# Road to an update of the European HEP Strategy

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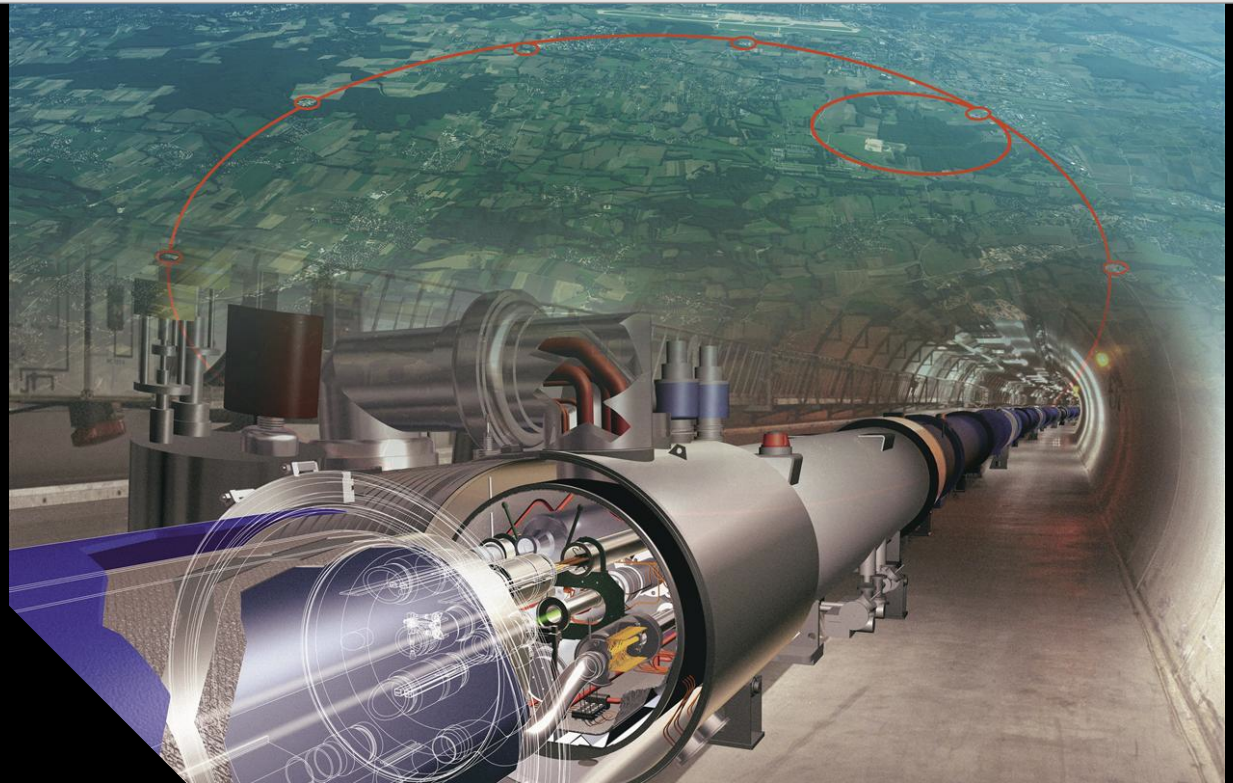
*ECFA chairperson*
*(https://ecfa.web.cern.ch)*

*Higgs Hunting*
*July 29 – 31, 2019*
*Paris*

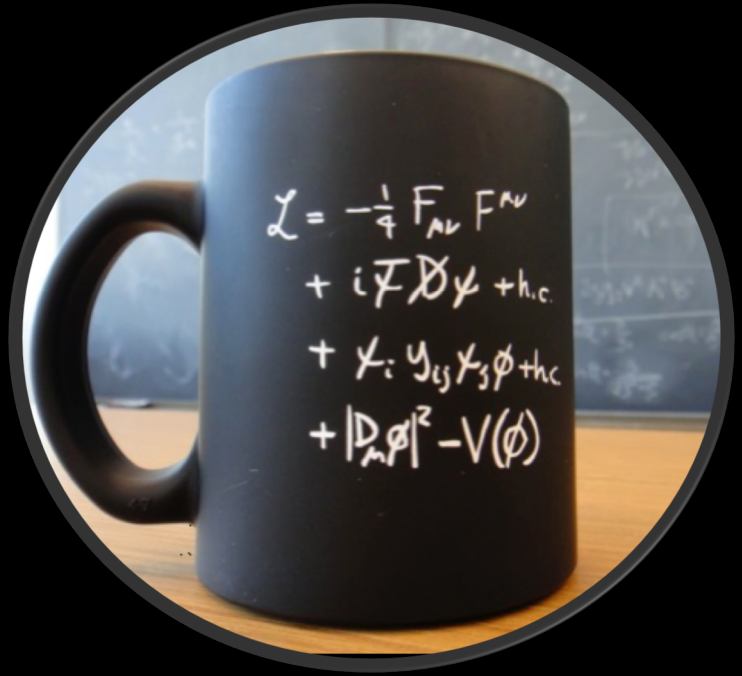


HEP@VUB BRUSSELS

VUB iihe BRUXELLES BRUSSEL

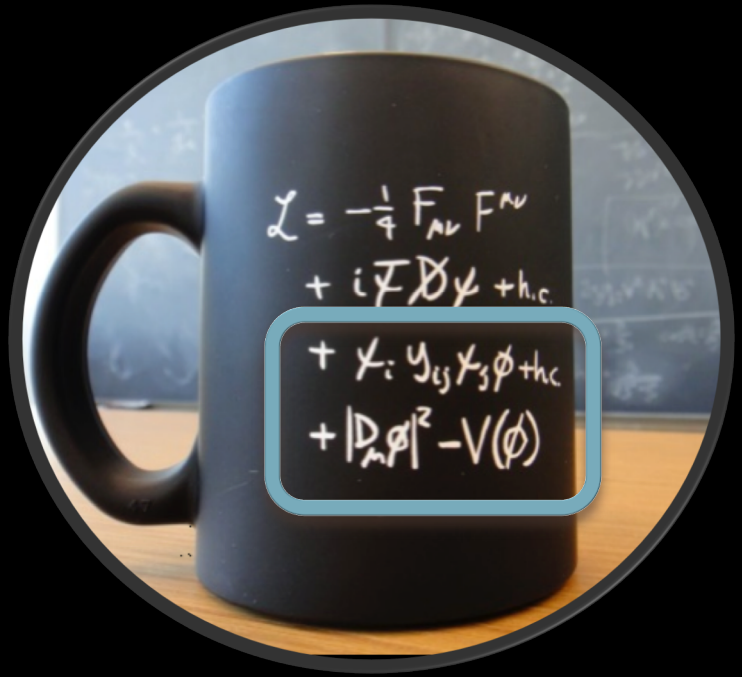
understand nature at the
largest and the smallest scales

# Particle Physics today



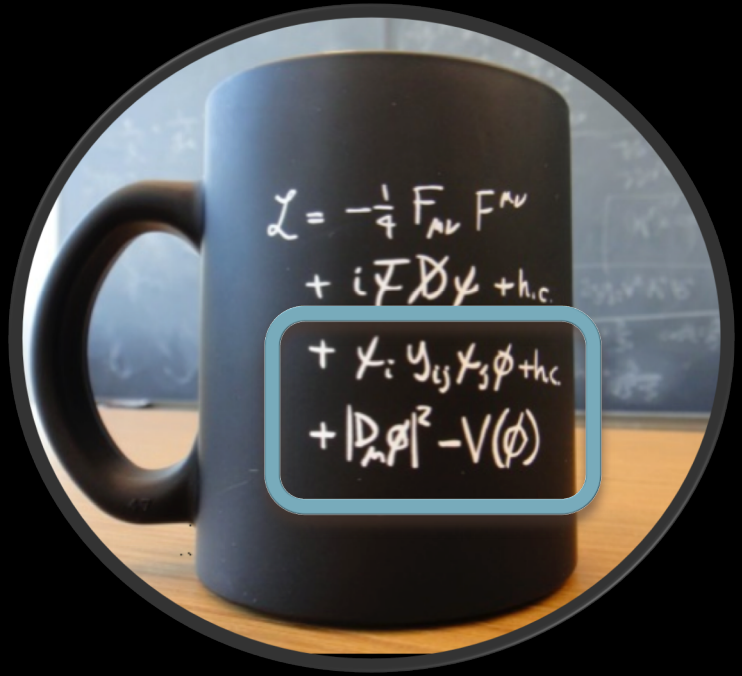

enormous success in describing matter at the smallest scales

# Particle Physics today




enormous success in describing matter at the smallest scales

# Particle Physics today




enormous success in describing matter at the smallest scales

describing ≠ understanding

# Key open questions for particle physics?

Riccardo Rattazzi
@ Granada

## Problems vs Mysteries

- Dark Matter
- Baryogenesis
- Strong CP
- Fermion mass spectrum & mixing

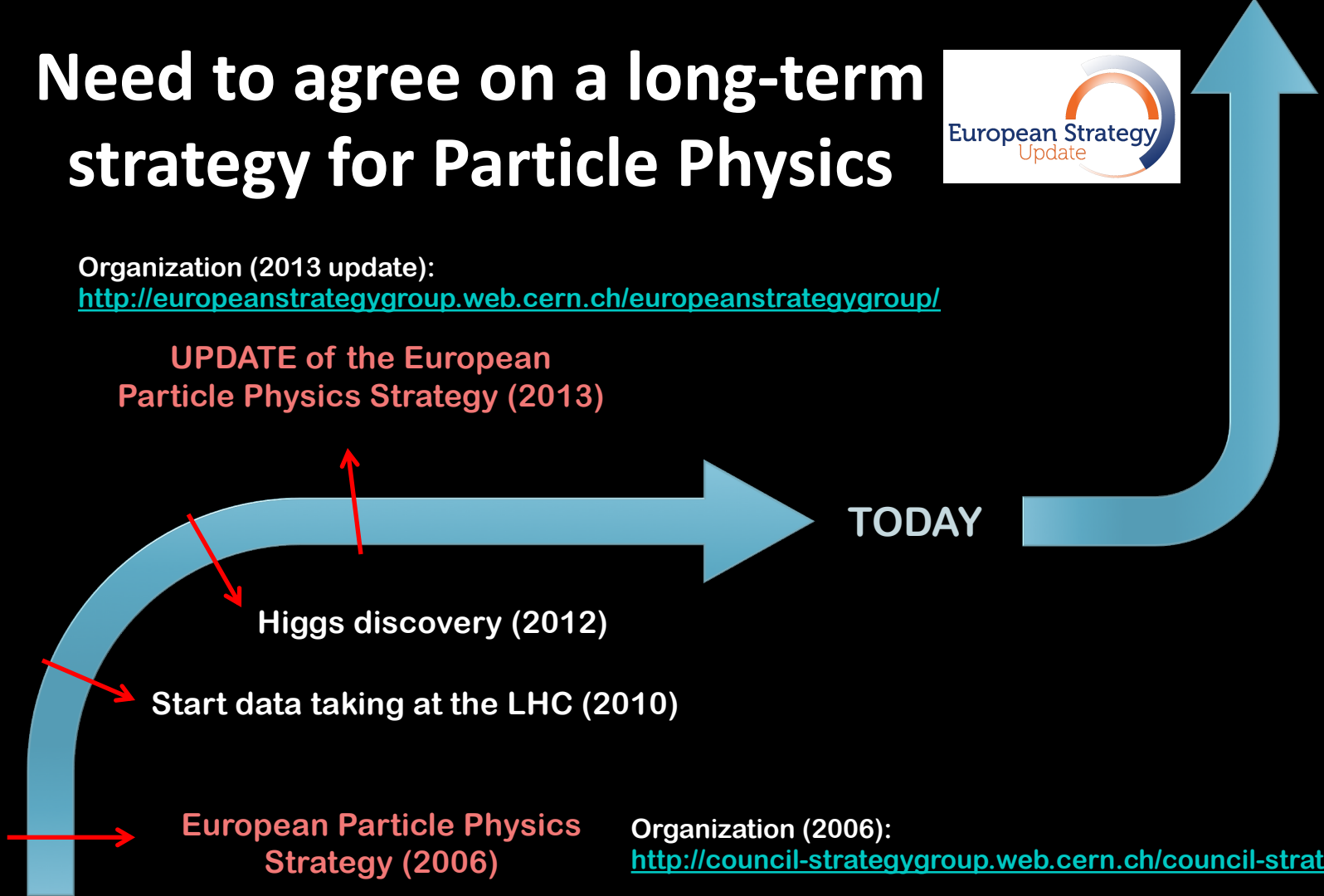
Plausible EFT solutions exist

- Cosmological Constant
- EW hierarchy
- Black Hole information paradox
- very Early Universe

Challenge or outside EFT paradigm

# Need to agree on a long-term strategy for Particle Physics

Organization (2013 update):
http://europeanstrategygroup.web.cern.ch/europeanstrategygroup/




Organization (2006):
http://council-strategygroup.web.cern.ch/council-strategygroup/

# The European Particle Physics Strategy 2013

https://cds.cern.ch/record/1567258/files/esc-e-106.pdf - *with the highest priority*

① Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.

② CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide.

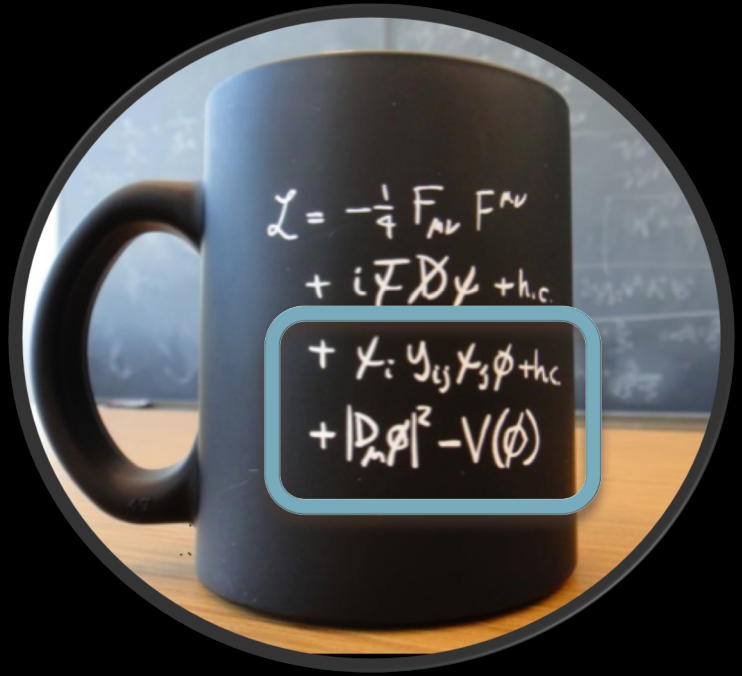
③ Europe looks forward to a [ILC] proposal from Japan to discuss a possible participation.

④ CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan.

# 1st priority

# LHC and HL-LHC

# The impact of the LHC




a MORE PRECISE and more COMPLETE description

connection

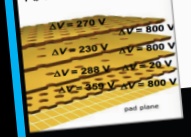

new physics

## ALICE – Upgrade LS2 – *study Quark-Gluon Plasma formed in nuclear collisions*

Monolythic-pixel Inner Tracking System
→ x3-5 better tracking precision

Pixel Muon Forward Tracker
→ non-prompt muons from B decays

GEM-based TPC readout
→ x100 readout rate in Pb-Pb




- Low-$p_T$ heavy-flavour mesons/baryons:
- Low-$p_T$ charmonia: c-cbar melting and
- Low-mass di-electrons: QGP thermal

## LHCb – Upgrade LS2

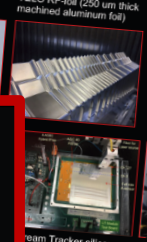
Construction well advanced

Will collect 50 $fb^{-1}$ at instantaneous lumi of $2x10^{33}cm^{-2}s^{-1}$
Full software trigger
New tracking detectors
New RICH photon detectors
New electronics read out at 40 MHz

Prototypes of DAQ board (PCIe40)

VELO RF-foil (250 um thick machined aluminum foil)

Machining and light scan of the scintillating fiber mats for the fibre tracker



Cherenkov ring from a full RICH MaPMT module

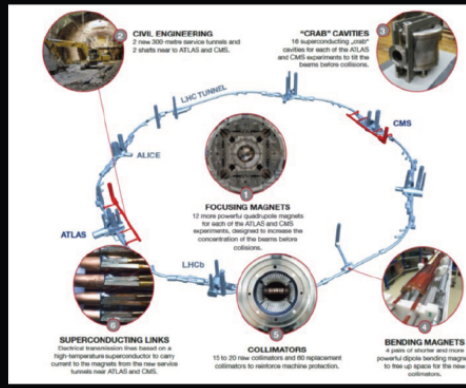
eam Tracker silicon or module under test

First scintillating fibre modules arriving at CERN

Calorimeter front-end board

Muon system readout ASIC

## High-Luminosity LHC: 300/fb (by 2023) → 3000/fb (by 2037)




HiLumi HL-LHC PROJECT

**New IR-quads $Nb_3Sn$ (inner triplets)**
**New 11 T $Nb_3Sn$ (short) dipoles**
Collimation upgrade
Cryogenics upgrade
Crab Cavities
Cold powering
Machine protection
Civil engineering

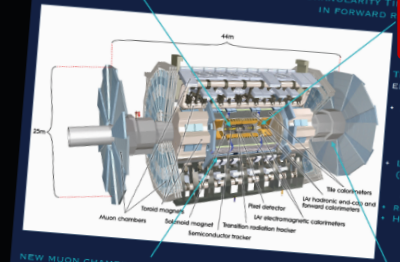
**Formal approval by CERN Council (June 2016)**
**Cost to Completion : 950 MCHF (material)**

Detector
plann

## ATLAS – Upgrade Phase II (LS3)

NEW ALL-SILICON INNER TRACKER (ITK) WITH ETA COVERAGE UP TO 4

HIGH GRANULARITY TI IN FORWARD R




TDAQ OFF-DETECTOR ELECTRONICS:

- LO HARDWARE TRIGGER:
  - LO CALORIMETER
  - LO TOPOLOGICAL
  - LO MUON
  - LO GLOBAL
- L1 HARDWARE TRIGGER (OPTION):
  - L1 GLOBAL
  - L1 TRACK TRIGGER
- READOUT SYSTEM
- HLT

NEW MUON CHAMBERS IN THE INNER BARREL REGION

FORWARD MUON TAGGER (OPTION)

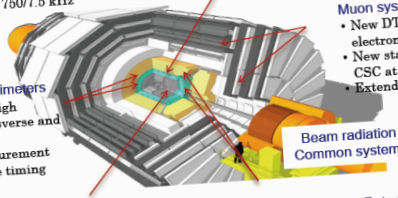
64

## CMS – Upgrade Phase II (LS3)

**Trigger/HLT/DAQ** (interim TDR submitted)
- Track information in trigger at 40 MHz
- 12.5 μs latency
- HLT input/output 750/7.5 kHz

**Barrel EM calorimeter**
- New FE/BE electronics for full granularity readout at 40 MHz - with improved time resolution
- Lower operating temperature (8∘)

**Muon systems**
- New DT & CSC FE/BE electronics
- New station to complete CSC at $1.6 < \eta < 2.4$
- Extended coverage to $\eta \simeq 3$



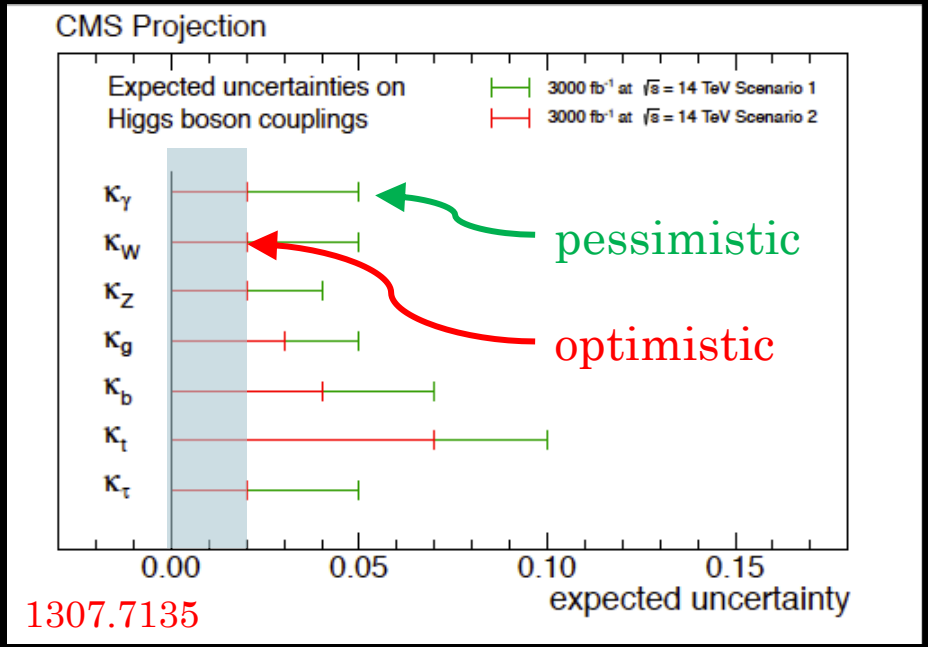
**New Endcap Calorimeters**
- Rad. tolerant - High granularity transverse and longitudinal
- 4D shower measurement including precise timing capability

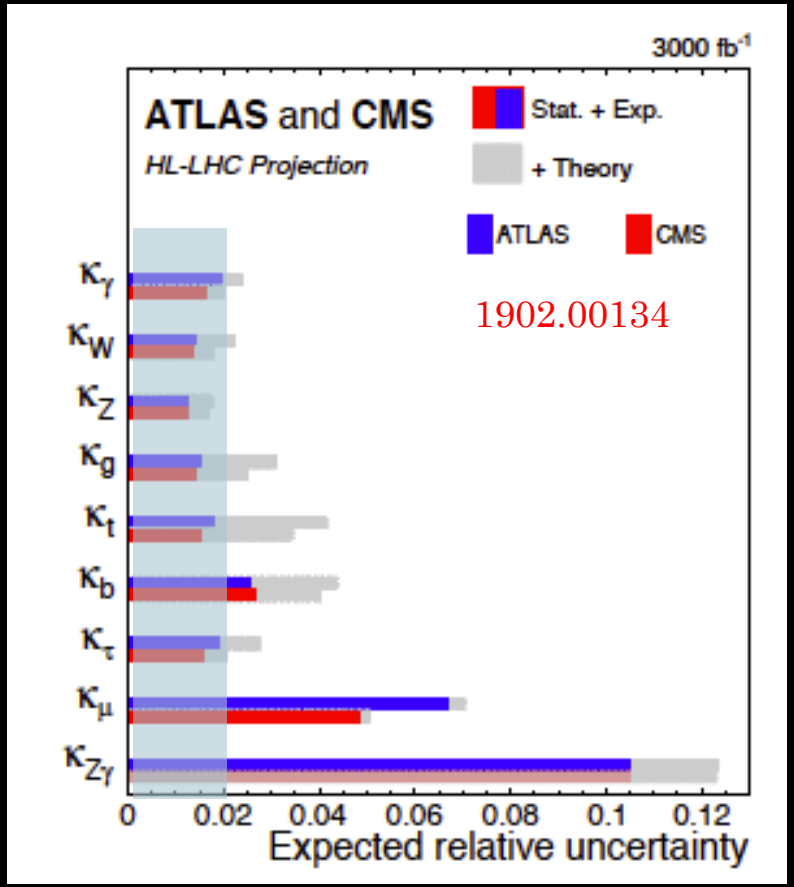
Beam radiation and luminosity
Common systems and infrastructure

**New Tracker**
- Rad. tolerant - increased granularity - lighter
- 40 MHz selective readout (strips) for Trigger
- Extended coverage to $\eta \simeq 3.8$

**MIP precision Timing Detector**
- Barrel layer: Crystal + SiPM
- Endcap layer: Low Gain Avalanche Diodes

# Potential HL-LHC performance in Higgs couplings
## *anno 2013 versus anno 2019*



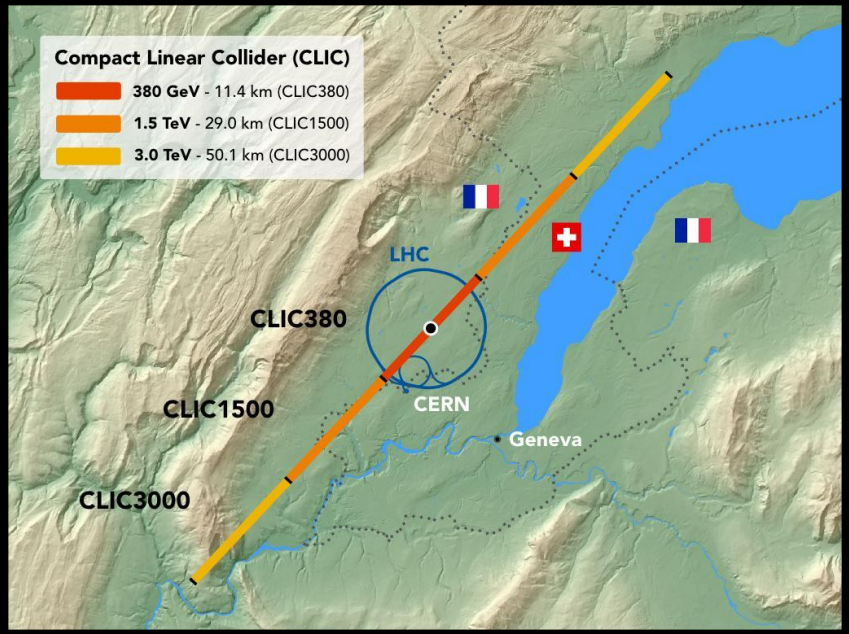

Taking into account innovative thoughts and research experience, what was optimistic in 2013 seems realistic in 2019.

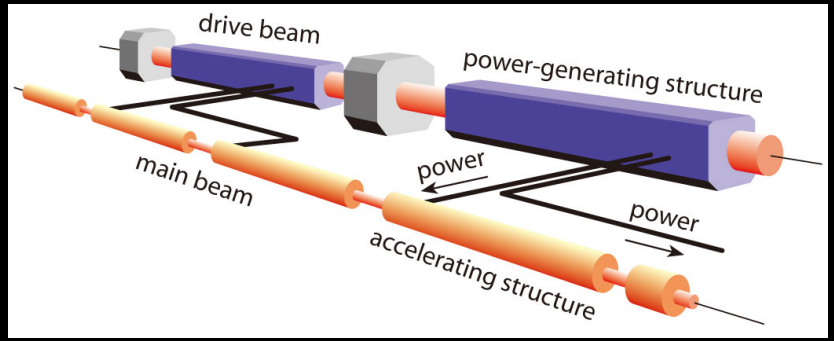
# 2nd priority

# Future colliders at CERN

# Concrete collider options studied at CERN

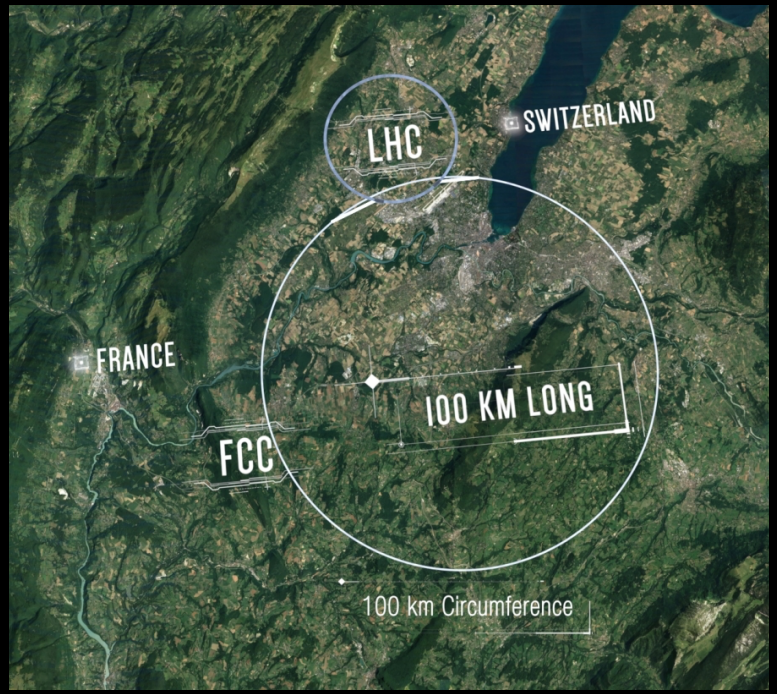
CLIC (ee), http://clic-study.web.cern.ch/



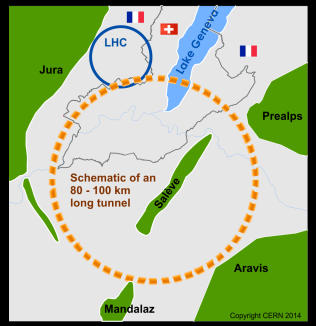



# Concrete collider options studied at CERN

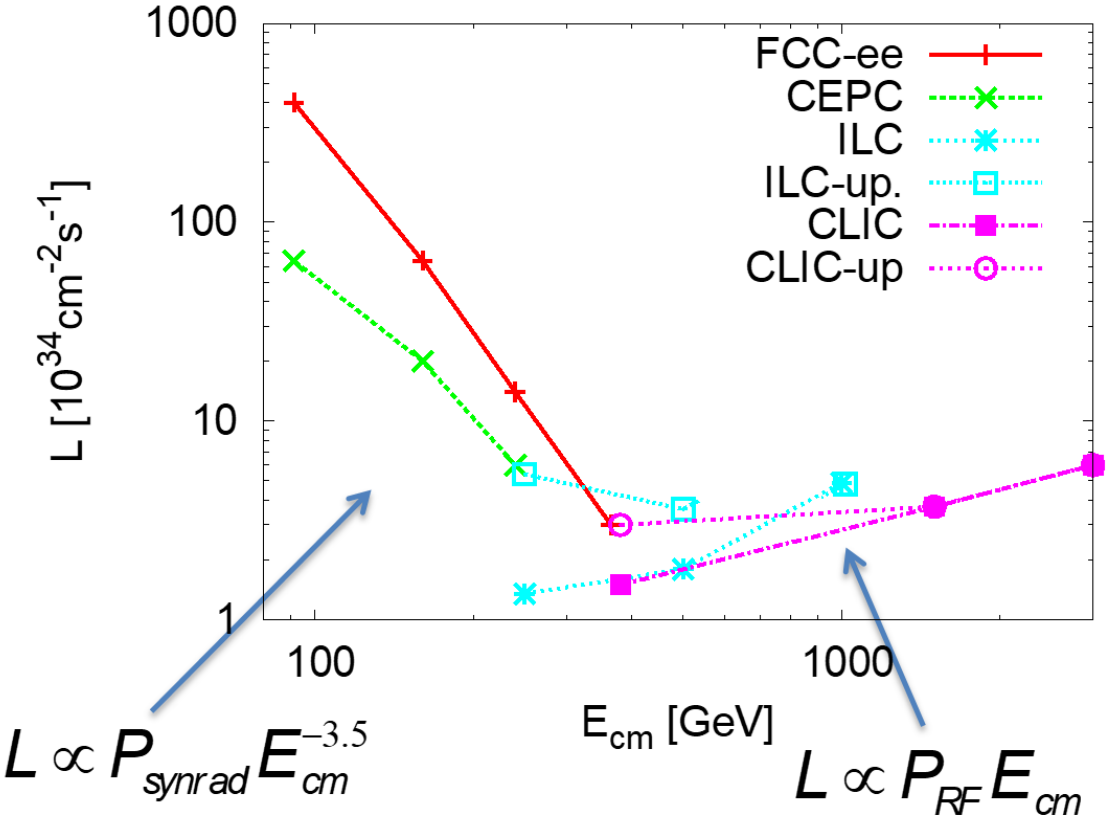
FCC (ee, ep, pp, pA, AA, eA), https://fcc-cdr.web.cern.ch/

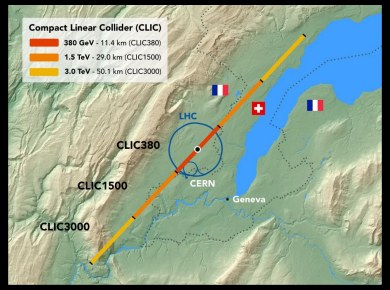



- **$e^+e^-$ collider (*FCC-ee*) @ 90-365 GeV** as potential first step
- ***pp*-collider (*FCC-hh*) @ 100 TeV**
- ***p-e* collider (*FCC-he*)**
- **HE-LHC** with *FCC-hh magnets*
- **$\mu\mu$ colider (*FCC-$\mu\mu$*)** option
- AA, Ap, Ae options

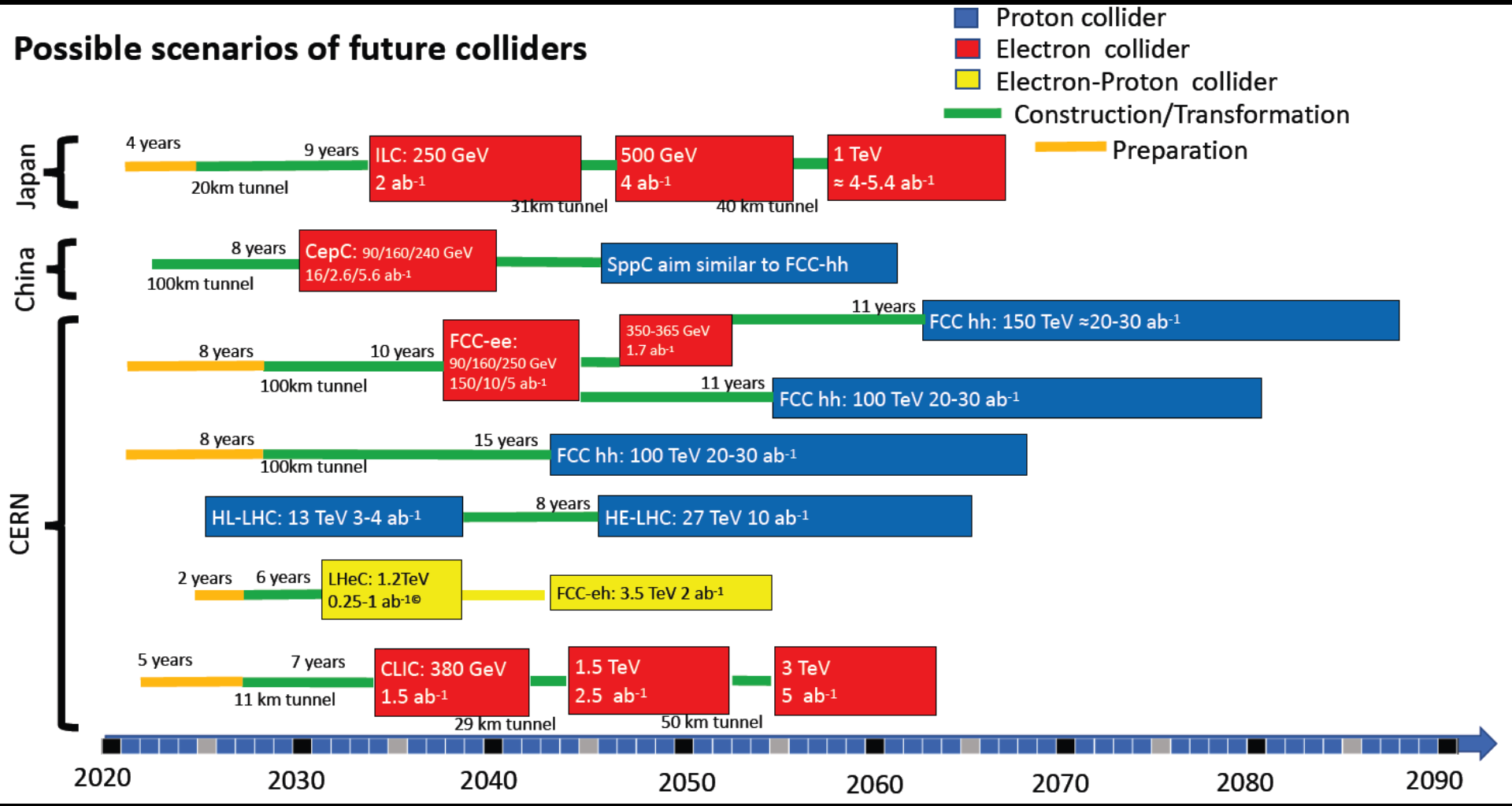


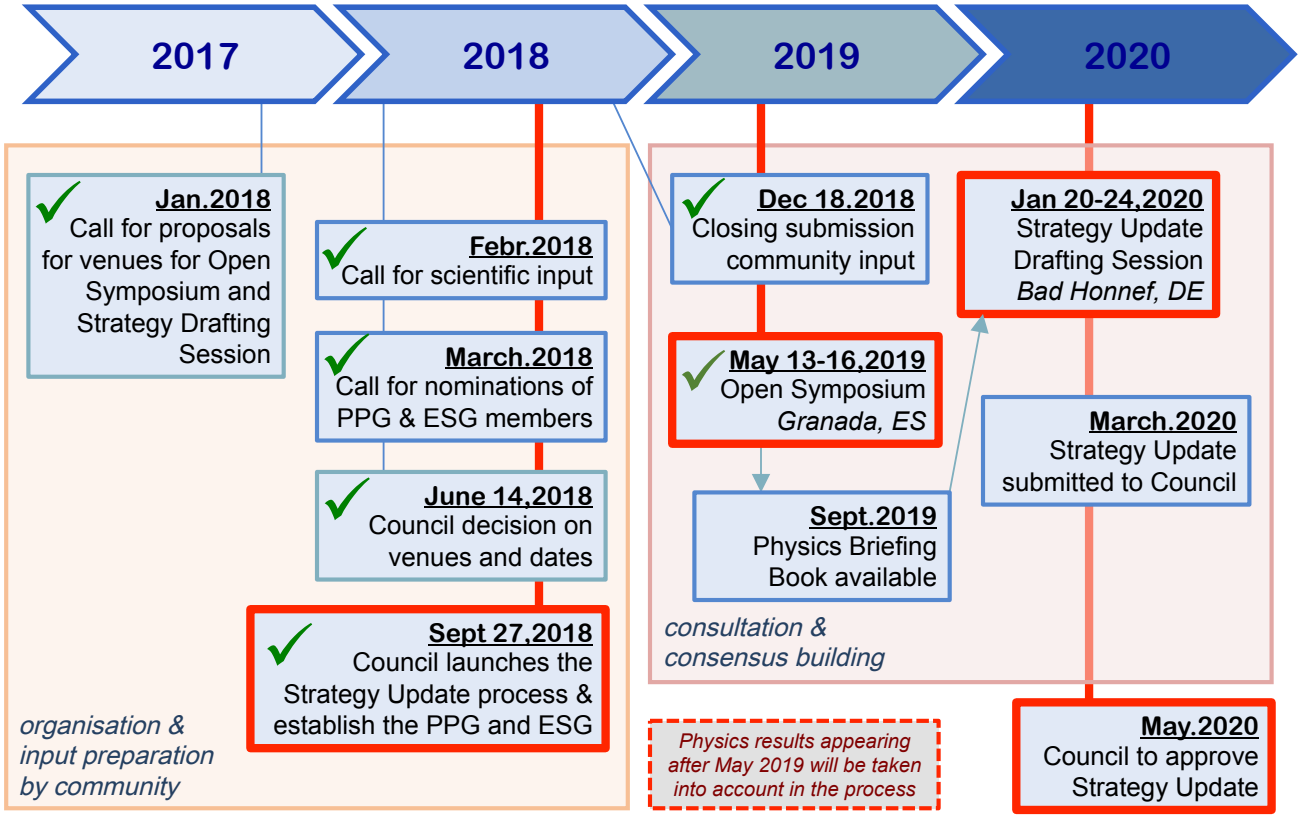

## Luminosity per facility



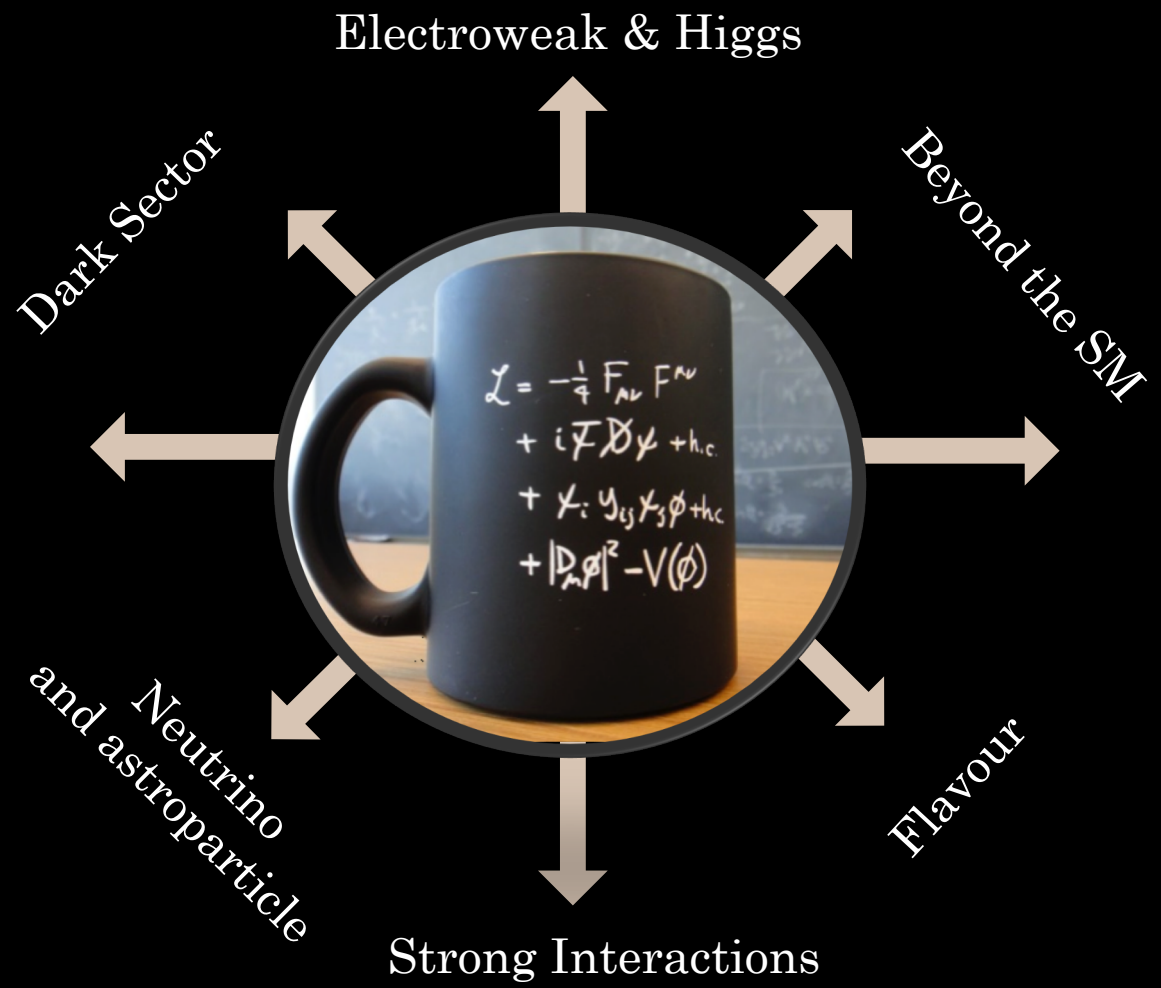
# Possible scenarios of future colliders




2017
2018
2019
2020
Jan.2018
Call for proposals for venues for Open Symposium and Strategy Drafting Session
Febr.2018
Call for scientific input
March.2018
Call for nominations of PPG & ESG members
June 14,2018
Council decision on venues and dates
Sept 27,2018
Council launches the Strategy Update process & establish the PPG and ESG
organisation & input preparation by community
Dec 18.2018
Closing submission community input
May 13-16,2019
Open Symposium
Granada, ES
Sept.2019
Physics Briefing Book available
consultation & consensus building
Physics results appearing after May 2019 will be taken into account in the process
Jan 20-24,2020
Strategy Update Drafting Session
Bad Honnef, DE
March.2020
Strategy Update submitted to Council
May.2020
Council to approve Strategy Update

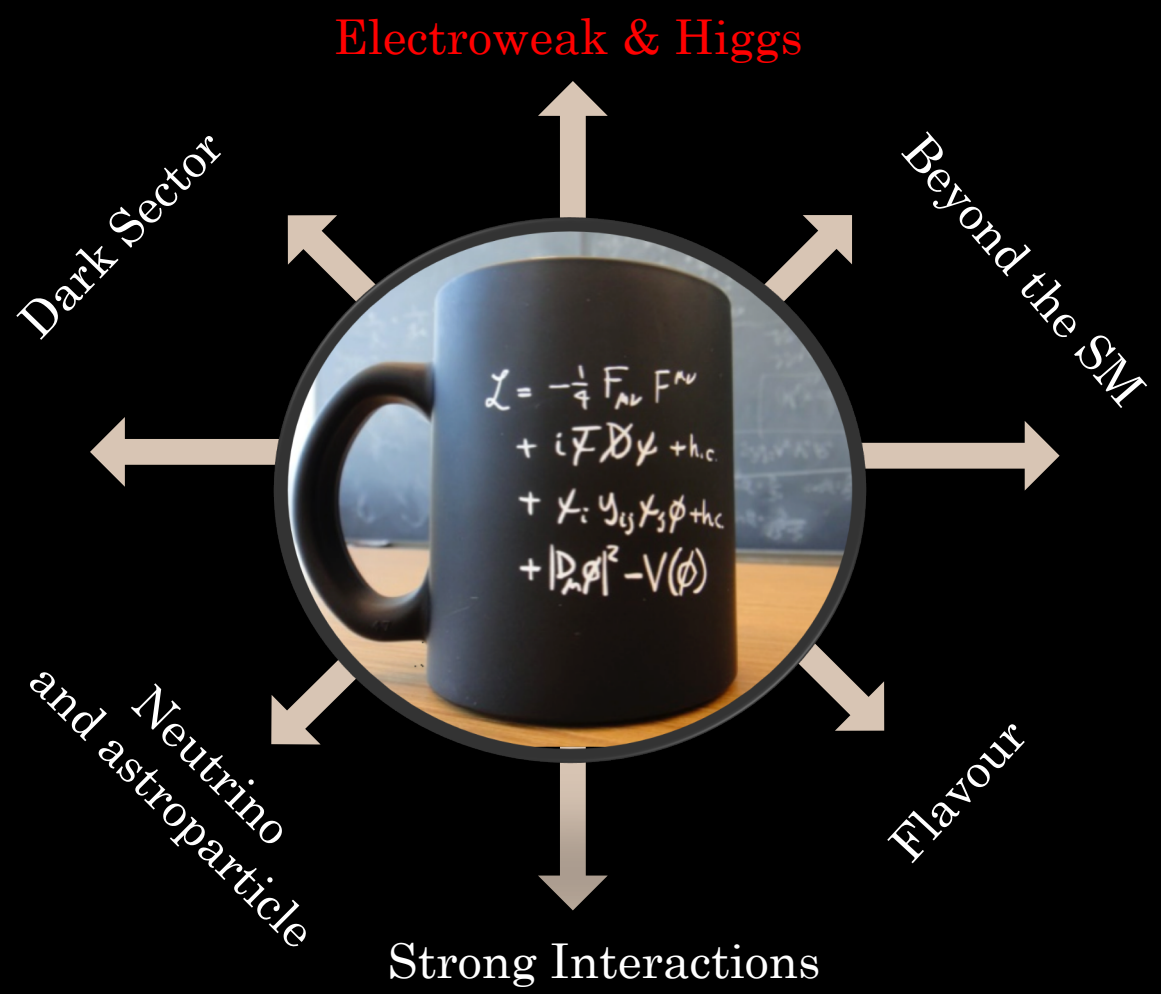
Open Symposium
Towards updating the European Strategy for Particle Physics
May 13-16, 2019, Granada, Spain
https://cafpe.ugr.es/eppsu2019/

# The Granada themes



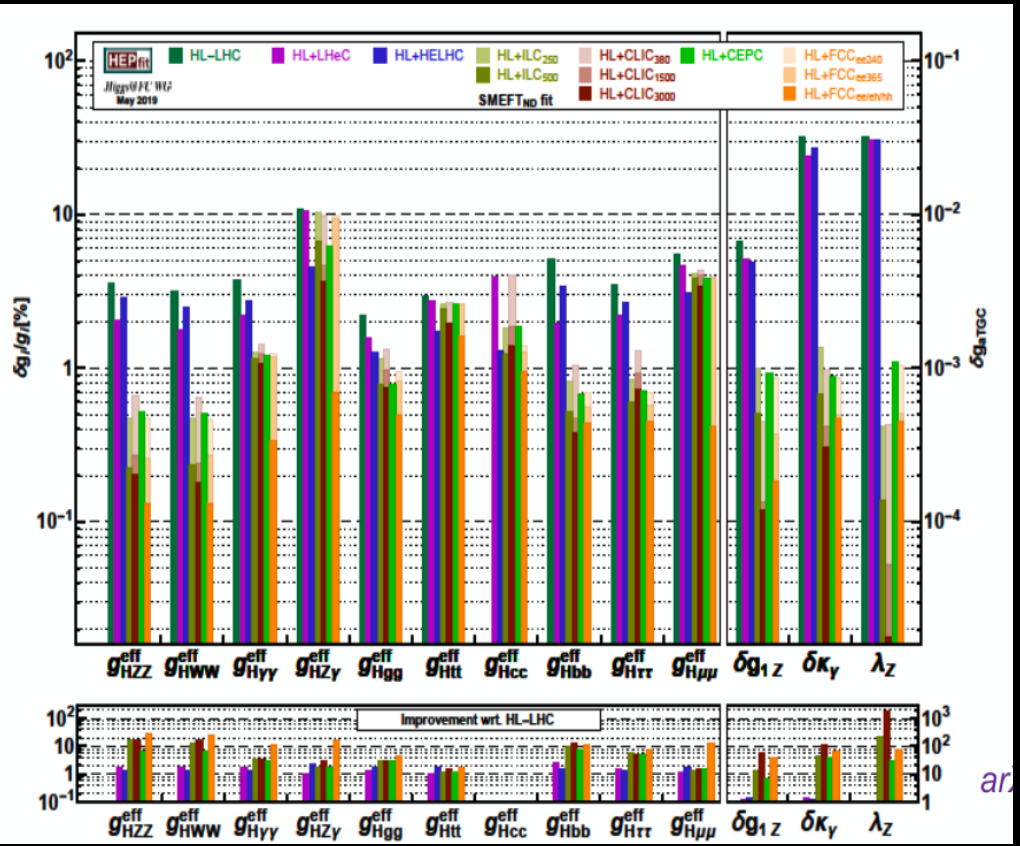
# The Granada themes

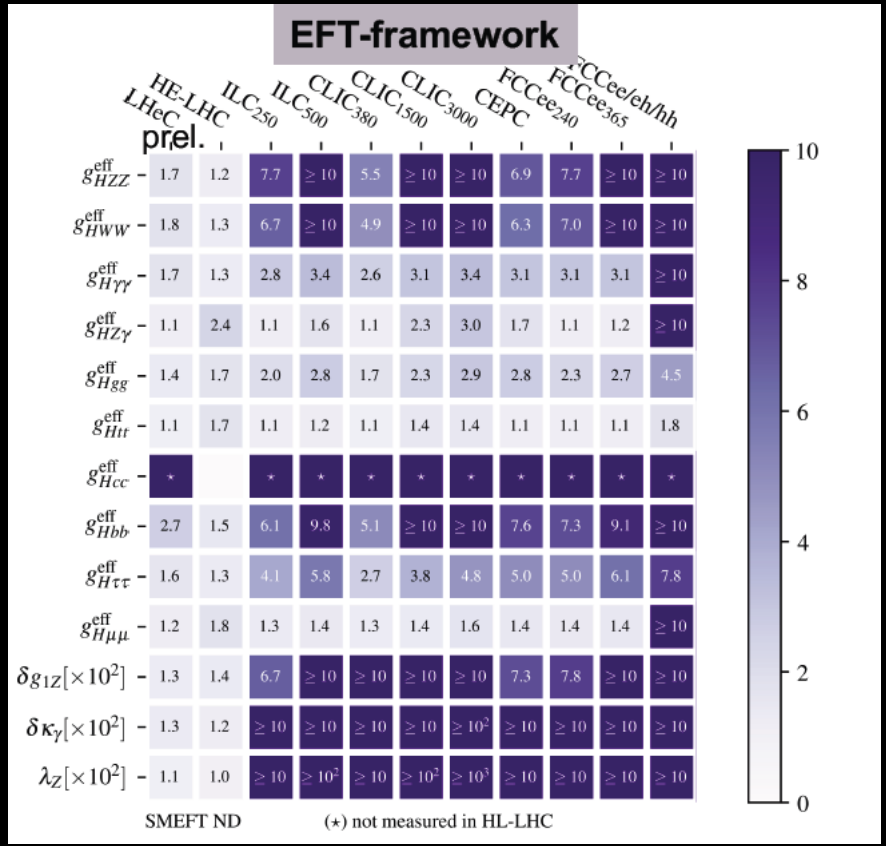
*EW & Higgs*



# Potential to measure Higgs couplings

*improvements wrt HL-LHC*




arXiv:1905.03764

Beate Heinemann @ Granada

# # of "largely" improved H couplings (EFT)

| | | Factor ≥2 | Factor ≥5 | Factor ≥10 | Years from $T_0$ |
|---|---|---|---|---|---|
| Initial run | CLIC380 | 9 | 6 | 4 | 7 |
| | FCC-ee240 | 10 | 8 | 3 | 9 |
| | CEPC | 10 | 8 | 3 | 10 |
| | ILC250 | 10 | 7 | 3 | 11 |
| 2nd/3rd Run ee | FCC-ee365 | 10 | 8 | 6 | 15 |
| | CLIC1500 | 10 | 7 | 7 | 17 |
| | HE-LHC | 1 | 0 | 0 | 20 |
| | ILC500 | 10 | 8 | 6 | 22 |
| hh | CLIC3000 | 11 | 7 | 7 | 28 |
| ee,eh & hh | FCC-ee/eh/hh | 12 | 11 | 10 | >50 |

13 quantities in total

NB: number of seconds/year differs: ILC $1.6 \times 10^7$, FCC-ee & CLIC: $1.2 \times 10^7$, CEPC: $1.3 \times 10^7$

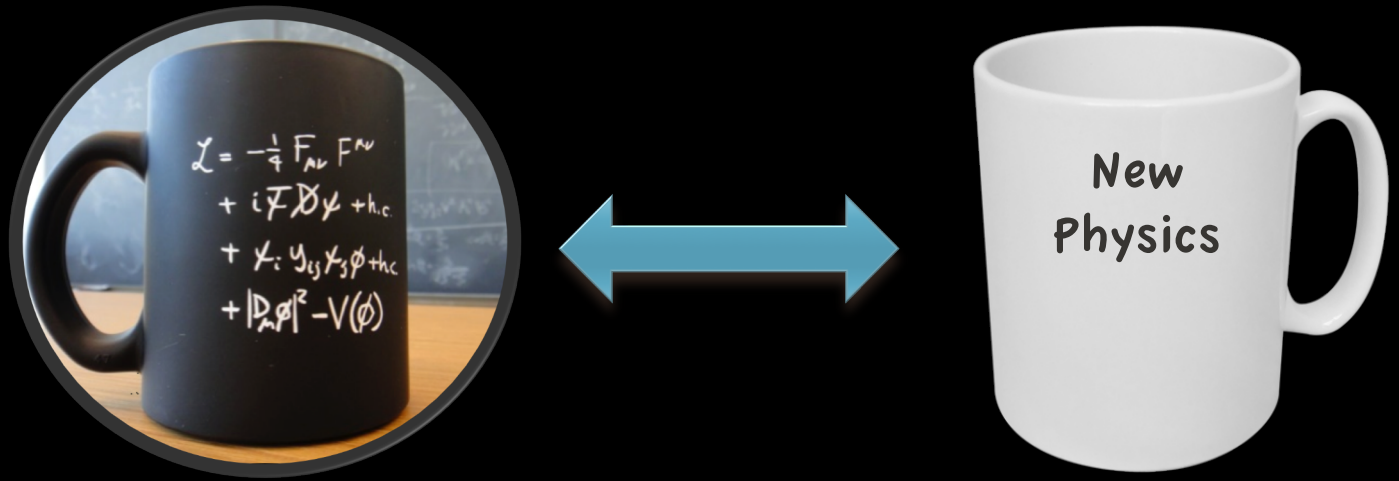
# The Granada themes

*EW & Higgs*

- Measuring Higgs couplings is perceived as one of the prime avenues in our search for new physics
- With the HL-LHC one can probe many Higgs couplings to the few percent level
- Additional to the HL-LHC sensitivity, all proposed first generation $e^+e^-$ colliders can achieve major and comparable improvements
- In a second stage, a higher energy $e^+e^-$ collider or hadron collider are important to reach the ultimate sensitivity

**There is new physics out there!**

and it should be our main objective to discover it




**The exploration of the scalar sector is only one avenue to search for it**

## Thoughts for today

- **How precise do you want to know the Higgs couplings?**

  In the pursuit for new physics, from what Higgs coupling precision do you stop learning about for example the hierarchy problem, or about dark matter via the invisible Higgs width, etc.?

- **How precise do you want to know the trilinear Higgs self-coupling?**

  What precision is required to learn sufficiently about the EW phase transition, for example if it is related to baryogenesis, or to connect Higgs physics with gravitational physics, for example gravitational waves?