



# *Neutrino Factory and Muon Collider Collaboration Meeting*

NFMCC/MCTF Status and Update

January, 2009

University of Mississippi

Alan Bross



# Welcome

## Collaboration Meeting XIV *Maybe the Last for "This" Collaboration*

- It has been a tough year
- Hopes for this past year as stated last year:
  - u First beam experiment in the MTA
    - s Not Yet. The MTA reconfiguration is complete, but no beam yet
  - u MICE makes first cooling measurement
    - s Not Yet. MICE has taken a lot of beam data, but spectrometers not quite there
  - u Neutrino Factory International Design Study
    - s Is moving along, progress made
  - u Muon Collider Design Effort
    - s Moving along - Good Progress
  - u Action on 5 Year Plan?
    - s Not quite yet

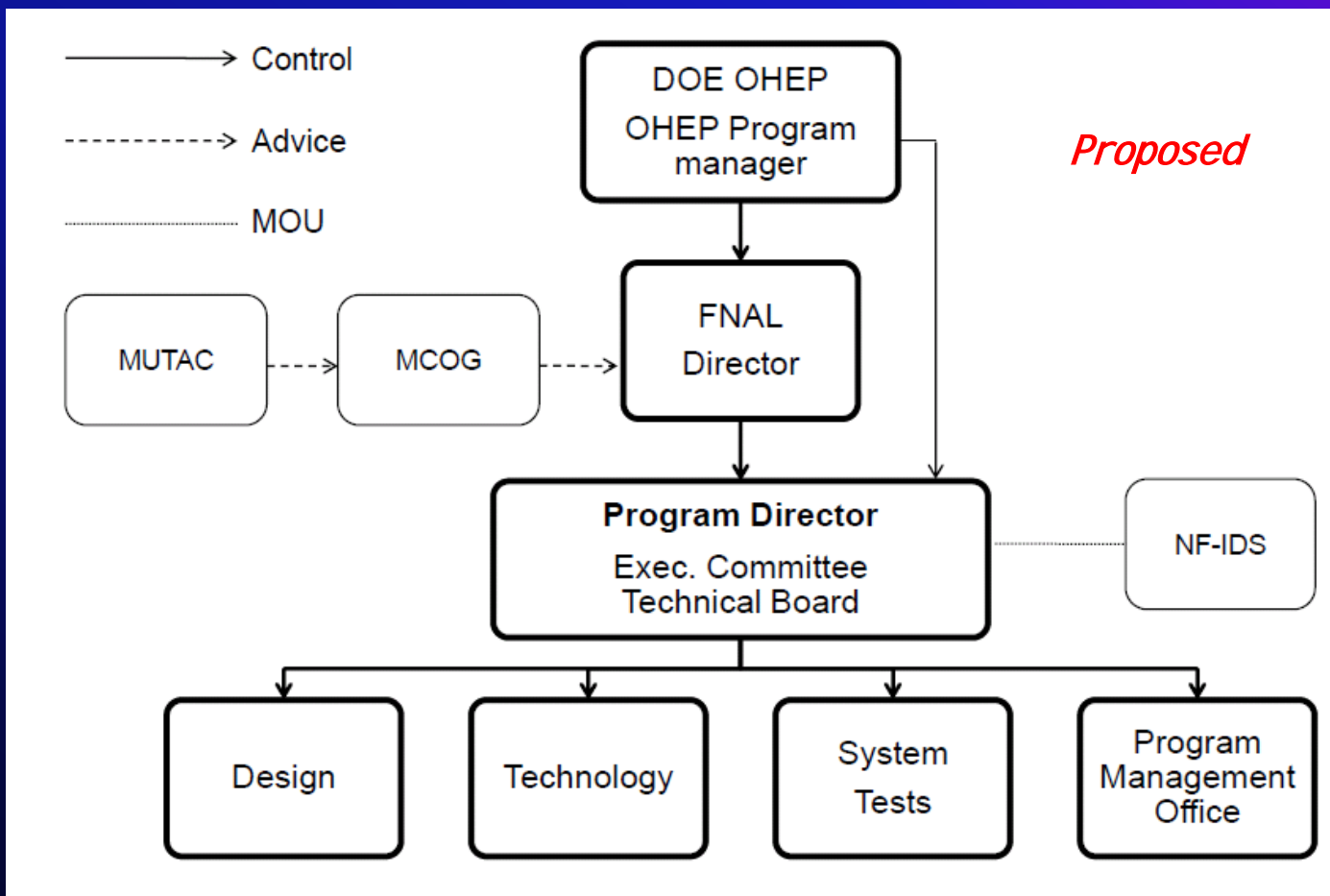


# What About That 5(ish) Year Plan?

- The Office of High Energy Physics believes that it is timely to mount a concerted national R&D program that addresses the technical challenges and feasibility issues relevant to the capabilities needed for future Neutrino Factory and multi-TeV Muon Collider facilities



# But, the DOE giveth and taketh *Muon Acceleration Program Org Chart*





But Remember Why We are Here



# Neutrino Factory

*Only Facility that has access to All Oscillation Channels*

$\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$	$\mu^- \rightarrow e^- \bar{\nu}_e \nu_\mu$	
$\bar{\nu}_\mu \rightarrow \bar{\nu}_\mu$	$\nu_\mu \rightarrow \nu_\mu$	disappearance
$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	$\nu_\mu \rightarrow \nu_e$	appearance (challenging)
$\bar{\nu}_\mu \rightarrow \bar{\nu}_\tau$	$\nu_\mu \rightarrow \nu_\tau$	appearance (atm. oscillation)
$\nu_e \rightarrow \nu_e$	$\bar{\nu}_e \rightarrow \bar{\nu}_e$	disappearance
$\nu_e \rightarrow \nu_\mu$	$\bar{\nu}_e \rightarrow \bar{\nu}_\mu$	appearance: "golden" channel
$\nu_e \rightarrow \nu_\tau$	$\bar{\nu}_e \rightarrow \bar{\nu}_\tau$	appearance: "silver" channel

## Ø 'Reference' Neutrino Factory:

- Ø  $3 \times 10^{21}$  useful decays/yr; exposure '5 plus 5' years

## Ø Two baselines ( $\gg 7500$ km & $\gg 4000$ km)

- Ø 50 kT magnetised iron detector (MIND) with MINOS performance - Golden Channel Detector
- Ø Backgrounds (for golden channel):
  - Ø Sign of mmis-ID'd
  - Ø Charm decays
- Ø  $E_{res} \sim 0.15 * E_\nu$

"Golden" ® Sign of mobserved in detector opposite to that stored in decay ring  
 $m \bar{t} \otimes n_e \bar{p} \quad n_m \otimes mp$



# And Still - No Facility can Do Better

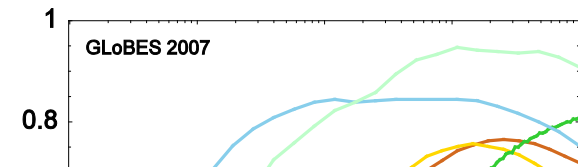
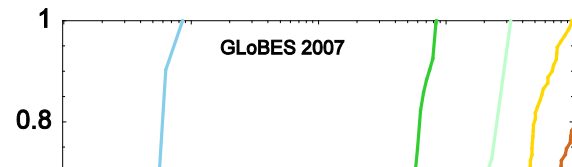
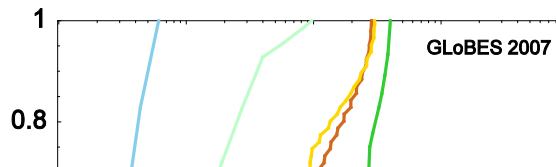
3s contours shown

I SS Physics Group Report: Rept.Prog.Phys. 72:106201,2009

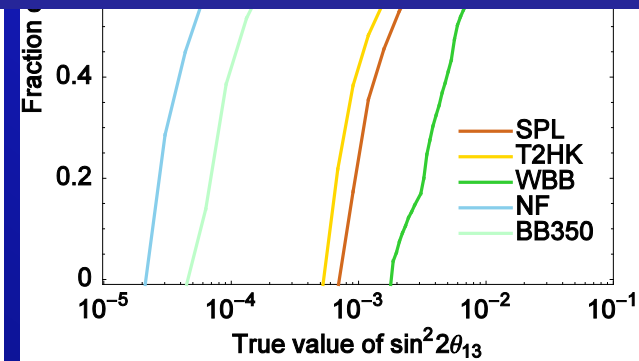
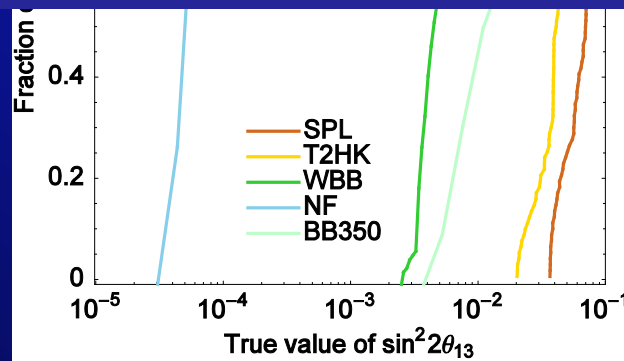
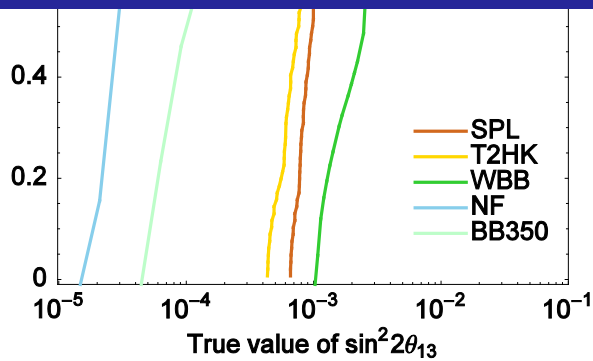
$\sin^2 2\theta_{13}$

Hierarchy

$\delta CP$



But Our Detractors Claim that Conventional Experiments are Good Enough



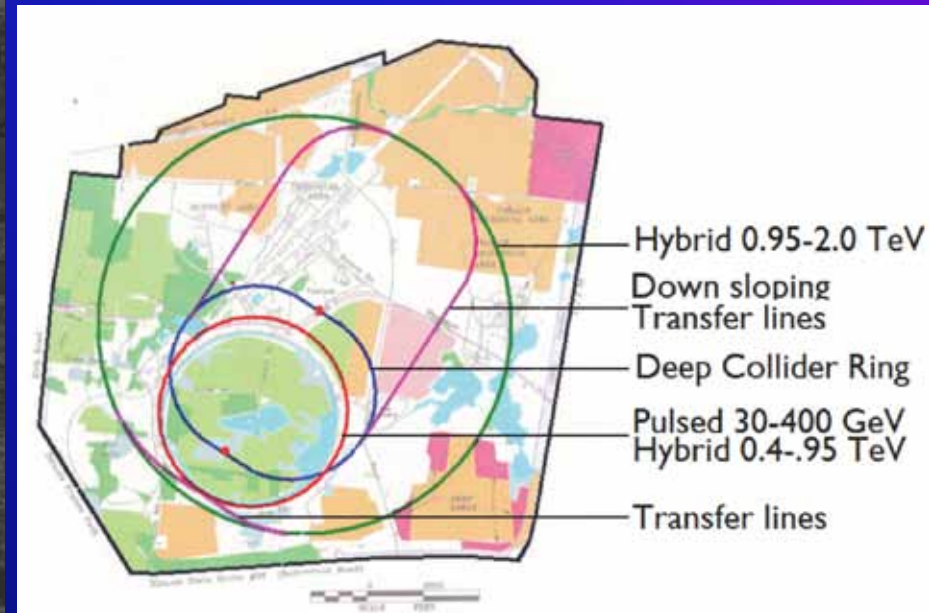
SPL: 4MW, 1MT H<sub>2</sub>O, 130 km BL  
 T2HK: 4 MW, 1MT H<sub>2</sub>O, 295 km BL  
 WBB: 2MW, 1MT H<sub>2</sub>O, 1300 km BL

NF: 4MW, 100KT MI ND, 4000 & 7500 BL  
 BB350:  $\theta=350$ , 1MT H<sub>2</sub>O, 730 km BL

# The Energy Frontier via $m\bar{m}$ Collisions



3 TeV Machine based on Recirculating Linear Accelerators & ILC SC RF



4 TeV Machine based on Rapid Cycling Synchrotron





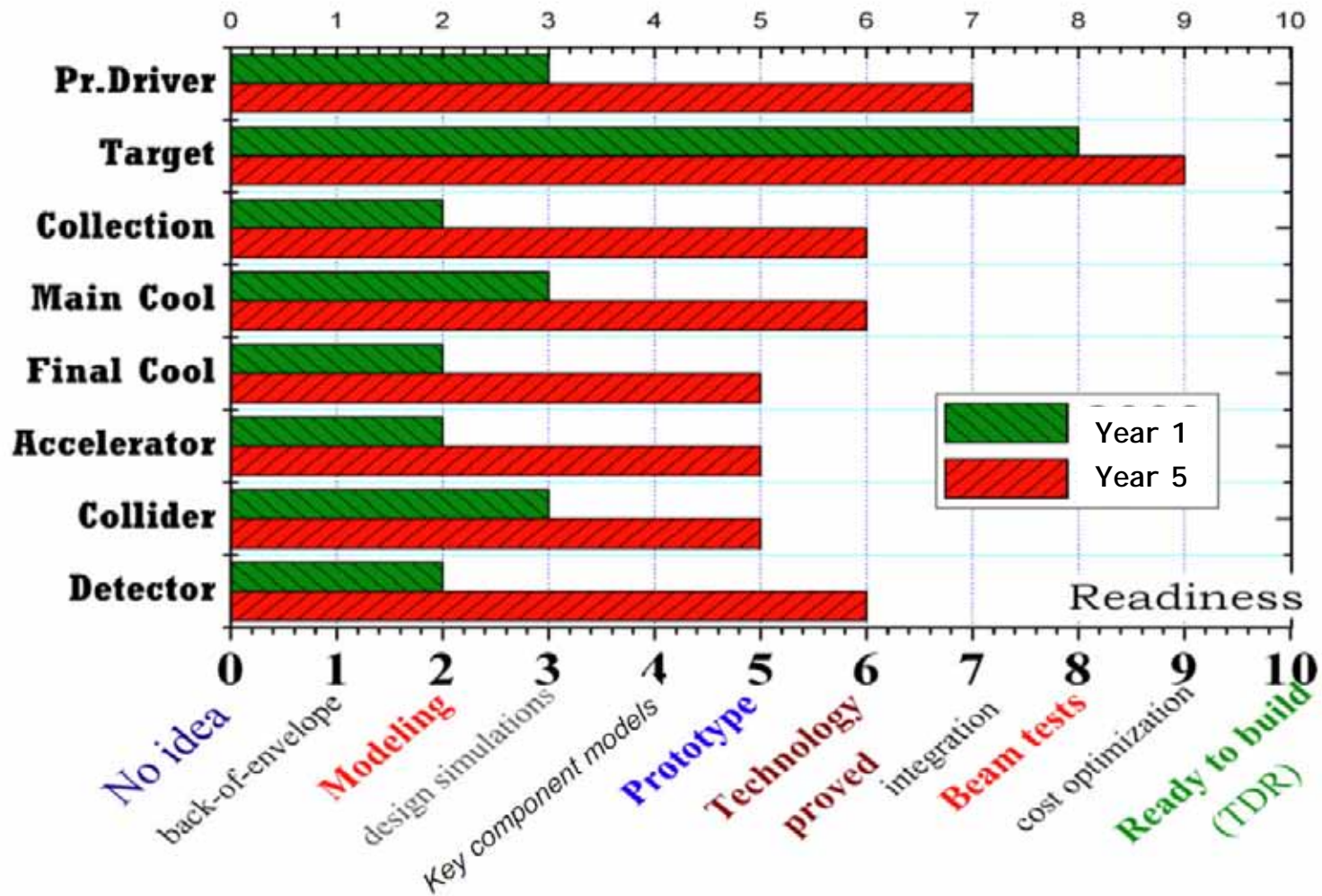
# Complexity of Colliders

	<b>LHC</b>	<b>MC</b>	<b>CLIC</b>
<b>state of the art magnets</b>	⊖	⊖	-
<b>state of the art R</b>	-	⊖	⊖
<b>S</b>	But not All Parts are the Same & Our Detractors Claim that the Muon Collider is Still 50 Years Away		
<b>beam dynamics</b>			
<b>Total # of elements</b>	<b>~4000</b>	<b>~4000</b>	<b>~200,000</b>
<b>Luminosity</b>	<b>&gt;1e34</b>	<b>&gt;1e34</b>	<b>&gt;1e34</b>



# Muon Collider Technical Foundation after 5 Years

## From Here to There





## Current Guidance From DOE

- The Office of HEP at the DOE supports the concept of the 5-7 year plan
- Requests Fermilab to form a National Muon Program
  - With Strong Desire to bring in International Participation
  - & With Strong University Participation
- However, sees an increase of scope over the current program at a X2 (at least initially). Increase could start as early as FY11.



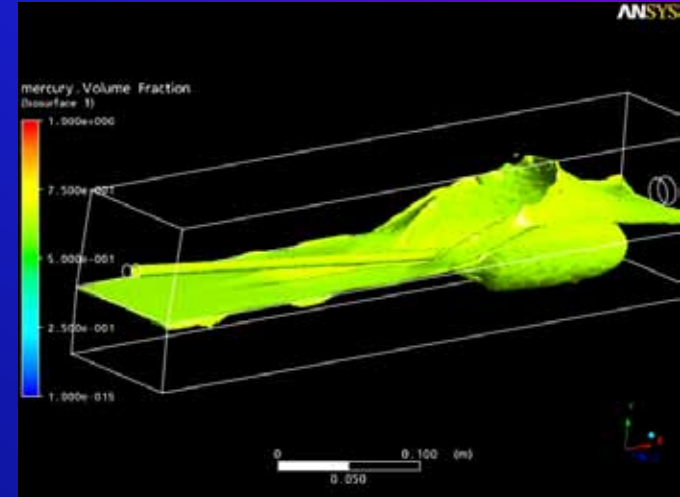
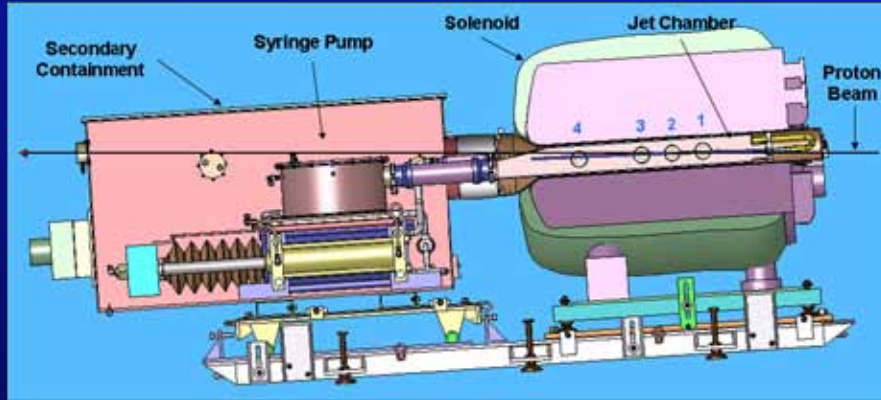
# The Evolving 5+ Year Plan

- **A joint US: NFMCC-MCTF Plan**
  - u A measured program based on the solid muon accelerator R&D achievements of the last decade
  - u Sufficiently ambitious to make substantial progress before the next round of long-term decisions by the particle physics community
  - u Includes accelerator, physics & detector studies (only accelerator part in this talk – we also have plans & estimates for physics & detector studies)
- **Meets our existing commitments (IDS-NF RDR, MICE) and in addition will deliver:**
  - u MC performance requirements based on physics
  - u A first end-to-end MC simulation
  - u Critical component development & proof-of-principle experiments
  - u A first MC cost estimate

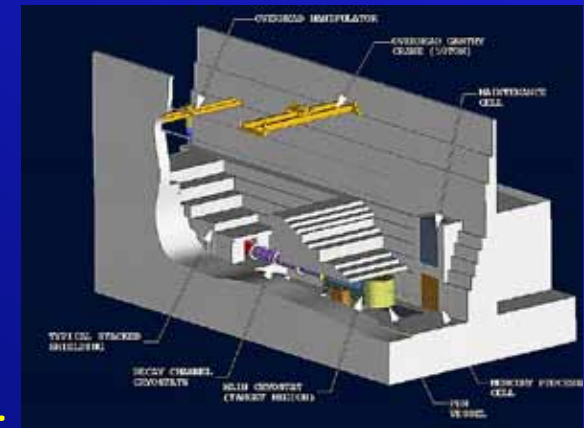


# Highlights Reel

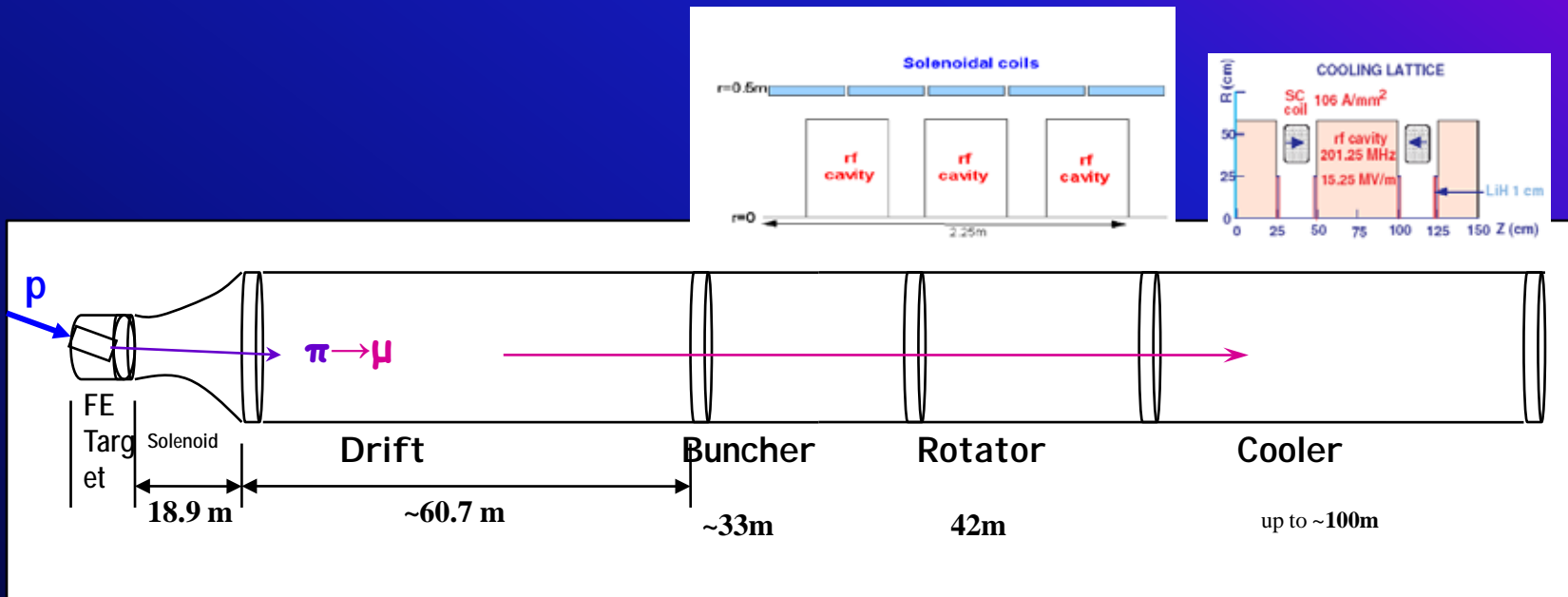
# Targety



- **MERIT is complete**
  - But much to do on the Target Station Design
- **Splash mitigation in the mercury beam dump.**
  - Possible drain of mercury out upstream end of magnets.
- **Downstream beam window.**
- **Water-cooled tungsten-carbide shield of superconducting magnets.**
- **HTS fabrication of the superconducting magnets.**
- **Improved nozzle for delivery of Hg jet**



# Front End Optimization



- Continuing front end IDS design study
- ~Biweekly phone Conference
- Meeting at RAL
  - December 14-18
- April at Fermilab (IDS meeting)



# RF Test Program

- Study the limits on Accelerating Gradient in NCRF cavities in magnetic field
- Fundamental Importance to both NF and MC
  - u Muon capture, bunching, phase rotation
  - u Muon Cooling
  - u Acceleration
- The MTA Reconfiguration is Complete – Ready for Beam (well maybe)
- You will hear about our 3-Pronged Attack
  - u MTA status, Reduce (eliminate) field emission in Vacuum RF, HP gas-filled cavities, Magnetic Insulation for vacuum RF, breakdown theory

*The single most critical  
Technical challenge for the NF & MC*



# MTA Reconfiguration complete



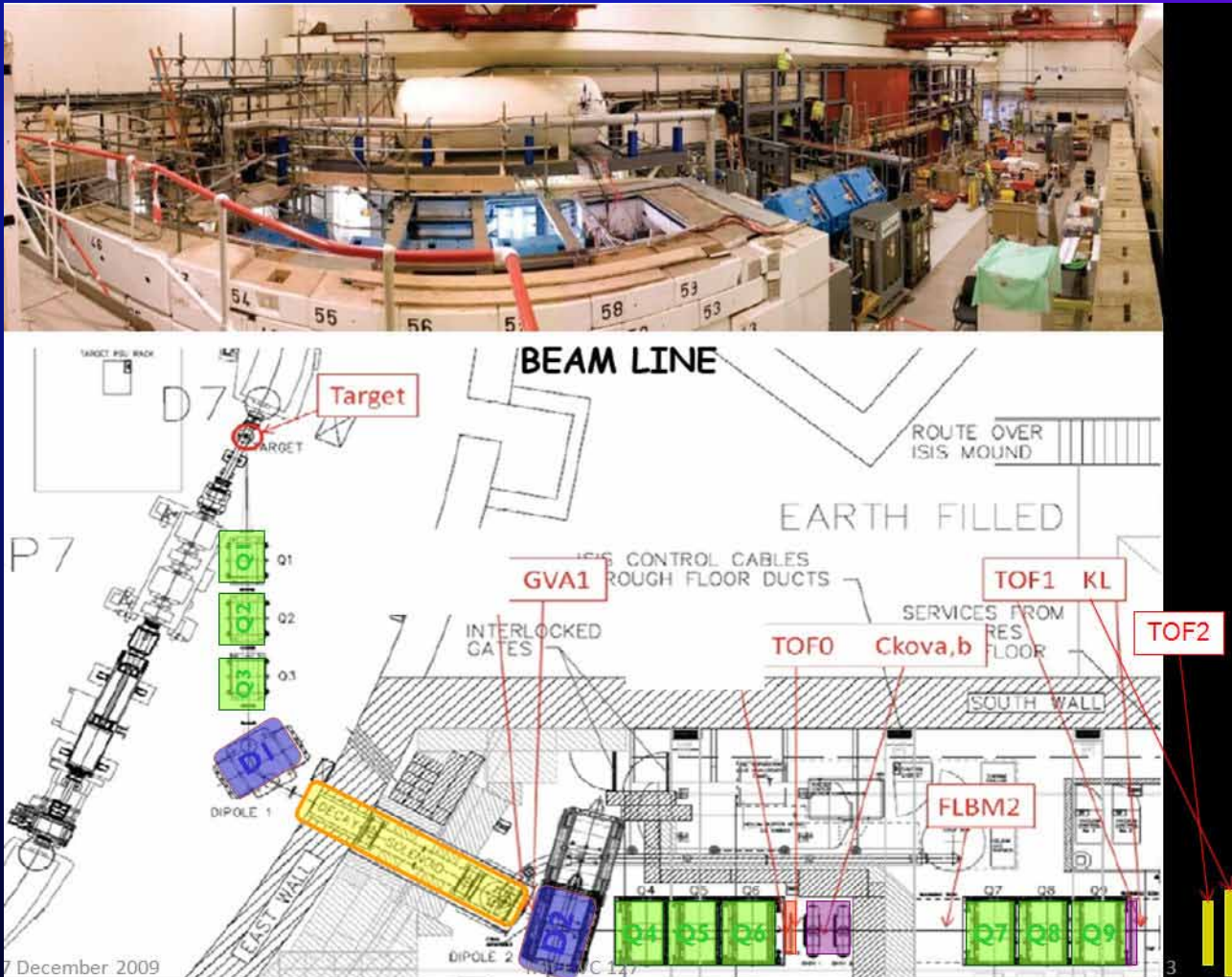
# MTA II



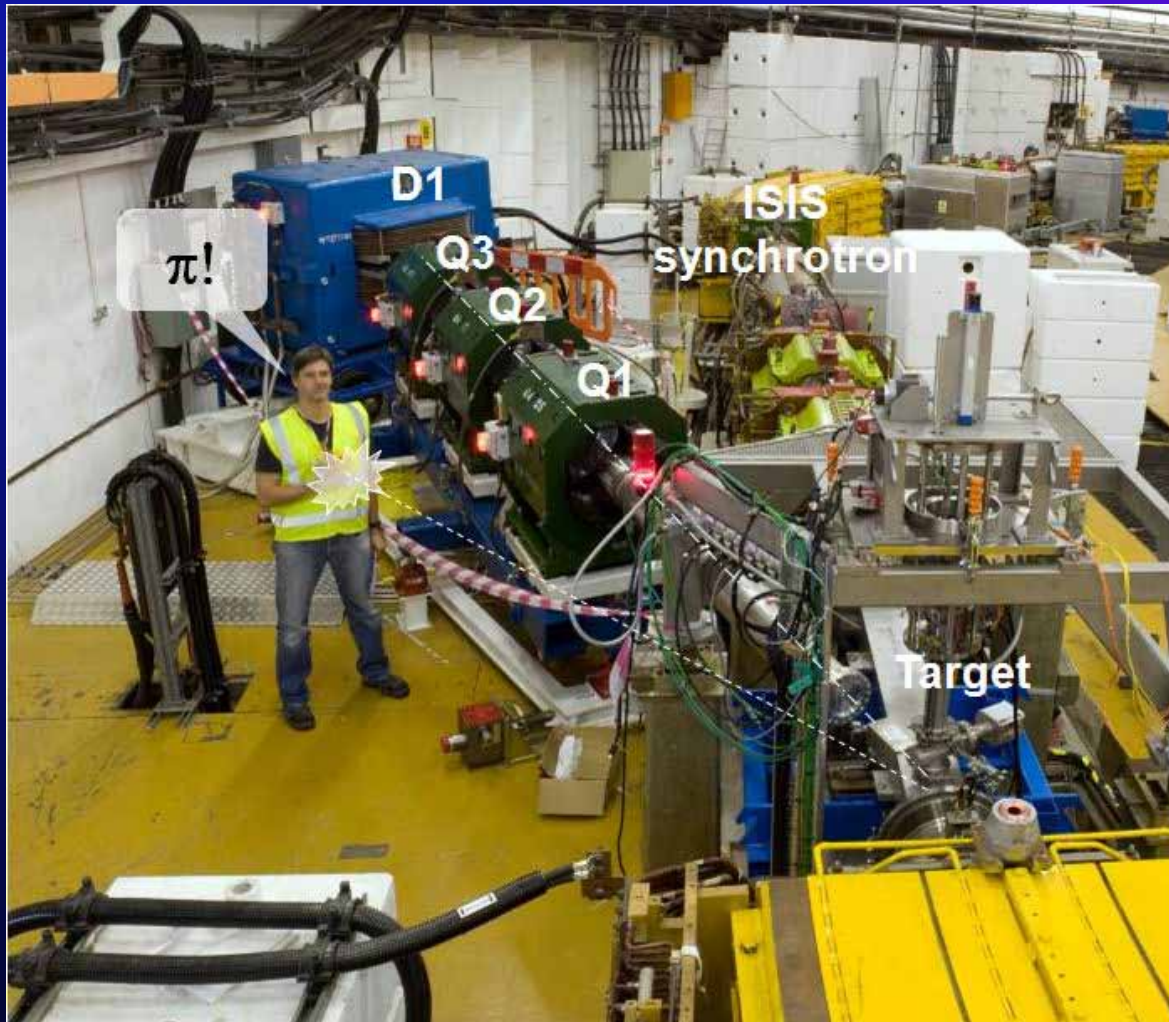
# Muon Ionization Cooling Experiment (MICE)



# MICE Beam Line Commissioned and Running



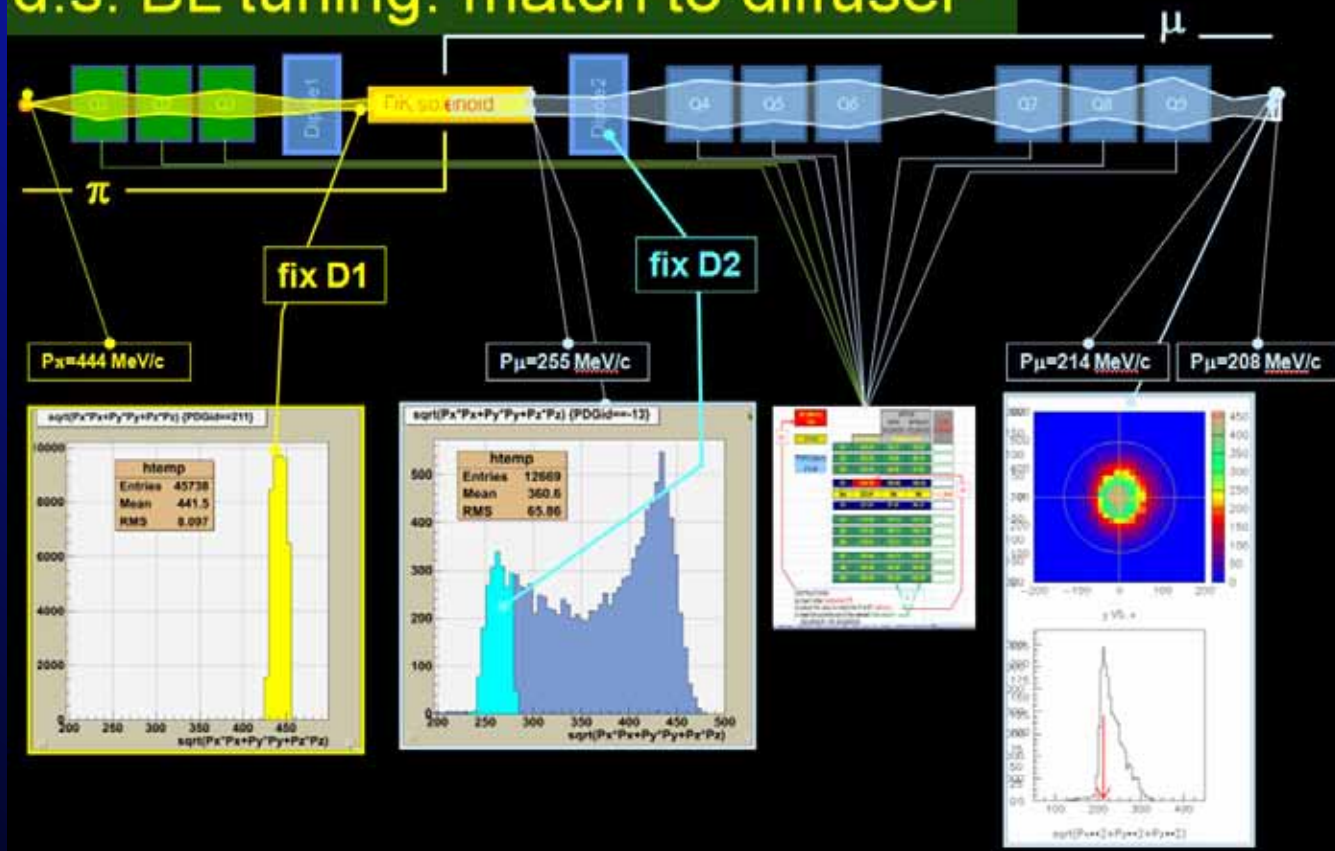
# MICE Target Tests



# MICE Beam Line Tuning

Now that Decay Solenoid is working well, can tune for Optimal myield

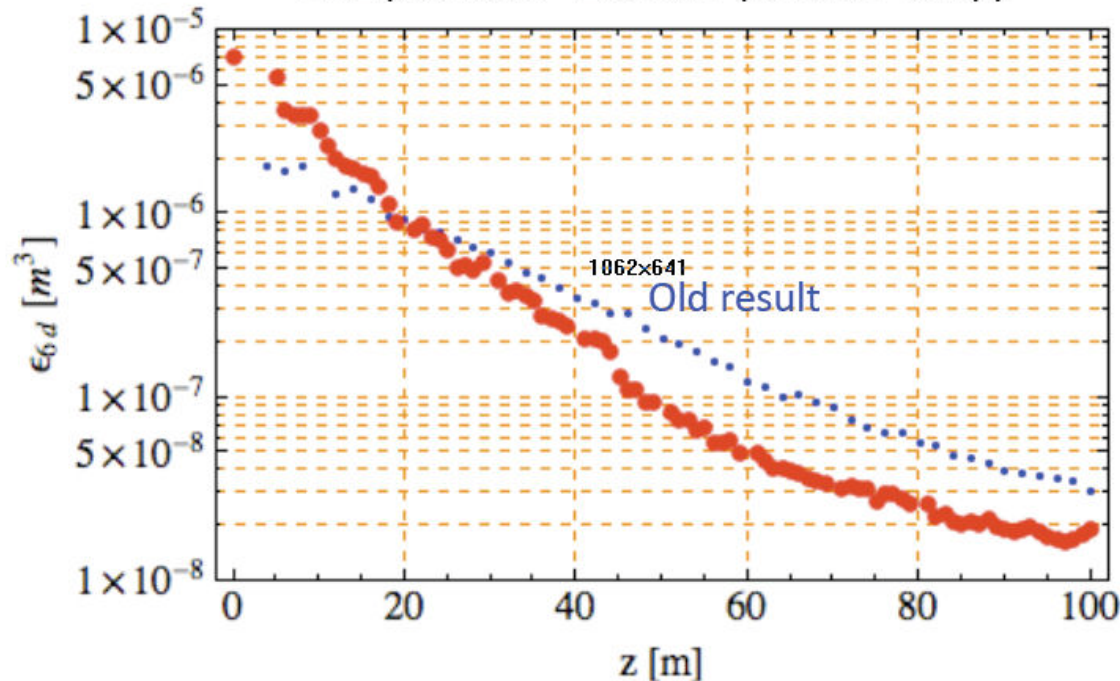
d.s. BL tuning: match to diffuser



# Design Studies - HCC

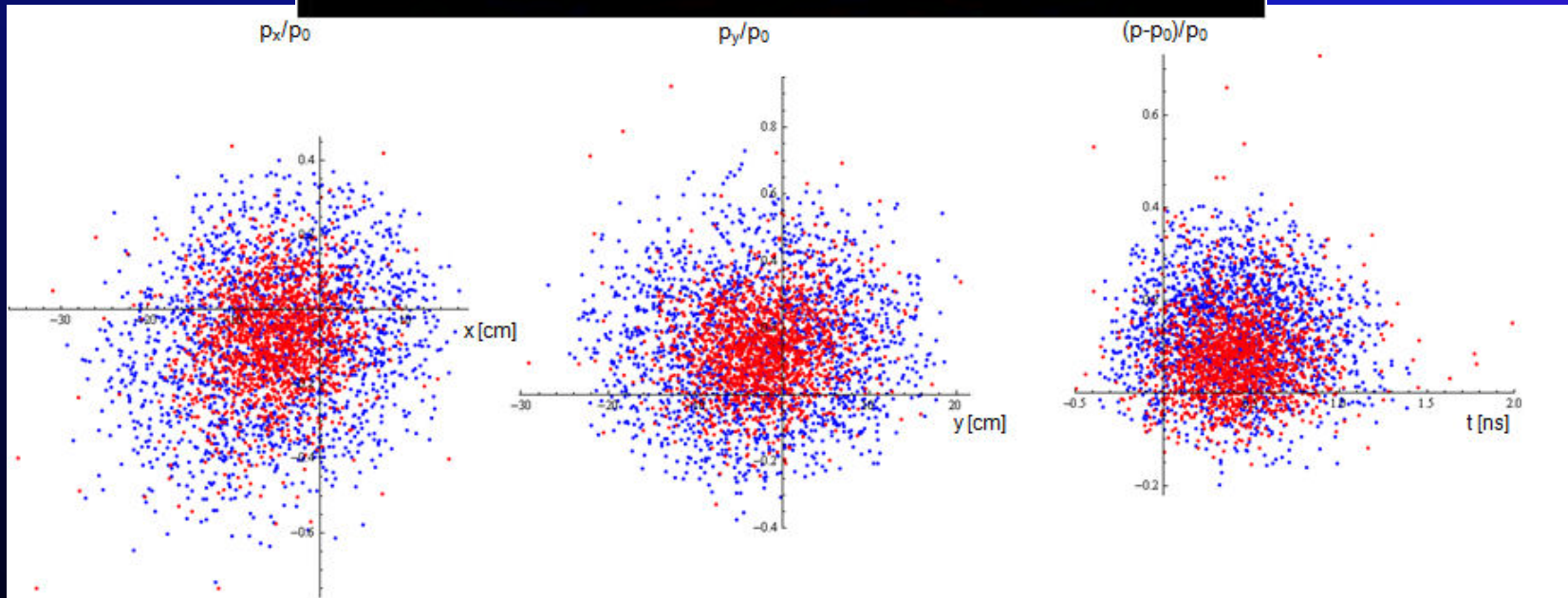
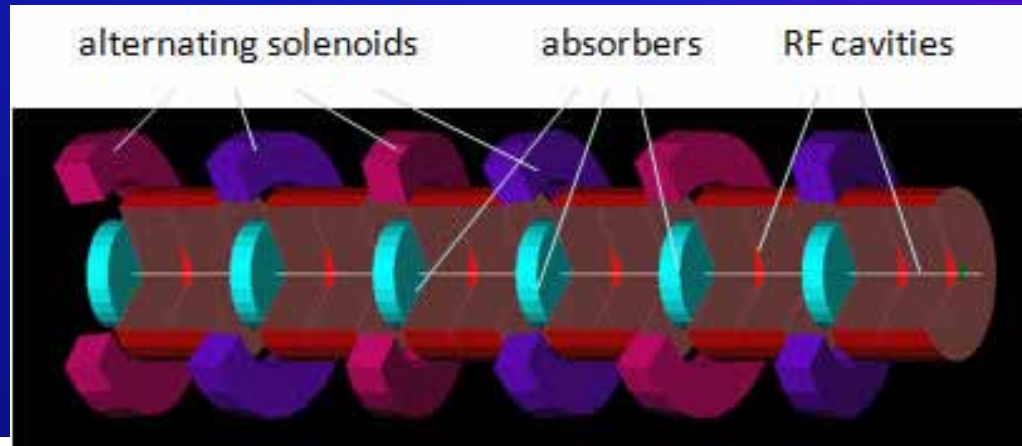
## Six-Dimensional emittance evolution in new HCC

$\nu = 400$  MHz,  $\kappa=1.0$ ,  $\lambda=1.0$  m  
 GH2 pressure = 200 atm (at room temp)



Cooling factor  $> 500 \sim 2^9$  @  $z = 100$  m

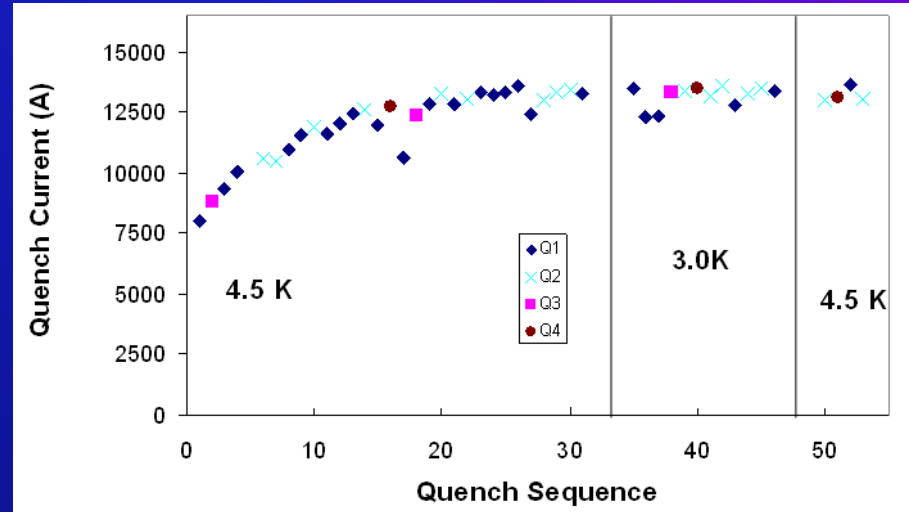
# Design Studies - HFOFO Snake



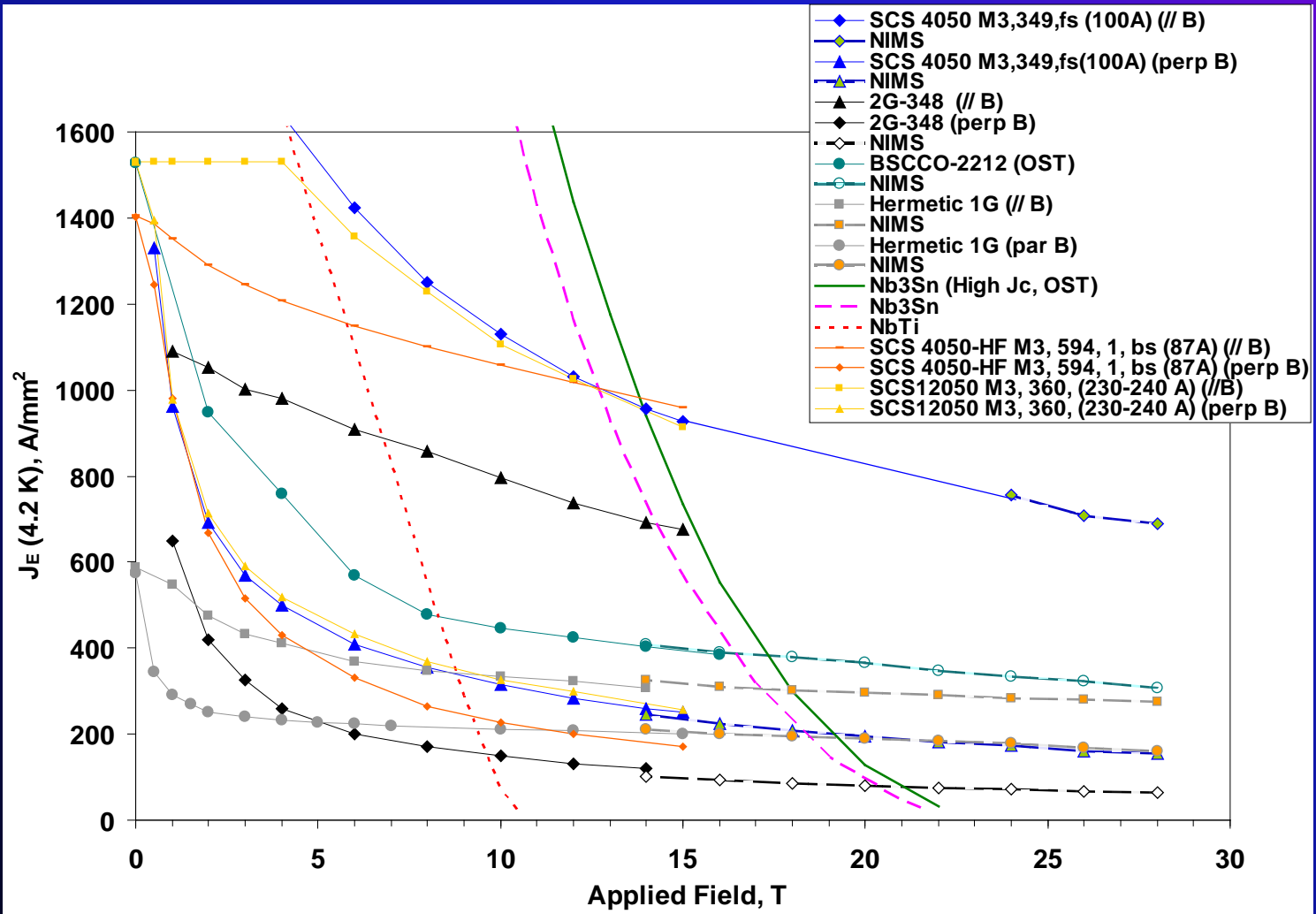


# Helical Cooling Magnets

4-Coil Prototype reached 85% of short sample limit



# HTS Conductor Studies



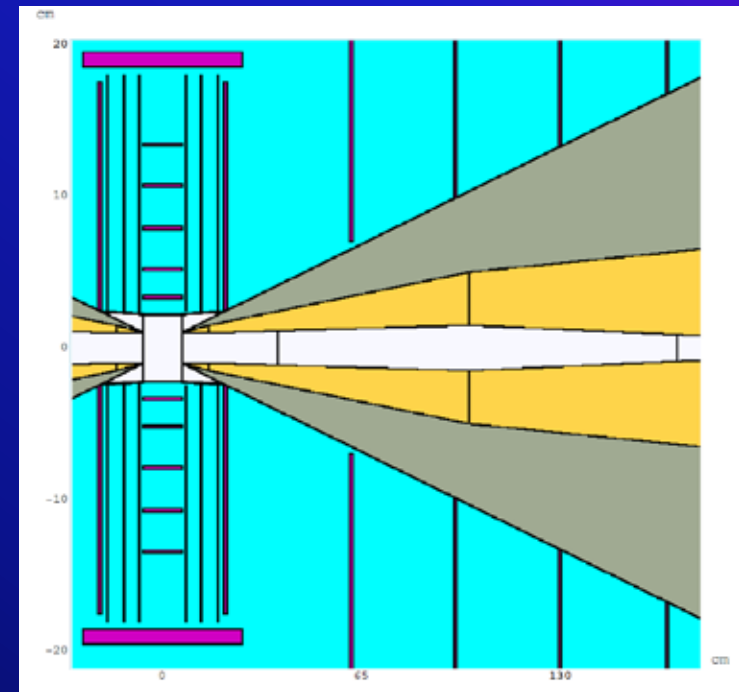
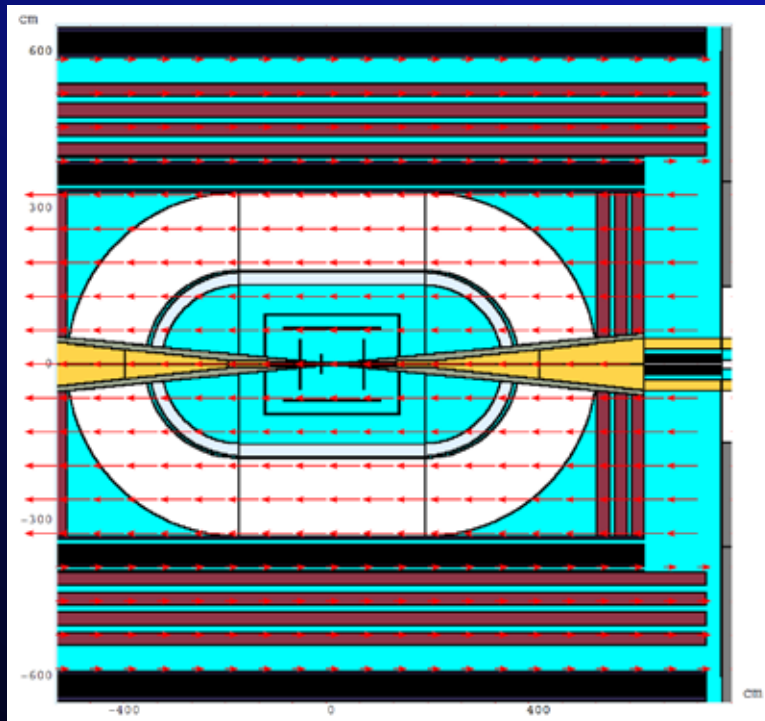


# HTS Cable Studies

Company	Conductor Type	Coil Geometry	Impregnation	Details of Test	SSL(14T)	Notes
American Superconductor	348 YBCO	Single Pancake	Stycast 2850FT	77K, 4.2K 0T-14T	98%	[Di:38mm-Do:43mm]
American Superconductor	Hermetic BSCCO2223	Single Pancake	Stycast 2850FT	77K, 4.2K 0T-14T	98%	[Di:38mm-Do:43mm]
American Superconductor	Hermetic BSCCO2223	Double Pancake	Stycast 2850FT	77K, 0T	67%	[Di:32mm-Do:43mm] <i>Bad Splice due to small outer radius and stiffness of tape</i>
SuperPower	YBCO M3-609 <i>(R&amp;D conductor)</i>	Single Pancake	Stycast 2850FT	77K, 4.2K 0T-14T	0%	[Di:38mm-Do:43mm] <i>Resistive Coil</i>
SuperPower	YBCO M3-569	Single Pancake	Stycast 2850FT	77K, 4.2K 0T-14T	29%	[Di:38mm-Do:43mm] <i>Low Ic, Low n values</i>
SuperPower	YBCO M3-569	Double Pancake	Stycast 2850FT	77K, 4.2K 0T-14T	22%	[Di:32mm-Do:43mm] <i>Low Ic, Low n values</i>
SuperPower	YBCO M3-569	Single Pancake	Dry	77K, 4.2K	76%	[Di:38mm-Do:43mm] <i>Tested in compression</i>
SuperPower	YBCO M3-569	Double Pancake	Dry	77K, 4.2K 0T-10T	40%	[Di:60mm-Do:62mm]
SuperPower	YBCO M3-569	Double Pancake	Dry	77K, 4.2K 0T-12T	87%	[Di:60mm-Do:62mm]

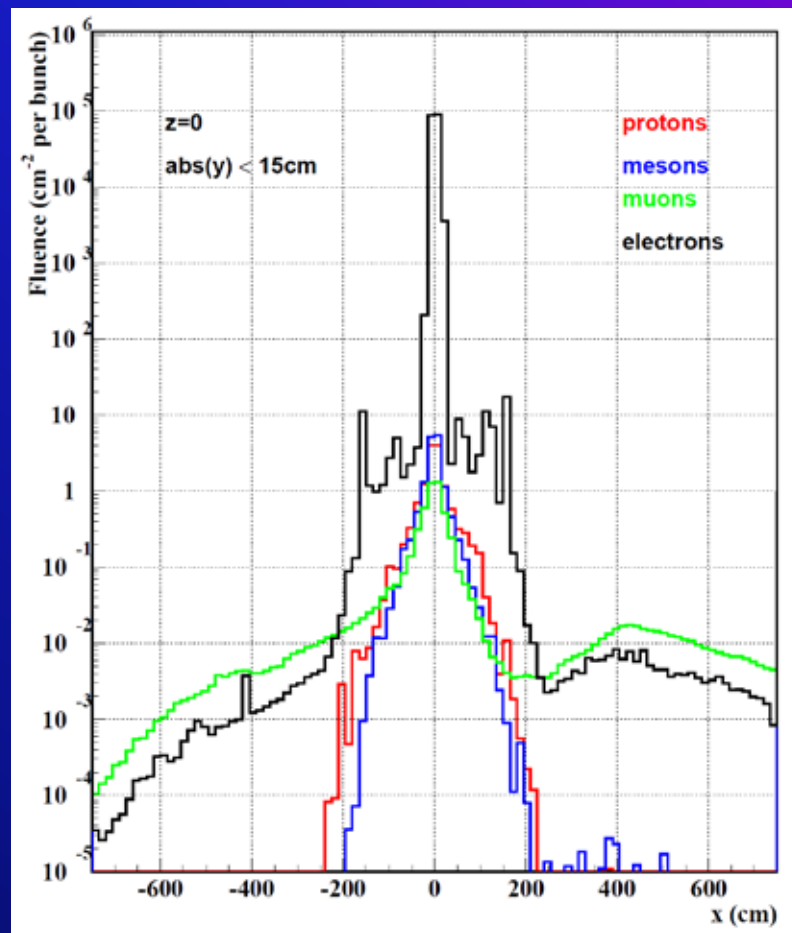
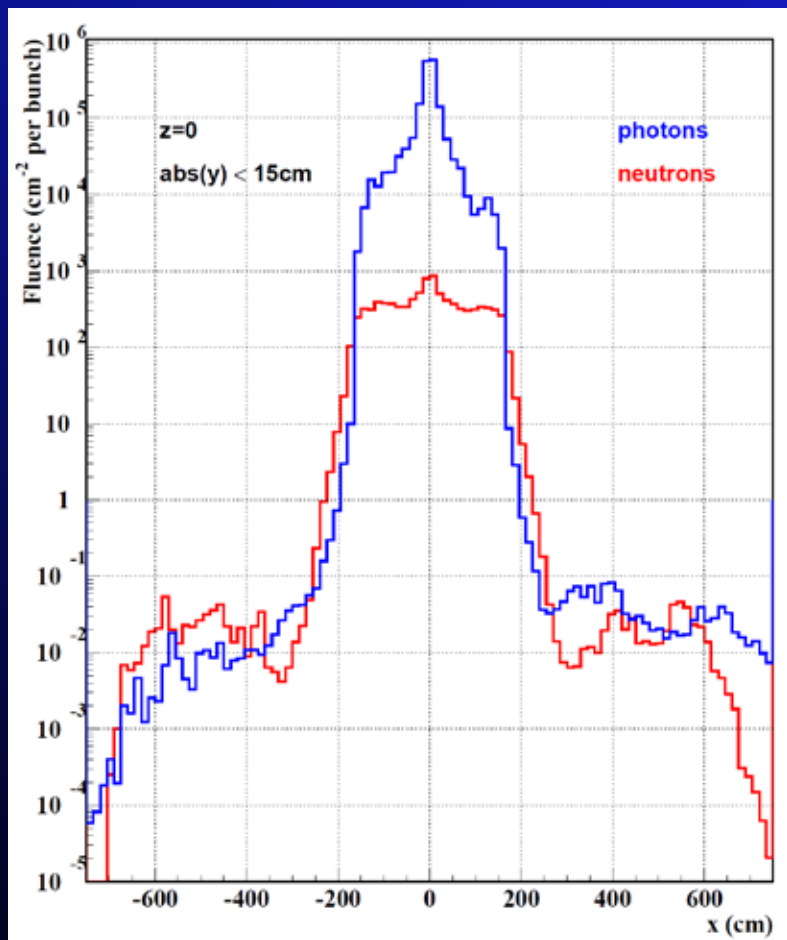
# Muon Collider - MDI Studies

- After a long Hiatus, work on studying machine-detector interface issues and backgrounds has begun again
  - Fermilab Physics - Detector WS in November



4<sup>th</sup> Detector Concept with new forward cone

# Detector Backgrounds



MORE WORK TO BE DONE



# Conclusions/Outlook

- We have managed to make progress this year in a number of areas, but have also experienced unfortunate delays in others
- This is the first time in many years, however, where the prospects for increased funding in Muon Accelerator R&D look promising
  - DOE supports this expanded effort (at least verbally at this point) and is likely to act quickly once the revised proposal is submitted
  - Goal to submit by the end of the month
- Can expect a formal review by spring



## Conclusions/Outlook

- The transition from the NFMCC/MCTF to the national MAP, will present us with challenges, but we are entering an exciting new phase of our work
- This represents the first real opportunity for a significant increase in effort/funding
- We have also received a good deal of exposure in the scientific press as of late with some rather interesting statements

"It would be nice to head in a direction that has some real innovation," W. Brinkman