IN2P3 contribution to PIP-II

Longuevergne David

On behalf of PIP-II team at IJCLab

OUTLINE

- What is PIP-II
    - Technical and scientific overview
    - General status
    - Project schedule
- IN2P3 contribution
    - Motivations
    - Scope of contribution
    - Deliverables
    - State of the art
    - R&D and upgrade for PIP-II
- Project management
    - Technical Review Plan and Schedule
    - Local organization
    - Cost distribution
    - Risk analysis

PIP-II Mission

PIP-II will enable the world’s most intense beam of neutrinos to the international LBNF/DUNE project, and a broad physics research program, powering new discoveries for decades to come.

PIP-II linac will provide:

Beam Power

- Meeting the needs for the start of DUNE (1.2 MW proton beam)

Flexibility

- Upgradeable to multi-MW capability for LBNF/DUNE
- Compatible with CW-operations which greatly increases the linac output
- Customized beams for specific science needs
- High-power beam to multiple users simultaneously

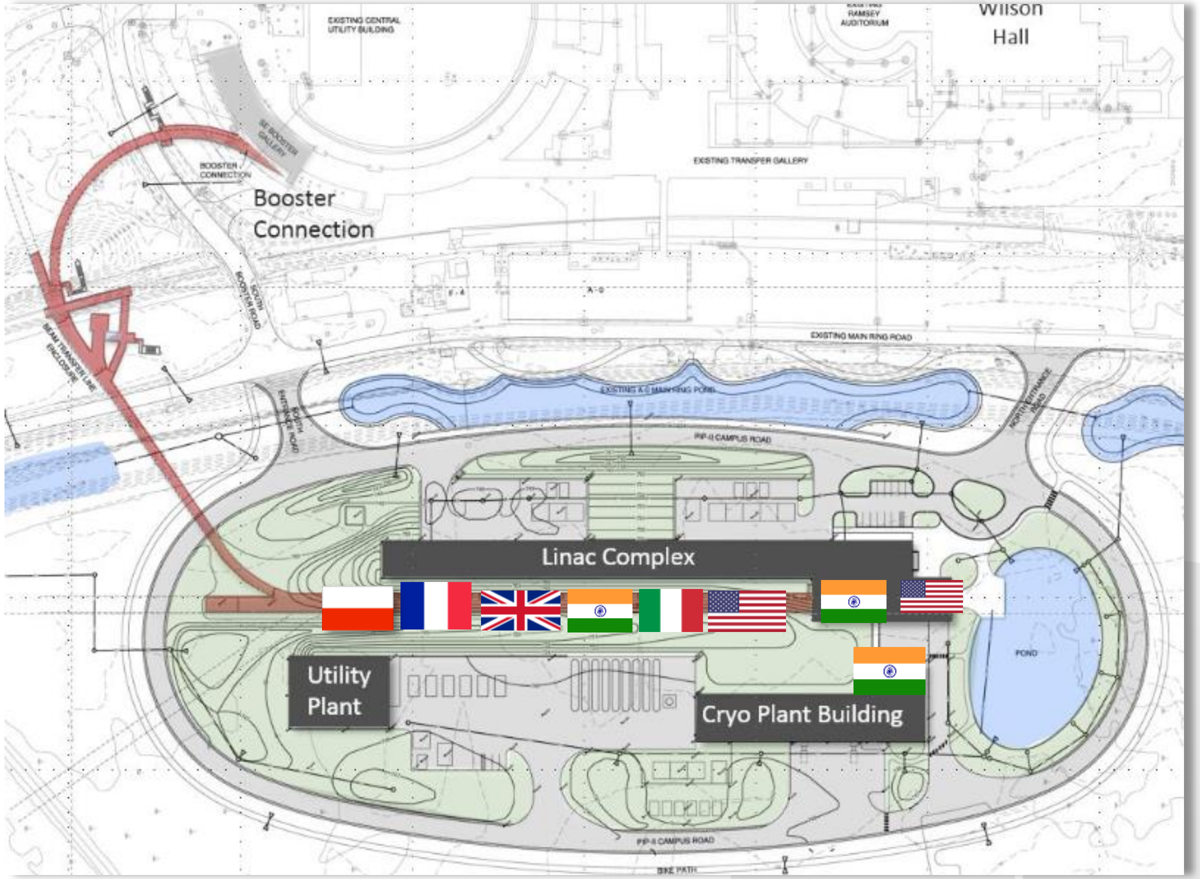
Reliability

- Fully modernizing the front-end of the Fermilab accelerator complex

Courtesy of Lia Merminga

PIP-II Scope

Courtesy of
Lia
Merminga



800 MeV H− linac
- Warm Front End
- SRF section

Linac-to-Booster transfer line
- 3-way beam split

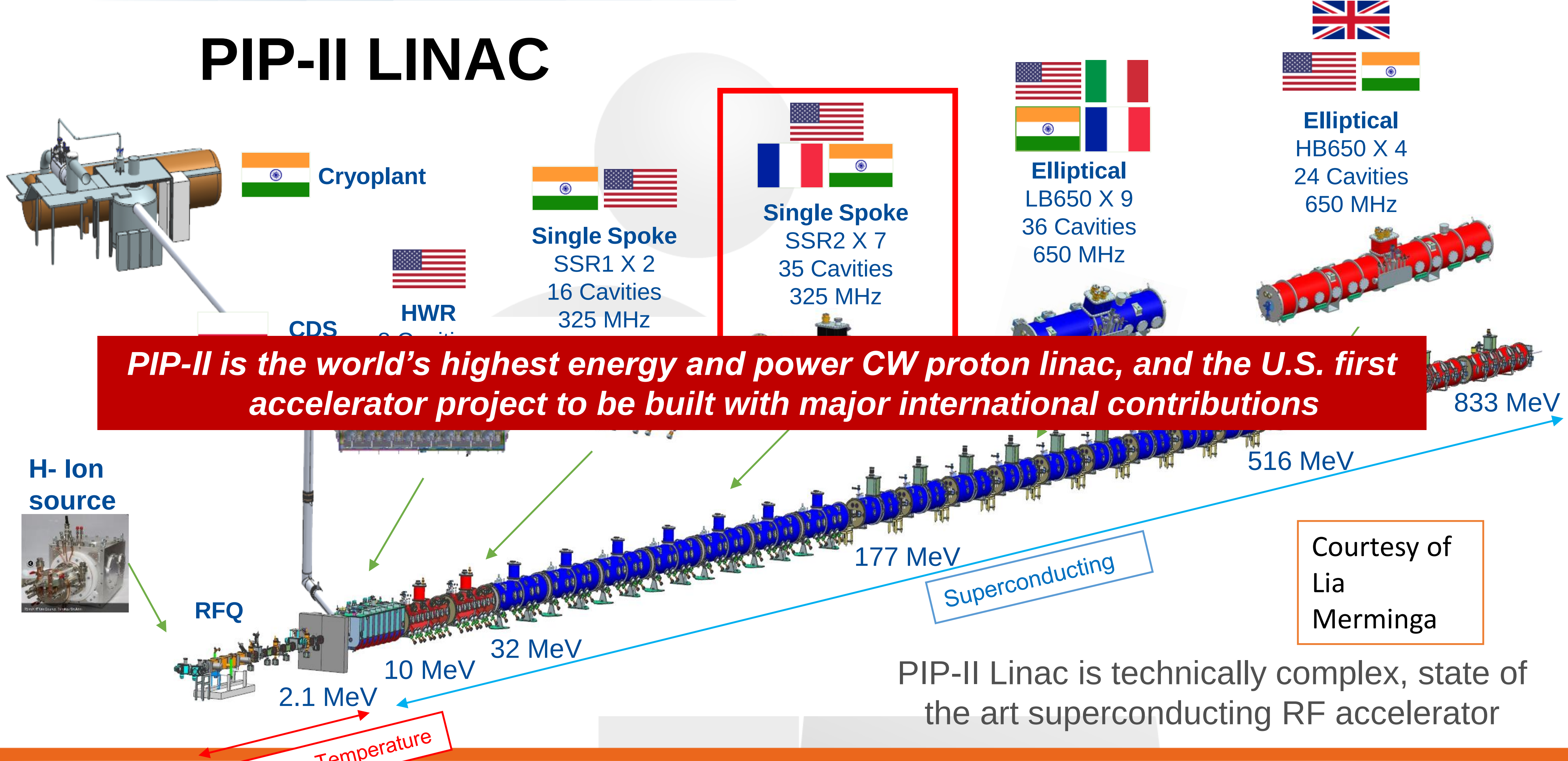
Upgraded Booster
- 20 Hz, 800 MeV injection
- New injection area

Upgraded Recycler & Main Injector
- RF in both rings

Conventional facilities
- Linac Tunnel includes 2 empty slots
- Upgrade capability to 1GeV

WHAT IS PIP-II ? Technical and scientific overview

PIP-II LINAC



Cryoplant

CDS

HWR

Single Spoke
SSR1 X 2
16 Cavities
325 MHz

Single Spoke
SSR2 X 7
35 Cavities
325 MHz

Elliptical
LB650 X 9
36 Cavities
650 MHz

Elliptical
HB650 X 4
24 Cavities
650 MHz

H- Ion source

RFQ

2.1 MeV

10 MeV

32 MeV

177 MeV

516 MeV

833 MeV

Superconducting

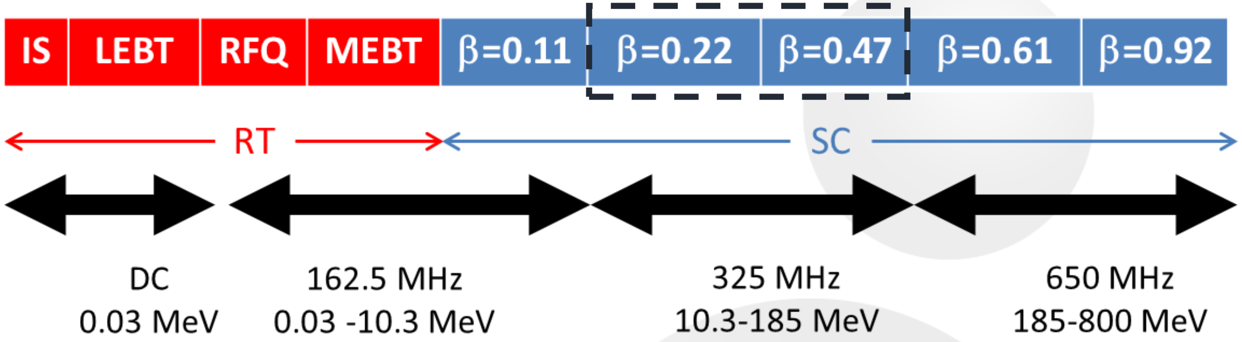
Room Temperature

PIP-II is the world's highest energy and power CW proton linac, and the U.S. first accelerator project to be built with major international contributions

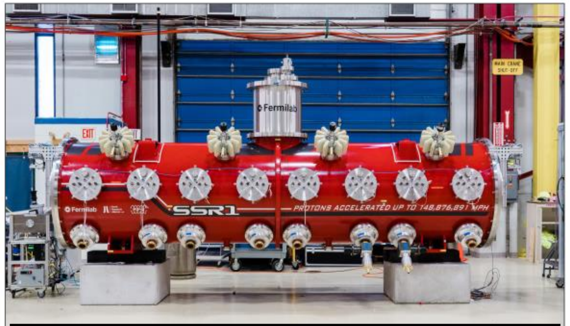
Courtesy of
Lia
Merminga

PIP-II Linac is technically complex, state of the art superconducting RF accelerator

SSR CRYOMODULES

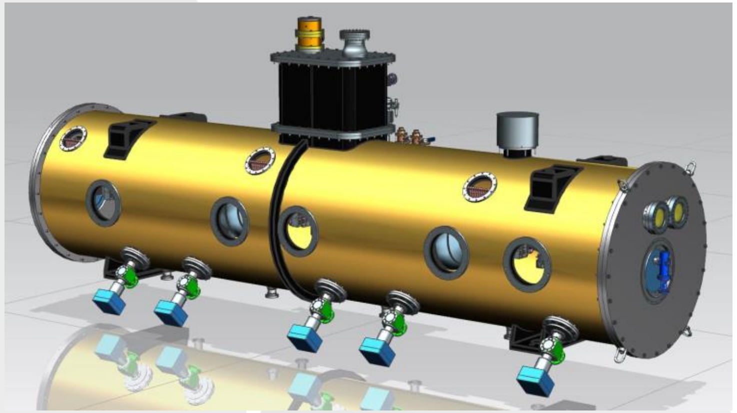


	SSR1	SSR2
# CMs	2	7
Cavities per CM	8	5
Solenoids per CM	4	3
CM configuration c: cavities; s: solenoids	4x (csc)	sccsccsc
CM length (m)	5.2	6.5

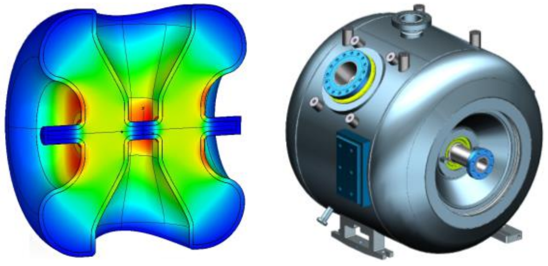


First SSR1 prototype cryomodule

Courtesy of Lia Merminga



Preliminary design of SSR2 cryomodule



Final design of SSR2 cavity

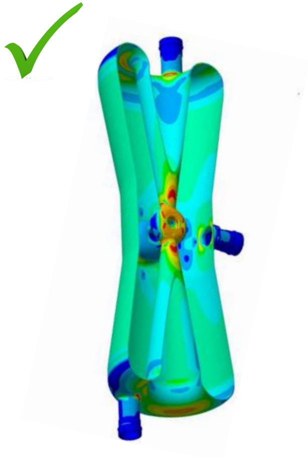
WHAT IS PIP-II ?

General status

✓

5.9 m

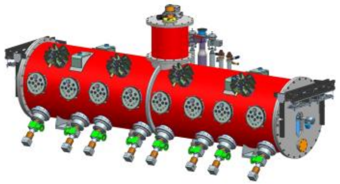
✓



Half Wave Resonator

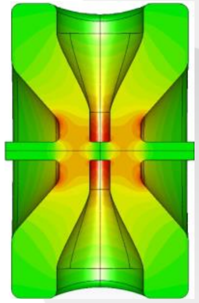
β=0.11 Q_0=0.85x10^{10}

✓



5.3 m

✓



Single Spoke

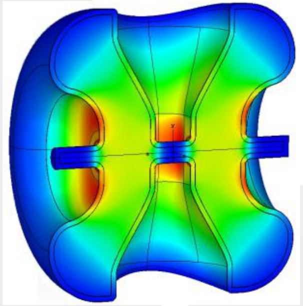
SSR1

β=0.22 Q_0=0.82x10^{10}

2023

6.5 m

Fabrication launched recently
First delivery end of 2021

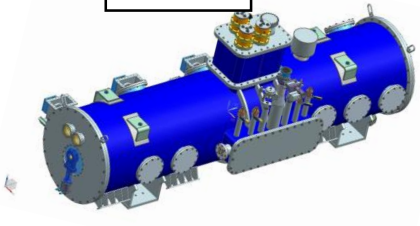


Single Spoke

SSR2

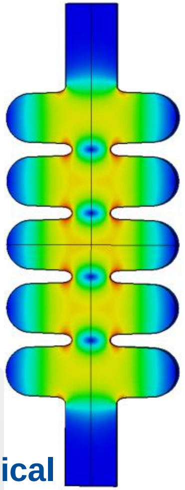
β=0.47 Q_0=0.82x10^{10}

2023



5.5 m

✓

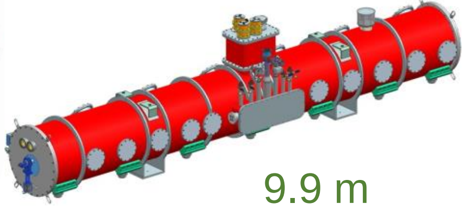


Elliptical

LB650

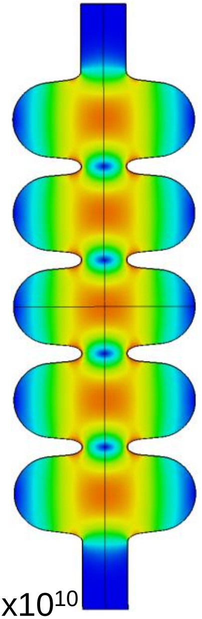
β=0.61 *Q_0=2.4x10^{10}

2021



9.9 m

✓



Elliptical

HB650

β=0.92 *Q_0=3.3x10^{10}

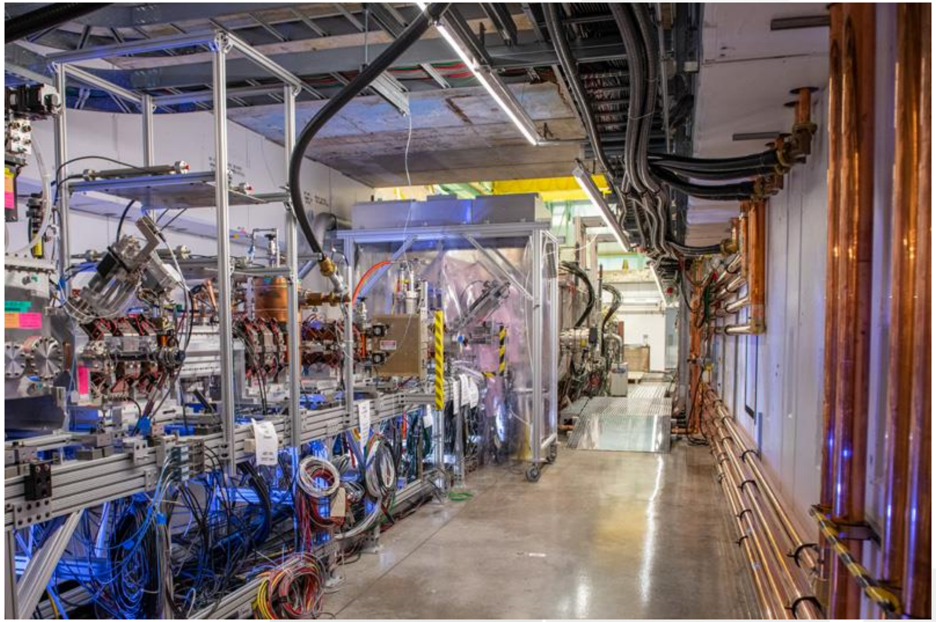
✓ Performance validated

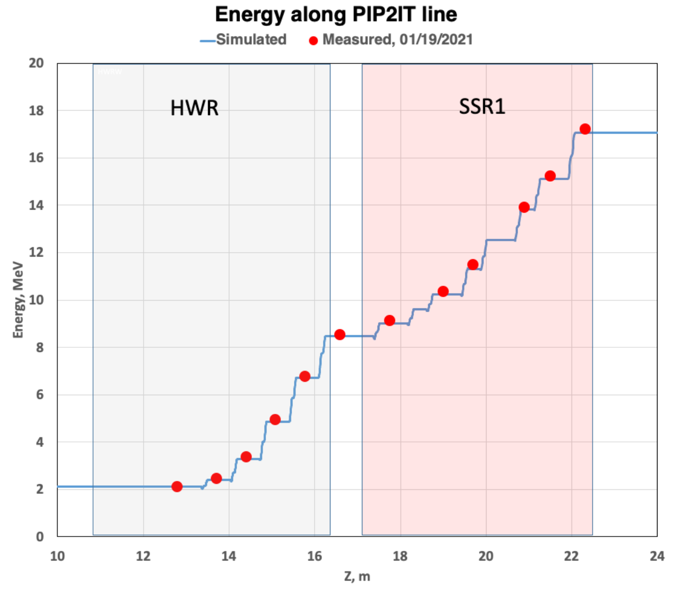
✓ Testing in progress   Dates: component built

Courtesy of Lia Merminga

WHAT IS PIP-II ? General status

PIP-II IT : testing facility



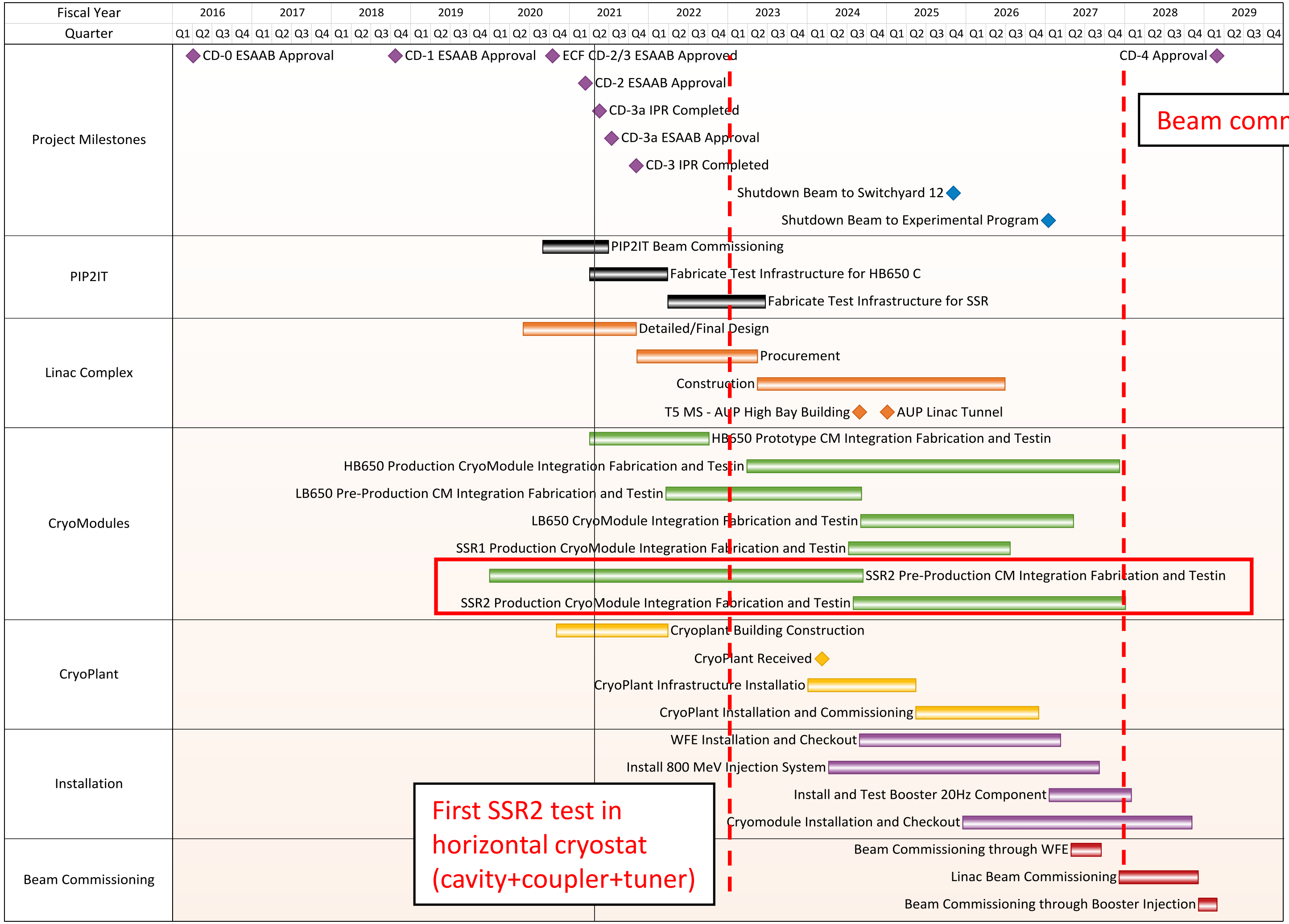


17 MeV achieved

Courtesy of Lia Merminga

WHAT IS PIP-II ?

Project Schedule



Beam commissioning

First SSR2 test in horizontal cryostat (cavity+coupler+tuner)

SSR2 cryomodule on critical path

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IN2P3 CONTRIBUTION TO PIP-II

Motivations

- Work in close collaboration with world-class accelerator laboratories
    - Improve technical skills : joint designs, benefit from lessons learned. « Win-win » collaboration.
    - Improve project management skills : high-level project management requirements at Fermilab (QA/QC)
- Be part of the development and construction of the world's highest energy and power CW proton linac
    - Proof of high skills and experience in the construction of superconducting linac (Spiral2, XFEL, ESS, MYRRHA, …). IJCLab has been approached by Fermilab
    - World-wide recognition
    - Involve and qualify European and French companies for production phase
- Motivate and boost SRF R&D pursued at IN2P3
    - Bring new collaboration opportunities
    - Upgrade IJCLab facilities in term of availability and reliability
- Serve the international DUNE collaboration in which many French physicists, engineers and technician will be involved

CONTRIBUTION DIVIDED INTO 2 PHASES :

- Prototyping (pre-production) phase (2020 – 2022) : aims at building components for the pre-production cryomodule and not meant to be installed on the accelerator

Done

Engaged (end of 2021)

To be done (2022)

  - Joint design of accelerator components : implementation of lessons learned from both FNAL and IJCLab
  - Fabrication of accelerator components in both continents (when possible) : qualification of at least 2 manufacturers => mitigation of risks. For cavities (RI and Zanon), couplers (CPI, PMB), tuners (PSI).
  - Surface processing, testing and validation of accelerator components at FNAL and IJCLab
  - Final qualification at FNAL in horizontal cryostat (cavity+tuner+coupler)

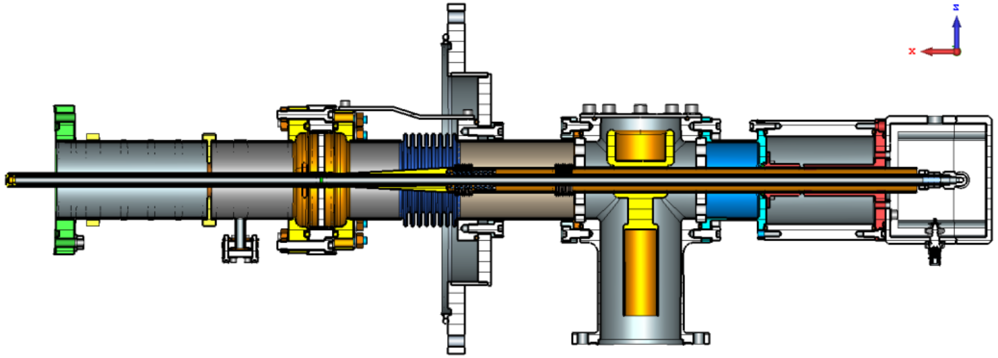
- Production phase (2022-2026)

Engaged (end of 2023)

To be done (2022 – 2026)

  - Upgrade of facilities at IJCLab (CV1250)
  - Implementation of lessons learned in joint final design
  - Support to fabrication follow-up of 33 cavities (for 6 cryomodules + 3 yield). 1 cryomodule procured by DAE.
  - Qualification and validation in vertical cryostat of the 33 cavities.
  - Shipping of cavities to FNAL

IN2P3 CONTRIBUTION TO PIP-II Deliverables



CAVITIES :

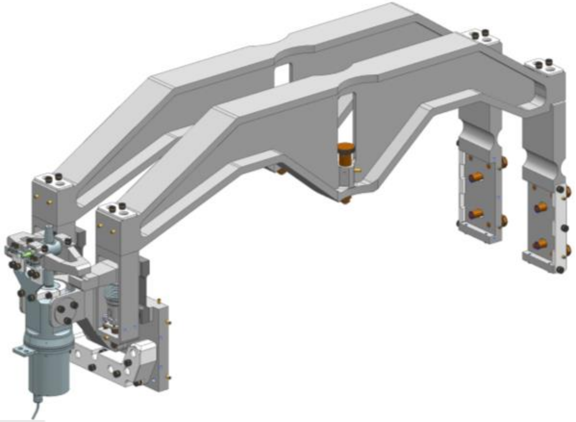
- **Prototyping Phase : 6 cavities built by 2 companies (Zanon and RI)**
  - Support fabrication follow-up of 3 cavities
  - Optimization of surface processing on 4 cavities
  - Validation in vertical cryostat of 4 cavities
  - Shipping of 4 cavities to FNAL
- **Production Phase: 33 cavities**
  - Support fabrication follow-up of 33 cavities
  - Validation in vertical cryostat of 33 cavities
  - Surface re-processing of cavities at IJCLab ~ 25%
  - Shipping of 33 cavities to FNAL

COUPLERS :

- **Prototyping Phase : 8 couplers**
  - Procurement of 4 couplers **(Done in November 2020)**
  - Shipping of 4 couplers to FNAL
  - Support during coupler RF conditionning at FNAL
- **Production Phase : X**

TUNERS :

- **Prototyping Phase : 5 tuners**
  - Procurement of 5 tuners
    (Done in November 2020)
  - Validation in vertical cryostat of 5 tuners
  - Shipping of 5 tuners to FNAL
- **Production Phase : X**



IN2P3 CONTRIBUTION TO PIP-II Deliverables

PROTOTYPING PHASE (2020 – 2022)

4 SSR2 Single Spoke Resonators

Fabrication follow-up,
QC inspection
Surface preparation

5 SSR2 Cold Tuner

Procurement
Fabrication
QC inspection

RF validation in vertical cryostat of 4 cavities

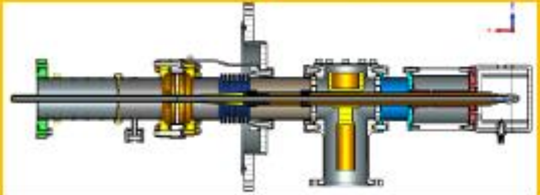
@ IJCLab

Transport to FNAL

RF validation in horizontal cryostat

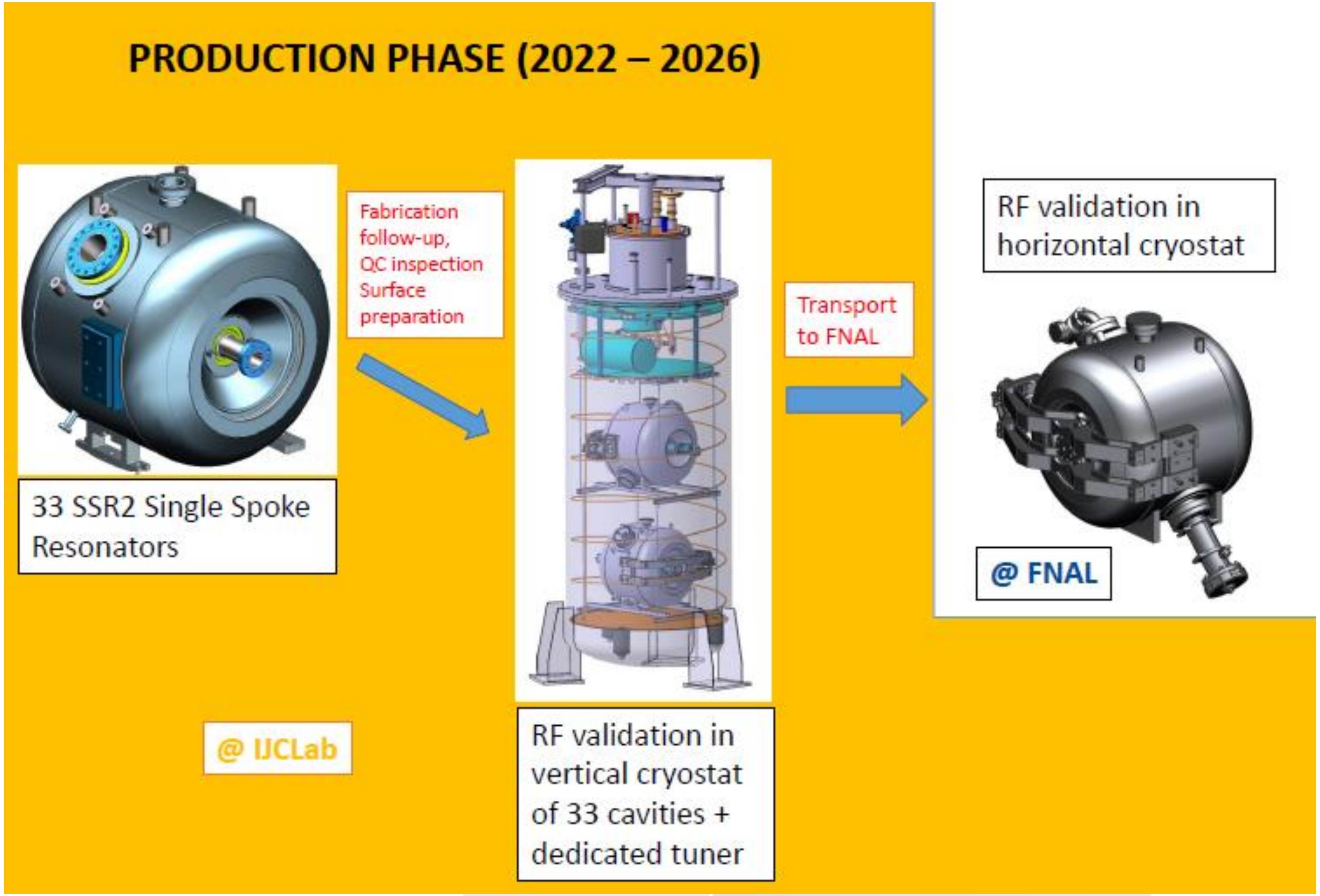
@ FNAL

Procurement
Fabrication
QC inspection
Transport to FNAL



4 SSR Power Coupler

IN2P3 CONTRIBUTION TO PIP-II Deliverables



PRODUCTION PHASE (2022 – 2026)

33 SSR2 Single Spoke Resonators

Fabrication follow-up, QC inspection Surface preparation

RF validation in vertical cryostat of 33 cavities + dedicated tuner

@ IJCLab

Transport to FNAL

RF validation in horizontal cryostat

@ FNAL

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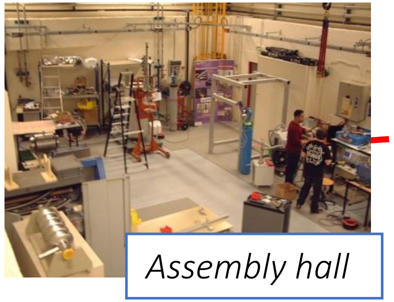
State of the art (SUPRATECH Platform)

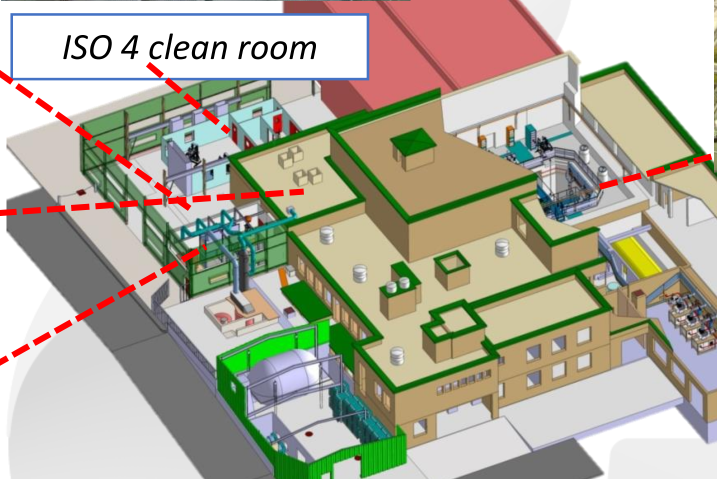
Vacuum furnace

ISO 4 clean room

Cryogenic test hall for cryomodules



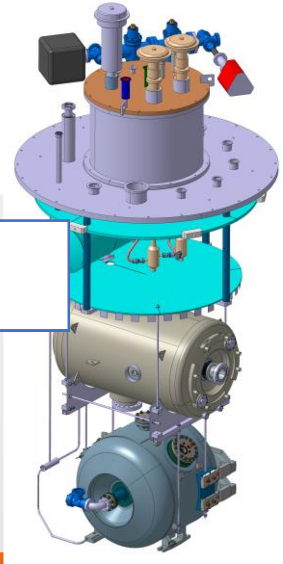
Assembly hall



Chemical etching lab (BCP only)

Helium liquefier

Vertical cryostat



+ Material science lab

PLATEFORME D'ANALYSE PANAMA

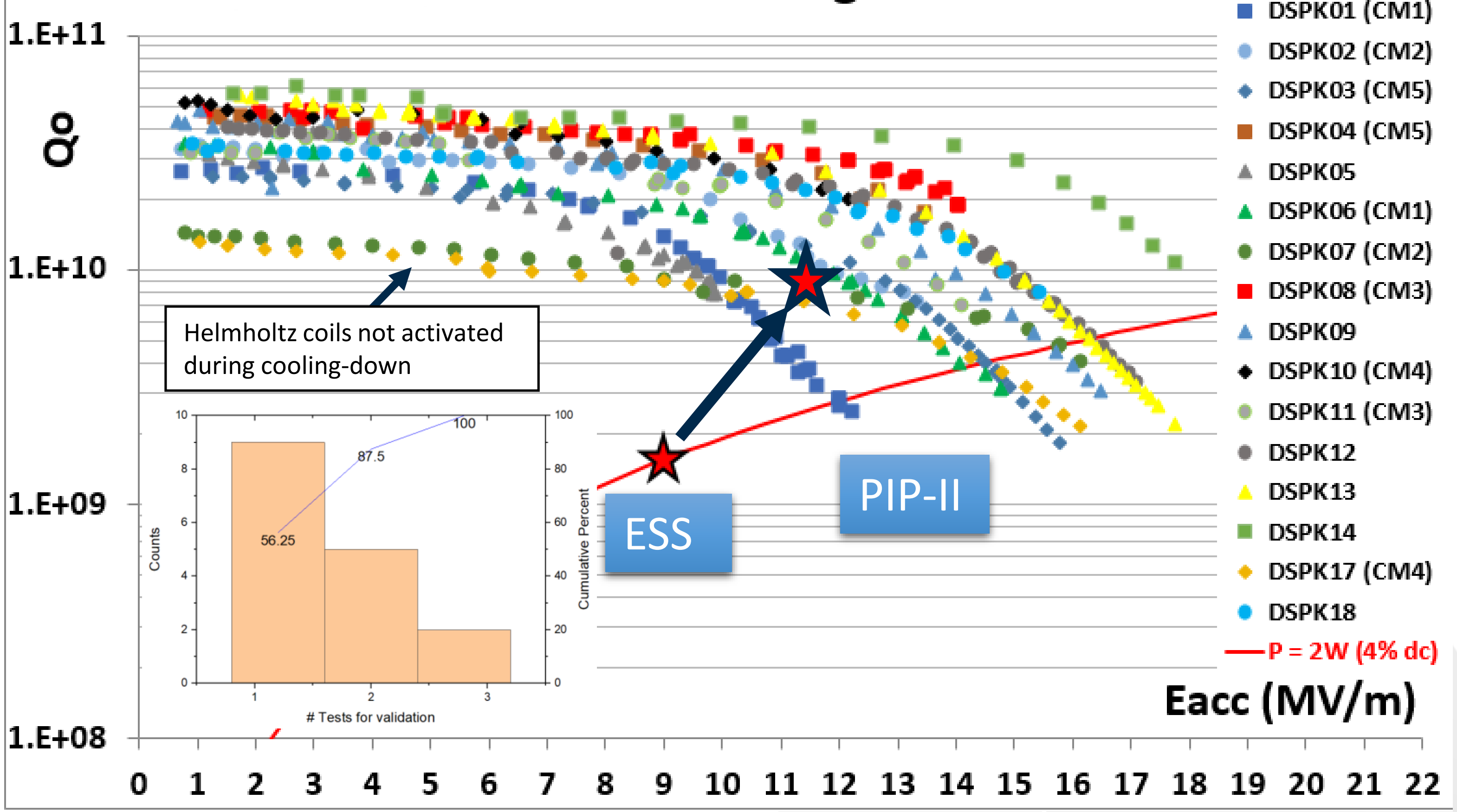
- GXRD
- SIMS
- Confocal microscope
- SEM (EDS, EBSD)
- SEY measurement

+ Other

- RRR measurement (Supratech)
- Conductivity (Supratech)
- TEM (Jannus Platform)

State of the art (ESS)

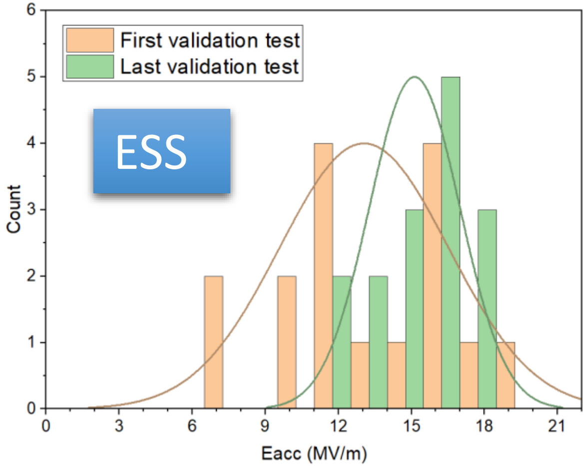
Double-Spoke
OK for CM integration



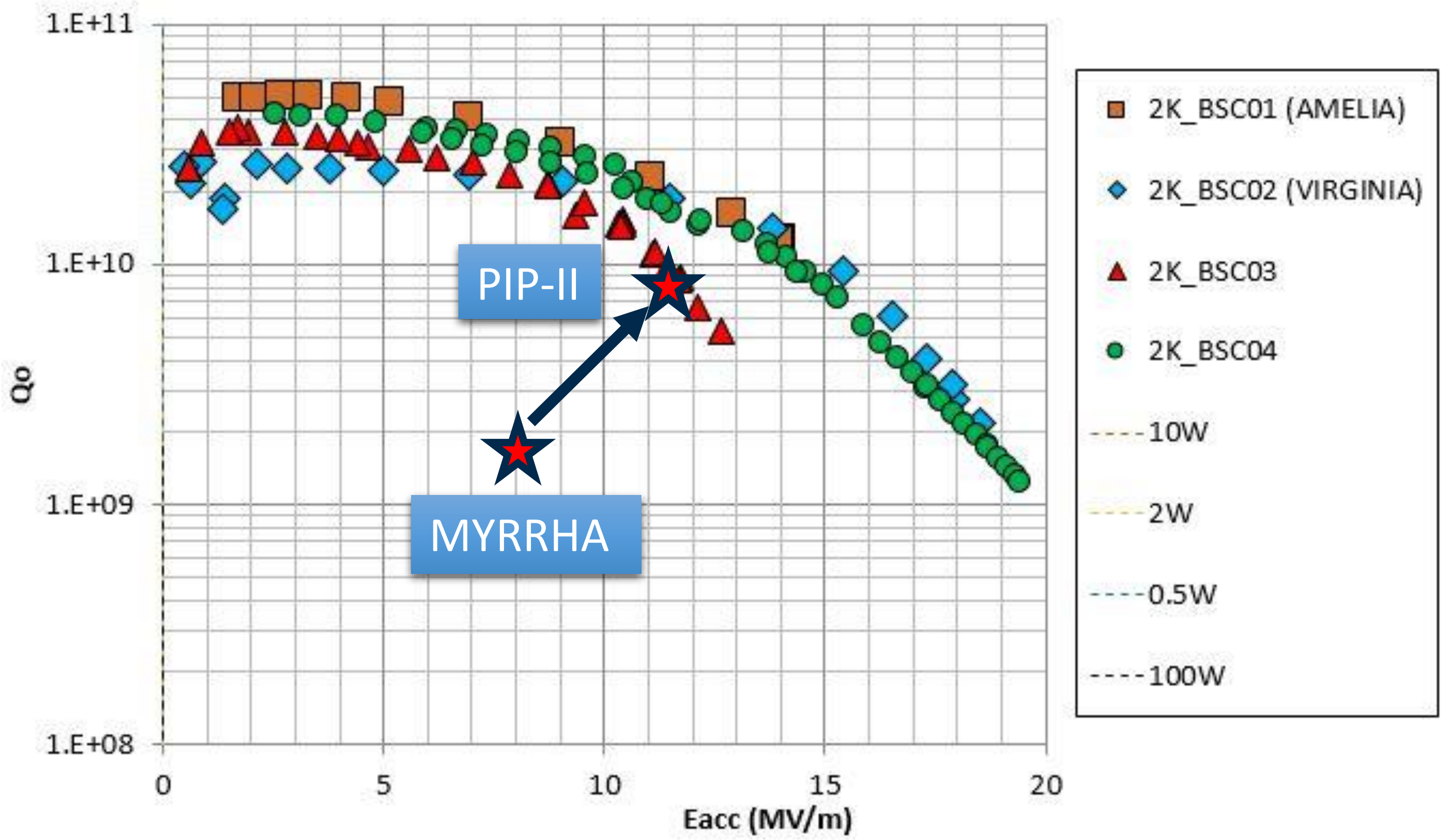
- PIP-II specifications not conservative, very ambitious specifications (Qo > 9E9 @ Eacc = 11.5 MV/m, Eacc-min = 13.7 MV/m).
- Most of validated ESS cavities meet these specifications (14/16)
- Validation yield for production ESS cavities

⇒ Reprocessing mainly due to field emission and induced quench

⇒ Reprocessing for frequency tuning not considered



State of the art (MYRRHA)



- 3 over 4 MYRRHA prototypes meet PIP-II specifications.

⇒ BSC03 surface processing not optimal

- R&D engaged during MYRRHA and to be pursued for PIP-II

⇒ Removal of flash BCP after furnace treatment (N2 Infusion-like process)

Checked
- ✓ Higher Qo
- ✓ Less steps in cavity life cycle
- ✓ Less risks

To be checked
- ✓ Frequency tuning possible after furnace treatment and without post-BCP?

⇒ Test of Nitrogen infusion/doping low frequency cavities (F<1.3 GHz)

Done
- ✓ Unsuccessful 1st test on 1.3 GHz elliptical cavity (IRFU)
- ✓ Furnace upgraded at IJCLab (N2 injection line)

To be done
- ✓ Qualify process on 1.3 GHz elliptical cavity
- ✓ Test on a MYRRHA cavity (352 MHz, 726 MHz and 1.3 GHz)

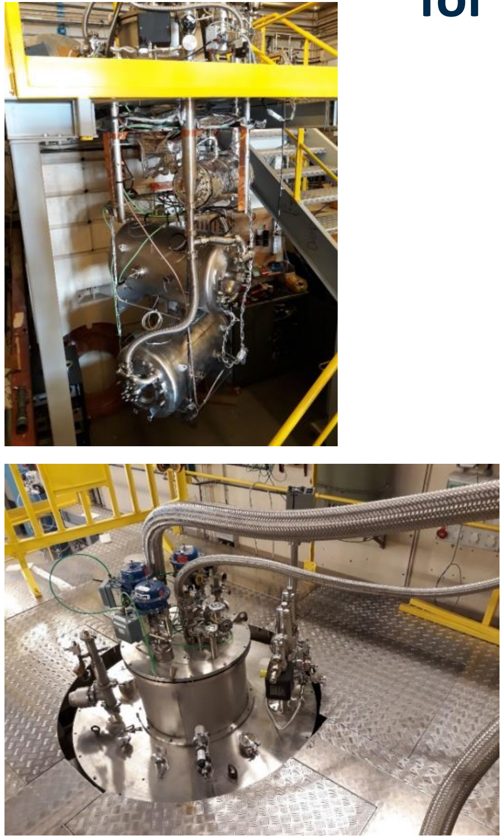
What kind of R&D and upgrades are integrated and necessary for PIP-II ?

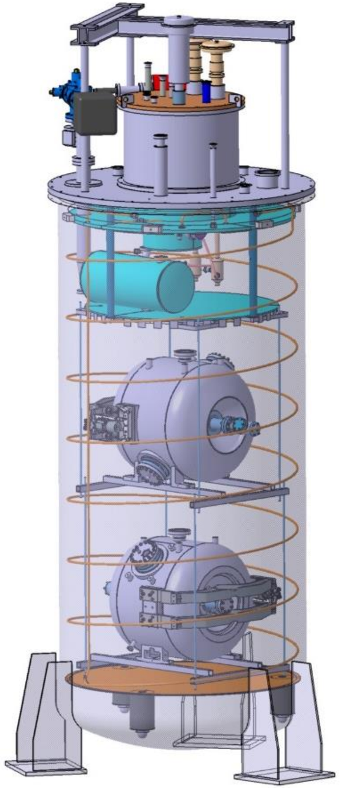
	CAVITY	COUPLER	TUNER
Prototyping	**Optimization of BCP process (rotational)** - Improve surface state - Lower surface contamination - Improve homogeneity of material removal	**Mitigation of multipacting** - Qualify efficiency of TiN coating during power conditionning (2 prototypes with TiN coating and 2 without)	**Optimization of switch limit system** - Improve robustness - Use standard components
	Removal of flash BCP after furnace treatment - Improve Qo (doping effect) - Simplify cavity life cycle - Mitigate of risks	**Necessity of power conditionning ?** - Study benefit of conditionning with / without bias - Simulate the loss of bias during operation	**Aging test at Nitrogen temperature** - Simulate several years of operation - Qualify robustness of full system - Identify weak points and upgrade
	Optimization of magnetic shielding in cryomodule - Measure magnetic sensitivity of cavity - Evaluate impact of cooling conditions and magnetic hygiene		
	Technology transfer of surface processing to industry - Work with companies and check compatibility of their facilities - Perform surface treatment at companies (BCP, furnace, …)		
Production	**Upgrade of Supratech infrastructure** - Improve reliability with new cryostat - Improve availability with upgraded helium supply chain	**Ponctual support (expertise) to FNAL team**	
	Statistics - Analyze impact of surface processing on performances - Lessons learned/best practice - Build a model and address loss mechanisms		

PROTOTYPING PHASE (2020 – 2022)

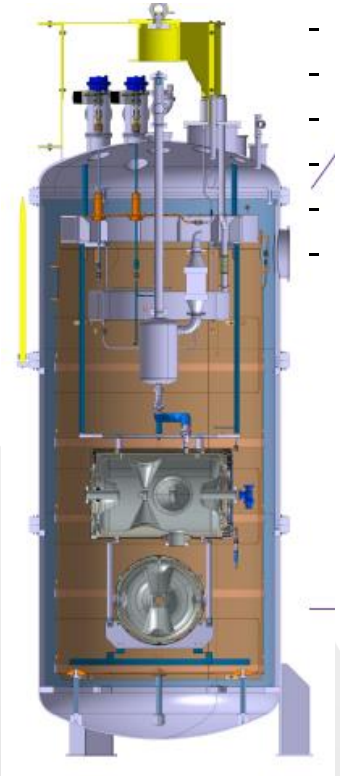
PRODUCTION PHASE (2024 – 2026)

CV800 : In operation but not optimal for production

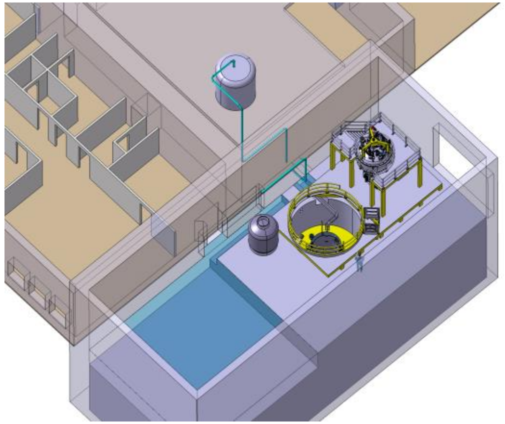




CV1250 : Existing but not operational



- Drill pit
- Equip with platform and shields
- Cryogenic distribution
- C&C (PLC)
- RF system
- Vacuum systems



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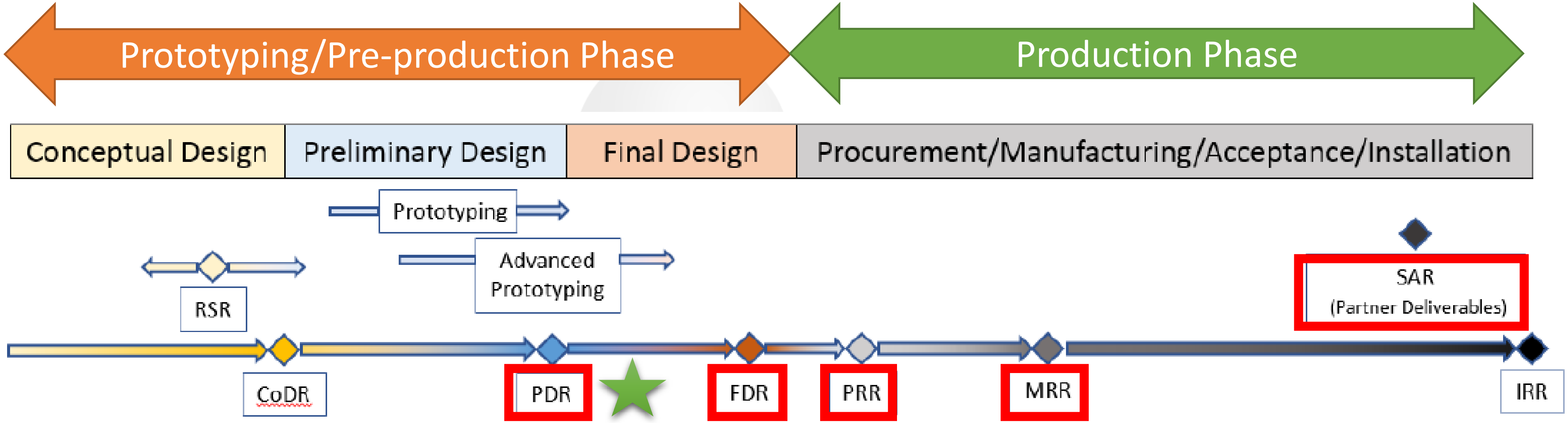
Project Management Technical Review Plan



Prototyping/Pre-production Phase

Production Phase

Conceptual Design | Preliminary Design | Final Design | Procurement/Manufacturing/Acceptance/Installation

Prototyping

Advanced Prototyping

RSR

CoDR

PDR

FDR

PRR

MRR

SAR
(Partner Deliverables)

IRR

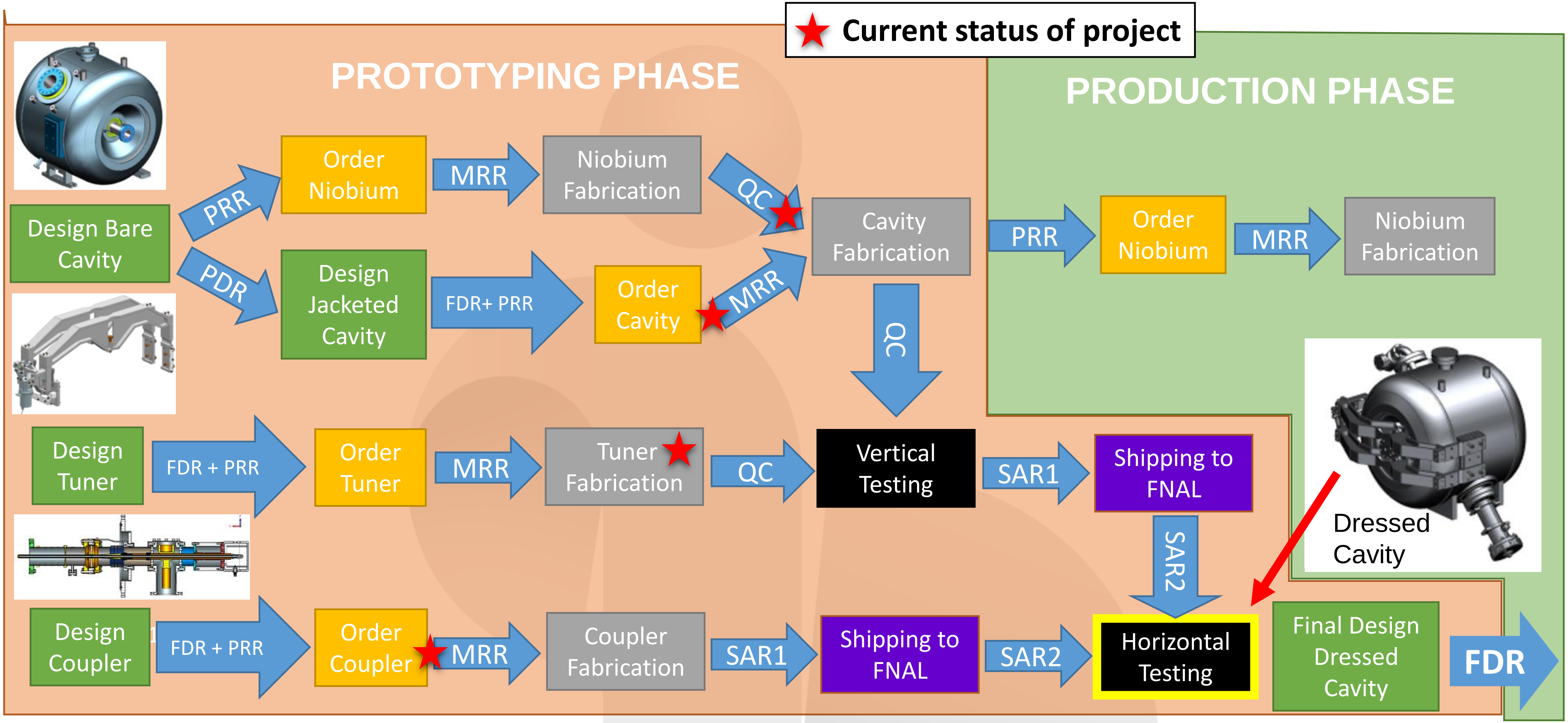
- All reviews are common FNAL/IJCLab but driven by FNAL
- FDR and PRR for prototype components (cavity, coupler and tuner) are closed
- MRR to be done for cavity and coupler
- FDR for production components will be common for cavity, coupler and tuner, will happen after horizontal test and will close prototyping phase.
- IJCLab will support FNAL for PRR and MRR for production phase
- SAR1 defined as System Acceptance Review at IJCLab
- SAR2 defined as System Acceptance Review at FNAL

◇ Review Milestone

RSR: Requirements and Specification Review
CoDR: Conceptual Design Review
PDR: Preliminary Design Review
FDR: Final Design Review
PRR: Procurement Readiness Review
MRR: Manufacturing Readiness Review
SAR: System Acceptance Review (Partner deliverables)
IRR: Installation Readiness Review

Project Management

Technical Review Plan



★ Current status of project

PROTOTYPING PHASE

Design Bare Cavity → PRR → Order Niobium → MRR → Niobium Fabrication → QC ★ → Cavity Fabrication

Design Bare Cavity → PDR → Design Jacketed Cavity → FDR+ PRR → Order Cavity ★ → MRR → Cavity Fabrication

Cavity Fabrication → QC → Vertical Testing

Design Tuner → FDR + PRR → Order Tuner → MRR → Tuner Fabrication ★ → QC → Vertical Testing

Vertical Testing → SAR1 → Shipping to FNAL → SAR2 → Horizontal Testing

Design Coupler → FDR + PRR → Order Coupler ★ → MRR → Coupler Fabrication → SAR1 → Shipping to FNAL → SAR2 → Horizontal Testing

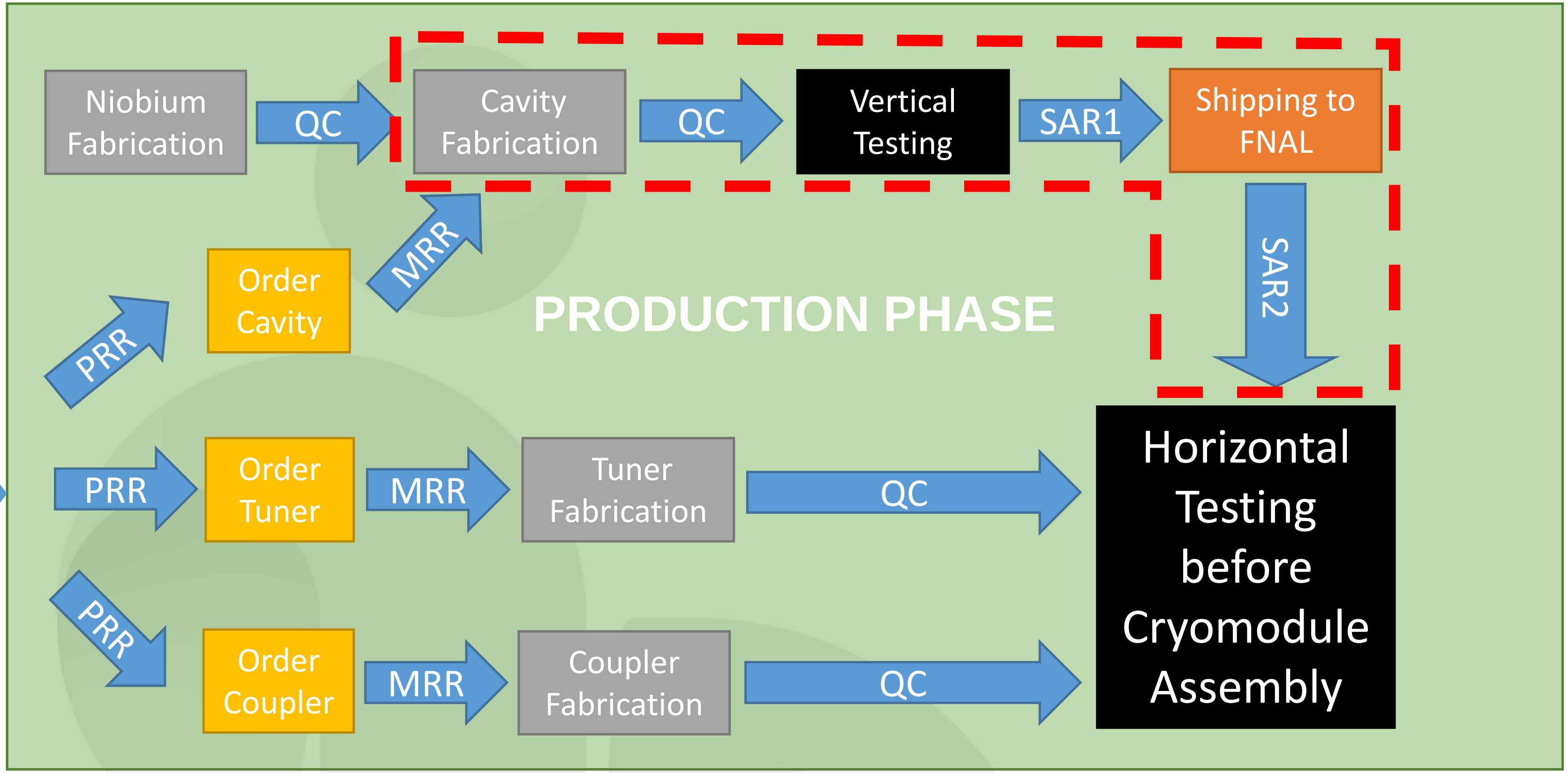
Dressed Cavity

Horizontal Testing → Final Design Dressed Cavity → FDR

PRODUCTION PHASE

PRR → Order Niobium → MRR → Niobium Fabrication

Project Management Technical Review Plan



FDR

PRODUCTION PHASE

Niobium Fabrication → QC → Cavity Fabrication → QC → Vertical Testing → SAR1 → Shipping to FNAL → SAR2 → Horizontal Testing before Cryomodule Assembly

PRR → Order Cavity → MRR → Cavity Fabrication

PRR → Order Tuner → MRR → Tuner Fabrication → QC → Horizontal Testing before Cryomodule Assembly

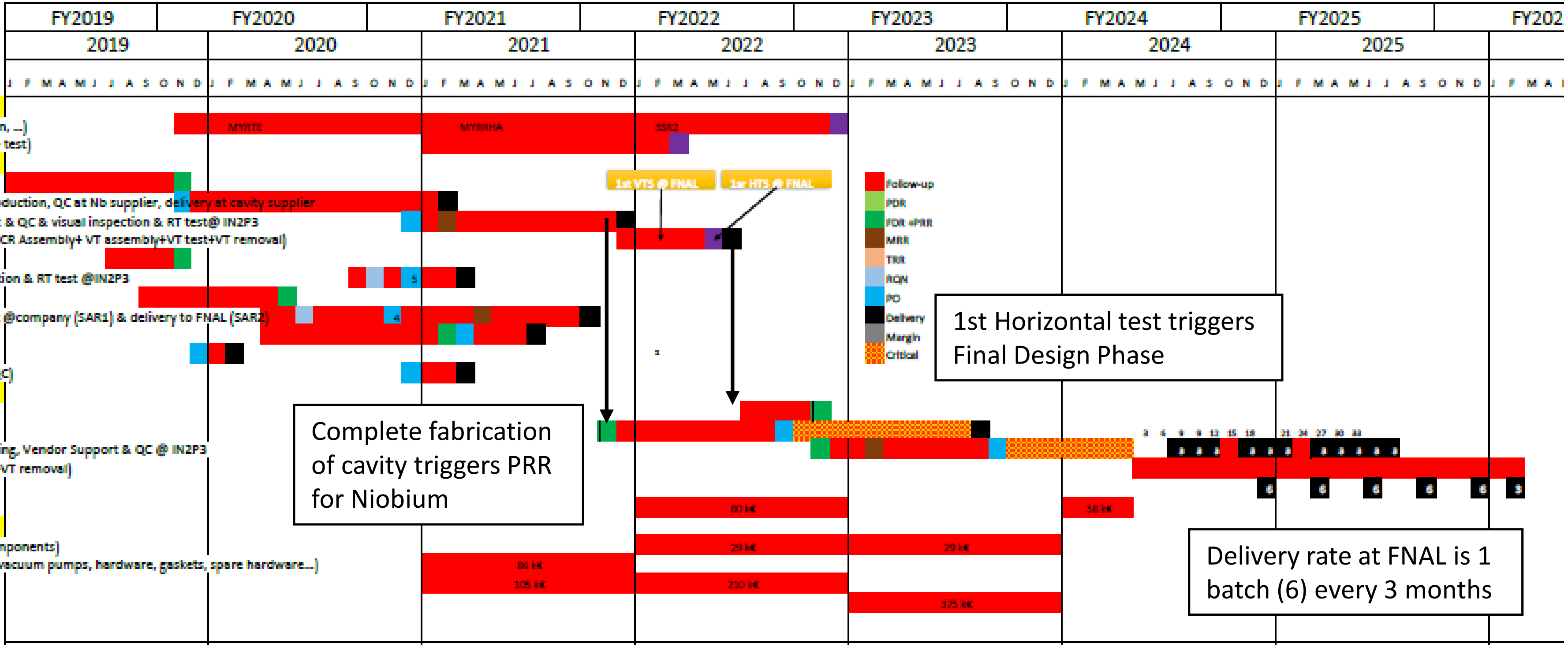
PRR → Order Coupler → MRR → Coupler Fabrication → QC → Horizontal Testing before Cryomodule Assembly

⬚ IN2P3 official contribution as described in PPD Part 2

IN2P3 could provide support on all activities (expertise)

Project Management Schedule

IN-Kind IN2P3 contribution



- 🟥 Follow-up
- 🟩 PDR
- 🟩 FDR +PRR
- 🟫 MRR
- 🟧 TRR
- 🟦 RQN
- 🟦 PO
- ⬛ Delivery
- ⬜ Margin
- ▨ Critical

SSR2 - R&D
SSR2 - Jacketed Cavities - Qo improvement tests (N2 doping/infusion, ...)
SSR2 - Jacketed Cavities - Tuner aging test (mechanical adaptation + test)
SSR2 - Prototype - CM0
SSR2 - Jacketed Cavities Cavities - Design
SSR2 - Jacketed Cavities - Nb Procurement by FNAL, Nb material production, QC at Nb supplier, delivery at cavity supplier
SSR2 - Jacketed Cavities - Jacketed Cav production, Vendor Support & QC & visual inspection & RT test@ IN2P3
SSR2 - Jacketed Cavities - Processing (BCP+HPR+Furnace+BCP+HPR+CR Assembly+ VT assembly+VT test+VT removal)
SSR2 - Tuners - Design
SSR2 - Tuners - Procurement, Vendor Support & QC & visual inspection & RT test @IN2P3
SSR2 - Power Coupler - Design
SSR2 - Power Coupler - Procurement, Vendor Support & QC RT test @company (SAR1) & delivery to FNAL (SAR2)
SSR2 - tooling (cavity support in clean room, etching lab and cart)
SSR2 - Valves (Procurement & QC)
SSR2 - RF feedthrough, blank flanges, adaptators (Procurement & QC)
SSR2 - Production - CM1-7
SSR2 - Dressed Cavities - Final Design
SSR2 - Jacketed Cavities - Nb Procurement, fabrication
SSR2 - Jacketed Cavities - Jacketed Cav Production+ surface processing, Vendor Support & QC @ IN2P3
SSR2 - Jacketed Cavities - Cold Tests @IN2P3 (VT assembly+VT test+VT removal)
SSR2 - Transport to Fermilab (cavity & tuner)
SSR2 - Procurement of tooling, RF feedthrough, valves, ...
SSR2 - Infrastructures for cavities
SSR2 - RF components for vertical test (LLRF, amplifier, spare RF components)
SSR2 - Vacuum components for cavity processing and vertical test (vacuum pumps, hardware, gaskets, spare hardware...)
SSR2 - Cryogenic distribution
SSR2 - CV1250 plateform and shielding

1st Horizontal test triggers Final Design Phase

Complete fabrication of cavity triggers PRR for Niobium

Delivery rate at FNAL is 1 batch (6) every 3 months

Completion of CV1250 end of 2023

Project Management Communication Plan

1. Between FNAL and IJCLab

- regular (almost weekly during very active period) technical meetings between Fermilab and IJCLab.
- Bi-weekly meeting (Technical coordinators of IJCLab and FNAL) : Status and Urgent Matters
- monthly “All partners” meeting involving Fermilab, DAE and IJCLab to exchange on technical advances specifically on Spoke Cryomodules (SSR1 and SSR2)
- monthly reporting including delivery forecast, achievements of the month, near term milestones, issues and possible recovery actions and priorities for next reporting period
- trimestrial coordination meeting named P2PEB (PIP-II Project Executive Board) involving all partners of the collaboration and serving as a forum to exchange on project updates (technical advances, project management, …) and as an international configuration change board.
- yearly technical workshop aiming at exchanging between all partner’s experiences and lessons learned on specific topics decided by technical coordinators and a scientific committee.

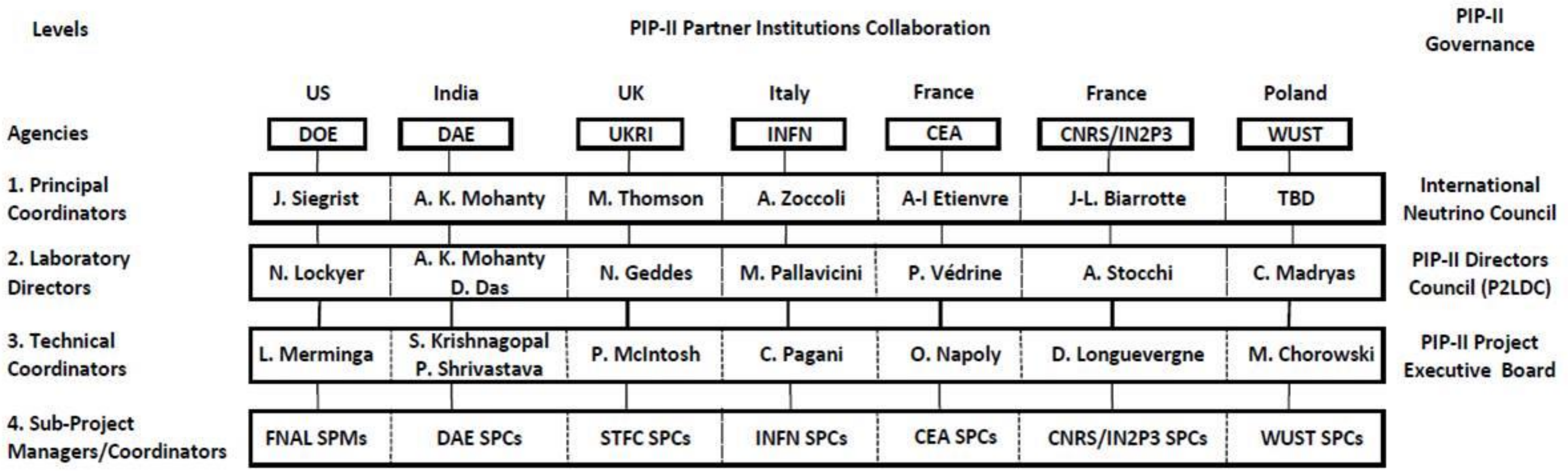
2. Between IN2P3 and IJCLab

- Yearly review by IN2P3 direction (Entretien Annuel Projet) of project status, encountered difficulties, project forecast of following years.
- Communication on demand

3. Within IJCLab

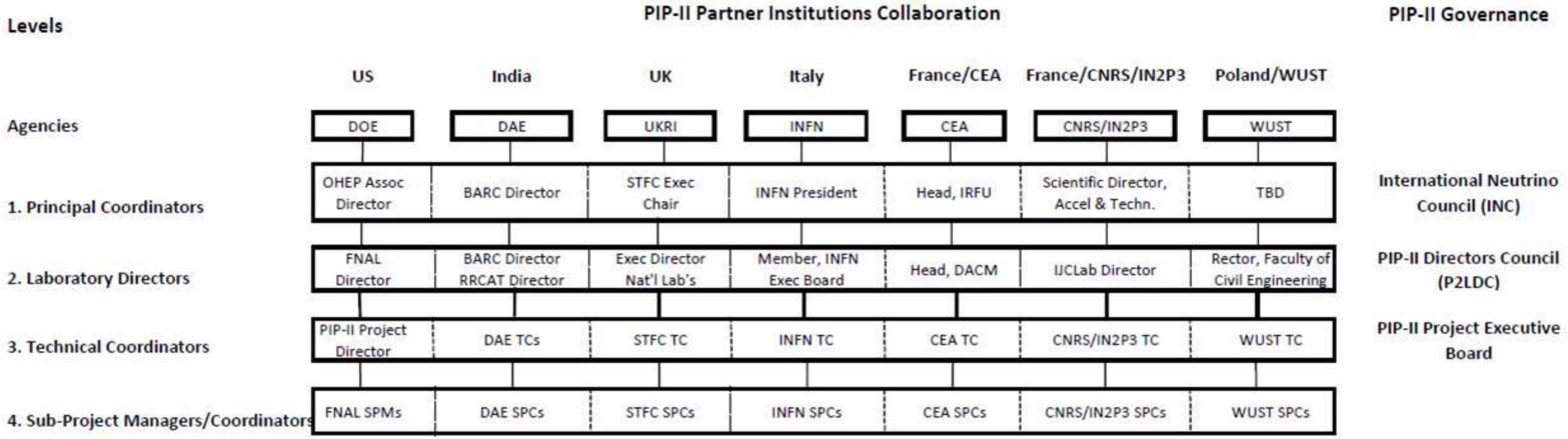
- Weekly meeting with all work-package leaders: check status, actions, risks, schedule
- Yearly review by CEMAP : inform IJCLab direction about project status, difficulties, …

Project Management International Organization



PIP-II Partner Institutions Collaboration

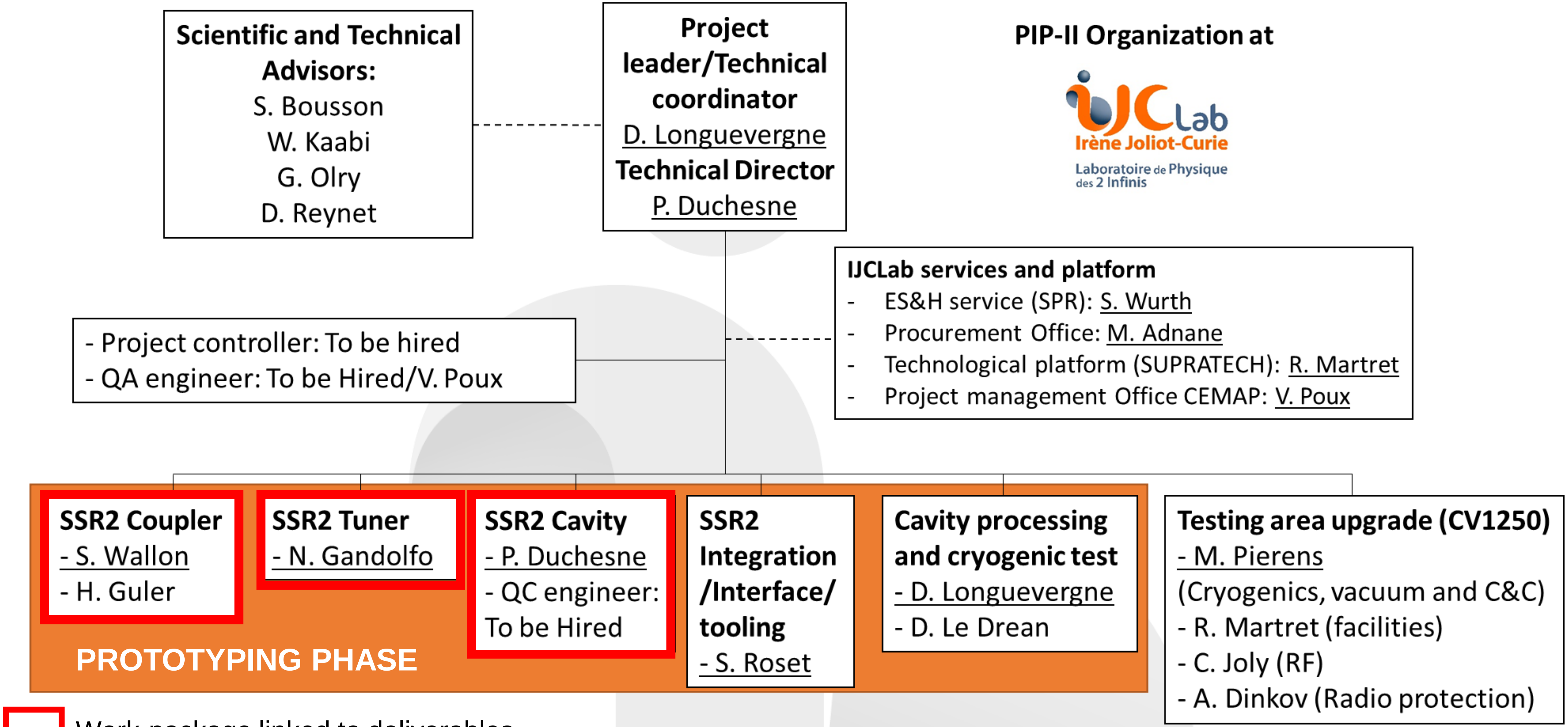
Levels	US	India	UK	Italy	France	France	Poland	PIP-II Governance
Agencies	DOE	DAE	UKRI	INFN	CEA	CNRS/IN2P3	WUST	
1. Principal Coordinators	J. Siegrist	A. K. Mohanty	M. Thomson	A. Zoccoli	A-I Etienvre	J-L. Biarrotte	TBD	International Neutrino Council
2. Laboratory Directors	N. Lockyer	A. K. Mohanty D. Das	N. Geddes	M. Pallavicini	P. Védrine	A. Stocchi	C. Madryas	PIP-II Directors Council (P2LDC)
3. Technical Coordinators	L. Merminga	S. Krishnagopal P. Shrivastava	P. McIntosh	C. Pagani	O. Napoly	D. Longuevergne	M. Chorowski	PIP-II Project Executive Board
4. Sub-Project Managers/Coordinators	FNAL SPMs	DAE SPCs	STFC SPCs	INFN SPCs	CEA SPCs	CNRS/IN2P3 SPCs	WUST SPCs	



PIP-II Partner Institutions Collaboration

Levels	US	India	UK	Italy	France/CEA	France/CNRS/IN2P3	Poland/WUST	PIP-II Governance
Agencies	DOE	DAE	UKRI	INFN	CEA	CNRS/IN2P3	WUST	
1. Principal Coordinators	OHEP Assoc Director	BARC Director	STFC Exec Chair	INFN President	Head, IRFU	Scientific Director, Accel & Techn.	TBD	International Neutrino Council (INC)
2. Laboratory Directors	FNAL Director	BARC Director RRCAT Director	Exec Director Nat'l Lab's	Member, INFN Exec Board	Head, DACM	IJCLab Director	Rector, Faculty of Civil Engineering	PIP-II Directors Council (P2LDC)
3. Technical Coordinators	PIP-II Project Director	DAE TCs	STFC TC	INFN TC	CEA TC	CNRS/IN2P3 TC	WUST TC	PIP-II Project Executive Board
4. Sub-Project Managers/Coordinators	FNAL SPMs	DAE SPCs	STFC SPCs	INFN SPCs	CEA SPCs	CNRS/IN2P3 SPCs	WUST SPCs	

Project Management Local Organization and human ressources



Scientific and Technical Advisors:
S. Bousson
W. Kaabi
G. Olry
D. Reynet

Project leader/Technical coordinator
D. Longuevergne
Technical Director
P. Duchesne

PIP-II Organization at

Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

IJCLab services and platform
- ES&H service (SPR): S. Wurth
- Procurement Office: M. Adnane
- Technological platform (SUPRATECH): R. Martret
- Project management Office CEMAP: V. Poux

- Project controller: To be hired
- QA engineer: To be Hired/V. Poux

SSR2 Coupler
- S. Wallon
- H. Guler

SSR2 Tuner
- N. Gandolfo

SSR2 Cavity
- P. Duchesne
- QC engineer: To be Hired

SSR2 Integration /Interface/ tooling
- S. Roset

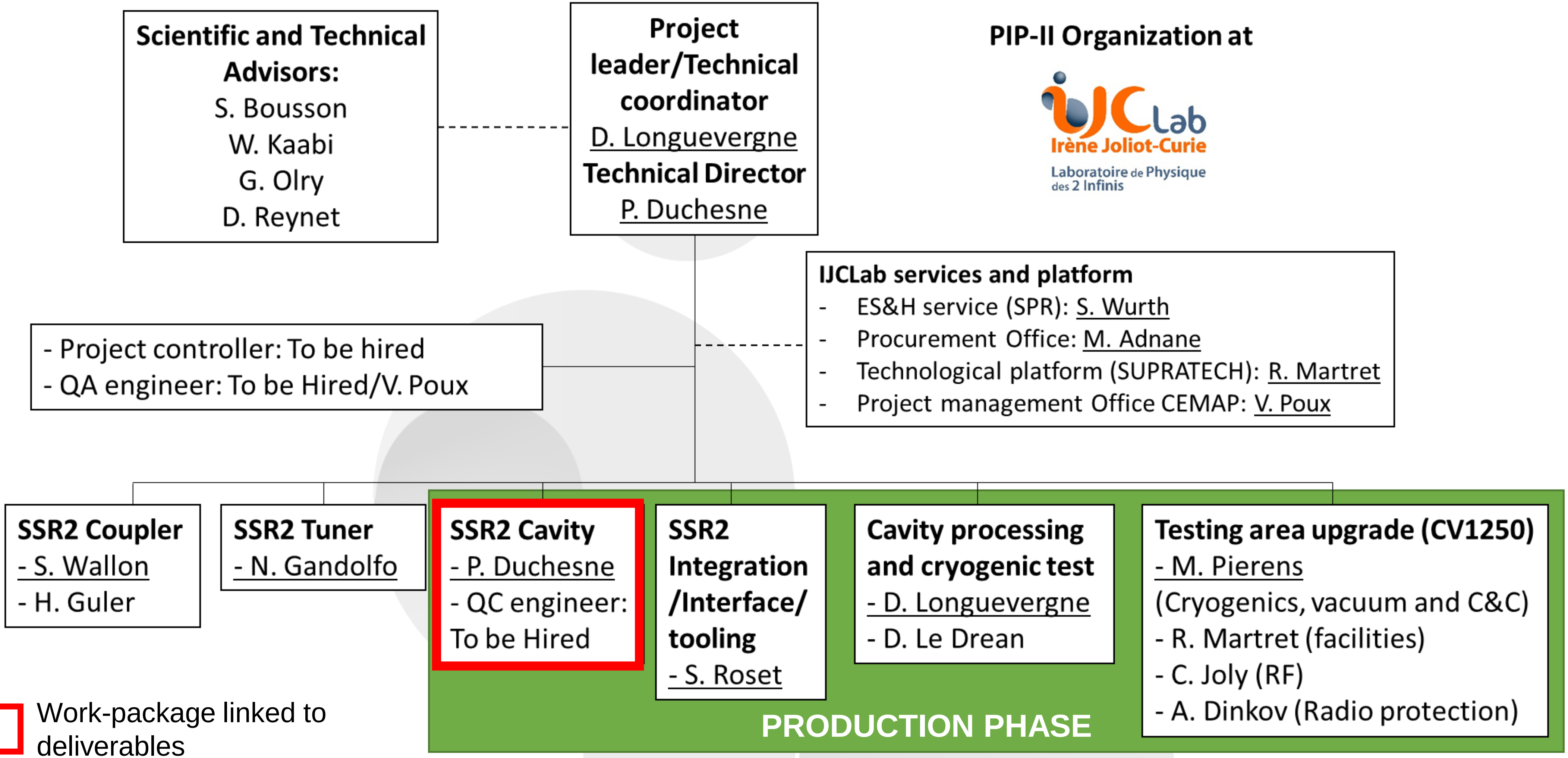
Cavity processing and cryogenic test
- D. Longuevergne
- D. Le Drean

PROTOTYPING PHASE

Testing area upgrade (CV1250)
- M. Pierens
(Cryogenics, vacuum and C&C)
- R. Martret (facilities)
- C. Joly (RF)
- A. Dinkov (Radio protection)

🟥 Work-package linked to deliverables

Project Management Local Organization and human ressources



Scientific and Technical Advisors:
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Project leader/Technical coordinator
D. Longuevergne
Technical Director
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PIP-II Organization at
IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

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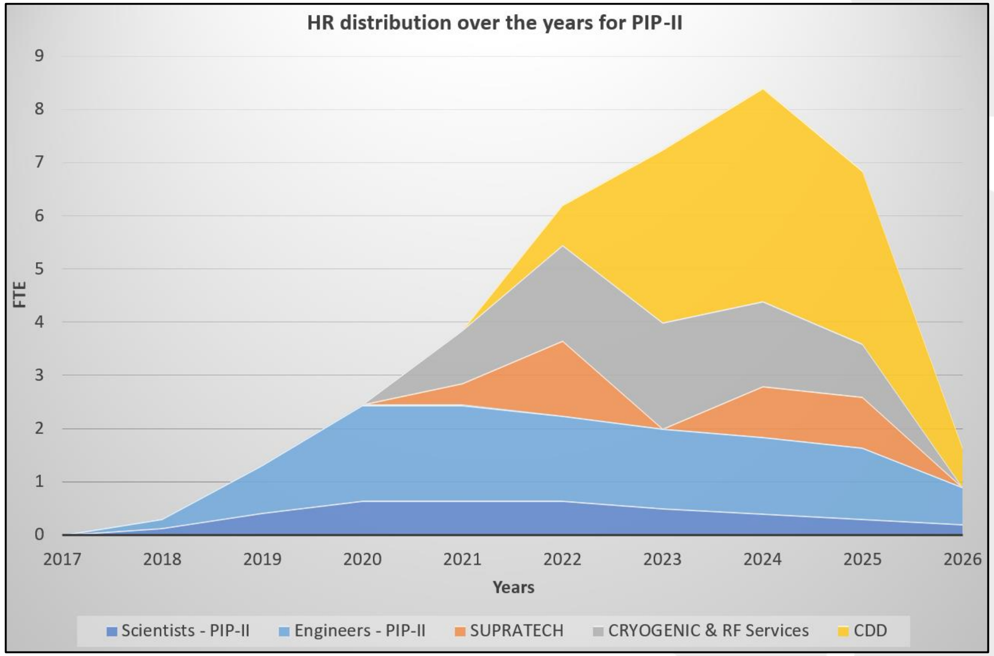
Testing area upgrade (CV1250)
- M. Pierens (Cryogenics, vacuum and C&C)
- R. Martret (facilities)
- C. Joly (RF)
- A. Dinkov (Radio protection)

PRODUCTION PHASE

☐ Work-package linked to deliverables

Project Management Local Organization and human ressources

	FTE	HR COST
TOTAL (Permanents + CDD)	**38.3**	**2 950 842.00 €**
TOTAL (Permanents) hors CDD)	**26.3**	**2 044 830.00 €**

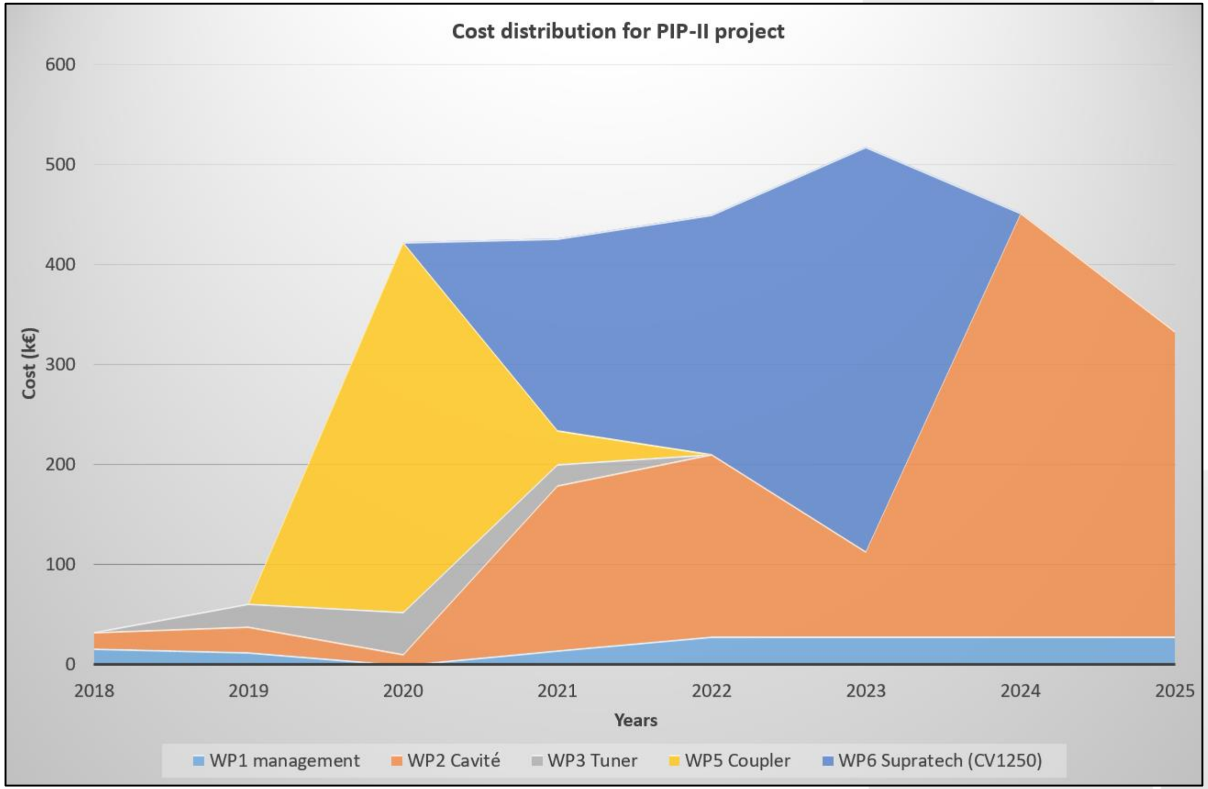


Nom des personnes	Statut	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total (FTE)
Scientists - PIP-II		**0%**	**14%**	**42%**	**65%**	**65%**	**65%**	**50%**	**40%**	**30%**	**20%**	**3.91**
D. Longuevergne	Responsable scientifique		14%	35%	50%	50%	50%	40%	30%	20%	10%	2.99
H. Guler	Expertise conditionnement coupleurs			7%	10%	10%	10%	5%	5%	5%	5%	0.57
W. Kaabi	Conseil coupleur				5%	5%	5%	5%	5%	5%	5%	0.35
TOTAL (FTE)		**0.00**	**0.14**	**0.42**	**0.65**	**0.65**	**0.65**	**0.50**	**0.40**	**0.30**	**0.20**	**3.91**

Nom des personnes	Statut	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total (FTE)
Engineers - PIP-II		**0%**	**17%**	**90%**	**180%**	**180%**	**160%**	**150%**	**145%**	**135%**	**70%**	**11.27**
P. Duchesne	Responsable technique + lot cavité		12%	35%	50%	70%	70%	85%	90%	90%	50%	5.52
N. Gandolfo	Responsable Lot Tuner			15%	35%	35%	35%	15%	10%	10%	5%	1.60
S. Wallon	Responsable Lot Coupleur			15%	25%	25%	25%	5%	5%	5%	5%	1.10
D. Reynet	Ingénieur Système		5%	10%	10%	10%	10%	10%	10%	10%	5%	0.80
V. Poux	Responsable Qualité IJCLab			10%	10%	10%	10%	10%	10%	10%	5%	0.75
S. Roset	Conception outillage/mécanique			5%	50%	30%	10%	25%	20%	10%		1.50
SUPRATECH		**0%**	**0%**	**0%**	**0%**	**40%**	**140%**	**0%**	**95%**	**95%**	**0%**	**3.70**
T. Pépin-Donat	Opérateur four et planning SUPRATECH					5%	25%		15%	15%		0.60
L. Renard	Opérateur Salle blanche SUPRATECH					10%	30%		25%	25%		0.90
N. Bippus	Opératrice Salle Blanche SUPRATECH					10%	30%		25%	25%		0.90
F. Rabehasy	Opérateur Salle Chimie SUPRATECH					5%	25%		15%	15%		0.60
L. My Vogt	Opérateur Salle Chimie SUPRATECH					10%	30%		15%	15%		0.70
CRYOGENIC & RF Services		**0%**	**0%**	**0%**	**0%**	**100%**	**180%**	**200%**	**160%**	**100%**	**0%**	**7.40**
F. Gallet	Opérateur Liquéfacteur + Upgrade CV1250					10%	20%	20%	20%	20%		0.90
M. Pierens	Opérateur Liquéfacteur + Upgrade CV1250					25%	40%	50%	40%	5%		1.60
F. Chatelet	Gestion cryo Cryostat					10%	20%	20%	20%	20%		0.90
G. Mavilla	Instrumentation + gestion cryo Cryostat + upgrade CV1250					25%	40%	40%	40%	30%		1.75
D. Le Dréan	Opérateur RF Cryostat					10%	20%	20%	20%	20%		0.90
S. Blivet	Infrastructure upgrade CV1250					10%	20%	20%	10%			0.60
TBD	Ingénieur radio-protection						10%	10%				0.20
TBD	Ingénieur RF Upgrade CV1250					10%	10%	20%	10%	5%		0.55
CDD		**0%**	**0%**	**0%**	**0%**	**0%**	**75%**	**325%**	**400%**	**325%**	**75%**	**12.00**
TBD	Contrôleur projet						25%	100%	100%	75%		3.00
TBD	Ingénieur qualité						25%	100%	100%	75%		3.00
TBD	Instrumentation + gestion cryo Cryostat + QC						25%	100%	100%	75%		3.00
TBD	Instrumentation + test RF + QC							25%	100%	100%	75%	3.00
TOTAL (FTE)		**0.00**	**0.17**	**0.90**	**1.80**	**3.20**	**5.55**	**6.75**	**8.00**	**6.55**	**1.45**	**34.37**

Cost distribution

The project cost is estimated at 5.7 million euros including FTE (permanent and non-permanent staff). The personnel cost is about 3 million euros including 900 k€ of non-permanent staff.

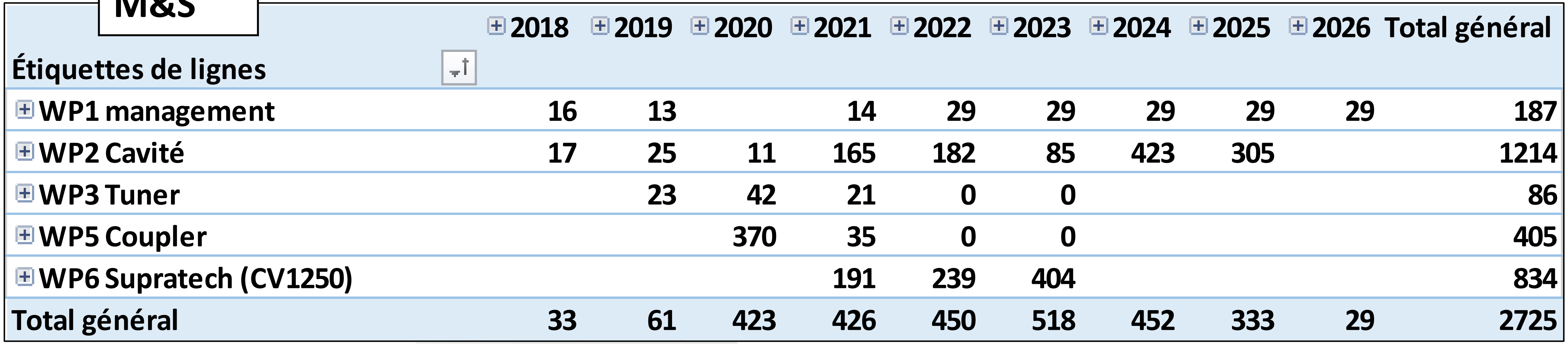


- In 2018, 2019 and 2020 : real costs (spent)
- Between 2021 and 2025 : requested budget with margin between 15% and 50% depending on risks and confidence of cost estimation (Helium, infrastructures).
- Distribution optimized to smooth yearly budget
- Full cost and distribution to be revised each year before IN2P3 project review (EAP)
- For 2021, budget allocated is 390 k€

Project Management

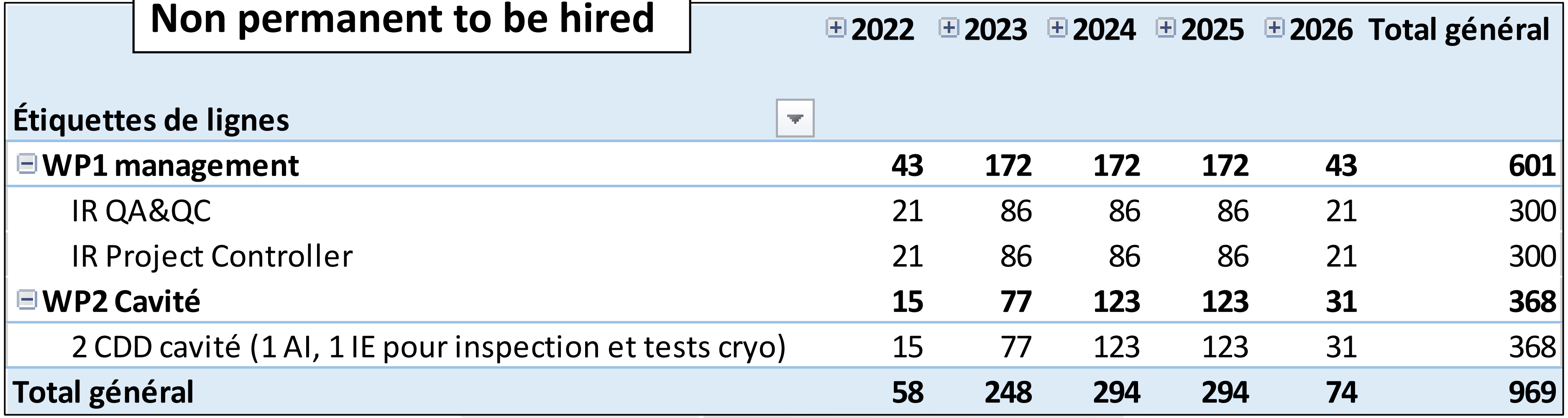
Cost distribution

M&S



Étiquettes de lignes	⊞ 2018	⊞ 2019	⊞ 2020	⊞ 2021	⊞ 2022	⊞ 2023	⊞ 2024	⊞ 2025	⊞ 2026	Total général
⊞ **WP1 management**	16	13		14	29	29	29	29	29	187
⊞ **WP2 Cavité**	17	25	11	165	182	85	423	305		1214
⊞ **WP3 Tuner**		23	42	21	0	0				86
⊞ **WP5 Coupler**			370	35	0	0				405
⊞ **WP6 Supratech (CV1250)**				191	239	404				834
Total général	33	61	423	426	450	518	452	333	29	2725

Non permanent to be hired



Étiquettes de lignes	⊞ 2022	⊞ 2023	⊞ 2024	⊞ 2025	⊞ 2026	Total général
⊟ **WP1 management**	43	172	172	172	43	601
IR QA&QC	21	86	86	86	21	300
IR Project Controller	21	86	86	86	21	300
⊟ **WP2 Cavité**	15	77	123	123	31	368
2 CDD cavité (1 AI, 1 IE pour inspection et tests cryo)	15	77	123	123	31	368
Total général	58	248	294	294	74	969

Project Management

Risk analysis and mitigation plan

STATUS OF RISK ANALYSIS:

On-going

- Step 1: Risk identification, integration in the project risk register
- Step 2: Risk assessment
- Step 3: Definition of actions for risk mitigation
- Step 4: Follow-up of preventive and corrective actions and risk control
- Step 5: Improve experience feedback (lessons learned)

Risks level definition

	Low Impact	Medium Impact	High Impact
Technical Impact	Somewhat sub-standard	Significantly sub-standard	Extremely sub-standard or KPP in jeopardy
	Can be repaired by the team	Can be repaired within IJCLab	Can be repaired only with external parties
Cost Impact	< 1% of project cost	1% - 5% of project cost	> 5% of project cost
	< 25 k€	25k€ - 100k€	> 100k€
Schedule Impact	< 2% of project duration	2 - 5 % of project duration	> 5 % of project duration
	<1 month	1 - 3 months	> 3 months

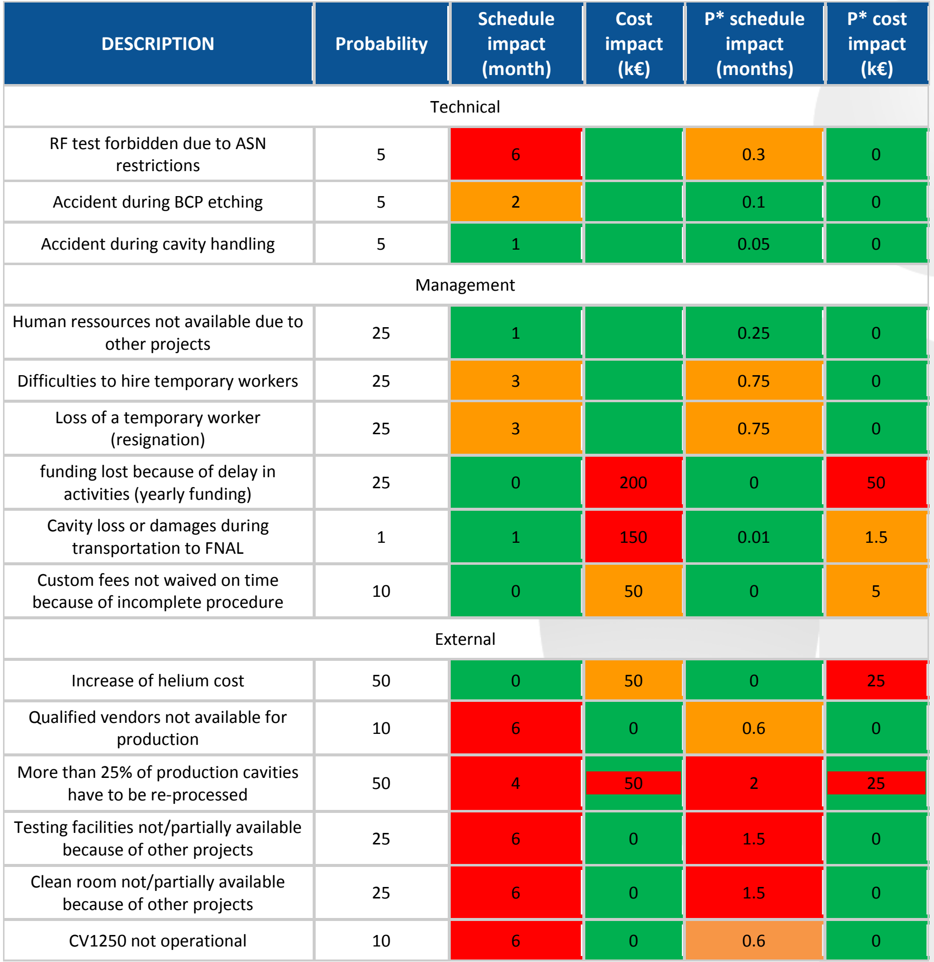
Risk criticity

	Low Impact	Medium Impact	High Impact
Very High. 64-100%	Medium	High	High
High 39-64%	Medium	High	High
Medium 21-39%	Low	Medium	High
Low 9-21%	Low	Medium	Medium
Very Low 0-9%	Low	Low	Medium

Project Management

Risk analysis and mitigation plan

Preliminary analysis (systemic)



DESCRIPTION	Probability	Schedule impact (month)	Cost impact (k€)	P* schedule impact (months)	P* cost impact (k€)
Technical					
RF test forbidden due to ASN restrictions	5	6	🟩	0.3	0
Accident during BCP etching	5	2	🟩	0.1	0
Accident during cavity handling	5	1	🟩	0.05	0
Management					
Human ressources not available due to other projects	25	1	🟩	0.25	0
Difficulties to hire temporary workers	25	3	🟩	0.75	0
Loss of a temporary worker (resignation)	25	3	🟩	0.75	0
funding lost because of delay in activities (yearly funding)	25	0	200	0	50
Cavity loss or damages during transportation to FNAL	1	1	150	0.01	1.5
Custom fees not waived on time because of incomplete procedure	10	0	50	0	5
External					
Increase of helium cost	50	0	50	0	25
Qualified vendors not available for production	10	6	0	0.6	0
More than 25% of production cavities have to be re-processed	50	4	50	2	25
Testing facilities not/partially available because of other projects	25	6	0	1.5	0
Clean room not/partially available because of other projects	25	6	0	1.5	0
CV1250 not operational	10	6	0	0.6	0

Risk evaluation

Risks	Schedule (month)	Cost (k€)
Systemic	6.41	81.5
Technical (cavity)	5.185	155.34
TOTAL	**11.6**	**237**

- Technical risks on cavity hold by FNAL.
- 3 critical risks identified :
  - Funding loss because of delays
  - Increase of helium cost
  - Re-processing rate of cavities
- Mitigation strategies:
  - Re-allocate budget within the year or anticipate expenses
  - Improvement of facilities (reduction of helium losses)
  - Coach and involve companies already in prototyping phase (under discussion with 2 companies involved in prototyping phase)

CONCLUSION (1)

- IN2P3 will contribute significantly to PIP-II project in both prototyping and production phase
  - Deliverables for prototyping phase (tuner and couplers) but not for production (since no TGIR funding).
  - Production phase consists in providing support (joint design), expertise (lessons learned) and service (cavity validation and shipping).
  - Full scope funded by IN2P3.
- Motivations are numerous:
  - Technical : Improve technical and project management skills. « Win-win » collaboration.
  - Scientific : Motivate SRF R&D pursued at IN2P3 and boost collaborations.
  - Political : Serve the international DUNE collaboration in which many French physicists involved.
- IJCLab well positionned:
  - FNAL is relying on IJCLab for validation of Spoke cavities in Europe (unique expertise and facilities).
  - Technical specifications for PIP-II SSR2 cavities are today met by most of ESS and MYRRHA cavities.
  - R&D program is defined to increase cavity validation yield and components reliability.
  - IJCLab can handle safely and successfully the cavity validation rate for production phase (~2 cavities/months) provided that current facilities are upgraded (Installation of new existing vertical cryostat CV1250).

CONCLUSION (2)

- Project management
  - Communication between FNAL and IJCLab is well established, monthly report to be started soon

Human ressources

  - PIP-II team at IJCLab is organized and sufficient to ensure completion of prototyping phase
  - Hiring of non-permanent dedicated personnels will be required for production phase. QA engineer and project controller will be required as well as 1 technical staff for cavity QC (best 1 for cavity testing for risk mitigation).

Schedule

  - FNAL and IJCLab schedules are aligned and well defined. General schedule is ambitious but most of « pressure » is hold by FNAL (procurements).
  - Schedule will tend to shift (sanitary crisis, …)

Cost

  - Total project cost estimated at 5.7 million euros for IN2P3 (3 millions for staff, 2.7 millions for M&S)
  - Cost distribution has been smoothened to fit yearly IN2P3 funding capabilities.
  - Margins (15%-50%) are included in total cost and refinement will be performed on a yearly basis.
  - Funding profile is very restrictive (expiring every year) but re-allocation or anticipation is possible.

Risks

  - Preliminary risk analysis outputs are acceptable in term of potential delays and extra cost.
  - FNAL is holding most of technical risks (procurement).

- IJCLab team highly motivated and already highly involved in prototyping and R&D

CONCLUSION SWOT

Strengths:

- Team is well experienced in series production (ESS) of Spoke resonators
- Current facilities are fully compatible with PIP-II Spoke resonators
- Technology transfer (surface processing of Spoke resonator and power coupler) to industries with which a lot of projects/interactions are already going on

Weaknesses:

- Some facilities need to be upgraded (vertical cryostat) to handle efficiently the series production (risk mitigation).
- IN2P3 funding is tight and might have difficulties to ensure complete funding (non-permanent human ressources + facilities upgrade)
- Profil of IN2P3 funding. Yearly funding will add uncertainties and difficulties to manage the project
- Too many key permanent staff: today human resources is sufficient but what about tomorrow in case of resignation?

Opportunities:

- Collaborate with Fermilab, one of the most experienced accelerator lab of the world, not only on PIP-II but also on R&D topics like Nitrogen doping/infusion.
- Collaborate with a lab very advanced in project managements methods
- Benefit from experience and lessons learned of the full collaboration
- Work on a world-class project with very high visibility
- Improve IJCLab's facilities for PIP-II and future projects.

Threats:

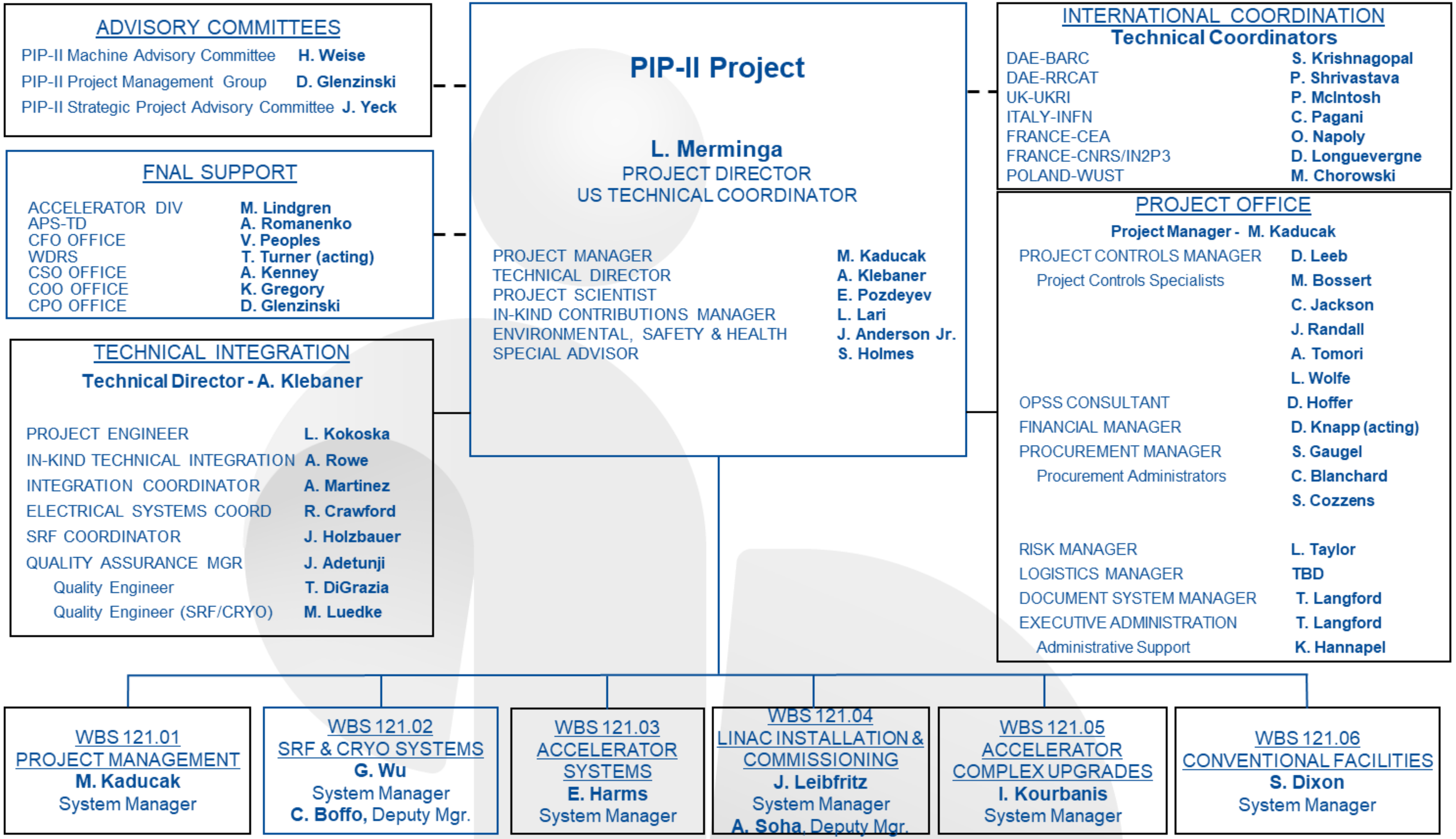
- On-going project ESS is delayed and could impact significantly PIP-II prototyping phase schedule
- Potential new projects (MYRRHA series production) could happen in the same period.
- Delays or extra cost due to export/import difficulties (VAT exemption)
- See risk analysis

BACK-UP SLIDES

Contexte général

- **Avancées projets :**
  - **PIP-II GROUNDBREAKING le 15 mars 2019**
  - **6 réunions de coordinations (P2PEB meeting : PIP-II Project Executive Board)**
  - **Revue DOE CD2 le 28 janvier 2020.**
  - **COVID-19 : retards conséquents sur le projet (CD-4 retardée de 15 mois à décembre 2028).**
  - **Eté 2020 : retour de MESRI sur financement TGIR (PIP-II -> CEA, DUNE -> CNRS).**
  - **Revue CD2 IPR le 6 octobre 2020 (revue des contributions In-Kind)**
  - **Décembre 2020 : Ajustement final de la contribution IN2P3**
- **Avancées techniques :**
  - **CAVITE SSR2 :**
    - Novembre 2019 : Commande du Niobium par FNAL chez Ningxia
    - Novembre 2019 : Revue finale cavité (FDR) à FNAL avec IJCLab
    - Mars 2020 : Publication appel d'offre cavités prototypes (FNAL + IJCLab)
    - Octobre 2020 : Livraison Niobium après validation échantillons par FNAL (RRR + méca)
    - Octobre 2020 : Commande des cavités prototypes 3 pour IJCLab + 3 FNAL (FNAL)
    - Février 2021: Revue outillage cavité pour commande (IJCLab, FNAL)
  - **TUNER SSR2 :**
    - Novembre 2019 : Revue finale Tuner (FDR)
    - Janvier 2020 : Réception des 12 actionneurs piezo.
    - Mars 2020 : Réception cartouche SSR1 pour test vieillissement dans boite à SAF.
    - En cours : CCTP en cours de finalisation
  - **COUPLEUR DE PUISSANCE SSR2 :**
    - Début 2020 : finalisation des simulations thermiques RF
    - Mai 2020 : Revue finale Coupleur (FDR)
    - Juillet 2020 : Publication appel d'offre pour 4 coupleurs prototypes (IJCLab)
    - Septembre 2020 : Réception de 2 offres.
    - Octobre 2020 : commande des 4 coupleurs prototypes (IJCLab)
    - Janvier 2021 : commande des 6 cavités prototypes (FNAL)
  - **ANALYSE DE RISQUE EN COURS**

Organization chart at FNAL



ADVISORY COMMITTEES

PIP-II Machine Advisory Committee	**H. Weise**
PIP-II Project Management Group	**D. Glenzinski**
PIP-II Strategic Project Advisory Committee	**J. Yeck**

FNAL SUPPORT

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WDRS	**T. Turner (acting)**
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COO OFFICE	**K. Gregory**
CPO OFFICE	**D. Glenzinski**

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PROJECT ENGINEER	**L. Kokoska**
IN-KIND TECHNICAL INTEGRATION	**A. Rowe**
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ELECTRICAL SYSTEMS COORD	**R. Crawford**
SRF COORDINATOR	**J. Holzbauer**
QUALITY ASSURANCE MGR	**J. Adetunji**
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PROJECT DIRECTOR
US TECHNICAL COORDINATOR

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TECHNICAL DIRECTOR	**A. Klebaner**
PROJECT SCIENTIST	**E. Pozdeyev**
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UK-UKRI	**P. McIntosh**
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Procurement Administrators	**C. Blanchard** **S. Cozzens**
RISK MANAGER	**L. Taylor**
LOGISTICS MANAGER	**TBD**
DOCUMENT SYSTEM MANAGER	**T. Langford**
EXECUTIVE ADMINISTRATION	**T. Langford**
Administrative Support	**K. Hannapel**

WBS 121.01
PROJECT MANAGEMENT
M. Kaducak
System Manager

WBS 121.02
SRF & CRYO SYSTEMS
G. Wu
System Manager
C. Boffo, Deputy Mgr.

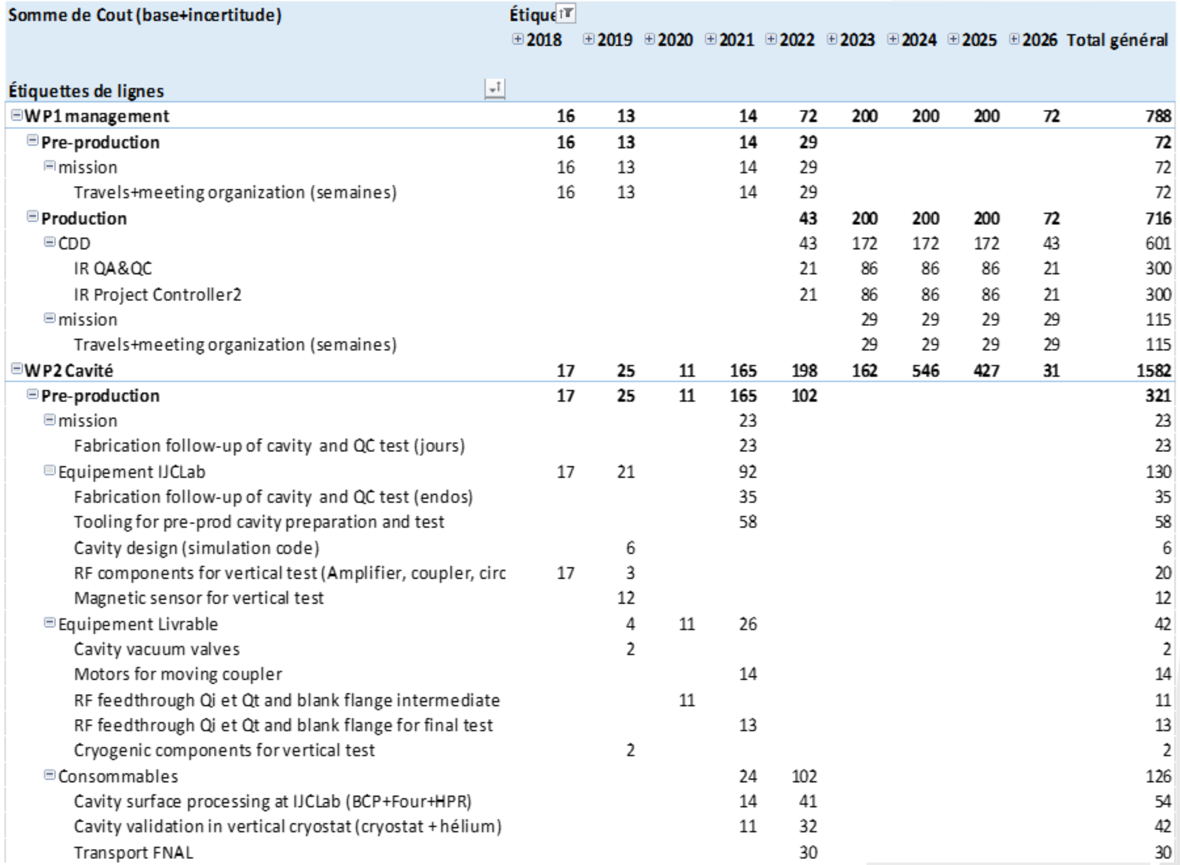
WBS 121.03
ACCELERATOR SYSTEMS
E. Harms
System Manager

WBS 121.04
LINAC INSTALLATION & COMMISSIONING
J. Leibfritz
System Manager
A. Soha, Deputy Mgr.

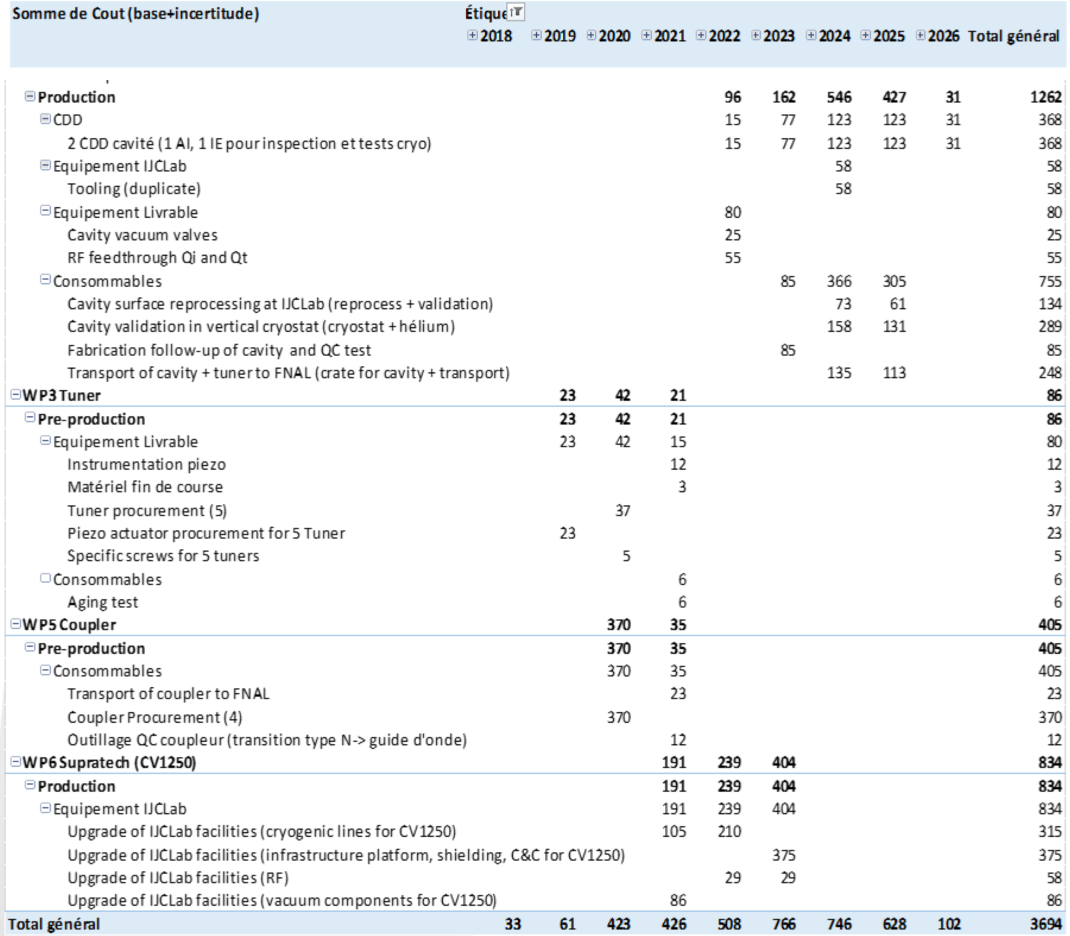
WBS 121.05
ACCELERATOR COMPLEX UPGRADES
I. Kourbanis
System Manager

WBS 121.06
CONVENTIONAL FACILITIES
S. Dixon
System Manager

Detailed cost distribution



Somme de Cout (base+incertitude)	Étique									
	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total général
Étiquettes de lignes										
WP1 management	**16**	**13**		**14**	**72**	**200**	**200**	**200**	**72**	**788**
Pre-production	**16**	**13**		**14**	**29**					**72**
mission	16	13		14	29					72
Travels+meeting organization (semaines)	16	13		14	29					72
Production					**43**	**200**	**200**	**200**	**72**	**716**
CDD					43	172	172	172	43	601
IR QA&QC					21	86	86	86	21	300
IR Project Controller2					21	86	86	86	21	300
mission						29	29	29	29	115
Travels+meeting organization (semaines)						29	29	29	29	115
WP2 Cavité	**17**	**25**	**11**	**165**	**198**	**162**	**546**	**427**	**31**	**1582**
Pre-production	**17**	**25**	**11**	**165**	**102**					**321**
mission				23						23
Fabrication follow-up of cavity and QC test (jours)				23						23
Equipement IJCLab	17	21		92						130
Fabrication follow-up of cavity and QC test (endos)				35						35
Tooling for pre-prod cavity preparation and test				58						58
Cavity design (simulation code)		6								6
RF components for vertical test (Amplifier, coupler, circ	17	3								20
Magnetic sensor for vertical test		12								12
Equipement Livrable		4	11	26						42
Cavity vacuum valves		2								2
Motors for moving coupler				14						14
RF feedthrough Qi et Qt and blank flange intermediate			11							11
RF feedthrough Qi et Qt and blank flange for final test				13						13
Cryogenic components for vertical test		2								2
Consommables				24	102					126
Cavity surface processing at IJCLab (BCP+Four+HPR)				14	41					54
Cavity validation in vertical cryostat (cryostat + hélium)				11	32					42
Transport FNAL					30					30



Somme de Cout (base+incertitude)	Étique									
	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total général
Production					**96**	**162**	**546**	**427**	**31**	**1262**
CDD					15	77	123	123	31	368
2 CDD cavité (1 AI, 1 IE pour inspection et tests cryo)					15	77	123	123	31	368
Equipement IJCLab							58			58
Tooling (duplicate)							58			58
Equipement Livrable					80					80
Cavity vacuum valves					25					25
RF feedthrough Qi and Qt					55					55
Consommables						85	366	305		755
Cavity surface reprocessing at IJCLab (reprocess + validation)							73	61		134
Cavity validation in vertical cryostat (cryostat + hélium)							158	131		289
Fabrication follow-up of cavity and QC test						85				85
Transport of cavity + tuner to FNAL (crate for cavity + transport)							135	113		248
WP3 Tuner		**23**	**42**	**21**						**86**
Pre-production		**23**	**42**	**21**						**86**
Equipement Livrable		23	42	15						80
Instrumentation piezo				12						12
Matériel fin de course				3						3
Tuner procurement (5)			37							37
Piezo actuator procurement for 5 Tuner		23								23
Specific screws for 5 tuners			5							5
Consommables				6						6
Aging test				6						6
WP5 Coupler			**370**	**35**						**405**
Pre-production			**370**	**35**						**405**
Consommables			370	35						405
Transport of coupler to FNAL				23						23
Coupler Procurement (4)			370							370
Outillage QC coupleur (transition type N-> guide d'onde)				12						12
WP6 Supratech (CV1250)				**191**	**239**	**404**				**834**
Production				**191**	**239**	**404**				**834**
Equipement IJCLab				191	239	404				834
Upgrade of IJCLab facilities (cryogenic lines for CV1250)				105	210					315
Upgrade of IJCLab facilities (infrastructure platform, shielding, C&C for CV1250)						375				375
Upgrade of IJCLab facilities (RF)					29	29				58
Upgrade of IJCLab facilities (vacuum components for CV1250)				86						86
Total général	**33**	**61**	**423**	**426**	**508**	**766**	**746**	**628**	**102**	**3694**

Human ressources evaluation (SUPRATECH)

Prototyping Phase

4 cavités (6 tests)

Production Phase

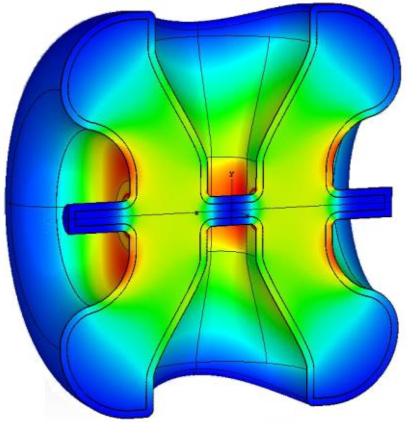
33+8 cavités à tester (8 à reconditionner)

Type	Description	Semaines	FTE	Semaines	FTE
recep	1 semaine/cav + prep 4 semaines	8	19%	8	19%
BCP	0.5 semaine/cav + prep 4 semaines + test bare cav	11	26%	12	29%
Salle blanche	2 semaines/cav + prep 4 semaines	16	38%	20	48%
Four	0.5 semaine/ cav + 1 semaine	3	7%	5	12%
cryo	1 semaine/ test + prep 4 semaines	8	19%	25	60%
test RF	0.5 semaine/test + prep 4 semaines	6	14%	14.5	35%
montage	1 semaine/test + prep 4 semaines	10	24%	25	60%

SSR2

Cavity

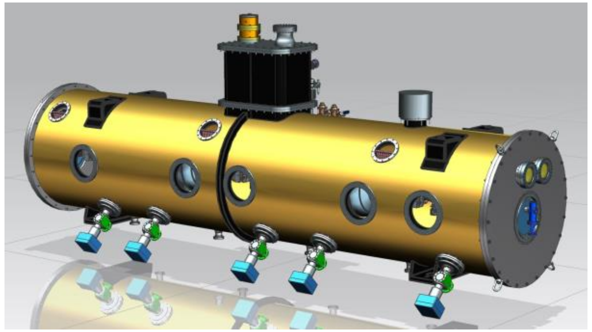
- Integrated design team: Fermilab, IN2P3 and DAE
- RF design completed
- Niobium production at vendor completed
- Prototype jacketed cavity procurement in progress
- SSR1 Coupler power capability demonstrated at >20 kW;
    - procurement is in progress

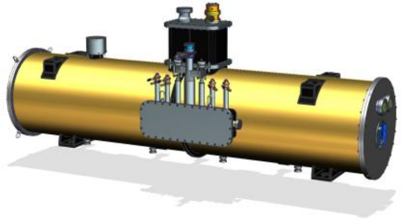


Parameters	SSR2 v 3.1
Optimal beta β_{opt}	0.472
Aperture [mm]	40
Frequency [MHz]	325
Effective length $2\beta_{opt}\lambda/2$ [m]	0.436
E_{peak}/E_{acc}	3.51
B_{peak}/E_{acc} [mT/(MV/m)]	6.75
G [Ohm]	115
R/Q [Ohm]	305.2
E_{peak} [MV/m] @ 5 MeV	40.2
B_{peak} [mT] @ 5 MeV	77.4
Max energy gain [MeV]	5.0
Max gradient [MV/m]	11.47

Cryomodule

- Design in progress by Fermilab, DAE





SSR2 Single Spoke

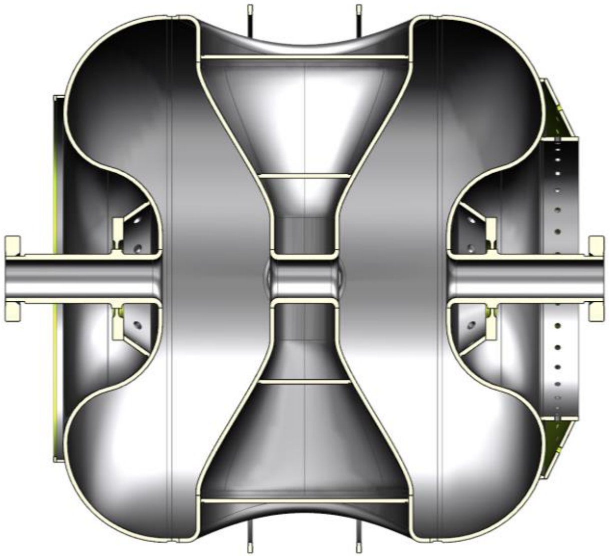
- RF design done at Fermilab
- Collaborative mechanical design

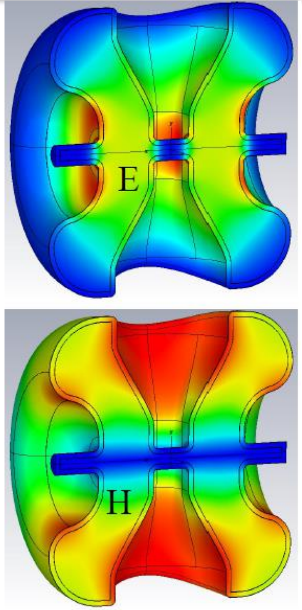
  FNAL/IPNO/BARC

✓ Material : Bulk Niobium
✓ $\beta = 0.472$
✓ $F_0 = 325$ MHz
✓ T : 2K
✓ Eacc : 11.5 MV/m
✓ Bpk/Eacc = 6.75 mT/MV/m
✓ Epk/Eacc = 3.5
✓ r/Q = 305 Ω
✓ G = 115

Jacketed Cavity

Bare Cavity

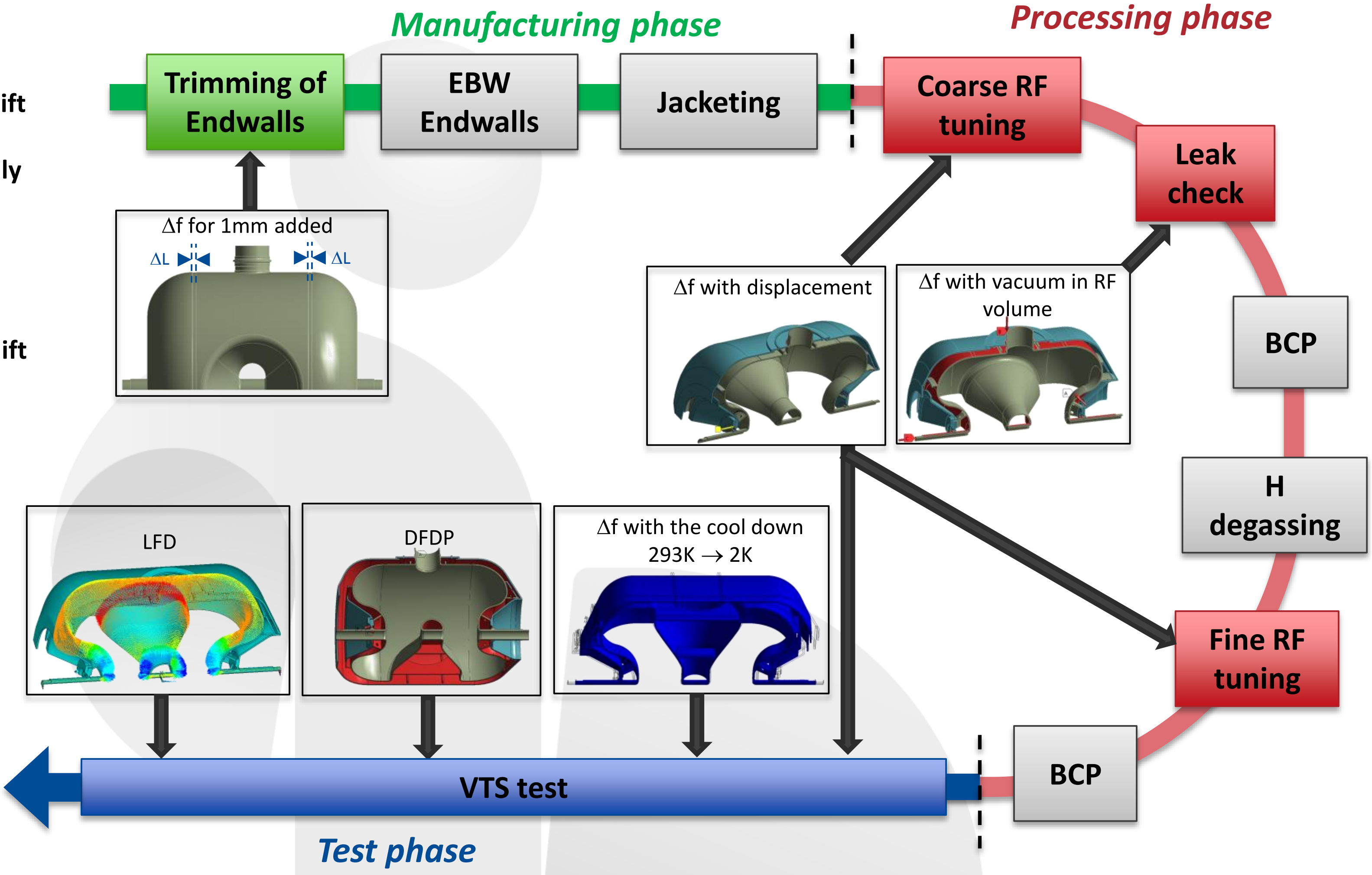




Frequency shift during manufacturing, processing & test

⬜ **Frequency shift measured experimentally**

🟩 🟥 🟦 **Calculable frequency shift**



Summary

- For all multiphysics analyses presented here, there's a good correlation between the FEM results and the measurements (SSR1, MYRRHA or ESS cavities)
- The DFDP has been minimized and meets the TRS
- The LFD has been minimized but doesn't meet the TRS with a tuner stiffness of 30 kN/mm
- The longitudinal stiffness of the cavity slightly exceeds the TRS value
- The tuning sensitivity meets the TRS

	TRS Value	FDR model
Sensitivity to LHe pressure fluctuations of dressed cavity, Hz/mbar	**< 25**	**-0.35**
Lorentz Force Detuning coefficient, Hz/(MV/m)^2	**< 4**	**-4.73**
Longitudinal stiffness, kN/mm	**< 16**	**16.7**
Tuning sensitivity, kHz/mm	**> 250**	**308**
Leak check, kHz	-	*-190.5*
Cool down from 293K to 2K, kHz	-	*+456.8*
Trimming 1mm added on each side, kHz	-	*+289.4*

Processing capabilities at IJCLab : SUPRATECH Platform

US Bath + detergent (cavity + tank)

Deionized water rinsing (cavity + tank)

BCP (cavity)

HPR (cavity)

Drying in clean room (cavity + tank)

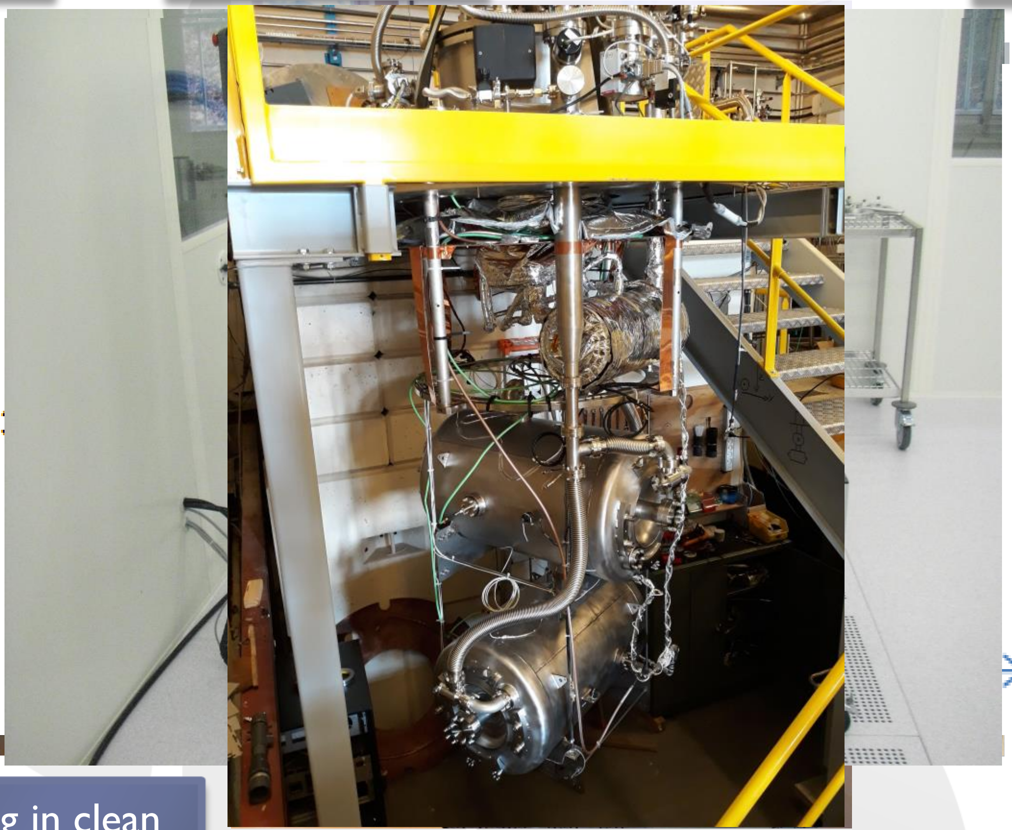
Furnace

BCP (cavity)

HPR (cavity)

Drying in clean room (cavity + tank)

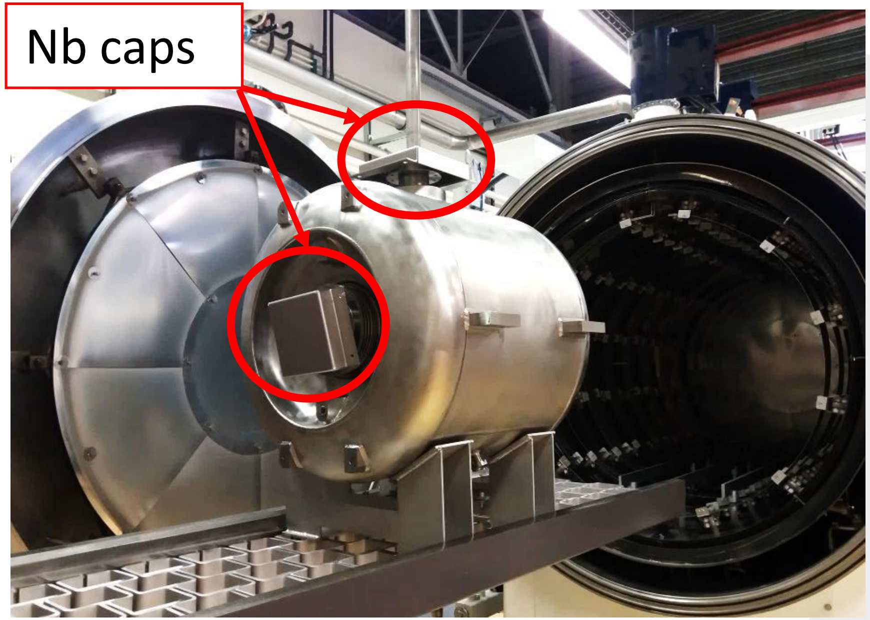
Assembly + VT test



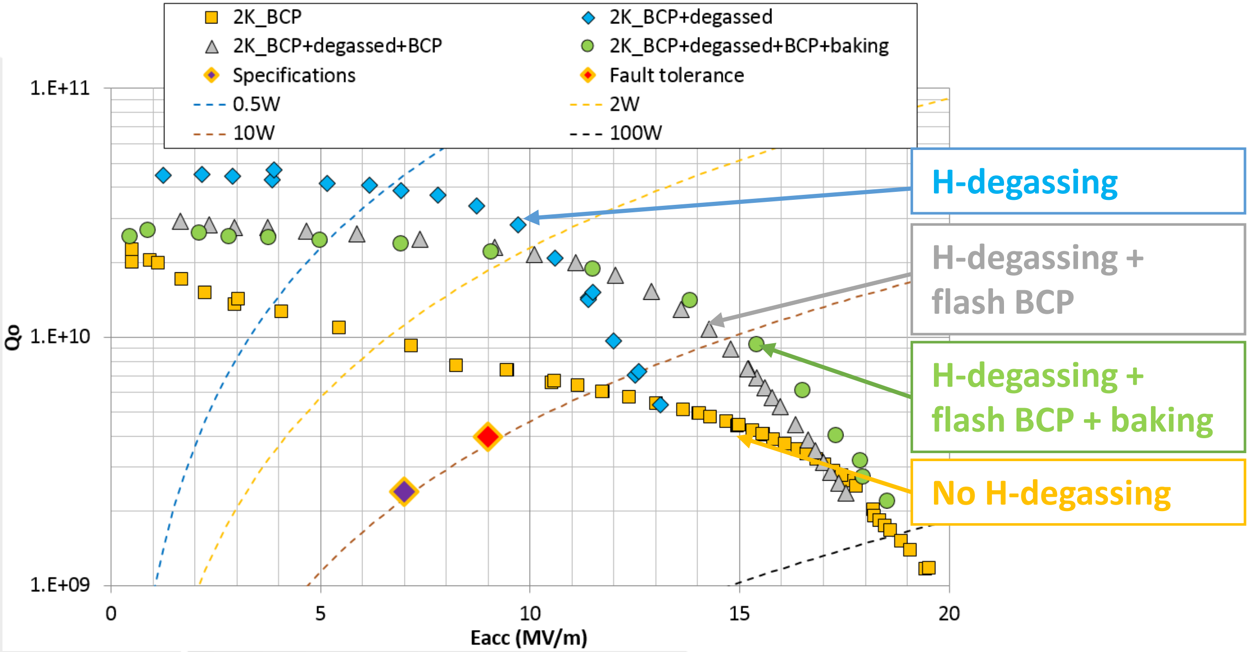
Current R&D on surface processing : MYRRHA Project

- No flash BCP after heat treatment

Bulk BCP 150-200 um → HPR → H-degassing 650°C 10h → ~~Flash BCP 20 um~~ → HPR


Nb caps

MYRRHA Simple Spoke Cavity



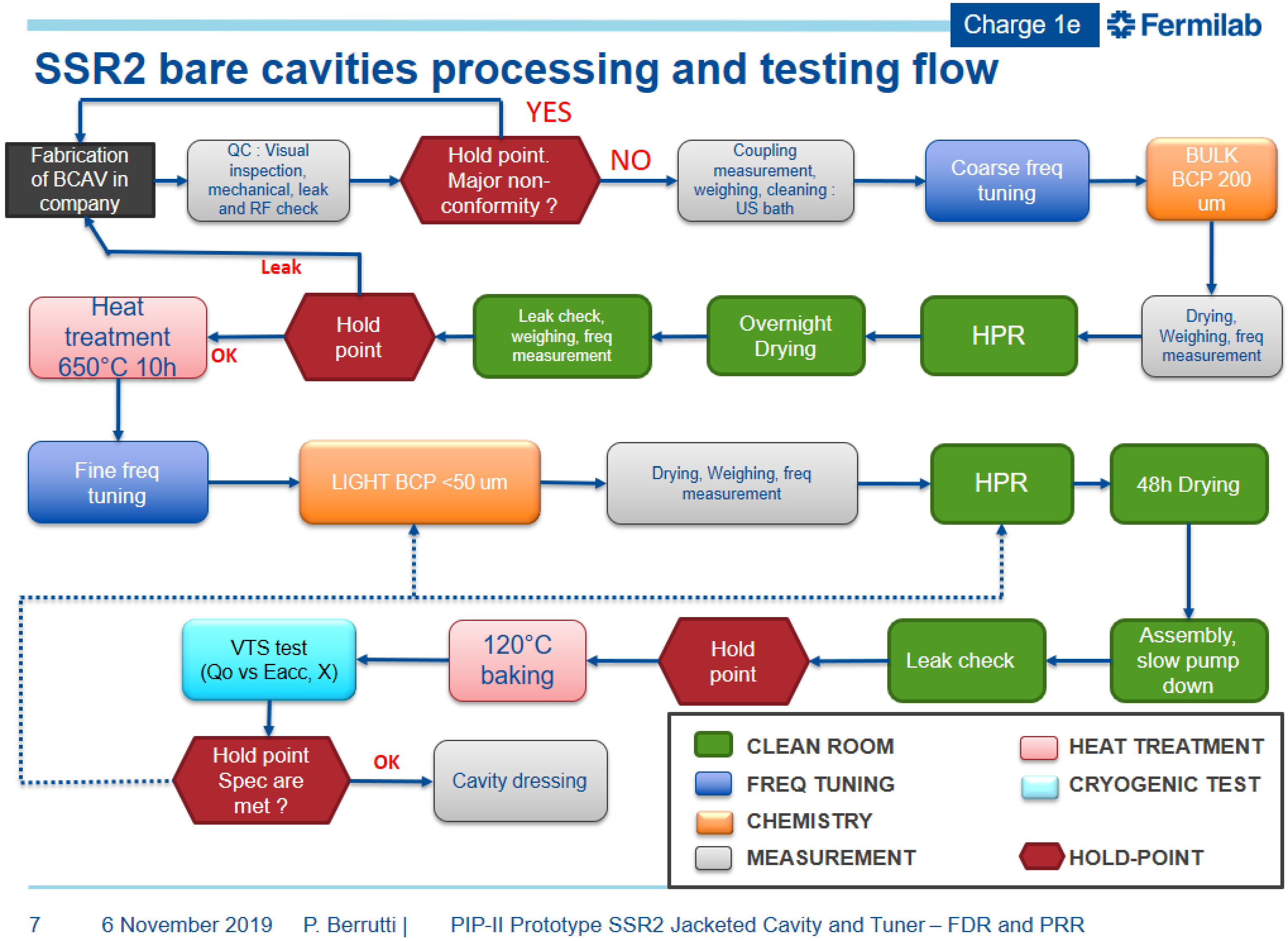
H-degassing

H-degassing + flash BCP

H-degassing + flash BCP + baking

No H-degassing

Preliminary cavity flow chart for cavity surface processing



Charge 1e
Fermilab

SSR2 bare cavities processing and testing flow

Fabrication of BCAV in company

QC : Visual inspection, mechanical, leak and RF check

Hold point. Major non-conformity ?

YES

NO

Coupling measurement, weighing, cleaning : US bath

Coarse freq tuning

BULK BCP 200 um

Drying, Weighing, freq measurement

HPR

Overnight Drying

Leak check, weighing, freq measurement

Hold point

Leak

OK

Heat treatment 650°C 10h

Fine freq tuning

LIGHT BCP <50 um

Drying, Weighing, freq measurement

HPR

48h Drying

Assembly, slow pump down

Leak check

Hold point

120°C baking

VTS test (Qo vs Eacc, X)

Hold point Spec are met ?

OK

Cavity dressing

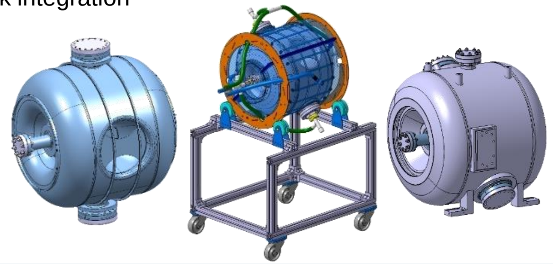
- 🟩 CLEAN ROOM
- 🟦 FREQ TUNING
- 🟧 CHEMISTRY
- ⬜ MEASUREMENT
- 🟥 HEAT TREATMENT
- ⬜ CRYOGENIC TEST
- ⬣ HOLD-POINT

7 6 November 2019 P. Berrutti | PIP-II Prototype SSR2 Jacketed Cavity and Tuner – FDR and PRR

4 PROTOTYPE CAVITIES TO PREPARE @ IJCLab

- Reception
- RF Tuning
- Bulk BCP
- Clean Room after bulk BCP
- 650°C baking
- RF Tuning
- Flash BCP
- Clean Room after flash BCP
- 120°C baking
- VTS Test

CAV N°1 **Checking material removal (measurements, uniformity):** Bulk BCP performed on the bare cavity with a dummy tank and return to the supplier for the tank integration

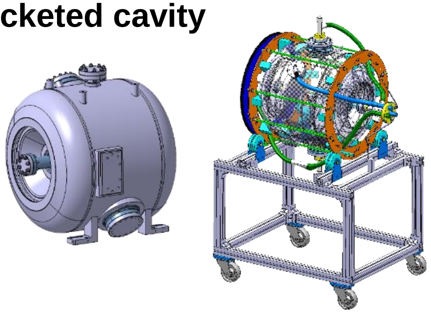


CAV N°2

CAV N°3

CAV FNAL

Bulk BCP performed on the jacketed cavity



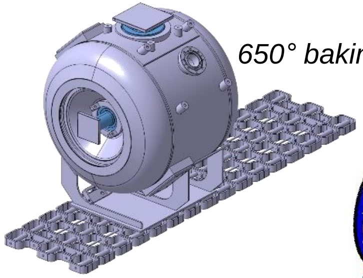
CAV N°1

CAV N°2

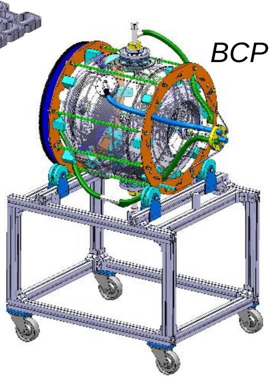
CAV N°3

CAV FNAL

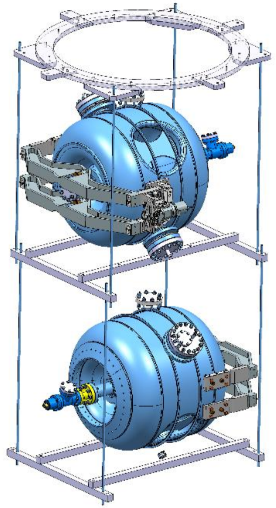
Same preparation steps after bulk BCP



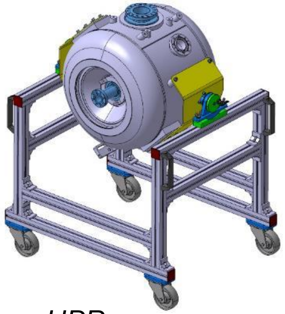
650° baking



BCP



VTS test



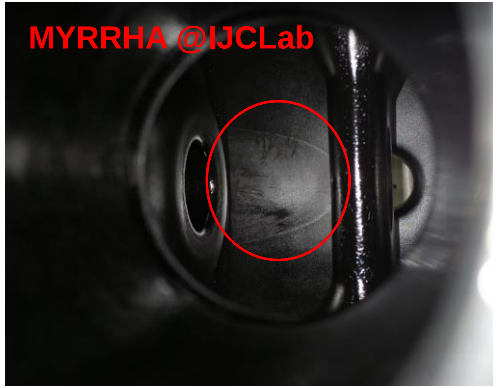
HPR cart

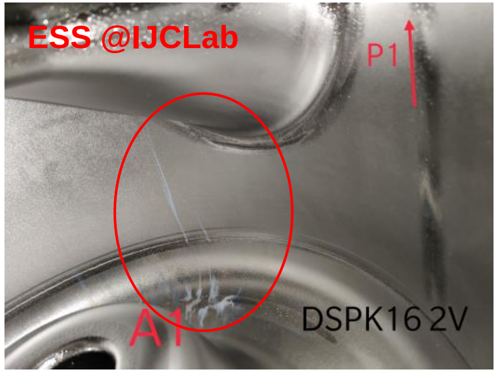
RF tuning

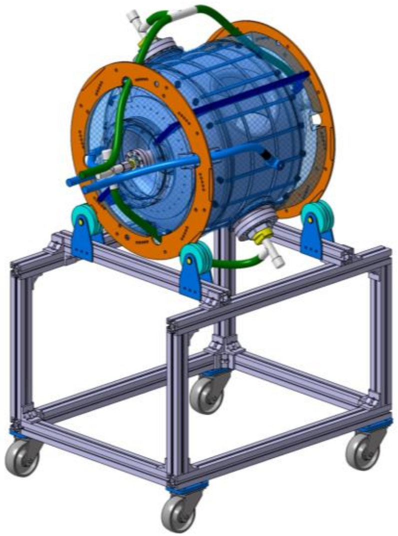
Upgrades for PIP-II : SSR2 prototype cavity processing

1. Improvement of BCP procedure

- How to have a better homogeneity of material removal ?
- How to avoid surface traces and white marks (coming from bubbles resting)



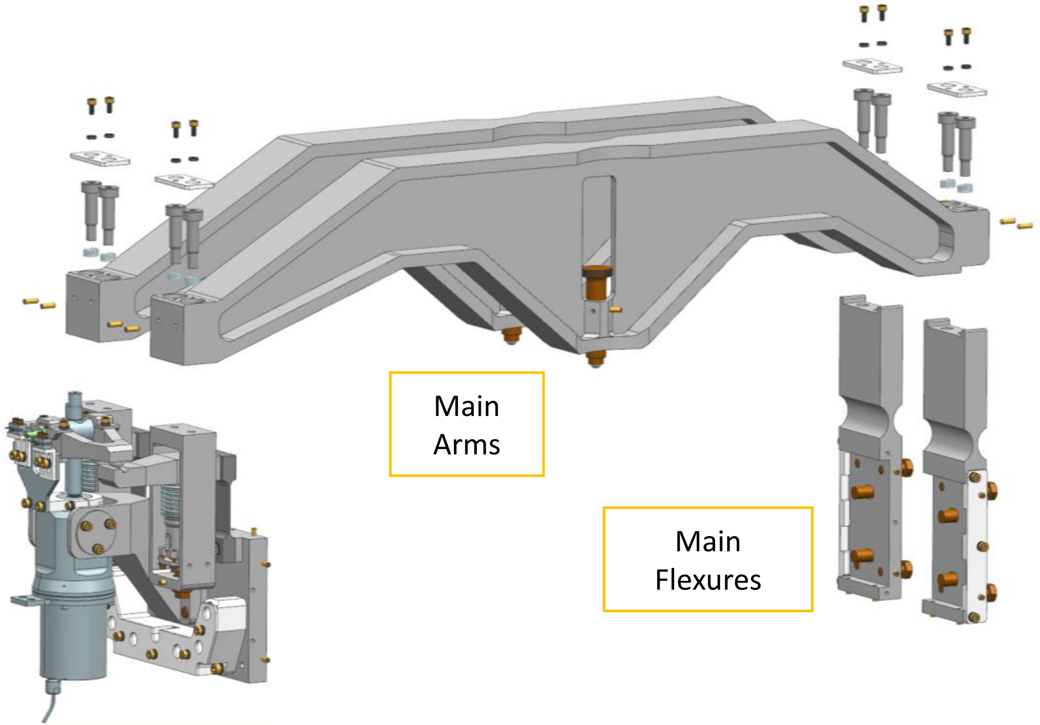


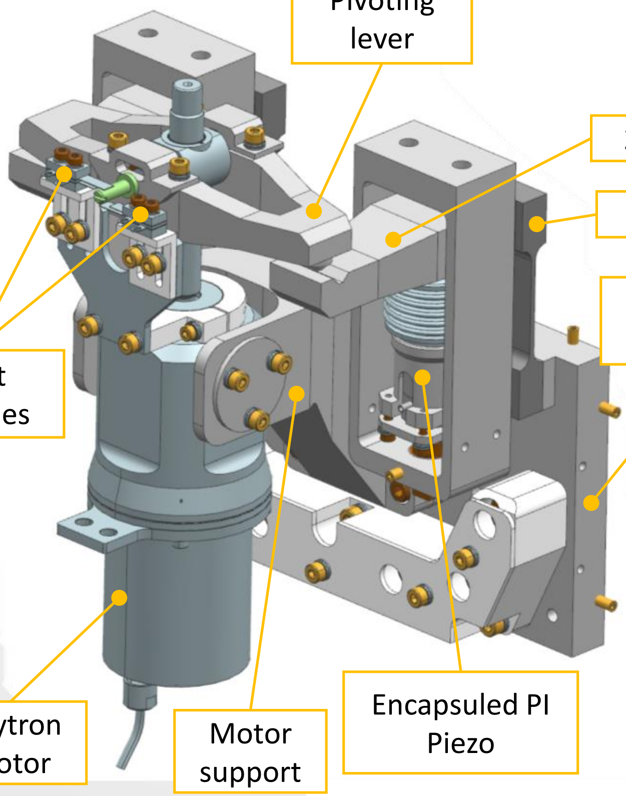


- Semi-rotational BCP bench (+/- 180°) at ~ 1 rpm
- Allow mixing of BCP mixture during the full process
- Avoid creation of bubbles
- Allow homogeneous water rinsing after acid draining

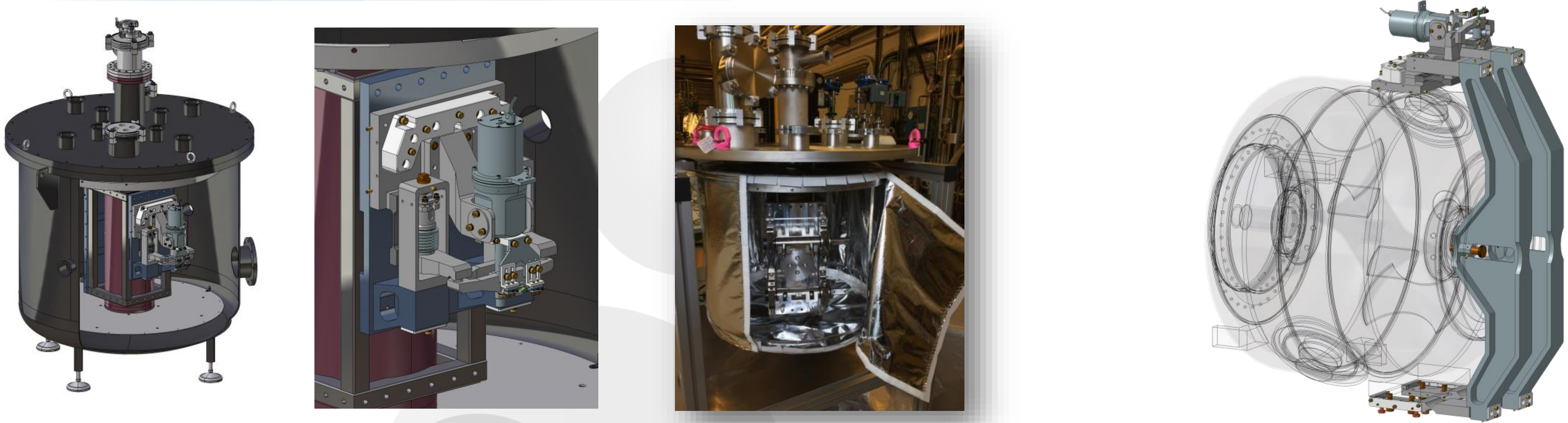
SSR2 Tuner

- Mechanical design completely done by FNAL
- Aging test of full system motor cartridge





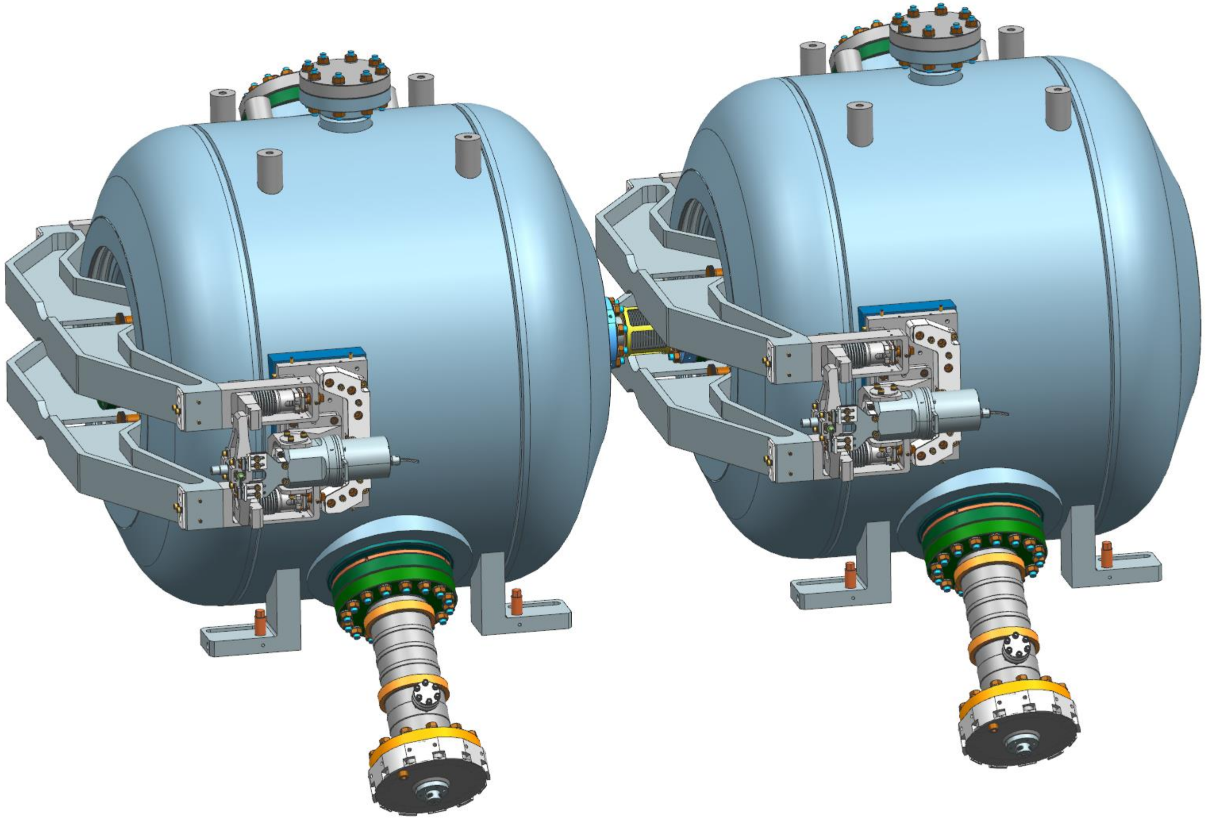
SSR2 Tuner aging



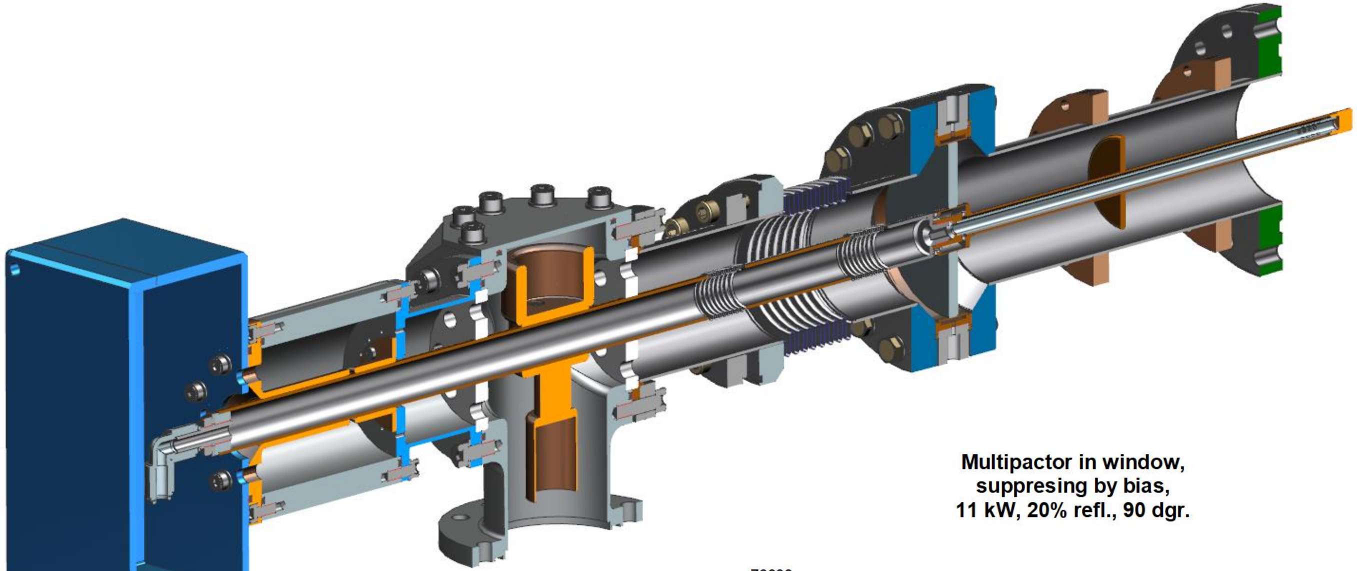
	j1	j2	j3	j4	j5	j6	j7	j8	j9	j10	j11	j12	j13	j14	j15	j16	j17	j18	j19	j20	j21	j22	j23	j24	j25	j26	j27	j28
	🟩	🟩	🟩	🟩	🟩	🟧	🟧	🟩	🟩	🟩	🟩	🟩	🟧	🟧	🟩	🟩	🟩	🟩	🟩	🟧	🟧	🟩	🟩	🟩	🟩	🟩	🟧	🟧
	Setting up phase							**Endurance phase**							**Regulation phase**				**Holding phase**					**End**				
Visual inspection	🟦	🟦																										
Installation			🟦																									
Coold down				🟦	🟦	🟦	🟦																					
Endurance								🟦	🟦	🟦	🟦	🟦	🟦	🟦														
Regulation															🟦	🟦	🟦	🟦										
Holding																			🟦	🟦	🟦	🟦	🟦					
Warm-up																								🟦				
Idle																									🟦	🟦	🟦	🟦

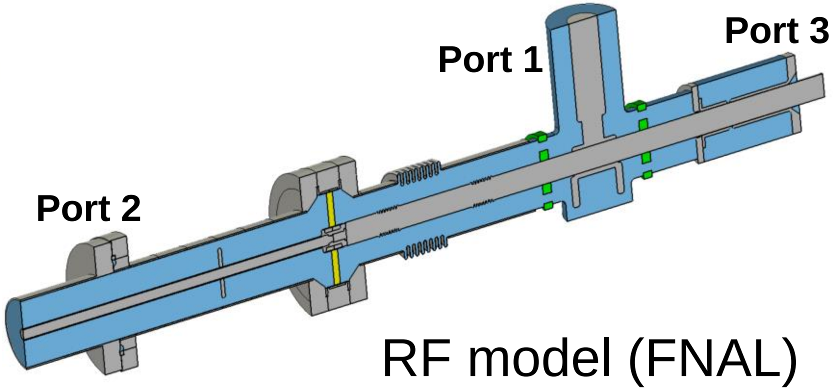
Summary

TRS parameter	Value	FDR results
Tuner passive stiffness, kN/mm	≥30	**36.2**
Slow tuner frequency range, kHz	≥ 130	**157**
Stepper motor resolution, Hz/step	≤ 9.5	**3.7 (4.8 max)**
Maximum force on the spindle system, N	1300	**1293 (for 157 kHz)**
Piezo tuner frequency range, Hz	≥ 700	**1136**
Piezo tuner frequency resolution, Hz	≤ 0.5	✓
Maximum operating force (each piezo capsule), N	2000	**1863**



SSR Coupler

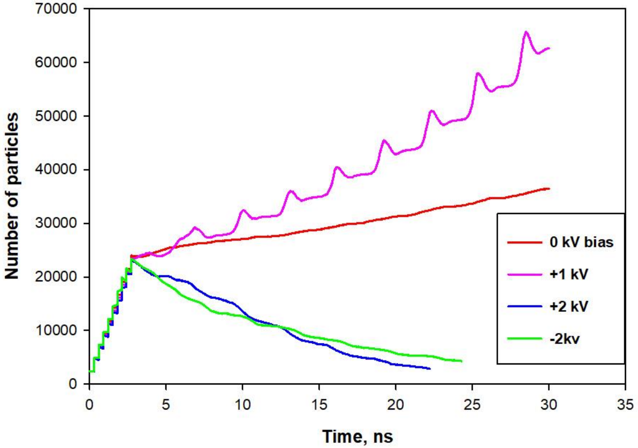


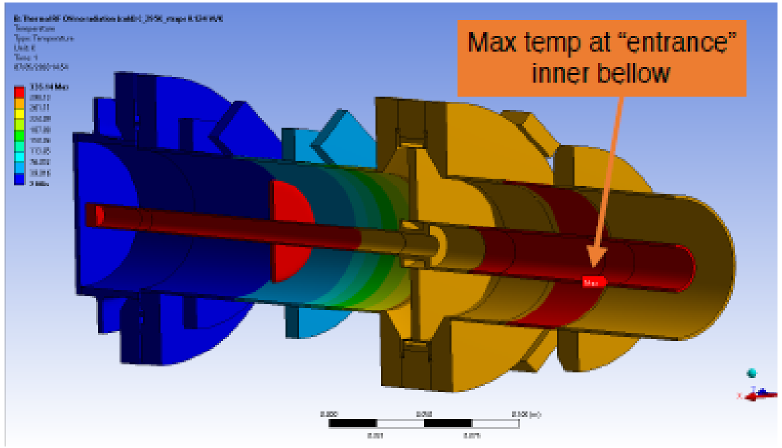


RF model (FNAL)

- RF design completely done by FNAL
- Mechanical design done by FNAL with some inputs from IJCLab : lessons learned from past experience (XFEL, …)

Multipactor in window, suppresing by bias, 11 kW, 20% refl., 90 dgr.



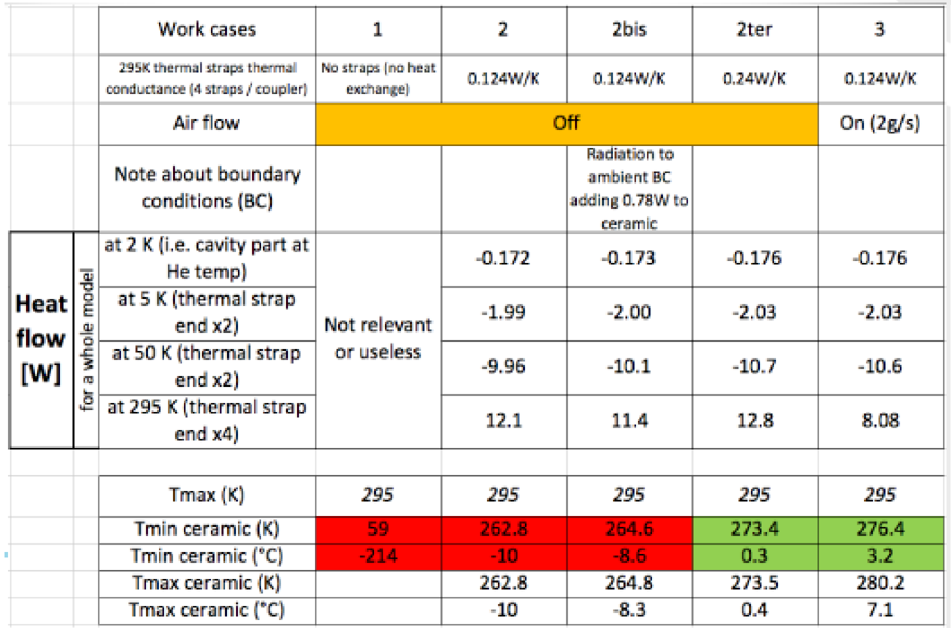


Max temp at “entrance” inner bellow

Thermal model (FNAL)

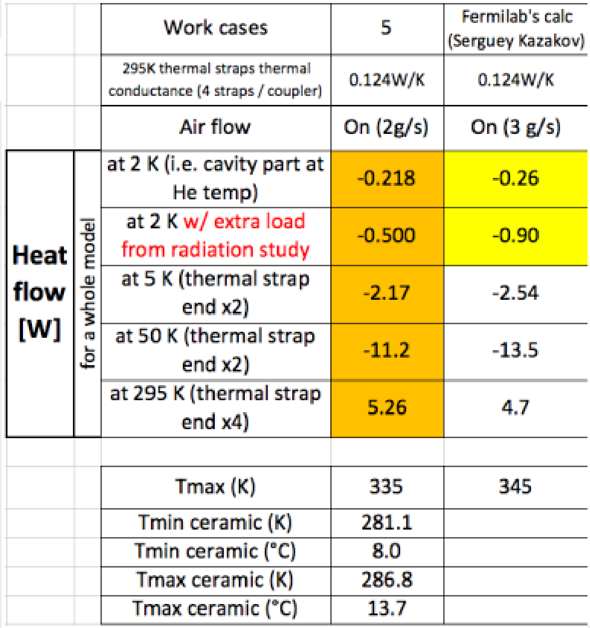
SSR Coupler

- Thermal analysis performed in parallel at IJCLab with Ansys (HFSS/Mechanical) : S. Wallon



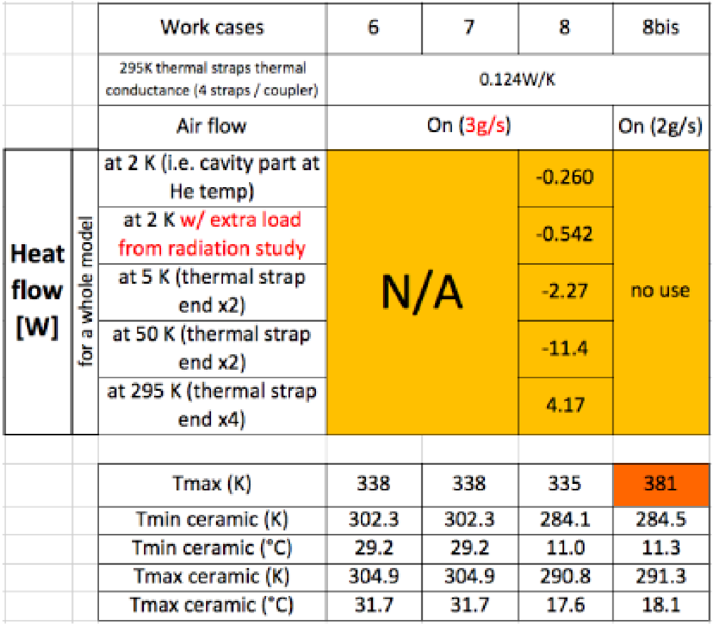
		Work cases	1	2	2bis	2ter	3
		295K thermal straps thermal conductance (4 straps / coupler)	No straps (no heat exchange)	0.124W/K	0.124W/K	0.24W/K	0.124W/K
		Air flow	Off				On (2g/s)
		Note about boundary conditions (BC)			Radiation to ambient BC adding 0.78W to ceramic		
Heat flow [W]	for a whole model	at 2 K (i.e. cavity part at He temp)	Not relevant or useless	-0.172	-0.173	-0.176	-0.176
		at 5 K (thermal strap end x2)		-1.99	-2.00	-2.03	-2.03
		at 50 K (thermal strap end x2)		-9.96	-10.1	-10.7	-10.6
		at 295 K (thermal strap end x4)		12.1	11.4	12.8	8.08
		Tmax (K)	*295*	*295*	*295*	*295*	*295*
		Tmin ceramic (K)	59	262.8	264.6	273.4	276.4
		Tmin ceramic (°C)	-214	-10	-8.6	0.3	3.2
		Tmax ceramic (K)		262.8	264.8	273.5	280.2
		Tmax ceramic (°C)		-10	-8.3	0.4	7.1

No RF Power (static case)



		Work cases	5	Fermilab's calc (Serguey Kazakov)
		295K thermal straps thermal conductance (4 straps / coupler)	0.124W/K	0.124W/K
		Air flow	On (2g/s)	On (3 g/s)
Heat flow [W]	for a whole model	at 2 K (i.e. cavity part at He temp)	-0.218	-0.26
		at 2 K w/ extra load from radiation study	-0.500	-0.90
		at 5 K (thermal strap end x2)	-2.17	-2.54
		at 50 K (thermal strap end x2)	-11.2	-13.5
		at 295 K (thermal strap end x4)	5.26	4.7
		Tmax (K)	335	345
		Tmin ceramic (K)	281.1	
		Tmin ceramic (°C)	8.0	
		Tmax ceramic (K)	286.8	
		Tmax ceramic (°C)	13.7	

With RF (nominal)



		Work cases	6	7	8	8bis
		295K thermal straps thermal conductance (4 straps / coupler)	0.124W/K			
		Air flow	On (3g/s)			On (2g/s)
Heat flow [W]	for a whole model	at 2 K (i.e. cavity part at He temp)	N/A		-0.260	no use
		at 2 K w/ extra load from radiation study			-0.542	
		at 5 K (thermal strap end x2)			-2.27	
		at 50 K (thermal strap end x2)			-11.4	
		at 295 K (thermal strap end x4)			4.17	
		Tmax (K)	338	338	335	381
		Tmin ceramic (K)	302.3	302.3	284.1	284.5
		Tmin ceramic (°C)	29.2	29.2	11.0	11.3
		Tmax ceramic (K)	304.9	304.9	290.8	291.3
		Tmax ceramic (°C)	31.7	31.7	17.6	18.1

With RF (full reflection)

Conclusion, fulfillment of requirements

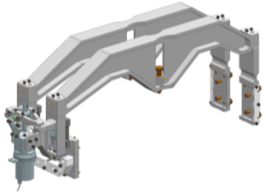
Electromagnetic parameter	Value	Y/N
Frequency, MHz	325	Y
Bandwidth(S_{11}<0.1), MHz	> 1	Y
Average nominal operating power, kW (CW, @20% reflection)	11	Y
Design and Acceptance Testing power, kW (CW, full reflection, any phase)	12	Y
Loaded Q	5.05E+6 ± 25%	Y
Maximum HV bias, kV	± 5	Y
Ceramic window dielectric loss constant	< 1E-4	Y

Mechanical Parameter	Value	Y/N
Input coaxial line aperture, mm	76.9	Y
Input coaxial line impedance, Ω	50	Y
Output coaxial line aperture, mm	72.9	Y
RF window	Single, RT	Y

Thermal parameter	Value	Y/N
Thermal intercepts (nominal), K	5 and 50	Y
Temperature at 5 K intercept, K	< 15	Y
Temperature at 35-50 K intercept, K	< 80	Y
Maximum 2K heat load, W	< 1.0	Y
Maximum 5K heat load, W	< 3.5	Y
Maximum 35-50K heat load, W	< 15	Y
Maximum ceramic flange temperature, K	< 325	Y
Antenna cooling media	Dry Air	Y
Air flow rate, g/s	< 3	Y
Max cooling air pressure drop, bar	< 1	Y
Air output temperature, K	< 323	Y

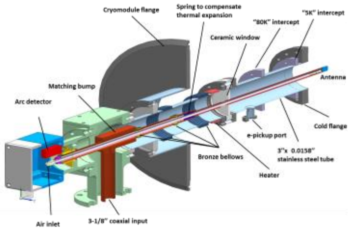
Diagnostic		Y/N
Temperature sensors (per each coupler)	see description above	Y
E-probe current monitor	1	Y
Vacuum pressure gauge in proximity of the ceramic windows	1	Y
Bias current monitor	1	Y
Bias voltage monitor	1	Y
Air output flow monitor	1	Y

Présentation du projet : PBS



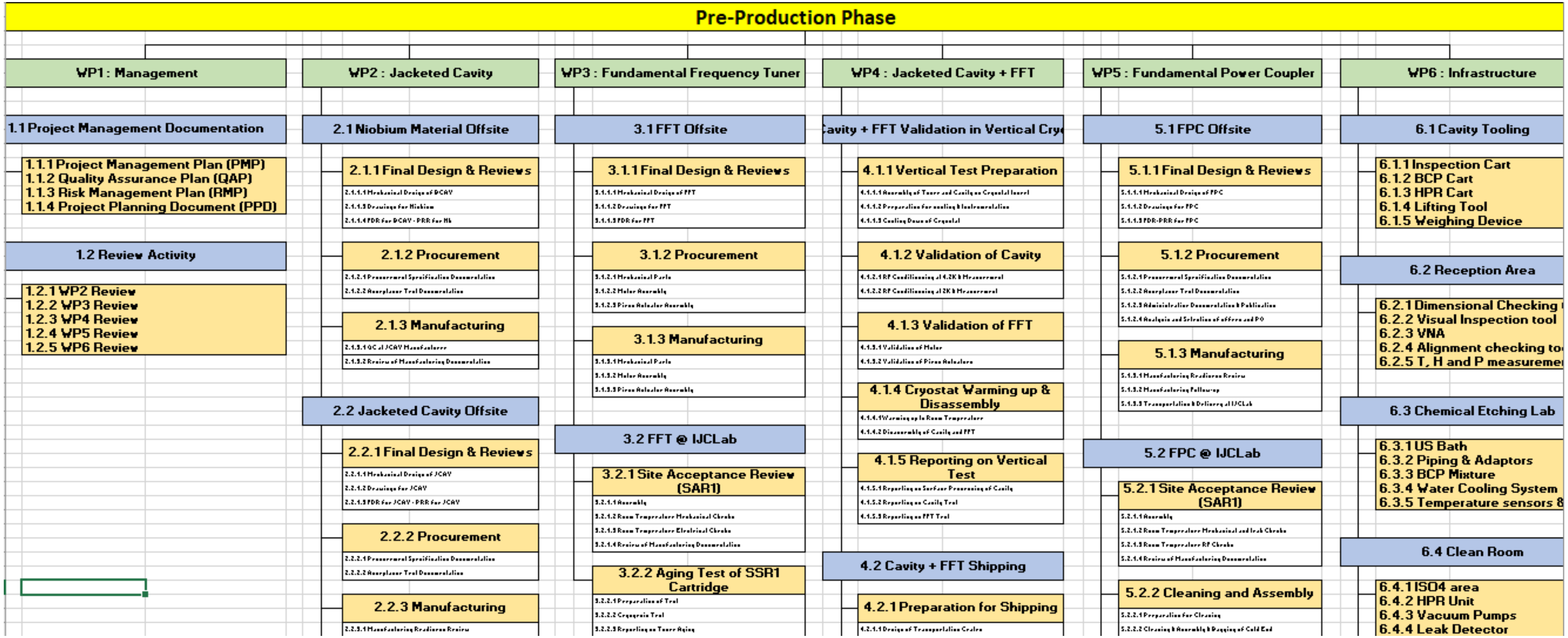
Dressed Single Spoke Resonator (FNAL)

- **1. Jaqueted Cavity F10118801**
  - 1.1 Niobium Material
    - 1.1.1 Sheet — To be refined by SPC
    - 1.1.2 Tube — To be refined by SPC
  - 1.2 Bare Cavity
    - 1.2.1 Resonator — To be refined by SPC
    - 1.2.2 Stiffener — To be refined by SPC
    - 1.2.3 Interface Pieces — To be refined by SPC
  - 1.3 Liquid Helium Containment Vessel
    - 1.3.1 Container — To be refined by SPC
    - 1.3.2 Interface pieces — To be refined by SPC
- **2. Fundamental Frequency Tuner F10119103**
  - .1 Mechanical Syste
    - 3.1.1 Main Arm
    - 3.1.2 Main Flexure
    - 3.1.3 Actuation Assembly
    - To be refined by SPC
  - 3.2 Geared Stepper Motor
    - 3.2.1 Stepper Motor
    - 3.2.2 Gear Box
    - 3.2.3 Spindle System
    - 3.2.4 Connector
    - 3.2.6 Controller
    - To be refined by SPC
  - 3.3 Piezo Actuato
    - 3.3.1 Actuator
    - 3.3.2 Connector
    - 3.3.3 Power Supply
    - 3.3.4 Controller
    - To be refined by SPC
- **3. Fundamental Power Coupler F101107445**
  - 4.1 Vaccum End
    - 4.1.1 Ceramic Window Assembly
    - 4.1.2 Antenna Assembly
    - 4.1.3 Vacuum Side Outer
    - 4.1.4 Ceramic Protections
    - 4.1.5 Interface Pieces
    - To be refined by SPC
  - 4.2 Air Side
    - 4.2.1 Inner Conductor
    - 4.2.2 Air Side Outer Conductor
    - 4.2.3 Matching Section
    - 4.2.4 Matching Section
    - 4.2.5 Instrumention Box
    - 4.2.6 Interface Pieces
    - 4.2.7 Power Supply
    - To be refined by SPC
- **4. Infrastructure (IJCLab)**
  - 5.1 Tooling
    - 5.1.1 Inspection Cart
    - 5.1.2 BCP Cart
    - 5.1.3 HPR Cart
    - 5.1.4 Lifting Tool
    - 5.1.5 Weighing Device
  - 5.2 Reception Area
    - 5.2.1 Dimensional Checkin
    - 5.2.2 Visual Inspection too
    - 5.2.3 VNA
    - 5.2.4 Alignment checking t
    - 5.2.5 T, H and P measurement Devices
  - 5.3 Chemistry Lab
    - 5.3.1 US Bath
    - 5.3.2 Piping & Adaptors
    - 5.3.3 BCP Mixture
    - 5.3.4 Water Cooling Sys
    - 5.3.5 Temperature sensors & Controller
  - 5.4 Clean Room
    - 5.4.1 ISO4 area
    - 5.4.2 HPR Unit
    - 5.4.3 Vacuum Pumps
    - 5.4.4 Leak Detector
    - 5.4.5 Particle Counter
  - 5.5 Vacuum Furnace
    - 5.5.1 Furnace
    - 5.5.2 Vacuum Pumps
    - 5.5.3 Loading Cart
    - 5.5.4 Niobium Caps
    - 5.5.5 RGA & Vacuum gauge
  - 5.6 Vertical Cryostat
    - 5.6.1 Cryostat
    - 5.6.2 Liquid Helium & N
    - 5.6.3 Vacuum Pumps
    - 5.6.4 Leak Detector
    - 5.6.5 VNA
    - 5.6.6 Sub atm Pumps
    - 5.6.7 Sensors (T, Mag)
    - 5.6.8 Cryogenic PLC
    - 5.6.9 RF equipement for Qo and Eacc
  - 5.7 Data & Storage
    - 5.7.1 Local Data Base ATRIUM
    - 5.7.2 Deliverable documentation
    - 5.7.3 Travelers (Vector)



Fichier complet accessible sur ATRIUM : [ATRIUM-390229]()

Présentation du projet : WBS



Pre-Production Phase

- WP1 : Management
  - 1.1 Project Management Documentation
    - 1.1.1 Project Management Plan (PMP)
    - 1.1.2 Quality Assurance Plan (QAP)
    - 1.1.3 Risk Management Plan (RMP)
    - 1.1.4 Project Planning Document (PPD)
  - 1.2 Review Activity
    - 1.2.1 WP2 Review
    - 1.2.2 WP3 Review
    - 1.2.3 WP4 Review
    - 1.2.4 WP5 Review
    - 1.2.5 WP6 Review
- WP2 : Jacketed Cavity
  - 2.1 Niobium Material Offsite
    - 2.1.1 Final Design & Reviews
    - 2.1.2 Procurement
    - 2.1.3 Manufacturing
  - 2.2 Jacketed Cavity Offsite
    - 2.2.1 Final Design & Reviews
    - 2.2.2 Procurement
    - 2.2.3 Manufacturing
- WP3 : Fundamental Frequency Tuner
  - 3.1 FFT Offsite
    - 3.1.1 Final Design & Reviews
    - 3.1.2 Procurement
    - 3.1.3 Manufacturing
  - 3.2 FFT @ IJCLab
    - 3.2.1 Site Acceptance Review (SAR1)
    - 3.2.2 Aging Test of SSR1 Cartridge
- WP4 : Jacketed Cavity + FFT
  - avity + FFT Validation in Vertical Cry
    - 4.1.1 Vertical Test Preparation
    - 4.1.2 Validation of Cavity
    - 4.1.3 Validation of FFT
    - 4.1.4 Cryostat Warming up & Disassembly
    - 4.1.5 Reporting on Vertical Test
  - 4.2 Cavity + FFT Shipping
    - 4.2.1 Preparation for Shipping
- WP5 : Fundamental Power Coupler
  - 5.1 FPC Offsite
    - 5.1.1 Final Design & Reviews
    - 5.1.2 Procurement
    - 5.1.3 Manufacturing
  - 5.2 FPC @ IJCLab
    - 5.2.1 Site Acceptance Review (SAR1)
    - 5.2.2 Cleaning and Assembly
- WP6 : Infrastructure
  - 6.1 Cavity Tooling
    - 6.1.1 Inspection Cart
    - 6.1.2 BCP Cart
    - 6.1.3 HPR Cart
    - 6.1.4 Lifting Tool
    - 6.1.5 Weighing Device
  - 6.2 Reception Area
    - 6.2.1 Dimensional Checking
    - 6.2.2 Visual Inspection tool
    - 6.2.3 VNA
    - 6.2.4 Alignment checking to
    - 6.2.5 T, H and P measureme
  - 6.3 Chemical Etching Lab
    - 6.3.1 US Bath
    - 6.3.2 Piping & Adaptors
    - 6.3.3 BCP Mixture
    - 6.3.4 Water Cooling System
    - 6.3.5 Temperature sensors 8
  - 6.4 Clean Room
    - 6.4.1 ISO4 area
    - 6.4.2 HPR Unit
    - 6.4.3 Vacuum Pumps
    - 6.4.4 Leak Detector

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