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MEBT status and plans

A. Shemyakin

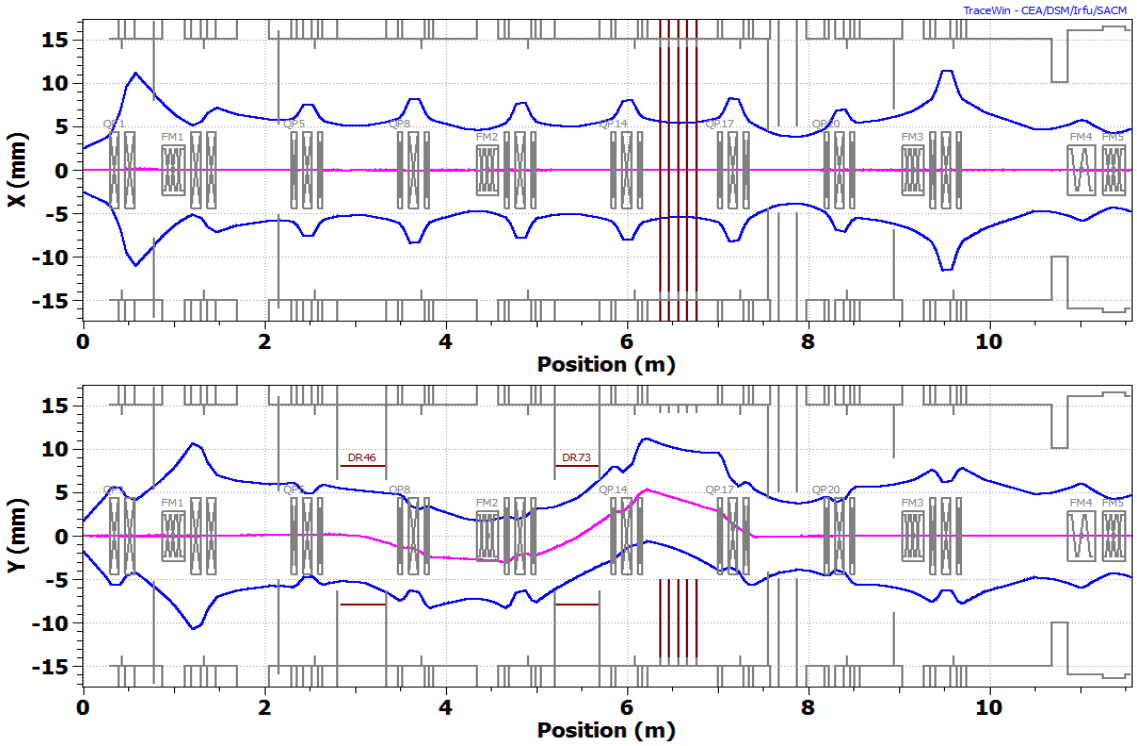
PIP-II Collaboration Meeting

9-10 November 2015

Outline

- Configuration and functions
- Components
- Commissioning plans
- MEBT at PXIE vs PIP-II

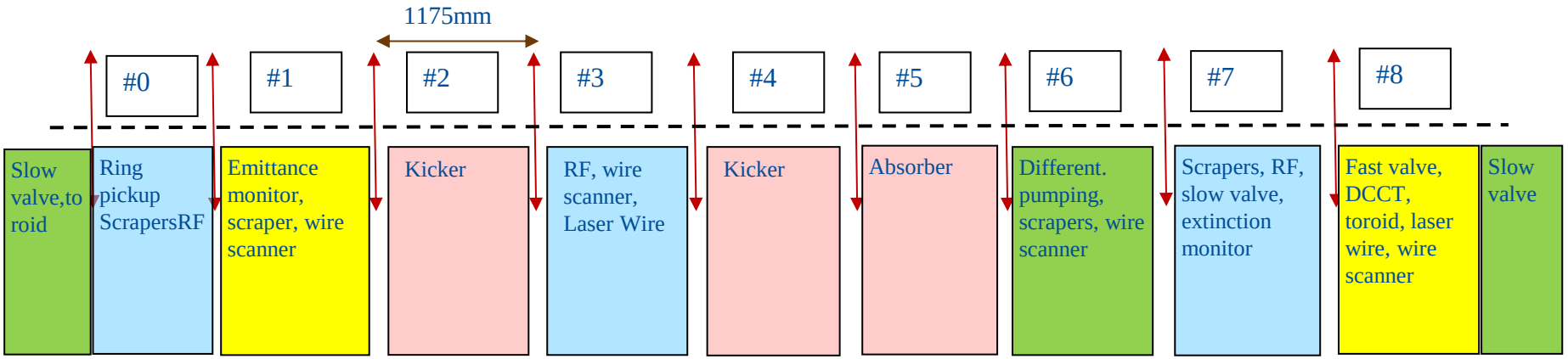
MEBT configuration



3σ envelopes of passing bunches.
2.1 MeV, 5 mA. TraceWin.
A. Saini.

- Two doublets and 7 triplets; three bunching cavities
  - No significant changes in the optical design since 2011
- Chopping system: two kickers and absorber
- Smaller beam size after absorber for differential pumping

MEBT functions



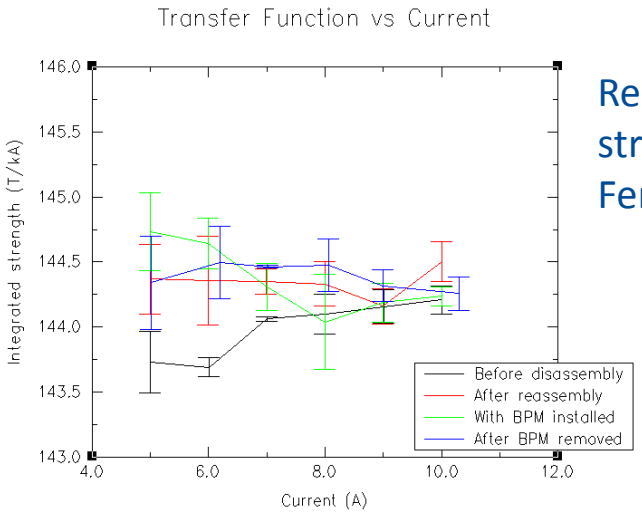
- Optical matching from RFQ and to HWR
- Chopping
  - Any bunch from initial CW train can be removed
- Scraping
- Transition from HV to particle-free, UHV part upstream of HWR
- Measuring beam parameters, MPS

MEBT components

- Magnets
- Bunching cavities
- Scraping system
- Chopping system
- Vacuum components
- Instrumentation- see Vic Scarpine’s talk

Magnets

- 25 quadrupoles, 9 dipole correctors (X&Y) + spares
  - Produced by BARC, India and delivered in batches
  - First two doublets with dipole correctors are installed on girder
    - Considered prototypes, but quality within specs
  - Four triplets are coming in June 2016
  - The rest in FY17
- Power supplies are inherited from ECool

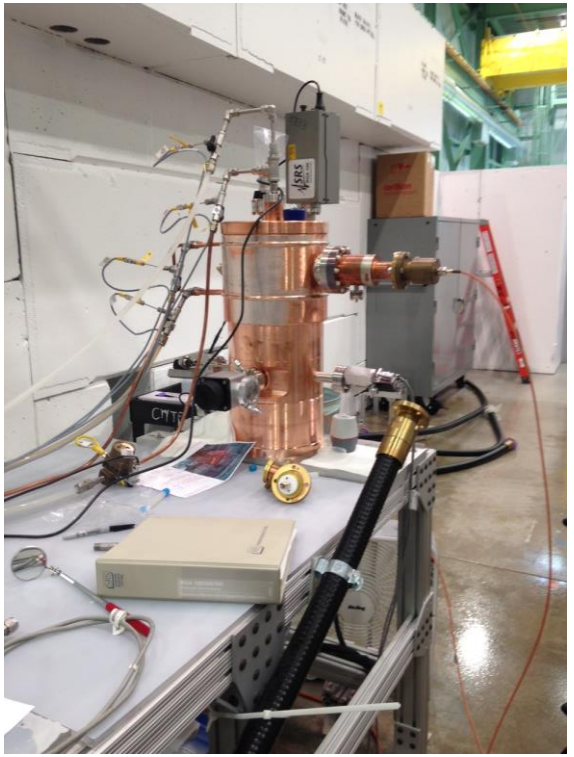


Relative quadrupole strength measured at Fermilab. M. Tartaglia

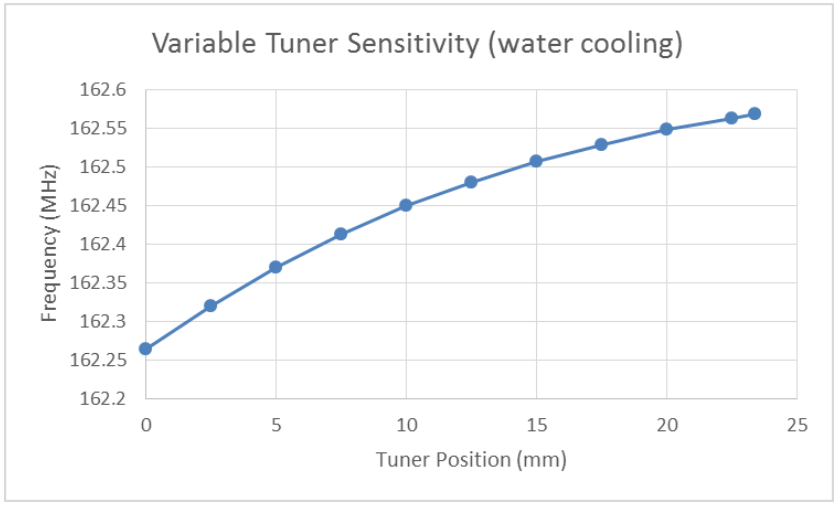
Two doublets and bunching cavity installed on a girder in the PXIE cave

Bunching cavities

- Designed by Fermilab, procured at HiTech
- A prototype was fully tested
  - A vacuum leak was cured with epoxy
  - Properties are within specs
- Three production cavities have been ordered
  - Delivery is expected in May 2016

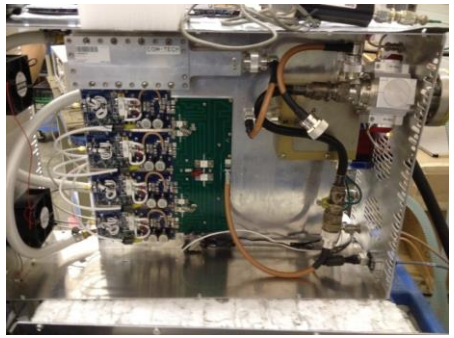


Prototype bunching cavity under testing in the PXIE cave (D.Sun, J.Steimel, D.Peterson)



Bunching cavity amplifiers

- Five units had been ordered and delivered
  - Comark 3 kW CW 162.5 MHz TAVD-600L
    - need ~1 kW for bunchers, 3 kW for the first HWR cavity
- All five returned to Comark for repair; two returned to FNAL
  - one of them failed again on flow meter fault
  - second can run CW at 3 kW with a 50 ohm load
    - does not operat correctly into a non 50 ohm load.
    - Same for all modified units, requiring a software revision. Status pending.
  - Waiting for response from Comark on how to proceed



COMARK Communications

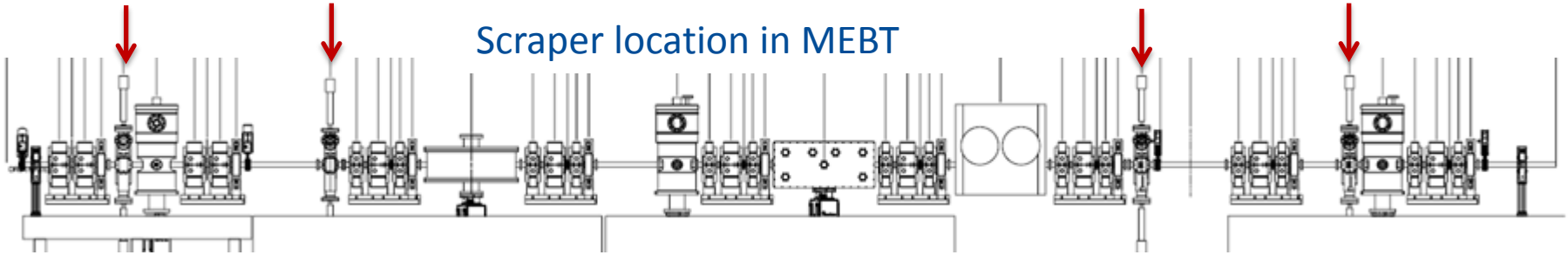
R. Pasquinelli,
D. Peterson

MEBT scraping system

- 4 scraper sets, 4 blades in each set. Will be used for
  - Diagnostic
    - Beam size and profile measurements; beam halo
  - Part of active protection system
    - Increased scraper current generates alarm signal for MPS
  - Scraping (the main function)
    - Scrape the beam halo or intercept the beam in case of incidents
- One set was successfully tested at LEBT
  - 100W/set rating

Single blade.
C. Baffes, K. Kendziora

Scraper location in MEBT



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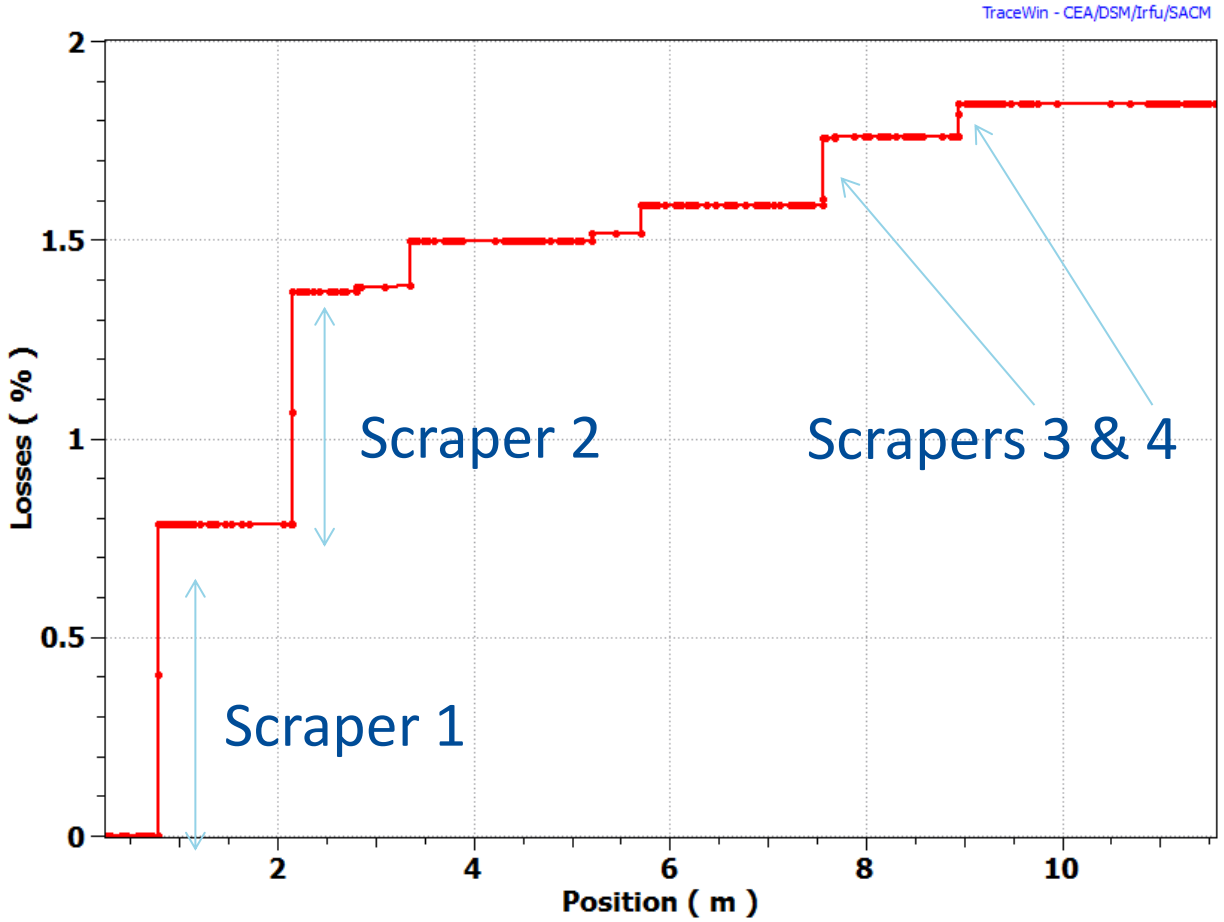
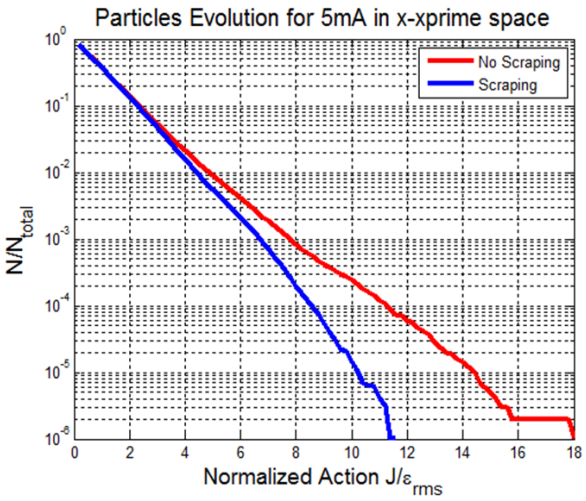
Nominal scraping scenario



Scraper 1	Scraper 2	Scraper 3	Scarper 4
0.8 %	0.6%	0.16 %	0.08 %

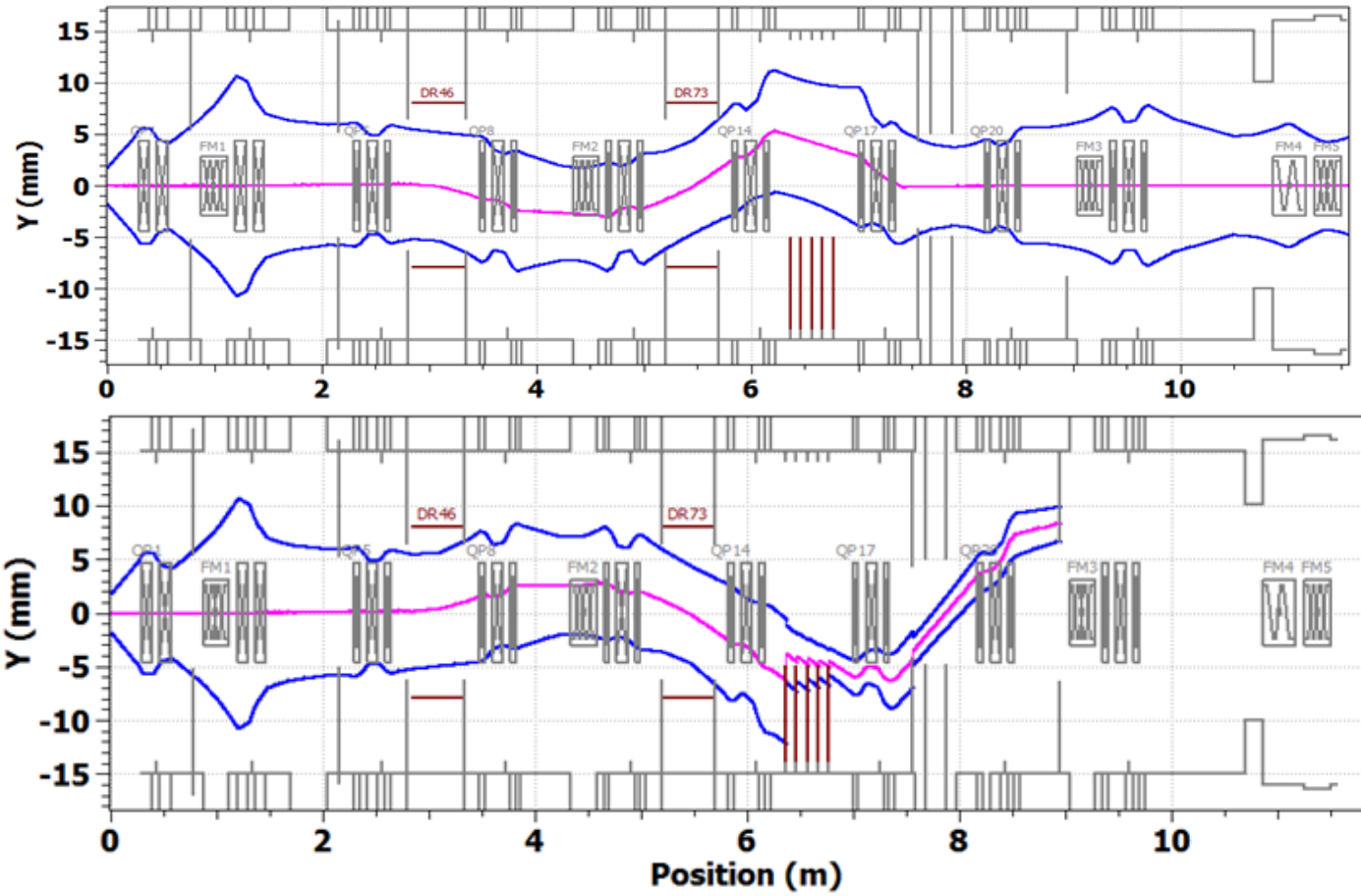
- Scraper positions are adjusted to be close to 90º of transverse phase advance
- Protect SRF from trajectory or envelope errors



Beam losses for passing bunches. Nominal beam (5 mA, $\varepsilon_{tr/z}$=0.21/0.28 µm). A. Saini.

Chopping system

- Two travelling-wave kickers working in synch and absorber
  - Two kicker versions, 50 Ohm and 200 Ohm



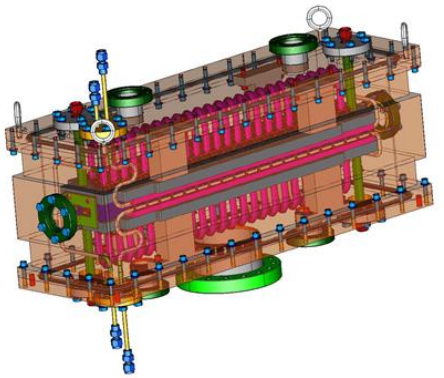
Passing bunch. -250V, +250V on upper plates.

Removed bunch. +250V, -250V on upper plates. Case with 0.05% of beam leaking to scrapers is shown.

3σ envelopes. 2.1 MeV, 5 mA. A. Saini.

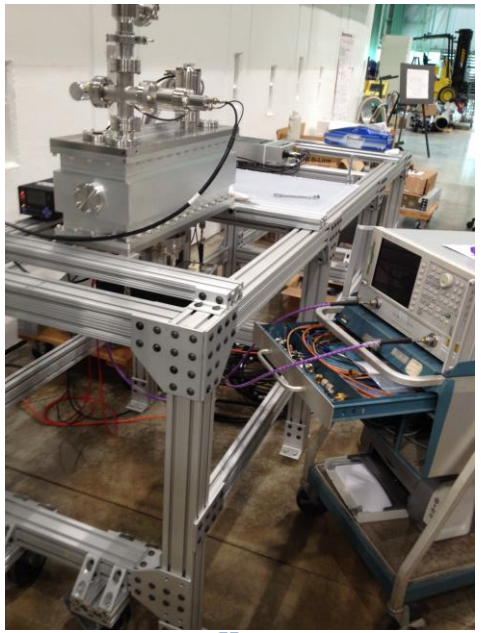
50 Ohm kicker

- Features
  - Bipolar signal; commercially available amplifier
  - bunches to be removed or passed are kicked in opposite directions
  - Plates connected in vacuum with 50 Ohm cables
- Status
  - One plate is successfully tested in vacuum
    - Full-power and RF measurements
  - Final prototype is fully assembled
    - Will be power-tested in coming months



3D model. A.Chen, M. Jones

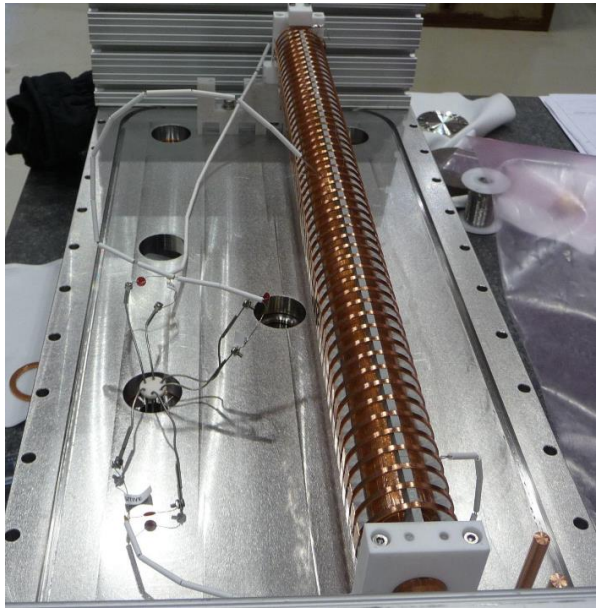
Half of the kicker (one plate) assembled. D.Sun



Kicker under testing. D.Sun, D. Peterson

200 Ohm kicker

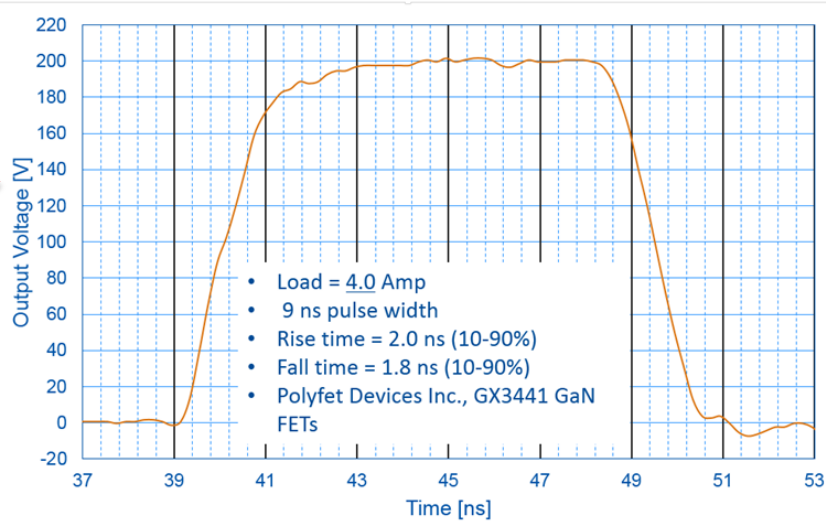
- Higher impedance allows considering a fast switch as a driver
  - Potentially simpler and cheaper solution; DC-coupled
- TW structure is a helix
- One vacuum-compatible helix was tested
  - Power testing in vacuum is successful
  - The phase velocity was found off by 5%; redesigned
- Parts for a complete kicker have been ordered
  - Will be fully tested before June 2016



Kicker prepared for power testing in vacuum.
A.Chen, G.Saewert

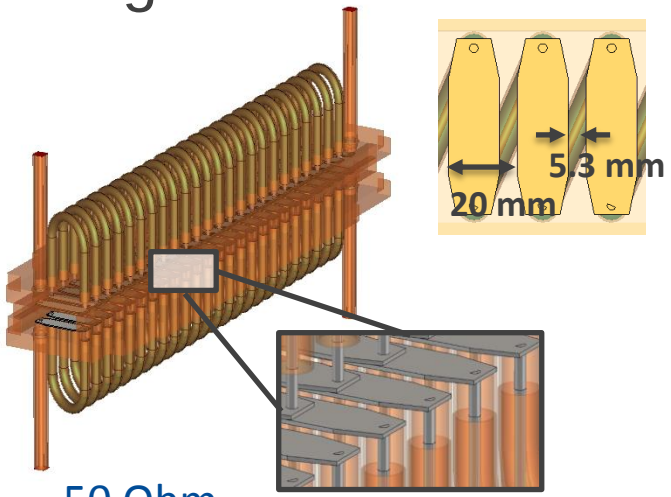
200 Ohm Helix Driver (G. Saewert)

- Initial scheme: bipolar cascode switch; 5 FETs each side
  - 500V with one side was demonstrated; 2.3/ 9 ns times
  - Bipolar: too high capacitance; dead time during transition
  - Found that driver jitter is low => can drive FETs individually
- Present stage: unipolar switch
  - Two FETs driven individually
  - matched to <0.2ns
  - 200V pulse with good rise/fall time
- New development
  - New GaN FETs, 650V rating
  - Switch with 3 FETs is being assembled; goal is ≥500V
  - Cooling scheme for CW (~35 MHz) is being designed

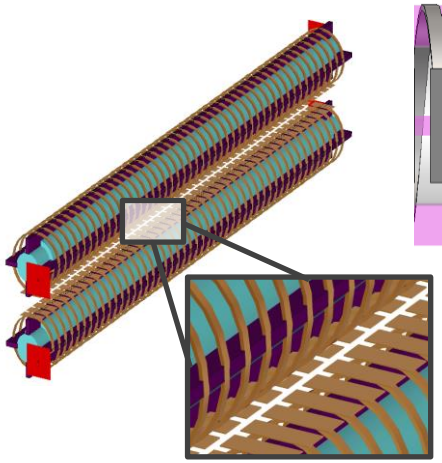


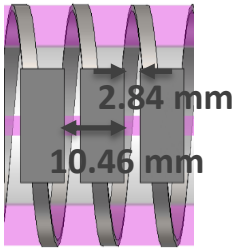
Kickers simulations (M. Hassan)

- Both kickers were simulated with time domain solver of CST
  - With all mechanical details and realistic pulse shapes
- Angles differ from the model of parallel plates by <10%



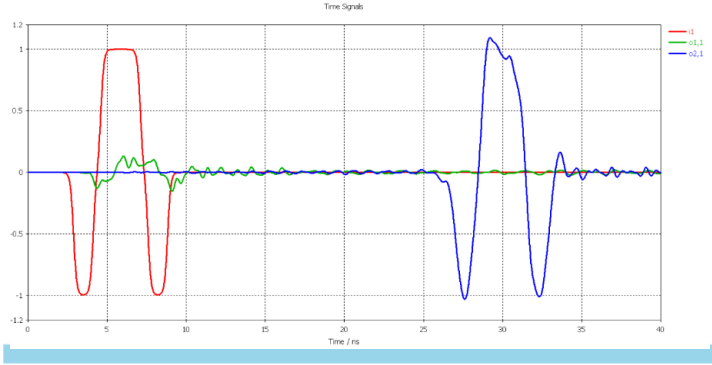
50 Ohm

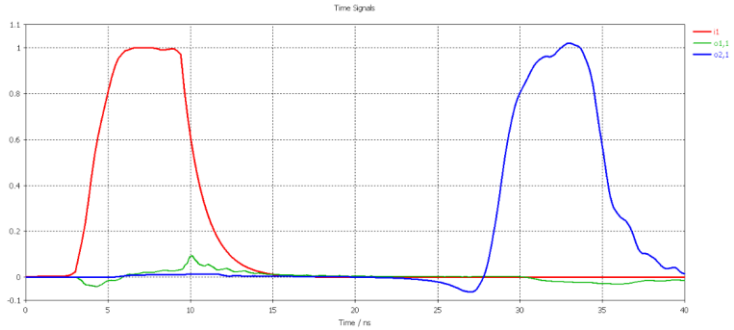




200 Ohm

Simulated geometries and propagated signals for two kickers

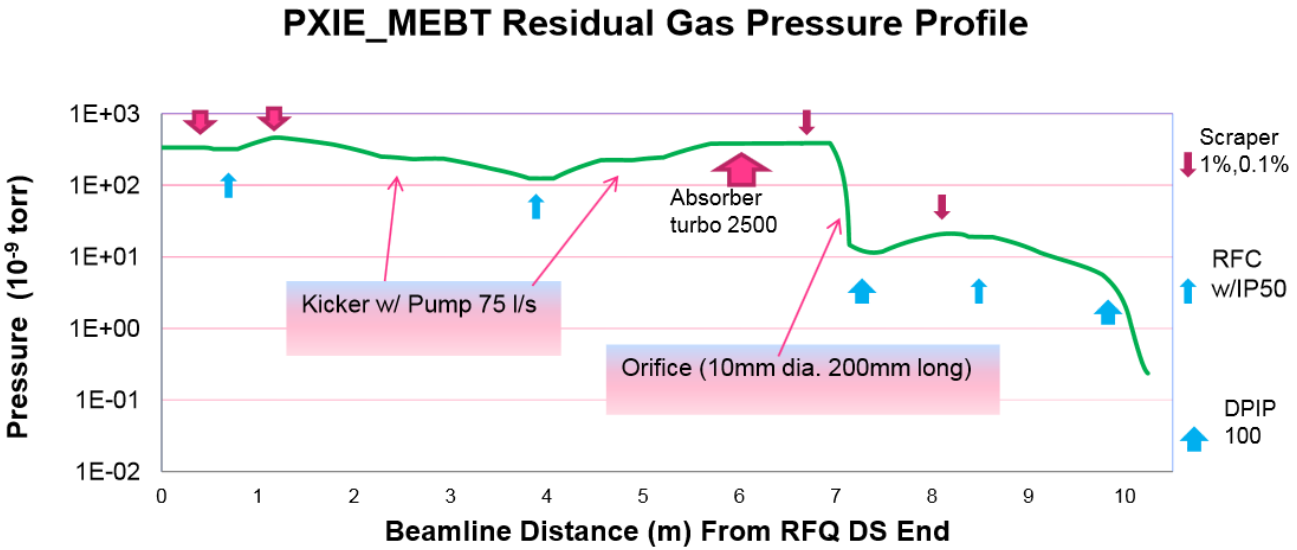




Fermilab PIP-II

Vacuum components

- MEBT vacuum concept did not change since 2012
  - HV in most of MEBT and UHV, particle-free in last ~3m



A. Chen

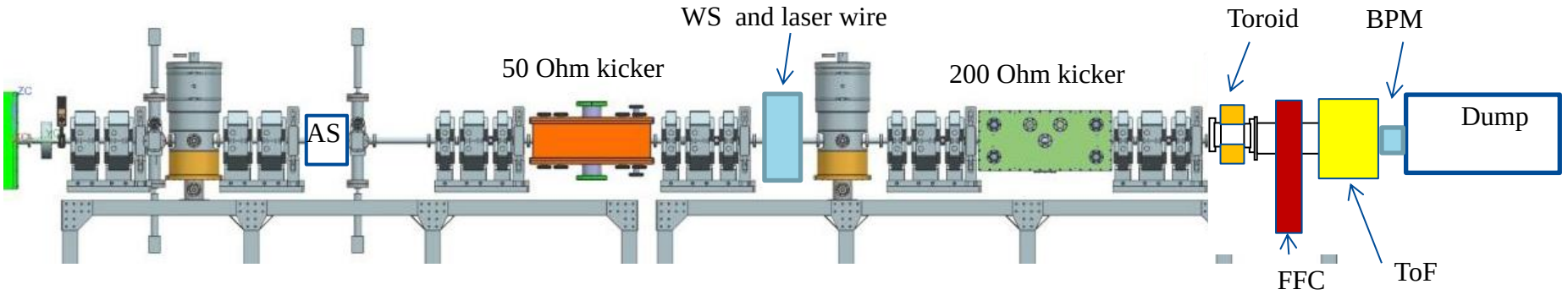
  - All vacuum equipment was identified and most purchased
  - Design of the differential pumping section will start in FY16
  - During PXIE operation, need to determine for PIP-II
    - Length of particle-free region
    - Fast acting valve system area (see C. Baffes' talk)

MEBT commissioning plans

- MEBT length will grow in 3 steps, determined by magnet delivery schedule
  - MEBT-1 – 2 doublets, 1 bunching cavity (FY16)
    - Main goal: commission the RFQ beam – see J. Steimel's report
    - Test absorber prototype with H- beam
  - MEBT-2 - + 4 triplets, 1 bunching cavity
    - Install in Jul-Sep 2016, run in Oct-Dec 2016
  - MEBT-3 - + 3 triplets, 1 bunching cavity
    - Install in Jan-Feb 2017, run Mar-Apr 2017
- The final MEBT (install in 2017)
  - Particle-free vacuum chamber in front of HWR
  - Final chopping system

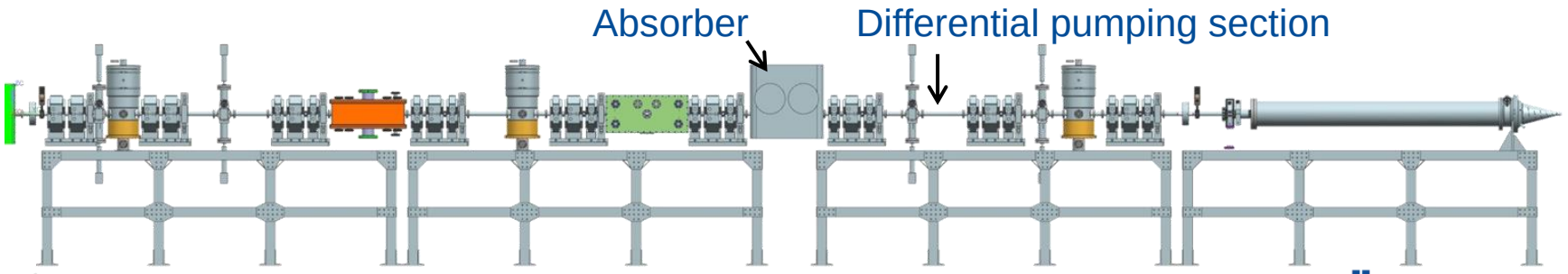
MEBT-2

- 2-3 versions differing by placement of diagnostics
- The main goal is to test kickers
  - Both prototypes are installed
  - Test: kickers survival and resulting angle
  - 50 Ohm: two 81.25 MHz CW drivers
  - 200 Ohm: two 500V switch prototypes
  - If lucky and time permits, may try to run them in synch aiming to observe separation of every other bunch
- Also: optics; tests of laser wire and extinction monitor (RWM)



MEBT-3

- All magnets, cavities, and scrapers are in final locations
- The last ~2m are “cleanable” but assembled not particle-free
- The kickers are 50 Ohm and 200 Ohm prototypes
- 5kW absorber prototype instead of full absorber
- Likely several versions similar to MEBT-1,2
- Main goals
  - Prepare beam for injection into HWR
  - Optics; UHV sections and differential pumping
  - Continue previous measurements



PXIE MEBT vs PIP-II MEBT

- While all PXIE MEBT components are designed to PIP-II specs, there may be differences
  - The ion source needs to be accessible during linac operation
    - Need a radiation wall (similar to SNS) in MEBT; might fit into one more section
  - PXIE experience may indicate a need for a longer particle-free region in MEBT
  - More detailed analysis of risks may require a longer distance from the MEBT chopper absorber to SRF to provide protection by the fast acting valve
  - Longer MEBT would require additional triplets and may need an additional bunching cavity