# Physics Prospects @future colliders


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**UK Future collider town-hall**
**6/7/2023**

# What can we hope for the future?

**Lepton Colliders** Cleaner environment

Precision frontier

- can make very precise measurements






**Hadron Colliders** Messier environment

Energy frontier:

- can push energy probed to 10s of TeV


# What do we hope to learn?

https://brve-prod-v1.generations.s3.us-east-1.amazonaws.com/images/665c051f-5540-4f33-b85e-da9ac2a81c36.webp

*Dear Santa Claus,*

*We have been good these past decades. Please could you now bring us*

- *a dark matter candidate*
- *an explanation for the fermion masses*
- *an explanation of matter-antimatter asymmetry*
- *an axion, to solve the strong CP problem*
- *a solution to fine tuning the EW scale*
- *a solution to fine tuning the cosmological constant*

*Thank you, Particle Physicists*

From G. Salam's talk@FCC-week 2023

Any future project will aim to address these questions

No guarantee that answers will be found

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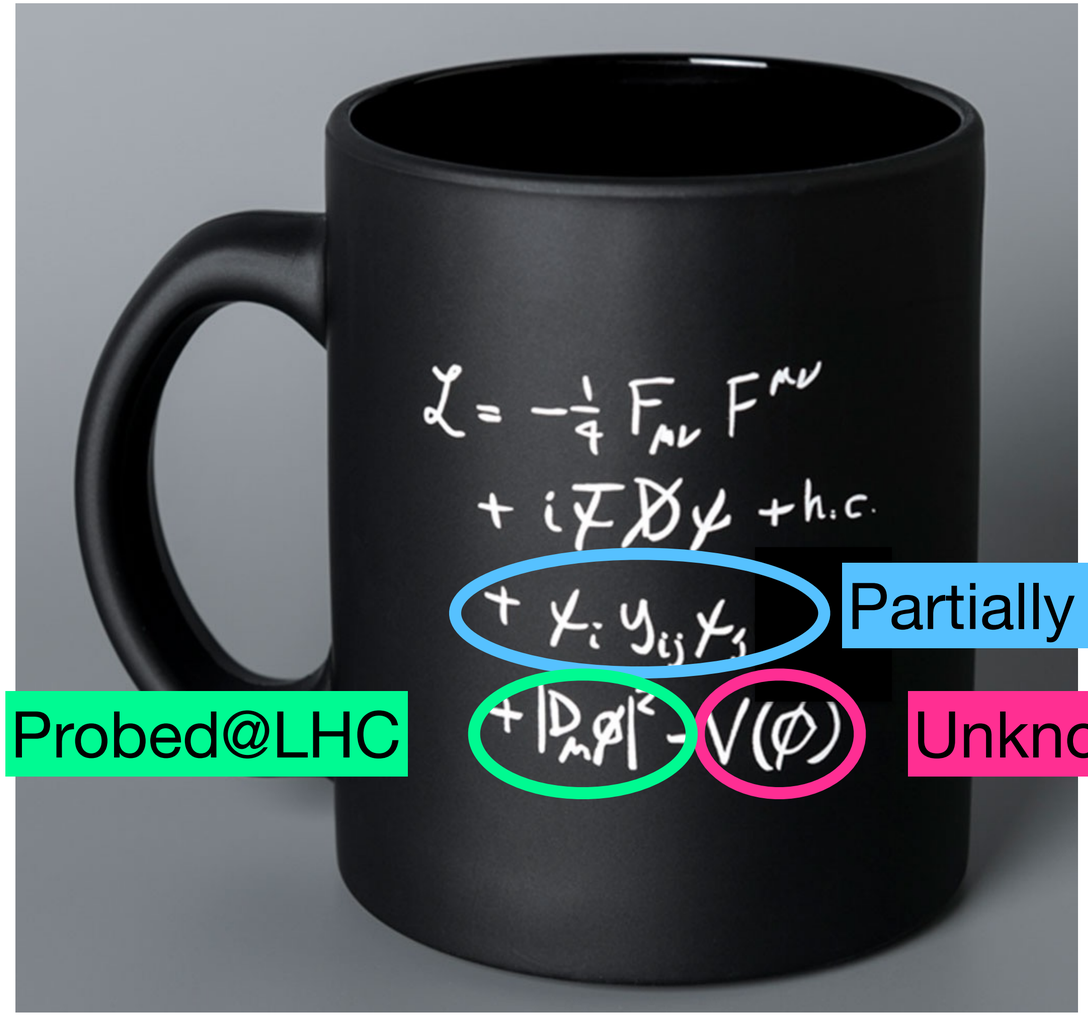
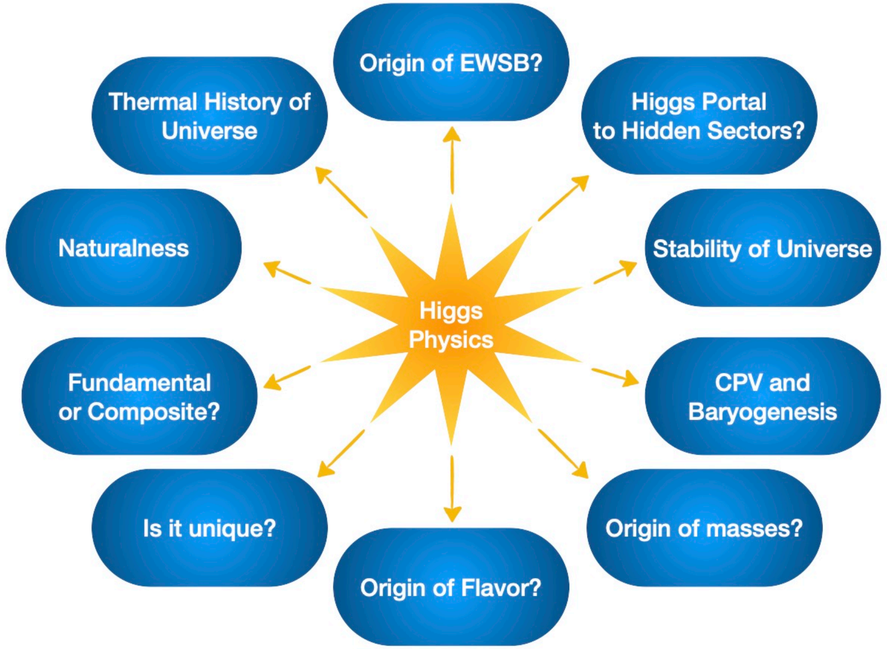
Then why do we bother?

# Are there any guaranteed gains from a future collider?

# Higgs precision

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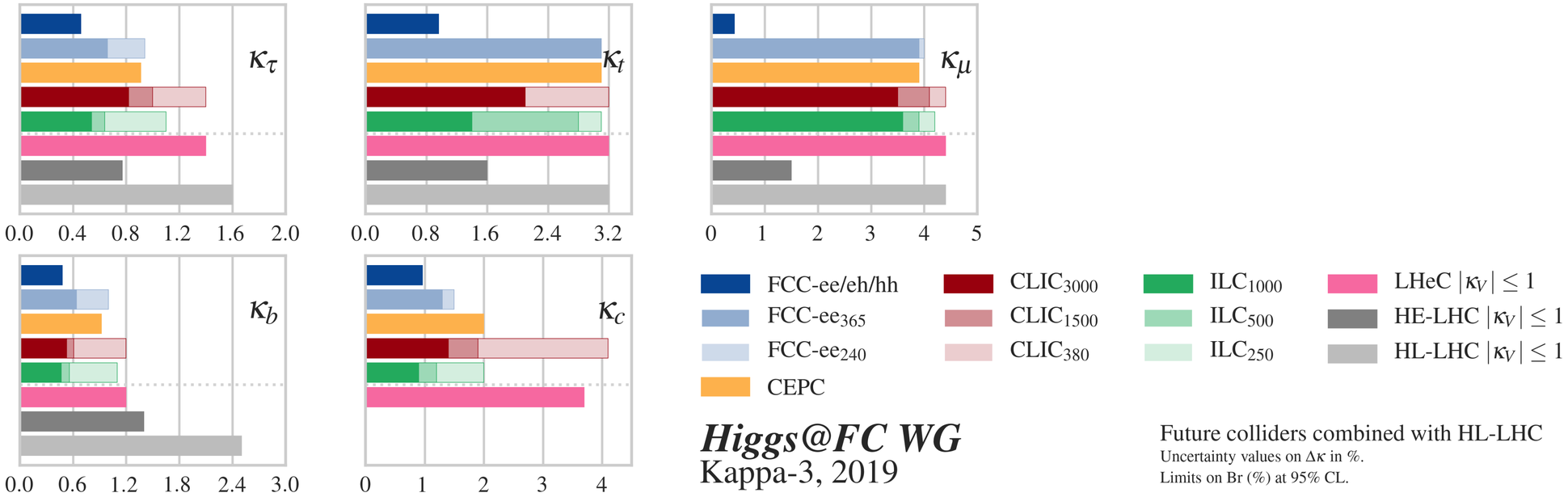
# Higgs: Yukawa couplings

Unprecedented precision expected: below 1% for 3rd generation

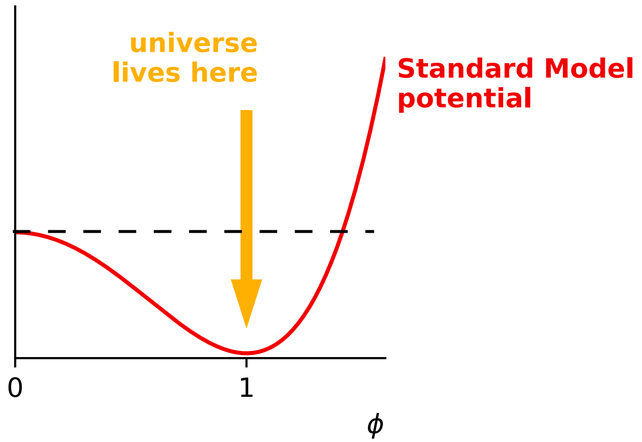


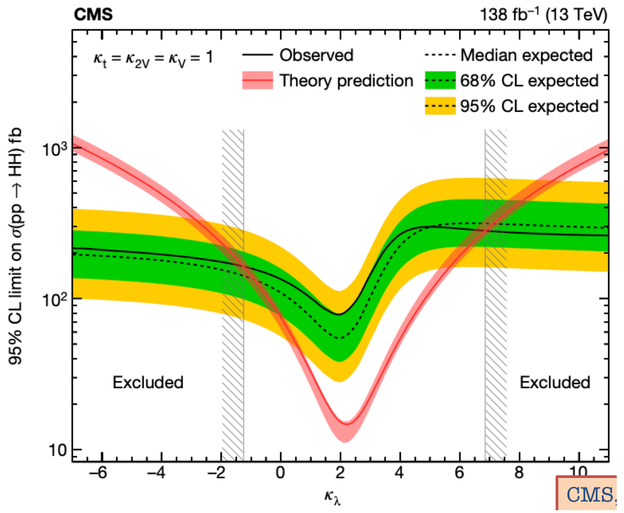

Hope to probe also: electron and strange Yukawa for the first time!

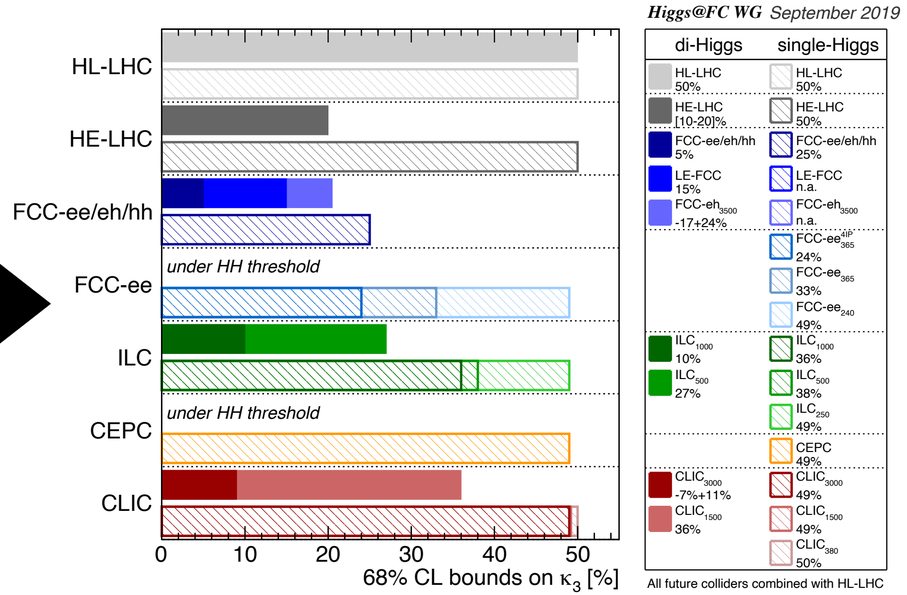
e.g. H to hadrons at FCC-ee (strange), ee@125GeV (electron)

# Higgs potential

$$V = -\mu^2 |\phi|^2 + \lambda |\phi|^4 + V_0 \qquad V = \frac{m_H^2 v^2}{8}\left(-1 + 4h^2 + 4h^3 + h^4\right)$$



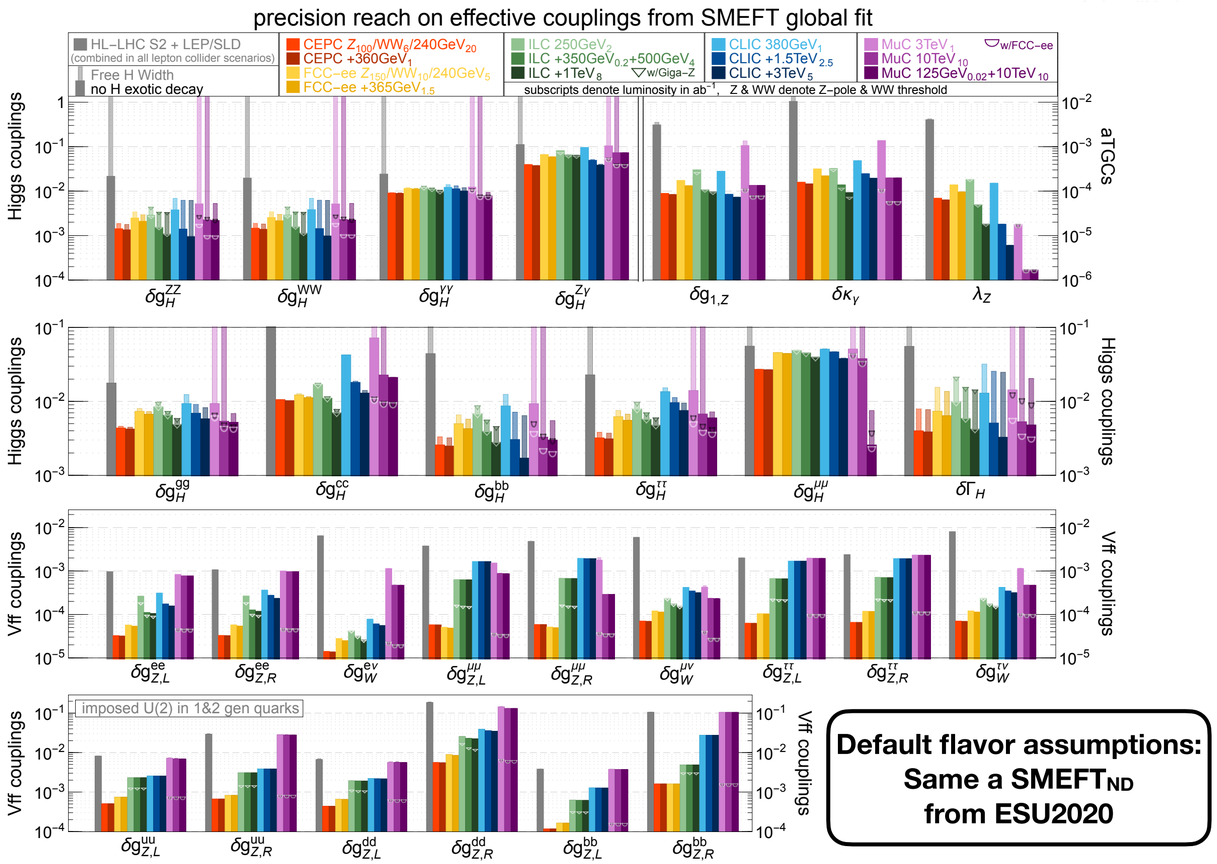




**Now** **Future**

The potential holds the key to: EWSB (and hence masses) and stability of the Universe

# Quantifying our knowledge




**Default flavor assumptions: Same a SMEFT$_{ND}$ from ESU2020**

Snowmass study: arXiv: 2206.08326

⚠ Busy plot: compare grey (HL-LHC) with yellow (FCC-ee) and dark yellow (FCC-ee+365)

- Typically bounds improve by more than an order of magnitude compared to HL
- This is true for both Higgs couplings and Vff couplings

**Precision gives an indirect energy reach!**

# How about new particles?

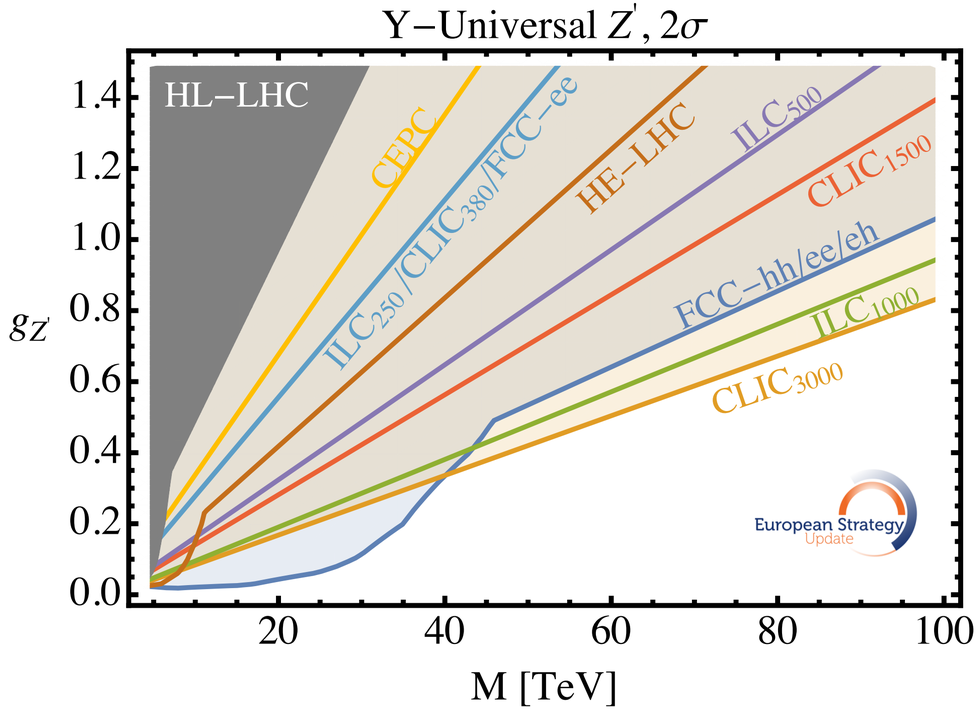
## Example: Z’

LHC
$pp$, 13 TeV, 139 fb$^{-1}$

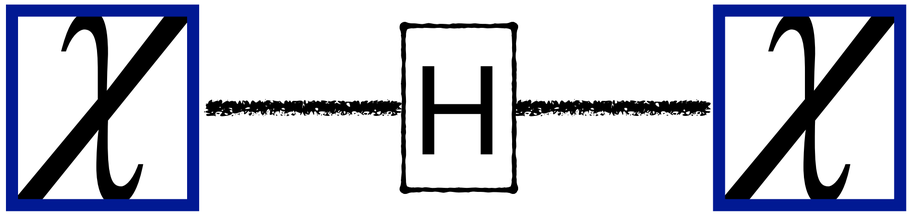
Exclusion limit ~ 5.1 TeV

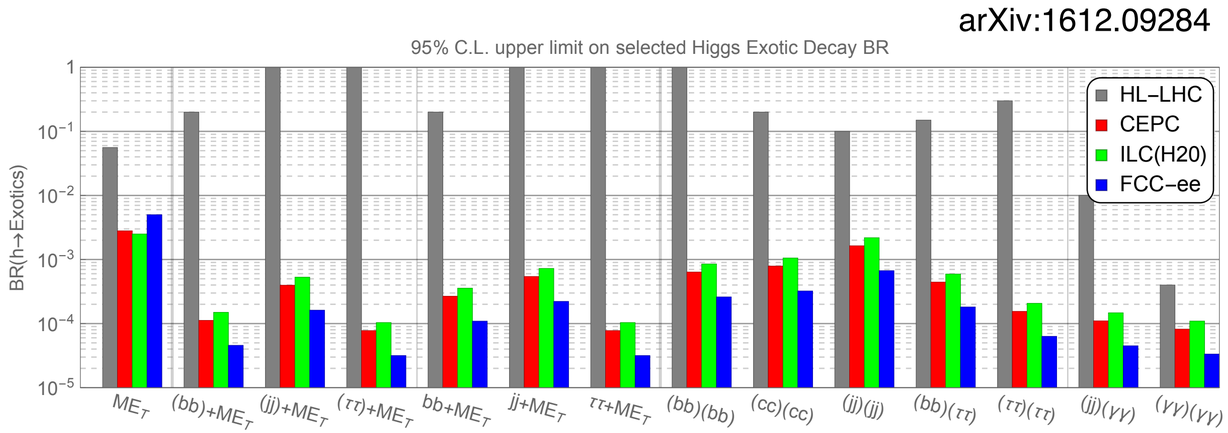
FCC-hh
$pp$, 100 TeV, 20 ab$^{-1}$

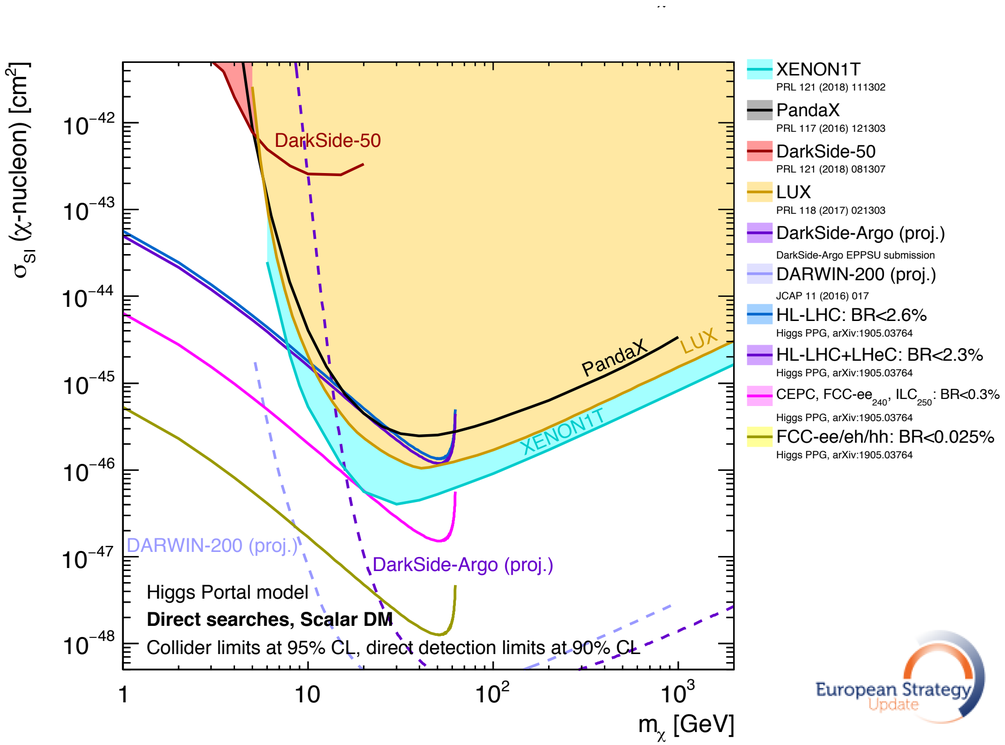
Exclusion limit ~ 41 TeV



# What about Dark Matter?



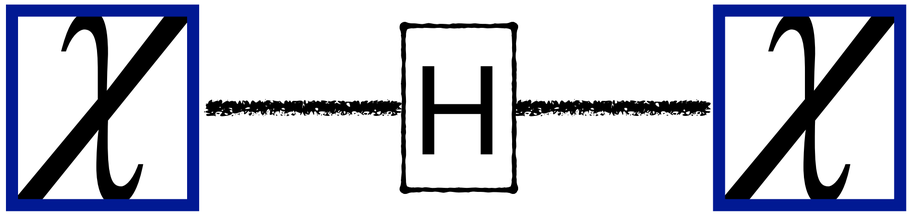



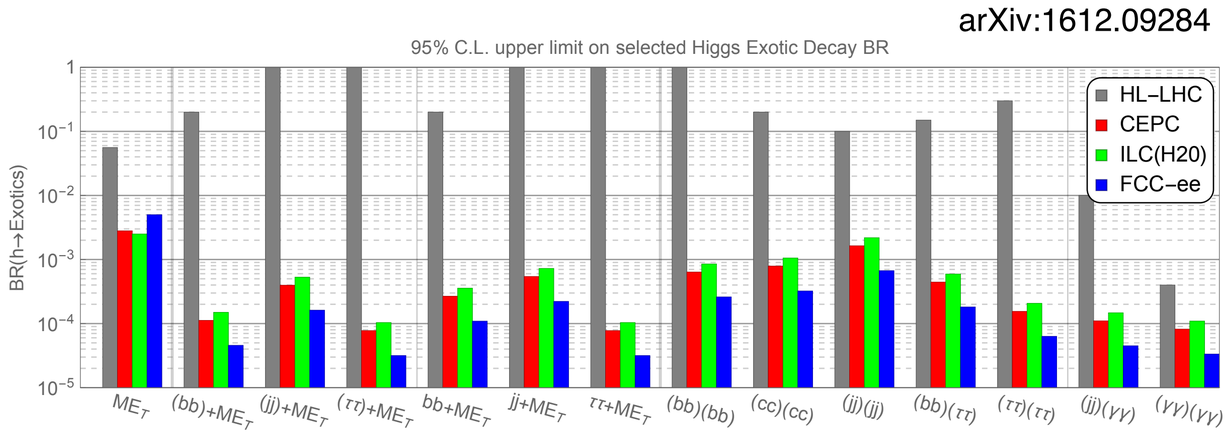



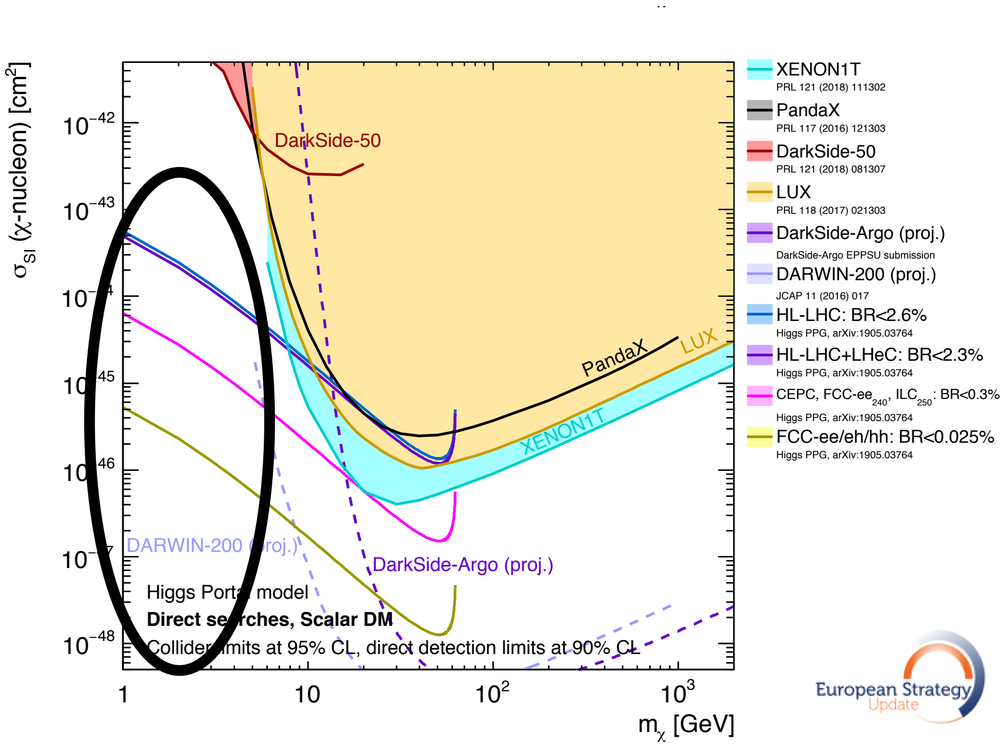

Dark Matter Portals through invisible Higgs width

Some regions: unique sensitivity from colliders

# What about Dark Matter?




Dark Matter Portals through invisible Higgs width

Some regions: unique sensitivity from colliders

# Physics prospects of future colliders

- ☑ Higgs couplings
- ☑ Higgs potential
- ☑ Indirect reach through precision measurements
- ☑ Direct reach of heavy particles
- ☑ Probing the dark sector

Thanks for your attention

# Useful slides & references

European strategy for Particle Physics Briefing book
https://arxiv.org/abs/1910.11775

Snowmass efforts:
https://www.slac.stanford.edu/econf/C210711/

FCC week 2023
https://indico.cern.ch/event/1202105/

Muon Collider Snowmass:
https://arxiv.org/pdf/2203.08033.pdf

Keynote talk on FCC Physics perspectives by Gavin Salam:
https://indico.cern.ch/event/1202105/contributions/5423455/attachments/2659121/4607170/fcc-london.pdf
FCC physics case by Matthew McCullough
https://indico.cern.ch/event/1202105/contributions/5396847/attachments/2659371/4606360/FCCWeek.pdf

# FCC-ee Physics Programme