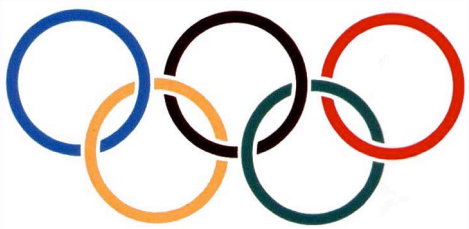


UW Analysis of Black Box B

Kyle Armour

On behalf of:

Matt Strassler, Steve Ellis, Jonathan Walsh

Department of Physics,

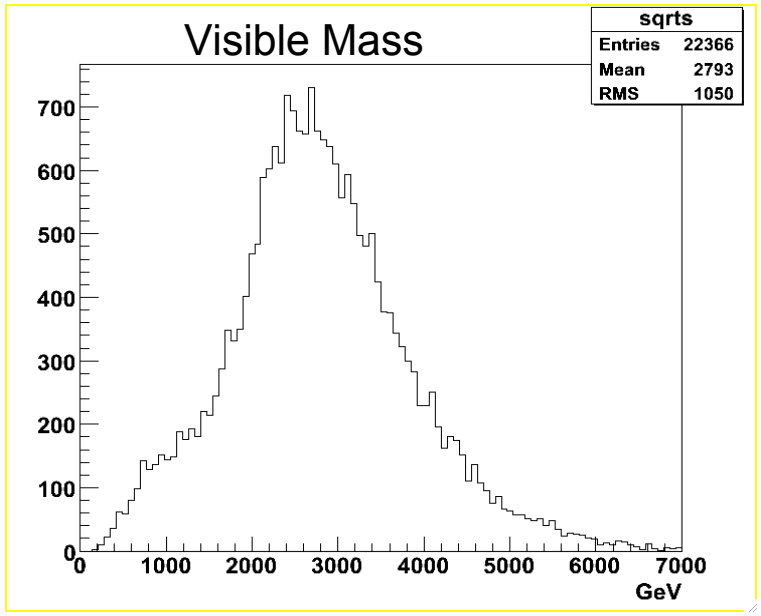
University of Washington

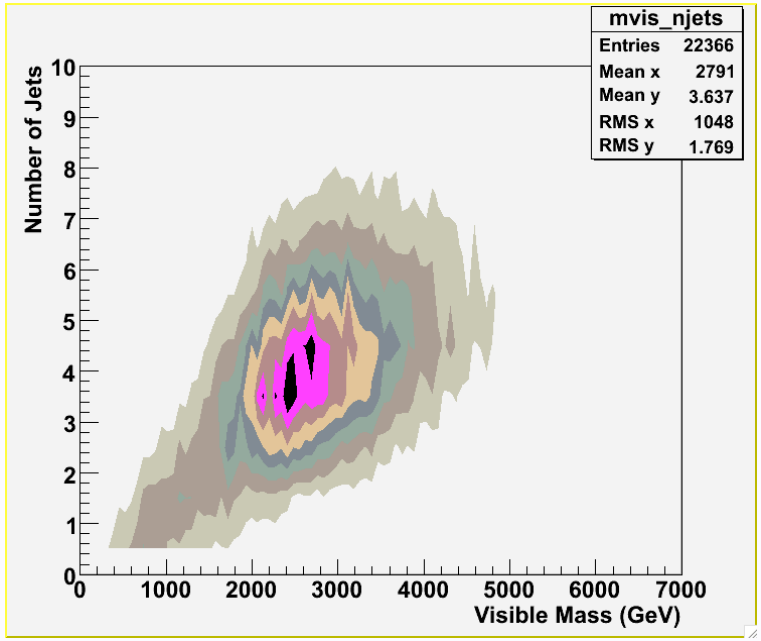
Outline

- Interesting features of Black Box B
  - What model independent information can be learned?
- Progress toward a possible model

Basic Plots

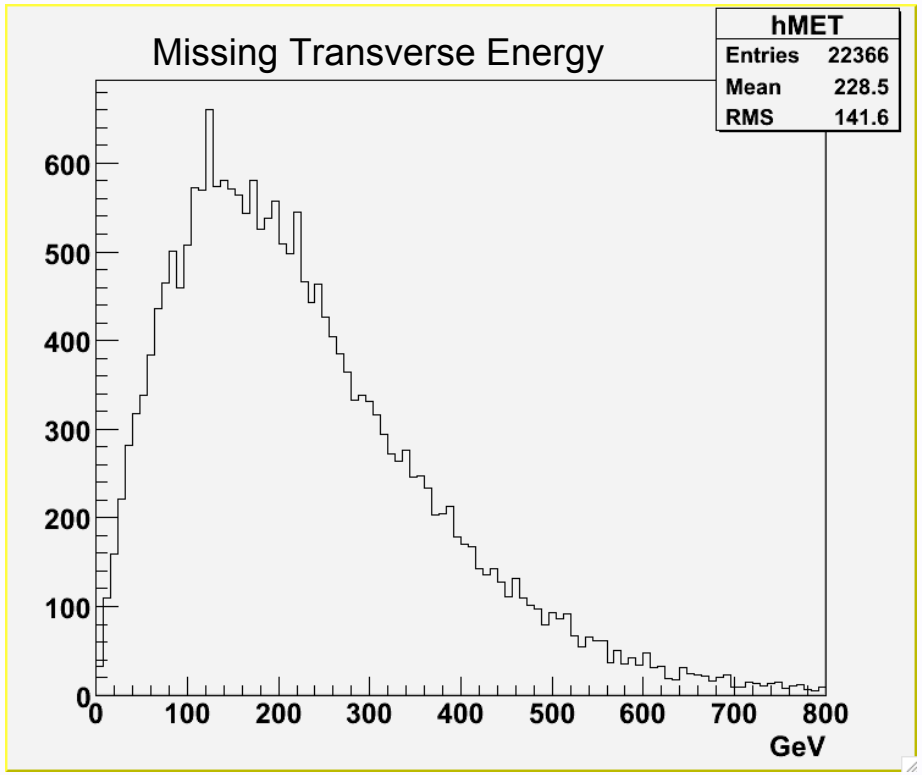
- High and Low mass regions, separated by number of jets
- Electroweak region below 1200 GeV
- Strong interaction region above 1200 GeV
  - More events implies higher cross section





Basic Plots

- Missing Transverse Energy



Low Mass - lepton and jet counters

Lepton (e, mu) charge	Number of events
3	18
2	113
1	276
0	662
-1	268
-2	77
-3	15

Object cuts:
20 GeV p_T cut on leptons
50 GeV p_T cut on jets

Jets \ Leptons	0	1	2	3	4	5
0	3	151	325	91	94	54
1	5	65	167	147	89	31
2	7	32	62	61	38	13
3	2	9	20	15	12	4

- Number of events with 0 photons: 1350
  Number of events with 1 photon: 75
- Very few b-tagged jets

Low Mass - lepton flavor

Single lepton

Lepton flavor	Number of events
e^-	28
e^+	20
mu^-	48
mu^+	41
tau^-	2
tau^+	1

- Very few taus

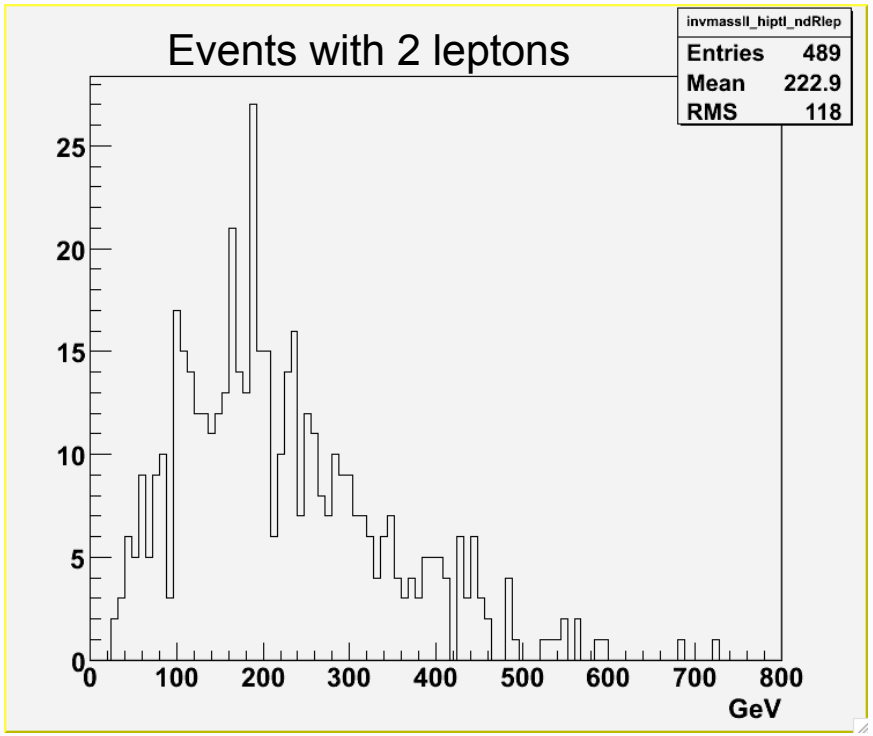
Dilepton

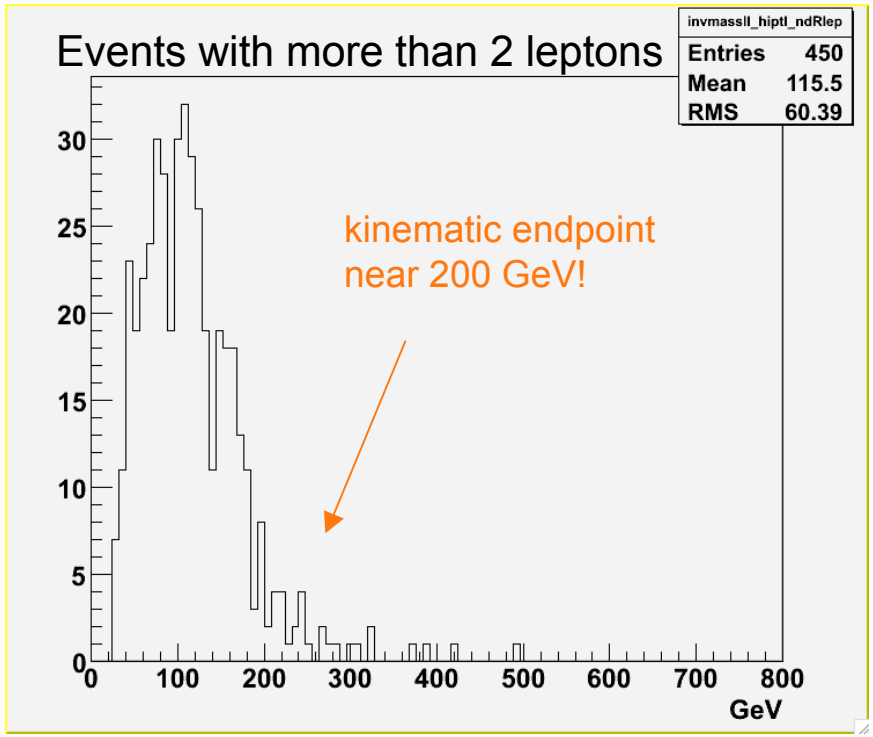
	tau^-	mu^-	e^-	e^+	mu^+	tau^+
tau^-	0	0	2	0	4	0
mu^-		6	16	120	126	7
e^-			3	88	147	1
e^+				5	21	1
mu^+					10	3
tau^+						0

- Opposite Sign (OS) leptons favored
- Arbitrary light (e, mu) flavor

Low Mass - Dilepton Invariant Mass

Invariant mass of highest p_T lepton and nearest (in DeltaR) OS lepton of arbitrary flavor





Other cuts:
Require lepton with p_T > 50 GeV

High Mass - lepton and jet counters

Lepton (e, mu) charge	Number of events
4	14
3	268
2	1657
1	4983
0	7194
-1	4942
-2	1614
-3	250
-4	14

Jets \ Leptons	0	1	2	3	4	5
0	2	17	98	55	57	44
1	13	86	273	306	213	125
2	77	320	774	977	612	166
3	208	796	1467	1462	698	206
4	284	1017	1535	1316	613	172
5	242	801	1145	826	356	110
6	179	443	587	430	177	51
7	93	258	284	175	64	21

High Mass - lepton flavor

Single lepton

Lepton flavor	Number of events
e^-	782
e^+	836
mu^-	985
mu^+	998
tau^-	32
tau^+	39

- Again, very few taus

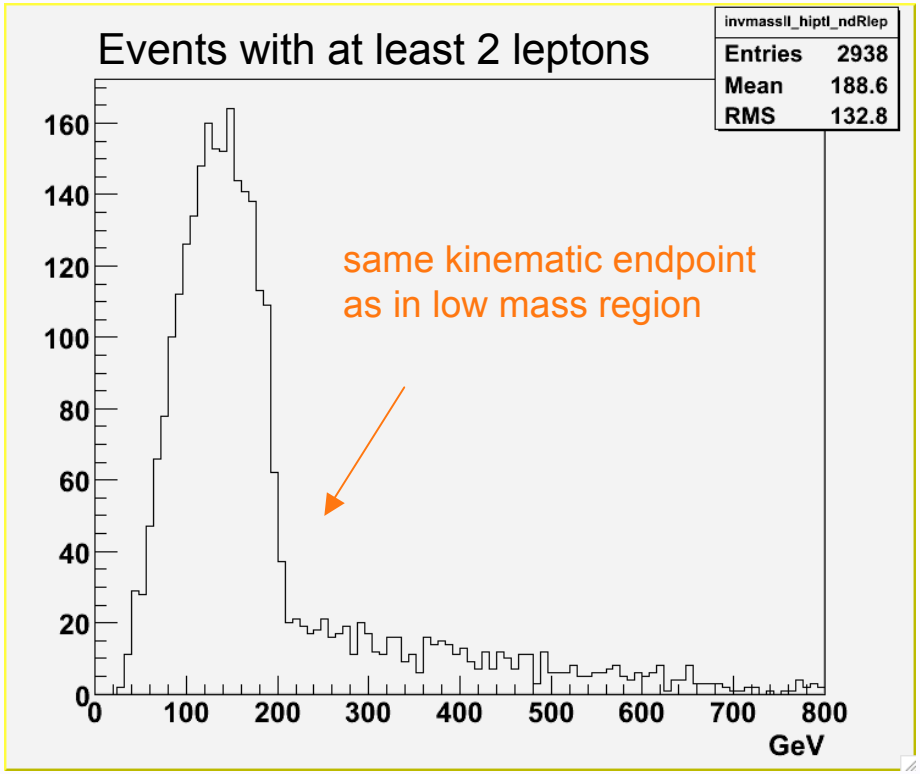
Dilepton

	tau^-	mu^-	e^-	e^+	mu^+	tau^+
tau^-	0	28	19	32	58	0
mu^-		315	524	845	1262	54
e^-			178	877	881	33
e^+				202	504	18
mu^+					341	21
tau^+						2

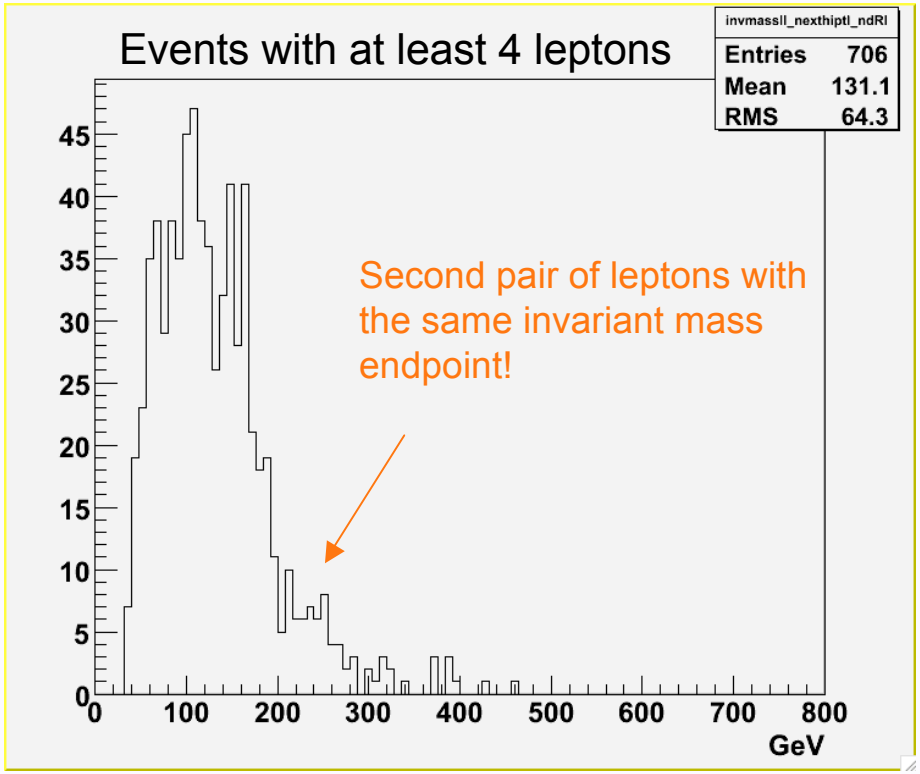
- OS leptons favored
- Arbitrary light (e, mu) flavor
- Similar structure as in low mass region

High Mass - Dilepton Invariant Mass

Invariant mass of highest p_T lepton and nearest (in DeltaR) OS lepton of arbitrary flavor



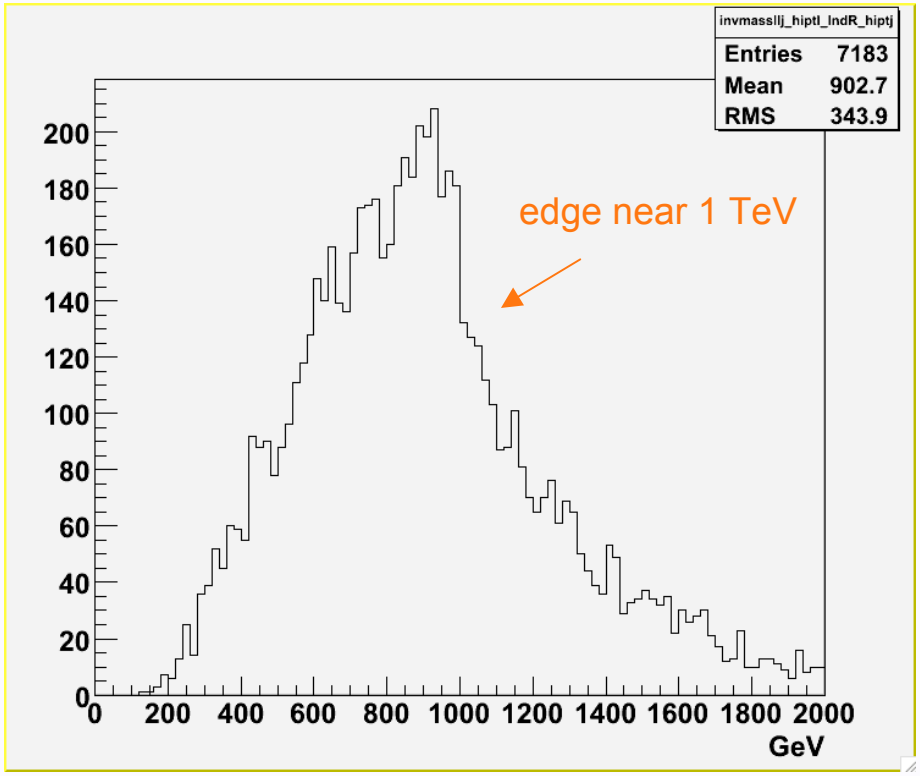
Invariant mass of next highest p_T lepton (not used in first pair) and nearest OS lepton of arbitrary flavor



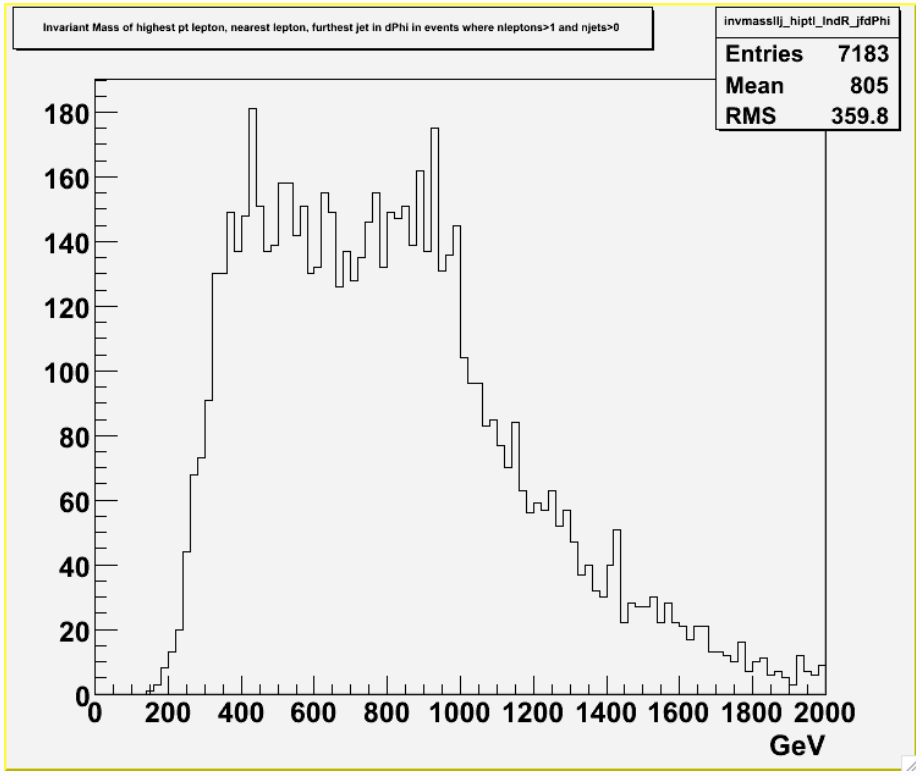
Other cuts:
Require two leptons with p_T > 125 GeV

High Mass - Dilepton+jet Invariant Mass

Invariant mass of first pair of OS leptons and highest p_T jet



Invariant mass of first pair of OS leptons and jet that is farthest away in Phi



Other cuts:
Require lepton with p_T > 125 GeV
Require jet with p_T > 125 GeV

Summary of interesting features

- Low mass region (~ few hundred GeV):
  - Many leptons and low numbers of jets indicates production of leptonic states, l_1, l_2, $l_{3, \ldots}$, massive repeaters of the Standard Model leptons
  - Many OS dilepton events (of arbitrary flavor), where dilepton invariant mass shows no well defined endpoint
  - Very few events with zero or one lepton, so l_1 produced in pairs

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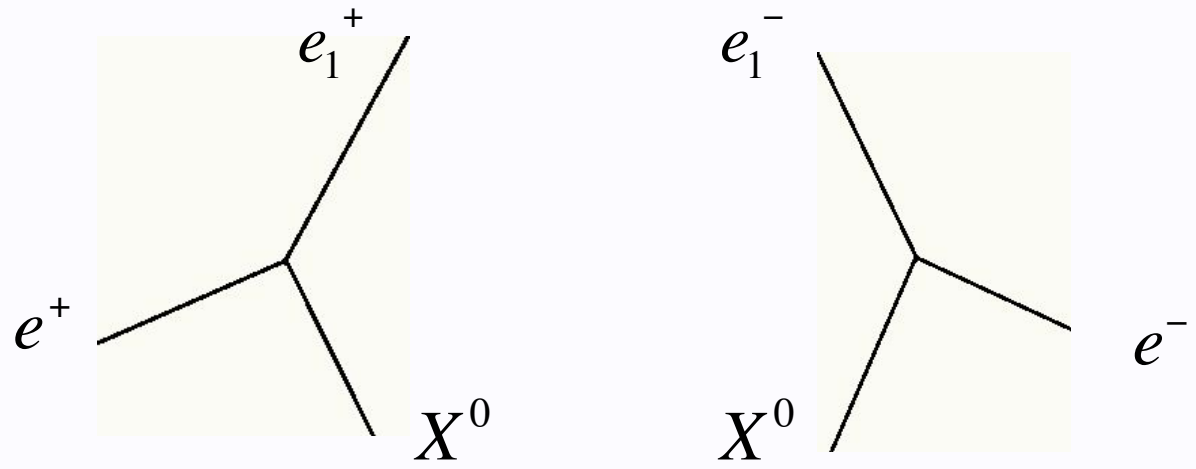

Where X^0 is stable and goes undetected

Summary of interesting features

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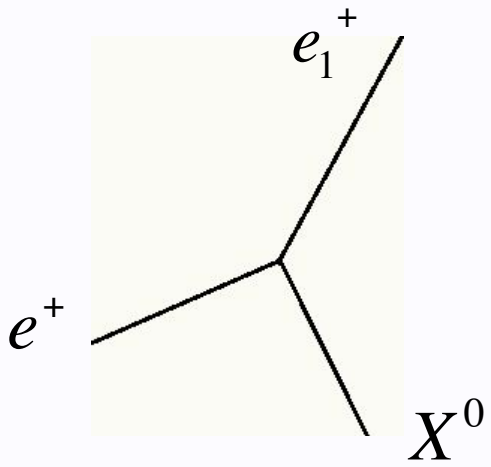
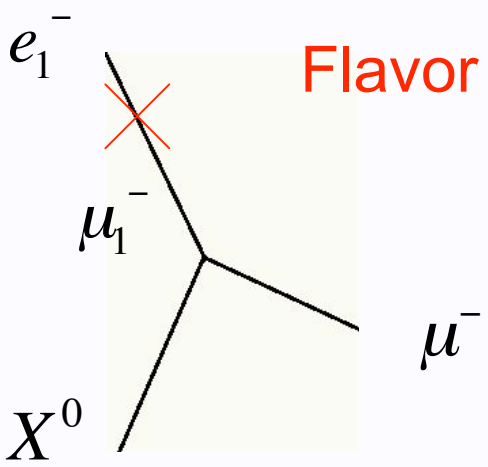


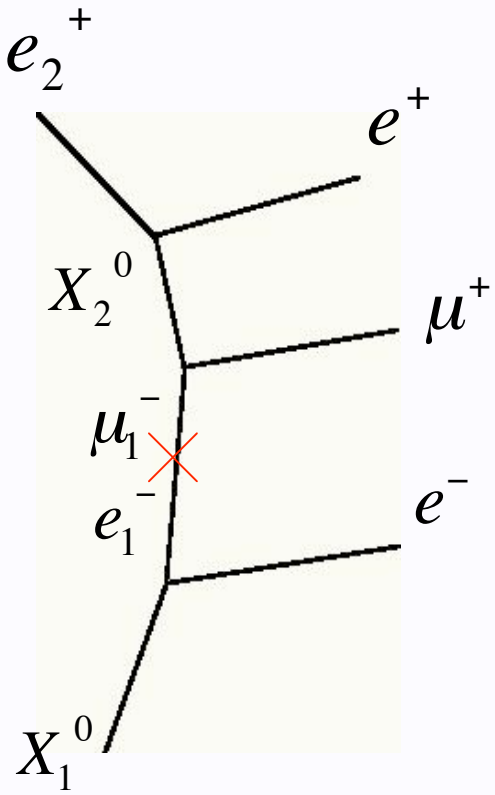


Flavor mixing!

Final state is OS leptons of arbitrary flavor + MET

Summary of interesting features

- Low mass region:
  - Cascade decays of a more massive leptonic state could produce multiple leptons
  - Suppose we had additional massive, neutral states X_1^0, X_2^0, X_3^0, …



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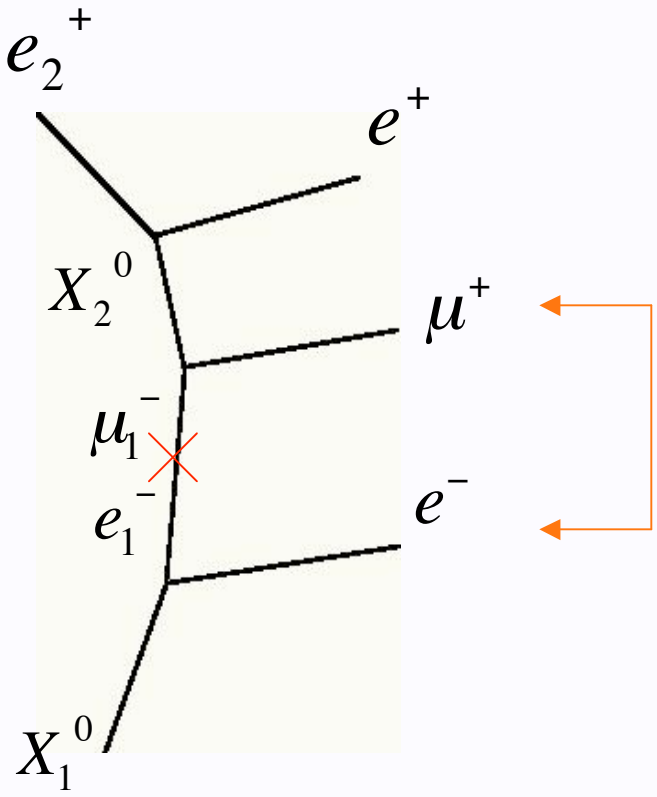
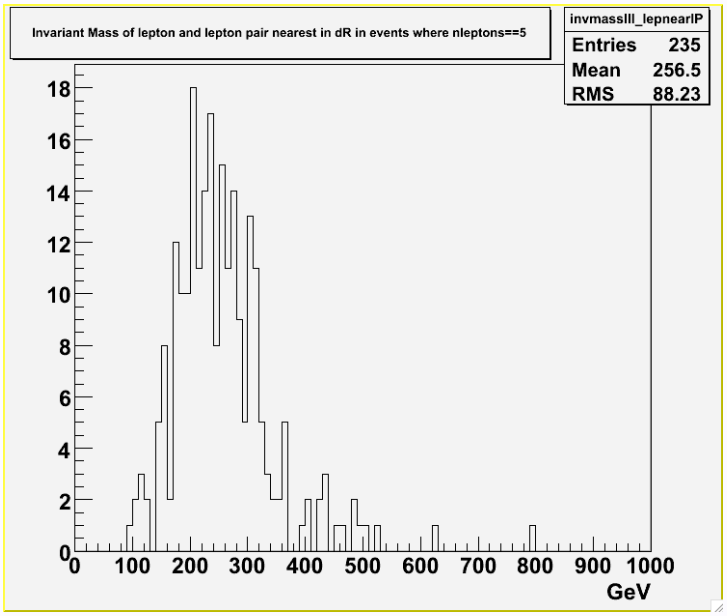


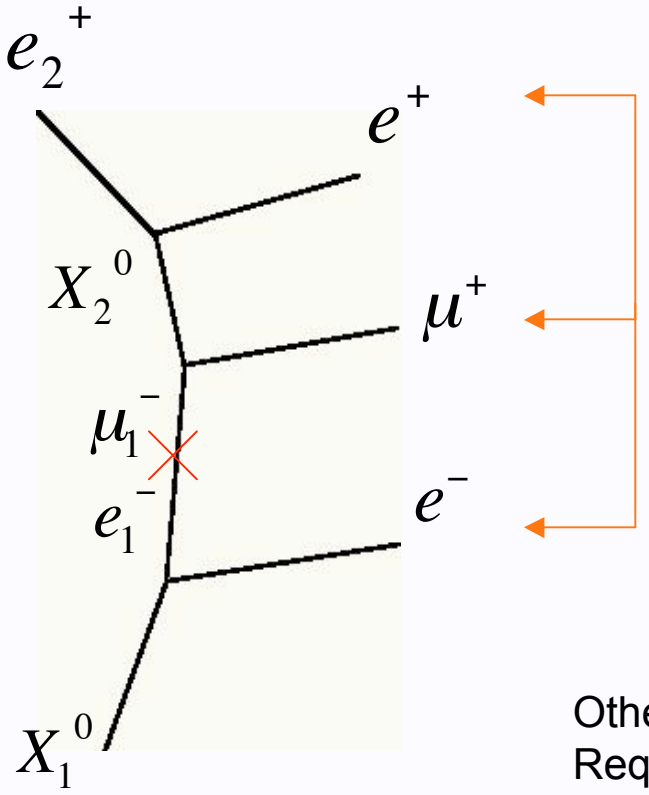
OS dilepton invariant mass endpoint near 200 GeV

$$M_{X_2^0} - M_{X_1^0} \approx 200\,GeV$$

Summary of interesting features

Invariant mass un-paired lepton and the lepton pair nearest in delta R, in events with 5 leptons and two found lepton pairs



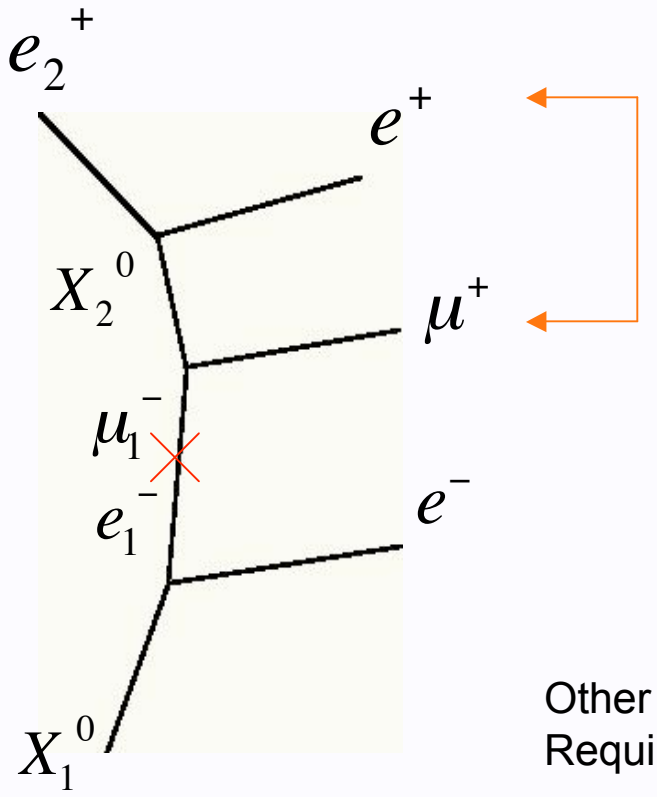


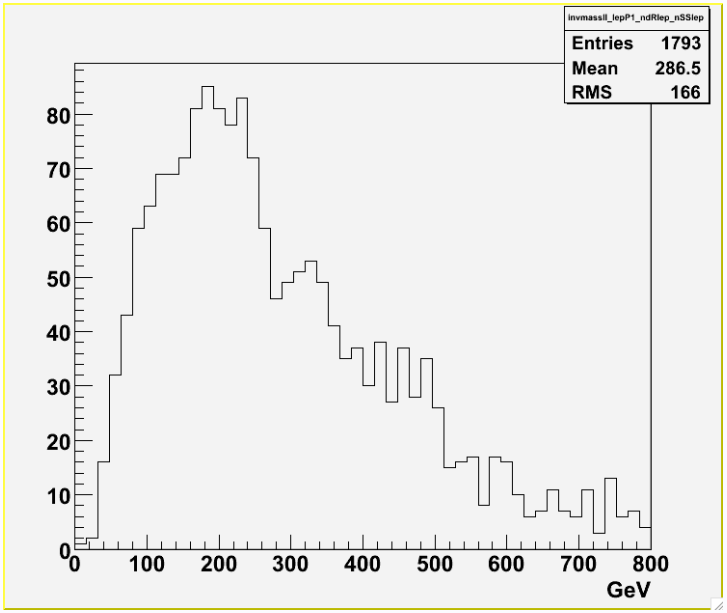
Can we see a trilepton invariant mass endpoint?

Other cuts:
Require two leptons with p_T > 125 GeV

Summary of interesting features

Invariant mass of the nearest lepton to a found lepton pair with the lepton of the same sign in the pair



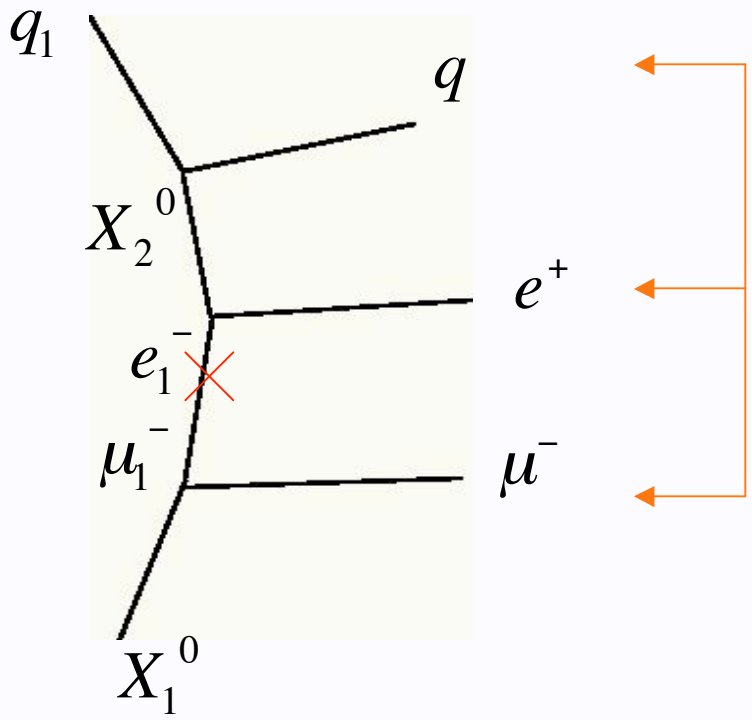


What about invariant an edge in the SS dilepton invariant mass spectrum?

Other cuts:
Require two leptons with p_T > 150 GeV

Summary of interesting features

- High mass (~ 1 TeV):
  - Production of colored objects, q_1, q_2, …
  - Same OS dilepton invariant as seen in low mass region
  - More jets indicates that these objects cascade down to the leptonic states, with an additional hadronic step



OS dilepton + jet invariant mass edge near 1 TeV

$$M_{q_1} - M_{X_1^0} \approx 1TeV$$

Summary of interesting features

- MET consistent with cascades, where X_1^0 carries off a relatively small amount of momentum (MET peaked around 150 GeV)
- Cascades, along with MET indicate a new global symmetry. This charge is conserved in each interaction, so all final states contain pairs of stable particles that carry this new charge
- Very few taus
  - Is this because our leptonic states at a few hundred GeV carry electron and muon lepton number only?
  - Or, more likely, because of poor tau reconstruction in PGS 4?
- Lack of charge asymmetry
  - We need processes that either start with a charge zero state, or somehow lose their charge information. This is a strong constraint!

Toward a possible model

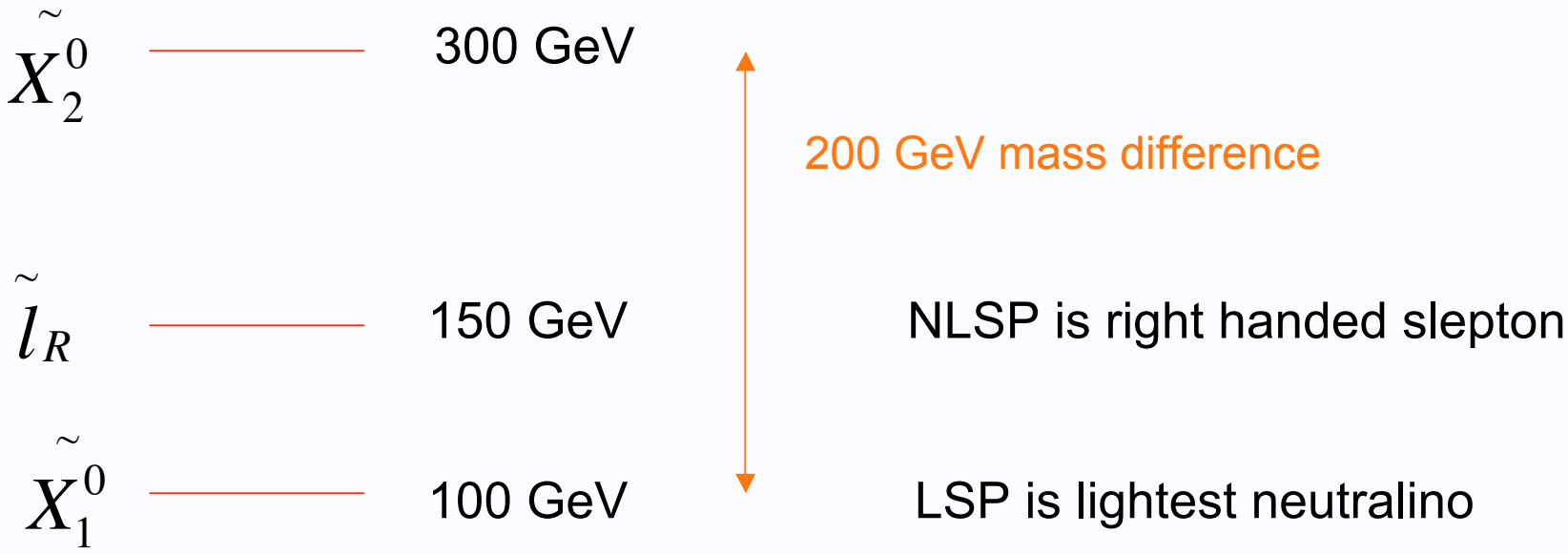
- An example of a model that has many of these desired features is SUSY

$\tilde{l}_R$ ——— 150 GeV NLSP is right handed slepton

$\tilde{X}_1^0$ ——— 100 GeV LSP is lightest neutralino

Toward a possible model

- An example of a model that has many of these desired features is SUSY



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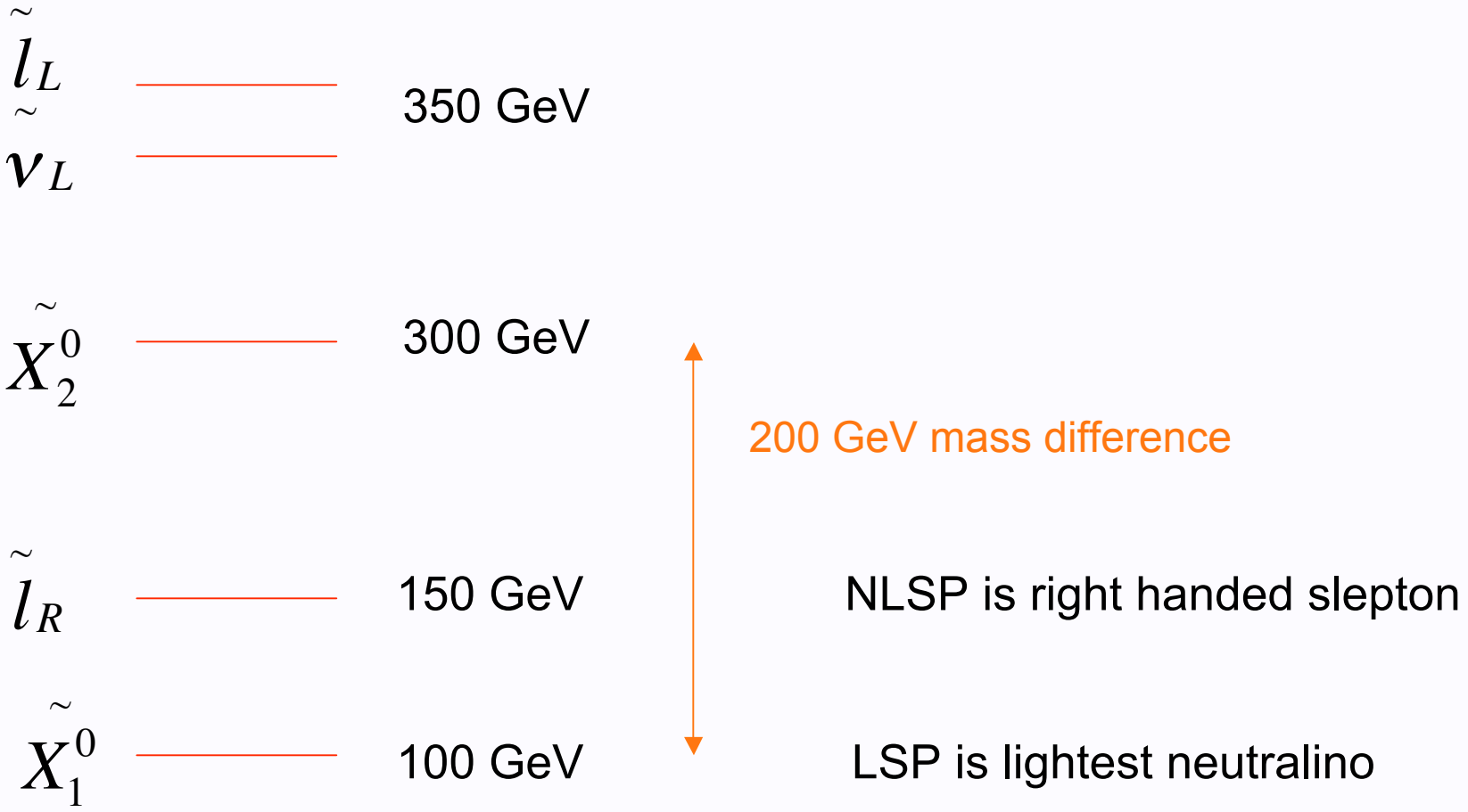
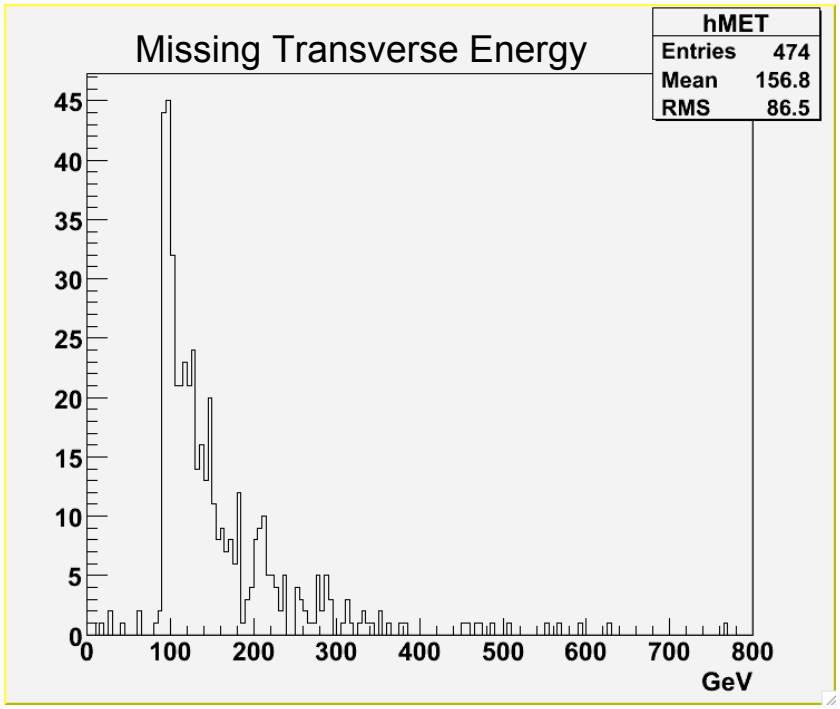


Toward a possible model

- Question: Is a neutralino LSP with mass near 100 GeV consistent with so few events with jets + MET in the low mass region?

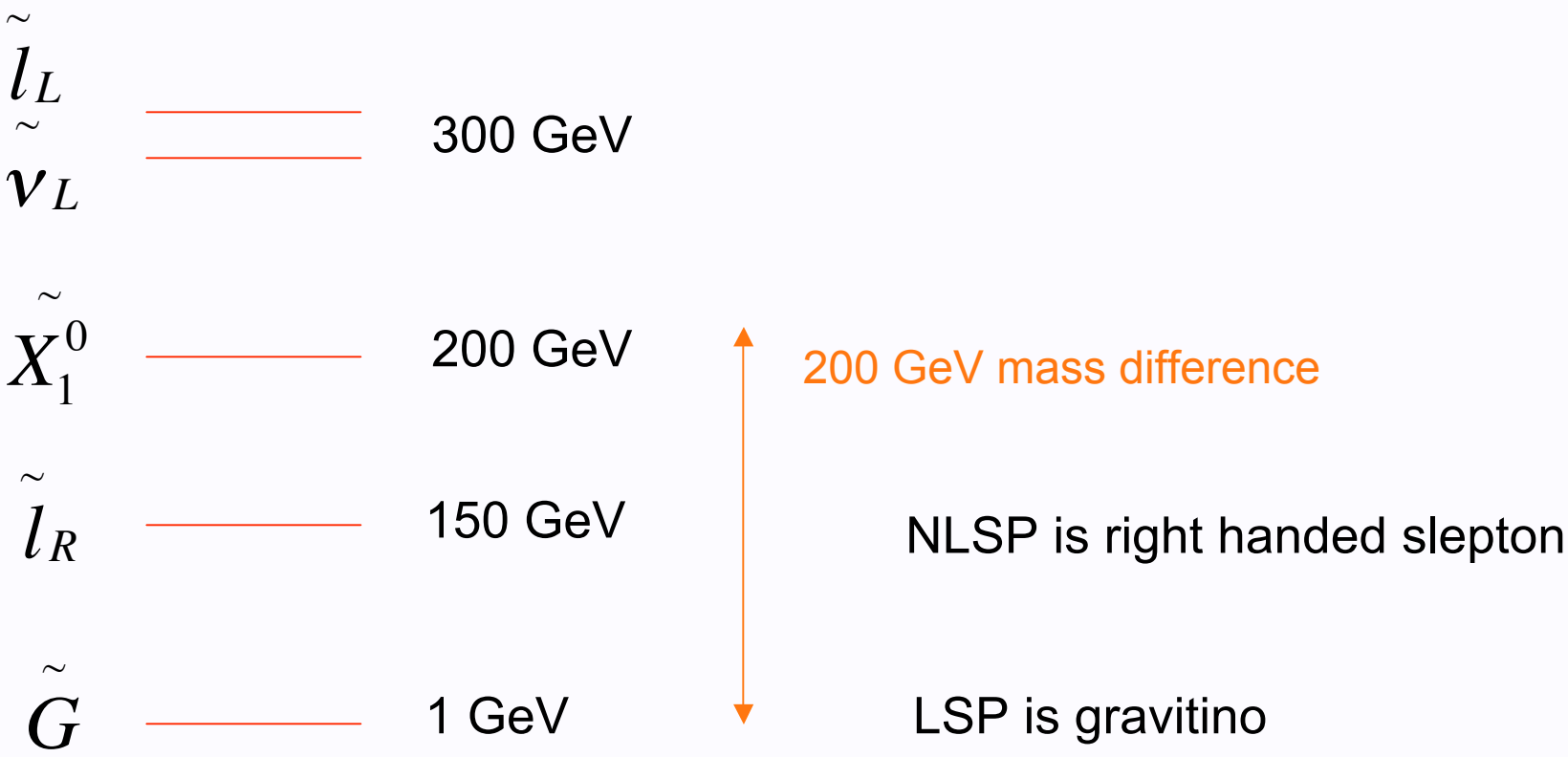
Almost 10% of events with pair production of X_1^0 pass the trigger!



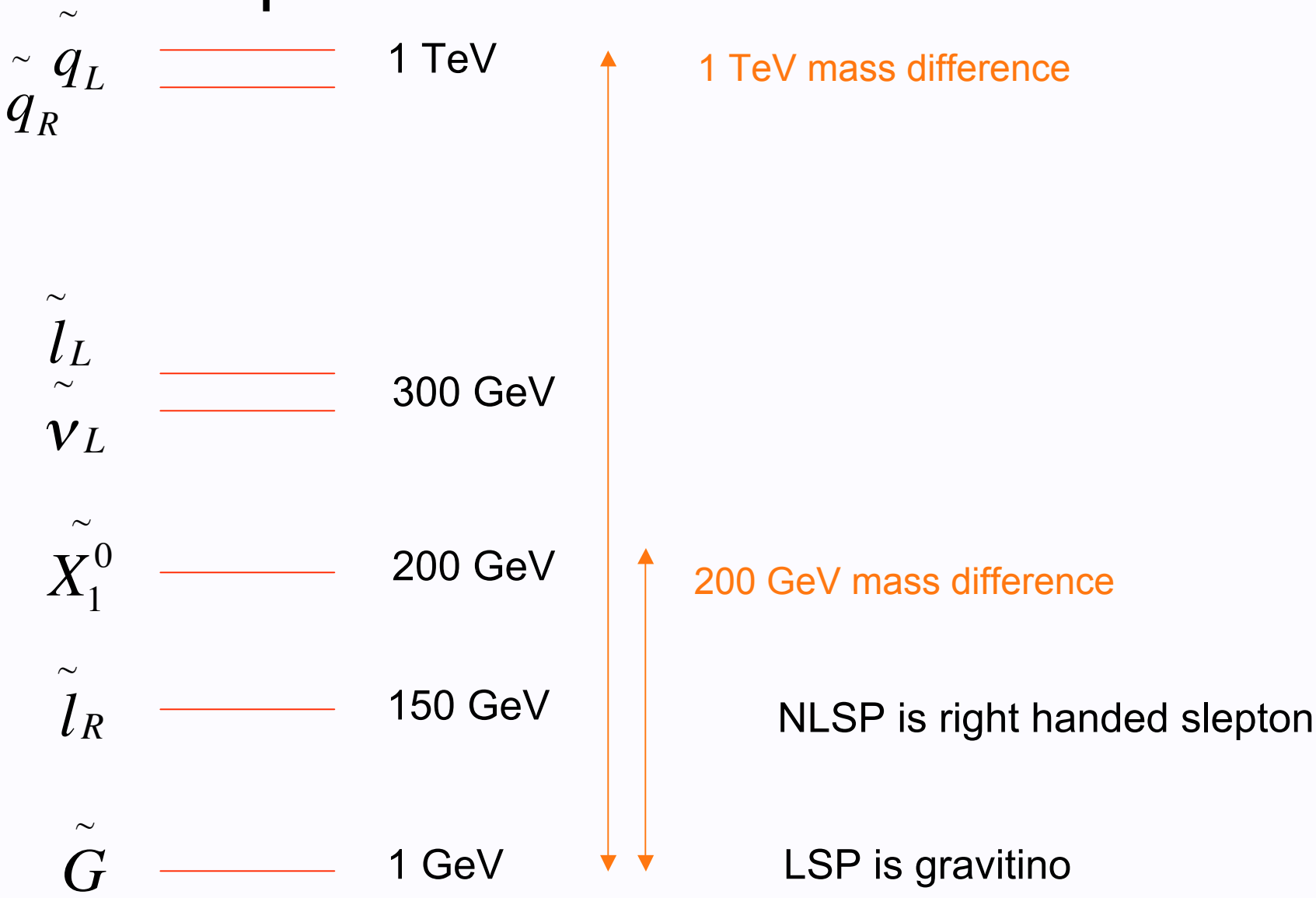
- Mainly passing MET trigger, due to initial state radiation

Toward a possible model

- Either the neutralino has a large mass, so that it's production rate is small (but then all masses must increase)
- Or the LSP is a different type of particle, with a very small production cross section



Toward a possible model



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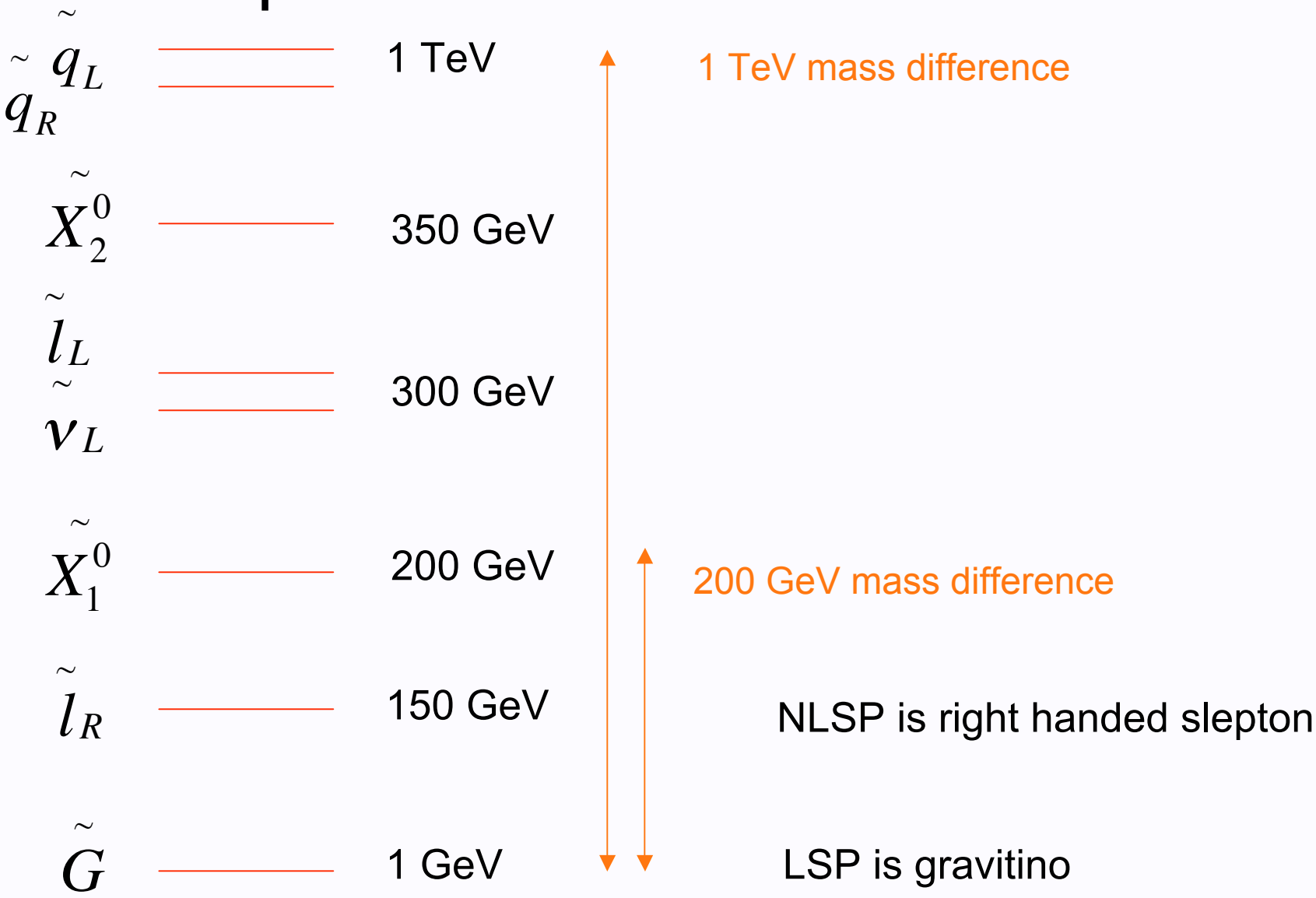

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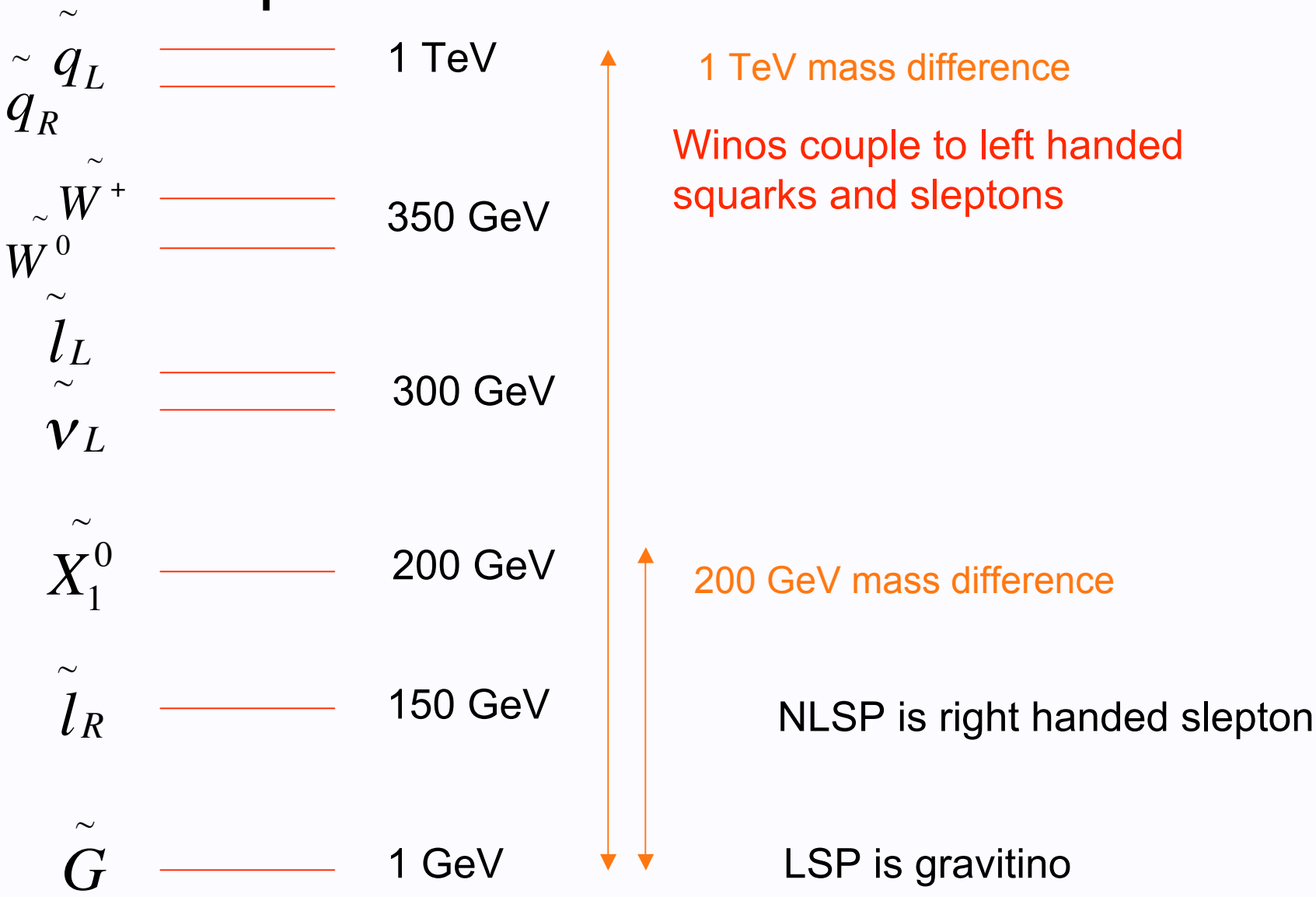
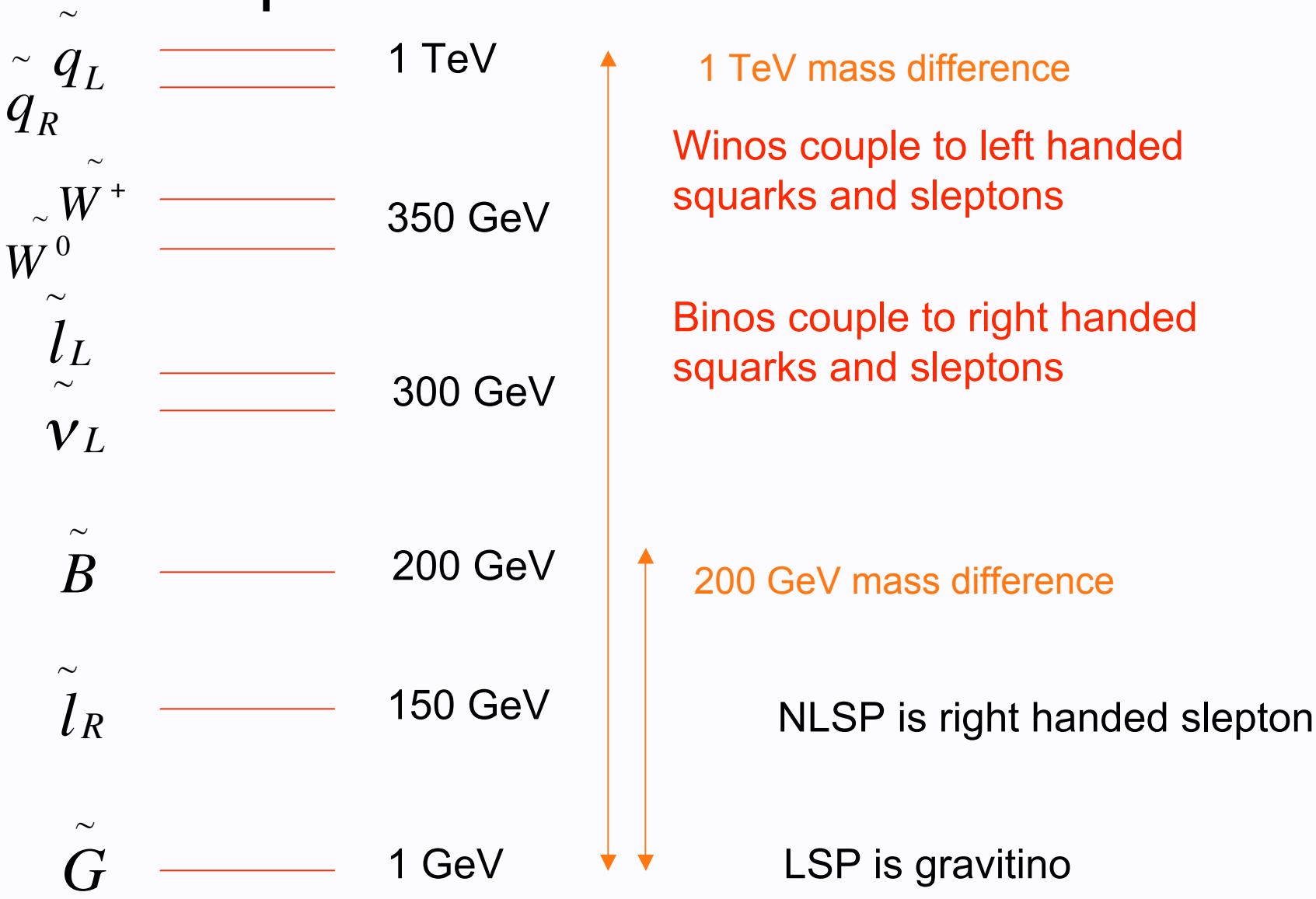
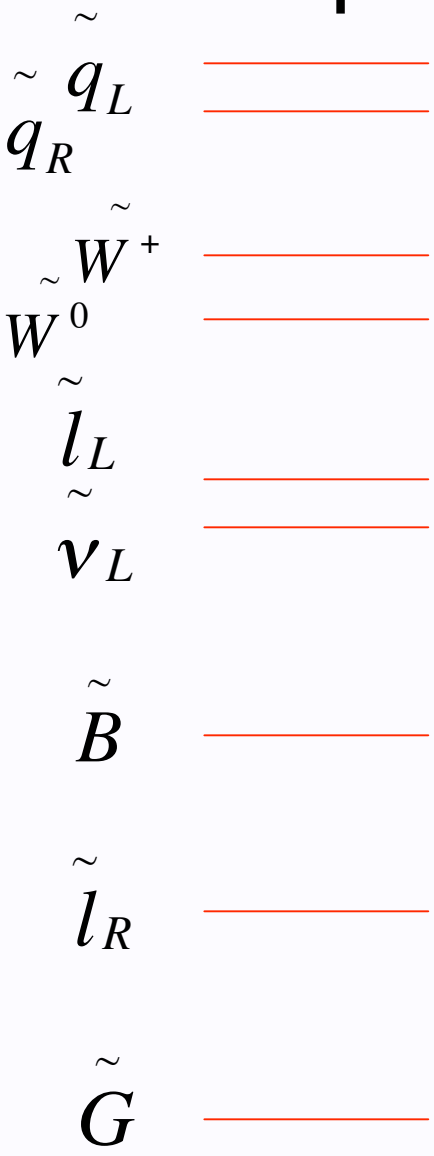


Toward a possible model



Toward a possible model

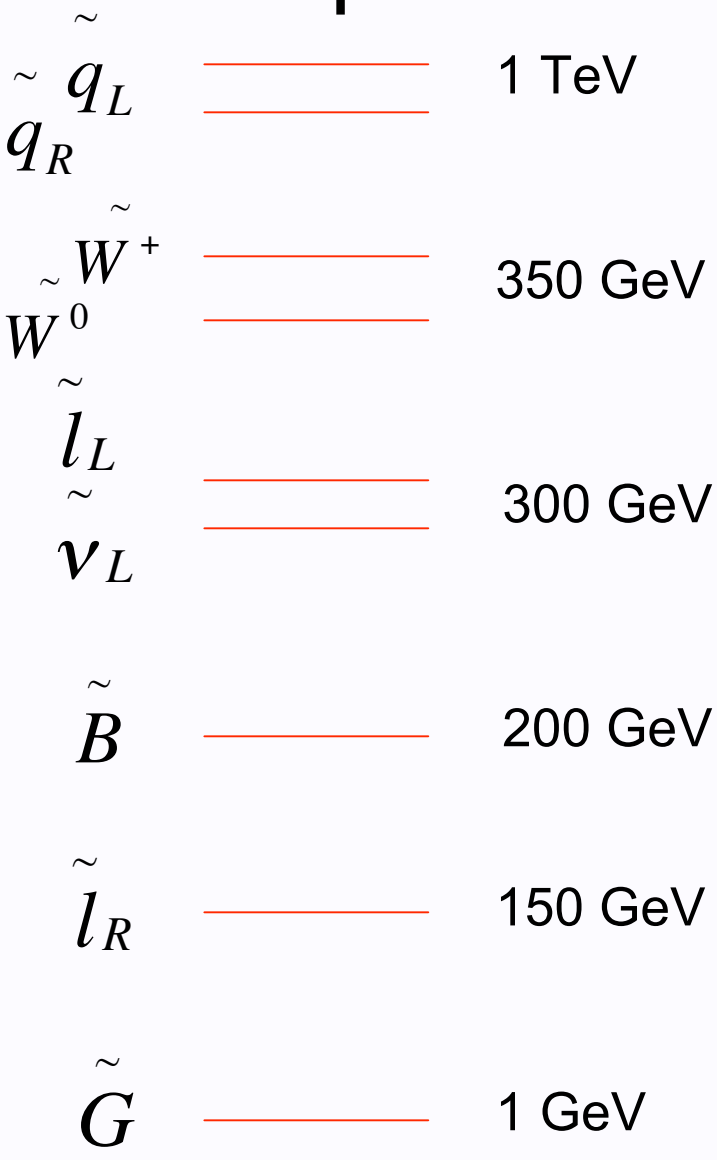


Gauge Mediated SUSY Breaking is flavor universal

$$\tilde{M}_0^2 \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} + \begin{bmatrix} \varepsilon_{11} & \varepsilon_{12} & \varepsilon_{13} \\ \varepsilon_{21} & \varepsilon_{22} & \varepsilon_{23} \\ \varepsilon_{31} & \varepsilon_{32} & \varepsilon_{33} \end{bmatrix}$$

Small off diagonal terms then give large flavor mixing, consistent with our observations of arbitrary lepton flavor

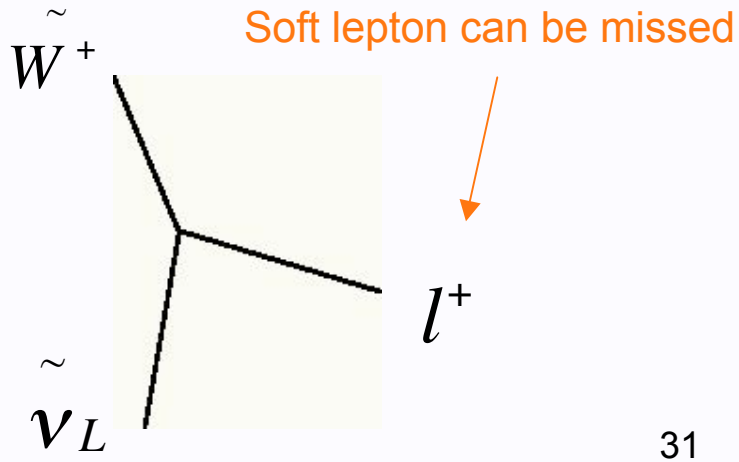
Toward a possible model



This looks promising… except how do we avoid charge asymmetries?

Maybe:

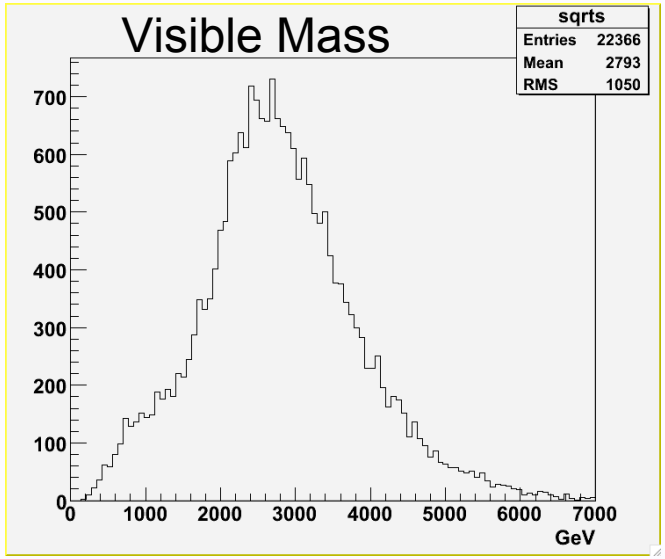
- Gluino mass large so that squark pair production is favored
- Small mass splitting between charged wino and sneutrino
- Small mass splitting between left handed slepton and bino

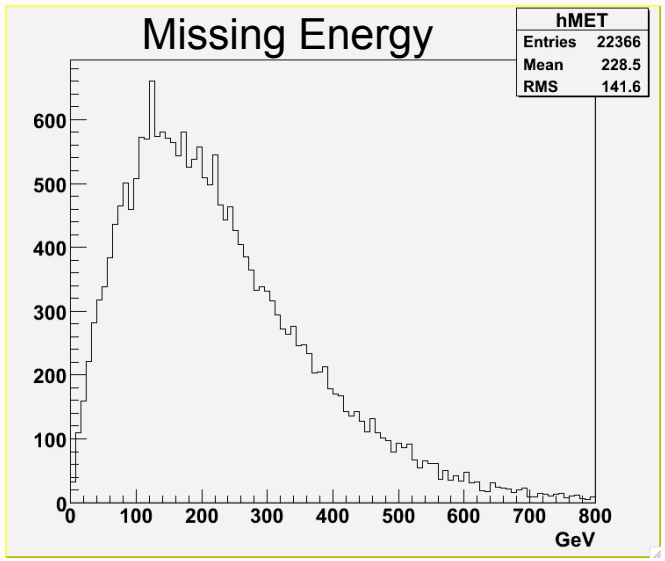


Simulation

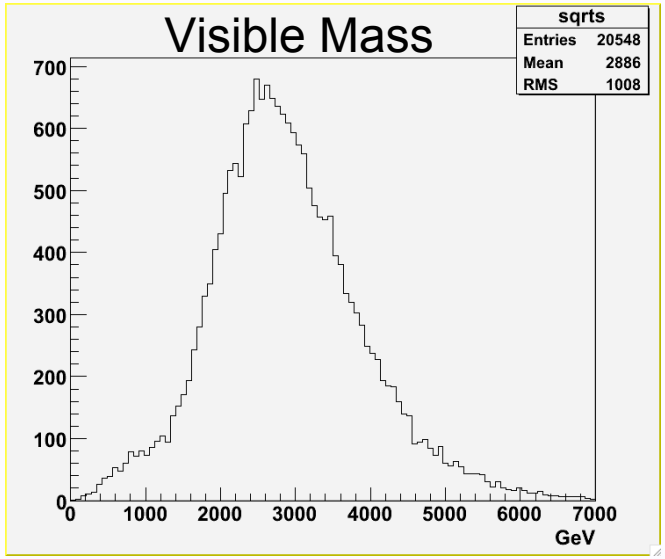
- Simulated 20 fb-1 of data, and it looks promising!

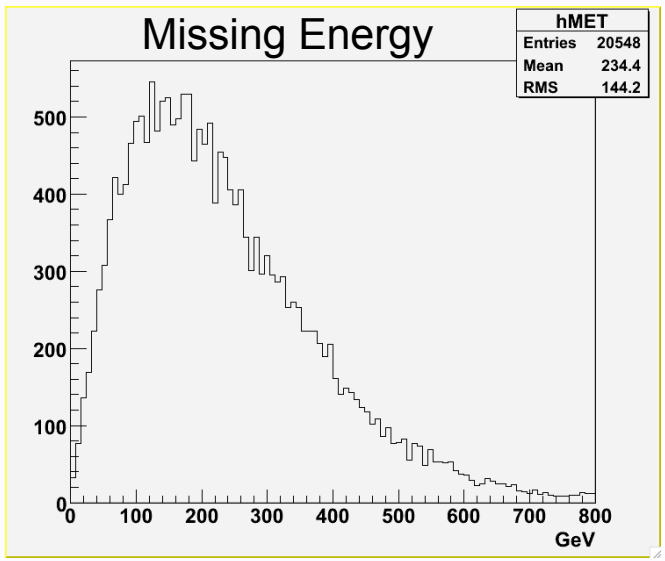
Black Box B





Simulation

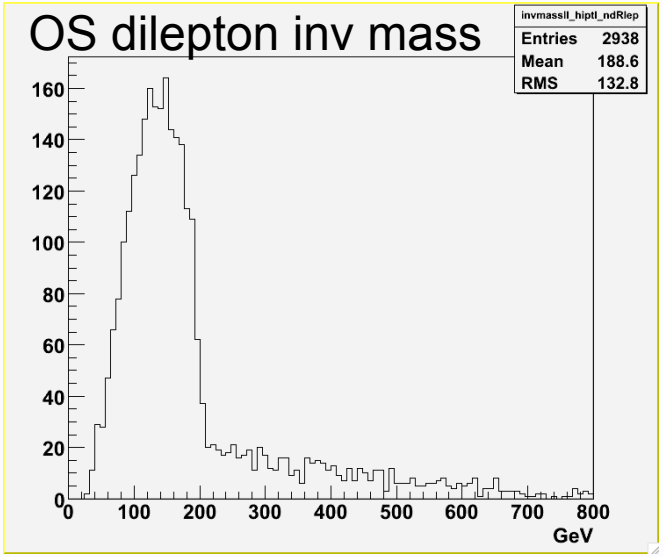


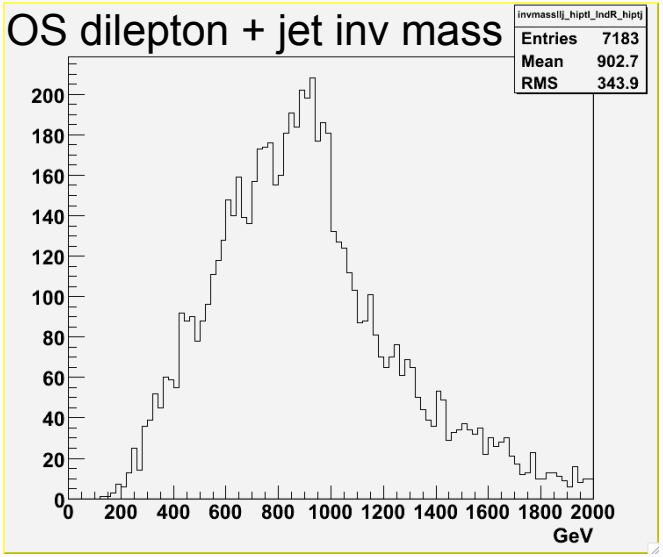


Simulation

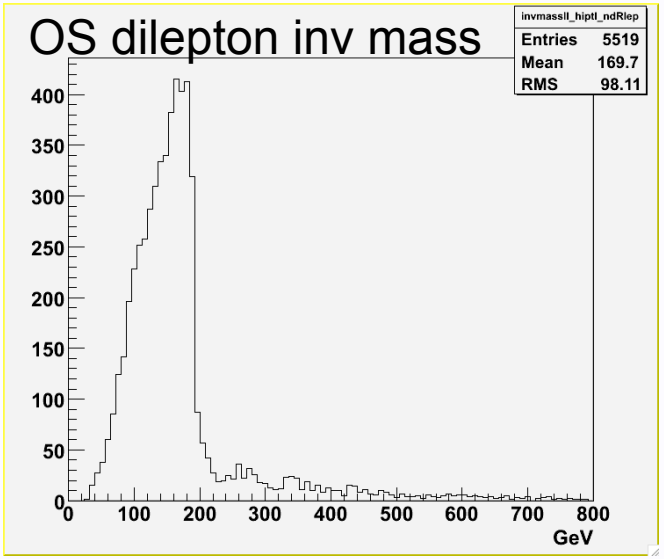
Looking good!

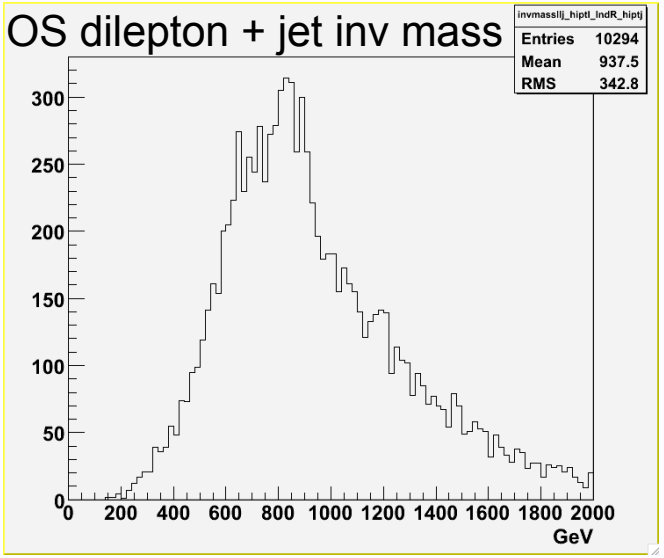
Black Box B





Simulation

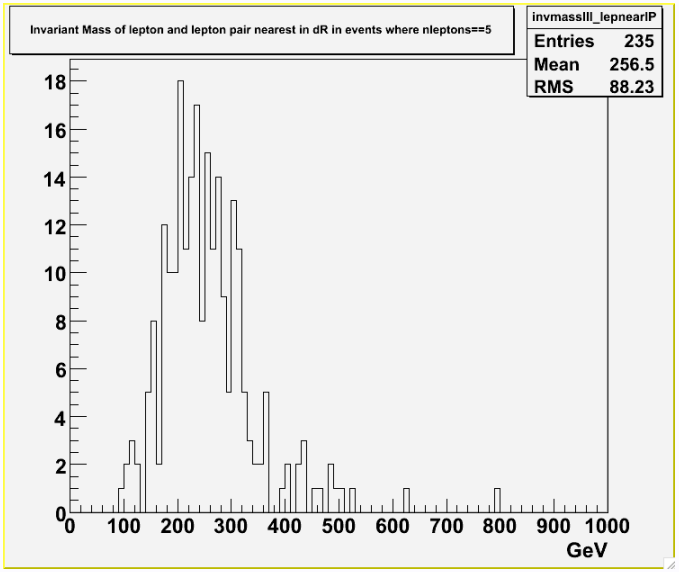


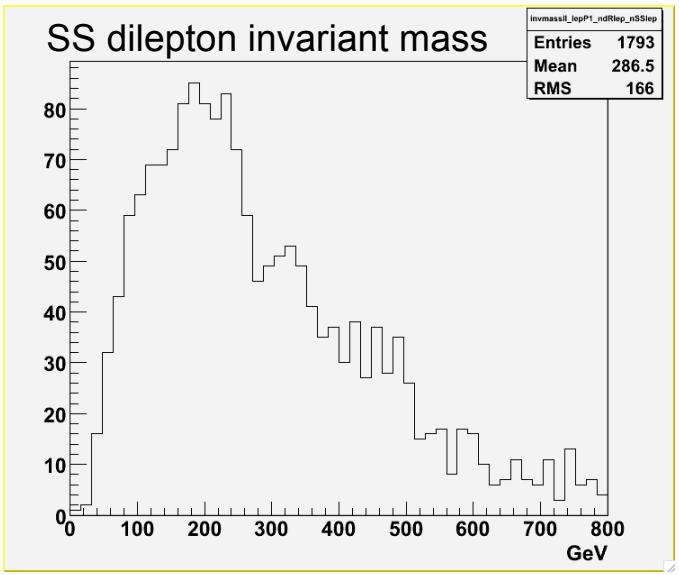


Simulation

hmmm…

Black Box B





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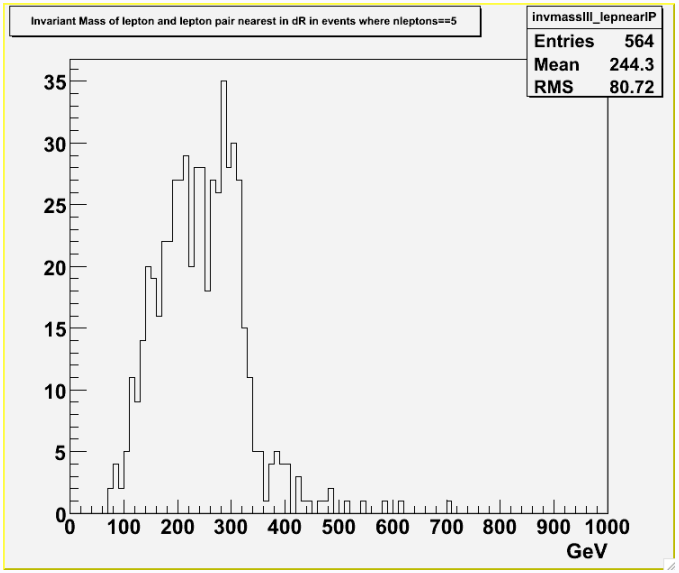

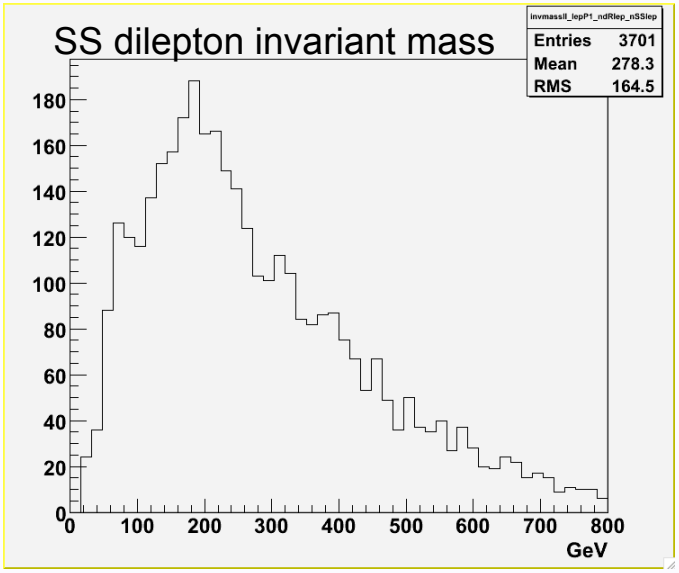

Simulation

Looking not so good

Black Box

Lepton (e, mu) charge	Number of events
4	14
3	286
2	1770
1	5259
0	7856
-1	5210
-2	1691
-3	265
-4	14

Number of Leptons	Number of events
0	1167
1	3812
2	6754
3	5956
4	3057
5	1001
6	248

Simulation

Lepton (e, mu) charge	Number of events
4	9
3	168
2	1289
1	4912
0	8667
-1	4377
-2	1051
-3	72
-4	3

Number of Leptons	Number of events
0	463
1	1891
2	4824
3	5856
4	5443
5	1754
6	296

Conclusions

- We see many interesting features in Black Box B
  - Endpoints in the OS dilepton invariant mass and trilepton invariant mass
  - Edge in dilepton+jet invariant mass
  - Lack of charge asymmetries
- Simulation of a gauge mediated SUSY breaking model
  - Decently reproduce the endpoints we've found
  - Too many leptons
    - Possibe to control this by changing masses?
  - Significant charge asymmetries
    - More difficult to control
  - Most likely not the correct model