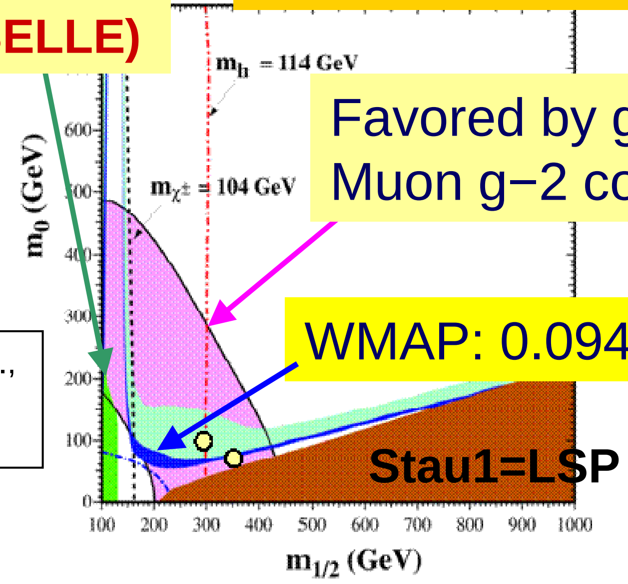
Searches at LHC for Physics Beyond the Standard Model

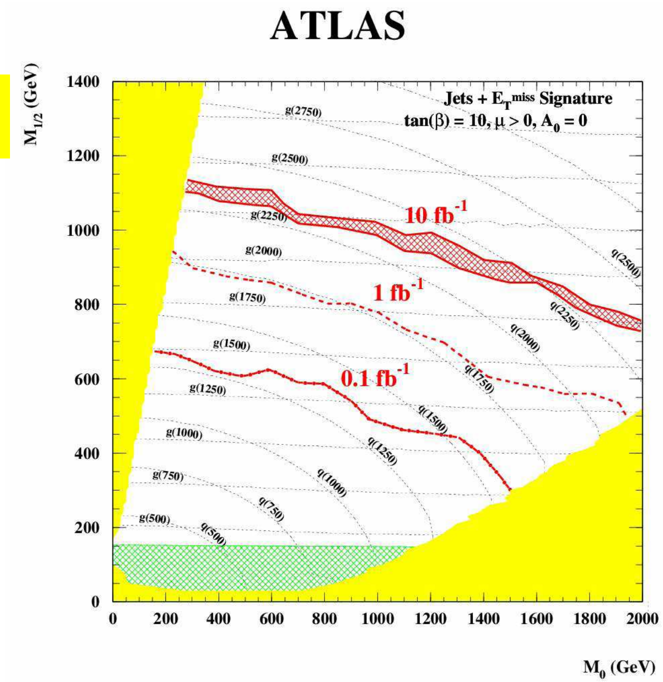
- SUSY
  - Inclusive search
  - Backgrounds
  - SUSY parameters
- Heavy long-lived particles
- Universal Extra Dimensions
- Black holes
- Resonances in the Drell-Yan mass distribution

SUSY Searches



J. Ellis et al., Phys. B565 (2003) 176.

Many SUSY searches are performed in the framework of mSUGRA



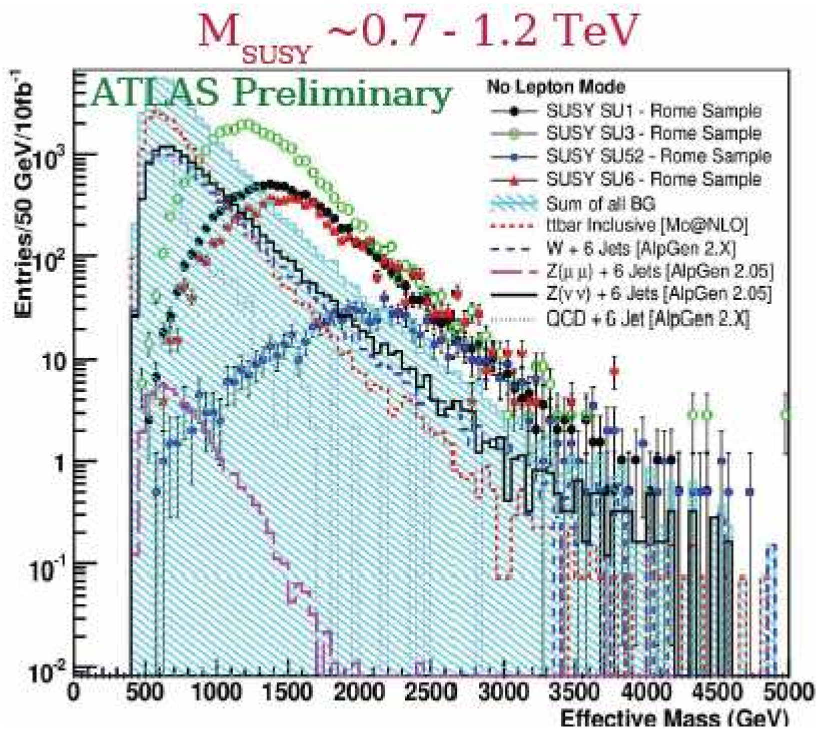
Aim of SUSY searches

- Find SUSY (or something new)
- Measure quantities (e.g. mass differences)
- Prove that it is SUSY
- Determine model parameters

Inclusive SUSY Search (Jets + missing Et)

Calculate effective mass from jet pt and missing transverse energy

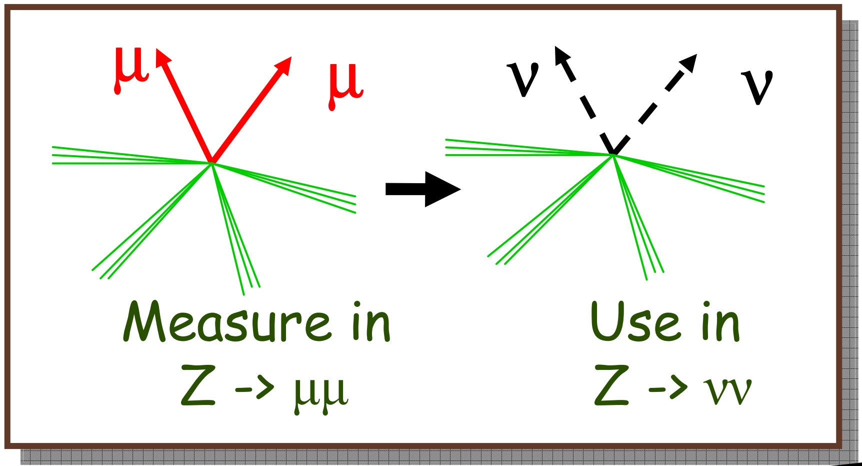
- Background estimates increased by Matrix Element Monte Carlo w.r.t. showering MC prediction
- Main backgrounds
  - Z(vv) + Jets
  - W + Jets
  - ttbar
- Backgrounds have to be estimated or checked with data

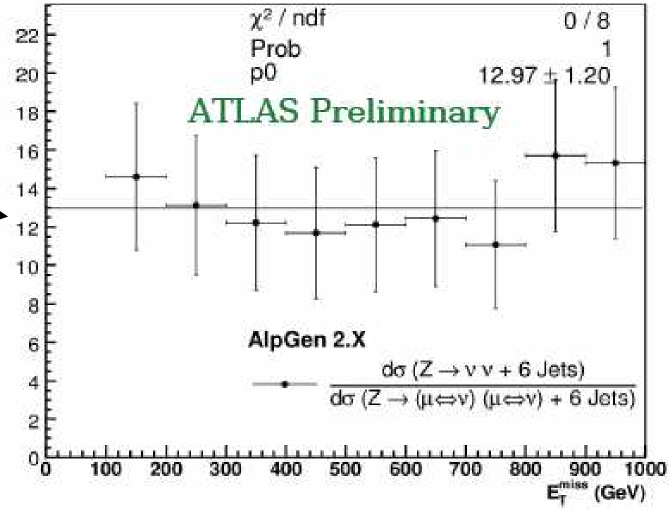


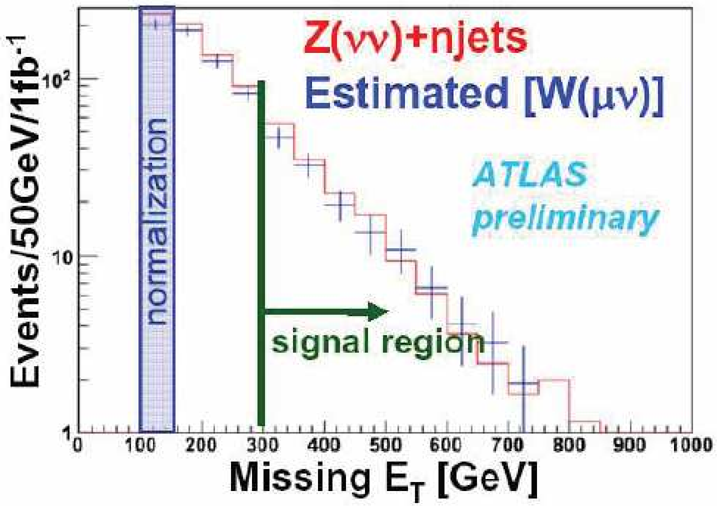
Backgrounds from Data

Replace observed μ by ν

- Z->μμ
  - clean sample
  - correct shape
  - small statistics







- W->μν
  - large statistics
  - a clean W+6jet sample

Background Normalization from Data

- Systematic uncertainties due to: Renormalization scale, factorization scale, PDF mostly effect normalization and not shape.
- Same normalization for Z->νν, Z->μμ, W->νμ
- Determine normalization from Z->μμ and apply to Z->νν, W->νμ

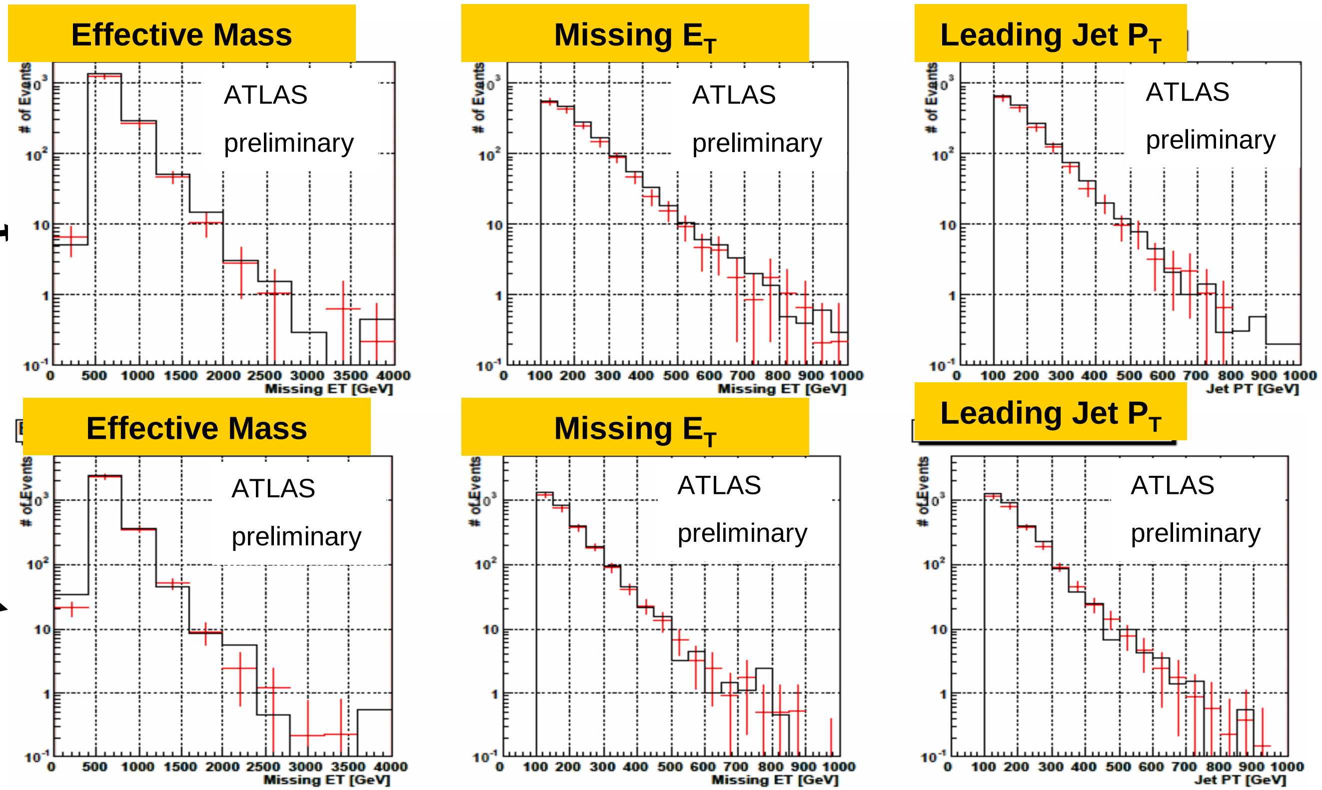
Test with "pseudo data" using different MC parameters

Z –> νν

230 +/- 15 (pseudo-data)
200 +/- 23 (estimation)

W –> lν

190 +/- 14 (pseudo-data)
185 +/- 21 (estimation)



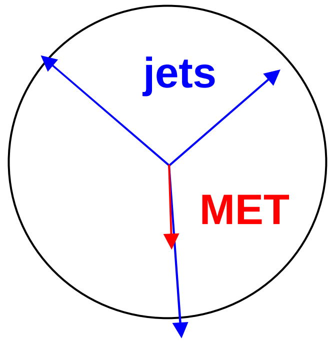
QCD Background

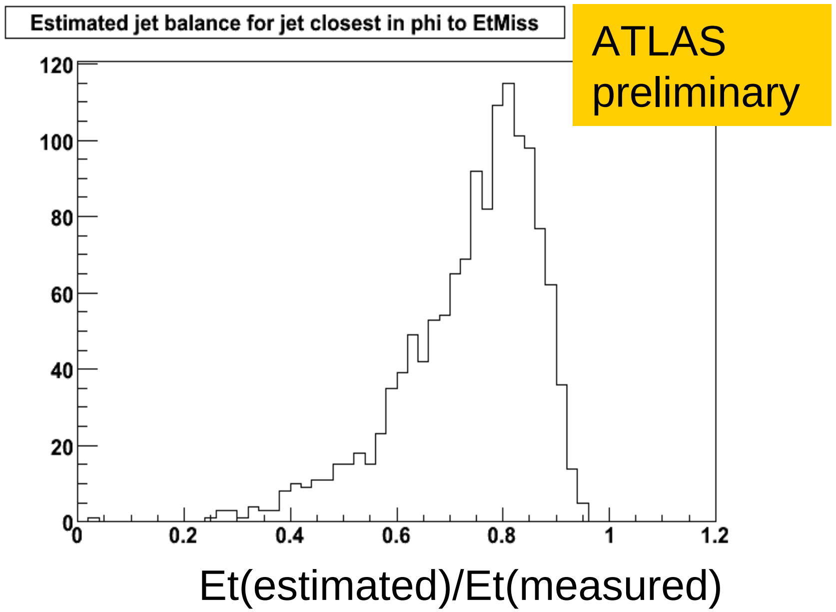
- Significant part with real missing Et from b- and c- decays
- Estimate effect of mismeasured jet energy with fast Monte Carlo
  - get transfer function from full detector simulation
  - get transfer function from data where missing Et points in jet direction

Select events with:

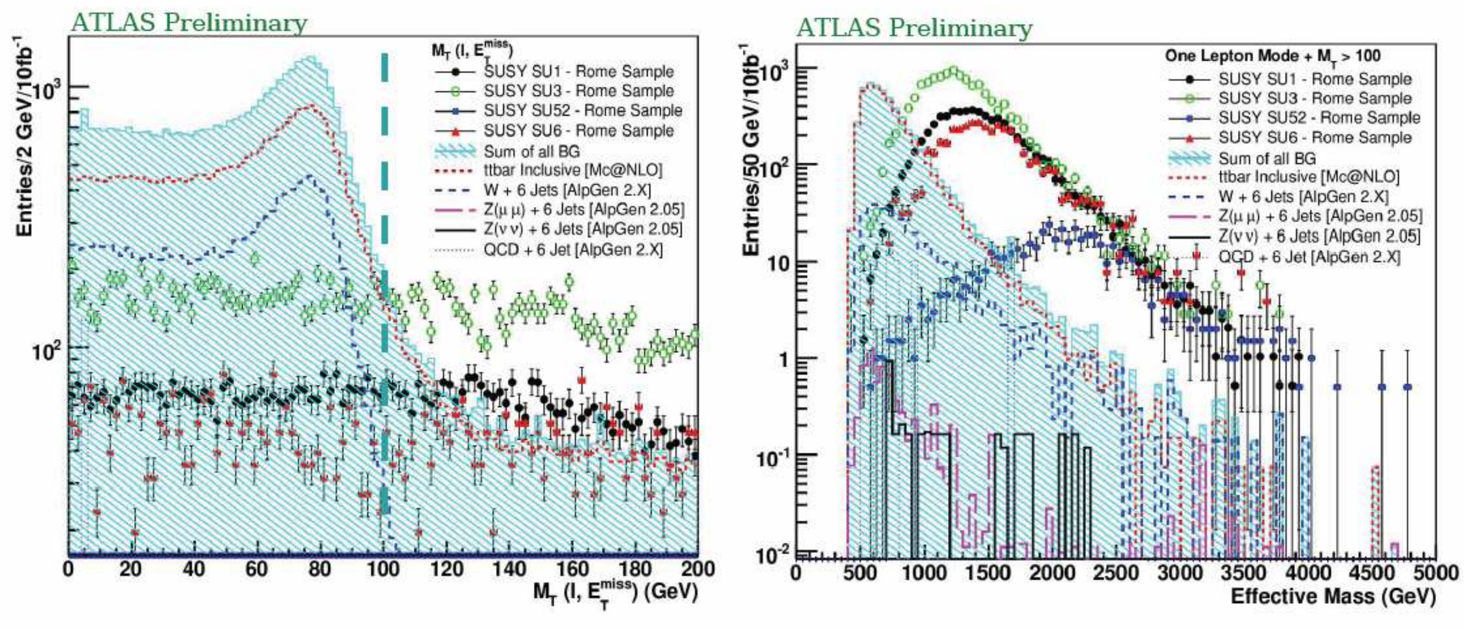
EtMiss > 100 GeV,

dPhi(EtMiss, jet) < 0.1





Inclusive SUSY Search (Jets+1lepton+missing Et)

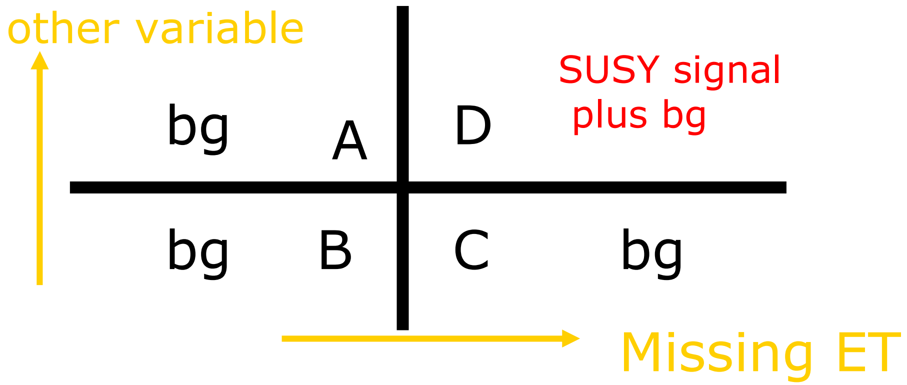


- Strong reduction of background due to lepton requirement
- Main background is ttbar
  - important contribution from blvblv with one missing lepton for M_T>100 GeV

Background from Data

Find second quantity not correlated to missing Et

General ideas:

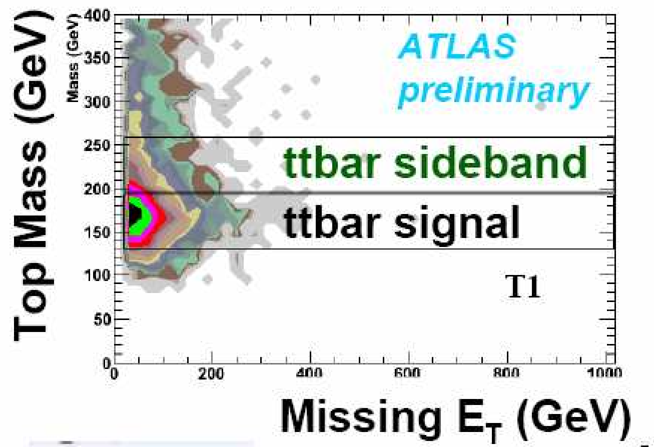


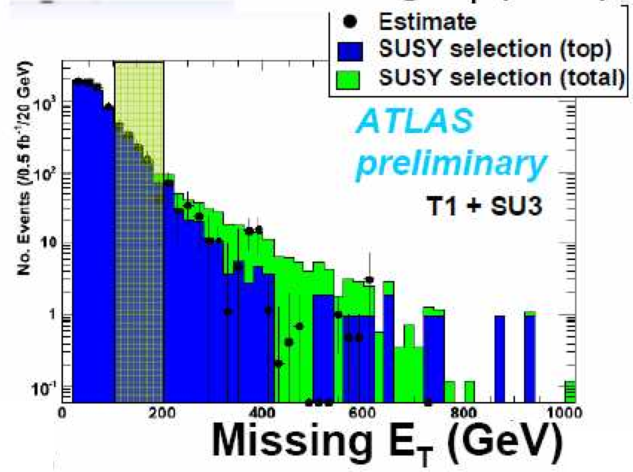
Bg in D = A x C/B

normalize to data

For ttbar-> bqqblv the top mass can be used as second quantity

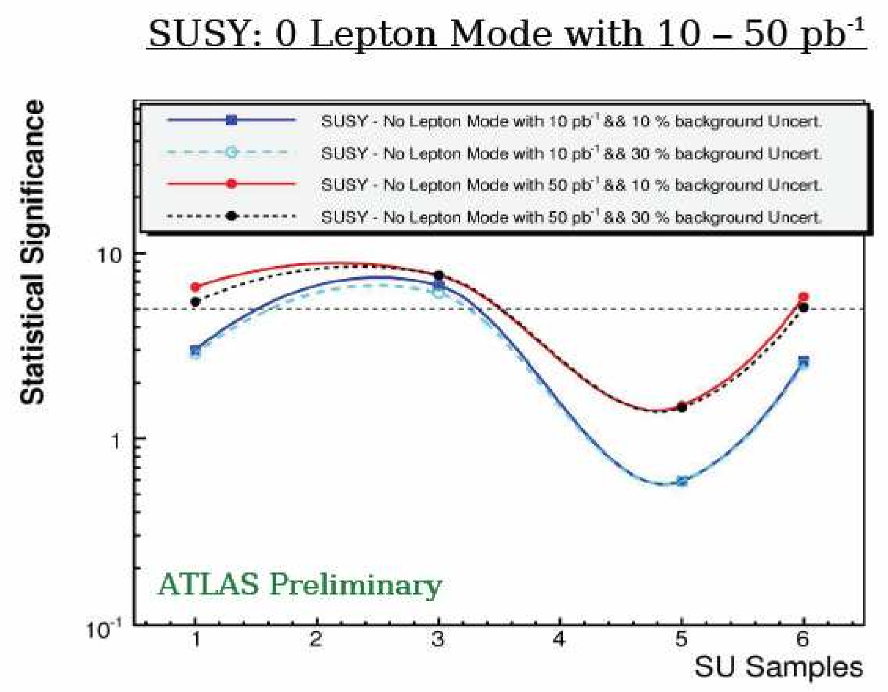
Contribution from ttbar->blvblv is under study

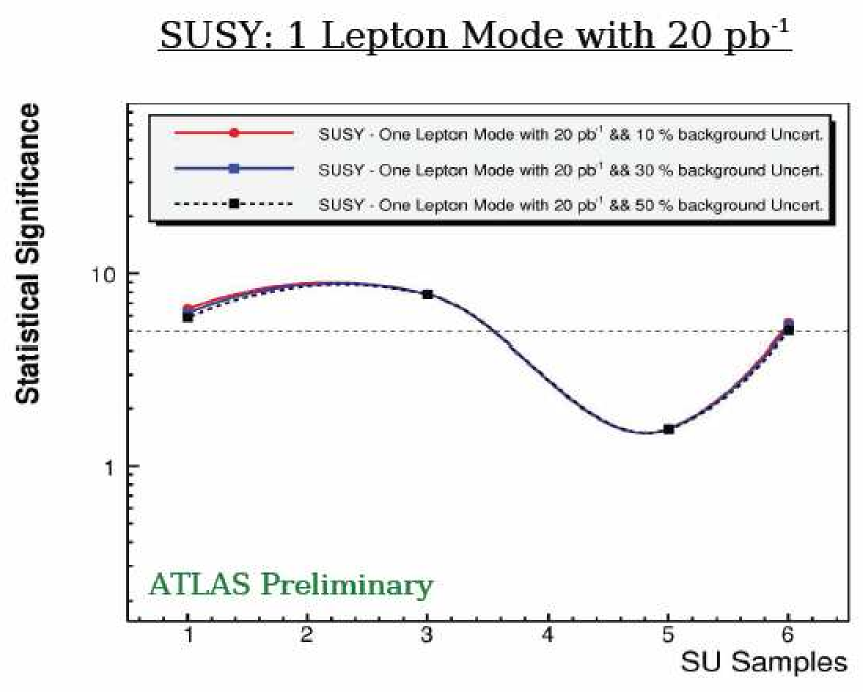




Expected significance

- The statistical significances have been studied including background uncertainties with the likelihood ratio method



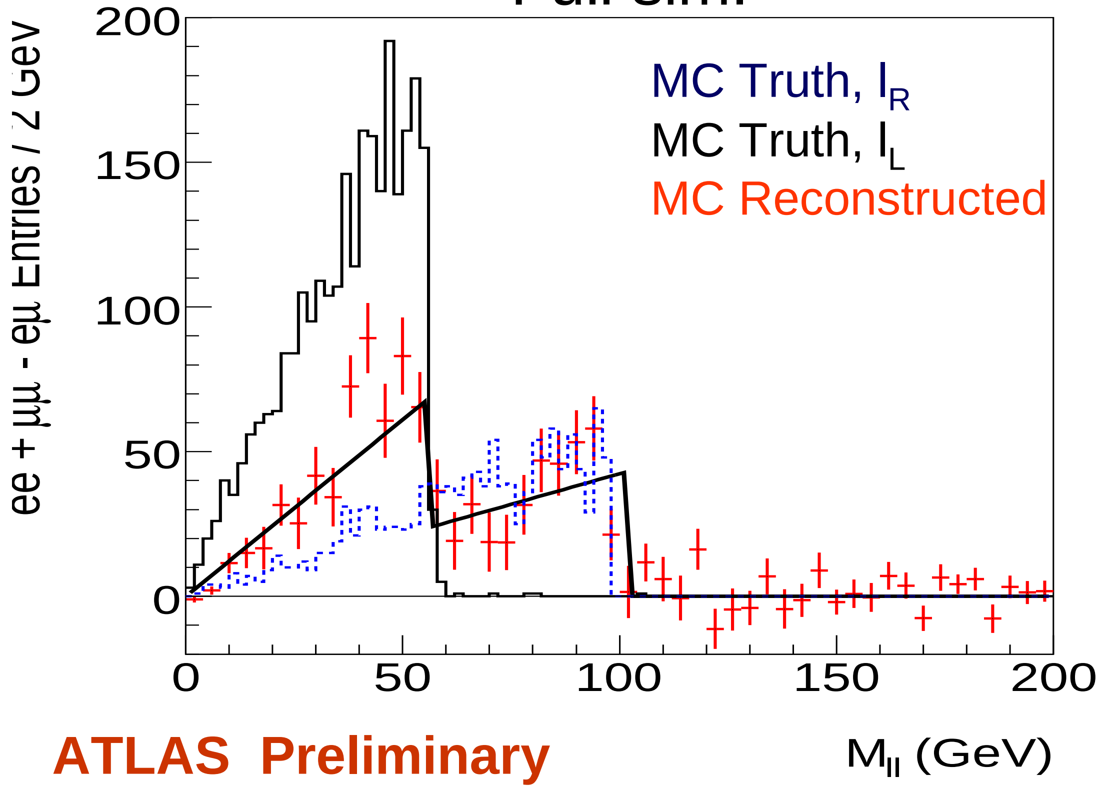


Determination of SUSY Parameters

$$\tilde{\chi}_2^0 \rightarrow l\tilde{l}_{R,L} \rightarrow ll\tilde{\chi}_1^0$$

264 154 , 255 137 GeV

Full sim. **20.6 fb^{-1}**



ATLAS Preliminary

Example:

Coannihilation point

- Two edges in lepton-pair-mass
- Estimate background from eμ events

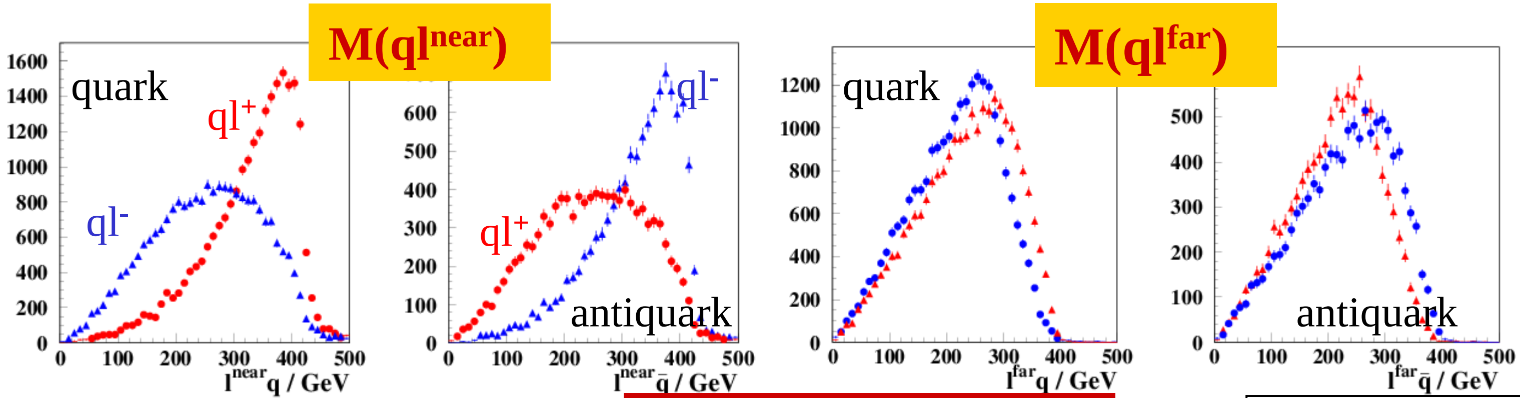
Spin Measurement

Spin: 0 1/2 0

First emitted lepton (“near”)

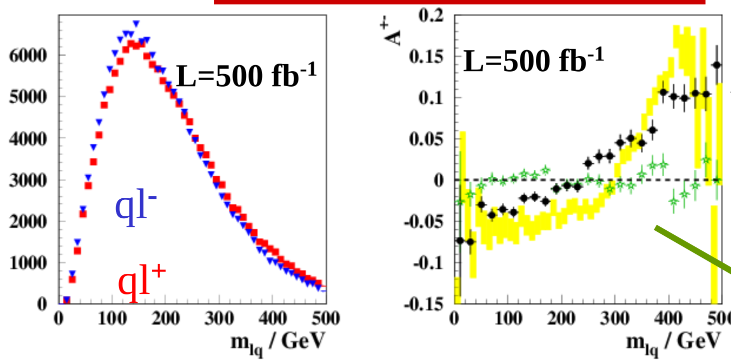
$$\tilde{q}_L \to q\tilde{\chi}_2^0 \to q\tilde{l}_R\, l^{near} \to q\, l^+ l^- + \tilde{\chi}_1^0$$

LHCC5:
m_0 =100 GeV
$m_{1/2}$ =300 GeV
A_0 =-300 GeV
$\tan(\beta)$ =2.1
sign(μ)=+



More quarks than antiquarks (pp collisions)
Remaining asymmetry:

ATLAS Fast Simulation



A. J. Barr
Phys.Lett.B596: 205-212,2004

After selection

Parton level x 0.6

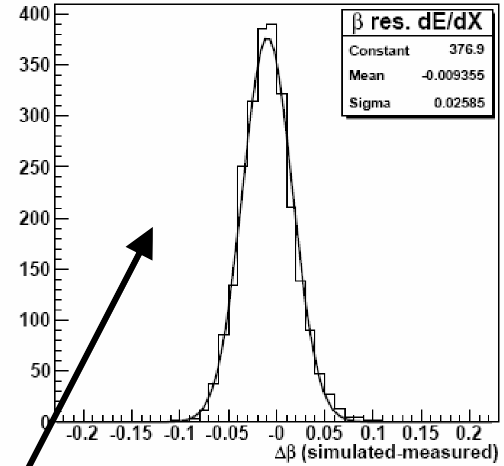
No spin correlations, no asymmetry

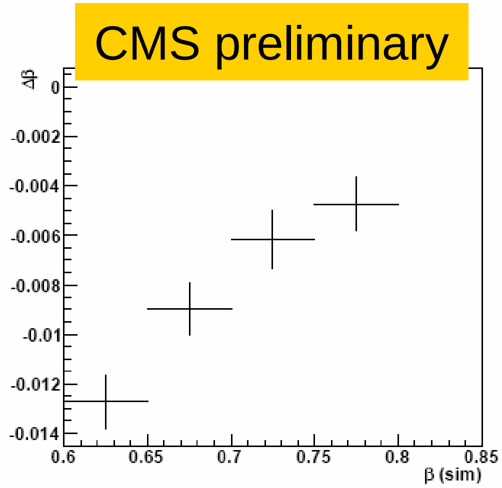
SPS1a Non-zero M(ql) asymmetry may be observed with 30fb-1

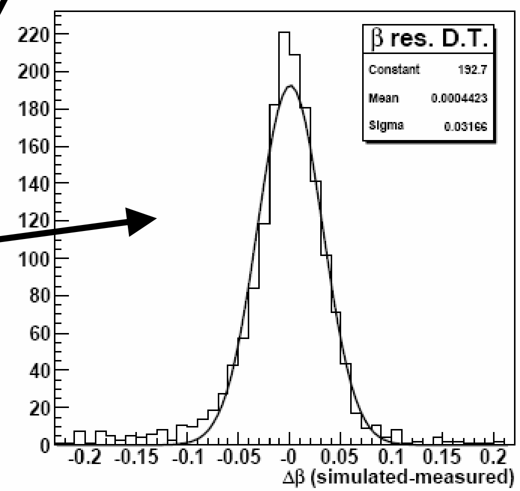
Search for Heavy Stable Particles

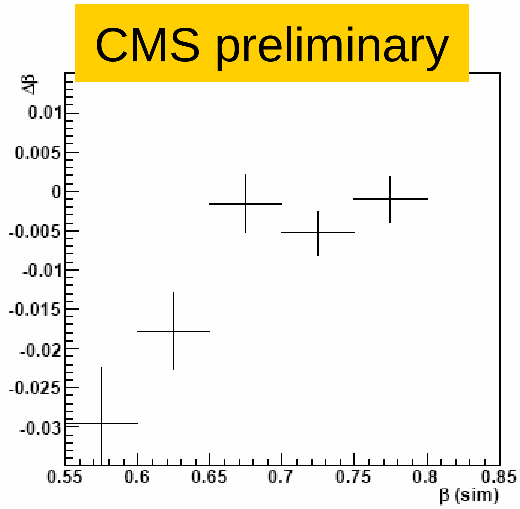
Predicted in various models

- Long lived stau as next to lightest particle in GMSB
- R-hadrons in Split-SUSY
  - Colored SUSY particle hadronizes (e.g. gluino)
- Determination of mass from momentum and velocity (β)
- β can be determined in the range from 0.6 – 0.8 by:
  - Energy loss in the tracker
  - Time of flight in the muon system







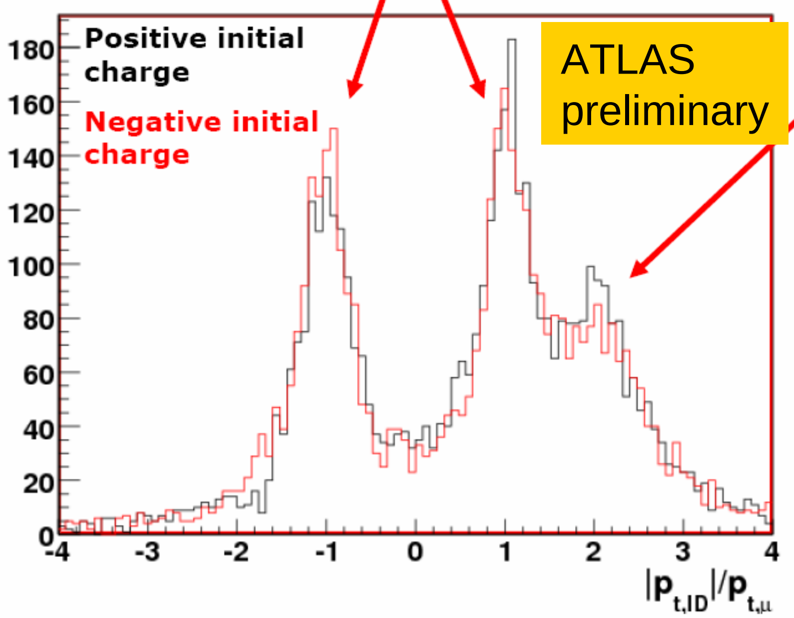


Search for Heavy Stable Particles

R–hadrons have hadronic interaction

- Energy/momentum mostly carried by SUSY particle
- Hadronic interactions will change the charge of the R-hadron

Charge can flip from ID to muon system



A factor ½ in pt means a factor 2 in charge.

Doubly charged particles in muon system

Examples:

$$\tilde{g}\rho^{+} + n \rightarrow \tilde{g}\Delta^{0} + \pi^{+}$$

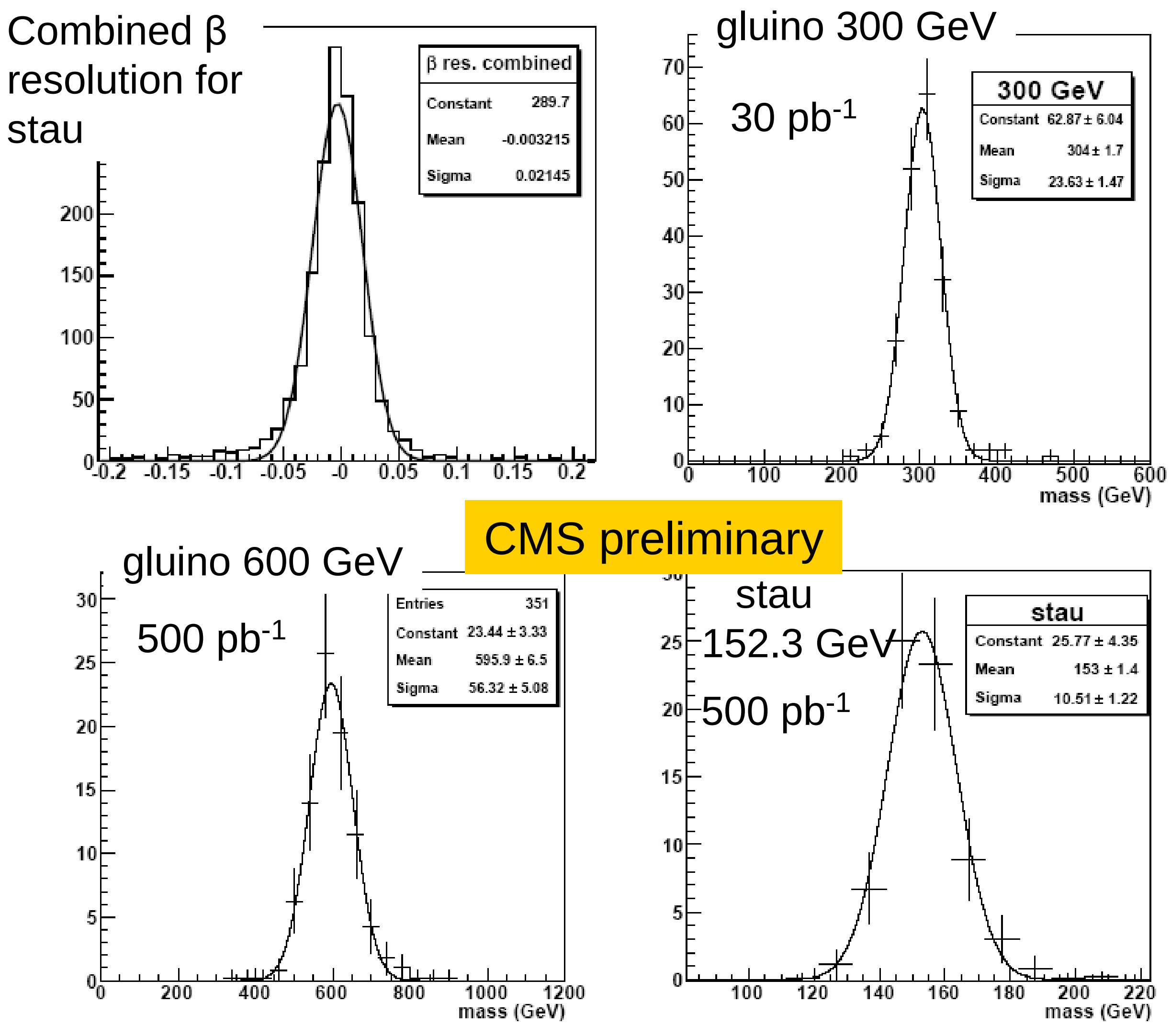
$$\tilde{g}\rho^{0} + p \rightarrow \tilde{g}\rho^{+} + n + \pi^{0}$$

$$\tilde{g}\rho^{+} + n \rightarrow \tilde{g}\Delta^{++} + \pi^{-}$$

Search for Heavy Stable Particles

Event selection

- $\beta(dE/dx) < 0.85$
  - to exclude MIPs
- $0.6 < \beta(dE/dx) < 0.8$
- $0.6 < \beta(TOF) < 0.8$
- m(dE/dx) > 30 GeV
  - to reject slow standard model particles
- number of tracker hits > 10
  - to eliminate fake tracks and optimize the quality of dE/dx
- pt cut at:
  - 150 GeV (300 GeV gluino)
  - 200 GeV (600 GeV gluino)
  - 80 GeV (152.3 GeV stau)
- expect< 25 BG events at L= 500 pb^{-1}
  - (zero unweighted MC events)

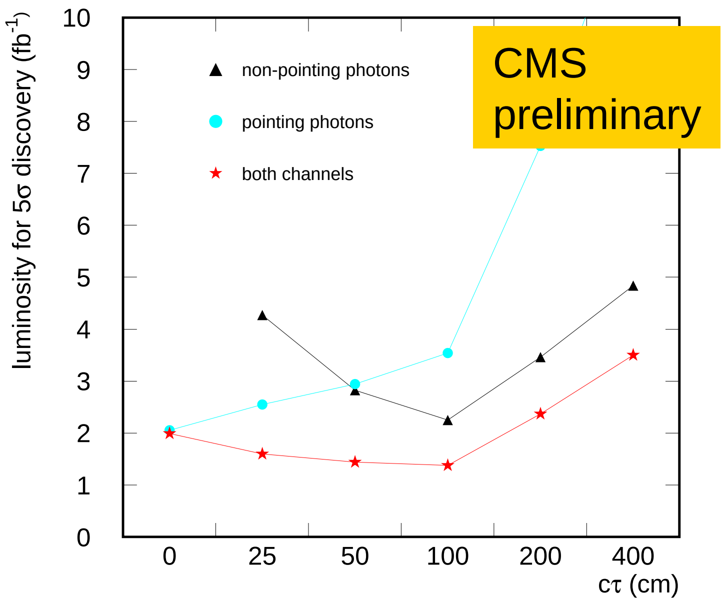


Search for Long-Lived Neutralinos

$$\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma$$

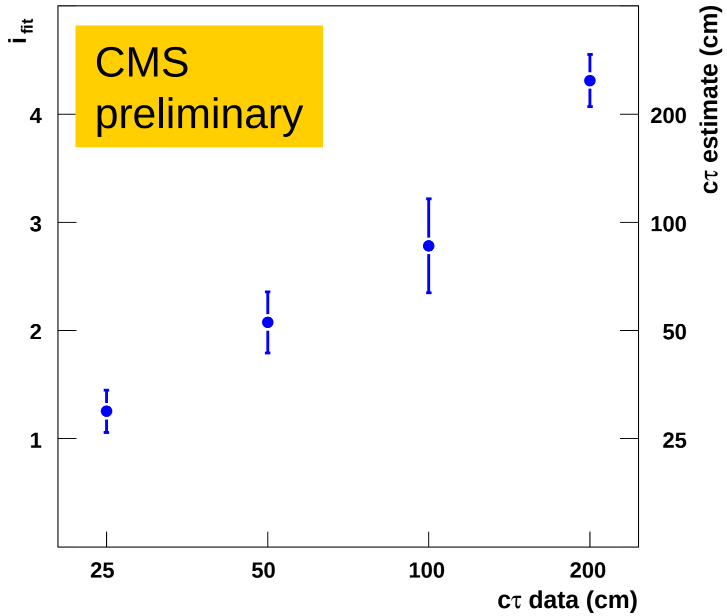
Event selection

- Isolated photon pt>80 GeV
- 4 Jets pt> 50 GeV
- missing energy > 160 GeV
  - not in Jet direction ($\Delta\varphi > 20^o$)



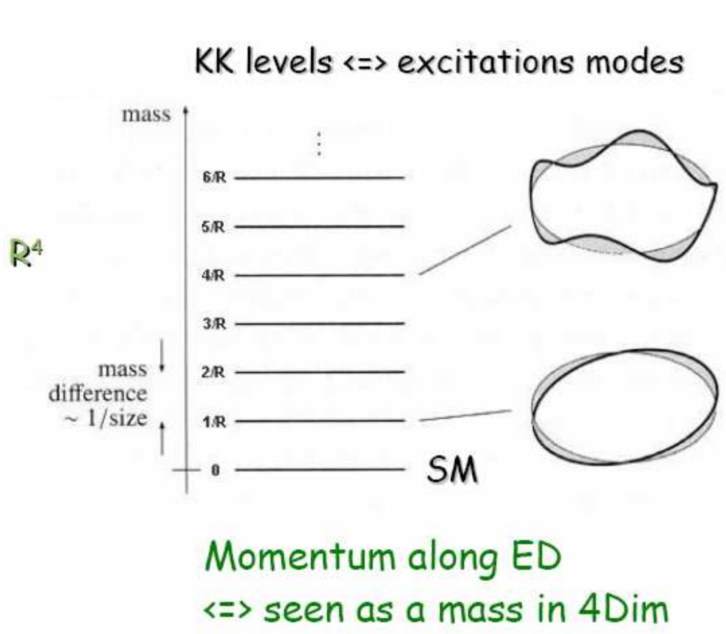
Lifetime reconstruction

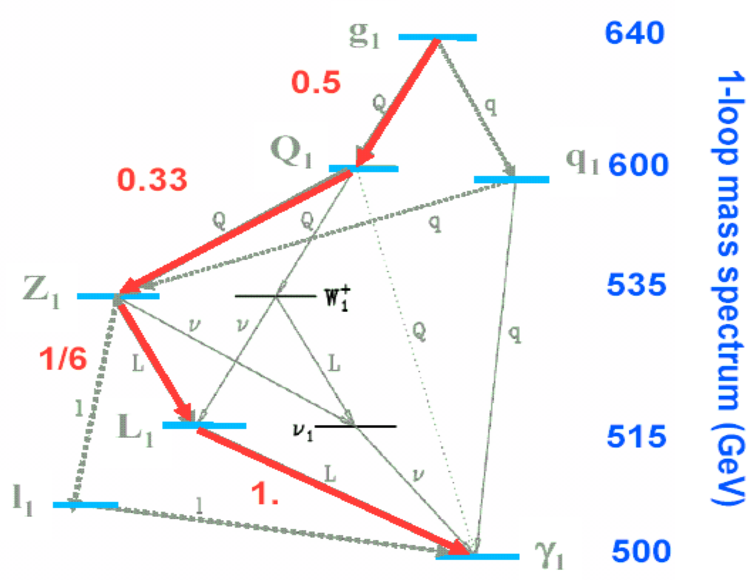
- photons from neutralino with finite lifetime are not pointing to primary vertex.
- shape of energy deposition in calorimeter depends on photon direction.
- sensitivity to log($c\tau$)



Universal Extra Dimensions (UED)

- mass $\quad m_n^2 = n^2/R^2 + m_0^2$
  - degenerate spectrum
- Conservation of KK parity $(-1)^n$
  - n=1 similar to SUSY but Spin(KK) = Spin(SM)
- 2^{nd} excitation can be singly produced





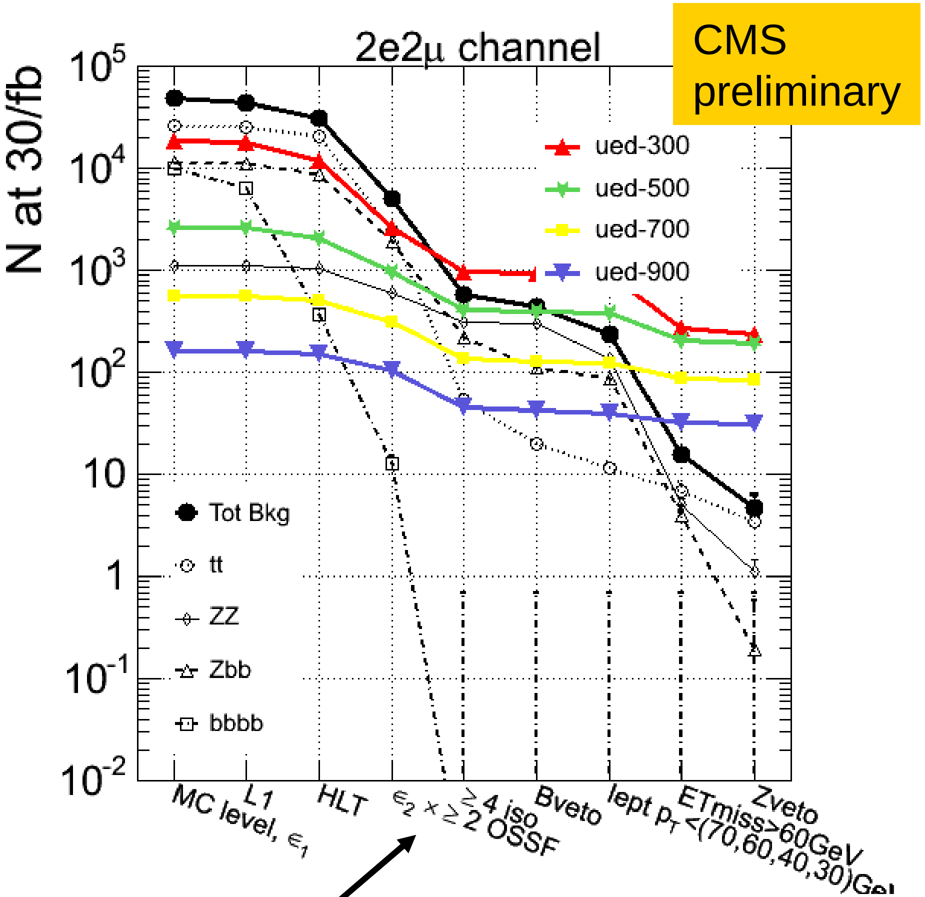
Long decay chains

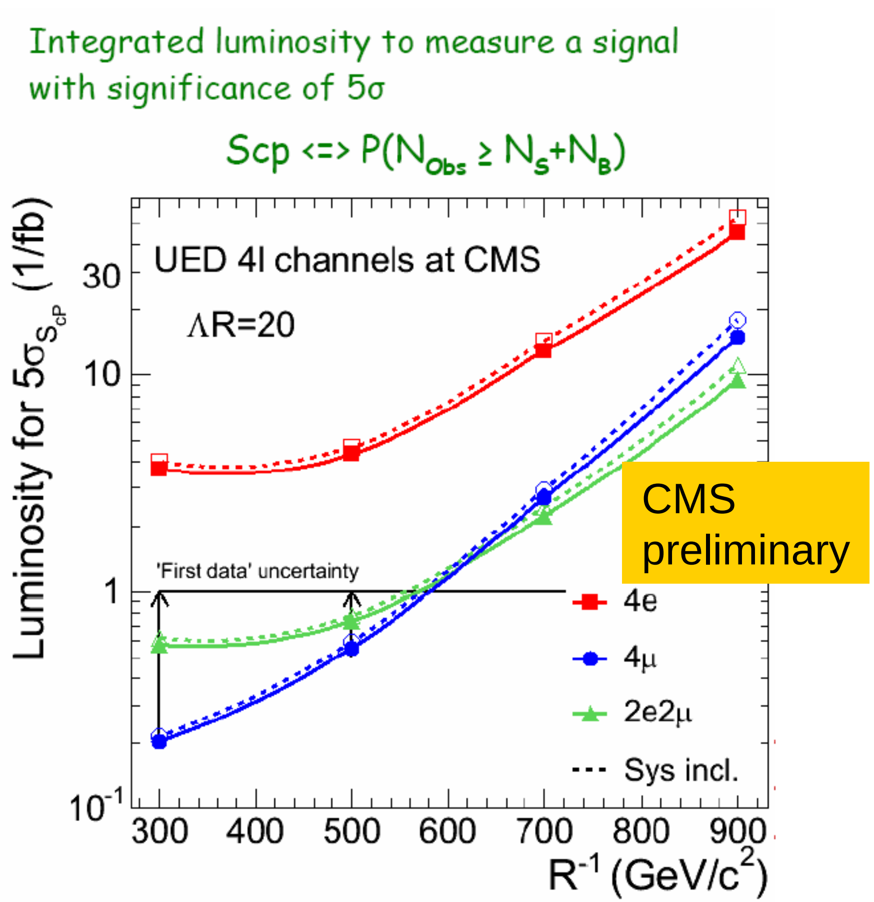
$$
\begin{aligned}
g_1 \to\ & q_1 + \bar{q} \\
& \hookrightarrow\ Z_1 + q \\
& \qquad \hookrightarrow\ l_1 + \ell^{\pm} \\
& \qquad\qquad \hookrightarrow\ \ell^{\mp} + \mathrm{LKP}(\gamma_1)
\end{aligned}
$$

Pair production of $g_1\, g_1$, $q_1\, g_1$ and $q_1\, q_1$

Signal: 4 leptons (2 pairs OSSF), jets, and missing energy

Universal Extra Dimensions (UED)

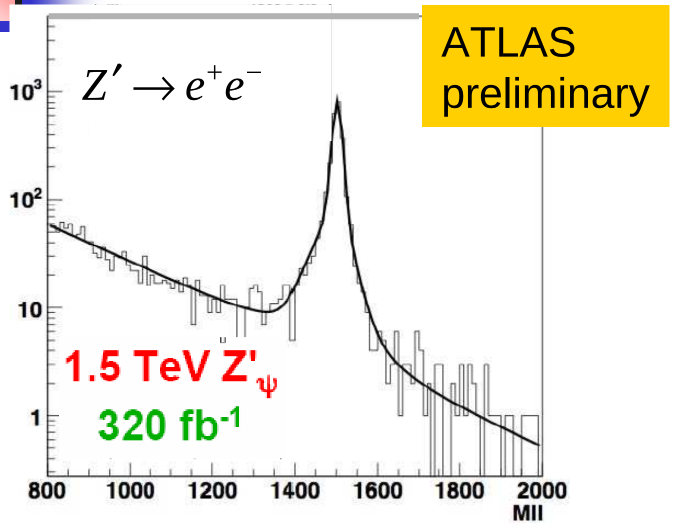


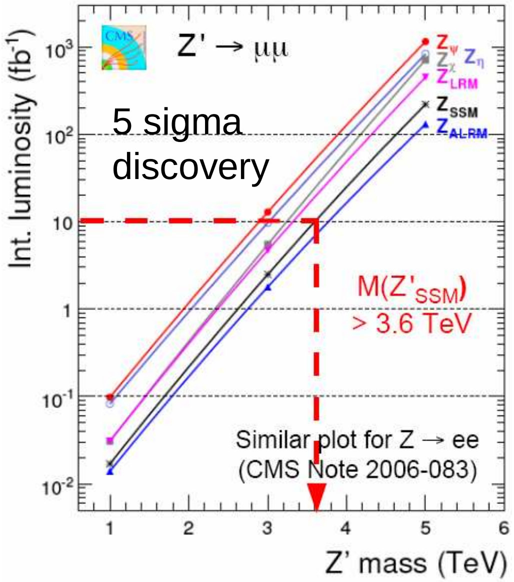


μ: pt> 5 GeV, |η|<2.4
e: pt> 7 GeV, |η|<2.5

Z veto: one OSSF
with M<5 GeV or M>80 GeV

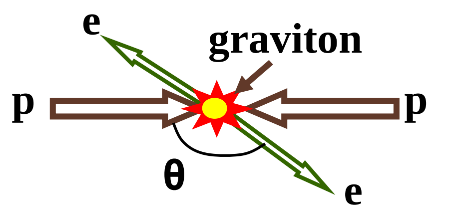
RS Gravitons & Heavy Bosons

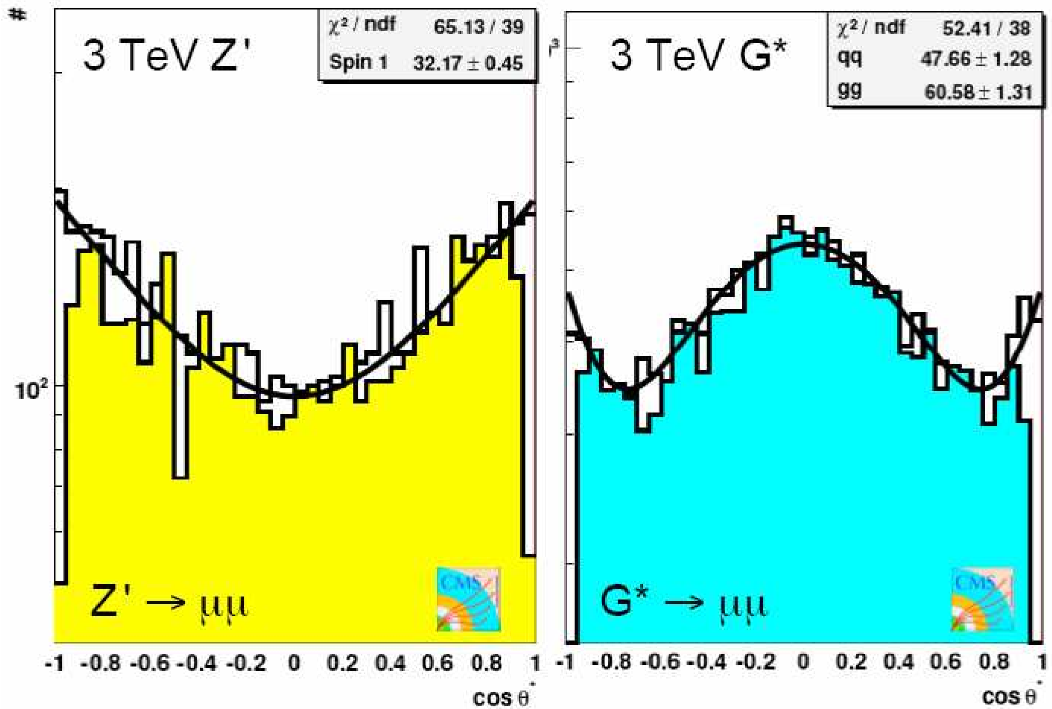




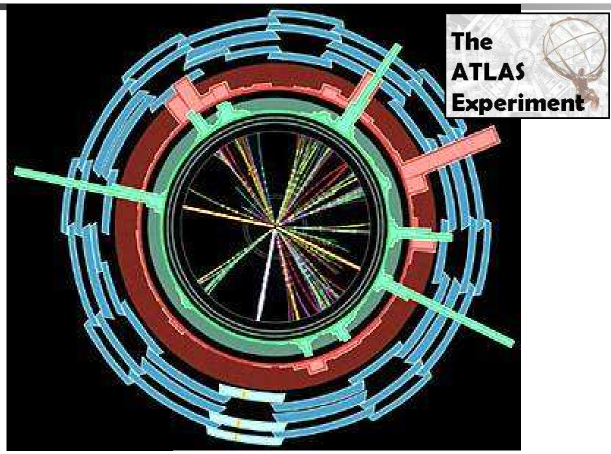
Characterisation

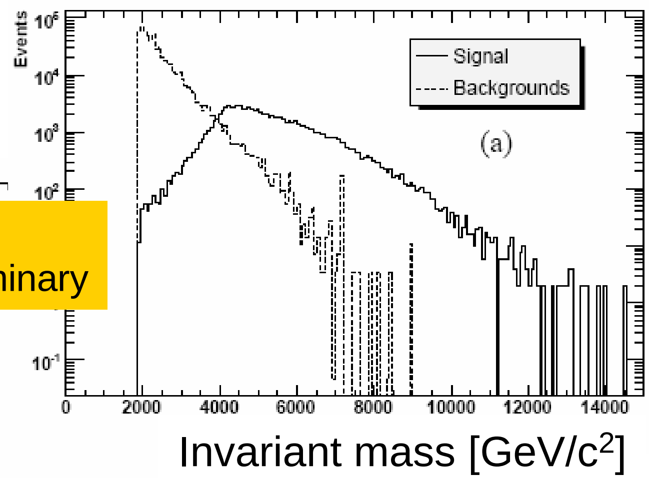
- Measure spin
  - G^* Spin 2
  - Z' Spin 1

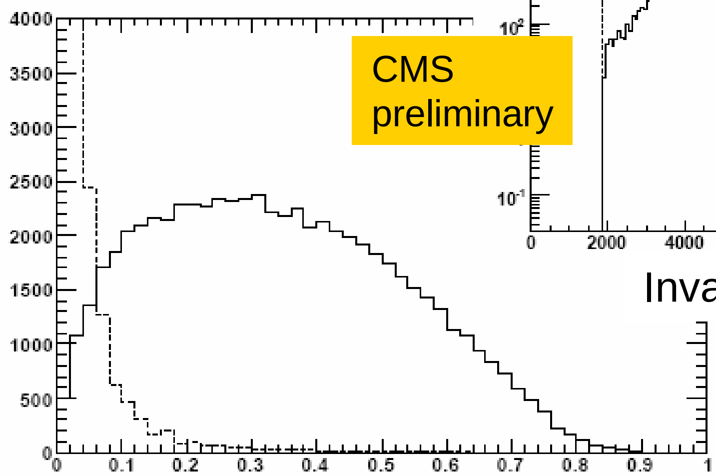




Spectacular States : Micro Black Holes







- Large EDs
- Micro black hole decaying via Hawking radiation
  - Photons + Jets + …
- We will certainly know something funny is happening
  - Large multiplicities
  - Large ET
  - Large missing ET
  - Highly spherical compared to BGs
- Theory uncertainty limits interpretation
  - Geometrical information difficult to disentangle

Conclusions

- ATLAS & CMS have significant discovery potential for physics beyond the standard model
- New physics could already show up in early data
- In order to claim a discovery on needs to understand the background
  - detector performance
  - standard model processes
- discovery of “something” is only first step, the second is to distinguish between models and determine parameters