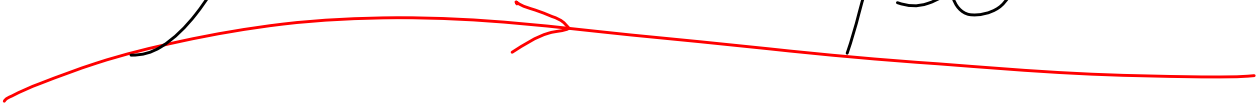



Why is the Higgs



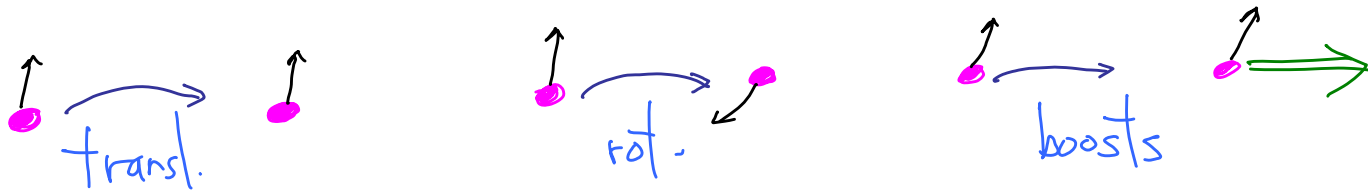
SO IMPORTANT?



What is Particle Physics!

What is a Particle ?

Spacetime Symmetries



Quantum Mechanics

$$|p^\mu, \sigma\rangle; \quad U(\Lambda) |p, \sigma\rangle = D_{\sigma\sigma'}(\Lambda) |p, \sigma'\rangle$$

“Particles are Unitary reps of Poincaré group”

↑ Quantum Mechanics ↑ Spacetime

Particle Physics = Study of
Fundamental Laws of Nature
governed by still-mysterious union of
Quantum Mechanics + Spacetime

17th → 20th Century Physics

March of REDUCTIONISM

March of SYMMETRIES

Whatever the Ultimate Theory

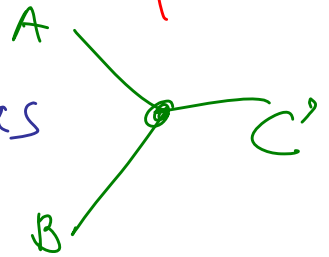
Relativity

Quantum Mechanics

Reductionism

↳ Massless particles

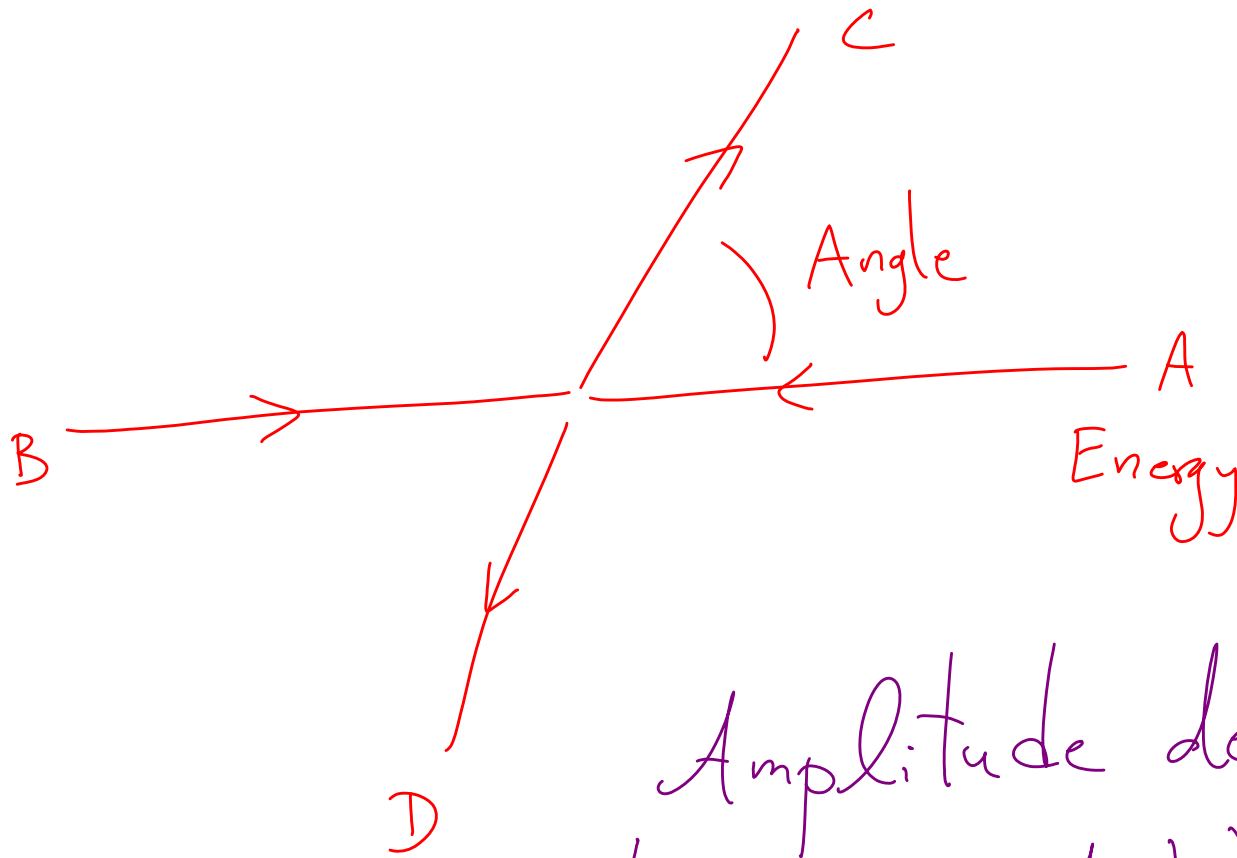
interacting as



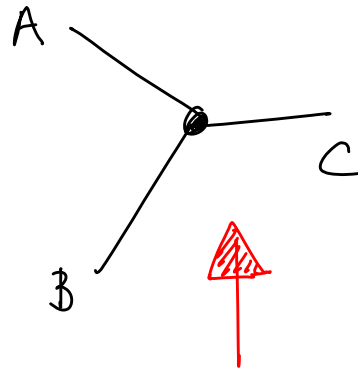
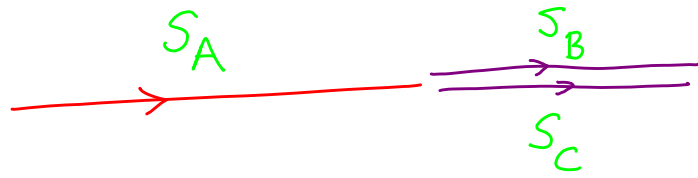
Symmetries

with spins $0, \frac{1}{2}, 1, \frac{3}{2}, 2$

[and  allowed for spin 0]

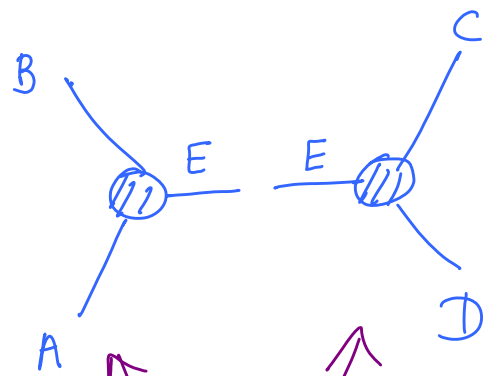
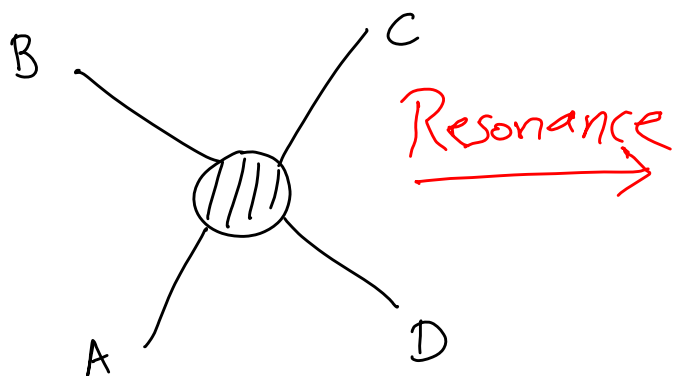


Amplitude depends of
(Energy, Angle), Complicated!



NO (Energy, Angle) \rightarrow COMPLETELY
FIXED
(up to strength)
by helicities!

Dictated by
Principles of
SPACETIME



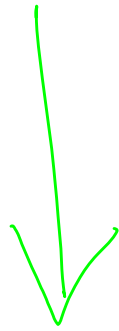
Again, Completely
Known

Dictated
By Principles of
QUANTUM
MECHANICS

Whatever the Ultimate Theory

Relativity

Quantum Mechanics



Massless

particles

Yang Mills

with spins

0, $\frac{1}{2}$, 1, $\frac{3}{2}$, 2

0

$\frac{1}{2}$

1

$\frac{3}{2}$

2

Gravity/
General Rel.

SUSY

LARGELY DICTATE GRAND

ARCHITECTURE OF PHYSICAL LAWS

What About The

Higgs ?



Amazing difference between massive +

massless particles

with spin: } Both SPACETIME
+ QM matter

massive $\uparrow S=1$


3
 spin

massless



2 helicities


One extra guy!




Belief in Principles Paid Off

0, $\frac{1}{2}$, 1, $\frac{3}{2}$, 2



Higgs is first "really new" particle
we've seen!

Simplest possible elementary particle

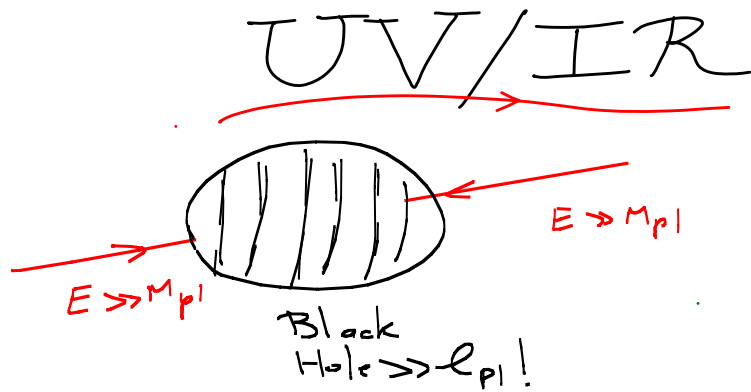
21st Century Revolutions

* Doom of Spacetime, End of Reductionism

* Why is the Universe Big? [Cosmological Constant Λ]

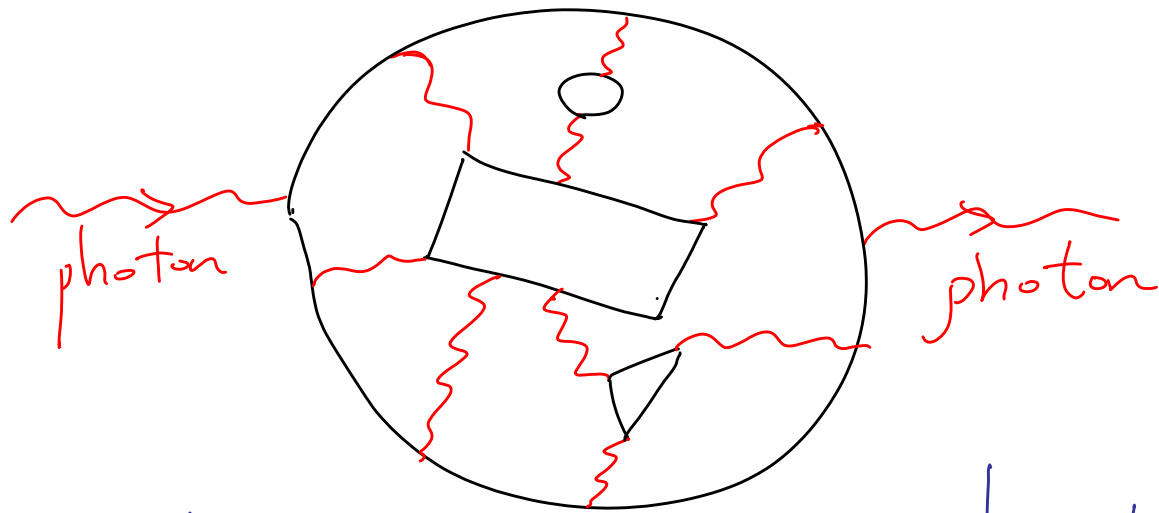
With Big Things in it? [Higgs m_h^2]

REALLY NEW IDEAS NEEDED,
beyond paradigms of spacetime + internal symmetries



High Energies
 Long Distances!

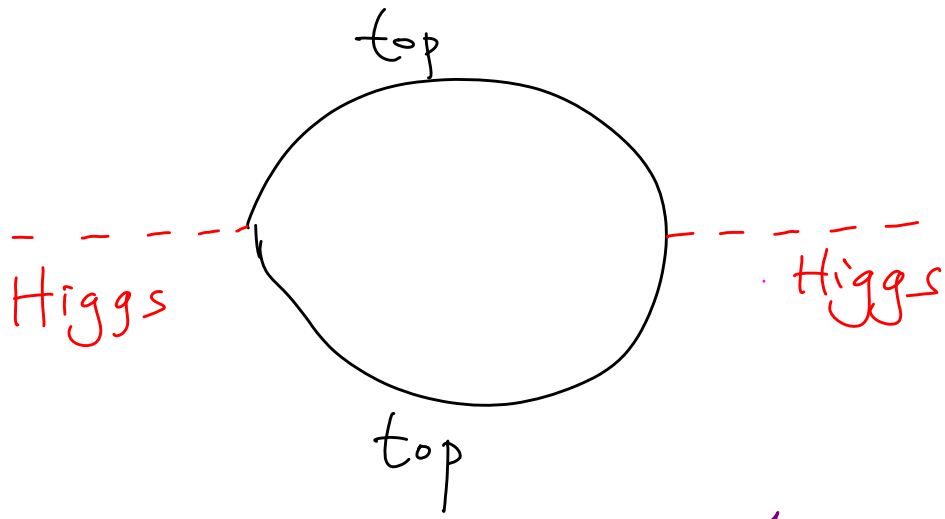
Reductionism + Wilsonian EFT Paradigm is **False**
 Fundamental Laws Nothing like that of
 Condensed Matter Physics — **FAR**
DEEPER + MORE RADICAL
 [But maybe only at Planck Scale?]



Photon MUST stay massless, because

$$\begin{array}{ccc} \# \text{ massless} & & \# \text{ massive} \\ \text{helicities} & \rightarrow & \text{spins} \\ & 2 \neq 3 & \end{array}$$

[This is why gauge fields + chiral fermions
can be easily engineered in Cond. Matter!]



massless spin 0 1 = 1 massive spin 0

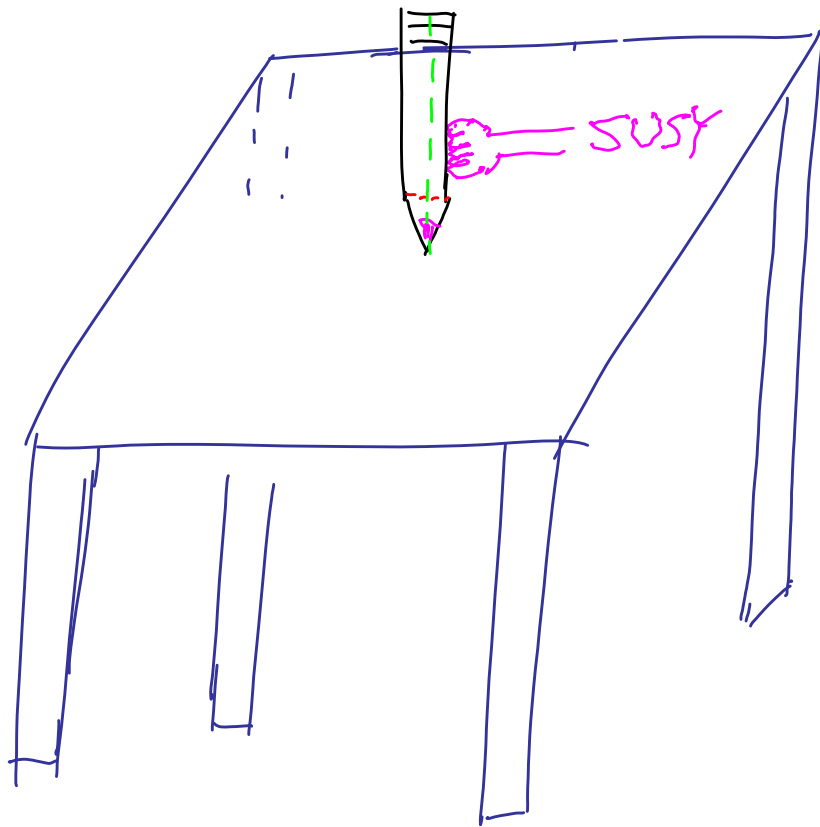
NO DIFFERENCE

WHY
ISN'T
HIGGS
ENORMOUSLY
MASSIVE?
PLANCKIAN?

[Higgs is Special! Does NOT naturally arise in Cond. Matter!]

Tame Violent Quantum Fluctuations?

↙ Vertical to $\sim 10^{-30}$ degrees



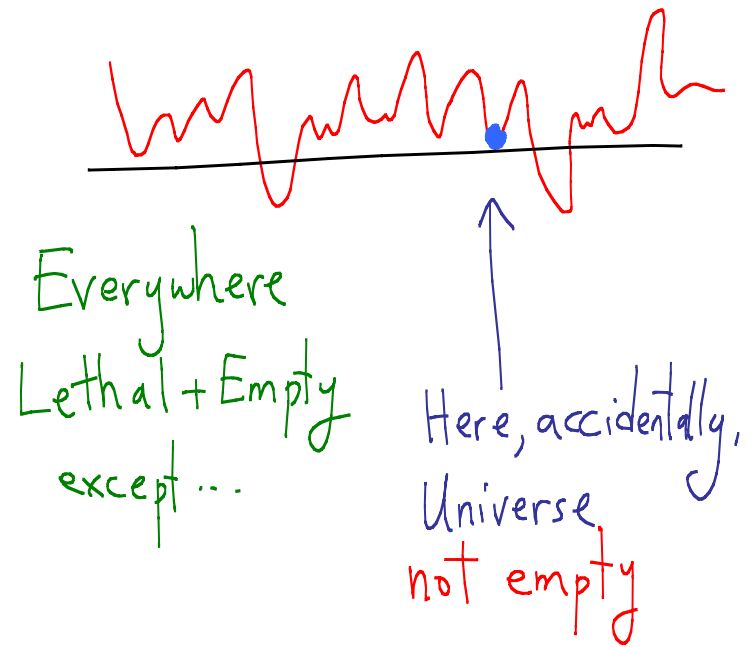
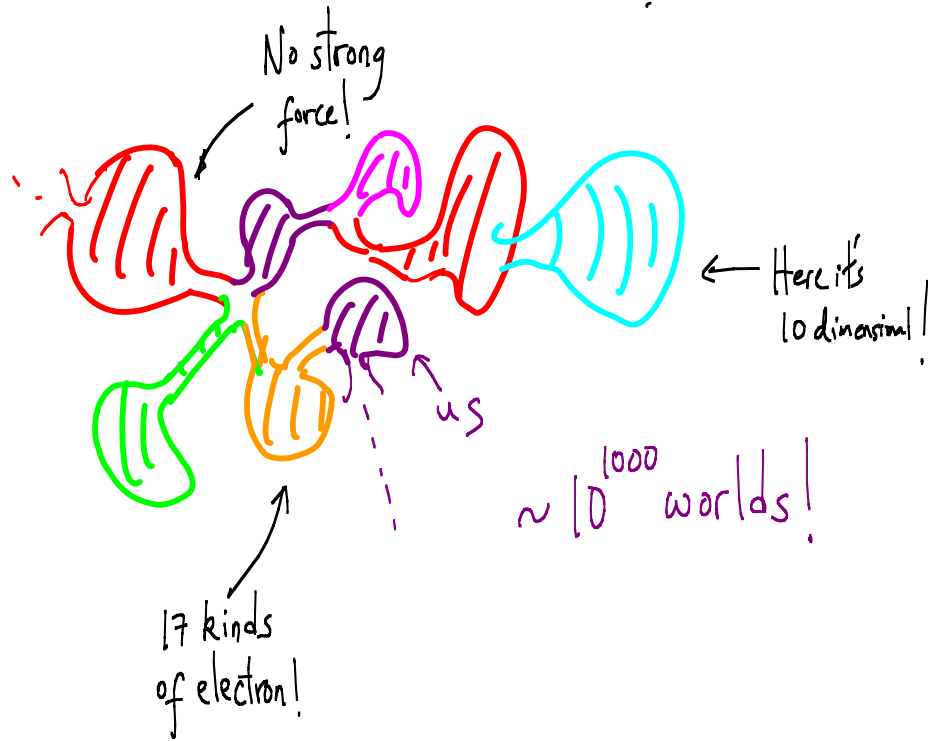
Where the Heck

is

Everybody?

(M?)

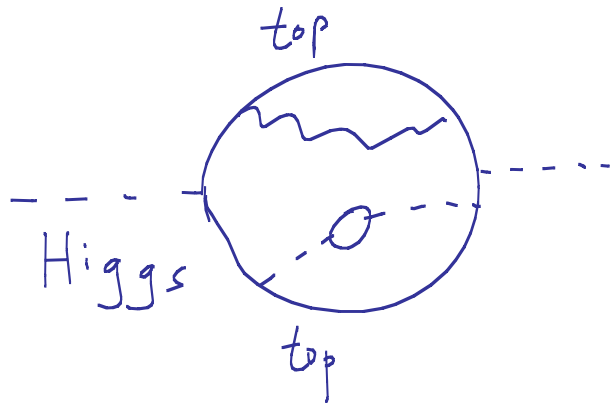
Are We a Tiny Part of Vast Multiverse?



... Might Cosmological History
be relevant for setting m_H^2 ? ...

... Might the UV/IR
connection — clearly violating the
usual Wilsonian paradigm at the
Planck scale — already be showing
up @ Hubble/Weak scale? ...

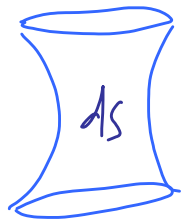
Λ + Higgs \rightarrow Beyond Symmetries



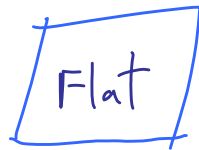
1 d of whether $m_h^2 > 0, = 0, < 0$

NO DIFFERENCE

Hierarchy Problem



$\Lambda > 0$



$\Lambda = 0$



$\Lambda < 0$

Same amount of symmetry
[$SO(5,1) \rightarrow \text{Poincaré} \rightarrow SO(4,2)$]

Cosmological Constant Problem

Emergent Spacetime?

We are clearly missing something
HUGE about Quantum Mechanics of
our Relativistic Vacuum!

Macroscopic Universe?

Higgs Discovery Crucial

Our Relativistic Vacuum is **Quantitatively**

Different than anything we've seen elsewhere in physics

NOT JUST @ Planck scale

ALREADY @ TeV scale

Higgs is Really New Physics!

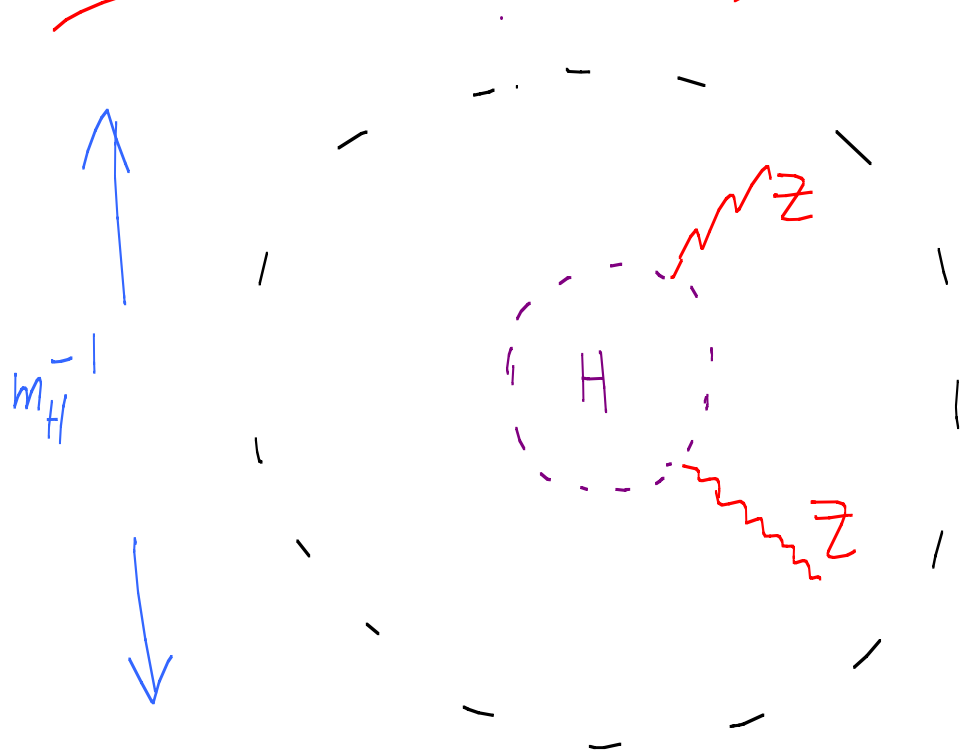
* We've never seen anything like it

* Harbinger of Profound New Principles
at work in quantum vacuum

PUT IT UNDER MICROSCOPE

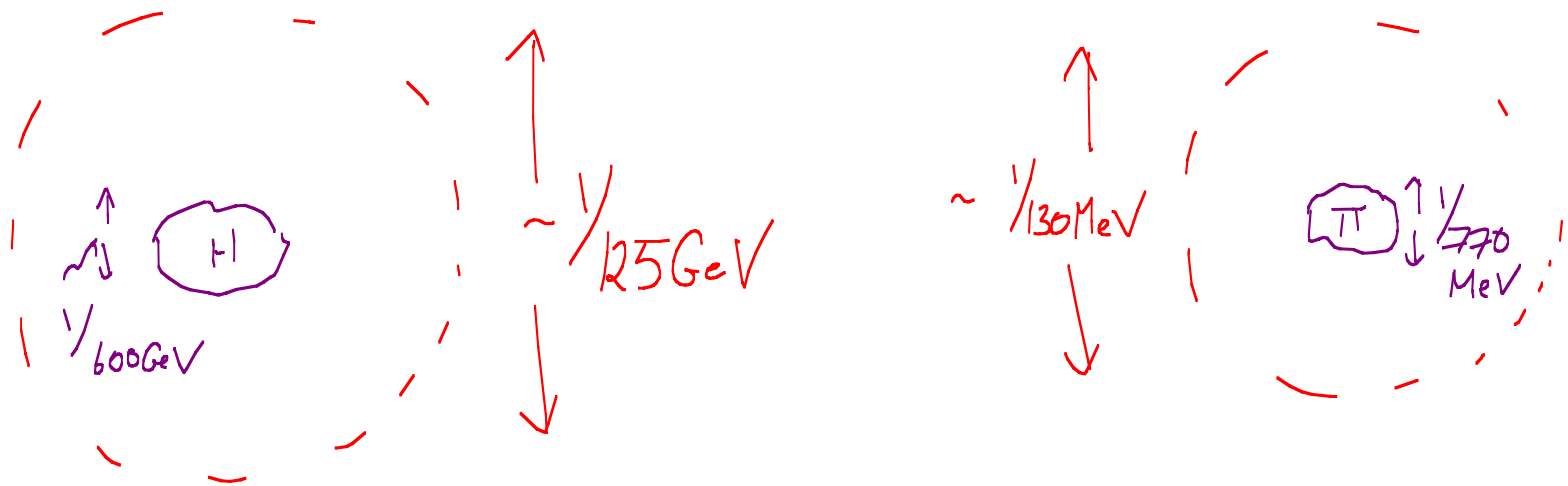
STUDY IT TO DEATH

Never Seen Point-Like Scalar

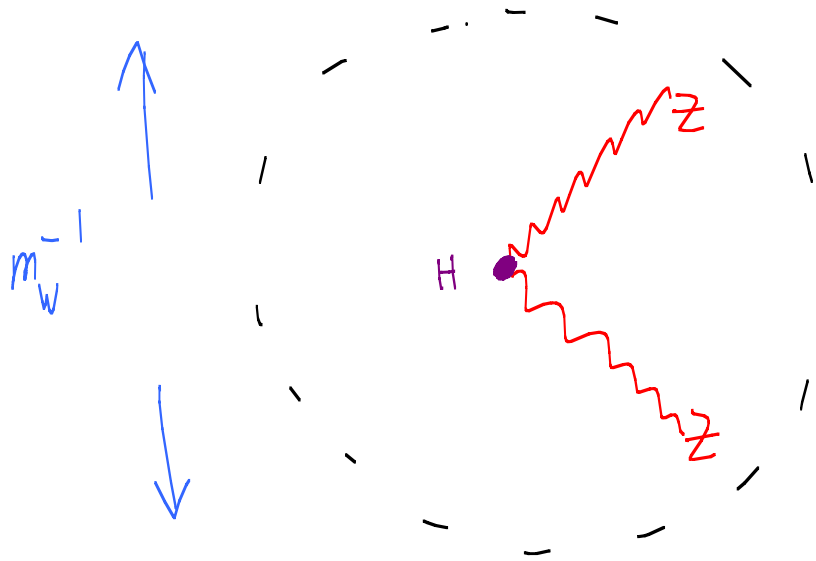


So, how
pointlike is
it? _a

But with LHC resolution,
Higgs could be about as elementary
as a "pion":



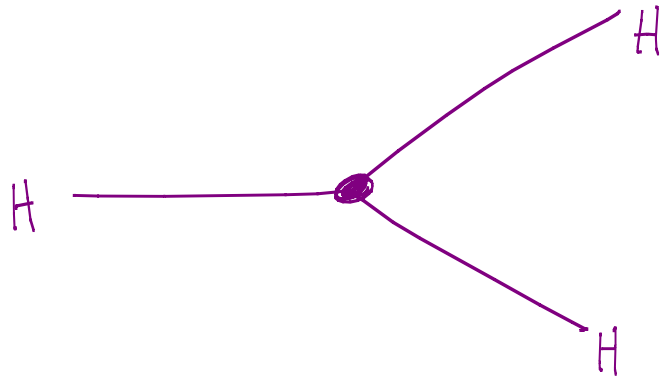
Never Seen Pion-Like Scalar



Higgs Factory
+

We will know
FOR SURE
if it's "like a Pion"

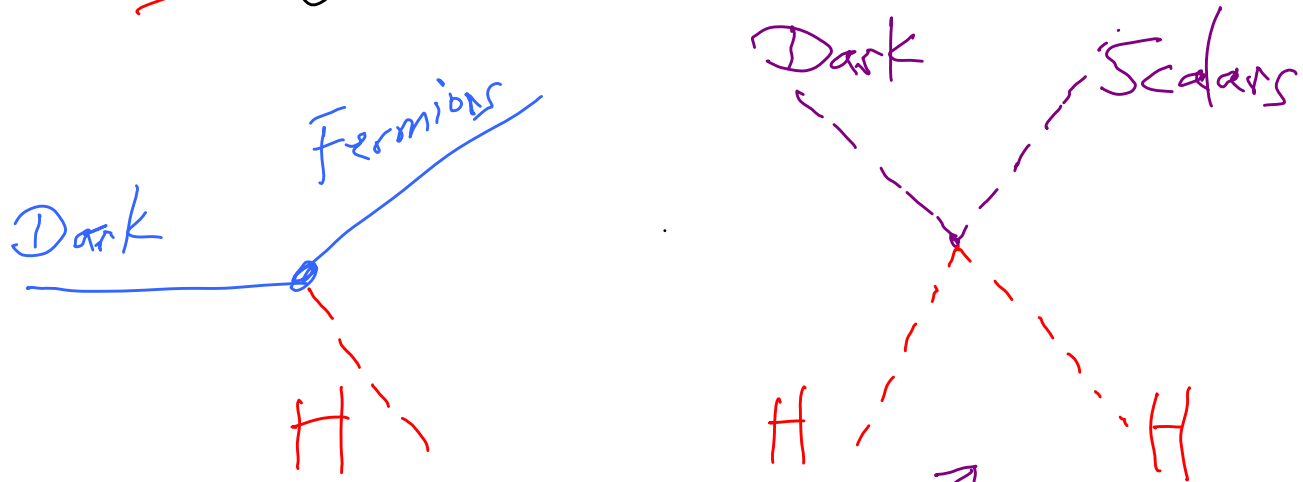
Never Seen Self-Interacting Fundamental Particles



100 TeV Collider

Measured to \sim few%

Higgs as a Portal



Large (dimensionless) couplings to
Dark Sectors / "Hidden Valleys"

Also, 100 TeV collider

blasts into the high energy

frontier. New particles $\sim 10 \times$ LHC reach.

Probes Higgs-rocking quantum fluctuations

with power $100 \times$ LHC

Outlook

In (not just) my view, the scientific issues we face today are the most difficult + profound ones our field has seen since the 1930s

The questions raised by the accelerating universe, and the higgs discovery, both go to the heart of our understanding of the nature of spacetime, quantum mechanics + the vacuum.

The Higgs is the most important
character in this drama — we can

put it under most incisive &
precise experimental scrutiny.

PUT IT UNDER MICROSCOPE

STUDY IT TO DEATH!