Why are we here?

Yuval Grossman

Cornell

Outline

- Introduction
- Why we think there is NP?
  - Data
  - Theory
- A different view on the hierarchy problem
- Instead of conclusions: What is our goal

Introduction

A lame joke

A lame joke

Why are we here? In order to find out why we are here

A lame joke

Why are we here? In order to find out why we are here

- This is not just a lame joke, it is really the reason we are here
- We like to find the very basic laws of physics that explain the world
- More generally, we try to see how we can move forward with all the constraints

This is really a big deal!

Few things we all know

- There are two ways to find NP
  - Find new states (direct)
  - Find virtual effects of new states (virtual)
- Direct give more information, but limited in reach
- Virtual give more reach, but may not be unique
  - EWP: 10^4 GeV
  - Flavor: 10^8 GeV
  - Neutrinos: 10^{15} GeV
  - Proton decay: 10^{16} GeV
  - CPT and Lorentz violation $> M_{Pl}$

Why do we think there is NP?

Two types of reasons: data and beauty

- Data
  - Dark matter
  - Baryogenesis
  - Neutrino masses (?)
- Beauty
  - Cosmological constant
  - Hierarchy problem
  - Flavor hierarchy problem
  - The strong CP problem
  - All the hints for a GUT

History of physics

Both types of problems led to new discoveries

- Data
  - Black body radiation
  - Constant of speed of light
  - Discovery of the top
- Beauty
  - The periodic table was a hint
  - Charm was predicted based on beauty
  - ...
- At times things are mixed: Relativity was discovered based on beauty and it helped to solve data problems

How to look for the NP?

- Ideally, we will do all the experiments we can and push them up to the theoretical uncertainties
- In practice we need to choose the “best” experiment. We look for what is most
  - Promising to find deviations
  - Interesting/pressing
  - Feasible (money)

The hierarchy problem

Closer look at the “beauty” problems

- Cosmological constant
- Hierarchy problem
- Flavor hierarchy problem
- The strong CP problem
- All hints for GUT

Q: Which one of these problems is more “pressing”?

Most common answer: the CC, because it involves a 10^{120} fine tuning and we have no theoretical idea

The hierarchy problem (yet again)

- The Higgs mass gets radiative corrections
- They are very sensitive to the cutoff, $m_h^2 \sim \Lambda^2$
- Since in the SM $\Lambda \sim M_{Pl}$ we see that we need to "fine tune" the tree level mass and the loop mass
- Why the electron mass is so small?
  - Set and forget!
- Why the Higgs mass so small?
  - Set and set and set...
- Hierarchy problems are "set and forget". Fine tuning problems are those that we cannot do it

Which type of problems are harder?

OJ Simpson and the hierarchy problem

What are the “promising” problems

- Problems are hints for something deeper
- All these hints give the same “probability” to find NP

$$1 - P \approx 1$$

- The hierarchy problem is different as the scale associated with it is the weak scale
- GUTs also have a scale, but the GUT scale cannot be probed directly
- The flavor problem does not have a scale associated with it

What is more “interesting”?

Are there problems that are more interesting?

- People like different colors and flavors
- We all agree that any clear deviation from the SM will be very interesting
- We do not need, or want, to say which experiment is more interesting

Bottom line: We think there is NP, but we are not yet know what it is

How do we look for NP?

What is the ultimate experiment?

We define

$$R_{NPC} \equiv \frac{\text{Prob to find NP}}{\text{Cost}}$$

- We like to do an experiment with high R_{NPC}
- In practice there are complications. There is a bound on the denominator, and we do not know the numerator
- Can we tell what is R_{NPC} for each item in the list below?
  - NSI in ν
  - Proton decay
  - SUSY at the LHC
  - ...

A quote from a wise person

- Of course we always try to get the very best, but what if we do not?
- A quote (free translation and modifications)

  "I was unable to write these seminal papers, unless I wrote all my other others. I need to keep on moving"
- In other words, what we care about is not to maximize $R_{NPC}(t)$ but we need to maximize the integral over a long time
- What is long? We need to identify the right time scale!
- What do you think?

Back to Snowmass

- We want to keep HEP running in the world, and in the US in particular
- This is politics, but the physics motivation is clear. We do good and we need to go on
- There are so many really nice experiments planed, and it is not clear which ones to choose
- So many possible NY times titles:
  - ... found that the proton is not stable
  - ... found new space dimensions
  - ... found that the electron is not fundamental

The last word

We need to think together

The three “frontiers” are only labels. We need to work together to be able to get deeper understanding of Nature

$$A + E + I = U \ (\neq O)$$