Beyond the Standard Model (theory)

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Brown University
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Outline of the talk

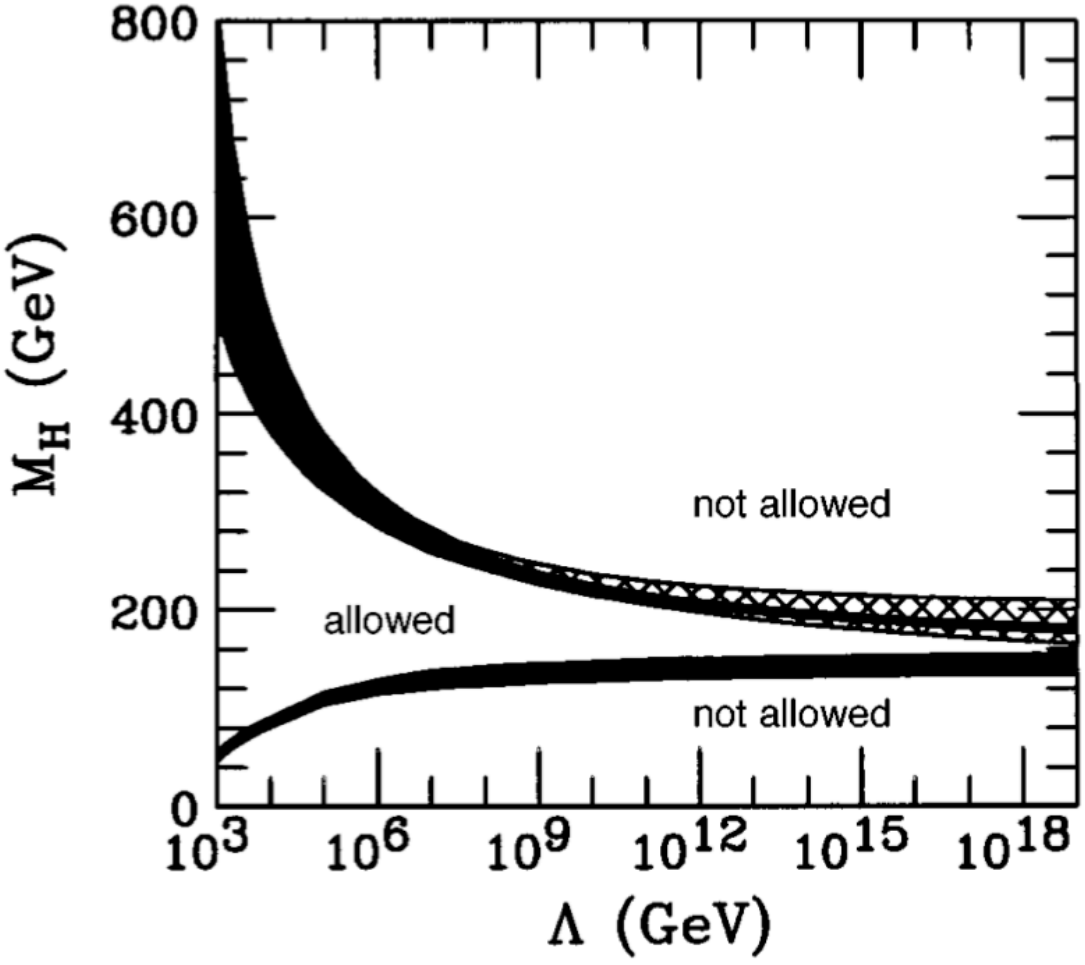
- The latest fashionable models? No.
  - Any given model is surely wrong
  - I haven't paid attention what they are

See review talks by
C. Csaki at APS'09
L.-T. Wang at DPF'09

- Let me instead talk about the HEP sociology.
  - interactions between theorists and experimentalists
  - the role of phenomenologists (model builders)
  - how best to make sense of the LHC results
    - experimentalists: please try to present your results in a model-independent way
    - theorists: please feel free to go ahead and analyze your own models
- Example
  - same-sign di-leptons and missing energy signature

Where is the new physics?

- Impact of the latest Higgs search limits



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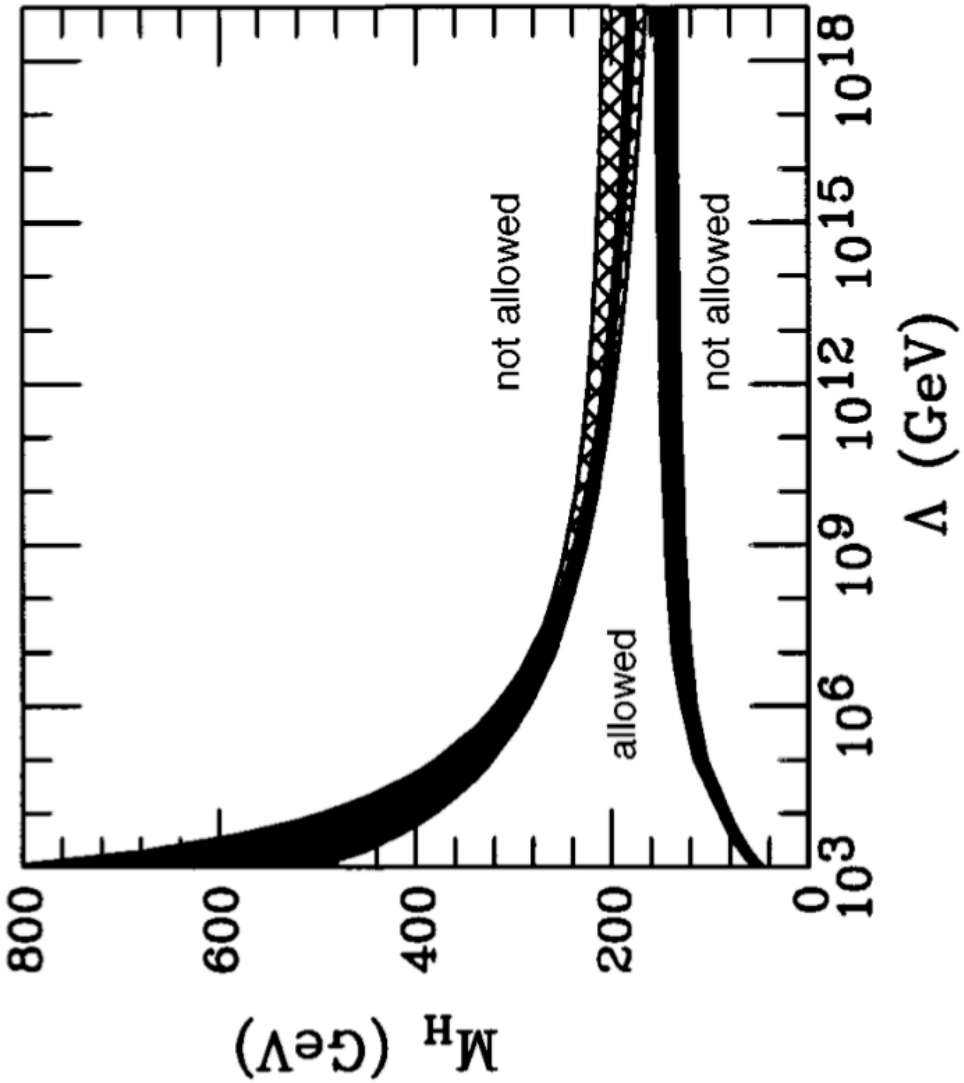

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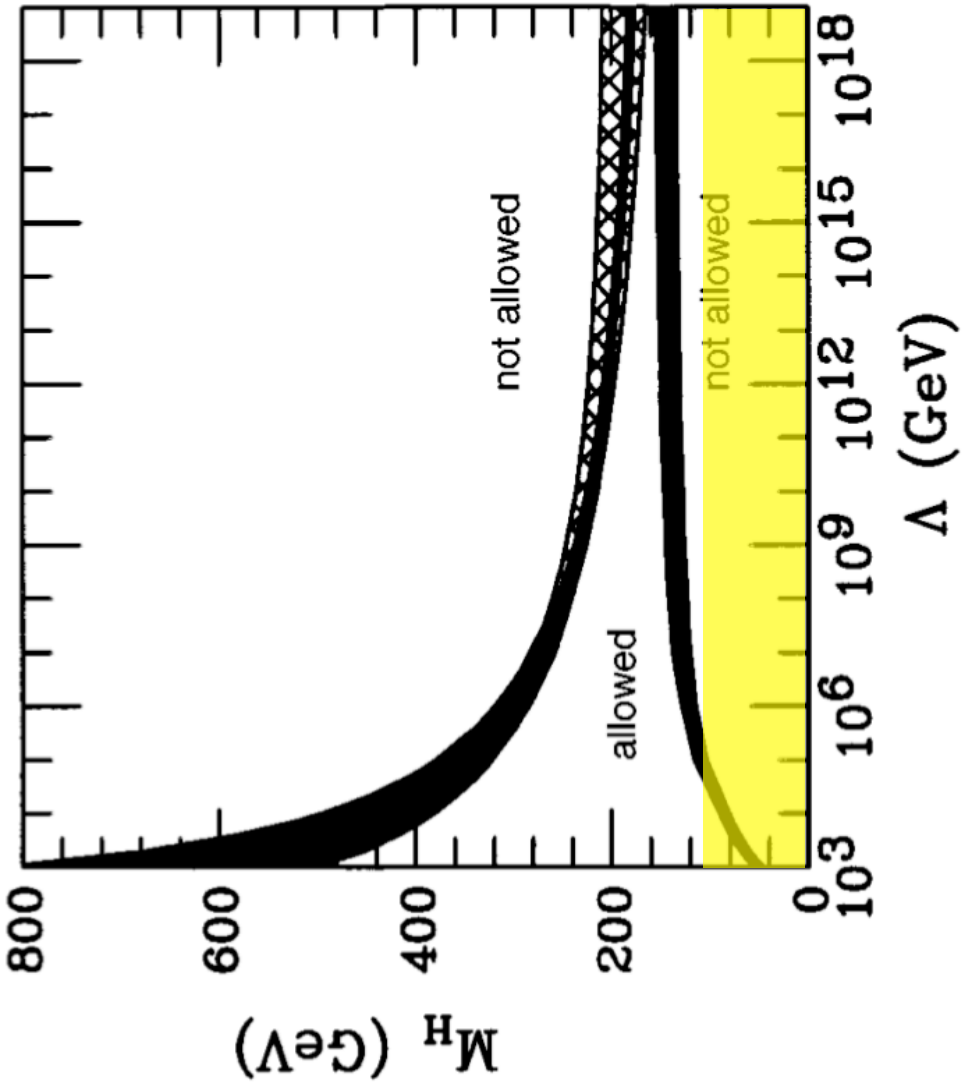

LEP

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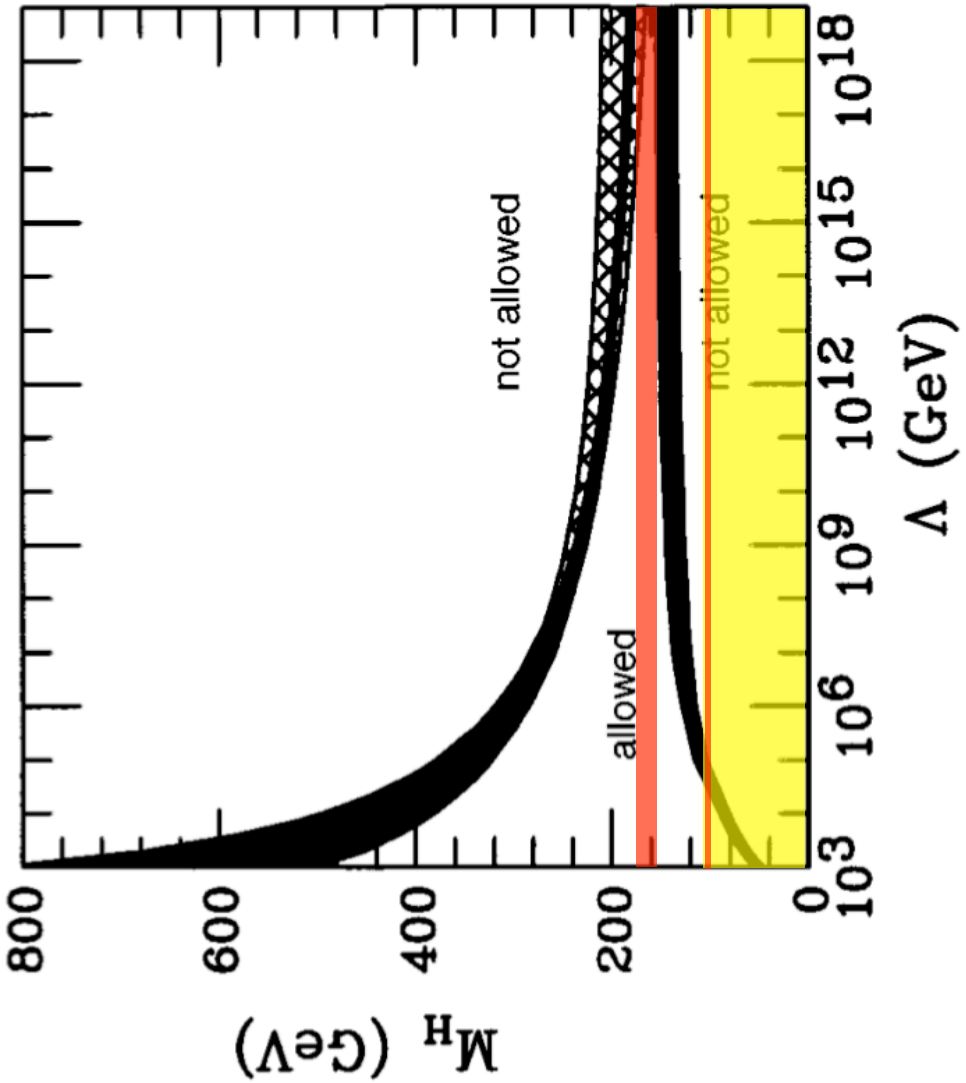

LEP

Tevatron

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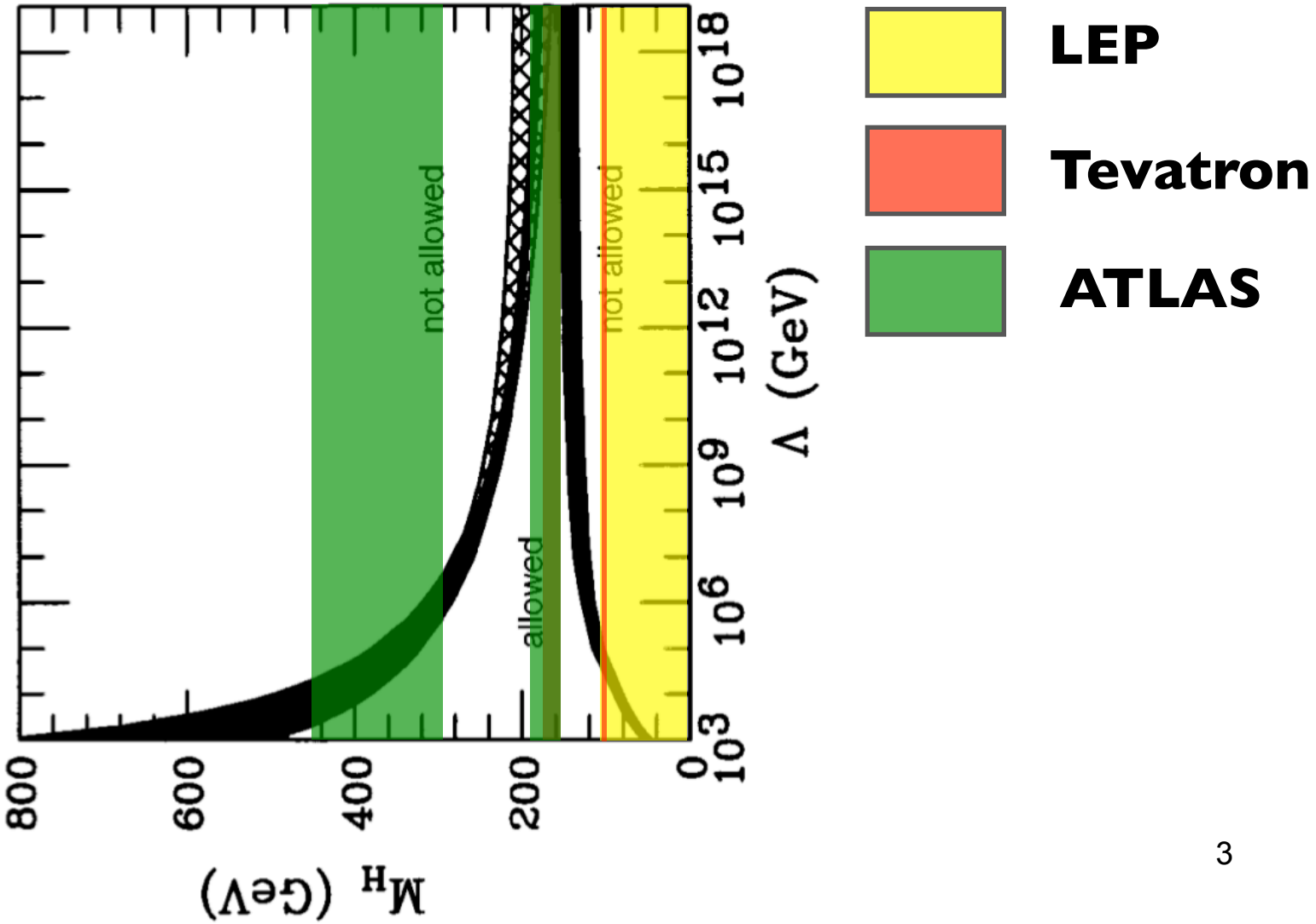

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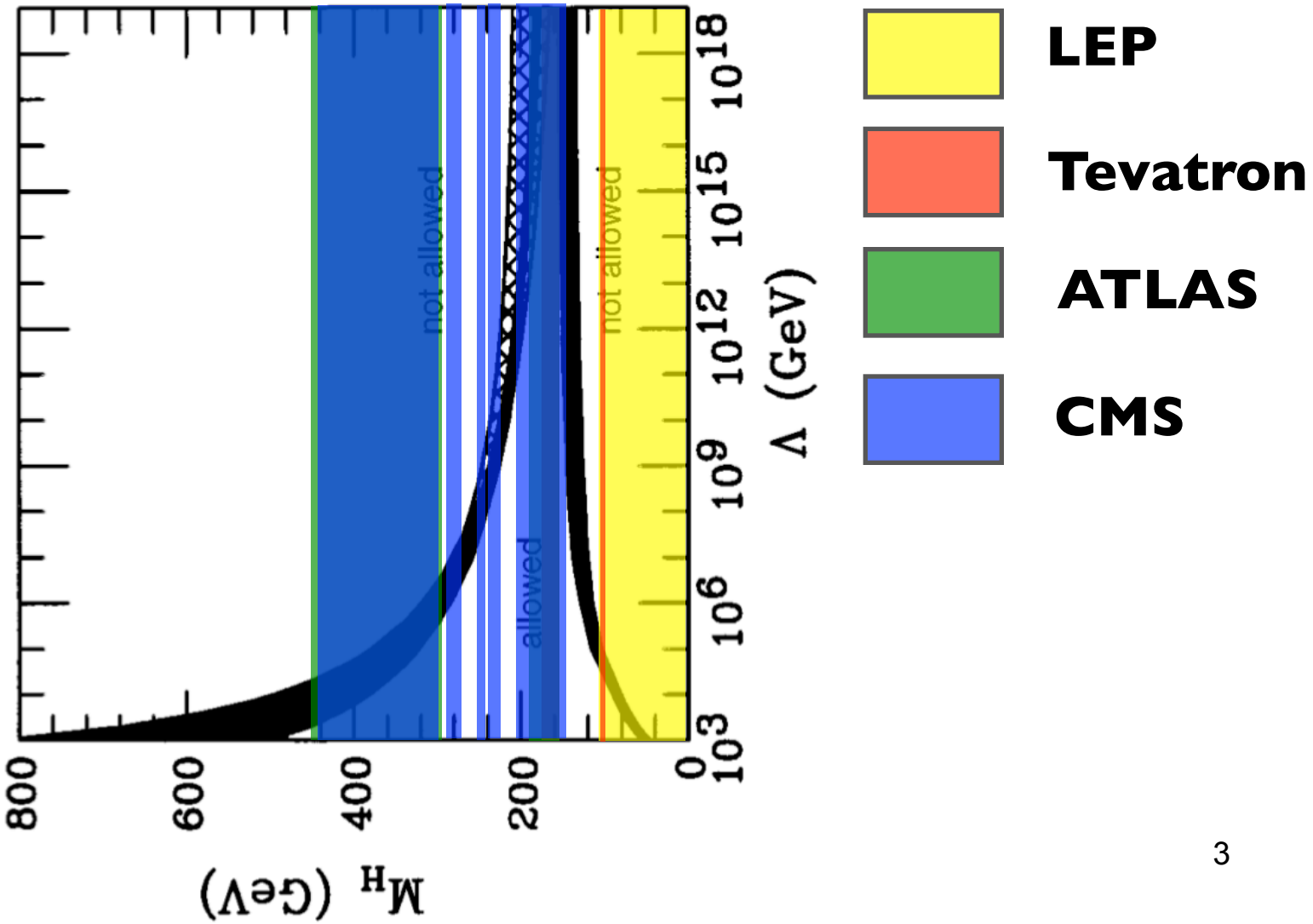

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- by a theorist/phenomenologist/experimentalist

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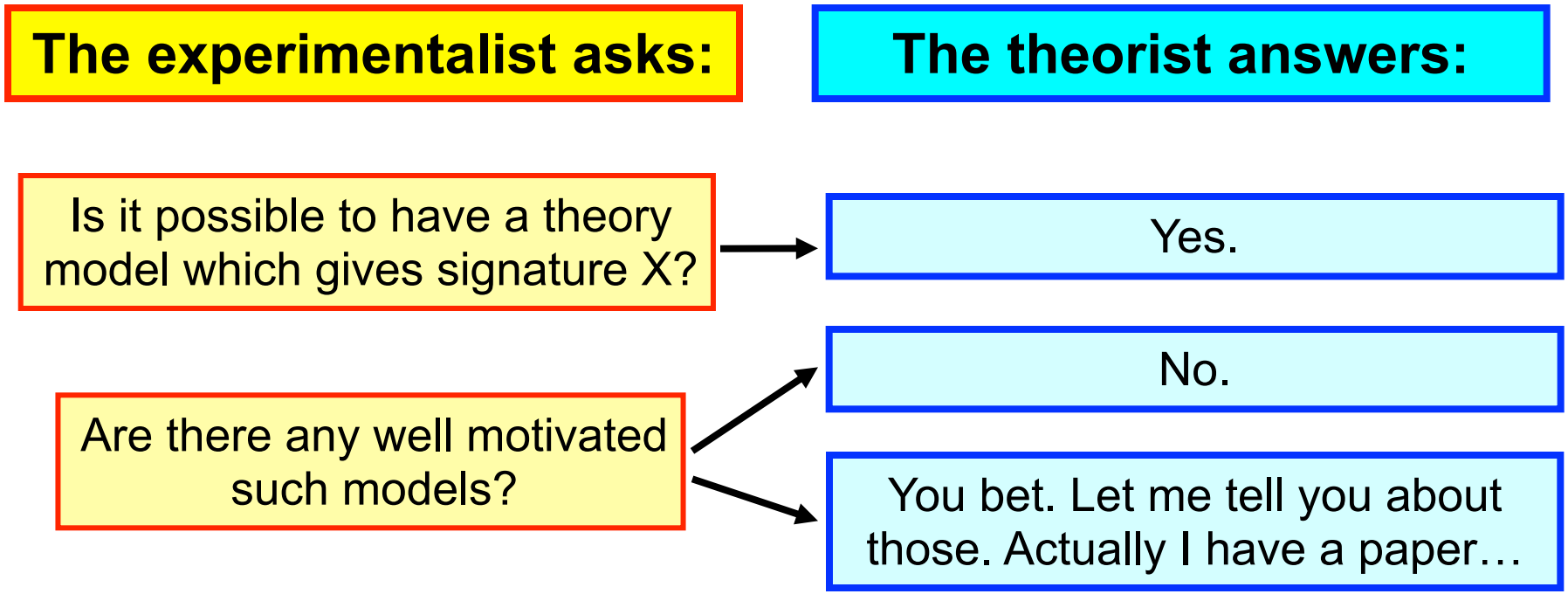

This talk is being given

- by a theorist/phenomenologist/experimentalist

The experimentalist asks:	The theorist answers:
Is it possible to have a theory model which gives signature X?	Yes.
Are there any well motivated such models?	No.
	You bet. Let me tell you about those. Actually I have a paper…
Is there any Monte Carlo which can simulate those models?	I'm the wrong person to ask. Ask a phenomenologist.

MC4BSM workshops: http://theory.fnal.gov/mc4bsm/

MC4BSM workshops

advertisement

- Held annually* since 2006:
  - Fermilab, 2006
  - Princeton, 2007
  - CERN, 2008
  - UC Davis, 2009 (jointly with "Missing Energy" workshop)
  - Copenhagen, 2010
  - Cornell, 2012
- Goal: "*to gather together theorists and experimentalists interested in developing and using Monte Carlo tools for Beyond the Standard Model Physics in an attempt to be prepared for the analysis of data focusing on the LHC*"
- BSM tool repositories:
  - http://www.phys.ufl.edu/~matchev/MC4BSM/writers.html
  - http://www.ippp.dur.ac.uk/montecarlo/BSM/
- Organizing committee(s):
  - H.-C. Cheng, C. Grojean, J. Hubisz, J. Lykken, K. Matchev, S. Mrenna, M. Perelstein, P. Skands.

Other venues

advertisement

- A sister European workshop: “TOOLS”
  - TOOLS 2006, Annecy
  - TOOLS 2008, MPI Munich
  - TOOLS 2010, Southampton
- LHC Olympics
  - CERN 2005, 2006
  - KITP Santa Barbara 2006
  - Princeton 2007
- Graduate-level summer schools
  - PiTP 2005, Princeton
  - PiTP 2007, Princeton
  - TASI 2011, Boulder
    - CompHEP/CalcHEP
    - PYTHIA
    - PGS
    - MicrOMEGAs

TASI 2011

Nowadays the tables have turned

- The stream of LHC data has changed the picture

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Experimentalist answers:

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Yes. ← Can LHC be sensitive to model X?

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Experimentalist answers:		**The theorist asks:**
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Not this particular model. In our note we only show MSUGRA plots.	←	Is there any analysis which is looking for this model?

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Experimentalist answers:		**The theorist asks:**
Yes.	←	Can LHC be sensitive to model X?
Not this particular model. In our note we only show MSUGRA plots.	←	Is there any analysis which is looking for this model?
Manpower. We do not have enough people to cover all possible theory models.	←	Why not?! It's a great model.

How does this problem arise?

- Number of theory models N_{models}
- Number of theorists $N_{theorists}$
- Number of experimentalists, e.g. represented by ATLAS/CMS authors $N_{authors}$
  - only some are doing physics: $N_{authorsDP}$
    - even fewer are **really** doing physics: $N_{authorsRDP}$
- The hierarchical ordering is as follows:

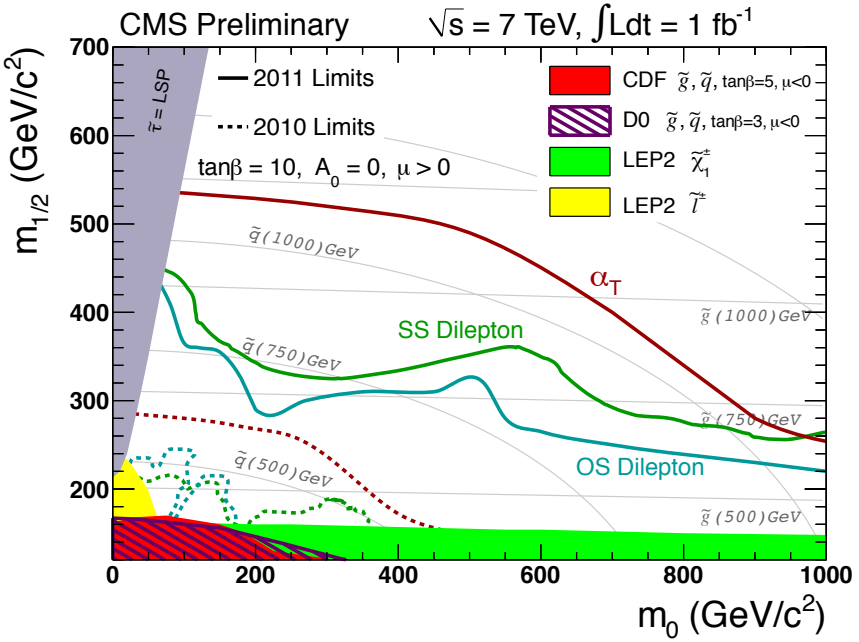
$$N_{models} \sim N_{theorists} \sim N_{authors} > N_{authorsDP} >> N_{authorsRDP}$$

Furthermore...

- Even within a given BSM model, there are many input parameters, presenting results in the full parameter space is quite labor intensive.

Generic SUSY

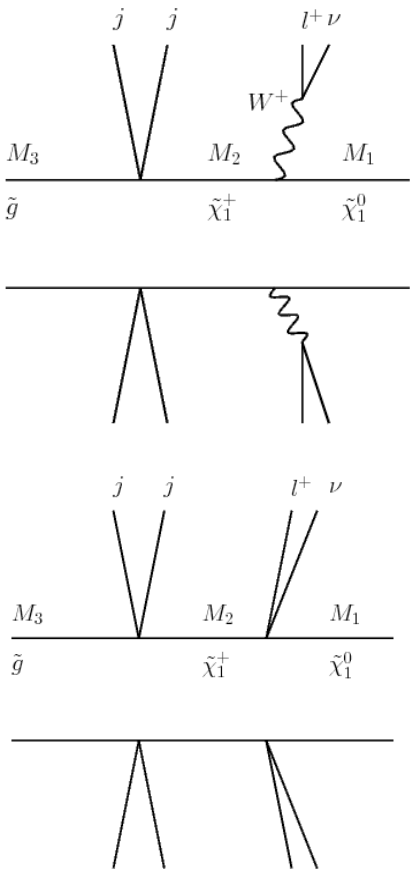
MSUGRA



The simplified model approach

$$\sigma \times BR \times \epsilon \times L = N_{events}$$

2 SS leptons+MET



- Identify a relevant event topology
- Parameterize the efficiency in terms of the relevant masses (M_1,M_2,M_3)
- Quote a limit on the raw signal rate

$$\sigma \times BR = \frac{N_{events}}{\epsilon \times L}$$

- The result can be immediately recycled and applied to other models
- Who should calculate $\epsilon(M_1, M_2, M_3)$?

Who calculates the efficiency?

- Ideally, the experimentalists.
  - they are the ones who know their detector best
  - but... limited manpower
- Theorists
  - lots of manpower
  - must rely on publicly available (often unvalidated) detector simulation software
    - cmsjet, atlfast, delphes, PGS (pretty good simulation),...
- Both
  - experimentalists provide emulation of the detector response (channel by channel?)
  - theorists use it in lieu of PGS to compute the limit

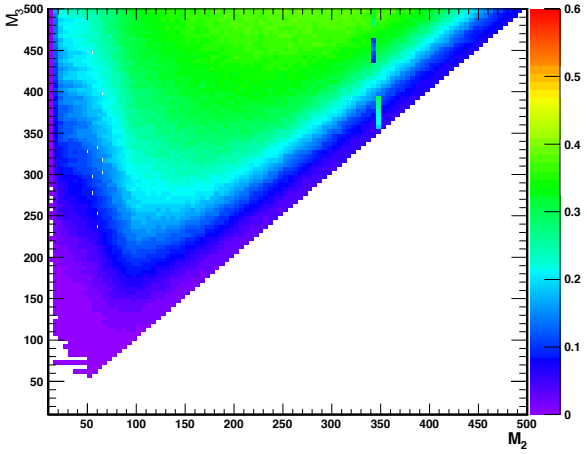
2 SS leptons + MET channel

CMS PAS SUS-11-010

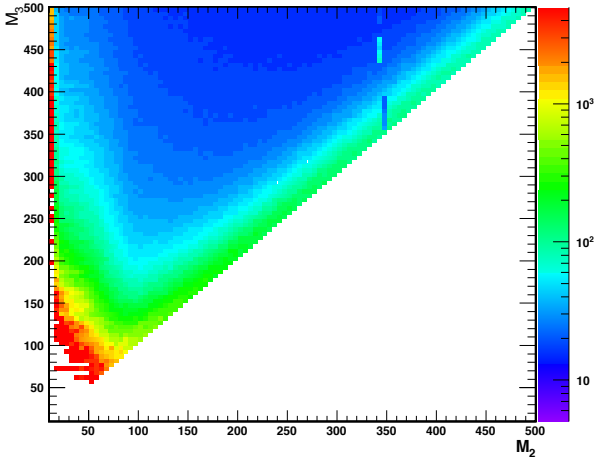
- Two preselection strategies
  - Inclusive (low P_T) leptons, high H_T>200 GeV
  - High P_T leptons (20,10), low H_T>80 GeV
- Four sets of (H_T,MET) cuts:
  - (400,120), (200,120), (400,50), (80,100)
- Sample PGS results for M_1=10 GeV:

KM,Park,Sarangi 2011

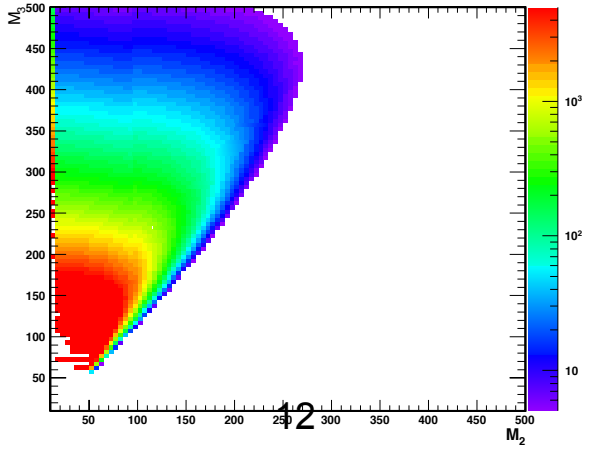
efficiency



MI limit on sigma*BR

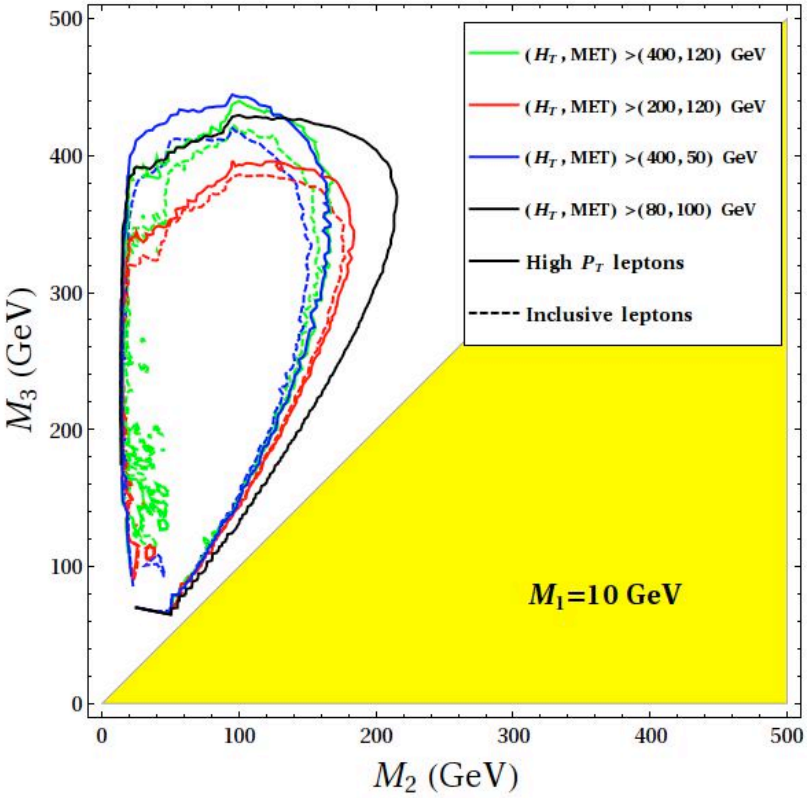


sigma*BR in SUSY



Model-independent* SUSY reach

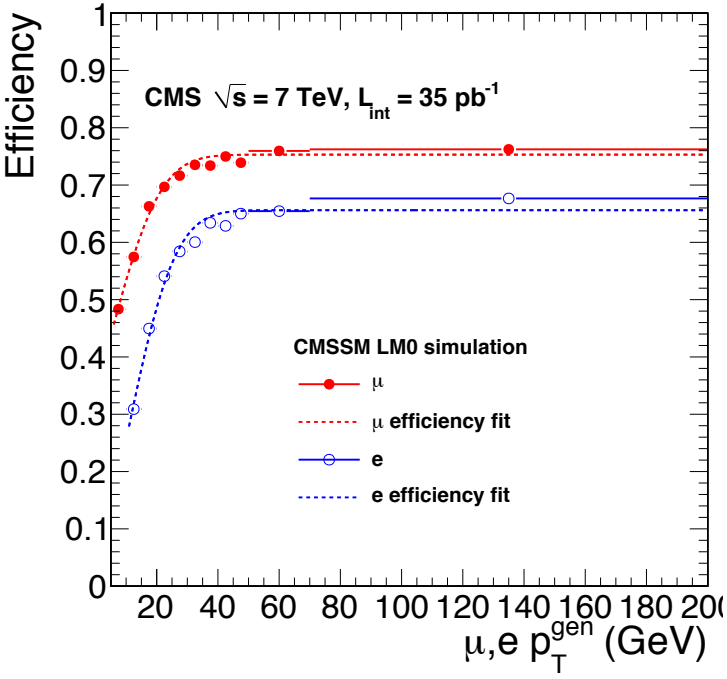
- Combination of the exclusion contours for all 7 search regions
- The same procedure can be applied to other theory models which exhibit the same event topology (UED, ...)
- For a similar analysis of the multijet channel, see Alves,Izaguirre,Wacker 2011



Alternative method: emulation

- The experiments provide fits to the average reconstruction efficiencies
  - e, mu and tau
  - now also for H_T and MET
- The curves are derived for a given benchmark point (LM0 or LM6)
- Correction for busy events
  - more likely to fail isolation

CMS PAS SUS-10-004

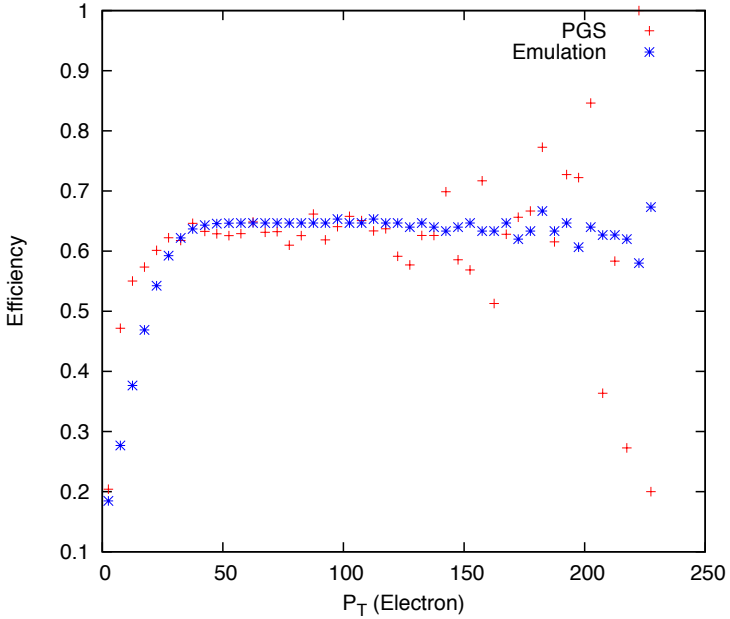


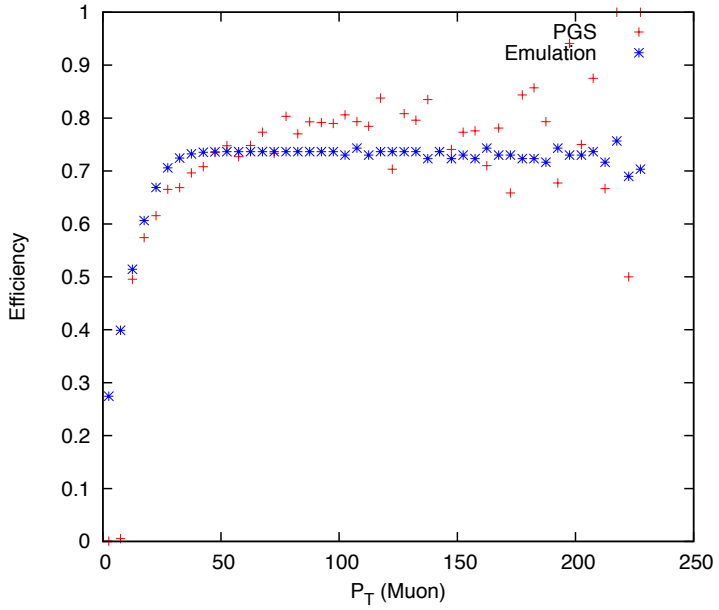
$$\epsilon(p_T, N_{trk}) = p_1 + p_2 \left(erf\left(\frac{p_T - p_T^{thr}}{p_3} \right) - 1 \right) - 0.1 \frac{N_{trk} - 25}{10}$$

How “good” is PGS?

- Comparison of PGS output to CMS emulation
  - lepton efficiencies at LM0 study point

KM,Park,Sarangi 2011





Conclusions

- Experimental collaborations:
  - try to present limits on sigma*BR in the general space of masses instead of specific models
  - where possible, publish emulations of the reconstruction efficiencies
- Theorists: DIY!

Theorists

And so, my fellow ~~Americans~~:

The LHC

ask not what ~~your country~~ can do for you -

The LHC

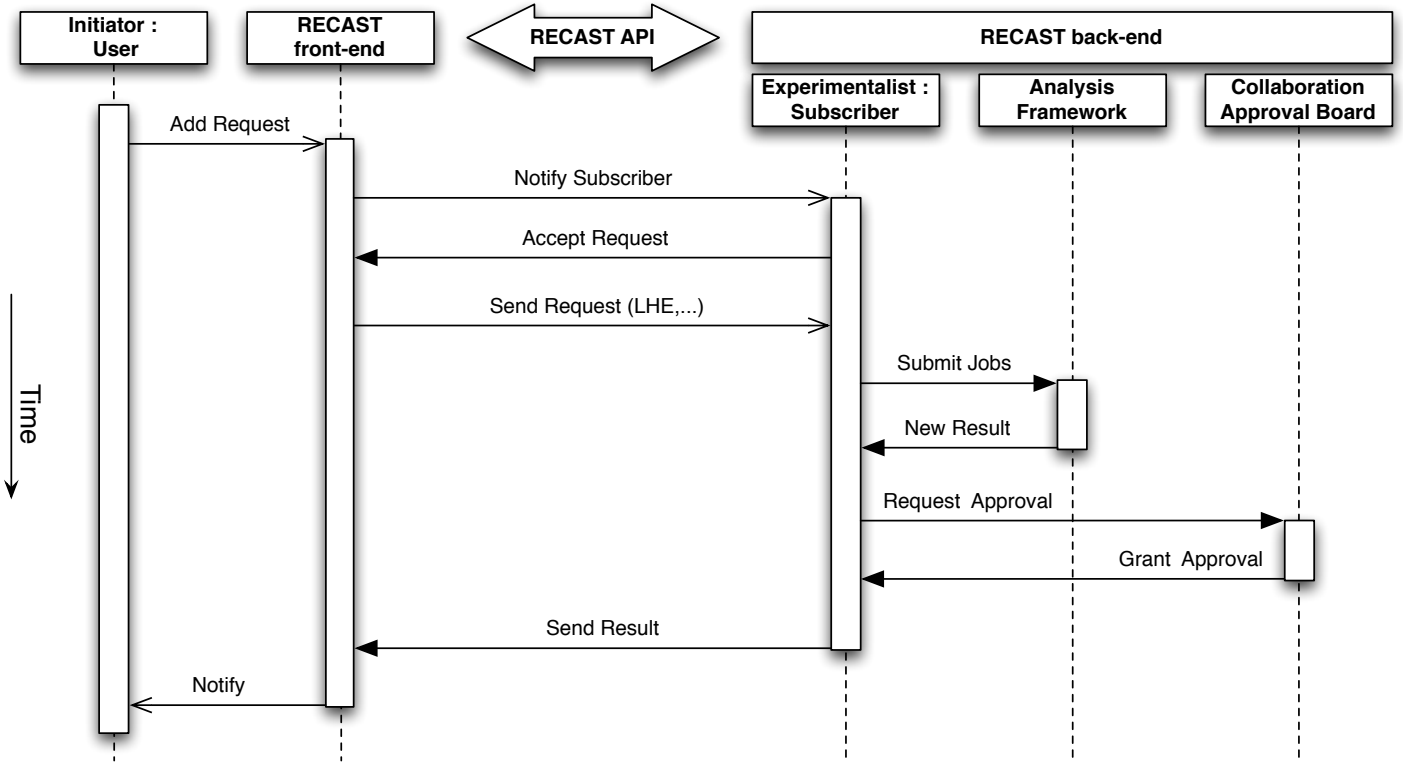
ask what you can do for ~~your country~~.

BACKUPS

One possible approach: RECAST

- Theorists ask the experimentalists very nicely to present limits for multiple models

Cranmer, Yavin 2010



The vicious circle

- Problem: even the minimal SUSY model (MSSM) has too many parameters
  - solution: take benchmark points within some good theory models with much fewer parameters (MSUGRA, GMSB)
- Problem: what is a good theory model?
  - solution(?): we don't know. Popular doesn't mean "good".
- Problem: then by focusing on these benchmark points we might be missing something important.
  - solution: look at benchmark points in non-minimal models
- Problem: but the non-minimal models have a lot of parameters again...
  - solution: then go back to the minimal models.