



U.S. DEPARTMENT OF  
**ENERGY**

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Science

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# Draft for PIP-II Machine Protection System (MPS) FRS

Alexander Shemyakin  
PIP-II Technical meeting  
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# Reasoning to start writing PIP-II MPS FRS now

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- Needed for progressing with the PIP-II design
  - Discussing the MPS hierarchy and scales should help for defining other systems
- To agree on possible MPS logic and try it at PXIE
  - The main goal of PXIE MPS is to protect the PXIE
  - Still, implementing elements of a structure applicable to PIP-II would be highly desirable
- B. Chase pointed out that the PIP-II MPS will heavily depend on the PIP-II High Performance Electronics and Timing System and is preparing a meeting on this system

# Preparation

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- Two meetings in a smaller group
  - B. Chase, P. Derwent, N. Eddy, M. Kucera, V. Lebedev, J. Patrick, V. Scarpine, A. Shemyakin, J. Steimel, G. Vogel, A. Warner
  - Materials are at
    - <http://pip2-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=46>
    - <http://pip2-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=24>
  - This FRS is meant to describe logic and typical numbers, while real implementation requires a much more technical and detailed document (TRS)
- FRS draft is in Teamcenter, ED0004250
  - A copy in PIP2 DB entry for this meeting

# Machine definition

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- PIP-II is a 2 mA CW, 800 MeV H- linac that should be capable of working initially in a pulse (0.55 ms, 20 Hz) mode for injection into the Booster.

# Summary of suggestions in the MPS FRS

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- Two-tier MPS: primary and secondary devices
- Scales for loss levels and response time
- Two-tier response to events

# Hierarchy of MPS – related devices

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- Primary and secondary devices
- Primary devices
  - Small number of devices responsible for a global protection in the Linac. Should guarantee that, when function properly, no dramatic damage can be caused by the beam.
  - High level of scrutiny. Specified in TRS with testing procedures. Modification require approval by the MPS coordinator.
  - Can't be masked.
- Secondary devices
  - Majority of devices. Typically protect local elements.
  - PIP-II MPS TRS should describe them broadly and specify the general protocol of interaction with MPS. Some devices can be masked.

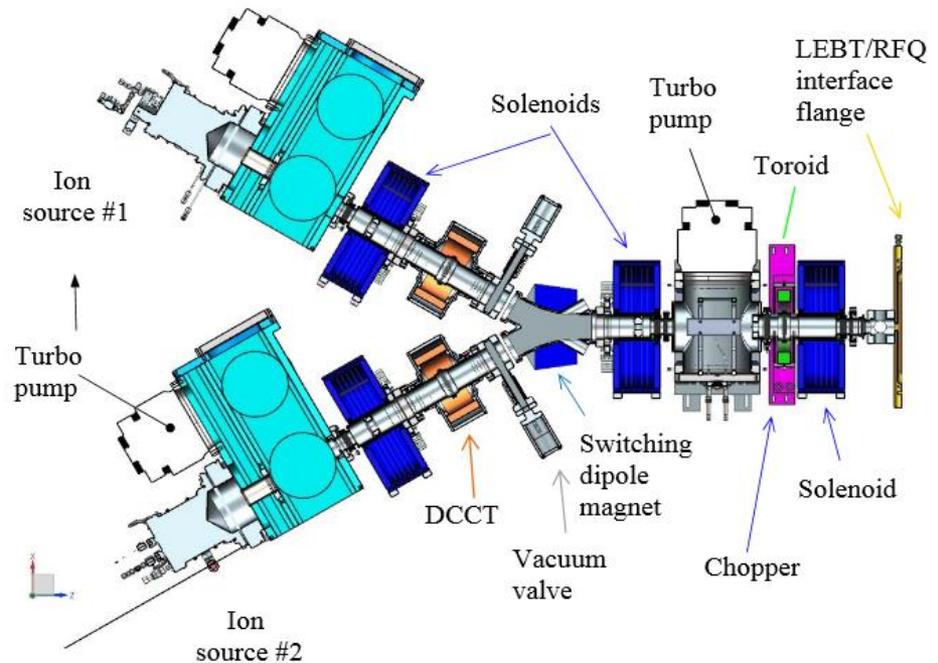
# Primary MPS devices (1) - sensing

- Signal from Fermilab Complex MPS
- System that compares the beam current measured in several locations downstream of MEBT
  - difference = beam loss
  - Inspired by SNS results and JLab experience
    - [http://accelconf.web.cern.ch/AccelConf/ibic2013/talks/thal2\\_talk.pdf](http://accelconf.web.cern.ch/AccelConf/ibic2013/talks/thal2_talk.pdf)
  - Current signal shape and amplitude need to be transmitted fast and accurately along the linac
  - Provides fast protection from large loss and slower from a low loss (scales are discussed later)
  - Might be a combination of pickups, toroids, and DCCT



## Primary MPS devices (2)

- Beam shutting – down
  - LEBT chopper, LEBT dipole, Ion Source modulator, Ion Source bias power supply
- Up to the end of MEBT, sensing is provided by secondary devices only (scrapers, DCCT, toroids, vacuum)
  - Scraping and bunch-by-bunch selection make this section too complicated to impose inflexible restrictions
  - Low energy and warm elements make it less vulnerable to beam losses



# Secondary MPS devices

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- The list of secondary sensing devices includes
  - Status signals from subsystems
    - A malfunctioning subsystem (e.g. RF amplifier) should drop the beam permit
  - Vacuum gauges
  - Positions of insertion devices
  - Indicators of beam losses (e.g. radiation monitors, scrapers)
- Possible secondary beam-shutting devices
  - MEBT chopper, switching magnets, separators
  - RFQ/LEBT timing (for pulse operation)
- Warm front end protection:
  - Robustness should be achieved by redundancy in secondary devices protecting the warm front end

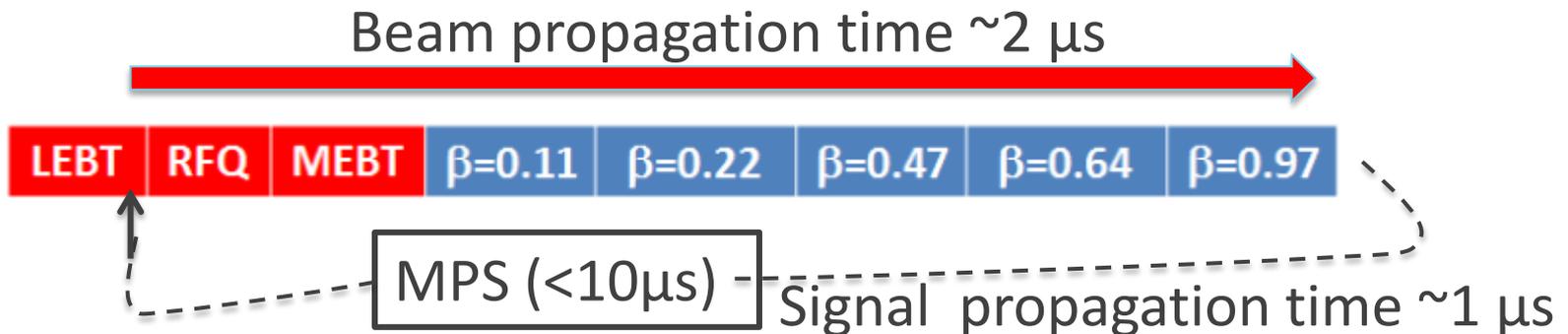
## Scales (primary system)

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- The primary sensing system that compares the beam current in various locations should identify the beam loss and drop the beam permit if the loss exceeds
  - $>500 \mu\text{A}$  while averaged over  $1 \mu\text{s}$
  - $> 5 \mu\text{A}$  averaged over one power line period ( $1/60 \text{ s}$ ) for operation in CW regime
- The primary system should drop the permit if it detects a large deviation of the measured beam pattern from the expected one.
  - current averaged over  $30 \mu\text{s}$  sliding time window exceeds the expected value by more than 20% of the beam current or  $20 \mu\text{A}$ , whichever is larger.
- The numbers may change after getting experience at PXIE

# Response to events (1)

- The beam can be shut off in one or two steps.
  - Step 1: The beam is shut off by the LEBT chopper within  $10\ \mu\text{s}$  after a system drops the beam permit. This time is measured as difference between moments of the permit drop in the location of the failure and disappearance of the beam at the entrance of the RFQ.
  - Step 2: If the average beam current measured by designated primary system devices doesn't drop below measureable level after  $15\ \mu\text{s}$ , the Ion Source modulator, LEBT dipole and the Ion Source bias power supply are turned off.



## Response to events (2)

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- MPS should be capable of
  - initiating both steps at once in potentially severe cases
  - assigning different latching scenarios to different events
    - Automatic restoring vs operator acknowledgement
- SNS experience
  - In 2009, had events with 24 mA “errant” beam being interrupted only after  $\sim 100 \mu\text{s}$  without dramatic damage
    - While it’s difficult to quantify this experience based on papers and discussions, PIP may have a large safety margin
  - SNS still had a strong negative effect of the errant beam on SRF cavity performance (needed to warm them up)
    - Pushed to  $6 \mu\text{s}$  beam exposure time (after detecting a fault)
    - Based on two toroids

## Further steps

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- Get feedback from the PIP-II team and modify the draft accordingly
  - Depending on outcome of discussions, may stay in a draft form until contours of underlying systems are more clear
- Start preparing MPS TRS. In part, experts need to agree on
  - timing system and interfaces
  - the boundary between Instrumentation and MPS
- Look at what can be tested at PXIE