On-Shell Effective Theories (OSET) or How to Characterize New Physics

(MARMOSET TUTORIAL, TOOLS08)

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A Comment for Motivation...

In trying to answer questions about:

the hierarchy problem, EW symmetry breaking, dark matter, the little hierarchy, the Higgs sector...

Theorists will undoubtedly want sound spectroscopic information
(What does this mean, and how do we get it?)

If we're confronted with something new, we'll want to understand it inside and out

But, top-down model fits, while insightful, don't count (BIAS, lack bottom-up clarity)

Signature information alone not enough (except in simple cases, Z')

What else can be done?

I want to revisit part of the round table discussion yesterday

(This will explain the role of OSETs and Marmoset)

How to pass information from the experiments to theorists and vice versa?

Let me focus on information relevant to claiming a discovery and understanding it

From the theory side:

Does a model exist in data (How to search and set limits)?

If there's a deviation, how can we check it (see M. Peskin's comments)?

If a deviation is real, what is it consistent with?

Experimental realities:

Searches require sensitivity (need accurate signal MC)

Analyses are very complicated (hard to change cuts...etc)

Providing 4-vectors is not a viable option

Mapping out the TeV scale may require **broad** exploration on the experimental side, beyond comparison to top-down models (especially if theorists are to understand the results)

Experimental realities may also require BSM theorists to be clever and selective about how/what results should be presented

What kind of flexibility might we need at the LHC for BSM studies?

Be prepared to explore and test:

A wide range of topologies (final states)

A wide range of kinematics

In an even wider range of models

...without assuming that the community believes in a particular "model" of the universe...that will come later

This may require some compromises with respect to the way things are done (i.e. at the Tevatron)

Many models to search for:

Can we reduce some of the redundancy by using general-purpose templates with a few parameters?

Can we make it easier to test assumptions about kinematics and topologies?

When we don't know what's going on, physics transparency will be key:

Can we make use of simplified (but good enough) descriptions just to get sound footing?

Marmoset was designed specifically to assists in broadly exploring BSM physics, helping to resolve the difficulties mentioned on the previous slide, taking advantage of certain simplifications

We CAN we make use of simplified, but "good enough" descriptions, just to get a sound footing.

A proof of concept is On-Shell Effective Theories (OSETs)

Marmoset is a tool that generates (using pythia) and organizes OSET MC.

Note: Marmoset is a very simple tool, not a significant contribution to existing simulation technology

Other sophisticated tools can support a similar organization (MadGraph for example)

Where do OSETs (Marmoset) play a role?

Confirming that a discrepancy in data is real is extremely hard!
Marmoset and OSETs **do not** play a role in this process

However, if consensus converges on the existence of some discrepancies...

Marmoset and OSETs may play a role:

to explore what is viable and what is not

to characterize deviations broadly (i.e. as much model-independence as possible) in terms of topologies, masses, and branching ratios

to publish results that fold in acceptance (up to a point) for setting limits

Tutorial Overview

I want to show you what Marmoset is for

So I'll begin with an example, and I'm going to jump around

then I'll explain...

theory background

usage (applications)

the code

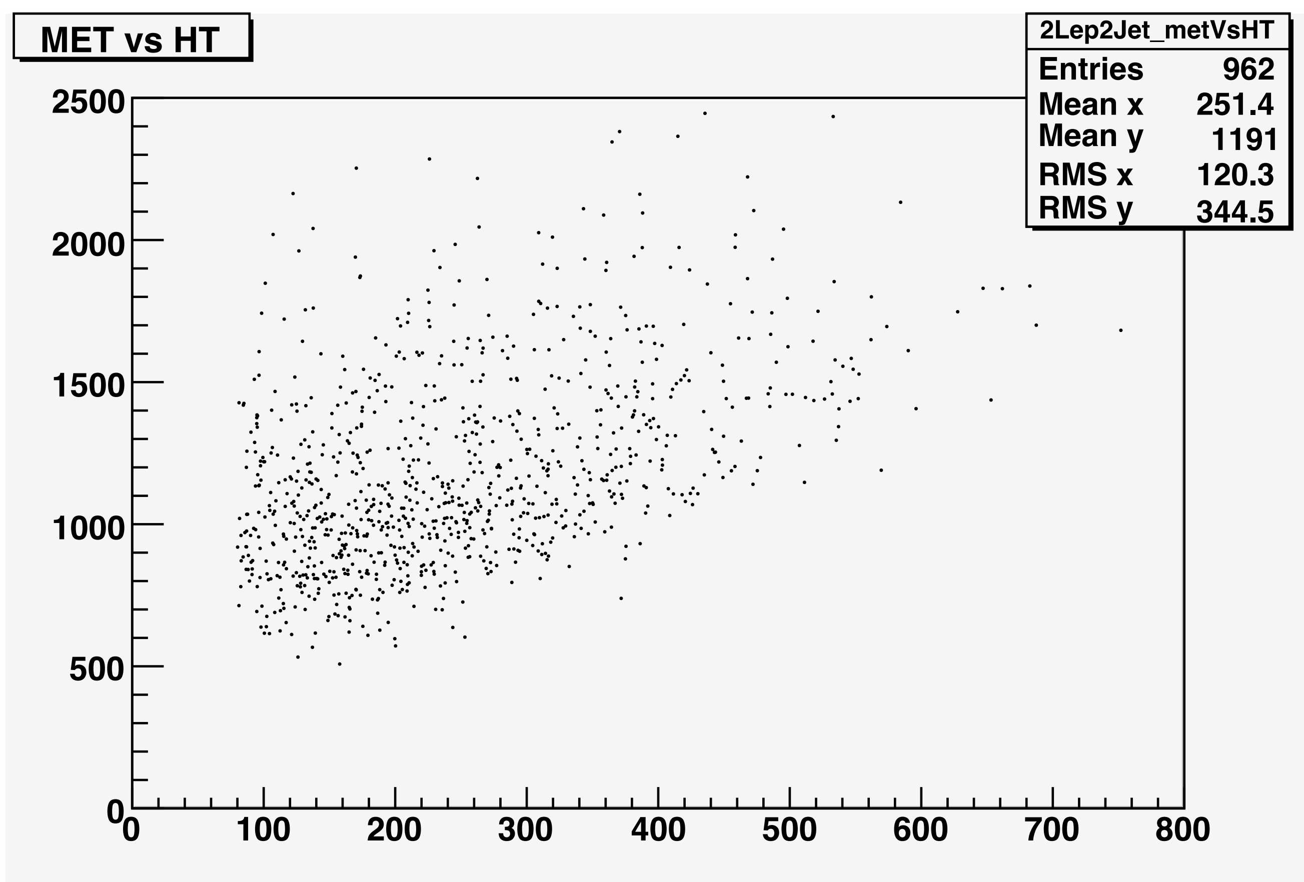
relation to other packages

Using OSETs: Example

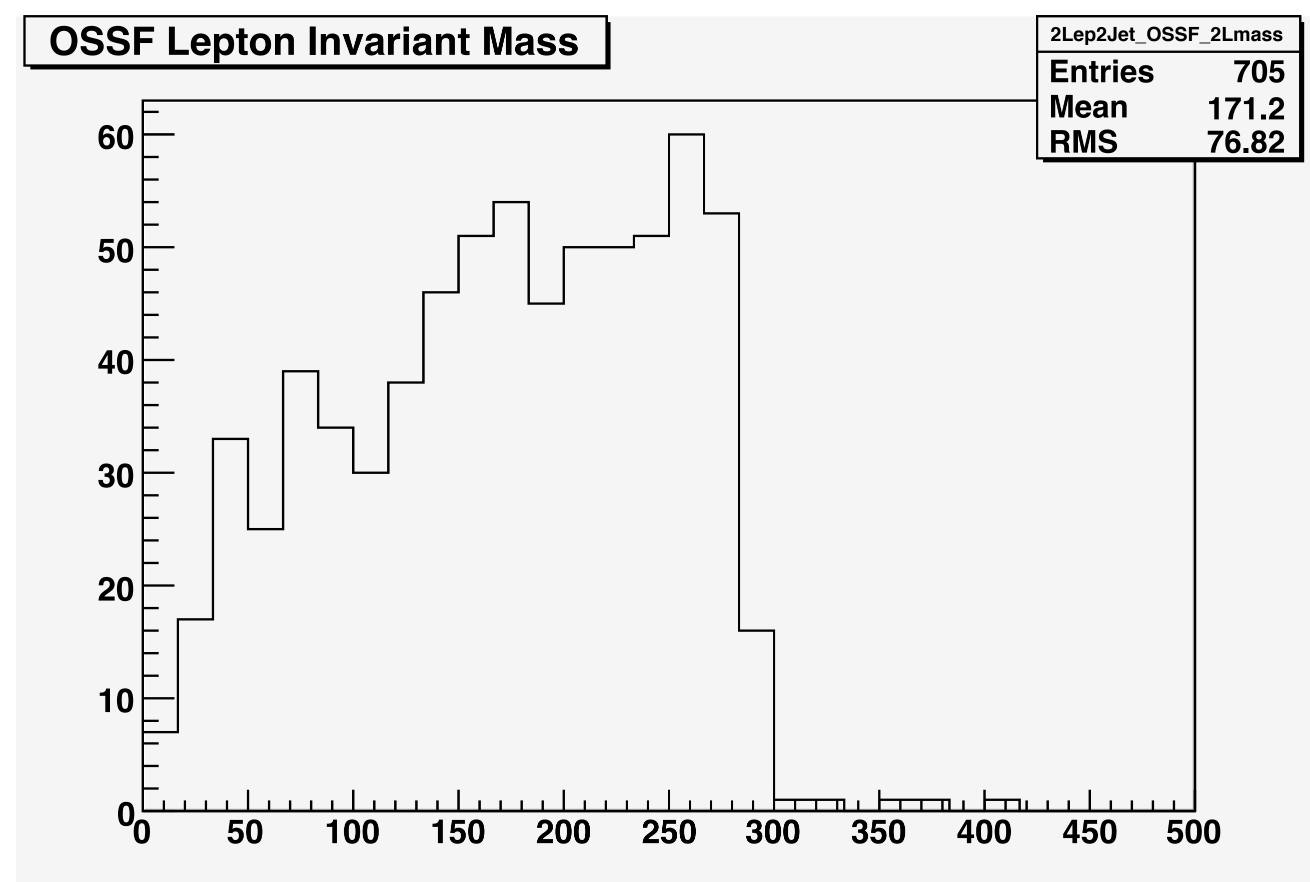
Suppose we encounter a "robust" deviation...

For example: Search Region: Multi-Jets + 2 leptons + MET
(and more leptons)

HT (GeV)



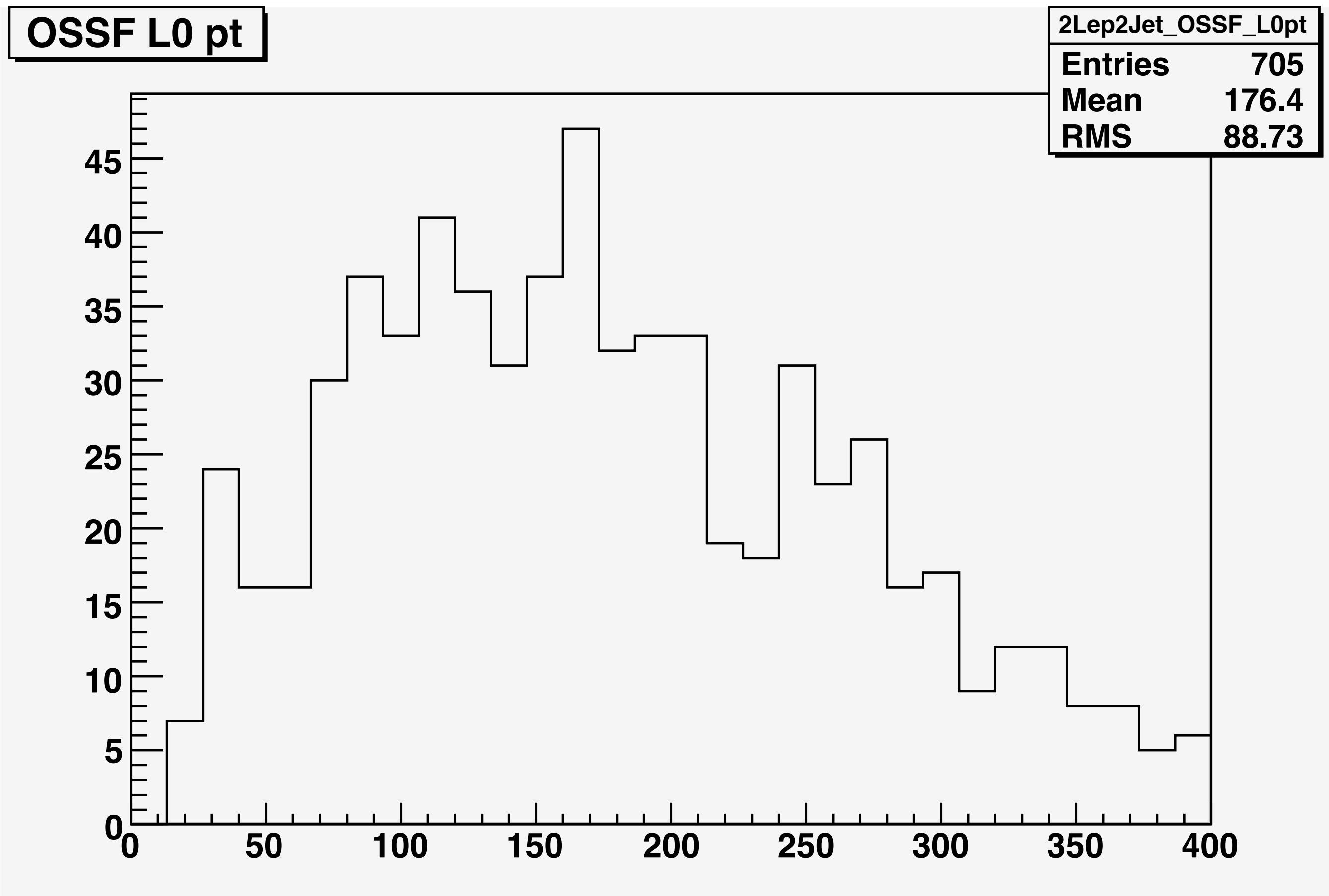
MET (GeV)

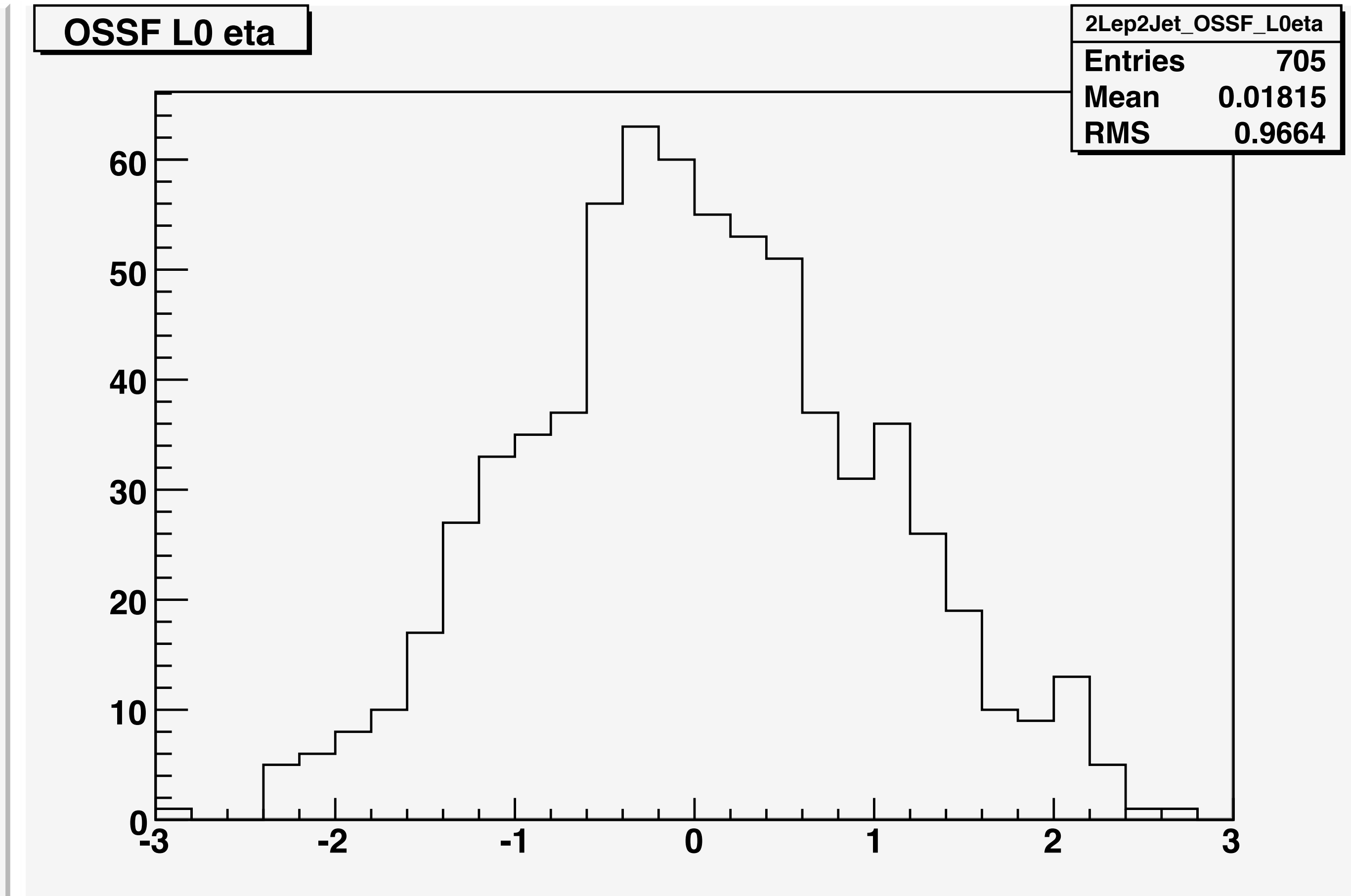


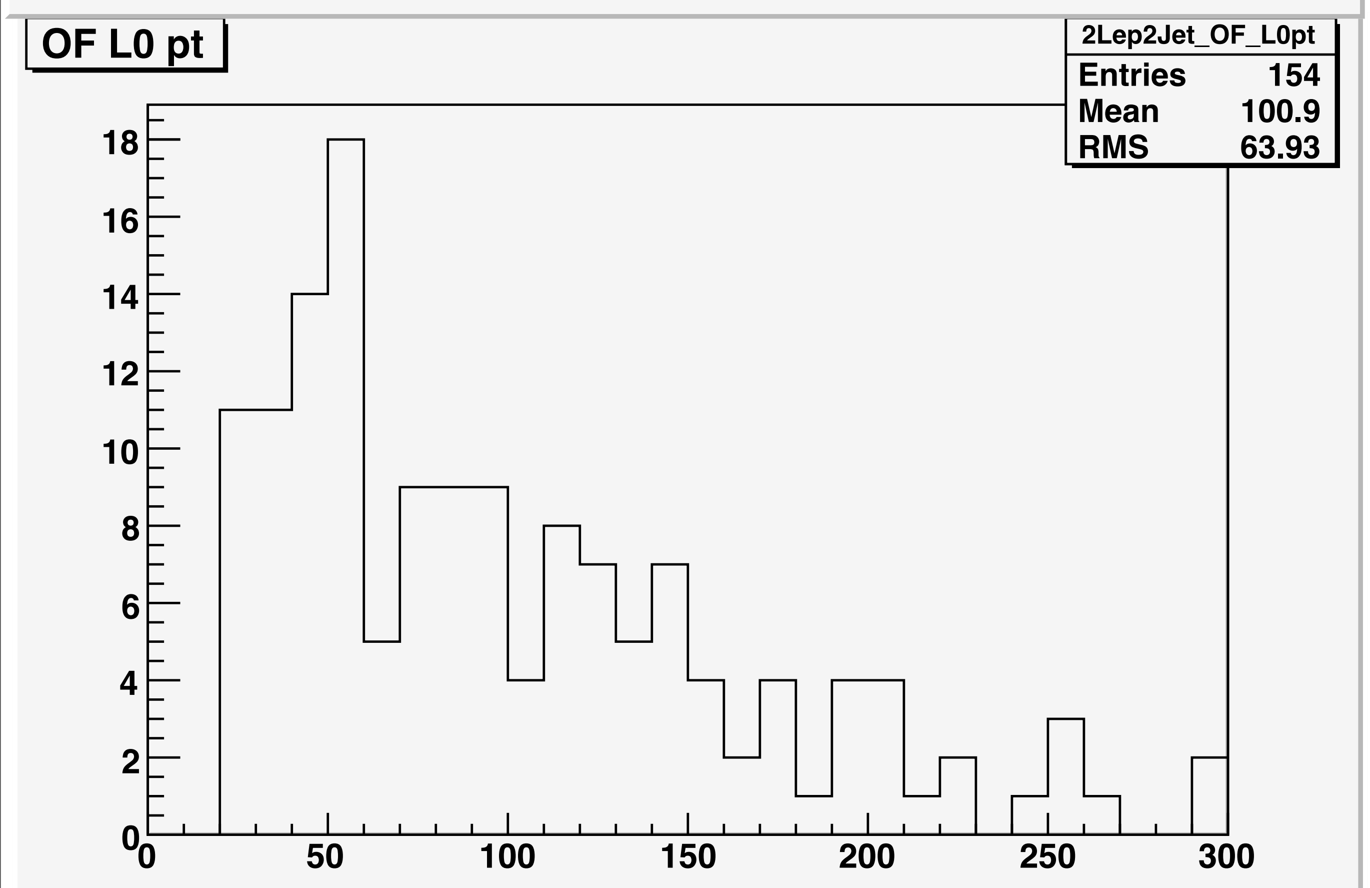
(Electron or Muon Same Flavor) l+l- invariant mass

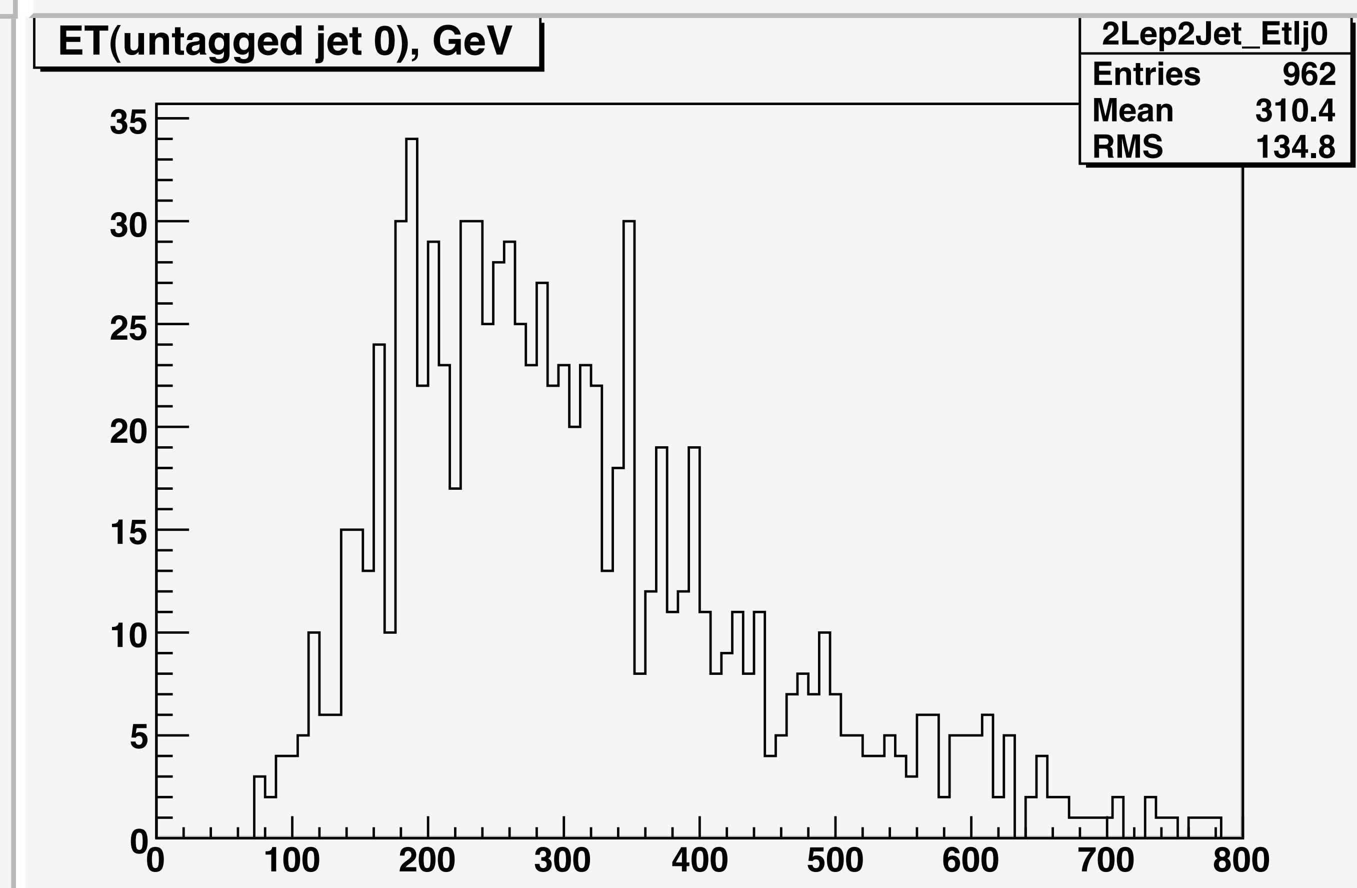
example "data" generated in pythia
detector simulation in PGS4

Example Primer Plots









...and many more plots

I’m not going to “solve” this example

Instead, I want to ask some sharp questions motivated by a small set of plots, and we’ll branch out from there

How to get started?

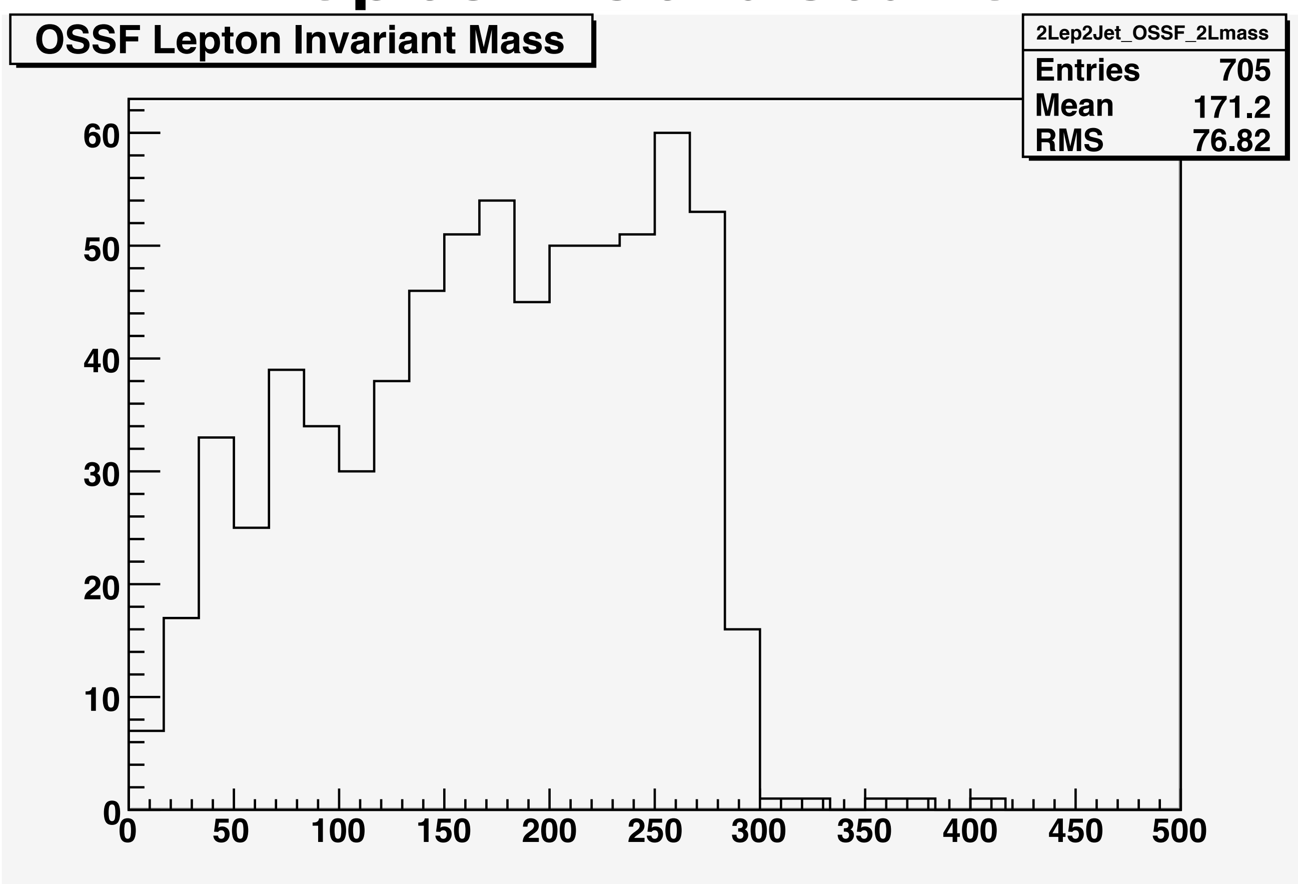
We want to reach a point where we're confident enough to use MC package X with Model Y implemented in detail, and perform further sophisticated measurements/ check predictions

We can go all out and do this for *many* different models...

For the moment though, let's just think in the language of particle production and decay (topology) and see what makes sense

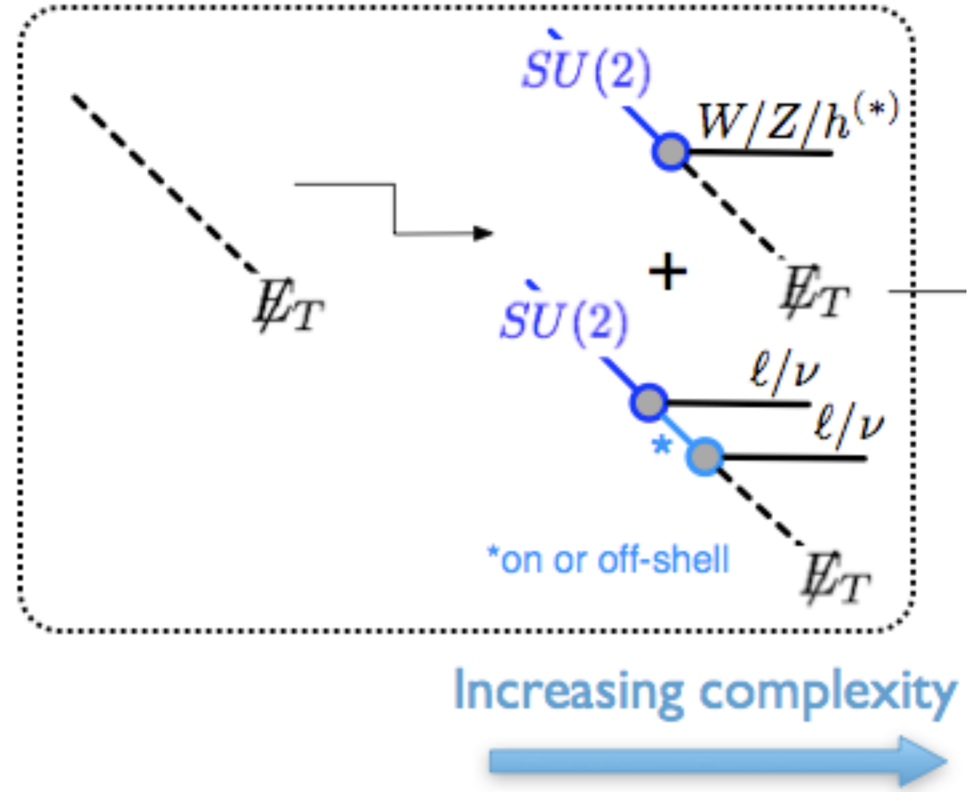
A Starting Point

Di-Lepton Structure



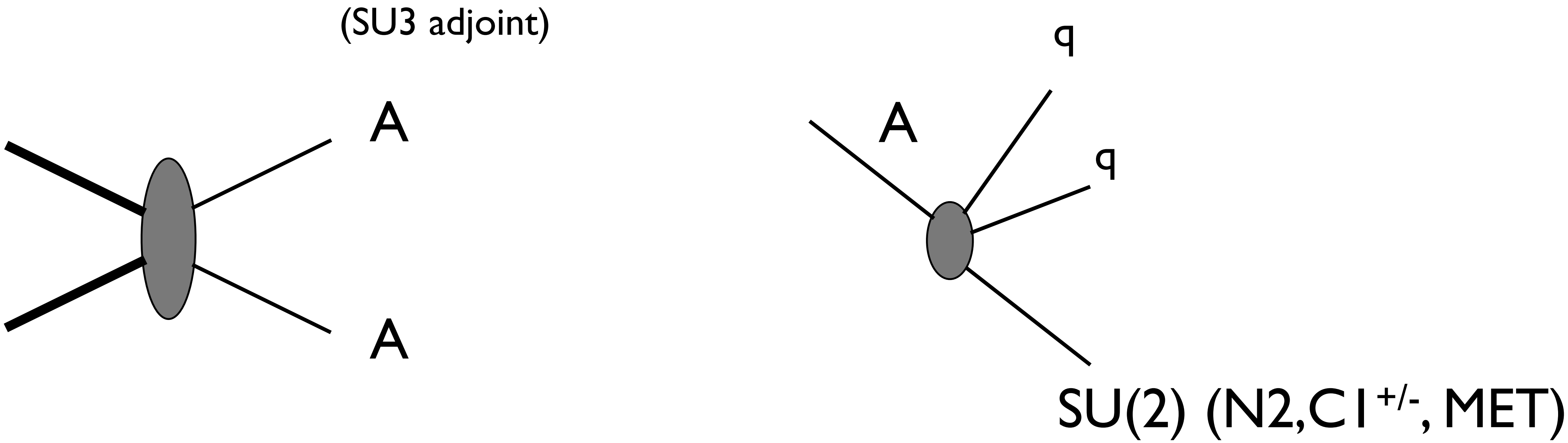
(Electron or Muon Same Flavor) l+l- invariant mass

Simple Topology Implication

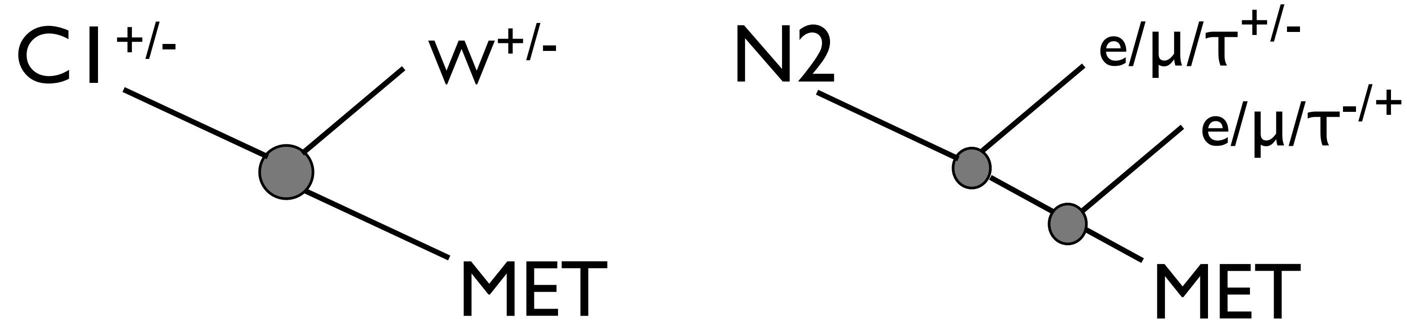


The leptons provide a handle on the SU(2) X U(1) structure

What about production possibilities?



From lepton structure:



Not a unique choice!

How should we simulate these topologies?

We can pick and choose topologies from different models with different assumptions...etc

or, we can drop as much detail as possible, keep the assumptions minimal

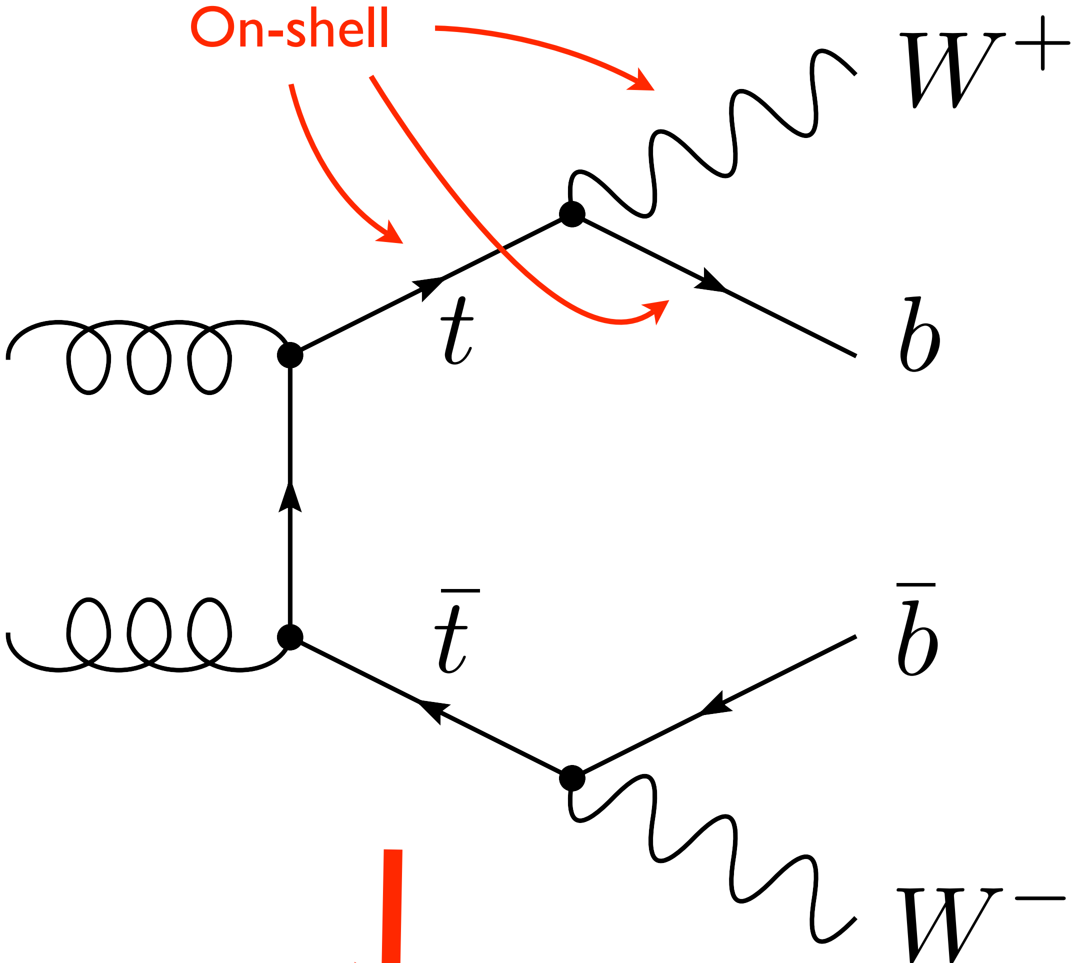
let's give the "simplicity as a guide" approach a go...

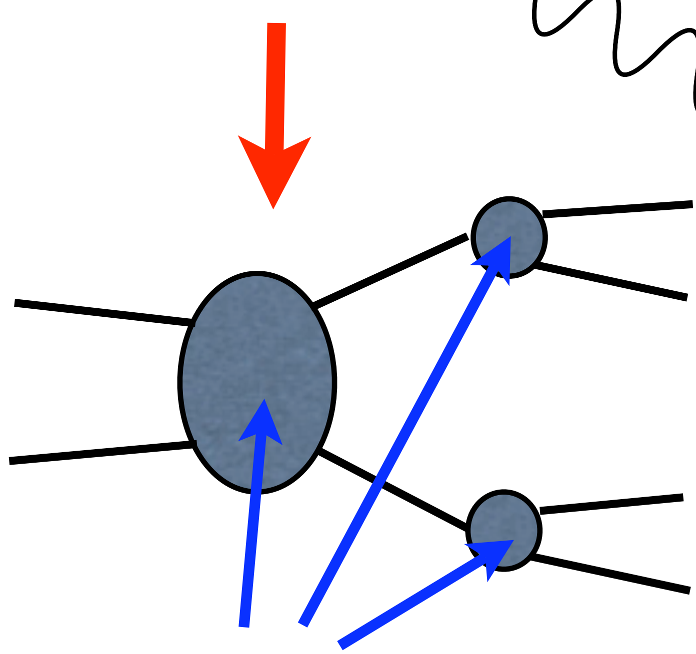
as a means of guiding ourselves out of the dark in this example

What's an OSET? The Basic Idea:

Example: Top Quark

Masses, Rates, and Topology vs. Amplitudes





Simple rules given for these parts

Dominant Top Properties:

$$\sigma(gg \to t\bar{t})$$

$$\mathrm{Br}(t \to bW)$$

$$m_t, m_W, m_b$$

Detailed Top Properties:

$d\sigma/d\hat{t}$

W helicity

t charge

Simulation...

Marmoset input (to be explained later):

```
MPT    : pdg=1000022 charge=0 color=0 mass=120
A            : charge=0 color=8 mass=680
Pmu- Pmu+    : charge=-3 color=0 mass=185
Pe- Pe+      : charge=-3 color=0 mass=185
Ptau- Ptau+ : charge=-3 color=0 mass=185
N2           : charge=0 color=0 mass=422
C1+ C1-      : charge=3 color=0 mass=280
```

New Particle Definitions
(masses and quantum numbers)

```
Pe- > e- MPT $ Bl
Pmu- > mu- MPT $ Bl
Ptau- > tau- MPT $ Bl

##### Other SU(2) decays ######
N2 > Pe- e+     $ Bsl
N2 > Pmu- mu+   $ Bsl
N2 > Ptau- tau+ $ Bsl

C1+ > W+ MPT

##### SU(3) decays #####
A > u ubar N2
A > d ubar C1+
```

Decays (branching ratios)

```
##### Production Modes #####
g g    > A A
```

Production modes (cross sections)

For the plots I’m about to show:

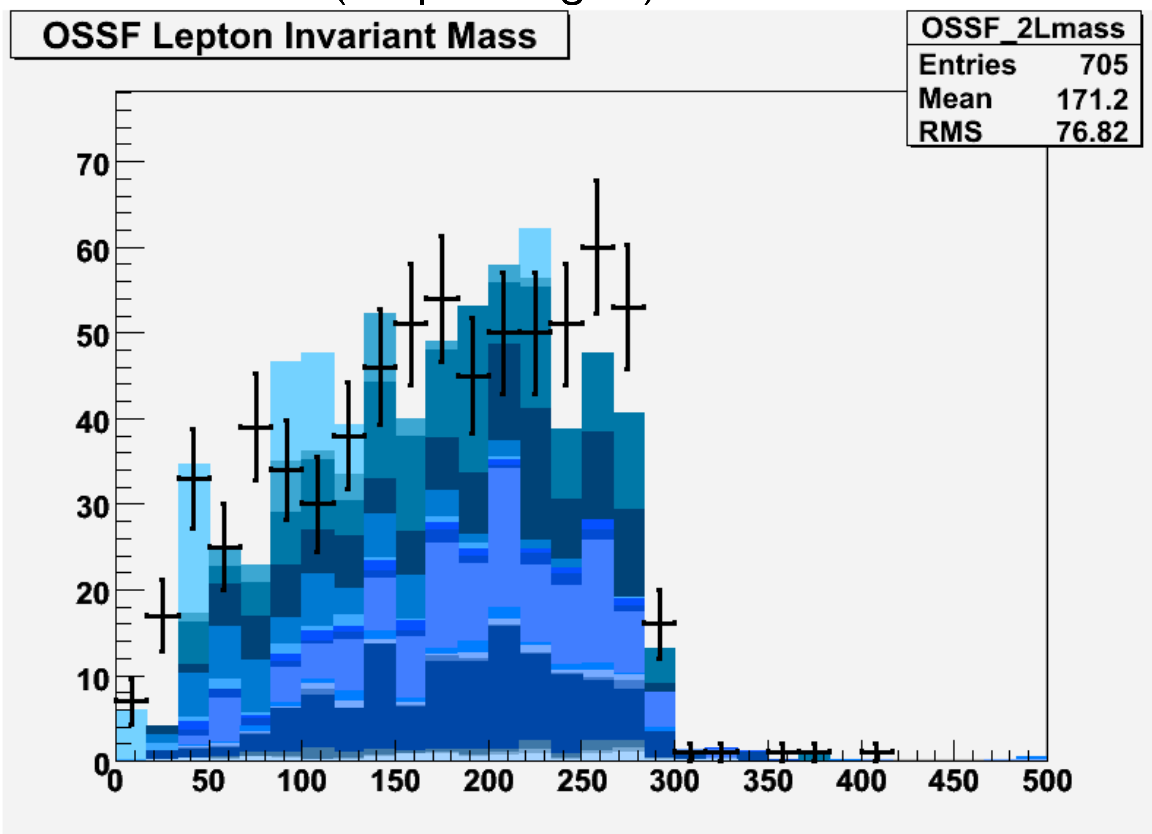
Events generated in Marmoset

Simulated through PGS4

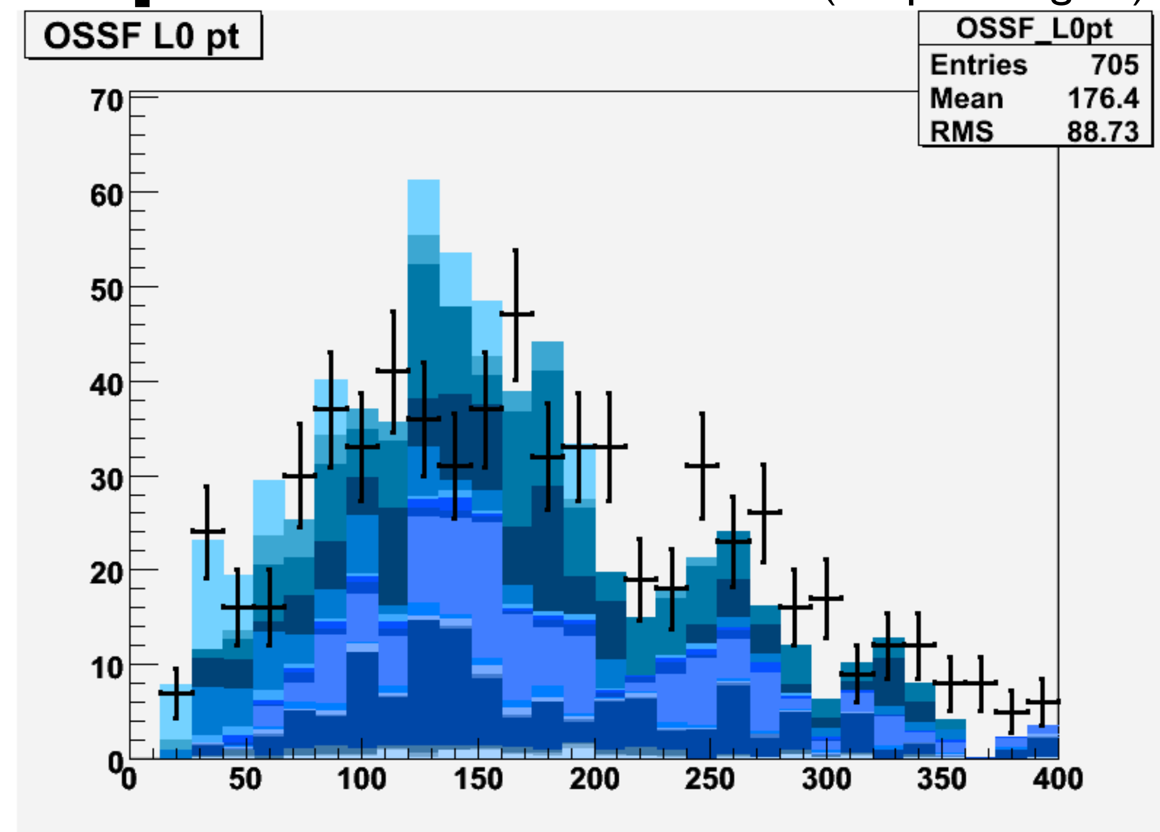
Composite OSETs assembled (mixed) and compared to signal

Basic Comparisons

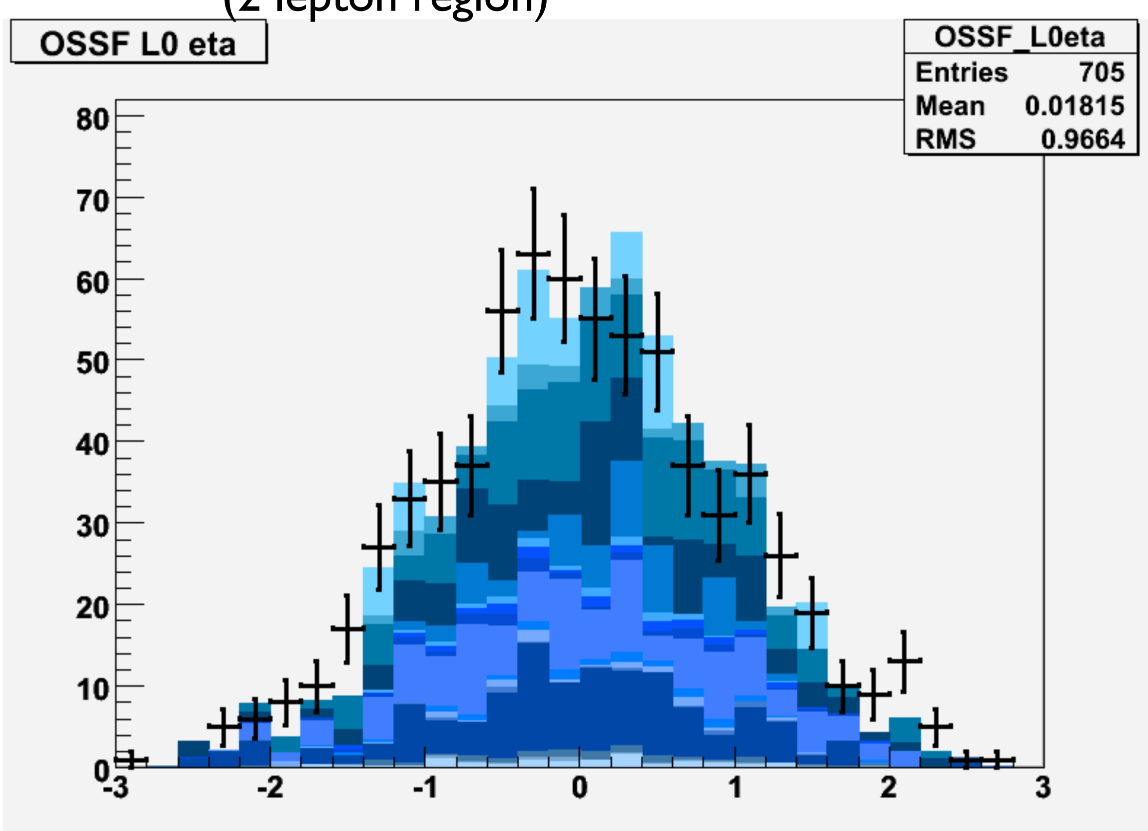
(2 lepton region)



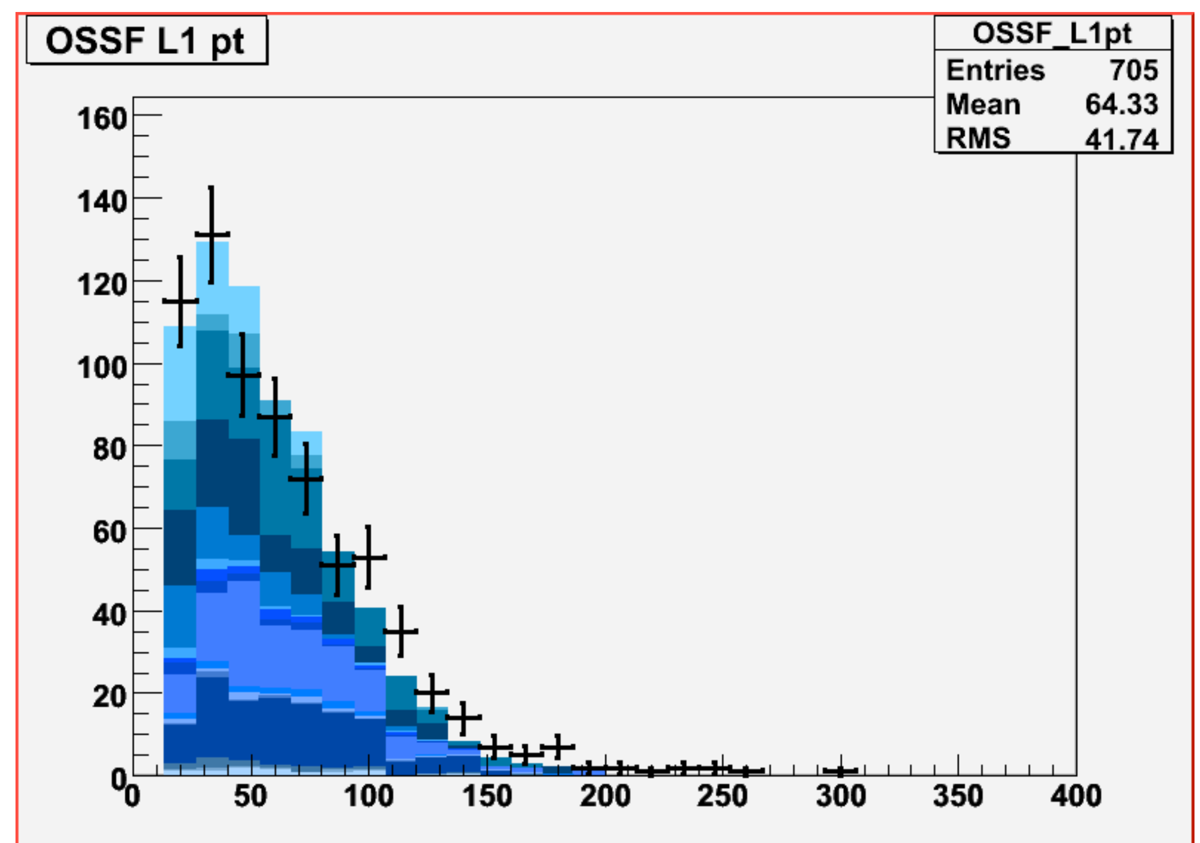
(2 lepton region)



(2 lepton region)



(2 lepton region)



Some branching ratio and cross section fitting is needed to get this far, but that is computationally for free anyway (re-weighting)

```
1: Sigma( g g > GL GL )          6500
2: Br( GL > N2 ubar u )          0.34
3: Br( GL > C1+ ubar d )         0.66
```

After some mass adjustments many signatures look "good"

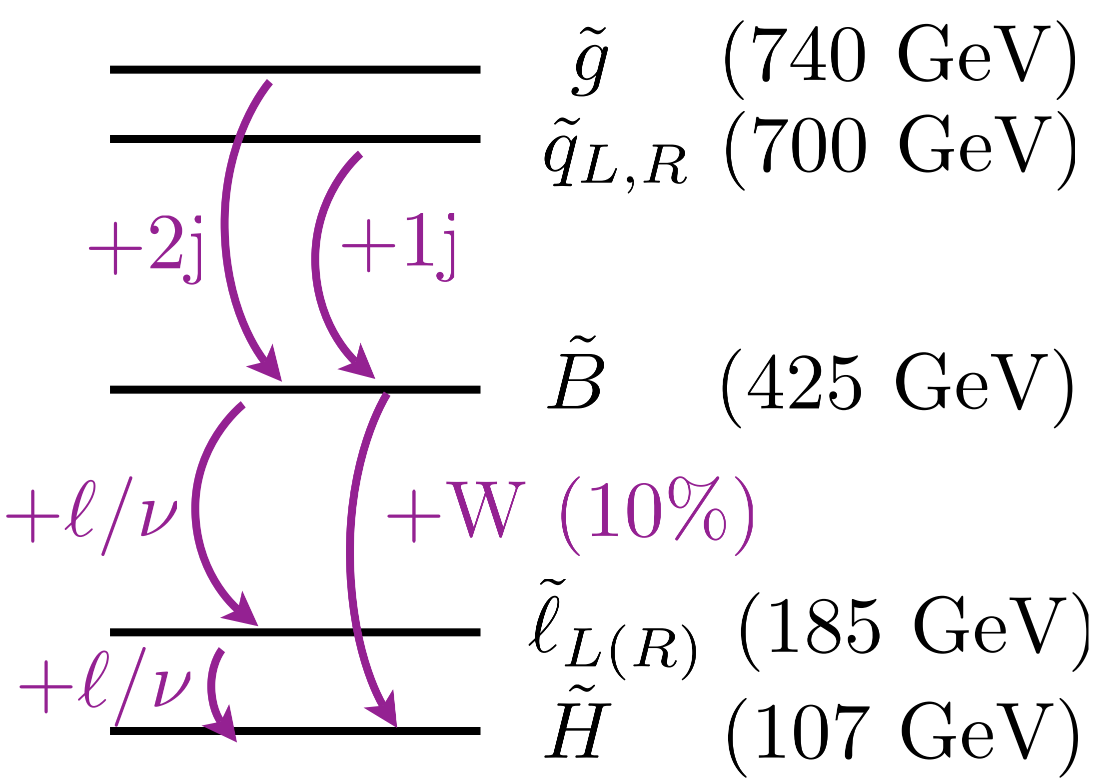
Even correlations in the different lepton regions look fairly good.

(This includes: lepton kinematics, high pt jet kinematics, invariant mass structure..etc)

We can also find a pythia SUSY model that explains these features about as well

(not well constrained)

$(\tilde{t}, \tilde{b}, \tilde{W}$ decoupled)

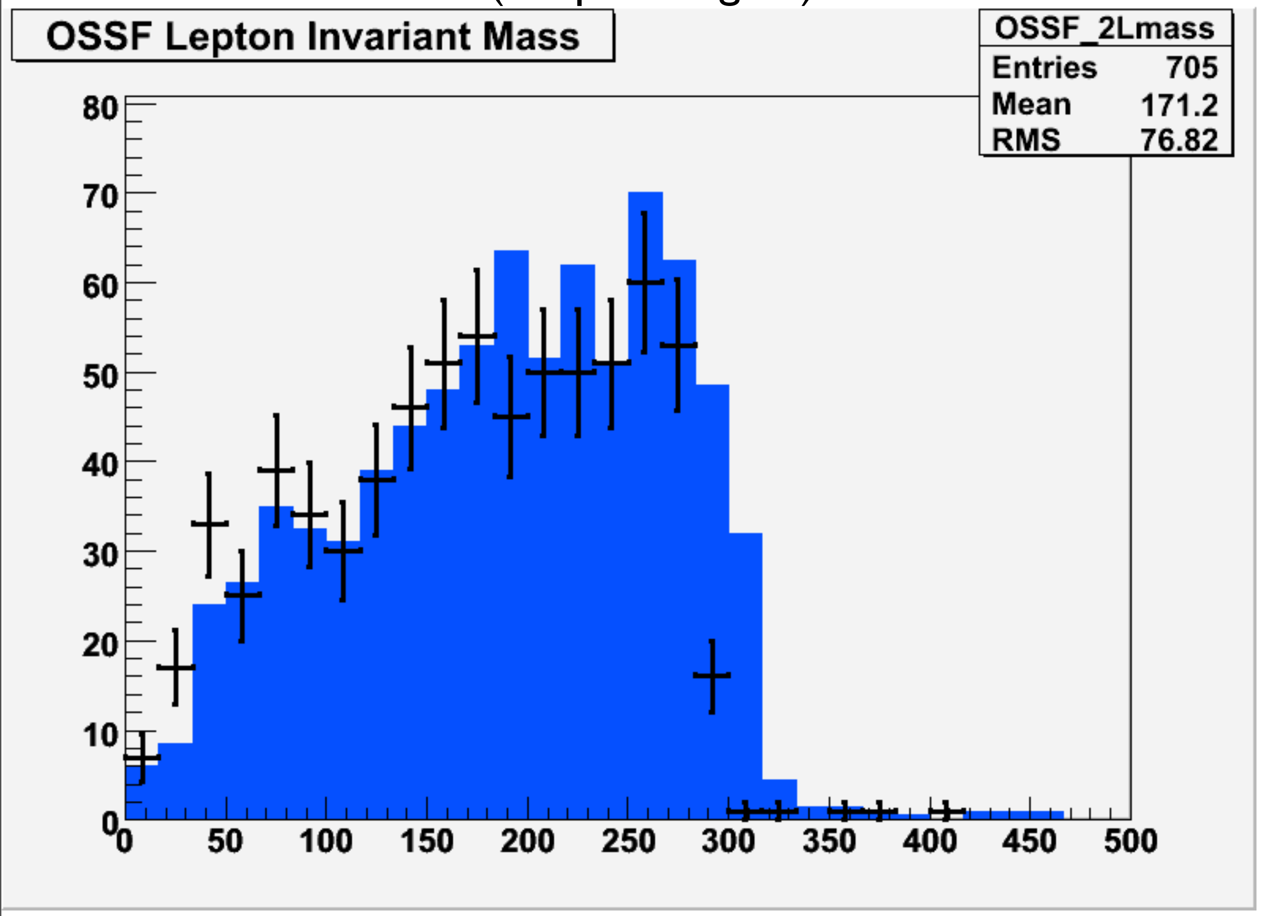


$\tilde{B}$ decays:

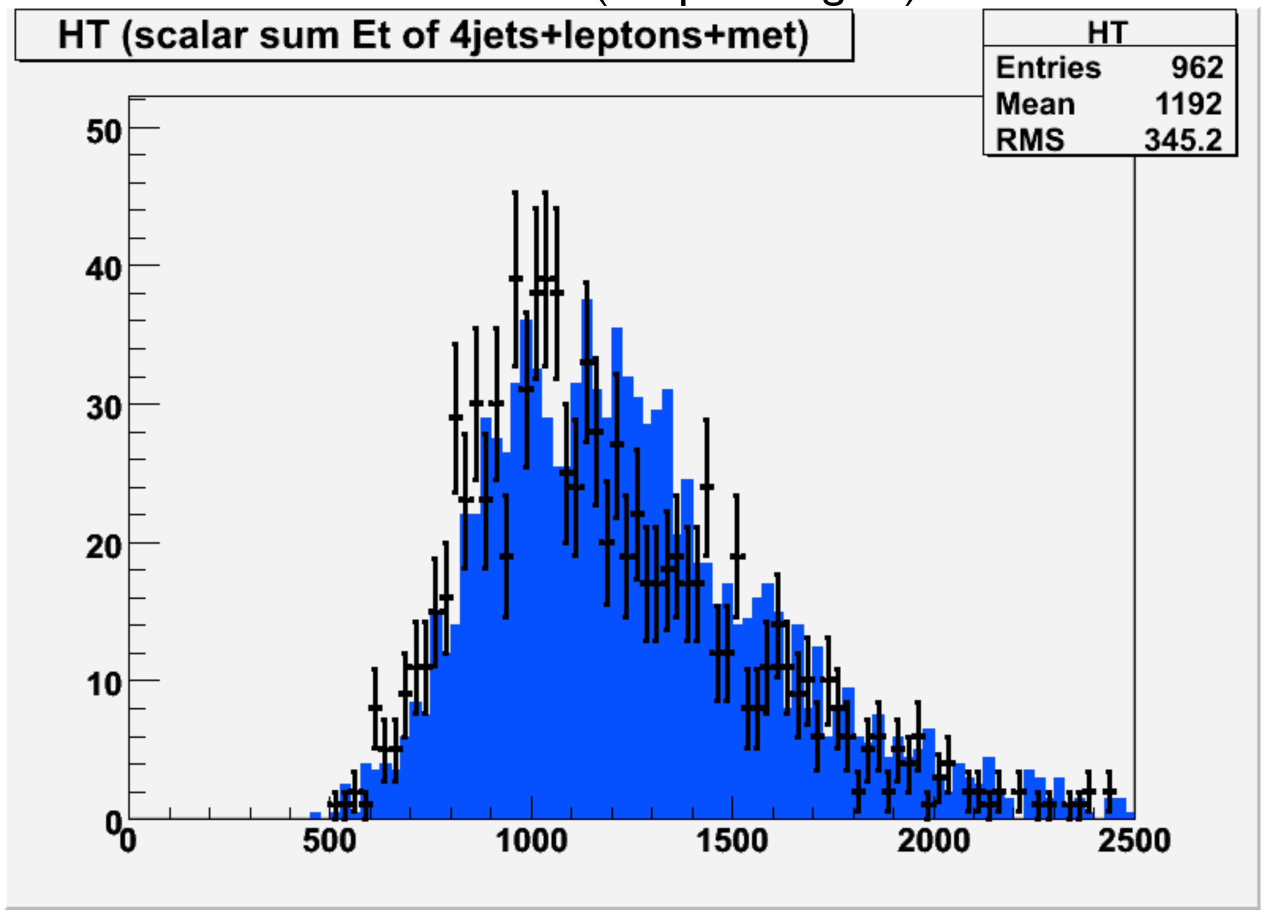
$\ell^+\ell^-$	63%
$\ell\nu$	20%
$\nu\nu$	6%
W	10%

Sample comparison...

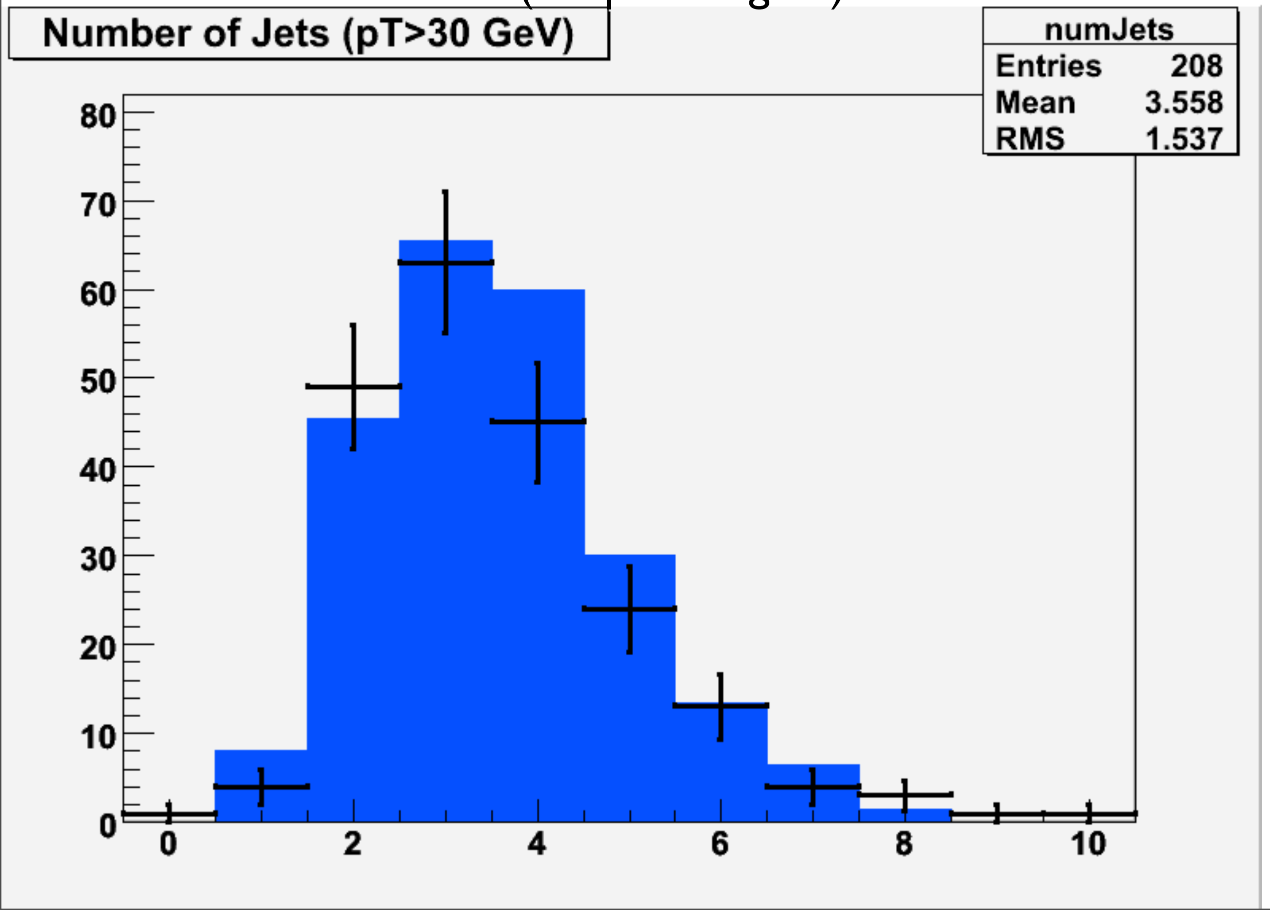
(2 lepton region)



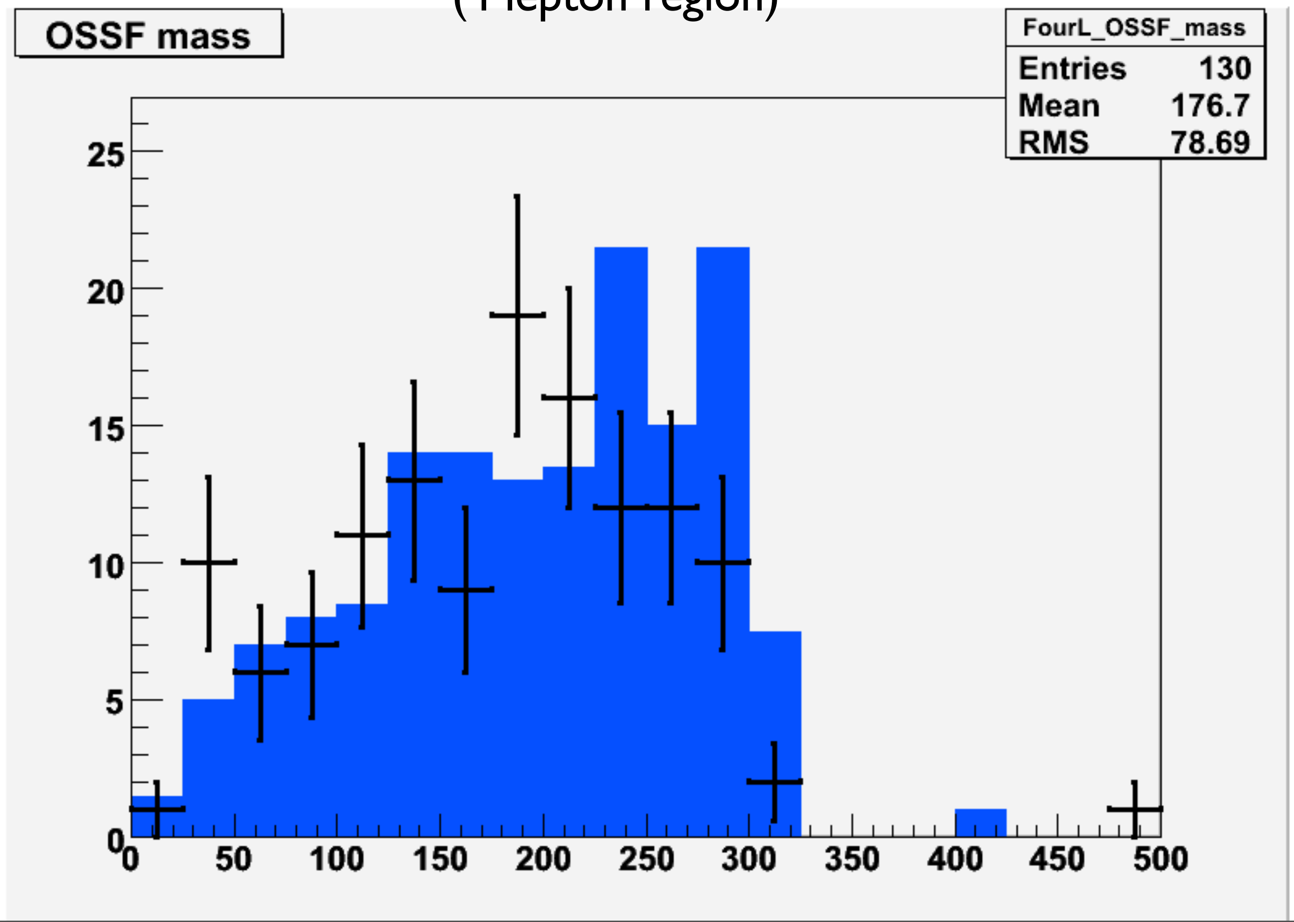
(2 lepton region)



(4 lepton region)



(4 lepton region)



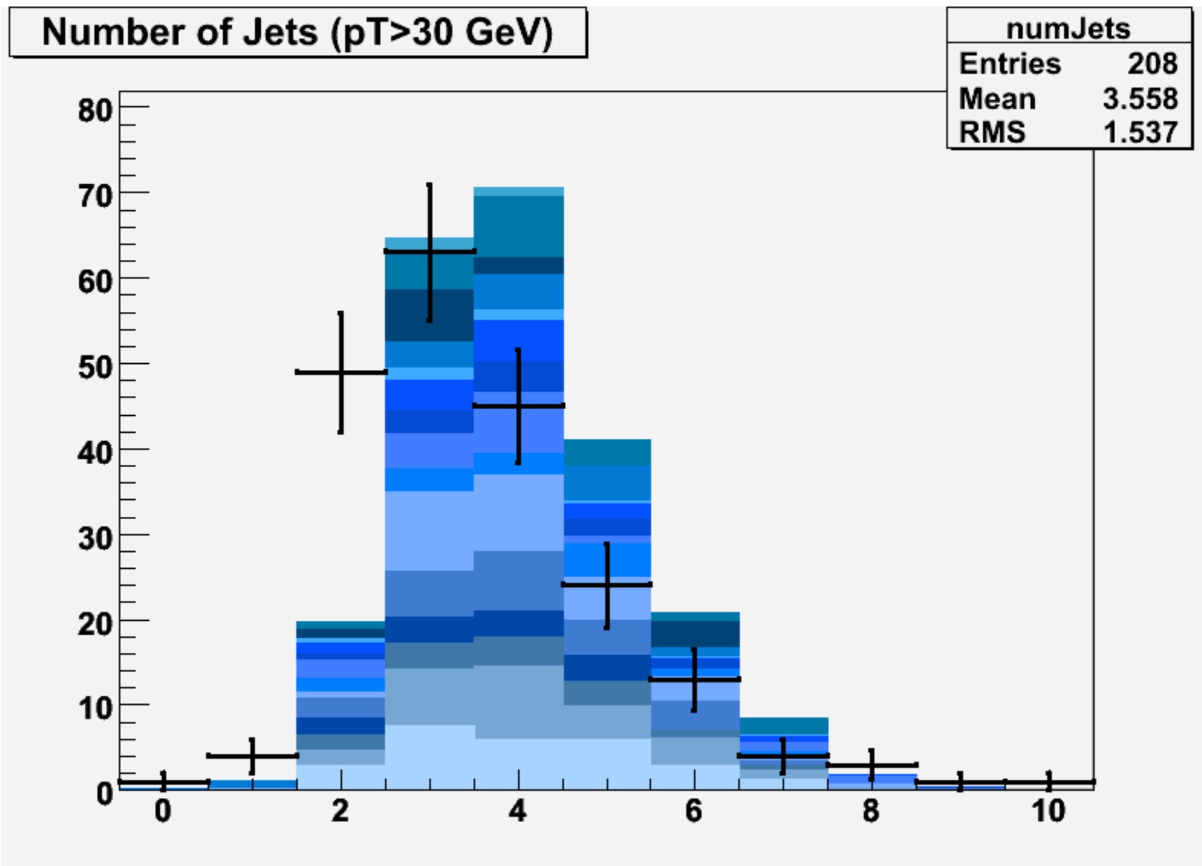
Both the SUSY model and the initial OSET have problems...

There are “discrepancies”...

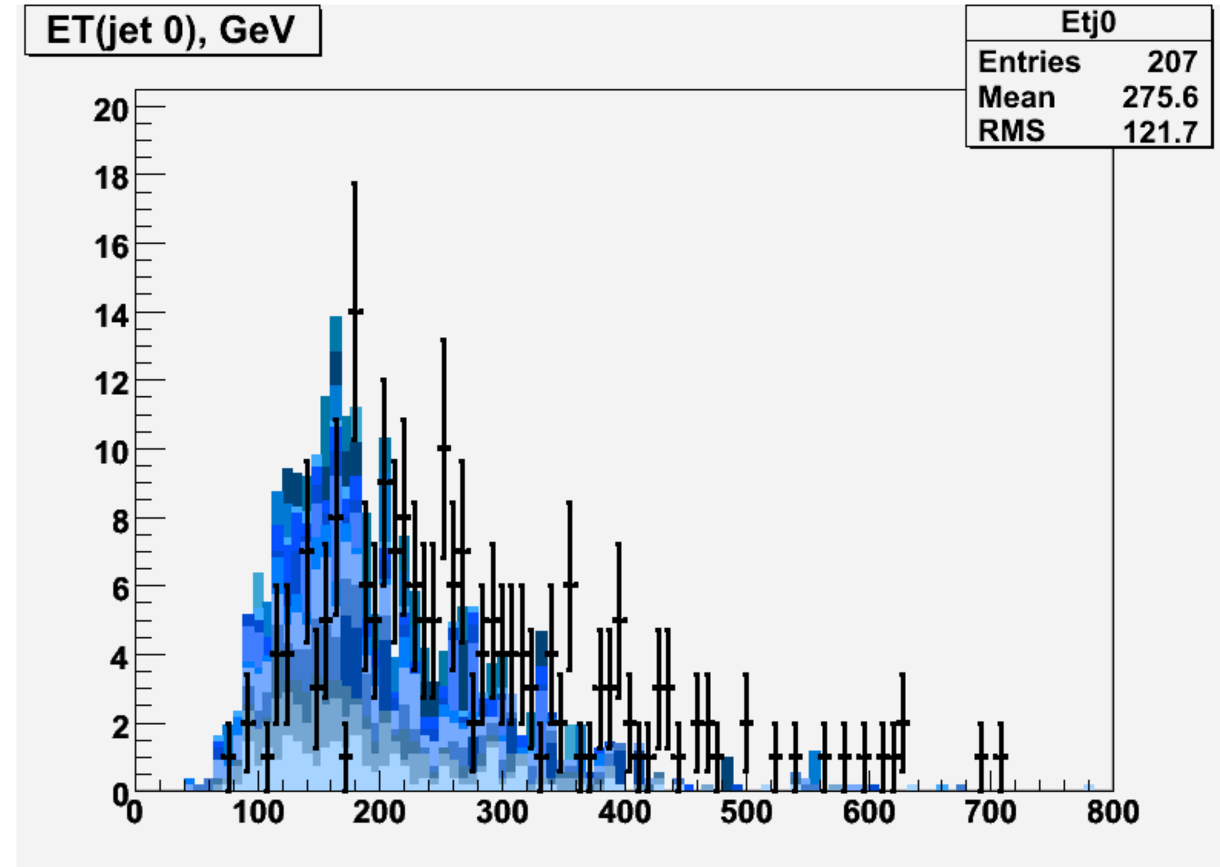
(By the way, both the initial OSET and the model are wrong, so one **must** be careful)

Sample "discrepancies"... for the OSET

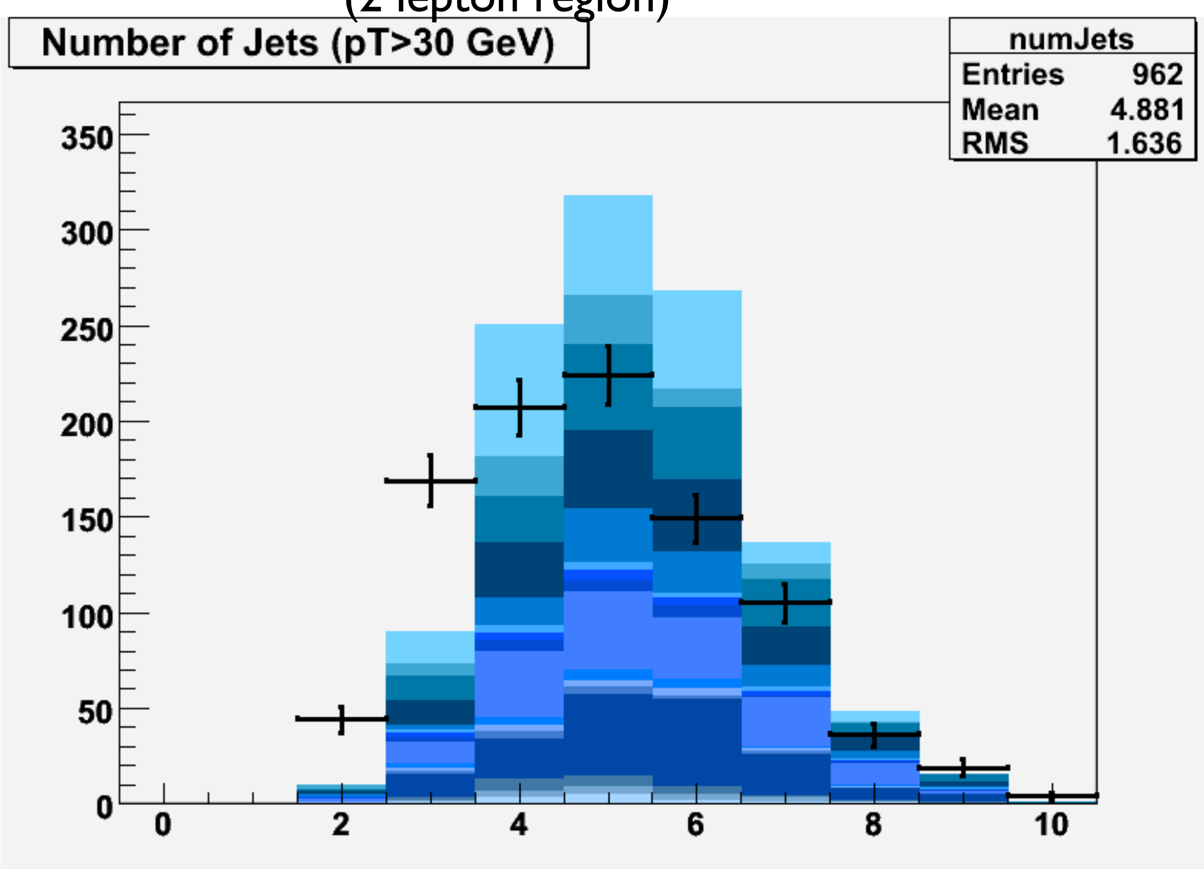
(4 lepton region)



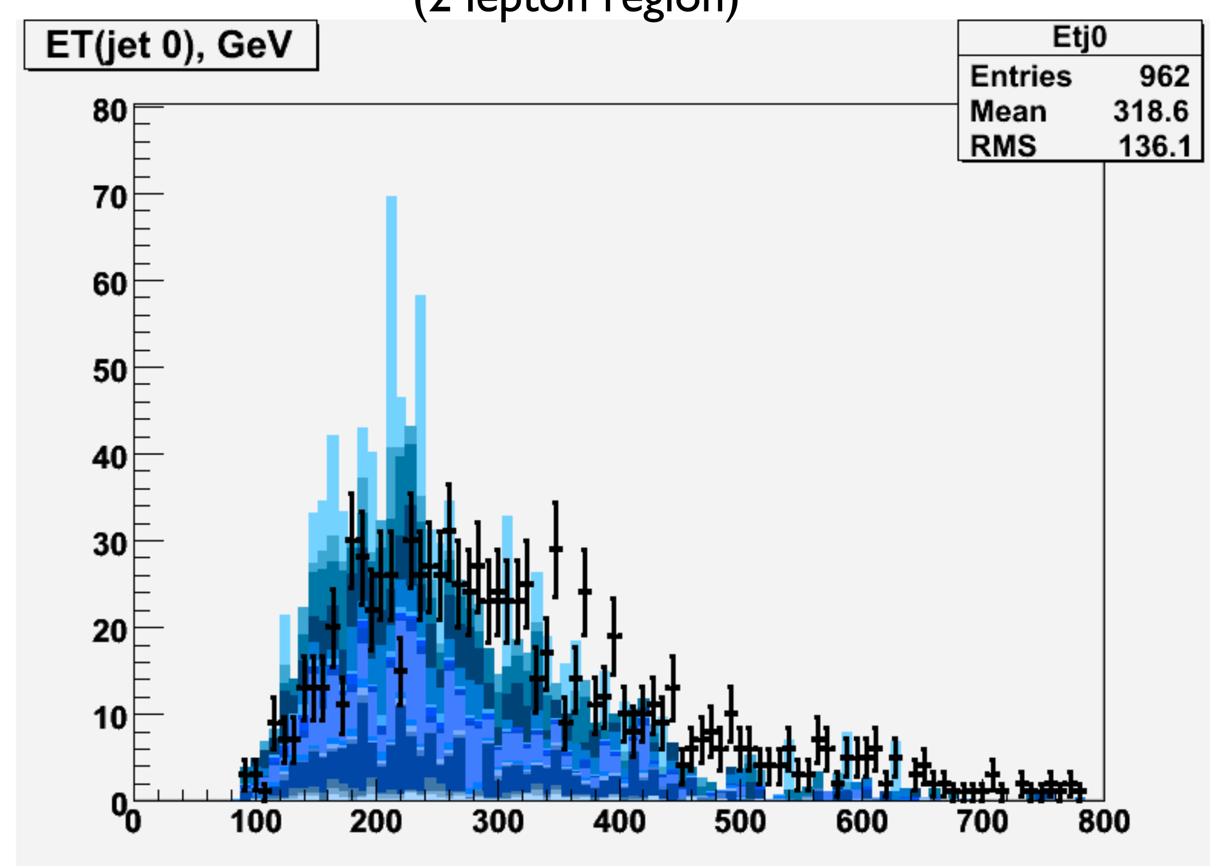
(4 lepton region)



(2 lepton region)

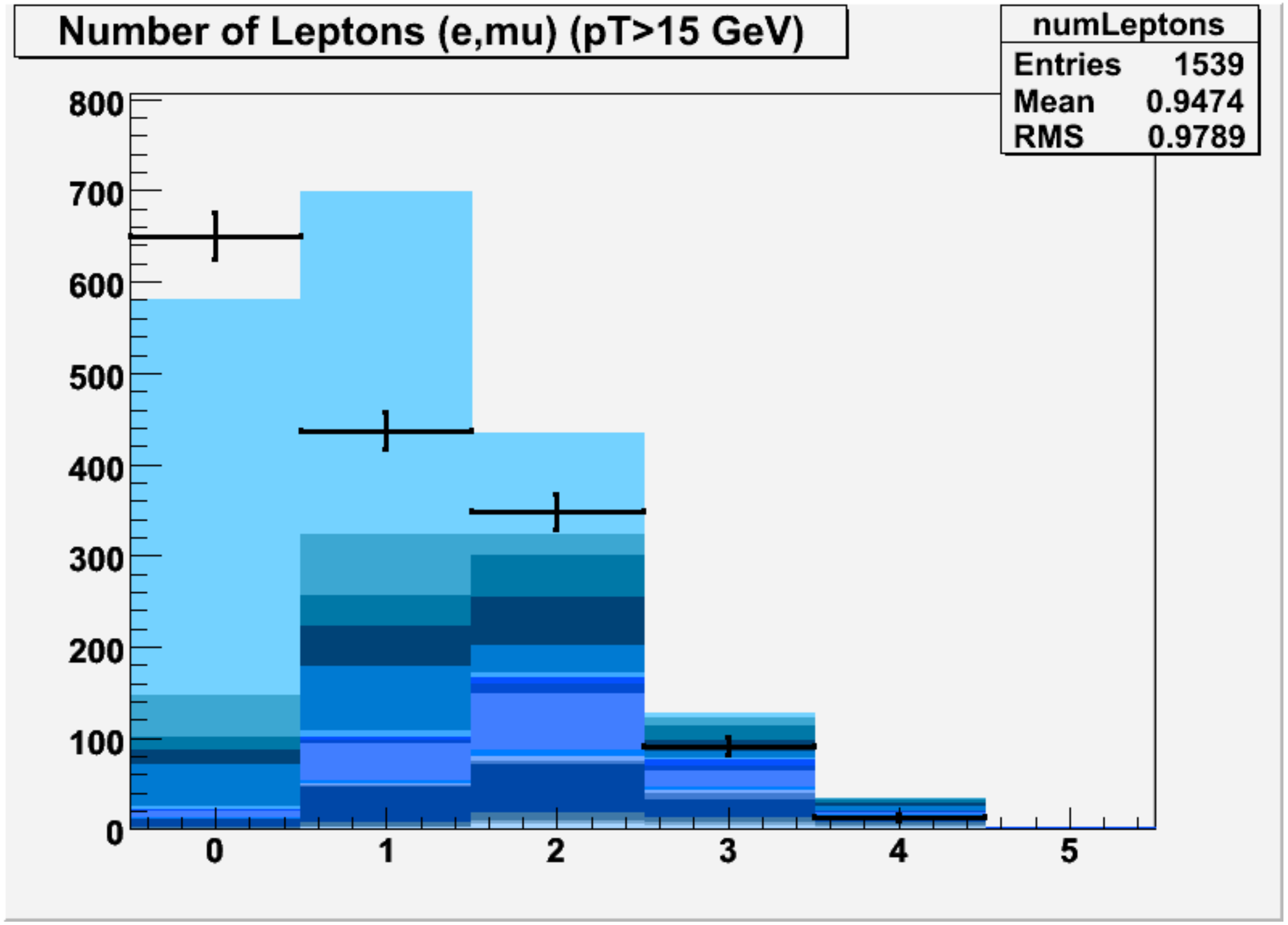


(2 lepton region)



As the low lepton multiplicity analyses become available... more problems emerge

(Inclusive Jets + MET)



(Jet definition different in the lepton rich searches shown before, so normalization cannot be compared so easily)

Of course, these distributions must be validated! We will trust some differences, not others.

Putting some work into optimizing, one can try to find variables that are robust (experimentally and theoretically) ***and*** constraining.

If we succeed in understanding these (or analogous) distributions, we learn that this guess had:

Too many high pt (>50 GeV) jets
Hardest jets are too soft
Higher multiplicity jets are too hard

*Clearly, there's other topologies to study, but we should understand how well we can claim the existence of any particular topology

Why does this BSM model not completely work?
This is a basic BSM analysis problem...

When we see poor agreement, what does it mean?

Do we have the correct processes, but incorrect modeling?

Do we have incorrect/incomplete topologies, but ok modeling?

...was the background validation wrong?

...or is everything bad?

To be conservative, we at least want to understand why certain classes of topologies fail to work, and how well the data constrains them, before we trust a fit to a large model parameter space or a larger OSET

Theory Discussion

Understand the approximations and how far we can expect them to hold

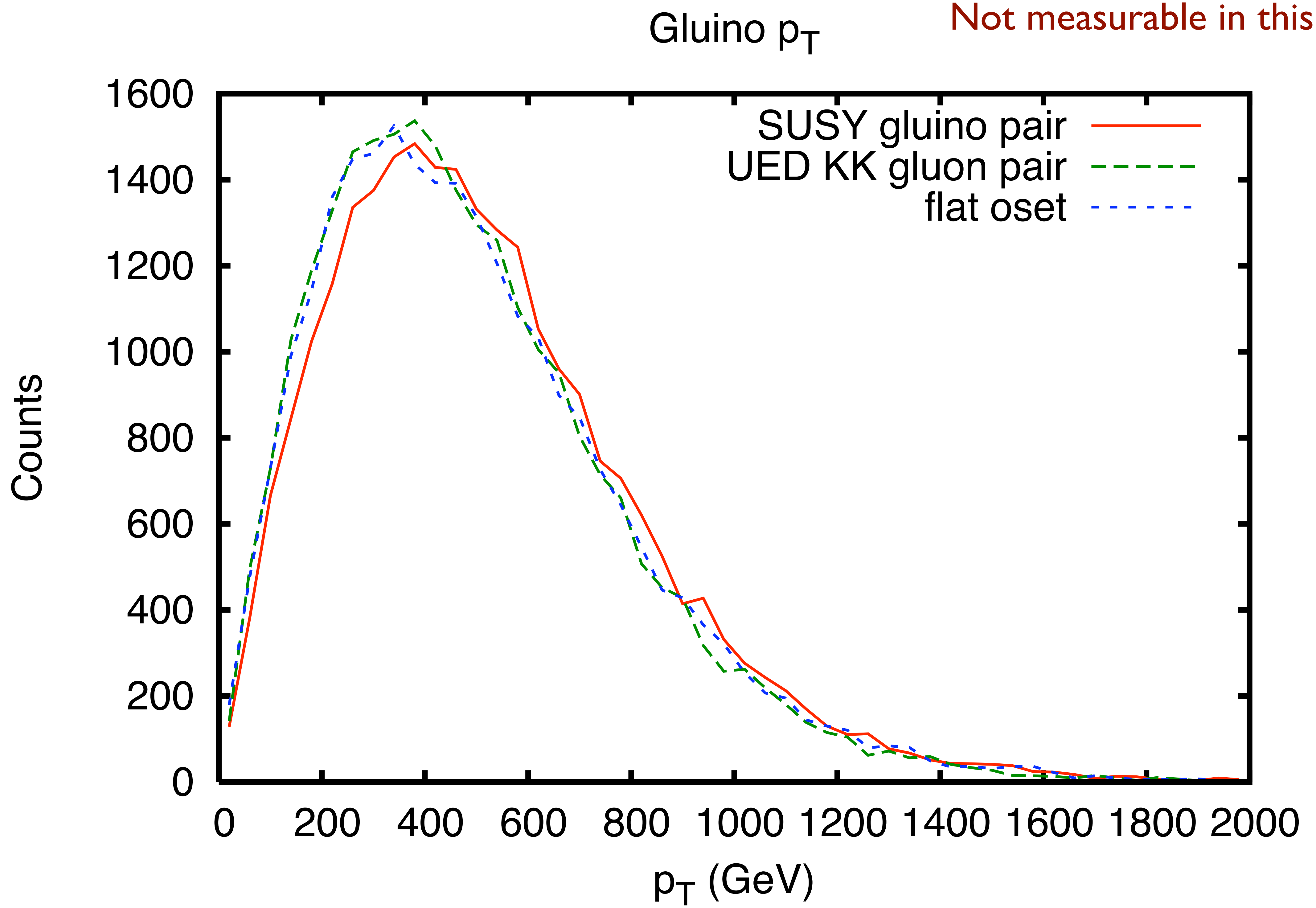
What should we be careful about?

How might we assess errors (conservatively)

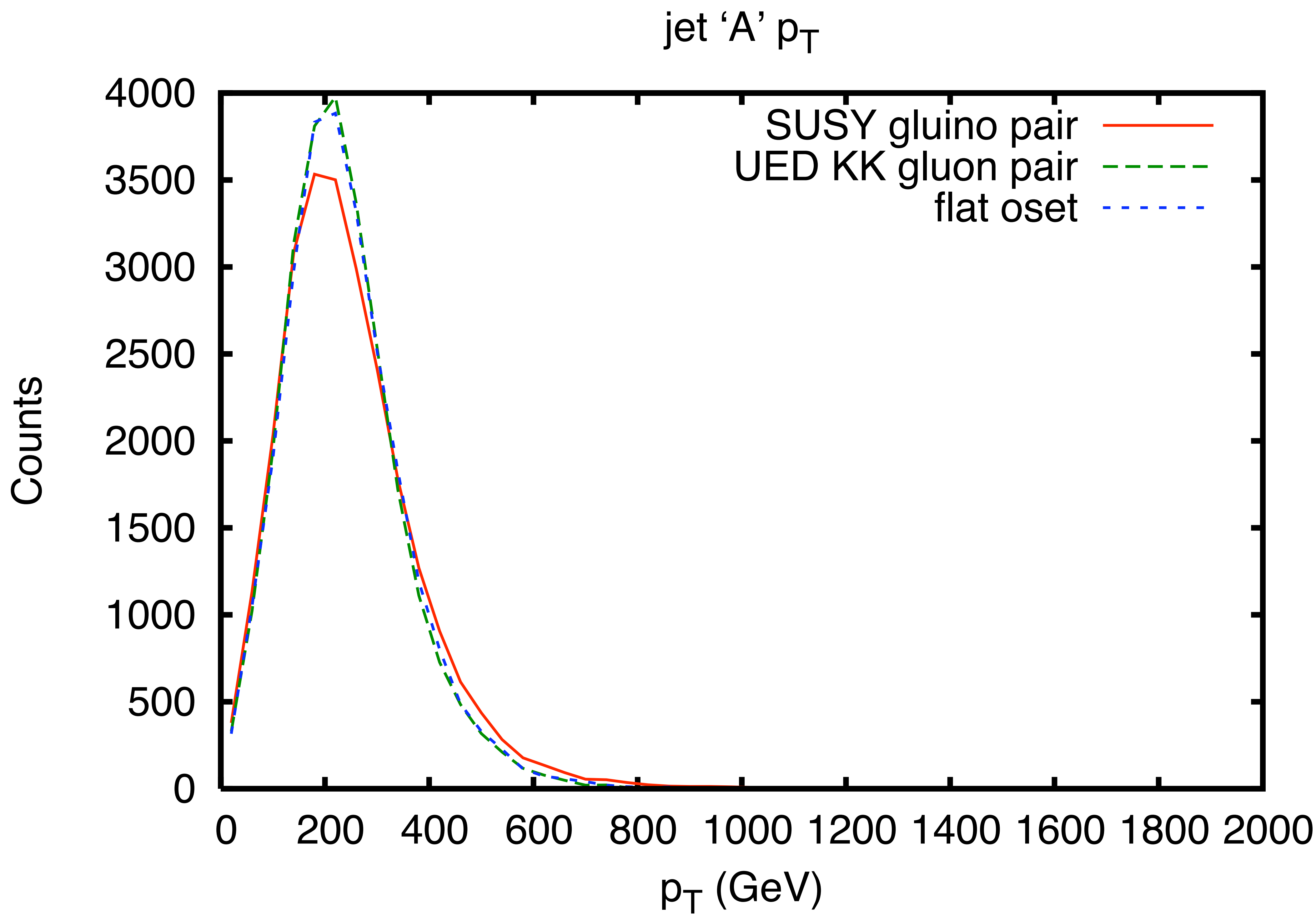
It's a virtue of OSETs that I can explain all the moving parts in ~10 minutes! This is the point. (The code will reflect this fact)

Recall the flat ME case...

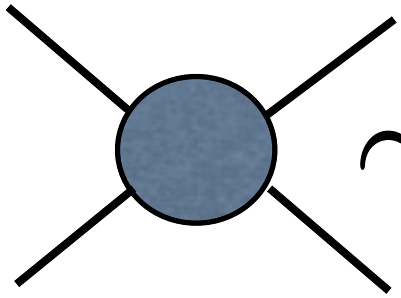
Just an example.
Not measurable in this case



Recall the flat ME case...



Adding Corrections:



Full ME

$$\sim |M|^2 = \sum_{p,q} C_{pq} X^p \xi^q$$

Contains CM threshold behavior

Contains CM angular and threshold structure

General Expansion

$$X \equiv \frac{s}{s_{th}}$$

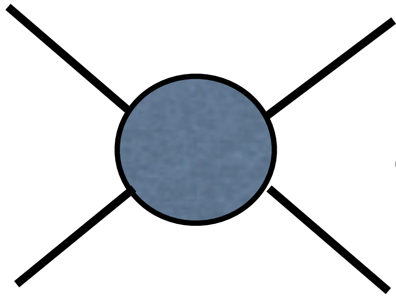
$$\xi \equiv \beta_{34} \cos(\theta)$$

Parton Luminosty

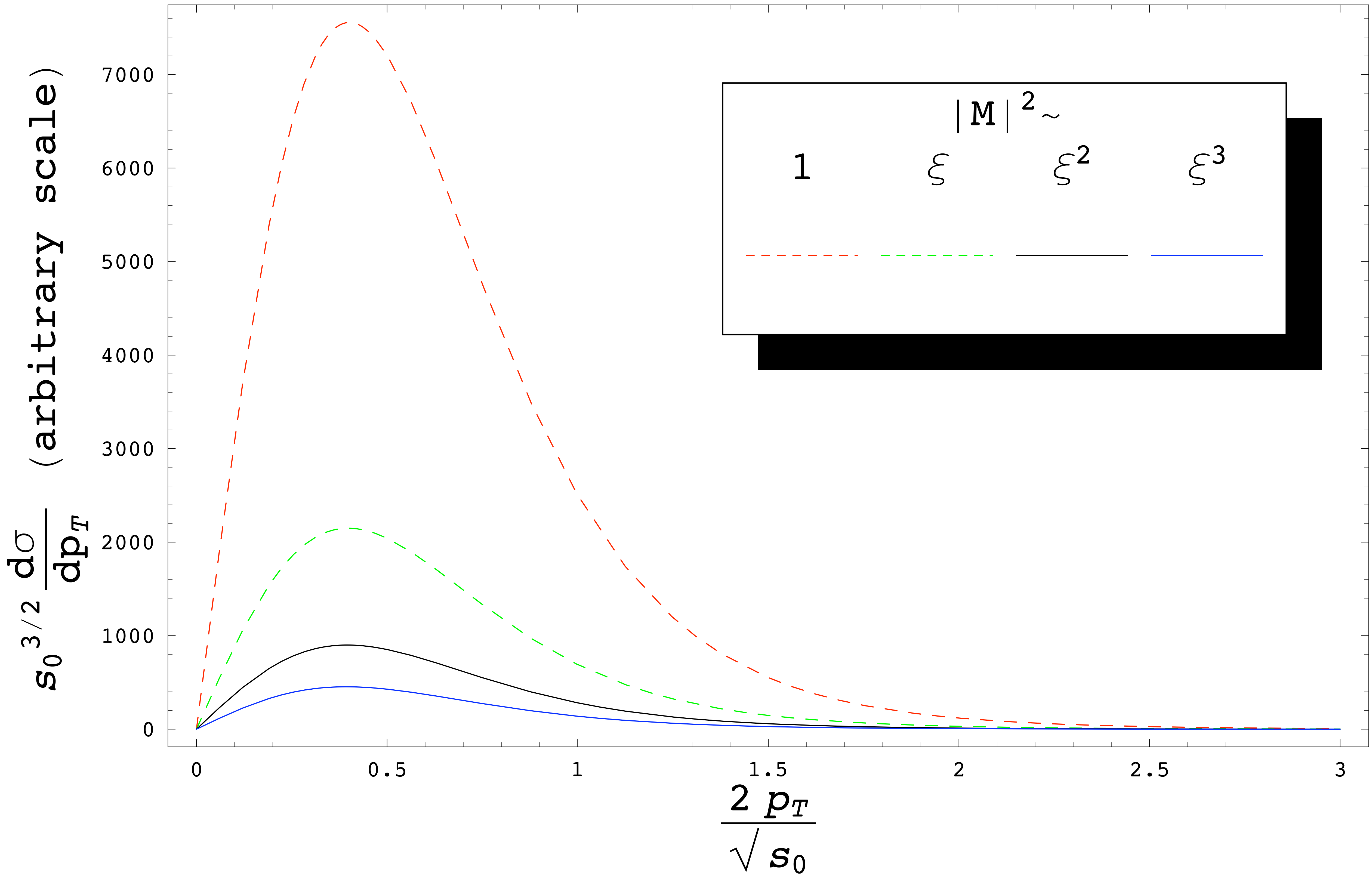
CM rapidity integrated

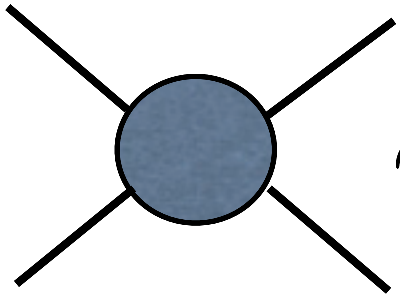
$$\rho_{PDF} \sim \tau^a \log(\frac{1}{\tau})$$

How much matrix element structure survives PDF convolution?



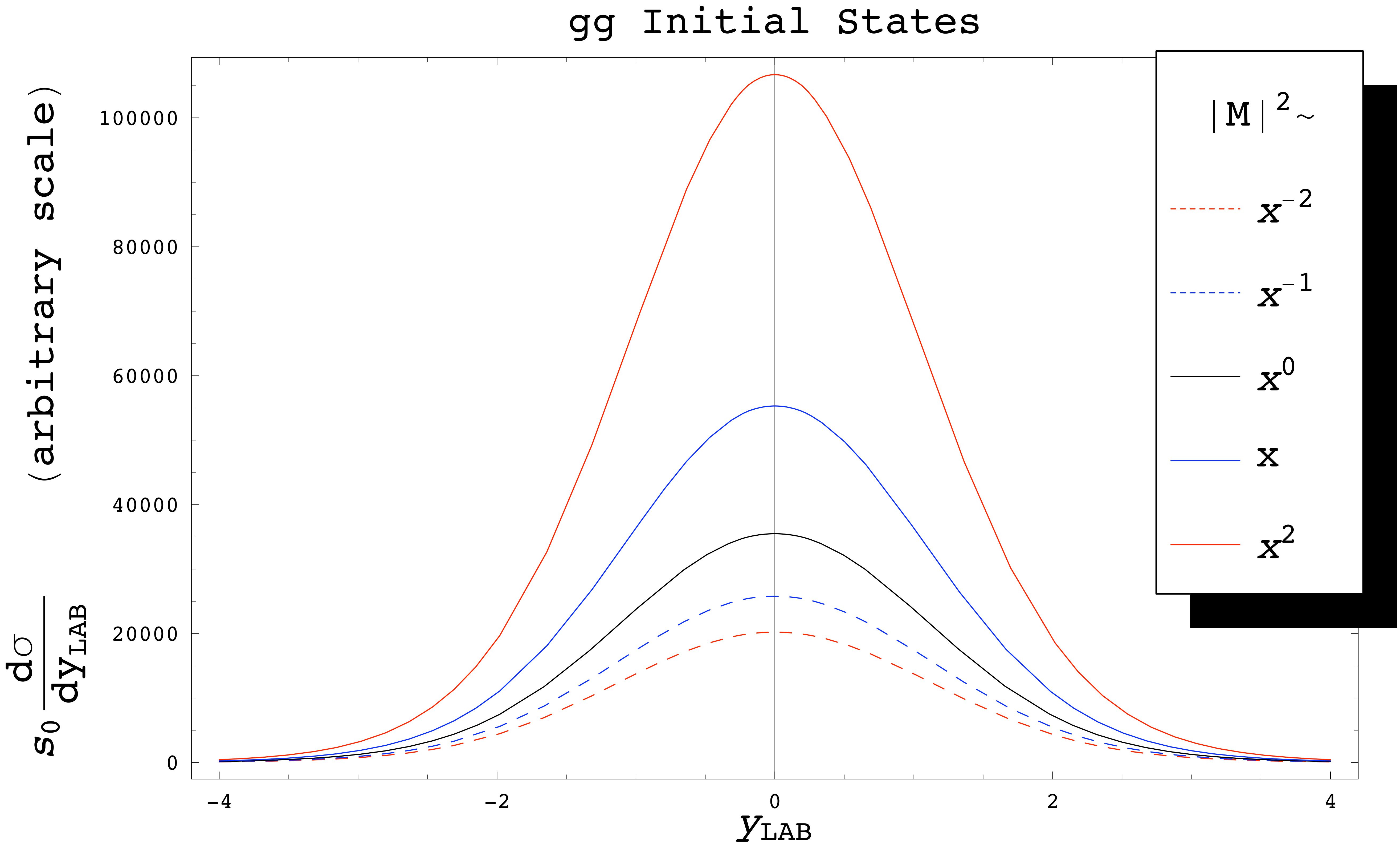
$\sim |M|^2 \sim X^q \xi^p$ ← Threshold Suppression

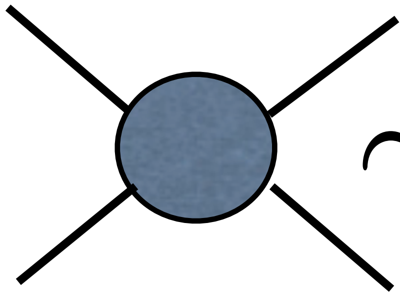




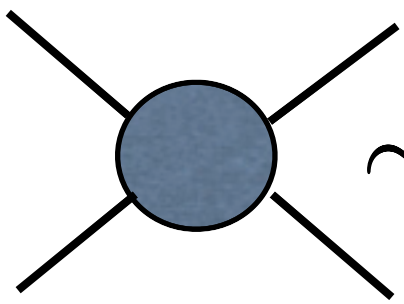
$$\sim |M|^2 \sim X^q \xi^p$$

Threshold Suppression



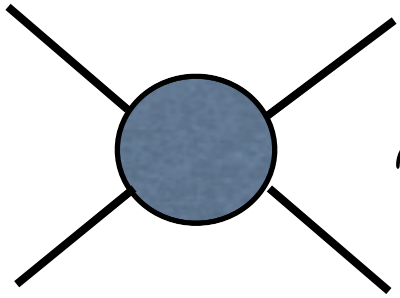


$$\sim |M|^2 = \sum_{p,q} C_{pq} X^p \xi^q$$

$\longrightarrow$ 

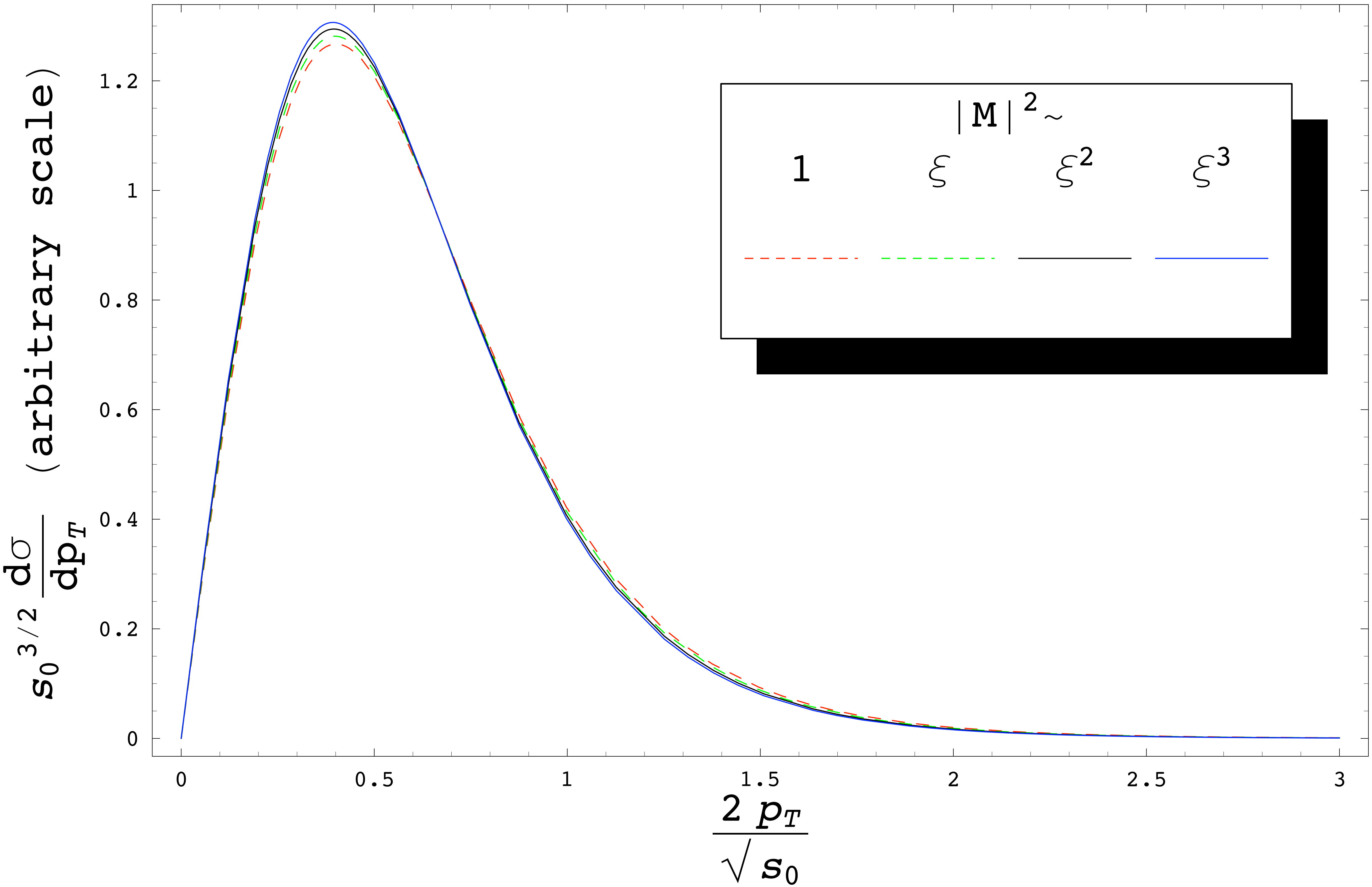
$$\sim |M|^2 \sim X^q \xi^p$$

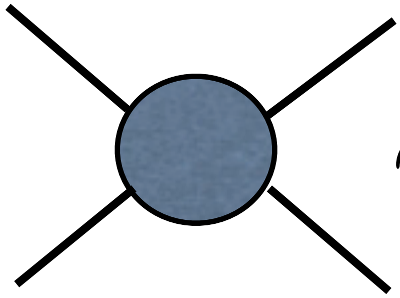
Only near-threshold behavior survives



$$\sim |M|^2 \sim X^q \xi^p$$

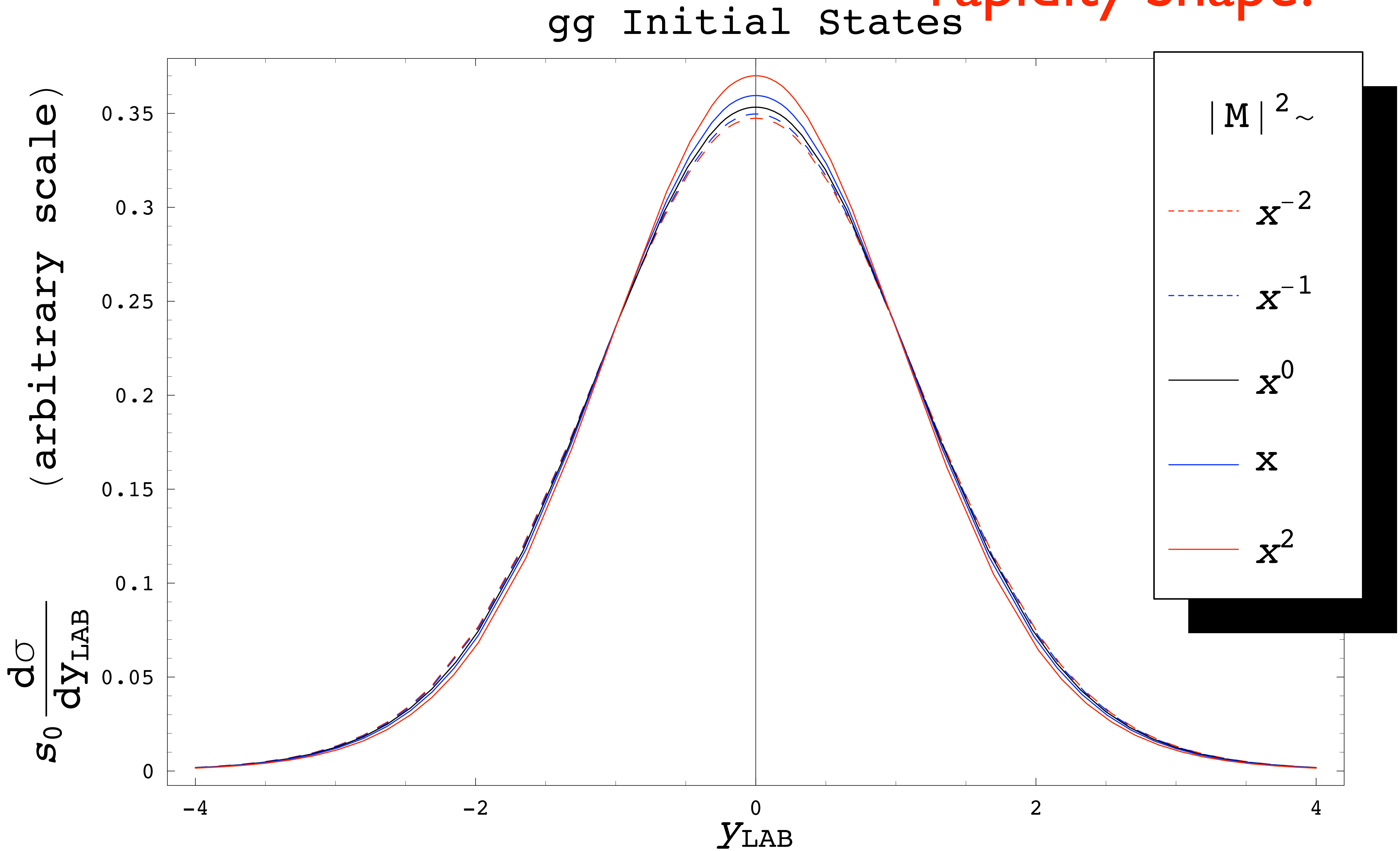
ξ-Independence of Transverse Shape!



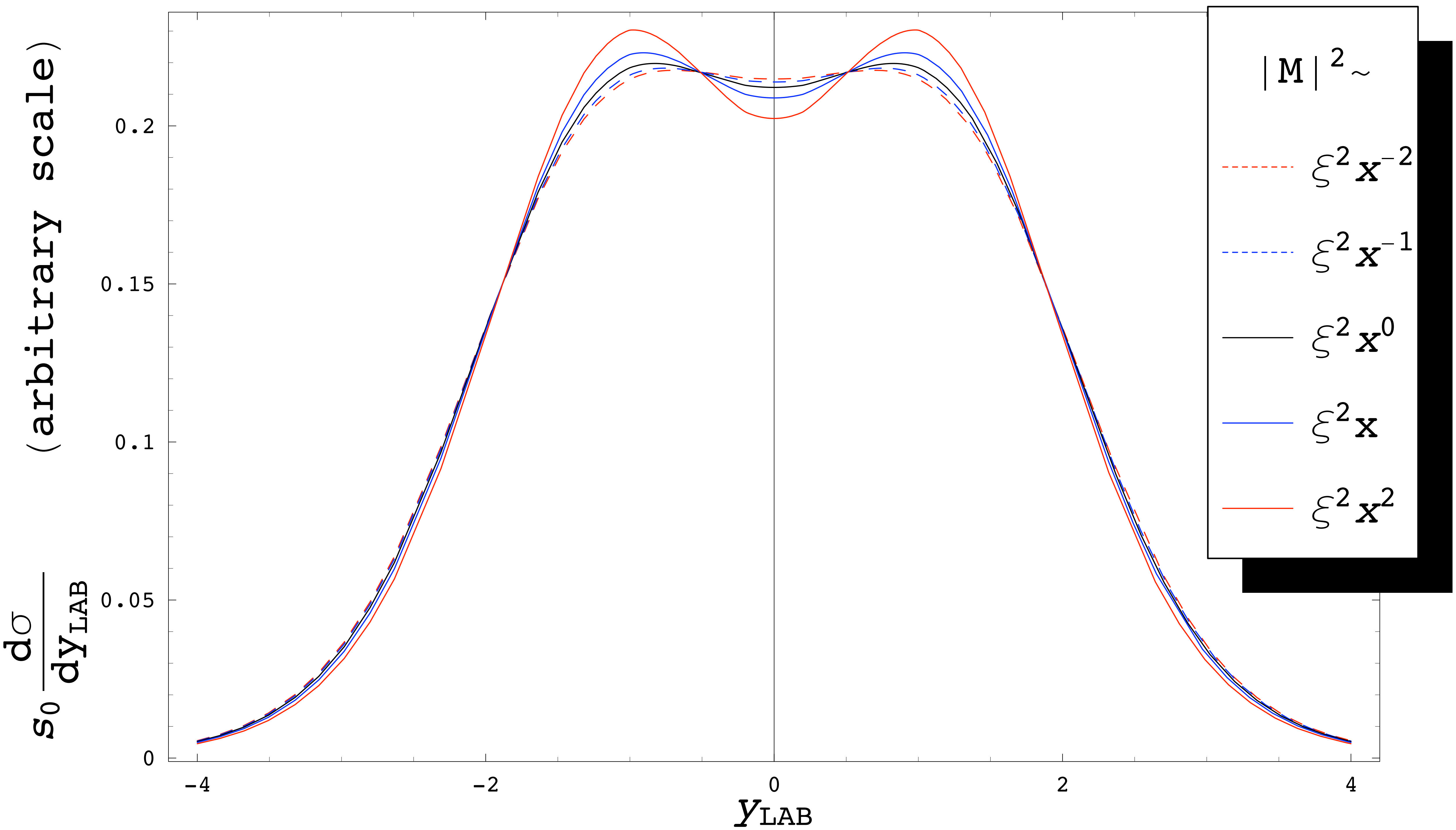


$$\sim |M|^2 \sim X^q \xi^p$$

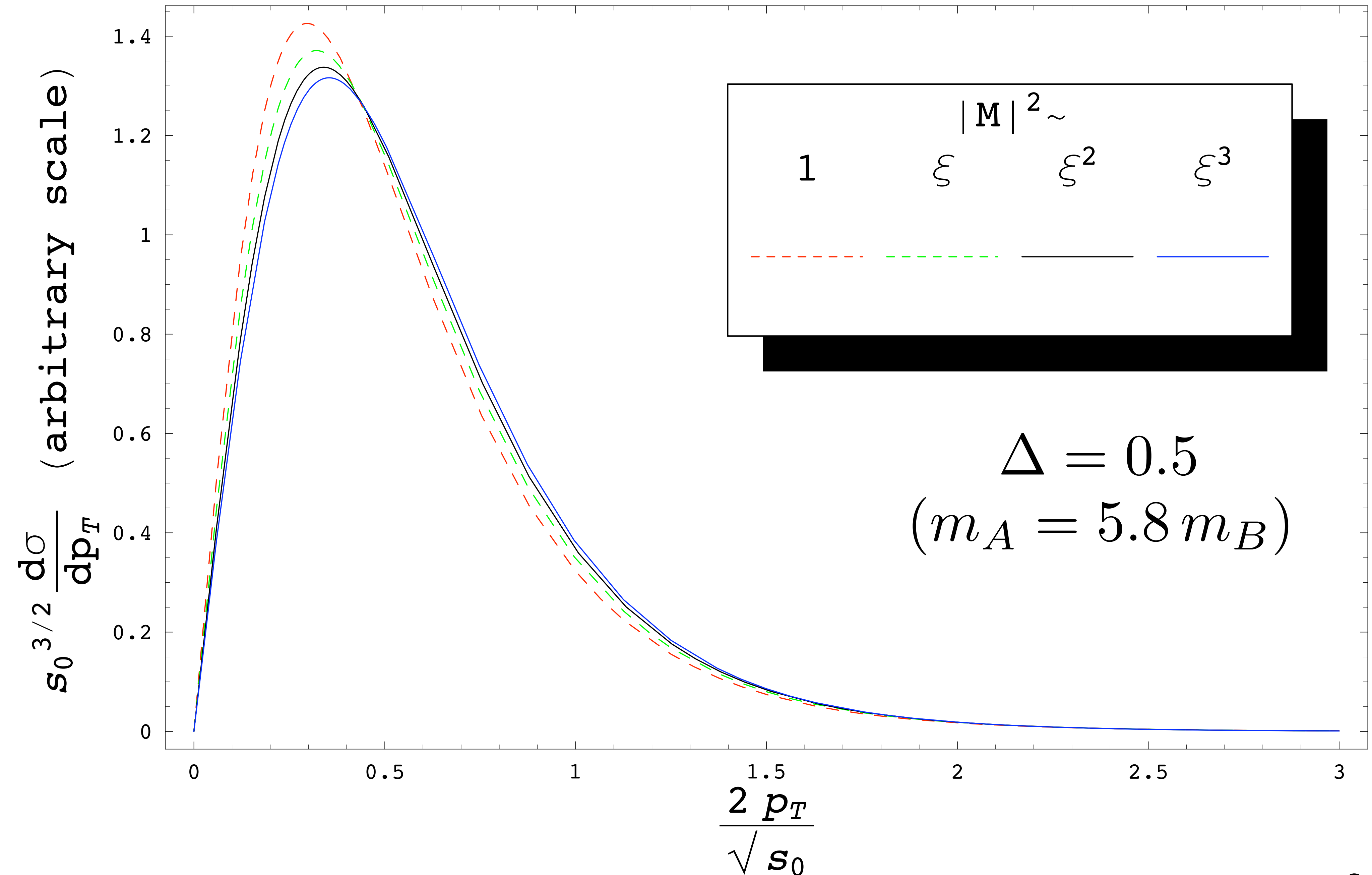
X-Independence of rapidity Shape!



Shape invariance even with non-trivial angular dependence in the ME...

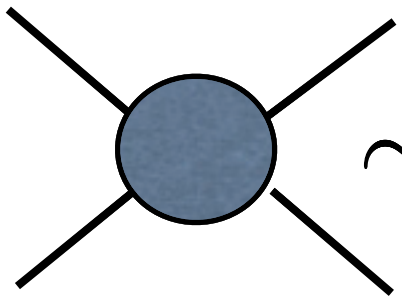


Finite Mass Corrections



$$\Delta = \left(\frac{m_A - m_B}{m_A + m_B}\right)^2$$

Shape Invariance



$\sim |M|^2 \sim X^q \xi^p$

PDF E_{cm} and y_{cm} homogeneity properties

Inclusive p_T shape invariant under:

$$|M|^2 \to |M|^2 \xi^m$$

Inclusive y_{lab} shape invariant under:

$$|M|^2 \to |M|^2 X^n$$

Simple "Universal" corrections to constant ME!

Messy collider environment turned to our advantage

Caveats:
- Correct PDFs necessary
- Large final state mass asymmetry requires care
- Transverse momentum-rapidity correlations not included beyond phase space

See: hep-ph/0703088 for detail...

Defining an OSET

Production:

$2 \to 1$ Use Breit Wigner

$2 \to 2$

Usually dominates

"Normal" Behavior

$$|\mathcal{M}|^2 = A + B\left(1 - \frac{s_{\rm thresh}}{s}\right)$$

or

"Contact" Operator Behavior

$$|\mathcal{M}|^2 = A + B\left(\frac{s}{s_{\rm thresh}} - 1\right)$$

Dominant ξ correction can be included (not usually necessary)

$2 \to 3$ Use "standard" modes with OSET decay scheme

Decay:

- Polynomial in $\cos\theta$: rank determined by spins, coefficients by masses. Spin correlations can be included...use a more powerful tool (i.e. MadGraph for example)

- Single-object lab-frame distributions, and many correlations, well approximated by phase space decays.

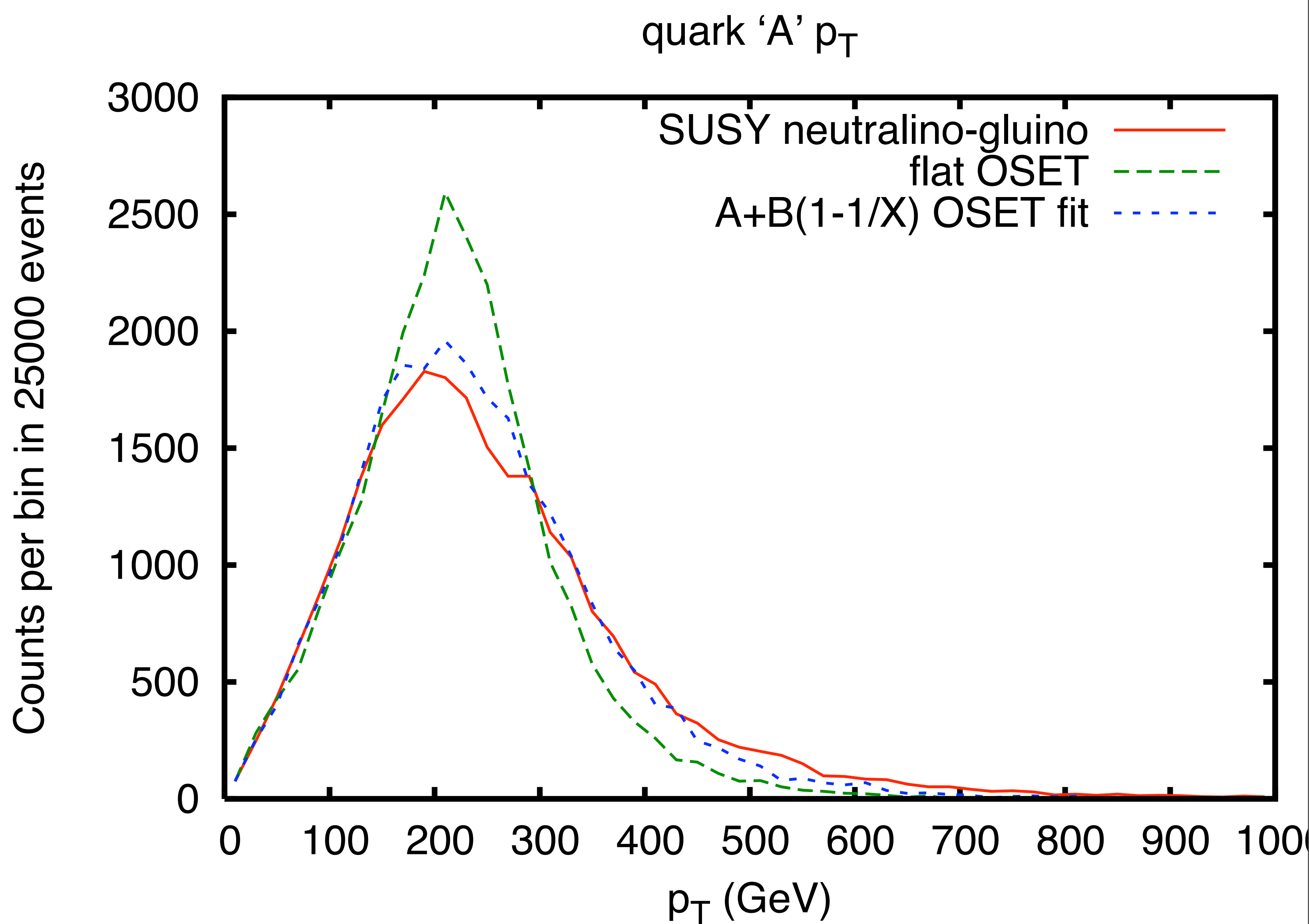
See: hep-ph/0703088 for detail...

“Normal” Behavior

$$m_{t\text{-chan}} \sim m_{\tilde{g}}$$

p-wave $\rightarrow$ suppressed near threshold.

$$\propto \beta^2$$



$$|\mathcal{M}|^2 = A + B\left(1 - \frac{s_{\text{thresh}}}{s}\right)$$

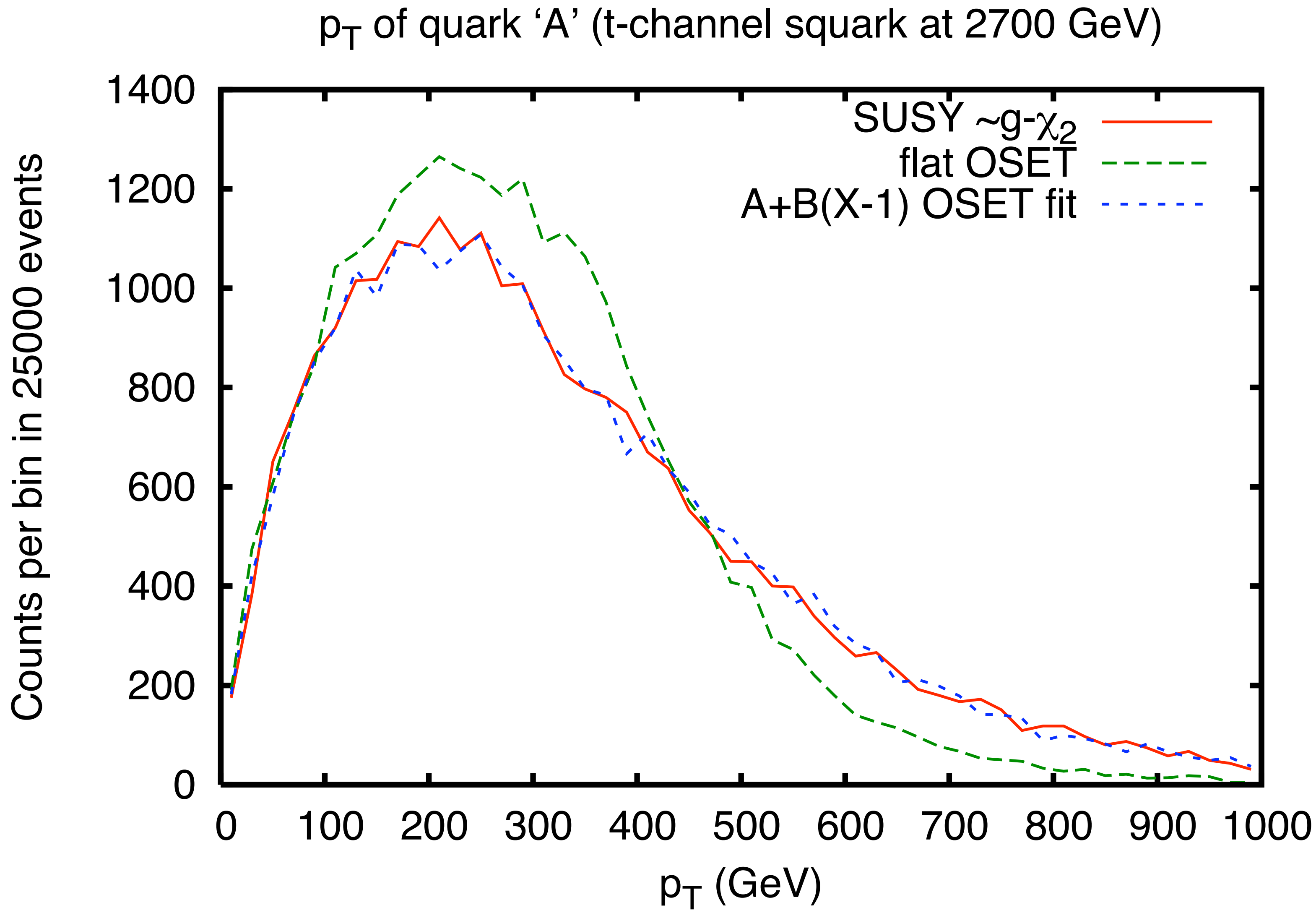
"Contact" Operator Behavior

$m_{t\text{-chan}} \gg m_{\tilde{g}}$

contact interaction

$|\mathcal{M}|^2 \propto s^2$

up to $\sqrt{s} \sim m_{t\text{-chan}}$



$$|\mathcal{M}|^2 = A + B\left(\frac{s}{s_{\text{thresh}}} - 1\right)$$

Theory Summary

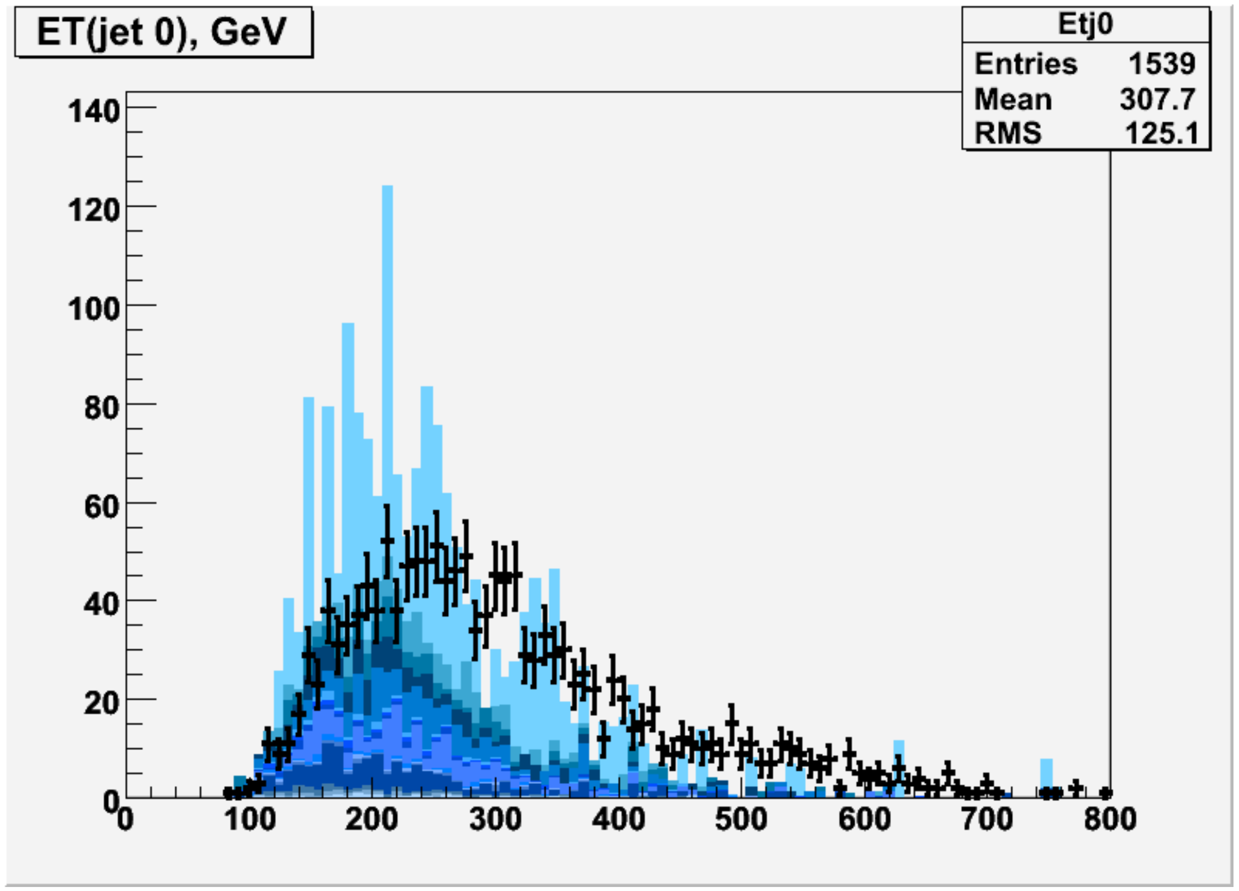
Production dynamics (and errors) can be studied using the full parameterization, including threshold corrections

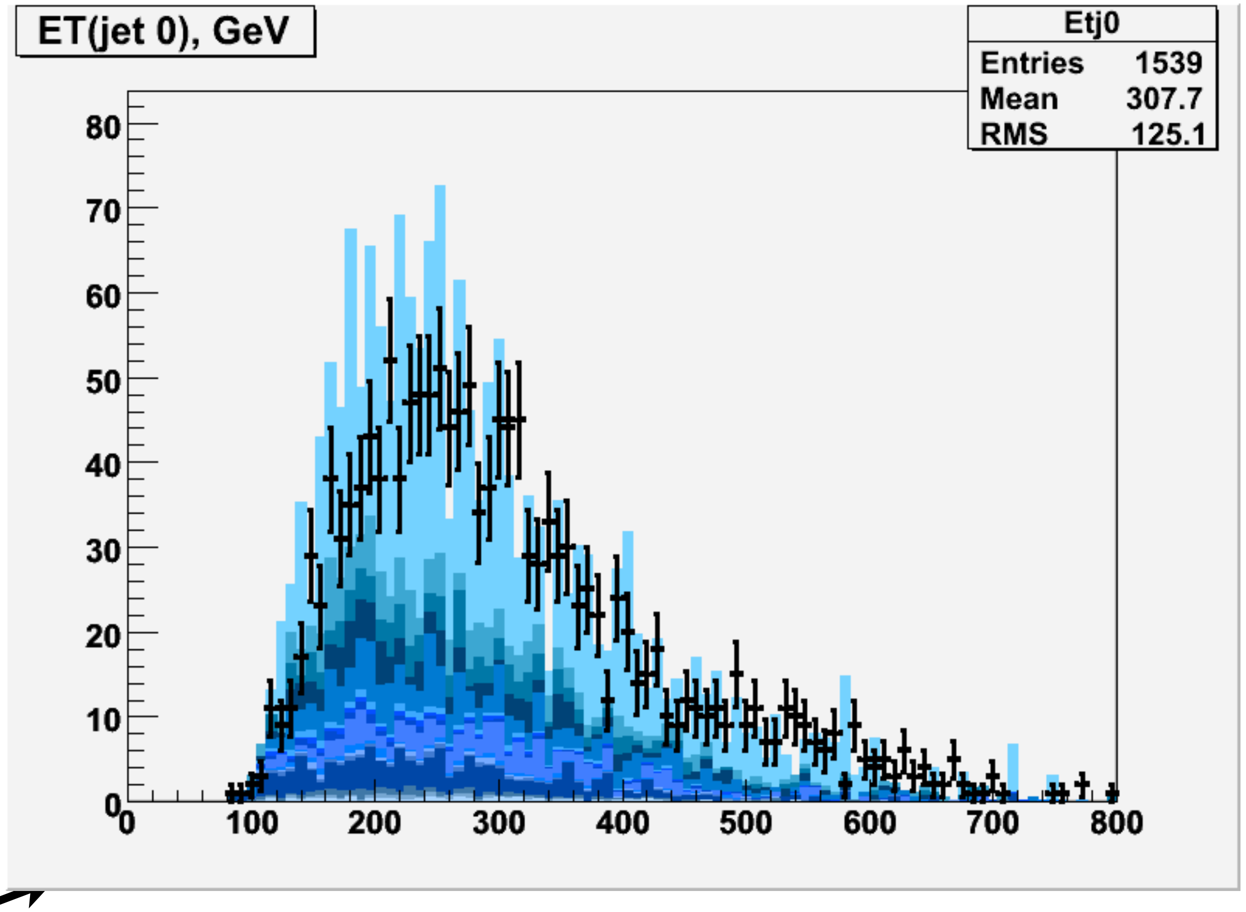
Spin correlations can also be studied, though they are less important for the signatures discussed here

Also **must account** for radiation (parton shower) uncertainty

Returning to the example...

Compare different production dynamics:





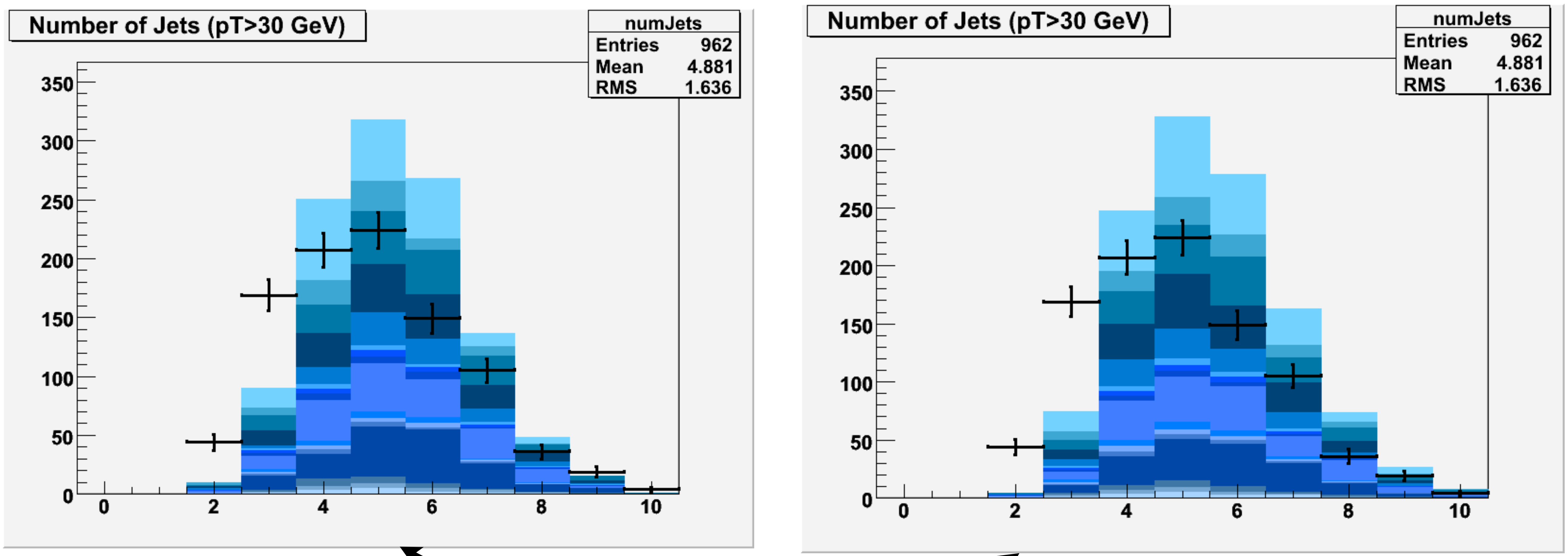
$$|\mathcal{M}|^2 = A + B\left(1 - \frac{s_{\rm thresh}}{s}\right)$$

Signal cut efficiencies for exclusive regions are altered (this is the main impact)

Primary mass vs production ME errors...

(Try to avoid conclusions that depend sensitively on this ambiguity)

Persistent problems...



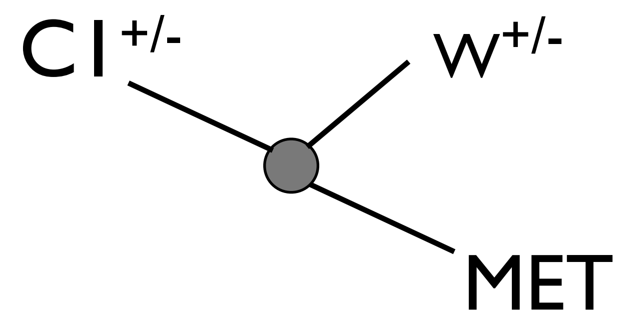
$$|\mathcal{M}|^2 = A + B\left(1 - \frac{s_{\rm thresh}}{s}\right)$$

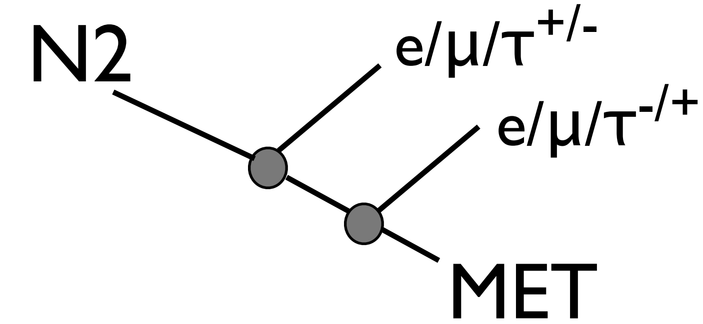
This difference (too many jets) persists even for high pt (very central) jets...still need to study showering...etc...

Setting aside detail, perhaps we should explore other processes

Studying the spectrum

Jet structure:

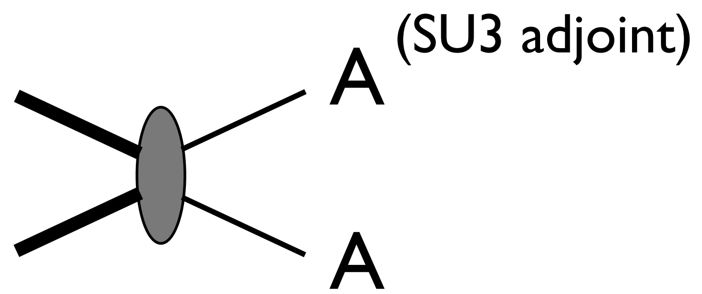


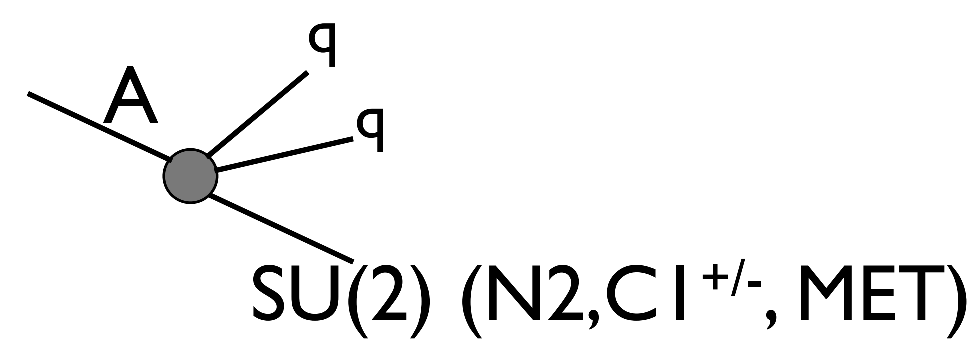


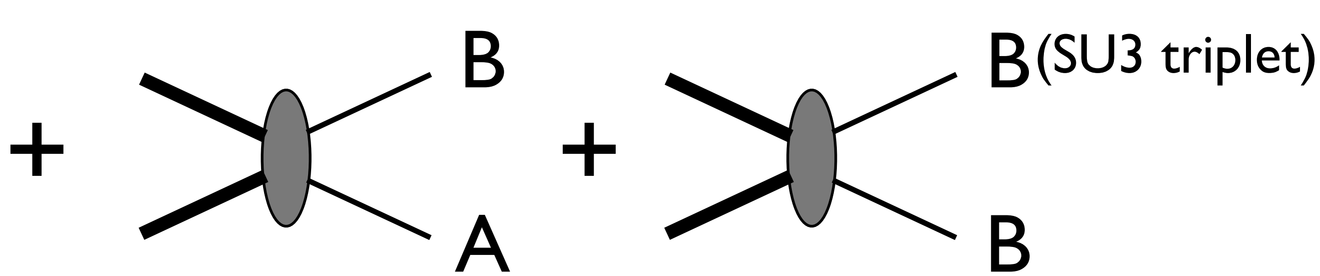
Too many high pt (>50 GeV) jets

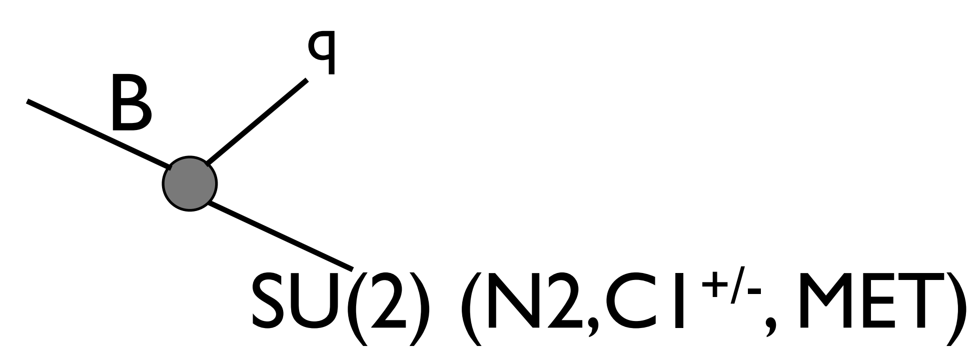
Hardest jets are too soft

Higher multiplicity jets are too hard









(A larger class of well-motivated topologies)

Before getting into this bigger OSET, now is a good time to go through Marmoset in more detail...

Introducing Marmoset

Marmoset is a pythia (6.411) based tool that handles OSET generation and organization

Authors: N. Arkani-Hamed, P.S., N. Toro, J. Thaler, L.T. Wang, S. Mrenna, B. Knuteson

I will summarize:

The organization

The implementation

Usage

Documentation:

http://www.marmoset-mc.net/wiki/doku.php

See: hep-ph/0703088 for detail...

[[marmoset]] MARMOSET

Show pagesource | Old revisions | Recent changes | Search

Trace: » marmoset

MARMOSET

Table of Contents

Mass **A**nd **R**ate **M**odeling in **O**n-**S**hell **E**ffective **T**heories

Marmoset is a strategy and a set of tools for characterizing and fitting physics beyond the Standard Model in a model-independent scheme. We introduce the idea of On-Shell Effective Theories (OSETs), which provide a flexible framework in which to describe new physics in terms of just the masses, production modes, and decay modes of candidate new particles. OSETs are well-suited for Monte Carlo-based analysis and interpretation of new physics at the LHC and TeVatron.

Publications and Seminars

Please look at the following preprints and seminar slides to learn more about Marmoset.

- Seminars
- hep-ph/0703088
- Marmoset webpage

Instructions

Caveat Emptor! MARMOSET is still (very much) under development, documentation is ongoing, and features may break from time to time. If you are surprised by its behavior or find a bug, please inform the authors and/or report it on the wiki support pages Support.

- Download and Installation
- Tutorial
- Workflow

Additional Information

- The Physics Behind Marmoset
- OSET File Format
- Available Matrix Elements
- Files in runDir
- Rate Fitting
- Executable Summary
- Dependencies

Support

Done

CVS checkout and installation (see docs)

```
cvs -d :pserver:anonymous@marmoset-mc.net:/usr/local/cvsroot checkout -r V0_05 Marmoset
cd Marmoset
make install
make environment
```

For more installation control:

```
cd Marmoset
cvs update -dP

make ../pythia6
pushd ../pythia6; cvs update -dP; popd
make libpythia.a

make ../stdhep-5-05-03
pushd ../stdhep-5-05-03 ; make stdhep ; make mcfio ; popd

make ../PGS
pushd ../PGS; make ; popd

make ../MPotato
pushd ../MPotato; cvs update -dP ; make ; popd

make ../HPGS
pushd ../HPGS; cvs update -dP ; popd
pushd ../HPGS/libraries/cernlib ; make ; popd
pushd ../HPGS/libraries/pgs ; make ; popd
pushd ../HPGS/libraries/isalib ; make ; popd
pushd ../HPGS/libraries/cernlib ; make ; popd

make
```

Marmoset is Pythia Based

- New production modes:
  `(modified PYSCAT, PYSIGH)`

$$|\mathcal{M}|^2 = 1,\ (1 - s_0/s),\ s/s_0, \text{etc.}$$

- Pythia decay tables for each topology `(call PYUPDA)`
- Book-keeping for different topologies (C++)

(MadGraph backend for exact hard processes with MARMOSET decays)

(OSET generation in ALPGEN also exists, but is not public)
See MC4BSM @ CERN '08

What code is installed(root is assumed):

```
philipschuster% ls
MG_ME        Marmoset    pythia6     stdhep-5-05-03
HPGS         PGS         MPotato
```

```
/Marmoset] philipschuster% ls
CVS      Marmoset    bin     lib     scripts     utilities
Makefile    README      doc     runDir      src
```

Makefile handles some environment variable setup (for executables)

To start an OSET study, create a working area:

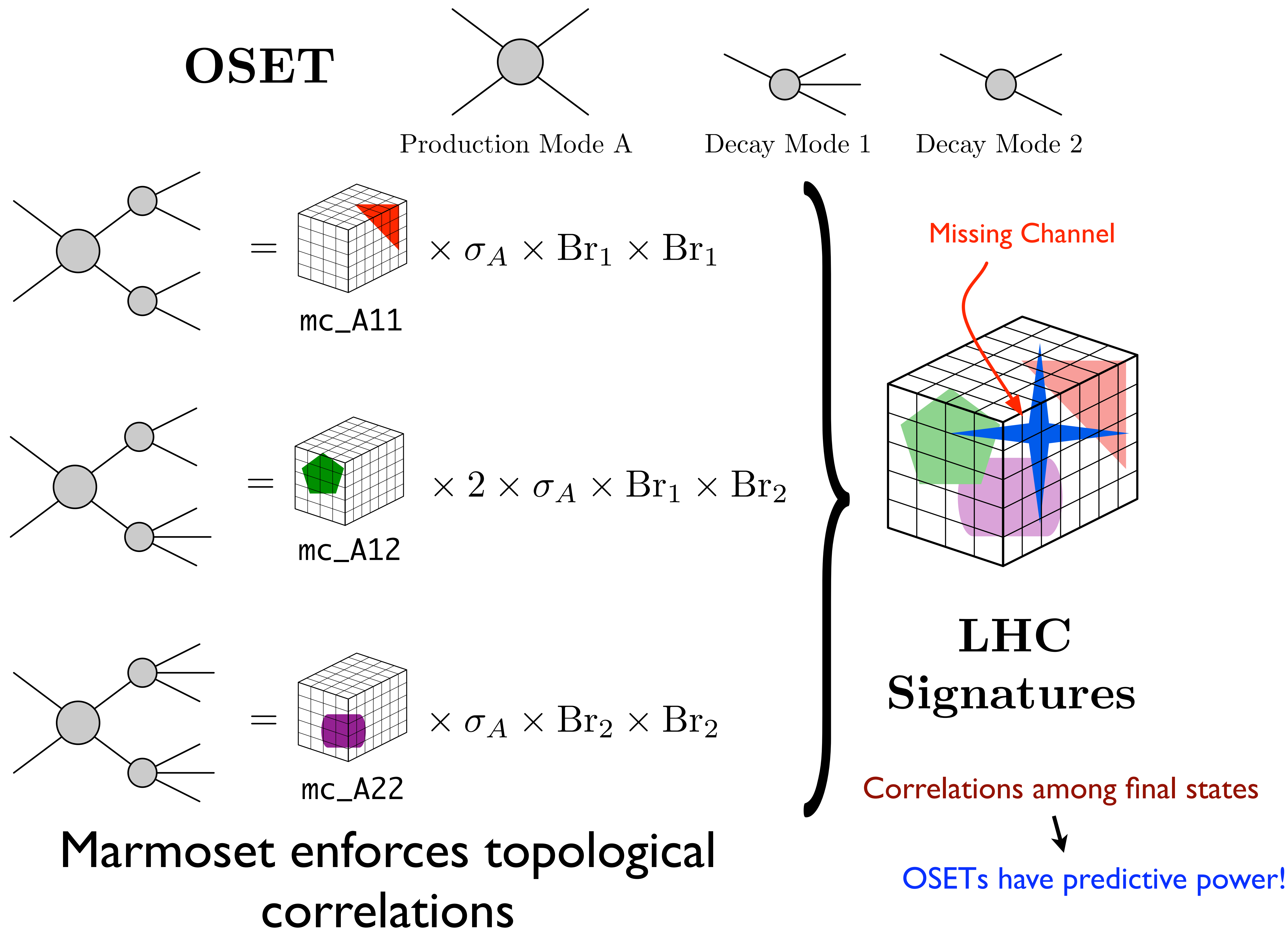
```
philipschuster% makeRunDir MyOSET
Valid runDir named MyOSET created.
```

Defining/Organizing an OSET

- Masses and SU(3) and U(1) quantum numbers of new particles, their production and decay modes **fully specify model**
- An OSET implies many topologies, and Monte Carlo is generated separately for each
- Topologies can be combined by weighting according to hadronic cross-sections and decay branching fractions

Take advantage of smart weighting scheme so that *large* parameter spaces can be scanned for free

Enforce topological final state correlations assuming some kind of cross section and branching ratio scheme


OSET
Production Mode A
Decay Mode 1
Decay Mode 2
$= \times \sigma_A \times \mathrm{Br}_1 \times \mathrm{Br}_1$
mc_A11
$= \times 2 \times \sigma_A \times \mathrm{Br}_1 \times \mathrm{Br}_2$
mc_A12
$= \times \sigma_A \times \mathrm{Br}_2 \times \mathrm{Br}_2$
mc_A22
Missing Channel
LHC Signatures
Correlations among final states
OSETs have predictive power!
Marmoset enforces topological correlations

A working area:

```
philipschuster% cd MyOSET
[/MyOSET] philipschuster% ls
analysis        mass_width_2004.mc  pars            settings
bkg             meta                processes
data            osets               pythia_ana
```

OSET files

GLobal OSET weighting information

OSET process card files and information

Now let’s define an OSET (relevant to the earlier example)

```
philipschuster% cp osets/SMparticles.oset osets/tools08.oset
philipschuster% emacs osets/tools08.oset
```

./osets/tools08.oset

The Standard Model (by default)

```
# Standard Model Particles

d dbar : pdg=1 charge=-1 color=3 mass=0.33
u ubar : pdg=2 charge=2  color=3 mass=0.33
s sbar : pdg=3 charge=-1 color=3 mass=0.5
c cbar : pdg=4 charge=2  color=3 mass=1.5
b bbar : pdg=5 charge=-1 color=3 mass=4.8
t tbar : pdg=6 charge=2  color=3 mass=175.0

e-     e+        : pdg=11 charge=-3 color=0 mass=0.00051
nu_e   nu_ebar   : pdg=12 charge=0  color=0 mass=0.0
mu-    mu+       : pdg=13 charge=-3 color=0 mass=0.10566
nu_mu  nu_mubar  : pdg=14 charge=0  color=0 mass=0.0
tau-   tau+      : pdg=15 charge=-3 color=0 mass=1.777
nu_tau nu_taubar : pdg=16 charge=0  color=0 mass=0.0

g     : pdg=21 charge=0 color=8 mass=0
gamma : pdg=22 charge=0 color=0 mass=0
Z0    : pdg=23 charge=0 color=0 mass=91.188
W+ W- : pdg=24 charge=3 color=0 mass=80.45
h0    : pdg=25 charge=0 color=0 mass=115.0
```

The user never bothers with this, but here it is anyway...

./osets/tools08.oset

A rather large OSET...

```
MPT   : pdg=1000022 charge=0 color=0 mass=120

####### New Particles #######
### SU(3) ###
A           : charge=0 color=8 mass=680
F           : charge=2 color=3 mass=700
### SU(2) ###
Pmu- Pmu+   : charge=-3 color=0 mass=185
Pe- Pe+     : charge=-3 color=0 mass=185
Ptau- Ptau+ : charge=-3 color=0 mass=185
N2          : charge=0 color=0 mass=422
C1+ C1-     : charge=3 color=0 mass=280

##### cascade objects decays ######
Pe- > e- MPT $ Bl
Pmu- > mu- MPT $ Bl
Ptau- > tau- MPT $ Bl

##### Other SU(2) decays ######
N2 > Pe- e+     $ Bsl
N2 > Pmu- mu+   $ Bsl
N2 > Ptau- tau+ $ Bsl

C1+ > W+ MPT

##### SU(3) decays #####
F > u N2
F > d C1+
F > u MPT

A > u ubar N2
A > u ubar MPT
A > d ubar C1+

##### Production Modes #####
g g    > A A
g u    > A F
g g    > F~ F
```

Freedom to define common coefficients

...all other coefficients are handled as initially unconstrained

Generation is a two-stage process:

Build the oset and assemble all the process card files

```
parseOSET
```

```
philipschuster% parseOSET
Welcome to parseOSET
Purpose: This script takes a .oset file and populates the necessary
         trees to give a complete OSET description.
  Usage: parseOSET <osets/OSETName.oset>
         parseOSET --interactive <osets/OSETName.oset> <treeName>
   Note: <osets/OSETName.oset> can also be replaced by <OSETName>.
```

Generate the events and write in the desired format

```
generateProcess  --lhe
                 --stdhep
                 --pgs4
```

```
philipschuster% generateProcess
Using default format: pgs4!
Purpose: This program takes one or more processes and generates Pythia input files,
         monte carlo, signature files, etc.
  Usage: generateProcess [options] < --all | --oset osetName | --osetFromCoef
osetName | --wtfile dir/wtfile.wt target_weight | tree1 ... treeN >

Generation modes:
     tree1 ... treeN  Generates fixed number of events for the listed trees

    --all    Generate fixed number of events for all processes defined in current directory

    --oset osetName   Generate fixed number of events for all processes associated with the
named OSET

    --osetFromCoef osetName   Generate events for all processes associated with the named
OSET;
             the number of events is determined from the file meta/osetName.coefs

    --wtfile dir/wtfile.wt target_wt   Generate events for processes listed in weightfile;
             the number of events is chosen to populate each process enough that its
             current weight would decrease to target_wt
```

...continued on next slide
(lots of options!)

```
Options:
            MULTIPROCESSOR:
    --multiProc num   Run MC on num local processors
    --PBS num     Run MC on num nodes controlled by PBS
    --condor num  Run MC on num nodes controlled by Condor
        [note: all CPUs must have read/write access to the working directory]
            GENERAL:
    -v   Verbose output
    --data   Treats files as data (different workflow)
    --compare comparefile(with --data)--generate MPOTATO comparison plot with comparefile
         instead of single-file plot
    --new    Don't use existing monte carlo
    --once   Only update each tree once, instead of updating until it's finished
            GENERATION:
    -n num   Bring total events generated per process to num (default 1000)
    -l lum   (with --data) Bring total luminosity generated per process to lum
    --max_events num (with --wtfile) Never generate more than num events (default 10000)
    --MadGraph   Perform event generation with MadGraph/MadEvent
            OUTPUT FORMAT:
     --no_mc | --setup | --format no_mc    No MC generation (just input file setup)
     --stdhep | --format stdhep    Output STDHEP file
     --lhe | --format lhe      Output LHE file
     --pgs4 | --pgs | --format pgs | --format pgs4      Output PGS4 file
     --hpgs | --format hpgs    Output HPGS file
     --ana  | --format ana     Generate pythia histograms with user pythia_ana code
             (can also use short form -t for --format)
    --L2 | --L1 | --L0    apply level 2/1/0 triggers (pgs4/hpgs)
    --T1 Tevatron Run 1 energies and CDF-like detector (hpgs, not compatible with triggers)
```

Running...

```
philipschuster% parseOSET osets/tools08.oset
```

...

inside meta/tool08.strgs

The weight

```
p000001 * Bl Bsl b5 Bl Bsl b5 s1 $ g g > ( A > ( N2 > e+ ( Pe- > e- MPT ) ) ubar u ) ( A
> ( N2 > e+
 ( Pe- > e- MPT ) ) ubar u )
p000002 * Bl Bsl b5 Bl Bsl b5 s1 $ g g > ( A > ( N2 > e+ ( Pe- > e- MPT ) ) ubar u ) ( A
> ( N2 > mu
+ ( Pmu- > mu- MPT ) ) ubar u )
p000003 * Bl Bsl b5 Bl Bsl b5 s1 $ g g > ( A > ( N2 > e+ ( Pe- > e- MPT ) ) ubar u ) ( A
> ( N2 > ta
u+ ( Ptau- > tau- MPT ) ) ubar u )
p000004 * Bl Bsl b5 b6 s1 $ g g > ( A > ( N2 > e+ ( Pe- > e- MPT ) ) ubar u ) ( A > MPT
ubar u )
p000005 * Bl Bsl b5 b1 b7 s1 $ g g > ( A > ( N2 > e+ ( Pe- > e- MPT ) ) ubar u ) ( A >
( C1+ > W+ MP
T ) ubar d )
p000006 * Bl Bsl b5 Bl Bsl b5 s1 $ g g > ( A > ( N2 > mu+ ( Pmu- > mu- MPT ) ) ubar u )
( A > ( N2 >
 e+ ( Pe- > e- MPT ) ) ubar u )
```

a long list of processes and weight coefficients...

```
%ls processes/
  p000001
  p000002
  p000003
  ...
```

One directory stores all info. for each process, so that they can be *reweighted* (same model but different prameters) or *recycled* (in a new but overlapping OSET)

```
%ls processes/p000001/
```

`p000001.model`	Marmoset description of particle content (so processes can be reused)
`p000001.strg`	Label for process; formula for calculating weight from parameters
`p000001.brtb`	Decay table
`p000001.proc`	Hard process info.
`p000001.card`	Event generation setup
`p000001.mcin`	Book-keeping – # events generated, etc.
`p000001.mcout`	

–passed to Pythia (.brtb, .proc, .card)

Tools provided that create composite OSETs from cross sections and branching ratios, using the process information assembled by Marmoset

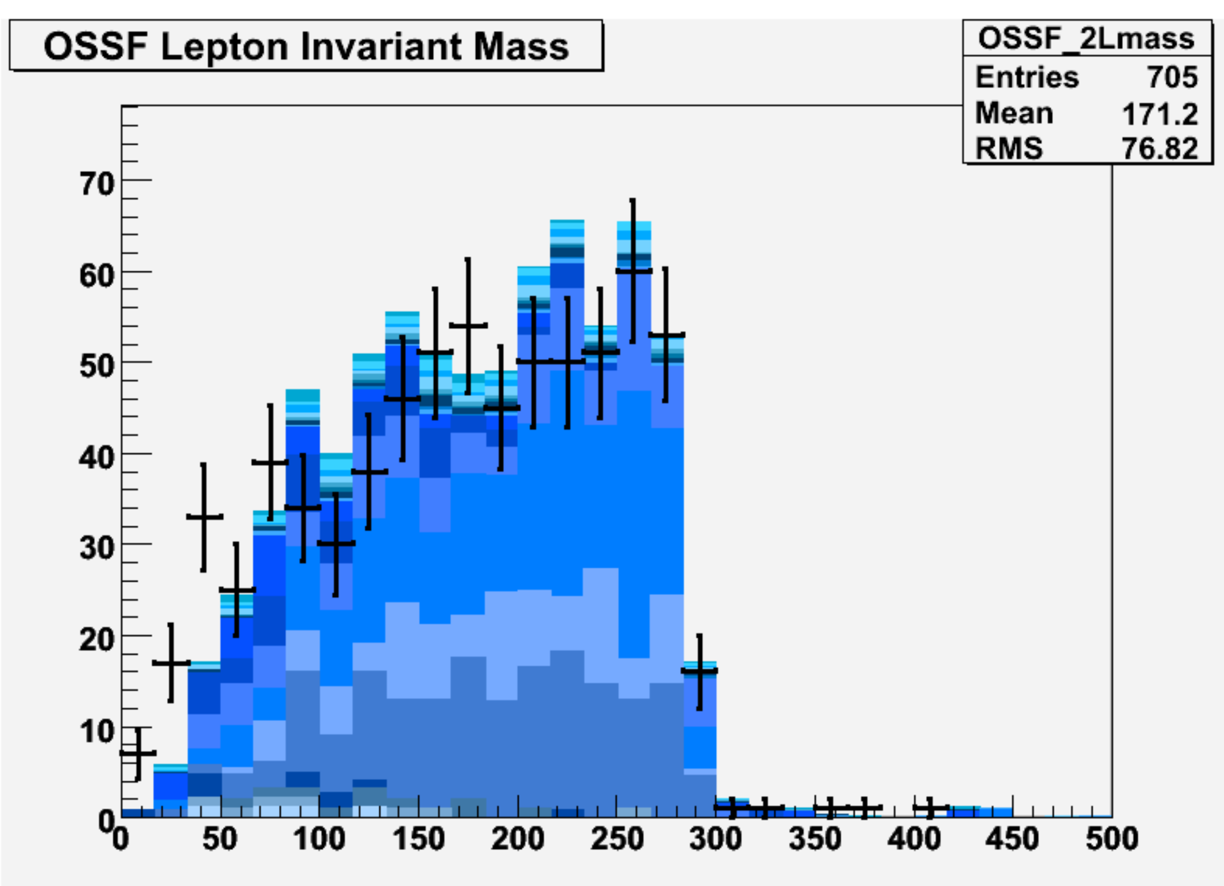
The weighting tools are *very* user dependent, and are continually evolving...

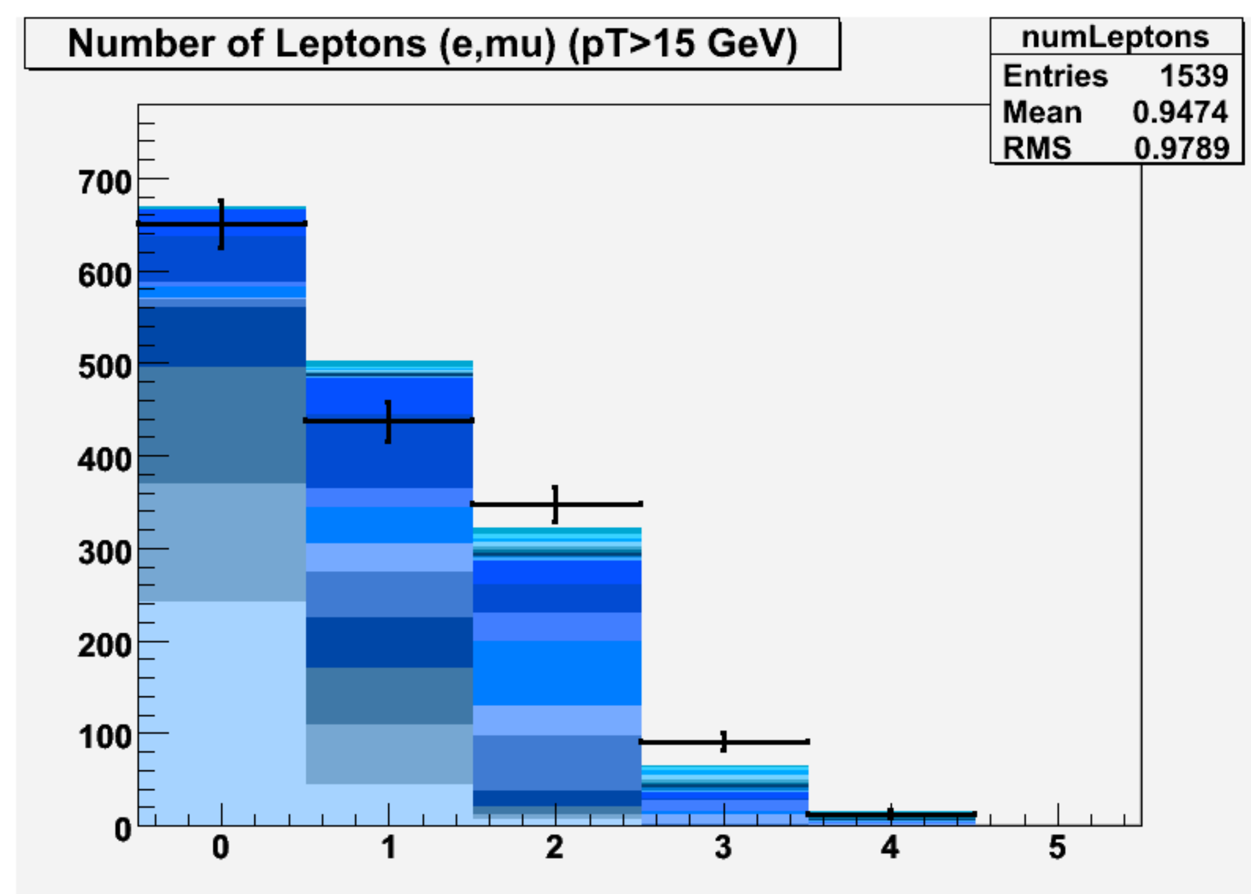
See the documentation for basic details, or ask in private

Some Comparisons

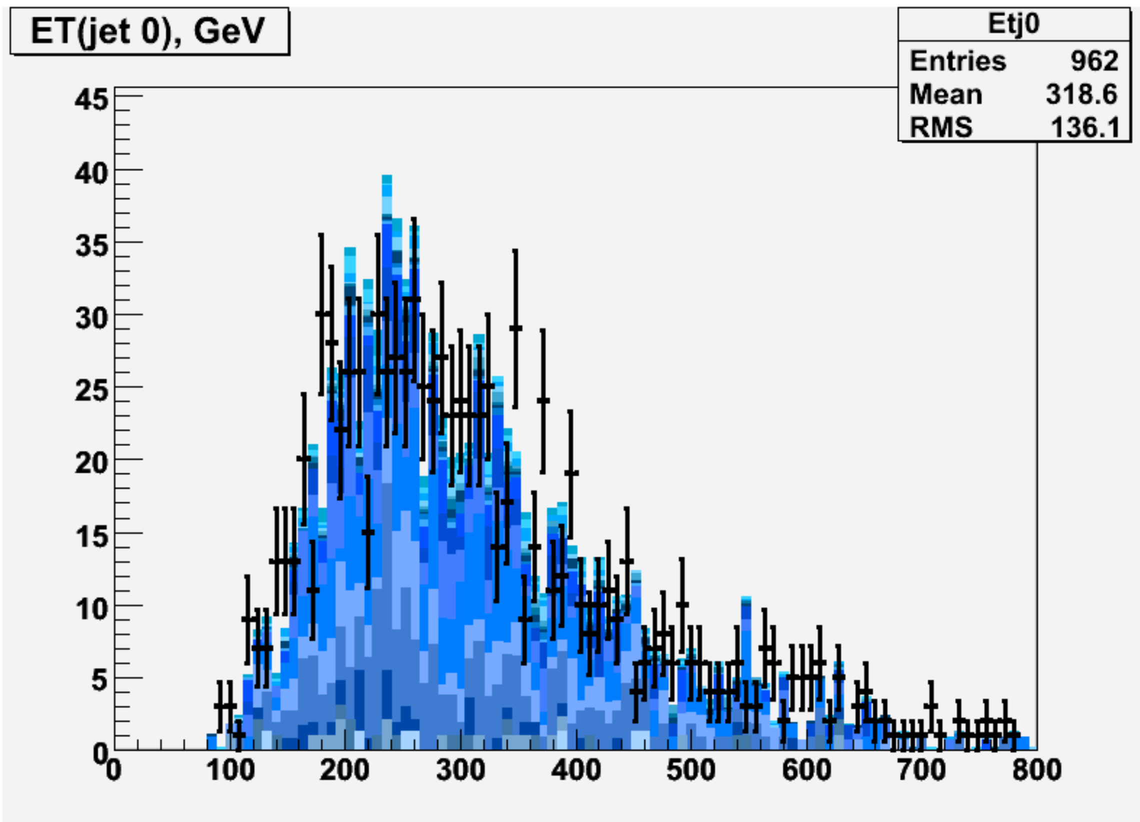
(with the larger OSET)

```
 1: Sigma( g g > GL GL )        2100
 2: Sigma( g u > Q1 GL )        2500
 3: Sigma( g g > Q1~ Q1 )       800
 4: Br( GL > Bino ubar u )      0.0
 5: Br( GL > MPT ubar u )       0.55
 6: Br( GL > Hi+ ubar d )       0.45
 7:   Br( Q1 > Bino u )         1
 8:    Br( Q1 > Hi+ d )         0
 9:    Br( Q1 > MPT u )         0
10: Br( Se- > e- MPT ), Br( Smu- > mu- MPT ), Br( Stau- > tau- MPT )        1
11: Br( Bino > e+ Se- ), Br( Bino > mu+ Smu- ), Br( Bino > tau+ Stau- )        1
12:  Br( Hi+ > W+ MPT )         1
```

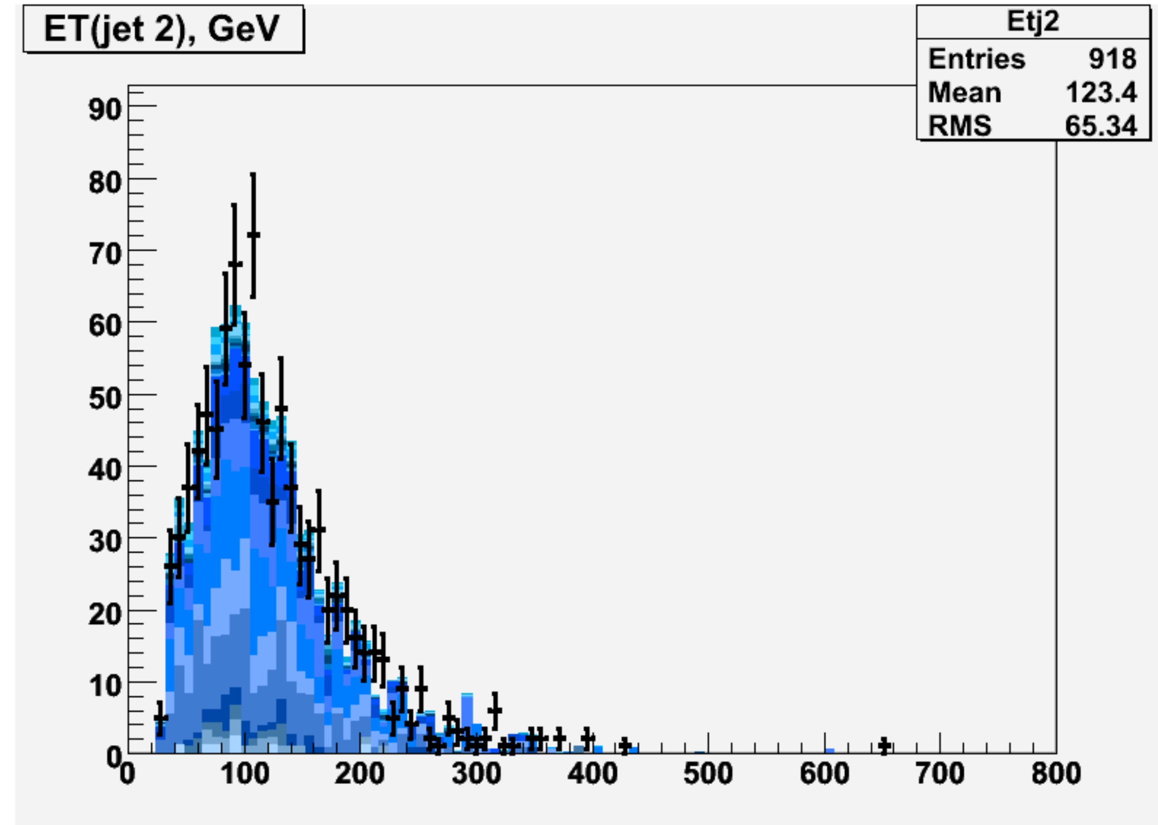




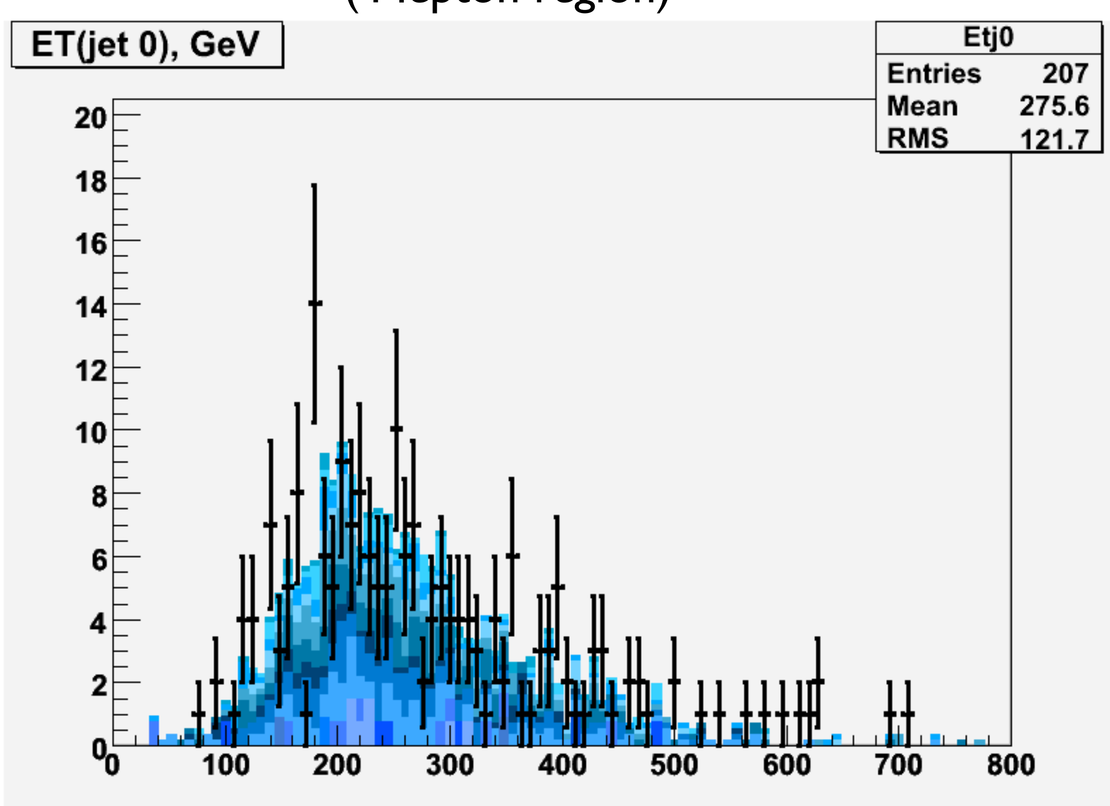
(2 lepton region)



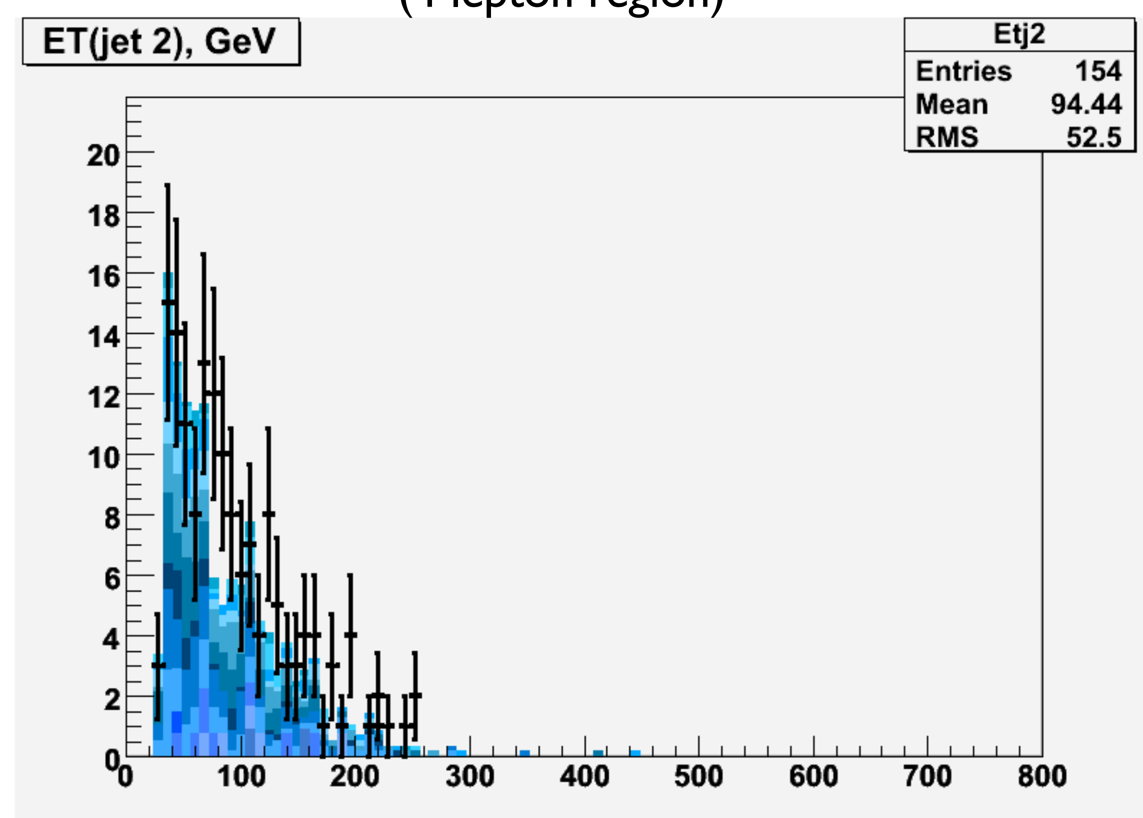
(2 lepton region)



(4 lepton region)



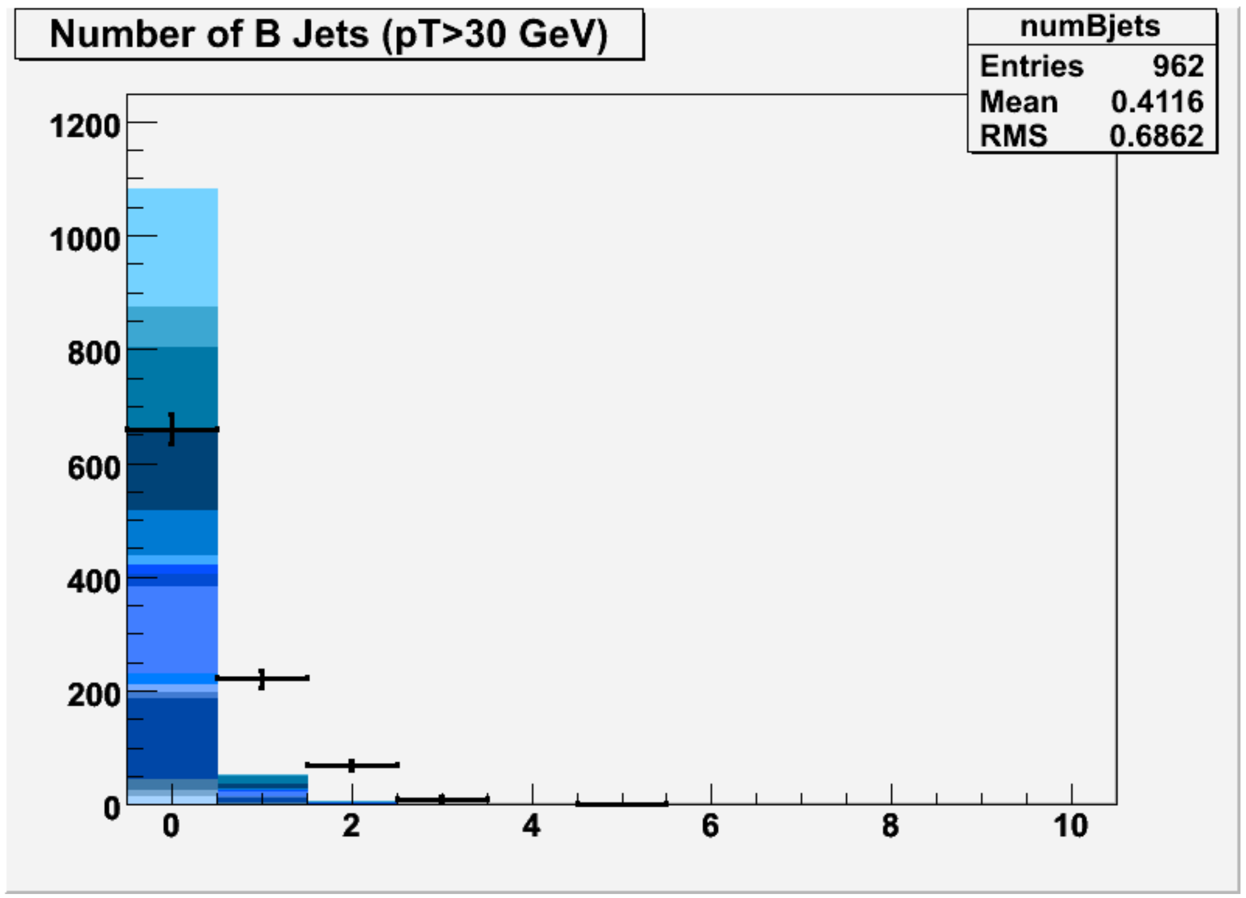
(4 lepton region)



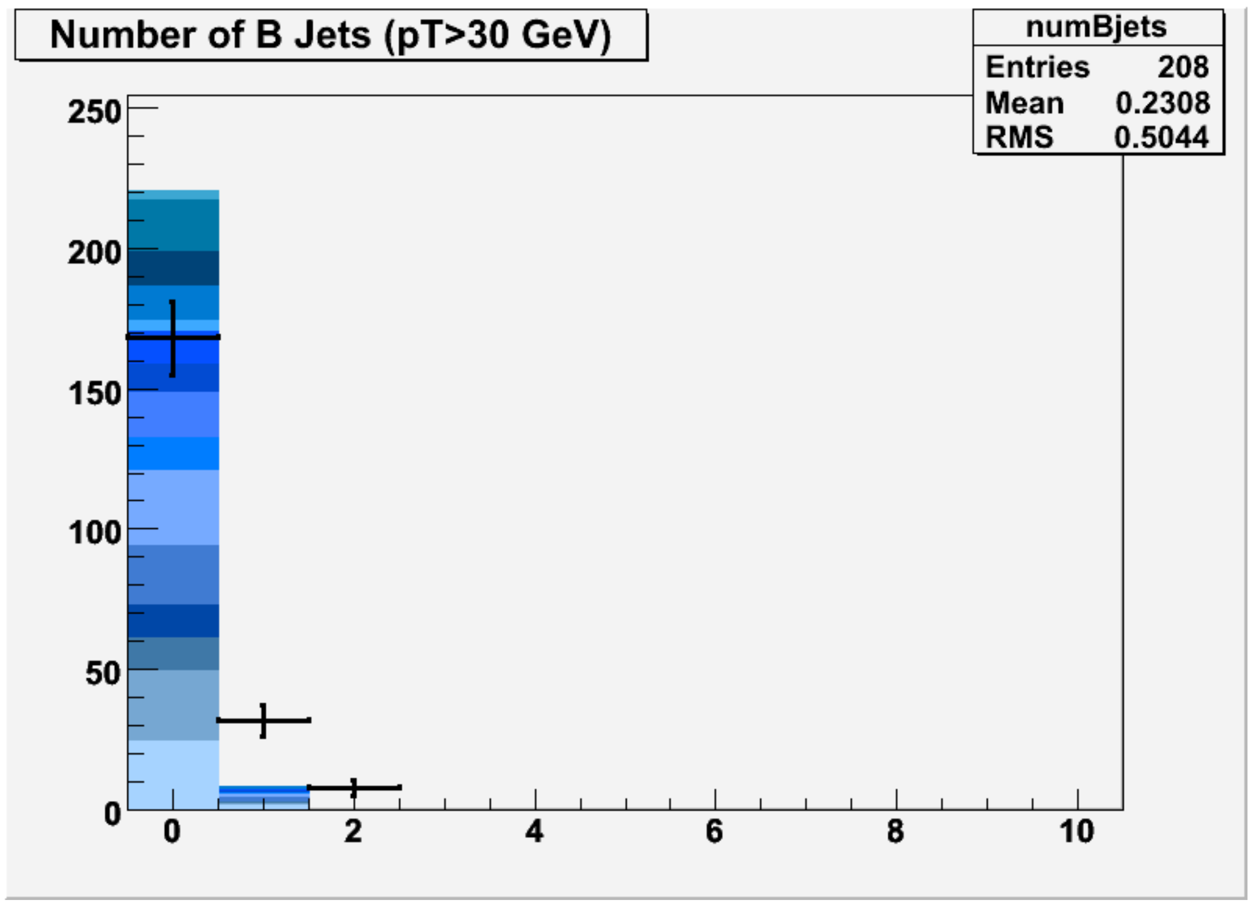
Still problems with the jets...

...and heavy flavor looks odd (once B-tagging starts to make sense)

flavor universality does not look consistent



(2 lepton region)



(4 lepton region)

More investigation needed...

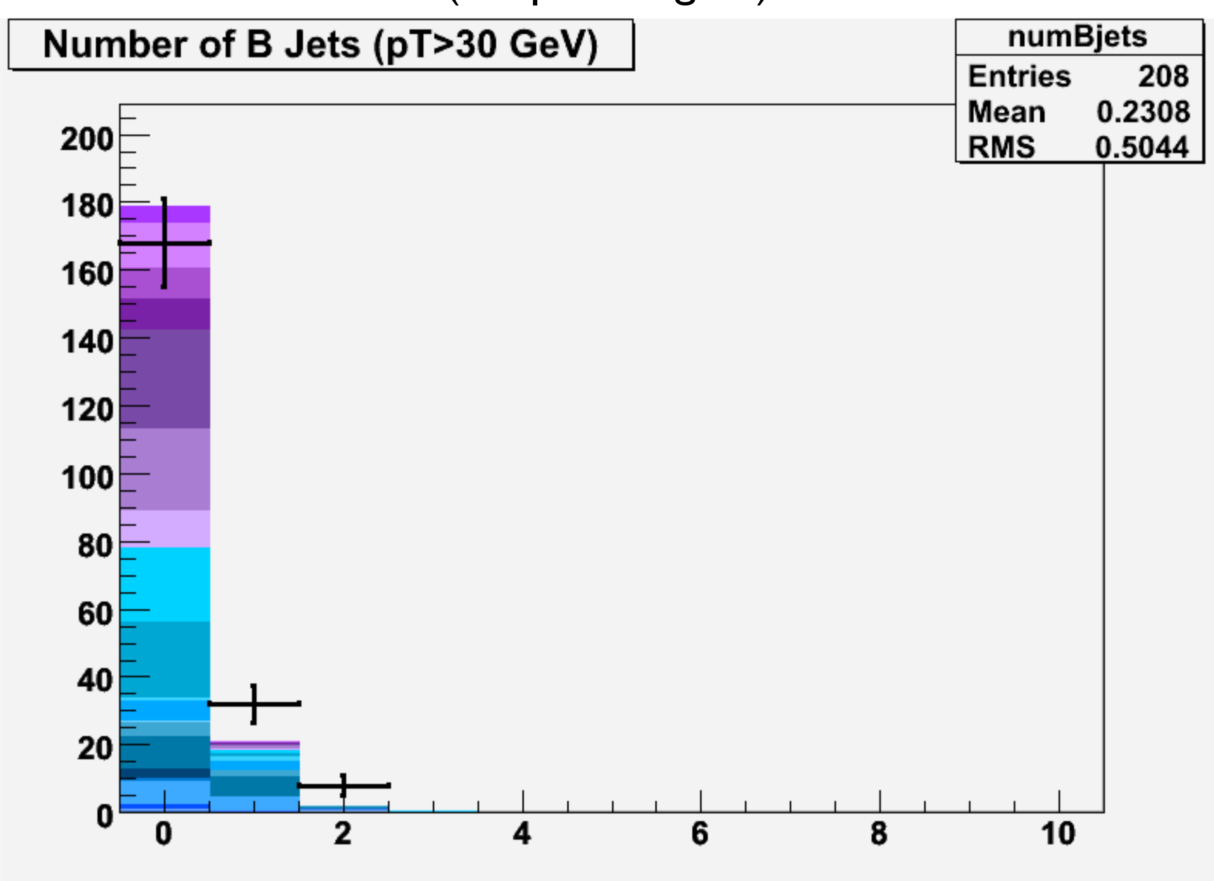
Identifying the presence of tops critical in this case...

Studying heavy flavor structure...

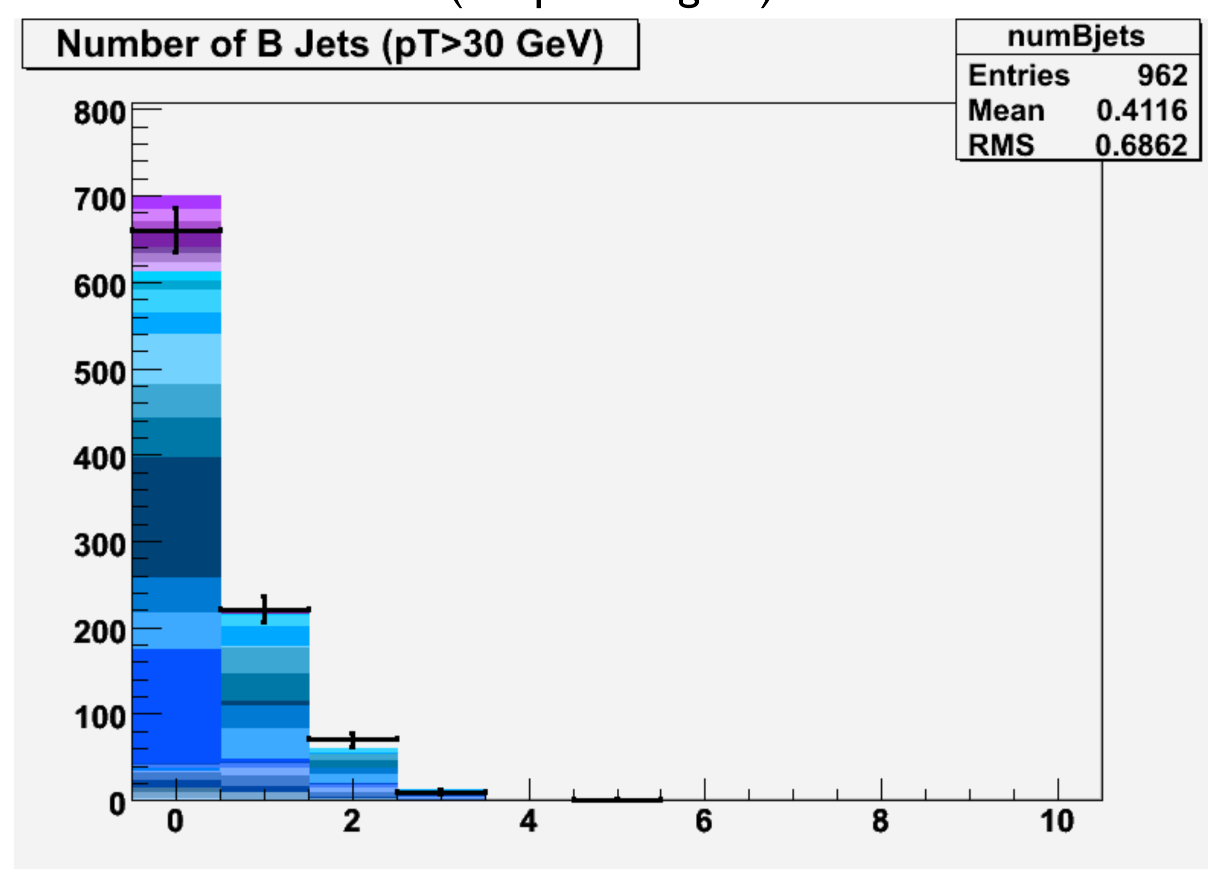
```
 1: Sigma( g g > GL GL )       2100
 2: Sigma( g u > Q1 GL )       2500
 3: Sigma( g g > Q1~ Q1 )        650
 4: Br( GL > Bino ubar u )          0
 5: Br( GL > MPT ubar u )       0.4
 6: Br( GL > Hi+ tbar b )       0.35
 7: Br( GL > Hi0 bbar b )       0.25
 8:   Br( Q1 > Bino u )          1
 9:    Br( Q1 > Hi+ d )          0
10:    Br( Q1 > MPT u )          0
11: Br( Se- > e- MPT ), Br( Smu- > mu- MPT ), Br( Stau- > tau- MPT )         1
12: Br( Bino > e+ Se- ), Br( Bino > mu+ Smu- ), Br( Bino > tau+ Stau- )    0.3333
13:   Br( Hi0 > W- Ch )          1
14:  Br( Hi+ > W+ MPT )          1
15: Br( Ch > MPT u dbar )          1
```

These numbers should only be taken as a rough guide!

(4 lepton region)



(2 lepton region)



The possible presence of top quarks means that we should go back and be more careful studying the leptons (from additional Ws)

Summary

7x higher energy than Tevatron → seeing and understanding new physics may not be statistics-limited! (it will take a while – for other reasons)

From the beginning, we can try to:

- Compare data to simple topology-level models
- Constrain the parameters of "proxy" models
- ...and eventually rule them out

OSET approach to BSM: learn as much as possible – model-independently – about what is, and what is not determined by data.

Applications...

(See talk by N. Toro @ KITP "Anticipating New Physics at the LHC Conference", June 4 '08)

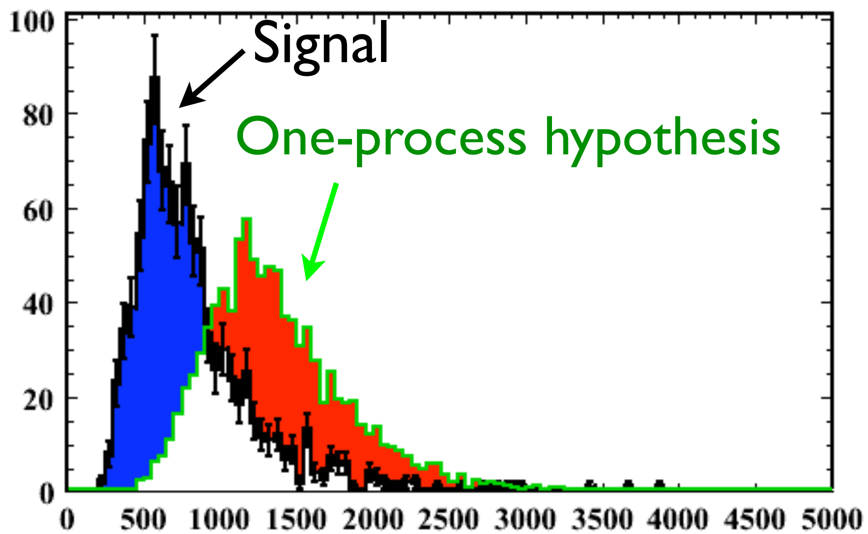
OSETs at CMS (OSETToolsPackage):

work with UCSB group members S. Koay, R. Rossin, J, Incandela

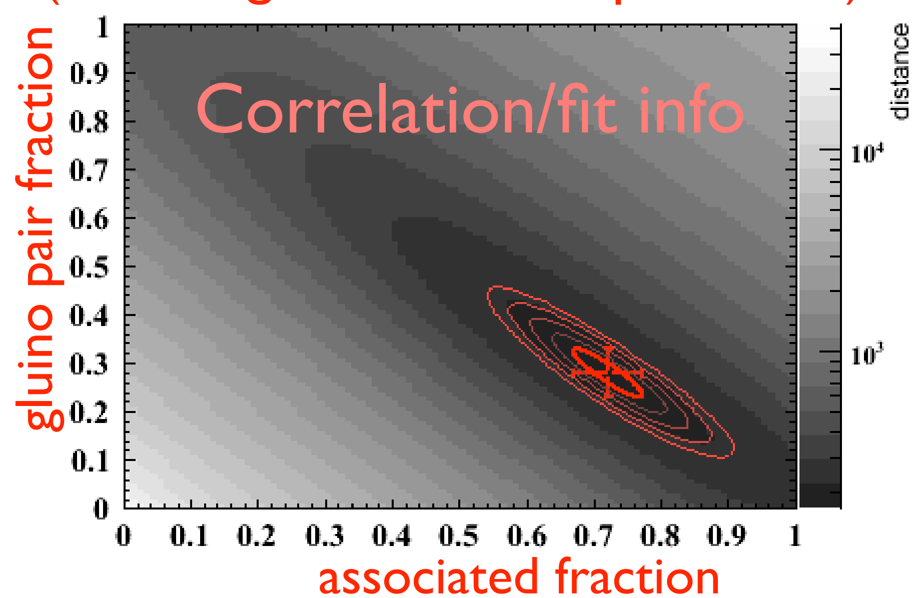
1) OSET Monte Carlo (easy) and bookkeeping (harder) in CMSSW framework

2) Quantitative tools for analysis of new-physics topologies, e.g.

How much of this process is allowed?
(model-independent bound)



What parameters are consistent?
(assuming no additional processes)



Set of "benchmark" topologies? (To provide guidance)

work in progress w/ J. Alwall, N. Toro

Developing robust discriminating variables for different processes

Summary

7x higher energy than Tevatron → seeing and understanding new physics may not be statistics-limited! (it will take a while – for other reasons)

<u>From the beginning</u>, we can try to:

- Compare data to simple topology-level models
- Constrain the parameters of "proxy" models
- ...and eventually rule them out

OSET approach to BSM: learn as much as possible – model-independently – about what is, and what is not determined by data. (Marmoset can help)

Backup...

A Proposal (request)

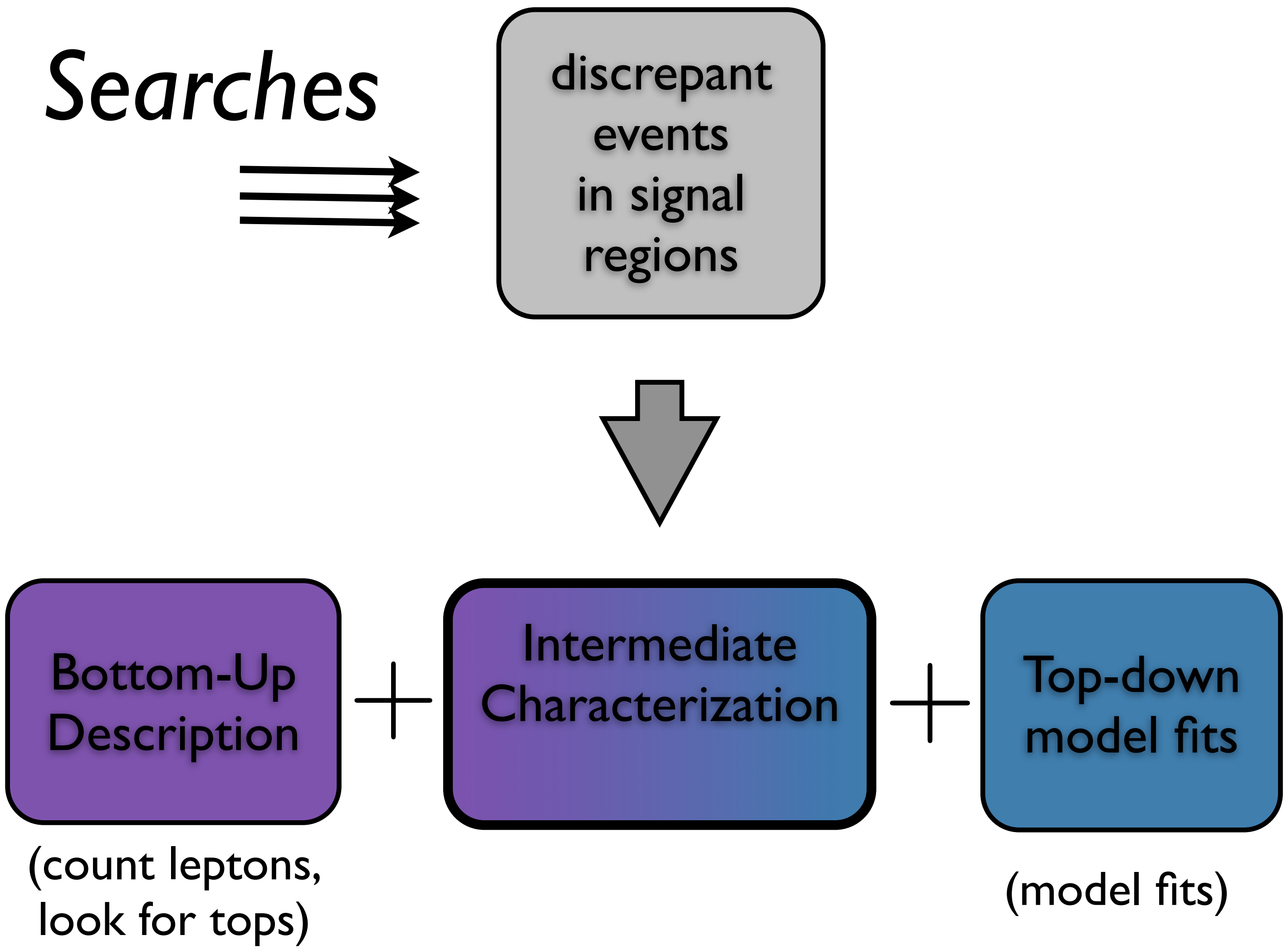
Characterize early data by identifying **consistent processes,** constraining their **masses** and relative **rates:**

1) **Simulate arbitrary processes** using a minimal parametrization (masses & rates) until greater experimental resolution is possible

2) **Constrain processes using broad kinematics, discriminating counts** (and sharp features whenever possible) – often hard to isolate

3) **Focus on "most pertinent" processes** – what they are depend on what's seen; **process groups that cover the MSSM** are a good starting point.

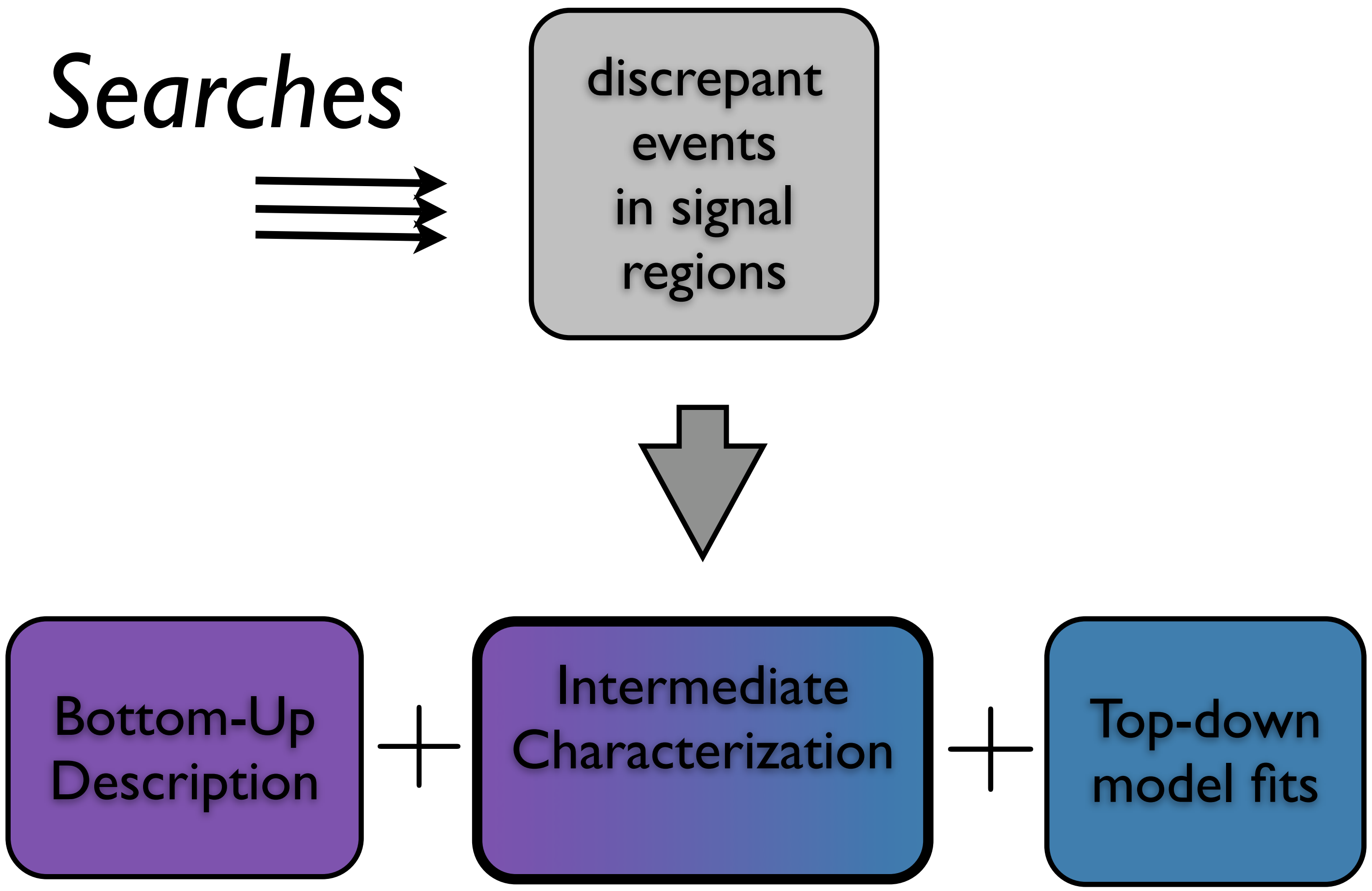
Caricature of First New Physics:



- Flexible to deal with surprises
- Check (don't just assume) models

- Rigid→predictions can be checked
- Incorporate theoretical input
- Informs continuing analyses/searches

Caricature of First New Physics:



(count leptons, look for tops)

(model fits)

- Flexible to deal with surprises
- Check (don't just assume) models

- Rigid→predictions can be checked
- Incorporate theoretical input
- Informs continuing analyses/searches

Is an intermediate characterization useful to the experiment?

- New resonance to 2 SM particles (e.g. Z' to $\mu^+\mu^-$) — **NO!** (very simple)
- significant signal in complicated final state, but few events or very low purity — **NO!** (weak resolving power)
- ...but hierarchy problem suggests complex, prolific, distinctive, surprising new physics. In this regime, characterizing the first new physics can motivate important studies that might otherwise not be emphasized

Will it be necessary?

- Yes, naive top-down expectations probably wrong

Is this possible?

- Early studies look promising, see this talk and (KITP June 4, '08)