

LEPTON-FLAVOR-UNIVERSALITY VIOLATION AND PROSPECTS AT BELLE II

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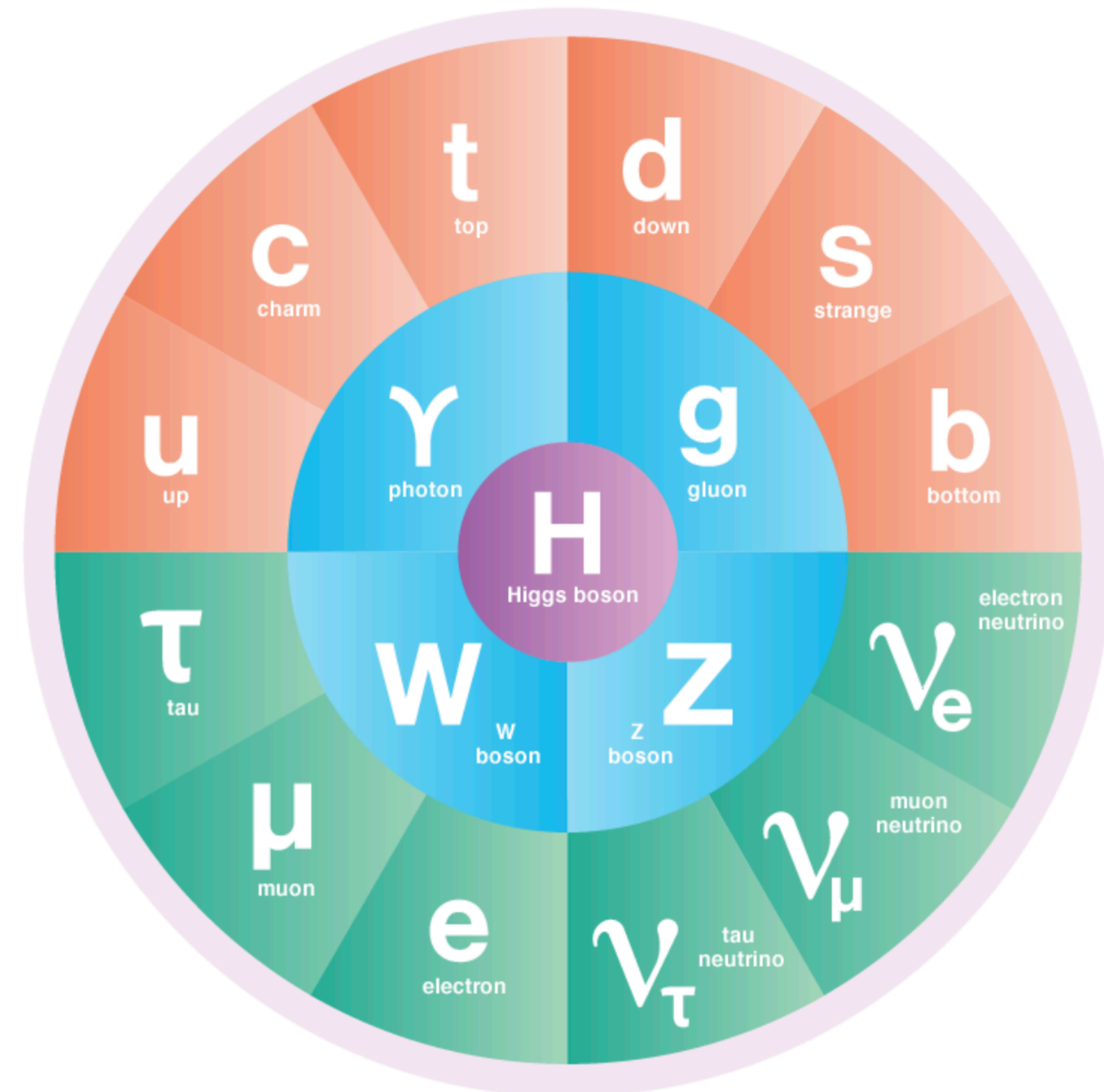
STANDARD MODEL OF PARTICLE PHYSICS

- Standard model (SM) describes three out of the four fundamental forces in nature
- Successful but incomplete, as it leaves open questions, such as dark matter, etc.

Determining the theory that completes the SM is the principal goal of today's particle physics

Look for non-SM particles:

- directly, in the high-energy collisions
- indirectly, with flavor physics



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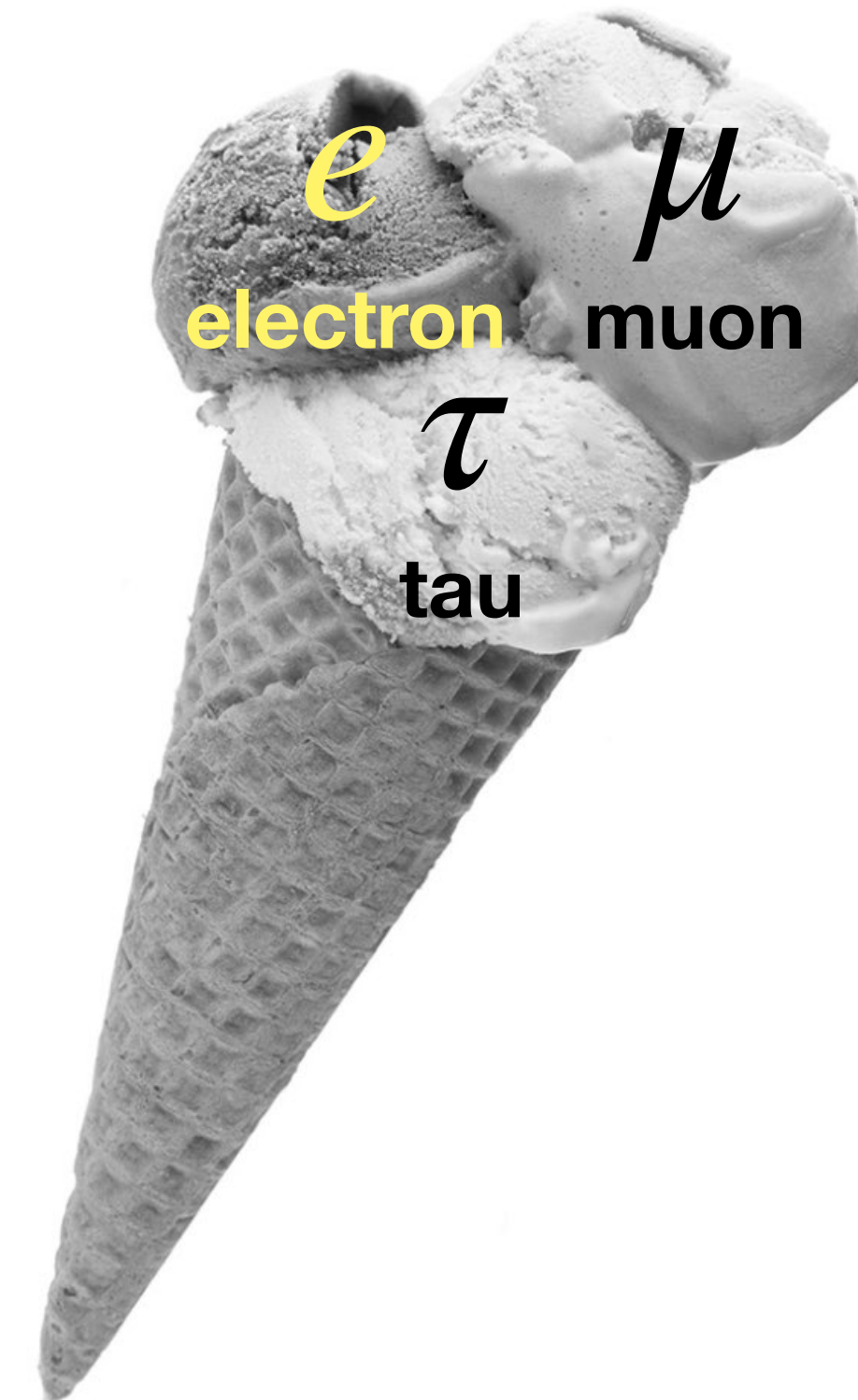
- Flavor is the property that distinguishes the various leptons in the SM
- Standard model: the flavors are “accidental”, **universality of lepton flavor**
- New physics: **why we have 3 flavors**, universality is not implied

=> Various ways to test the LFU, e.g.

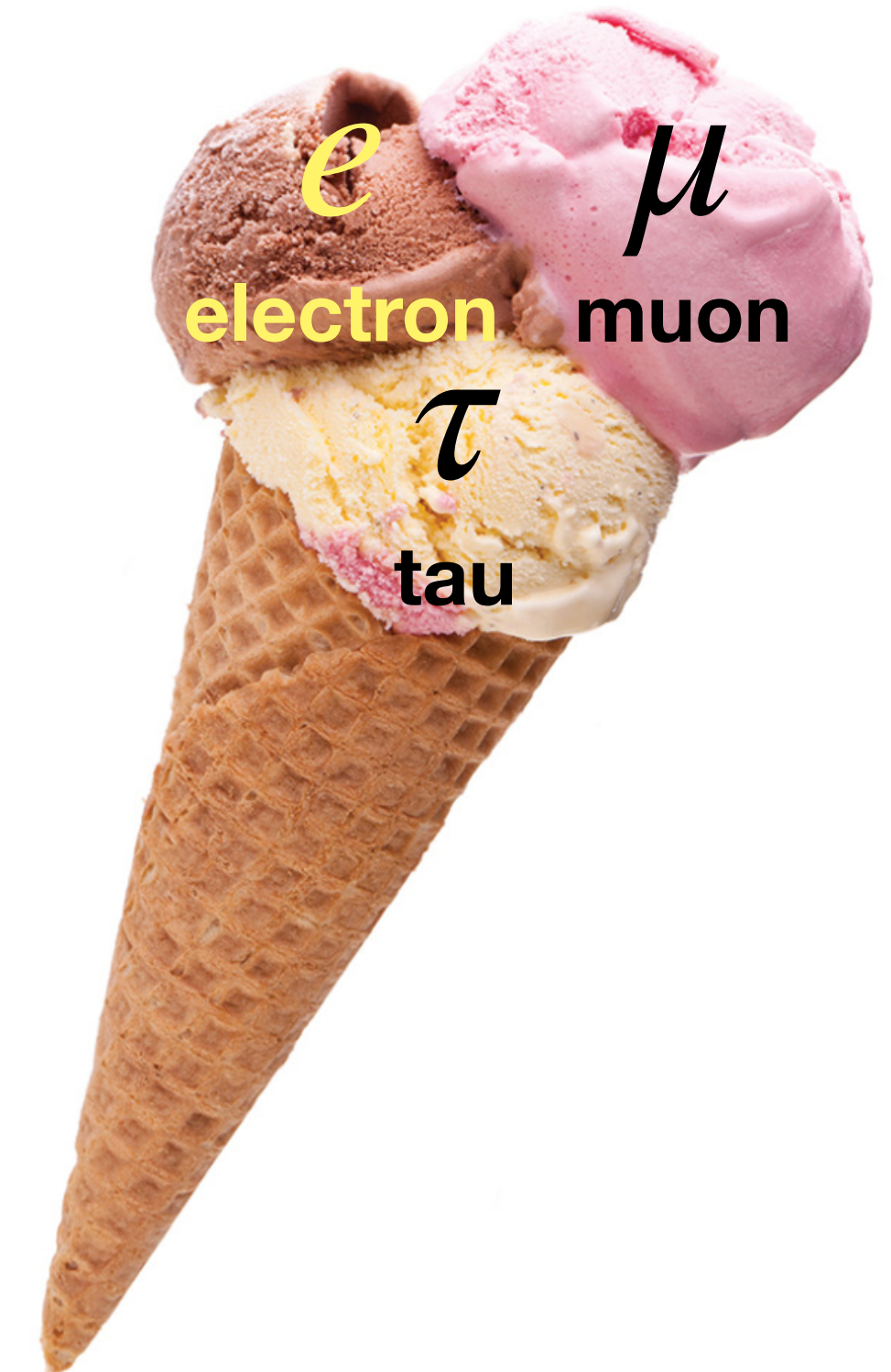
$$R_{\tau/\ell}^B = \frac{\Gamma(B \rightarrow X\tau)}{\Gamma(B \rightarrow X\ell)}$$

Need to produce *B*-meson samples

Standard model



New physics



***B* meson:** spin-0 bound state of a "b" quark with a lighter "u" or "d" partner. Massive (5 GeV) and long-lived (1.5 ps).

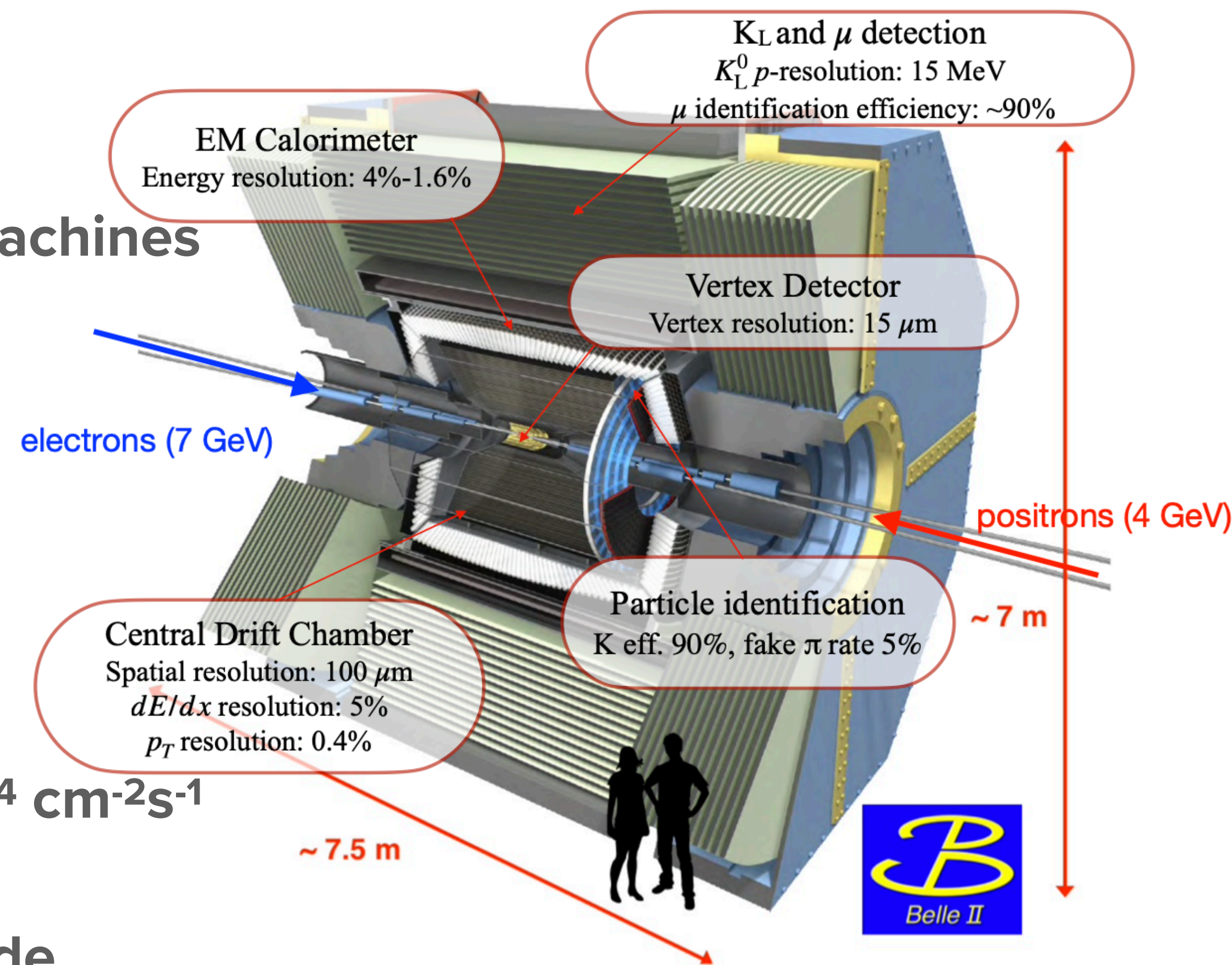
BELLE II EXPERIMENT @ SUPERKEKB

Energy-asymmetric e^+e^- collisions at 10.58 GeV
corresponding to the $\Upsilon(4S)$ -resonance mass

- Clean experimental environment wrt hadron machines
- Similar performance for electrons and muons
- B produced in pairs
- Well defined initial energy
- Nearly full 4π coverage

Belle II status:

- world-record luminosity by SuperKEKB $4.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- collected $\sim 430 \text{ fb}^{-1}$ of data: **450M $B\bar{B}$**
- now starting \sim one year stop for a partial upgrade
- expect $\mathcal{O}(10) \text{ ab}^{-1}$ of data



LFU TESTS IN SEMILEPTONIC B DECAYS

- Semileptonic decays mediated by $b \rightarrow c\ell\nu$:
large decay rates \sim few %

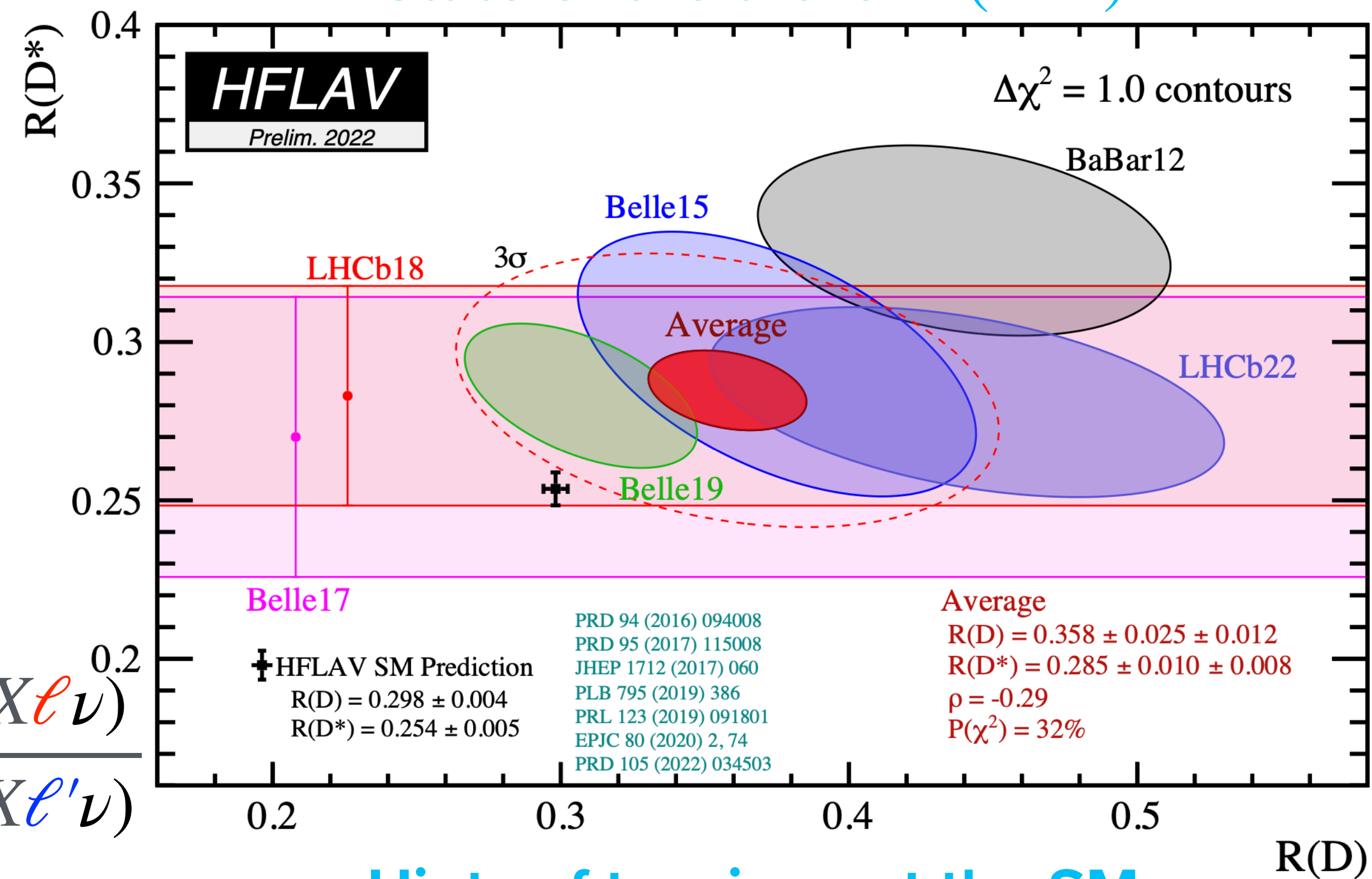
$$R(D^{(*)}) = \frac{\mathcal{B}(B \rightarrow D^{(*)}\tau\nu)}{\mathcal{B}(B \rightarrow D^{(*)}\ell\nu)} \quad (\ell = \mu, e)$$

- Belle II should provide the most precise measurement with more data

In a meanwhile, measure $R(X_{\ell/\ell'}) = \frac{\mathcal{B}(B \rightarrow X\ell\nu)}{\mathcal{B}(B \rightarrow X\ell'\nu)}$

- $R(X_{e/\mu}) = 1.033 \pm 0.010 \pm 0.020$
most precise LFU test with semileptonic B decays
- Going to probe LFU inclusively with $R(X_{\tau/\ell})$

State-of-the-art for $R(D^{(*)})$



Hints of tension wrt the SM

LFU TESTS IN RARE B DECAYS

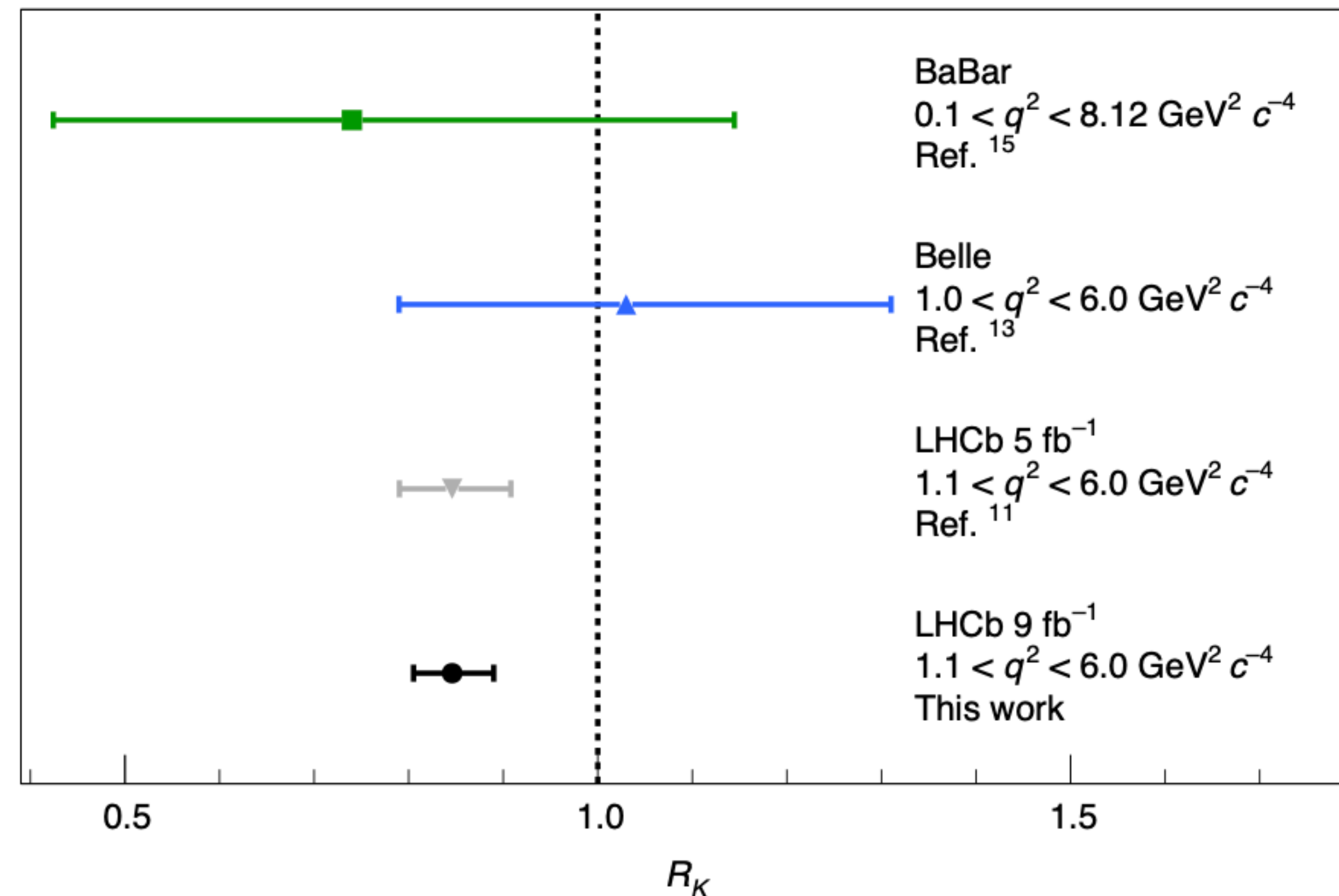
- Rare decays mediated by $b \rightarrow s \ell \ell$:
small decay rates $\sim 10^{-7} - 10^{-6}$

- $$R(K) = \frac{\mathcal{B}(B \rightarrow K \mu \mu)}{\mathcal{B}(B \rightarrow K e e)}$$

- Non-SM particles can affect the ratio

Belle II should provide an independent test to confirm the tension with few ab^{-1}

State-of-the-art for $R(K)$

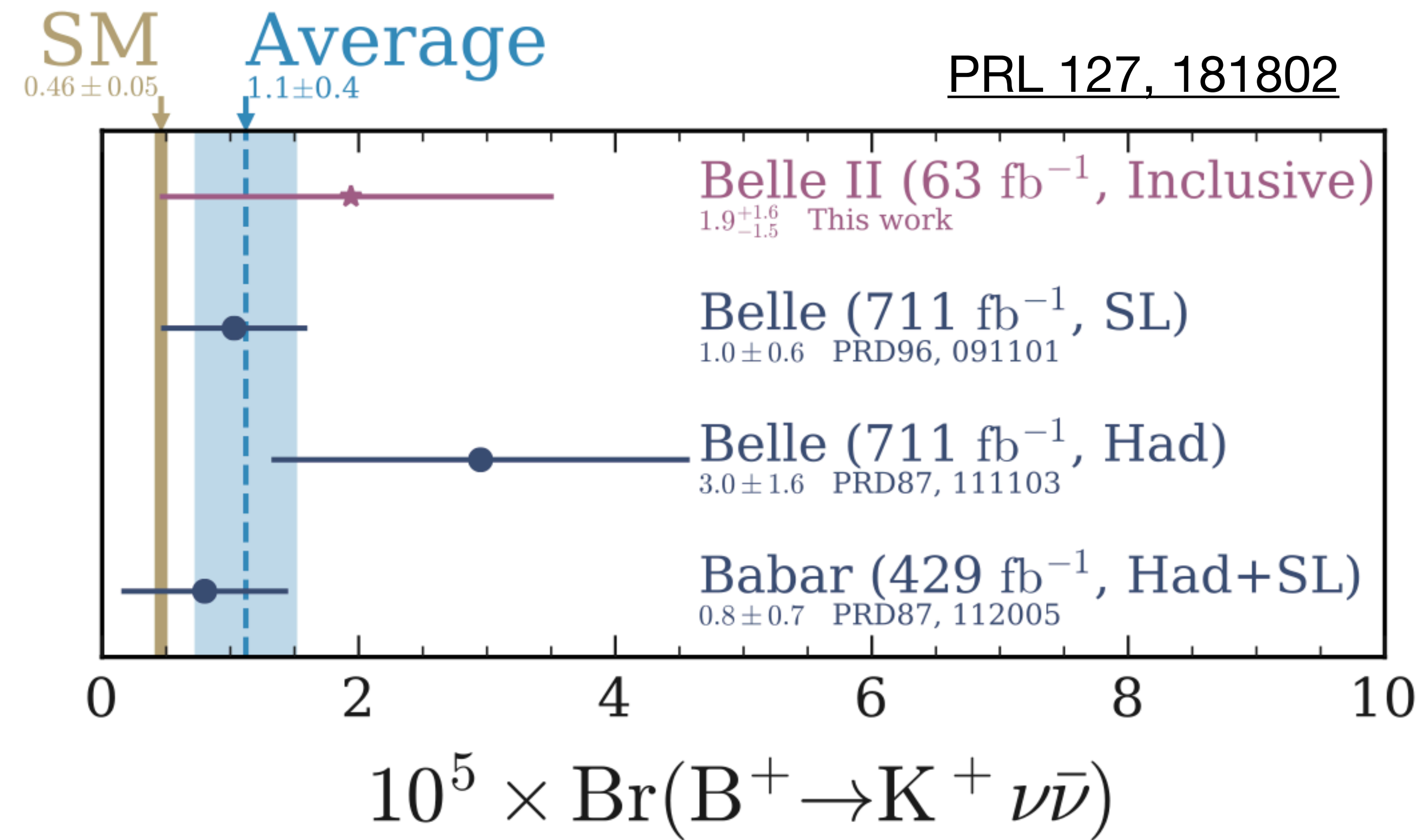


2— 3σ tension wrt the SM

COMPLEMENTARY TEST

- $B^+ \rightarrow K^+ \nu \bar{\nu}$ should be sensitive to same non-SM physics (if any) as $B^+ \rightarrow K^+ \ell^+ \ell^-$
- Unique opportunity for Belle II

Belle II solid result already with 63 fb^{-1}



SUMMARY

- Presence of flavor is a fundamental mystery of the nature, not explained by the SM
- New physics is potential to explain flavor
- Lepton-flavor-universality tests are powerful to probe non-SM
- Several experimental measurements show hints of discrepancy wrt SM in B decays
- Belle II is on the way to confirm (or not) the anomalies

BACKUP

PROJECTIONS

