Suppose there is evidence for a (or several) new particle(s) at the LHC with 1 fb^{-1} at 7 TeV: how well would one know the properties of such a new state from the early data?

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(Imperial College London)

International Workshop on Linear Colliders 2010

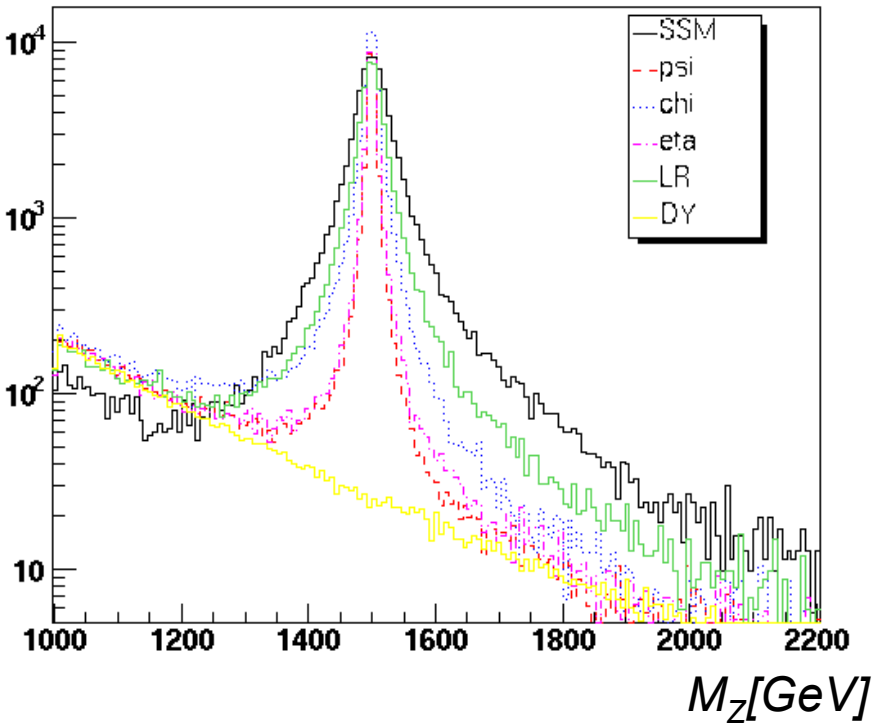
Session: Physics scenarios at the LHC and their possible impact on the LC

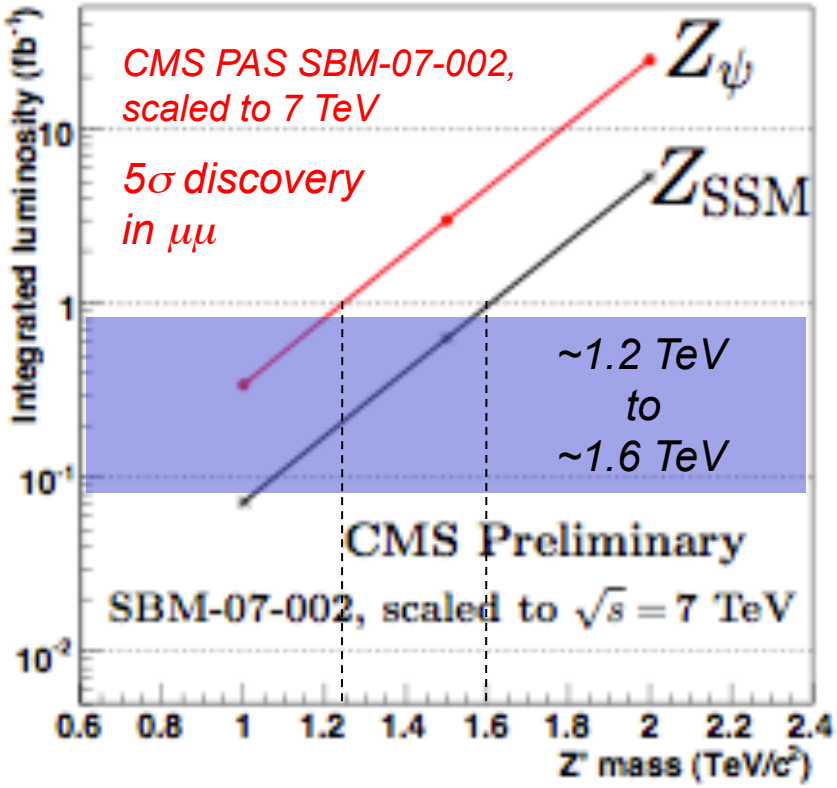
- *Two (Extreme) Examples*
- *High Mass Di-lepton Resonances – the "easy" case*
- *SUperSYmmetry – the tough case*

Dilepton Resonances – "Easy" Case

- Predicted in many SM extensions
- Low, well understood background dominated by DY
- Very clear signature over negligible background
- Sensitivity beyond the Tevatron (1 TeV SSM Z') with ~100 pb^{-1}

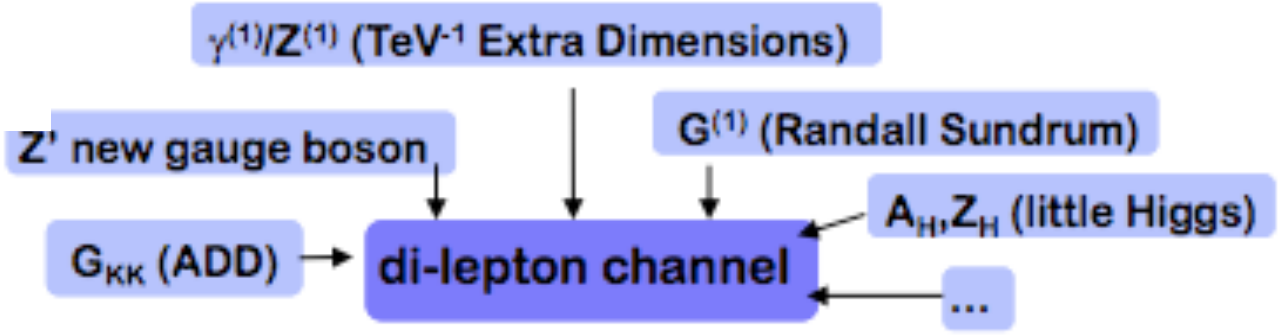
$M_{Z'}$=1.5 TeV





Di-lepton Resonances – "Easy" Case

At the LHC they are predicted to arise in many BSM models:



In case of a signal:

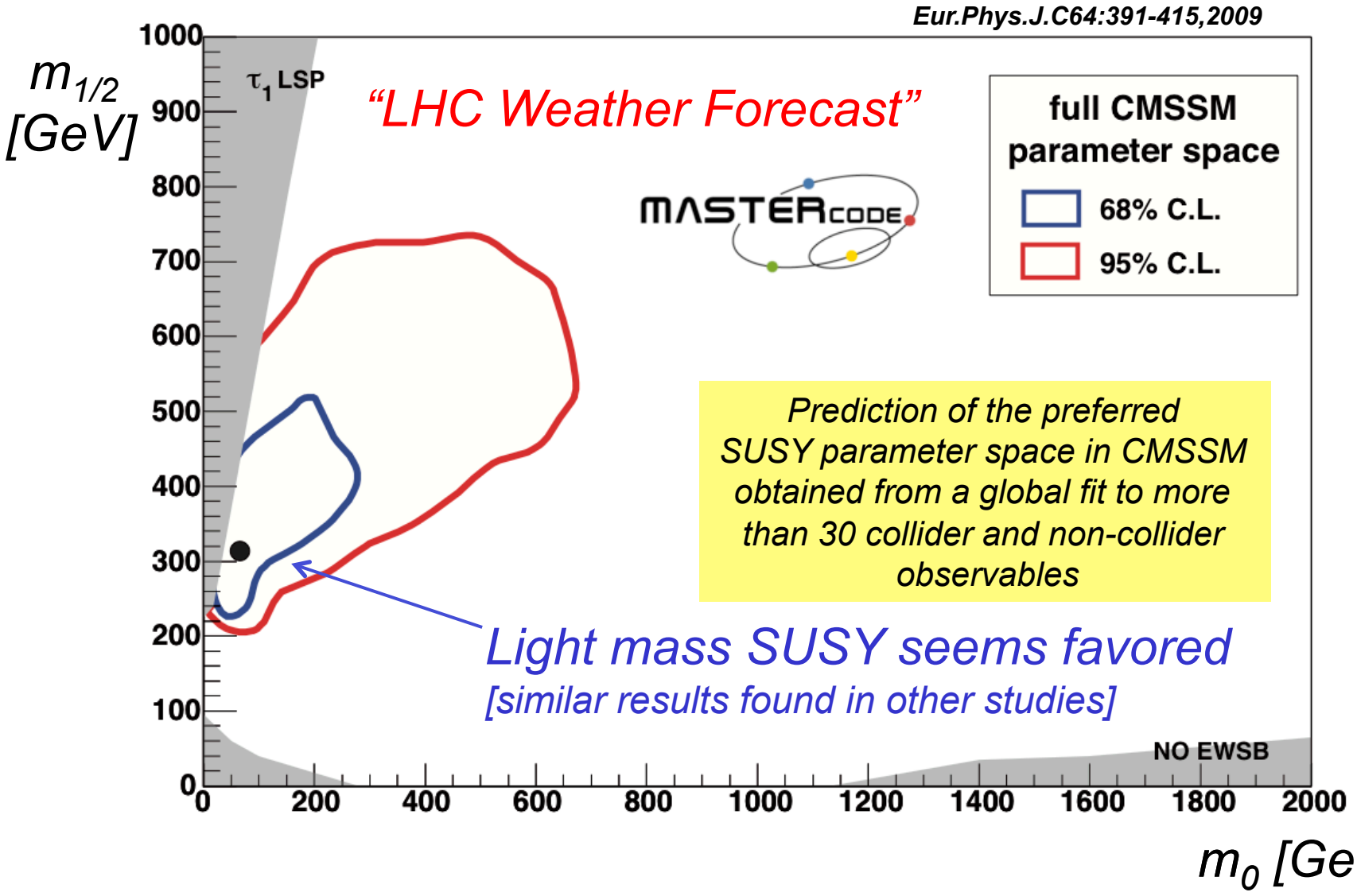
- *Measure mass and width*
- *Measure production cross section*
- *Verify or falsify existences in other channels:*

  muon, electron, photon, jet, cross object

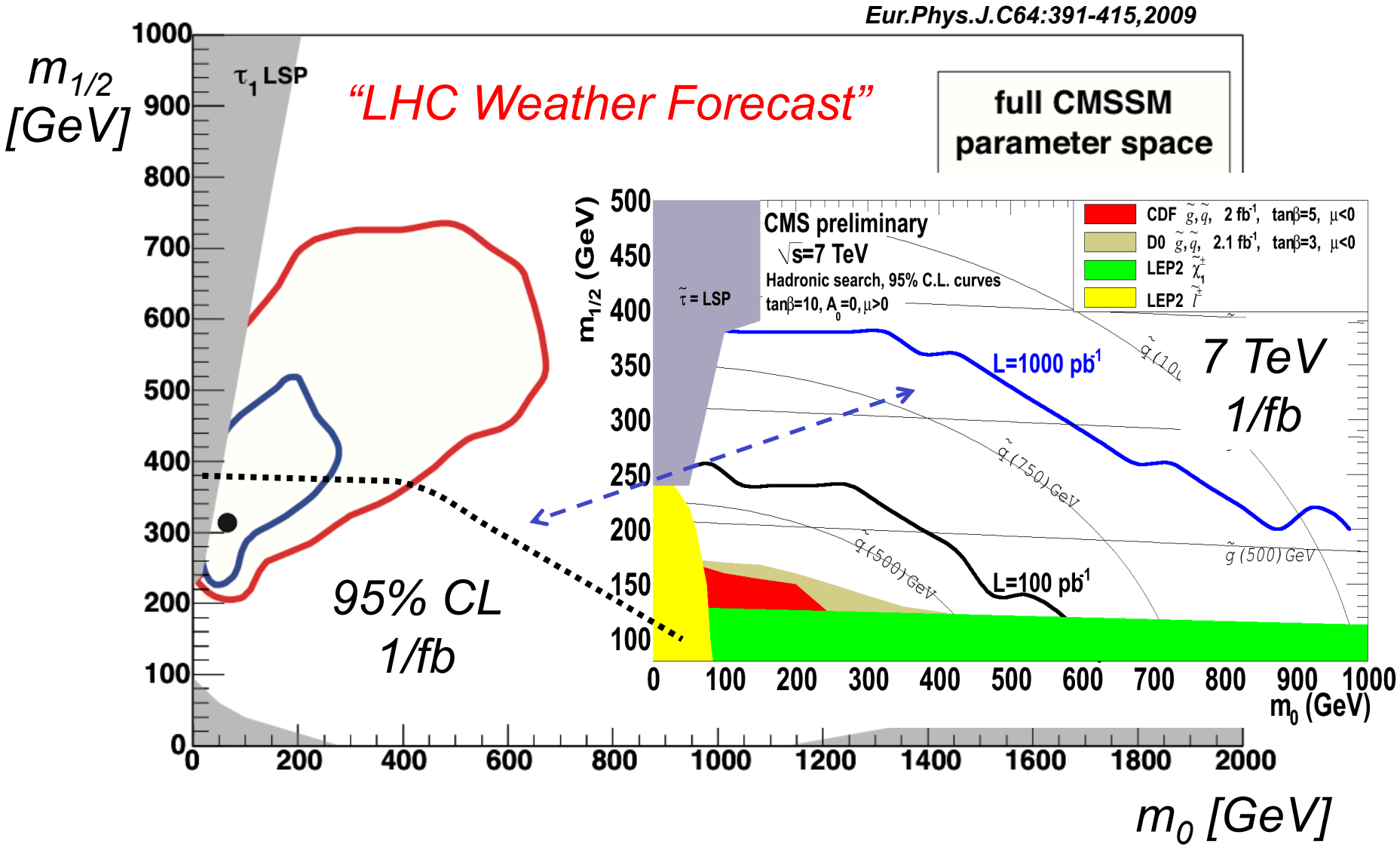
Example: signal in muon and electron channel but not in photon: likely U(1) like (Z')

Should be able to know already several properties after 1/fb

SUSY: What to Expect?



What can be covered - Example

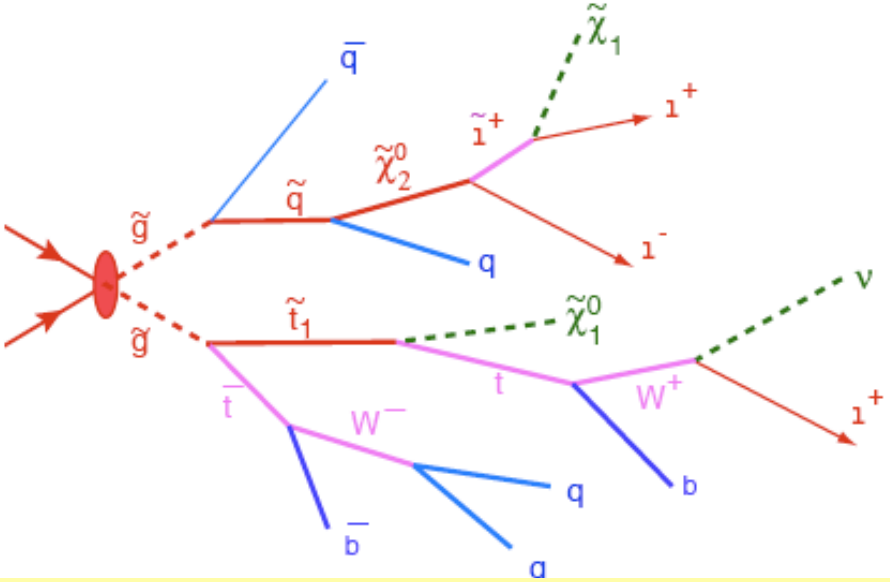


What do we call a "SUSY search"?

The definition is purely derived from the experimental signature.

Therefore, a "SUSY search signature" is characterized by

Lots of missing energy, many jets, and possibly leptons/photons in the final state



Missing Energy:

- *from LSP*

Multi-Jet:

- *from cascade decay*

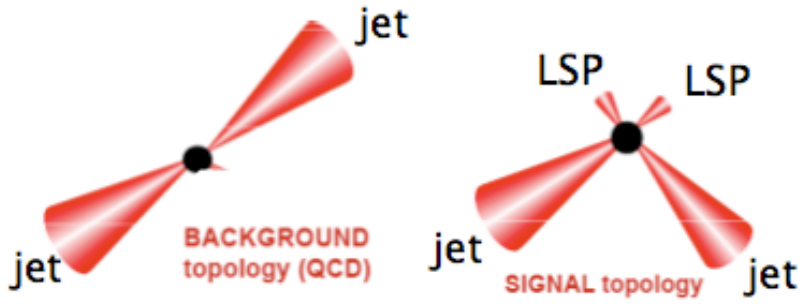
Multi-Leptons:

- *from decay of charginos/ neutralios*

Experimentally very challenging topologies. The first searches are mainly inclusive searches trying to find a deviation for the SM. There are not much handles at a hadron collider to measure detailed properties of such demanding decay chains.

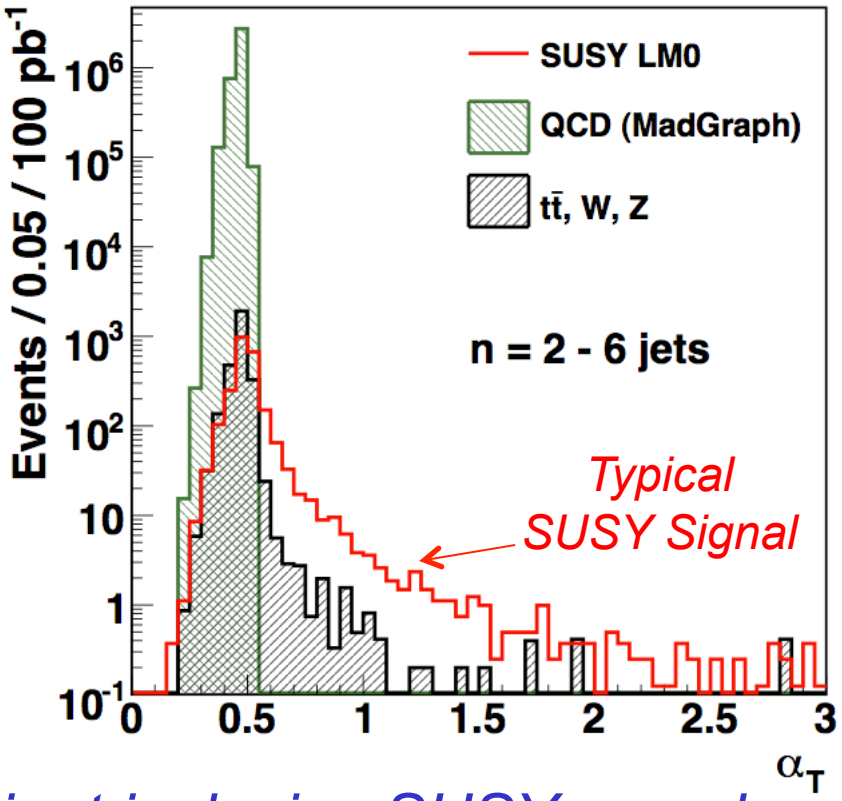
SUSY Discovery Searches – An Example

PRL101:221803 (2008) & CMS-PAS-SUS-09-001



$$\alpha_T = \frac{E_{T\,j2}}{M_{T\,j1\,j2}} = \frac{\sqrt{E_{T\,j2}/E_{T\,j1}}}{\sqrt{2(1-\cos\Delta\varphi)}}$$

Initially two jet search – now extended to Njets

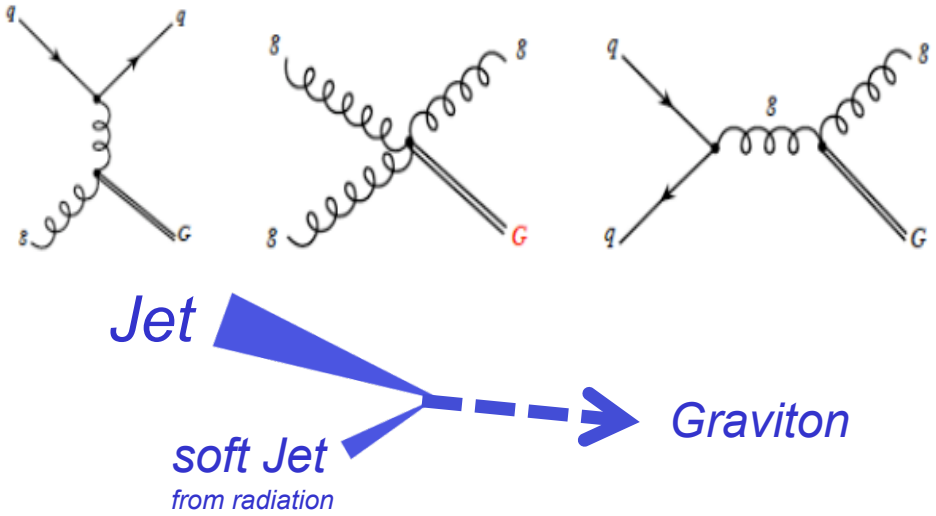


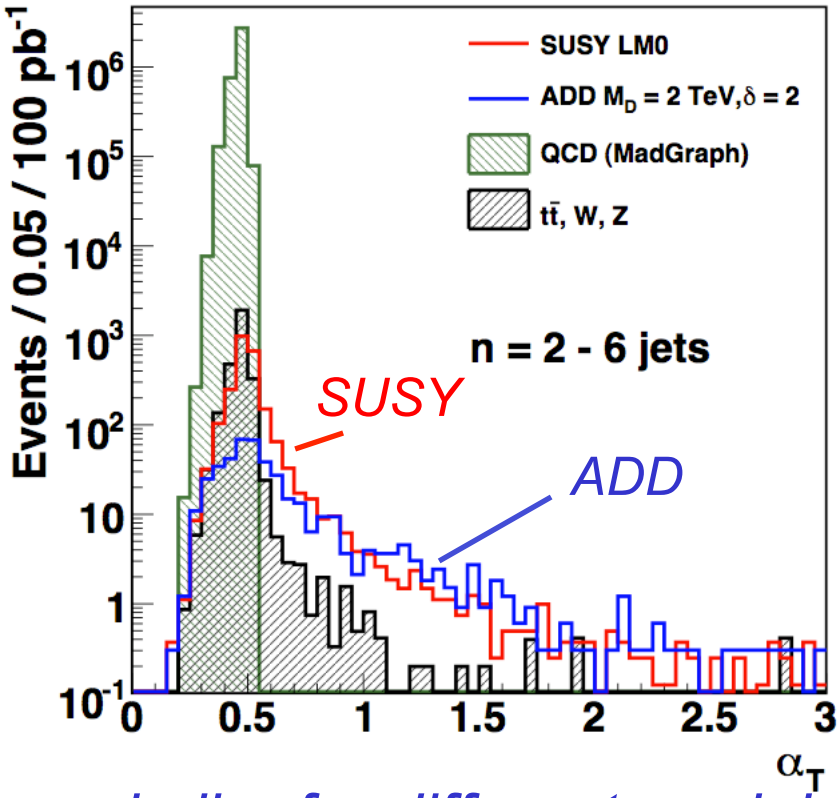
Example of a very robust and efficient inclusive SUSY search:

- **Clear separation from background (especially QCD) and signal**
- **Perfectly balanced events (QCD) have α_T = 0.5 (cut at α_T >0.5)**
- **Robust against detector effects**

But it might not be SUSY …

Another missing energy signature.
*This time **extra dimensions (ADD)**.*





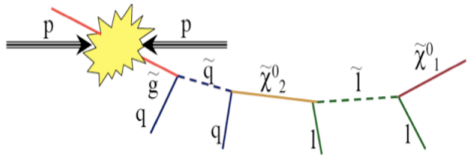
Missing energy signatures are rather similar for different models

- **Need to study properties in different channels, jet multiplicities, etc.**
- **Could take some time to narrow down the possible model candidates**
- **In general, inclusive searches are good for discovery but not optimal to study underlying properties – need to be more exclusive.**

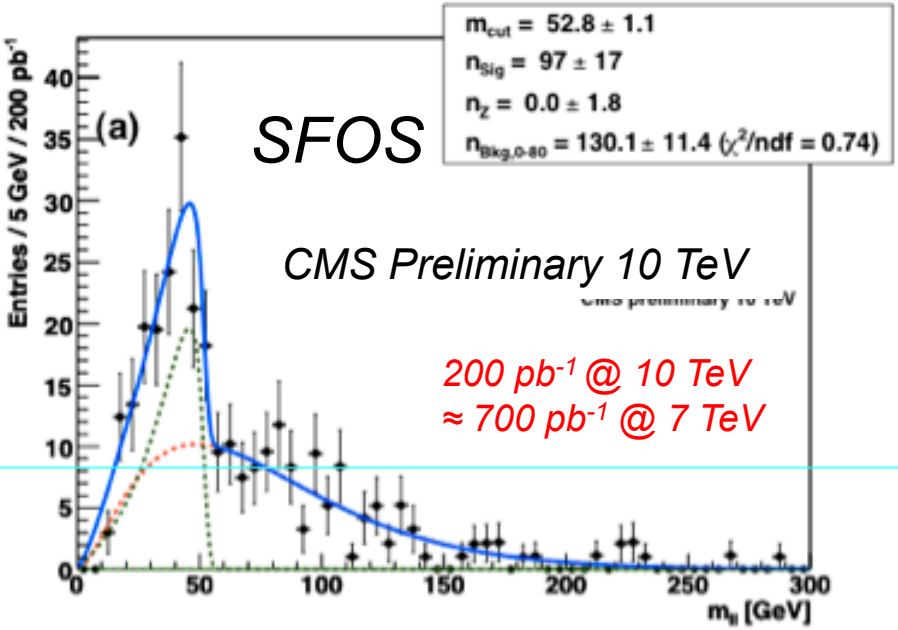
First Kinematic Measurements

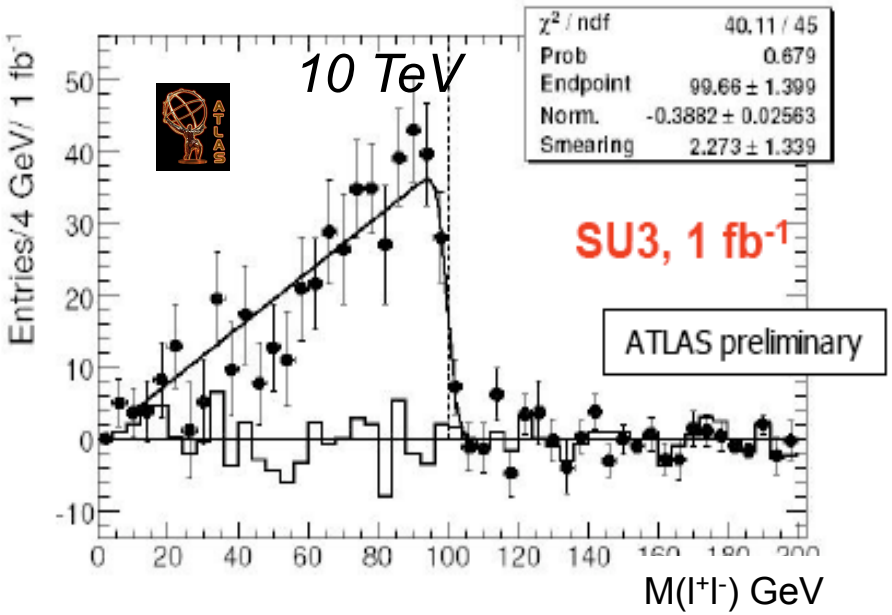
IF we are lucky we might see spectacular signals giving rise to first mass clues

Look for generic signatures of cascade decays:



Jets + E_t^{miss}
+SFOS di-leptons



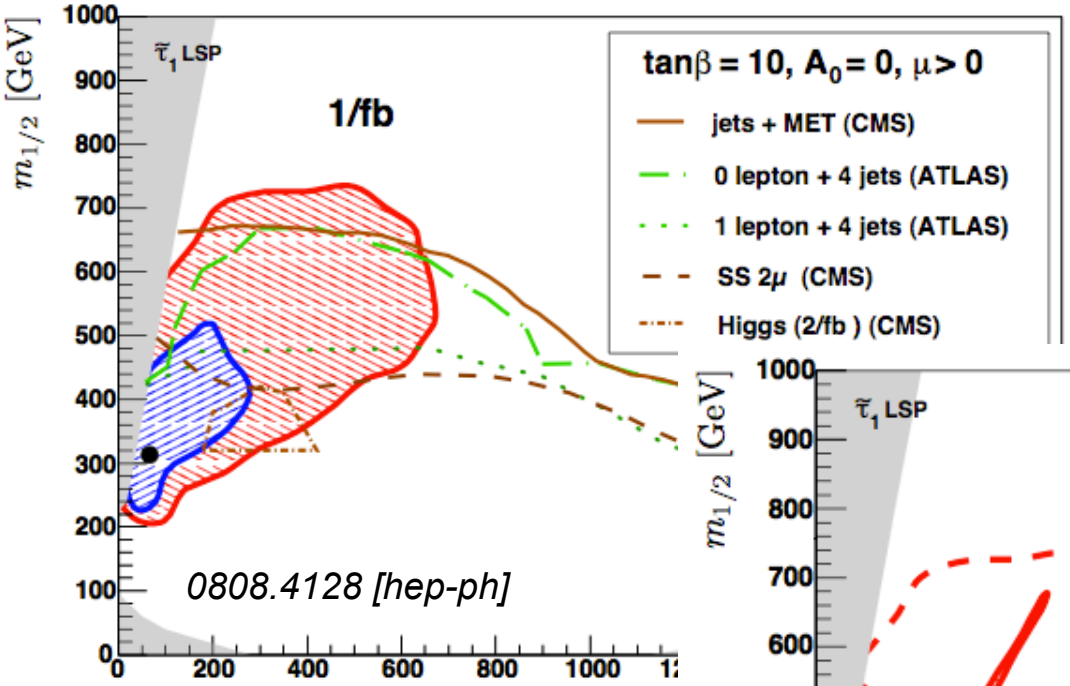


$$M_{\ell\ell}^{max} = M(\tilde{\chi}_2^0)\sqrt{1-\frac{M^2(\tilde{\ell}_R)}{M^2(\tilde{\chi}_2^0)}}\sqrt{1-\frac{M^2(\tilde{\chi}_1^0)}{M^2(\tilde{\ell}_R)}}$$

ATLAS covariance matrix for the SU3 benchmark point at 1/fb @ 10 TeV

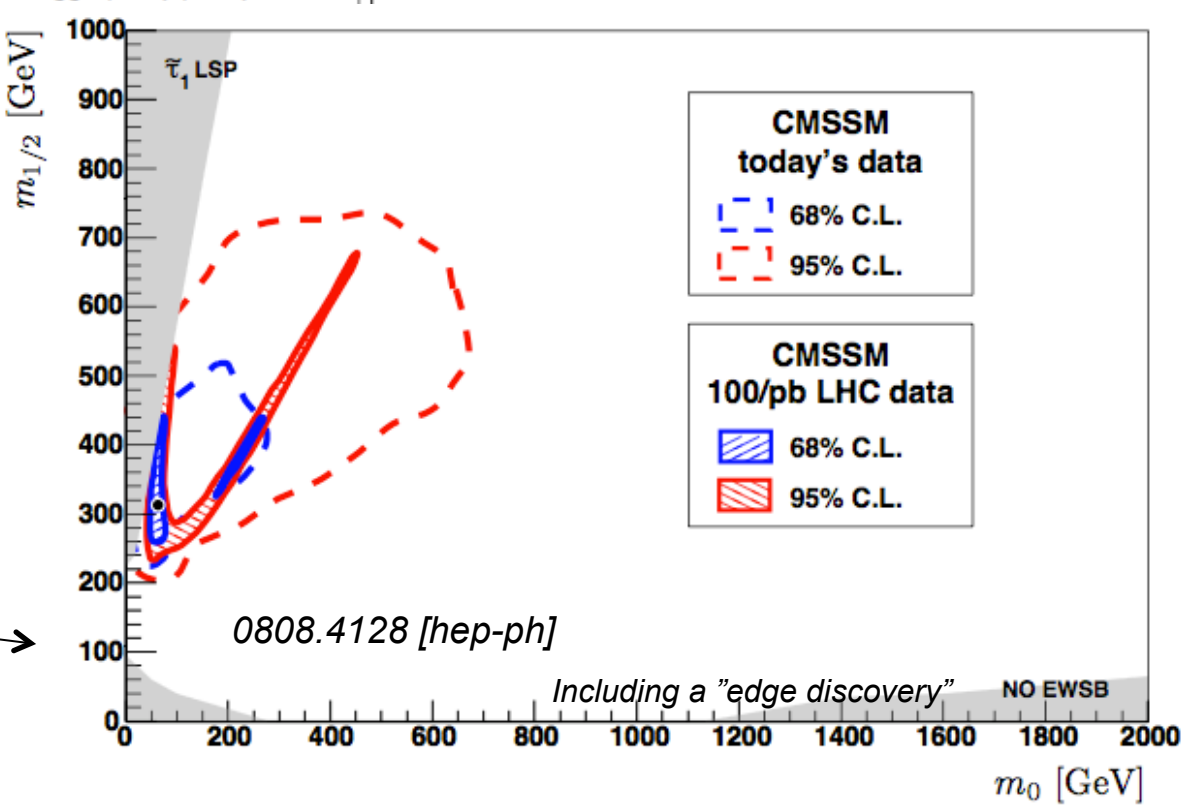
	$m_{\chi_1^0}$	$m_{\chi_2^0}-m_{\chi_1^0}$	$m_{\tilde{l}}-m_{\chi_1^0}$	$m_{\tilde{q}}-m_{\chi_1^0}$
$m_{\chi_1^0}$	3.72×10^3	53.40	1.92×10^3	10.75×10^2
$m_{\chi_2^0}-m_{\chi_1^0}$		3.6	29.0	−1.3
$m_{\tilde{l}}-m_{\chi_1^0}$			1.12×10^3	4.65
$m_{\tilde{q}}-m_{\chi_1^0}$				14.1

First Mass Clues can help to constrain



Before an "edge" measurement

After an "edge" measurement



What might we know in 2012?

- Di-lepton resonances – the "easy" case
  - Mass and (first) width measurements
  - First cross section information
  - Model categorization according to final states
- SUSY (missing energy signature) – the tough case
  - Rough estimate of the mass - 600 to 800 GeV for 1/fb @ 7 TeV
  - Undetectable particles in the decay chain
  - Possibly some first mass clues from "edge" measurements
  - Categorization in topologies Etmiss+jets, +Leptons, Photons using e.g. effective models (OSET's et al)
  - Are some particles Majorana-like (i.e. same-sign signatures)

But there will be may things which we likely won't know

- All particles in spectrum/decay chain(s)
- Their properties like mass, spin, etc
- The exact origion of the underlying new physics stucture

What might we know in 2012?

- Di-lepton resonances – the "easy one"
  - Mass and (first) width measurements

The Question:

"Suppose there is evidence for a (or several) new particle(s) at the LHC with 1 fb^{-1} at 7 TeV: how well would one know the properties of such a new state from the early data?"

My Answer:

We could already know a lot but it could also take more time and ingenuity to reveal in more detail the underlying properties of New Physics.

  - Their properties like mass, spin, etc
  - The exact origion of the underlying new physics stucture

What might we know in 2012?

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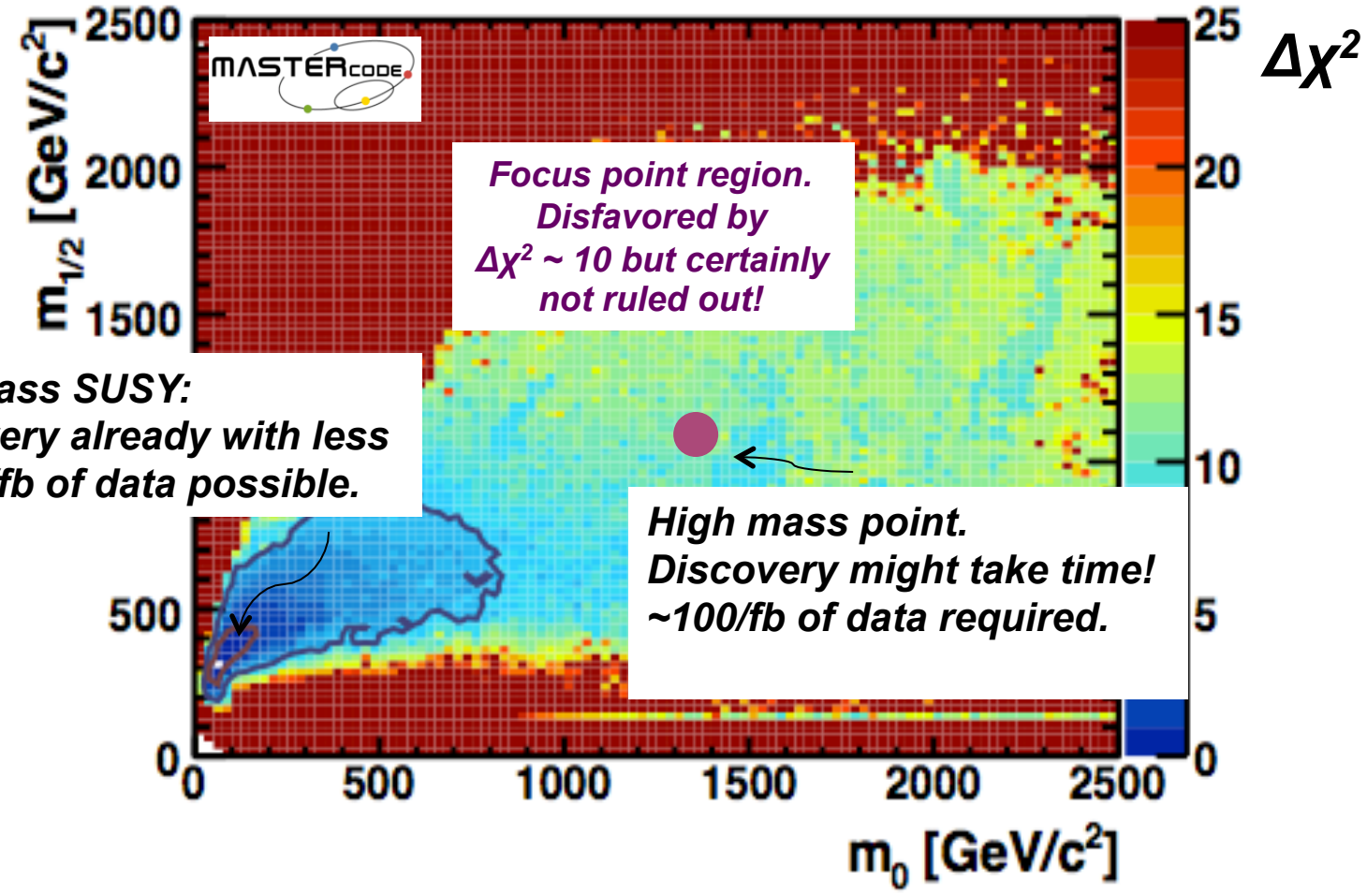
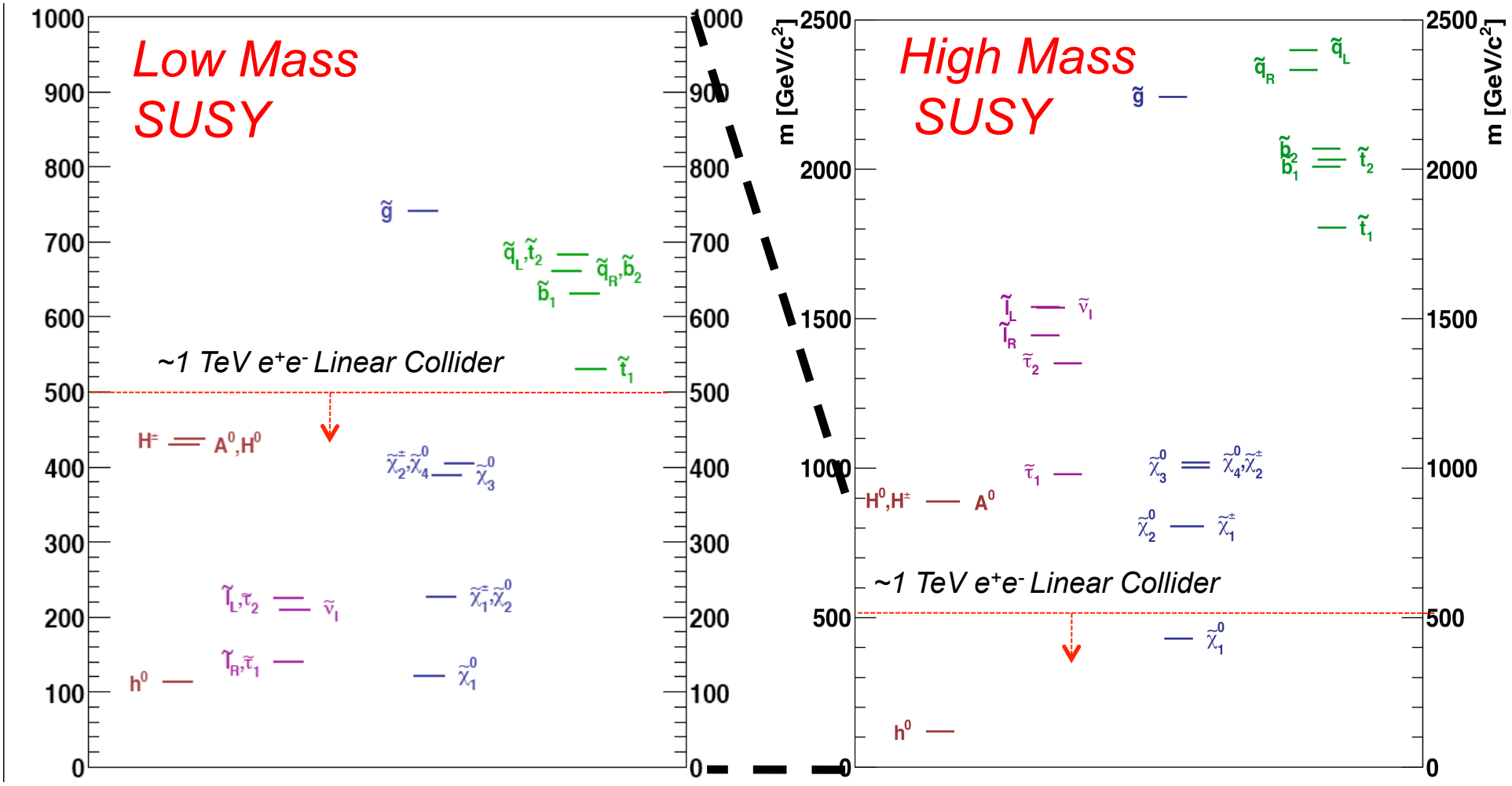
New Physics Mass Scale - SUSY



Mass Scale & LC



Already knowing the mass scale of NP would help a lot!

Imperial College London

Backup Material