Projections for SUSY Searches at the LHC (ATLAS/CMS) for 200 pb^{-1} and 1 fb^{-1}

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On behalf of the ATLAS and CMS collaborations

Why Susy?

- SM can not be the ultimate theory even if it does an excellent job in describing physics at the weak scale
  - No Dark Matter candidate, not enough CP violation
  - Not aesthetically pleasing (hierarchy problem)
- Susy. While solving the hierarchy problem it also:
  - Provides Dark Matter candidates
  - Has a better unification of couplings
  - Predicts the mass scale of Susy particles ~1TeV

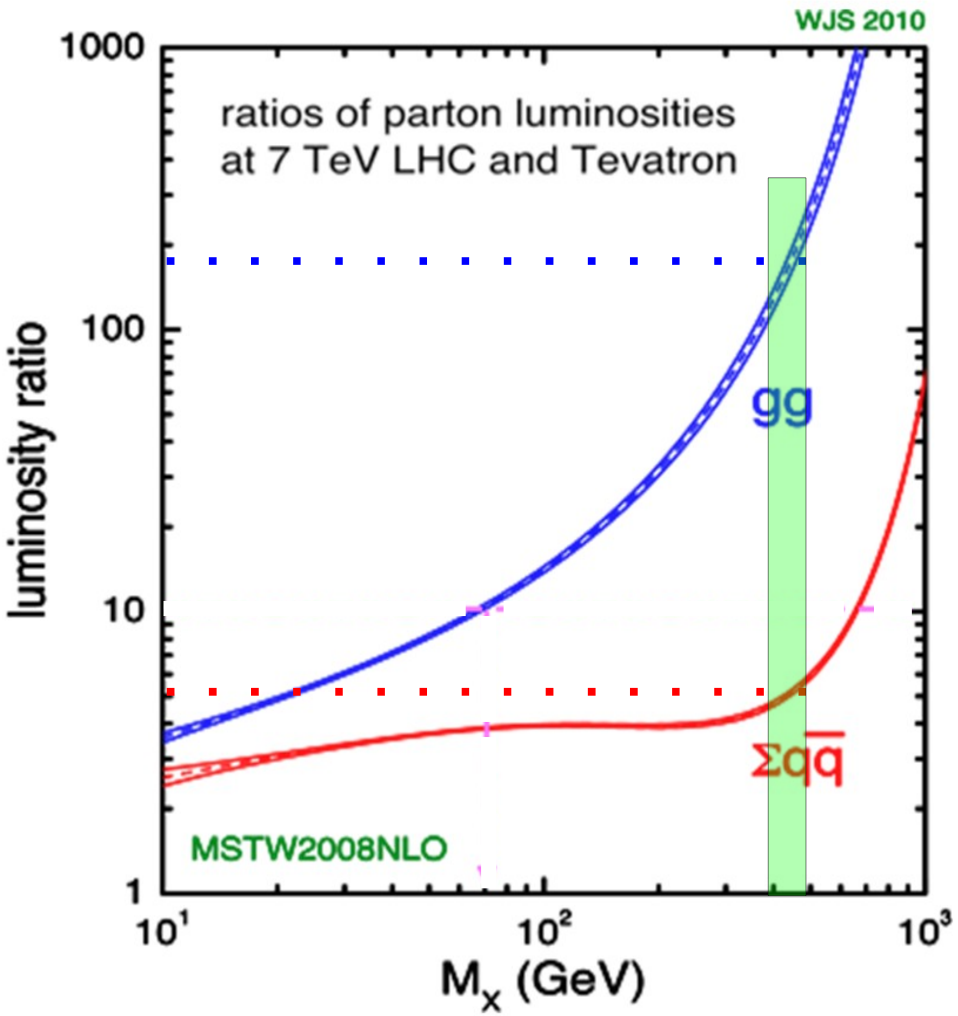
OK. I buy it. How much data do I need?

O(100) pb^{-1}, why so early?

- Tevatron has integrated >10 fb^{-1} at $\sqrt{s}$=2TeV in D0+CDF
- LHC is expected to deliver ~100 pb^{-1} by the end of 2010 and ~1 fb^{-1} at $\sqrt{s}$=7TeV before the 2012 shutdown

- Even "just" at $\sqrt{s}$=7TeV the production of heavy particles (M_X~400-500GeV) via gg will be boosted by O(100) and via qq by ~5.

Yes, you can graduate w/ a SUSY thesis before you grow old.

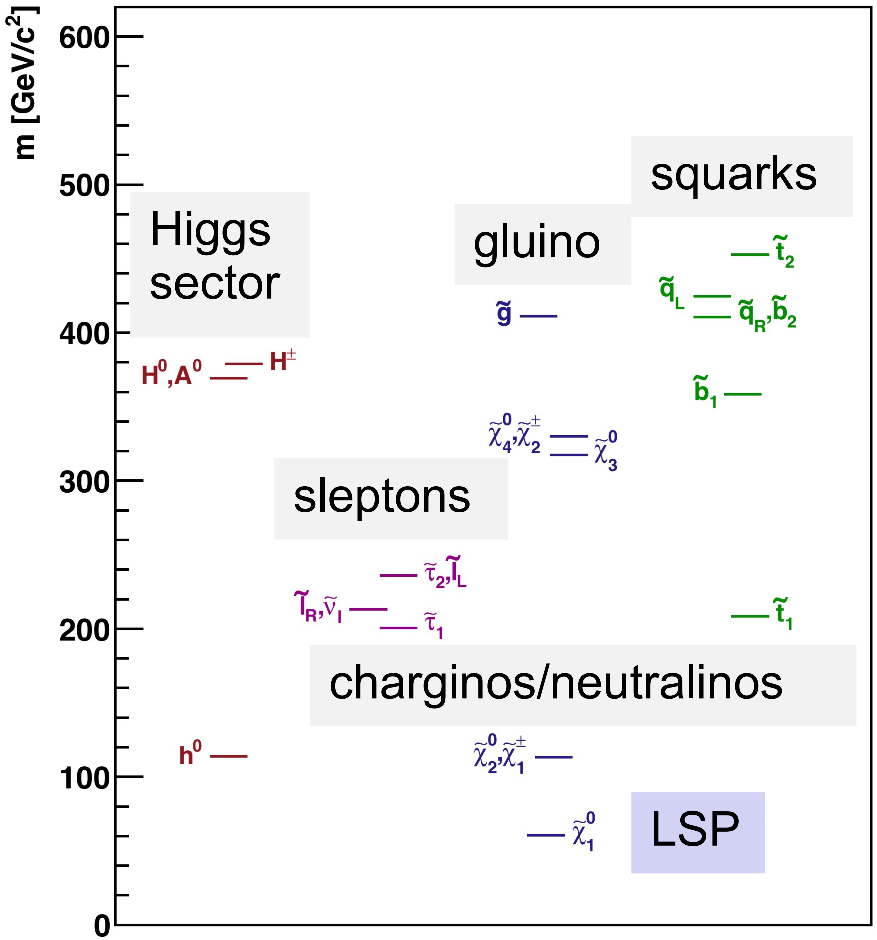


mSUGRA vs GMSB vs ...

- MSSM has > 100 parameters, need more constraints
- mSUGRA provides a convenient framework (4+1 free parameters) for assessing the discovery potential for R-conserving SUSY with χ^0_1 LSP
- Advantages:
  - Few parameters, most studied incarnations of the MSSM, not yet ruled out by data.
- Disadvantages:
  - Not fully representative of SUSY (e.g. fixed mass relation between Mgluino and MLSP)
  - Other SUSY breaking scenarios lead to different EW-scale phenomenology,
    - e.g. Gauge Mediated Susy Breaking with gravitino LSP and $\tilde{\tau}$ or χ^0_1 NLSP

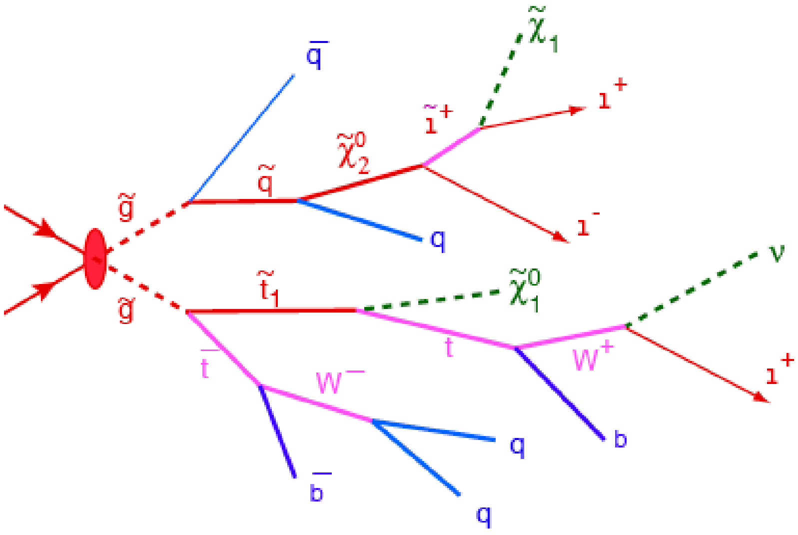
Benchmark points

- Choose a set of points representative of a range of topologies and areas of the phase space
  - mSUGRA
  - GMSB
  - Split Susy
- In this talk will often use a mSUGRA low mass point as benchmark (SU4/LM0)
  - $M_0=200$, $m_{1/2}=160$, $A_0=400$, $\tan(\beta)=10$, $\mathrm{sign}(\mu)=+1$
  - Just above Tevatron reach



Search strategy

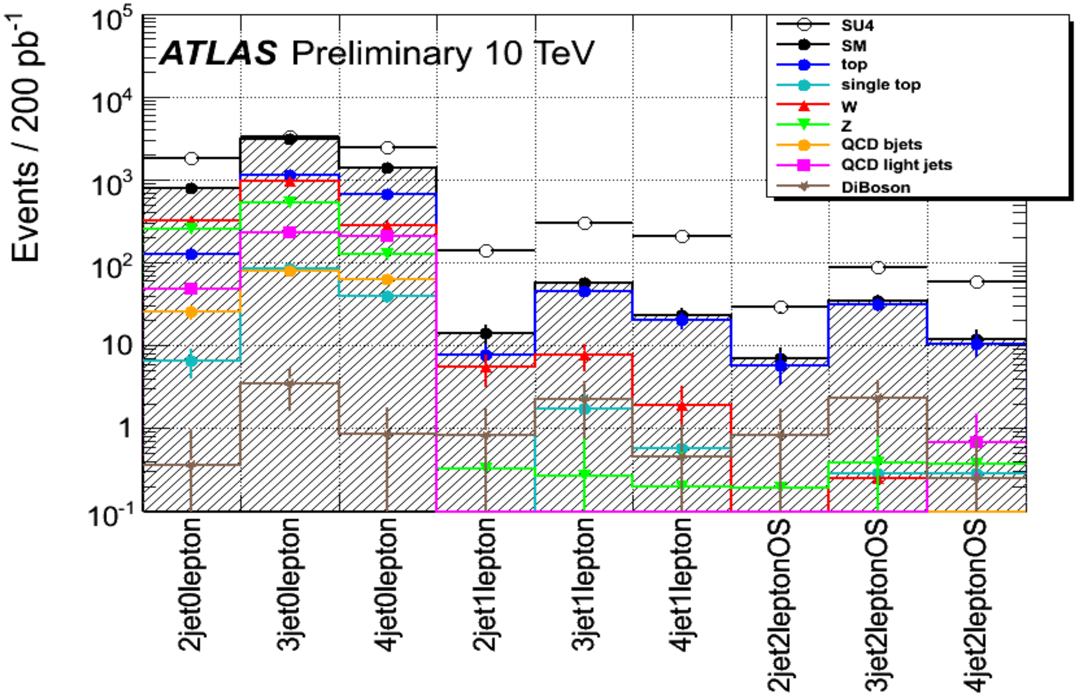
- This is a possible SUSY signature.
  - Production via strong interaction
    - Depends only on masses
  - Decay details do actually depend on the model
  - Once $\tilde{g}\tilde{g}$, $\tilde{g}\tilde{q}$, $\tilde{q}\tilde{q}$ are produced expect high pT jets and/or leptons (photons) from the chain and MET from the LSP.



- While designing a search, focus on robust and simple signatures
  - Common to a large variety of models
  - Let the SM backgrounds decide on the feasibility, not the models

Topologies

- *Categorise by final state*



Pre-selection Cuts:

- Jet ET > 100 (40) GeV
- $\Delta\Phi(\text{jet}_i,\text{MET}) > 0.2$ rad
- Lepton ET > 20 (10) GeV
- MET > 80 GeV
- Meff = ΣETjet + ΣETlep + MET
- MET > 0.2-0.3 x Meff
- MT > 100 GeV

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  - *Look in all the signatures*
  - *After loose preselection SU4 already provides a good S/B for most channels (@10TeV) if you believe in the MC*

Key is measuring SM backgrounds from data

All hadronic signatures

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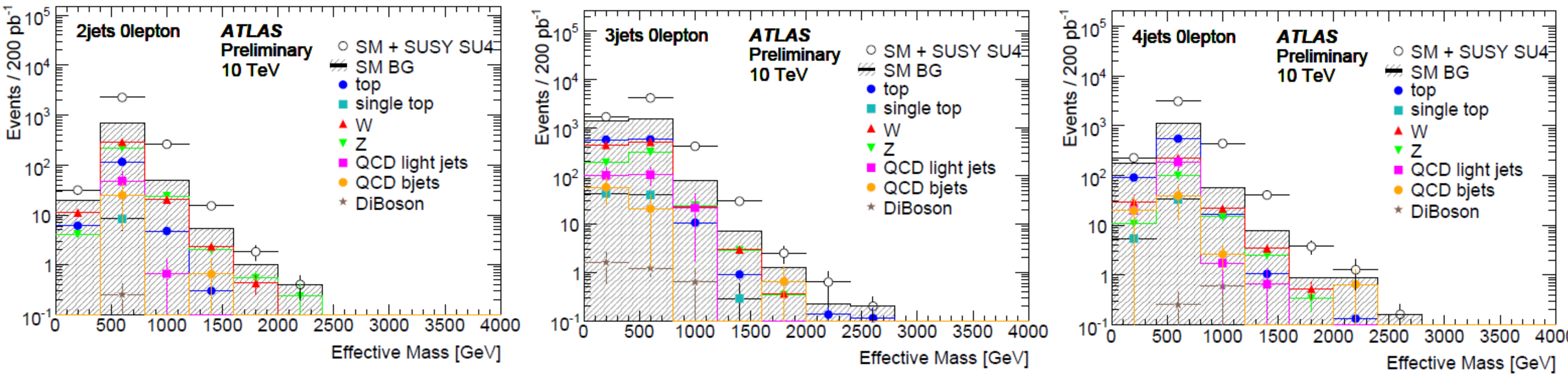
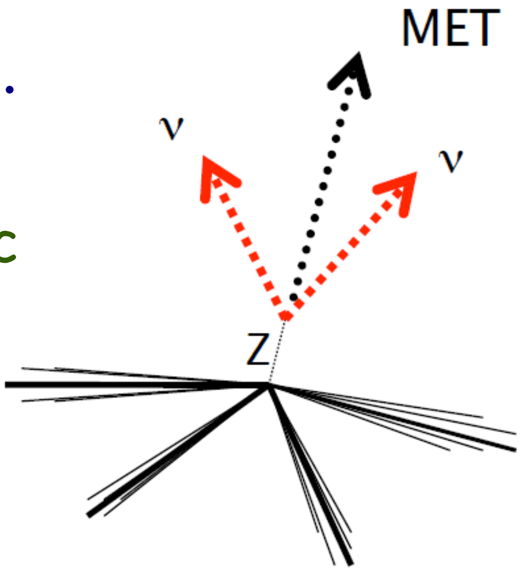
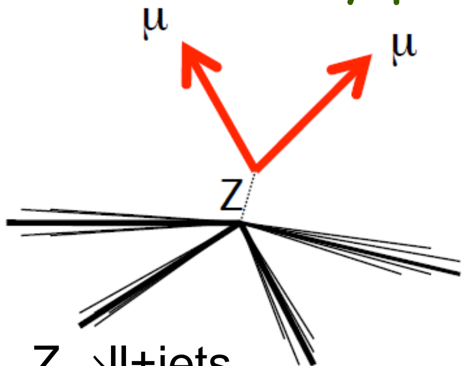


- SU4 clearly visible in all the jet multiplicities. “Just” have to:
  - Understand half a dozen SM backgrounds
  - Understand the detector and beam related effects
  - *All of the above in a data driven way. Piece of cake.*
- This signature, albeit very challenging, is very generic. BSM has to show-up (also) in this channel.

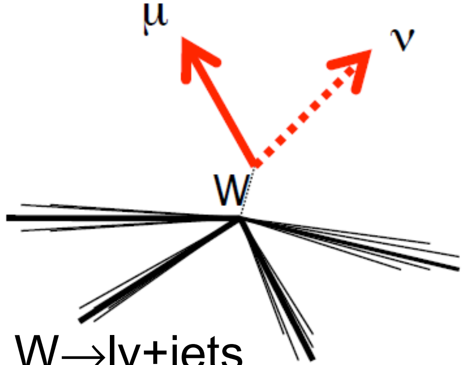
All hadronic background estimate

- Data driven background estimates. An example. $Z \to \nu\nu$+jets
  - Irreducible background for the fully hadronic searches, at any jet multiplicity.
  - Use similar signatures to estimate in SM dominated regions and project in search region.
  - Many possible approaches.

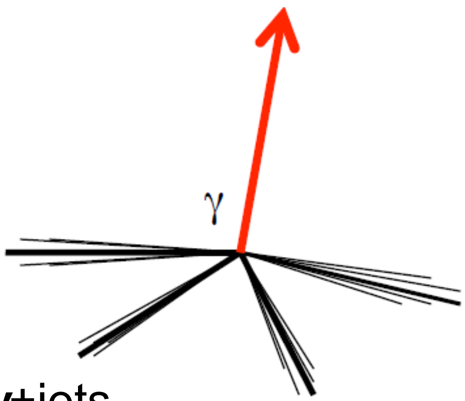




$Z \to ll$+jets
Pros: Clean and direct
Cons: Low statistics



$W \to l\nu$+jets
Pros: Larger stat
Cons: backgrounds from SM and BSM

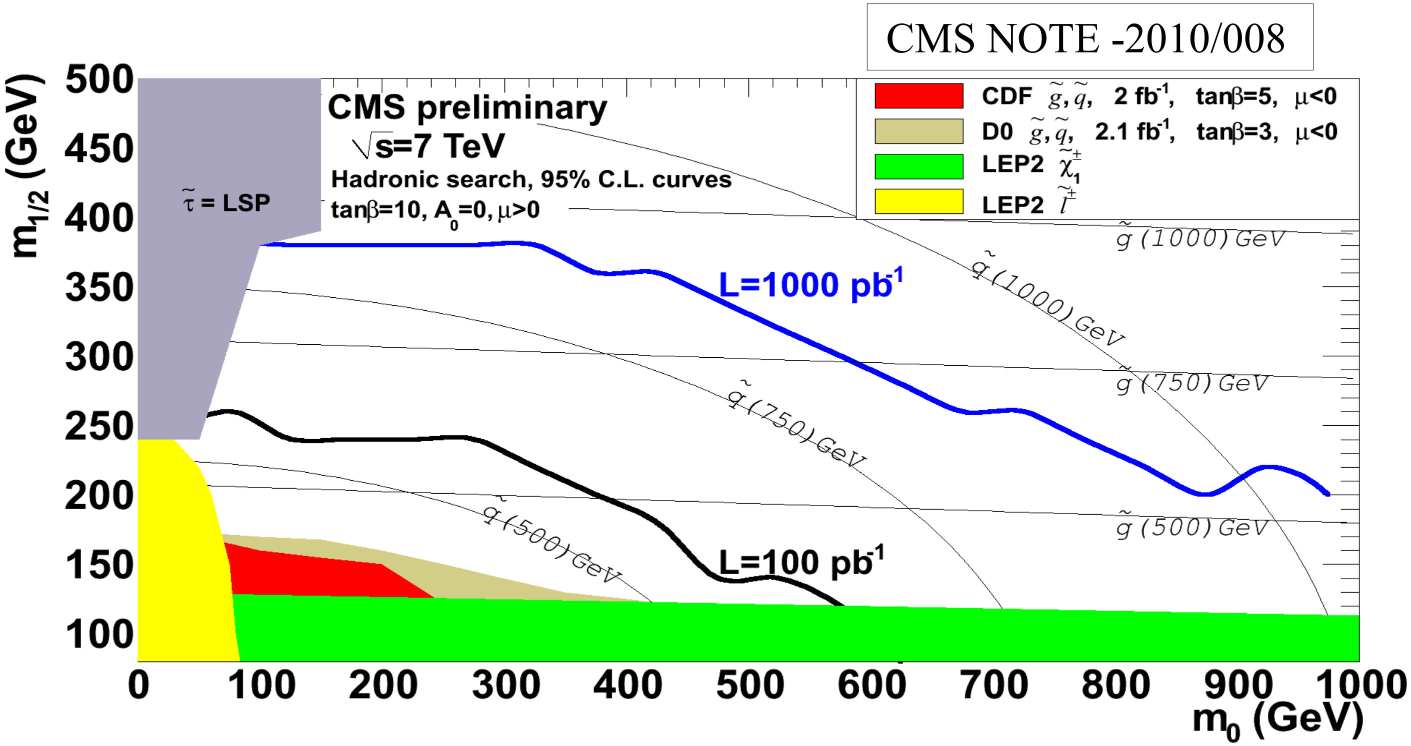


γ+jets
Pros: large stat, clean at high E_T
Cons: backgrounds at low E_T, theoretical error

Will pursue them all. Redundancy is good.

CMS PAS SUS-08-002

All hadronic sensitivity



- CMS sensitivity to fully hadronic final states in the m_0-$m_{1/2}$ plane extends far beyond the current limits from Tevatron with ~100pb^{-1} @7TeV
  - Assumed a 50% systematics uncertainty on the backgrounds
- **NB: These and all the sensitivity curves in this talk are based on reasonable, conservative, but still MC, estimates for the background uncertainties.**

Single-leptonic signatures

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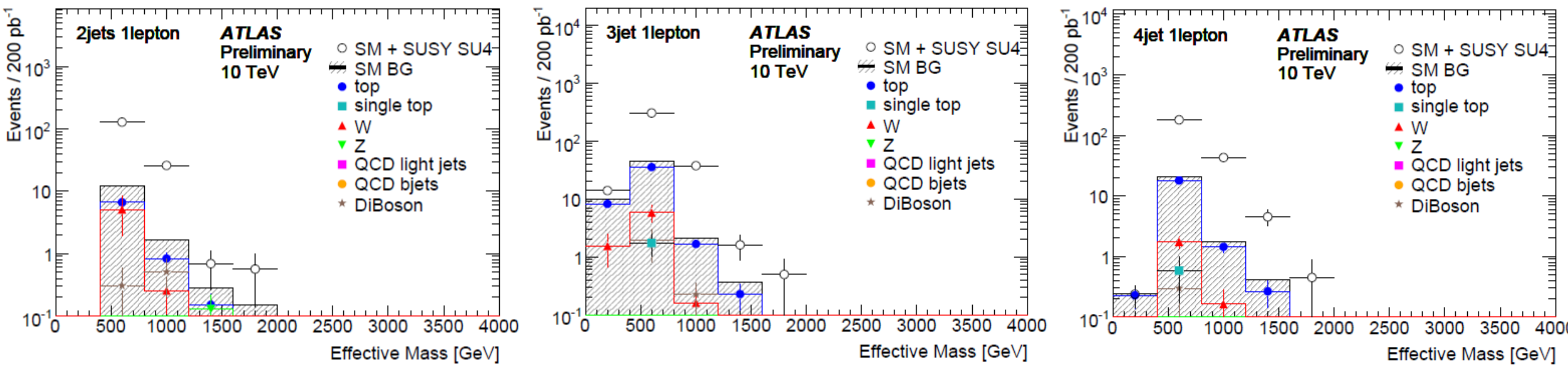

- Lepton requirement suppresses QCD
- Top/W dominant backgrounds (->real MET and lepton)
- Again. SU4 clearly visible in all the jet multiplicities
  - According to MC...

Single-leptonic background estimate

- Background estimates on data (or data+MC):
  - Matrix method
    - 2 discriminating/uncorrelated variables, e.g. M_T and MET
    - Pros: Fully data driven
    - Cons: Assumes vanishing correlation, overestimate background when signal contaminates the control regions
  - Tile method.
    - Uses 2 discriminating variables with background shapes from MC to get the SM tile fractions $f_A^{SM}, \ldots, f_D^{SM}$
    - Assume independence of variables for signal, no request on background
    - Solve/fit for the number of SM and signal events in every tile
    - Not sensitive to signal contamination

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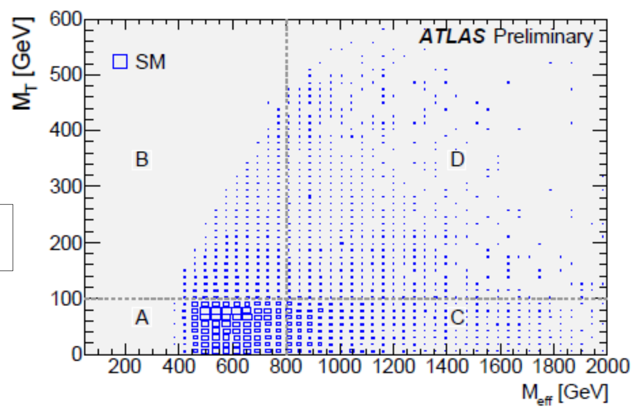
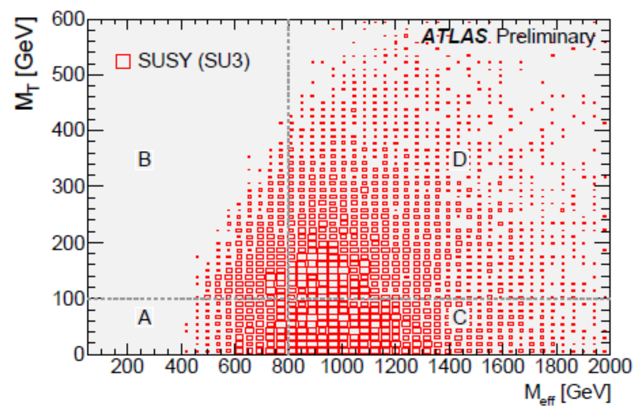
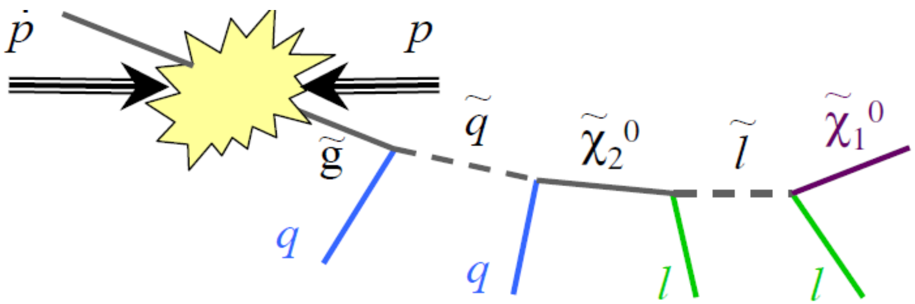




Double-leptonic signatures

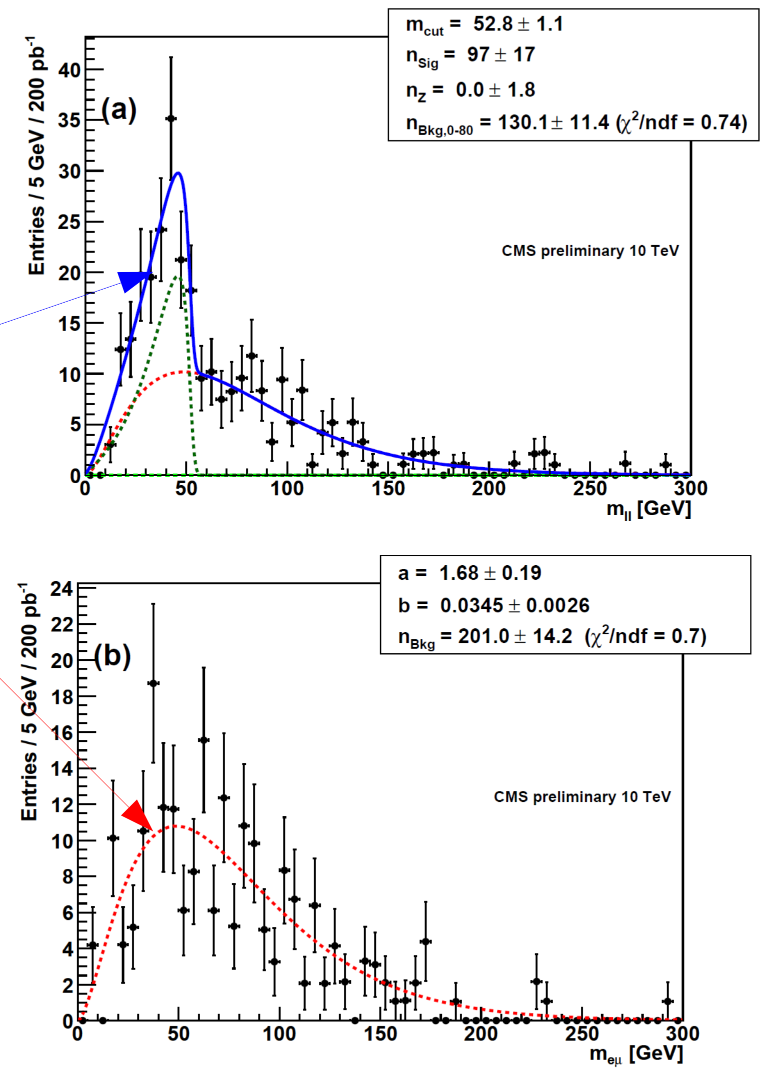


- Low yield, clean samples.
- Same Flavour, Opposite Sign:
  - Use opposite flavour samples to estimate the SM background.
    - Simultaneous fit to SF and OF invariant mass distributions
  - LM0 discovery w/ 200pb^{-1} (@10TeV)
  - Mass edge resolved w/ <5% uncertainty.

$$(m_{ll}^{max})^2 = \frac{\left(m^2_{\tilde{\chi}_2^0} - m^2_{\tilde{l}}\right)\left(m^2_{\tilde{l}} - m^2_{\tilde{\chi}_1^0}\right)}{m^2_{\tilde{l}}}$$

- 2/3 body decay not distinguishable

CMS PAS SUS-09-002



Discovery + characterization

Leptonic sensitivity

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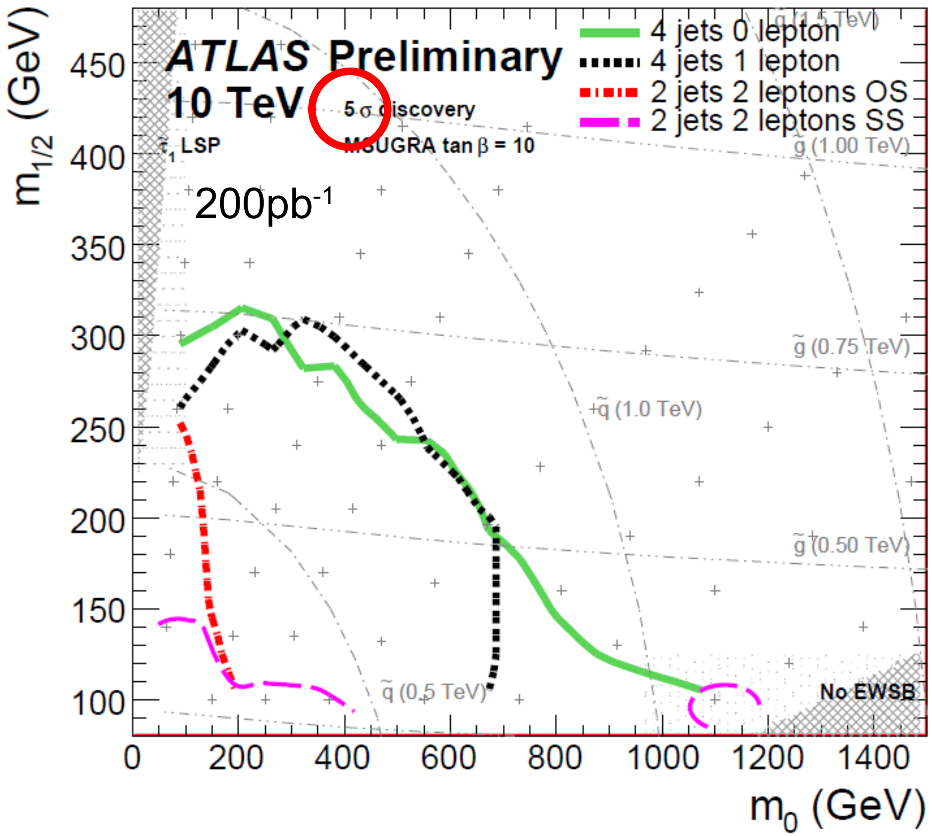
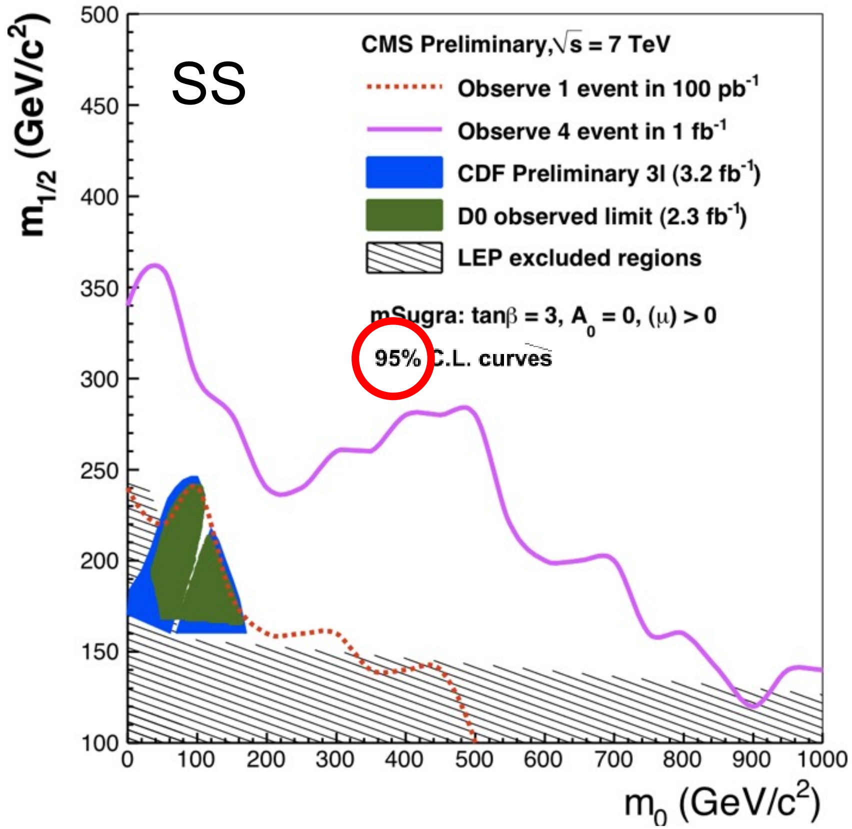


CMS NOTE -2010/008



- Match the Tevatron sensitivity with O(100) pb^{-1}
  - 50% systematic uncertainty assigned to the SM background

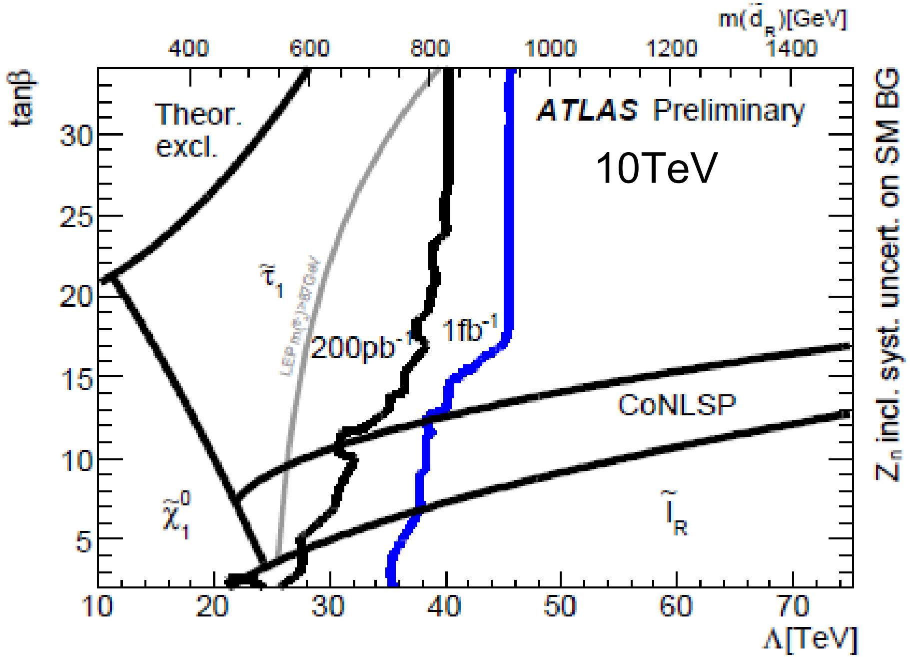
GMSB with τ

- In the simplest versions of GMSB, the spectrum and other observables depend on just a handful of parameters:
  - M_m; N_5; Λ ; tan(β); sign(μ); C_{grav};
- R-parity → LSP ($\tilde{G}$) is stable. The identity of the NLSP determines the phenomenology

1) Neutralino: prompt or displaced photons

2) Stau: cascade decays of $\tilde{q}$ and $\tilde{g}$ -> highly energetic jets, many τ leptons, and MET due to the escaping $\tilde{G}$.

Selection Cuts:
- 2 Jet ET > 100 (50) GeV
- ΔΦ(jeti,MET) > 0.2 rad
- 2 Hadronic τ ET > 20 GeV
- MET > 280 GeV



$M_m = 250$ TeV, $N_5 = 3$, sgn$\mu = +$ and $C_{grav} = 1$

ATL-PHYS-PROC-2010-013

Before conclusions

- On June 4th, ATLAS and CMS held a meeting on "Characterization of New Physics at the LHC", also know as the "inverse problem".
- In words:

  "The first physics beyond SM to be discovered at LHC will be SUSY, whether it is SUSY or not."

  Anonymous (but wise)

Before conclusions

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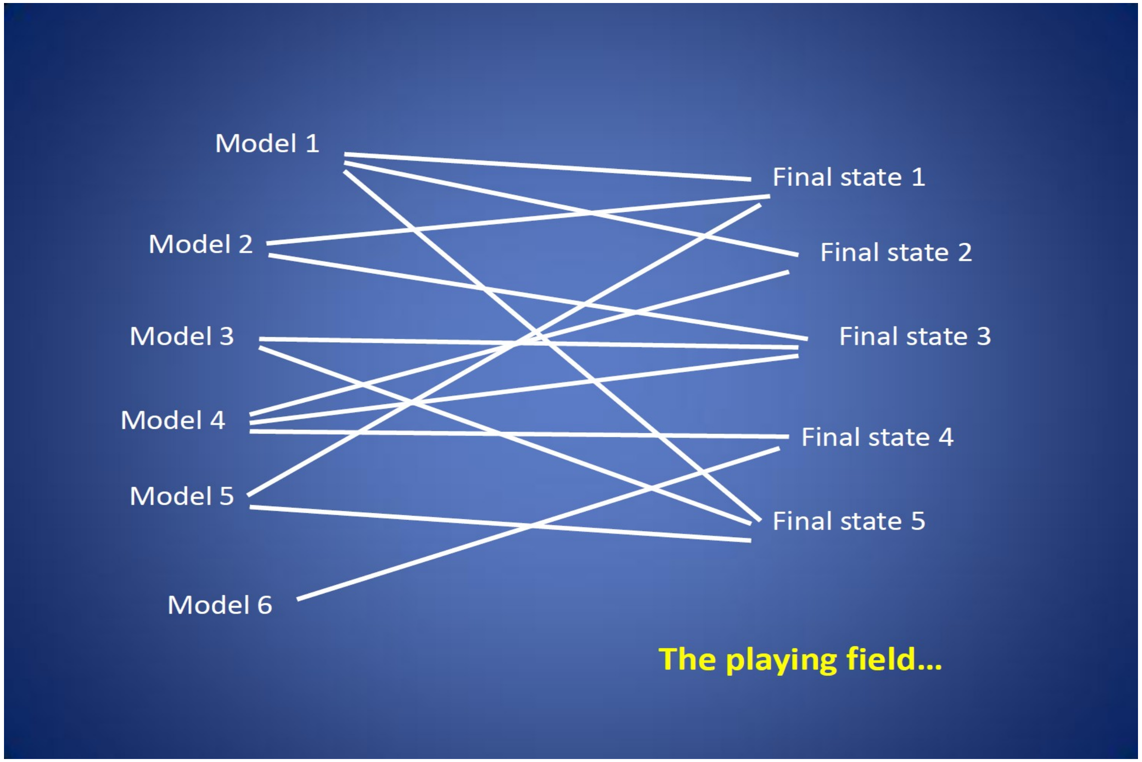
- In pictures:



Paul de Jong

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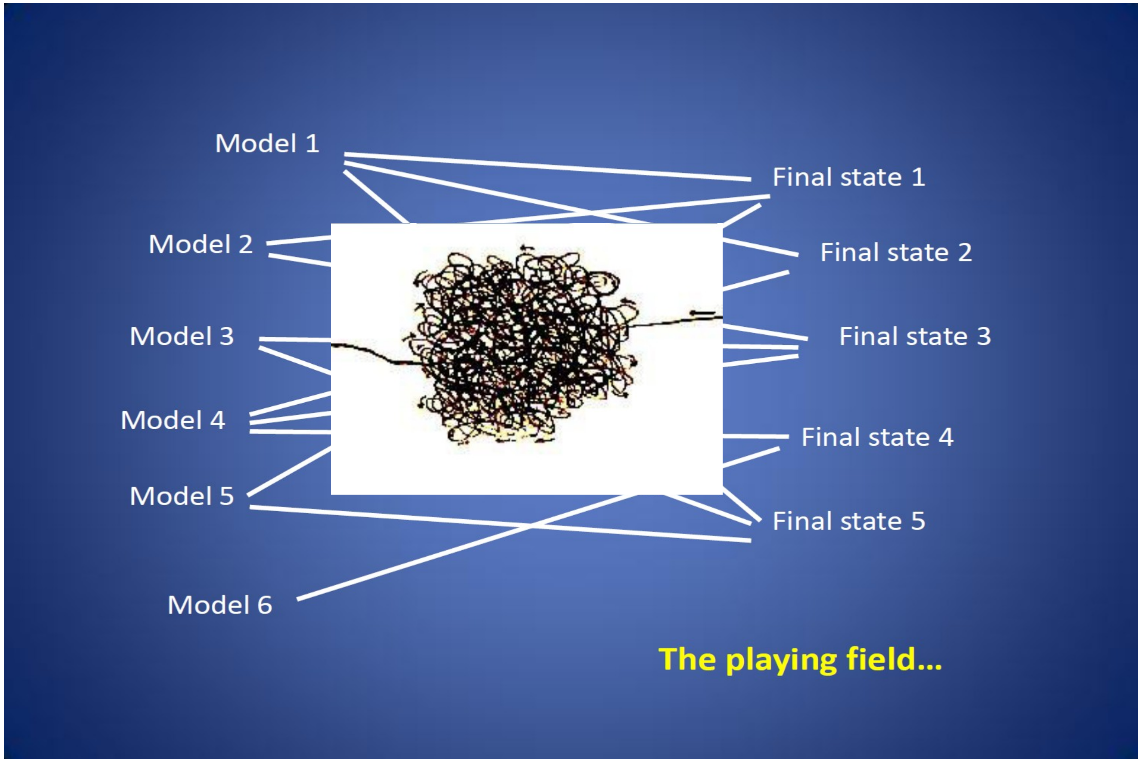

Paul de Jong

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SS searches

# jets	Models	2 l		3 l		4l	
		0 MEt	MEt	0 MEt	MEt	0 MEt	Met
0	LRSM, model independent, 331, SU(15)	X		X		X	
2	SUSY, LRSM, Majorana neutrinos, right handed VB	X	X				
4	SUSY SO(10), right handed VB, Neutrinos & charged leptons from 4th gen & E6GUT, possibly Higgs	X				X	
6	Little Higgs, 4th generation, new fermion production		X				
>2/3	4th generation	X	X	X	X		

Paul de Jong

Before conclusions

Paul de Jong (Nikhef)
On behalf of ATLAS

- **Maximizing the information contents of our papers**

- **Characterizing excesses**

In the model-based approach we would try and quantify how well a model fits, and with what parameters. E.g. SUSY fitters.

In a bottom-up approach we would focus on feature extraction
→What characteristic items are we seeing in our data
ATLAS studies: di-lepton mass edges, lepton-jet edges
what can we say about particle spins
stransverse mass, con-transverse mass

A further idea for bottom-up approaches: look at topologies
What are the characteristic topologies we are seeing in our data?
Can we identify general decay modes, decay chains?

Before conclusions

Joe Incandela
UC Santa Barbara
On behalf of CMS

If we see evidence of New Physics it will probably not have a unique interpretation.

Theorists have spent years asking what is beyond the SM

- They're interested in how results will be communicated to them.
- Experimentalists will need some guidance if the signals are rich
  - How shall we communicate what we see?
    - Across experiments? With theorists ?

An example of a possible joint effort

- ATLAS and CMS search groups and theorists
  - Theorists provide benchmark topologies ("Topology sets")
    - Model-inspired but more general

Summary

- It could be useful to form a joint effort of ATLAS, CMS and Theorists to characterize new physics in LHC data
  - A simplified model spectra approach solves many of the problems/constraints faced by experimentalists and is very attractive as an addition to interpreting data in the context of complicated parameter spaces.

Before conclusions

- There will be another workshop in November. Stay tuned

Summary

- ATLAS and CMS will enter into new territory with as little as 100 pb^{-1} for many SUSY searches
- Key element to sensitivity is background estimation via data driven approaches
- Sensitive to a wide variety of models
  - So wide that we will not be able to discriminate among them
- Luxury question: how to characterize new physics?
- No unique answer, bottom-up AND top-down, … we keep thinking

Summary

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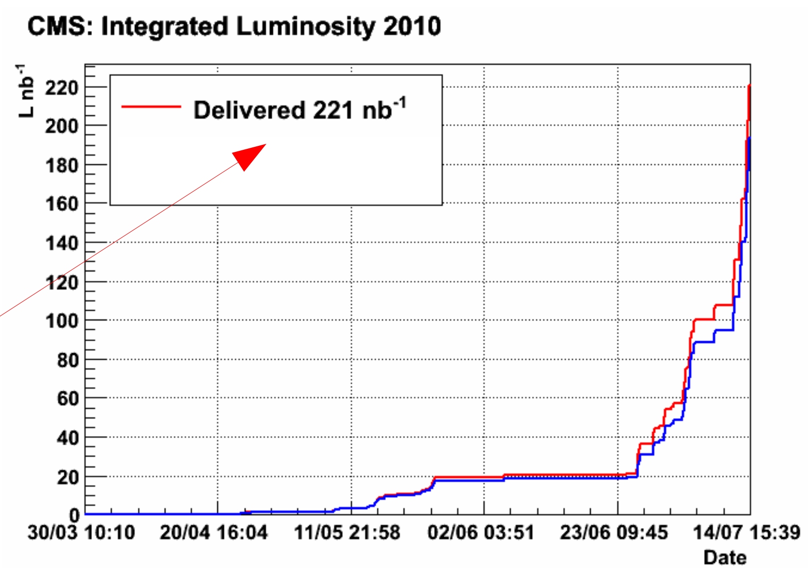
- Luxury question: how to characterize new physics?
- No unique answer, bottom-up AND top-down, … we keep thinking
- In the meanwhile: data are coming. We are almost there, just other 3 orders of magnitude



Backup

Sensitivity vs √s

- The loss of sensitivity from 10TeV to 7TeV can be recovered by increasing the luminosity by ~3