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Superconducting RF: Strategy and Organization

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PIP-II Machine Advisory Committee Meeting

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Outline

- The linac basic parameters and operating regimes
- General issues
- Strategy and status of R&D
- Strategy of design and prototyping
- Synergy and conflicts to other projects
- Organization
- Summary

General issues

- The PIP-II linac requires the fabrication and integration of
  - 126 superconducting cavities of
  - 5 different geometries (HWR, spoke and elliptical), operating at
  - 3 different frequencies (162.5, 325 and 650 MHz), and deployed in
  - 25 cryomodules.
- General issues
  - Compatibility with subsequent CW operations
    - High Q0 program
  - Microphonics in low-current, pulsed operations
  - Development of fabrication/assembly capabilities in North America and India

Strategy and status of R&D – High Q0

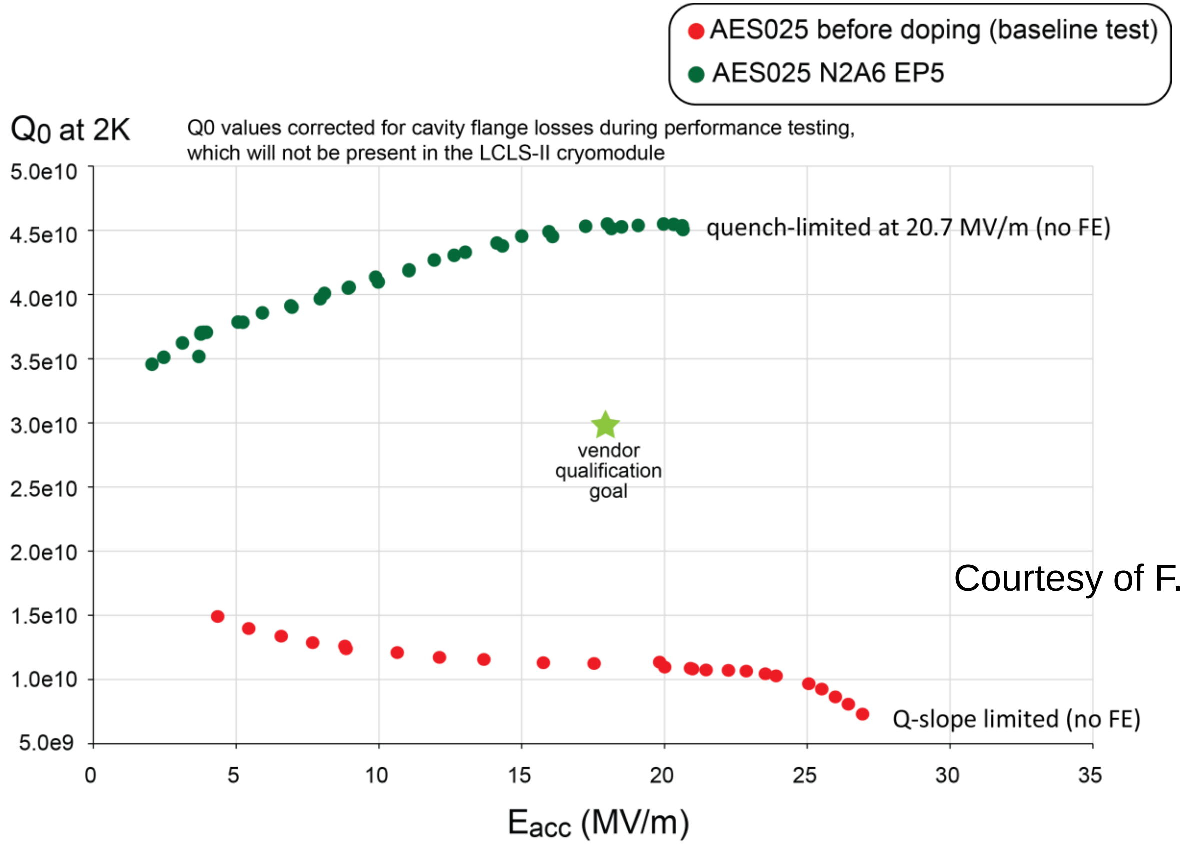
High Q0:

- N-doping evolved from discovery to proven technology;
- It is a basic technology for LCLS II, operating at 1.3 GHz;
- Same sequence of investigations
  - Single cell cavity tests;
  - Five cell cavity tests;
  - Dressed five cell cavity tests in HTS-2
- Necessary to finalize the technology proof at 650 MHz.
- Flux expulsion and field sensitivity studies drives CM design decisions
  - Magnetic shielding strategy
  - CM component design choices
  - Remnant or generated field mitigation

Strategy and status of R&D – High Q0

- SRF Research milestone – Successful nitrogen doping technology transfer to industry for LCLS-II production
- Four times higher Q (cavity efficiency) at LCLS-II operating gradient

A. Grassellino



Courtesy of F. Marhauser

Strategy and status of R&D – Resonance Control

Lorentz Force Detune:

Pulsed SRF accelerators, existing and projects	Half-bandwidth, Hz	LFD, Hz	LFD/HBW
SNS (LB/HB)	550/500	300/100	0.55/0.2
ESS (HB)	500	400	0.8
FLASH/XFEL (electrons)	185/141	550	3/4
PIP II (LB/HB)	29/29	253/317	9/11

Lorentz Force Detune is an issue!

Strategy and status of R&D – Resonance Control

Resonance control (LFD and microphonics)

- Controlling detuning in the PIP-II cavities
  - Critical to the successful operation of the machine
  - Requires a combination of passive and active measures
  - Requires a coordinated effort across the entire machine
    - Cavity, Cryomodule, Cryogenic, RF, Mechanical, Civil,…
- Even with the best passive measures, active control will be required
- Considerable progress on active control has already been made here at FNAL
- Considerably more work on active control will be required before a viable resonance control system for the machine can be designed and deployed

Strategy and status of R&D – Resonance Control

Resonance control (LFD and microphonics) What Has Been Accomplished So Far

- Adaptive LFD Control Algorithm
  - developed at FNAL for NML/CM1
  - Tested at KEK during the S1G cryomodule test at KEK in 2011 with 4 distinctly different ILC cavity/tuner designs
  - Suppressed detuning from several hundreds of Hz to several 10s of Hz in all four cavity/tuner types
- Microphonics suppression in SSR1
  - CW tests using in 2011 and 2014 yielded promising results <1 Hz RMS

(W. Schappert, Y. Pischalnikov)

Resonance control (LFD and microphonics) What Still Needs to be Done

- PIP-II resonance control strategy
  - Measure cavity piezo/detuning and stored-energy/detuning transfer functions
  - Extract an approximate low order transfer function using proven system-identification techniques (Kalman-Ho Minimal State Space Realization)
  - Construct a combined optimal electro-mechanical controller (Linear-Quadratic Gaussian Regulator) from the low-order transfer function
  - Resulting controller is mathematically optimal in the Least-Squares sense
- Improvements and testing of algorithm will be implemented during cold testing program at STC.

(W. Schappert, Y. Pischalnikov)

Strategy of CM design and prototyping

- All CM designs are based on SSR1-type concept
- SSR1 and SSR2 design similarities:
  - Mechanical Tuners and resonance control strategies
  - Low df/dP cavity and helium vessel integrated designs
  - High Power RF couplers
  - Cavity string support structure
  - Cryogenic plumbing
  - Solenoids
  - Significant number of common parts
- LB 650 and HB 650 design similarities implements the same strategy as SSR:
  - Mechanical Tuners and resonance control strategies
  - Low df/dP cavity and helium vessel integrated designs
  - High Power RF couplers
  - Cavity string support structure
  - Cryogenic plumbing
  - Significant number of common parts

Strategy of design and prototyping – IIFC Partnership

- Strong IIFC collaboration necessary to develop CMs and critical LINAC components
- FNAL responsible for fully functional integrated LINAC, but relies heavily on IIFC partner development of critical devices
- IIFC organizations responsible for the PIP II CMs and Components:
  - SSR1 – Fermilab
  - SSR2 – BARC (dressed cavity only)
  - LB 650 – VECC (dressed cavity only)
  - HB 650 – RRCAT/Fermilab (strong overlap).
- Strong cooperation is necessary between:
  - Fermilab and BARC on SSR1 and SSR2 CMs;
  - Fermilab, VECC and RRCAT on LB 650 and HB 650.

Synergy and conflicts with other projects

❑ Other projects in Technical Division:

- LCLS II – design, prototyping and production of seventeen 1.3 GHz CMs and two 3.9 GHz CMs by end of CY18.
- LARP – Crab Cavity for LHC
- Mu2e experiment
- SRF R&D Program

❑ Synergy with LCLS II:

- Experience in mass production of the CMs;
- Synergy in design and development of CMs, cavities and components, production effort (tuners, He vessels, couplers, etc.)
- High Q0 program
- Resonance control program

❑ Potential Conflicts – parallel projects:

- Facilities
- People

SRF Suite of SRF Facilities

- Cavity Processing
  - ANL/FNAL Superconducting Surface Processing Lab (EP, BCP)
  - IB4 Cavity Processing Lab (EP, CBP)
  - Several cleanrooms (HPR, clean assembly)
- RF Measurements and Tuning Lab
- Heat Treatment
  - Two large 1000C Vacuum Degassing Ovens
  - Two low temperature 300C ovens
- Performance Testing
  - Vertical Test Area (three large test dewars)
  - Horizontal Test Area (two horizontal test cryostats)
  - RF coupler processing and test stand
- Cryomodule Assembly Facilities
  - ICB, MP9, Lab2
- Cryomodule Test Facility

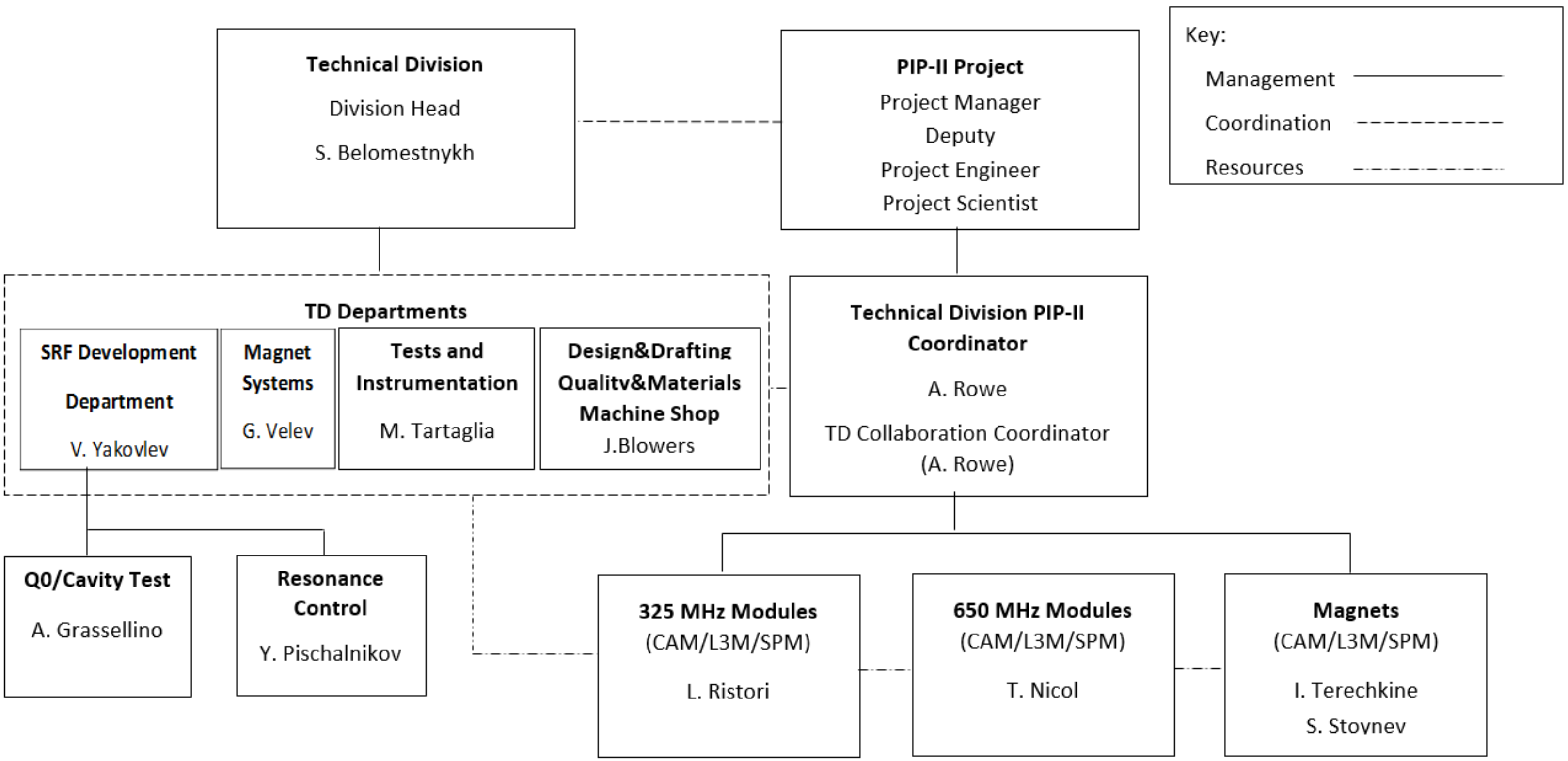
Conflicts Mitigation – new facility development for PIP-II

- New facility at Lab2 to resolve LCLS-II CM production conflicts:

- Dynamic assignment of people
- Projects are at different stages, requiring different specialists
- Project timelines (development & production) are an advantage

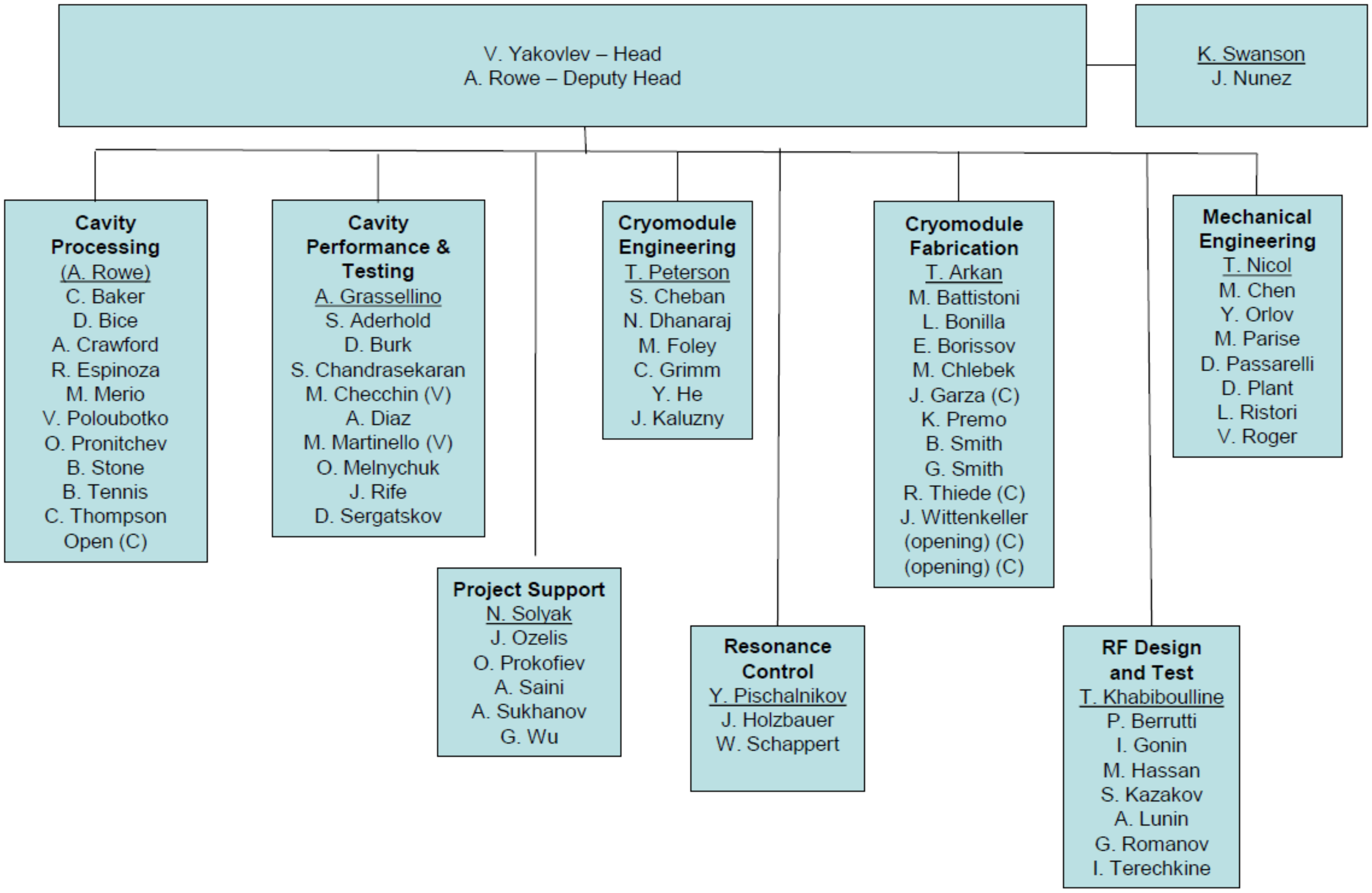
Organization – PIP-II

Organization of the PIP II project in the Technical Division:



Organization – SRF Development Department

SRF Development Department – Complete set of experts:



Summary

- The goal is to complete design and prototyping of the SRF linac critical elements in order to start building in 2019-2020 and to abide by the DOE CD3a/b deliverables
- Critical issues of the designs are identified
- The R&D and design strategies are developed and ongoing
- Synergy and conflicts to the other projects are identified and addressed
- The Project organization is functioning