6D ionization cooling demonstration

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Vacuum RF 6D cooling mini-workshop

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6D ICE goals

- Description: Development of experimental concepts and hardware specifications necessary to validate the feasibility of 6D ionization cooling.
- Bench test:
  - Cooling channel: will be based on the choices made as part of the Initial Baseline Selection process in D&S by FY15. One of the key options is a Vacuum RF cooling channel cell, latter stage with 650 MHz RF is preferred, but can be challenging given the muon beam we are likely to have.
  - Hardware: component development will take place through the TD effort. Targeting component availability by conclusion of Phase II (FY18).
  - Systems Demonstration:
    - Test of 6D cooling cell components.
    - Integration issues.
    - Developing detailed specifications for the tests.

6D ICE goals (contd.)

- Develop an instrumentation plan for characterizing the performance of a 6D cooling channel:
  - Instrumentation techniques.
  - Performance evaluation vs intensity (current efforts are based on the nuSTORM beam).
- Evaluate the necessity for a beam demonstration:
  - We cannot launch a demonstration unless we have a clear path to success.
  - Any demonstration is likely to be expensive, overall requires a very careful cost-benefit analysis.
  - Except for a few cases (nuSTORM), impacts on working facilities are likely.
- Is there a route that would provide hardware that could immediately address experimental needs?

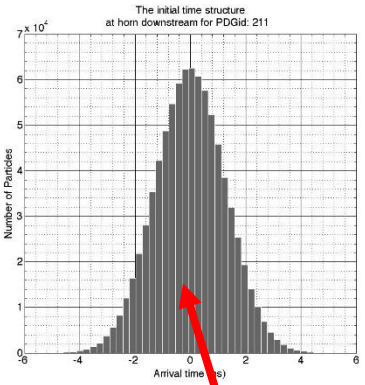
Deliverables

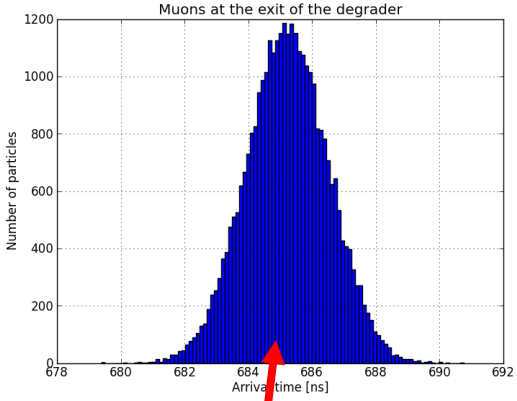
- Feasibility Phase I through FY15:
  - Development of a plan for a MAP 6D cooling bench test.
  - Close coordination with D&S and TD activities.
  - Development of a suite of experimental options.
  - Report during FY15.
- Feasibility Phase II through FY18:
  - Detailed evaluation of potential beam demonstrations.
  - Setup for the 6D bench test.
  - Possible proposal at the conclusion of the Feasibility Assessment.

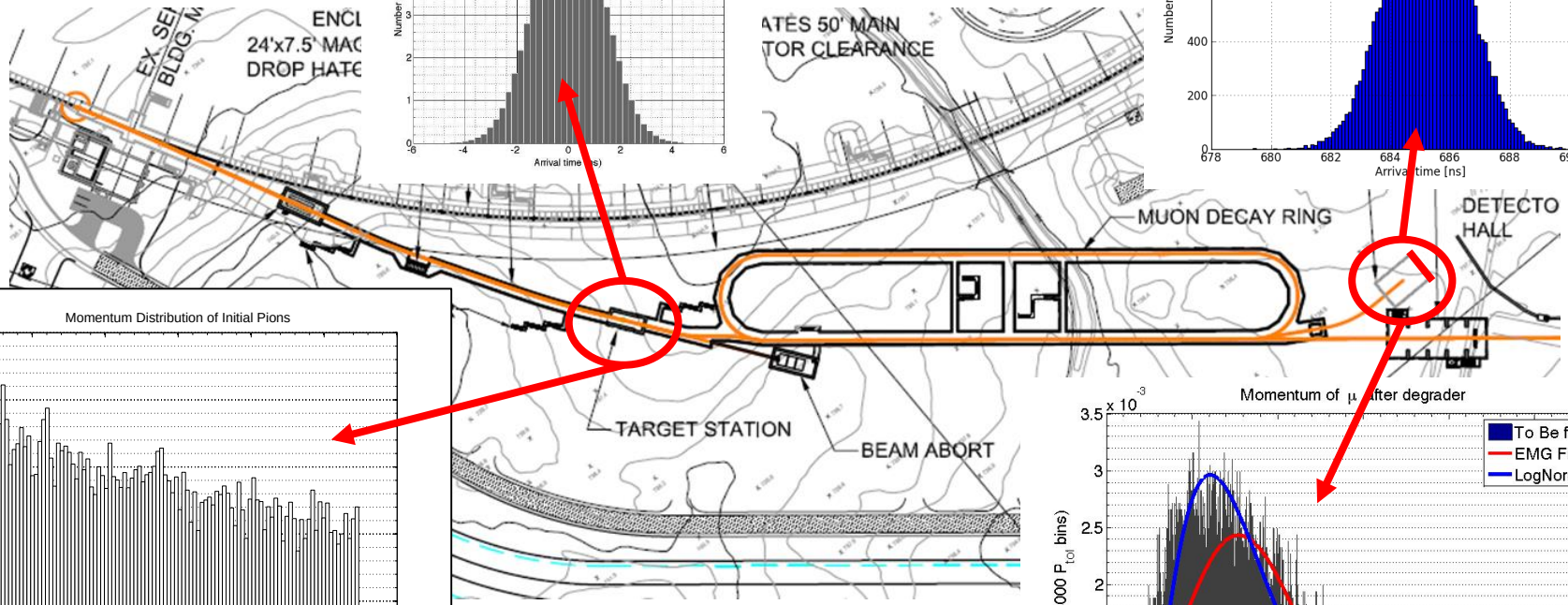
Muon beam options

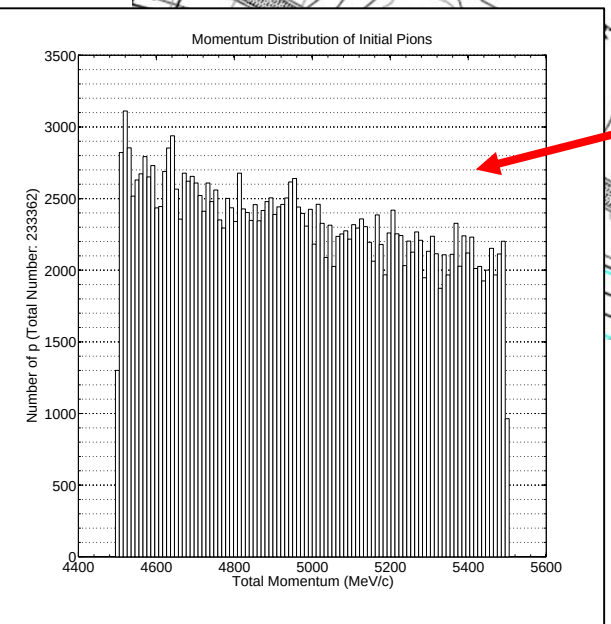
- “Beyond MICE” experiment utilizing the existing infrastructure:
  - the scene is set,
  - depends on the MICE timeline,
  - Impact on ISIS,
  - low muon intensities.
- nuSTORM:
  - “spent” beam, little overhead,
  - little/no disruption to the running neutrino program,
  - relatively high muon beam intensity.

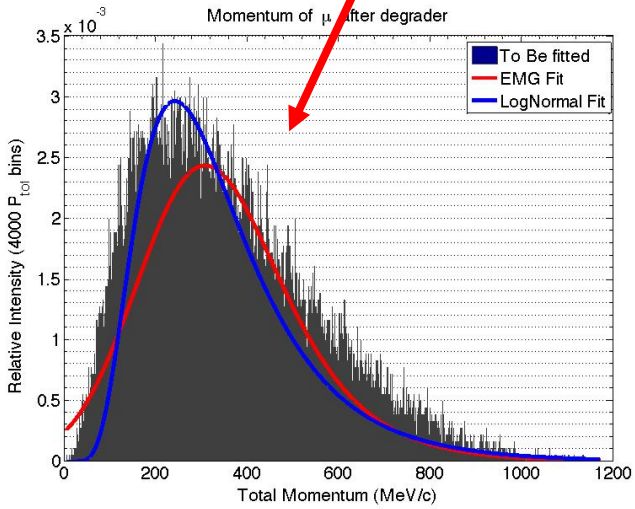
Muon beam @ nuSTORM







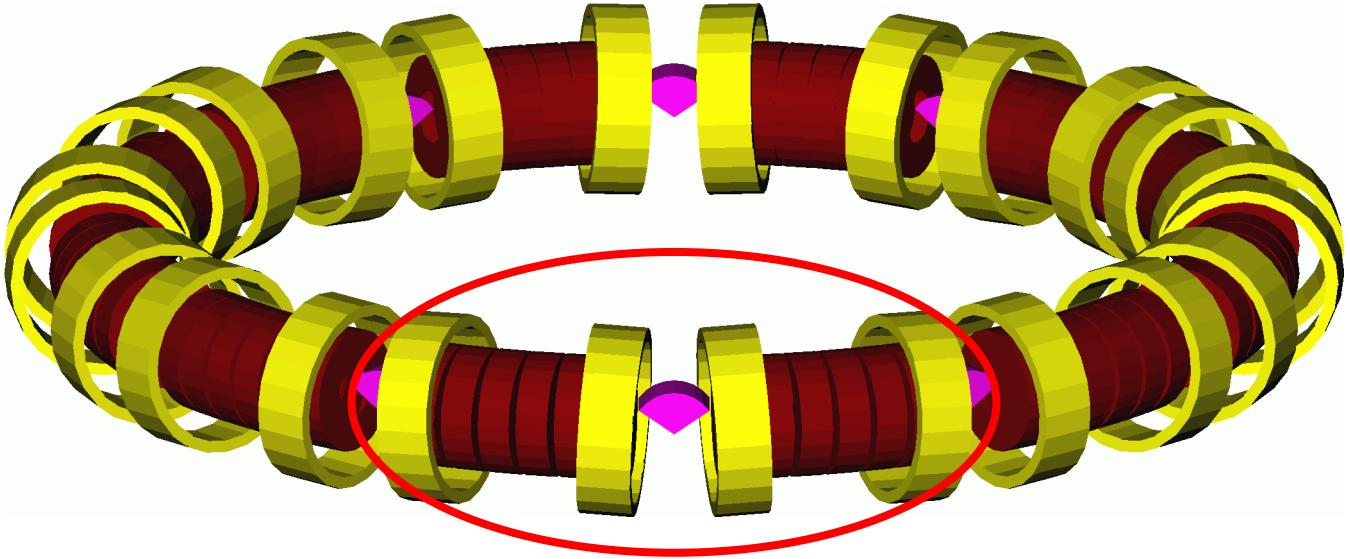




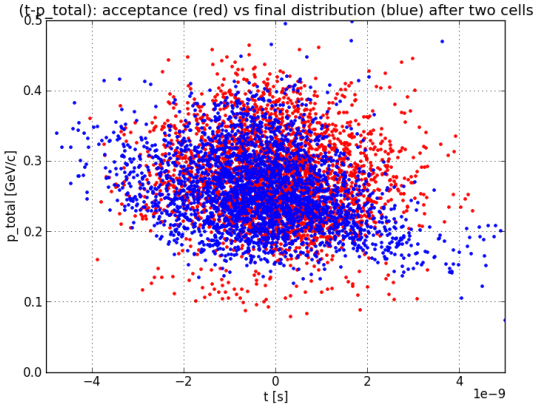
Simulations by Ao Liu

Cooling cells

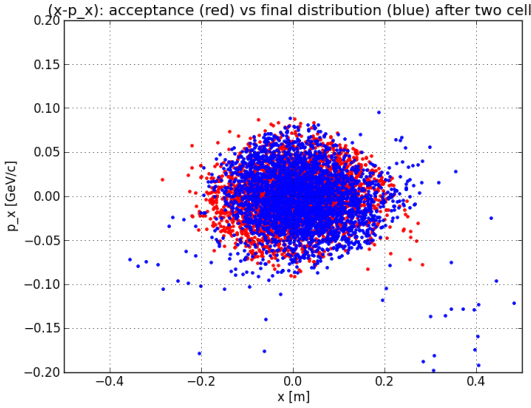
- Two cells of a basic 201.25 MHz RFOFO cooling channel.
- No matching section.
- Aperture is limited to 25 cm (for beam size calculation).
- 9.4% transmission within aperture cuts.



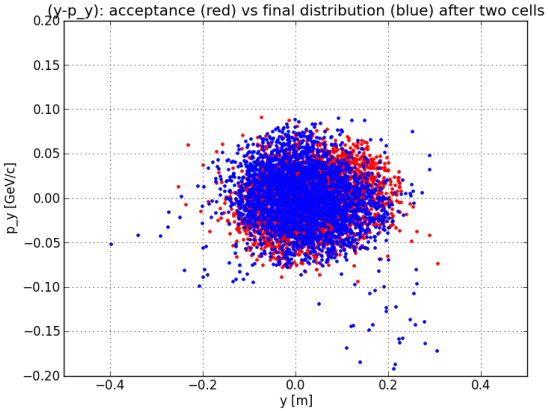
Distribution before and after



(ΔT-P_{total})



(x-p_x)



(y-p_y)

Acceptance (red) and distribution
after two cooling cells (blue)

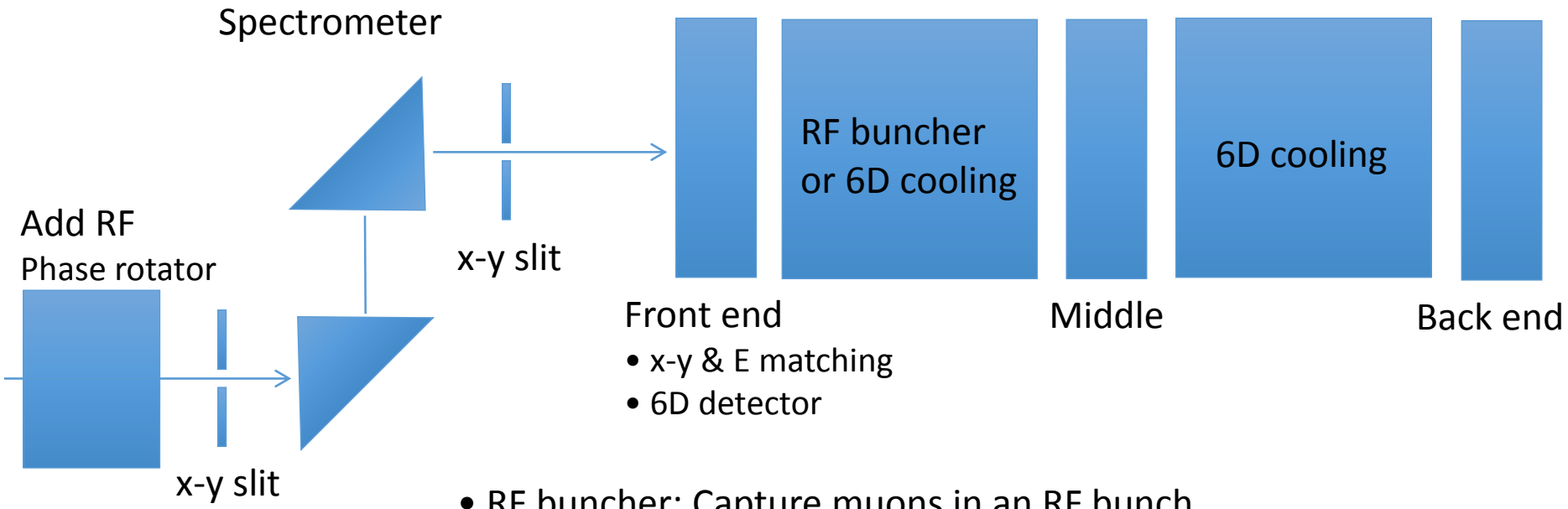
- No observable cooling in transverse or longitudinal direction, but no heating either.
- Matching section is required.
- The result will be worse with a 325 MHz cell.

nuSTORM beam structure

- 80-85 bunches @ 53 MHz (18.8 ns)
- About 1.33 sec apart
- 10^{10} muons per pulse in the range (0,300) MeV/c
- How to match to the experiment?
  - 53x6 = 318 MHz, 53x12 = 636 MHz, 53x15 = 795 MHz
- More cooling cells vs more precise diagnostics?
- Longitudinal diagnostics: single-particle vs multi-particle?
- Background is not an issue (simulated by Ao Liu)

(Slide by Katsuya Yonehara)

Example: Use nuSTORM beam



- RF buncher: Capture muons in an RF bunch
  Possibly, it can be a 6D cooling lattice with zero-crossing RF system w/o cooling material
- Add RF phase rotator in front of a spectrometer
  Increase number of useful muons in a 6D cooling

Summary

- The above discussion is not unique to the nuSTORM beam
- 6D ICE detectors should be relatively independent of the cooling channel choice
- Once we have decided on the Vacuum RF 6D cooling scheme + bench test cell, the simulations can be redone with that particular channel (and corresponding matching section) in mind.