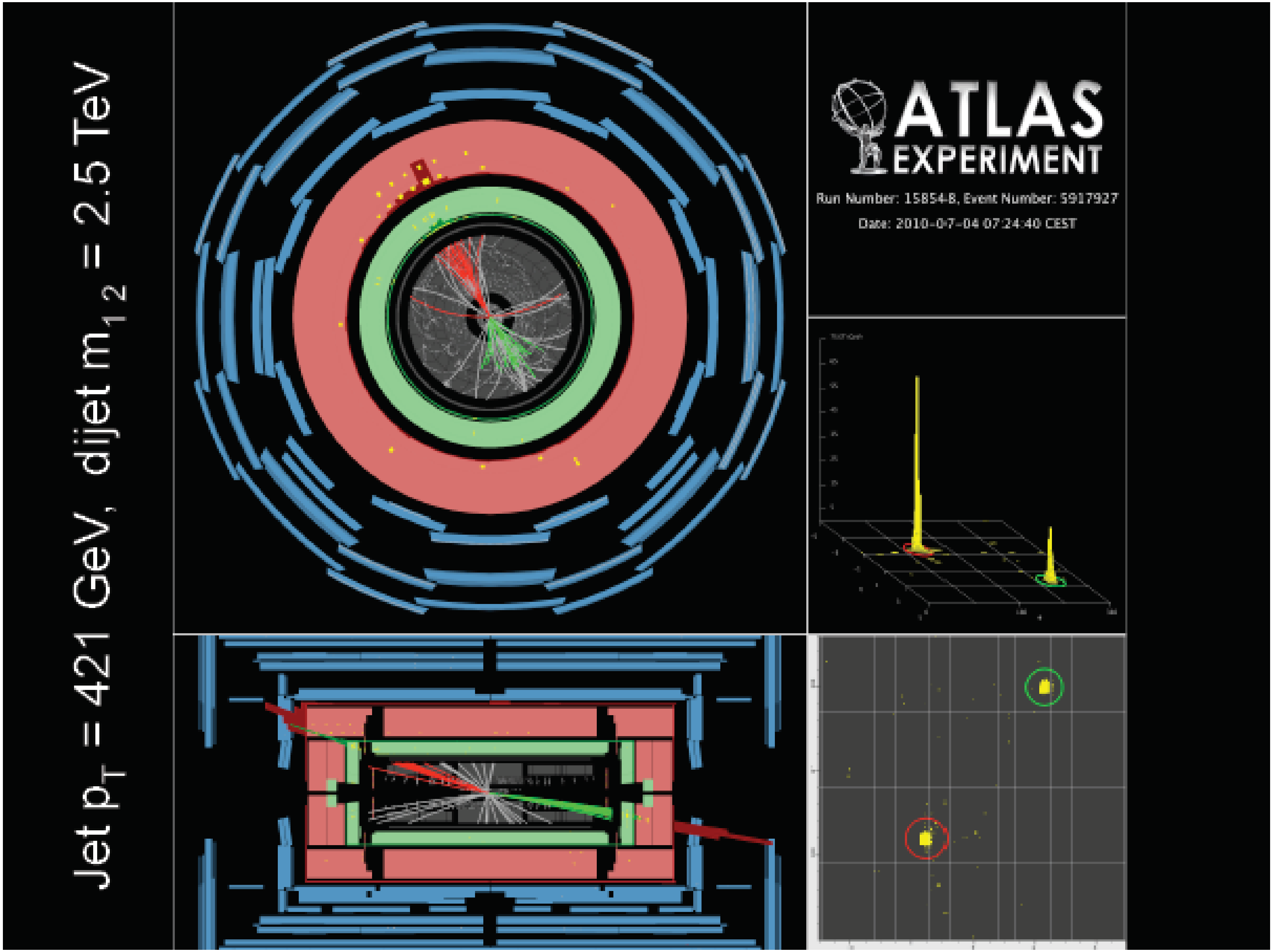
ttbar “e+jets” candidates





ttbar “e-mu +jets” candidates





Jet p_T = 421 GeV, dijet m_{12} = 2.5 TeV
ATLAS
EXPERIMENT
Run Number: 158548, Event Number: 5917927
Date: 2010-07-04 07:24:40 CEST

Jet p_T = 1120 GeV (!)