PIP-II R&D program: SSR1 Status

Donato Passarelli

DOE Independent Project Review of PIP-II

15 November 2016

Donato Passarelli

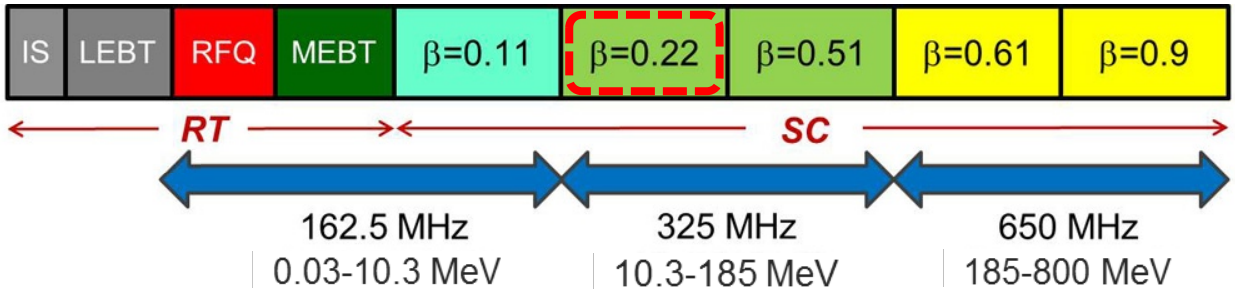
- Role on PIP-II
  - SSR1 Cryomodule System Manager
- Relevant Experience
  - Jacketed SSR1 cavities and tuners: design, manufacturing, and testing
  - Six years in Technical Division, SRF Dept.
  - Mechanical Engineer, PhD 2015 University of Pisa

Outline

- SSR1 cryomodule for PIP-II
  - R&D program and milestones
- Status of SSR1 cryomodule
  - String assembly
    - Jacketed cavities
    - Input power coupler
    - Solenoids and beam position monitors
  - Cold mass assembly
    - SSR1 tuner
- SSR1 CM schedule
- SSR1 Team and work packages
- Collaboration within IIFC on SSR1 cryomodule
  - Jacketed cavities at BARC
  - Production tuners
- Summary

SSR1 cavities and cryomodules for PIP-II

- Single Spoke Resonators of type 1 (SSR1) - superconducting cavities - with β_{opt} = 0.22 operating at 325 MHz are employed for the acceleration from 10.3 MeV to 35 MeV

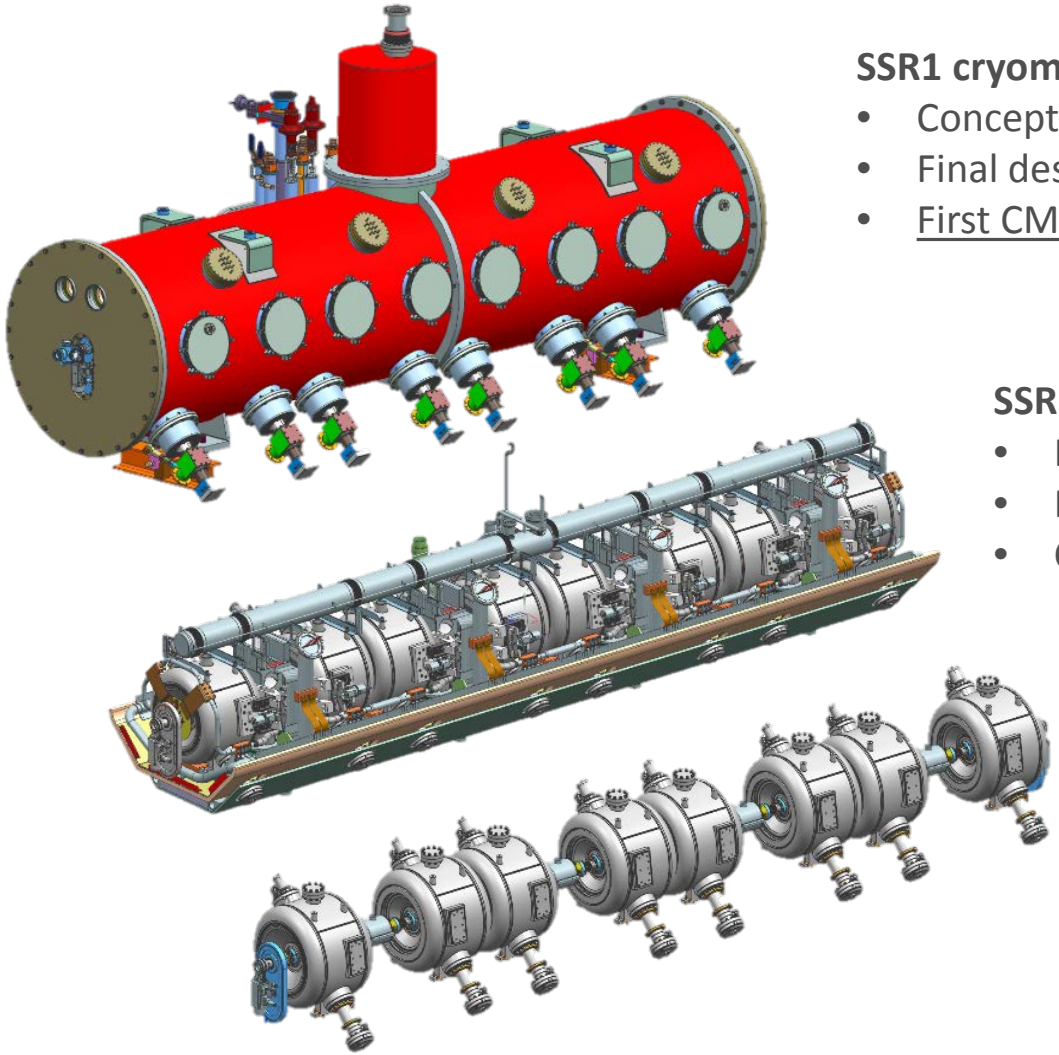


- 16 SSR1 cavities and 8 focusing lenses compose the two SSR1 cryomodules for PIP-II

Section	Freq. (MHz)	Energy (MeV)	Cav/mag/CM	Gradient (MV/m)	Q_0@2K (10^{10})	CM Configuration	CM length (m)
HWR (β_G=0.11)	162.5	2.1-10	8 /8*/1	8.2	0.5	8 x (sc)	5.8
SSR1 (β_G=0.22)	325	10-35	16 /8*/ 2	12	0.8	4 x (csc)	5.2
SSR2 (β_G=0.47)	325	35-185	35 /21*/ 7	11.4	1.0	sccsccsc	6.5
LB650 (β_G=0.61)	650	185-500	33 /22**/ 11	16.6	1.5	fdcccfd	7.1
HB650 (β_G=0.92)	650	500-1000	42 / 16**/ 7	17	2.0	fdccccccfd	9.5

SSR1 R&D phase: scope and milestones

- **Design, make and qualify critical components, and assemble one SSR1 cryomodule for PIP2IT**



SSR1 cryomodule – Top assembly

- Conceptual design: completed
- Final design: ~85% completed
- First CM delivered by Sep 2018

SSR1 coldmass

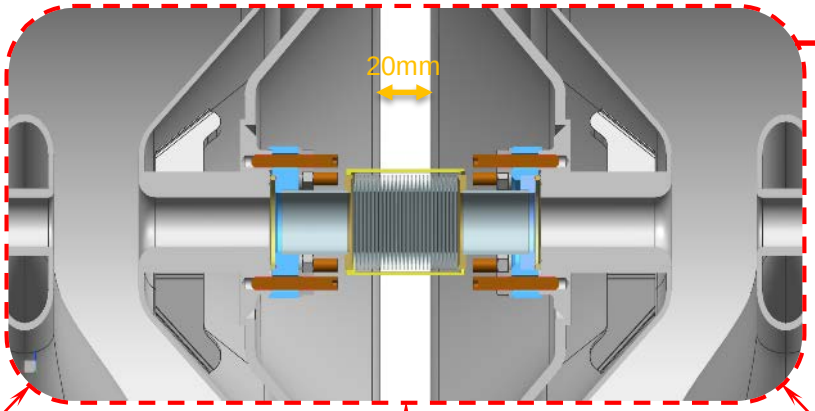
- Final design: ~85% completed
- Procurement: ~60% completed
- Coldmass assembled by Jan 2018

SSR1 string assembly

- Final design: 100% completed
- Procurement: 100% completed
- Assembly completed by Oct 2017

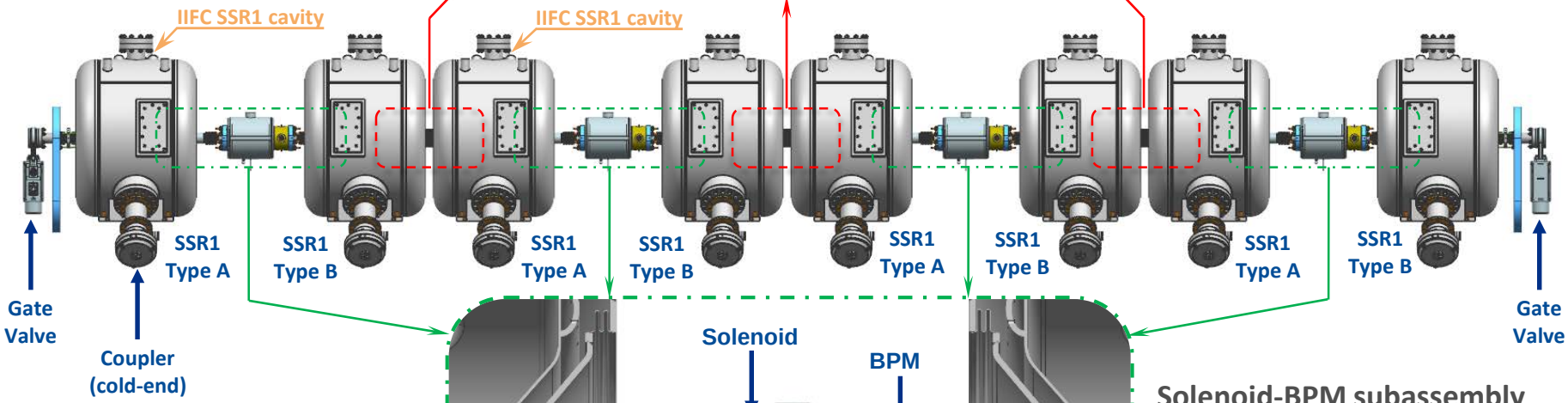
SSR1 String Assembly: design status

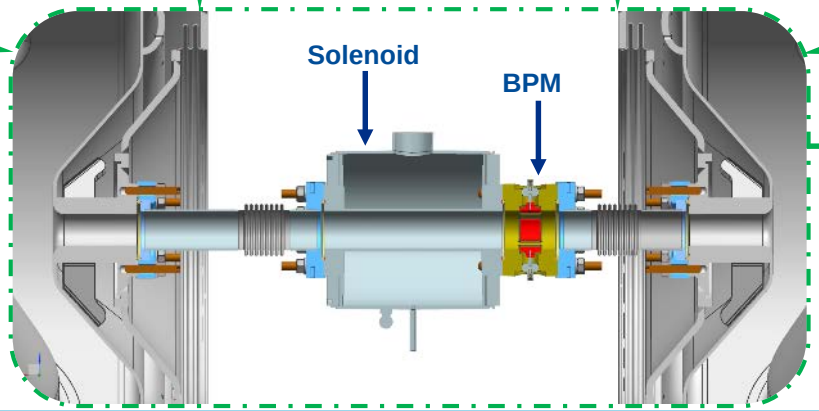
- **Status of design: completed**
  - Drawings and documents are in the approval phase
  - Many lessons learned and challenges addressed



Interconnection cavity-cavity

- Ultra High Vacuum connection
- Edge-welded bellows
- Al-diamond seals
- SiBr set screws
- 316L stainless nuts and washers





Solenoid-BPM subassembly

- Hydro-formed bellows
- Ultra High Vacuum connections
- Al-diamond seals
- SiBr set screws
- 316L stainless nuts and washers

SSR1 string assembly: procedures and facility

- **General Particle-free assembly procedure** is under development ED0004656

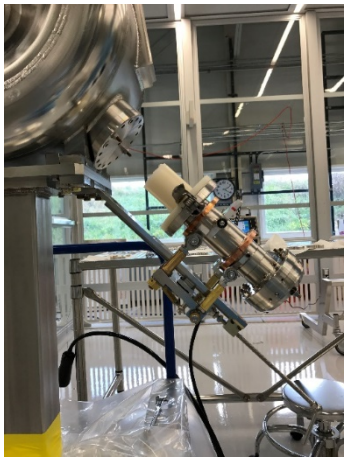
- **The customized particle free procedure** for SSR1 flanged connections ensures high reliability and avoids catastrophic damaging of cavity flange threaded holes (ED0004744)
- **Procedure was successfully validated on two units**

- **The cleanroom at Lab 2 is ready to receive the SSR1 string assembly**
  - Cleanroom construction completed and qualified
  - Vacuum cart assembled and qualified to provide field emission free venting and pump out
  - Ultra Pure Water system and ultrasonic cleaners are fully operational
  - 900 gal liquid nitrogen dewar installed outside to supply building with nitrogen gas for cleaning parts; line installation completed and undergoing commissioning

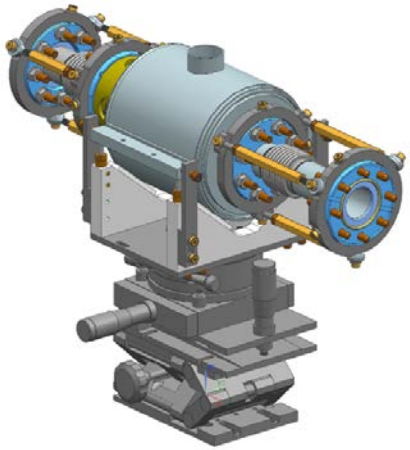
SSR1 string assembly: tooling

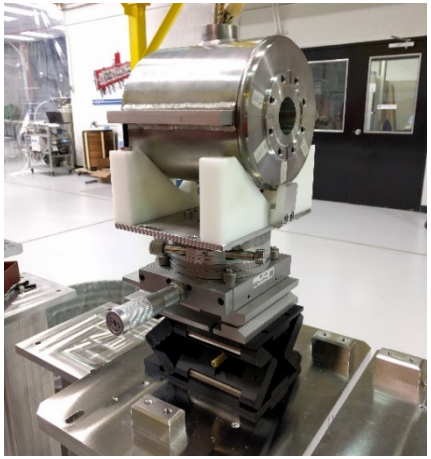
- **Design and procurement of tooling for the string assembly is completed.**

- Coupler installation tooling: F10048182

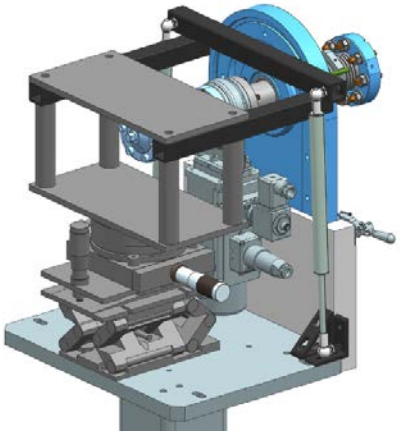


- Solenoid assembly tooling: F10054275



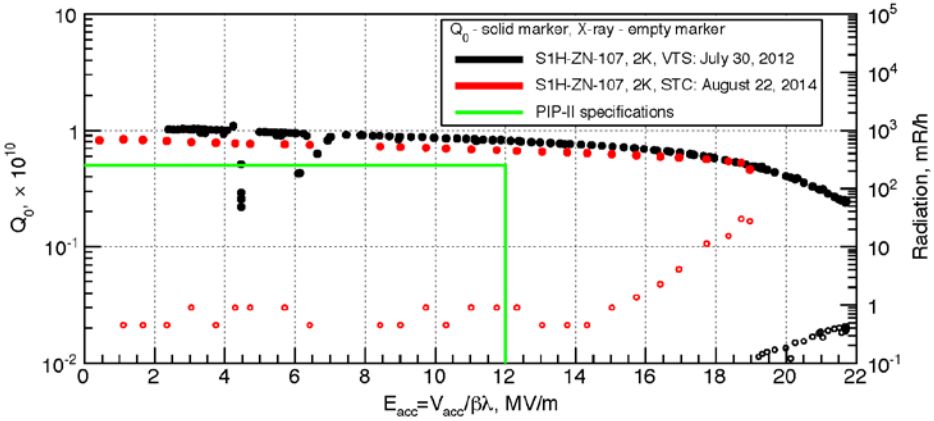


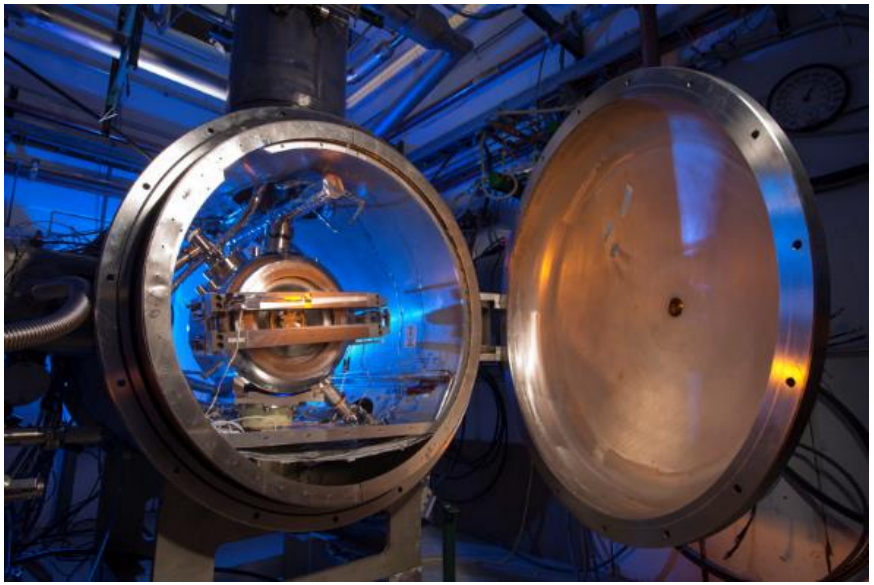
- End-pipe installation tooling: F10058069



- Movable rail system: F10044542

Jacketed SSR1 cavities: status

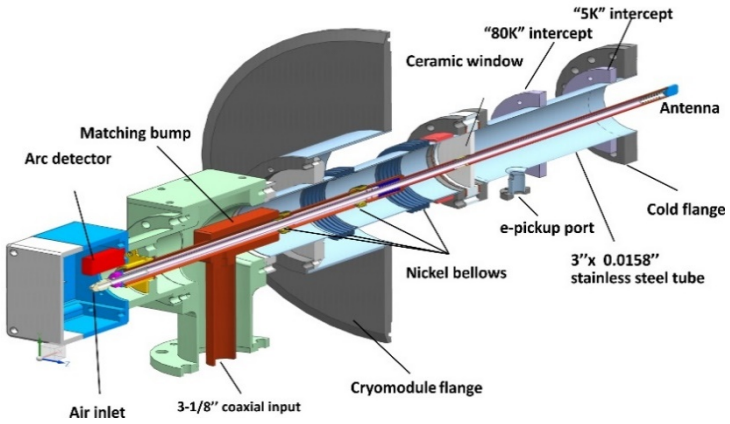




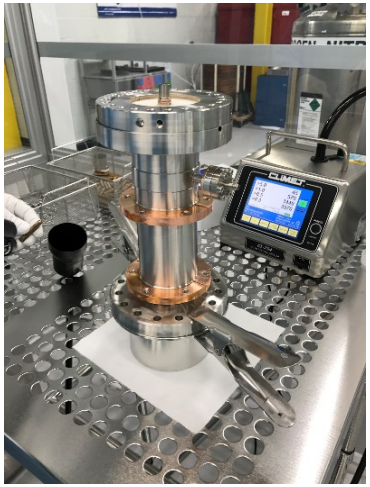
- **Eight jacketed SSR1 cavities** (made by Fermilab) are ready to be qualified at 2K in the Spoke Test Cryostat (STC) at Fermilab
- **First jacketed cavity (S1H-NR-107) was tested** three times in the STC:
  - Prototype coupler and prototype tuner installed
  - Performance of cavity, coupler and tuner were confirmed [1, 2]
  - Studies of resonance control have been carried out*
- **Qualification of production of nine jacketed SSR1 cavities** (8 made by Fermilab and 2 made by IIFC) in the STC has started and it will be completed by August 2017
  - Procedures to fully prepare the cavity for STC qualification were written and experimentally qualified
  - Qualification test plan was defined (ED0005578)
    - Meet the gradient and the quality factor
    - Perform any needed MP and FE conditioning
    - Check input coupler and tuner performance

[1] Result of Cold Tests of the Fermilab SSR1 Cavities, A. Sukhanov et al., Proceedings of LINAC2014, Geneva, Switzerland
[2] Performance of the Tuner Mechanism for SSR1 Resonators During Fully Integrated Tests at Fermilab, D. Passarelli et al., SRF2015, Canada
** See presentation for DOE IPR: Resonance Control of Cavities by W. Schappert*

Main Power Couplers: status



- **Prototype main power couplers**
  - Design, procurement and testing: completed
  - Three prototypes were procured and tested *[1]*:
    - All units were successfully tested up to 30 kW (in full reflection mode) on the RF test stand at room temperature
    - One unit was tested to failure at 47 kW (in full reflection mode) on the RF test stand at room temperature
    - One unit was successfully qualified during tests in STC
    - Several lessons learned

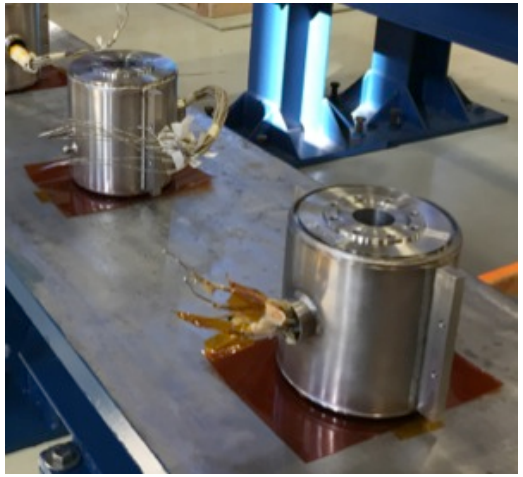


- **Production main power couplers**
  - Design completed *[2]*
  - Procurement and testing: in progress
  - Procedures for conditioning and free particles assembling were written and qualified
  - 10 production coupler vacuum ends are in procurement
  - 2 out of 10 units were delivered, conditioned and successfully tested up to at 20kW, in full reflection on the RF test stand at room temperature
  - First unit successfully installed jacketed cavity (S1H-NR-112) for cold test at STC

[1] Testing of 325 MHz Couplers at Test Stand in Resonance Mode, S. Kazakov, et al., SRF2015, Whistler, Canada
[2] Mechanical Design of a High Power Coupler for the PIP-II 325 MHz SSR1 RF Cavity, O. Pronitchev, et al., SRF2015, Whistler, Canada

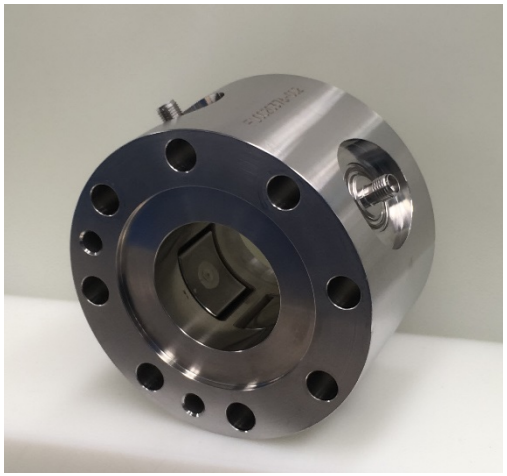
Solenoids and Beam Position Monitors

- **Four production solenoids** were successfully designed, procured and qualified.



ED0001264

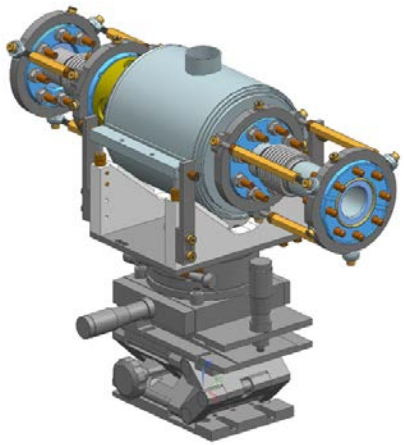
- **Four production BPMs** were successfully designed, procured and qualified *[1]*.

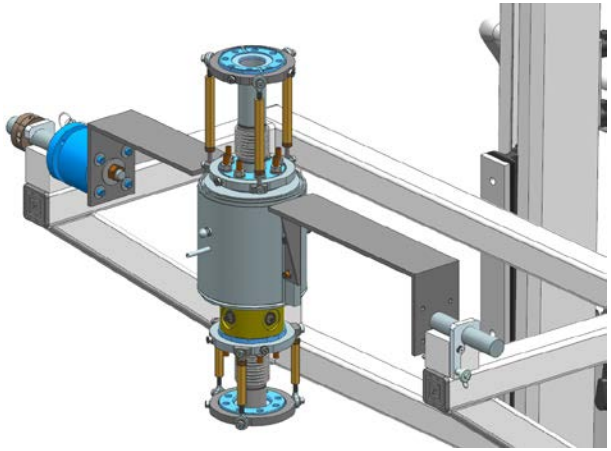


Joint collaboration ANL &FNAL

ED0005680

- **Free particle assembling procedure** of the solenoid/BPM sub-assembly is under development

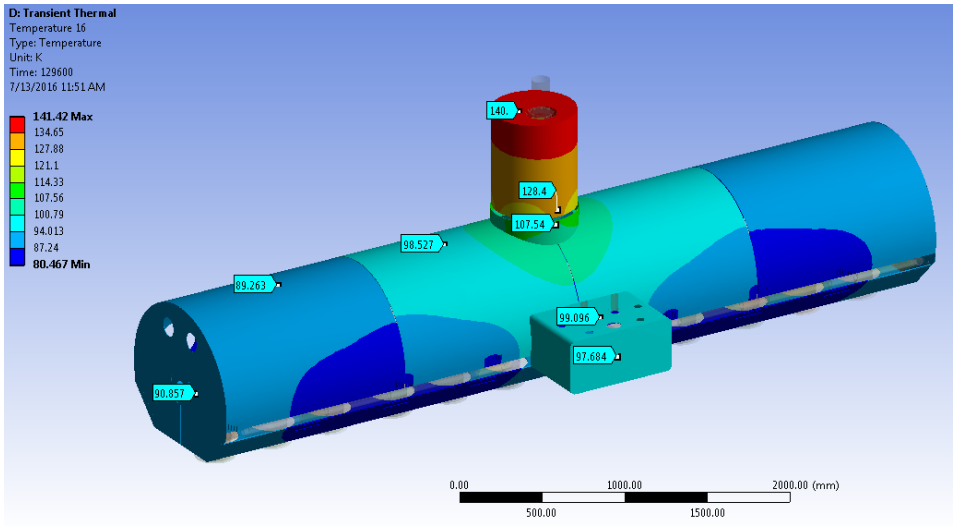


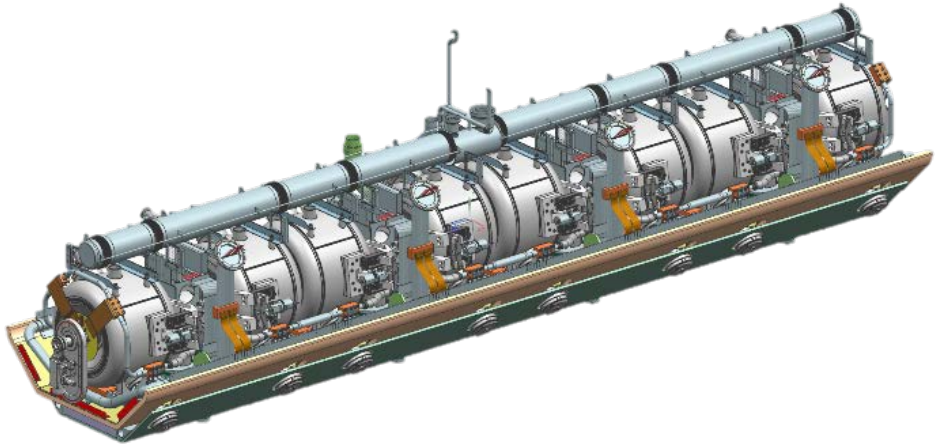


[1] Development of a Low-Beta Button BPM for PXIE Project, A. Lunin, et al., IBIC2013, Oxford, UK

SSR1 coldmass: design status

- **The design of the coldmass is quite mature**
  - Structural and thermal analyses completed
  - Piping system, thermal shields and magnetic shields were conceptualized [1]
  - Strong back and support post were designed and procured
  - Estimation of cavities and solenoids misalignments due to cooldown (293K --> 2K) done



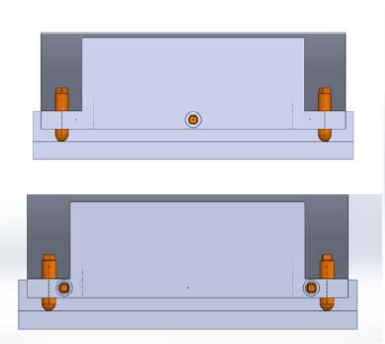


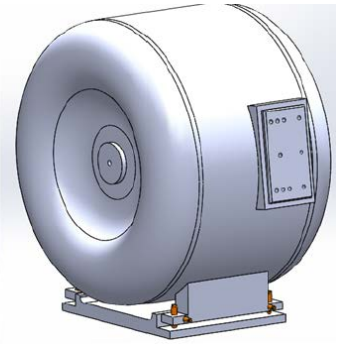
[1] SSR1 Cryomodule Design for PXIE, T. Nicol et al., Proceedings of PAC2013, Pasadena, CA USA

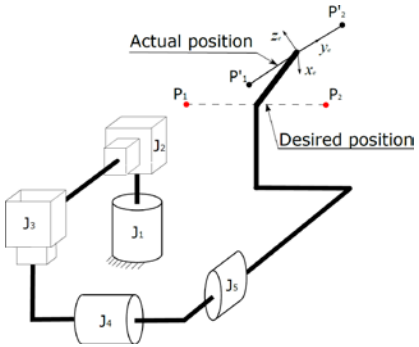
SSR1 coldmass: procurement and assembly

- **Several components were already procured**: strongback, support post, cavity adapting plate, solenoid adapting plate, vacuum vessel (top assembly).

- **Analytical model to systematically align cavities in the coldmass**

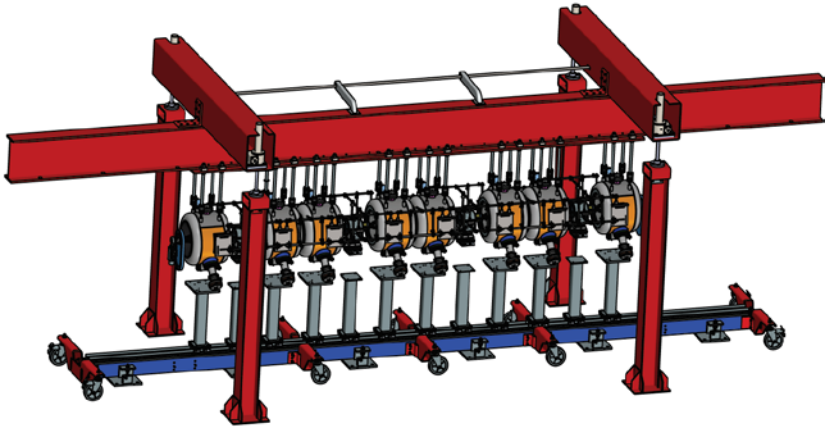






- The cavities will be aligned according to the geometric axis with the help of the laser tracking technology
- The model helps to reach the desired position by suggesting the rotation to be applied at each of the seven screws

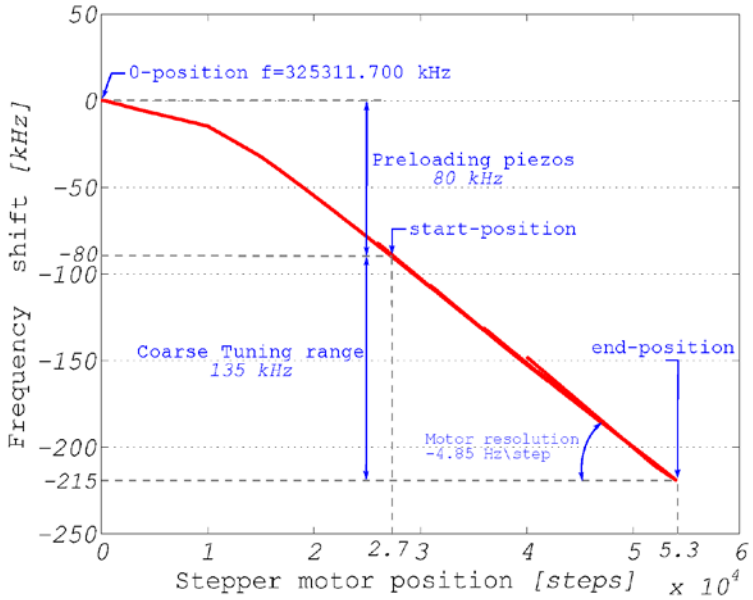
- **Conceptual design of string assembly/coldmass lifting tooling**

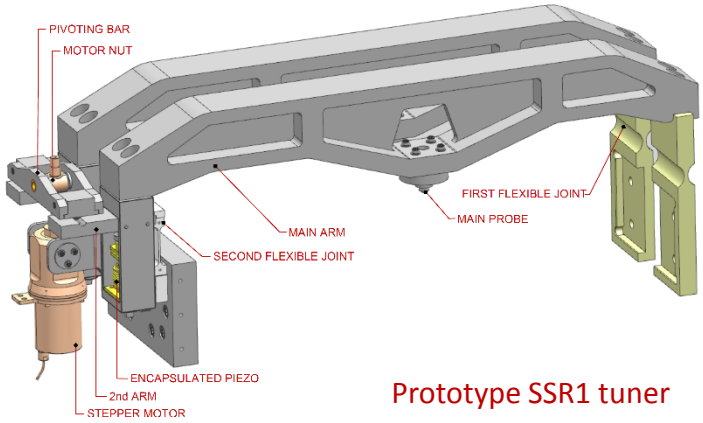


- The conceptual design includes a portal structure realized with standard steel beams and a mechanical lifting system
- Structure designed to minimize the deformation during the lifting operation
- The design includes an external frame on the string so as to protect itself and support the solenoids
- Designed to be also compatible for 650 coldmass

SSR1 tuner: status

- **Prototype SSR1 tuner**
  - Design completed and one unit was prototyped *[1]*
  - Successfully tested at 293K and cold temperature *[2]*
- **Production SSR1 tuner**
  - Design on the way of completion
  - 10 units will be procured (+2 units from IIFC)
  - Qualification at STC will be performed

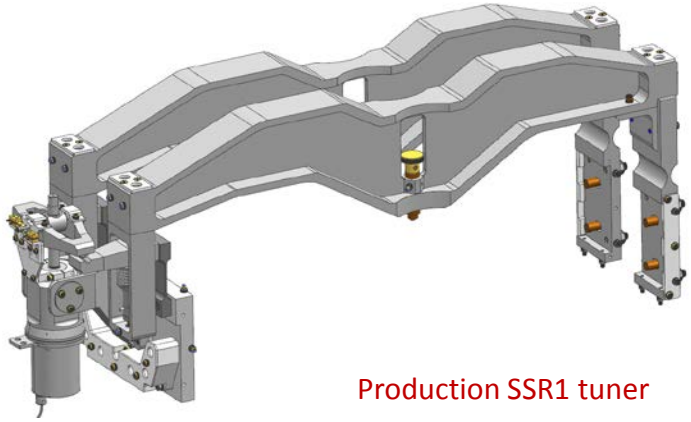




Prototype SSR1 tuner

Main changes:

- Reliability of the piezos: integrating pre-encapsulated piezos stacks
- Easier installation
- Easier handling: reducing the overall weight



Production SSR1 tuner

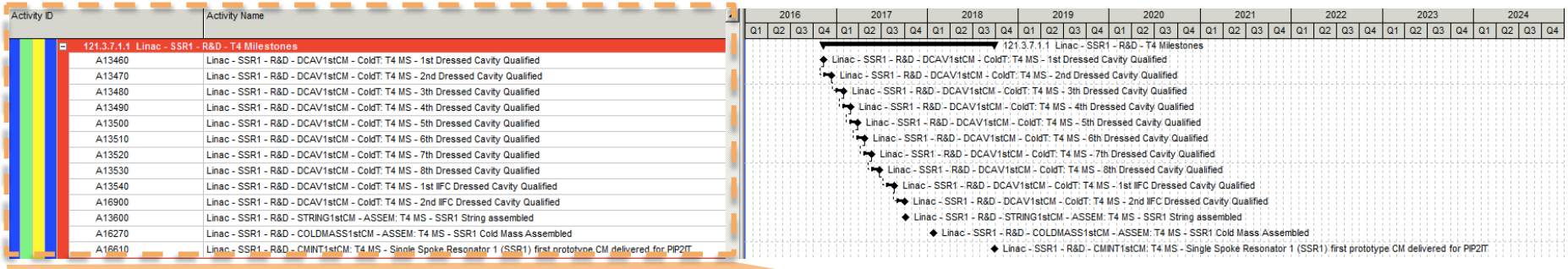
[1] SSR1 Tuner Mechanism: Passive and Active Device, D. Passarelli et al., Proceedings of LINAC2014, Geneva, Switzerland

[2] Performance of the Tuner mechanism for SSR1 Resonators During Fully Integrated Tests at Fermilab, D. Passarelli et. al., SRF2015, Canada

SSR1 CM Schedule

Charge Item: #3

Lari



Activity ID	Activity Name
121.3.7.1.1	Linac - SSR1 - R&D - T4 Milestones
A13460	Linac - SSR1 - R&D - DCAV1stCM - ColdT: T4 MS - 1st Dressed Cavity Qualified
A13470	Linac - SSR1 - R&D - DCAV1stCM - ColdT: T4 MS - 2nd Dressed Cavity Qualified
A13480	Linac - SSR1 - R&D - DCAV1stCM - ColdT: T4 MS - 3th Dressed Cavity Qualified
A13490	Linac - SSR1 - R&D - DCAV1stCM - ColdT: T4 MS - 4th Dressed Cavity Qualified
A13500	Linac - SSR1 - R&D - DCAV1stCM - ColdT: T4 MS - 5th Dressed Cavity Qualified
A13510	Linac - SSR1 - R&D - DCAV1stCM - ColdT: T4 MS - 6th Dressed Cavity Qualified
A13520	Linac - SSR1 - R&D - DCAV1stCM - ColdT: T4 MS - 7th Dressed Cavity Qualified
A13530	Linac - SSR1 - R&D - DCAV1stCM - ColdT: T4 MS - 8th Dressed Cavity Qualified
A13540	Linac - SSR1 - R&D - DCAV1stCM - ColdT: T4 MS - 1st IIFC Dressed Cavity Qualified
A16900	Linac - SSR1 - R&D - DCAV1stCM - ColdT: T4 MS - 2nd IIFC Dressed Cavity Qualified
A13600	Linac - SSR1 - R&D - STRING1stCM - ASSEM: T4 MS - SSR1 String assembled
A16270	Linac - SSR1 - R&D - COLDMASS1stCM - ASSEM: T4 MS - SSR1 Cold Mass Assembled
A16610	Linac - SSR1 - R&D - CMINT1stCM: T4 MS - Single Spoke Resonator 1 (SSR1) first prototype CM delivered for PIP2IT

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PIP-II

SSR1 Cryomodule Work Packages

Charge Item: #4

Mitchell

PIP-II 325 MHz CAM & Level 3 Mgr. – L. Ristori

SSR1 Cryomodule System Manager – D. Passarelli

SSR1 Cryomodule Technical Advisors (alphabetical order):

- RF – Timergali Khabiboulline
- Cryogenics – Tom Nicol
- Mechanical Engineering – Youri Orlov
- Chemical Processing – Allan Rowe

Work Packages	Lead Engineer (Alternate)	EPDM Document
SSR1 CRYOMODULE	D. Passarelli	ED0001256
SSR1 COLD MASS	D. Passarelli (V. Roger)	ED0004503
SSR1 CURRENT LEADS	T. Nicol (V. Roger)	ED0004584
SSR1 STRING	M. Parise	ED0004502
SSR1 JACKETED CAVITY	D. Passarelli	ED0001234
SSR1 BARE CAVITY	L. Ristori	ED0001240
SSR1 TUNER	D. Passarelli	ED0001246
SSR1 FOCUSING LENS	I. Terechkine	ED0001264
SSR1 INPUT COUPLER	S. Kazakov (O. Pronitchev)	ED0001258

- Lead Engineers appointed for each work package
- EPDM sheets managed in Teamcenter by each Lead Engineer
- EPDM sheets promoting adherence to Fermilab Engineering Manual
- EPDM sheets provide “bookmarks” to relevant documentation in TC

ED0004600

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PIP-II

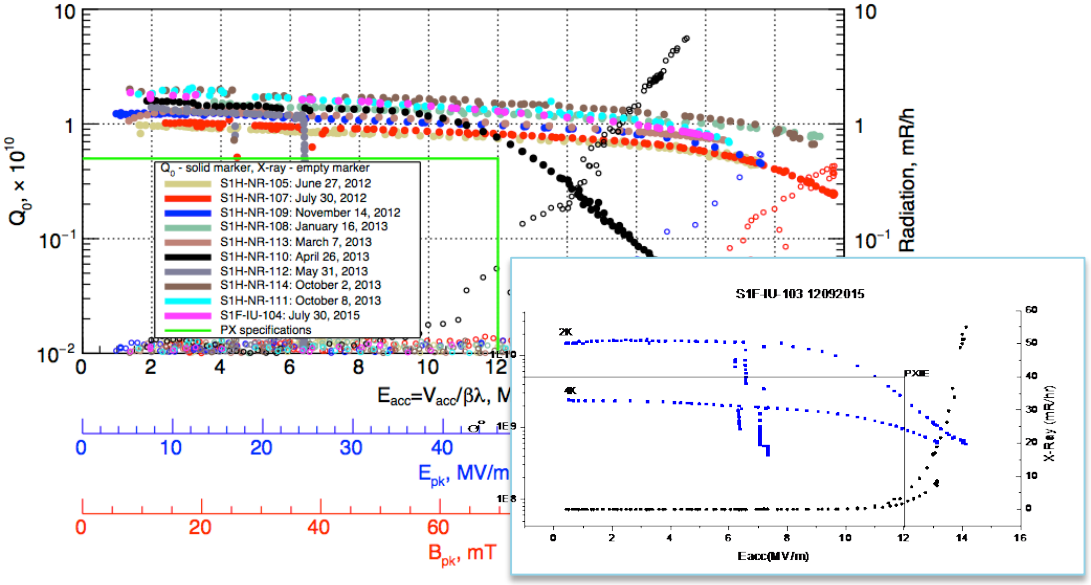
IIFC on SSR1 cryomodule: status

Charge Item: #6

Mishra

- **IIFC SSR1 cavities**
  - Two bare SSR1 cavities were received from IUAC, chemically processed and cold-tested at Fermilab *[1]*.
    S104 yielded excellent results, S103 presented issues.
  - Jacketing will happen at BARC.
  - Delivery to FNAL by May 2017 for qualification and integration in SSR1 CM
  - Additional actions after receiving: QC inspection, Processing, Qualification at STC

- **IIFC SSR1 tuner**
  - The design of the production SSR1 tuner will be completed in several weeks and the entire package of drawings will be shared with Indian collaborators.
  - Delivery of two units to FNAL by July 2017



[1] Cold Tests of SSR1 Resonators Manufactured by IUAC for the Fermilab PIP-II Project, L. Ristori et. al, SRF15 Conference

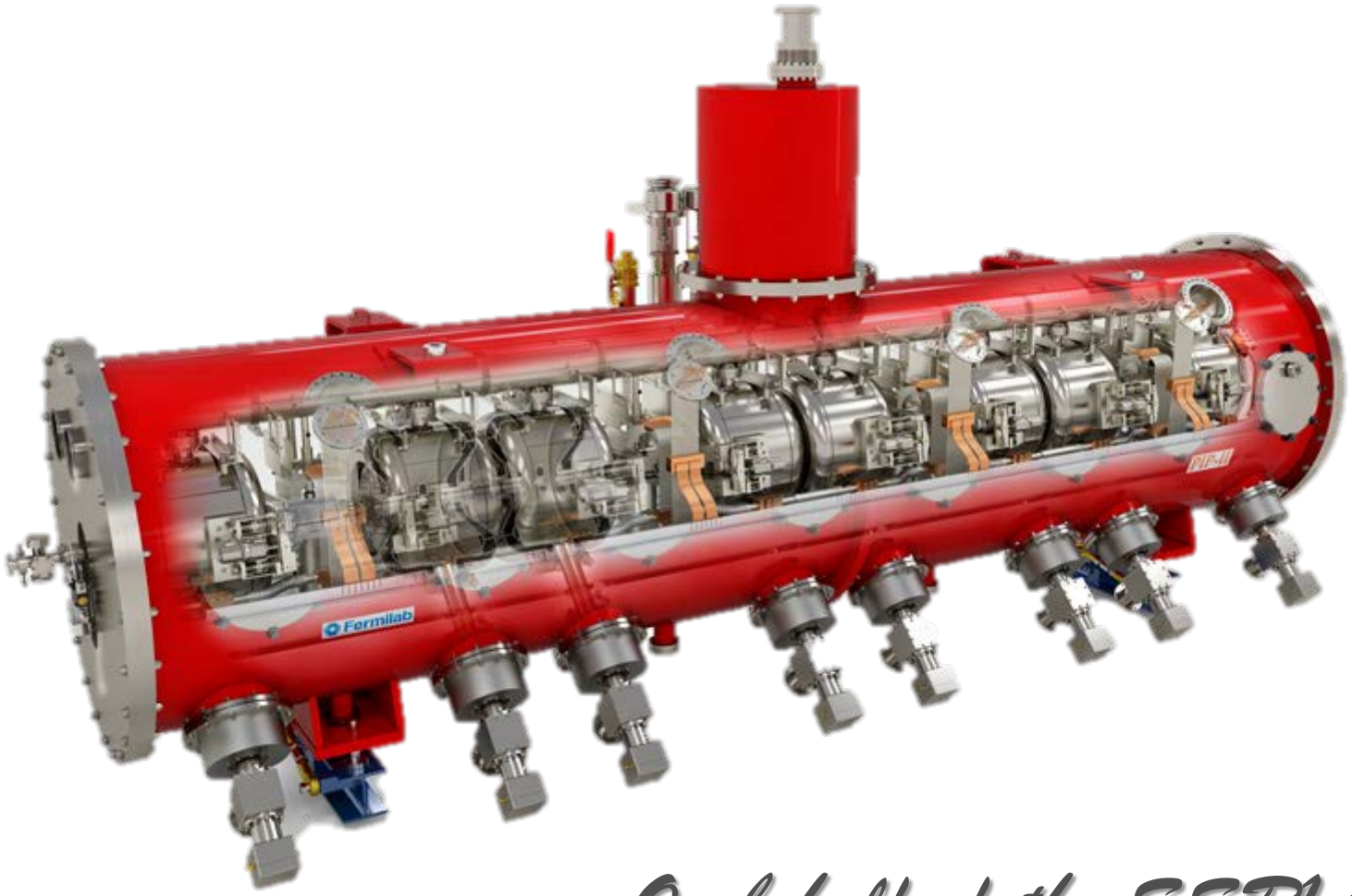
Fermilab

PIP-II

Summary

- The design of the SSR1 cryomodule is advanced. Critical components that have been prototyped have met the requirements.
- Technical and cost risks associated with the performance of the SSR1 cryomodule are mitigated for the most part by qualifying all production cavities with coupler and tuner in the Spoke Test Cryostat (STC).
- The technical team is formed by engineers, scientists and technicians with previous experience in SRF. Work packages and lead engineers are clearly identified.
- Collaboration within IIFC on SSR1 is well defined. We expect to have successful contributions to the construction of the first SSR1 cryomodule.
- Delivery of the first SSR1 cryomodule to PIP2IT is expected by September of 2018.

Thank you for you attention



On behalf of the SSRI team