MUON COLLIDER TASK FORCE

Overview of organization, activities, and plans

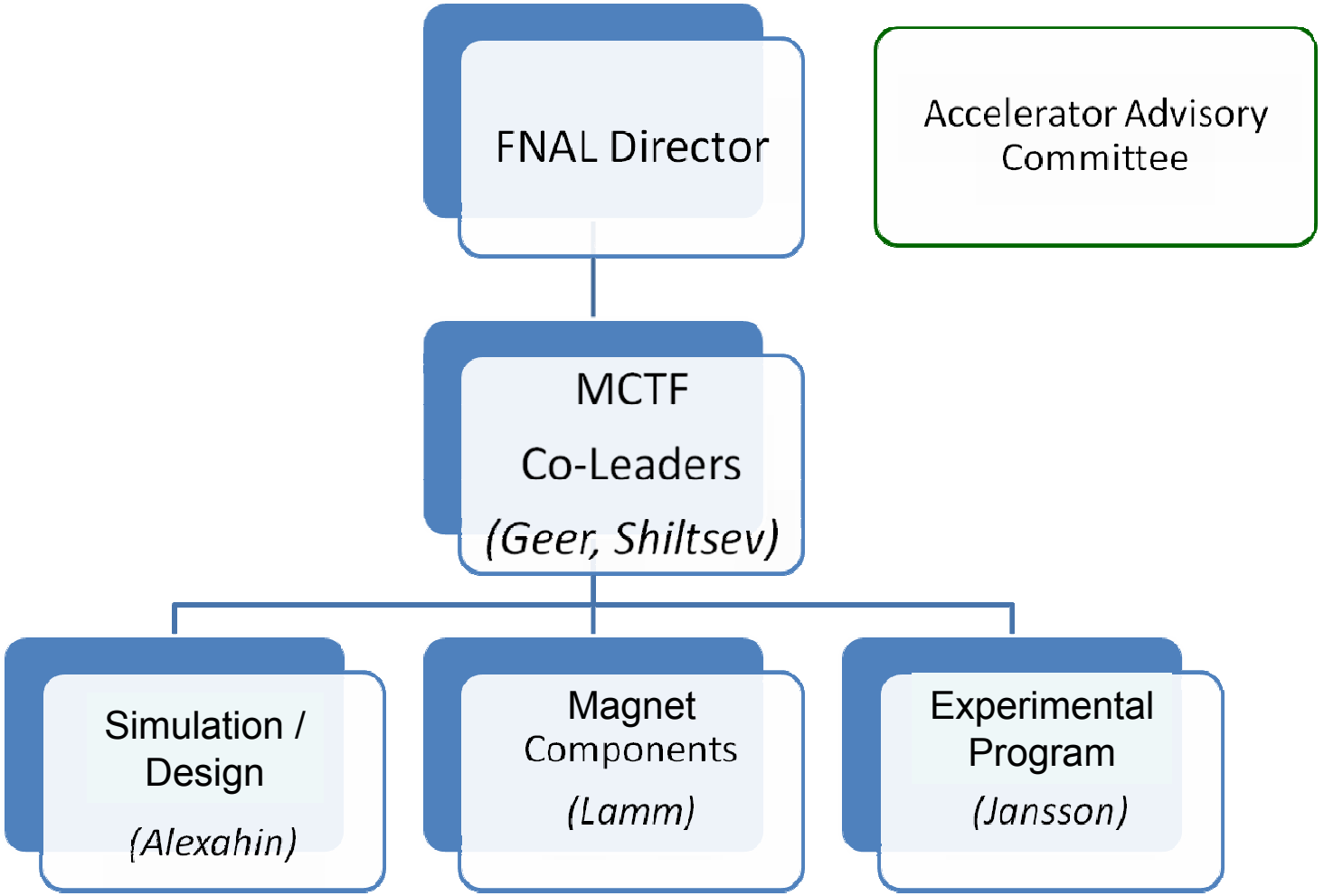
CHARGE

- Charge from the Fermilab Director (July 2006)
  - "…the Muon Collider represents a possible long term path for extending the energy frontier in lepton collisions beyond 1 TeV."
  - "…Task Force to develop a plan for an advanced R&D program aimed at the technologies required to support the long term prospects of a Muon Collider. "
  - requested for September 2006: A report outlining a plan for developing the Muon Collider concept based on recent ideas in the realm of ionization cooling.
- Initial proposal delivered Sept. 2006

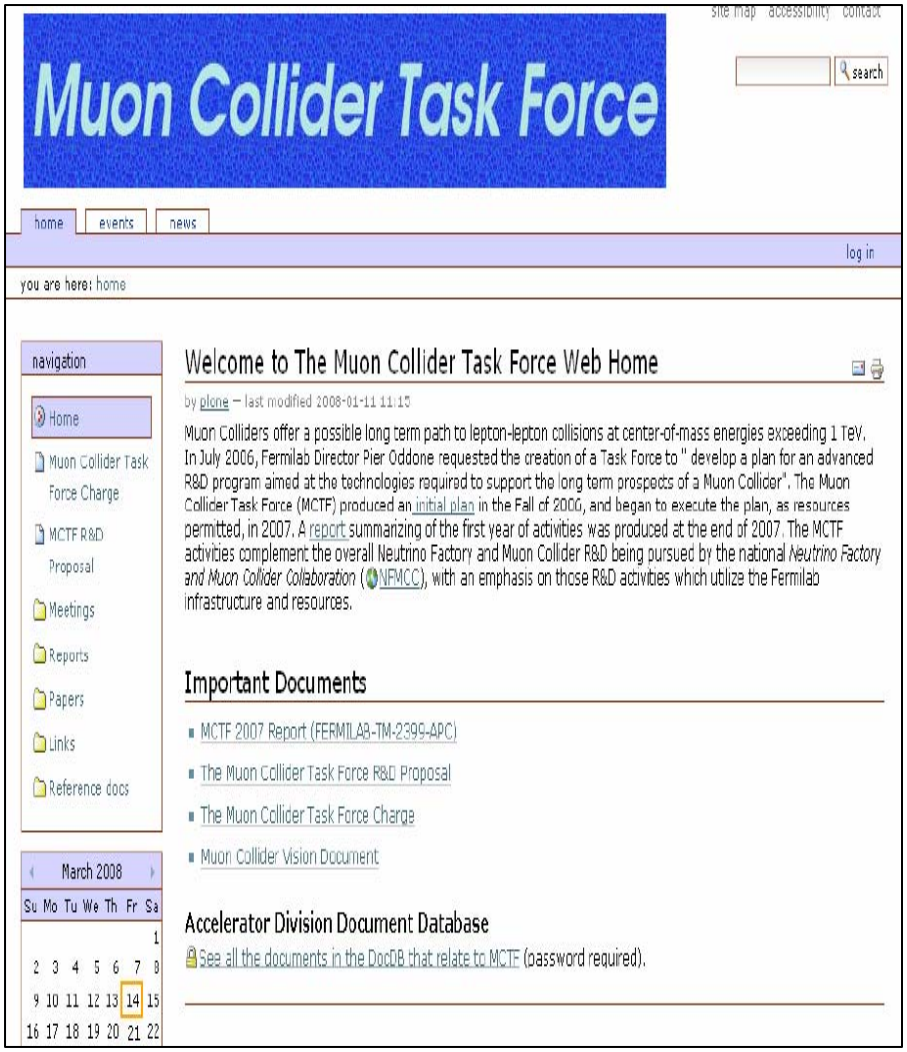
  → https://mctf.fnal.gov/muoncollider_aard_proposal_v3.doc
- Report on first years activities delivered in Dec. 2007

  → FNAL-TM-2399

ORGANIZATION

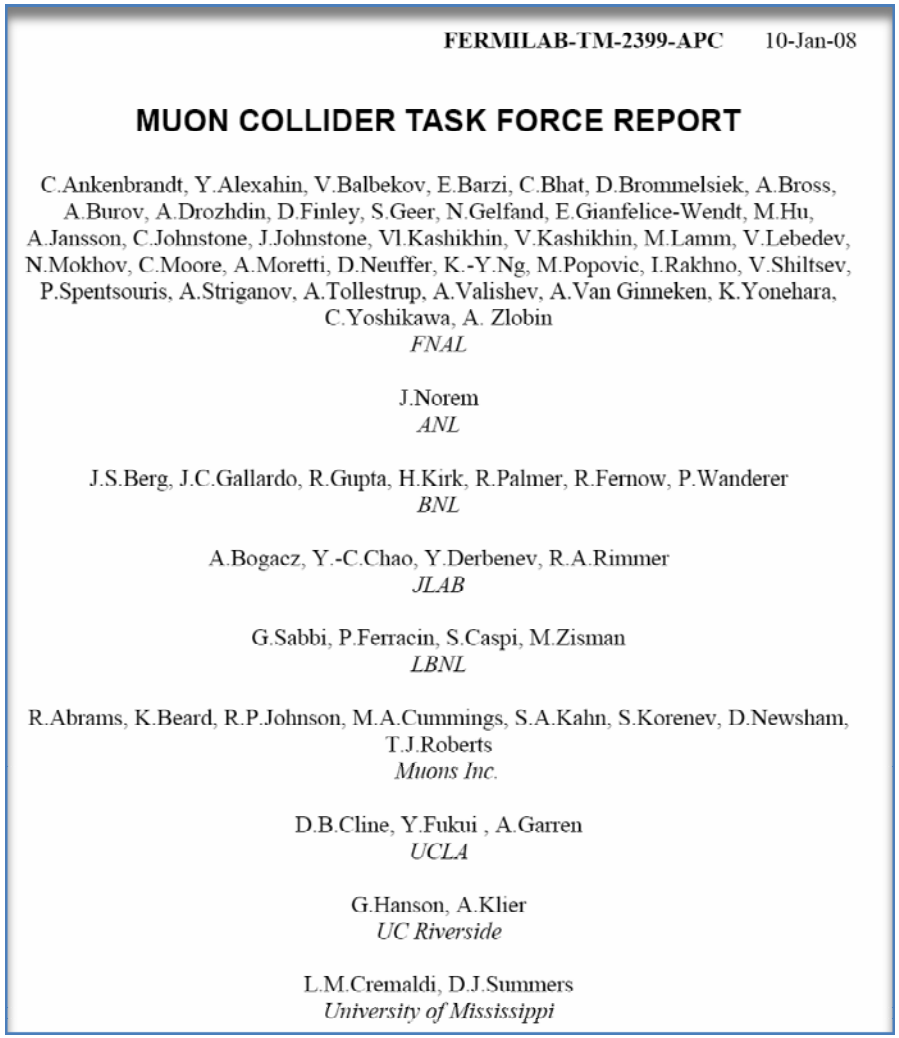


MCTF WEBSITE



- MCTF website:
  http//mctf.fnal.gov
- APC Muon Dept. website:
  http://apc.fnal.gov/groups2/muon.shtml

MCTF REPORT



FERMILAB-TM-2399-APC 10-Jan-08

MUON COLLIDER TASK FORCE REPORT

C.Ankenbrandt, Y.Alexahin, V.Balbekov, E.Barzi, C.Bhat, D.Brommelsiek, A.Bross, A.Burov, A.Drozhdin, D.Finley, S.Geer, N.Gelfand, E.Gianfelice-Wendt, M.Hu, A.Jansson, C.Johnstone, J.Johnstone, Vl.Kashikhin, V.Kashikhin, M.Lamm, V.Lebedev, N.Mokhov, C.Moore, A.Moretti, D.Neuffer, K.-Y.Ng, M.Popovic, I.Rakhno, V.Shiltsev, P.Spentsouris, A.Striganov, A.Tollestrup, A.Valishev, A.Van Ginneken, K.Yonehara, C.Yoshikawa, A. Zlobin
FNAL

J.Norem
ANL

J.S.Berg, J.C.Gallardo, R.Gupta, H.Kirk, R.Palmer, R.Fernow, P.Wanderer
BNL

A.Bogacz, Y.-C.Chao, Y.Derbenev, R.A.Rimmer
JLAB

G.Sabbi, P.Ferracin, S.Caspi, M.Zisman
LBNL

R.Abrams, K.Beard, R.P.Johnson, M.A.Cummings, S.A.Kahn, S.Korenev, D.Newsham, T.J.Roberts
Muons Inc.

D.B.Cline, Y.Fukui , A.Garren
UCLA

G.Hanson, A.Klier
UC Riverside

L.M.Cremaldi, D.J.Summers
University of Mississippi

- Report on first year of MCTF activities:

https://mctf.fnal.gov/annual-reports/mctf-report-2007_v9.doc

- Delivered Dec. 2007 (final version Jan 2008)

- Participation from:
  - 9 Institutions
  - 64 People

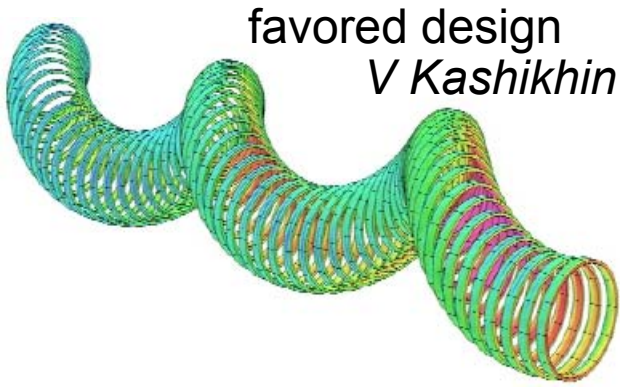
MCTF ACTIVITIES

- With the NFMCC, prepare the way for a “Muon Collider Feasibility Study” in ~FY011-FY012 with main MCTF focus on 6D Cooling R&D and Collider Ring Design

- Present MCTF Activities
  - Helical Cooling Channel design, simulation & component tests
  - Additional cooling channel simulation studies for last cooling channel stages (“FOFO Snake”)
  - HTS conductor & magnet studies (for end of cooling channel)
  - Collider Ring Lattice Studies
  - Parameter Studies (MC parameter list, wall plug power)
  - Physics, Detector & Background Studies
  - First look at using ILC cavities (beam loading issues)

HCC ACTIVITIES

- A Helical Cooling Channel filled with high pressure H_2 gas has been proposed by Derbenev & Johnson (Muons Inc). MCTF goal: do what is necessary to find out whether this idea is a viable & attractive option.
- Develop & simulate HCC design, including RF cavities, with realistic engineering constraints.
- Build & test a 4-coil HCC model magnet.
- Test in a beam an RF cavity filled with high hydrogen gas at high pressure.
- Near-Term Goals
  - Establish whether an HCC is viable and define a prototype HCC section to build and test in the next few years.

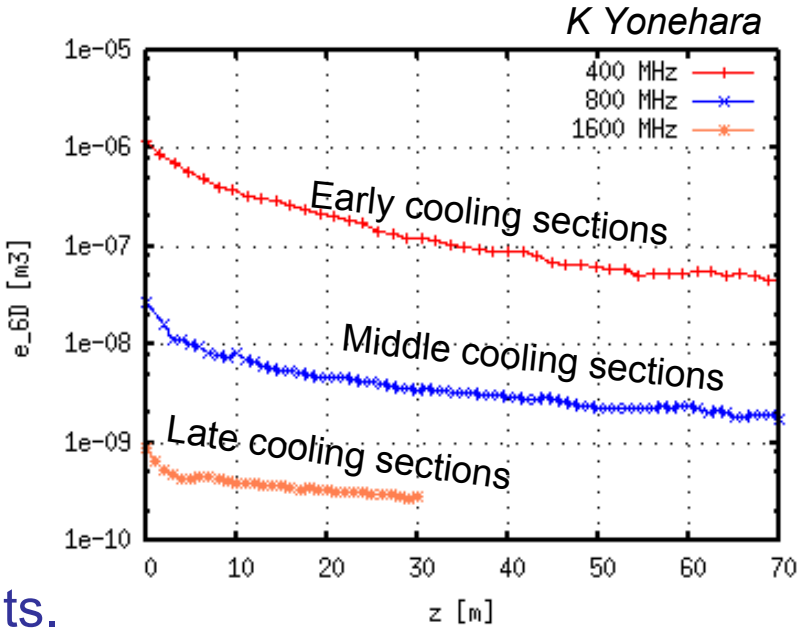


- Beam follows helical trajectory
- Longitudinal & transverse degrees of freedom mix
- Transverse $\rightarrow$ 6D cooling

HCC SIMULATIONS

- Motivation
  - Early simulations ignored engineering constraints, for example it was assumed $R_{cavity} > R_{coil}$.
  - A more realistic simulation is needed before we can conclude that an HCC is viable & attractive.

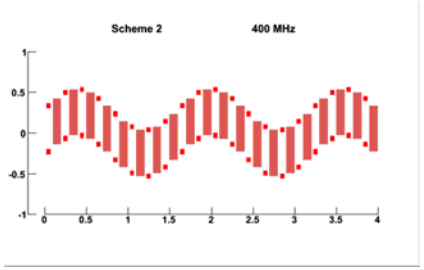
- MCTF Progress & Plans
  - Independent simulation (V. Balbekov) confirmed main results (K. Yonehara).
  - Studies show when R_{cavity} reduced there is a loss in performance.
  - Coming year: Continue simulation studies with more realistic engineering constraints.



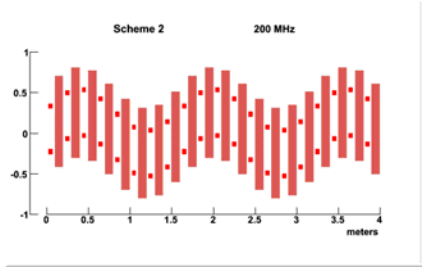
MCTF

RF INTEGRATION IN HCC

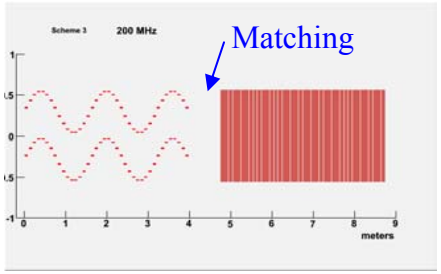
- 3 options identified for RF integration in HCC. →
  - Which options are practical?
  - What impact do their details have on HCC performance ?
  - Want an answer before we decide what to prototype & test
- MCTF Progress & Plans
  - Assembled team to get some engineering input →
  - first understanding of coil-rf separation.
  - In coming year, define prototype & begin the design.
- More details
  - See A. Jansson's talk



RF inside coils

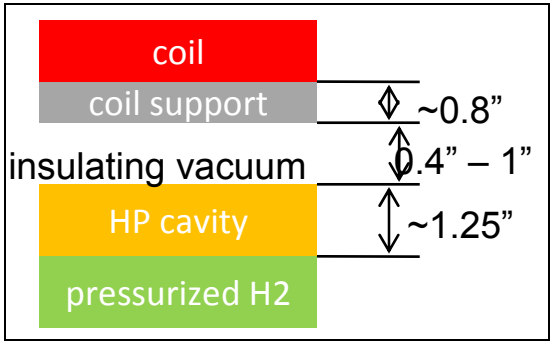


coils inside RF



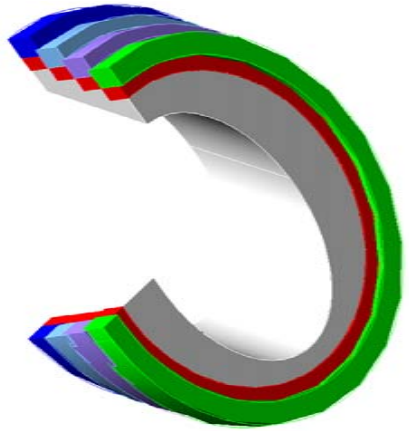
separated RF sections

A Jansson, K Yonehara, V Kashikin, M Lamm, J Theilacker, A Klebaner, D Sun, A Lee, G Romanov, D Broemmelsiek, G Kutznetsov, A Shemyakin



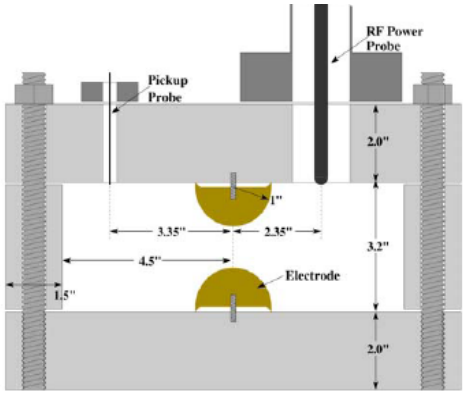
HCC RF 4 COIL TEST

- Motivation
  - Validate mechanical structure & winding technology
  - Develop field quality measurement
  - Study quench protection issues
- Progress
  - Muons Inc. STTR phase 2 funds obtained to support labor for design, fabrication & test (materials + contract labor from MCTF funds).
  - Mechanical & magnetic design completed, and conductor obtained & tested
  - Procurement in progress
  - Plan pre-fabrication review in May & test at end of FY08
- More details
  - See S. Zlobin's talk



HIGH PRESSURE RF FOR HCC

- Motivation
  - Within the HCC, hydrogen gas at high pressure is used to both suppress RF breakdown in a magnetic field (already demonstrated without beam) & provide the energy loss media for the cooling channel.
  - Not clear that HPRF cavities will work in an ionizing beam … for the HCC concept its crucial that we find out.

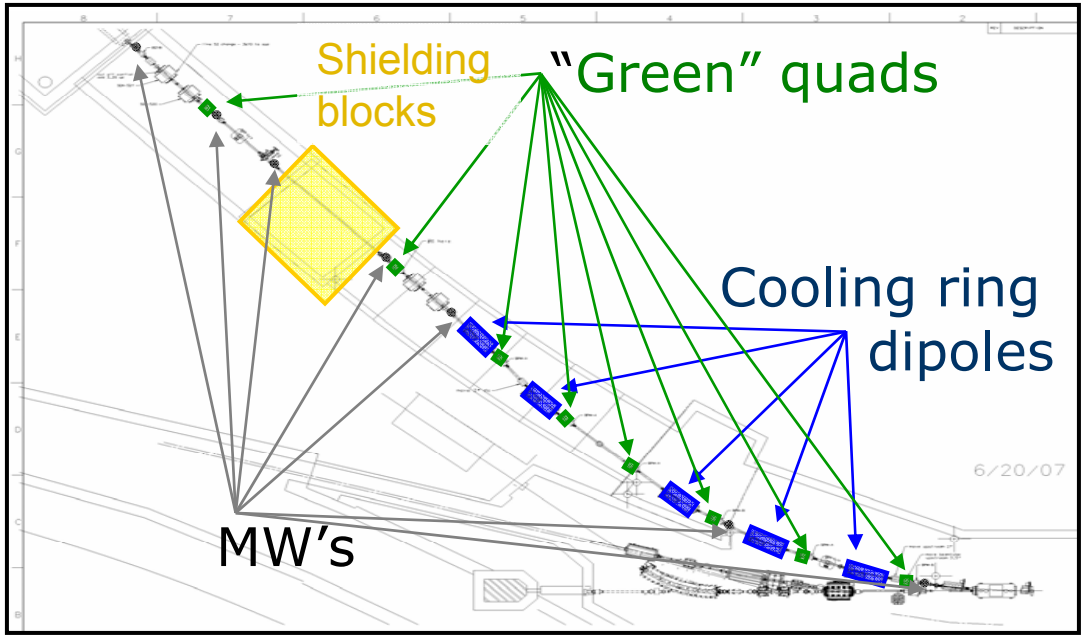


Muons Inc. Test Cell

- MCTF Progress & Plans
  - Plan to test Muons Inc. HPRF cell in a beam at the MUCOOL Test Facility.
  - In 2007 most of the beamline was built (major activity)
  - Plan to complete beamline this calendar year.
  - If results are encouraging, next step would be to build and test a real HPRF cavity in an appropriate magnetic field.

MCTF

BEAMLINE FOR HPRF TEST



BEAMLINE AS INSTALLED

- Beamline installation nearing completion
  - Significant accomplishment in last year
  - Need linac access to complete
- More details:
  - See C. Johnstone's talk on beamline (& A. Bross talk)
  - See A. Jansson's talk on experimental program

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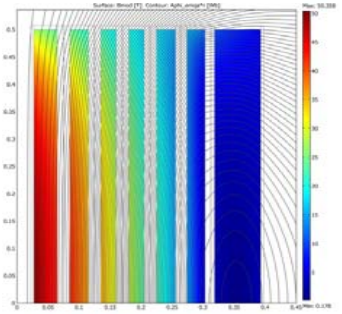
HTS CONDUCTOR & MAGNET R&D

- Motivation
  - Existing very high field resistive/SC hybrids solenoids ➔ Megawatt power, one-of-a-kind, expensive to build/operate.
  - Hybrid SC magnet with HTS insert proposed for end of cooling channel (Note: HTS solenoid insert operating at 25T already demonstrated).
  - Muons Inc. with FNAL has initiated a small scale R&D activity .
  - MCTF Plan→ Study magnet issues and study materials & properties as a function of field, field angle, & temperture, for fields >25T.

- Progress
  - Magnet challenges identified: stress management, conductor performance, quench protection ➔ focus on conductor development
  - Sample holder built, Ic vs B measured for several materials, up to 28T; made cable; Plans progress-ing for National Collaboration on HTS conductor development.

- More details
  - Conductor R&D: See S. Zlobin's talk
  - National Collaboration: See A. Tollestrup's talk



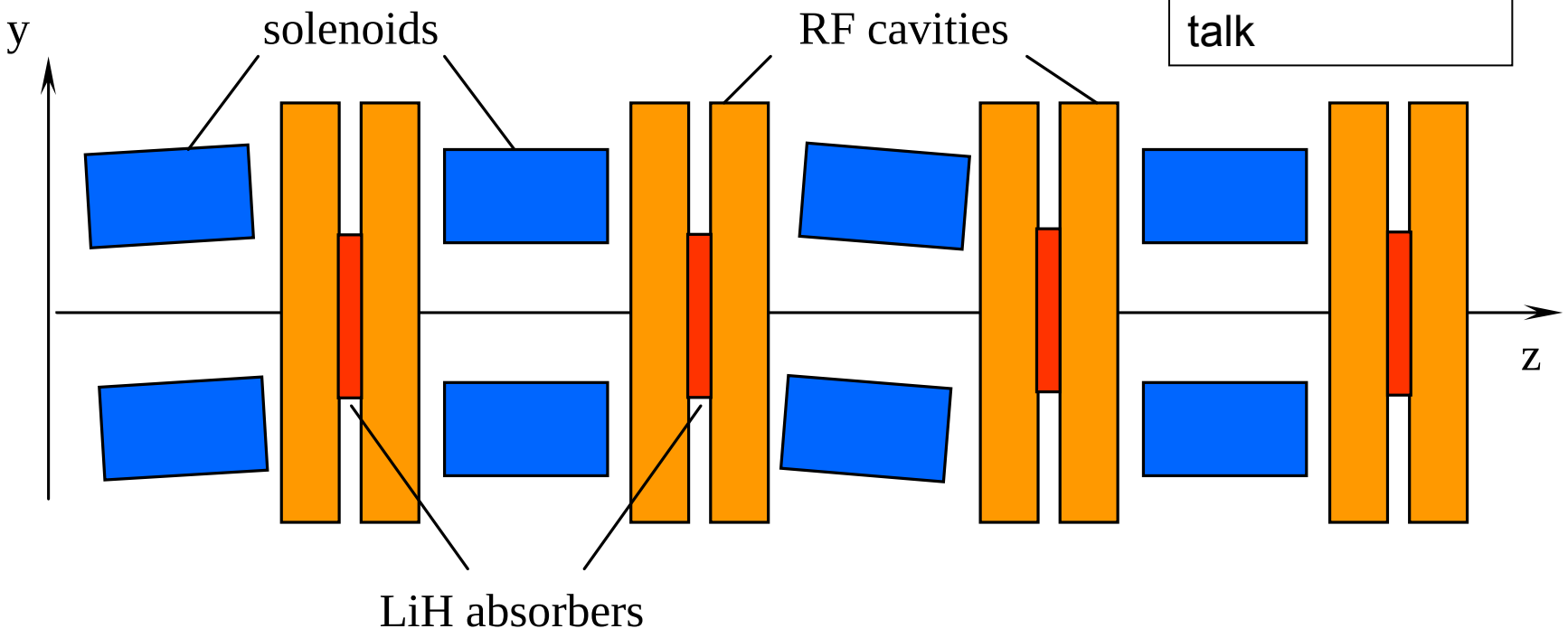
50T Field map

ADDITIONAL COOLING CHANNEL STUDIES

Y. Alexahin

201 MHz "FOFO Snake"

More details: see R. Palmer's talk

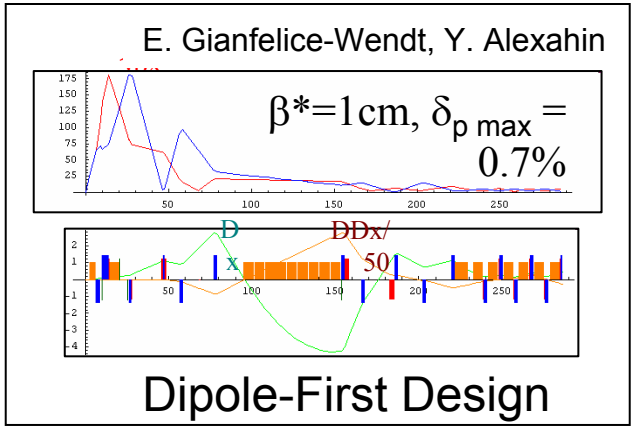


Cell length =3.2 m, solenoid inner radius = 40cm, Bmax=2.4 T at p=100MeV/c
HPRF cavities 2×16cm long, E=25MV/m, GH2 fill with density 10% of LH2
Emittance decrement 1/25m, equilibrium emittances ~3 π·mm

COLLIDER RING DESIGN

- "High"- & "Low"- emittance Muon Collider designs have been proposed … both have pros and cons.
  - Previous "High-emitt." design had insufficient dynamic aperture.
  - "Low-emittance" parameters are more speculative.

- MCTF Progress
  - New "dipole-first" scheme comes close to high-emitt. parameters (with sufficient dynamic aperture).



Dipole-First Design

- Plans
  - Start preliminary detector-shielding studies to see if "dipole-first" scheme viable (background issues)
  - Continue exploring possibilities for lower-emittance designs.

- More details
  - See R. Palmer's Talk

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PARAMETER STUDIES

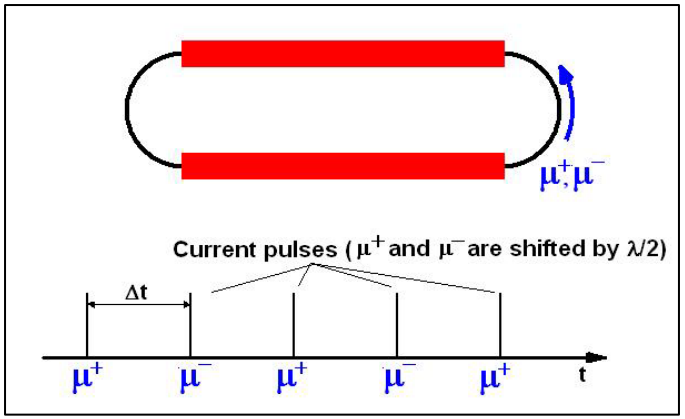
Muon Collider Parameters

	Low Emit.	High Emit.	MCTF07
√s (TeV)	1.5		
Av. Lum (10^{34}/cm^2/s) *	2.7	1	1.33-2
Av. Bending field (T)	10	6	6
Mean radius (m)	361.4	500	500
No. of IPs	4	2	2
Proton Driver Rep (Hz)	65	13	40-60
Beam-beam parmtr/IP	0.052	0.087	0.1
β* (cm)	0.5	1	1
Bunch length (cm)	0.5	1	1
No. bunches / beam	10	1	
No. muons/bunch (10^{12})	1	20	11.3
Norm. Trans. Emit. (μm)	2.1	25	12.3
Energy spread (%)	1	0.1	0.2
Norm. long. Emit. (m)	0.35	0.07	0.14
Total RF voltage (GV)	$407\times10^3\alpha_c$	0.21**	0.84**
Muon survival Nμ/Nμ0	0.31	0.07	0.2
μ+ in collision / proton	0.047	0.01	0.03
8 GeV prtn beam power	3.62***	3.2	1.9-2.8

Wall Plug Power Estimates

	MC1999	HE2008	HE2008	LE2008	LE2008
Collider cm Energy (TeV)	3	1.5	3	1.5	3
Luminosity (1e34)	7	1	3	3	3.5
Emittance (pi mm mmrad)	50	25	25	2.1	2.1
Rep rate (Hz)	15	13	8	65	32
Muons/beam (1e12)	8	2	2	1	1
PD beam power (MW)	4	4	2	3.6	8
Muon beam power (MW)	57.6	6.24	7.68	15.6	15.36
TOTAL wall plug power (MW):	204	60	83	166	158
PD (MW)		16	11	68	35
Bunching Ring(s) (MW)		4	4	4	4
Target station (MW)		1	1	1	1
Collection system (MW)		4	4	4	4
Cooling system (MW)		4	12	2	2
Acceleration (MW)	130	25	32	81	93
Beamlines		2	4	2	4

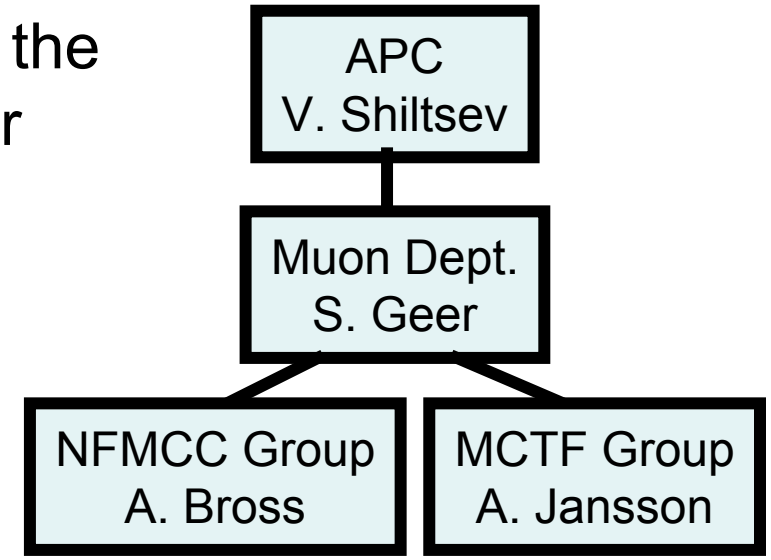
OTHER STUDIES



- First look at beam loading for acceleration of intense muon bunches using ILC cavities (V. Yakovlev, N. Solyak)
  - See Talks by R. Palmer & S. Berg
- Physics Studies
  - Last detailed MC physics study a decade ago
  - Physics study group initiated (C. Hill & E. Eichten) with first mini-workshop held (5th March 2008)
  - In coming year, will build on this activity and begin to update our understanding of detector/background requirements.
  - See Talk by E. Eichten
- Workshops
  - Additional Low Emittance MC workshop this year co-organized with Muons Inc. & NFMCC (→ bi-annual ?), Workshop on DWA-ILA for muon acceleration (Feb 2008).

FUNDING FOR NFMCC & MCTF ACTIVITIES WITHIN FERMILAB

- All MCTF & NFMCC activities at Fermilab are pursued within the framework of the Accelerator Physics Center (APC) Muon Dept.
- Provides mechanism for allocating resources to support both NFMCC & MCTF activities at FNAL
- Worked well in this last (very tough) year



CURRENT BUDGET (M&S fully loaded)

APS Muon Dept. Resources (M$)

	FY07 Spent	FY08 Allocated *
	4.4	4.1
M&S	1.1	0.9
SWF	3.3 **	3.2 **

**DoE specified funding cap on all muon accelerator R&D at Fermilab*

** ~14 FTEs → ~ 50% for MCTF & 50% for NFMCC activities

FY08 M&S DIRECT vs REQUEST

Activity	FY07 Spent	FY08 Allocated	FY08 Request
HCC Magnet	58	60	230 [2)]
HTS	0	50	200 [3)]
MTA Beamline	573	220	300 [4)]
MUCOOL	50	160	280 [5)]
MICE	160	60	60
MCTF RF			120 [6)]
6D HCC Section			100 [7)]
Travel	91	30	80 [1)]
TOTAL	**932**	**580**	**1370**

FY08 FUNDING REQUEST NOTES

1) Needed to meet travel needs associated with MICE
2) To move beyond initial "4 coil test" towards building an HCC section.
3) to exploit HTS conductor R&D momentum initiated with SBIR, and to push ahead with initiating a national HTS magnet collaboration needed to get our feet on the ground with this technology.
4) The MTA beamline estimate is 300k$. Completing the beamline so that the first HPRF test can be made in FY08 is a priority.
5) Needed to complete the presently planned MUCOOL RF R&D in FY08 before the MICE solenoid arrives early FY09 (→ scheduling conflict)
6) Needed to extend the RF R&D to explore "magnetic insulation" against RF breakdown.
7) Needed to begin work towards bench testing an HCC 6D cooling section … first step towards a 6D cooling experiment.

TOWARDS A 5 YEAR PLAN

- Have started working towards a joint NFMCC-MCTF 5 year plan
  - Many uncertainties about funding levels we should be planning for, but we have a first understanding of the resources needed to deliver "Muon Collider Feasibility Study" by FY011-12.
  - Activities at Fermilab would need to be ramped up significantly over the next few years (to support both NFMCC and MCTF activities). Our working model is:
    - Ramp up FNAL effort to 24 FTEs (SWF = 6M$/yr)
    - Ramp up FNAL M&S to 3M$/yr (assume total national investment (SWF+M&S) in NF+MC R&D ramped up to 25 M$/year)
- We think a reasonable goal would be to have a joint NFMCC-MCTF draft 5-year plan by August
  - In a year we will know more about HCC, which will guide us in deciding what needs to be prototyped.

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5 YEAR FUNDING MODEL (M$)

MUON COLLIDER R&D at FERMILAB

Activity	**FY09**	**FY10**	**FY11**	**FY12**	**FY13**
Travel	100	100	100	100	100
MTA Tests & infrastructure	200	200	200	200	200
MUCOOL & MICE	300	300	300	300	300
6D Cooling Section	300	600	1000	2000	2000
HTS*)	200	300	400	400	400
M&S TOTAL	**1100**	**1500**	**2000**	**3000**	**3000**
SWF (FTE)	**4000 (18)**	**4500 (21)**	**5000 (22)**	**5500 (23)**	**6000 (24)**

*) Includes support for model magnet building at the national labs

SUMMARY

- MCTF has just completed its first year of activities
  - We have made a solid start within the present tight funding constraints
  - Progress documented in the MCTF "annual report"

- MCTF activities focused on R&D to inform "MC Feasibility Study", with main emphasis on 6D cooling channels & MC ring design
  - Complete 6D cooling scheme simulated end-to-end
  - RF tested in magnetic field & short cooling section bench-tested
  - MC ring design with parameters consistent with the cooling channel performance.

- To accomplish these goals on a reasonable timescale we believe we need to ramp up the support at FNAL over the next few years
  - Support NFMCC activities at FNAL plus MCTF activities → M&S ~ 3m$/yr, SWF ~ 6M$/yr (~24 FTEs).
  - Given the goals, we consider this to be the minimum support required. There is no contingency in our estimates (contingency= time).
  - Vital for our plans that MC R&D caps permit this growth.
  - Aim to have a joint NFMCC-MCTF draft 5 year plan by August (available for next MUTAC)