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New Physics Model Discrimination on first LHC data

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New Physics Model Discrimination on first LHC data

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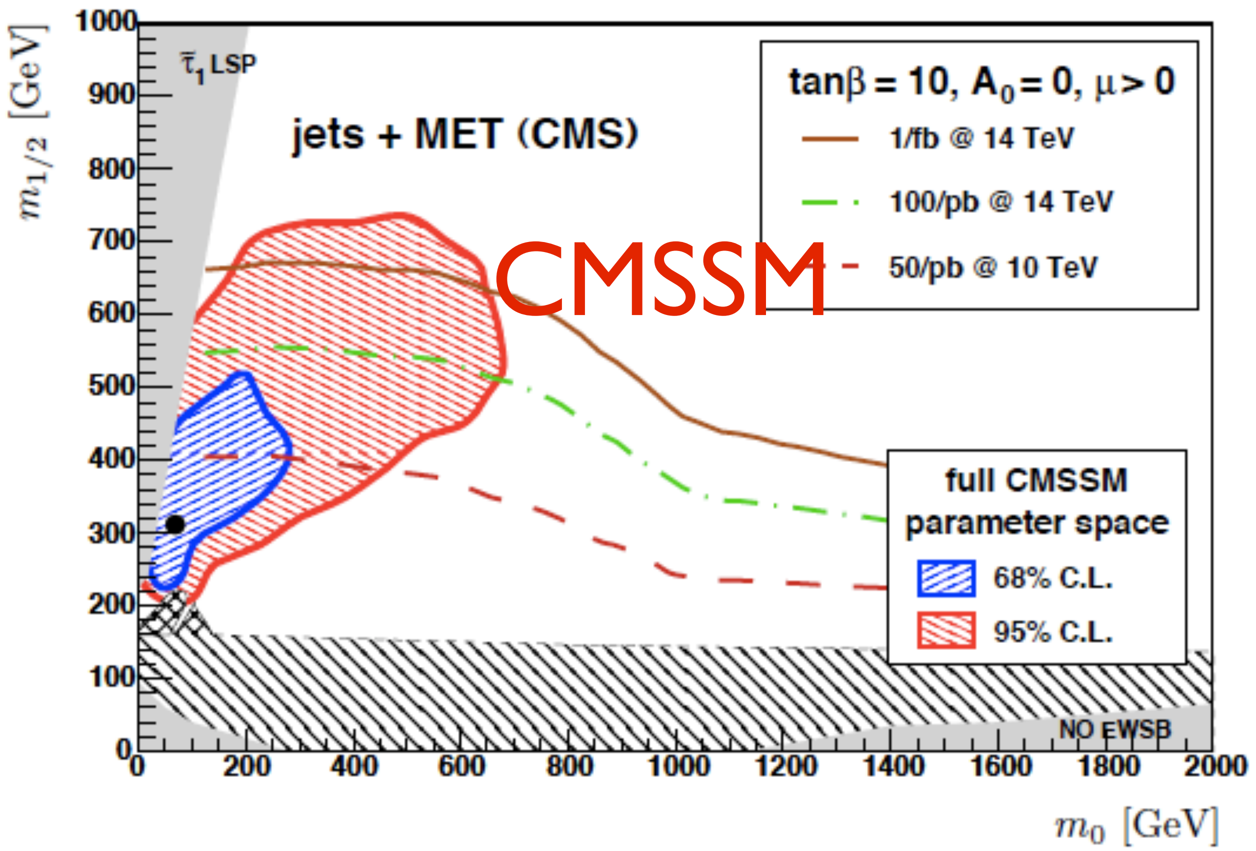
Based on J. Hubisz, JL, M. Pierini, M. Spiropulu, arXiv0805:2398

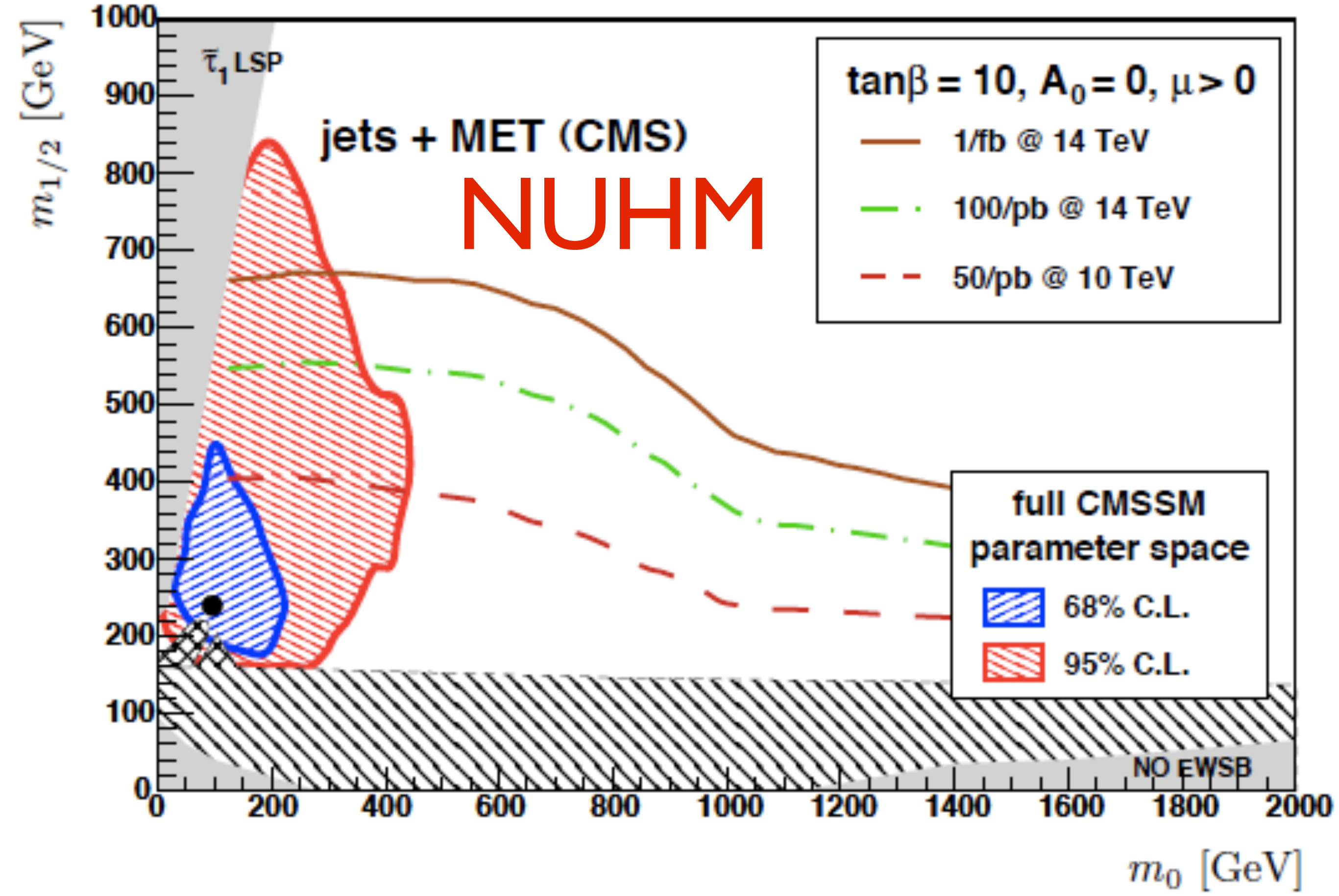
Outline

- An early LHC discovery and the inverse problem
- The Look-Alikes: different models looking the same in a detector
- The ingredients for a Look-Alikes analysis on early discovery:
    - A data analysis ("the Box")
    - A detector simulation
    - A set of discriminating robust variables
    - A statistical definition of the discrimination
- 14 TeV results:
    - LL SUSY discrimination
    - SUSY vs non-SUSY models
- 10 TeV results: the LL analysis as a tool to scan parameter space
- The next step: NP diagnostic for LHC, a.k.a. the NP Doctor House

An early LHC discovery?

O. Buchmueller *et al.* **JHEP 0809:117,2008**. [**arXiv:0808.4128** [hep-ph]]



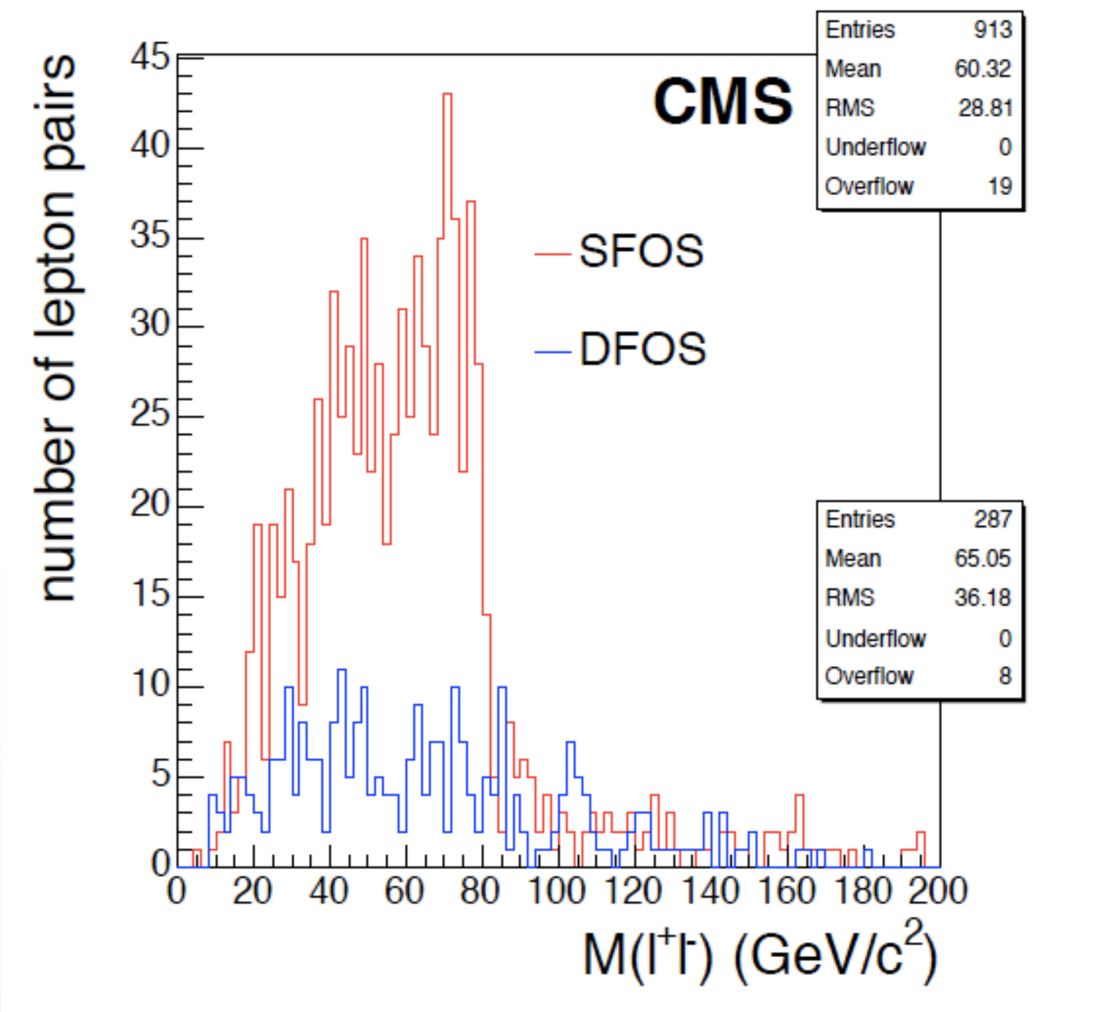


- The first LHC data can already provide a NP discovery if nature is particularly kind (light particles and strong couplings giving large cross sections, as in mSugra)
- NP searches look for an excess of events in some data analysis means. More than one model can explain the observed excess (look-alike models). The disentangle of the various possibilities is the first step for the full characterization of the NP Lagrangian

Inclusive vs. Exclusive

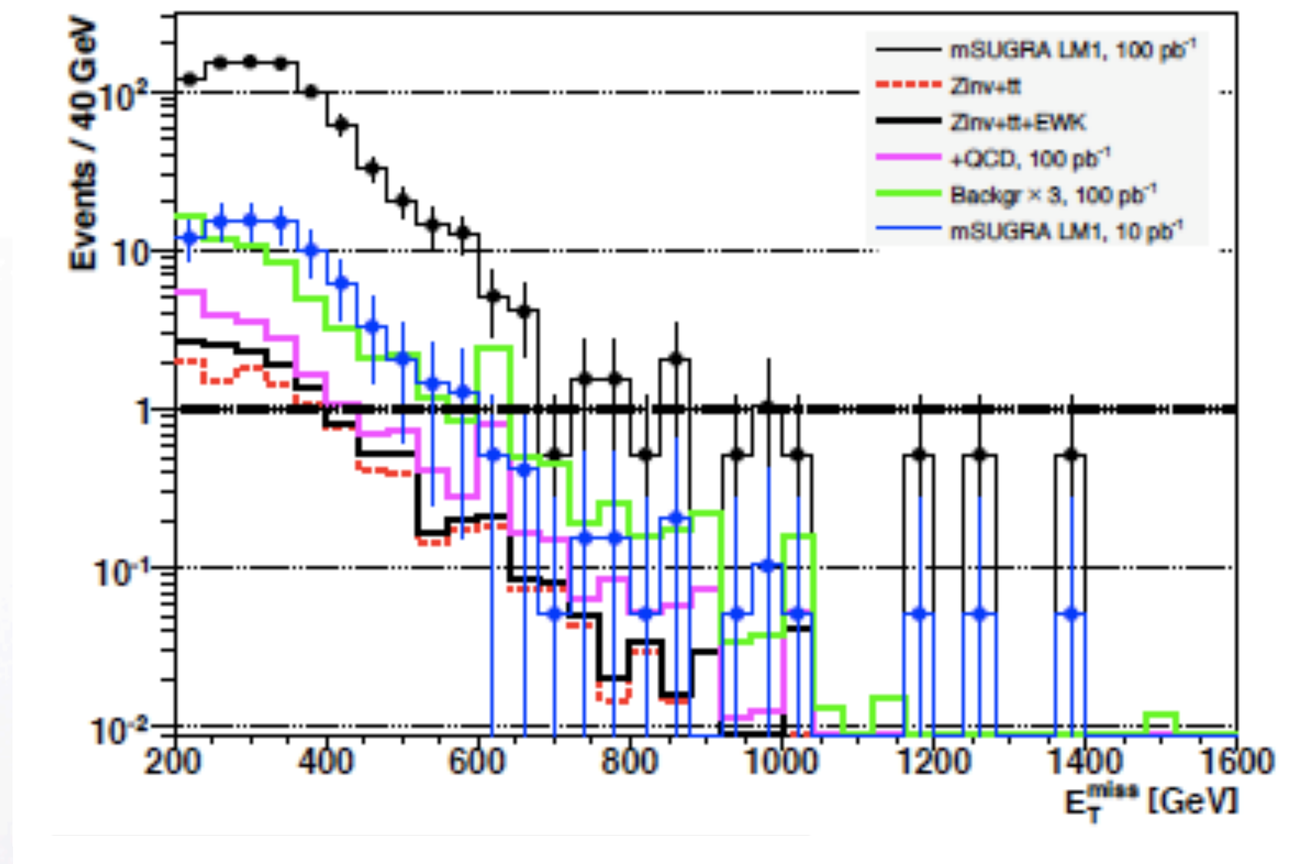
Exclusive Analyses

- small signal efficiency
- precise characterization of NP events



Inclusive Analyses

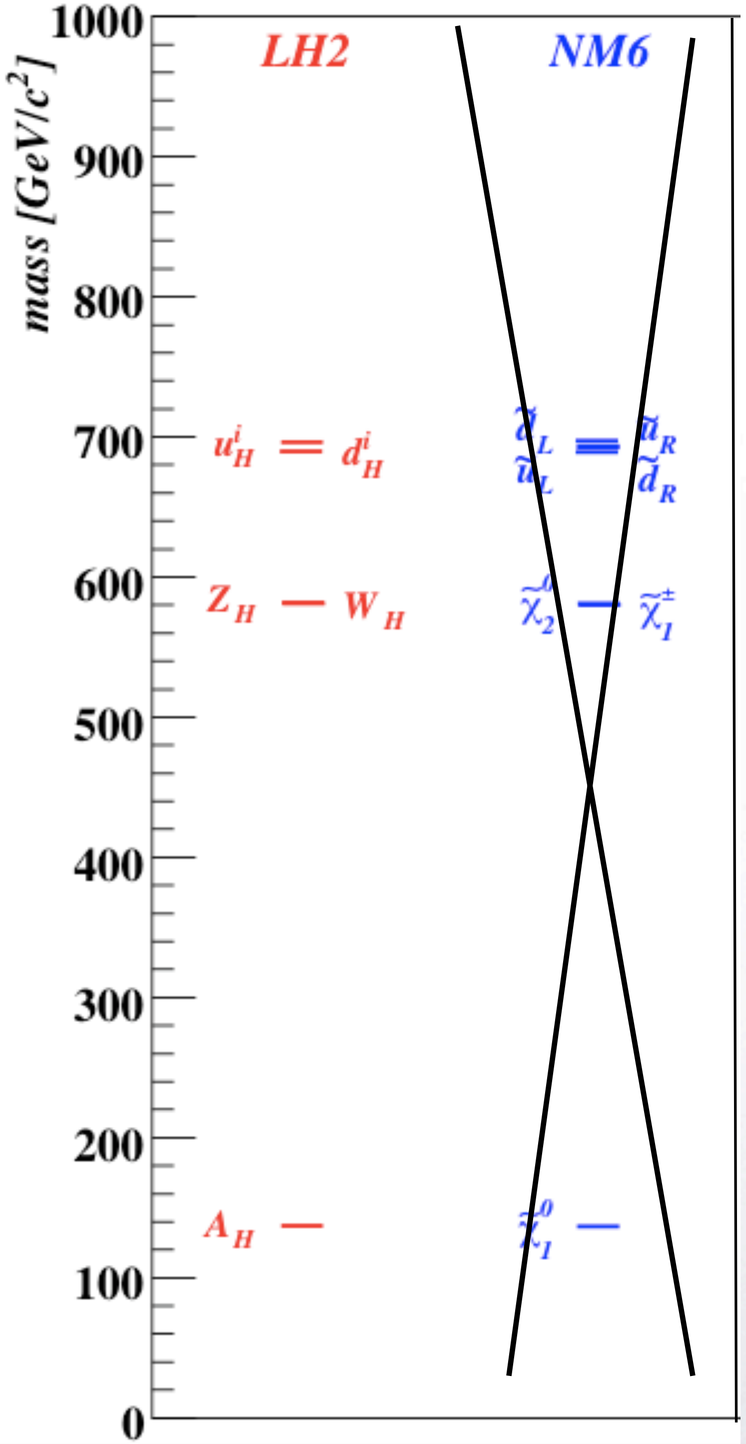
- large signal efficiency
- poor characterization of NP events



- Most likely, the discovery will come from an inclusive analysis. Does it mean that the characterization of the new theory will be poor? Not necessarily...

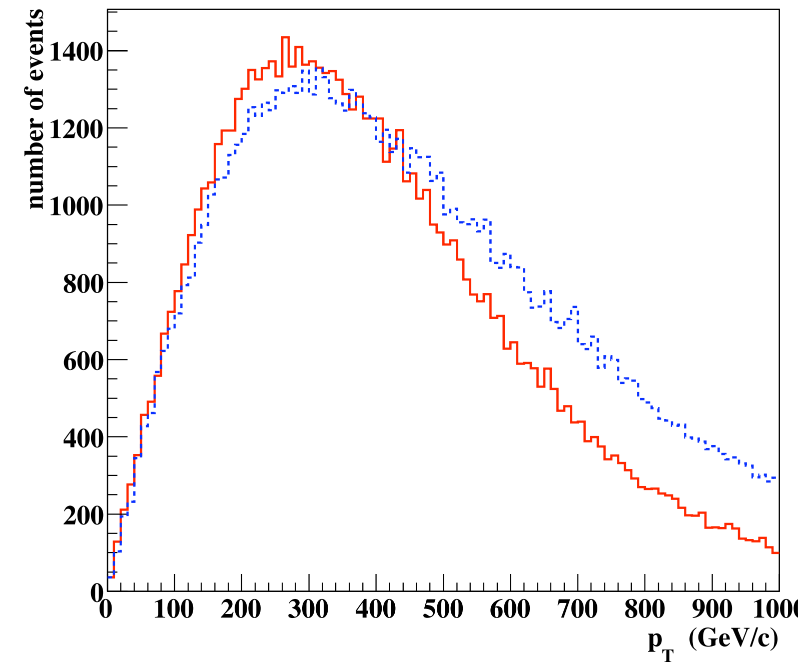
Look-alike models

LH2 and NM6 have the same mass spectrum but they are not LL models



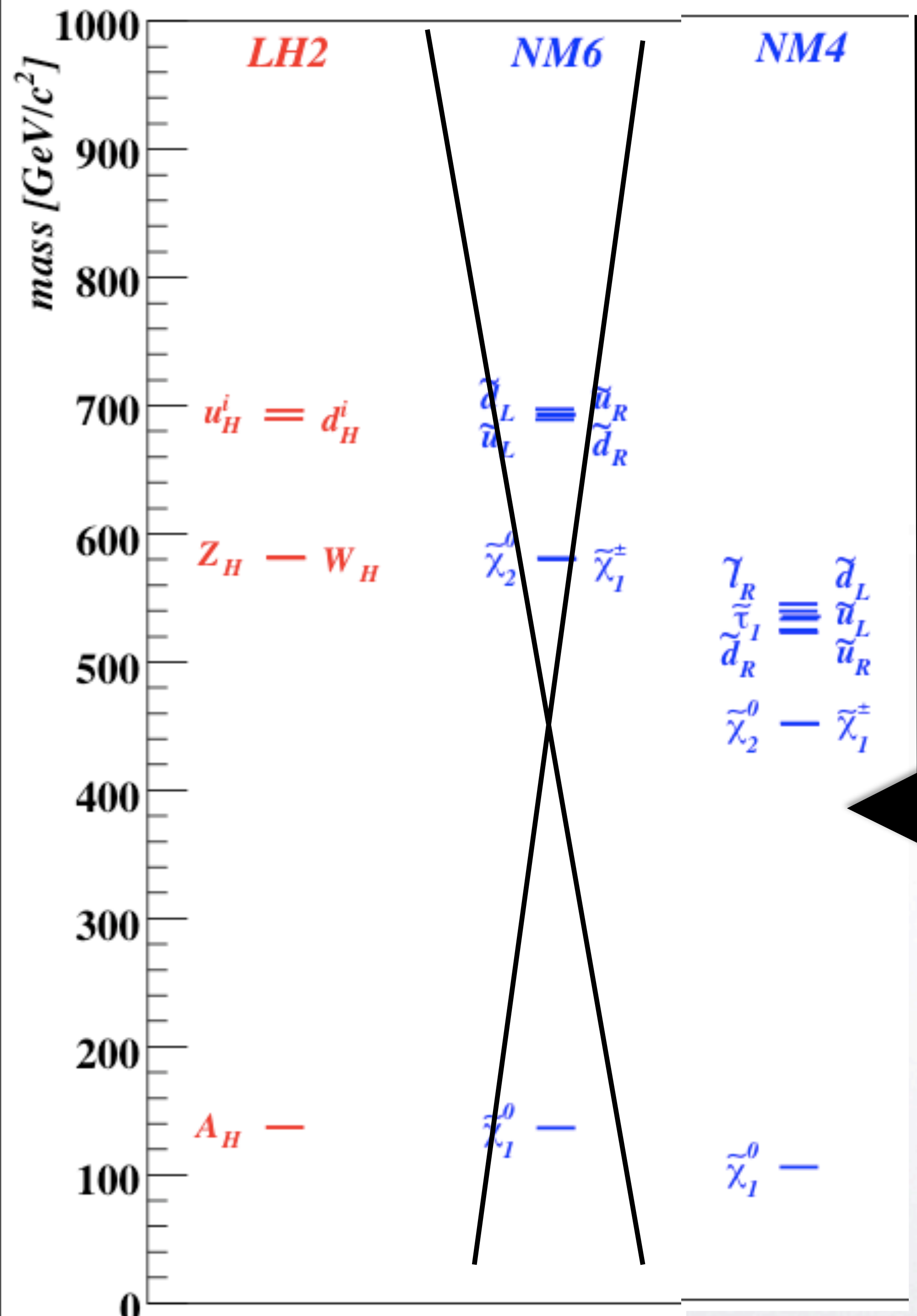
model LH2: LO cross section = 6.5 pb
model NM6: LO cross section = 2.3 pb

model LH2: signal efficiency after MET selection = 14%
model NM6: signal efficiency after MET selection = 19%



Lesson: the cross sections and signal efficiencies depend on the matrix elements, and the matrix elements depend on both the masses and the spins of the parent partner particles produced in the underlying 2-> 2 subprocess

Look-alike models



- On first data, a discovery of NP from an inclusive search will be an excess of events in some variable, related to the presence of two DM particles in the event (MET, Ht, ...)
- Two models can give the same yield (for a given set of experimental requirements even if
  - The spin of the particles is different
  - The mass spectrum is different
  - The spectrum of final-state particles is different

SUSY vs Little Higgs

If LH2 is the NP theory, NM4 would give a yield in agreement with observation within the Poisson error.

The two models cannot be distinguished with the simple result of the search. This is because we are using only the yield to characterize the events

- good for the search
- very bad for the phenomenology

“20 questions” at the LHC

•if there are N models in the theory space, it might seem that we will need N-1 successful binary comparisons to find the true model

•but as the game “20 questions” illustrates, a reasonably clever person can find the true answer with of order Log(N) comparisons

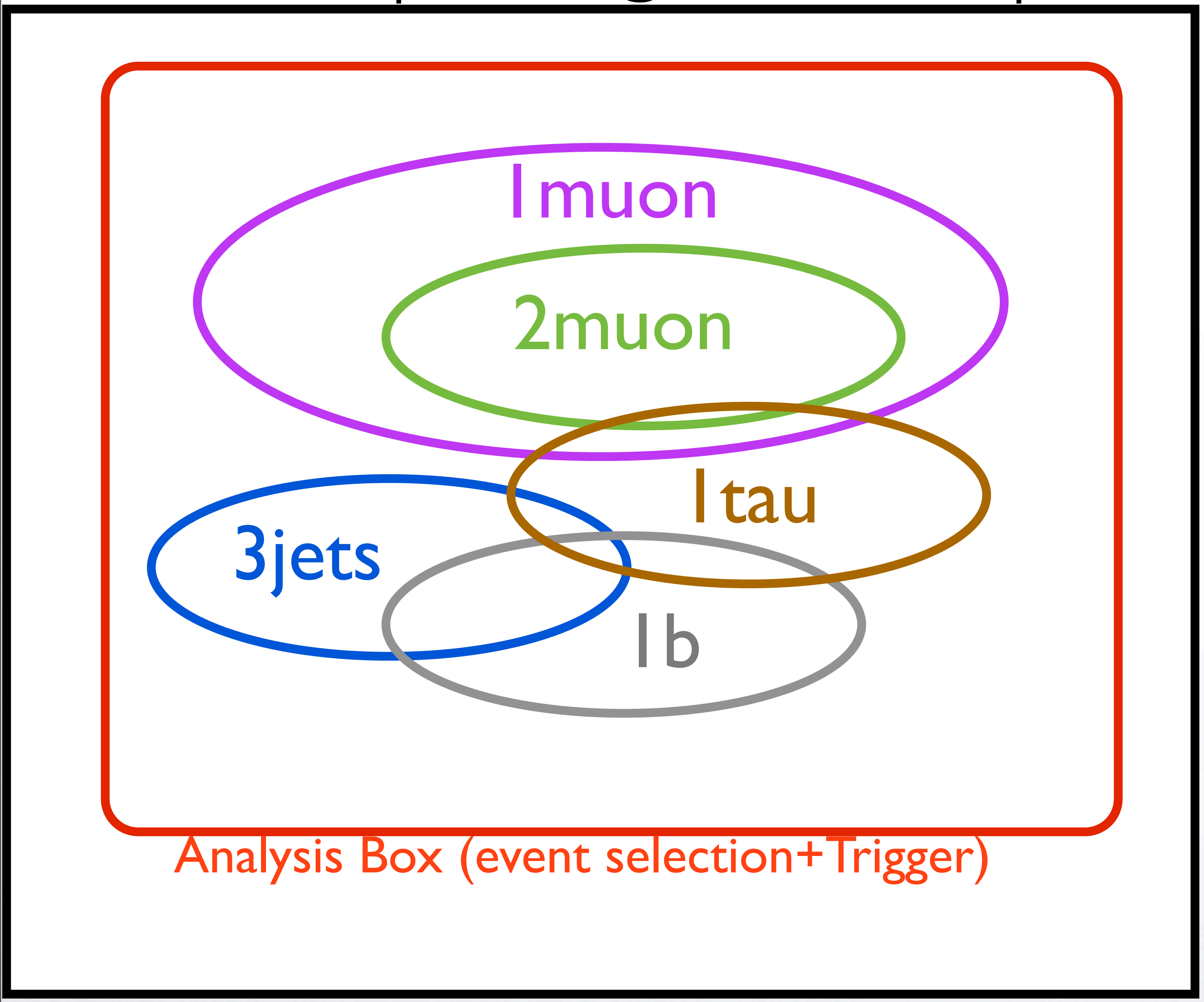
•to do this efficiently at the LHC, we will need to know a lot about both the theory space and the data

•as in the game “20 questions”, the answers to the first few questions determines what questions you ask later

•so the real urgency is to design the first few questions!!

Look-alike Analysis Boxes

SUSY events produced @ collision in 100 pb-1



- There is much more information in the dataset than the number of events seen

- Partial BR are sensitive to couplings and mass spectrum

- On first data, counting object is easier than any analysis of the shape of any variable

- One can use ratios of yield (such as Nev(1muon)/Nev)) to characterize the model and compare the predictions to the data. Some of the uncertainties will cancel out

- The analysis (a set of cuts) can be applied together with different trigger requirements (defined seeding the analysis with different trigger paths): MET, Muon, DiJet, TriJet

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Choosing the Reference Analysis

•dark matter exists

•a plausible hypothesis, yet to be confirmed, is that a significant fraction of this dark matter consists of thermal relic particles left over from standard radiation-dominated cosmological evolution

•to produce the observed relic density, these particles should be weakly interacting and have (roughly) Terascale masses

•they presumably also carry some new conserved quantum number, to explain their stability; charged or colored partners of this dark matter particle would also carry this quantum number

•these partners would be copiously pair-produced at the LHC, with subsequent decays to dark matter particles and SM particles

Choosing the Reference Analysis

missing energy from SUSY

- thus the most generic signature of dark matter at the LHC is “missing energy” in association with energetic jets and leptons
- many SUSY models produce such signatures
- the weakly interacting dark matter candidate is the lightest superpartner, the LSP: the spin 1/2 lightest neutralino, the spin 3/2 gravitino, or a spin 0 sneutrino
- stability is provided by conserved R parity
- at the LHC, an invisibly decaying or long-lived NLSP can be mistaken for an LSP

missing energy from non-SUSY

several BSM models achieve an attractive picture of electroweak symmetry breaking, in accord with all current data, without invoking supersymmetry with Terascale superpartners

some of these models also have natural dark matter candidates, stabilized by the same discrete symmetry that suppresses tree level contributions to precision electroweak and flavor-changing processes

- Little Higgs: the dark matter candidate is a spin 1 vector boson partner stabilized by conserved T parity;
- 5-dimensional Universal Extra Dimensions: the dark matter candidate is a spin 1 vector boson partner stabilized by conserved KK parity
- 6-dimensional UED: the dark matter candidate is a spin 0 vector boson partner stabilized by conserved KK parity

Reference Analysis

CMS Physics TDR Vol. II, CERN/LHCC 2006-021

Table 4.2: The $E_{\mathrm{T}}^{\mathrm{miss}}$ + multi-jet SUSY search analysis path

Requirement	Remark
Level 1	Level-1 trigger eff. parameter.
HLT, $E_T^{miss} > 200\,\mathrm{GeV}$	trigger/signal signature
primary vertex ≥ 1	primary cleanup
$F_{em} \geq 0.175$, $F_{ch} \geq 0.1$	primary cleanup
$N_j \geq 3$,$\lvert\eta_d^{1j}\rvert < 1.7$	signal signature
$\delta\phi_{min}(E_T^{miss} - jet) \geq 0.3$ rad, $R1, R2 > 0.5$ rad,	
$\delta\phi(E_T^{miss} - j(2)) > 20°$	QCD rejection
$Iso^{ltrk} = 0$	ILV (I) $W/Z/t\bar{t}$ rejection
$f_{em(j(1))}$, $f_{em(j(2))} < 0.9$	ILV (II), $W/Z/t\bar{t}$ rejection
$E_{T,j(1)} > 180\,\mathrm{GeV}$,$E_{T,j(2)} > 110\,\mathrm{GeV}$	signal/background optimisation
$H_T > 500\,\mathrm{GeV}$	signal/background optimisation
SUSY LM1 signal efficiency 13%	

- we will assume that the discovery is made with this analysis; the look-alike analysis depends on the form of the discovery analysis
- the signature is large MET plus >= 3 jets; no leptons are required; in fact there is an indirect lepton veto to suppress Standard Model backgrounds

Event Generation

•the CMS mSUGRA benchmarks generated by
Isajet 7.69 + Pythia 6.4

•general low scale MSSM models generated by
Suspect 2.3.4 + MadGraph 4.2 + Bridge + Pythia 6.4

•Little Higgs with T parity implemented (by us) in
MadGraph 4.2 + Bridge + Pythia 6.4

- Events are passed to PGS (with perfect detector resolution) to add detector geometry, tracks bending, and compute calorimetric deposits
- Detector effects are applied with standalone code, tuned to CMS PTDR performances

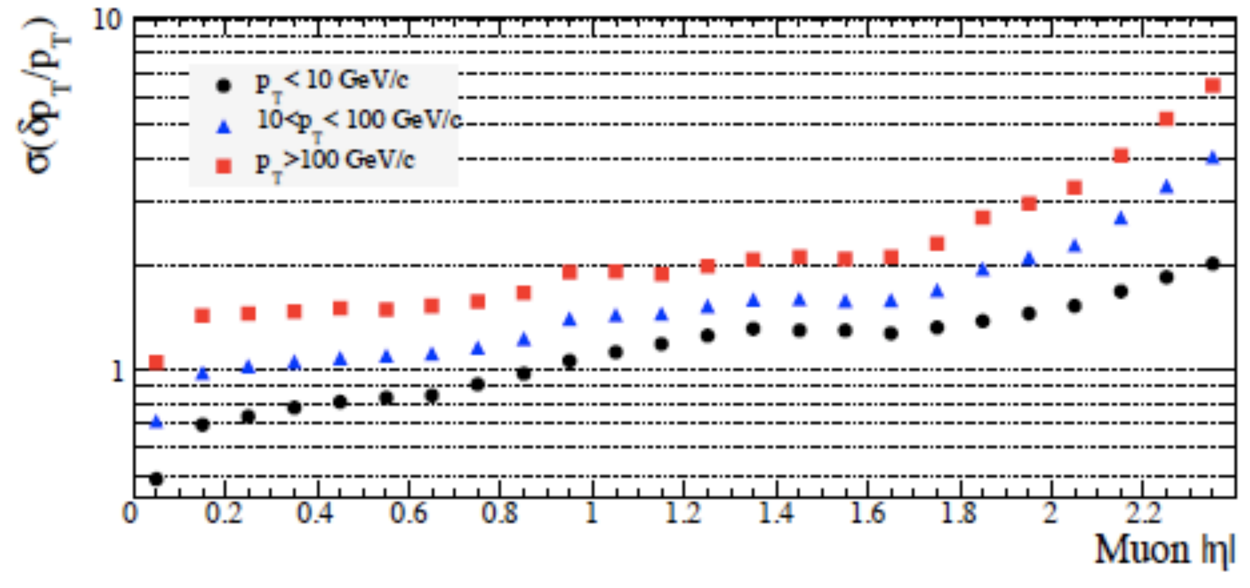
Detector Simulation

- We take CMS as a reference detector (a similar study could be done with ATLAS)

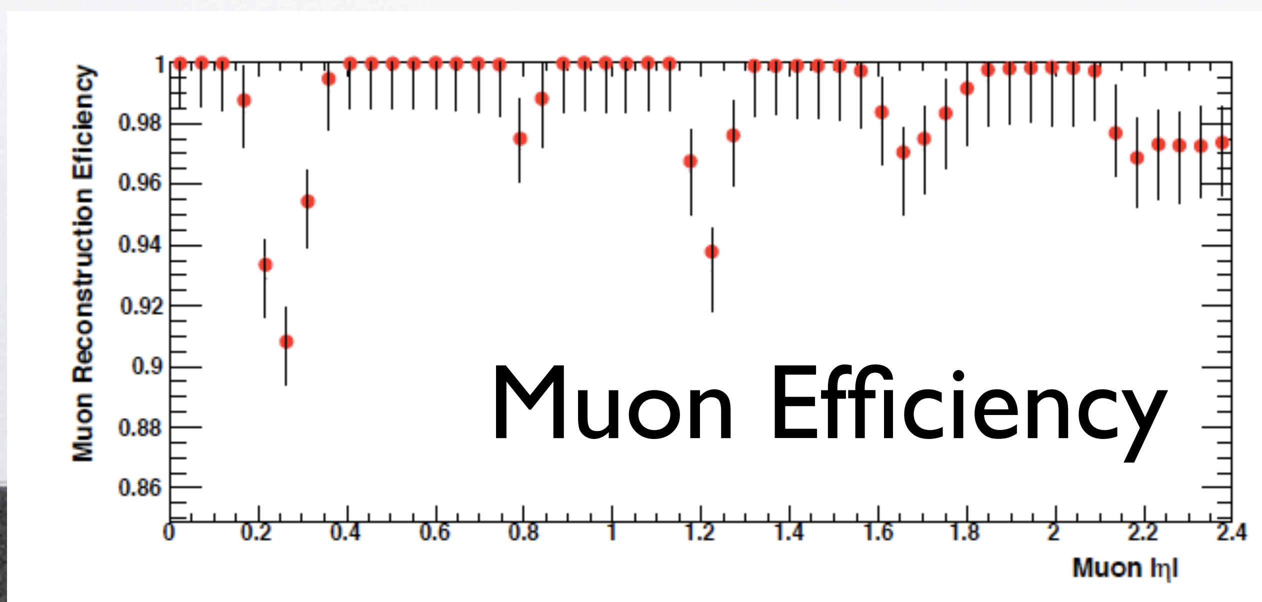
- Detector resolution through lookup tables (from PTDR)

Smearing applied to tracks, muons, electrons, MET and jets

$$\begin{aligned} p_T^{RECO} &= p_T^{GEN} + \Delta p_T(p_T^{GEN}, \eta_T^{GEN}) \\ \eta^{RECO} &= \eta^{GEN} + \Delta\eta(p_T^{GEN}, \eta_T^{GEN}) \\ \phi^{RECO} &= \phi^{GEN} + \Delta\phi(p_T^{GEN}, \eta_T^{GEN}) \end{aligned}$$

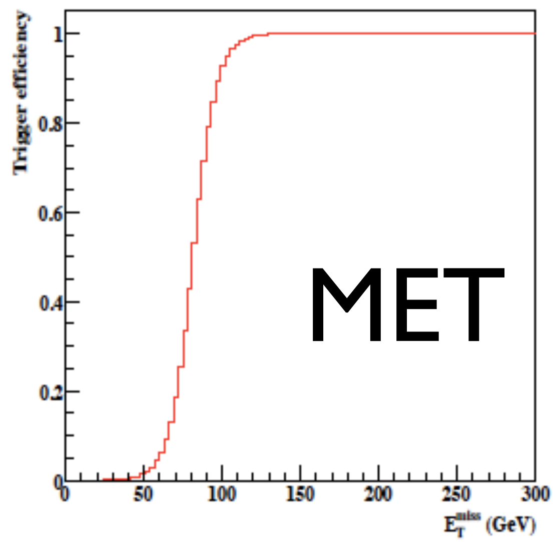


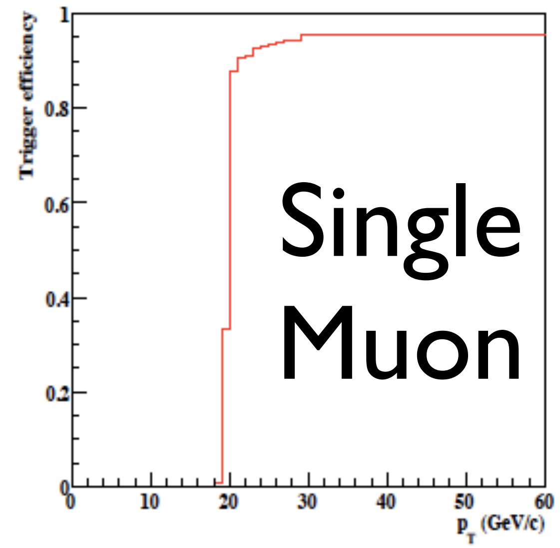
- Detector inefficiencies with hit-or miss

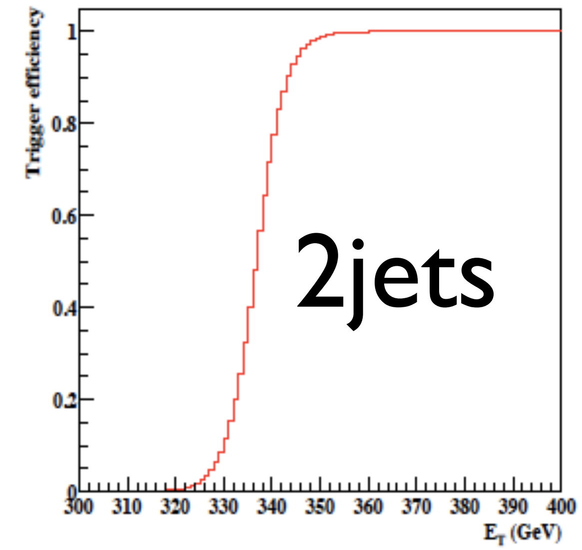


Detector Simulation

- Trigger parameterized through turn-on curves







- Signal efficiency can be predicted with good accuracy (<10% error)
- No control on fakes in background (not relevant in this study)

Cut/Software	Full	Fast
Trigger and $E_T^{\rm miss} > 200$ GeV	53.9%	54.5%
$N_j \geq 3$	72.1%	71.6%
$\lvert\eta_d^{j1}\rvert \geq 1.7$	88.1%	90.0%
QCD angular	75.6%	77.6%
$Iso^{lead\ trk} = 0$	85.3%	85.5%
$E_{T,1} > 180$ GeV, $E_{T,2} > 110$ GeV	63.0%	63.0%
$H_T > 500$ GeV	92.8%	93.9%
Total efficiency	12.9%	13.8%

B and tau identification

•when mature tau- and b-tagging becomes available, it will be a powerful discriminator

•even before this, we should still be able to create subsamples enriched in b's

B-tagging

•we tried a very simple algorithm based on muons inside jets, i.e. attempting to tag muons from semileptonic B (or Lambda_b) decays

•it has a low efficiency, ~5% for actual b-jets from SUSY

•it has a reasonable purity, >70% for many SUSY models

tau-tagging

•we tried a very simple algorithm based on single track jets with high thresholds, attempting to tag single-prong hadronic taus, and taus decaying to electrons that reconstruct as jets

•it has a reasonable efficiency, 12 to 21% for actual taus from SUSY

•it has a low purity, 8 to 55% for SUSY models

•the efficiency and purity are best for SUSY models with lots of taus

Discriminating Variables

$$r(BOX)(MET) = \frac{Nev(BOX)}{Nev(MET)}$$ (BOX=Muon, DiJet, TriJet)

$$r(nj)(3j) = \frac{Nev(>=njets)}{Nev}$$ (n=4,5)

$$r\,(a\ mu,\ b\ j)\ (c\ mu,\ d\ j) = \frac{Nev(>=a\ muons\ \&\&\ >=b\ jets)}{Nev(>=c\ muons\ \&\&\ >=d\ jets)}$$

- r(2mu)(1mu)
- r(2mu,4j)(1mu,4j)

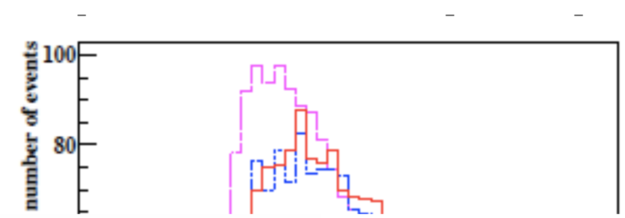
$$r\,(mu+)\ (mu-) = \frac{Nev(>=muon+)}{Nev(>=muon-)}$$

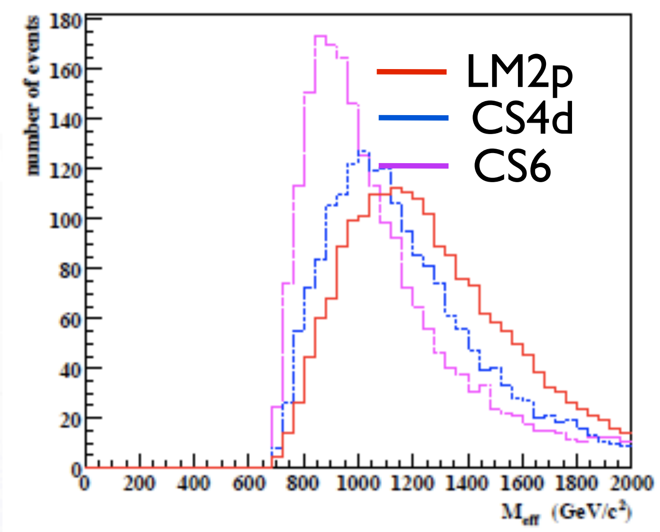
$$r\,(tau\text{-}tag) = \frac{Nev(>=1\ tau\text{-}tag)}{Nev}$$

$$r\,(b\text{-}tag) = \frac{Nev(>=1\ b\text{-}tag)}{Nev}$$

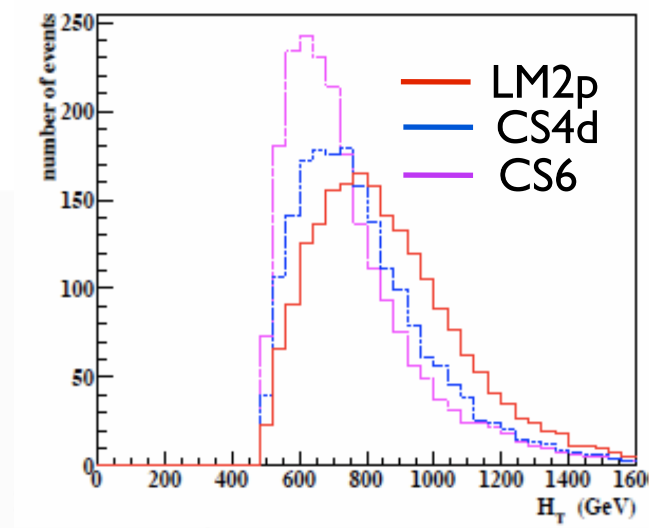
Kinematic Variables

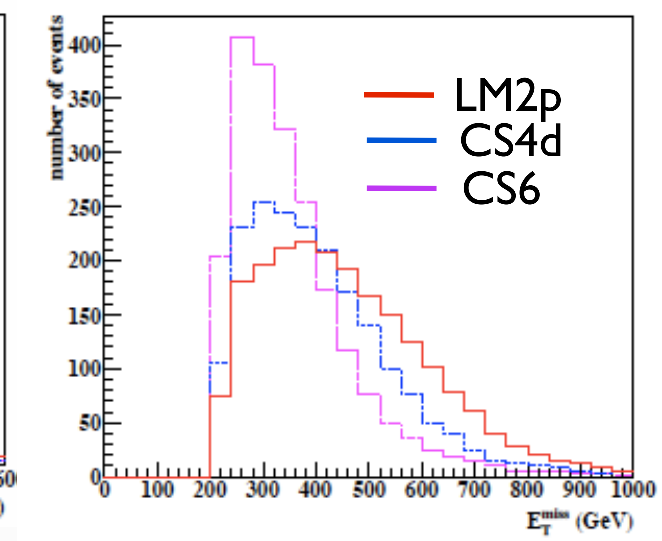
Kinematic variables are very informative on the details of the model (mass spectrum, etc)
The full shape might be difficult to control at startup
A more robust possibility is to use the fraction of event d





LM2p
CS4d
CS6





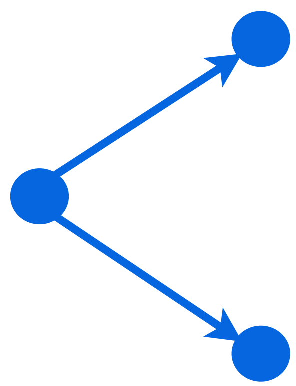
$$r(\text{VAR } X/Y) = \frac{Nev(\text{VAR}>X)}{Nev(\text{VAR}>Y)} \quad (X>Y)$$

(Y not specified if Y=0)

- r(MET320)(MET220)
- r(MET420)(MET220)
- r(MET520)(MET220)
- r(M1400)
- r(M1800)
- r(M1800)(M1400)
- r(HT900)
- r(Meff1400)

Stransverse Mass mT2

A. Barr, C. Lester, D. Summers, P. Stephens

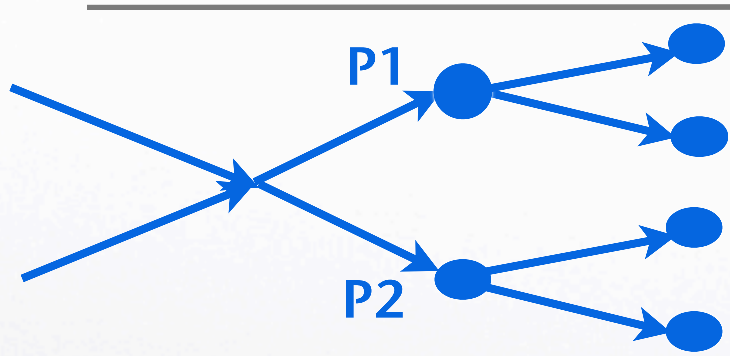


$$m_{\mathrm{P}}^2 = m_{\mathrm{dm}}^2 + m_X^2 + 2\left(E_T^X E_T^{\mathrm{dm}} \cosh(\Delta y) - \mathbf{p}_T^X \cdot \mathbf{p}_T^{\mathrm{dm}}\right)$$

$$m_T^2 = m_{\mathrm{dm}}^2 + m_X^2 + 2\left(E_T^X E_T^{\mathrm{dm}} - \mathbf{p}_T^X \cdot \mathbf{p}_T^{\mathrm{dm}}\right)$$

$$\boxed{m_T \le m_{\mathrm{P}}}$$

in a 2-body decay, the transverse mass is bounded from above by the mass of the parent particle



- pair-produce parent particles of the same mass
- if we could measure everything, then we would get two m_T 's per event; both would be bounded by m_{P}, so $\max(m_T^1, m_T^2)$ is also bounded by m_{P}

- suppose we don't know the pT of each dm particle separately, but we measure p_T^{miss} = the sum of the two dm particle pT's
- consider all possible decompositions of p_T^{miss} into two pT's; one of these decompositions is the correct one. now define:

$$m_{T2}^2 = \min_{p_T^{(1)} + p_T^{(2)} = p_T^{\mathrm{miss}}} \left[\max\left[m_T^2(m_{\mathrm{dm}}; p_T^{(1)}), m_T^2(m_{\mathrm{dm}}; p_T^{(2)})\right]\right]$$

$$\boxed{m_{T2} \le m_{\mathrm{P}}}$$

Stransverse Mass mT2

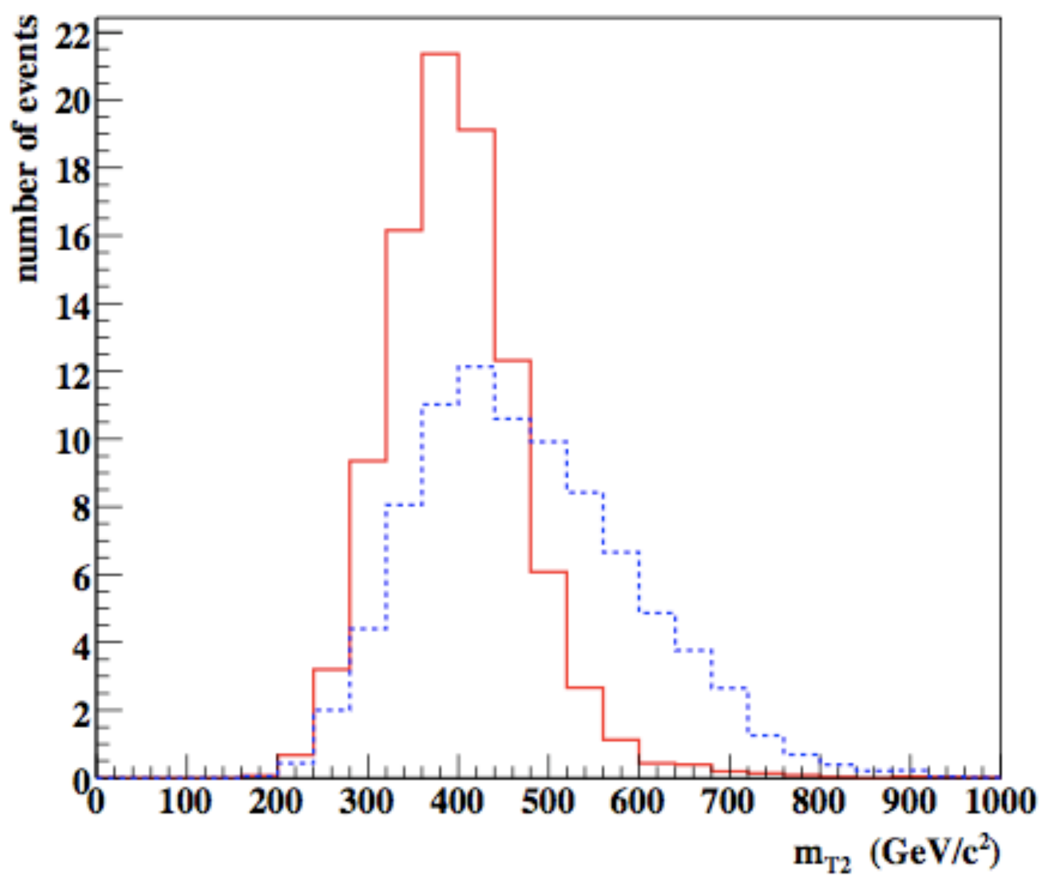


FIG. 35: Comparison of the m_{T2} distribution of the CS6 "data" (solid red line) to that of the theory model LM2p (dashed blue line) for 100 pb^{-1}. Here m_{T2} is computed using the LSP mass of the theory model LM2p.

- Compute the variable according to the "model" for both data and model (to fix the LSP mass assumption)
- Use a large and inclusive bin definition as for the other variables

$$r(mT2\text{-}X)\text{-}MODEL = \frac{Nev(mT2>X)}{Nev}$$

r(mT2-300)
r(mT2-400)
r(mT2-500)
r(mT2-600)

$$r(mT2\text{-}X/Y)\text{-}MODEL = \frac{Nev(mT2>X)}{Nev(mT2>Y)}$$

(X>Y)

r(mT2-600/300)
r(mT2-600/400)
r(mT2-600/500)
r(mT2-500/300)
r(mT2-500/400)
r(mT2-400/300)

Hemisphere Separation

We use an algorithm that attempts the separation of reconstructed objects into two hemispheres, corresponding to the decay chains of the two heavy objects

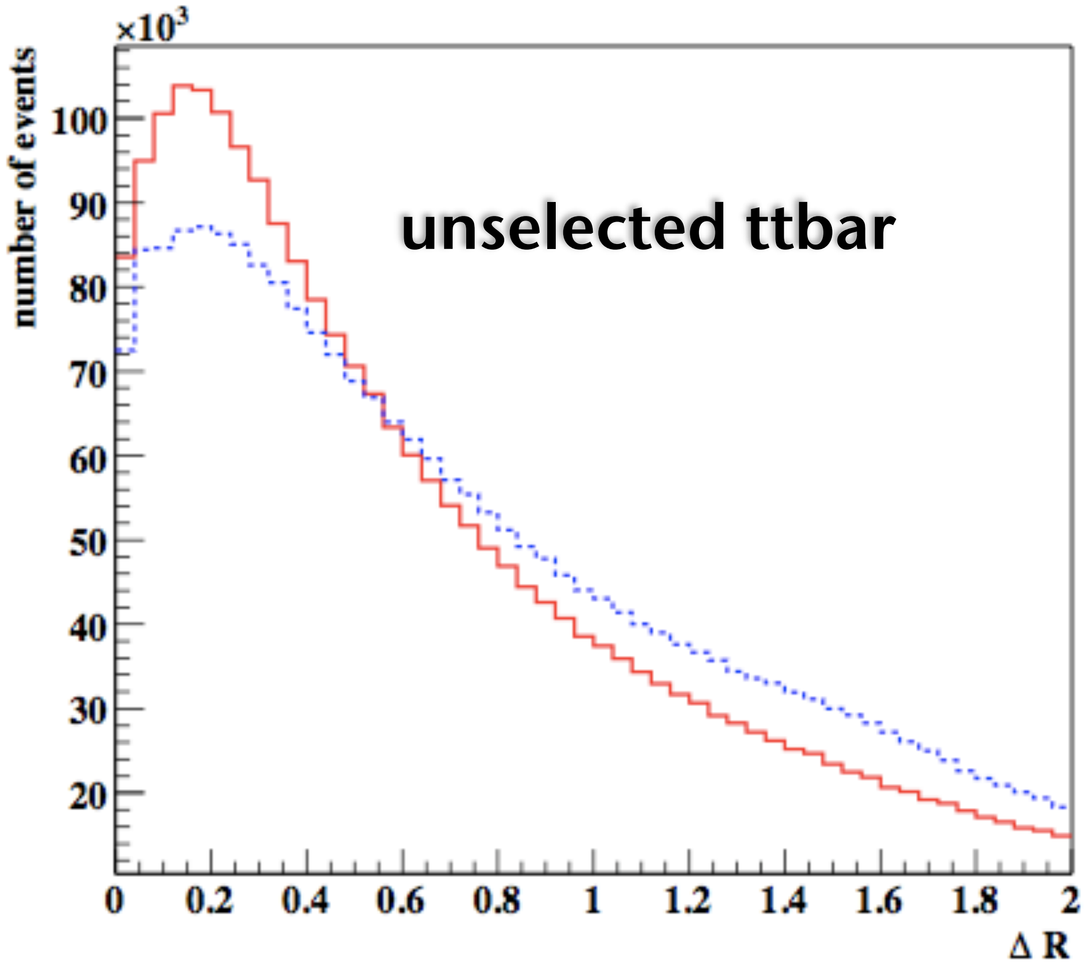


FIG. 16: The distribution of the ΔR separation between the η-ϕ direction of the parent top quark and the reconstructed hemisphere axis. This is from 3,000,000 `Pythia` $t\bar{t}$ events with no selection. The solid red line is for the leading hemisphere, while the dashed blue line is for the second hemisphere.

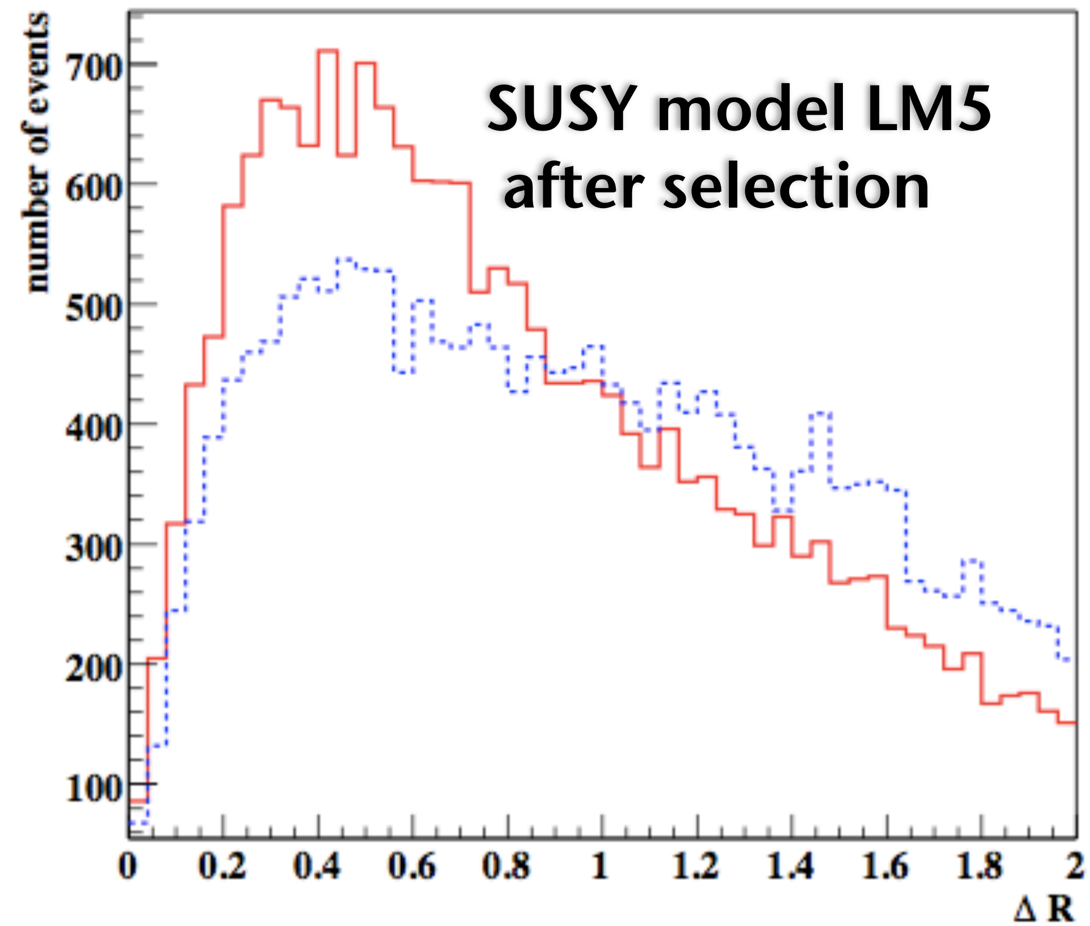


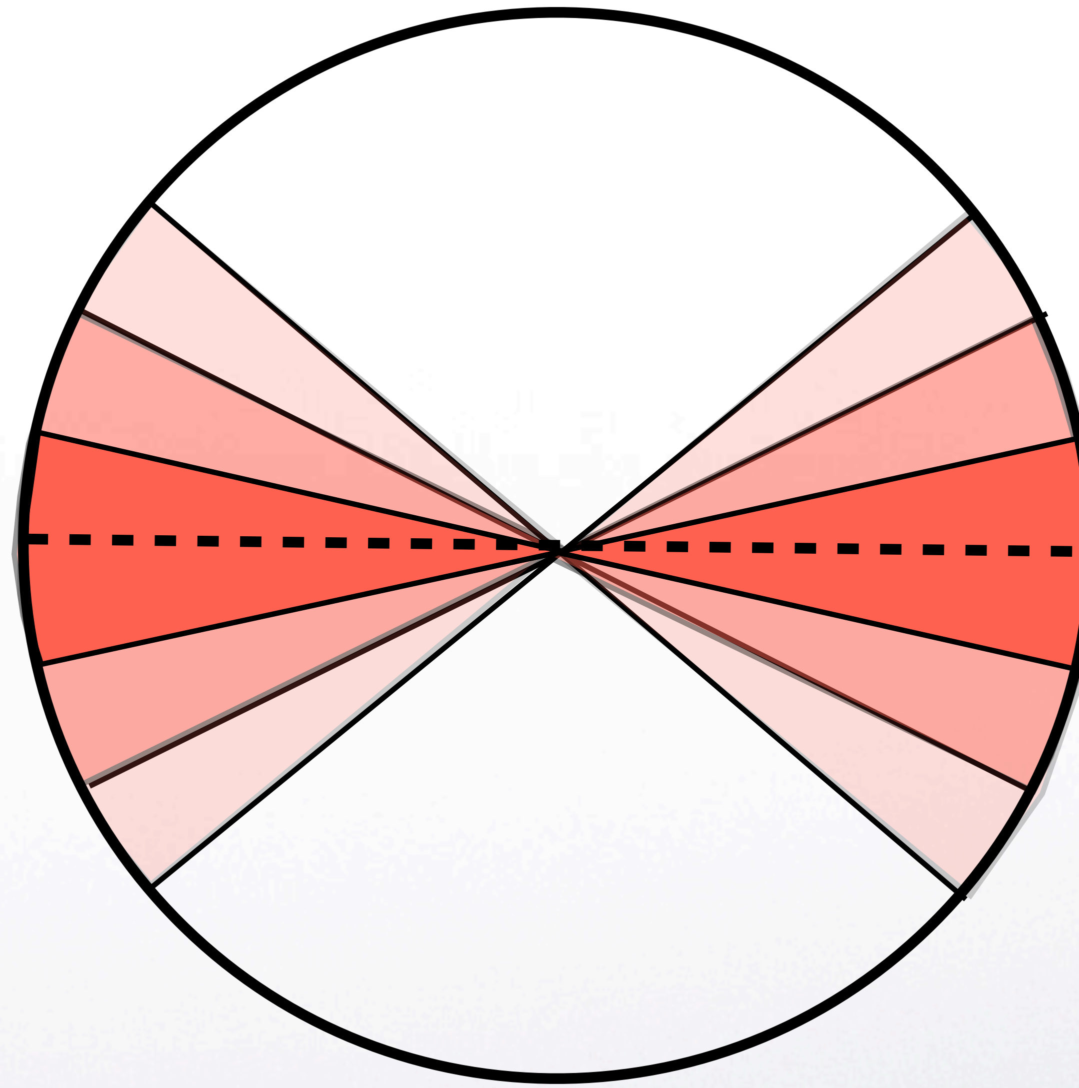
FIG. 15: The distribution of the ΔR separation between the η-ϕ direction of the parent superpartner and the reconstructed hemisphere axis. This is from 24,667 events of model LM5 passing our selection. The solid red line is for the leading hemisphere, while the dashed blue line is for the second hemisphere.

Topology of the Event

Once the hemispheres are defined, we use track-counting variables to characterize the topology of the event

- We consider slices of transverse plane around the hemisphere direction, each region delimited by +/- α (α =15°,30°,...,90°)

- we count the number of tracks N^n_{trk} in each slice



Summed over the two hemispheres

$$r(\text{nt Cone } \alpha) = \frac{\text{Nev}(\geq n \text{ tracks between } +/- \alpha)}{\text{Nev}}$$

Difference over the two hemispheres

$$r(\text{Dnt Cone } \alpha) = \frac{\text{Nev}(\Delta(\text{tracks}) \geq n \text{ between } +/- \alpha)}{\text{Nev}}$$

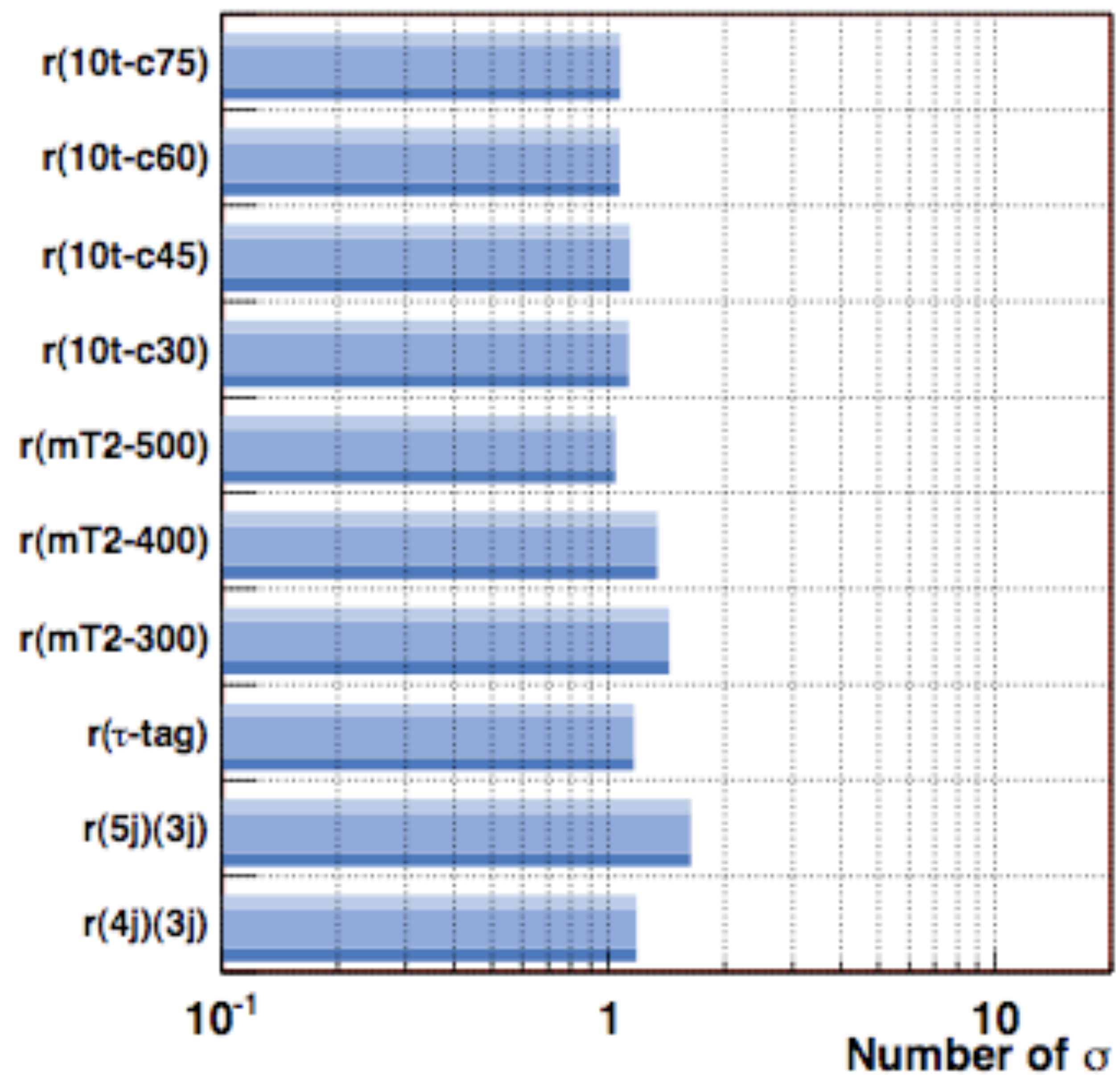
Statistical Definition of LL separation

•Two models are considered as input. One of the two plays the role of the "data", the other being a possible (but wrong) explanation of the excess

•The model is considered a look-alike of the "data" if the number of predicted and observed events are within the 2sigma (errors discussed in the next slide)

•If the model is a look-alike of the "data", each discriminating variable is computed for both the data and the model

•The pull of each variable is considered and the largest observed deviation is taken as the statistical discrimination of the model (no double counting of differences)



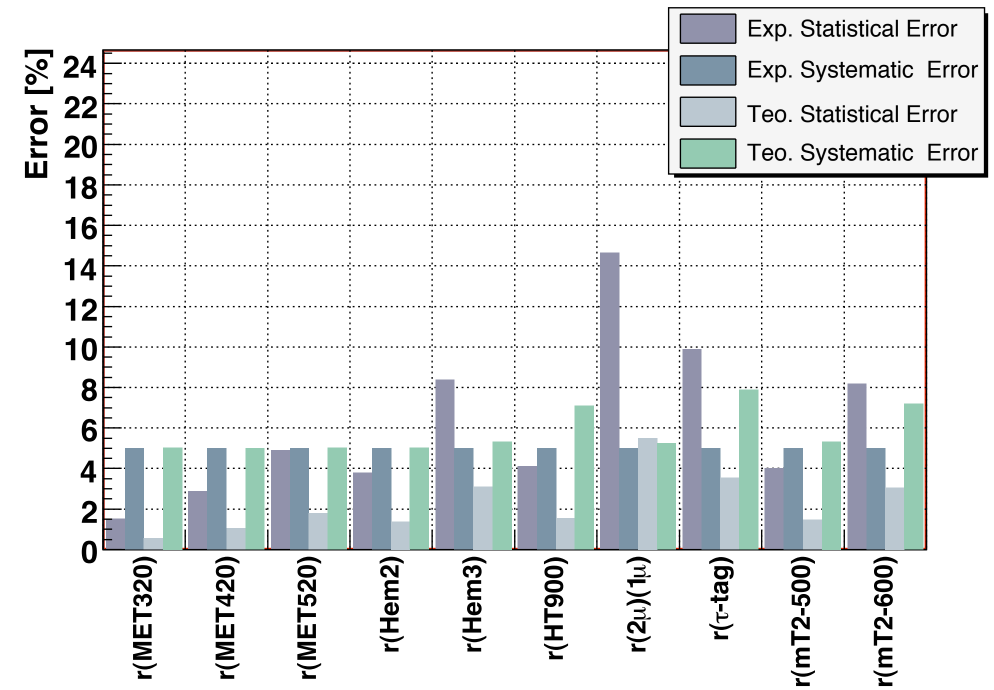
The error associated to a comparison

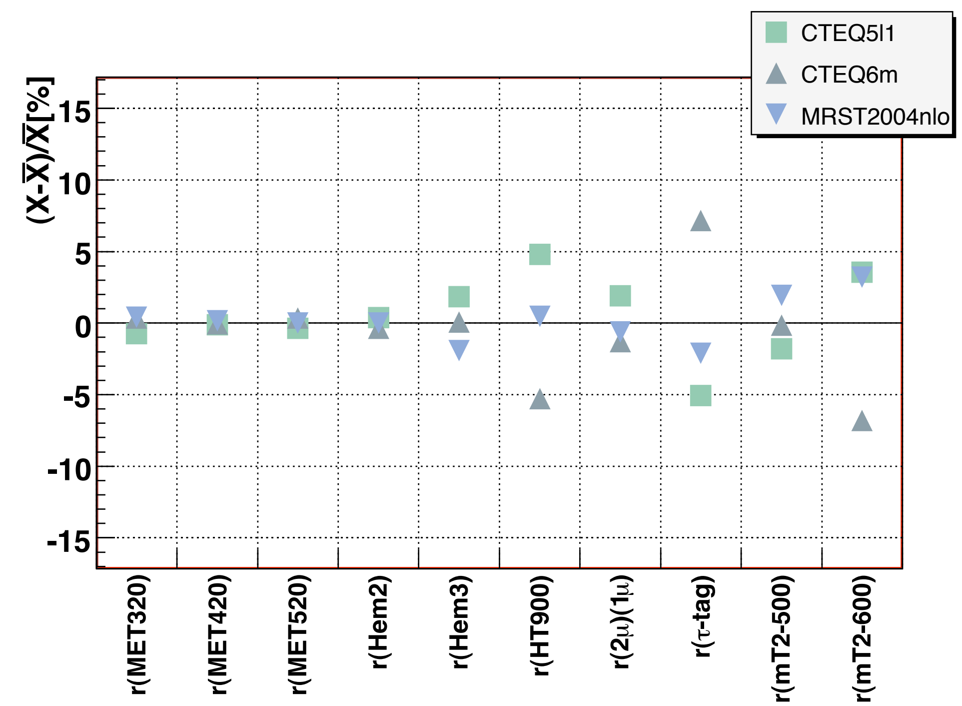
- experimental statistical uncertainty: the Poisson error on the number of "events" in the inclusive counts that define a given ratio, after rescaling to 100 pb-1.

- theoretical statistical uncertainty: the (small) Monte Carlo statistical error from simulating a finite number of events

- experimental systematic uncertainty: estimated as 5% for the ratios, from detector effects that do not cancel (or cancel in part) in the ratios

- theoretical systematic uncertainty: pdf errors very crudely estimated directly for each observable by using three different pdfs and looking at the spread in values; assume additional 5% relative QCD scale uncertainty in the ratios





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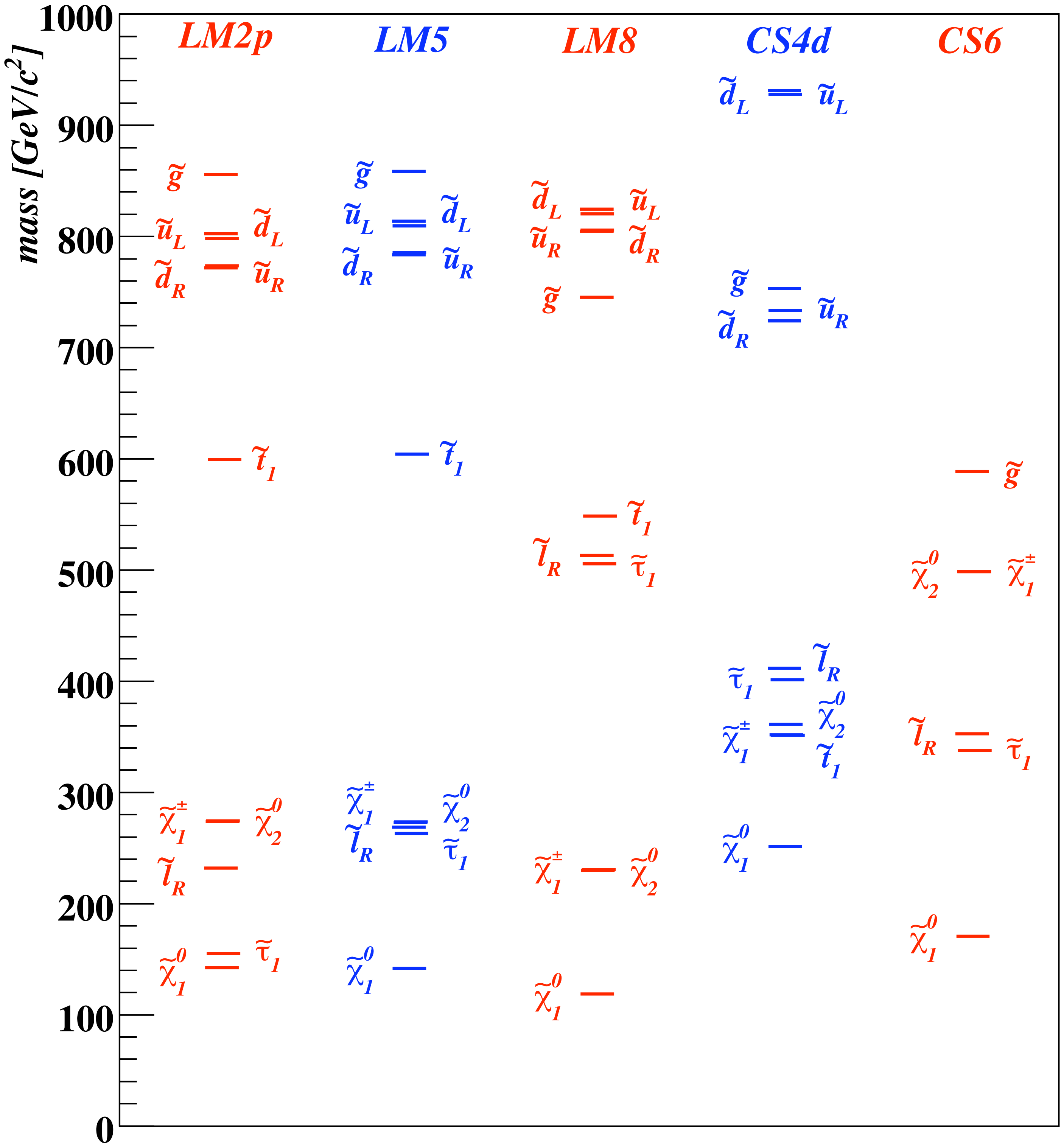
MET discovery scenario with ~100 pb-1

- we will assume that a >5 sigma excess is observed in the reference >=3 Jets+MET analysis with the first 100 pb-1 or less of understood LHC data
- this should be the case if there is a BSM source of large missing energy + energetic jets with a cross section of at least a few pb.
- we want to design a strategy to rapidly narrow the list of candidate theories at, or close to, the moment of discovery
- we want to do this taking into account uncertainties of the LHC experiments during the 100 pb-1 era
- We give two examples of the analysis for 14 TeV data
- We use the analysis as a tool to scan the mSugra and associate to each point a probability of describing the data

Group I

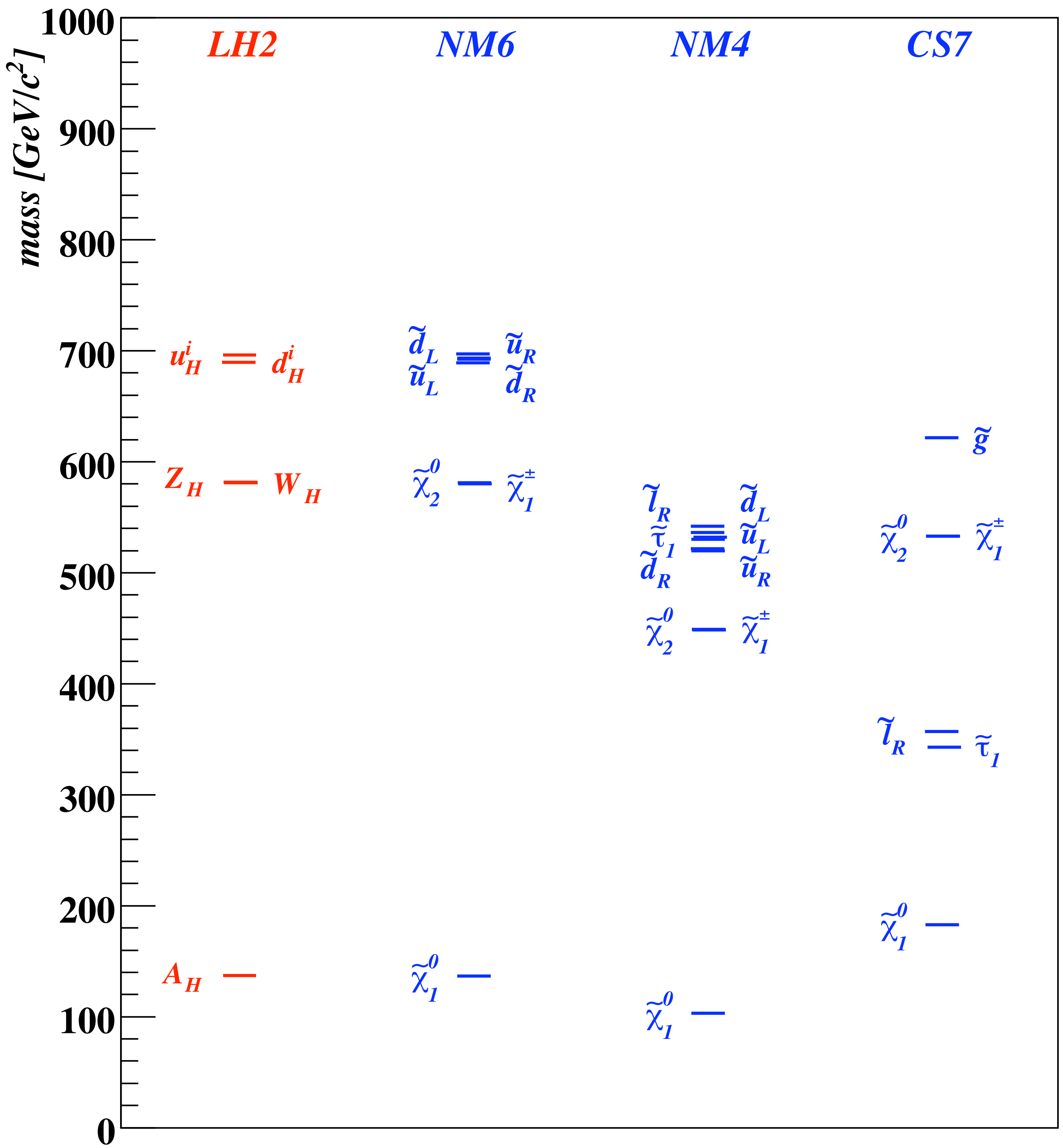


- Group 1 consists of 6 SUSY models
- all 6 models are look-alikes of our MET analysis, producing ~200 signal events in 100 pb-1
- the first three are mSUGRA SUSY models
- CS4d is a "compressed SUSY" model
- CS6 is a general MSSM model with a light gluino and heavy squarks

Results: SUSY vs SUSY

- the best discriminators vary depending on the models
- for 100 pb-1, we get >5 sigma discrimination in at least one ratio for 9 out of 26 pairwise comparisons
- for 1000 pb-1, we get >5 sigma discrimination in at least one ratio for 23 out of 26 pairwise comparisons
- worst case: LM2p vs LM5; best discriminator after 1000 pb-1 is the tau ratio, 3.1 sigma
- second worst case: CS4d vs LM8; best discriminator after 1000 pb-1 is the jet ratio r(5j)(3j), 4.2 sigma

Group2



- •Group 2 consists of 3 SUSY models and one non-SUSY
- •LH2 is a Little Higgs with T-parity model
- •LH2, NM4, and CS7 are look-alikes of our MET analysis, producing ~100 signal events in 100 pb-1
- •SUSY model NM6 has the same spectrum as non-SUSY LH2, modulo a 2 TeV gluino
- •However NM6 turns out NOT to be a look-alike of LH2 in our analysis

Results: SUSY vs non-SUSY

the mT2 ratios for LH2 are larger, reflecting the fact that the parent particles in LH2 are ~700 GeV vs ~550 GeV in NM4

however the Meff and HT ratios in LH2 are smaller; this is from the spin differences in the matrix elements, and enhanced production in NM4 from t-channel exchange of the very heavy gluino

LH2 vs. NM4 [100 pb^{-1}]			
Variable	LH2	NM4	Separation
MET			
r(mT2-500)	0.16	0.05	4.87
r(mT2-400)	0.44	0.21	4.84
r(mT2-300)	0.75	0.54	3.49
r(Meff1400)	0.11	0.25	2.99
r(mT2-500/300)	0.21	0.09	2.98
r(M1400)	0.07	0.19	2.69
r(mT2-400/300)	0.58	0.40	2.48
r(HT900)	0.13	0.24	2.34
r(MET420)	0.48	0.37	2.00
r(mT2-500/400)	0.36	0.22	1.47

Table 21. Best discriminating ratios in the MET box, with separations in units of σ, for the comparison of LH2 vs.NM4, taking LH2 as the "data", assuming an integrated luminosity of 100 pb^{-1}.

LH2 vs. NM4 [1000 pb^{-1}]			
Variable	LH2	NM4	Separation
MET			
r(mT2-500)	0.16	0.05	14.11
r(mT2-400)	0.44	0.21	11.13
r(mT2-500/300)	0.21	0.09	8.52
r(Meff1400)	0.11	0.25	7.24
r(M1400)	0.07	0.19	6.57
r(mT2-300)	0.75	0.54	6.26
r(mT2-400/300)	0.58	0.40	5.77
r(HT900)	0.13	0.24	5.67
r(M1800)	0.02	0.07	4.82
r(MET420)	0.48	0.37	4.32

Table 36. Best discriminating ratios in the MET box, with separations in units of σ, for the comparison of LH2 vs.NM4, taking LH2 as the "data", assuming an integrated luminosity of 1000 pb^{-1}.

Results: SUSY vs non-SUSY

LH2 versus CS7: though a look-alike of LH2, CS7 is almost 100% gluino pair production, which is qualitatively quite different

Meff and HT do not discriminate, but mT2 does; also the CS7 gluino events have higher jet multiplicity and are more symmetrical between hemispheres than the LH2 "data"

LH2 vs. CS7 [100 pb^{-1}]			
Variable	LH2	CS7	Separation
MET			
r(mT2-500)	0.27	0.08	6.68
r(MET420)	0.48	0.20	6.49
r(MET520)	0.21	0.07	5.06
r(MET320)	0.78	0.53	4.29
r(mT2-500/300)	0.32	0.12	4.24
r(4j)(3j)	0.36	0.61	4.04
r(mT2-400)	0.63	0.40	4.00
r(mT2-300)	0.85	0.62	3.55
r(mT2-500/400)	0.43	0.19	3.52
r(Hem1)	0.79	0.63	2.59

Table 22. Best discriminating ratios in the MET box, with separations in units of σ, for the comparison of LH2 vs.CS7, taking LH2 as the "data", assuming an integrated luminosity of 100 pb^{-1}.

LH2 vs. CS7 [1000 pb^{-1}]			
Variable	LH2	CS7	Separation
MET			
r(mT2-500)	0.27	0.08	18.87
r(MET420)	0.48	0.20	16.73
r(MET520)	0.21	0.07	14.49
r(mT2-600)	0.05	0.01	14.11
r(mT2-500/300)	0.32	0.12	11.17
r(mT2-500/400)	0.43	0.19	9.77
r(mT2-600/300)	0.06	0.01	9.77
r(mT2-400)	0.63	0.40	8.46
r(MET320)	0.78	0.53	8.17

Table 38. Best discriminating ratios in the MET box, with separations in units of σ, for the comparison of LH2 vs.CS7, taking LH2 as the "data", assuming an integrated luminosity of 1000 pb^{-1}.

Results: SUSY vs non-SUSY

did we prove that the signal was non-SUSY?

- obviously not, but we are not attempting this
- we are looking for guidance about the underlying theory model at, or close to, the moment of discovery
- what we have shown is that part of this guidance can trace back to the spins of the parent partners in the 2->2 process
- mT2 is very helpful is this regard, because to first approximation the mT2 ratios don't care about the spin of the parents, while other kinematic observables do care

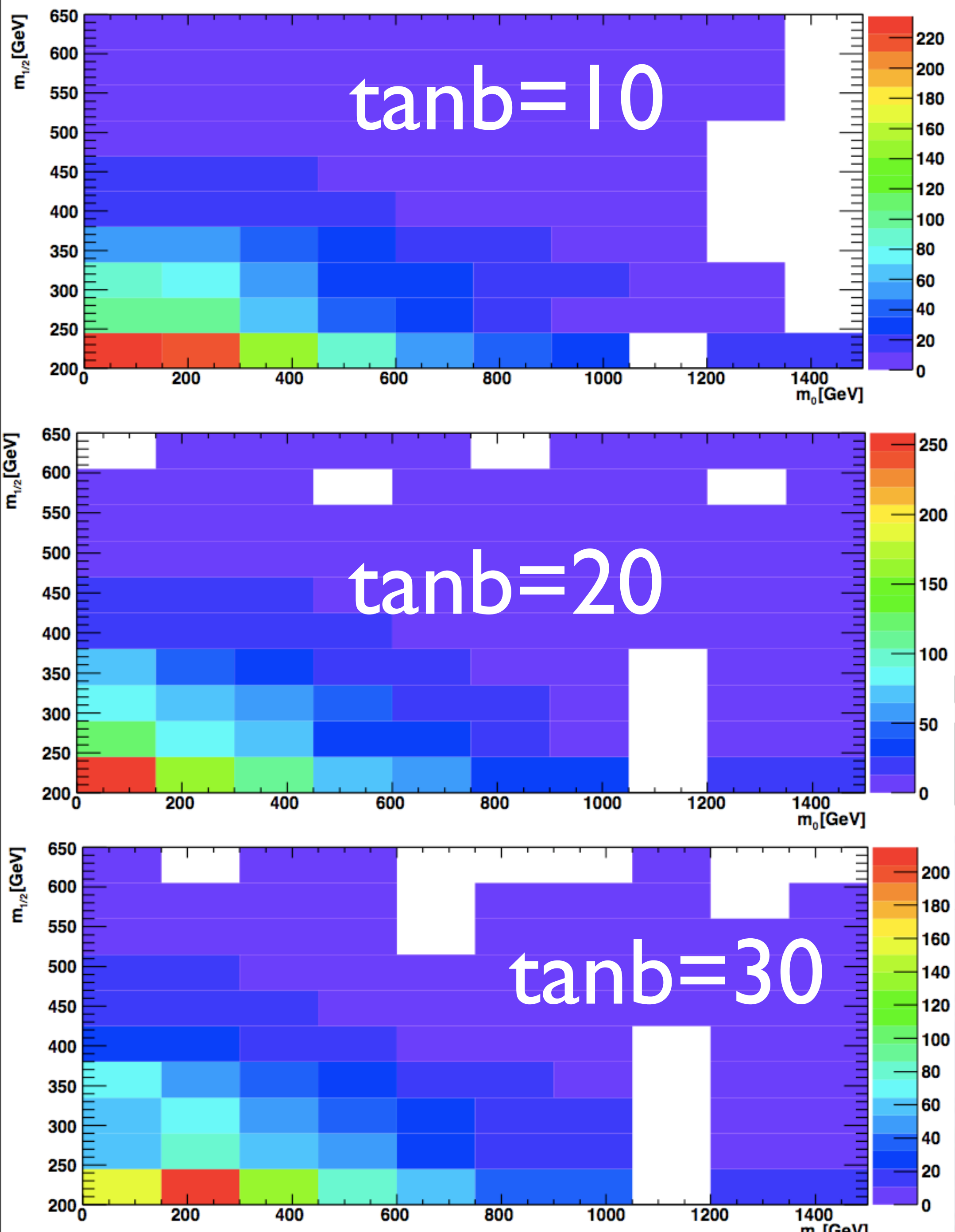
General Comments

- generally the results are very encouraging, especially considering that we aren't using leptons
- the real power comes from having many different robust observables, sensitive to different features of the models
- to do this right, we need a unified validated platform for simulating the theory models
- we need to populate the theory space by incorporating many more models on the unified platform

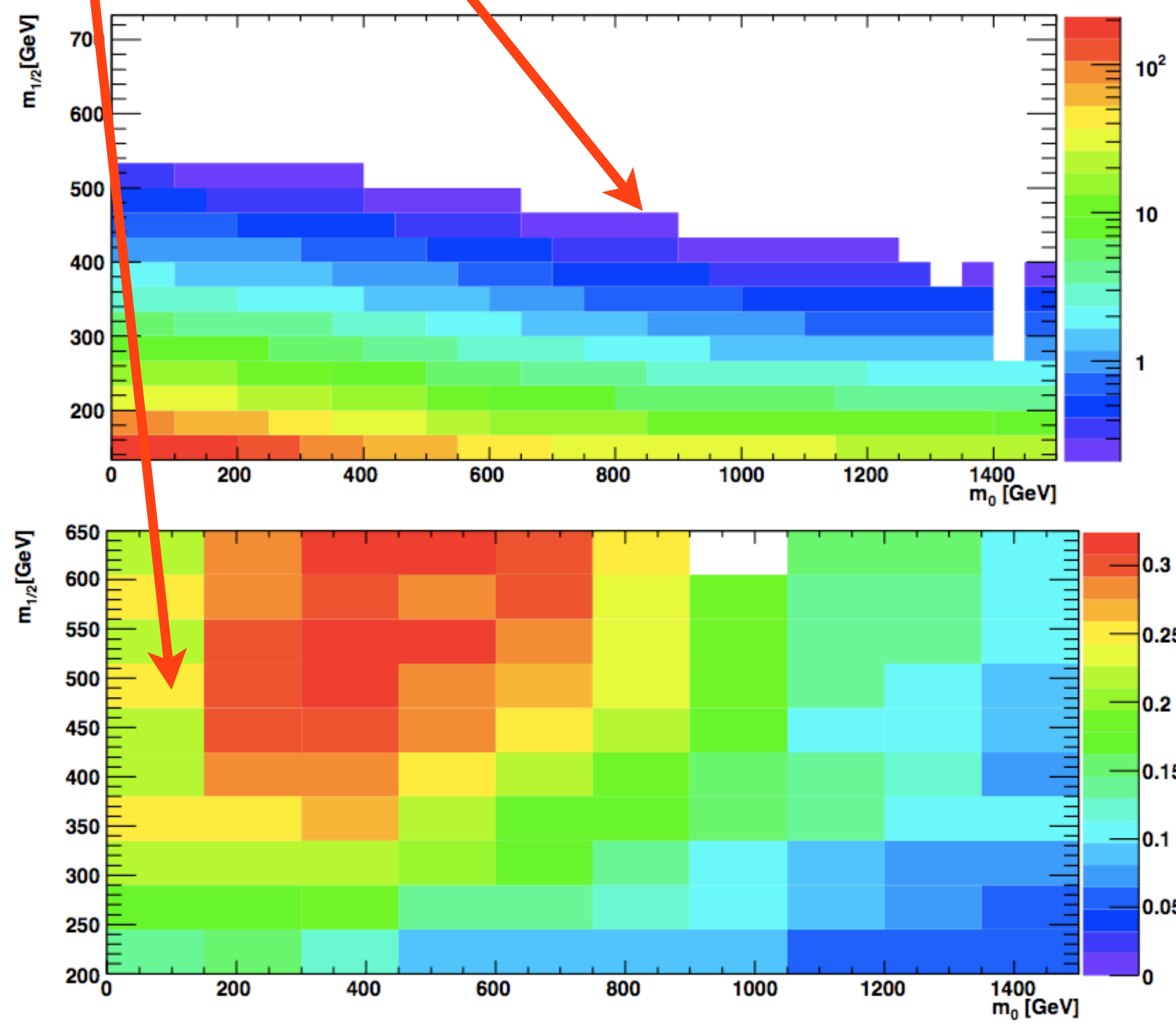
Outline

- An early LHC discovery and the inverse problem
- The Look-Alikes: different models looking the same in a detector
- The ingredients for a Look-Alikes analysis on early discovery:
    - A data analysis ("the Box")
    - A detector simulation
    - A set of discriminating robust variables
    - A statistical definition of the discrimination
- 14 TeV results:
    - LL [illegible] discrimination
    - SUSY vs non-SUSY models
- **10 TeV results: the LL analysis as a tool to scan parameter space**
- The next step: NP diagnostic for LHC, a.k.a. the NP Doctor House

Expected Yields



Nev = eff x L x σ



All the pointes predicting the wrong Nev (within 3sigma) are considered as excluded. But what about the others?

The mSugra LL Groups @10TeV

M01Group100	m0	75	m12	267.5	tanb 10	Nev=100	xsec = 8.6
M02Group100	m0	75	m12	267.5	tanb 20	Nev=119	xsec = 8.7
M03Group100	m0	75	m12	312.5	tanb 10	Nev= 84	xsec = 4.8
M04Group100	m0	75	m12	312.5	tanb 20	Nev= 85	xsec = 4.8
M05Group100	m0	225	m12	267.5	tanb 10	Nev=102	xsec = 7.0
M06Group100	m0	375	m12	222.5	tanb 20	Nev=112	xsec = 17.1
M07Group100	m0	525	m12	222.5	tanb 10	Nev= 88	xsec = 11.6
M08Group100	m0	525	m12	222.5	tanb 30	Nev= 83	xsec = 11.5

mSugra LL points for 100 events observed on data

M01Group150	m0	75	m12	222.5	tanb 30	Nev=152	xsec = 35.4
M02Group150	m0	225	m12	222.5	tanb 20	Nev=163	xsec = 25.5
M03Group150	m0	375	m12	222.5	tanb 10	Nev=152	xsec = 17.2
M04Group150	m0	375	m12	222.5	tanb 30	Nev=129	xsec = 17.2

mSugra LL points for 150 events observed on data

M01Group200	m0	225	m12	222.5	tanb 10	Nev=213	xsec = 25.6
M02Group200	m0	225	m12	222.5	tanb 30	Nev=215	xsec = 25.6

mSugra LL points for 200 events observed on data

Results Group100

Model	Separation in 100pb^{-1}	Variable	Box
M02Group100	3.3	r(10t Cone30)	Muon
M03Group100	2.3	r(DiJet)(MET)	DiJet
M04Group100	2.7	r(5j)(3j)	Muon
M05Group100	2.9	r(D20 Cone75)	MET
M06Group100	4.0	r(20t Cone75)	DiJet
M07Group100	2.4	r(20t Cone30)	TriJet
M08Group100	2.6	r(10t Cone60)	DiJet

mT2 not included (for technical reasons)

Good separation for all the points already with 100pb-1

Results Group150 and Group200

Model	Separation in 100pb^{-1}	Variable	Box
M02Group150	2.8	r(Muon)(MET)	Muon
M03Group150	3.5	r(Muon)(MET)	DiJet
M04Group150	3.5	r(M1400)	Muon

Model	Separation in 100pb^{-1}	Variable	Box
M01Group200	2.3	r(20t Cone30)	Muon

Outline

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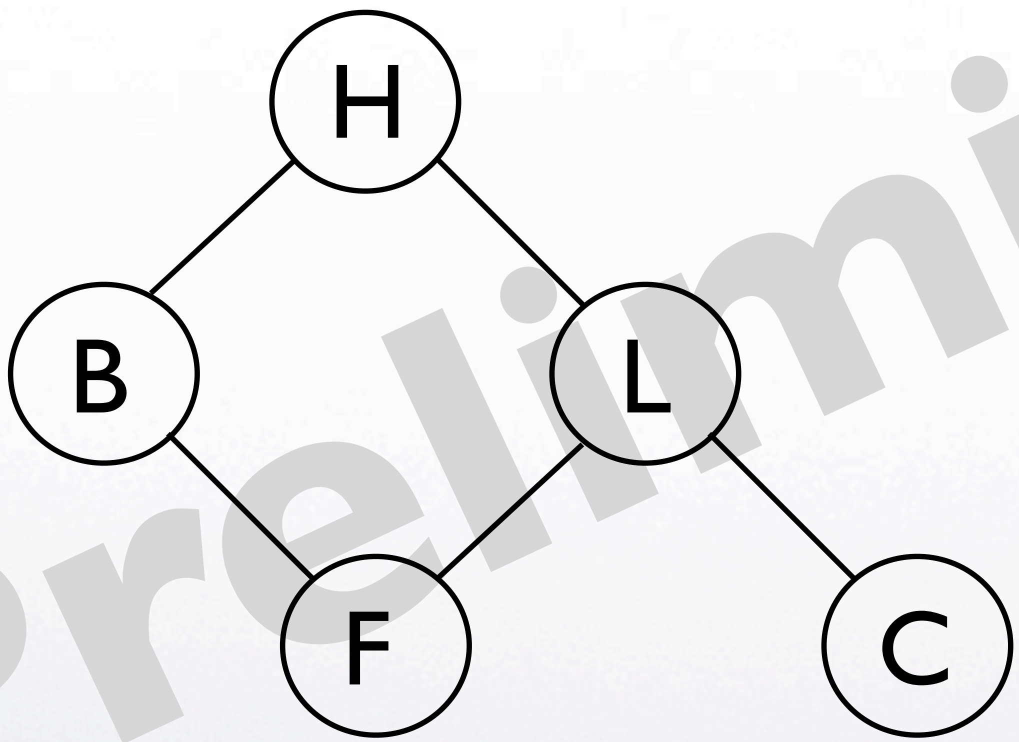
Solving the inverse problem is very similar to a medical diagnosis

- For a given disease, previous studies allow to quantify the probability that a medical test gives some result
- The tests can be performed on the patient



H: history of smoking?
B: bronchitis?
L: Lung Cancer?
F: Fatigue?
C: Chest X-ray output

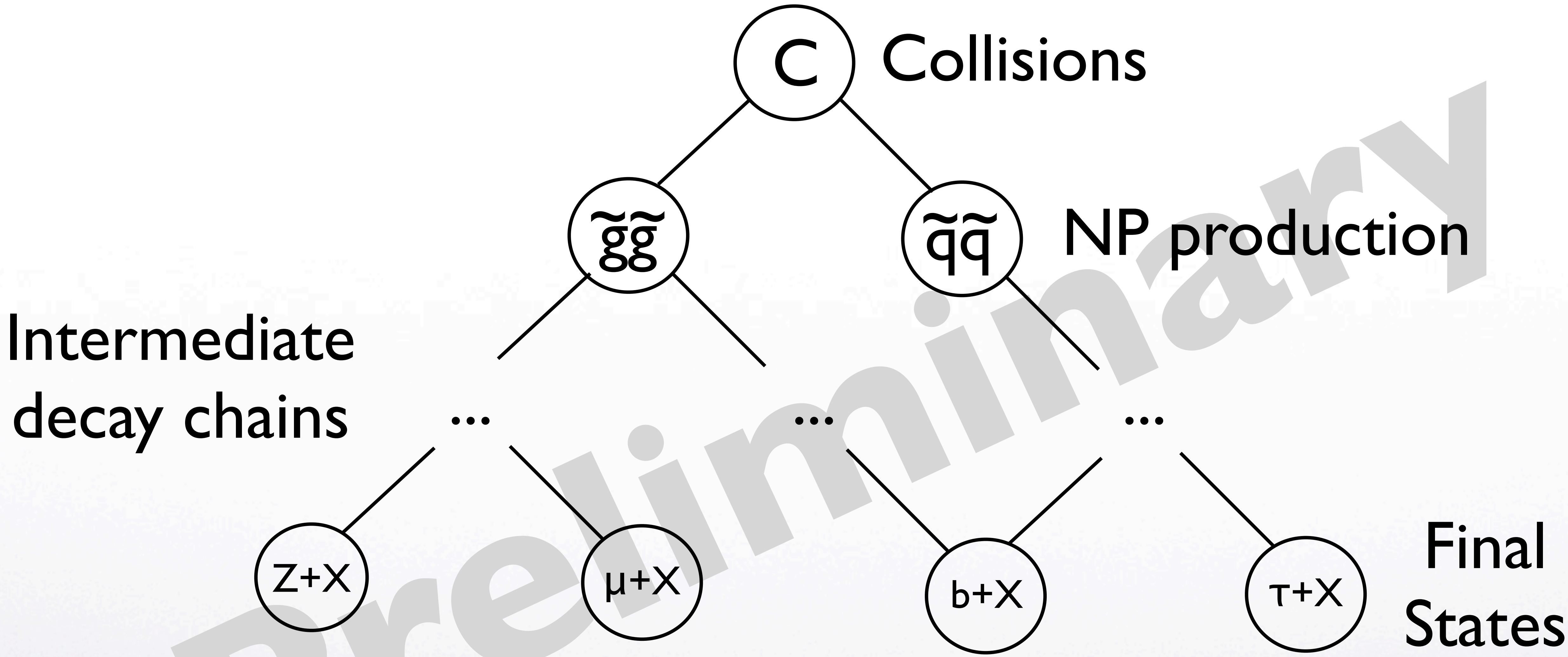
Neapolitan 2004

- Bayesian networks can be used to invert the casual relation and deduce the disease from the output of the tests

Bayesian Network and LHC inverse problem

- The Markov condition: given a network G and a set of probabilities P, the system (G,P) satisfies the Markov condition if any variable X in G is conditionally independent on the variable it does not come from, given the set of all the parents
- Causality is a sufficient condition for (G,P) to satisfy the Markov condition, provided the fact that all the casual connections are explicit in the network
- For a casual network G the probability P are well approximated by the frequencies
- In our case
  - The relative BR in the decay of NP particles gives the set of probabilities P
  - For a given decay chain, one can define the probability of producing a given final state
  - By specifying all the possibilities, one can define a bayesian network (G,P)
  - By measuring the relative fractions of the final states on data (as in our LL analysis) one can associate a probability to any model

A Toy Example



- There is no limit to the complexity of the network
- SM background can be incorporated as new branching of the network (provided the understanding of detector effects) or subtracted
- OSET approach can be incorporated in this scheme

LL analysis with and without BN

- The approach is very similar to our LL analysis
- In LL analysis, the maximal separation is taken not to over-count the differences
- In a Bayesian Network the correlations are taken into account by the causal connections
- The approach naturally incorporates the SM as part of the Signal, rather than the background (but it can be taken out if data are background subtracted)
- The approach can benefit from advanced tools developed in other fields
- The approach can be generalized to extend effective approaches (like OSET)
- The probability output can be used as a statistical weight to associate to a given point of the parameter space. This allows to connect the LL approach to the indirect bounds from EWfit, UTfit, and other observables (g-2, rare B decays, etc)
- Work in progress, first results soon

Conclusions

- The LL analysis is an interesting tool to disentangle the underlying theory from impostors in case of an early discovery
- By exploiting all the feature of an excess sample, it allows to guess the features of the underlying theory through a “20-questions” approach
- The approach can be used to integrate the first LHC results with the NP parameter scans based on indirect constraints
- A generalization of the approach, based on Bayesian Networks, is under development. More complicated, but more powerful (since correlations are taken into account)