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
WHAT IS PIP-II?

Technical and scientific overview

**PIP-II Scope**

**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

Courtesy of Lia Merminga
WHAT IS PIP-II? Technical and scientific overview
WHAT IS PIP-II?

Technical and scientific overview

**PIP-II LINAC**

**H- Ion source**

**RFQ**

**Cryoplant**

**CDS**

**HWR**

**8 Cavities**

**16 Cavities**

**32 Cavities**

**325 MHz**

**35 Cavities**

**325 MHz**

**650 MHz**

**Elliptical**

**HB650 X 4**

**24 Cavities**

**650 MHz**

**Elliptical**

**LB650 X 9**

**36 Cavities**

**650 MHz**

**Single Spoke**

**SSR1 X 2**

**16 Cavities**

**325 MHz**

**Single Spoke**

**SSR2 X 7**

**35 Cavities**

**325 MHz**

**Elliptical**

**HB650 X 4**

**24 Cavities**

**650 MHz**

**Elliptical**

**LB650 X 9**

**36 Cavities**

**650 MHz**

**Superconducting**

**833 MeV**

**516 MeV**

**177 MeV**

**10 MeV**

**32 MeV**

**2.1 MeV**

**Room Temperature**

Courtesy of Lia Merminga

**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.

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

09/02/2021

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WHAT IS PIP-II?

Technical and scientific overview

SSR CRYOMODULES

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DC 0.03 MeV 162.5 MHz 0.03 -10.3 MeV 325 MHz 10.3-185 MeV 650 MHz 185-800 MeV

# CMs | SSR1 | SSR2
---|------|------
2 | 7

Cavities per CM | 8 | 5

Solenoids per CM | 4 | 3

CM configuration: c: cavities; s: solenoids

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CM length (m): SSR1 5.2, SSR2 6.5

First SSR1 prototype cryomodule

Final design of SSR2 cavity

Preliminary design of SSR2 cryomodule

Courtesy of Lia Merminga

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WHAT IS PIP-II?

General status

Fabrication launched recently
First delivery end of 2021

5.9 m
5.3 m
6.5 m
5.5 m
9.9 m

Half Wave Resonator
β = 0.11  Q₀ = 0.85 x 10¹⁰

Single Spoke
SSR1
β = 0.22  Q₀ = 0.82 x 10¹⁰

Single Spoke
SSR2
β = 0.47  Q₀ = 0.82 x 10¹⁰

Elliptical
LB650
β = 0.61  *Q₀ = 2.4 x 10¹⁰

Elliptical
HB650
β = 0.92  *Q₀ = 3.3 x 10¹⁰

Performance validated
Testing in progress
Dates: component built

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WHAT IS PIP-II?

General status

PIP-II IT: testing facility

17 MeV achieved

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WHAT IS PIP-II?

Project Schedule

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

SSR2 cryomodule on critical path
• What is PIP-II
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  • 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
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
  - 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)**
  - 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)
  o Support fabrication follow-up of 3 cavities
  o Optimization of surface processing on 4 cavities
  o Validation in vertical cryostat of 4 cavities
  o Shipping of 4 cavities to FNAL
- Production Phase: 33 cavities
  o Support fabrication follow-up of 33 cavities
  o Validation in vertical cryostat of 33 cavities
  o Surface re-processing of cavities at IJCLab ~ 25%
  o Shipping of 33 cavities to FNAL

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

COUPLERS:
- Prototyping Phase: 8 couplers
  o Procurement of 4 couplers (Done in November 2020)
  o Shipping of 4 couplers to FNAL
  o Support during coupler RF conditioning at FNAL
- Production Phase: X
PROTOTYPING PHASE (2020 – 2022)

- Fabrication follow-up, QC inspection, Surface preparation
- 4 SSR2 Single Spoke Resonators

- RF validation in vertical cryostat of 4 cavities
  - @ IJCLab

- 5 SSR2 Cold Tuner

- Procurement, Fabrication, QC inspection

- 4 SSR Power Coupler

- RF validation in horizontal cryostat

- Transport to FNAL

- @ FNAL
IN2P3 CONTRIBUTION TO PIP-II

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

Transport to FNAL

RF validation in horizontal cryostat

@ ICLab

@ FNAL
• What is PIP-II
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• Project management
  • Technical Review Plan and Schedule
  • Local organization
  • Cost distribution
  • Risk analysis
ISO 4 clean room

Vacuum furnace

Assembly hall

Cryogenic test hall for cryomodules

Chemical etching lab (BCP only)

Helium liquefier

Vertical cryostat

IN2P3 CONTRIBUTION TO PIP-II

State of the art (SUPRATECH Platform)

+ Material science lab
  - GXRD
  - SIMS
  - Confocal microscope
  - SEM (EDS, EBSD)
  - SEY measurement

+ Other
  - RRR measurement (Supratech)
  - Conductivity (Supratech)
  - TEM (Jannus Platform)
• PIP-II specifications not conservative, very ambitious specifications ($Q_o > 9 \times 10^9 @ E_{acc} = 11.5 \text{ MV/m}, E_{acc\text{-}min} = 13.7 \text{ MV/m}$).

• 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

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IN2P3 CONTRIBUTION TO PIP-II

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)
    - Higher Qo
    - Less steps in cavity life cycle
    - Less risks
    - Frequency tuning possible after furnace treatment and without post-BCP?
  - Test of Nitrogen infusion/doping low frequency cavities (F<1.3 GHz)
    - Unsuccessful 1st test on 1.3 GHz elliptical cavity (IRFU)
    - Furnace upgraded at IJCLab (N2 injection line)
    - 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?

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<th>CAVITY</th>
<th>COUPLER</th>
<th>TUNER</th>
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| **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 conditioning (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 | **Necessity of power conditioning ?**  
- Study benefit of conditioning 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 |

<table>
<thead>
<tr>
<th>Prototyping</th>
<th>CAVITY</th>
<th>COUPLER</th>
<th>TUNER</th>
</tr>
</thead>
</table>
| **Optimization of magnetic shielding in cryomodule** | - Measure magnetic sensitivity of cavity  
- Evaluate impact of cooling conditions and magnetic hygiene | | |

<table>
<thead>
<tr>
<th>Prototyping</th>
<th>CAVITY</th>
<th>COUPLER</th>
<th>TUNER</th>
</tr>
</thead>
</table>
| **Technology transfer of surface processing to industry** | - Work with companies and check compatibility of their facilities  
- Perform surface treatment at companies (BCP, furnace, …) | | |

<table>
<thead>
<tr>
<th>Production</th>
<th>CAVITY</th>
<th>COUPLER</th>
<th>TUNER</th>
</tr>
</thead>
</table>
| **Upgrade of Supratech infrastructure** | - Improve reliability with new cryostat  
- Improve availability with upgraded helium supply chain | | |

<table>
<thead>
<tr>
<th>Production</th>
<th>CAVITY</th>
<th>COUPLER</th>
<th>TUNER</th>
</tr>
</thead>
</table>
| **Statistics** | - Analyze impact of surface processing on performances  
- Lessons learned/best practice  
- Build a model and address loss mechanisms | | |

<table>
<thead>
<tr>
<th>Production</th>
<th>CAVITY</th>
<th>COUPLER</th>
<th>TUNER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ponctual support (expertise) to FNAL team</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PROTOTYPING PHASE (2020 – 2022)
CV800 : In operation but not optimal for production

PRODUCTION PHASE (2024 – 2026)
CV1250 : Existing but not operational
- Drill pit
- Equip with platform and shields
- Cryogenic distribution
- C&C (PLC)
- RF system
- Vacuum systems
• 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
• 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
PROTOTYPING PHASE

- Design Bare Cavity
- Design Jacketed Cavity
- Design Tuner
- Design Coupler
- Order Niobium
- Niobium Fabrication
- Order Cavity
- Tuner Fabrication
- Coupler Fabrication
- Vertical Testing
- Shipping to FNAL
- Horizontal Testing
- Final Design Dressed Cavity

PRODUCTION PHASE

- Order Niobium
- MRR
- Niobium Fabrication
- MRR
- Cavity Fabrication
- QC
- SAR1
- Shipping to FNAL
- SAR2
- Dressed Cavity
- FDR

Current status of project
IN2P3 official contribution as described in PPD Part 2

IN2P3 could provide support on all activities (expertise)
**Project Management**

**Schedule**

<table>
<thead>
<tr>
<th>IN-Kind IN2P3 contribution</th>
<th>FY2019</th>
<th>FY2020</th>
<th>FY2021</th>
<th>FY2022</th>
<th>FY2023</th>
<th>FY2024</th>
<th>FY2025</th>
<th>FY2026</th>
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<tbody>
<tr>
<td></td>
<td>2019</td>
<td>2020</td>
<td>2021</td>
<td>2022</td>
<td>2023</td>
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</tr>
</tbody>
</table>

- **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**

09/02/2021

Conseil scientifique IN2P3 – IN2P3 contribution to PIP-II - Longuevergne
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

Local Organization and human resources

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

PROTOTYPING PHASE

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

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

Project leader/Technical coordinator
- D. Longuevergne

Technical Director
- P. Duchesne

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

09/02/2021 Conseil scientifique IN2P3 – IN2P3 contribution to PIP-II - Longuevergne
Project Management
Local Organization and human resources

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

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

PIP-II Organization at

IJCLab services and platform
- ES&H service (SPR): S. Wurth
- Procurement Office: M. Adnane
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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

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

PRODUCTION PHASE
### Project Management

**Local Organization and human resources**

---

**TOTAL (Permanents + CDD)**
38.3 2 950 842.00 €

**TOTAL (Permanents) hors CDD**
26.3 2 044 830.00 €

---

### FTE HR COST

<table>
<thead>
<tr>
<th>Nom des personnes</th>
<th>Statut</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>Total (FTE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. Longuevergne</td>
<td>Responsable scientifique</td>
<td>14%</td>
<td>35%</td>
<td>50%</td>
<td>50%</td>
<td>40%</td>
<td>30%</td>
<td>20%</td>
<td>10%</td>
<td>9.01</td>
<td>10%</td>
<td>3.91</td>
</tr>
<tr>
<td>H. Guler</td>
<td>Expertise conditionnement coupleurs</td>
<td>7%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>0.57</td>
<td>5%</td>
<td>0.35</td>
</tr>
<tr>
<td>W. Kaabi</td>
<td>Conseil coupleur</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
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</tr>
</tbody>
</table>

**TOTAL (FTE)**
0.00 0.14 0.42 0.65 0.65 0.58 0.40 0.30 0.20 3.91

---

### HR distribution over the years for PIP-II

<table>
<thead>
<tr>
<th>Nom des personnes</th>
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<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
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<th>2023</th>
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<th>2025</th>
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<td>40%</td>
<td>30%</td>
<td>20%</td>
<td>10%</td>
<td>9.01</td>
<td>10%</td>
<td>3.91</td>
</tr>
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<td>Expertise conditionnement coupleurs</td>
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<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>0.57</td>
<td>5%</td>
<td>0.35</td>
</tr>
<tr>
<td>W. Kaabi</td>
<td>Conseil coupleur</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
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</tbody>
</table>

**TOTAL (FTE)**
0.00 0.14 0.42 0.65 0.65 0.58 0.40 0.30 0.20 3.91

---

### Scientists - PIP-II

<table>
<thead>
<tr>
<th>Nom des personnes</th>
<th>Statut</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
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<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
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</thead>
<tbody>
<tr>
<td>D. Longuevergne</td>
<td>Responsable scientifique</td>
<td>14%</td>
<td>35%</td>
<td>50%</td>
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<td>30%</td>
<td>20%</td>
<td>10%</td>
<td>9.01</td>
<td>10%</td>
<td>3.91</td>
</tr>
<tr>
<td>H. Guler</td>
<td>Expertise conditionnement coupleurs</td>
<td>7%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>0.57</td>
<td>5%</td>
<td>0.35</td>
</tr>
<tr>
<td>W. Kaabi</td>
<td>Conseil coupleur</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL (FTE)**
0.00 0.14 0.42 0.65 0.65 0.58 0.40 0.30 0.20 3.91

---

### Engineers - PIP-II

<table>
<thead>
<tr>
<th>Nom des personnes</th>
<th>Statut</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>Total (FTE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. Duchesne</td>
<td>Responsable technique + lot cavité</td>
<td>12%</td>
<td>35%</td>
<td>50%</td>
<td>50%</td>
<td>40%</td>
<td>30%</td>
<td>20%</td>
<td>10%</td>
<td>5.52</td>
<td>10%</td>
<td>1.17</td>
</tr>
<tr>
<td>N. Gandolfo</td>
<td>Responsable Lot Tuner</td>
<td>15%</td>
<td>35%</td>
<td>35%</td>
<td>35%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>1.60</td>
<td>10%</td>
<td>0.30</td>
</tr>
<tr>
<td>S. Wallon</td>
<td>Responsable Lot Couplage</td>
<td>15%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>5%</td>
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<td>5%</td>
<td>0.22</td>
</tr>
<tr>
<td>D. Reynet</td>
<td>Ingénieur Système</td>
<td>5%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>0.80</td>
<td>10%</td>
<td>0.16</td>
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<tr>
<td>V. Poux</td>
<td>Responsable Qualité IJCLab</td>
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<tr>
<td>S. Roset</td>
<td>Conception outillage/mécanique</td>
<td>5%</td>
<td>50%</td>
<td>30%</td>
<td>25%</td>
<td>20%</td>
<td>10%</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL (FTE)**
0.00 0.17 0.90 1.80 3.20 5.55 6.75 8.00 6.55 1.45 34.37
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

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

<table>
<thead>
<tr>
<th>Étiquettes de lignes</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>Total général</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP1 management</td>
<td>43</td>
<td>172</td>
<td>172</td>
<td>172</td>
<td>43</td>
<td>601</td>
</tr>
<tr>
<td>IR QA&amp;QC</td>
<td>21</td>
<td>86</td>
<td>86</td>
<td>86</td>
<td>21</td>
<td>300</td>
</tr>
<tr>
<td>IR Project Controller</td>
<td>21</td>
<td>86</td>
<td>86</td>
<td>86</td>
<td>21</td>
<td>300</td>
</tr>
<tr>
<td>WP2 Cavité</td>
<td>15</td>
<td>77</td>
<td>123</td>
<td>123</td>
<td>31</td>
<td>368</td>
</tr>
<tr>
<td>2 CDD cavité (1 AI, 1 IE pour inspection et tests cryo)</td>
<td>15</td>
<td>77</td>
<td>123</td>
<td>123</td>
<td>31</td>
<td>368</td>
</tr>
<tr>
<td>Total général</td>
<td>58</td>
<td>248</td>
<td>294</td>
<td>294</td>
<td>74</td>
<td>969</td>
</tr>
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</table>
Risks level definition

<table>
<thead>
<tr>
<th>Technical Impact</th>
<th>Low Impact</th>
<th>Medium Impact</th>
<th>High Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can be repaired by the team</td>
<td>Somewhat sub-standard</td>
<td>Significantly sub-standard</td>
<td>Extremely sub-standard or KPP in jeopardy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost Impact</th>
<th>Low Impact</th>
<th>Medium Impact</th>
<th>High Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1% of project cost</td>
<td>&lt; 25 k€</td>
<td>1% - 5% of project cost</td>
<td>&gt; 5% of project cost</td>
</tr>
<tr>
<td>&lt; 2% of project duration</td>
<td>&lt;1 month</td>
<td>2 - 5 % of project duration</td>
<td>&gt; 5 % of project duration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Schedule Impact</th>
<th>Low Impact</th>
<th>Medium Impact</th>
<th>High Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 month</td>
<td>1 - 3 months</td>
<td>&gt; 3 months</td>
<td></td>
</tr>
</tbody>
</table>

Risk criticity

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

STATUS OF RISK ANALYSIS:
- 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)
# Project Management

## Risk analysis and mitigation plan

### Preliminary analysis (systemic)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Probability</th>
<th>Schedule impact (month)</th>
<th>Cost impact (k€)</th>
<th>P* schedule impact (months)</th>
<th>P* cost impact (k€)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>RF test forbidden due to ASN restrictions</td>
<td>5</td>
<td>6</td>
<td>0.1</td>
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<tr>
<td>Accident during BCP etching</td>
<td>5</td>
<td>2</td>
<td>0.1</td>
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<tr>
<td>Accident during cavity handling</td>
<td>5</td>
<td>1</td>
<td>0.05</td>
<td></td>
<td>0</td>
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<tr>
<td><strong>Management</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Human resources not available due to other projects</td>
<td>25</td>
<td>1</td>
<td>0.25</td>
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<td>0</td>
</tr>
<tr>
<td>Difficulties to hire temporary workers</td>
<td>25</td>
<td>3</td>
<td>0.75</td>
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<td>Loss of a temporary worker (resignation)</td>
<td>25</td>
<td>3</td>
<td>0.75</td>
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<tr>
<td>Funding lost because of delay in activities (yearly funding)</td>
<td>25</td>
<td>0</td>
<td>200</td>
<td>0</td>
<td>50</td>
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<tr>
<td>Cavity loss or damages during transportation to FNAL</td>
<td>1</td>
<td>1</td>
<td>150</td>
<td>0.02</td>
<td>1.5</td>
</tr>
<tr>
<td>Custom fees not waived on time because of incomplete procedure</td>
<td>10</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td><strong>External</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase of helium cost</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Qualified vendors not available for production</td>
<td>10</td>
<td>6</td>
<td>0</td>
<td>0.6</td>
<td>25</td>
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<tr>
<td>More than 25% of production cavities have to be re-processed</td>
<td>50</td>
<td>4</td>
<td>50</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Testing facilities not/partially available because of other projects</td>
<td>25</td>
<td>6</td>
<td>0</td>
<td>1.5</td>
<td>25</td>
</tr>
<tr>
<td>Clean room not/partially available because of other projects</td>
<td>25</td>
<td>6</td>
<td>0</td>
<td>1.5</td>
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<tr>
<td>CV1250 not operational</td>
<td>10</td>
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### Risk evaluation

<table>
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<th>Risks</th>
<th>Schedule (month)</th>
<th>Cost (k€)</th>
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<tr>
<td>Systemic</td>
<td>6.41</td>
<td>81.5</td>
</tr>
<tr>
<td>Technical (cavity)</td>
<td>5.185</td>
<td>155.34</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>11.6</strong></td>
<td><strong>237</strong></td>
</tr>
</tbody>
</table>

- 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)
• 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).
• Project management
  • Communication between FNAL and IJCLab is well established, monthly report to be started soon
  • PIP-II team at IJCLab is organized and sufficient to ensure completion of prototyping phase
  • Hiring of non-permanent dedicated personnel 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).
  • 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, …)
  • 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.
  • 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
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)
  - COVID-19 : retards conséquents sur le projet (CD-4 retardée de 15 mois à décembre 2028).
  - Été 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 boîte 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

PIP-II Project
L. Merminga
PROJECT DIRECTOR
US TECHNICAL COORDINATOR

PROJECT MANAGER
M. Kaducak

TECHNICAL DIRECTOR
A. Klebaner

PROJECT SCIENTIST
E. Pozdeyev

IN-KIND CONTRIBUTIONS MANAGER
L. Lari

ENVIRONMENTAL, SAFETY & HEALTH SPECIAL ADVISOR
J. Anderson Jr.
S. Holmes

INTERNATIONAL COORDINATION
Technical Coordinators
- DAE-BARC
- DAE-RRCAT
- UK-UKRI
- ITALY-INFN
- FRANCE-CEA
- FRANCE-CNRS/IN2P3
- POLAND-WUST

S. Krishnagopal
P. Shrivastava
P. McIntosh
C. Pagani
O. Napoli
D. Longuevergne
M. Chorowski

PROJECT OFFICE
Project Manager - M. Kaducak
Project Controls Manager - D. Leeb

OPSS CONSULTANT
D. Hoffer

FINANCIAL MANAGER
D. Knapp (acting)

PROCUREMENT MANAGER
S. Gaugel

Procurement Administrators
C. Blanchard
S. Cozzens

RISK MANAGER
L. Taylor

LOGISTICS MANAGER
TBD

DOCUMENT SYSTEM MANAGER
T. Langford

EXECUTIVE ADMINISTRATION
T. Langford
K. Hannapel

ADVISORY COMMITTEES
- PIP-II Machine Advisory Committee
  H. Weise
- PIP-II Project Management Group
  D. Gienzinski
- PIP-II Strategic Project Advisory Committee
  J. Yeck

FNAL SUPPORT
- ACCELERATOR DIV
  M. Lindgren
  A. Romanenko
  V. Peoples
- CFO OFFICE
  T. Turner (acting)
- WDRS OFFICE
  A. Kenney
  K. Gregory
- CEO OFFICE
  D. Gienzinski
- CFO OFFICE
  D. Gienzinski

TECHNICAL INTEGRATION
Technical Director - A. Klebaner
- PROJECT ENGINEER
  L. Kokoeka
  A. Rowe
  A. Martinez
  R. Crawford
  J. Holzbauer
  J. Adetunji
  T. DiGrazia
  M. Luedke

QUALITY ASSURANCE MGR

QUALITY ENGINEER (SRF/CRYO)

WBS 121.01
PROJECT MANAGEMENT
M. Kaducak
System Manager

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

WBS 121.03
ACCELERATOR SYSTEMS
E. Harms
System Manager

WBS 121.04
LINE 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

09/02/2021
Conseil scientifique IN2P3 – IN2P3 contribution to PIP-II - Longuevergne
Detailed cost distribution

Somme de Cout (base+incarctude)   Étiqueté T

<table>
<thead>
<tr>
<th>Étiqueté</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
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<tr>
<td>2 COO cavité (1 A1, 1 B1 pour inspection et tests cryo)</td>
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<td>17</td>
<td>17</td>
<td>17</td>
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<tr>
<td>Equipment ICLab</td>
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<td>Equipment Livable</td>
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<td>RF feed-through Qp et Qp and blank flange intermediate</td>
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<tr>
<td>RF feed-through Qp et Qp and blank flange for final test</td>
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<td>Cryogenic components for vertical test</td>
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<td>Cavity surface processing at ICLab (96P+144HPFR)</td>
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</tbody>
</table>

| Total général |      |      |      |      |      |      |      |      |      | 3694         |

09/02/2021
Conseil scientifique IN2P3 – IN2P3 contribution to PIP-II - Longuevergne
### Prototyping Phase

- **4 cavités (6 tests)**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Semaines</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>recep</td>
<td>1 semaine/cav + prep 4 semaines</td>
<td>8</td>
<td>19%</td>
</tr>
<tr>
<td>BCP</td>
<td>0.5 semaine/cav + prep 4 semaines + test bare cav</td>
<td>11</td>
<td>26%</td>
</tr>
<tr>
<td>Salle blanche</td>
<td>2 semaines/cav + prep 4 semaines</td>
<td>16</td>
<td>38%</td>
</tr>
<tr>
<td>Four</td>
<td>0.5 semaine/ cav + 1 semaine</td>
<td>3</td>
<td>7%</td>
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<tr>
<td>cryo</td>
<td>1 semaine/ test + prep 4 semaines</td>
<td>8</td>
<td>19%</td>
</tr>
<tr>
<td>test RF</td>
<td>0.5 semaine/test + prep 4 semaines</td>
<td>6</td>
<td>14%</td>
</tr>
<tr>
<td>montage</td>
<td>1 semaine/test + prep 4 semaines</td>
<td>10</td>
<td>24%</td>
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</table>

### Production Phase

- **33+8 cavités à tester (8 à reconditionner)**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Semaines</th>
<th>FTE</th>
</tr>
</thead>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>48%</td>
</tr>
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<td></td>
<td>5</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14.5</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>60%</td>
</tr>
</tbody>
</table>
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

Cryomodule

- Design in progress by Fermilab, DAE

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

- RF design done at Fermilab
- Collaborative mechanical design FNAL/IPNO/BARC

Material: Bulk Niobium
- $\beta = 0.472$
- $F_0 = 325$ MHz
- $T : 2K$
- $E_{acc} : 11.5$ MV/m
- $B_{pk}/E_{acc} = 6.75$ mT/MV/m
- $E_{pk}/E_{acc} = 3.5$
- $r/Q = 305$ $\Omega$
- $G = 115$
Frequency shift during manufacturing, processing & test

Manufacturing phase
- Trimming of Endwalls
- EBW Endwalls
- Jacketing

Processing phase
- Coarse RF tuning
- Leak check
  - BCP
  - H degassing
  - Fine RF tuning

Test phase
- VTS test

Frequency shift measured experimentally
- Calculable frequency shift
- Frequency shift for 1mm added
- $\Delta f$ with displacement
- $\Delta f$ with vacuum in RF volume
- $\Delta f$ with the cool down $293K \rightarrow 2K$
- $\Delta f$ for 1mm added

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

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

Drying in clean room (cavity + tank) → HPR (cavity) → BCP (cavity)
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

H-degassing
H-degassing + flash BCP
H-degassing + flash BCP + baking
No H-degassing

MYRRHA Simple Spoke Cavity
Preliminary cavity flow chart for cavity surface processing

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?
  - Heat treatment 650°C 10h
  - Fine freq tuning
  - VTS test (Qo vs Ecc, X)
  - Hold point Spec are met?
  - Cavity dressing
- Hold point
  - Leak check, weighing, freq measurement
  - Overnight Drying
  - Light BCP <50 um
- Drying, Weighing, freq measurement
- HPR
- 48h Drying
- Assembly, slow pump down
- Leak check
- Hold point
- Coarse freq tuning
  - coupling measurement, weighing, cleaning US bath
  - BULK BCP 200 um
- Drying, Weighing, freq measurement
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 Bulk BCP performed on the jacketed cavity

CAV N°3 Bulk BCP performed on the jacketed cavity

CAV FNAL

CAV N°1 Same preparation steps after bulk BCP

CAV N°2

CAV N°3

CAV FNAL

650°C baking

RF Tuning

Clean Room after bulk BCP

Flash BCP

Clean Room after flash BCP

120°C baking

VTS Test

HPR cart

RF tuning

VTS test
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

03/12/2020
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 | Install | Coold down | Endurance | Regulation | Holding | Warm-up | Idle |
## Summary

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

- 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, suppressing by bias, 11 kW, 20% refl., 90 dgr.

RF model (FNAL)

Thermal model (FNAL)
SSR Coupler

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

<table>
<thead>
<tr>
<th>Work cases</th>
<th>1</th>
<th>2</th>
<th>2bis</th>
<th>2ter</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>295K thermal straps thermal conductance (4 straps / coupler)</td>
<td>No straps (no heat exchange)</td>
<td>0.124 W/K</td>
<td>0.124 W/K</td>
<td>0.24 W/K</td>
<td>0.124 W/K</td>
</tr>
<tr>
<td>Air flow</td>
<td>Off</td>
<td>On (2 g/s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Note about boundary conditions (BC)</td>
<td>Radiation to ambient BC adding 0.78 W to ceramic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat flow [W] for a whole model</td>
<td>at 2 K (i.e. cavity part at He temp)</td>
<td>-0.172</td>
<td>-0.173</td>
<td>-0.176</td>
<td>-0.176</td>
</tr>
<tr>
<td></td>
<td>at 5 K (thermal strap end x1)</td>
<td>-1.99</td>
<td>-2.00</td>
<td>-2.03</td>
<td>-2.03</td>
</tr>
<tr>
<td></td>
<td>at 50 K (thermal strap end x2)</td>
<td>-9.96</td>
<td>-10.1</td>
<td>-10.7</td>
<td>-10.6</td>
</tr>
<tr>
<td></td>
<td>at 295 K (thermal strap end x4)</td>
<td>12.1</td>
<td>11.4</td>
<td>12.8</td>
<td>8.08</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>T_max (K)</th>
<th>295</th>
<th>295</th>
<th>295</th>
<th>295</th>
<th>295</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_min ceramic (K)</td>
<td>39</td>
<td>292.8</td>
<td>292.8</td>
<td>273.4</td>
<td>276.4</td>
</tr>
<tr>
<td>T_min ceramic (°C)</td>
<td>-71.4</td>
<td>-45.6</td>
<td>-45.6</td>
<td>0.3</td>
<td>3.2</td>
</tr>
<tr>
<td>T_max ceramic (K)</td>
<td>262.8</td>
<td>264.8</td>
<td>273.5</td>
<td>280.2</td>
<td></td>
</tr>
<tr>
<td>T_max ceramic (°C)</td>
<td>10</td>
<td>8.3</td>
<td>8.3</td>
<td>7.1</td>
<td></td>
</tr>
</tbody>
</table>

No RF Power (static case)

With RF (nominal)

With RF (full reflection)
## Conclusion, fulfillment of requirements

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

<table>
<thead>
<tr>
<th>Mechanical Parameter</th>
<th>Value</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input coaxial line aperture, mm</td>
<td>76.9</td>
<td>Y</td>
</tr>
<tr>
<td>Input coaxial line impedance, Ω</td>
<td>50</td>
<td>Y</td>
</tr>
<tr>
<td>Output coaxial line aperture, mm</td>
<td>72.9</td>
<td>Y</td>
</tr>
<tr>
<td>RF window</td>
<td>Single, RT</td>
<td>Y</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Diagnostic</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature sensors (per each coupler)</td>
<td>see description above</td>
</tr>
<tr>
<td>E-probe current monitor</td>
<td>1</td>
</tr>
<tr>
<td>Vacuum pressure gauge in proximity of the ceramic windows</td>
<td>1</td>
</tr>
<tr>
<td>Bias current monitor</td>
<td>1</td>
</tr>
<tr>
<td>Bias voltage monitor</td>
<td>1</td>
</tr>
<tr>
<td>Air output flow monitor</td>
<td>1</td>
</tr>
</tbody>
</table>
Présentation du projet : PBS

Fichier complet accessible sur ATRIUM : ATRIUM-390229
Fichier complet accessible sur ATRIUM : **ATRIUM-390229**