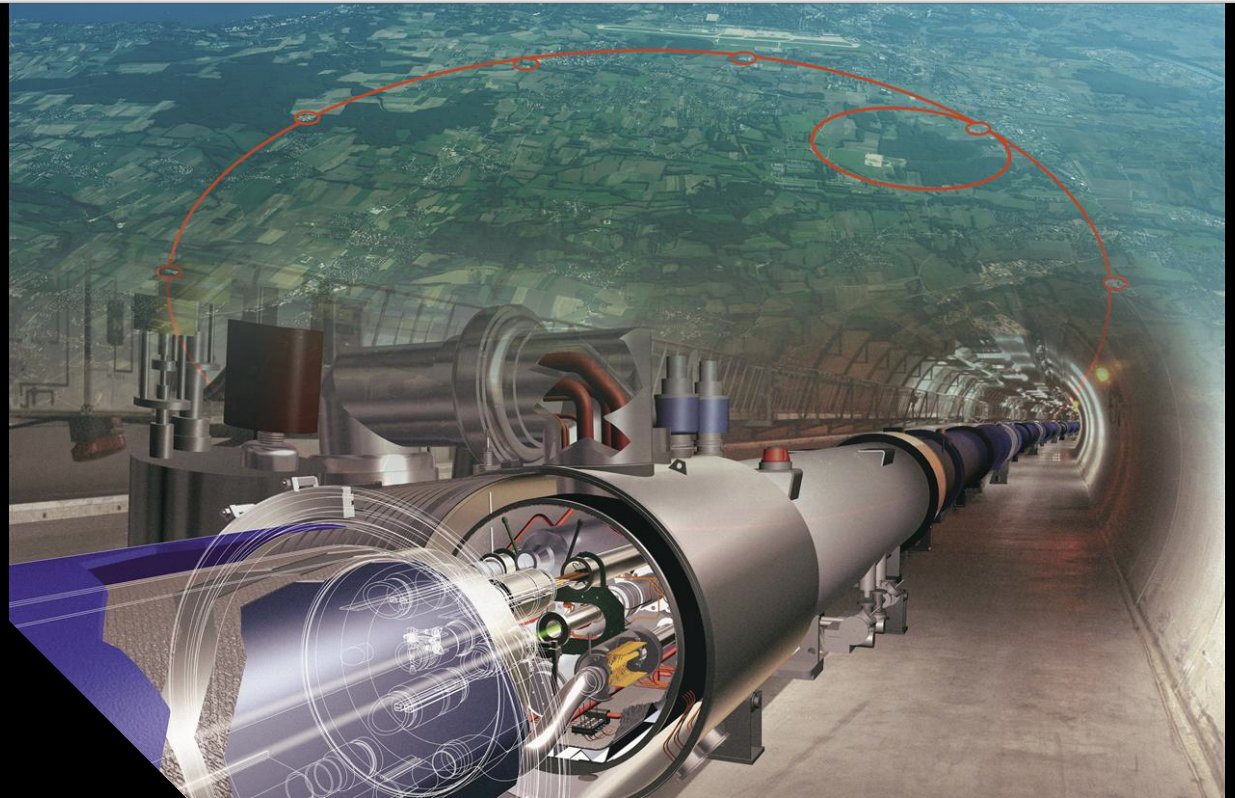
Particle Physics Report from the European Region

Jorgen D'Hondt
ECFA chair-elect

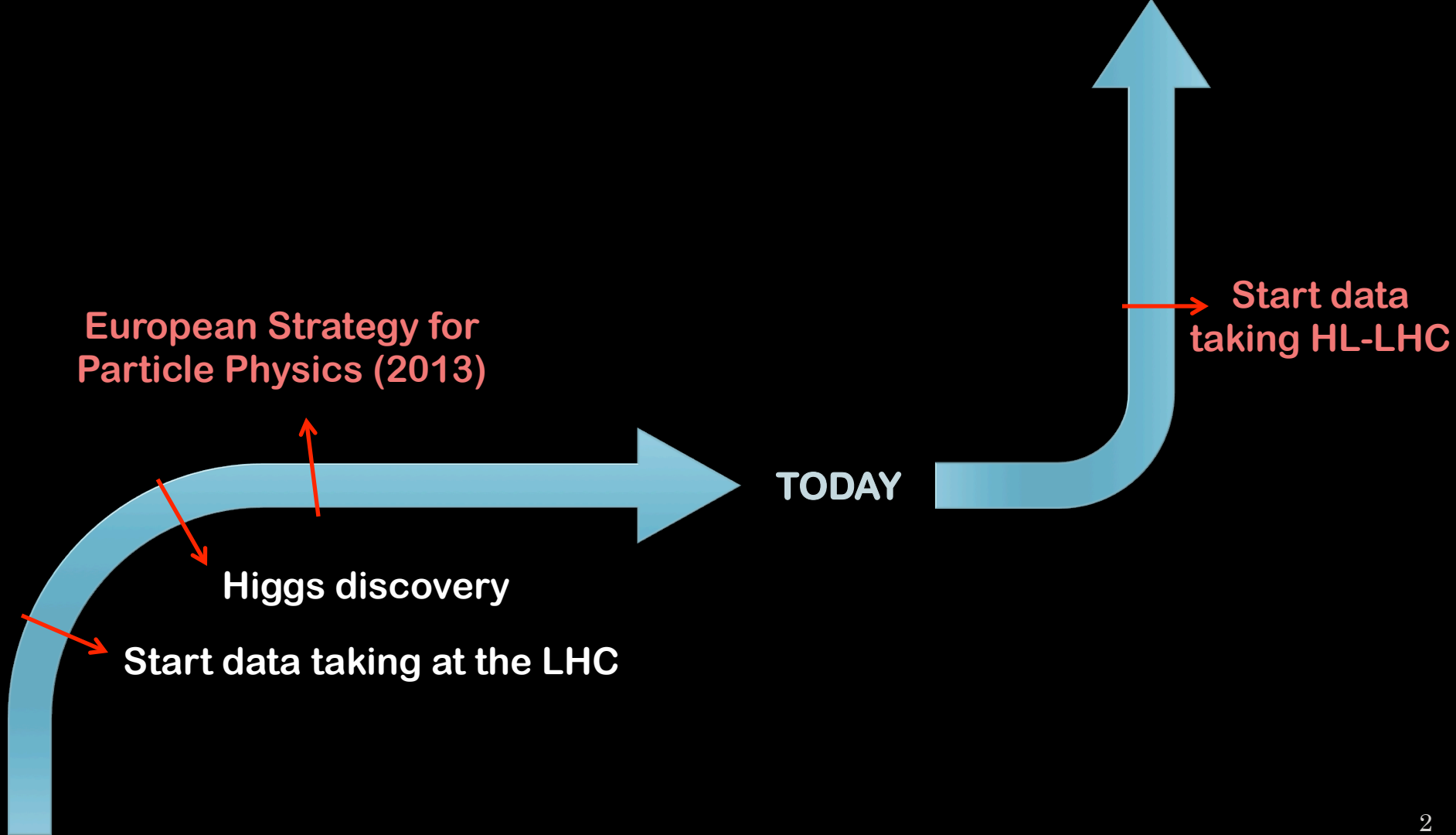
ICFA 2017 Seminar
6-9 November
Ottawa, Canada



HEP@VUB
BRUSSELS

VUB

iihe
BRUXELLES BRUSSEL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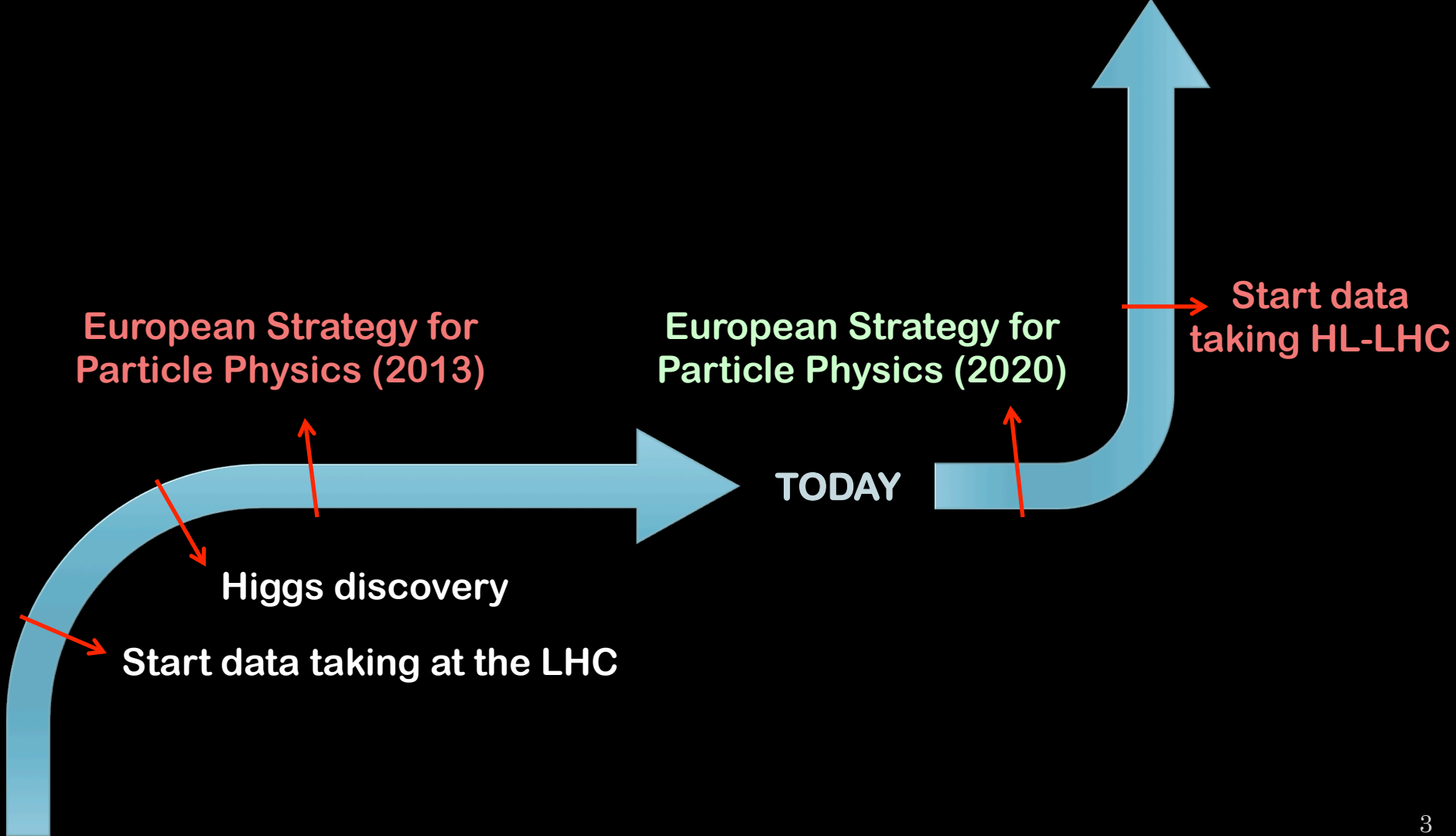
taking HL-LHC
TODAY
Higgs discovery
Start data taking at the LHC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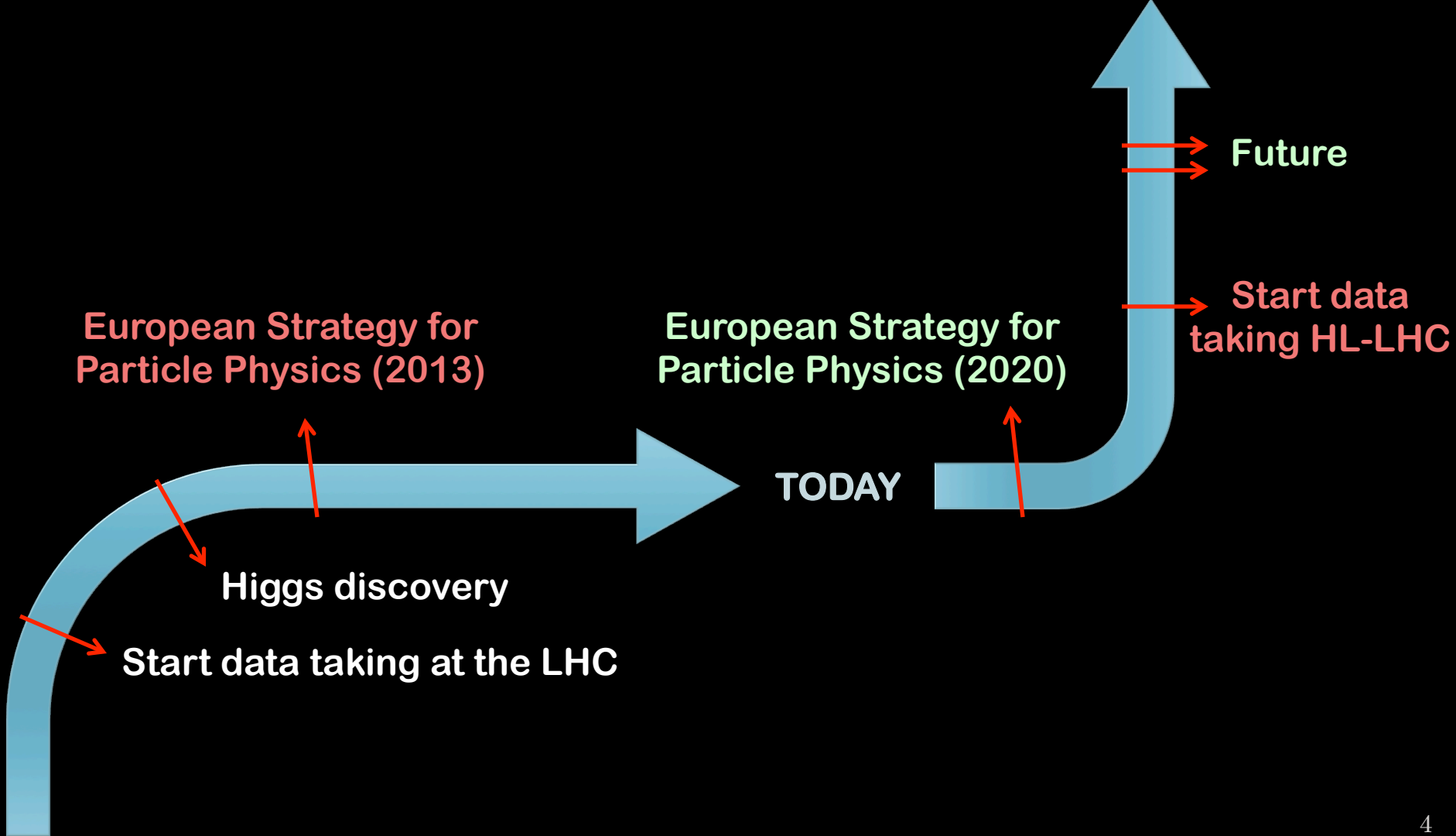
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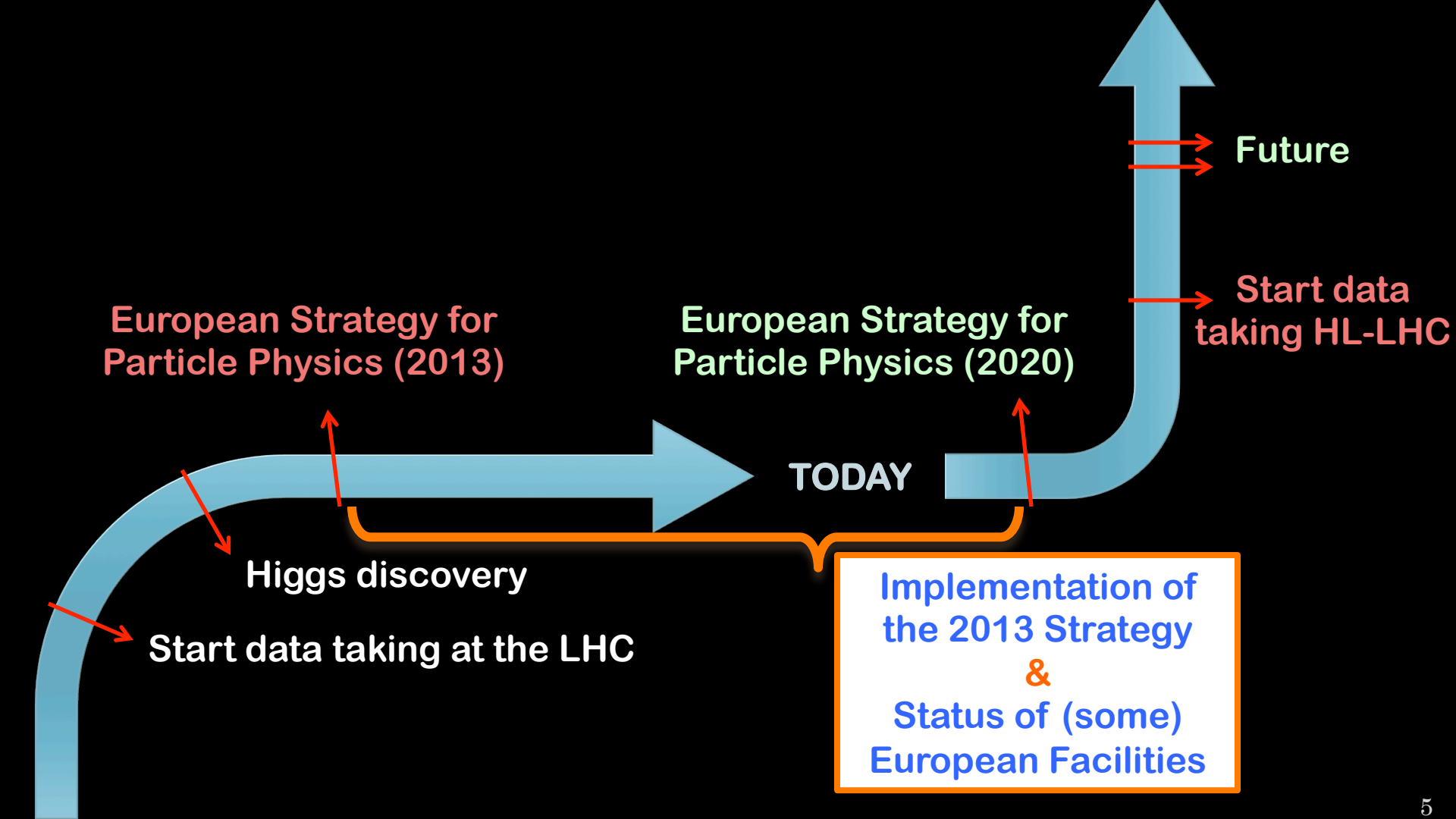
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Implementation of the 2013 Strategy
&
Status of (some) European Facilities


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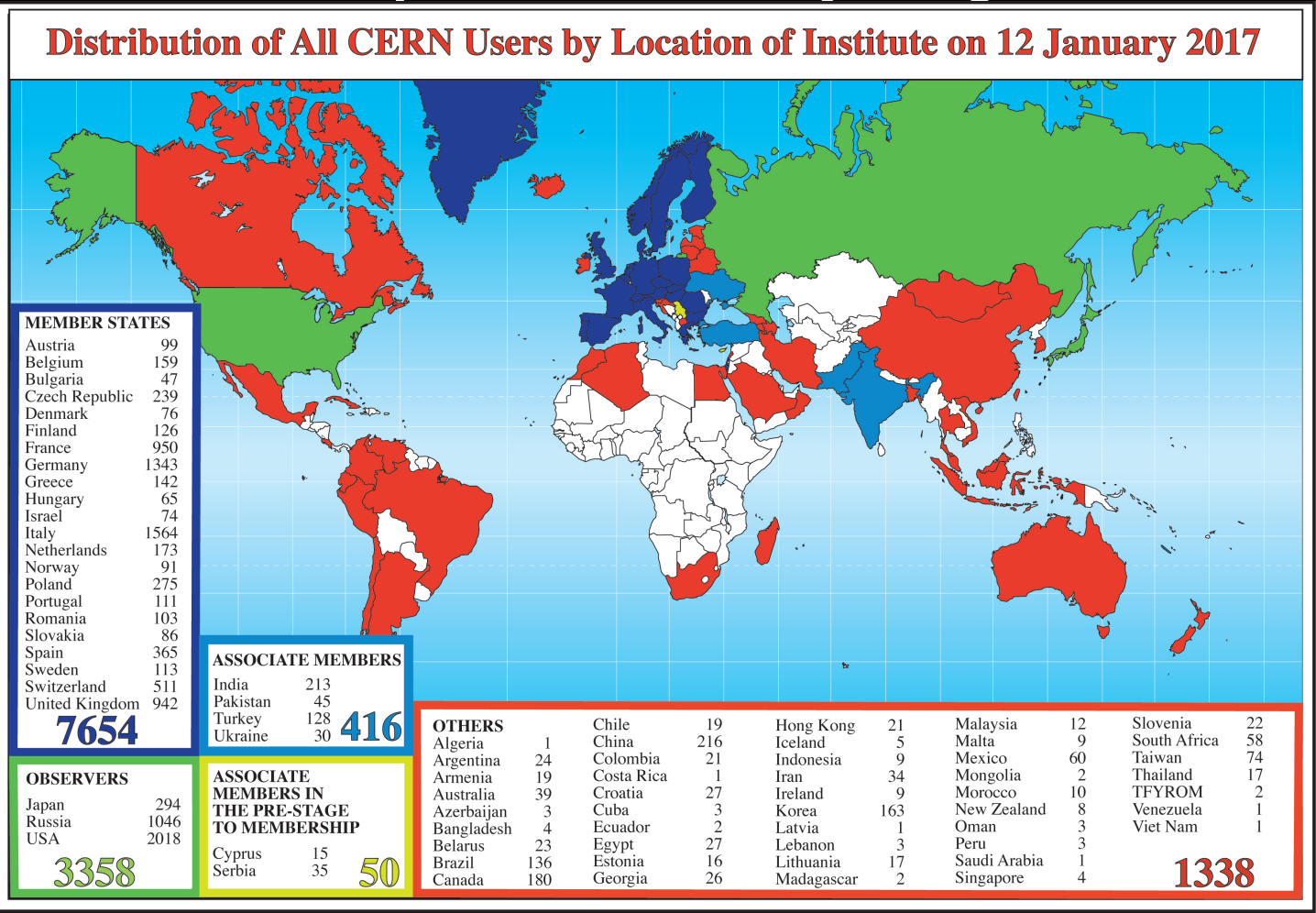
Implementation of the 2013 Eur. Strategy for Particle Physics

A regional strategy implemented in a worldwide context

Key information from the presentation of the CERN DG (F. Gianotti) to Council, Sept 2017

Approved by Council, March 2014:
"… since the Director-General has the mandate to execute all the Council's decisions, it follows that the Director-General should also be responsible for the implementation of the European Strategy for Particle Physics."

CERN, the European Laboratory for global collaboration



12816 users

60% from member states

European institutions are involved in Particle Physics experiments worldwide

Implementation of the 2013 Eur. Strategy for Particle Physics

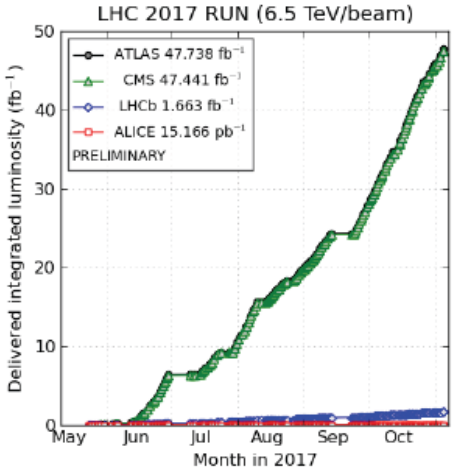
Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities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

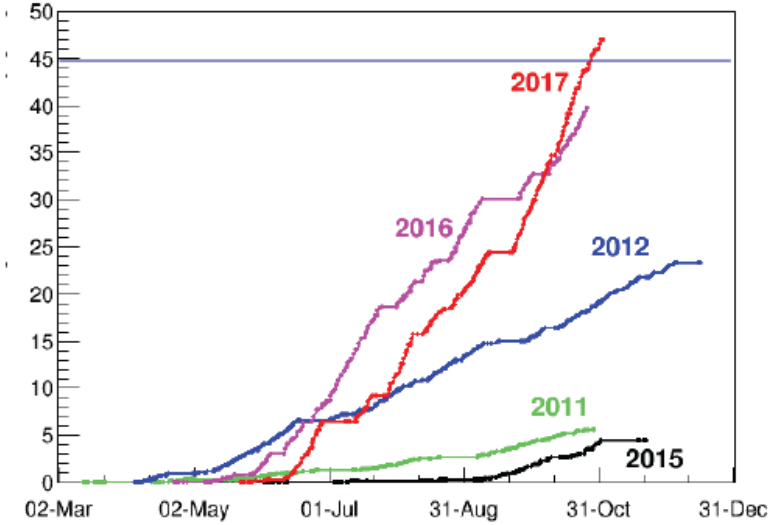
- Running at 13 TeV, beyond design luminosity, goal is 300/fb by end of Run3 (2023)
- HL-LHC approved by Council in June 2016, goal is 3000/fb by ~2037
- LIU (injector upgrade), HL-LHC and detector upgrades on schedule for installation in LS2 and LS3
- Expect to move to 14 TeV after LS2; exploring possibility to push energy to "ultimate" value (15 TeV) in Run4++

information from the ESPP implementation report of CERN DG at the Council meeting of Sept 2017

CERN and the LHC – integrated performance (up to 4th November)

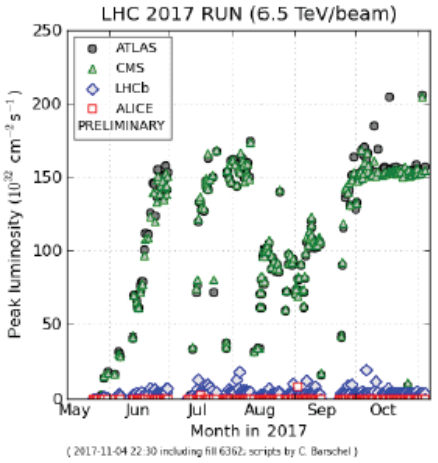
2017 goal:
45 fb^{-1}

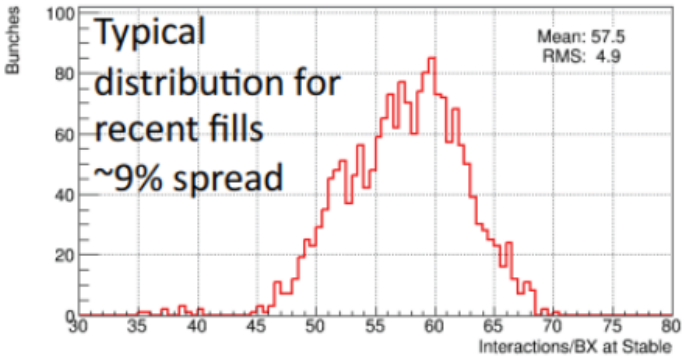




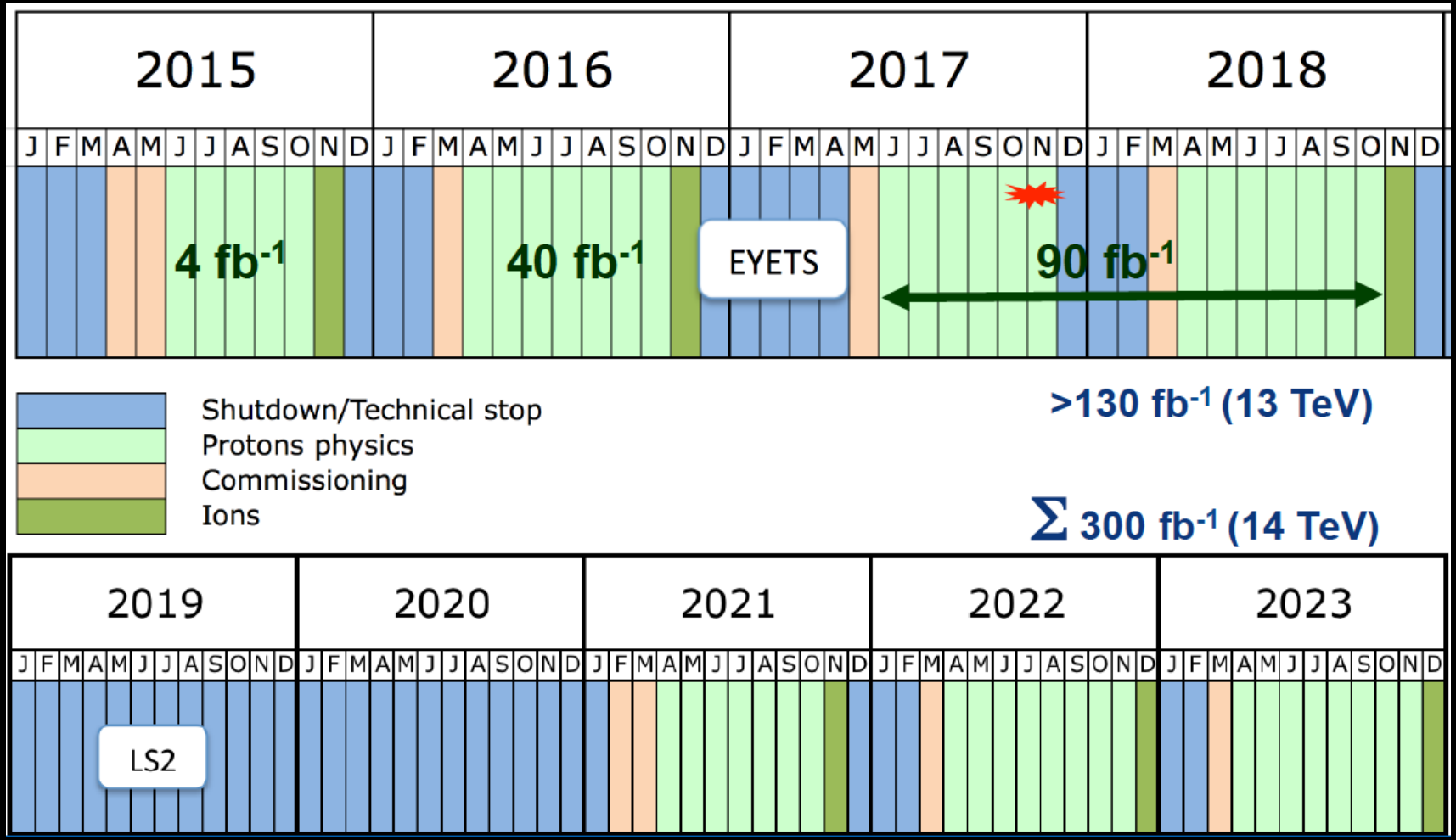
Peak luminosity
2.2 10^{34} cm^{-2} s^{-1}

With luminosity levelling at
1.5 10^{34} cm^{-2} s^{-1}

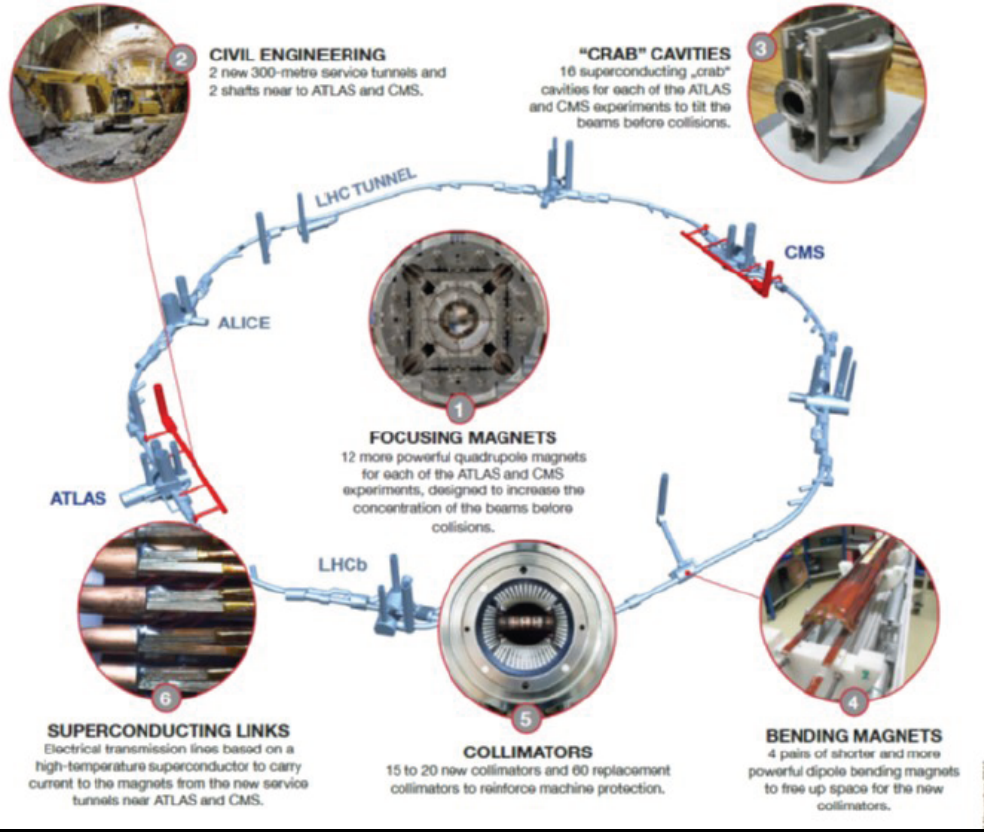




CERN and the LHC – Run 2 and 3



CERN and the High-Luminosity LHC: 300/fb → 3000/fb



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

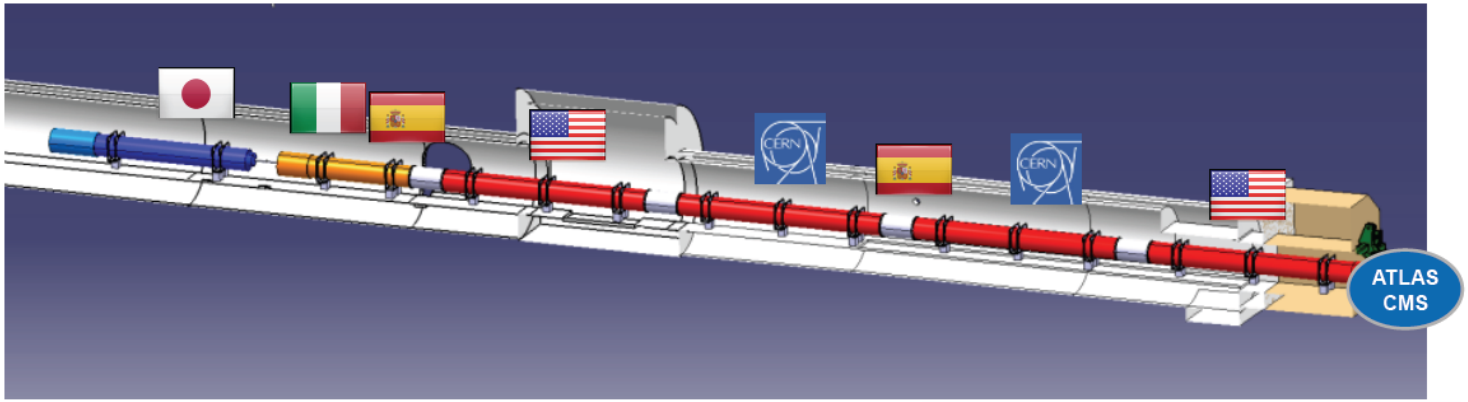
Formal approval by CERN Council (June 2016)

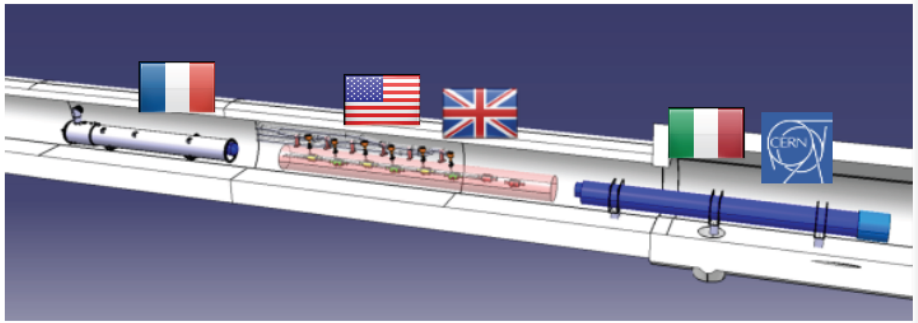
Cost to Completion : 950 MCHF (material)

CERN and the High-Luminosity LHC: construction phase

In-kind contributions and collaborations for design, prototypes, production and tests

Discussions are ongoing with other countries, e.g India, Canada, Russia, China,...





Q1-Q3 : R&D, Design, Prototypes and in-kind **USA**
D1 : R&D, Design, Prototypes and in-kind **JP**
MCBX : Design and Prototype **ES**
HO Correctors: Design and Prototypes **IT**
Q4 : Design and Prototype **FR**

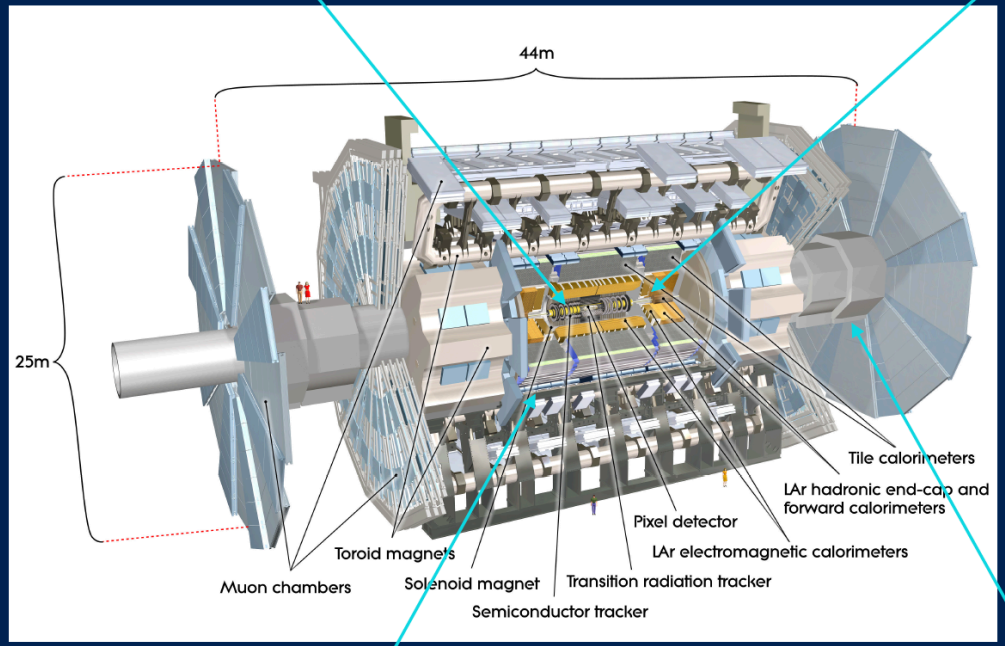
CC : R&D, Design and in-kind **USA**

CC : R&D and Design **UK**

ATLAS – Upgrade Phase II

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

HIGH GRANULARITY TIMING DETECTOR (HGTD) IN FORWARD REGION (OPTION)



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)

Technical Design Reports (TDR) under review or being prepared:

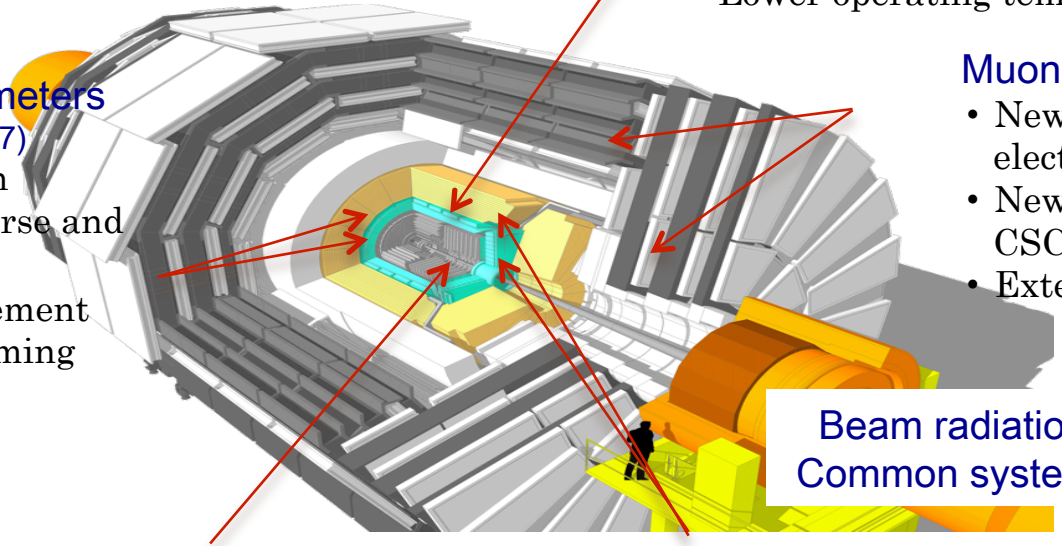
- Silicon Tracker: strip part approved, pixel part to be submitted by 15 Dec.
- Muon and Calorimeter (Liquid Argon and Tile) TDRs under review
- TDAQ TDR to be submitted by 15 Dec. 2017

CMS – Upgrade Phase II

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 (TDR submitted)
- New FE/BE electronics for full granularity readout at 40 MHz - with improved time resolution
- Lower operating temperature (8◦)

New Endcap Calorimeters (to be submitted Nov 2017)
- Rad. tolerant - High granularity transverse and longitudinal
- 4D shower measurement including precise timing capability



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

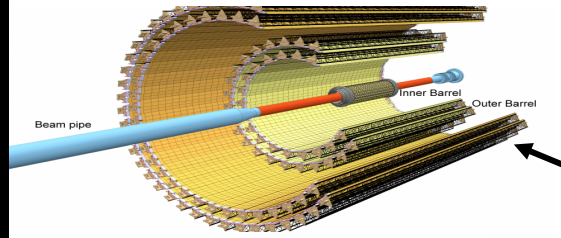
Beam radiation and luminosity
Common systems and infrastructure

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

MIP precision Timing Detector (to be submitted Nov 2017)
- Barrel layer: Crystal + SiPM
- Endcap layer: Low Gain Avalanche Diodes

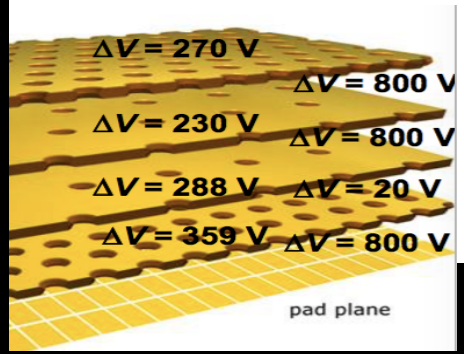
ALICE – Upgrade LS2 – *study Quark-Gluon Plasma formed in nuclear collisions*

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



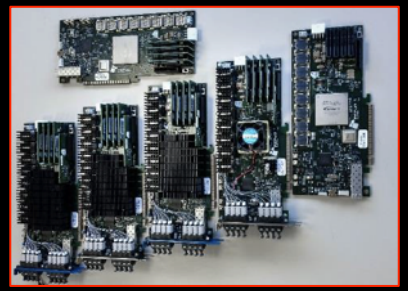
- Low-p_T heavy-flavour mesons/baryons: characterize QCD with heavy quarks
- Low-p_T charmonia: c-cbar melting and re-generation in deconfined system
- Low-mass di-electrons: QGP thermal radiation via virtual photons

LHCb – Upgrade LS2

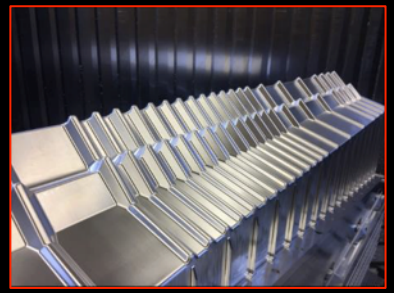
Construction well advanced
aim at installation in 2019

- 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

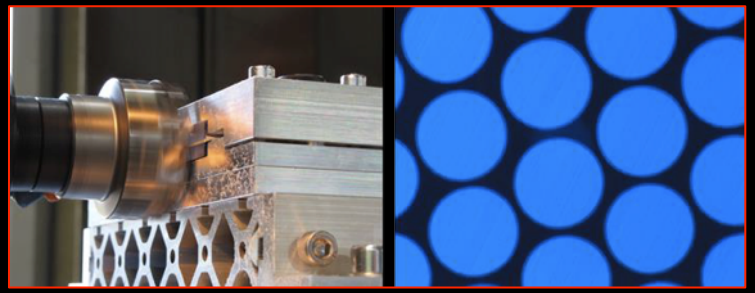
Prototypes of DAQ board (PCIe40)

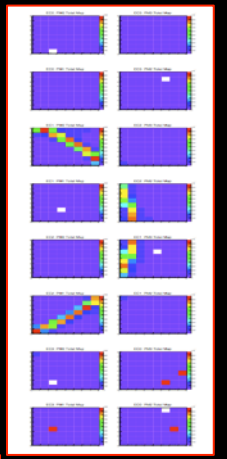


VELO RF-foil (250 um thick machined aluminum foil)

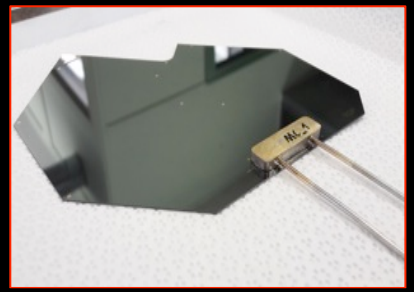


Machining and light scan of the scintillating fiber mats for the fibre tracker

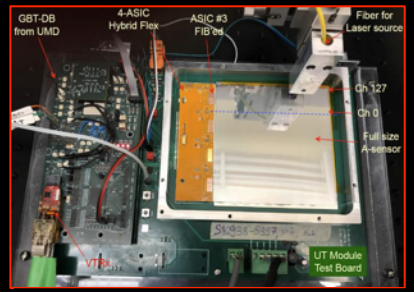




Cherenkov ring from a full RICH MaPMT module

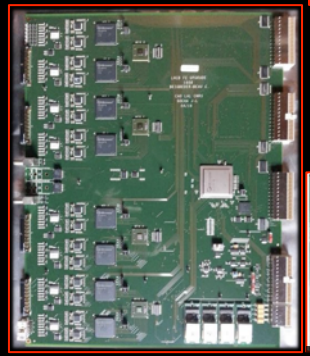


Si mchannel cooling plate for VELO with soldered connector



Upstream Tracker silicon sensor module under test

First scintillating fibre modules arriving at CERN



Calorimeter front-end board

Muon system readout ASIC

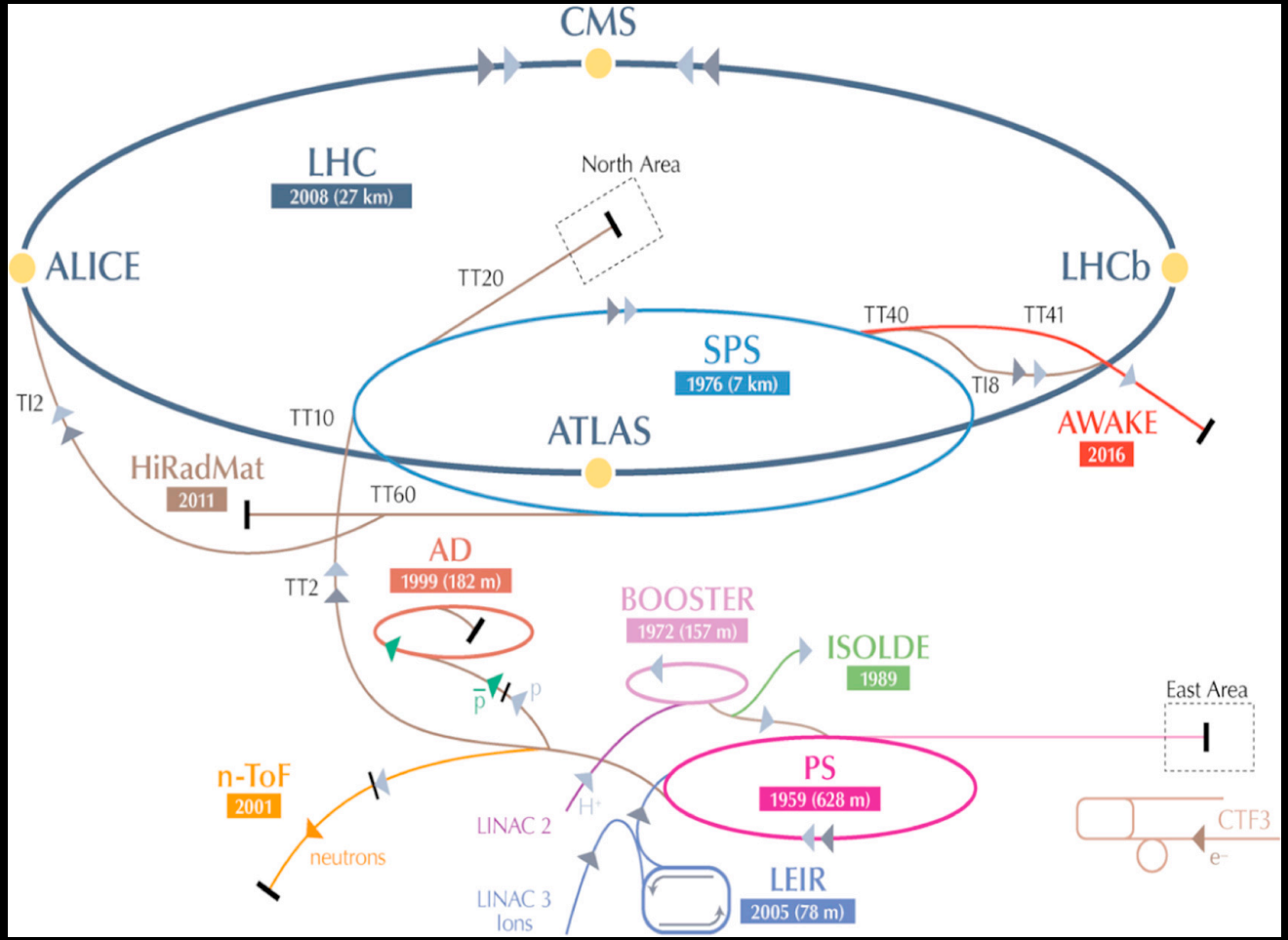
Implementation of the 2013 Eur. Strategy for Particle Physics

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.

- CLIC working on implementation plan & cost reduction as input to ESPP; CTF3 completed
- FCC design studies started in 2014 → CDR in 2018 as input to ESPP
- Superconducting magnets being developed mainly within HL-LHC and FCC projects
- Efforts on SCRF intensified (HIE-ISOLDE, LHC spares, HL-LHC crab cavities, etc.)
- New acceleration techniques being explored: AWAKE
- Strong collaborations and complementarity with labs and institutes worldwide (CEA, CIEMAT, DESY, INFN, RAL, FNAL, KEK, etc.)

information from the ESPP implementation report of CERN DG at the Council meeting of Sept 2017

Accelerator R&D – Advanced Proton Driven Plasma Wakefield Acceleration Experiment (AWAKE)



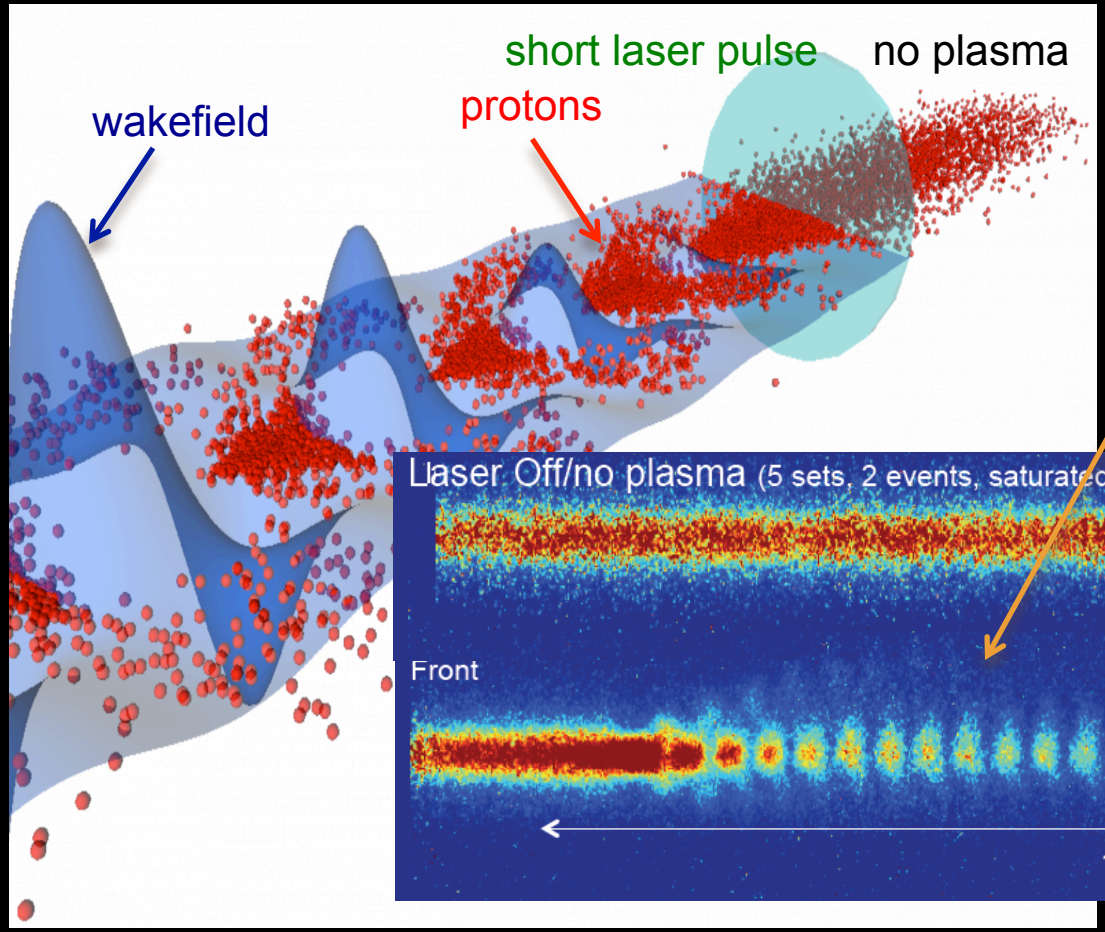
The AWAKE project is a demonstrator experiment for plasma wakefield acceleration.

The objective is to accelerate an electron beam to few GeV in a 10m plasma cell using 400 GeV proton beams from the Super Proton Synchrotron at CERN.

AWAKE Collaboration:
16 institutes worldwide

Accelerator R&D – Advanced Proton Driven Plasma Wakefield Acceleration Experiment (AWAKE)

Patric Muggli, SPSC presentation, Oct 2017
preliminary results



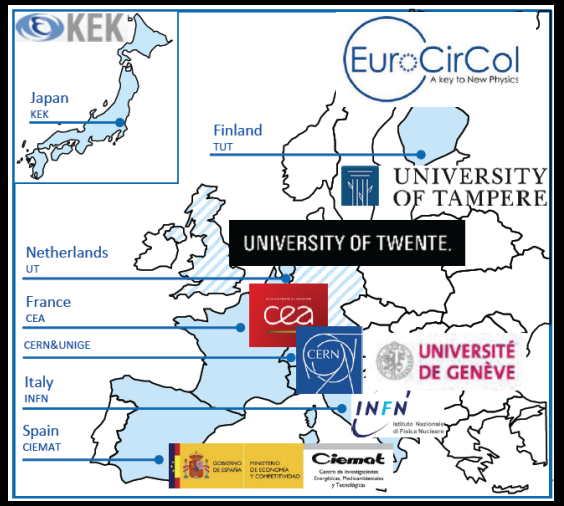
Clear observation of the modulation

Soon start with electron acceleration

SC Magnet R&D – *16 T magnets would allow doubling the energy of the LHC machine (HE-LHC)*

EuroCirCol WP5 (until 2019)

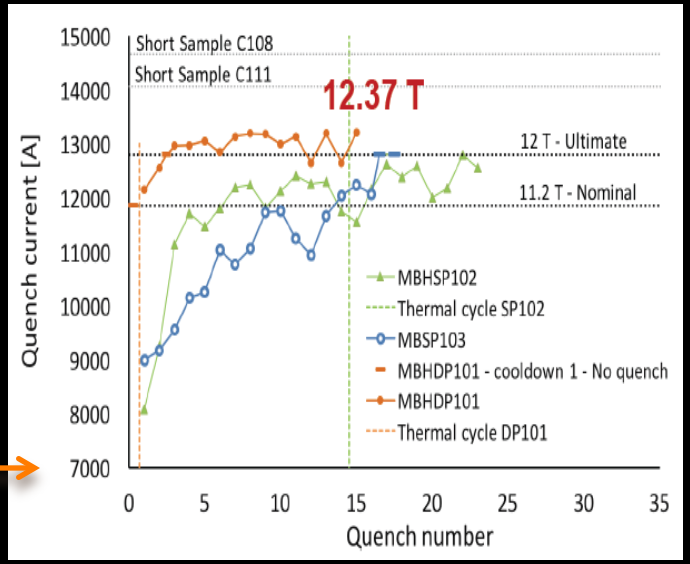
Feed the FCC CDR with a baseline design and a cost model for 16 T magnets

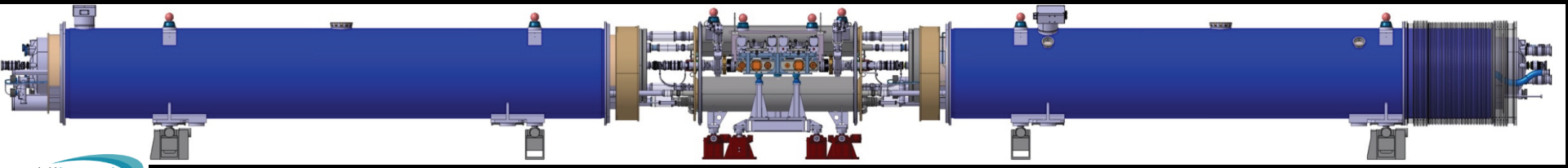


HiLumi LHC

To make space for the new HL-LHC collimators, replace a standard Dipole by a pair of shorter 11 T dipoles producing the same integrated field

demonstrator short dipoles perform well





HiLumi HL-LHC PROJECT

Implementation of the 2013 Eur. Strategy for Particle Physics

There is a strong scientific case for an electron-positron collider, … Europe looks forward to a proposal from Japan to discuss a possible participation.

- Many ongoing collaborations and synergies CLIC-ILC on accelerators (beam dynamics, damping rings, beam delivery systems, etc.) and detectors (CERN Linear Collider Detector group)
- CERN-KEK cooperation agreements (e.g. accelerator studies at ATF-KEK); CERN's help for civil engineering and geological studies of tunnel layout in Japan
- ILC action plan in Europe being prepared and presented to Council
- Waiting for a statement from the Japanese Government for their willingness to host ILC before end of 2018 (to figure in update of European Strategy)

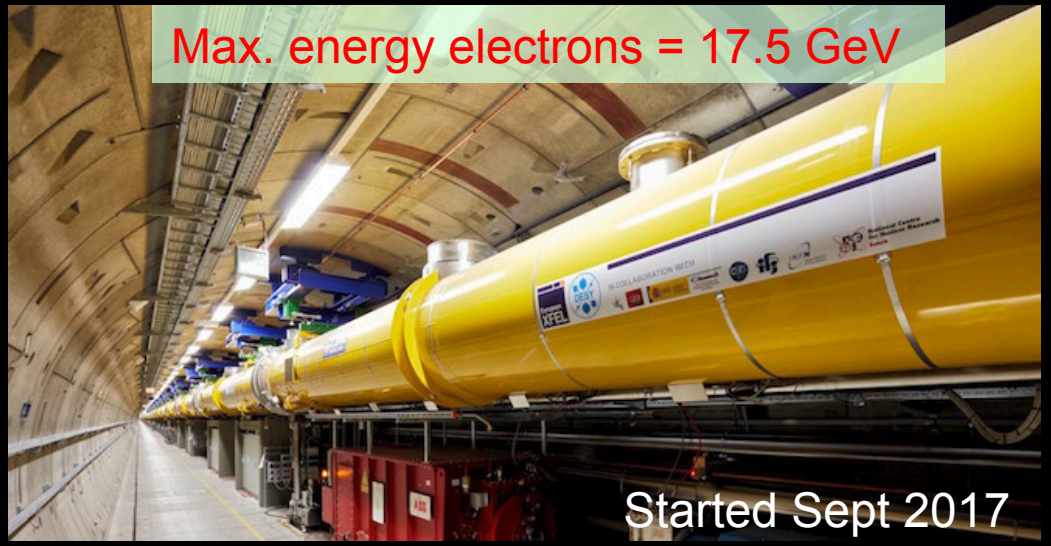
information from the ESPP implementation report of CERN DG at the Council meeting of Sept 2017

The European XFEL at DESY

The 3.4 km long European XFEL generates extremely intense X-ray flashes to be used by researchers from all over the world.

Construction cost 1.2 B Euro (58% from Germany & various in-kind contributions).

World's longest SC linear accelerator (1.7 km) providing the energy needed to generate the XFEL's X-ray flashes.



First mass production in industry of SC radio frequency TESLA technology, essential towards the ILC (from about 100 accelerator modules at the XFEL to about 2000 at ILC).

XFEL : 80% of the cavities reach a gradient of 33 MV/m
ILC : 90% of the cavities need a gradient of 35 MV/m

Denis Kostin @ LCWS2017, Oct 24

This demonstrates the goal for the ILC is potentially achievable, and the XFEL project established teams of experienced researchers and industrial partners.

Implementation of the 2013 Eur. Strategy for Particle Physics

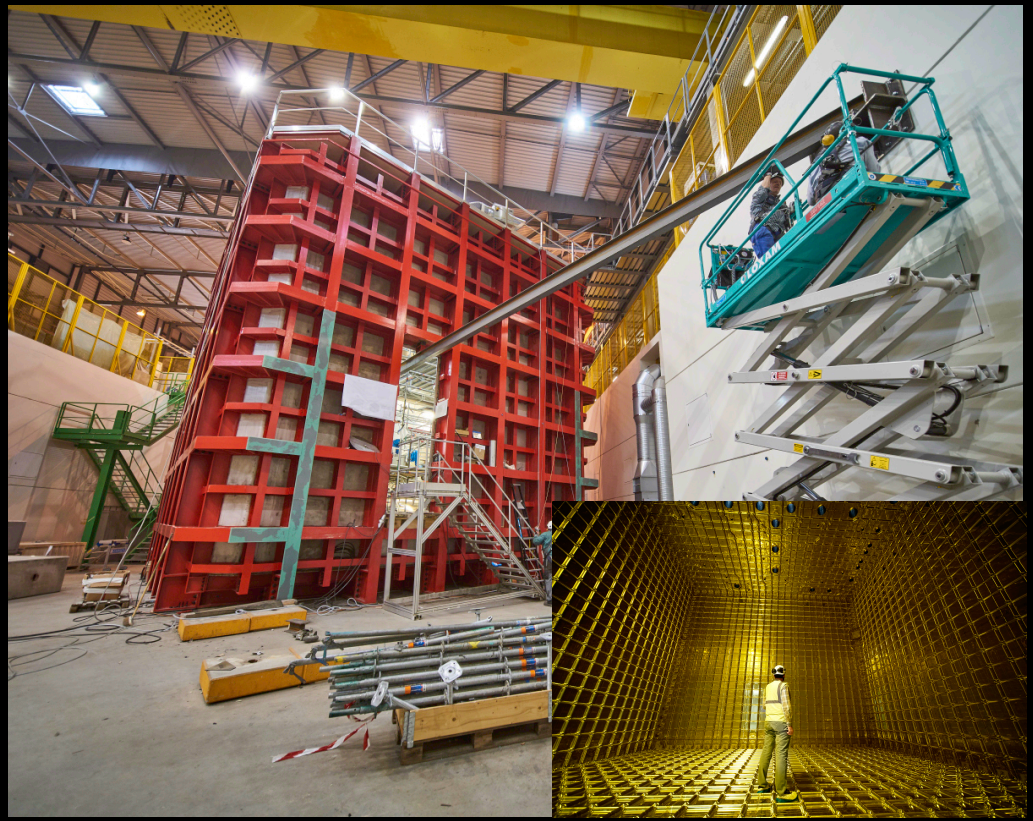
CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan.

- CERN Neutrino Platform established in 2014 → became a project in 2016
- North Area extended to provide test beams and space for detector prototypes
- Supports detector R&D and construction in Europe (e.g. BabyMIND for T2K, DUNE prototypes, Near Detectors for both)
- CERN building first of four cryostats for DUNE detector based on new (for HEP) technology
- Neutrino group set up in EP in 2016 to carry out software and physics activities in synergy with TH, and help enhance coherence of efforts in the European community (e.g. currently providing forum for Near Detectors discussions and studies → Summer 2017 WS)

information from the ESPP implementation report of CERN DG at the Council meeting of Sept 2017

CERN's Neutrino Platform as a European "portal" to accelerator-based neutrino facilities worldwide

protoDUNE detectors at CERN

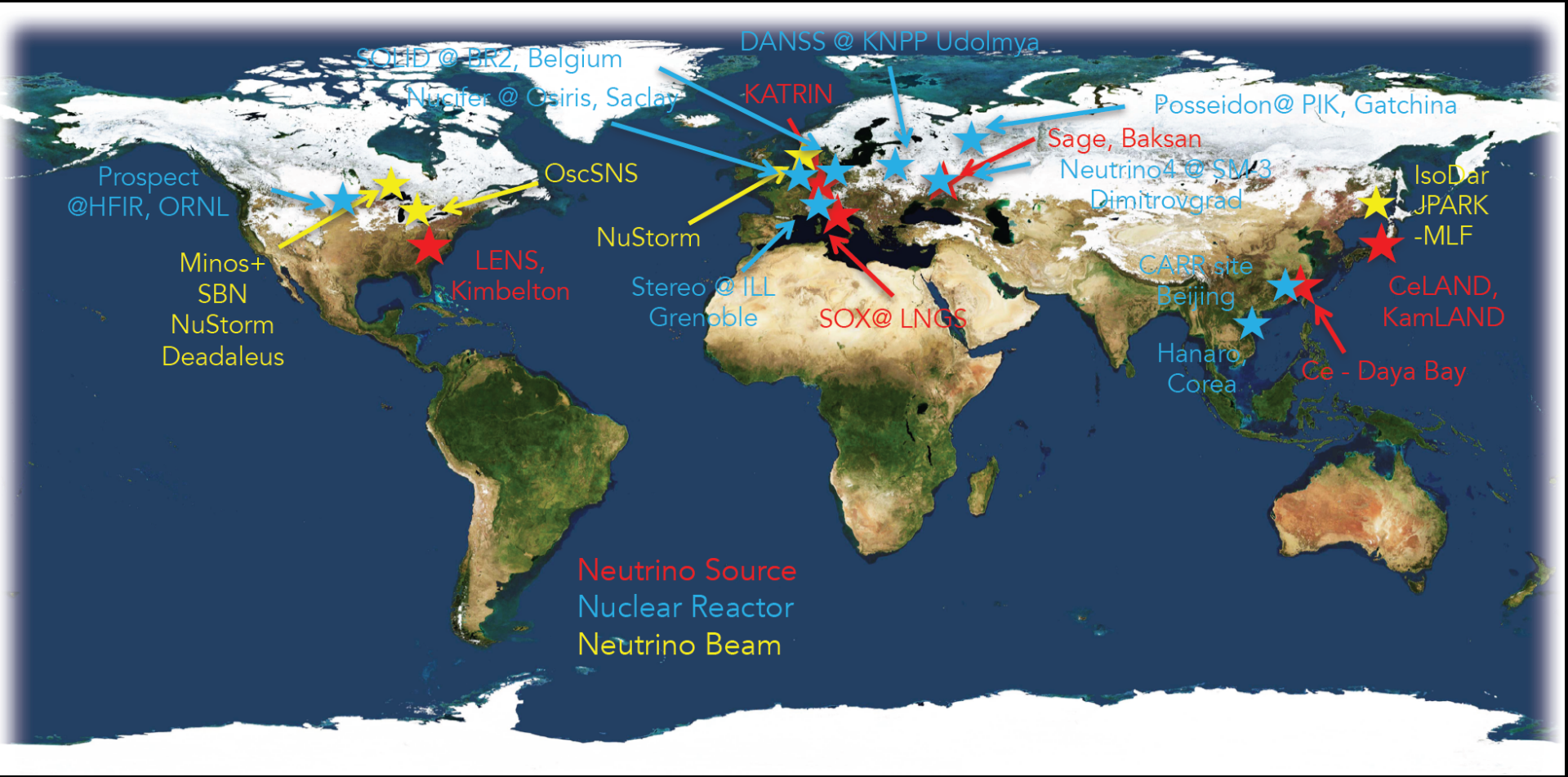


Baby MIND from CERN to Japan

The Neutrino Platform is CERN's undertaking to foster and contribute to fundamental research in neutrino physics at particle accelerators worldwide.

Neutrino PLATFORM

Neutrino research in the European Region



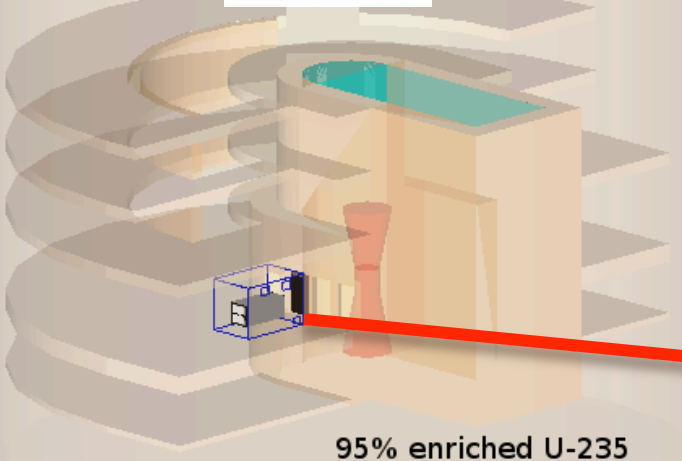
from Th. Lasserre (EPS-HEP plenary, July 2017)

Reactor facilities for Particle Physics in the European Region

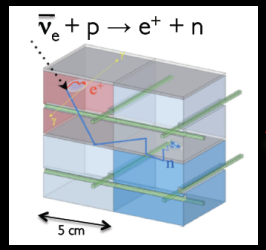
BR2 @ SCK-CEN
Belgium

6 to 11m from reactor core

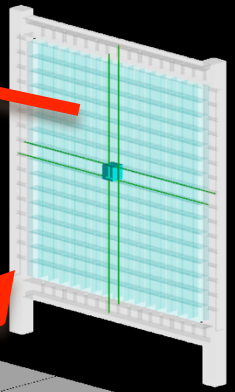
SoLid



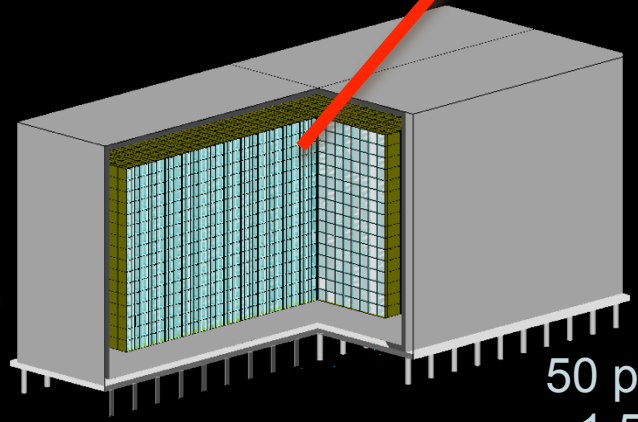
95% enriched U-235
0.5m core diameter
access ports for experiments



12800 cubes
3200 readout fibers



Being installed



50 planes
1.5 ton

Implementation of the 2013 Eur. Strategy for Particle Physics

Experiments studying quark flavour physics, dipole moments, charged-lepton violation and performing other precision measurements ... with neutrons, muons and antiprotons may give access to higher energy scales than direct particle production ... They can be based in national laboratories, with a moderate cost … Experiments in Europe with unique reach should be supported, as well as participation in experiments in other regions of the world.

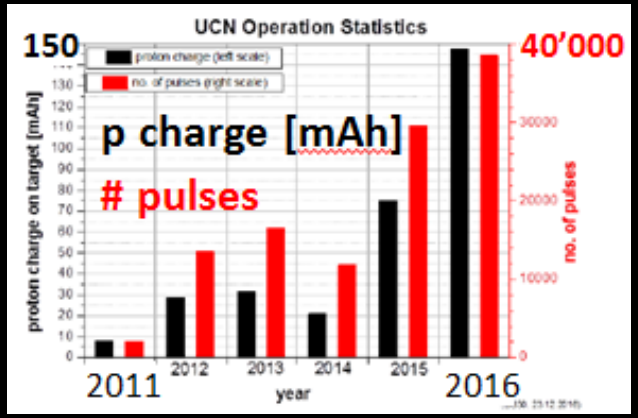
- Discussed e.g. in the framework of LDG and ECFA plenary sessions (esp. outside CERN)
- Recognized Experiments @ CERN (REC): approved experiments from particle physics and nearby disciplines (e.g. astroparticle and GW) with substantial participation of CERN Member State physicists. REC benefit from intellectual exchanges with scientists at CERN and, within available CERN resources, from usage of computing, infrastructure for meetings, access to test beam and laboratory equipment. Examples of REC: MEG, Belle-II, Panda.
- Physics Beyond Collider Study Group set up in 2016 to explore compelling projects complementary to high-energy colliders → report in 2018 as input to the ESPP. Targeting mainly projects at CERN's injectors, but looking more broadly to experiments that can be realised in other labs with CERN support (e.g. axion searches).

information from the ESPP implementation report of CERN DG at the Council meeting of Sept 2017

PSI and proton beams on target

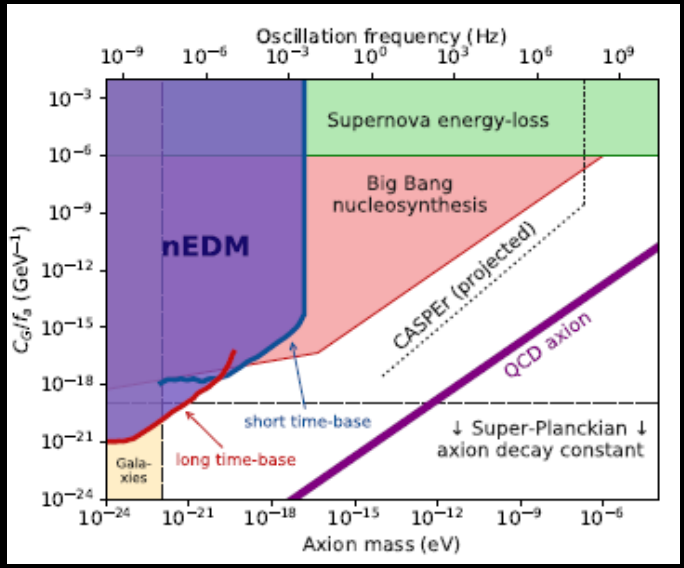
Ultra Cold Neutron source:

- world-leading performance



Neutron EDM collaboration:

- completed data taking of nEDM with highest sensitivity data set
- started construction of n2EDM for improved sensitivity by an order of magnitude
- search for oscillating nEDM sets first lab limits on axion-DM couplings to gluons



Muon physics collaborations:

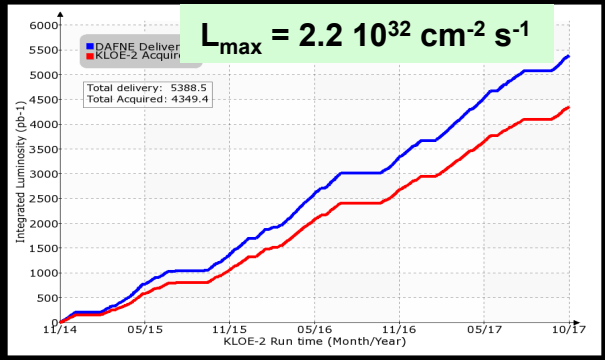
- **MEG** final result in 2016: BR($\mu \to e\gamma$) < 4.2 x 10^{-13}
- **MEG II** started commissioning for improvement by order of magnitude
- **Mu3e** aiming at 3 orders of magnitude improvement
- **CREMA** measurements of muonic He Lambshift, MuSun of μd-capture rate complete
- **MUSE** to compare e & μ scattering for proton radius

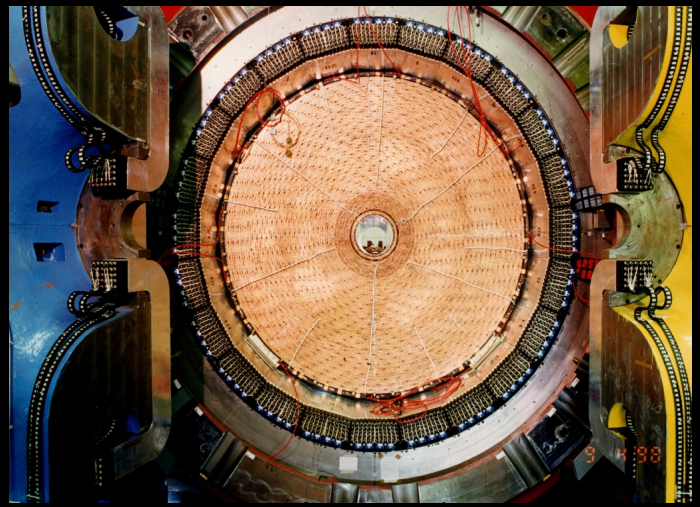
INFN Frascati: DAΦNE e^+e^- collider and the KLOE experiment

Most luminous lepton collider at low energies (1 GeV c.m.)

Operating at Φ meson for **KLOE2** detector. Target: **5/fb** of data collected by March 2018 (end of data taking)

KLOE2 physics reach: CPT interferometry, rare K decays, hadron physics





Rest of 2018 DAFNE dedicated to **PADME**

Beam dump experiment for Dark Boson mediators searches at low mass (<20 MeV) $e^+e^- \rightarrow \chi\chi$

Goal > 10^{13} positrons on target

In 2019 **SIDDHARTA2** run: 1st measurement of the 1S transition of K^+D kaonic atom (**1/fb**)

Test of QCD symmetry breaking (K-N interaction)

End of collider mode in DAFNE in early 2020 - Possible operation as accelerator facility under investigation by INFN – ideas and proposals are welcome !

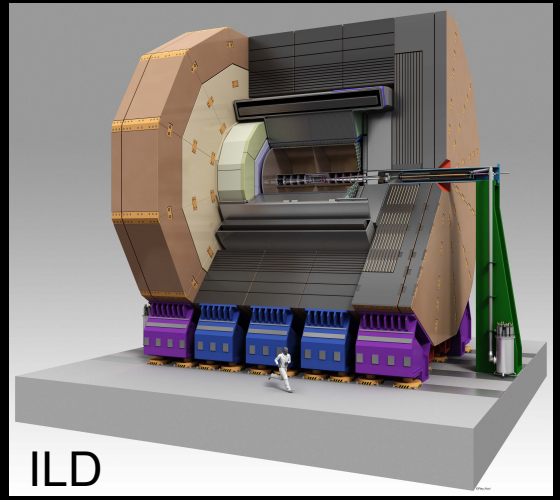
Implementation of the 2013 Eur. Strategy for Particle Physics

Detector R&D programmes should be supported strongly at CERN, national institutes, laboratories and universities. Infrastructure and engineering capabilities for the R&D programme and construction of large detectors, as well as infrastructures for data analysis, data preservation and distributed data-intensive computing should be maintained and further developed.

- Detector R&D: intense activities at CERN and laboratories/institutes across Europe: generic R&D (e.g. CERN RDx projects, EU projects) and targeted (Phase-2 detector upgrades, Linear Collider Detector group, Neutrino Platform, etc.). Since few years also includes knowledge transfer activities (e.g. medical applications). Review panels put in place by ECFA (covering particle and astroparticle) and ICFA.
- Data, software and computing: conceptual, design and prototyping efforts to address the requirements of the HL-LHC phase started at CERN with Member States and in the broader framework of European Open Science Cloud (EIROforum paper on Federated Scientific Data Hub). Tomorrow's SW requirements being addressed by HEP Software Foundation (White Paper in preparation)

information from the ESPP implementation report of CERN DG at the Council meeting of Sept 2017

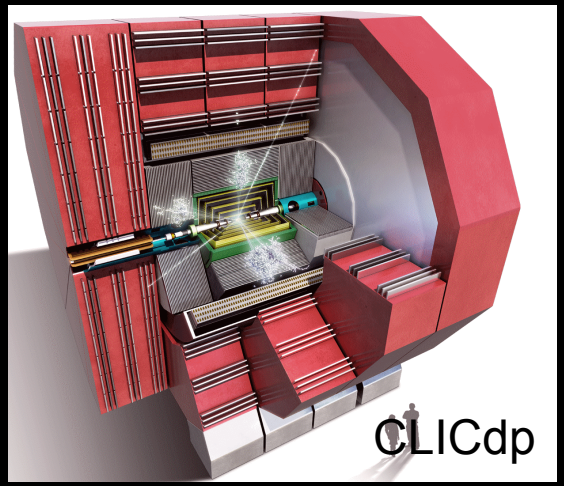
Linear Collider detector & physics studies: Europe engaged

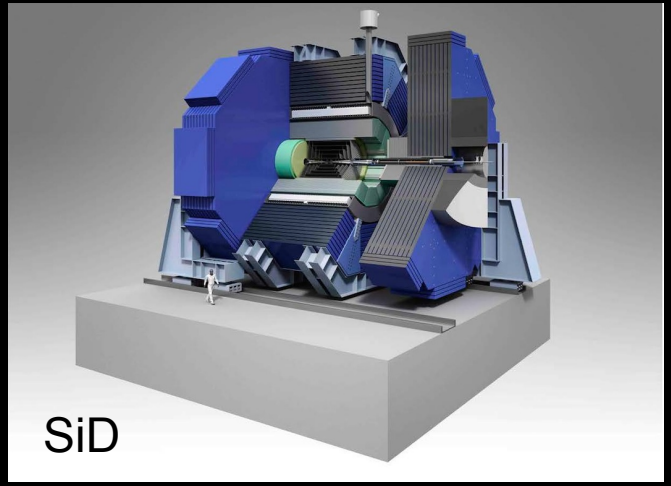


The LCC physics & detector directorate is responsible for activities that advance the physics and detectors of the linear collider.

Three detector concepts:

- ILC: 71 institutions mostly from the European Region
- SiD: 24 institutions many from the European Region
- CLICdp: 29 institutions mostly from the European Region





Three detector R&D groups:

- CALICE: 57 institutions mostly from the European Region
- LCTPC: 32 institutions many from the European Region
- FCAL: 14 institutions mostly from the European Region

Implementation of the 2013 Eur. Strategy for Particle Physics

In the coming years, CERN should seek a closer collaboration with ApPEC on detector R&D with a view to maintaining the community' s capability for unique projects in this field.

- Relations with ApPEC and astroparticle community cover more than detector R&D
- CERN Director for Research and Computing attends ApPEC General Assembly meetings
- Many REC experiments from astroparticle physics: Auger, AMS, Fermi, IceCube, ArDM, CTA, LIGO, VIRGO, Km3Net, JUNO, SNO+, etc.
- CERN TH Institutes cover astroparticle and cosmology topics
- Working together on future exa-scale computing (e.g. agreement signed with SKA)
- CERN offers test beams, irradiation facilities, equipment/support for tests (e.g. Aria/ DarkSide)
- End of August: joint CERN-LIGO/Virgo meeting to identify areas of collaboration (from physics to governance, vacuum and cryogenics, civil engineering, etc.)

information from the ESPP implementation report of CERN DG at the Council meeting of Sept 2017

ApPEC roadmap

European Astroparticle Physics Strategy 2017-2026

http://www.appec.org/roadmap

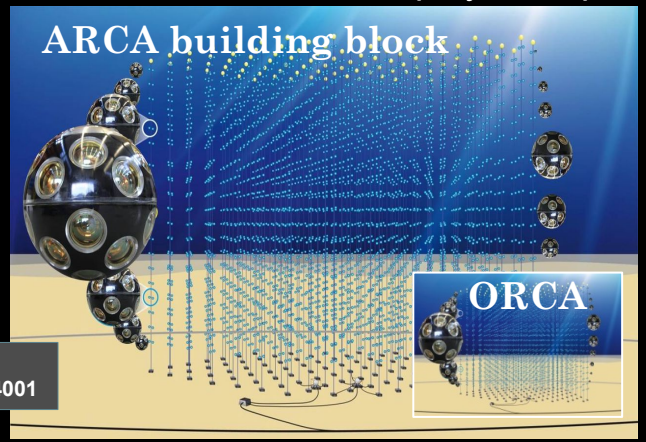
KM3NeT, neutrino observatory in the Mediterranean – deployment has started

ARCA: *Astrophysical Research with Cosmic in the Abyss*

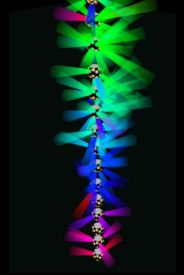
- 2 'building blocks' of 115 lines in Italy
- Find the sources of PeV cosmic (IceCube) neutrinos: excellent angular resolution for each neutrino flavour
- First lines deployed, planned completion 2022

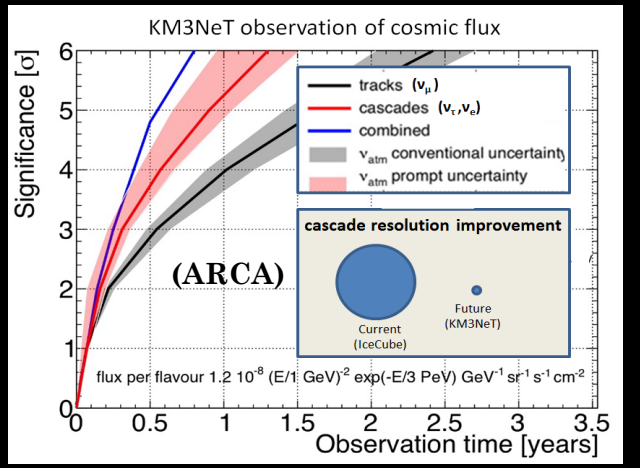
ORCA: *Oscillations Research with Cosmics in the Abyss*

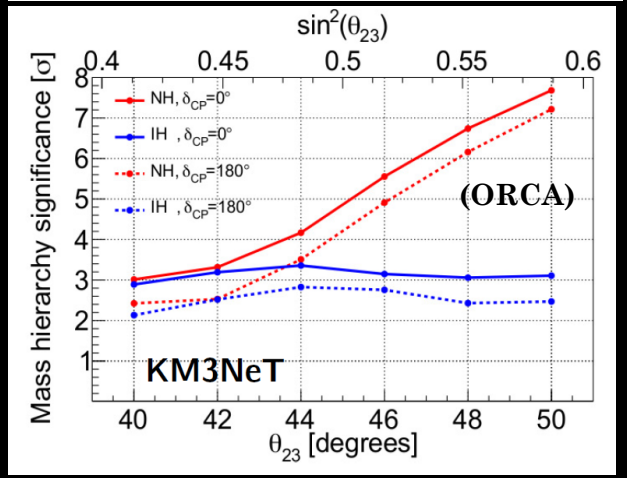
- Densely instrumented block of 115 lines in France
- Atmospheric neutrinos between 1 and 100 GeV
- Mass hierarchy: 3σ in 4 years for all θ_{23} + ν_τ appearance + new physics + θ_{23} + Dark Matter
- Planned completion: 2020, First line deployed Sept. 22; all sensors working



Muon Event in 1st ORCA line







Letter of Intent:
J.Phys. G43 (2016) no.8, 084001

Underground facilities for Part Phys in the European Region

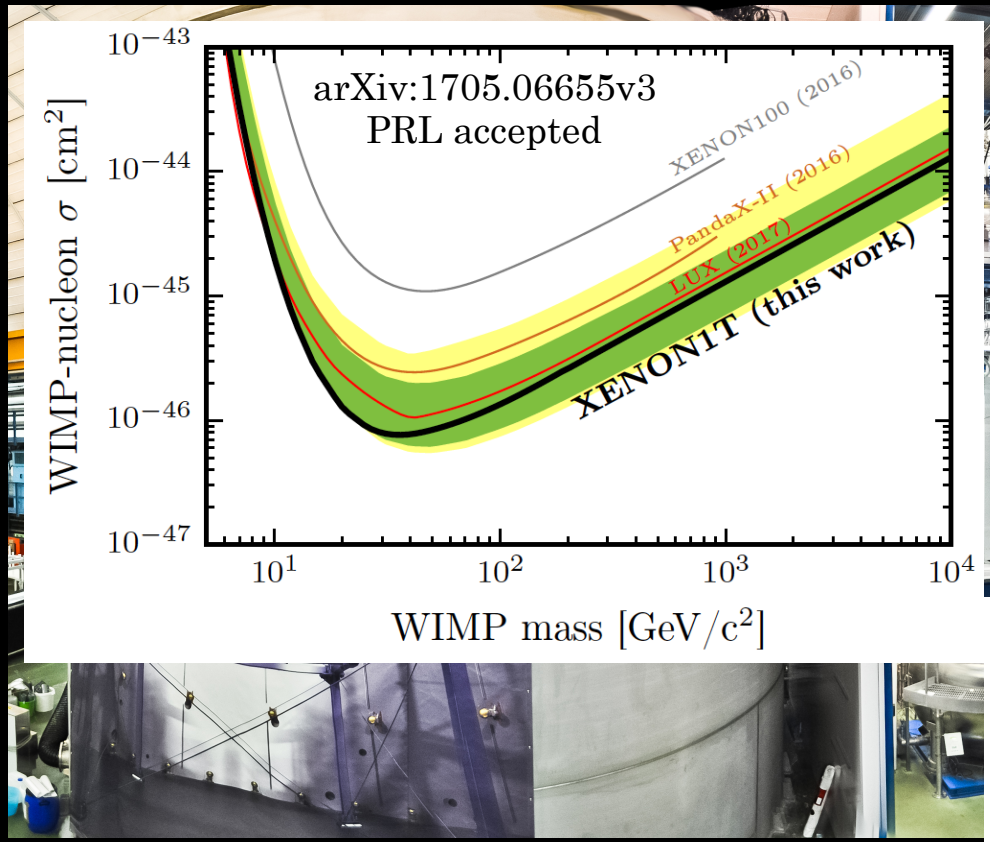
image courtesy of Susana Cebrián, "Science goes underground"

Underground facilities for Part Phys in the European Region

The XENON1T experiment at the Laboratori Nazionali del Gran Sasso (LNGS) is the first WIMP dark matter detector operating with a liquid xenon target mass above the ton-scale.

"The Xenon1T Dark Matter experiment"
arXiv:1708.07051v1

Underground facilities for Part Phys in the European Region



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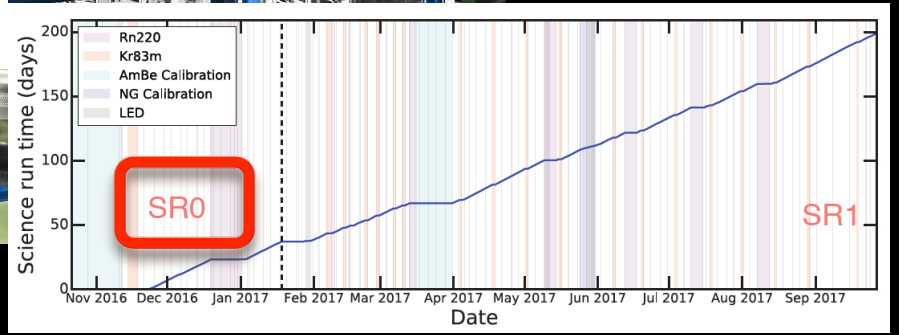

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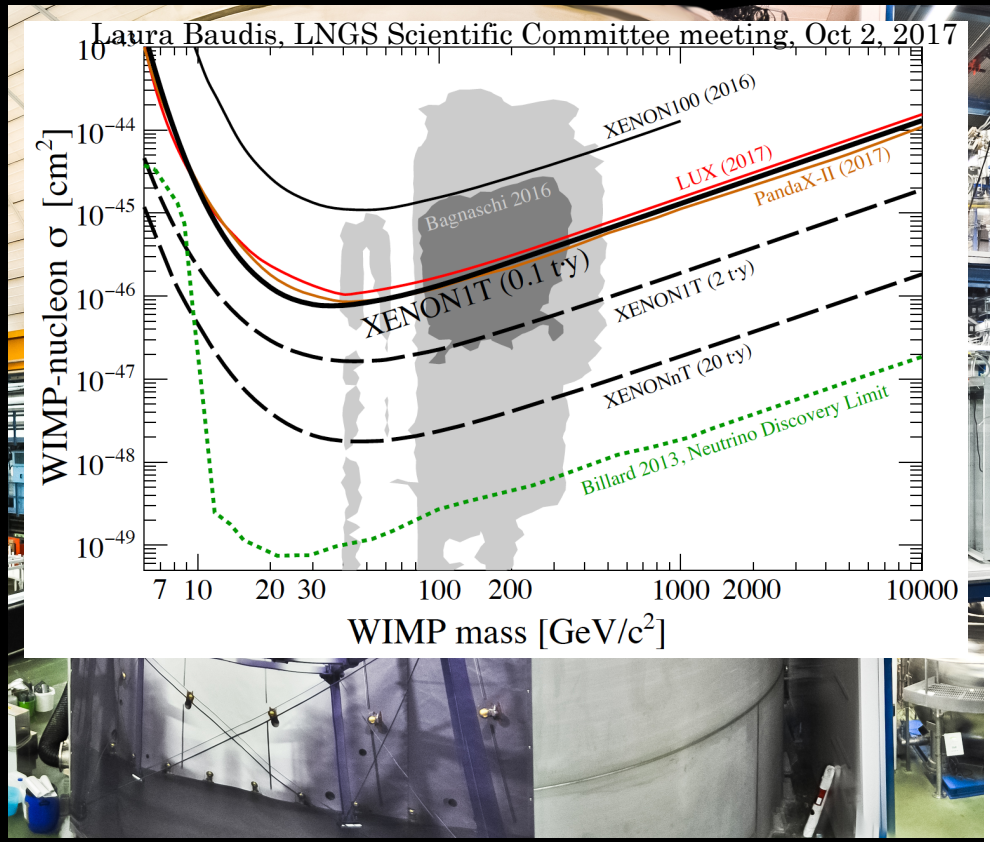
Underground facilities for Part Phys in the European Region



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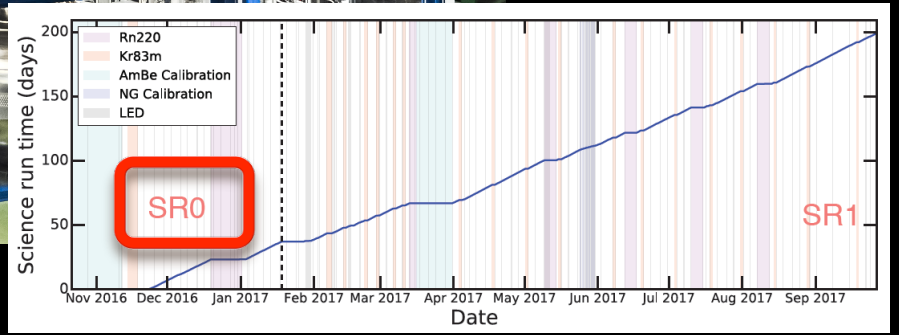


"The Xenon1T Dark Matter experiment"
arXiv:1708.07051v1

Implementation of the 2013 Eur. Strategy for Particle Physics

A variety of research lines at the boundary between particle and nuclear physics require dedicated experiments. The CERN Laboratory should maintain its capability to perform unique experiments. CERN should continue to work with NuPECC on topics of mutual interest.

- CERN has compelling programme in (or at the boundary with) nuclear physics: ISOLDE, HIE-ISOLDE, n_TOF, COMPASS, HI programme (NA61, LHC experiments), AD
- 2017 NuPECC Long-Range Plan (report finalised in a meeting at CERN in March 2017): CERN experiments appear in all six domains considered by NuPECC
- CERN Director for Research and Computing regularly attends NuPECC meetings
- In addition: ongoing collaborations (mainly on accelerator aspects) with GSI/FAIR, ESS, etc.

information from the ESPP implementation report of CERN DG at the Council meeting of Sept 2017

CERN and the HIE-ISOLDE facility: Phase-2 (2017-2018)

The new energy window gives the opportunity to address new physics questions → 35 experiments approved

European Spallation Source (ESS) – near Lund, Sweden

A European Research Infrastructure Consortium (ERIC) for a multi-disciplinary research facility based on the world's most powerful neutron source.

The ESS will boost the high precision and high sensitivity frontier of particle physics, with indirect sensitivity to new phenomena on a mass scale of 1-100 TeV.

- **ANNI** (design available): a cold neutron beam facility to study for example the neutron beta decay, hadronic weak interactions, EDM of the neutron.

- **UCN** source (LoI submitted): ultra-cold neutrons with densities exceeding 10^4 per cm^3 and adequate magnetic shielding to study for example the EDM of the neutron, the neutron lifetime.

- **NNBAR** (LoI submitted): search for neutron-antineutron oscillations three orders of magnitude better compared to previous experiments.

A Scientific and Technical Advisory Panel (STAP) for fundamental physics has been established to advise and later to review the instrument proposals and Letters of Intent (LoI).

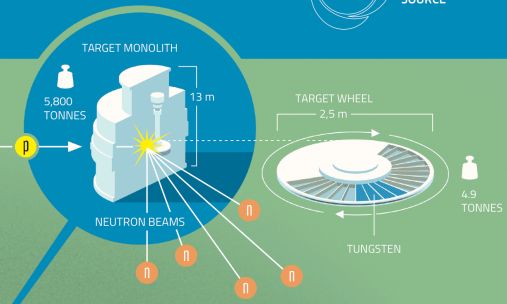
European Spallation Source

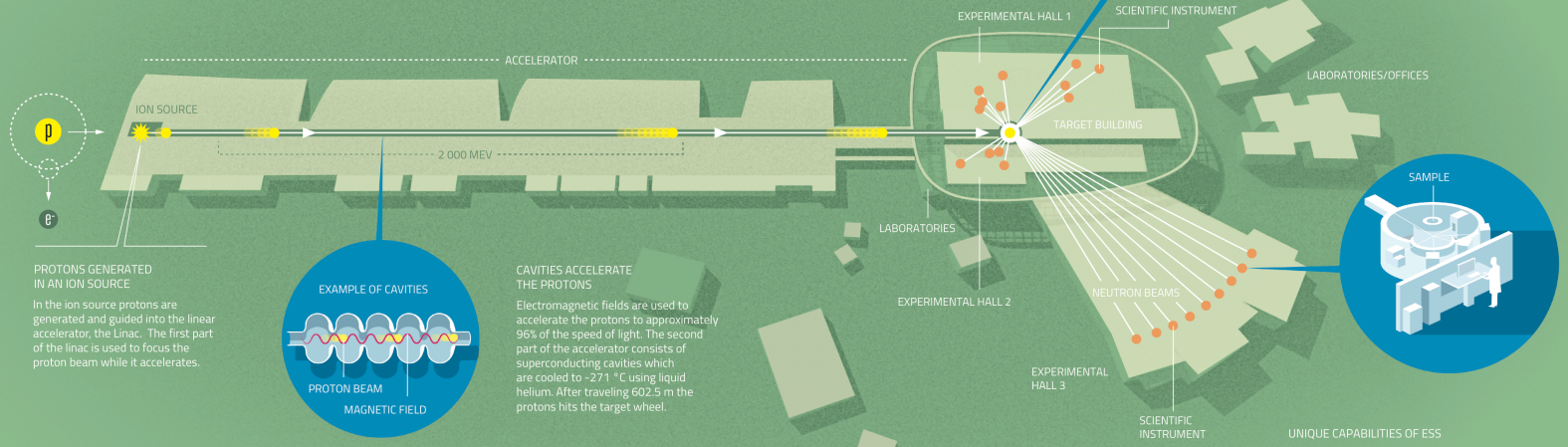
EUROPEAN SPALLATION SOURCE

The European Spallation Source (ESS) is a multi-disciplinary research centre based on the world's most powerful neutron source. ESS will give scientists new possibilities in a broad range of research, from life science to engineering materials, from heritage conservation to magnetism. ESS is a pan-European project, with Sweden and Denmark serving as host countries. The main research facility is being built in Lund, Sweden, and the Data Management and Software Centre (DMSC) is located in Copenhagen, Denmark.

THE TARGET IS THE NEUTRON SOURCE

When the accelerated protons hit the rotating tungsten target wheel spallation occurs and neutrons are scattered from the tungsten nucleus. The more neutrons produced and collected in the target, the "brighter" the neutron source. The neutrons are directed through moderators and neutron guides to the scientific instruments where they are used for experiments. The Target monolith consists of the Target wheel, moderators, cooling systems and shielding and weighs approximately 5,800 tonnes.





PROTONS GENERATED IN AN ION SOURCE

In the ion source protons are generated and guided into the linear accelerator, the Linac. The first part of the linac is used to focus the proton beam while it accelerates.

CAVITIES ACCELERATE THE PROTONS

Electromagnetic fields are used to accelerate the protons to approximately 96% of the speed of light. The second part of the accelerator consists of superconducting cavities which are cooled to -271 °C using liquid helium. After traveling 602.5 m the protons hits the target wheel.

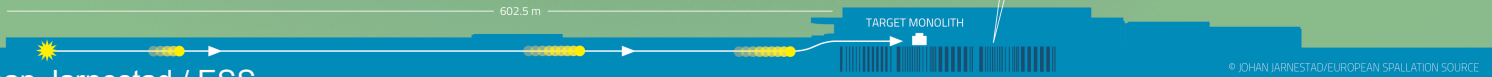
TOTAL BUILDING AREA 65 000 m²

The ESS facility will be approximately 650 metres in total length. The target building will be 125 metres long, and about 30 metres high. The 537-meter-long accelerator tunnel is built underground and will be covered with soil.

Concrete:	50 000 m³
Rebar:	6 000 tonnes
Pipes:	40 km
Cables:	2,000 km
Total volume:	400,000 m³

PILES TO AVOID MOVEMENTS

The heavy Target building and experimental halls are resting on a total of 6,400 piles of different types, in order to avoid unwanted movements in the structure.



UNIQUE CAPABILITIES OF ESS

ESS will have 22 tailor-made instruments located in three experimental halls. Neutrons are excellent for probing materials on an atomic and molecular level – everything from motors and medicine, to plastics and proteins. The neutrons hit the sample and detectors register the neutron scattering, giving precise information about the material's structure and dynamics.

Credit: Johan Jarnestad / ESS

Aerial view October 2017

Construction Financing	BUDGET	HOST COUNTRIES SWEDEN & DENMARK	NON-HOST MEMBERS	IN-KIND CONTRIBUTIONS
	€1.843 Billion	47.5%	52.5%	€747.5 Million

ESS is working with 15 nations, nearly 40 European in-kind partner institutions, and more than 130 collaborating institutions worldwide.

Outreach and Communication in particle physics

International Particle Physics Outreach Group

CERN Courier March 2017

Viewpoint

Reaching out in the era of big science

Now a formal collaboration, IPPOG provides a new force for global particle-physics outreach.

CERN director for international relations, Charlotte Warakaulle, signs the memorandum of understanding with IPPOG chairperson Hans Peter Beck on 19 December, allowing the IPPOG collaboration to officially enter into force.

By Hans Peter Beck

Establishing and maintaining a strong link between science and society is vital, and is something that has long been recognised by CERN. Writing in 1972, former Director-General Victor Weisskopf put it well when he argued that a concerted effort towards the presentation and popularisation of science would "provide a potent antidote to overspecialisation, bring out clearly what is significant in current research, and make science a more integral part of the culture of today".

Forty-five years later, as we enter the so-called "post-factual world" emerging from political ideologies in a growing number of modern democracies, it is more important than ever for science and society to maintain an open and transparent dialogue. It has also become evident that the tools and methods currently used to support such a dialogue have not been as successful as we would have hoped. Indeed, many excellent outreach activities at research centres, universities and museums often attract only those people who are already interested and appreciative of the basic and fundamental relevance of science.

Without compromising established methods, we must explore new paths to engage citizens – especially the young. Reaching out to high-school students and their teachers to convey the methods and tools used in fundamental science is a strong investment in the future. While only a fraction of young students will become scientists, and fewer still will become particle physicists, all will become ambassadors for the scientific method and evidence-based decision-making. Developing a dialogue with those who have left school early raises important challenges of its own, and requires that scientists take courageous steps. Partnering with artists, musicians and celebrities, for instance, has enormous potential to get science into the spotlight.

Hans Peter Beck is chairperson of IPPOG, member of the ATLAS experiment and a reader at the University of Bern. (Image credit: C Marcellon.)

But it involves a delicate balance between raising curiosity and descending into trivialities.

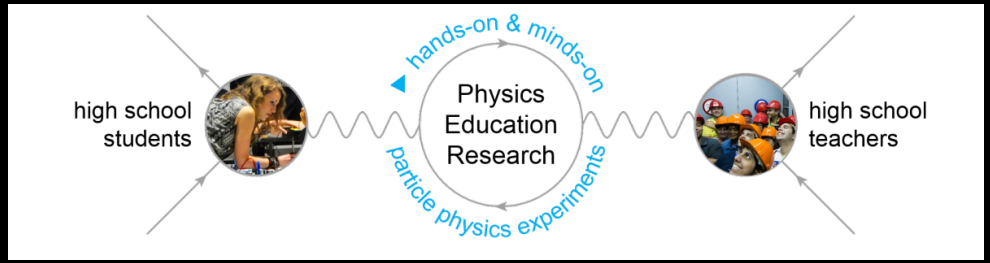
The International Particle Physics Outreach Group (IPPOG) is making a concerted and systematic effort to present and popularise particle physics across all audiences and age groups. Established 20 years ago following the recommendations of former CERN Director-General Christopher Llewellyn Smith, IPPOG has evolved from a European to a global network that involves countries, laboratories and scientific collaborations active in particle-physics research. It is best known for its International Masterclasses (IMC) programme, which evolved in the mid-1990s from national outreach efforts in the days of the LEP collider and has gone from strength to strength. Since 2005, the programme has offered high-school students the opportunity to become physicists for a day by performing a tailor-made physics analysis involving real LHC data (*CERN Courier* June 2014 p37). In terms of numbers, last year's edition of the IMC included 213 institutions in 46 countries and around 13,000 students took part.

Particle physics has become a truly global activity, with experimental collaborations such as those of the LHC experiments featuring thousands of researchers from all over the world. With this trend, IPPOG is evolving further to cover more countries, laboratories and experiments spanning all aspects of collider and non-collider research, including astroparticle physics and accelerator and detector technology. This expanding remit demands that IPPOG adopts a more formal structure to guarantee the quality and sustainability of its work.

Following the model of collaboration in experimental particle physics, on 19 December IPPOG became a formal scientific collaboration based on a memorandum of understanding. A total of 13 countries have now signed as members, with several candidate members expected to join soon, and each is required to contribute a membership fee weighted by its GDP and the size of its particle-physics community. Laboratories and even individual scientific collaborations are also part of IPPOG, where they contribute to the expert knowledge and skills required to inspire young thinkers.

The new collaboration status of IPPOG, and CERN's formal membership, demonstrates a clear commitment to sustainable science outreach. With further countries and organisations expected to join soon, and others invited to get involved, the worldwide particle-physics community has a strong partner at hand when reaching out to wider society in diverse ways that are adapted for every target audience.

Activities throughout Europe and at CERN with national & international teachers programmes, the new **S'Cool LAB**



A formal collaboration for **IPPOG** with an MoU
(International Particle Physics Outreach Group)

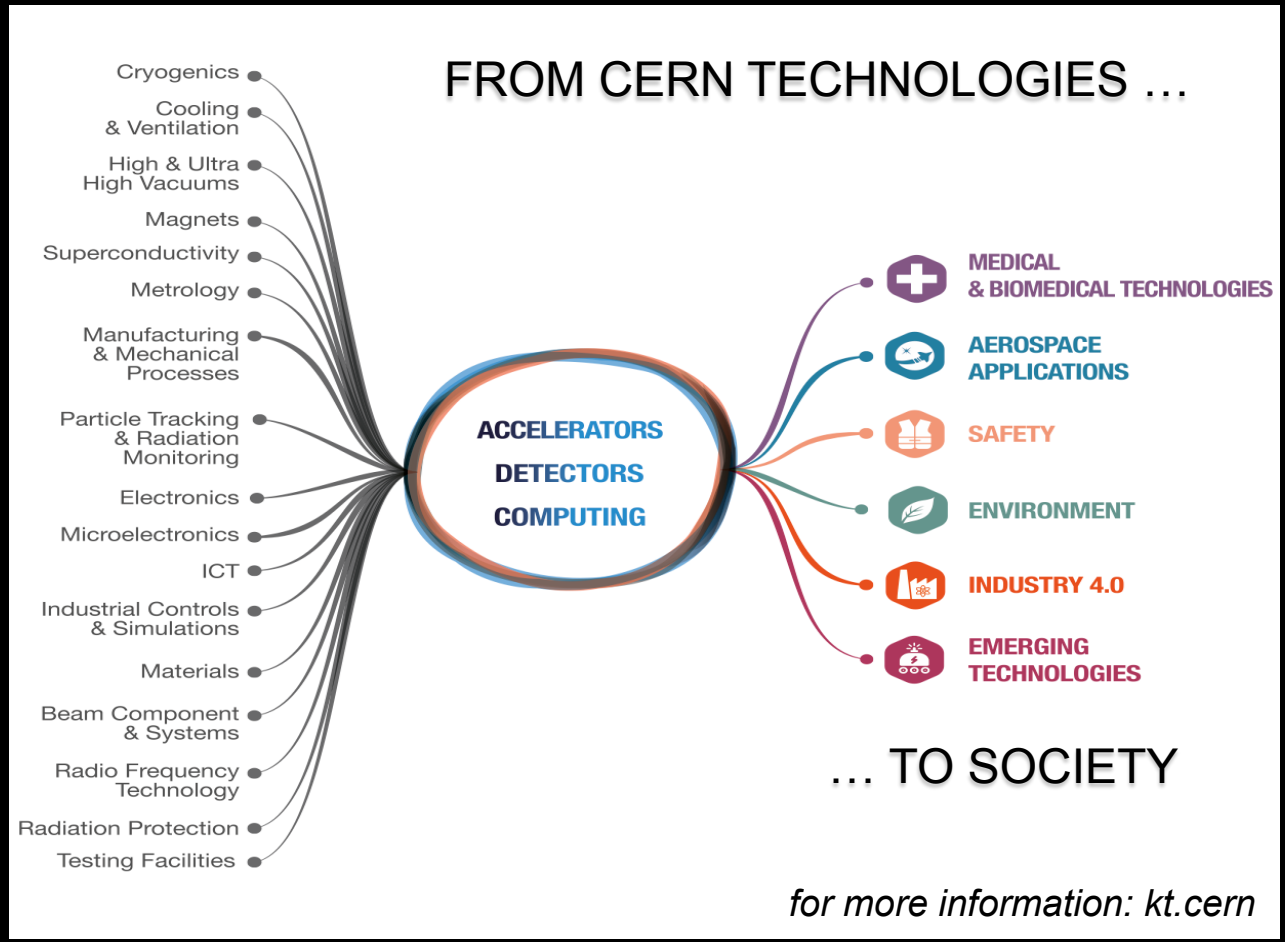
- Collaboration established: 19 December 2016
- Annual membership fees of countries based on GDP and community
- Experiments and labs involved as well

With the IPPOG budget from the Membership Fees ca 50k€ annually, we can improve IPPOG's communication, develop, print and distribute educational material, give support to global or otherwise worth while activities.

Implementation of the 2013 Eur. Strategy for Particle Physics

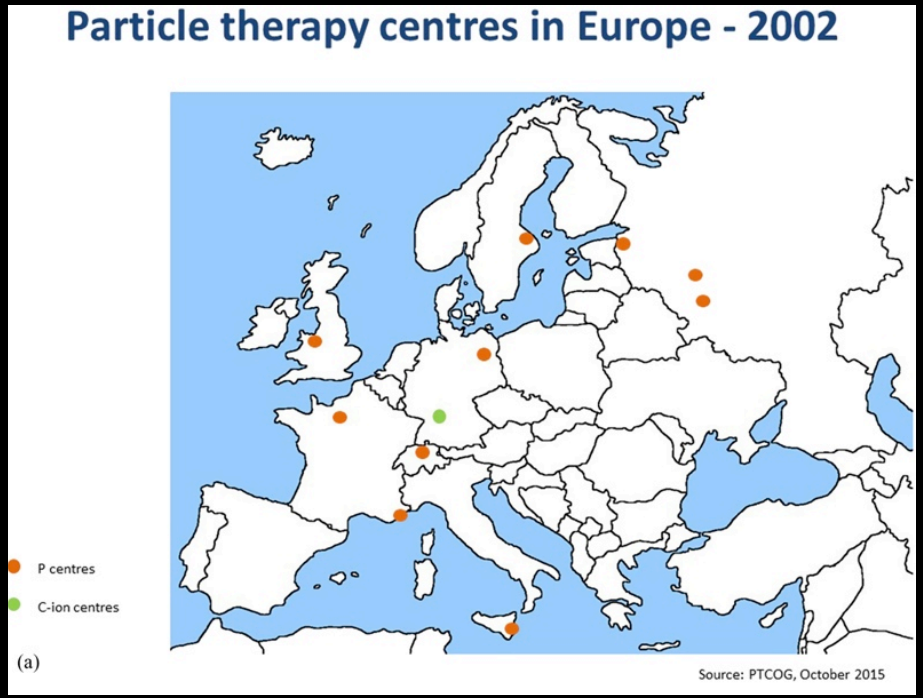
HEPTech should pursue and amplify its efforts and continue reporting regularly to the Council

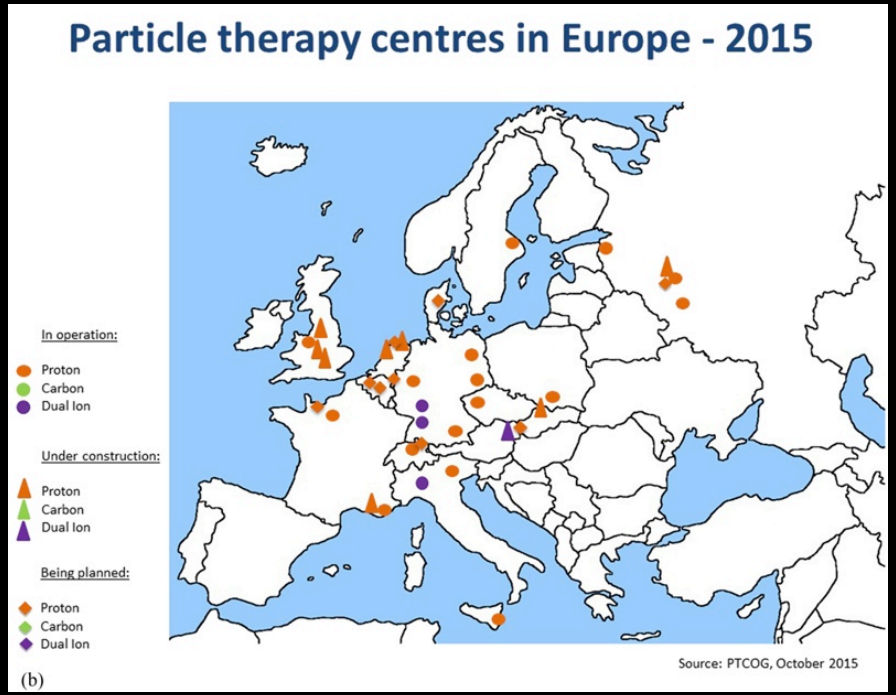
- Since 2011 CERN signed more than 250 licenses and other kind of agreements with industry and other partners
- Ever year several tens of new technology disclosures (91 in 2016)
- 18 new start-ups are using CERN technologies since 2012



European Particle Physics and Particle Therapy

European Network for Light Ion Therapy (ENLIGHT) since 2002





information from Manjit Dosanjh, "From Particle Physics to Medical Applications", IOP Publishing 2017, Bristol, UK


Future
Start data taking HL-LHC
European Strategy for Particle Physics (2020)
European Strategy for Particle Physics (2013)
TODAY
Higgs discovery
Start data taking at the LHC
Implementation of the 2013 Strategy
&
Status of (some) European Facilities

Particle Physics at the eve of a European Strategy Update

- The timing of the Strategy Update is dictated by physics considerations, for the coming Update this are mainly the results of the experiments at the LHC Run2.
- Other key considerations will be the ongoing design studies and updated plans for future colliders (ILC, CLIC, FCC), exploration of opportunities for non-collider projects at CERN and elsewhere, and R&D work on accelerator technologies.
- The results from other running experiments and facilities and the status of the various neutrino physics projects across the world will be further important factors.
- By the end of 2018, significant input from all the above activities should be available.
- Taking into account inputs from scientists and institutions worldwide is essential to deliver a proper Update of the European Strategy for Particle Physics.

The Strategy Update Organisation

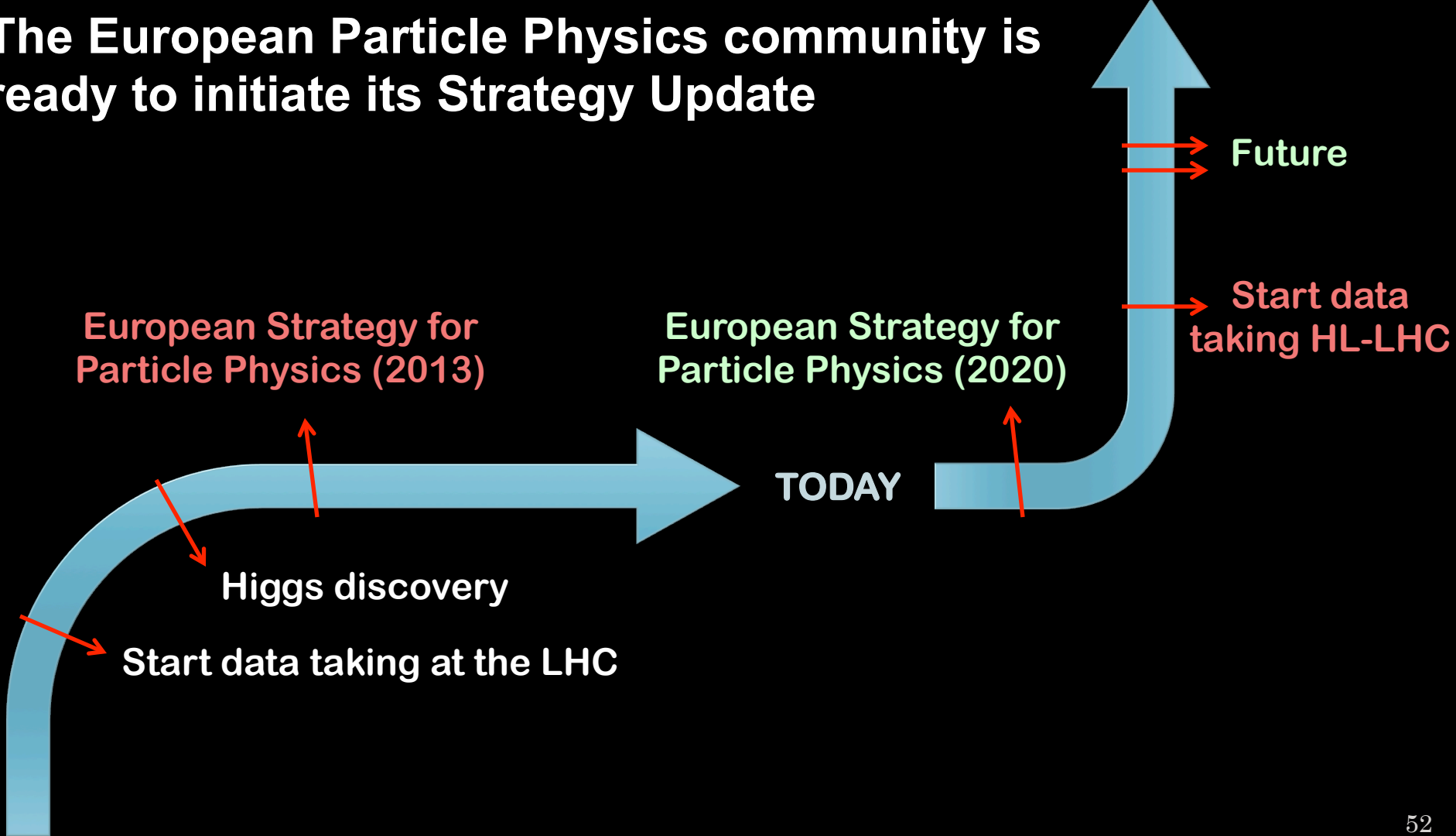
- The timeline to present an Updated European Strategy for Particle Physics (ESPP) is May 2020. Taking into account previous experience, the Update process will be launched formally by Council at its September 2018 session.
- The Update of the ESPP is prepared by the European Strategy Group (ESG), a dedicated body setup for the period of the Update discussions comprising representatives from all stakeholders.
- The ESG is assisted by a Physics Preparatory Group (PPG) who would be responsible for gathering the scientific input of the community reported in a Briefing Book.
- The Strategy Secretariat to coordinate the preparation work.
- The mandates of the ESG, PPG and Strategy Secretariat terminate upon Council's approval of the ESPP Update.

The Strategy Update Organisation – timeline

- 2017: appointment of the Strategy Secretariat :
  - Halina Abramowicz
    Strategy Secretary, chairperson of the Strategy Secretariat and of the ESG and the PPG
  - Keith Ellis
    SPC chairperson
  - Jorgen D'Hondt
    (incoming) ECFA chairperson
  - Lenny Rivkin
    chairperson of the European Particle Physics Laboratories Group

- 2018: appointment of the ESG and the PPG by Council in September 2018, and formal launch of Update process
- 2019: broad consultation by PPG, including Town Meeting(s)
- 2020: drafting the Update by the ESG, and adoption by Council in May 2020

The European Particle Physics community is ready to initiate its Strategy Update



Many thanks to several colleagues for their input

Joachim Mnich, Fabiola Gianotti, Eckhard Elsen, Halina Abramowicz, Sijbrand de Jong, Gerda Neyens, Klaus Kirch, Lenny Rivkin, Freddy Bordry, Pierluigi Campana, Frédéric Hemmer, Aart Heijboer, Giovanni Passaleva, Hans-Peter Beck, Andrea Dainese, Federico Antinori, Giovanni Anelli, Karl Jakobs, …

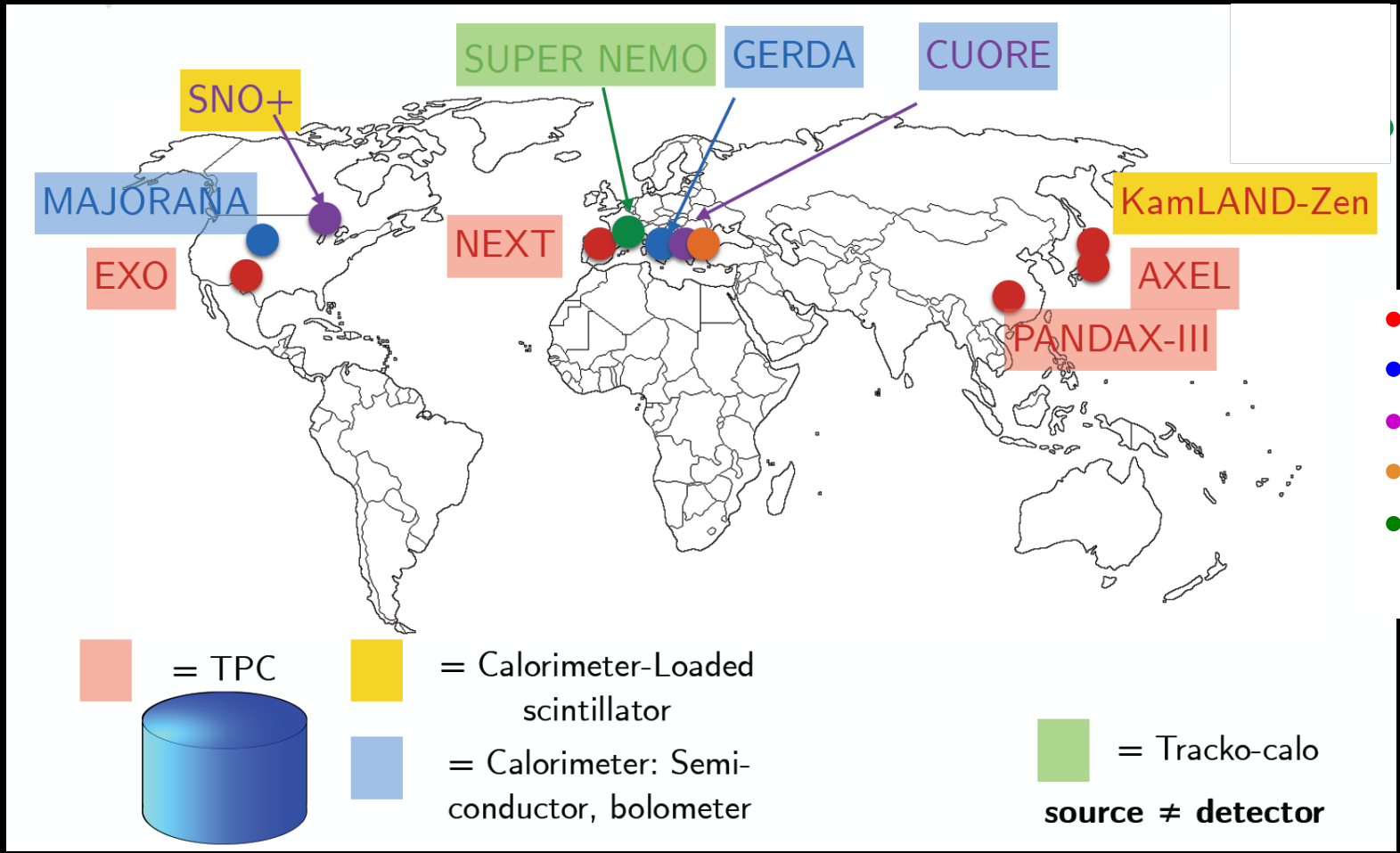
Implementation of the 2013 Eur. Strategy for Particle Physics

Europe should support a diverse, vibrant theoretical physics programme, ranging from abstract to applied topics, in close collaboration with experiments and extending to neighbouring fields such as astroparticle physics and cosmology. Such support should extend also to high-performance computing and software development.

- CERN TH Department restored in 2016 → enhanced visibility inside and outside CERN
- CERN TH provides: high-quality research on broad range of areas; focal point for European theory community (~ 750 visitors/year); (increasing) support to CERN experimental activities
- Intense activity of "TH Institutes" covering particle physics, astroparticle, cosmology (involve also external organisers, attended by worldwide community)
- Collaboration agreements with several Institutes
- Cluster for parallel simulations of QCD and other computations in theoretical physics. Computing and software aspects also addressed within ongoing efforts to build future computing infrastructure and software for HEP

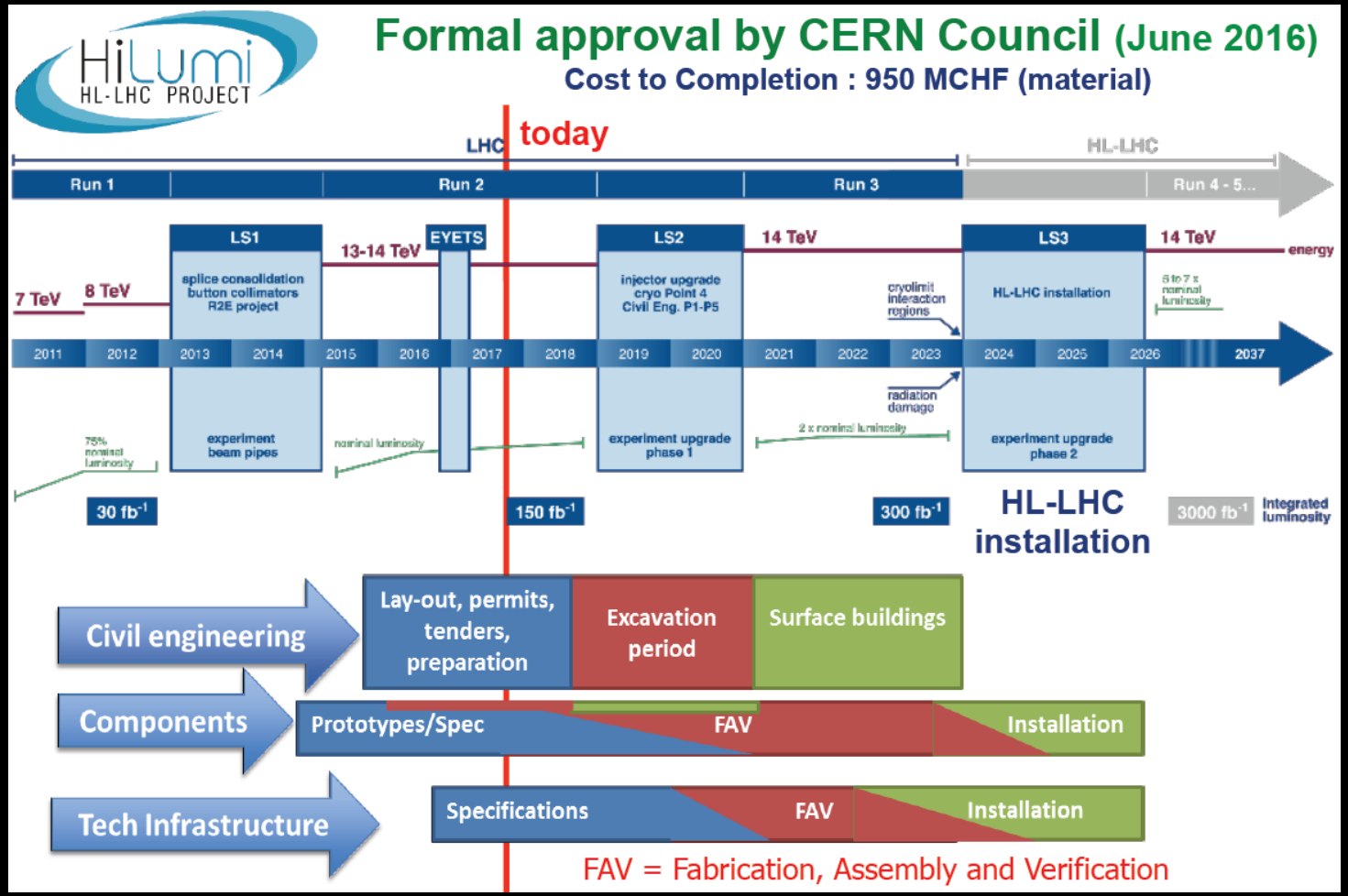
information from the ESPP implementation report of CERN DG at the Council meeting of Sept 2017

Neutrinoless Double Beta Decay in the European Region



from N. Lopez (Kyoto HE seminar)

CERN and the High-Luminosity LHC: construction phase



ATLAS – Upgrade Phase I

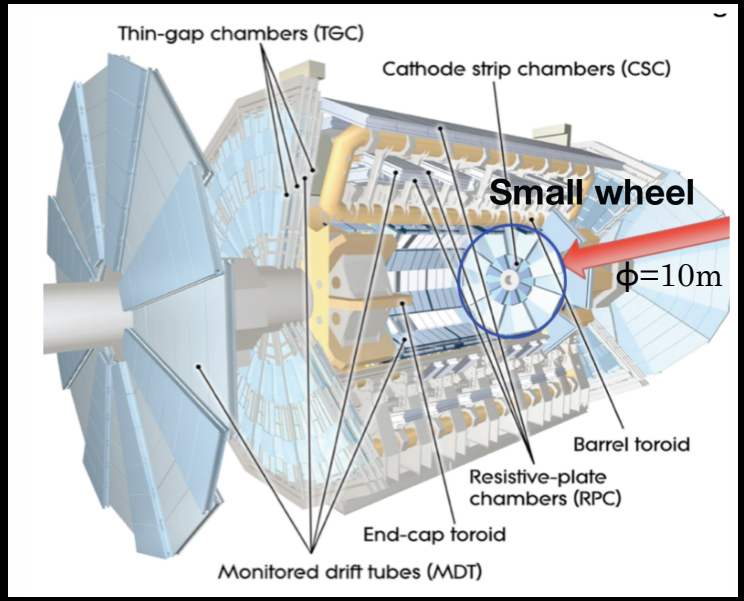
New Small Wheel: improve end-cap muons trigger/tracking capabilities at high rate *(being constructed)*

Fast Tracker: provide “fast” tracks at HLT input *(installation and commissioning phase)*

Liquid Argon Calorimeter: increased LAr readout granularity for improved shower shape information at trigger level *(good progress)*

TDAQ System: improve L1 hardware for calorimeters and muons, and upgrade DAQ hardware *(good progress)*

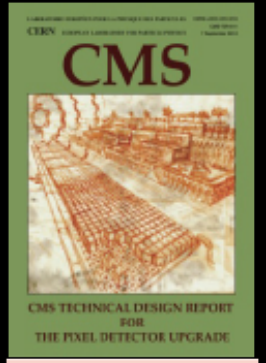
ATLAS Forward Proton: AFP enriches forward physics programme *(AFP DAQ integrated in ATLAS)*



CMS – Upgrade Phase I

Since the initial construction of CMS the pile-up increased to twice the design and new technology opportunities appeared.

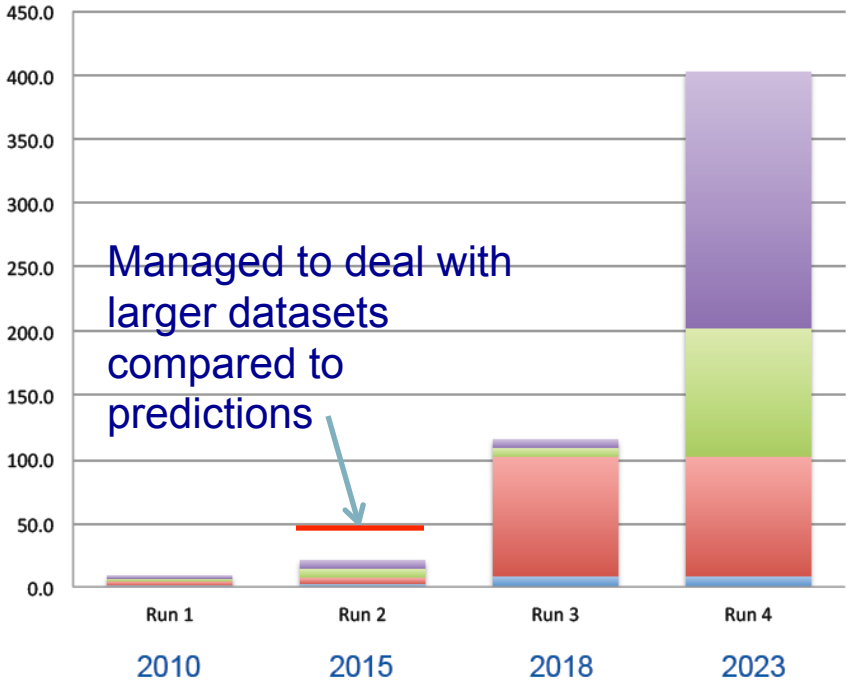
- **New Pixel Tracker**: a barrel part with 4 layers and 3 forward disks, as well as a new readout chip
  → *installed E-YETS 2016-2017*
- **Level-1 Trigger**: to cope with the higher rate the calorimeter and muon L1 trigger system is being upgraded as well as the global trigger
  → *installed and commissioned in 2014-2016*
- **Hadron Calorimeter**: new electronics to be installed for the HF to allow timing based background rejection and new SiPM's for the barrel and endcap (HB/HE) readout
  → *installation HF electronics YETS 2015-2016*
  → *HCAL installation during LS2*



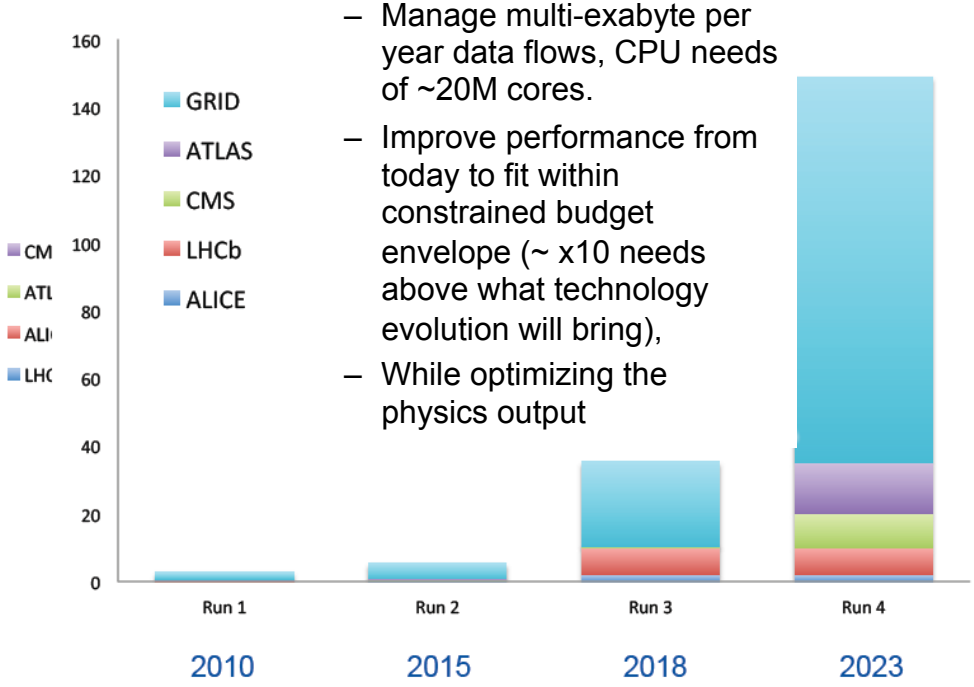
LHCb – Further Upgrade

- Aim at installation in LHC long shutdown 4 (LS4) around 2030
- Goal: collect >300 fb^{-1}
- Largely new detectors
- Expression of Interest submitted beginning 2017
- A physics case document in preparation

Computing : challenges for HL-LHC



Data: ~50 PB/year → 400 PB/year

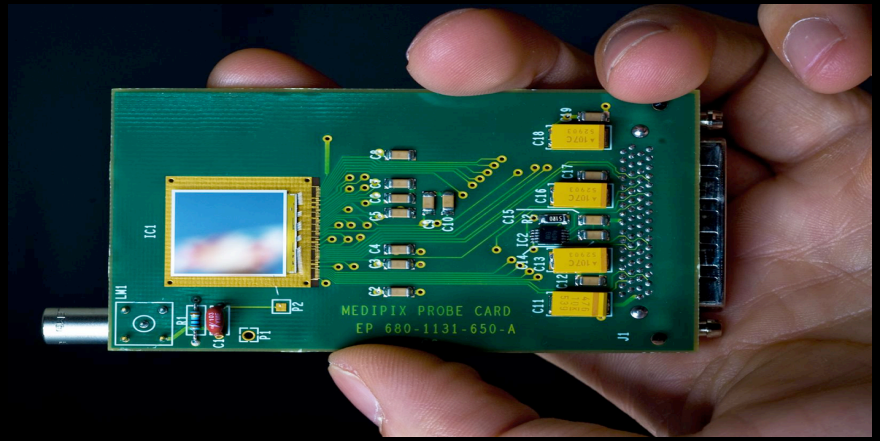


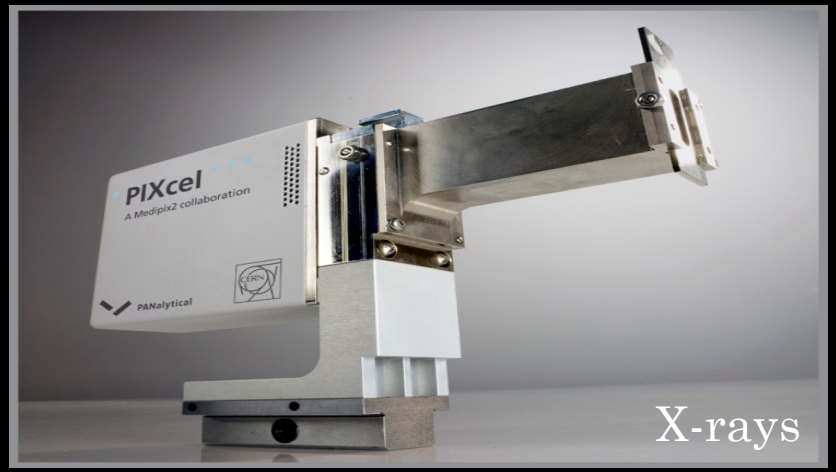
- Manage multi-exabyte per year data flows, CPU needs of ~20M cores.
- Improve performance from today to fit within constrained budget envelope (~ x10 needs above what technology evolution will bring),
- While optimizing the physics output

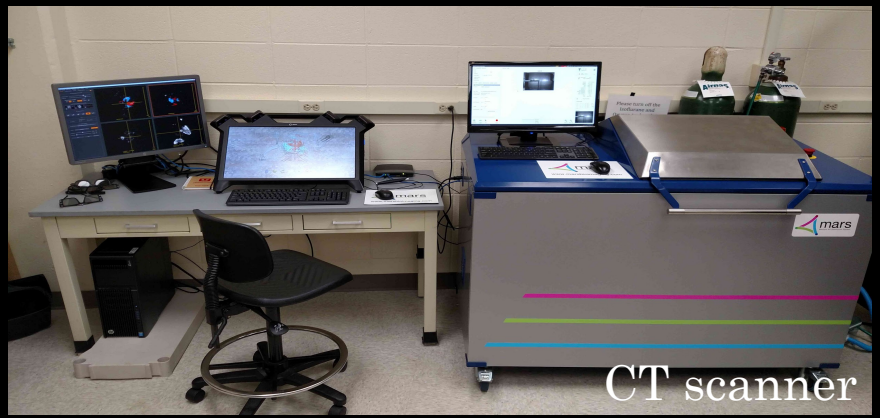
Compute: Growth > x50

The Medipix technology, https://medipix.web.cern.ch/

a family of chips for hybrid pixel detectors

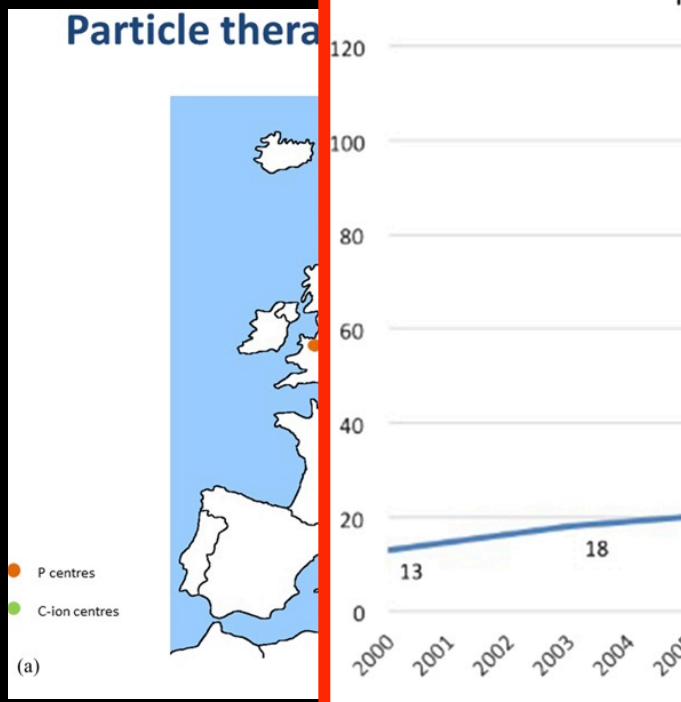






European Particle Physics and Particle Therapy

European Network for Light Ion Therapy (ENLIGHT) since 2002



information from Manjit Dosanjh, "From Particle Physics to Medical Applications", IOP Publishing 2017, Bristol, UK