SUSY searches with inclusive missing energy signatures in ATLAS

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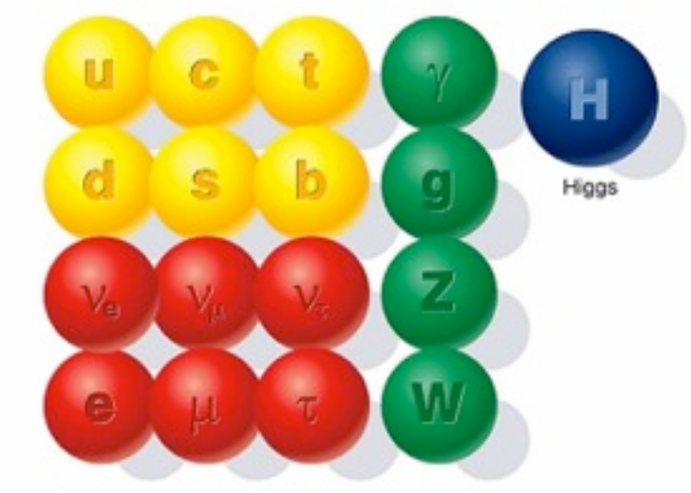
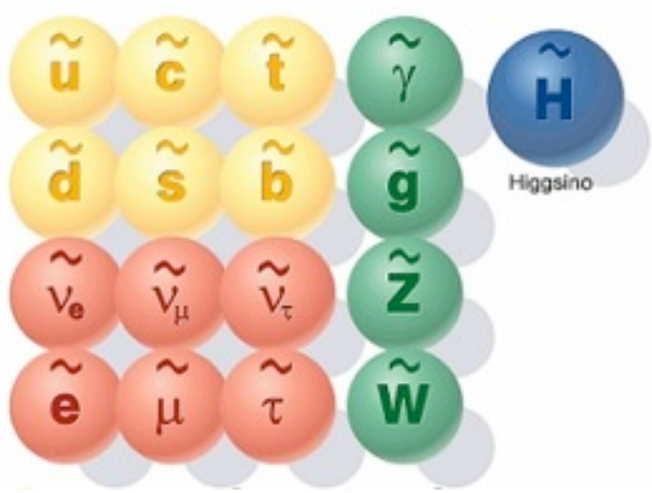
(on behalf of the ATLAS collaboration)

Supersymmetry





- Symmetry between force and matter
- Every elementary SM particle has a super partner that differs by a half-unit of spin

- A parity, $R_p = (-1)^{2s+B+L}$ is even for all the SM particles and odd for all their super partners

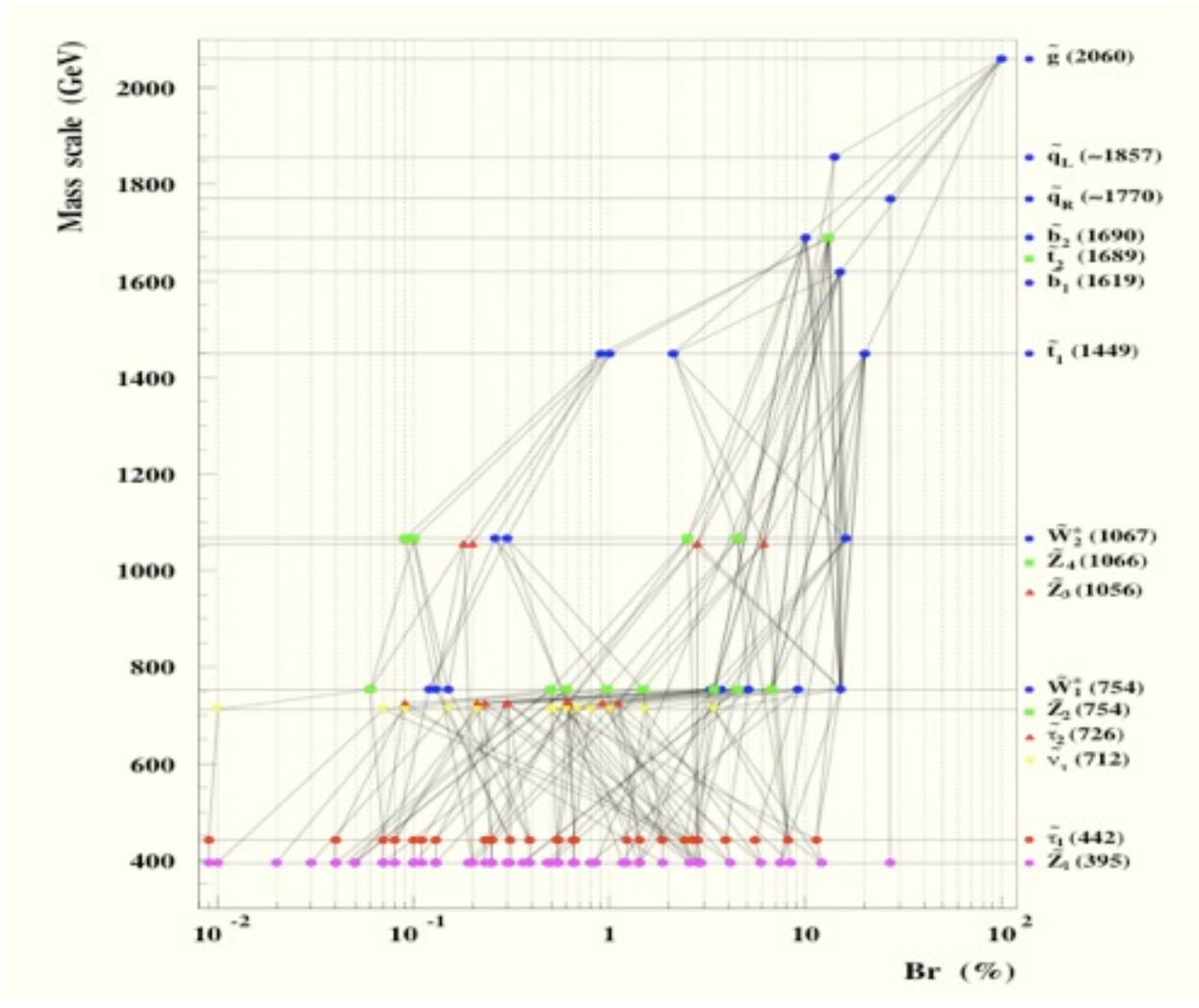
R_p conserved

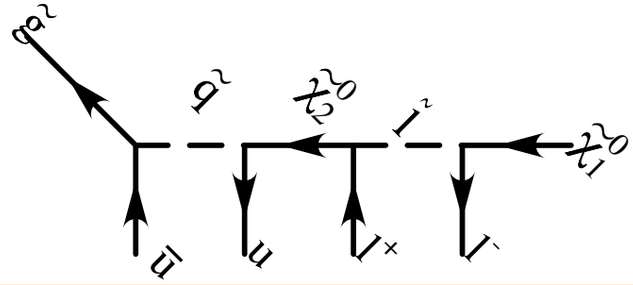
- **Lightest supersymmetric particle (LSP) is stable: Its a neutral particle that escapes detection causing a large missing energy in the event**
- **Signature for dark matter**

- For the R-parity conserving scenario ATLAS considers the **minimal SUperGRAvity (mSUGRA)** along with other models like GMSB, NUHM

Inclusive SUSY search strategy in ATLAS

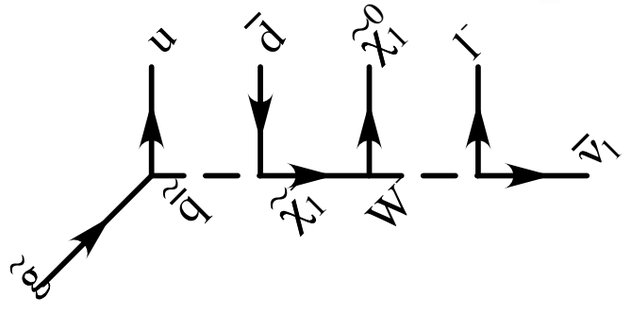
- Cascade decays of heavier colored particles like gluinos and squarks produce large missing energy, multiple high-pT jets and leptons in the final state





Signatures ATLAS is looking for

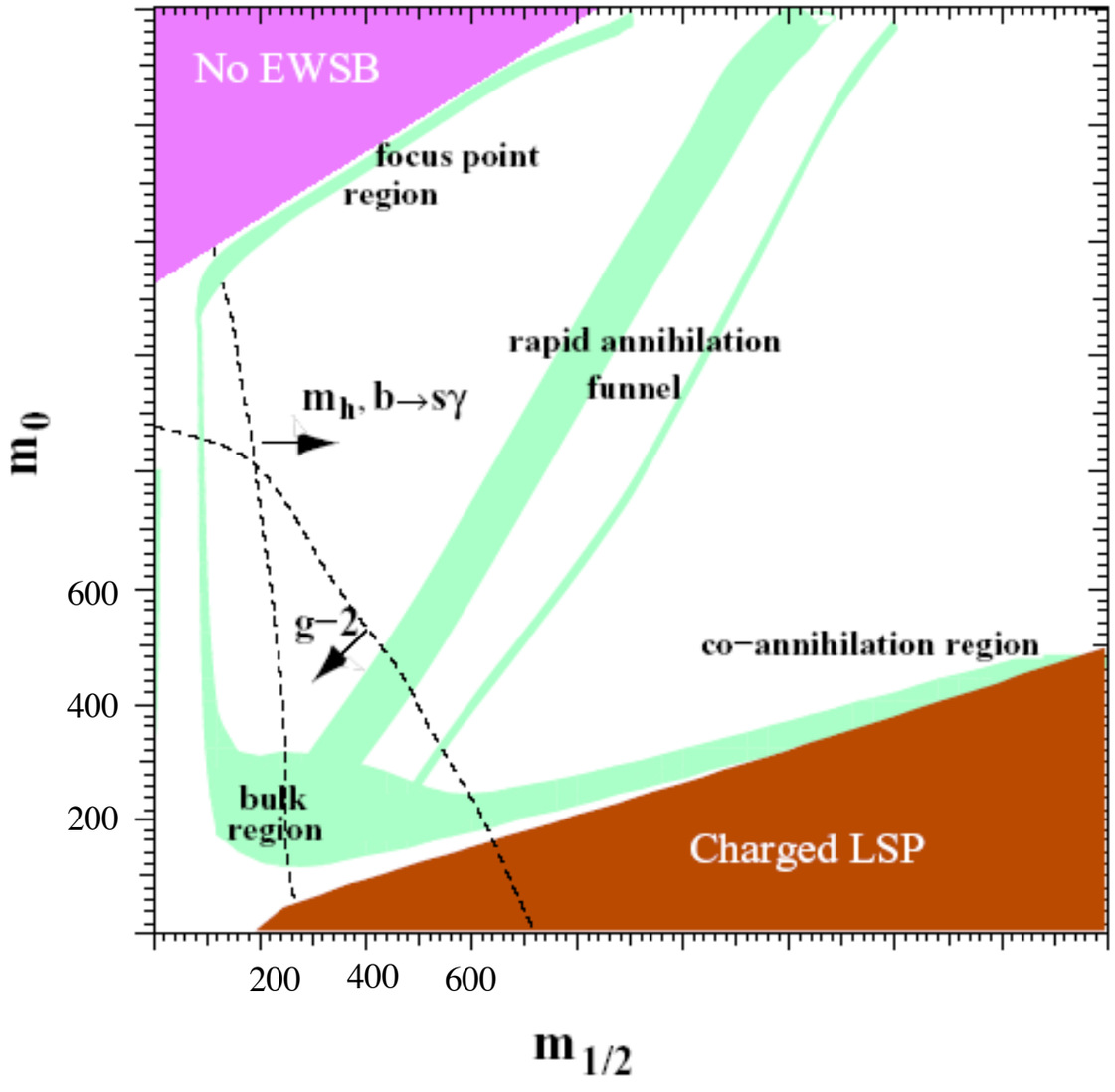
- Large missing transverse energy
- multiple high-pT jets
- Zero, one or multiple leptons



Some benchmark points

- ATLAS covers a wide range of SUSY signals using mSUGRA model
- This is governed by five parameters : **m_0, $m_{1/2}$, A_0, tanB, sign(mu)**
- Some benchmark mSUGRA signal points considered

Parameter	SU1	SU3	SU4
m0	70	100	200
m1/2	350	300	160
A0	0	-300	-400
tanB	10	6	10
sign(mu)	+	+	+
$m_{\tilde{g}}, m_{\tilde{q}}$	830, 760	720, 620	420, 420

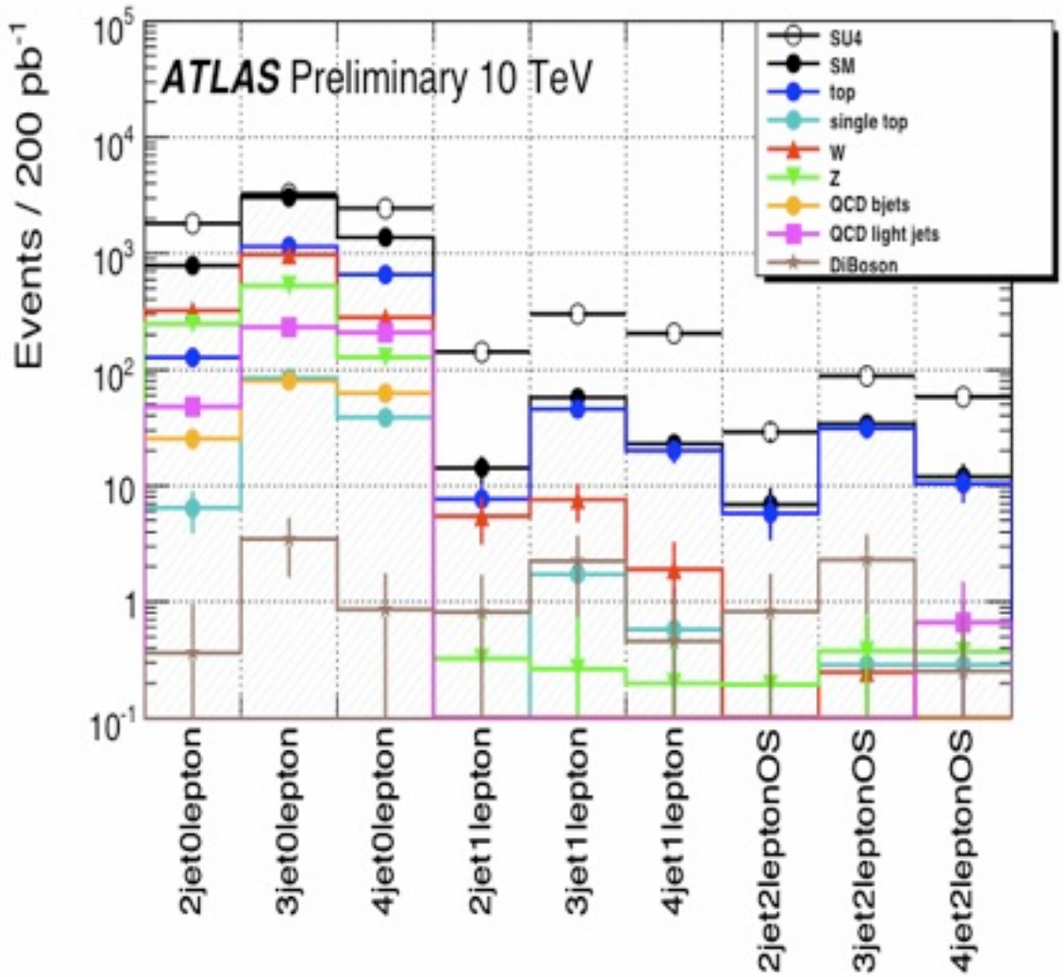


❖**Tevatron limit is close to SU4**

Signatures by exclusive lepton(s), inclusive jets and missing energy (mET)

- A number of combinations with different lepton and jet multiplicities

mET + [Njet > 0 / Njet = 0] + [0 lepton / 1 lepton / 2 lepton OS, SS / 3 lepton]



0 lepton + jets + mET :

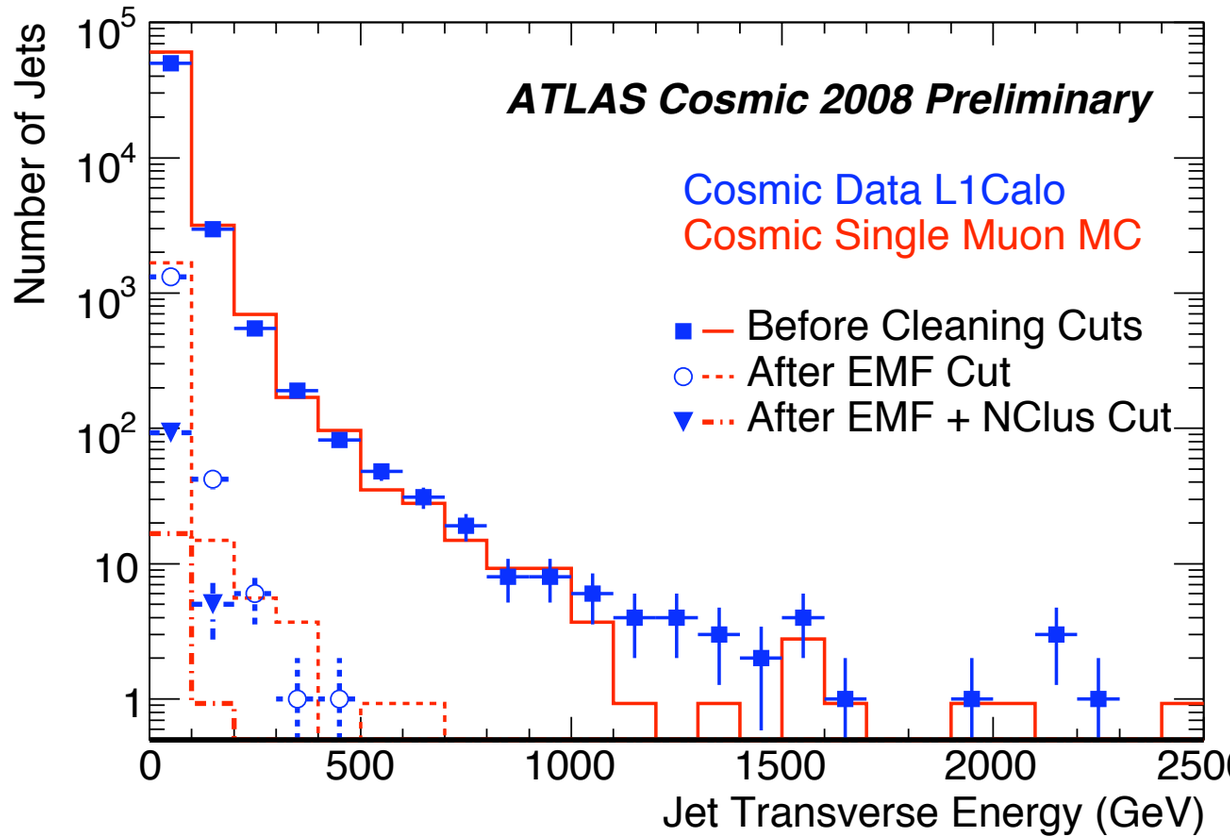
- Good understanding of mET is required
- Fake missingET due to cosmics, detector effects/failure

1 or multi-lepton + jets + mET :

- Cleaner than the above
- Understanding the SM background is more important

jets and mET cleaning using cosmic data

- Understanding the jet energy and missing energy spectrum and to clean up the fake mET is very crucial for physics searches like SUSY
- ATLAS took cosmic data for a long period in 2008
- Cosmic rays that pass through the calorimeter system and deposits a large amount of energy are compared with MC simulation



- A good representation of data can be seen. Effective clean up for the fake mET (rejection ~ 99.9%) while keeping all the good physics events

Jets + mET search in ATLAS - 1

$\sqrt{s} = 10\ \mathrm{TeV}, \int \mathrm{Ldt} = 200\ \mathrm{pb}^{-1}$

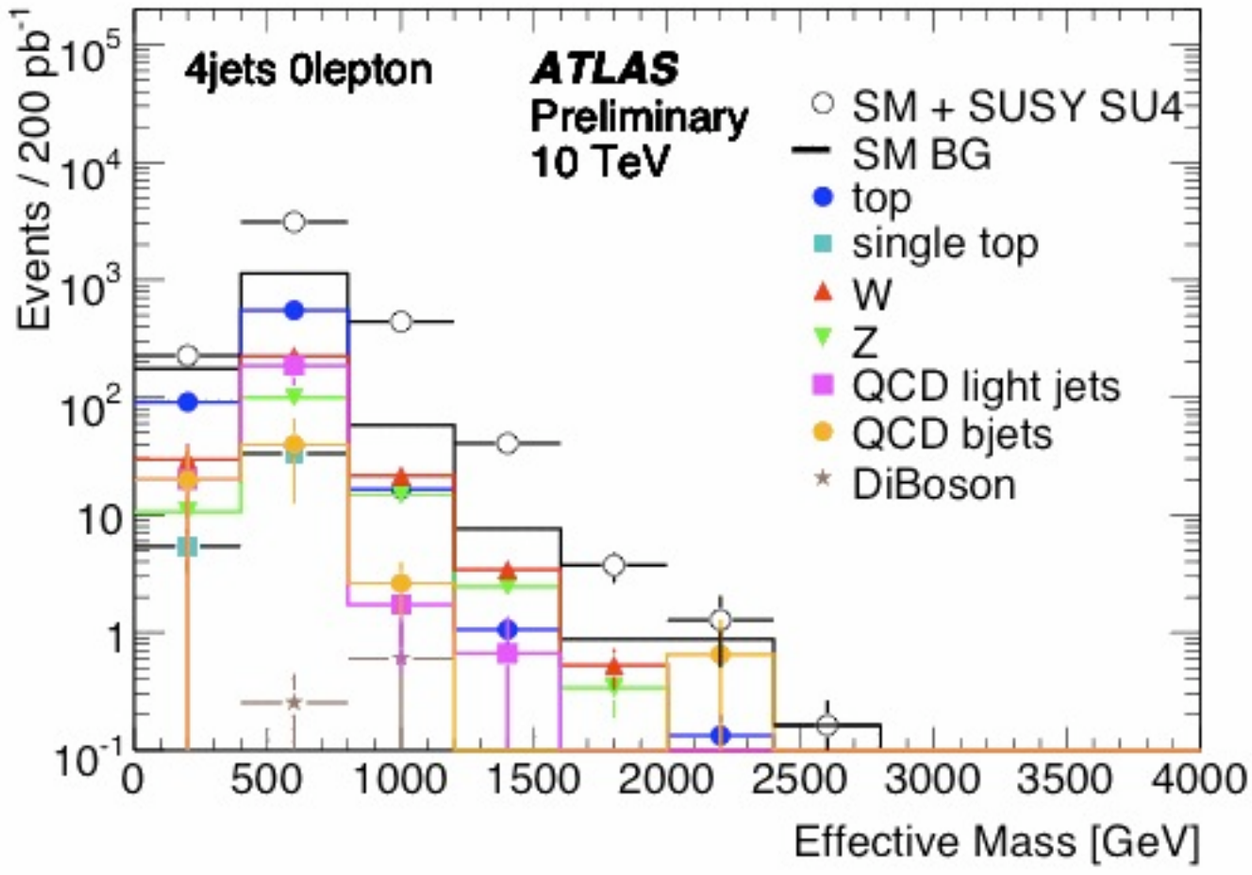
Least model dependent signature

❖**4 or more high-pT jets + large missing energy**

Main backgrounds : QCD, tt

suppressed by simpler yet harder kinematic cuts

➡at least 4 jets: pT(100,40,40,40) GeV
➡mET > 80 GeV
➡mET > 0.2*Effective Mass
➡Transverse sphericity > 0.2
➡dPhi(jets, mET) > 0.2
➡Effective Mass > 800 GeV



Effective Mass, $M_{\mathrm{eff}} = \sum_{i=1}^{N} p_T^{jet,i} + \sum_{i=1}^{N} p_T^{lep,i} + \not{E}_T$

After the cuts, tt and Z->νν are the dominant SM backgrounds

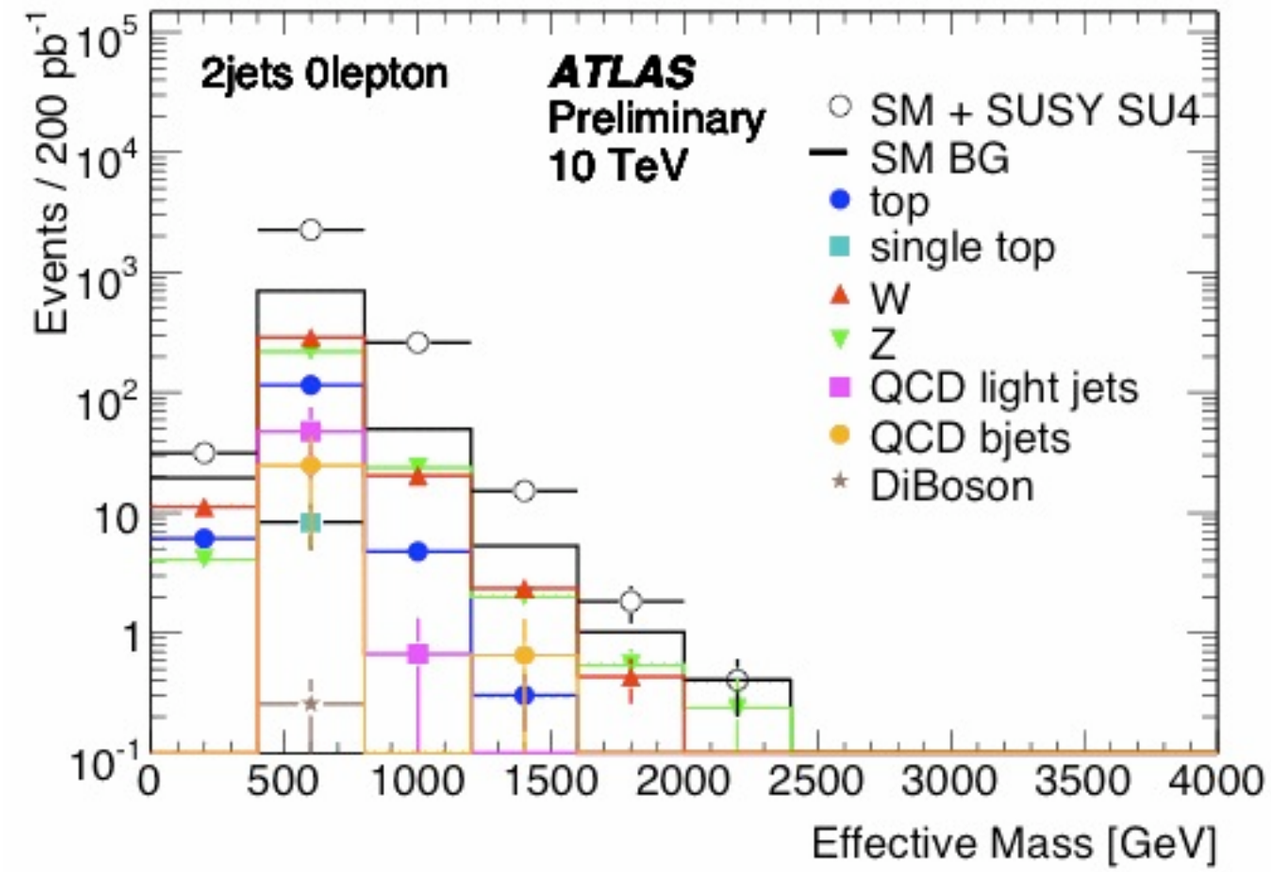
➡**Expected SM BG events : 70 for 200 pb^{-1} at 10 TeV**

➡**Good chance to discover SUSY with this channel**

Jets + mET search in ATLAS - 2

$\sqrt{s} = 10\ \mathrm{TeV}, \int \mathrm{Ldt} = 200\ \mathrm{pb}^{-1}$

- Similar analysis as the earlier, but with inclusive lower jet multiplicities (2jets and 3 jets)
  - Control the increasing QCD background by applying harder jet pT cuts



➡at least 2 jets: pT(180, 50) GeV
➡mET > 80 GeV
➡mET > 0.3*Effective Mass
➡dPhi(jets, mET) > 0.3

- **Comparable backgrounds from tt, W+jets and Z+jets**
- **QCD background is much smaller than others**
- **Understanding of fake mET in the real data is necessary for the jets +mET channels**

1 lepton + jets + mET in ATLAS - 1

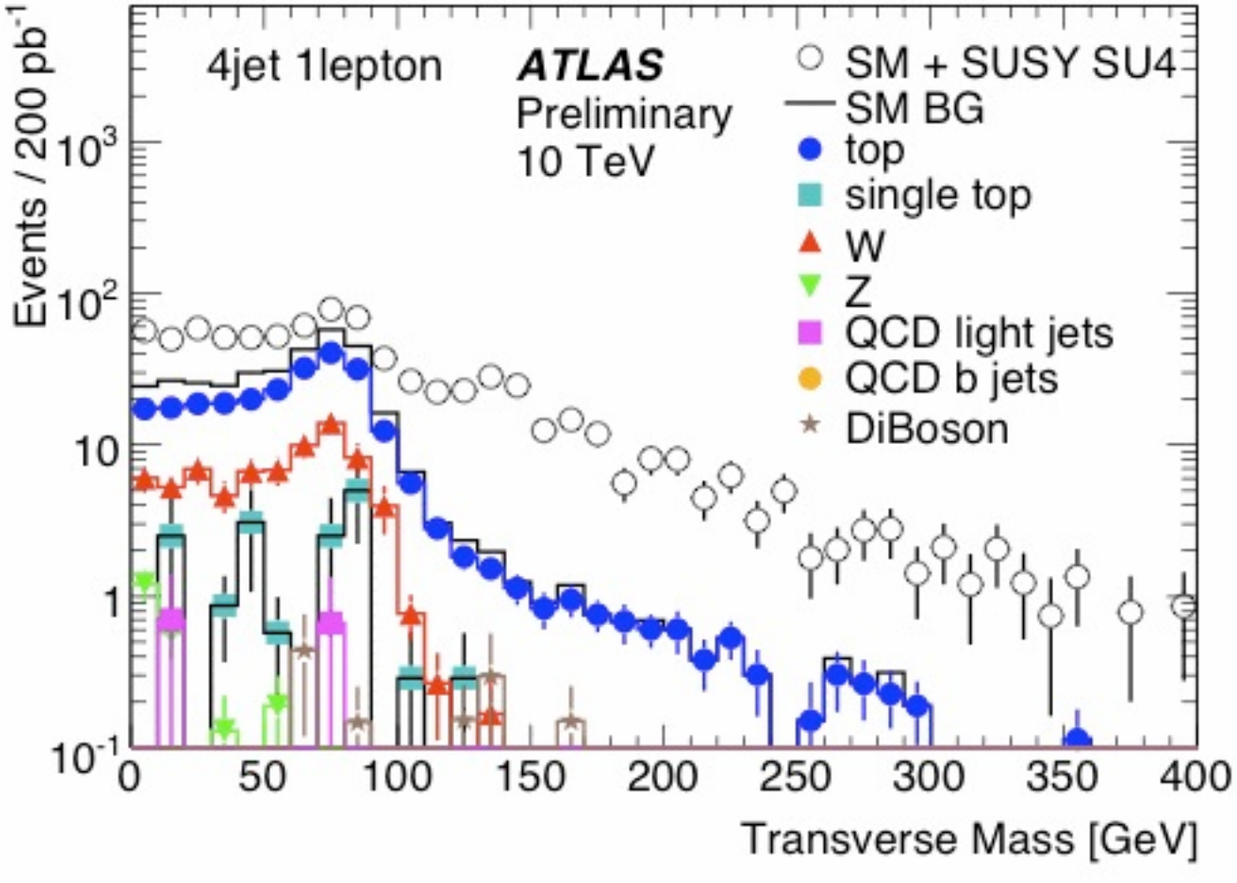
$$\sqrt{s} = 10\ \mathrm{TeV}, \int \mathrm{Ldt} = 200\ \mathrm{pb}^{-1}$$

- Cleaner channel than the generic search of **0 lepton + jets + mET**
- QCD background can be controlled by requiring high pT lepton in the event
- Keep similar hard pT cuts for jets as the zero lepton analysis
- The lepton in the event leads to further discriminating variable between the signal and background like the **Transverse Mass (M_T)**

$$M_T = \sqrt{2\ p_T^{lep}\ \not{E}_T\ \left(1 - \cos\Delta\phi(p_T^{lep}, \not{E}_T)\right)}$$

➡Transverse mass acts as a good variable to select control samples for the SM BG

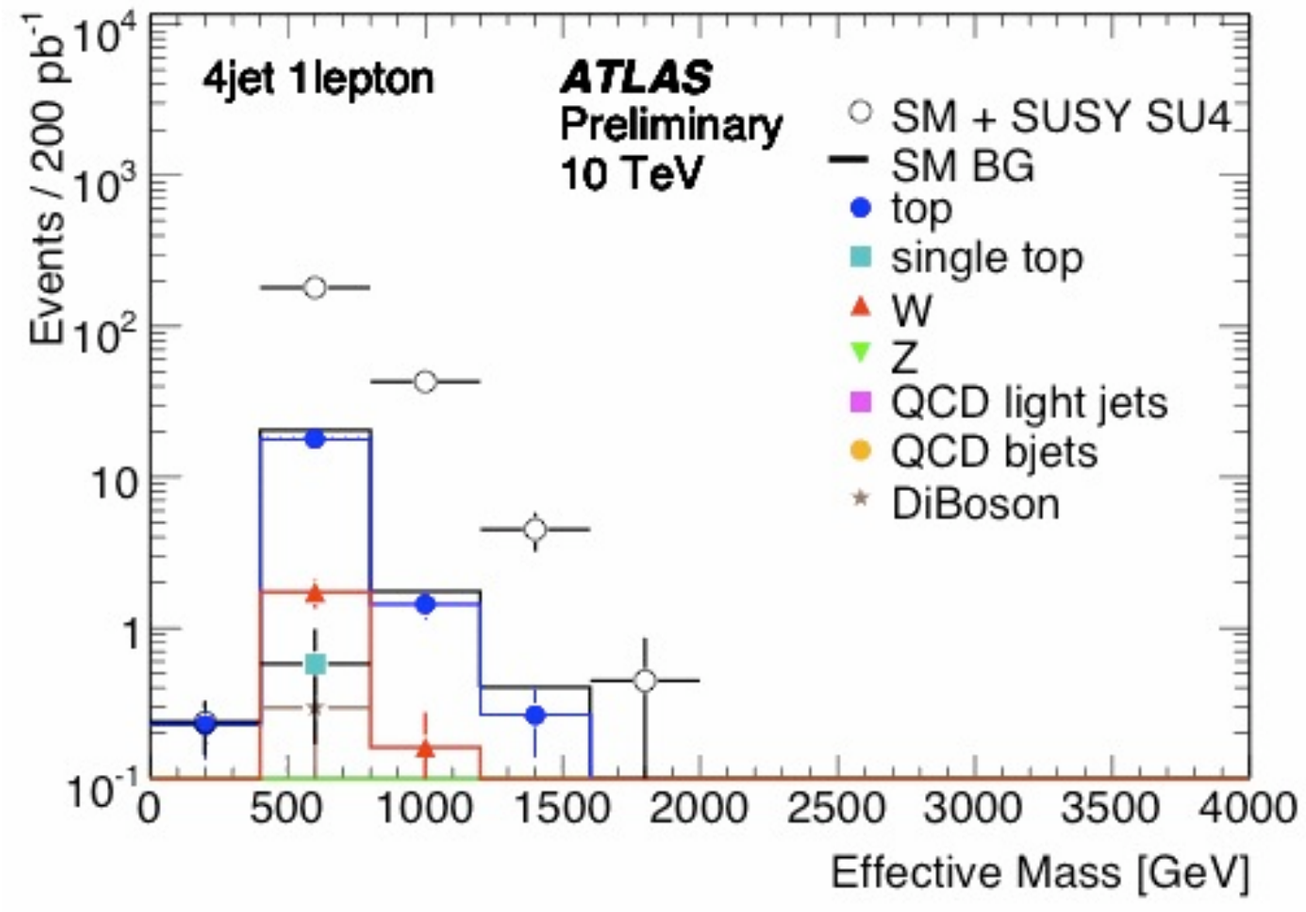
➡This variable can be used to estimate the SM BG from the real data along with other variable like mET



1 lepton + jets + mET in ATLAS - 2

$\sqrt{s} = 10\ \mathrm{TeV}, \int \mathrm{Ldt} = 200\ \mathrm{pb}^{-1}$

- Analysis includes high-pT lepton and jets to suppress the SM BG
- Clear excess of SUSY signal after the event selection cuts



➡1 lepton with pT > 20 GeV
➡at least 4 jets: pT(100,40, 40, 40) GeV
➡mET > 80 GeV
➡mET > 0.2*Effective Mass
➡Transverse sphericity > 0.2
➡Transverse Mass > 100 GeV

- tt is the dominant SM BG
- Excellent signal to noise ratio

❖Consider as the "golden" channel to discover SUSY in ATLAS

multi-lepton + jets + mET in ATLAS - 1

$\sqrt{s} = 10\ \mathrm{TeV}, \int \mathrm{Ldt} = 200\ \mathrm{pb}^{-1}$

- More isolated leptons in the final state
  - Decrease in the production cross section, yet more clean environment

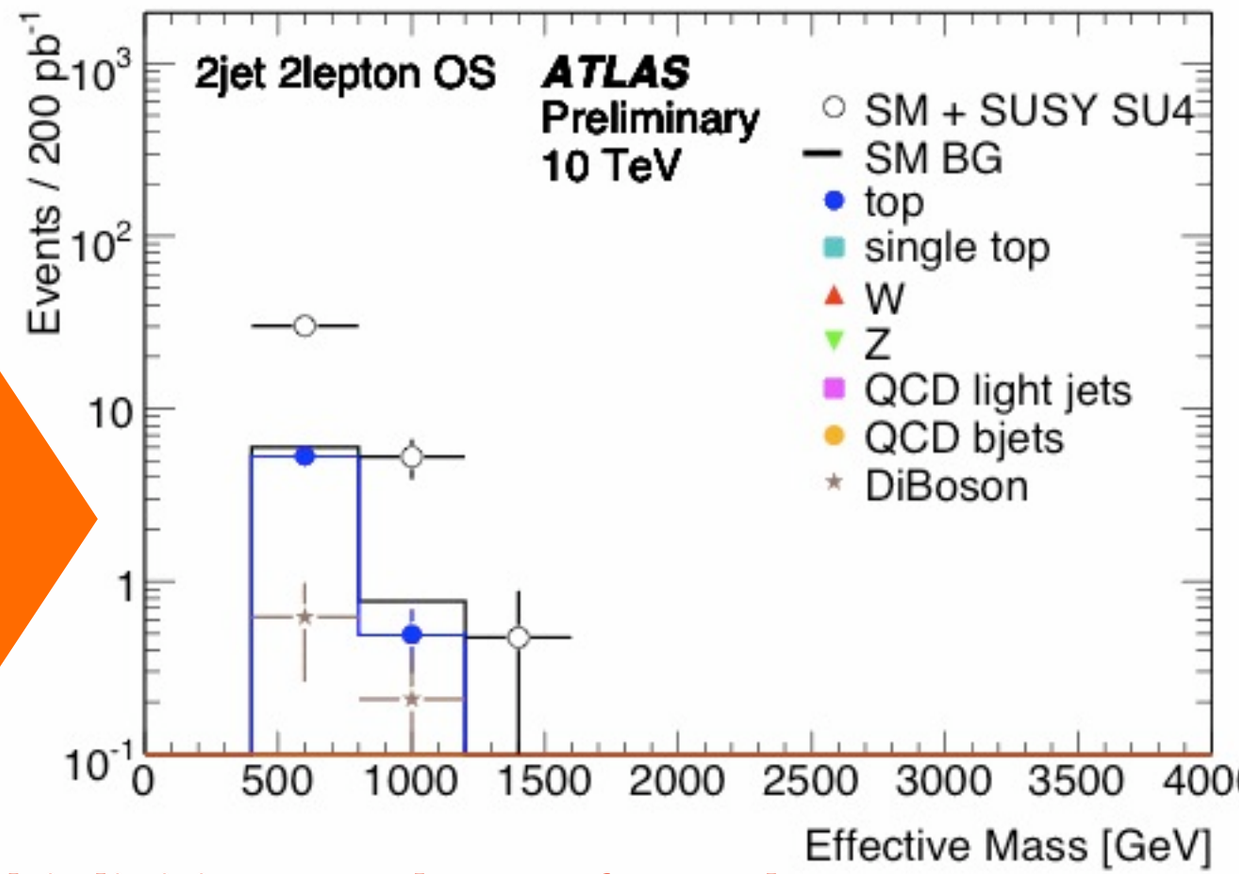
2 lepton + jets + mET

- **2 lepton channel can be divided into two categories based on the electric charge of the two leptons**

  same-sign (SS) and opposite sign (OS)

OS dileptons

- ➡**2 OS lepton with pT > 10 GeV**
- ➡**at least 2 jets: pT(180,50) GeV**
- ➡**mET > 80 GeV**
- ➡**mET > 0.3*Effective Mass**
- ➡**Transverse sphericity > 0.2**



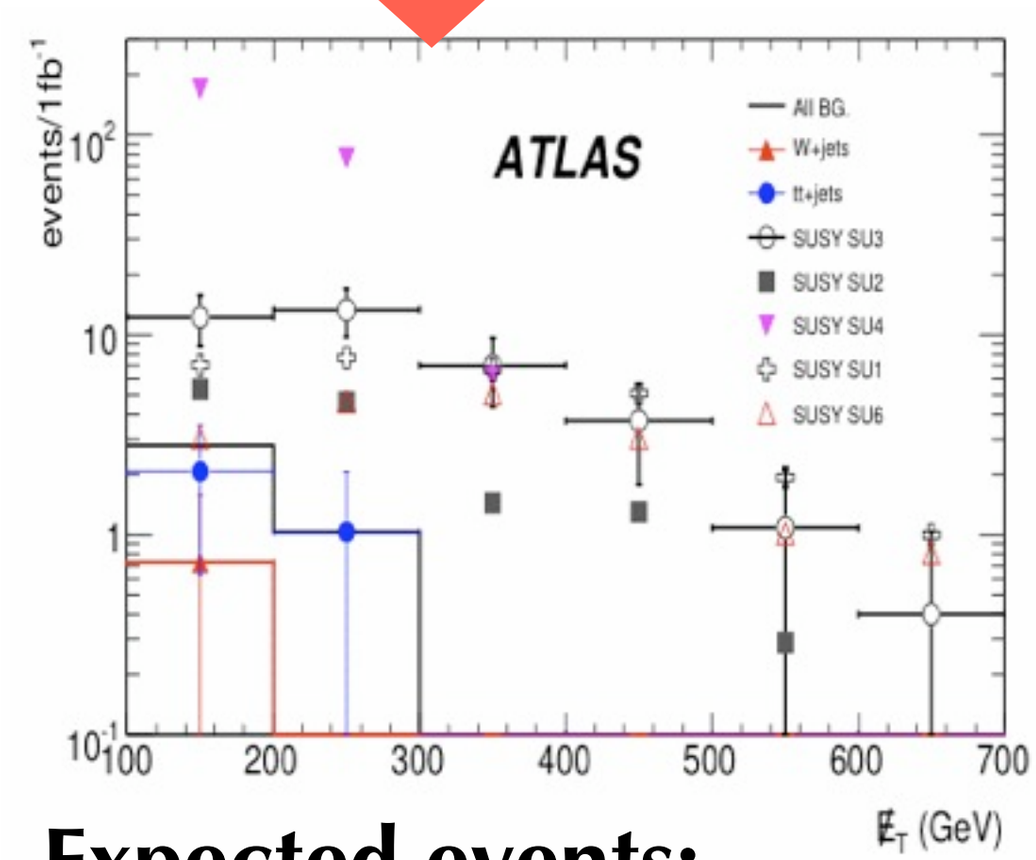
❖**Similar analysis with higher jet multiplicities are also performed**

multi-lepton + jets + mET in ATLAS - 2

$\sqrt{s} = 14$ TeV, $\int Ldt = 1$ fb^{-1}

SS dileptons

- ➡2 SS lepton with pT > 20 GeV
- ➡at least 4 jets: pT(100,50, 50, 50) GeV
- ➡mET > 100 GeV
- ➡mET > 0.2*Effective Mass



Expected events:

- **SU3 ~25, SM BG ~2**
- **Significance ~8 sigma**

- Scarce production via SM processes makes it an almost background-free channel
- In SUSY the SS dilepton production can be large via the gluino-gluino production

3 lepton channel

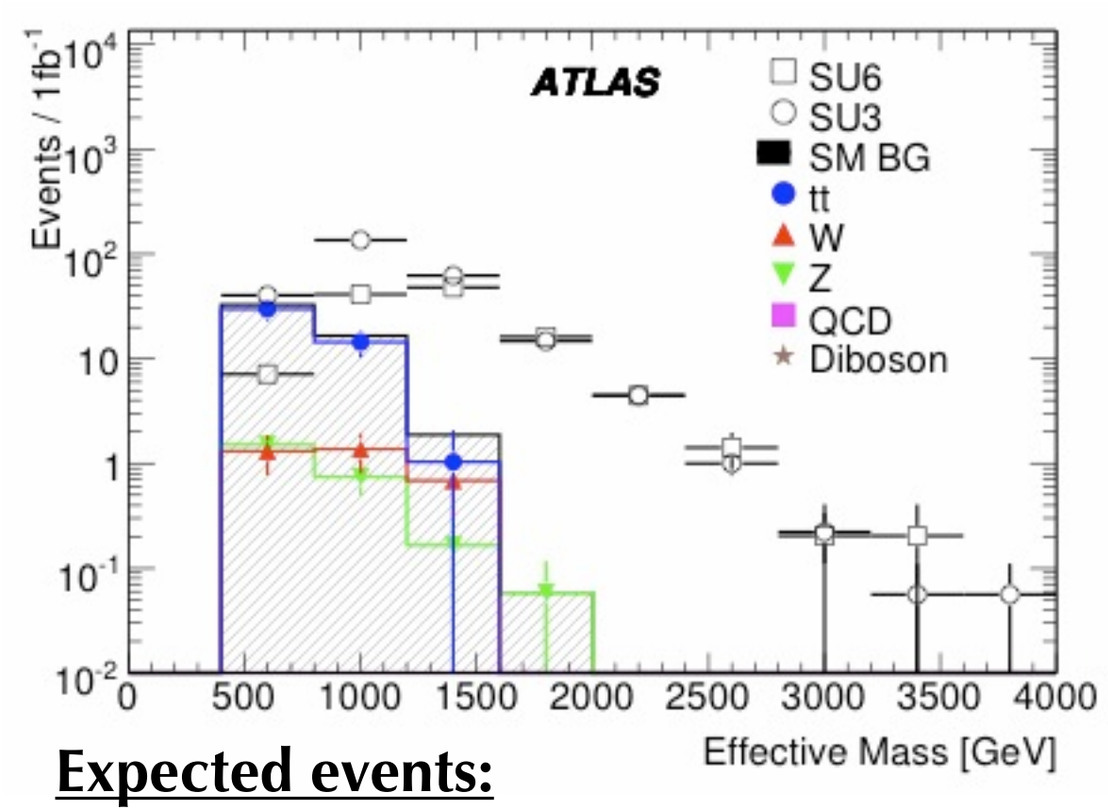
- Look for different sources of trilepton production via sparticles decay
- Very low background, but also lower signal production
- Production with and without mET has been investigated
- We can have a discovery beyond 5 sigma for this channel

tau/b-jets + mET in ATLAS

$\sqrt{s} = 14$ TeV, $\int Ldt = 1$ fb^{-1}

Tau-jets + mET

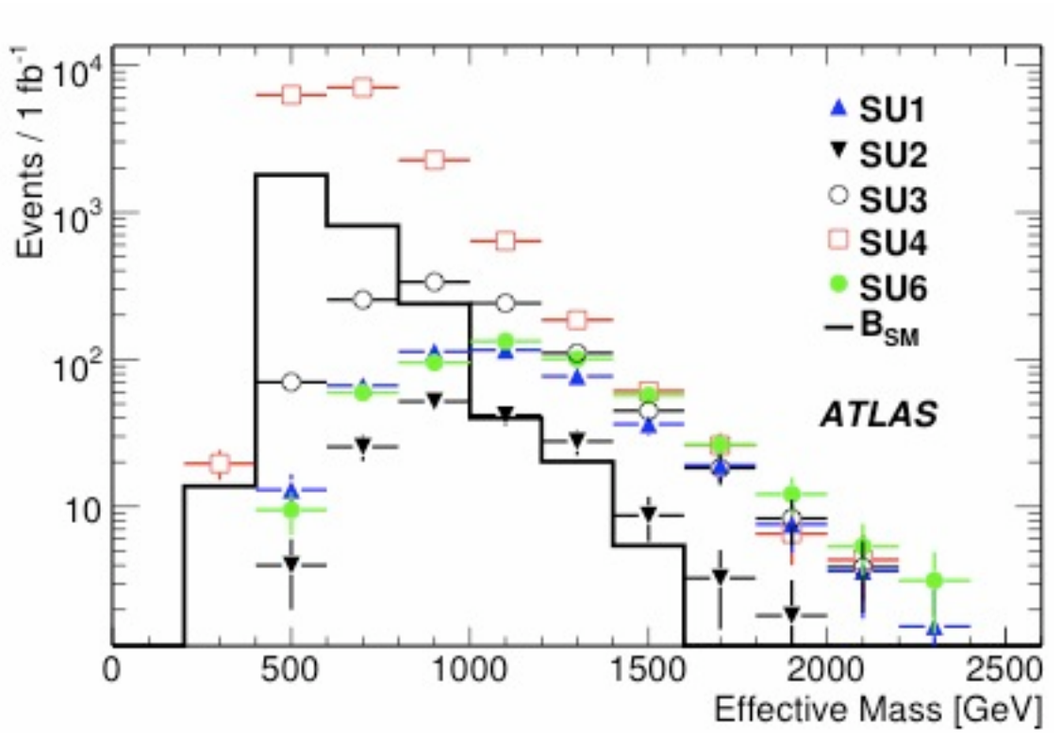
- Generically, SUSY models may not follow lepton universality, so tau decays can be dominant, especially with higher tanB
- To understand from data:
  - -Reconstruction of taus
  - -The rate of a jet faking a tau



Expected events:

- **SU3~250, SM~50**
- **Significance ~ 12 sigma**

b-jets + mET



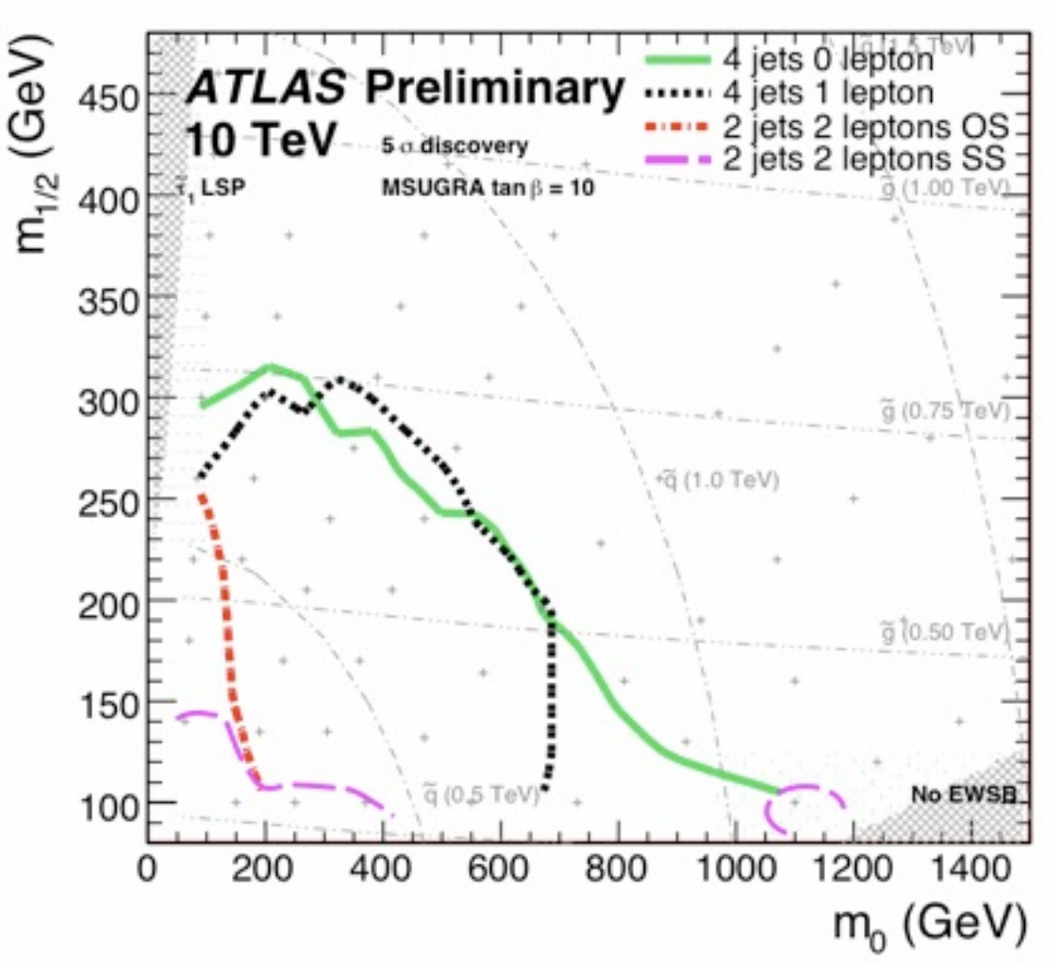
- Requiring a b-quark in the jets+mET analysis suppresses the QCD background to percentage level
- SUSY processes will produce a lot of bb in the cascade, thus it can have a good chance of discovery

Expected events:

- **SU3~400, SM~70 (Effective Mass > 1 TeV)**
- **Significance ~ 13 sigma**

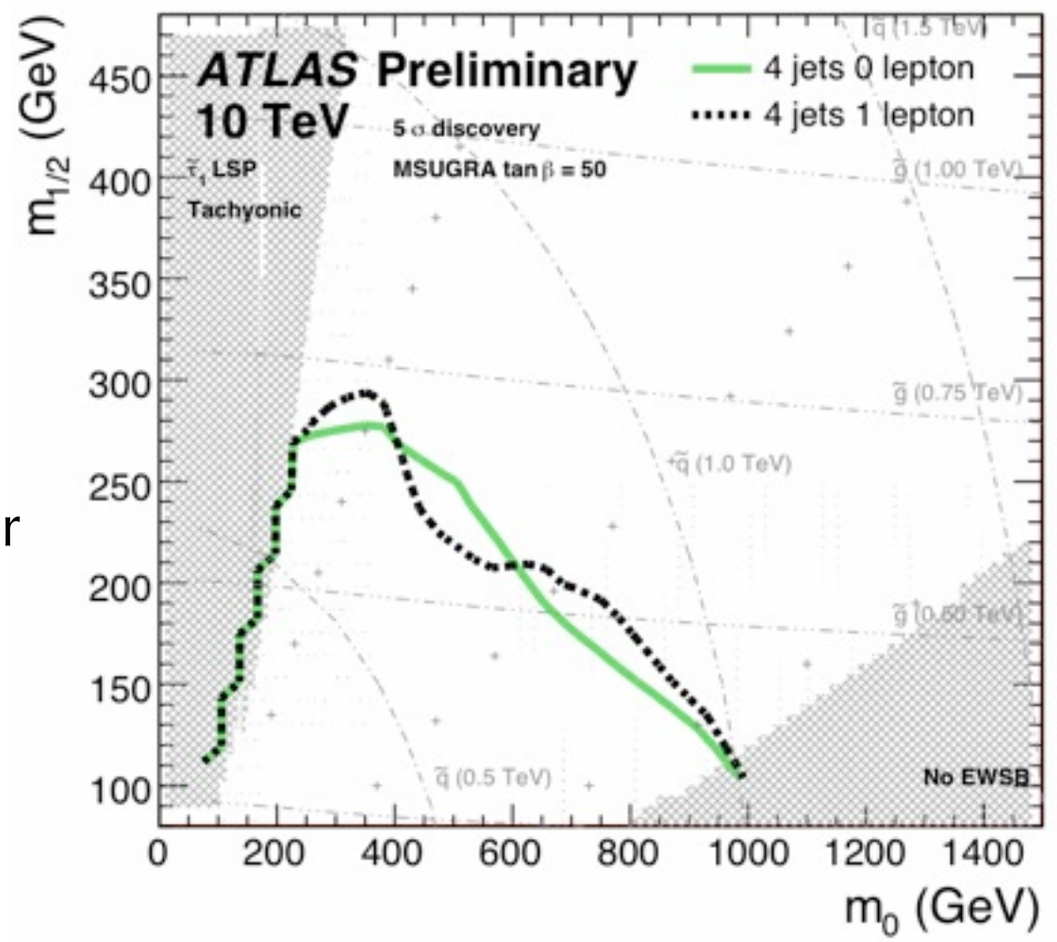
Discovery reach using mSUGRA scan

$\sqrt{s} = 10\ \text{TeV}, \int \text{Ldt} = 200\ \text{pb}^{-1}$



- Scans are done with mSUGRA grid points using a parametrized and fast simulation of the ATLAS detector
- SUSY spectra were generated using ISAJET
- These scans ignore the dark matter and few other constraints

  (can be referred as possible patterns of LHC signatures, but not as a true theory)



- ATLAS can discover new territory with almost every analysis channel
- 0 lepton can be the best channel to discover SUSY if the mET and QCD background is well understood from the data
- 1 lepton can be referred as a “golden” channel to discover SUSY in ATLAS

Summary

- Discovery of Supersymmetry need to be confirmed not by only a single channel, but by several channels, and also by both ATLAS and CMS
- It is necessary to explore all the channels regardless of the sensitivity of the channel (we don't know what nature have stored for us)

- ATLAS has covered a wide range of analysis in both 14 TeV and 10 TeV CM energy
- 0 lepton and 1 lepton channels can be considered the frontier analysis, but other channels also have good sensitivity to discover SUSY

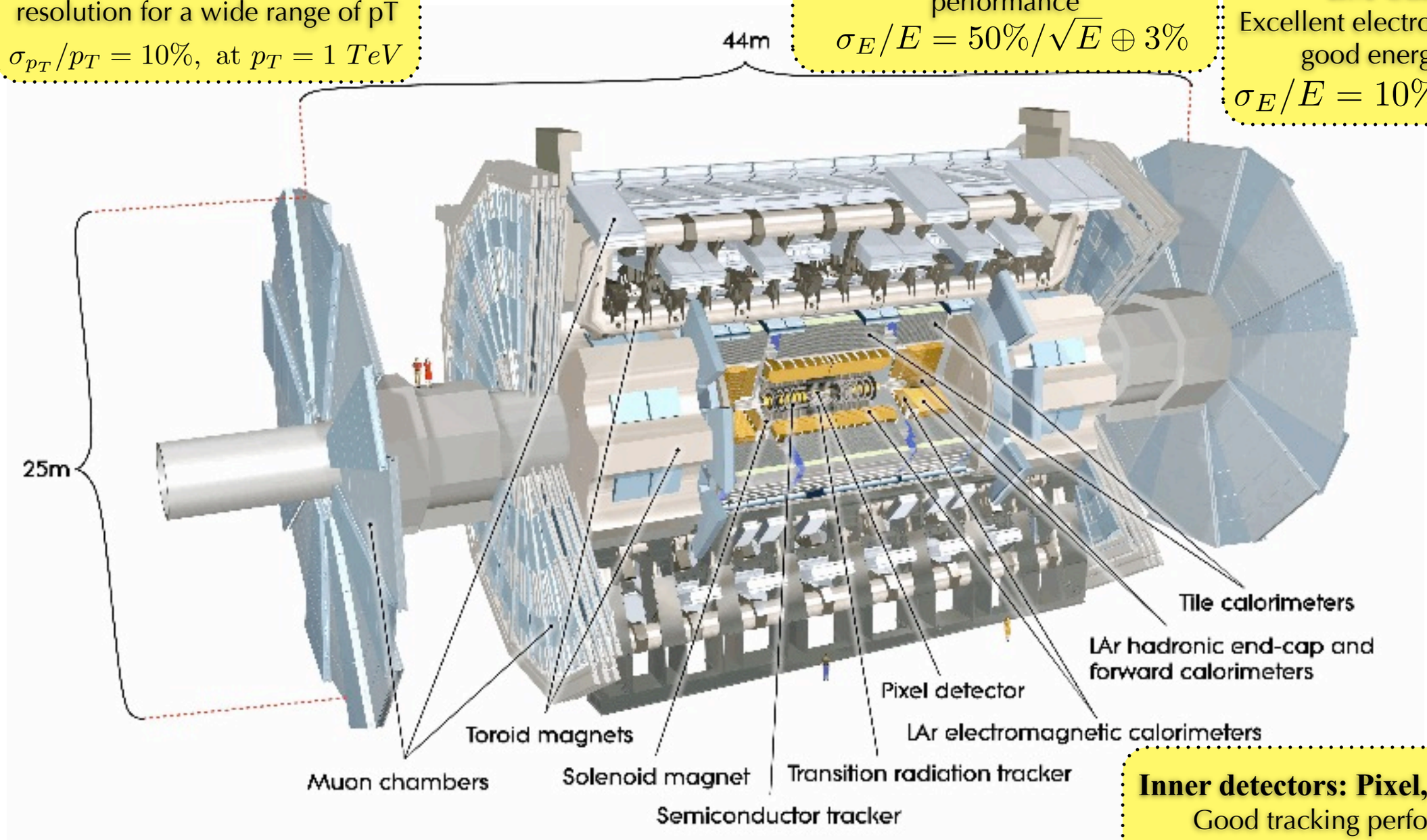
- The methods of doing the analysis in these channels will not be very different in the lower CM energies (if LHC starts with a lower CM energy)
- Lets hope for a discovery, but be prepared for an exclusion

Overview of the ATLAS detector and performance

Muon spectrometer
Good muon ID and momentum resolution for a wide range of pT
$\sigma_{p_T}/p_T = 10\%,\ \text{at}\ p_T = 1\ TeV$

Hadronic Calorimeter
Good jet and missing energy performance
$\sigma_E/E = 50\%/\sqrt{E} \oplus 3\%$

EM Calorimeter
Excellent electron and photon ID, good energy resolution
$\sigma_E/E = 10\%/\sqrt{E} \oplus 0.7\%$



Inner detectors: Pixel, SCT, TRT
Good tracking performance
$\sigma_{pT}/p_T = 0.05\%\ p_T \oplus 1\%$

Magnets: 2T solenoid (Inner detectors), 0.5T Toroids (Muon system)