Fermilab's Muon Collider Task Force (MCTF): Progress Report & Outlook

Vladimir Shiltsev

CONTENT

- Technical Progress Highlights:
  - 5 year plan : after Aug'08 MUTAC
  - Project-X and Muon Collider/Neutrino Factory design
  - simulations of cooling channel (HCC and snake)
  - Collider Ring optics v1.0 release
  - MTA beamline progress
  - HPRF test results
  - Magnet R&D progress
- Budget (issues)
- Next steps
  - 5-yr plan and Project-X …and ADS
  - Detector R&D and theory
  - HTS collaboration and MCTF
  - Other collaborations

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"The 5 Year Plan"

(developed by All-US Community, coordinated by MCCC)

- **Goals** :

see S.Geer's and other talks Tue

I. establish feasibility of a Muon Collider by 2012-13

II. deliver MC-DFS by 2013 and NF-RDR by 2012

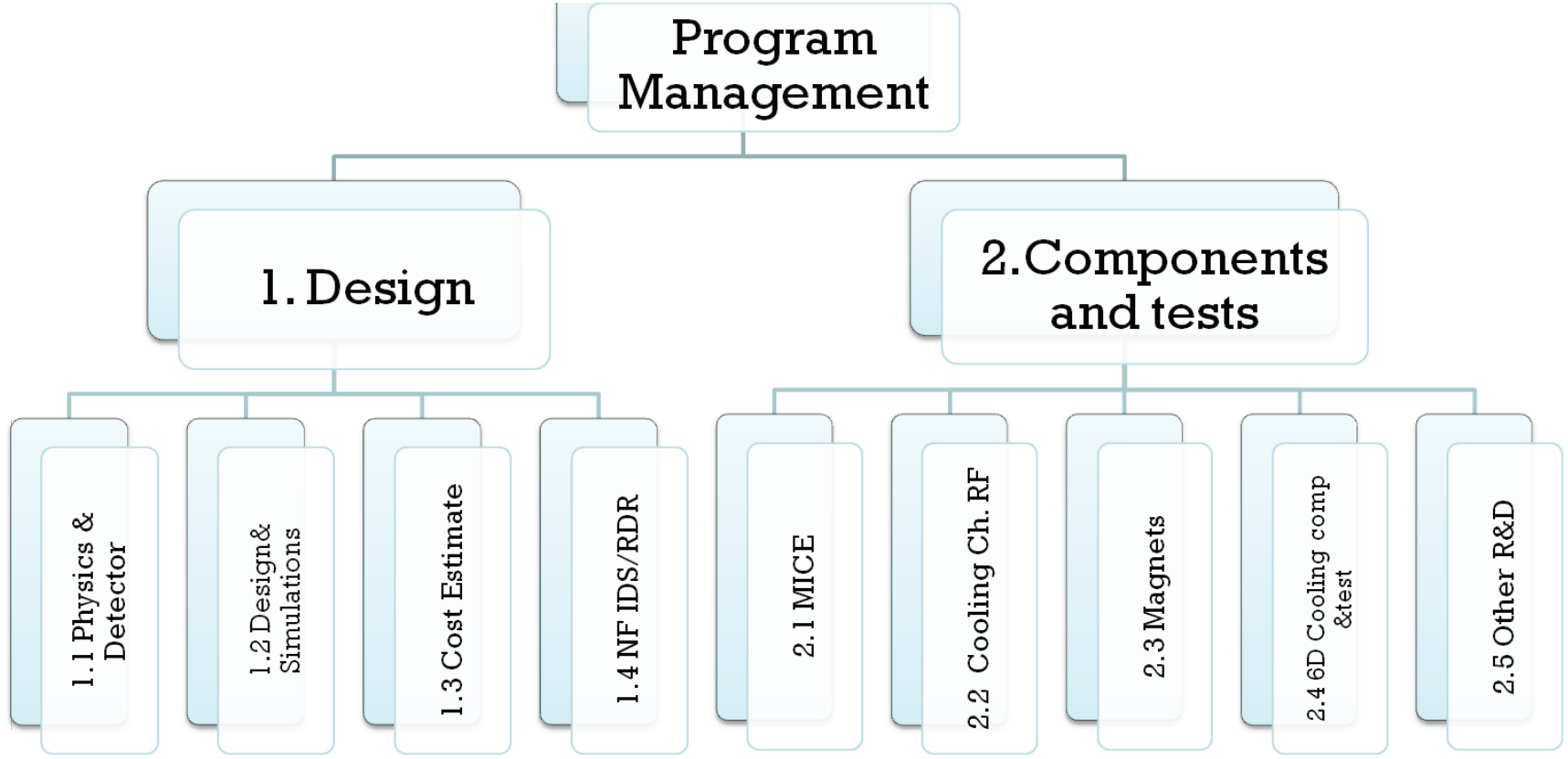
III. greatly narrow technology options, end-end simul's

IV. give cost estimates for MC and NF

- **Staged approach: PD → MCTF → NF → MC**

- pefectly aligned with Fermilab's long term plan outlined in Steering Group Report and P5 report

Elements of the R&D Plan



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5-Year Plan of Muon Accelerator R&D

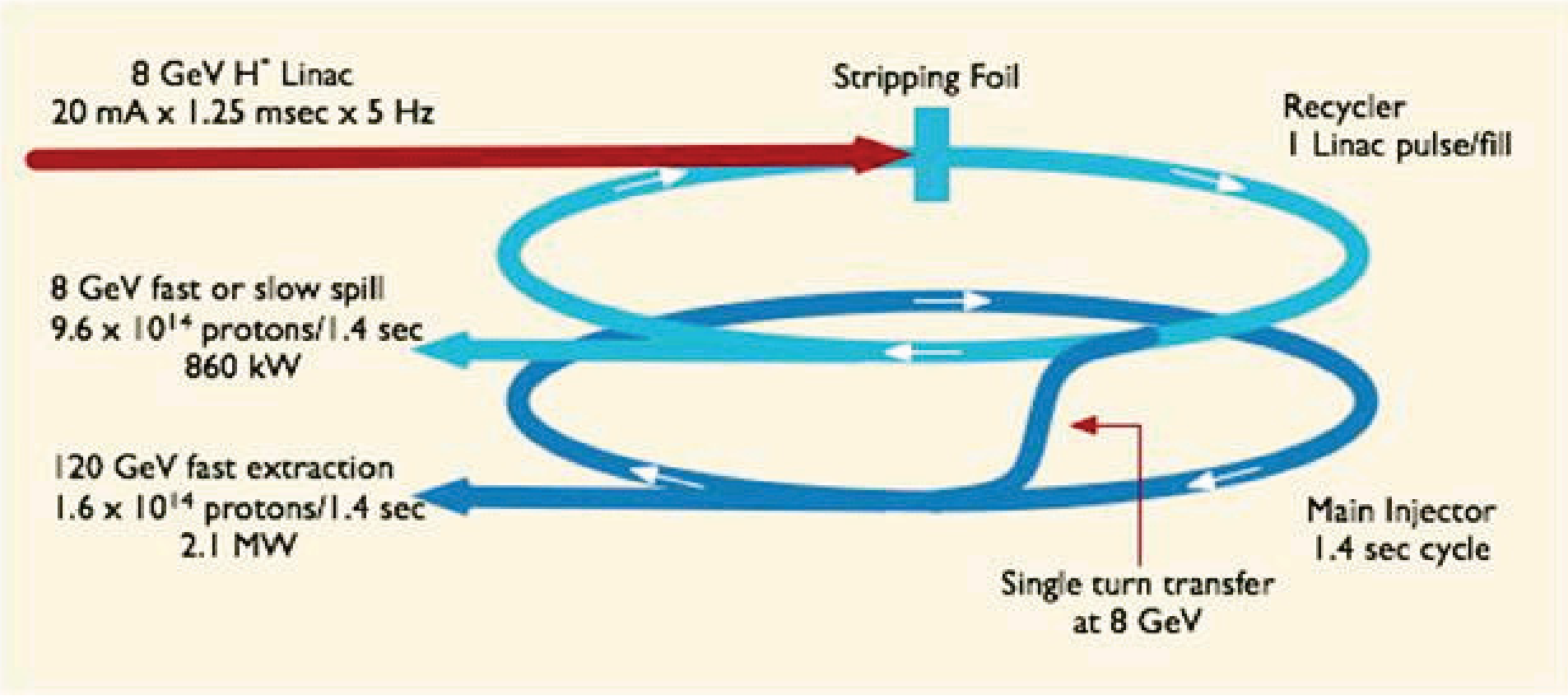
- v1.0 presented to MUTAC in Aug'08
- 1 hr briefing of D.Kovar and J.Blazey Nov'08
- Presented at the Dec'08 DoE review of Accelerator Science
  - Outlined by the "central team"
  - Elaborated coherently in presentations of 4 labs
    - FNAL, LBNL, BNL and ANL
- Formally submitted to DoE in Dec'08
  - Accompanied by the MCOG letter
- Current status: "interesting… wait" (CR, ARRA, budget, etc)

PROJECT X = FERMILAB'S FUTURE

from S.Holmes , Pr-X Dir.Review

- A multi-MW Proton Source (aka Project X) is the lynchpin of Fermilab's strategy for future development of the accelerator complex:
  - Energy Frontier:
    Tevatron → ILC or Muon Collider as options for the Fermilab site
    - Aligned with ILC technology development;
    - Preserves Fermilab as potential site for ILC or a Muon Collider
  - Intensity Frontier:
    NuMI→ NOνA→ LBν/μ2e→ multi-MW Proton Source → NuFact
    - Steady increase in power and baseline length up to 2 MW @ 1300 km;
    - Several x 100 kW to rare processes experiments;
    - Preserves Fermilab as potential site for a Neutrino Factory

PROJECT X and MUON COMPLEX



- Initial Configuration Document: 1 MW @ 8GeV
- MC/NF need: ~4MW@ different beam structure

Project-X Timeline

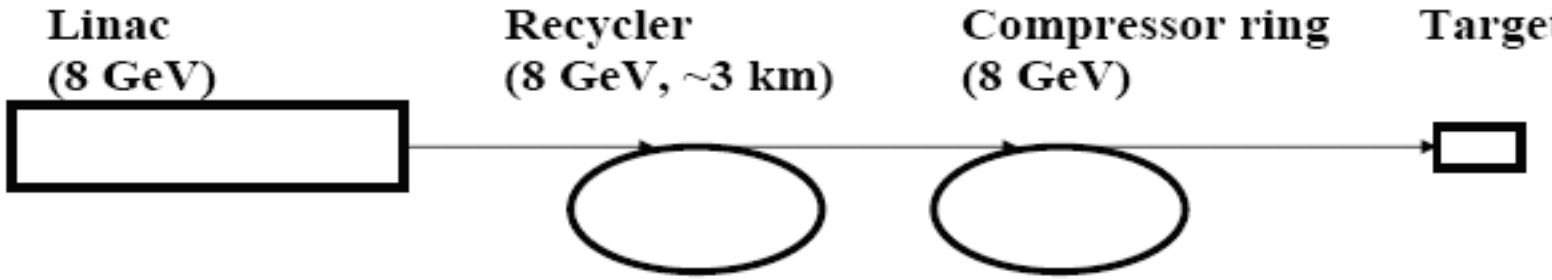
- Collaboration is being formed (08-09)
- FNAL Director's Preliminary Cost and Schedule Review (Mar'09)
- Technically limited schedule:
  - CD-0 July 2009
  - CD-1 December 2010
  - CD-2 July 2012
  - CD-3 August 2013
  - CD-4 March 2018

RD&D

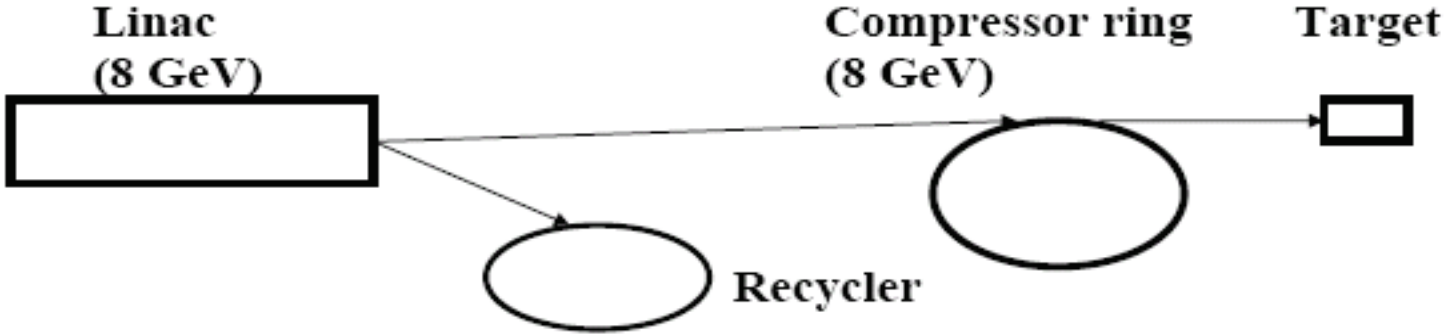
PED

POST-"PROJECT X" : CHOICES

- Present Project-X with injection to Recycler + Compressor ring

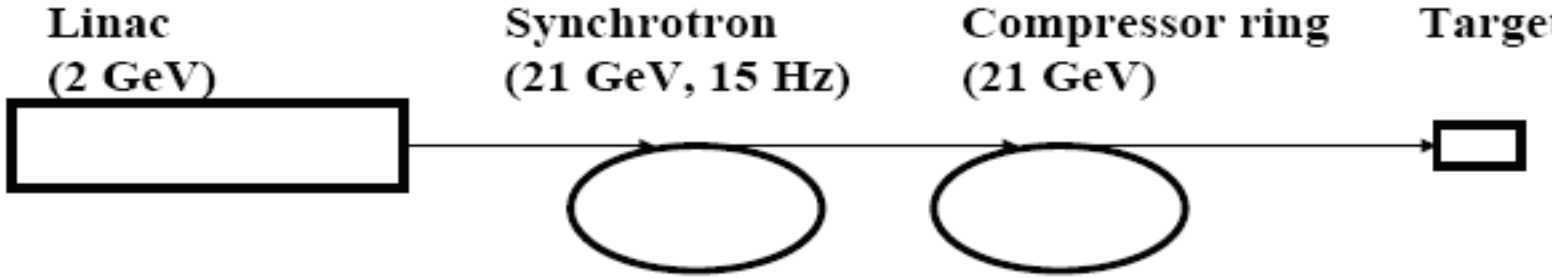


- Project-X linac + Compressor ring with direct H^- strip injection



V.Lebedev

- Alternative Project-X + compressor ring



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COMPRESSOR RING ISSUES

- Focusing on the target
- Longitudinal and transverse stability of high Intensity bunches
  - Space-charge
  - Impedance, e-p instability
- Preliminary conclusions:
  - specialized 8 GeV compressor ring feasible for 1 MW in a single bunch mode at 15 Hz
  - further beam power increase possible with either better collection scheme, or bunch merging or with larger energy, (e.g. 21 GeV) ring

V.Lebedev
M.Popovic
C.Ankenbrandt

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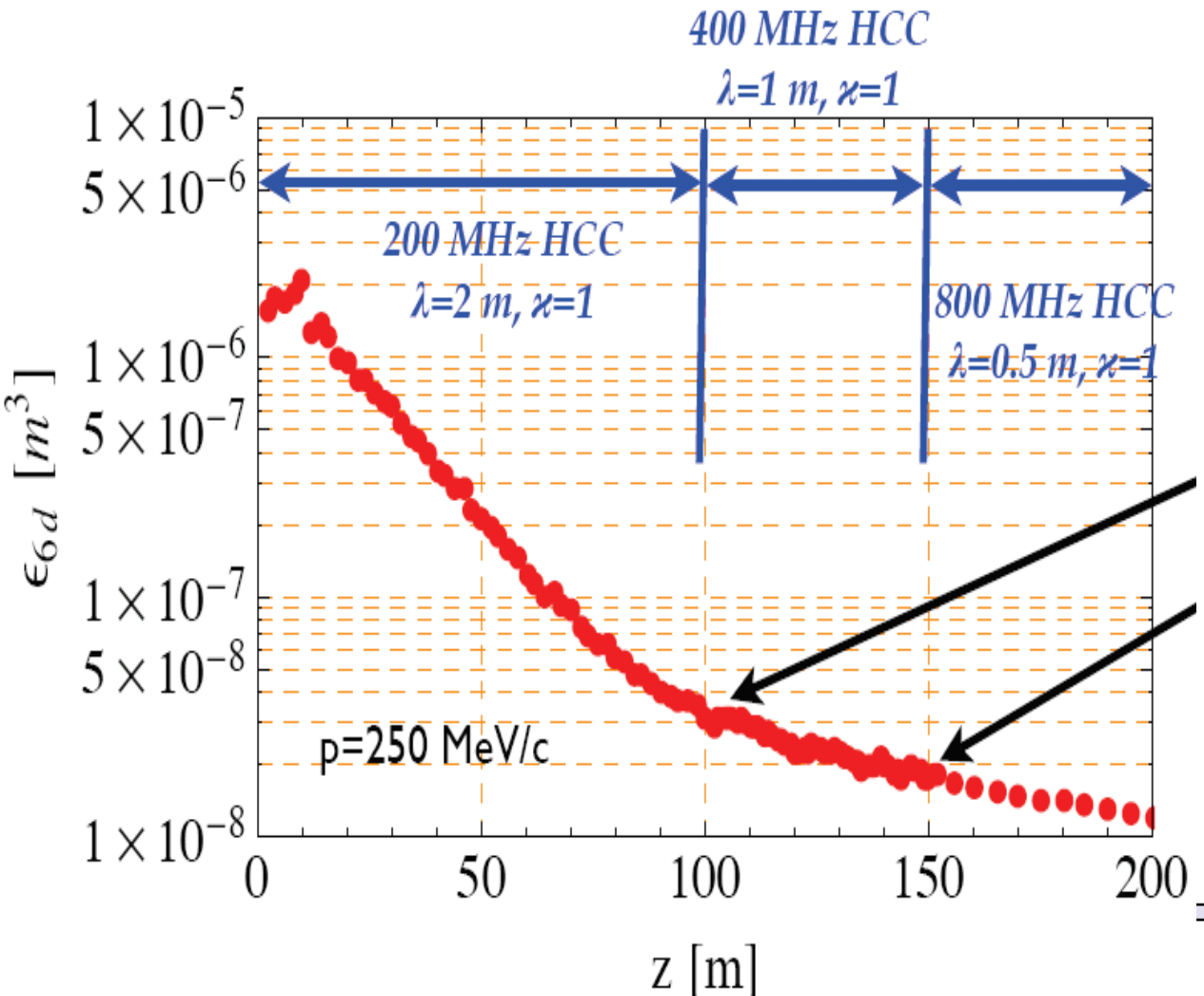
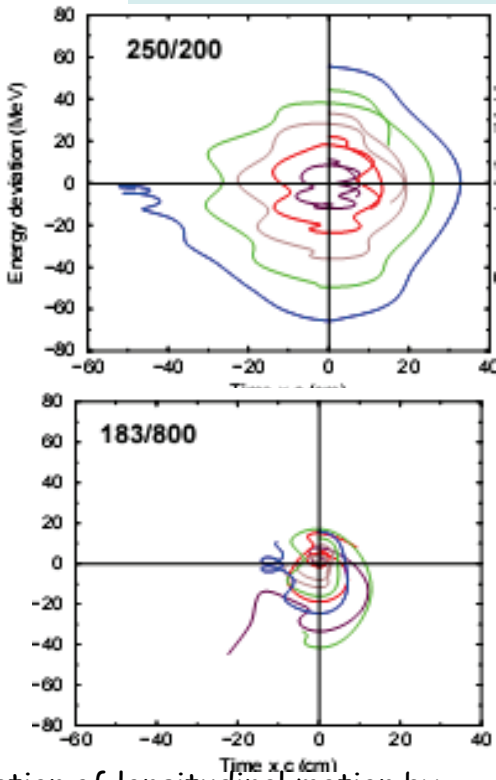
COOLING CHANNEL SIMULATIONS

- Thorough analysis of HCC (incl 60T)

K.Yonehara
V.Balbekov





Perturbation of longitudinal motion by betatron oscillations decreases the channel acceptance

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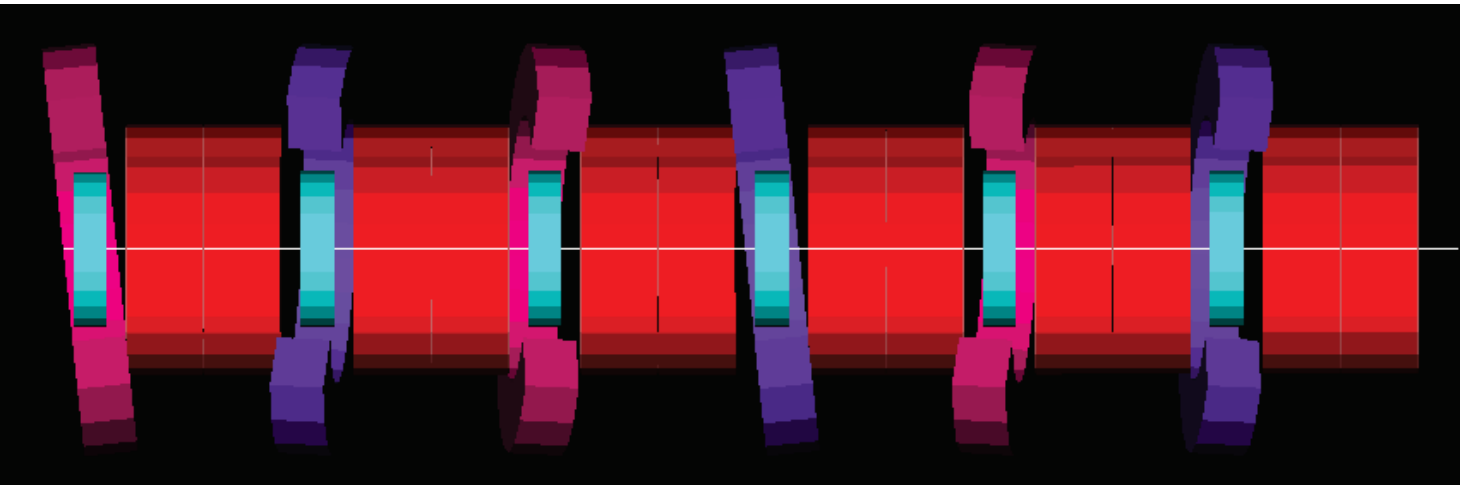
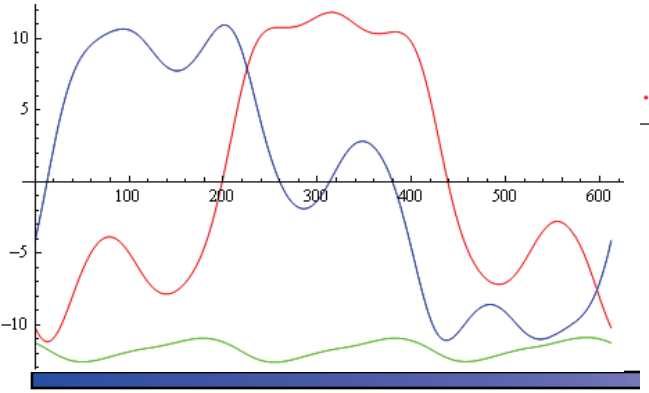
"FOFO-SNAKE" **6D** COOLING

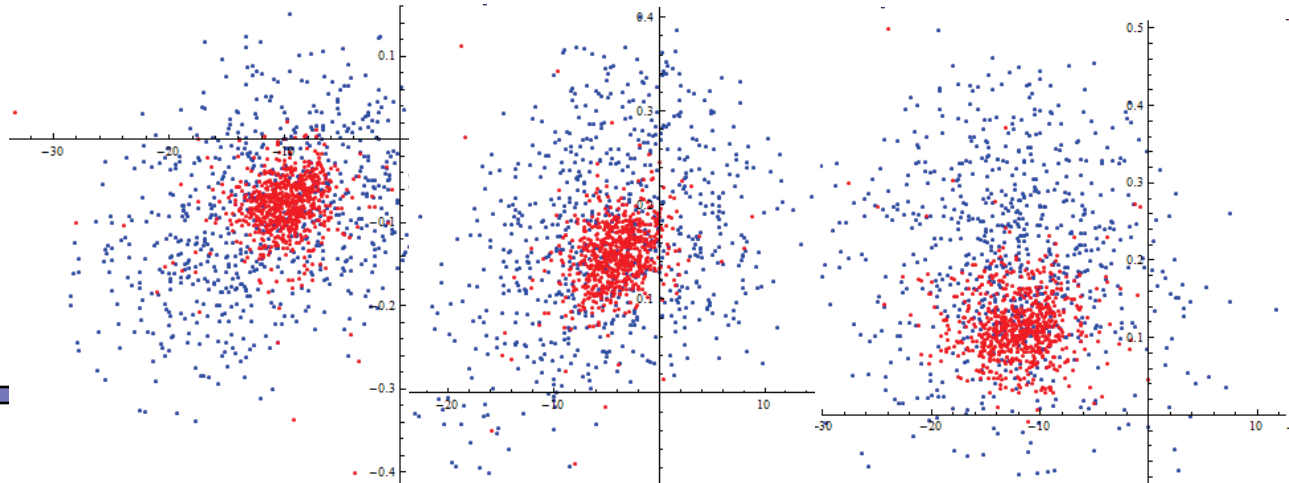
- Very promising and less technologically challenging scheme **cools both μ+ and μ-!**



Yu.Alexahin – see his talk



V.Shiltsev



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COLLIDER RING OPTICS PROGRESS

- v1.0 officially released

Yu.Alexahin,
E.Gianfelice-Wendt - talks

Muon Collider Task Force

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"Dipole first" option

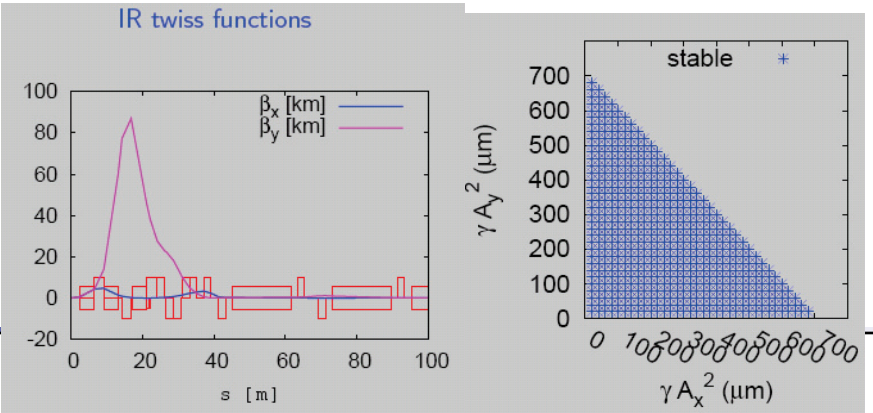
▲ Up one level

MAD8 lattice file by Yuri Alexahin – last modified 2009-03-12 18:35

a very preliminary version

Promising approach for β*=10 mm

Good DA for dP/P=±0.5%



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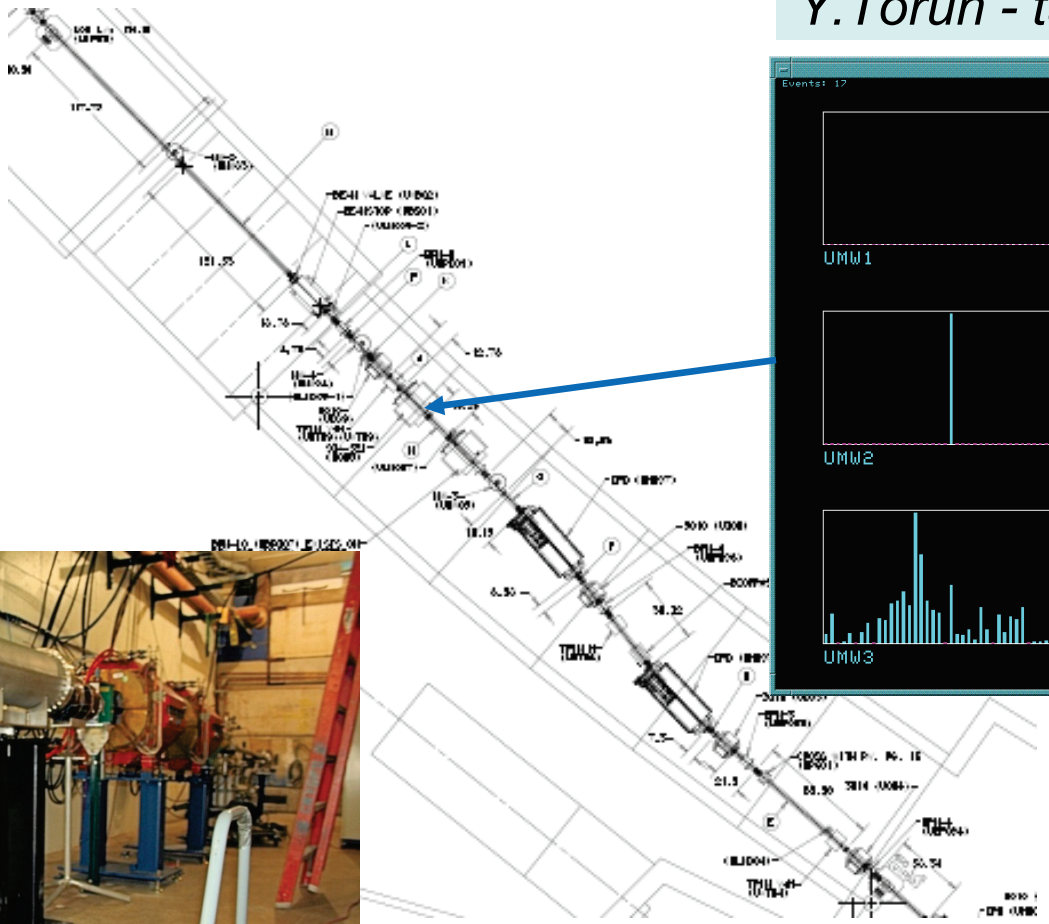
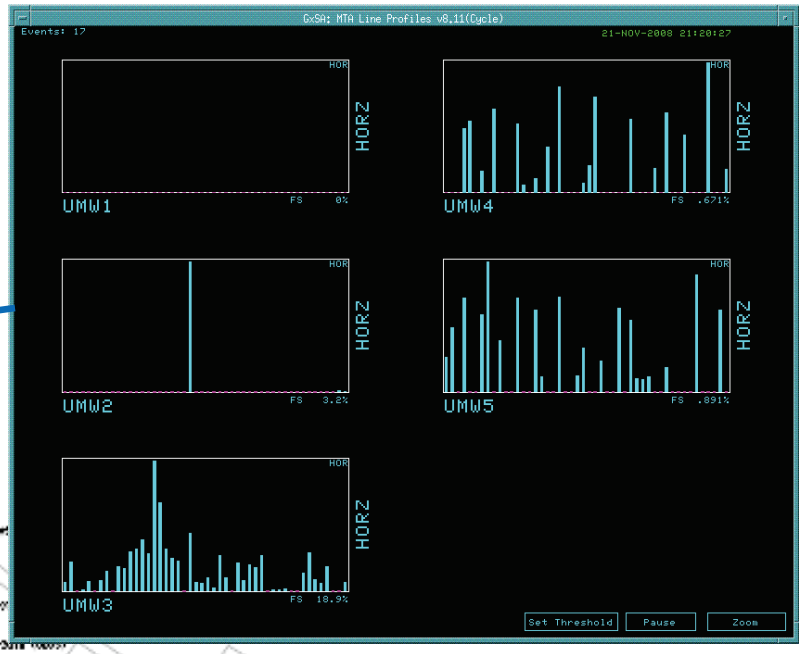
First beam in MTA line

Beam to first beam stop, visible on multiwire 3m upstream

AD/ExtBeams, MS & ESH Dept
many from MCTF
Y.Torun - talk





MuCool Test Area- Reconfiguration

AD, PPD, APC, Y.Torun - talk

- Reconfiguration Tasks (started, ongoing)
  - Installation of LN_2 and LHe transfer line system
  - Raising equipment to beam height
  - Re-routing RF power (201 MHz coax & 805 MHz waveguide)
  - Cryo plant commissioning
  - Cryo Instrumentation and Magnet Cryo Hook up
  - New Pit Shielding Wall

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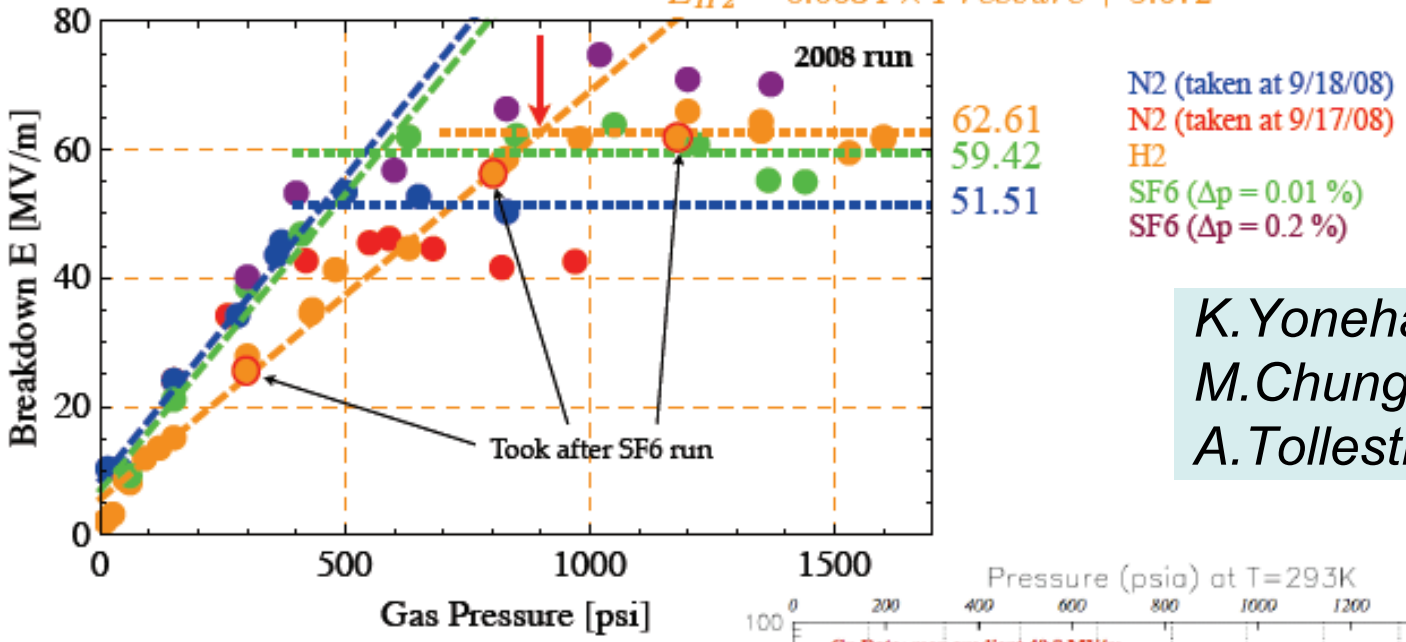
HPRF tests (w/o beam)

$E_{N2} = 0.0941 \times Pressure + 8.606$

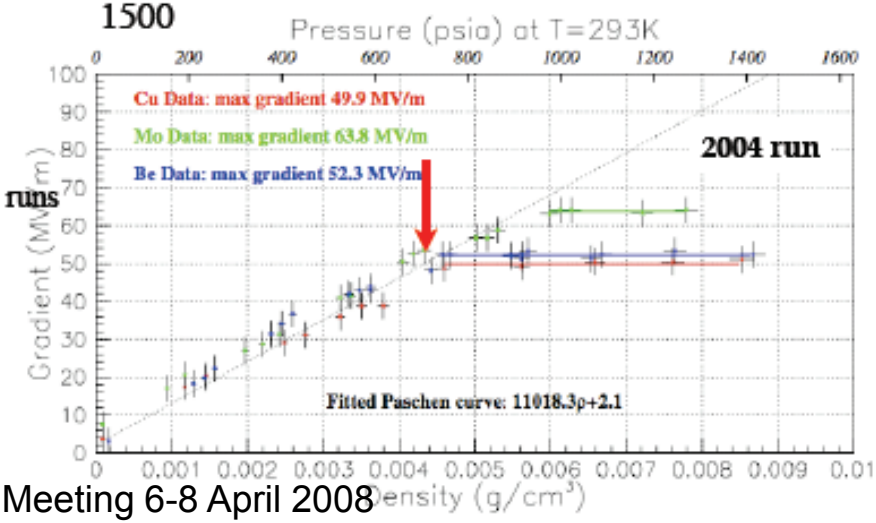
$E_{SF6} = 0.0919 \times Pressure + 7.060$

$E_{H2} = 0.0634 \times Pressure + 5.672$



K.Yonehara – talk
M.Chung, A.Jansson, A.Tollestrup

- Procedure: N2 run → H2 run → SF6 run
- Maximum field in 2008 run is ~20 % increased
- Good agreement of the Paschen slope between both ('08 & '04) runs
- Knee pressure (red arrow in upper plot) in 2008 run is 900 psi while that in past run (red arrow in lower plot) is 700 psi
- Increment of field in 2008 run can be real
- Plateau is different with different gas
- SF6 has big ambiguity



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Magnet R&D Progress

- Focus on the muon cooling channel magnets
  - Helical solenoids for 6D muon beam cooling
  - Very high field solenoids for the final muon cooling
- Magnet R&D
  - Conceptual design studies of Cooling Channel Magnet Systems
    - Helical solenoids for HCC “front” and “far” ends
    - 50 T solenoid
  - Magnet Technology Development
    - Short HS models
    - HTS solenoid inserts
  - R&D for SC Materials in support of magnet program (with National Labs and Industry)
    - Participation in National HTS Program

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4-Coil Model HSM01

Table 1: Solenoid Parameters

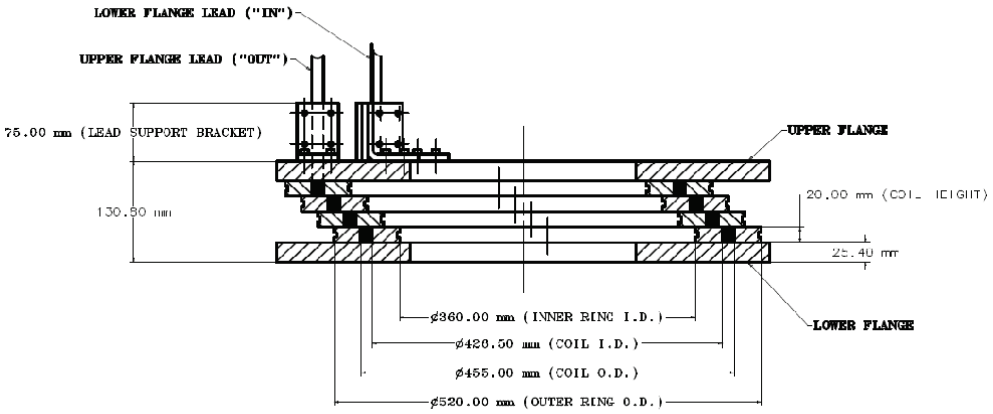
Parameter	Units	Value
Coil inner diameter	mm	426
Coil outer diameter	mm	455
NbTi superconducting cable	mm	12.34 x 1.46
Cable critical current at 7 T, 4.2 K	A	9660
Jc (non-Cu)	A/mm^2	1730
Copper to superconductor ratio		1.5:1
Strand diameter	mm	0.8
Helical orbit radius	mm	255
Number of turns per coil		10
Coil width	mm	20

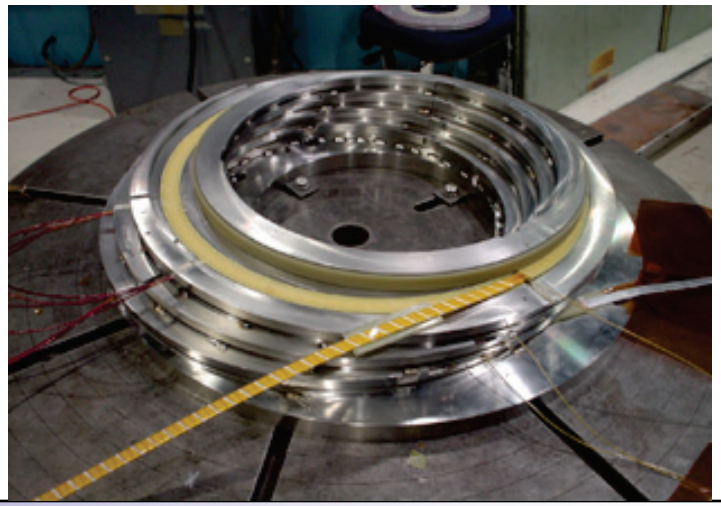
M.Lamm, A.Zlobin, et al
Muons Inc
V.Kashikhin – talk

Coil is wound from Rutherford-type superconducting cable (SSC) on a stainless steel bobbin

The short model consists of four superconducting coils with support structures and end flanges

Achieved 85% of short-sample limit!





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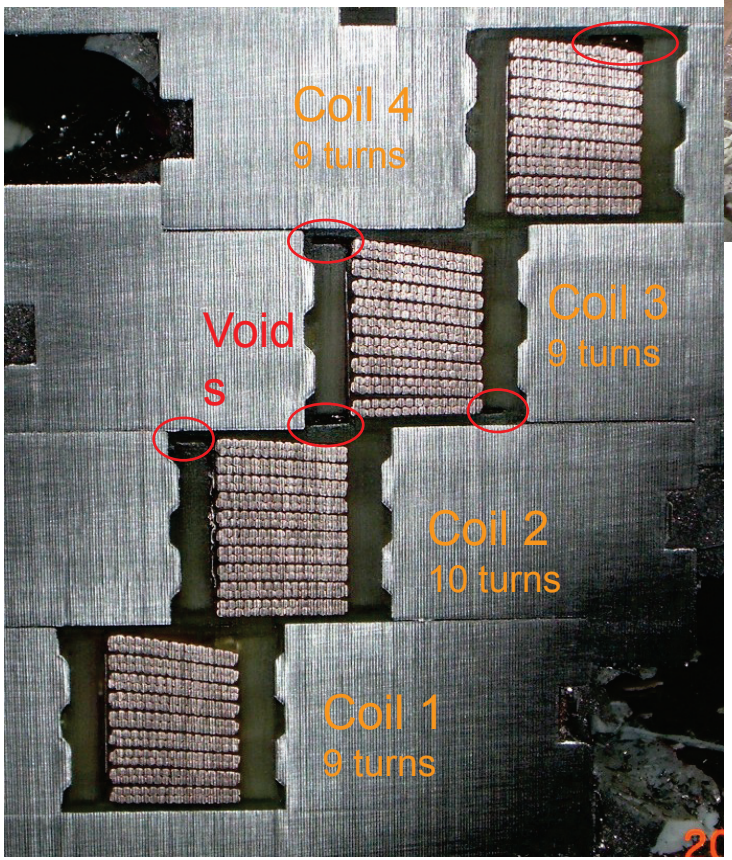
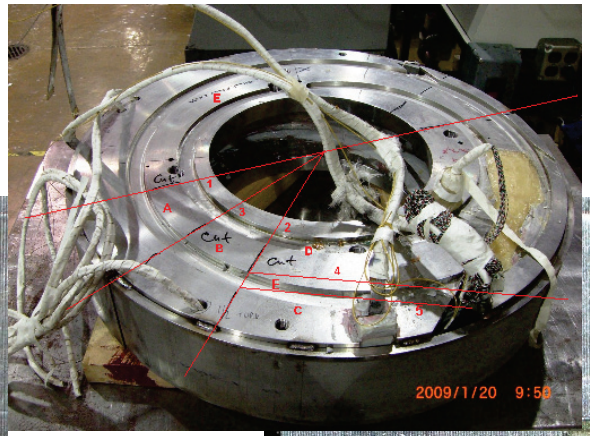
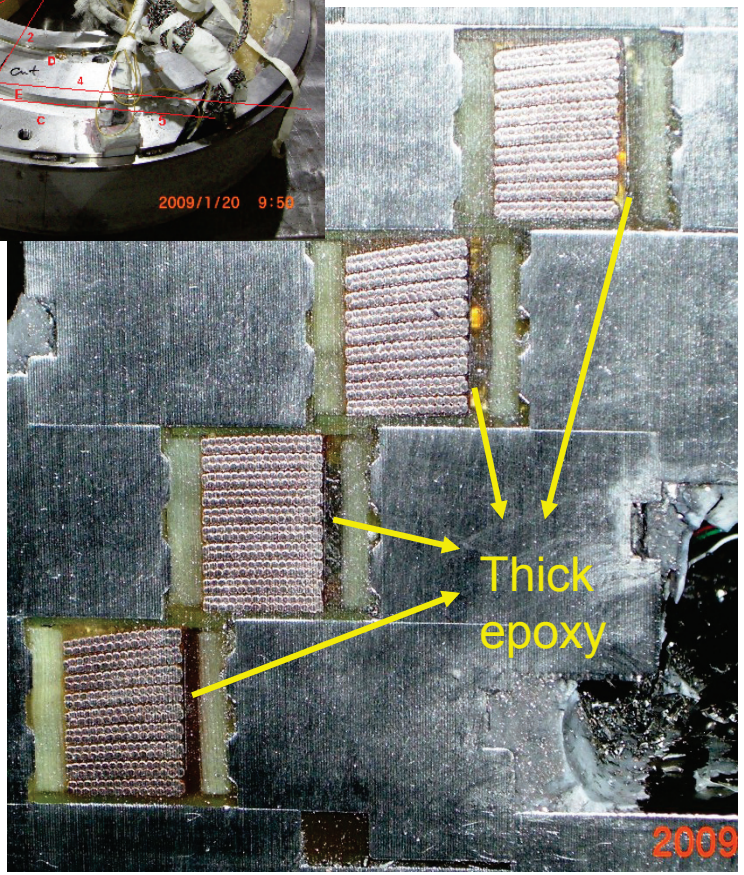
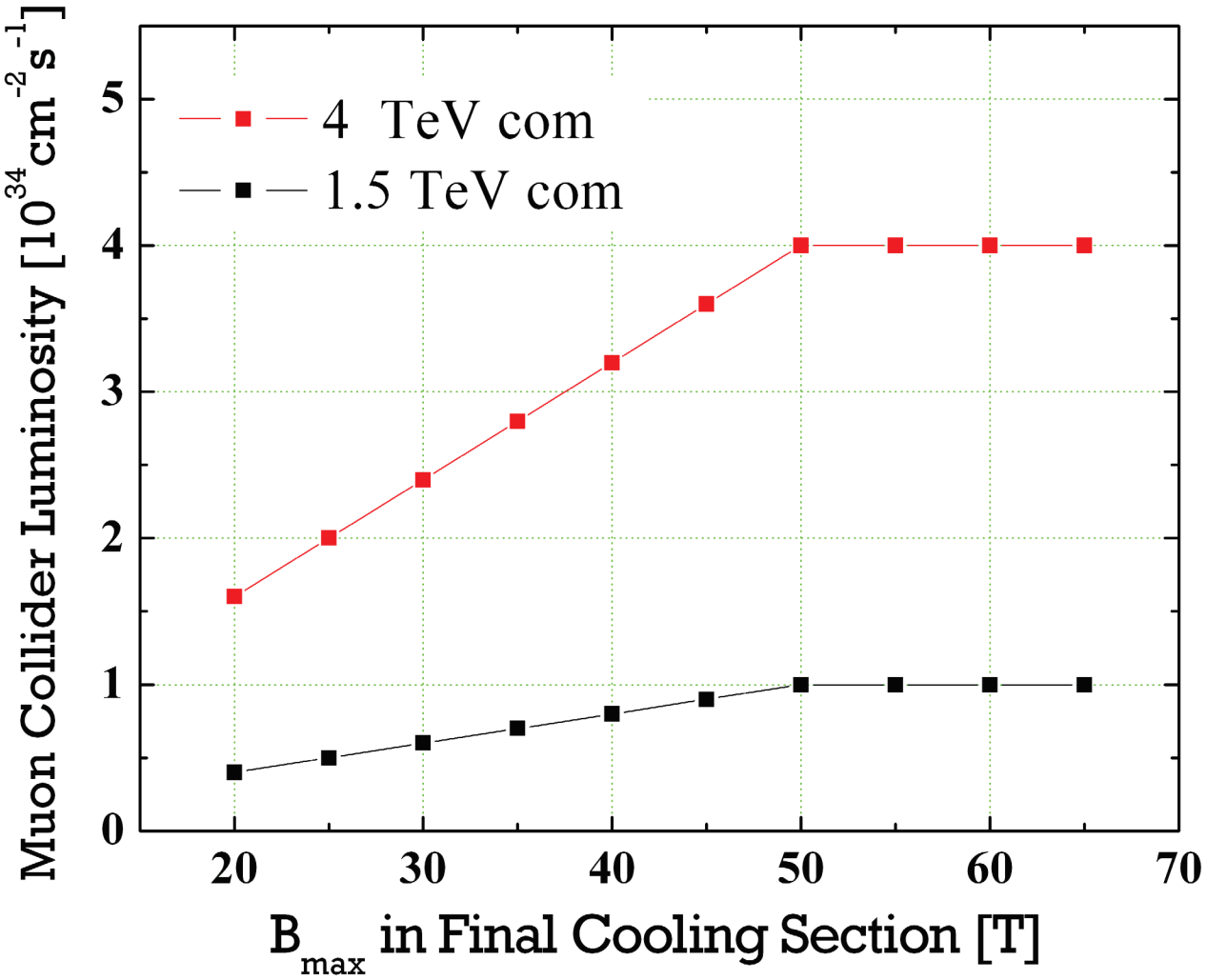
HSM01 Autopsy



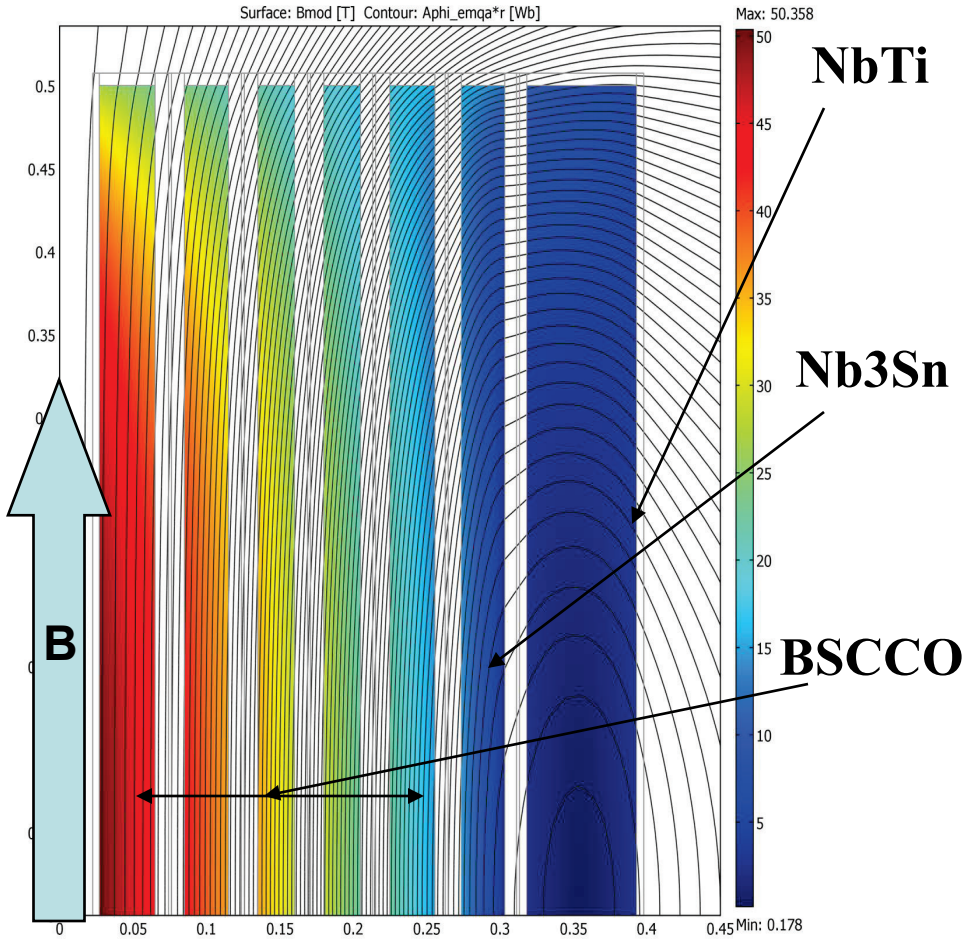




50 T Solenoids for Final Cooling Stage



50 T Solenoid Conceptual Design



Basic Parameters
- Inner bore diameter 50 mm
- Length 1 meter
- Fields 30 T or higher ➔
  - HTS materials

Key design issues:
- superconductor Jc
- effect of field direction on Ic in case of HTS tapes
- stress management
- quench protection
- cost

Conceptual design:
- hybrid coil design
- coil sections

Work in progress:
- Conductor
- Quench protection

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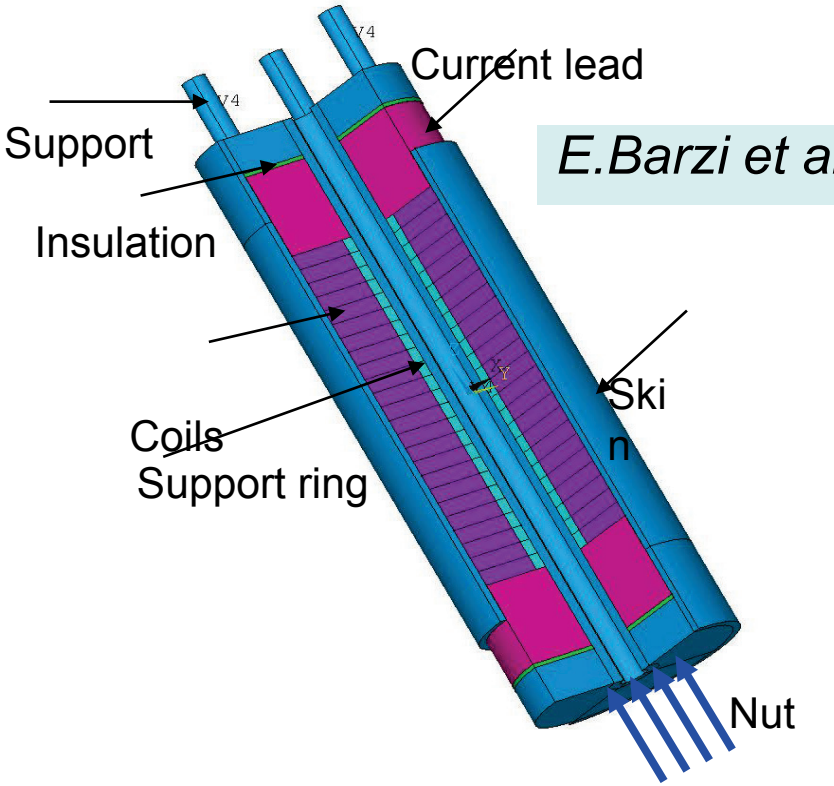
HTS Magnet R&D

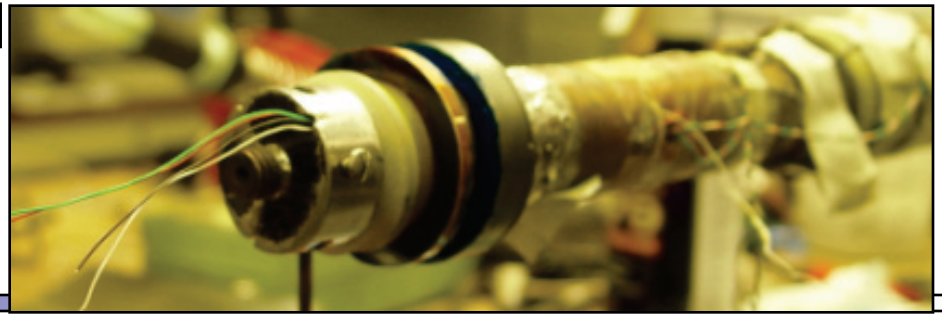
- Single and double layer HTS coils designed and tested:

  98%-22% of SSL!

- Modular HTS test facility designed and being procured
  - Test many coils inside 16T solenoid
- BSCO-2212 cable and wire work will be done within National Collaboration



E.Barzi et al



Very High Field SC Magnet Collaboration

Fermilab

THE APPLIED SUPERCONDUCTIVITY CENTER · NHMFL · FSU · HIGH MAGNETIC FIELD LABORATORY · FSU · UF · LANL · FLORIDA STATE UNIVERSITY · 1851

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BERKELEY LAB

AFRD ACCELERATOR & FUSION RESEARCH DIVISION

BROOKHAVEN NATIONAL LABORATORY

NIST

TEXAS A&M UNIVERSITY

A. Tollestrup - talk

- The immediate goals (~2 years):
  - **The immediate goal (2 years) is to understand if Bi 2212 is a suitable vehicle for this task.**
  - **develop the technology to build magnets with B>30 T**

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MCTF M&S Budget

Troublesome Tendency

- FY07 actual muon M&S was **1034k$** direct
- FY08 actual muon M&S was **672k$** direct
- FY09 guidance 08/08/08 is **470k$** direct
- FY09 CR holdback 10/14/08 **170k$** direct
- 09CR's over + 220k$ carryover 690k$ direct
- FY10 budget ??

To revert the tendency = 5yr Plan + Interim Support

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MCTF FY09 M&S

(k$, direct)

Activity	FY09 in 5 Year Plan	FY08 APC Carryover	FY09 Budget *	YTD OBL as of March 31
MTA Absorber	220	220 →	0 *	167
MTA Operations	150		150	176
HP RF test	170		120	5
MICE	90		90	36
Vacuum RF	80		70	
HTS	200		40	0
6D HCC Section	150		0	0
Mgmnt/Other	160		0	29
TOTAL	**1210**	**220**	**470**	**414**

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Immediate Needs (M&S, k$)

- **VITAL** **380k$**
  - MTA infrastructure 150k$
  - TD magnets 150k$
  - MICE 50k$
  - HPRF tests 30k$
- **High Priority** **450k$**
  - 2nd 805 MHz cavity 30k$
  - 805 circulator 50k$
  - TD magnets 200k$
  - MTA RF 70k$
  - HPRF sim/studies 50k$

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Next Steps (1)

1. Promote the 5 year plan :
   - Hope for MUTAC's help
   - Work with DOE OHEP (eg brief on detector and HEP)
   - Get reviewed and (hopefully) approved
2. In meantime, progress as much as we can in:
   - Understand physics potential and luminosity requirements of Z' or Higgs factories
   - Increase detector R&D effort and IR/detector background simulations
     - In PPD/Detector R&D Department (M.Demarteau)
     - Boost ED/IR optics/Detector work (full time visitor)
   - 6D cooling modeling – fair comparison of 3 methods
     - DA, survival rate, cooling rate, final emittances

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Next Steps (2)

3. Improve interface with Project-X:
   - Set a coordination group (PX/MC/NF) to specify upgrade
   - Move toward specific bunch compressor design
   - Stay in touch with “Super-upgrade for ADS” think tank
4. Get beam in MTA hall and do 1st experiment (HPRF):
   - Est. safety control & do more beam tests before 1st stop
   - Properly address all safety issues in the hall and around
     - Complete and submit SAD to DOE, get approval (3 mos?)
   - (need the approval) get the beam to the 2nd beam stop
     - Will do beam emittance measurements before 06/15 shutdown
     - Send into the HPRF can
   - all that carefully interlaced with reconfiguration, RF tests, and HPRF test

Next Steps (3)

5. Magnets:

- HTS-collaboration gets ARRA, good sign – must capitalize
- Build dedicated HTS test facility (already proposed)
- Conductor studies, design, tests (25-30T as 1st step)
- HS test model #2

6. Collaborators:

- we should get in & learn from HGRF collaboration
- Can we benefit from NML Users facility ? (May '09 Wrksh)
  - Possibilities of R&D (A.Jansson)
- SBIRs companies (Muons Inc, X-Tech, FarTech, etc)
  - Communicate better our priorities
- ICL(A.Kurup,L.Jenner), IIT(Y.Torun), BINP (A.Netepenko)

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Summary

- MCTF progressed on carrying out impressive R&D program
  - (Together with NFMCC) 5 year R&D plan submitted to DoE
  - First look into Project-X upgrade specs and compressor ring
  - optimized cooling channels : HCC and FOFO snake
  - Collider Ring optics v1.0 release
  - Beam sent along the MTA beamline
  - New HPRF test results with different gases, optical diagnostics
  - 4-coils test, HTS coils tested
- Next steps:
  - Focus on having 5-yr plan reviewed and approved
  - execute plans of technical developments
    - Simulations, modeling and design (including IR and detector)
    - Get beam in MTA , do HPRF test with beam
    - Develop magnets for MC/NF – HCC coils and HTS (cable, design, some tests)
    - (more details in following talk)