The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA
International Atomic Energy Agency

2045-10

Joint ICTP-INFN-SISSA Conference: Topical Issues in LHC Physics

29 June - 2 July, 2009

Standard Model Measurements

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Standard Model Physics with Early LHC Data

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Outline

- **Introduction**
- **Minimum bias and underlying event studies**
- **J/Psi and Y measurements**
- **W and Z measurements**
- **Conclusions**

Some detector pictures

Introduction. The LHC and "early physics"

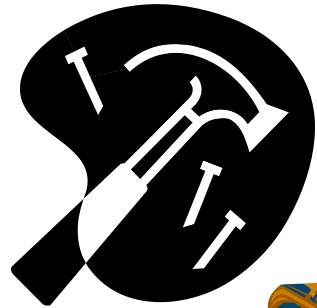
Preparing for the re-start (email from the CERN DG)

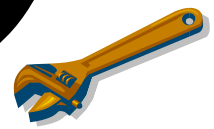
"The good news is that all the measurements done so far indicate that we will be ready by September or October to run the LHC safely in the range 4-5 TeV per beam. The food for thought is that the same tests tell us that before we can run safely above 5 TeV, more work is needed"

Early Physics at the LHC

- **"Early" is a matter of definition. Something we can do in 09/10**
- **I will use public results for 14TeV collisions (mostly ATLAS)**
- **I will not cover aspects covered by other talks (eg Jets/Etmiss, top, searches)**
- **Still lots of food for thought. Many things will change with data**

ATLAS tasks for 2009-10





Commission the detector

We need to get data out of it

Commission the trigger

We can’t analyse events if we don’t trigger them

Commission the analysis/offline software

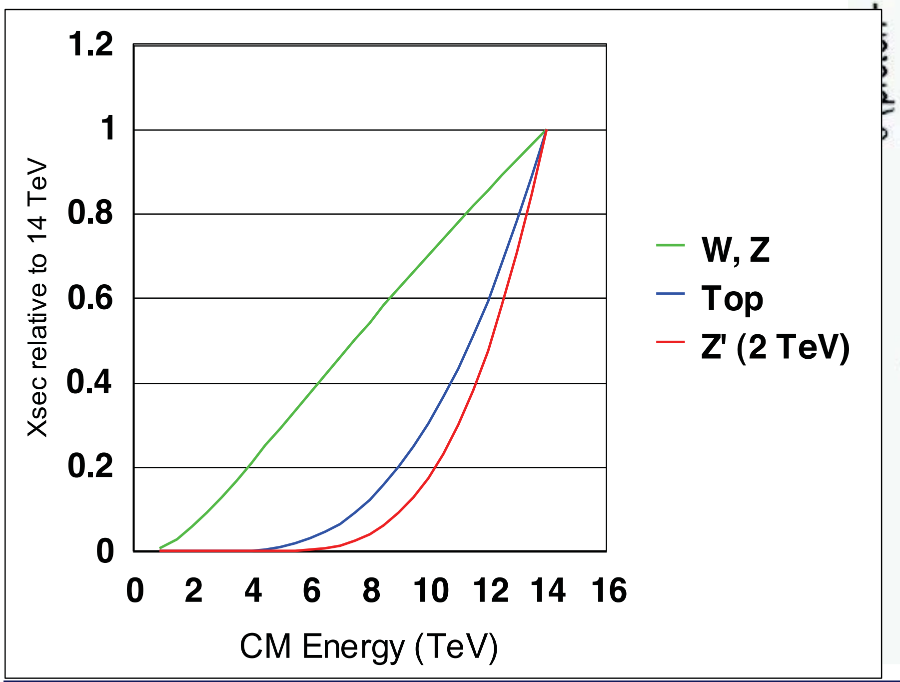
We need to process analyse the events

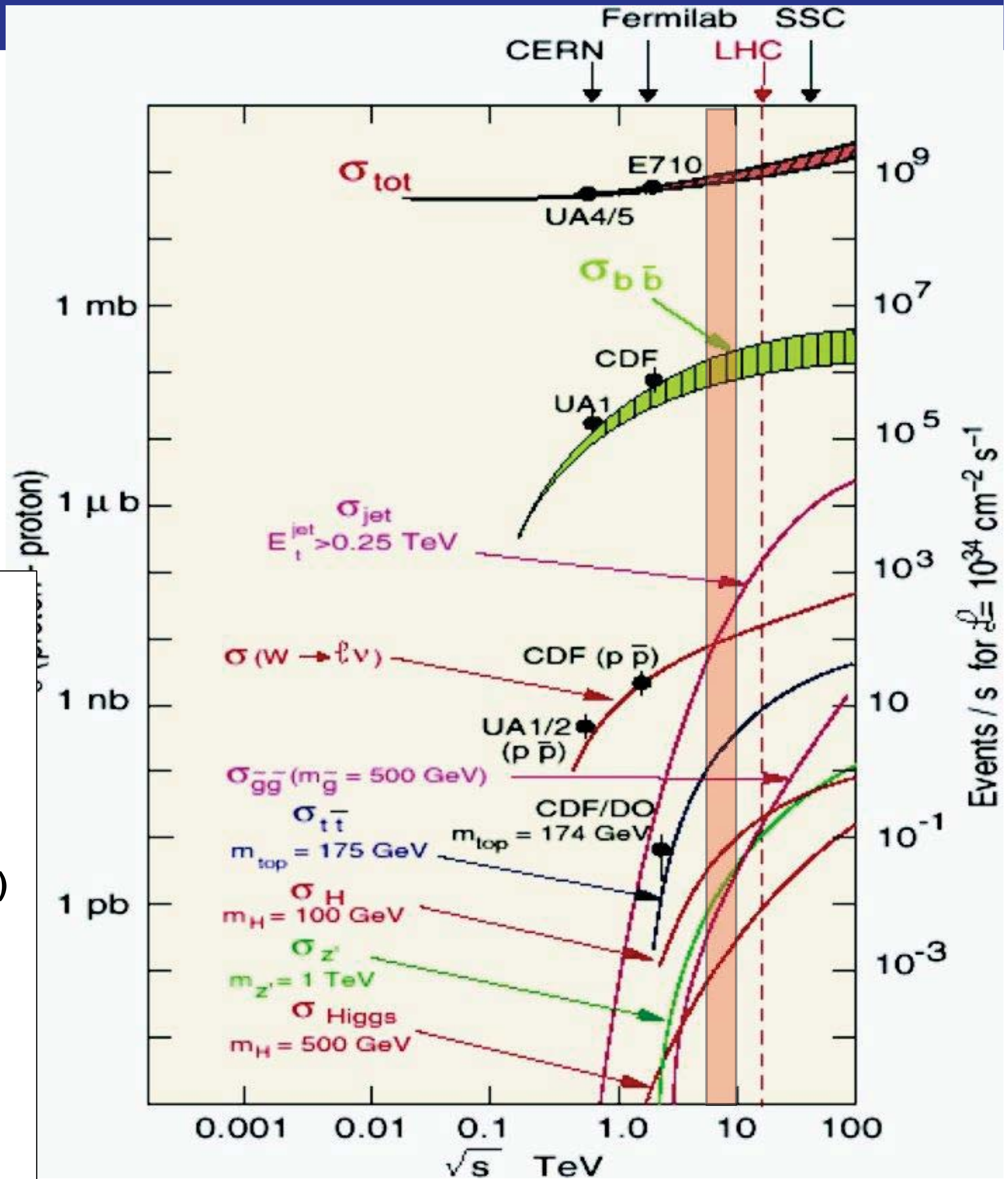
Do some Physics

- **We will measure SM objects (W, Z, top, …) and understand backgrounds to new Physics**
- **We will not improve SM measurements (eg W mass)**
- **We will measure production Xsec in a new energy range**
- **We will be on the lookout for new physics**

LHC rates

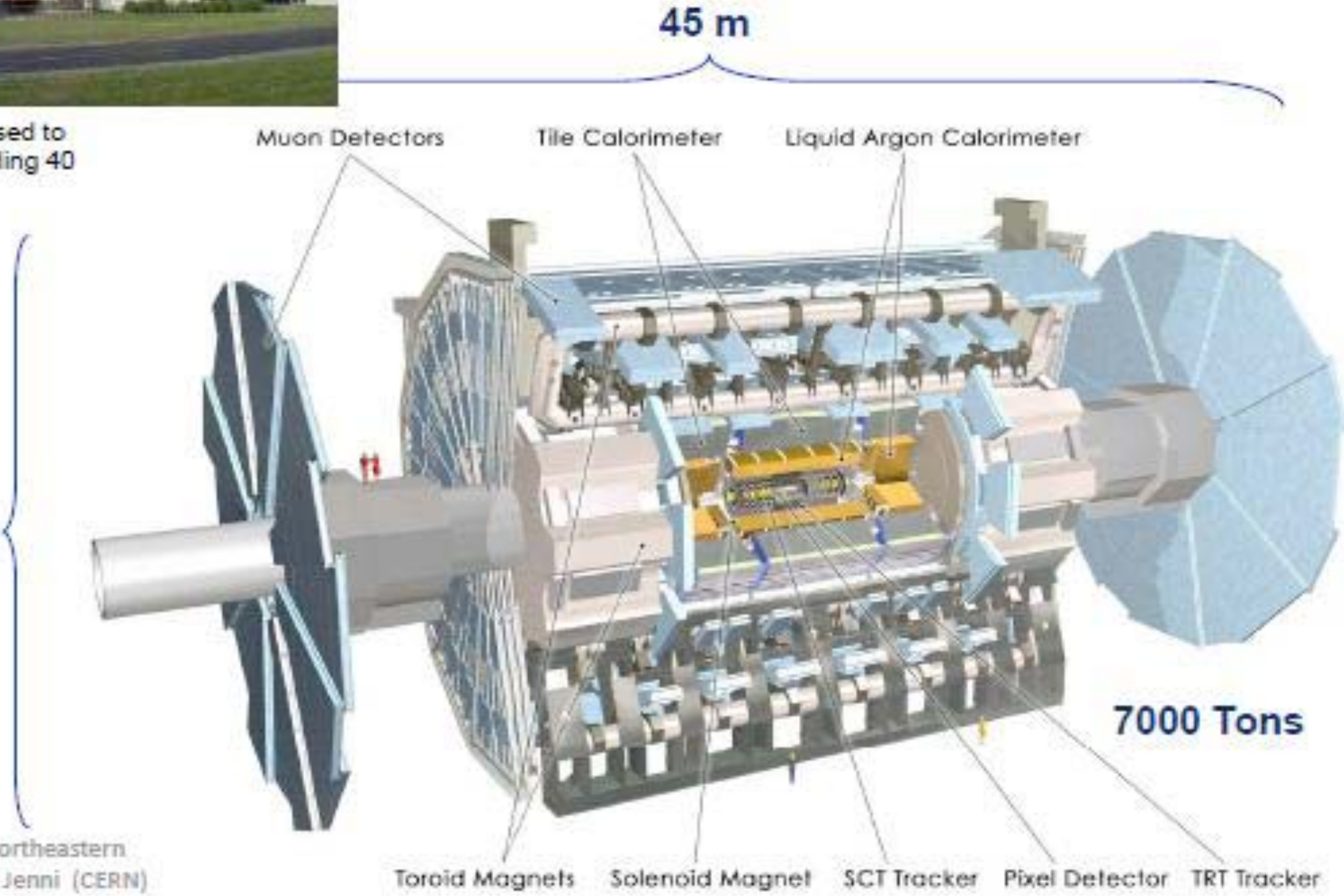
- Running at 10 TeV takes ~twice as much data as 14 TeV for equivalent sensitivity
- Running at 8 TeV takes ~twice as much data as 10 TeV for equivalent sensitivity
- Below 8 TeV things go "pear shaped" quickly.





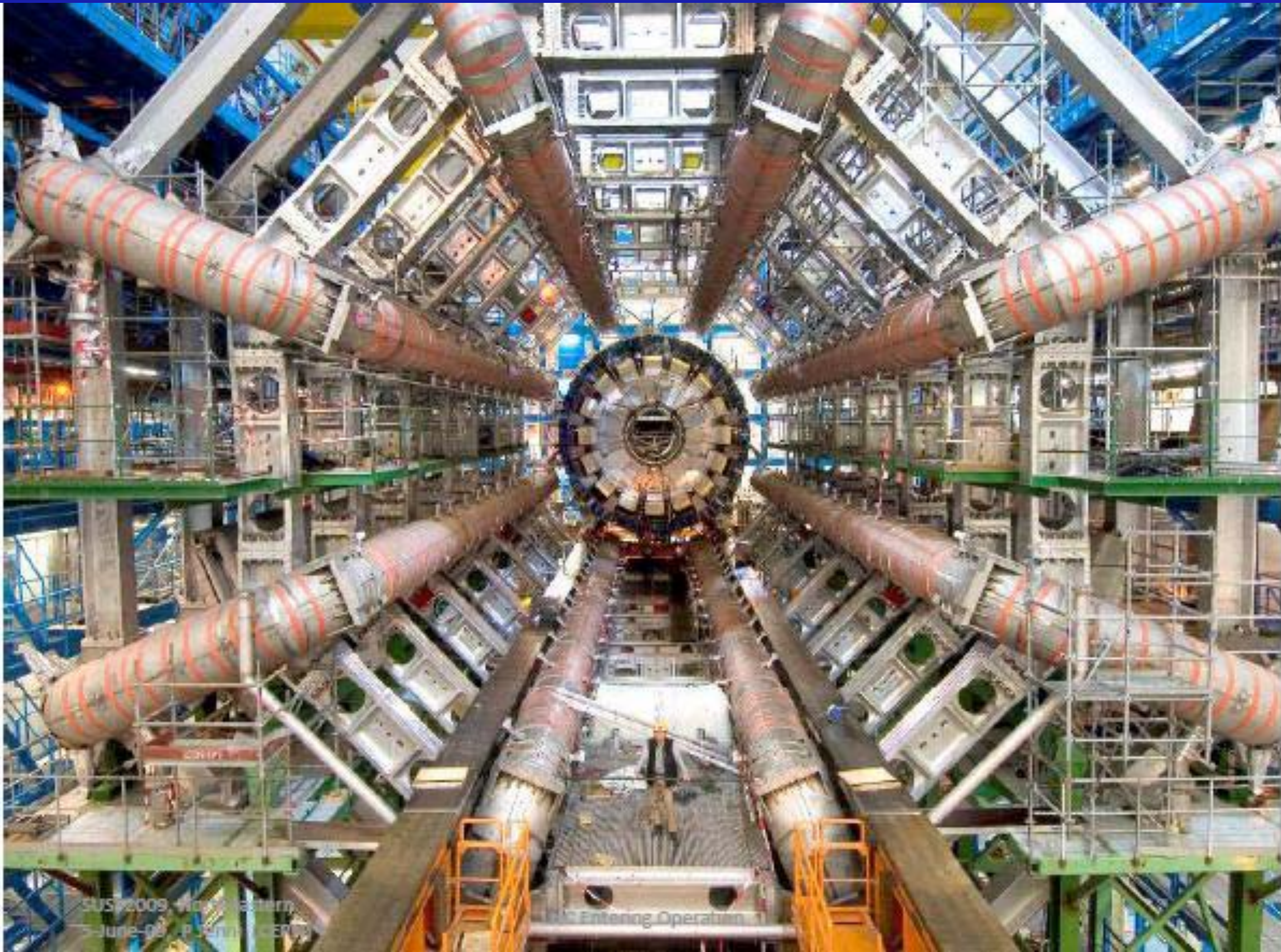
ATLAS Detector

ATLAS superimposed to the 5 floors of building 40

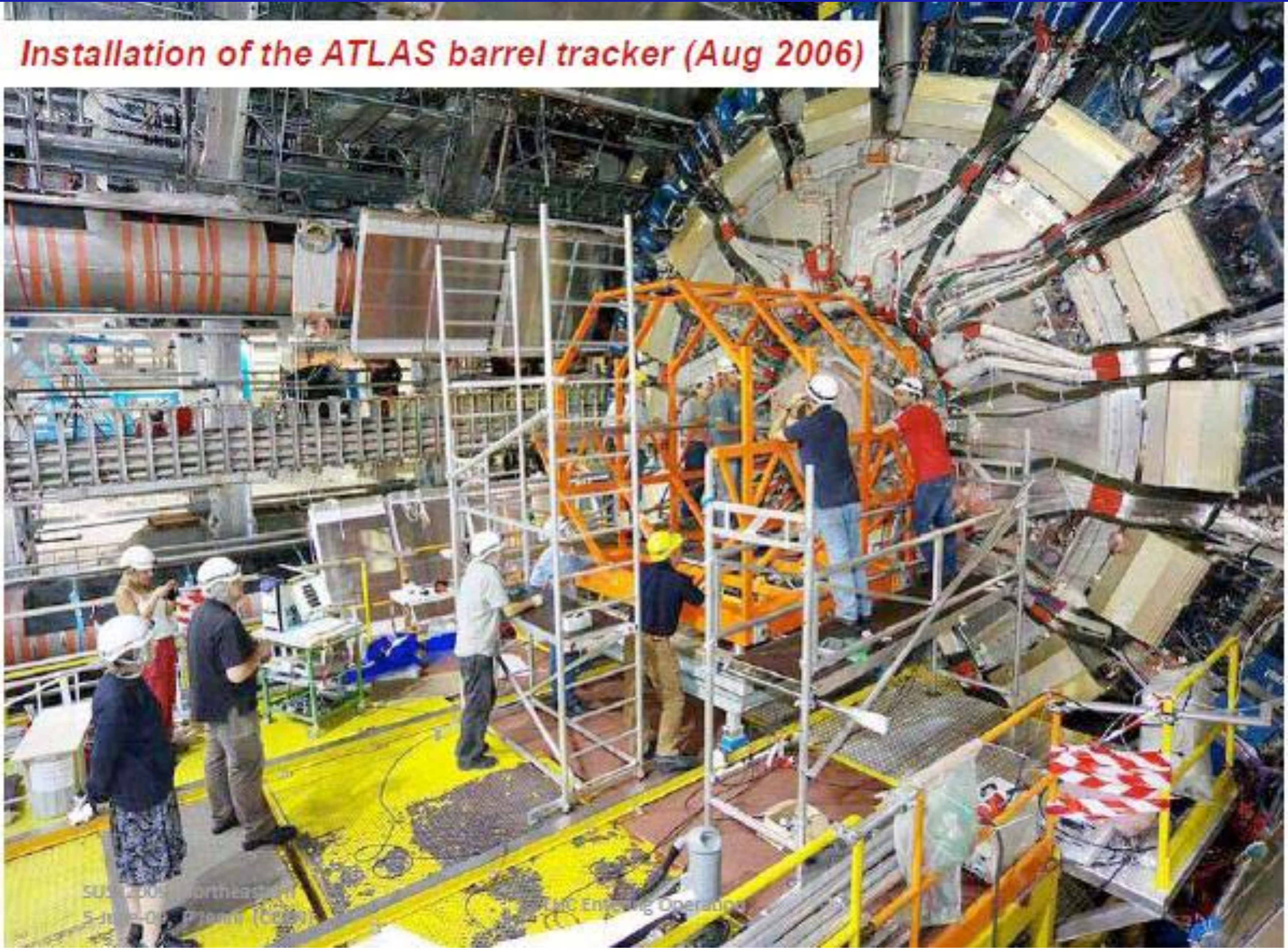


SUSY2009, Northeastern
5-June-09, P Jenni (CERN)


CMS before closure



Installation of the ATLAS barrel tracker (Aug 2006)



ATLAS and LHC Schedule

Outline

- Introduction

Everyday's Physics

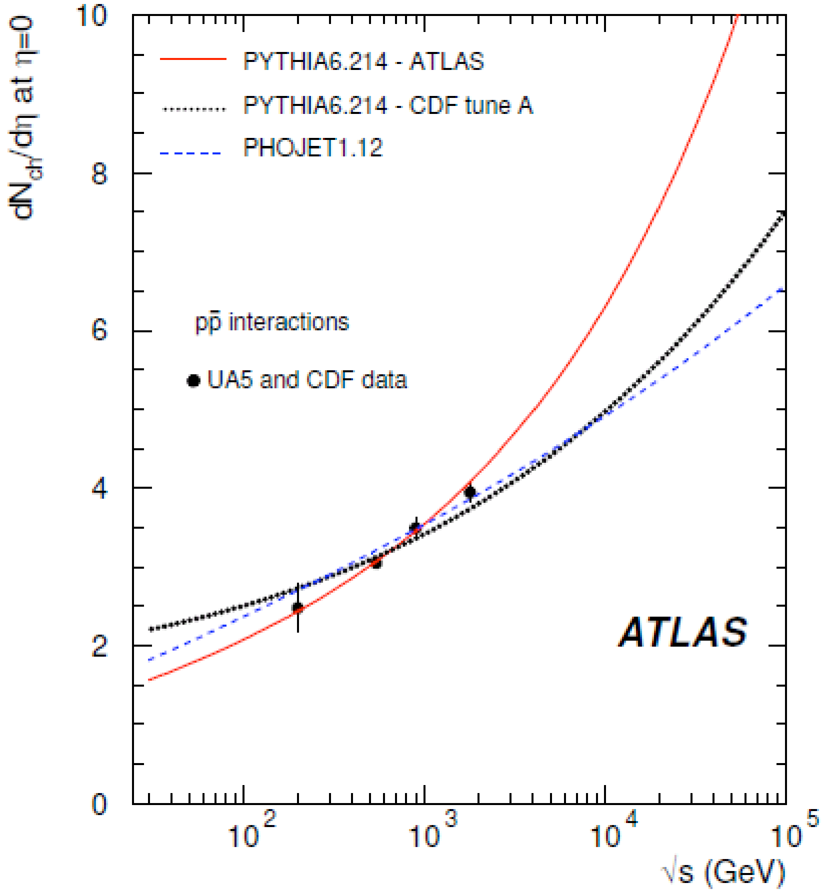
- **Minimum bias and underlying event studies**
- J/Psi and Y measurements
- W and Z measurements
- Conclusions

Minimum Bias events at ATLAS

Minimum bias will dominate the LHC scene

Each event accompanied by up to 20 Min Bias collisions

Min Bias as "early" physics measurement

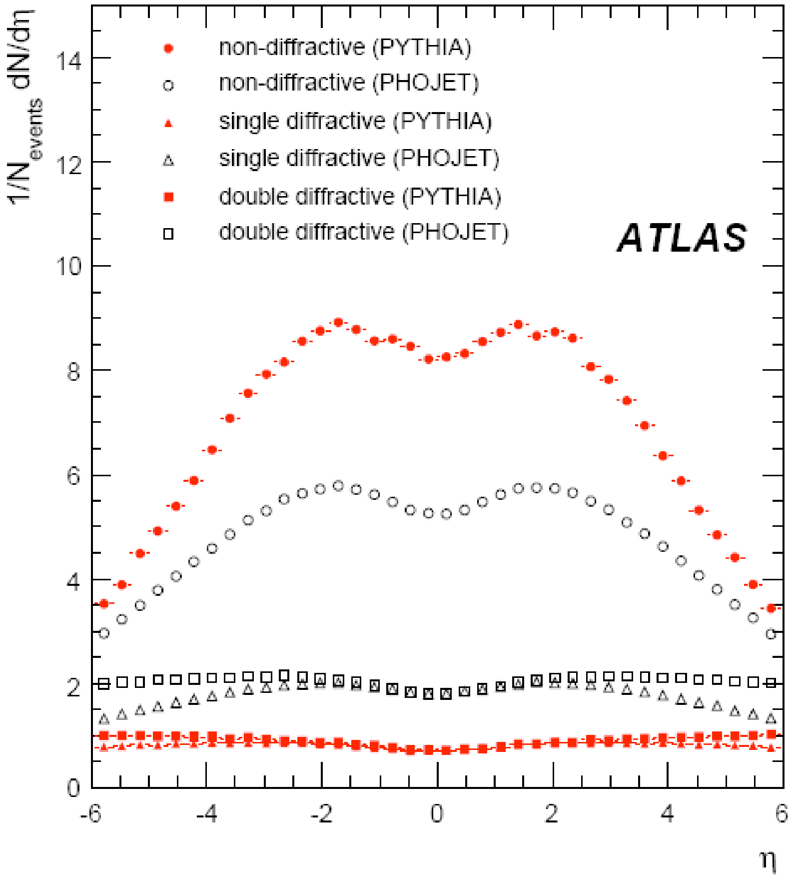


$$\sigma_{tot} = \sigma_{elas} + \sigma_{sd} + \sigma_{dd} + \sigma_{nd}$$

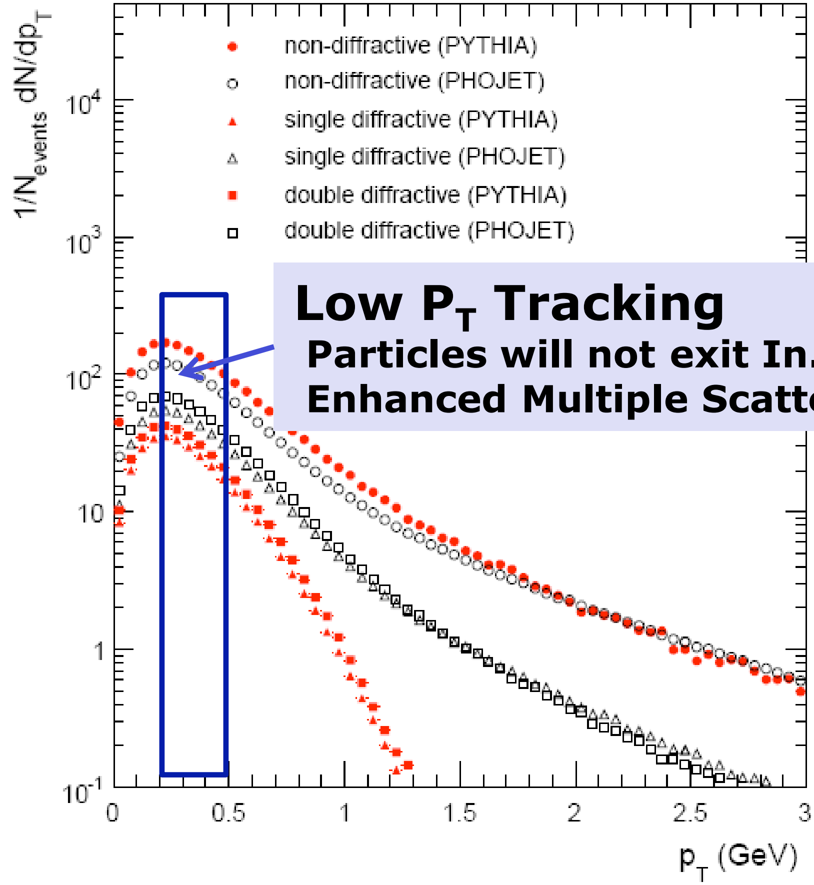
Process	Cross-section (mb)@14Tev	
	PHOJET	PYTHIA
Non-Diff.	69	55
Single Diff.	11	14
Double Diff.	4	10
Central Diff.	1	-
Inelastic	85	79
Elastic	35	23
Total	120	102

Minimum bias Events properties

Charged particle density vs pseudorapidity



Charged particle density vs P_T

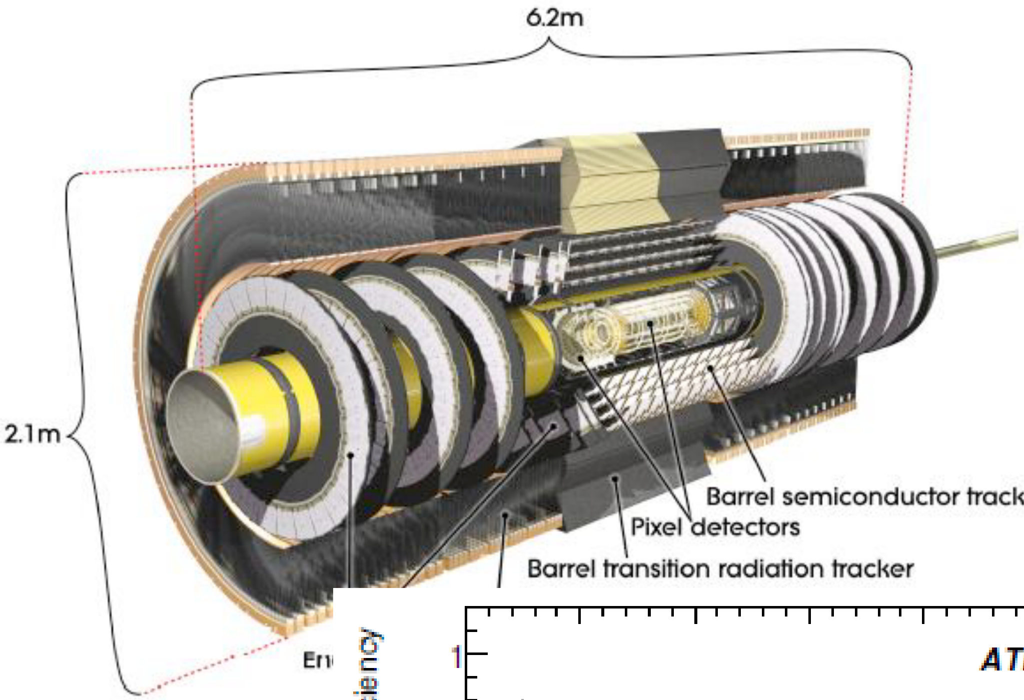


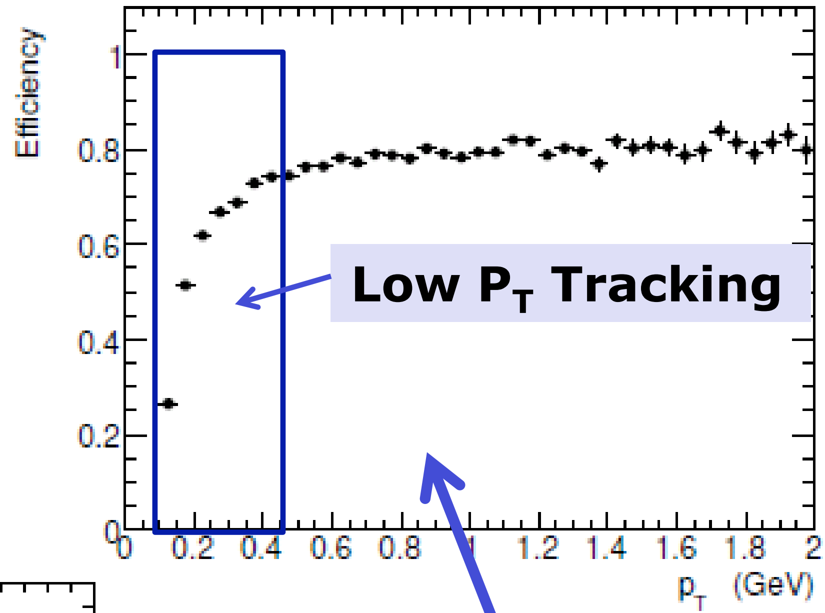
Low P_T Tracking

Particles will not exit In.Det.

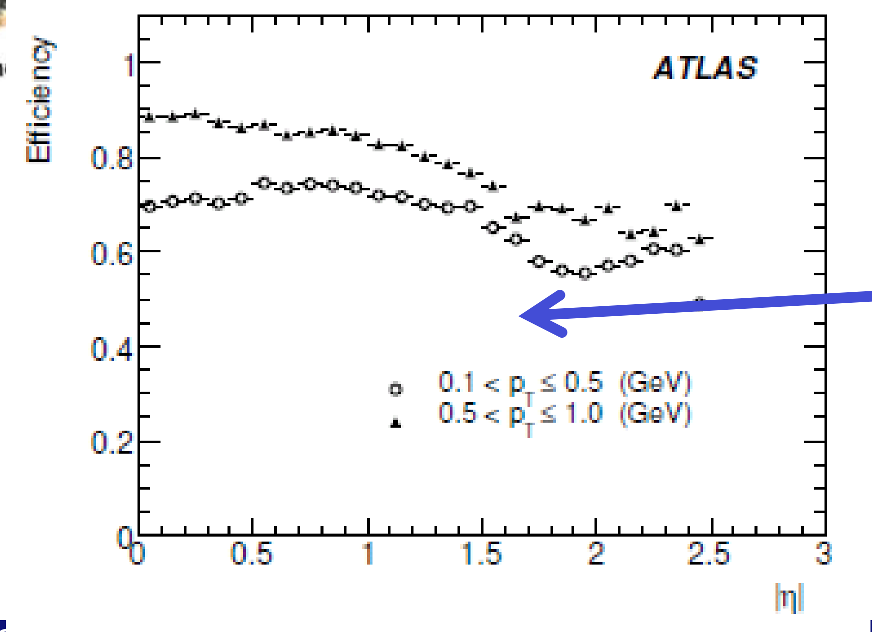
Enhanced Multiple Scattering

Tracking Efficiency Corrections





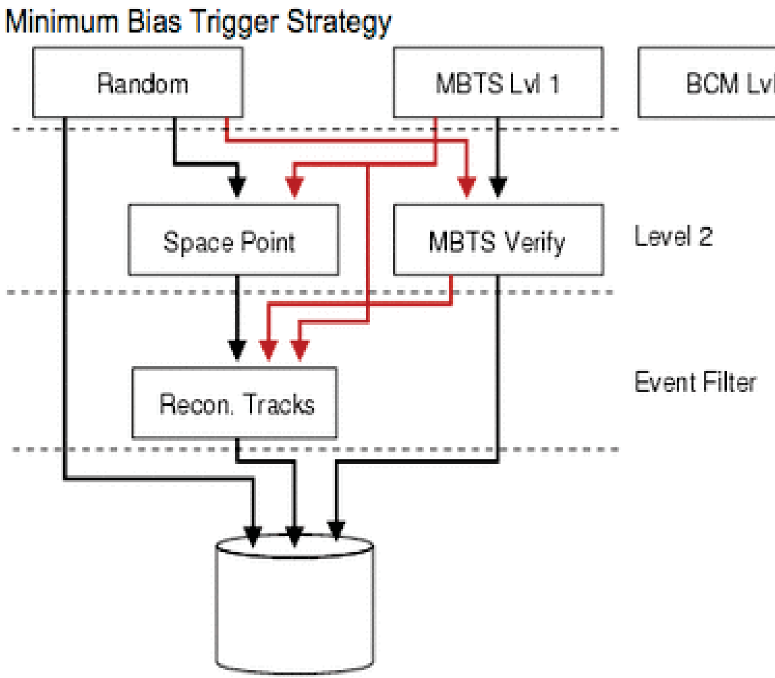
Low P_T Tracking

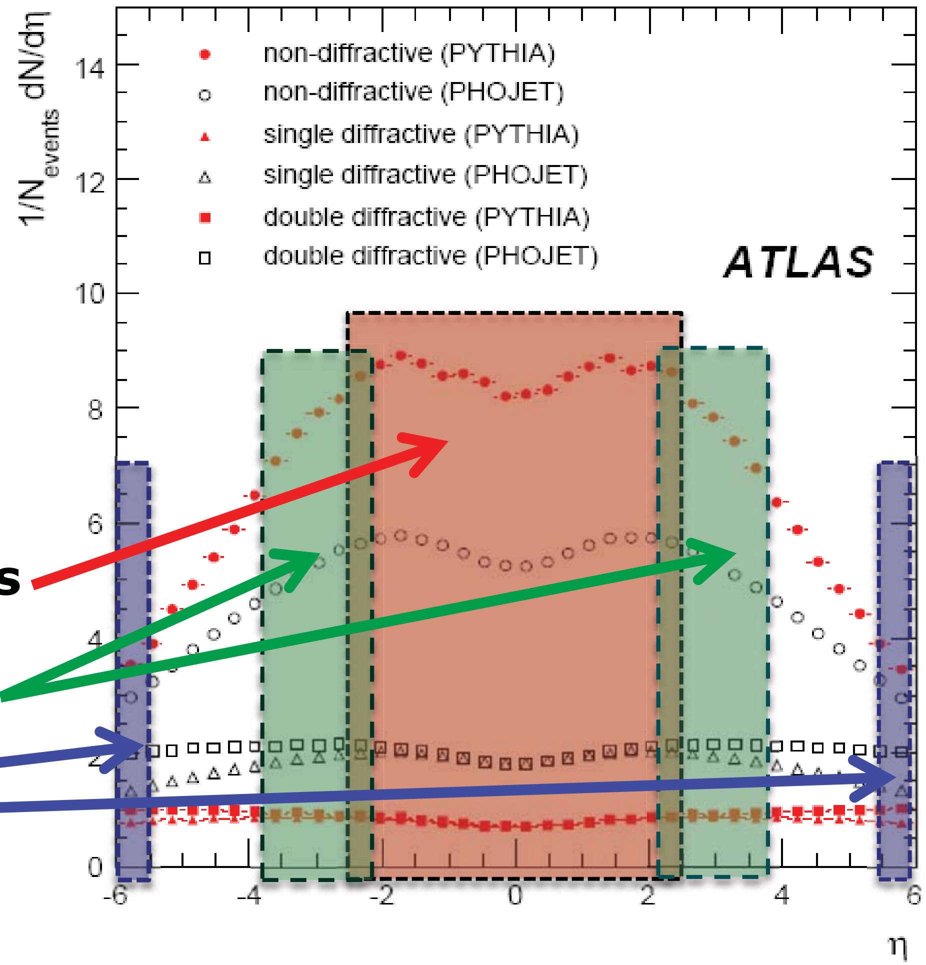


Efficiency as a function of P_T and Eta.

Define a MC based correction. $C(\eta,P_T)$

Triggering Minimum Bias events



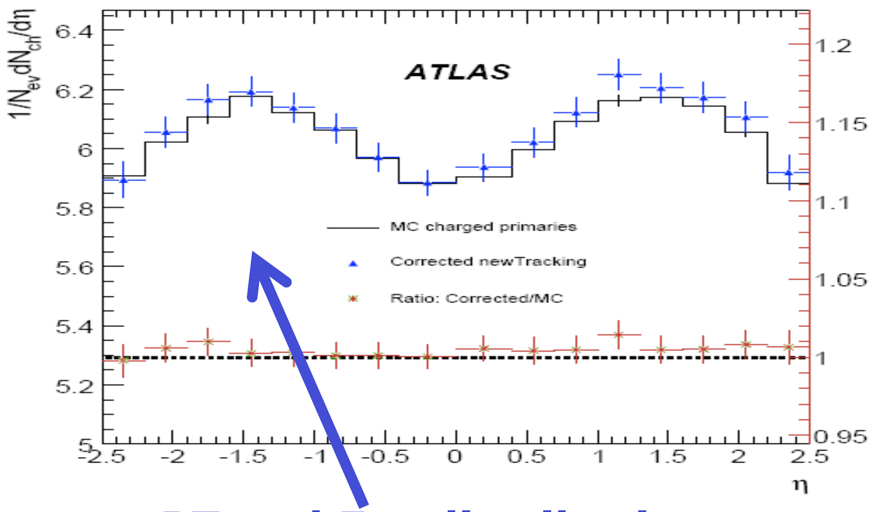


Inner detector Space points

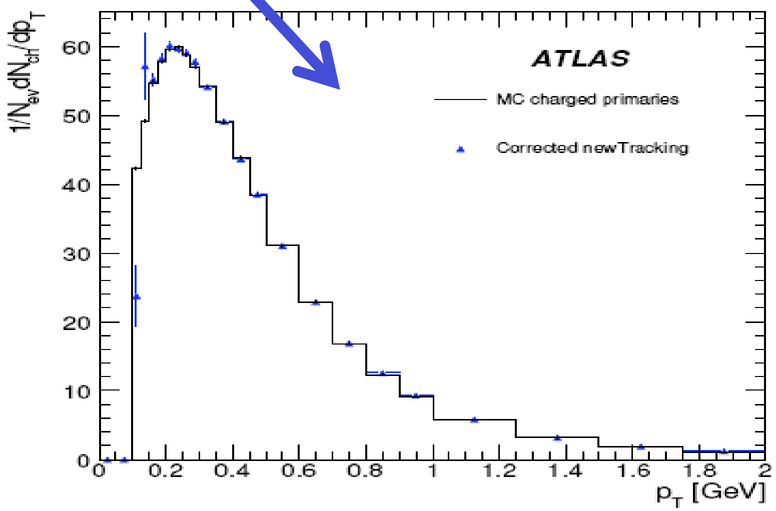
Minimum Bias Scintillators

LUCID

Work out a trigger efficiency correction



PT and Eta distribution of charged particles after corrections



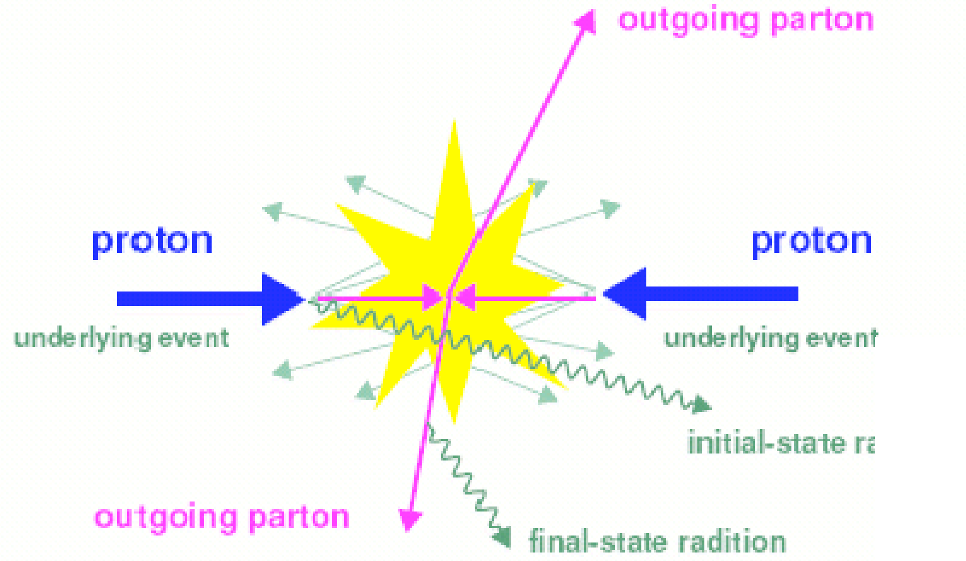
Tuning with early data needed

Systematic uncertainties

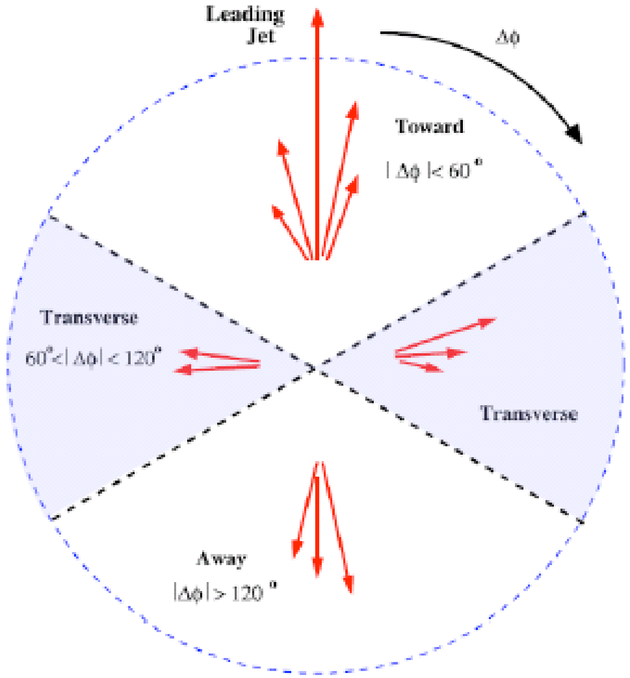
Name	Estimated Uncertainty
Track Selection Cuts	2%
Mis-estimate of Secondaries	1.5%
Vertex Reconstruction Bias	0.1%
Misalignment	6%
Beam-gas and pileup	1%
Particle Composition	2%
Diff. Cross Sections (NSD)	4%
Total	8%

Underlying event measurement

What is the UE?



UE observables:
Transverse <Nchg>
Transverse <ΣpT>



- Modeling of UE important for precise high-pT measurements

- Important ingredient for jet and lepton isolation, energy flow, jet tagging, etc

Underlying event measurement

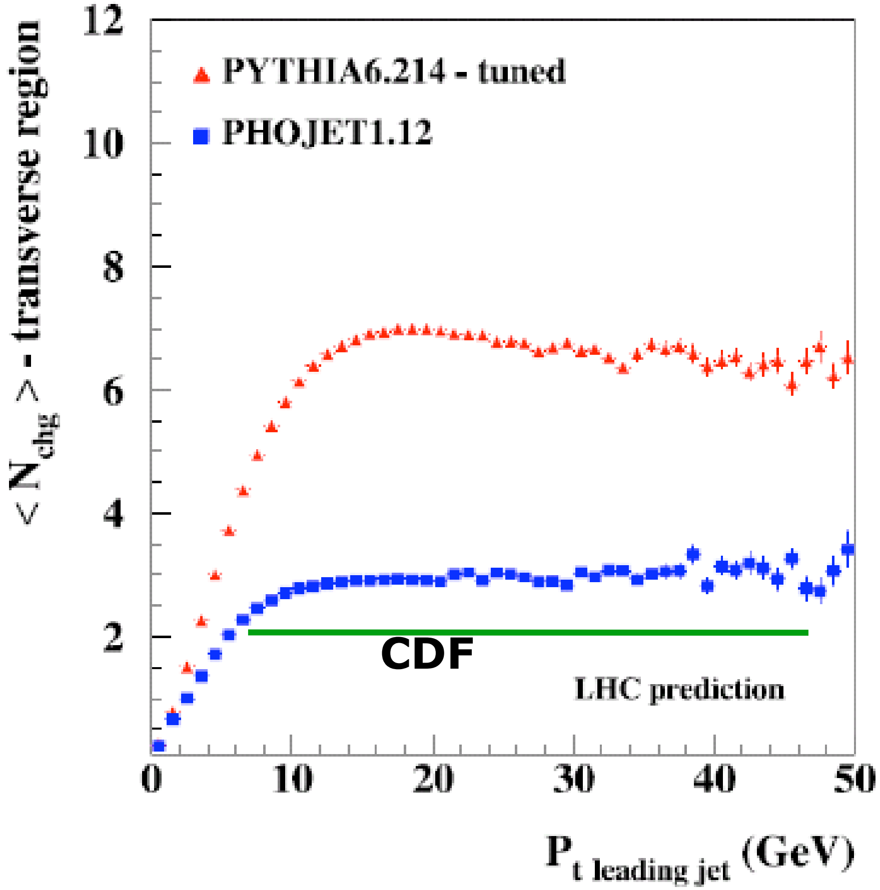
Jet events ideal for studying UE

– Tons of jet events at the LHC

– 'Transverse' region wrt direction of leading jet is very sensitive to the UE (c.f. CDF)

Large discrepancy between different models

– Measurement needed to understand high P_T physics



EPJ C 50, 435 (2007)

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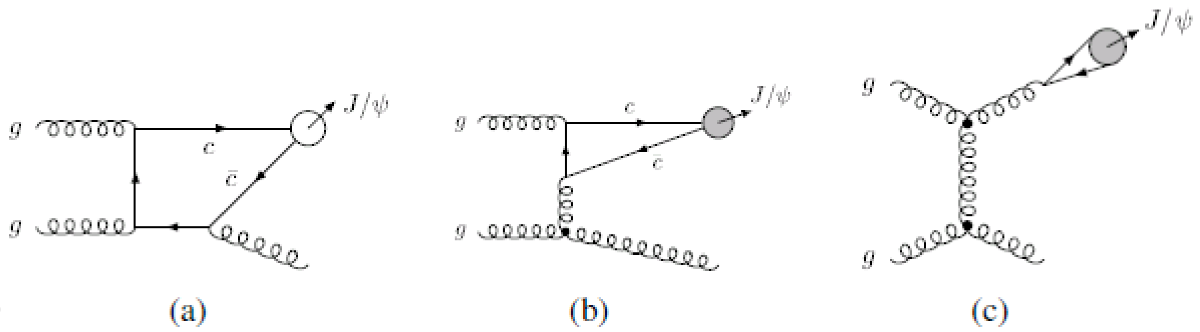
J/ψ and Υ production

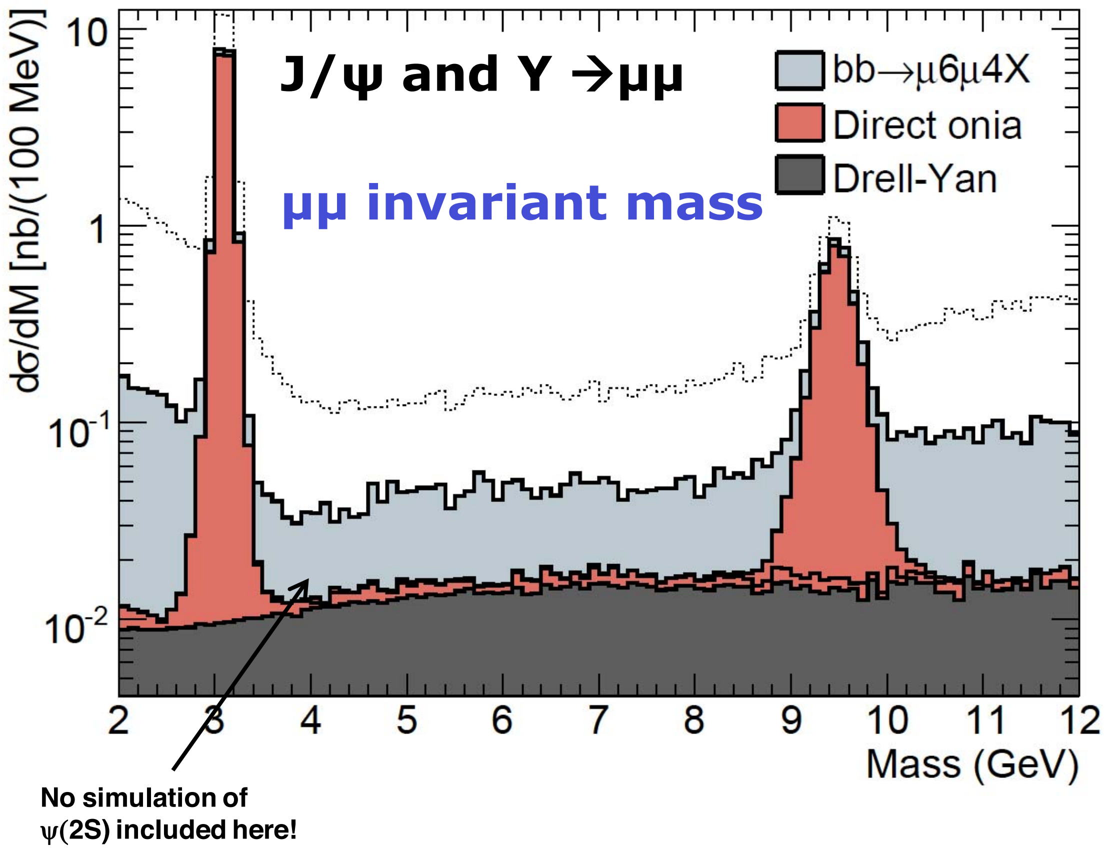
In 1pb^{-1}:

~30K J/ψ

~4K Υ

(large trigger influence)





Standard candles

Calibrate the detector

Monitor alignments

Test reconstruction

Test of QCD models

Production cross section

Polarisation

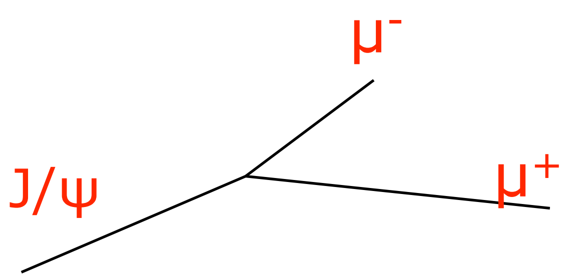
B-Physics signature

Decay product of "rare" proces

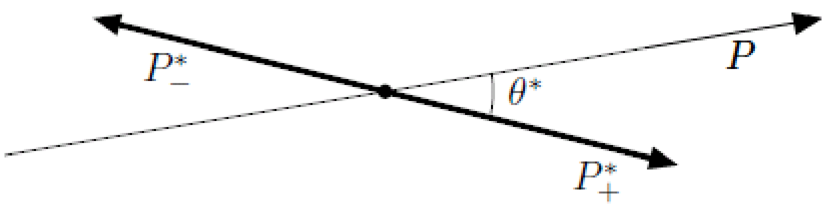
Triggering quarkonia

Only boosted J/ψ (and Υ) can be detected and triggered

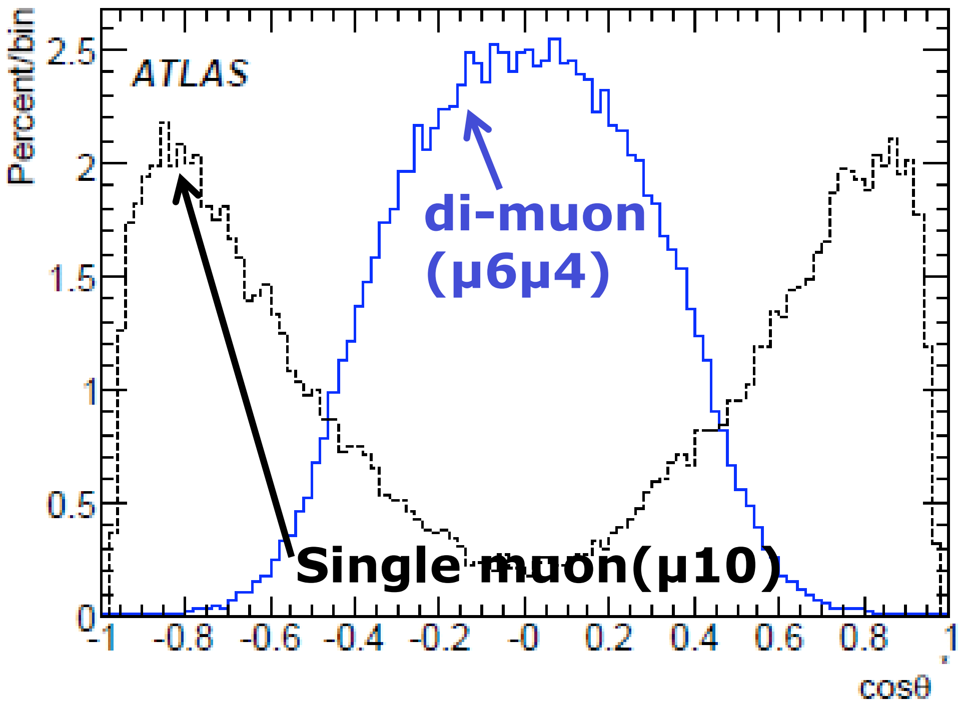
Detector frame:



J/ψ rest frame:

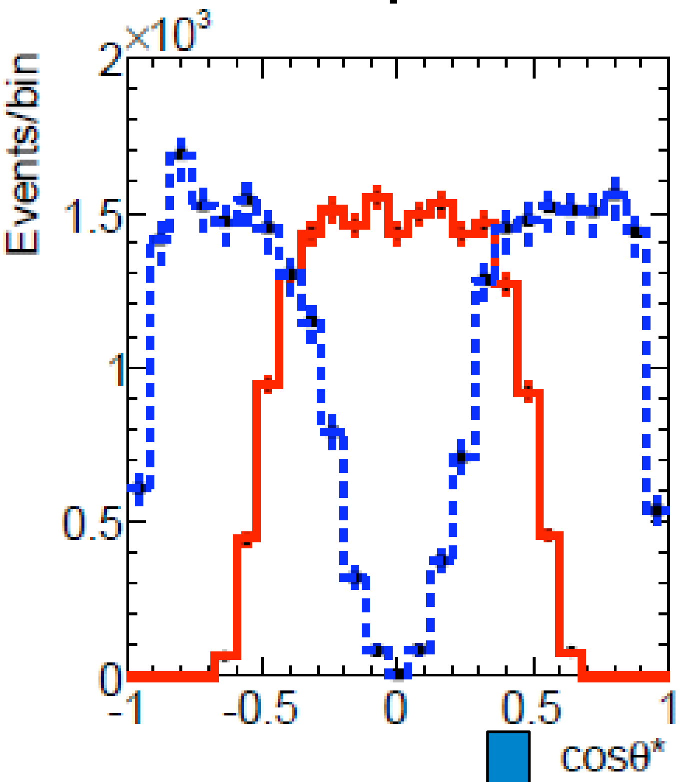


cos θ* distribution for events with 1 and 2 triggered muons (flat polarisation simulated)



Polarisation and cross section measurement

RAW data
$15 < P_T < 17$GeV

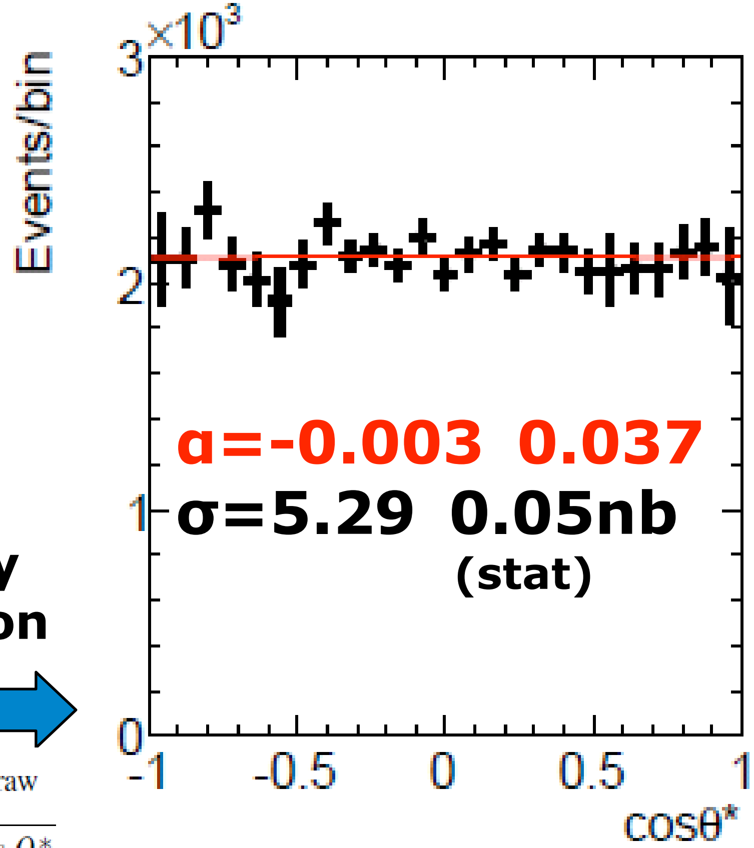


Efficiency correction

$$\frac{dN^{cor}}{d\cos\theta^*} = \frac{1}{\mathscr{A}(p_T, \cos\theta^*) \cdot \varepsilon_1 \cdot \varepsilon_2} \cdot \frac{dN^{raw}}{d\cos\theta^*}$$

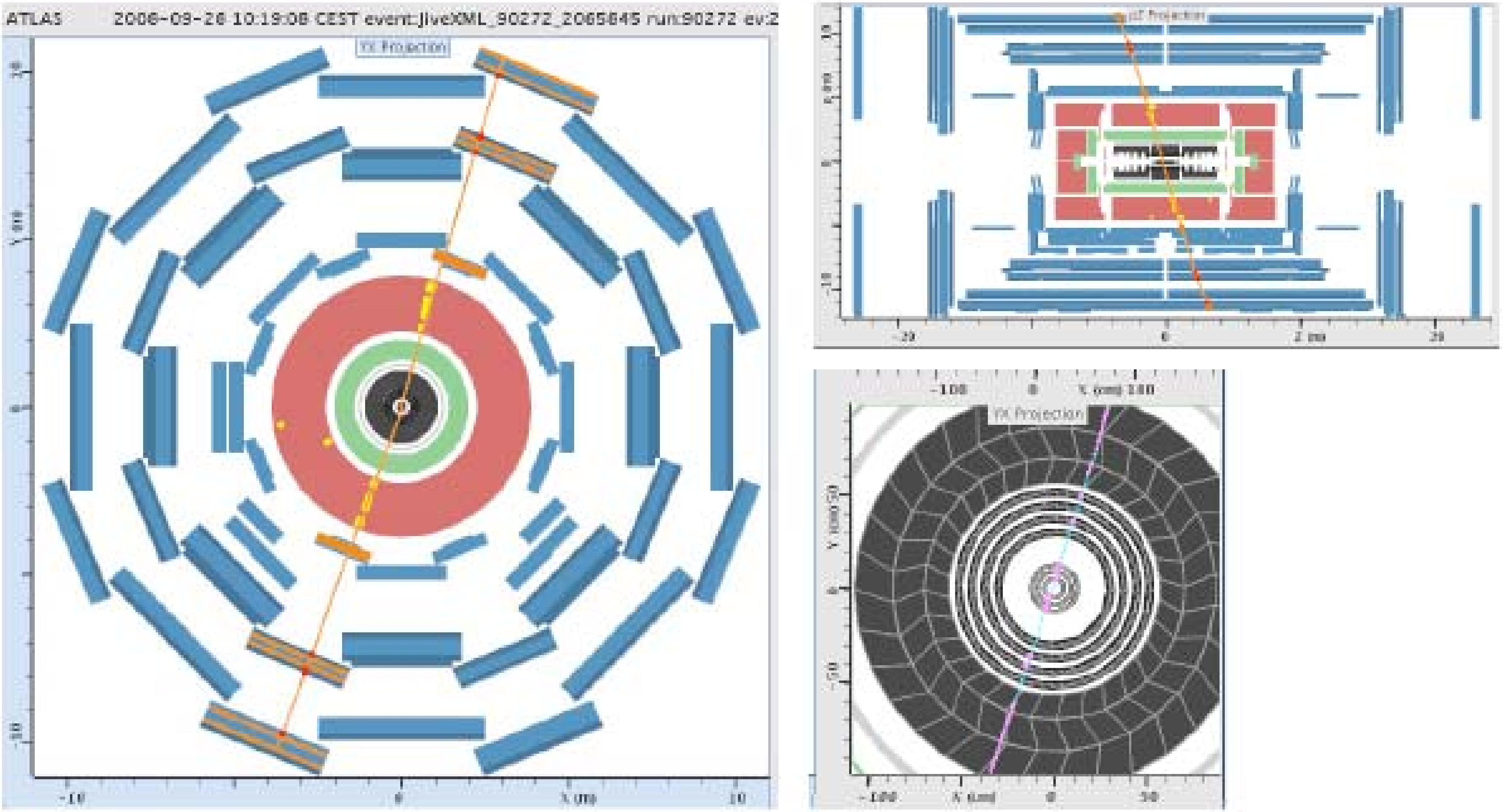
Fit function:

$$\frac{dN}{d\cos\theta^*} = C\,\frac{3}{2\alpha+6}\left(1+\alpha\cos^2\theta^*\right)$$



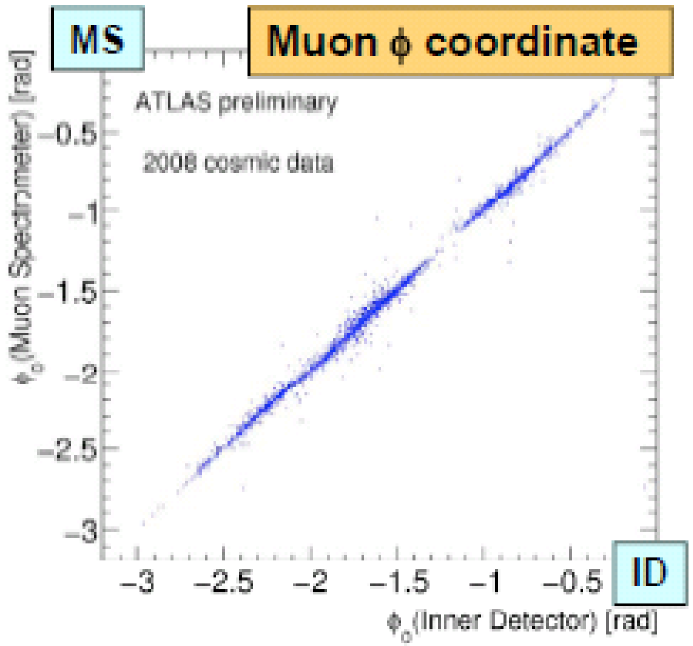
Before we move on to the next topic...

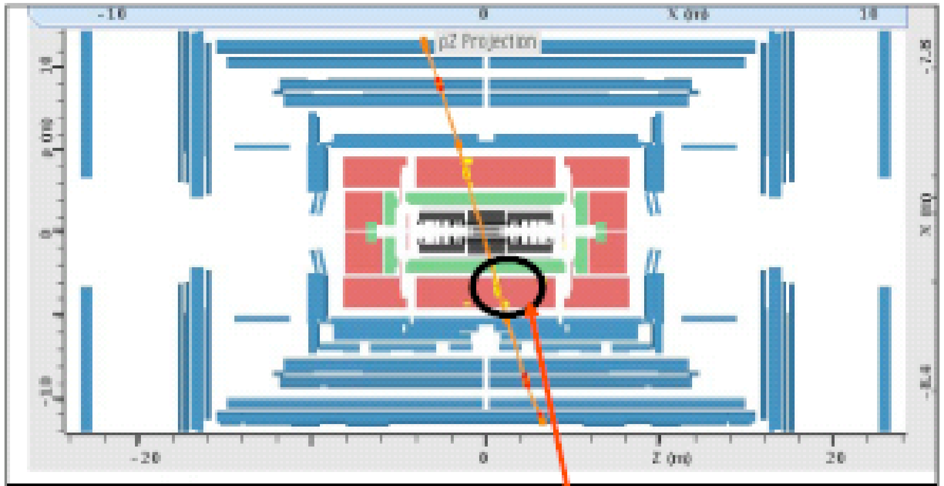
A cosmic muon through the whole ATLAS detector...



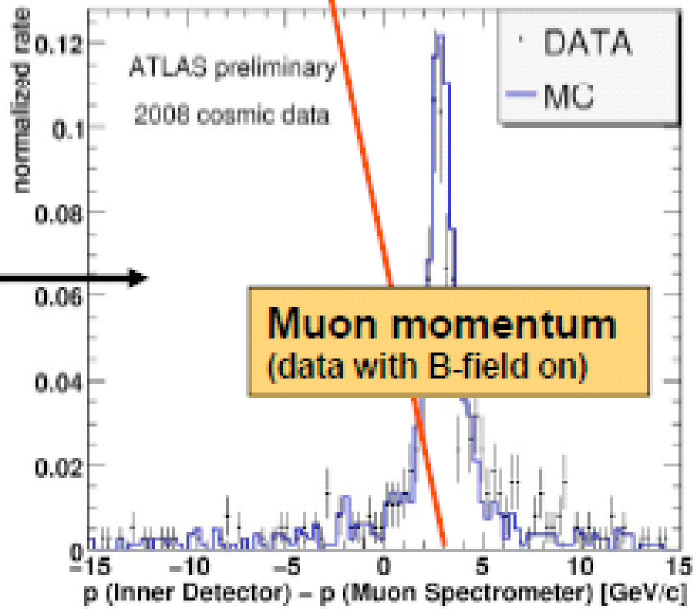
Cosmic Ray studies

Correlation between measurements in the ATLAS Inner Detector and Muon Spectrometer





Difference between the muon momentum measured in the ID and in the MS for tracks in the bottom part of the detector (~ 3 GeV energy loss in the calorimeter)



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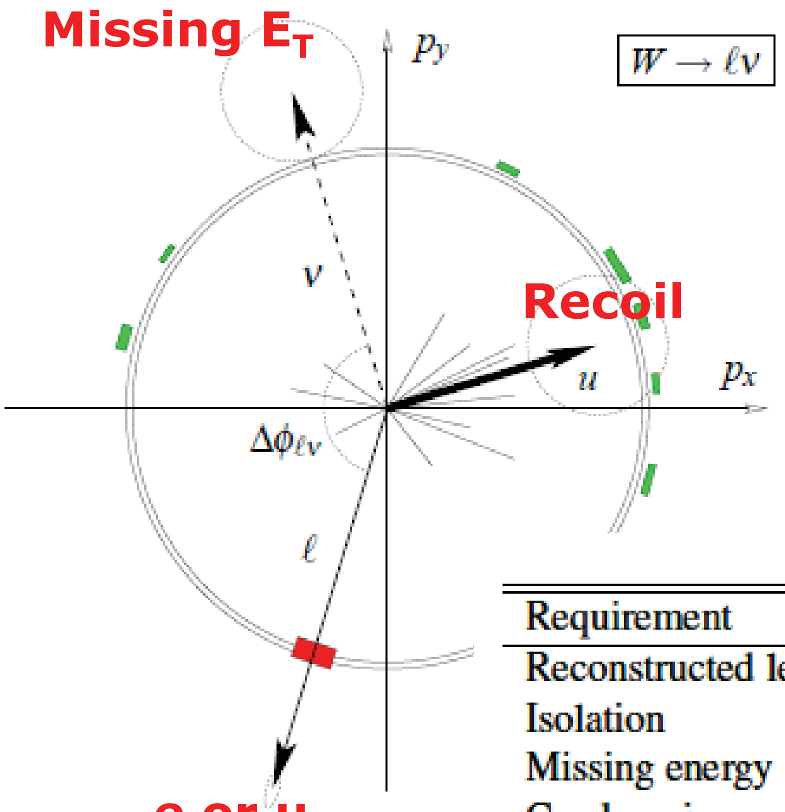
First Z and W to be observed Before X-mas

W →e ν and W →μ ν
Used for W Physics



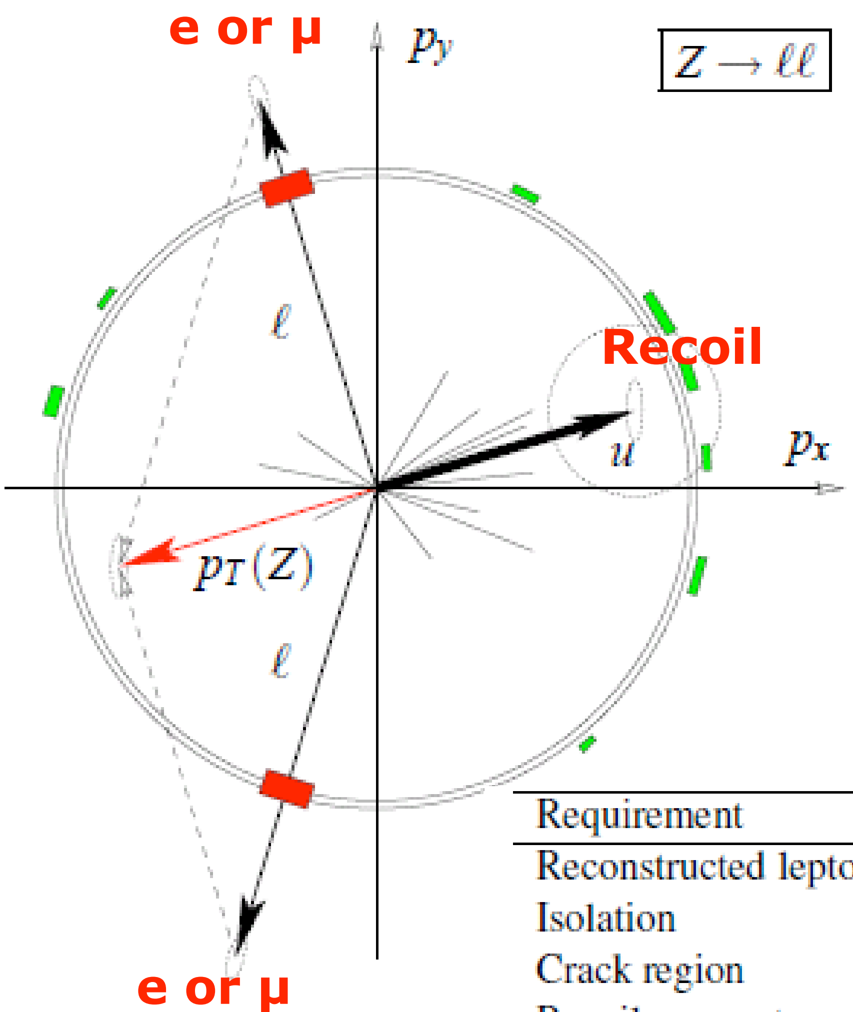
190,000 events in 15pb^{-1}
(in a few months?)
Background to many processes
Eg top, Higgs, SUSY, etc

Signature:

Isolated electron or muons
Central lepton reconstruction
Missing ET
Low recoil momentum

Requirement	$W \to e\nu$	$W \to \mu\nu$
Reconstructed lepton	$p_T > 20$ GeV, $\lvert\eta\rvert < 2.5$	$p_T > 20$ GeV, $\lvert\eta\rvert < 2.5$
Isolation	$E_T^{\text{cone}}/E_T < 0.2$	
Missing energy	$\not{E}_T > 20$ GeV	$\not{E}_T > 20$ GeV
Crack region	Remove $1.30 < \lvert\eta\rvert < 1.60$	
Recoil momentum	$p_T < 50$ GeV	

Z production at the LHC



13,000 events in 15pb^{-1}
(in a few months?)

Background to many processes
Eg top, Higgs, SUSY, etc

Signature:

Two Isolated electron or muons
Central lepton reconstruction
Low recoil momentum

Requirement	$Z \to ee$	$Z \to \mu\mu$
Reconstructed leptons	$p_T > 20$ GeV, $\vert\eta\vert < 2.5$	$p_T > 20$ GeV, $\vert\eta\vert < 2.5$
Isolation	$E_T^{\mathrm{cone}}/E_T < 0.2$	
Crack region	Remove $1.30 < \vert\eta\vert < 1.60$	
Recoil momentum	$p_T < 50$ GeV	

W and Z cross section

Number of observed events (statistics)

Number of background events (theory)

$$\sigma = \frac{N - B}{\mathscr{L}\, A\, \varepsilon}$$

Efficiency (reconstruction and trigger)

Luminosity (machine parameter)

Acceptance (Physics: PDFs, non-perturbative)

For 50pb^{-1} (no lum uncertainty)

σ(W→eν)=20520 40 1060
σ(W→μν)=20530 40 630
σ(Z→ee)=2016 16 83
σ(Z→μμ)=2016 16 76

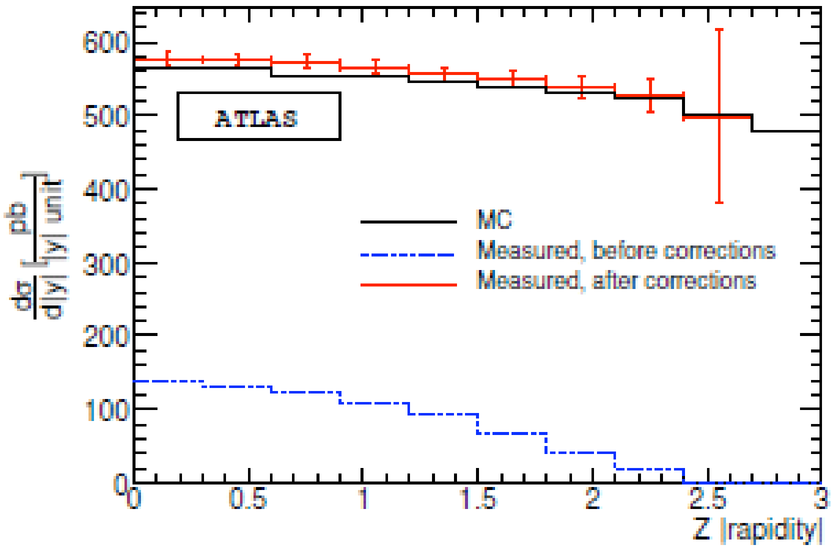
Main uncertainty: Acceptance

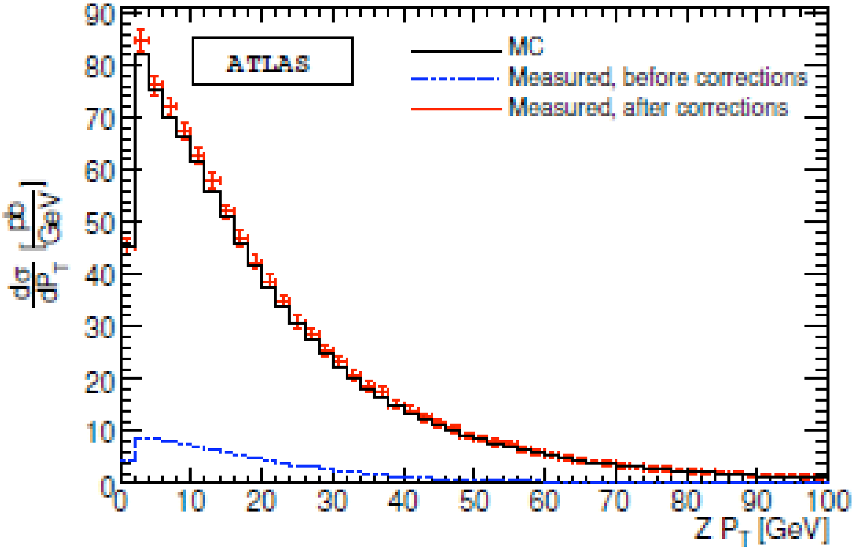
lum uncertainty factorised in σ(W)/σ(Z)

W and Z differential cross section

Measure $d\sigma/dy$ and $d\sigma/dP_T$ to understand and tune the model of Z (and W) production

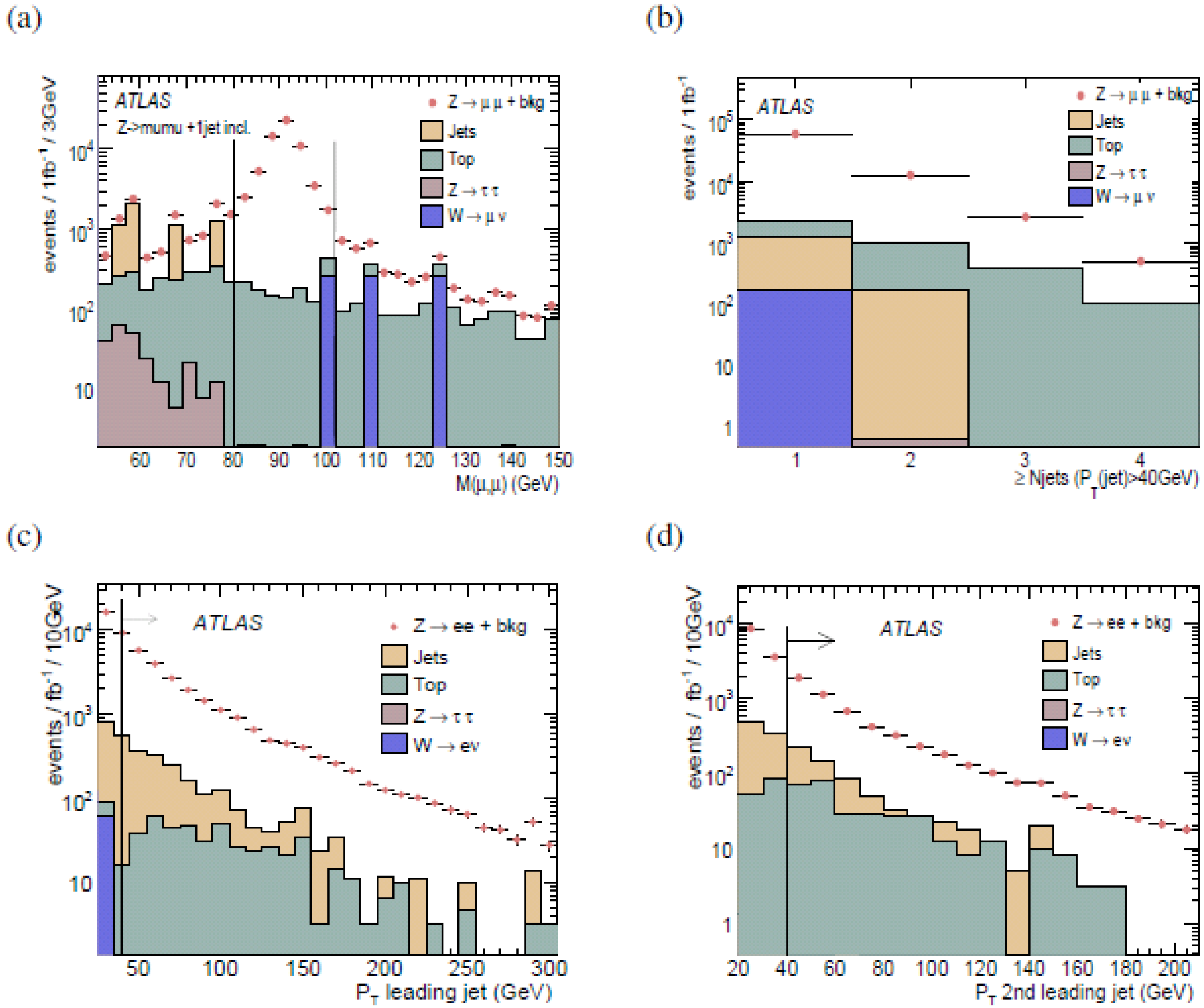
200pb^{-1}





Measuring Z+Jet events

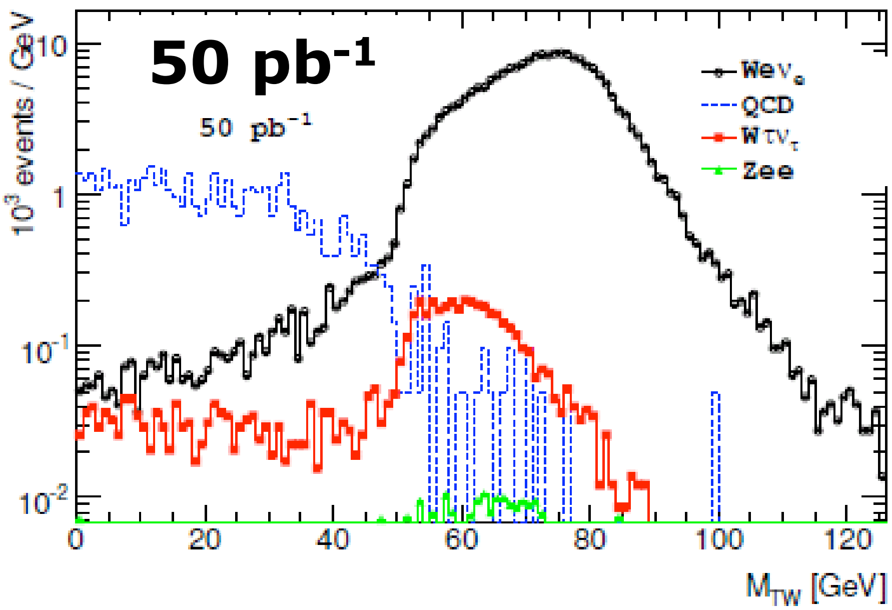
Z+jet kinematic as a test of MC generators we use for background studies

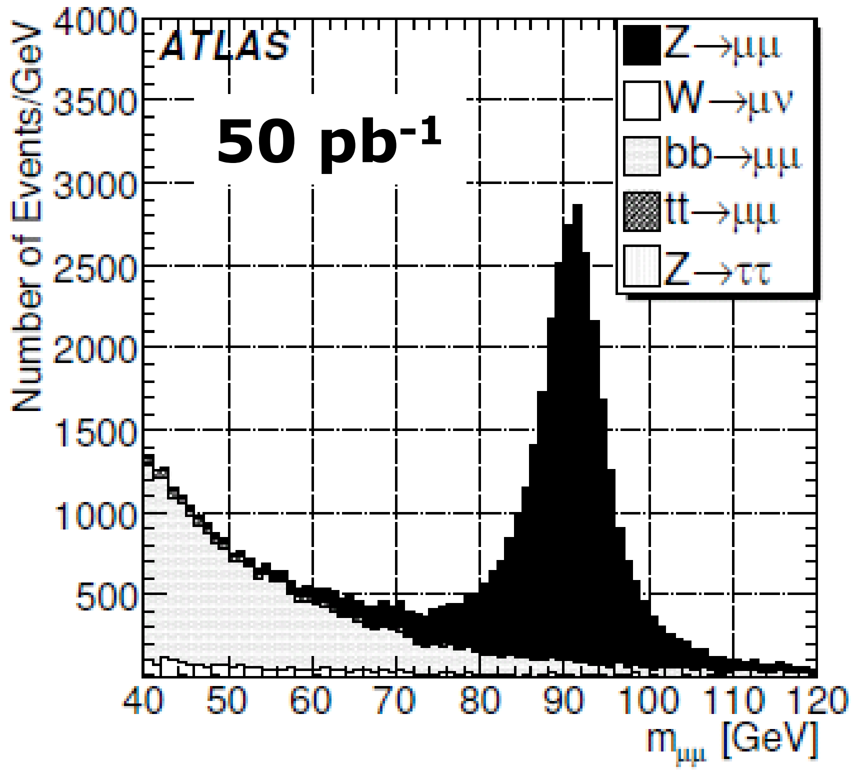


W and Z mass reconstruction

Useful for detector alignment and calibration studies

W→eν Transverse mass





Z→μμ mass

W mass measurement

From LEP and TeVatron:

M_W=80.399 0.025GeV

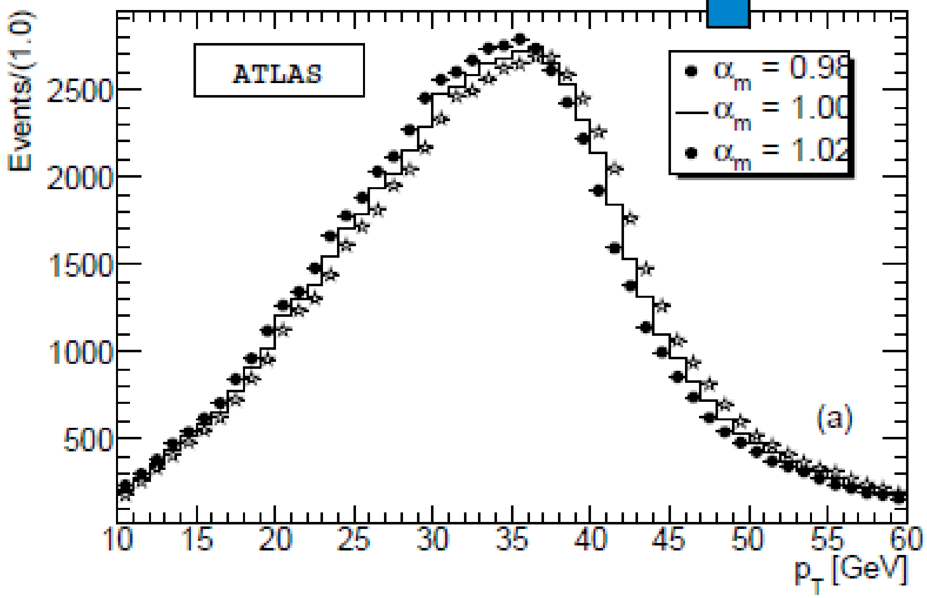
LHC goal (10fb^{-1}):

~5 MeV error

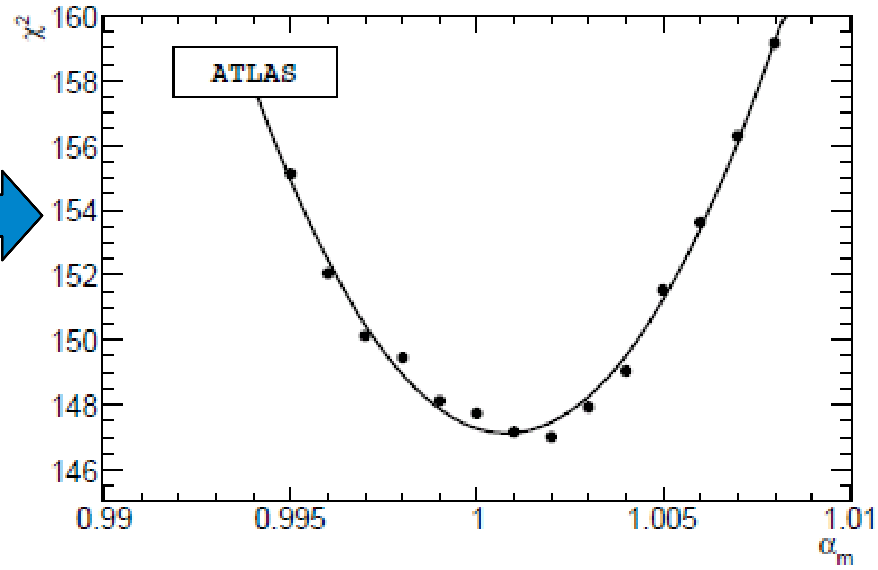
W→ ev

15pb^{-1}

Use MC with different m_W values for a template fit



Use well known m_Z to understand m_W systematic



m_W(fit) = 80.47 0.12GeV

Systematic errors are the complicate part of the analysis

m_W systematic errors

Energy Scale: in-situ calibration of Z events

Energy resolution and tails

Hard work (and data) are needed for a competitive measurement

15pb^{-1}

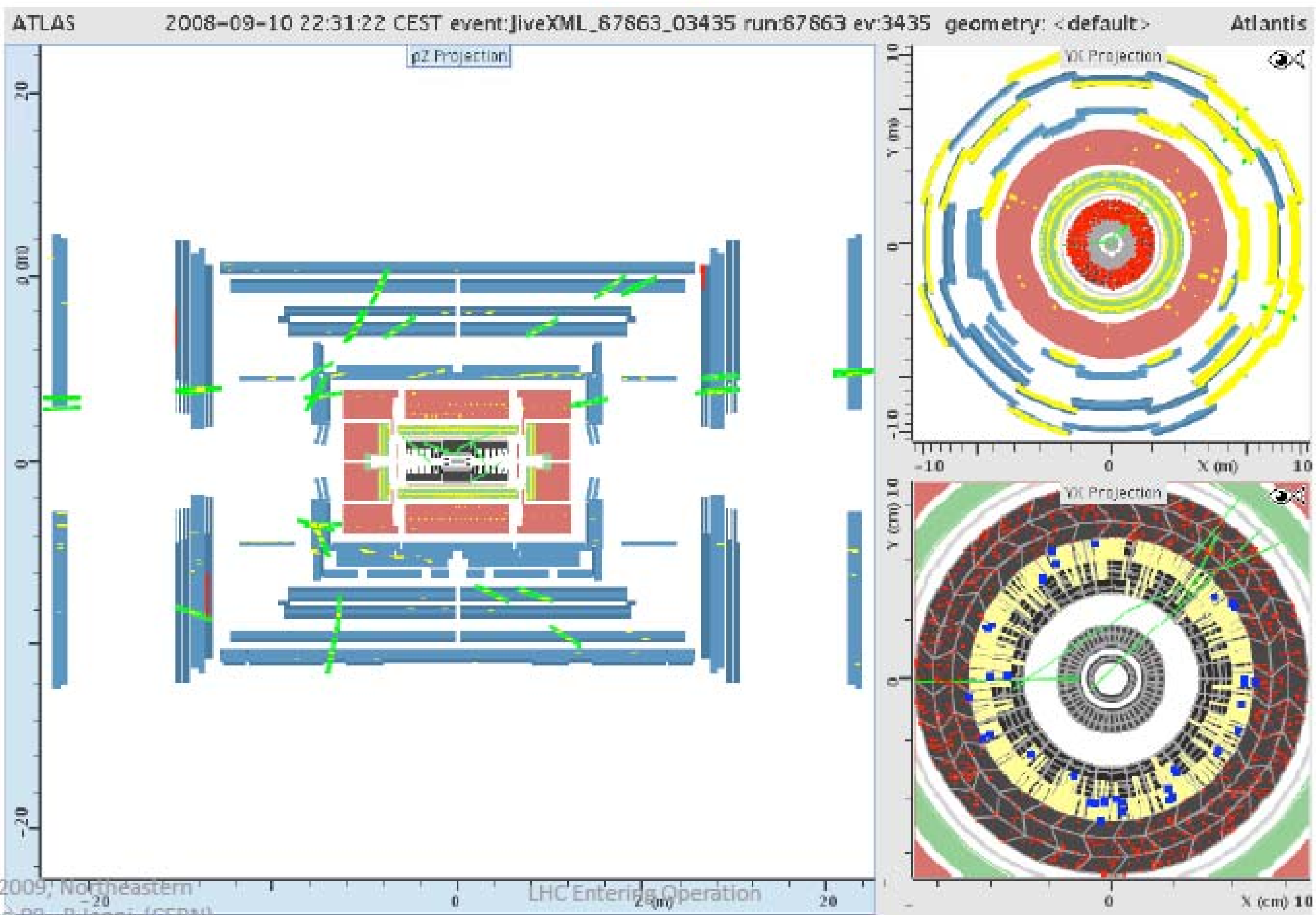
Lepton efficiency

Recoil estimation

Method	$p_T(e)$ [MeV]	$p_T(\mu)$ [MeV]	$M_T(e)$ [MeV]	$M_T(\mu)$ [MeV]
δm_W (stat)	120	106	61	57
δm_W (α_E)	110	110	110	110
δm_W (σ_E)	5	5	5	5
δm_W (tails)	28	< 28	28	< 28
δm_W (ε)	14	–	14	–
δm_W (recoil)	–	–	200	200
δm_W (bkg)	3	3	3	3
δm_W (exp)	114	114	230	230
δm_W (PDF)	25	25	25	25
Total	167	158	239	238


Excitement in the ATLAS Detector Control Room:
The first LHC events on 10th September 2008
SUSY2009, Northeastern
5-June-09, P.Jenni (CERN)

A busy beam-halo event with tracks bent in the Toroids from the start-up day



10th September 2008 in the CMS Control room

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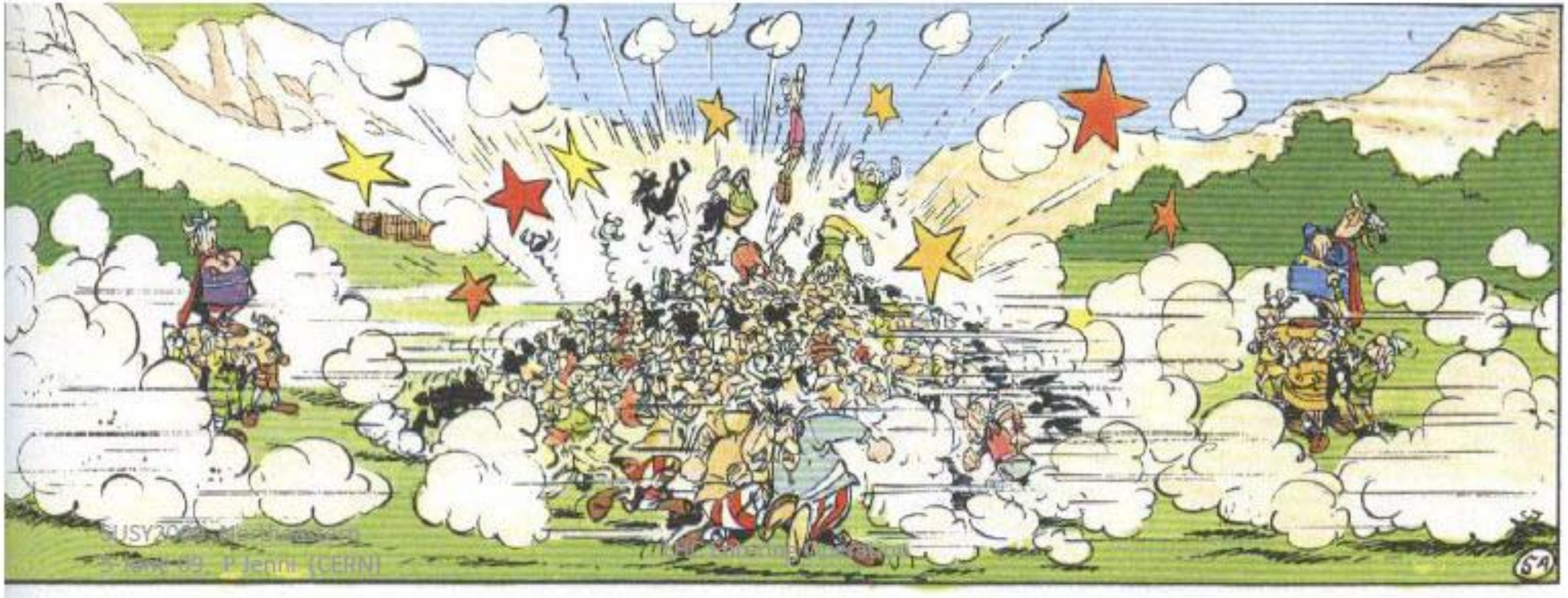
- **Conclusions**

Will my next talk contain real pp collision results?

Something to look forward to

First pp collisions?



... or first ATLAS-CMS physics discussion?

Conclusions

- The first physics measurements will be in the Standard Model domain
- Our understanding of the Standard Model and its parameters will improve with time (and our understanding of the detector)
- We will improve precise measurements of quantities such as m_W, m_{top}, $\sigma(W)/\sigma(Z)$, TGC couplings, etc.
- This talk just scratched the surface! More to come with real data