6D Cooling Section Bench Test and 6D Experiment Planning

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Content

- Strategy to demonstrate 6D ionization cooling channel
- Bench Test
- Role of Simulations
- 6D Cooling demonstration experiment
- Summary

6D Demo Strategy

- MICE is both technology demo and beam experiment at the same time
- Assuming MICE is successful in demonstrating transverse muon cooling and emittance exchange, our assessment is that most of the technical risk is related to remaining untested 6D cooling technology (i.e. can we build and operate the channel as designed).
- Separate bench test tech demo from beam test for 6D cooling!
- Only bench test will actually be carried out during the 7-year MAP programme:
  - Show that the cooling channel design can be implemented in practice, and operated within its design parameters.
  - No beam is needed for such a bench test demonstration.
- In addition - study and make plans for a 6D cooling experiment.

6D Channel Section Bench Test

- The section of channel tested on the bench should be long enough to address the relevant integration issues
  - Cavities should be operated in their design field
  - Enough cavities, magnets and absorbers should be installed to verify spatial compatibility of e.g. plumbing, etc.
- The channel section for a bench test may be different (e.g., shorter) than what is needed for a beam test.
  - Try to maintain compatibility

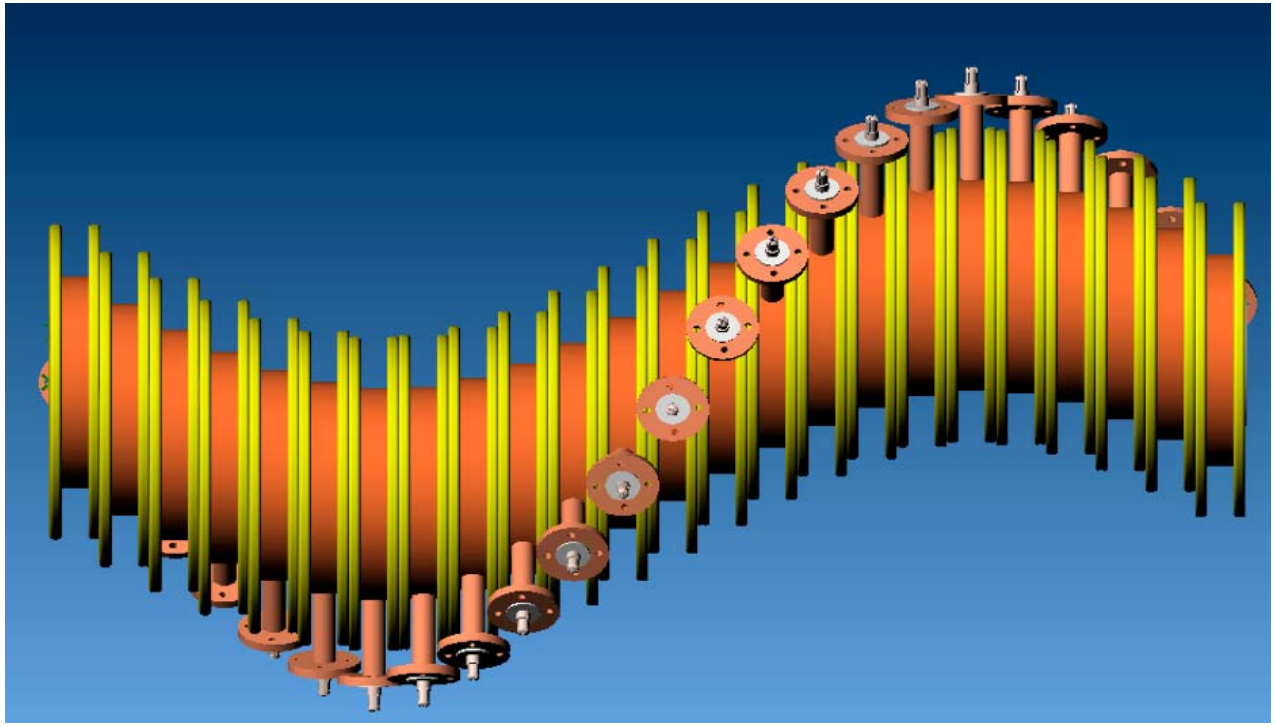
Bench Test in MAP

- The combined efforts within the MAP *Design and Simulations* and *Technology Development* sections will enable us to identify a suitable candidate for a baseline 6D channel by the end of FY2012.
- The primary selection criterion for the channel will be the simulated performance
  - when operating within the limitations (e.g., on cavity gradient) established by the R&D program over the next few years.
  - If there is >1 viable candidate, the secondary criterion will be estimated cost and technical risk (e.g., complexity).
- Bench test can be carried out in our MTA facility within the time frame of this proposal.

HCC Bench Test

- Helical Cooling Channel:
  - Helical solenoid with pressurized gas filled RF cavities inside
  - Most challenging integration, but compact

- Likely layout
  - 1 helix period magnet
  - 3 or more cavities in central region (at least one powered)



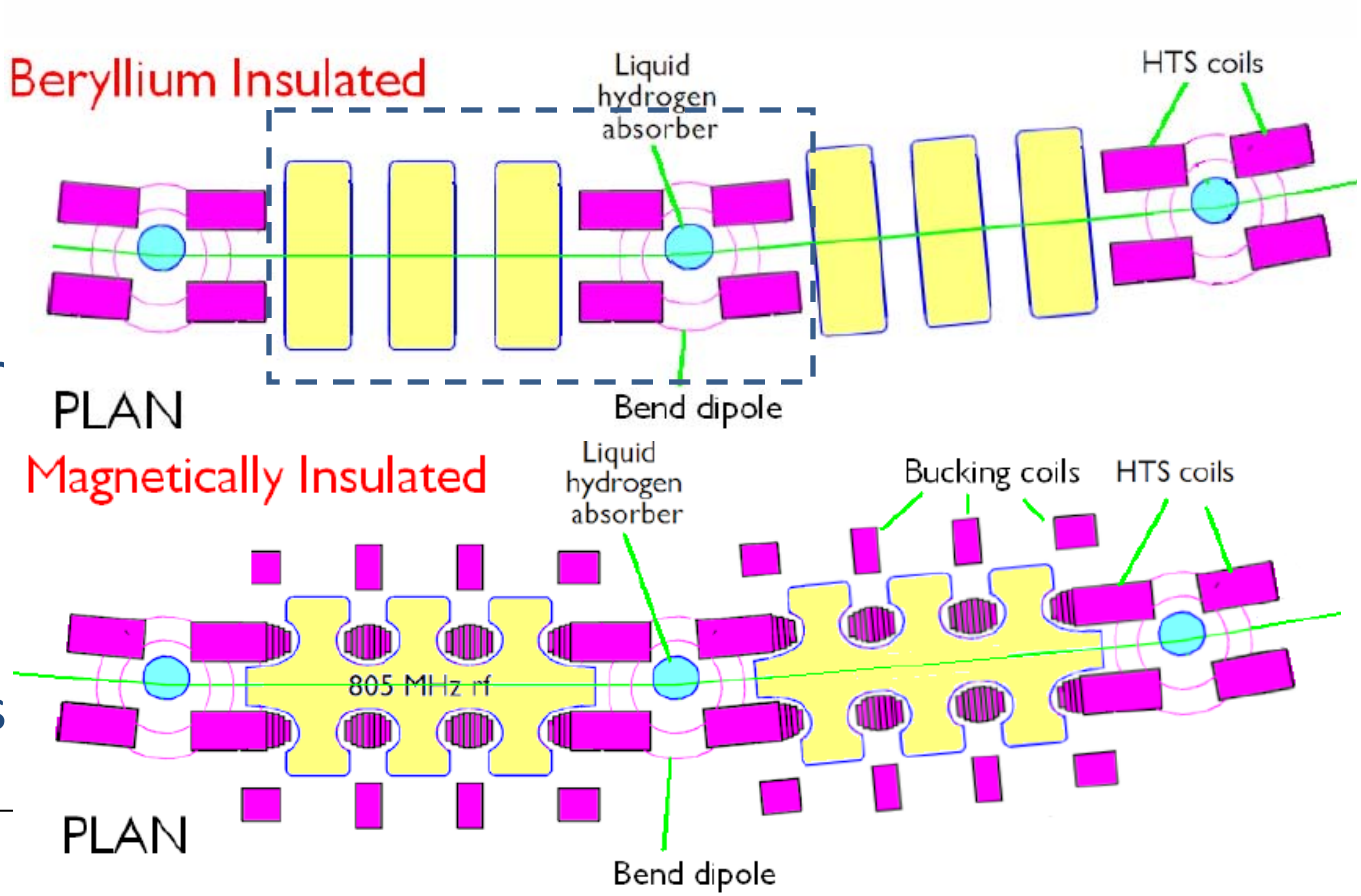
Guggenheim Bench Test

- The Guggenheim cooling channel lattice options:
  - RF cavities with, e.g., Be coating
  - RF cavities with magnetic insulation

  } + wedge absorber

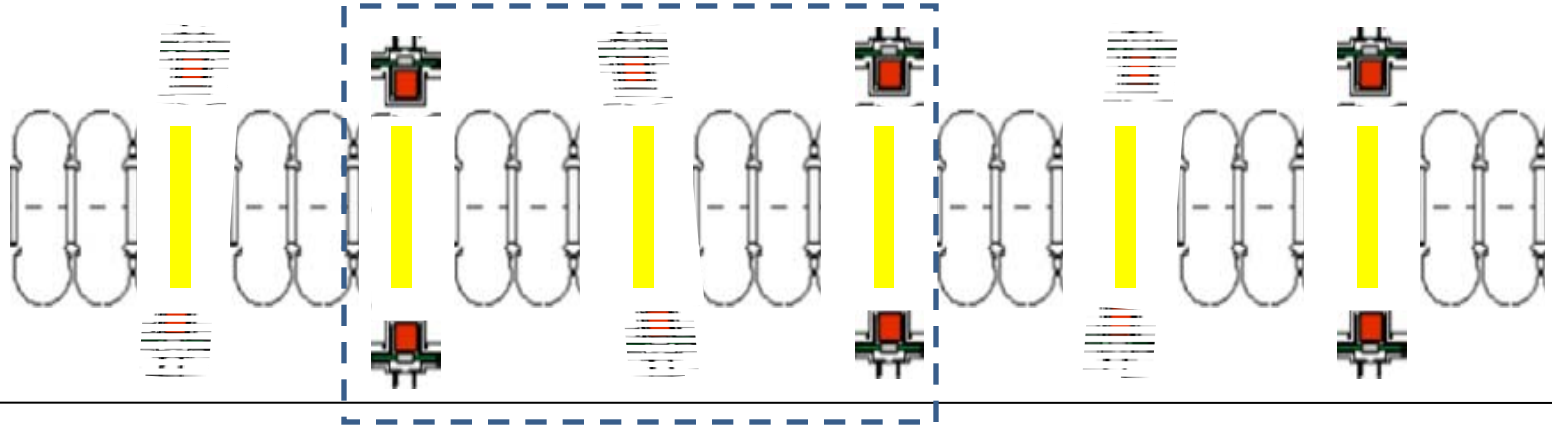
- Likely layout:

  1 basic cell
  - 1 LH2 absorber
  - 2 focus solenoid(s)
  - 1 Cavity string (+ mag ins coils if needed)



Helical FOFO Snake Bench Test

- Helical FOFO Snake channel:
  - Simple, straight lattice with tilted solenoids
  - Accepts muons of both charges
- Possible layout: 1/2 basic cell
  - 3 solenoids
  - 2 cavity strings
  - 1 LiH absorber



Timeline and Milestones

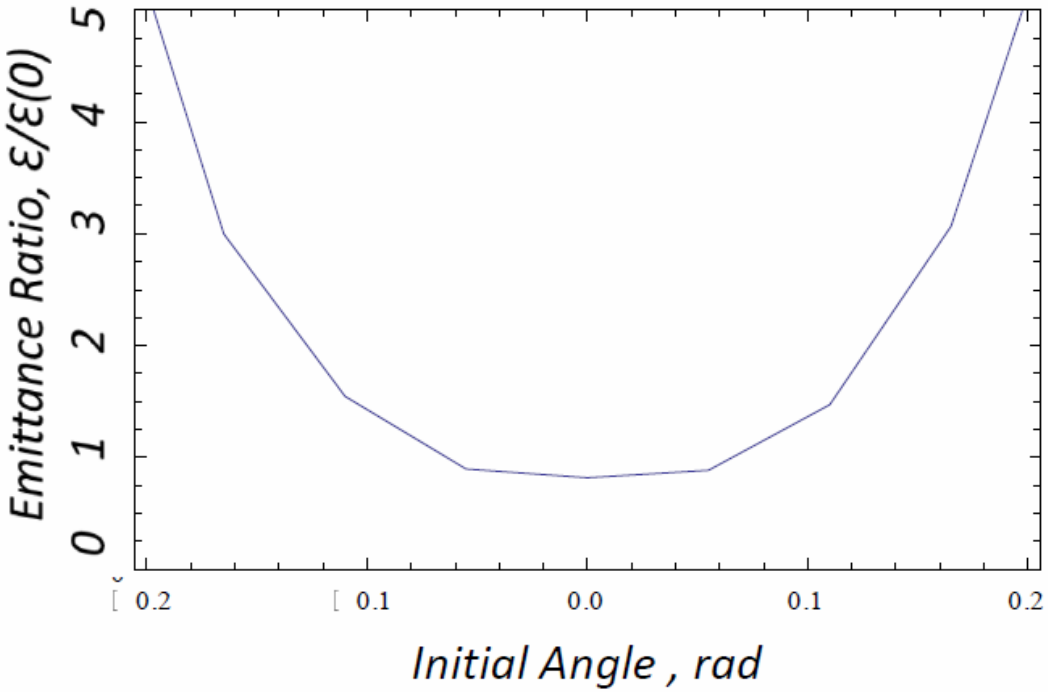
Date	Milestone	Designation	Deliverables[a)]
FY10	Study possible minor extensions to MICE	ST10.1	DR
FY11	Deliver Spectrometer Solenoids to RAL	ST11.1	DR
FY12	Deliver first RFCC module to RAL	ST12.1	DR, MR
FY13	Initial specification of 6D cooling bench test	ST13.1	DR, MR
FY14	Finalize 6D cooling bench test specification	ST14.1	DR, MR
FY15	Initial component specifications for 6D cooling experiment	ST15.1	MR
FY16	Install 6D cooling bench test section in MTA	ST16.1	MR
	Prepare proposal for 6D cooling experiment	ST16.2	FR, ER

DR: design report (MAP technical note); ER: external review; FR: formal report; MR: MAP (internal) review.

6D *Experiment* Strategy

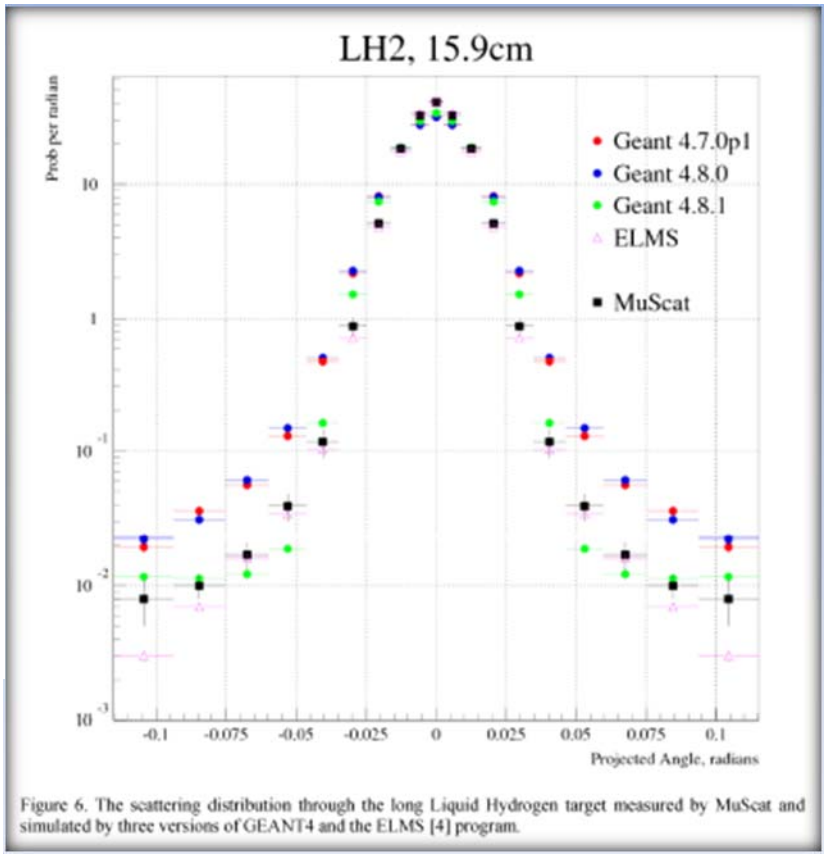
- To arrive at an optimal experimental setup, we need to carry out
  - A simulation effort to understand what aspects of the cooling channel performance need to be tested, and to what accuracy. This will include determining the required length of cooling channel, the required beam parameters, and the analysis approach.
  - A diagnostics/detector effort to determine how best to measure the muon beam to the required accuracy.
  - A design/integration effort to specify, and define a layout for, the experiment. This will be coordinated with the bench test activity, to ensure to the extent possible that the cooling channel hardware built for the bench test can also be used for a beam test. This will also include finding a suitable location and designing a muon beam line.
- Many details undefined until baseline channel has been selected.
  - Focus on making MICE a success, as it will provide valuable input

Examples: MICE Emittance vs Initial Angle & MUSCAT



Emittance out for pencil beam (zero initial emittance), as a function of initial angle.

- Emittance out depends strongly on angle in for angles > ~50mrad.
- This corresponds roughly to the tails of the H2 scattering distribution.



Results from MuScat experiment (100-200 MeV/c muons, TRIUMF)
M Ellis et al,
AIP Conf. Proc. Vol. 896, pp. 168-177

Simulation Effort

- Maxwell's equations, ionization energy loss and multiple scattering are quite well known.
  - We expect any surprises will likely come from the a) detailed distributions (tails) and/or correlations between straggling and scattering; b) high intensity effects (space-charge, plasma, etc)
  - These subtleties are not easily measured with the MICE approach of analyzing the data set as a virtual beam.
- In addition, rms emittance is not a conserved quantity in a non-linear system.
  - May get artificial emittance increment/decrement due to mismatch, even without absorber
  - May need a blinding scheme to avoid confirmation bias.

Simulation Effort

- Sensitivity to all kinds of errors will need to be studied

- A lot of the mechanics for this study can be tested on, and benefit, MICE.

Muon Accelerator R&D Test Facilities

- MTA (now – 2016)
  - Tests of components, RF studies, 6D channel bench test
- MICE (now – 2013+)
  - Demo of 4D cooling, wedge tests
- 6D Ionization Cooling Facility (after MAP, 2016 +)
  - Demonstration of 6D cooling with intense muon beam

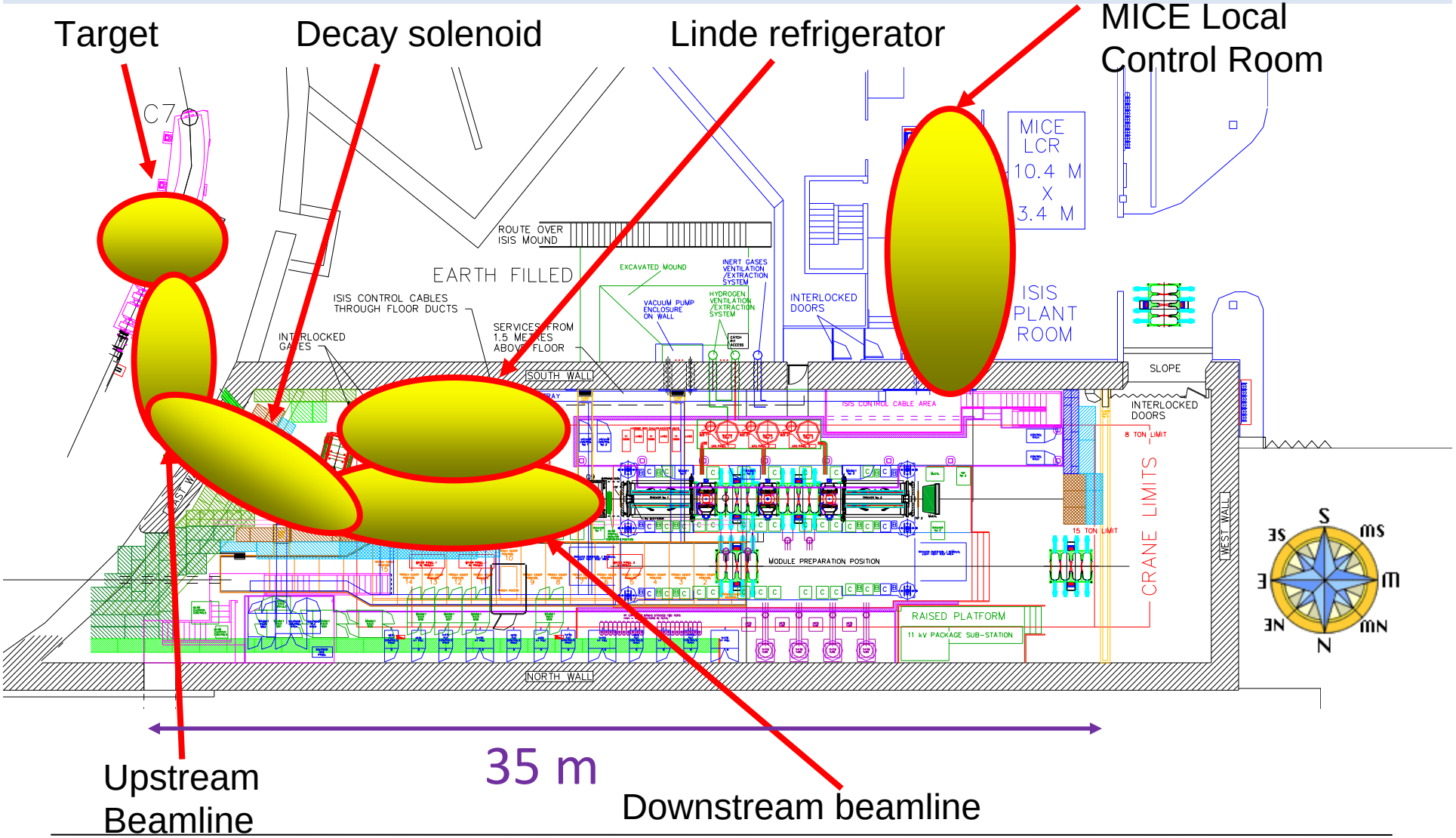
Example: reduction of 6D emittance by a factor of 5 (1.7 per plane) requires ~60 m of the 6D channel

6D Facility Requirements

- Appropriate timeline:
  - The facility has to be available sometime after 2015
    - when 6D cooling technology chosen and proven
- Technical:
  - i) space; ii) beam parameters; iii) cost
- Desirable features:
  - Get proton beam from existing facility
    - E.g., Main Injector, or, later on, from the Project-X
  - Be upgradable/expandable to take high intensity beam (eg from Project-X) for full muon bunch intensity R&D
  - Possible modification to be employed as the MC or NF Front End

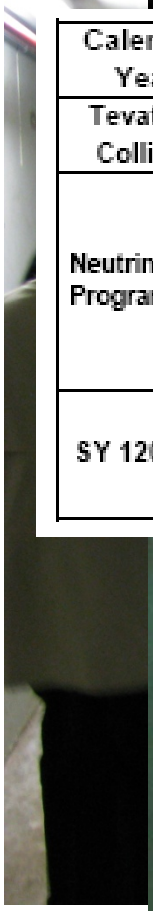
MICE Hall

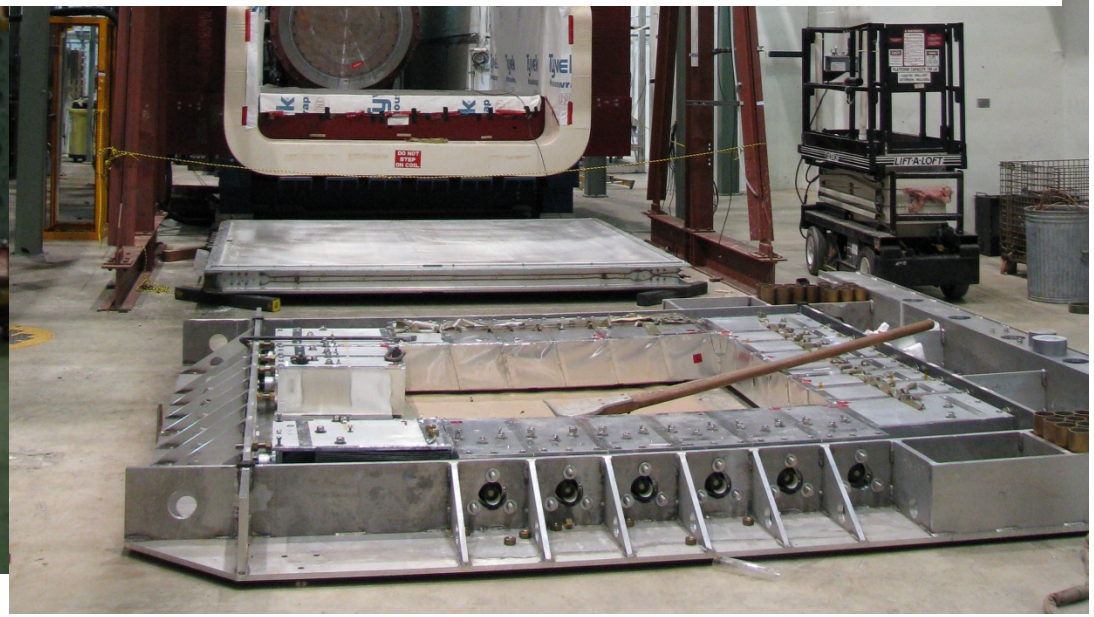
- Space very limited
- ISIS is not right source



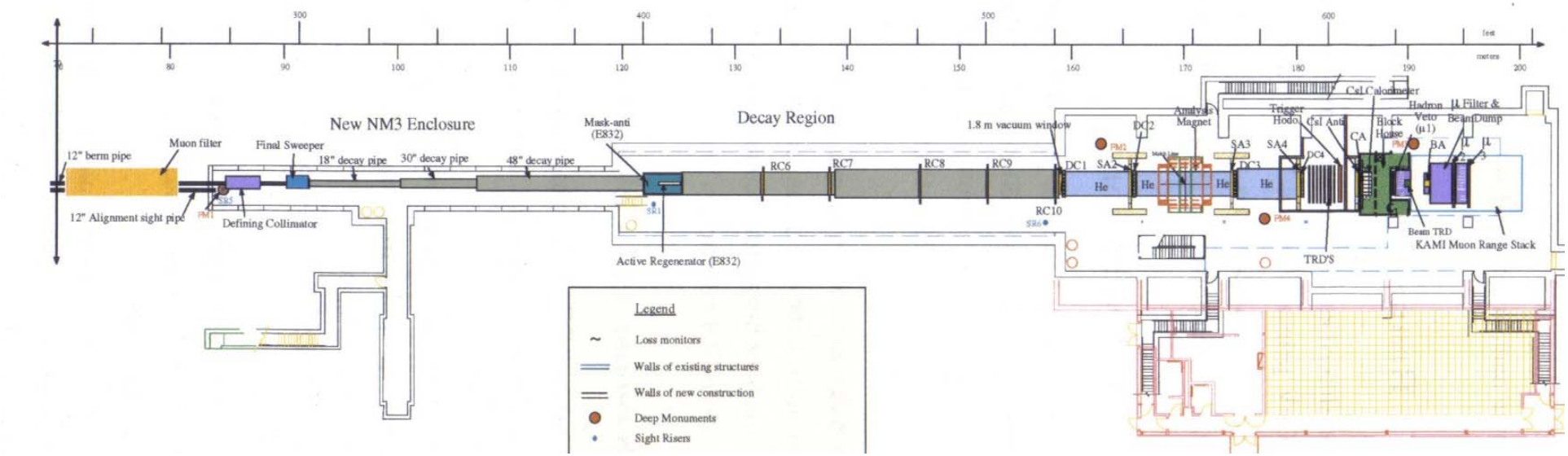
KTeV Hall

Calendar Year		2010	2011	2012	2013
Tevatron Collider		CDF & DZero	CDF & DZero	OPEN	OPEN
Neutrino Program	B	MiniBooNE	MiniBooNE		OPEN
		OPEN	OPEN	MicroBooNE	MicroBooNE
	MI	MINOS	MINOS		OPEN
		MINERvA	MINERvA		MINERvA
		ArgoNeuT			
				NOvA	NOvA
SY 120	MT	Test Beam	Test Beam		Test Beam
	MC	OPEN	OPEN		OPEN
	NM4	E-906/Drell-Yan	E-906/Drell-Yan		E-906/Drell-Yan





Muon R&D Facility at KTeV Hall



- ~120 m long: 35m x4x3m + 40m x7x6 m + 45m x17x12m
- Control room and PS areas; 25-ton crane, water, lots of electric power available
- 120 GeV, 3-8ns short bunches from Main Injector with N_p=(1-40)e10/bunch – already available

Summary

- 6D Cooling Channel *Bench Test*
  - Will show that the cooling channel design can be implemented in practice, and operated within its design parameters.
  - The channel scheme selection anticipated by the end of FY2012
  - No beam is needed for such a bench test demonstration
  - Can be carried out in MTA facility
  - Together with MICE, will provide input for the design of 6D cooling demonstration experiment
- 6D Cooling *Demonstration Experiment* (not part of MAP)
  - the need will be assessed after the completion of MICE and bench test of a section of 6D cooling channel
  - the plans for such an experiment will be developed under MAP