The standard model, supersymmetry and CMS

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Introduction

- The standard model
- Supersymmetry
- Initial issues
- Constraining our models
- Signals of supersymmetry
- SUSY at CMS

The standard model

- Majority of evidence so far in *good* agreement with standard model predictions,
  - Electroweak Precision Observables [**EWPO**] (anomalous magnetic moment of electron, M_t, M_W)
  - Rare Decays (B-physics)
- Evidence for discrepancies and limitations,
  - Anomalous magnetic moment of the muon a_μ
  - Relic Ω_{CDM}
  - Quadratic divergences in radiative corrections to m_H

Supersymmetry

- Superpartners with Δs=½
- Must be a broken symmetry,
  - No observations of these particles yet
  - Need to introduce new mass terms to the lagrangian

$$q \to \tilde{q}$$
$$l \to \tilde{l}$$
$$\nu \to \tilde{\nu}$$
$$W^{\pm} \to \tilde{W}^{\pm},\ Z^0 \to \tilde{Z}$$
$$g \to \tilde{g}$$
$$B \to \tilde{B}$$
$$H \to \tilde{H}$$
$$\tilde{W}^{\pm}, \tilde{B} \to \tilde{\chi}^0$$
$$\tilde{W}^{\pm}, \tilde{H}^{\pm} \to \tilde{\chi}^{\pm}$$

Initial issues

- Similar problem to SM – parameters
- Get 19 → 104< (depending on symmetry breaking mechanism) parameters
- 3 problems,
  - Motivation for fine tuning (same as SM)
  - Enormous parameter space – computational issues
  - No predictive ability

The MSSM

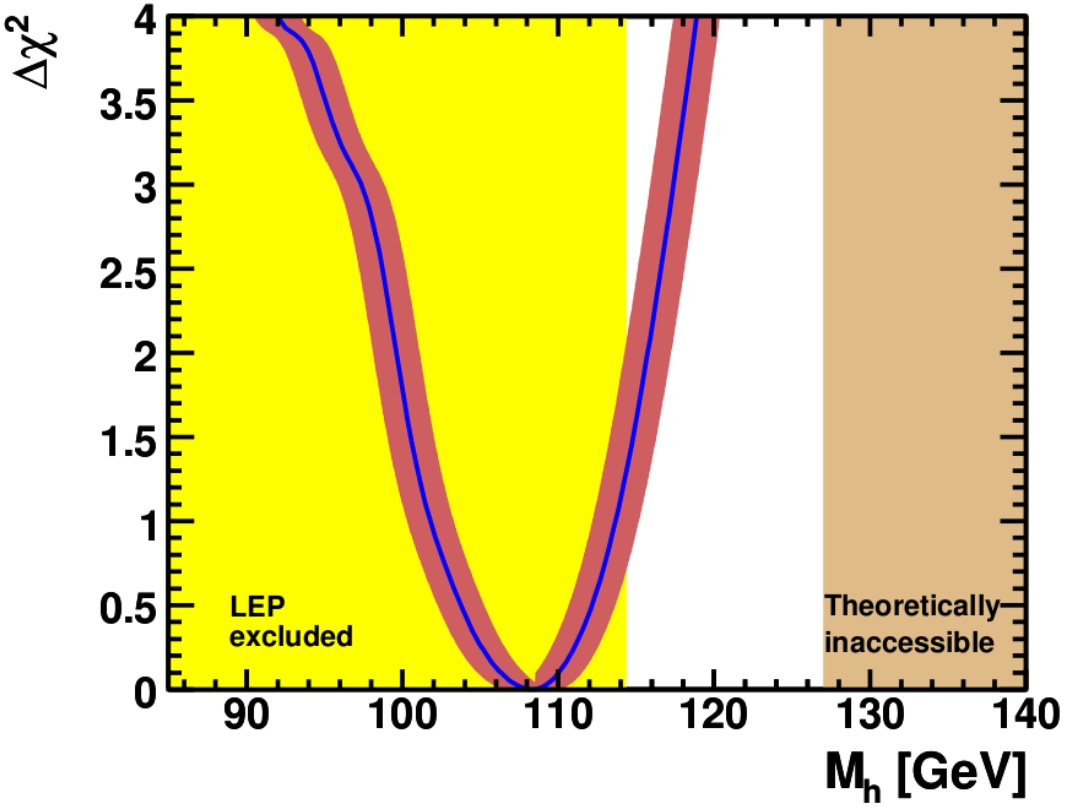
- Many parameters, but can still realise “appealing” behaviour of SUSY
- Relax constraints on baryon and lepton number conservation
- Enforce R-parity, defined as $R=(-1)^{3(B-L)+2S}$
- B,L: baryon-, lepton- number, S: spin
- R_{SM}=+1, R_{SUSY}=-1, leads to *only* pair-production
- LSP particle is stable $\rightarrow$ Ω_{CDM} candidate!

Further constraints

- Would be good to make predictions
  - Insist on universality at the GUT scale i.e.
    - Gaugino masses $M_1 = M_2 = M_3 = m_{1/2}$
    - Sfermion masses $A_b = A_t = A_\tau = A_0$
- Require two more parameters for the higgs sector
  - tan(β) – ratio of Higgs field vacuum expection
  - Sign of μ – Higgs mixing parameter
- Results in the constrained MSSM (CMSSM)
- Have reduced SUSY to 4 parameters and a sign

Making predictions

- Essential that one doesn't get too hung up on the theory...
- Look at how EWPOs (m_Z, m_W, etc.) and rare decays (BR(b→sγ), etc.) can constrain our parameter space
- Do a multi-parameter fit, minimising a global χ^2 function



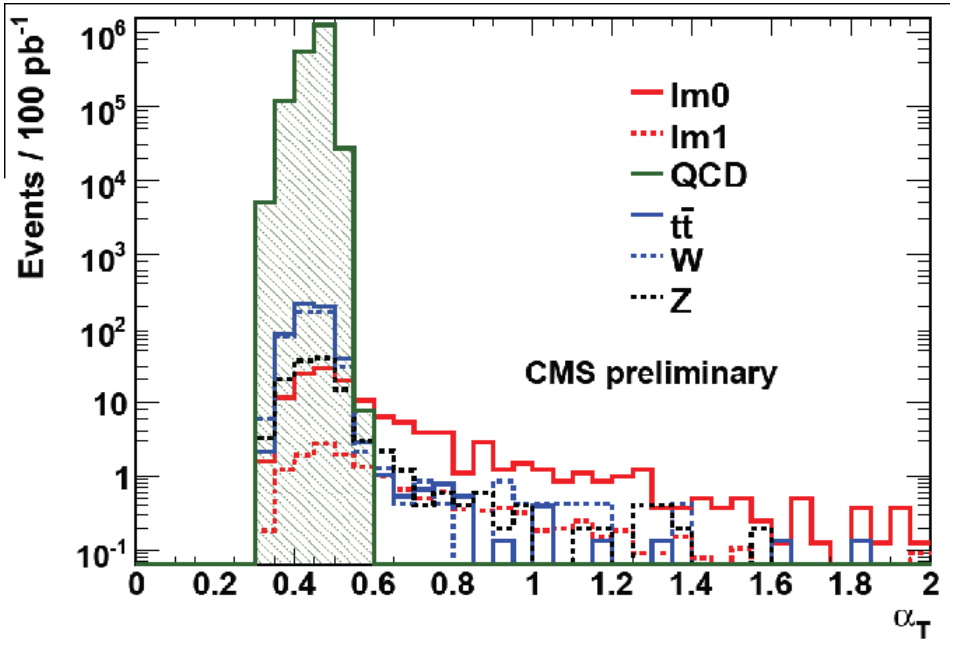
$$\chi^2 = \sum_i^N \frac{(C_i - P_i)^2}{\sigma(C_i)^2 + \sigma(P_i)^2} + \sum_i^M \frac{(f_{SM_i}^{obs} - f_{SM_i}^{fit})}{\sigma(f_{SM_i})^2} + \ldots$$

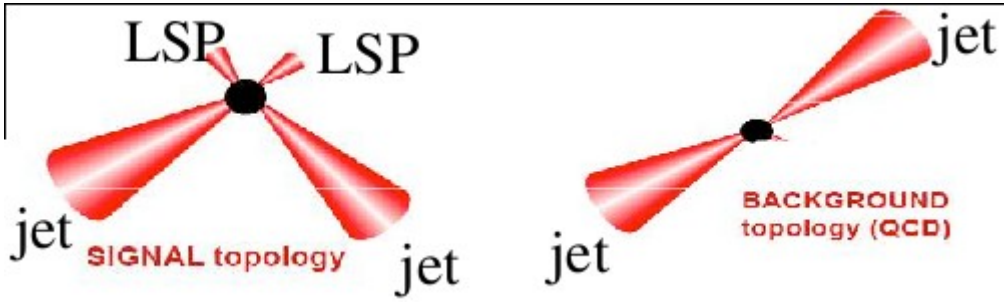
Signs of supersymmetry

- What specific signals could one get from SUSY at the LHC?
  - Same Sign Dilepton
    - Suppressed in SM – so a low background channel
    - Main background is QCD Dijet, top quark, electroweak boson production
  - Opposite Sign Dilepton
    - e.g. $\tilde{\chi}_2^0 \rightarrow l\, l\, \tilde{\chi}_1^0$
    - Linear rise with invariant mass of leptons, with a cut-off at the kinematic limit (characterised by $m_{\tilde{\chi}^0_2} - m_{\tilde{\chi}^0_1}$)
    - Can calculate the position of this cut off beforehand

Signs of SUSY - ME_T

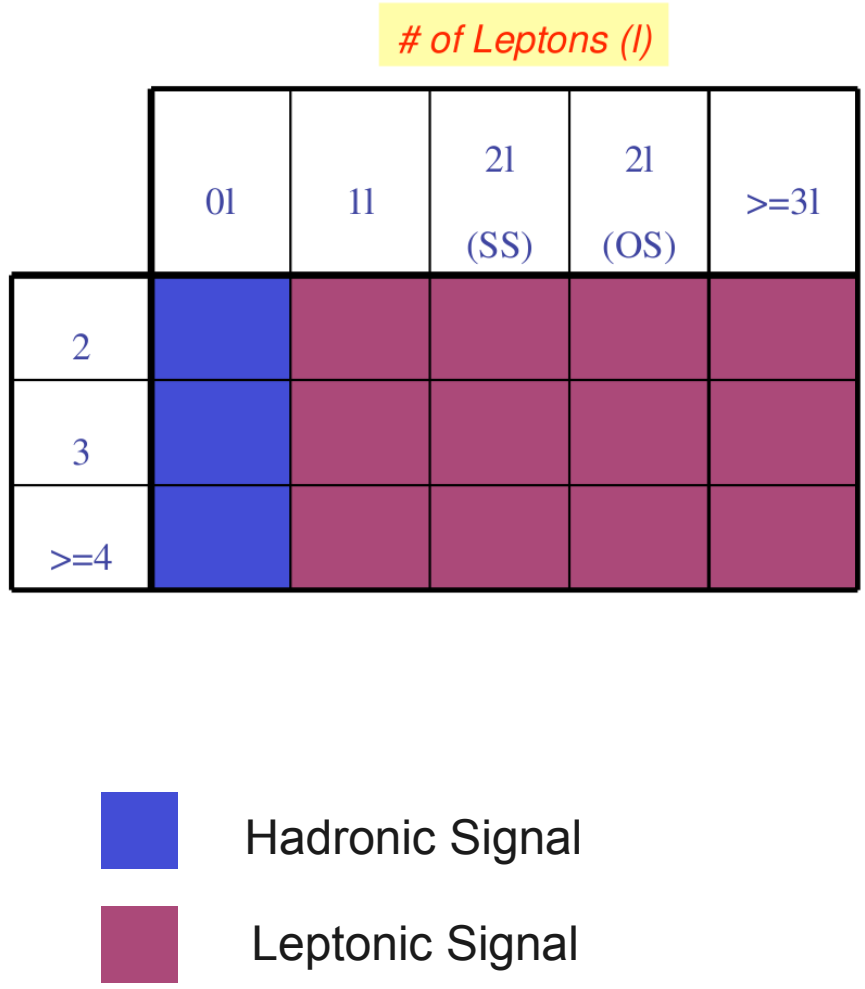
- *Both* signals also have missing E_T (LSP escaping)
- Can parametrise this with α_T, the "balance" of the event jets
- Allows for effective cuts on the SM background



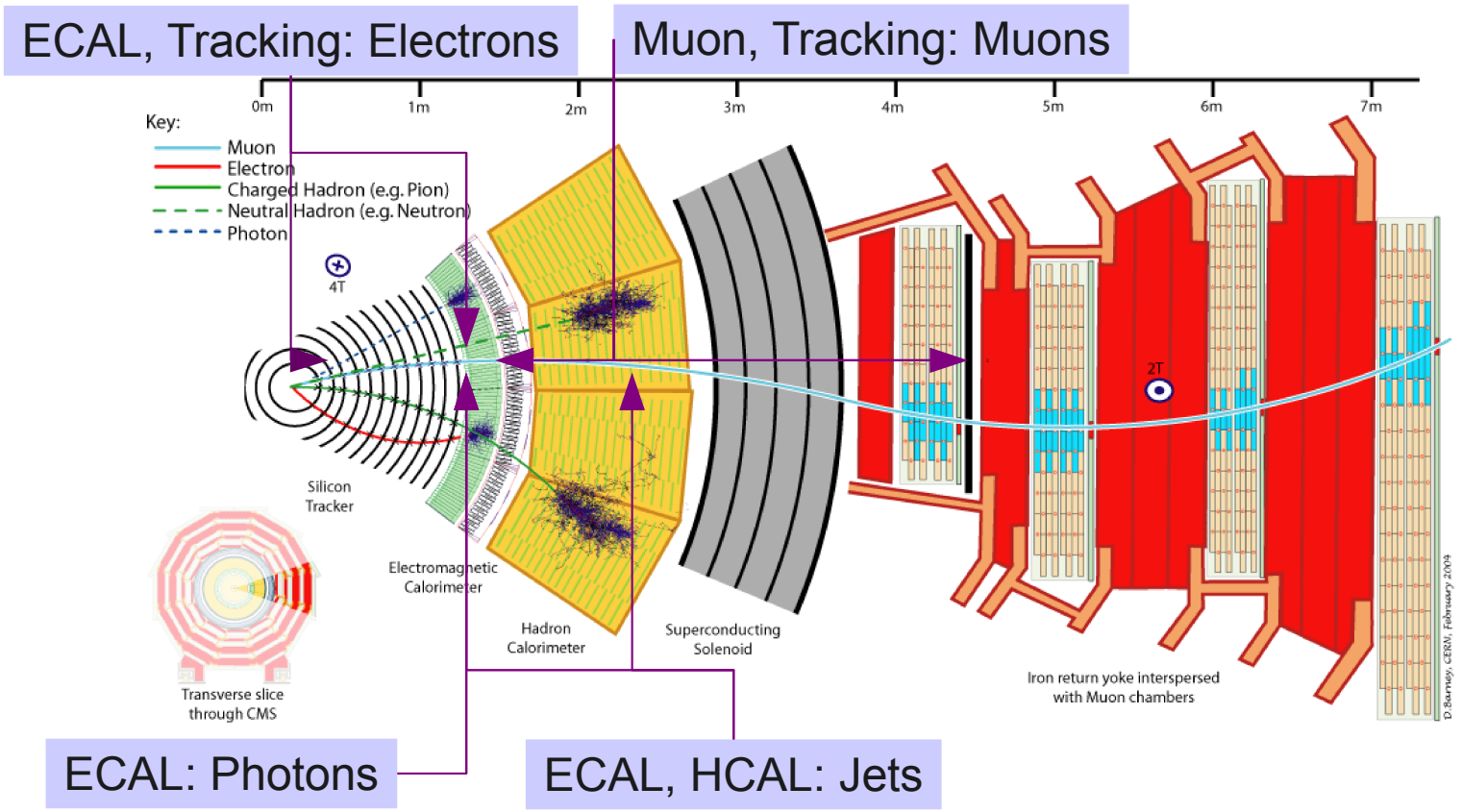


SUSY at CMS

- Missing E_T – don't need absolute $\sqrt{s}$
- Cuts in place to eliminate main background
- Several leptonic signals → ECAL plays an important role
- 0l events have the highest cross-section



SUSY at CMS (2)



Can see that SUSY requires analysis of data from all the different components of CMS

Summary

- Can phenomenologically motivate constraints on general SUSY
- Have well defined signals for SUSY at CMS
- For particular models can generate likelihood functions to limit parameter space
- Good prospects for the understanding of new physics at the LHC