Physics Beyond the Standard Model in ATLAS

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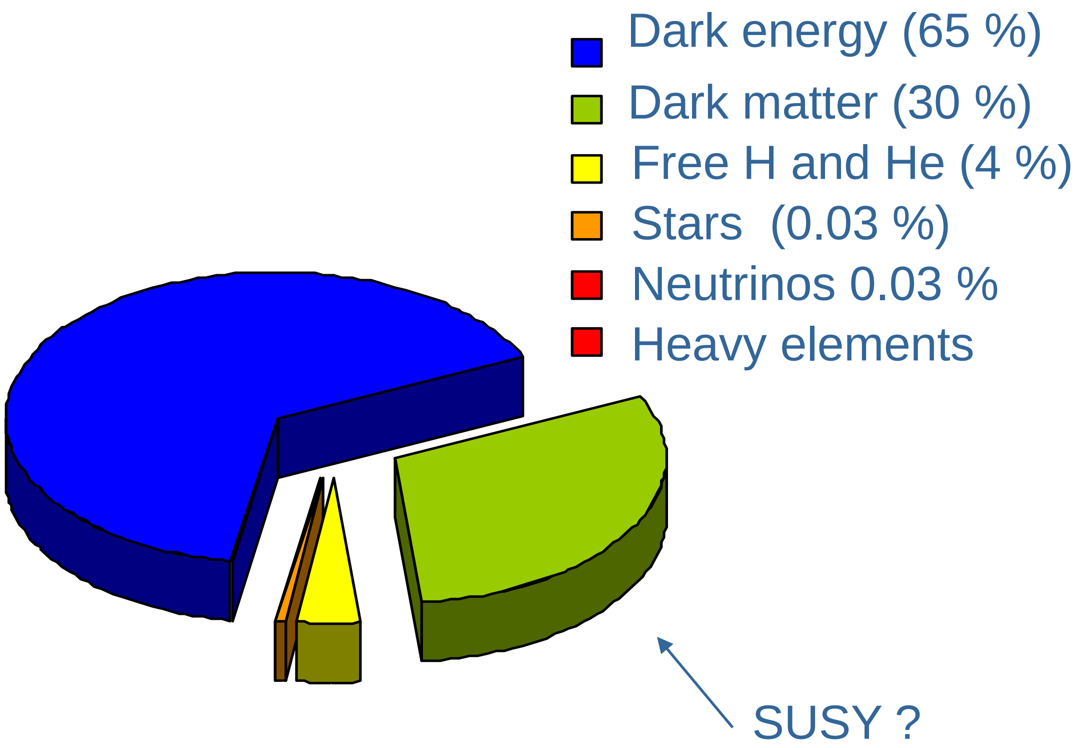
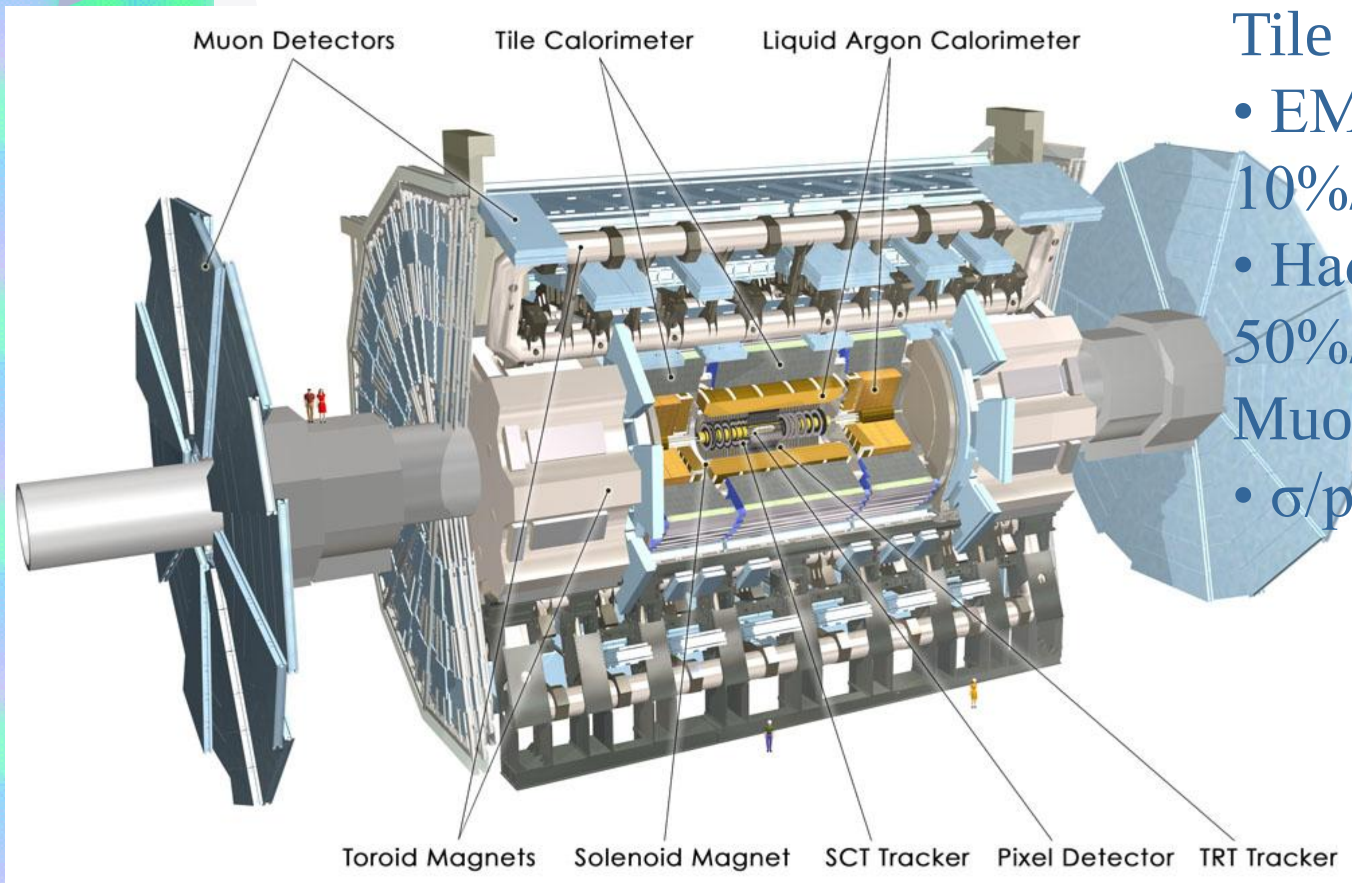
On behalf of ATLAS collaboration

Motivation for BSM



The ATLAS Detector



Calorimeters:

- Liquid Ar EM Cal, Tile Had.Cal
- EM: $\sigma E/E = 10\%/\sqrt{E} \oplus 0.7\%$
- Had: $\sigma E/E = 50\%/\sqrt{E} \oplus 3\%$

Muon spectrometer

- $\sigma/pT \approx 2\text{-}7\%$

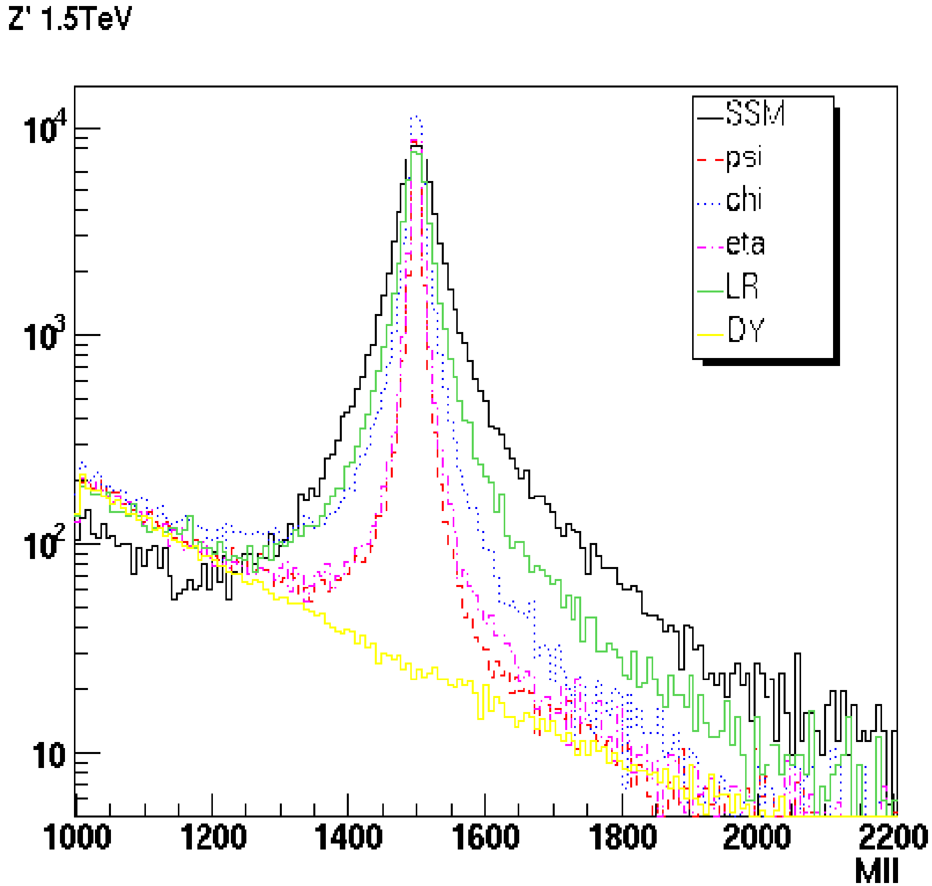
	Expected Day 0	Ultimate goal
ECAL uniformity	**~ 1% ATLAS** **~ 4% CMS**	**< 1%**
Lepton energy scale	**0.5—2%**	**0.1%**
HCAL uniformity	**2—3%**	**< 1%**
Jet energy scale	**<10%**	**1%**
Tracker alignment	**20—200 μm in Rφ**	***O*(10 μm)**

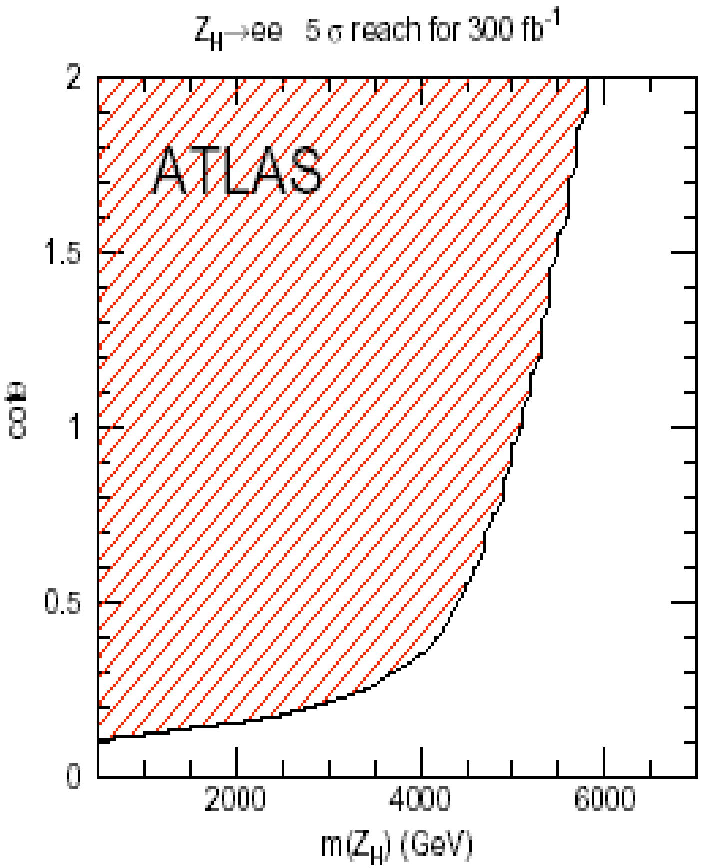
Z` to leptons

- Arise in many BSM scenarios such as:
- Z' gauge boson from extended symmetry (GUTs)
- ZH in Little Higgs models
- Kaluza-Klein excitation of gauge boson (extra dimensions)
- Drell-Yan is main background, and falls with mass
- < 1 event for M=1.5 TeV in 1 fb-1
- Z' with SM couplings has σ * BR(ee) ~ 160 fb for

  M=1.5 TeV ~80 events in 1 fb-1 for $\varepsilon = 0.5$ ($|\eta| < 2.5$)

Z' width gives first handle on model discrimination
Ultimate mass reach ~ 5 TeV for Z'(SSM) with 100 fb-1



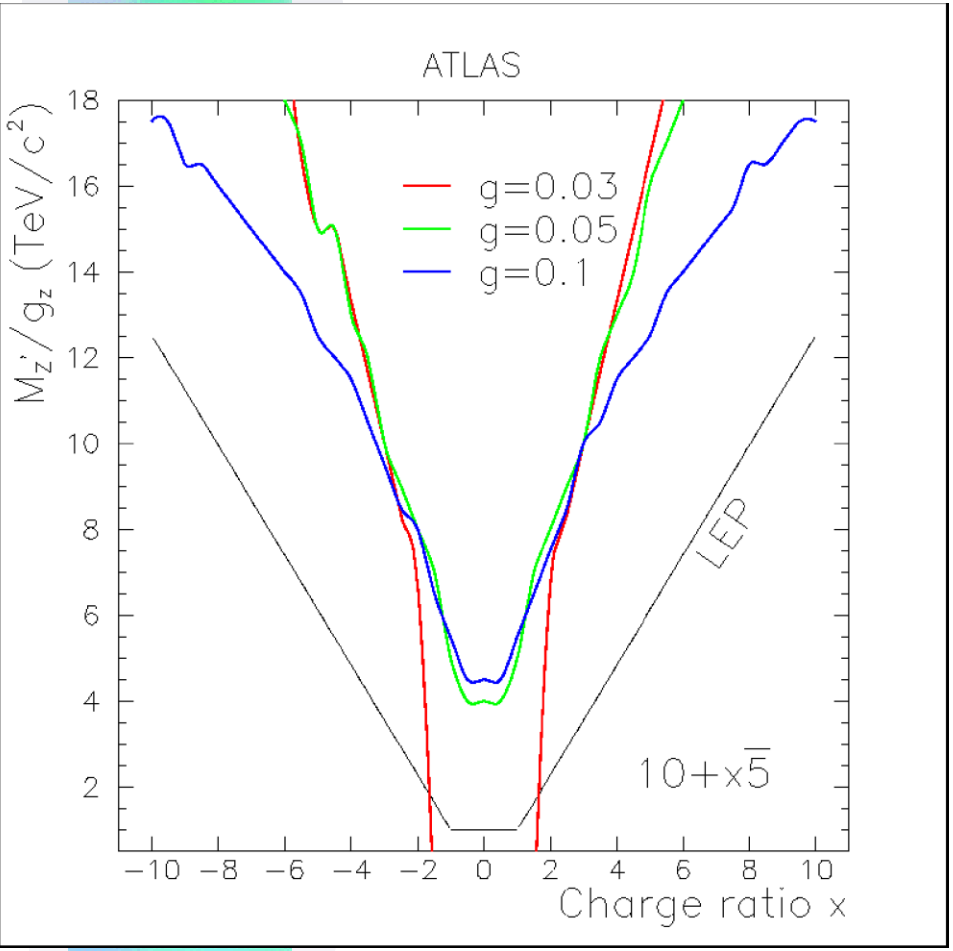


T.Rizzo hep-ph/0610104

Measurements after discovery

- Distinguish between models via:
- $\sigma \cdot \Gamma_{\ell\ell}$
- Forward-backward asymmetry
- Measure spin
- Measure couplings

Model independent analysis



CDD parameterization (M.Carena et al,Phys Rev D 70,093009(2004)

Takes into account both experimental limits and general theoretical assumptions

3 parameters remains free in 4 classes

$M_{Z'}$, global $g_{Z'}$, parameter x describing the relative coupling strength

Area below the curves would be discovered **[Ledroit 06]**

Resonances in WZ system

ATLAS note COM-PHYS-2006-041

Electroweak symmetry breaking is still NOT understood.

Several alternate models are seriously under study at the LHC

Expected sensitivity :

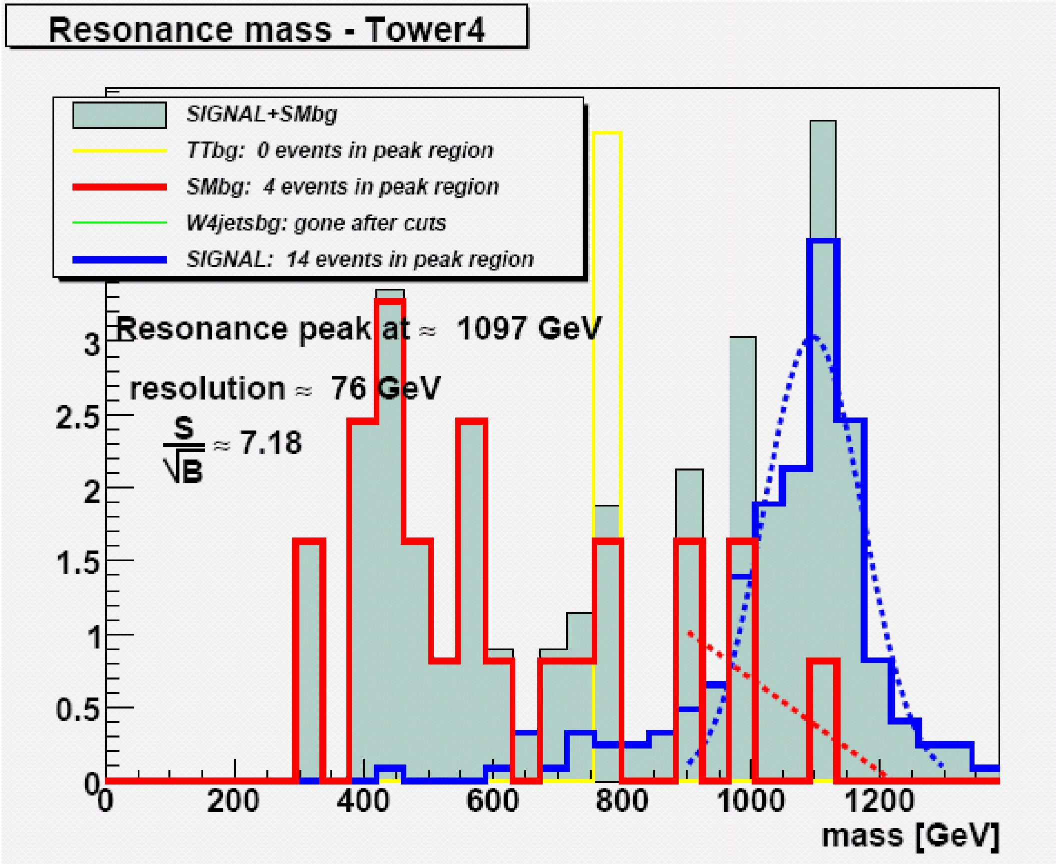
1.15 TeV

100 fb^{-1} in WZ to jjll, lvjj

300 fb^{-1} in WZ to lllv

750 GeV resonance

100 fb^{-1} in WZ to jjll



Extra dimensions

- **Several scenarios**

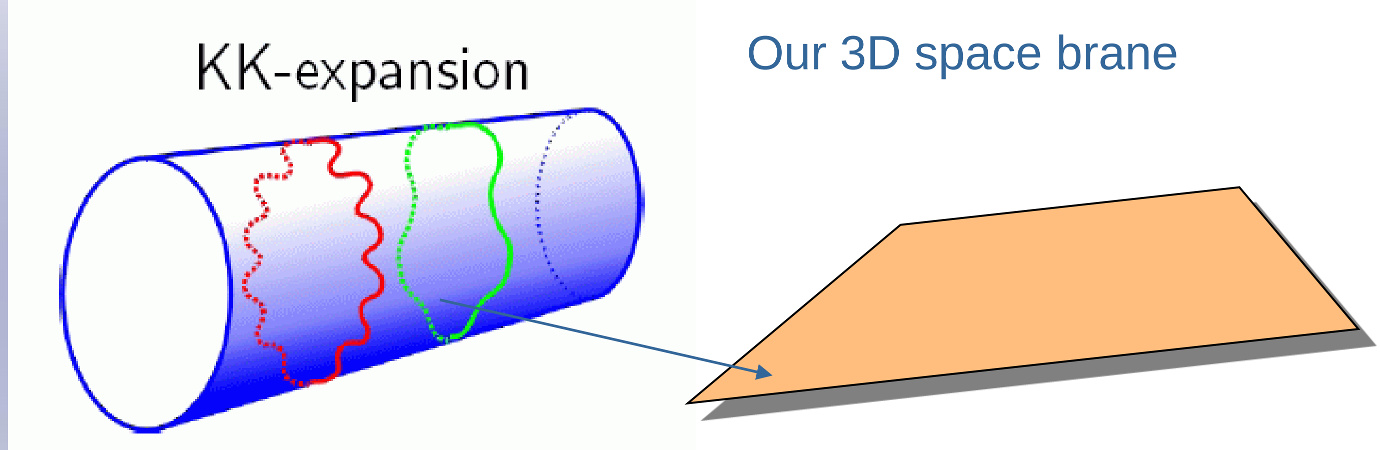
ADD
Only gravitons propagate in bulk.
Mass splitting 1/*R*:
Continuum of graviton states
Virtual graviton exchange and real graviton production
Black holes

Warped ED
Graviton resonances'
Radio
Black holes

Universal ED
Bosons can propagate in bulk
KK pair production

ADD

- $d + 3$ space like dimensions (bulk)
- Compactified to radius R
- Only gravitons are allowed into all dimensions
- SM particles bound to 3-dimensional submanifold (brane)



- KK excitations of graviton – how we "see" graviton in our 4D when it moves in nD space

Compactification leads to quantized momentum in ED

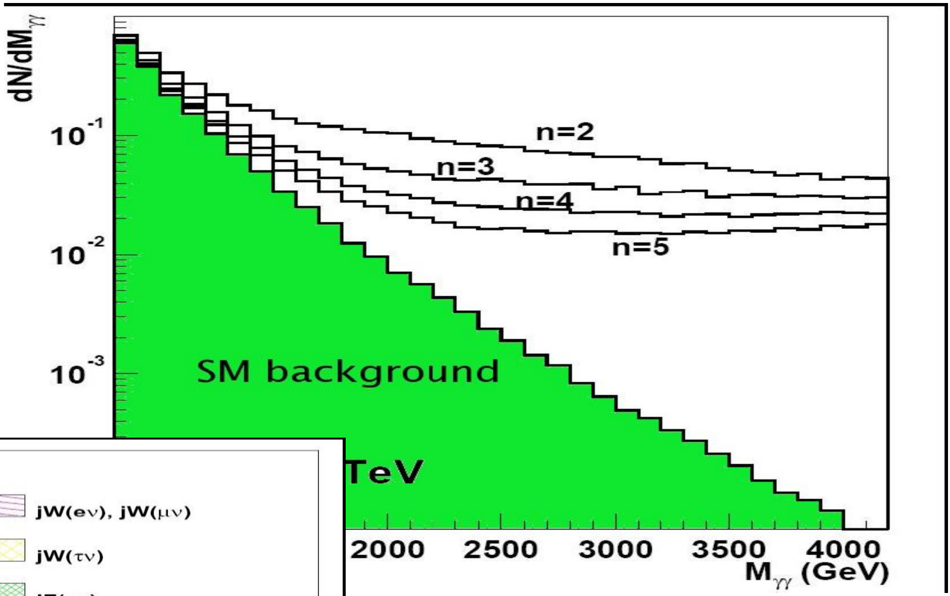
ED momentum of graviton would be seen in 4D worlds as mass

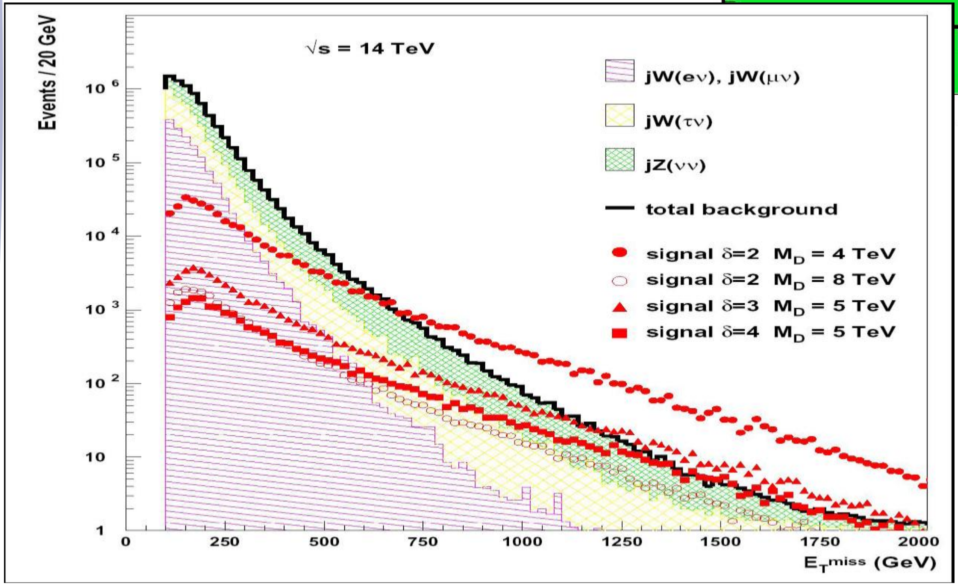
- KK tower – bunch of KK states with different masses

Virtual graviton exchange and real graviton production.

Observe tower of KK gravitons

*G** → $\gamma\gamma$, *l*−*l*+
5 σ sensitivity at 100 fb−1 for
MS = 6.3 . . . 7.9 TeV (*n* = 5 . . . 2)
v.Kabachenko,A.Myagkov,A.Zenin





Vacavant & Hinchliffe, JPG 27(2001) 1839

WARPED EXTRA DIMENSIONS

Randall and Sundrum

k / M_{Pl} is varies

SM lives in TeV brane; Gravity lives everywhere

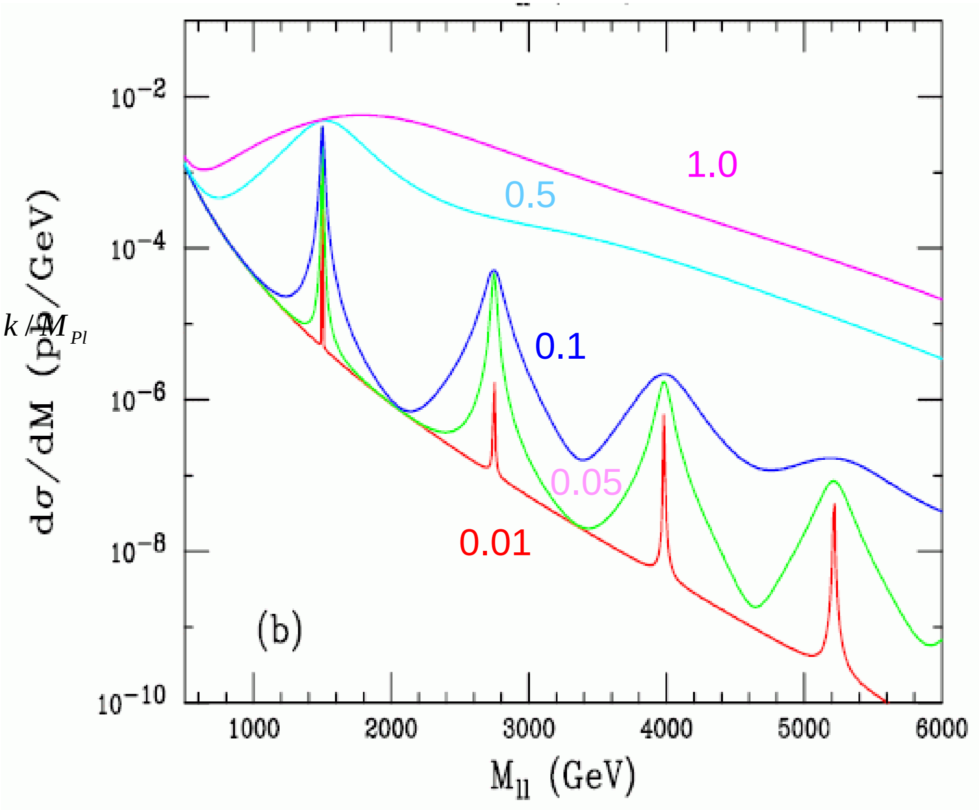
'Non-factorizable' or warped geometry

Metric:

$$ds^2 = e^{-2k|y|}\eta_{\mu\nu}dx^{\mu}dx^{\nu} - dy^2$$

- $\eta_{\mu\nu}$ = diag(1,-1,-1,-1)
- $M_{Pl}^2 = (M_5^3 / k)x(1 - e^{-2xkR})$
- Mpl / k ~ 10^{1-2}
- MPl – Planck mass in 4D, M 5D Planck mass

$$m_{n=} = x_n k e^{-\pi kR}$$

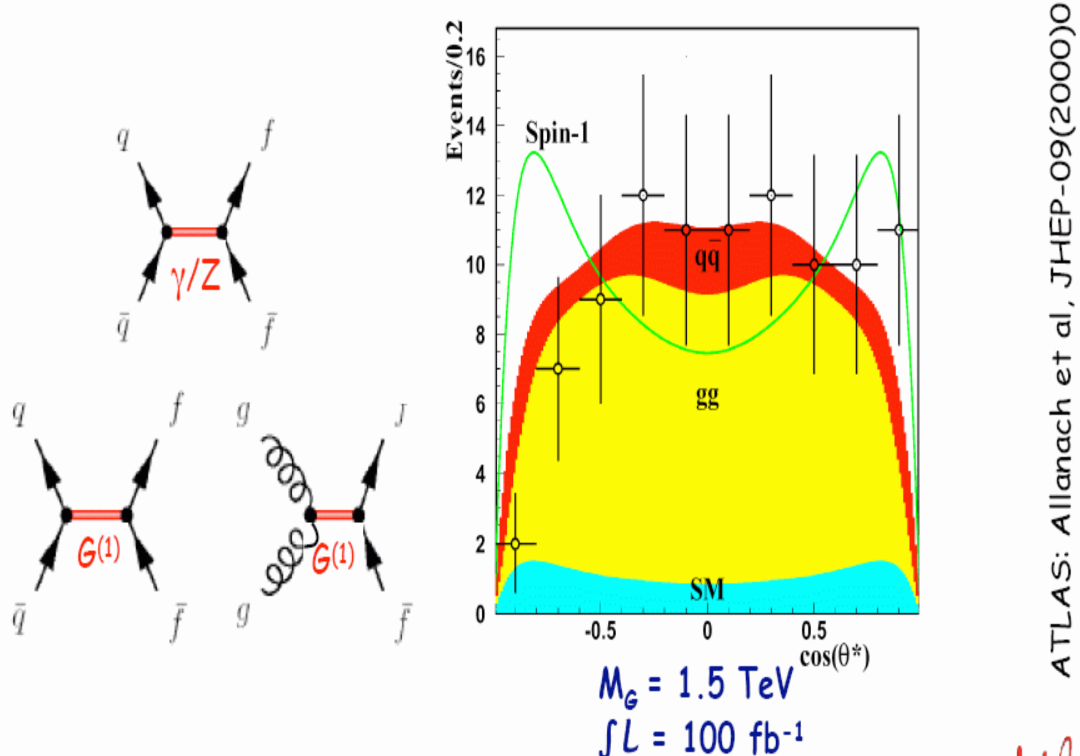


H. Davoudiasl, J.L. Hewett and T.G. Rizzo: hep-ph/0006041

Identification of the graviton nature

Other decay channels: $G^{(1)} \to \gamma\gamma$ vs. $Z' \to \gamma\gamma$ not allowed

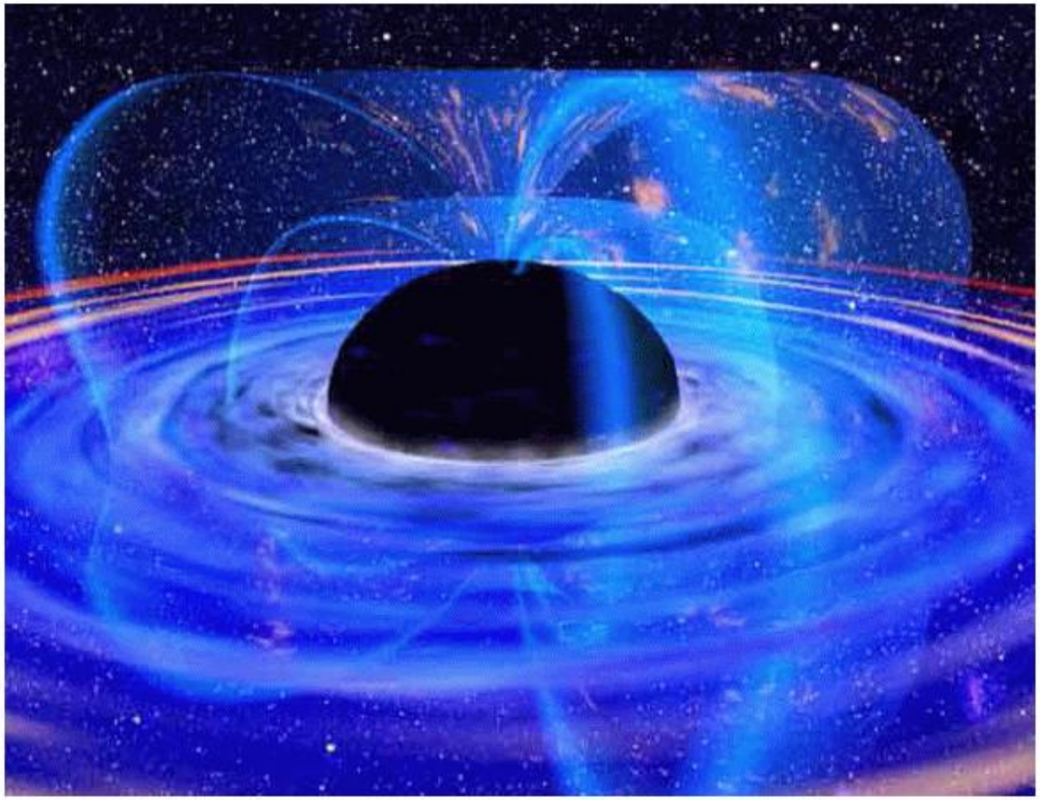
Angular distribution: spin 2 vs. spin 1



Caroline Collard, LLR, Ecole Polytechnique   WIN'05, 6-11/06/2005   14

Spin measurement via decay angle distribution ~50-100 events needed to distinguish spin-2 RS graviton from spin-1 Z'

BLACK HOLES IN EXTRA DIMENSIONS



Main properties of BH production and decay

Schwarzschild radius RS:

4D (our world): $R_s = (2/M_{Pl}^2)M_{BH}/c^2 \sim 10^{-38}\ fm$

4D + n: $R_s = (1/M_D)(M_{BH}/M_D)^{1/(n+1)} \sim 10^{-4}\ fm$

for MD ~ 1 TeV

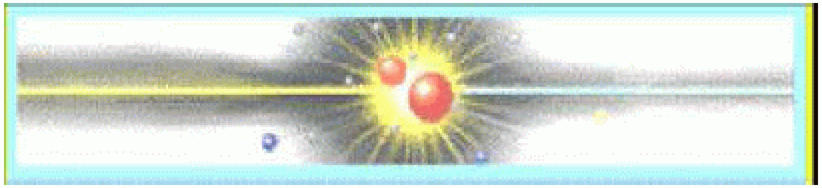
Black holes can be produced if partons with sqrt(s) =MBH

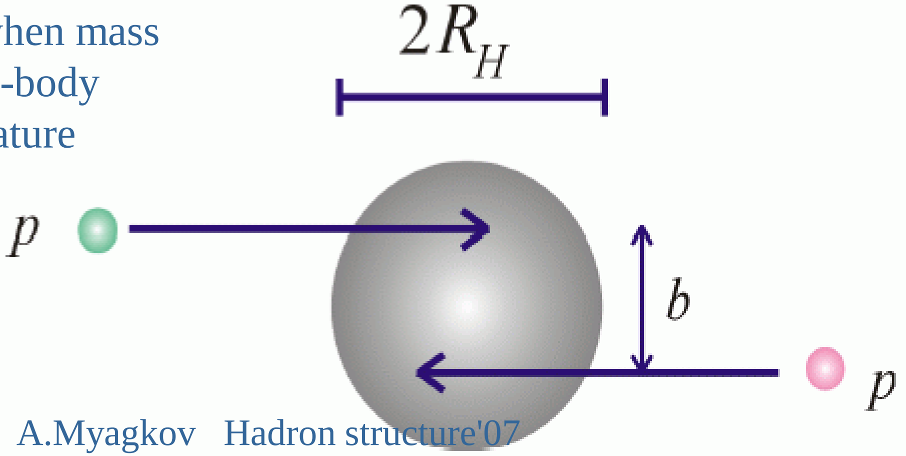
MBH pass at radius smaller then RS

$\sigma \sim \pi R_S^2$ **- geometrical radius**

for MD ~ 1 TeV ~ 1 Black Hole per second at LHC !

BH decays via Hawking evaporation. It stops when mass of the BH approaches M_D via emission of black-body radiation with a characteristic Hawking temperature



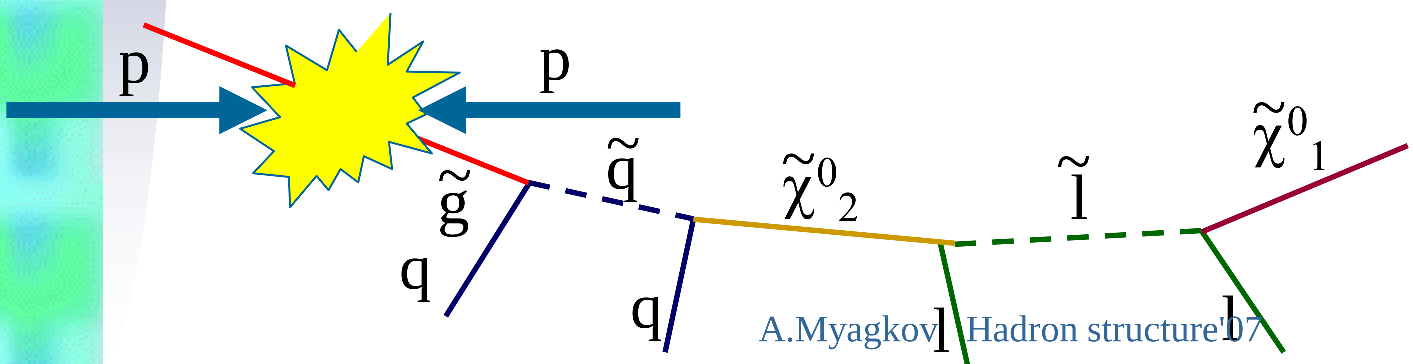


Other early searches for 'exotics'

- In ATLAS 'Exotics' refers to anything BSM besides SUSY and Higgs (SM, SUSY)
- Other resonances...
- lepton – jet resonances
- Leptoquarks,
- E6-inspired exotic quarks → W or Z + jet
- Heavy leptons → W or Z + lepton
- lepton – MET resonances
- W' gauge bosons
- WH Little Higgs
- photon-jet or photon-lepton resonances
- excited quarks
- excited leptons
- ... and spectacular signatures such as many high pt leptons and jets
- microscopic black holes from extra-dimensional models
- Searches for excesses in tails will take longer e.g. Drell-Yan tail
- Extra dimensions
- Compositeness

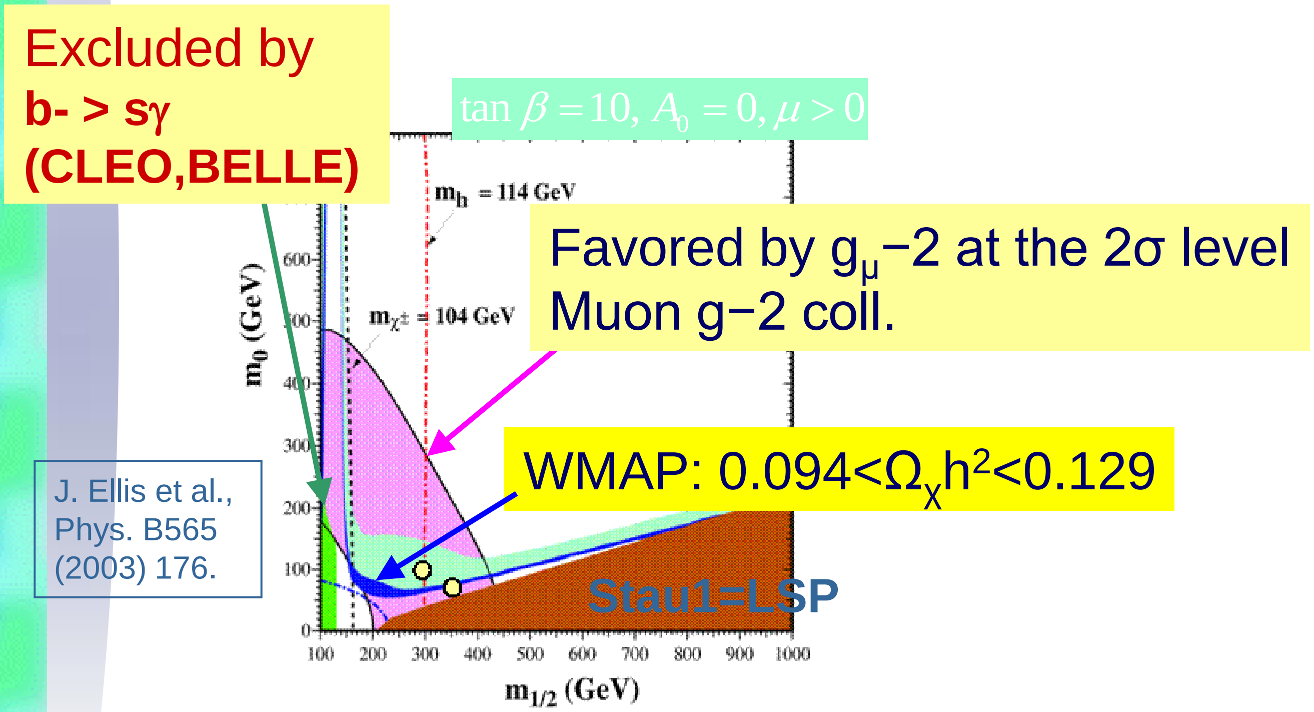
Supersymmetry

- **Well motivated extension to the Standard Model.**
- **Heavy strongly interacting particles (gluinos/squarks) are produced in pp collisions**
- **⇨ big cross sections**
- **Long chain of decays ⇨ many high transverse objects**
- **Stable undetected LSP (if R parity is conserved)**
- **⇨ large missing energy**



mSUGRA framework has 5 parameteres -

$$m_{0,} m_{1/2}, A_0, \tan(\beta), \mathrm{sgn}(\mu)$$



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

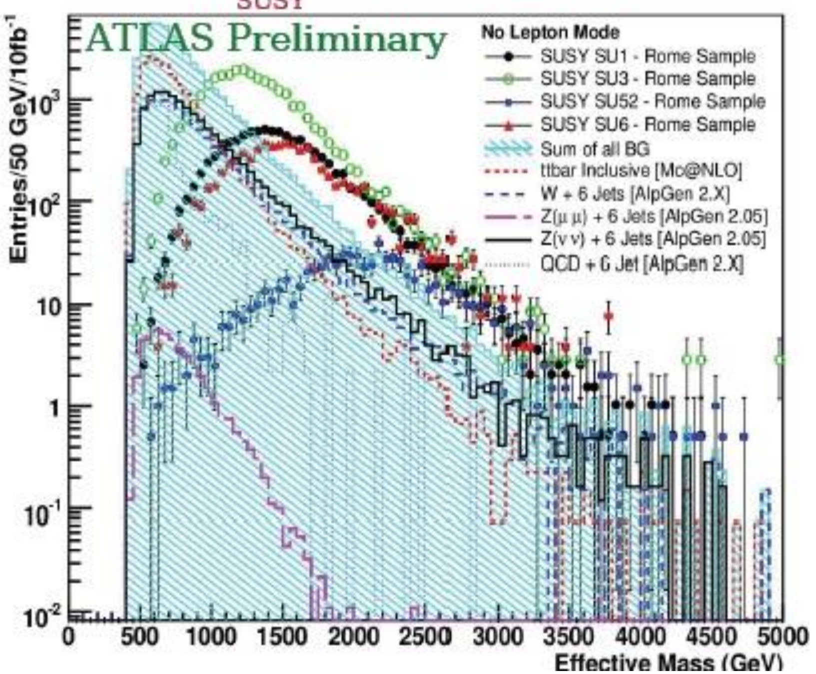
R.Strohmer WIN07

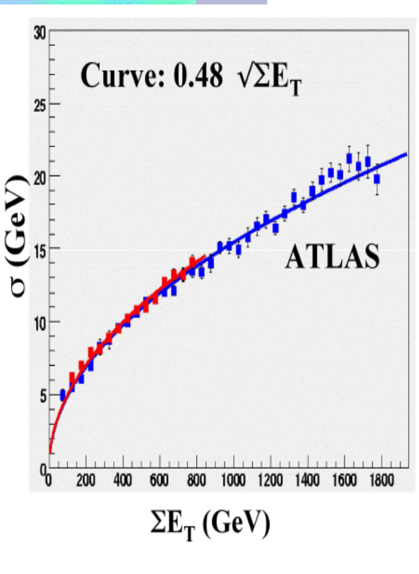
Inclusive SUSY Search (Jets + missing Et)

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(νν) + Jets, W + Jets, ttbar

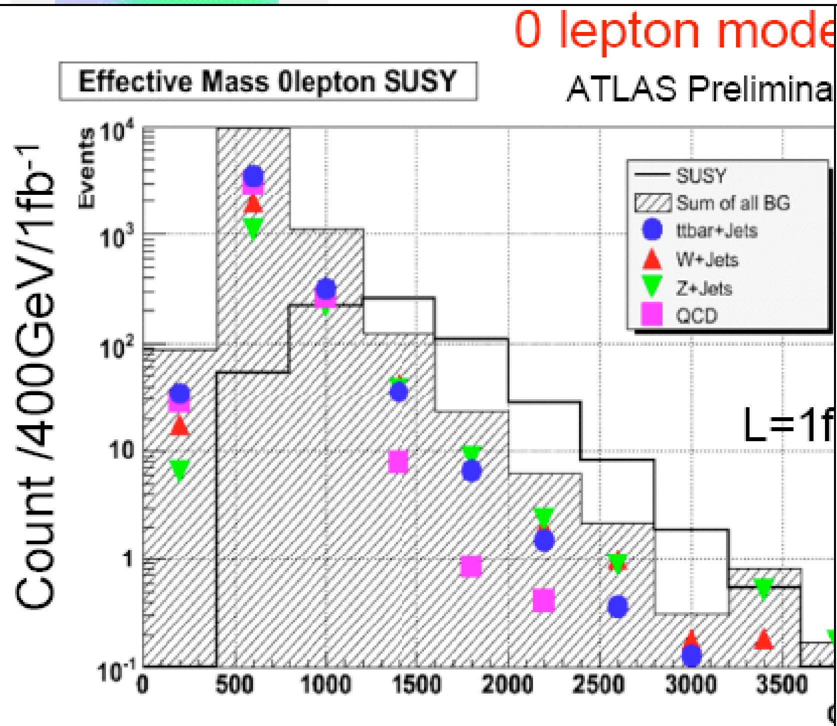
M_{SUSY} ~0.7 - 1.2 TeV

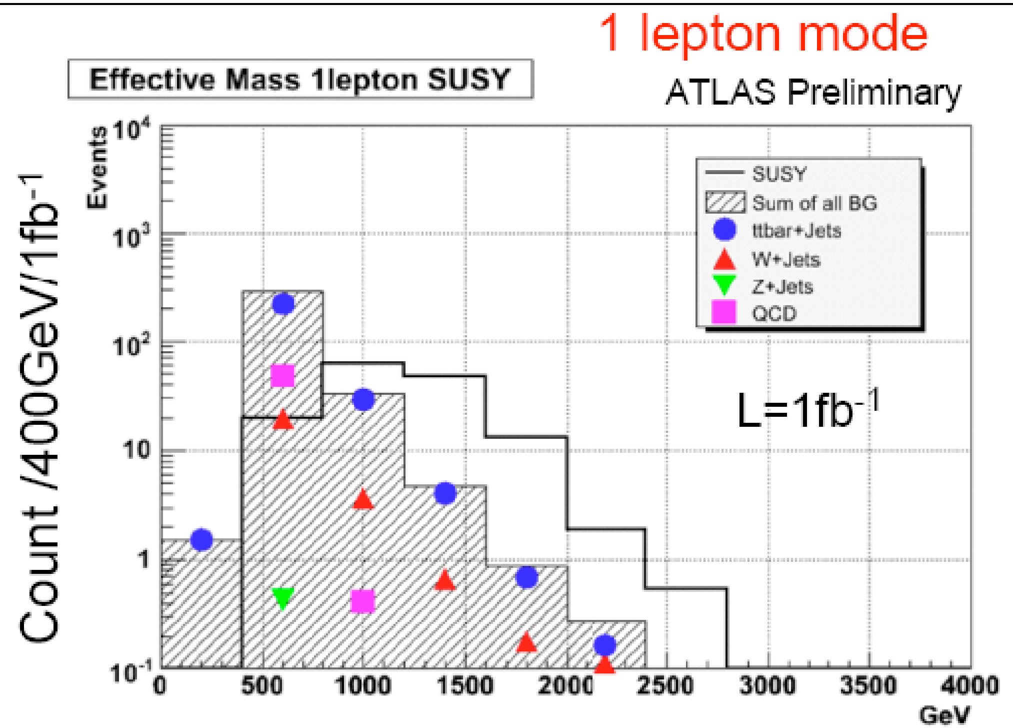




R.Strohmer WIN07

0 and 1-lepton (e,μ) channels



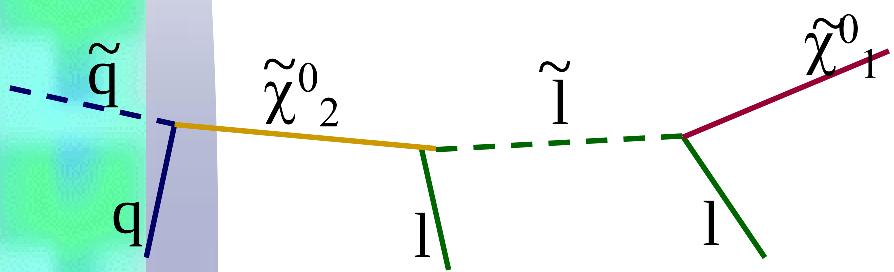


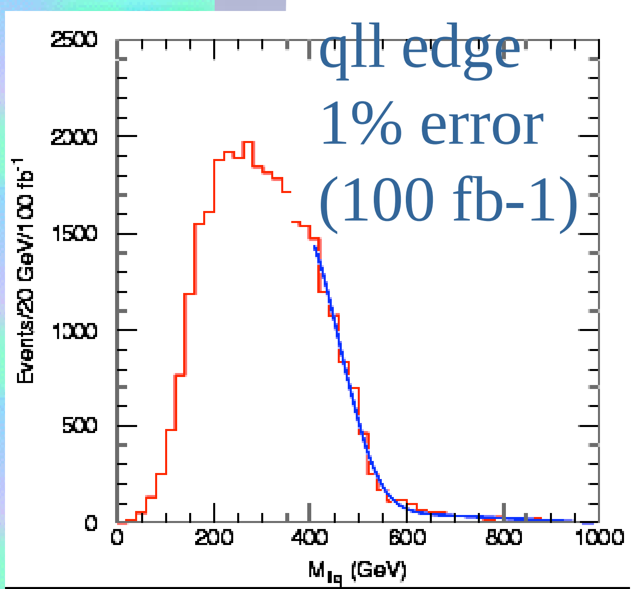
Roughly equal BsG contributions from ttbar, W+jet, Z+jets
QCD multijet BG (with real or fake Etmiss) also significant; difficult to simulate
Lower statistics but bkg more manageable (mainly ttbar)

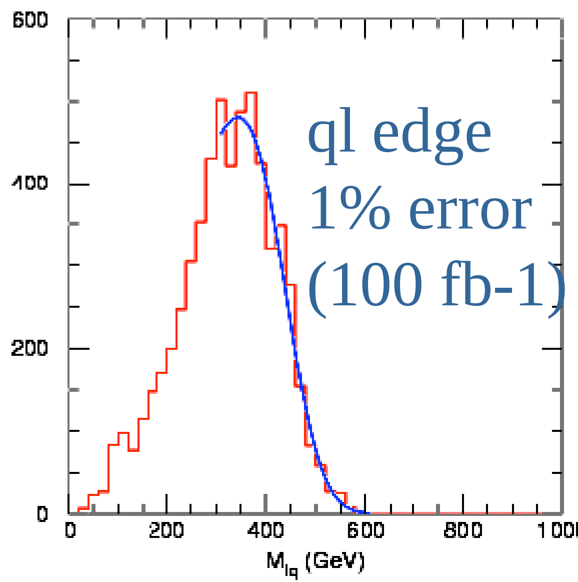
) ≈ 1 TeV, tanβ = 10
Bkg from Alpgen 2.05
“Fast” detector simulation

Exclusive studies
Measurements with Squarks

- Dilepton edge starting point for reconstruction of decay chain.
- Make invariant mass combinations of leptons and jets
- Sensitivity to individual sparticle masses.







SUSY scenarios

- Most studies in ATLAS done in the context of Minimal Supersymmetric SM (MSSM) with R-parity conservation
- SUSY breaking scenarios:
- mSUGRA - minimal SuperGravity (most studied)
- GMSB - Gauge Mediated SUSY Breaking
- AMSB - Anomaly Mediated SUSY Breaking
- Split-SUSY
- Not believing that any of these models is a true description of Nature.
- Aim is to cover a broad range of experimental signatures in a self-consistent way

Gluino R-hadrons

- Split-SUSY propose a way to break symmetry at scale above 1000 TeV.
- Gluino will form a hadronic bound state (R hadron) which is sufficiently stable.
- Since a gluino is a color octet, then R-hadron can reverse the sign of its charge whilst undergoing nuclear scattering in a calorimeter

Results for L= 2 fb

S.Hellman,D.Milstread,M.Ramstedt

ATL-COM-PHYS-2005-065

- Direct search for massive long-lived particles with different sign in ID and Muon Spectrometer

- Search of 2 like sign tracks in Muon Spectrometer

- **Signal (500 GeV) 1742**
- **Bckg 17**

- **Signal (1 TeV) 16**
- **Bckg 1.6**

- **Signal (500 GeV) 1488**
- **Bckg 11.3**

- **Signal (1 TeV) 13**
- **Bckg 0.8**

Conclusions

- **There are a lot ways to extend SM**
- **After calibration and understanding of the detector ATLAS has nice possibility to find and study new phenomena.**

- **Back-up Slides**

Measurements with Squarks

- Dilepton edge starting point for reconstruction of decay chain.
- Make invariant mass combinations of leptons and jets
- Sensitivity to individual sparticle masses.