

Effective Field Theory: a framework to connect physics at different scales

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FH Fellow Meeting, 28/04/2023

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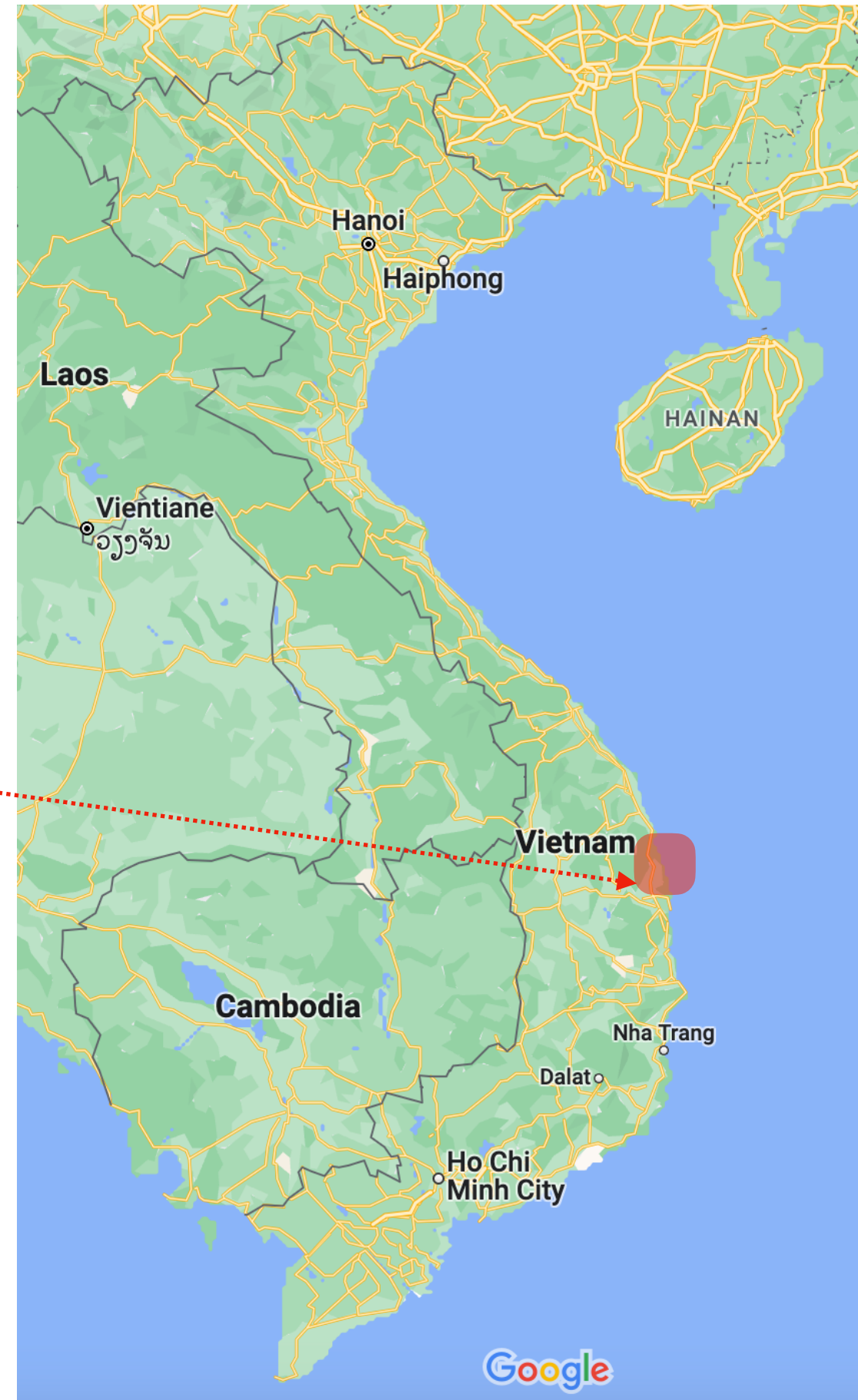


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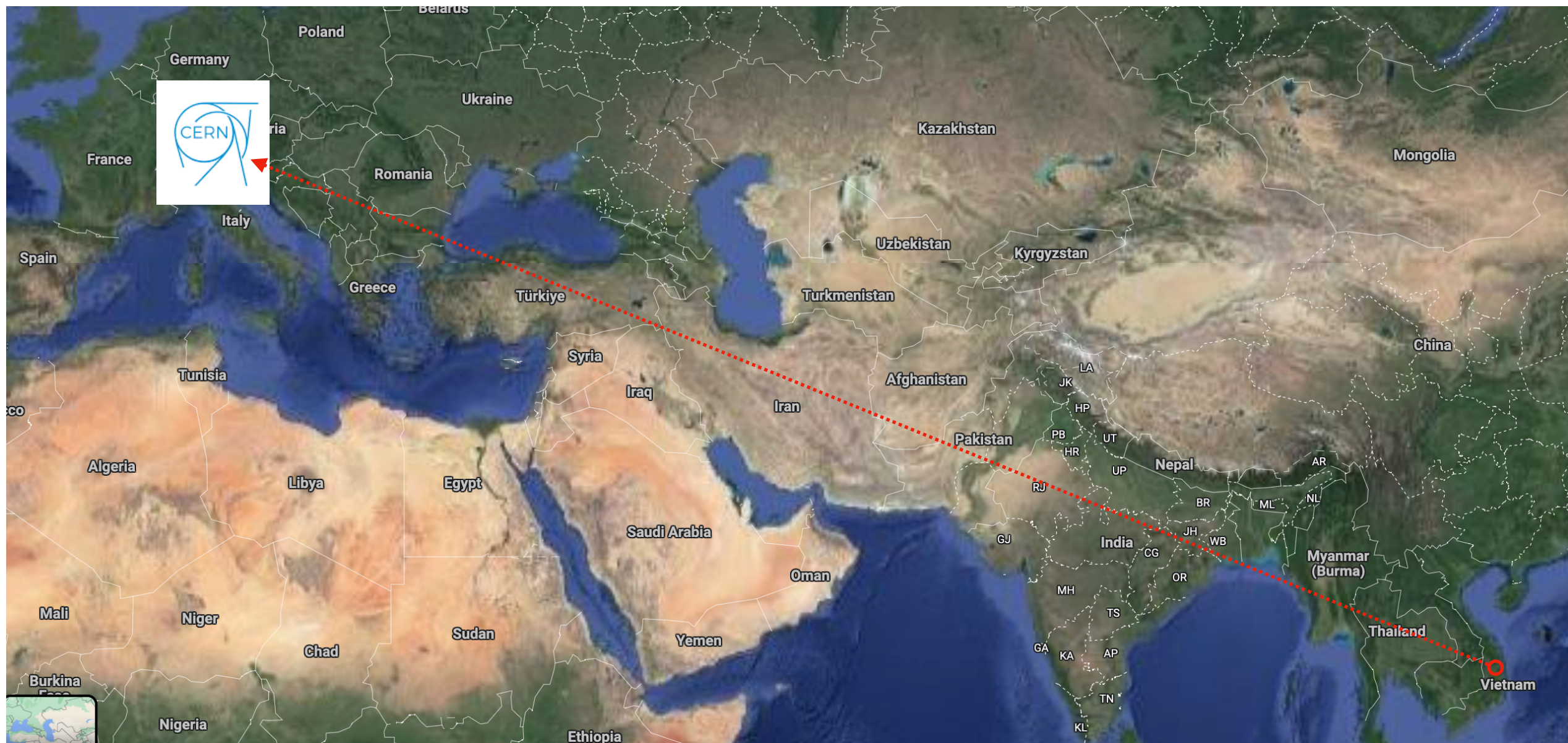
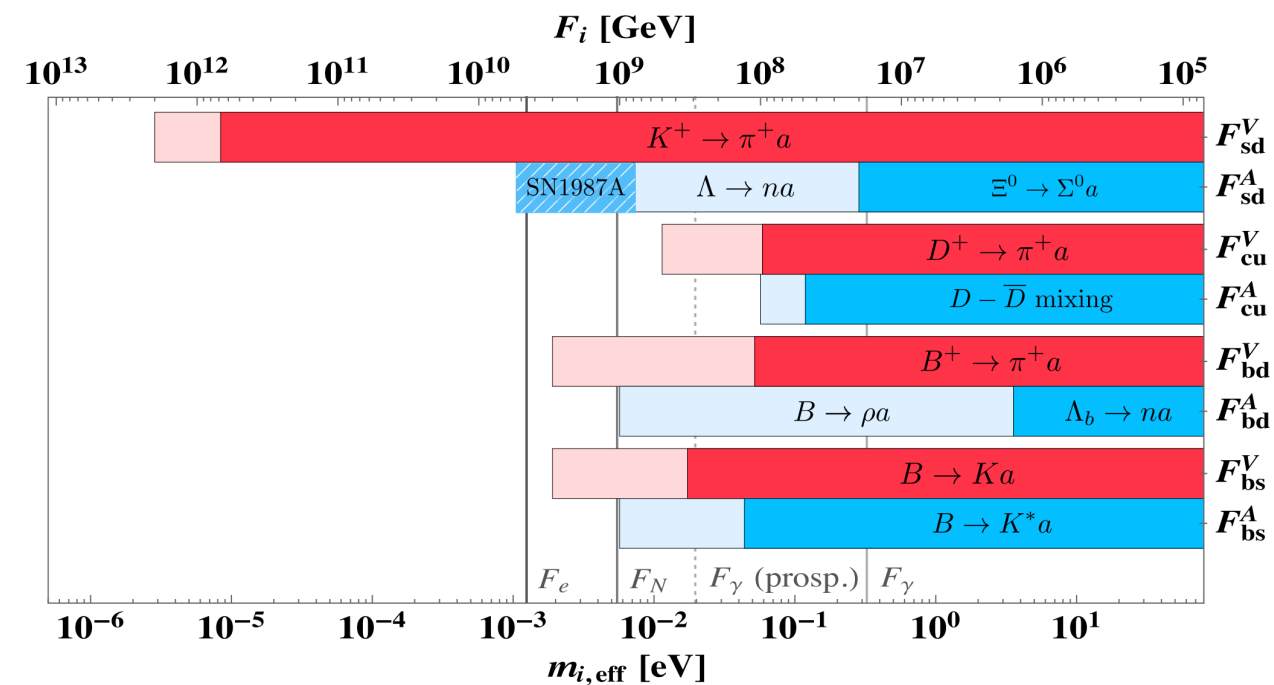
Scattering process $e^+ + e^- \rightarrow t + \bar{t}$ and fully polarized top quark decays
in Standard Model Effective Field Theory

ICISE
(International Centre for Interdisciplinary Science and Education)



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- CERN Summer Internship in Theory division
 - Quark flavour phenomenology of the QCD axion



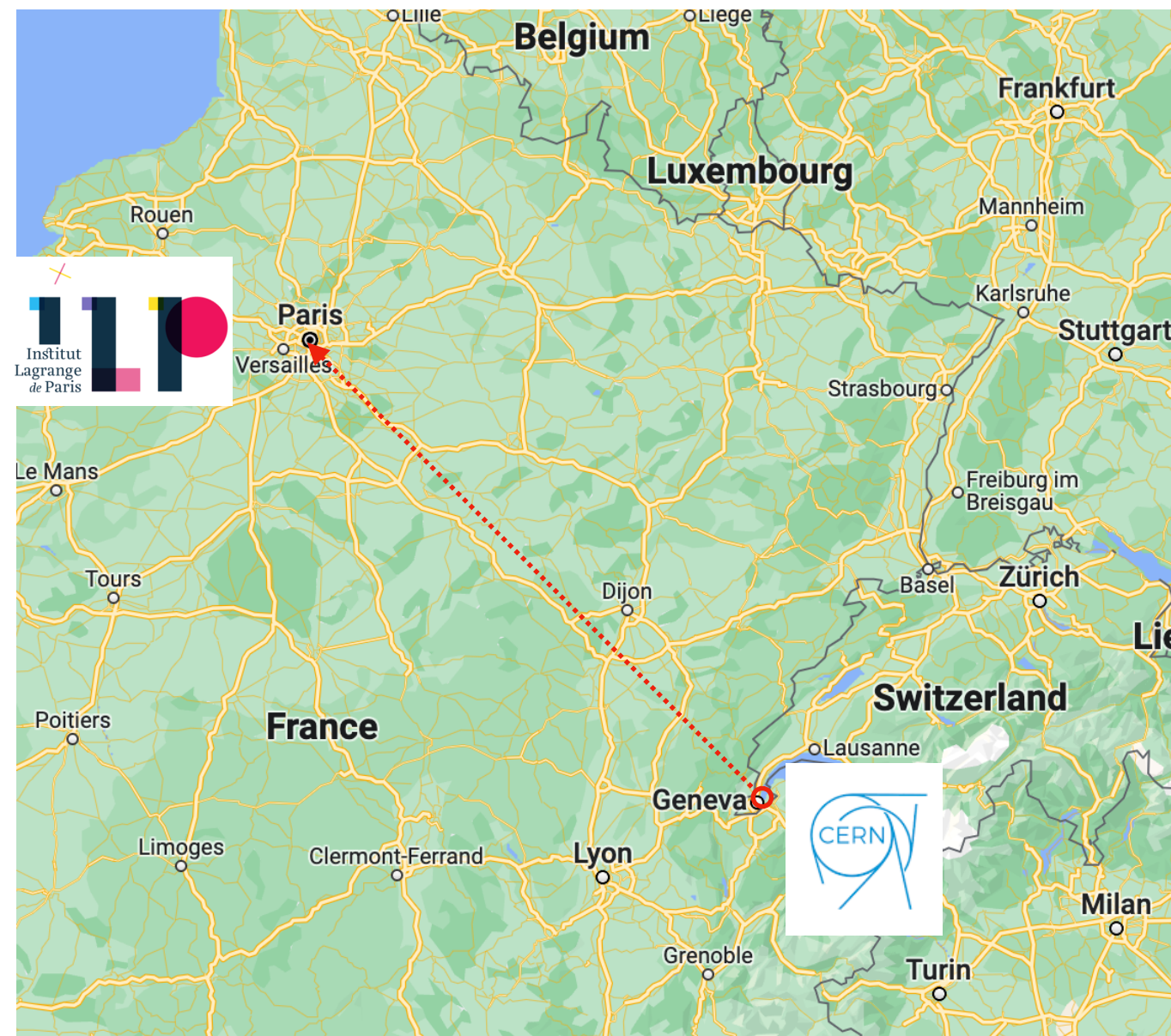
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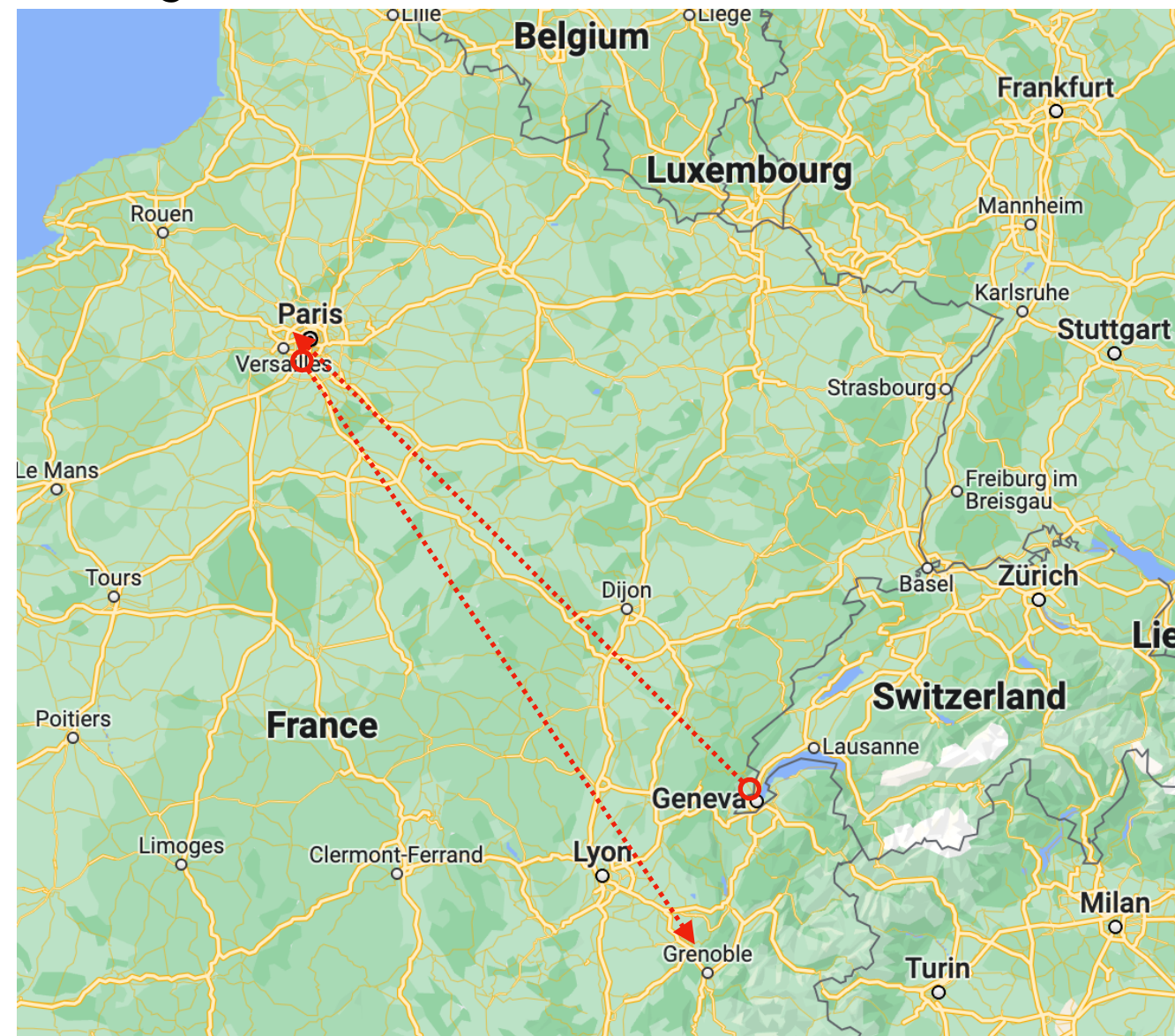
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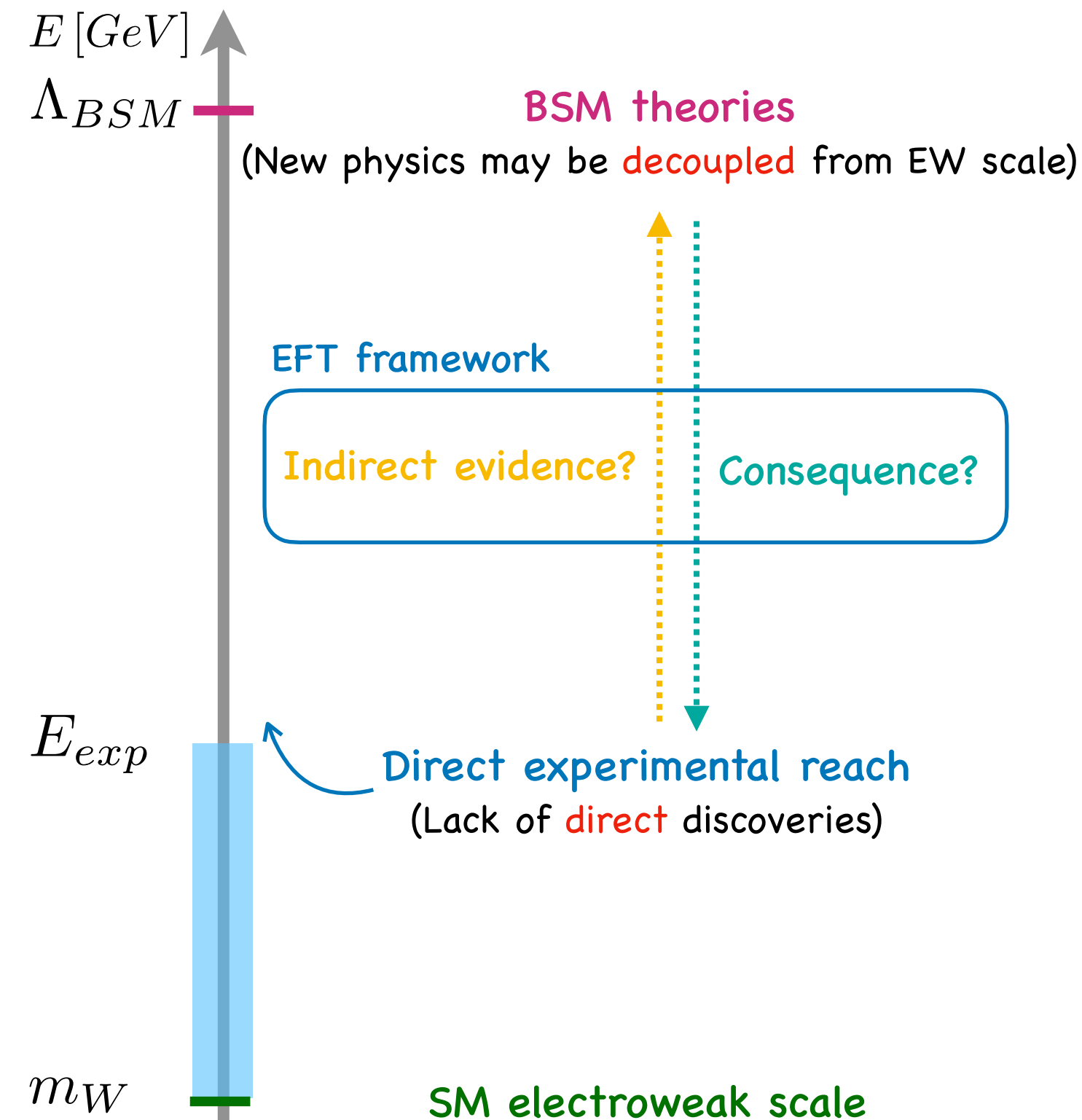
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Implications of Effective Field Theories in
Particle Physics Phenomenology

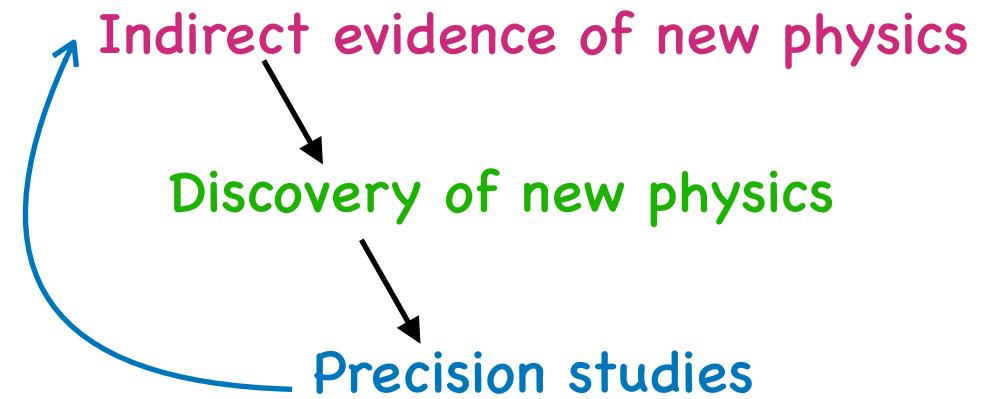


My works in EFT (1): Why effective field theory?

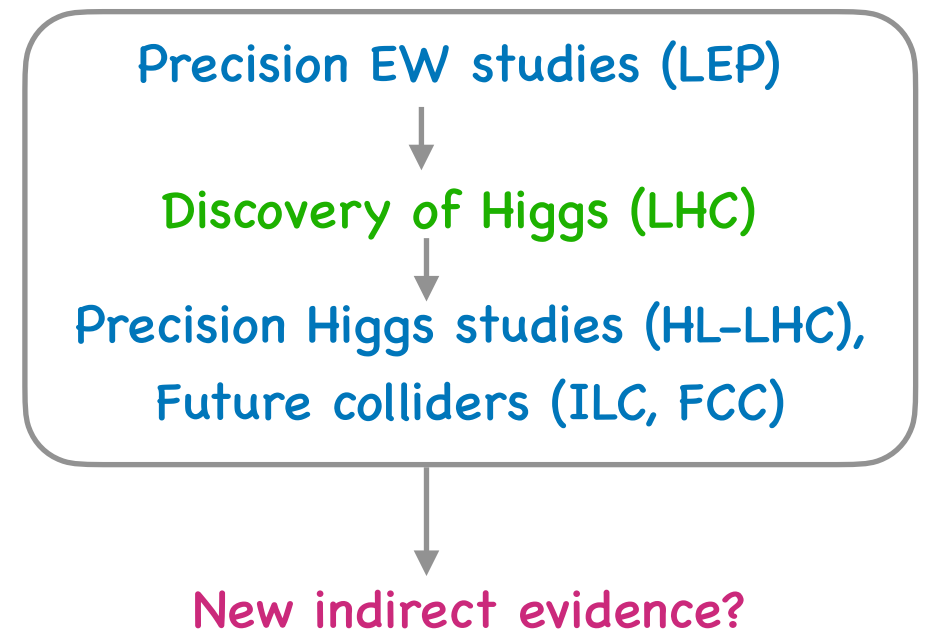
- No signal of BSM at LHC so far



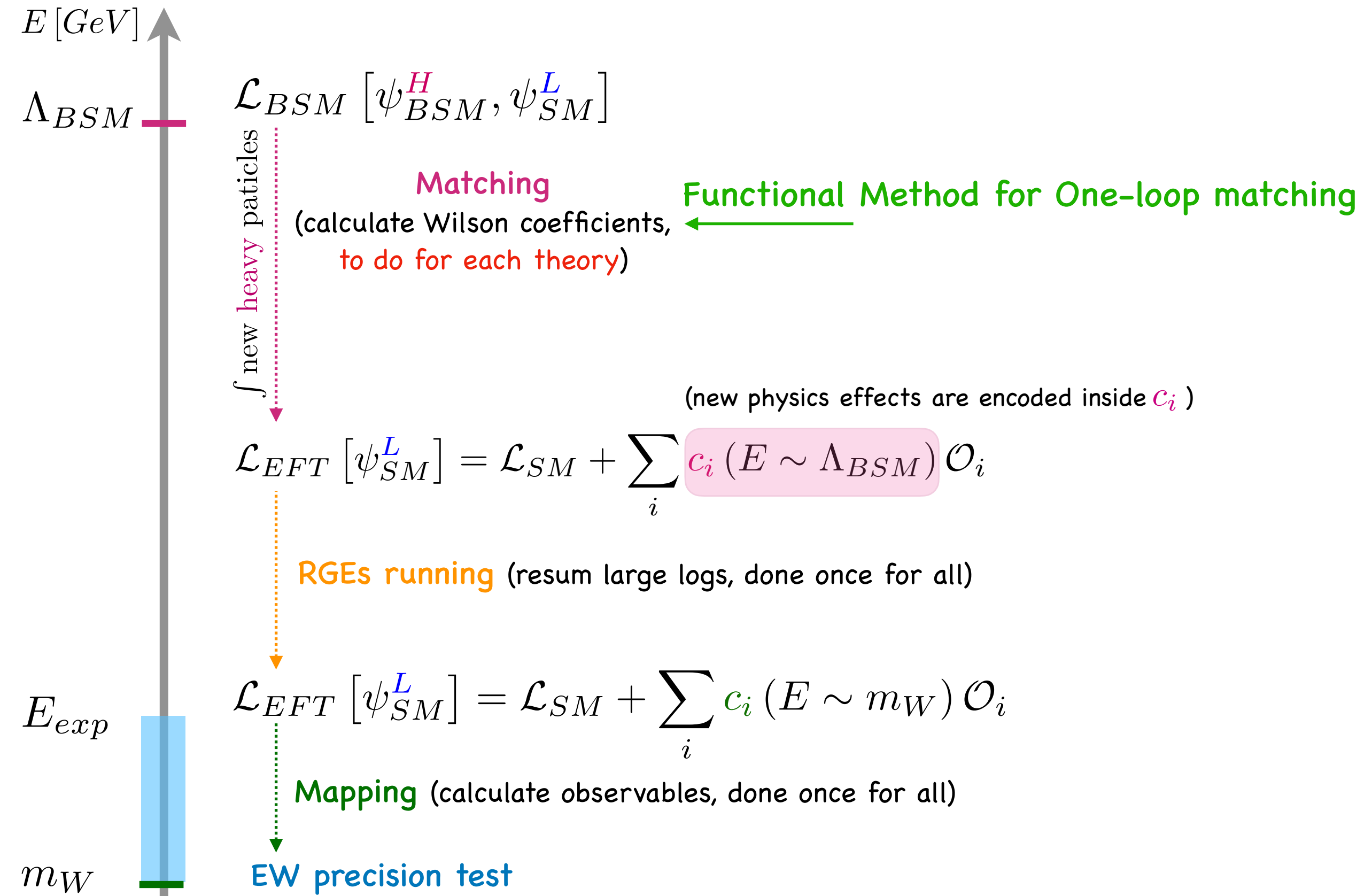
- Historically:



Example:



My works in EFT (2): From UV to IR (top-down approach)



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Functional matching method:

- **Direct approach** to perform the matching calculations
- Universal coefficients (loop-integrals) can be pre-computed **once and for all**

The spirit of Universal One-Loop Effective Action (UOLEA):

$$\mathcal{L}_{BSM} [\psi_{BSM}^H, \psi_{SM}^L]$$

State-of-the-art techniques:

Path integral manipulations
Expansion by regions
Covariant Derivatives Expansion

UOLEA *

Matrix trace evaluation

$$\mathcal{L}_{EFT} [\psi_{SM}^L] = \mathcal{L}_{SM} + \sum_i c_i (E \sim \Lambda_{BSM}) \mathcal{O}_i$$

=> Start directly from UOLEA !!!

For example,

$$\begin{aligned} \mathcal{L}_{UOLEA} = \frac{c_s}{(4\pi)^2} \text{tr} \left\{ M^4 \left[-\frac{1}{2} \left(\log \frac{M^2}{\mu^2} - \frac{3}{2} \right) \right] + M^2 \left[- \left(\log \frac{M^2}{\mu^2} - 1 \right) U \right] \right. \\ + M^0 \left[-\frac{1}{12} \left(\log \frac{M^2}{\mu^2} - 1 \right) G_{\mu\nu}^{\prime 2} - \frac{1}{2} \log \frac{M^2}{\mu^2} U^2 \right] \\ + \frac{1}{M^2} \left[-\frac{1}{60} (P_\mu G_{\mu\nu}')^2 - \frac{1}{90} G_{\mu\nu}' G_{\nu\sigma}' G_{\sigma\mu}' - \frac{1}{12} (P_\mu U)^2 - \frac{1}{6} U^3 - \frac{1}{12} U G_{\mu\nu}' G_{\mu\nu}' \right] \\ + \frac{1}{M^4} \left[\frac{1}{24} U^4 + \frac{1}{12} U (P_\mu U)^2 + \frac{1}{120} (P^2 U)^2 + \frac{1}{24} (U^2 G_{\mu\nu}' G_{\mu\nu}') \right. \\ \left. - \frac{1}{120} [(P_\mu U), (P_\nu U)] G_{\mu\nu}' - \frac{1}{120} [U [U, G_{\mu\nu}']] G_{\mu\nu}' \right] \\ + \frac{1}{M^6} \left[-\frac{1}{60} U^5 - \frac{1}{20} U^2 (P_\mu U)^2 - \frac{1}{30} (U P_\mu U)^2 \right] \\ \left. + \frac{1}{M^8} \left[\frac{1}{120} U^6 \right] \right\} \end{aligned}$$

Example

Input: BSM theory

P: Kinetic momentum operator"

U: Coupling matrix

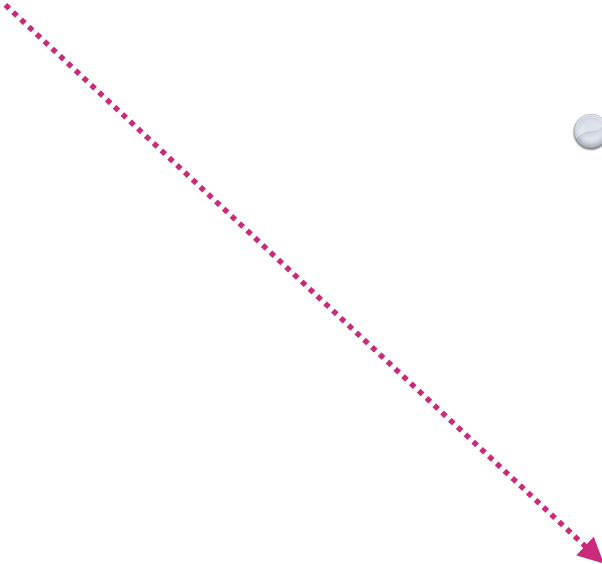
Output: EFT Lagrangian

Effective operators

1-loop coefficients

My works in EFT at DESY:

Studying EFT from both top-down & bottom-up approach

$$\mathcal{L}_{BSM} [\psi_{BSM}^H, \psi_{SM}^L]$$


- Any theoretical constraints for the Wilson coefficients?

=> Positivity in EFT

$$\mathcal{L}_{EFT} [\psi_{SM}^L] = \mathcal{L}_{SM} + \sum_i c_i (E \sim \Lambda_{BSM}) \mathcal{O}_i$$

- In the presence of QCD instantons,
how EFT operators can contribute to CP-odd observable in SM?