INFN per PIP-II – Proton Improvement Plan II

Rocco Paparella per il team SRF LASA

Consiglio di Sezione INFN

29.6.2020

A Partnership of:

- US/DOE
- India/DAE
- Italy/INFN
- UK/UKRI-STFC
- France/CEA, CNRS/IN2P3
- Poland/WUST

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

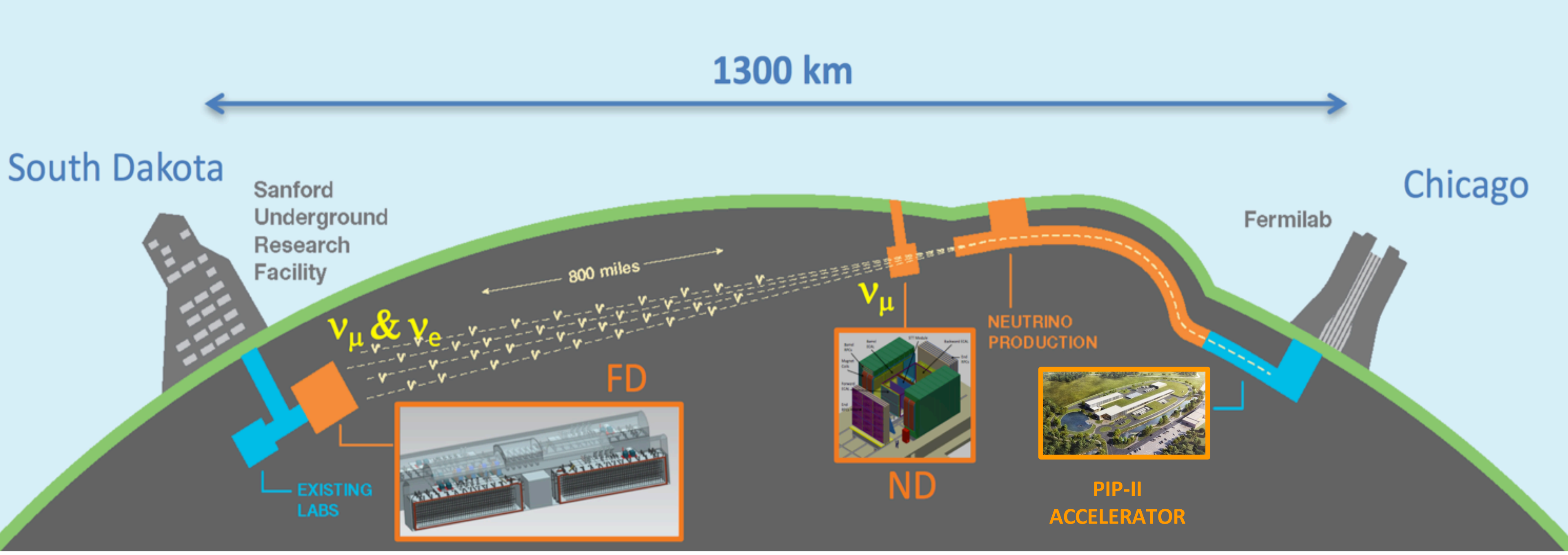
- Build a world-class neutrino program
  - definitive measurements of neutrino oscillations, search for proton decay and neutrinos from supernova bursts
- Host it as a global project
- Upgrade Fermilab accelerator complex to provide >1 MW proton beam

Recommendation 13: Form a new international collaboration to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S. To proceed, a project plan and identified resources must exist to meet the minimum requirements in the text. LBNF is the highest priority large project in its timeframe.

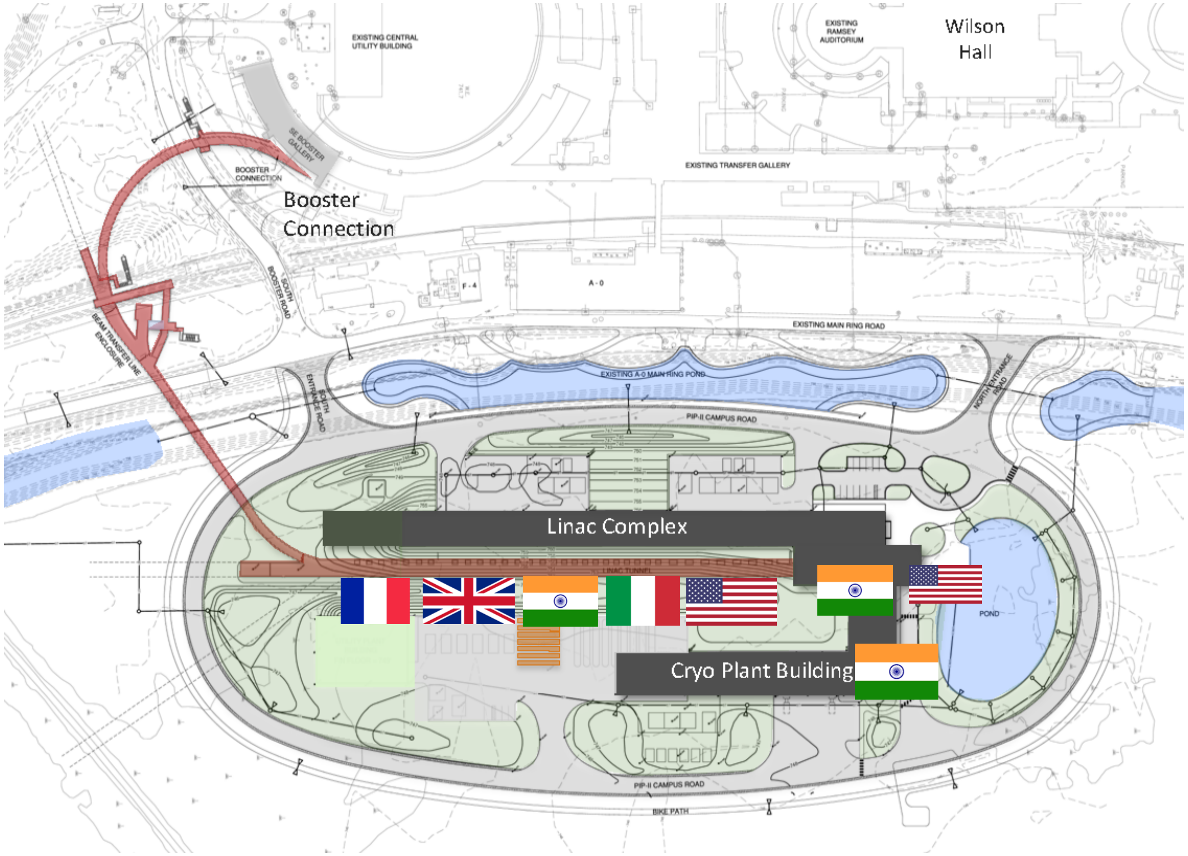
Recommendation 14: Upgrade the Fermilab proton accelerator complex to produce higher intensity beams. R&D for the Proton Improvement Plan II (PIP-II) should proceed immediately, followed by construction, to provide proton beams of >1 MW by the time of first operation of the new long-baseline neutrino facility.

PIP-II / LBNF / DUNE

- Powerful proton beams (**PIP-II**)
  - 1.2 MW upgradable to multi-MW to enable world's most intense neutrino beam
- Dual-site detector facilities (**LBNF**)
  - Deep underground cavern (1.5 km) of 70kt liquid argon fiducial volume
  - A long baseline (1300 km)
- Deep Underground Neutrino Experiment (**DUNE**)
  - Liquid Argon – the next-generation neutrino detector



PIP-II Scope



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

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

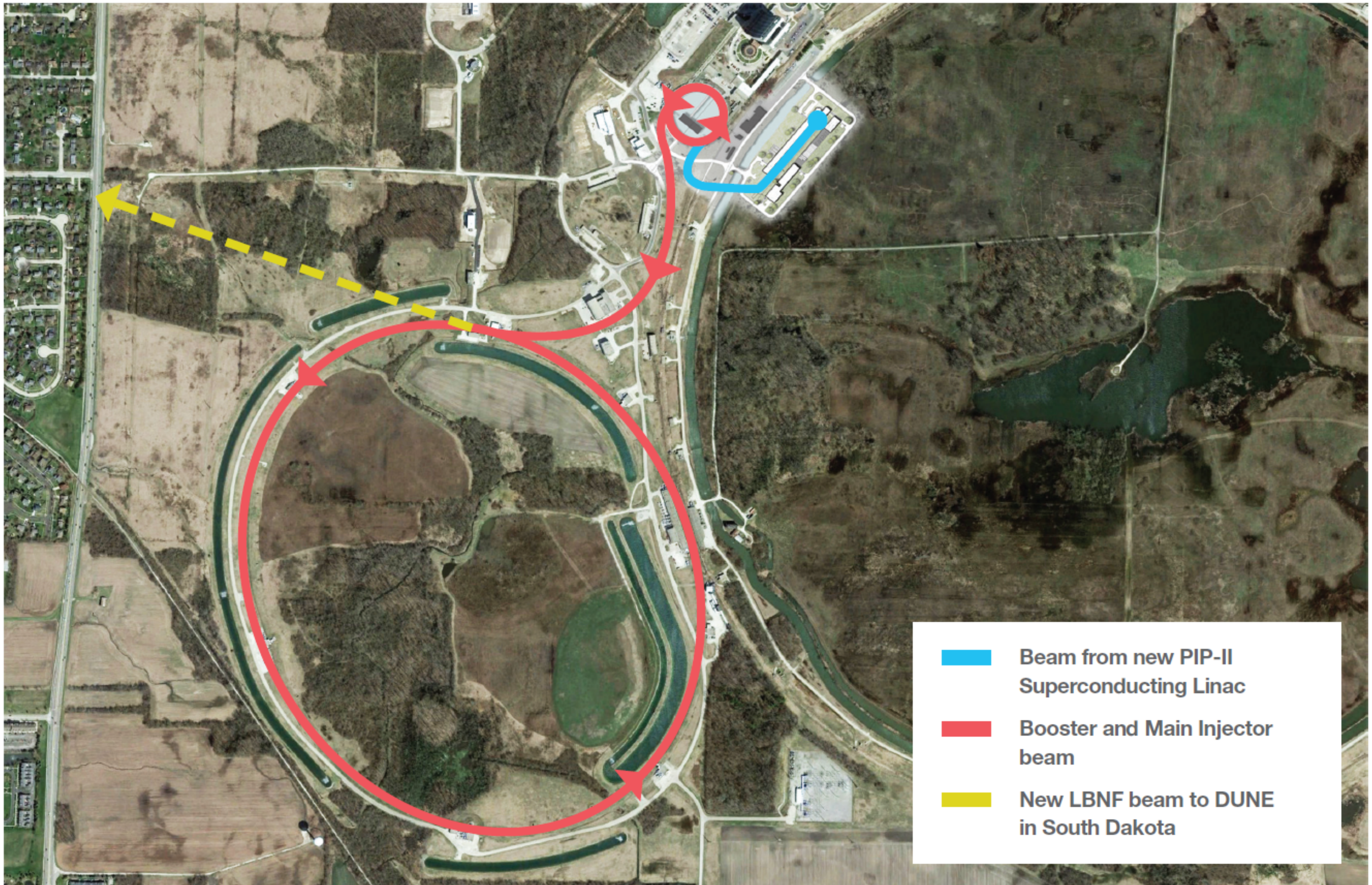
Upgraded Booster
- 20 Hz, 800 MeV injection
- New injection area

Upgraded Recycler & Main Injector
- RF in both rings

Conventional facilities
- Site preparation
- Cryoplant Building
- Linac Complex
- Booster Connection

New scope was recently included under direction of the DOE, enabling the complex to reach 1.2 MW proton beam on LBNF target.

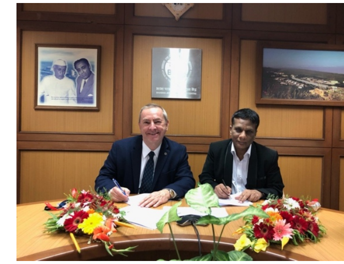
Fermi National Accelerator Laboratory May 2018



The PIP-II project will supply powerful neutrino beams for the LBNF/DUNE experiment.

PIP-II International Partners, Expertise and Capabilities

India, Department of Atomic Energy (DAE) (started 2009)
BARC, RRCAT, VECC; also IUAC



Substantial engineering/manufacturing experience
Superconducting magnets for LHC; 2 GeV synch light source

Italy, INFN (started 2016)

Internationally recognized leader in superconducting RF technologies
SRF cavity and cryomodule fabrication for XFEL; SRF cavities for ESS

UK, UKRI (started 2017)

Substantial engineering and manufacturing experience
Construction, operation of synch light & neutron sources
SRF cavity processing and testing for ESS

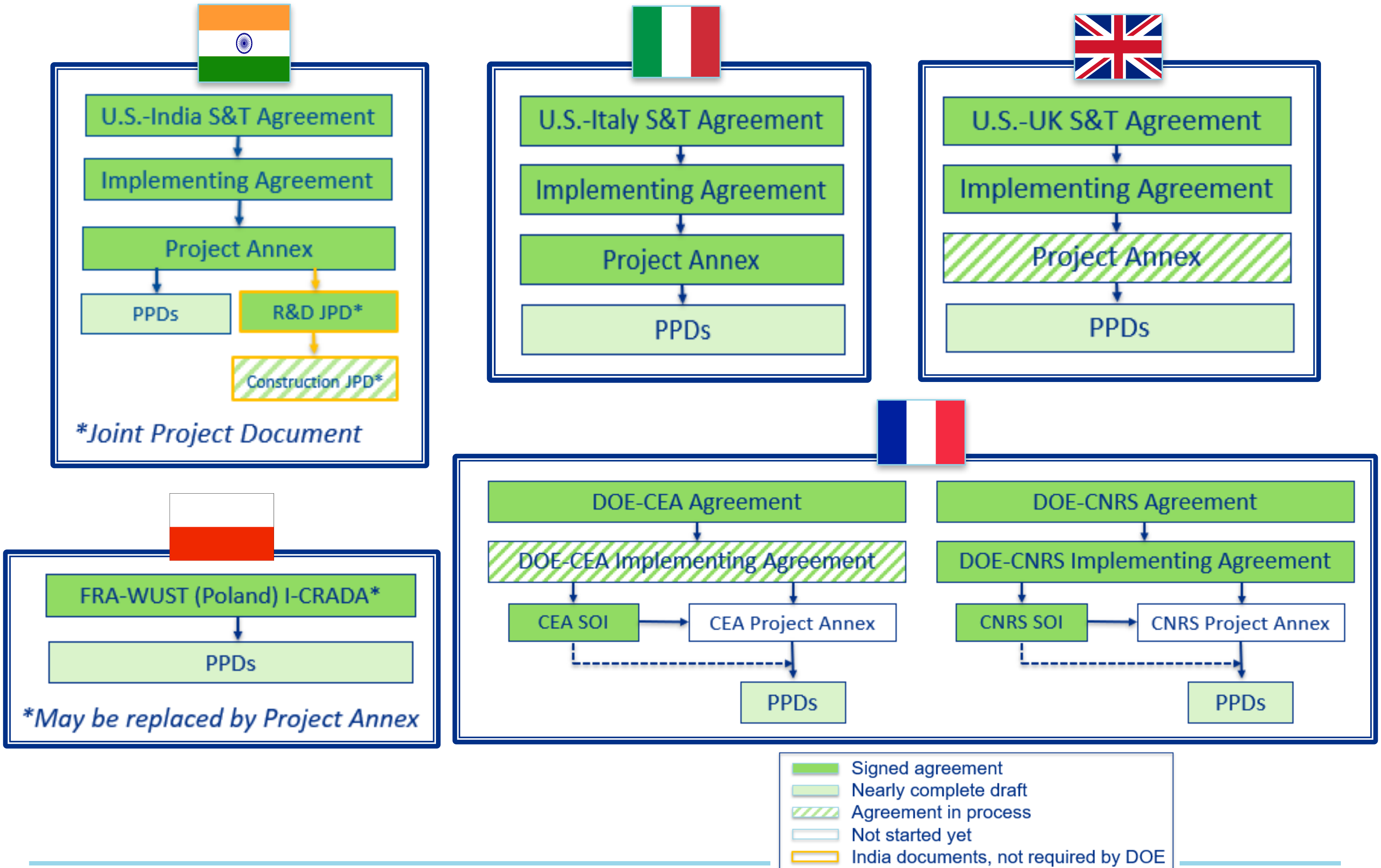
France, CEA, CNRS/IN2P3 (started 2017)

Internationally recognized leader in large-scale CM assembly
CM assembly for European XFEL and ESS
SSR2 cavities and couplers for ESS

Poland, WUST (started 2018)

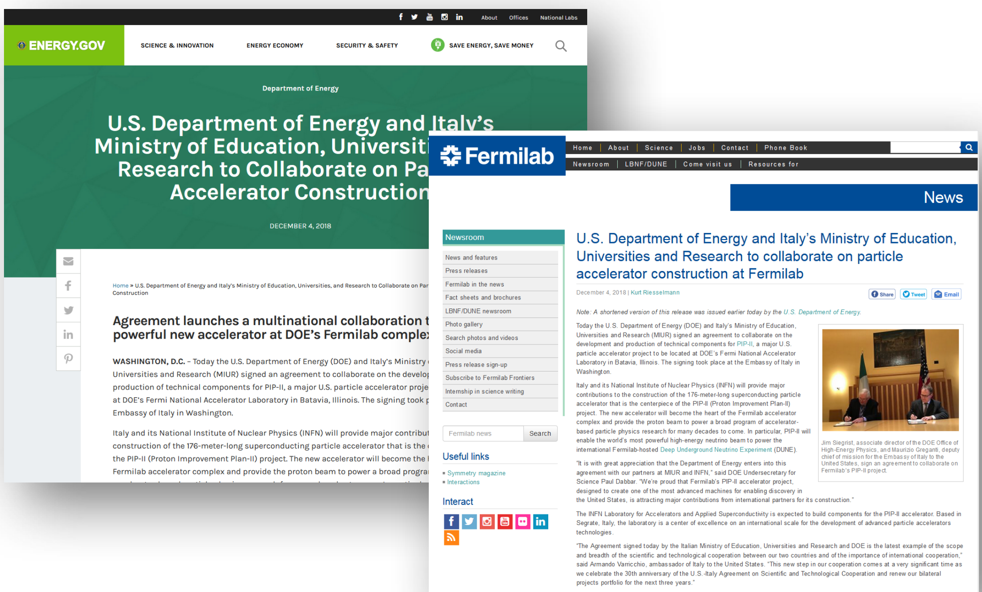
Substantial engineering and manufacturing experience
CDS, LLRF, QC for XFEL and ESS

Status of PIP-II International Agreements



INFN & PIP-II

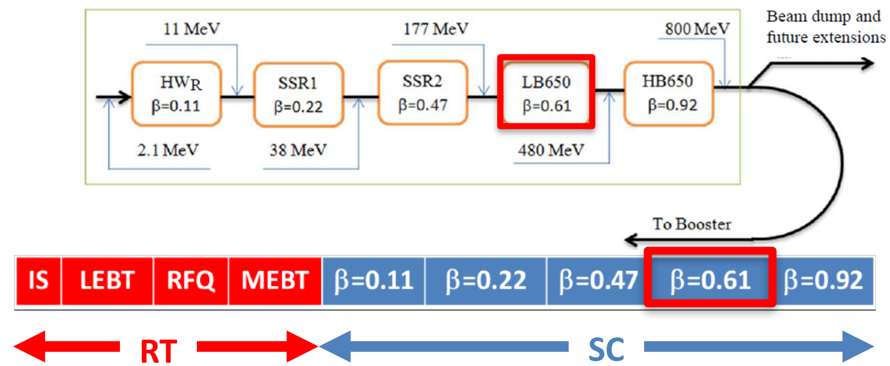
- **A long-term fruitful Collaboration exists between Fermilab and INFN.**
  - A first agreement between DoE and Italian Ministry of Education, University and Research (MIUR) in July 2017 quote **high power proton accelerators.**
  - Green light in 2018 from MIUR for an Italian participation to the realization of PIP-II through **an in-kind contribution mediated by INFN LASA.**
  - INFN-LASA is today expected to build the 650 MHz cavities required by the low-beta section of the front-end linac, as **signed by US Department of Energy and Italian MIUR on December 4th 2018.**

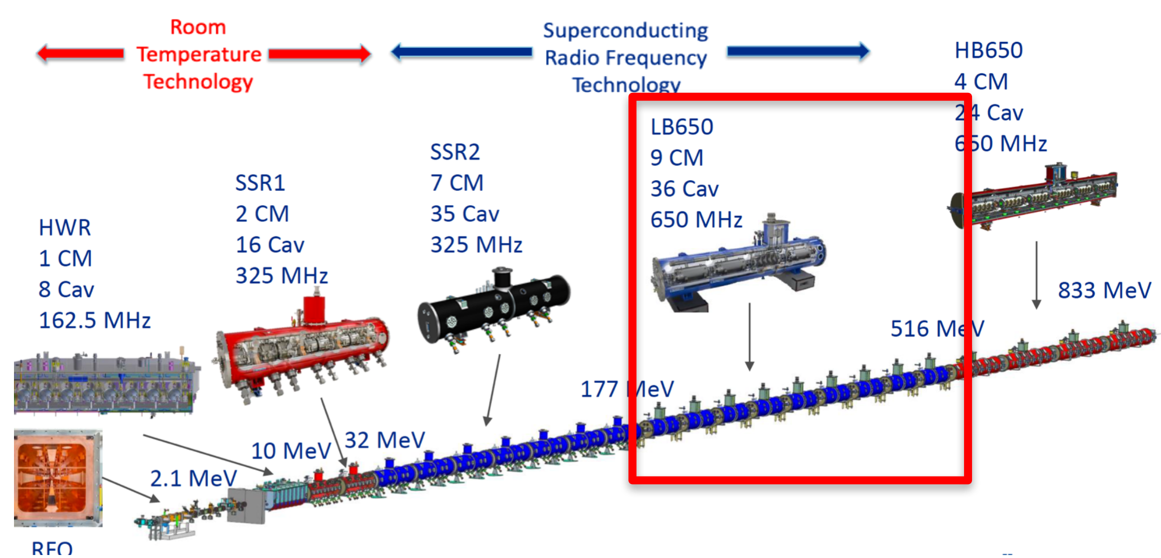



December 4th, 2018, the U.S. DOE and Italy's MIUR agreement signed

The PIP-II linac

- **800 MeV, 2 mA H- beam.**
- Final energy up to 120 GeV using Booster and Main Injector.
- Modern superconducting linac of **CW-capable** components, initially operated in **pulsed mode**.
- 23 CMs, 119 cavities of 5 types





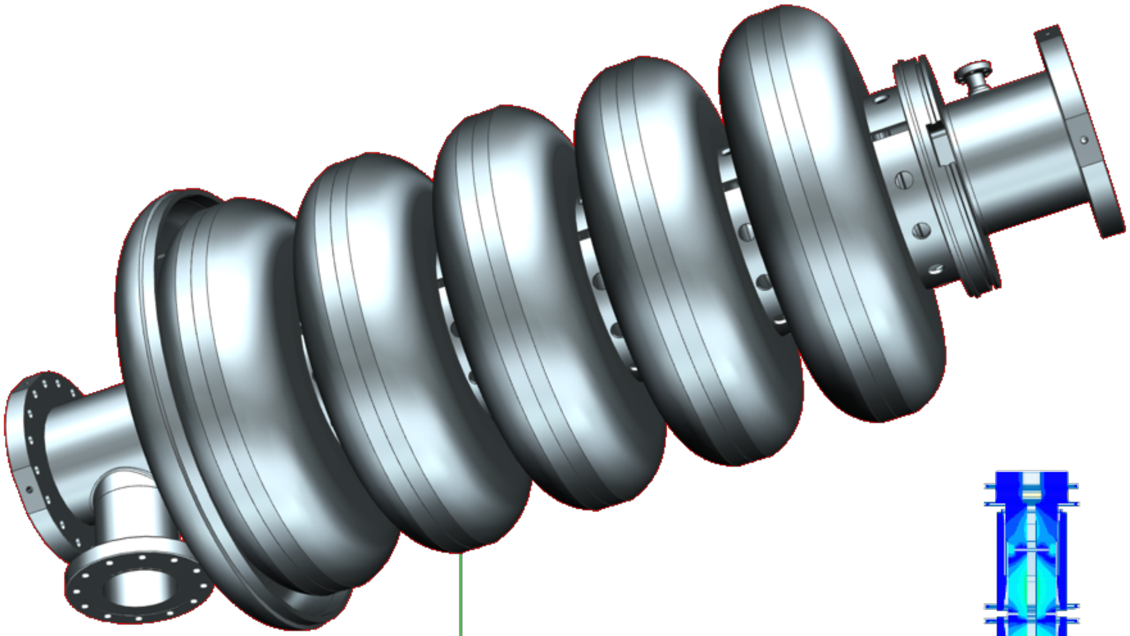
PIP-II LB650 Project Specifications	
Acc. Gradient	16.9 MV/m
Q_0	$2.4\ 10^{10}$
RF rep rate	20 Hz/0.55 ms to CW
Beta	0.61

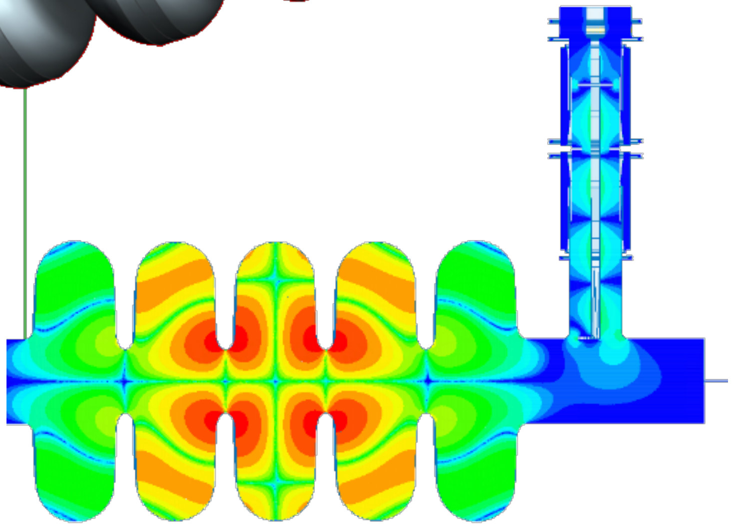
Low-Beta (LB650, β=0.61) cryomodule and cavity specifications

INFN-LASA contribution to PIP-II

- INFN-LASA contribution **will cover** the needs of LB650 section, and this includes:
  - **38 SC cavities** required to equip **9 cryomodules** with 2 spares, delivered **as ready for string assembly**.
  - **Qualification** via vertical cold-test provided by INFN through a **qualified cold-testing infrastructure** acting as a subcontractor
  - **Compliance** to the **PIP-II System Engineering Plan**.
- INFN - LASA already achieved:
  - a **novel RF and mechanical design for the LB650 cavities** that then became the official cavity design. It's fully plug compatible with the Fermilab technical interfaces and meeting performance requirements.
  - Single-cell and multi-cell **LB650 prototypes** with the tooling and recipes required for inner surface treatments
  - Finalization of **Project Plan Document** describing INFN in-kind contribution
  - Engagement of mutual technical teams

INFN LB650 Cavity Design



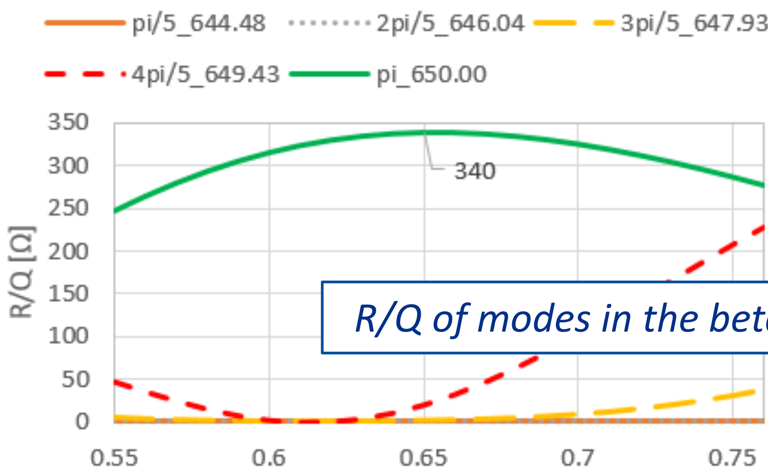


Example of **EM analyses performed**: Dipole HOM at 1678 MHz showing partial reflections in the FPC

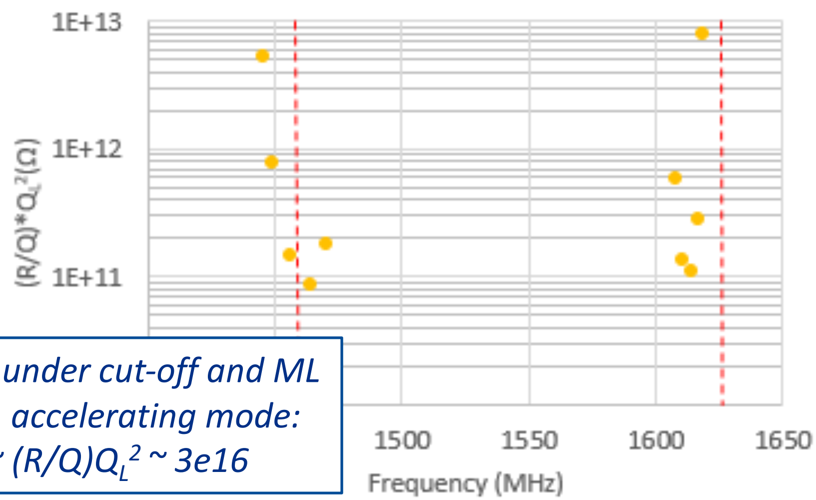
INFN LB650 for PIP-II, cold cavity	
$\beta_{geometric}$	0.61
Frequency	650 MHz
Number of cells	5
Iris diameter	88 mm
Cell-to-cell coupling, k_{cc}	0.95 %
Frequency separation π-4π/5	0.57 MHz
Eq. diameter - IC	389.8 mm
Eq. diameter - EC	392.1 mm
Wall angle – Inner & End cells	2 °
Effective length (10*L_{hc})	704 mm
Optimum beta β_{opt}	0.65
E_{peak}/E_{acc} @ β_{opt}	2.40
B_{peak}/E_{acc} @ β_{opt}	4.48 mT/(MV/m)
R/Q @ β_{opt}	340 Ω
G @ β_{opt}	193 Ω
Inner cells stiffening radius	90 mm
External cells stiffening radius	90 mm
Wall thickness	4.2 mm
Longitudinal stiffness	1.8 kN/mm
Longitudinal frequency sensitivity	250 kHz/mm
LFD coefficient *k_{ext} at 40 kN/mm*	-1.4 Hz/(MV/m)^2
Pressure sensitivity *k_{ext} at 40 kN/mm*	-11 Hz/mbar
Maximum Pressure *VM stress at 50 MPa*	2.9 bar
Maximum Displacement *VM stress at 50 MPa*	1.5 mm

Electromagnetic Design

High-Order Modes risks have been assessed and neither instabilities (klystron-type or Beam-Breakup) nor additional cryogenic losses are posing critical issues.

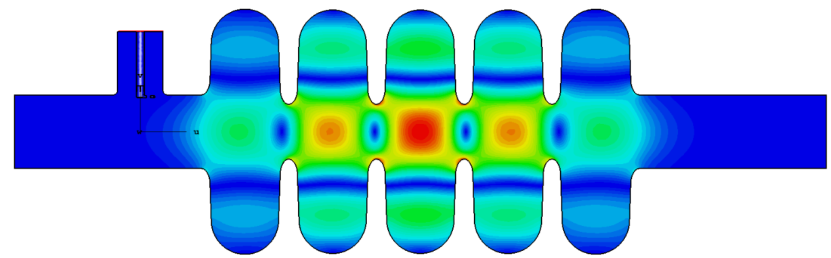


R/Q of modes in the beta range

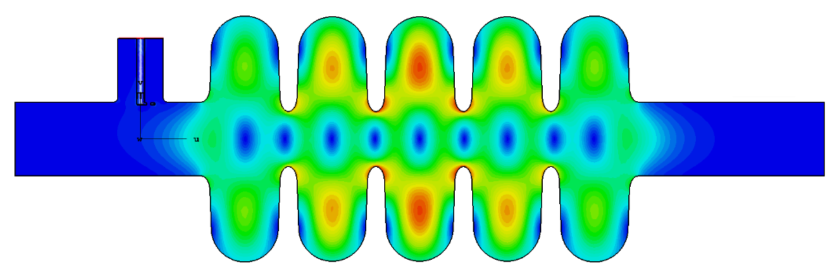


Monopoles under cut-off and ML
Reference, accelerating mode:
20 W ~ $(R/Q)Q_L^2$ ~ 3e16

Last mode in 2nd monopole passband,
+8 MHz away from 9th ML



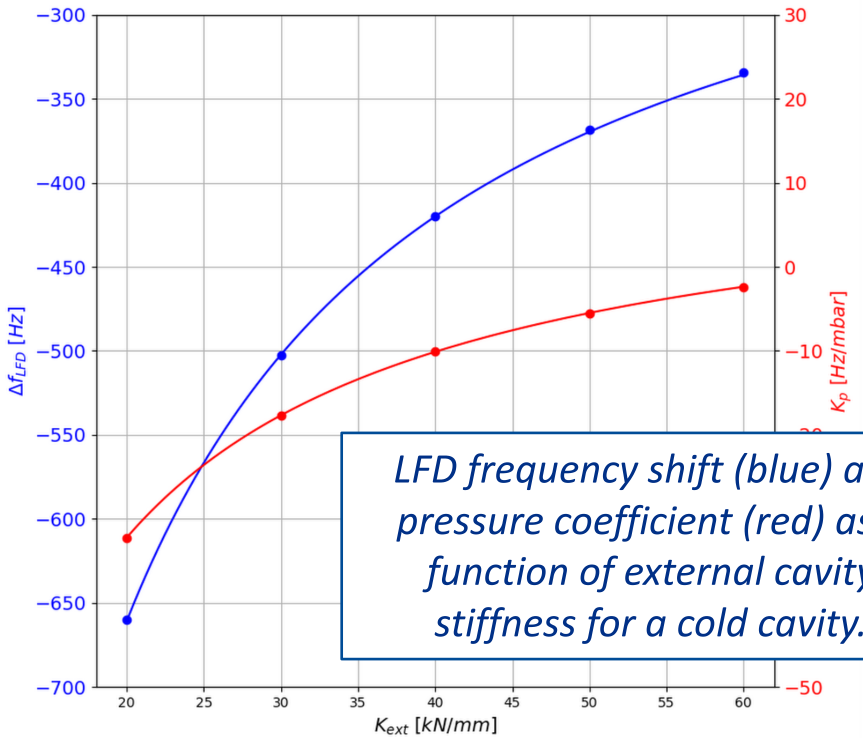
Last mode in 3rd monopole passband,
-6.5 MHz away from 10th ML



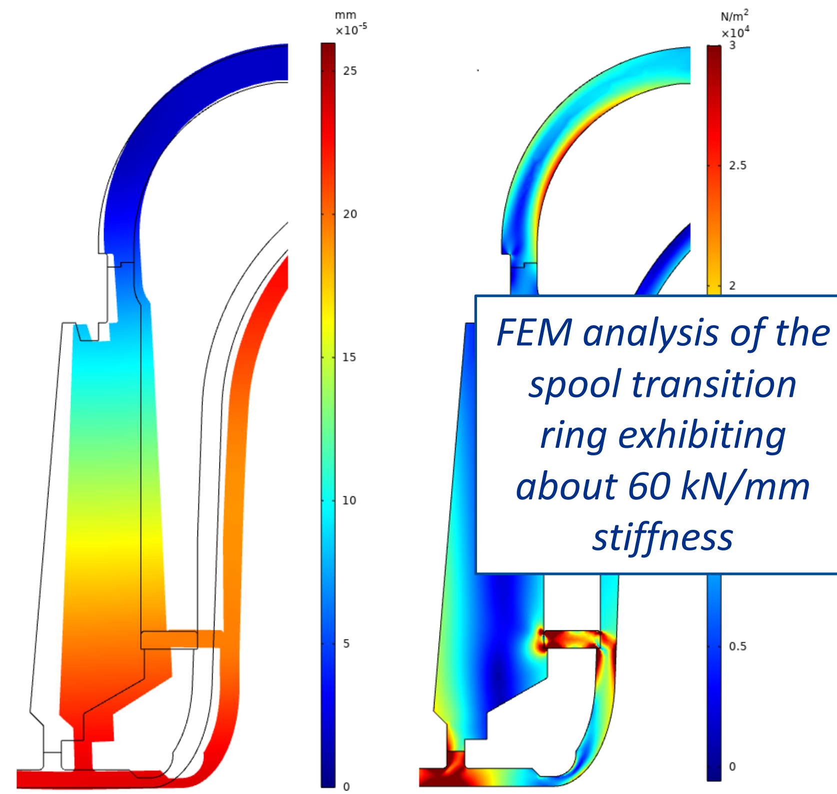
Mechanical Design

The relatively small beam current of PIP-II results in an external Q of the cavity as high as 10^7 that in turns implies a narrow bandwidth of the accelerating mode.

In order to have a stable beam acceleration, an extremely strict control of the Lorentz Force Detuning (LFD, or pulsed RF) and microphonic is required: the PIP-II operational scenario reveals to be an uncharted territory in terms of detuning control.



LFD frequency shift (blue) and pressure coefficient (red) as a function of external cavity stiffness for a cold cavity.

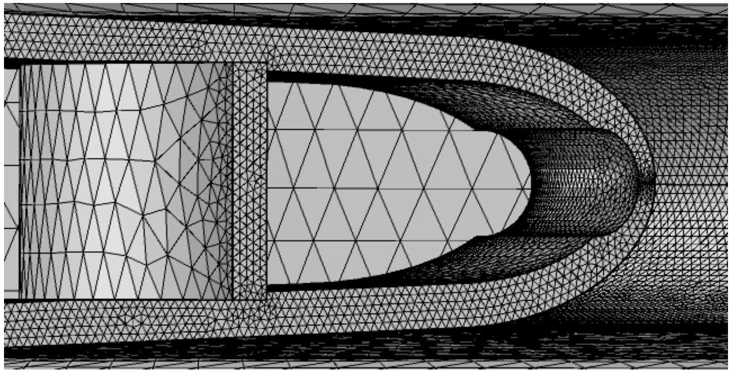


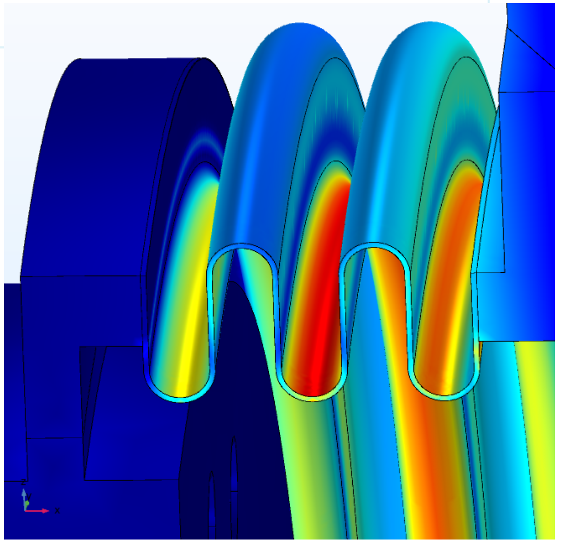
FEM analysis of the spool transition ring exhibiting about 60 kN/mm stiffness

PIP-II ES&H at Fermilab

- Extensive **finite element analysis** of the cavity included simulations to evaluate the integrity of the cavity per the **Fermilab ES&H Manual** within *Mechanical, Cryogenic and Structural Safety* chapter.
- The simulations include several cases to ensure that the operating loads are below the maximum allowable limits:
  - protection against plastic collapse
  - local failure, buckling.
  - Ratcheting or fatigue failure

Successful Proto FDR at Fermilab on 7-8 Nov. 2019

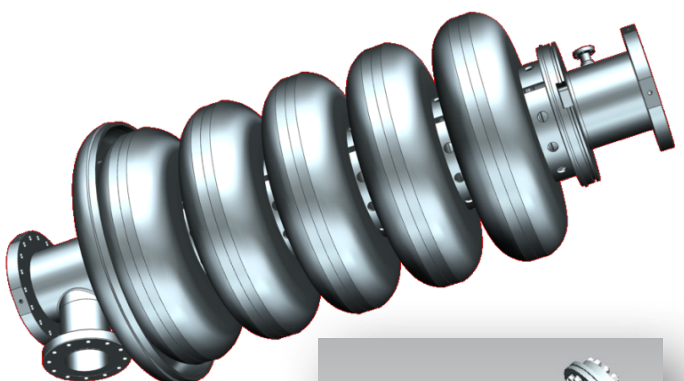


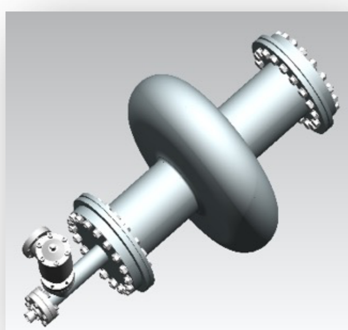


From design to prototype

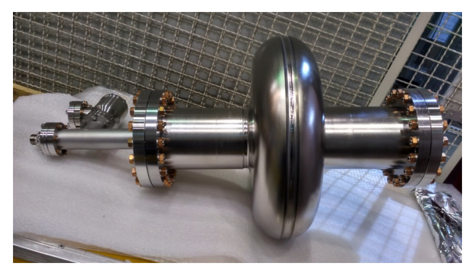
In order start validating cavity design, fabrication procedures and surface treatments, several **prototype cavities** already manufactured:

- **5 single-cell cavities**, realized with terminal half cells
- **2 complete 5-cell cavities**, fully compliant to the current state of cavity interfaces as per Fermilab specifications.
  - Eddy Current scanning of Nb sheets done at DESY as for the ESS cavities.





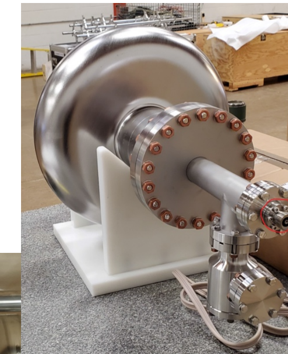
INFN prototypes as designed

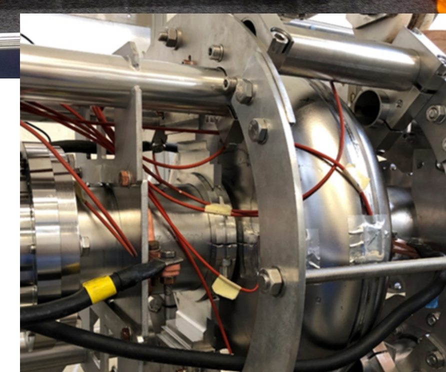


LB650 cavities

INFN LB650 Prototypes

- **3 cavities at Fermilab**
  - **LB650 PIP2_L001** prototype, as welded
  - LB650 EZ_SCCFG005 single-cell test cavity, as welded
  - ESS-like prototype, 702.4 MHz, 6-cells, b=0.67 with LG niobium, ready for VT
  - samples from niobium sheets for material analyses
- **3 cavities at LASA**
  - **LB650 PIP2_L002** prototype, already tuned for FF and frequency
  - 3 LB650 single-cell test cavities, as welded (EZ_SCCFG004, EZ_SCCLG001 EZ_SCCLG002)
- **1 cavity at Zanon**
  - EZ_SCCFG003 LB650 single-cell test cavity





INFN-LASA and Fermilab parallel agenda items

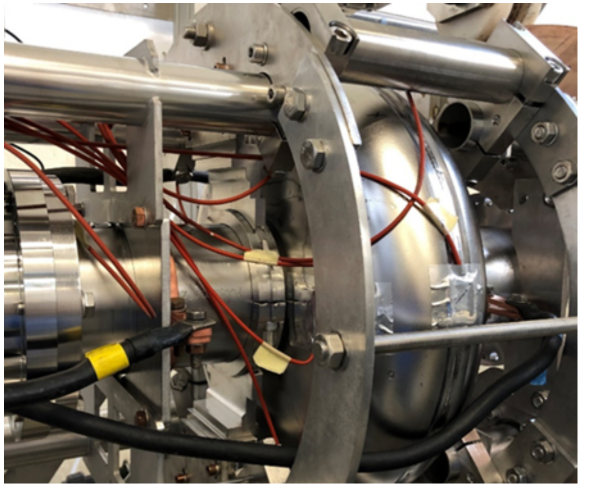
- **Electro-Polishing RF surface treatment**: specific tools are being developed and the process recipe is being optimized for the PIP-II geometry with steep cell walls.
  - The difference in size and shape requires a **careful optimization** of treatment parameters and **electrode geometry** with respect to 1.3 GHz tesla-shaped cavities
- Surface treat and **qualify by means of vertical tests** in both infrastructures the existing prototypes
- In-depth **characterization of magnetic flux expulsion** performances of the Niobium material of these prototypes at the VTS facility at FNAL.
- Jacketing and dressing of at least one multi-cell prototype to conclude this phase with an **horizontal test with power coupler** by mid 2021*.

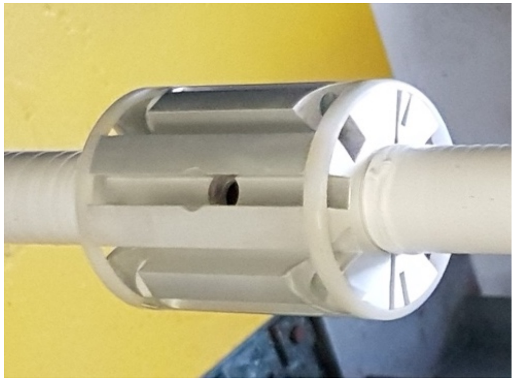
* Effects of COVID-19 lockdowns still to be defined

Development of EP for PIP-II at INFN-LASA

The already existing EP plant at E. Zanon (used for XFEL and LCLS-II cavity production) is being optimized on the new cavity geometry and shape.

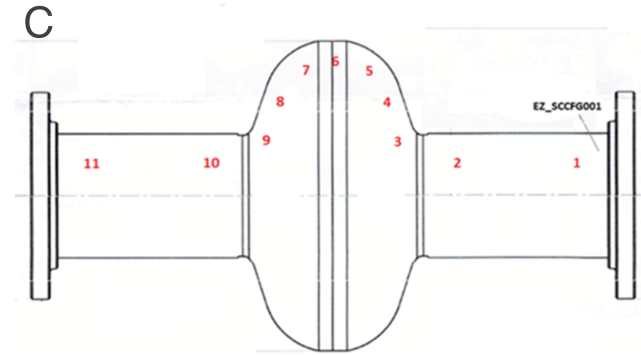
- Rotating frame properly **adapted to host LB650 single cell** cavities.
- Cathode shielded (50% of coverage) with a PTFE tape in correspondence of the beam tubes
- External water cooling spraying system is installed on the beam tubes
- Thermocouples and a US probe for **online thickness measurement** on cavity surface.
- An Al cylindrical enlargement has been procured to increase cathode surface and get 1:10 electrode-to-cavity surface ratio.
- **Acid and water cooling improved** for colder temperature (down to less than 10 °C for flash EP)



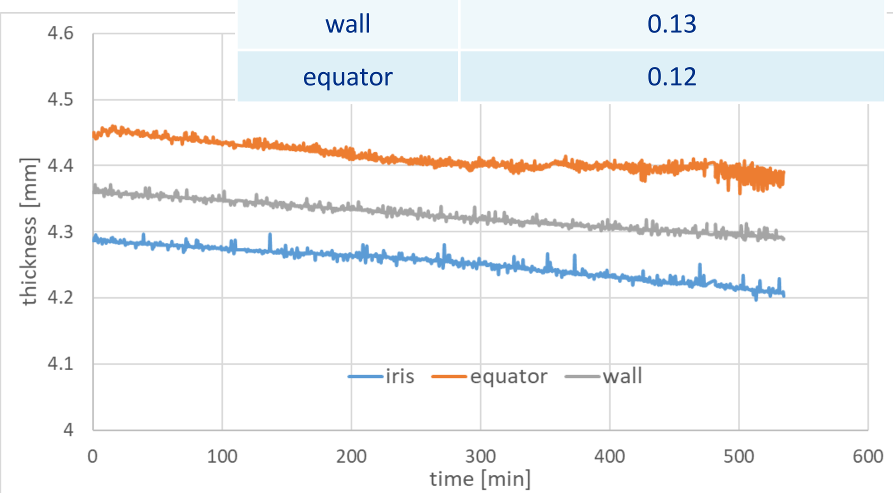


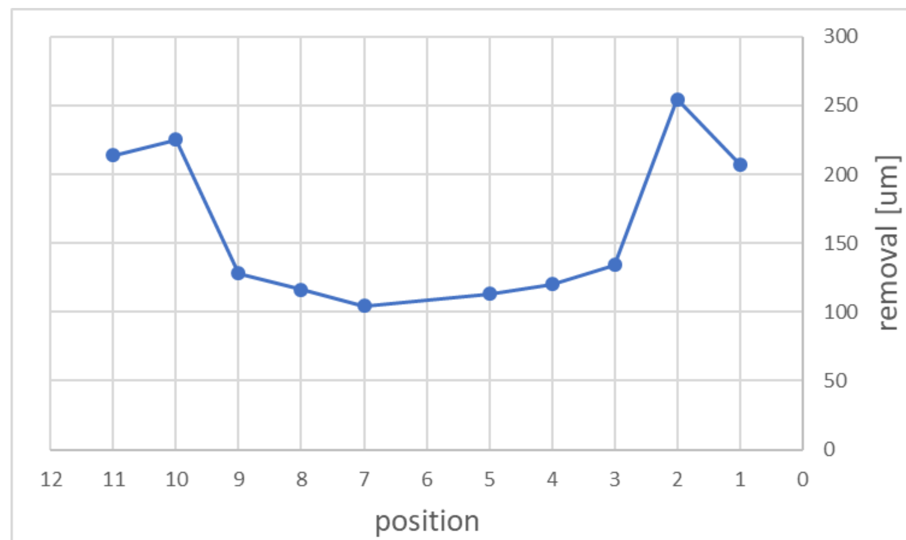
INFN LB650 – Bulk EP on single-cell

- Bulk EP done on LB650 FG001 single-cell at Zanon on refurbished EP plant (previously used for E-XFEL and LCLS-II)
  - Removal: 157 μm avg. (target is 150 μm)
  - Acid inlet temperature (at beginning of process): 15° C
  - Treatment divided in two steps over 2 days (6.5-6.6)
  - Calculated sensitivity: -1.48 kHz/μm
  - Calculated etching rate [avg.]: 0.14 μm/min
  - Calculated iris/equator removal ratio: 1.7



position	etching rate (linear fit) [μm/min]
iris	0.15
wall	0.13
equator	0.12





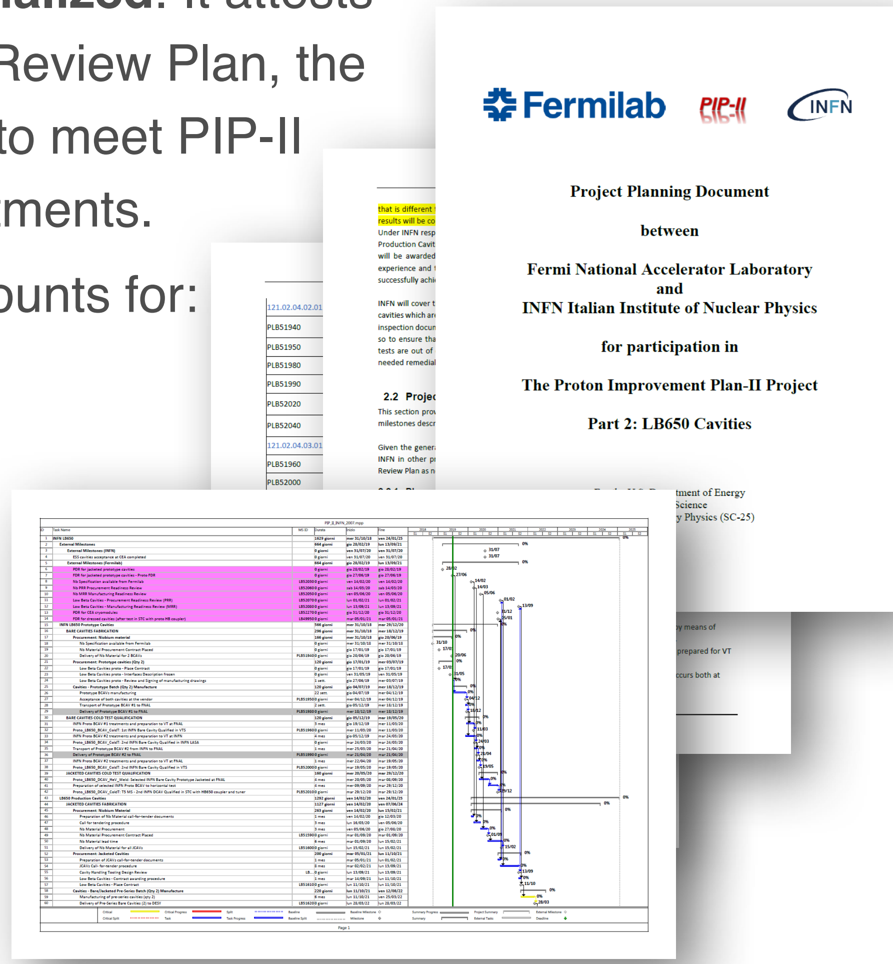
INFN-LASA infrastructure upgrades

INFN cold test **infrastructure at LASA is being upgraded**.

- Cylindrical **cryo-perm inner shield** ordered in order to halve the currently measured 8 mG average remnant field in the cavity equator region.
  - Test installation successfully done at LASA, next heat-treatment
- Development of active and dynamic local magnetic field cancelling through combined use of **Helmholtz's coils** and **flux-gate** sensors
  - Setting almost zero residual magnetic field when SC transition occurs
- Boost in cryogenic plant performances:
  - Higher cryogenic power, up to 70 W at 32 mbar
  - Refilling at 2.0 K option ordered, to extend cavity testing time by means of **counter-flow heat-exchanger** followed by a **Joule-Thomson expander.**
  - Faster cool-down rate, now at about 1-1.5 K/min

PPD and planning for the series production

- **Project Planning Document (PPD) finalized**. It attests the compliance to the PIP-II Technical Review Plan, the procedure issued by Fermilab in order to meet PIP-II technical, schedule and budget commitments.
- For each In-Kind Contributor, PPD accounts for:
  - Scope of Work, high-level activities
  - Description of Deliverable Components and Documentations
  - Project Schedule and Key Milestones
  - Project Management and Control
  - Risk Management, Quality Assurance and Safety
  - Formal system acceptance
- **Key Milestones** agreed upon

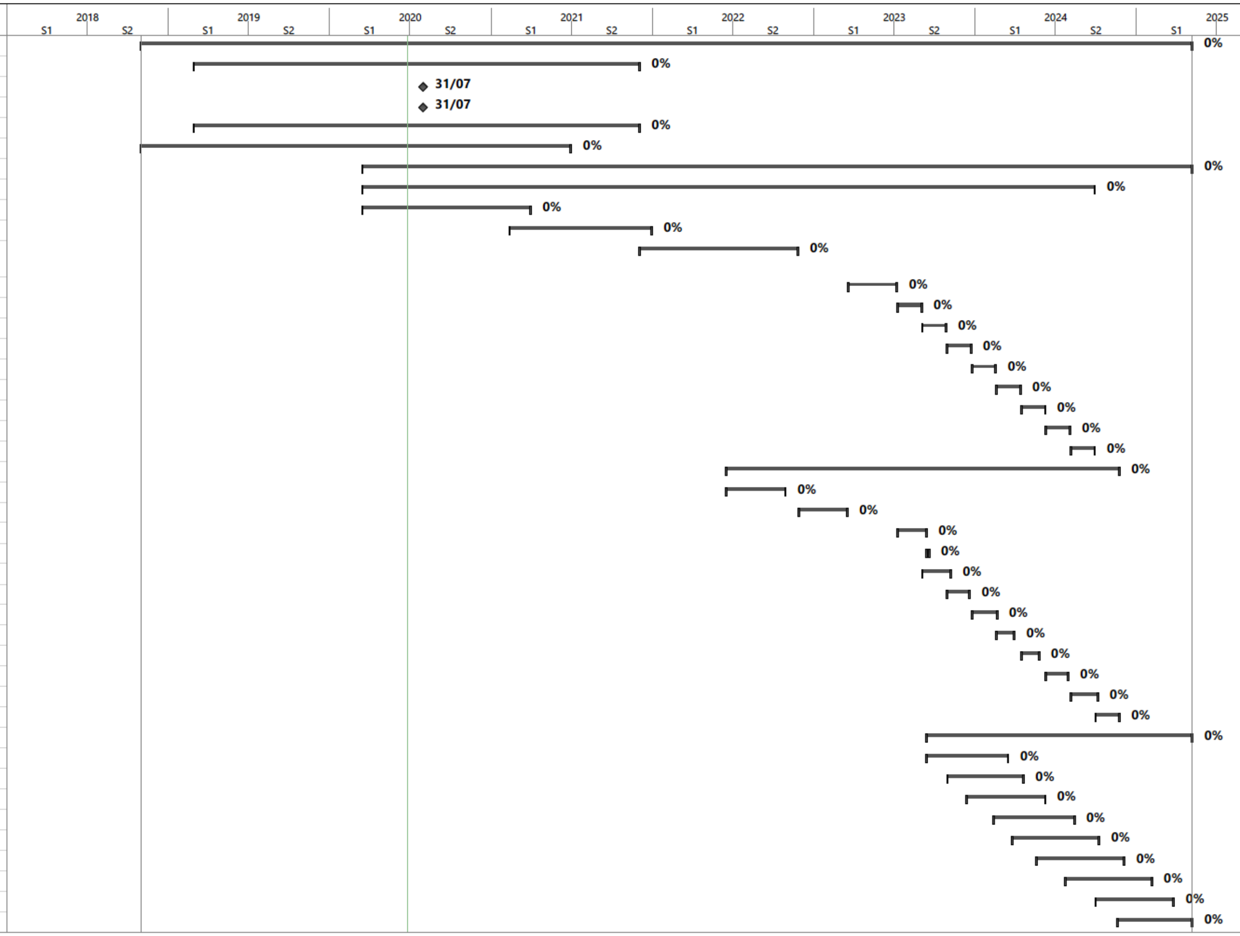


Schedule as from PPD – pre COVID-19!

Realistic schedule developed within an early/late delivery scheme, with the latter already aligned with Fermilab expectations for CM schedule.

2020_03_26 - PIP_II_INFN

Task Name	Durata	Inizio	Fine
INFN LB650	1701 giorni	mer 31/10/18	mar 06/05/25
External Milestones	722 giorni	gio 28/02/19	gio 02/12/21
External Milestones (INFN)	0 giorni	ven 31/07/20	ven 31/07/20
ESS cavities acceptance at CEA completed	0 giorni	ven 31/07/20	ven 31/07/20
External Milestones (Fermilab)	722 giorni	gio 28/02/19	gio 02/12/21
INFN LB650 Pre-Production Cavities	697 giorni	mer 31/10/18	mer 30/06/21
LB650 Production Cavities	1342 giorni	lun 16/03/20	mar 06/05/25
JACKETED CAVITIES FABRICATION	1185 giorni	lun 16/03/20	ven 27/09/24
Procurement: Niobium Material	272 giorni	lun 16/03/20	mar 30/03/21
Procurement: Jacketed Cavities	229 giorni	ven 12/02/21	mer 29/12/21
Cavities - Bare/Jacketed Pre-Series Batch (Qty 2) Manufacture	256 giorni	ven 03/12/21	ven 25/11/22
Cavities - Batch 1 (Qty 4) Manufacture	80 giorni	lun 20/03/23	ven 07/07/23
Cavities - Batch 2 (Qty 4) Manufacture	40 giorni	lun 10/07/23	ven 01/09/23
Cavities - Batch 3 (Qty 4) Manufacture	40 giorni	lun 04/09/23	ven 27/10/23
Cavities - Batch 4 (Qty 4) Manufacture	40 giorni	lun 30/10/23	ven 22/12/23
Cavities - Batch 5 (Qty 4) Manufacture	40 giorni	lun 25/12/23	ven 16/02/24
Cavities - Batch 6 (Qty 4) Manufacture	40 giorni	lun 19/02/24	ven 12/04/24
Cavities - Batch 7 (Qty 4) Manufacture	40 giorni	lun 15/04/24	ven 07/06/24
Cavities - Batch 8 (Qty 4) Manufacture	40 giorni	lun 10/06/24	ven 02/08/24
Cavities - Batch 9 (Qty 4) Manufacture	40 giorni	lun 05/08/24	ven 27/09/24
COLD TEST QUALIFICATION	636 giorni	ven 17/06/22	ven 22/11/24
Cavities - 2 x Bare Pre-Series Qualification	96 giorni	ven 17/06/22	ven 28/10/22
Cavities - 2 x Jacketed Pre-Series Qualification	80 giorni	lun 28/11/22	ven 17/03/23
Cavities - Batch 1 (Qty 4) Qualification	47 giorni	lun 10/07/23	mar 12/09/23
Cavities - Batch 1 + 2 pre-series (Qty 6) Qualification	4 giorni	mer 13/09/23	lun 18/09/23
Cavities - Batch 2 (Qty 4) Qualification	46 giorni	lun 04/09/23	lun 06/11/23
Cavities - Batch 3 (Qty 4) Qualification	37 giorni	lun 30/10/23	mar 19/12/23
Cavities - Batch 4 (Qty 4) Qualification	41 giorni	lun 25/12/23	lun 19/02/24
Cavities - Batch 5 (Qty 4) Qualification	30 giorni	lun 19/02/24	ven 29/03/24
Cavities - Batch 6 (Qty 4) Qualification	30 giorni	lun 15/04/24	ven 24/05/24
Cavities - Batch 7 (Qty 4) Qualification	36 giorni	lun 10/06/24	lun 29/07/24
Cavities - Batch 8 (Qty 4) Qualification	45 giorni	lun 05/08/24	ven 04/10/24
Cavities - Batch 9 (Qty 4) Qualification	40 giorni	lun 30/09/24	ven 22/11/24
FINAL ACCEPTANCE	430 giorni	mer 13/09/23	mar 06/05/25
Cavities - Batch 1 + 2 pre-series (Qty 6) Acceptance	133 giorni	mer 13/09/23	ven 15/03/24
Cavities - Batch 2 (Qty 4) Acceptance	124 giorni	mar 31/10/23	ven 19/04/24
Cavities - Batch 3 (Qty 4) Acceptance	128 giorni	mer 13/12/23	ven 07/06/24
Cavities - Batch 4 (Qty 4) Acceptance	130 giorni	mar 13/02/24	lun 12/08/24
Cavities - Batch 5 (Qty 4) Acceptance	141 giorni	lun 25/03/24	lun 07/10/24
Cavities - Batch 6 (Qty 4) Acceptance	142 giorni	lun 20/05/24	mar 03/12/24
Cavities - Batch 7 (Qty 4) Acceptance	140 giorni	mar 23/07/24	lun 03/02/25
Cavities - Batch 8 (Qty 4) Acceptance	127 giorni	lun 30/09/24	mar 25/03/25
Cavities - Batch 9 (Qty 4) Acceptance	122 giorni	lun 18/11/24	mar 06/05/25



Final remarks

- The final impact of COVID-19 lockdowns will be addressed as soon as each every partner restarts
  - A coherent, realistic and integrated schedule has been created
  - The actual amount of shift in time still to be defined
- 2021 activities at INFN-LASA
  - Complete 2nd part of test program on LB650 single-cell
    - Preparation for VT with high-Q recipe, to be compared to reference E-XFEL recipe results (2020)
    - Cold-test at LASA
  - Complete qualification of LB650 prototype #2
    - Preparation for VT with high-Q recipe
    - Cold test at LASA
  - Follow-up at Fermilab with the LB650 horizontal test
  - Start of series production CFTs (Nb and cavities)

Final remarks

- LASA cryogenic infrastructure is going to be central
  - Delivering all qualification VTs during prototyping phase alongside to a state-of-the-art facility at Fermilab's VTS
  - Backing-up the external qualified VT infrastructure (DESY) for critical cavities requiring special diagnostics or test features:
    - X-ray spectroscopy, cryo X ray detection
    - Quench second sound detection and analysis
    - Fast thermometry
    - Lower temperature, down to 1.5 K
    - And others under development

Final remarks

- Besides few technical challenges unique to this project, the overall envelope of INFN-LASA contribution to PIP-II is comparable to the contribution to ESS project:
  - PIP-II can benefit substantially from the know-how and the competencies earned by INFN-LASA team during the E-XFEL and ESS projects in terms of design, production, quality control, document and data management.
  - The team working at INFN-LASA for the ESS shall be the reference for PIP-II

Chart for DOE as in PPD

	US-DOE	INFN-MIUR
Principal Coordinator	J Siegrist	MIUR reference
Laboratory Director	N Lockyer	A Zoccoli
Technical Coordinator	L Merminga	C Pagani
Sub-Project Managers/Coordinators	S Chandrasekaran	R Paparella

INFN-LASA SRF Team

2020

- 1 Associato Senior
- ~~1 DR (pensione 1 luglio)~~
- 1 Ricercatore TI
- 3 Tecnologi TI
- 1 Tecnologo TD
- 3 AR Tecnologi
- ~~2~~ CTER TI (1 pensione 1 settembre)
- ~~1 CTER TD (rinunciato 30 aprile)~~
- Servizi LASA

2021

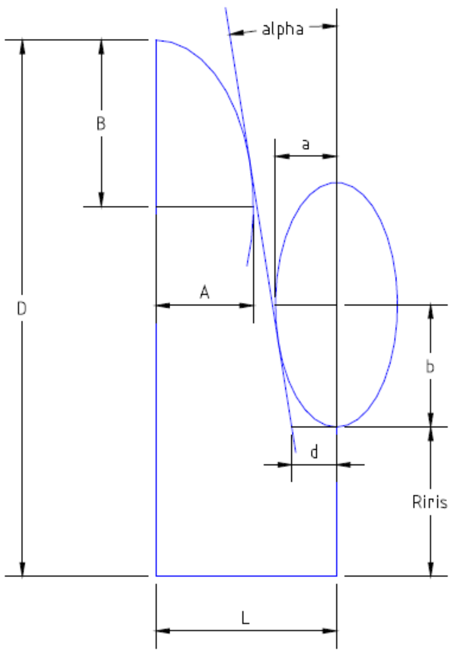
- 1 Associato Senior
- 1 Ricercatore TI
- 3 Tecnologi TI
- 1 Tecnologo TD (TI quando stabilizzato)
- 3 AR Tecnologi
- 1 CTER TI
- 1 CTER TD (elettrotecnico)?
- 2 CTER TD (meccanici/progettisti)?
- Servizi LASA

Extra slides

INFN PIP-II Cavity Design

INFN LB650 RF Design rationales:

- **Cell coupling k_{cc}** optimized assuming TESLA-type cavity as a reference, of the quantity **$N^2/(\beta k_{cc})$,** where N is number of cells, β relative velocity. It models field-flatness sensitivity to cell frequency errors.
- End Cell frequency tuning achieved by **increasing the diameter of the whole terminal cell** thus preserving its round shape and symmetry.
- Maximize G factor while **preserving sidewall angle at 2°** avoiding potentially negative value during the cavity field flatness tuning stage.
- Achieve a **large frequency separation** between π and 4/5 π modes.



Parameters	INFN	FNAL_upd	Jlab	VECC	SNS
βgeo	**0.61**	0.61	0.61	0.61	0.61
frequency (MHz)	**650**	650	650	650	805
number of cells	**5**	5	5	5	6
Iris diameter (mm)	**88**	83	100	96	86
cell-to-cell coupling (%)	**0.95%(↗+23%)**	0.75	1.4	1.24	1.53
Equator diameter (mm)	**389.84**	389.9	380.4	394.8	327.5
Equator ratio R=B/A	**1**	1.07	0.89	1.07	1
Iris ratio r=b/a	**1.77**	1.79	1.47	2.25	1.7
wall angle (inner HC, °)	**2**	2	0	2.4	7
wall angle (end HC,°)	**2**	0.7	0	4.5	8.36/10
Effective length (10*Lhc,mm)	**704**	705	694	703.4	
optimum βopt	**0.65**				
Epeak/Eacc @βopt	**2.40 (↗+3%)**	2.33	2.71	3	2.71
Bpeak/Eacc (mT/(MV/m)) @βopt	**4.48 (↗+2%)**	4.41	4.78	4.84	5.72
R/Q (Ω) @βopt	**340 (↘-4%)**	356	297	296	279
G (Ω) @βopt	**193**	187	190	200	179

Cavity design rationales

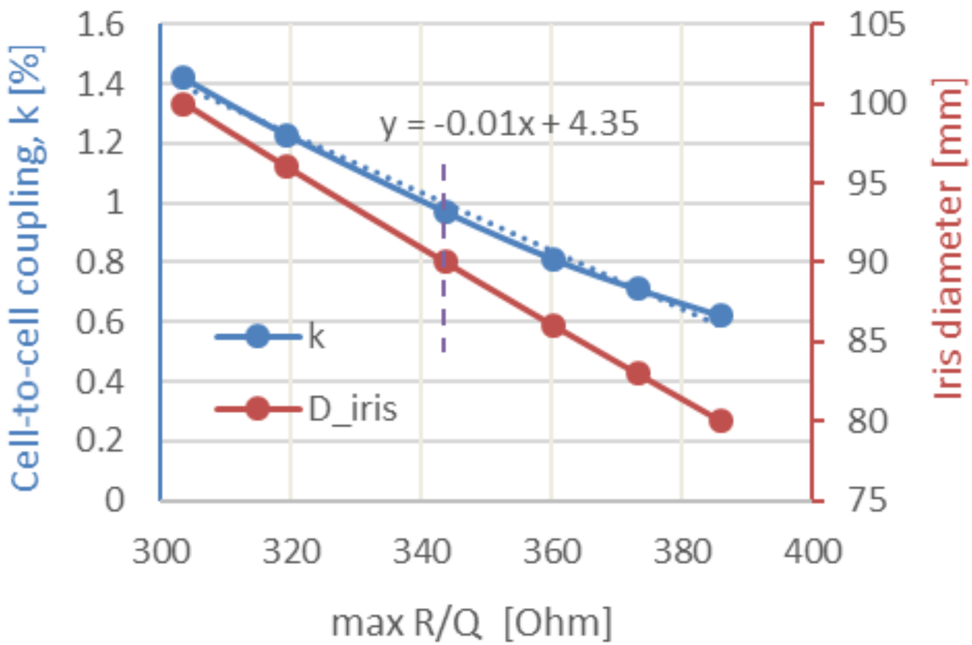
PIP-II cavities are required to be **compatible with CW operation** thus the RF duty factor is not a knob for tuning the dynamic heat load and a high accelerating efficiency in terms of R/Q is instead necessary. In addition, the relatively small beam current of PIP-II (2 mA) results in high external Q of the cavity that implies a **narrow bandwidth** of the accelerating mode.

The **sensitivity of field-flatness** to frequency errors is measured by the ratio:

$$N^2 / \beta k_{cc}$$

N number of cells
β rel. velocity
k_{cc} coupling factor

k_{cc} and iris diameter vs. max R/Q



Comparing existing successful cavities a ***k_{cc} ≥ 0.95 %*** is assumed for PIP-II LB650 cavity

Cav	N	β	k_{cc} (%)	$N^2/(\beta k_{cc})$
TESLA	9	1	1.87	4331
SNS MB	6	0.61	1.52	3883
ESS MB	6	0.67	1.55	3467
PIP-II LB650	5	0.61	**0.95**	4331

Niobium material specifications

A first set of specifications has been issued jointly by INFN and Fermilab for the ongoing manufacturing of prototypes.

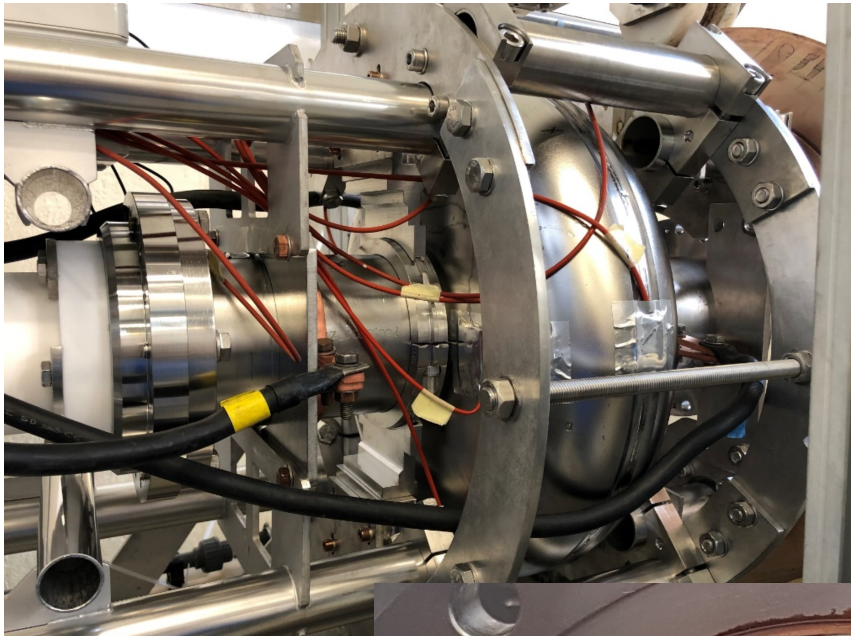
- based on assessed physical and chemical values from E-XFEL and ESS productions
- introducing, for the first time, a harder constrain in the allowed ASTM grain size.
  - Each Niobium sheet shall still be fully recrystallized, exhibit uniform size and equal axed grains
  - predominant size ASTM 5 (0.065 mm) but it's requested to have no grains larger than ASTM 4 (0.090 mm) as well as no grains smaller than ASTM 6 (0.045 mm).

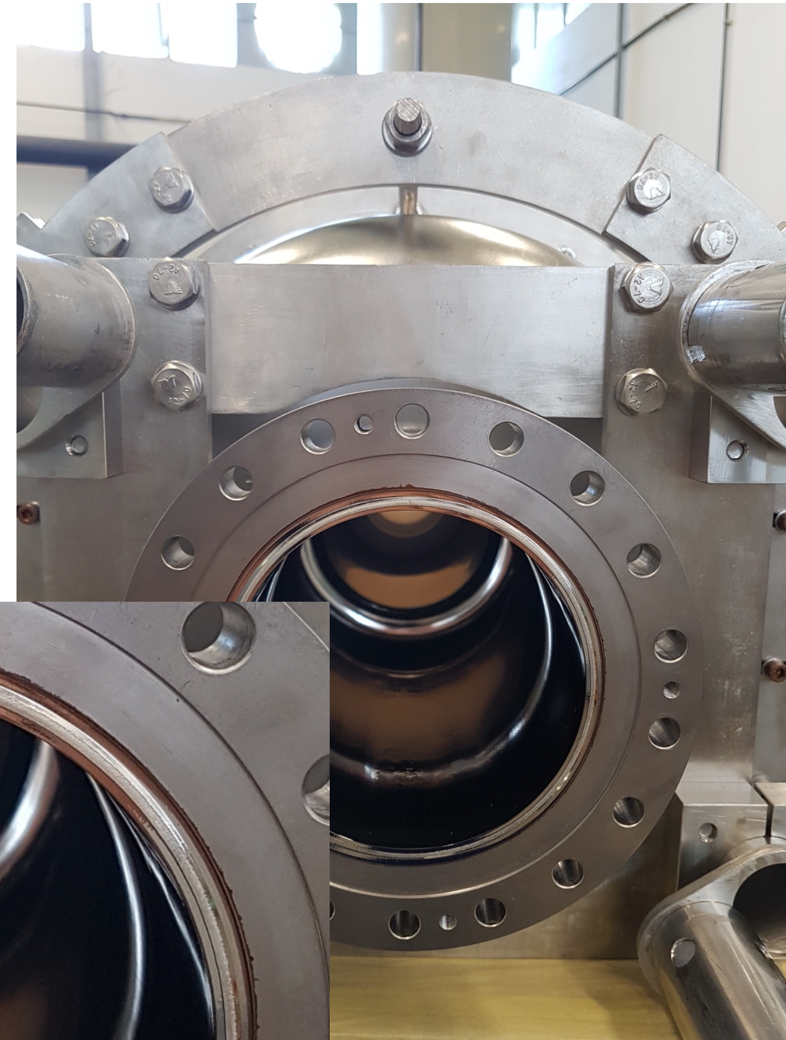
In-depth characterization of magnetic flux expulsion capabilities for this niobium will be allowed by cold qualification test of INFN-LASA prototypes at the VTS facility at Fermilab.

PIP-II: INFN-LASA prototypes plans

- First single cell cavity prototype treated with standard XFEL recipe, **for reference**:
  - 200 μm bulk EP + 700 $^{\circ}$C HT + final EP + 120 $^{\circ}$C bake
  - Cavity test @ INFN-LASA
- **Single cell cavity prototype** retreated with high-Q recipe as agreed with Fermilab:
  - Cavity tested again @ INFN-LASA
  - Results are compared with the «standard recipe» ones (and also with FNAL results on single cell LB cavities)
  - Once qualification values for E_{acc}, Q_0 are reached, we consider the surface treatment validated for LB single cell cavity
- **Multicell cavity prototype** treated with high-Q recipe, basing on previous results on single cells:
  - Cavity tested @ INFN-LASA
  - Once qualification values for E_{acc}, Q_0 are reached, we consider the surface treatment validated for LB multicell cavity.

Surface treatments for PIP-II cavities





INFN team for the PIP-II

In DOE words, we expect MIUR to act as Principal Coordinator and INFN President as Laboratory Director in INFN in-kind organization chart.

- **Here's the chart as included in CD2 Pcoordinat**

	US-DOE	INFN-MIUR
Principal Coordinator	J Siegrist	MIUR reference - tbd
Laboratory Director	N Lockyer	A Zoccoli
Technical Coordinator	L Merminga	C Pagani
Sub-Project Managers/Coordinators	S Chandrasekaran	R Paparella

The team currently working at **INFN for the ESS** shall be a reference.

Project Leader
P. Michelato

Technical Coordinator
D. Sertore

Scientific Advisor
C. Pagani

RF Measurements
A. Bosotti

Cold Testing
R. Paparella

Treatments
M. Bertucci

Technical Support
M. Fusetti
M. Bonezzi
V. Vizziello

Quality Management
L. Monaco
T. Grimaldi

Engineering
A. D'Ambros

INFN and Fermilab Collaboration

- INFN and Fermilab have a long tradition of fruitful collaboration on High Energy Physics and accelerator physics and technology
- INFN Scientists spent years at Fermilab contributing to the top discovery (Tevatron)
- INFN Scientists are participating in the Fermilab neutrino and muon programs
- INFN/Fermilab joint effort in TESLA contributed significantly to the setting of the modern SRF technology.
- After the Cold Recommendation for the global Linear Collider, INFN-LASA helped Fermilab to setup ILC SRF Infrastructures.

INFN-LASA and Fermilab collaborations

- Cryomodule assembling tools, developed by INFN-LASA for TESLA/XFEL and globally distributed for ILC and LCLS-II

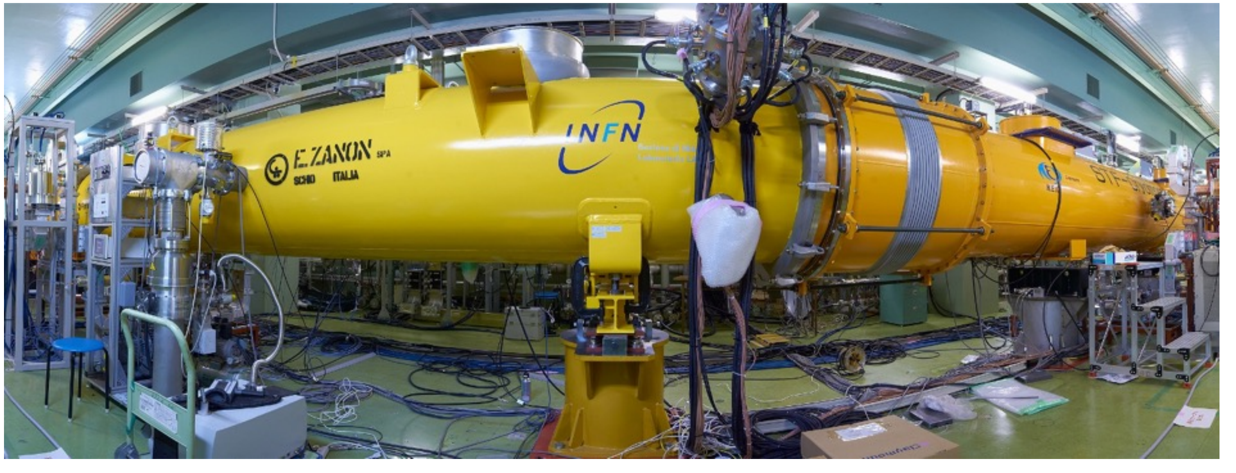





INFN-LASA and Fermilab collaborations

- CM2 Cold mass equipped with Fermilab ‘short’ cavities and INFN Blade tuners

- Special 4 cavity Module and tuners for S1-Global at KEK



PIP-II: INFN-LASA prototypes status

- PIP-II **single-cell cavity prototypes** will be shared so to optimize the recipe for surface treatment (bulk EP + HT + doping + ….)
  - 5 cavities already produced.
  - One has already been shipped to Fermilab.
- **2 completely jacketable 5-cell cavities**, fully compliant to the current state of cavity interfaces as per Fermilab specifications.
  - Eddy Current scanning of Nb sheets at DESY performed, no sheet rejected.
  - Delivery to Fermilab by Feb. 2020.
- An **ESS-like prototype**, 702.4 MHz, 6-cells, b=0.67, has also been shipped to FNAL to anticipate the setting-up of low-beta multi-cell EP infrastructure.
  - This cavity, treated with ESS recipe, has been already tested at LASA.

PIP-II: INFN-LASA prototypes plans

- First single cell cavity prototype treated with standard XFEL recipe, **for reference**:
  - 200 μm bulk EP + 700 ˚C HT + final EP + 120 ˚C bake
  - Cavity test @ INFN-LASA
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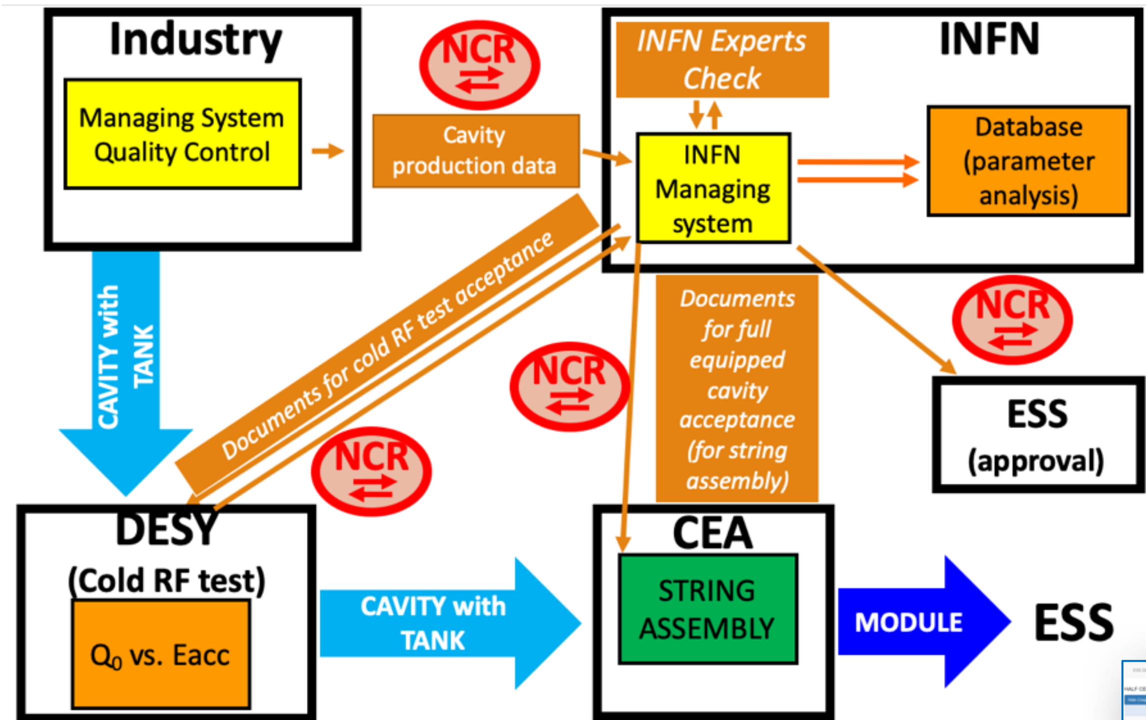
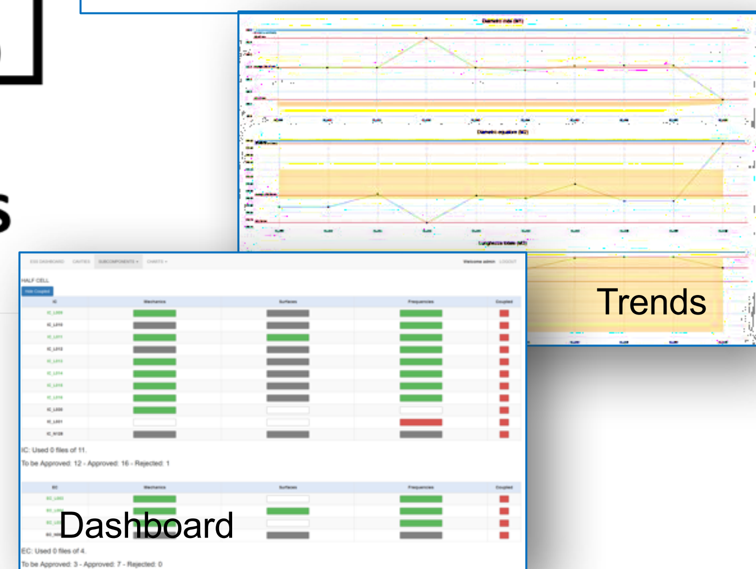
  - Cavity tested @ INFN-LASA
  - Once qualification values for E_{acc}, Q_0 are reached, we consider the surface treatment validated for LB multicell cavity.

PIP-II: QA

Making use of INFN-LASA experience on ESS for the PIP-II



- ≈ 100 documents /cavity
- Total of **> 4000** documents to be:
  - Exchanged among:
  - **EZ – INFN – ESS - CEA**
  - Managed and stored with **INFN ALFRESCO DMS**
  - **Analyzed** for statistics, deviations, guidance and **feedback** for production



Document and data management developed in the framework of brightness collaboration

Summary

- INFN and Fermilab have a long tradition of fruitful collaboration on High Energy Physics and accelerator physics and technology
- The INFN in kind for PIP-II is part of a wider collaboration between Fermilab and INFN to jointly promote the neutrino physics at Fermilab (DUNE, Icarus, CLOE, etc.)
- The SRF experience of INFN LASA in developing and supplying in kind components to international projects perfectly fits the PIP-II scope
- The work on design and prototypes is going as planned
- The PIP-II schedule as presented in the PPD is fully consistent with the expectations based on our experience