中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

Searching for New Physics in Higgs Physics

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arXiv:191x.abcde[hep-ph],
and arXiv:191y.ijklm[hep-ph]

The Energy Frontier

Origin of Mass

Matter/Anti-matter Asymmetry

Dark Matter

Origin of *Universe*

Unification of *Forces*

New Physics Beyond the Standard *Model*

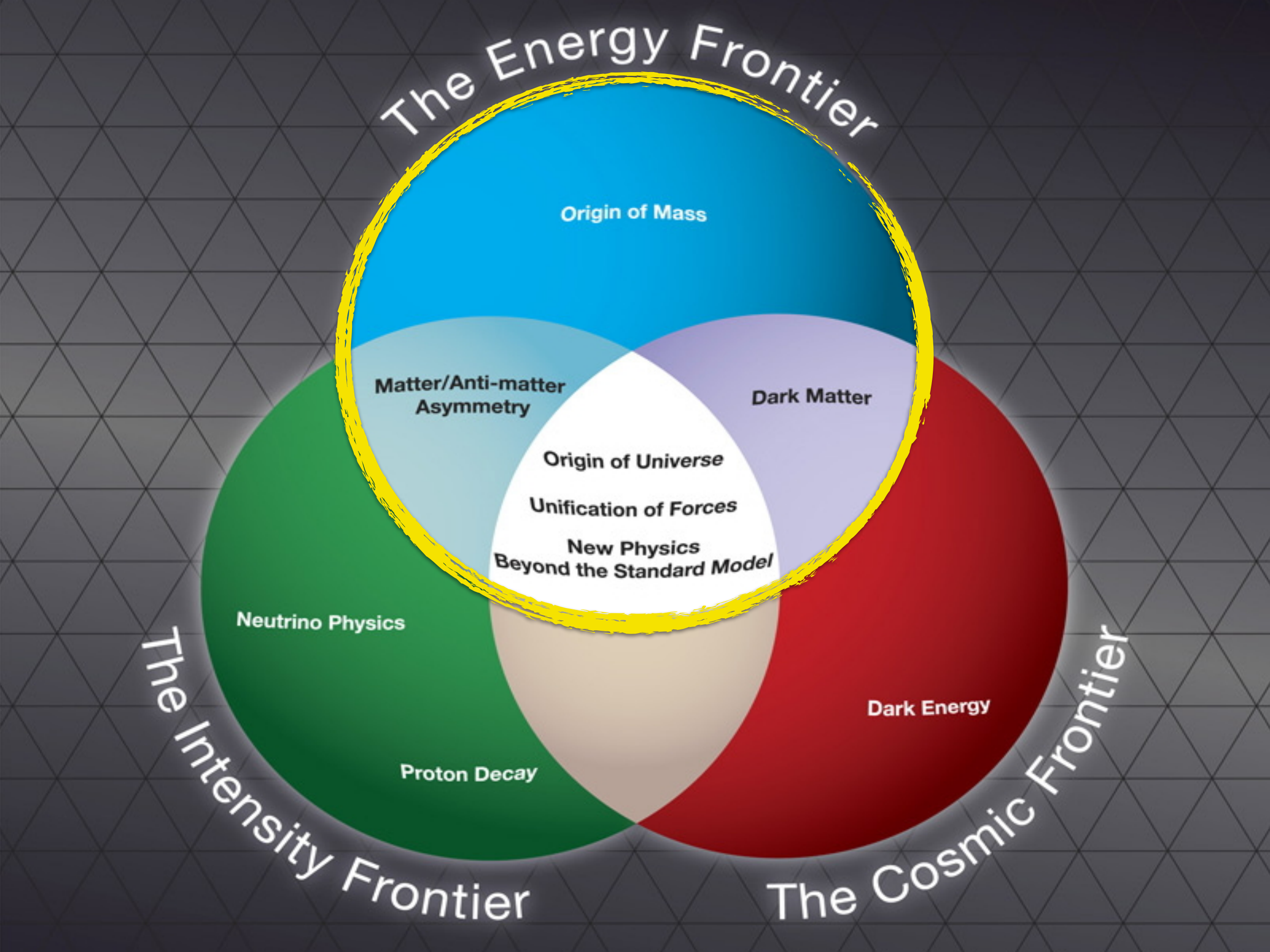
Neutrino Physics

Proton Decay

Dark Energy

The Intensity Frontier

The Cosmic Frontier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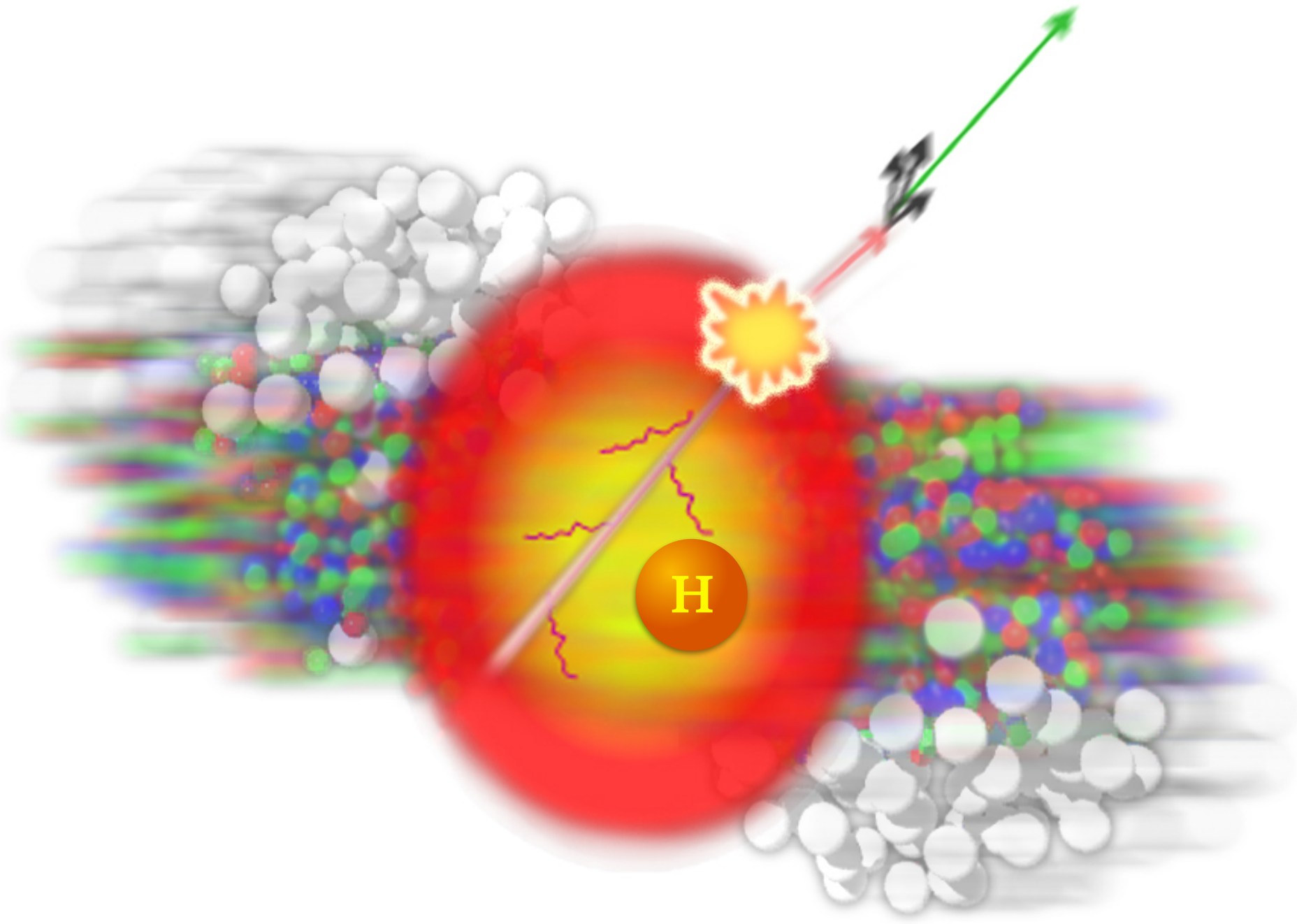
Where to search for new physics?

What can we learn with the LHC and future Higgs factory?

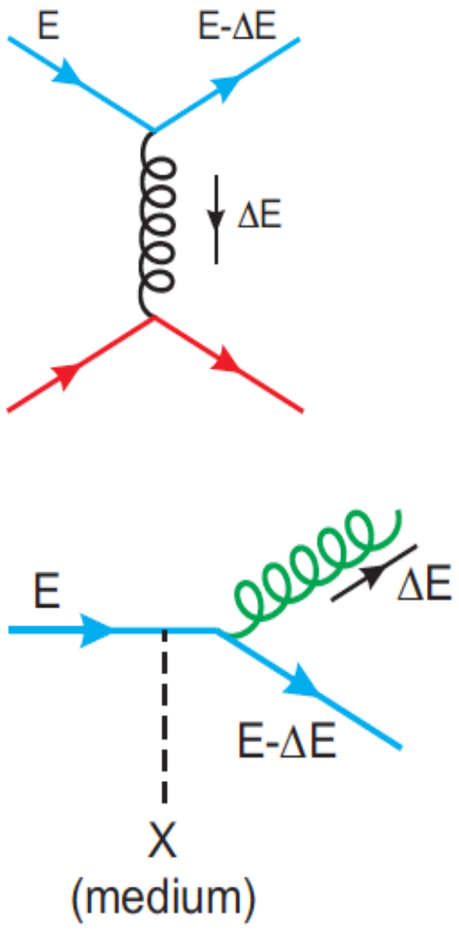
Production and Hadronic Decays of Higgs Bosons in Heavy-Ion Collisions

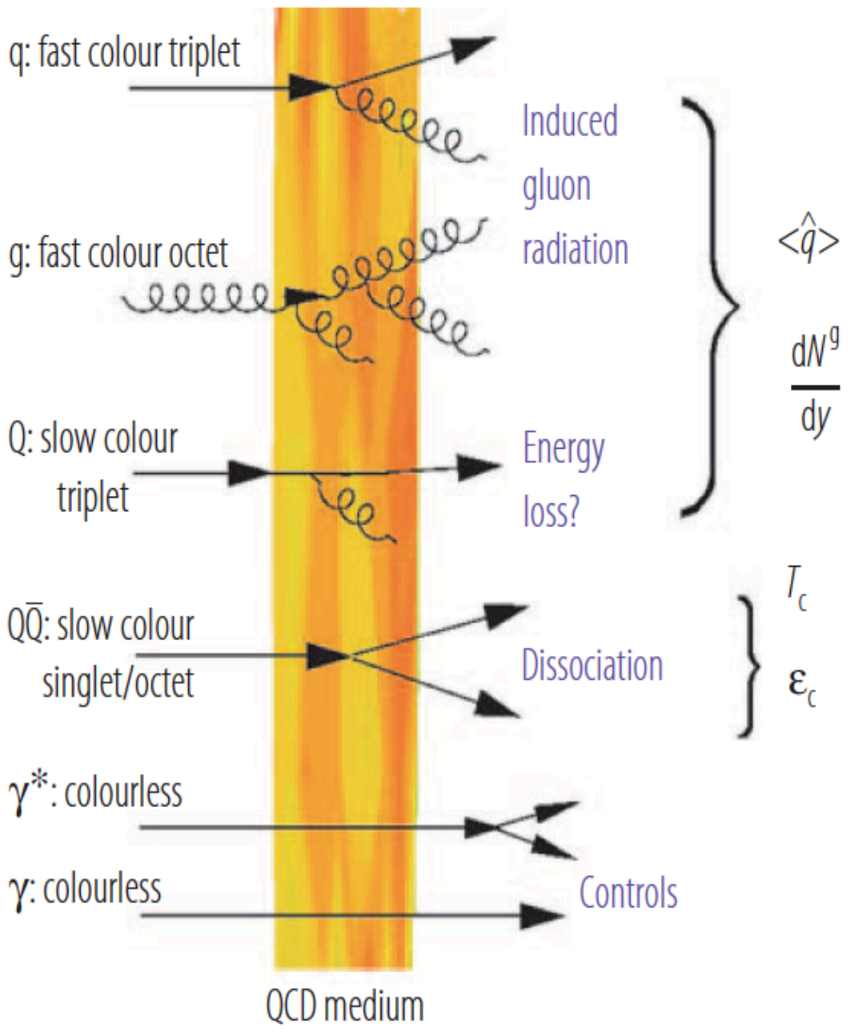


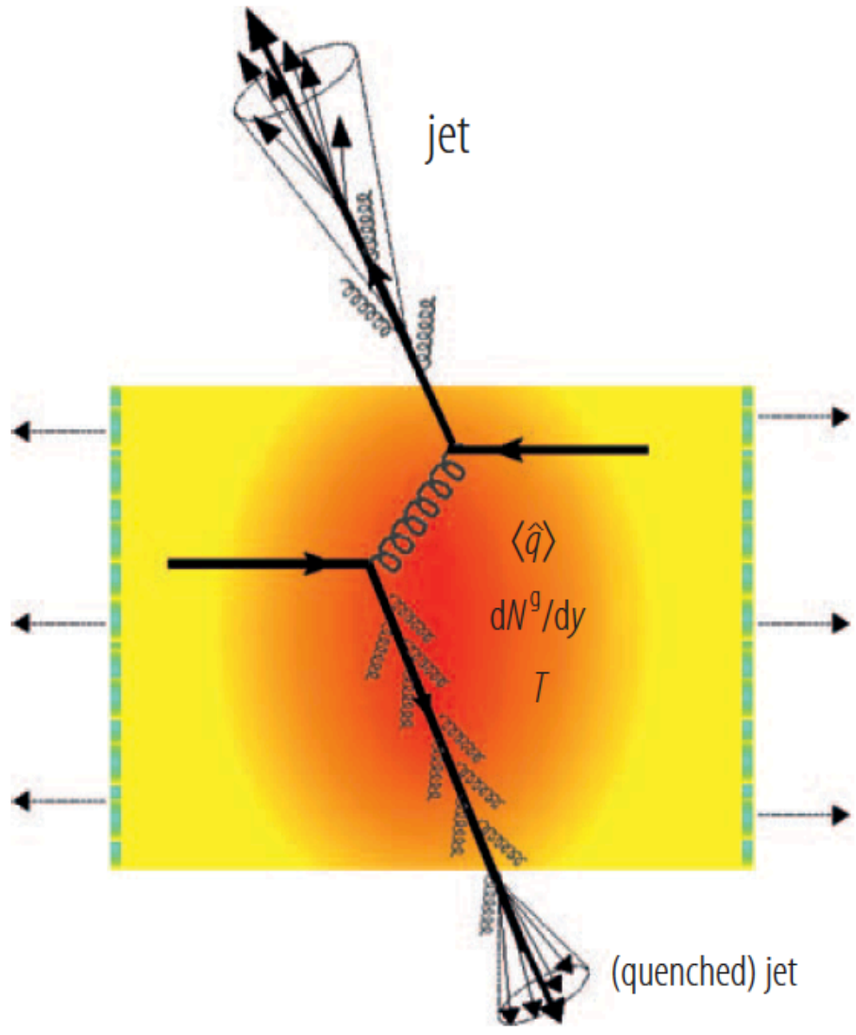
Phys. Rev. Lett ***122****, 041803 (2019)*

Heavy-Ion Collision at the LHC

- **Jet Quenching**: the quark and gluon travel in the hot dense phase, the QGP, will lose their energy by collisions and radiations.







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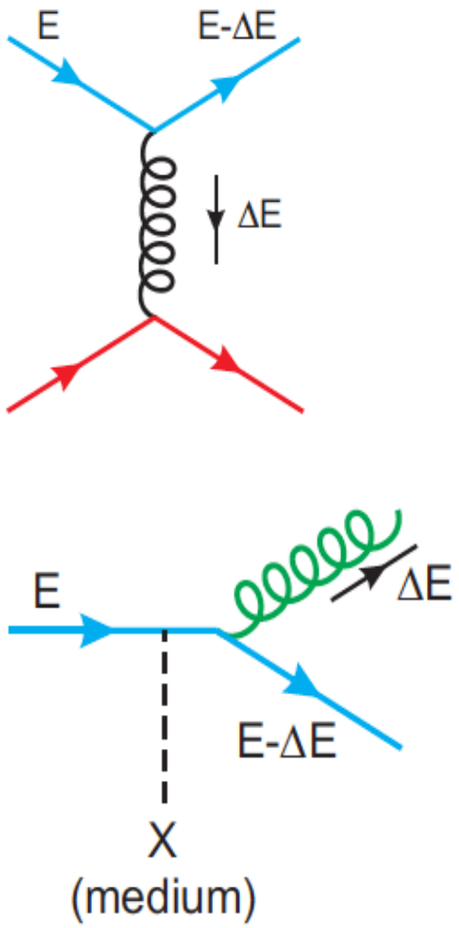
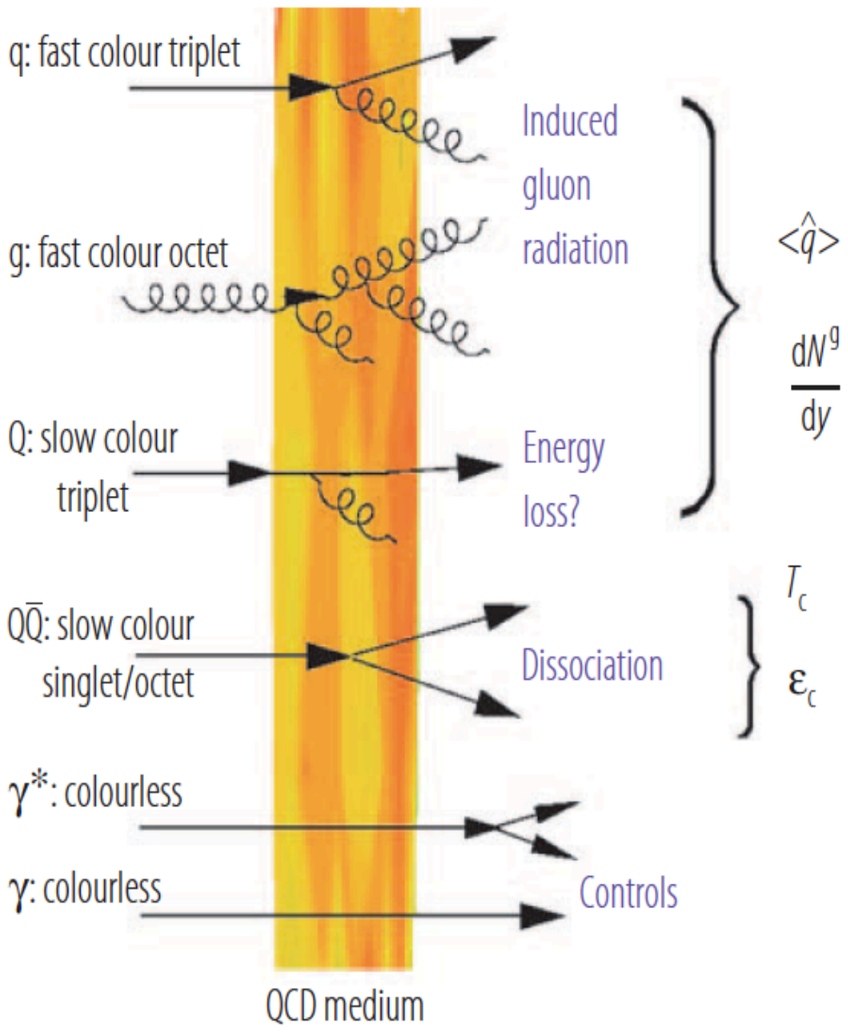
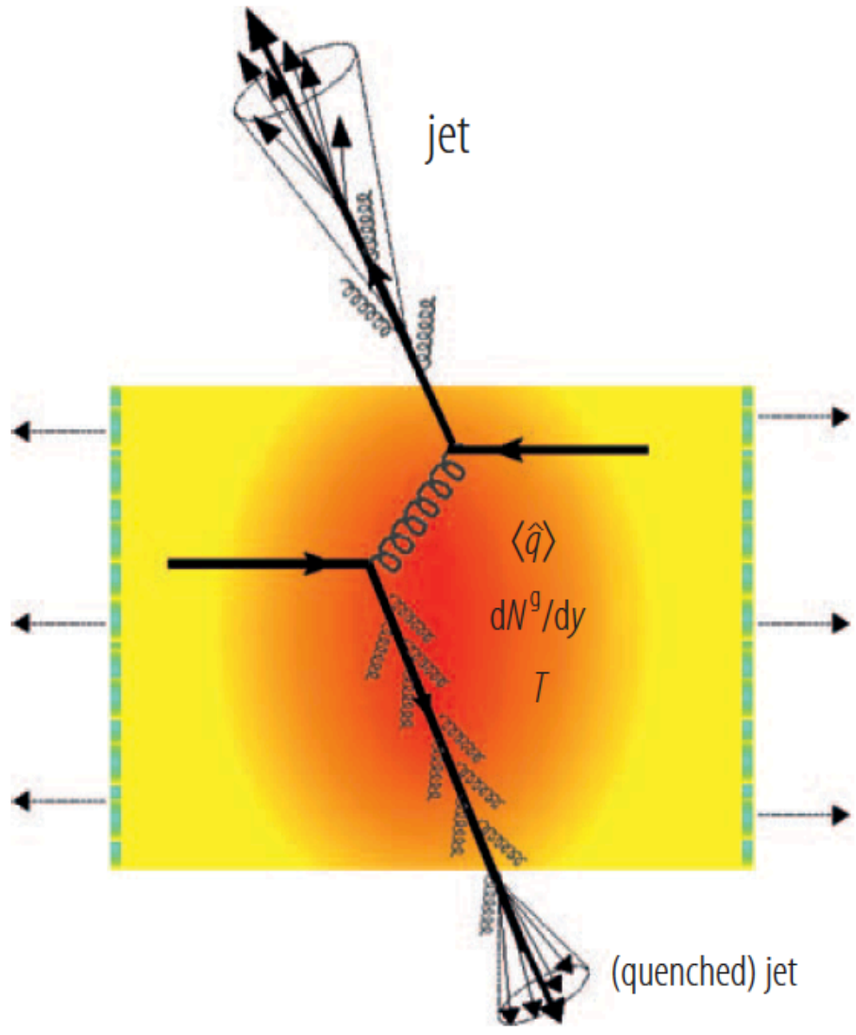


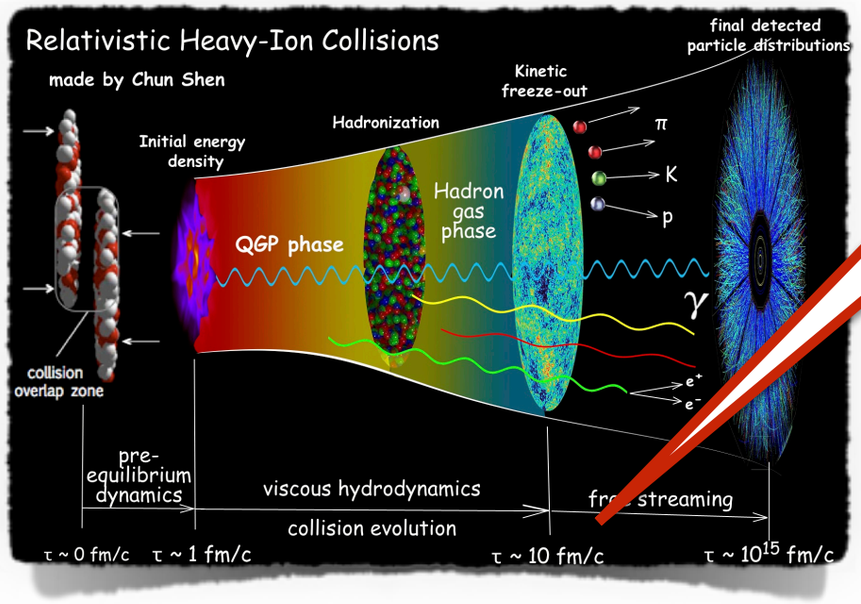




How about the Higgs boson?

Heavy-Ion Collision at the LHC

- The lifetime of the QGP produced in the heavy-ion collision at the LHC.



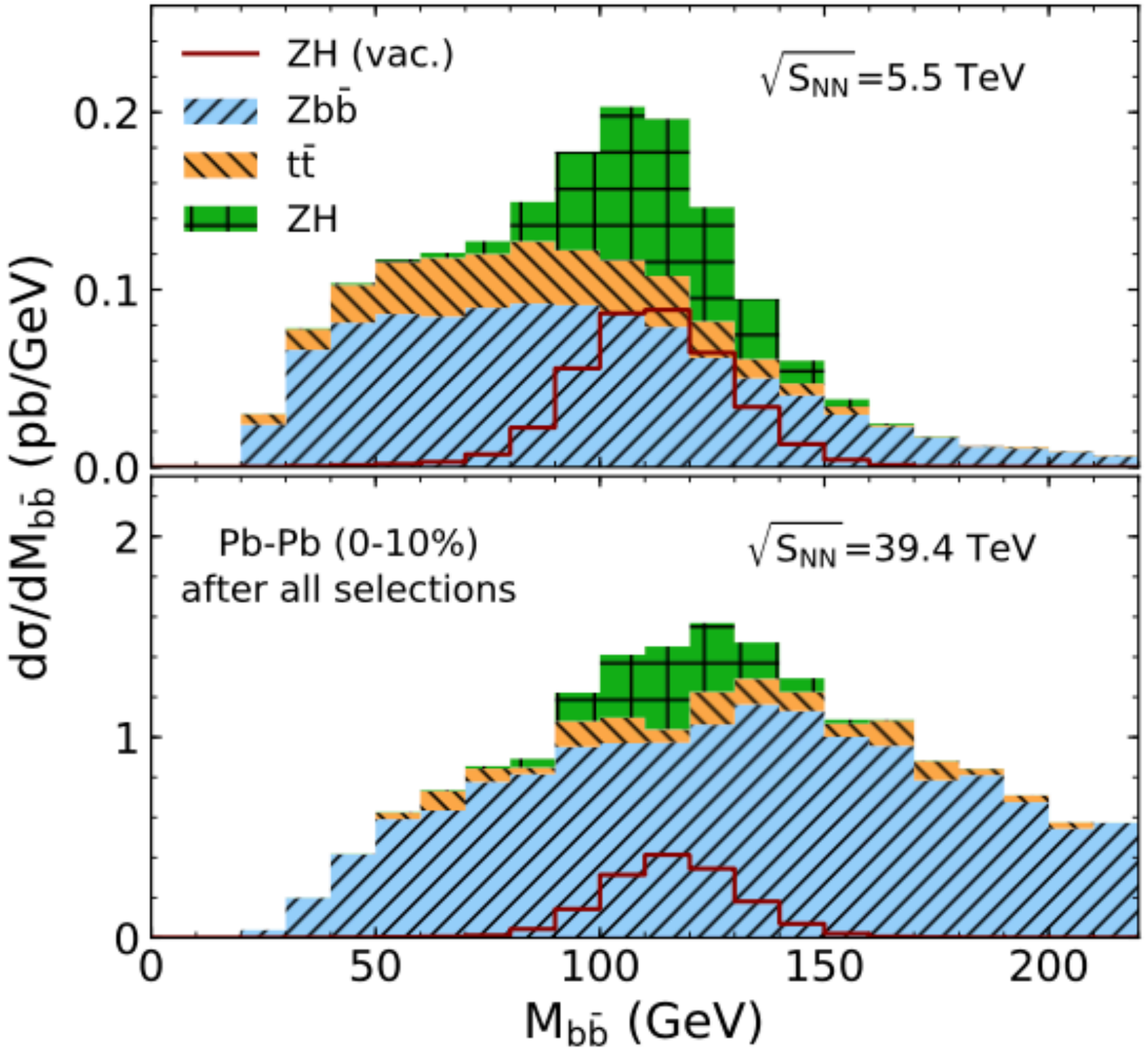
Lifetime ~ 10fm/c

$$1\mathrm{fm/c} = \frac{10^{-15}\mathrm{m}}{2.99792458 \times 10^{8}\mathrm{m/s}} = 3.33564 \times 10^{-24}\mathrm{s}$$

$$= \frac{3.33564 \times 10^{-24}\mathrm{s}}{6.58 \times 10^{-25}\mathrm{s} \cdot \mathrm{GeV}} = \frac{1}{197\mathrm{MeV}}$$

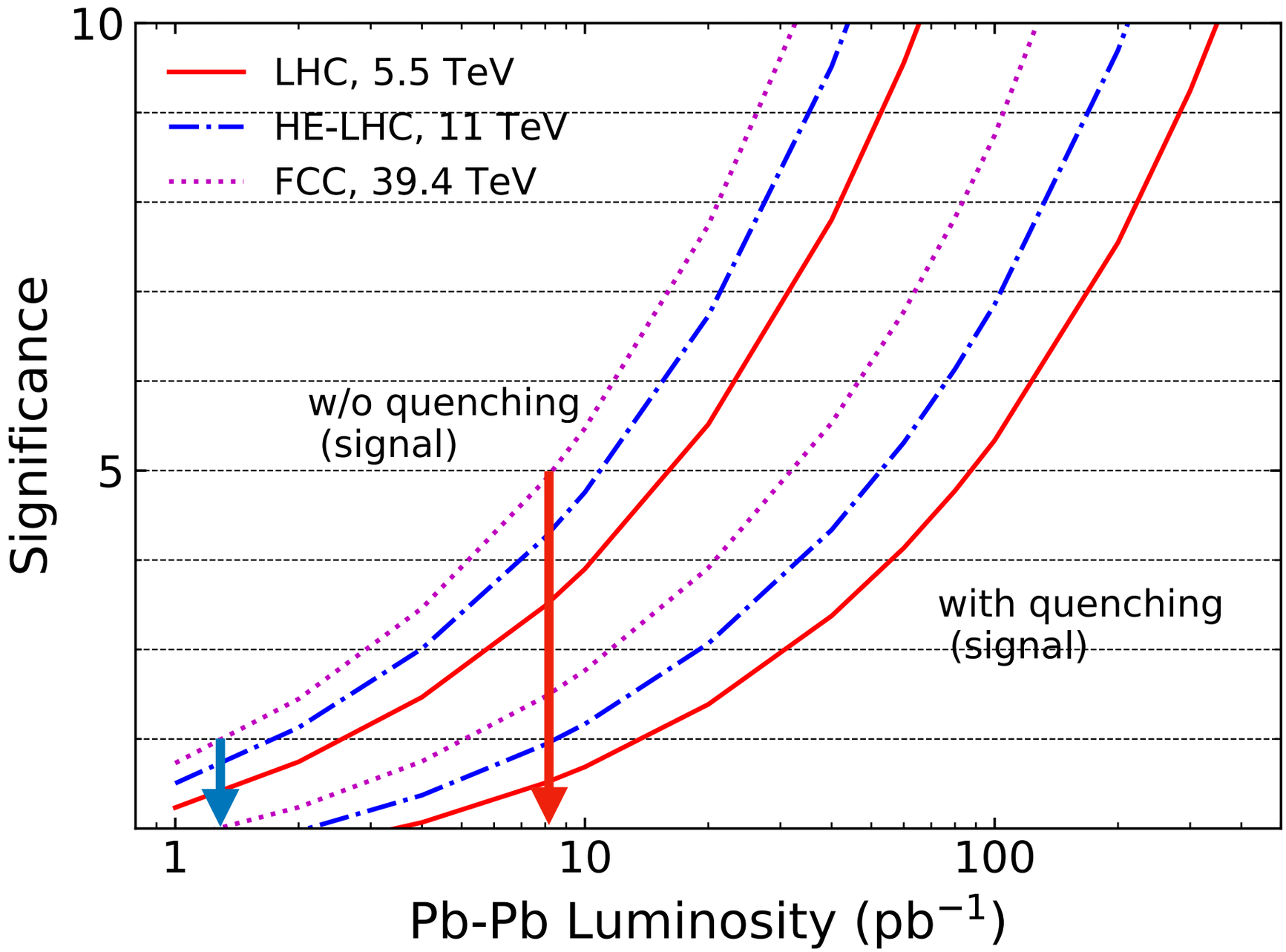
Higgs in Heavy-Ion Collision

- Collider simulation.



Higgs in Heavy-Ion Collision

- Significance at the LHC and future hadron colliders.



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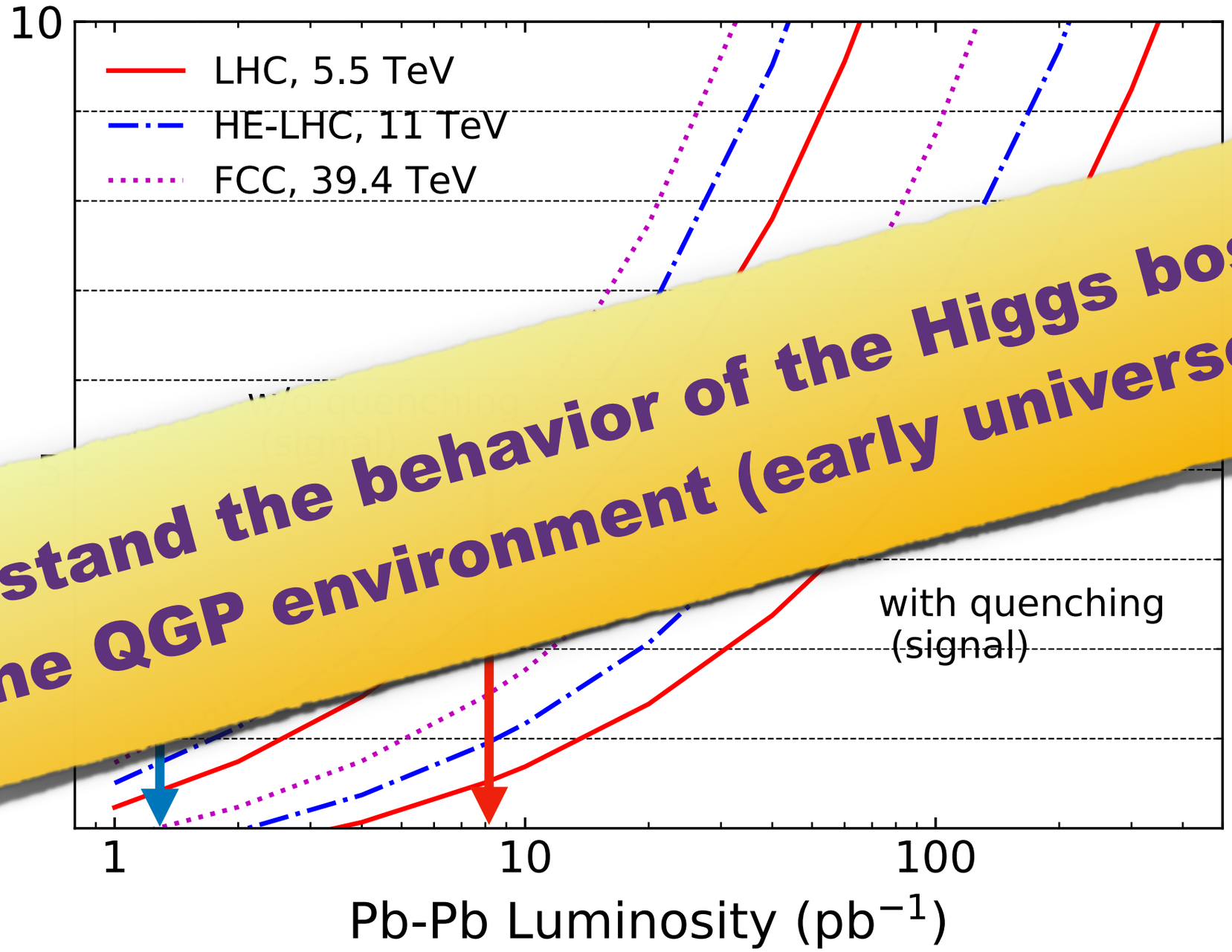
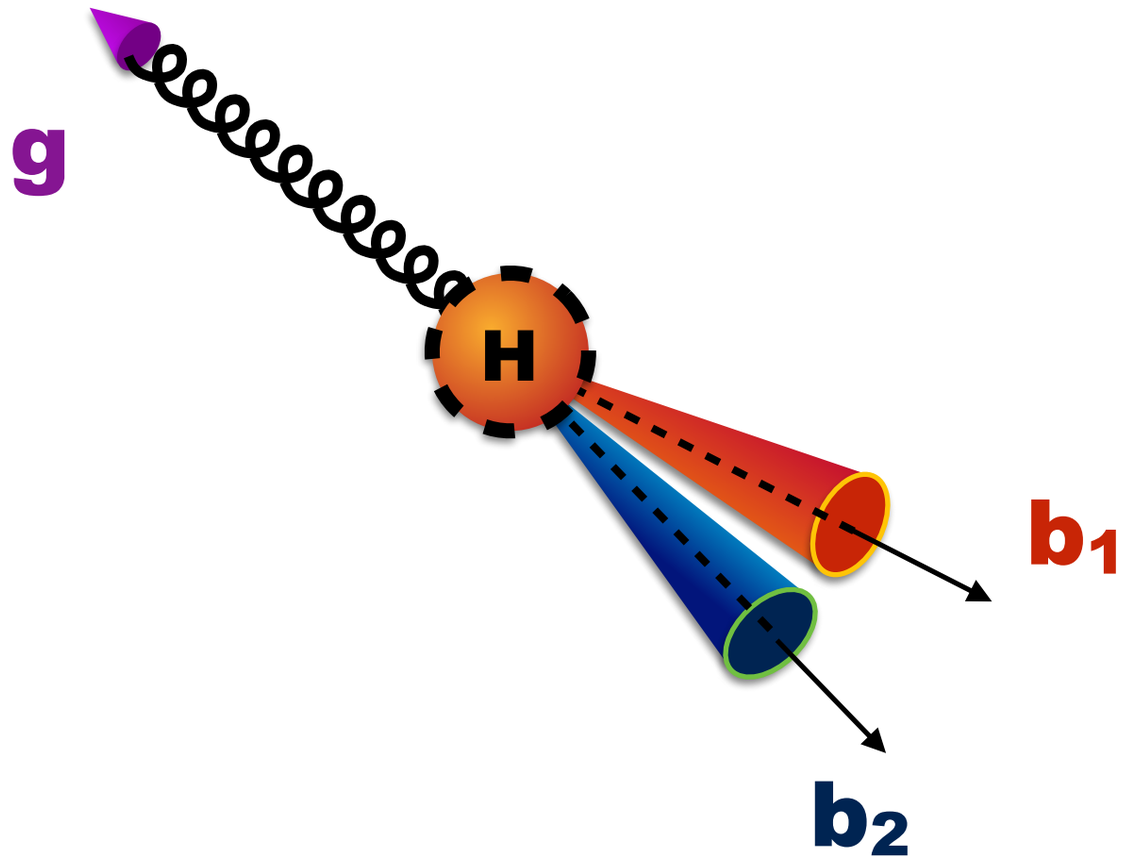


Understand the behavior of the Higgs boson in the QGP environment (early universe)!

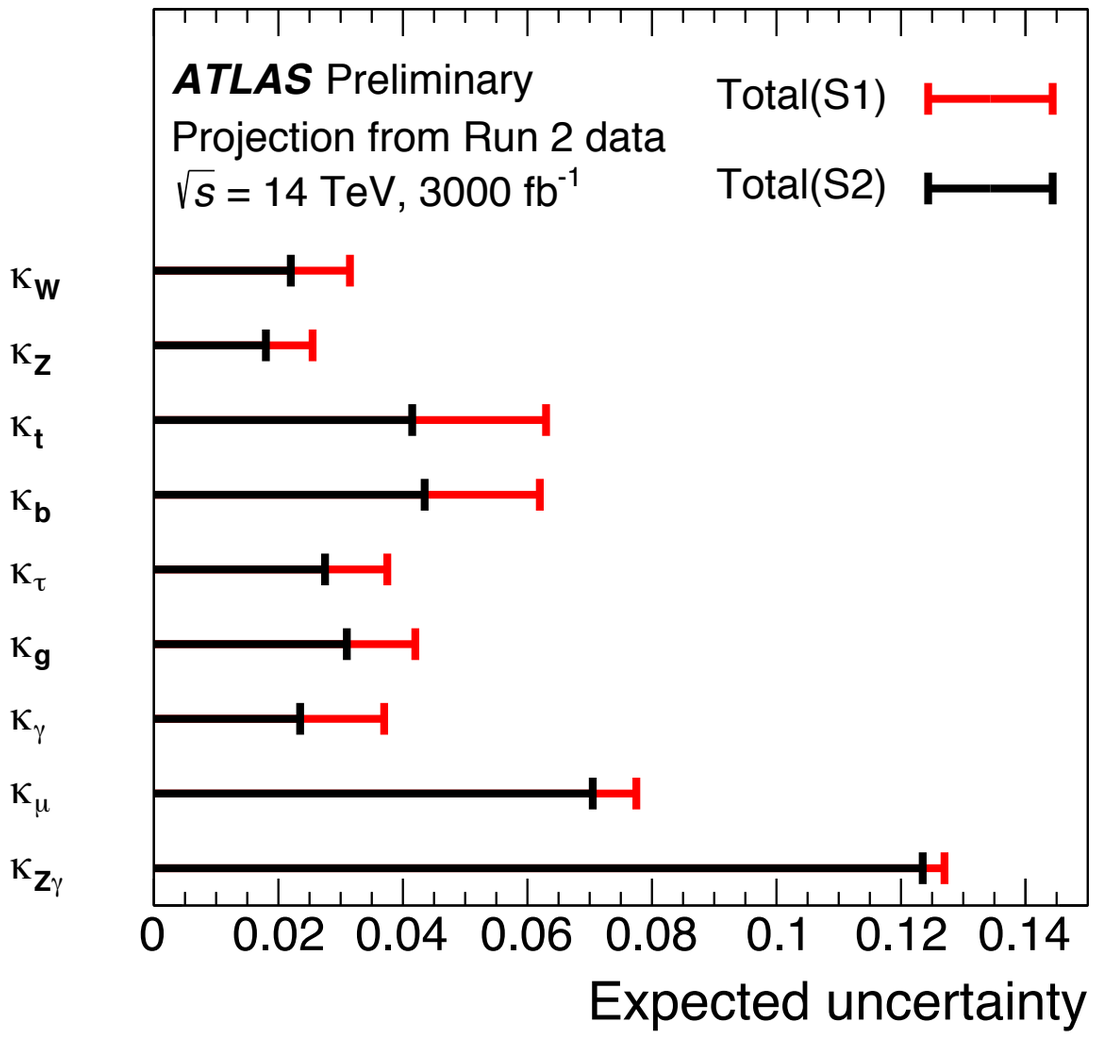
Studying the Phase Angles in the Yukawa Interactions

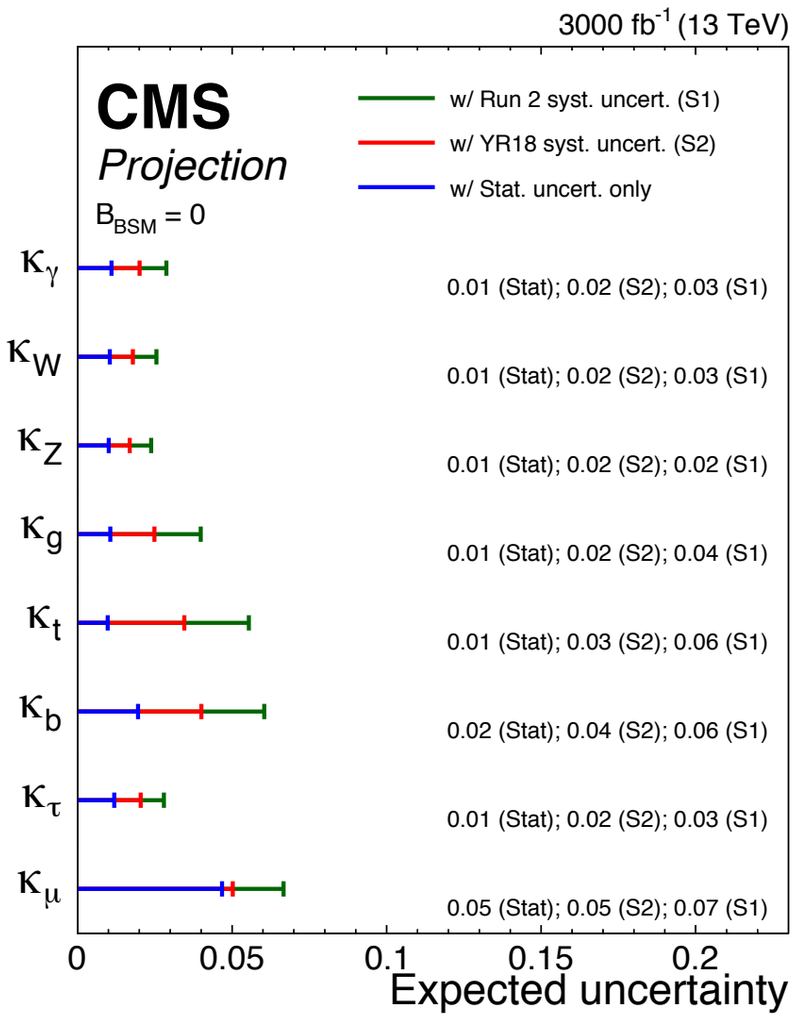


arXiv:191x.abcde[hep-ph],
and arXiv:191y.ijklm[hep-ph]

An Era of Precisely Higgs Physics

- More precisely result in near future.





ATLAS Collaboration, ATLAS-PHYS-PUB-2018-054;
CMS Collaboration, CMS PAS FTR-18-011.

An Era of Precisely Higgs Physics

- Generic form of the SFF interaction

$$\mathscr{L} = y_f h \bar{f} (\cos\alpha_f + i\gamma_5 \sin\alpha_f) f$$

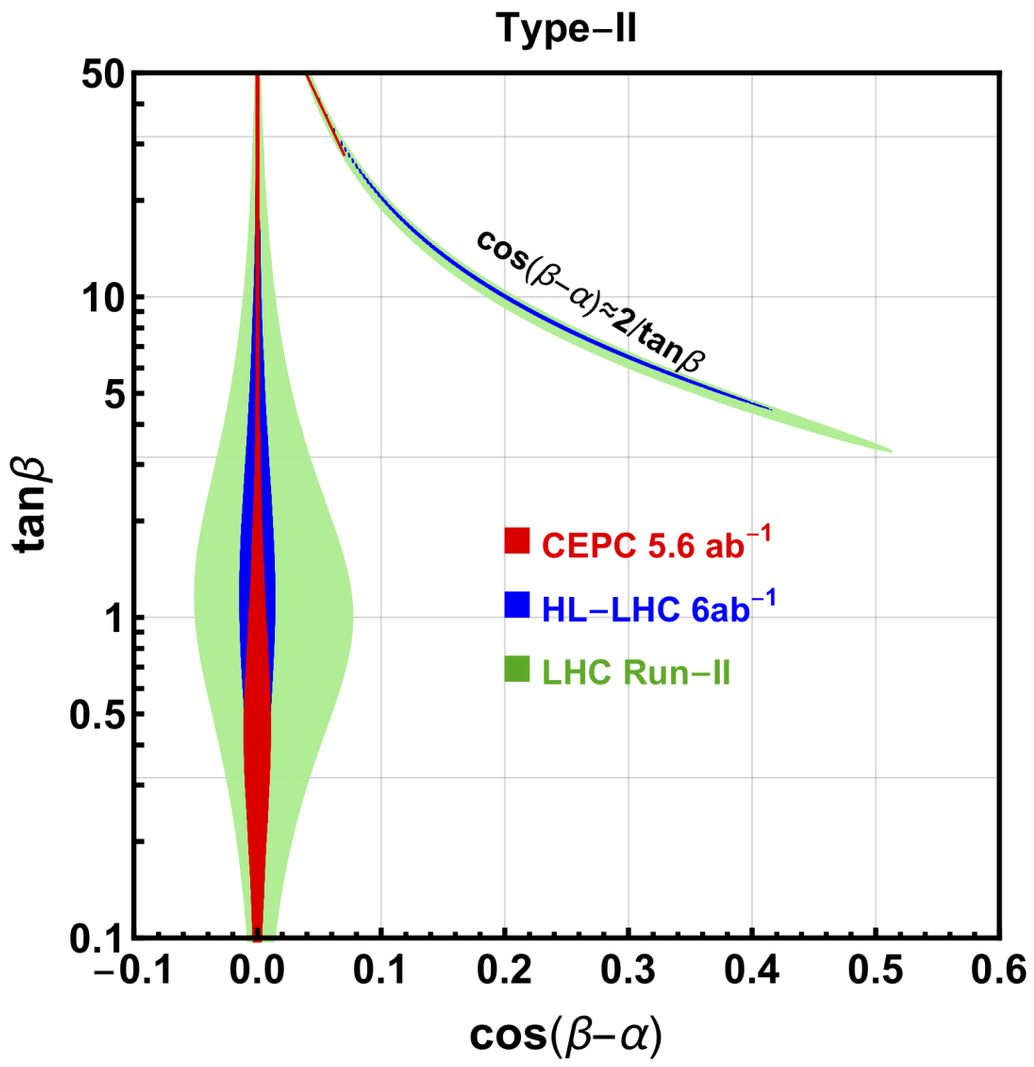
$$y_f \in \mathbb{R}^+, \quad \alpha_f \in (-\pi, \pi]$$

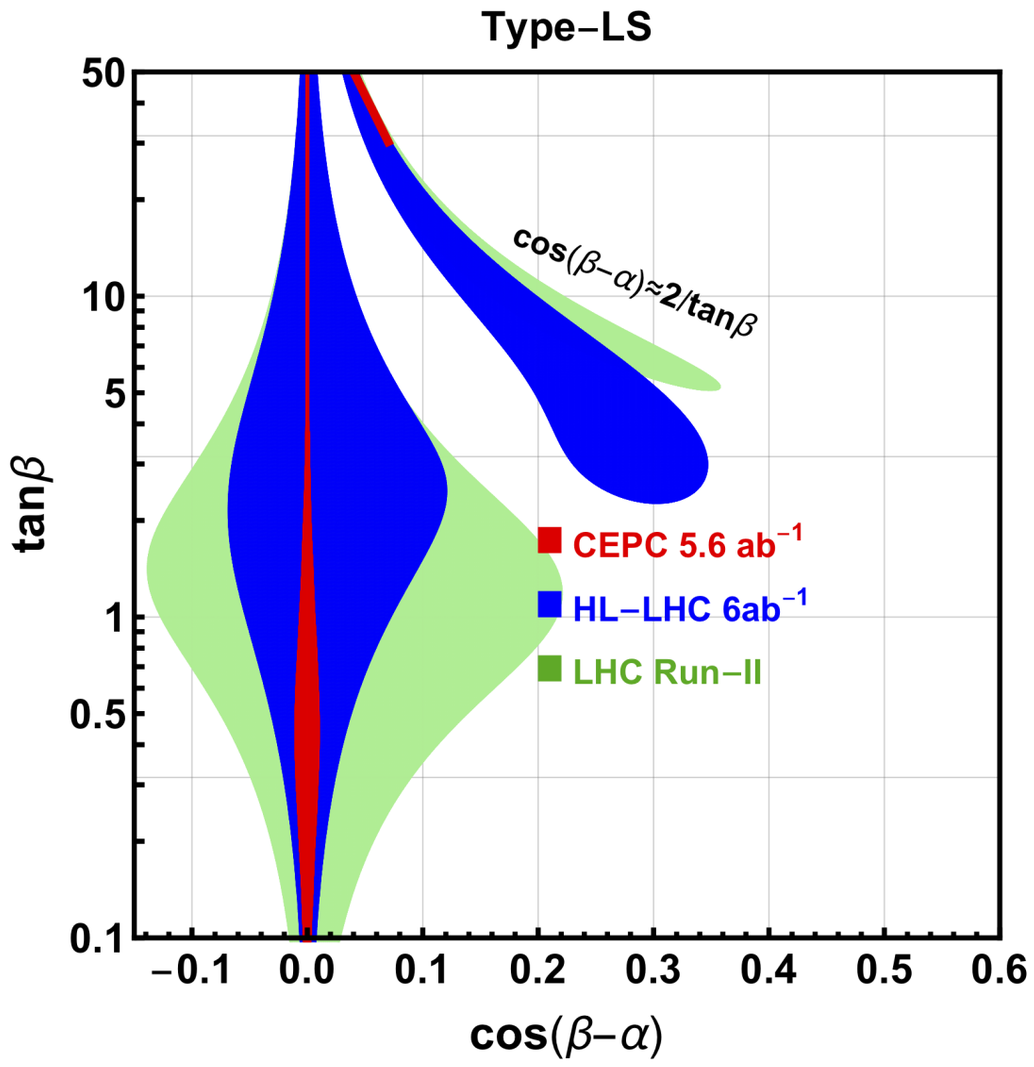
- The non-zero phases in the Yukawa interactions are evidence of new sources of EWSB and might be important for us to understand the matter-antimatter asymmetry in our universe.

- Can we measure the α_f ?

Phase in bottom-quark Yukawa Interactions

- Very interesting parameter.
- Exp: 2HDMs





Wei Su, arXiv:1910.06269[hep-ph].

Phase in bottom-quark Yukawa Interactions

- Indirect measurement (e.g. EDM).

- Hadronic EDMs (90% C.L.):

$$\frac{y_b}{y_b^{\mathrm{SM}}} |\sin\alpha_b| < 5$$

- Electron EDM (90% C.L.):

$$\frac{y_b}{y_b^{\mathrm{SM}}} |\sin\alpha_b| < 0.4$$

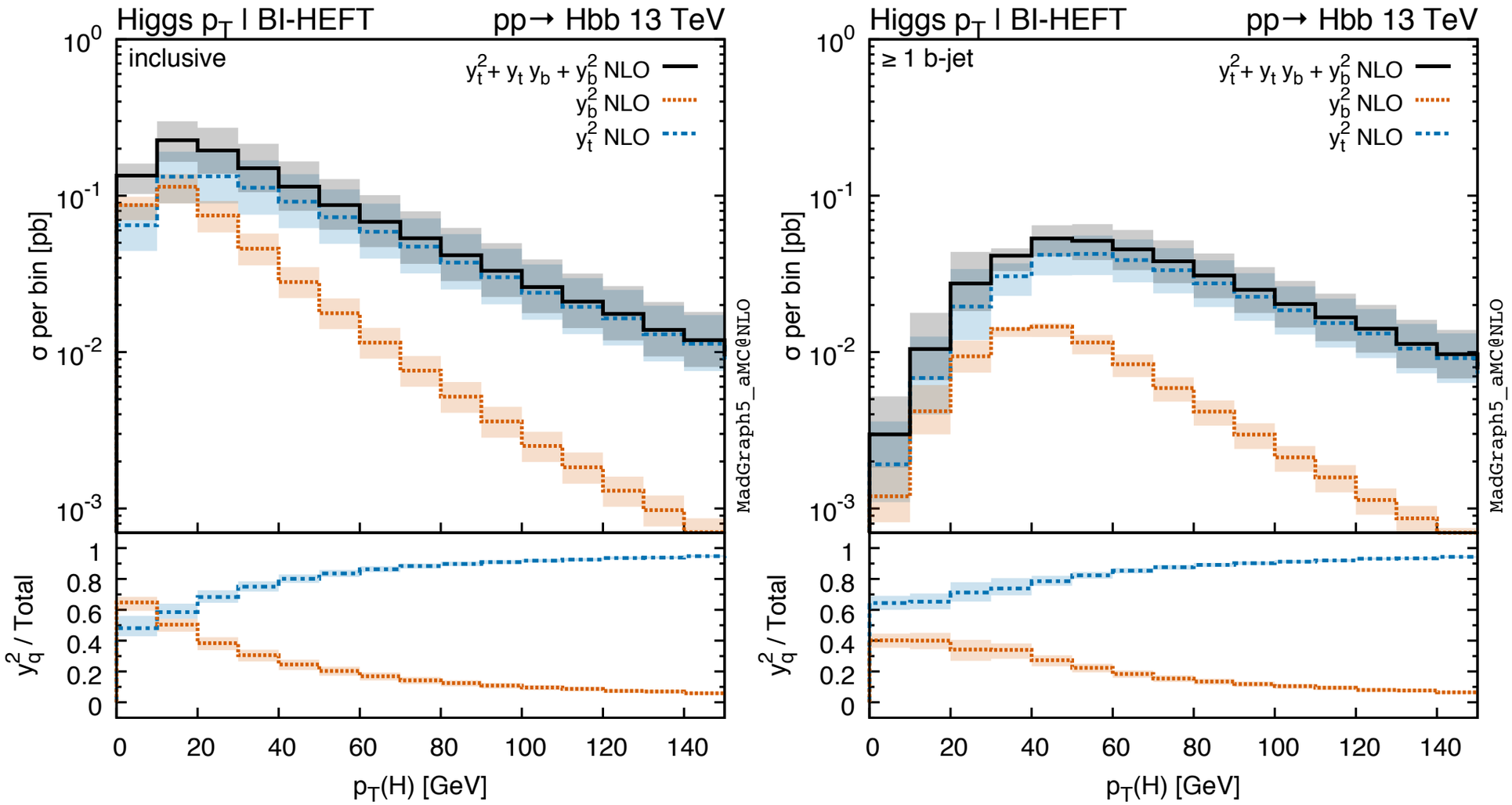
- But indirectly measurements are suffered by the NP contributions to the loop…

J. Brod and E. Stamou, arXiv:1810.12303[hep-ph].

Phase in bottom-quark Yukawa Interactions

- Very difficult at the LHC!

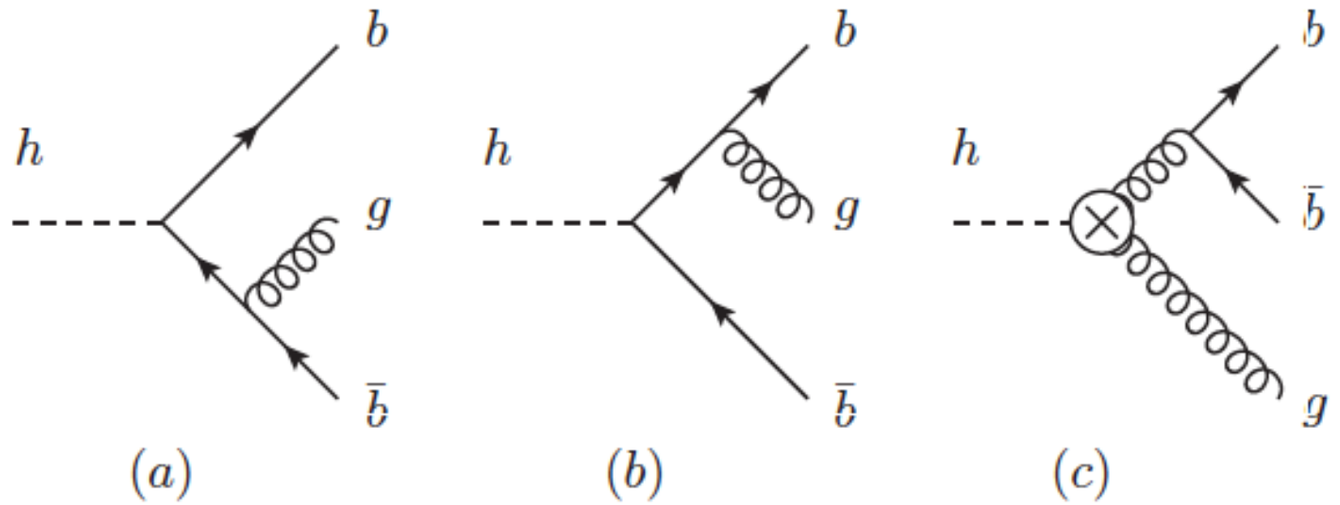
- Direct: large background, large contribution from Hgg.



N. Deutschmann, F. Maltoni, M. Wiesemann and Marco Zaro, JHEP 1907 (2019) 054.

Phase in bottom-quark Yukawa Interactions

- Interference in Higgs decay:

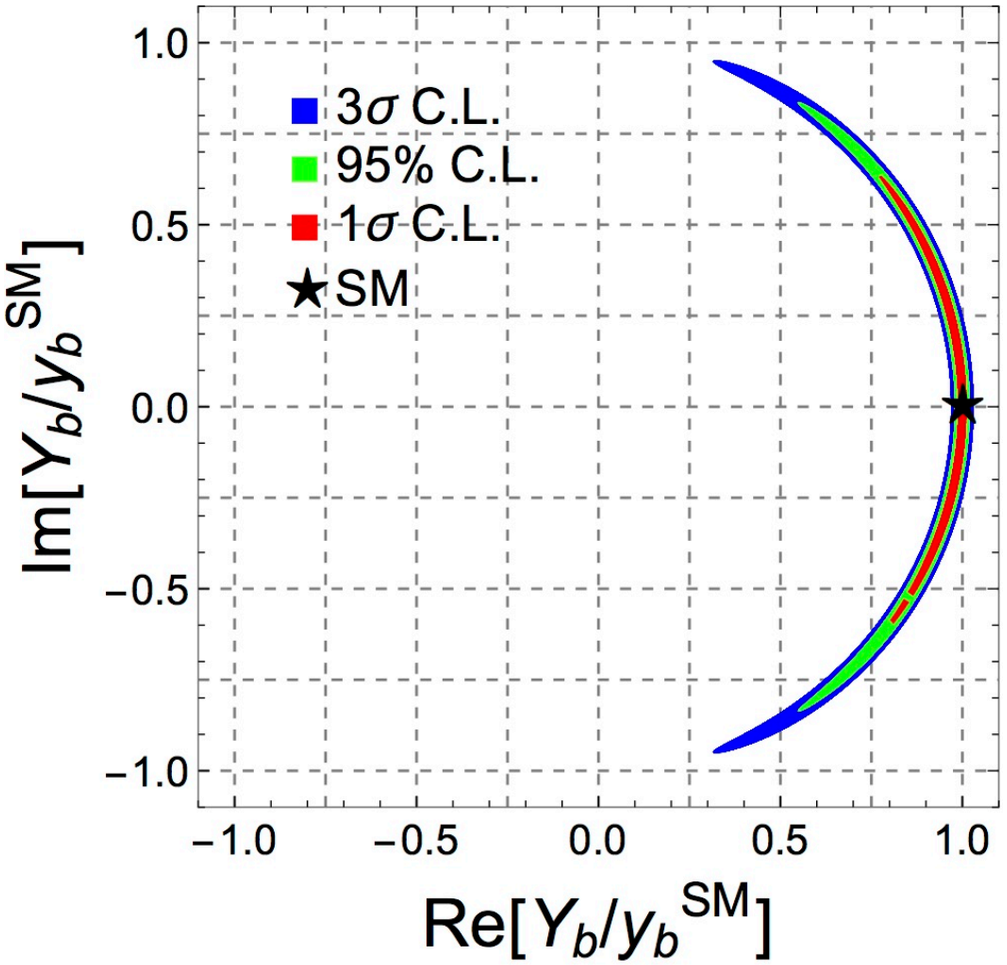


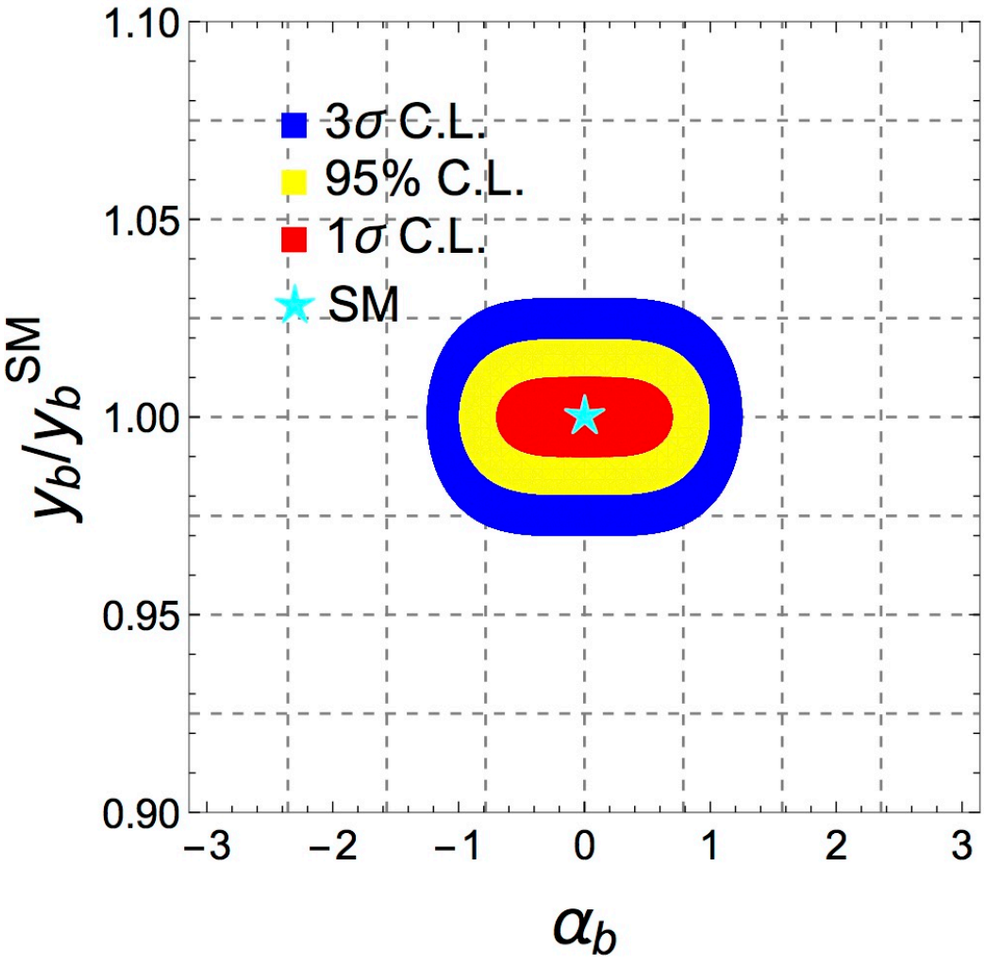
- Advantage: the Hgg interaction can be well measured at both the LHC and the Higgs factory, with the information of the Lorentz structure.

$$hG^a_{\mu\nu}G^{a,\mu\nu} \quad \textbf{vs} \quad hG^a_{\mu\nu}\tilde{G}^{a,\mu\nu}$$

Results

- 240GeV Higgs factory with 5.6ab^{-1} integrated luminosity.

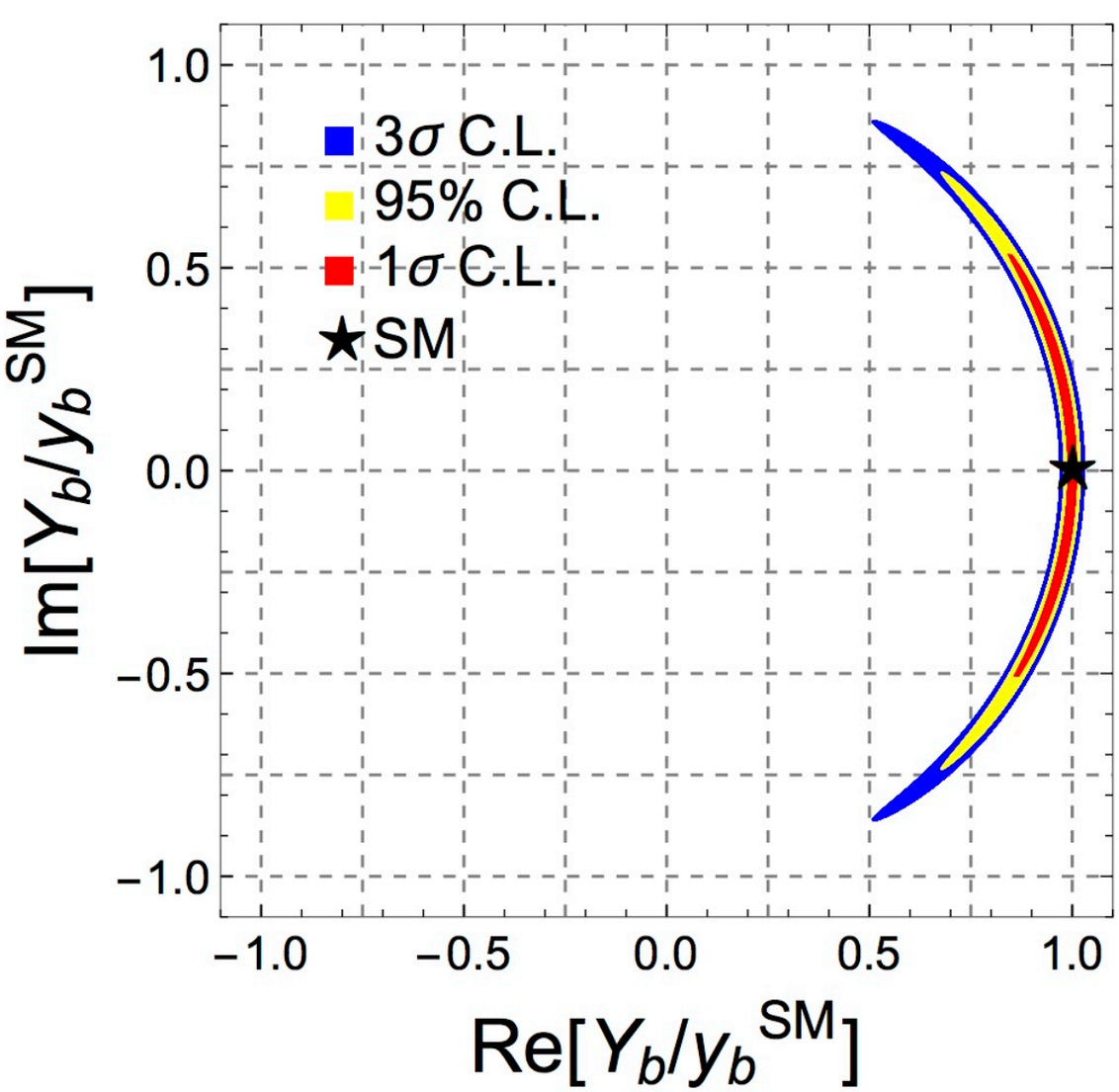


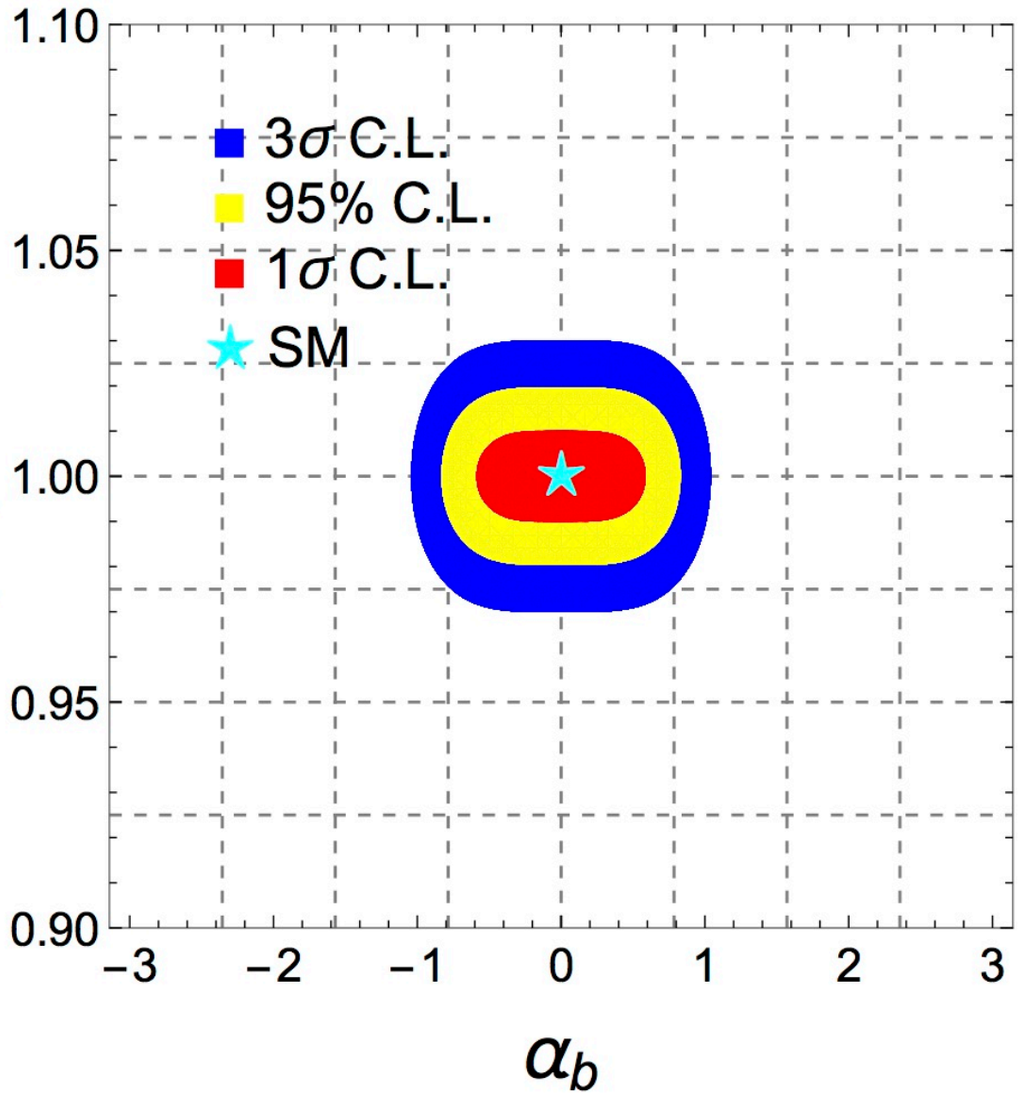


$\delta\alpha_b \sim 40^\circ$

Results

- 240GeV Higgs factory with 5.6ab^{-1} integrated luminosity+ 365GeV Higgs factory with 1.5ab^{-1} integrated luminosity.





$\delta\alpha_b \sim 34^\circ$

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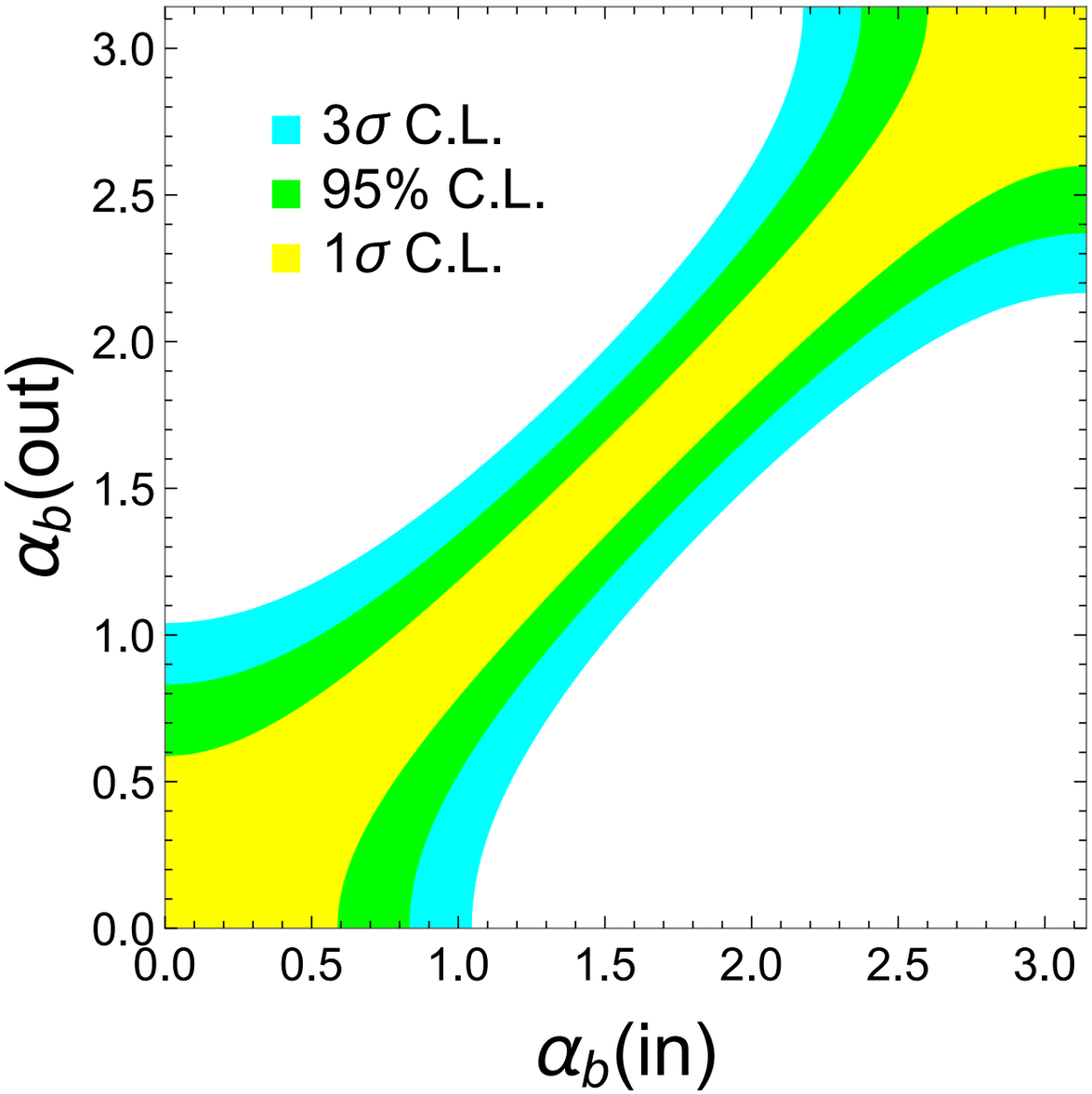

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- The property of the Higgs boson in extreme environment.

- The interacting strength and the Lorentz structure between the Higgs boson and the SM particles.

- For us phenomenologist: proposing more and more interesting observables which are robust (less model dependent) and clearly (show specific property of particles). WHY?

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Thank you!