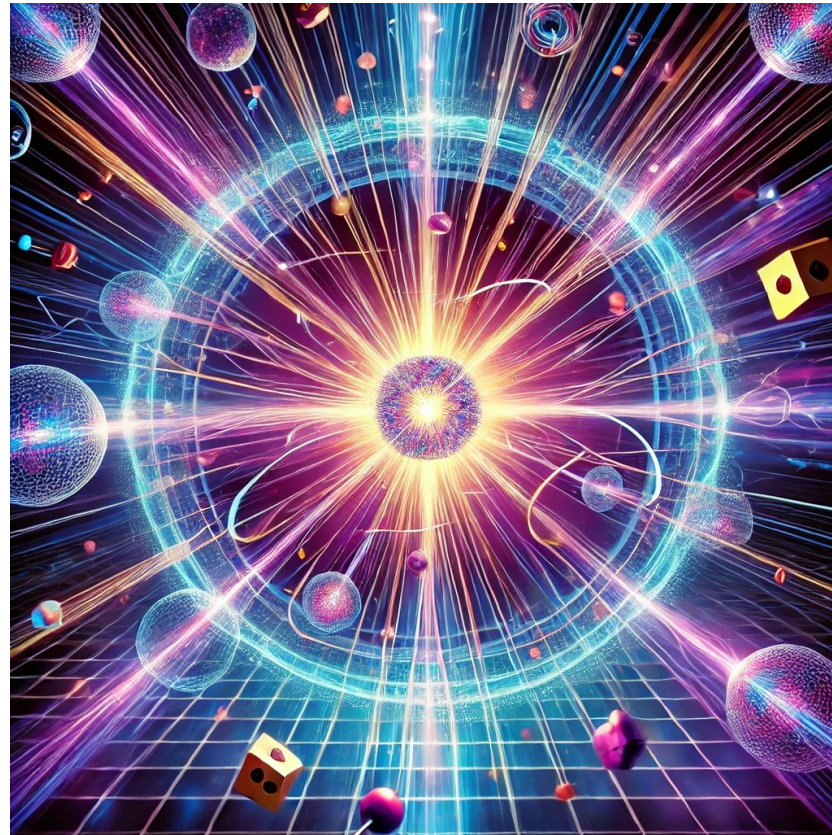
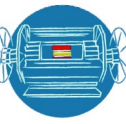


L1 Higgs Force



IFIC General Assembly
19/12/2024

ChatGPT image on Higgs Force
and interaction with other particles



EXCELENCIA
SEVERO
OCHOA



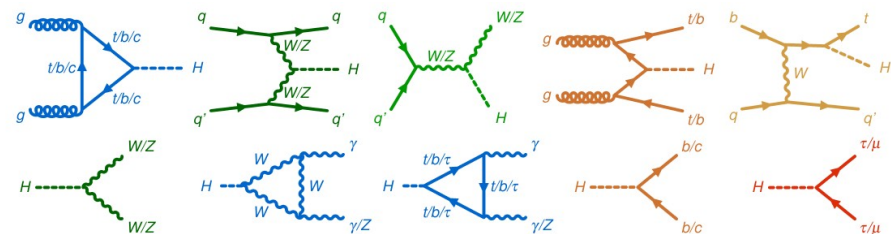
- Line related to the origin of mass:
 - Higgs sector, interaction with other particles, fundamental forces, new BSM interactions, Dark Matter, etc.
- Coordinators: L. Fiorini, S. Martí, G. Rodrigo, A. Santamaria
- The first L1 Higgs Force scientific days, 27-28 May 2021
 - Location: Zoom only
- The second L1 Higgs Force scientific days, 3-4 December 2024
 - Location: IFIC+Zoom
 - Three sessions
 - This time we sent request for contribution abstracts via indico.
 - Twelve abstracts in total.
 - We accepted all the contributions.
 - One talk was later cancelled by the speaker.
 - 8 review talks
 - 3 lightning talks
 - Closure was the IFIC Seminar on Next Generation Parton Showers by A. Soto.

ATLAS Higgs measurements



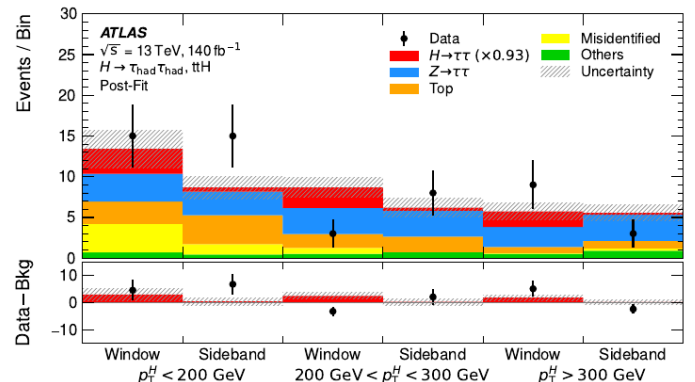
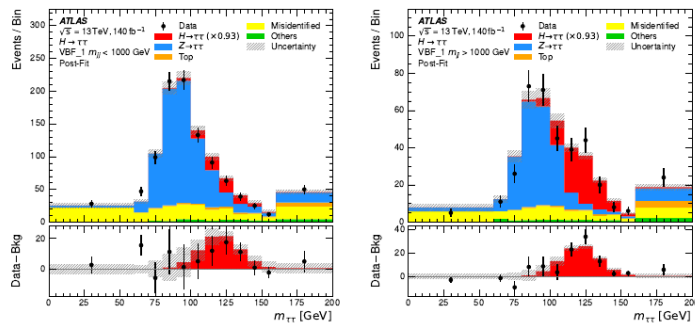
X. Poveda

ATLAS Measurement of Higgs boson production cross section in $H \rightarrow \tau\tau$ in the Simplified Template Cross-section (STXS) scheme.



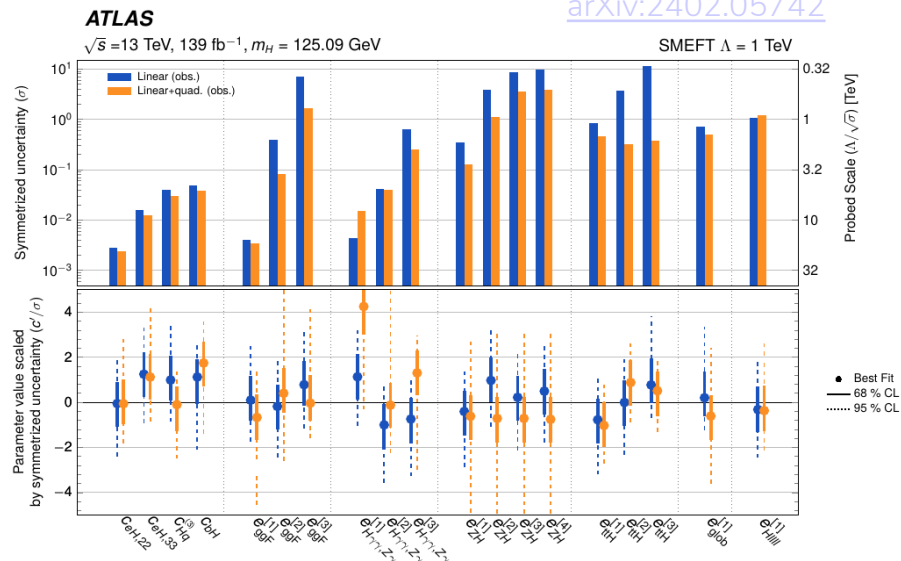
- Best measurement for VBF cross-section to date
- Results are also interpreted in terms of constraints to Wilson coeff. of SMEFT operators

arXiv:2407.16320



$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_i^{N_d=6} \frac{c_i}{\Lambda^2} \mathcal{O}_i^{(6)} + \dots$$

arXiv:2402.05742



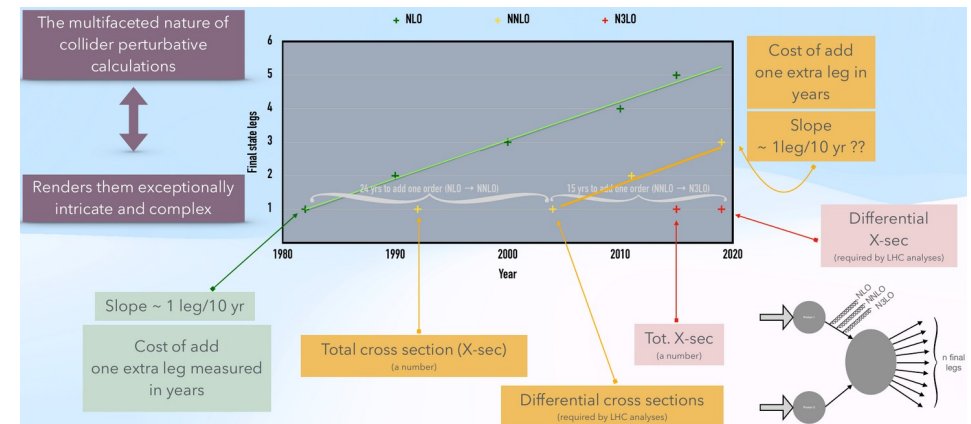
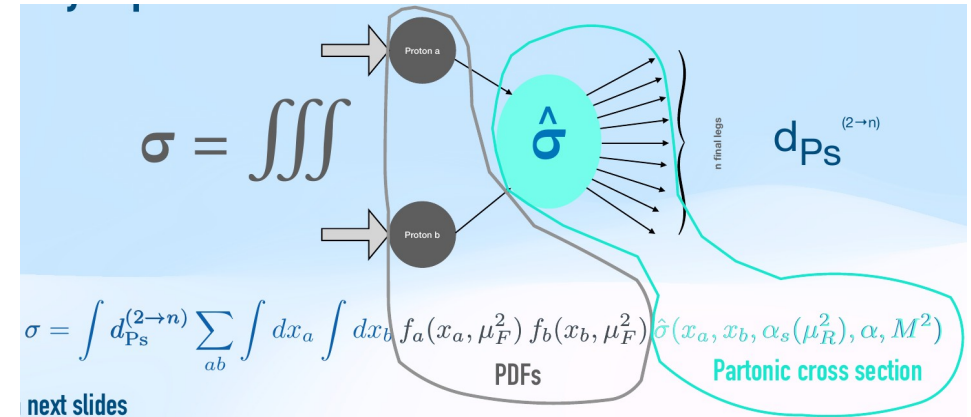
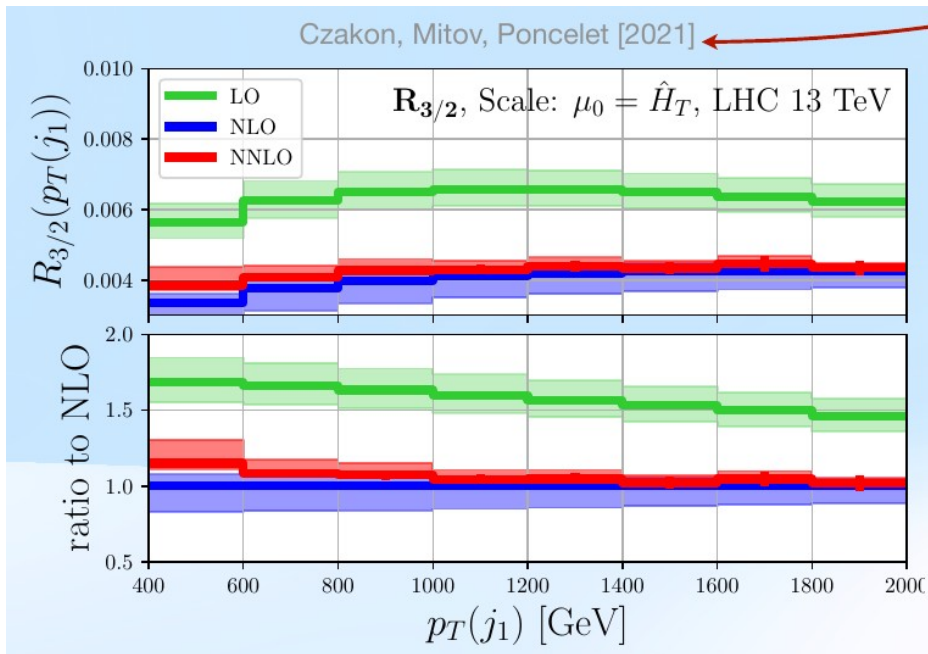
Perturbative QCD for LHC and more



L. Cieri

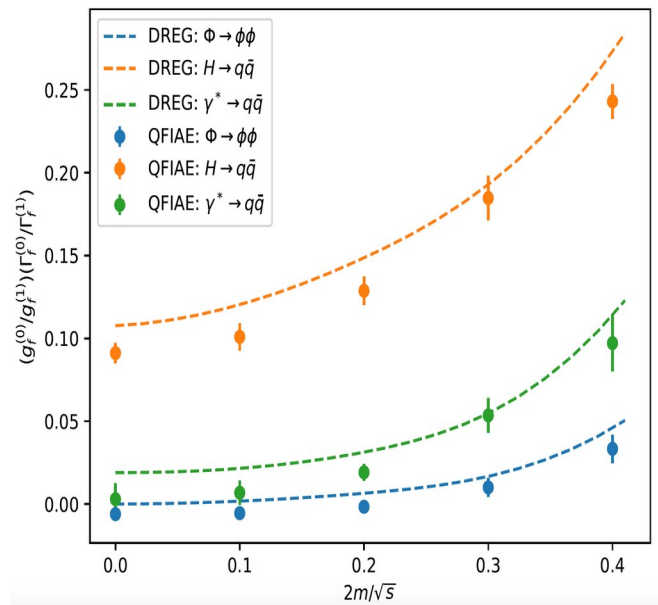
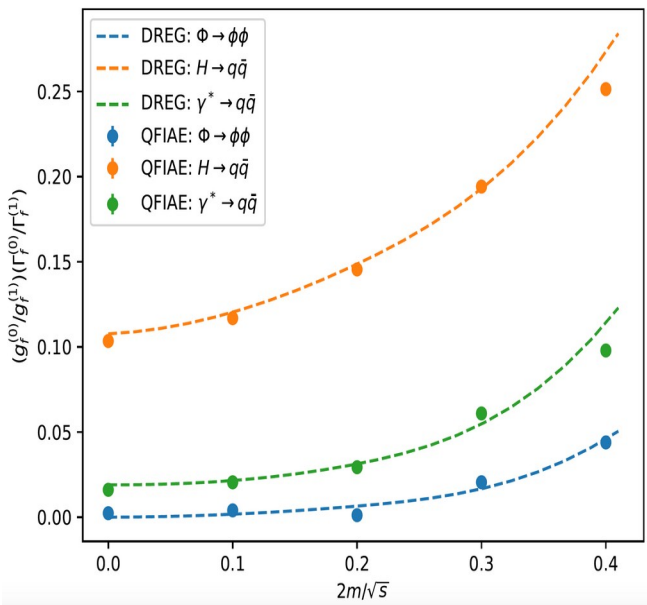
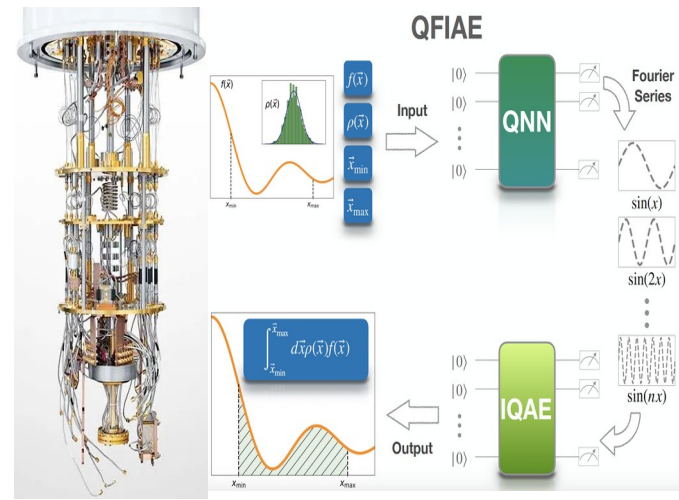
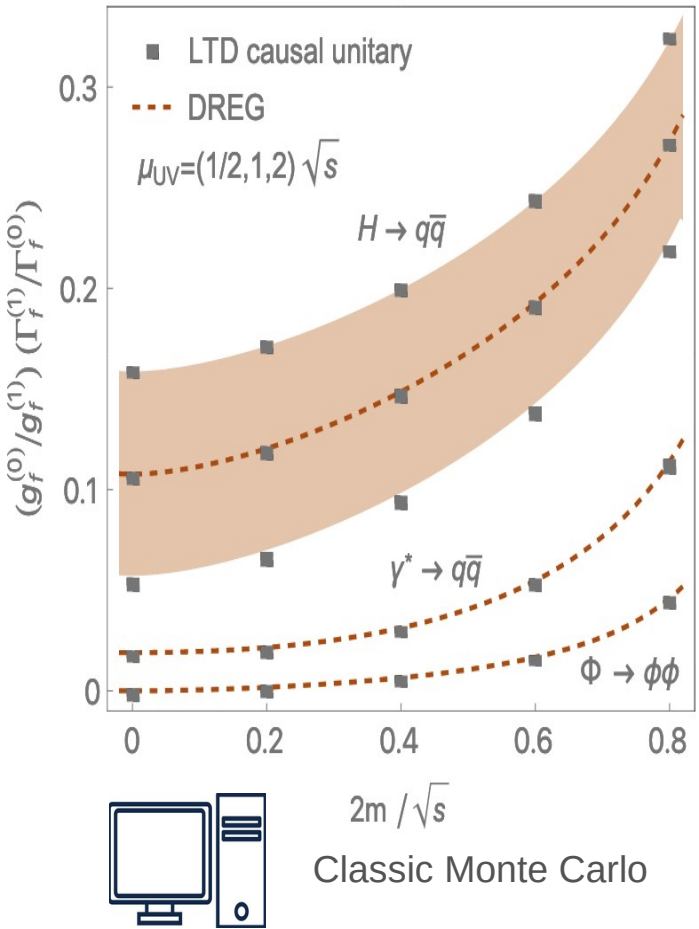
- Theory predictions are becoming a limiting factor for some of the LHC measurements, in particular the ones involving QCD processes.
- Requires improvements of precision of partonic xsec, PDF, parton shower, etc...

3 jets production at NNLO



- Quest for more precise TH tools (N³LO or even N⁴LO)
- more precise PDFs \rightarrow New fitting techniques and more data and N3LO PDFs
- NNLO TH calculations at higher multiplicities, more efficient MC for fix. order tools (CPU cost)
- Quantum Computing \rightarrow Quantum Algorithms

Decay rate of the Higgs boson



Quantum Fourier Iterative Amplitude Estimation QFIAE

J.J. Martínez de Lejarza, M. Grossi, L. Cieri, G. Rodrigo, [[2305.01686](#)]

Quantum integration of decay rates at second order in perturbation theory

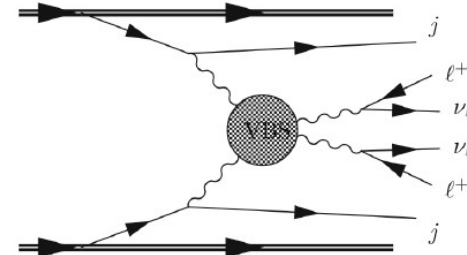
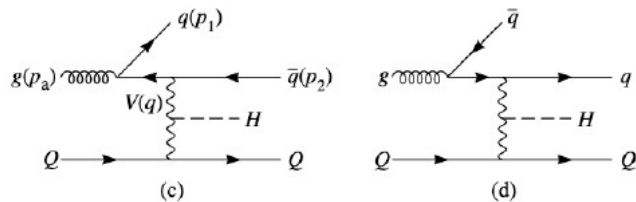
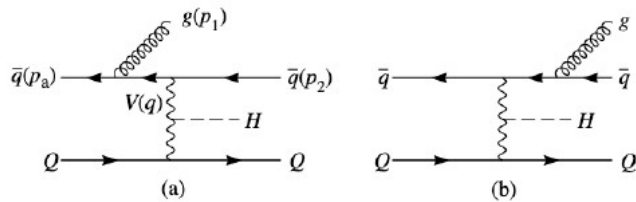
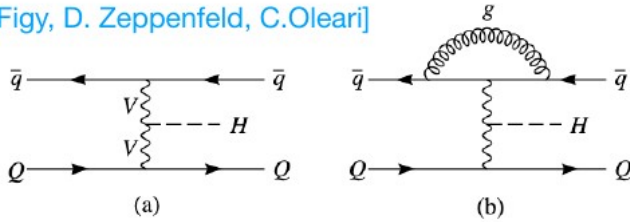
J.J. Martínez de Lejarza, D.F. Rentería Estrada, M. Grossi, G. Rodrigo, [[2409.12236](#)]

Rewording Theoretical Predictions at Colliders with Vacuum Amplitudes, S. Ramírez, P.K. Dhani, G.F.R. Sborlini, G. Rodrigo, [[PRL133\(2024\)211901](#)]

Vacuum amplitudes and time-like causal unitary in the loop-tree duality, LTD Collaboration, [[2404.05492](#)]

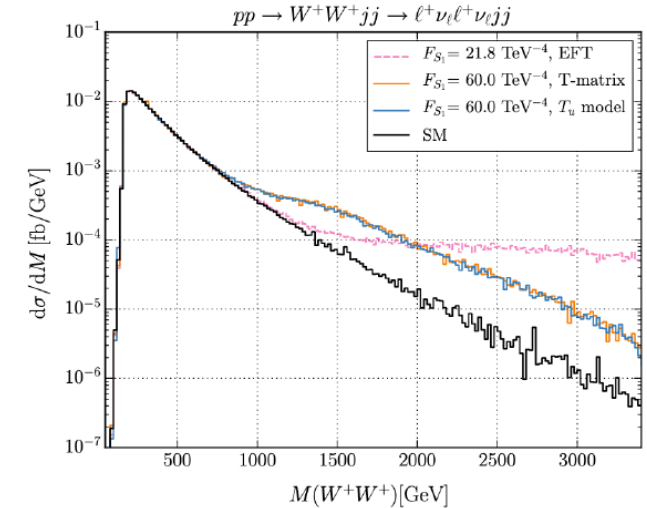
- Precise Electroweak predictions are becoming more and more important, because the LHC Higgs Physics program is entering a new era of precision measurements.

[T. Figy, D. Zeppenfeld, C. Oleari]



[G. Perez, M. Sekulla, D. Zeppenfeld]

[G. Perez, M. Sekulla, D. Zeppenfeld]



- **VBFNLO 3.0** is based at IFIC

• website: <https://ific.uv.es/vbfnlo>

• New interesting enhancements: new processes, parallelization through OpenMPI, T_u unitarization, BLHA interface

• Public repository: <https://github.com/vbfnlo/vbfnlo>

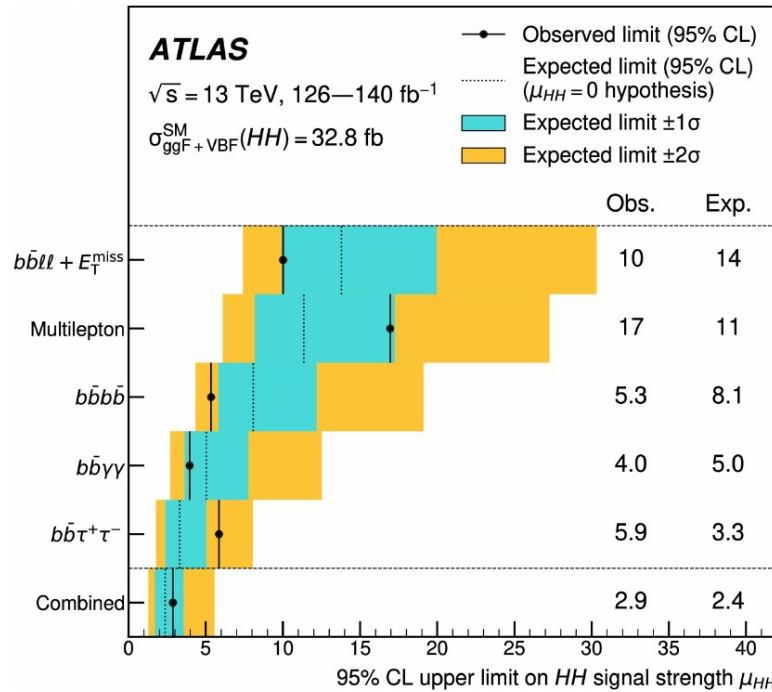
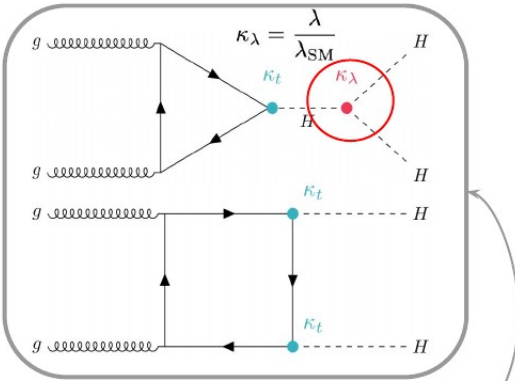
• Email: vbfnlo@ific.uv.es

DiHiggs searches with ATLAS

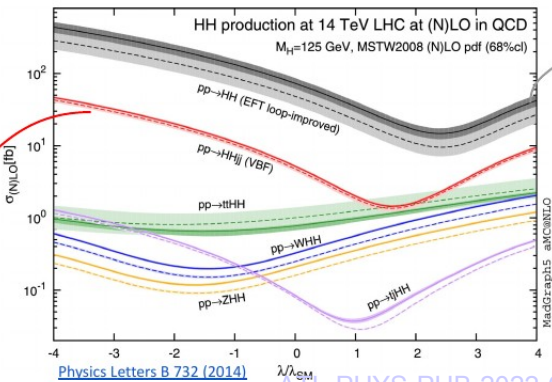


F. Curcio

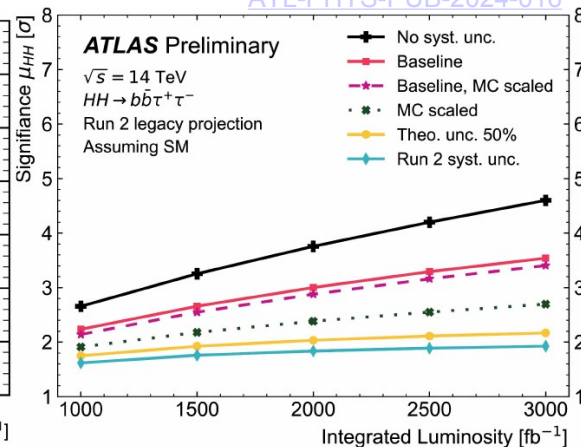
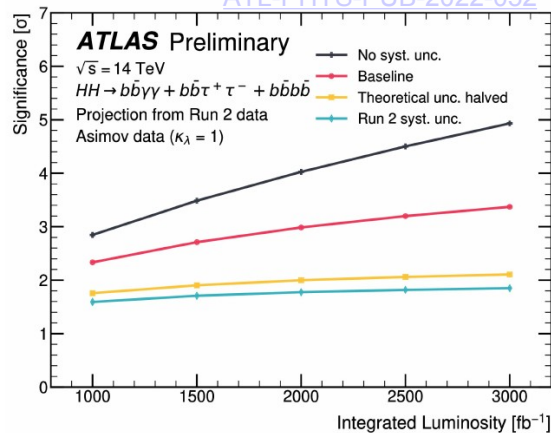
Search for elusive diHiggs production to measure the Higgs self-coupling parameter



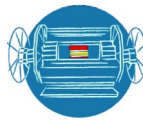
- Measuring the Higgs self-coupling to understand the Higgs potential and validating the Higgs mechanism in SM and BSM scenarios.
- Experiments are constantly improving their sensitivity (exp. techniques+more data)



ATL-PHYS-PUB-2022-052



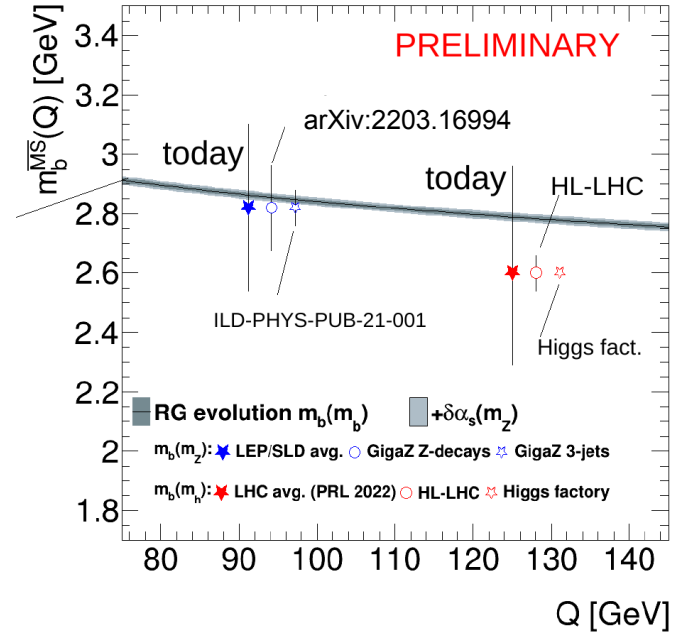
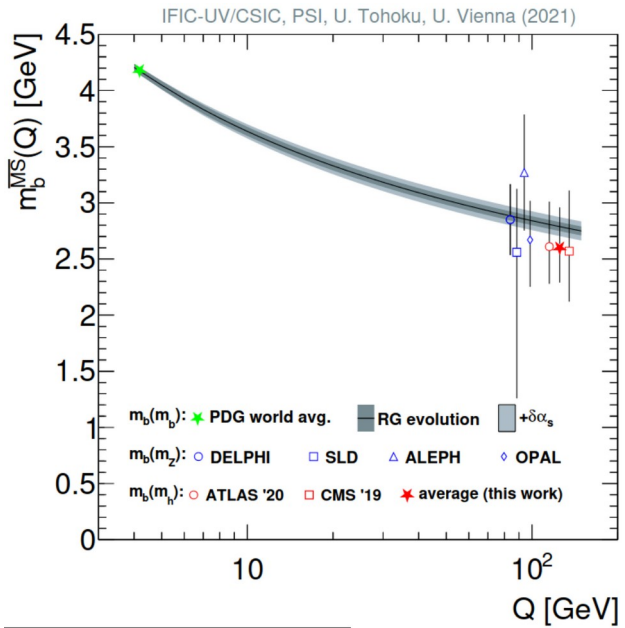
- results for the $b\bar{b}rr$ channel are updated on the right plot wrt to ones included in the combination (left plot)
- improvement of around 20%
- as good as the combination after being updated



Experimental evidence for scale evolution

The Higgs decay to bottom quarks is a perfect laboratory to study the bottom quark mass:

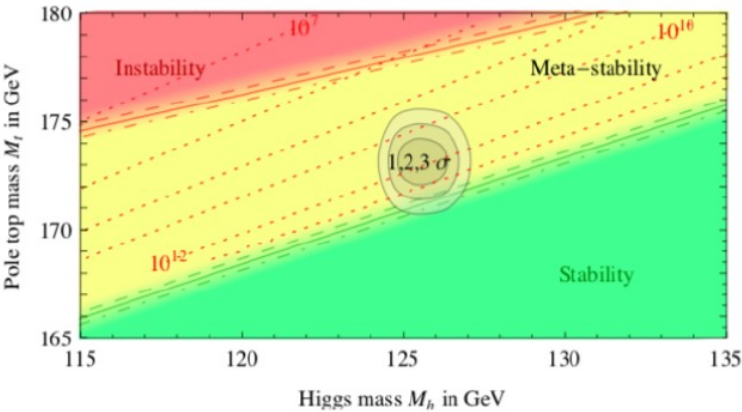
- Quadratic dependence on m_b
- EW process, rate decoupled at LO from strong coupling as precise predictions available
- Well-defined natural scale m_H
- Use ratio precise Higgs measurements ($H \rightarrow ZZ^*$) to constrain other cross sections and branching fractions
- $m_b(m_H) = 2.60^{+0.36}_{-0.30} \pm 0.06 \text{ GeV (theory)}$ in good agreement with $2.79^{+0.03}_{-0.02} \text{ GeV}$ from evolving the world average for $m_b(m_b)$ to m_H .



- Higgs factory can provide high-precision $m_b(m_H)$ + running top quark
- Near future: joint measurement of m_b and Y_b and improved $H \rightarrow bb$ measurements.

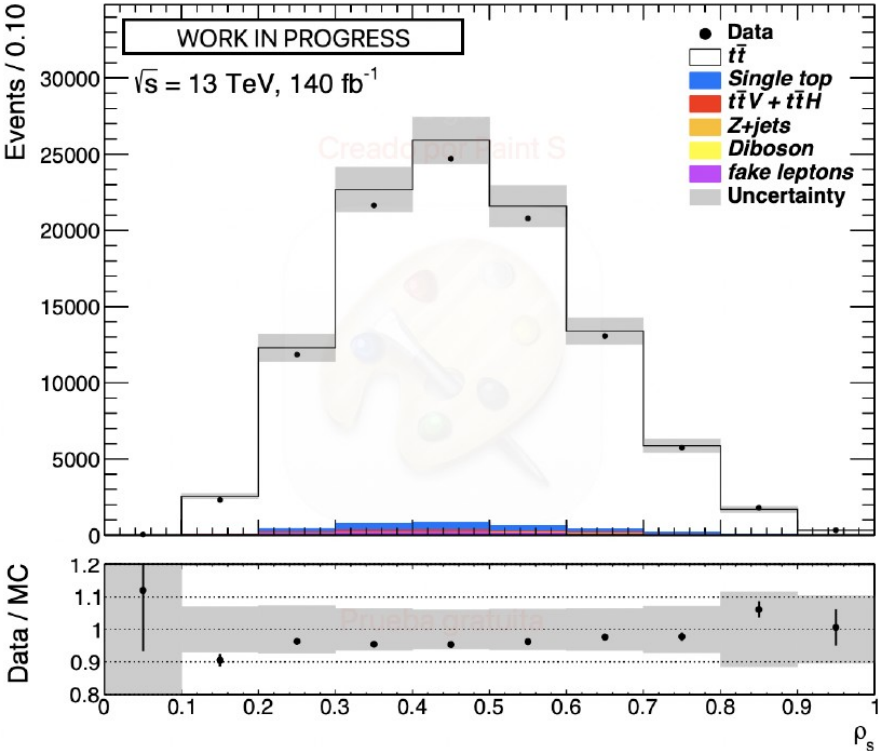
Experimental evidence for scale evolution

- The top pole mass values affects several other important parameters of the SM
- A mass measurement can be obtained from the measurement of the $t\bar{t} + 1\text{jet}$ xsec



Top-quark mass measurement using observable \mathcal{R} :

$$\mathcal{R}(m_t^{pole}, \rho_s) = \frac{1}{\sigma_{t\bar{t}+1\text{-jet}}} \frac{d\sigma_{t\bar{t}+1\text{-jet}}}{d\rho_s}(m_t^{pole}, \rho_s), \quad \rho_s = \frac{2m_0}{\sqrt{S_{t\bar{t}+1\text{-jet}}}}$$



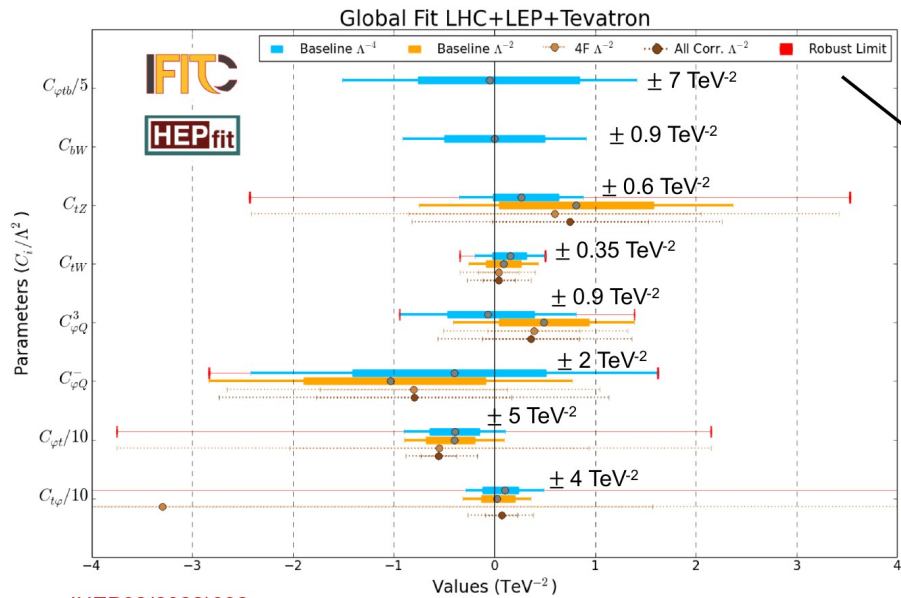
- Precision measurement involving complex statistical model
- Best result from the fit to 2 → 3 calculations: total uncertainty ~ 1.3 GeV.
- 2 → 7 calculation which includes top-decay and off-shell effects also in progress.

SMEFT Constraints from Top



M. Moreno

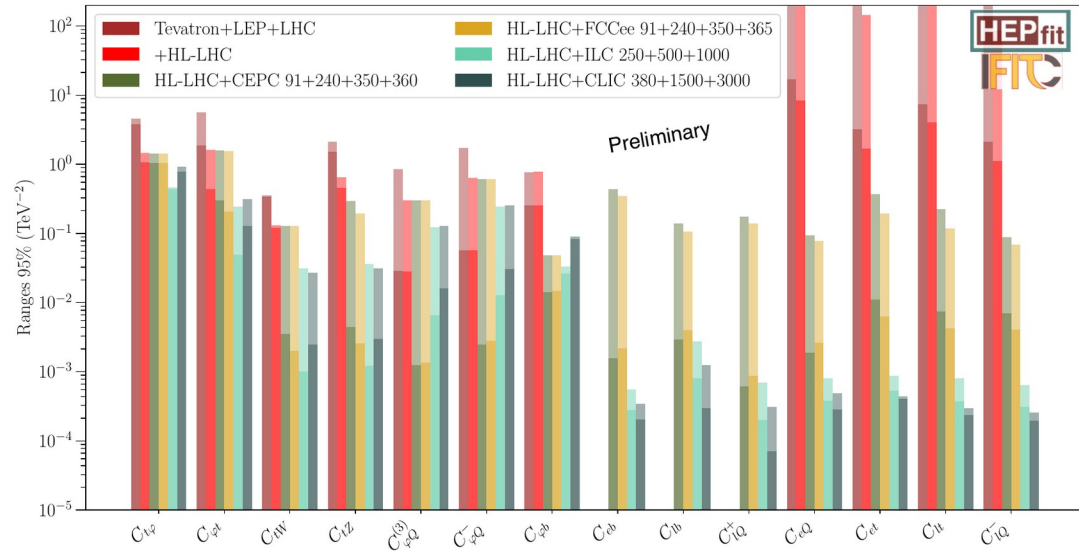
- Constraints on Top-quark related Wilson coefficient with HEPFit using LHC meas.
- Top quark couples to other SM fields through its gauge and Yukawa interactions
- High statistics at the LHC: $t\bar{t}$ +bosons (g, Z, W and H) became available



JHEP02(2022)032

Solid bars: individual fit
Shaded bars: global fit

Linear fit



- Global SMEFT analyses are expanding and new available experimental results allow to constrain a set of the SMEFT operators, especially the ones related to Top quark.

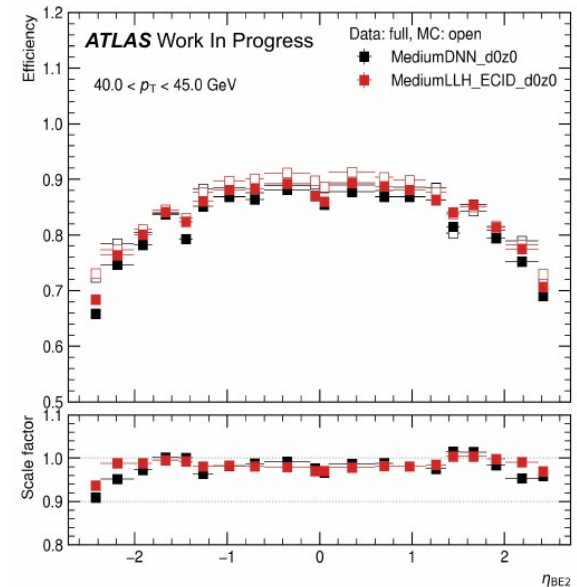
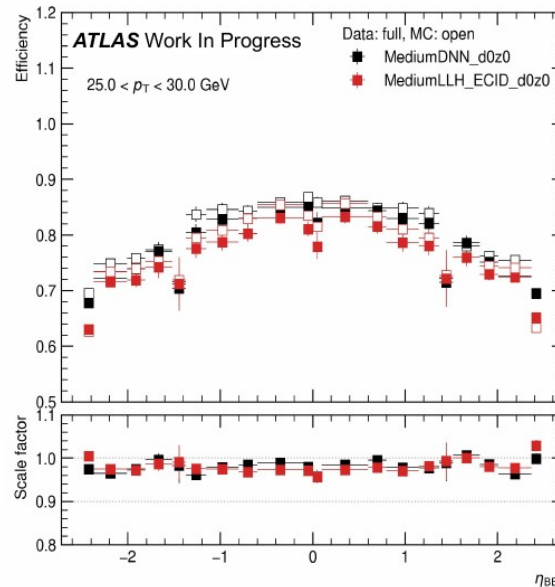
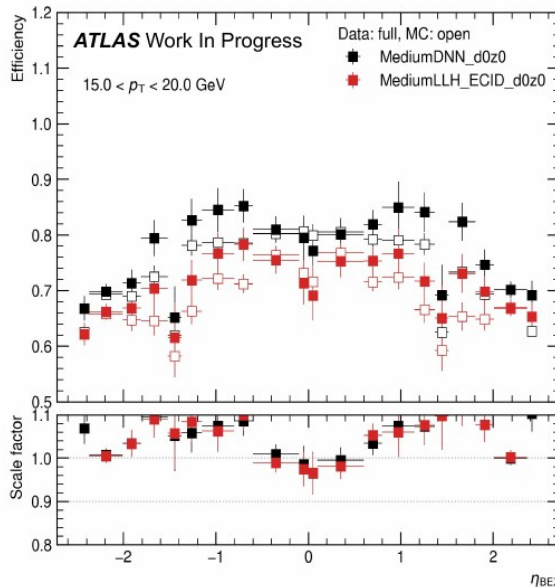
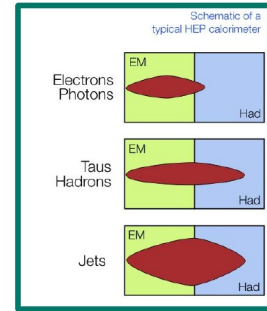
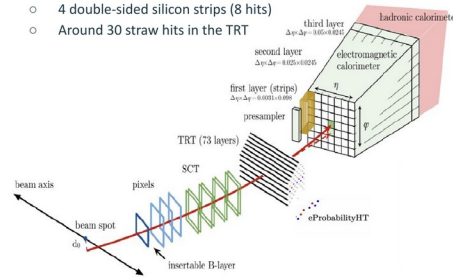
Electron ID with DNN



E. Valiente

Better experimental results are possible at LHC thanks to novel experimental techniques.

- An electron usually hits:
 - 3 pixel layers (+ insertable B-layer)
 - 4 double-sided silicon strips (8 hits)
 - Around 30 straw hits in the TRT



- New ML algorithm implemented for electron ID with multiple advantages
- Multiscore classification performed allowed for different electron classes (signals and backgrounds).
- Better signal efficiency @ constant background rejection.

- Electric dipole moment of electron is tiny in the SM and experimental limits leave room for BSM effects.
- Aligned two Higgs doublet model (A2HDM) is a simple extension of the SM, that can provide CP violation in both scalar and Yukawa sector resulting in values of eEDM reachable by future experiments.

☞ **SM Value:** eEDM starts at **4-loop**

$$d_e^{\text{SM}} \approx 10^{-38} \text{ e cm}$$

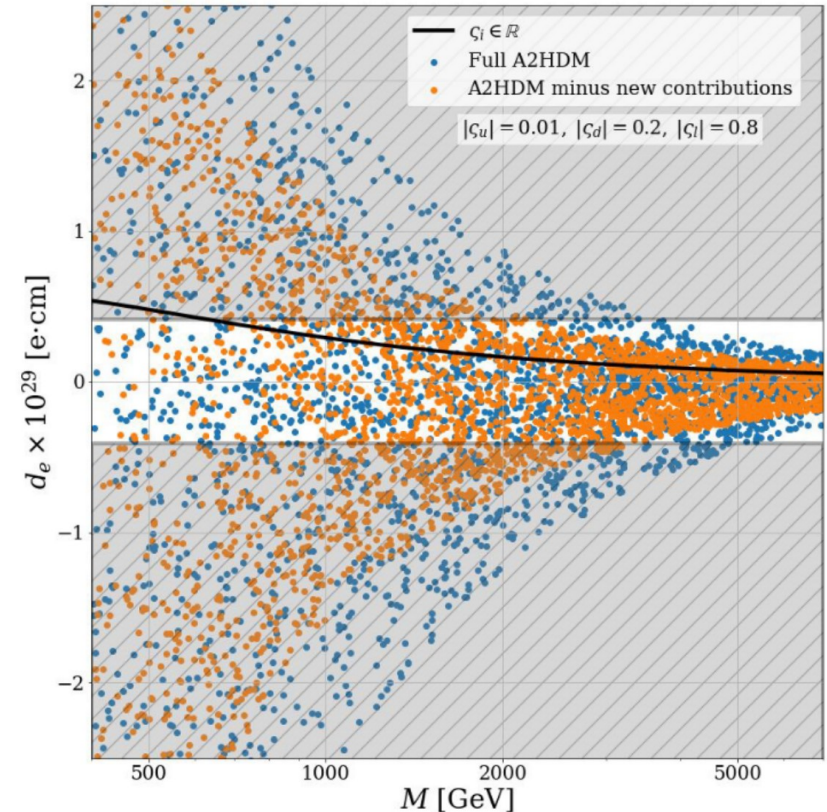
☞ **Majorana neutrinos:** eEDM starts at 2-loop

☞ **Type-I seesaw:** $d_e^{\text{seesaw-I}} \leq 10^{-33} \text{ e cm}$

☞ **Expt. bound:** $|d_e^{\text{Exp}}| \leq 4.11 \times 10^{-30} \text{ e cm}$ (90% C.L.)

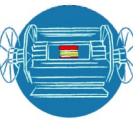
Roussy et al. Science 381 (2023) 6653

☞ **Motivation:** Room for BSM Physics,
Observed BAU suggests CPV beyond CKM matrix



- EDM is an interesting observable, sensitive to CPV.
- A2HDM can incorporate new sources of CPV in scalar potential as well as in Yukawa interaction, and thus it can generate larger eEDM than SM.

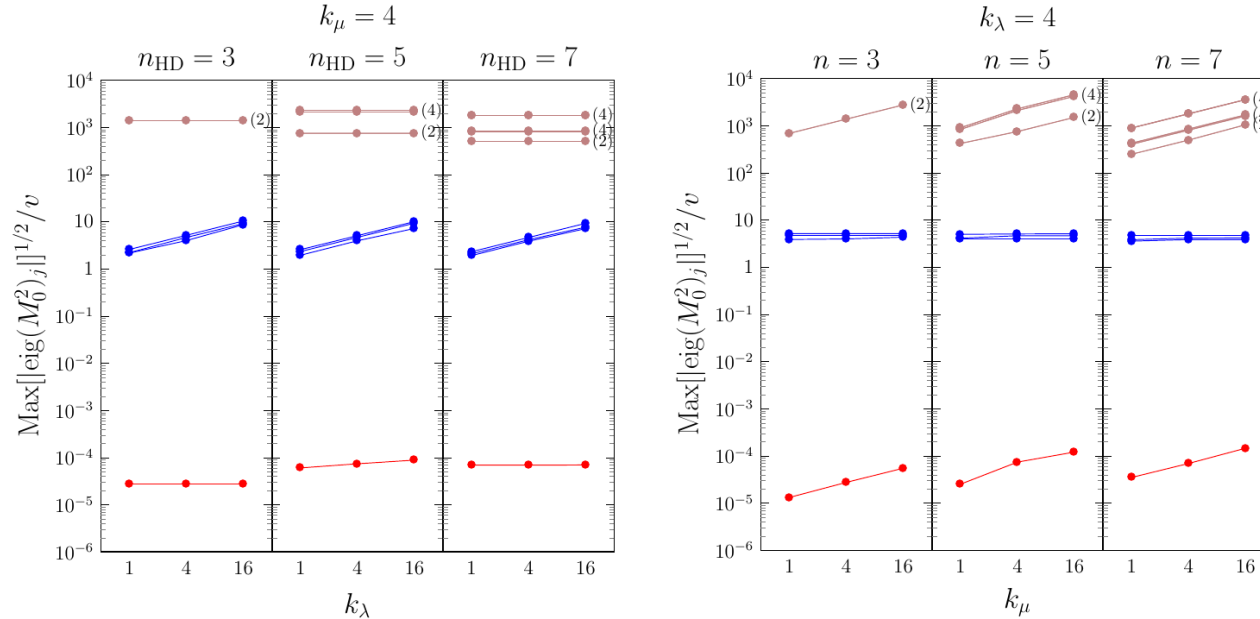
Light states multi-Higgs with CP violation



M. Nebot

- In multi-Higgs doublet models (nHDM) with Spontaneous CPV, it might be expected a regime where all new scalars have masses much larger than the electroweak scale.

Neutral mass matrix



- Numerical zero Goldstone
- Three light $\mathcal{O}(v)$ states, sensitive to k_λ , insensitive to k_μ
- $2n - 4$ heavy states, insensitive to k_λ , sensitive to k_μ

But that is not the case:

- one charged and three neutral scalars emerge, having $\mathcal{O}(v)$ masses.

Open ends

- Generic phenomenological prospects related to the light states?
- Symmetry interpretation?

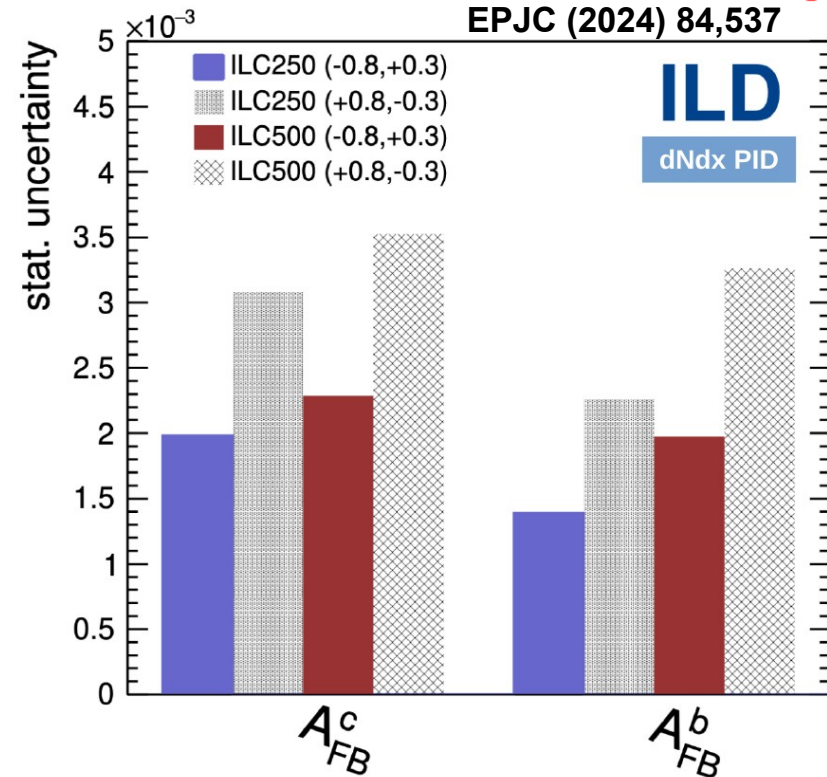
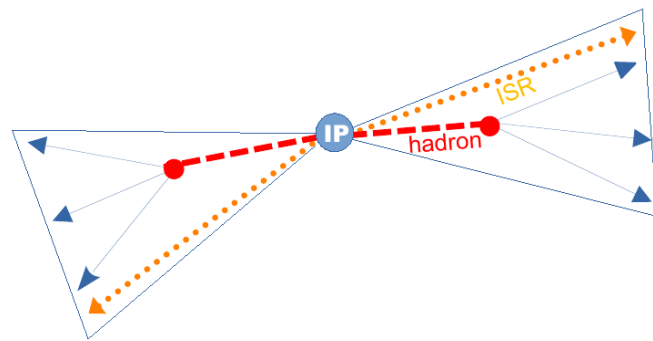
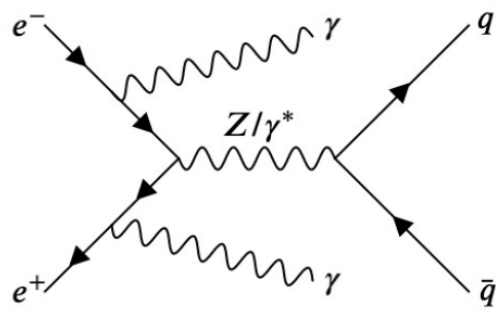
Gauge-Higgs unification @ILC



J. Marques

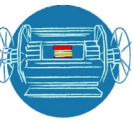
- Experimental prospects for measuring differential observables in $e^+e^- \rightarrow qq$ at the ILC motivated by Gauge Boson-Higgs unification theories, predicting resonances with masses of $O(10 \text{ TeV}) \rightarrow$ only indirect hints are possible at LHC or e^+e^- colliders.
- Study for ILC with baseline energies: 250 and 500 GeV.

$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$



- ILC offers good capabilities to explore these signatures and discriminate GHU vs SM:
 - High energy reach.
 - Electron and positron beam polarization.

Conclusions



Merry Christmas!



ChatGPT idea of the new IFIC building