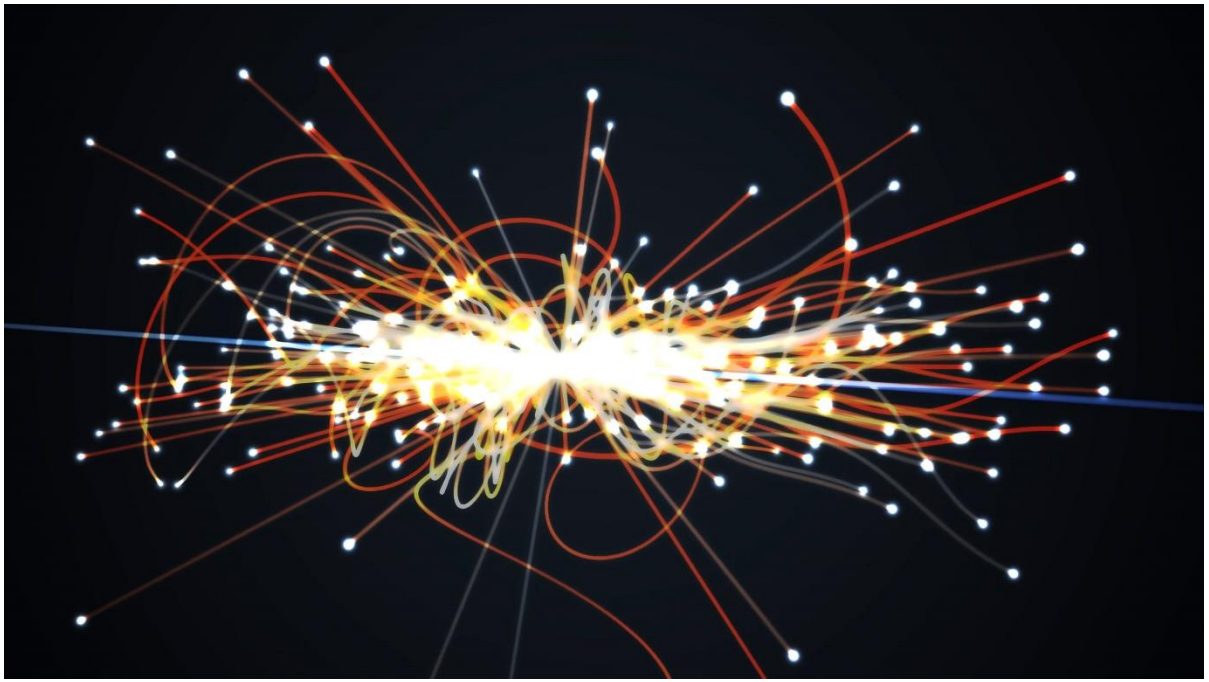
Particle Physics Challenges



Lance Dixon & Nima Arkani-Hamed

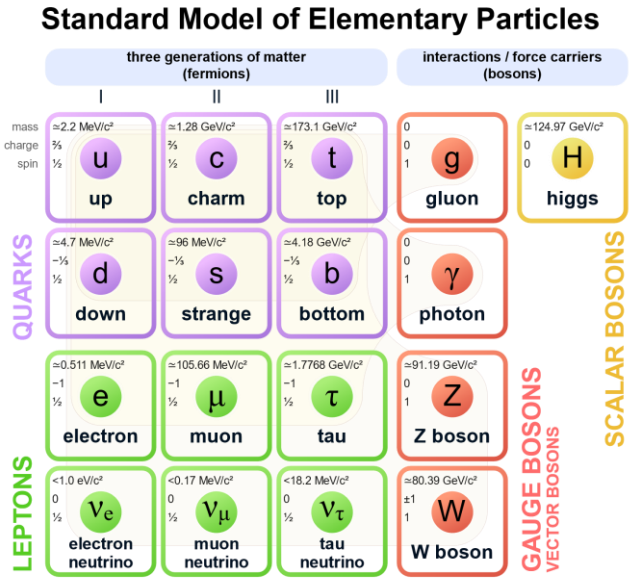
Strings 2021 Discussion

1 July 2021

SLAC
NATIONAL ACCELERATOR LABORATORY

Victims of our own success

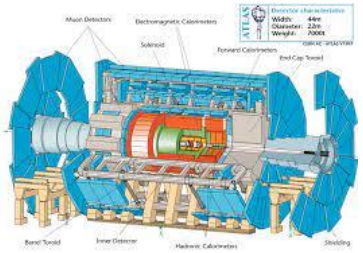
Answers so many questions, but obviously not all



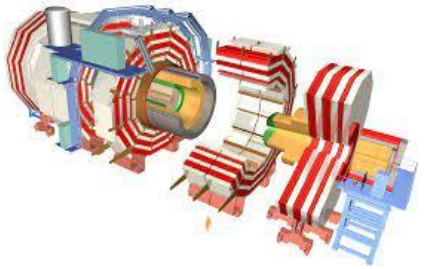
With Higgs, self-consistent, so doesn't provide many clues to its eventual downfall/extension

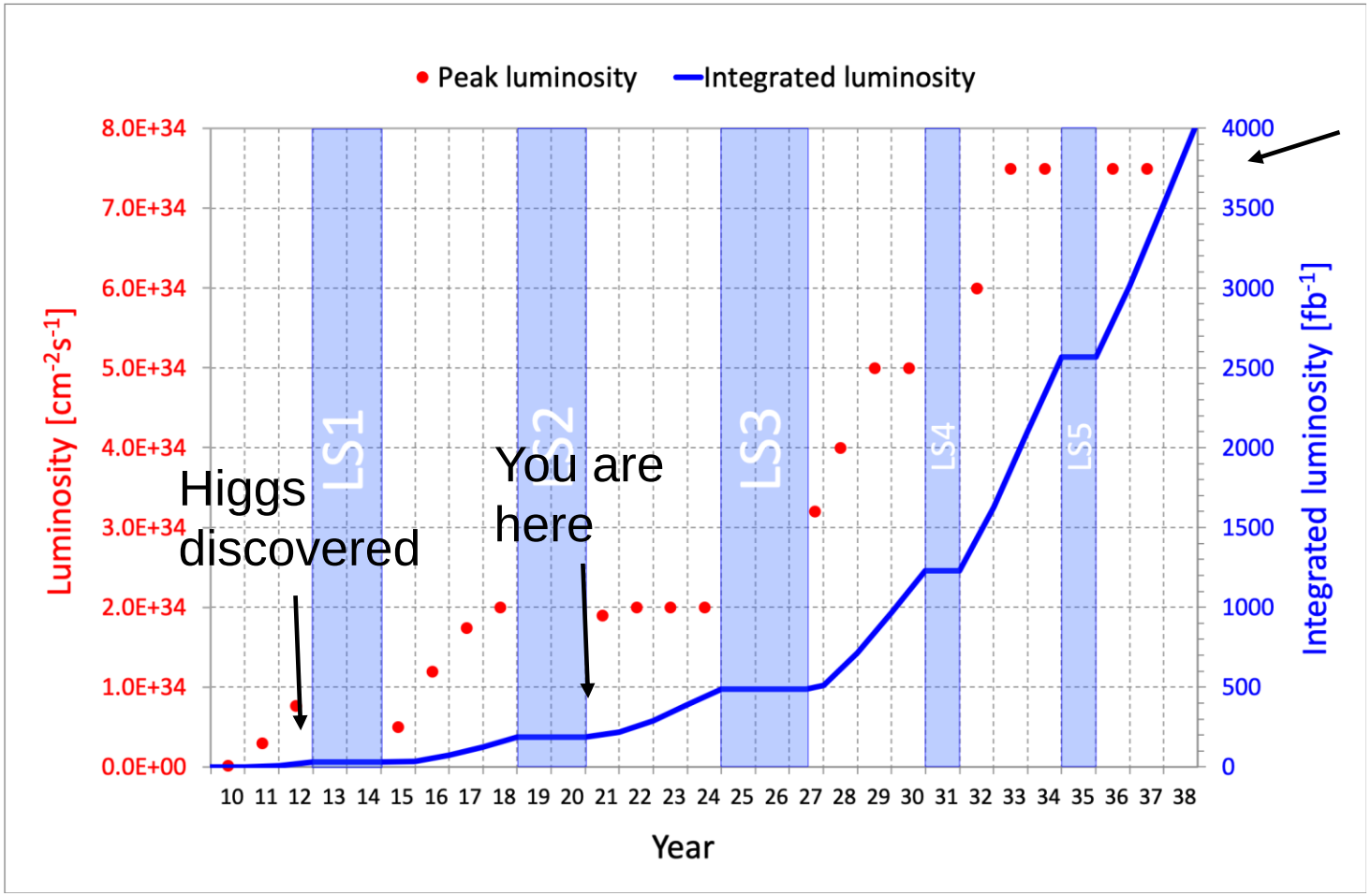
Missing: Dark matter, inflation/dark energy, baryon asymmetry, neutrino mass generation, flavor structure, gauge unification, a "natural" origin for the weak scale,…

And of course: The graviton (but for that we have string theory)



LHC energy frontier
luminosity projections



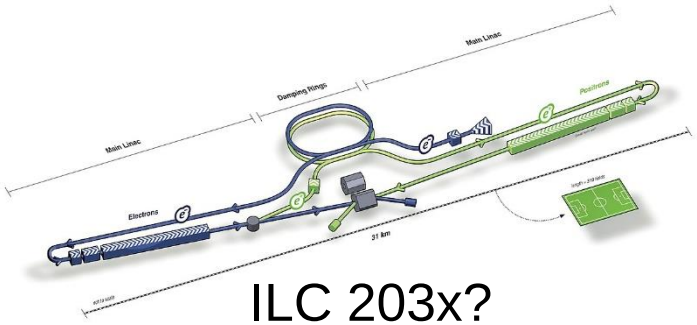


Final goal over 10x now →

10x more new particles produced (if there), ~3x-10x better on rare Higgs modes, other precision measurments

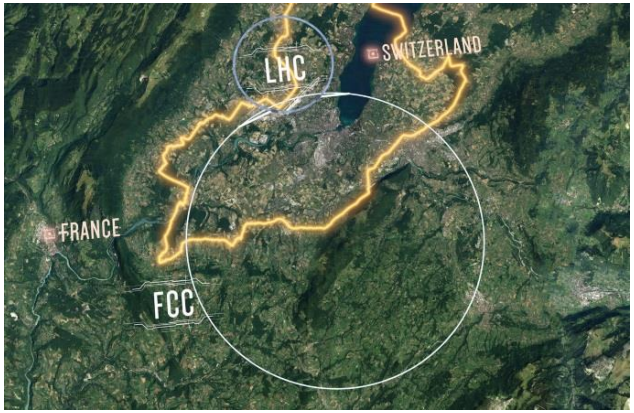
Future of the energy frontier

LHC → high luminosity LHC → 2037

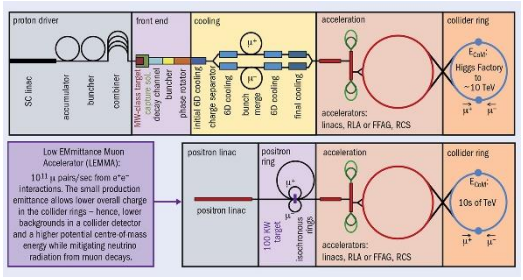


ILC 203x?

CCC 203x??



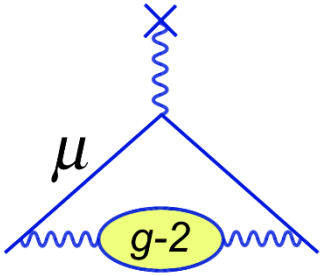
FCC ee 204x? → pp or CEPC?

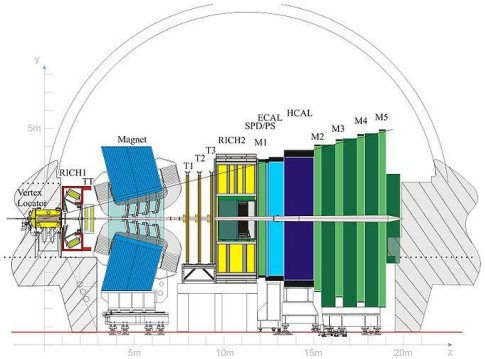


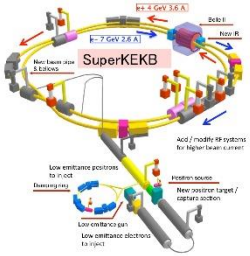
muon collider 204x???

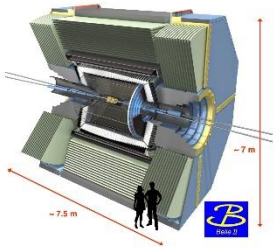
plasma or direct laser acceleration???

Also flavor/precision/rare physics

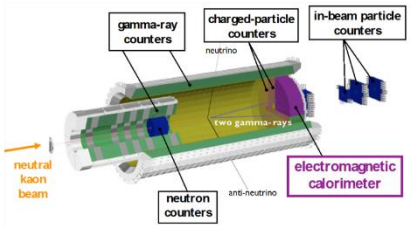


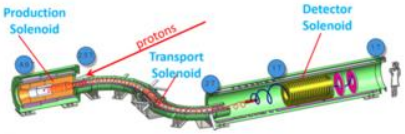






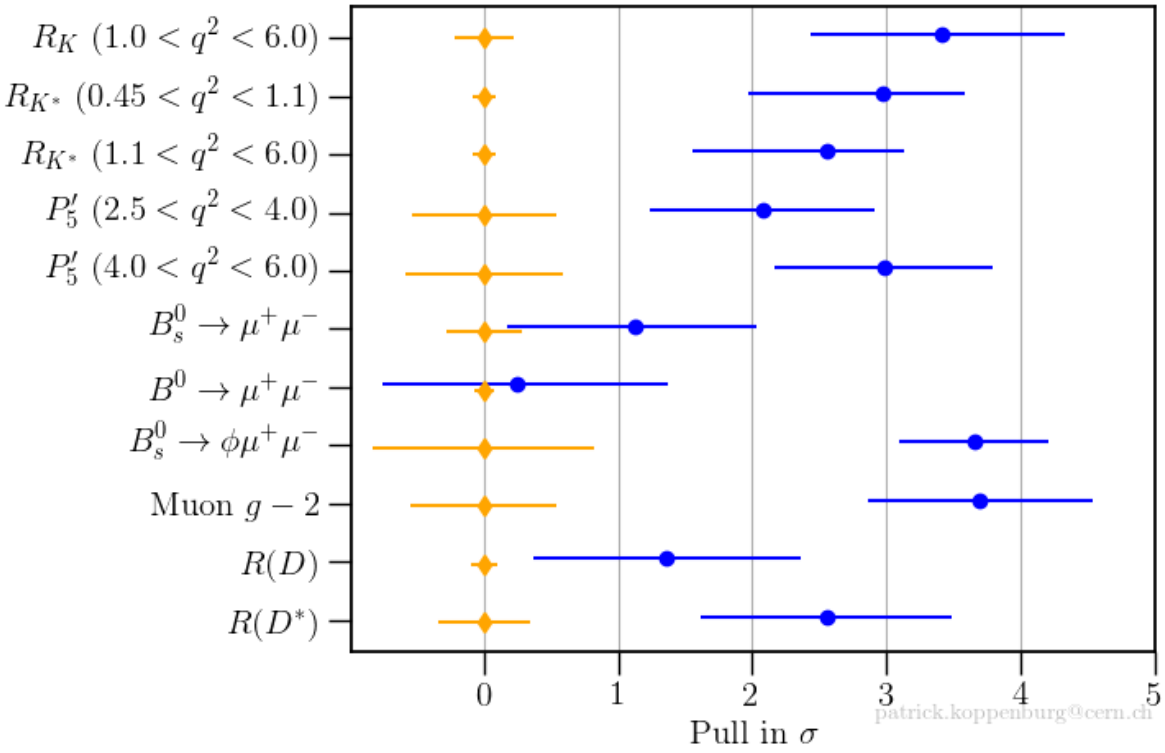
KOTO @ JPARC





+ …

Currently, many flavor discrepancies summarized by "mu-anom" (rhymes with Q-anon)



$\sim B \to K\mu^+\mu^-$

$\sim B \to K^*\mu^+\mu^-$

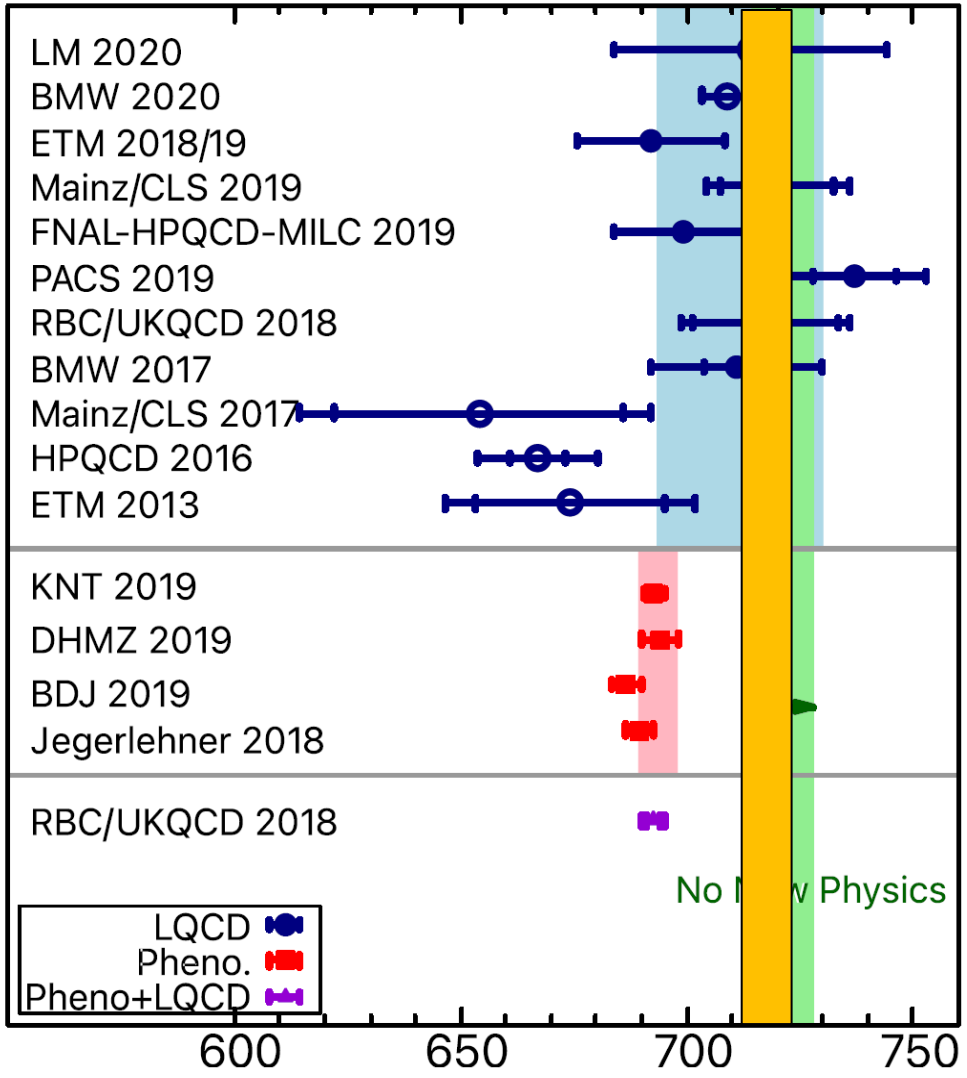
$\sim B \to K^*\mu^+\mu^-$, angular asymmetry

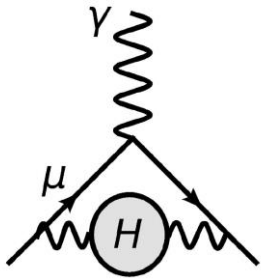
$$\frac{B \to D^{(*)}\tau\nu}{B \to D^{(*)}\mu\nu}$$

https://twitter.com/PKoppenburg/status/1374276867843309569

As of March 23, 2021, P. Koppenburg (LHCb)

Wrinkle in muon g-2 theory from lattice





Biggest uncertainty: hadronic vacuum polarization (HVP)
Traditionally calculated by a dispersion relation + e^+e^- data
Newer lattice results still have larger errors (except BMW).
But all since 2017 lie to right, would reduce 4.2σ discrepancy

T. Blum, talk at BAPTS March, 2021 + FNAL g-2 result

What can theorists do?

- Think of new, theoretically “compelling” and experimentally predictive frameworks for new physics, especially those with novel signatures.
- Compute precise consequences of SM where needed experimentally, and/or devise new ways to analyze data, including machine learning when helpful
- Apply theoretical technology to new arenas (e.g. scattering amplitudes for LIGO).

Let’s discuss the future further!