6D Ionization Cooling Demonstration Experiment (6DICE)

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WBS 4.2: 6D Cooling Demonstration

- Description: Development of experimental concepts and hardware specifications necessary to validate the feasibility of 6D ionization cooling.
- Scope:
  - Bench test.
  - Beam test (if any).
  - Intensity test with protons.

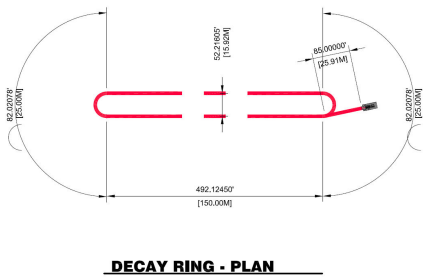
Bench Test

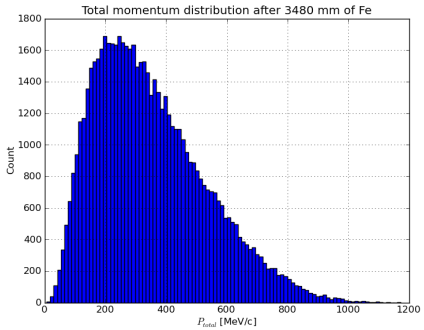
- Cooling Channel Choice:
  - Will be based on the choices made as part of the Initial Baseline Selection process in D&S by FY15. (There will be a cooling channel selection discussion on Friday 8-9 am, Comitium).
  - The key options are
    - Variant of a Guggenheim channel cell, preferably last stage with 650 or 805 MHz RF, see also TD-D&S-MASS Cooling session on Friday, 11:30-12:00).
    - Helical Cooling Channel section, four coils with RF incorporated, see also TD-D&S-MASS Cooling session on Friday, 12:00).
- Hardware Development:
  - Component Development will take place through the TD effort.
  - Targeting component availability by conclusion of Phase II ($\sim$FY18).
- Systems Demonstration:
  - Test of 6D cooling cell components.
  - Integration issues.
  - Developing detailed specifications for the tests.

Beam Test = Characterization of Muon Beams in a 6D Cooling Channel

- Develop an instrumentation plan for characterizing the performance of a 6D cooling channel:
  - Instrumentation techniques.
  - Performance evaluation vs intensity (6D distribution from νStorm should be available in $\sim$ a month).
- 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 (e.g. the νSTORM "spent" beam, next slide), impacts on working facilities are likely.
- Is there a route that would provide hardware that could immediately address experimental needs?

νStorm Facility as R&D Platform





- 5 GeV/c pions are injected at the end of the straight section.
- Only 48% of the pions decay in the injection straight.
- The pions remaining at the end of the straight are not transported by the arc.
- The power within the pion beam is 2–3 kW, $\Rightarrow$ absorber.
- 3480 mm of Fe degrader produce a 200 MeV/c central momentum muon beam.

- If it is decided that the beam test is required, the goal is to put together a section of the cooling channel of choice, long enough to demonstrate 6D cooling.
- νStorm facility can act as a muon source (on the order of 10^{10} muons per 1 μs pulse) for the 6D cooling demonstration experiment without disrupting main νStorm experimental program, and at little additional cost.
- This makes νStorm a potential R&D platform in the framework of MASS.

High Intensity Test with Protons

- "Missing physics" issues are of particular concern for the performance of a 6D cooling channel:
  - space charge screening in material,
  - ionization of material,
  - plasma effects from ionized electrons and ions,
  - Tom Roberts keeps a comprehensive list.
- MICE, being a single particle experiment, will not address those effects.
- Explore options for confirming elements of the performance with high intensity beams:
  - At what intensities do we expect various processes to become apparent? (Coordinate with D&S to estimate the impact of specific physics processes.)

High Intensity Test with Protons, contd.

- High intensity muon beam is not available (we don't have a MC yet), $\Rightarrow$ scaled test with protons.
- Proton beam demonstration options ($\sim 10^{12}$ ppb): location, experimental accessibility, cost.
- Proton beam options:
  - 400 MeV proton beam at the MTA,
  - 2.5 MeV proton beam at ASTA,
  - Booster/MI proton beam,
  - New small proton ring = not likely to be funded, time is limited.

Deliverables

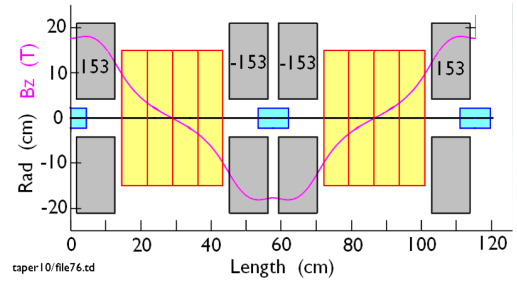
Feasibility Phase I through FY15:

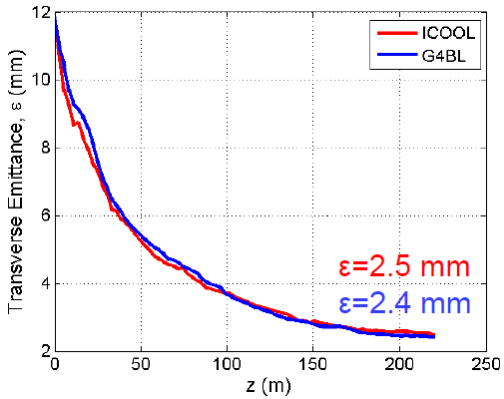
- Development of a plan for a MAP 6D cooling bench test.
- Close coordination with D&S and TD activities.
- Development of a suite of experimental options.
- Report during FY15.

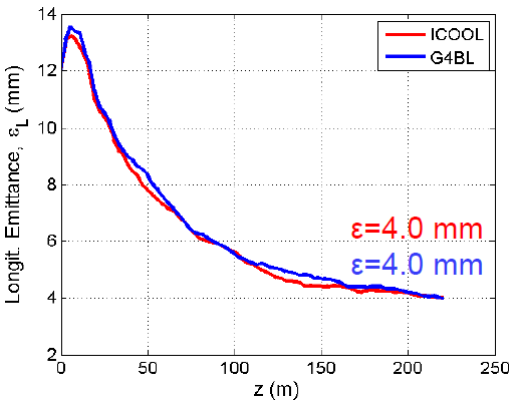
Feasibility Phase II through FY18:

- Detailed evaluation of potential beam demonstrations.
- Setup for the 6D bench test.
- Possible proposal at the conclusion of the Feasibility Assessment.

Progress on Guggenheim and relatives

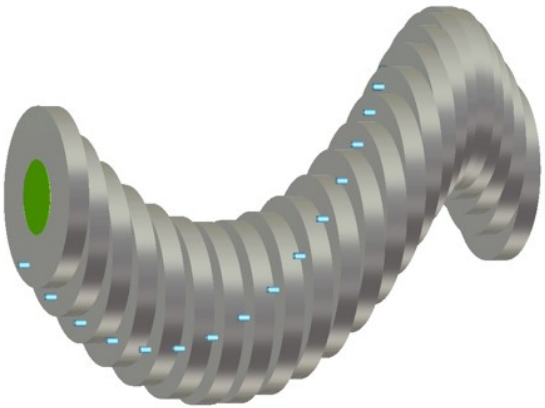






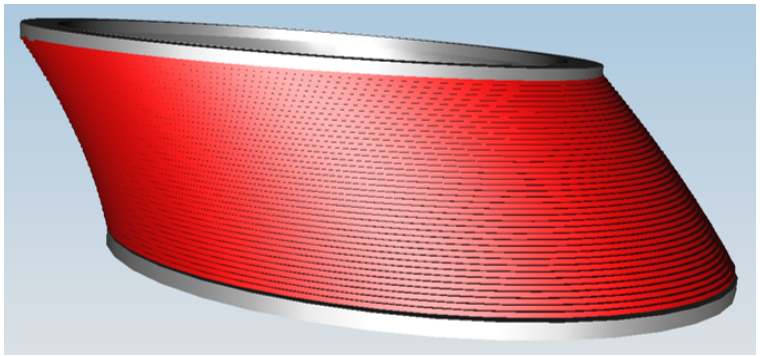
- Organized bi-weekly 6DICE meetings, keep track of the recent progress on the design of both channels: Guggenheim (and all its relatives) and HCC.
- The new rectilinear half-flip snake channel looks promising:
  - (+) Straight = easier engineering.
  - (+) Uses flat absorbers rather than wedges.
  - (+) Accepts both signs.
  - (+) Performance is comparable to the canonical Guggenheim.
  - (-) Designs are multiplying just when we need to be converging towards the down-selection decision.
  - (-) Lack of engineering design and proposed tests.
- More details in Diktys' talk on Friday (11:45 am).
- R&D towards a 325/650 MHz channel by popular demand.

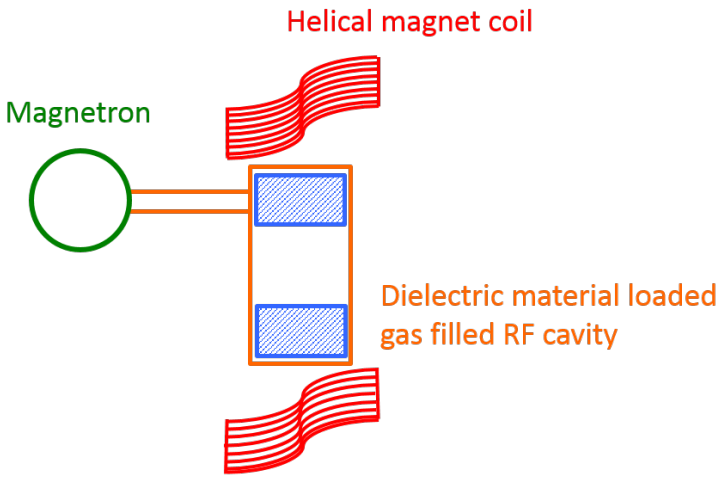
Progress on HCC



- HCC progress (see also Cary's talk on Friday (12 noon):
  - (+) Coil pancakes were assembled and tested.
  - (+) Technical demo side is generally more advanced than for the Guggenheim.
  - (+) Matching sections design is well underway.
  - (-) Incorporating RF is still an issue.
  - (-) Need a configuration of conductors that generate desired field.
- See also `https://indico.fnal.gov/conferenceDisplay.py?confId=6960`. Poster by Gene Flanagan in the poster session: design of a 1 m HCC segment ready in a year.
- Gas-filled RF cavity looks promising even for the most severe muon collider beam parameters.

Progress on HCC, contd.





- Surface breakdown of dielectric material seems to be suppressed by buffer gas in the cavity.
- Magnetron seems to be a good RF source for HCC RF.
- Make coil structure smooth to reduce discontinuity in the field (top figure).
- Demonstrate HCC segment at MTA.
- Plans for 2013:
  - Material search for dielectric loaded RF.
  - R&D magnetron.
  - R&D HCC magnet.
- Plans for 2014:
  - Design a short demonstration channel.
  - Beam test in a gas filled RF test cell.

Summary

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- R&D progress on both key cooling channels and their derivatives.
- Guggenheim derivatives are multiplying in anticipation of the baseline selection.
- Design of a 1 m segment of 805 MHz HCC that could be used for a bench test should be ready in a year.
- 6D simulation of the potential beam test at νStorm = in $\sim$ a month when the longitudinal distribution is available.

Discussion

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- In order to compare apples to apples we need a set of requirements for both channels (frequency, number of cells, initial and final emittances, etc.)
- Shift from the canonical 201/402/805 MHz frequencies towards 325/650 MHz.
- Katsuya suggested that we might consider some sort of a “generic” bench test that will not concentrate on any single channel but rather provide useful input for both.
- High intensity test with protons $\Rightarrow$ facility/availability/cost.

Thanks!