Characterization of Early Excesses Using Simplified Models

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Scenario:

Discovery of solid excesses in channels involving jets, leptons and missing energy

How characterize/present these excesses?

Traditional approaches to characterizing excesses

- Constrained models (mSUGRA, mGMSB,...)
  - Difficult to compare other models, parameter correlations (probably) not in data
- Full or restricted MSSM / other models
  - Many flat/unconstrained directions, non-transparent parameter relations, spurious results due to statistical fluctuations. Risk for duplication of efforts
- Unconstrained bottom-up approaches
  - Computationally costly, risk spurious results from statistics

Our proposal

Small set of minimal “simplified models” that

- Are “SUSY-like”: SM particle partners, parity, neutral “LSP” (SUSY, UED, LH, RS w/ parity)
- Capture most important SUSY-like characteristics
- Minimize number of parameters (reduce flat directions/spurious results)
- Allow comparison of theory to data without detector effects/SM backgrounds/details of analysis
- Allow qualitative characterization of deviations and provide hints for model-building

Questions for first excesses

1) Which colored particles dominate production?

2) Which color-singlet decay channels are present, and in which fractions?

3) How b-rich are the events?

Possible to just read off exp. plots?

Questions for first excesses

1) Which colored particles dominate production?

- "quark partners ↔ 2 jets, gluon partners ↔ 4 jets, associated ↔ 3 jets" – but depends strongly on mass hierarchies
- Large effects of QCD ISR/FSR radiation
- Need jet count data and distributions – difficult experimentally and simulation-wise

Questions for first excesses

2) Which color-singlet decay channels are present, and in which fractions?

- Leptons “easy”, but must account for different jet/MET cuts in different signal regions, detector efficiencies, SM backgrounds
- Difficult to distinguish W and lν

Questions for first excesses

3) How b-rich are the events?

- Proportion of b-tagged events to untagged events – but tagging efficiency/mistag rate depend on number of jets in event, p_T and rapidity etc.

Questions for first excesses

So answer is NO –

Not possible to read off exp. plots
– even for these “simple” questions!

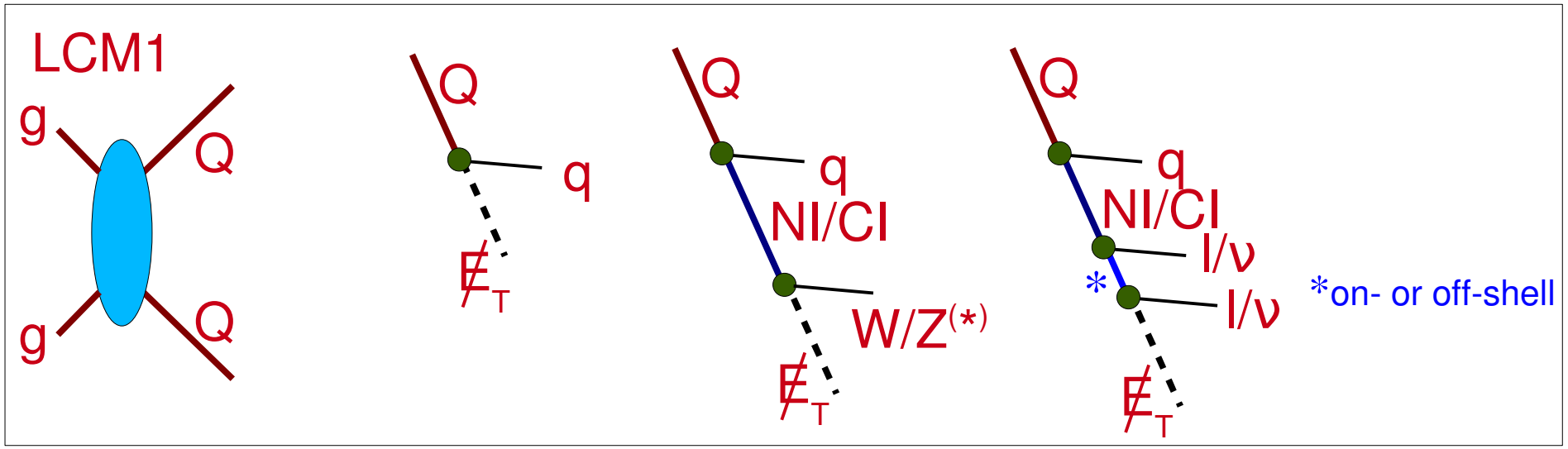
4 simplified models

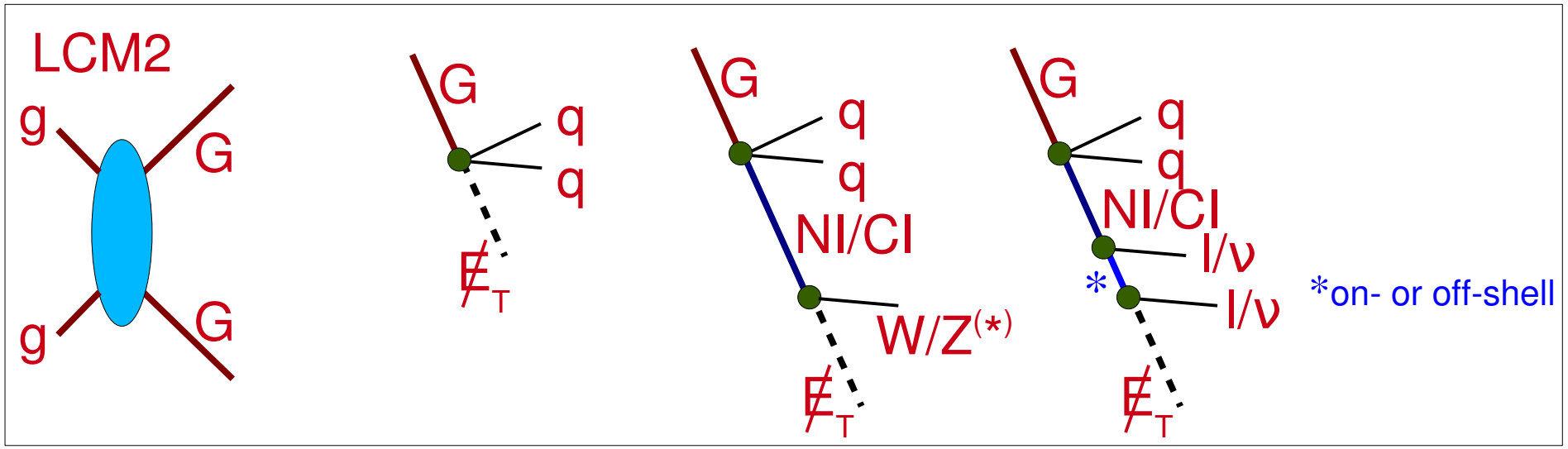
- 2 lepton cascade models
  - to study leptonic decays
- 2 heavy flavor models
  - to study heavy flavor content

Separate comparison for lepton and heavy flavor properties to keep models and fits simple

4 simplified models

- Lepton cascade models



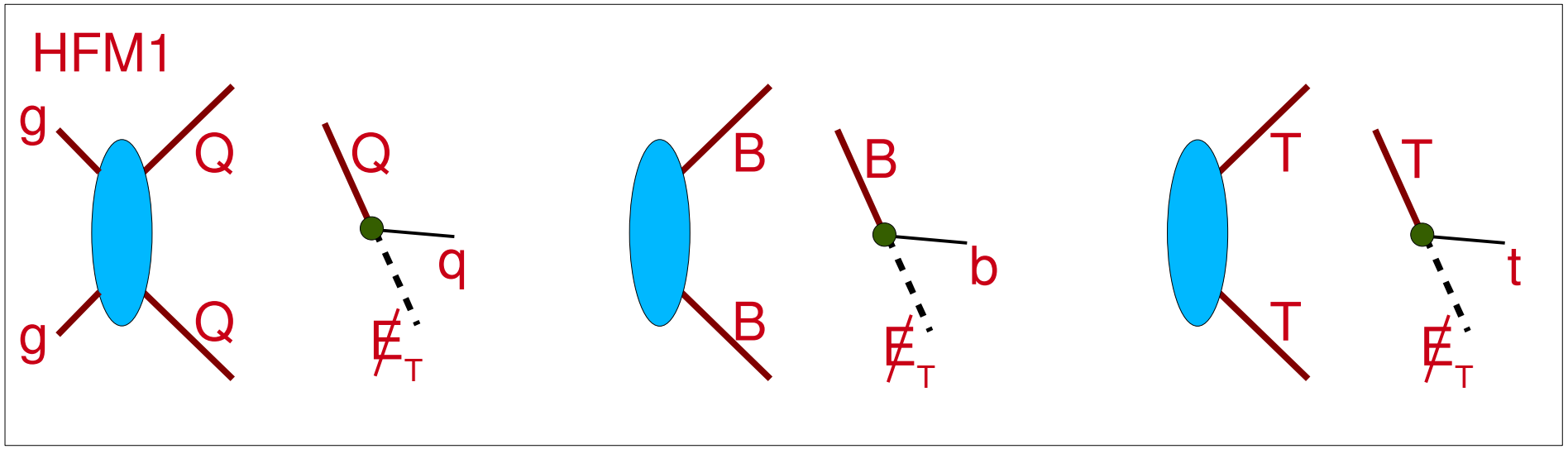


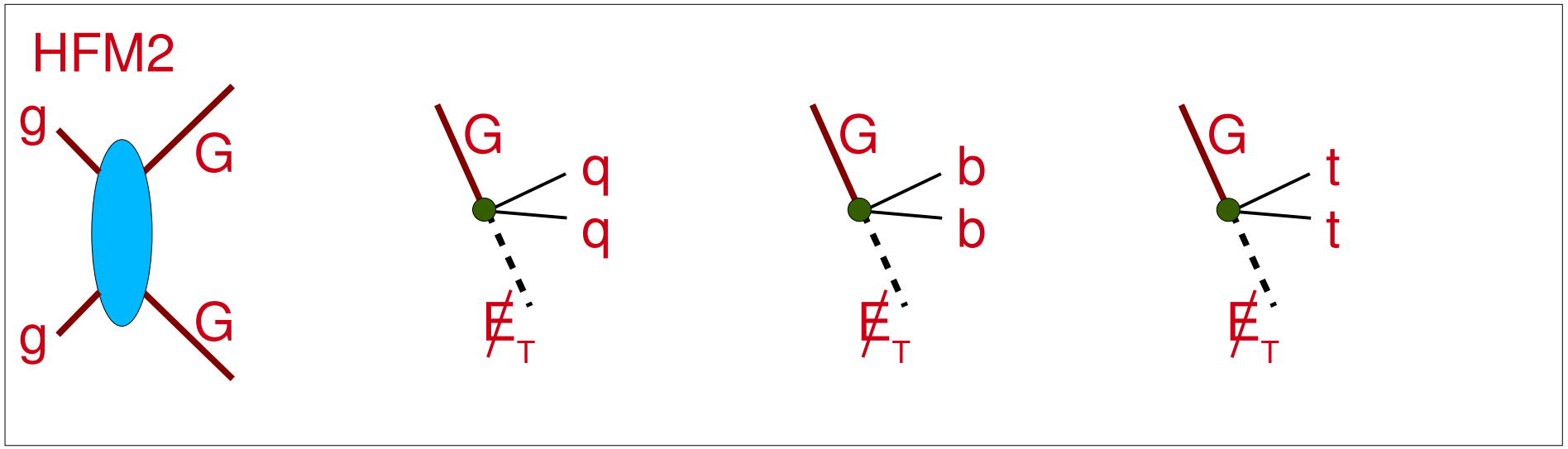
4 simplified models

- Lepton cascade models
  - LCM1 purely quark-partner initiated
  - LCM2 purely gluon-partner initiated
  - 3(-4) masses, 1 cross section, 4 BRs
  - Masses from kinematic distributions, xsec/BR from lepton counts (max. 4-5 parameters in fit)
  - Fits to extremes: LCM1 / 2; only W / only lν
  - Publish diagnostics plots (lepton counts, jet counts, kinematic distributions)

4 simplified models

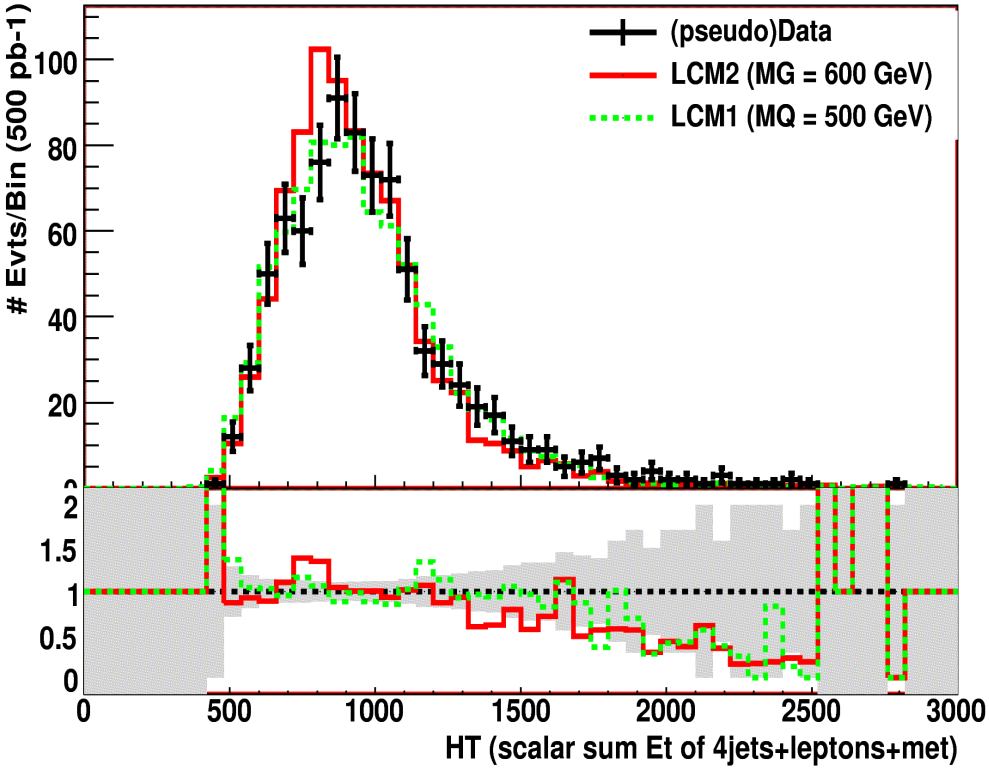
- Heavy flavor models



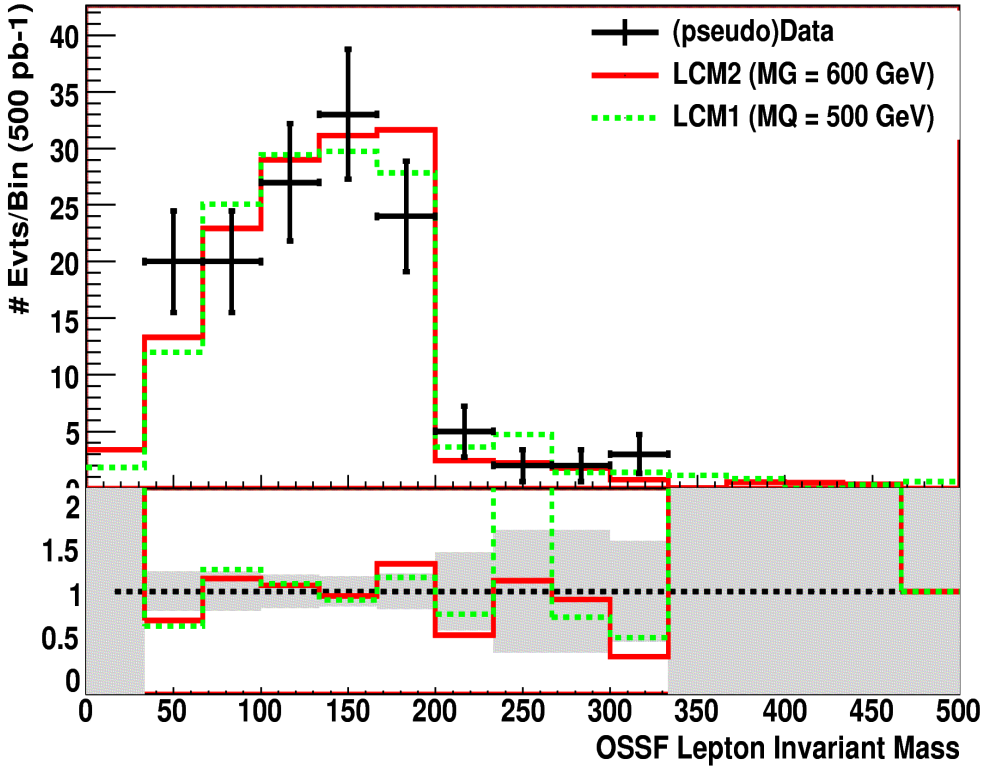


Simple example

When underlying physics "looks like" the simplified models, can be used directly for model comparisons



H_T (effective mass)



Dilepton invariant mass

Simple example

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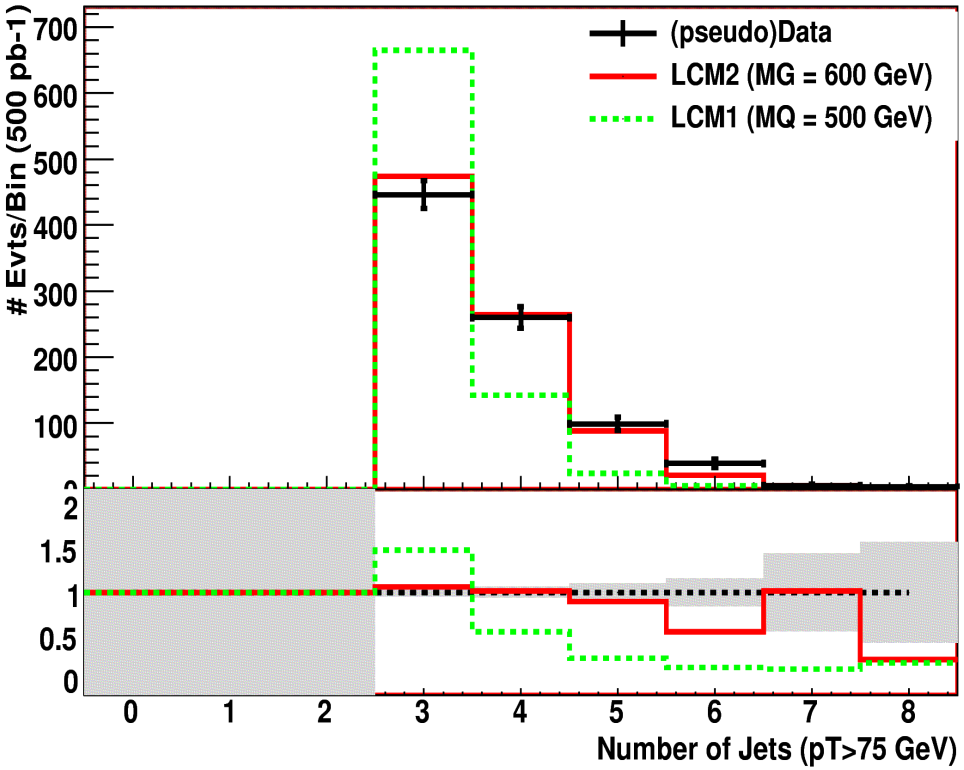
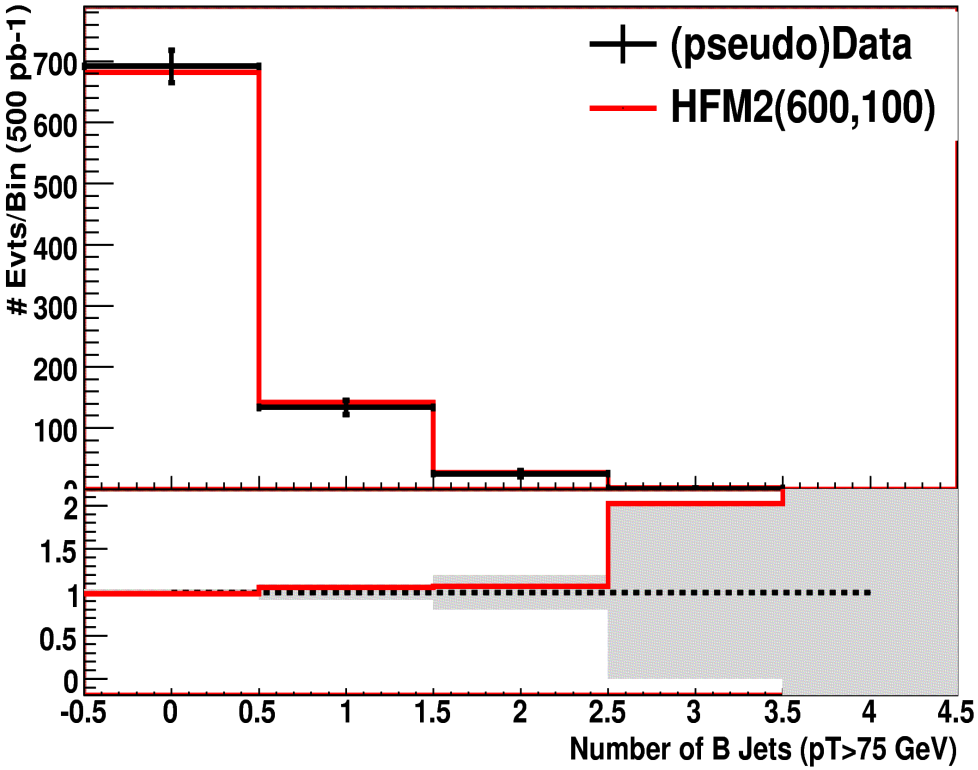


Number of jets above 75 GeV



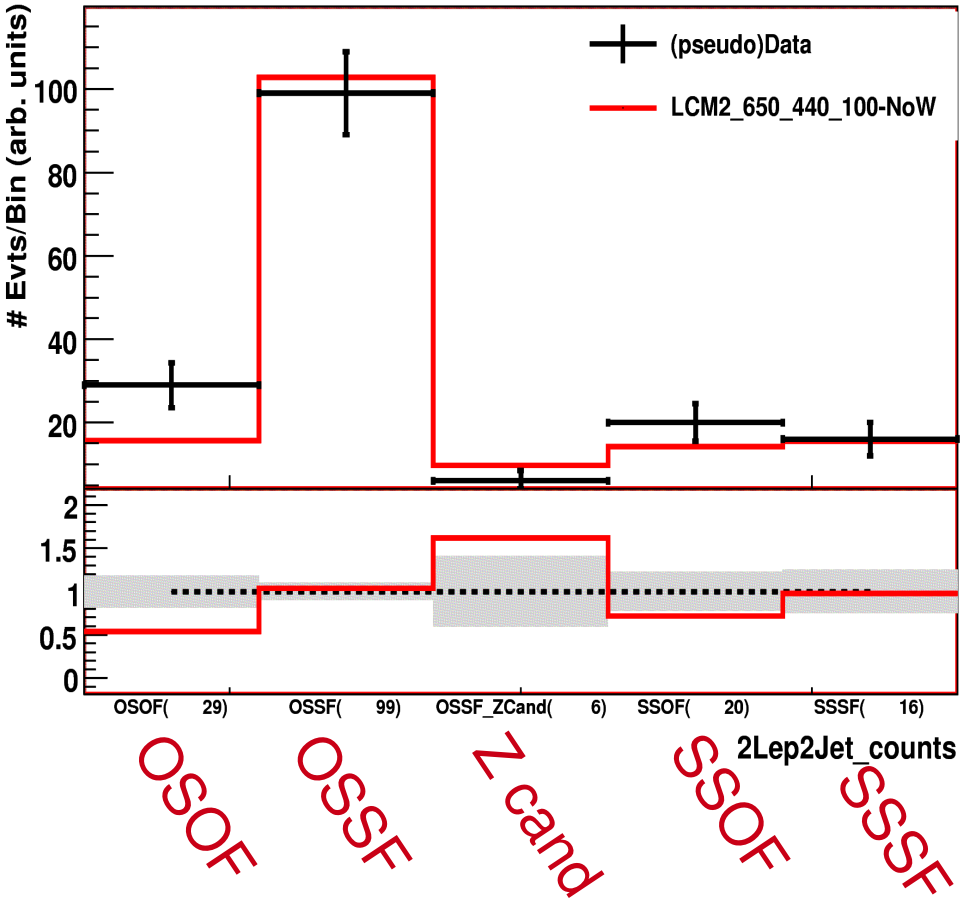
Number of b jets above 75 GeV

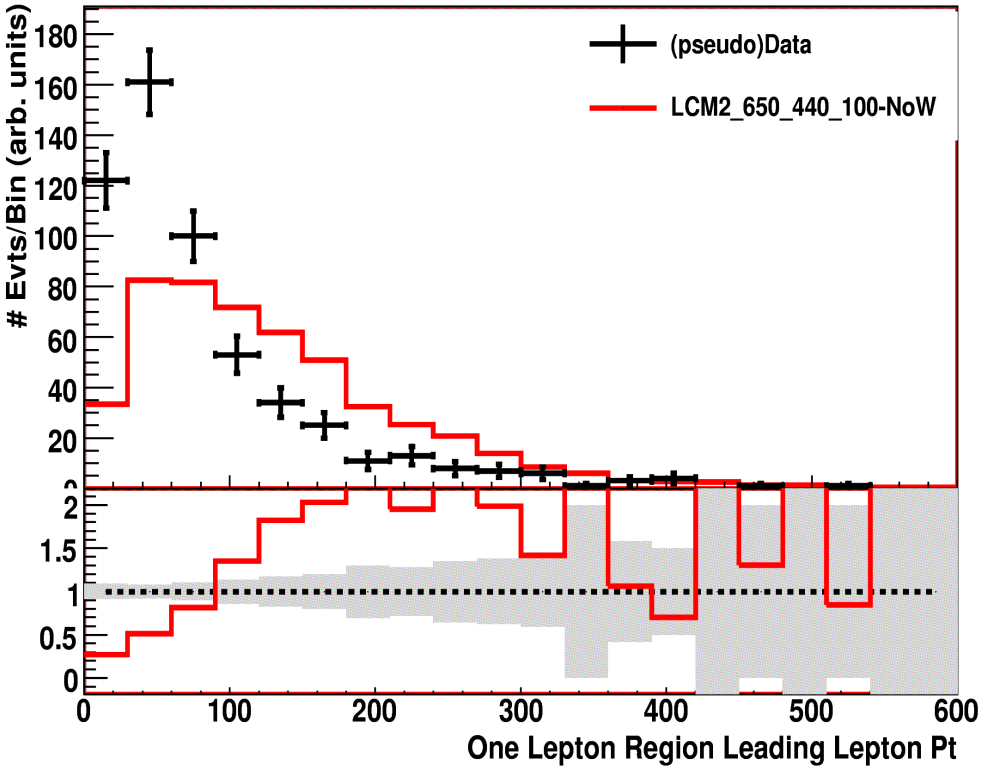
LCM2/HFM2 "perfect fit" – use as standin for data

Complicated example

What if underlying physics is more complicated?

Details of deviations indicate what might be “missing”





One-lepton p_T

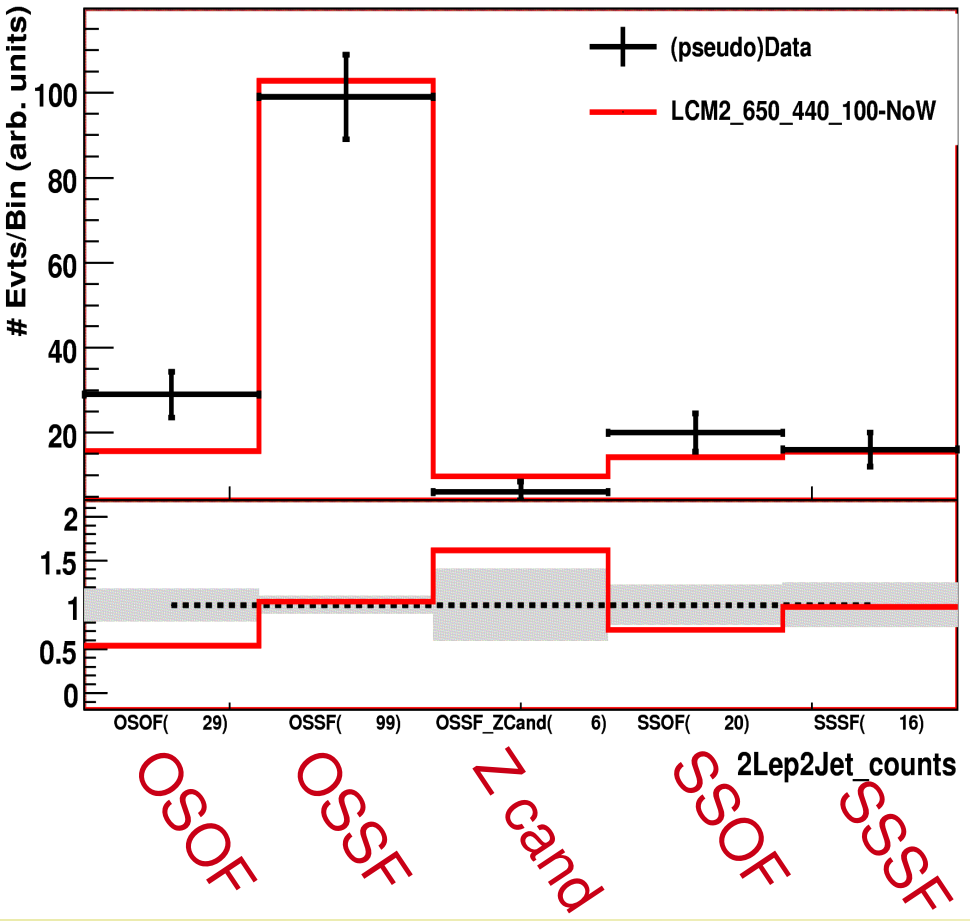
How to use published fits?

- Fits presented together with diagnostics plots
- “Good fit” can be directly compared with theory
- “Bad fit” hints at what is missing (multiple species production, multiple cascade decays, top in cascades, ...)
- Models can be simulated using theory tools: compare plots to diagnostics plots!

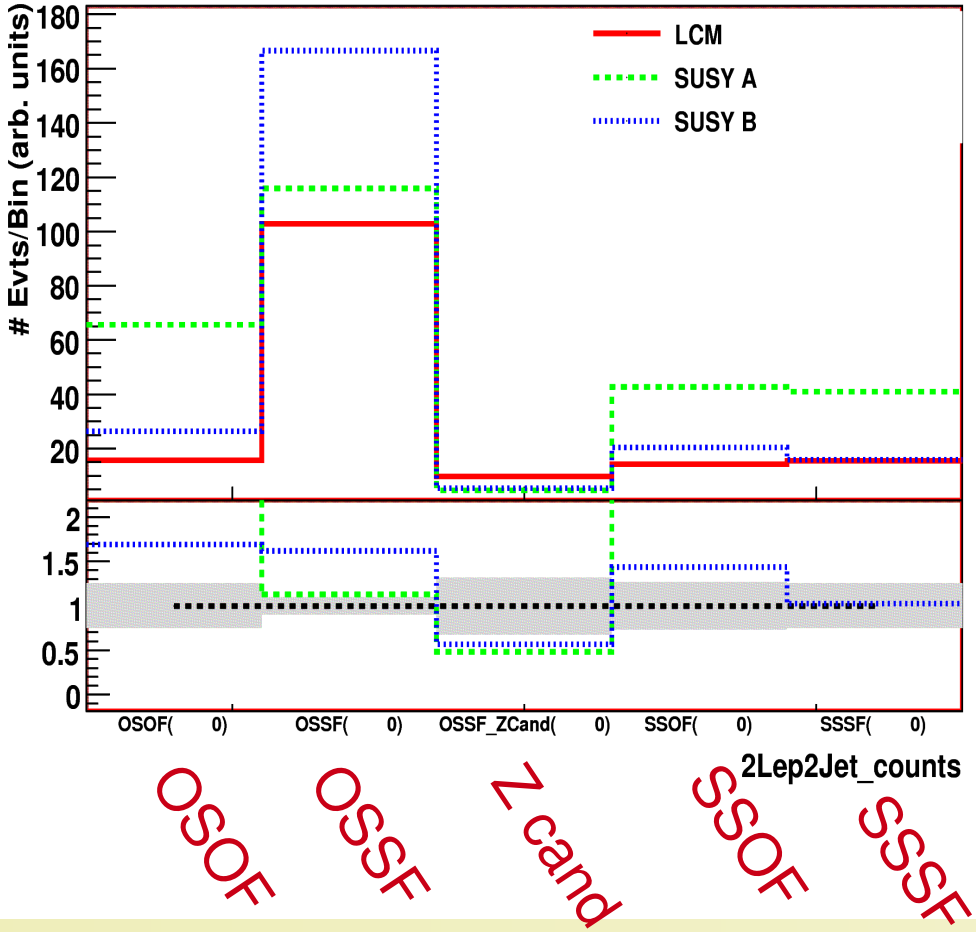
Model building from simpl. models

Compare two full SUSY models (A and B) to simplified model fit

Comparison simpl. model-data (done by experiments)



Comparison SUSY models to simpl. model (by theorist)



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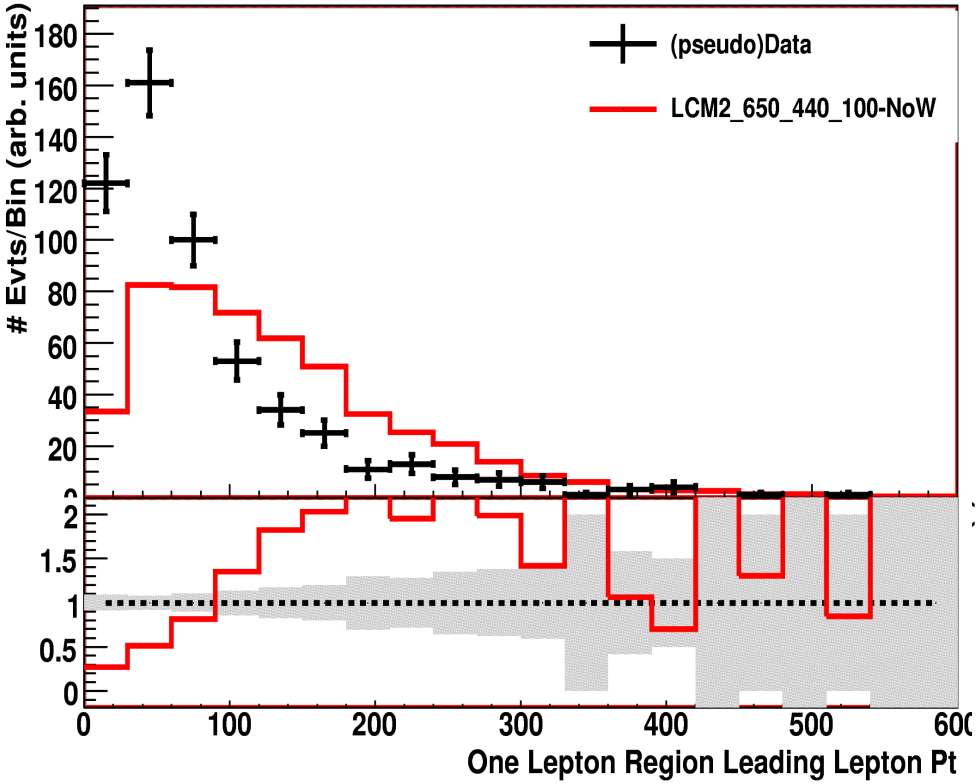

One-lepton p_T

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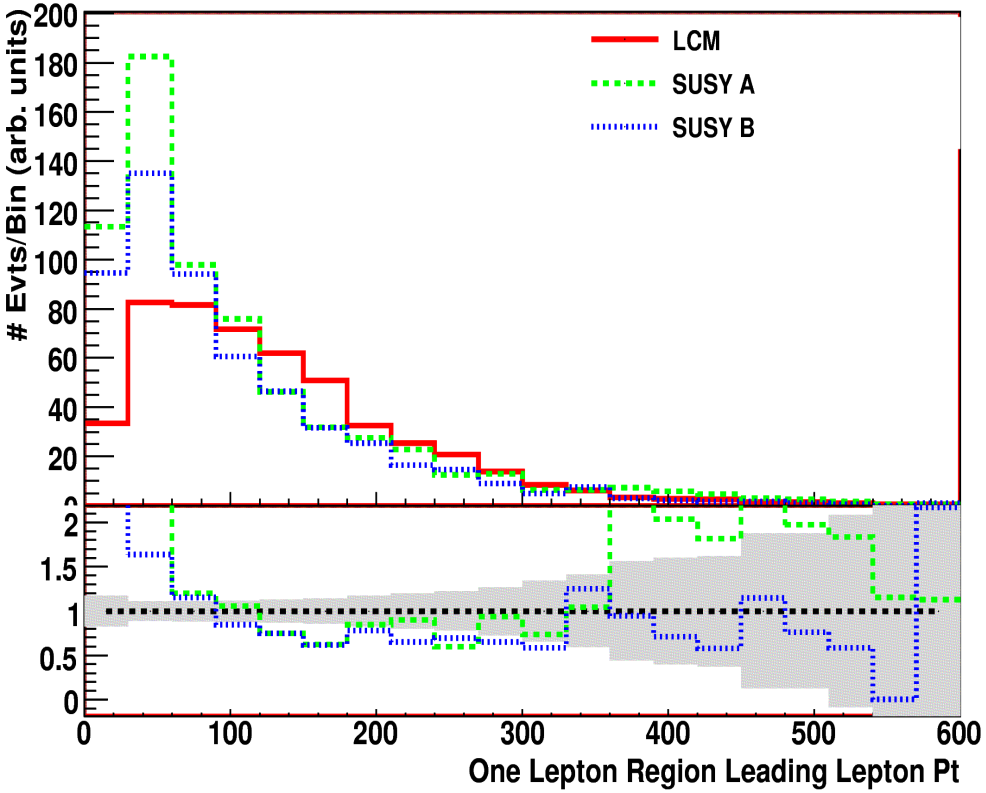


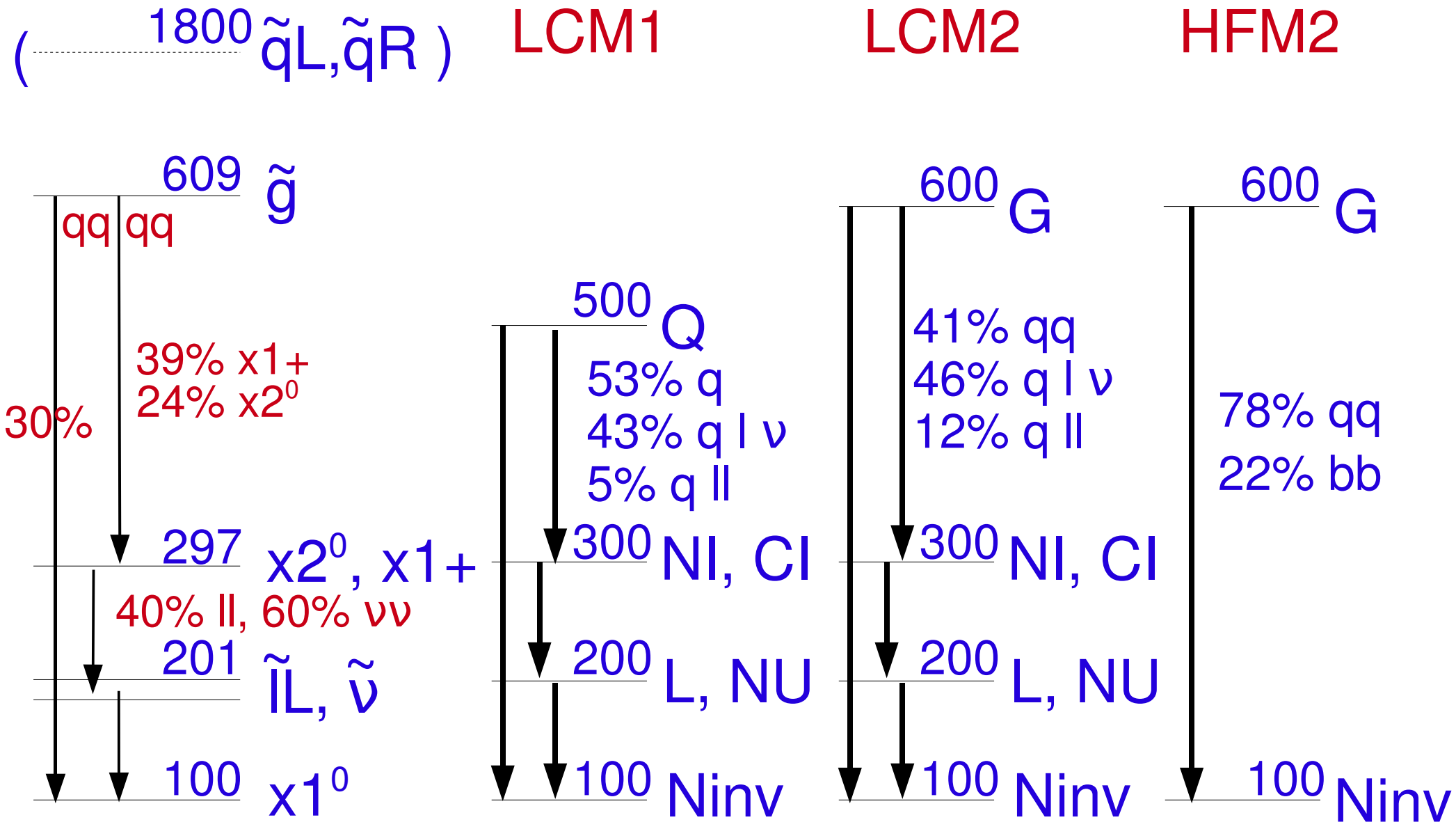
One-lepton p_T

Conclusions

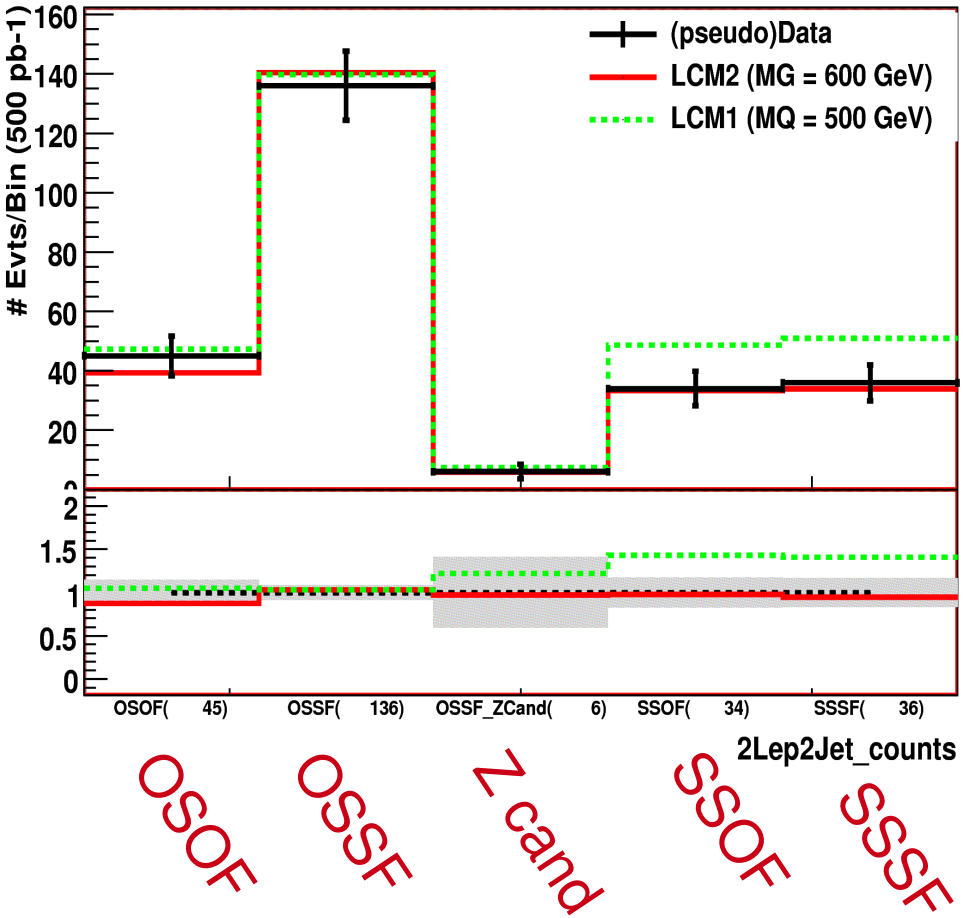
- Suggestion for characterization of first excesses: Minimal models with few and easy-to-interpret parameters
- Four simplified models
  - Quantitative answers to basic questions about mass spectrum and jets, leptons, b content
- Model fits + diagnostics plots / pulls
  - Qualitative conclusions about unmodeled physics
- Qualitative/quantitative comparisons to theory possible for theorists

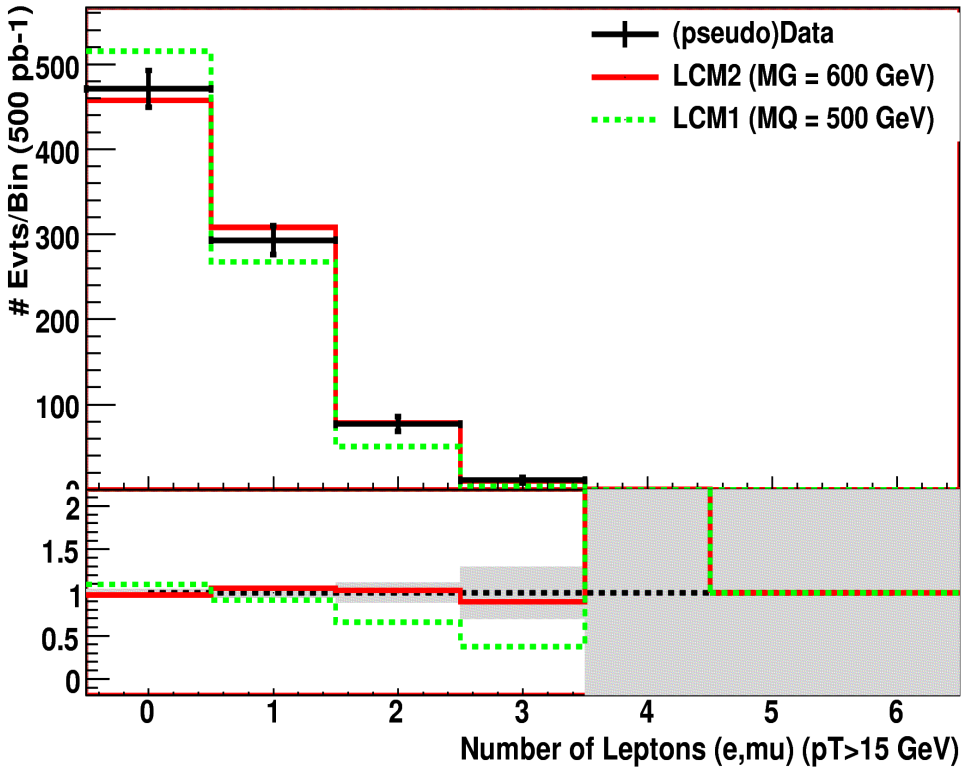
Back-up slides

Spectra for simple example



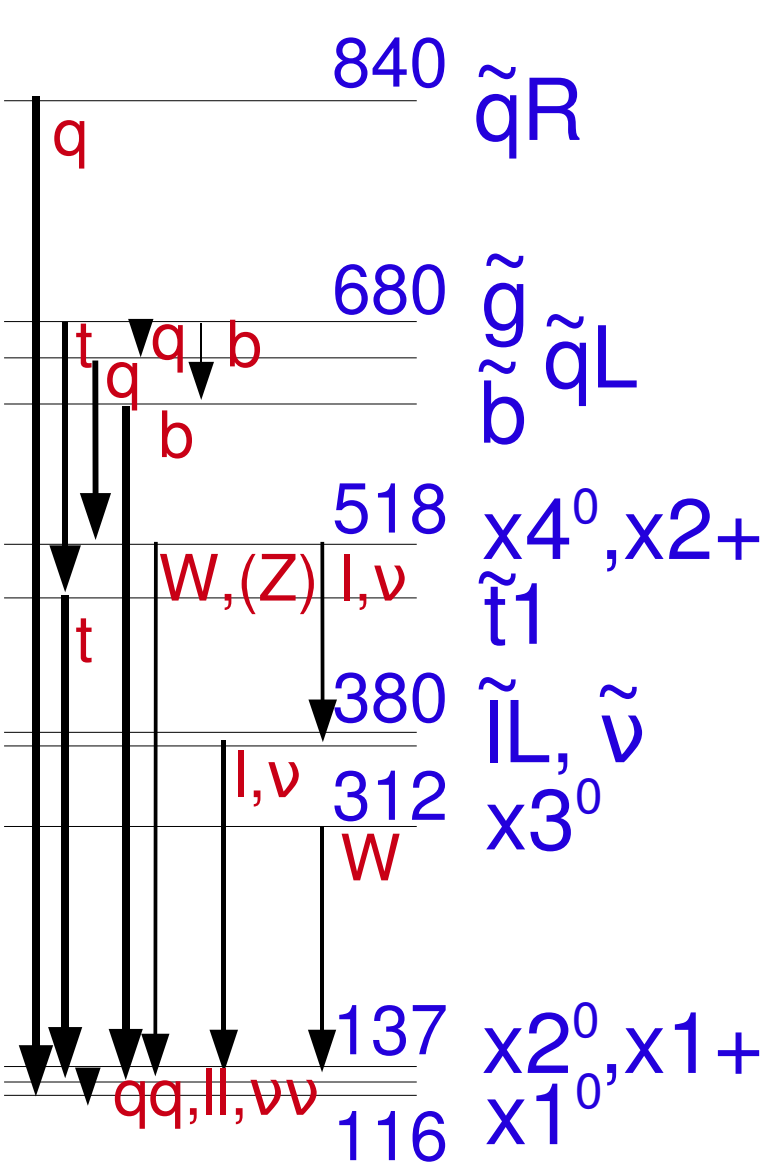
Simple example – more plots

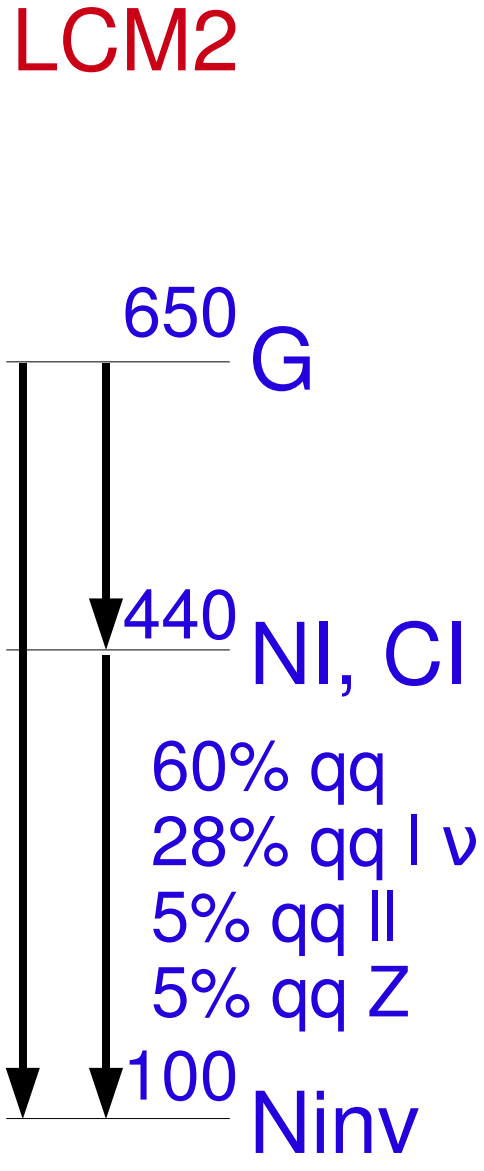


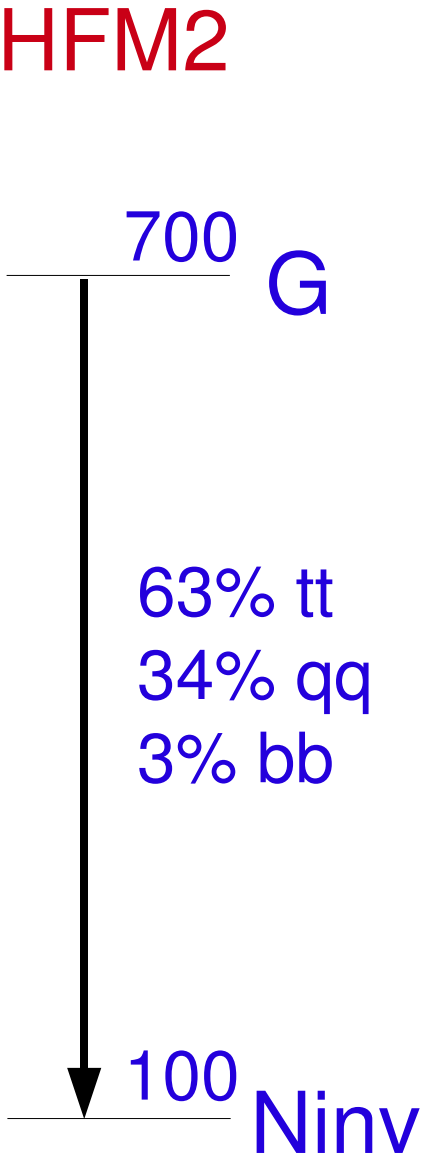


Number of leptons in lepton-incl. signal region

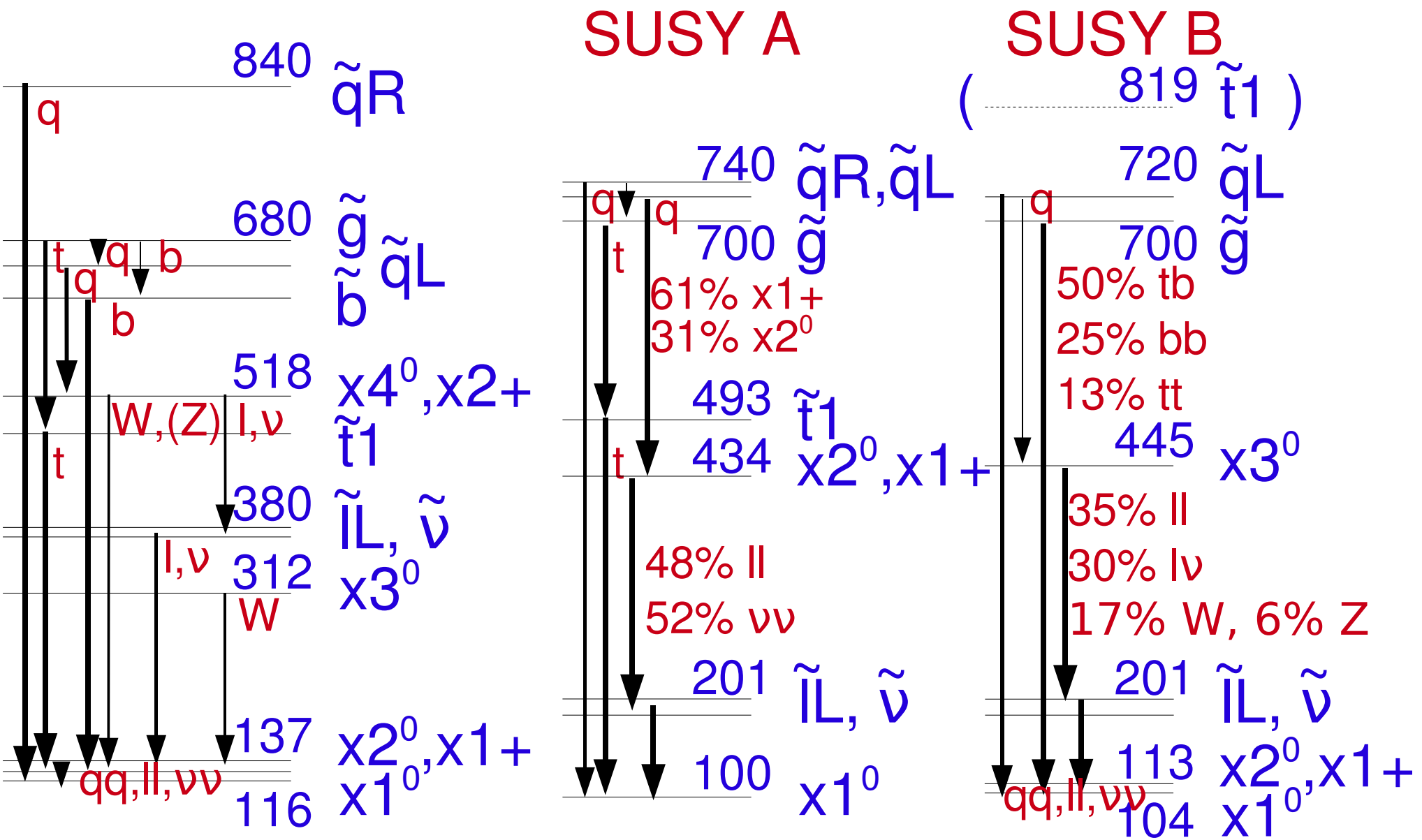
Spectra for complicated example



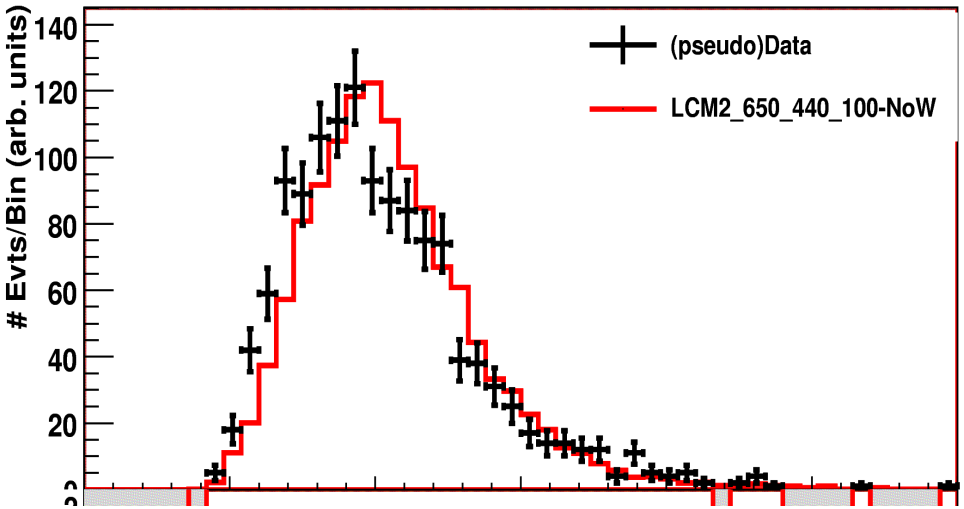


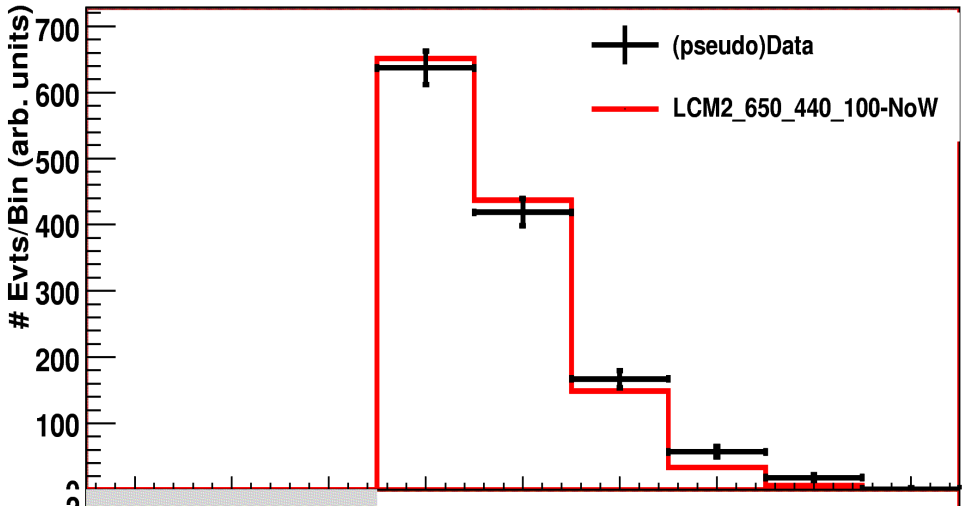


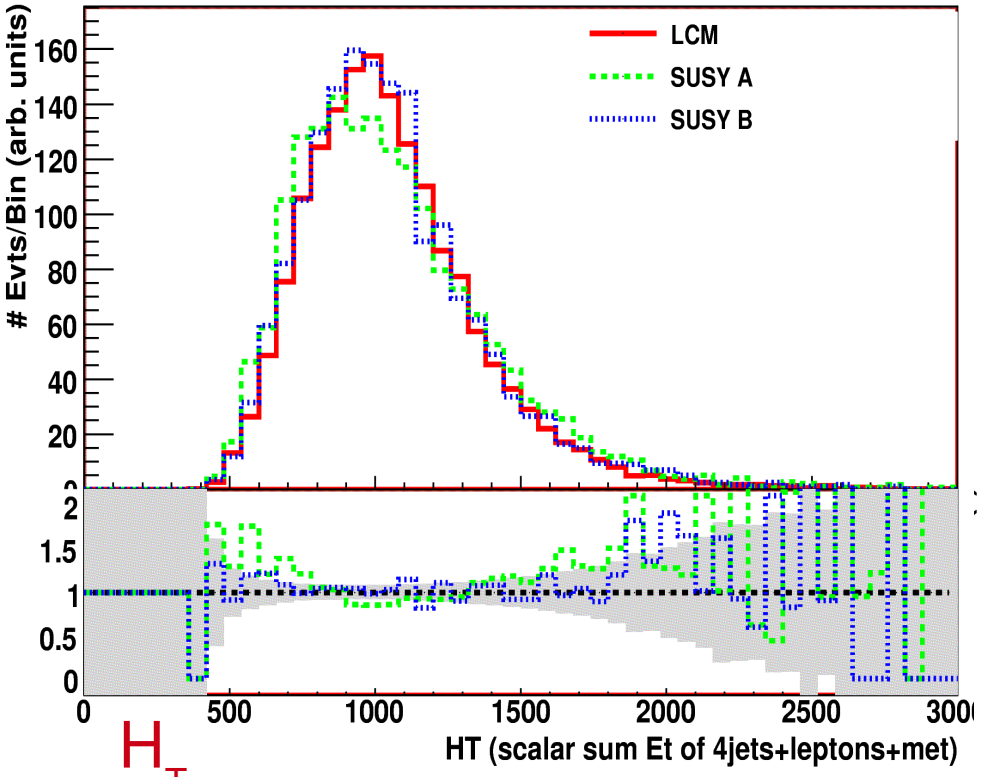
Spectra for MSSM models A & B



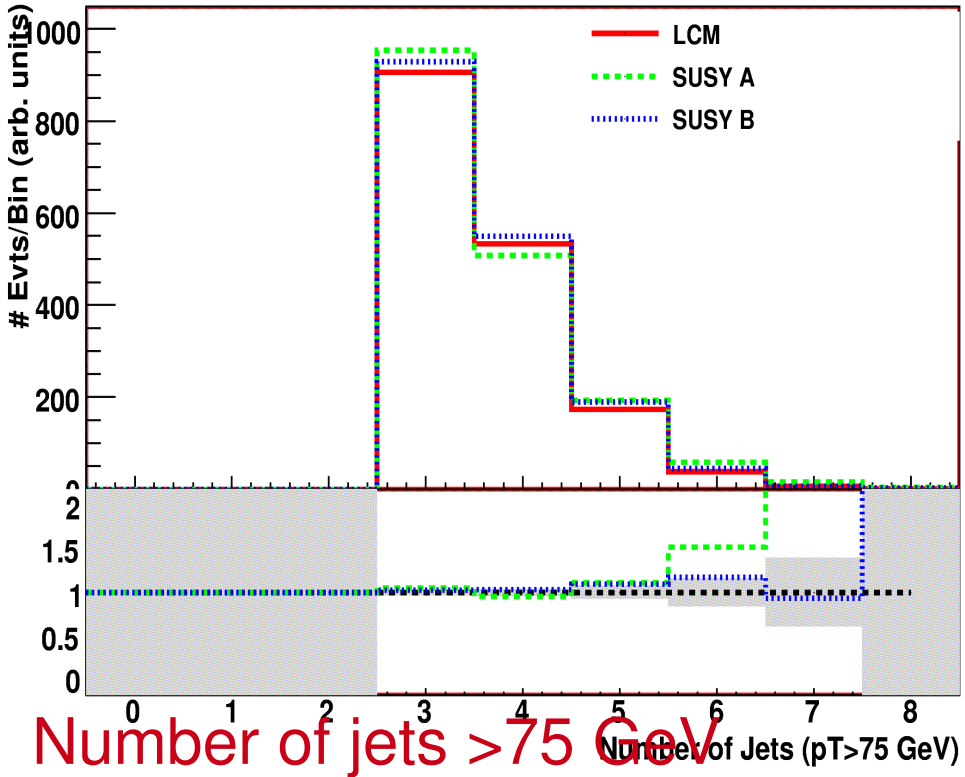
Complicated example – more plots





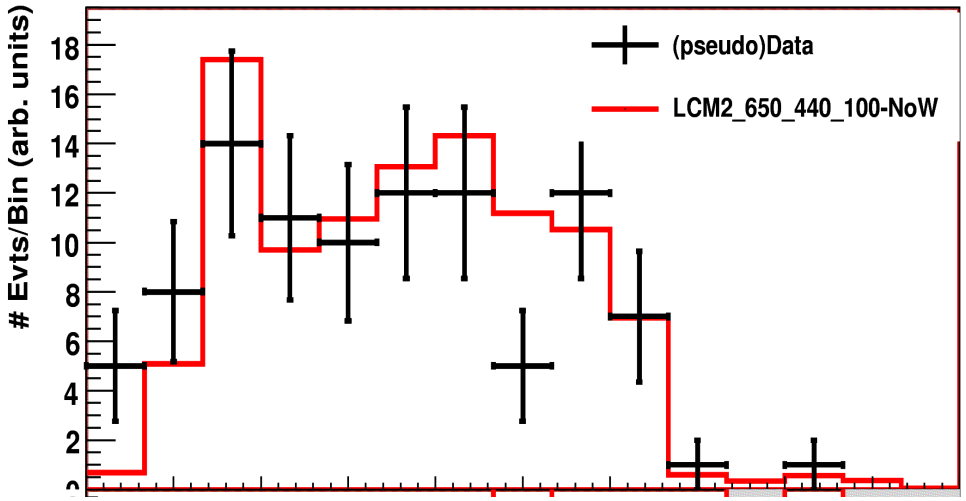


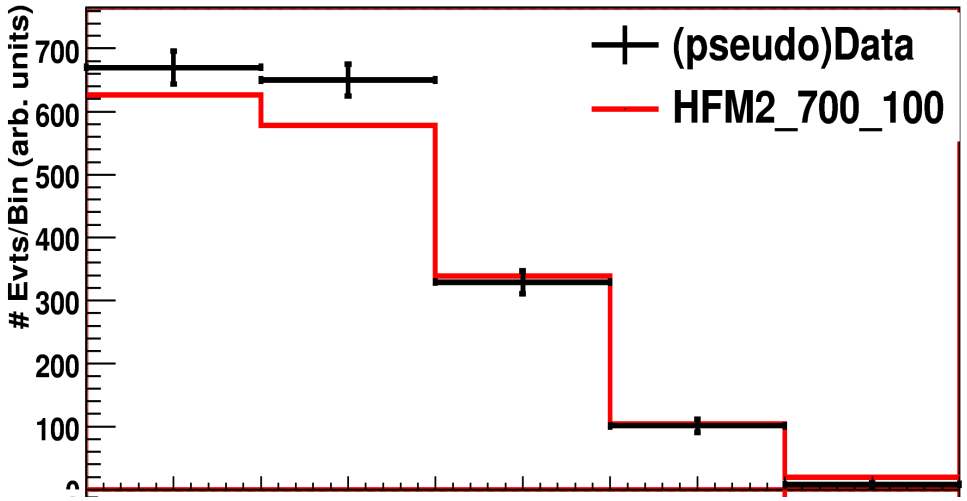
H_T

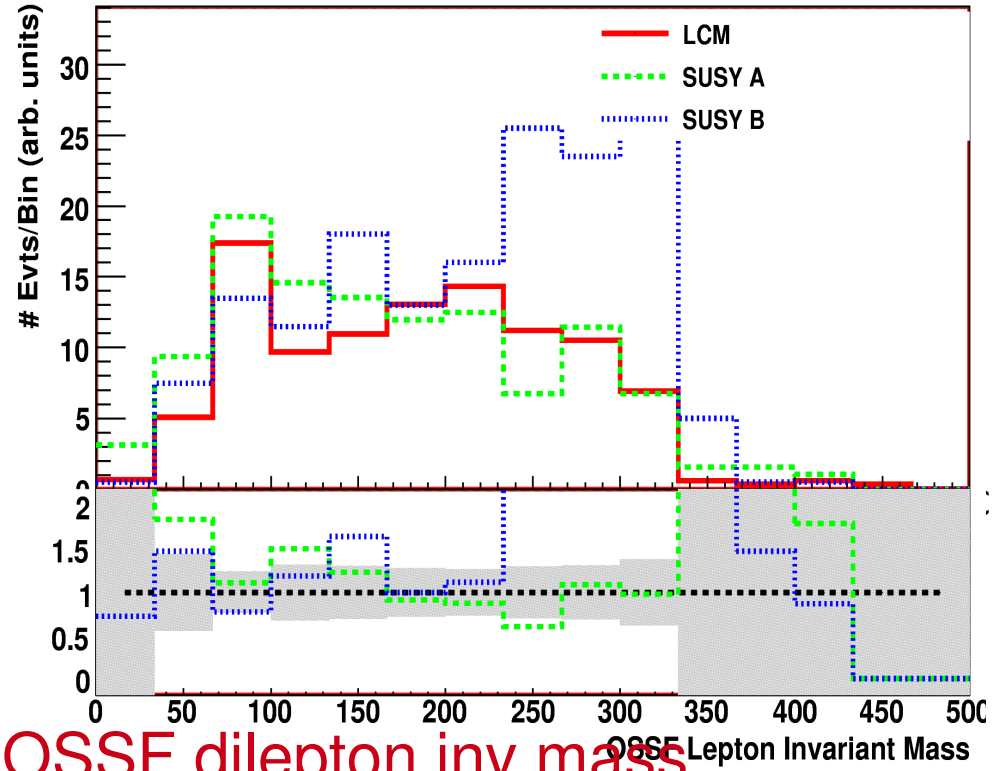


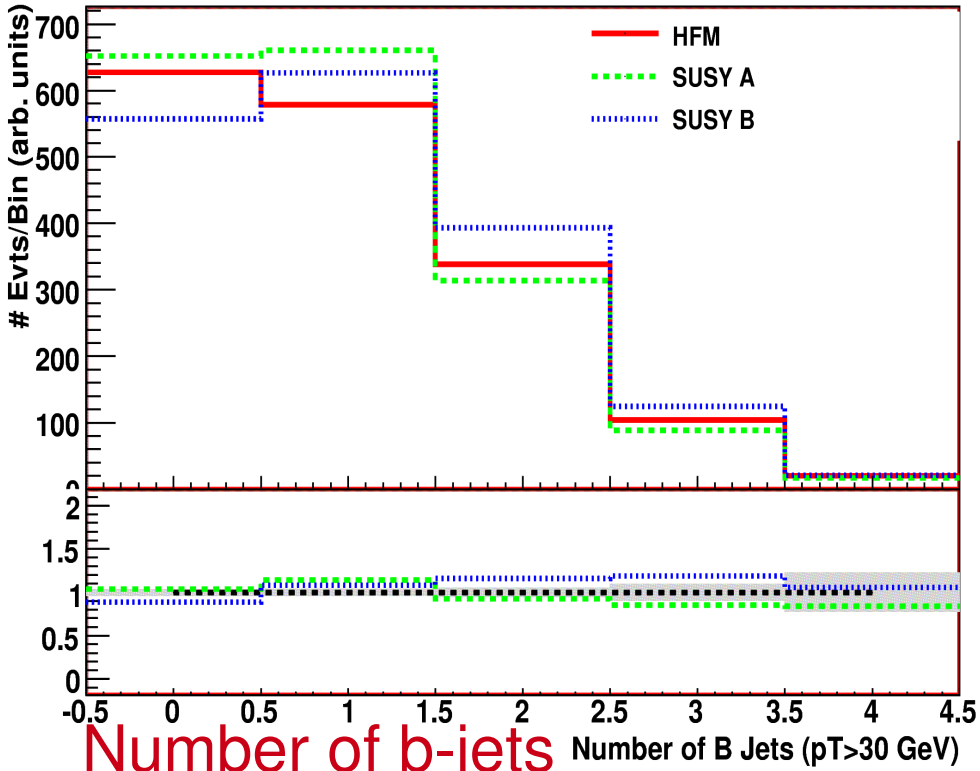
Number of jets >75 GeV

Complicated example – more plots





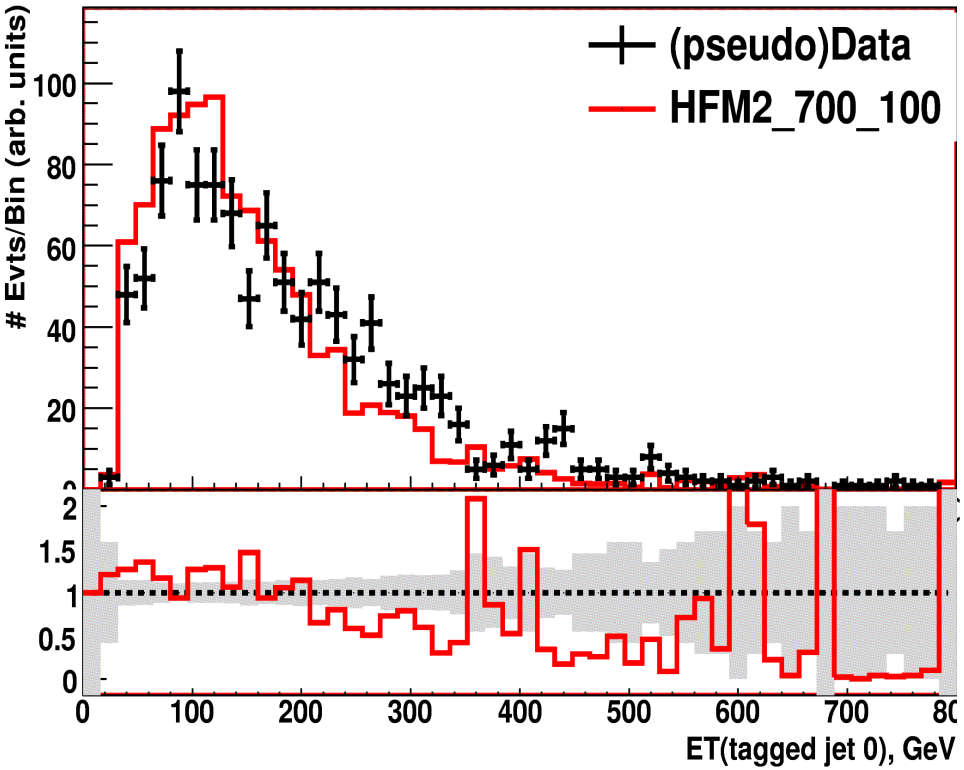


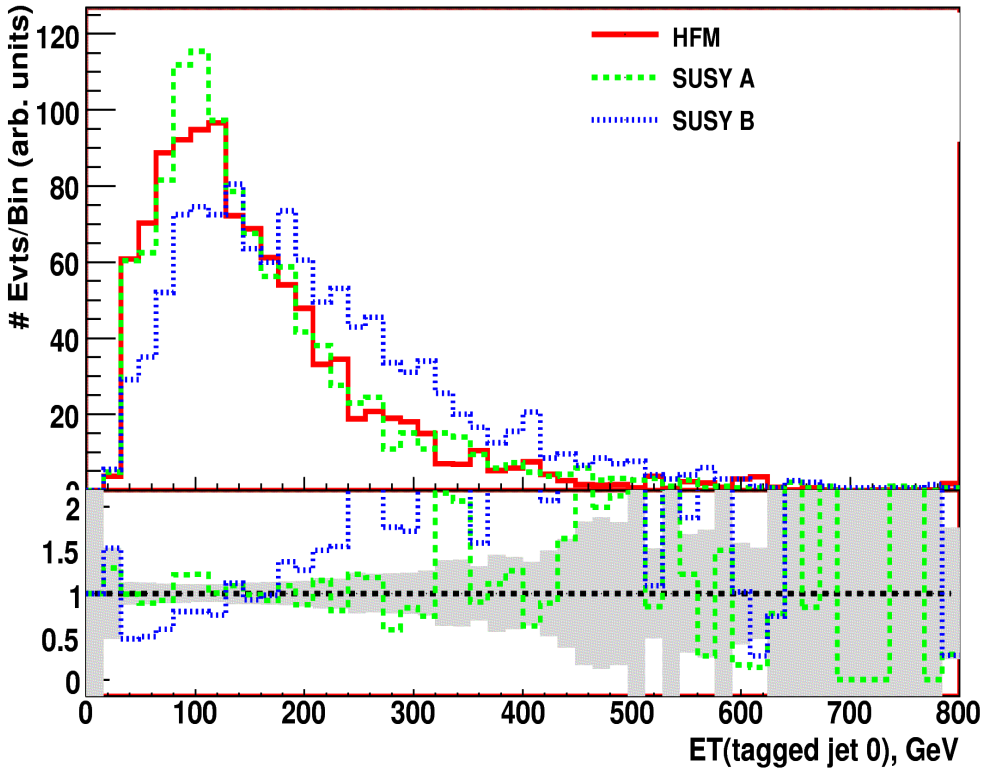


OSSF dilepton inv.mass

Number of b-jets

Complicated example – more plots





Hardest b-jet p_T

4 simplified models – HFM

- Heavy flavor models
  - Detector-independent b-jet fraction estimate
  - Fitted only using b-jet counts
  - Masses from LCM fits, 2-3 xsecs/BRs to fit
  - Top quarks included as check – fitted using different lepton-number regions (esp. interesting if lepton fits indicate presence of W in decays)
  - Flavor-neutral production or 3rd generation enhanced?