Welcome to the Accelerators and Technologies Sector of CERN

Y. Papaphilippou, Accelerator and Beam Physics group leader, on behalf of the Accelerator and Technologies Sector management

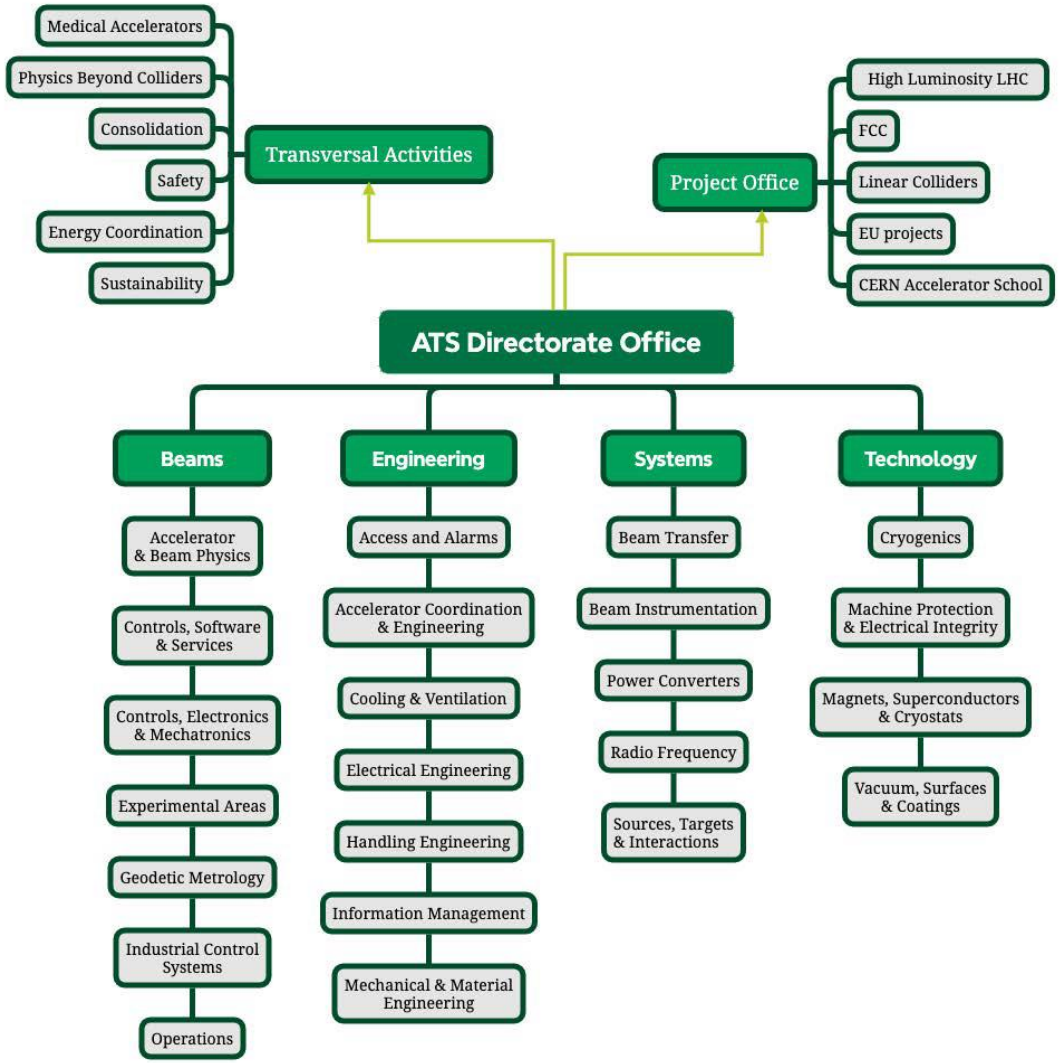
Thanks to Mike Lamont and ATS colleagues for the slides

ATS structure and Demographics

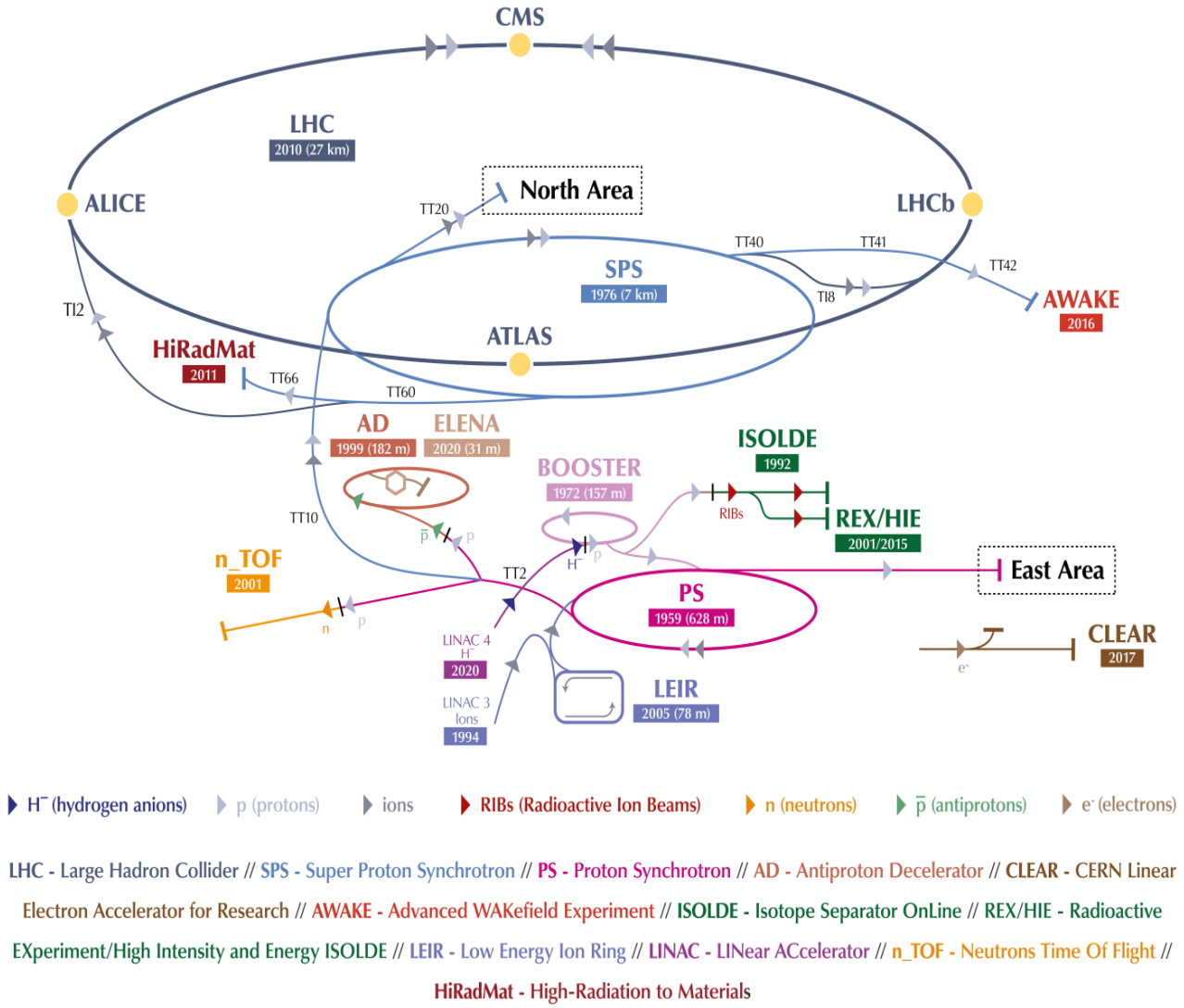
- Operates, maintains, consolidates, upgrades the world's largest accelerator complex and associated technical infrastructure++

- 1289 staff (~13% women)
- 475 fellows/graduates (~26% women)
- 520 associates (~26% women)
- Contract personnel

- ~50% of CERN Annual budget (M+P)
- Facilities used by 12,000 scientists from around the world



CERN Accelerator Complex



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

CERN Proton chain

1. **LINAC-4** 160MeV (**H-**)
2. **Proton Synchrotron Booster** 2GeV
3. **Proton Synchtrotron** 26GeV
4. **Super Proton Synchrotron** 450 GeV
5. **Large Hadron Collider** 7Tev

CERN Ion chain

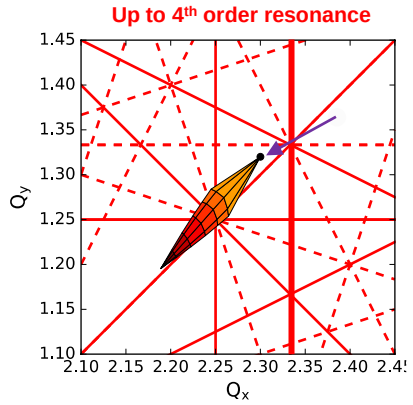
1. **LINAC-3**
2. **Low Energy Ion Ring**
3. **Proton Synchtrotron**
4. **Super Proton Synchrotron**
5. **Large Hadron Collider**

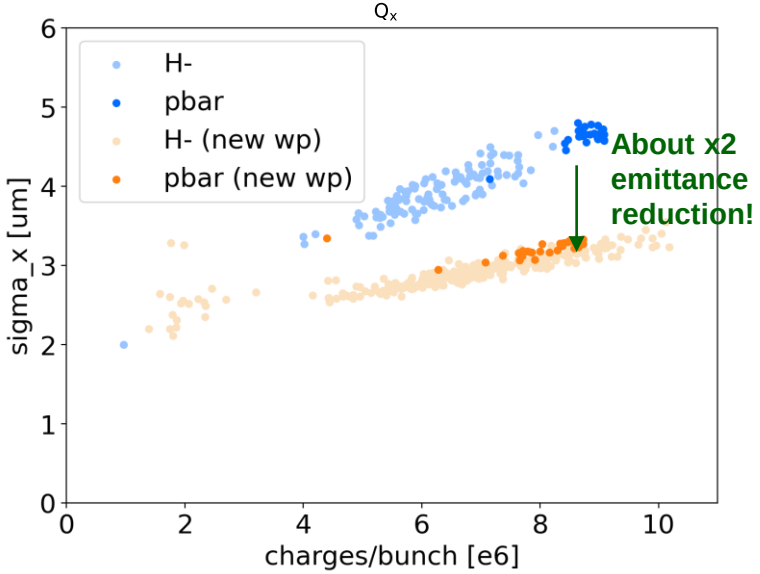
Other facilities & experiments: n_TOF, ISOLDE, East Area, North Area, HiRadMat, AWAKE, CLEAR (electrons), AD & ELENA (Antiprotons)

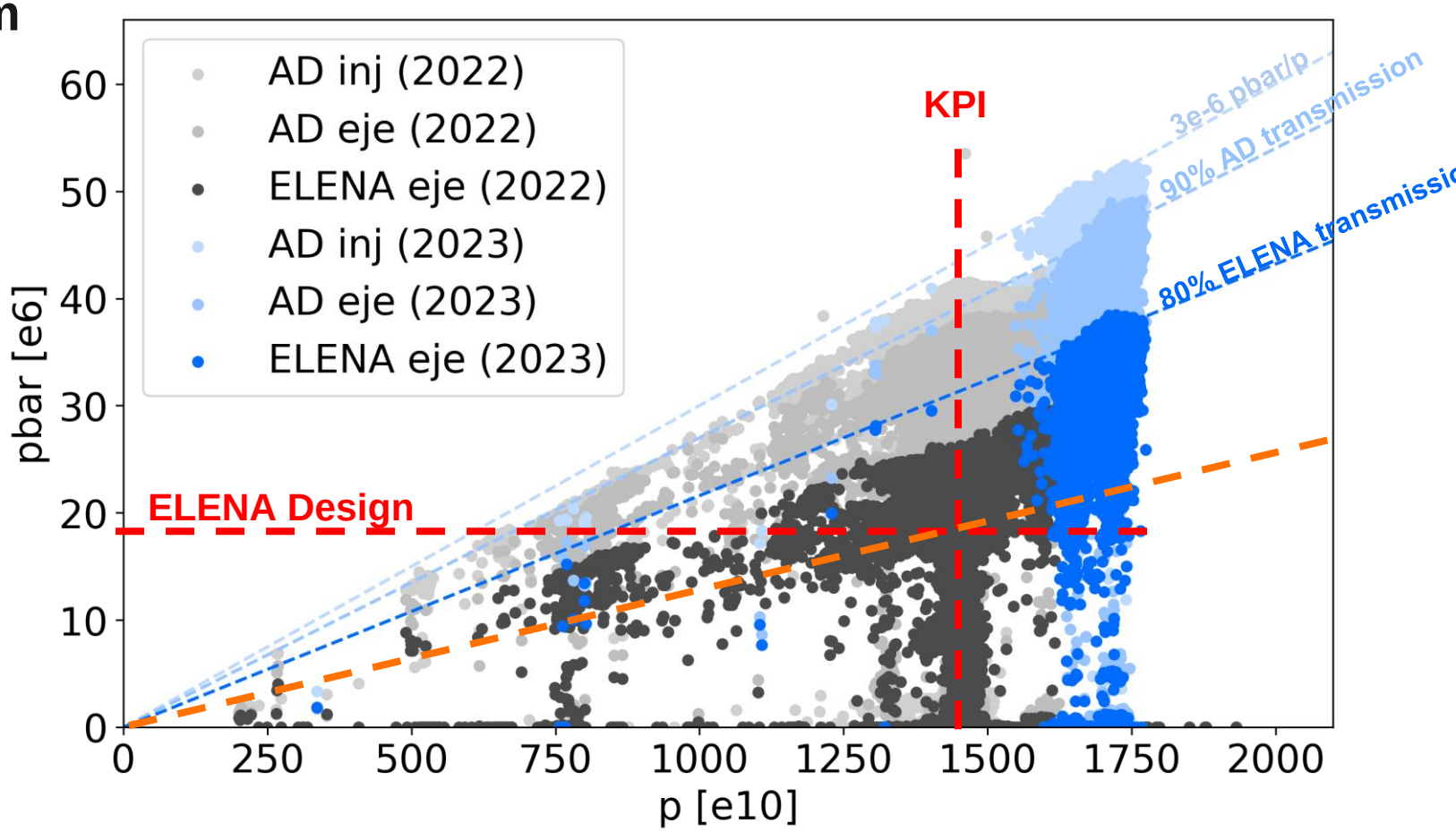
AD/ELENA operation and performance

Excellent year for AD/ELENA with **performance improvements**!

New **working poi**nt to avoid **3rd order resonance**, clear **reduction** of **beam size**

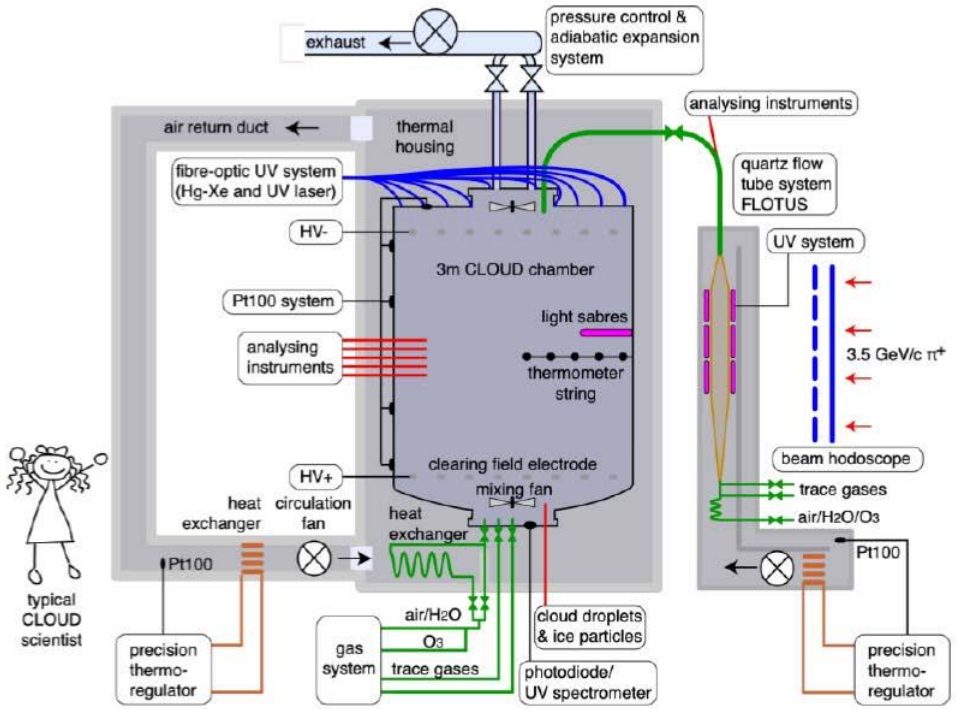




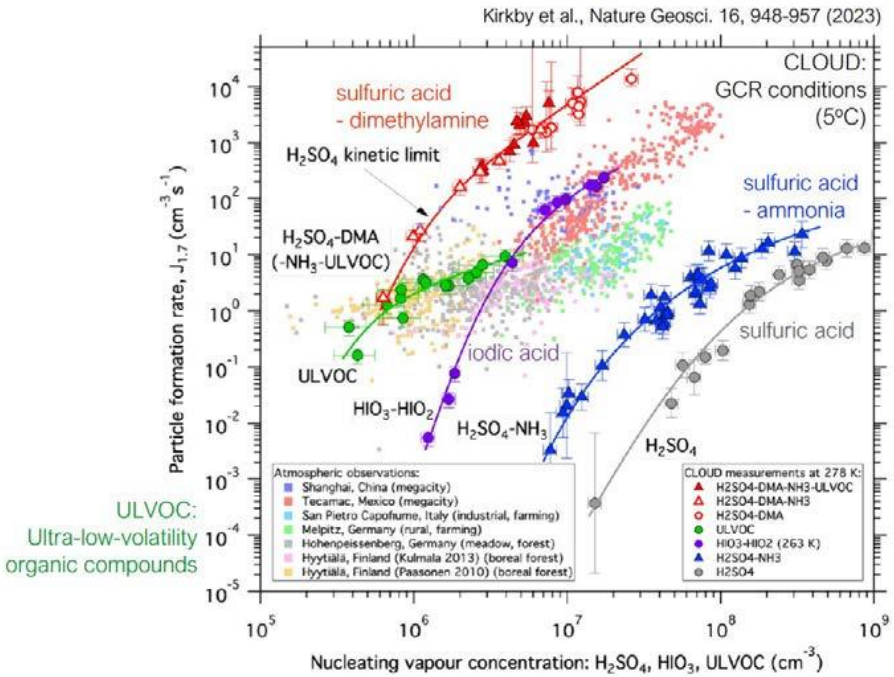


CLOUD – East area

- Key features:
  - Low contaminants
  - Atmospheric concentrations
  - Precise and steady control of all conditions over long periods:
    - vapours
    - T, UV
    - ionisation (n, gcr, π)
  - Comprehensive analysis instruments
  - FLOTUS (FLOw TUbe System)



New particle formation from CLOUD



ULVOC: Ultra-low-volatility organic compounds

- CLOUD measurements so far indicate that GCR ions account for 27% of global CCN for low clouds
- However GCR variations over solar cycle change CCN by only 0.2%, which is not climatically significant

CLOUD aims to help with interpretation of new particle formation in different atmospheric environments, and to provide a mechanistic foundation for air quality and climate models.

The SPSC **congratulates** CLOUD on a series of successful upgrades and measurements, and **acknowledges** the steady stream of publications and continued impact of the experiment.

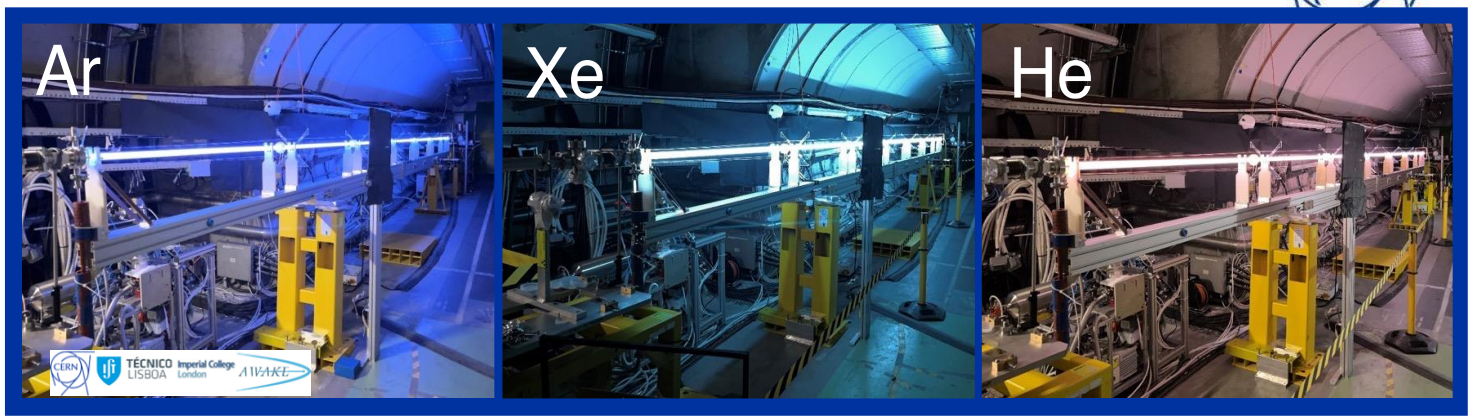
AWAKE – Plasma Wakefield acceleration experiment

Run 2b (2023-24)

10 m long discharge plasma source:

➔ Unique opportunity for 3-week tests in AWAKE in 2023

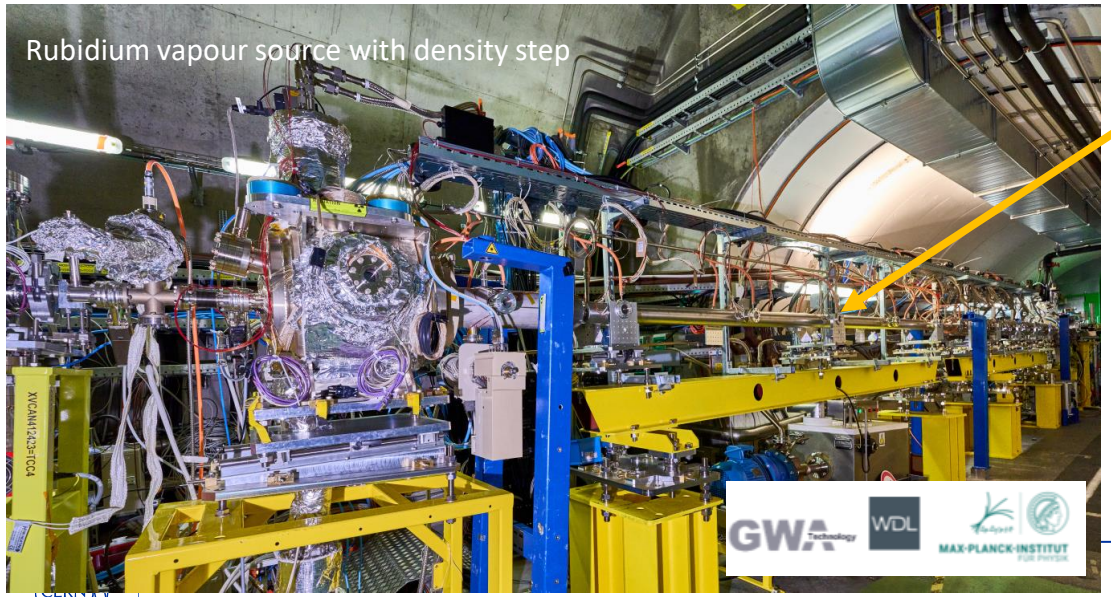
➔ Candidate for Run 2c/d and particle physics applications (5-200m plasma).

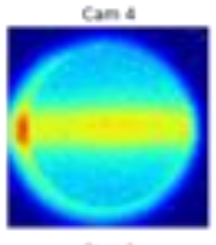


New 10 m long rubidium vapour source with a density step

➔ density step allows to maintain a large amplitude of the wakefields.

➔ Clear effects of the density step seen in 2023 Run.

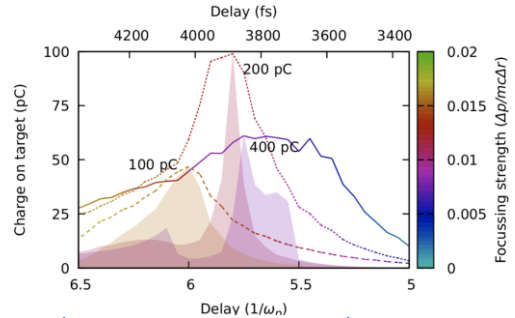




Plasma light with camera through viewport

+ many Users from collaborating institutes

Preparation for Run 2c

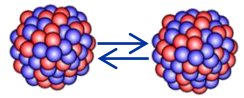


Electron injection tolerance studies

Acceleration of test electrons:

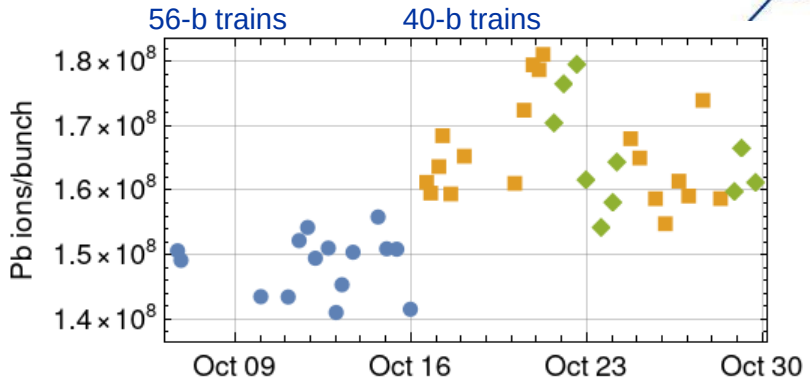
Energy of accelerated e- approximately double for this density step.

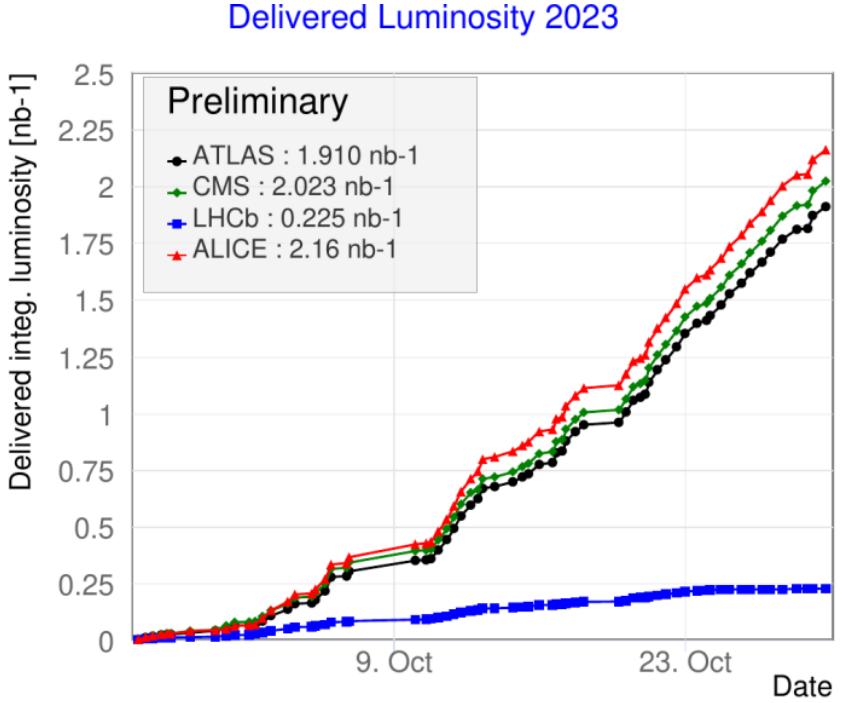
LHC lead ion run



- **2023 Pb ion run carried out in September-October**
- **Ion run relied on several new concepts**

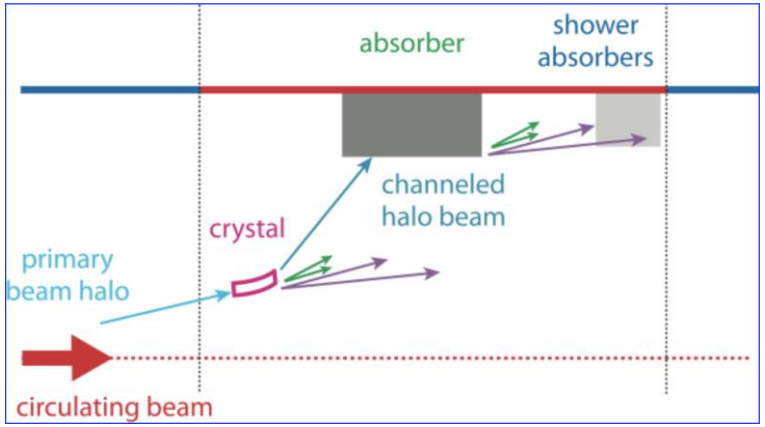
  ⟶ **All successfully used in operation, despite various challenges**



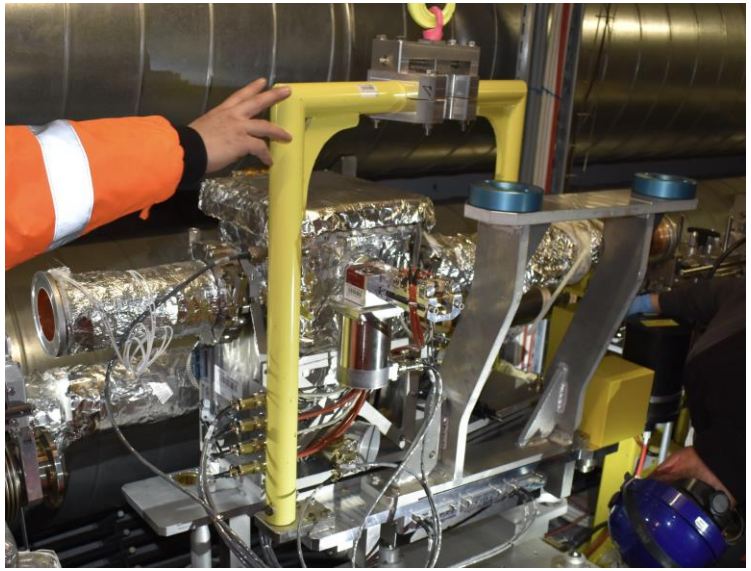


First deployment of crystal collimation

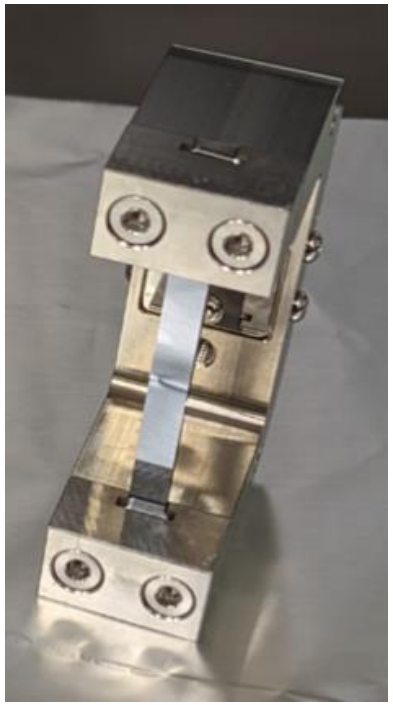
Crystal collimation scheme (illustrative)



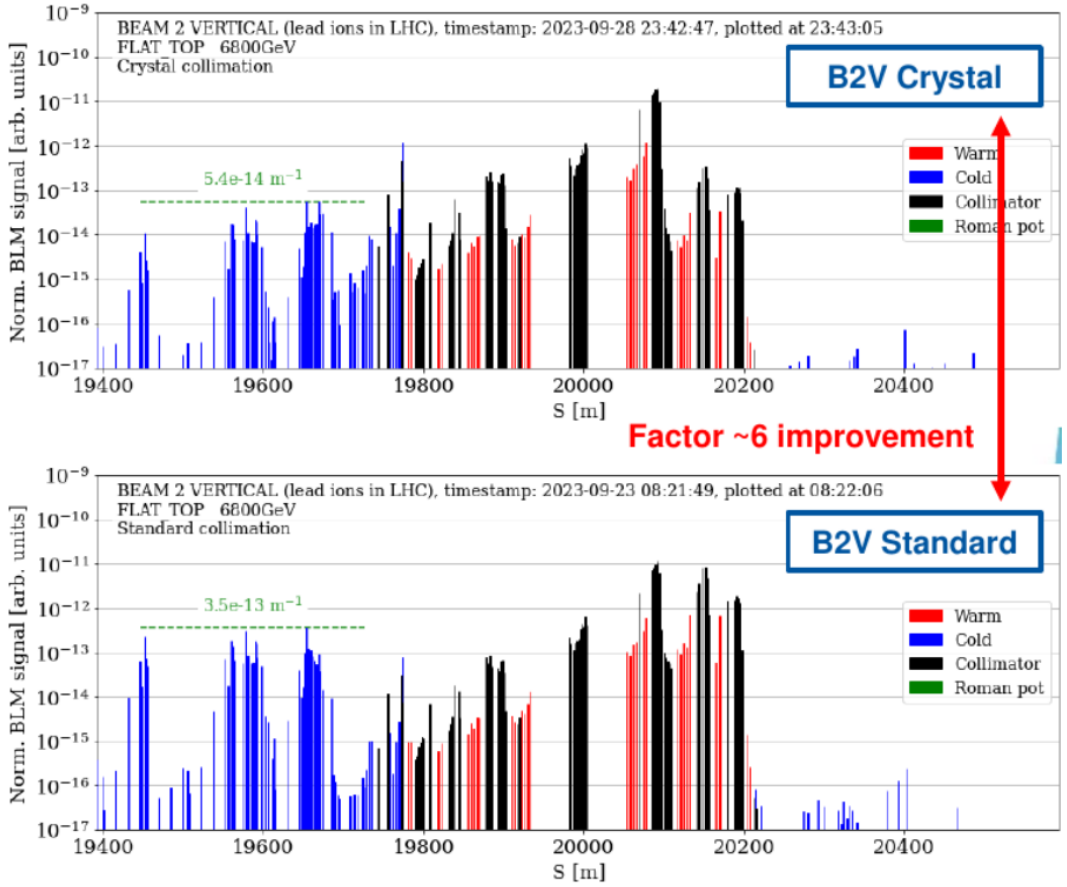
Built as a part of the HL-LHC upgrade (WP5) and installed in LS2 + YETS2022



- First operational deployment of crystal collimation scheme
- **Excellent cleaning performance achieved with lead beams at 6.8 Z TeV !**
  - Standard collimation **improved by more than a factor 5**



4mm-long LHC crystal



HL-LHC technology landmarks

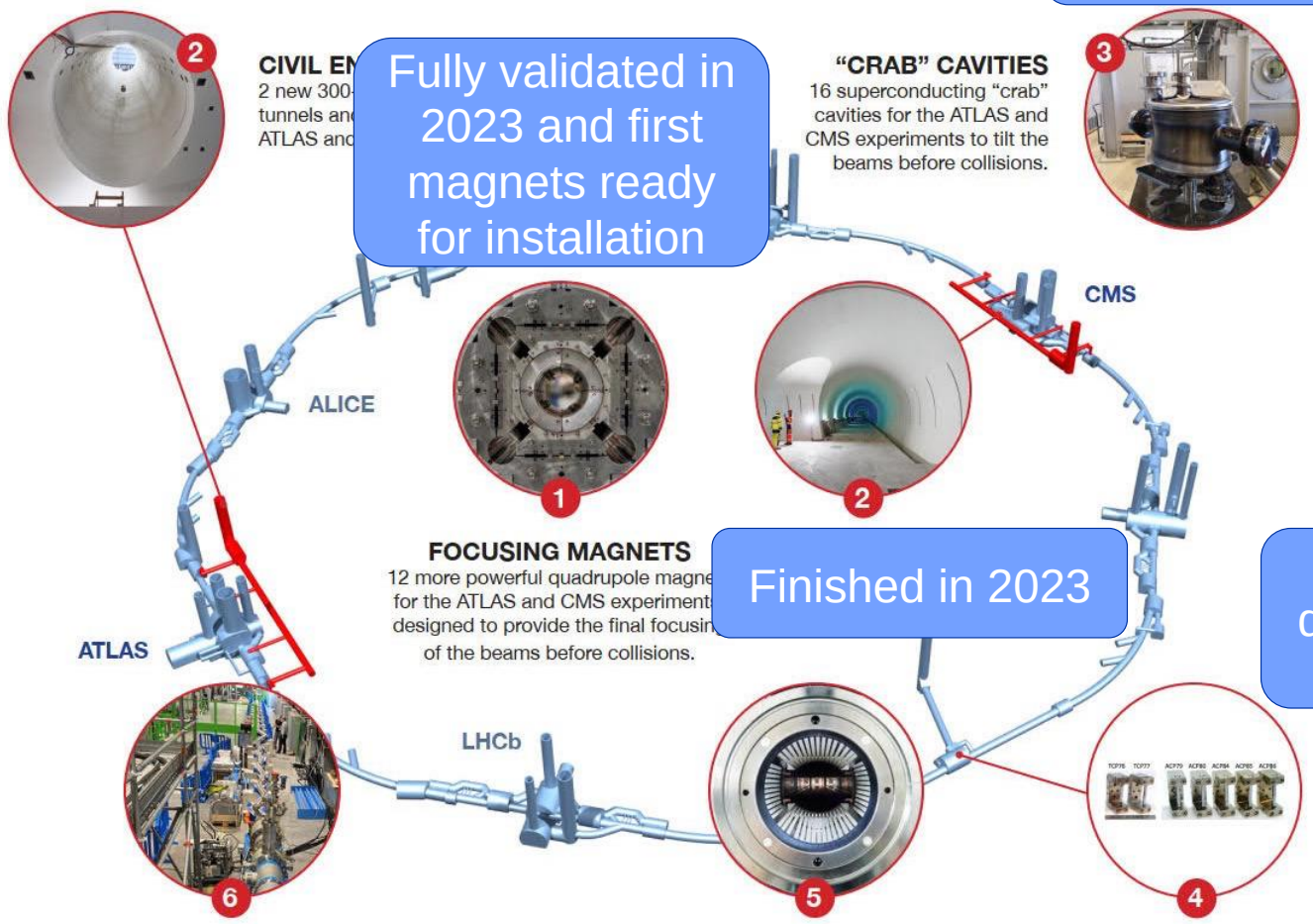
Series production in Industry well underway

Finished in 2023

Fully validated in 2023 and first magnets ready for installation

HL-LHC has many challenging novelties covering a broad technology spectrum

Technology intensive project!



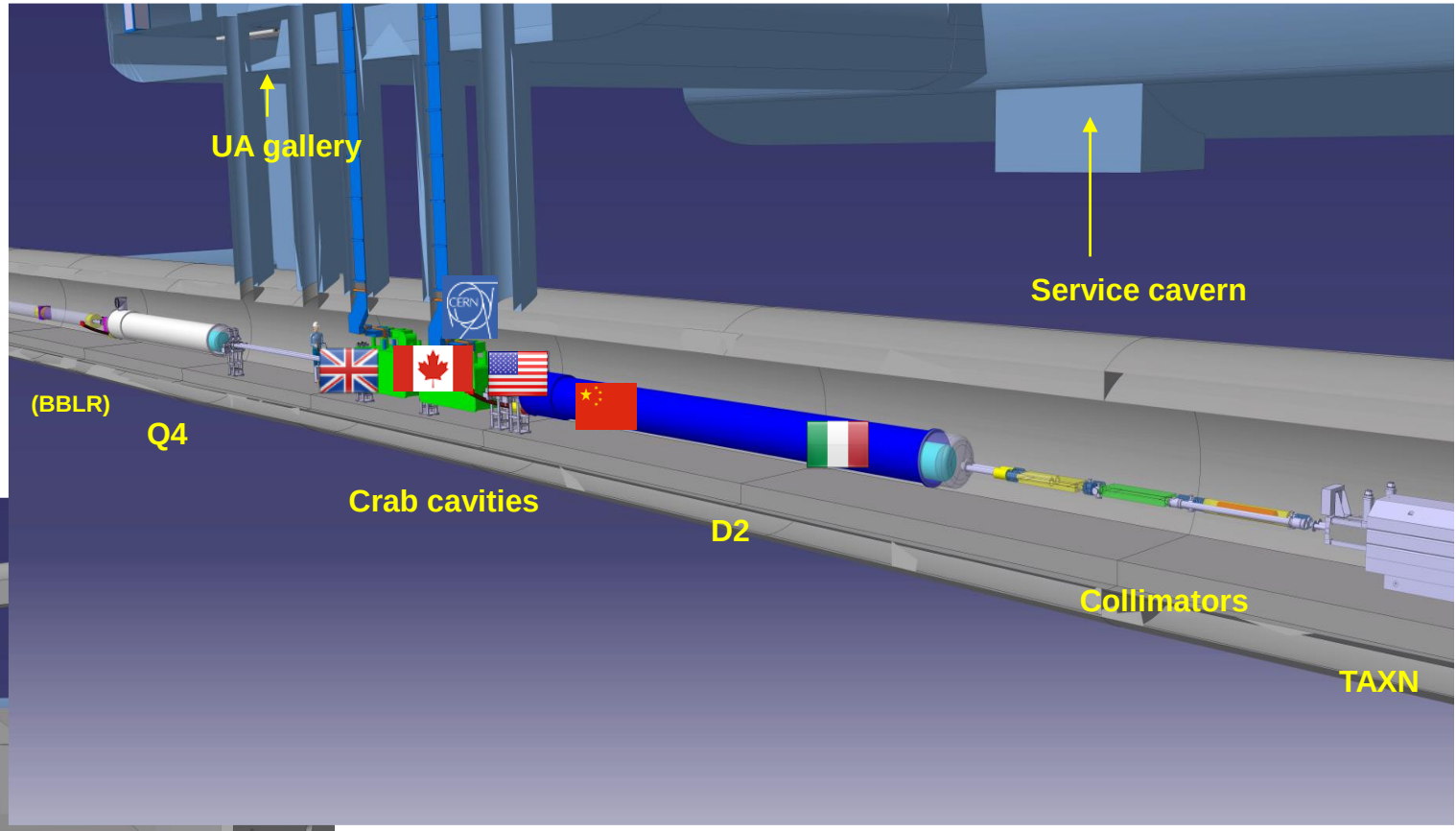
Finished in 2023

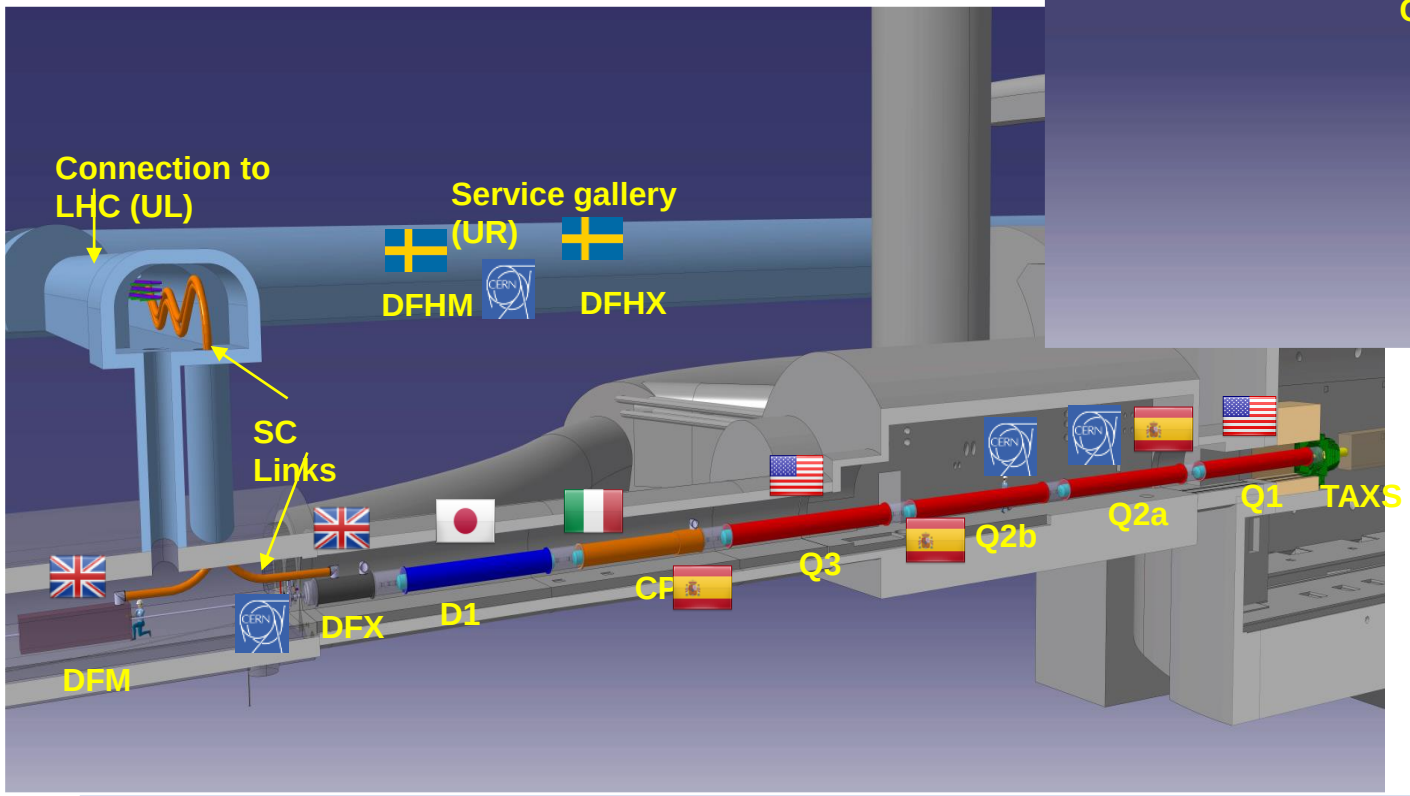
Successfully deployed in 2023 Pb-Pb run

Complete Prototype System installed in SM18 and under test

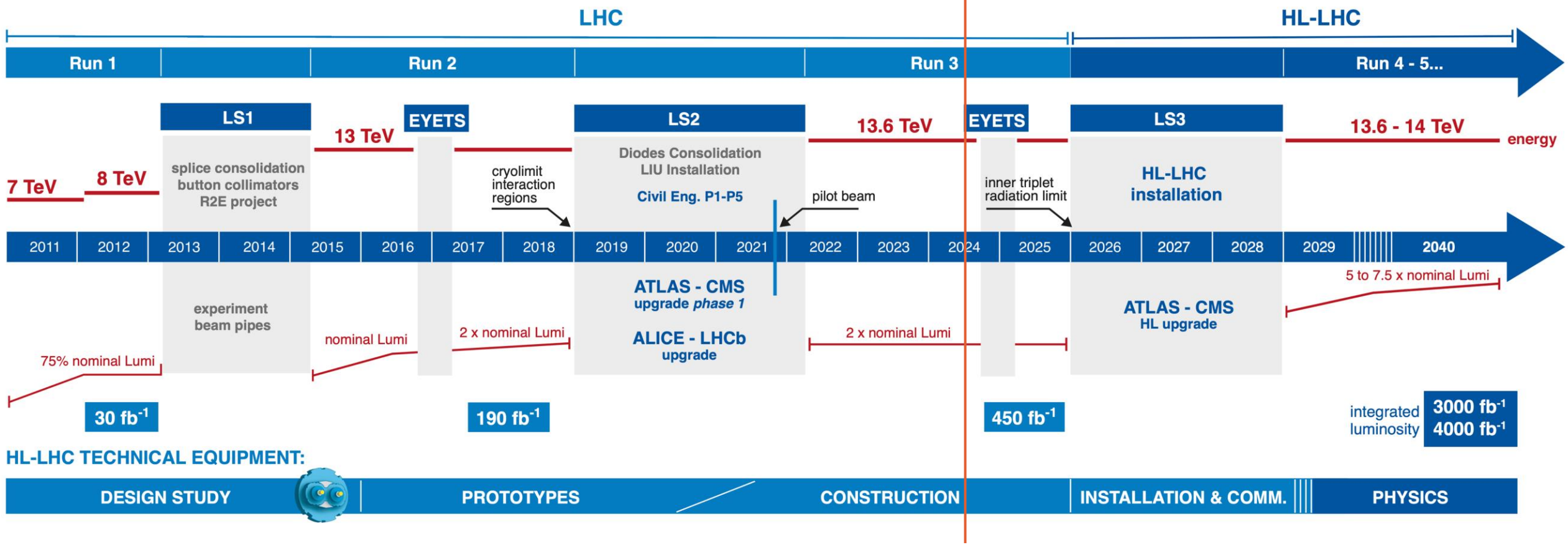
½ system already installed for Run 3

International Collaboration





LHC / HL-LHC Plan

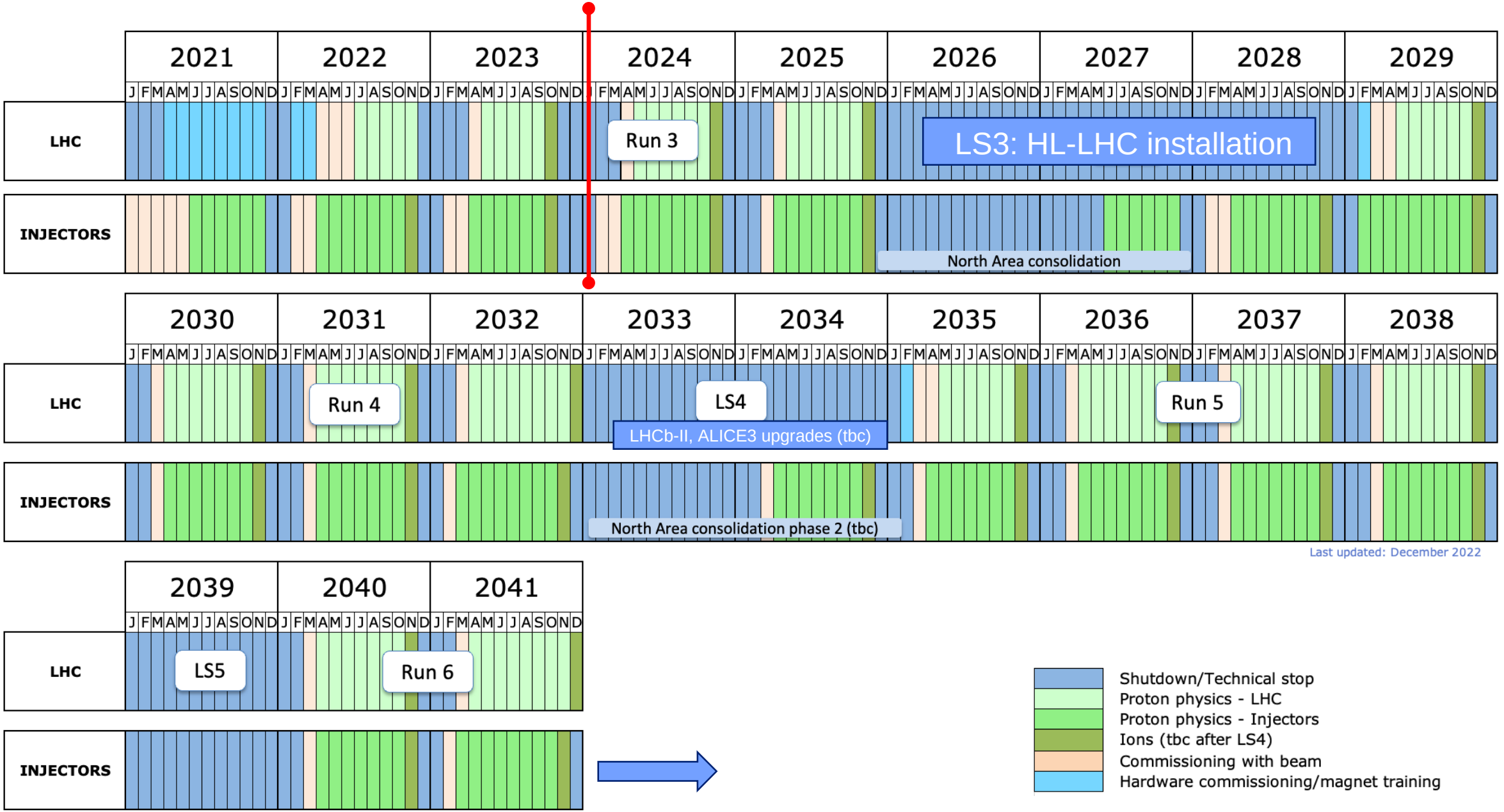


HL-LHC TECHNICAL EQUIPMENT:

HL-LHC CIVIL ENGINEERING:

10 years of Magnet development for HL-LHC

Indicative timeline - full and diverse physics programme



Future Collider Options

Within specified timeframe (start ops. ~2045)

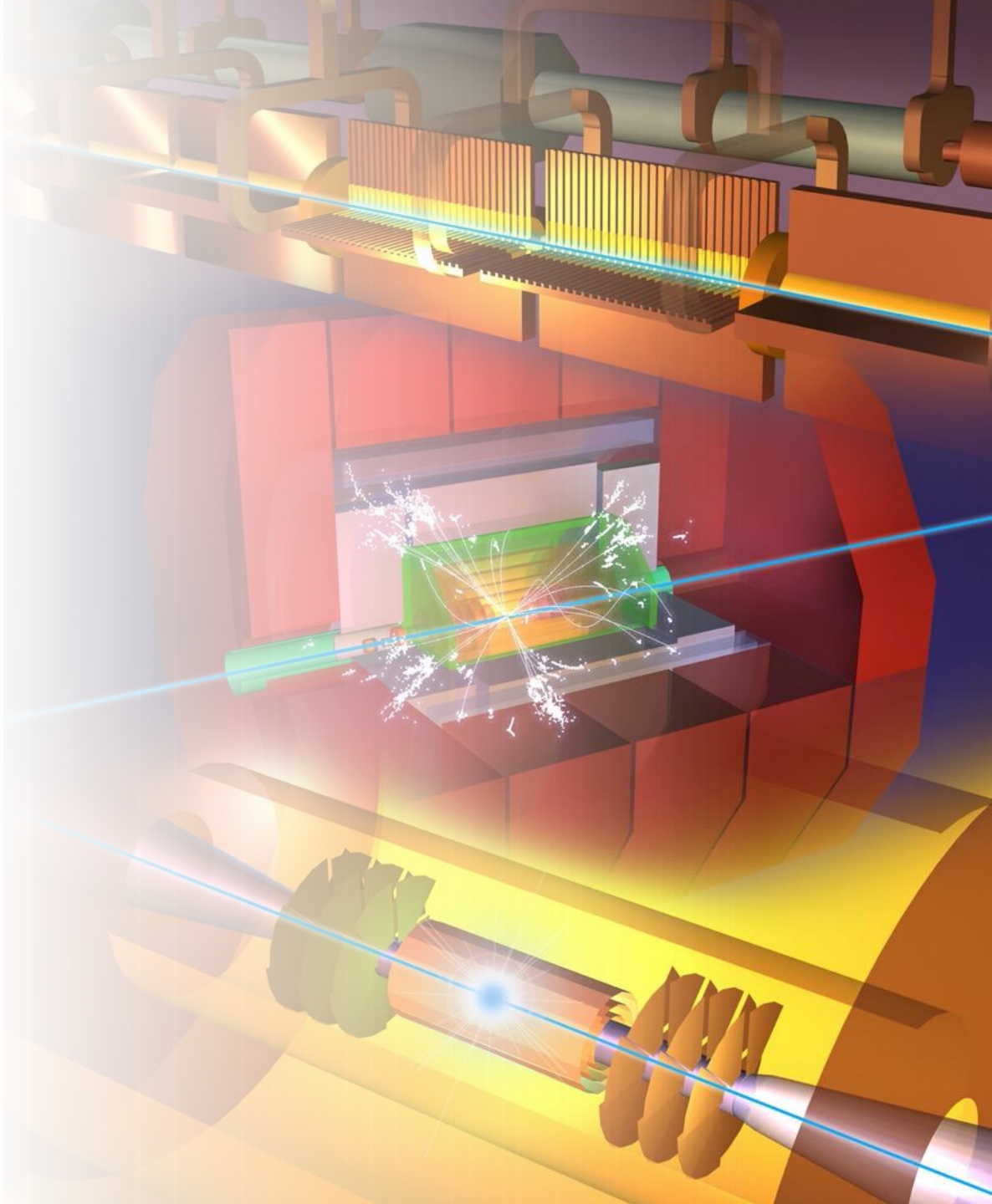
- FCC-ee
- CLIC-380
- (ILC-250, LEP3, LHeC, HE-LHC)

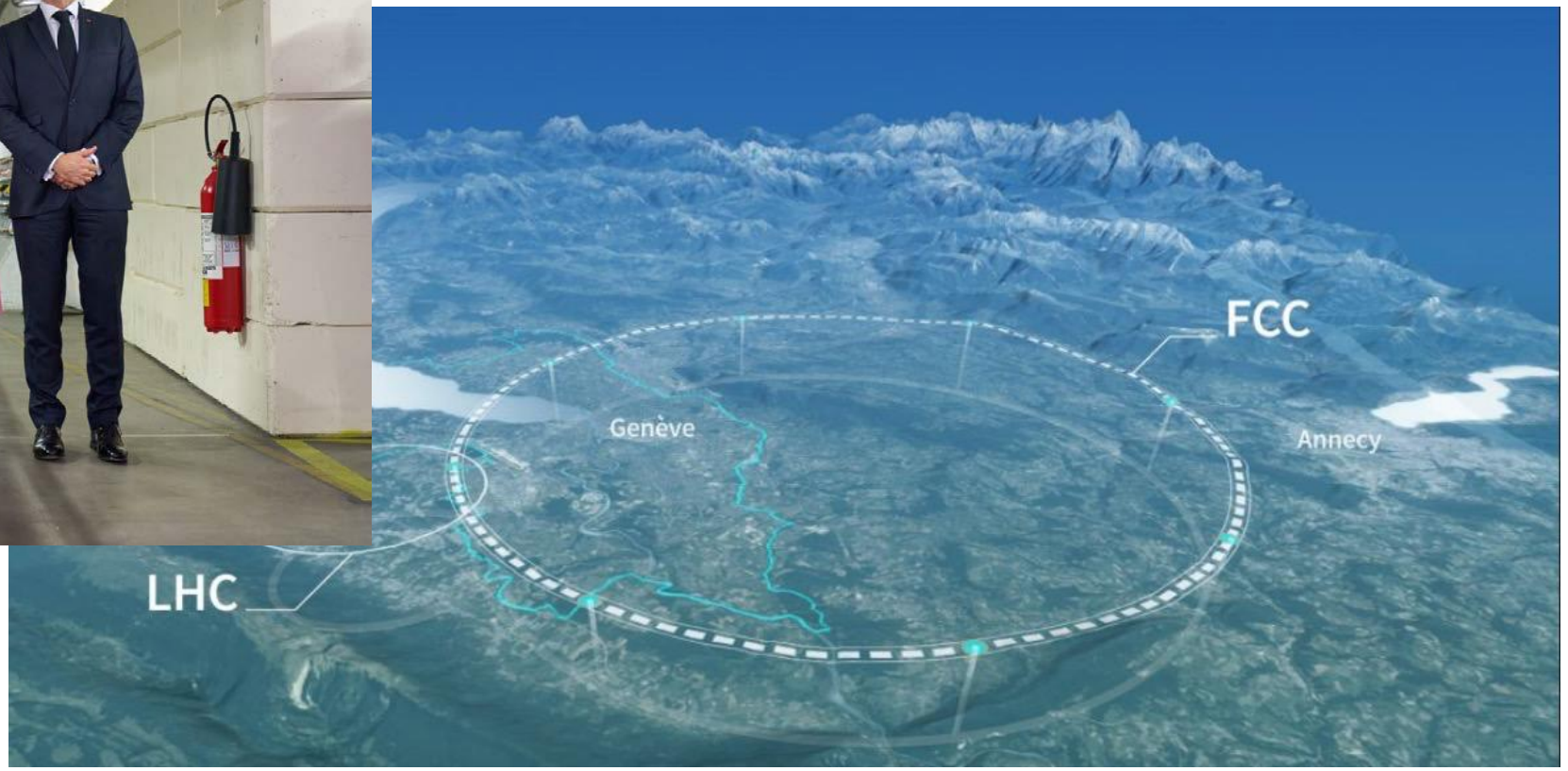
Outside specified timeframe

- FCC-hh (natural follow-on to FCC-ee)
- Muon Collider

Options possibly in timeframe not at CERN: ILC, CEPC, C^3

CEPC has just released their TDR!





FCC

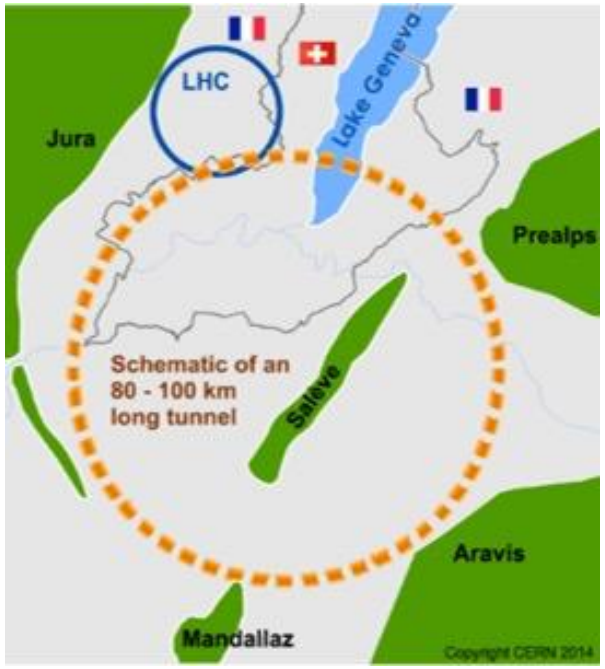
Feasibility study - good progress, mid-term review just gone
High-level interest building

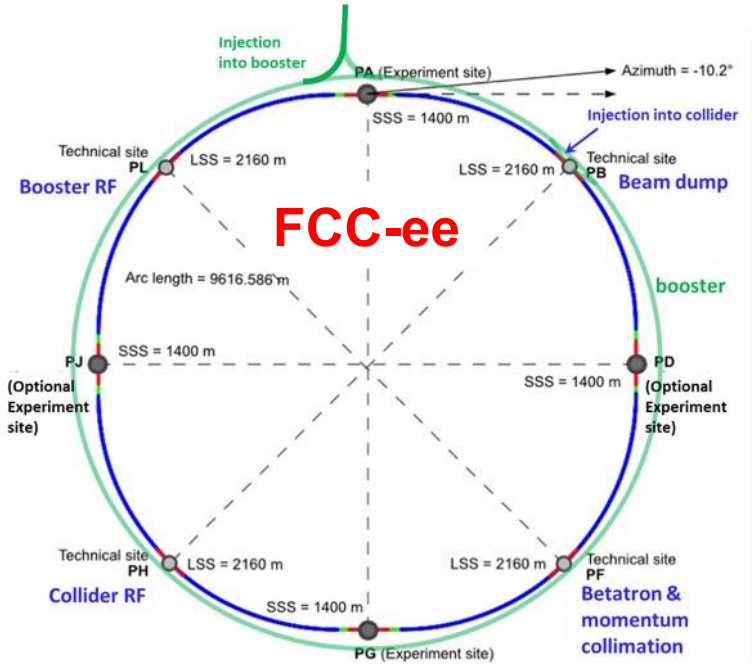
FUTURE CIRCULAR COLLIDER

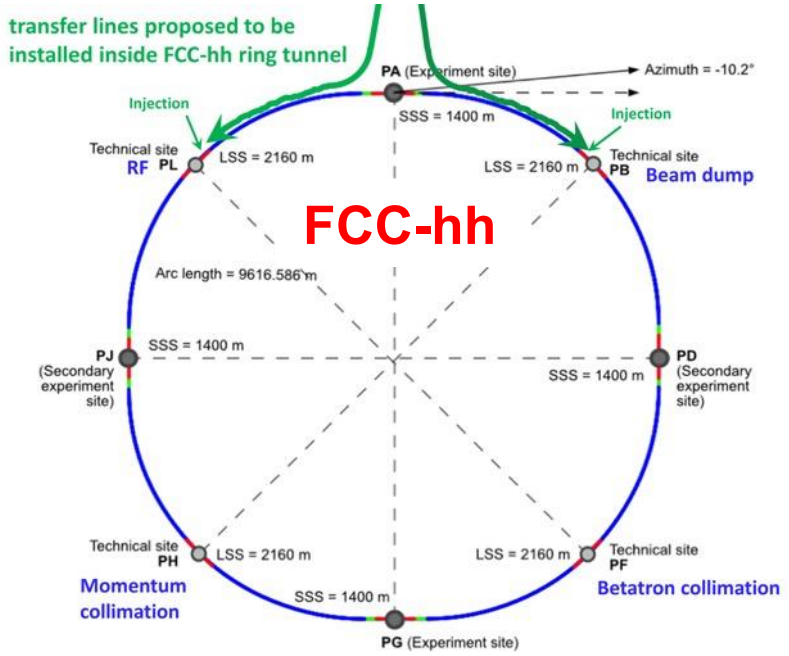
FCC integrated program

Comprehensive long-term program maximizing physics opportunities:

- Stage 1: FCC-ee (Z, W, H, $t\bar{t}$) as Higgs factory, electroweak & top factory at highest luminosities
- Stage 2: FCC-hh (~100 TeV) as natural continuation at energy frontier, with ion and eh options





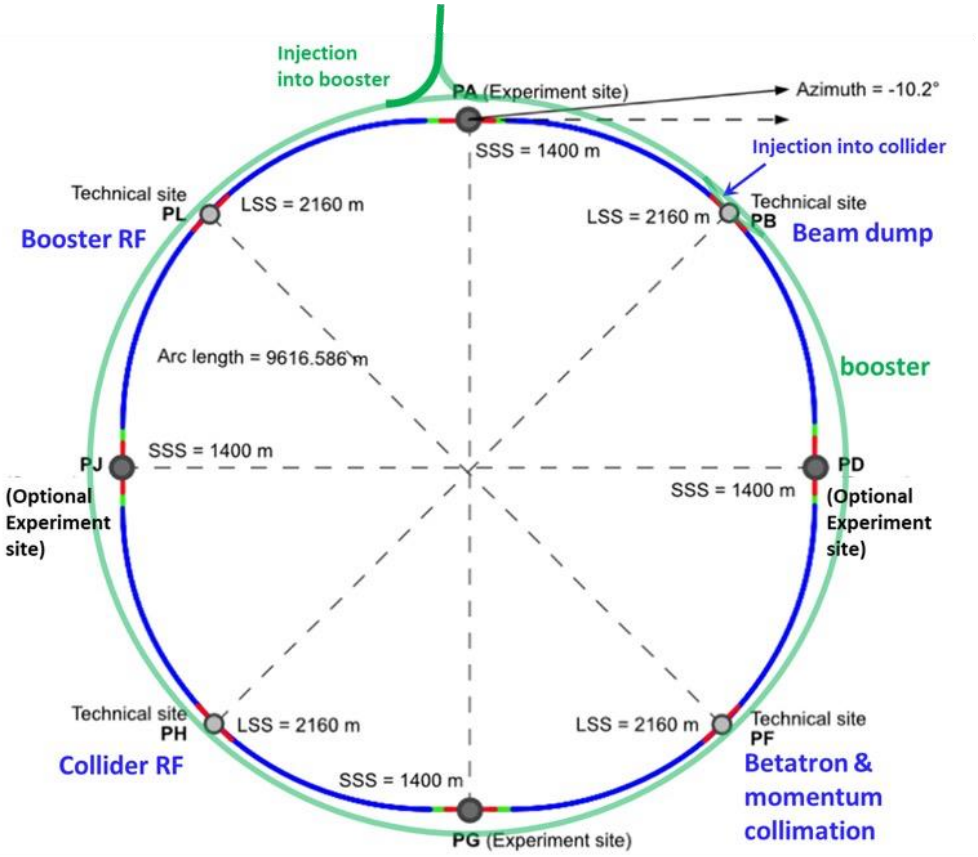


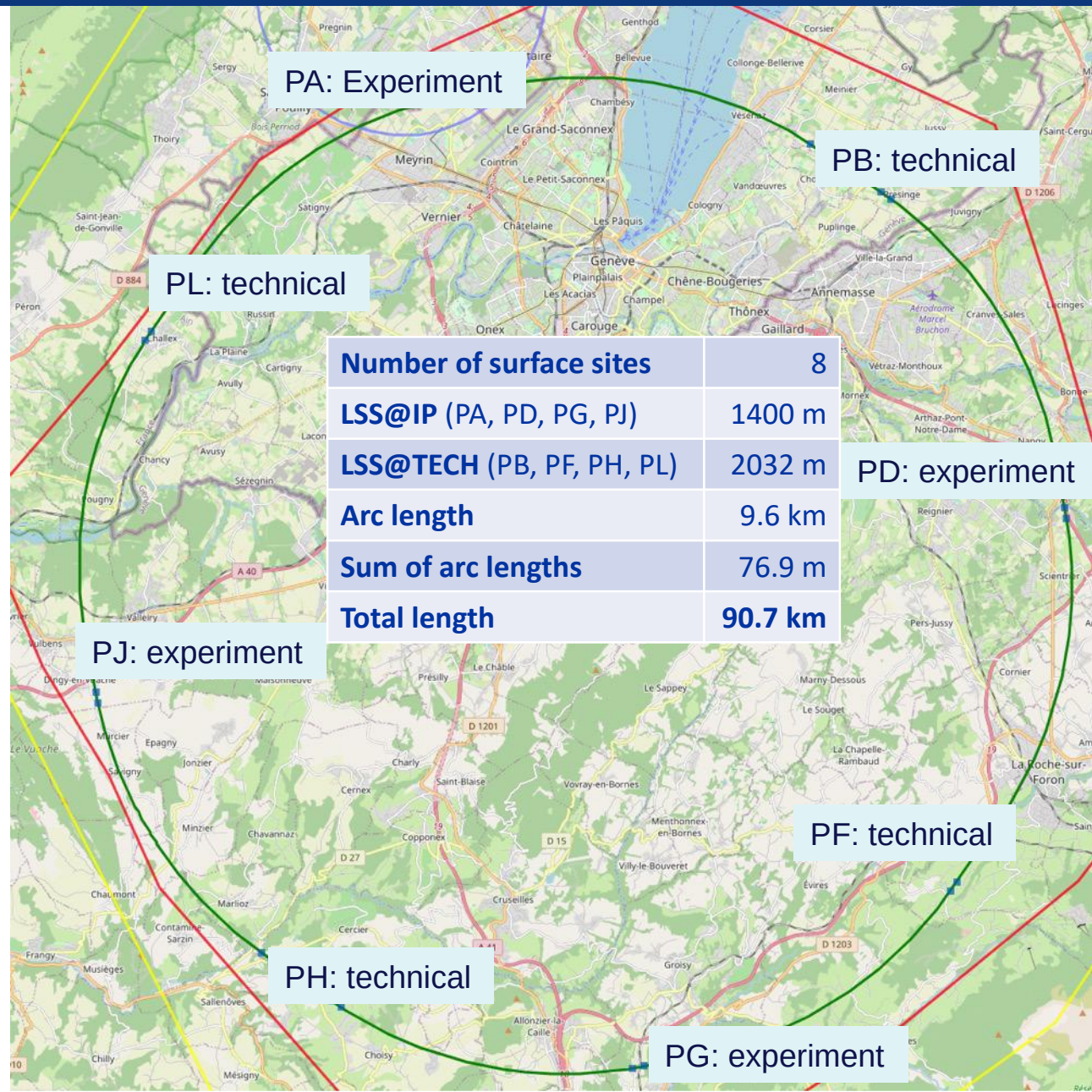
Feasibility study (2021 – 2025) ongoing

Major achievement: optimization of the ring placement
Layout chosen out of ~100 initial variants, based on geological, urban, environmental & infrastructure constraints.

Lowest-risk baseline: 90.7 km ring, 8 surface points

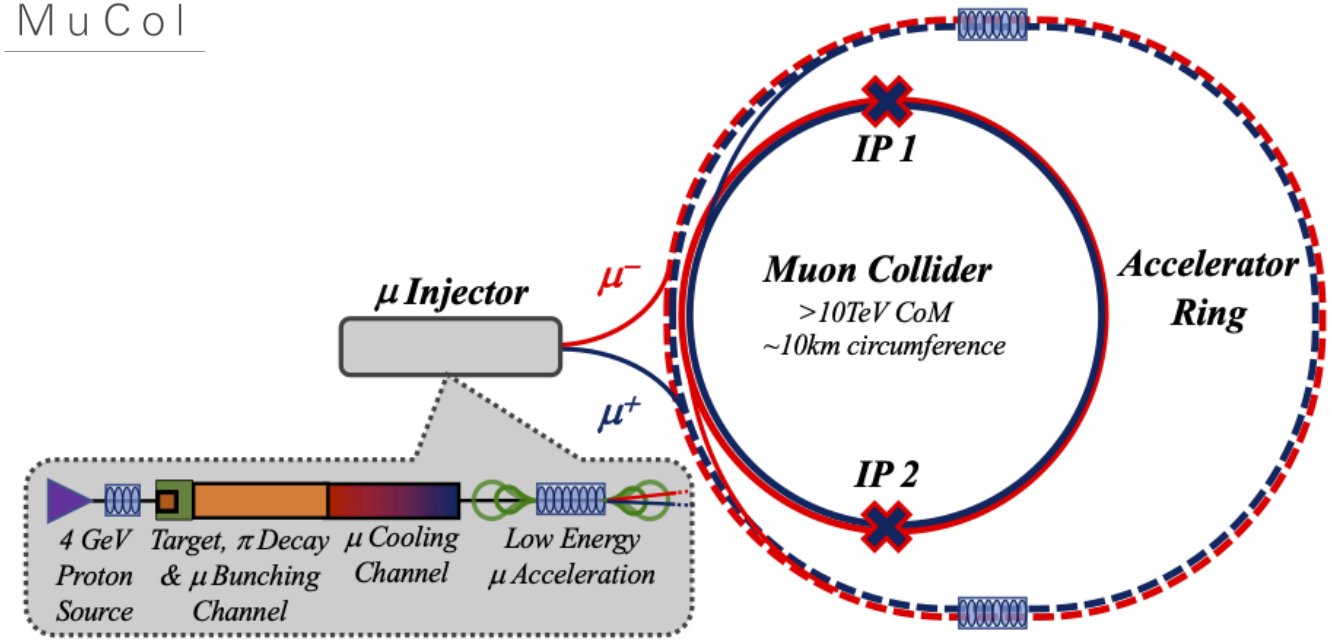
Whole project now adapted to this placement





Number of surface sites	8
LSS@IP (PA, PD, PG, PJ)	1400 m
LSS@TECH (PB, PF, PH, PL)	2032 m
Arc length	9.6 km
Sum of arc lengths	76.9 m
Total length	**90.7 km**

Muon Collider Goal and Plans



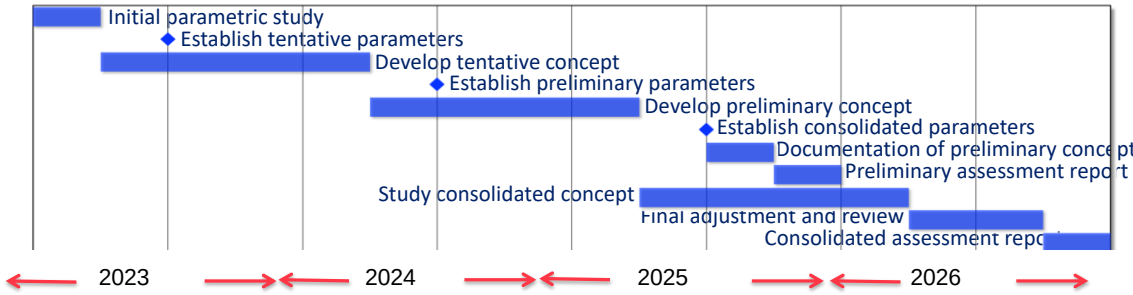
Collaboration is growing

- **68 signatories**, several from US, other partners
- MuCol EU co-funded Design Study now fully active
- Strong US interest: community ask in P5

Goals

- Focus on **10 TeV** (integrated luminosity 10 ab^{-1})
- Consider potential **initial stage** to start operation before 2050
  - Lower energy (maybe 3 TeV)
  - Or lower luminosity with later upgrades

Consider roadmap defined by magnets, demonstrator and detector



Magnets

Has been reviewed by expert panel

Anticipate technology for first stage to be **mature in O(15 years):**

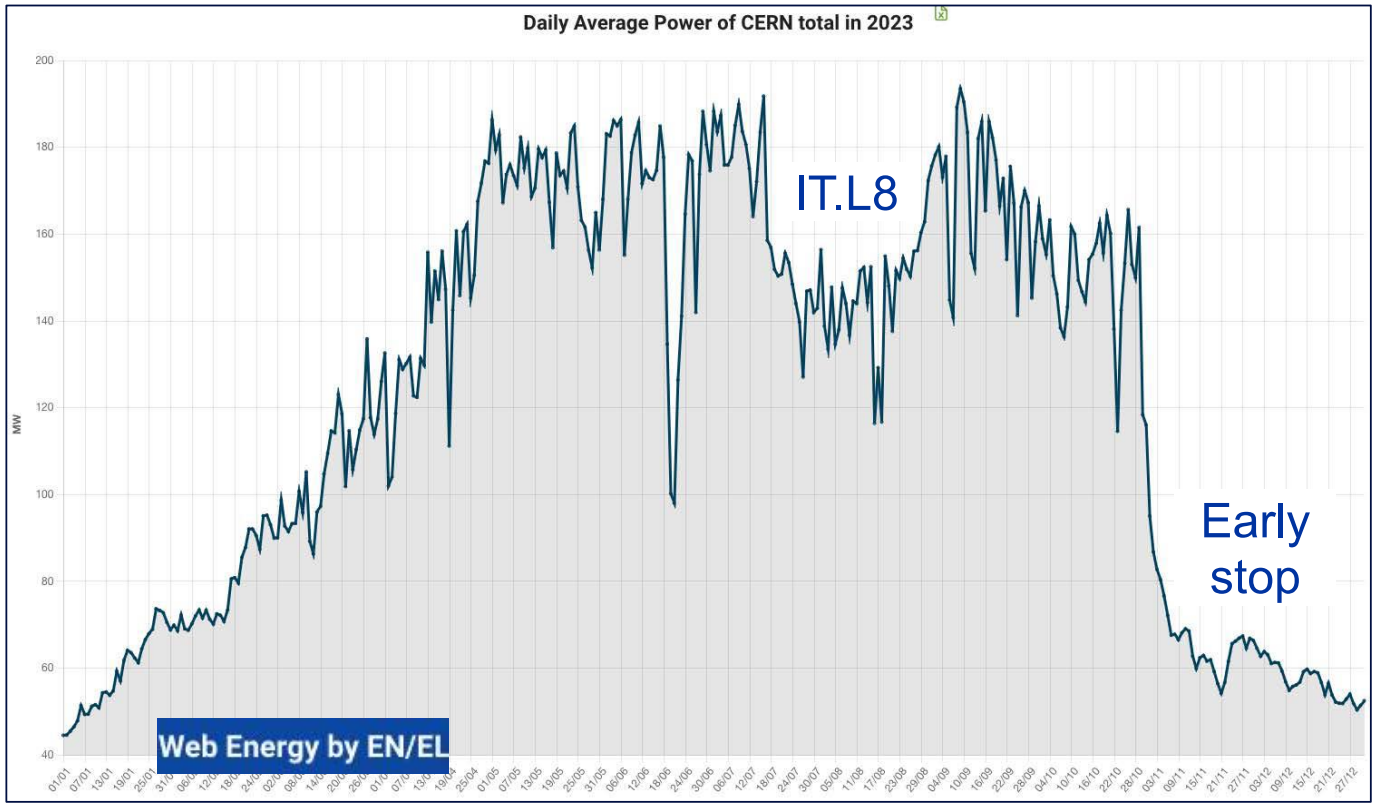
- **HTS solenoids** in muon production target, 6D cooling and final cooling
  - HTS tape can be applied more easily in solenoids
  - Strong synergy with society, e.g. fusion reactors
- **Nb_3Sn 11 T magnets** for collider ring (or HTS if available)

For second stage can use **HTS or hybrid collider ring magnets**

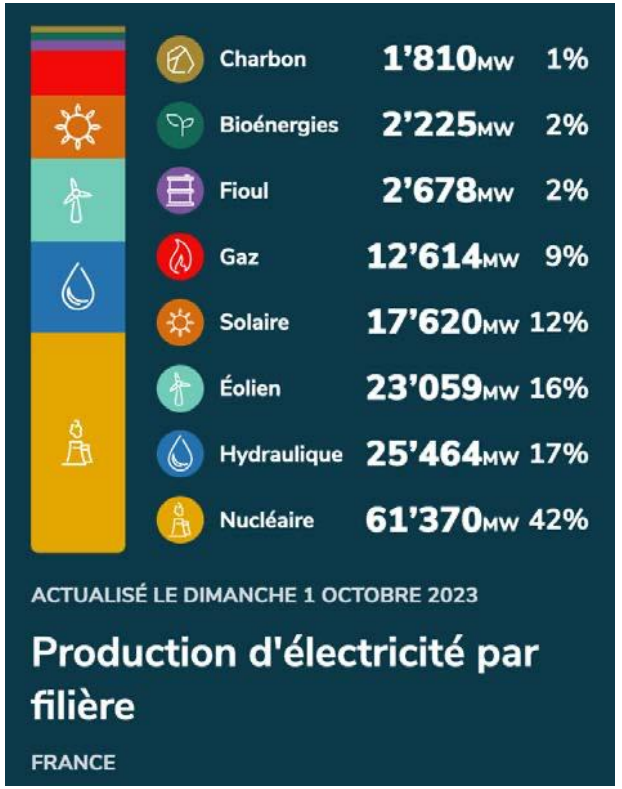
https://www.rte-france.com/en/home

CERN electricity consumption 2023

Total 1,080 GWh **LHC ~55% inc. experiments**



All pulled from the French Grid

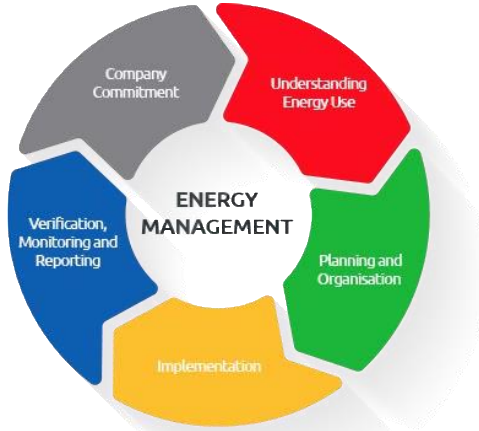


Energy Pathways to 2050 →

Achieving carbon neutrality will require transforming the economy and lifestyles, and restructuring the power system in such a way as to allow electricity to replace fossil fuels as the country's leading energy source

BETTER: ISO 50001 certification

- CERN is the first Laboratory ISO 50001 certified.
- Certification implies the establishment of improvement goals, and of continuous monitoring.
- The process is not limited to the experts on the field: the line and top management have to be continuously informed of the status of the KPIs and take action.
- The Energy Management Panel (standard and Enlarged) are the bodies used to manage and control Electricity Consumption.



afaq
AFNOR CERTIFICATION

Certificat
Certificate

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AFNOR Certification certifie que le système de management mis en place par :
AFNOR Certification certifies that the management system implemented by:

Organisation européenne pour la Recherche nucléaire (CERN)
European Organization for Nuclear Research (CERN)

pour les activités suivantes :
for the following activities:

RECHERCHE FONDAMENTALE EN PHYSIQUE DES PARTICULES.

FUNDAMENTAL RESEARCH IN PARTICLE PHYSICS.

a été évalué et jugé conforme aux exigences requises par :
has been assessed and found to meet the requirements of:

ISO 50001 : 2018

et est déployé sur les sites suivants :
and is developed on the following locations:

Adresse	N° SIREN
Esplanade des Particules 1 CH-1211 GENÈVE 23	
9001, route de Saint-Genis FR-01280 PREVESSIN MOENS	445403488

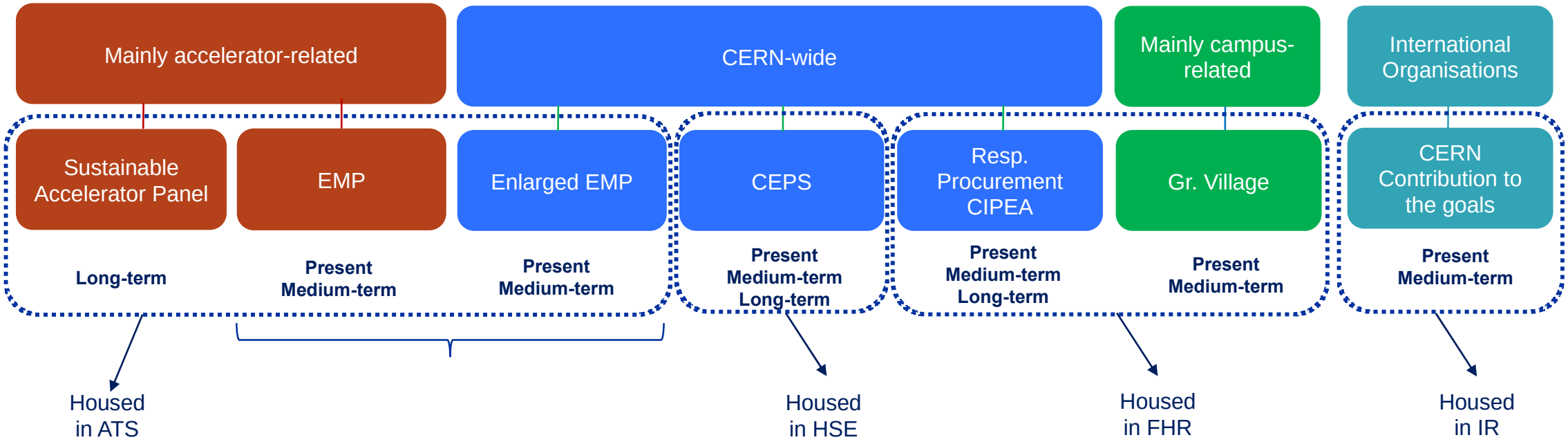
(L'ensemble des activités de l'entreprise sur les sites donnés est couvert par la certification)
(The scope of certification covers all activities carried out on the above-mentioned locations)

Ce certificat est valable à compter du (année/mois/jour) *This certificate is valid from (year/month/day)* 2023-02-02 Jusqu'au *until* 2026-02-01

Julien NIZRI
Directeur Général d'AFNOR Certification
Managing Director of AFNOR Certification

Flashez ce QR Code pour vérifier la validité du certificat

Sustainability related panels/activities at CERN

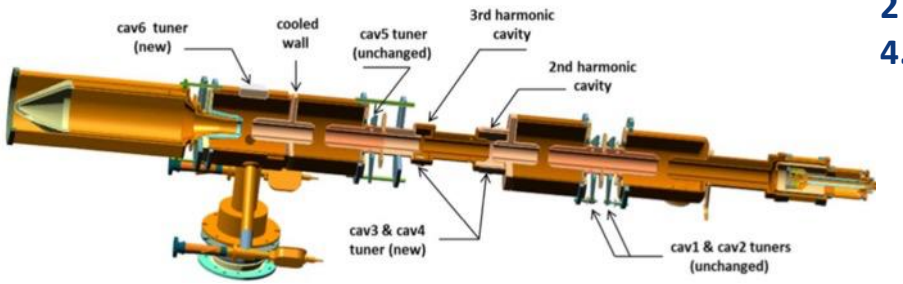


FUTURE CIRCULAR COLLIDER

FCC-ee R&D Examples

Efficient RF power sources

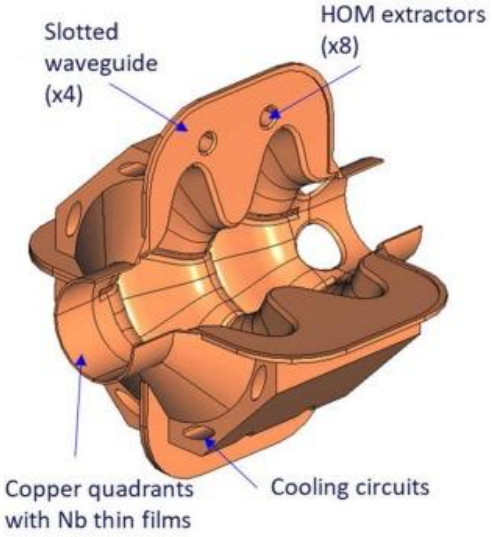
(400 & 800 MHz)



High efficiency klystrons & scalable solid-state amplifiers, FPC & HOM coupler, cryomodule, thin-film coatings

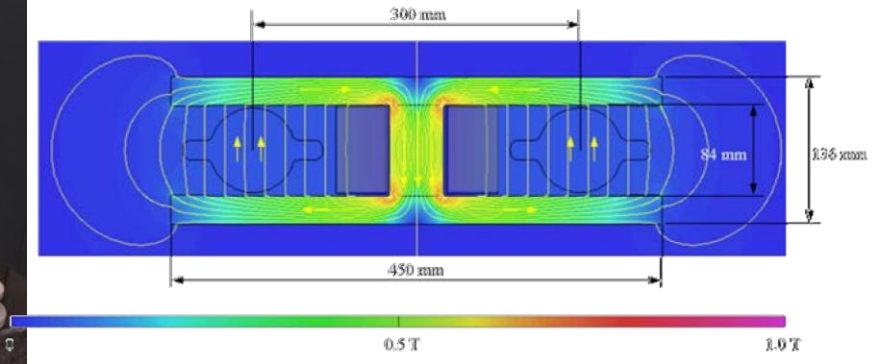
Efficient high-Q SC cavities

400 MHz 1 & 2 cell Nb/Cu, 4.5 K



Slotted Waveguide Elliptical cavity (SWELL) for high beam current & for high gradient

Energy **efficient** twin aperture **arc dipoles**



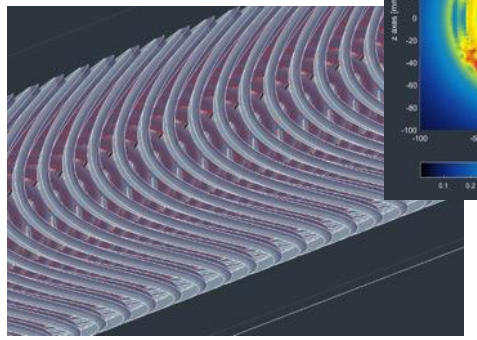
2840 x ~21 m -> 60 km

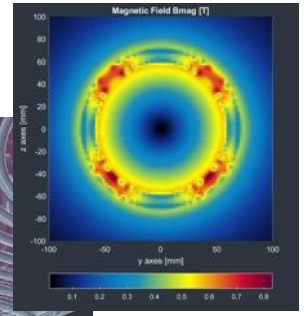
Under study: **CCT HTS quads & sexts for arcs**

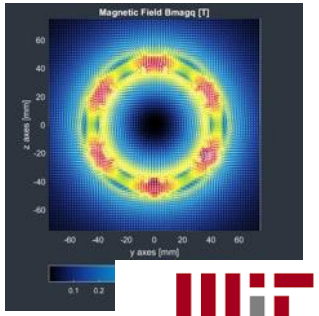
- **reduce energy consumption** by O(50 MW)

PAUL SCHERRER INSTITUT

PSI



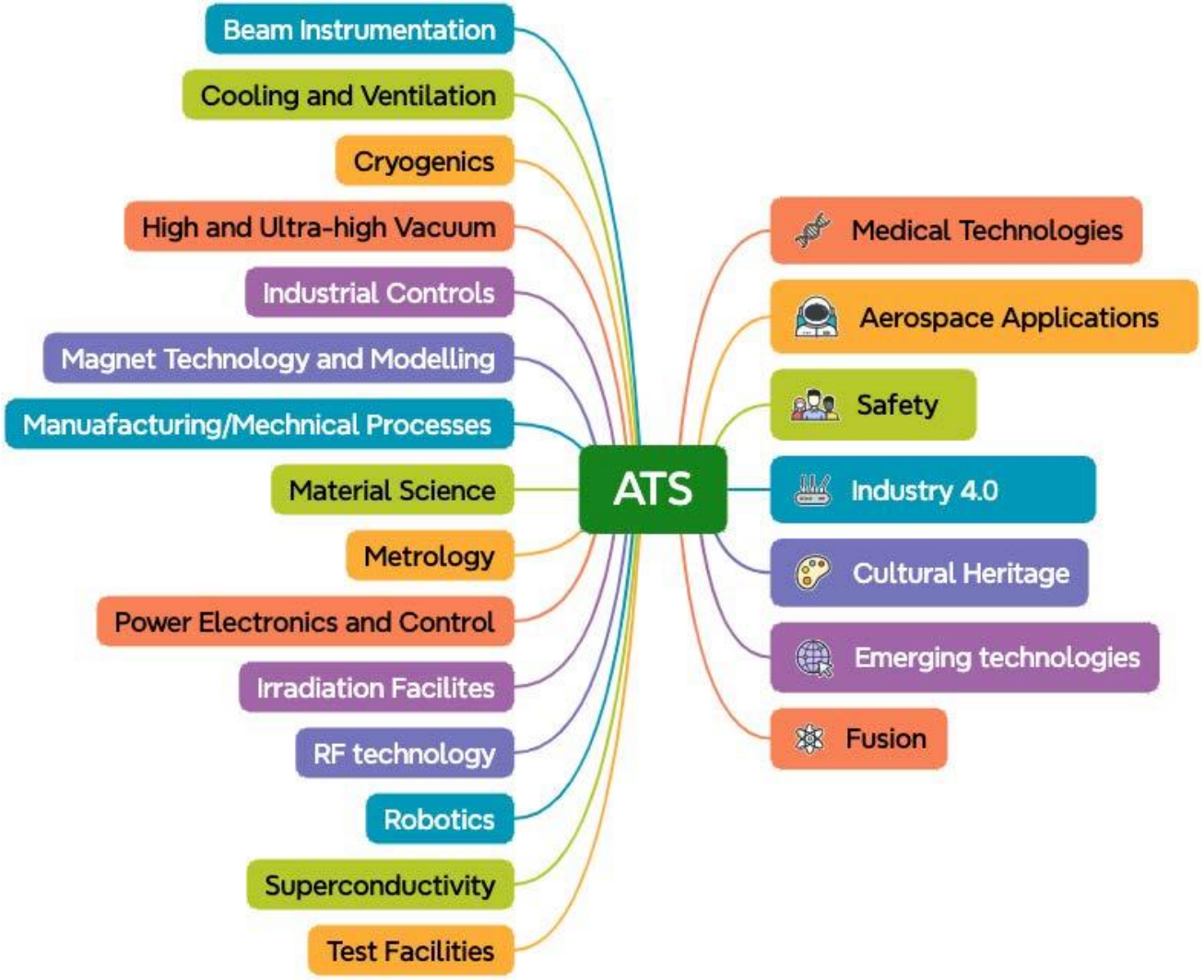




Massachusetts Institute of Technology

Knowledge Transfer

Lots going on…



CIPEA – Flagship Projects under Implementation

RENEWABLE AND LOW-CARBON ENERGY

Agreement with **GTT** to support the design of large cryostats for the maritime transportation of liquid hydrogen

GTT Technology for a Sustainable World

CLEAN TRANSPORTATION AND FUTURE MOBILITY

Partnership with **Airbus** to assess SC power distribution options for future electric/hybrid airplanes using liquid hydrogen

AIRBUS

CLIMATE CHANGE AND POLLUTION CONTROL

Collaboration with **ESA** Phi-lab to develop AI algorithms to analyse Earth Observation space images for climate monitoring

esa

SUSTAINABILITY AND GREEN SCIENCE

Project with **ABB** to improve energy efficiency of CERN cooling and ventilation with smart sensors and digital twins

ABB

ATS Fusion Technology Coordination Unit

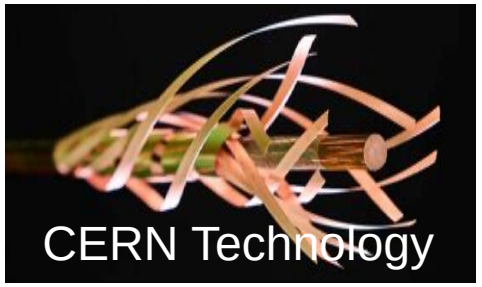
M. Battistin, B. Bordini, L. Bottura, E. Chesta L. Scibile, J.P. Tock, R. Veness

KT initiatives

Advise, coordinate, facilitate

Public sector:
ITER
EUROFusion
F4E
UKAEA
…

Private sector:
Gauss Fusion
Tokamak Energy
Rolf Kind
…



This is coordination, FTCU not necessarily owners of agreements (ATS or KT activities)

Partnership with AIRBUS on superconductivity

In 2022, CERN and Airbus UpNext started an innovation partnership to evaluate how superconductivity can be useful in future zero-emission aircraft.
In 2023, a superconductive demonstrator has been built at CERN, and first results of the tests came end 2023.

We are also happy to conclude the year with the successful test of the SCALE system that we have conceived and built for Airbus: a novel light (< 300 g/m) REBCO cable operated in DC mode at 4 kA (+/- 2 kA) at up to 68 K. This measurement relied on the 600 A HTS REBCO HL-LHC current leads, also successfully qualified during the test campaign.

A. Ballarino, *et al.*

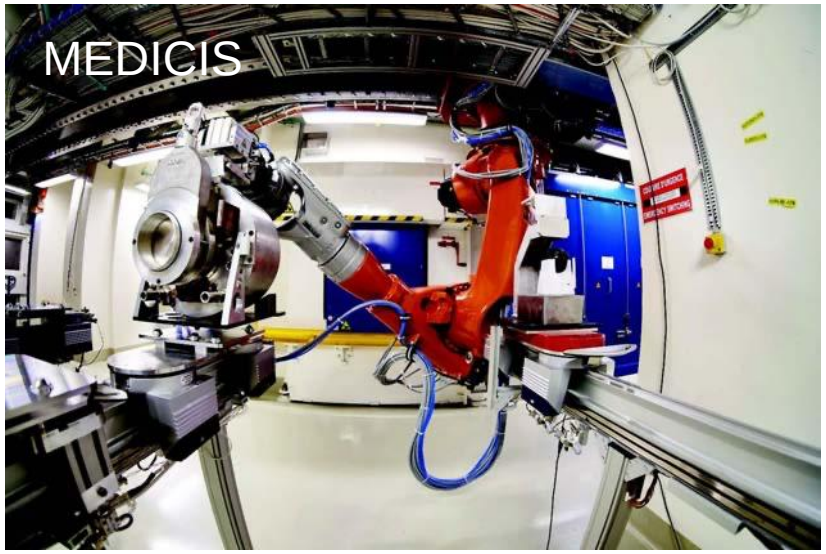
Collaboration with META

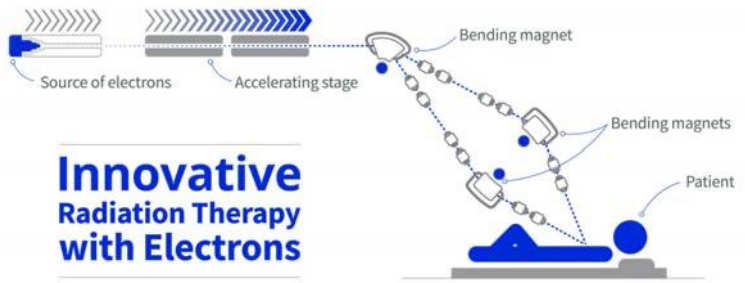
Agreement signed to investigate a possibility of using superconducting links for the power distribution in META’s data center.

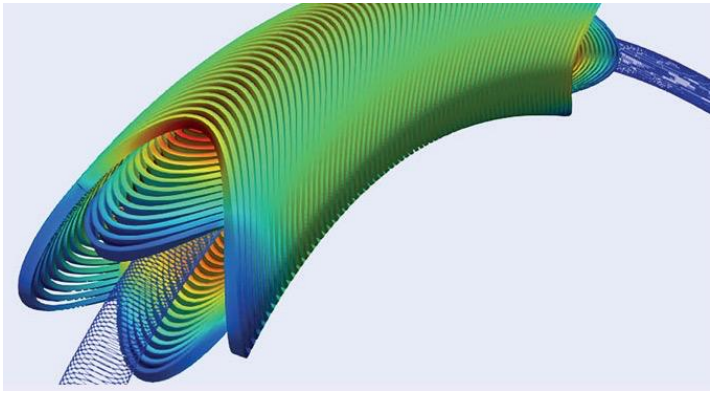
ATS – significant engagement in HORIZON

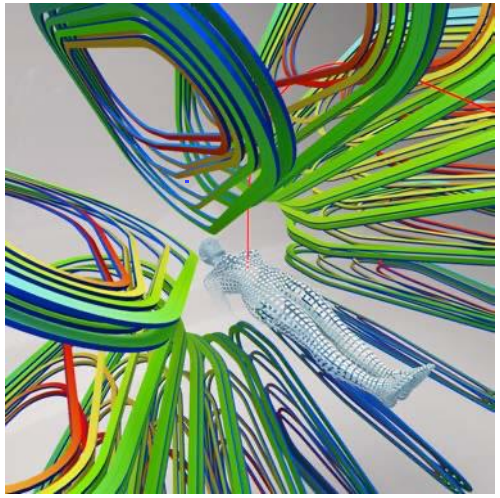
All of these projects back by European wide collaboration

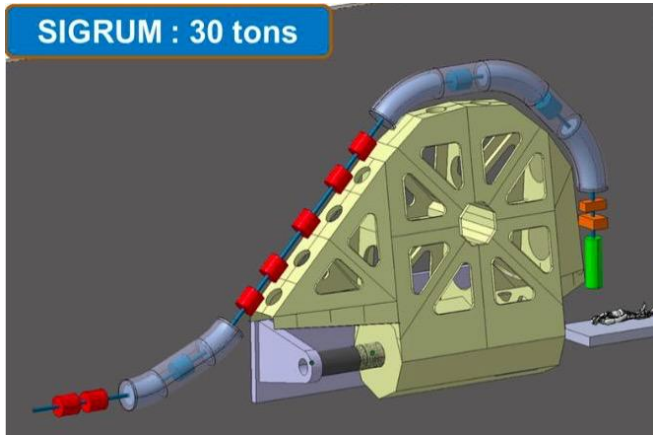
HORIZON		
	CALL	SUBJECT
PRISMAP	INFRAIA-2020	European medical isotope programme: Production of high purity isotopes by mass separation
HITRIplus	INFRAIA-2020	Heavy Ion Therapy Research Integration plus
POSEIDON	CL5 CLIMATE	POwer StoragE In D OceaN
HEARTS	CL4 SPACE	High-Energy Accelerators for Radiation Testing and Shielding
TRUSTroke	HLTH-2022-STAYHLTH	TRUSTWORTHY AI FOR IMPROVEMENT OF STROKE OUTCOMES
LISA	H2020-MSCA-ITN	Laser Ionization and Spectroscopy of Actinide elements
FCCIS	INFRADEV-2019	Future Circular Collider Innovation Study
RADNEXT	INFRAIA-2020	RADiation facility Network for the EXploration of effects for indusTry and research
I.FAST	INFRAINNOV-2020	Innovation Fostering in Accelerator Science and Technology
EURO-LABS	INFRA-2021-SERV	EUROpean Laboratories for Accelerator Based Science
MuCol	INFRA-2022-DEV	Design Study for a Muon Collider complex at 10+ TeV center of mass











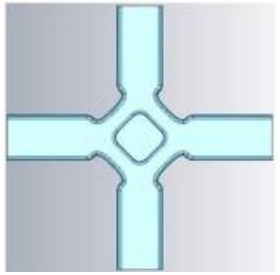
Medical

Wide range of initiatives!

MARCHESE
Machine learning based human recognition and health monitoring system

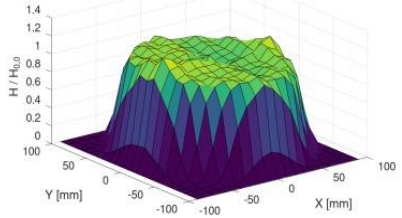
An innovative FLASH VHEE radiotherapy facility

Ongoing collaboration between CERN, CHUV and THERYQ for the design and construction of a radiotherapy facility using a unique accelerator based on CLIC technology (DEFT).

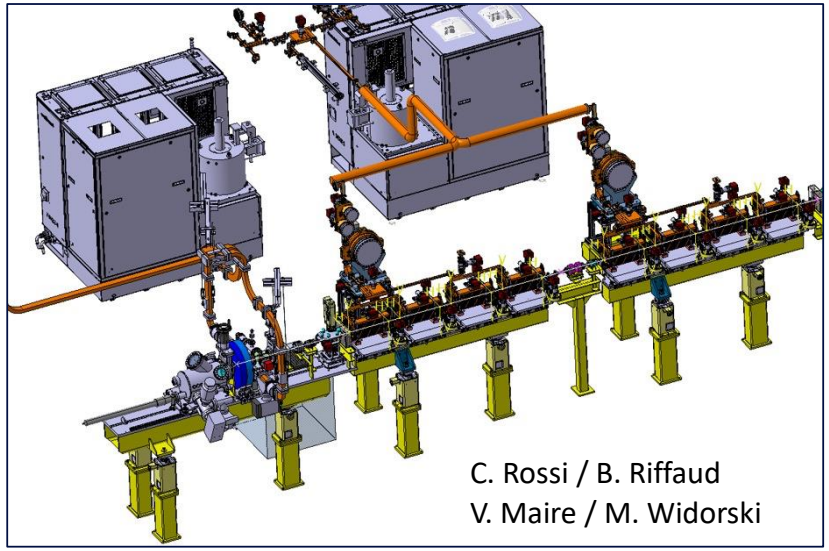


A. Latina / A. Malyzhenkov / A. Grudiev

New accelerating cell design to compensate octupolar effect



The RF design and beam dynamics for DEFT are <u>VERY</u> challenging -> uniformity with the large required field



C. Rossi / B. Riffaud
V. Maire / M. Widorski

Confidential

Construction site of the future bunker, CHUV, Lausanne.

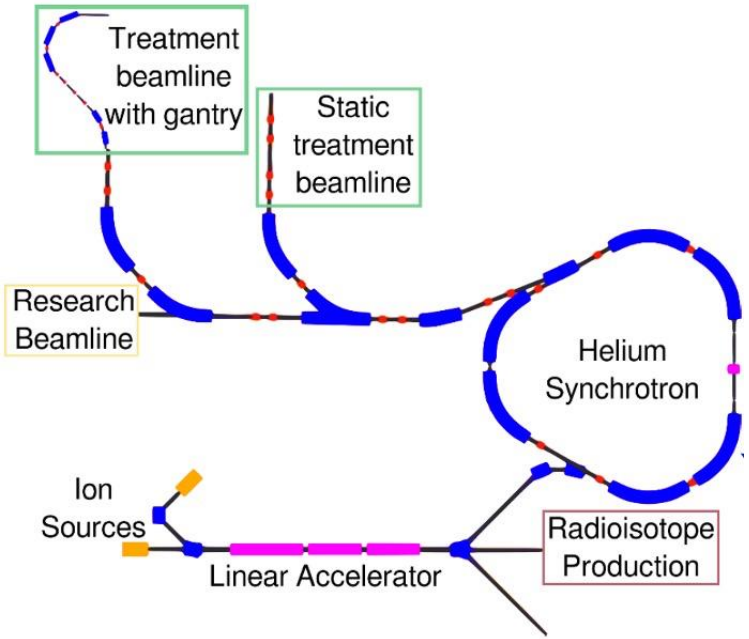
First clinical trials ~2027

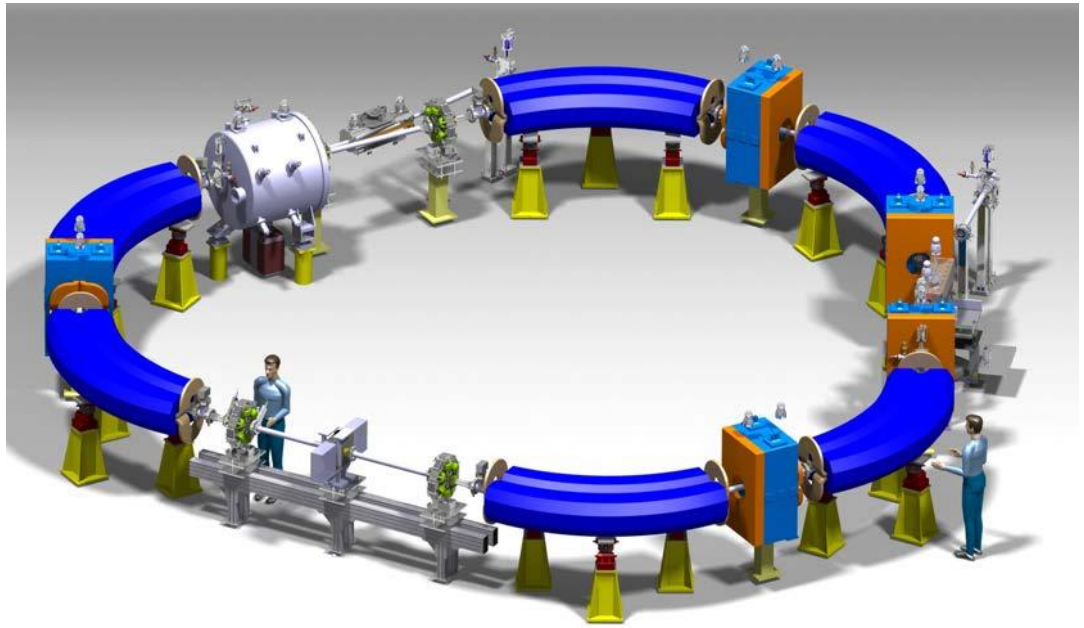
Acknowledgments – Walter Wuensch, Olivier Brunner

NIMMS (Next Ion Medical Machine Study)

Building on CERN expertise to develop **a portfolio of technologies** that can be used in a next generation facility

Multi-ion synchrotron (beyond p and C-ions)
Compact and cheaper superconducting synchrotron
Compact ion linac
Superconducting gantries
Higher beam intensity, faster extraction; real time imaging



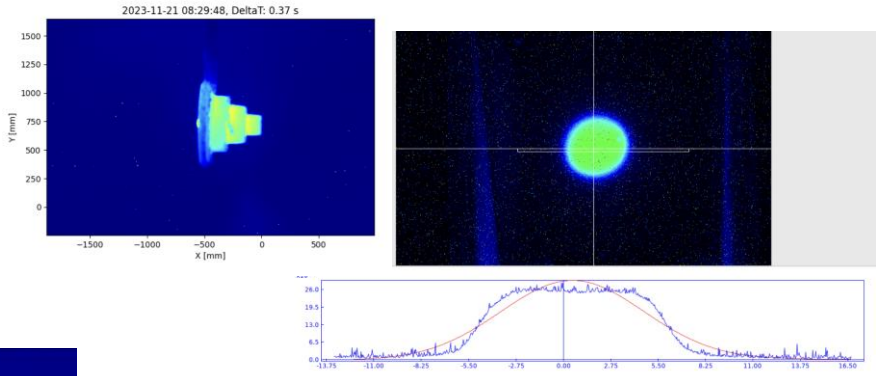


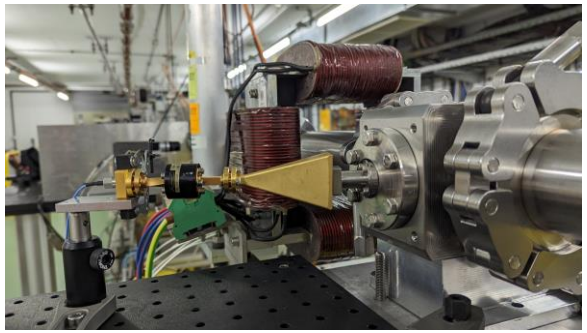
Operation 2023

- 27 Experiments
- About 18 User Groups internal/external
- More than 13 external collaborating institutes
- Beam from February 27th to December 15th (with 3 weeks summer stop)
- 39 weeks of operation in total

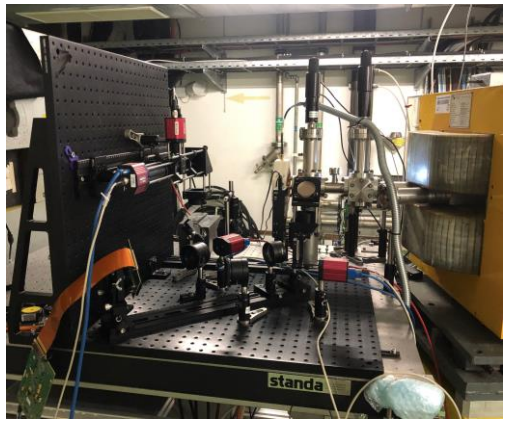
A few Highlights

Double-scattering system for uniform beam delivery for VHEE radiotherapy (CERN/Oxford U.)

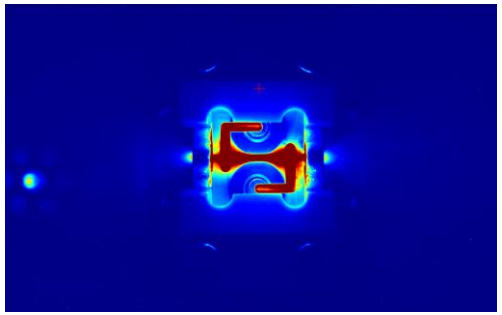




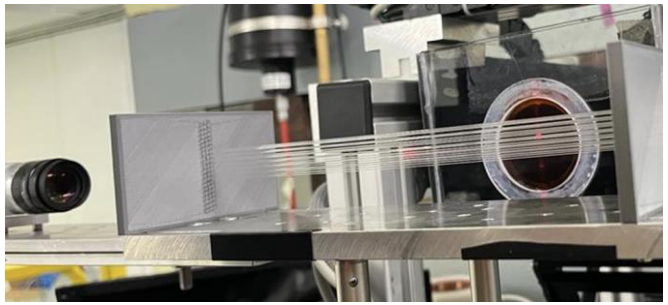
AWAKE Cherenkov Diffraction Radiation BPM



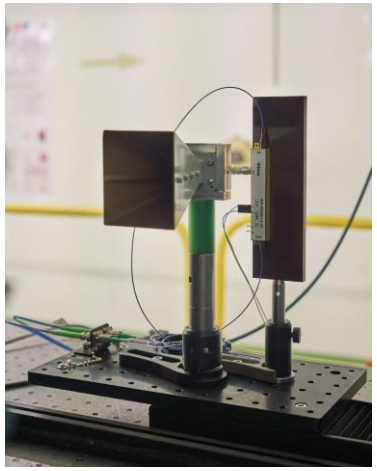
Novel OTR-based emittance meas. system for AWAKE (Liverpool U.)



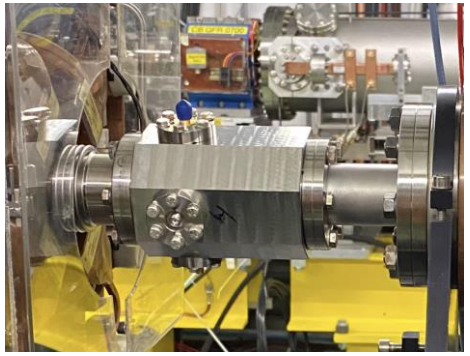
Plasma lens defocusing tests (Oslo U./CERN/Oxford U./DESY)



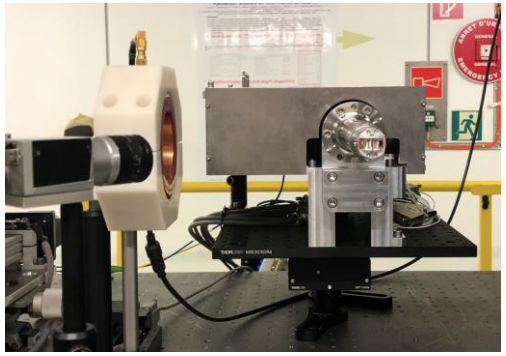
Fibre-optic beam profile and dose monitor for VHEE radiotherapy at ultra-high dose dates(CERN/Oxford U.)



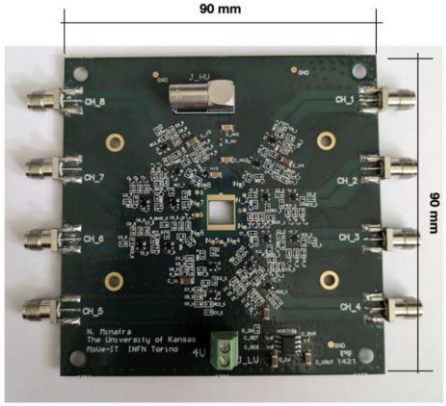
Coherent Cherenkov diffraction radiation dielectric buttons (FCC-ee bunch length monitors)



Broadband Pick-up for the PSI Positron Production Project (FCC-ee collaboration)



Bunch Profile Monitor for FCC-ee (Karlsruhe)



Beam testing of PCB + detectors using different technologies (Kansas U.)

Real-time dosimetry for VHEE radiotherapy using cuvettes (Strathclyde U.)