Update on PIP2IT warm front end (December 2017 – January 2018*)

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PIP-II Technical meeting
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* Period after the last update on December 5, 2017
Outline

• Highlights of MEBT-3.1 run
  – Note on MPS with RPUs
• Current shutdown
• Coming MEBT-3.2 run
• Further plans
MEBT-3.1 run

- Nov 27, 2017 – January 19, 2018
  - All focusing elements are in the final positions and operational
  - Fast Faraday cup and emittance scanner are at the MEBT end
  - Both kicker prototypes operational
  - Absorber prototype in location of the future absorber
  - Differential Pumping Insert (10 mm ID, 200 mm length)
Main goals for MEBT-3.1 run

- Characterize 50 Ohm kicker ✓
  - D. Sun’s report on Jan 16; L. Prost’s report on Jan 30
- Beam through Differential Pumping Insert ✓x
  - 10 µs beam (high power postponed to the coming run)
  - DPI works as expected for vacuum (A. Chen’s report on Jan 23)
- Operation of two kickers in sync ✓
  - Next slide
- Measure the beam properties at the MEBT exit ✓
  - J.-P. Carneiro’s today’s report on longitudinal measurements
  - A. Saini will report on Feb 27 on transverse measurements
  - Complete set of measurements, but some discrepancies persist
    - Longitudinal emittance is the biggest concern
Operation of two kickers in sync

- 50 Ohm kicker amplifiers generate a 81.25 MHz sine wave
  - D. Sun and LLRF group’s efforts
- 200 Ohm kicker switch produces waveform deflecting every other bunch of 162.5 MHz train
  - G. Saewert, D. Frolov, and LLRF group
- Kickers are phased with beam separately
- With both kickers on, one of trajectories is deposited to a scraper, another one is passed to the dump
Phase portraits with two kickers

- Total deflection is OK
  - There are indications of perturbations, not observed in measurements with 200 Ohm kicker only and "flat’ beam
- Might be not-optimum kicker phasing or large bunch length

January 3, 2018. 5 mA beam. No tail scraping upstream.
MPS with Ring Pickups

• Operated with 3 Ring Pickups (RPU)
  – Comparison of RPU#2 vs RPU#1 allows for controlling the beam loss between them when the beam is sent to the absorber prototype
• Since RPU depends on the bunch length (but not on the pulse length), a calibration procedure is required
Calibration of RPUs for high-power operation with MPS

- With absorber prototype moved out and kickers off, pass the beam cleanly to the dump at a safe pulse length (10 µs) and desired settings of the bunching cavities
  - Relying on absolute calibration of toroids and beam dump
  - Look at \((\text{RPU#2})/(\text{RPU#1})\) ratio and use it as a reference for a good transmission
- Move the absorber prototype in
- Enable MPS with threshold for \((\text{RPU#2})/(\text{RPU#1})\) ratio set ~3% below its good transmission level
  - 3% value is determined by the noise and remaining variation of RPU signals with the pulse length
- Increase the pulse length to ms
- Procedure worked
Side note on MPS for PIP-II

- The scheme with RPUs works good for PIP2IT. However, RPUs do not provide absolute values of the beam current, so the scheme relies on
  - Calibration procedure with 10 µs pulses
    - Beam properties are the same at any pulse length due to the special LEBT scheme
  - Fixed bunch length after the calibration
  - Independence of the RPU signal on the pulse length (up to CW)
- Need to decide what MPS elements will be used in PIP-II warm front end (to proceed with mechanical design)
  - E.g. using ACCTs instead of RPUs would significantly increase the period between elements
  - Plan to have a corresponding meeting next week
Operation with absorber prototype

- In MEBT-3.1, the absorber prototype was in the location of future full-power absorber
  - The main goal was to learn how to operate it
    - MPS, beam positioning, tuning, gas load, ...
- Maximum power to the absorber prototype was 2 ms x 20 Hz x 10 mA x 2.1 MeV = 0.8 kW (no hard limit)
  - LLRF group implemented 5 ms x 20 Hz mode in RFQ
  - Vacuum in the absorber chamber grew up to 6.E-6 Torr
    - Will install a dedicated turbo pump during the ongoing shutdown
Light from the absorber prototype

- Camera was installed (R. Thurman-Keup) to catch a thermal light expected at ~several kW level of average power
- Very unexpected: light from absorber surface at a low power
  - starting from $0.3 \text{ ms} \times 20 \text{ Hz} \times 5 \text{ mA} \times 2.1 \text{ MeV} = 60 \text{ W}$
  - Nothing similar was observed even at 10x higher power when theis absorber prototype was at the end of MEBT
  - Major difference is much worse vacuum

Light from the beam (left) and image of the absorber surface illuminated by flashlight (right) at the same camera position. 16-Jan-2018, B. Hanna and C. Richard). 3 ms x 20 Hz x 10 mA.
Current “RFQ” shutdown

- 4 weeks shutdown; expect to start beam in week of Feb 19
  - Led by C. Baffes; majority of technical work by D. Lambert and C. Exline
- The main goal is to address RFQ issues
  - All fixed tuners are replaced to move the resonant frequency to the design value of 162.50 MHz (by ~80 kHz) ✓(preliminary)
    - LBNL made simulations and supplied the drawings
    - J. Steimel, D. Sun; C. Baffes, D. Lambert;
  - RFQ couplers replacement (S. Kazakov, TD RF group)
    - New design with ceramics sealed with O-rings instead of brazing
      - S. Kazakov’s report on Jan 30
      - New couplers are installed and tuned
      - High-power test will start this week
Shutdown: work in MEBT

• A set vacuum protection tests (A. Chen; to continue in April)
• Multiple tasks in MEBT
  – Replacing Buncher #1 by the last production cavity
    • The prototype cavity will be a spare
  – Finish installation of all scrapers (+ 4 plates); RPU#3; turbo
  – Instrumentation: wire scanner prototype; Bergoz ACCT, vacuum chamber for the laser wire; laser hut outside of the cave
Plan for MEBT-3.2 run

- Last long run (~ 7 weeks) before installation of cryomodules
  - Starting in the week of Feb 19; stopping in the week of April 9
- The main goals
  - RFQ on frequency and in CW
    - Priority for resonance control studies and other RF-related issues
  - CW beam
    - Requires MPS and Instrumentation studies
    - Long runs with beam to the dump and to the absorber prototype
- Long list of other studies is being discussed
  - Intention is to have studies more focused and better prepared
- Cryo distribution system work outside of the cave is starting
  - Need to proceed with in-cave work in April
    - Which determines the end of MEBT-3.2 run
Present study list

- Bunchers phasing procedure and stability
- Longitudinal measurements (may be with FFC near RFQ)
- Transverse optics stability
- Collimation studies
- 50 Ohm kicker vs energy
- Extinction measurements (including with two kickers)
- Bunch length (measured with kickers)
- Differential Pumping Insert cooling
- Instrumentation:
  - Wire scanner, new ACCT, BPM phases, RPU 3\textsuperscript{rd} harmonics
- Intensity modulation sensitivity (to prepare for the laser wire)
- Light from absorber prototype (+ video system)
Preparing for the 2 – year shutdown

• Putting efforts into conservation of the warm front end would help its re-start after installation of cryomodules

• Need to formulate the conservation status
  – Water drain? Power disconnects? Vacuum?
  – Policy on electronics (should not be touched?) etc.
  – ACNET pages, programs?

• Would be very useful to document the working machine
  – Need to define a doable scope
    • Photos
    • Copies ACNET parameters at operational conditions
    • Description of running procedures, links to descriptions of instruments, reports…
  – May devote the last week of the run for documenting
“Summer run”

- We are requesting from management a 3-week run in summer (~July 23) with narrow goals
  - Test the full-scale MEBT absorber (~20 kW)
    - J. Batko’s report on Nov 28, 2017
    - Ready to be procured; waiting for approval by management
  - Laser wire tests
    - All main components are on hand but will take time to assemble
    - V. Scarpine’s report on Jan 16, 2018
- Unlikely to fit too many other studies because of time constrains (due to cryo distribution system work)
Summary

- Most of R&D goals for PIP2IT warm end are reached
  - However,
    - Longitudinal emittance is a concern
    - Many other smaller questions and operational issues remain
- The biggest missing part, CW operation, should be demonstrated in the coming MEBT-3.2 “March” run
  - Ongoing shutdown should prepare the RFQ for CW operation
  - Upgrades to MPS should provide additional protection layers
- Testing the MEBT absorber and the laser wire would noticeably decrease the technical risks
  - Need money now and 3 weeks to run the beam in Summer’18
- Need to think how to prepare the machine for 2-year gap in operation