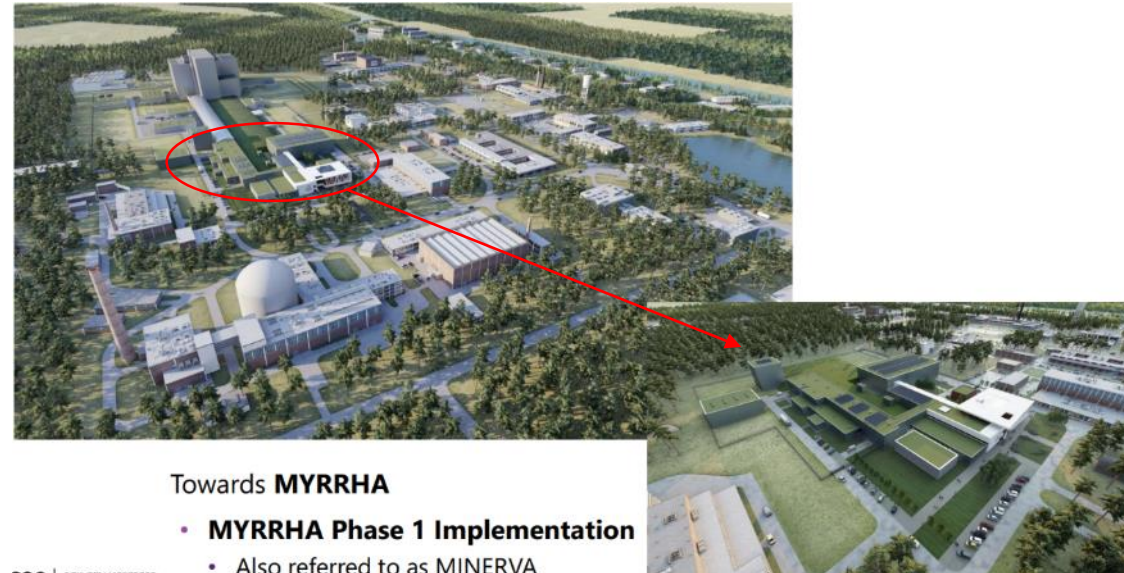


Status of IN2P3 contributions to MYRRHA and ESS

Guillaume Olry
Pôle Accélérateurs - Service RF

Context

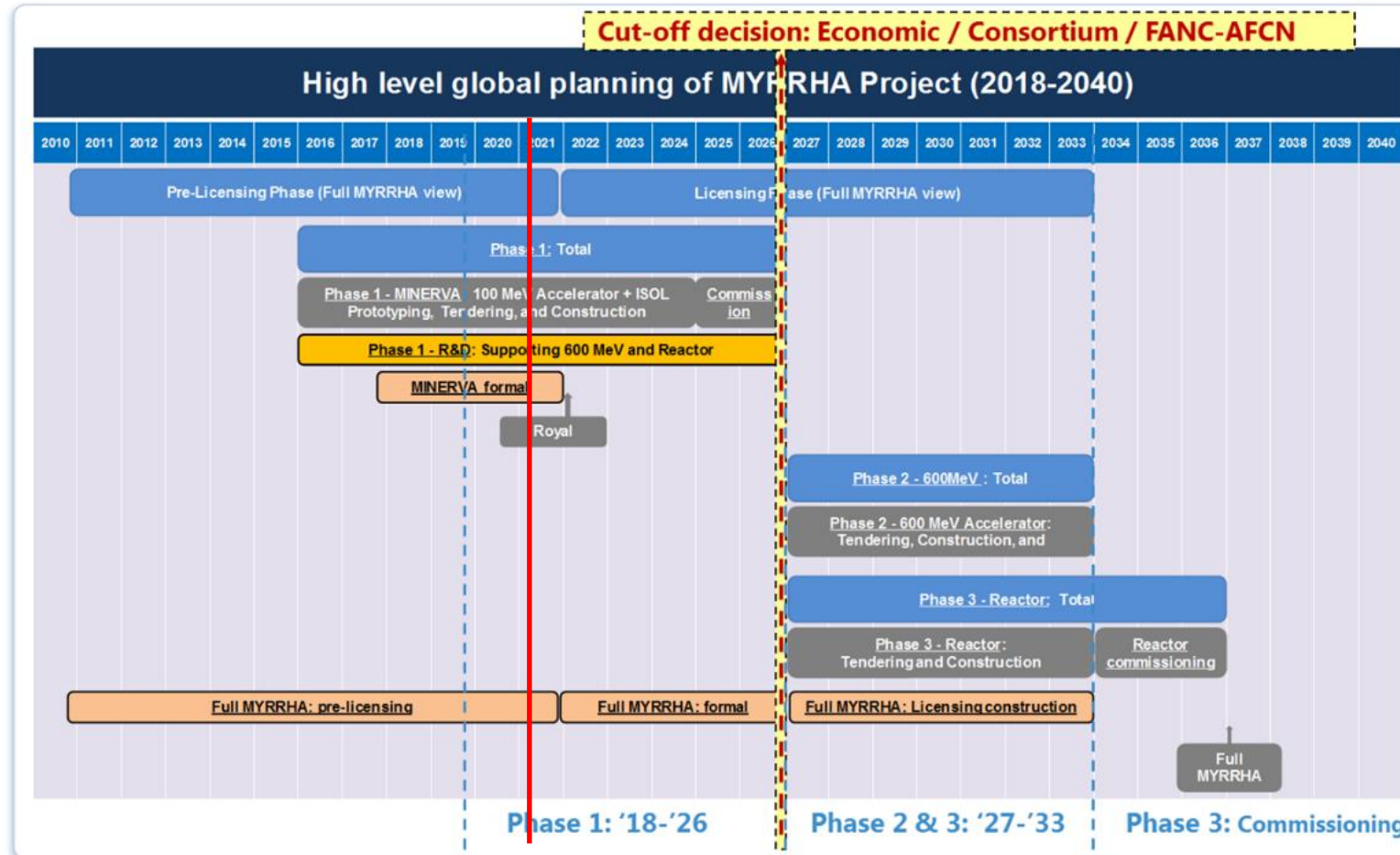
- IN2P3 involvement for the development of an ADS facility at Mol started more than 20 years ago and has strengthened mainly through several R&D programs within the several Framework Programs supported by the EU: PDS-XADS, IP-EUROTRANS, CDT, MAX and MYRTE
- Main objectives of MYRRHA:
 - Build a 600 MeV and 5 mA proton beam linac
 - Injection of the beam into a sub-critical reactor
 - Study the feasibility of the nuclear wastes transmutation
- Key date: September 7th, 2018: official agreement of the Belgium Council of Ministers to build the Phase 1 of MYRRHA (so-called MINERVA)
 - 558 M€ (2019-2038)
 - Build MINERVA 100 MeV
 - Pursue the studies of the 600 MeV linac



3 laboratories of IN2P3 involved:

- **IJCLab**
- **IPHC**
- **LPSC**

Full project official schedule



Project Agreements

2 contracts signed in 2017 : RSN F. Bouly (LPSC)

- NR1 (2017-2020): perform specific studies to help bringing the design of the 100 MeV MYRRHA accelerator dedicated to the construction phase.
- NR2 (2017-2020): design, manufacture and test of a prototype accelerating module representative of the 15 to 100 MeV energy section of the MYRRHA accelerator.

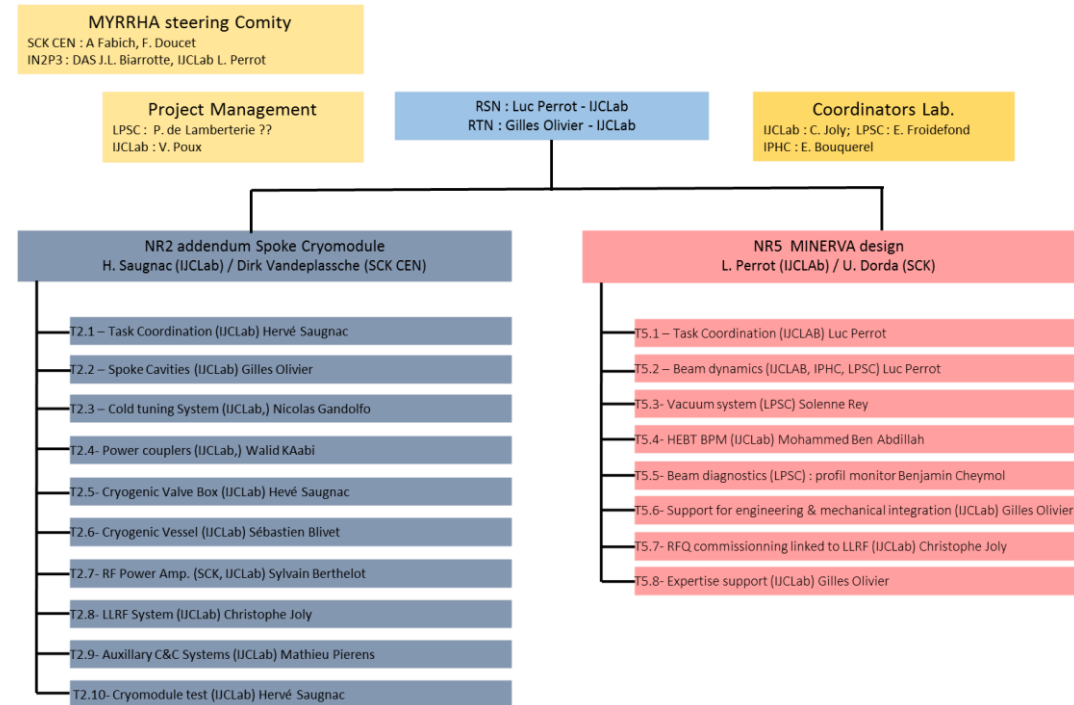
2 contracts signed in 2020 : RSN L. Perrot (IJCLab)

- NR2 addendum (2020-2022): pursue the preparation, assembly and tests of the cryomodule done in NR2
- NR5 (2020-2024): pursue the studies done in NR1 with a dedicated support to the procurements of the series cryomodules and their installation.

1 contract under discussion

- NR6: qualification tests of critical components for the series

Project organization chart



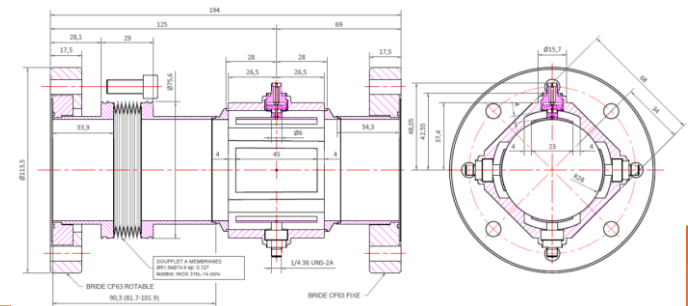
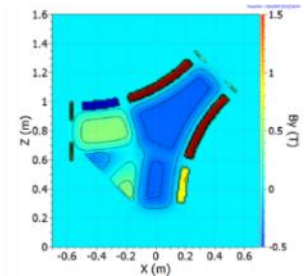
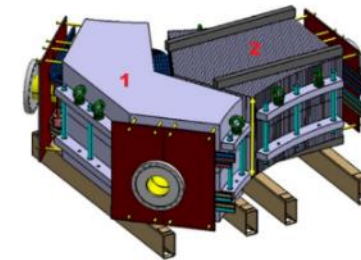
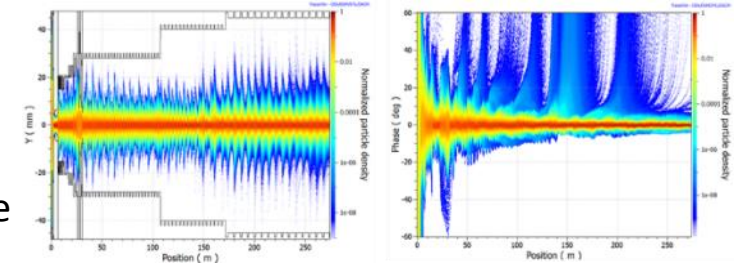
NR2 : 1.1M€ ,185h.m

NR5 : 0.8M€ , 141h.m

NR1 status (IJCLab, LPSC, IPHC): completed to 100%.

3 years Project Agreement signed in July 2017

- Task 1 : General coordination of all the CNRS contributions defined in the frame of the CNRS/SCK CEN Project Agreements
- Task 2 (LPSC, **IJCLab**, IPHC): Beam dynamics studies
- Task 3 (LPSC): Design of the fast switching magnet of the 17MeV MEBT3,
- Task 4 (LPSC): Design of the whole accelerator vacuum system,
- Task 5 (**IJCLab**): Development of beam position monitor diagnostics systems.

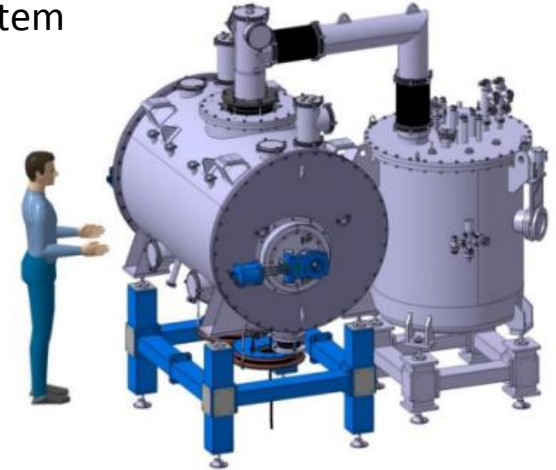


NR2 + addendum status (IJCLab, LPSC): completed to 70%

3 years Project Agreement signed in July 2017

Main goal: to design, build and test an “elementary brick” of the Spoke section linac (17 to 100MeV) composed of a fully equipped cryomodule and its cryogenic system

- Design of the cavities, power coupler, tuning system, cryostat, valve box, LLRF C&C system
- Follow-up of the fabrication
- Preparation and qualification test of each individual component
- Assembly of the cryomodule
- Qualification test of the cryomodule at 2K and high-power
- Validation of the fault-tolerance strategy



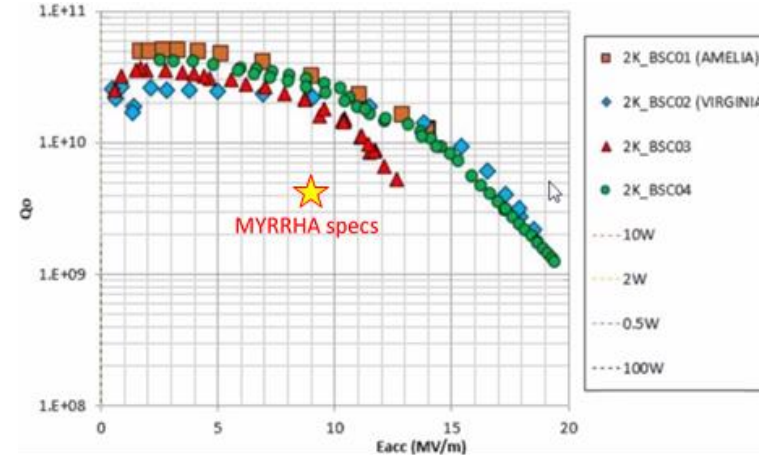
→ Significant delays in publishing and awarding two contracts (couplers and valve box) by the SCK CEN

→ Original NR2 contract extended for a period of 2 additional years (Addendum up to mid 2022)

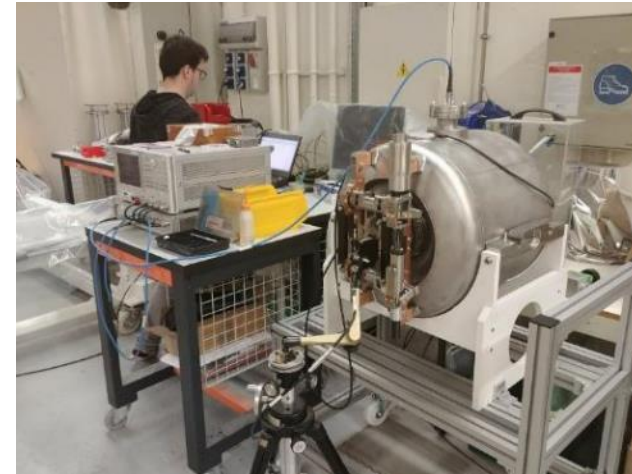
Extension will allow to complete the studies and perform the final test of the prototype cryomodule.

NR2 status (WP leader : H. Sagnac IJCLAB)

	Completed to
• T2.1 – Task Coordination (IJCLab, LPSC)	
• T2.2 – Spoke Cavities (IJCLab)	99%
• T2.3 – Cold tuning System (IJCLab, LPSC)	75%
• T2.4- Power couplers (IJCLab, LPSC)	85%
• T2.5- Cryogenic Valve Box (IJCLab)	85%
• T2.6- Cryogenic Vessel (IJCLab)	90%
• T2.7- RF Power Amp. (SCK, IJCLab)	95%
• T2.8- LLRF System (IJCLab)	85%
• T2.9- Auxillary C&C Systems (IJCLab)	95%
• T2.10- Cryomodule test (IJCLab)	60%

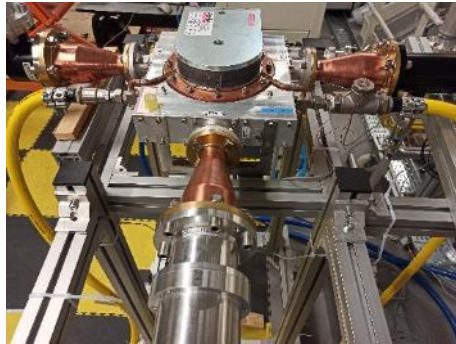


Vertical tests
of the Spoke
cavities



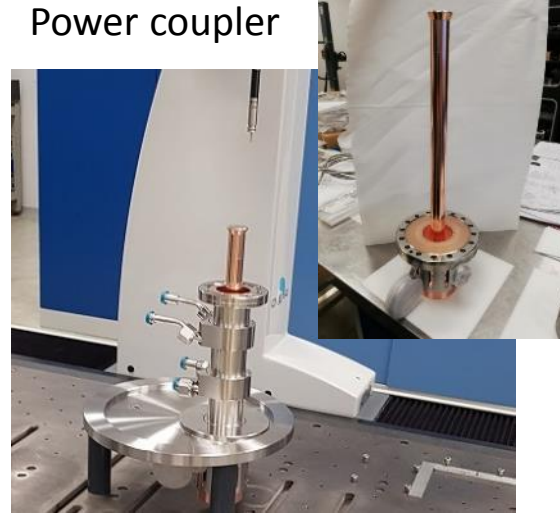
Test at 300K
of the tuning
system

NR2 status

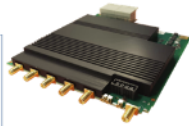
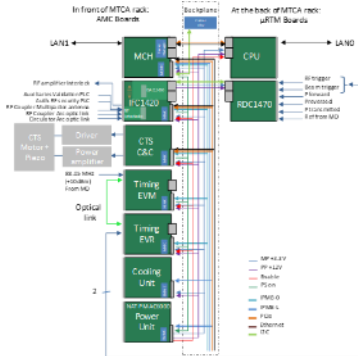


Circulator of
the 20kW
amplifier
under test

Power coupler



Test bench for the
conditioning of the couplers
(installation under progress)



LLRF



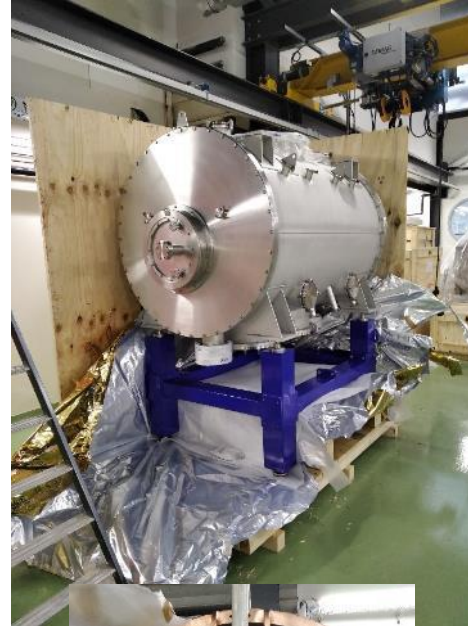
Cavity for the RF
conditioning of the
couplers



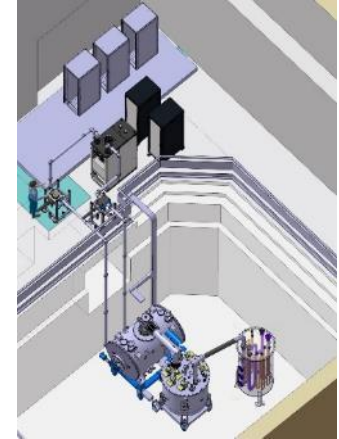
NR2 status



Valve box
(final leak
test)



Vacuum
vessel
delivered @
IJCLab and its
installation
under
progress



NR5 status (IJCLab, LPSC and IPHC)

PA just started in November 2020 for a period of 4 years.

NR6 status (IJCLab)

Ongoing discussions on the qualification test of the critical components for the series: up to 60 Spoke cavities, 60 cold tuning systems and 60 power couplers.

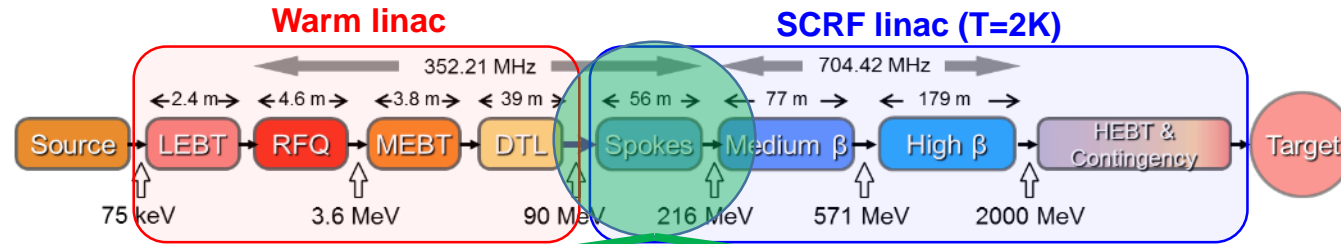
PhD thesis

2 defences in 2021 (CIFRE LPSC/ACS and IJCLab/Thales)

1 started in November 2020 (CIFRE IJCLab/ACS)

1 planned in Sept 2021 at LPSC (IN2P3 support)

Context



The 13 (+1) spoke cryomodules composing the first superconducting acceleration stage of ESS.



WP4

The full cryogenic distribution system for the spoke section (13 valve boxes, cryolines, cryo end box)



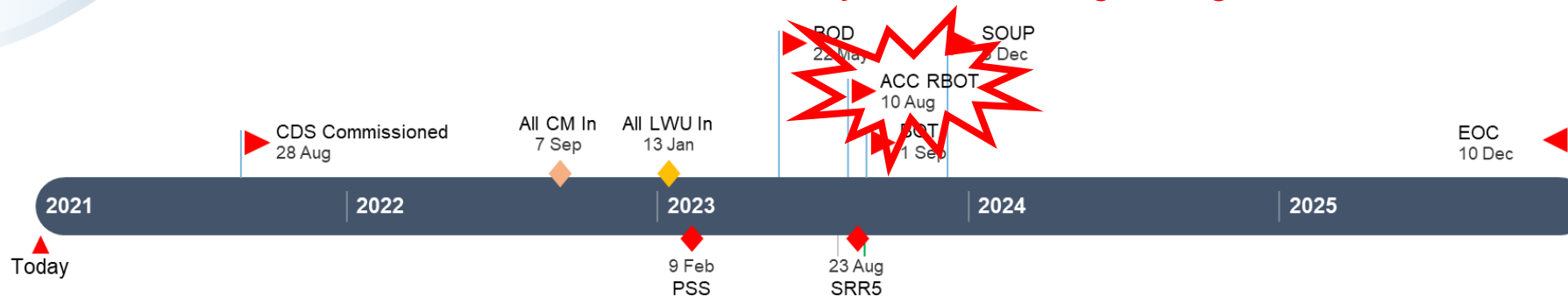
WP11

Since 2014: more than 93 FTE (incl. prototype studies and in-kind) have been involved into the WP4, WP5 and WP11. 19 FTE in 2020. Estimation for 2021 ~17 FTE and 4 FTE for 2022.

NB: The overall Human Resources planned on in-kind participation is already used...

Planning

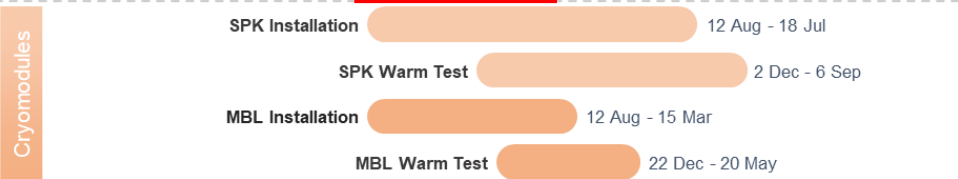
Accelerator Ready Beam On Target: August 2023



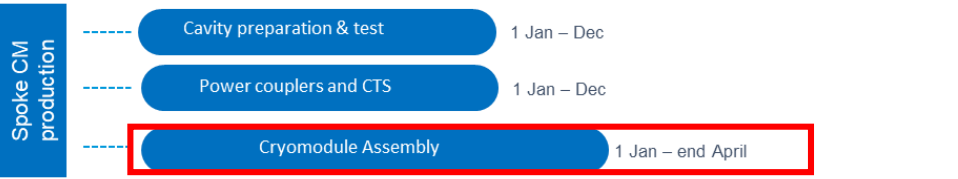
WP11



WP4



WP4



WP11



CDS

Cryomodules

WP4: Cryomodules

Cavities

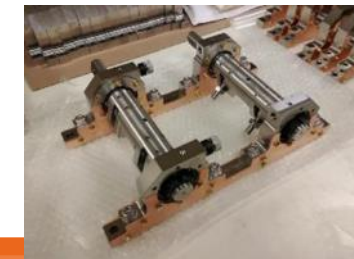
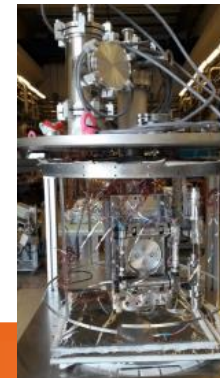
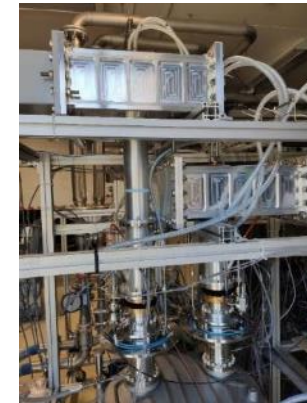
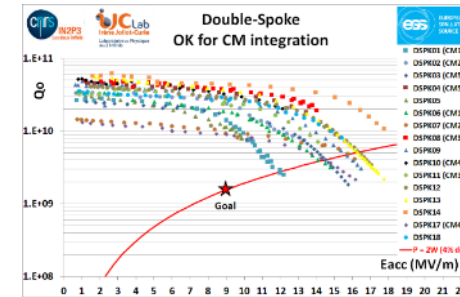
- ❑ All spoke cavities have been delivered (2 last ones in July 2020).
- ❑ 16 cavities tested @2K within the specifications ($E_{acc} > 9 \text{ MV/m}$ & $Q_0 > 1.5 \cdot 10^9$)
- ❑ **All remaining cavities tested before end 2021**

Power couplers

- ❑ Fabrication close to completion (3 to be delivered)
- ❑ 16 couplers successfully conditioned
- ❑ **All remaining couplers will be conditioned before end 2021**

Cold tuning system

- ❑ All parts fabricated and received
- ❑ 23 tuners have been successfully tested up to now
- ❑ The remaining 7 CTS will be tested **before summer 2021**



WP4: Cryomodules

Fabrication: 95% of the parts fabricated and delivered (vacuum vessels, magnetic shielding, warm-to-cold transitions...)

Assembly:

- ❑ 4 CMs assembled in 2020 with several issues...
 - CM1 **vented** after an accidental pick-up breakage: on hold.
 - CM2 assembled, sent to Uppsala and tested: **RF and cryo performances OK**, but **a failure on one cold tuning system**: repaired, dispatch next Thursday.
 - CM3 assembled, but **a small leak on beam vacuum detected** at the end of the assembly process: disassembled, diagnostic under progress.
 - CM4 assembly completed and tested @ Uppsala. **95% validated!**
- ❑ Since January 1, 2021:
 - CM5: assembly in progress: ready at the end of next week.
 - CM6: cavity string in clean room is achieved...waiting for cryostating.
 - CM7: cavity string assembly in clean room will start in 2 weeks.

CM assembly @IJCLab



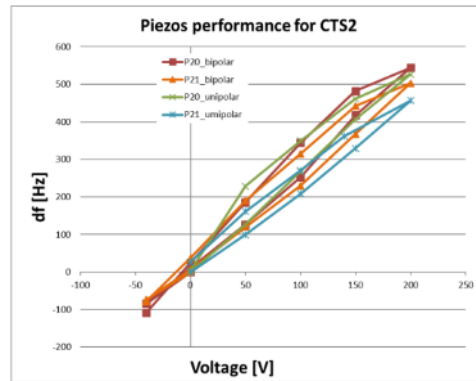
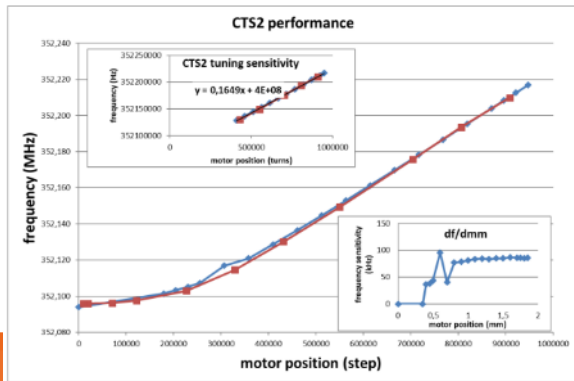
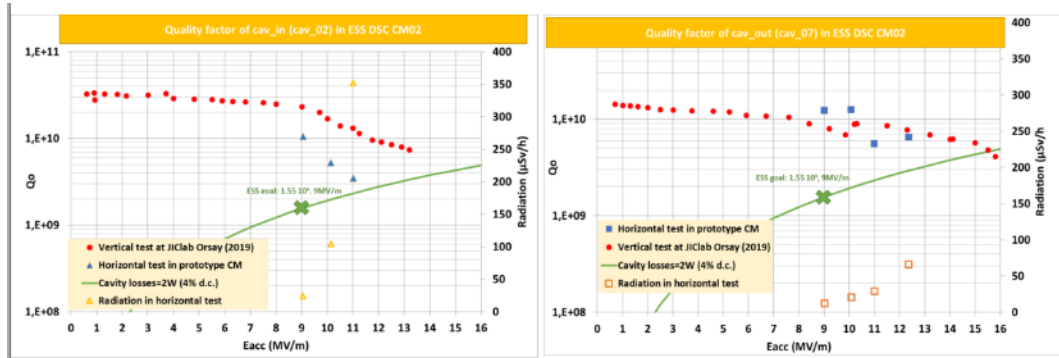
CM testing @Uppsala



WP4: Cryomodules

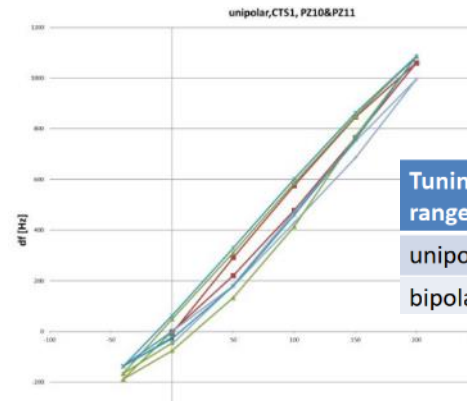
CM2 test results @ Uppsala

- Cavities and 1 tuning system performances: OK.
- Vacuum and cryogenics: OK.



CM4 preliminary test results @ Uppsala

- Both cavities and tuning systems performances: OK.



Tuning range	PZ10	PZ11	PZ10 & PZ11
unipolar	603 Hz	526 Hz	1060 Hz
bipolar	758 Hz	620 Hz	1273 Hz

- Vacuum and cryogenics: OK.
- Heat loads: to be measured

→ IJCLab assistance @ Uppsala for CM02 & CM04 installation into the bunker

WP11: Cryogenic Distribution Line

Status of the valve boxes & header units

- 3 first VBs & 6 HUs delivered to Lund in February 2020 **but rejected due to several poor quality welds** only detected at the end of the fabrication. Additionally, ESS requested piping modifications at the end of August 2020 and **new quality criteria (not specified to IJCLab since their release in 2018)** → all VBs & HUs started to be reworked.
- 3 reworked VBs are ready for delivery.
- **Main concern is related to quality acceptance procedure and criteria before shipment: strategy between ESS and IJCLab for SAT is close to an agreement.**
- 3 other VBs are about to be finished.
- **Delivery of all VBs and all HUs being rescheduled with ESS.**



Valve boxes during test



Header units during assembly

WP11: Cryogenic Distribution Line

Status of the auxiliary lines and end box

- Fabrication and installation was performed during 2020, and pressure tests occurred in September 2020.
- **Severe issue** during pressure tests (bellow buckling...because of the supplier not respecting PED) → the lines were damaged.
- **Lines have been dismantled and our subcontractor has been appointed for repair and re-installation. New bellows ordered.**
- End-box: final control of the internal piping by the Institut de la soudure done last week. Waiting for the report.



Auxiliary lines

End box



- Installation of all spoke CDS parts (new auxiliary lines, valve boxes, header units and end box) in the tunnel planned to start in Feb 21 and be completed at the end of July 2021.
- Ready for the global cooldown in August 2021

- **IJCLab is building the CM and CDS Spoke section with challenging performances → so far the individual tests of cavities, couplers and tuning systems are within the ESS specifications → validation of their design!**
- **WP4 has been severely impacted for 1 year now by the COVID19 pandemic (~6 months of delay).**
 - Production, preparation and tests of the cryomodule individual components are well advanced
 - Cryomodule production planning suffered from several events (failure, leak, accidental break) but procedures and additional quality controls are now well in place and teams are skilled and trained.
 - 1st cryomodule is almost qualified !
 - Actions taken for mitigation: 14th cryomodule and second cryomodule assembly line (→ operational).
- **WP11 : impacted by the COVID19 pandemic (delays at suppliers premises...) and also by the evolution of the ESS specifications during the manufacture of the VB, HU and End-Box.**
 - Issues with the quality of welds are hopefully solved and an agreement between ESS and IJCLab for the FAT/SAT is about to be found.
- **Key role of the platform “SUPRATECH”**
- **Future projects supported by IN2P3 as MYRRHA and PIP-II will benefit from ESS experience**