Summary slides of PIP-II – related reports at IPAC’15

V. Lebedev, A. Shemyakin

PIP-II technical meeting
April 28, 2015
Delegates – total 45 from Fermilab

• I found 10 associated with PIP-II
  ▪ Awida Mohamed
  ▪ Berrutti Paolo
  ▪ Derwent Paul
  ▪ Grassellino Anna
  ▪ Johnson David
  ▪ Lebedev Valeri
  ▪ Pischalnikov Yuriy
  ▪ Romanov Gennady
  ▪ Shemyakin Alexander
  ▪ Sukhanov Alexander

• +ANL, LBNL, UCL
Awida Mohamed

• 2 posters
DEVELOPMENT OF 650 MHZ $\beta=0.9$ 5-CELL ELLIPTICAL CAVITIES FOR PIP-II* (WEPTY017)
M. Awida#, Mike Foley, Charles Grimm, Ivan Gonin, T. Khabiboulline, Andrei Lunin, and V. Yakovlev, Fermilab, Batavia, IL 60510, USA

Measured Field Flatness

Measured Frequency Spectrum

Measured Trapped Modes

Picture of the prototype cavities; B9A-AES-007, B9A-AES-008, B9A-AES-009, and B9A-AES-010

End Tuner  Blade Tuner

End Stiffening Ring Radius
Current: 126 mm
Proposed: 110 mm

Middle Stiffening Ring Radius
Current: 134 mm
Proposed: 110 mm

Simulated $df/dP$

Simulated LFD

Old $\beta=0.9$ (blue) and new $\beta=0.92$ (red) cell shapes
A chopper with a pre-programmed timeline is used in MEBT to format the bunch pattern and structure the beam. The helical kicker has been thoroughly modelled. Pitch of 0.425 in is recommended to match the beam velocity with dielectric support height of 0.285 in to get the 200 Ω characteristic impedance.
Berrutti Paolo - WEPTY019 Transverse Field Perturbation For PIP-II SRF Cavities

- Paolo Berrutti, Timergali N. Khabiboulline, Valeri Lebedev, Vyacheslav P. Yakovlev
Transverse Field perturbation for PIP-II SRF Cavities
WEPTY019

• Transverse field perturbation for Coaxial cavities, quadrupole component and multipole expansion:
  - HWR
  - SSR1
  - SSR2 new design (vs 2.6.0)

• Transverse field perturbation for 650 MHz multi-cell cavities, dipole component (due to coupler) and multipole expansion:
  - LB 650 MHz
  - HB 650 MHz

• Conclusions:
  - compensation for quadrupole with correctors for SSR2
  - no quadrupole and dipole negligible for both 650 MHz
Proton Improvement Plan-II (PIP-II) is the centerpiece of Fermilab’s plan for upgrading the accelerator complex to establish the leading facility in the world for particle physics research based on intense proton beams. PIP-II has been developed to provide 1.2 MW of proton beam power at the start of operations of the Long Baseline Neutrino Experiment (LBNE), while simultaneously providing a platform for eventual extension of LBNE beam power to >2 MW and enabling future initiatives in rare processes research based on high duty factor/higher beam power operations. PIP-II is based on the construction of a new, 800 MeV, superconducting linac, augmented by improvements to the existing Booster, Recycler, and Main Injector complex. PIP-II is currently in the development stage with an R&D program underway targeting the front end and superconducting rf acceleration technologies. This paper will describe the status of the PIP-II conceptual development, the associated technology R&D programs, and the strategy for project implementation.
Grassellino Anna- MOYGB2 High Q0 Development

- This presentation should cover the current status of high Q0 SRF research, including development of an industrial process for nitrogen doping of niobium to produce reliably in high volume, \( Q_0 > 2.7 \times 10^{10} \) in SRF cavities at 2K.
Developed 2 potential injection upgrade designs:
1) 3 bump in existing straight section length
2) 4 bump in a lengthened straight by modifying gradient magnet length
Both keep OBUMP magnet field to 3 kG

Absorbed dose in gradient magnet 4 Mgy/yr in 1) and 0.12 Mgy/yr in 2).
Additional optimization continues.

Investigated both transverse and longitudinal painting scenarios – no serious issues identified; foil temperature not a problem.
Lebedev Valeri

- Will present two Arun’s posters
- MOPMA014  Design of Superconducting CW linac for PIP-II, Arun Saini, Valeri Lebedev, Nikolay Solyak, Vyacheslav P. Yakovlev
- WEPTY031  Estimation of Cryogenic Heat Loads in Cryomodule due to Thermal Radiation, Arun Saini, Valeri Lebedev, Nikolay Solyak, Vyacheslav P. Yakovlev
Proton Improvement Plan (PIP) -II is a proposed roadmap to upgrade existing proton accelerator complex at Fermilab. It is primarily based on construction of superconducting (SC) linear accelerator (linac) that would be capable to operate in continuous wave (CW) mode. This paper will present reference design of SC linac and discuss motivations and requirements resulting in this layout and beam optics.

- **Layout of 800 MeV superconducting CW linac**
  - No. of section, focusing period, transition energy in each section are discussed.

- **Beam optics through SC linac**
  - Beam envelope
  - RMS emittance
  - Beam stripping

- **RF parameters of Beamline elements**
  - Gradient in cavities
  - Magnetic strength
  - Cryogenic power etc.
Poster-2: Estimation of Cryogenic Heat Loads in Cryomodule due to Thermal Radiation

Primary Author: Arun

Cryogenic is major cost contributing factor in high intensity superconducting (SC) continuous wave (CW) accelerators. Thermal radiations coming through warm-ends of cryomodule and room temperature parts of power coupler result in additional cryogenic heat loads. Excessive heat load may degrade overall performance of cavity and it could also lead to quench. In this paper we present studies performed to estimate heat load due to thermal radiation in 650MHz cavity cryomodule in high energy section of PIP-II SC linac.

• Each cryomodule in 650 MHz section is separated by room temperature part.
  – Thermal radiation from both ends of cryomodule results in additional cryogenics load.
  – Cryogenic load is estimated for high beta 650 MHz cryomodule.

• Thermal radiation coming from room temperature part of power coupler is also estimated.

• Consequences and mitigation scheme is proposed.
Pischalnikov Yuriy

- 2 posters
Compact tuner is designed for future accelerators CW and pulsed RF-power modes. Tuner for elliptical cavities 1,3GHz and 650MHz.

Active tuner components (electromechanical actuator and piezo-actuator) with long lifetime. Products of joint programs of FNAL with Phytron & PI Ceramic.

Designated R&D program to study lifetime of piezo and motor.

At this moment LCLS II Tuner piezo-stacks run for 1*1010 pulses without degradation.
CW Microphonics Compensation down to 11 mHz for two hours. Discussion of algorithms, hardware, and future efforts.

Compensation of Lorentz Force Detuning is pulsed and CW operations. Discussion of methods, algorithms, and future efforts.
SIMULATION OF MULTIPACTING IN SC LOW BETA CAVITIES AT FNAL

Gennady Romanov, Paolo Berrutti, Timergali N. Khabiboulline

Location of the most intense multipacting

Total SEY of the niobium used in the simulations

Verification of the MP simulations with baked Nb

Proposed geometry change in SSR2 cavity

Effect of the modification
A PERPENDICULAR BIASED 2ND HARMONIC CAVITY FOR THE FERMILAB BOOSTER
C.Y. Tan, R.L. Madrak, W. Pellico, G. Romanov, D. Sun, I. Terechkine

F = 76.76 – 105.85 MHz
V_{max} = 125 kV
Rep. rate = 15 Hz
Thermal losses = 1.56 kW
Garnet Al800:
\[4\pi M_s = 800 \text{ G}; \varepsilon = 14.4;\]
Curie temp. = 200° C;
\[\Delta H = 1.7 \div 5 \text{ Oe}\]
Scheme for a Low Energy Beam Transport with a non-neutralized section
A. Shemyakin**, L. Prost, Fermilab

This discusses the possibility and rationality of imposing an un-neutralized transport in portion of the LEBT adjacent to RFQ. For estimations, we will use the parameters from PXIE.

Beam envelopes calculated with VACO starting with a beam distribution with constant current density (red) and a Gaussian current density distribution (orange).
To validate the concept of the front-end of PIP-II, a test accelerator (a.k.a. PXIE) is under construction. The ion source and LEBT, which includes 3 solenoids, several clearing electrodes/collimators and a chopping system, have been built, installed, and commissioned to full specification parameters. This report presents the outcome of our commissioning activities, including phase-space measurements at the end of the beam line under various neutralization schemes obtained by changing the electrodes’ biases and chopper parameters.

Phase space portraits for neutralization enhanced and ion clearing configurations.
A cryomodule of 325 MHz Single Spoke Resonator type 1 (SSR1) superconducting RF cavities is being built at Fermilab for the PIP II project. Ten SSR1 cavities were manufactured in industry and delivered to Fermilab. Nine of the produced SSR1 cavities have been successfully tested in the Fermilab Vertical test stand (VTS) before jacketing in Helium vessel. Qualification of the jacketed SSR1 cavities complete with tuner and high power coupler is an important step of the cryomodule assembly. In this paper we report on the ongoing efforts of high power tests of jacketed SSR1 cavities at the Fermilab Spoke test cryostat (STC). We present performance parameters achieved by the cavities during these tests.
The PXIE accelerator is the front-end test stand of the proposed Proton Improvement Plan (PIP-II) initiative: a CW-compatible pulsed H- superconducting RF linac upgrade to Fermilab's injection system. The PXIE Ion Source and Low-Energy Beam Transport (LEBT) section are designed to create and transfer a 1-10 mA H- beam, in either pulsed (0.001-16 ms) or DC mode, from the ion source through to the injection point of the RFQ. This paper discusses the range of diagnostic tools - Allison-type Emittance Scanner, Faraday Cup, Toroid, DCCT, electrically isolated diaphragms - involved in the commissioning of the beamline and preparation of the beam for injection into the RFQ. The paper also outlines the use of the PXIE LEBT as a test bench for MEBT diagnostics such as a four-jawed beam scraper for protection and collimation. The most recent experimental data from the completed LEBT beamline is presented.
Andrew Ryan Lambert, Allan J. DeMello, Matthew Hoff, Derun Li, Tianhuan Luo, John William Staples, Steve Virostek (LBNL Richard Andrews, Curtis Baffes, Gennady Romanov, Danny Snee, Jim Steimel

PXIE is a prototype front end system for the proposed PIP-II accelerator upgrade at Fermilab. An integral component of the front end is a 162.5 MHz, normal conducting, CW (continuous wave), radio-frequency quadrupole (RFQ) cavity that was designed and is being fabricated by LBNL. This RFQ will accelerate a continuous stream of up to 10 mA of H- ions from 30 keV to 2.1 MeV. The four-vane, 4.45 meter long RFQ consists of four modules, each constructed from 2 pairs of identical modulated vanes. Vane modulations are machined using a custom carbide cutter designed at LBNL. Other machined features include ports for slug tuners, pi-mode rods, sensing loops, vacuum pumps and RF couplers. Vanes at the entrance and exit possess cutbacks for RF matching to the end plates. The vanes and pi-mode rods are bonded via hydrogen brazing with Cusil wire alloy. The brazing process mechanically bonds the RFQ vanes together and vacuum seals the module along its length. Vane fabrication is successfully completed, and the braze process has proved successful. Delivery of the full RFQ beam-line is expected in the middle of 2015.
ANL- Ostroumov

- FRXB3  Advances in CW Ion Linacs
Advances in CW Ion Linacs (Invited Talk)

P. Ostroumov

- Focus on ANL-developed advanced technology for CW ion linacs
- Design and operation of 60 MHz CW RFQ for heavy-ion linac
- Design of cryomodules for QWRs and HWRs
  - Compact design, conical shape of cavities, solenoid focusing, dipole coils
  - Alignment of solenoid-cavity string
- Resonators
  - Multi-physics design, minimize $E_{\text{ACC}}/E_{\text{PEAK}}$, $E_{\text{ACC}}/B_{\text{PEAK}}$, reduced losses, conical shape for QWRs and HWRs
  - Fabrication: SS vessel, Nb-SS transitions, wire EDM (including beam aperture)
  - EP after all mechanical work is complete
  - Performance, peak electric fields in operation are $\sim$60 MV/m, residual resistance is below 3 nOhm
- Resonator sub-systems: adjustable RF couplers, tuners, LLRF
- Operational experience with the cryomodule of QWRs
- Application: ATLAS, FRIB, PIP-II, ADS
Slide for IPAC2015: Cold Testing Results for the PIP-II HWR Power Coupler
Cold RF Testing of the Half-wave Cavity and RF Power Coupler

Left – Cold RF window and bellows assembly

• The ‘2 K’ flange is the upper CF flange in this view
• The ‘80 K’ flange is the lower CF flange

Right – Complete coupler assembly as viewed from below the half-wave cavity

• Coupler assembly was thermally stable for tested RF powers up to 5 kW
• Multipacting between 500 W and 2.5 kW conditioned easily and did not limit that rate at which the forward power was increased
Slide for IPAC2015 Contribution:
Design and Fabrication Status of a High Performance 2K Cryomodule for Half-Wave Resonators
**Project-X Half-Wave Resonator Cryomodule**

- **Helium Manifold**
- **Cavity/Solenoid Alignment Rails**
- **Cut-Away View of Cryomodule**
- **Lid**
- **Sub-Atmospheric Heat Exchanger**
- **Vacuum Vessel**

**Dimensions:**

- 2.1 m x 2.2 m x 6.3 m

- **2 K Cryomodule** housing 8 SCRF half-wave resonators and 8 NbTi 6 T solenoids.
- **First low-beta cryomodule** for 2 K.

Visit WEPTY007 For More Information
Slide for IPAC2015 Contribution:
Half-Wave Resonators for High-Intensity Proton Beams
Project-X Half-wave Resonators

- Highly optimized “hourglass” shape for improved RF performance.
- Surface processing with the ANL Low-Beta EP tool after construction finished.
- 2 prototypes tested and 7 more cavities being built.

Prototype Test Results

![Prototype Test Results](image)

- Cavity Cryogenic Power = 2 W
- Accelerating Gradient (MV/m)

Visit WEPTY006 For More Information
Slide for IPAC2015 Contribution:
Preservation of Quality Factor of Half Wave Resonator During Quenching in the Presence of Solenoid Field
Project-X Half-Wave Resonator & Magnetic Field Sensitivity

- To decrease the accelerator lattice length we have integrated x-y steering coils into the focusing solenoid package.

- Important design issue:
  - Minimize stray field at the RF cavity to prevent performance degradation due to trapped magnetic flux.

- Measured RF surface resistance with a sensitivity of ±0.1 nOhm before and after each quench of the cavity.

- The cavity was quenched with the solenoid and the steering coils energized.

- No quantifiable change to the cavity RF surface resistance.

Visit WEPTY009 For More Information