Leptons Galore!

Veronica Sanz (YorkU)

Assamagan (BNL), Rolli (Tufts), Tarem, Tenenbaum (Technion)
ATLAS full simulation

De Simone (MIT), Skiba (Yale), Fan (Yale&IAS)
arXiv:0903.5305 [hep-ph] Phys. Rev. D80 (2009)

Martin (Yale&FNAL)
arXiv:0907.3931 [hep-ph]. Accepted JHEP

Overview

Part 1 - Your Wishlist

Part 2 - Two scenarios of EWSB

Part 3 - High leptonic multiplicity

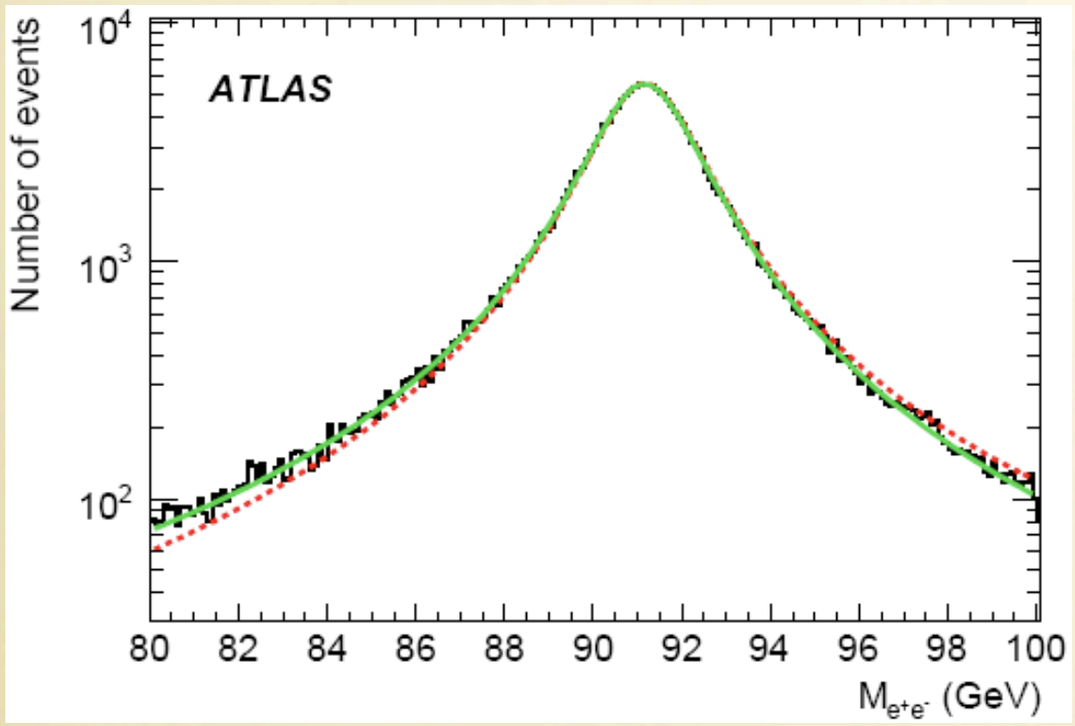
Part 4 - What ATLAS is doing

Part 1 - Your Wishlist

Experimentalists are going to be very busy...

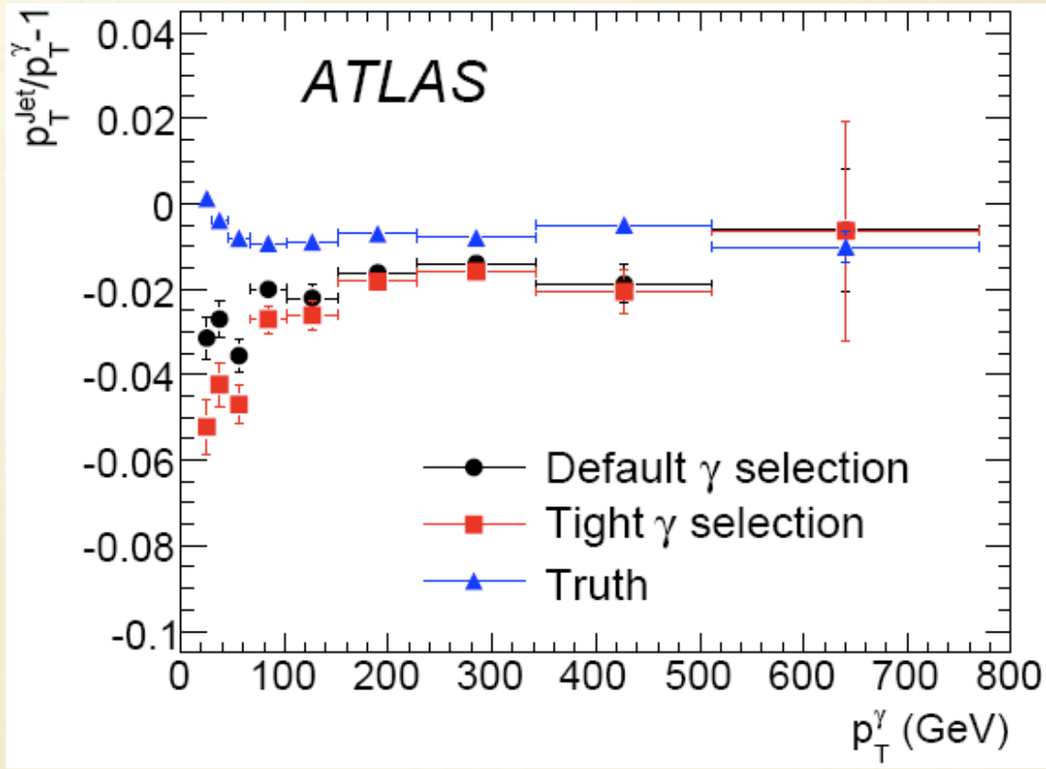
Calibrating detector w/ standard candles

$Z \to e^+e^-$



electrons

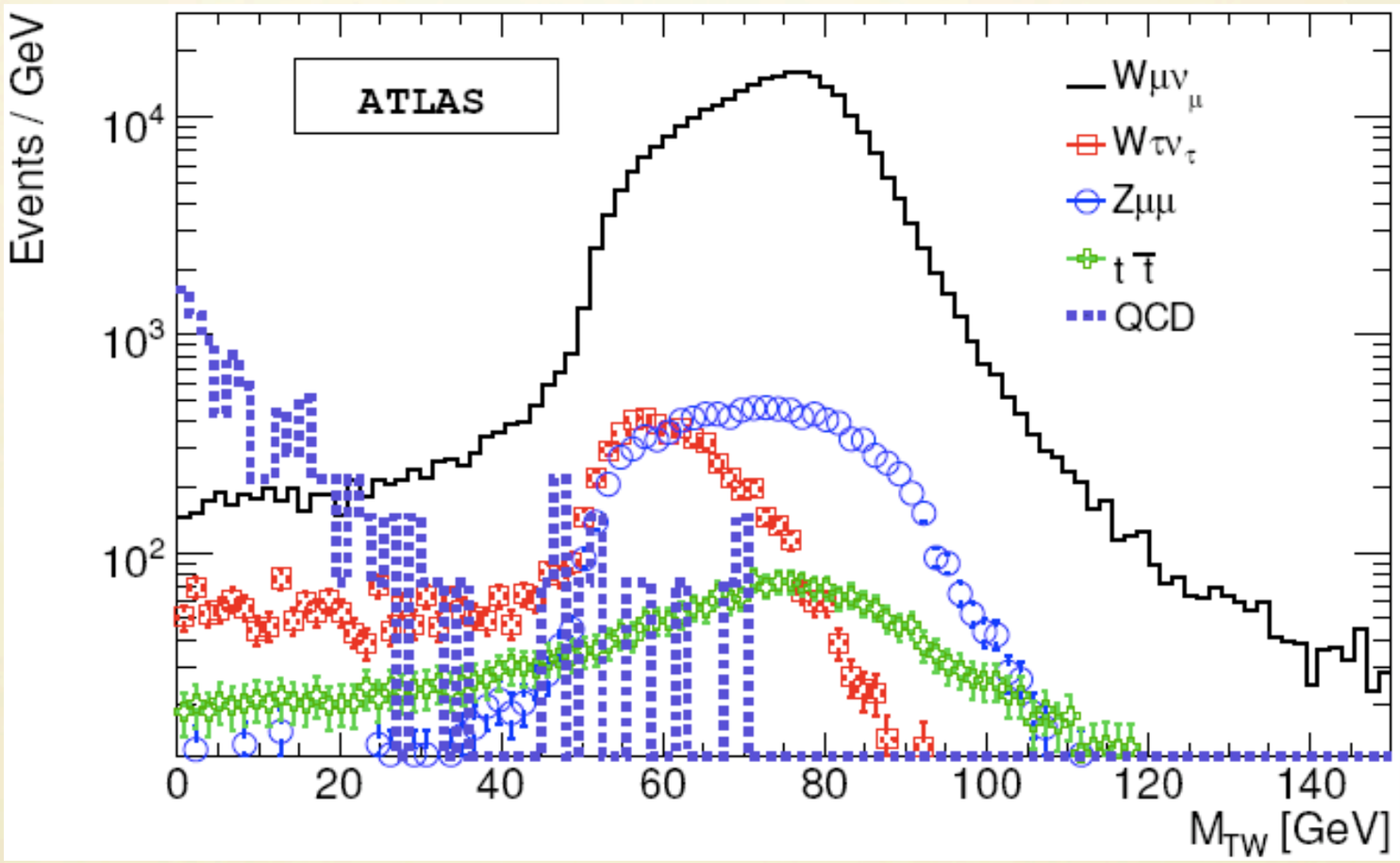
$Z/\gamma +$ jets



jets

ATLAS Collaboration, *Expected Performance of the ATLAS Experiment - Detector, Trigger and Physics,* http://arxiv.org/abs/0901.0512

Measuring EW cross sections



W mass, top mass...

ATLAS Collaboration, *Expected Performance of the ATLAS Experiment - Detector, Trigger and Physics*, http://arxiv.org/abs/0901.0512

But would you hope for New Physics ?

But would you hope for
New Physics ?

Where?

But would you hope for
New Physics ?

Where?

di-jets

jets+missing energy

But would you hope for New Physics ?

Where?

huge background

di-jets

jets+missing energy

Disclaimer:
my personal take
on this

But would you hope for New Physics ?

Where?

huge background

di-jets

hard missing ET calibration

jets+missing energy

Disclaimer: my personal take on this

But would you hope for New Physics ?

Where?

pb production cross section
Leptons, many of them!
No missing energy

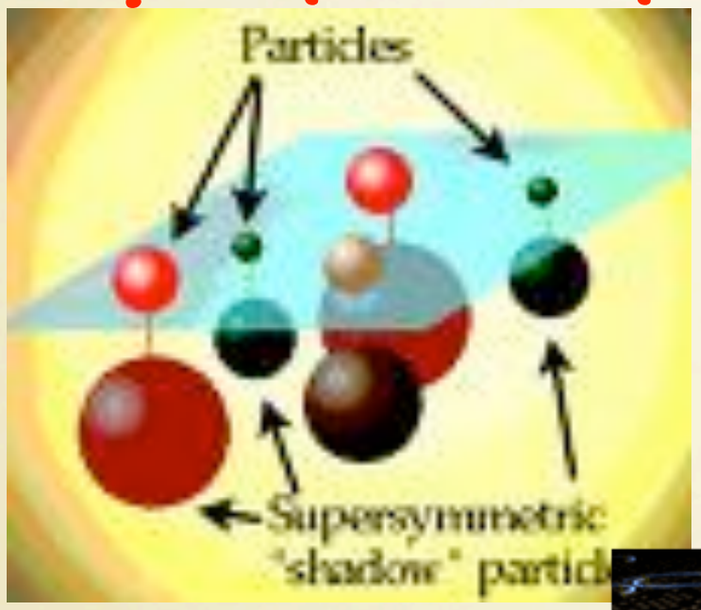
My wishlist

Two (Three) scenarios of EWSB

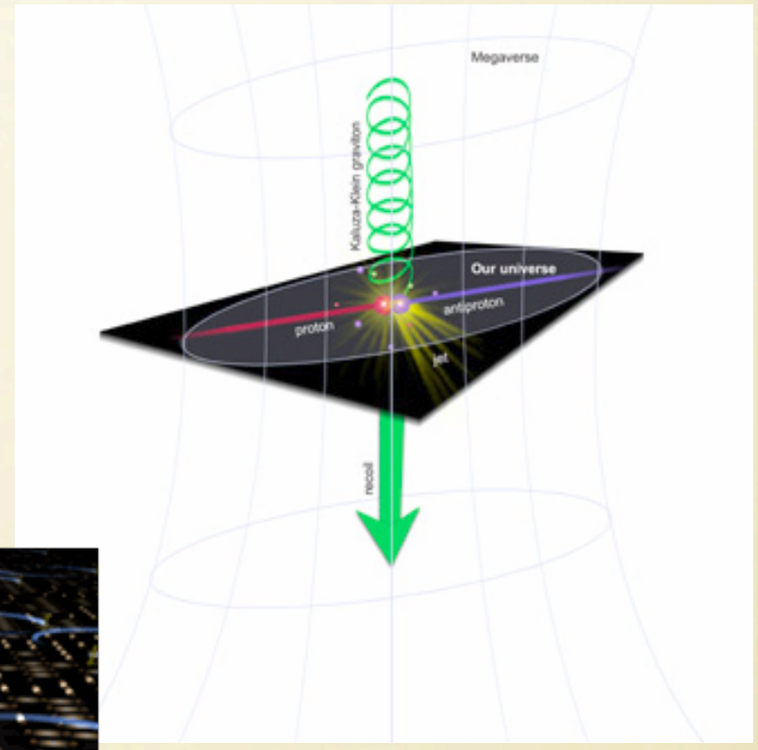
Many New Physics models
Hierarchy between Planck scale
and Electroweak scale

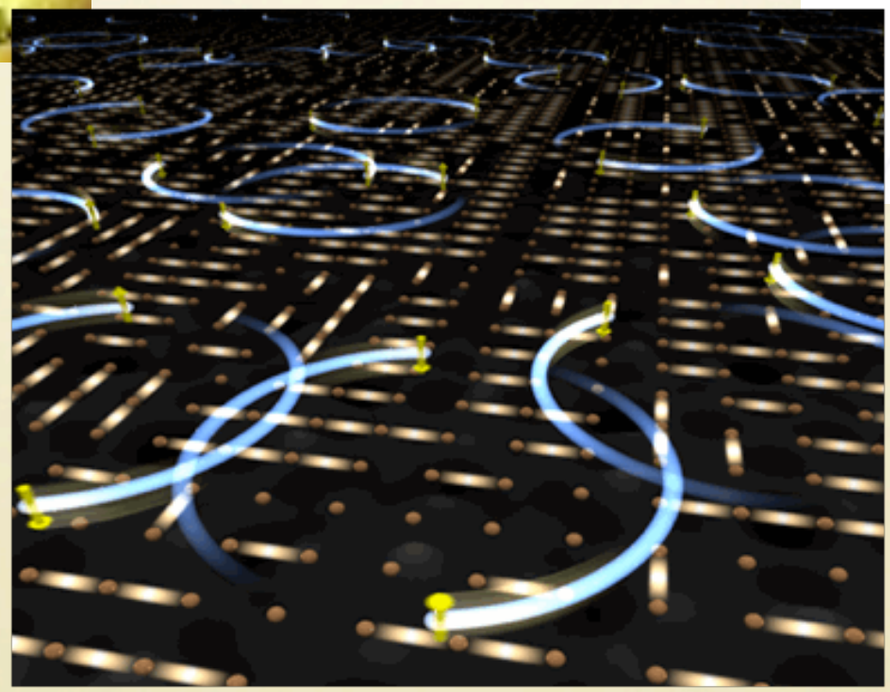
Two (Three) scenarios of EWSB

Supersymmetry



Extra-Dimensions

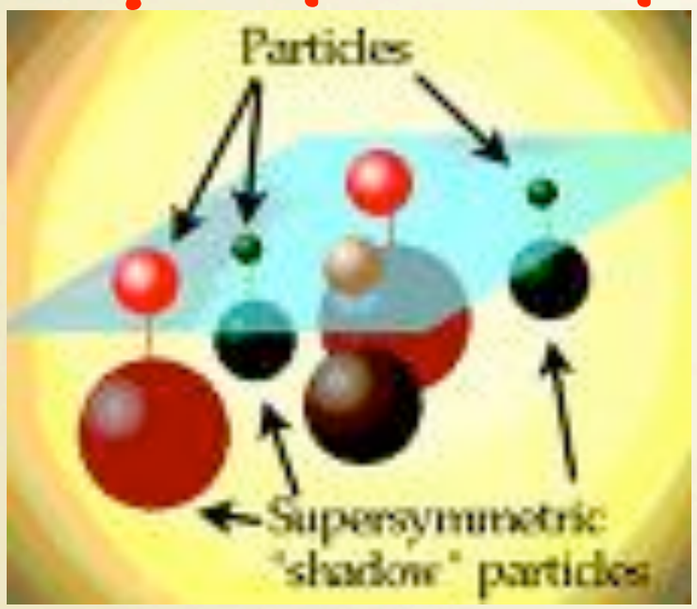




Technicolor

Two (Three) scenarios of EWSB

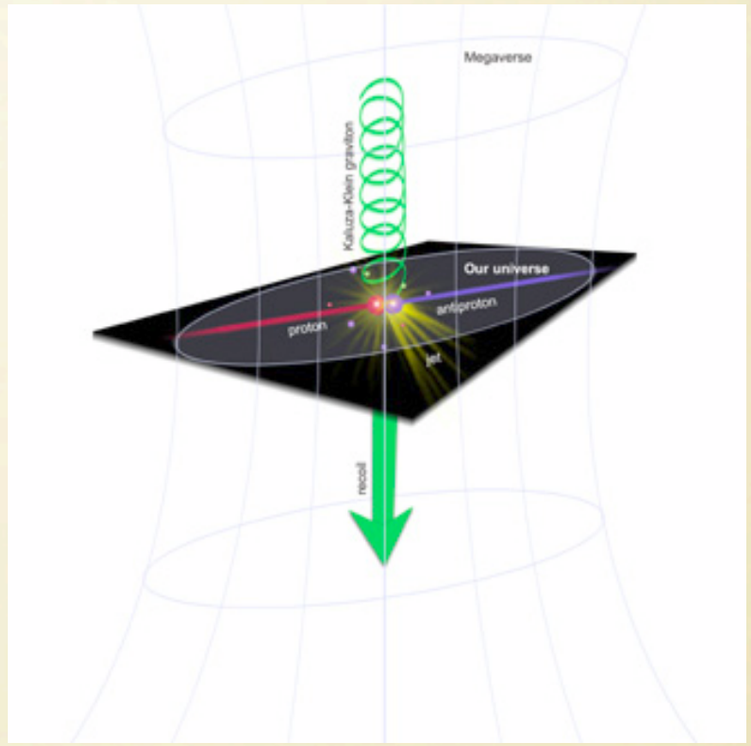
Supersymmetry



Solution 1 - It's a symmetry
(which needs to be broken)

Two (Three) scenarios of EWSB

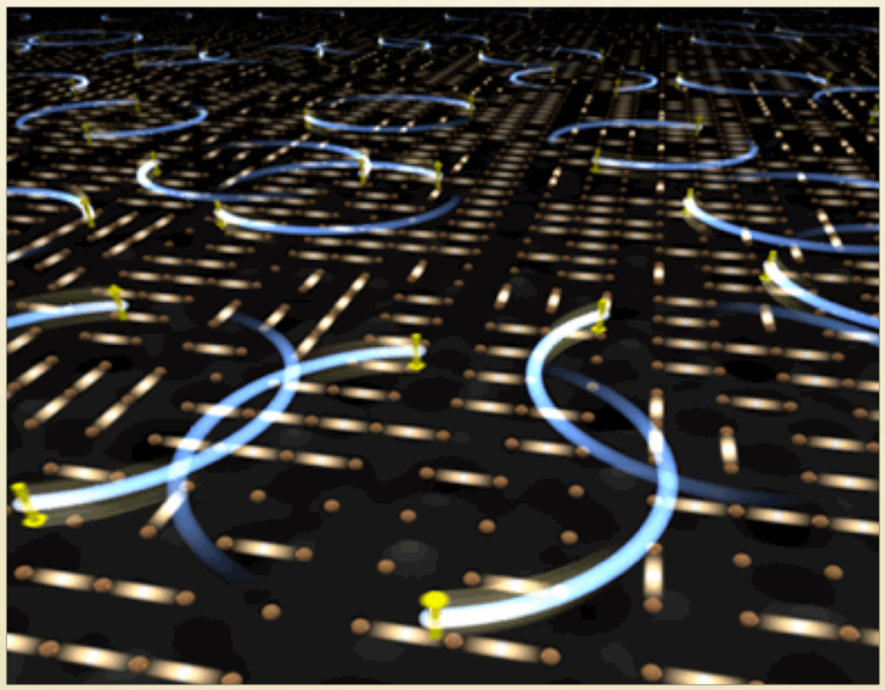
Extra-Dimensions



Solution 2 - It's just a perspective issue (what you thought large, is actually small)

Two (Three) scenarios of EWSB

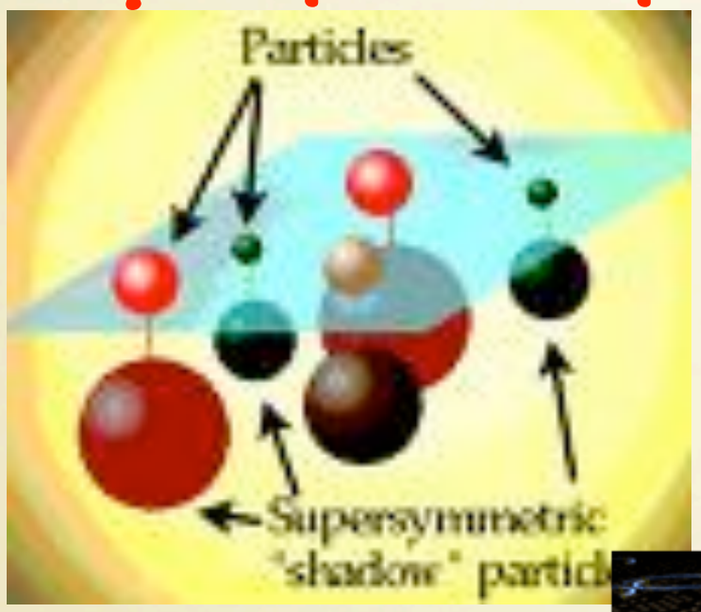
Solution 3 - It's deja-vu
(and therefore scary)



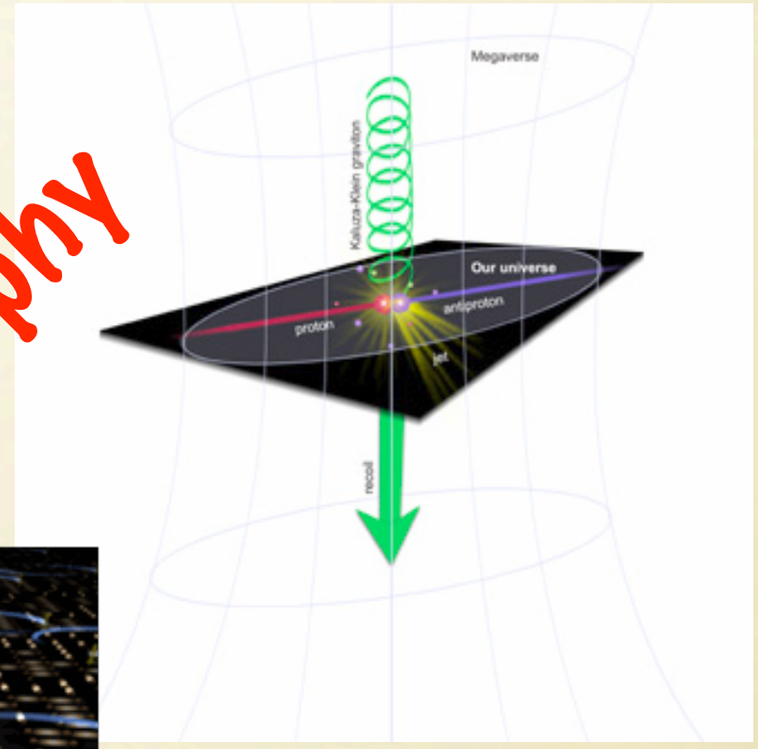
Technicolor

Two (Three) scenarios of EWSB

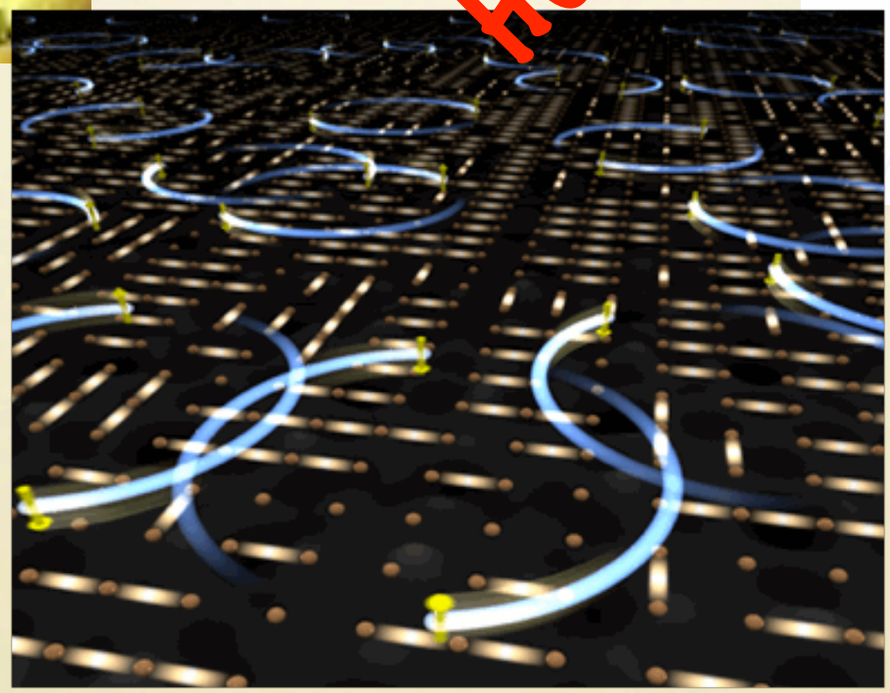
Supersymmetry



Extra-Dimensions



AdS/CFT Holography



Technicolor

Part 3 - High leptonic multiplicity

Is this anywhere in those models?

pb production cross section

Leptons, many of them!

No missing energy

Part 3 - High leptonic multiplicity

Is this anywhere in those models?

pb production cross section
Leptons, many of them!
No missing energy

YES!

Example 1 - Leptogenic Supersymetry

Phys. Rev. D80 (2009)

Spectrum

$\tilde{g}$

$\tilde{q}$

$\tilde{\chi}$

$\tilde{\ell}_2$

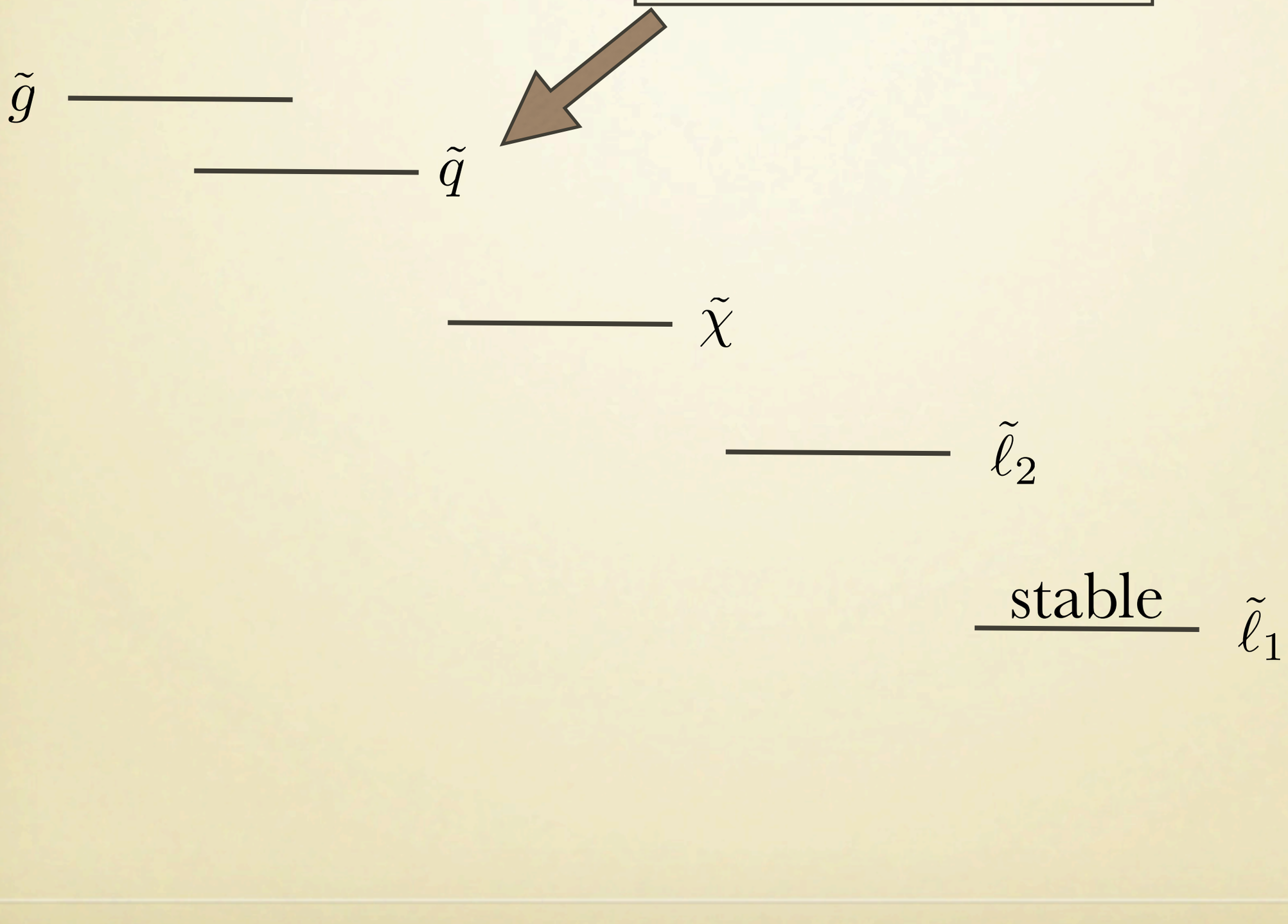
stable $\tilde{\ell}_1$

(for collider)

Spectrum

Pair produced

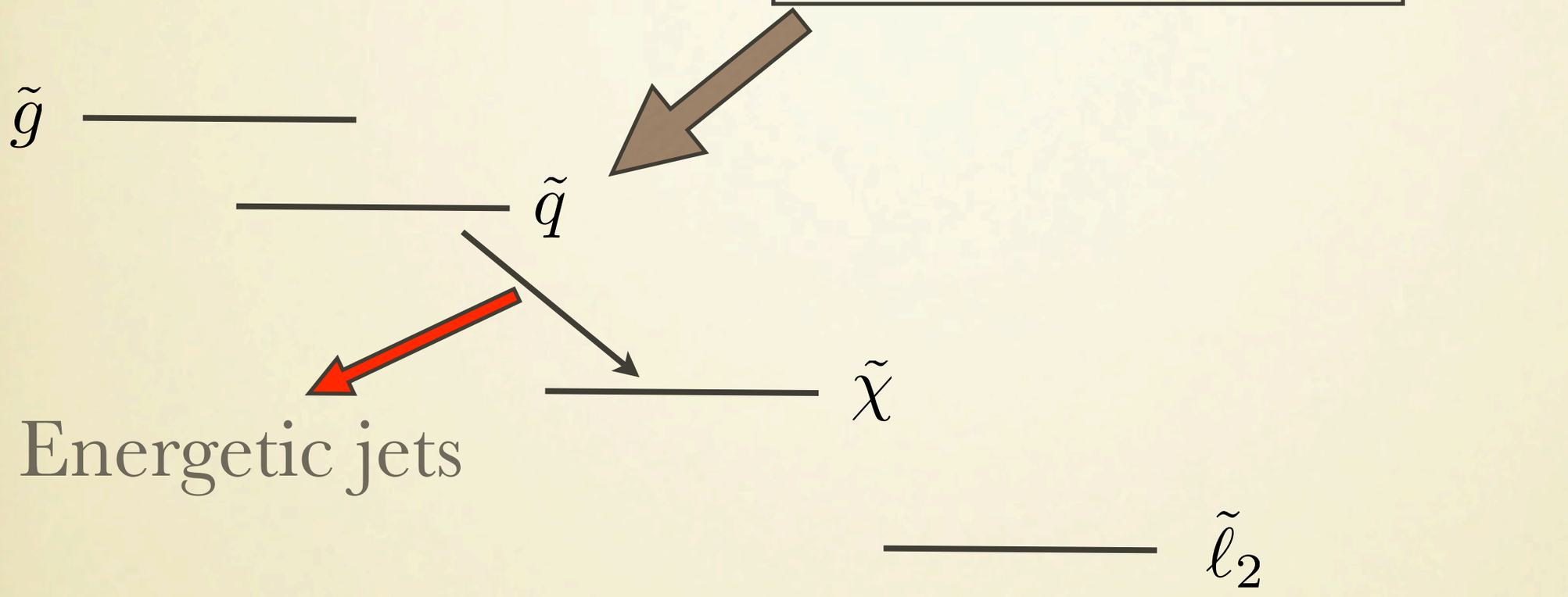
$\sigma_{prod} \sim pb$



Spectrum

Pair produced

$\sigma_{prod} \sim pb$

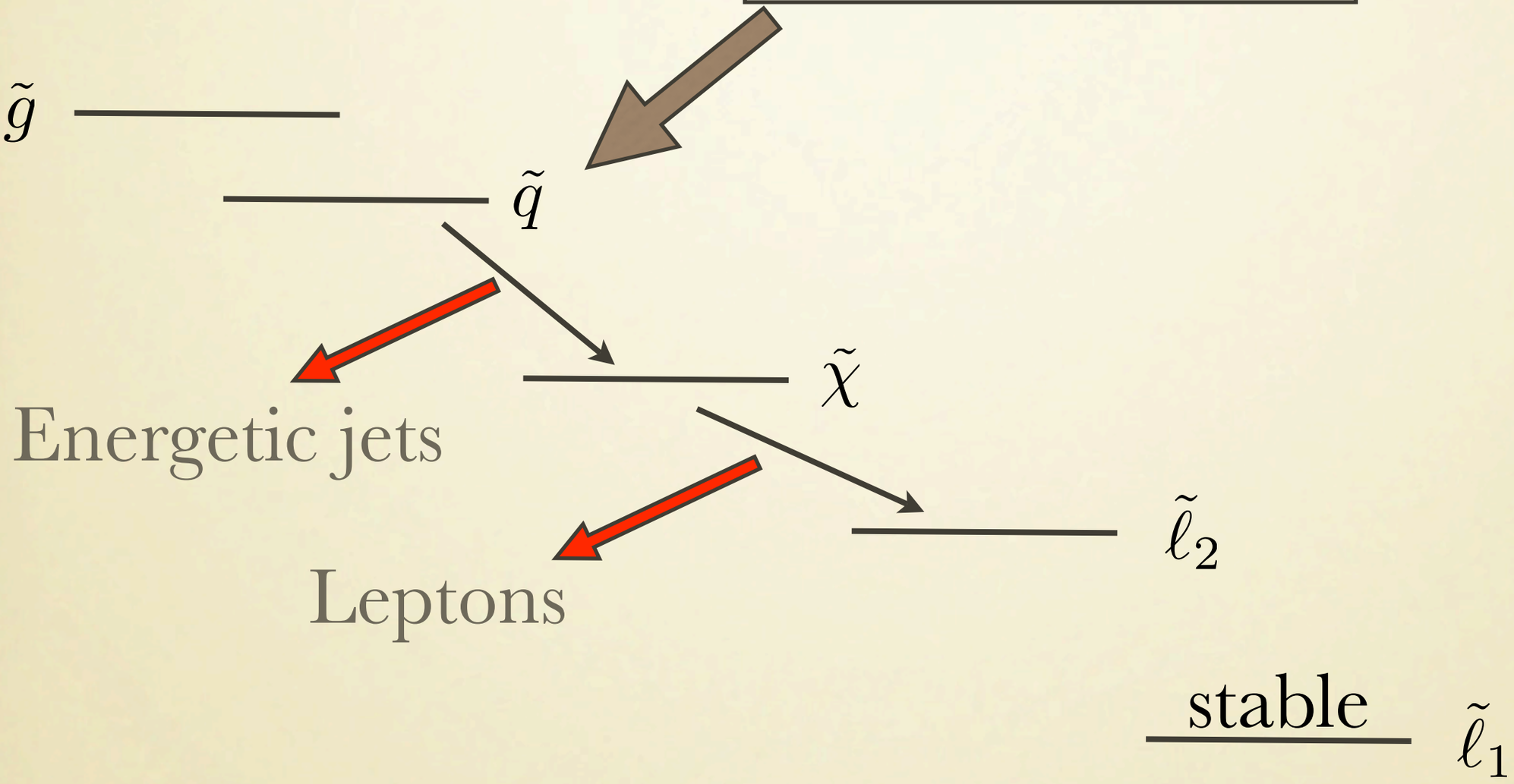


Energetic jets

Spectrum

Pair produced

$\sigma_{prod} \sim pb$



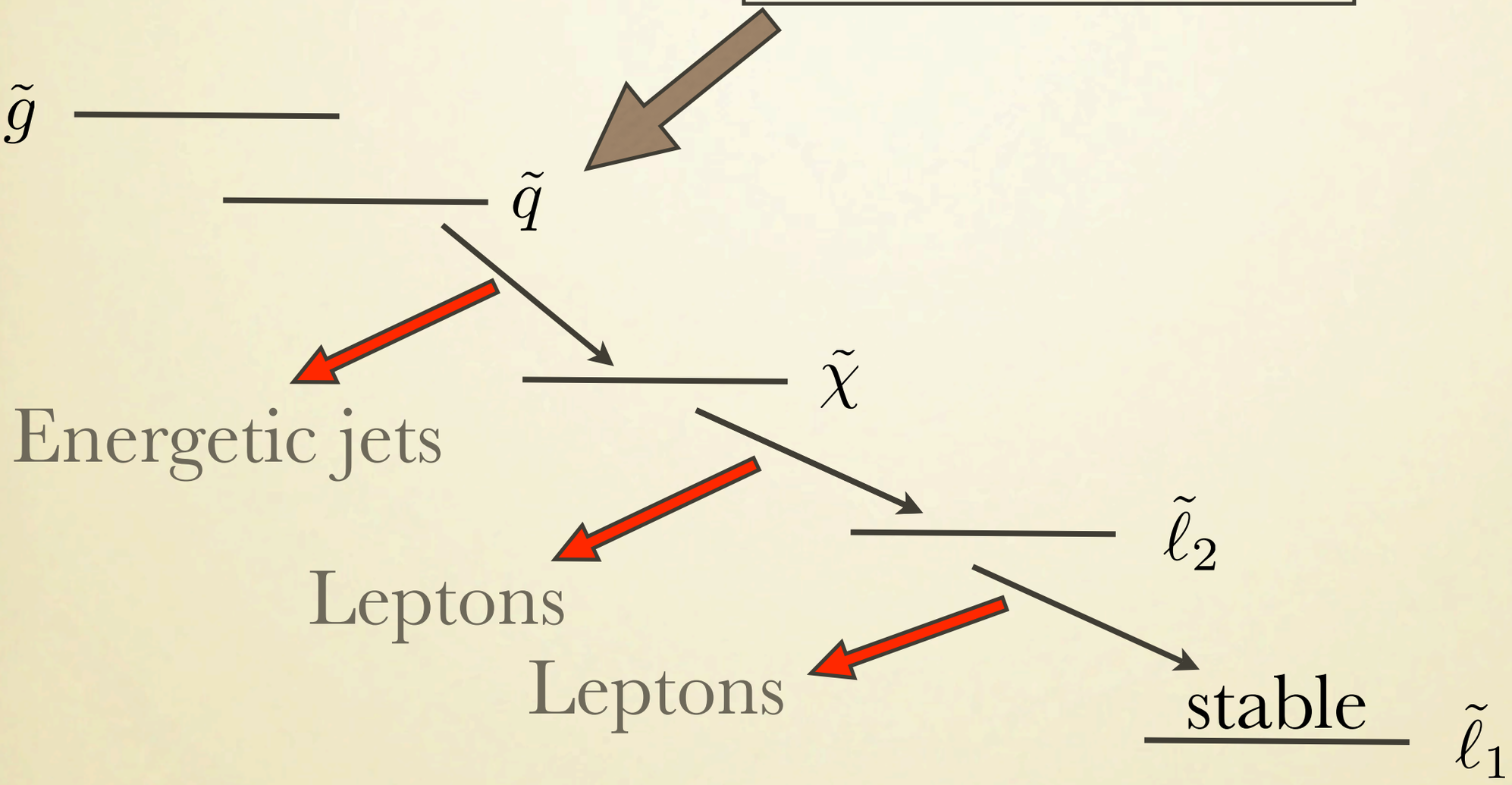
Energetic jets

Leptons

Spectrum

Pair produced

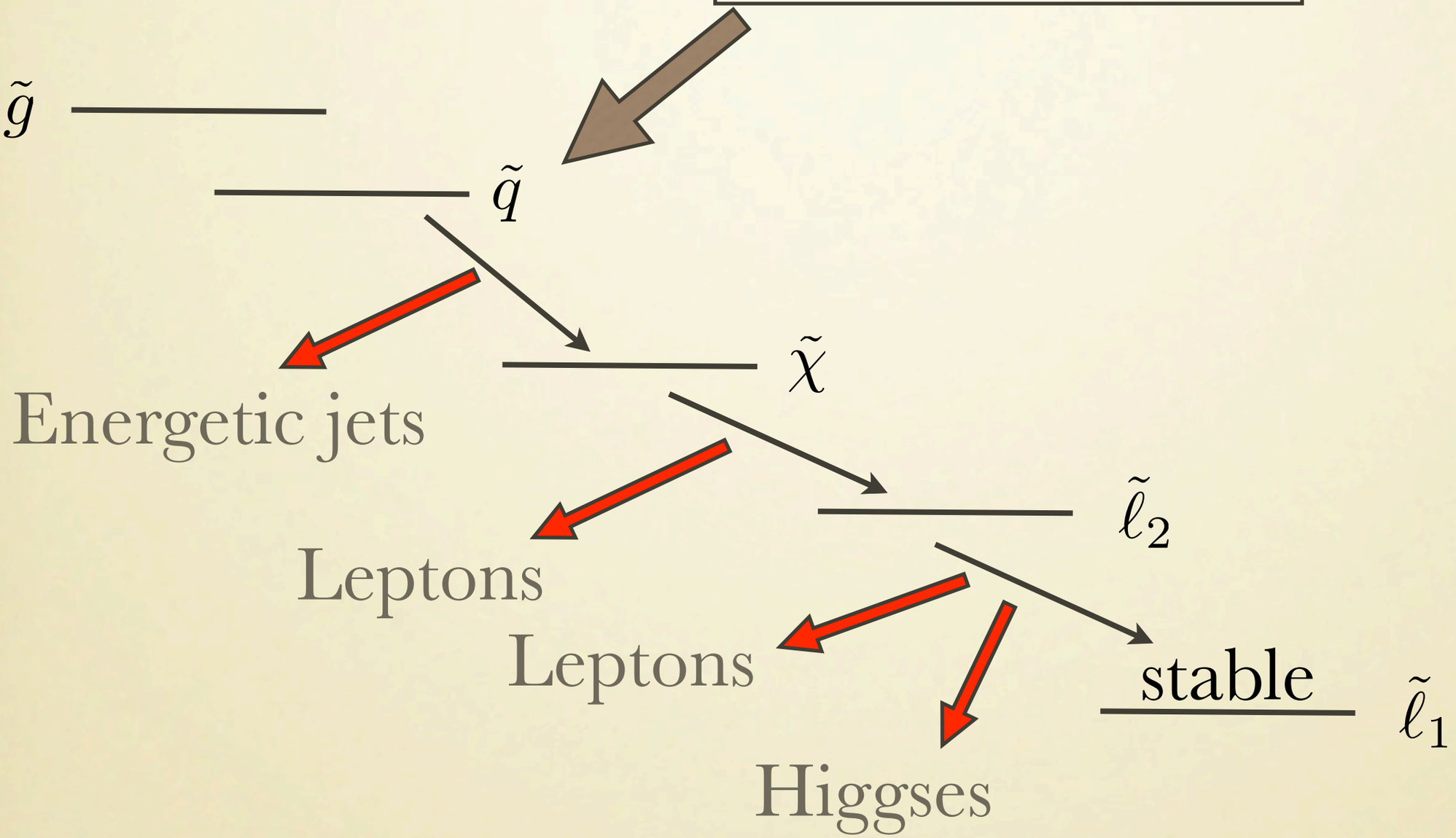
$\sigma_{prod} \sim pb$



Spectrum

Pair produced

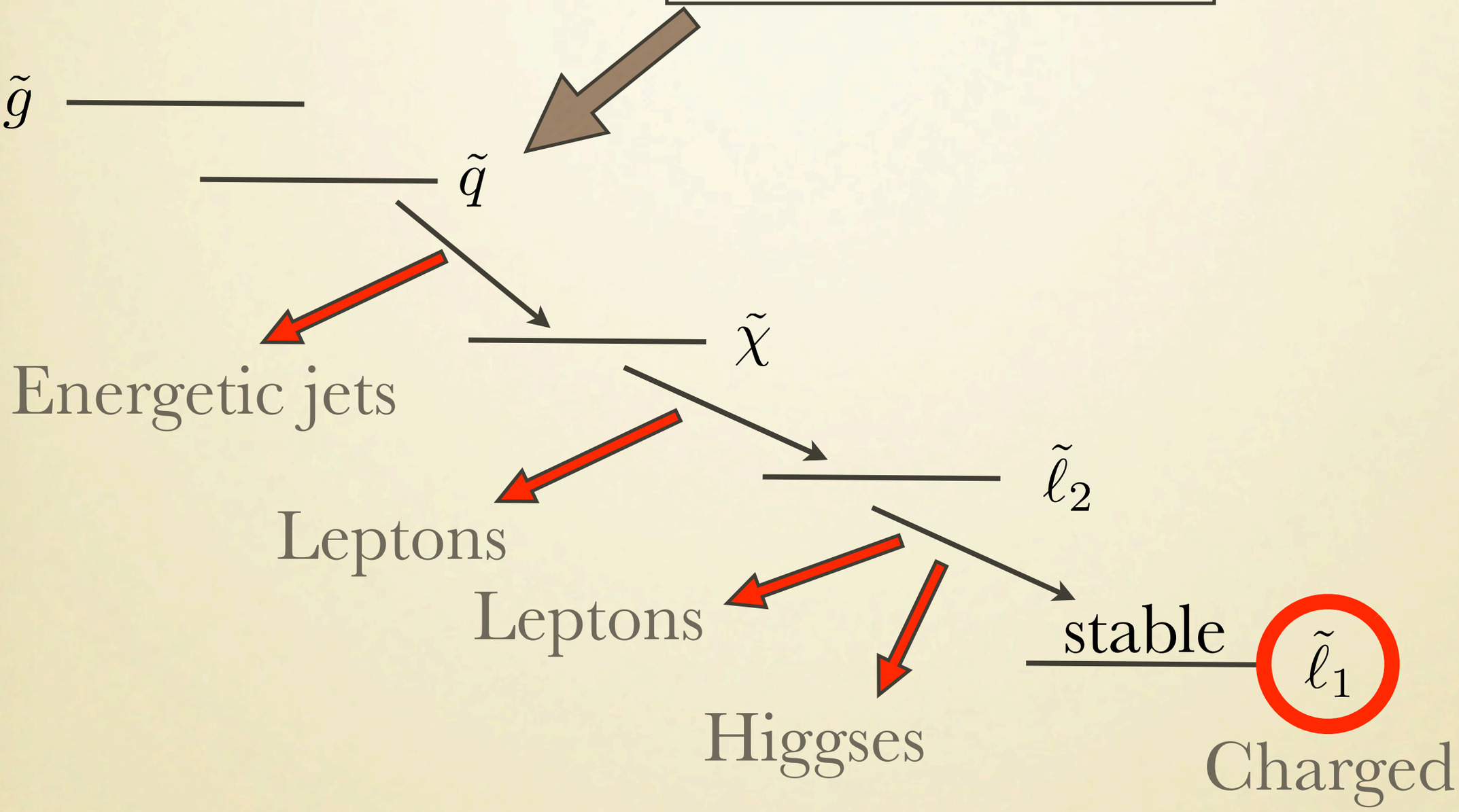
$\sigma_{prod} \sim pb$



Spectrum

Pair produced

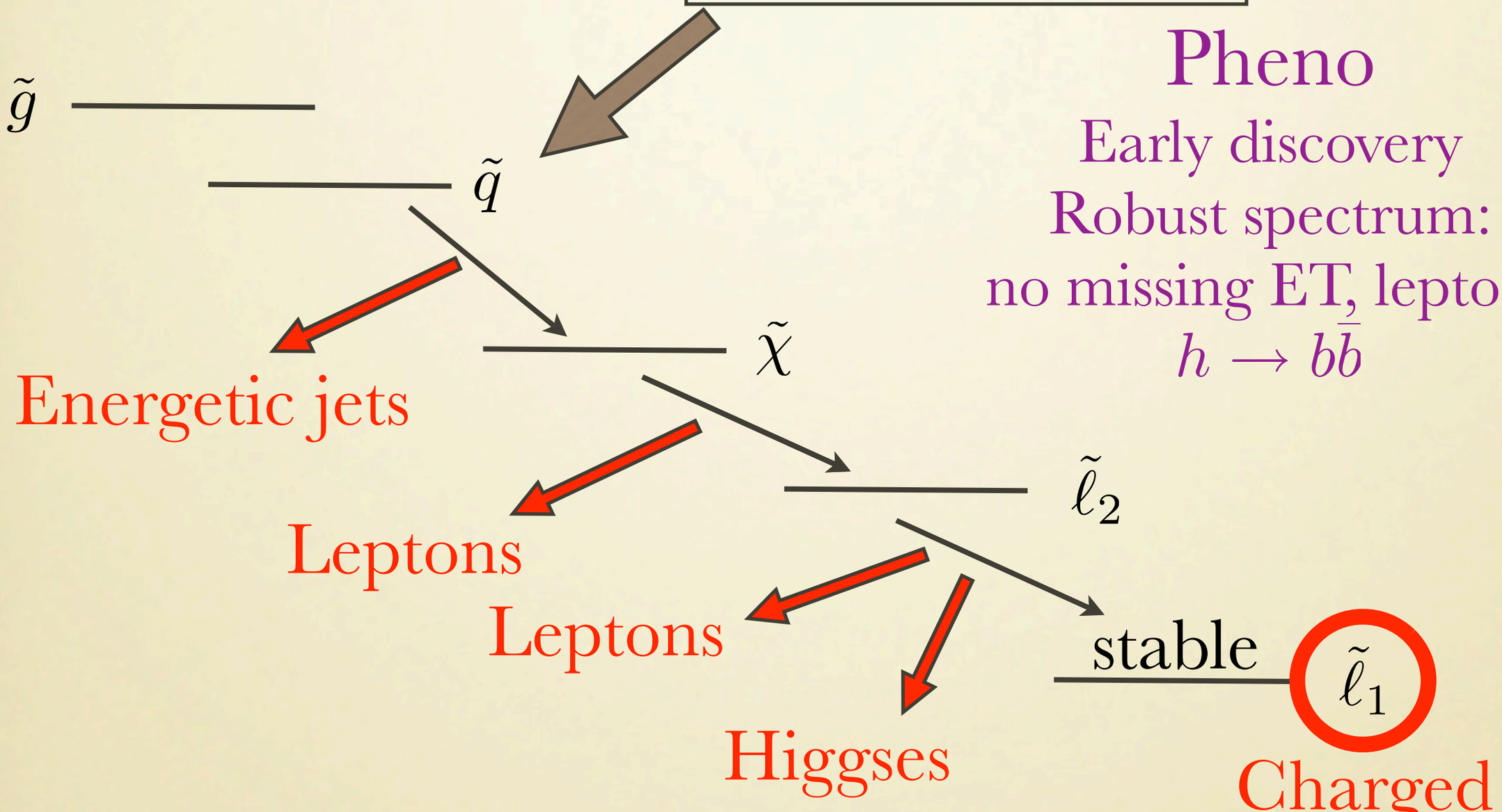
$\sigma_{prod} \sim pb$



Spectrum

Pair produced

$\sigma_{prod} \sim pb$



Pheno

Early discovery

Robust spectrum:

no missing ET, leptons

$h \to b\bar{b}$

Example 2- Cured Higgsless

arXiv:0907.3931 [hep-ph]. JHEP.

Higgsless is a model in warped extra-dimensions

No Higgs

=A Technicolor scenario

In Higgsless

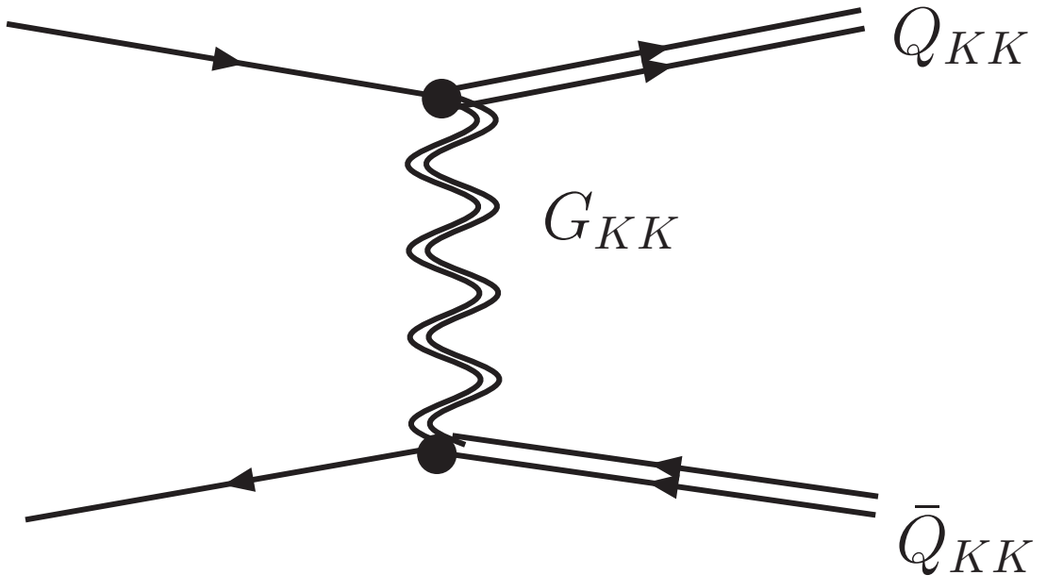
spin 1 and 1/2 resonances degeneracy

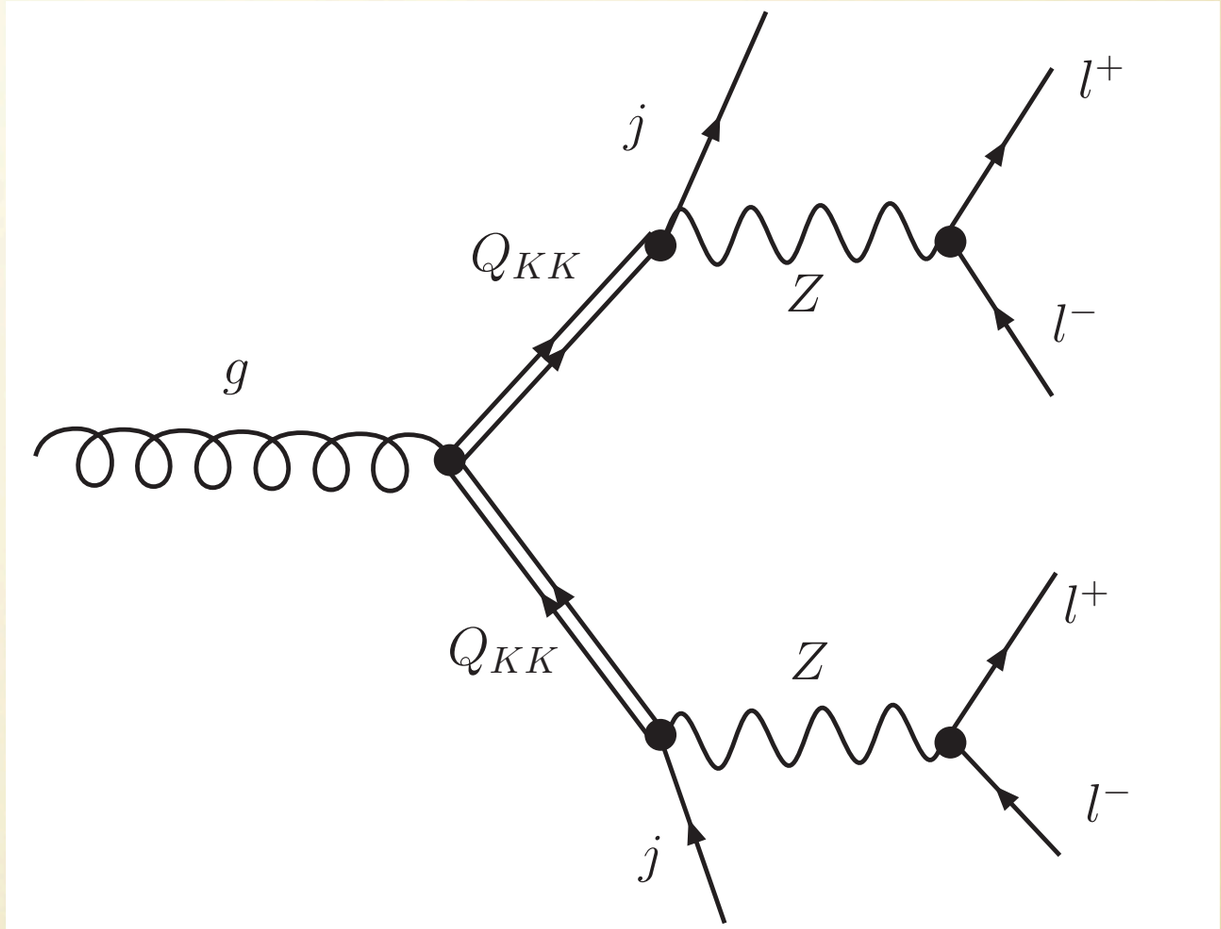
$$m_{Q_{KK}} \sim m_{W_{KK}} \lesssim 1\text{TeV}$$

techni-baryons and techni-mesons

MASS-MATCHING

Pair production of KK fermions





Pheno

Early discovery

Robust spectrum:

no missing ET, leptons

4 lepton channel in SUSY

-Stable charged particles
-Why sleptons are muons
-Missing mass

All the plots for Lepto-SUSY

Simulation parton level MadGraph

shower/had PYTHIA 6.4

Leptons in the $|\eta| < 2.5$ region, $p_T > 10$ GeV

and parton level isolation cuts $\Delta R_{\ell\ell}, \Delta R_{\ell j} < 0.4$

Jets in the $|\eta| < 2.5$ region, $p_T > 15$ GeV

and post-PYTHIA isolation cuts $\Delta R_{\ell j} > 0.4$

In our final analysis program used smearing and efficiencies copy/paste ATLFAST's subroutines

ElectronSmearer.cxx

JetSmearer.cxx

but not MuonSmearer.cxx, too hard for us (approx. treated muons as electrons...)

Everywhere: 14 to 10 TeV rescale by a factor 3

When are the sleptons collider stable?

In gauge mediation gravitino DM

gravitino-slepton have Planck suppressed couplings

long-lived natural

In lepto-SUSY

$$m_{\tilde{\tau}} < m_{\tilde{e},\tilde{\mu}}$$

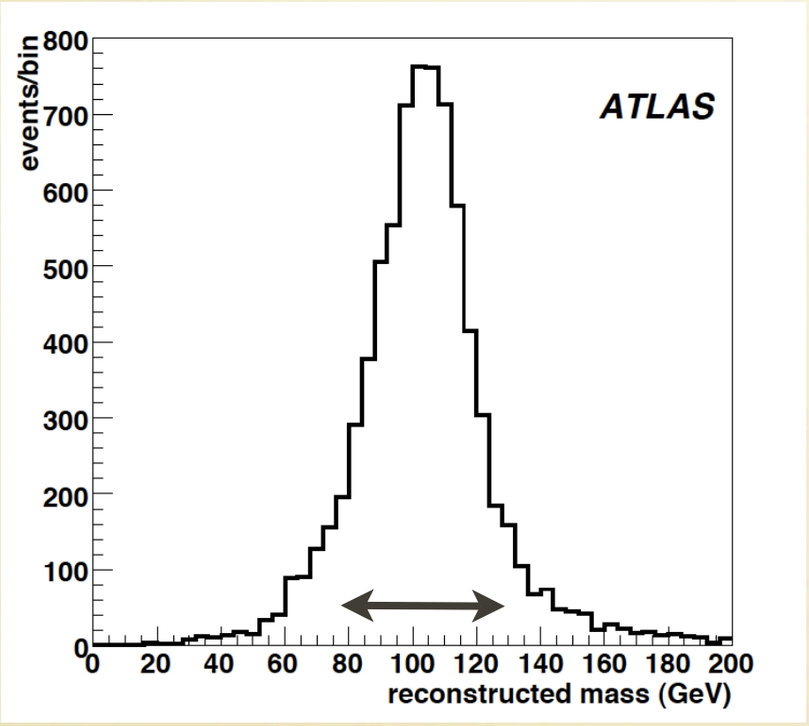
$\tilde{\ell}_R \to \ell_R \tau_R \tilde{\tau}_R$ but no kink and leptons too soft

Co-slepton scenario as in G2b in old ATLAS-TDR

Note- This is not G2b! ordering spectrum different, fewer leptons

Long-lived slepton hits like a muon with a lower β

- Time of flight ⇒ **Muon chambers**
- Specific ionization ⇒ **Tracker and/or e.m. calorimeter**



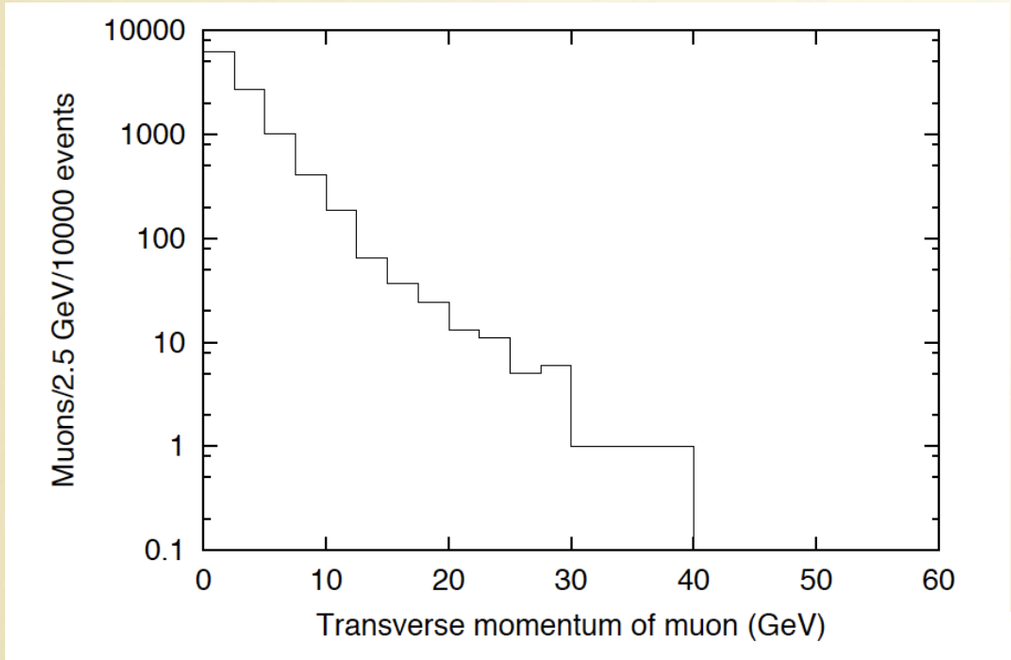
From ATLAS-TDR 2008

Mass reconstruction and charge ID

Main problems:

1. BGs --instrumental (?) and SM
2. slow: BC time
3. fast: beta error

BGs: b-decay muons

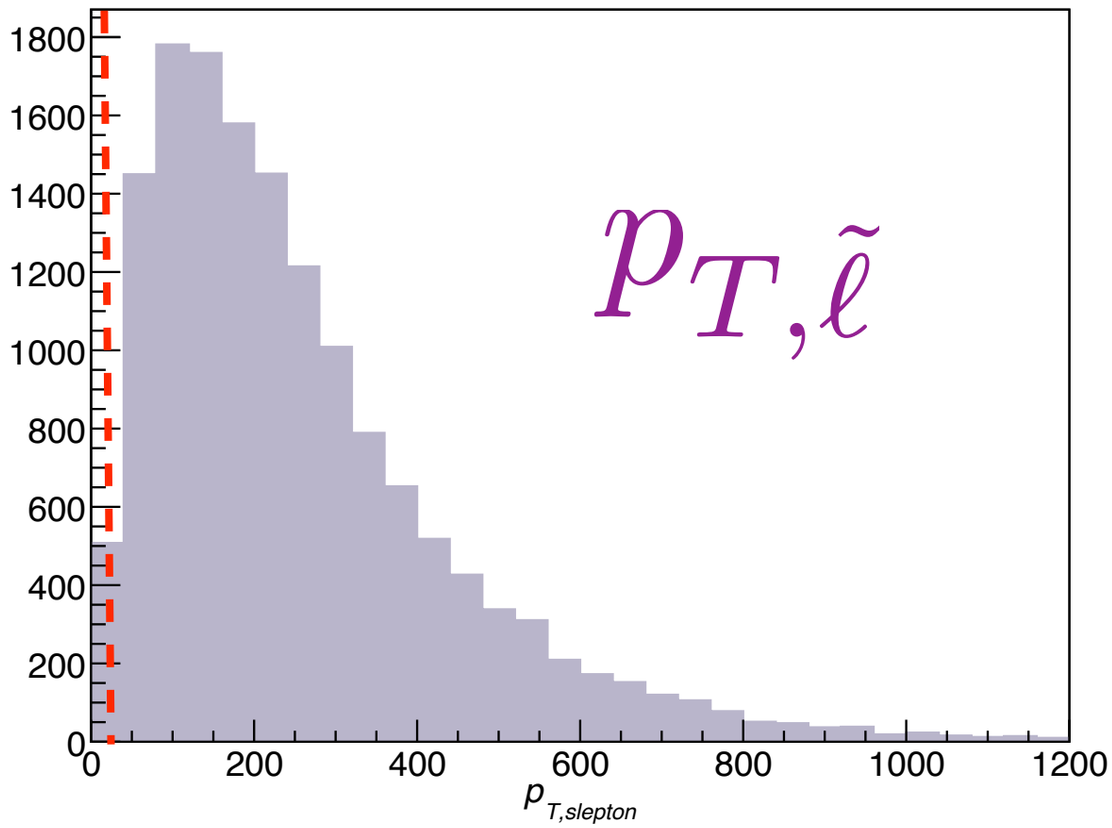


Allanach et al. hep-ph/0108097

$$p_T > 50 \text{ GeV}$$

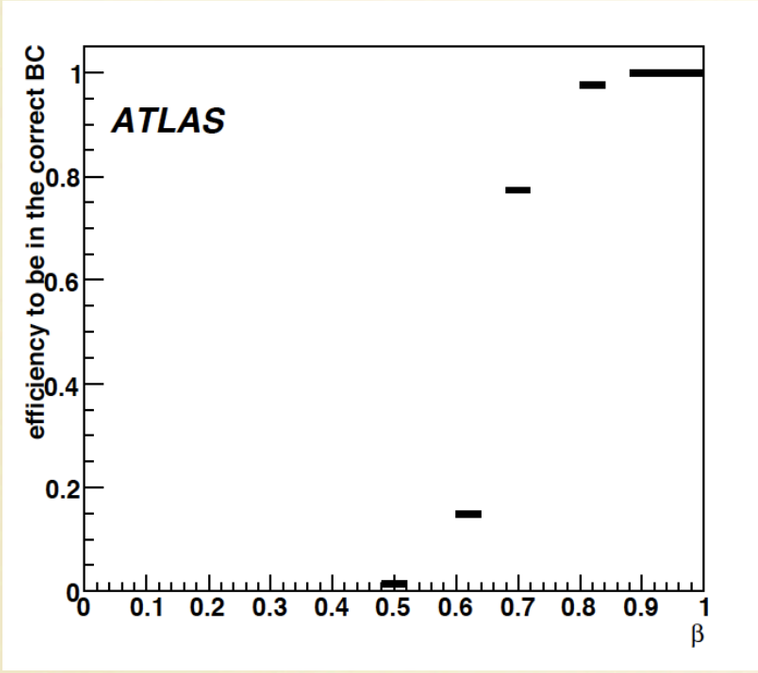
SIGNAL

No problem,
all high-pT



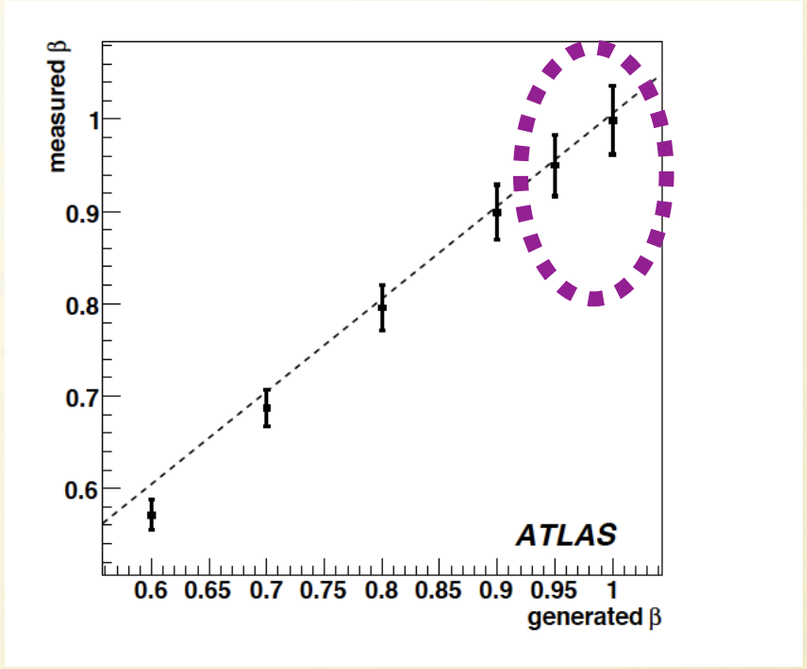
Missing it

TOO SLOW

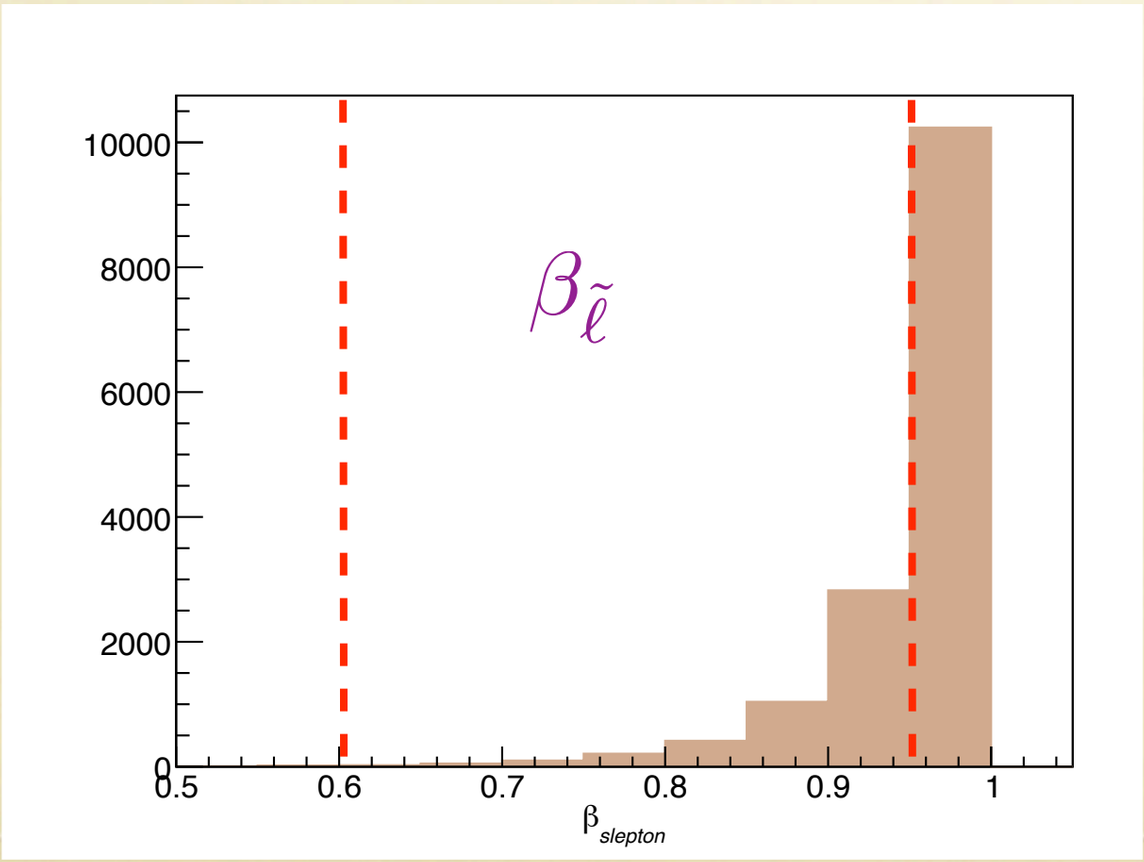


MisIDing it

TOO FAST



From ATLAS-TDR 2008

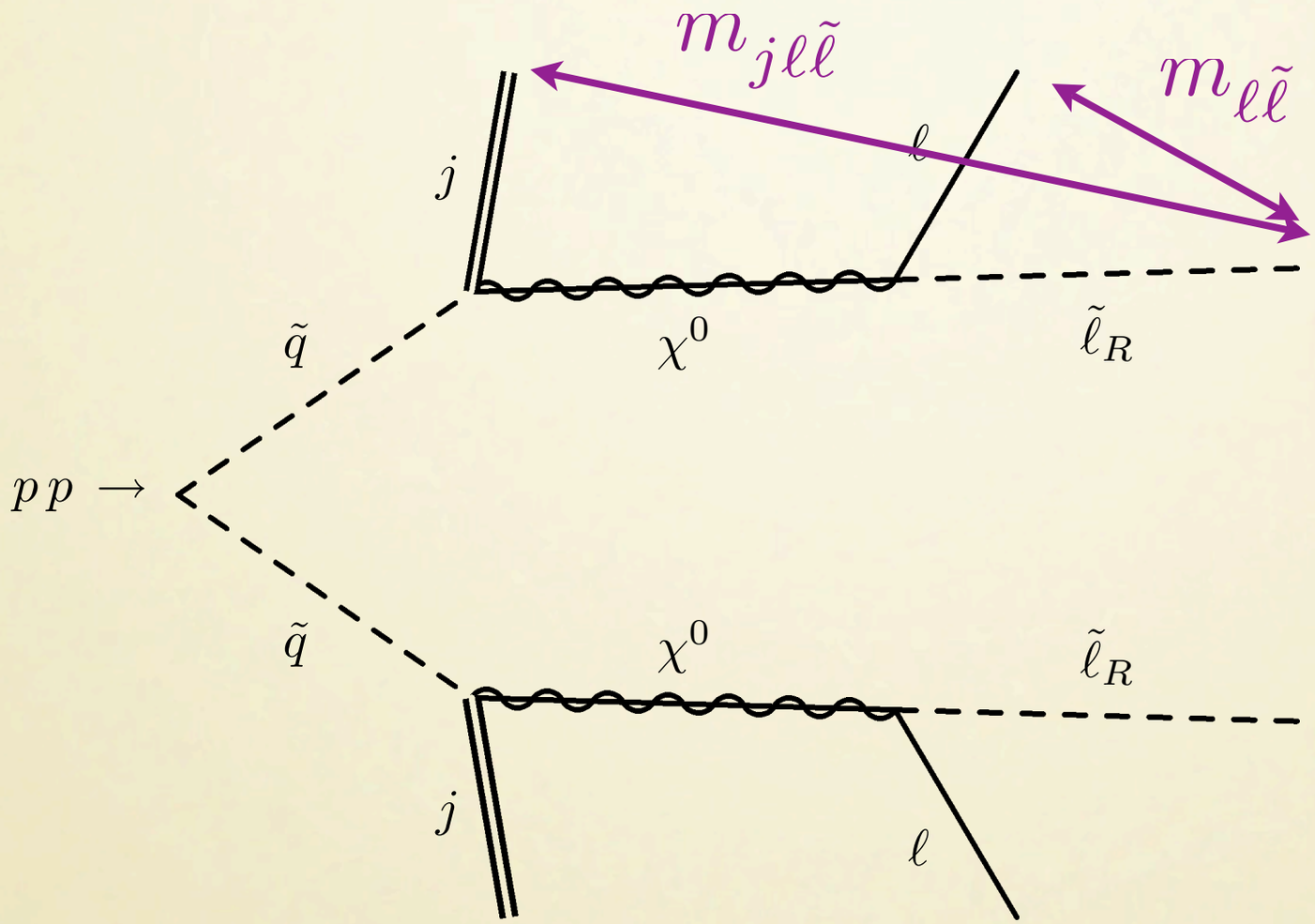


SIGNAL

Many of them are fast sleptons misID as muons

An example

$$2\ell + 2\tilde{\ell} + 2j = 4\ell + 2j$$



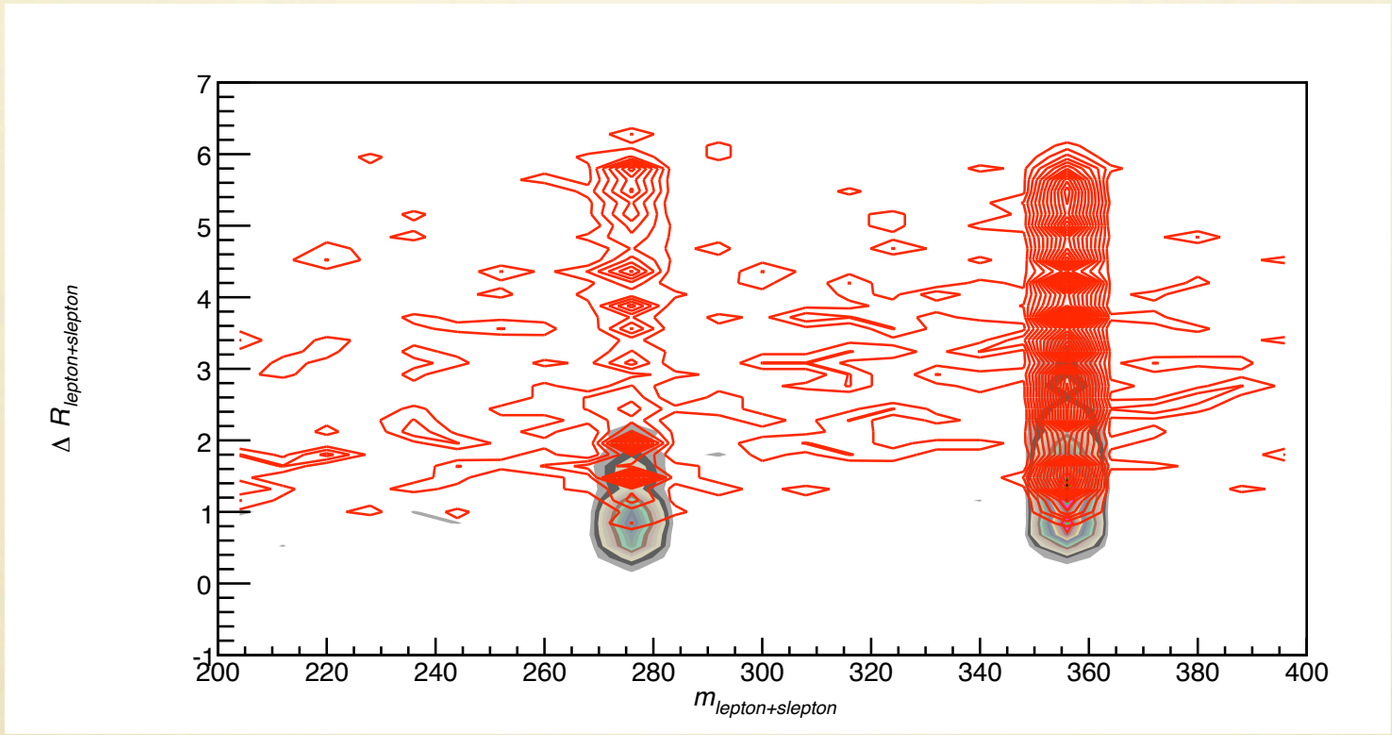
Now these guys are *muons*!

No missing energy cut required

Number of lepton selection

Strategy to reduce combinatorics

Take 4 leptons and look for OSL with smaller delta R



$\Delta R_{\ell\tilde{\ell}}$

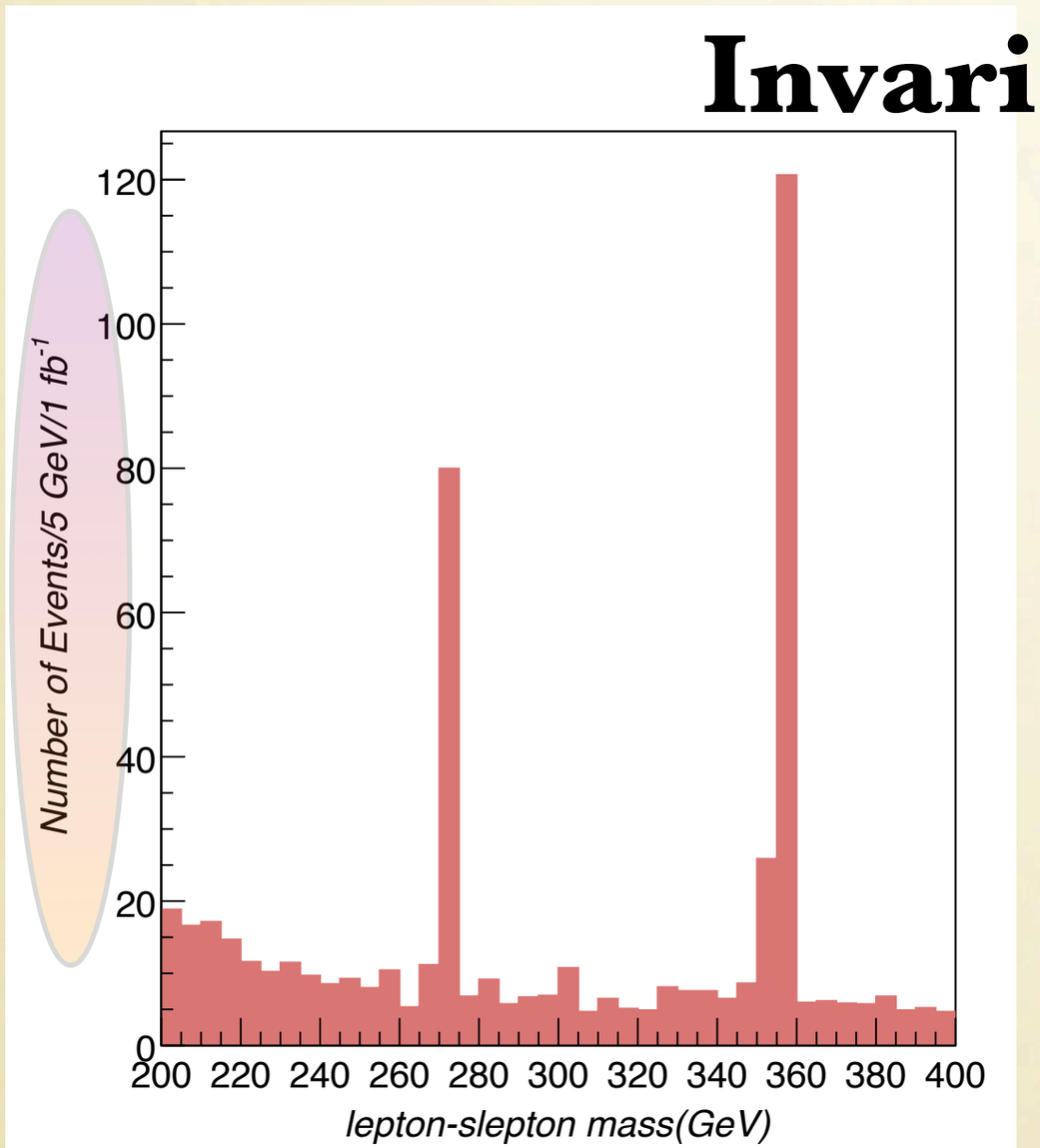
$m_{\ell\tilde{\ell}}$

Reconstructing the invariant mass

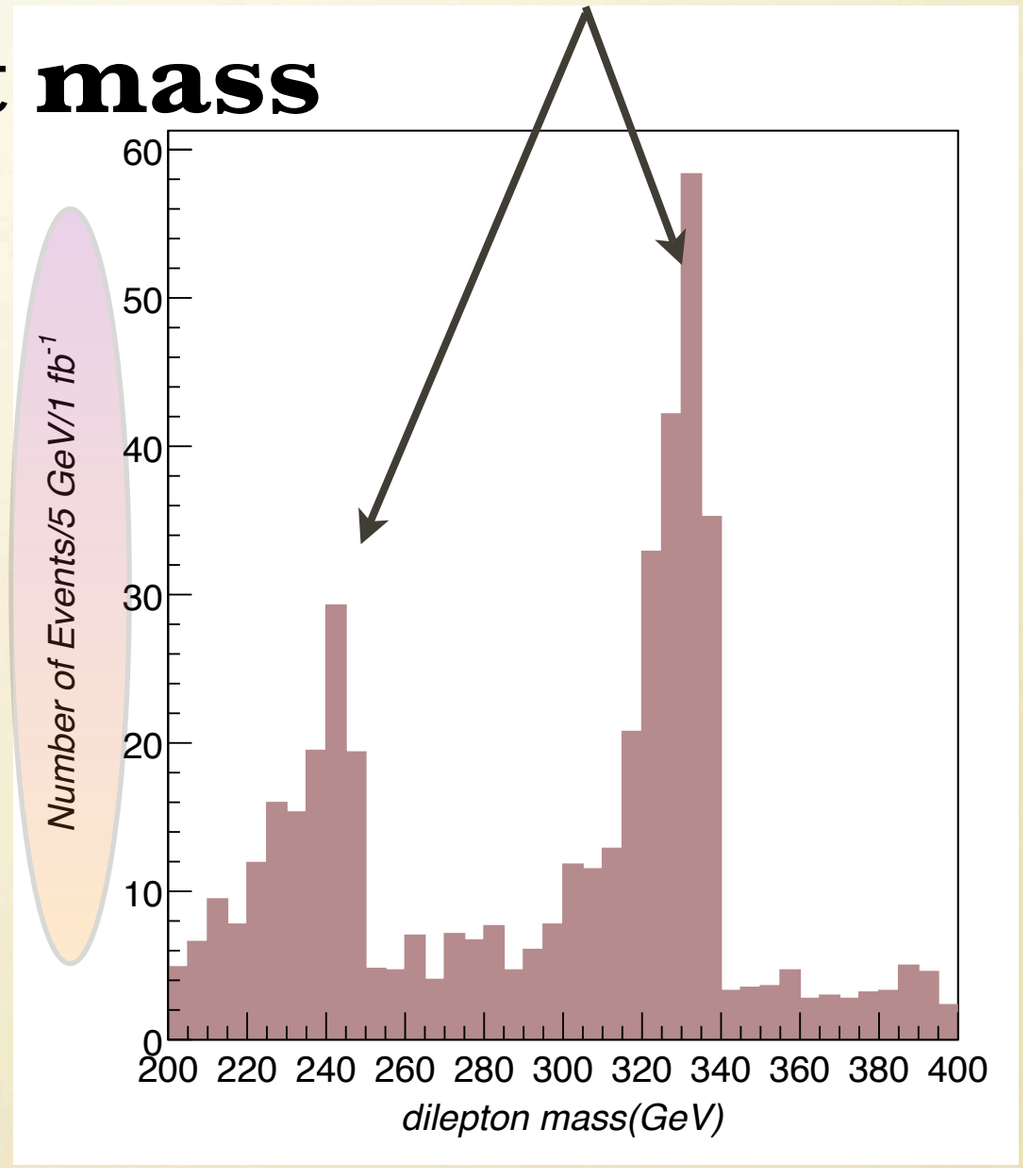
Missing mass

similar to

transverse mass



slepton ID



slepton misID

4 lepton channel Extra-Dimensions and Technicolor

All the plots for Higgless

Simulation parton level MadGraph

shower/had PYTHIA 6.4

detector effects Pretty Good Simulator

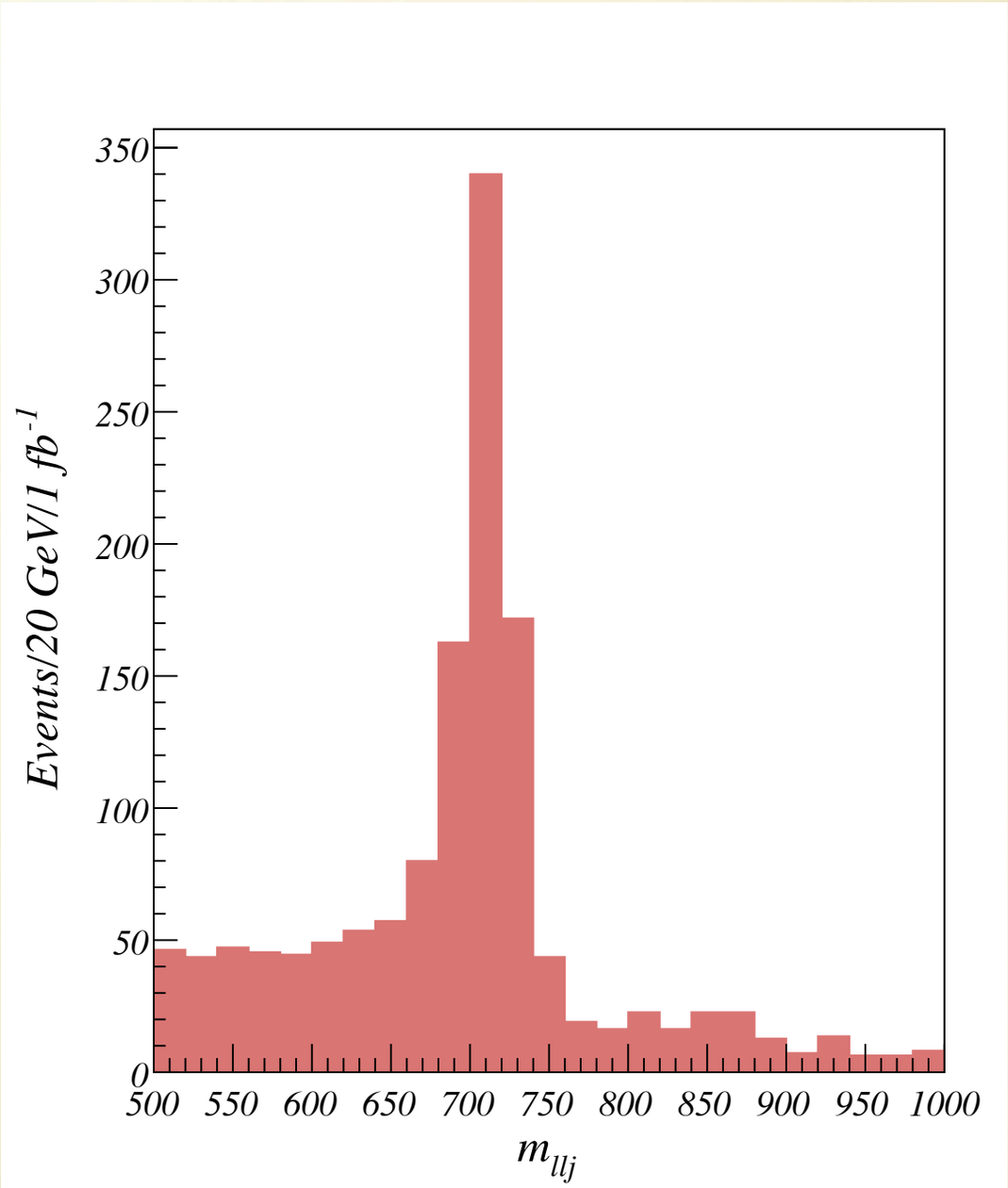
No missing energy cut required

Number of lepton selection

Strategy to reduce combinatorics

Take 4 leptons and look for OSL with smaller delta R

KK quark mass reconstruction



Stepping back

Don't need to buy into a model

If there is a new heavy quark at about 1 TeV

and it can decay to Z bosons

pb production cross section

4 leptons + 2 jets signal

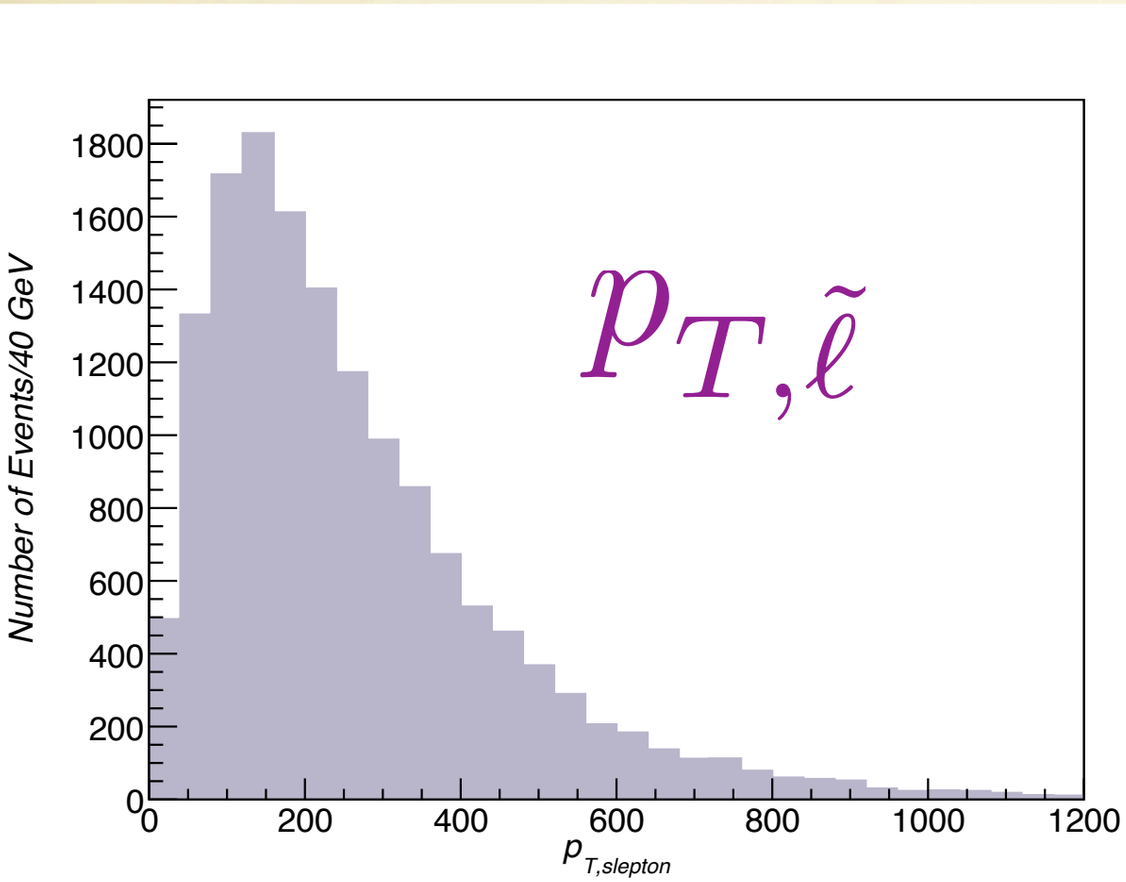
no missing ET

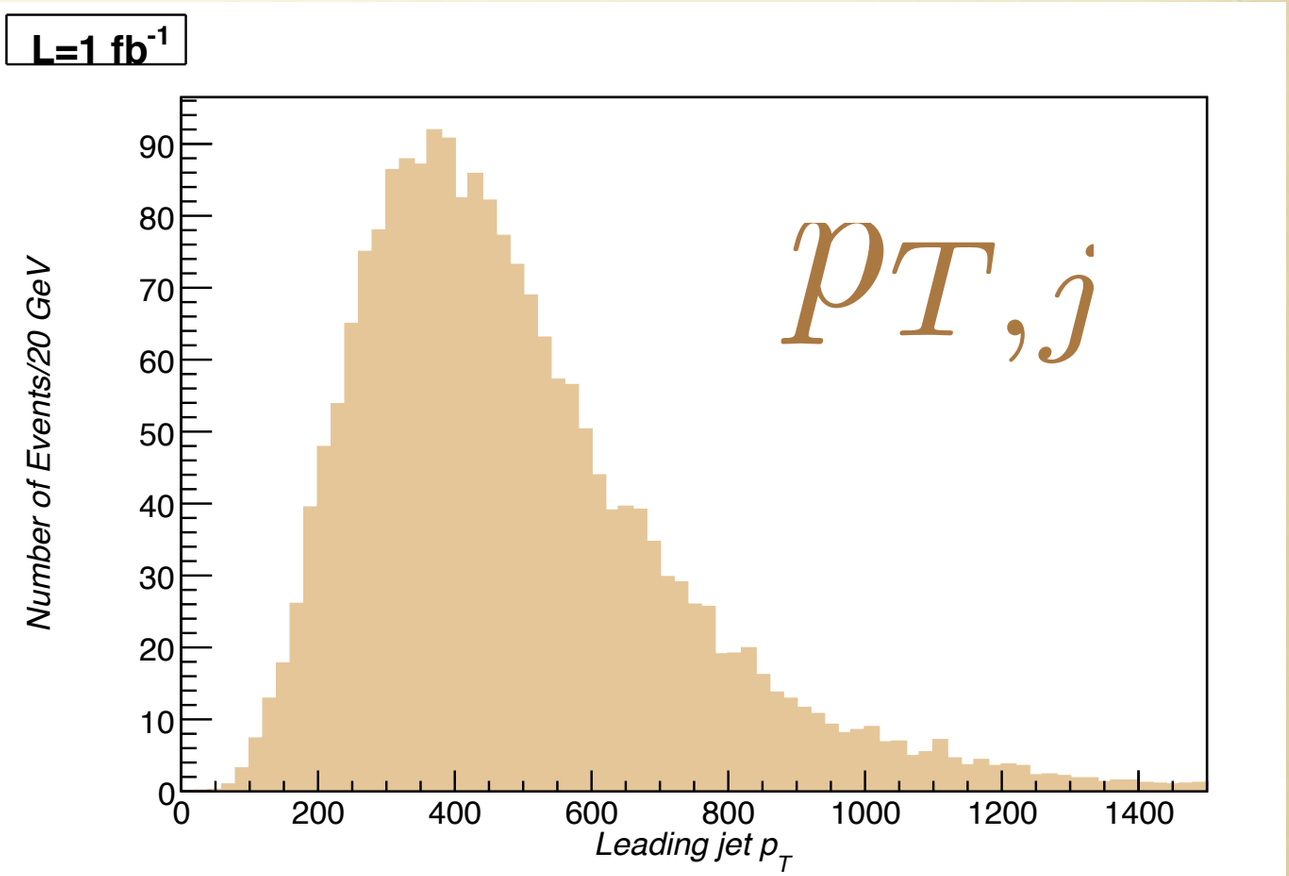
Interlude: SM backgrounds

So far, all plots no SM backgrounds

Q. What are the BGs for $4\ell + 2j$

when everybody is pretty hard?





Handles to reject BG:

isolation, hardness, sleptons as muons

We didn't use:

missing ET, slepton ID

Efficiencies for fakes

jet faking electron 10^{-4}

jet faking muon? we used 10^{-4}

(gross overestimate!)

b decay producing isolated lepton $5\,10^{-3}$

Generated SM BGs with ALPGEN and MG

$t\bar{t} + \text{jets}$

$W + \text{jets}$

QCD jets

$W\,Z + \text{jets}$

$Z\,Z + jets$

$Z + jets$

$b\,\bar{b}\,Z/\gamma$

None above fb after applying:

$$
\begin{aligned}
n_\ell &= 4 \\
n_j &\geqslant 2 \\
p_{T,j} &\geqslant 100\ \text{GeV} \\
p_{T,\ell} &\geqslant 50\ \text{GeV, (leading)} \\
\Delta R &\geqslant 0.4\ \text{all objects}
\end{aligned}
$$

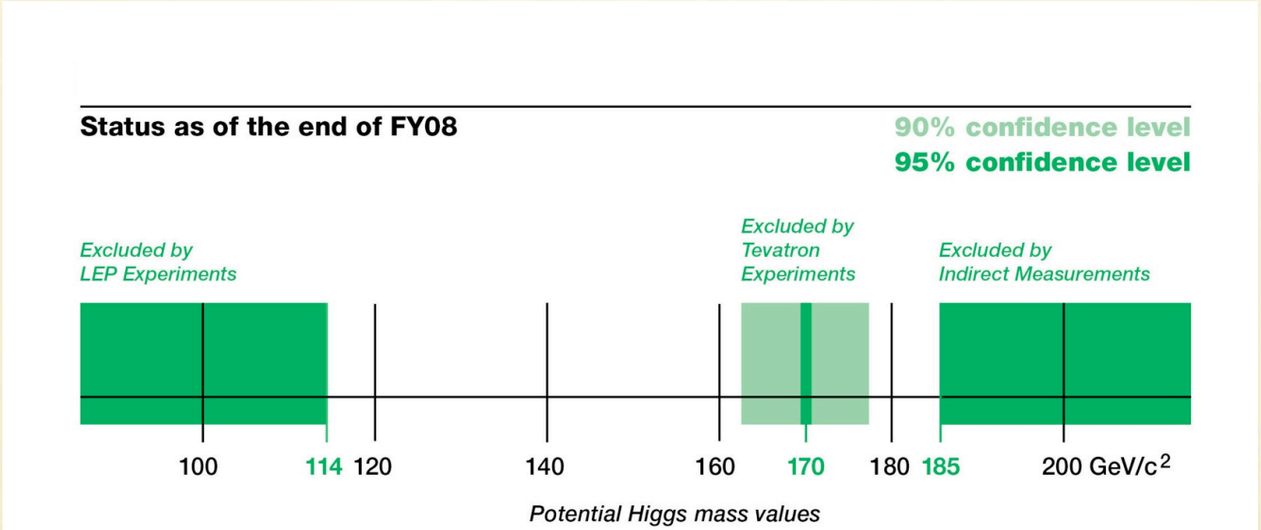
What ATLAS is doing

Common lore

Light Higgs, bbar too hard, di-photon

AND

TeVatron bounds+ SUSY Higgs



BUT

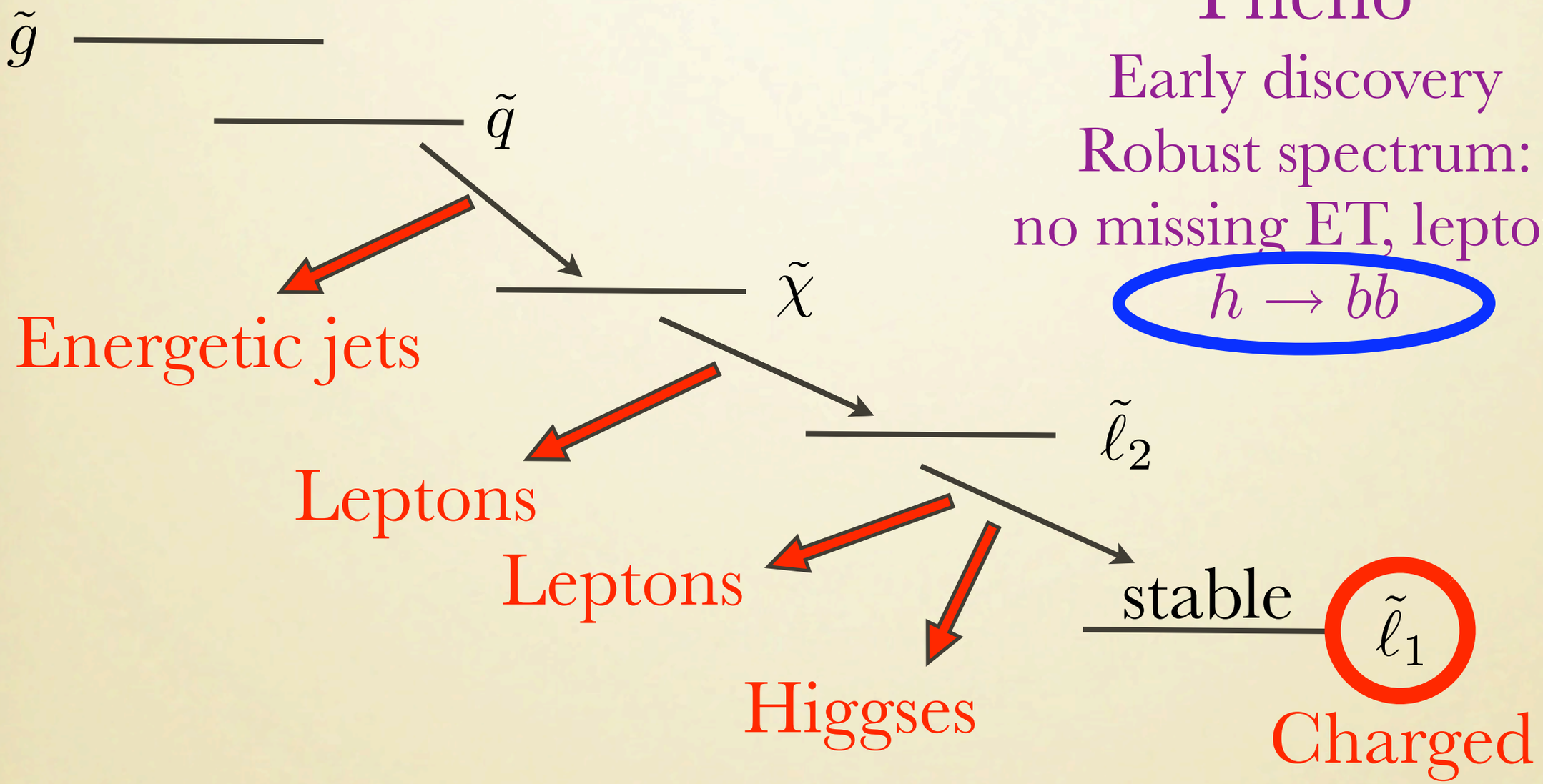
if h to bbar with 4 leptons, BGs are no longer an issue

In general, worth looking at Higgs with more handles

no missing energy cut?

no b-tagging?

Wait for full simulation



Pheno

Early discovery

Robust spectrum:

no missing ET, leptons

$h \to bb$

with Assamagan (BNL), Rolli (Tufts), Tarem, Tenenbaum (Technion)

ATLAS-Higgs full-simulation of Lepto-SUSY

Validation and approval done

full simulation is carried out

Once the MC sample is generated

we will study

1. High leptonic multiplicity
2. Higgs to bbar
3. long-lived sleptons
4. signature based analysis

$4\,\ell + X$

Useful for all those models

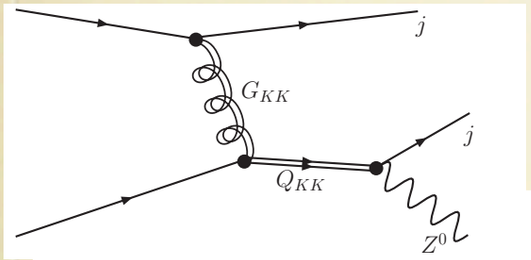
More things to do

Other well-motivated Higgs+leptons searches?

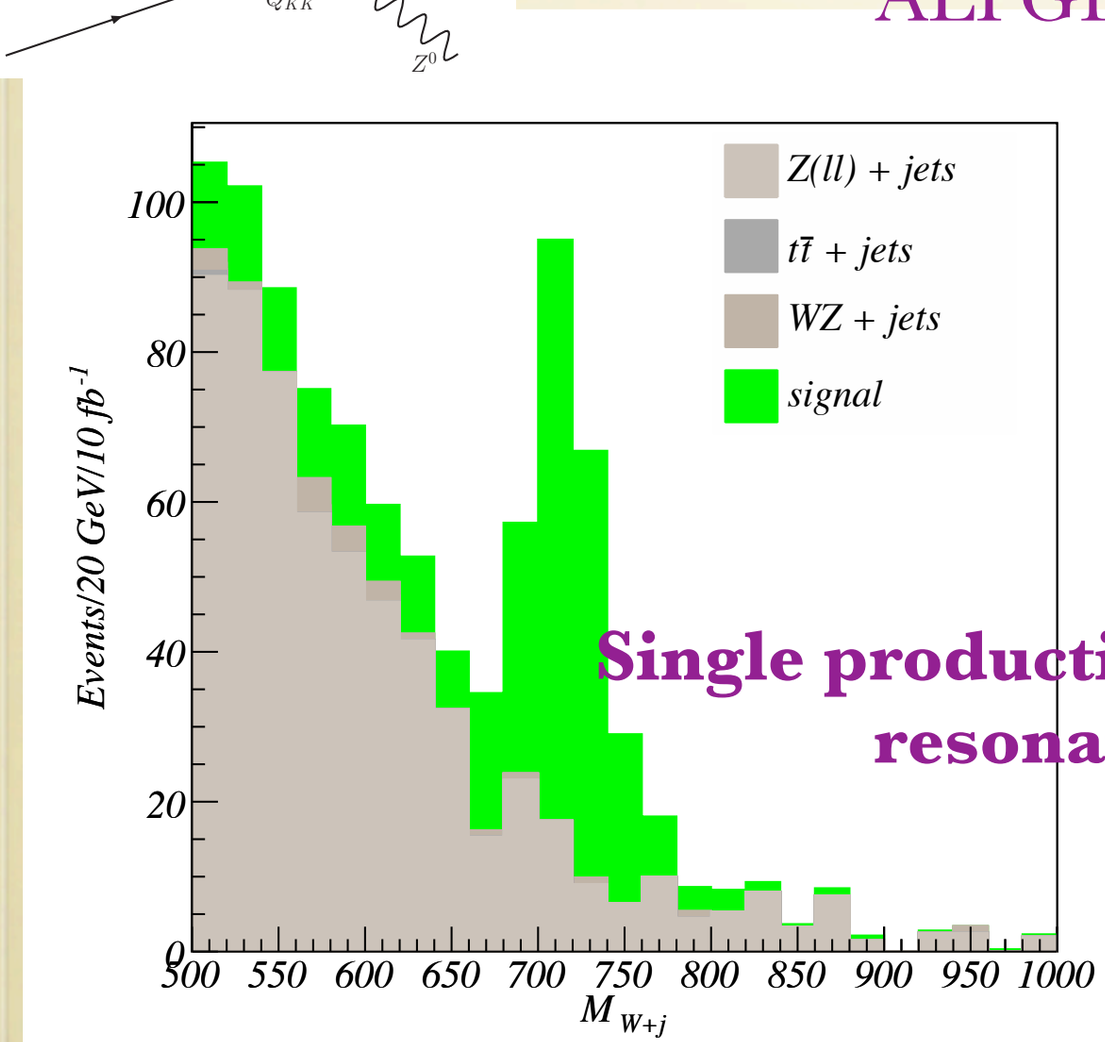
Specially after TeVatron results

More things to do

EWPT means mass matching
ex. techni-baryons=techni-mesons

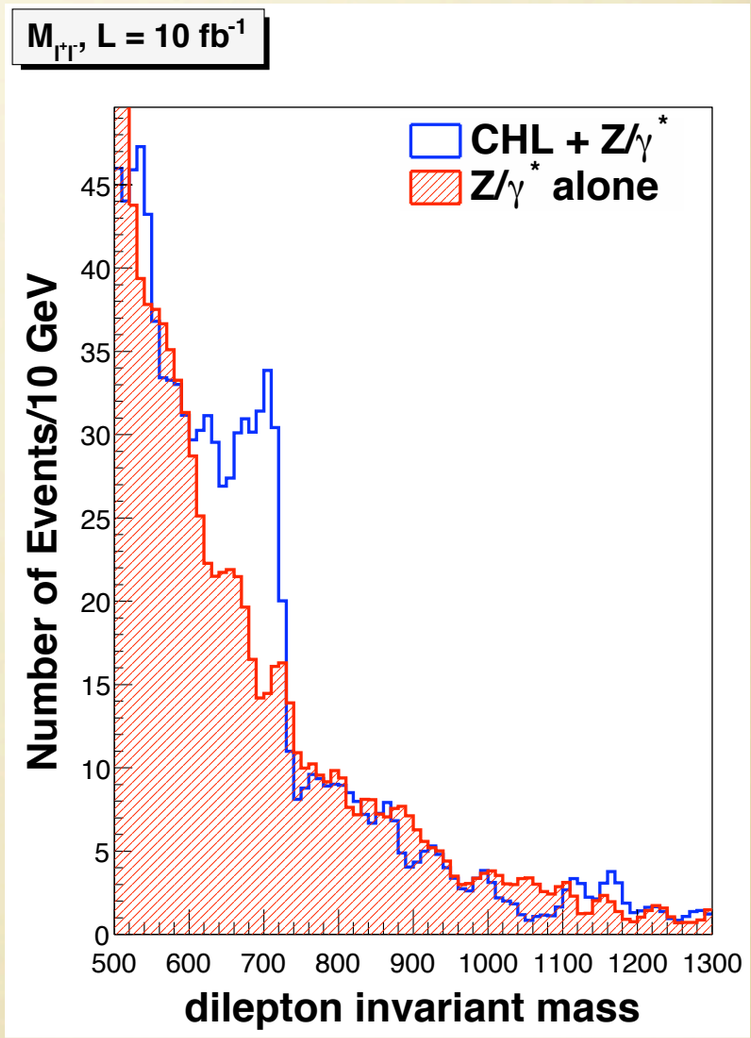


BGs are very important
ALPGEN good enough?



Single production fermion resonance

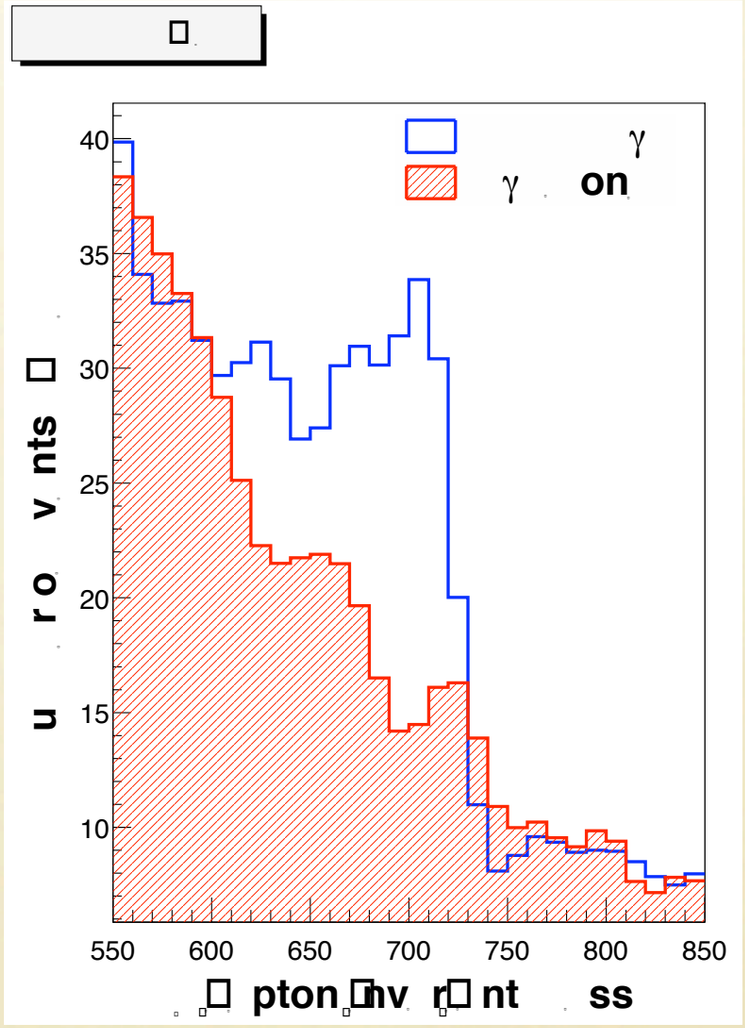
Neutral resonance dilepton channel



More things to do

In all models of extra-dimensions,
B' and W3' resonances are very close to each other

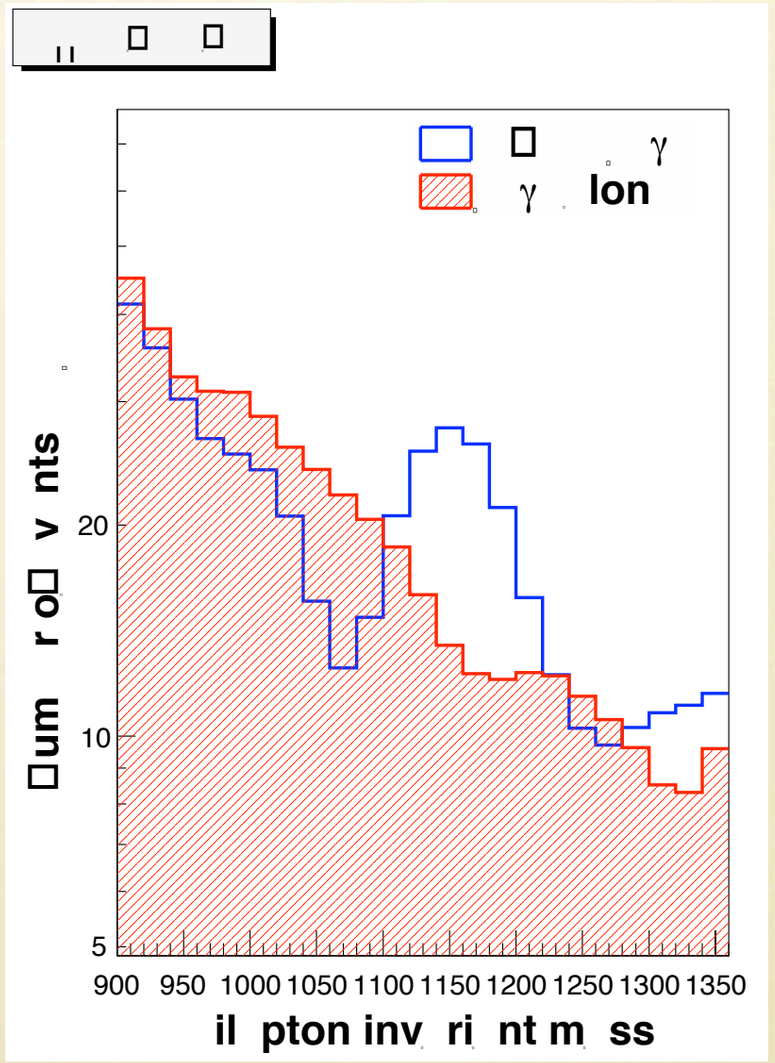
Neutral resonance dilepton channel



More things to do

In all models of extra-dimensions,
there are several tiers of resonances
large Nc or low Nc

Example: second tier in Cured Higgsless



Conclusions

Early signatures are all around the place

We need to look for them

Spectrum ordering important cascade decays

(mSUGRA-like isn't generic)

Don't give up hope on early Higgs physics

Here, two examples in completely different setups

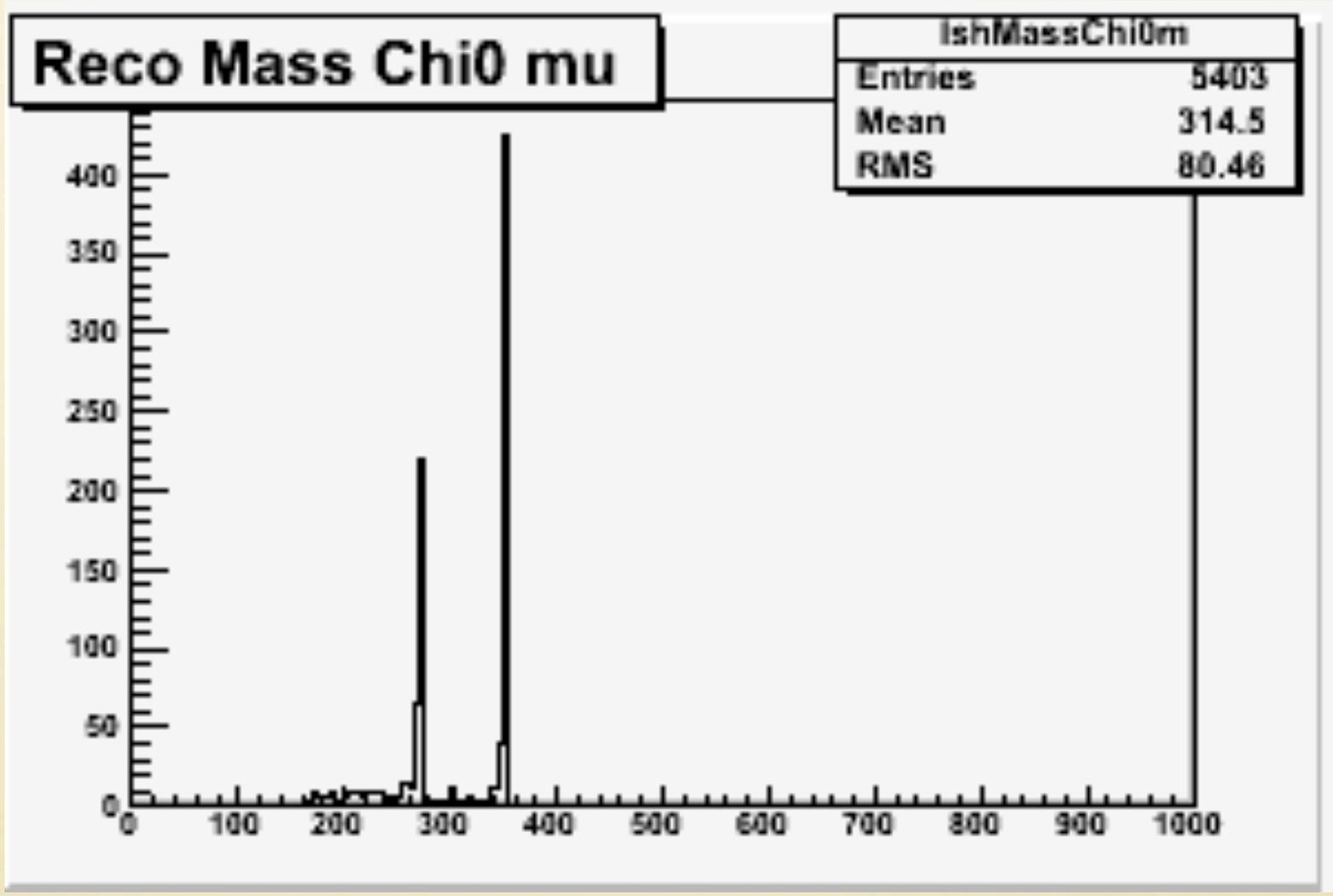
discovery reach below 1 fb^-1

Pheno

Early discovery

Robust spectrum:

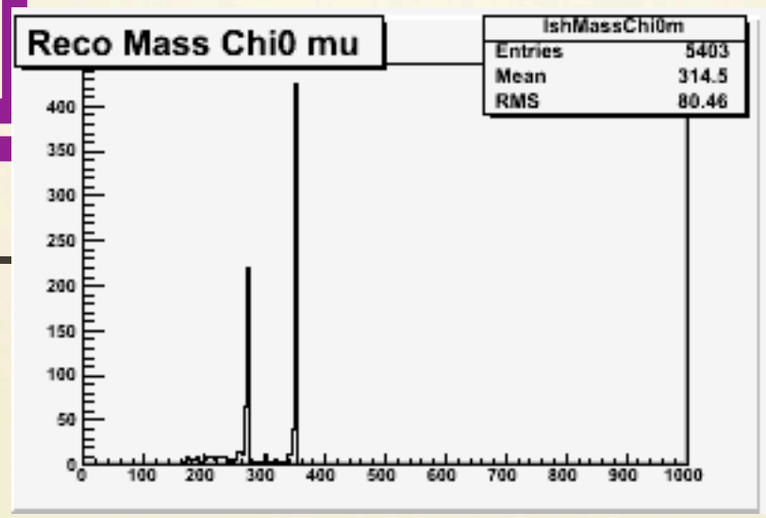
no missing ET, leptons


Reco Mass Chi0 mu
IshMassChi0m
Entries 5403
Mean 314.5
RMS 80.46
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
1000

Gauginos heavier scalars

$\tilde{g}$ ——————

——————— $\tilde{q}$

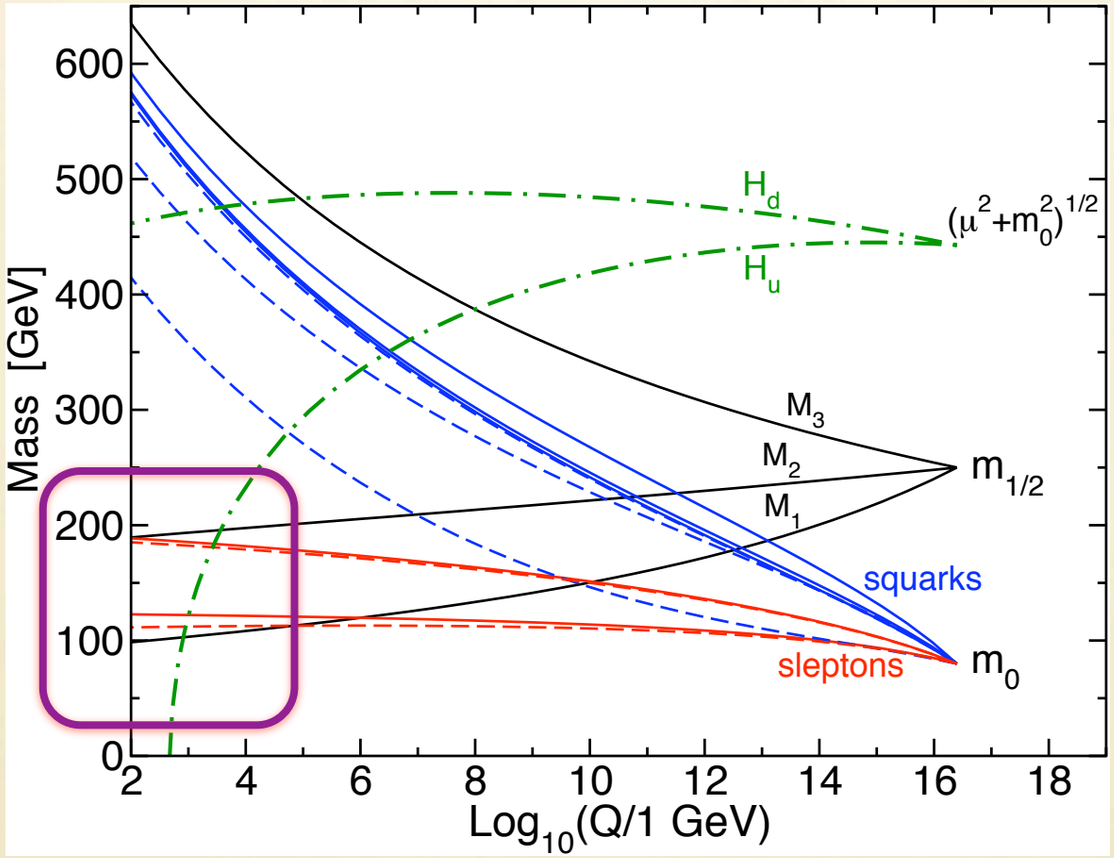


$\tilde{\ell}_2$

stable $\tilde{\ell}_1$

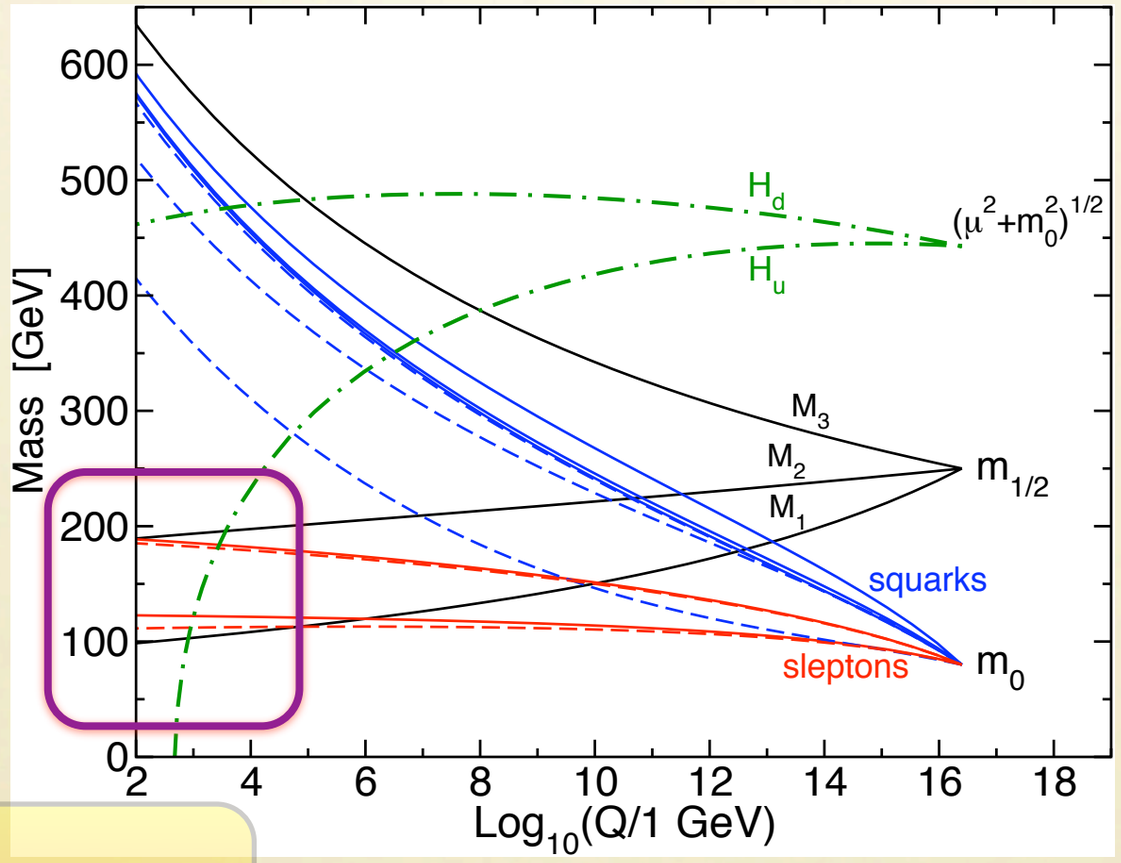
Close but no cigar

Not in mSUGRA, AMSB or GMSB benchmark points



From Martin, *A SUSY PRIMER*

Not in mSUGRA, AMSB or GMSB benchmark points



Long running

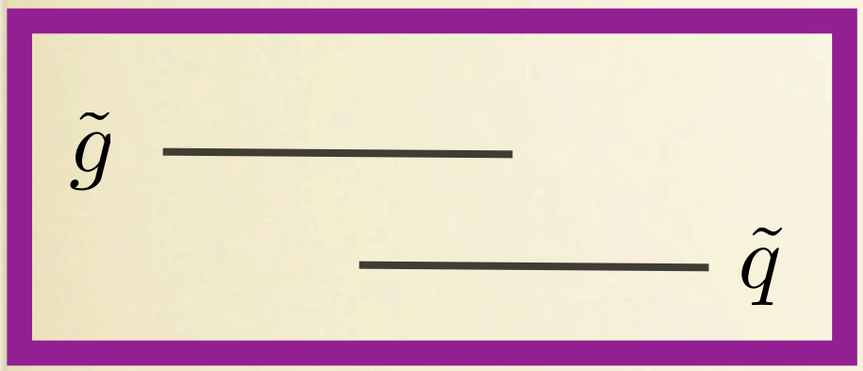
Neglect threshold effects

From Martin, *A SUSY PRIMER*

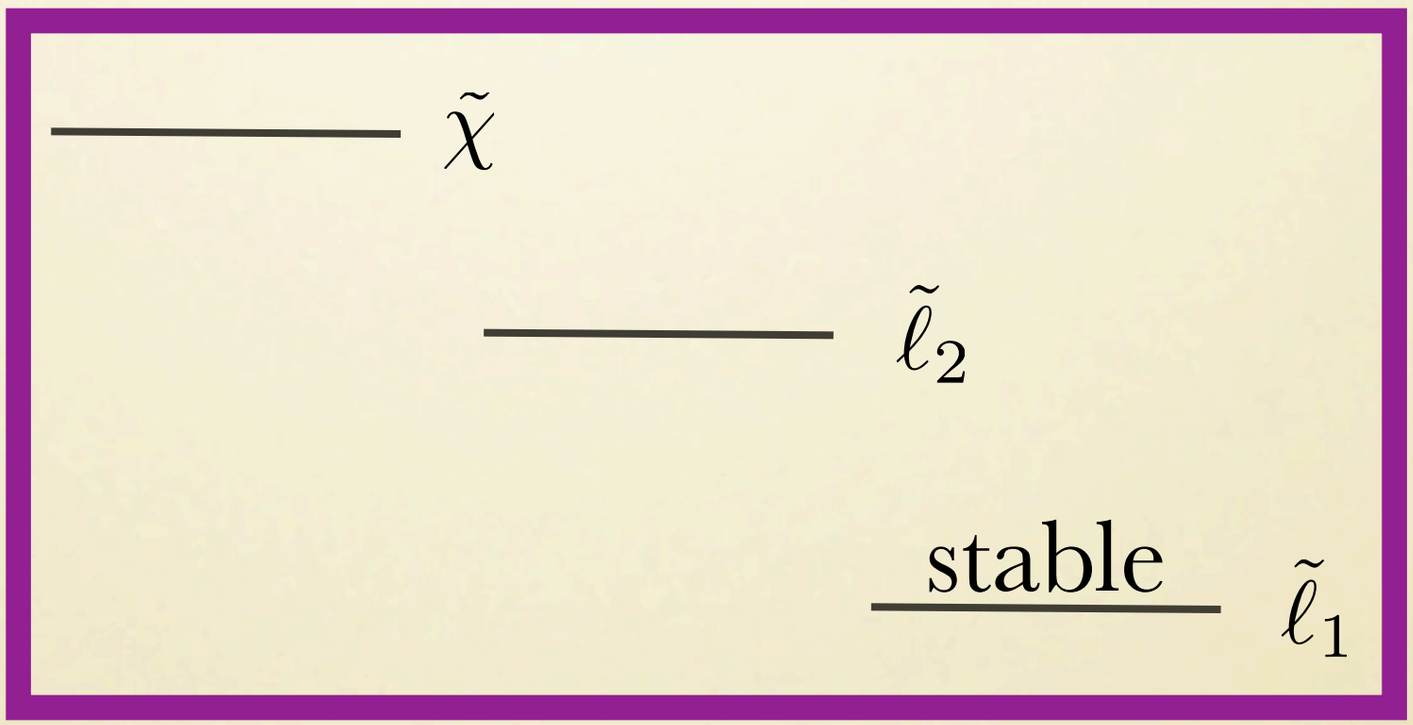
BUT this is not generic of SUSY

in low-scale gaugino mediation

GMSB with large Nmess, AMSB ...



Gauginos heavier scalars



Two benchmark scenarios

Higgs 115 GeV
sleptons 110 GeV

LS1: squark masses 1 TeV
LS2: squark masses 520-700 GeV

Production cross sections (fb)

Benchmark	LHC(14)	LHC(10)	TeVatron
LS1	2170	680	0.09
LS2	13700	5040	0.00