Prospettive in Esperimenti di Fisica delle Particelle agli Acceleratori

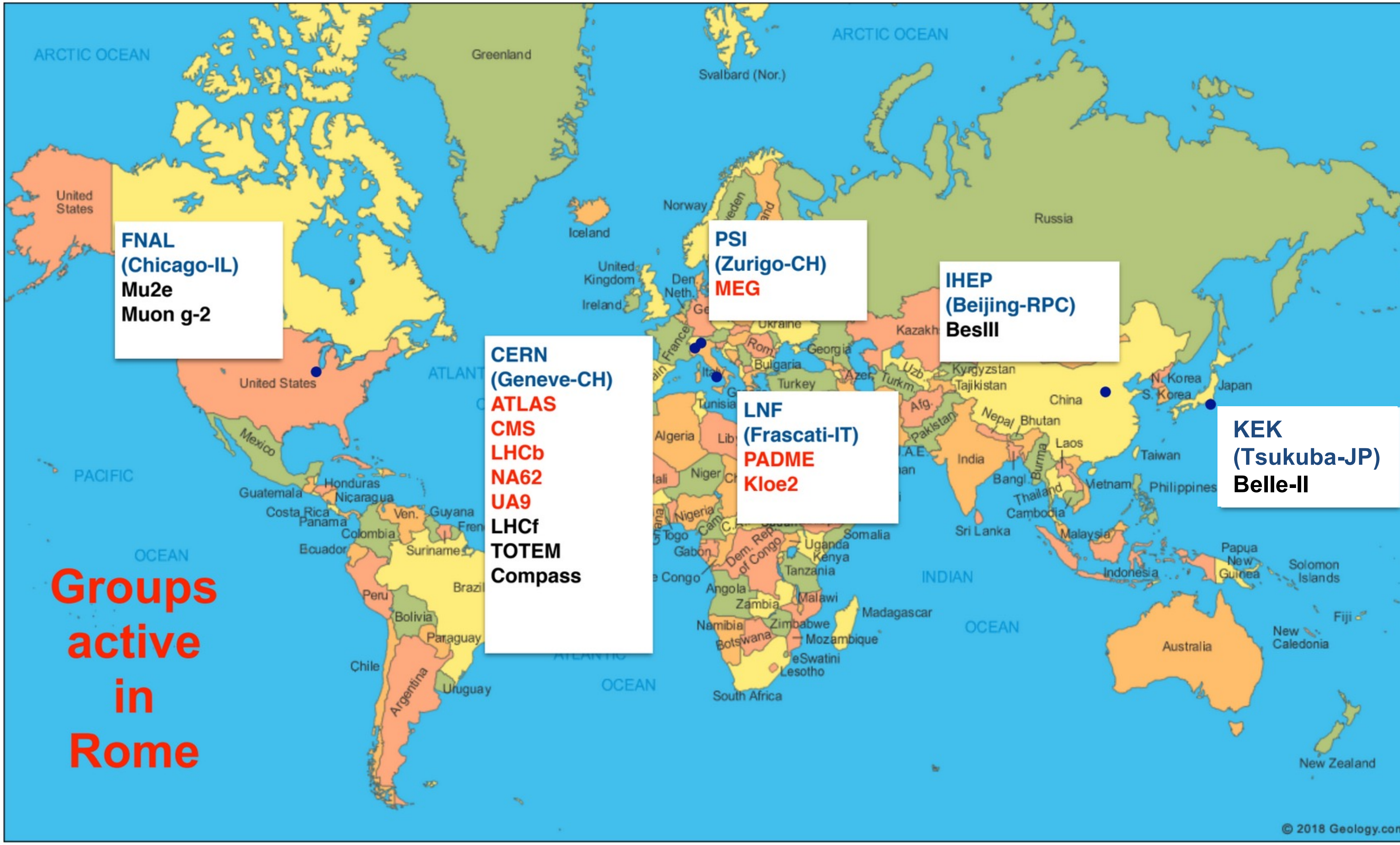
C.Voena

Retreat della Sezione INFN di Roma

Assisi, 13-15 Giugno 2022

INFN
Istituto Nazionale di Fisica Nucleare

Experiments and Accelerators



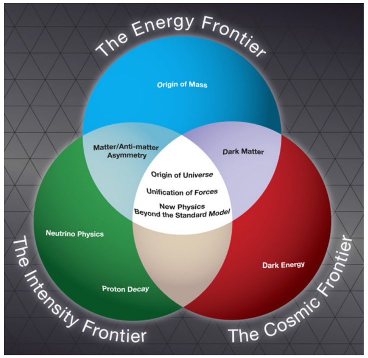
Where We Are

- The **Standard Model** (SM) of Particle Physics seems incomplete:

  - Neutrino are massive
  - Dark Matter (DM) is required
  - Pattern of quark/neutrino masses and mixing not understood
  - Origin of the CP asymmetry in the Universe not understood
  - Fine tuning problems
  - ...

⇒ **Quest of New Physics (NP)**

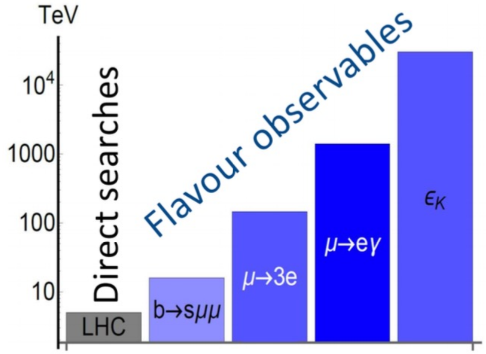
Particle Physics Crossroads



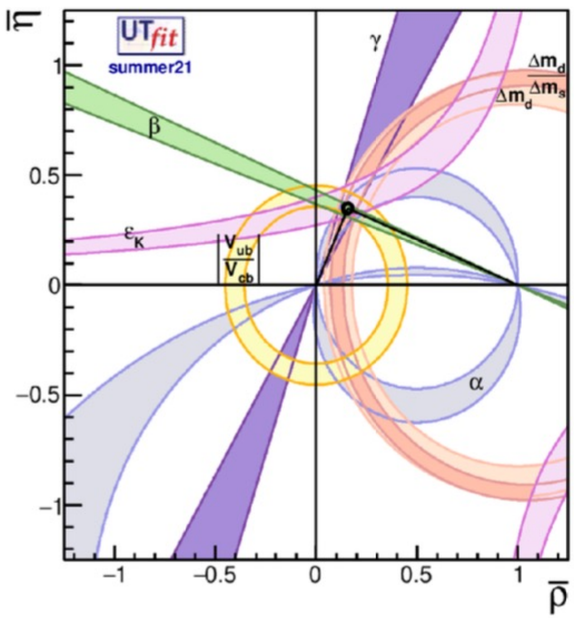
- What experiments are telling us, so far:

  - Great success of SM predictions
    ⇒ NP effects, if any, are "small"
  - **No new particles** unambigously observed
  - **No DM** unambigously observed
  - **Some "anomalies"** vs SM expectations are observed

Direct vs Indirect Searches



Success of SM CKM Pattern



Cabibbo-Kobayashi-Maskawa mechanism
=> **CP violation in quark sector**

$$\bar{\rho} = 0.157 \pm 0.012$$ ~8%

$$\bar{\eta} = 0.350 \pm 0.010$$ ~3%

At the current level of precision all measurements are consistent and intersect the apex of the triangle

- At the current level of precision all measurements are consistent and intersect the apex of the triangle
- It's now time to **push the precision to check for NP** effects. Does the triangle really close?
- E.g. The angle γ can be measured from tree-level decays (negligible theory prediction)

CKM tests: γ angle

	Precision
Now	4°
Belle II (50/ab)	1.5°
LHCb (50/fb)	1°
Belle II (250/ab)	0.8°
LHCb (300/fb)	0.35°

2032

Run4 HL-LHC

The SM (?) Higgs Boson

- Millions of Higgs boson collected to LHC (Run1-2) in 10 years since discovery
  - Observation all third generation couplings
  - Detailed measurement of many H properties
  - Run3 is approaching. HL-LHC ~2026

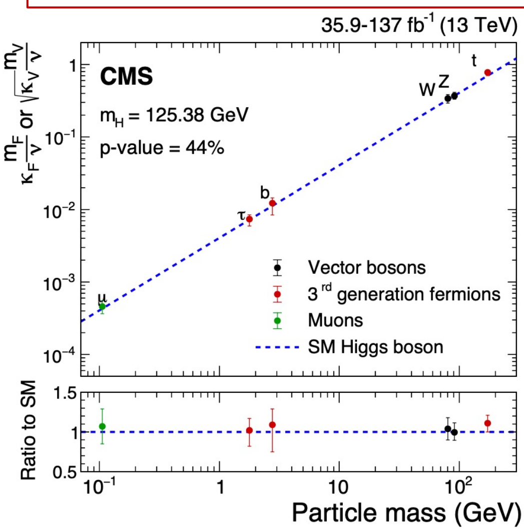
The Higgs boson seems "Standard" so far. We need to

→ Improve precision on observed properties

→ Complete the picture: study rare and not observed yet properties

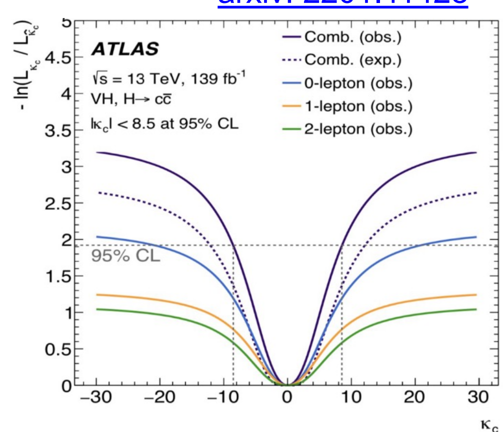
Higgs couplings

precision 2-5% for most of the couplings at HL-LHC



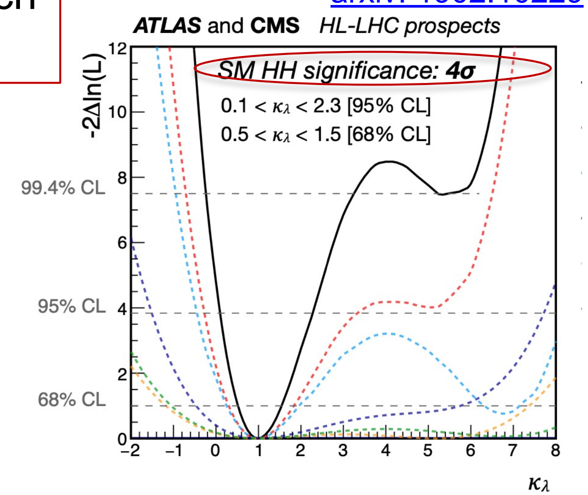
charm coupling:
present limit on yield ~30 times above SM value.
Direct measurement within reach of HL-LHC (if SM)

arxiv: 2201.11428



self-coupling (λ_{HHH})

arxiv: 1902.10229



New Physics Searches at LHC

- Search for direct production of new particles in many modes => not found so far, constraints on mass

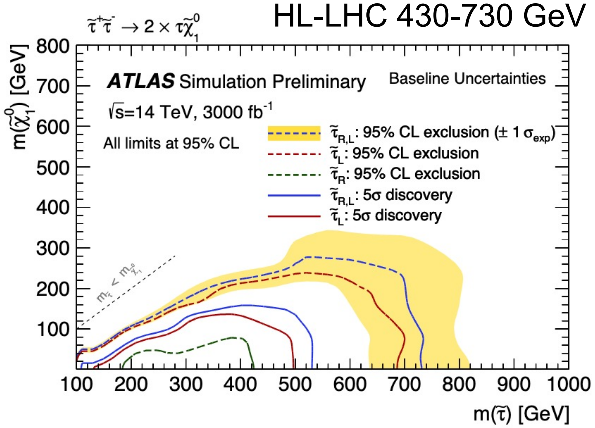
- Some "bumps" found...need more data

SUSY searches

- Limits for strong SUSY production are above 1 TeV
- Still opportunities in EW sector
- Limited phase space remains

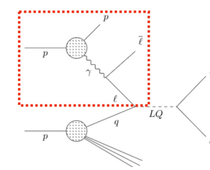
Snowmass Mar21

stau exclusion: Run2 120-390 GeV
HL-LHC 430-730 GeV

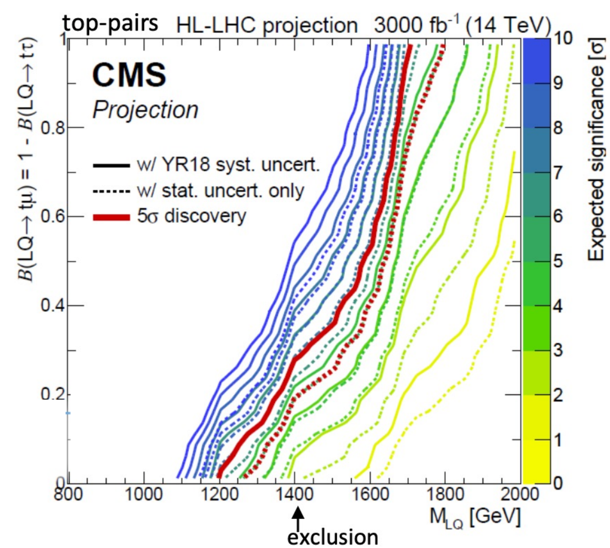


Lepto-Quark searches

- Can explain flavor anomalies
- Search with PPS detector using lepton induced production @CMS-Rome



Snowmass Mar21

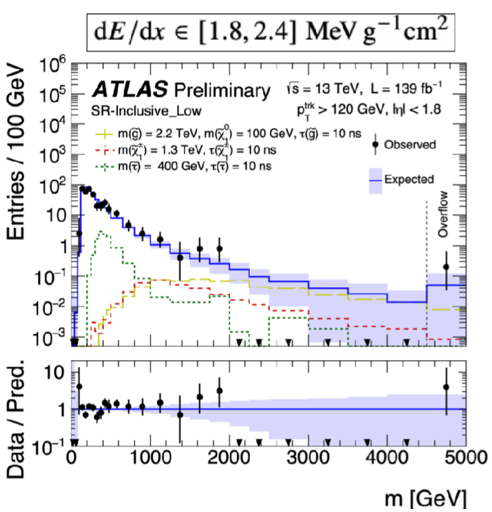


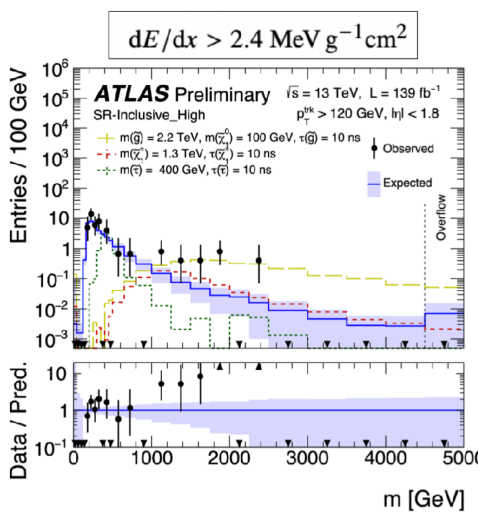
New Physics Searches at LHC

Long lived particles

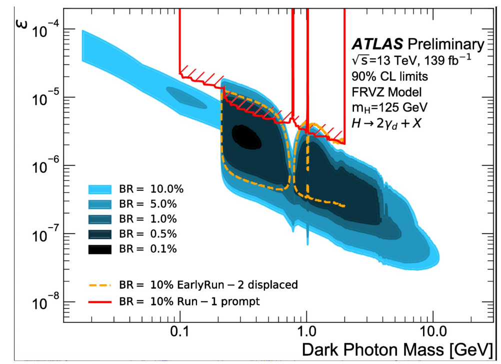
- promising direction to expand LHC seatches
- signature based search

New result:
excess observed in ATLAS at high mass
abnormal dE/dx in ATLAS pixel
caveat: inconsistency with tof [Moriond22]



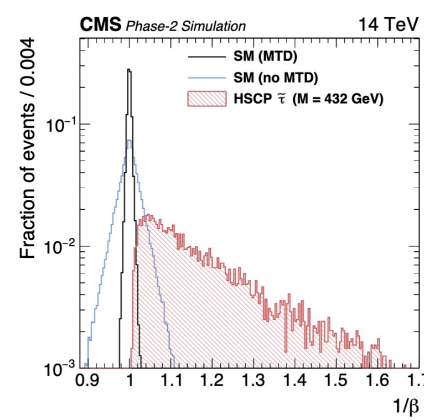


Search for light long-lived neutral particles that decay to collimated pairs of leptons or light hadrons in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector [ATLAS-Conf-2022-01]



Upgraded CMS detector with MTD has a direct impact on LL topology

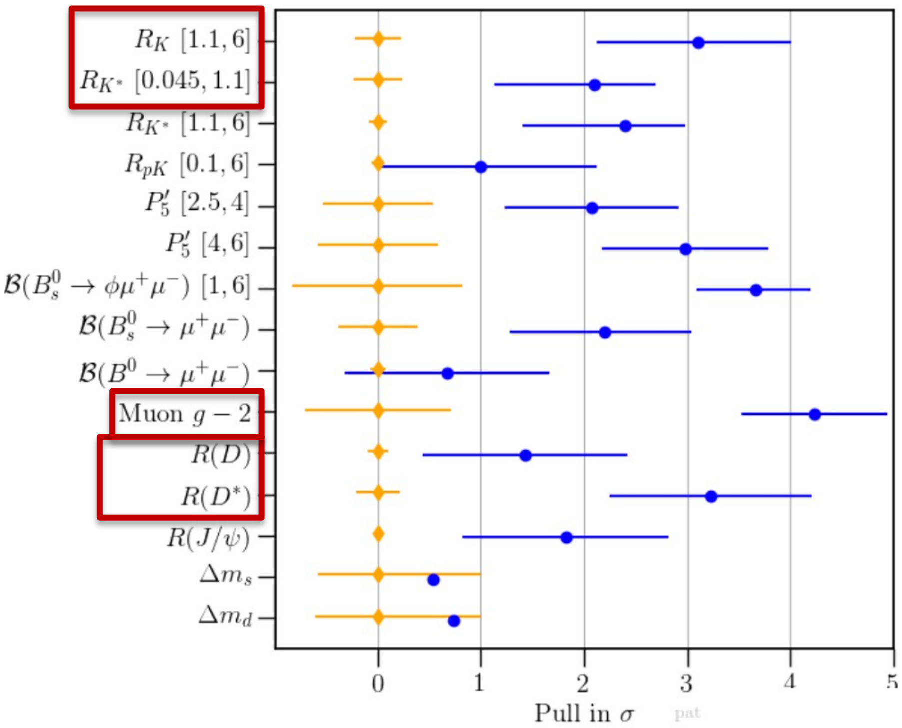
[MTD TDR]



Precision Tests with Flavor

- Search for deviations from SM predictions
- **Observed some anomalies…hints for NP?**

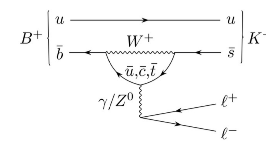
Flavor Anomalies



Lepton Flavor Universality

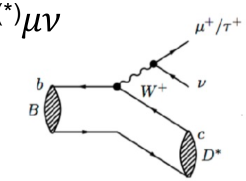
- In the SM the only flavour non-universal terms are the 3 lepton masses
- If NP couples in a non-universal way to the 3 lepton families => compare classes of rare decays involving different lepton pairs
- Subject of extensive research program at LHCB & BelleII

$B \to K^{(*)} ll$

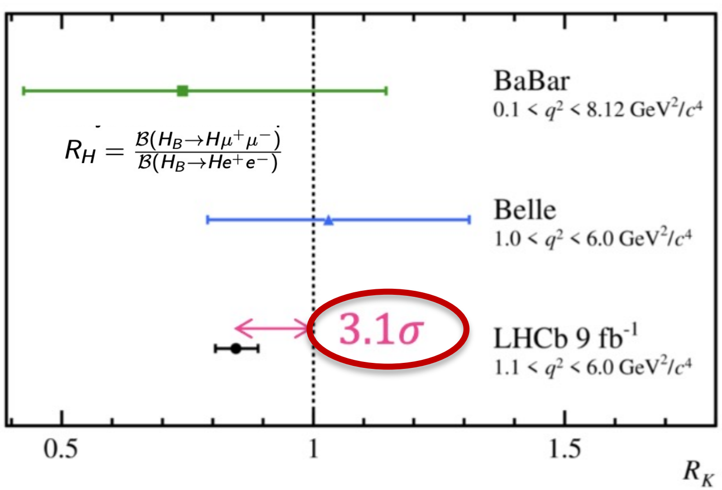


tree-level process

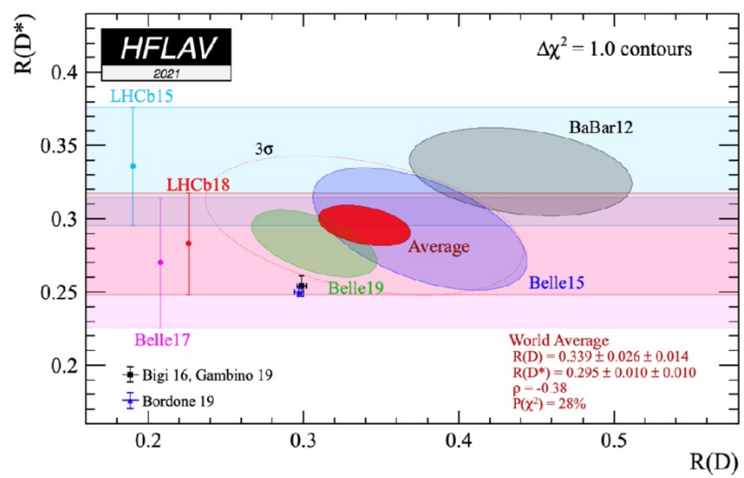
$B \to D^{(*)} \mu\nu$



Lepton Universality Tests	Current LHCb (up to 9 fb^{-1})		Upgrade I (23 fb^{-1})	Upgrade I (50 fb^{-1})	Upgrade II (300 fb^{-1})
R_K ($B^+ \to K^+\ell^+\ell^-$)	0.044	[12]	0.025	0.017	0.007
R_{K^*} ($B^0 \to K^{*0}\ell^+\ell^-$)	0.12	[61]	0.034	0.022	0.009
$R(D^*)$ ($B^0 \to D^{*-}\ell^+\nu_\ell$)	0.026	[62, 64]	0.007	0.005	0.002



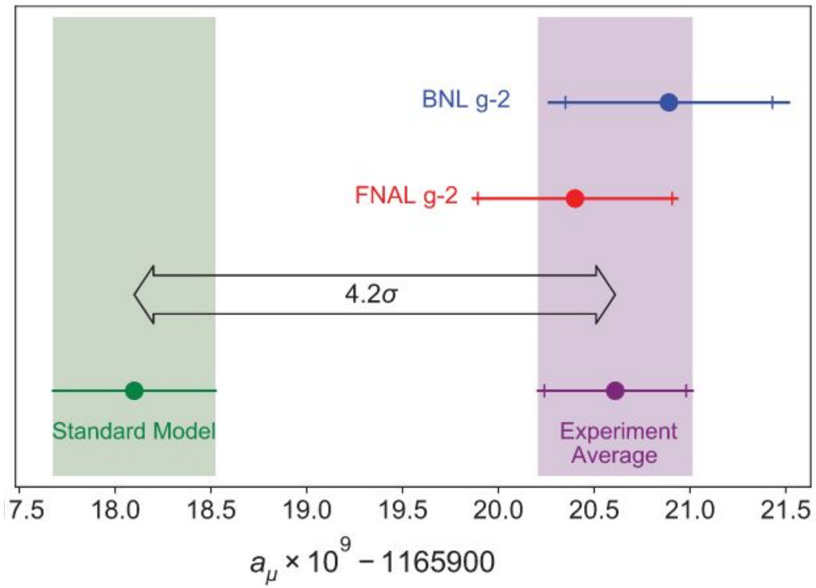
$(B \to D^{(*)-}\tau^+\nu)/(B \to D^{(*)-}\mu^+\nu)$

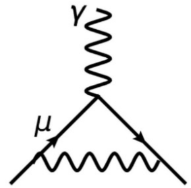


The Long Standing Anomaly: g-2

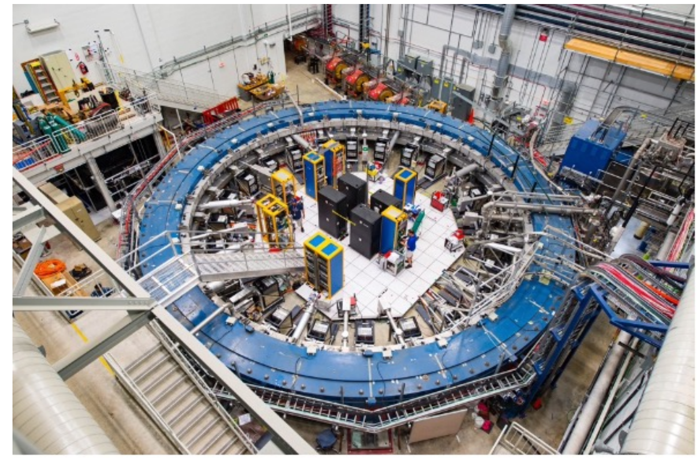
- Muon anomalous magnetic moment

  [PRL 126, 141801 (2021)]

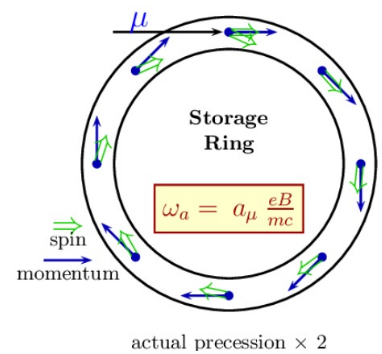




The FNAL E989 storage ring



Electromagnetic spin precession in laboratory frame



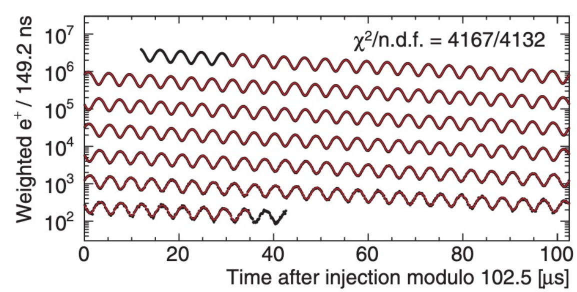
Cyclotron frequency

Thomas-Bargmann-Michel-Telegdi Equation (T-BM

$$\vec{\Omega} = \vec{\Omega}_0 - \vec{\Omega}_c = \boxed{\frac{q}{m}\left[a\vec{B} - \frac{a\gamma}{(\gamma+1)}\left(\vec{\beta}\cdot\vec{B}\right)\vec{\beta} - \left(a + \frac{1}{1-\gamma^2}\right)\frac{\vec{\beta}\times\vec{E}}{c}\right]}$$

$$\boxed{+\frac{\eta q}{2m}\left[\vec{\beta}\times\vec{B} + \frac{\vec{E}}{c} - \frac{\gamma}{(\gamma+1)c}\left(\vec{\beta}\cdot\vec{E}\right)\vec{\beta}\right]}$$

EDM contribution



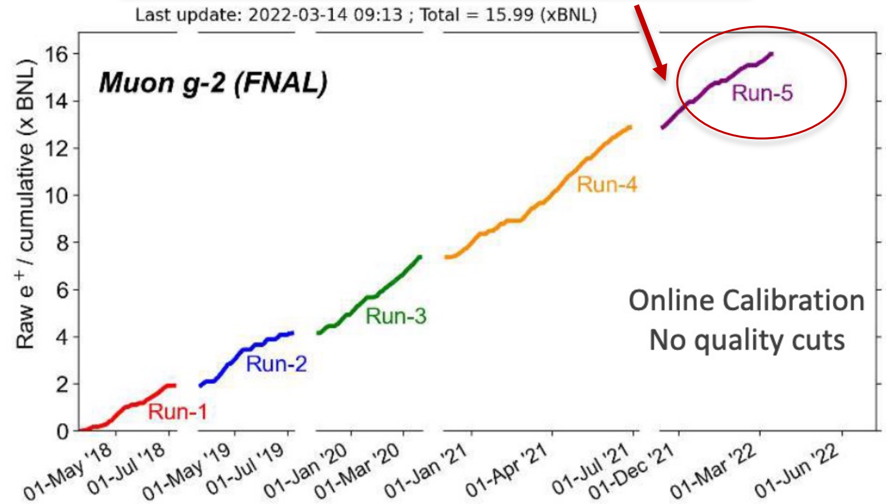
g-2 Perspective

- Analysis of E989 Runs 2&3 ongoing
  - expected statistical uncertainty ~200 ppm (from 434)
  - improvements to reduce systematic errors: goal~100ppb

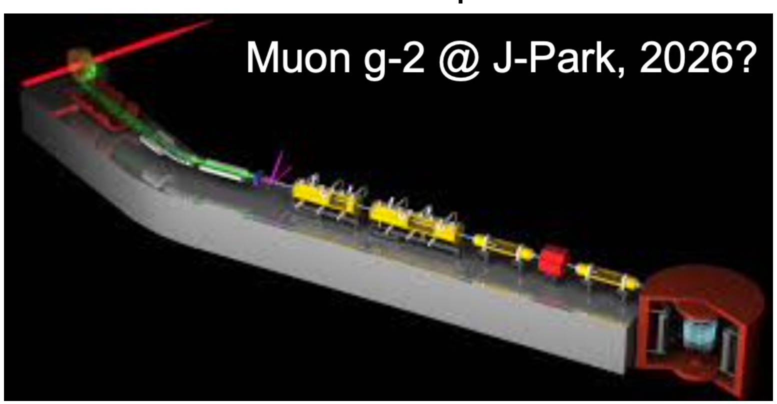
  [Phys.Rep 887 (2020)](#)

- **Theory initiative** to reduce theoretical uncertainties
  - Data-driven: dispersive approach key to sub-percent precision
  - Lattice QCD
  - Consistency mandatory for NP discovery

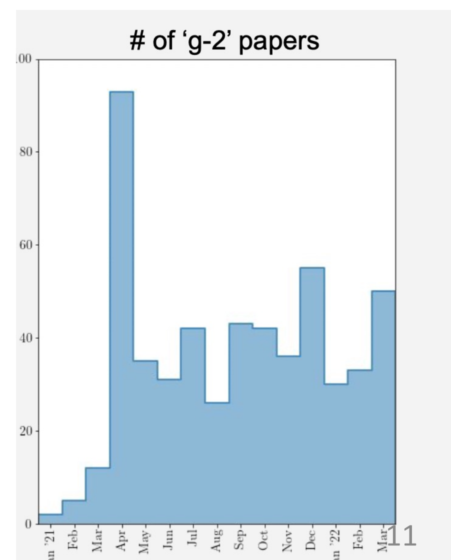
expected error: ~0.15 ppm



Future alternative experiment



Several Beyond Standard Model Interpretations (some connected to LFU)



Dipole Interactions in Effective Field Theory

- EFT Framework: at the experimental energy scale (mμ) processes can be described by an effective Lagrangian

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \sum_{d\geq 5} \frac{c_{ij}^{(d)}}{\Lambda_{NP}^{d-4}} O_{ij}^{(d)}$$

Processes intrinsically connected (dipole operator)

g-2

$$a_{\ell_i} = -\frac{4m_{\ell_i}}{e} \operatorname{Re} c_R^{\ell_i \ell_i}$$

Muon EDM

$$d_{\ell_i} = -2 \operatorname{Im} c_R^{\ell_i \ell_i}$$

$$\boxed{\mathcal{H}_{\text{eff}} = c_R^{\ell_f \ell_i}\, \bar{\ell}_f \sigma_{\mu\nu} P_R \ell_i F^{\mu\nu} + \text{h.c.}}$$

Predictions from NP models quite model dependent: need to push the sensitivity as much as possible

$$\text{Br}[\mu \to e\gamma] = \frac{m_\mu^3}{4\pi\,\Gamma_\mu}\left(|c_R^{e\mu}|^2 + |c_R^{\mu e}|^2\right)$$

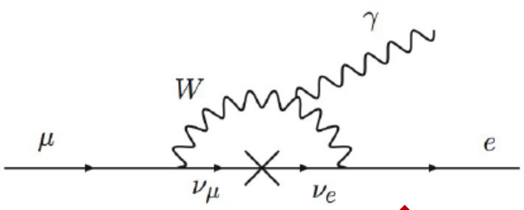
Charged Lepton Flavor Violation

Charged Lepton Flavor Violation

- cLFV interactions are processes that don't conserve lepton family number

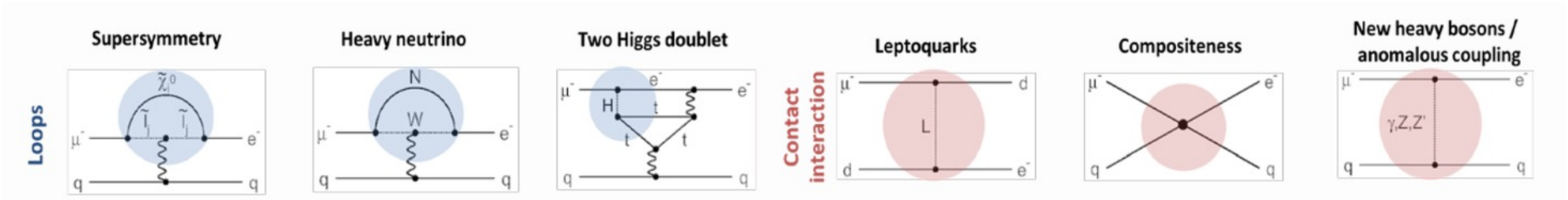
$$\text{e.g. } \mu \to e,\ \tau \to \mu\mu\mu\ ,\ K_L \to \mu e,\ H \to \tau\mu, \ldots$$

- Flavor in the SM
  - Quark flavor is violated in weak decays (CKM matrix)
  - Neutral lepton flavor is violated (neutrino oscillatios)



- What about charged flavor?
  - Lepton flavor accidentally conserved in SM with massless neutrino
  - **Add Dirac ν masses to SM: lepton flavor violated, but incredibly tiny rates**

Observation of cLFV is a unambigous signal of
Physics beyond the Standard Model



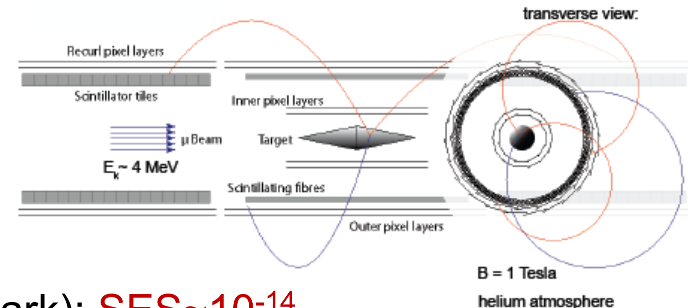
The Muon Golden Channels

- Muon processes provided powerful constraints due to the avaibility of intense beam and the relatively ling muon lifetime
- Already probe NP mass scale at the level of 10^3 TeV
- **Complementarity is the key**

Mu3e (PSI)

$\mu \to$eee

- expect sensitivity: $\sim 10^{-15}$
- data taking in 2022++



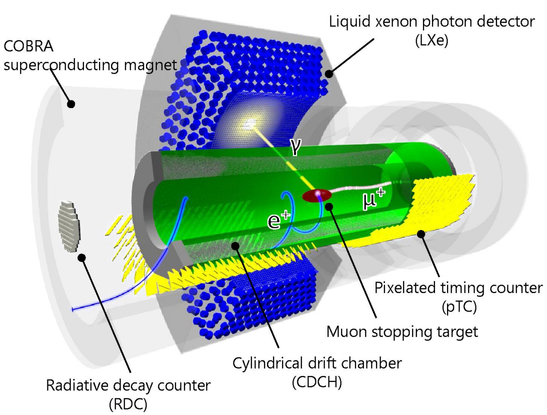
μN$\to$eN

- DeeMee(J-Park): SES$\sim 10^{-14}$
- COMET: SES$\sim 10^{-17}$
- Mu2e: SES$\sim 10^{-17}$
- data taking in 2022++

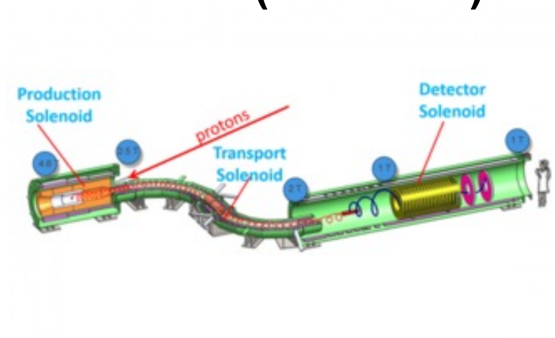
MEG-II (PSI) 

$\mu \to$eγ

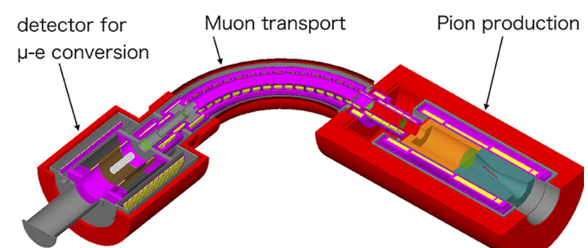
- expected sensitivity $\sim 6\mathrm{x}10^{-14}$
- data taking in 2022



Mu2e (Fermilab)



COMET (J-Park)



COMET Phase-I Layout

Muon EDM

- The need of non-standard CPV sources to explain the matter-antimatter asymmetry of the universe motivates many searches for EDM

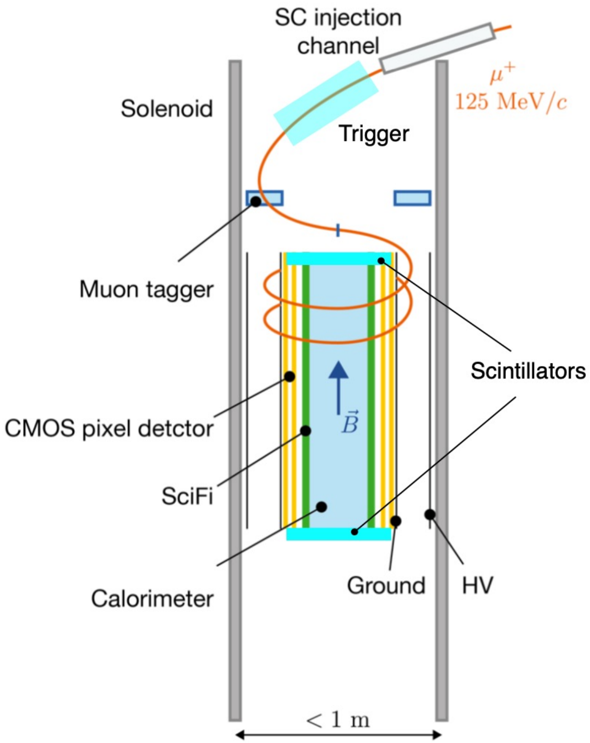
$|d_\mu|_{\rm ind} \leq 1.6 \times 10^{-27}\, e\,{\rm cm}$ Indirect from electron EDM (MLV assumption)

$|d_\mu|_{\rm exp} \leq 1.5 \times 10^{-19}\, e\,{\rm cm}$ Direct byproduct from g-2

MuEDM proposal at PSI  LoI

- The frozen spin technique
  - an electric field is applied to cancel the horizontal spin precession
  - spin is locked parallel to the momentum
  - vertical precession

Expect to improve the present limit by 3 orders of magnitude
- could start data taking 2028



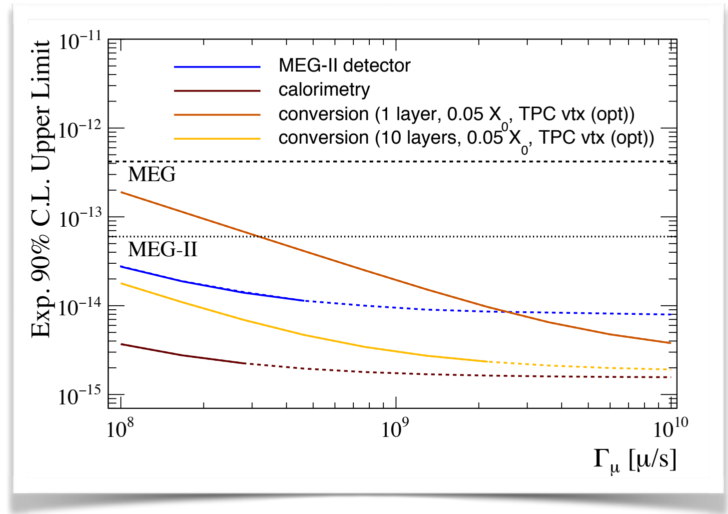
Future Accelerators/Experiments

Muon facilities

- Several proposals for next generation experiments

- **HIMB @PSI**
  - current PSI muon beamline 2×10^{8} mu/s
  - proposed HIMB at PSI – 10^{9}-10^{10} mu/s
  - possibility to reach sensitivity 10^{-15} in $\mu\rightarrow e\gamma$

[Eur. Phys. J. C 78, 37 (2018)](#)



- **PIPII at FNAL**
  - will deliver 1.2MW proton beam for LBNF but only a fraction of the available beam is used => opportunity for new muon experiments
  - Mu2e-II (10^{-18})
  - cLFV in muon decay and transitions, muonEDM

Advanced muon facility at FNAL (AMF)

The Fermilab connection

aMUSE

EU funded network
based at the Muon Campus
at FNAL for LVF,g-2, muon collider
(INFN, Sapienza...)

[web-page](#)

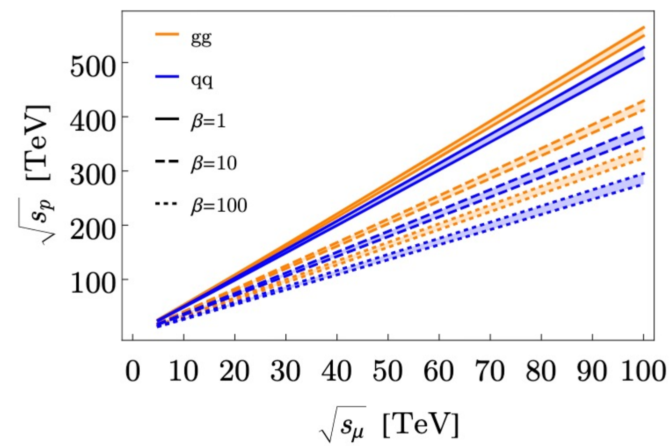
The Muon Collider Project

- A $\mu^+\mu^-$ collider can extend the lepton high energy fronteer in the multi-TeV range

  - No synchrotron radiation
  - but muon lifetime
  - technological challenge

International MUON Collider Collaboration

arxiv 2103.14043



- Muon production schemes
  - proton based
  - LEMMA proposal $e^+e^- \to \mu^+\mu^-$ close to production thresold

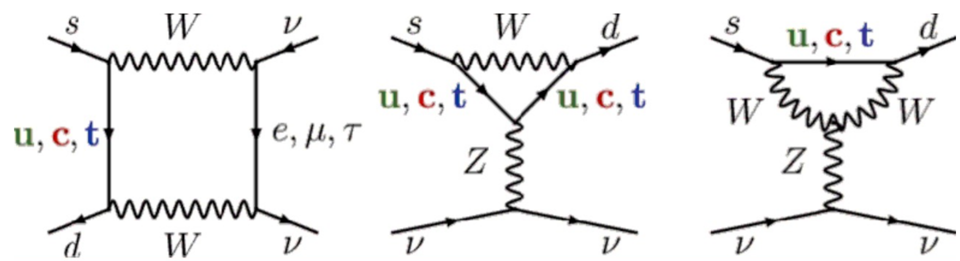
  - very small emittance is obtainable => no cooling needed
  - low background
  - large boost at production
  - much smaller muon production cross section

Multi Higgs & Higgs self coupling

$\sqrt{s}$ (lumi.)	3 TeV (1 ab^{-1})	6 (4)	10 (10)	14 (20)	30 (90)	Comparison
WWH ($\Delta\kappa_W$)	0.26%	0.12%	0.073%	0.050%	0.023%	0.1% [41]
$\Lambda/\sqrt{c_i}$ (TeV)	4.7	7.0	9.0	11	16	(68% C.L.)
ZZH ($\Delta\kappa_Z$)	1.4%	0.89%	0.61%	0.46%	0.21%	0.13% [17]
$\Lambda/\sqrt{c_i}$ (TeV)	2.1	2.6	3.2	3.6	5.3	(95% C.L.)
$WWHH$ ($\Delta\kappa_{W_2}$)	5.3%	1.3%	0.62%	0.41%	0.20%	5% [36]
$\Lambda/\sqrt{c_i}$ (TeV)	1.1	2.1	3.1	3.8	5.5	(68% C.L.)
HHH ($\Delta\kappa_3$)	25%	10%	5.6%	3.9%	2.0%	5% [22, 23]
$\Lambda/\sqrt{c_i}$ (TeV)	0.49	0.77	1.0	1.2	1.7	(68% C.L.)

The Kaon Way to NP: $K\rightarrow\pi\nu\nu$

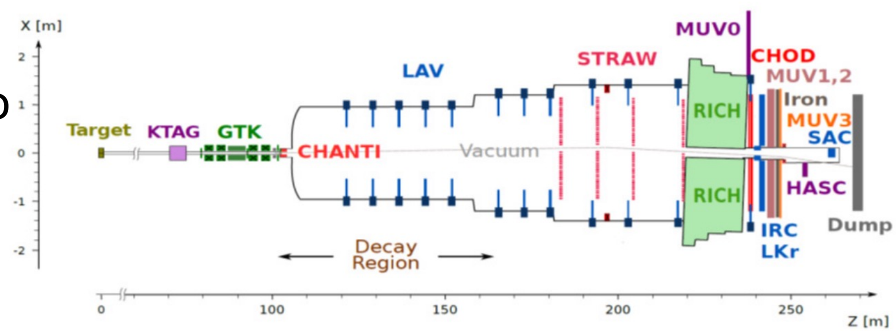
- Extremely rare
- Precise SM prediction



Mode	Expected BR_{SM}	Experimental status
$K^+\rightarrow\pi^+\nu\nu$	$(8.60\pm0.42)\times10^{-11}$	$(10.6\pm4.0)\times10^{-11}$ (NA62 Run 1) arxiv 2103.15389
$K_L\rightarrow\pi^0\nu\nu$	$(2.94\pm0.15)\times10^{-11}$	$BR<300\times10^{-11}$ at 90% CL (KOTO 2015 data) arxiv 1910.07148

- Plans by 2025
  - o(10%) uncertainty on $K^+\rightarrow\pi^+\nu\nu$ (Na62)
  - SM sensitivity, o(10^{-11}) on $K_L\rightarrow\pi^0\nu\nu$ (Koto, possible KOTO-Phase2)

Na62 detector @CERN

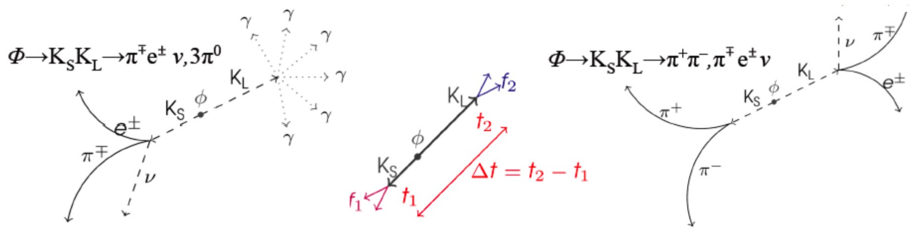


- Future prospects: beam intensity up to x 6 vs Na62
  - a $K^+\rightarrow\pi\nu\nu$ experiment aiming at 5% precision (400 SM events)
  - a $K_s\rightarrow\pi\nu\nu$ experiment (KLEVER) aiming at 20% precision (60 SM events)

The Kaon Way to NP: KLOE-2

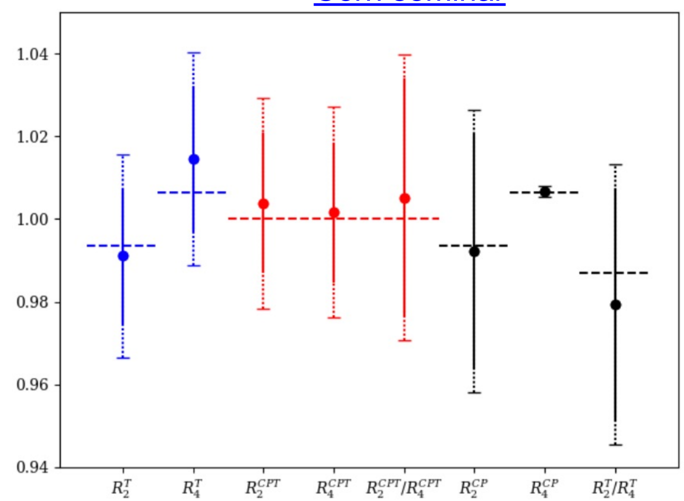
- **T, CP, CPT tests** in neutral kaon transitions at KLOE-2 (2022)

Processes under study



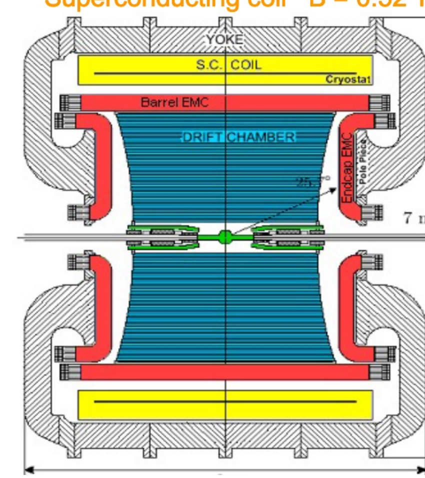
$$
\begin{aligned}
R_2^T &= 0.991 && \pm 0.017_{stat} \pm 0.014_{syst} \pm 0.012_D, \\
R_4^T &= 1.015 && \pm 0.018_{stat} \pm 0.015_{syst} \pm 0.012_D, \\
R_2^{CPT} &= 1.004 && \pm 0.017_{stat} \pm 0.014_{syst} \pm 0.012_D, \\
R_4^{CPT} &= 1.002 && \pm 0.017_{stat} \pm 0.015_{syst} \pm 0.012_D, \\
R_2^{CP} &= 0.992 && \pm 0.028_{stat} \pm 0.019_{syst}, \\
R_4^{CP} &= 1.00665 && \pm 0.00093_{stat} \pm 0.00089_{syst}, \\
R_2^T / R_4^T &= 0.979 && \pm 0.028_{stat} \pm 0.019_{syst}, \\
R_2^{CPT} / R_4^{CPT} &= 1.005 && \pm 0.029_{stat} \pm 0.019_{syst}.
\end{aligned}
$$

Cern seminar



KLOE detector @ LNF

Superconducting coil B = 0.52 T

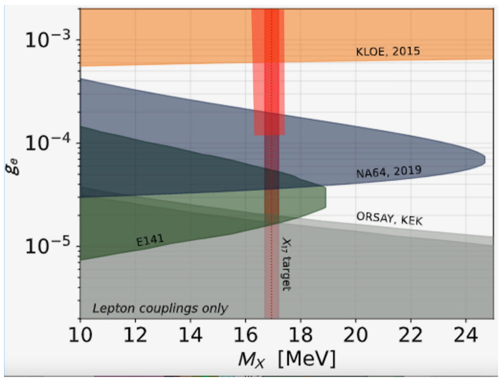


- Unique data sample @ϕ(1020) many other measurements to come!

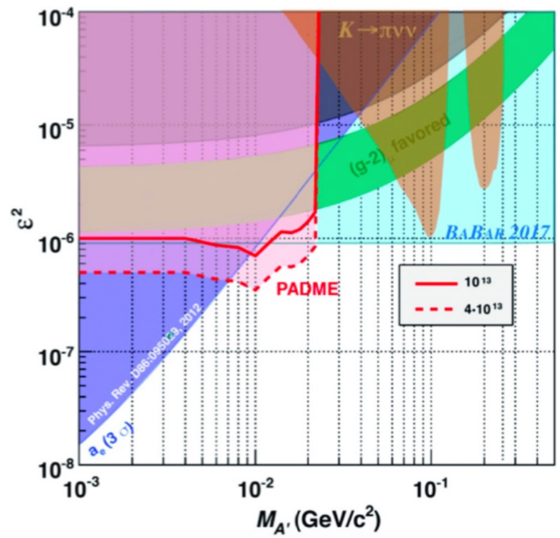
Dark Photon @Padme

- Fixed target, missing mass experiment looking for **dark photons A'**
- A' production and decay
  - $e^+e^- \to A'\gamma$
  - A' invisible decay
- Goal is 4 x 10^{13} POT (positron-on-target)
- RunII (~6×10^{12} POT), analysis on-going
- **Proposal to extend the program** at the Dafne complex (5 years) with a high luminosity extracted beam

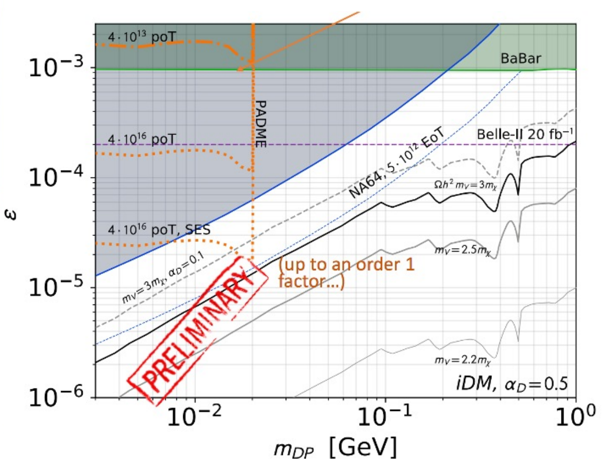
X17 "resonant" run in Sep22



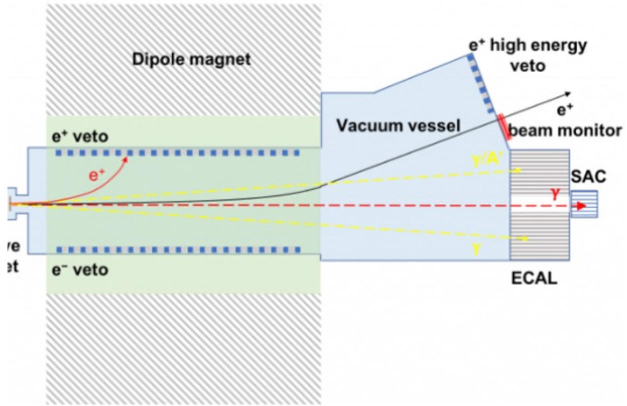
Padme goal: 4 x10^{13} POT



Possible extension: 4 x10^{16} POT



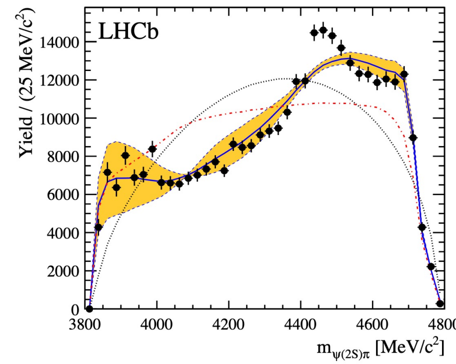
PADME@ LNF



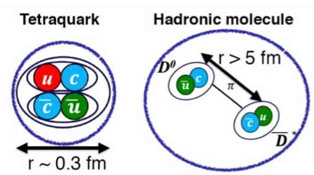
Modern Hadron Spectroscopy

- Recent observed states: Ω_c^{**0}, $\Xi_b(6327)^0$, $\Xi_b(6333)$, T_c^{++}
- Current Players: LHCb, BelleII, BesIII, GlueX, ATLAS, CMS
- Future facilities: Electron-Ion Collider (approved), super charm-tau factory (proposed), PANDA (planned)

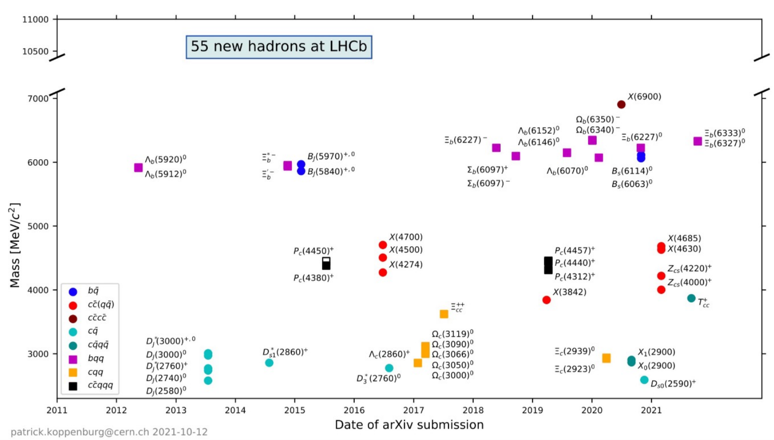
A model-independent confirmation of the Z(4430)− state Phys. Rev. D 92, 112009

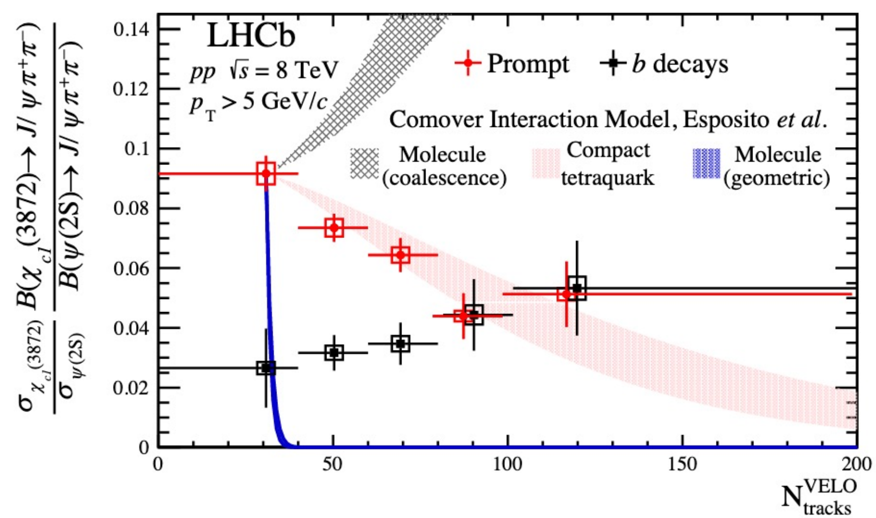


Observations of new states challenge our current understanding of QCD



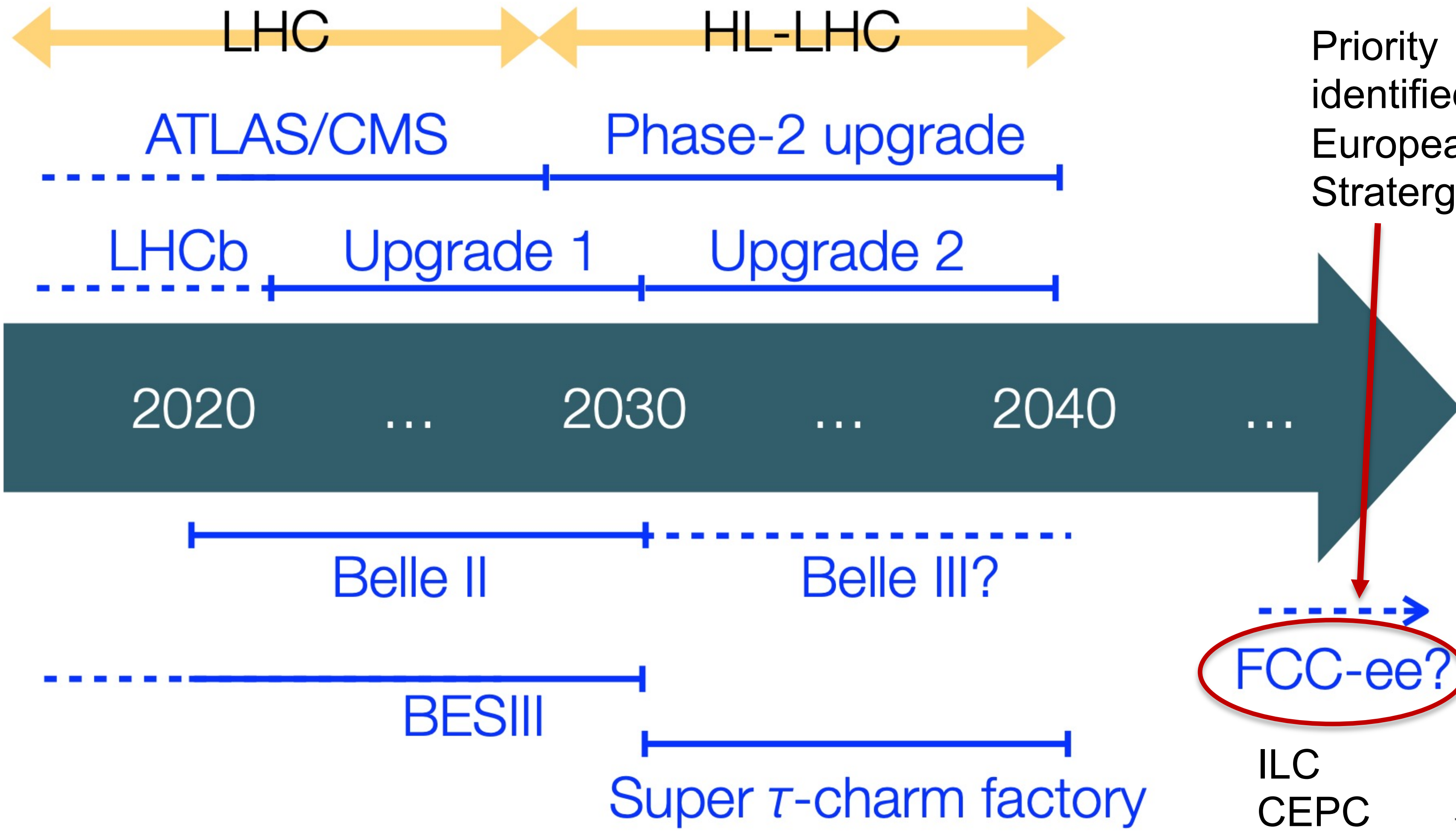
Understanding the nature of X(3782)





Future Accelerators/Experiments

Collider & Linear machines



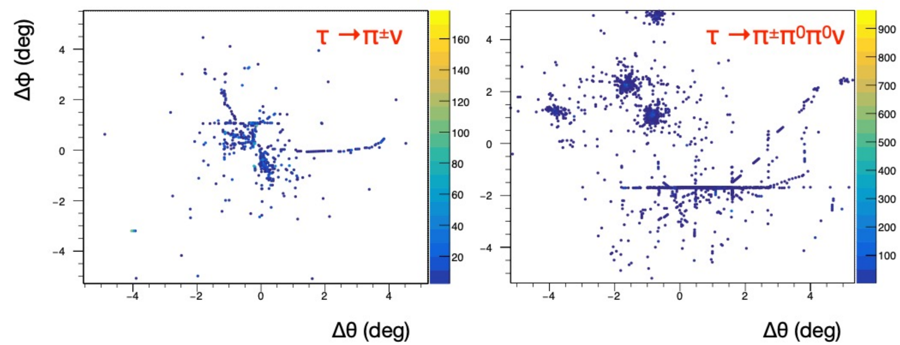
Priority identified by European Strategy

ILC
CEPC
FCC-hh
....

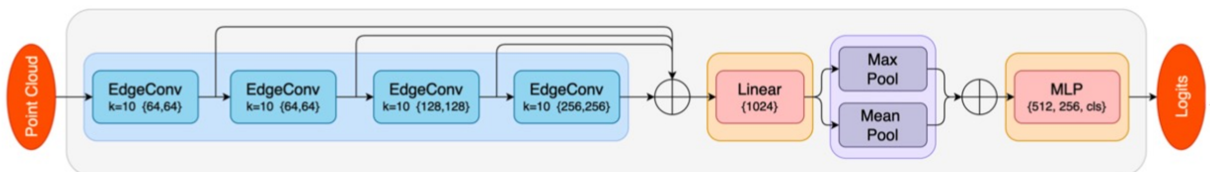
Future Accelerators/Experiments

FCC activities in Rome

Innovative detectors
AI methods for particle flow

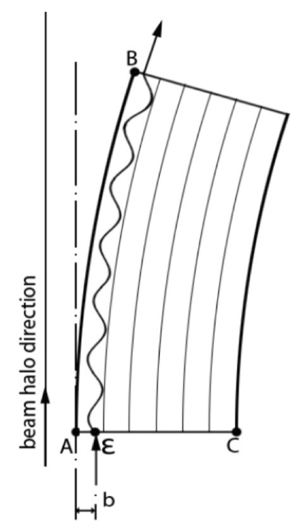


Bayesian graph NN for tau identification
in the IDEA dual readout calorimeter @ FCC



Crystal channelling in bent crystal

- use of crystal developed by UA9/Crysbeam (bent crystal as particle beam manipulators)
  - extracted beam for LHC fixed target (**ALICE**)
  - measurement of baryon EDM & MDM (**SELDOM**)
  - positron crystal extraction from DAFNE: search for light DM with many more EOT in future PADME-2 (**SHERPA**)



Activities in Rome

Massimo Corradi

H→WW, H →bb, HH
Higgs-top Yukawa
Higgs mass (4l and combined)
di-tau production
Search for mono-jets, LLP, invisible Higgs
Muon detector and trigger upgrade
ML techniques for trigger on FPGA

Riccardo Paramatti

Higgs properties
New Physics Searches (LQ)
Search for LL particles
Search for Tetraquarks
LFU in B decays
EM calorimeter upgrade
New timing detector for HL-LHC

Davide Pinci

LFU in semileptonic decays
Λ_b decays
Charmonium exotic states
Luminosity measurement
Upgrade of muon detector

Paolo Valente

Data analysis
X17 search

Cecilia Voena

MEGII analysis
X17 search
Drift chamber
MuonEDM proposal
Future $\mu\rightarrow e\gamma$
aMuse network

Mauro Raggi

Dark matter and dark photon searches
K_L->$\mu\rightarrow\pi\nu\nu$ in Klever
Trigger Upgrade

Fabio Anulli

Studies on Physics Reach
Machine-Detector Interface
LEMMA

Paolo Gauzzi

Non local quantum effects in the entangled K states
Test of CPT symmetry
Search for ALPS
Search for new gauge bosons
η meson
Rare Kaon decays

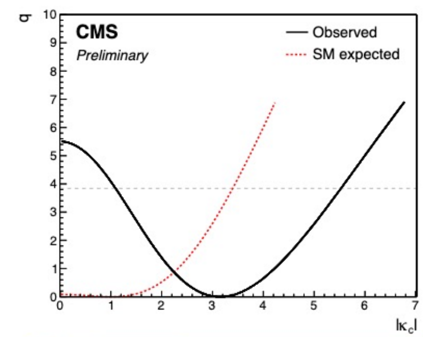
Backup

CMS Higgs to Charm Coupling

Moriond EW 2022

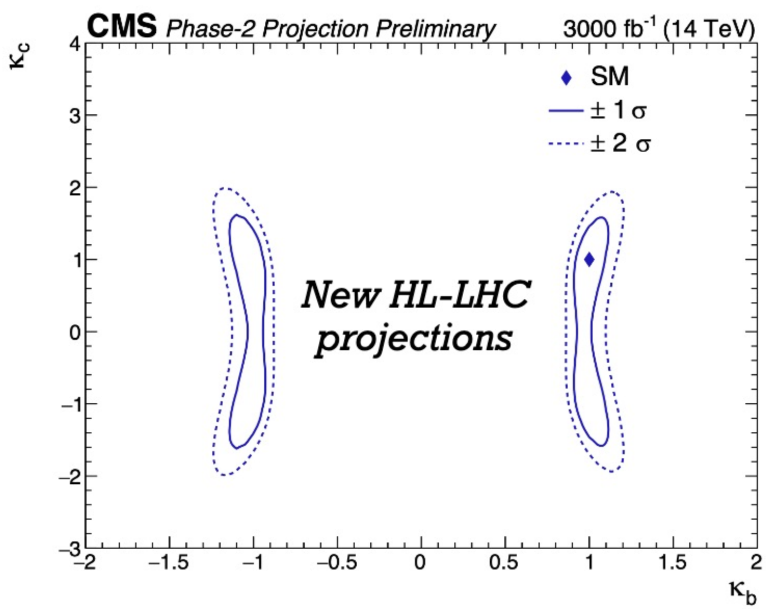
- Measurements of [W/Z]Z→cc signal demonstrates reliability of methods in data.
- Contraints on y_c comparable to what had previously been expected at end of HL-LHC!
- Updated projections for HL-LHC:
  - *With these results, a huge step forward towards measuring H→cc at the HL-LHC!*

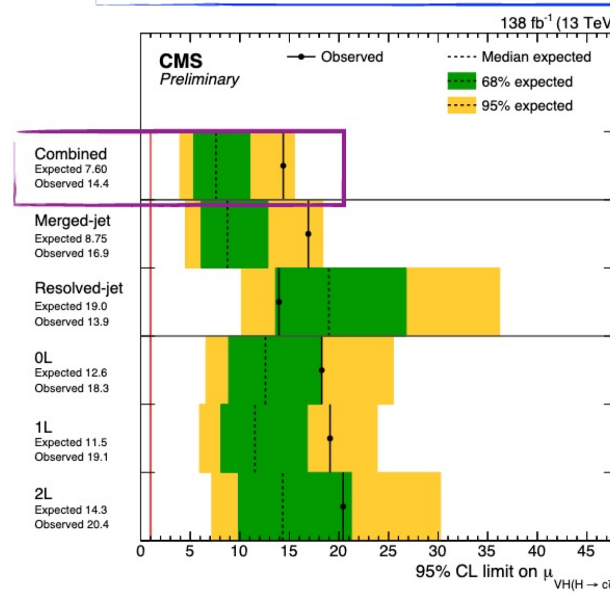
NEW 2022!

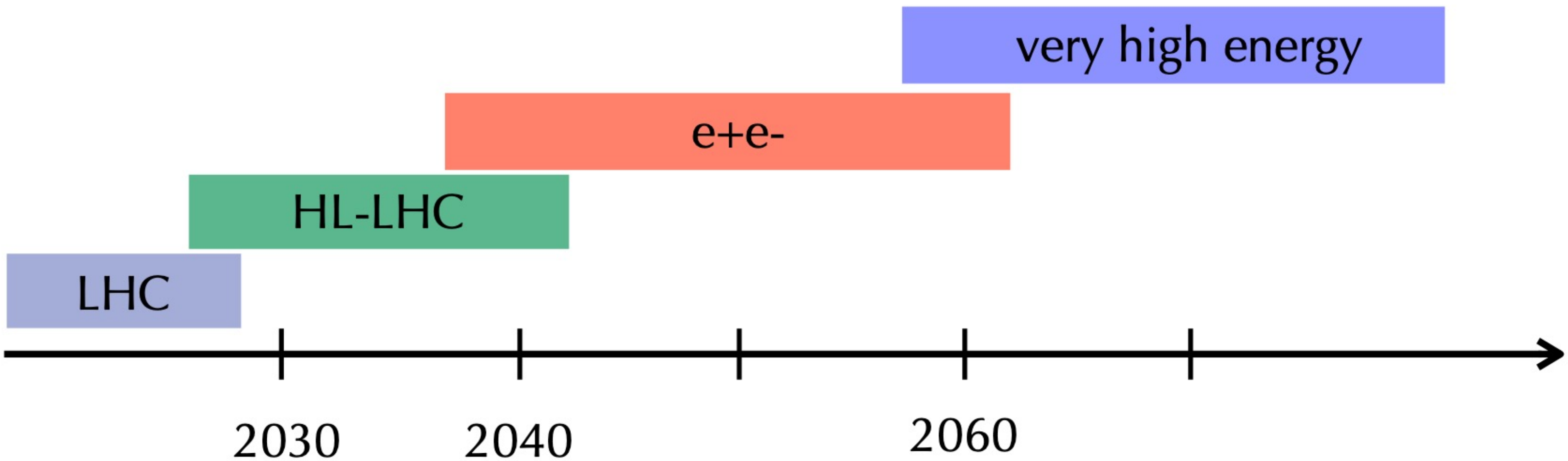


$1.1 < \kappa_c < 5.5$ (<3.4 exp.)

BR(H→cc) < 14 (8) x SM @95% C.L.

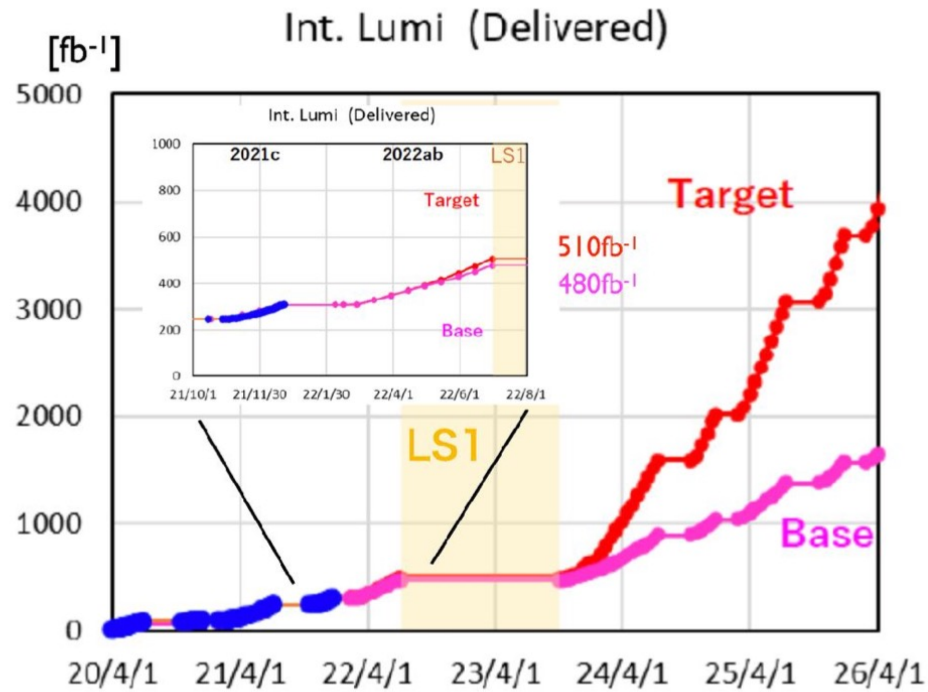






H couplings to:	**O(5-15)%**	**O(0.1-1)%**	**O(1)‰**
H self-coupling to	**<O(50)%**	**O(20)%**	**O(1)%**

Belle II schedule



- Running since 2019, int. L = 380 fb^{-1}
- Target int. L = 50 ab^{-1} by 2032
  - LS1 (summer 2022-fall 2023): mainly to replace PXD
  - LS2 (~2026-2027): upgrade SuperKEKB, to reach target $L = 6.5\times10^{35}$ cm^{-2}s^{-1}, and parts of the detector, to improve robustness against machine backgrounds
- Future upgrades (beyond the currently planned program)
  - beam polarization for precision electroweak (and τ) physics
  - Belle III at ultra-high luminosity? Target $L > 10^{36}$ cm^{-2}s^{-1}, int. L = 250 ab^{-1}

B→$\mu\mu$ Combination

LHCb-CONF-2020-002
CMS PAS BPH-20-003
ATLAS-CONF-2020-049

- **LHCb**, PRL 118 (2017) 191801

$B(B_s^0 \to \mu^+\mu^-) = (3.0 \pm 0.6^{+0.3}_{-0.2}) \times 10^{-9}$ 7.8σ

$B(B^0 \to \mu^+\mu^-) < 3.4 \times 10^{-10}$ @ 95 % CL

- **CMS**, JHEP 04 (2020) 188

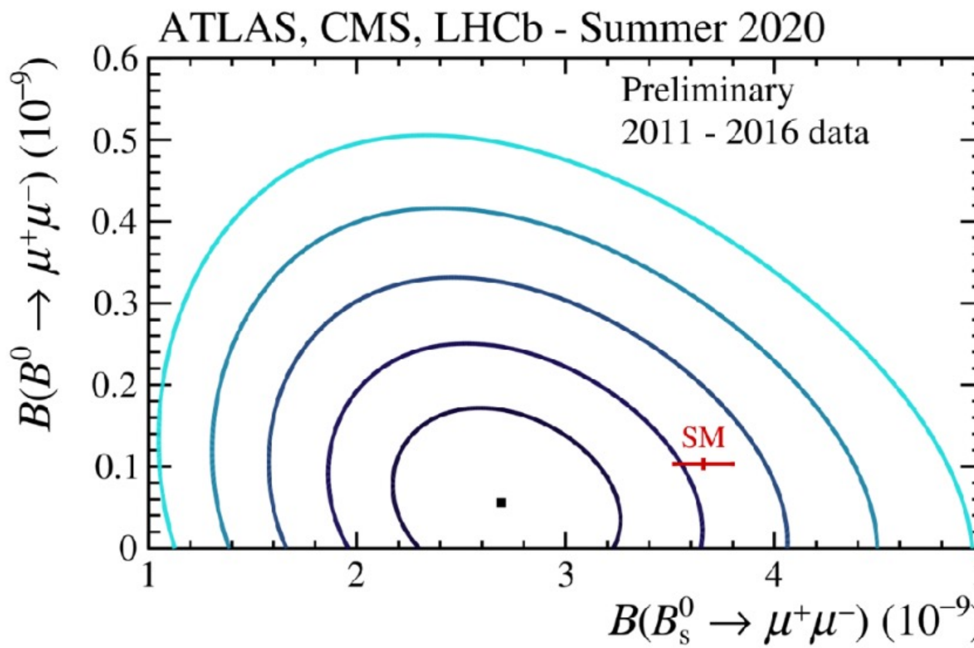
$B(B_s^0 \to \mu^+\mu^-) = (2.9 \pm 0.7\,(\mathrm{exp}) \pm 0.2\,(\mathrm{frag})) \times 10^{-9}$ 5.6σ

$B(B^0 \to \mu^+\mu^-) < 3.6 \times 10^{-10}$ @ 95 % CL

- **ATLAS**, JHEP 04 (2019) 098

$B(B_s^0 \to \mu^+\mu^-) = (2.8^{+0.8}_{-0.7}) \times 10^{-9}$ 4.6σ

$B(B^0 \to \mu^+\mu^-) < 2.1 \times 10^{-10}$ @ 95 % CL



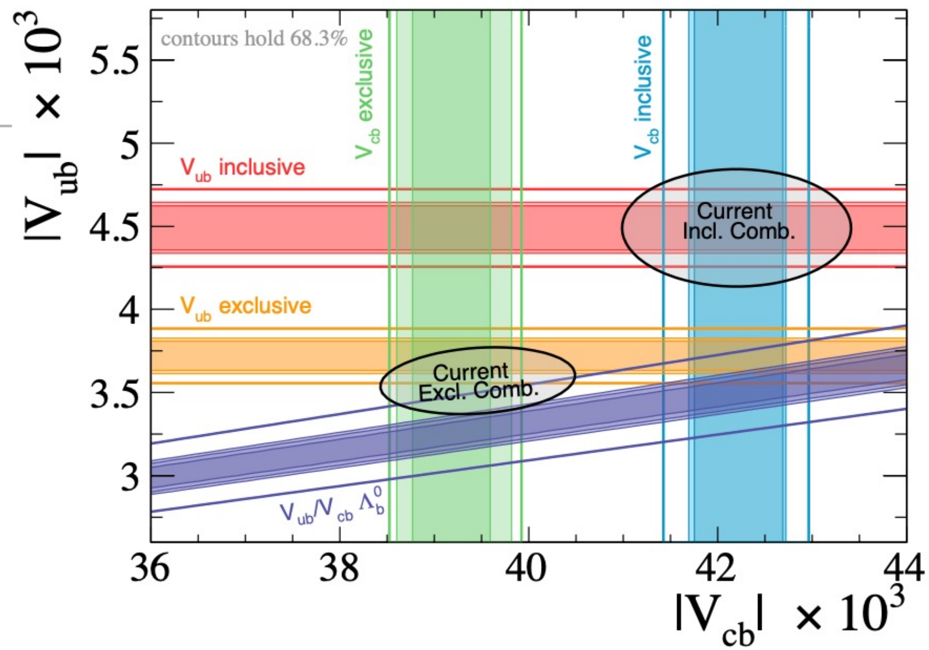
$$\mathscr{B}(B_s^0 \to \mu^+\mu^-) = (2.69^{+0.37}_{-0.35}) \times 10^{-9}$$

$$\mathscr{B}(B^0 \to \mu^+\mu^-) < 1.9 \times 10^{-10} \text{ @ 95 \% CL}$$

2.1 σ below SM prediction (2D compatibility)

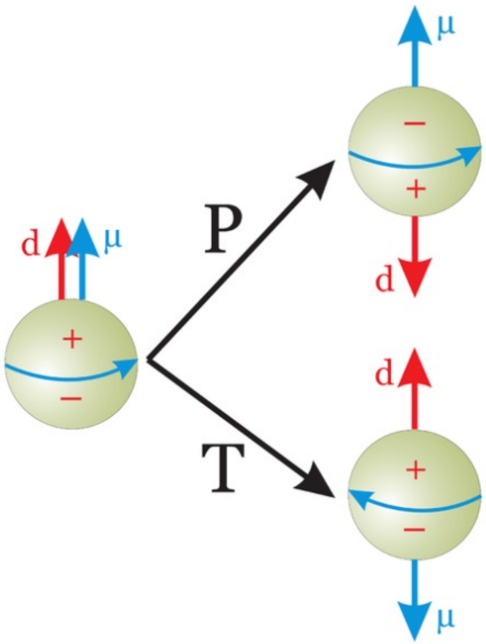
CKM tests: V_{ub}, V_{cb}

- Long-standing discrepancy between exclusive and inclusive determinations
- Belle II will drive the global progress throughout the next decade
- LHCb can achieve competitive sensitivity on the ratio $|V_{ub}|/|V_{cb}|$ using Λ_b and B_s decays



Measurement	Current Uncertainty (Ref. [35])	Projected Uncertainty Belle II $5\,ab^{-1}$	Belle II $50\,ab^{-1}$	LHCb $8\,fb^{-1}$	LHCb $22\,fb^{-1}$	LHCb $50\,fb^{-1}$
$\|V_{ub}\|$ inclusive	5.1%	3.4%	3.0%	-	-	-
$\|V_{ub}\|$ exclusive	5.1%	2.5%	2.1%	-	-	-
$\|V_{cb}\|$ inclusive	1.9%	1.3%	1.2%	-	-	-
$\|V_{cb}\|$ exclusive	1.8%	1.6%	1.1%	-	-	-
$\|V_{ub}\|/\|V_{cb}\|$	6.9%	-	-	3.4%	2.9%	2.1%
$B^- \to \tau^- \overline{\nu}$	9.5%	4.7%	2.2%	-	-	-
$B^0 \to \pi^- \ell^+ \nu$	4.3%	2.0%	1.5%	-	-	-

Dipole Moments



Magnetic dipole moment

$$U = -\,\vec{\mu} \cdot \vec{B}$$ **P- and T-even**

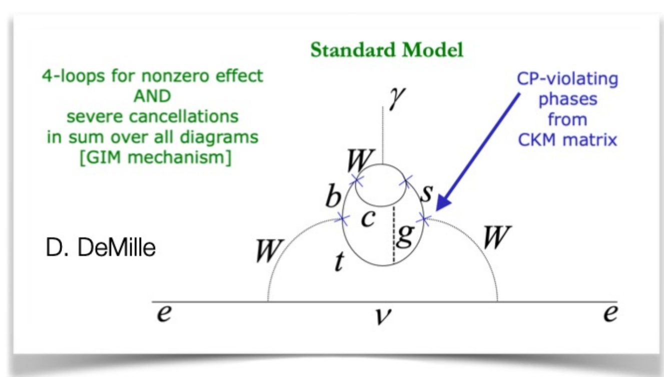
Electric dipole moment

$$U = -\,\vec{d} \cdot \vec{E}$$ **P- and T-odd** **CPV!!!**

$$\boxed{\vec{\mu} = \frac{ge}{2mc}\vec{s}}$$

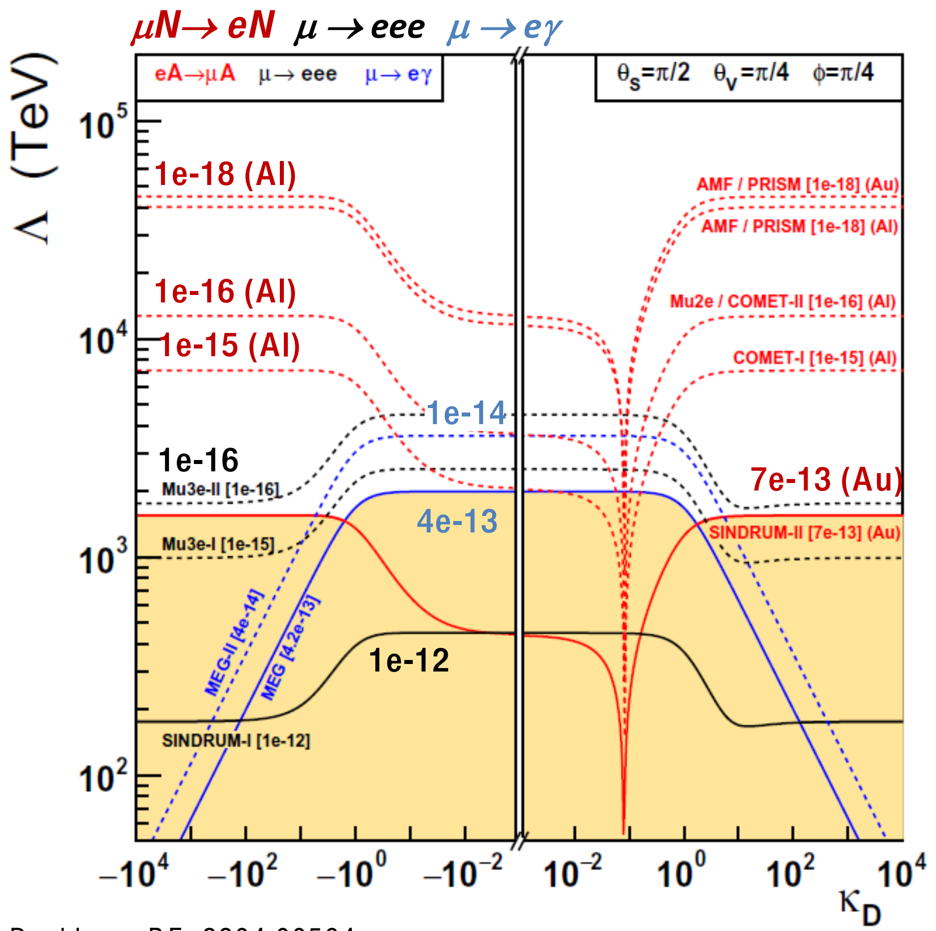
$$\boxed{\vec{d} = \frac{\eta e}{2mc}\vec{s}}$$

- EDMs of fundamental particles imply CP violation (CPV)
  - leptons EDM in the SM from CKM phases in loops involving quarks —> very small, not accessible



12

Reach on NP mass scale of past and future experiments as a function of κ_D



S. Davidson, BE, 2204.00564

$\kappa_D = cotan(\theta_D - \pi/2)$

κ_D: relative strength of dipole vs four-fermion operators (inspired from the "κ parameterization" in 1303.0497)

$|\kappa_D| \ll 1$ dipole dominant
$|\kappa_D| \gg 1$ four-fermion dominant

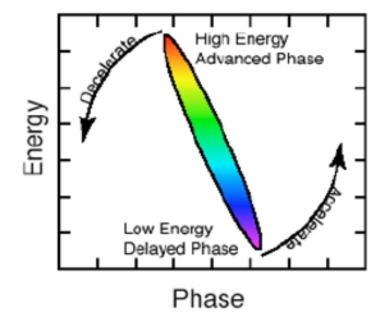
Upcoming experiments will probe NP mass scale above 10^4 TeV over a large fraction of the parameter space

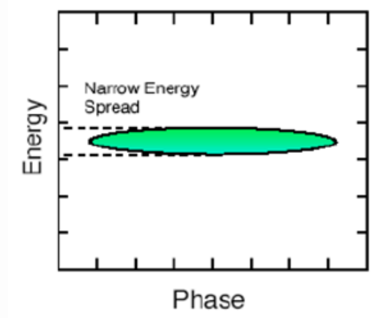
A systematic way of deriving the reach / complementarity of the main muon reactions

New beam for conversion experiment, based on the PRISM (Phase Rotated Intense Slow Muon beam) concept proposed by Y. Kuno and Y. Mori

PRISM concept:

- High intensity (MW) proton beam with very short pulse duration hit target in a capture solenoid, producing $\pi \rightarrow \mu$
- Inject muons into a fixed-field alternating gradient (FFA) ring
- Phase rotates to reduce the beam energy spread (slow down leading edge, accelerate trailing edge)
- Pion contamination is drastically reduced during phase rotation (O(μs))
- Extract purified muon beam to detector

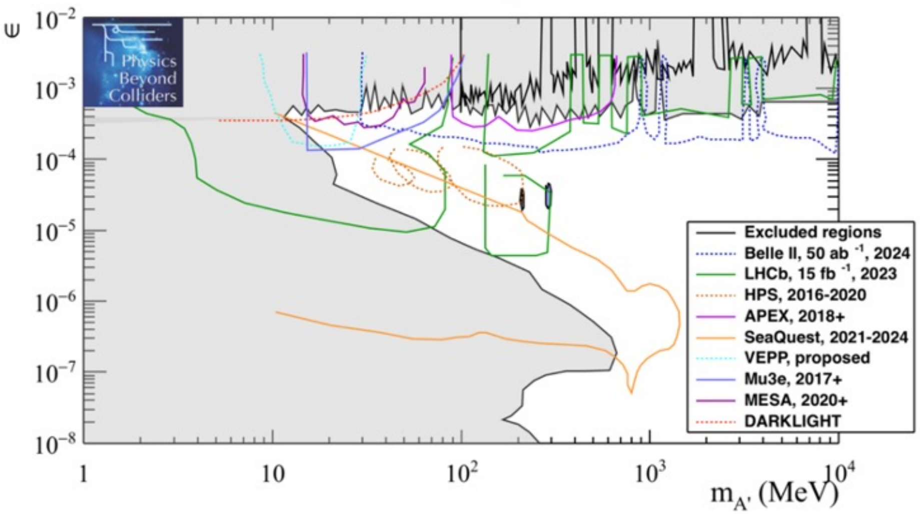




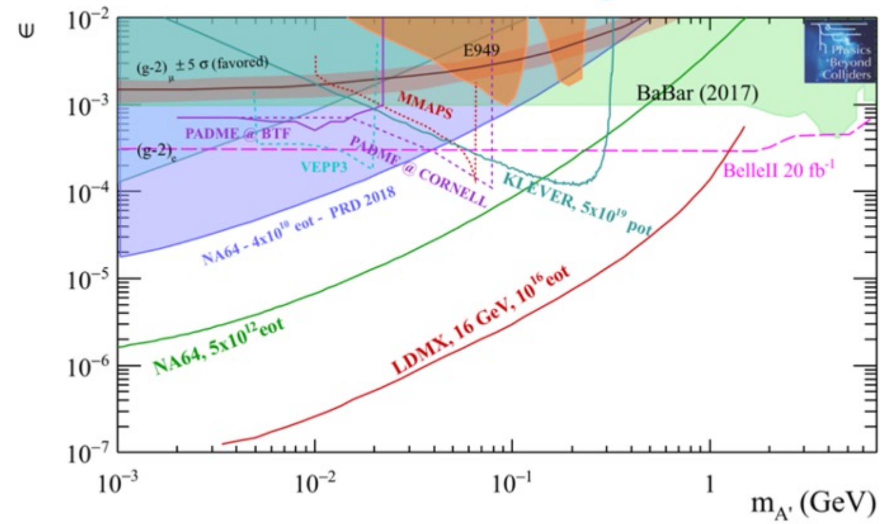
Requires a compressed proton bunch and high power beam to achieve high μ rate
$\rightarrow$ PIP II with a compressor ring (bunch size limit is much too small for the FFA)

PADME

Visible decays



Invisible decays



- Visible e± based experiment
  - Belle II >20 MeV
  - VEPP, DarkLight probably not taking place
  - MESA >2024
  - HPS sensitive to higher masses
- Invisible e± based experiment
  - Belle II projection (to be confirmed)
  - NA64
  - LDMX far in time