

# BSM intro

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# Introduction

- **Stochastic gravitational wave signal** from PTA's and **neutrino map of our galaxy** just some of the latest exciting results of *fundamental physics*
- Reminder: these and others previously were *decades in the making*
- **Particle physics** is a core pillar of fundamental science; **FCC** *guarantees exciting results* for decades to come

# Introduction

- How can we **guarantee exciting results** *without a no-lose theorem*?
- **Exploration** and **fundamental measurements** are exciting in themselves: those are our no-lose guarantees
- They tell us *something new about our universe* **regardless of the outcome**

# The open questions for FCC to explore

- What is the **origin of the Higgs**?
- What is the **origin of matter**?
- What is the **origin of flavour**?
- What is the **origin of dark matter and neutrinos**?
- What is the **origin of the Standard Model**?
- What is the **origin of astrophysical and cosmological signals**?

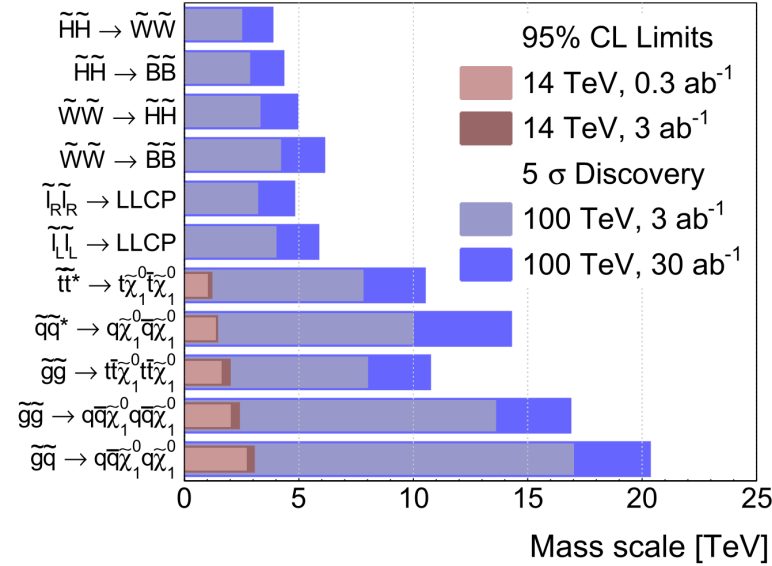
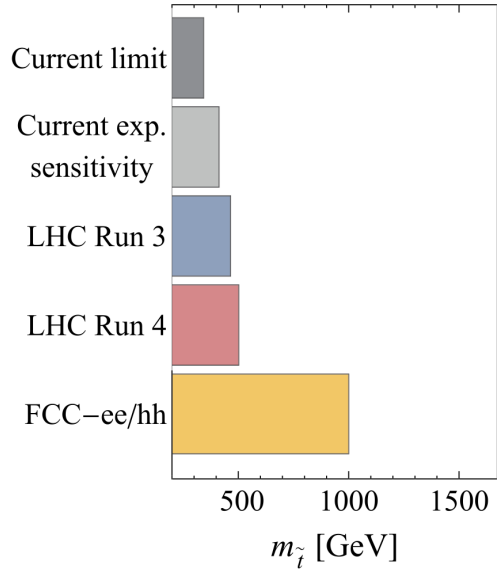
# What is the origin of the Higgs?

- Higgs boson is a new window on fundamental scalar sector
- We understand the origin of EWSB, but seek a deeper explanation of the Higgs itself
- Expect the Higgs to emerge from or be coupled to a deeper theory
- Associated with some of the deepest mysteries in particle physics

# Origin of the Higgs

FCC CDR Vol. 1

**Note:** naturalness aside, still motivation in exploring origin of Higgs in models from which it emerges, where its mass is *calculable*

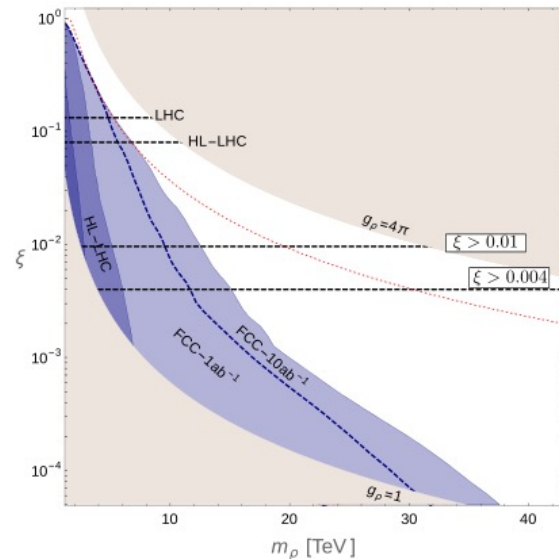
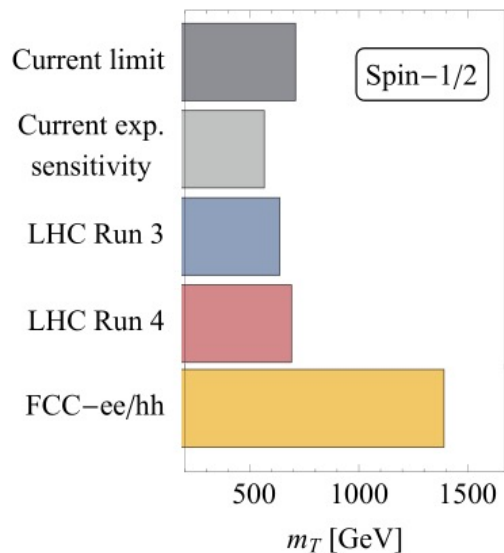


## • Supersymmetry

- Massless spins 0,  $\frac{1}{2}$ , 1,  $\frac{3}{2}$ , 2 *only*
- Spin  $\frac{3}{2}$  *must* be supersymmetric
- (Ir)relevant for solving **naturalness**?

## • Composite Higgs / extra dimensions

- Is the Higgs **elementary** or **composite**?
- Are there *accessible* extra dimensions?

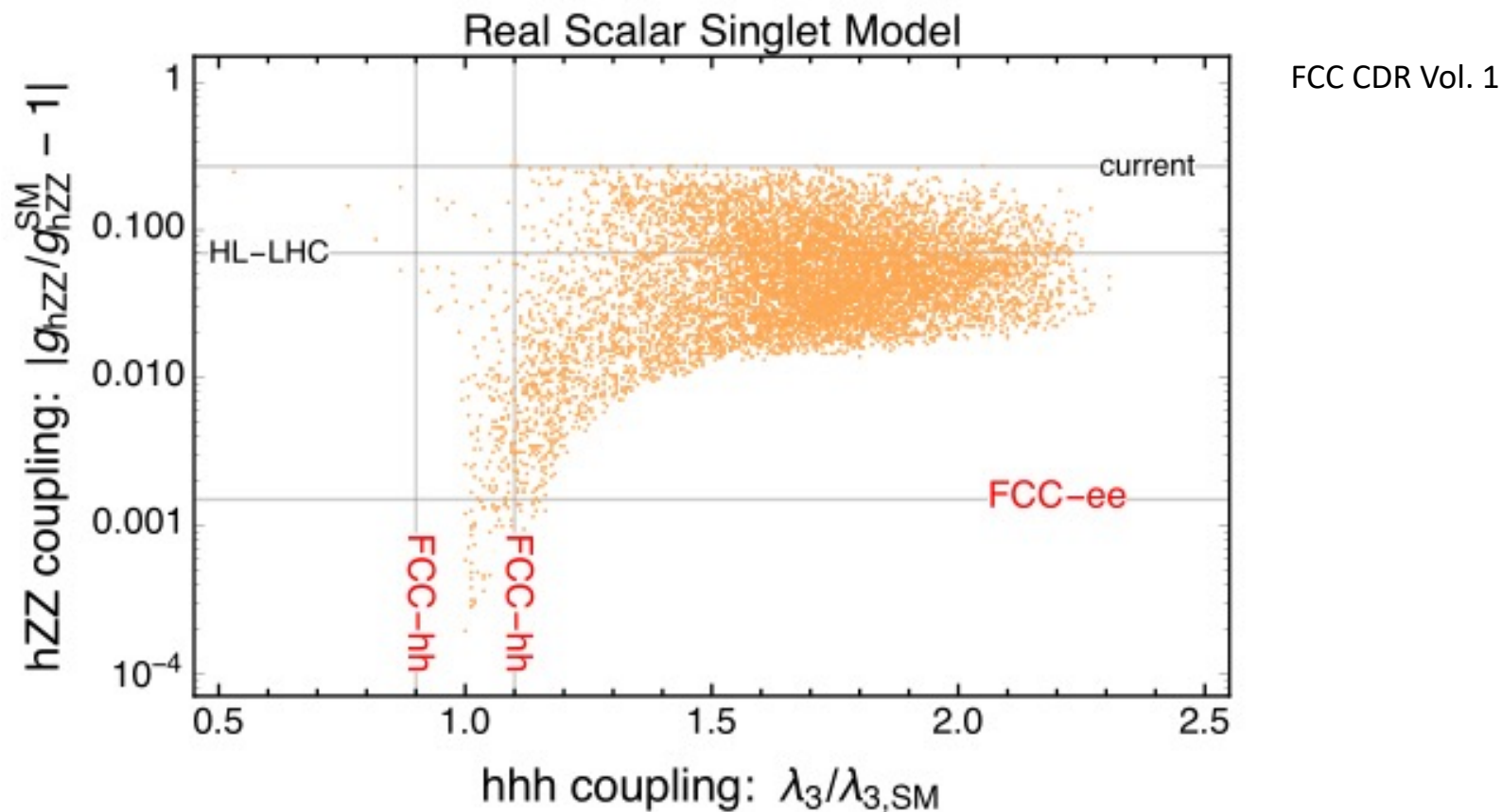


# What is the origin of matter?

- Establishing the nature of the electroweak phase transition is a flagship case for FCC
- Tells us about an important epoch in our cosmological history and whether it had a role to play in determining the matter-antimatter asymmetry
- New sources of CP violation generic in BSM

# Origin of matter

- Nature of the **electroweak phase transition**: *first or second order?*



- *Potential corroboration* with **gravitational wave signal** at LISA

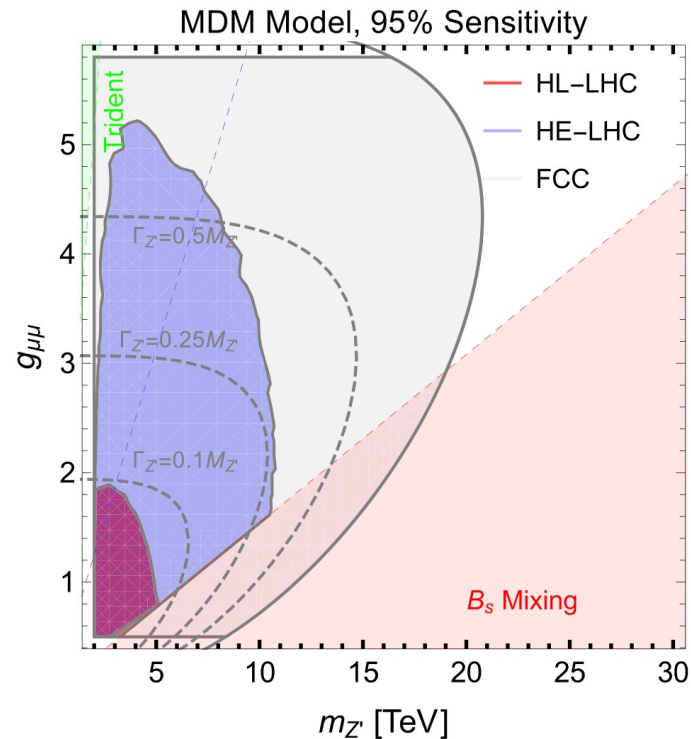


# What is the origin of flavour?

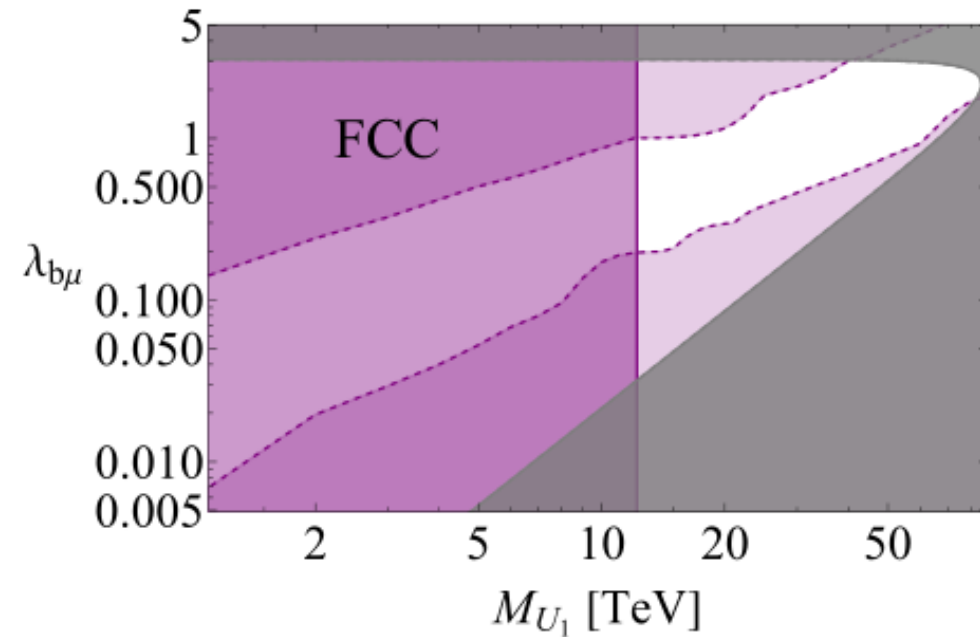
- Don't understand the origin of pattern of Yukawas and CKM
- FCC-ee is a heavy flavour and tau factory
- Improve flavour physics and explore flavour models involving new symmetries and forces
- First- and second-generation Yukawa couplings are targets
- FCC-ee s-channel Higgs resonance?

# Origin of Flavour

- B anomalies may be going away, but flavour still one of **the most sensitive probes of new physics** (*which may or may not be related to the origin of flavour*)



Allanach, Corbett, Dolan, You [1810.02166]



Azatov et al [2205.13552]

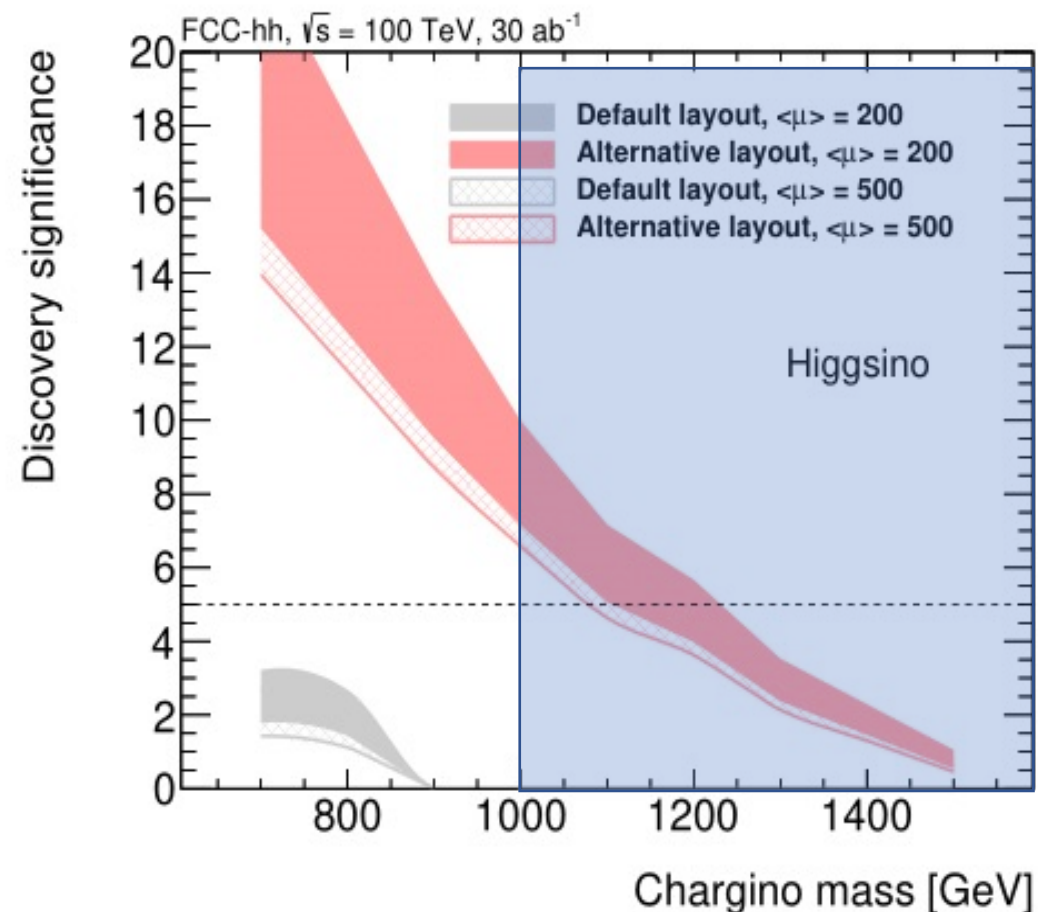
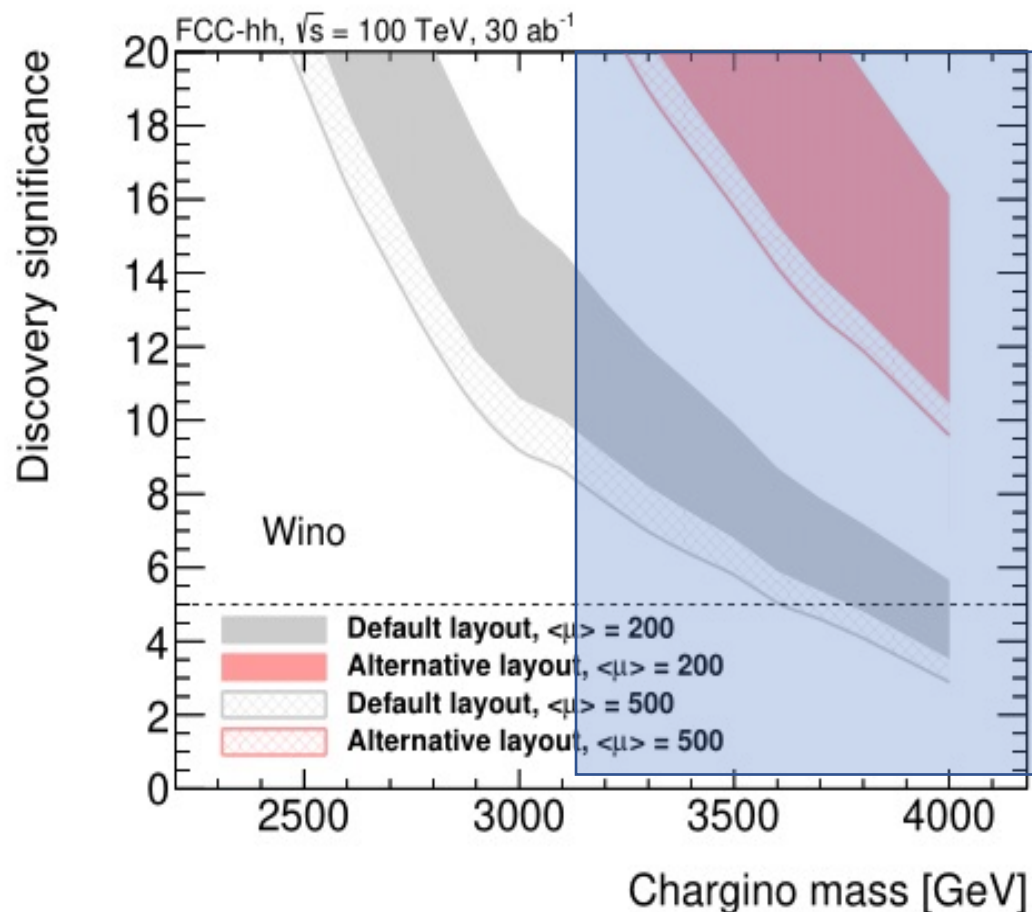
- Shows FCC-hh can probe **directly** most of the range that flavour physics is indirectly sensitive to

# What is the origin of dark matter and neutrinos?

- FCC-ee can explore the dark sector of our universe
- Could harbour dark matter, heavy neutral leptons, heavy axions, dark photons, long-lived particles, ... ?
- FCC-hh uniquely sensitive to TeV-scale WIMPs
- Parasite detectors extends capabilities for neutrino physics, long-lived particles, forward physics

# Origin of dark matter

- Coverage of *entire* **doublet** and **triplet thermal WIMP** mass range



# What is the origin of the Standard Model?

- Generally, the SM is low-energy EFT of UV theory that it originates from
- SM EFT is Fermi theory of the 21<sup>st</sup> century: up to experiment to place bounds and determine EFT cut-off scale
- Wilson coefficients parametrise fundamental interactions at higher scales
- FCC programme is the most powerful general survey of this uncharted territory

# What is the origin of astro/cosmo signals?

- Sources of stochastic GW or high-energy gamma rays may be due to physics only accessible to FCC
- e.g. Electroweak or dark sector phase transition, TeV WIMP annihilation, non-Gaussian signatures of Higgs metastable vacuum
- Corroborating potential signals one of the most exciting possibilities

# Conclusion

- FCC may be viewed as a *general-purpose* **particle observatory**
- **Look inwards** toward smallest scales in **new regimes** of precision and energy
- Objective is to **explore the fundamental origins** of our universe and its laws
  - **Not** to promise new discoveries! *Doing good science is its own reward*
- **Win-win** proposition:
  - **Economically** – return on investment  $> 1$
  - **Societally** – cultural impact, scientific training, inspiration
  - **Physics deliverables** – comprehensive programme of *guaranteed results*