PERLE
Powerful energy
recovery linac experiments

MAX FEST

Achille Stocchi
IJCLab, Université Paris-Saclay/IN2P3-CNRS

Liverpool, 9th December 2022

Genesis of very fruitful scientific activity and of a friednship !

I Knew “in person” Max at the beginning of 2010.

The framework was the discussion for the future
of ep physics and LHeC

The first and short discussion, immediately showed
what an East German and an Italian are capable of...
a mixture of visionary, somewhat dreamy projects...

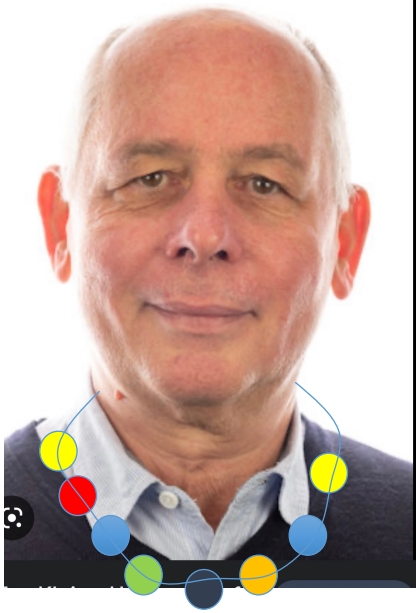
from that point on,
our meetings always end with

Avanti and wunderbar !

MAX

and

PERLE



Which in fact I proposed to Louvre instead of

La jeune fille au collier de perles
VERMEER. Musée du Louvre

The short story of the PERLE Genesis

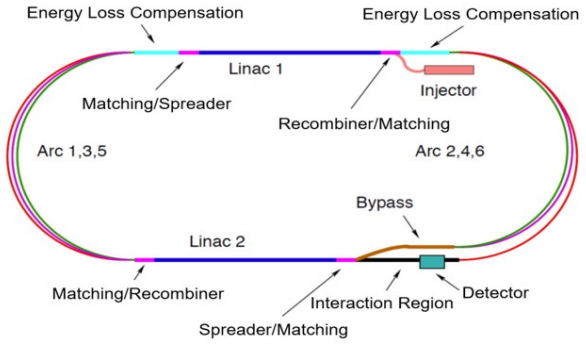
- Future **particle physics imposes strong challenges on accelerators** and requires a variety of **accelerator R&D programs** not only to meet the foreseen performances, but also to **lower their energetic consumption and enhance their efficiency**.
  → Energy Recovery Linacs offer one of the main options for energy frontier colliders

- To probe **deep inelastic scattering at high energy** and to study the **Higgs boson**, LHeC proposes a high luminosity collider using the HL-LHC protons and an intense electron beam.

- For the electron beam, the ERL scenario has many advantages :
  - High luminosity, low interference for installation next to LHC, machine size, energy consumption
  - Concept also applied to the FCC-eh design

- **The ERL-ring collider concept of LHeC based on**
  - synchronous operation of HL-LHC and 50 GeV electron beams
  - circumference of e- loop about 1/5 of that of LHC (5.3 km)
  - luminosity of 10^{34} $cm^{-2}.s^{-1}$

  → Multi-turn ERL (3+3 passes), 50 GeV, RF frequency: 801 MHz, 20 mA beam current (6 x 20 = 120mA load in the cavities).

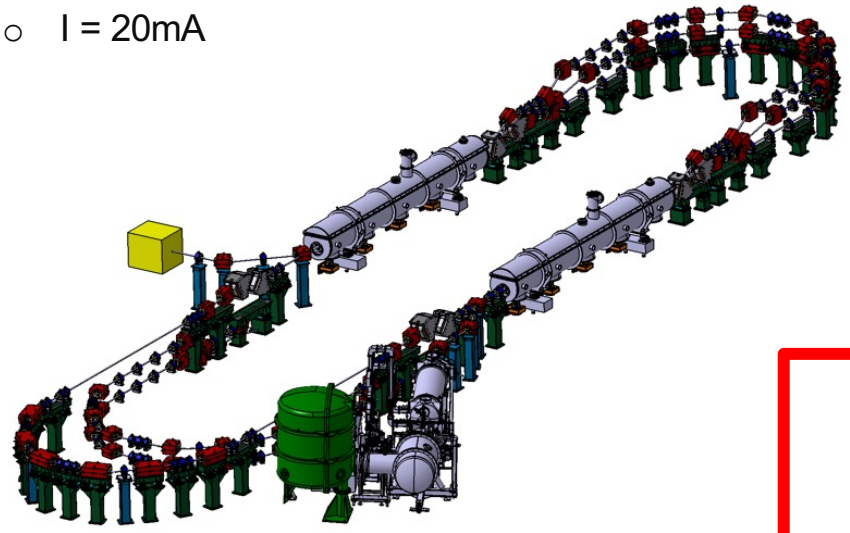


The short story of the PERLE Genesis

PERLE: A testbed to explore and validate a broad range of accelerator phenomena & technical choices on the pathway to the LHeC and other new frontier machines realisation.

Main challenges: Multi-turn, high bunch charge, high power energy recovery, …

- 2 Linacs (Four 5-Cell 801.58 MHz SC cavities)
- 3 turns (164 MeV/turn)
- Max. beam energy 500 MeV
- I = 20mA

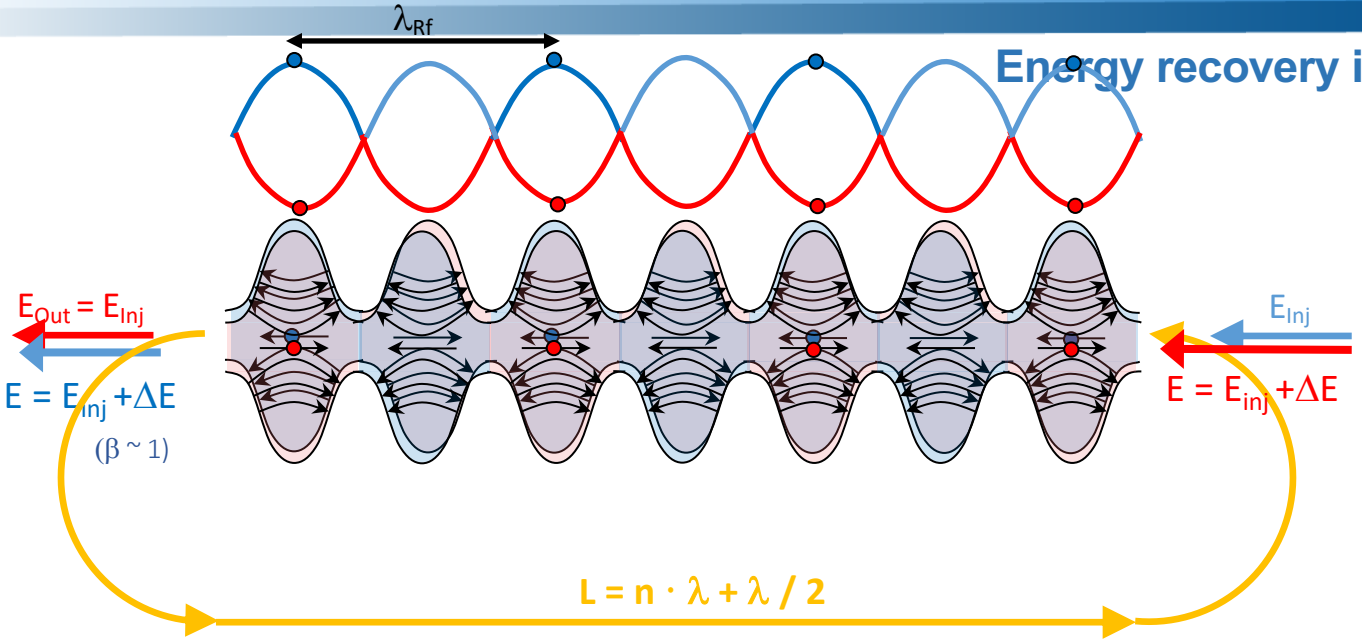


Target Parameter	Unit	Value
Injection energy	MeV	7
Electron beam energy	MeV	500
Normalised Emittance $\gamma\varepsilon_{x,y}$	mm mrad	6
Average beam current	mA	20
Bunch charge	pC	500
Bunch length	mm	3
Bunch spacing	ns	25
RF frequency	MHz	801.58
Duty factor		CW

- high currents → high luminosity
- high energies and stay compact

Provided we can implement multi-turn, high power = high current x energy ERL machine

ERL how it works



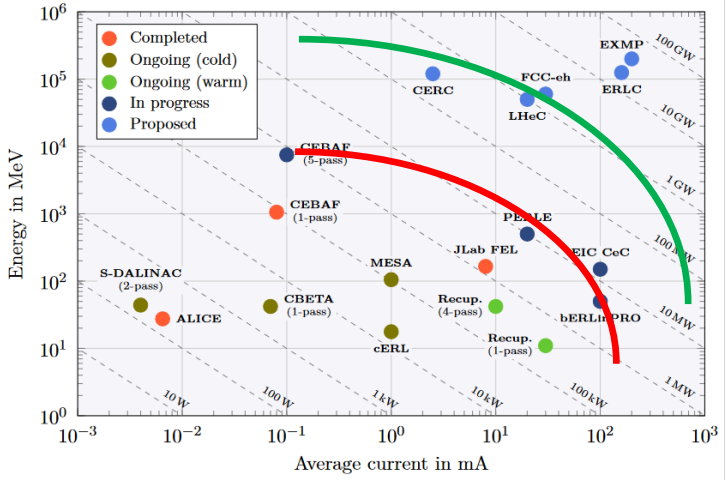
- Energy supply → acceleration
- Deceleration = "loss free" energy storage (in the beam) → Energy recovery

Take the best of storage rings and linear accelerator :

High average beam power in compact machine,

excellent beam parameters with high flexibility

- Idea from Tinger in 1965, has been tested in different facility.
- ERL became really viable with recent advances in SRF technologies
- We are today capable to go a step forward to make this concept "incontournable" for HEP and many applications (nuclear RIB, FELs, Compton light sources and high current electron cooler



2013…

PERLE

Powerful Energy Recovery Linac for Experiments

Conceptual Design Report

to be published in J.Phys.G

CDR 2017…

CELIA Bordeaux, MIT Boston, CERN, Cockcroft and
ASTeC Daresbury, TU Darmstadt, U Liverpool, Jefferson Lab
Newport News, BINP Novosibirsk, IPN and LAL Orsay

May 13th, 2017

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Internal Note

Report number	CERN-ACC-NOTE-2018-0086
Title	**PERLE: A High Power Energy Recovery Facility for Europe A contribution to the Update of the European Strategy on Particle Physics**
Author(s)	Klein, Max (University of Liverpool (GB)) ; Stocchi, Achille (Centre National de la Recherche Scientifique (FR))
Corporate author(s)	CERN. Geneva. ATS Department
Imprint	18 Dec 2018
Subject category	Accelerators and Storage Rings
Study	CERN LHeC
Keywords	PERLE
Abstract	The efficient recovery of power, to re-excite cavities from the used beam, was proposed in 1965. Major advances in superconducting RF technology, as quantified by cavity quality factors Q0 in excess of 1010, and the consideration of multi-turn recirculator passages, have opened the door to the green generation of high energy, high brightness, high current electron beams. The facility PERLE, here presented to the formation of the European Strategy for Particle Physics, is being designed as a new generation facility reaching for the first time into the 10 MW power regime of beam current and energy. The PERLE Collaboration comprises currently ten institutions. With Daresbury (UK), Darmstadt (D), Jlab (US) and Novosibirsk (Ru) there are four laboratories, which have been pioneering the development of ERL technology, together with three leading laboratories on superconducting RF (SRF) technology, CERN, Orsay (LAL and IPN) and Saclay CEA, and others. PERLE has been designed in support of the LHeC development, which defines its configuration (3 turn recirculator), its frequency (802 MHz, synergetic with FCC requirements) and electron current (20 mA or 500 pC in the LHC, 40 MHz time structure). This contribution, based on the 2017 PERLE CDR [1] and recent progress, describes the purpose, the parameters and configuration as well as the main components, including the successfully built first 802 MHz SC Niobium cavity with a large dynamic range and a Q0 exceeding 3 · 1010. Based on in-kind contributions including re-use of existing components, especially the source (Daresbury, ALICE) and cryomodule (CERN, SPL), PERLE is expected to be operational at Orsay in the early twenties in an initial configuration subsequently upgradeable to full energy. The facility has the main goal of developing ERL technology, especially SRF, for application in high energy colliders, especially LHeC and FCC, as well as to develop techniques for multi-turn, high current ERL operation, complementary to and collaborating with the upcoming 1.3 GHz facilities CBETA at Cornell and bERLinPro and others. As such it represents a major contribution to the development of energy and intensity frontier accelerators, the innovation through technology of which compares well with plasma wakefield R&D; for high gradient acceleration. The uniquely demanding parameters of PERLE make it a most powerful facility for lower energy precision electron beam physics in the areas of electroweak interactions, proton radius, search for dark bosons, or for the investigation of the unknown charge density of heavy nuclei such as the magic 132Sn as a striking example for a PERLE nuclear physics programme. From PERLE a 5 MeV energy photon beam can be derived of an intensity more than a factor of 100 higher than at ELI, which is a base for novel photo-nuclear physics or the production of medical radio-isotopes. As this paper is being submitted, the leading laboratories are signing Memoranda of Understanding for the foundation of the PERLE Collaboration. Being hosted at Orsay, in one of Europe's larger n… laboratories, PERLE is ideally suited to support our joint particle physics future at CERN and to also maintain more than one of our larger associated research infrastructures at the highest le… urope and beyond.
Submitted by	julia.double@cern.ch

2018…

Preparation to ESPP

Deliberation Document
on the 2020 update of the European Strategy for Particle Physics

2020…

In addition to the high field magnets the accelerator R&D roadmap could contain:

- the R&D for an effective breakthrough in plasma acceleration schemes (with laser and/or driving beams), as a fundamental step toward future linear colliders, possibly through intermediate achievements: e.g. building plasma-based free-electron lasers (FEL). Developments for compact facilities with a wide variety of applications, in medicine, photonics, etc., compatible with university capacities and small and medium-sized laboratories are promising;
- an international design study for a muon collider, as it represents a unique opportunity to achieve a multi-TeV energy domain beyond the reach of e^+e^- colliders, and potentially within a more compact circular tunnel than for a hadron collider. The biggest challenge remains to produce an intense beam of cooled muons, but novel ideas are being explored;
- a vigorous R&D on high-intensity, multi-turn energy-recovery linac (ERL) machines, promoting the realisation of a demonstrator with a view also to low-energy applications.

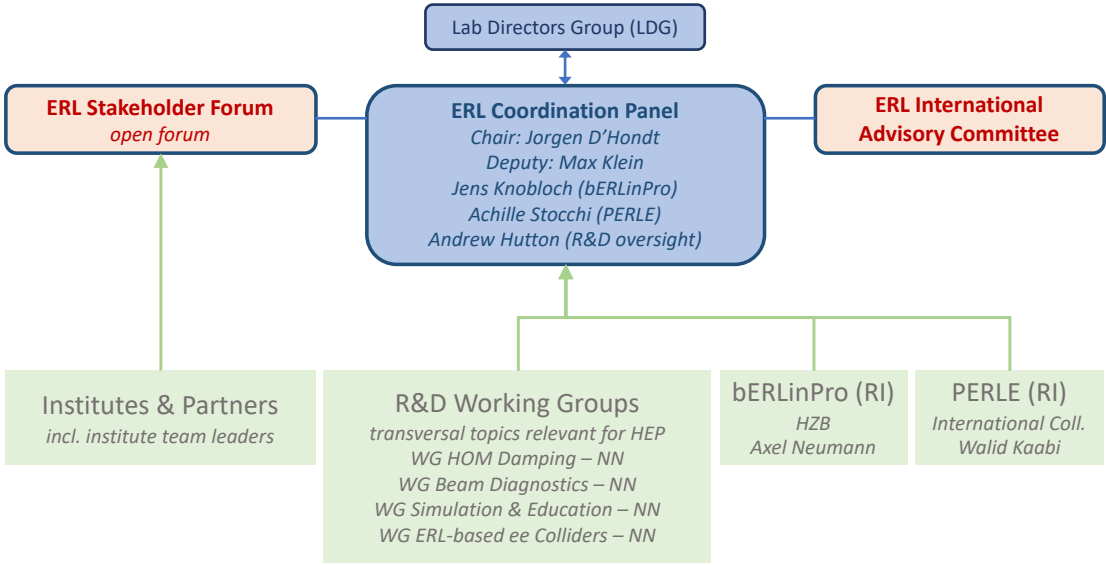
Reduction in energy consumption is an important consideration in accelerator design. Substantial progress has been achieved in the development of superconducting and normal-conducting high-gradient accelerating structures. This technology, which is needed for the e^+e^- colliders, is also driven by light source facilities all over the world.

- **Fall 2020:** The LDG decided to create Expert Panels for each of the five selected priority areas for accelerators R&D.

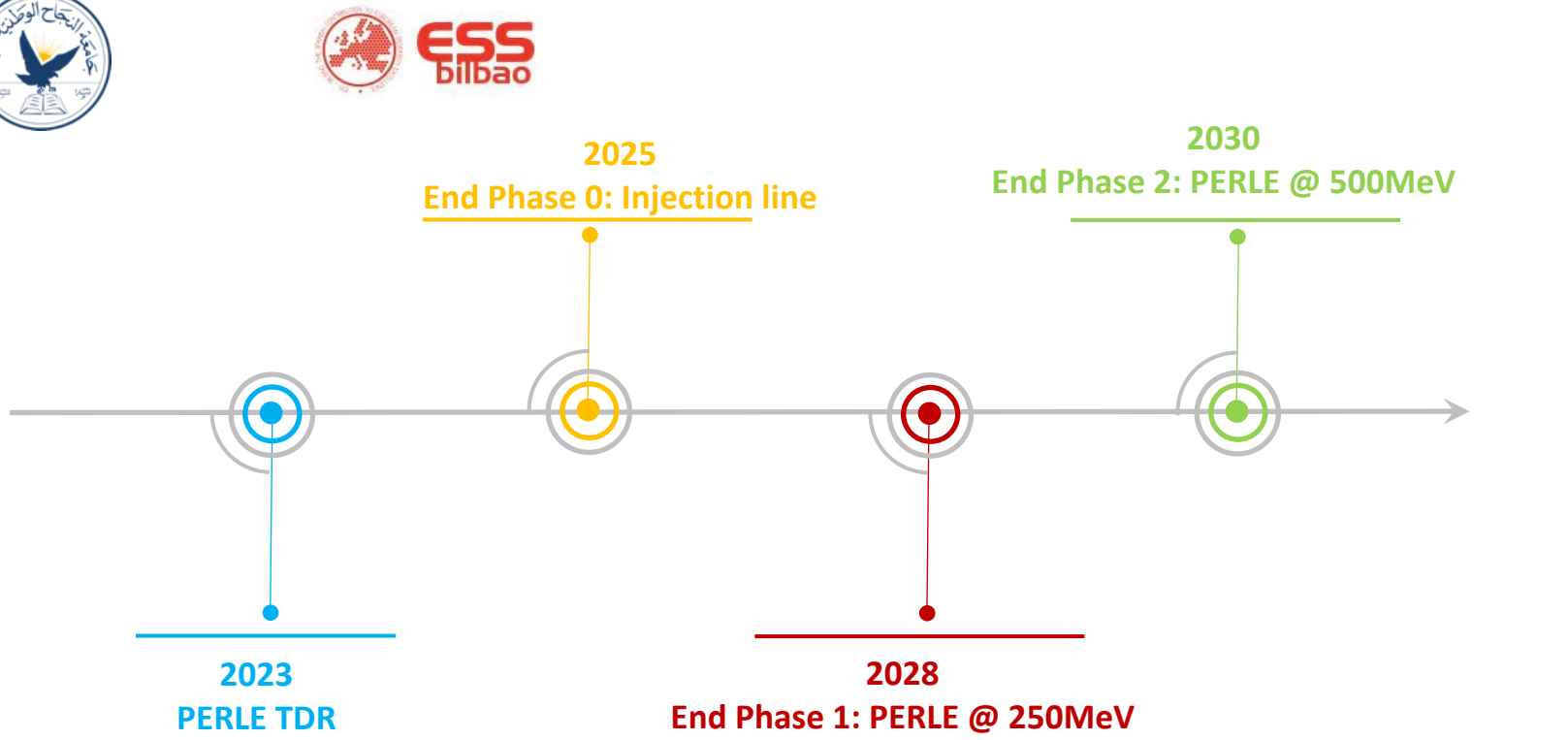
- **Dec 2021**: Accelerators roadmap presented and approved by the CERN Council and recently published (**March 2022**) as the CERN Yellow Report: https://doi.org/10.23731/CYRM-2022-001

Vol. 1 (2022): European Strategy for Particle Physics - Accelerator R&D Roadmap

- **Sept 2022** to follow the implementation of the Accelerators Roadmap new panels have been created to follow the implementation reporting to LDG and CERN Council

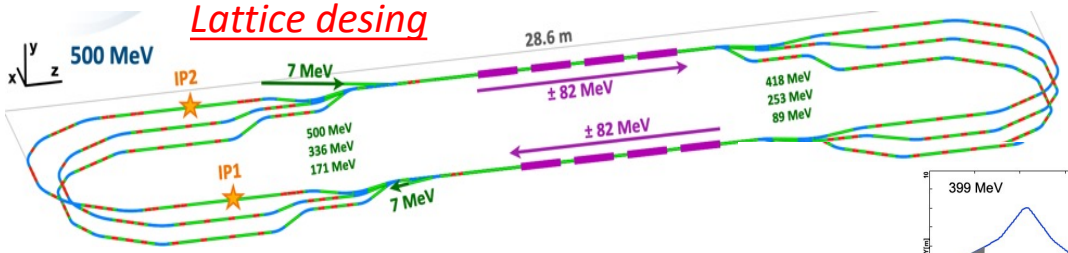


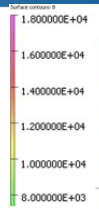
PERLE an International Collaboration

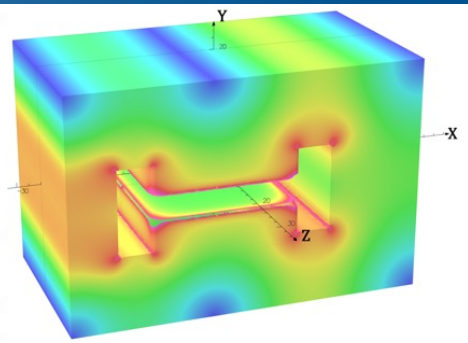


Quite a lot of news and progress in the last year !

Lattice desing

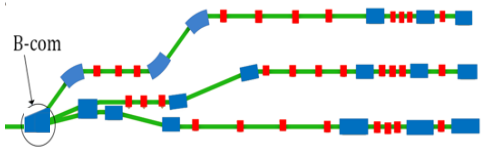


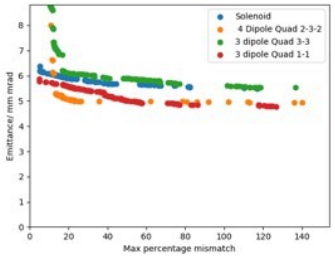


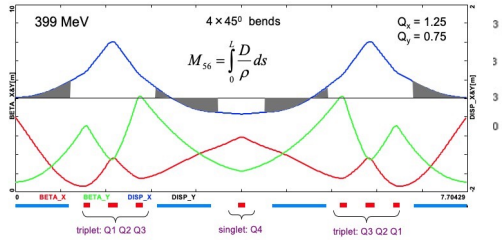


BCom magnet

Merging schemes

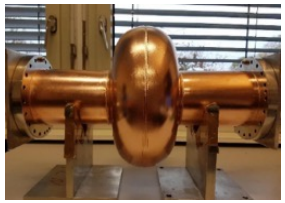


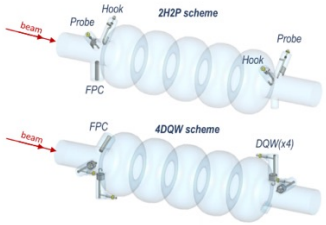


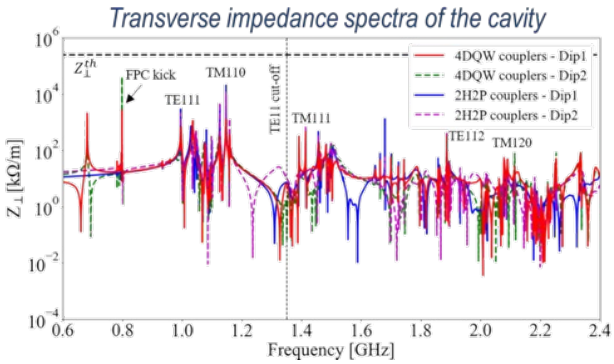


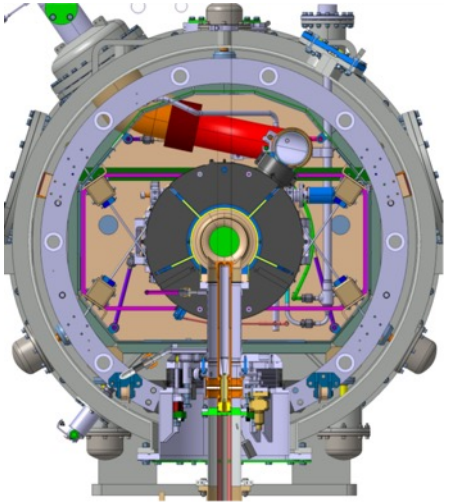
Lattice consolidation & detailed Beam dynamic studies

ESS Crymodule









Cavity design and production

HOM couplers studies and production

Quite a lot of news and progress in the last year !

DC gun installation progress

IGLOO : fully equipped bunker (radioprotection, crane, electrical power, compressed air …)

February 2022

Installation of HV Vessel

June 2022

Installation of HV columns

July 2022

Test of HV vessel tightness

September 2022

December 2022

Caro Max….

To work with you is an honor and always a great pleasure

I think it was fruitful and we have still plenty of ideas for the future and many came from you !

Caro Max….

…Your knowledge and on your trust on future are a true inspiration for me

I have learnt a lot from you

I’m happy and honored to be your friend

Today is a Fest Day !

MaxKleinFest

but after that it's back to work

we need you and your guidance and ideas !

uno
per tutti
tutti per uno

WUNERBAR !!

AVANTI !!

one
for all
all for one