Early physics with Atlas at LHC

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On behalf of the Atlas Collaboration

Outline

- Atlas Experiment Physics goals
- Next LHC run conditions
- Physics processes observable with early data
- In-situ detector calibration with collision events
- Early measurement of physics processes
- Conclusions

14th Lomonosov Conference on Elementary Particle Physics
Moscow , 19 August 2009

Atlas Physics goals

- Search and discover of:
  - the Higgs Boson for masses ~ 0.1-1 TeV
  - Supersymmetry
  - New Physics foreseen by other models beyond SM

- Precision measurements of SM processes

- Ability to detect and measure unexpected effects due to unforeseen scenarios

At which conditions the full physics goals can be achieved?

The necessary conditions are :

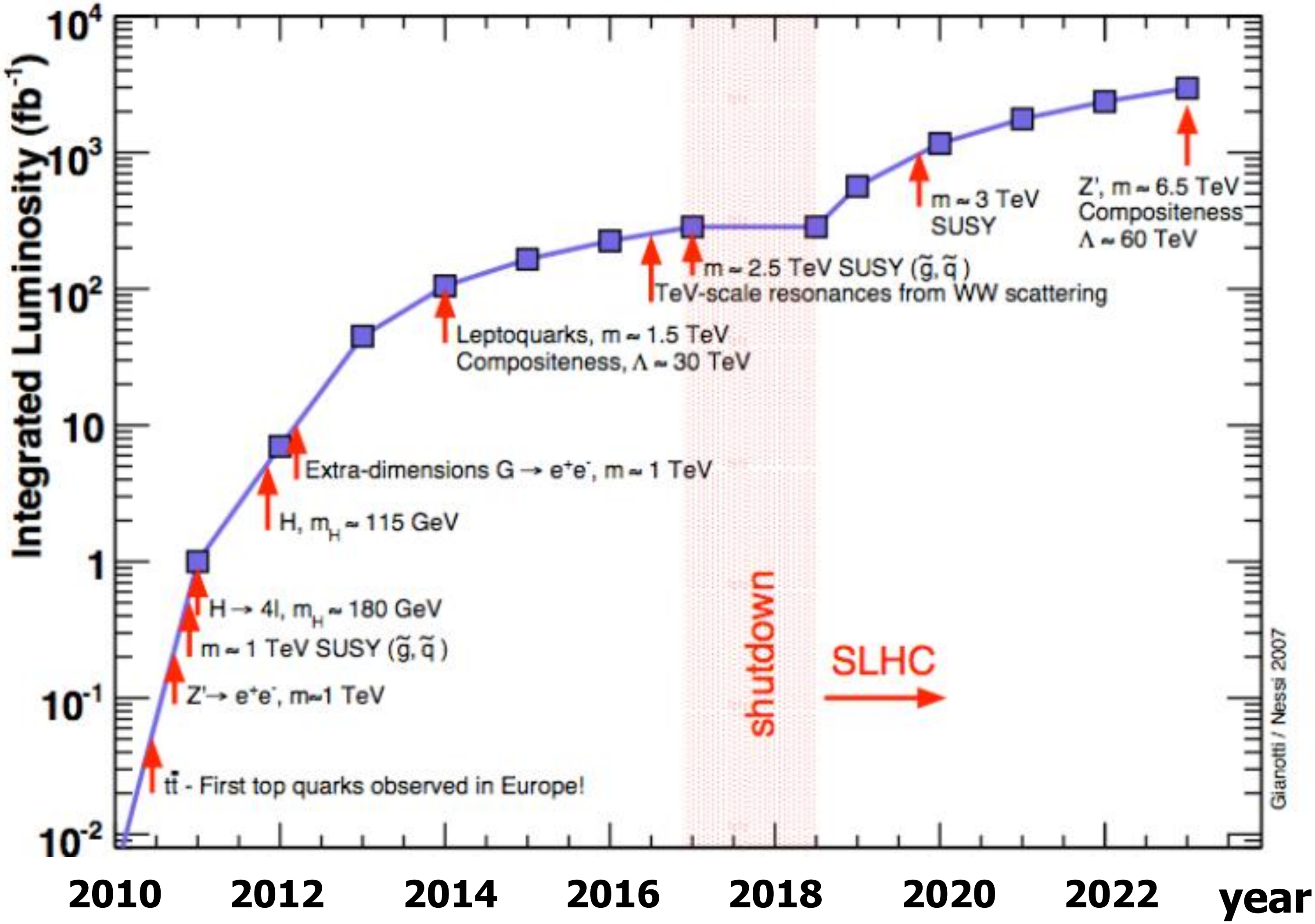
On the LHC side

- High collision energy
- High integrated luminosity

On the Atlas side

- Achievement of the detector nominal performances
- Accurate measurement of the characteristics of the most frequent physics processes which constitute background for the rare processes

This will require years of LHC running and of Atlas data analysis



Integrated Luminosity (fb^{-1})
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
2010
2012
2014
2016
2018
2020
2022
year
$t\bar{t}$ - First top quarks observed in Europe!
Z'→ e+e-, m≈1 TeV
m ≈ 1 TeV SUSY ($\tilde{g}$, $\tilde{q}$)
H → 4l, m_H ≈ 180 GeV
H, m_H ≈ 115 GeV
Extra-dimensions G → e+e-, m ≈ 1 TeV
Leptoquarks, m ≈ 1.5 TeV
Compositeness, Λ ≈ 30 TeV
TeV-scale resonances from WW scattering
m ≈ 2.5 TeV SUSY ($\tilde{g}$, $\tilde{q}$)
m ≈ 3 TeV
SUSY
Z', m ≈ 6.5 TeV
Compositeness
Λ ≈ 60 TeV
shutdown
SLHC
Gianotti / Nessi 2007

What are the perspectives of

the first Atlas run ?

Next LHC run conditions

LHC will start in fall 2009

Energy will be 3.5 – 5 TeV per beam

Luminosity will be ~ $10^{31} – 10^{32}$

The run will continue in 2010

Luminosity Integrated will be ~ 100 pb^{-1}

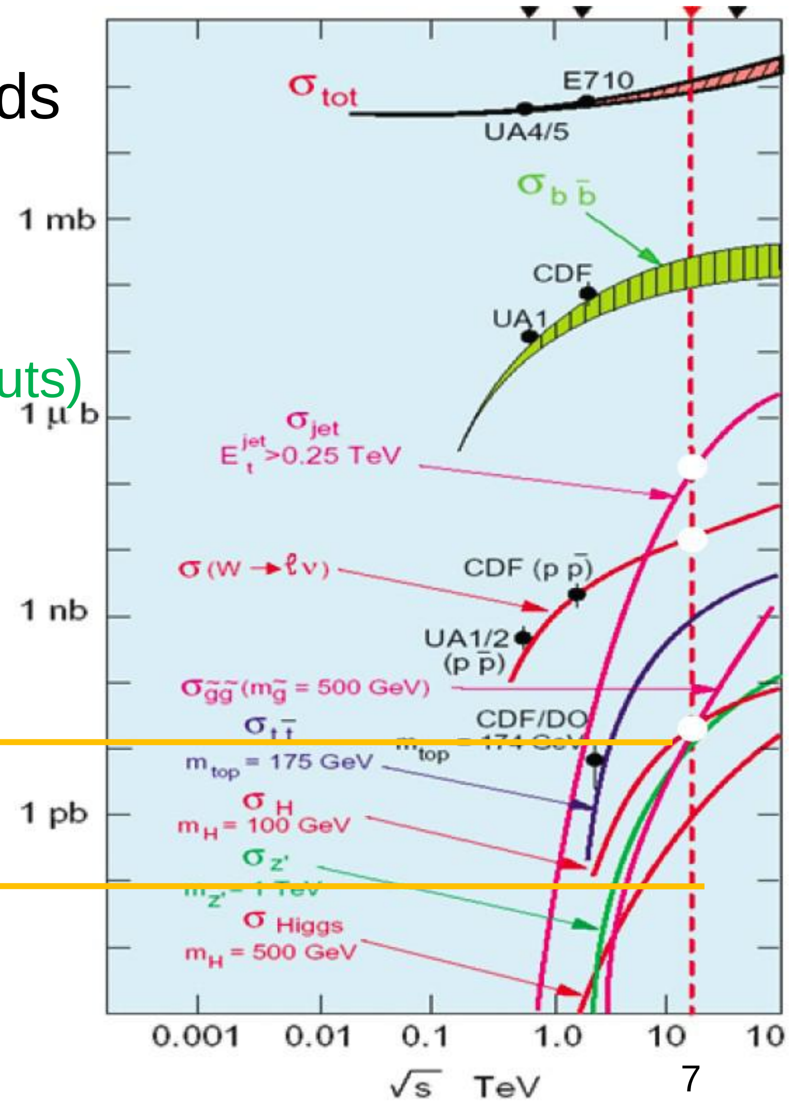
Physics processes observable with early data

The observability of a process depends on:

- the number of events produced $= L_{int} \cdot \sigma$
- the trigger efficiency (η-φ acceptance, p_T cuts)
- the background

1000 events produced / 100 pb-1

10 events produced / 100 pb-1



With the first ~100 pb-1 of collision data at 10 TeV

Measurement of Physics processes

- Particle multiplicity in minimum bias
- Jet cross-section
- W, Z cross-sections
- tt cross-section

…………

Improvement of MC calculation ingredients

- Improve knowledge of PDF with W/Z
- Tuning of MC (minimum-bias, underlying event, tt, W/Z+jets, QCD jets,…)

New discoveries

SUSY up to gluino and squark masses of ~ 0.75 TeV ?
Discover a Z' up to masses of ~ 1 TeV ?

Detector performance and in-situ calibration

	Initial	Ultimate	Physics samples for calibration
ECAL uniformity	**~2.5%**	**0.7%**	**Isolated electrons, $Z \rightarrow ee$**
e/γ E-scale	**2-3%**	**<0.1%**	**J/ψ, $Z \rightarrow ee$, E/p for electrons**
Jet E-scale	**5-10%**	**1%**	**$\gamma/Z + 1j$, $W \rightarrow jj$ in tt events**
ID alignment	**20-200 μm**	**5 μm**	**Generic tracks, isolated μ, $Z \rightarrow \mu\mu$**
Muon alignment	**40-1000 μm**	**40 μm**	**Straight μ, $Z \rightarrow \mu\mu$**

Channels (examples ...)	Expected events in ATLAS after cuts $\sqrt{s}$= 10 TeV, 100 pb^{-1}
$J/\psi \rightarrow \mu\,\mu$	~ 10^6
$\Upsilon \rightarrow \mu\,\mu$	~ 5 10^4
$W \rightarrow \mu\,\nu$	~ 3 10^5
$Z \rightarrow \mu\,\mu$	~ 3 10^4
$tt \rightarrow W\,b\,W\,b \rightarrow \mu\,\nu + X$	~ 350

Minimum Bias

Goals of the study of the min. bias events :

Measure the properties of the inelastic pp interaction processes in a new energy regime

Determine the characteristics of the background at high luminosity due to pile-up events

Detector performance required :

Unbiased trigger

Tracking efficiency at low p_T

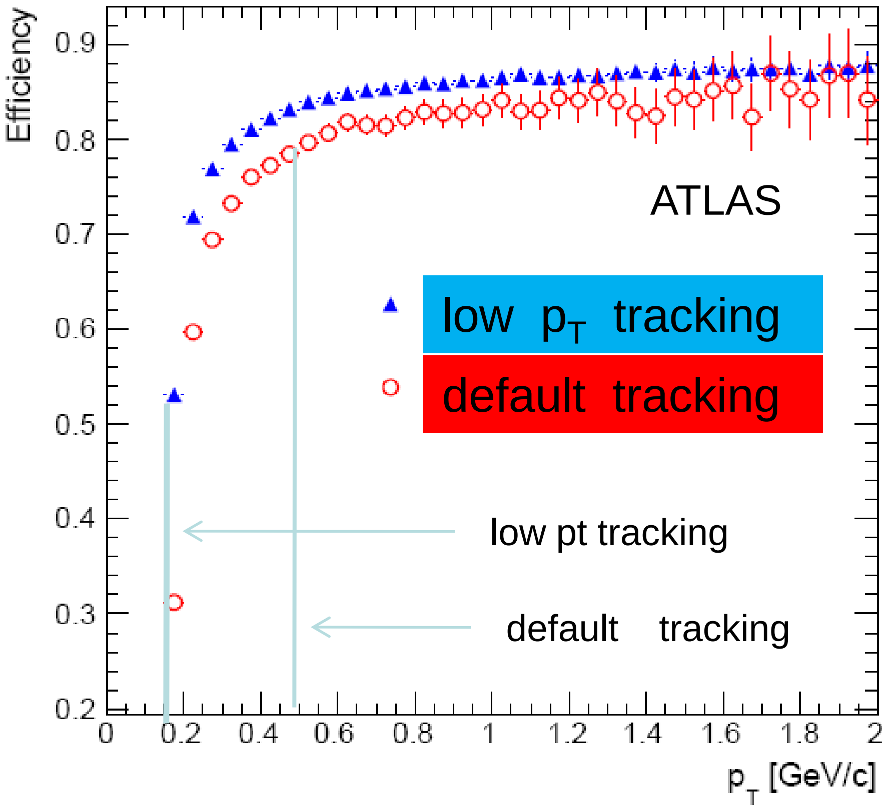
ID tracking

- The ID consists of many layers of Pixel , Si microstrip (SCT) and TRT (gas based transition radiation detector) in a Solenoidal field of 2 Tesla

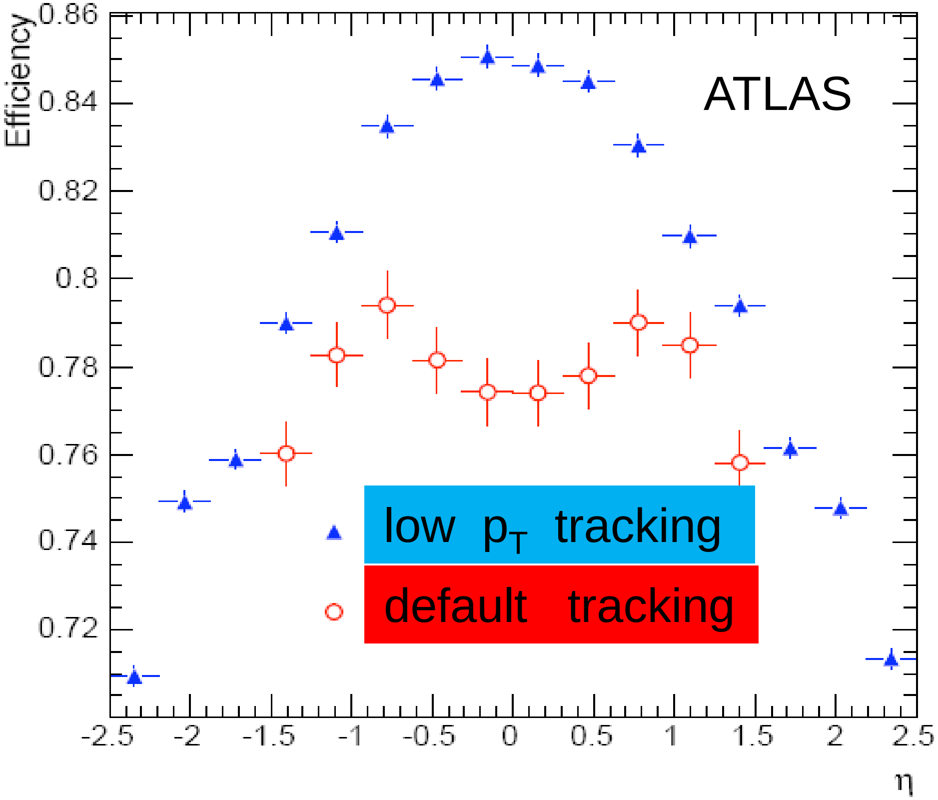
- Tracks with p_T>500 MeV traverse the full inner detector

- Tracks with p_T>150 MeV traverse the full Si precision tracker (Pixel and SCT)

Low pt tracking performance

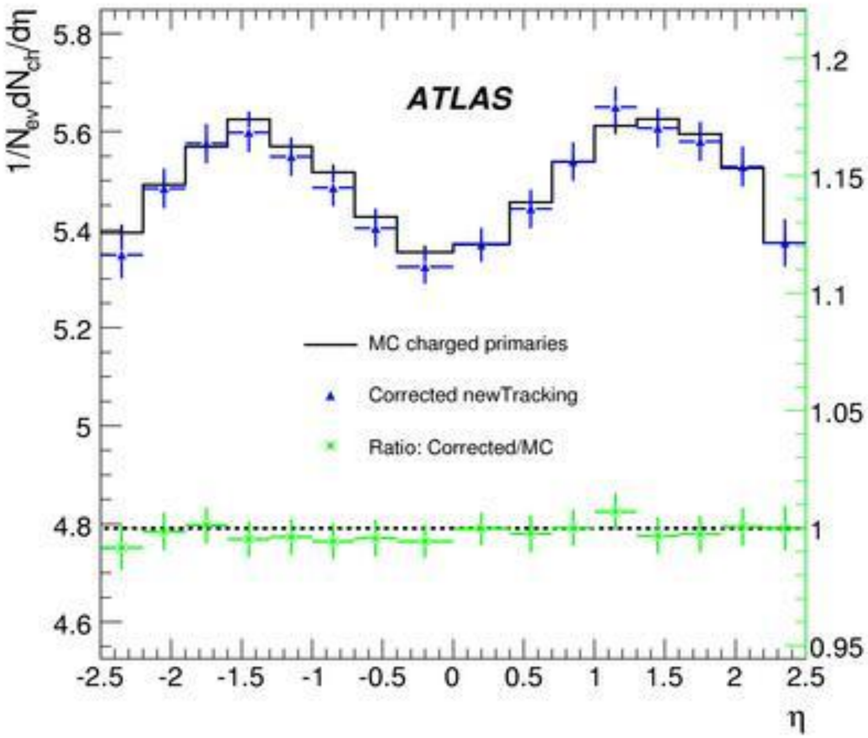


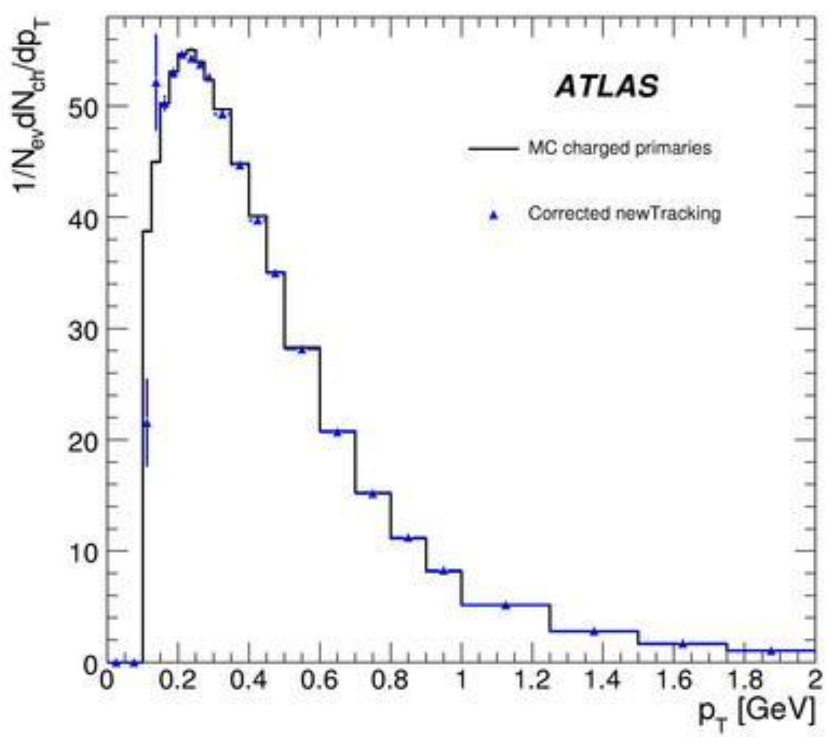
Tracking efficiency vs p_T
($-2.5 < \eta < 2.5$)



Tracking efficiency vs η
($P_T > 150$ MeV)

Measurement of the η and p_T distributions

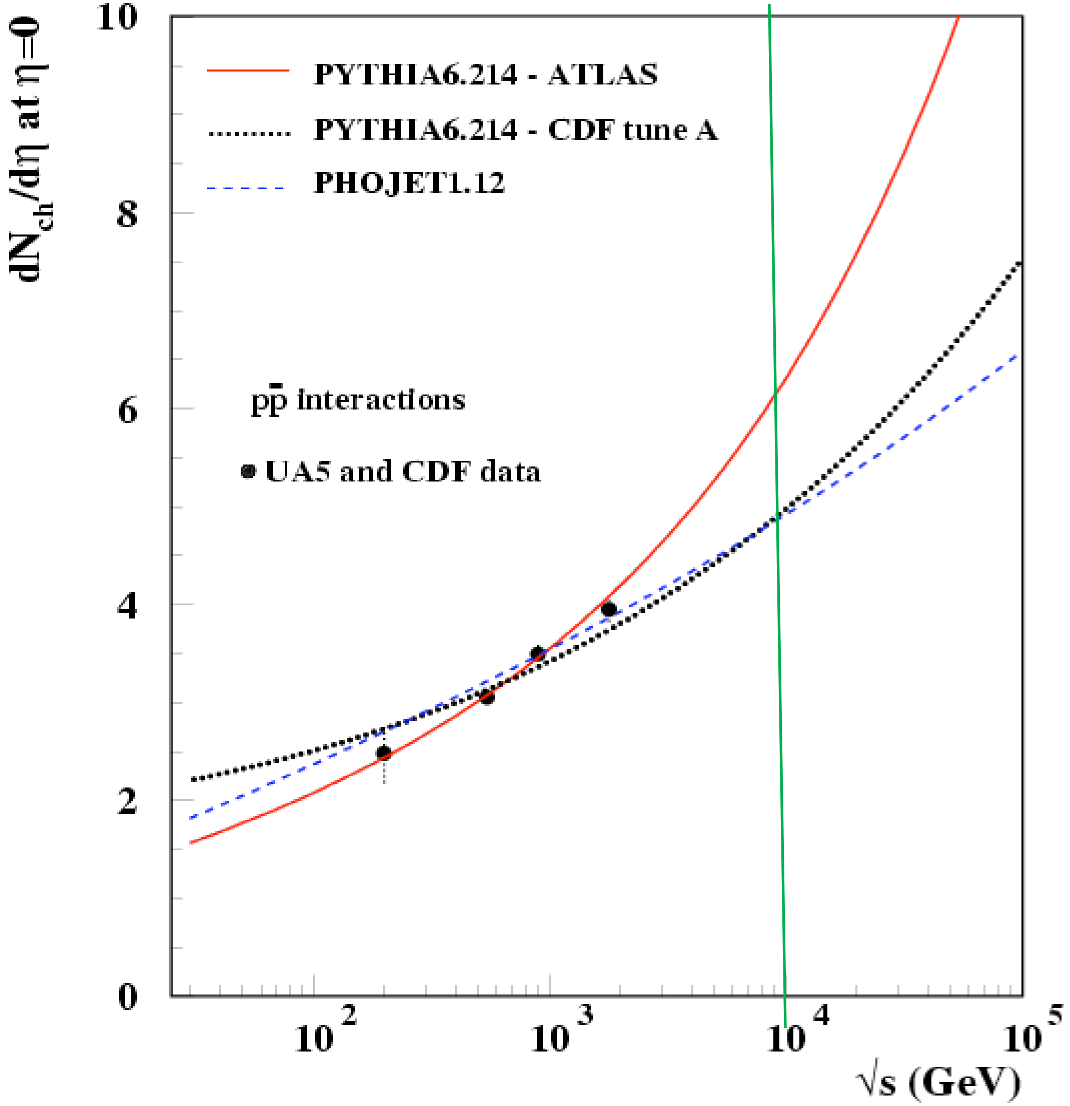




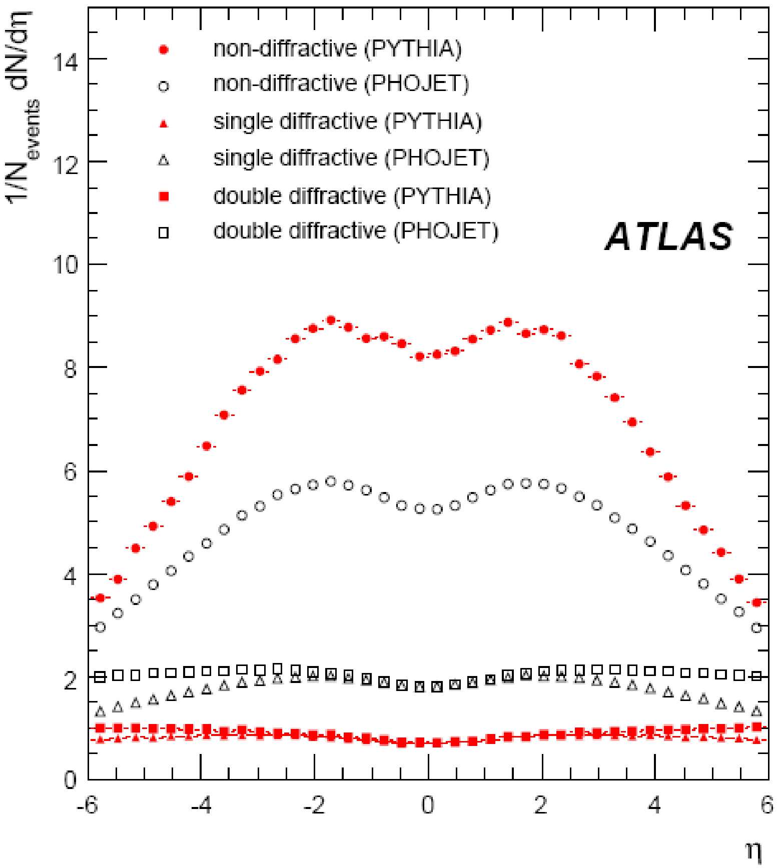
η distribution

p_T distribution

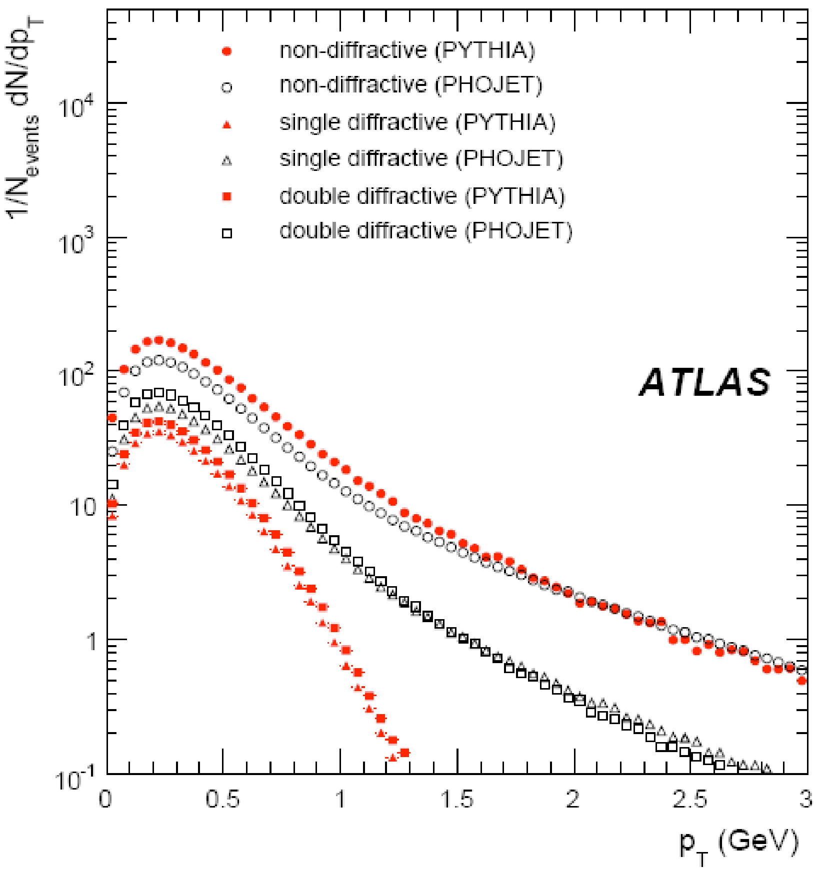
Present Expectations



Present Expectations



η distribution



pt distribution

QCD jet physics

Goals of the study of the high p_T jet events :

Measure the properties of the very hard pp interaction processes

Look for deviations from QCD predictions due to New Physics
(quark substructure, resonant production, large extra dimensions,…)

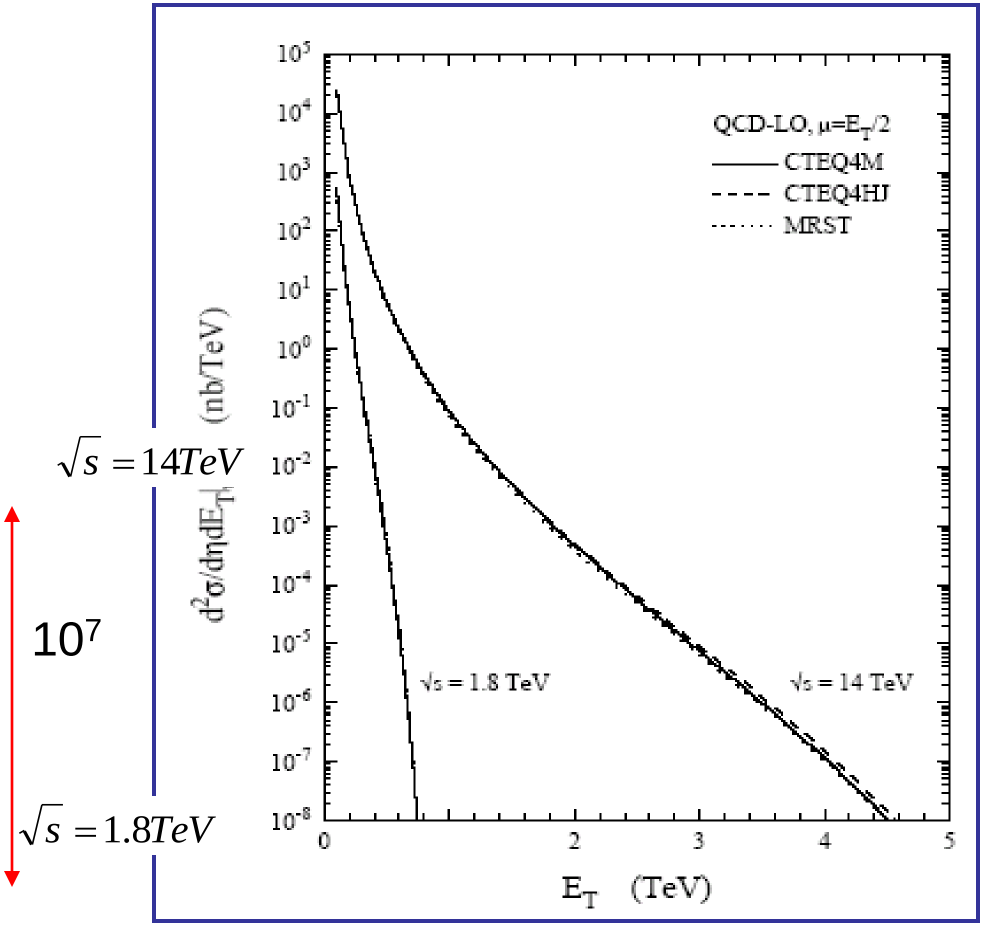
Determine the characteristics of the background from QCD events for the observation of other processes

Detector and analysis performance required :

Use of a jet algorithm appropriate for comparison with theoretical calculations (colinear and infrared safe)

Absolute calibration of the jet energy scale

Expected Jet inclusive E_T distribution

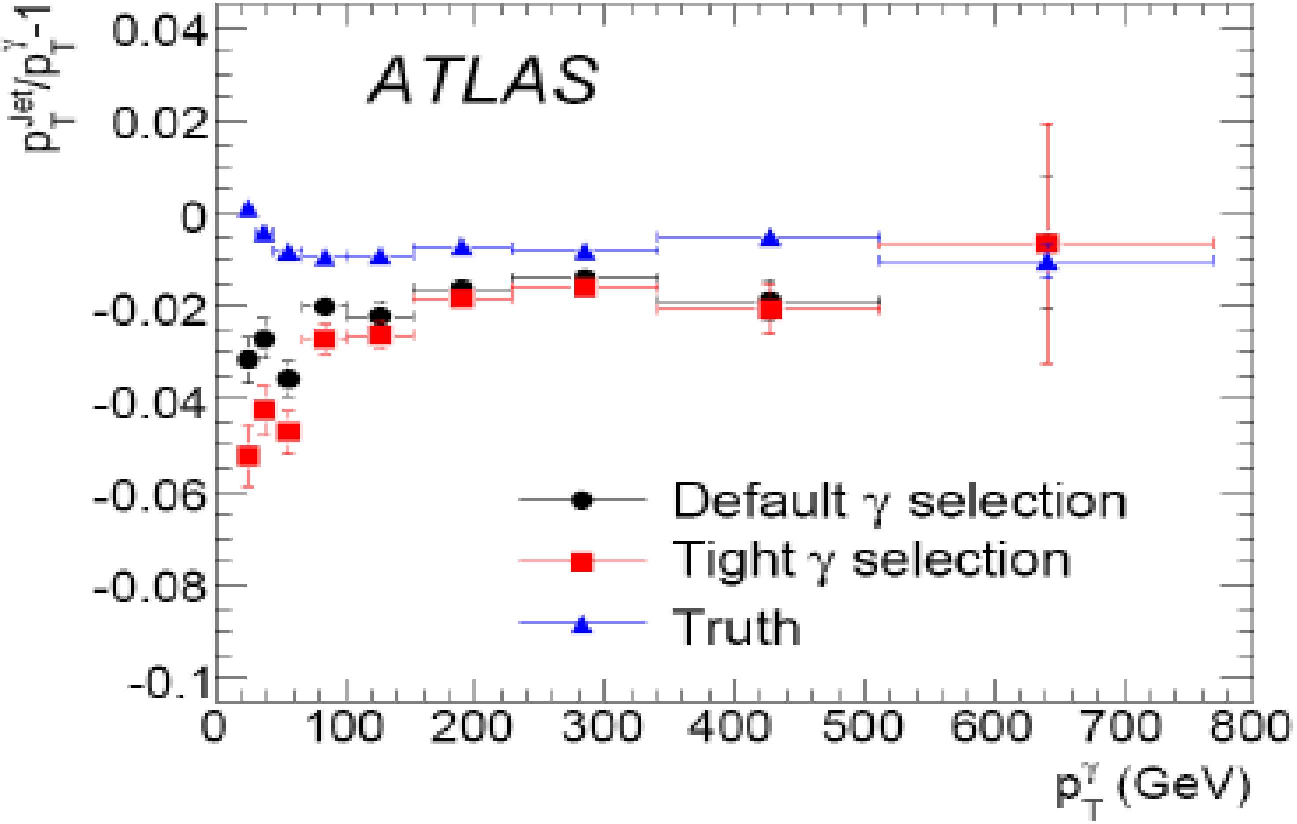


10 pb^{-1} @ 14 TeV -> O(100) jet p_T > 1TeV
D0 e CDF p_TMax = 700 GeV

Calibration of the Jet Energy Scale

- The jet energy has to be corrected for detector effects(non compensation, noise, cracks….) and for physics effects (clustering, fragmentation, ISR and FSR, UE….)
- The procedure is rather complex
- In-situ calibration with physics processes (dijet, γ/Z + jet, multijet, W->jet jet) is used to estimate systematic uncertainty and resolution and to perform the final tuning of the jet energy scale

γ-jet p_T balance



With 100 pb-1 statistical uncertainty on JES ~ 1-2% for 100-200<pT<500GeV

Systematics from physics ~ 1-2% (ISR/FSR, UE)

W and Z physics

Goals of the study of the W and Z events :

Measure their production cross-sections known theoretically with uncertainty ~ 1%

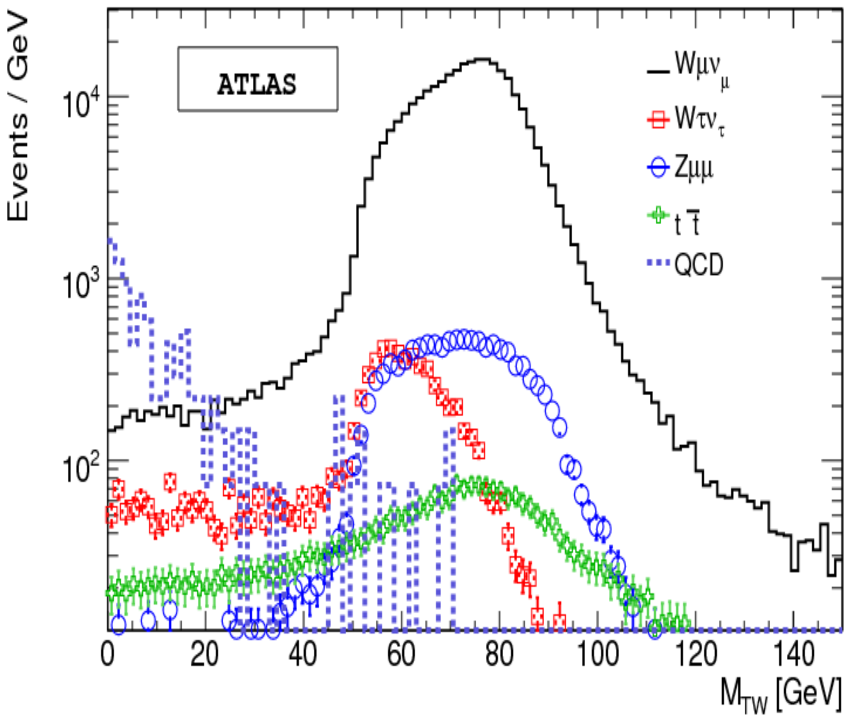
Measure p_T distribution to probe QCD initial parton radiation

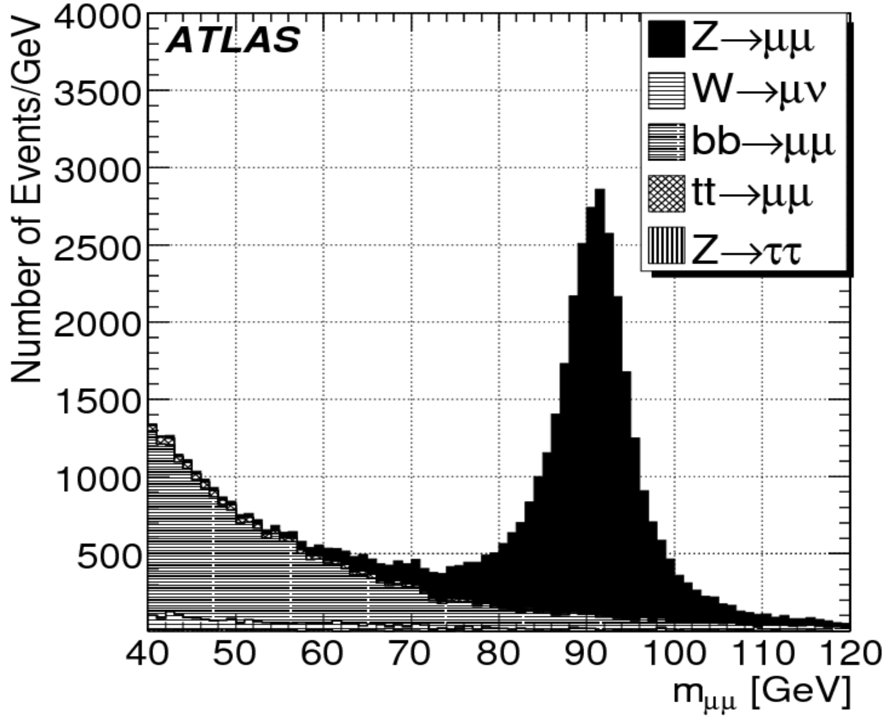
Measure rapidity distribution to probe parton density functions (PDF)

Detector performance :

Use well known properties of the events to perform in-situ detector calibration (absolute energy and momentum scale, resolution, trigger and reconstruction efficiency)

Measurement of W and Z cross-sections
(L_{int} 50 pb-1)





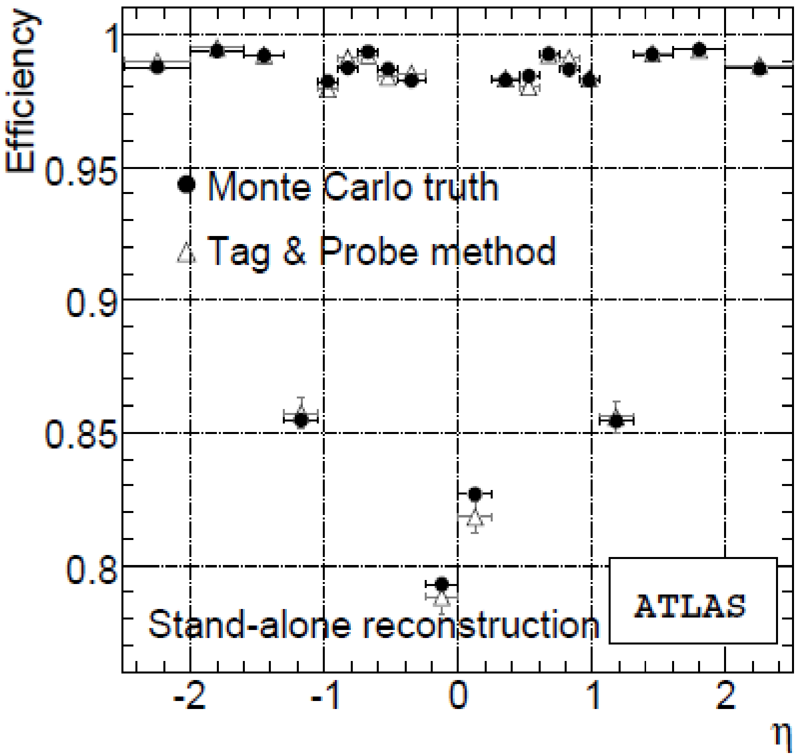
Process	$N(\times 10^4)$	$B(\times 10^4)$	$A \times \varepsilon$	$\delta A/A$	$\delta\varepsilon/\varepsilon$	σ (pb)
$W \to e\nu$	22.67 ± 0.04	0.61 ± 0.92	0.215	0.023	0.02	$20520 \pm 40 \pm 1060$
$W \to \mu\nu$	30.04 ± 0.05	2.01 ± 0.12	0.273	0.023	0.02	$20530 \pm 40 \pm 630$
$Z \to ee$	2.71 ± 0.02	0.23 ± 0.04	0.246	0.023	0.03	$2016 \pm 16 \pm 83$
$Z \to \mu\mu$	2.57 ± 0.02	0.010 ± 0.002	0.254	0.023	0.03	$2016 \pm 16 \pm 76$

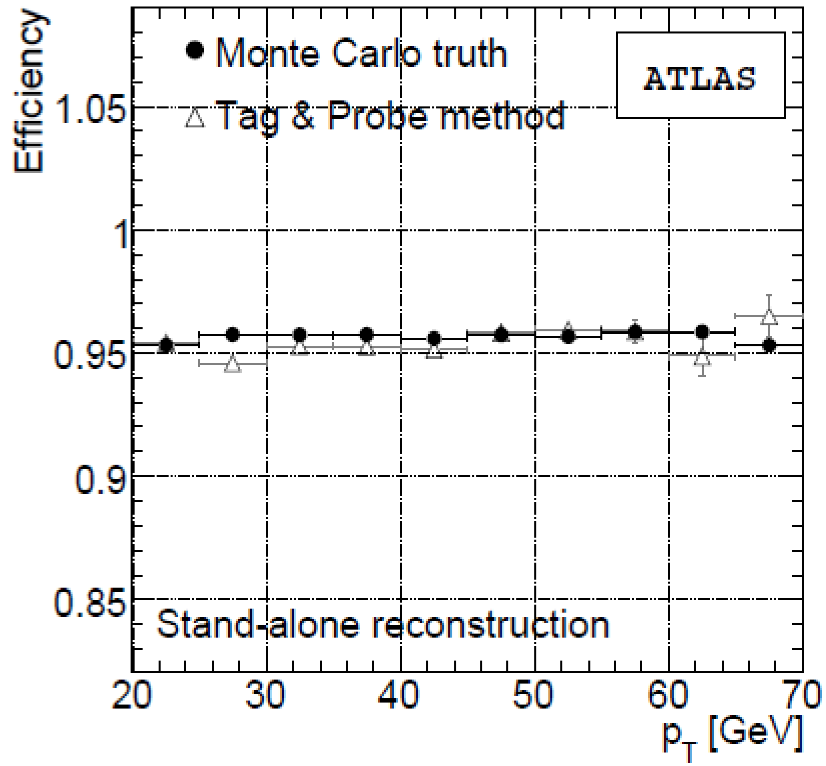
In-situ calibration of the μ reconstruction efficiency from events Z→μμ

Tag and probe method

tag μ : μ fully identified in the detector (ID and MS track)

probe μ : ID track forming the Z mass with the tag μ





Efficiency vs η and p_T : in-situ calibration compared with MC truth

t t   physics

Goals of the study of the t t events :

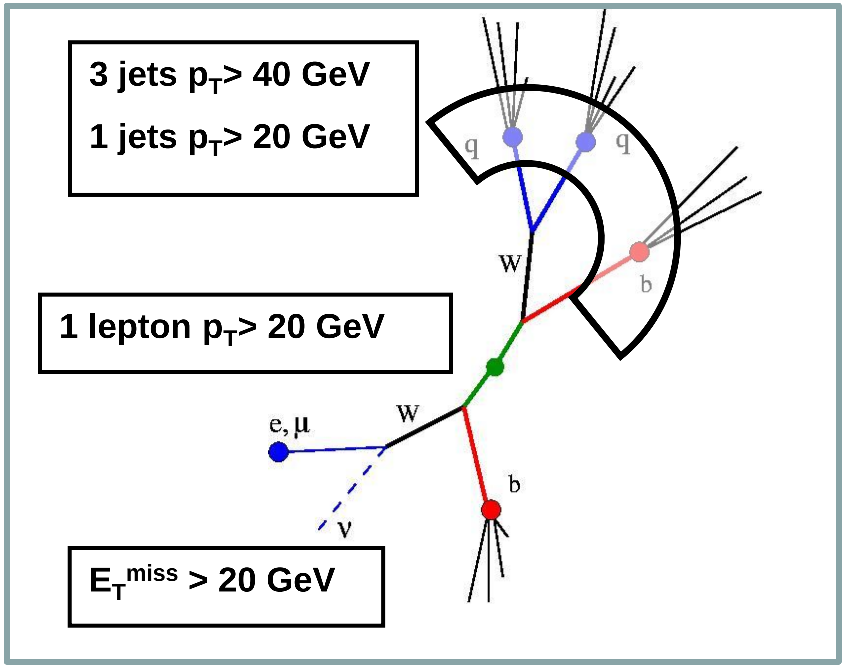
Measure tt cross-section
Study top properties and decay

Detector performance :

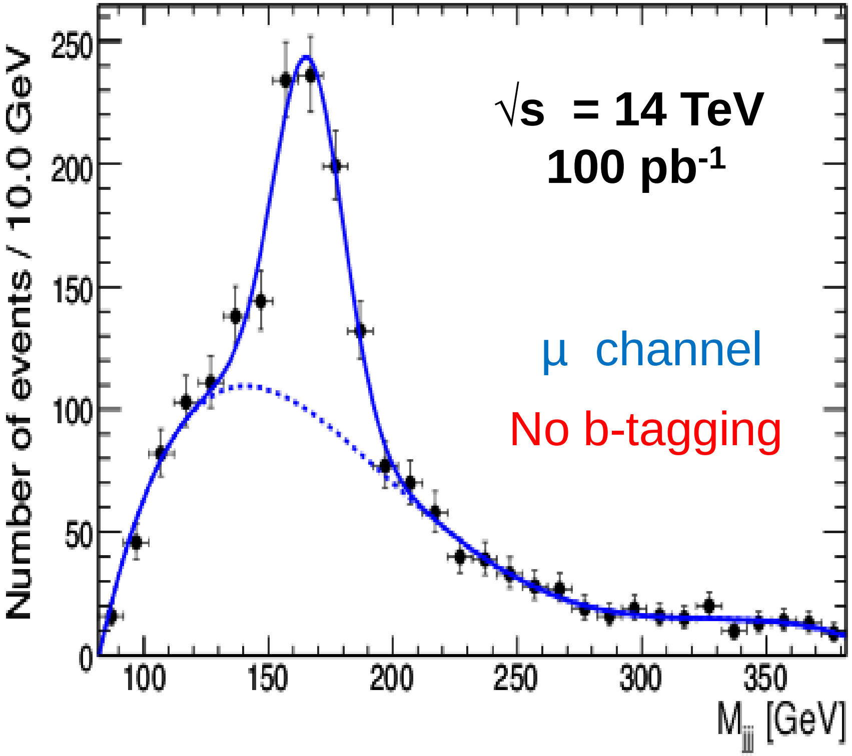
In-situ detector calibration (b-tagging efficiency, light jet energy scale)
using b-jet and W->jj from tt events

tt signal

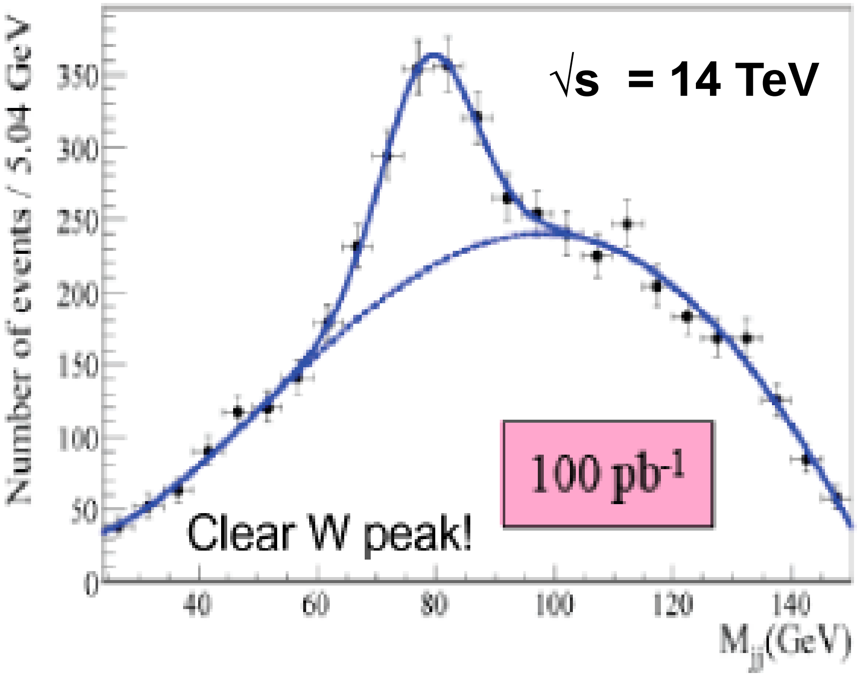
Single Lepton channel

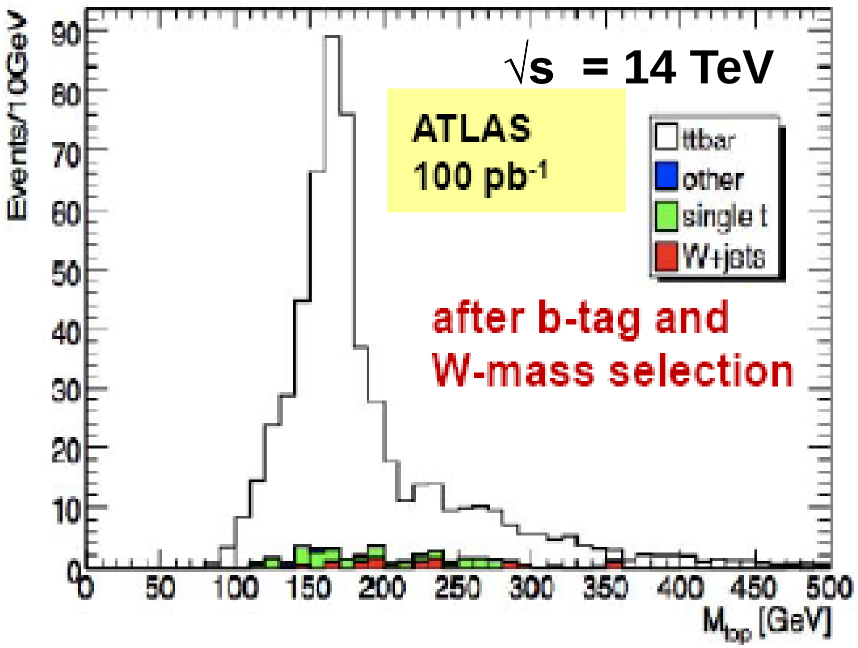


tt -> Wb Wb -> ℓνb qqb



three jet mass





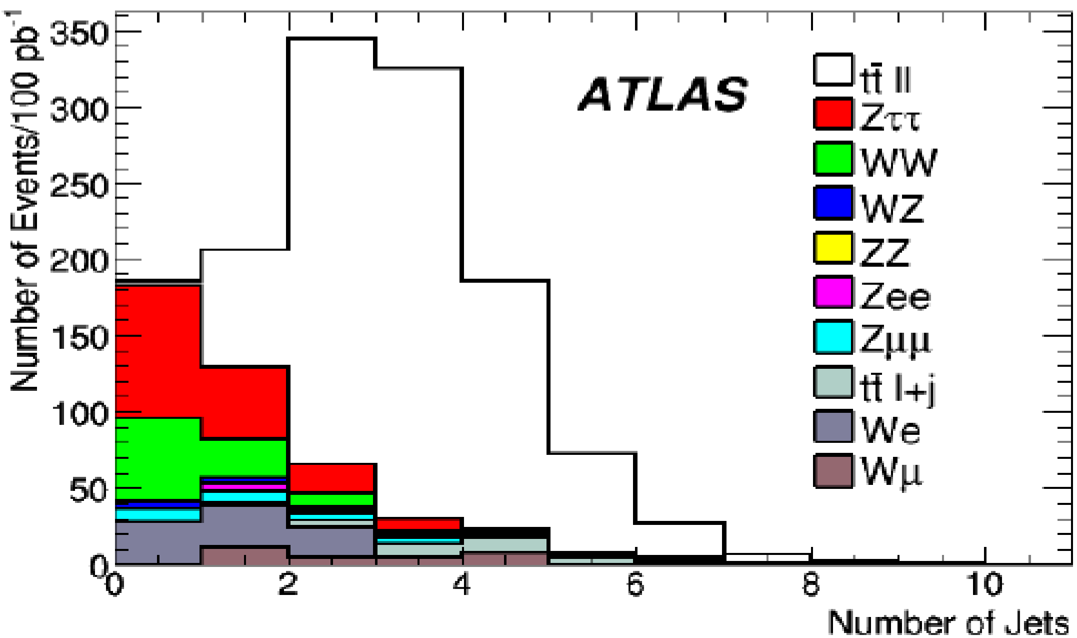
Cross section measurement (test of perturbative QCD) with data corresponding to 100 pb^{-1} possible with an accuracy of ±10-15%

Errors are dominated by systematics
(jet energy scale, Monte Carlo modeling (ISR, FSR),...)

tt signal

Di-lepton channel : **tt -> Wb Wb -> ℓνb ℓνb**

2 leptons with p_T>20 GeV
E_T^{miss}> 25 GeV (30 for ee/μμ)
Veto Z-mass window (85-95 GeV)



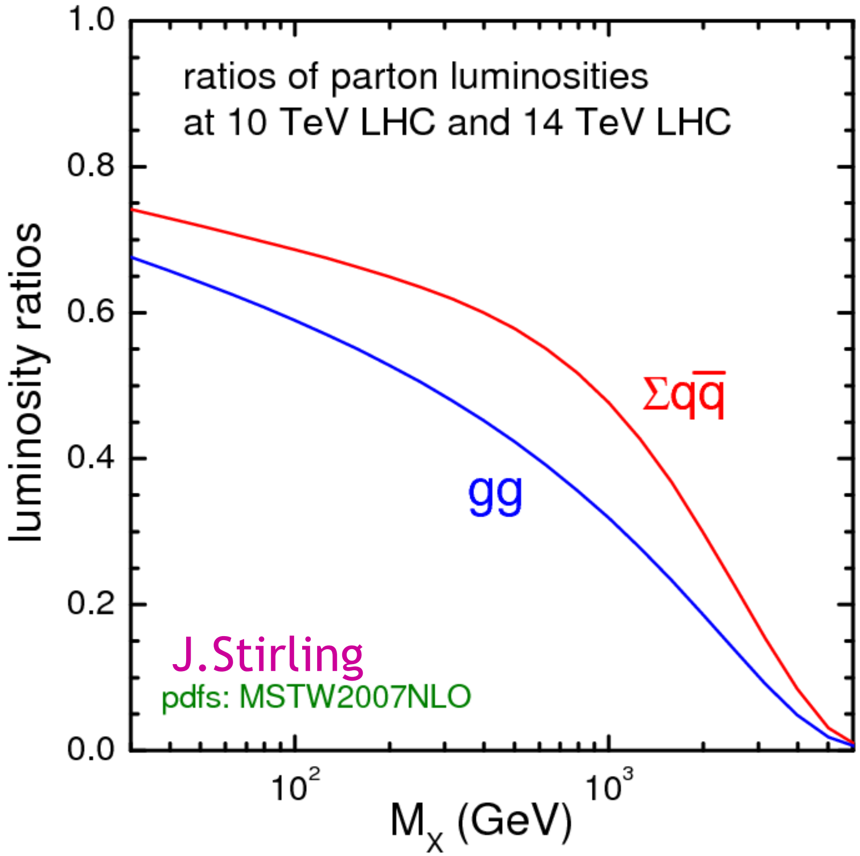
(p$_T$>20 GeV)

Signal shows up with low background in the sample with N_{jet} ≥ 2

Systematic uncertainties smaller than for the single lepton channel

Early discoveries of New Physics ?

10 TeV vs 14 TeV



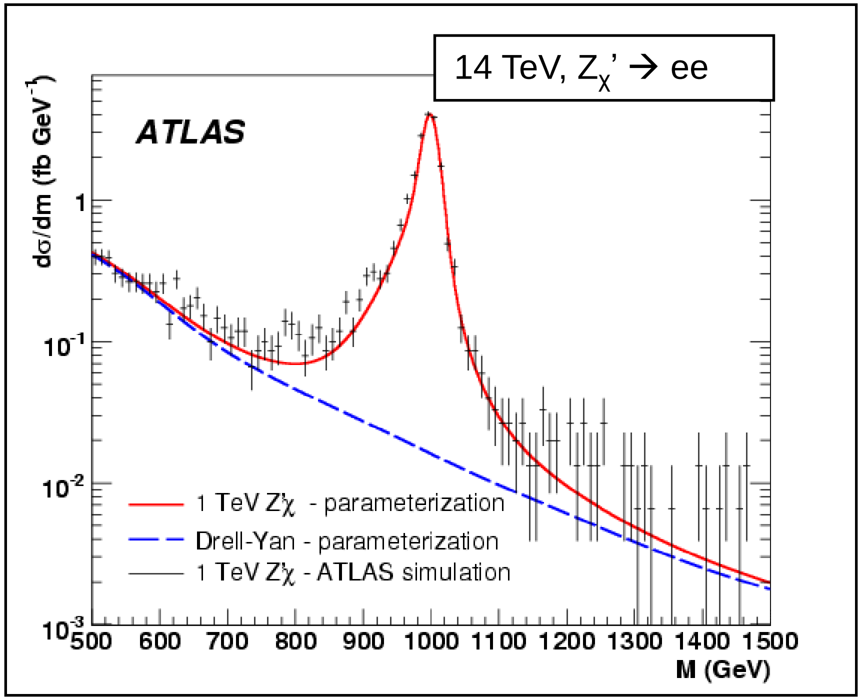
At 10 TeV, more difficult to create high mass objects

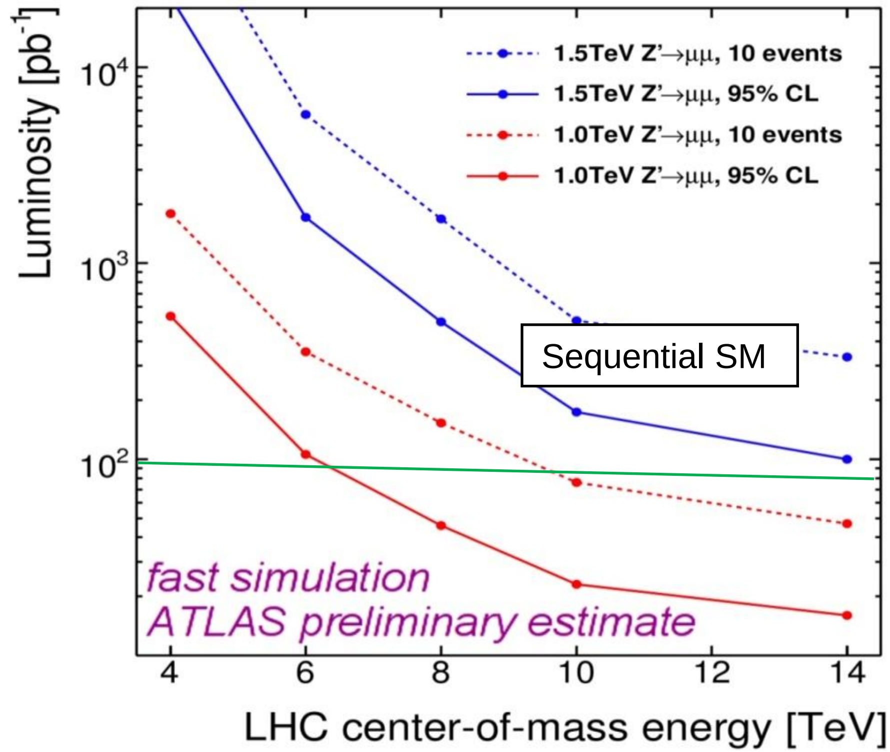
Below about 300 GeV, this suppression is <50% (process dependent)

Above ~ 1 TeV the effect is more marked

Some simulation results reported have been obtained at 14 TeV
They are to be scaled to 10 TeV taking into account the ratio of parton luminosities

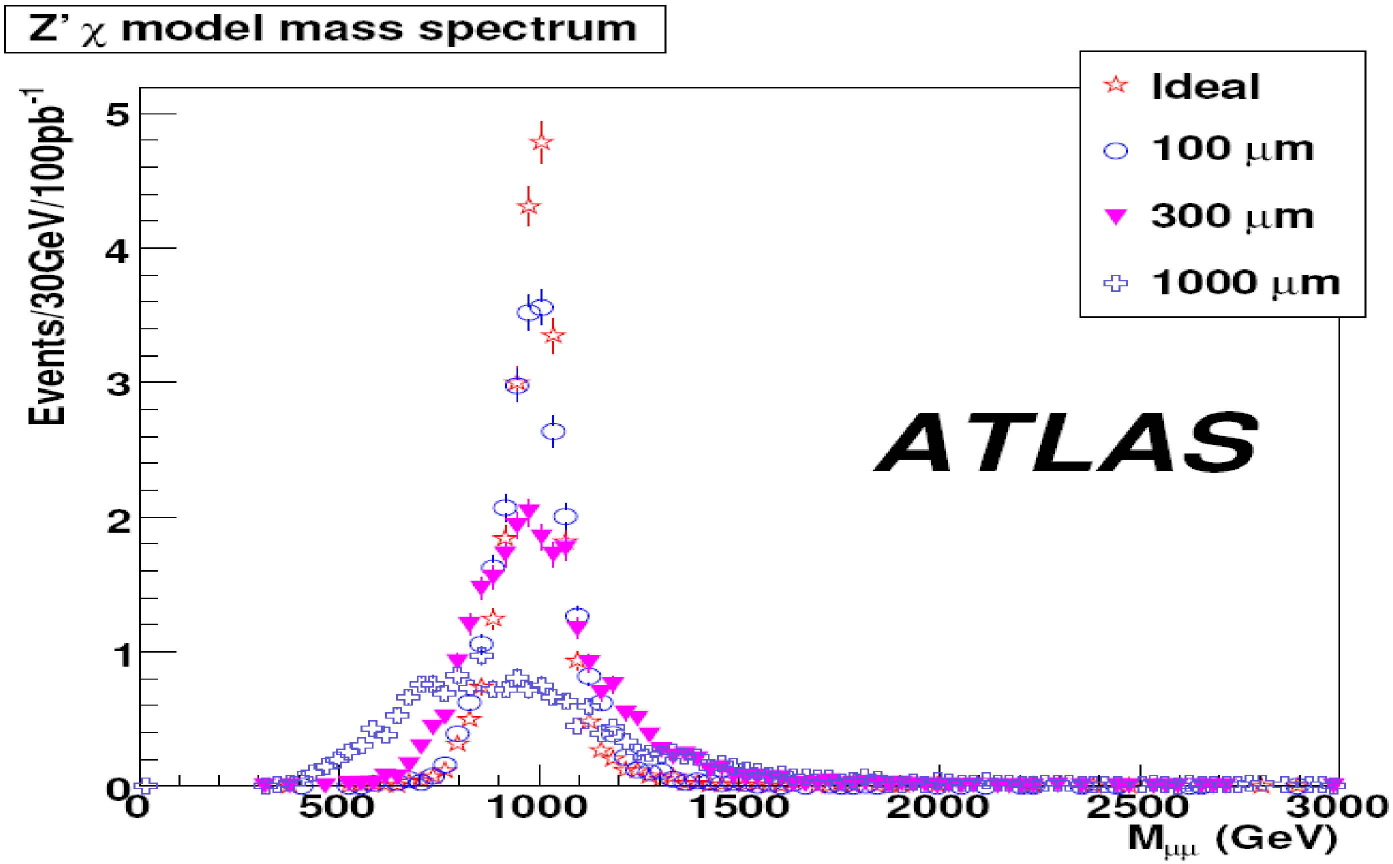
Z' → l l





- Signal is (narrow) mass peak above small and smooth SM background
- Discovery for m ~ 1 TeV possible with 100 pb^{-1} at 10 TeV

The observation of Z’->ll signal does not require ultimate detector performance

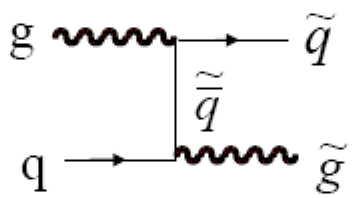


Effect of misalignement of the μ chambers on the $M_{\mu\mu}$ signal from Z’->μμ events

SUSY

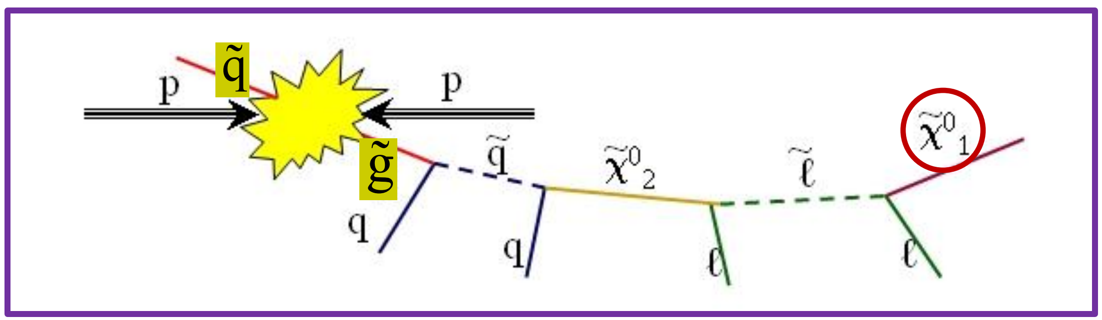
Squarks and gluinos produced via strong processes → large cross-section

e.g.



M (GeV)	σ (pb)
500	100
1000	1
2000	0.01

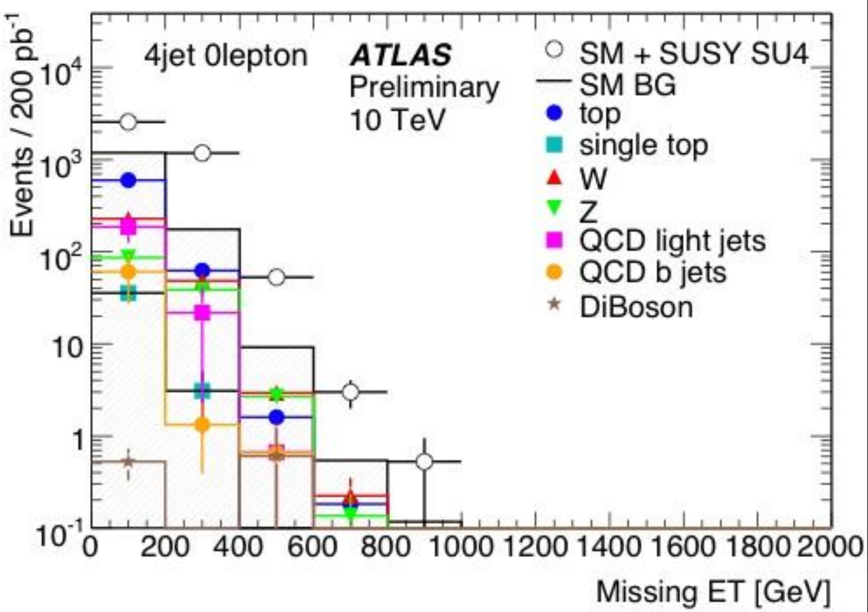
for $m(\tilde{q},\tilde{g}) \sim 1$ TeV **~ 100 events produced with 100 pb^{-1}**

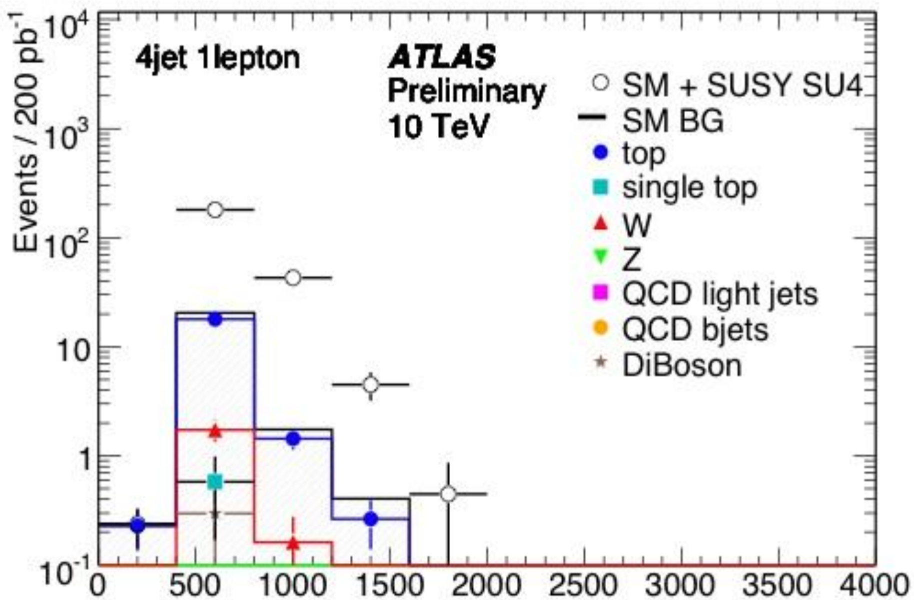


Spectacular final states : many jets, leptons, missing transverse energy

Simulation at $\sqrt{s}$ = 10 TeV   200 pb^{-1}

for $m(\tilde{q},\tilde{g}) \sim 410$ GeV



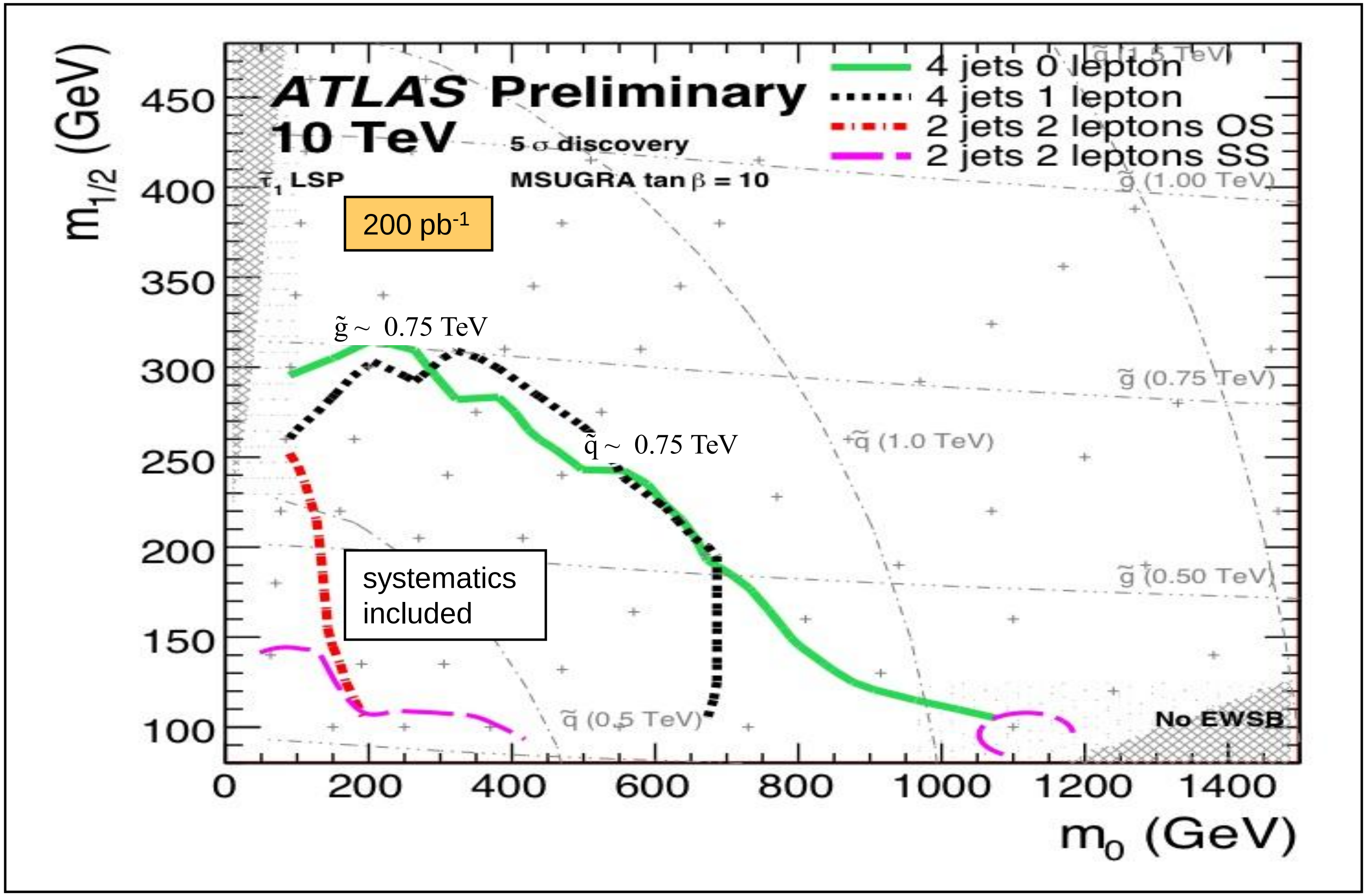


$$M_{\text{eff}} \equiv \sum_{i=1}^{4} p_T^{\text{jet},i} + \sum_{i=1} p_T^{\text{lep},i} + E_T^{\text{miss}}$$

Jets + E_T^{miss}

Jets + E_T^{miss} + lepton

Discovery reach



Discovery up to m ~ 750 GeV with 200 pb^{-1} at $\sqrt{s}$ =10 TeV

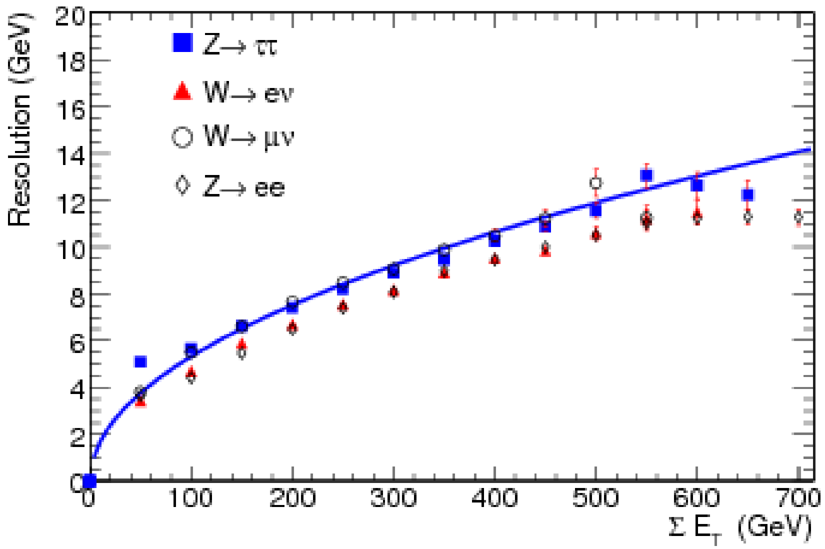
Detector and analysis performance required:

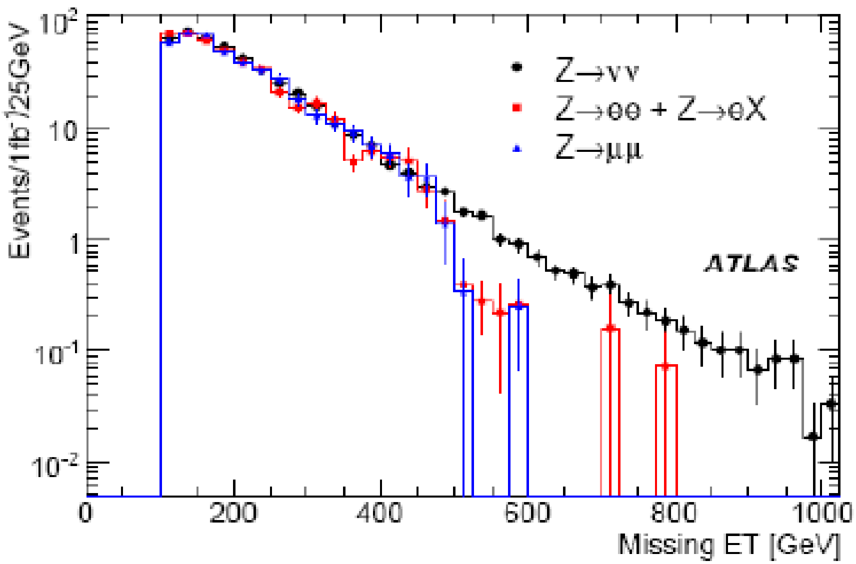
Understanding the fake missing transverse energy coming from instrumental effects
(noise, cracks, beam gas scattering, machine background,…)

Understanding the physics background from SM processes

E_T^{miss} can be checked with known processes

Data-driven methods to estimate the background can be used





Conclusions

- **The study of a variety of SM processes in a new energy regime and the search for some of the new particles foreseen by the models beyond the SM are the physics prospects of the first LHC run.**
- **The analysis of the data collected will also provide the verification and the tuning of the Atlas detector calibration, necessary to improve the performances and reduce the systematics.**
- **With a well understood and calibrated detector unexpected effects possibly leading to surprising discoveries can be looked upon.**

Atlas eagerly waits for LHC collisions !