MEBT Vacuum Protection of SRF For PXIE and PIP-II

C. Baffes, A. Chen
Fermilab

PIP-II Technical Meeting
May 12 2015

Document DB# 1373

U.S. DEPARTMENT OF ENERGY

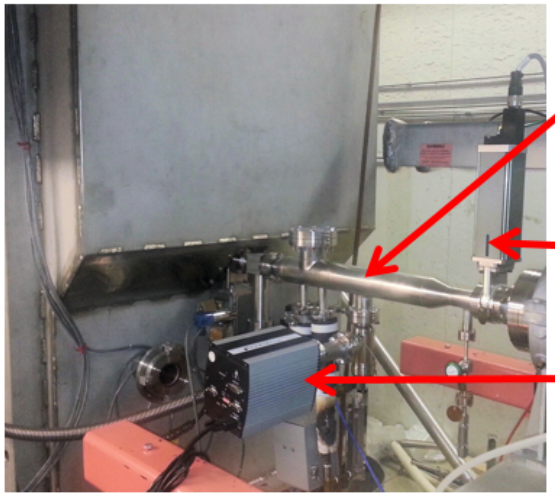
Fermilab

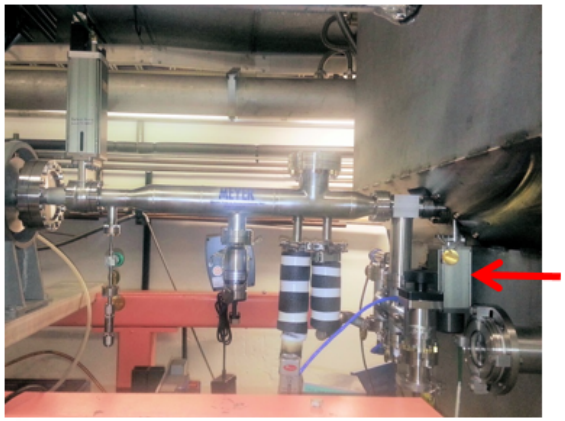
Background

- SRF cavities can be degraded or even destroyed by loss of vacuum
  - Transport of particles into cavity
  - Condensation on cavity walls
- High-pressure gas loads will propagate down the beamline at ~speed of sound
  - ~3.4E2 m/s for air
  - ~5E2 for water vapor
  - Shockwaves travel faster than this but can be passively dissipated
- Conventional mitigation is use of a fast-closing valve
  - Manufactured by VAT
  - System closing times 10-40ms (depending on valve size)
  - Requires distance between trigger gauge and valve
- MAC has noted the vulnerability of our SRF
  - Also related is the length of the MEBT that should be “particle free” assembly

ANL ATLAS Implementation

Issue of Maintaining the Clean Vacuum Space (a.k.a. Protection from the ATLAS Users)





- 80 Kelvin ~1/2 meter long liquid nitrogen cooled cold traps installed at the entrance and exit for clean cryomodules
- Volatiles, water, particulates adsorb to the surface of a 2.5" cm diameter copper tube
- Gate valves at the entrance and exit of the Cryomodule are interlocked to cold trap ion gauges
- A fast acting valve (~10 mS) will isolate experimental areas from the accelerator in the event of a vacuum accident

M. Kelly, Z. Conway

Active protection - fast valve

- DN-40 Version
- Advertised closing time ~13ms – fastest model available
- Dedicated fast gauges and controller
- Makes a positive seal

Fast valve testing at CERN

WEPME039 Proceedings of IPAC2014, Dresden, Germany

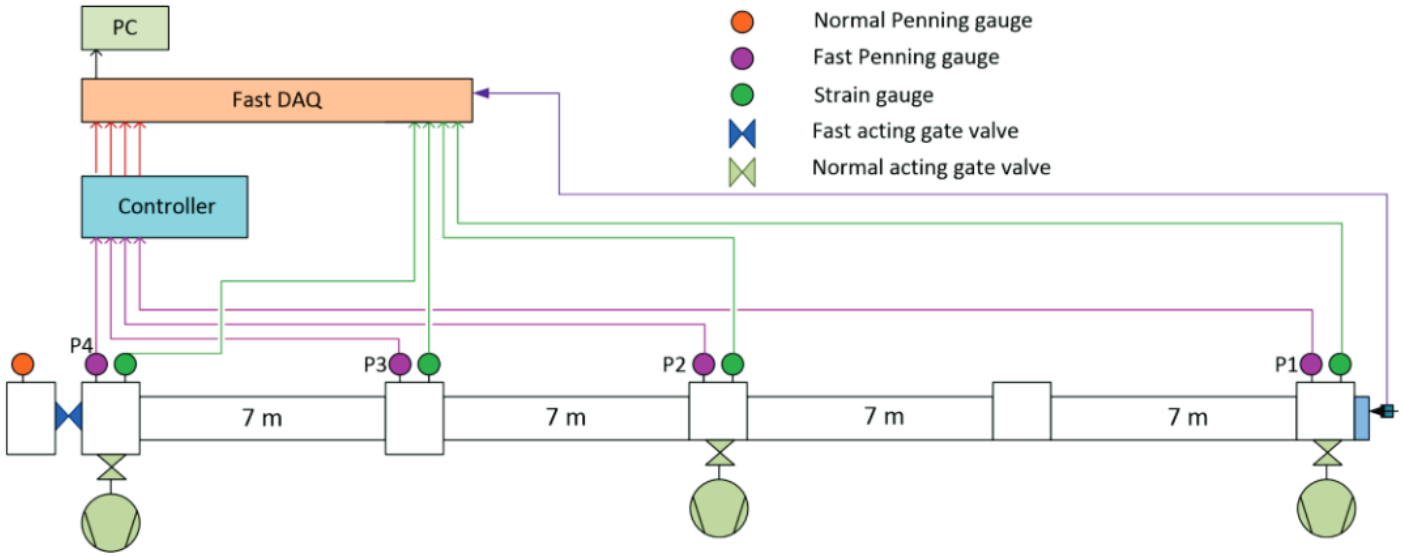


Figure 1: Schematic view of the experimental set-up.

M. Ady et al. [1]

Ongoing work at CERN
Fast valve testing

- Shock wave propagation speeds of 500-900m/s
- Valve closing time < 10ms

M. Ady et al. [2]

Initial pressure wave at ~10^{-3} torr, not enough to move particles

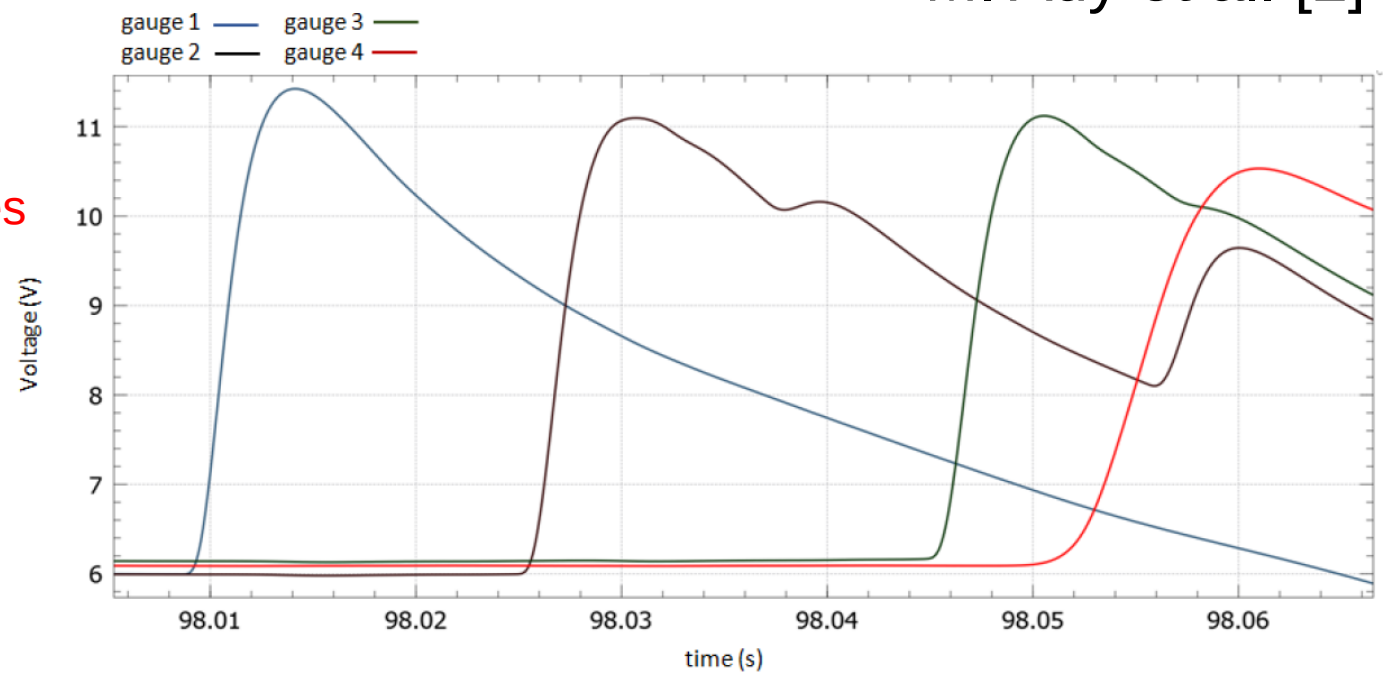


Figure: pressure signals for the four gauges at test #120, where the average propagation speed was 780m/s. In less than 60ms, the shockwave reached the end of the system and all gauges saturate.

Passive protection - baffling

- Baffles attenuate shock waves
  - Propagation speed can be reduced to ~speed of sound
  - Likely reduce particle transport
  - Natural to implement as part of our differential pumping orifice

Takiya et al [3]

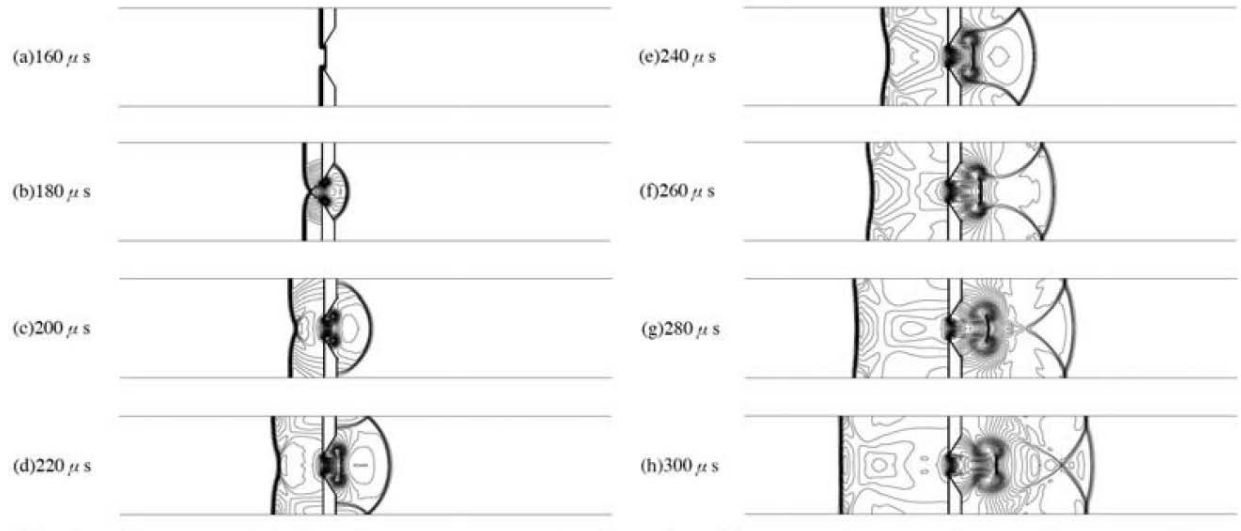
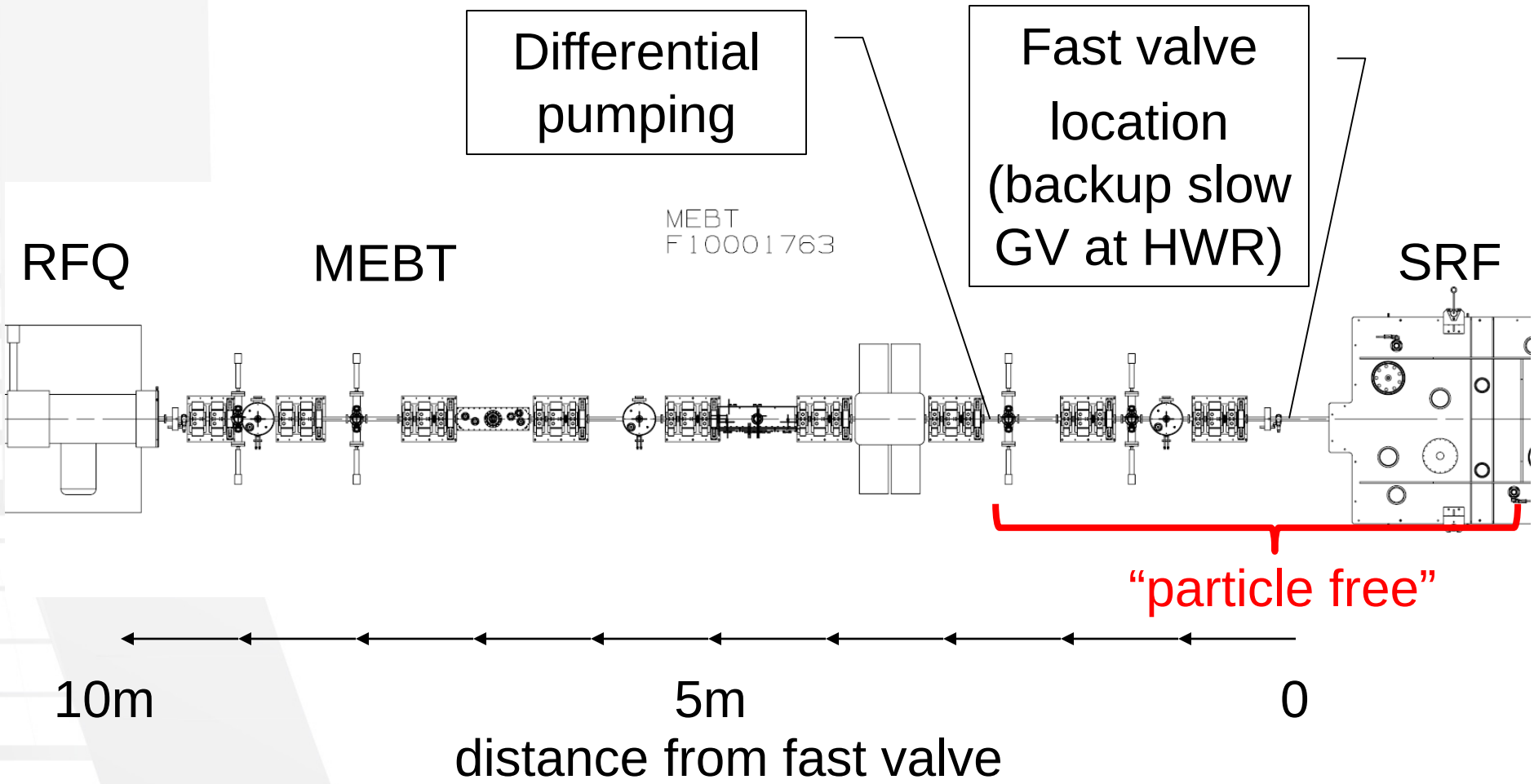


Fig.3 Sequential density contours during shock wave interaction with an orifice

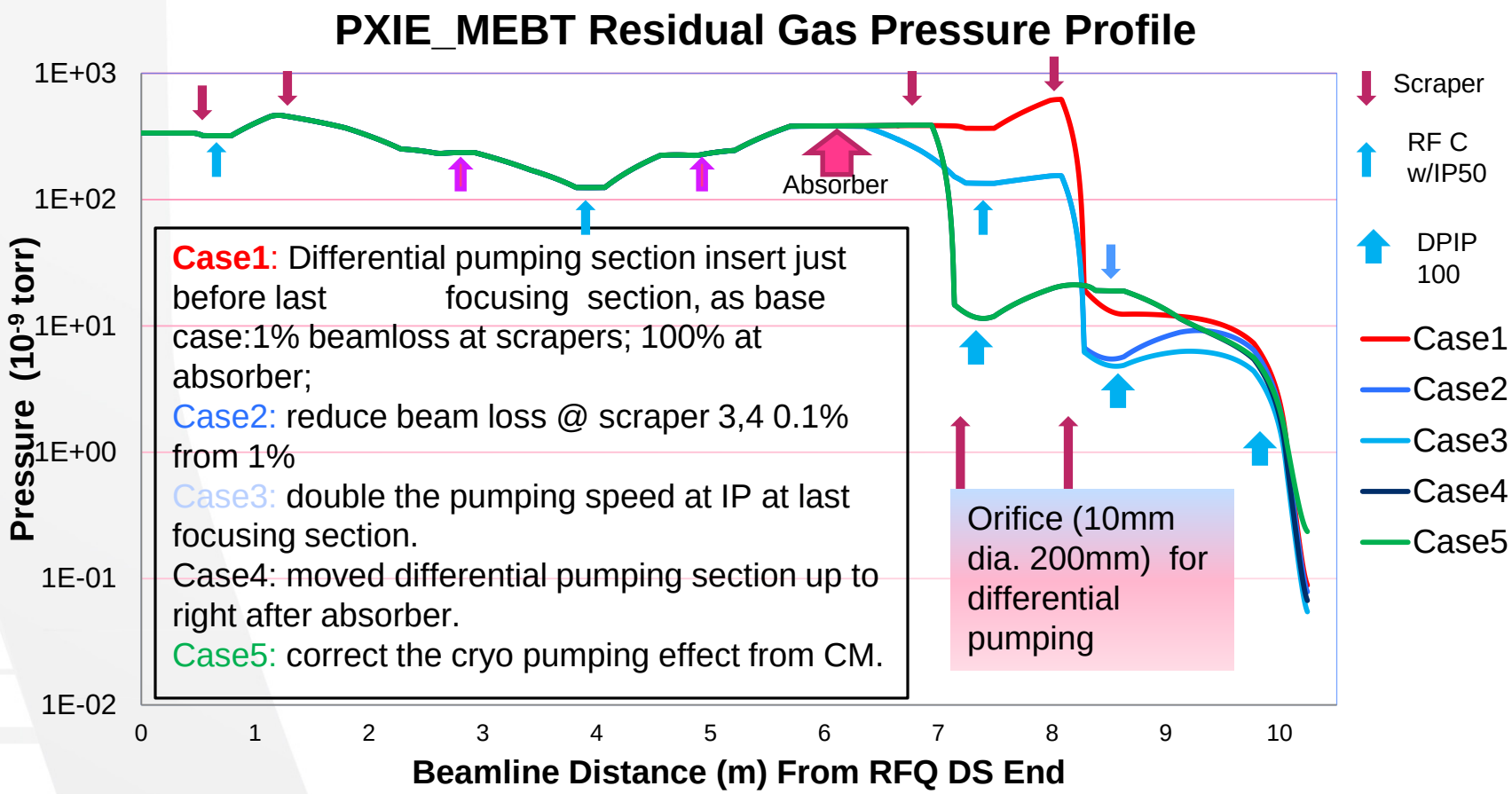
First-order protection calculations

- Assume inrush gas velocity at 500m/s
  - Speed of sound for water vapor
  - Implied in this assumption is affective baffling to limit velocity
- Assume 13ms as valve close time (manufacturer spec)
- Need ~6.5m minimum between gauge and valve

Current PXIE MEBT Layout



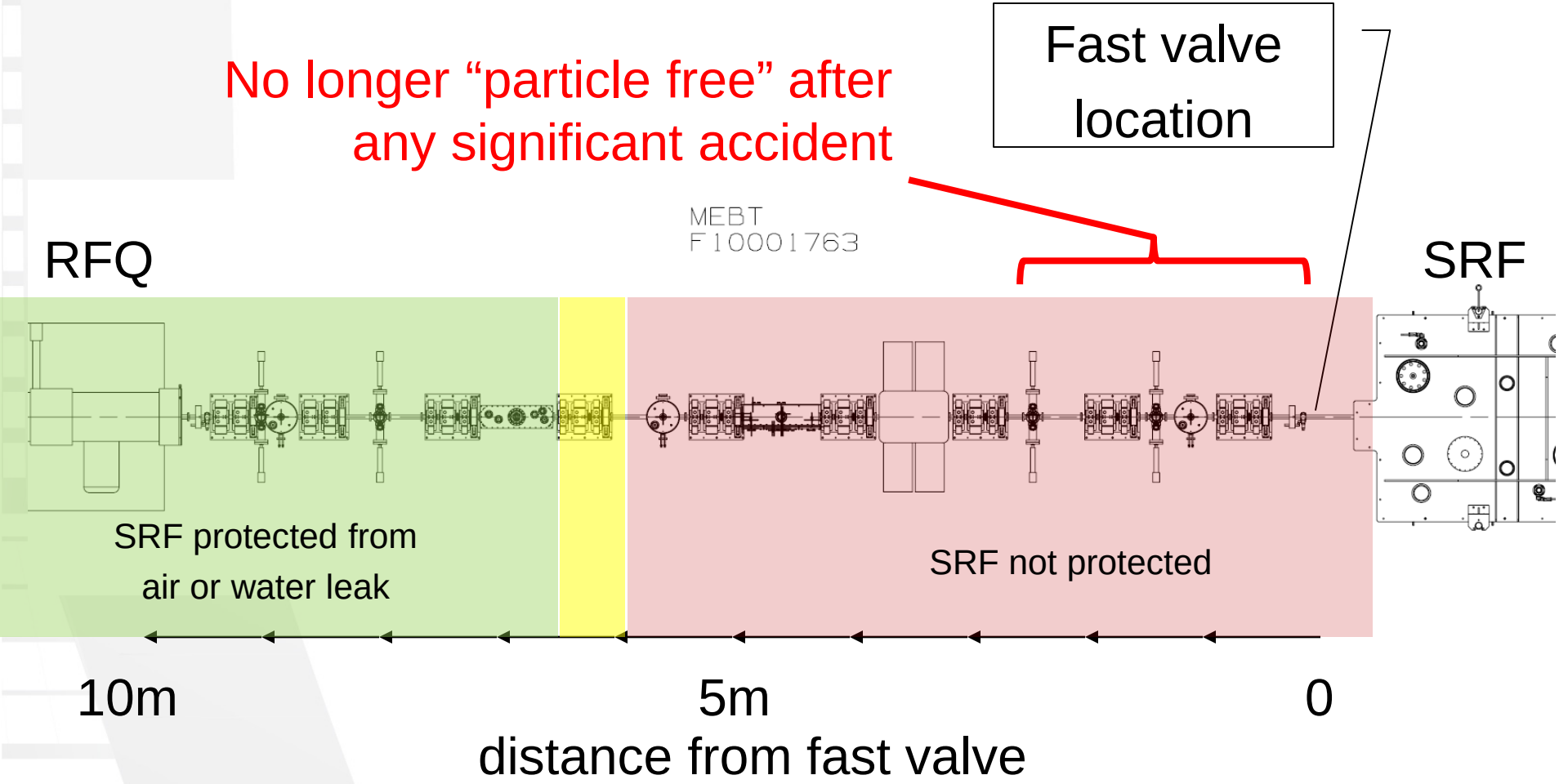
PXIE Vacuum *(pressure profile in MEBT)*



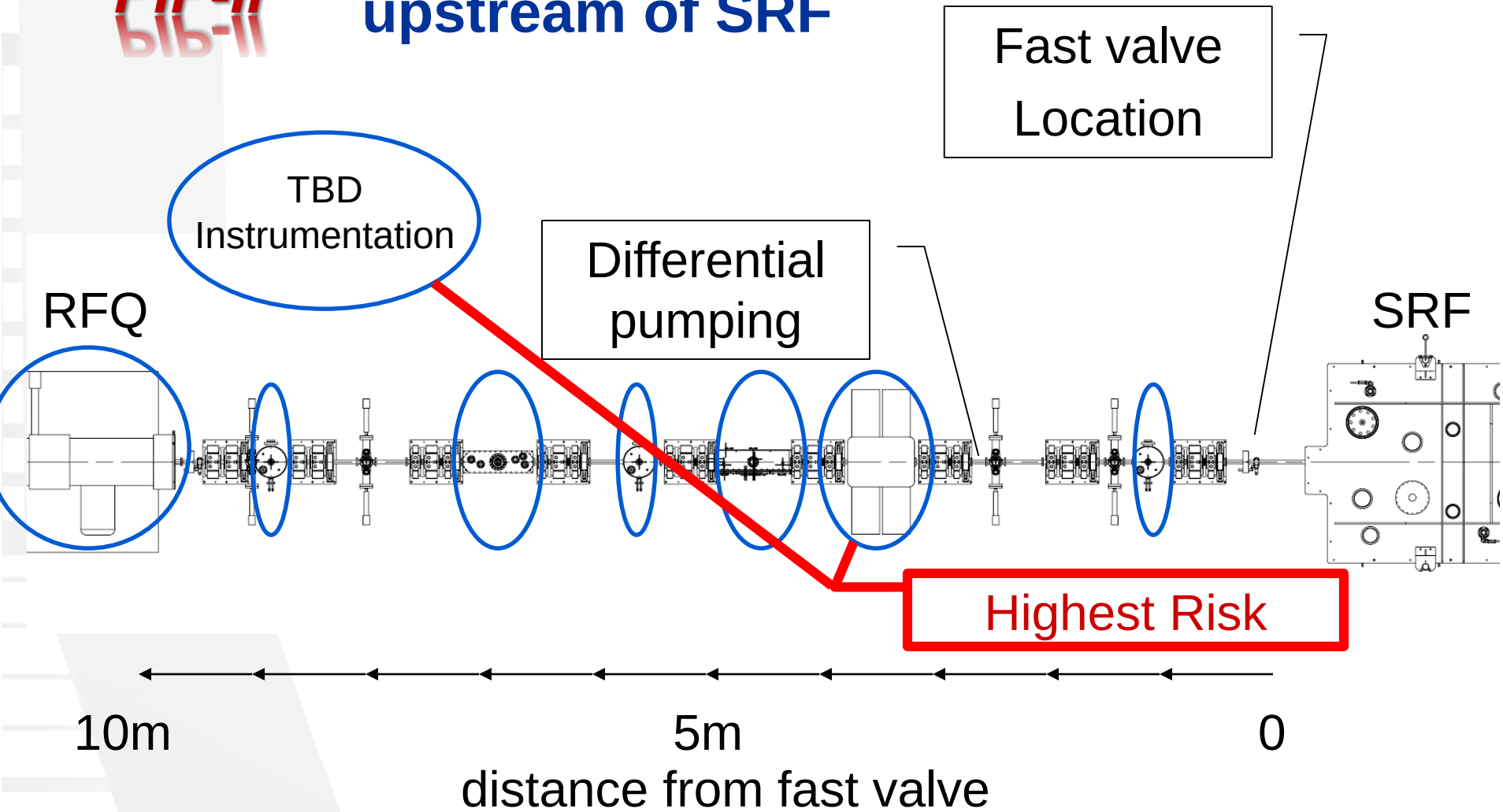
Fermilab

Areas protected by fast valve
Assuming ~13ms close time

No longer “particle free” after any significant accident



Water-cooled components upstream of SRF



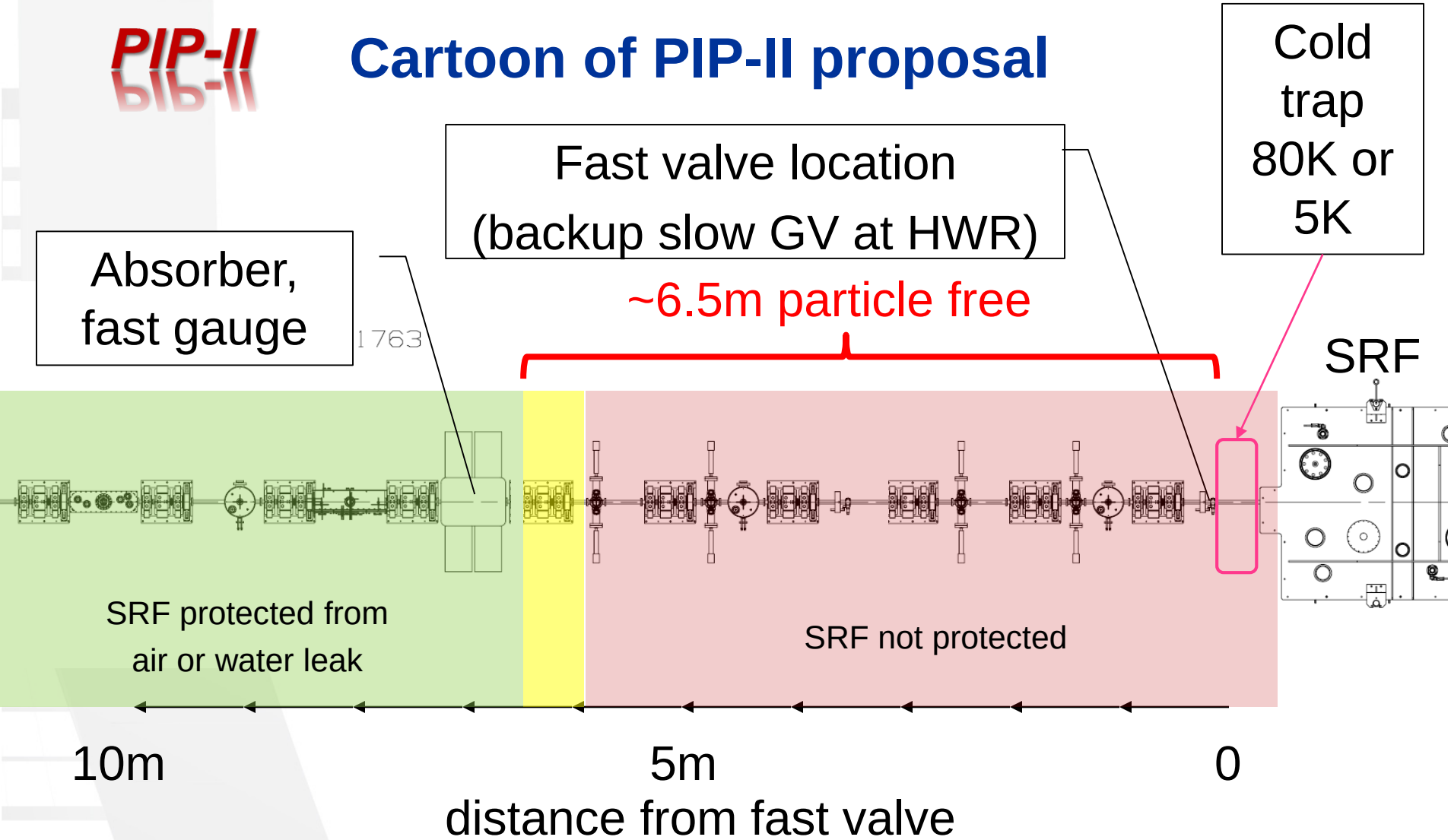
Possible Mitigations for PXIE

- Option 1 – minimally invasive
  - No changes to MEBT length
  - Implement baffling in differential pumping section to attenuate shockwave propagation
  - Limit or eliminate water-cooled beam-intercepting instrumentation within ~7m of fast closing valve
- Option 2 Menu – more invasive
  - Increase MEBT length by 1 triplet period to push high-risk components further away from SRF
    - Uses spare triplet planned for delivery by BARC
  - Extend particle free section by some TBD amount
    - Questionable benefit if we do not extend MEBT
  - Implement cold trap just outboard of cryomodule
    - In MEBT and/or HEBT as design constraints allow
- Both options carry a level of risk that may be appropriate for PXIE, but not for PIP-II

Proposed mitigation for PIP-II

- Increase MEBT length by ~3.5m (3 triplet periods)
  - Allows for SRF to be protected from failure in beam absorber
- Implement cold trap outboard of cryomodules
- Disallow high-risk features in unprotected section
  - Water-cooled beam-intercepting devices
  - Turbo pumps
- Design unprotected section to minimize risks
  - Particle free assembly practices in entire unprotected section
    - But only helps for one accident!
  - Revisit design details of water cooled devices that do not intercept beam
  - Optimize baffling in differential pumping section
  - Careful design of vacuum interfaces, interlocks, and servicing procedures
- Designate locations for backup fast valves between cryomodules to protect the majority of the cryomodule string

Cartoon of PIP-II proposal



Possible Mitigations for PXIE

- Option 1 – minimally invasive
  - No changes to MEBT length
  - Implement baffling in differential pumping section to attenuate shockwave propagation
  - Limit or eliminate water-cooled beam-intercepting instrumentation within ~7m of fast closing valve
- Option 2 Menu – more invasive
  - Increase MEBT length by 1 triplet period to push high-risk components further away from SRF
    - Uses spare triplet planned for delivery by BARC
  - Extend particle free section by some TBD amount
    - Questionable benefit if we do not extend MEBT
  - Implement cold trap just outboard of cryomodule
    - In MEBT and/or HEBT as design constraints allow
- Both options carry a level of risk that may be appropriate for PXIE, but not for PIP-II

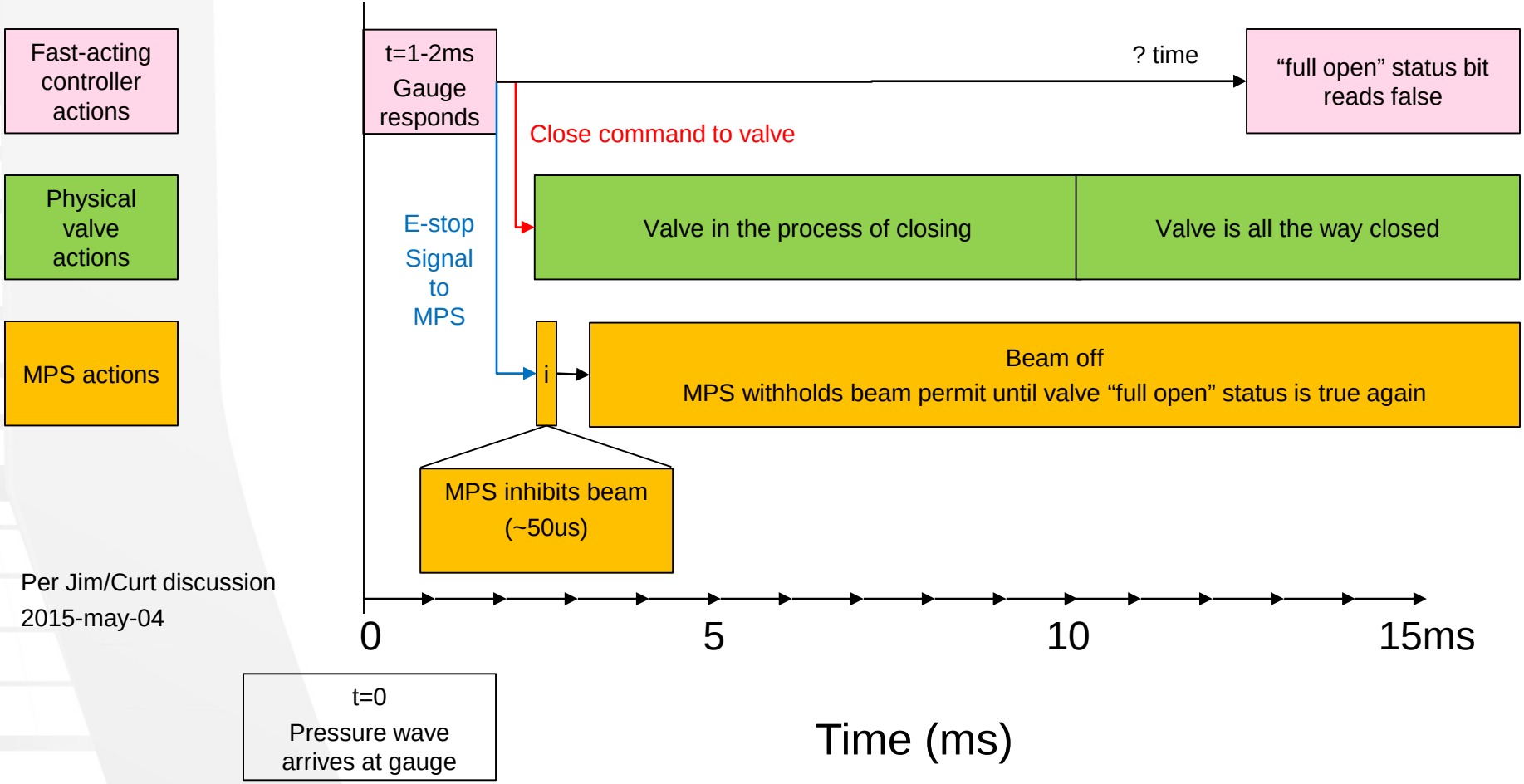
References

[1] M. Ady et al., “LEAK PROPAGATION DYNAMICS FOR THE HIE-ISOLDE SUPERCONDUCTING LINAC,” Proceedings of IPAC2014

[2] M. Ady et al., “Measurement campaign of 21-25 July 2014 for evaluation of the HIE-ISOLDE inrush protection system, CERN EDMS No. 1414574

[3] T. Takiya1 et al., “Shock Wave Attenuation by Means of Built-in Baffles in a Tube,” Adv. Studies Theor. Phys., Vol. 6, 2012, no. 5, 233 - 244

MPS Integration Architecture/Timeline



Per Jim/Curt discussion
2015-may-04