Kickoff Meeting!

EFO2 EW Physics: Higgs as a portal to BSM Physics

Isobel Ojalvo (Experiment) and Patrick Meade (Theory) - 5/15/20

Who are your topical conveners?

Isobel Ojalvo

CMS experiment

Princeton University

Patrick Meade

Yang Institute for Theoretical Physics

Stony Brook University

Our goal today

- Review the Snowmass Process
- What our group is and how it relates to others
- Why are we doing this and what do we want from you?
- Some examples
- Discussion/Questions! (Raise your hand or type in chat)

The Snowmass process

- An opportunity for the entire HEP community to come together to create (and document) a vision for the future of particle physics for the US and international partners
- This is a study group - "Science First!"
- The report will serve as input to P5 (Particle Physics Project Prioritization Panel) that formulates a 10-year plan (20-year vision) for the US (within funding constraints)

The Snowmass process (cont)

- Last Snowmass took place 2012-2013: snowmass reports, P5 report
- The aim again is to produce a report documenting our scientific vision
- To make this effort a success: Widely engage the community, hear ideas from everyone, (see snowmass young), let's be ambitious!

The Snowmass: Energy Frontier

Snowmass divided into 10 frontiers

Energy Frontier
Neutrino Physics Frontier
Rare Processes and Precision
Cosmic Frontier
Theory Frontier
Accelerator Frontier
Instrumentation Frontier
Computational Frontier
Underground Facilities
Community Engagement Frontier

Electroweak Physics:
EF01: Higgs boson properties and couplings
EF02: Higgs boson as a portal to new physics
EF03: Heavy flavor and top-quark physics
EF04: Electroweak precision physics:

QCD and Strong Interactions:
EF05: Precision QCD
EF06: Hadronic structure and forward QCD
EF07: Heavy Ion

BSM Physics:
EF08: Model-specific explorations
EF09: More general explorations
EF10: Dark-matter at colliders

Confused? Unsure where your idea belongs?
Please write to us and we'll be happy to confirm or direct you to the right people!

Energy Frontier divided into 10 topical groups

What's the charge of this topical group?

Higgs as a portal to BSM Physics

- Note for theorists… this isn't just the Higgs portal, although if you were at EF10 yesterday it's also part of our work too
- More generally if it has a Higgs and is connected to BSM physics it's related to our work, hence our email mailing list name the EF conveners gave us

SNOWMASS-EF-02-BSM_HIGGS@FNAL.GOV

What's the charge of this topical group?

Higgs as a portal to BSM Physics

- What are some of the big questions?
  - Is there something more to EWSB?
  - Is there a solution for the naturalness problem?
  - Higgs and EW phase transition
  - Higgs and Flavor
  - Higgs portal...

But what about?

EF01: EW Physics: Higgs Boson properties and couplings

- Well if you have any deviation from the SM it's BSM Higgs so… EF01 is a set of measure 0 (just kidding!)
- However it's not so simple to delineate, the EF conveners have tried to set up rough delineations but there's a ton of overlap
  - E.G. EW phase transition, implicitly is all about triple Higgs couplings/Di-Higgs but "phase space" of interest may differ

Luckily... EF01 and EF02 are all of Higgs

So between the 2 groups we hope to have

4π coverage

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4π coverage

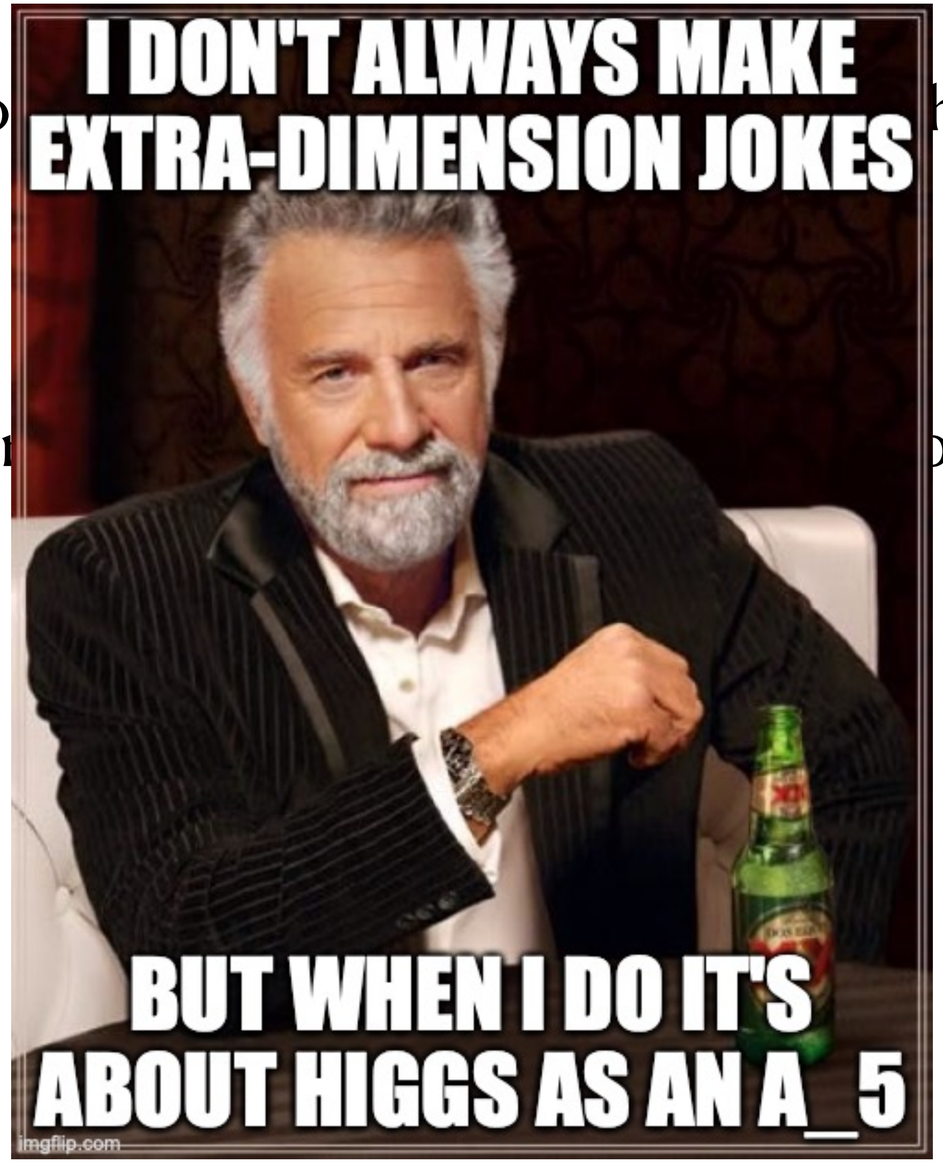
or if Higgs is part of a extra dimensional d+1 representation...

$$\frac{2\pi^{d/2}}{\Gamma(d/2)}$$ coverage

Luckily… EF01 and EF02 are all of Higgs

So have

or onal



Luckily… EF01 and EF02 are all of Higgs

But seriously, if you submit a Letter of Intent (LOI) -

all EF topical conveners see it!

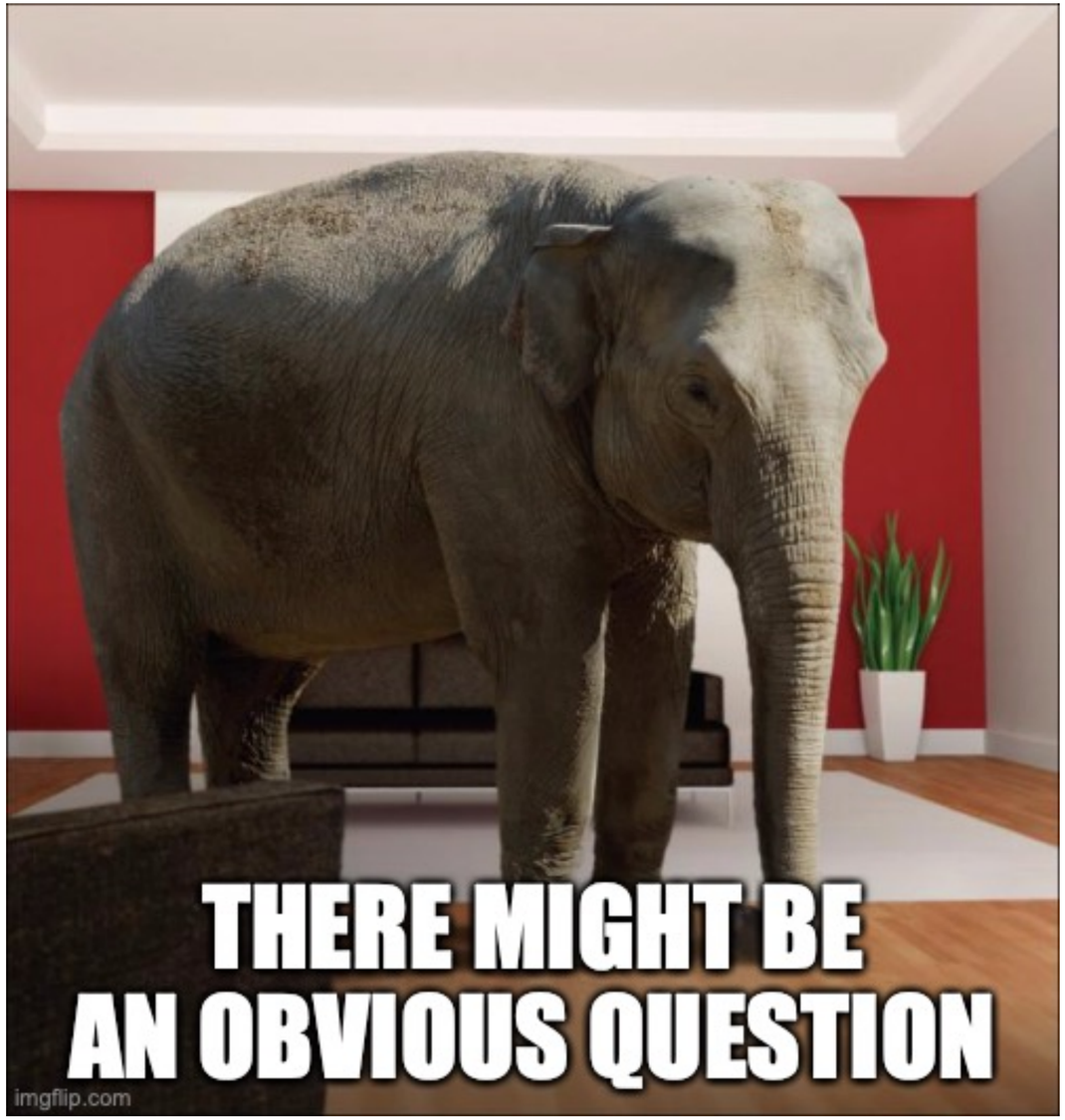
Half of EF02's bi-weekly community meetings

will be joint with EF01 at this point

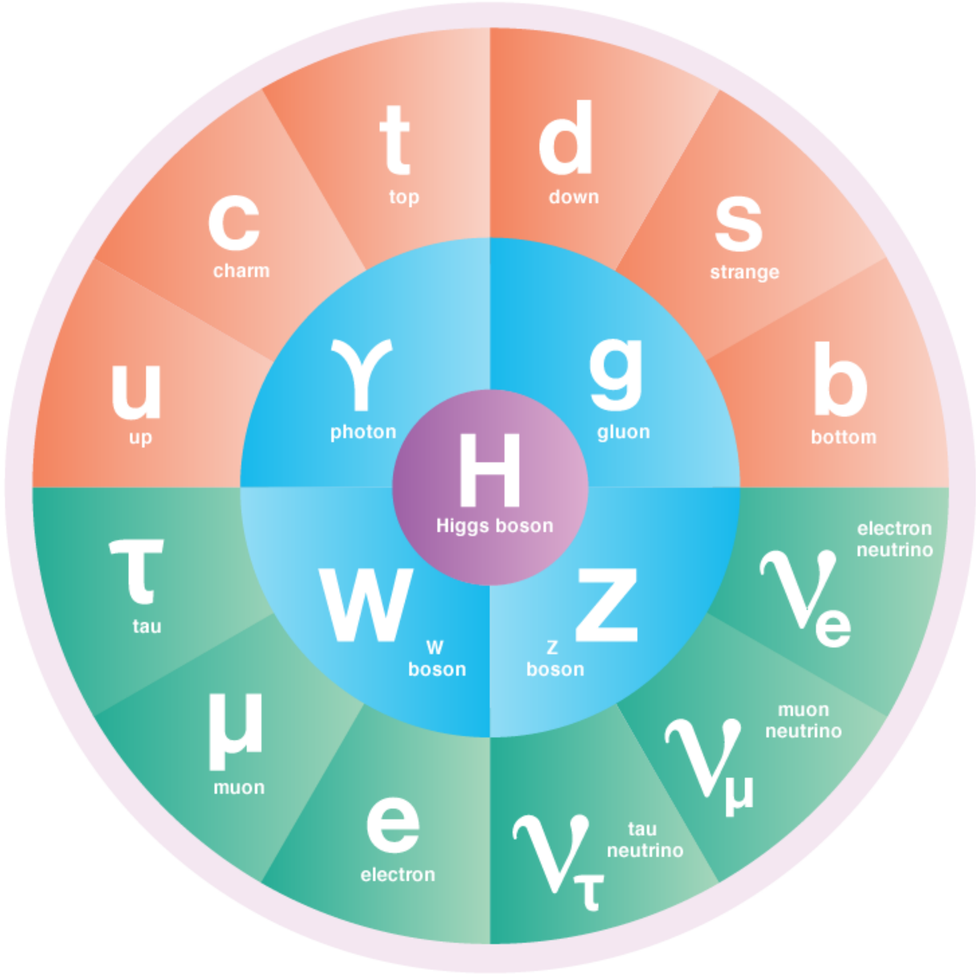
Participate in both as much as possible, and we'll figure out the organizational things for write-ups… the physics is what we're interested in!

Now...

Now...



Since the Higgs is central to everything about the SM



There have been a million studies of it already!

Why are we doing this again?

ESG, yellow papers, white papers, CDRs, TDRs,

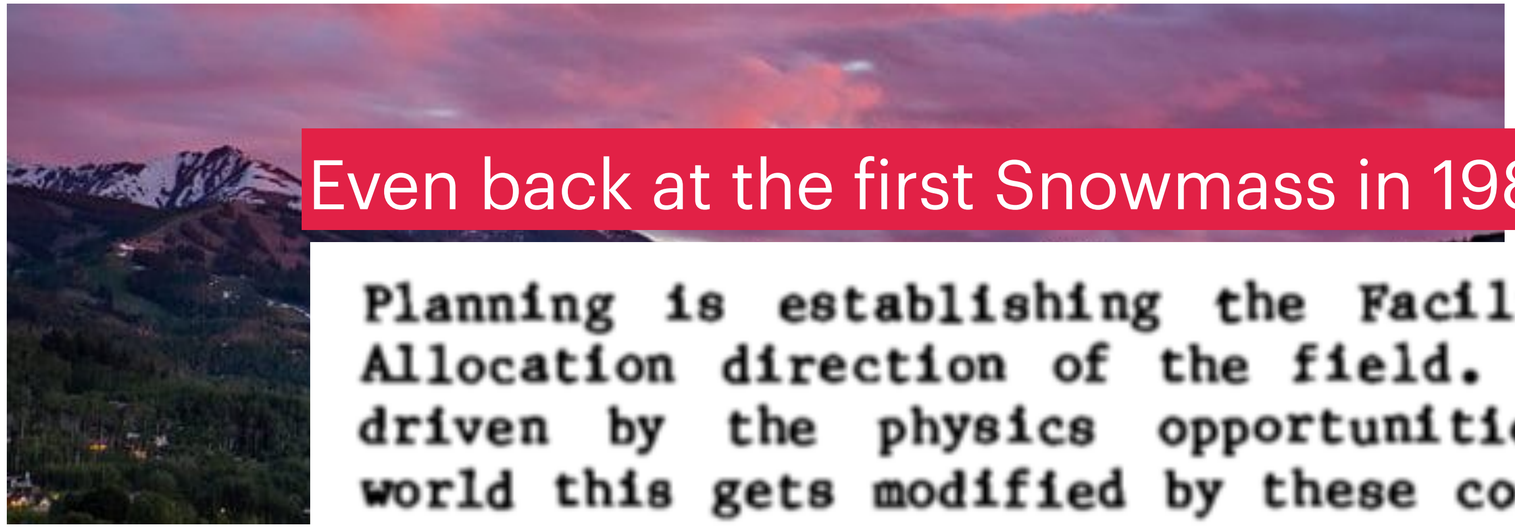
and wasn't Snowmass 2013 just yesterday?

Why are we doing this again?

Why are we doing this again?

P5

Why are we doing this again?



Even back at the first Snowmass in 1982 they understood...

Planning is establishing the Facility and Resource Allocation direction of the field. Hopefully it is driven by the physics opportunities; in the real world this gets modified by these considerations:

- money
- pork barrel
- survival imperative (at both laboratory and university group level)
- competition
- geography
- and strong personalities.

Why are we doing this again?

Things can change with more work, e.g. triple Higgs at 100 TEV

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$$hh \to b\bar{b}\gamma\gamma$$

Snowmass 2013

1308.6302

Weiming Yao

8% on triple Higgs 3/ab

Mangano, Ortona, Selvaggi

2004.03505

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Okay maybe a bad example because I've listed statistical only

However *lots* of work has gone into better understanding signal, BGs, systematics etc!

Why are we doing this again?

Things can change with more work, e.g. triple Higgs at 100 TEV

$pp \to hhh \to b\bar{b}b\bar{b}b\bar{b}$

But again *LOTS* of great work
has been put in by FCC-XX, CEPC/SPPC, ILC, CLIC etc
not just for this channel, and recently,
so what is there to do?

8% on triple Higgs 3/ab

2.5% on triple Higgs 30/ab

Okay maybe a bad example because I've listed statistical only

However *lots* of work has gone into better understanding signal, BGs, systematics etc!

Even worse… the USA has no official HEP collider planned

Reflection can bring opportunity

US has no official HEP collider planned

Obviously we want to help guide prioritization of projects through lens of BSM/Higgs

However... nothing stops you from dreaming big!

We of course welcome updates of existing studies!

But we’re also looking for the crazy ideas!


ONE DOES NOT SIMPLY
INVENT A NEW COLLIDER
imgflip.com

although not unprecedented for snowmass...

HADRON HADRON COLLIDER GROUP*

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F. Paige, BNL
E. Platner, BNL
H. Sticker, Rockefeller U.
M. Tannenbaum, BNL
H. Williams, U. Penn.
R. Wilson, Columbia U.

1. Introduction

The objective of this group was to make a rough assessment of the characteristics of a hadron-hadron collider which could make it possible to study the 1 TeV mass scale. Since there is very little theoretical guidance for the type of experimental measurements which could illuminate this mass scale, we chose to extend the types of experiments which have been done at the ISR, and which are in progress at the SPS collider to these higher energies. Initially we chose to call these experiments "bellwether experiments" for reasons of convenience. In the absence of any alternative predictions we assumed that the cross sections for these standard experiments could be obtained either by extrapolating perturbative QCD models of hadrons to center of mass energies of 40 TeV or by extrapolating phenomenological parameterization of data obtained from experiments done in the center of mass energy range of 20 to 60 GeV to 40 TeV. For each bellwether we asked up to what mass (or momentum transfer Q) could a significant (> 100) number of events be seen in 10^7 seconds. While it is unlikely

The *First* Snowmass - 1982

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Snowmass 1982

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Before listing the bellwether experiments chosen, it is appropriate to check in Websters to see exactly what a "bellwether" is. "1. a wether, or male sheep, which leads the flock, with a bell on his neck. 2. a leader of a thoughtless crowd." We hope definition 1 applies.

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They also had their own sense of humor...

Snowmass 1982

Just might take an extraordinary long time to implement...

PHYSICS WITH LINEAR COLLIDERS IN THE TEV CM ENERGY REGION

F. Bulos[†], V. Cook[*], I. Hinchliffe[**], K. Lane[††],
D. Pellet[⊗], M. Perl[†], A. Seiden[Δ], H. Wiedemann[†]

Design Goals

The physics as described in previous sections calls for maximum center-of-mass energies of at least 1000 GeV and possibly above. We will therefore explore the parameters of linear colliders from about 400 GeV up to 2000 GeV. As we mentioned before, the luminosity is limited by the electrical power available to the collider. In this study we have arbitrarily assumed a maximum electrical power of

$$P_{AC} = 100 \text{ MW} \qquad \text{(VII.1)}$$

Snowmass 1982

Yet at the same time, we're still talking O(1)* or less changes to ideas put forth 40 years ago!!

If you don't believe me, check it out:

https://lss.fnal.gov/conf/C8206282/

This goes for theory too....

BEYOND THE STANDARD MODEL

G.L. Kane
Randall Laboratory of Physics, University of Michigan, Ann Arbor, MI 48109

M.L. Perl
SLAC, Stanford, CA 94305

In studying physics "Beyond the Standard Model" we have made a number of assumptions. The most fundamental of these assumptions are that it is worthwhile to try to study Beyond the Standard Model even though no one knows what direction will be fruitful, and that such a study will be useful in making decisions about future facilities if choices must be made.

Snowmass 1982

This goes for theory too....

Randall Laboratory

Our plan for this report is then

1. Introduction
2. General Behavior of Particle Interactions At High Energy
3. New Leptons of Conventional Types
4. New Quarks of Conventional Types
5. Deviations from Standard Model Predictions
6. Grand Unified Theories
7. Higgs Physics Beyond the Standard Model, charged Higgs
8. Technicolor
9. Supersymmetry
10. The Flavor Problem
11. Constituent Ideas
12. Anomalous Currents and Interactions
13. Non-standard Objects

Snowmass 1982

This goes for theory too....

BEYOND THE STANDARD MODEL

G.L. Kane

Randall Laborato

Okay certain things we figured out...

14. What if there is no Standard Model Z°?

Another direction in which we might find ourselves is that the standard model is only a low energy phenomenological theory, and the fundamental gauge bosons $W^{\pm}$, Z° do not exist. We should know whether nature is like this within about a year; before then, it may be worthwhile to think a little about what kind of machines would be most useful if we need to choose.

Snowmass 1982

So with many ideas for experiments and theory around for so long, what are our goals/steps?

(suggestions only)

Critically Examine

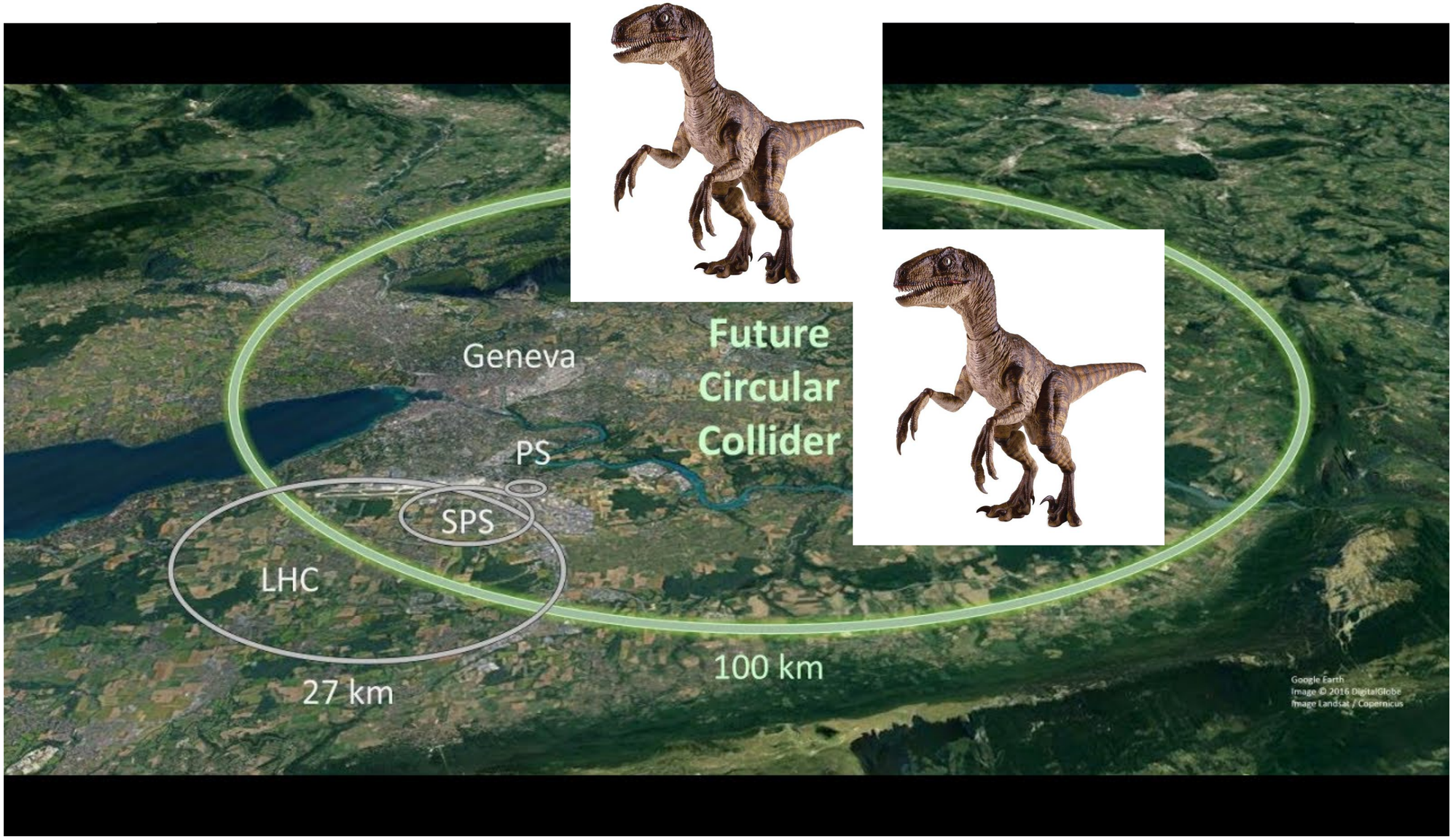
Existing Studies

Help suggest priorities

There's a lot out there...

Reflect about physics goals and targets - have to get hands dirty (Peskin/Mangano)

There's a lot out there...



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New Ideas

Theoretical

Experimental

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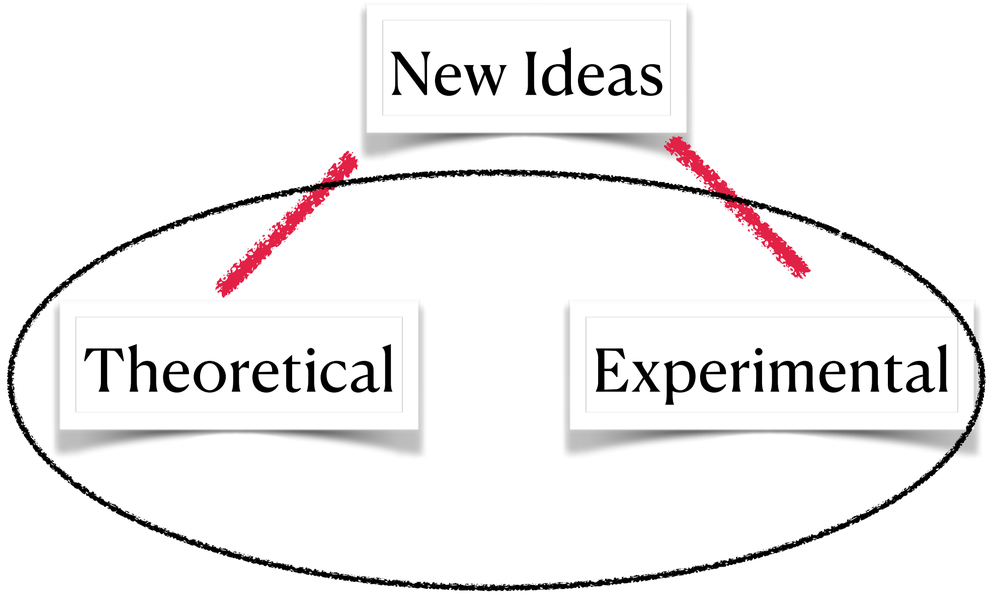


Synergy

Easy to tell you to come up with something new...

Examples???

Easy to tell you to come up with something new...

Examples???

As any parent learns, do as I say not as I do...

Electroweak Phase Transition

Physics Opportunities of a 100 TeV Proton-Proton Collider

Nima Arkani-Hamed[a], Tao Han[b], Michelangelo Mangano[c], Lian-Tao Wang[d]

singlet scalar - Higgs model

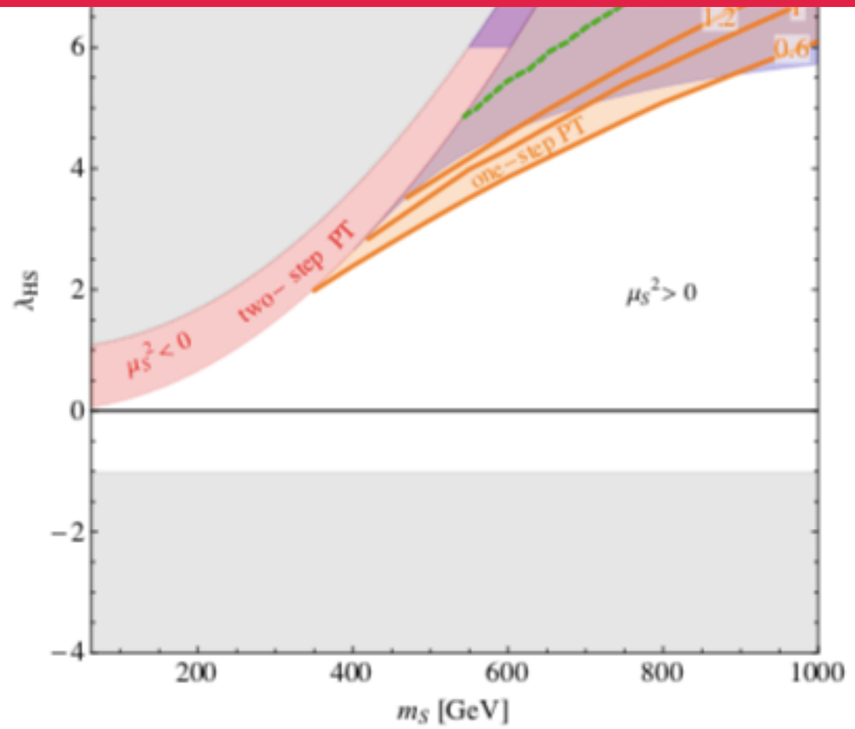


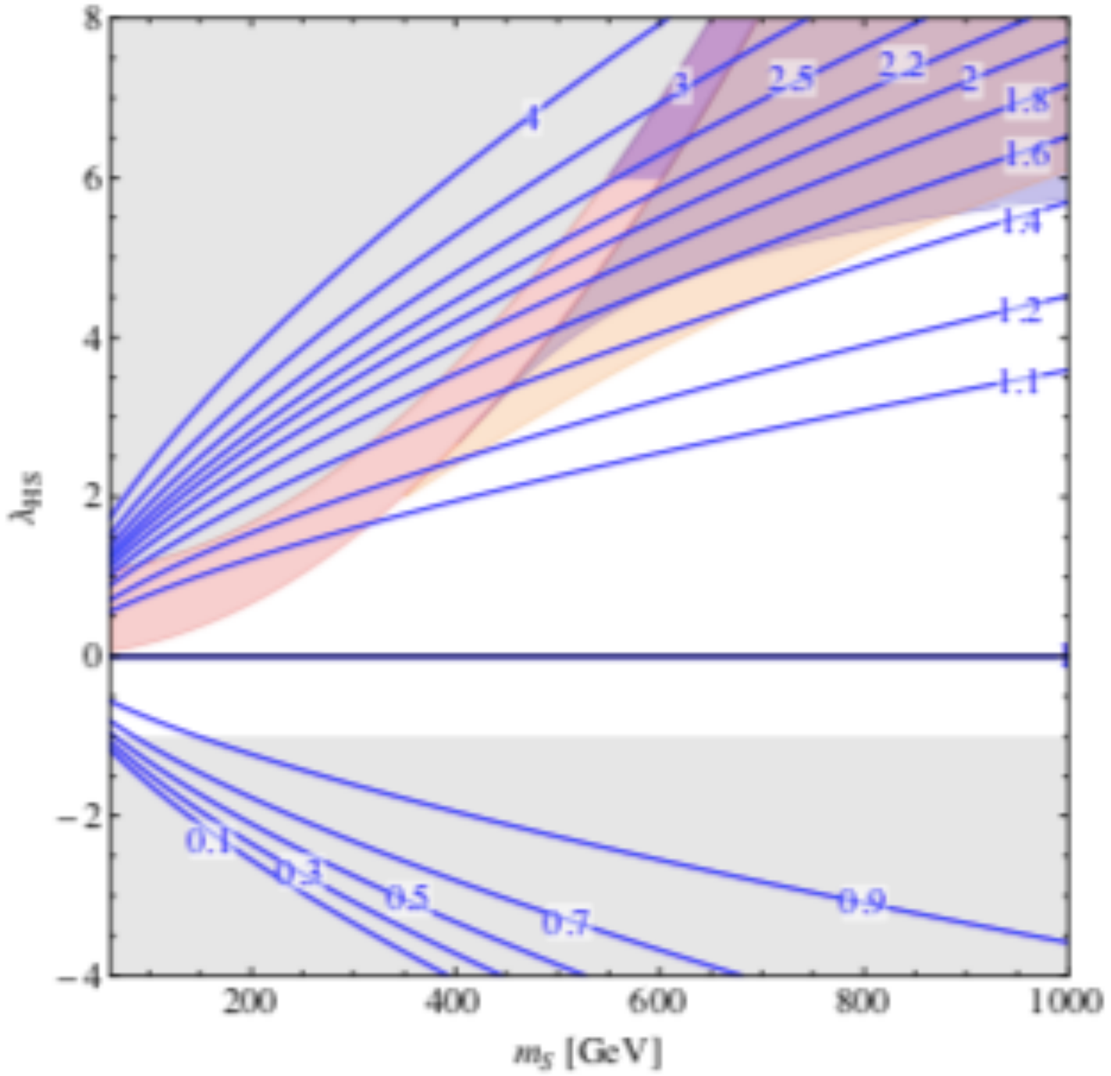
Figure 10: Parameter space with first order phase transition in the Z_2 model [26]. Red shaded region: for $m_S^2 < 0$ (m_S^2 is denoted as μ_S^2 in this figure [26]), it is possible to choose $\lambda_S = \kappa/2$ (in Eq. (12)) to get tree-induced two-step first-order electroweak phase transition. Orange contours: value of v_c/T_c for $m_S^2 > 0$. The orange shaded region indicates $v_c/T_c > 0.6$, where a one-step transition can be sufficiently first-order for electroweak baryogenesis. Above the green dashed line, singlet loop corrections generate a barrier between $h = 0$ and $h = v$ even at zero temperature, but results in the dark shaded region might not be reliable.

singlet scalar - Higgs model

El tion

Phy -Proton

Nima Ar un-Tao Wang[d]



Shift in Triple Higgs as benchmark!

Electroweak Phase Transition - Obvious

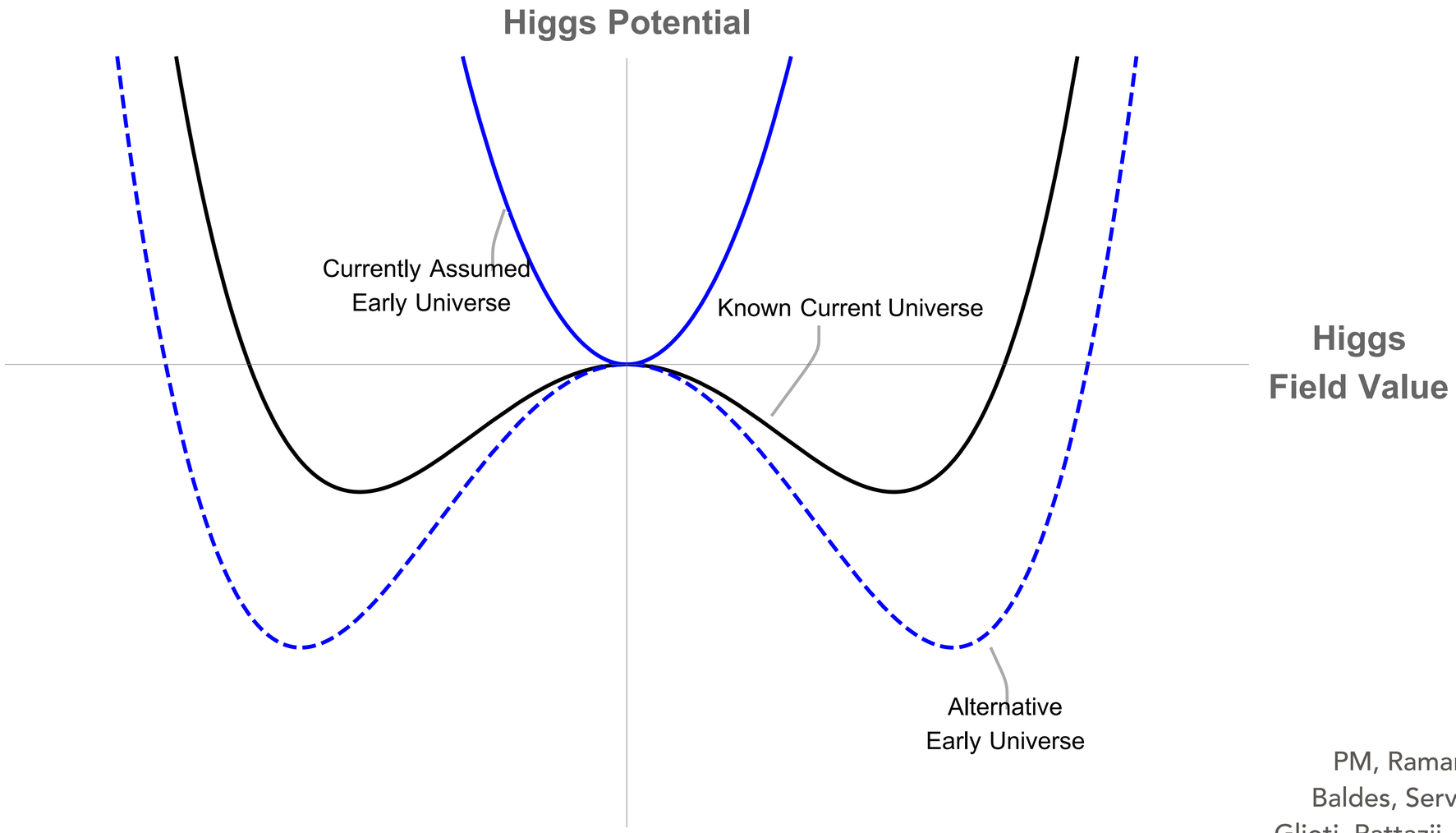
7.1 High-Temperature Symmetry Restoration

One of the most important concepts in modern particle theory is that of spontaneous symmetry breaking (SSB). The idea that there are underlying symmetries of Nature that are not manifest in the structure of the vacuum appears to play a crucial role in the unification of the forces. In all unified gauge theories—including the standard model of particle physics—the underlying gauge symmetry is larger than that of our vacuum, whose symmetry is that of $SU(3)_C \otimes U(1)_{EM}$. Of particular interest for cosmology is the theoretical expectation that at high temperatures, symmetries that are spontaneously broken today were restored [1], and that during the evolution of the Universe there were phase transitions, perhaps many, associated with the spontaneous breakdown of gauge (and perhaps global) symmetries. In particular, we can be reasonably confident that there was such a phase transition at a temperature of order 300 GeV and a time of order 10^{-11} sec, associated with the breakdown of $SU(2)_L \otimes U(1)_Y \rightarrow U(1)_{EM}$. Moreover, the vacuum structure in many spontaneously broken gauge theories is very rich: Topologically stable configurations of gauge and Higgs fields exist as domain walls, cosmic strings, and monopoles. In addition, classical configurations that are not topologically stable, so-called nontopological solitons, may exist and be stable for dynamical reasons. Interesting examples include soliton stars, Q-balls, nontopological cosmic strings, and so on [2].

The cosmological production, and subsequent implications, of such topological defects will occupy much of this Chapter. The possibility that the Universe undergoes inflation during a phase transition will be the subject of the next Chapter. Before discussing topological defects and their production in cosmological phase transitions, we will review some general

Kolb & Turner

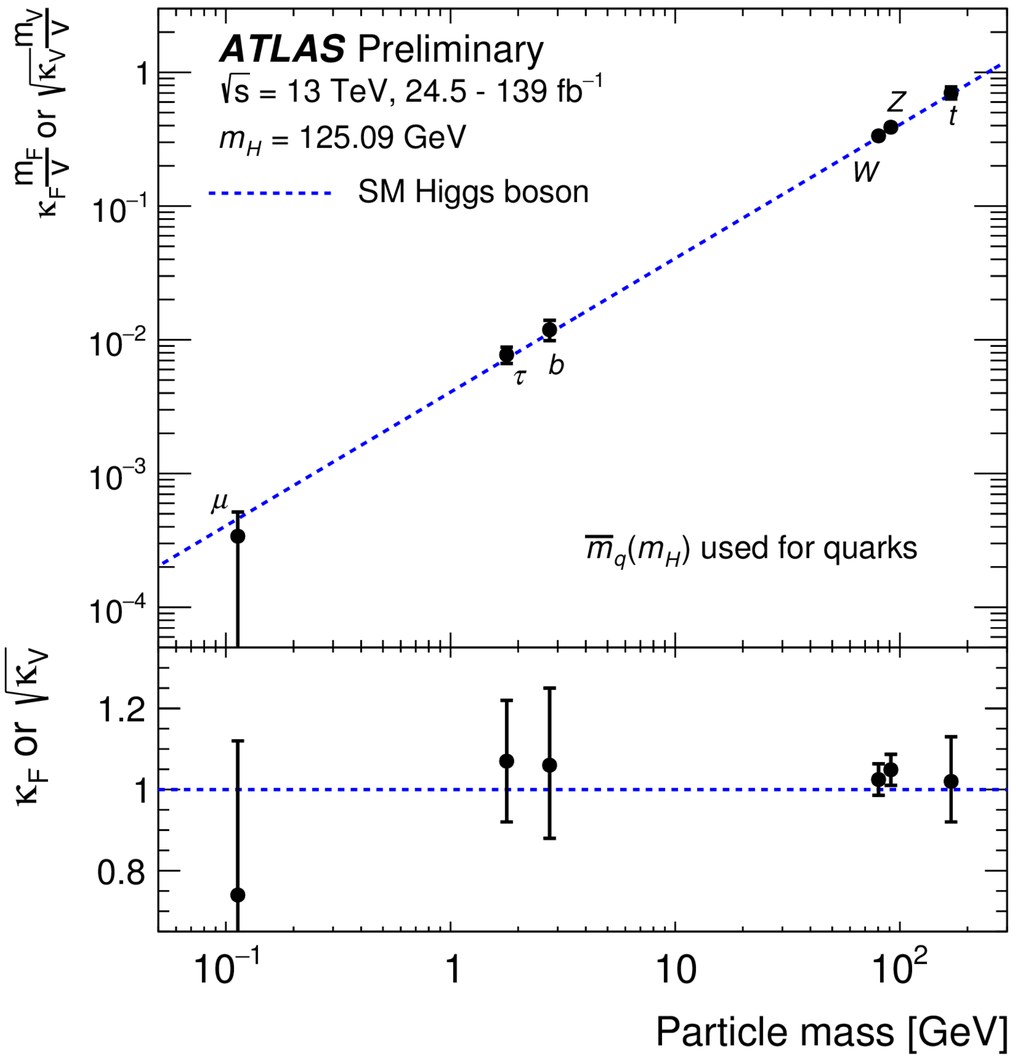
Electroweak Phase Transition - Not at EW scale or ever?



PM, Ramani 1807.07578
Baldes, Servant 1807.08770
Glioti, Rattazii, Vecchi 1811.11740

Triple Higgs benchmarks completely changed, need much higher precision

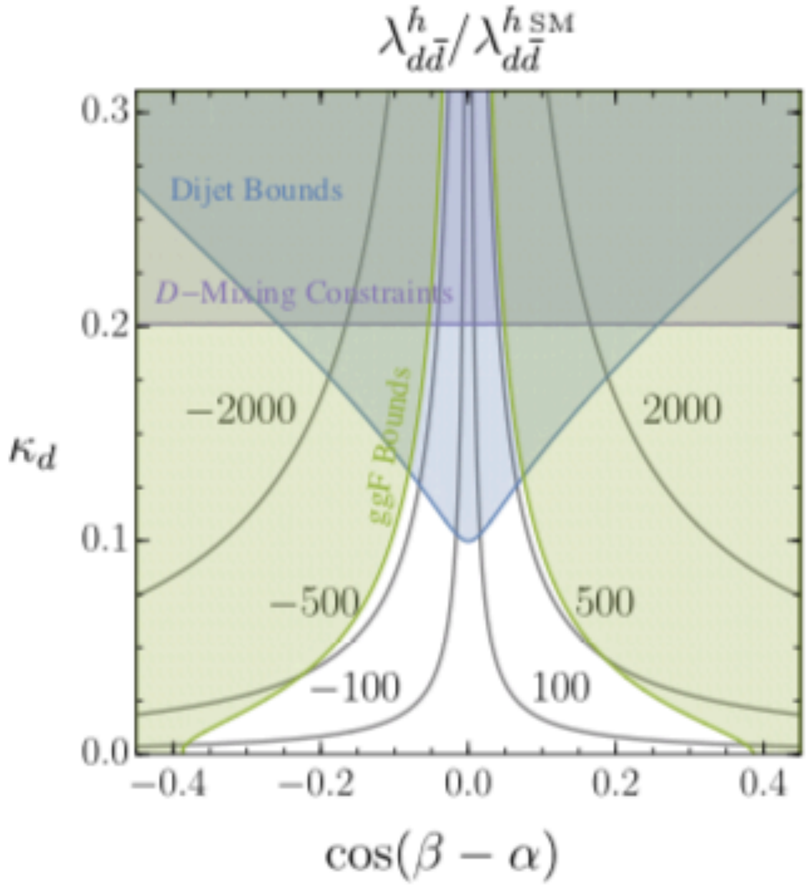
Higgs and Flavor

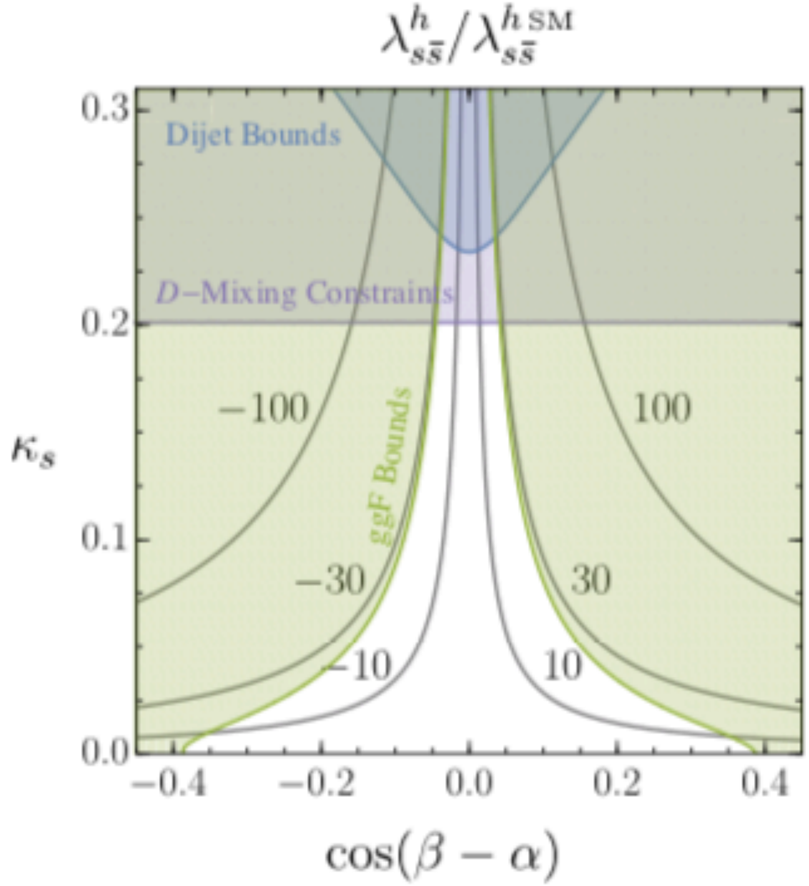


We're used to thinking that biggest deviations should be for heaviest particles

Motivation - MFV and Naturalness

THERE ARE FLAVORFUL MODELS WHERE THE MASS/COUPLING RATIO CAN BE PARAMETRICALLY DIFFERENT, SATISFY CONSTRAINTS, AND OCCUR ONLY IN LIGHT GENERATIONS!





1811.00017 D. Egaña, S. Homiller, PM
1908.11376 D. Egaña, S. Homiller, PM

Those were just 2 quick theory examples...
but qualitatively new things can still exist for Higgs

***and* it can mean new experimental ideas are needed!**

Those were just 2 quick theory examples...
but qualitatively new things can still exist for Higgs

***and* it can mean new experimental ideas are needed!**

Now it's your turn - Snowmass is grassroots!

Pitch the updates, new ideas and everything in between!

Before discussion, nuts & bolts

Communication

Email: SNOWMASS-EF-02-BSM_HIGGS@FNAL.GOV

Slack Channel: ef02-higgs_bsm

Twiki: https://snowmass21.org/energy/higgs_bsm

Meetings calendar: https://snowmass21.org/energy/start#topical_group_pages

How do you get us your ideas?

Email us!

Come to Meetings!

Fill out Google Form for preliminary ideas!

Last but not least, LOI submission!

Tentative Timelines into Fall

May 21st (indico)- Full day Meeting for Energy Frontier (lots of time for discussion across topics)

May 27 (indico to follow) - First Joint EF01 & EF02 Meeting

Summer 2020 (indico) - Alternate between joint EF01/02 and EF02 meetings

July XX- official snowmass meeting with rough ideas?

Fall - FNAL meeting in person? (Possibly hybrid EF02 focus meeting)

Updates will be sent via EF02 email/slack channel/EF02-twiki

Please get us your ideas ASAP, even if it's only half-baked!

Questions/Comments/Discussion

How to benchmark for new physics for BSM Higgs? SPS1A? Models/concepts?

How to organize coverage?

EWSB

Flavor

EWPT

Higgs Friends (singlet, 2HDM, more)

Naturalness

Higgs Potential

Signal based?

Exotic Decays

Higgs Portal

What else?