LHC and CERN programme

Frédérick Bordry

4th Joint HiLumi LHC-LARP Annual Meeting

KEK – Japan – 17th November 2014

www.cern.ch

Outline

- **LS1 status**

- **Run 2 (from LS1 to LS2)** ⇒ ***13-14 TeV***
- **LS2 and Run 3** ⇒ **300 fb^{-1}**

- **High Luminosity LHC project**
- **LHC Roadmap up 2035** ⇒ **~3'000 fb^{-1}**

- **Neutrino platform**
- **Fixed target programme**
- **Post-LHC machines**

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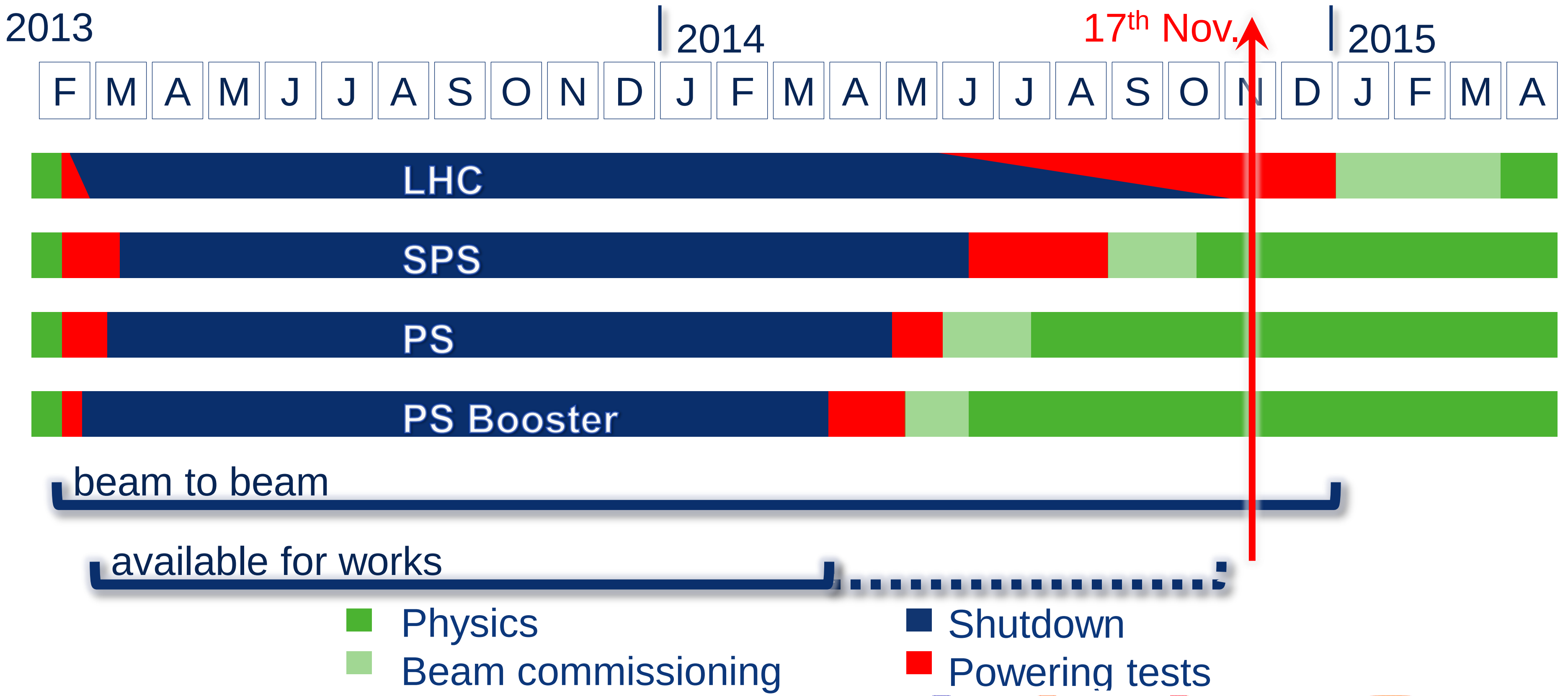
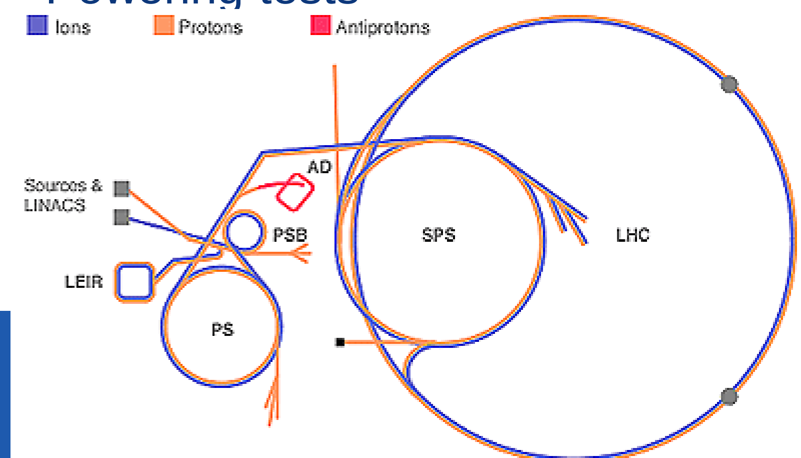
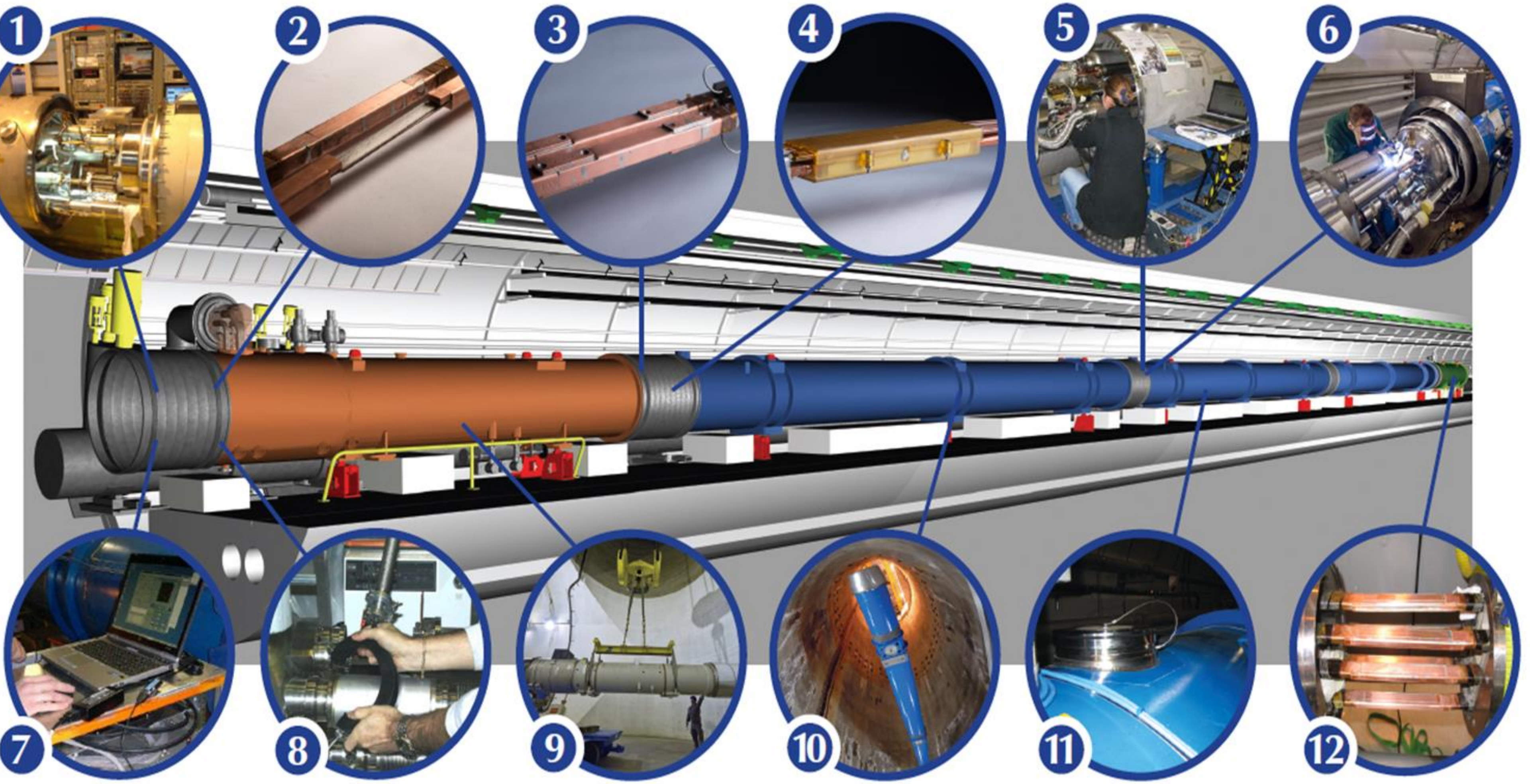
LS 1 from 16th Feb. 2013 to Dec. 2014





The main 2013-14 LHC consolidations

1. 1695 Openings and final reclosures of the interconnections
2. Complete reconstruction of 3000 of these splices
3. Consolidation of the 10170 13kA splices, installing 27 000 shunts
4. Installation of 5000 consolidated electrical insulation systems
5. 300 000 electrical resistance measurements
6. 10170 orbital welding of stainless steel lines

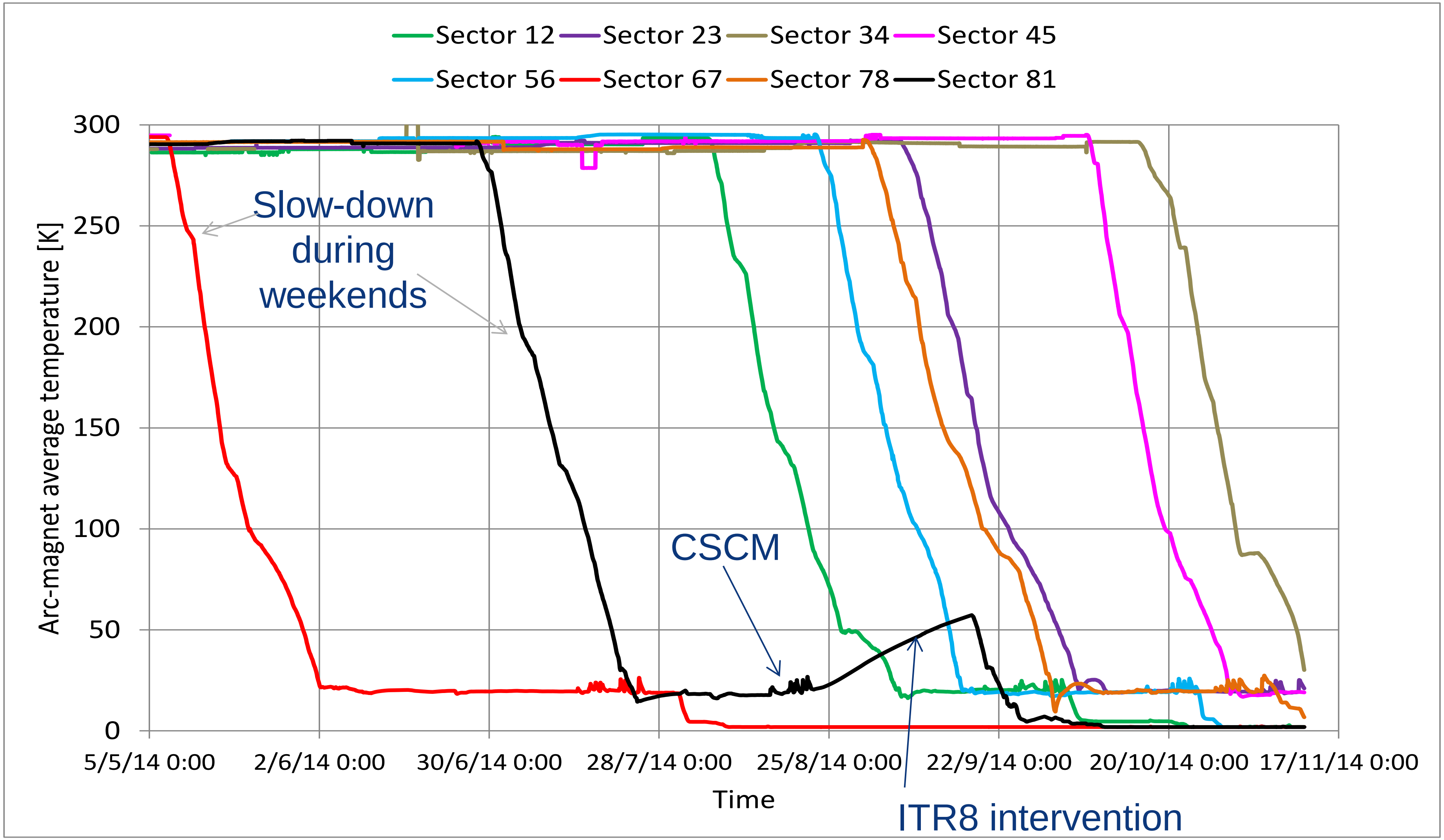


7. 18 000 electrical Quality Assurance tests
8. 10170 leak tightness tests
9. 3 quadrupole magnets to be replaced
10. 15 dipole magnets to be replaced
11. Installation of 612 pressure relief devices to bring the total to 1344
12. Consolidation of the 13 kA circuits in the 16 main electrical feed-boxes

Closure Nb1695 the last one! 18th June 2014

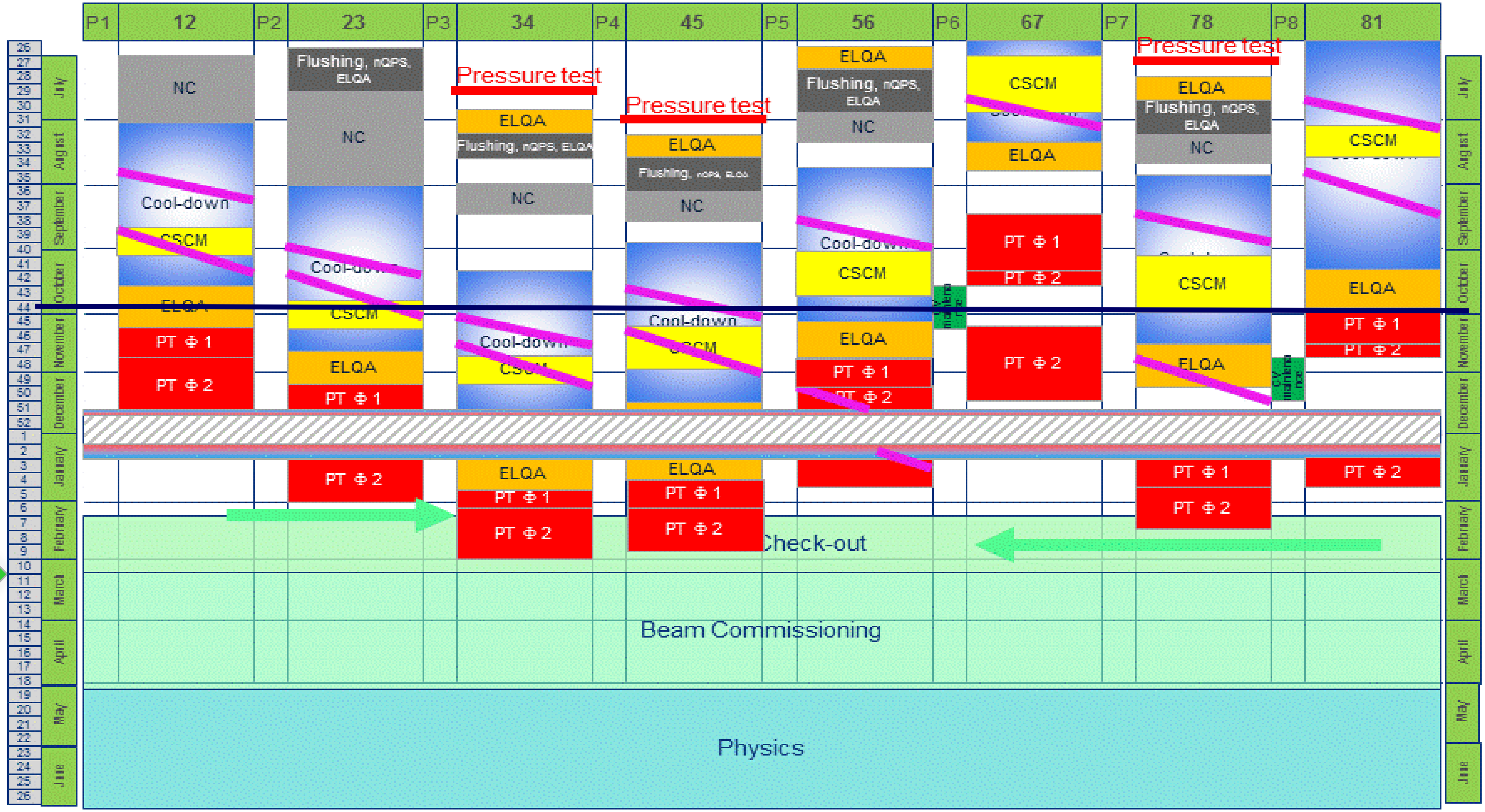
NTUA (GR), HNINP, WUT (PL), JINR (Dubna)

Cool-down of LHC sectors



LHC schedule V4.1

Safety First,
Quality Second,
Schedule Third



1st beam (March 2015)

Maximum beam energy : **13 TeV c.m. in 2015**

Decision to run at a **maximum** energy of 6.5 TeV per beam during the powering tests and during 2015.
(10 to 15 training quenches per sector are expected to be needed to reach that energy).

"We accept the risk that results from late quench tests could force to run at lower energy"

Emilio Meschi – LHC physics coordinator

NO change of beam energy in 2015.

A decision regarding the possibility of increasing the energy will be taken later in 2015, based on the experience gained in all eight sectors at 6.5 TeV per beam during powering tests and operation with beams.

LHC goal for **2015 and for Run 2 and 3**

Priorities for the 2015 run :

- **Establish proton-proton collision at 13 TeV with 25ns and *low* β* to prepare production run in 2016.**
  Optimisation of physics-to-physics duration

- **Later in 2015: decision on special runs "when and duration" (90m optics): not in the 1st part of the year. Waiting LHCC recommendation**

- **Pb-Pb run: one month at the end of 2015**

The goal for Run 2 luminosity is 1.3 x 10^{34} cm^{-2} s^{-1} and operation with 25 ns bunch spacing (2800 bunches), giving an estimated pile-up of 40 events per bunch crossing.

"A maximum pileup of ~50 is considered to be acceptable for ATLAS and CMS"

LHC goal for **2015 and for Run 2 and 3**

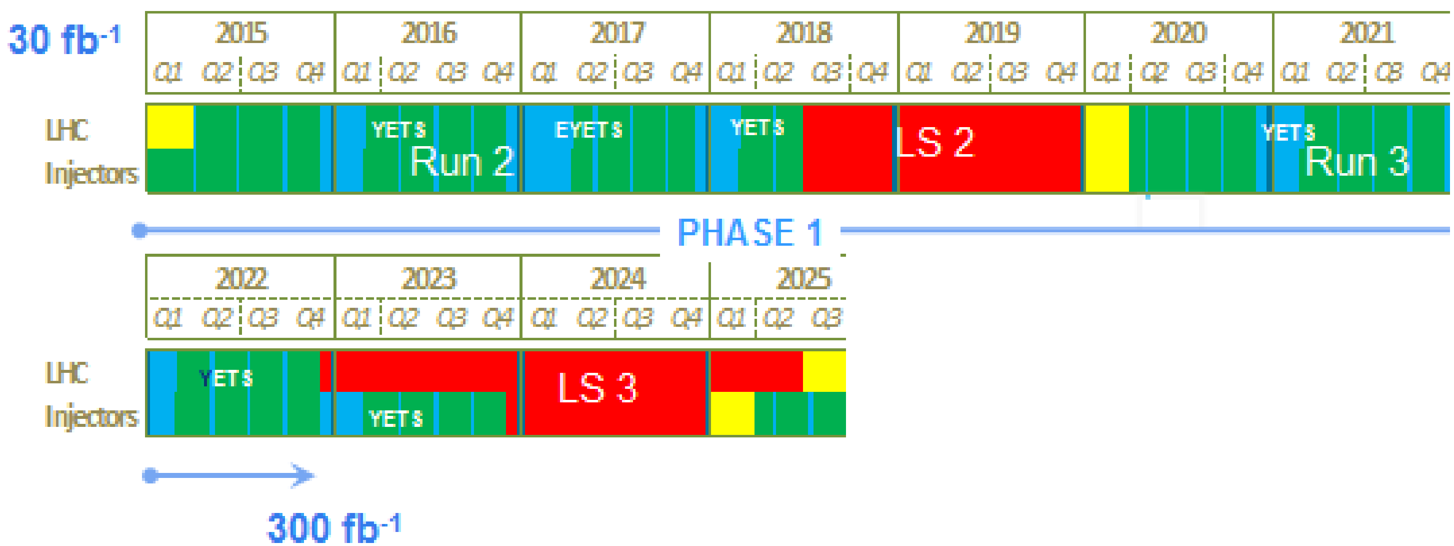
Integrated luminosity goal:

2015 : 10 fb^{-1}

Run2: ~100-120 fb^{-1}

(better estimation by end of 2015)

300 fb^{-1} before LS3



CERN Medium – Long Term Strategy

The CERN Medium Term Plan approved by June'14 Council, implements the European Strategy including a long-term outlook.

The scientific programme is concentrated around four priorities:

1. **Full LHC exploitation** – the highest priority - including the construction of the High Luminosity Upgrade until 2025
2. **High Energy Frontier** – CERN's role and preparation for the next large scale facility
3. **Neutrino Platform** – allow for to contribute to a future long baseline facility in the US and for detector R&D for neutrino experiments
4. **Fixed-target programme** – maintain the diversity of the field and honour ongoing obligations by exploiting the unique facilities at CERN

European Strategy for Particle Physics

The European Strategy for Particle Physics Update 2013

Near-term & Mid-term High-energy Colliders

LARGE HADRON COLLIDER

- **The HL-LHC is strongly supported and is the first high-priority large-category project in our recommended program. It should move forward without significant delay to ensure that accelerator and experiments can continue to function effectively beyond the end of this decade and meet the project schedule.**
- *Recommendation 10:* ***Complete the LHC phase-1 upgrades, and continue the strong collaboration in the LHC with the phase-2 (HL-LHC) upgrades of the accelerator and both general-purpose experiments (ATLAS and CMS). The LHC upgrades constitute our highest-priority near-term large project.***

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HL-LHC from a study to a PROJECT

300 fb^{-1} → 3000 fb^{-1}

including LHC injectors upgrade **LIU**

(Linac 4, Booster 2GeV, PS and SPS upgrade)

Goals and means of the LIU project

Increase intensity/brightness in the injectors to match HL-LHC requirements

⇒ Enable Linac4/PSB/PS/SPS to accelerate and manipulate higher intensity beams (efficient production, space charge & electron cloud mitigation, impedance reduction, feedbacks, etc.)

⇒ Upgrade the injectors of the ion chain (Linac3, LEIR, PS, SPS) to produce beam parameters at the LHC injection that can meet the luminosity goal

Increase injector reliability and lifetime to cover HL-LHC run (until ~2035) closely related to consolidation program

⇒ Upgrade/replace ageing equipment (power supplies, magnets, RF…)

⇒ Improve radioprotection measures (shielding, ventilation…)

Courtesy of Malika Meddahi

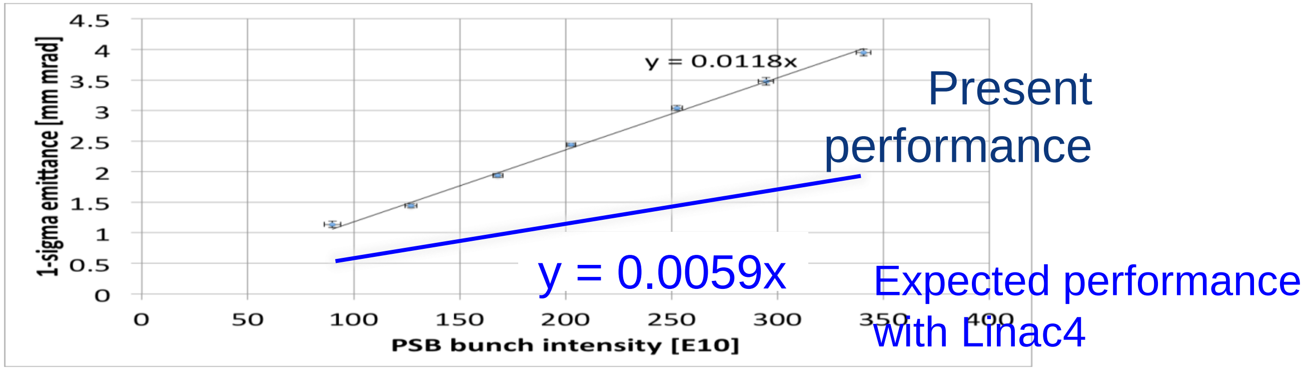
LIU Proton target → HL-LHC beam parameters

25 ns	$\mathcal{N}$ (x 10^{11} p/b)	ε (μm)	B_l (ns)
Achieved in 2012	1.2	2.6 (std) 1.4 (BCMS)	1.5
HL-LHC	2.3	2.1	1.7

Injectors must produce 25 ns proton beams with about double intensity and higher brightness: A cascade of improvements is needed across the whole injector chain to reach this target

Ex: Linac4 will replace Linac2

12 MeV acceleration validated



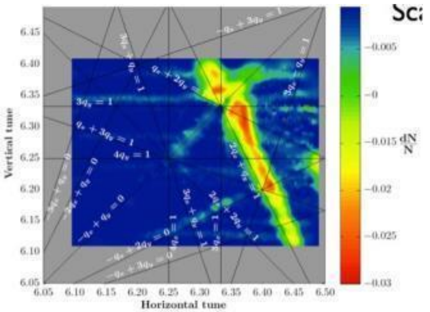
LS2 : (mid 2018-2019), LHC Injector Upgrades (LIU)

LINAC4 – PS Booster:

- H^- injection and increase of PSB injection energy from 50 MeV to 160 MeV, to increase PSB space charge threshold
- New RF cavity system, new main power converters
- Increase of extraction energy from 1.4 GeV to 2 GeV

PS:

- Increase of injection energy from 1.4 GeV to 2 GeV to increase PS space charge threshold
- Transverse resonance compensation
- New RF Longitudinal feedback system
- New RF beam manipulation scheme to increase beam brightness



SPS

- Electron Cloud mitigation – strong feedback system, or coating of the vacuum system
- Impedance reduction, improved feedbacks
- Large-scale modification to the main RF system

These are only the main modifications and this list is far from exhaustive

Project leader: Malika Meddahi, Deputy: Giovanni Rumolo

Goal of High Luminosity LHC (HL-LHC):

The main objective of HiLumi LHC Design Study is to determine a hardware configuration and a set of beam parameters that will allow the LHC to reach the following targets:

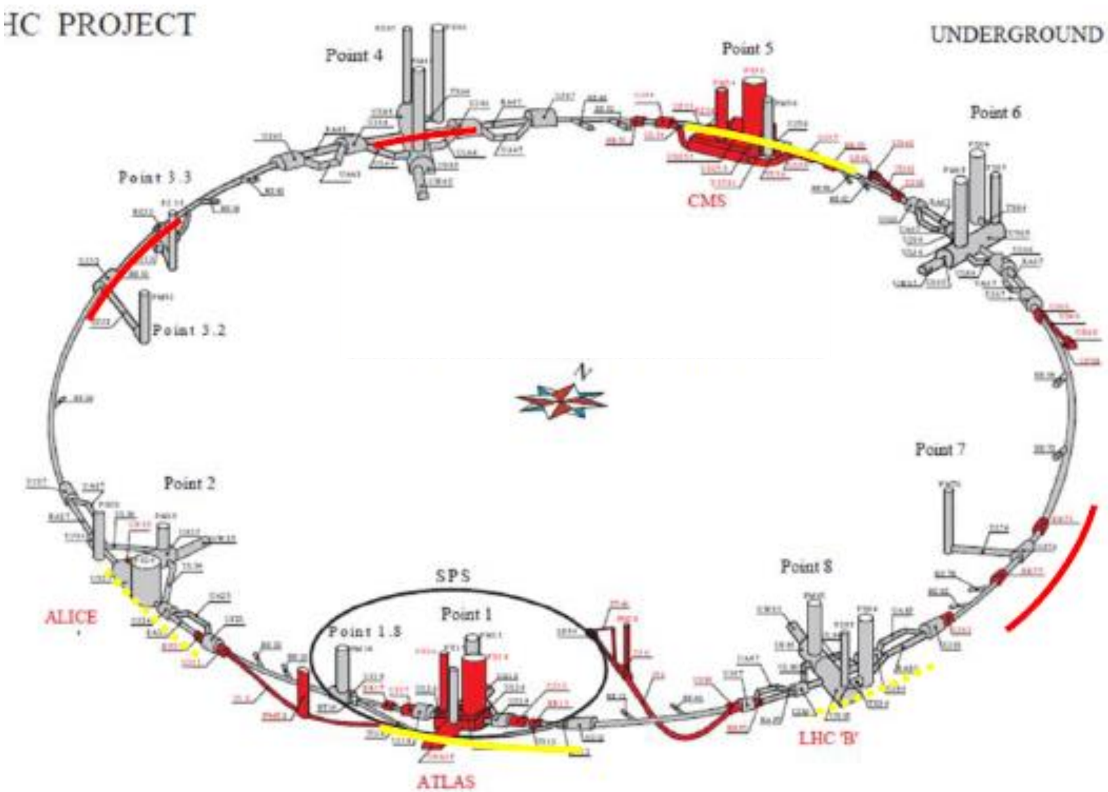
Prepare machine for operation **beyond 2025 and up to 2035**

Devise beam parameters and operation scenarios for:

- enabling a total integrated luminosity of **3000 fb^{-1}**
- implying an integrated luminosity of **250-300 fb^{-1} per year**,
- design for μ ~ **140 (~ 200)** (➔ peak luminosity of **5 (7) 10^{34} cm^{-2} s^{-1}**)
- design equipment for 'ultimate' performance of **7.5 10^{34} cm^{-2} s^{-1}** and **4000 fb^{-1}**

=> Ten times the luminosity reach of first 10 years of LHC operation

The 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
- …

Major intervention on more than 1.2 km of the LHC

Project leader: Lucio Rossi; Deputy: Oliver Brüning

High Luminosity LHC

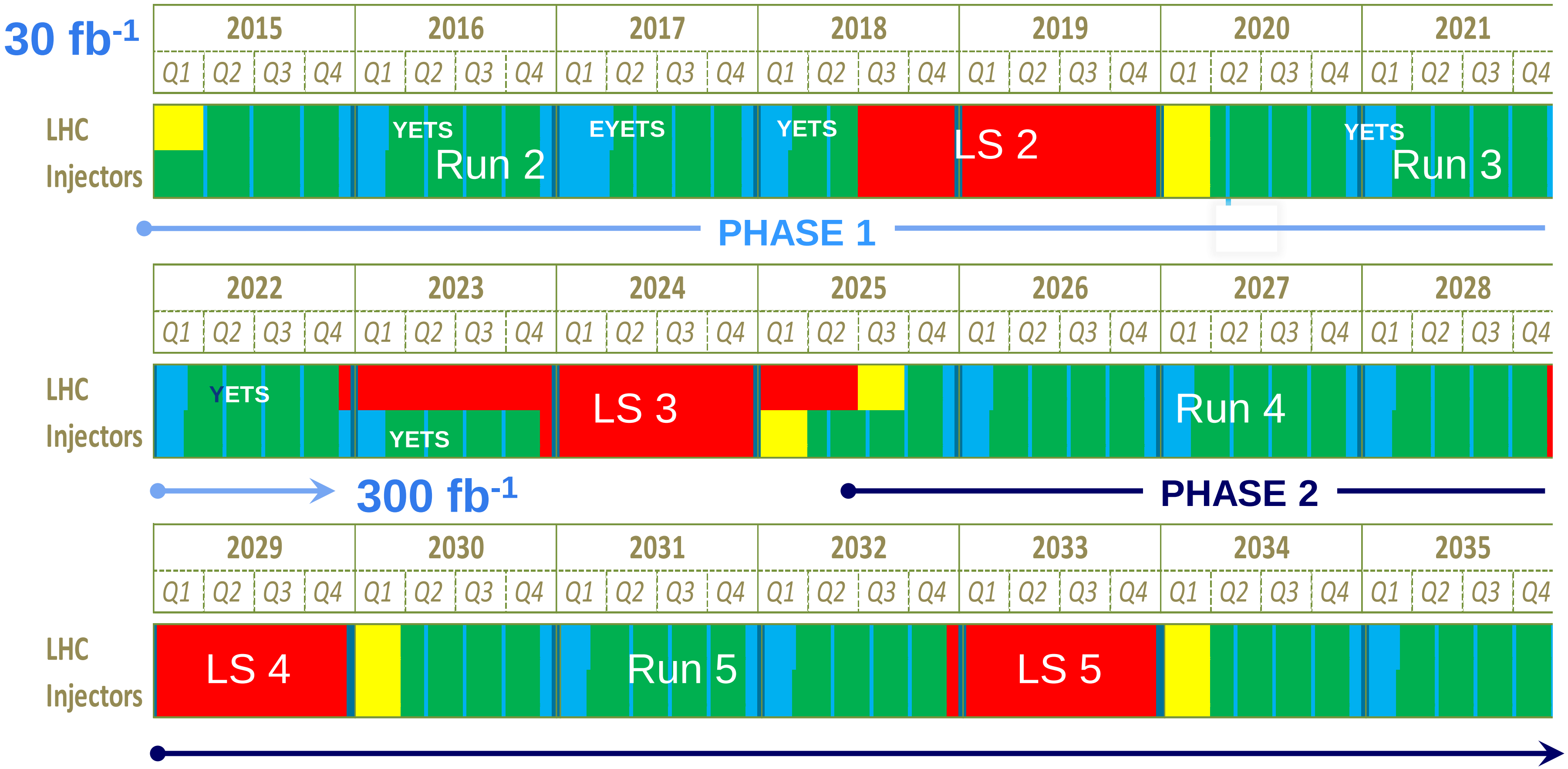
High Luminosity LHC Participants

LHC roadmap: schedule beyond LS1

LS2 starting in 2018 (July) => 18 months + 3 months BC
LS3 LHC: starting in 2023 => 30 months + 3 months BC
Injectors: in 2024 => 13 months + 3 months BC

- Physics
- Shutdown
- Beam commissioning
- Technical stop

(Extended) Year End Technical Stop: (E)YETS



Goal of 3'000 fb-1 by mid 2030ies

The European Strategy for Particle Physics Update 2013

There is a strong scientific case for an **electron-positron collider**, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded.

The **Technical Design Report of the International Linear Collider (ILC)** has been completed, with large European participation. **The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate.**

Europe looks forward to a proposal from Japan to discuss a possible participation.

European Strategy for Particle Physics
CERN MTP

Rapid progress in neutrino oscillation physics, with significant European involvement, has established a strong scientific case for a long-baseline neutrino programme exploring CP violation and the mass hierarchy in the neutrino sector.

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

CERN Council in June 2014 has decided to implement the proposed Medium Term Plan (MTP) which contains an allocation of resources in the next 5 years dedicated to the Neutrino CERN Platform

This will cover:

- Generic ν detector R&D including large prototypes
- Design and generic R&D on ν beams
- The construction of a new experimental hall dedicated to neutrinos (Nord Area extension : EHN1) with charged test beams capabilities
- The reinforcement of various Technical/Scientific groups at CERN (cryogenics, physics, ….) which will support the activities of the platform
- The support with detectors and components of the Short Baseline/LBNF program at FNAL
- Support to various design/feasibility studies on this field (NUSTORM, ESS beam, …..)

CERN Neutrino Platform

2014 -2018

Neutrino detectors R&D

WA104: rebuild ICARUS T600 in bldg 185 and make it ready for a FNAL beam

WA104: R&D on an AIR core muon detector (NESSiE) or eventually integrate a solenoid in the main TPC

WA105: R&D on 2 phases large LAr TPC prototypes

MIND : R&D on muon tracking detectors

LBNF : Test of a LBNE module inside the WA105 cryostat

CERN Medium – Long Term Strategy
CERN's Fixed-target programme

European 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 (Nuclear Physics European Collaboration Committee) on topics of mutual interest.

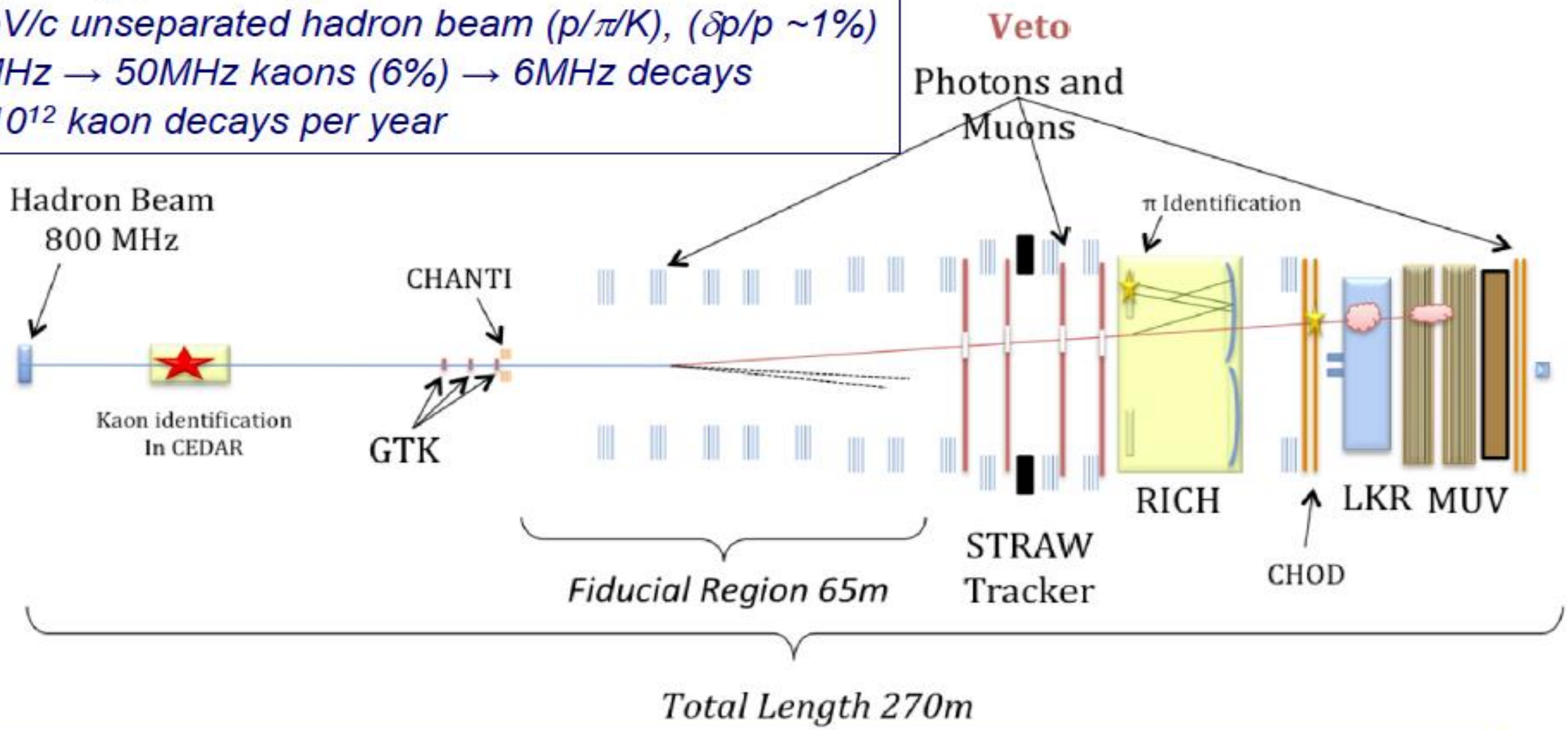
Unique facilities

- Na61, Na62
- N-Tof area 2
- HIE-ISOLDE construction
- ELENA construction including consolidation of the AD facility
- Maintain experimental areas for fixed-target experiments

- Earmarked materials funding for TSR integration at CERN
  - Possible only after LS2, clarification of manpower support needed

The NA62 detector for $K^{\pm} \rightarrow \pi^{\pm}\nu\bar{\nu}$

- *SPS primary protons @ 400GeV/c*
- *75GeV/c unseparated hadron beam (p/π/K), (δp/p ~1%)*
- *750MHz → 50MHz kaons (6%) → 6MHz decays*
- *4.8×10^{12} kaon decays per year*



NA62 timeline:

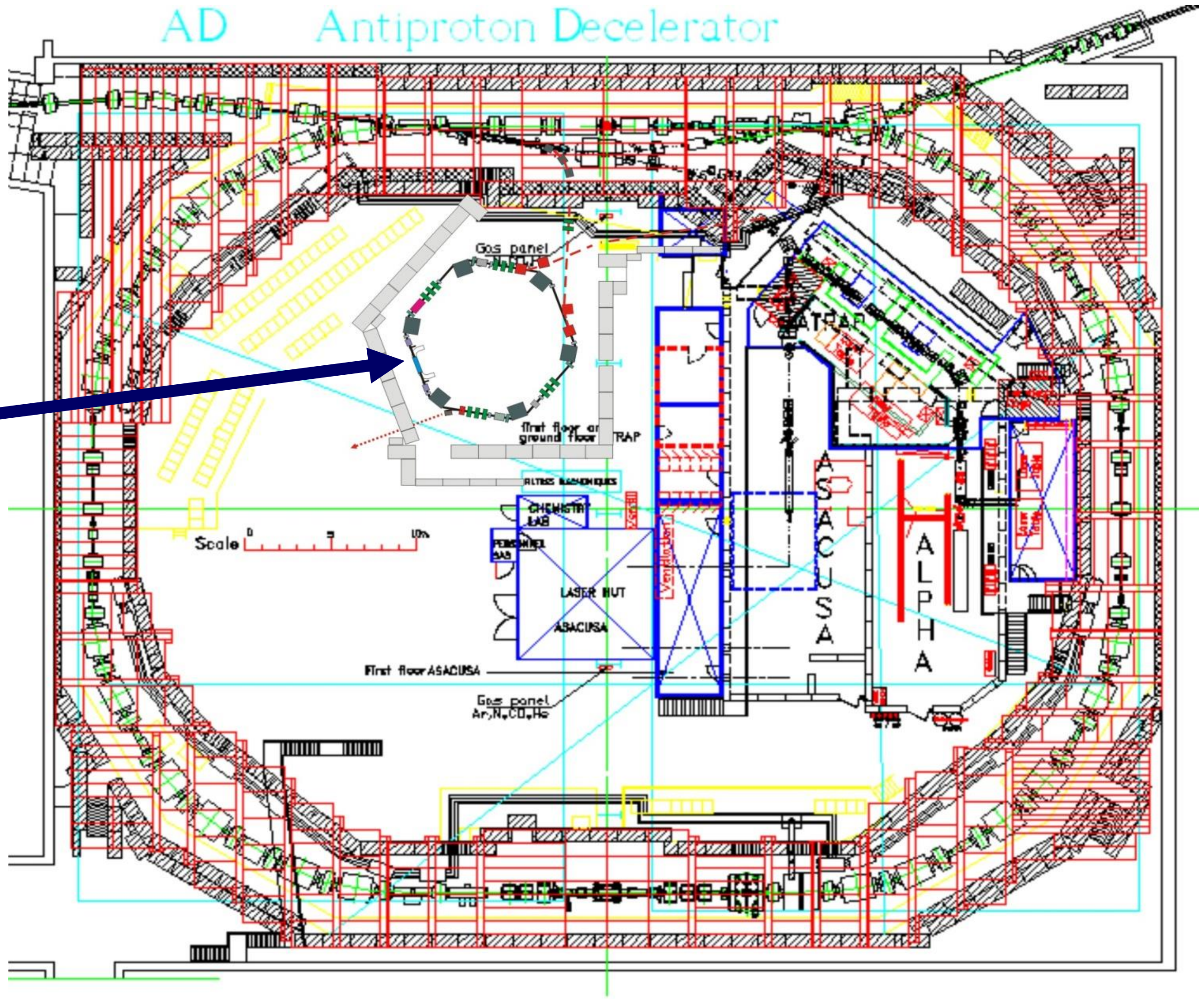
- *first technical run in autumn 2012 including many parts of the experiment*
- *2013: complete detector installation*
- *2014-?: data taking with full detector*

(driven by CERN accelerator schedule)

AD UPGRADE

Additional decelerating and cooling ring:

E_{kin} = 5 MeV → 100 KeV



Expected gains :

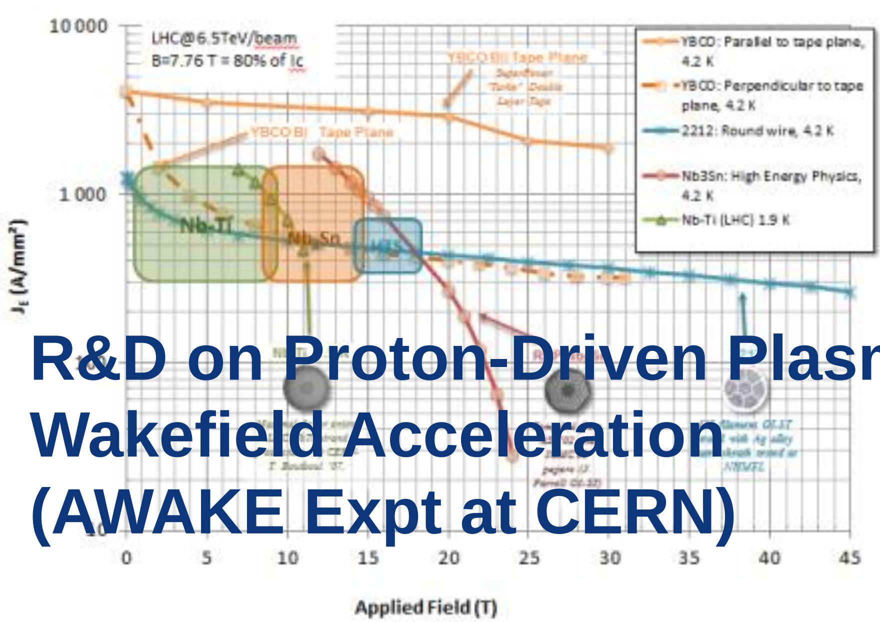
- **1 to 2 orders of magnitude in trapping efficiencies**
- **Parallel running of all experiments**
- **Increased number of hosted experiments**

Construction started, time scale ~2015-16

“to propose an ambitious **post-LHC accelerator project at CERN** by the time of the next Strategy update”

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.***

HFM - FCC



HGA - CLIC

R&D on Proton-Driven Plasma Wakefield Acceleration (AWAKE Expt at CERN)

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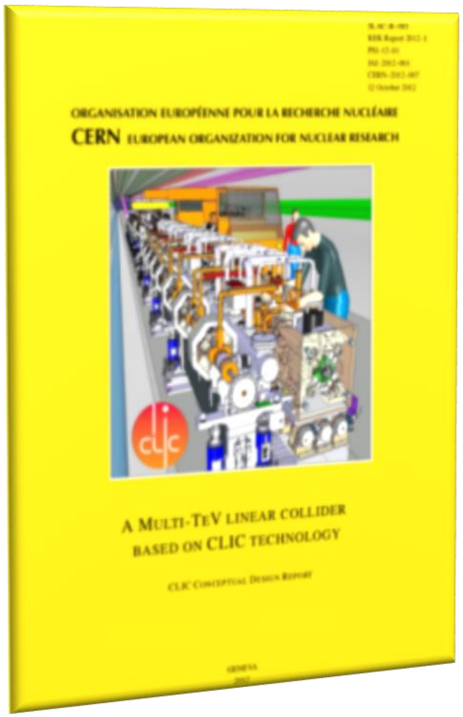
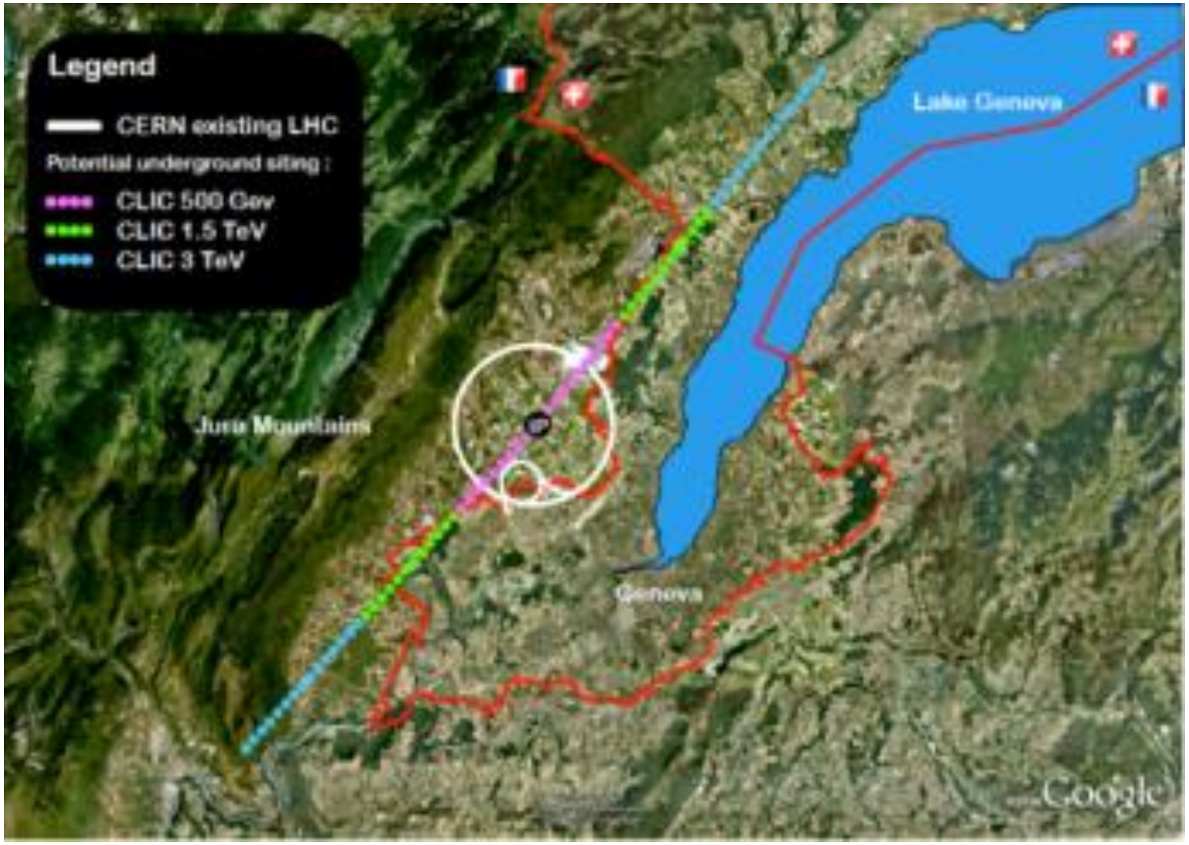




Highest possible energy e^+e^- with CLIC (CDR 2012)

Multi-lateral collaboration

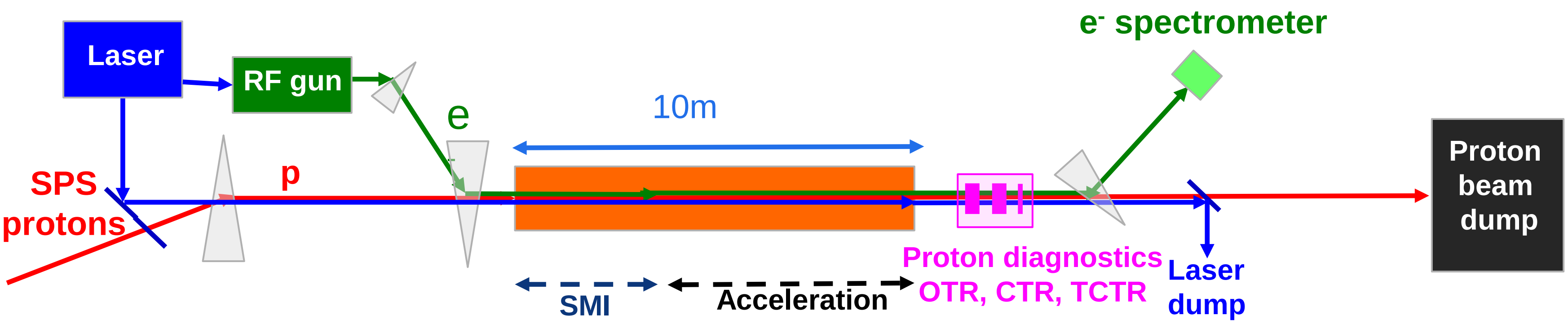
AWAKE

- **AWAKE**: Advanced Proton Driven Plasma Wakefield Acceleration Experiment
  - Use SPS 400 GeV/c proton beam as **drive beam**
  - Inject 15 MeV/c electron beam as **witness beam**
  - 2 TW laser beam for plasma ionization and seeding of the Self-Modulation-Instability (i.e. production of micro-bunches from long SPS bunch)
- Proof-of-Principle Accelerator R&D experiment at CERN
  - **First proton driven wakefield experiment worldwide**
  - Demonstration of high-gradient acceleration of electrons
- AWAKE Collaboration: 16 Institutes world-wide

Final Goal: Design high quality & high energy electron accelerator based on acquired knowledge.

Courtesy Edda Gschwendtner

AWAKE Experimental Program



- Perform **benchmark experiments using proton bunches** to drive wakefields for the first time ever.
- Understand **the physics of self-modulation instability** processes in plasma.
- **Probe the accelerating wakefields with externally injected electrons**, including energy spectrum measurements for different injection and plasma parameters.

Beam-Driven Wakefield Acceleration: Landscape

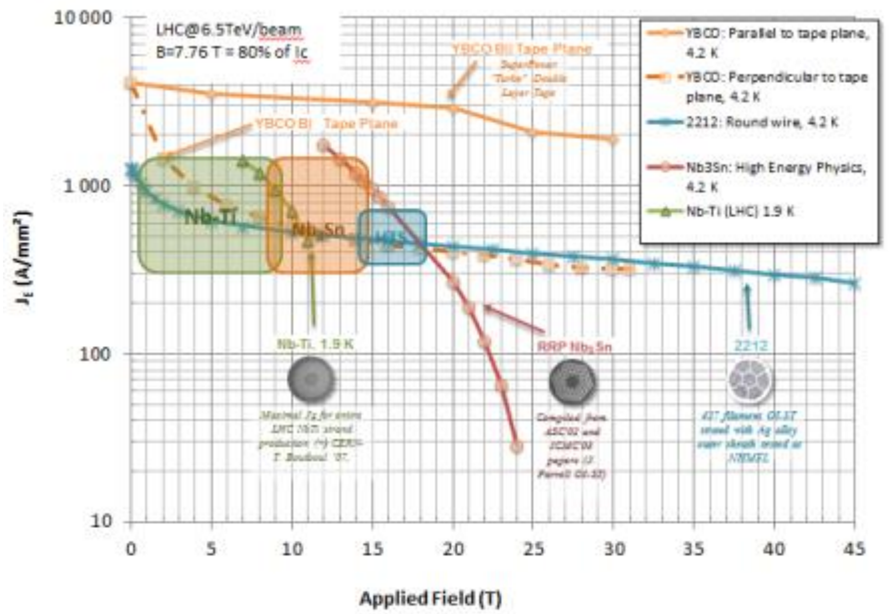
Facility	Where	Drive (D) beam	Witness (W) beam	Start	End	Goal
AWAKE	CERN, Geneva, Switzerland	400 GeV **protons**	Externally injected electron beam (PHIN 15 MeV)	2016	2020+	**Use for future high energy e-/e+ collider.** - Study Self-Modulation Instability (SMI). - Accelerate externally injected electrons. - Demonstrate scalability of acceleration scheme.
SLAC-FACET	SLAC, Stanford, USA	20 GeV electrons and positrons	Two-bunch formed with mask (e^-/e^+ and e^--e^+ bunches)	2012	Sept 2016	- Acceleration of witness bunch with high quality and efficiency - Acceleration of positrons - FACET II proposal for 2018 operation
DESY-FLASH Forward	DESY, Hamburg, Germany	X-ray FEL type electron beam 1GeV	D + W in FEL bunch. Or independent W-bunch (LWFA).	2016	2020+	- Application (mostly) for x-ray FEL - Energy-doubling of Flash-beam energy - Upgrade-stage: use 2 GeV FEL D beam
DESY-Zeuthen	PITZ, DESY, Zeuthen, Germany	20 MeV electron beam	No witness (W) beam, only D beam from RF-gun.	2015	~2017	- Study Self-Modulation Instability (SMI)
Brookhaven ATF	BNL, Brookhaven, USA	60 MeV electrons	Several bunches, D+W formed with mask.	On going		- Study quasi-nonlinear PWFA regime. - Study PWFA driven by multiple bunches - Visualisation with optical techniques

“to propose an ambitious **post-LHC accelerator project at CERN** by the time of the next Strategy update”

CERN should undertake design studies for accelerator projects in a global context,

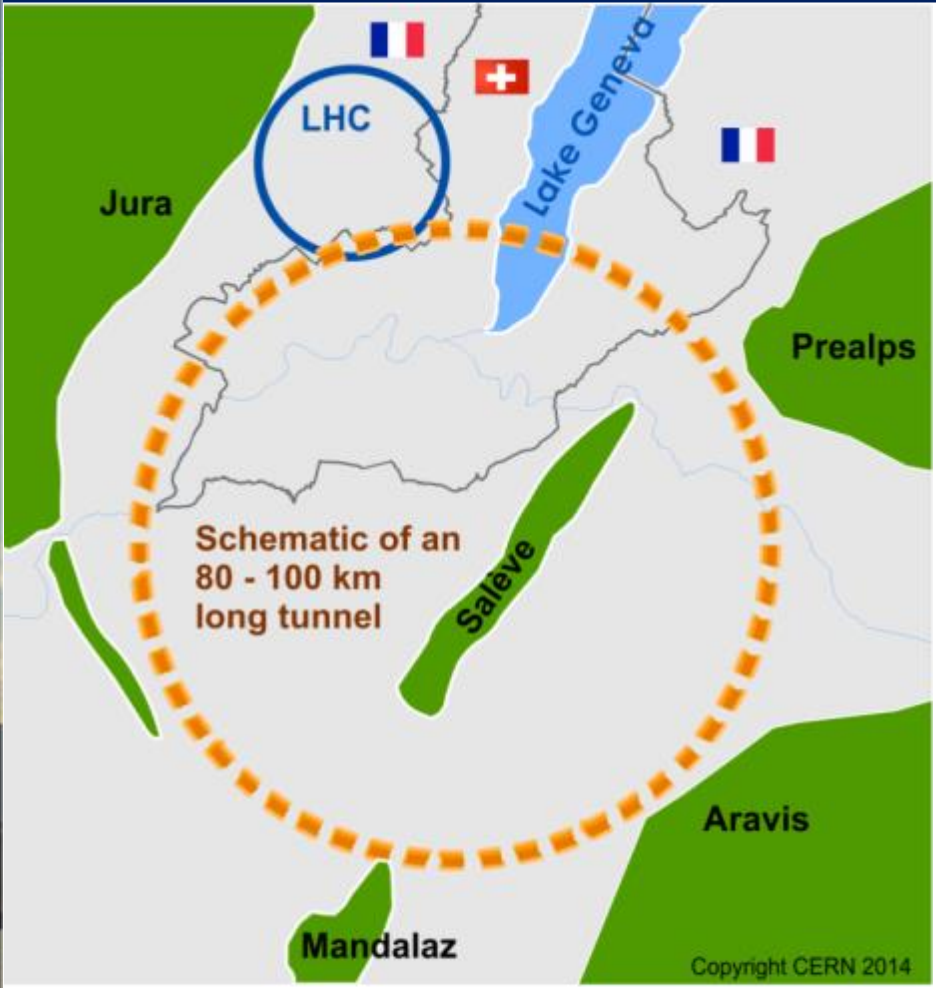
*with emphasis on **proton-proton and electron-positron high-energy frontier machines**. These design studies should be coupled to a vigorous accelerator **R&D programme**, including **high-field magnets and high-gradient accelerating structures**, **in collaboration with national institutes, laboratories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

HFM – FCC-hh



HGA - CLIC

ider Study - SCOPE
or the next ESU (2018)



ructure in Geneva area

High-field magnet R&D (FCC-hh)

FHC baseline is 16T Nb_3Sn technology for ~100 TeV c.m. in ~100 km

Develop Nb_3Sn-based 16 T dipole technology,
- conductor developments
- short models with sufficient aperture (40 – 50 mm) and
- accelerator features (margin, field quality, protect-ability, cycled operation).

Goal: 16T short dipole models by 2018/19 (America, Asia, Europe)

In parallel HTS development targeting 20 T (option and longer term)

Goal: Demonstrate HTS/LTS 20 T dipole technology:
- 5 T insert (EuCARD2), ~40 mm aperture and accelerator features
- Outsert of large aperture ~100 mm, (FRESCA2 or other)

High-field SC magnet R&D for FCC will be a "natural" continuation of HL-LHC developments and ensure continuation of of long-lasting worldwide research efforts and efficient use of past investments

FCC Week 2015

23-27 March 2015

Washington D.C. (USA)
Europe/Zurich timezone

Search

REGISTRATION IS OPEN!

This **first Annual Meeting of the Future Circular Collider study** is an important milestone to conclude the first, exploratory phase, leading to the identification of the baseline for the further study. Organized as an IEEE conference, it will provide the opportunity for re-enforcing the cohesion of the community and to catalyse cross-fertilization within the FCC study.

This event will follow the traditional layout of plenary and parallel sessions with invited contributions. Plenary sessions will give an overview about the ongoing activities across all parts of the study and serve informing study members about the main boundary conditions and working hypothesis. Parallel sessions will focus on specific areas of the study and a limited number of contributed 10' presentations are foreseen, to enable communication of key findings of ongoing work with significant impact on the subsequent study phases in an efficient way. We encourage submission of proposals which will be reviewed by the organising committee.

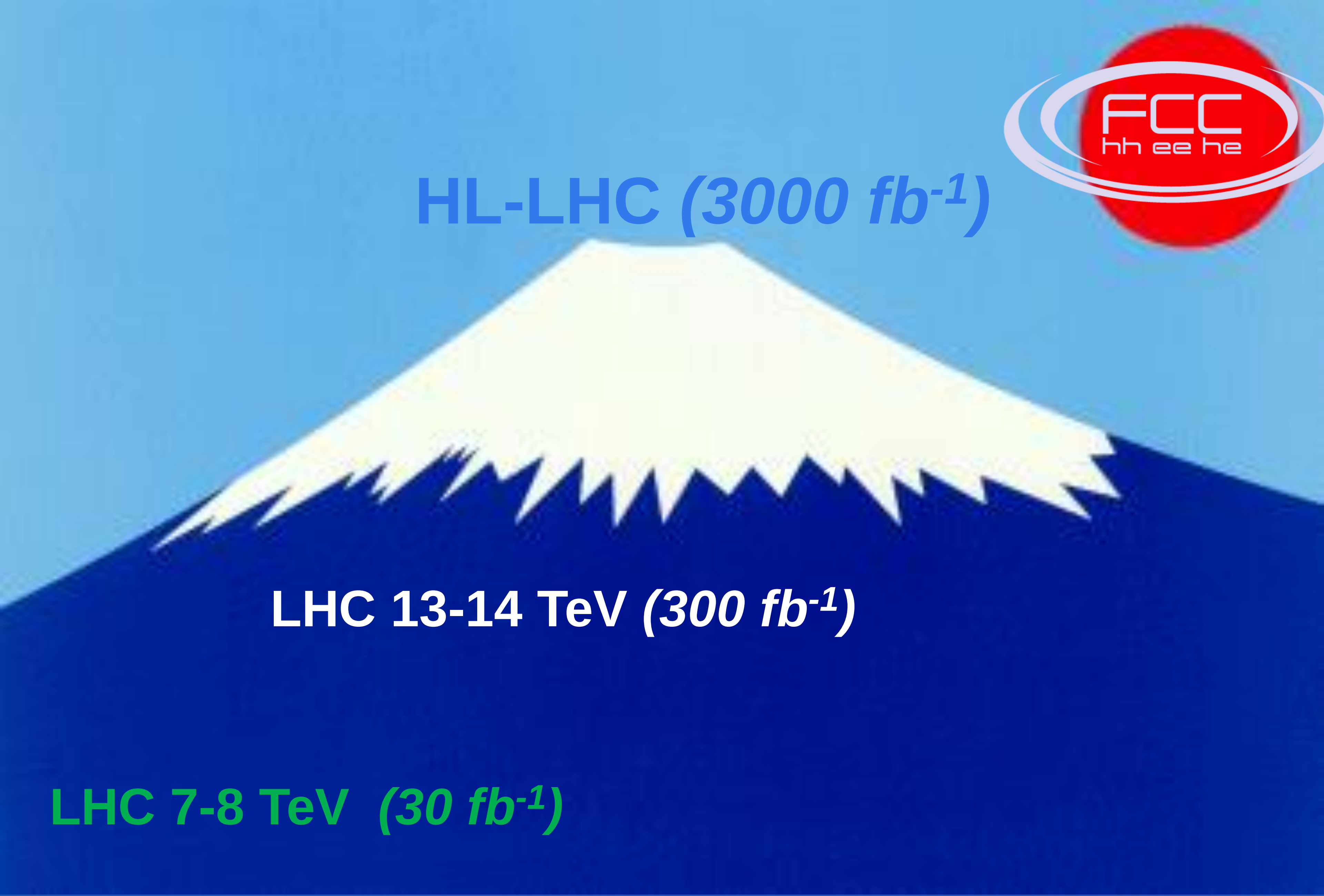
Satellite meetings for related projects and governance bodies will be included the program. Participation of industry is highly encouraged and supported via a dedicated industry track and a micro exhibition, focusing on superconducting cable technology. Communication and equal opportunity aspects will be addressed in dedicated working group meetings.

Plenary and parallel session contributions are by invitation only.

An open scientific fast track provides the opportunity to present findings of ongoing work with significant impact on the further study and of high importance to the FCC study community.

Registration is mandatory.

IEEE EuCARD² ECFA


FCC
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HL-LHC (3000 fb-1)
LHC 13-14 TeV (300 fb-1)
LHC 7-8 TeV (30 fb-1)

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Thanks for your attention