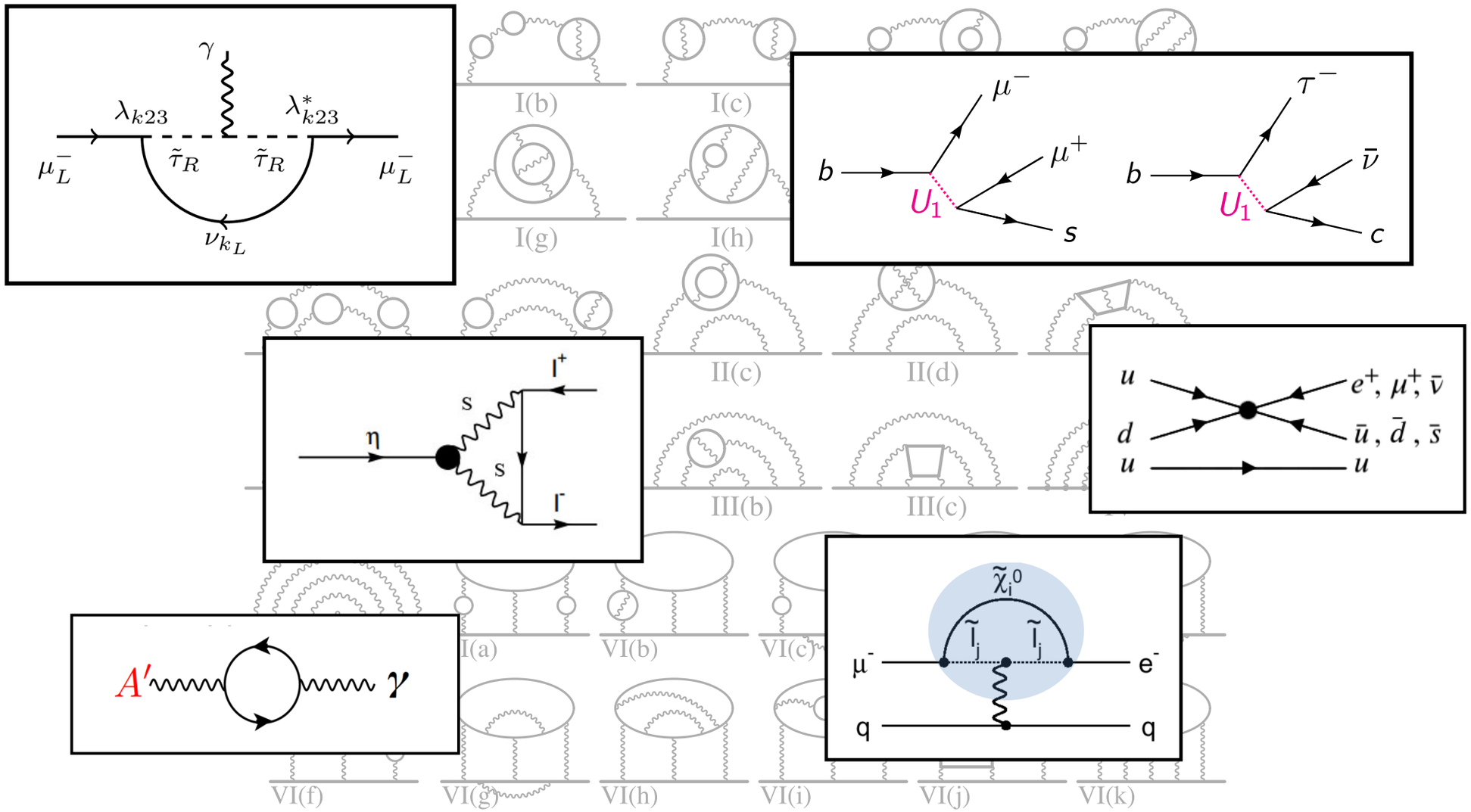
Rare Processes and Precision Measurements

Summary of activities

Angelo Di Canto

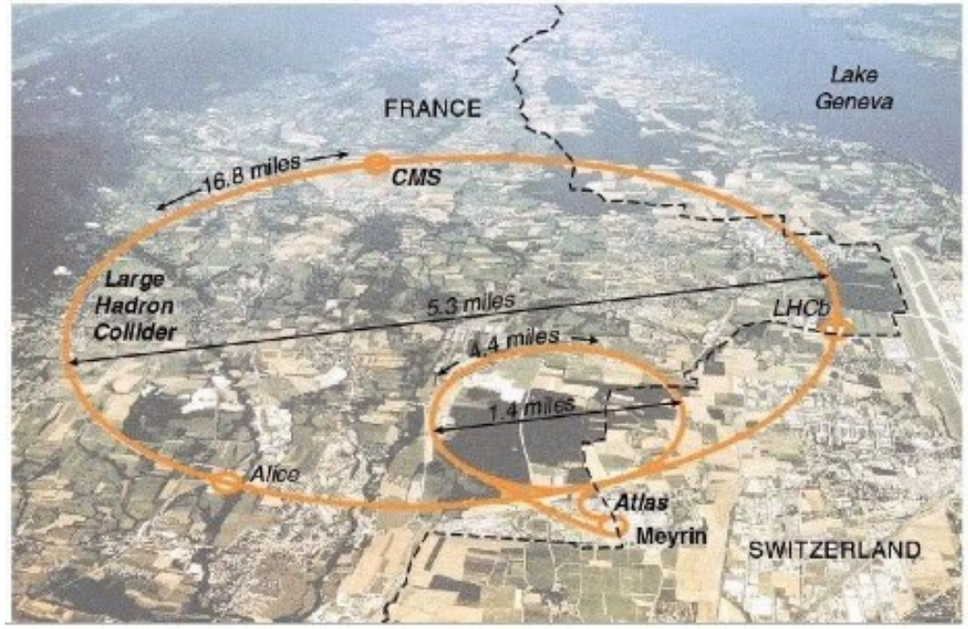
BNL Snowmass retreat day — Dec 17, 2021

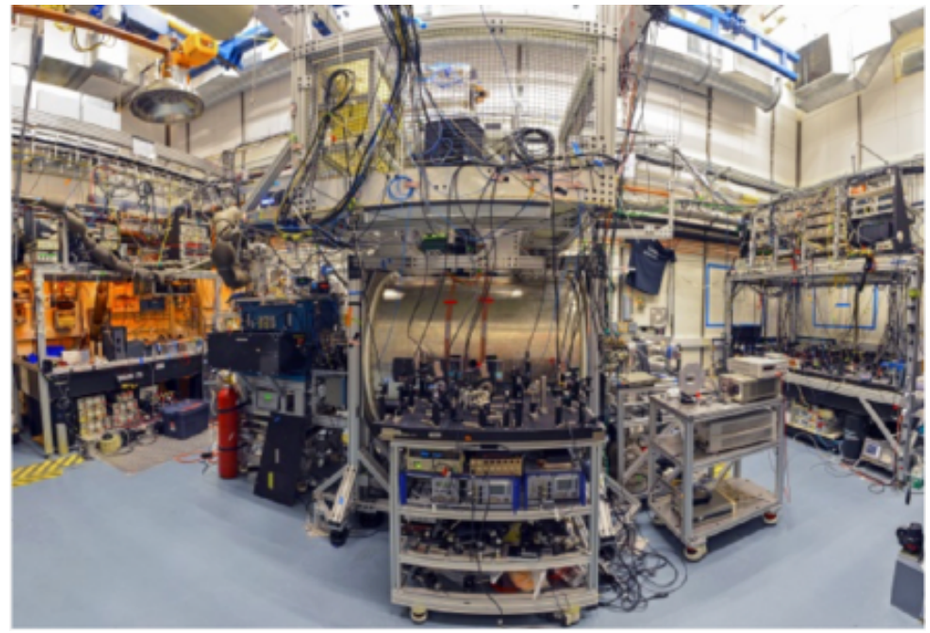
Rare Processes and Precision Measurements



Probing beyond-standard-model physics with precision measurements and rare/forbidden processes from as many directions as possible

Rare Processes and Precision Measurements





Experimental efforts range from from (big) collider-based experiments to “table-top” experiments. Need intense sources and ultra-sensitive detectors.

Frontier organization

- Frontier conveners: Marina Artuso, Robert Bernstein, Alexey Petrov
- Topical groups:

  RF1: Weak decays of b and c quarks — A. Di Canto, S. Meinel

  RF2: Weak decays of strange and light quarks — E. Goudzovski, E. Passemar

  RF3: Fundamental Physics in Small Experiments — P. Winter, T. Blum

  RF4: Baryon and Lepton Number Violating Processes — P. Fileviez Perez, A. Pocar

  RF5: Charged Lepton Flavor Violation — B. Echenard, S. Davidson

  RF6: Dark Sector Studies at High Intensities — M. Williams, S. Gori

  RF7: Hadron Spectroscopy — T. Skwarnicki, R. Lebed

- Liaisons with other frontiers:

  Energy: M. Franco Sevilla

  Neutrino: R. Bernstein

  Cosmic: S. Gardner

  Theory: A. Petrov

  Accelerator: R. Bernstein

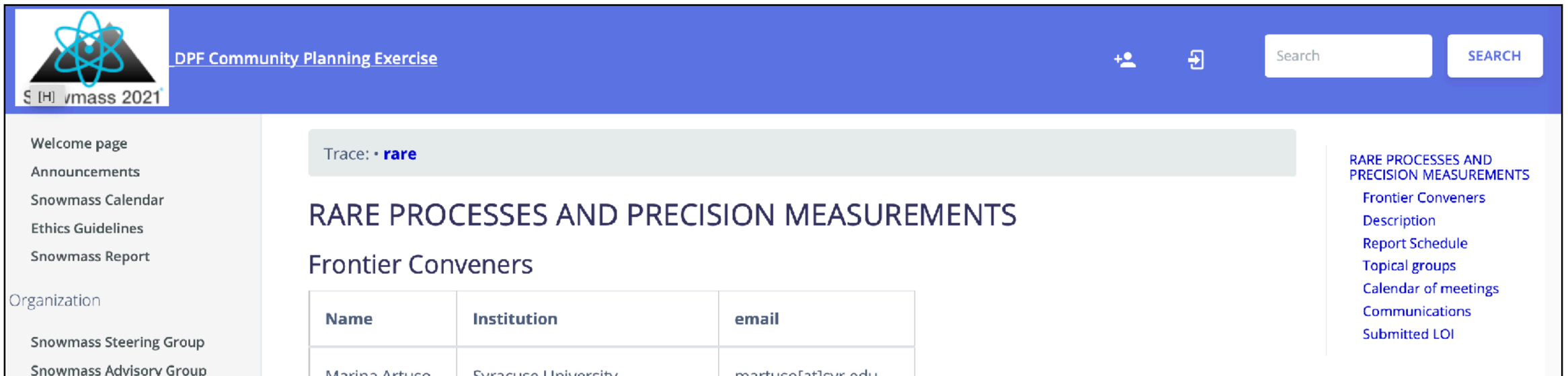
  Instrumentation: M. Artuso

  Computational: M. Williams

  Community Engagement: S. Middleton

214 LOIs received

https://www.snowmass21.org/rare/start



Exciting physics

- Several hints of deviations from the standard model in measurements within our frontier, *e.g.*:

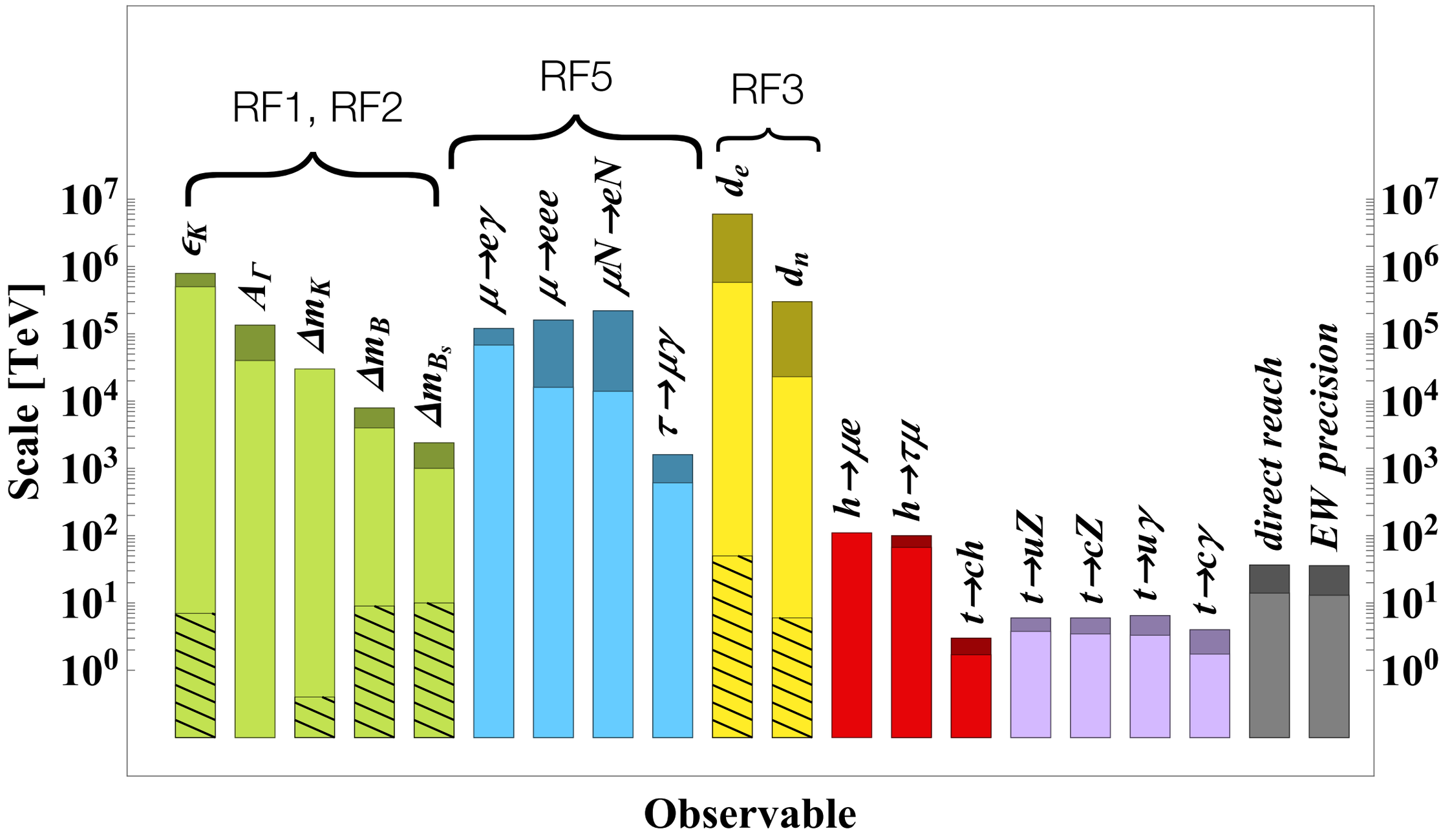
RF1
- $b \to s l^+ l^-$ decays (l=e,μ): violation of lepton-flavor universality in $R(K^{(*)})$, various branching fractions and angular observables
- $b \to c \tau^- \bar{\nu}$ decays: violation of lepton-flavor universality in $R(K^{(*)})$, $R(J/\psi)$
- Inclusive-exclusive discrepancies in $|V_{ub}|$ and $|V_{cb}|$
- $\bar{B}_{(s)} \to D_{(s)} h^-$ (h=K,π) branching fractions

RF2
- First-row CKM unitarity test
- KOTO anomaly in $K_L \to \pi^0 \nu \bar{\nu}$

RF3
- Neutron lifetime puzzle
- Muon and electron g–2

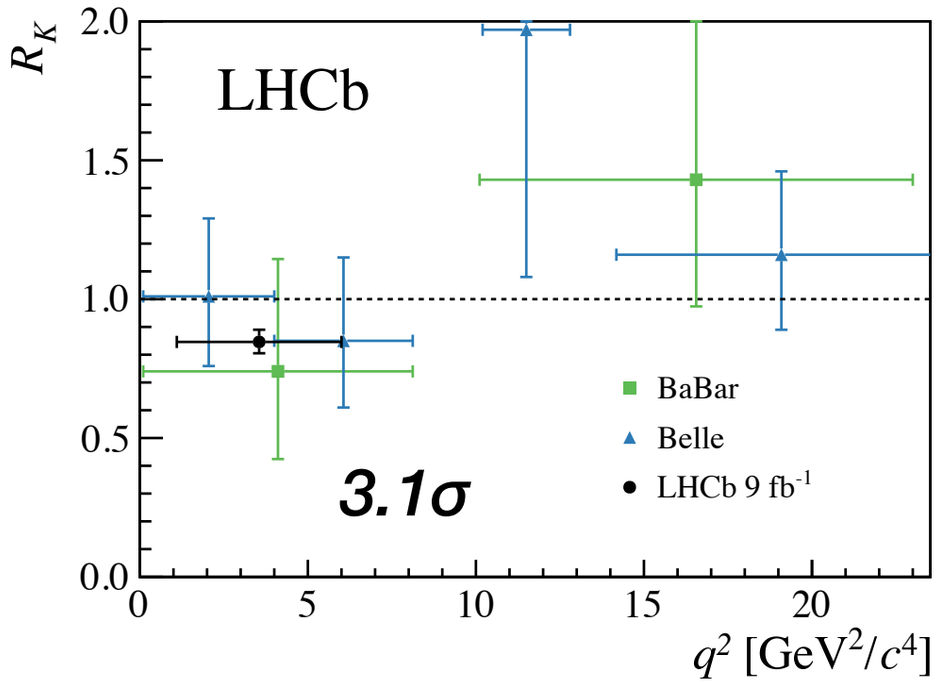
- Regardless of whether these particular anomalies will survive, the “rare and precision” approach of searching for new physics helps to identify future directions at the energy frontier being sensitive to mass scales much higher than those directly accessible

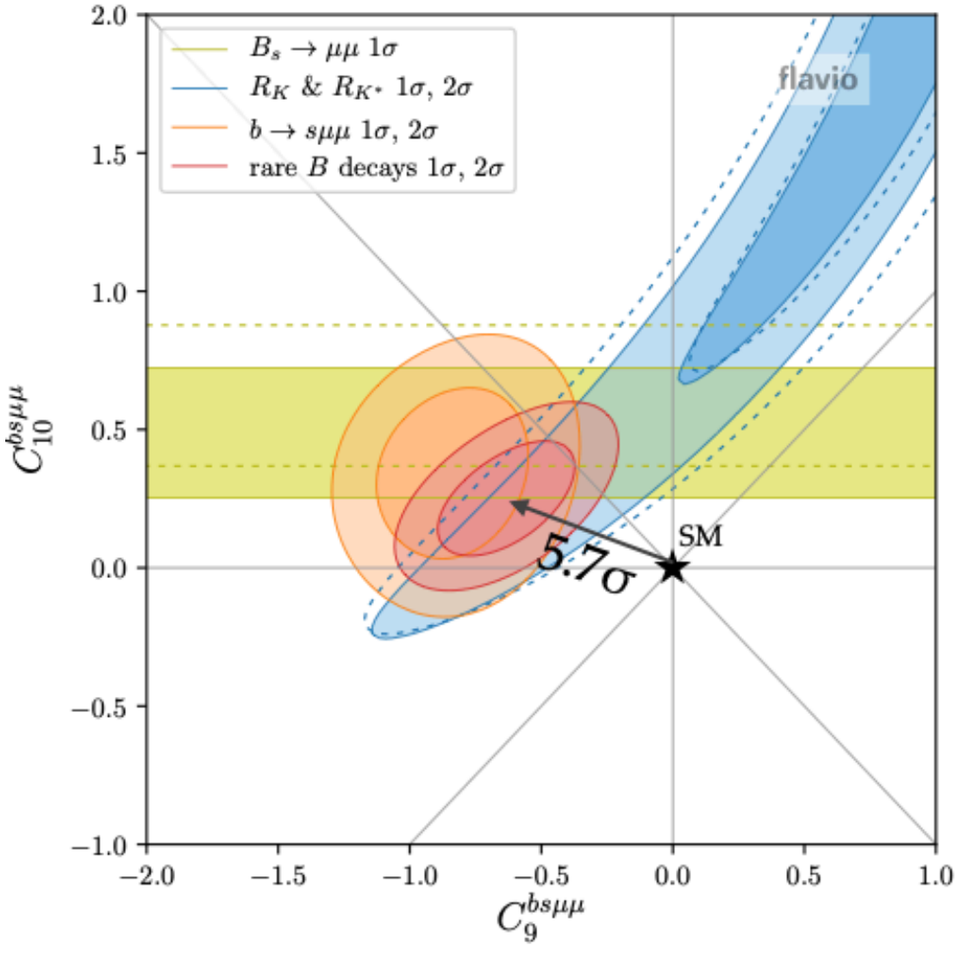
Impressive reach

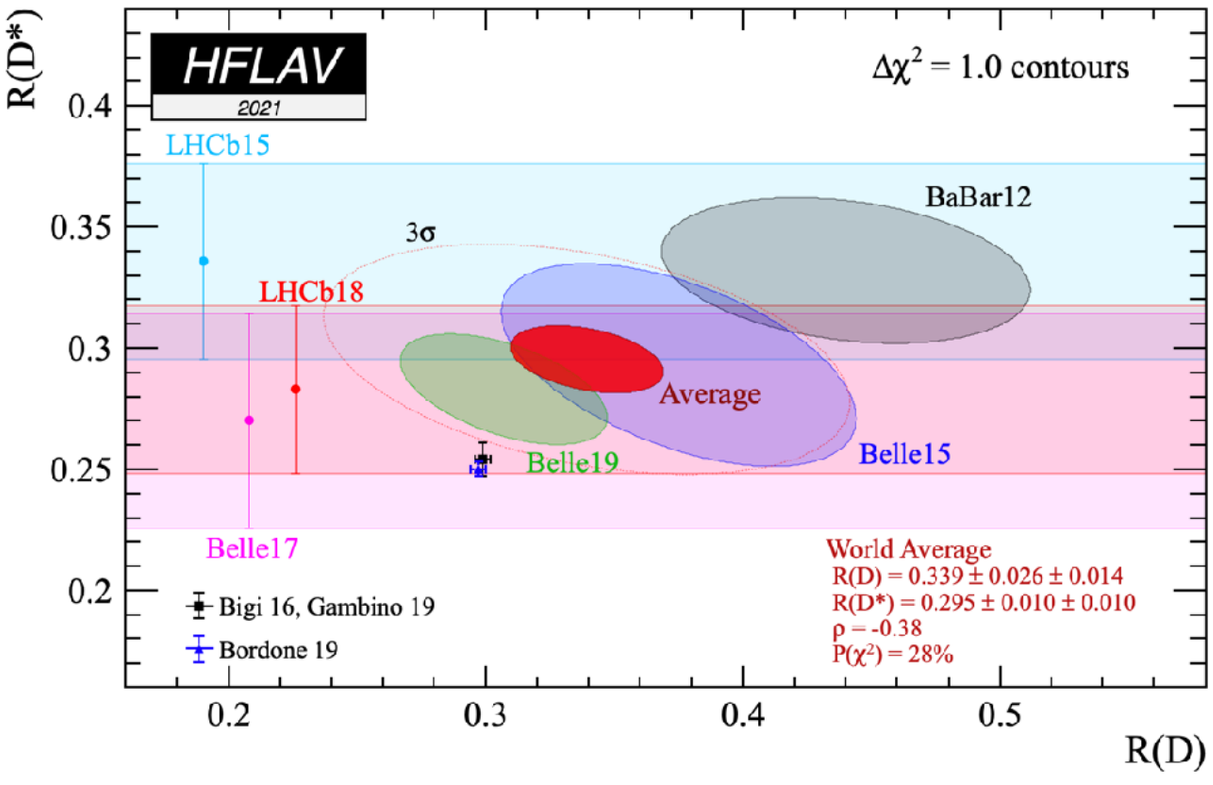


RF1: *b* and *c* decays

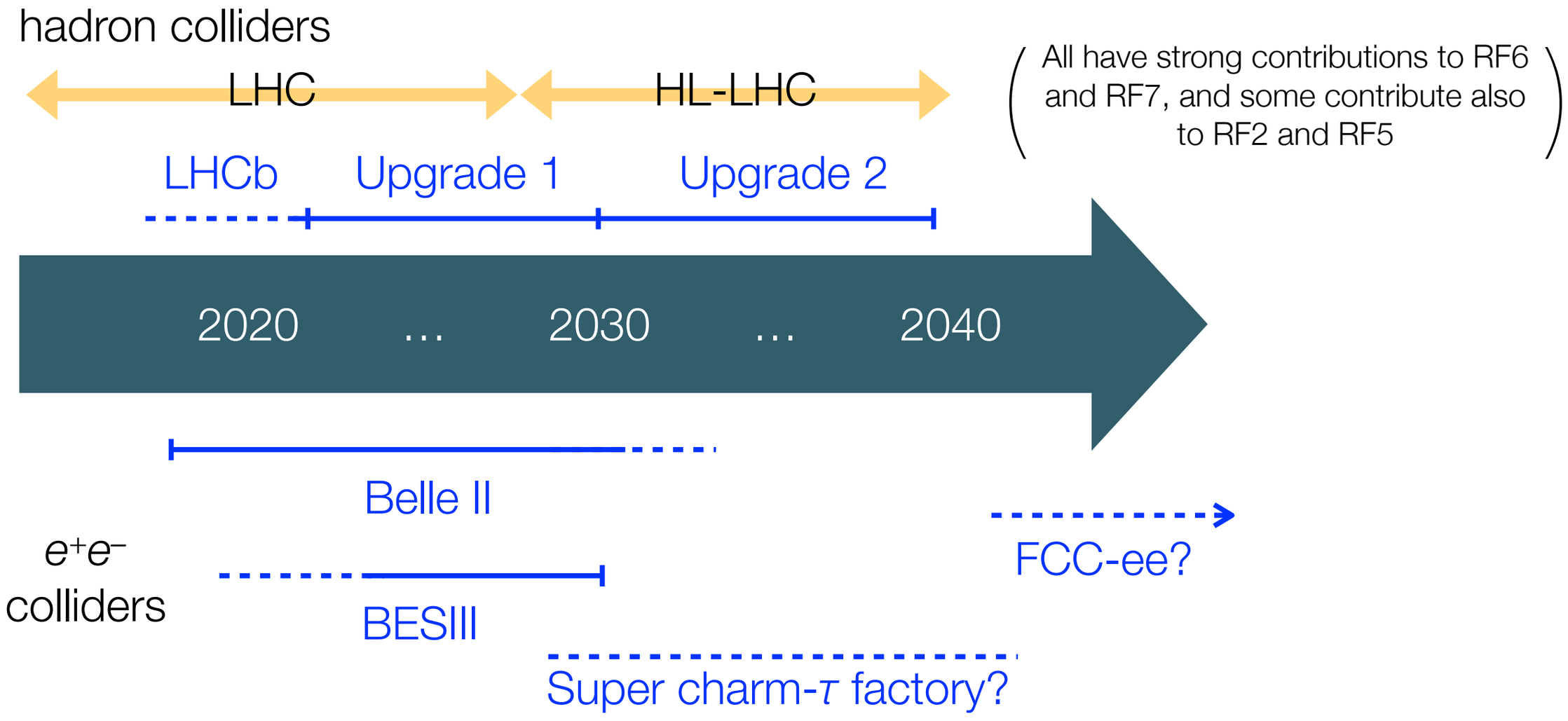
- Rich, diverse and model-independent probe for new physics, which has often revealed itself in very unexpected ways
- One example: the only promising hints of new physics from the LHC seem to be emerging from flavor with the anomalies in $b \to s l^+ l^-$ and $b \to c \tau^- \bar{\nu}$ decays







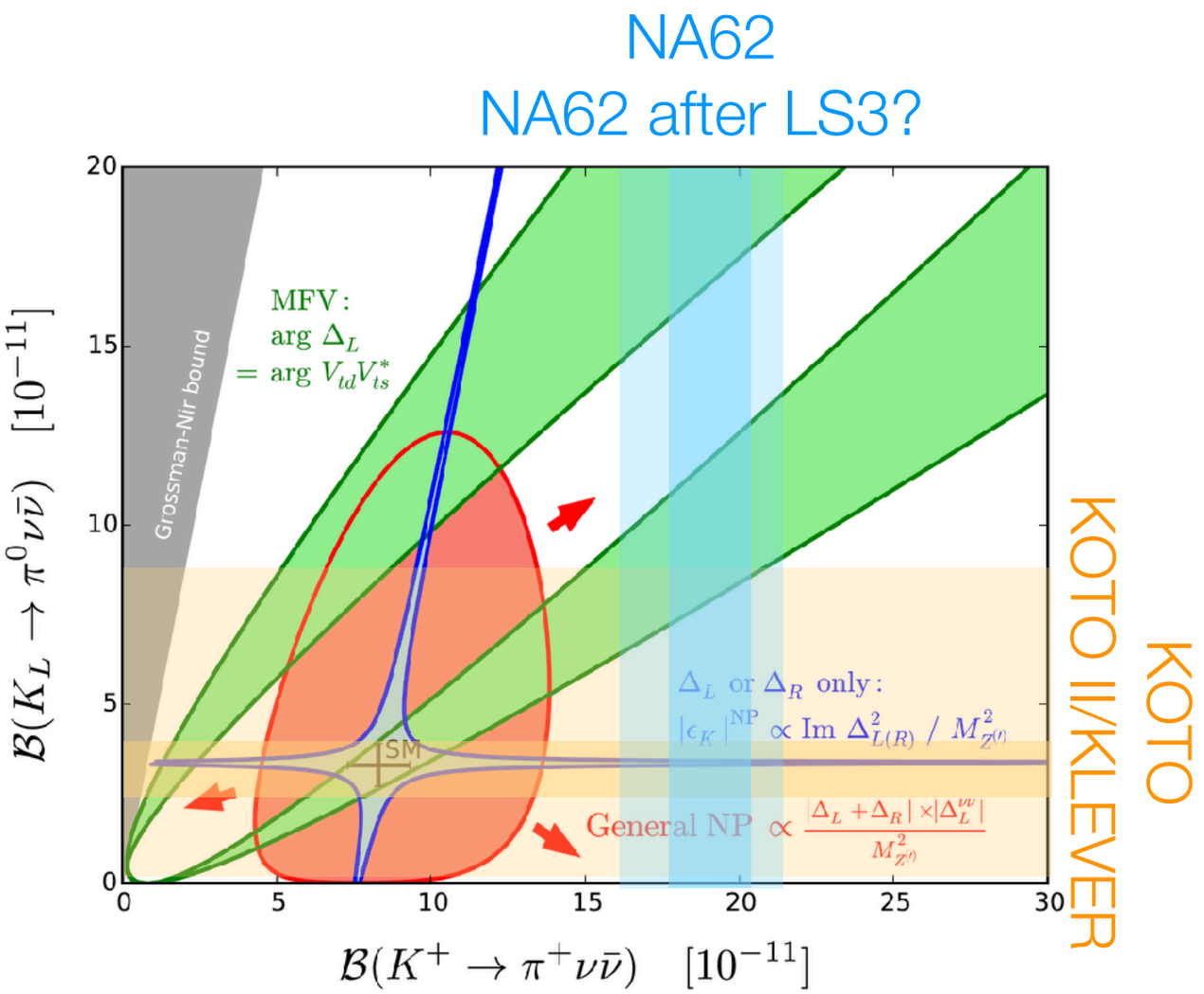
RF1: experiments



- Need to support ongoing programs at Belle II, LHCb and BESIII; endorse a strong heavy-flavor program during HL-LHC (with construction of LHCb phase-2 upgrade) and beyond (*e.g.*, at FCC-ee)
- Opportunity for BNL contribution to quark-flavor physics beyond Belle II

RF2: rare kaons decays

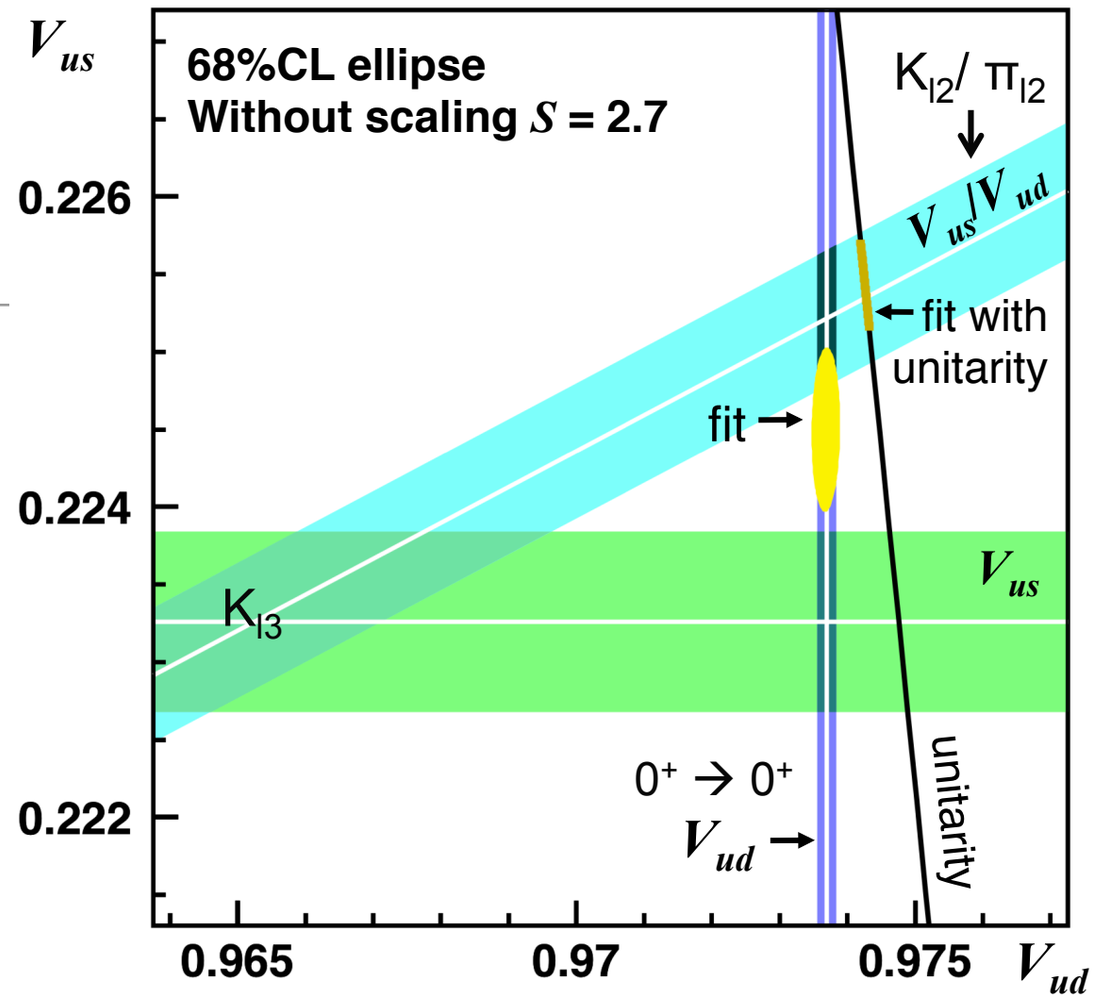
- Support ongoing and next-generation experiments on rare K^+ and K_L decays
  - Run NA62 at higher beam intensities after LHC LS3
  - KOTO expected to reach 1 SM event sensitivity by 2025; both KOTO II and KLEVER aim at O(100) SM events with S/B=1



- Rare K_S and strange hyperons decays at LHCb phase-2 upgrade
- Strong interest at BNL

RF2: rare pion decays

- Inconsistency of first-row CKM unitarity relation resulting from improved theory inputs
  - Mostly driven by $|V_{ud}|$ from super-allowed $0^+ \rightarrow 0^+$ β decay
- Cleanest way to extract $|V_{ud}|$ is from $\pi^+ \rightarrow \pi^0 e^+ \nu$ decays
  - Pioneer experiment: 10x improvement in precision (down to 0.06%)
    - Also interesting prospects for lepton-flavor-universality test in $\pi^+ \rightarrow l^+ \nu$ decays
- BNL interest



Fit results, no constraint

V_{ud} = **0.97368(14)**

V_{us} = **0.22450(35)**

χ^2/ndf = 7.2/1 (0.7%)

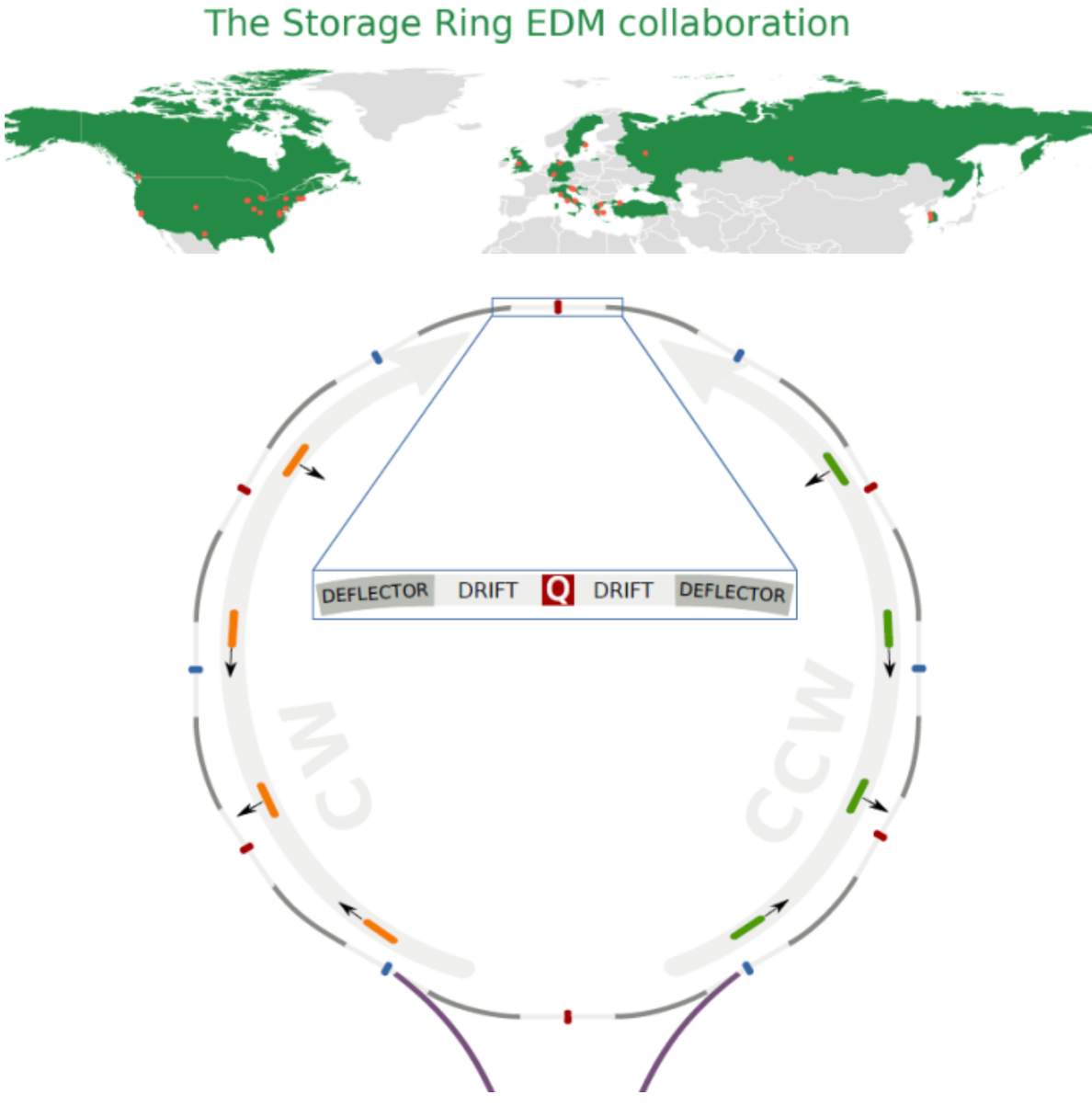
Δ_{CKM} = **–0.00154(32)**

–4.8σ

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1 + \Delta_{CKM}$$

RF3: Fundamental physics in small experiments

- EDMs strong part of the research program for the next decade, especially with prospects for storage ring pEDM
  - BNL interest (see Bill's talk)
- Magnetic dipole moments (electron, muon) also have timelines that span the next decade; the Fermilab muon *g*–2 result may clarify the path forward
- Experiments to study gravity, Lorentz (CPT) and fundamental symmetries



pEDM sensitivity
~10^{-29} *e* cm

Strong connections with other frontiers

- Energy, Cosmic and Neutrino: lots of overlapping physics
- Theory: progress in lattice QCD and development of more realistic simulations
- Instrumentation: timing detectors, low-mass tracking, …
- Accelerator: new accelerator concepts for high-intensity muon beams
- Computational: efficient processing of large data volumes and improved algorithms for data reduction/online selections

Summary of the summary

- Diverse and exciting physics in Rare Processes and Precision Measurements

- Strong BNL interest in many areas (heavy flavor, rare kaon and pion decays, EDMs, …)

- Need Snowmass/P5 to explicitly recognize the importance of this physics and prioritize support for ongoing and future experiments

Towards the frontier report

https://indico.fnal.gov/event/51844/overview

Snowmass Rare and Precision Measurements Frontier Spring Meeting

16-19 May 2022
America/New_York timezone

Overview

Scientific Programme

Pre-registration (to indicate interest in attending either in-person or virtually)

Participant List

Joachim Brod, Alan Schwartz

brodjm@ucmail.uc.edu

alan.j.schwartz@uc.edu

This meeting will occur approximately two months before the main Snowmass Meeting in July. The purpose of the meeting is to collectively assess the physics impact, feasibility, and priority of the numerous physics initiatives currently being studied. The goal is to produce and prioritize a list of measurements with the highest prospects for uncovering New Physics over the next ten years. Some of the meeting might be available remotely, i.e., held in hybrid mode; in that case there will be a fee for remote attendance.

Starts May 16, 2022, 9:00 AM
Ends May 19, 2022, 5:00 PM
America/New_York

Alexey Petrov
Marina Artuso
Robert Bernstein

Local Organizing Committee:

Joachim Brod, Alan Schwartz (Chairs)

Phil Ilten, Kay Kinoshita, Mike Sokoloff, Jure Zupan

Registration
You are registered for this event.

67 See details