SUSY at ATLAS:

Getting Ready for Data

Rencontres de Moriond, 18 - 25 March, 2006

For the ATLAS Collaboration

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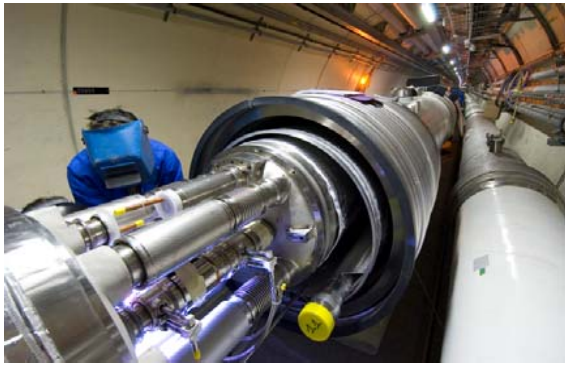
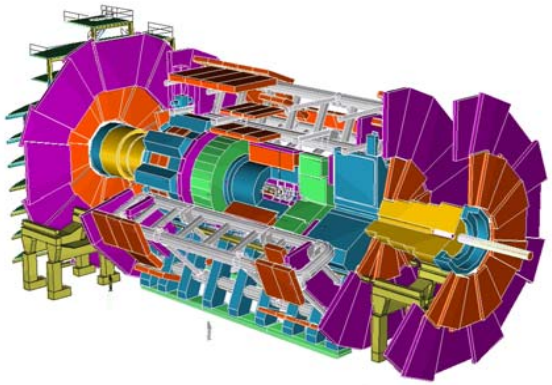
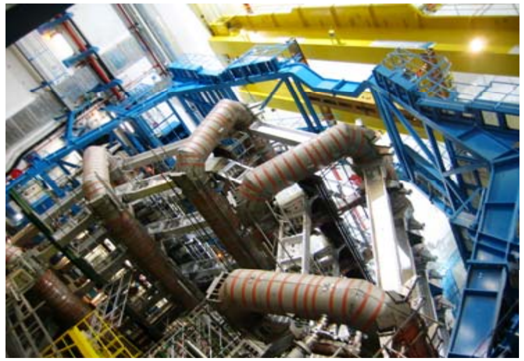


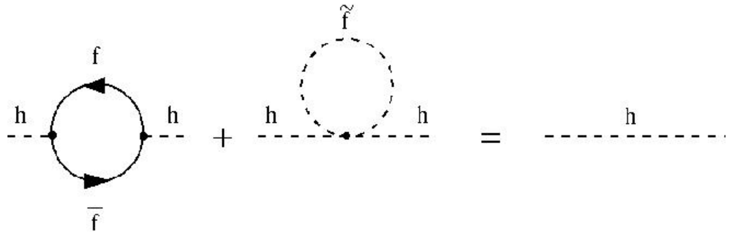




Supersymmetry

Symmetry has played fundamental role in the development of particle physics

- Does nature obey a space-time symmetry that transforms fermions into bosons?
- This idea of Supersymmetry (SUSY) has tantalized physicist for 3 decades.

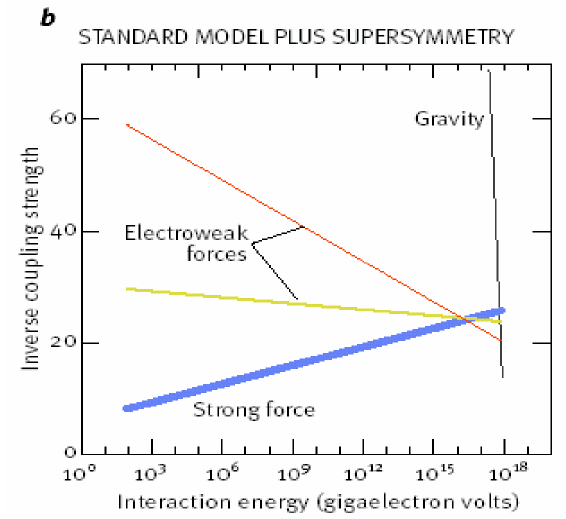


Two theoretical arguments for its existence

- Hierarchy Problem
  - -- SUSY stabilizes the Higgs mass.
- Unification of couplings
  - -- SUSY unifies three couplings close to planck scale.

One experimental question

- Constituent of Dark Matter in the Universe?
  - -- SUSY provides a viable candidate.

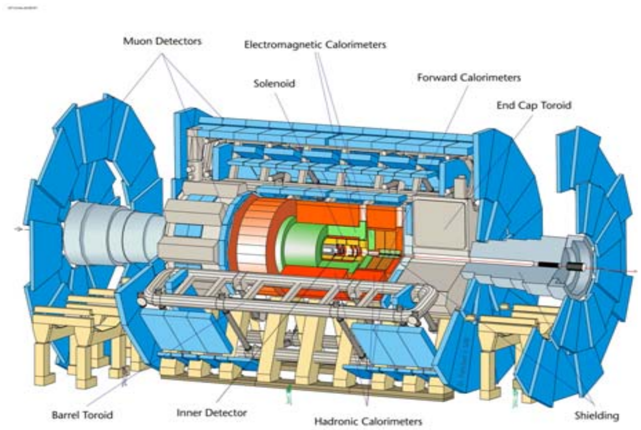


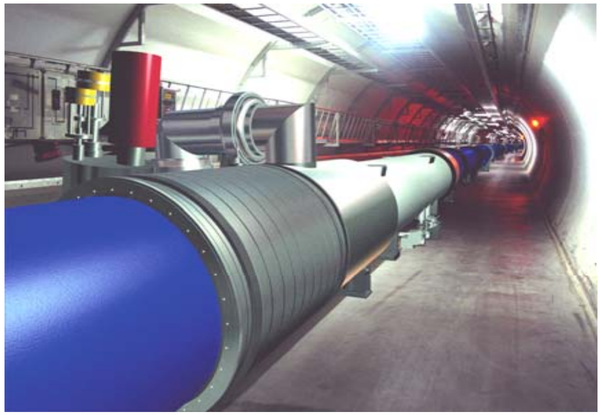
LHC experiments ATLAS and CMS will probe large SUSY parameter space → this talk on ATLAS.

SUSY@ATLAS

Atlas is a large and complex HEP detector

- Readout channels: Calorimeter (200K), Muon (1.5M) and Tracking (140M).
- Collision rate 40MHz; 23 interaction/crossing at design luminosity; ~1725 particle produced.
- ~ 10 peta-byte worth of data every year.
- Detector commissioning is under way.
- 3rd data challenge to test software and analysis setup to start soon
- It will be a new regime of distributed analysis with data and MC spread across the world.
- And, not too far in the future (mid 2007), the first beam is expected in the LHC ring.





Expected Event Rates ($10^{33} cm^{-2} sec^{-1}$)

Process	Events/s	Events for 10 fb^{-1}	Total statistics collected at previous machines by 2007
$W \rightarrow e\nu$	15	10^8	10^4 LEP / 10^7 Tevatron
$Z \rightarrow ee$	1.5	10^7	10^7 LEP
$t\bar{t}$	1	10^7	10^4 Tevatron
$b\bar{b}$	10^6	$10^{12} - 10^{13}$	10^9 Belle/BaBar ?
H m=130 GeV	0.02	10^5	?
$\tilde{g}\tilde{g}$ m= 1 TeV	0.001	10^4	---
Black holes	0.0001	10^3	---

- W,Z and Top will serve as calibration sample.
- Once running begins, systematics issues will quickly dominate over statistics

ATLAS SUSY Studies

In the past (ATLAS Physics Technical Design Report (TDR) 1998)

- The studies used fast simulation (physics process+parametrized detector sim.)
- Many studies that focused on discovery potential and properties of s-particle.

Now: Preperation for 1st Physics

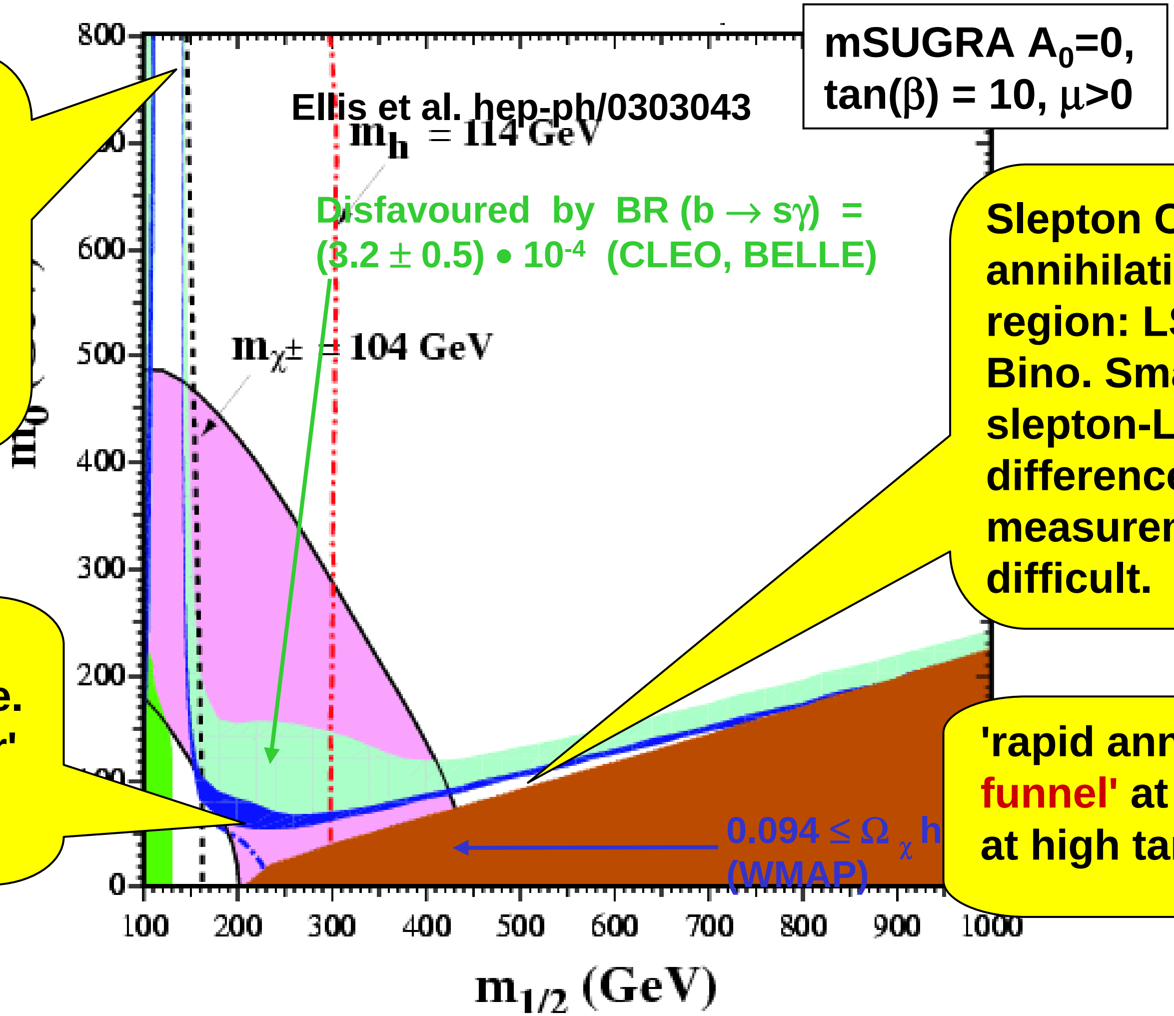
- Studies with detailed detector simulation underway
  - SUSY events provide a good test for reconstruction and calibration.
  - Data challenge studies with specific SUSY points -- understanding the logistics of moving large data samples and analysis enviorenment.
- Strong emphasis on background estimation
  - Development of tools and techniques that can be reliably used and help in the discovery potential.
- For discovery - Focus on inclusive signatures in the beginning.

Data Challenge 2 studies

DC2/Rome studies used WMAP constraint as guidance to generate samples at different SUSY points.

'Focus point' significant higgsino component to LSP enhances annihilation to gauge bosons

'Bulk' : t-channel slepton exchange. 'Bread and Butter' region for LHC.

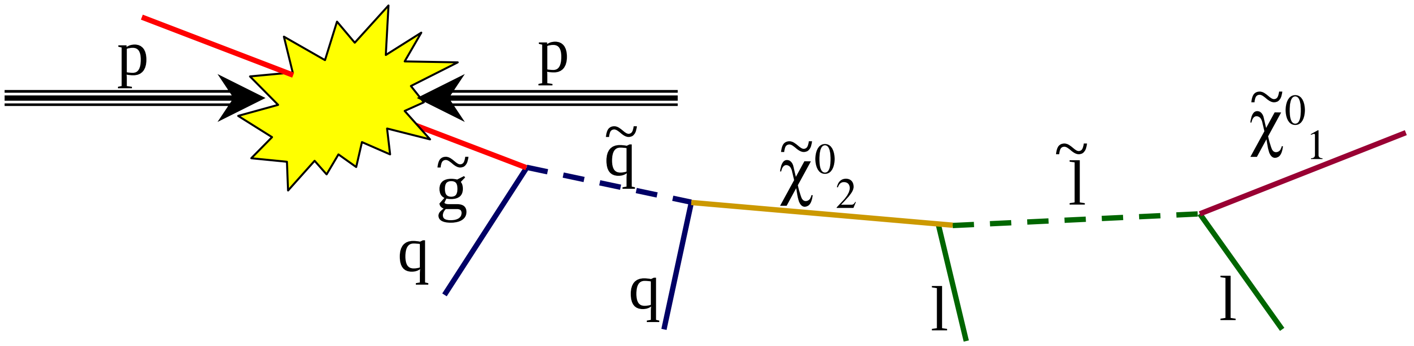


Slepton Co-annihilation region: LSP ~ pure Bino. Small slepton-LSP mass difference makes measurements difficult.

'rapid annihilation funnel' at Higgs pole at high tan(β)

SUSY Signatures

- Q: What do we expect SUSY events at LHC to look like?
- A: Look at typical decay chain:



- Strongly interacting sparticles (squarks, gluinos) dominate production.
- Heavier than sleptons, gauginos etc., $\rightarrow$ cascade decays to LSP.
- Long decay chains and large mass differences between SUSY states
  - Many high p_T objects observed (leptons, jets, b-jets).
- If R-Parity conserved LSP (lightest neutralino in mSUGRA) stable and s-particle pair produced.
  - Large E_T^{miss} signature.
- Closest equivalent SM signature t $\rightarrow$ Wb.

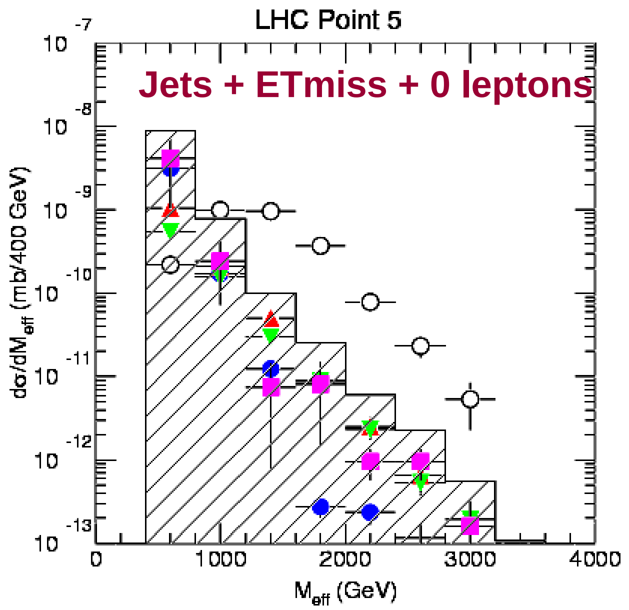
Inclusive Signatures

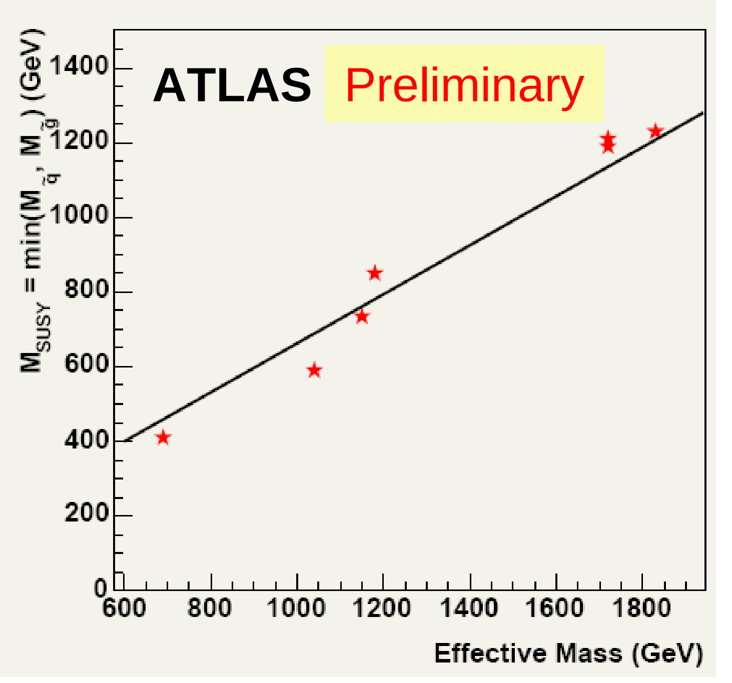
SUSY events dominated by jets + E_T^{miss} + n-leptons

Effective Mass variable: $M_{eff} = \Sigma|p_T^i| + E_T^{miss}$.
- discriminate SM and SUSY
- correlated with SUSY mass scale

$$M_{eff} \propto M_{SUSY} = \min(m_{\tilde{g}}, m_{\tilde{q}})$$

General selection cuts -
- 2 jet with p_T>100 GeV, 4 jets with p_T>50 GeV
- E^T_{MISS} > max(100 GeV,0.2M_{eff})
- Transverse spherecity S_T>0.2
- No isolated muon or electron with p_T>20 GeV (0-lepton case)





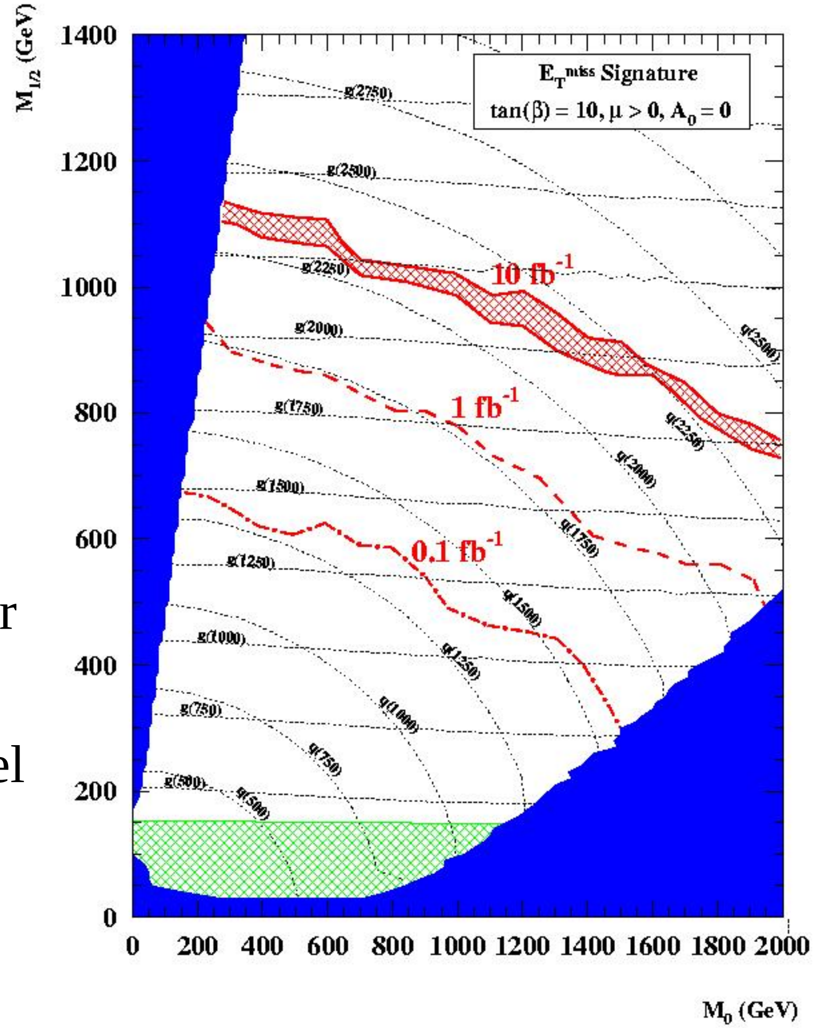
SUSY Search Potential

Expected Sensitivity (TDR)

- A scan was performed in m_0 - $m_{1/2}$ plane to estimate signal siginificance
  - -- Mass scale of 2 TeV with $10 fb^{-1}$
  - -- Mass scale of 1.5 TeV with $1 fb^{-1}$

Some Caveats

- The studies only used statistical error
- SM background generated with parton shower
  - -- Multi-jet cross-section were low.
- Detector was simulated with parametric model (ATLFAST)
  - -- Detector E_t^{miss} estimates were low.



New studies to map the expected sensitivity.

In general - Factor of two change in background moves the curves by few tens of GeV

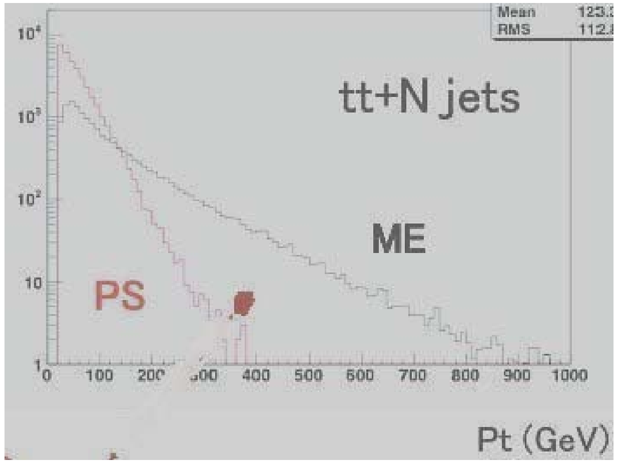
Backgrounds to SUSY

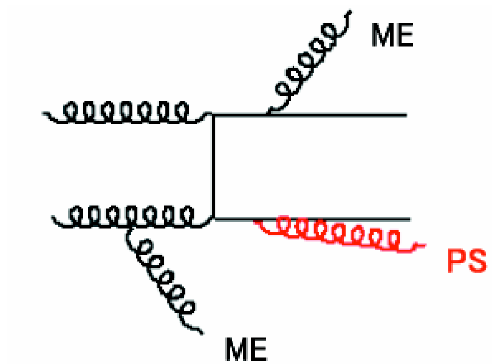
Main backgrounds for jets + E_T^{miss} + n-leptons →

tt(→bblνlν) + Njets
tt(→bblνqq) + Njets
W(→lν) + Njets
Z(→νν) + Njets
Z(→ττ) + Njets
QCD QQ+Njets (Q=b,c semileptonic decay)
QCD mlutijets (light flavor)

Parton showering and number of hard jets

- PS good good approximation in collinear region.
- but, PS has problem in high pt region
- hard jets not emitted in parton showering

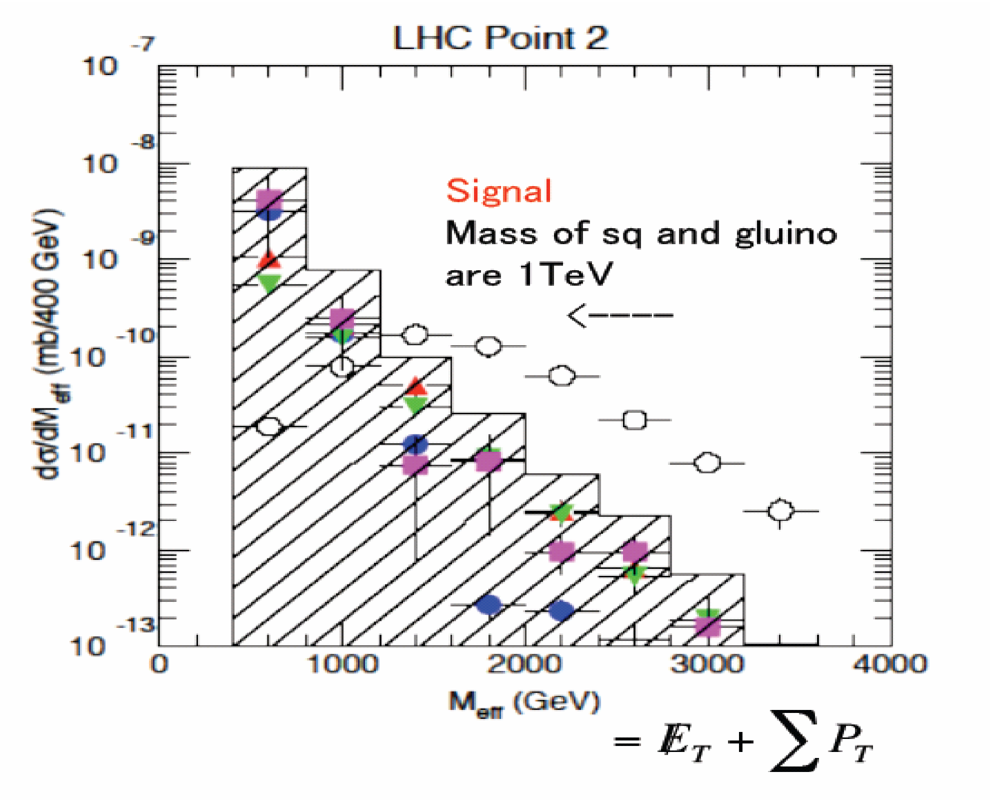


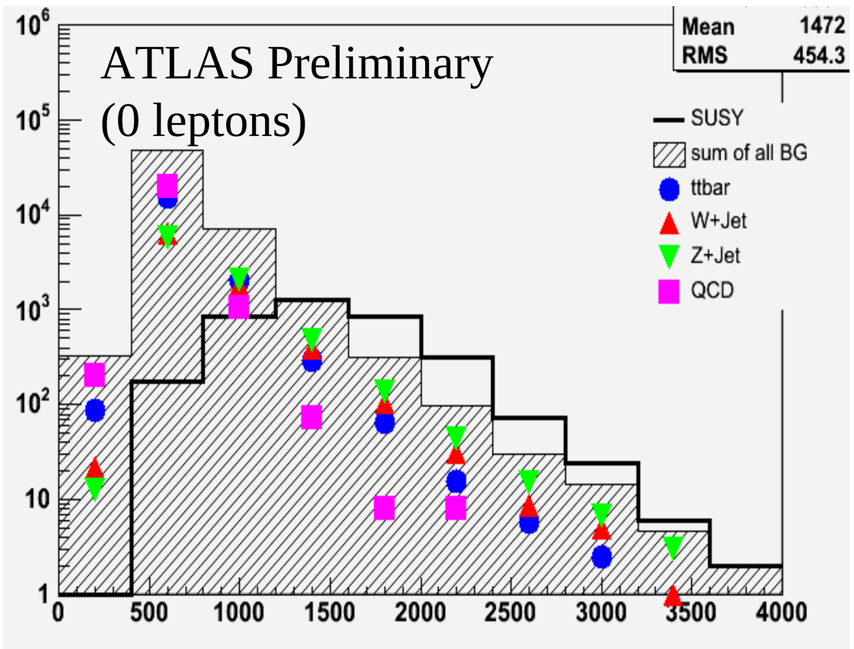


- hard jets should be estimated by matrix element (ME) calculation (ALPGEN)

Parton shower vs Matrix Element

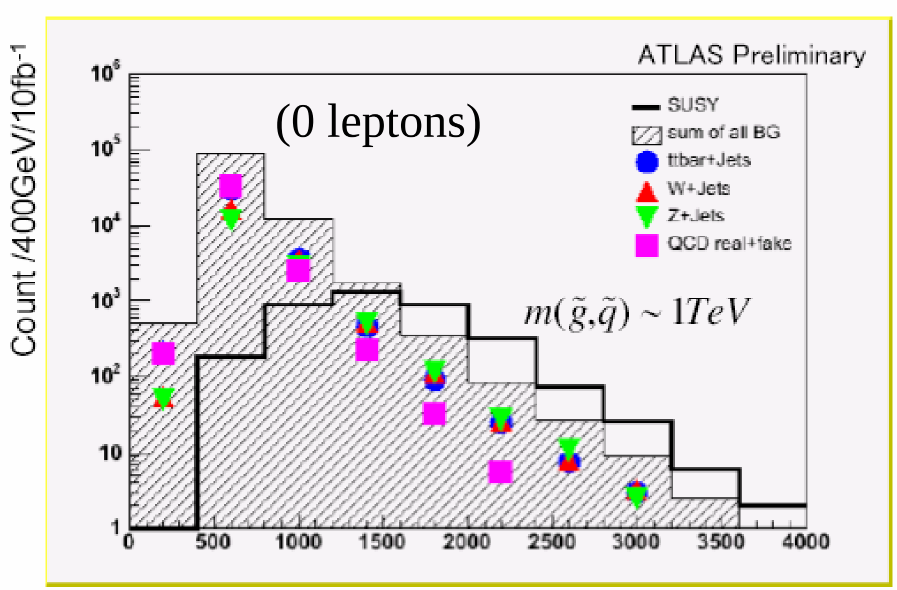
- Recent studies with ALPGEN + PYTHIA (MLM match) + ATLFAST
- Background increases by about 2-5 times.

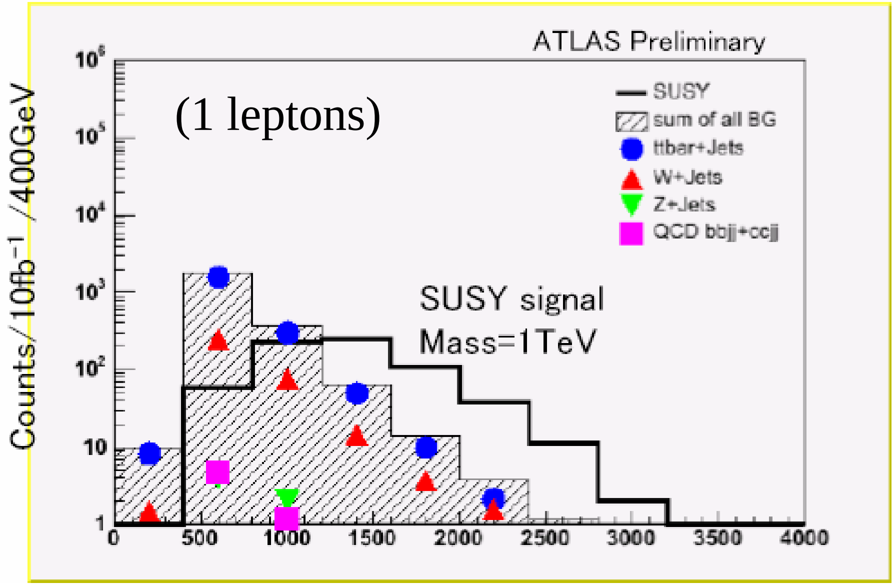




PS vs ME (cont.)

- 1-lepton mode better than 0-lepton for S/B
  - dominant background is Top





- E^T_{MISS} Missing energy crucial for SUSY searches.
  - Missing energy from multiple jets can be controlled by tighter cuts.

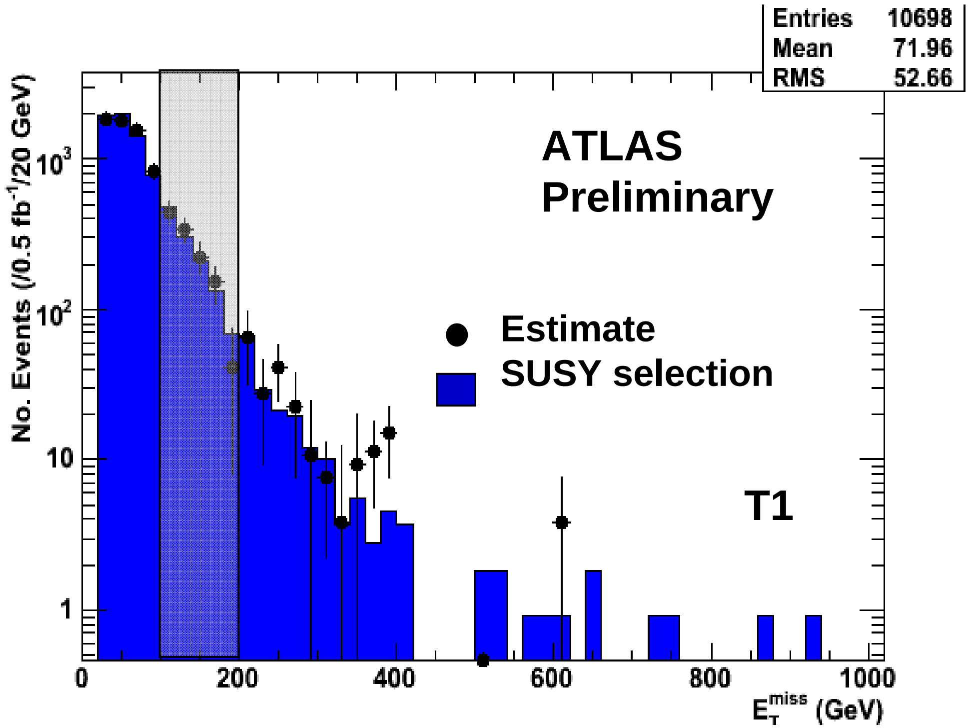
Top background

Top event topology similar to SUSY - dominant SM background.

Studies to design methods to estimate background from data

An example to estimate top background from data,

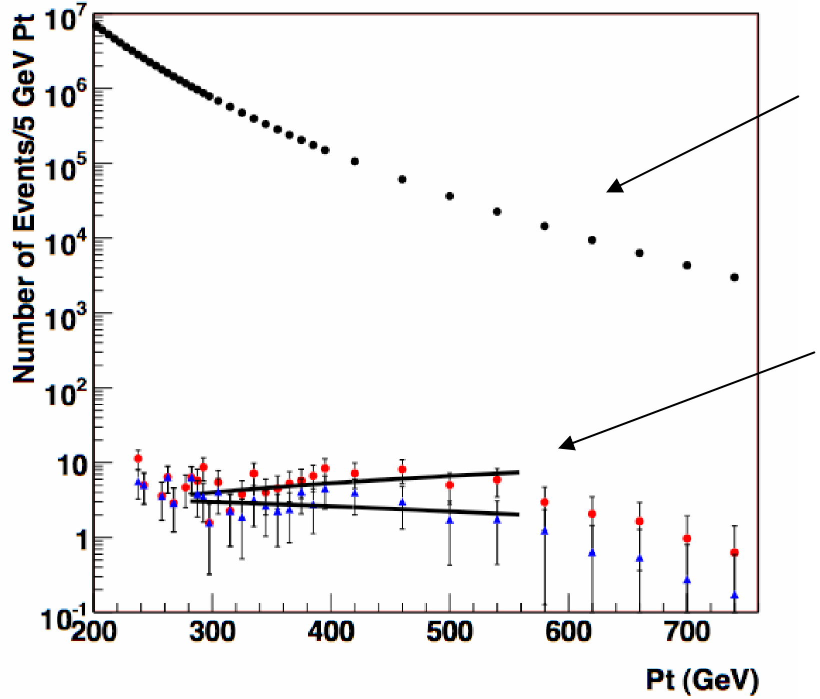
- Top mass is largely uncorrelated with E_t^{miss} (calibration variable).
- Reconstruct Top in a mass window (140-200) GeV
- Normalize E_T^{miss} distribution for SUSY selection in low etmiss region
- Extrapolate to high etmiss region to estimate the background



QCD background

Very large cross section of QCD can create backgrounds to SUSY

- Missing energy is produced either from heavy quark decay or jet mis-measurements in detector (Fake missing energy).
- Impossible to do full detector simulation (Geant4) sample size needed by QCD
  - -- need robust fast detector simulation
  - -- estimates from data



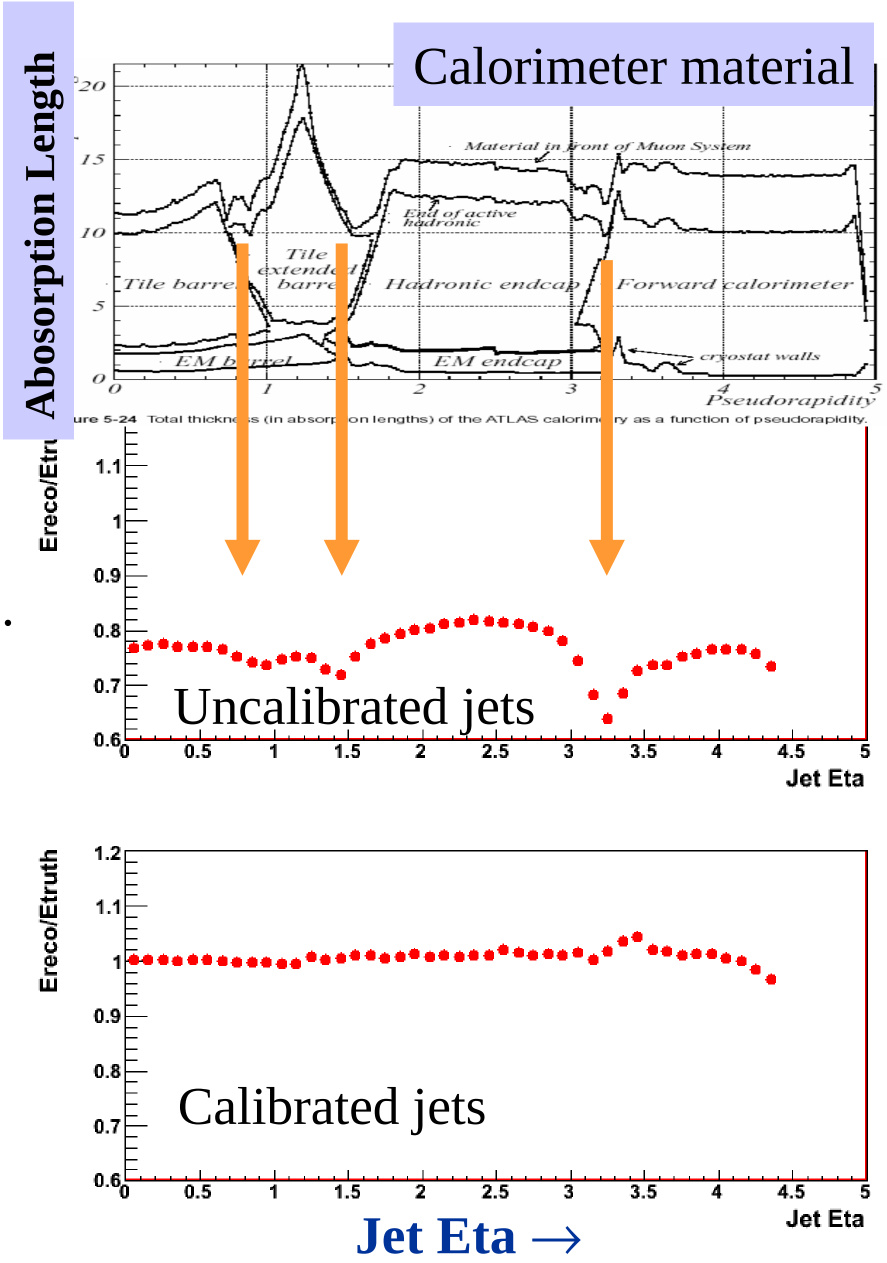
QCD spectrum: PYTHIA

QCD events passing SUSY selection cuts in bins of hard scattering Pt. Fast parametric detector simulation used.

Jets/EtMiss

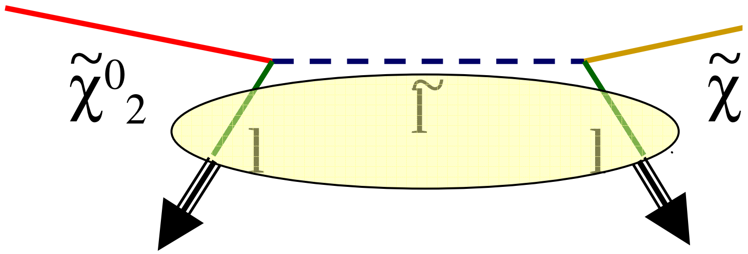
Good Jets and E_T^{miss} performance crucial for SUSY searches

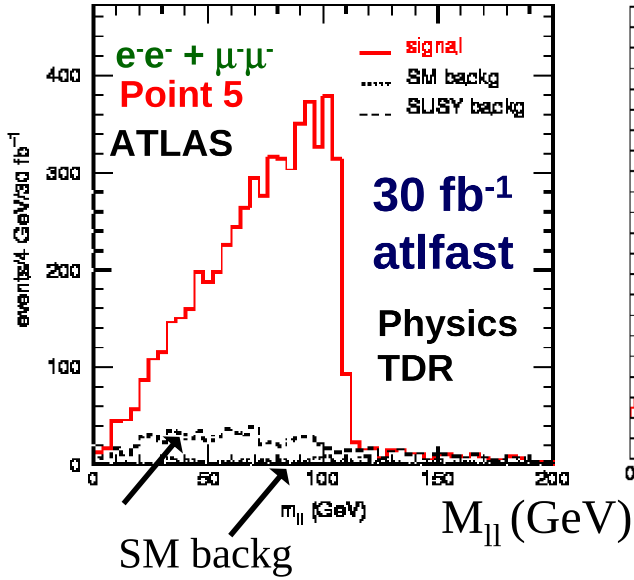
- Jet scale will be monitored with in-situ calibration samples Top and Z+jet sample.
- Poor jet resolution will directly effect missing energy estimate.
- For discovery the jet scale requirement is ~10%.
- To measure SUSY masses the requirements are more stringent ~ 1%.

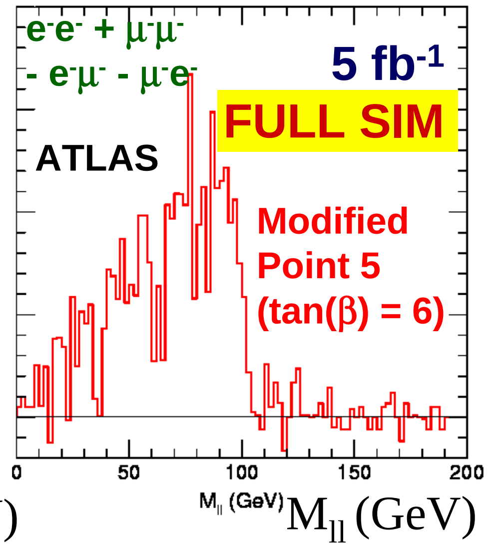


Exclusive Signatures

- **If SUSY is discovered - nest step to measure of the sparticle masses**
- **Two invisible LSP in each event, so no direct mass measurement possible.**
- **Obtain kinematic edges from invariant mass distributions of involved particles, e.g. dilepton distribution m_{ll}.**
- **Remove SUSY/SM BG using OppositeFlavor/OppositeSign (OF/OS) pairs, .e.g: $e^+e^- + \mu^+\mu^- - e^+\mu^- - \mu^+e^-$**







$$M_{ll}^{\max} = M(\tilde\chi_2^0)\sqrt{1-\frac{M^2(\tilde l_R)}{M^2(\tilde\chi_2^0)}}\sqrt{1-\frac{M^2(\tilde\chi_1^0)}{M^2(\tilde l_R)}} = 108.93\ \mathrm{GeV}$$

Ambreesh Gupta

Summary

- **SUSY is one of the primary goals of ATLAS.**
- **SUSY searches will commence on Day 1 of LHC operation.**
- **Many studies of exclusive channels already performed.**
- **Lots of input from both theorists (new ideas) and experimentalists (new techniques).**
- **Renewed emphasis on use of full simulation tools.**
- **Big challenge for discovery will be understanding systematics.**
- **Big effort ramping up now to understand how to exploit first data in timely fashion**
  - **Calibrations**
  - **Background rejection**
  - **Background estimation**
  - **Tools**
  - **Prescale strategy**