ATLAS Prospects for W/Z+jets measurements

(IFAE-Barcelona)

M. Martinez

Berkeley WorkShop on Boson+jets Production, LBNL, March 2008

Outline

- The LHC
- Cross Sections at 14 TeV
- ATLAS
- e,μ, jets energy scale
- Z+jets Studies
- Underlying Event
- As background for SUSY
- One Final Remark

- W+jets studies still in progress (work until now focused on PDF uncertainties…)

Not really public yet!!

Draft version 1.0

ATLAS CSC NOTE
W/Z+jets

March 20, 2008

W/Z + jets CSC Note

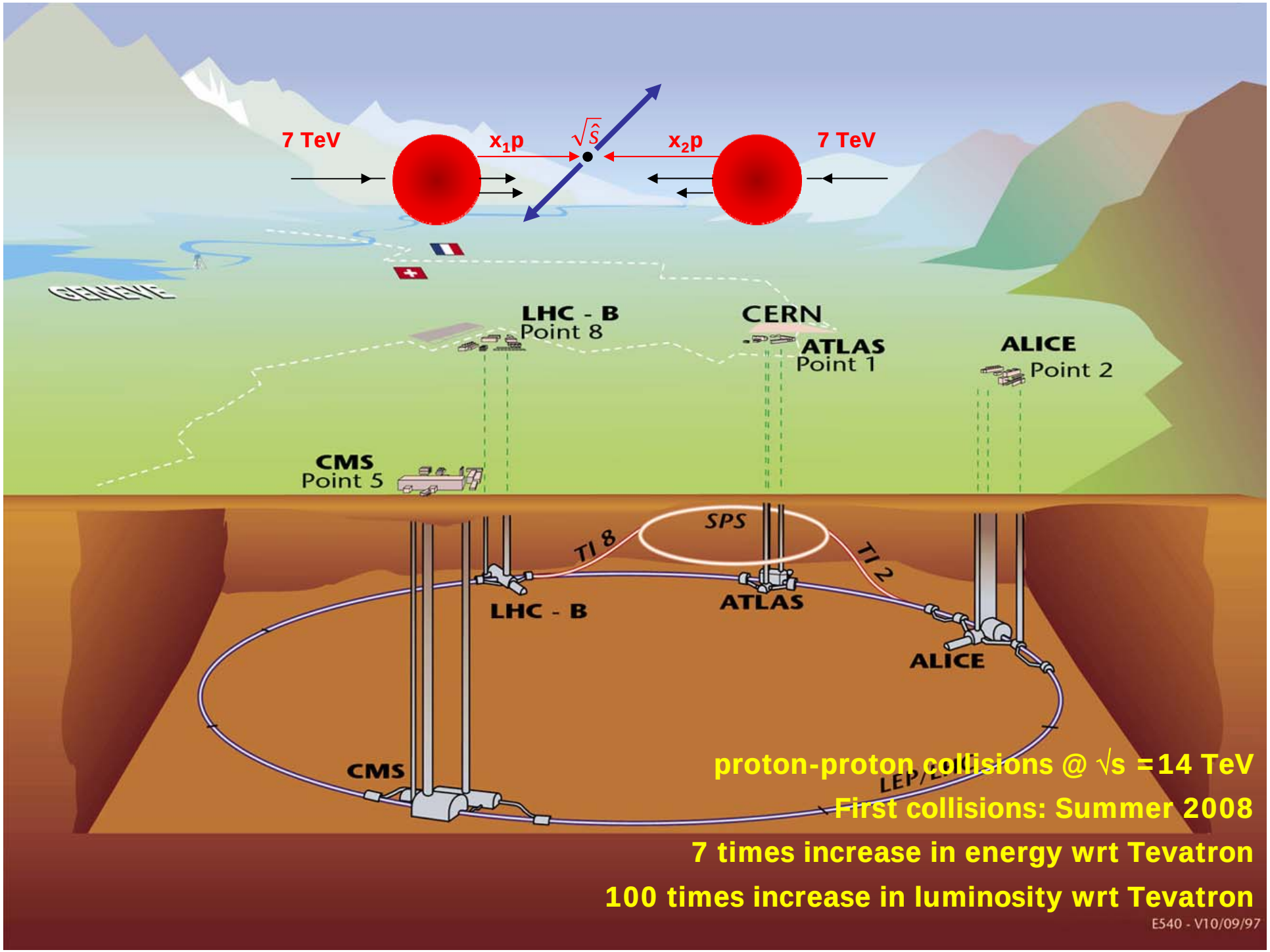
W/Z + jets CSC authors

Abstract

The production of a W or Z boson in conjunction with jets is an interesting process in its own right as well as a signal channel (and background) for many interesting standard model and beyond standard model physics signals. Final states with 2,3,4 or more jets accompanying a W/Z boson will be observable at the LHC and will serve as a crucial part of the ATLAS physics program. The variety of possible jet multiplicities allows for precision tests of jet reconstruction algorithms and techniques. In addition, the reconstruction of leptons and of missing transverse energy becomes more complex in the presence of a multi-jet final state. In this note, we will quantify the differences of lepton, missing transverse energy and jet reconstruction with respect to that observed in inclusive W and Z production.

The wide kinematic range for production of W/Z + jets allows serves as a testing ground for perturbative QCD predictions, both fixed order alone and in conjunction with parton shower Monte Carlos. As an example, the possible large rapidity separations between pairs of jets allows for tests for the applicability and importance of BFKL-type logarithms.

MC Work on Z+jets in ATLAS in collaboration with U. Blumenschein & E. Segura (IFAE-Barcelona)
…following our steps at CDF

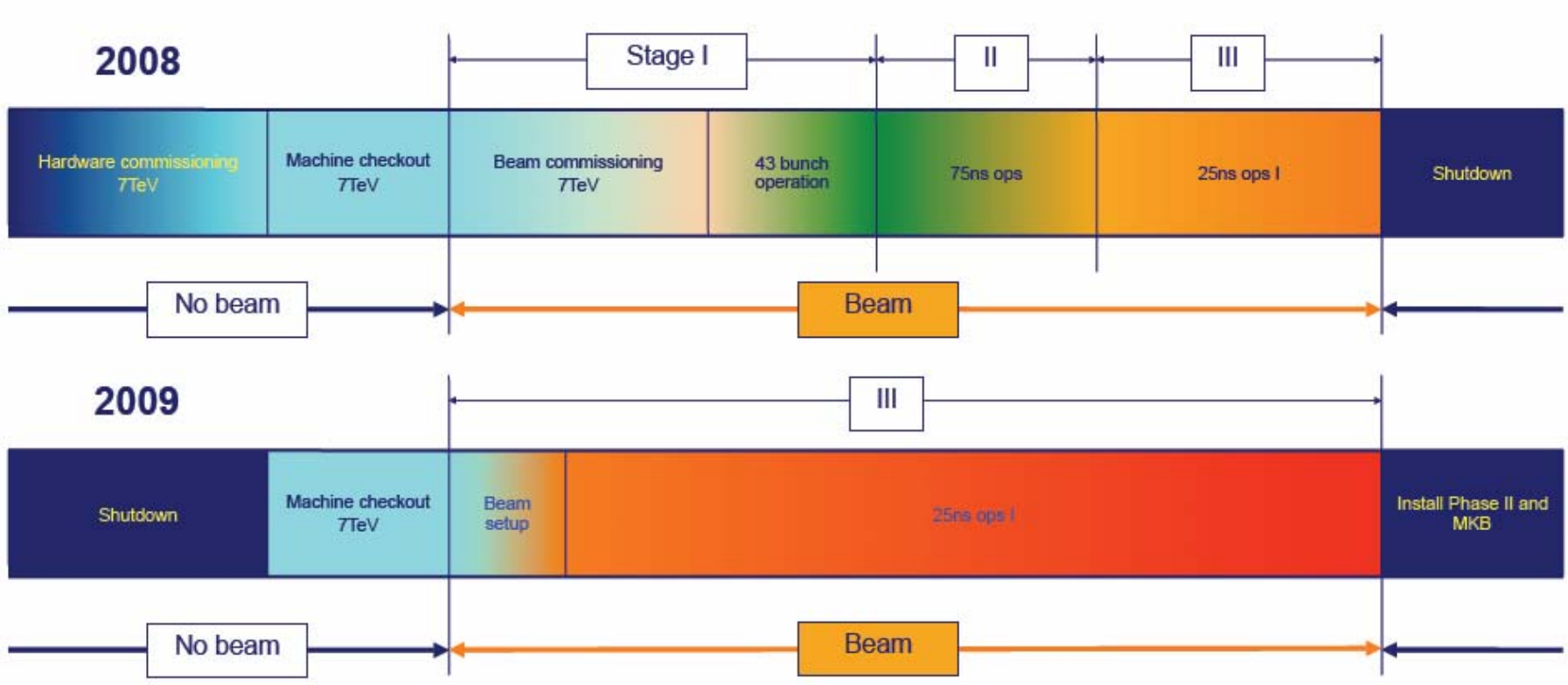

7 TeV
x_1p
$\sqrt{\hat{s}}$
x_2p
7 TeV
GENEVE
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
proton-proton collisions @ √s =14 TeV
First collisions: Summer 2008
7 times increase in energy wrt Tevatron
100 times increase in luminosity wrt Tevatron
E540 - V10/09/97

LHC Schedule

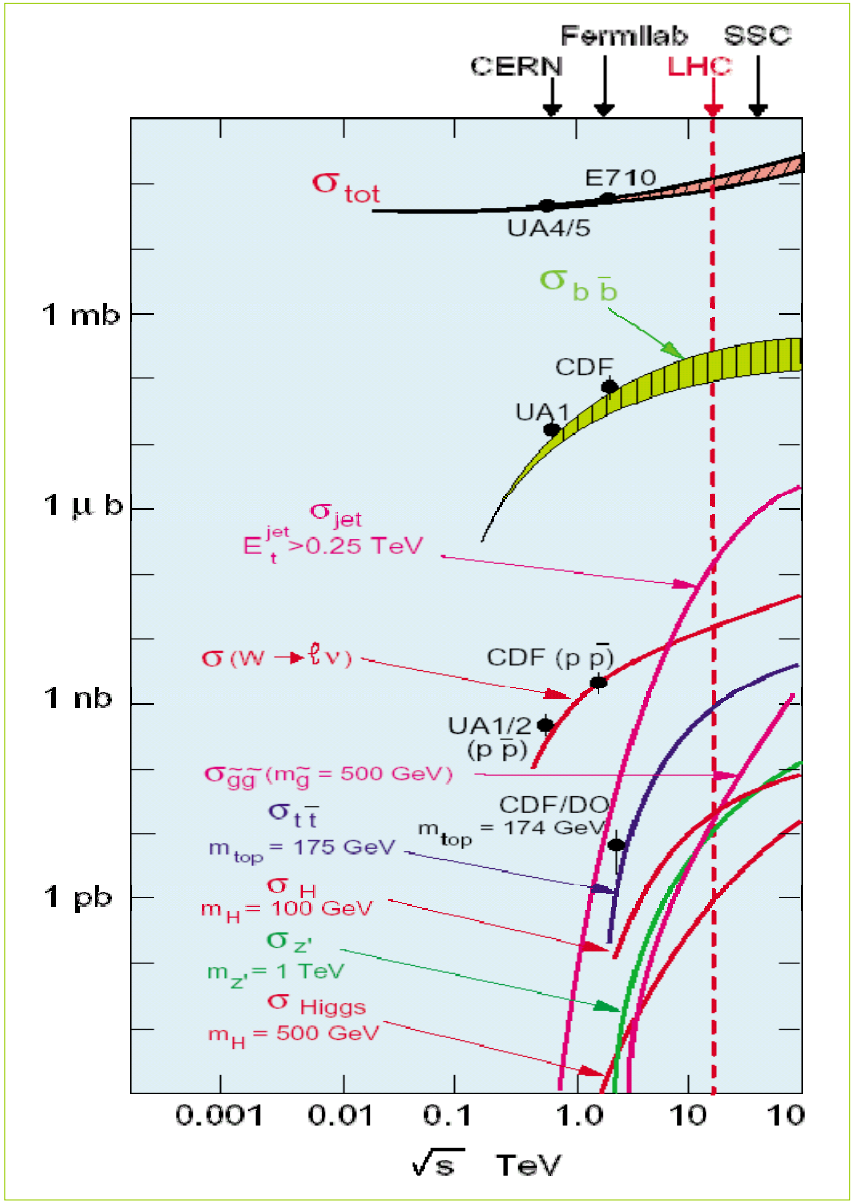
- End of May 2008: machine closed
- End of June 2008: beam commissioning at 7 TeV

→ **1-2 months for colliding beams at 14 TeV**

→ **10^{32} $cm^{-2}s^{-1}$ by end 2008 (~100 pb^{-1} int. luminosity)**



Cross Sections



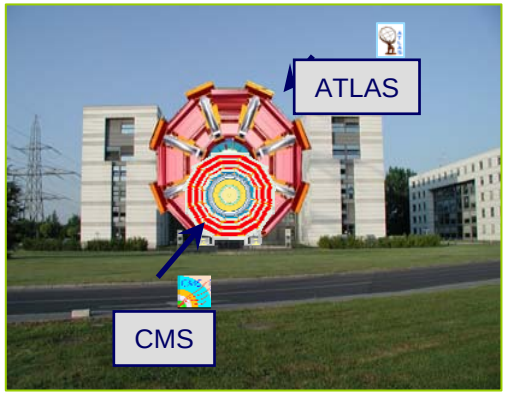
Process	σ (nb)	Events ($\int \mathcal{L} dt$ = 100 pb^{-1})
Min bias	10^8	~10^{13}
bb	$5 \cdot 10^5$	~10^{12}
Inclusive jets p_T > 200 GeV	100	~ 10^7
$W \to e\nu, \mu\nu$	15	~ 10^6
$Z \to ee, \mu\mu$	1.5	~ 10^5
tt	0.8	~ 10^4

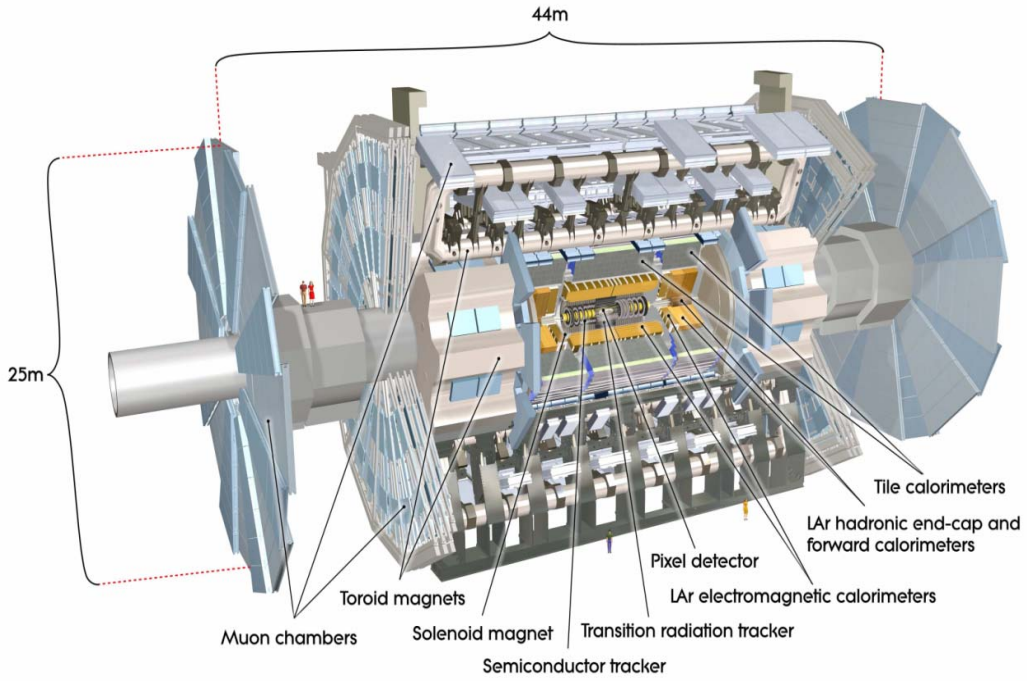
Illustrative trigger menu at $\mathcal{L} = 10^{31} \mathrm{cm}^{-2}\mathrm{s}^{-1}$ (ATLAS):

Signature	Examples of physics coverage		Rates(Hz)
minimum bias	Prescaled trigger item		10
e10,2e5	b,c→e,W,Z,Drell-Yan,tt,J/ψ,Υ	electrons	~27
γ20,2γ15	Direct photon, photon pairs, γ-jet balance	photons	~7
μ10,2μ4	b,W,Z,Drell-Yan,tt,J/ψ,Υ	muons	~22
j120,4j23	QCD,high p_T and multi-jet final states	jets	~13
τ20i+$e10_{\mu 6}$	Z→$\tau\tau$	taus	4
τ20i+xE30	W,tt	tau+$\not{E}_T$	~10
	Prescaled,calibration,monitoring triggers		~17
Total HLT rate			~100

Huge sample of Ws and Zs already with 100 pb^{-1}

The ATLAS Detector





Tracking (|η|<2.5, B=2T) :

Si pixels and strips
Transition Radiation Detector (e/π separation)

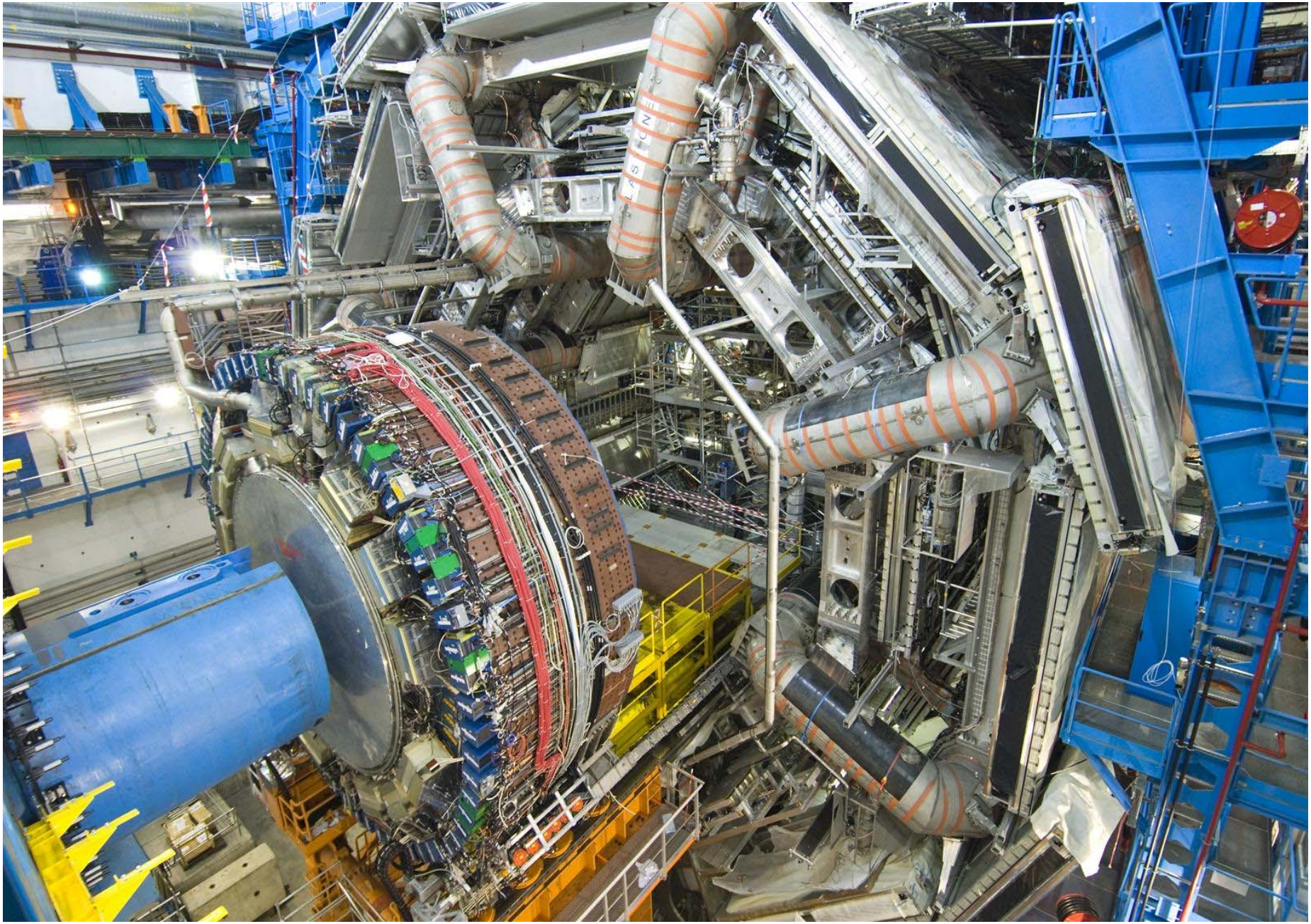
Calorimetry (|η|<5) :

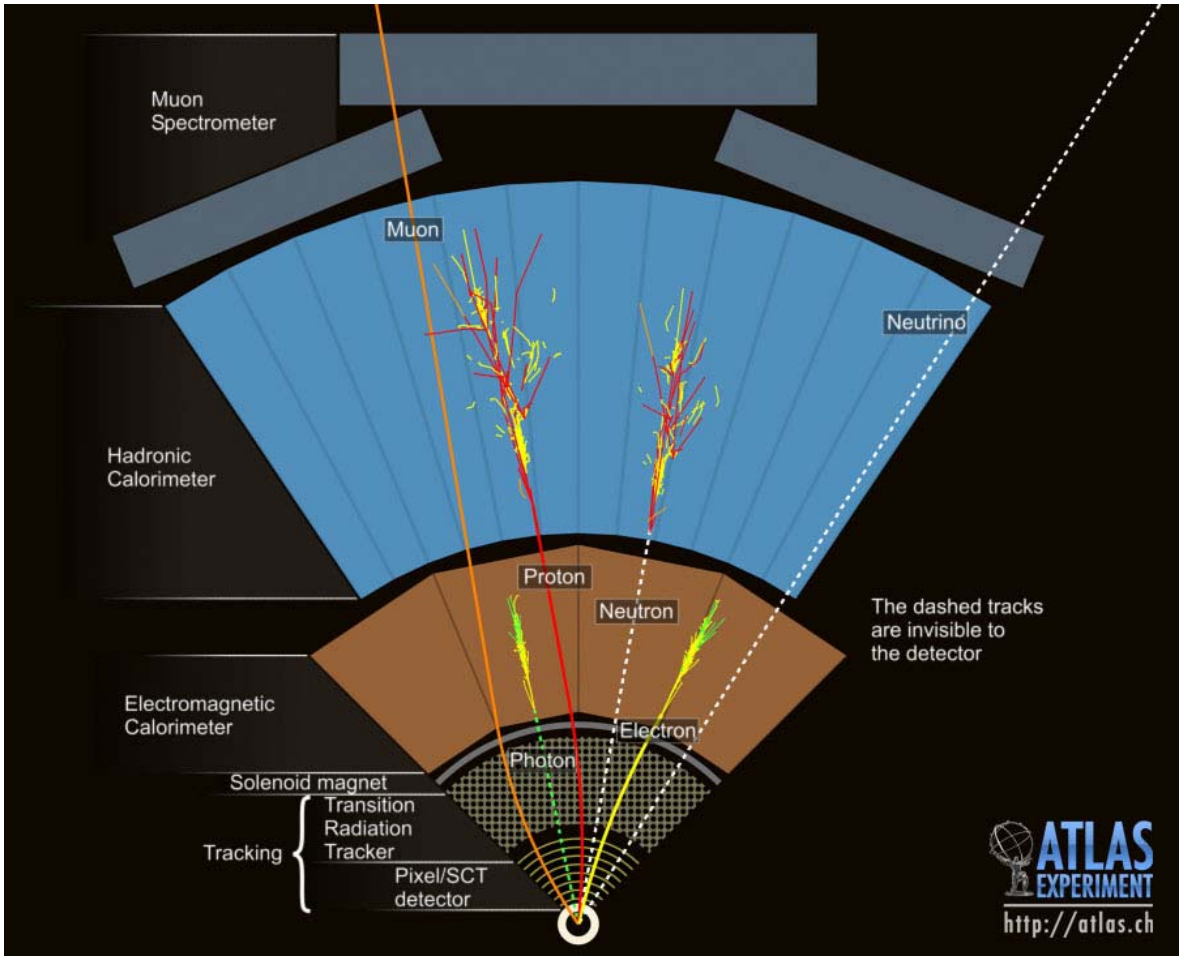
EM : Pb/LAr with Accordeon shape
HAD : Fe/scintillator (central)
Cu-W/Lar (forward)

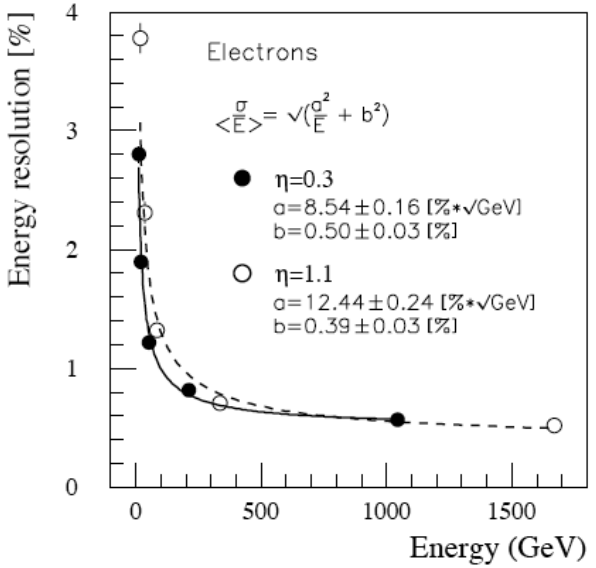
MuonSpectrometer (|η|<2.7) :

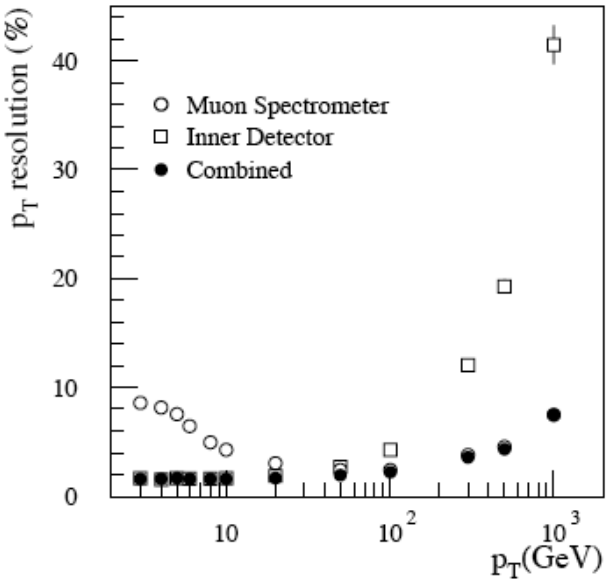
air-core toroids with muon chambers

Detector component	resolution	η coverage
Tracking	$\sigma_{p_T}/p_T = 0.05\%\ p_T \oplus 1\%$	$\lvert\eta\rvert < 2.5$
EM calorimetry	$\sigma_E/E = 10\%/\sqrt{E} \oplus 0.7\%$	$\lvert\eta\rvert < 3.2$
Hadronic calorimetry (jets)		
barrel and end-cap	$\sigma_E/E = 50\%/\sqrt{E} \oplus 3\%$	$\lvert\eta\rvert < 3.2$
forward	$\sigma_E/E = 100\%/\sqrt{E} \oplus 10\%$	$3.1<\lvert\eta\rvert<4.9$
Muon spectrometer	$\sigma_{p_T}/p_T = 10\%/p_T$ @ p_T=1 TeV	$\lvert\eta\rvert < 2.7$



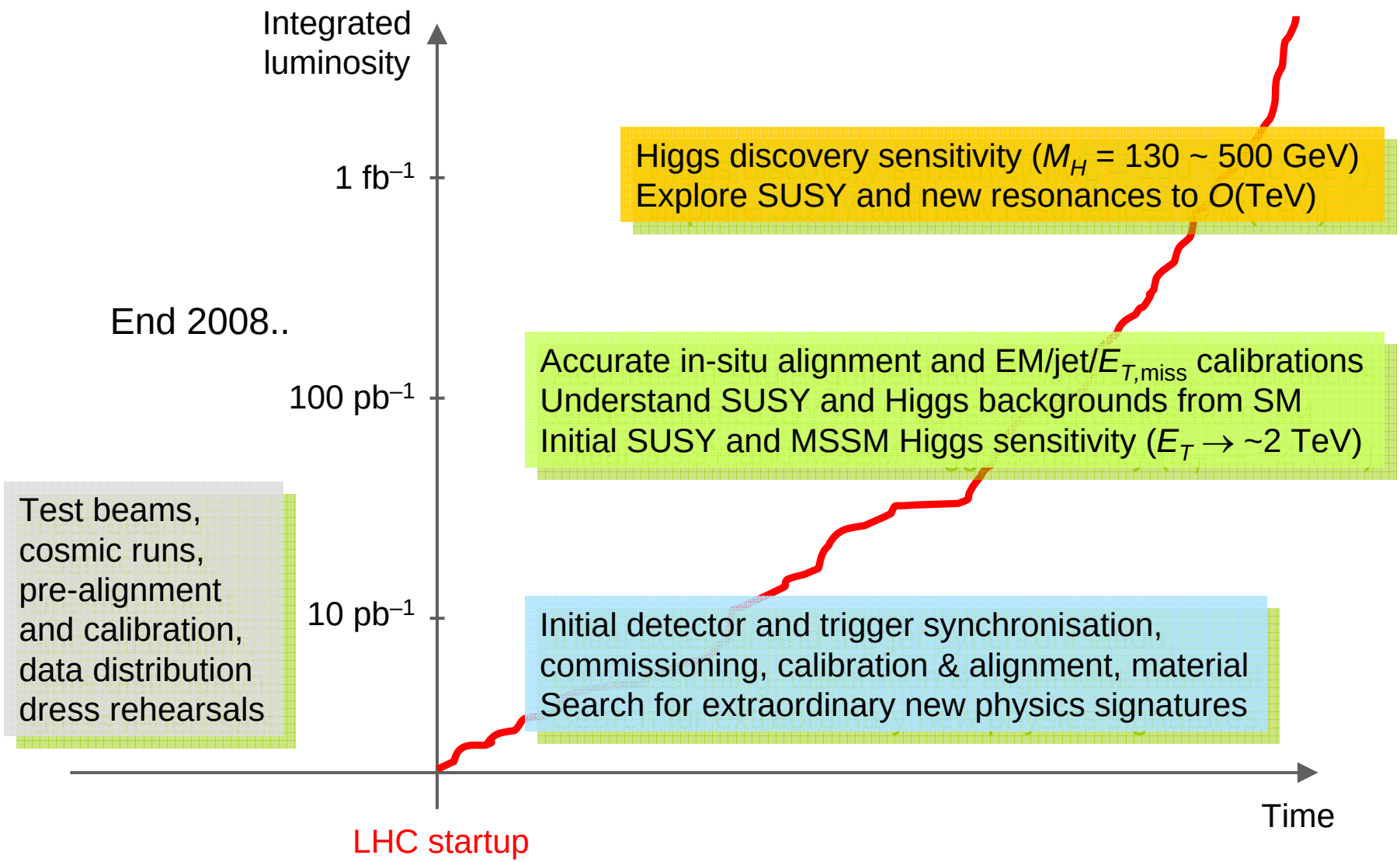




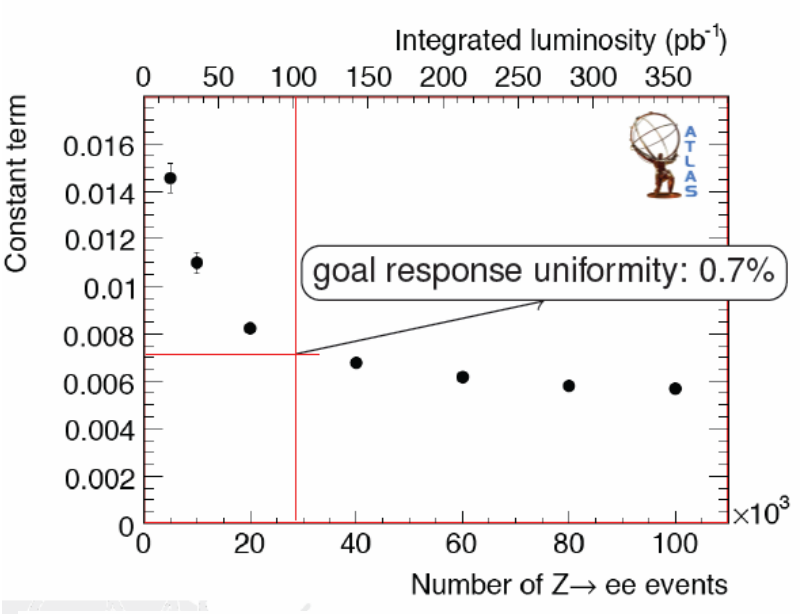


ATLAS	Expected performance day-1
ECAL uniformity	1-2% (~0.5% locally)
e/γ E-scale	~ 2 %
HCAL uniformity	~ 3 %
Jet E-scale	< 10%
Tracking alignment	10-200 μm in Rφ Pixels/SCT
Muon alignment	~ 1 mm

Start-up Programme in a Nutshell

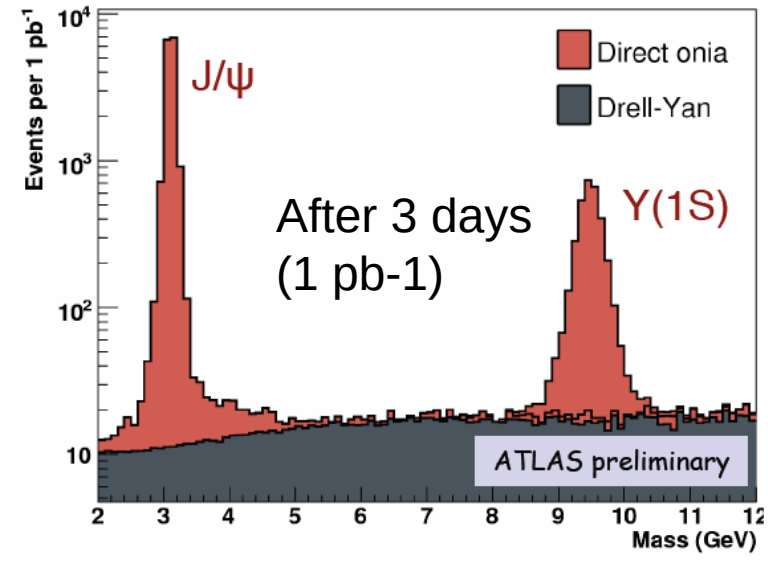


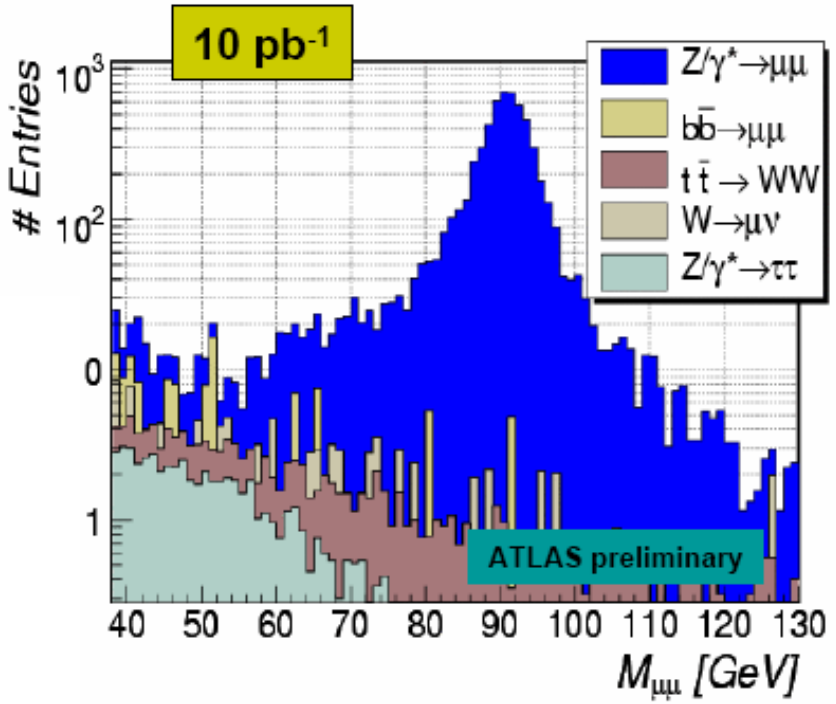
e,μ calibration/alignment



Z→ ee will be used to fix em scale

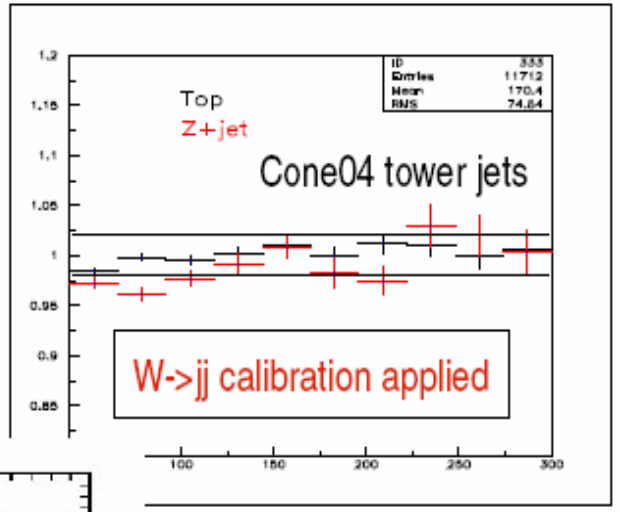
Di-muons will be used to alignment and determination of momentum scale (to 1% accuracy…with 30.000 Zs)



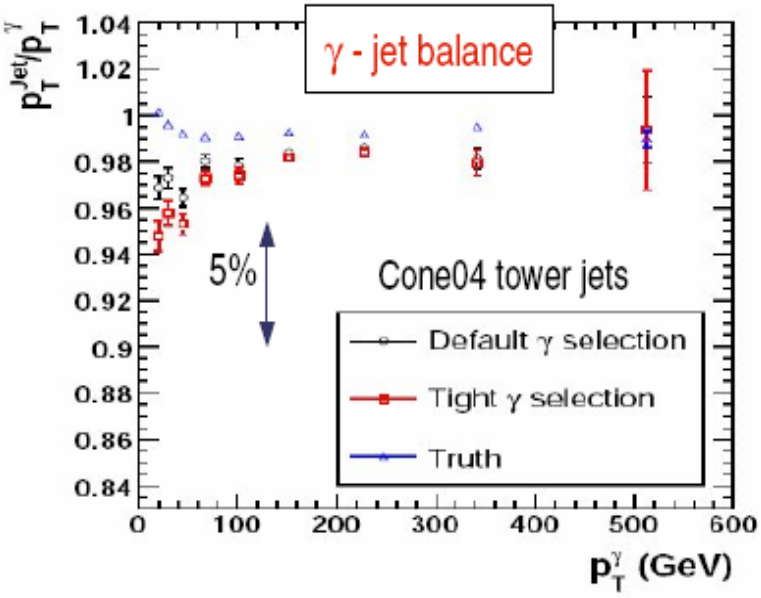


ATLAS: In-situ calibration

- Validate and fine-tune hadronic energy scale
- Hadronic -> parton scale: evaluate physics effects
- JES resolution
- Systematic uncertainty on Jet energy scale



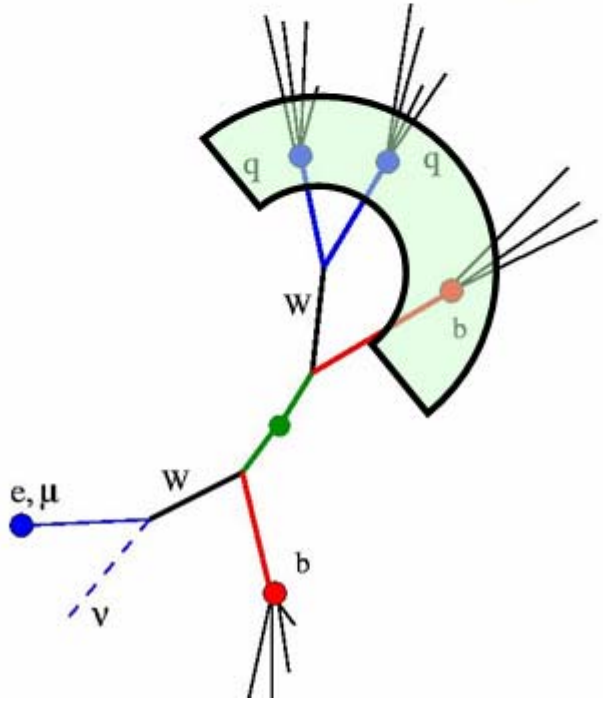
- **Photon+jets: Jet scale vs EM scale**
  - Large background for soft γ
  - Large statistics
- **Z+jets: jet scale vs EM scale**
  - Clean topology
  - lower statistics
- **Dijets:**
  - Uniformity in eta
  - Calibration of very hard jets
  - Jet energy resolution
- **Ttbar -> W+jets**
  - Reconstruct W->jj mass
  - Applicable to other processes

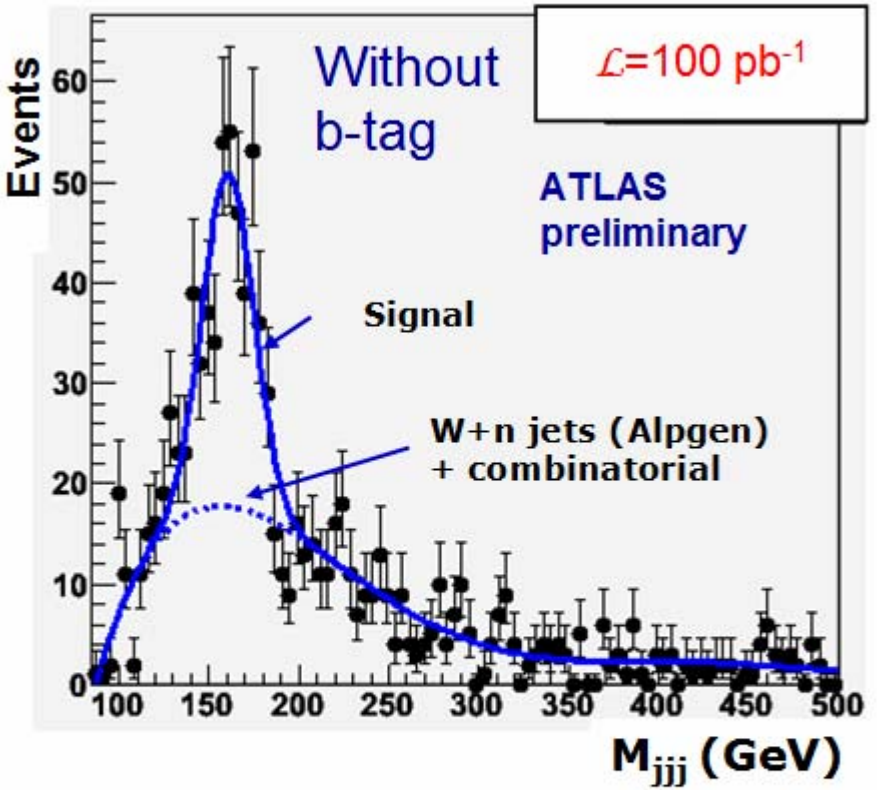


- **Limitations:**
  - Low-PT (~10-150 GeV): Systematics: Underlying Event, ISR/FSR, fragmentation
  - Medium PT:(~150- 500 GeV): Large precision expected from γ+jets
  - Large PT: limited by statistics -> extrapolations, multi-jet balancing

Using Top!!

- Event selection:
  - no b-tag yet on day-1 (might not be well understood)
  - Isolated lepton : $p_T > 20$ GeV
  - missing $E_T > 20$ GeV
  - 4 jets $p_T > 40$ GeV
  - 3 jets with highest $\Sigma\ p_T$





Z→ee + jets reconstruction

Electron Selection

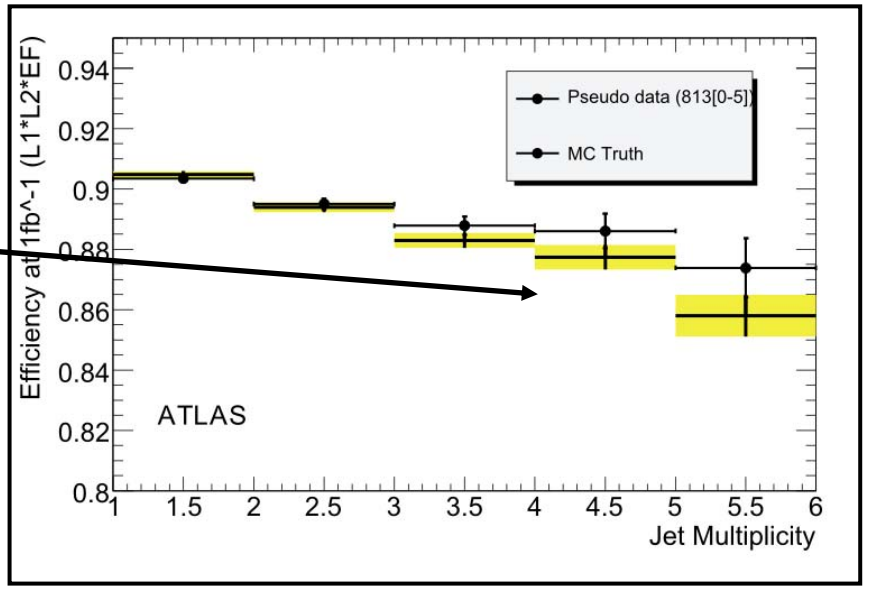
Trigger e25i (isolation at L1)
Electron ID cuts
P_T > 25 GeV/c
$|\eta|$ < 2.5 (excluding [1.37-1.52] crack)

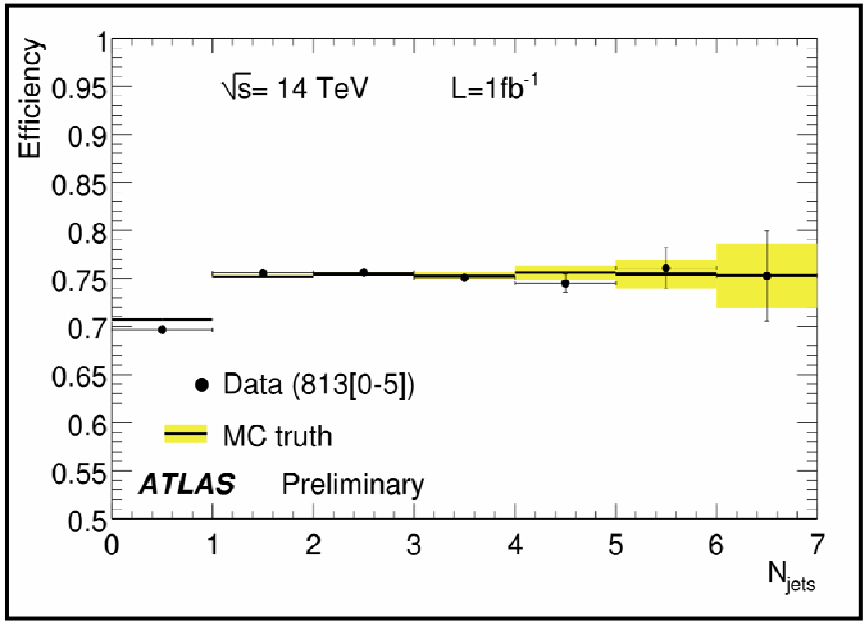
Z→ee selection

81 < M_{ee} < 101 GeV/c2
ΔR_{ee} > 0.2

Jets

Cone algorithm R=0.4
P_T > 40 GeV/c
$|\eta|$ < 3
ΔR_{ej} >0.4
Corrected back to hadron level



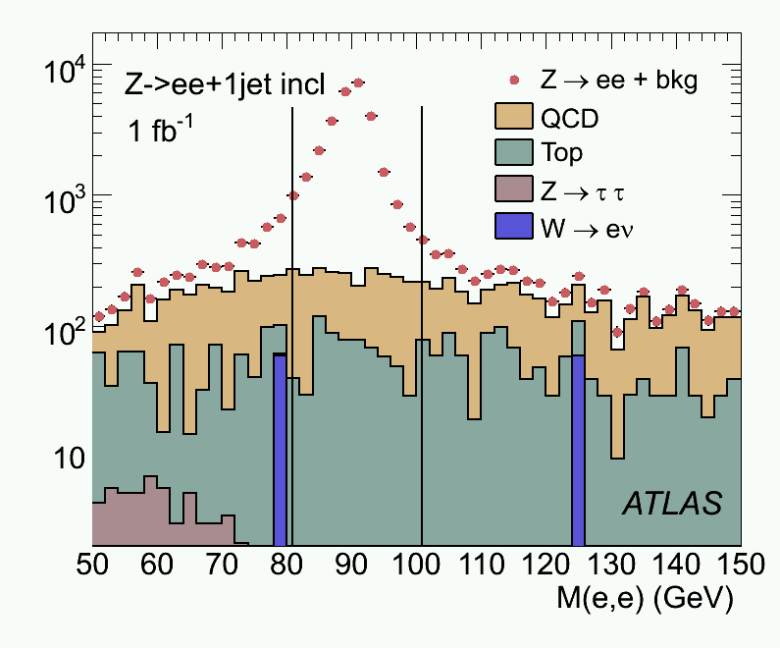


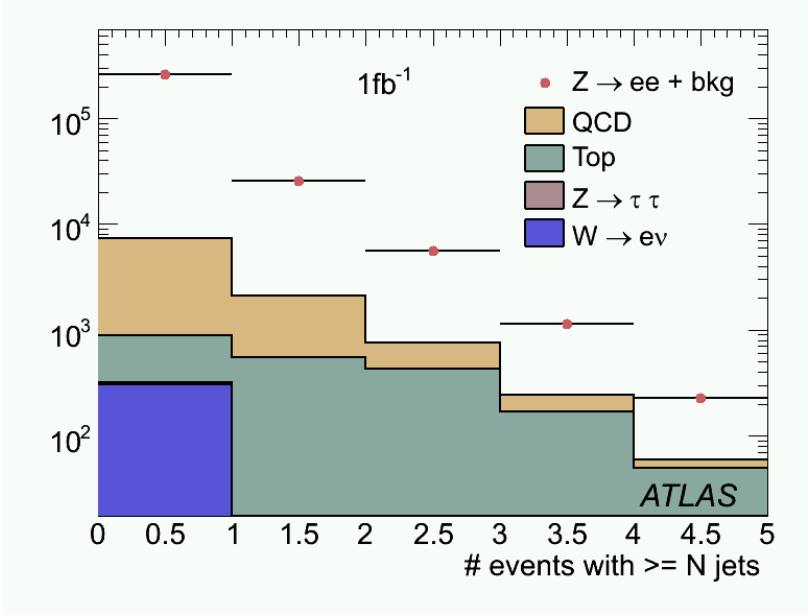
Comparison with MC (Z→ee+jets)

- Z+jets using ALPGEN+HERWIG
  (normalized to DY cross section from MCFM)

- Backgrounds generated with PYTHIA
- tt generated with PYTHIA and MC@NLO

- QCD from filtered dijet PYTHIA sample

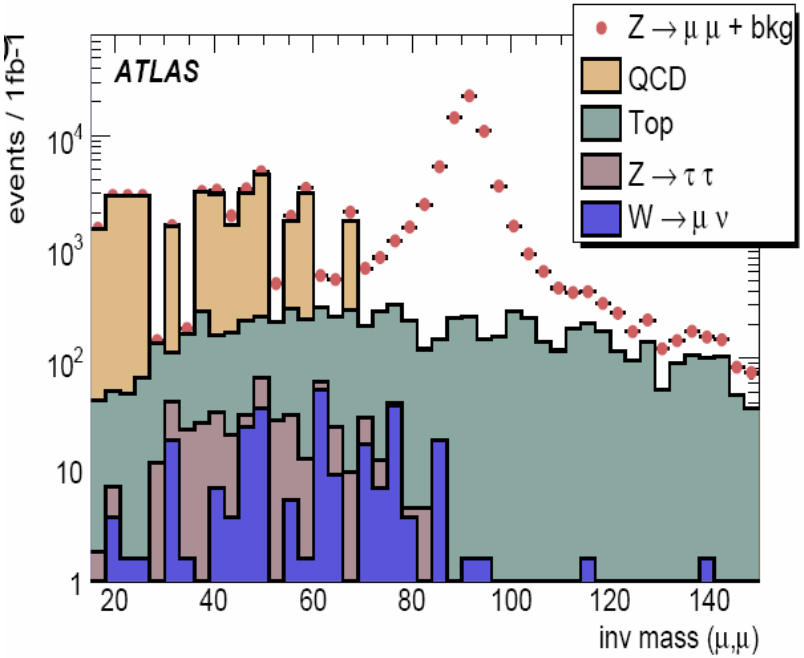


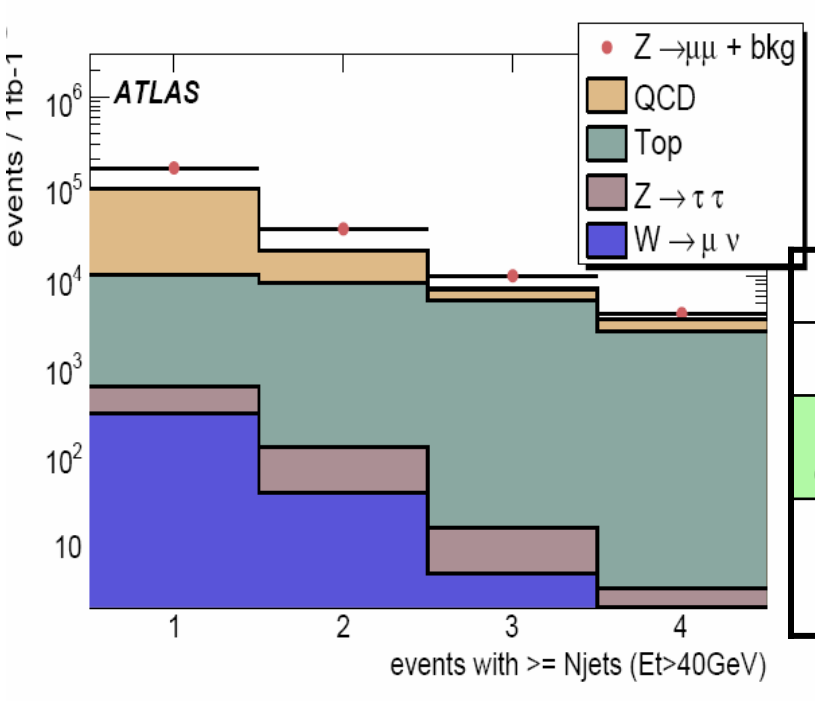


Backg	Z+ >=1j	Z+ >=2j	Z+ >=3j
QCD	~6%	~6%	~7%
tt	~2%	~8%	~15%
Z→ττ + W→ eν	< 1%	<1%	<1%

Z→ μμ results

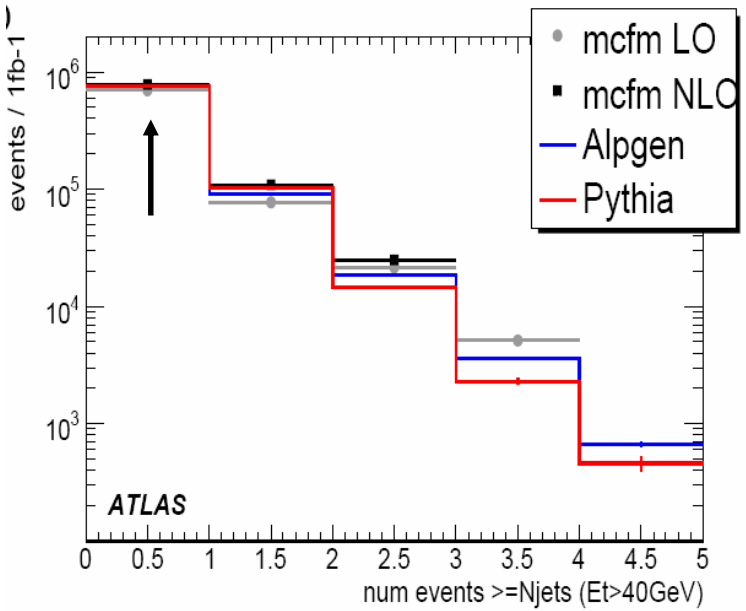
- isolated muons pt>15 GeV
- Z+jets using ALPGEN+HERWIG (normalized to DY cross section from MCFM)
- Backgrounds generated with ALPGEN
- QCD (bb) from filtered PYTHIA sample





Backg.	Z+ >=1j	Z+ >=2j	Z+ >=3j
QCD(bb)	~2%	~5%	-
tt (ALPGEN/PYTHIA)	2%/1.5%	7%/6%	**20%/12%**
Z→ττ + W→ μν	< 1%	<1%	<1%

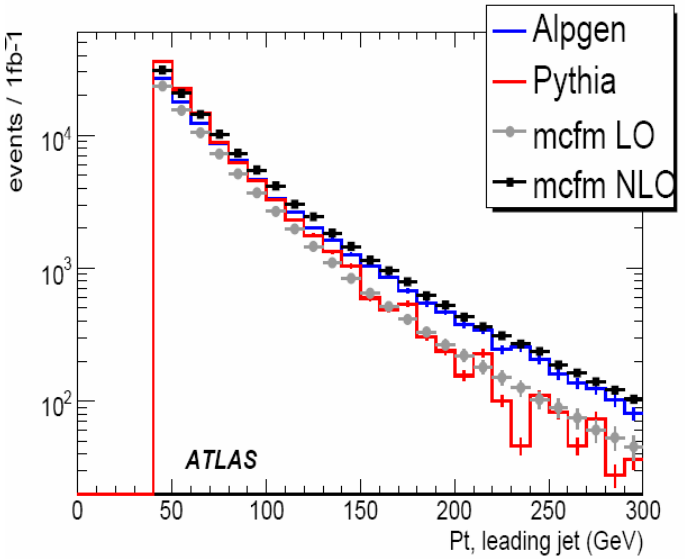
Comparison with MCFM

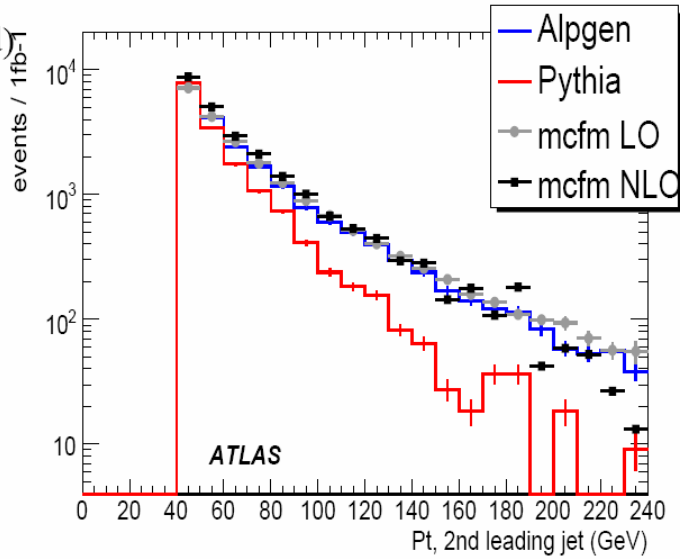


Comparison with MCFM predictions
(CTEQ6.1 $\mu = M_Z^2 + P_t(Z)^2$)
(corrected for non-pQCD effects a la CDF)

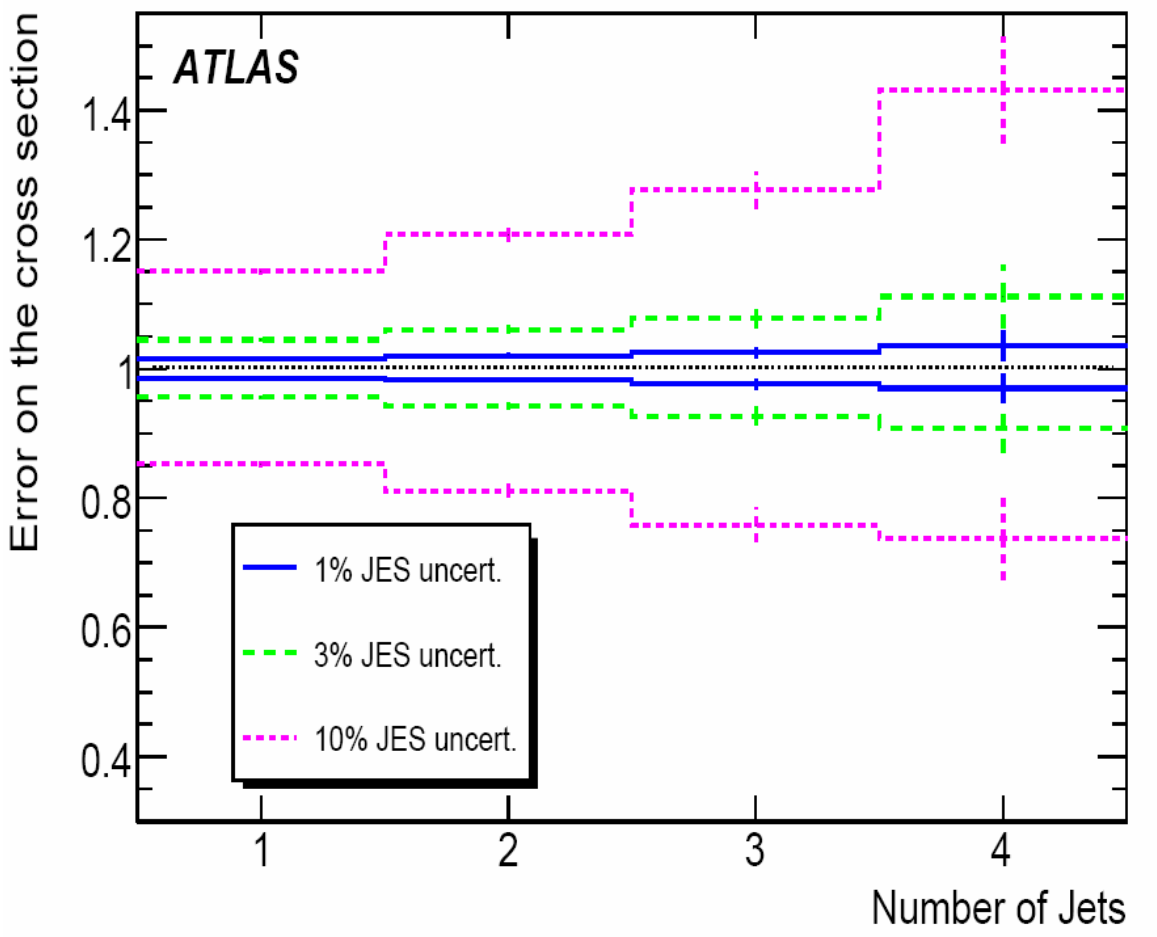
From the comparison:

ALPGEN and MCFM+non-pQCD agree
PYTHIA (2-1 process) too soft (as expected ?)



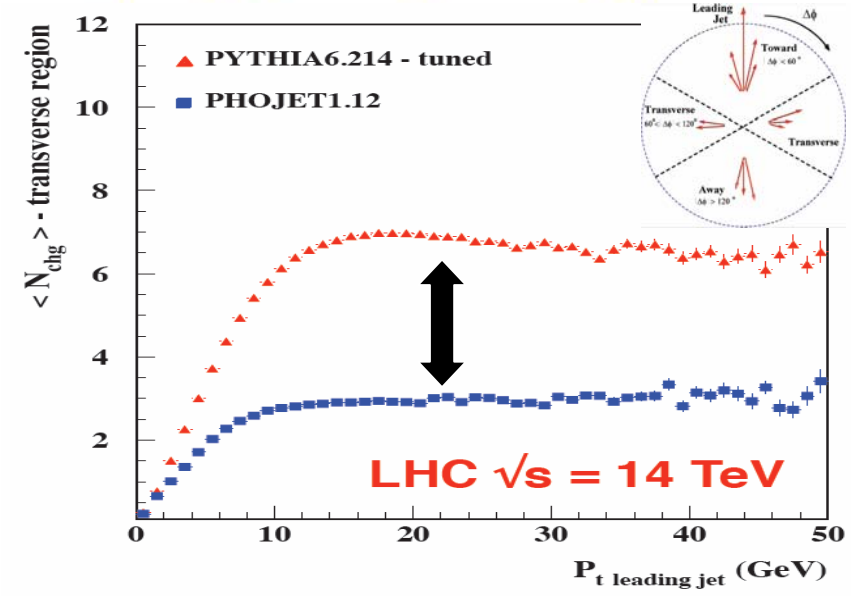


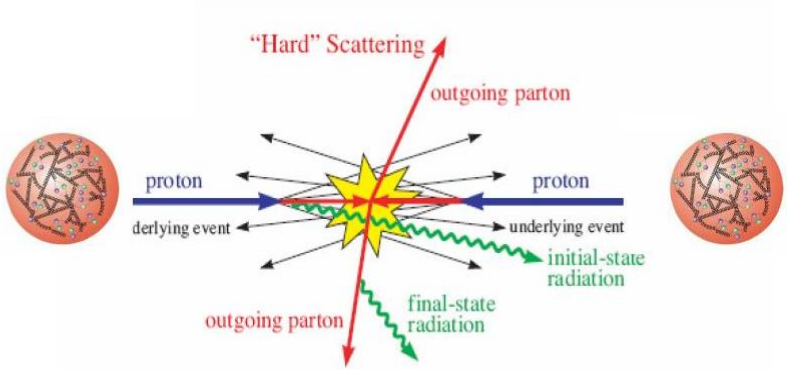
Jet Energy Scale Uncertainty



At day 1 jet rates not known better than 20%-40%
With time 10% can be reached…

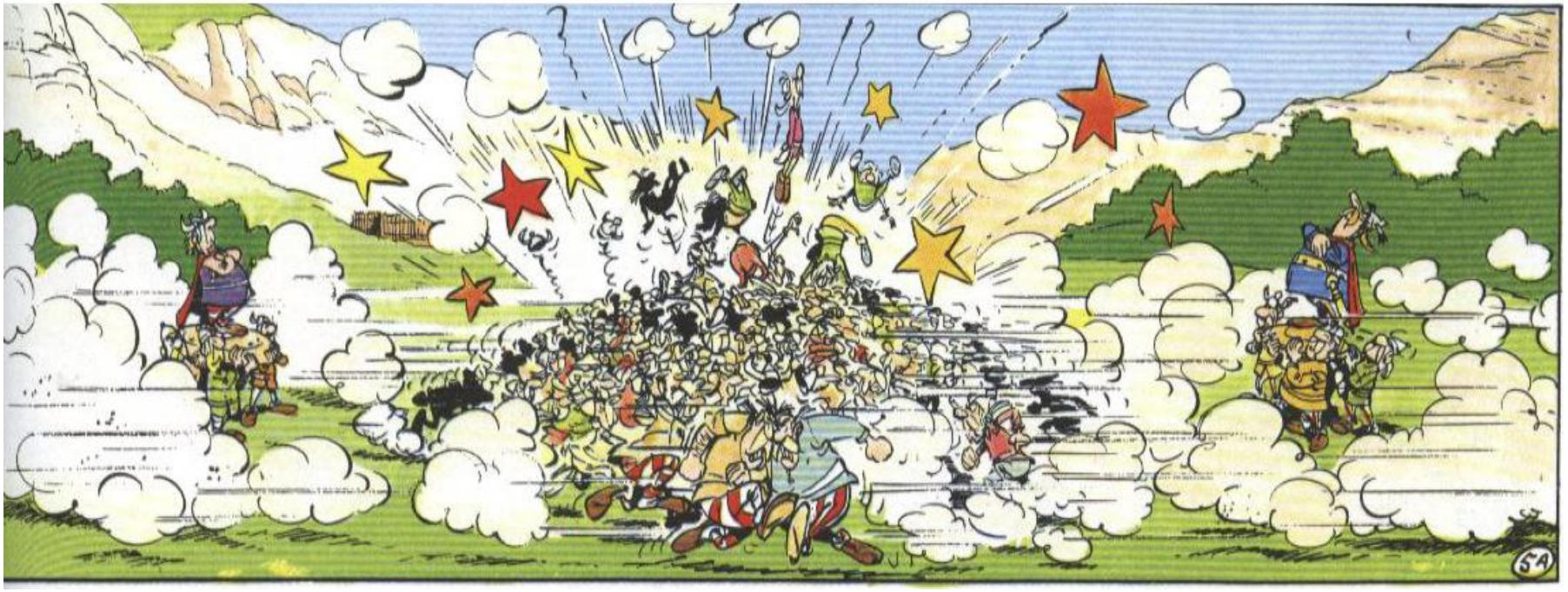
Notes on Underlying Event



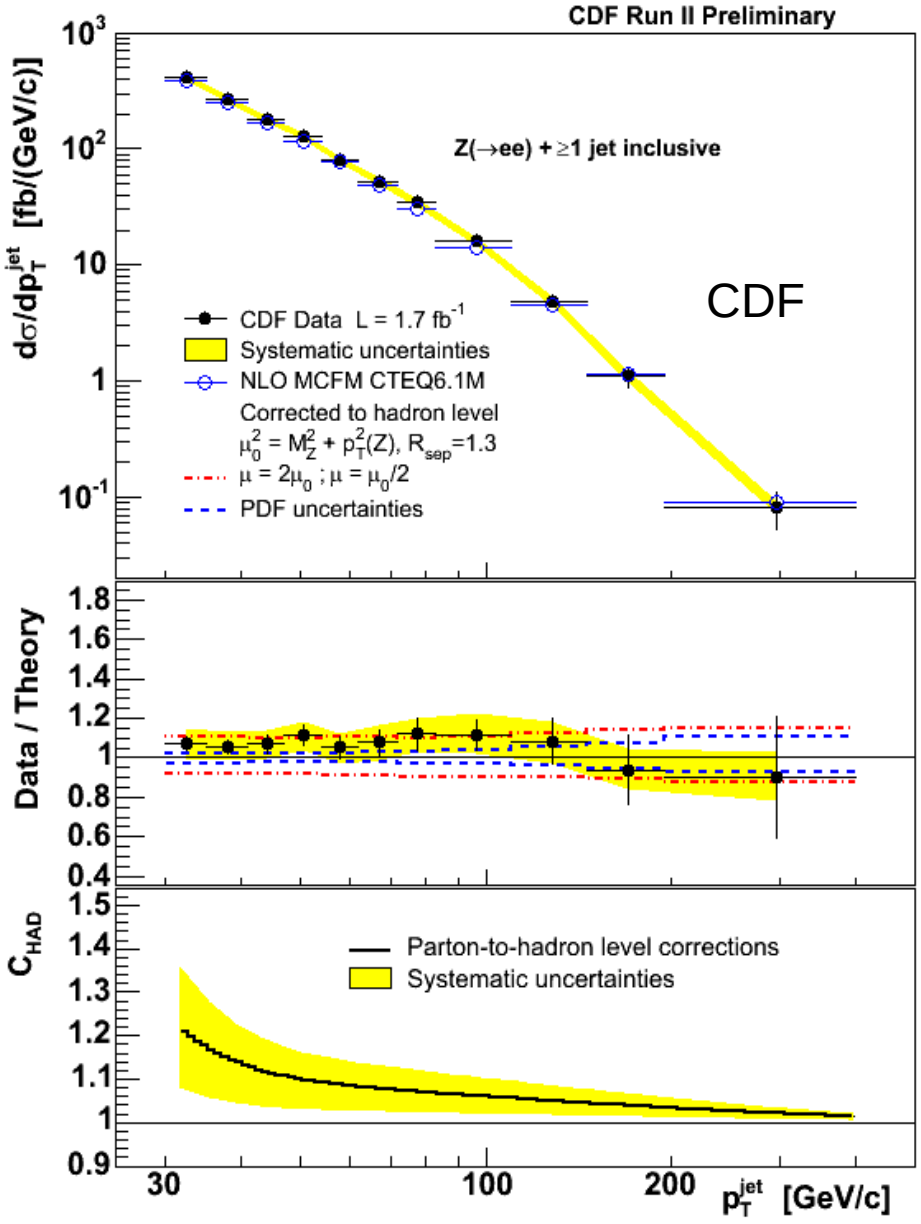


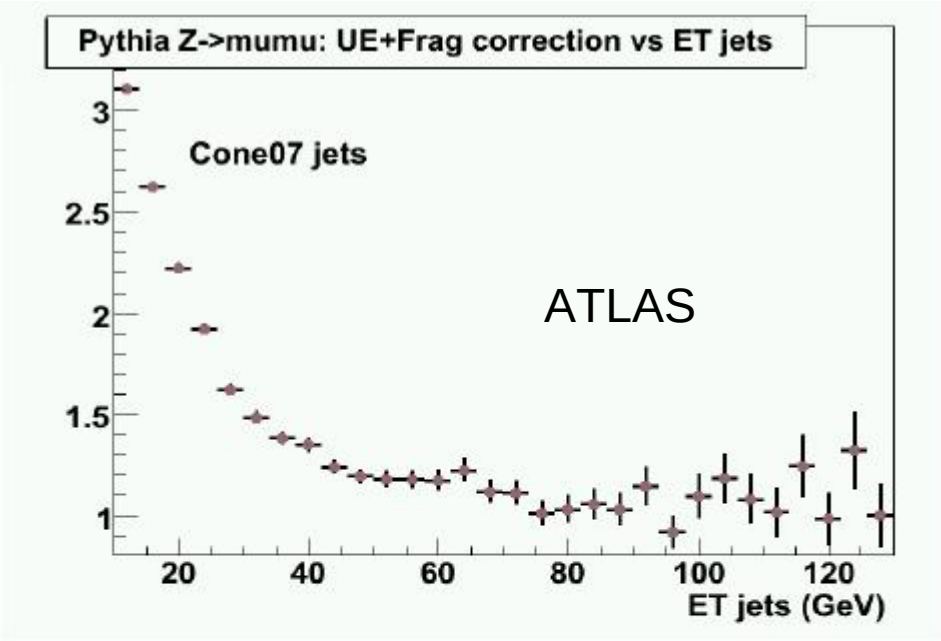
This is a clear unknown at LHC energies

- Dependence with physics process
- How "hard" will be ?



Underlying Event





According to PYTHIA:
25% - 30% higher non-pQCD correction
at low pt in ATLAS compared to CDF

Of course this is totally model dependent…
(E-flow measurement in the transverse
plane must be in the first to-do list)

SUSY vs Z+jets

SM E_T^{miss} sources

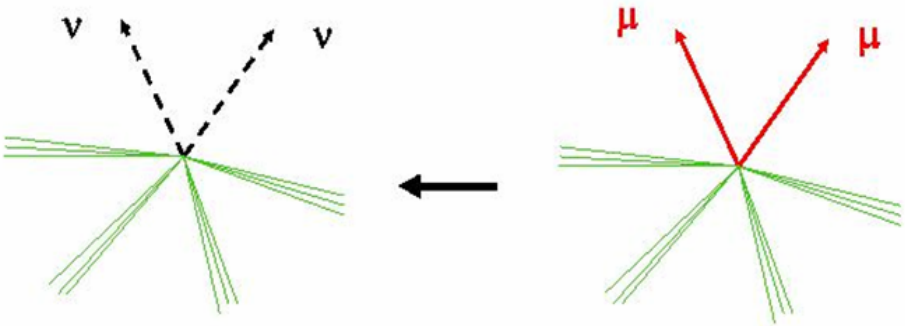
- **$Z \rightarrow \nu\nu$ + n jets**
- **$W \rightarrow l\nu$ + n jets**
- **$W \rightarrow \tau\nu$ + (n-1) jets (τ fakes jet)**

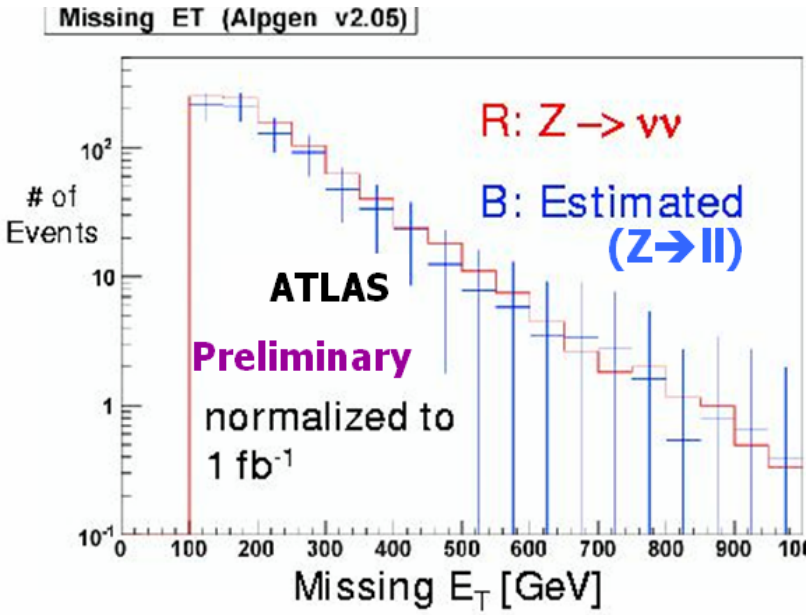
Use $Z \rightarrow l^+l^-$ + n jets (e or μ) as control sample

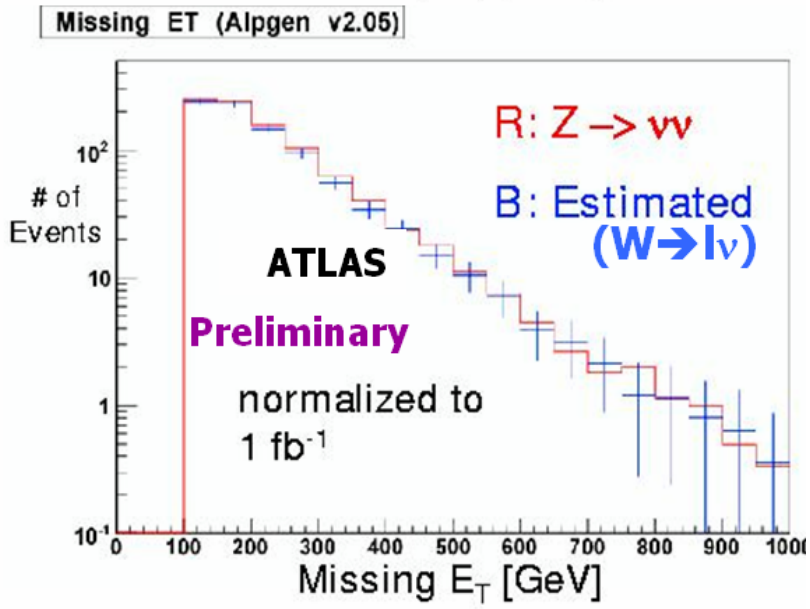
- **Tag leptonic Z and use to validate MC / estimate E_T^{miss} from $p_T(Z)$ & $p_T(l)$**

Alternatively tag $W \rightarrow l\nu$ + n jets and replace lepton with ν (0l):

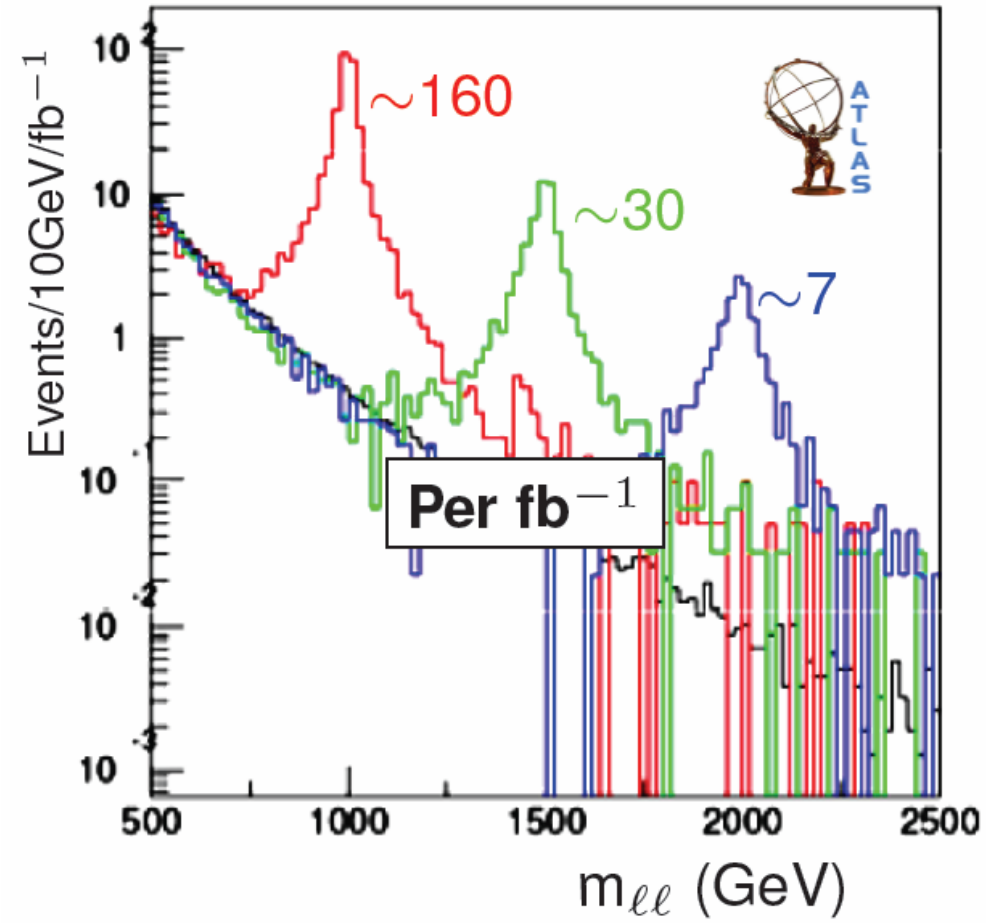
- **higher stats**
- **biased by presence of SUSY**







My Dream (X´→ e^+e^-)



Mass (TeV)	$\int \mathcal{L}dt$ for discovery
1	**~70 pb^{-1}**
1.5	~300 pb^{-1}
2	~1.5 fb^{-1}

…or at least that we would not need a real princess to find the pea.. (under the SM background)