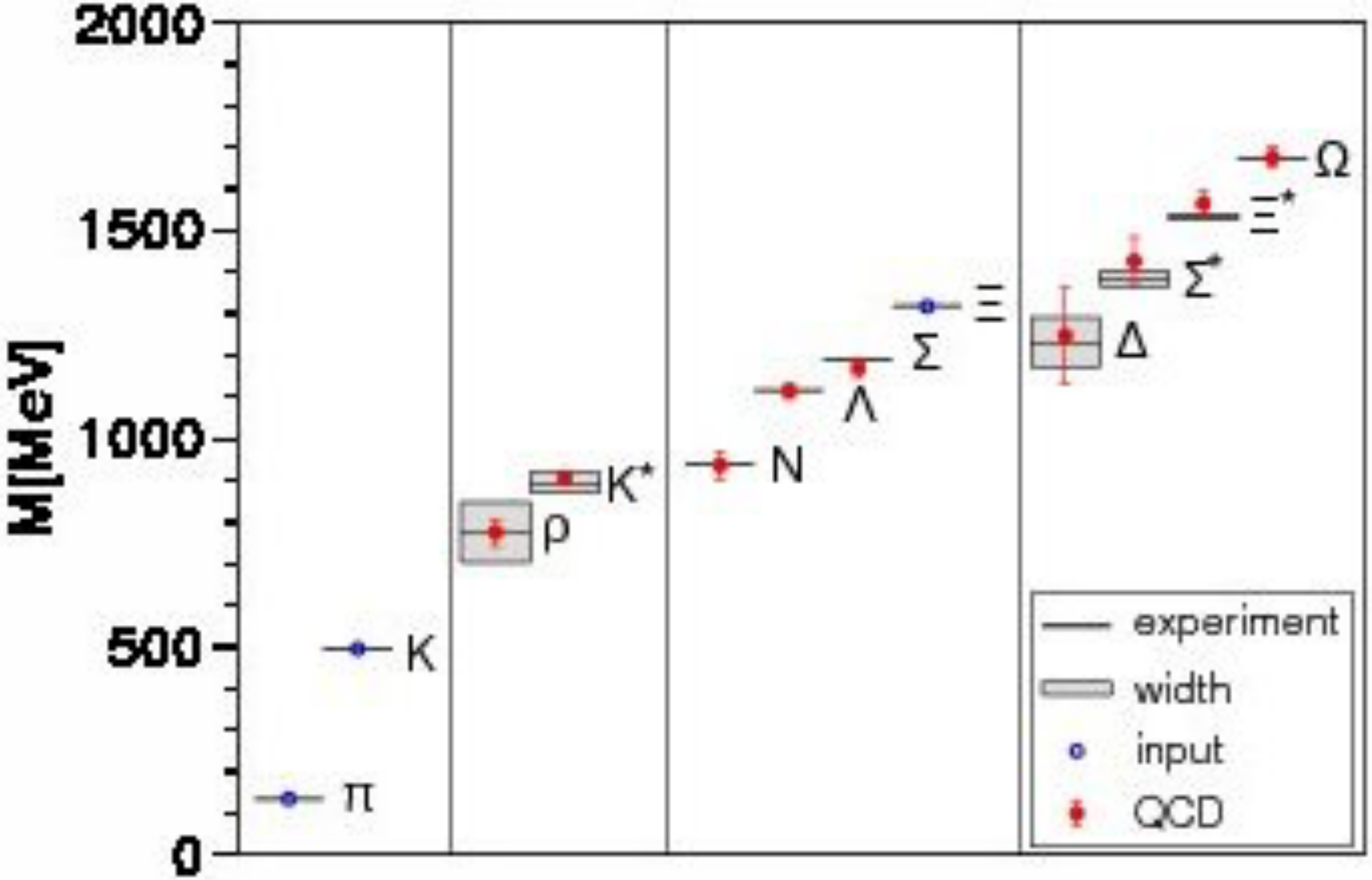
Theory Vision

Advertisements, Anticipations, Aspirations

The Standard Model: Glory and Discontents

Our current core theories are a glorious success. They provide an adequate foundation, in fundamental law, for chemistry, biology (probably), and all plausible forms of engineering.

They support long, complex calculations that connect physical reality to ideal mathematical principles. For example:


2000
1500
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M[MeV]
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Ξ*
Ω
experiment
width
input
QCD

But they are not as beautiful as they should be.

$$\begin{pmatrix} u & u & u \\ d & d & d \end{pmatrix}^{L}_{1/6}$$

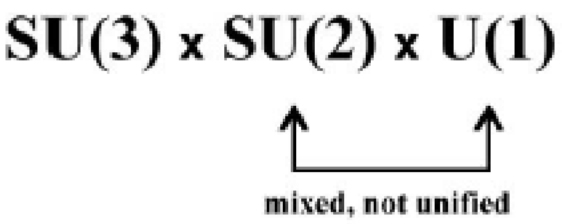
$$\begin{pmatrix} \nu \\ e \end{pmatrix}^{L}_{-1/2}$$

$$\begin{pmatrix} u & u & u \end{pmatrix}^{R}_{2/3}$$

$$\begin{pmatrix} d & d & d \end{pmatrix}^{R}_{-1/3}$$

$$\begin{pmatrix} e \end{pmatrix}^{R}_{-1}$$

$$\nu^{R}$$



SU(3) x SU(2) x U(1)

three fundamental "forces"

(plus gravity)

six fundamental "materials"

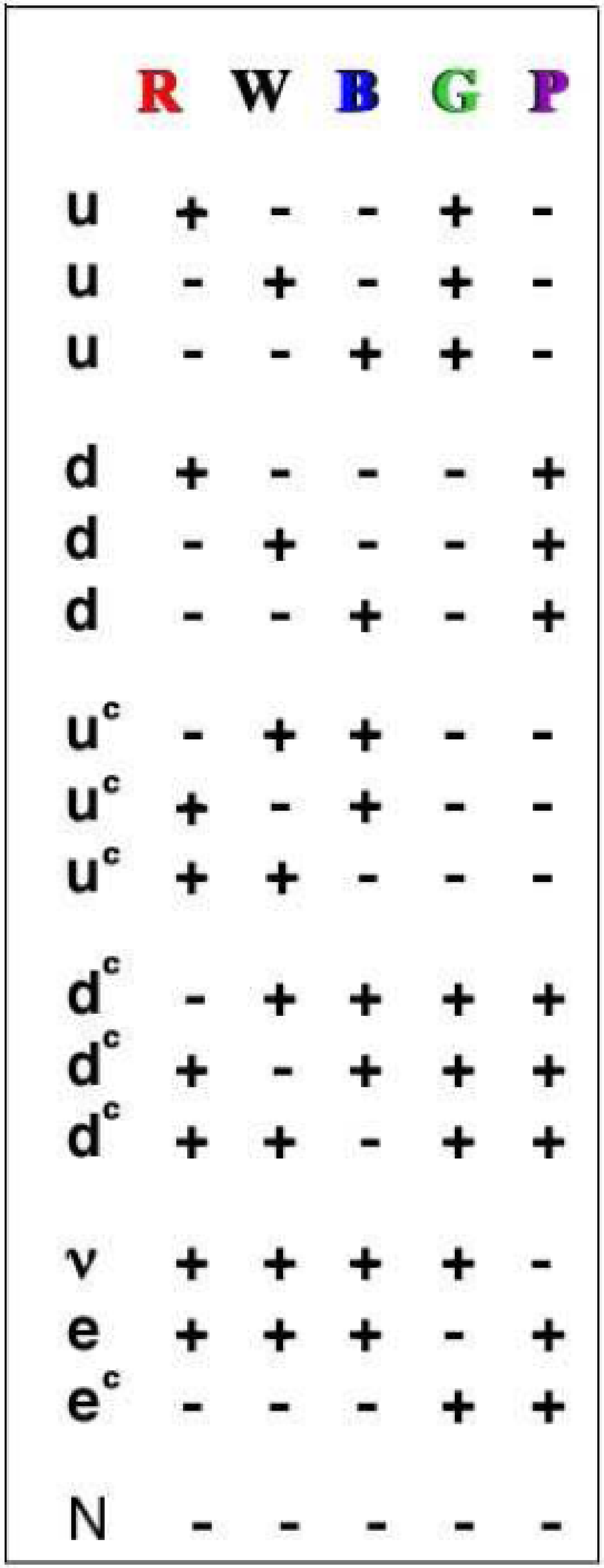
(plus 2 repeats)

(plus Higgs particle)

And they leave big questions, including the nature of dark matter and dark energy, unanswered.

Unification

One “material”

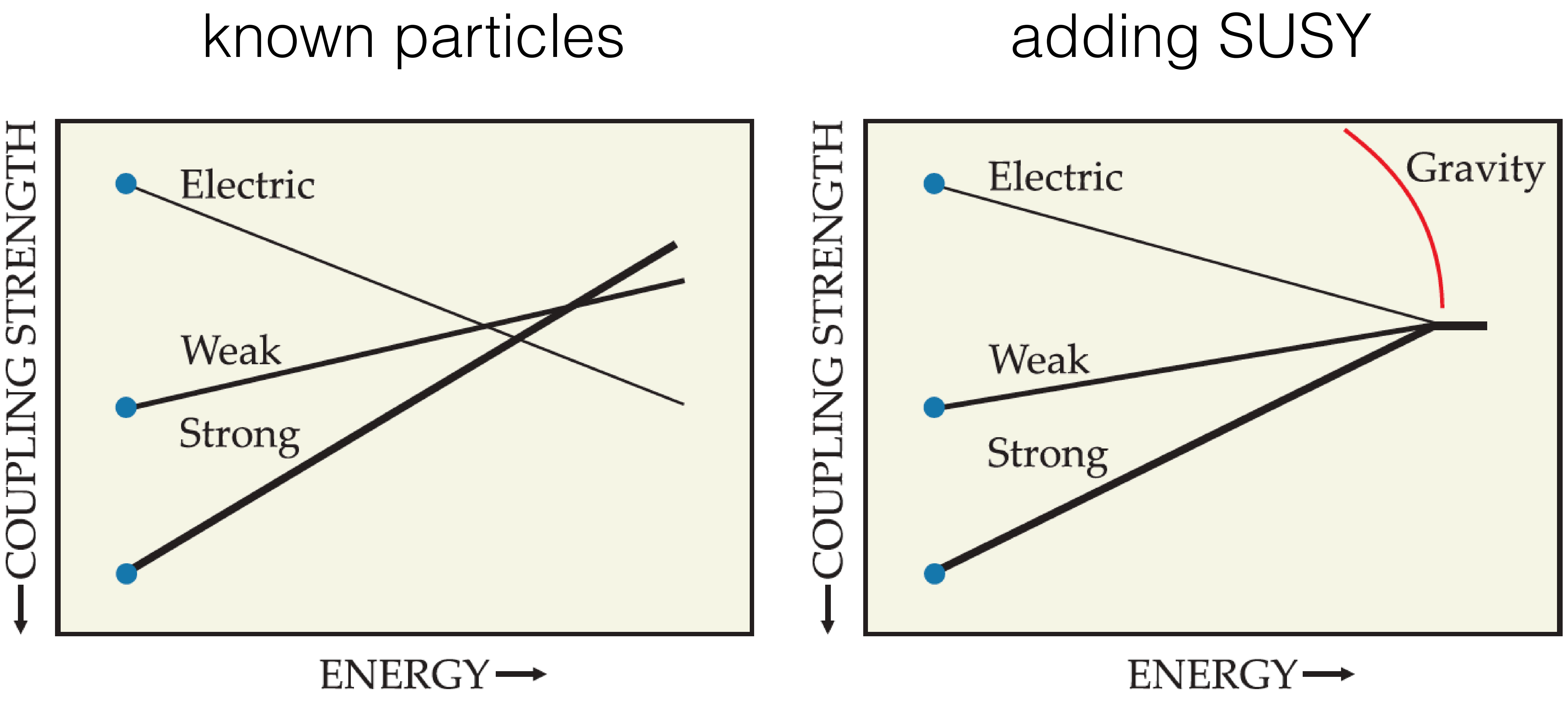


	R	W	B	G	P
u	+	-	-	+	-
u	-	+	-	+	-
u	-	-	+	+	-
d	+	-	-	-	+
d	-	+	-	-	+
d	-	-	+	-	+
u^c	-	+	+	-	-
u^c	+	-	+	-	-
u^c	+	+	-	-	-
d^c	-	+	+	+	+
d^c	+	-	+	+	+
d^c	+	+	-	+	+
ν	+	+	+	+	-
e	+	+	+	-	+
e^c	-	-	-	+	+
N	-	-	-	-	-

Hypercharge Y = -1/6 (R+W+B) + 1/4 (G+P)

SO(10)

One “force”



unification of forces

Low-energy supersymmetry, however, has a lot to answer for:

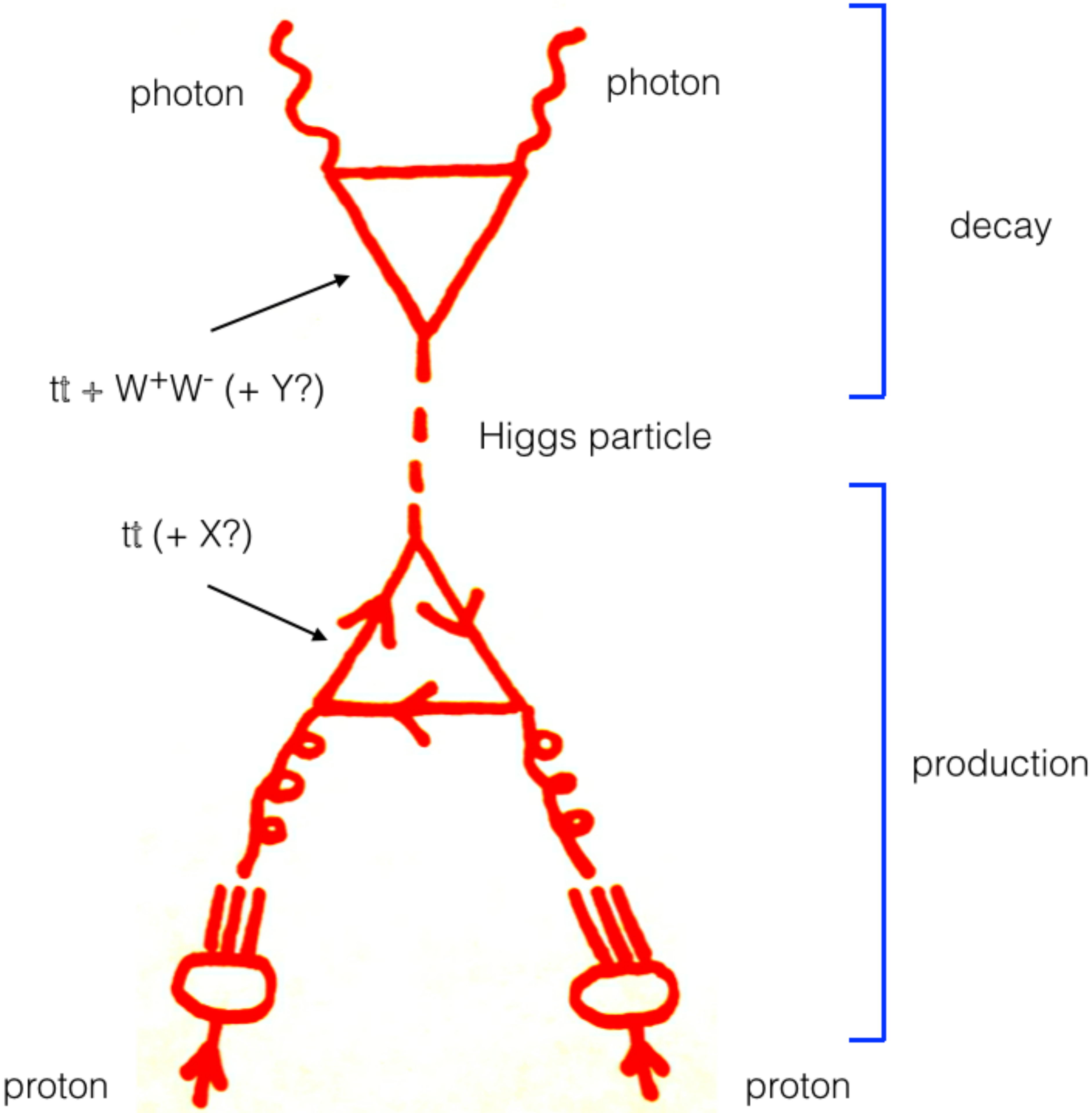
possible proton decay

possible CP violation

“conspiratorial” Higgs structure

New Strong Interactions?

Recall how the Higgs particle was first revealed:



photon

photon

decay

$t\bar{t}$ + W^+W^- (+ Y?)

Higgs particle

$t\bar{t}$ (+ X?)

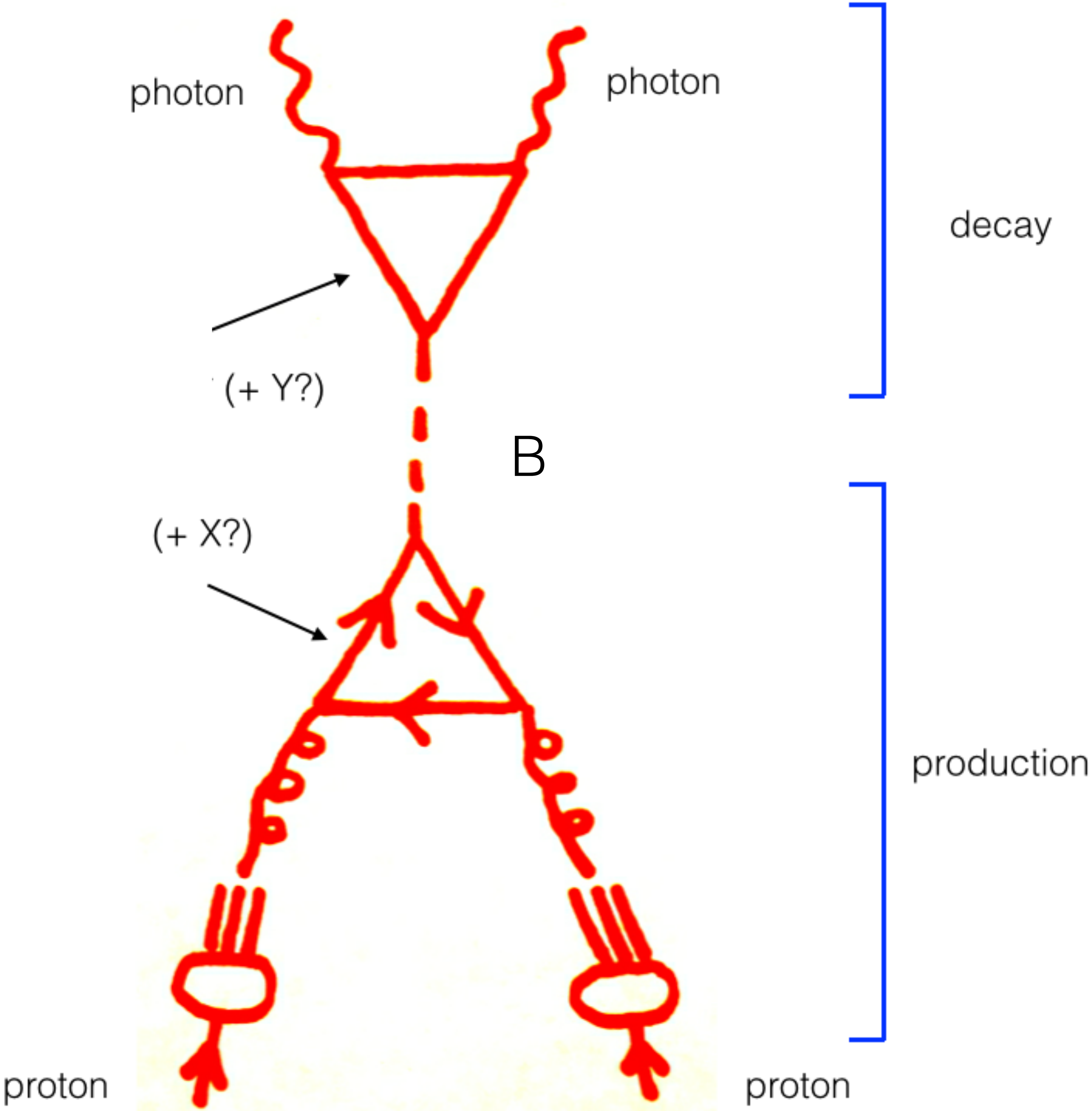
production

proton

proton

While other interpretations may be viable, the most straightforward interpretation of a possible 750 GeV γγ enhancement involves effective couplings of the same Boson-Gaugon-Gaugon (BGG) type, with tree-graph couplings absent, or subdominant.

B could be a meson bound by a new strong interaction, where the “hyper-quarks” also carry SU(3)xSU(2)xU(1) charges.


photon
photon
decay
(+ Y?)
B
(+ X?)
production
proton
proton

Models of this kind appear extravagant, but they can be *consistent* with coupling unification, if the new structures form complete SU(5) multiplets.

Alternatively, “lopsided” models of this kind might fix the unification without introducing supersymmetry. But this requires that they be lopsided in just the right way.

My view: If B persists, the gods have been toying with us.

Flavor Physics and Higgs Couplings

Our core theories contain three kinds of nonlinear couplings:

- gauge gold
- gravity gold
  - cosmological term BIG embarrassment
- higgs
  - gauge gold
  - fermion Yukawa (masses and mixings) shambles
  - self coupling (including *bare mass*) embarrassment

The Higgs mass^2 is the only subcritical (superrenormalizable) term in our core Lagrangian. It can support expansion: It is, plausibly, a *portal* to new physics.

Possibilities include mixing with other scalars, including “hidden” (SU(3)xSU(2)xU(1)) sectors, or the many neutral scalars of supersymmetry.

For experimentalists: It is important to check the apparent minimality of Higgs couplings.

For theorists: It is important to anticipate deviations.

T and Its Breaking

Great puzzle: Why T?

Why approximate T?

Kobayashi and Maskawa mostly nailed it, but they left a loose end: color E·B (θ term).

That interaction, if present, induces an electric dipole moment for the neutron.

One calculates $| \theta | < 10^{-10}$ - very “unnatural”.

There are prospects for measuring the electric dipole moment of the *proton* at an accelerator, adapting techniques previously used to measure the muon g-2.   One might gain several (3?) orders of magnitude in sensitivity.

This could increase the pressure on supersymmetry …

and also get close to predicted axion residuals.

Axions

To address the θ problem, one can introduce a new symmetry*, the Peccei-Quinn (PQ) symmetry*.

PQ symmetry* must be spontaneously broken, at a large mass scale F.

That symmetry* breaking leads to a new particle, the *axion*, with remarkable properties.

The properties - and early-universe production - of axions depend on F. For a wide range of F values - $F > 10^{11}$ GeV - axions provide the dark matter.

(Experimental constraints yield $F > 10^9$ GeV)

Detecting the axion background is very challenging, but far from hopeless. (Cf. gravity waves).

There are brilliant initiatives responding to the challenge: ADMX, CAPP, CASPr, abracadabra …

Quantum Questions

Einstein is reported to have said “Insanity is doing the same thing over and over, and expecting a different result.”

By that criterion, LEP was a *very* insane enterprise.

Particle physics is definitely, in Sidney Coleman’s phrase, “Quantum Mechanics in Your Face”.

Can we access / exploit the more subtle aspects of quantum theory?

Can we identify Bell and GHZ - like phenomena in existing data sets, differently analyzed?

Are there entangled structures in jets? In protons? Propagating out of collisions?

… ?

Ultimate Questions

$$[x_j, p_k] = i\hbar\,\delta_{jk}$$

$$[T^a, T^b] = i f_c^{ab}\, T^c$$

The world simply is.

In my consciousness
Tethered to my brain and body
Fleeting images come to life -
Of the world, samples only.

The world simply is,
It does not happen.