Physics Program: Future Plans

Jan 27th 2023

FCC Physics Week

Matthew McCullough
(Also on behalf of Frank Simon)

Looking Back

The past year has seen the consolidation of physics groups and the commencement of a number of activities in:

- Precision Electroweak
- Higgs
- QCD
- BSM
- Flavour

Including mini-workshops.

Looking Back

The output of these workshops included the identification of numerous observables, experimental tasks that require further attention/consolidation.

- Quark/Gluon/Flavour discrimination
- Luminosity precision
- Triple gauge couplings
- Timing
- LFU
- Tau lifetime
- …

Looking Back

Theory challenges have also been further clarified and investigated, including

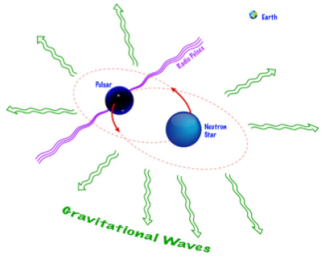
- Refinement of the overall physics case and its communication.
- Broader exploration of the theory landscape for BSM, in particular in Higgs sector and naturalness.
- Advanced understanding of precision and QCD challenges, bottlenecks, and mitigation strategies.
- Beginnings of comprehensive exploration of flavour opportunities.

This Week

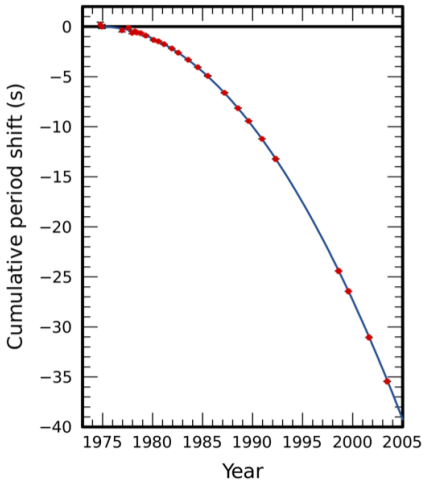
- Refinement of the overall physics case and its communication.

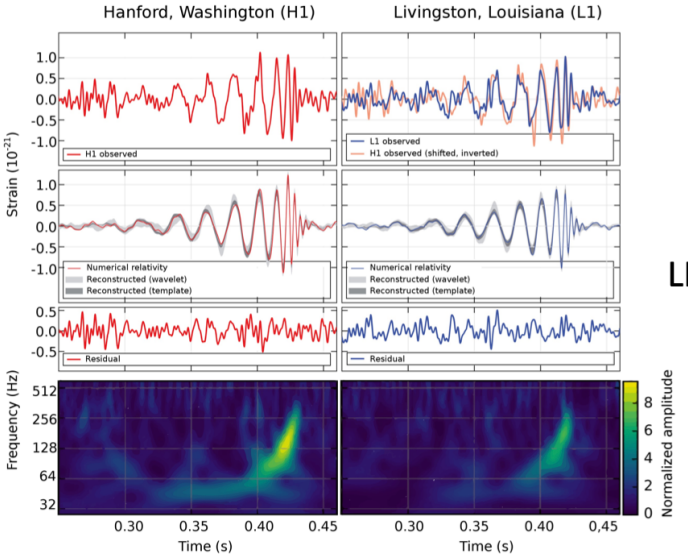
- Follow up **indirect observations** with **direct exploration**

Tevong You



Hulse-Taylor binary neutron+pulsar system





LIGO+VIRGO

- **Note:** in astro/cosmo, observing *known* objects and processes **in new regimes** or to **better accuracy** is reason enough to keep making progress!

This Week

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- Follow **direct observations** with **direct exploration**

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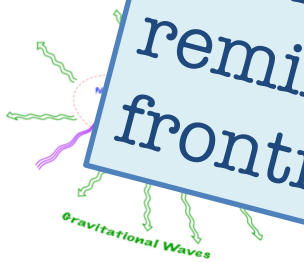
Sharing the excitement of precision and reminding of FCC-ee strength as intensity frontier discovery machine.



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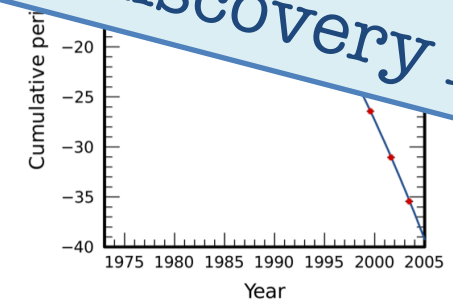

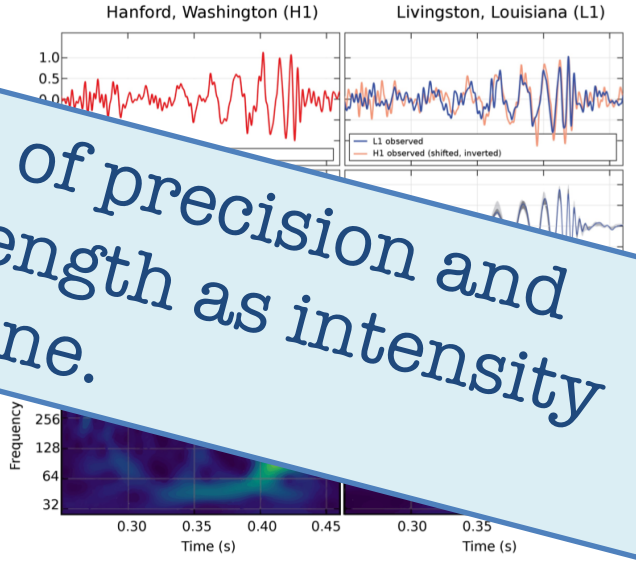

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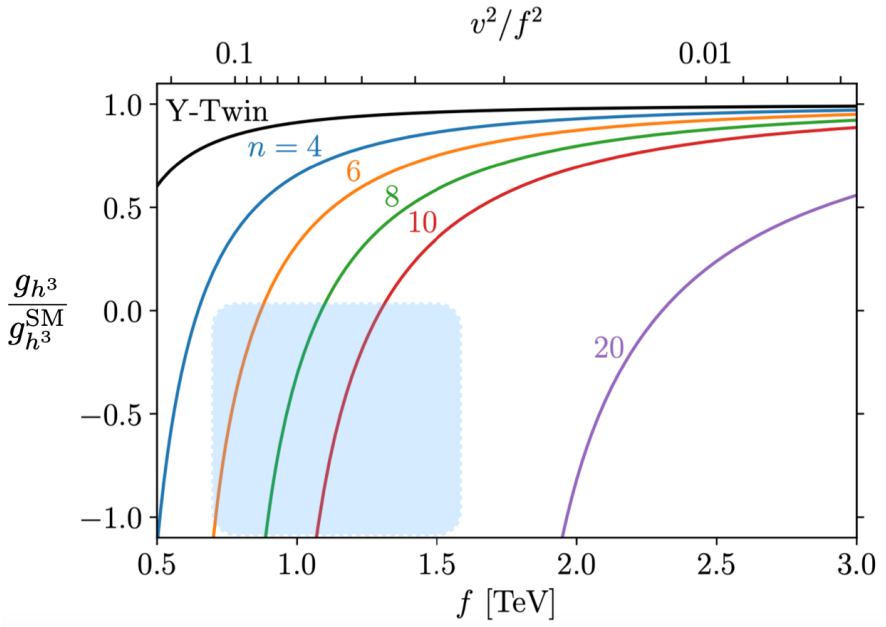
This Week

- Broader exploration of the theory landscape for BSM, in particular in Higgs sector and naturalness.

Finally: the Higgs self-coupling

For Gegenbauer's Twin, corrections are parametrically enhanced

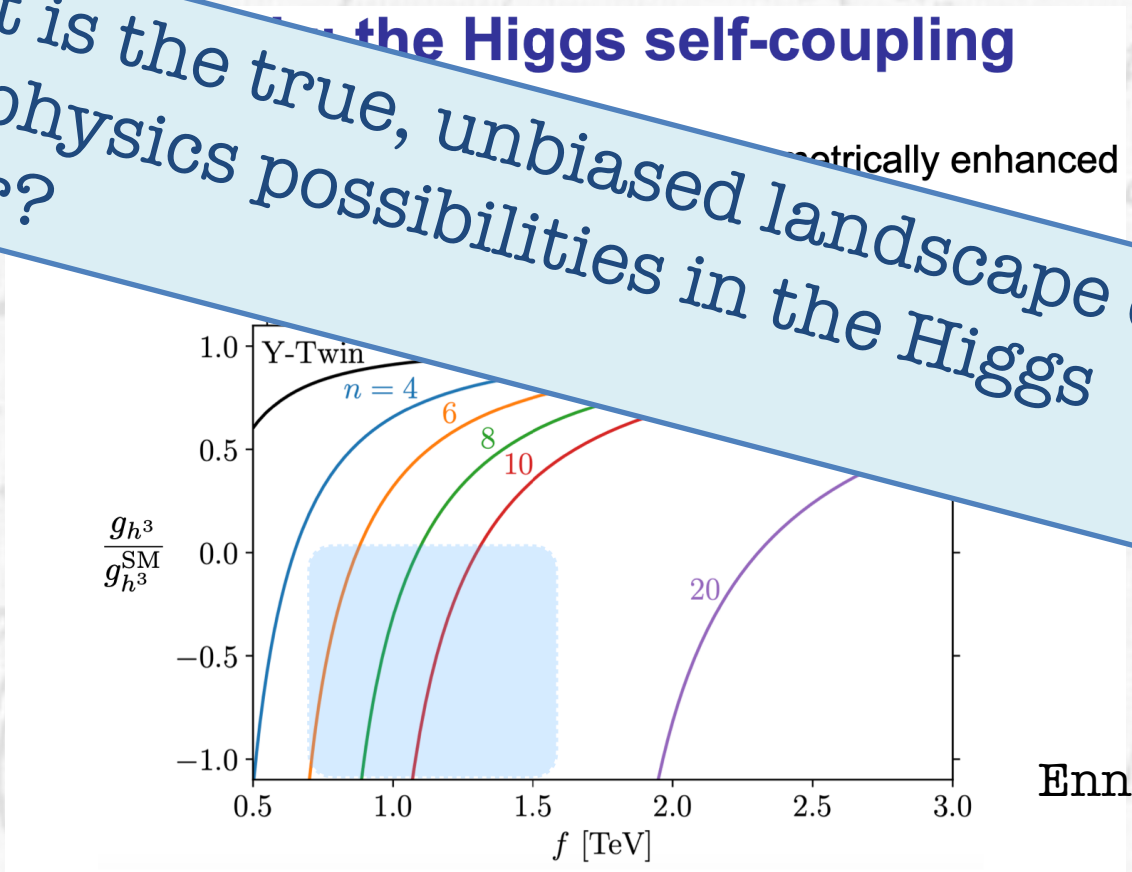


Ennio Salvioni

This Week

- Broader exploration of the theory landscape for BSM, in particular in Higgs sector and na[illegible]lness.

What is the true, unbiased landscape of new physics possibilities in the Higgs sector?



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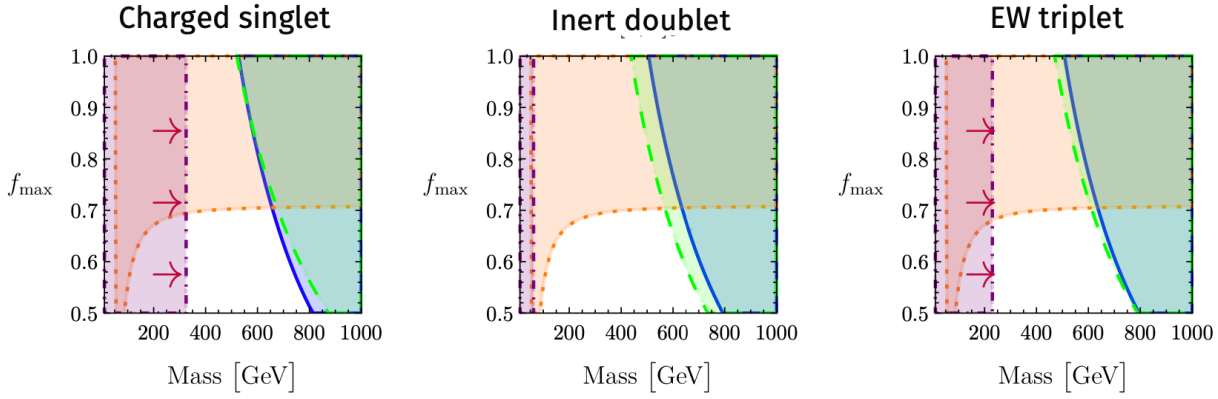

Orange, dotted:
κ_γ or κ_g

Blue, solid:
perturb. unitarity $\lambda_{h\Phi}$

Green, dashed:
Higgs cubic

Purple, dot-dash:
Direct search

Nightmare scenario of neutral scalar singlet remains open.
$\kappa_\lambda \sim 5\%$ measurement of FCC-hh closes off everything.

Dave Sutherland

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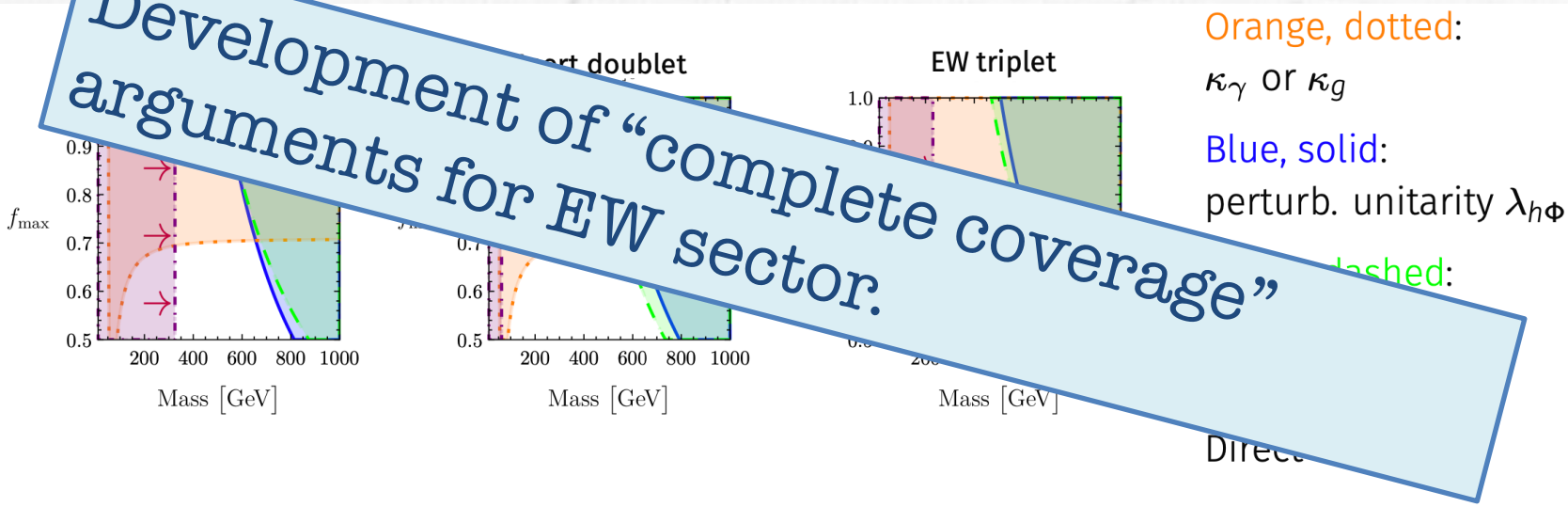

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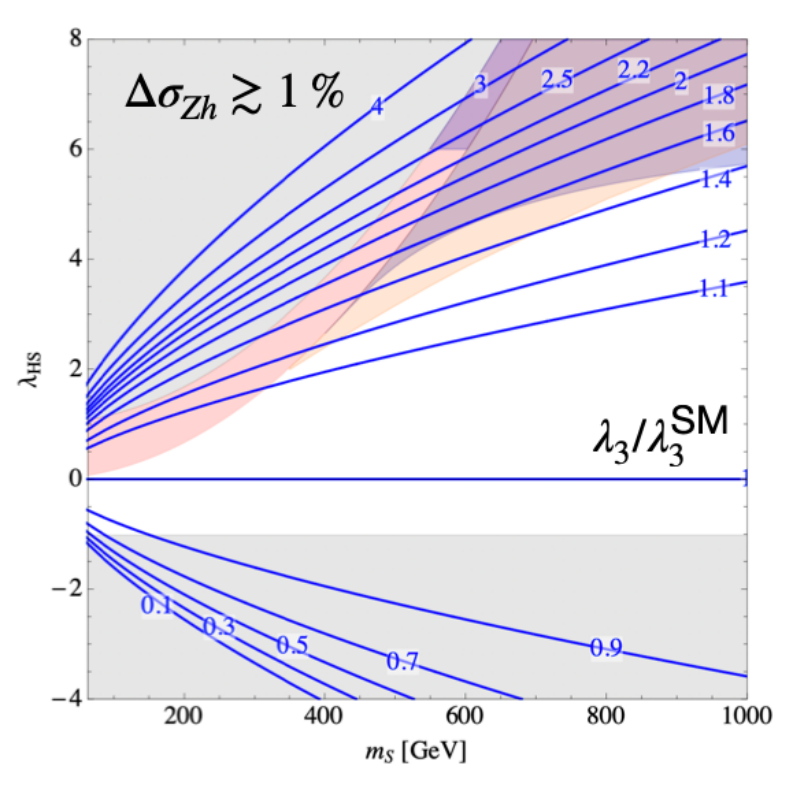
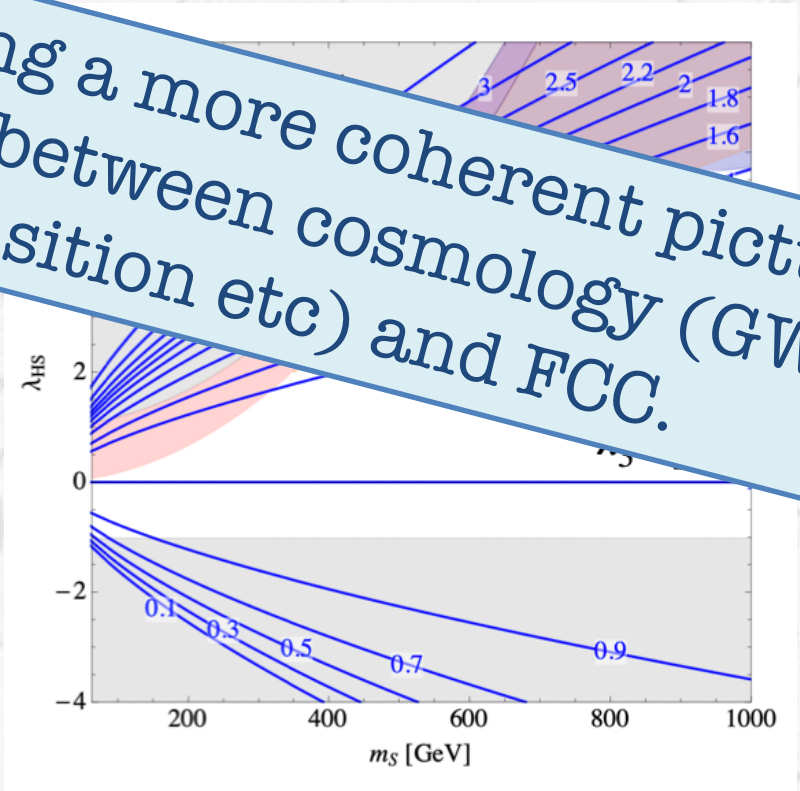


Simone Blasi

This Week

- Broader exploration of the theory landscape for BSM, in particular in Higgs sector and na[illegible]lness.

Developing a more coherent picture for the interplay between cosmology (GW, EW phase transition etc) and FCC.



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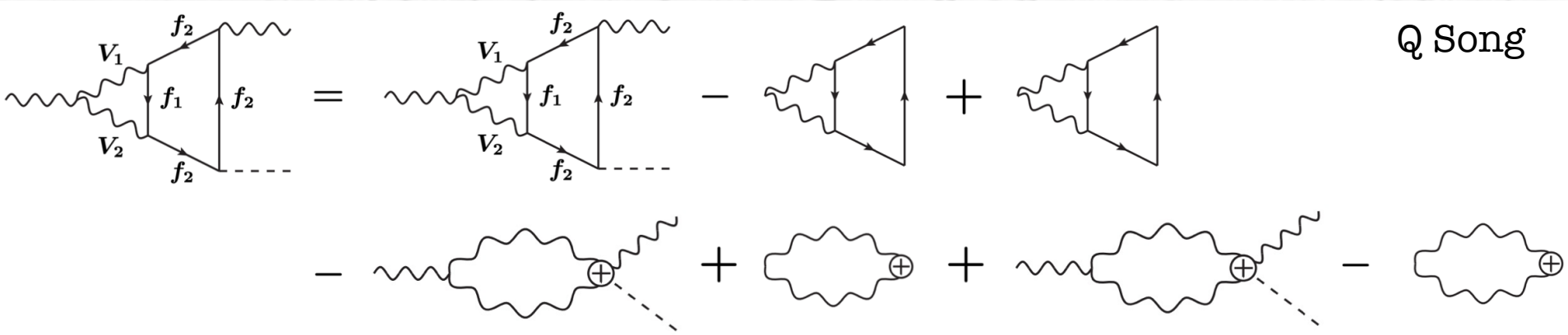
This Week

- Advancing understanding of precision and QCD challenges, bottlenecks, and mitigation strategies.



Q Song

This Week

- Advancing understanding of precision and QCD challenges, bottlenecks, and mitigation strategies.

David d'Enterria

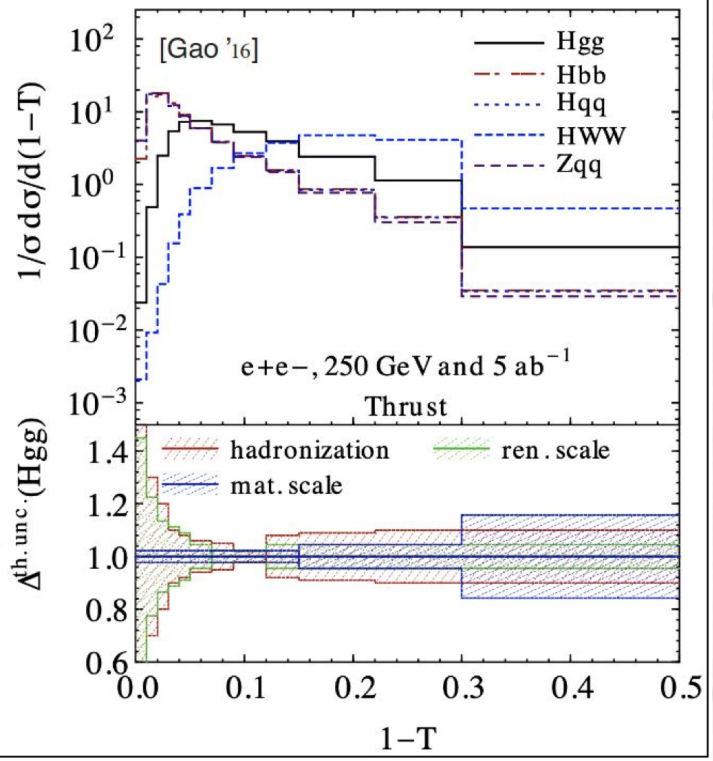
1. Precise α_s determination is needed to accurately & precisely predict all SM x-sections & decay rates (Higgs, top, EWPOs,...)
2. Higher-order (N^nLO, N^nLL) calculations crucial to gain precise control over hadronic final states and jet dynamics.
3. Heavy/light quark & gluon separation (flavour tagging, substructure,...) is key for multiple SM measurements (e.g. H Yukawas) and BSM searches (e.g. $X \rightarrow jj$ decays).
4. Non-perturbative QCD (hadronisation, colour reconnection,...) impacts studies with hadronic final states: $e^+e^- \rightarrow$ WW,ttbar ($\rightarrow$jets), m_W, m_{top} extractions.
5. @ FCC-hh, accurate knowledge of parton densities at high-*x* (BSM) and saturation dynamics at small-*x*, MPI dynamics,… is fundamental.

This Week

- Advancing understanding of precision and QCD challenges, bottlenecks, and mitigation strategies.

Monni/Siodmok

- However, hadronisation remains the main bottleneck
  - e.g. thrust in Higgs decays (MC variation in plot)
- Increase in energy insufficient for suppression ($Q \sim m_H$)



This Week

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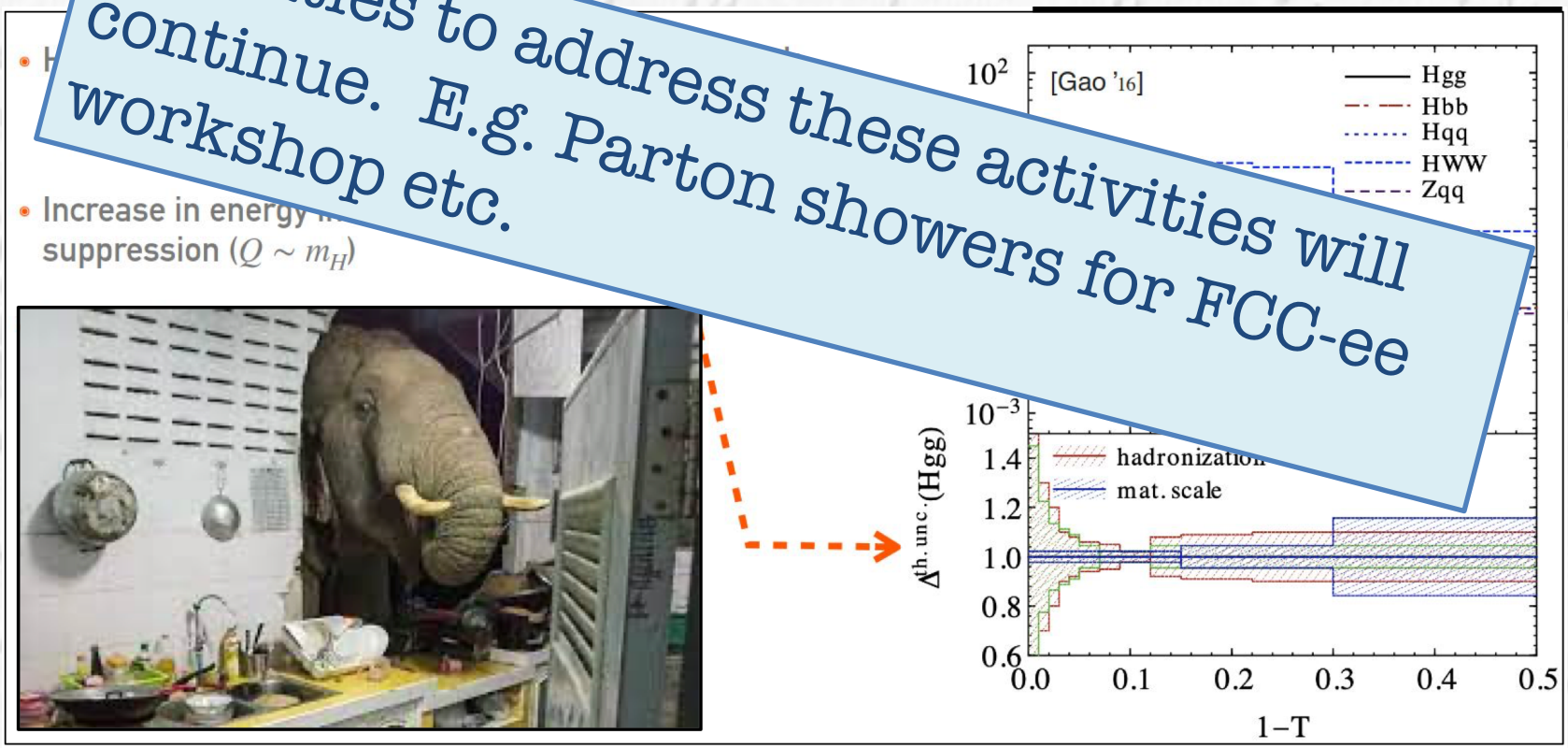
Monni/Siodmok

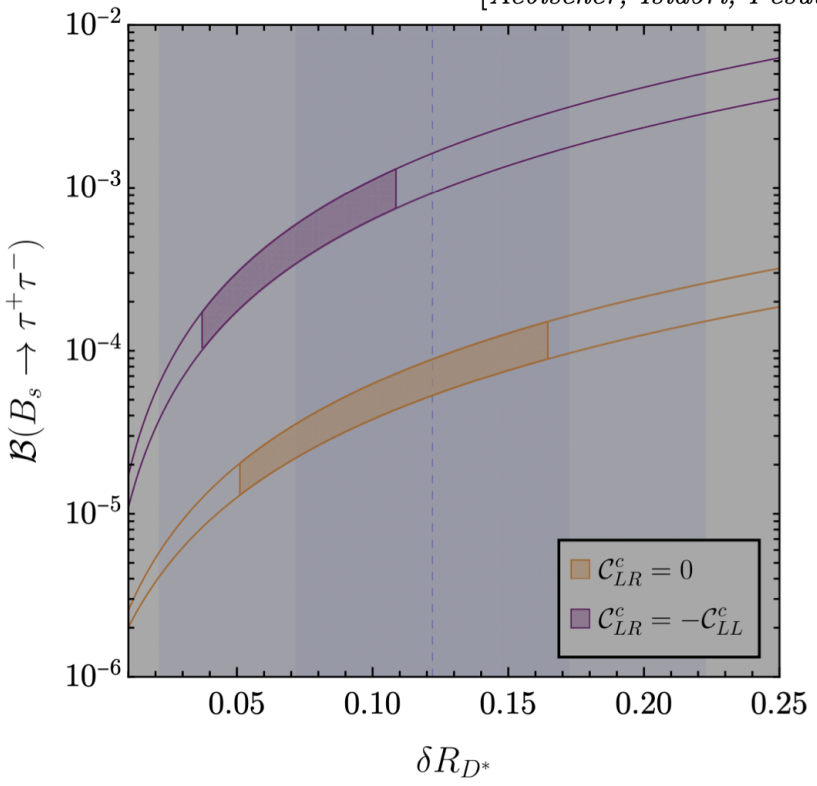
Activities to address these activities will continue. E.g. Parton showers for FCC-ee workshop etc.

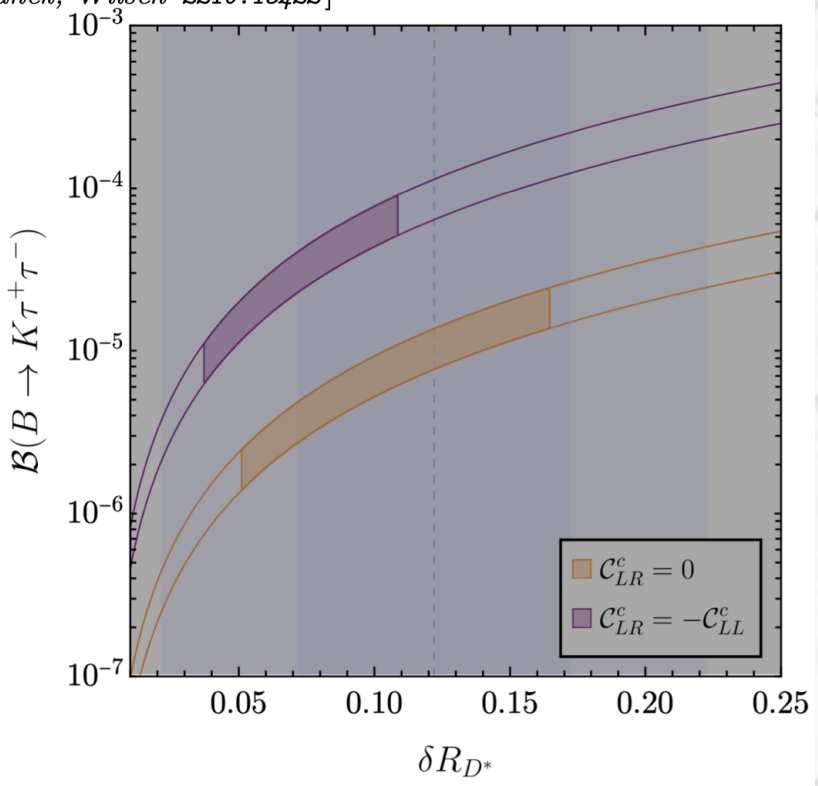


This Week

- Beginnings of a comprehensive exploration of flavour opportunities.

[*Aebischer, Isidori, Pesut, Stefanek, Wilsch 2210.13422*]





= FCC-ee

Lukas Allwicher

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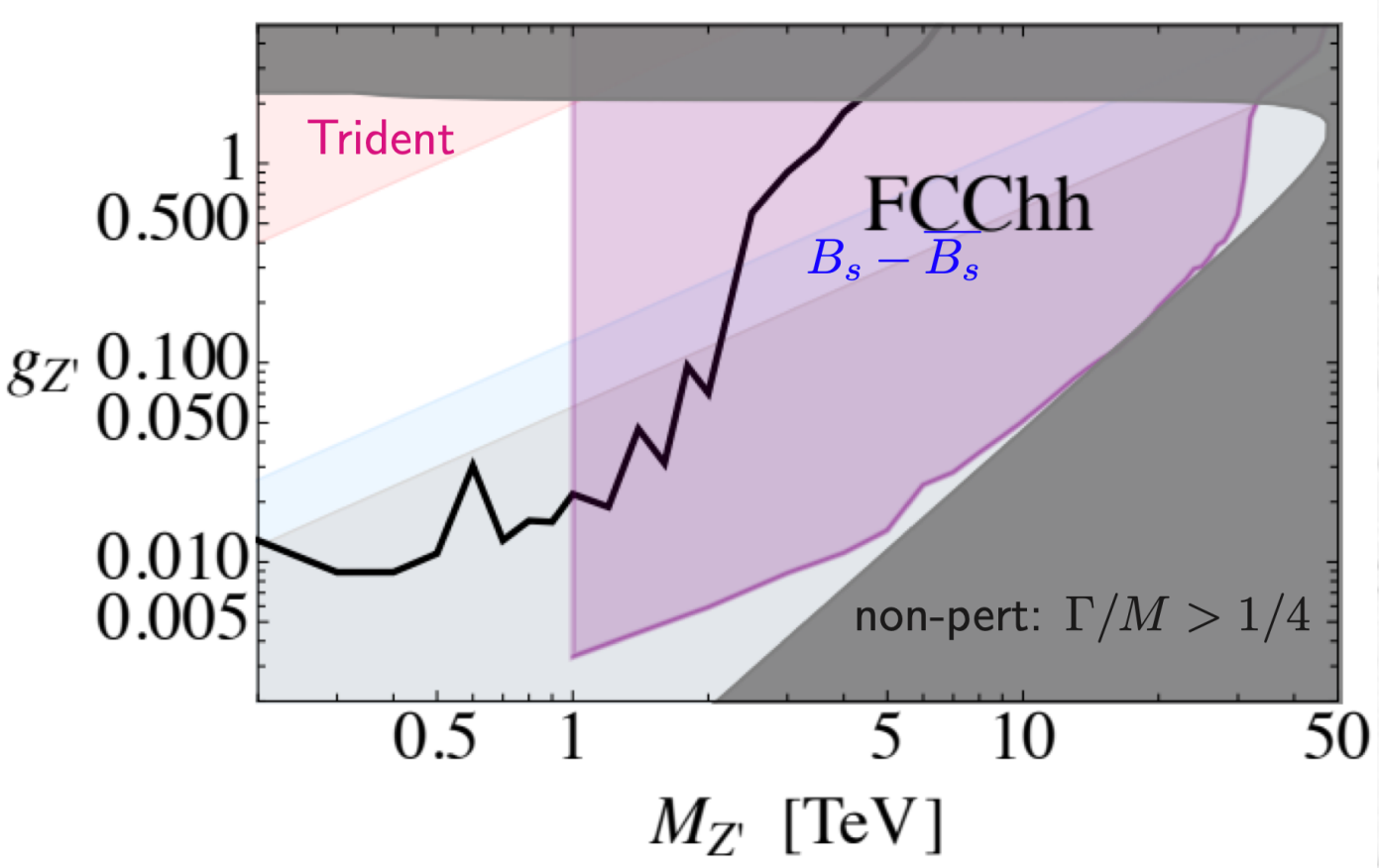

Ben Allanach

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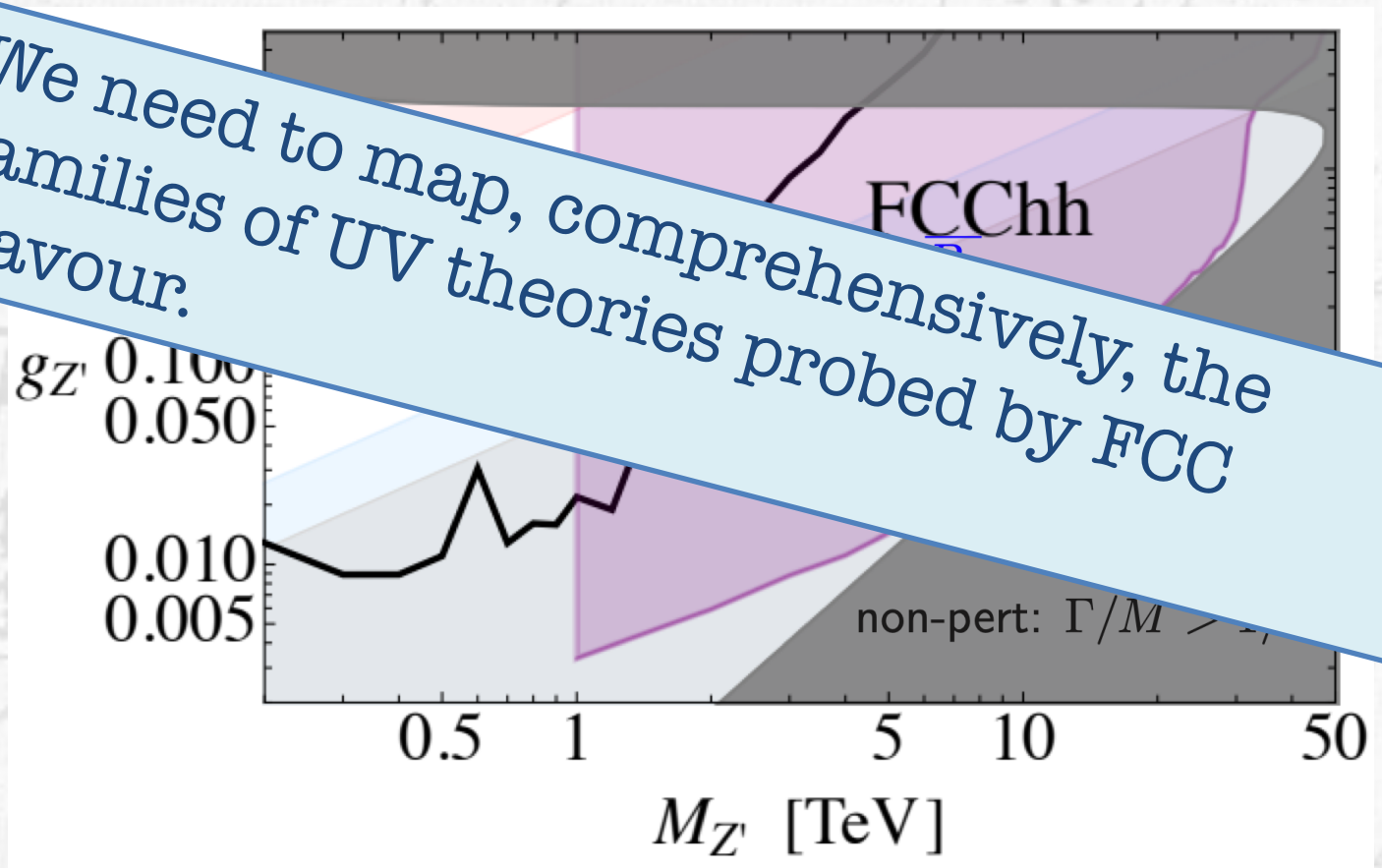

We need to map, comprehensively, the families of UV theories probed by FCC flavour.

Ben Allanach

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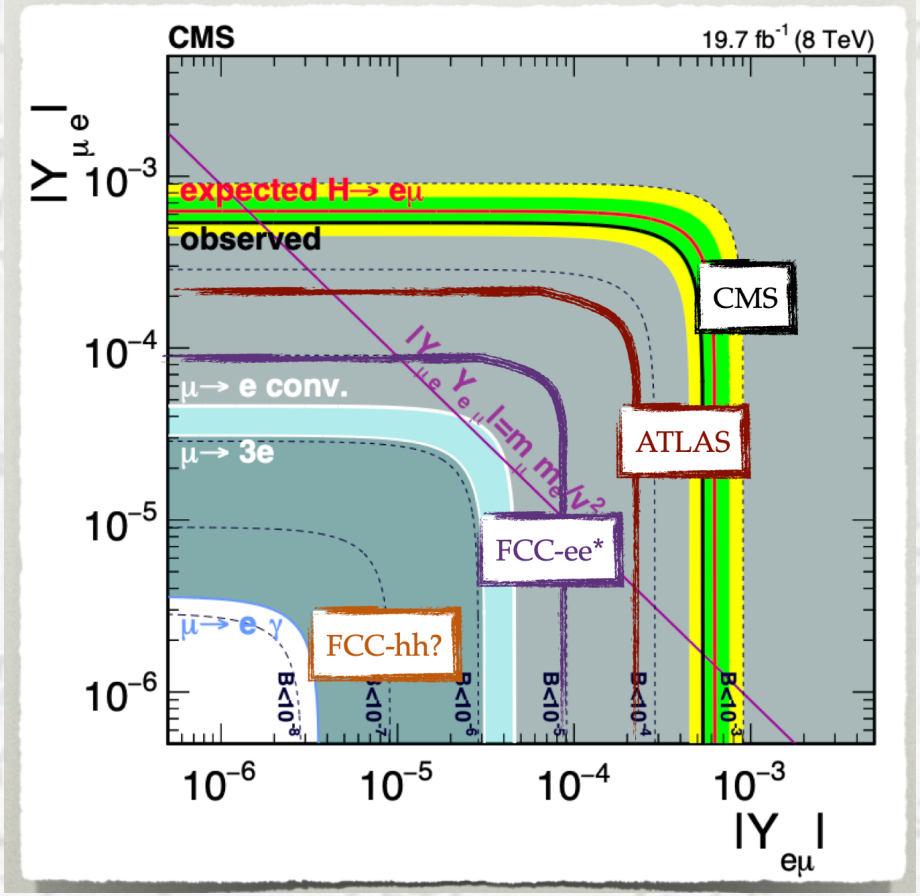

Jure Zupan

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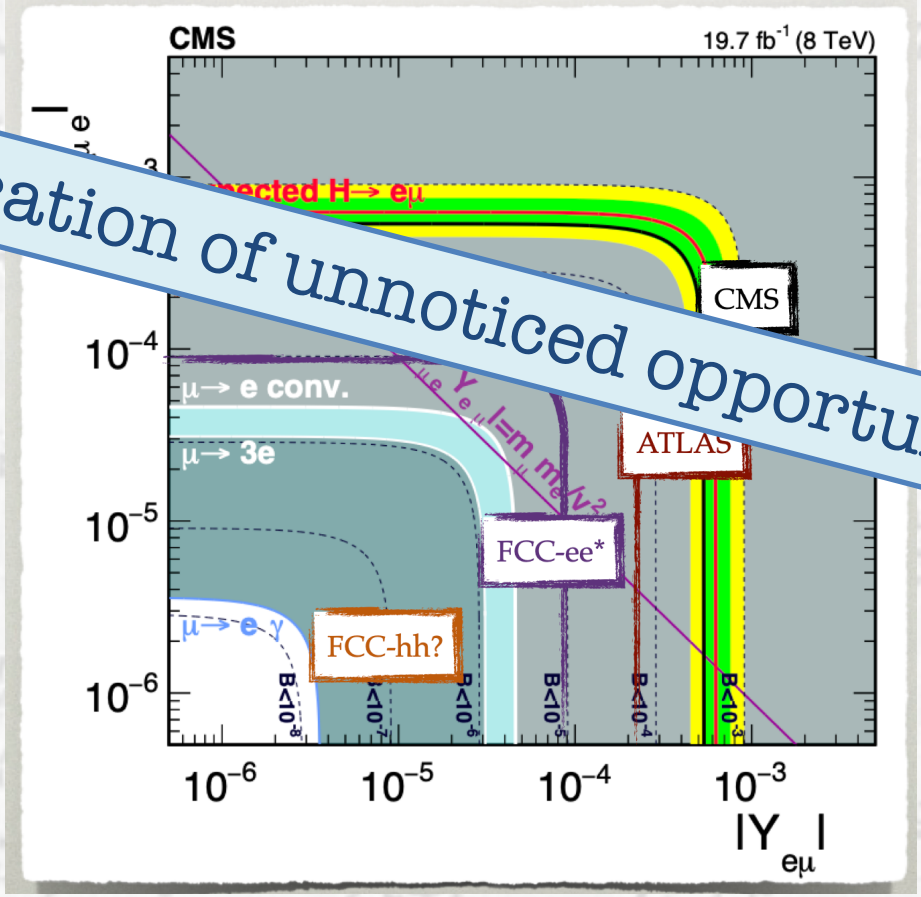

Identification of unnoticed opportunities.

Jure Zupan

This Week

- Beginnings of comprehensive exploration of flavour opportunities.

- Lattice QCD crucial input to SM tests
- calculation of a number of quantities mature with good control of systematic effects and small errors
- clear path towards continued improvements, reduction of error for QCD predictions

- There are exciting new developments that will
  - allow to further increase precision (example QCD+QED)
  - extend the set of quantities accessible to lattice computations (example 2nd order Weak processes, spectral-function reconstruction — there are many more, see Lattice 2022)

I am very optimistic that further advances in theoretical physics, algorithms and computing will bring
- increased precision
- wider set of quantities for which lattice can make reliable predictions

This is extremely exciting given the prospect and time scale of FCC

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What are the opportunities for lattice?

Andreas Juttner

Looking Forward

The main item on the agenda is

Mid-Term Review Report

All developments will need to be condensed for the report, but also supporting documentation for each group.

Content will depend on the deliverables.

Looking Forward

In the mean time, continue…

- Community building, including with early-career physicists.
- Global engagement with national communities.
- Advocating for the incredible physics program of FCC.

Summary

Big tunnels = progress!