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SCHOOL ON PHYSICS AT LHC: "EXPECTING LHC"
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Supersymmetry at LHC
Part II
(Inclusive Searches)

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These are preliminary lecture notes, intended only for distribution to participants.

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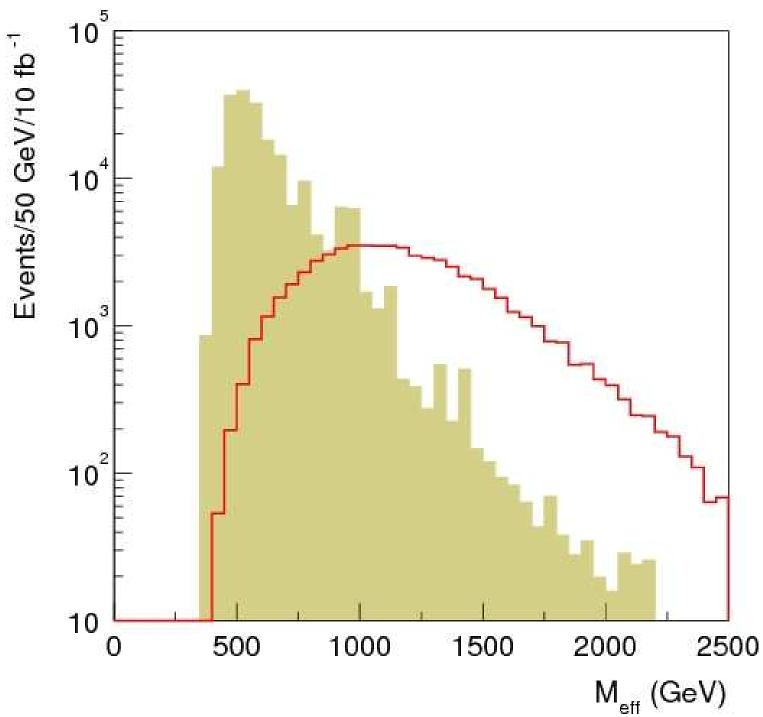
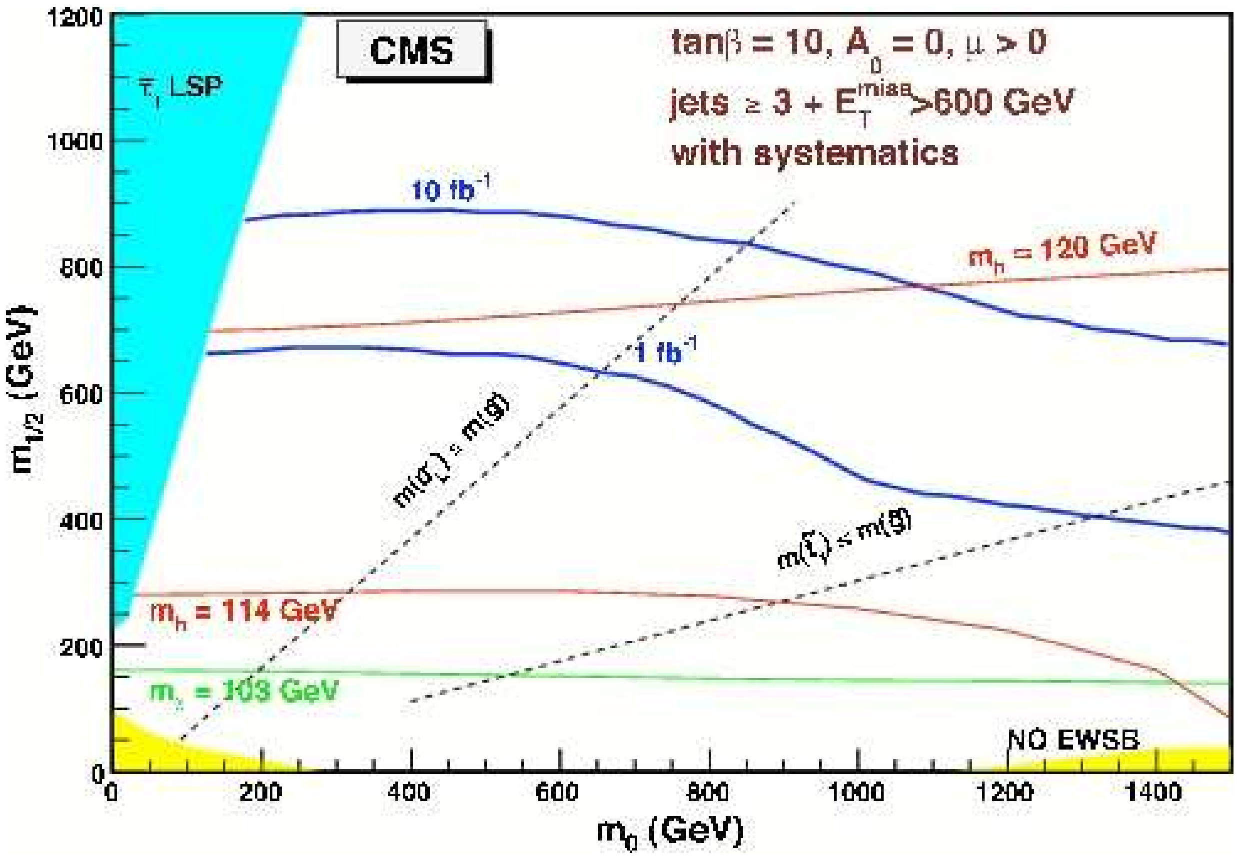
Inclusive searches

- At least 4 jets and etmiss
- $M_{eff} = pt_1 + pt_2 + pt_3 + pt_4 + \text{etmiss}$
- Peak correlates somewhat to mass of gluino/squark
- Very large rates
- More on background estimates later. Must measure and understand them before any discovery

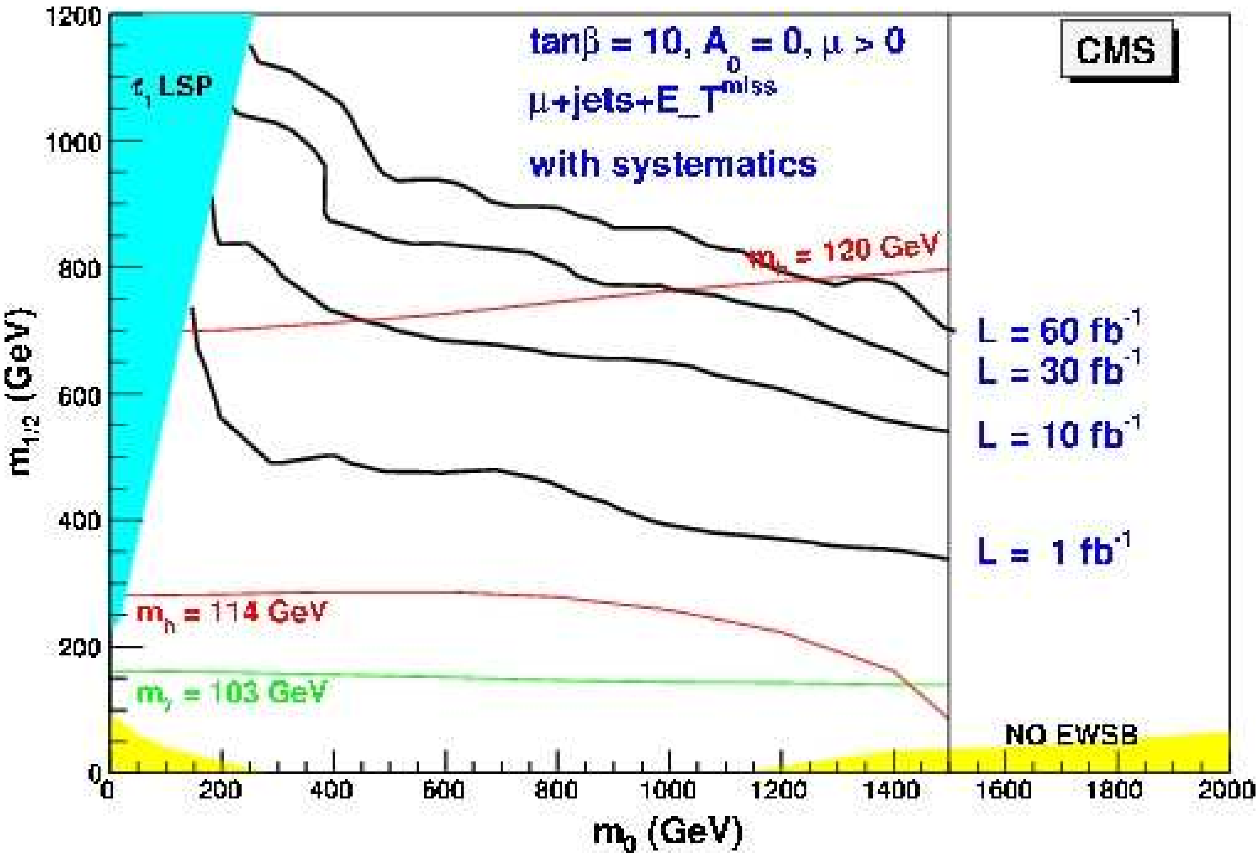


Mass reach



Energy is more important than luminosity

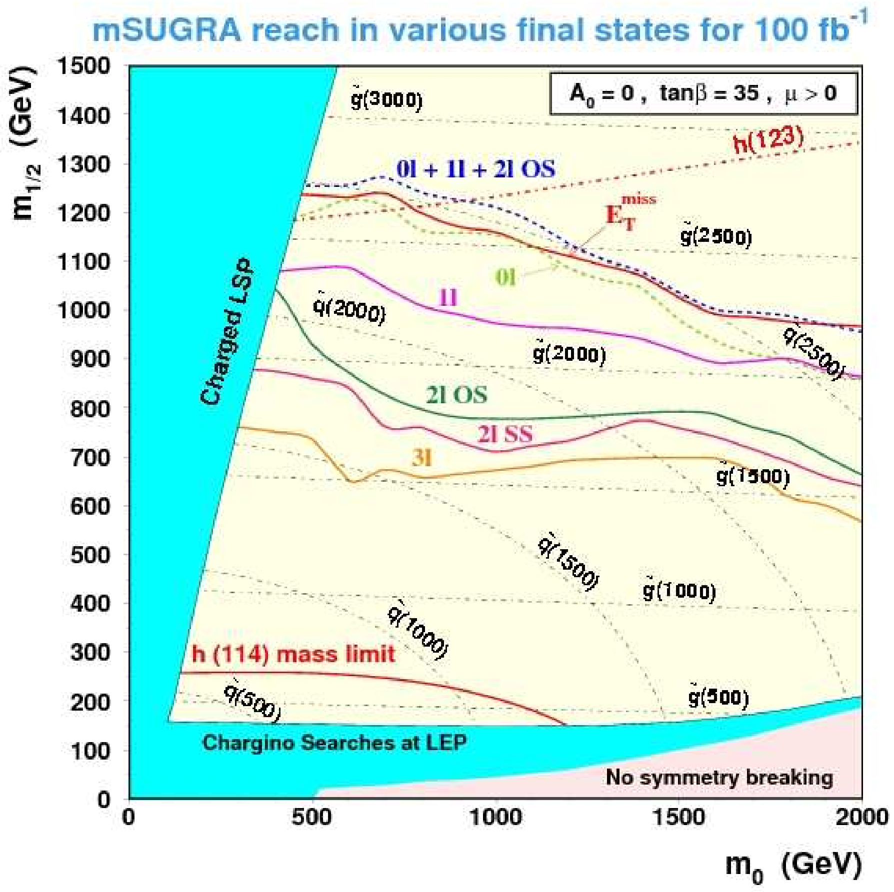
Mass reach



Jets plus muons

Mass reach

Reach increases slowly with luminosity



A very clean final state

- Gluinos are majorana particles

$$\tilde{g}\tilde{g} \rightarrow q\bar{q}\tilde{\chi}^{+} q\bar{q}\tilde{\chi}^{-}$$

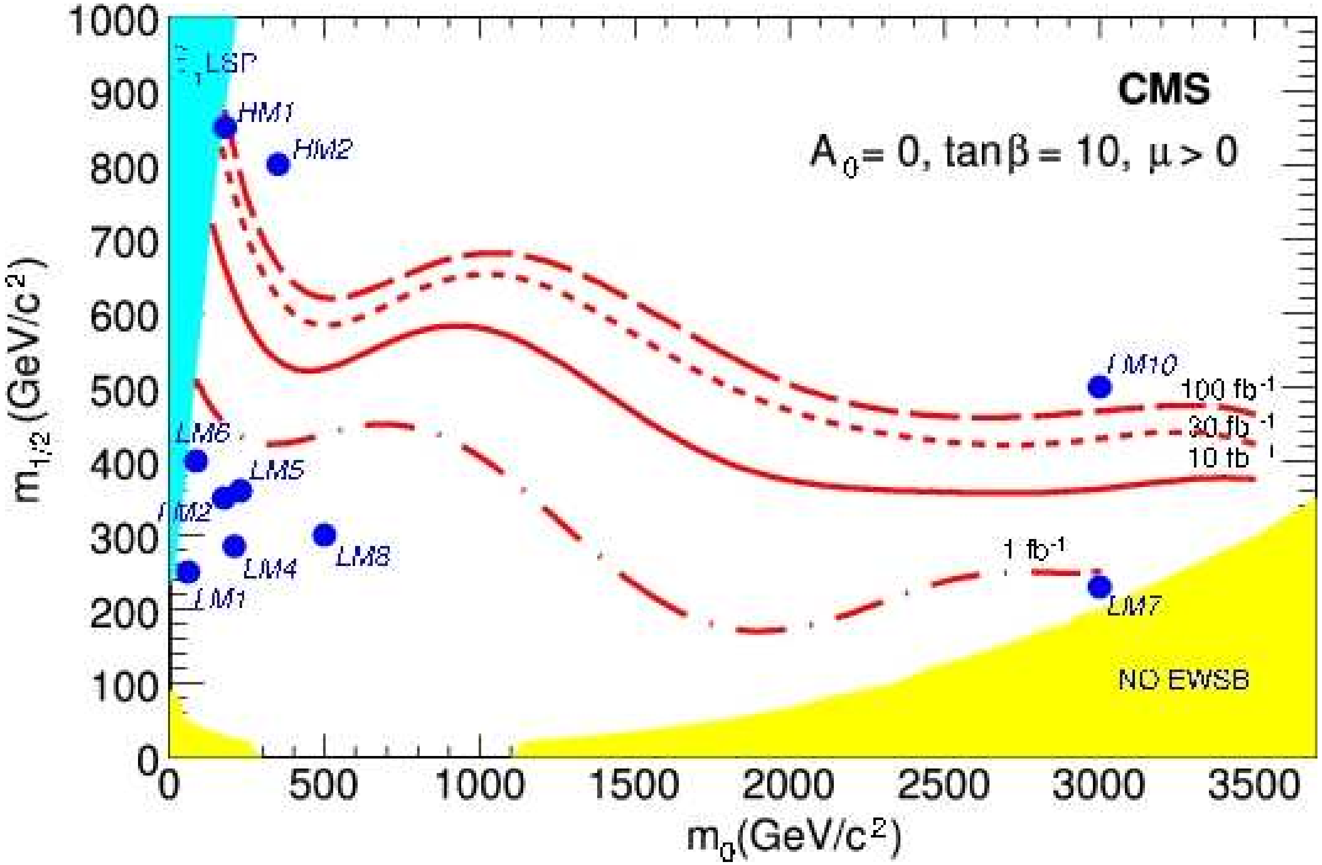
AND

$$\tilde{g}\tilde{g} \rightarrow q\bar{q}\tilde{\chi}^{+} q\bar{q}\tilde{\chi}^{+} \qquad \tilde{\chi}^{+} \rightarrow \ell^{+}\nu\tilde{\chi}_{1}^{0}$$

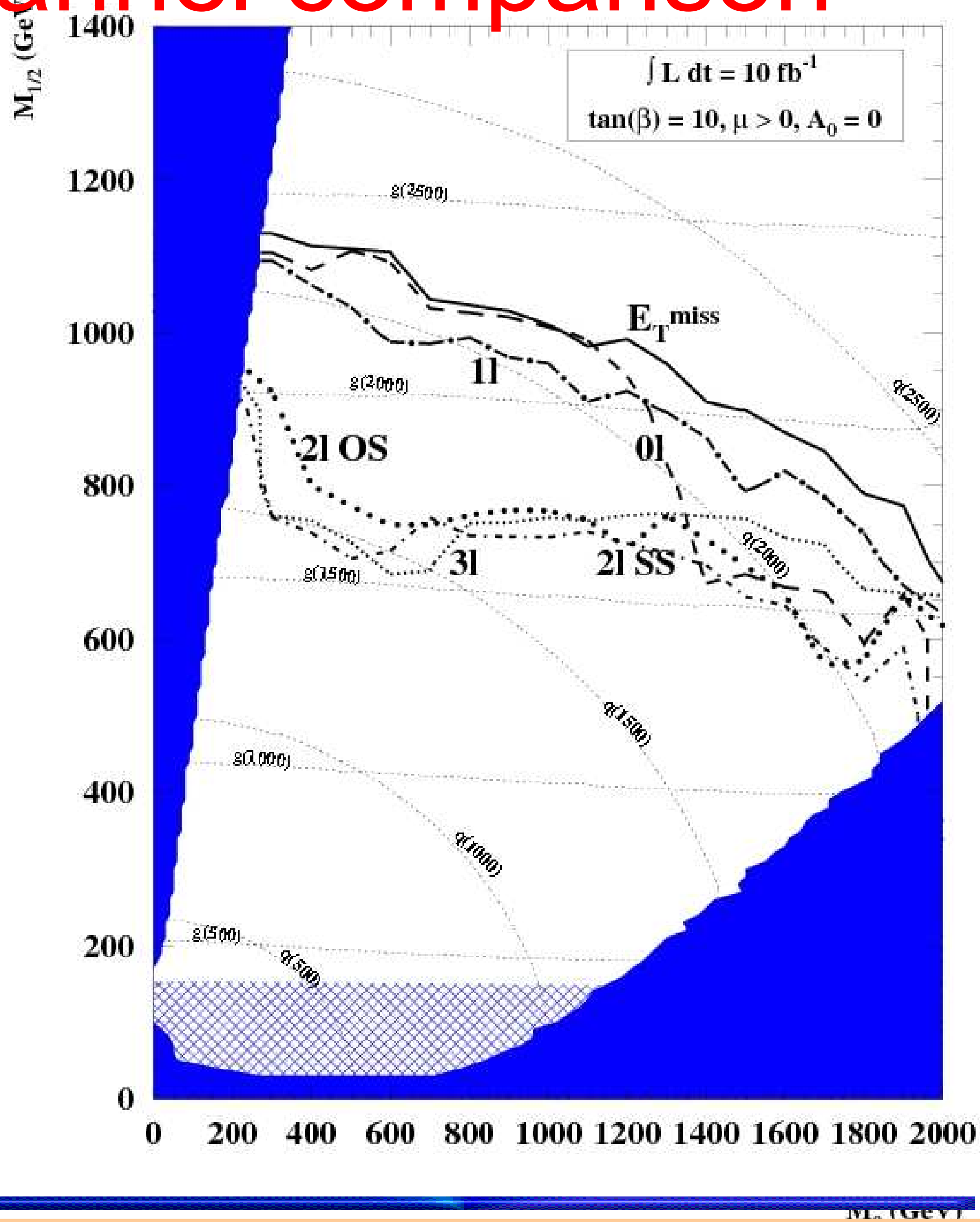
Dominant background sources of isolated lepton pairs give only opposite sign

$$t\bar{t} \rightarrow W^{+}W^{-}b\bar{b}$$

Same sign muons



Mass reach: channel comparison



Can also require one or more leptons

May be more robust

Digression on simulations

- Varying degrees of sophistication
- Run an event generator: Makes a list of particles ({\it e.g} Pythia) THEN
- ``Full simulation''
- Full material description of detector
- Track particle: model its interactions, follow all the secondaries with energy above some threshold
- Translate ``hits'' into simulated electronic signals
- Now event looks like a real event: reconstruct it using same software
- Advantage: Full description
- Disadvantage: Slow (~15 mins per event), can only be done by large team
- Varying degrees of sophistication
- Low energy hadronic interactions, geometry is hard

Digression on simulations

- ``Fast simulation (theorists version)"
- Assume perfect detector: Apply jet finding algorithm
- Smear, electron, muon, jet momenta and missing ET. using some resolution function
- Advantage. Very fast (comparable to generation time), can by done by one or two people
- Disadvantage: Only as good as resolution function: problems in ``tails"

Digression on simulations

- ``Fast simulation (experimenters version)"
- Response of individual particles is parametrized.
- Might use ``full'' for some particles (Photons) and parametrized for others (pions)
- May use full reconstruction.
- Needs a small team
- In practice all are used: Theorists version is often good enough for evaluating a model

Input to simulation

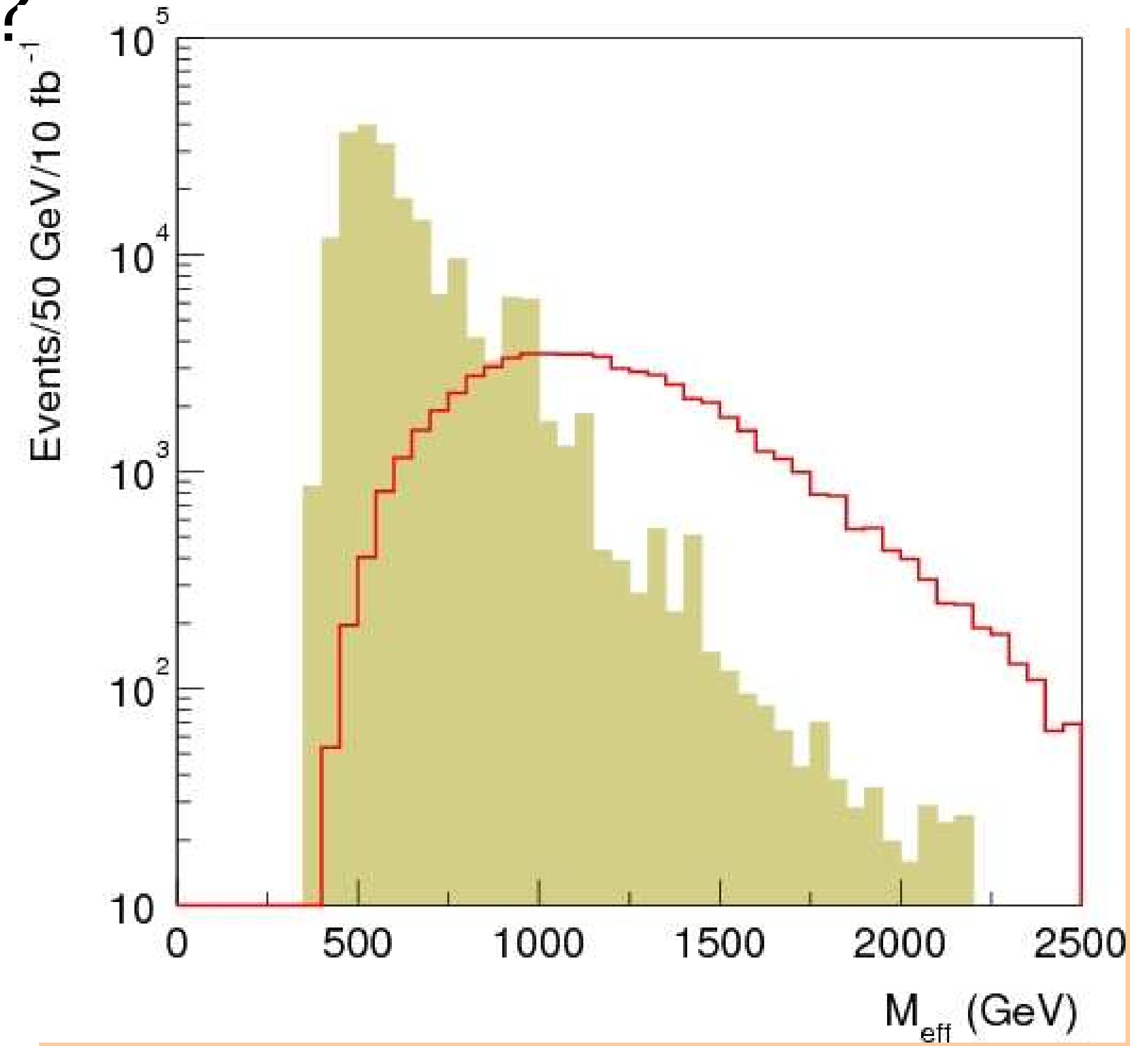
- Monte Carlo generators are needed
- It is now easy to add a new model to an existing event generator by conforming making input files containing vectors in a simple well defined format. "Les Houches format"
- If you are a theorist with a new model that you care about you can do this via a publication.
- Others can then use your model and reference you.
- There is little motivation to implement someone else's model

Background isses

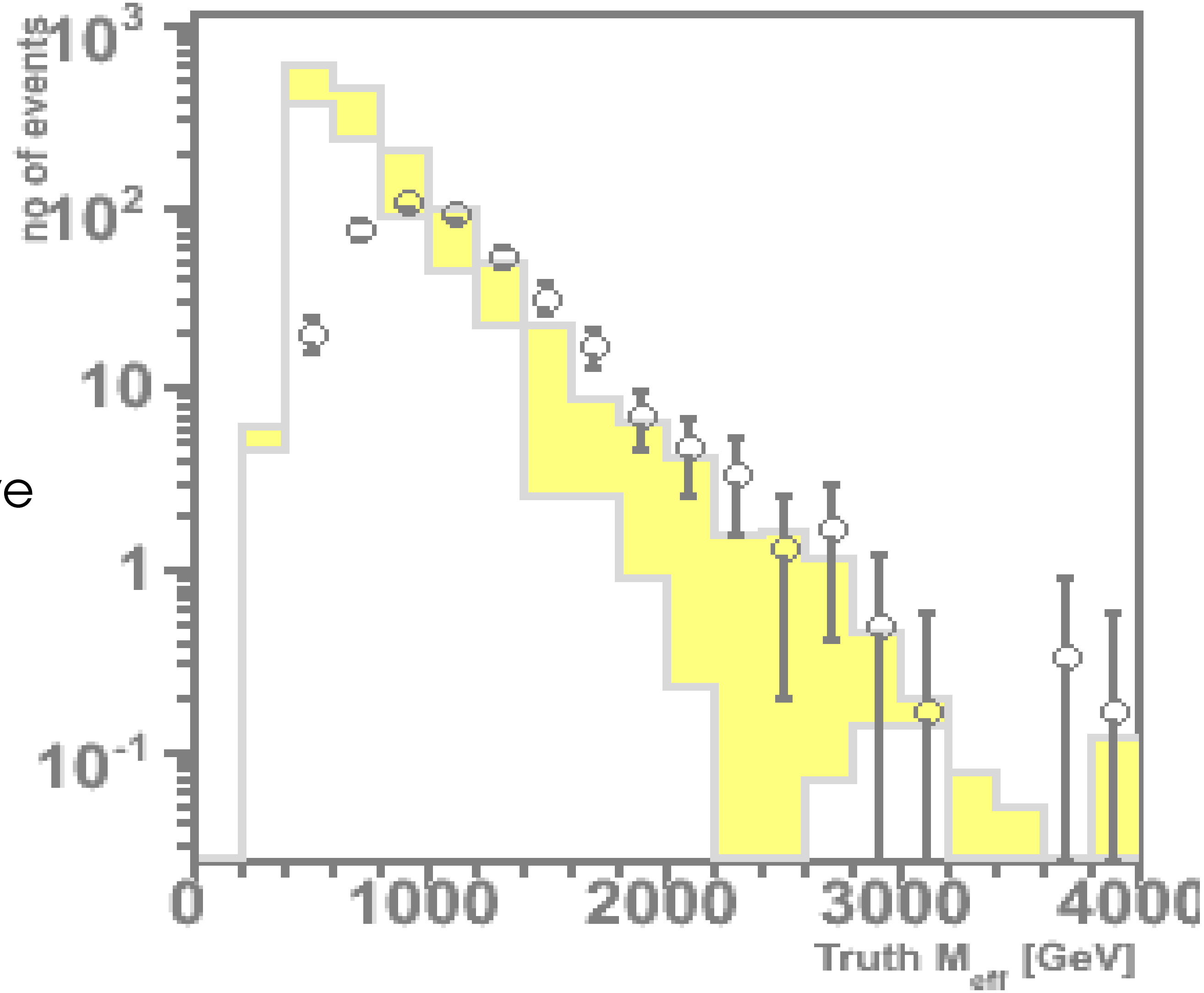
- Need to "rediscover the standard model" before claiming new things
- Some processes W and top are well understood at Tevatron and we expect no surprises at LHC
- For a new signal, determine the most important background sources and calibrate them in regions where there is no signal.

Inclusive SUSY

- This looked good?

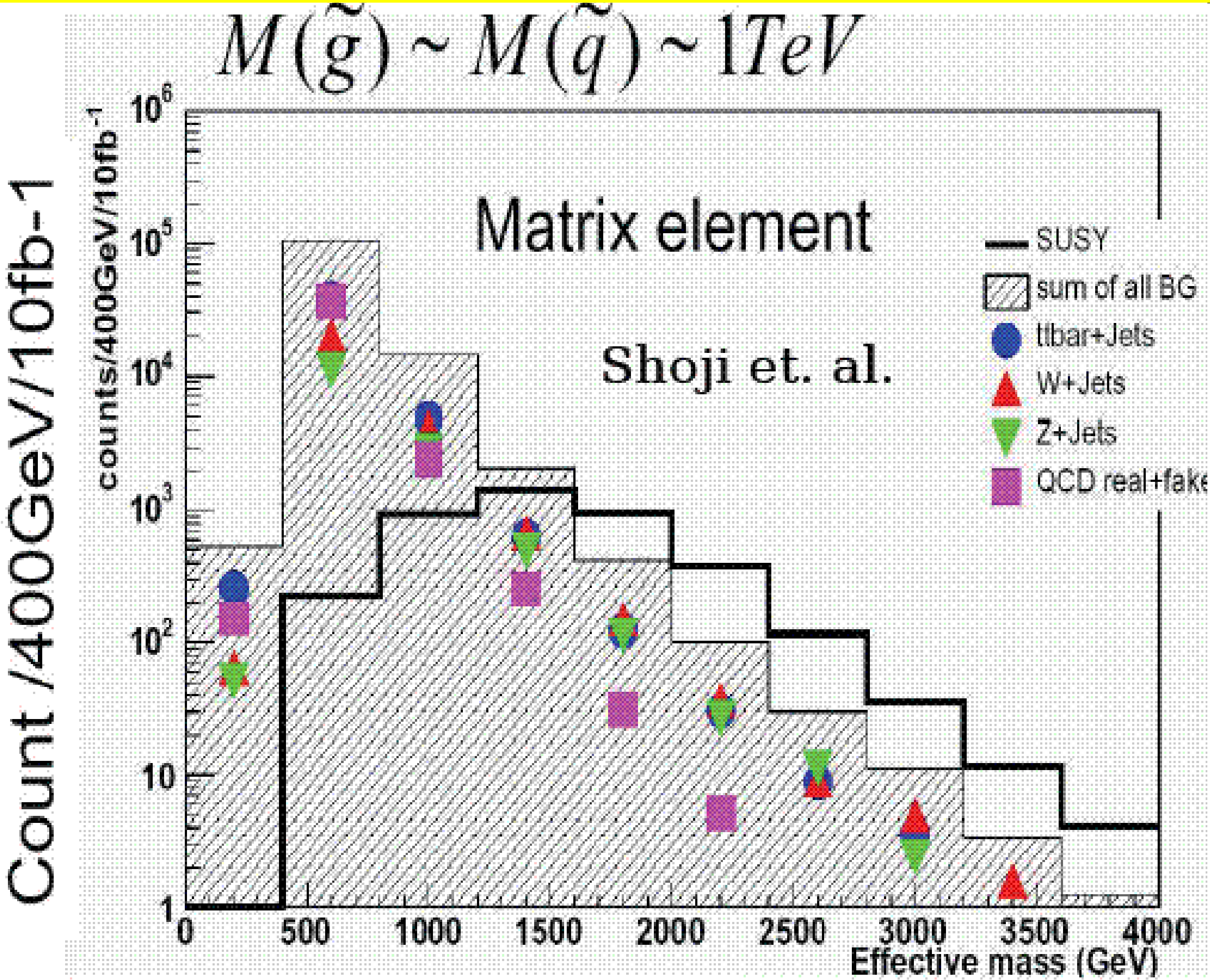


Inclusive SUSY



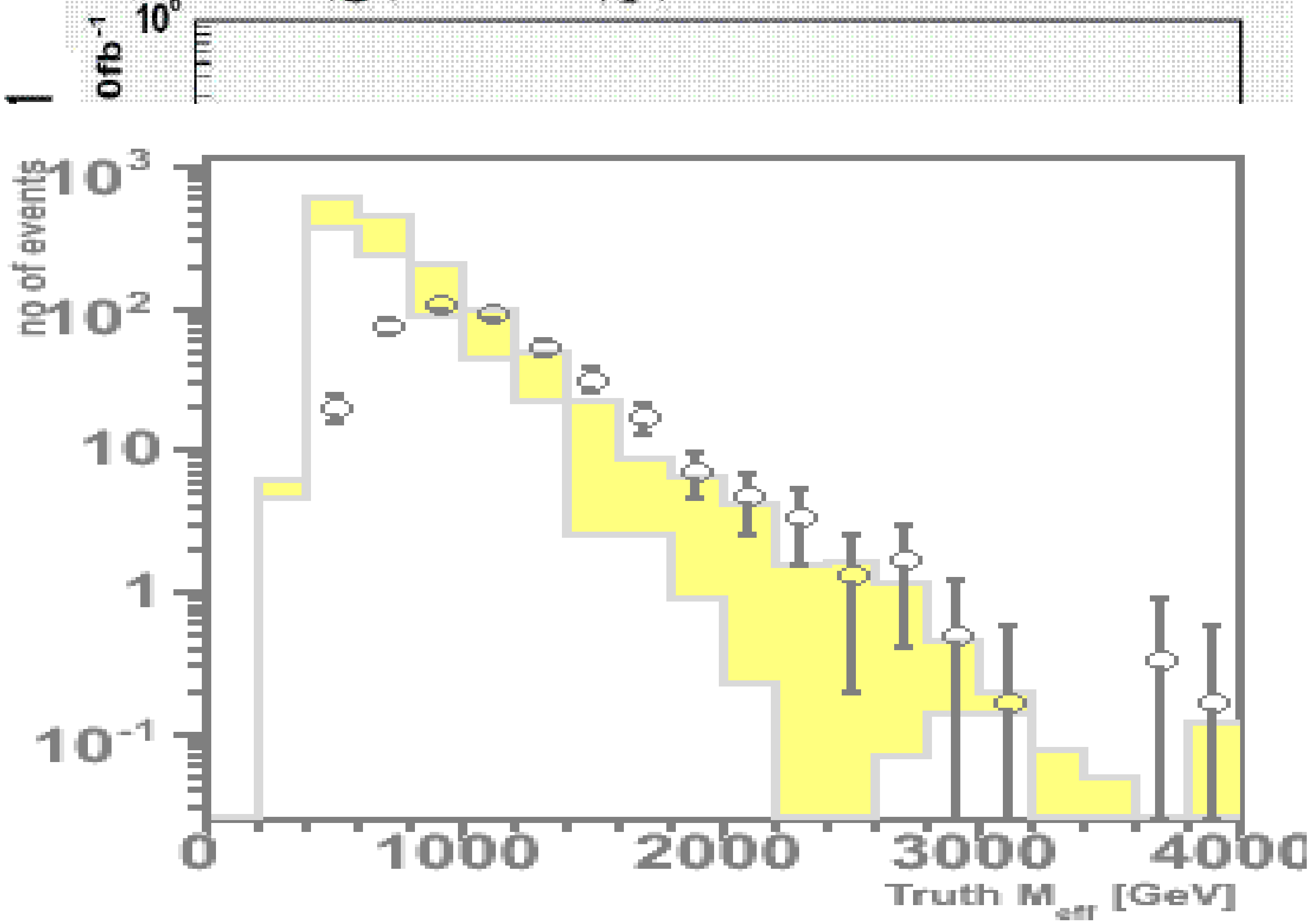
Would you believe this?

Another estimate from Alpgen



Comments on background

$$M(\tilde{g}) \sim M(\tilde{q}) \sim 1TeV$$



Should we worry about this?

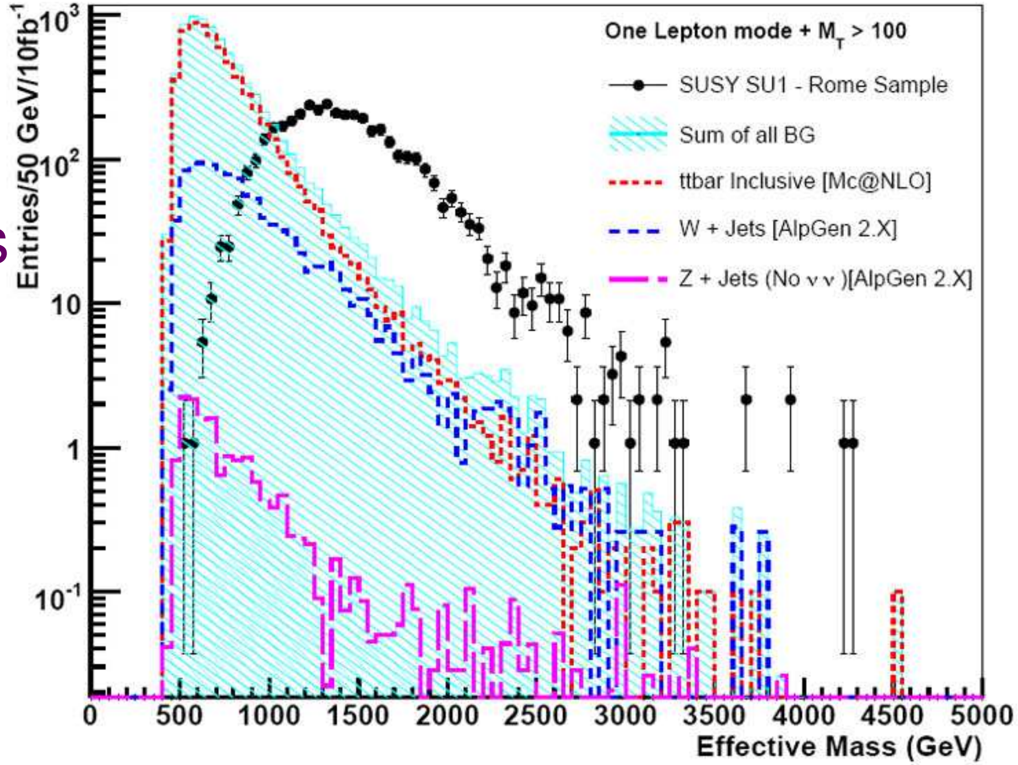
- Yes, if you claim to understand QCD: there are factors of 10 here!
- Yes, if you keep looking at the same variable
- No, if you remember that you have many variables
- Now: few physicists, no data, infininte candidate models
- Soon: much data, many physicsts, few viable models

Comments on SUSY backgrounds

- Final state is complex
- Background has many components
- Some are hard to calculate
- Previous page shows two versions of Pythia!!
- Don't panic: Many quantities to measure

Need better control of background

- Try adding a lepton.
- S/B Better. Why?
- Look at the components
- Example has Susy masses ~700 GeV



Calculating Backgrounds

- This means modeling QCD properly
- Inclusive processes such as W and H rates are well calculated to NNLO and reliably predicted. Uncertainties from structure functions can be be quantified.
- Process with several scales are harder. B cross section at LHC where $s \gg m^2_b$
- Hardest are final states with large numbers of jets. Unfortunately this is what we care about for new physics

Measuring Backgrounds

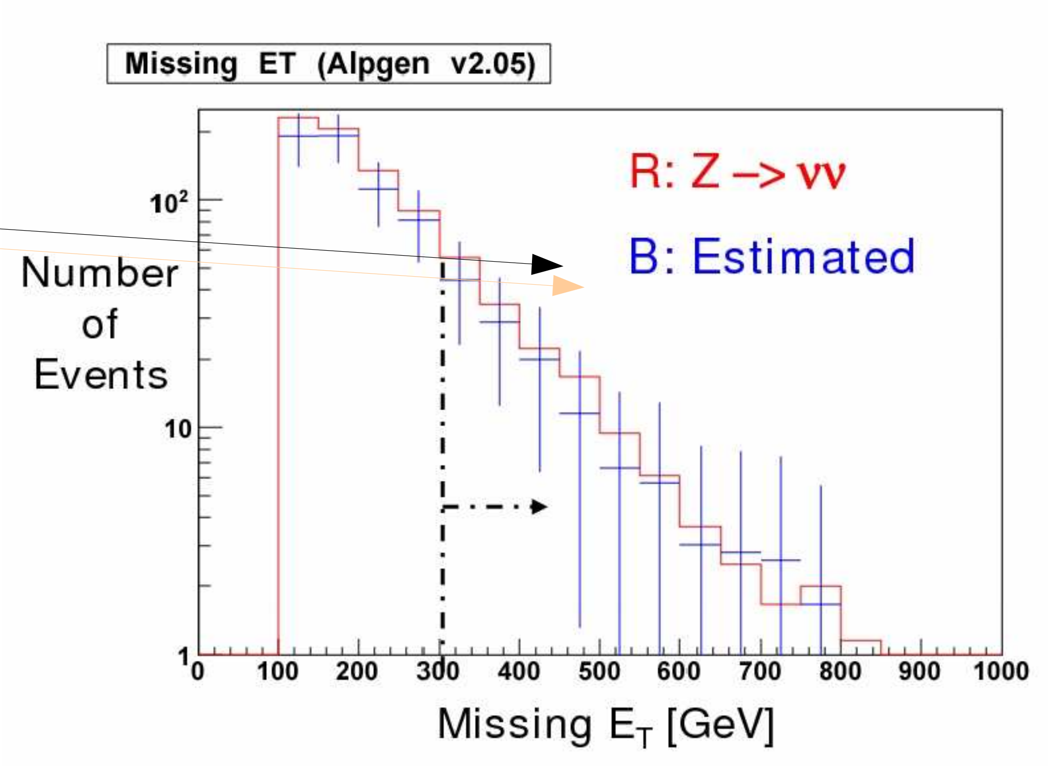
- Eventually we will have tools with very small uncertainties
- "in the long term we will all be dead"
- Meanwhile measure everything. Consider Missing Et

SM sources of missing Et

- Perfect detector and no Monte Carlo
- Need multijet+ missing et plots
- Take same jet configuration and look for μ+μ- instead of missing ET.
- If these events are dominated by ones where m(μ+μ-) =M(Z), then we have "Z+jets"
- Can predict background in multijet+ missing et from Z+jets with Z –>$\nu\nu$. Does this agree with measurement? Yes, publish limit. No, work harder

Missing Et from Z

From measured Z μμ



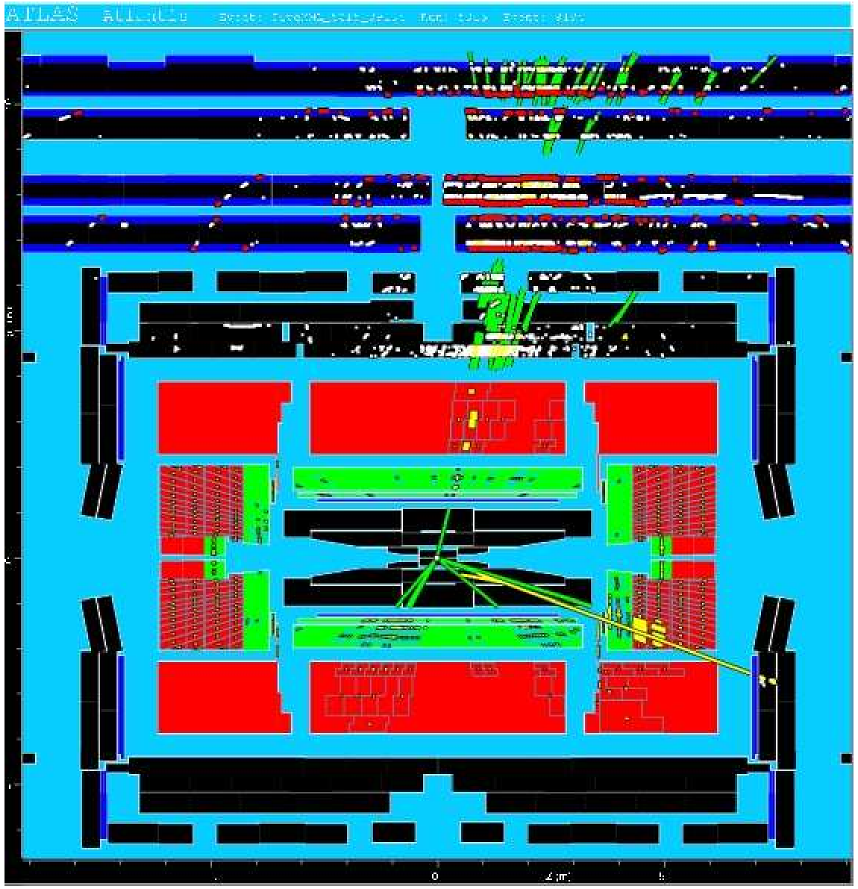
Not quite so easy: muon detection not perfect: acceptance and efficiency

Missing Et broken detector

- Holes.
- Poor measurements (particularly of jets)
- Incomplete coverage
- Dead regions
- Noise
- Missing Et is a “garbage collector”

Missing Et: broken detector: look at odd events

This is an event not completely contained



Backgrounds with a lepton

- Electron could be a fake (can measure this)
- Real high pt leptons come from W or Z
- Measure in some regime, extrapolate
- Study in a region of no signal and extrapolate
- Cut harder
- I will do this in examples of mass measurements