US Muon Collider R&D Intiative- MCTF

Andreas Jansson (Fermilab)

Outline

- Muon Collider Task Force (MCTF) background and organization
- Current MCTF R&D Focus
- Future plans

Also see other talks by eg:

Bob Palmer, Rol Johnson, Eliana Gianfelice-Wendt, Mike Lamm…

Why MCTF?

Back to the energy frontier

Can do precision physics

Compact – fits on Fermilab site

Muon Collider Task Force

In July 2006, FNAL Director requested a Task Force aimed at technologies needed for a Muon Collider

Strategy:

- **Strengthen accelerator R&D activities hosted at FNAL**
- **Focus on critical R&D needing enhanced support**
- **Complement ongoing R&D pursued by NFMCC**
- **Collaborate closely with NFMCC and Muons Inc.**

GOAL:

Develop designs and technologies so that, within a few years (by ~2012) the community will know whether Muon Colliders are a realistic option for the future, & have a plan & timeline for the remaining R&D

MCTF Scope

In October 2006, MCTF submitted initial R&D plan:

Focus on Collider Ring design & cooling channel development <u>beyond what is needed for a neutrino factory</u>

Proposed to start with 2.8M$/year M&S budget, ramp up to 5M$/yr

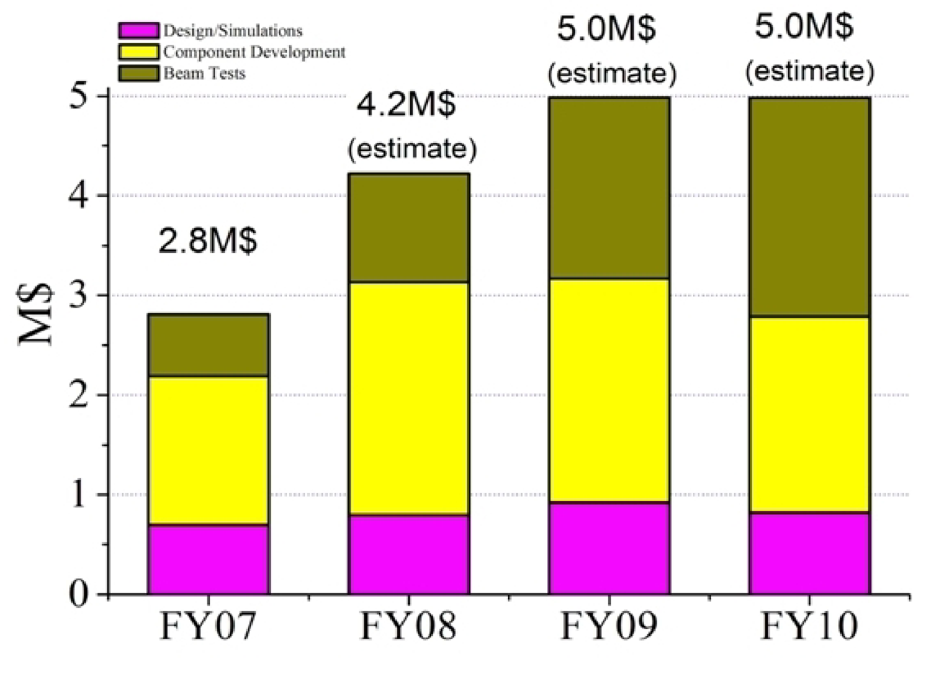


Figure 5: Estimated Muon Collider AARD budget profile.

MCTF Activities

Muon Collider Design and Simulations

- to establish the required cooling parameters

Component Development

- Helical Magnets
- HTS High-Field Solenoids
- Pressurized RF Cavities

Beam tests

- High Pressure Cavity tests
- 6D Cooling Channel Experiment

MCTF and NFMCC Co-ordination

Mar'07: **S. Holmes asked that a NFMCC & MCTF Coordinating Committee be formed to coordinate the NFMCC & MCTF Muon Collider activities & ensure the overall R&D is coherent & effective**

MEMBERS:

Alan Bross: NFMCC co-spokesperson, MCTF Str.Grp. Member

Steve Geer: MCTF co-leader, NFMCC Exec. Board Member

Harold Kirk: NFMCC co-spokesperson

Vladimir Shiltsev: MCTF co-leader

Mike Zisman: NFMCC Project Manager

First meeting March 19th, 2007. Meets ~1/month, in addition to working weekly meetings of NFMCC and MCTF, annual workshops, etc.

New Accelerator Physics Center

Created June'07

ACCELERATOR PHYSICS CENTER
V.Shiltsev, Director
M.Church, Deputy Director
M.Bruce, Admin Associate
(A.Nestander), Budget Mgr.

ILC Beam Physics Department
(N.Solyak), Head
D.Bogert
Y.Torun (FNAL/IIT)
S.Singatulin(GS)
(J.Volk)

ILC Modeling Group
M.Church (GL)
F.Ostiguy
(A.Valishev)

HINS Department
R.Webber, Head
J.P.Carneiro
D.Johnson
K.Koch
R.Madrak
E.Peoples
H.Piekarz
J.Steimel
D.Wildman
R.Zwaska
(G.Apollinari) (B.Hanna)

Muon Accelerator R&D Department
S.Geer, Head

MCTF Experiment Group
A.Jansson (GL)
K.Yonehara
C.Yoshikawa (GS)
A.Kurup (ICL Fellow)
(C.Ankenbrandt)
(D.Broemmelsiek) (M.Hu)
(F.Garcia) (V.Kashikhin)
(M.Lamm) (E.Prebys)

NFMCC Group
A.Bross (GL)
M.Ellis
A.Moretti
D.Neuffer
X.Yang (ICL Fellow)
(M.Geynisman)
(C.Johnstone)
(A.Klebaner)
(M.Popovic) (A.Tollestrup)

US PAS Office
S.Winchester (GL)
W.Barletta, Director (GS)
I.Novitskaia

Accel.Education Dept.
(V.Lebedev), Head
(V.Yarba), Deputy

Accel.PhD Program
(M.Syphers, Comm.Chair)

Grad.students	*(mentor)*
T.Koeth	(H.Edwards)
D.McCarron	P.Spentzouris
U.Mavric	(B.Chase)
R.Miyamoto	(A.Jansson)
A.Paytyan	(H.Edwards)
A.Poklonsky	(D.Neuffer)
P.Snopok	(C.Johnstone)
P.Yoon	(W.Chou)

Peoples Fellowship
(M.Church, Comm.Chair)

Accelerator Summer Students Program
(A.Shemyakin)

LHC Accelerator Group
T.Sen (GL)
J.Johnstone
H.J.Kim
J.Slaughter
(R.Flora) (E.Gottschalk)
(E.Harms) (E.McCrory)
(D.McGinnis) (R.Pasquinelli)

Theory/Simulation Group
Yu.Alexahin (GL)
V.Balbekov
N.Gelfand
E.Gianfelice-Wendt
V.Kamerdzhiev
G.Kuznetsov(GS)
L.Vorobiev (GS)

Energy Deposition Group
N.Mokhov (GL)
A.Drozhdin
M.Kriss
S.Striganov
N.Nakao (GS)
I.Rakhno (GS)

Exper. AAR&D Group
P.Piot (GL)
(L.Bellantoni) (H.Edwards)
(R.Fliller) (S.Nagaitsev)
(C.Y.Tan) (M.Wendt)

(CPA Group of CD)
(P.Spentzouris, GL)
(J.Amundson) (P.Lebrun)
(L.Michelotti) (E.Stern)
(V.Ivanov, GS) (D.Dechow, V)

Steering Group Guidance

August '07 report:

In all scenarios … "R&D for future accelerator options concentrating on a neutrino factory and muon collider should be increased"

Group 5 (Colliders beyond LHC and ILC) recommended for Muon Collider R&D in the US: "… a minimum of 20M$ annually and 100FTE appropriate skill set …"

http://www.fnal.gov/directorate/Longrange/Steering_Public/

MCTF – the first year

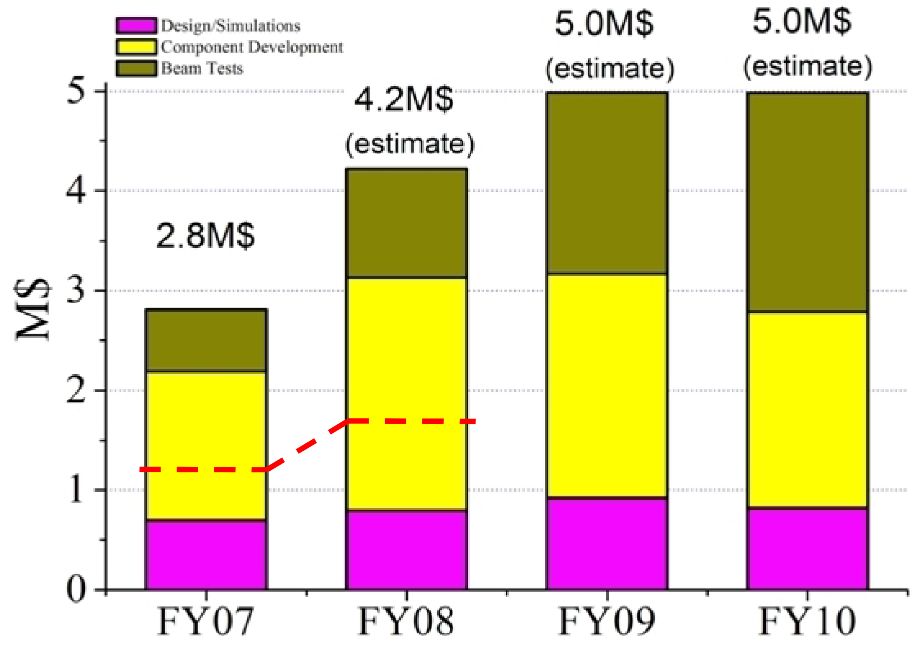
Focused on collider parameters, MTA beamline, and preparations for a 6D cooling experiment

Draft annual report available at http://mctf.fnal.gov

In reality, muons got 1.1M$

M&S in FY07 (continuation of existing program, plus MTA proton beamline)

FY08 is first year of real MCTF budget. Guidance is 1.6M$/yr. Now considering how to prioritize program.



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High- or Low-Emittance ?

High-Emittance Strategy (pursued by MCTF + NFMCC)
Package muons into 1 bunch/sign/cycle with number muons limited by beam-beam tune shift.

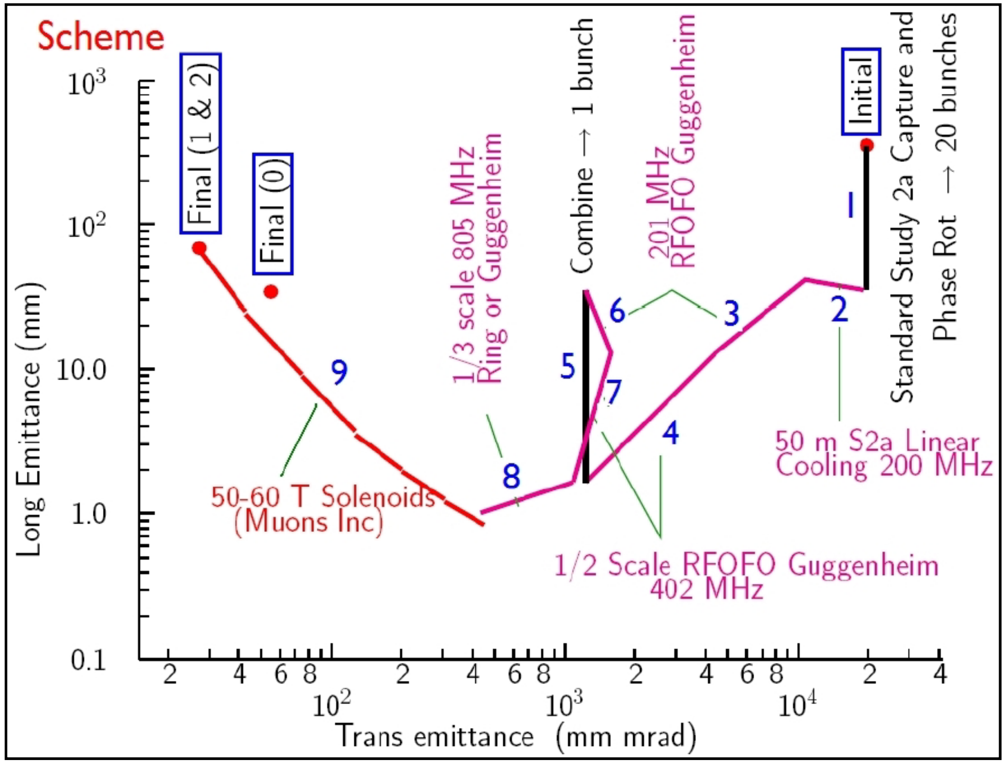
Low-Emittance Strategy (pursued by MCTF + Muons Inc)
Lower number muons/bunch with many bunches/ cycle → lower transverse emittance at beam-beam tune shift limit.

Pros & Cons:
Collider ring design for high-emit. case exists … low emit. ring design harder. Additional technologies needed for low emit., but may yield higher luminosity.

In both cases we may be able to use ILC cavities !

Cooling Channel Simulations

Simulations exists for all high-emit. cooling channel pieces. Not all matching simulated.



Requires "Guggenheim" channel, rebuncher, & HTS solenoids at end.

First part of low-emit. cooling channel also simulated. Requires "Helical Magnets", & high-pressure rf cavities.Last part of channel requires development of concepts (e.g. "Parametric Ionization Cooling")

Muon Collider Parameters

- MCTF intermediate collider parameters based on collider design work
- See Eliana's talk

	Low Emit.	High Emit.	MCTF06	MCTF07
$\sqrt{s}$ (TeV)	1.5			
Av. Luminosity ($10^{34}/cm^2/s$) *	2.7	1	1	1.33
Av. Bending field (T)	10	6	8.33	6
Mean radius (m)	361.4	500	363.8	500
No. of IPs	4	2	2	2
Proton Driver Rep Rate (Hz)	65	13	60	40
Beam-beam parameter/IP	0.052	0.087	0.1	0.1
β* (cm)	0.5	1	3	1
Bunch length (cm)	0.5	1	2	1
No. bunches / beam	10	1	1	1
No. muons/bunch (10^{11})	1	20	12	11.3
Norm. Trans. Emit. (μm)	2.1	25	13	12.3
Energy spread (%)	1	0.1	0.1	0.2
Norm. long. Emit. (m)	0.35	0.07	0.14	0.14
Total RF voltage (GV) at 800MHz	406.6 $\times 10^3 \alpha_c$	0.21**	$0.26 \times 10^3 \alpha_c$	0.84**
Muon survival $N\mu/N\mu0$	1	0.07	1	0.2
μ+ in collision / proton	0.075***	0.01	0.15	0.03
8 GeV proton beam power	1.1 f_{loss} ♣	3.2	0.6 f_{loss} ♣	1.9

RF in magnetic fields

- All muon cooling schemes involve RF operating in strong magnetic fields.
  - Open cell vacuum cavities
  - Bucking coils to reduce fields at cavities
  - Magnetically shielded cavities
  - Pressurized cavities
- MCTF focus on HPRF, discussing magnetically shielded cavities

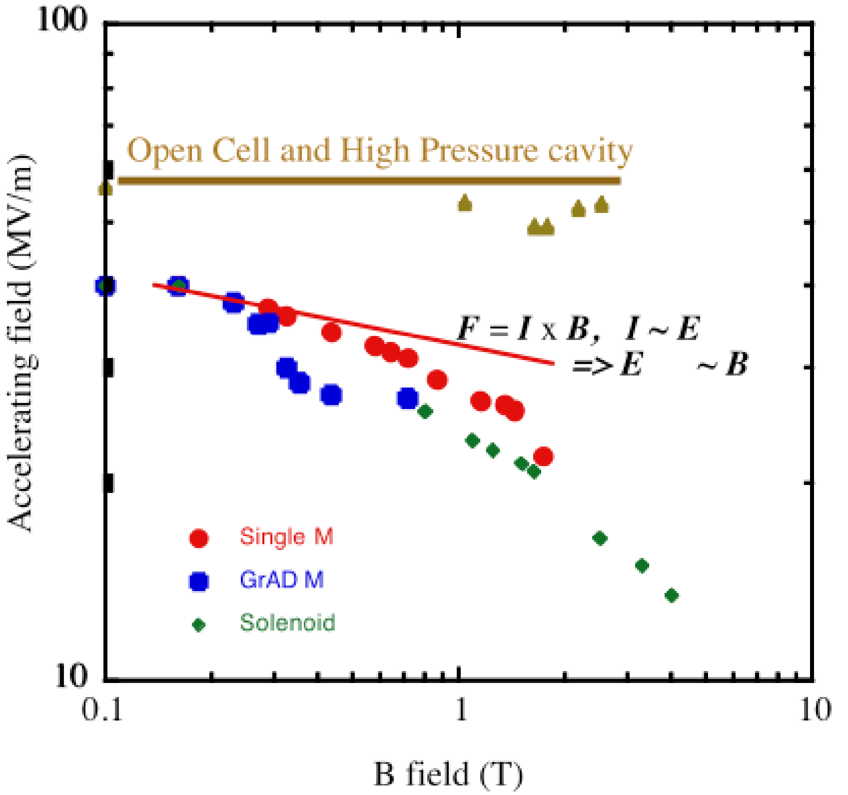
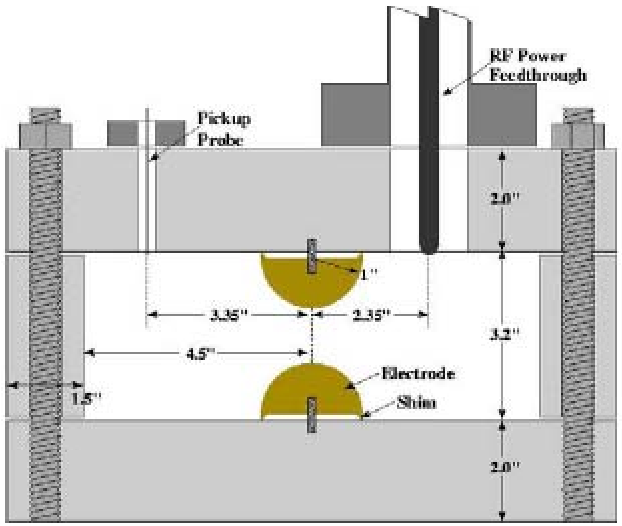
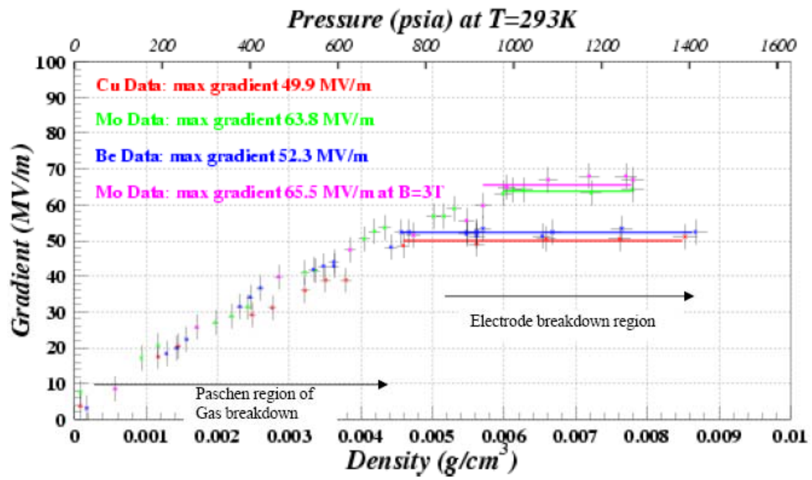


Figure from J. Norem

Pressurized RF cavities

- Pressurized hydrogen in cavity acts both as absorber and to suppress breakdown.
- No degradation of gradient with B-field observed.
- Cavity from Muons Inc, tested by Fermilab and Muons Inc staff in MTA.

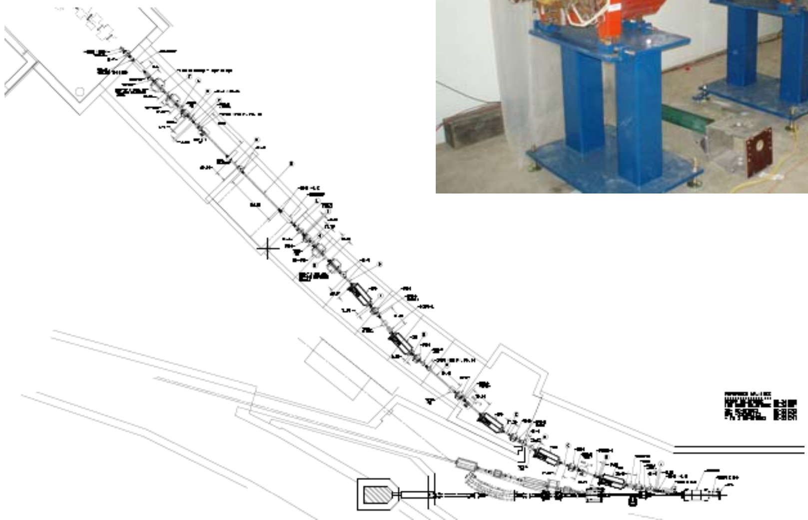




P. Hanlet *et al*, EPAC'06

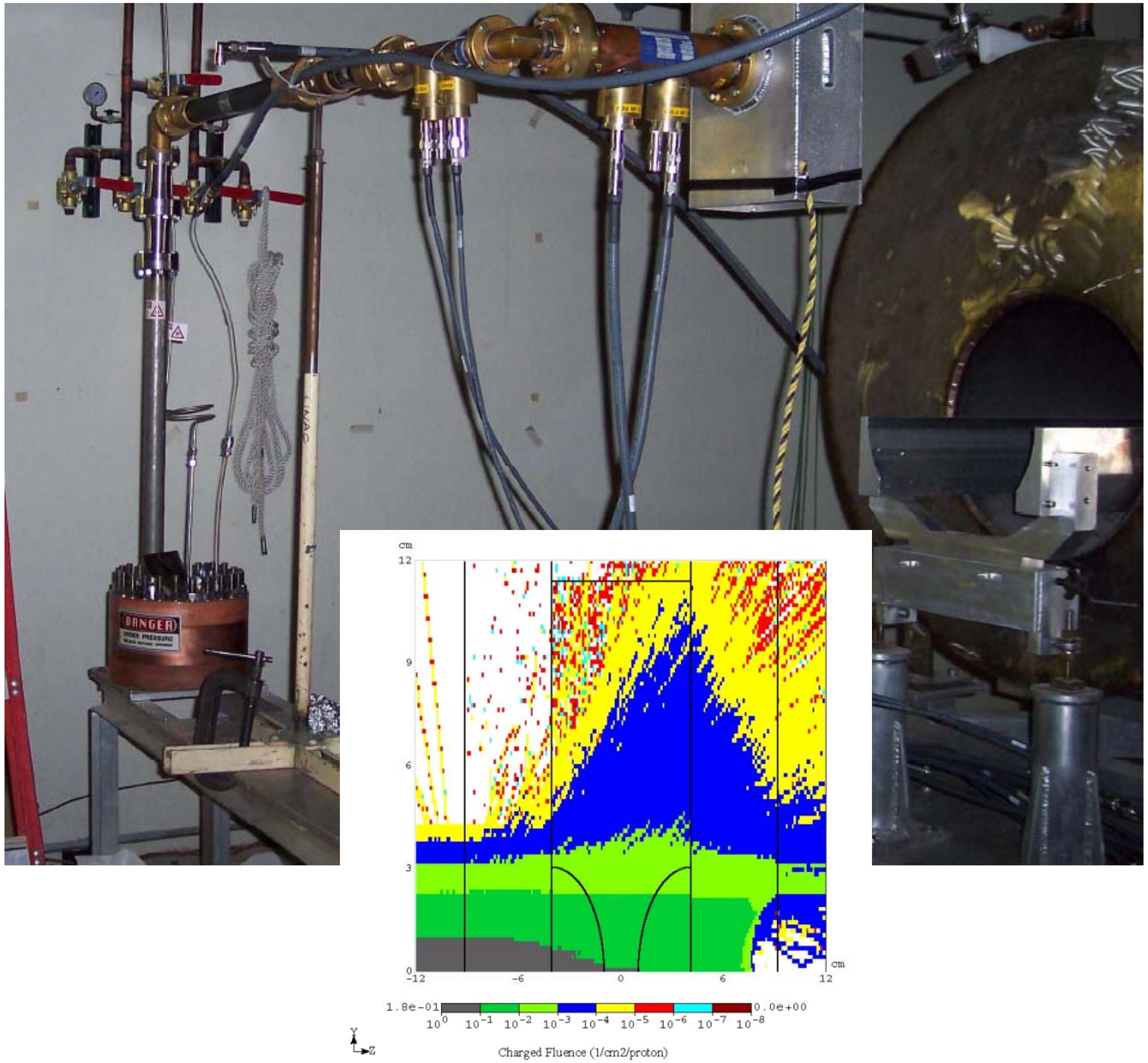
MTA beamline

- Intense beam will generate lots of ionization
  - How long do the electrons live (ms or ps)?
  - Where do the ions go?
  - Does the cavity still work?
- To test pressurized RF with intense beam, need protons to MTA.
- Beamline installation ongoing, expect first beam in ~spring 2008.



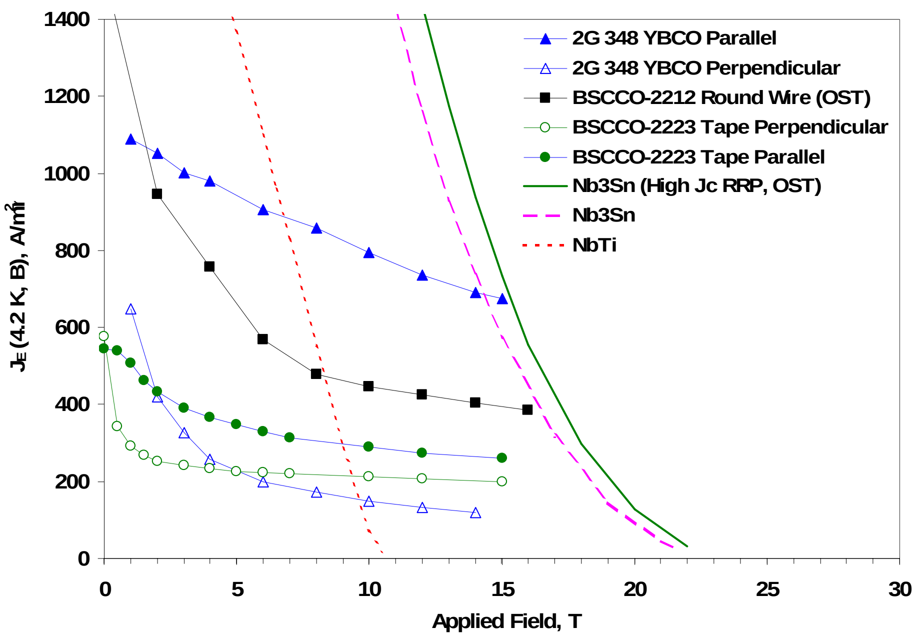
FY’08 HPRF plans

- First test using existing (Muons Inc) test cell will tell us a lot.
- Depending on outcome, either mitigate problems or build next test cavity



High field solenoids

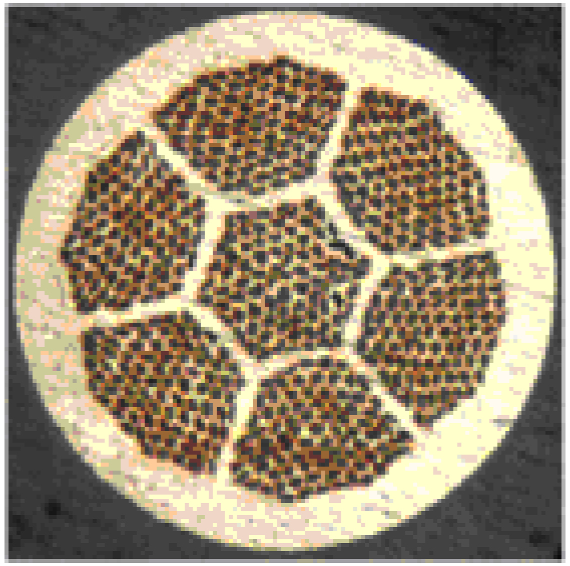
- To minimize the effect of multiple scattering, very strong focusing is needed in the end of the channel.
- 50T solenoid are needed for final cooling.
- Need to understand if HTS is a viable option
- See Mike Lamm's talk



Plot from E. Barzi

FY'08 HTS plans

- HTS conductor tests on existing strands
- Invest in billets for future conductor tests
  - Long lead time
- Partner with other labs for testing.
  - Build national HTS collaboration and seek additional funding for conductor development



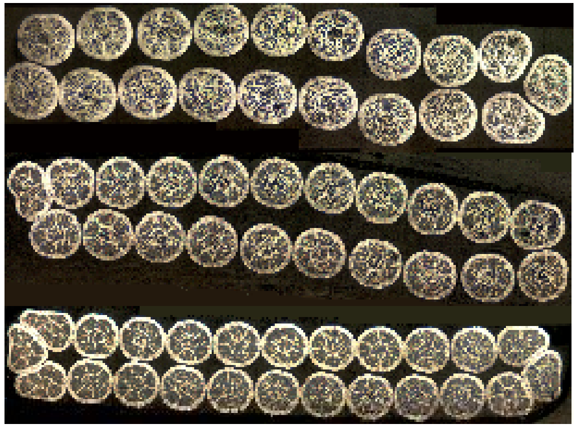


Photo from E. Barzi

Helical Cooling Channel

- Ionization cooling is inherently transverse
- Can cool longitudinally using wedge absorber in dispersive region.
- Can also use path-length difference inside gas-filled magnet.
- Possible to arrange fields to get 6D cooling in continuous absorber
- See Rol's talk

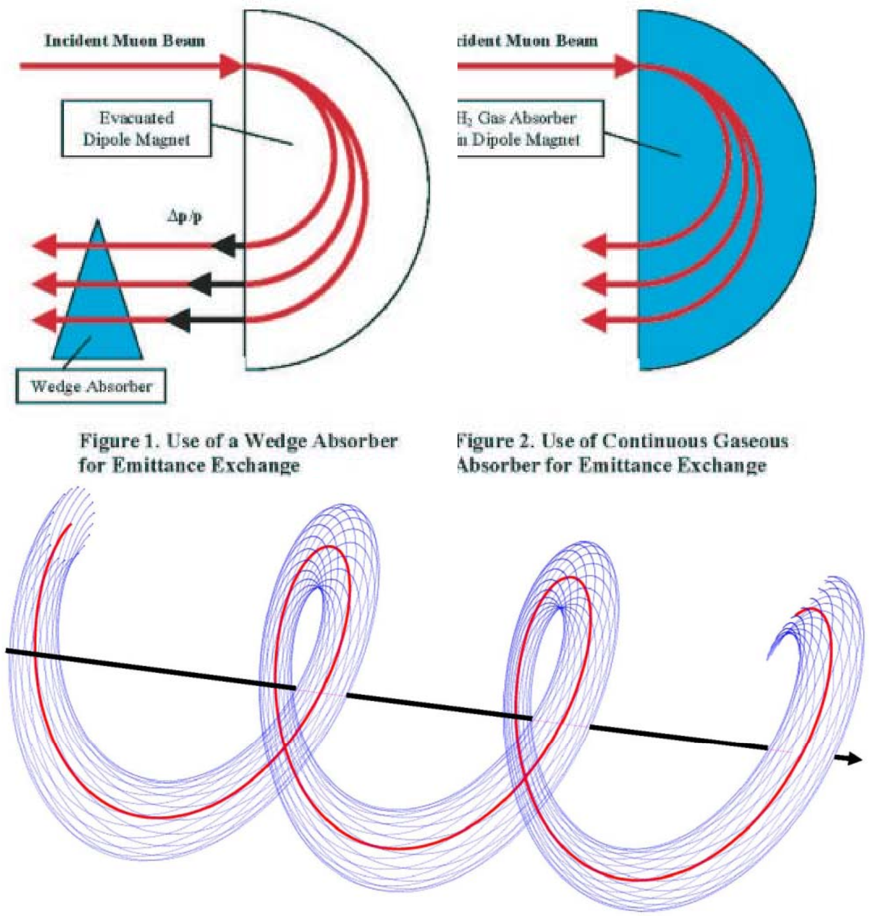


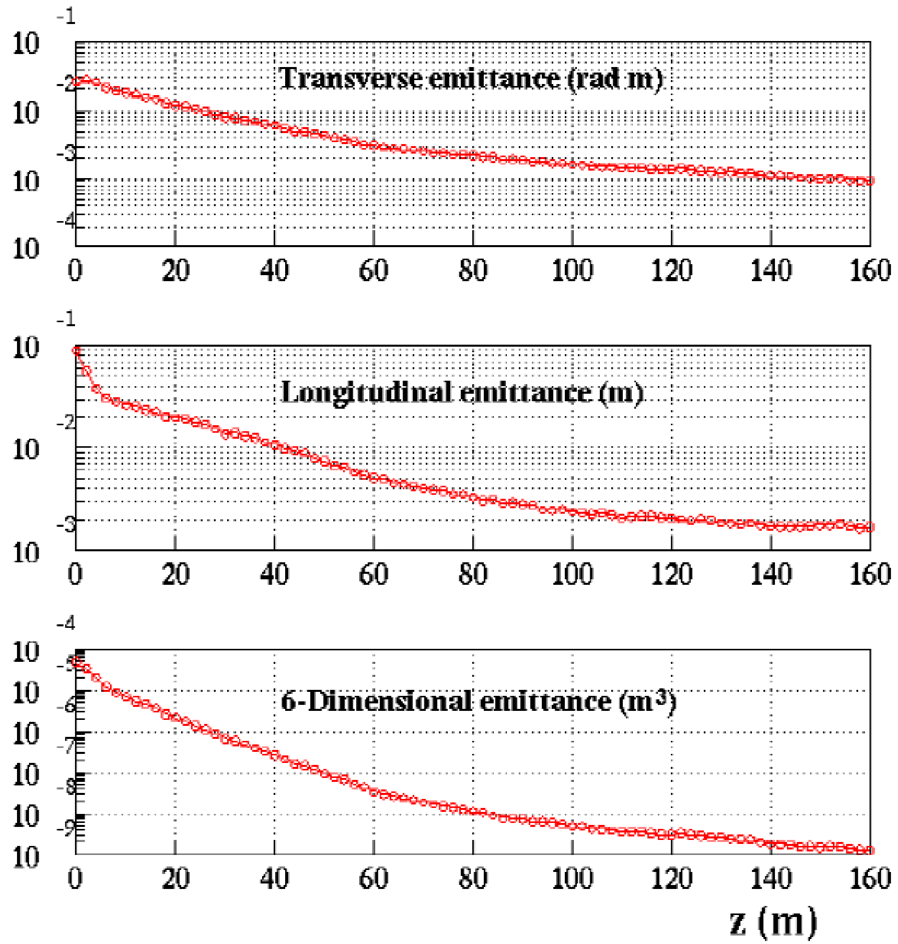
Figure 1. Use of a Wedge Absorber for Emittance Exchange

Figure 2. Use of Continuous Gaseous Absorber for Emittance Exchange

Y. Derbenev and R. Johnson, PRST-AB 8, 041002 (2005)

6D cooling experiment

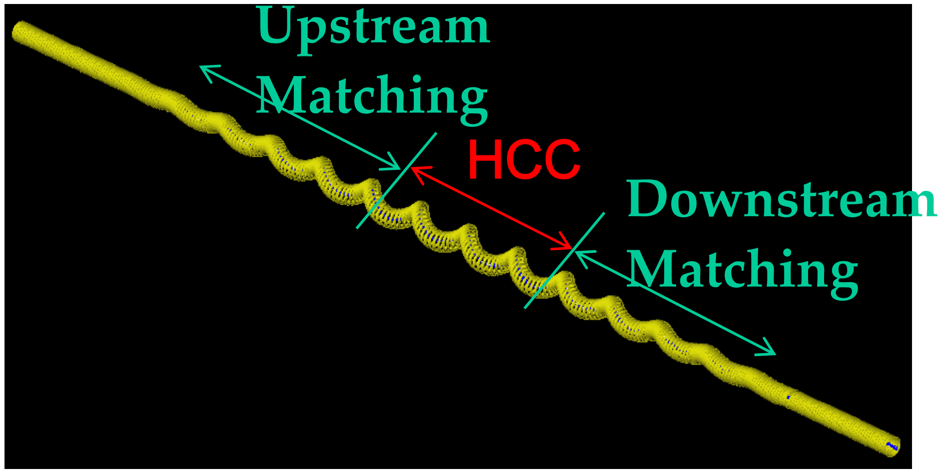
- HCCs promises 6D cooling factors of 50,000 in channels of ~200m, based on simulations.
- An experiment is needed to verify these simulations.

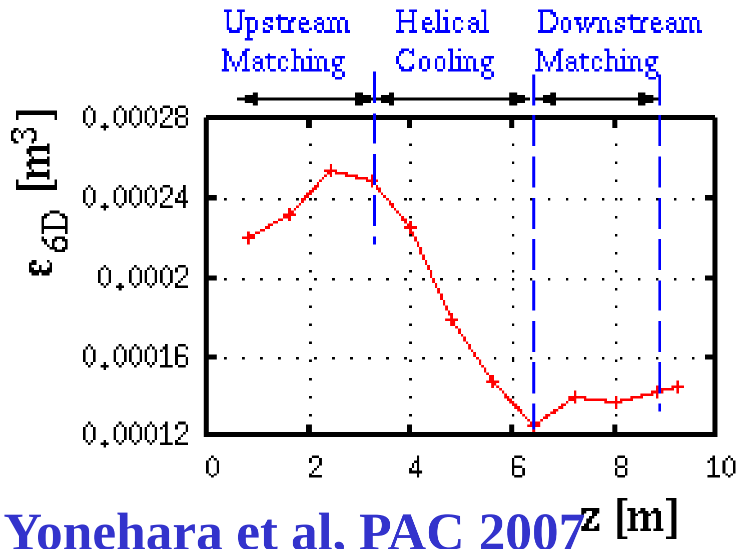


R.P. Johnson *et al*, COOL 2005

MANX

- No RF, LHe absorber and tapered fields to match energy loss.
- Investigating two possible locations at Fermilab (KTeV and MTA).
- Experiment could be done either with single muons, or muon "beamlets".
- Detector development needed (eg SciFi in LHe)



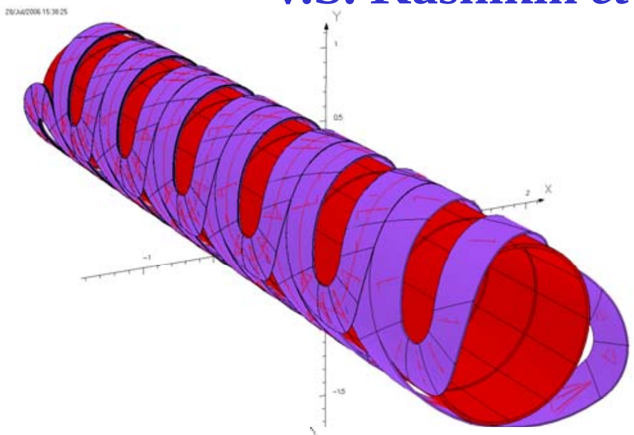


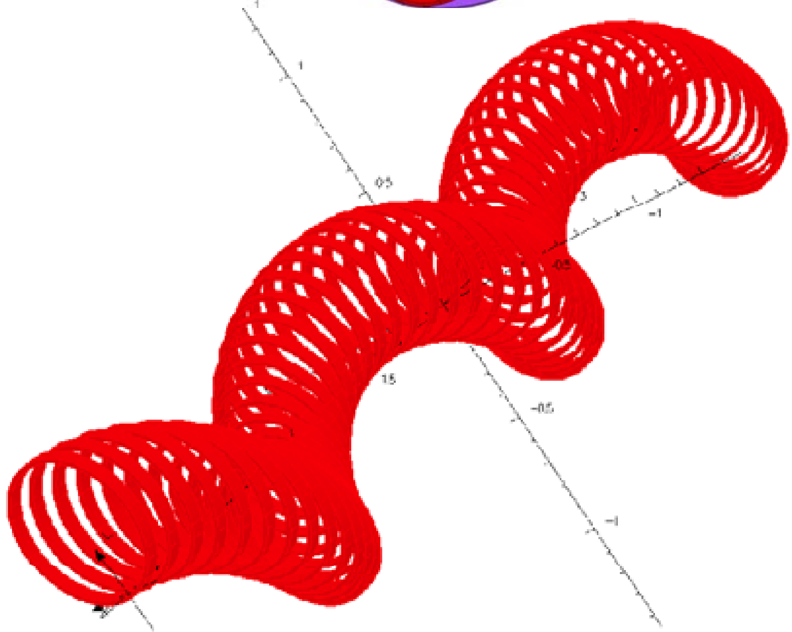
K. Yonehara et al, PAC 2007

HCC magnet design

V.S. Kashikin *et al*, ASC 2006

- HCC requires solenoid, helical dipole and helical quadrupole field components.
- Can be generated by discrete solenoid coils offset transversely in helical pattern.
- Simpler to build, and may allow RF cavities between coils.





FY'08 HCC plans

- Build and test a subscale section (4 coils) of helical solenoid magnet
  - partially funded by Muon Inc SBIR.
  - Will keep TD magnet people busy for most of '08
- Define 6D cooling experiment parameters and start detailed design of the magnet.
- Determine best location (muon beamline).

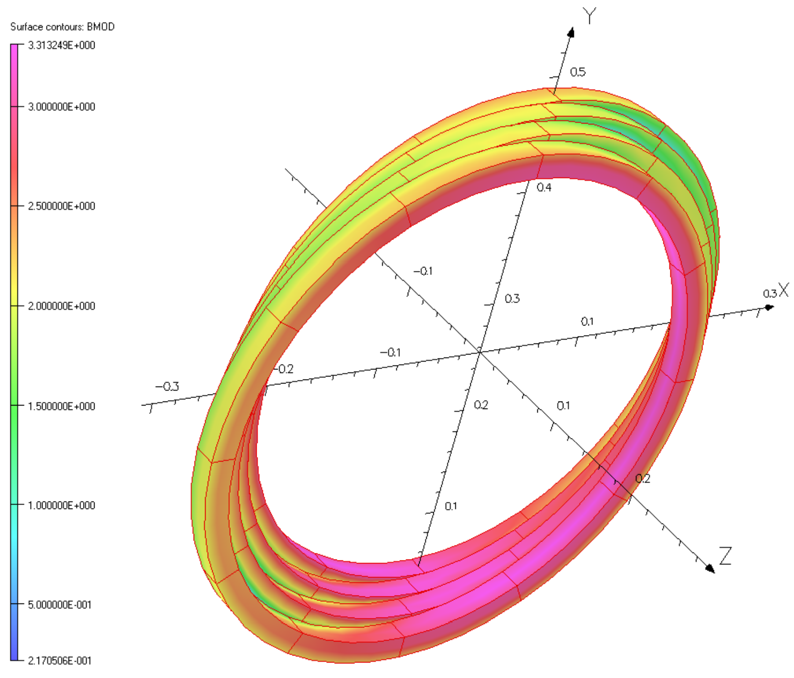
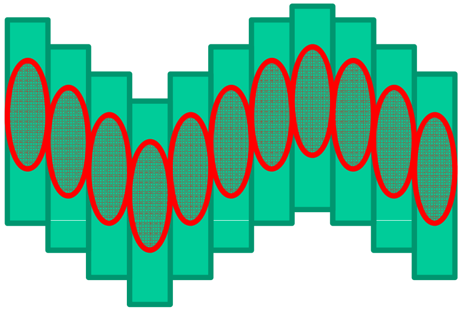


Figure from V. Kashikin

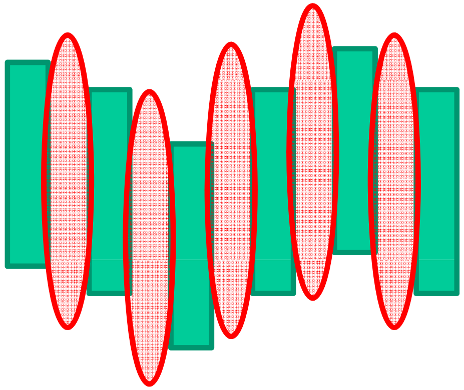
RF in HCC

- *A 'real' HCC needs RF!*
- *Three options studied:*

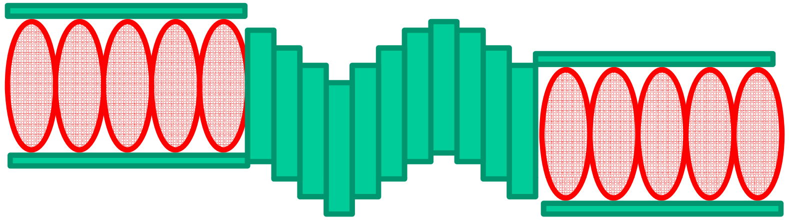
1) RF inside coils
   - Simulates OK, but cavity frequency restricted to fit radially. Reduces acceptance



2) RF in between coils
   - Simulations OK for very short cavities. Not sure if practical.



3) Separate HCC and RF sections
   - Not yet shown to work in simulations. Large time spread in HCC + matching.



Budget crunch

- A large component of the proposed $5M MCTF budget was intended for a 6D cooling experiment.
- With the current budget outlook, may need to rethink
  - Is a cooling channel test w/o RF the right thing to do?
  - Can it give timely results with limited funds?
  - Is there a simpler, more generic test that can be done to validate simulations?

Cooling experiment strategy

Assuming HPRF test with beam is successful:

Option 1

- Build tapered magnet and test cooling properties without RF, using LHe as absorber
- Follow up by adding RF section and upgrading to H2 gas as absorber
- Demonstrates "cooling", but does not develop technology by ~2012

Option 2

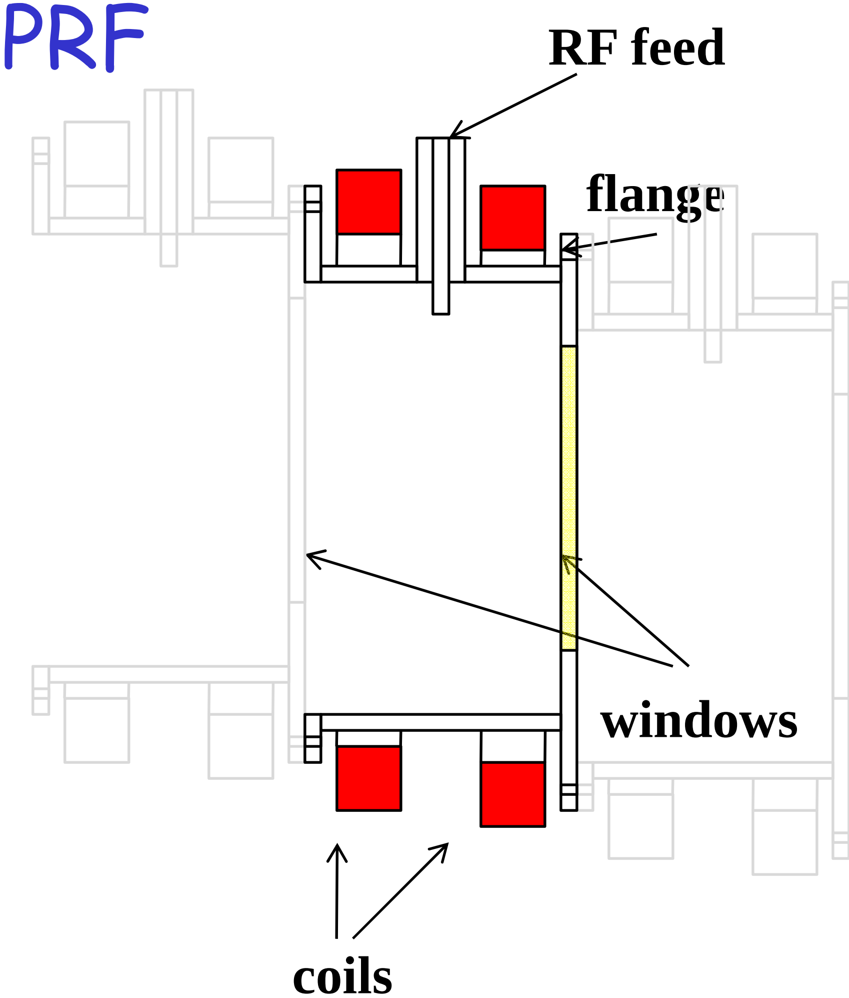
- Design and build a short section of HCC including HPRF, test on bench or in beam.

~2012

- Add more sections for a full-blown 6D cooling experiment.
- Develops technology, but does not demonstrate cooling in HCC by ~2012

6D cooling channel strategy cont'd

- Pending results from HPRF measurements, pursue both options in parallel
  - Further simulations of cooling channels with separate HCC and RF sections
  - Modular design of HCC section with RF



Summary

Aim of MCTF is to boost muon collider R&D in ways that complement and strengthen existing efforts (e.g. NFMCC and Muonc Inc)

Goal is to show muon colliders as a viable path by ~2012.

Strong moral support (director, steering group etc), but budget not yet up to speed.

Need to think hard about how to prioritize program within limited budget.

An important milestone will be the HPRF experiment with beam.