TAU SIGNATURES IN SUSY EVENTS AT ATLAS

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OUTLINE

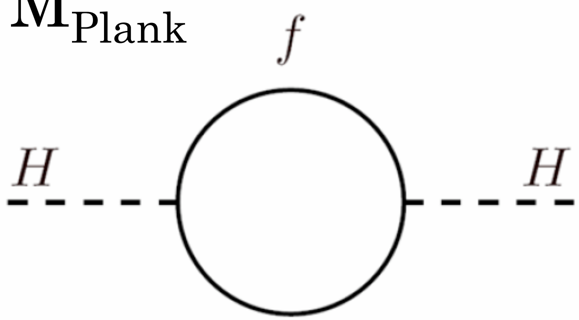
- Introduction
- SUSY tau signatures
- Tau reconstruction in ATLAS
- SUSY searches in Tau final states at Sussex
- Conclusions and Outlook

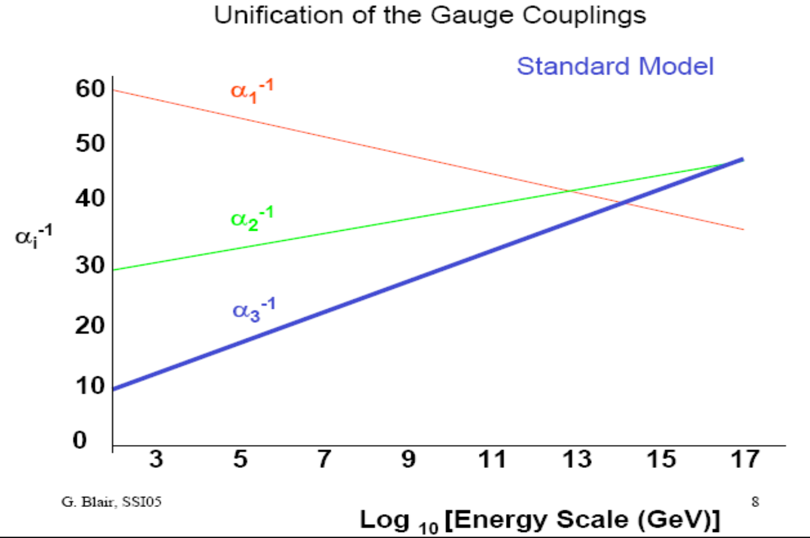
INTRODUCTION

- LHC has recently started its operations at 7 TeV
  - Current luminosity ~10^{28} cm^{-2}s^{-1}
  - See Pedro's talk for details
- Plan is to run continuously for the next 18 months
  - allow experiments to collect ~2 fb^{-1} for first physics analyses
  - Main focus at start up is going to be initially detector performance and "rediscovery" of SM physics
  - Also "new physics" searches may be possible in some channels
- At the same time, longer-term objectives must not be neglected
  - Physics reach will be different at O(50pb^{-1}), O(200pb^{-1}), O(2fb^{-1}) and more…

Looking for physics Beyond the SM

- SM is widely believed to be an effective theory valid only up to a given scale $\Lambda << M_{Plank}$
  - does not contain gravity
  - hierarchy/naturalness problem
    - $M_{EW} << M_{Plank}$
    - Fine-tuning
  - unification of couplings
- Need a more fundamental theory of which the SM is an approximation at low energy



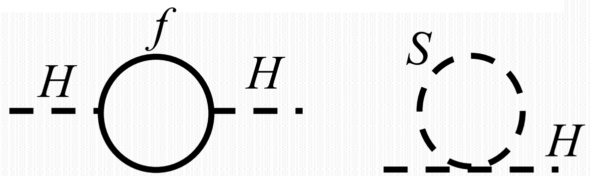


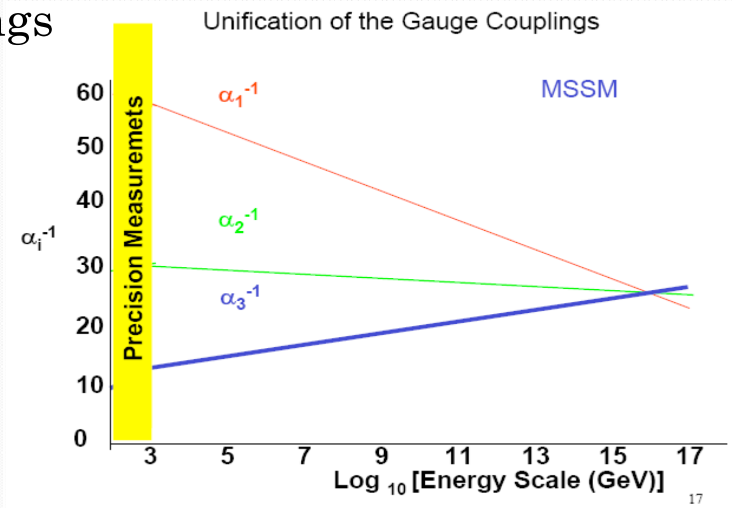
SUSY IS A SOLUTION….

- Space-time symmetry relates fermions with bosons

$$Q|boson\rangle = |fermion\rangle \quad \text{and} \quad Q|boson\rangle = |fermion\rangle$$

  - every SM field has a "spartner'
    - same mass, spin differing by ½
    - identical gauge numbers and couplings

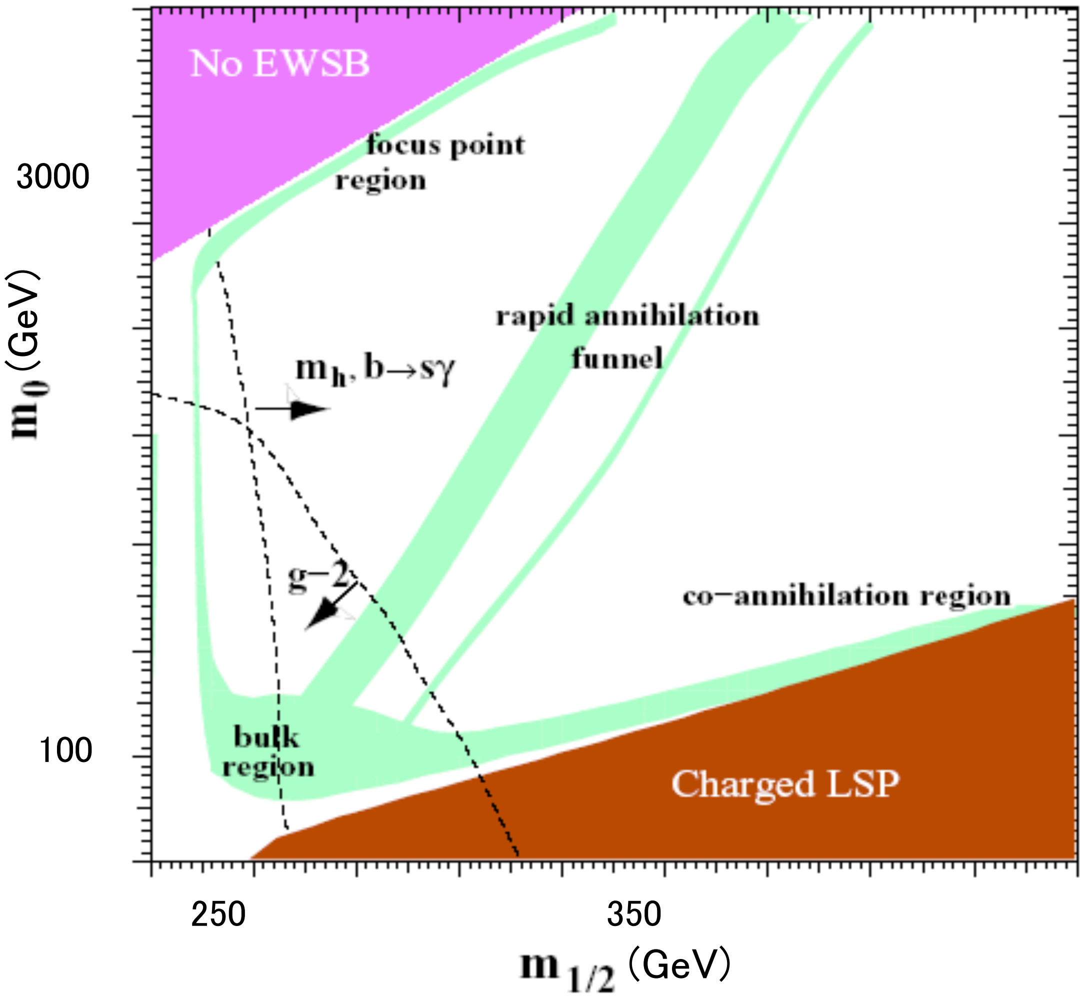




- Must be a broken symmetry
  - spartners have never been observed
- Assume R_p conservation:
  - pair production of sparticles
    - in scattering of SM particles (e.g. pp at LHC)
  - stable Lightest SUSY particle (LSP)
    - lightest neutralino – good candidate for Dark Matter

mSUGRA PARAMETER SPACE

- Assuming R-parity conservation, 4 regions of the parameter space are compatible with WMAP results



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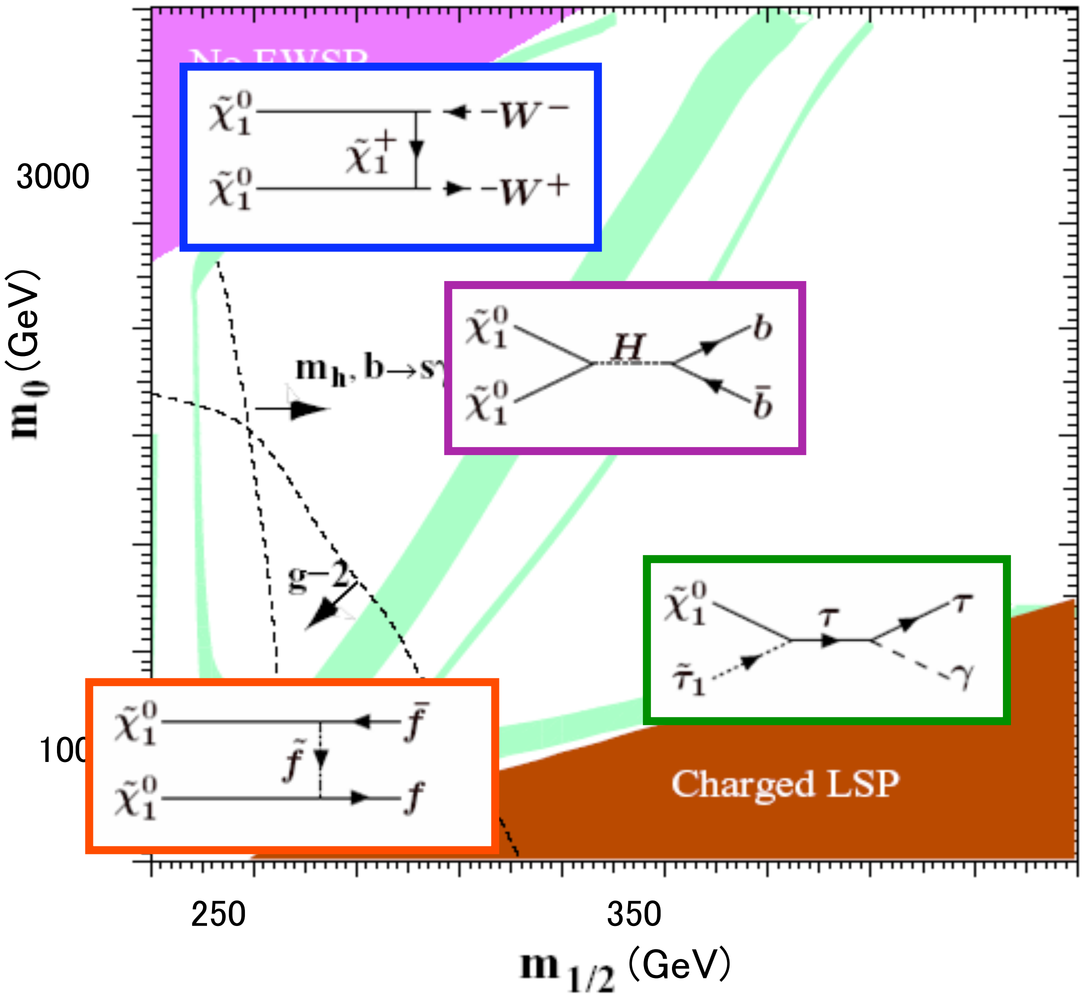


bulk: LSP annihilation to ff via sfermion exchange

focus point: annihilation to WW, ZZ

co-annihilation: small NLSP-LSP mass difference, typically coannihilation with stau

Higgs funnel: decay to fermion pair through resonant A exchange – high tanβ

INCLUSIVE TAU SIGNATURES

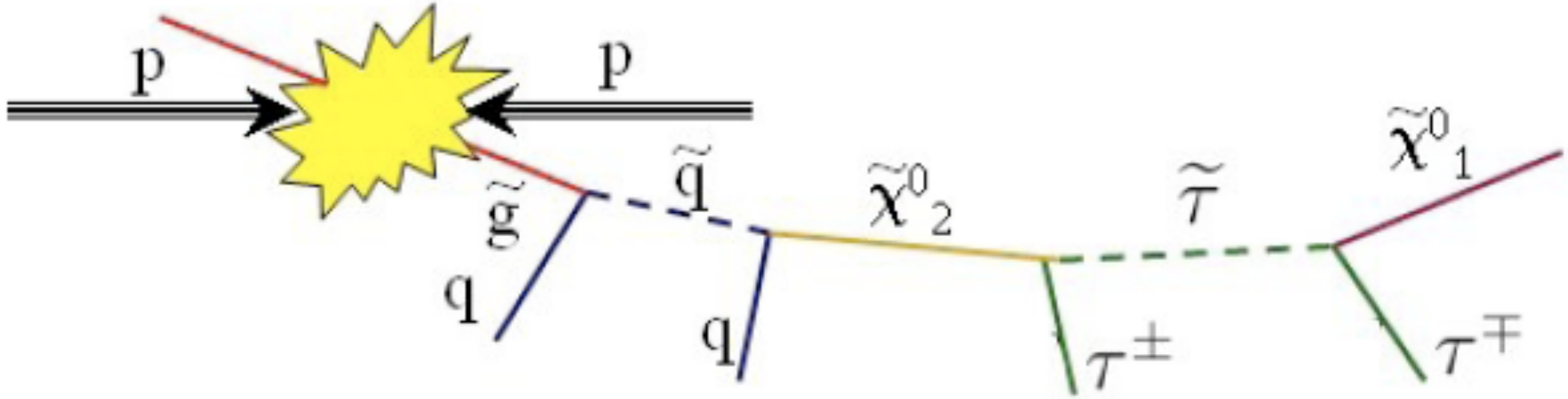
- SUSY models generally violate e/μ/τ universality
  - τ decays can be dominant, especially for tanβ >>1
- It is therefore very important to search for SUSY in τ final states
  - Only hadronic tau decays are being investigated
  - Main backgrounds: jets from ttb or QCD events
  - Need to study in detail fake tau rates
- Inclusive di-tau events can contribute to the determination of SUSY parameters
  - use end-point of the invariant mass distribution from

$$\tilde{\chi}_2^0 \to \tilde{\tau}_1 \tau \to \tilde{\chi}_1^0 \tau^{\pm} \tau^{\mp}$$

    - depends on the masses of $\tilde{\chi}_2^0$, $\tilde{\chi}_1^0$ and $\tilde{\tau}_1$
    - enhanced BR for $\tilde{\chi}_2^0 \to \tilde{\tau}_1^{\pm} \tau^{\mp}$ decay due to large L-R mixing in stau sector

TAU FINAL STATES IN SUSY

- $\geq 1\ \tau + \geq 1$ e/μ leptons + high P_t jets + E_t^{miss}



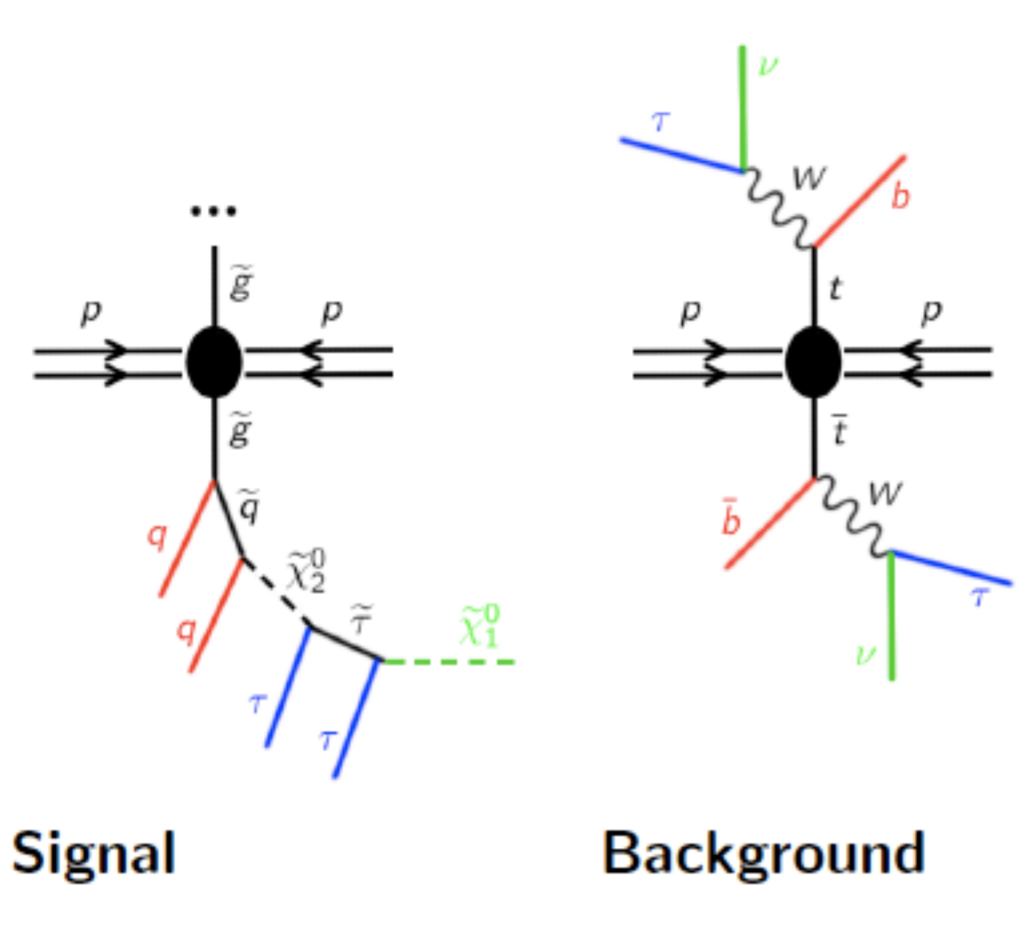
- Several possible final states
  - 1τ + 1l, 1τ + 2l, 2τ + 1l, etc…

(see eg Lykken & Matchev, arXiv:hep-ex/9910033v1)

- Will be important to look into statistical combination of the results coming from the different analyses

MAIN BACKGROUNDS

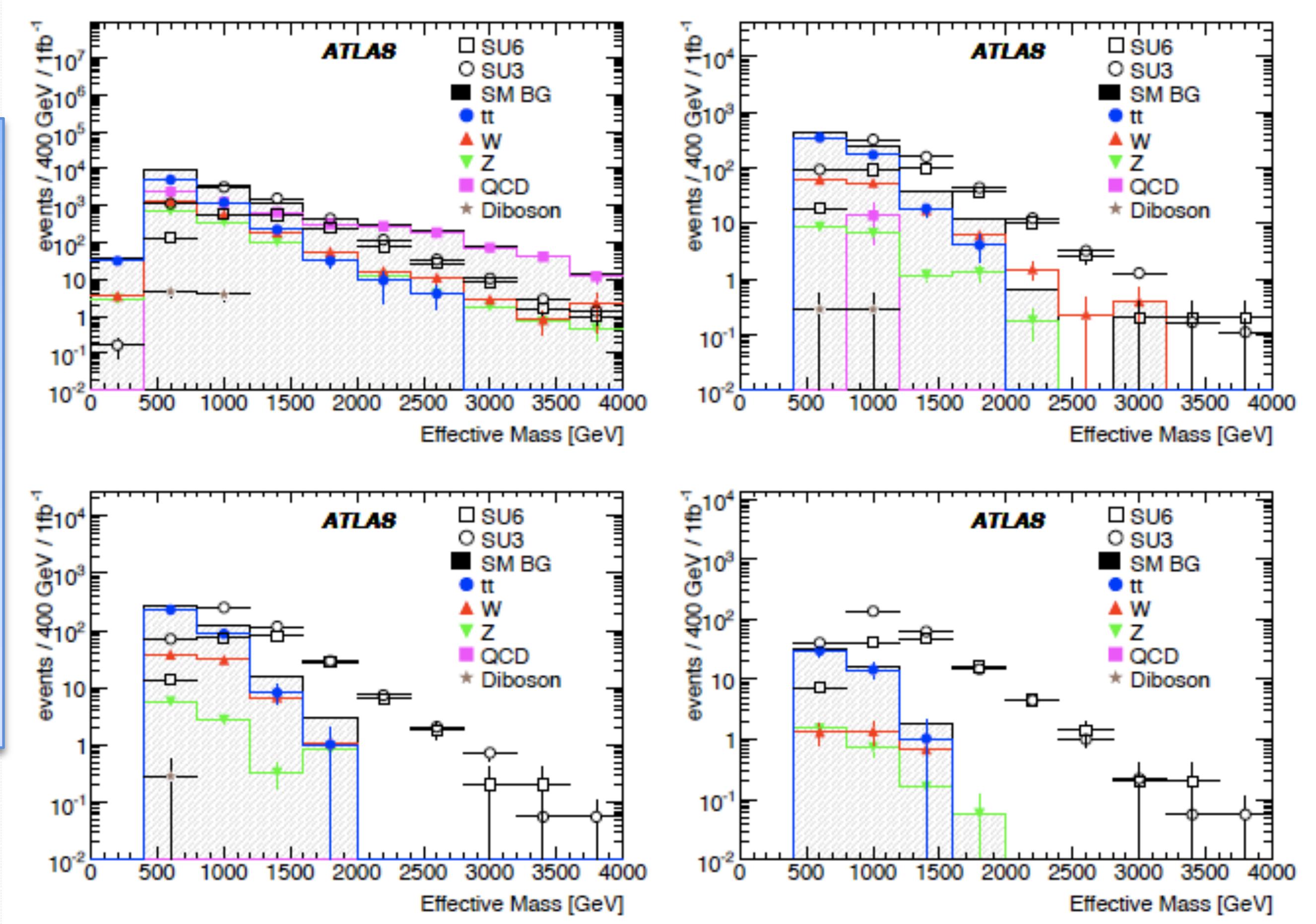
- QCD and ttb events are the main backgrounds



INCLUSIVE SEARCHES WITH ≥1 τ IN FINAL STATE

- Distribution of M_{eff} for SUSY signal and SM bg

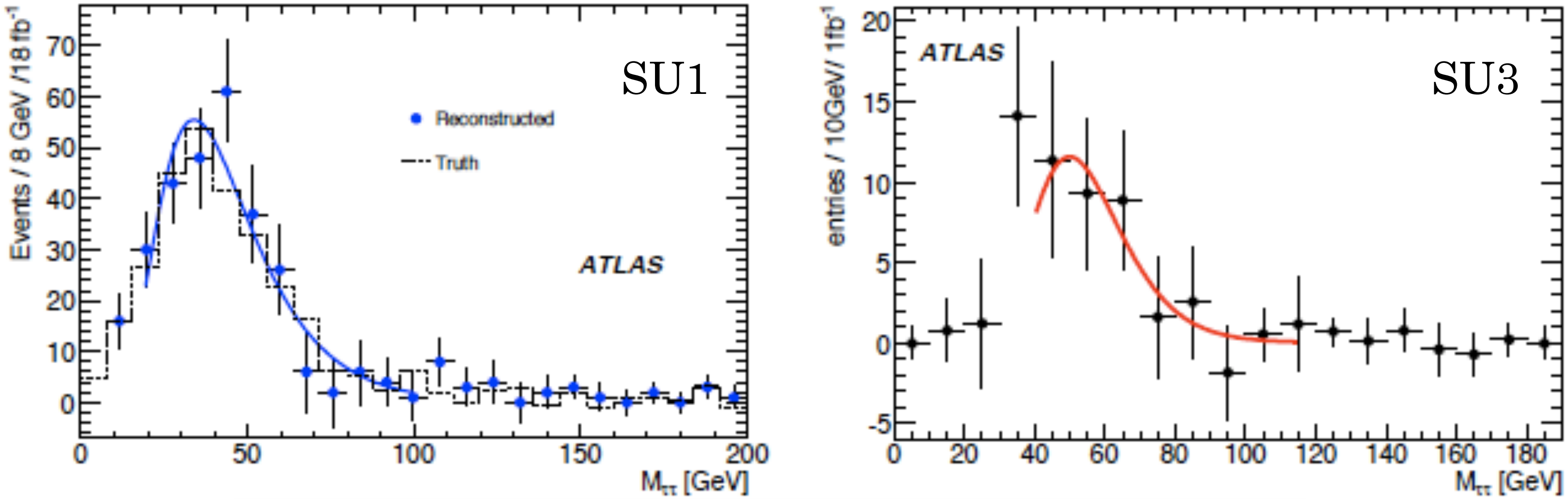
$$M_{\text{eff}} \equiv \sum_{i=1}^{4} p_T^{\text{jet},i} + \sum_{i=1} p_T^{\text{lep},i} + E_{\text{T}}^{\text{miss}}$$



arXiv:0901.0512, CERN-OPEN-2008-20

DETERMINATION OF DI-TAU ENDPOINT

- Look at di-tau final states ($\tilde{\chi}_2^0 \rightarrow \tilde{\tau}_1 \tau \rightarrow \tilde{\chi}_1^0 \tau^{\pm} \tau^{\mp}$)
- In contrast to $\tilde{\chi}_2^0$ decays into e/μ, di-τ invariant mass spectrum does not have a sharp endpoint



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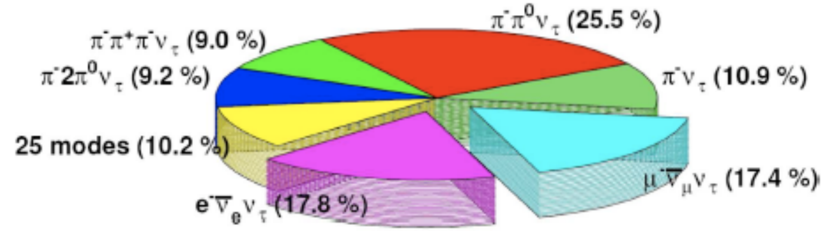
Invariant mass distribution of opposite-sign τ pairs

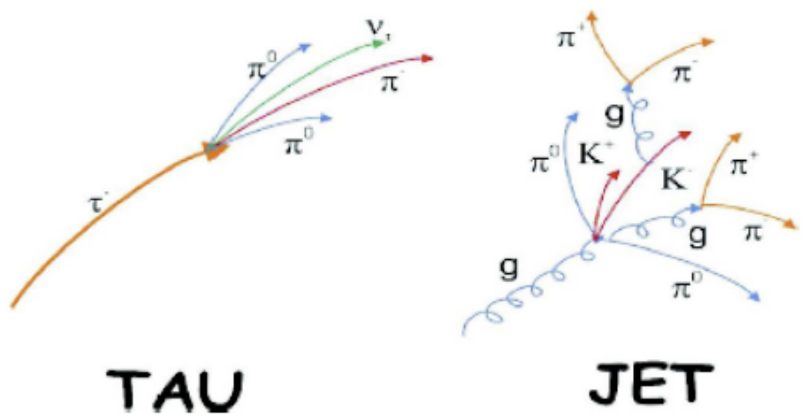
Due to presence of neutrinos, $m_{\tau\tau}$ falls off smoothly below max value ($m_{ll}^{edge} = m_{\chi_2^0} - m_{\chi_1^0}$)

TAU CHARACTERISTICS

- Crucial to reconstruct and identify taus in the busy environment of the LHC events

  - $m_\tau \sim 1.7$ GeV
  - $c\tau = 87\mu m$
  - Hadronic decays are well collimated collection of charged and neutral p/K
  - Most have 1 or 3 charged tracks
  - Leading pion reproduces well direction of primary τ

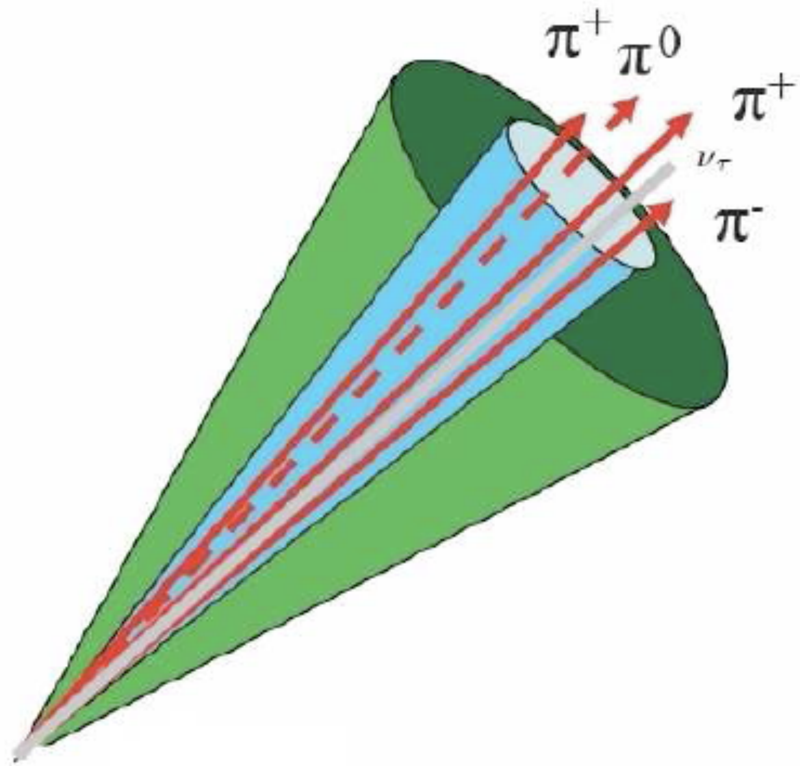




- Tau decays are very well understood
- Will be used for testing detector performances as well as searches for "new physics"

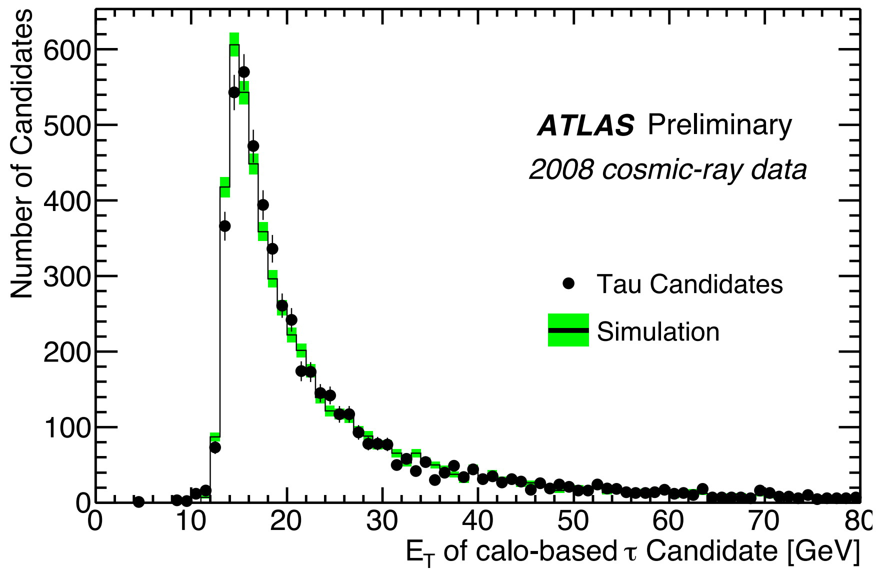
Reconstruction of tau leptons

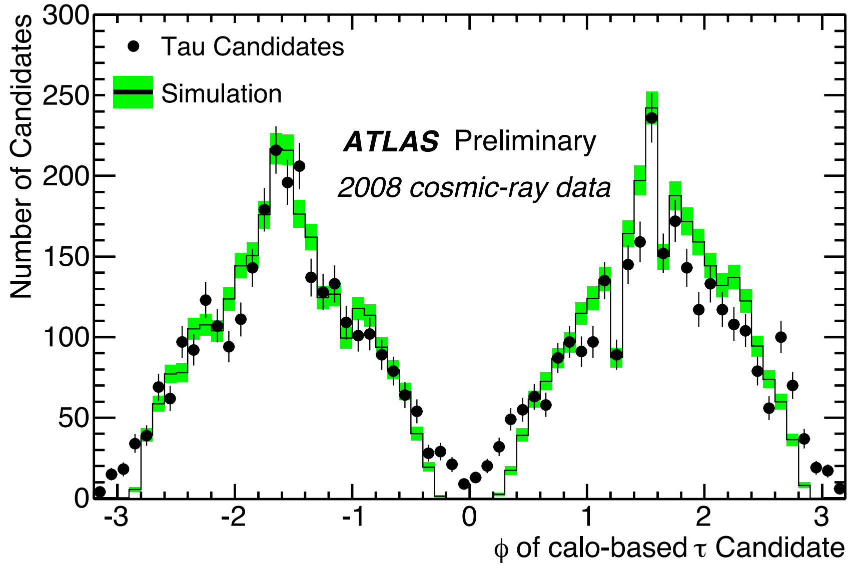
- Tracking
  - low track multiplicity (1 or 3)
  - collimated tracks
  - secondary vertex reconstruction (3-prong events)
  - isolation from other tracks (cone variable)
- Calorimetry
  - collimated energy deposits in calorimeter
  - strong EM component (1-prong)
  - possibility to identify π^0 clusters
  - use EM and HAD component



DATA/MC COMPARISON USING COSMICS EVENTS

- Tools developed for tau reconstruction have been tested on real data using the 2008 cosmics runs
- Variables used for τ-ID have been compared between data and cosmics MC events

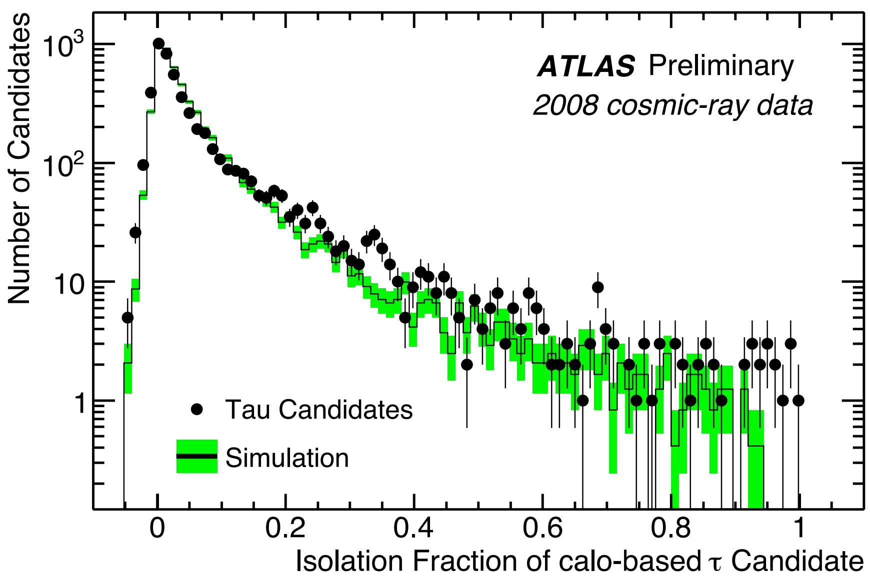




TAU IDENTIFICATION

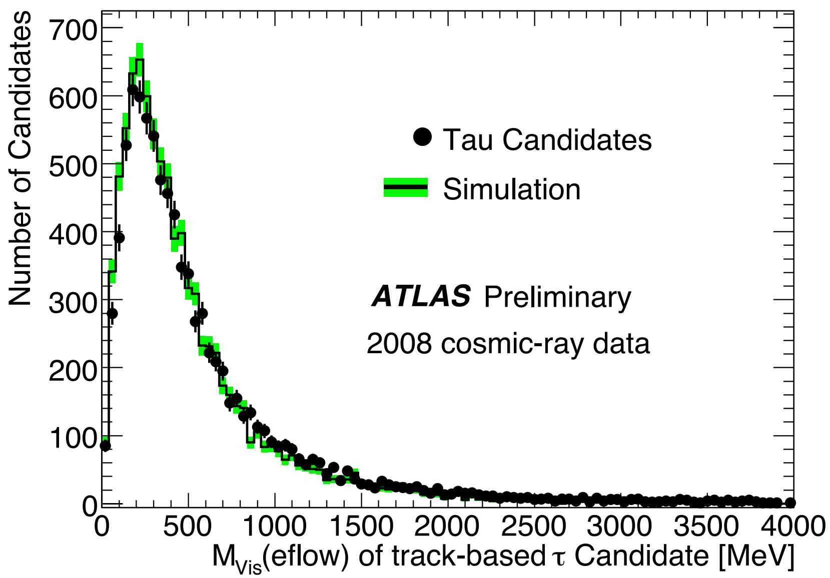
- Isolation fraction

$$I = \frac{\sum E_{\mathrm{T}}(0.1 < \Delta R < 0.2)}{\sum E_{\mathrm{T}}(\Delta R < 0.4)}$$



- Visible mass

$$m_{\mathrm{vis}} = \sqrt{(\sum E_i)^2 - (\sum \vec{p}_i)^2}$$



TAU IDENTIFICATION – CONT.

- Use a "safe" approach based on the use of a small number of well understood variables
- Two different approaches

CALORIMETER APPROACH	CALORIMETER+TRACKING APPROACH
• Shower Radius im EM Calorimeter • Isolation Fraction • Width in Strip Layer • $E_T(EM)/E_T$	• Variables from 'Calorimeter Approach' • + Width of Track Momenta • + E_T/p_T(Leading Track) • + $E_T(HAD)/\sum p_T$ • + $E_T(EM)/\sum p_T$ • + $\sum p_T/E_T(EM+HAD)$

- Plan to use these for very first data

SUSY searches at Sussex

- Group already leading 'traditional' 3-lepton SUSY searches
  - e/μ final states only
- Started working on 3-lepton final states with taus
  - 2l + 1τ – extension of traditional 3-l analysis
    - 1l + 1τ used as starting point for the analysis
  - 2τ + 1l – extension of 2τ analysis
- Possibility to look into 3τ final states
  - possibly limited by high rate of fake taus

WORK IS IN PROGRESS…

- Develop and consolidate an inclusive analysis for lepton(s)+tau(s) final states
- Study effects of different tau-id choices on analysis sensitivity
- Tailor cuts for background rejection to tau multiplicity
- Develop techniques to study detector and trigger performances in presence of
  - lepton(s)+tau(s)
  - extra jets
  - Missig E_t
- For example:
  - jet-taujet overlap and taujet fake rates in a jet-rich environment
  - electron-taujet overlap
  - tau efficiencies in a jet-rich environment
  - trigger studies: lep+tau(+etmis) trigger vs lep+jet(+etmis), etc
  - statistical combination of channels
  - and more…

Conclusions and outlook

- LHC has started taking data, with main focus currently on detector performances and SM physics
- It is important to start looking at long-term analysis plans for $100pb^{-1}$ and beyond
- SUSY searches in tau final states very important for some of the standard benchmark mSUGRA scenarios
- Sussex leads 3-lepton analyses with e/μ in final states
- Multi-lepton SUSY analyses that include taus under development