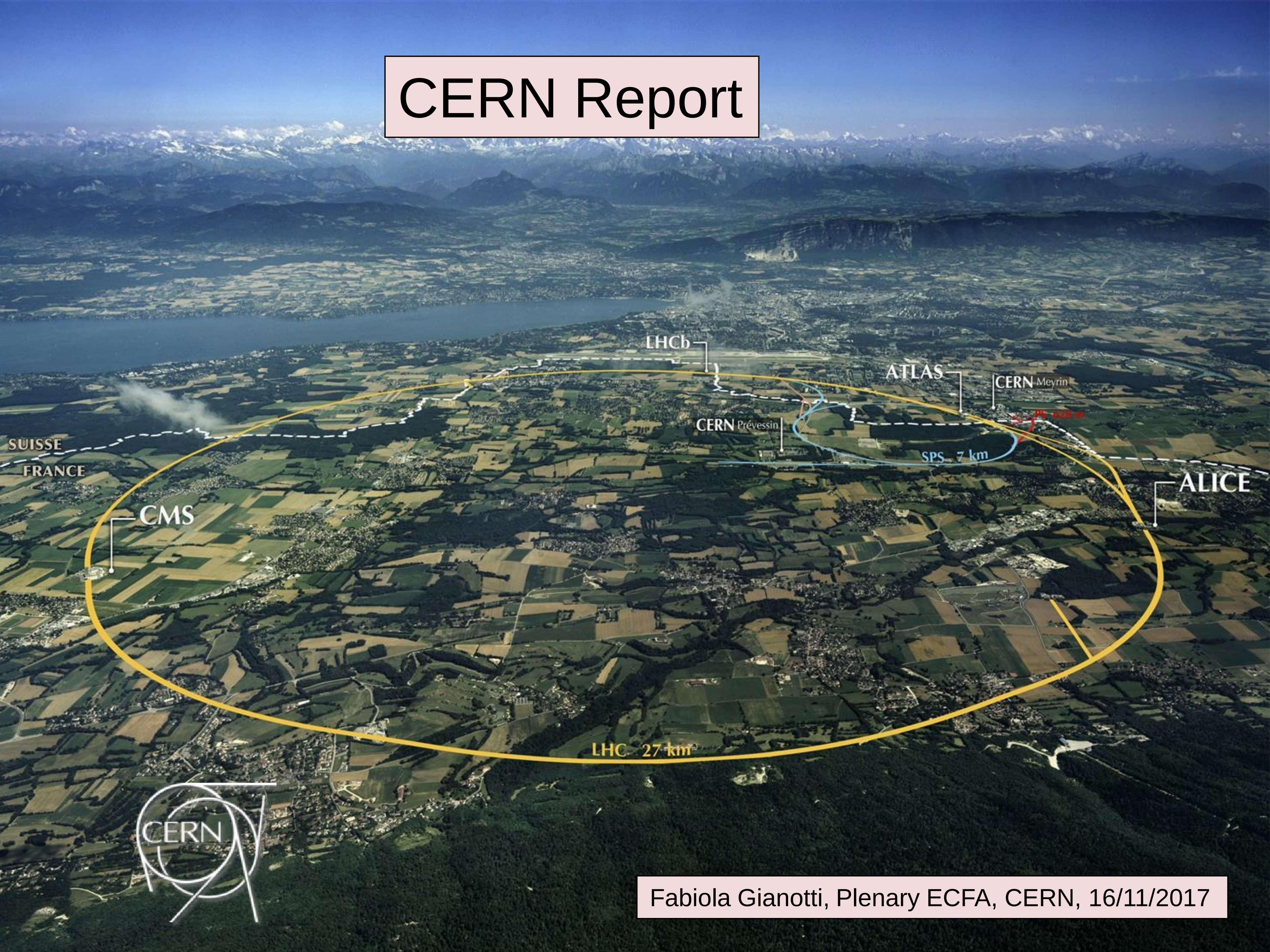
CERN Report



Fabiola Gianotti, Plenary ECFA, CERN, 16/11/2017

Outline

- Scientific programme
- Financial and human resources
- Other (recent) news

Scientific programme

Scientific programme (based on ESPP) : **3** pillars

Full exploitation of the LHC:

- ❑ successful operation of the nominal LHC until end 2023 (Run 2, LS2, Run 3) → 300/fb
- ❑ construction & installation of LHC upgrades: LIU (LHC Injectors Upgrade) and HL-LHC → 3000/fb

Note: expect to move to 14 TeV operation in Run 3. Currently also exploring the possibility to achieve "ultimate" energy of 15 TeV in Run4++

Scientific diversity programme serving a broad community:

- ❑ ongoing experiments and facilities at Booster, PS, SPS and their upgrades (HIE-ISOLDE, ELENA)
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Preparation of CERN's future:

- ❑ vibrant accelerator R&D programme exploiting CERN's strengths and uniqueness (including superconducting high-field magnets, AWAKE, etc.)
- ❑ design studies for future high-energy accelerators: CLIC, FCC (includes HE-LHC)
- ❑ future opportunities of diversity programme: Physics Beyond Colliders Study Group

Important milestone: update of the European Strategy for Particle Physics (ESPP)

Timeline of the ESPP update

The strategy update is prepared by the European Strategy Group (ESG)
The Physics Preparatory Group (PPG) provides scientific input
(includes ECFA Chair and 4 members proposed by ECFA)
The Strategy Secretariat coordinates the preparation work

September 2017: Strategy Secretariat appointed by Council
Chairperson: Halina Abramowicz (→ also chair of ESG and PPG)
SPC Chair: K. Ellis
ECFA Chair: J. D'Hondt (to be endorsed at this meeting)
LDG* Chair: L. Rivkin
*LDG=Laboratory Directors Group

September 2018: appointment of PPG and ESG by Council → formal start of the ESPP

2019: broad consultation with the community, including 1-2 open meetings

May 2020: approval of the ESPP update by Council

Scientific input (e.g. design studies for future projects, results from current projects) to be submitted by end 2018.

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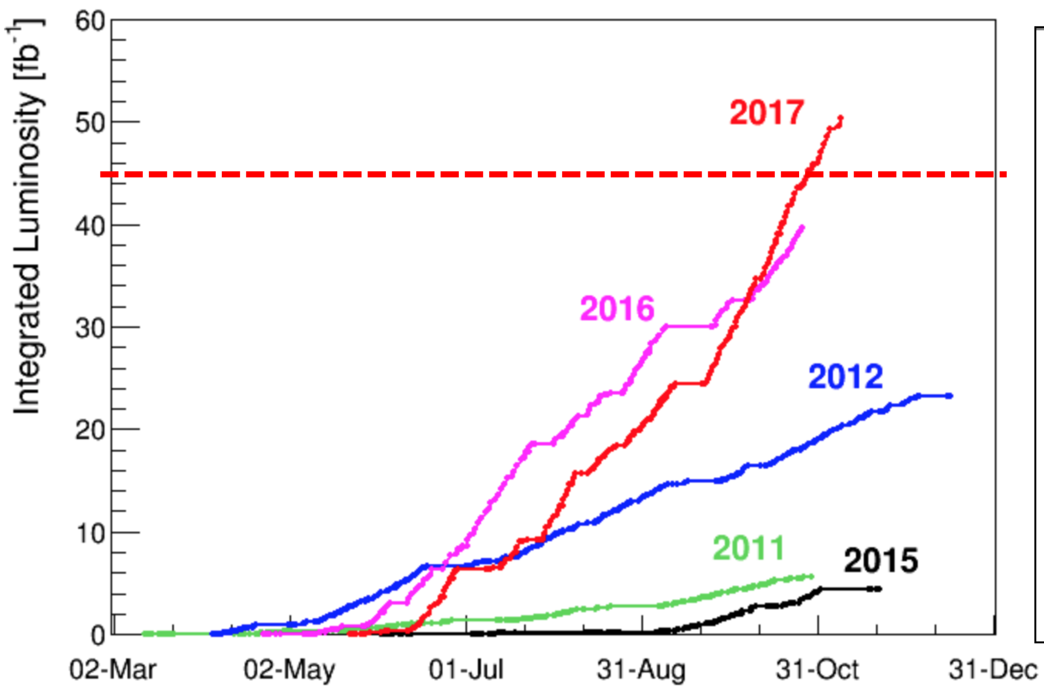
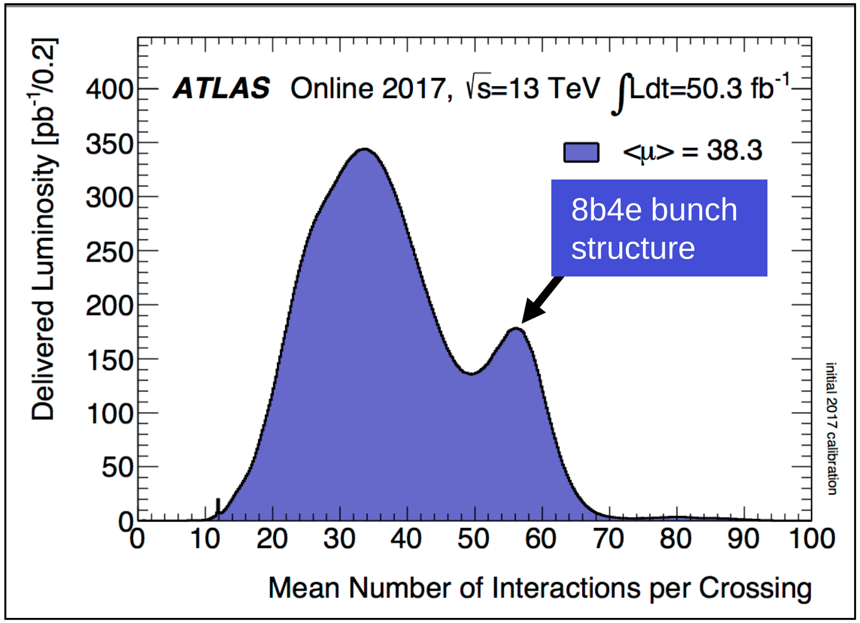
Outstanding performance of accelerator complex in 2017

- Peak luminosity: ~ 2.2 x 10^{34} cm^{-2} s^{-1} (nominal is 1.0 x 10^{34}) → levelled at 1.5 x 10^{34}
- Integrated luminosity: ~ 50 fb^{-1} ATLAS and CMS, ~ 1.8 fb^{-1} LHCb, 17 pb^{-1} ALICE
  In spite of problems in S12 (likely accidental intake of air during cool-down beg 2017)

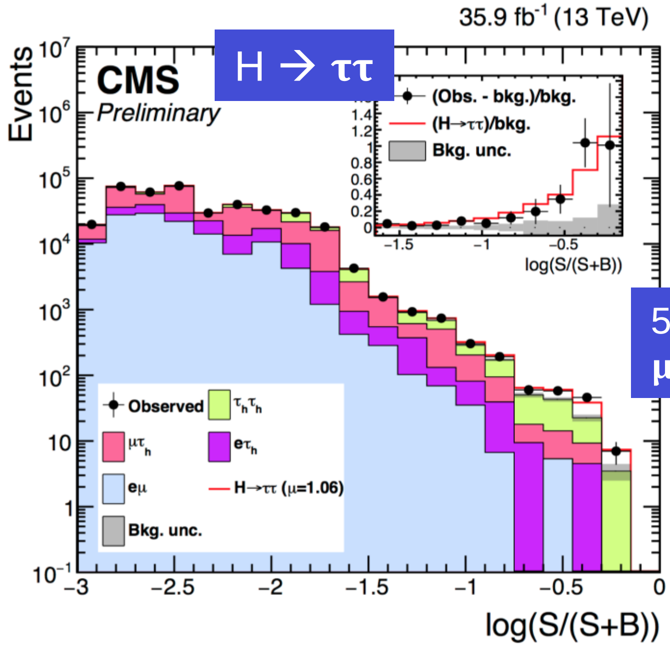
- Total int. luminosity at 13 TeV: ~ 95 fb^{-1} ATLAS, CMS, ~ 4 fb^{-1} LHCb, ~ 37 pb^{-1} ALICE
- Total int. luminosity since 2010: ~ 123 fb^{-1} ATLAS, CMS, ~ 7.5 fb^{-1} LHCb, ~ 51 pb^{-1} ALICE



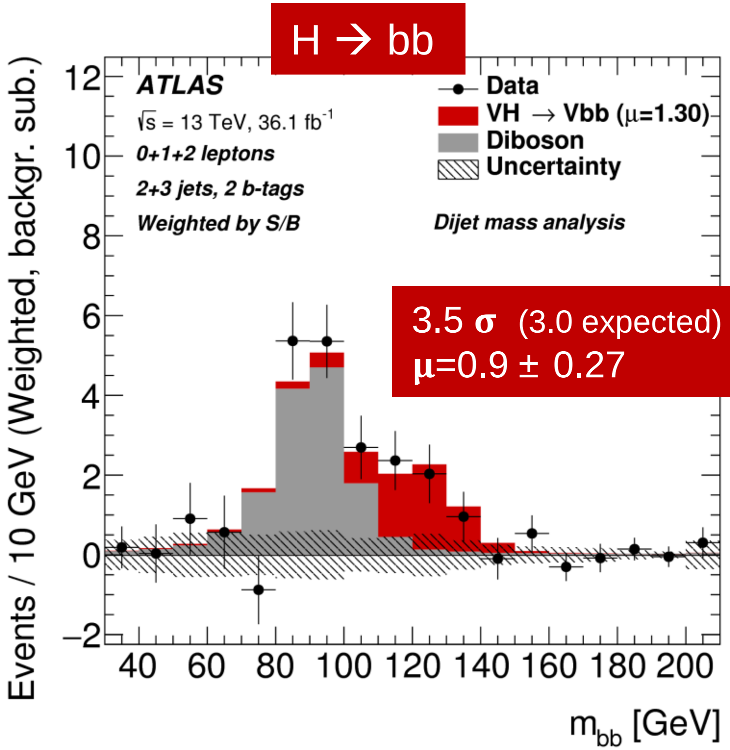


Now special runs: √s=5 TeV (reference run for Pb-Pb collisions); **β*** = 50-100 m at √s=900 GeV
YETS starts 4 December (1 week earlier to allow CMS to intervene on Pixels electronics)

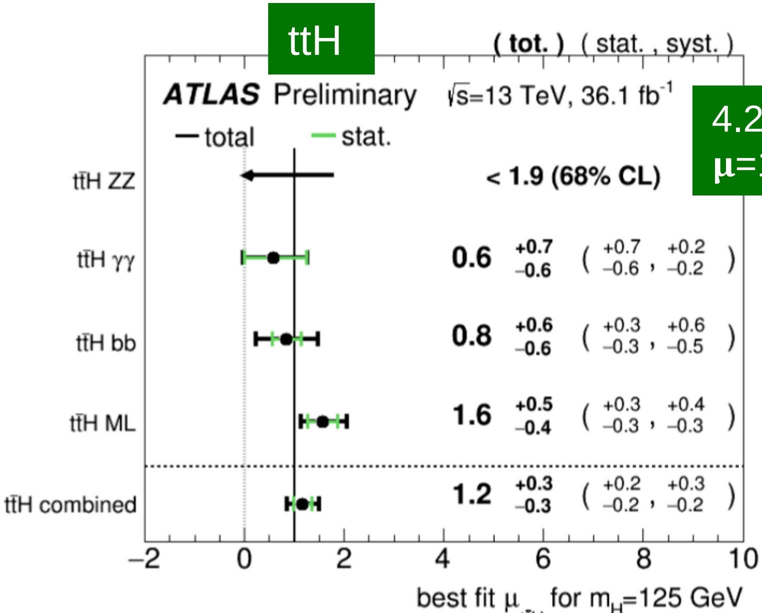
Higgs couplings to 3rd generation fermions well established



5.9 σ (5.9 expected)
μ=1.09 ± 0.26



3.5 σ (3.0 expected)
μ=0.9 ± 0.27



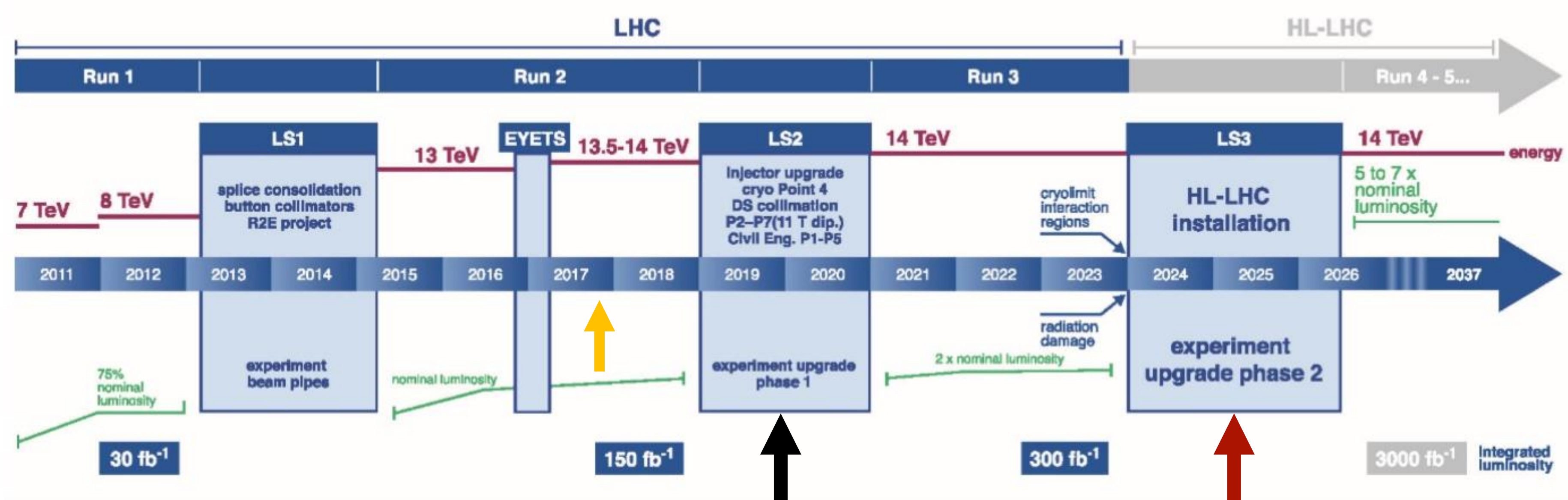
4.2 σ (3.8 expected)
μ=1.2 ± 0.3

Note: very complex final state topologies, huge backgrounds → excellent detector performance, exquisite control of the backgrounds and sophisticated analysis techniques required

LHC upgrades (LIU + HL-LHC): parameters and timeline

Nominal LHC: $\sqrt{s}$ = 14 TeV, L= 1×10^{34} cm^{-2} s^{-1}
Integrated luminosity to ATLAS and CMS: 300 fb^{-1} by 2023 (end of Run 3)

HL-LHC: $\sqrt{s}$ = 14 TeV, L= 5×10^{34} cm^{-2} s^{-1} (levelled)
Integrated luminosity to ATLAS and CMS: 3000 fb^{-1} by ~ 2035



LS2 (2019-2020):
- ❑ LHC Injectors Upgrade (LIU)
- ❑ Civil engineering for HL-LHC equipment @ P1,P5
- ❑ 11 T dipoles P7
- ❑ Phase-1 upgrade of LHC experiments

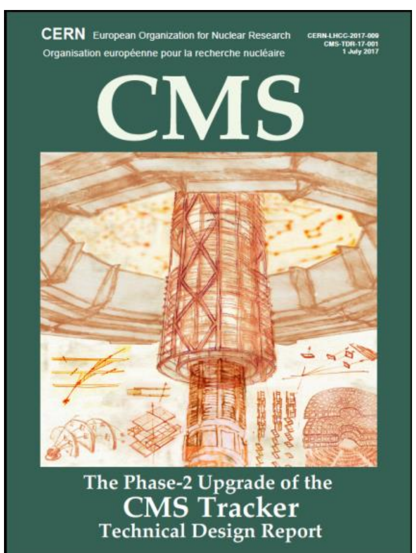
LS3 (2024-2026):
- ❑ **HL-LHC installation**
- ❑ Phase-2 upgrade of ATLAS and CMS

LHC detectors' upgrades

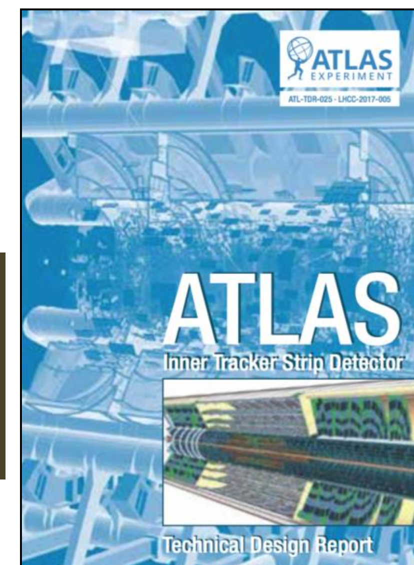
First LHCb fibre modules arriving at CERN

ALICE and LHCb upgrades on schedule for installation in LS2

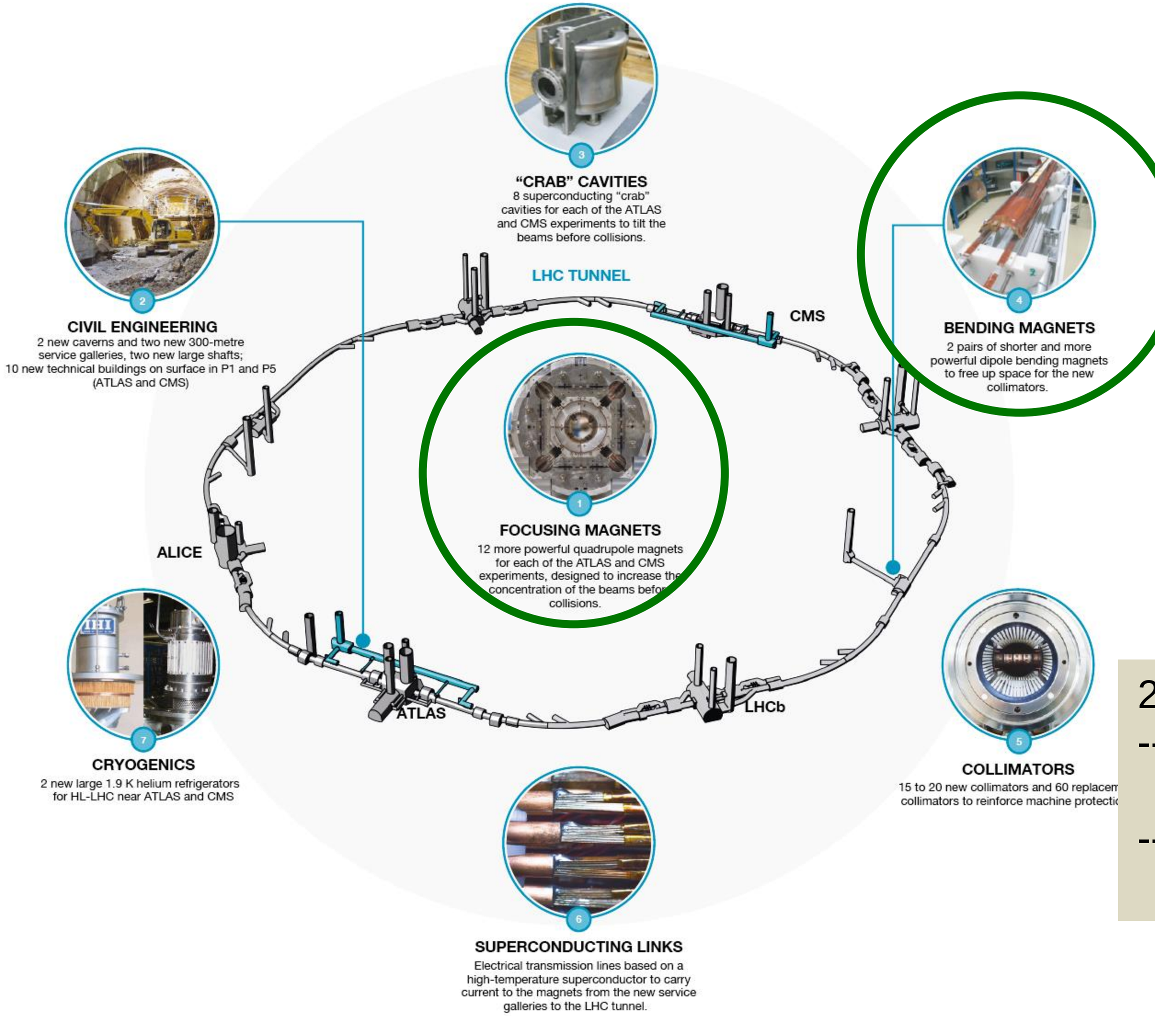
Production of GEM readout chambers for ALICE TPC



~10 TDR for Phase-2 upgrade of ATLAS and CMS submitted or being submitted → huge review work by LHCC and UCG → (ambitious) goal is to complete process by April 2018 RRB



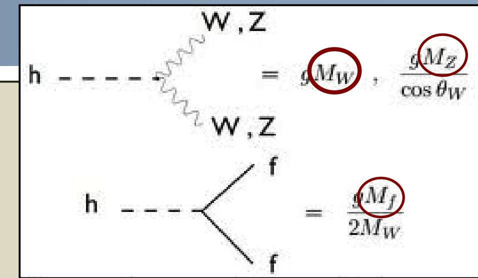
HL-LHC



2017 milestones:
- -- manufacturing first full-length (5.5 m) 11 T Nb_3Sn dipole prototype;
- -- procurements of full amount of Nb_3Sn wire.

Crucial development: next-generation superconducting magnets (11 T dipoles and 12 T peak field quadrupoles) based on Nb_3Sn → milestone also for future colliders (HE-LHC, FCC).
Short prototypes achieved nominal fields in 2015-2016.

HL-LHC physics case



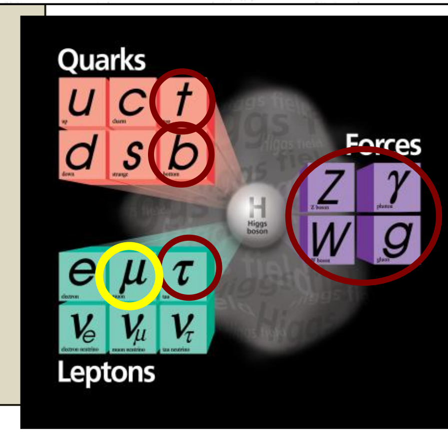
1 Precise measurements of the Higgs boson

Impact of New Physics on Higgs couplings **k** to other particles:

$\Delta\kappa/\kappa \sim 5\%/\Lambda^2_{NP}$ (Λ_{NP} in TeV)

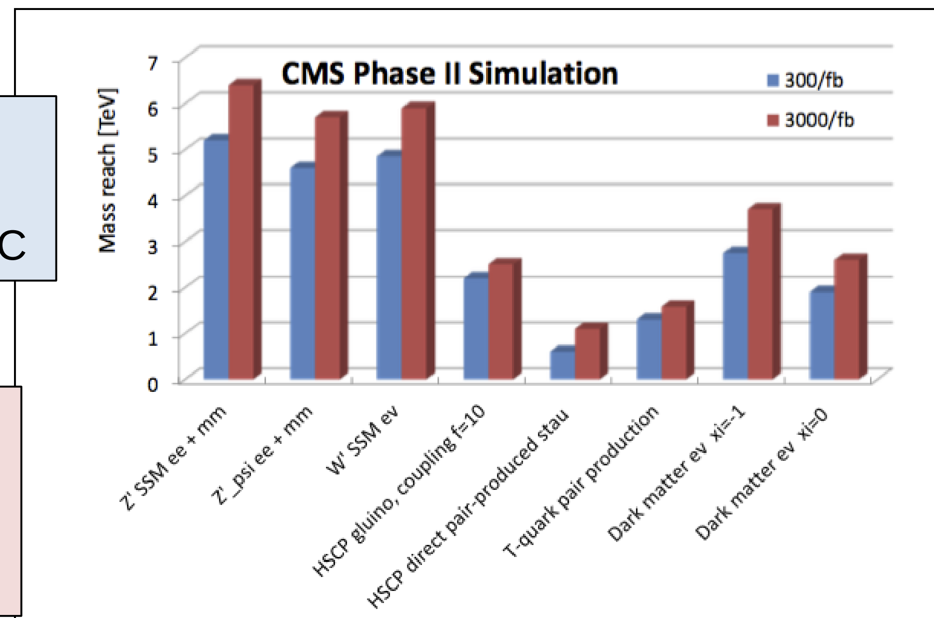
Precision: ~10% at nominal LHC → ~2-5% at HL-LHC

In addition: measure H couplings to second-generation particles through rare H→ μμ decay. Nominal LHC: only couplings to (heavier) third-generation particles (top-quark, b-quark, τ-lepton) accessible



2 Discovery potential for new particles

~20-30% larger (up to m ~ 8 TeV) than nominal LHC



3 If new particles discovered in Run 2-3:

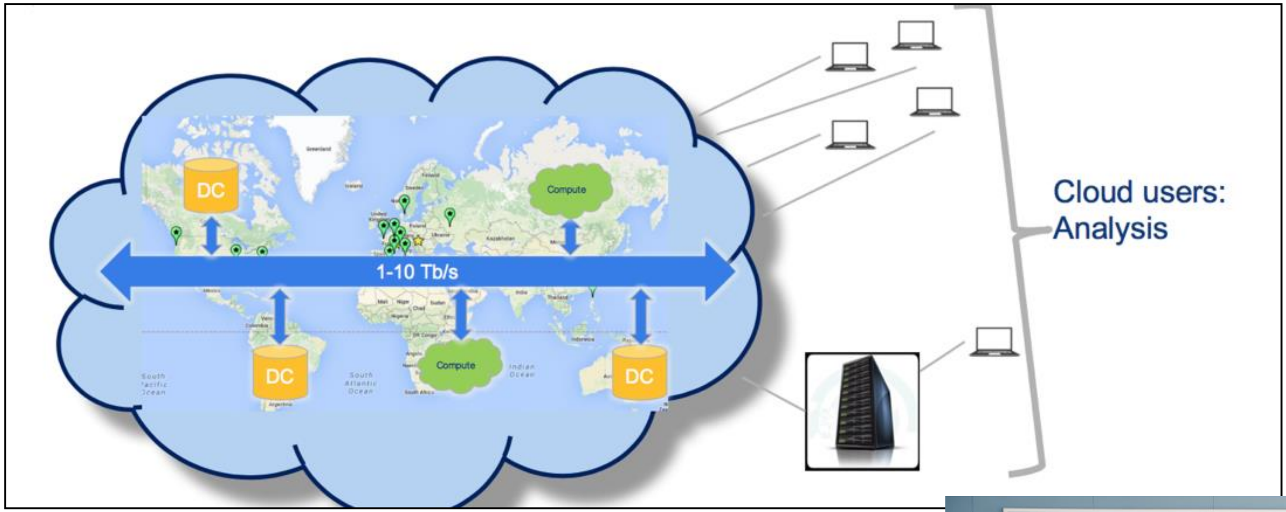
→ HL-LHC may find more and provide first detailed exploration of the new physics with well understood machine and experiments

Future computing

Main challenges for computing in HL-LHC era: store, process, access from all over the world and analyze multi-exabyte data samples. CERN has huge experience with big data → working with EIROforum organisations and EC (EOSC project)

Strategy paper on Federated Scientific Data Hub: based on ~ 10 big centres (5-10 MW each) providing storage, needed services, plug-in processing power, and capability to use heterogeneous resources (HPC, public ad commercial clouds, etc.) → seen from users as single virtual data centre

Data cloud for storage and compute



Agreement signed in July between CERN and SKA (Square Kilometer Array) for collaboration on extreme-scale computing high-throughput fibre network, exabyte-scale data processing, storage and distribution).
Similar challenges expected for HL-LHC and SKA mid 2020s

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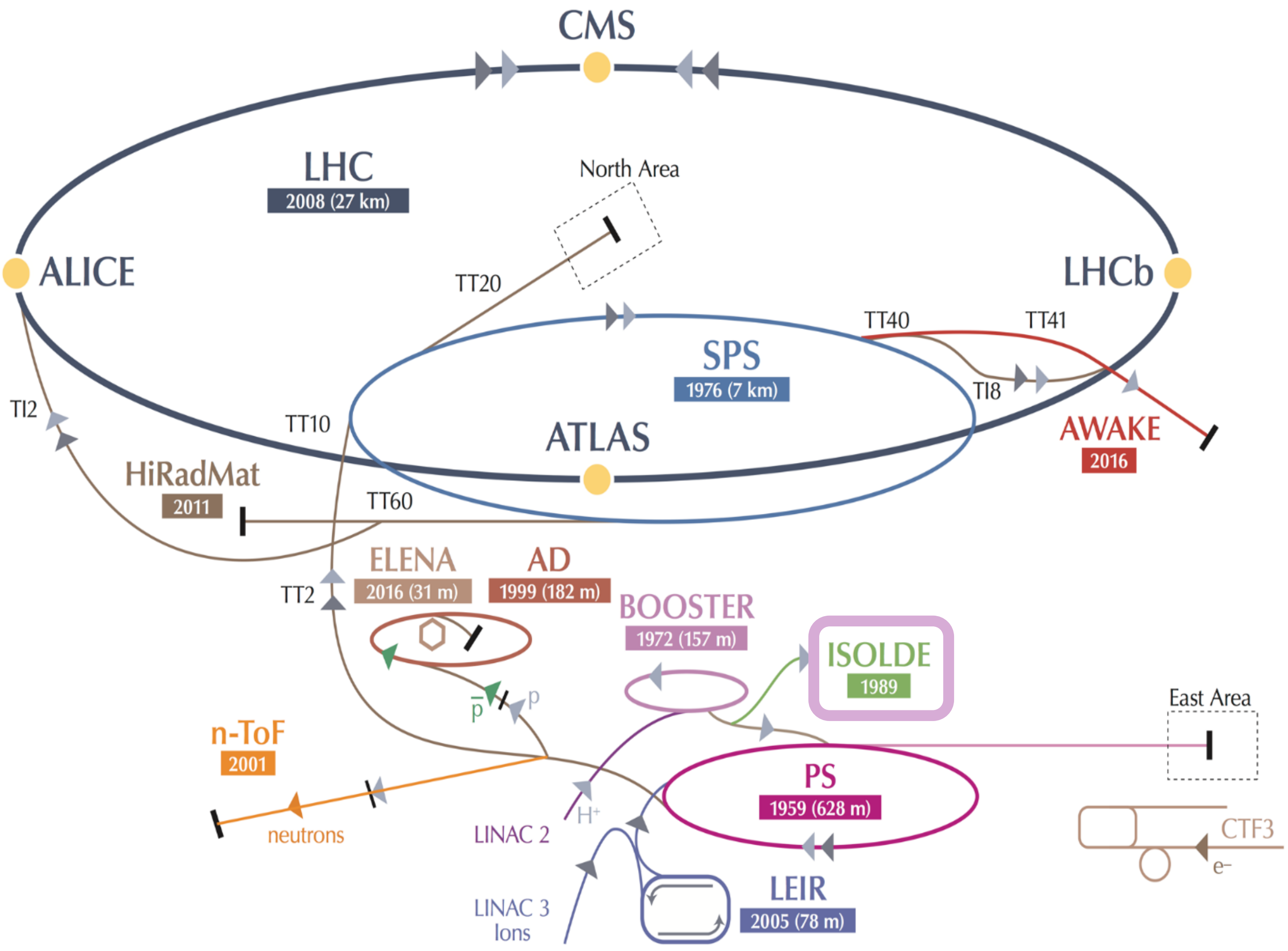
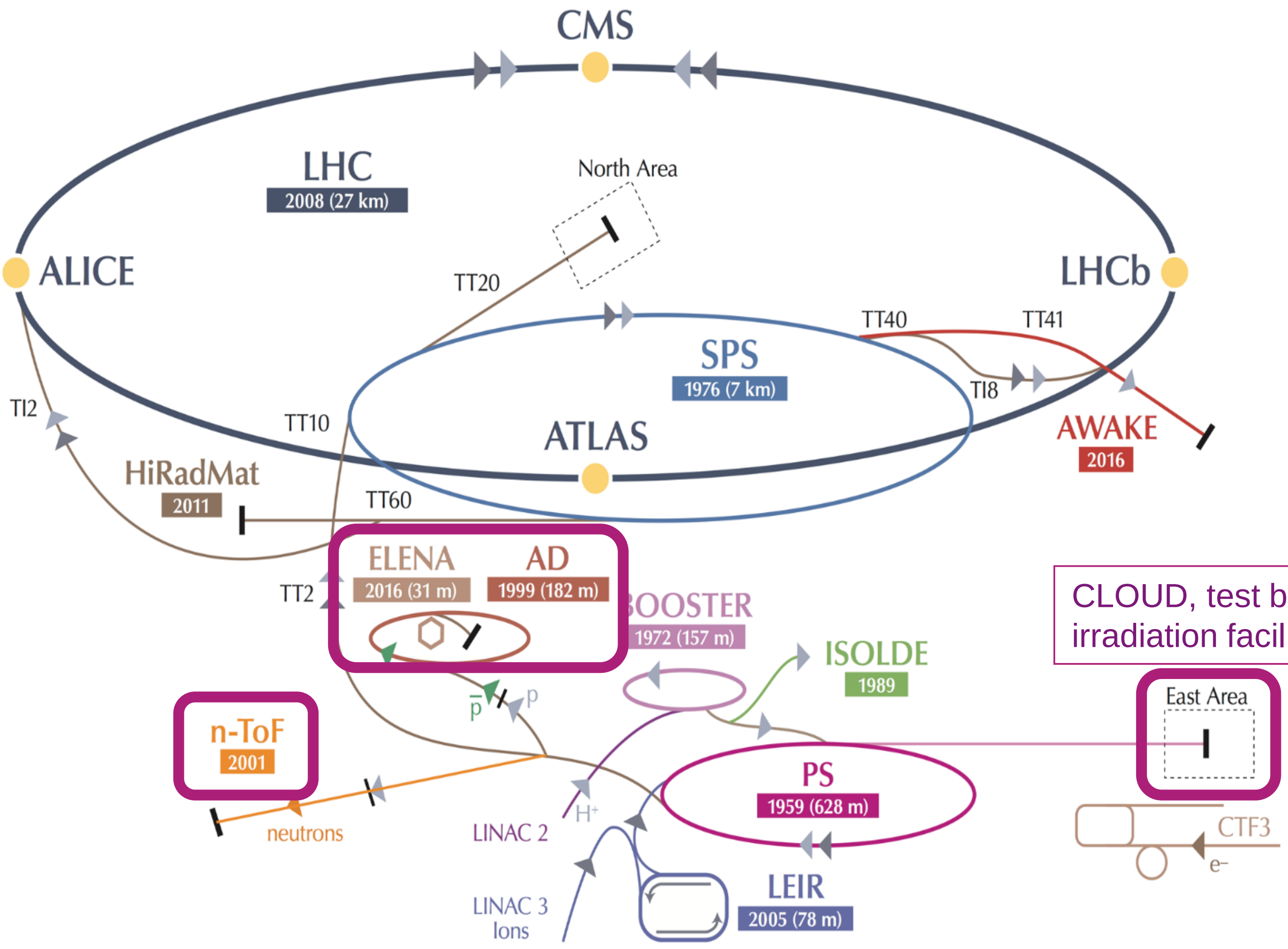
CERN's scientific diversity programme



Exploits unique capabilities of CERN's accelerator complex

CERN’s scientific diversity programme



CLOUD, test beam, irradiation facilities

Exploits unique capabilities of CERN’s accelerator complex

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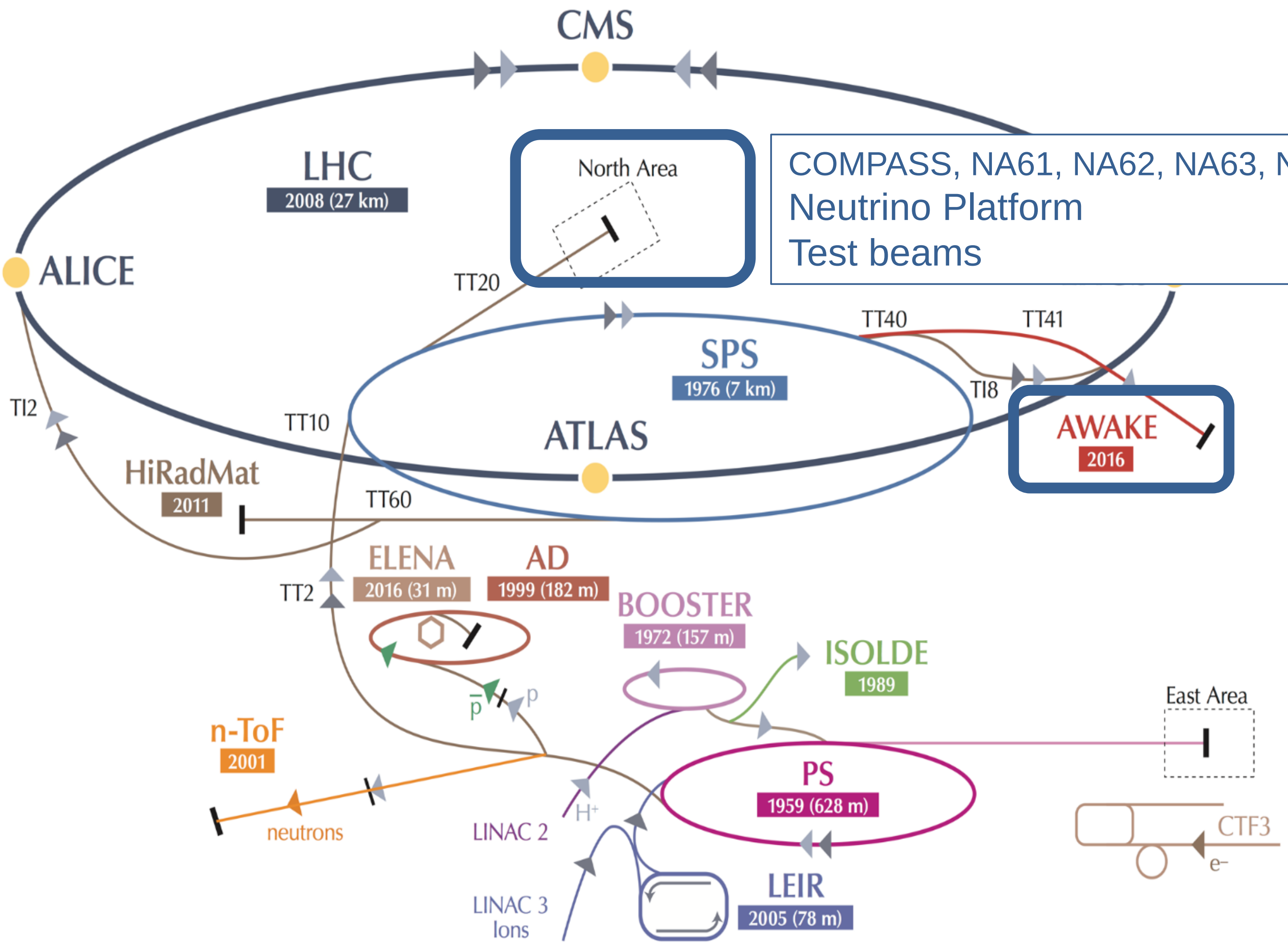

COMPASS, NA61, NA62, NA63, NA64
Neutrino Platform
Test beams

Exploits unique capabilities of CERN's accelerator complex

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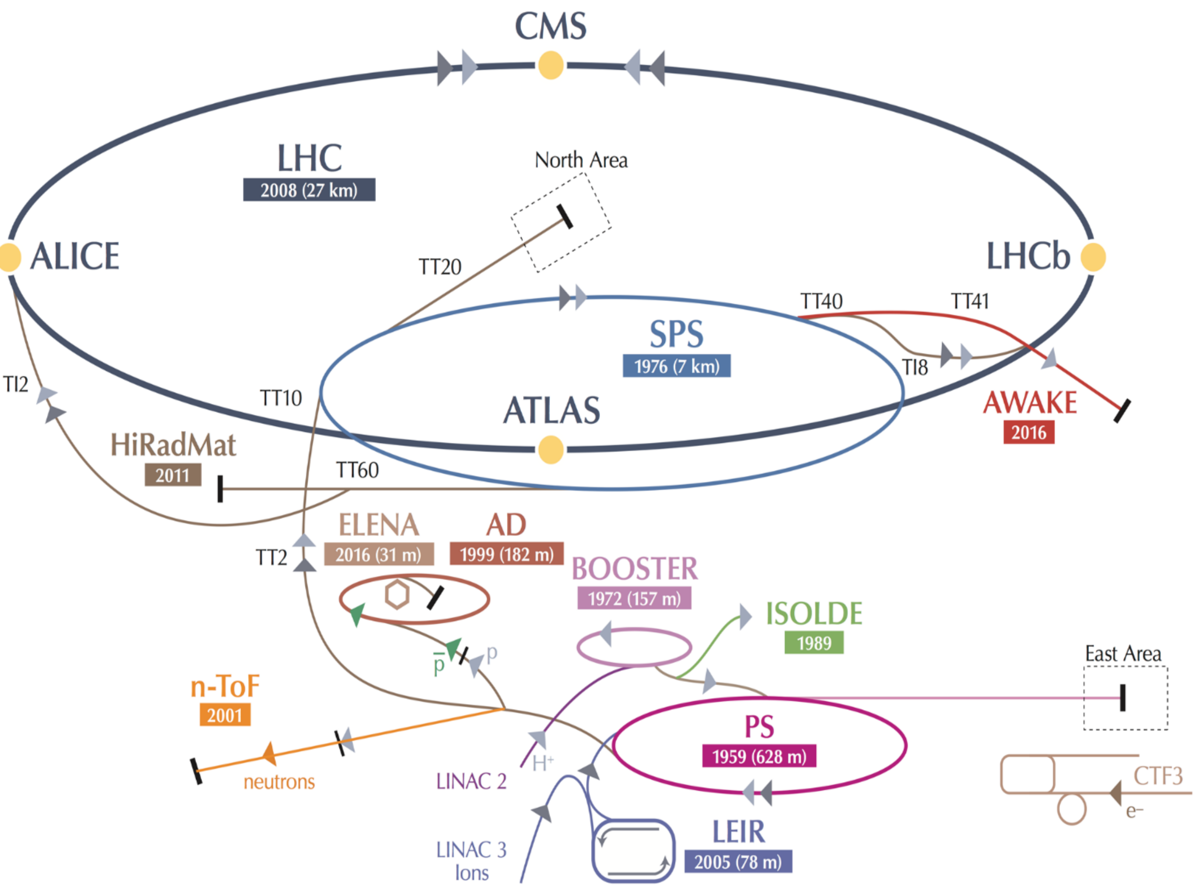


~20 projects, > 1200 physicists

AD: Antiproton Decelerator for antimatter studies

AWAKE: proton-induced plasma wakefield acceleration

CAST, OSQAR: axions

CLOUD: impact of cosmic rays on aeorosols and clouds → implications on climate

COMPASS: hadron structure and spectroscopy

ISOLDE: radioactive nuclei facility

NA61/Shine: heavy ions and neutrino targets

NA62: rare kaon decays

NA63: interaction processes in strong EM fields in crystal targets

NA64: search for dark photons

Neutrino Platform: **ν** detectors R&D for experiments in US, Japan

n-TOF: n-induced cross-sections

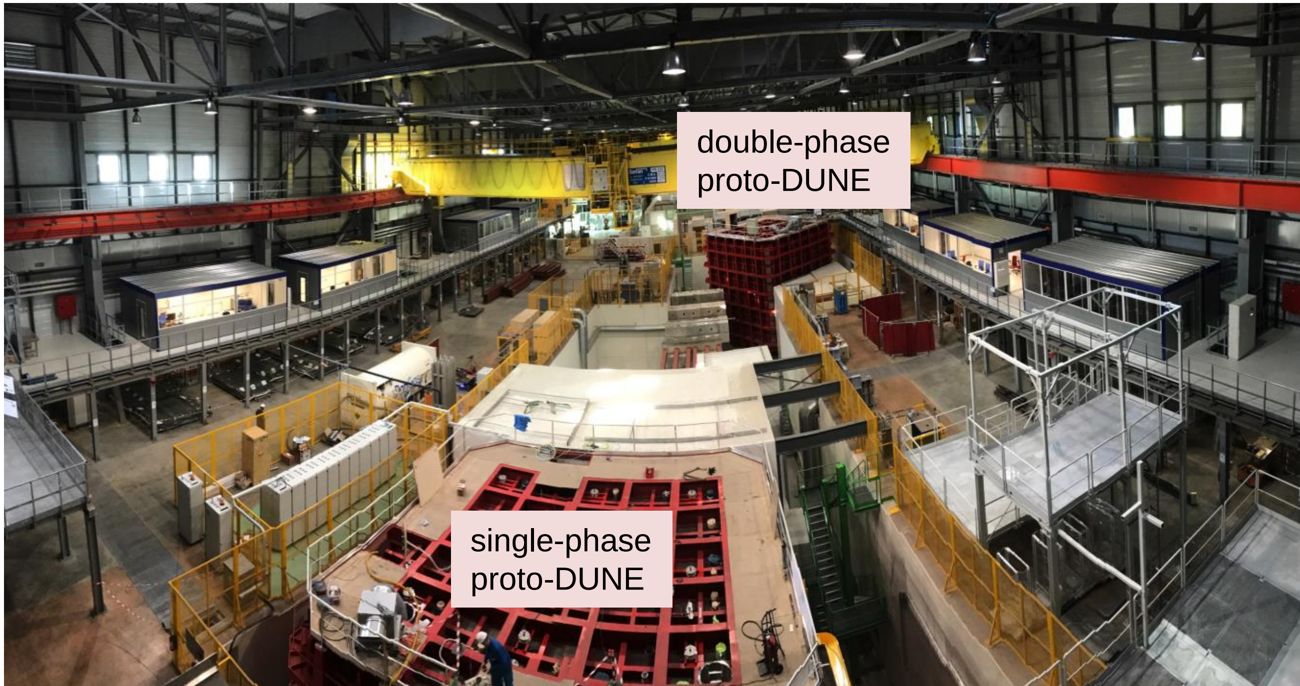
UA9: crystal collimation

CERN Neutrino Platform

Mission:

- Provide charged beams and test space to neutrino community → North Area extension
- R&D to demonstrate large-scale LAr technology (cryostats, detectors, …); construction of cryostat for first DUNE module; participation in construction and test of two prototypes of DUNE detector: single and double-phase LAr TPC, ~ 6x6x6 m^3, ~ 700 tons
- Support European participation in neutrino projects in US and Japan (efforts started recently also on near detectors, bringing together DUNE and T2K)
- Physics activities in Neutrino Group in EP Department and “task force” in TH Department

ICARUS 600 t detector (two modules) now at FNAL, after refurbishment at CERN, to take part in short baseline neutrino programme.



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See talks by J. Fuster, L. Linssen, M. Benedikt and P. Muggli tomorrow

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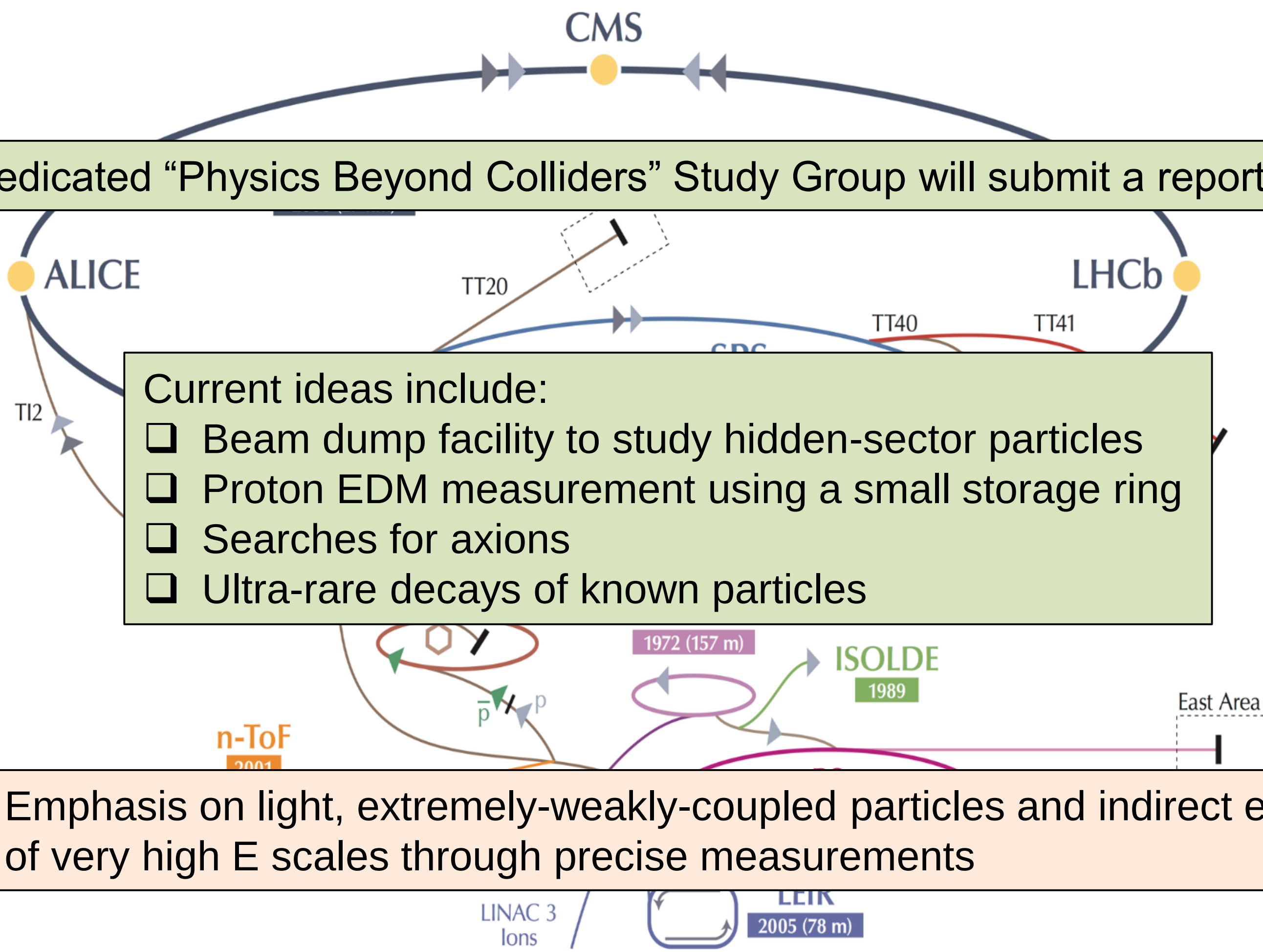
Future scientific opportunities other than high-E colliders

We are also exploring the unique opportunities offered by the (very rich) CERN accelerator complex and infrastructure to address the outstanding questions in today's particle physics through projects complementary to high-E colliders and other initiatives in the world



Dedicated "Physics Beyond Colliders" Study Group will submit a report to ESPP

Current ideas include:

- Beam dump facility to study hidden-sector particles
- Proton EDM measurement using a small storage ring
- Searches for axions
- Ultra-rare decays of known particles

Emphasis on light, extremely-weakly-coupled particles and indirect exploration of very high E scales through precise measurements

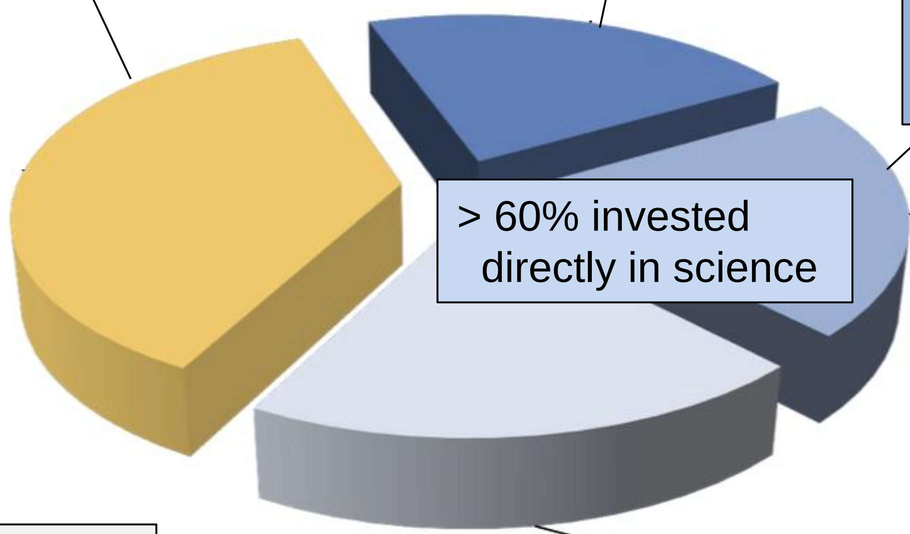
Financial and human resources

Budget’s main components

Infrastructure, services and centralised expenses(*): ~ 470 M (~ 37%)
Energy and water (65 M), Safety (48 M), Site maintenance, logistics, security (80 M), Site renovation & buildings (35 M), Informatics (60 M), Int. Rel. (17 M), Administration (50 M), etc.
(*) Some expenses have corresponding revenues

New scientific projects and studies: ~ 280 M (22%)
LIU, HL-LHC, HIE-ISOLDE, AD-ELENA, Neutrino Platform, FCC, CLIC, Physics Beyond Colliders, AWAKE, R&D

LHC: ~ 270 M (21%)
Operation and consolidation of accelerator (160 M), detectors (65 M), computing (45 M)

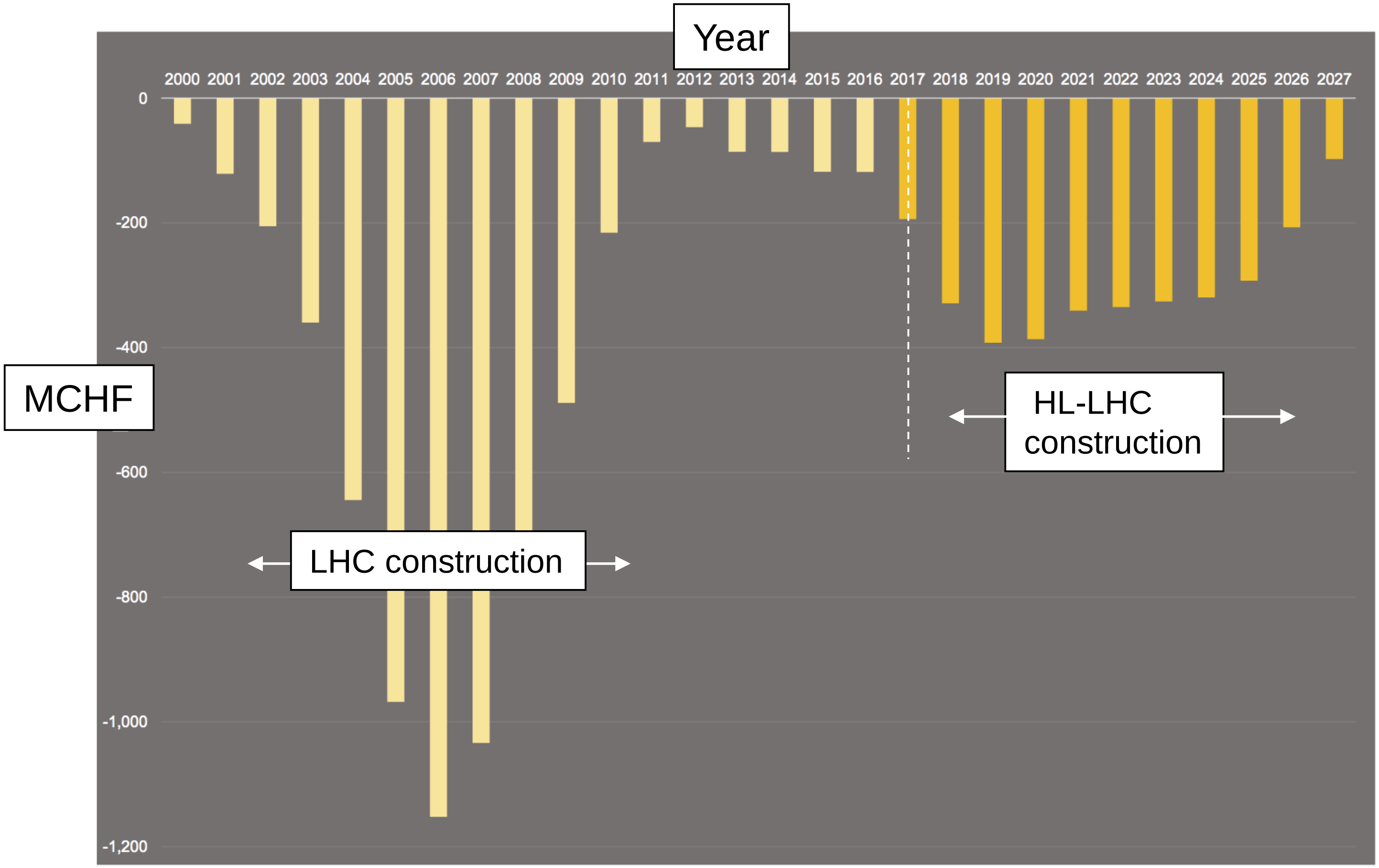


> 60% invested directly in science

2018 budget (M+P):
total income: ~1.2 BCHF

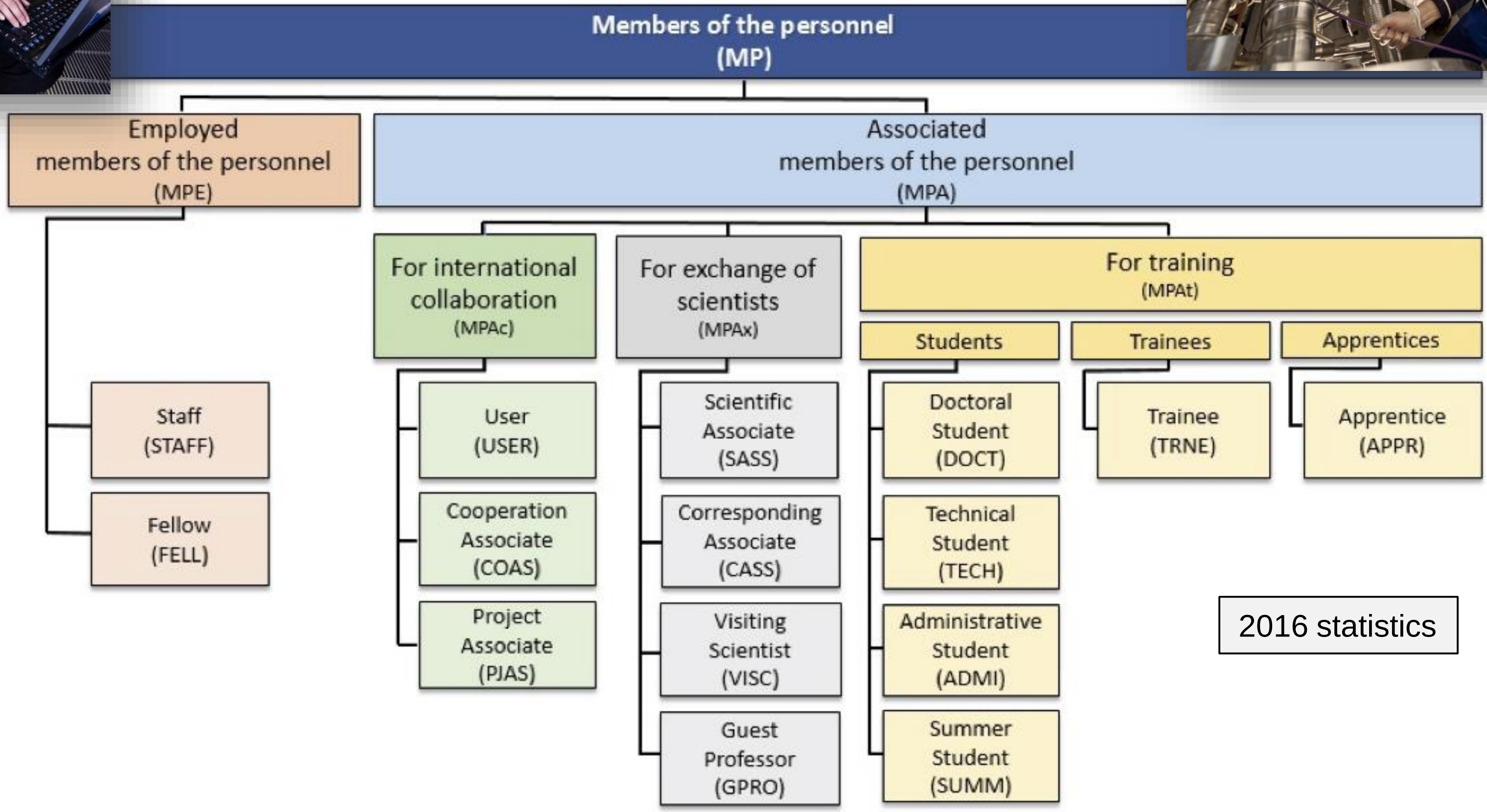
Other scientific programme: ~ 250 M (20%)
- Non-LHC experiments, theory, KT, etc.
- Operation and consolidation of injectors and exp. areas (170 M)

Cumulative Budget Deficit vs time



- ❑ CERN's budget has been constant for many years
- ❑ CERN's projects, including BIG projects (LHC and now HL-LHC), built within constant budget
- ❑ When CBD exceeds annual cash management capacity of ~-250 MCHF, additional resources needed → Council approved a credit facility with the European Investment Bank at the time of LHC construction and now again for HL-LHC

Personnel (I)



2016 statistics

Total: ~ **16800** people

Staff: ~2560

Users: 11821 (~38% from NMS)

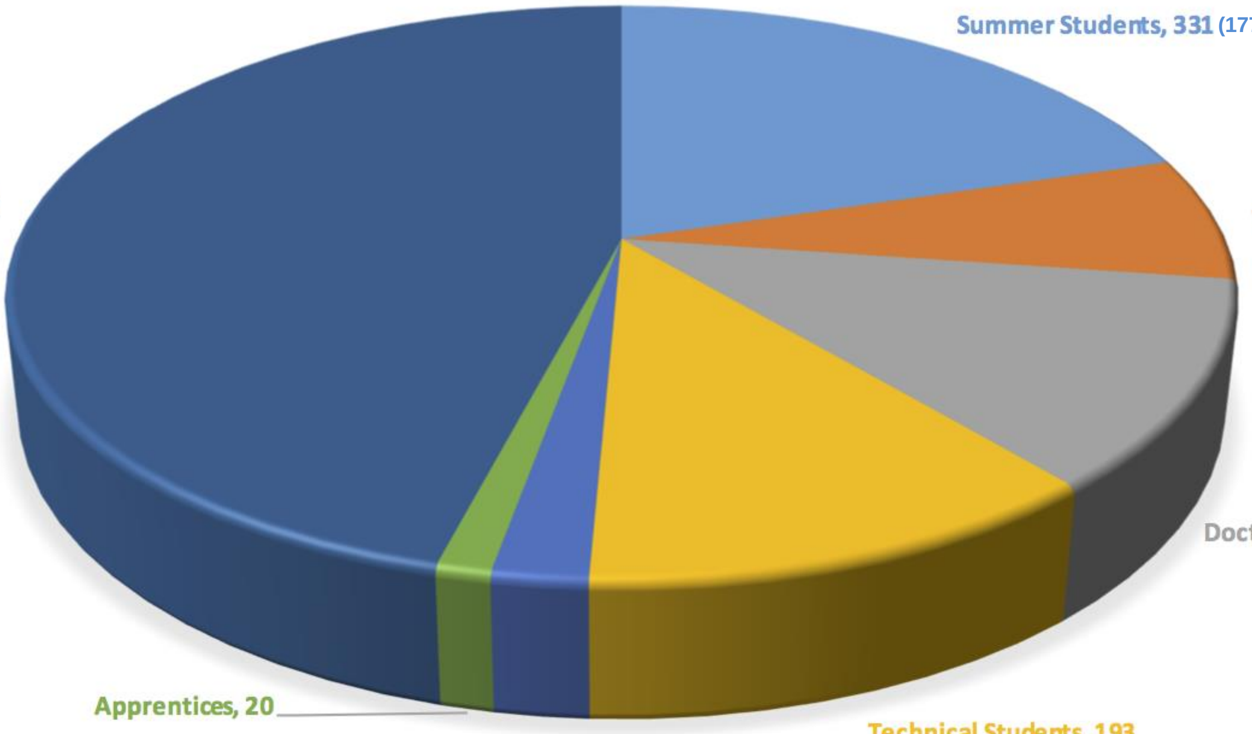
Female scientists: 12% staff (~ 4% in 1995)→ 23% fellows

Senior staff: ~23% of M population (was ~ 23% in 1995), ~13% of F population (was ~ 3% in 1995)

Personnel (II)

Training and education: one of our core missions

2016 statistics



~ 1600 young people trained at CERN every year

Other (recent) news

(Associate) Membership and geographical enlargement

22 Member States:

Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom

7 Associate Member States:

Cyprus*, India, Pakistan, Serbia*, Slovenia*, Turkey, Ukraine

* in the pre-stage to Membership

6 Observers:

Japan, Russia, USA, European Union, JINR, UNESCO

~50 ICA (International Cooperation Agreements):

with non-Member States, some with countries with developing particle physics communities (CERN mission is also to help build capacity and foster growth of particle physics worldwide).

Last one signed with Nepal.

Red: joined since last Plenary ECFA (November 2016)

Mini-ATTRACT Phase-1 funded by H2020

ATTRACT:
Initiative to help develop next generation detection and imaging technologies, bringing together research community (which provides most stringent requirements) and industry (especially SMEs)
→ foster multidisciplinary cross-fertilization of new concepts, ideas, prototypes.

Promoting organisations: CERN, EMBL, ESO, ESRF, European XFEL, ILL, Aalto University, EIRMA (European Industrial Research Management Association), ESADE Business School

Application for funding from FP9 (Maxi-ATTRACT), with "prototypes" (Mini-ATTRACT) in H2020

Mini-ATTRACT Phase-1: applied in March for call INFRA-INNOV-01-2017: **20 M€** for single project
→ **successful**
18 M€ will be allocated to 180 innovative projects selected by independent scientific committee of world experts (through a competitive call expected beg 2018)
→ the 180 selected projects will receive 100k€ each → progress monitored after 1 year

Mini-ATTRACT Phase-2 (~2020): submission to a future expected H2020 call: if successful, best projects out of the 180 will receive additional funding (expect ~3-4 M€ to ~6-7 selected projects).

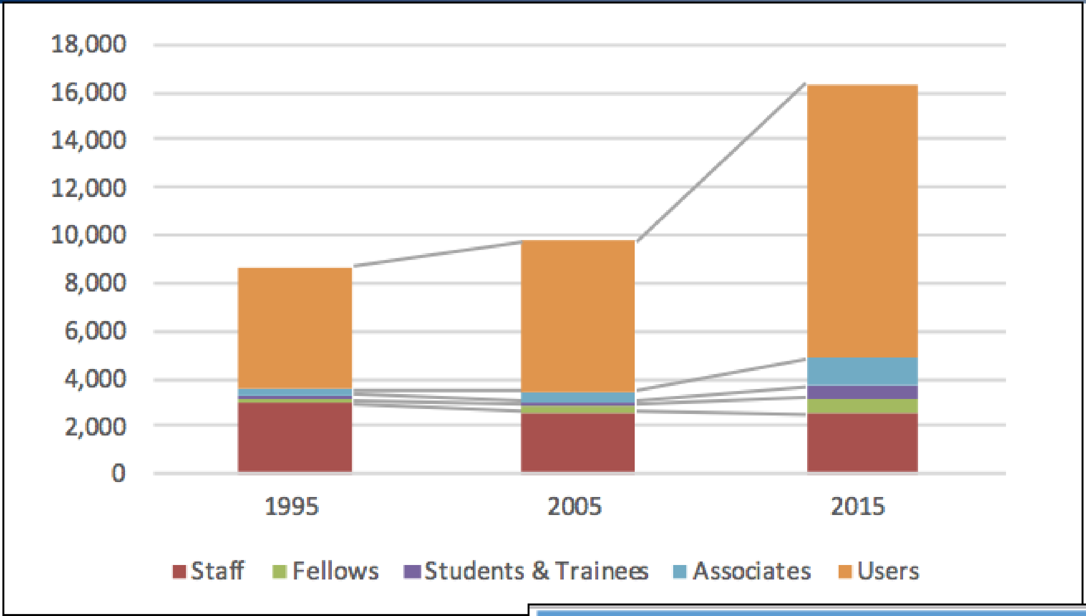
Great opportunity for HEP community to get (competitive) additional resources to explore new concepts and technologies and to benefit from manufacturing know-how from industry.


LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
ALICE
CMS
LHC 27 km
CERN

THANK YOU!

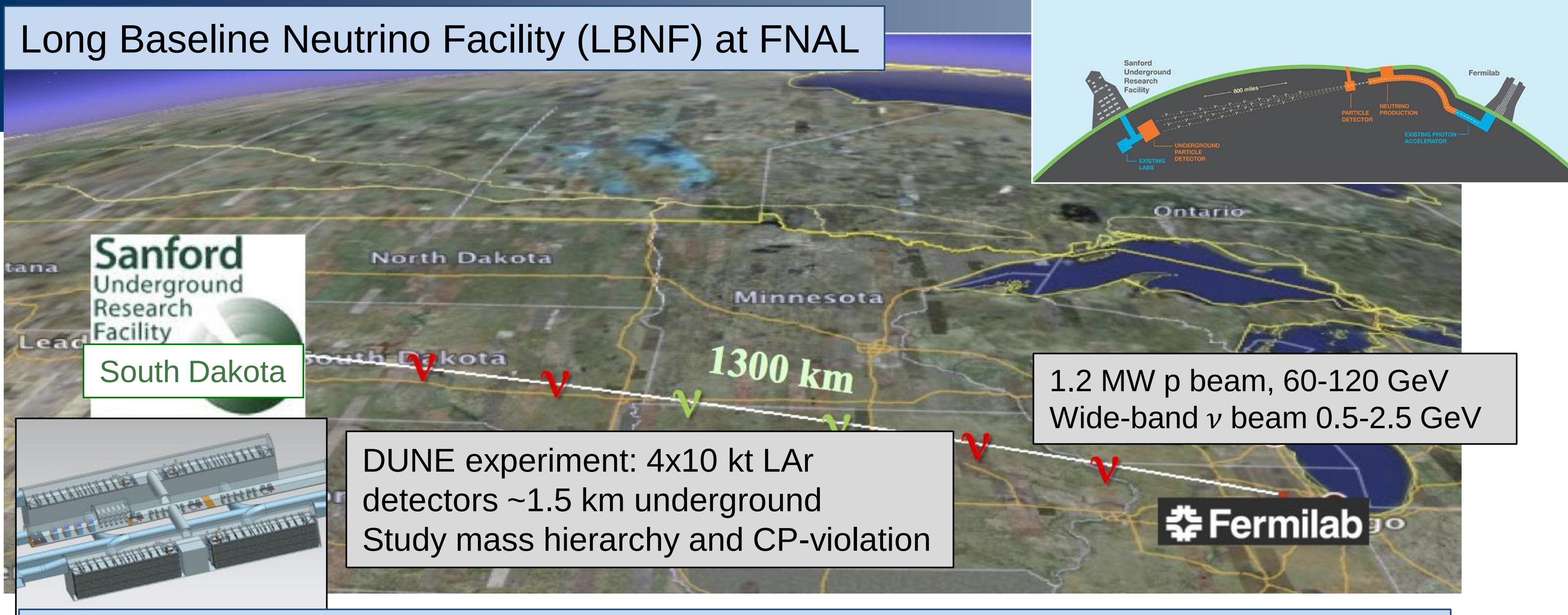
SPARES

Personnel: evolution of various categories with time



Number of heads on 31 December	1995	2005	2015
Staff	2,938	2,635	2,531
Fellows	174	246	645
Students & Trainees	236	180	539
Associates	167	397	1,156
Users	5,186	6,333	11,454
Total	8,701	9,791	16,325
Users/staff	1.8	2.4	4.5
Fellows, students, trainees /staff	0.14	0.15	0.47
All MPs/staff	3.0	3.7	6.5

Long Baseline Neutrino Facility (LBNF) at FNAL



Sanford Underground Research Facility

South Dakota

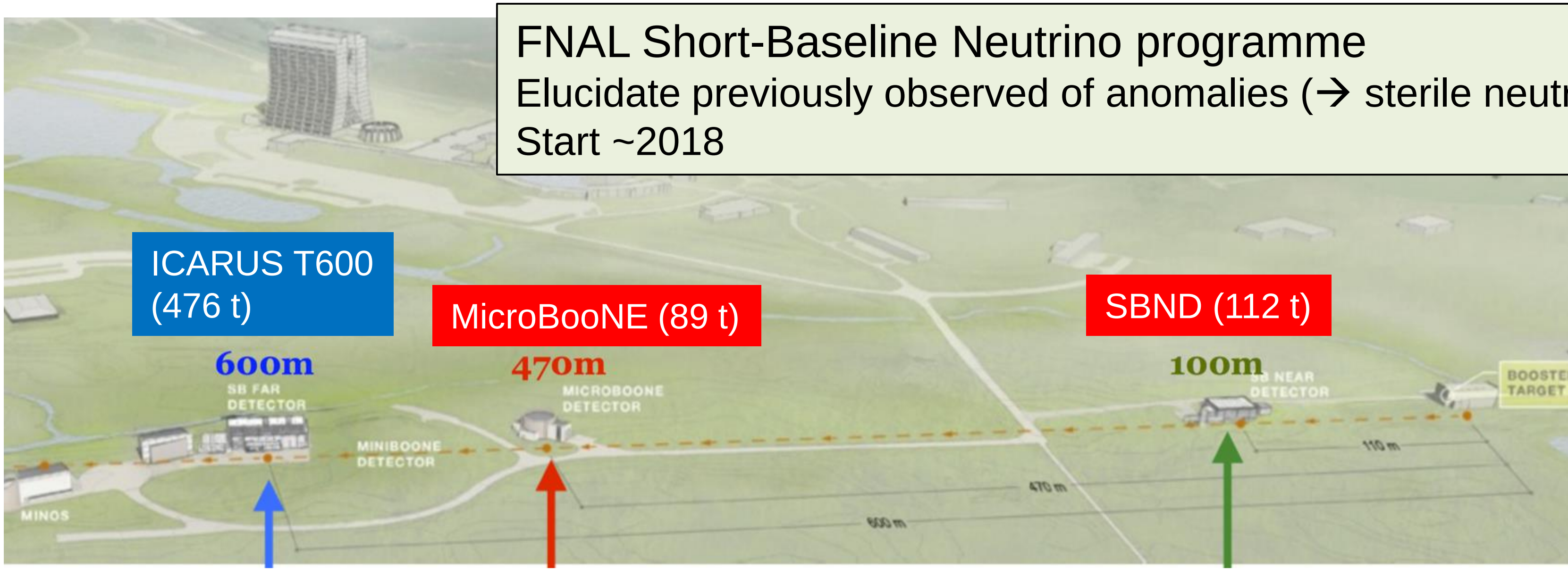
DUNE experiment: 4x10 kt LAr detectors ~1.5 km underground
Study mass hierarchy and CP-violation

1.2 MW p beam, 60-120 GeV
Wide-band ν beam 0.5-2.5 GeV

Far site construction started 2017, 1st detector installed ~2022, beam from FNAL ~ 2026

FNAL Short-Baseline Neutrino programme

Elucidate previously observed of anomalies (→ sterile neutrinos?)
Start ~2018



ICARUS T600 (476 t)

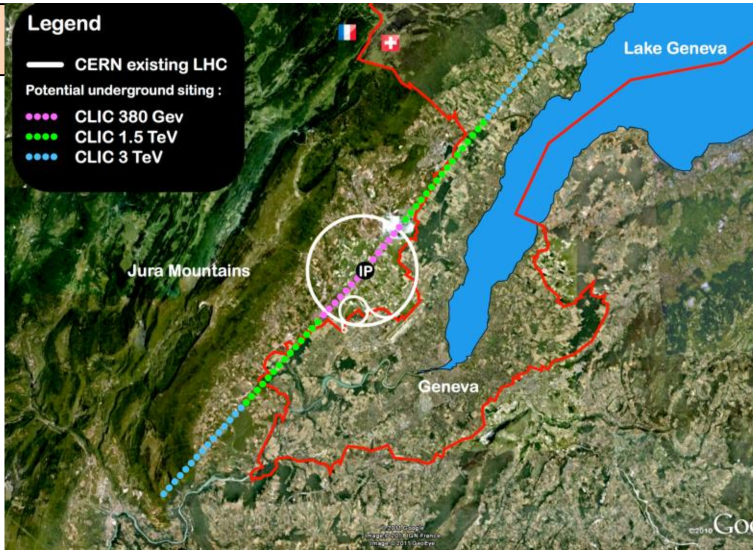
MicroBooNE (89 t)

SBND (112 t)

Compact Linear Collider (CLIC)

Most recent plan: start at √s=380 GeV for H and top physics

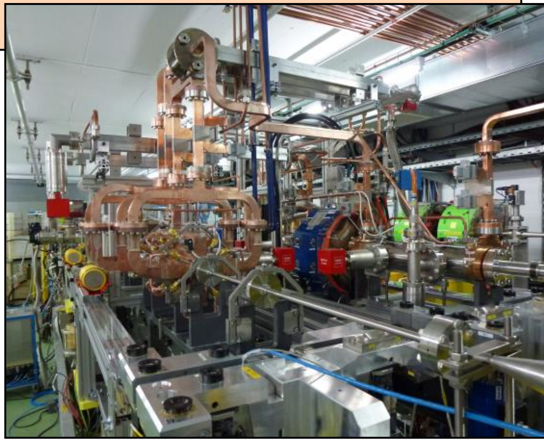
Parameter	Unit	380 GeV	3 TeV
Centre-of-mass energy	TeV	0.38	3
Total luminosity	$10^{34}cm^{-2}s^{-1}$	1.5	5.9
Luminosity above 99% of √s	$10^{34}cm^{-2}s^{-1}$	0.9	2.0
Repetition frequency	Hz	50	50
Number of bunches per train		352	312
Bunch separation	ns	0.5	0.5
Acceleration gradient	MV/m	72	100



Physics goals:

- ❑ Direct discovery and precise measurements of new particles (coupling to Z/γ*) up to m~ 1.5 TeV
- ❑ Indirect sensitivity to E scales Λ ~ O(100) TeV
- ❑ Measurements of "heavy" Higgs couplings: ttH to ~ 4%, HH ~ 10%

Test of CLIC two-beam acceleration concept at CTF3 ended in 2016
→ 80-220 MeV LINAC now available for users as standalone facility
(CLEAR: CERN Linear Electron Accelerator for Research)

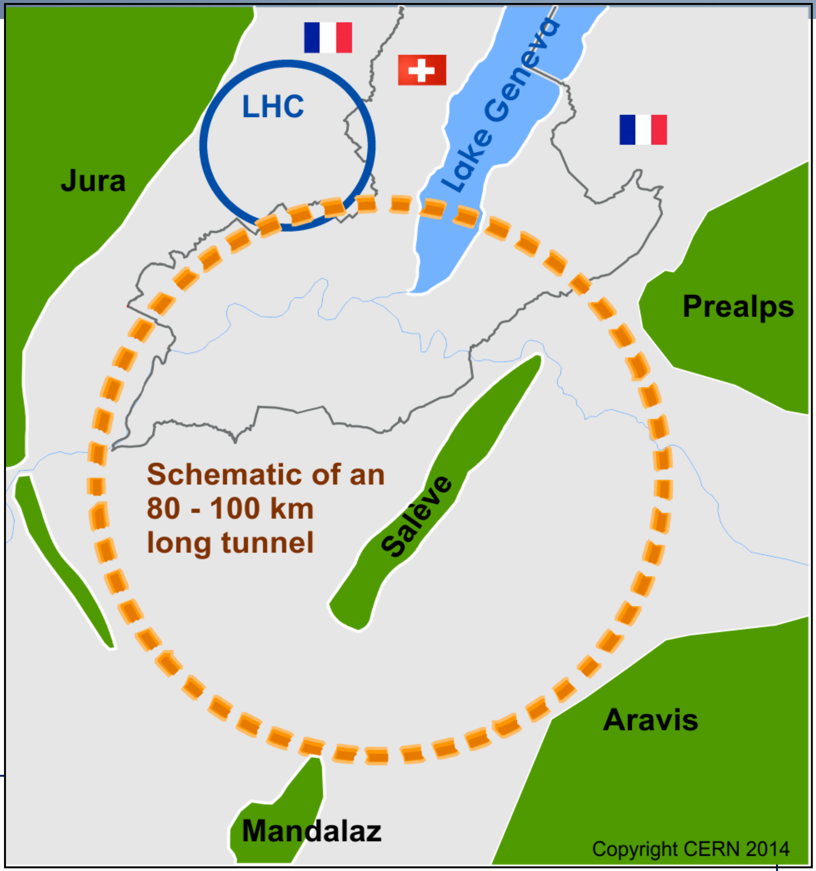


CLIC construction could technically start ~2025, duration ~6 years for √s ~ 380 GeV (11 km Linac) → physics could start by ~2035
Note: 3 TeV needs 50 km accelerator

Future Circular Colliders (FCC)

Conceptual design study of a ~ 100 km ring:

- **pp collider (FCC-hh)**: ultimate goal
  $\sqrt{s}$~ 100 TeV, L~2x10^{35}, 4 IP, ~20 ab^{-1}/expt
- **e^+e^- collider (FCC-ee)**: possible first step
  $\sqrt{s}$~ 90-350 GeV, L ~ 200-2 x 10^{34}; 2 IP
- **pe collider (FCC-he)**: option
  $\sqrt{s}$~ 3.5 TeV, 1 IP, L~10^{34}



Also part of the study: HE-LHC**:** FCC-hh dipole technology (~16 T) in LHC tunnel → $\sqrt{s}$ ~ 28 TeV

FCC-hh: a ~100 TeV pp collider is expected to:

- explore directly the 10-50 TeV E-scale
- conclusive exploration of EWSB dynamics
- say the final word about heavy WIMP dark matter

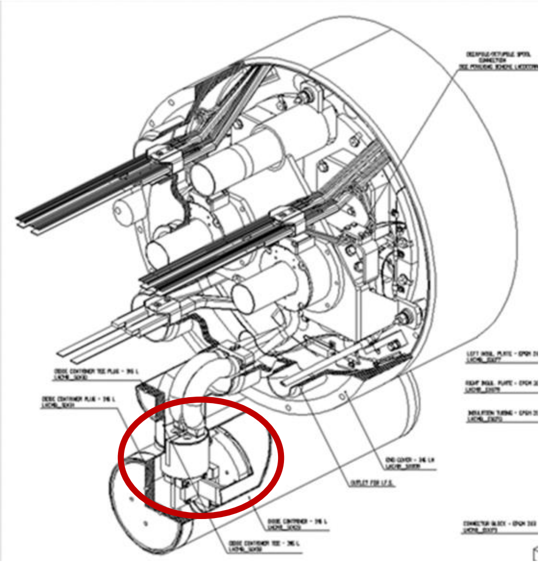
FCC-ee: 90-350 GeV

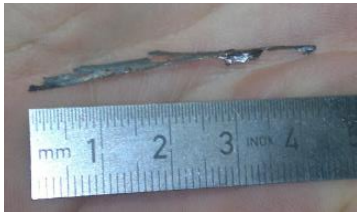
- measure many Higgs couplings to few permill
- indirect sensitivity to E-scale up to O(100 TeV) by improving by ~20-200 times the precision of EW parameters measurements, ΔM_W < 1 MeV, Δm_{top} ~ 10 MeV

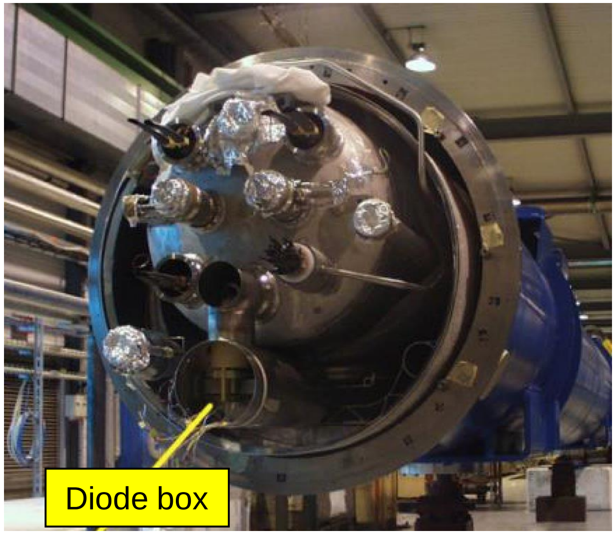
Consolidation of LHC cold bypass diodes in LS2

Each LHC dipole (1232 in total) equipped with cold bypass diode for (fast) extraction of the current in case of quench

Two shorts to ground during magnet training in 2015 and 2016 campaigns due to metallic dust transported by He flow following a quench and falling by gravity inside diode box







Both shorts successfully burned with electrical discharge from a capacitor. BUT: rudimentary method → if it fails, need to warm up → ~3 months stop of LHC

Risk of such shorts every time magnets are retrained; also major obstacle to reach 7 TeV
Solution: improve diode electrical insulation → need warm up and opening of each box
→ unique opportunity in LS2 as little work in LHC tunnel (most of work in injectors for LIU)