Opportunities at large facilities

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The nightmare scenario?

The nightmare scenario?

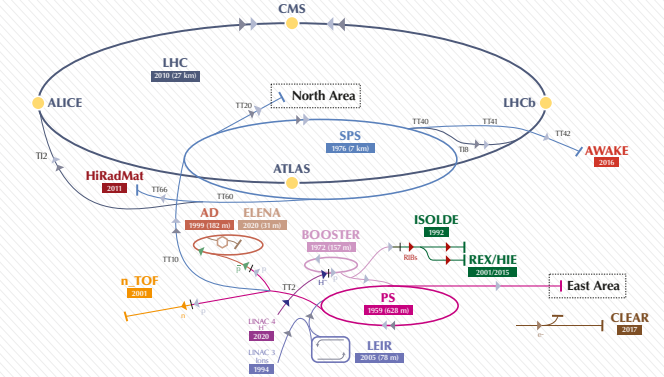
It doesn’t have to be

Where we go from here

- *Need* to look for indirect evidence
- *Need* to look everywhere
- *Need* to get the most out of each experiment

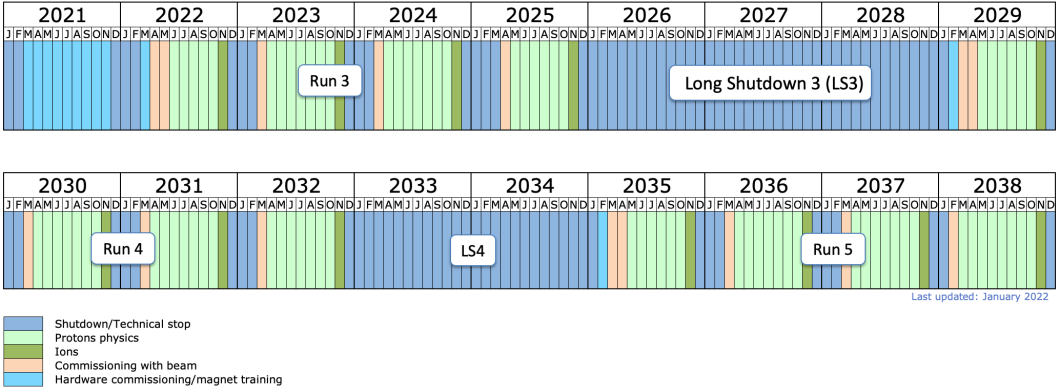
Including the LHC

Including the LHC



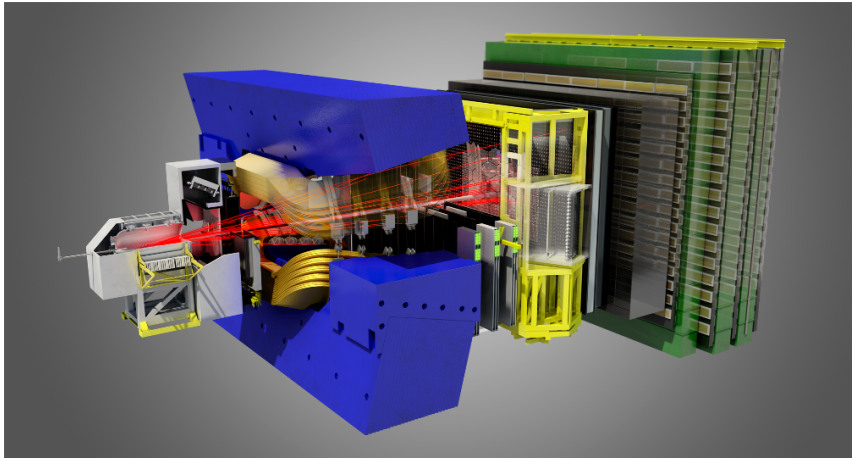
LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - Antiproton Decelerator // CLEAR - CERN Linear Electron Accelerator for Research // AWAKE - Advanced WAKefield Experiment // ISOLDE - Isotope Separator OnLine // REX/HIE - Radioactive EXperiment/High Intensity and Energy ISOLDE // LEIR - Low Energy Ion Ring // LINAC - LINear ACcelerator // n_TOF - Neutrons Time Of Flight //

Timeline


2021
2022
2023
2024
2025
2026
2027
2028
2029
J F M A M J J A S O N D
Run 3
Long Shutdown 3 (LS3)
2030
2031
2032
2033
2034
2035
2036
2037
2038
Run 4
LS4
Run 5
Last updated: January 2022
Shutdown/Technical stop
Protons physics
Ions
Commissioning with beam
Hardware commissioning/magnet training

LHCb

A flexible, general-purpose detector



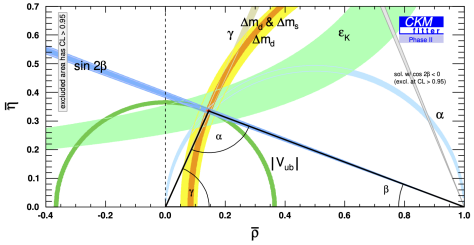
Not just *b* (and *c*) physics

Opportunities across the frontier

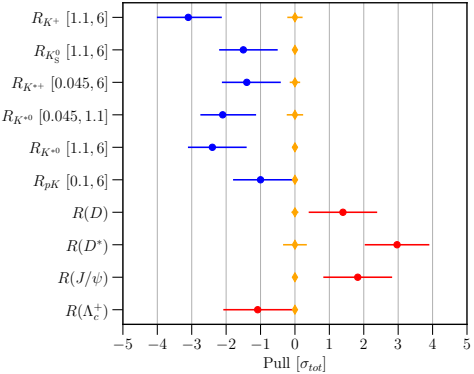
- Kaon decays (RF 2)
- BLV, LNV, LFV in decays (RF 4 and RF 5)
- Dark sectors (RF 6)
- Electroweak measurements
- Nuclear physics
- . . . ?

b-physics

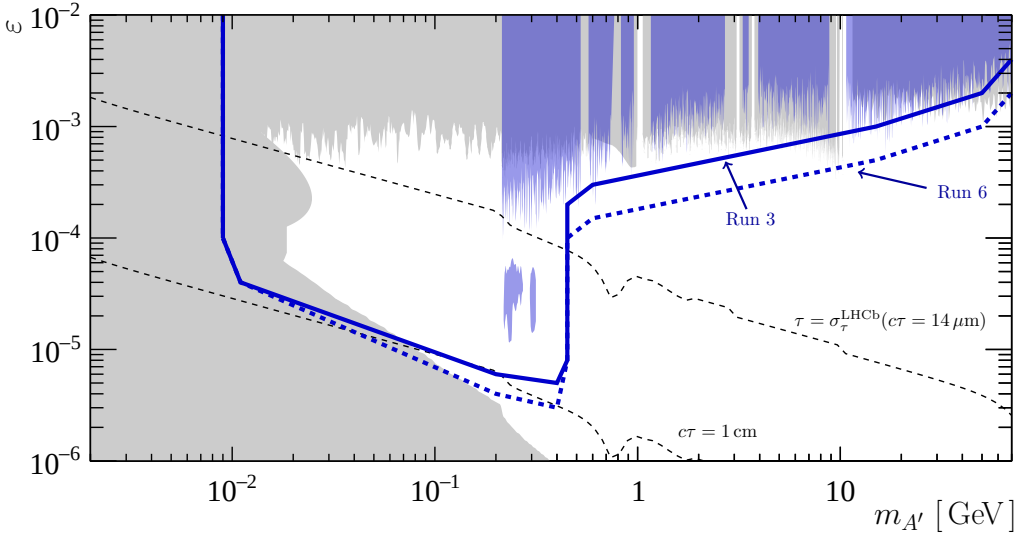
Unitarity triangle in 2030s



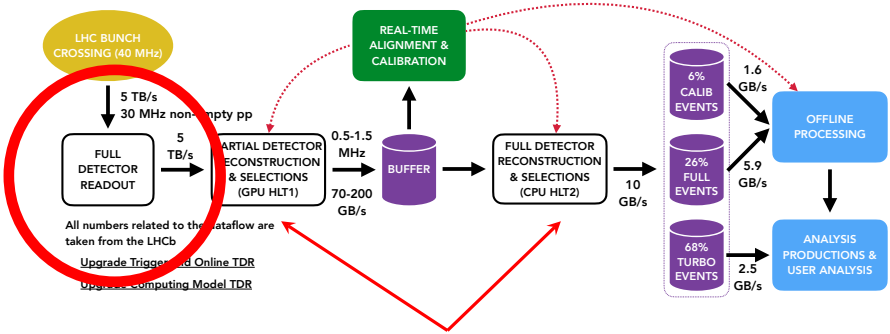
Current anomalies



Dark sectors

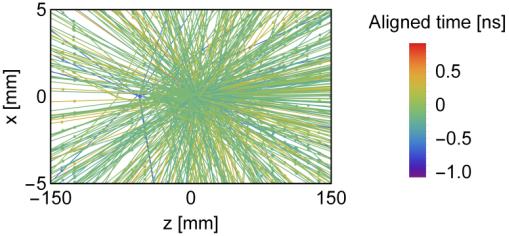


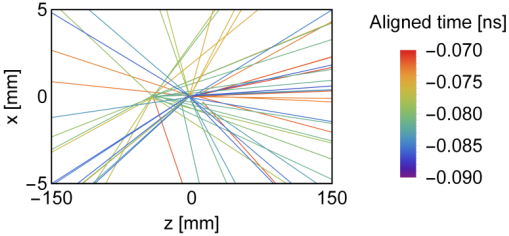
Upgrade I


LHC BUNCH CROSSING (40 MHz)
5 TB/s
30 MHz non-empty pp
FULL DETECTOR READOUT
5 TB/s
PARTIAL DETECTOR RECONSTRUCTION & SELECTIONS (GPU HLT1)
0.5-1.5 MHz
70-200 GB/s
BUFFER
REAL-TIME ALIGNMENT & CALIBRATION
FULL DETECTOR RECONSTRUCTION & SELECTIONS (CPU HLT2)
10 GB/s
6% CALIB EVENTS
26% FULL EVENTS
68% TURBO EVENTS
1.6 GB/s
5.9 GB/s
2.5 GB/s
OFFLINE PROCESSING
ANALYSIS PRODUCTIONS & USER ANALYSIS
All numbers related to the dataflow are taken from the LHCb
Upgrade Trigger and Online TDR
Upgrade Computing Model TDR
Software trigger

Upgrade II

- Plans for Upgrade II outlined in recently released FTDR
- Requires new detector R&D: one exciting aspect is picosecond timing throughout the detector



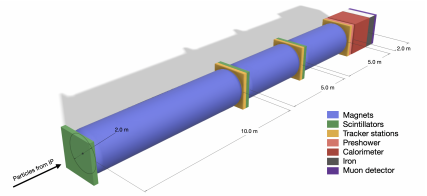


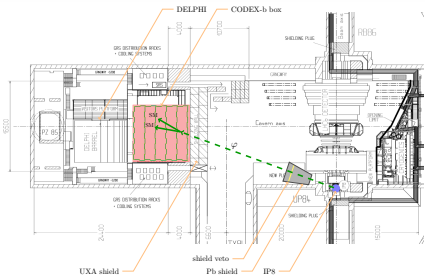
CMS and ATLAS

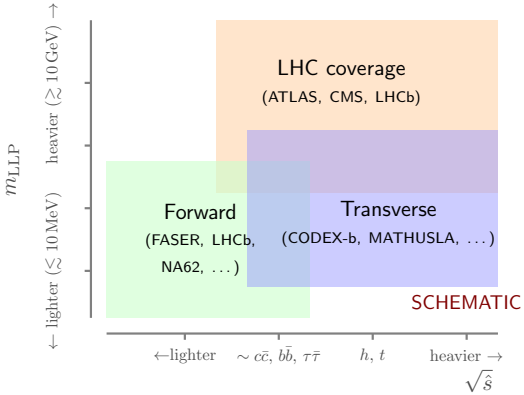
- ATLAS and CMS also contribute for B decays
- CMS projects $B_s^0/B^0 \to \mu^+\mu^-$ unc. of 7/16%
- Other possibilities:
  - $K^{*0}\mu^+\mu^-$ angular analysis
  - ϕ_s in $B^0 \to J/\psi\,\phi$
  - Hadron spectroscopy

LHC experiments

FASER and Codex-b, et al

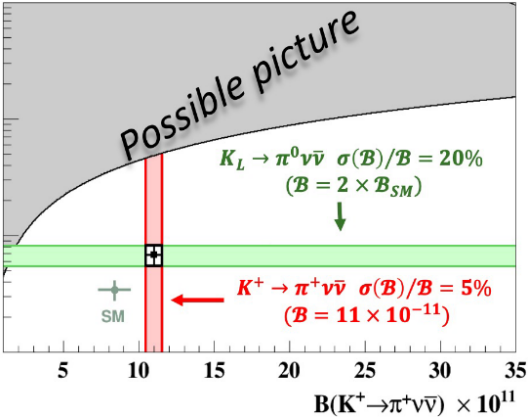


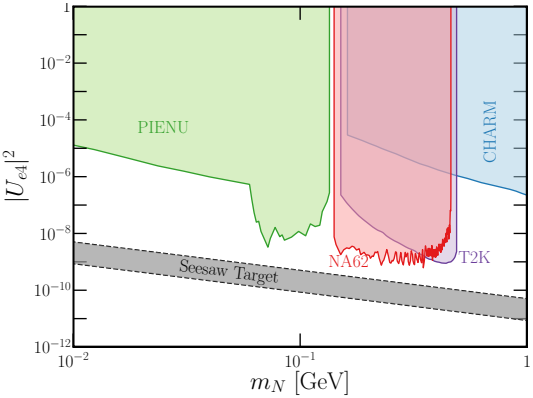




Kaon physics at SPS

Rare decays and dark sectors

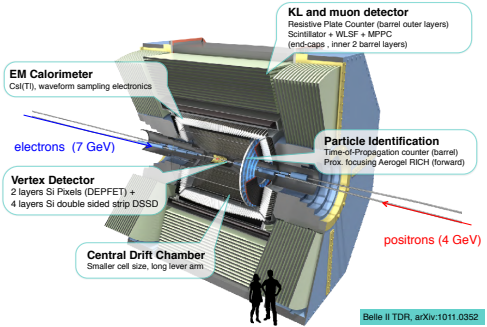




from E. Goudzovski talk on Monday, arXiv:2201.07805, arXiv:2204.13394

Belle II and SuperKEKB

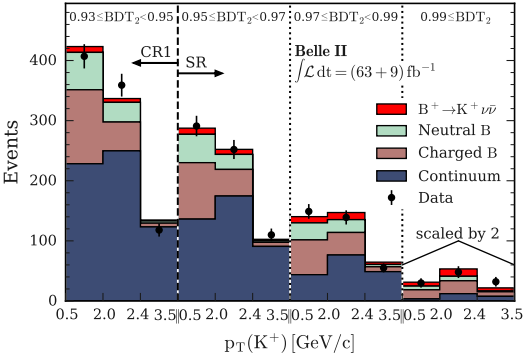
- Program just getting started
- Possibilities beyond *b*-physics in LFV, dark sectors, and more



Belle II

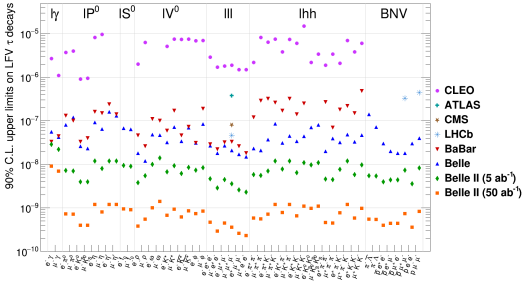
b physics

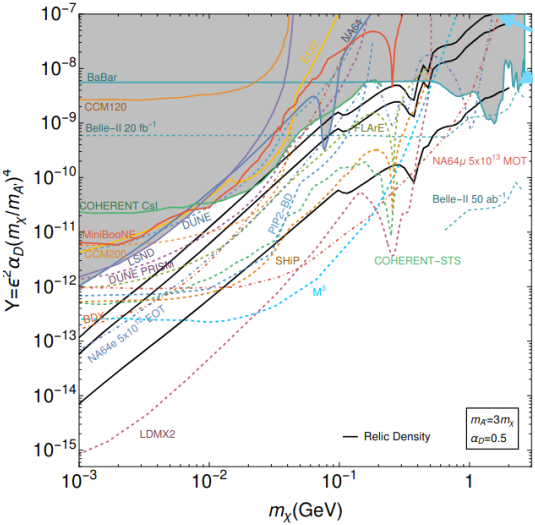
- Unique strengths for decays with missing particles
- $B \to K \nu \bar{\nu}$ projection $\sigma \approx 10\%$ of SM
- And many more, *e.g.* inclusive semileptonic decays



Belle II

LFV and dark sectors

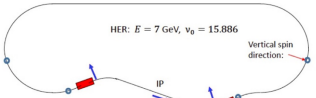




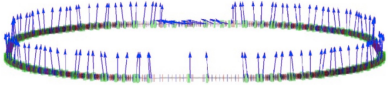
Belle II upgrade

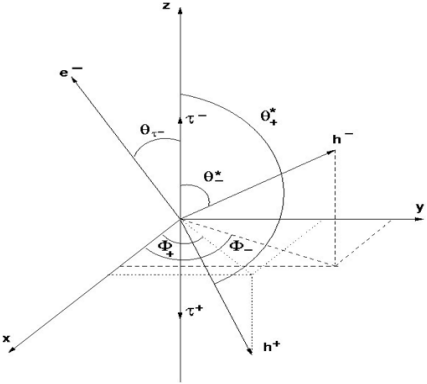
Including polarized beam

- Possibility to upgrade for more luminosity beyond 50 ab^{-1}



Spin direction is vertical in the main part of HER. Then it is rotated to the horizontal plane by the set of two solenoids, which are comprising the 90^0 spin rotator.



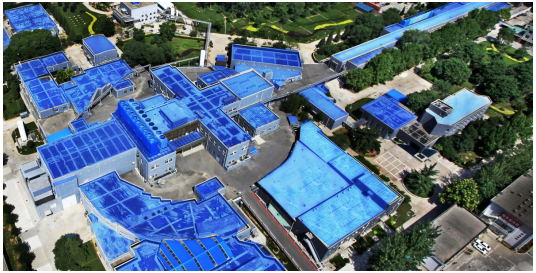


- Measure τ g-2

BES III

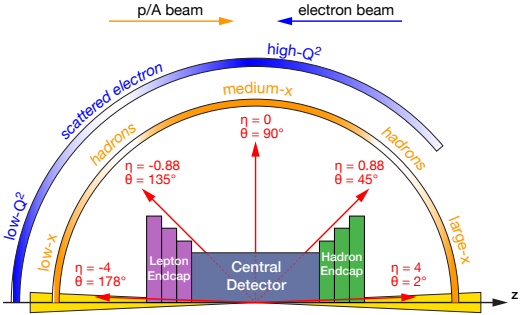
+ Super tau-charm factory

- e^+e^- in the τ/charm region important part of total flavor program
- Higher luminosity STCF upgrade proposed



Electron Ion Collider

- Physics plan touches on this frontier:
  - Heavy neutral leptons
  - Hadron spectroscopy
- Worth pursuing more involvement?



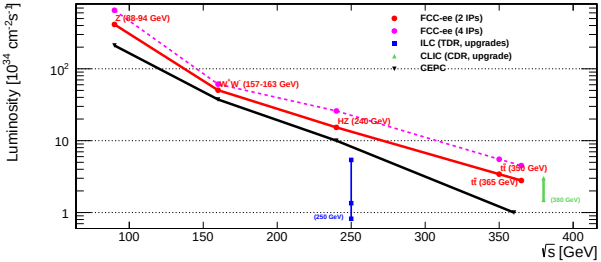
What’s on the horizon?

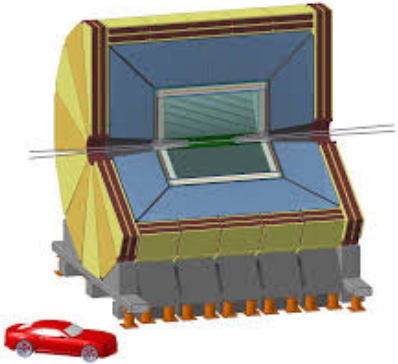
Thinking ahead

- Short and medium term: LHC until $\sim$ 2040
- Belle II until 2030+, more if upgraded
- Opportunities with other experiments ongoing or planning for 2030s
- Operations, analysis, and upgrades cover the 10+10 Snowmass timescale
- Longer term: colliders don't just materialize
- Frontier needs an opinion on which options worth pursuing

FCC-(ee)

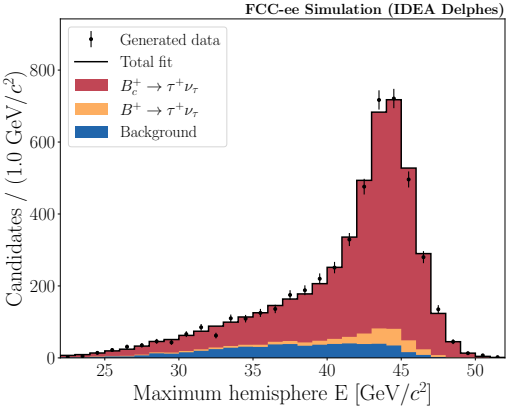
- Opportunities for precision measurements across the energy range





B physics prospects

- Can measure decays unavailable elsewhere, like $B_c^+ \to \tau\nu$



Particle production (10^9)	$B^0/\bar{B}^0$	B^+/B^-	$B_s^0/\bar{B}_s^0$	$B_c^+/\bar{B}_c^-$	$\Lambda_b/\bar{\Lambda}_b$	$c\bar{c}$	$\tau^+\tau^-$
Belle II	27.5	27.5	n/a	n/a	n/a	65	45
FCC-ee	620	620	150	4	130	600	170

arXiv:2203.06520, 2105.13330, talk by S. Monteil yesterday

Other future colliders

- Are there RPF possibilities at a linear Higgs factory?
- Would a muon collider be better?

Refer to earlier talk by M. Franco Sevilla

Conclusions

- Search for new physics requires a broad program
- Large collider facilities provide many opportunities, important to make the most of them
- Extracting maximum physics from LHC and Belle II a top short and medium term priority
- Need to start thinking about $>$ 15 years:
  - Is the message that the next large facility should wait for a clear target?
  - Is broad program of FCC-ee attractive?
  - Regardless: ensure that multipurpose detectors are useful for precision studies