"SUSY07" The 15th International Conference on
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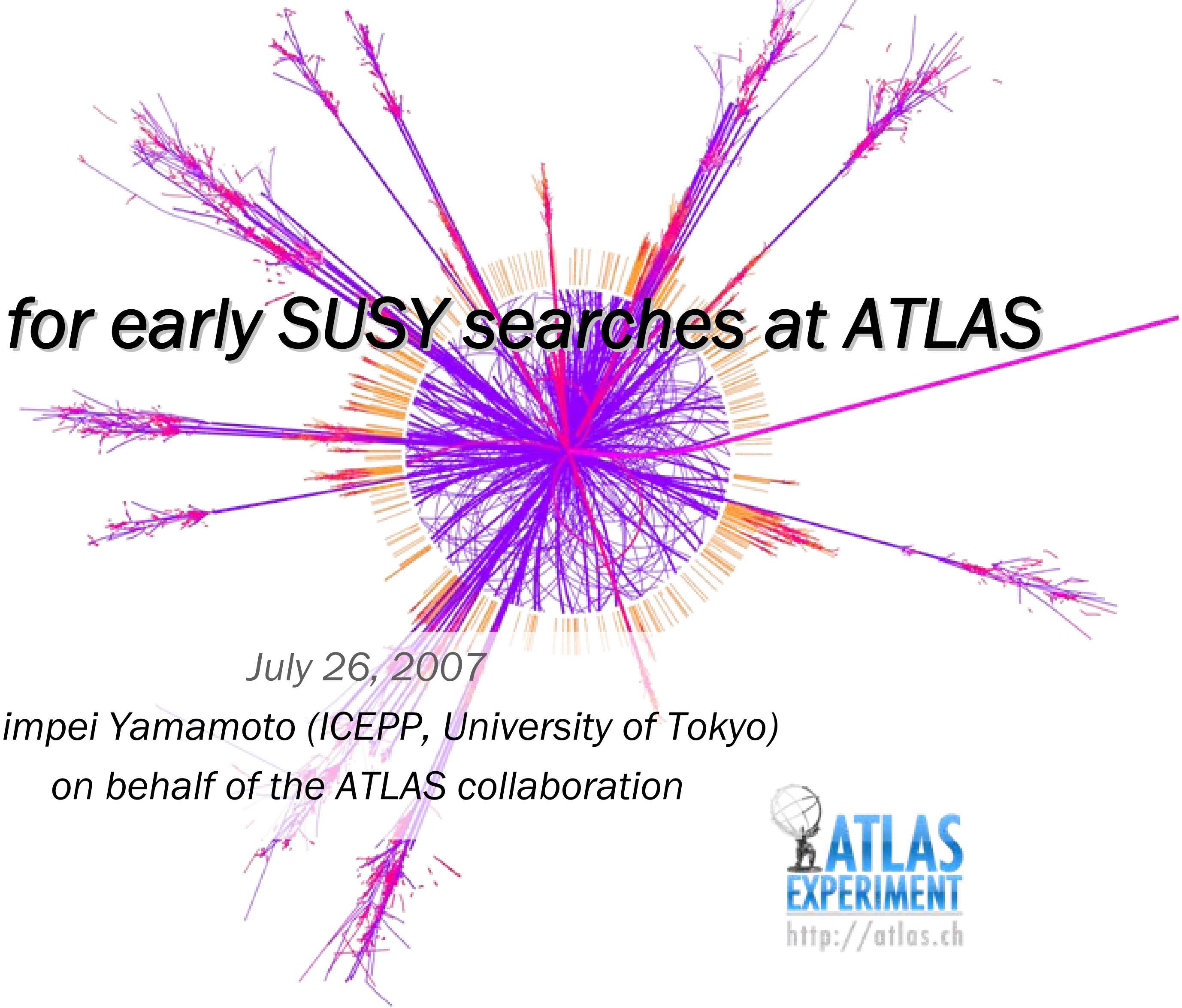

Strategy for early SUSY searches at ATLAS

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on behalf of the ATLAS collaboration

ATLAS EXPERIMENT
http://atlas.ch

Outline

- ✓ Introduction
- ✓ Strategy for early SUSY searches
- ✓ Commissioning for missing transverse energy
- ✓ Data-driven estimation for SUSY backgrounds
- ✓ Summary

Introduction

- ✓ *Large Hadron Collider (LHC) is getting ready for 2008 spring startup with hardware fully commissioned up to E_{beam}=7TeV.*
- ✓ *ATLAS, one of two general purpose experiments/detectors at LHC, is also approaching completion toward the first p-p collision at sqrt(s)=14TeV in 2008 summer.*

Current SUSY studies at ATLAS:

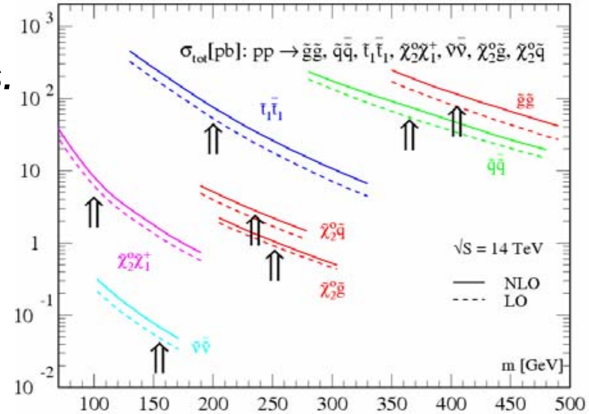
- *Usual SUSY breaking scenarios: mSUGRA, GMSB, AMSB*
- *Full detector simulation basis for detector commissioning and understanding systematics.*
- *Techniques to estimate background using real data.*
- *(Post-discovery measurements of mass scale etc. and unusual signatures of long-lived stau and R-hadron.)*

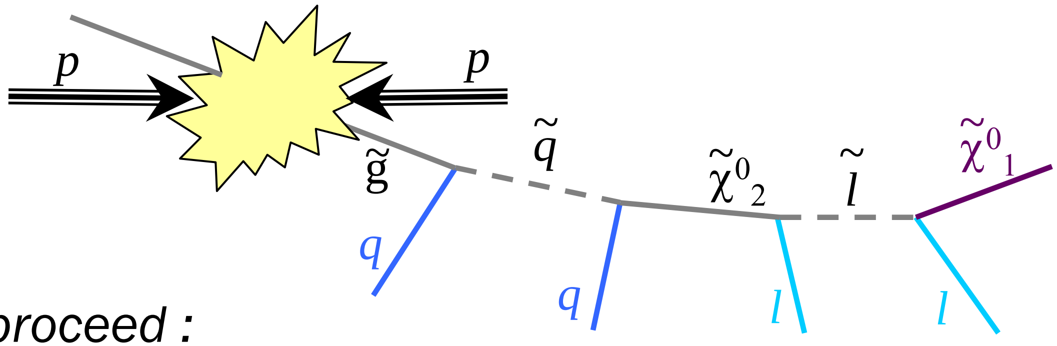
This talk focuses on the early SUSY searches (first data of $10^{31\text{-}32}cm^{-2}s^{-1}$, up to ~$1fb^{-1}$)

1. Strategy for early SUSY searches

Strategy for early SUSY searches

- ✓ We use the golden discovery channels "multi-Jets + n-leptons + E_T^{miss}"
  - Fair and less model-dependent features of SUSY :
    - gluinos/squarks are produced via strong interactions.
    - gluinos/squarks are heaviest.
    - their decays give rise to high-p_T jets
    - neutralinos/charginos decay via emission of leptons
    - (assuming R-parity conservation) LSP is stable and neutral, escaping from the detector (large E_T^{miss})





- ✓ Early SUSY studies will proceed :
  - Commissioning for missing transverse energy (E_T^{miss}) → part 2.
  - Data-driven background estimation → part 3.

Need to establish a robust background estimation

Event topologies and baseline selection

Early searches try to cover a broad range of experimental signatures, but they are classified based on the event topology:

Large E_T^{miss} +

Jet multiplicity	Additional signature	SUSY scenario	Backgrounds
≥ 4	No lepton	mSUGRA, AMSB, split SUSY, heavy squark	QCD, ttbar, W/Z
	One lepton (e,μ)	mSUGRA, AMSB, split SUSY, heavy squark	ttbar, W
	di-lepton	mSUGRA, AMSB, GMSB	ttbar
	di-tau	GMSB, large tan β	ttbar, W
	γγ	GMSB	free
~2		light squark	Z

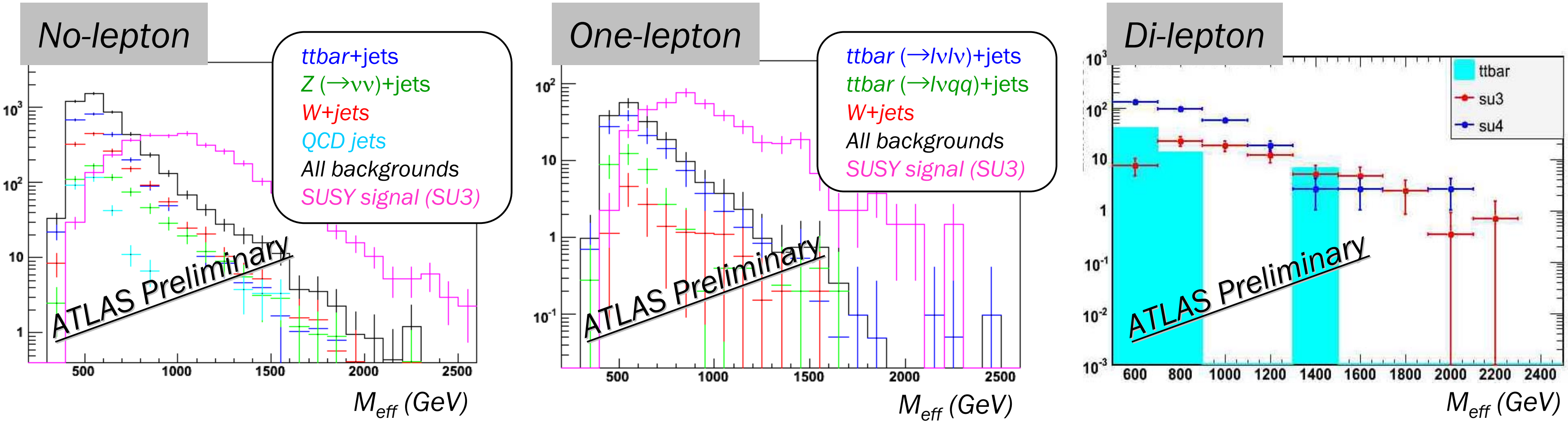
Baseline selection (to be optimized)

- ✓ *Jet multiplicity ≥ 4, p_T^{1st} > 100GeV, p_T^{others} > 50GeV*
- ✓ *E_T^{miss} > max(100GeV, 0.2xM_{eff})*
- ✓ *Transverse sphericity > 0.2*
- ✓ *(Additional cuts depending on signature)*
  - *Transverse mass > 100GeV , p_T^{lepton} > 20GeV (for one-lepton mode)*

SUSY searches with each event topology

- *Effective mass ($M_{eff} = \Sigma_i p_T^i + E_T^{miss}$) discriminates SUSY and SM backgrounds.*
- *Moreover, M_{eff} is strongly correlated to the mass of sparticles produced via p-p collisions.*
- *We hopefully find excess over the background estimation in the signal region of large M_{eff}.*

Benchmark point SU3:
m_0=100GeV, $m_{1/2}$=300GeV, A_0=-300, tanβ=6, sign(μ)=+

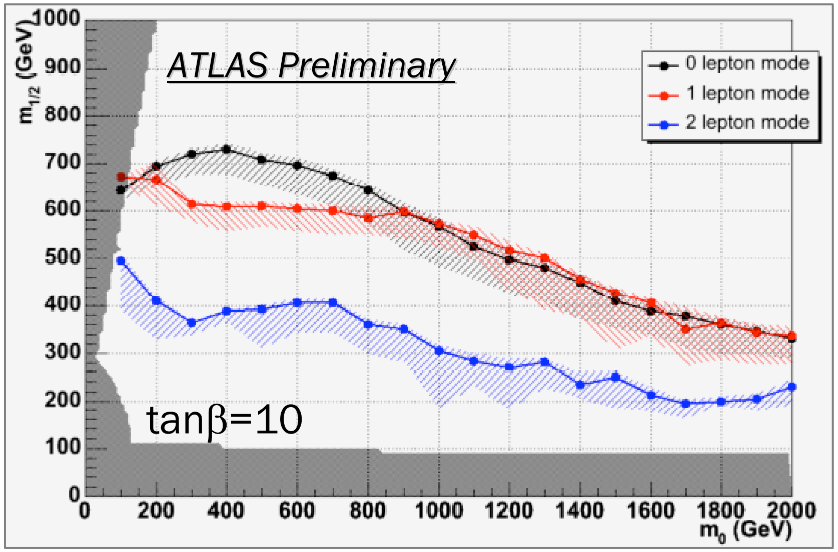


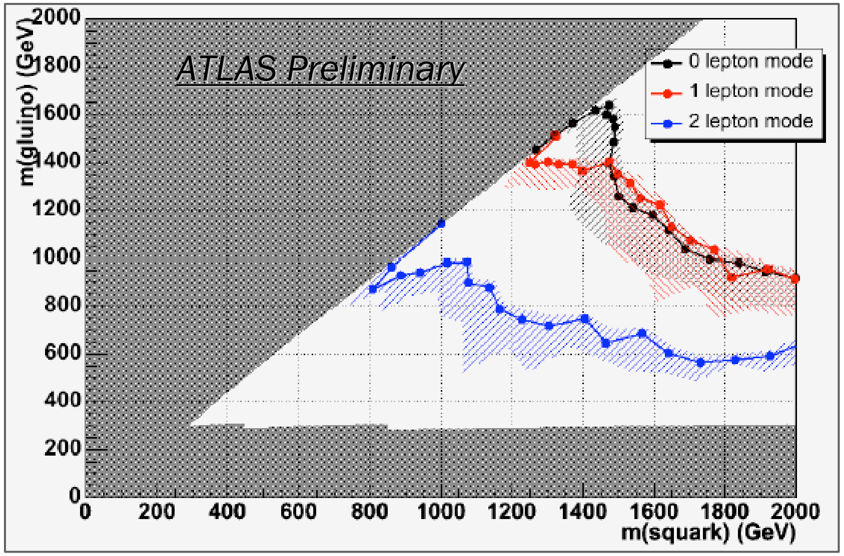
(full detector simulation, $1fb^{-1}$)

Discovery potential with L~1fb^{-1}

- ✓ 5σ-discovery potential on $m_{1/2}$-m_0 (m_{gluino}-m_{squark}) space is shown.
  - Require S>10 and S/sqrt(B)>5
  - Factor of 2 generator-level uncertainty included (hatched)

- ✓ ATLAS has the potential for discovery of ~1TeV scale SUSY with first data for each event topology.
  - Also shows a stable potential against tanβ.

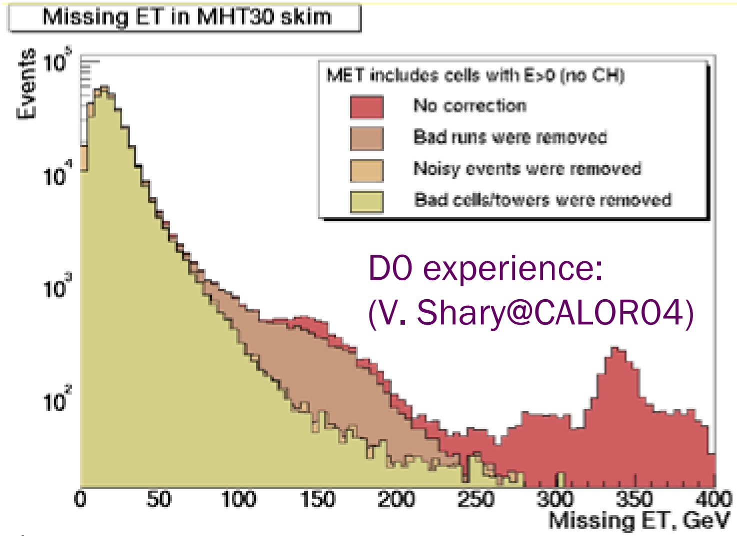




2. Commissioning for missing transverse energy using early data

Transverse missing energy

- E_T^{miss} is a discriminating variable for SUSY discovery
  - Our searches rely on the excess in the $E_T^{miss}(M_{eff})$ distribution.
- However, controlling its energy scale and resolution is very difficult experimentally.
  - Fake muons
  - Dead material and crack
  - Industrial effects in the detector
    (hot, dead and noisy calorimeter cells)
- Large tail in E_T^{miss} due to the fake is serious for SUSY searches.
  - Especially for QCD-jet background
    (almost no truth E_T^{miss}, but large x-section)



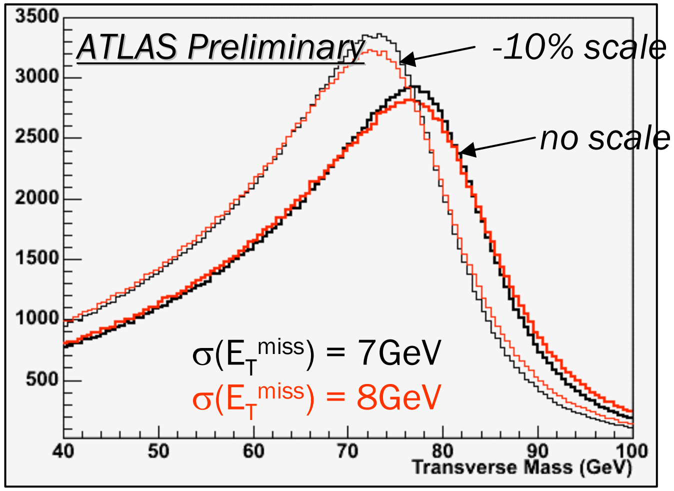
D0 experience:
(V. Shary@CALOR04)

In-situ measurements for E_T^{miss} scale/resolution determination and understanding of fake E_T^{miss} sources are our priorities straight.

In-situ measurements for E_T^{miss} scale/resolution determination

$W \to l\nu$ sample

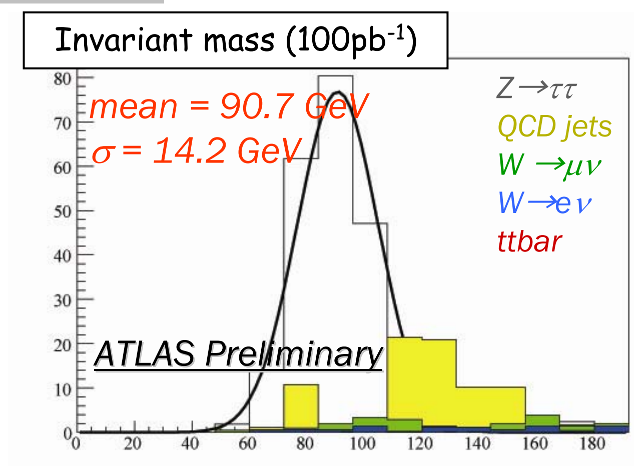
Shape of transverse mass distribution depends on E_T^{miss} scale and resolution.

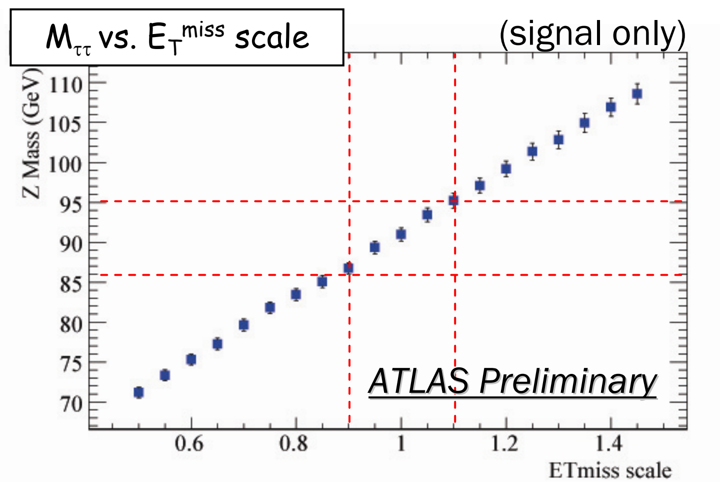


$Z \to \tau\tau$ (l-h channel) sample

Use the collinear approximation for mass reconstruction.

$\sigma(M_{\tau\tau}) \sim E_T^{miss} / |\sin\phi_{\tau\tau}|$



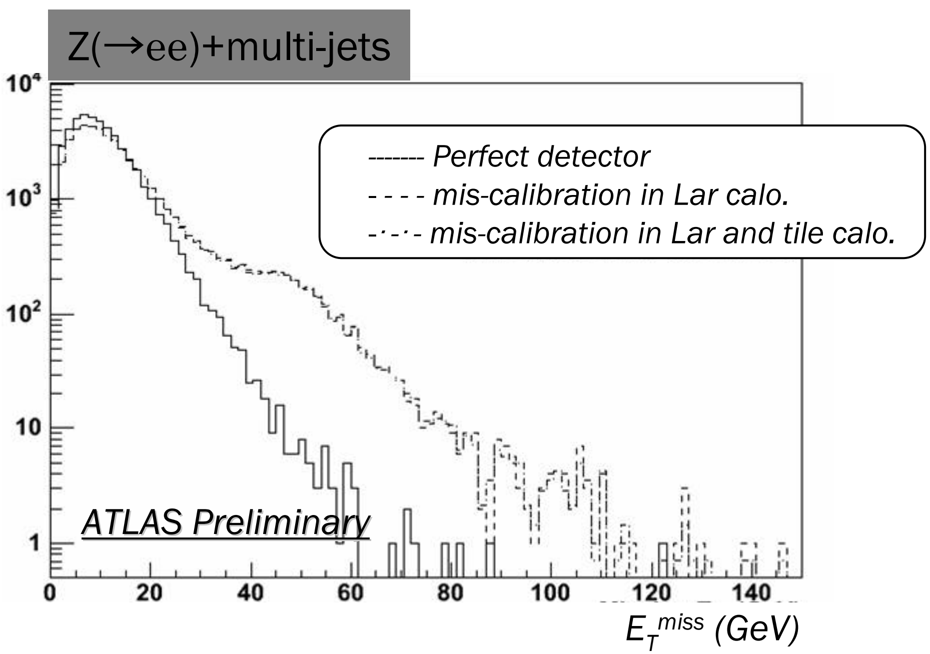


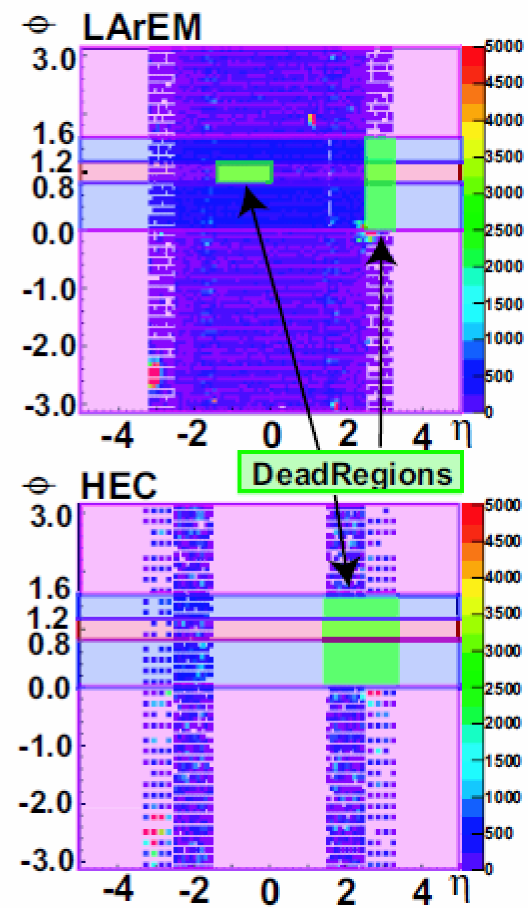
10% in E_T^{miss} scale ⇔ 3% shift in Z mass

Fake and large E_T^{miss} tails

- ✓ *The industrial effect in the detector is crucial.*
- ✓ *Its suppression is under study.*
  - *Online/offline monitoring tools*
  - *Event-by-event basis corrections*

Detector failure (example):
- 0.1% LAr EM HV lines
- 2 LAr Frond-end crate (barrel and endcap)
- 2 tile drawers





3. Data-driven background estimation for early SUSY searches

Data-driven background estimation for no-lepton signature

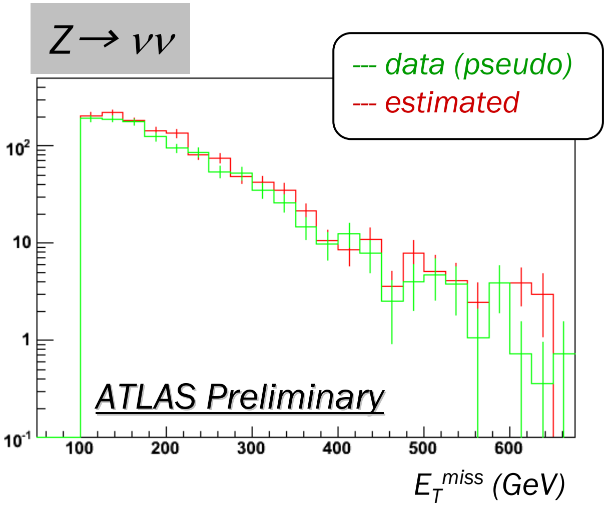
Even if we get early indications, they cannot justify the discovery of "beyond SM":

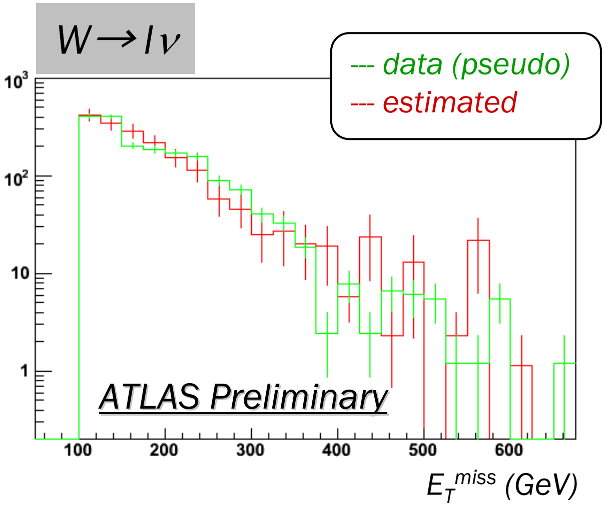
- *Generator-level uncertainties affect the normalization and shapes of backgrounds.*

We use the real data for BG estimations (data-driven)

Example of $Z(\to \nu\nu)$ background in no-lepton mode:

- ✓ *determine the BG MC normalization factor by comparing $Z \to ll$ data with MC*
- ✓ *apply it to normalize the MC distribution of $Z \to \nu\nu$.*
- ✓ *it can be also applied to $W \to l\nu$ (almost the same production mechanism)*

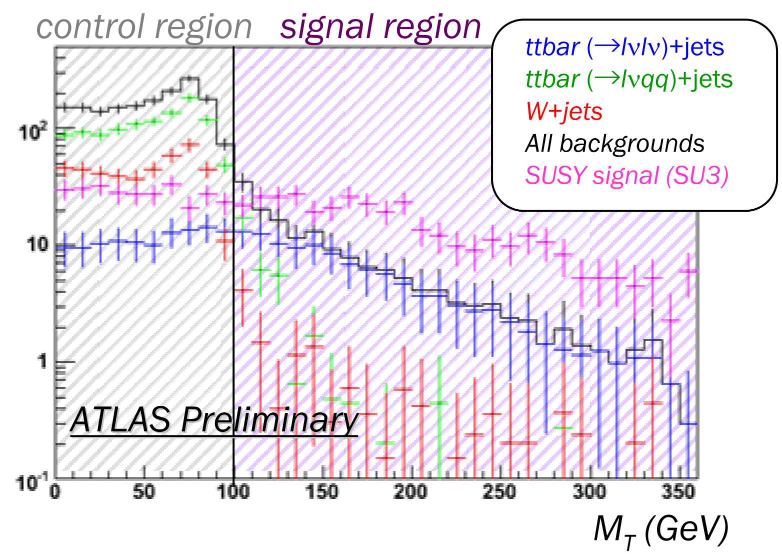


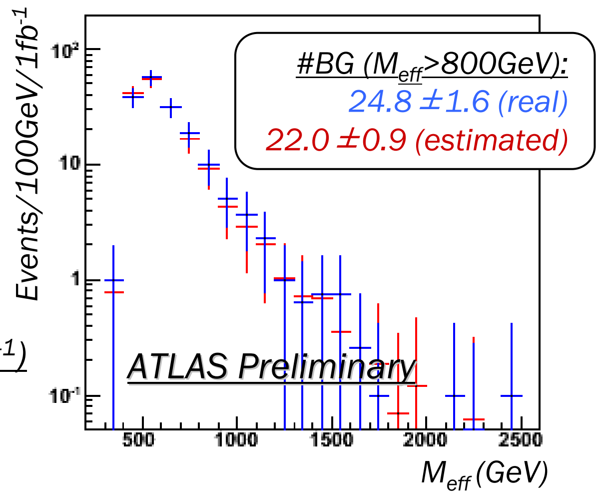


This scaling method works fine!

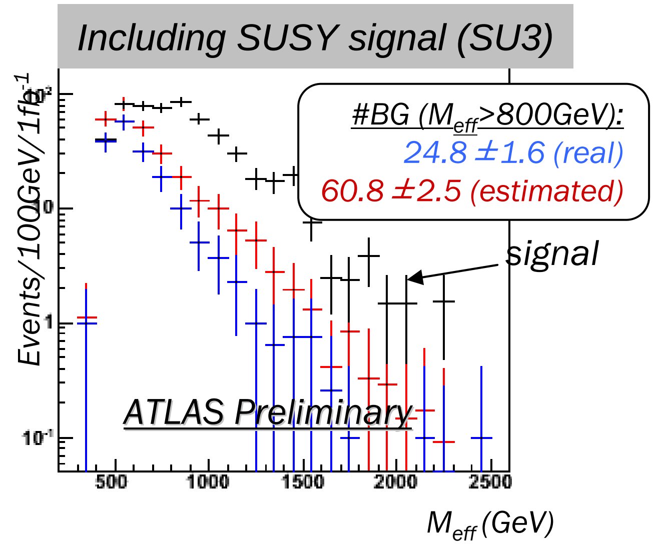
Data-driven background estimation for one-lepton signature

1. Isolate the background and signal processes based on transverse mass (control sample with <100GeV, signal sample with >100GeV)
2. Estimate the E_T^{miss}/M_{eff} shapes of background processes using control sample
3. Determine the normalization of backgrounds with low E_T^{miss} regions of control and signal samples.





effective mass (@1fb^{-1})



- Satisfying performances with the M_T discrimination technique.
- However, taking account of SUSY signal contamination in the control sample, this estimate appears to be over the mark. (By a factor of 2.5 for SU3)

QCD background estimation

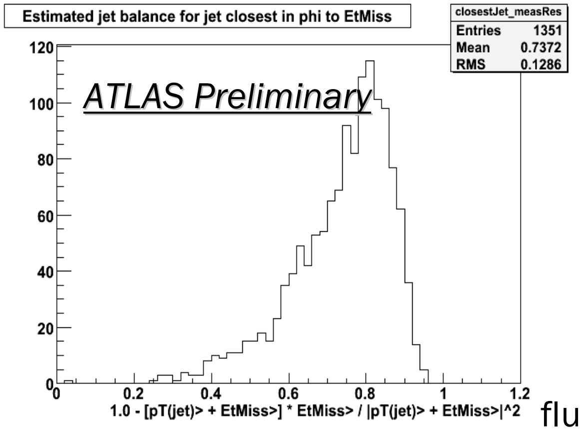
- ✓ QCD background is hard to estimate based on MC:
  - Mainly originated from the industrial fake E_T^{miss}
  - Full understanding of detector response needs time… (difficult at the early stage)

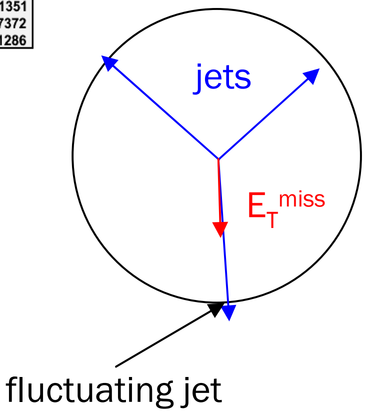
<u>Method of estimate :</u>

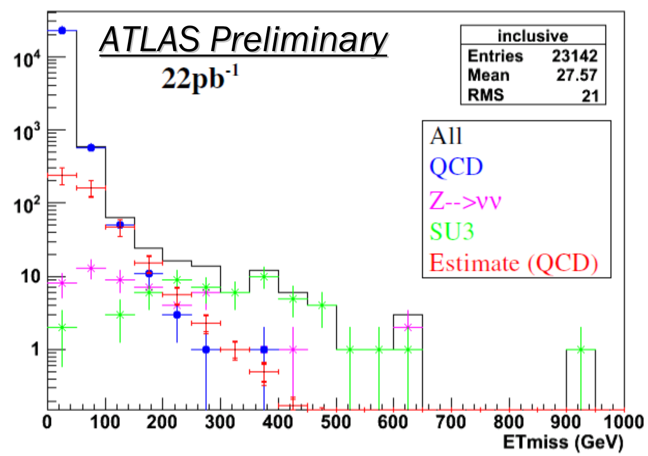
step 1: Measure jet smearing function from data

- Select events: E_T^{miss} > 60 GeV, $\Delta\phi(E_T^{miss}$, jet) < 0.1
- Estimate p_T of jet closest to E_T^{miss} as $p_T^{estimate} = p_T^{jet} + E_T^{miss}$

step 2: Smear QCD events with low E_T^{miss} by the smearing function.







Reproduces the E_T^{miss} tail well!

Summary

- ✓ *The countdown to the startup of LHC and experiments has begun, and studies of early SUSY searches and detector commissioning have been performed actively.*
- ✓ *The discovery potential using early data (1fb^{-1}) reaches ~1TeV scale SUSY with each event topology.*
- ✓ *However, establishing robust background estimations is crucial for the discovery at the early stage.*
  - *Origins of fake E_T^{miss} and tails are going to be made known with the full detector simulation.*
  - *New techniques for E_T^{miss} calibration have been also performed.*
  - *Variety of data-driven SM background estimations have been studied.*

Large efforts of many working groups toward the early discovery.

News of "beyond SM" hopefully in 2009 summer!

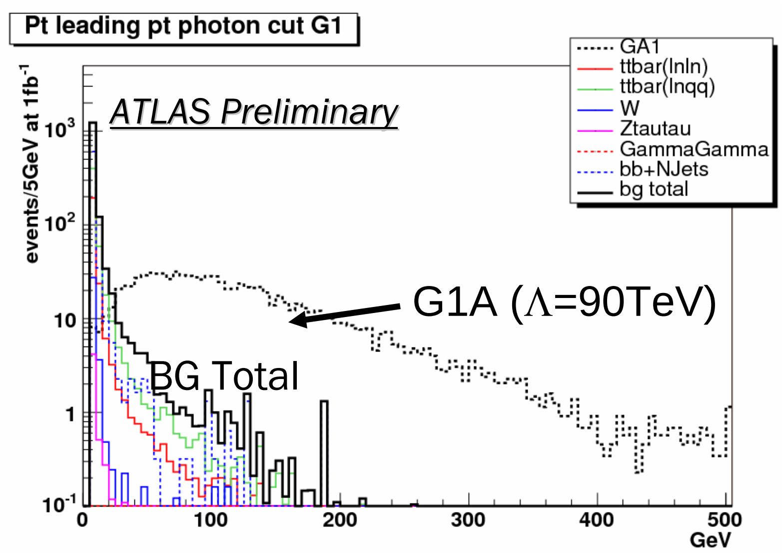
SUSY search with gamma signature

Non-pointing photon is a distinctive signature of GMSB:

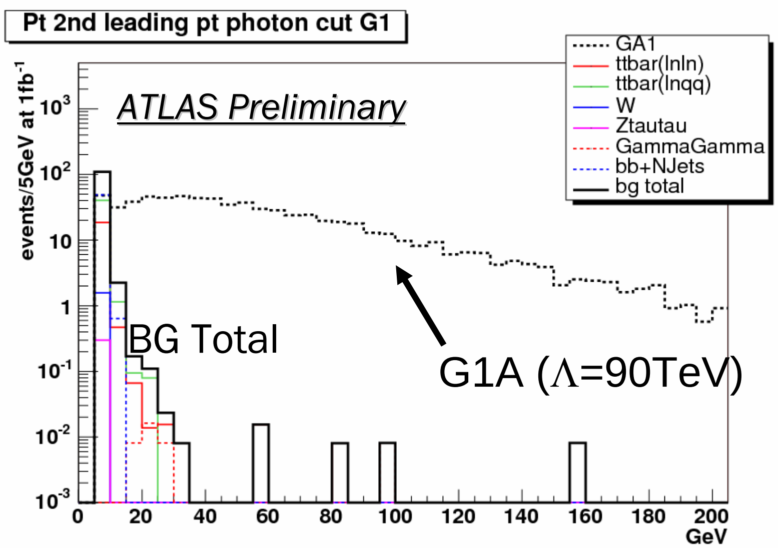
- *NLSP decays only via gravitational coupling*
- *NLSP could have a long lifetime*

ATLAS could cover GMSB requiring "photons + multi-jets + large E_T^{miss}".

L=1fb^{-1}



Leading Photon Pt (GeV)



2nd Leading Photon Pt (GeV)

ttbar background estimation

1. Top mass is largely uncorrelated with E_T^{miss}
   - used as a calibration variable
2. Select semi-leptonic top candidates
   - mass window: 140-200 GeV
3. Contributions of combinatorial BG to top mass are estimated from the side-band events (200GeV<m_{top}<260GeV)
4. Normalize the E_T^{miss} distribution in low E_T^{miss} region where SUSY signal contamination is small.
5. Extrapolate it to high E_T^{MISS} region and estimate the background with SUSY signal selection.