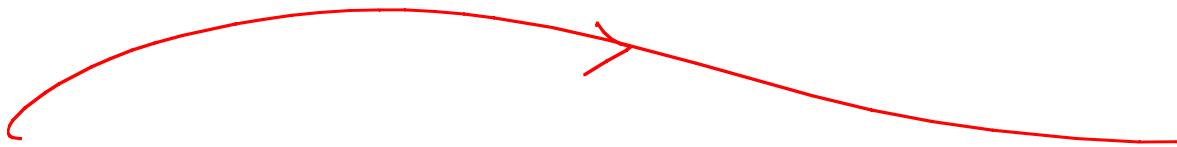


Physics Motivations

for

100 TeV Colliders

First + Foremost



* It's the OBVIOUS FUTURE

* BIG machines

BIG physics ideas

Lifeflood of The Field

Clearly, how to proceed
will depend on first LHC13
results.

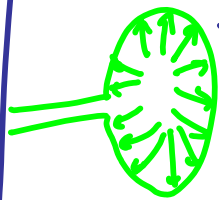
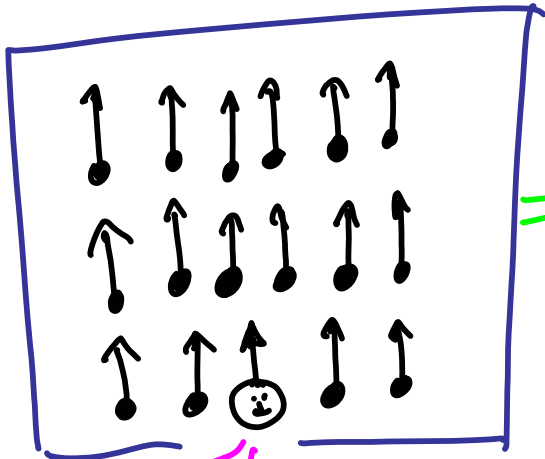
But in every scenario I can imagine,
we will need the 100 TeV
pp machine

Higgs Discovery Crucial

Light Higgs

↓
Our Vacuum is Qualitatively
Different than Random C.M. System
[AKA "Random Metal"]

Never seen before in "state of nature"

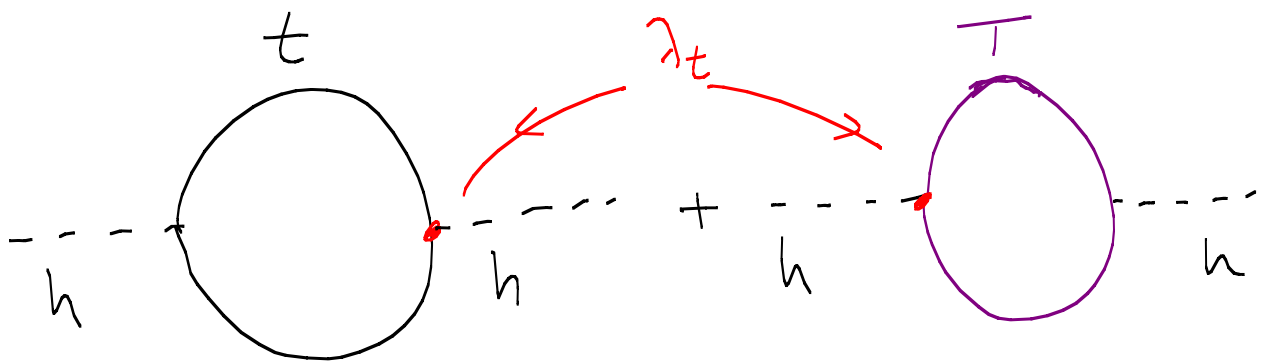


"fine-tuning"



Why are we all pointed in same direction?

Ultimate Fate of Naturalness

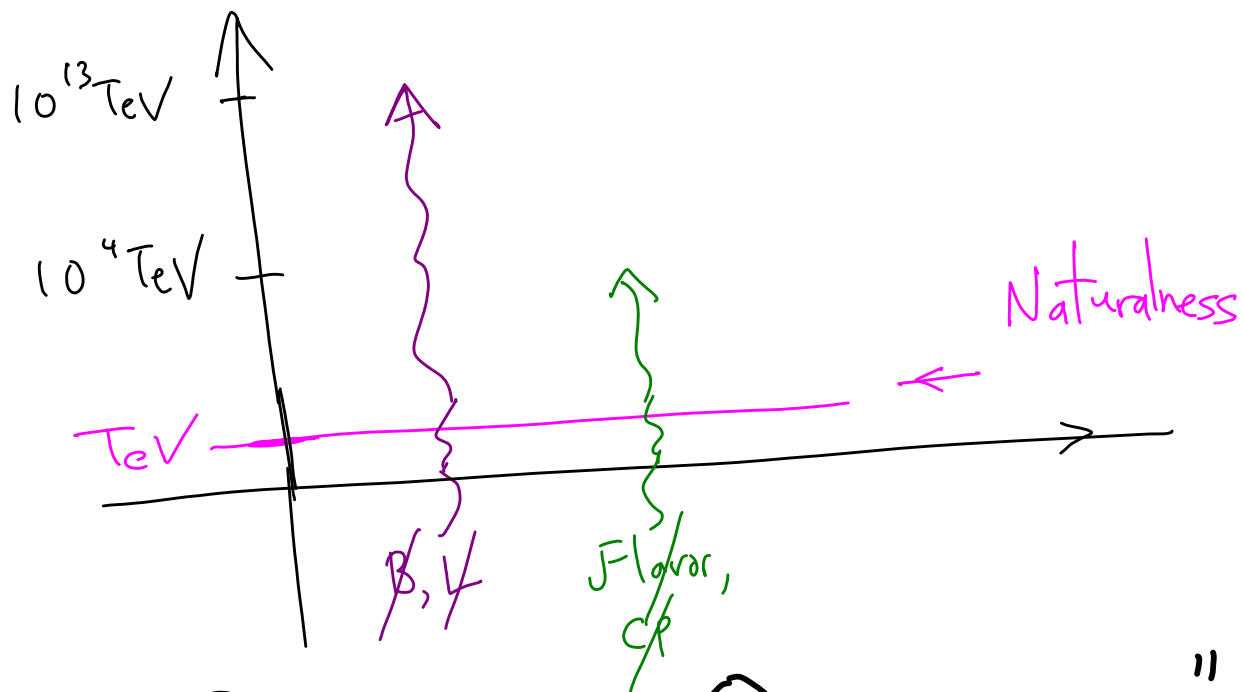


T colored, $\Delta^{\text{tuning}} \sim \text{few} \times \left(\frac{400 \text{ GeV}}{m_T} \right)^2$

But Where Is Everybody?



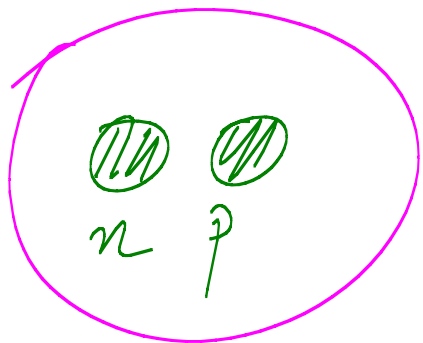
Tension Driving BSM Physics For 30 yrs



"NOT PROBLEMS - OPPORTUNITIES"

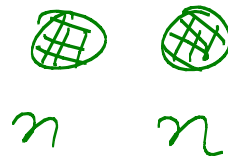
No new physics so far @ LHC
is putting broad idea of
Naturalness under somewhat more
pressure

Nucl. Phys. is Confusing Because it's Tired!



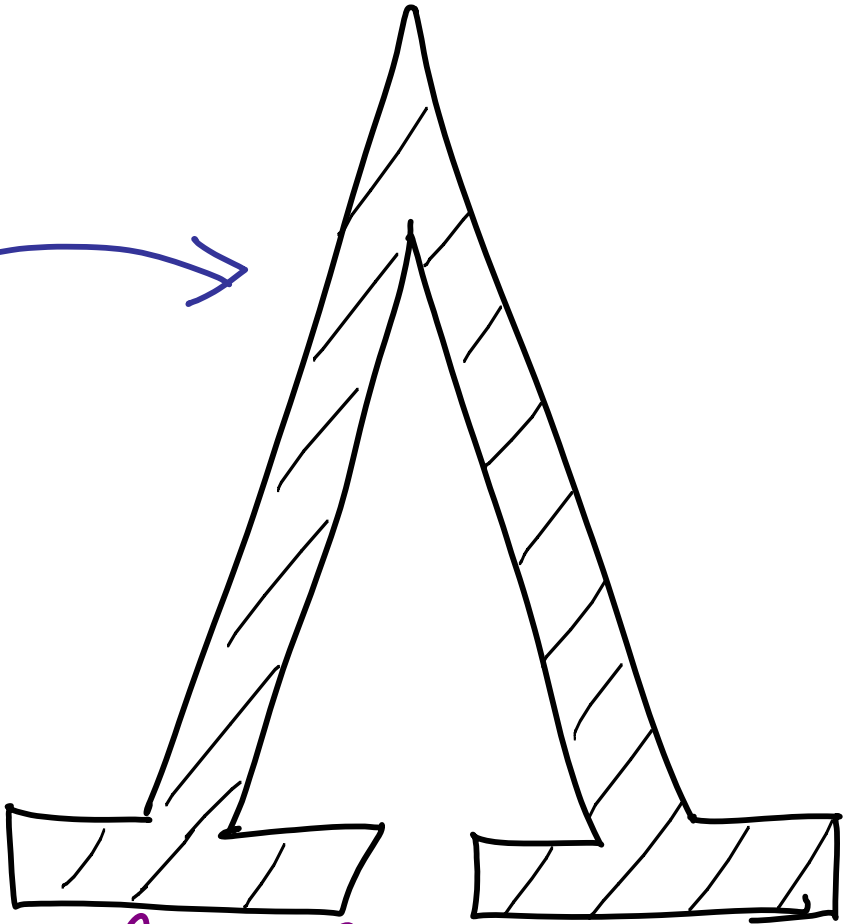
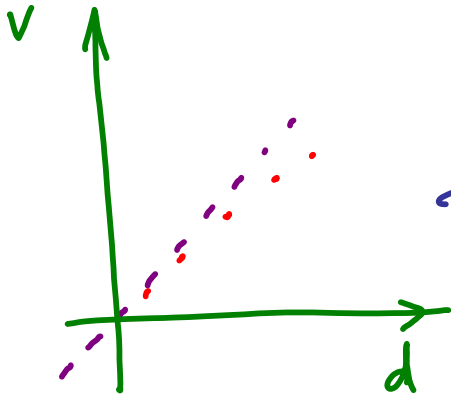
Binding Energy
 $\sim 2 \text{ MeV}$

$\sim 20\%$ accident



Not bound by
 $60 \text{ keV}(!)$,

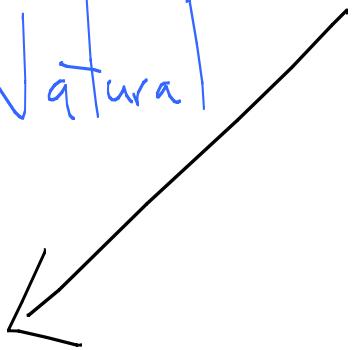
$\sim 1\%$ accident



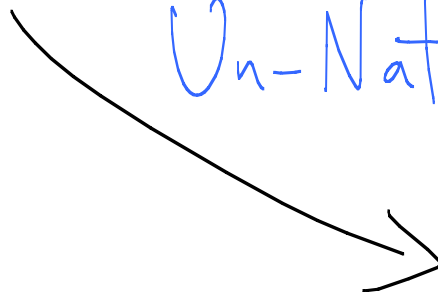
NATURALNESS

Crucial Fork in the Road

Natural



Un-Natural



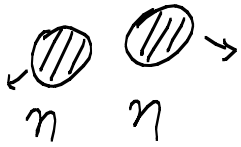
BIG NEW
PRINCIPLES

EVEN BIGGER
PARADIGM SHIFT
Like CC?
HOW TUNED?

Higgs + Nothing Else @ LHC?

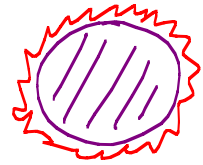
A Fine-tuning of at
least 1% for weak scale
CONVINCING?

There are many $\sim 1\%$ level "accidents"



Two neutrons
not bound by
60 keV!

Low Quadrupole
of CMB power



Moon
eclipsing the
sun

Adding "EWSB" to this list from
L.H.C would be fascinating, but not KNOCKOUT

How will we know?

- Higher Energy!!

- * Find Something! → End of discussion!
- * Find Nothing → Tuning $\propto E_{\text{machine}}^2$

- Rare processes
- Precision measurements

} Indirect,
Linear
gain intuning

* Tuning probe $\propto E_{\text{cm}}^2$

* Higgs + nothing else @ 100 TeV

$\Rightarrow \sim 10^{-4}$ tuning!

* Never seen this level of tuning
in particle physics - NEW.

CAN'T SHRUG SHOULDERS

* In my view, even this "worst-case scenario" would be
~ 100 X more shocking +
dramatic than nothing but Higgs@LHC

MORTAL BLOW
TO NATURALNESS

This alone fully
justifies the march to

100 TeV

* Circular e^+e^- machine

Higgs Factory plays very important,
complementary role

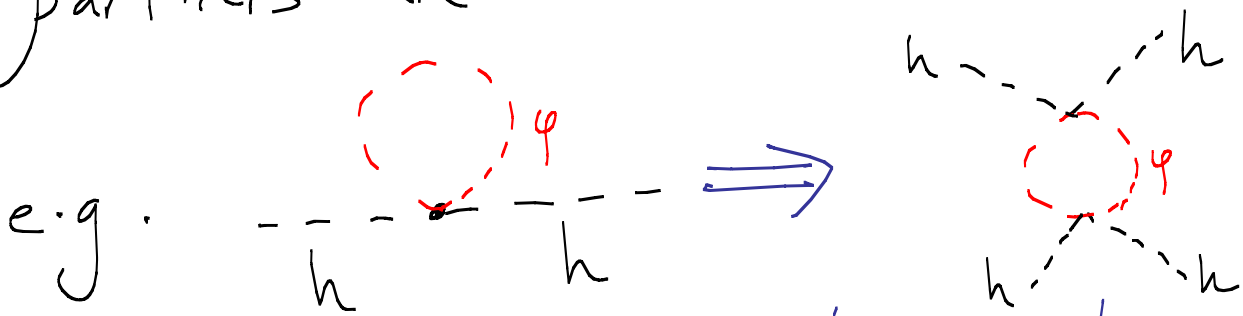
Looking for $\frac{h^+h(h @ b^c)}{\Lambda^2}$, $\frac{(h^+D_h)^2}{\Lambda^2}$, ...

* Tera-Z particularly
exciting + powerful probe!

Also: naturalness "no lose theorem"

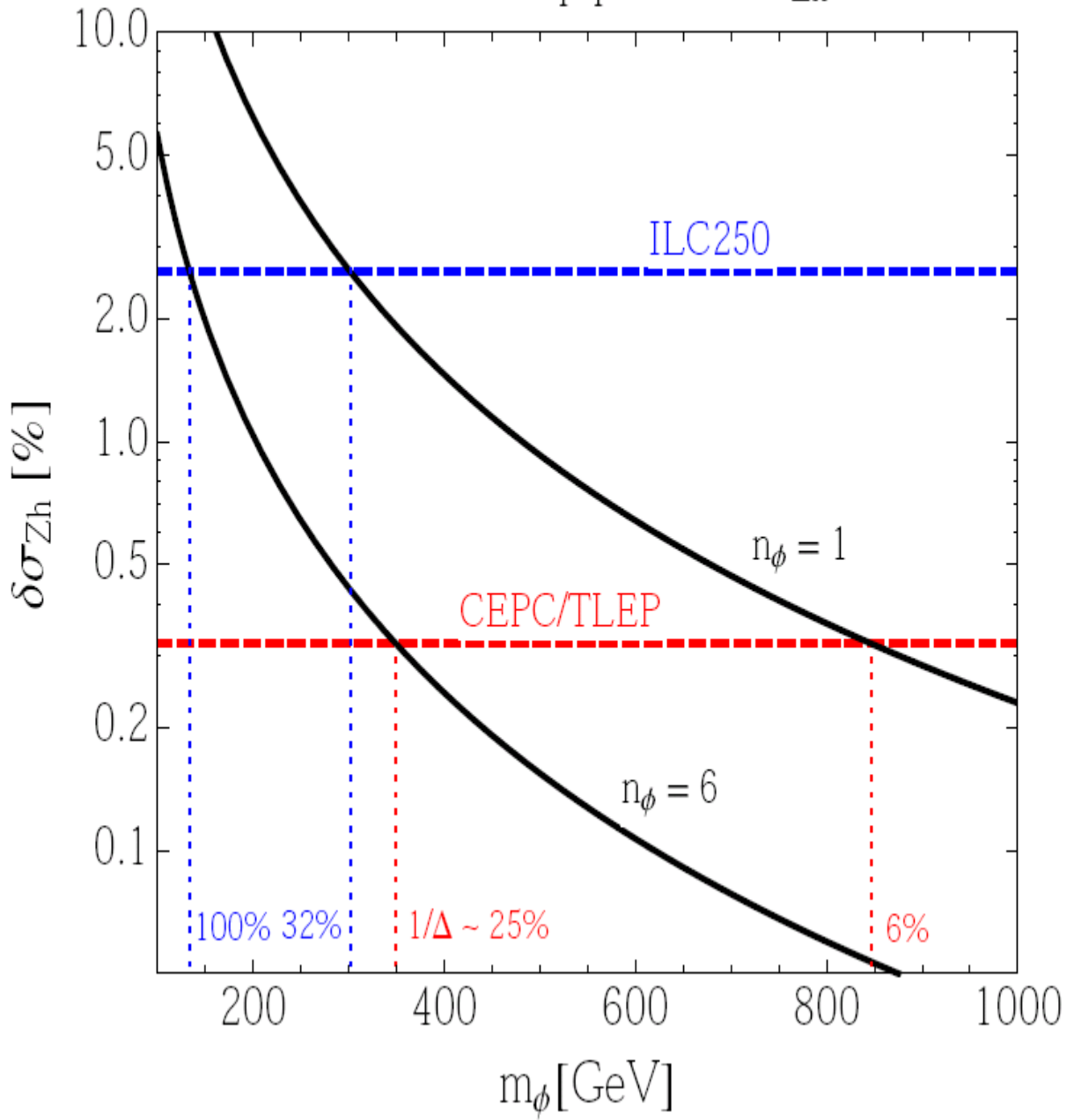
[Craig et. al.]

Perhaps higgs is natural, but top partners are not colored?

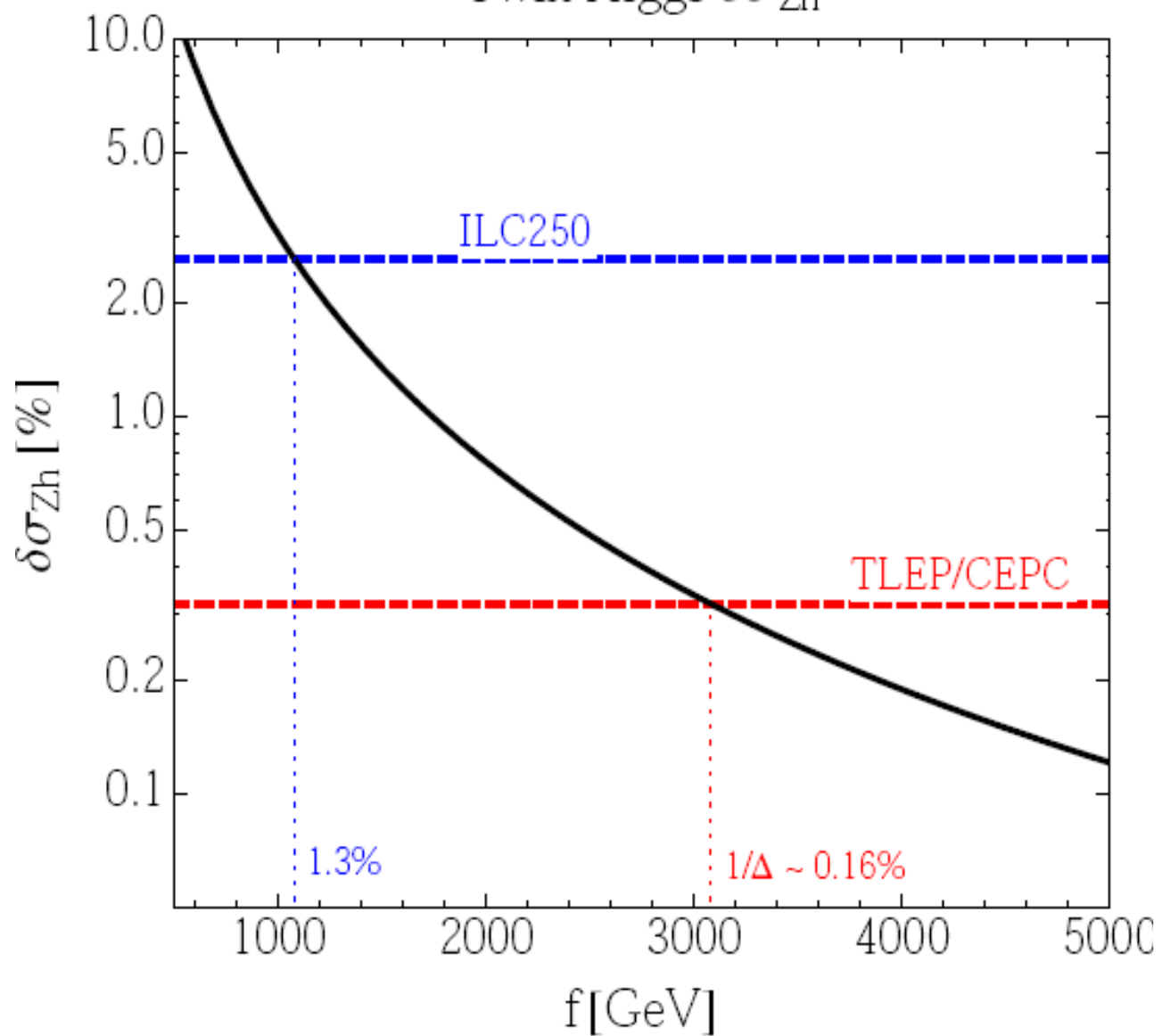


$\Rightarrow \sim 1\%$ mod to hZ coupling

Invisible top partner $\delta\sigma_{Zh}$

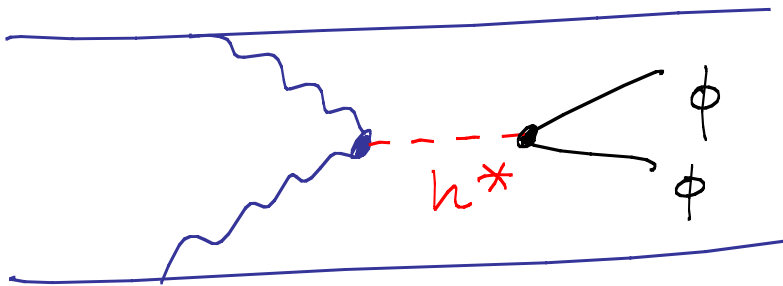


Twin Higgs $\delta\sigma_{Zh}$

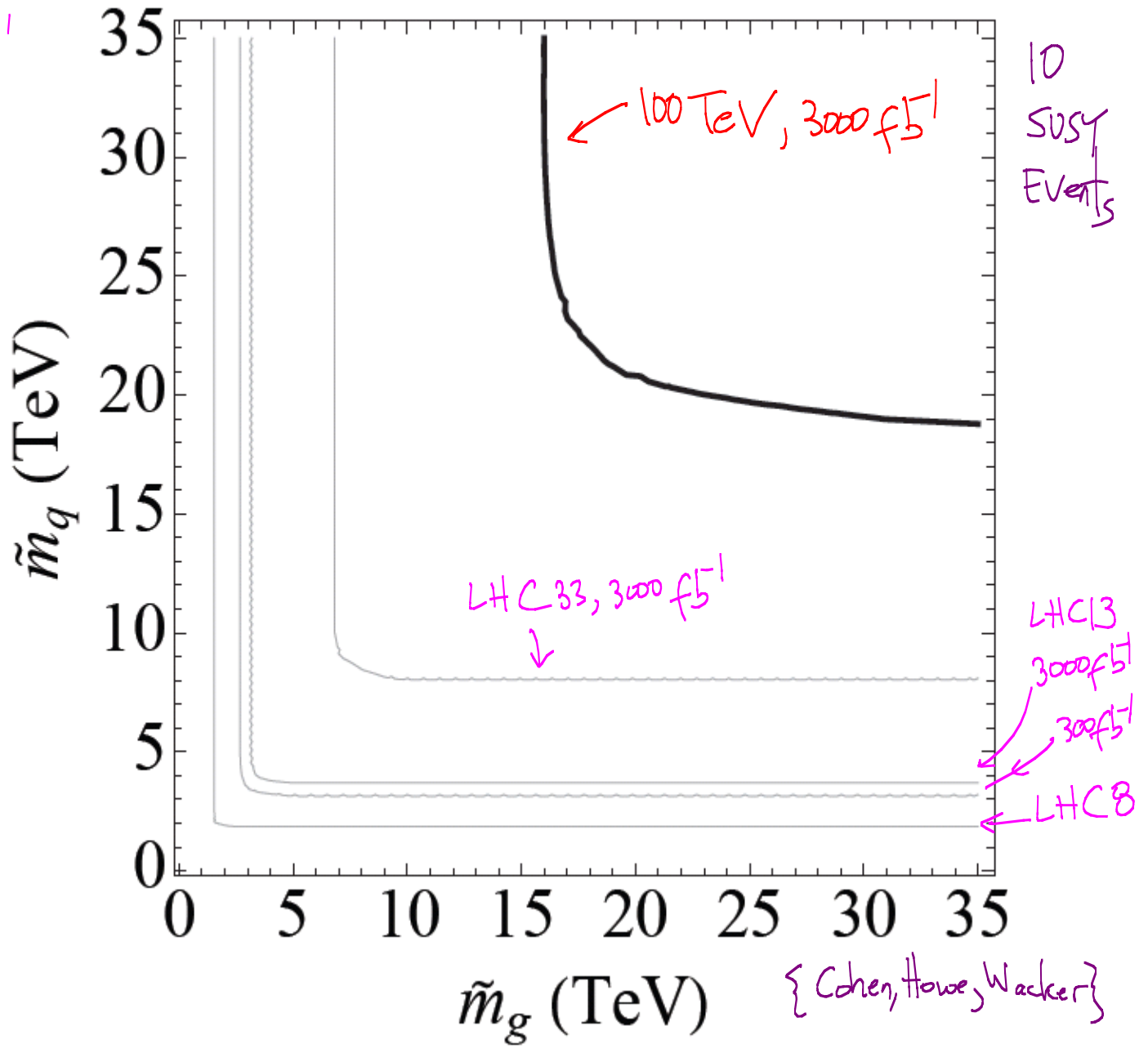


+ Obvious follow-up in

pp collisions :



• If instead, we are "just"
~1% unlucky, LHC could
still miss every thing, but
100 TeV pp ~~will~~ catch the
new physics



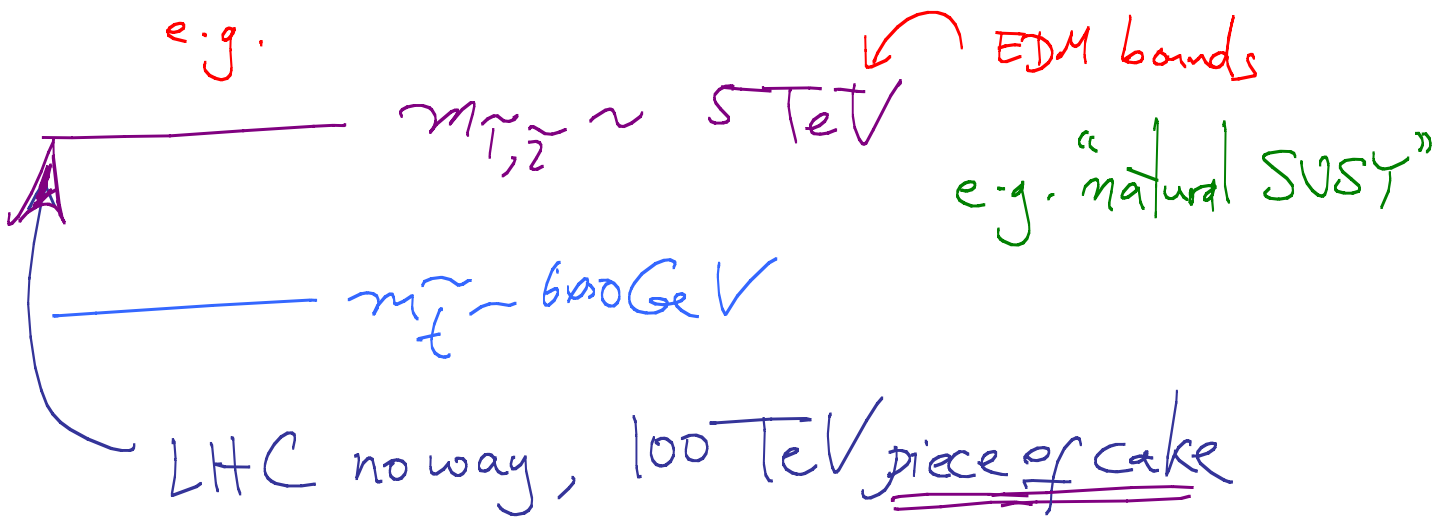
What if L.H.C discovers

(relatively) Natural spectrum?

IT's not 1995....

"Discover SUSY@LHC,
precision study @ 500 GeV
ILC"

* What we already know from LHC makes it implausible that we'll see whole spectrum of new physics, even if it's relatively natural:



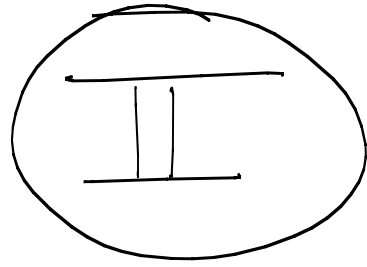
More generally, we will want a
factory for new colored particles,

to study how they make higgs

Natural [e.g. SUSY coupling

relations] \rightarrow RATE $\propto E_{CM}^{5 \rightarrow 6}$

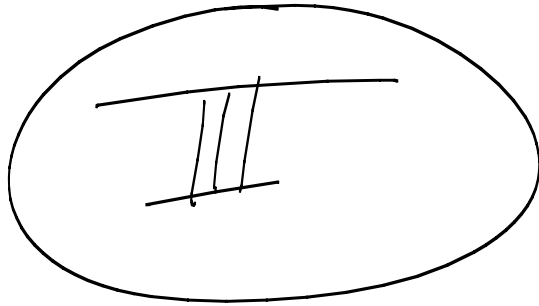
$\sim 10^3$ gain @ 100 TeV



← Lian-Tao's
Talk

Robust probe of up to ~ few
TeV electroweak particles.

{ WIMPS could very easily be
here — LHC not ideal "DM factory" }



For the first time, rich
+ alive possibilities for Collider

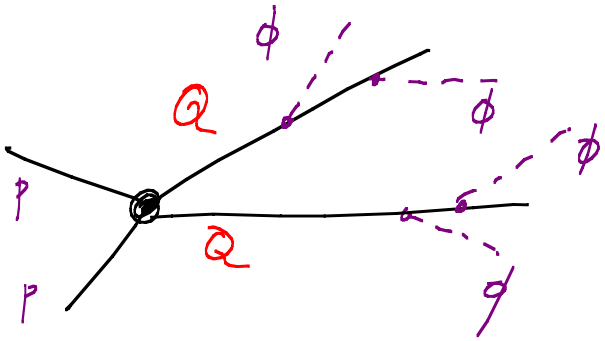
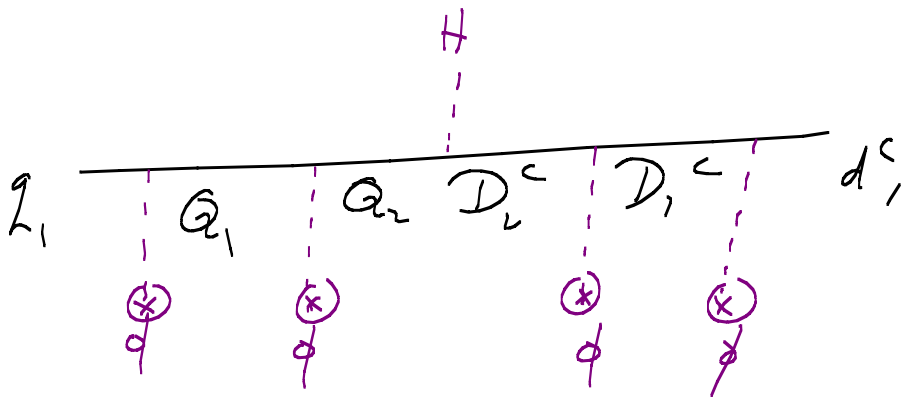
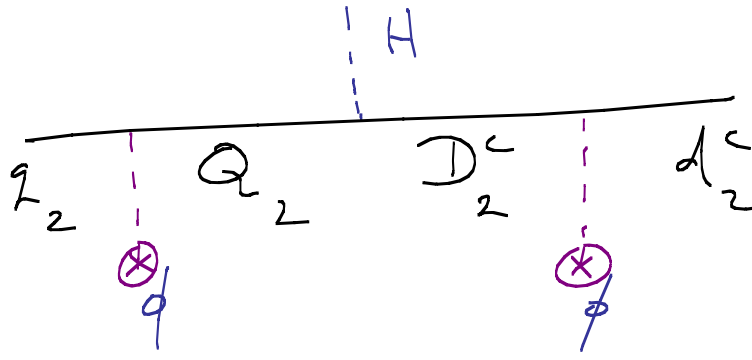
Flavor Physics

* Not possible to generate flavor
@ \sim TeV scale + not be
dead by FCNC's \Rightarrow

no flavor collider physics @ LHC.

* Not so already if new physics
@ 10 TeV...

e.g.



Long cascade
decays w/ fingerprint
of flavor symmetry
structure.

* $\sim 10^{11}$ tops - we can

start probing

interesting
~~many~~

levels of top flavor

Also, we have ongoing probes of
CP and Flavor, e.g. electron
EDMs, $\mu \leftrightarrow e$ conversion, ...

Any positive signal must come from
new physics @ 10-100 TeV scale,
can expose it directly with 100 TeV machine

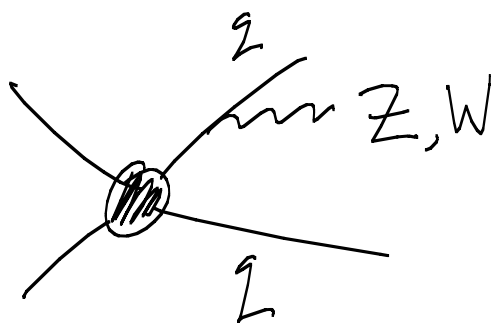
IV

Some qualitatively new aspects
of 100 TeV collisions —

e.g. $SU(2) \times U(1)$ finally
looks unbroken! W/Z "radiation"
significant — ν 's + DM more
"visible" [Hook, Katz]

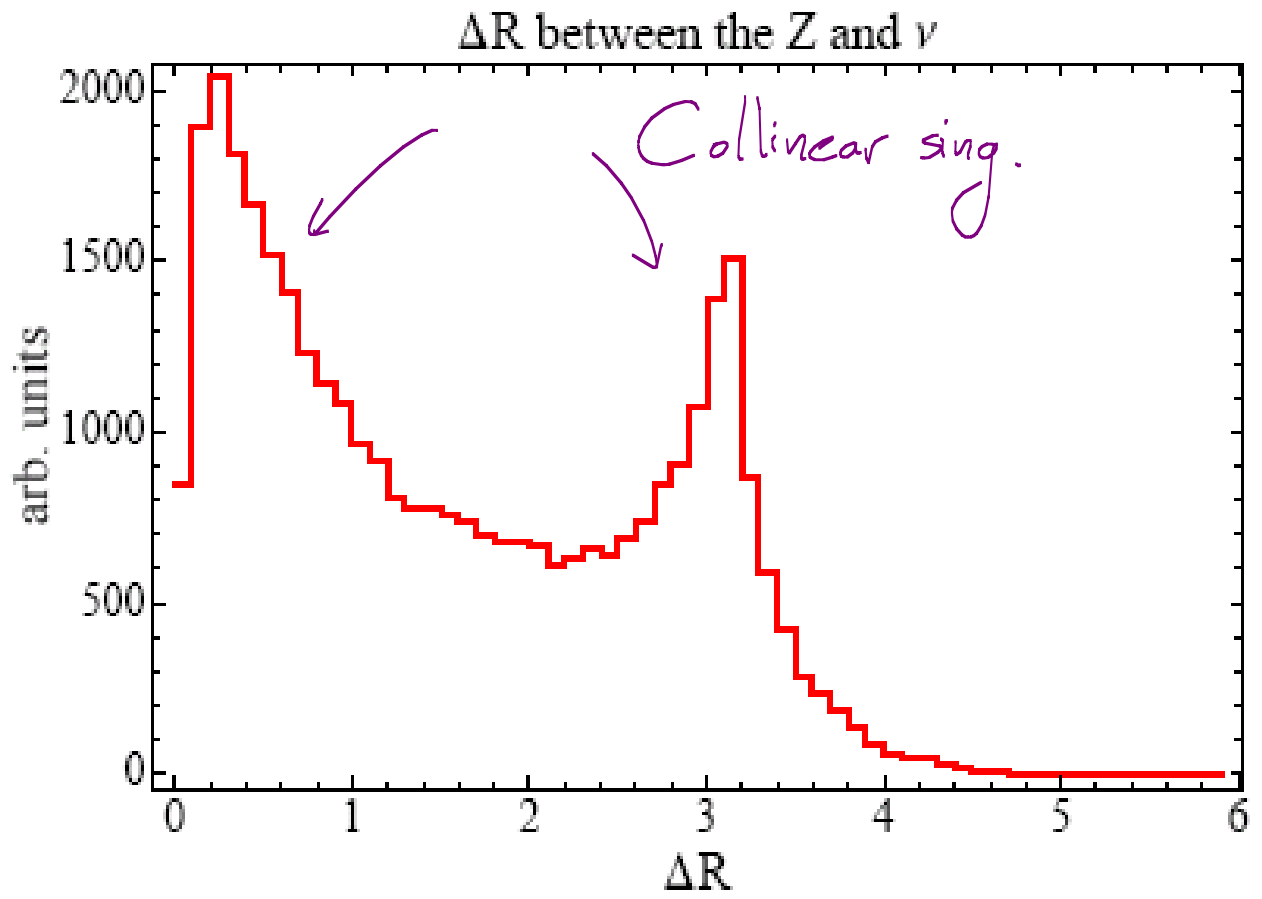
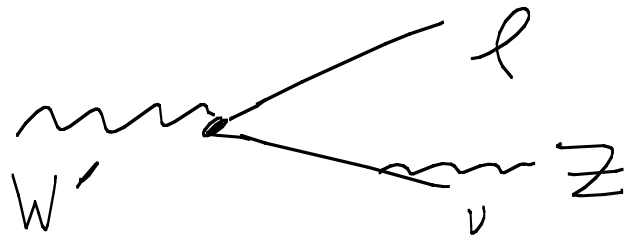


*~ 10%
of dijets
@ 10 TeV
have W/Z's!*

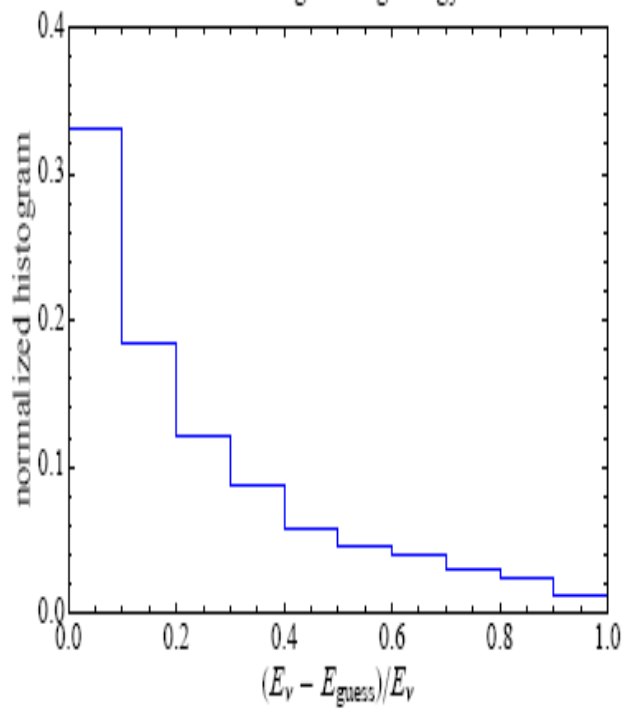


$$\frac{4\alpha_2}{\pi} \log^2 \left(\frac{5 \text{ TeV}}{m_Z} \right)$$

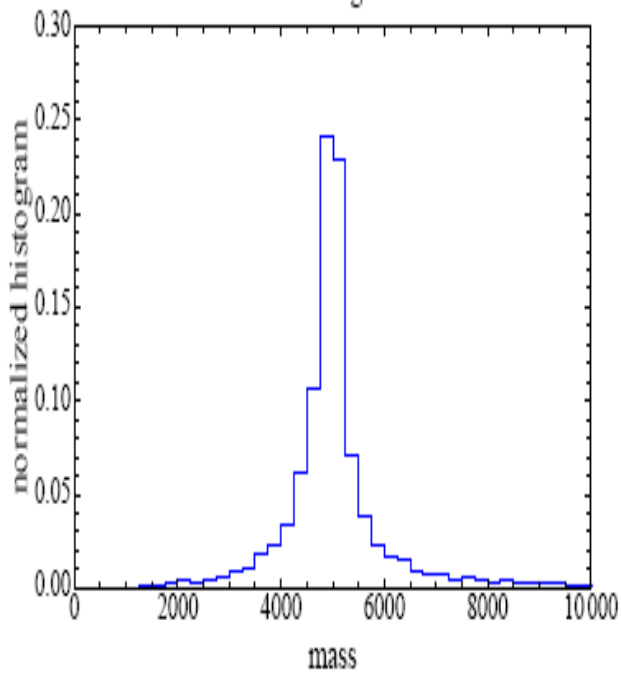
not small!

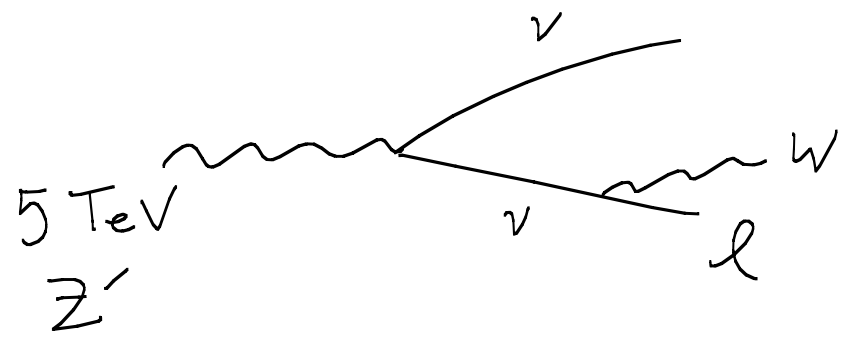
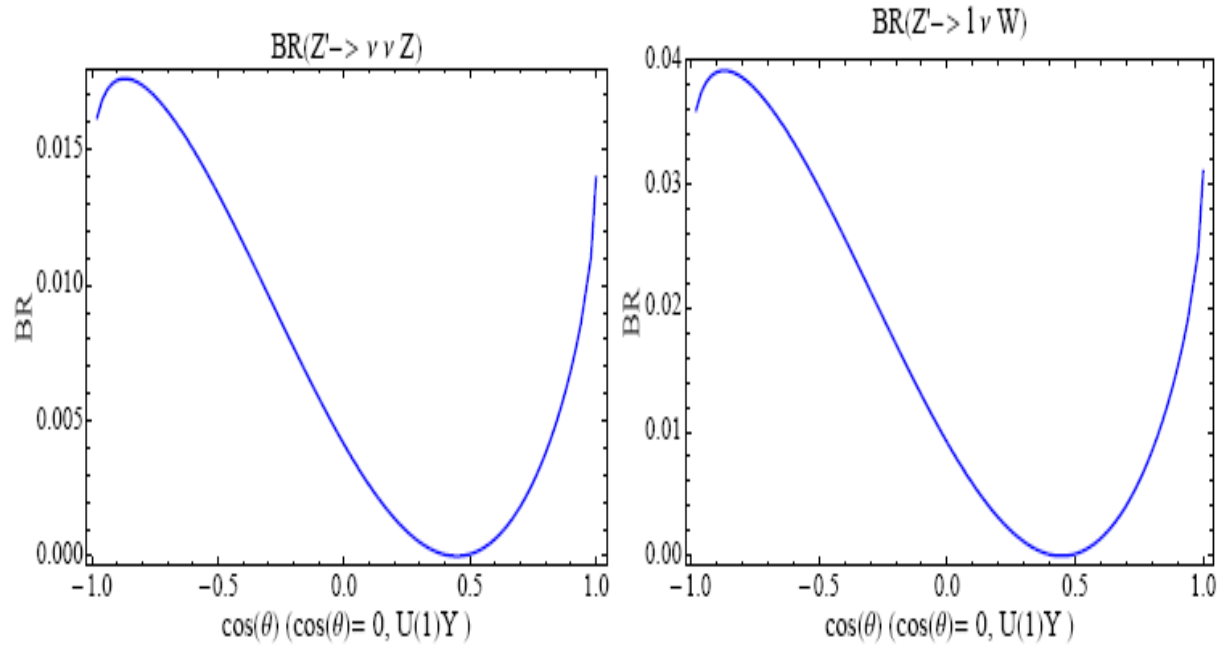


Guessing missing energy



Reconstructing W mass





Large # of other big physics:

* WW scattering (!)

* Probe of Ewk phase transition
+ Ewk Baryogen [Meade]

(Again: complem. between e^+e^- + pp modes)

⋮

* It's the OBVIOUS FUTURE

* BIG machines

BIG physics ideas

Lifeflood of The Field

ASK NOT WHAT
BIG CIRCULAR COLLIDERS
CAN DO FOR YOU, ASK
WHAT YOU CAN DO FOR
BIG CIRCULAR COLLIDERS!

Please join in the ongoing
efforts @ CERN, and
our new initiative @ IHEP,
Center For Future HEP

Kickoff Mtg: Feb 23-25

Fermilab has

a CRITICAL

role in this endeavour

[Accelerator/High Field Magnets/Physics...]