Neutrino Factory and Muon Collider Collaboration Meeting

Highlights Reel

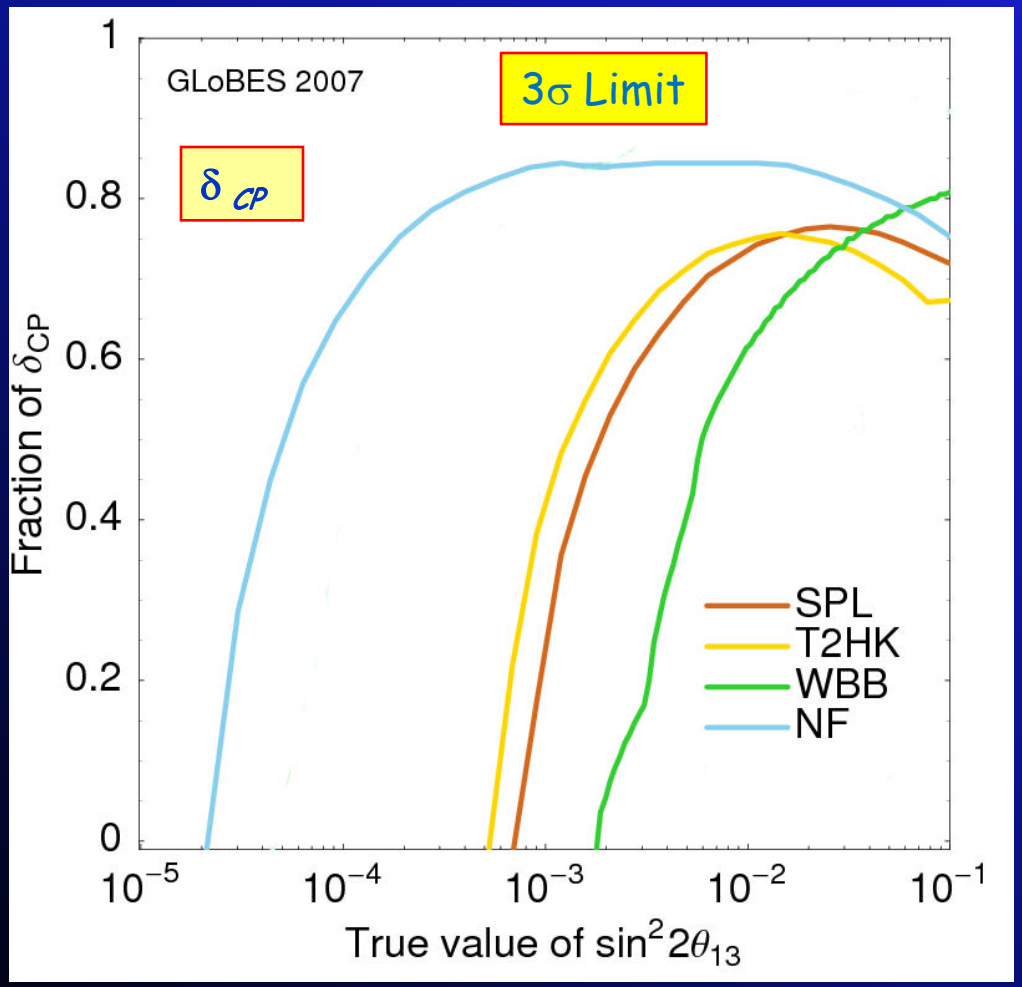
MCTF Meeting

2/5/09

Alan Bross

Physics & Detector

NF Motivation - Physics Reach (ISS)



- The NF gives the best Physics Reach
  - NF ≡ Precision
- Even with $\sin^2 2\theta_{13}$ in the range of 5×10^{-4} to 10^{-3}, these very aggressive "conventional" experiments – Run Out of Steam
- Similar arguments can be made for $\sin^2 2\theta_{13}$ discovery reach and determination of the neutrino-mixing mass Hierarchy

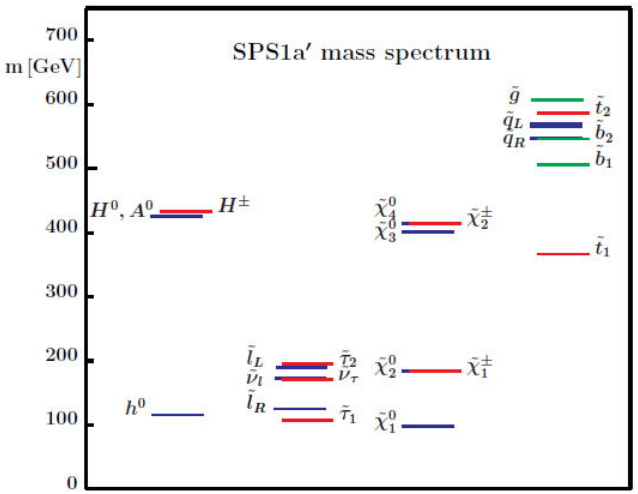
SPL: 4MW, 1MT H_2OC, 130 km BL
T2HK: 4 MW, 1MT H_2OC, 295 km BL
ProjX: 2MW, 1MT H_2OC, 1300 km BL

NF: 4MW, 100KT MIND, 4000 & 7500 BL

MC Motivation

- Fine tuning problems in the cMSSM - Allow nonuniversal $m_{1/2}$

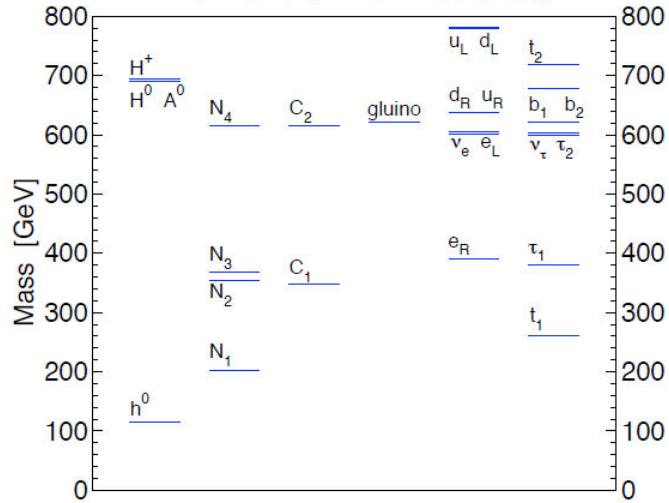
cMSSM ILC Benchmark



Many visible superpartners within reach of the ILC (500 GeV).
All pair production thresholds are below 1.2 TeV.

Compressed SUSY

S. Martin [PR D75:115005,2007]

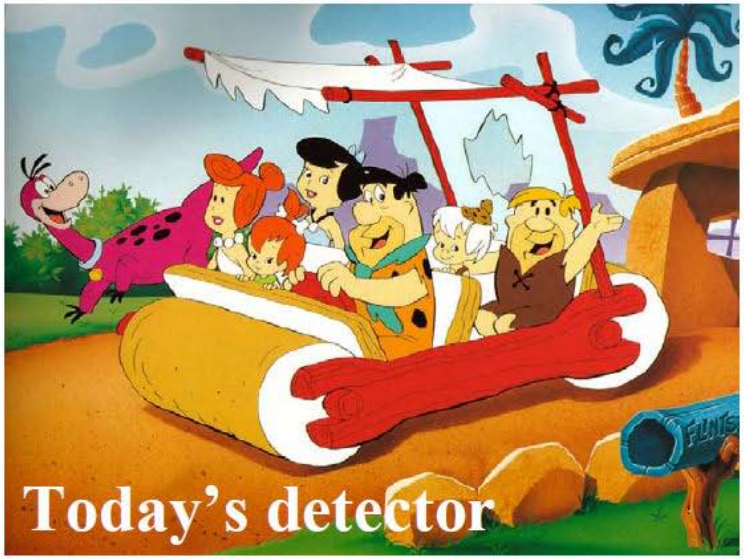


No visible superpartners within reach of the ILC (500 GeV).
All pair production thresholds are below 1.6 TeV.

Supersymmetry provides strong case for a multi-TeV lepton collider

Detector – Don't be Timid

- Feels a bit like …

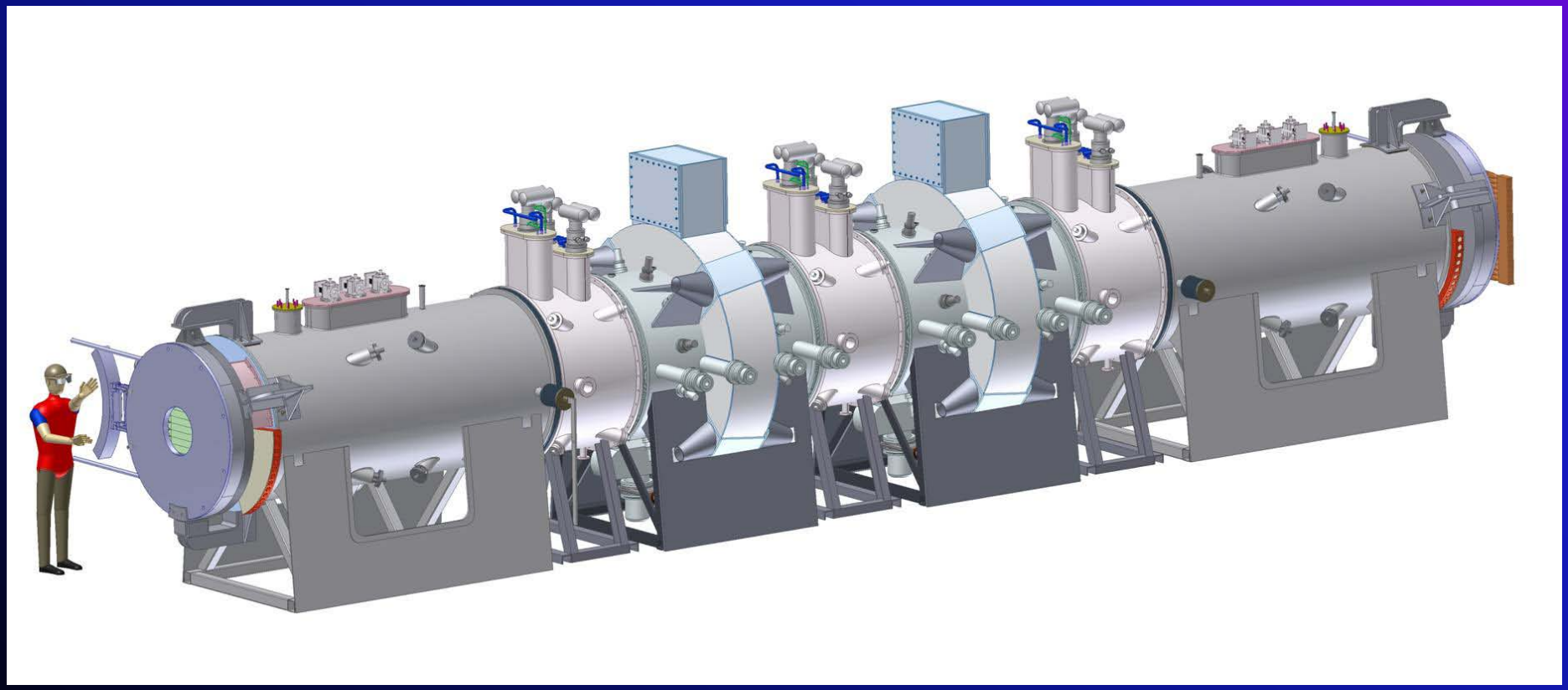


Folds into a briefcase !

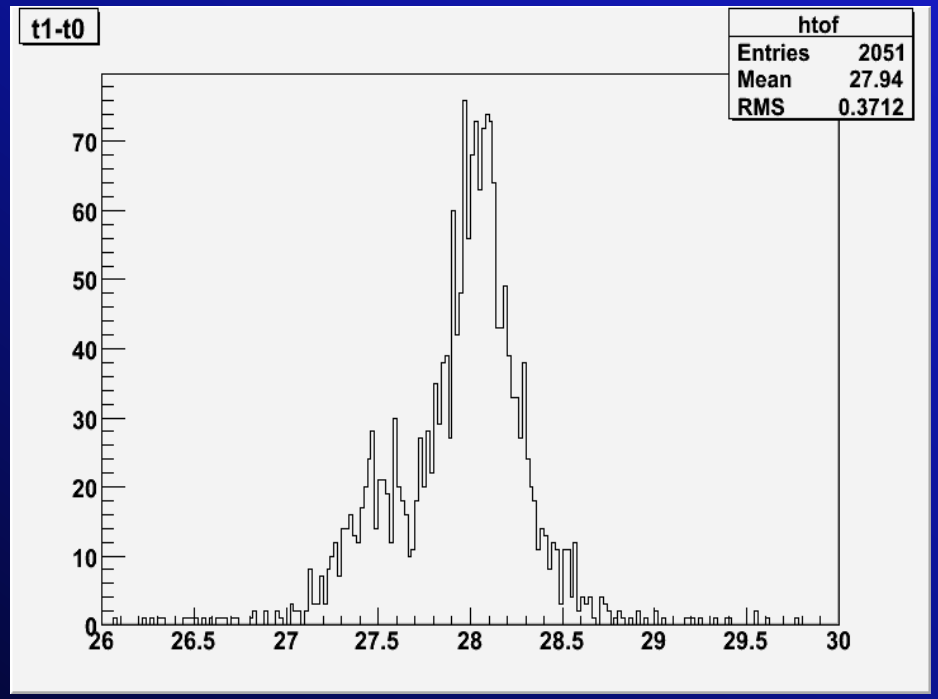
Detector – But you Have to be Realistic

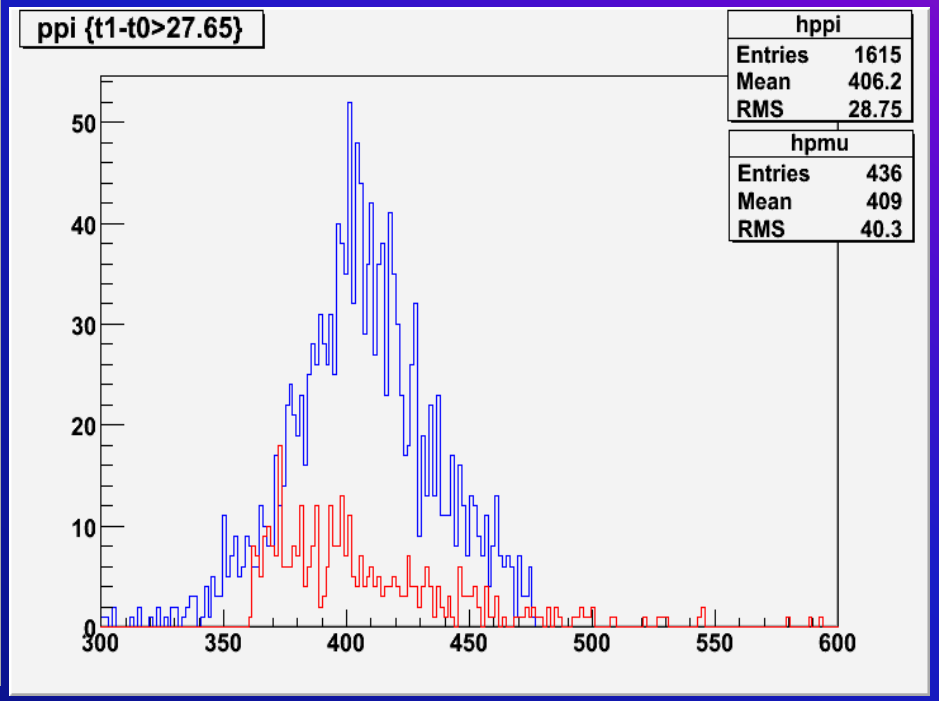
- A full updated background study should get high priority, with full simulation of the beam line delivery system and the machine detector interface elements
- The results of this study could dictate the design of the detector. Without this information, the evaluation of the physics reach may be seriously misjudged
- Study of physics reach should include peripheral measurements such as luminosity spectrum, energy and polarization

Muon Ionization Cooling Experiment (MICE)



MICE

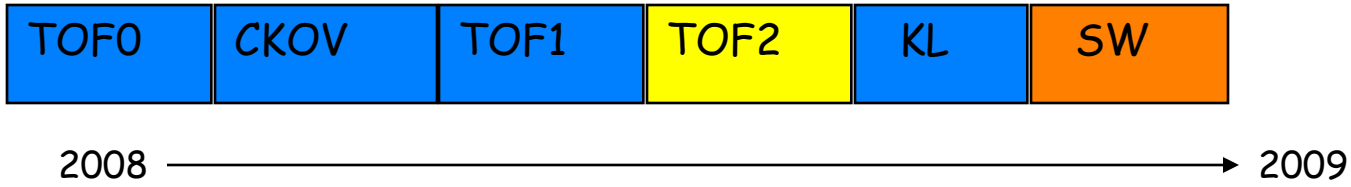




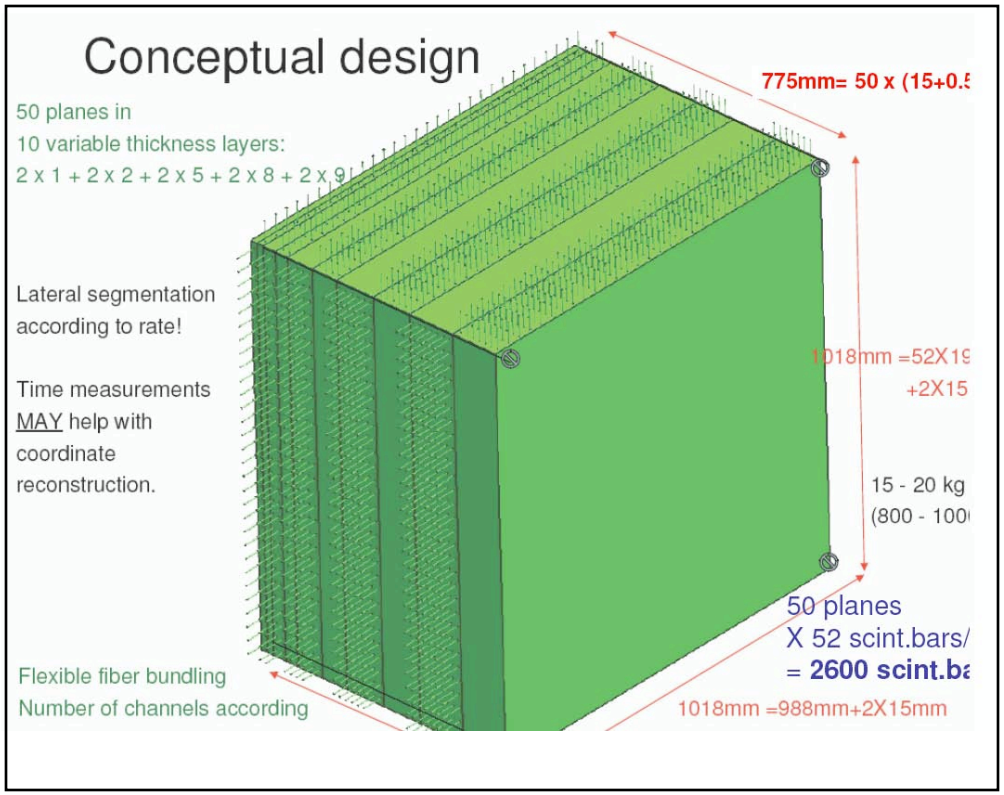
- First muons observed
- You will get an update on the status of the experiment

PID Summary

- Major progress on PI Systems in 2008.
- TOF 0/1/KL installed in MICE Hall and commissioned with beam .
- TOF1/2 shield plates and stands being fabricated.
- TOF2 delivery in 2009. **SW in progress.**
- TOF/CKOV/KL/SW Electronics near completion.



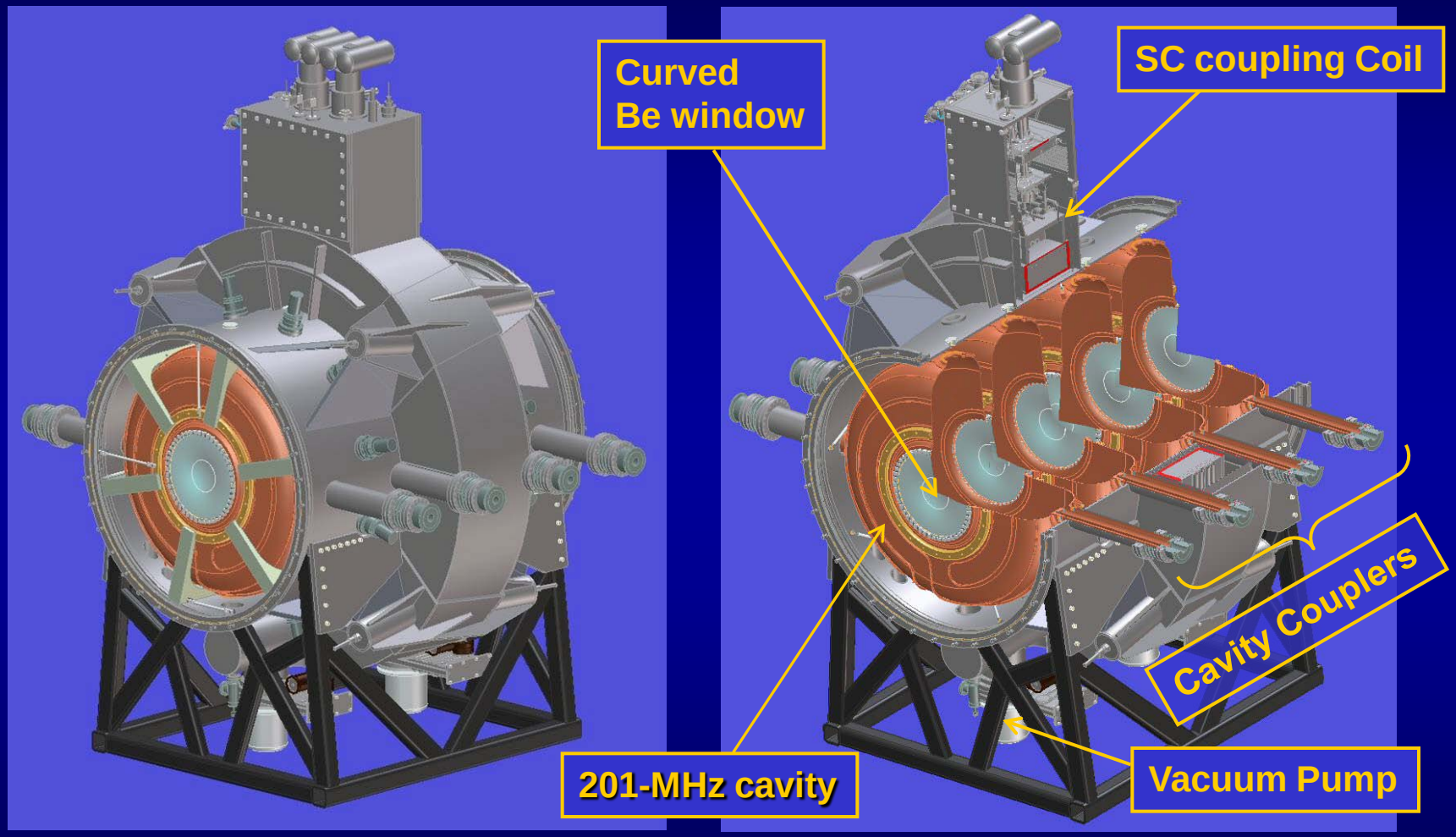
SW - Fiber Calorimeter



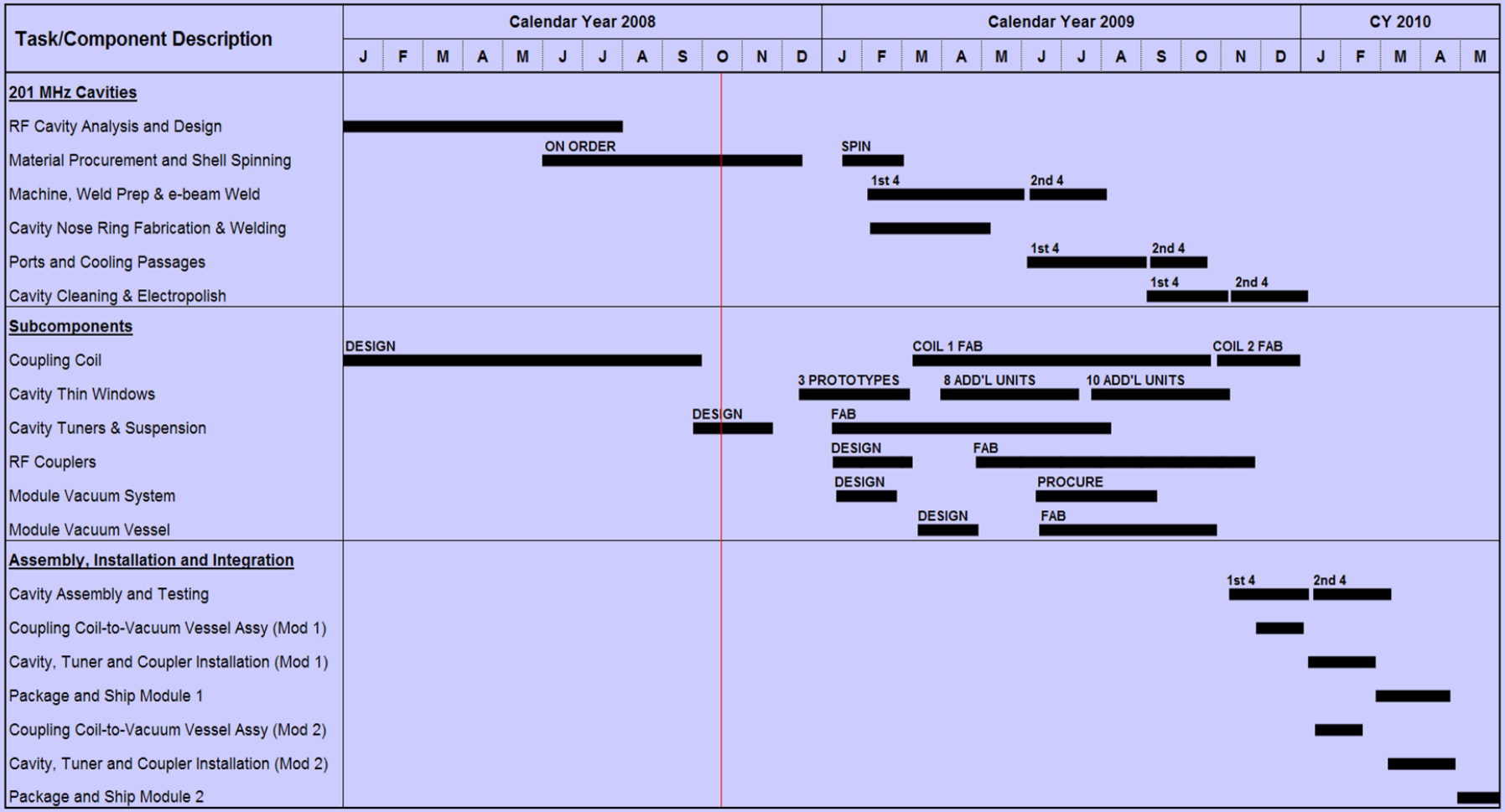
Sci/Fi Calorimeter

- Trieste- PMTs, Mech
- Roma III
- Fermilab- Sci/fibers
- Geneva- Electronics
- expected 2009

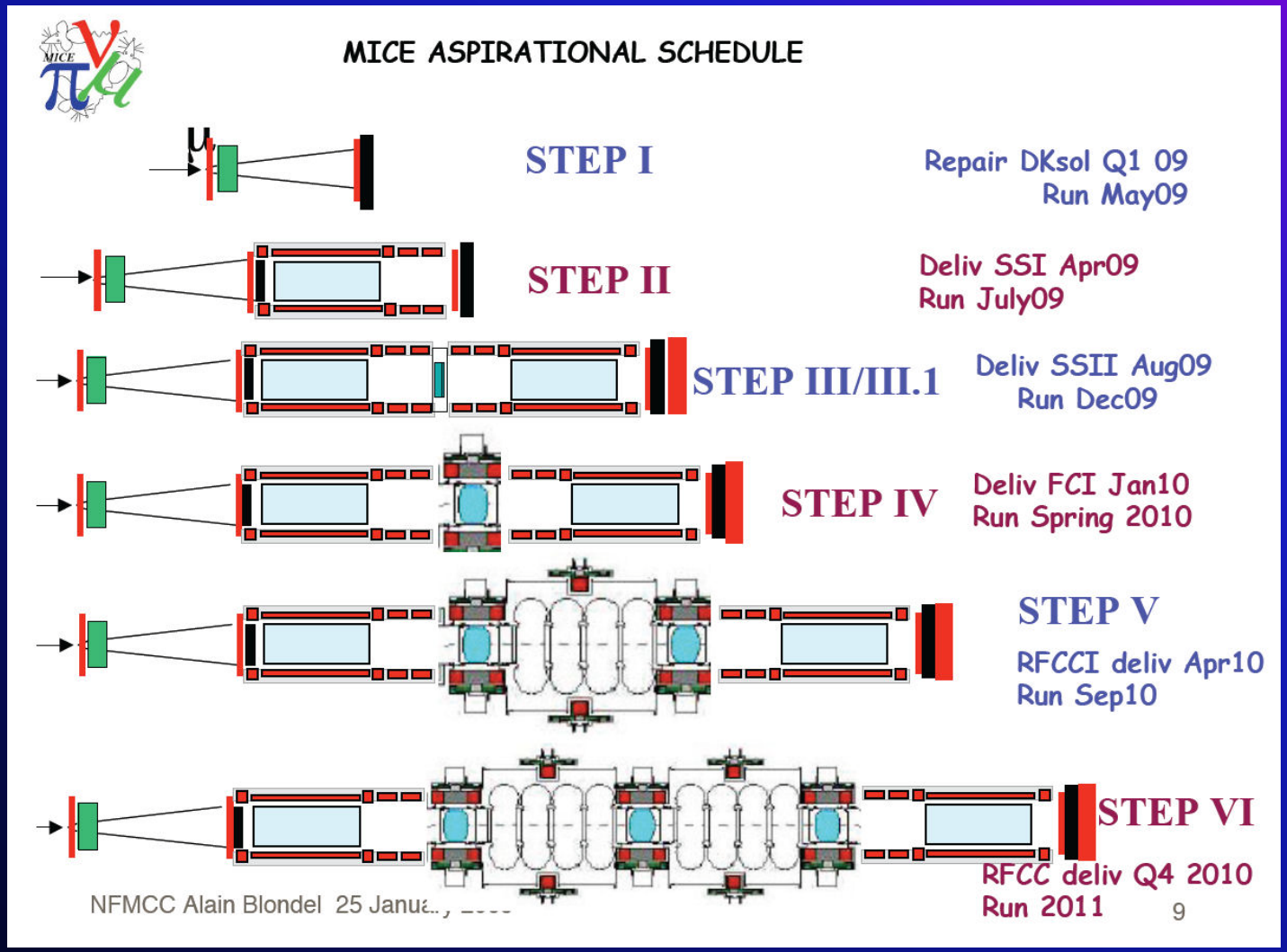
RFCC Module


Curved
Be window
SC coupling Coil
Cavity Couplers
201-MHz cavity
Vacuum Pump

Schedule Summary



"I Have a Dream"



Core Program

Targetry R&D: Mercury Intense Target Experiment
MERIT
Co-Spokespersons: Kirk McDonald
Harold Kirk

Ionization Cooling R&D: MuCool and MICE
MuCool Spokesperson: Alan Bross
US MICE Leader: Dan Kaplan

Simulations & Theory
Coordinator: Rick Fernow

Fermilab Muon Collider Task Force

PM Report

Issues

- Three categories where additional support is needed:
  - completing our hardware commitments to international experiments
    - MICE hardware commitments will be honored at present budget levels, but at least 1 year late
      - any substantial need for contingency would result in further delays
  - restoring the health of our simulations and theory effort
    - manpower has eroded away after years of flat budgets
      - need effort for IDS-NF, MICE analysis, EMMA design, and MC design work
        - need to assess resource needs (not just $ issue)
  - launching new initiatives, especially RF work
    -
- 5-year R&D plan (~$90M) has been submitted to DOE
  - no response yet; expect formal review at some point
  - support from MUTAC will be very helpful
    - need to strive for this at next review (April 6-8, 2009 at Fermilab)

Summary and Outlook

- Despite limited funding, NFMCC continues to make progress on carrying out its R&D program
  - initial 201-MHz cavity tests with magnetic field launched
  - MICE spectrometer solenoid fabrication nearly completed
  - completed ISS; paper "almost" published (JINST)
    - IDS-NF under way
  - completed MERIT beam run
    - data analysis under way
- Our work provides potential choices for HEP community
  - muon-based accelerators/colliders offer advantages over other approaches
    - they also provide an intense source for low-energy muon physics
- We have been disciplined and effective in carrying out our R&D tasks continue to make good use of our funding
  - but, it is getting harder

MuCool

RF Test Program

- Study the limits on Accelerating Gradient in NCRF cavities in magnetic field
- It has been proposed that the behavior of RF systems in general can be accurately described (predicted) by universal curves
  - Electric Tensile Stresses are important in RF Breakdown events
- This applies to all accelerating structures
- Fundamental Importance to both NF and MC
  - Muon capture, bunching, phase rotation
  - Muon Cooling
  - Acceleration

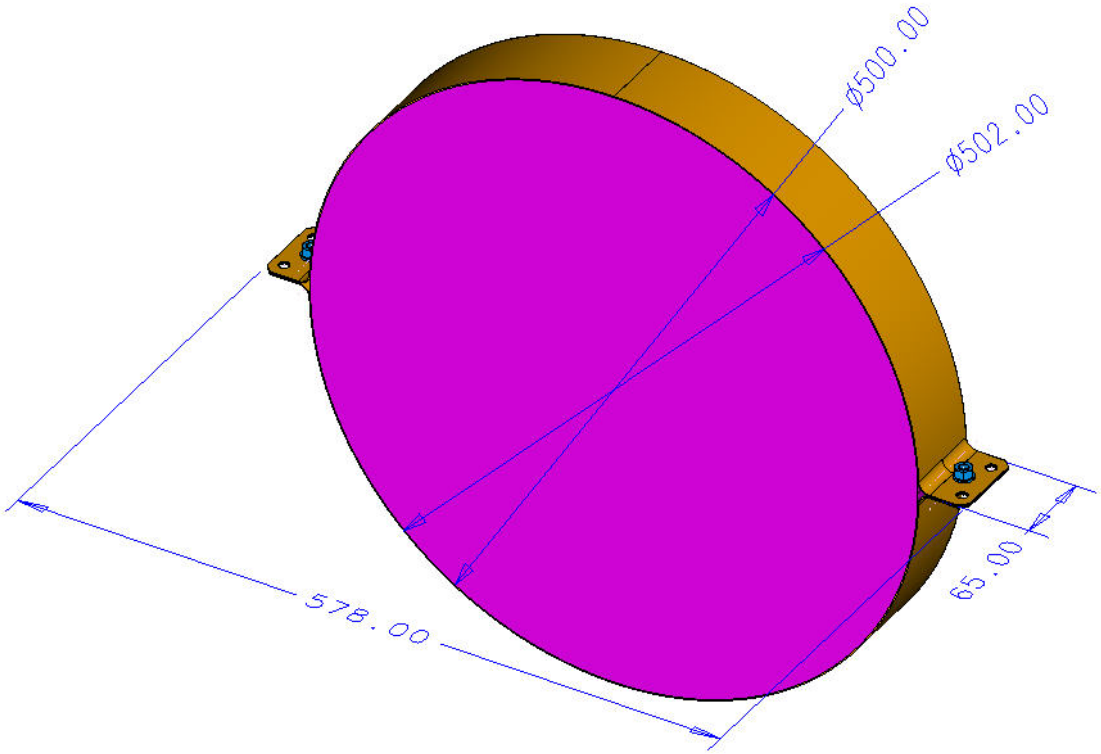
Arguably the single most critical Technical challenge for the NF & MC

- You will hear about our 3-Pronged Attack
  - Reduce (eliminate) field emission in Vacuum RF, HP gas-filled cavities, Magnetic Insulation for vacuum RF

MuCool

- Summary
  - Vacuum RF with B –BIG Problem
    - Solutions
      - Processing – SCRF, ALD ….
    - HP RF (H_2)
    - Magnetic Insulation
- Status
  - First Linac beam commissioning
  - Within weeks of closing up the MTA to prepare for restart of RF program and beam

LiH Absorber for MICE Step III.1



Status of Negotiations with Y12

- All the technical specifications and production issues are resolved
- The only outstanding issue was coating the parts with a water vapor barrier
  - Parylene C (Preferred)
  - Epoxy
- The coating is a safety issue only
  - For both Fermilab and RAL
- But has led to a protracted discussion because of cost

Breaking News: Y12 has determined a way to reduce the cost
And it is now within our budget.
Waiting for New Proposal and then will place the order

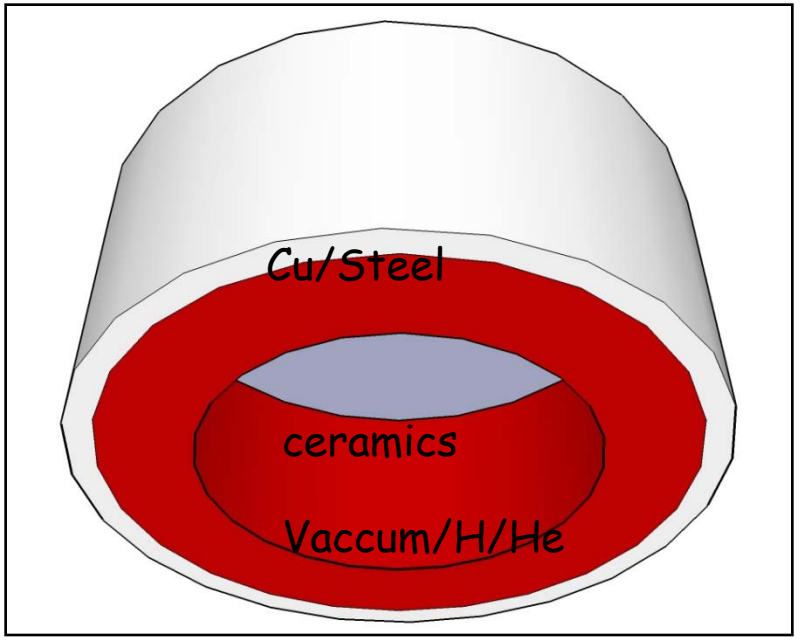
MuCool

Some New Stuff

Dielectric Loaded RF Cavities

New type of cavity is suggested.

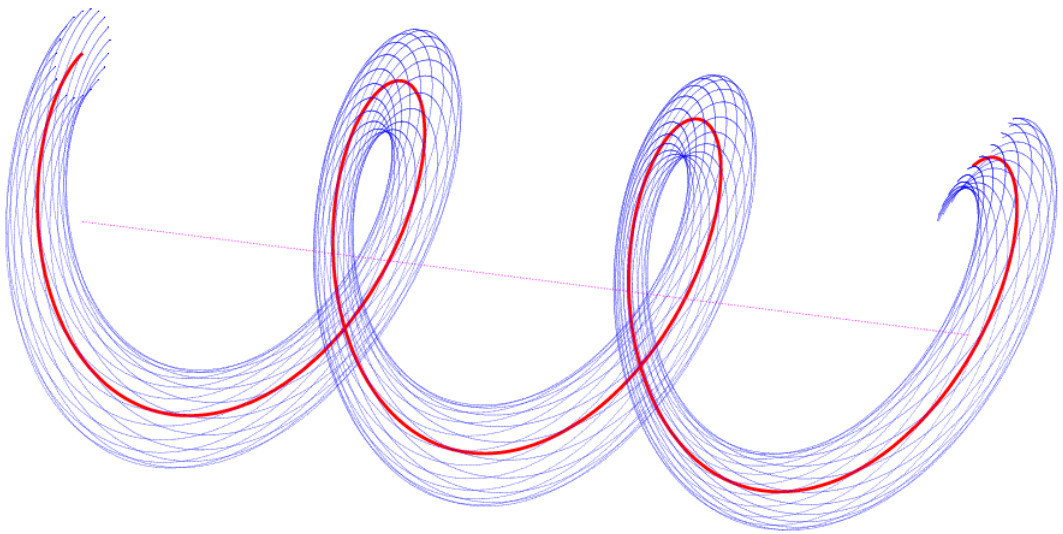
The idea came from conversation with Chuck and Yonehara.



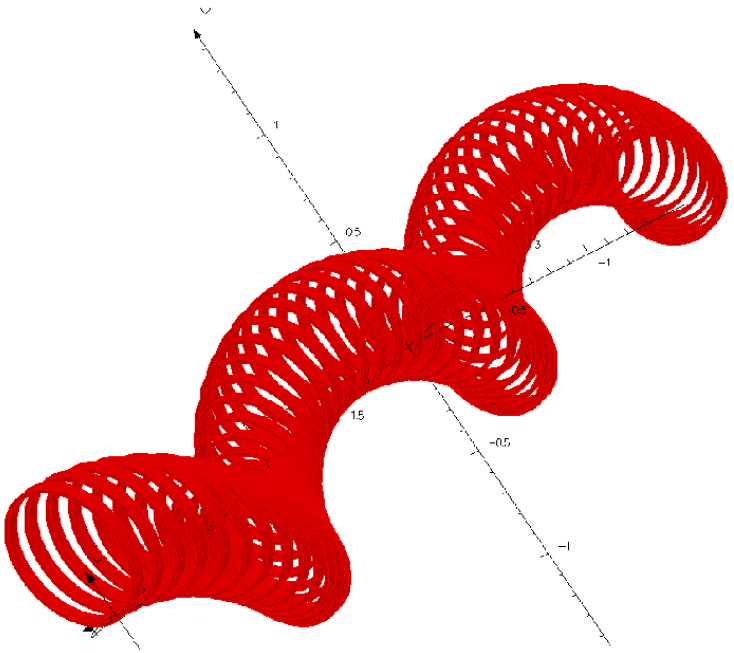
I was told that Al suggested something like this.

Muons, Inc.

HCC Concept

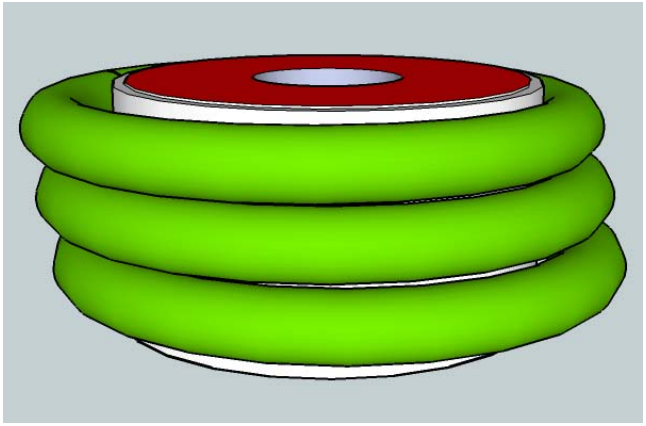


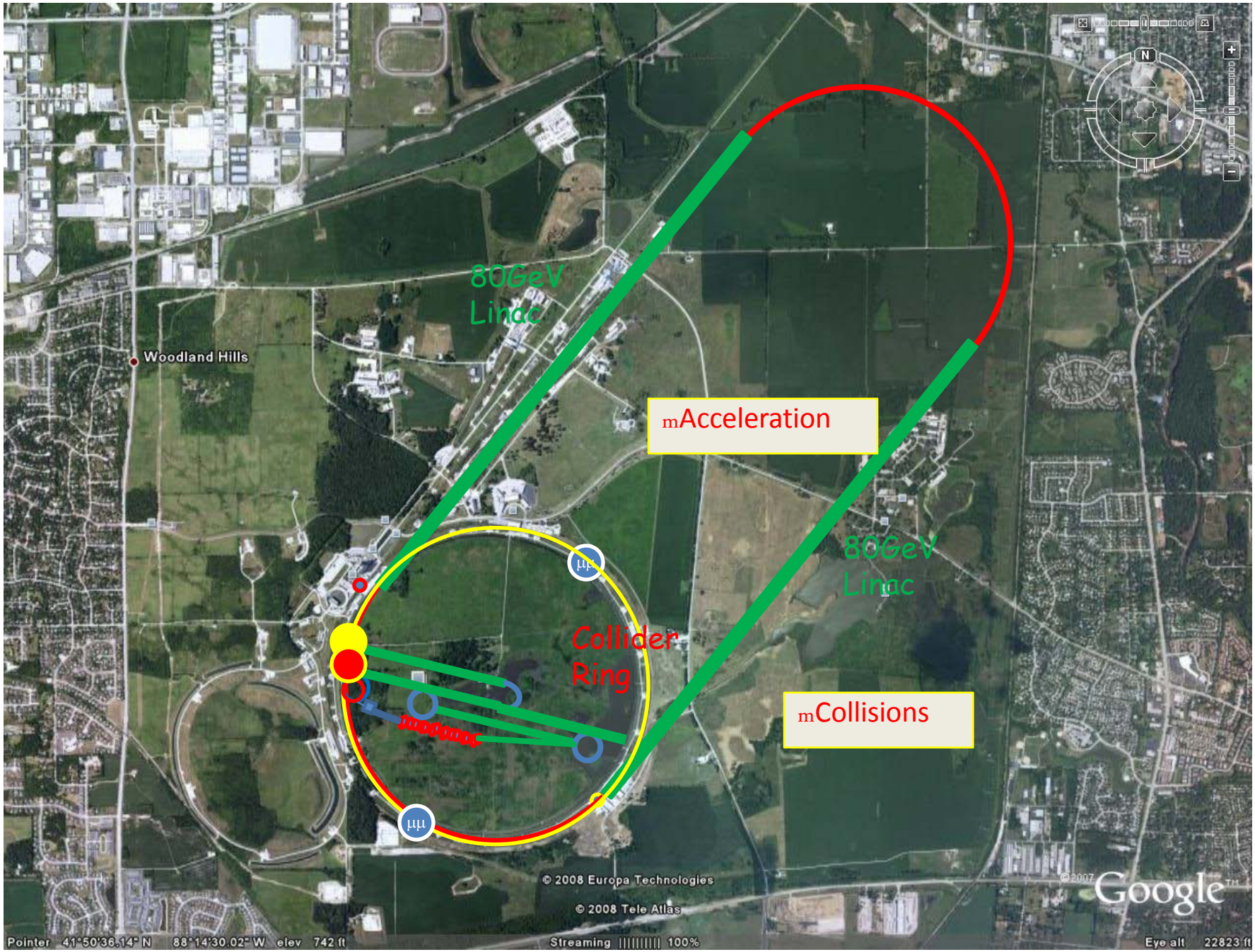
Central Orbit and Beam Envelope



Set of Coils

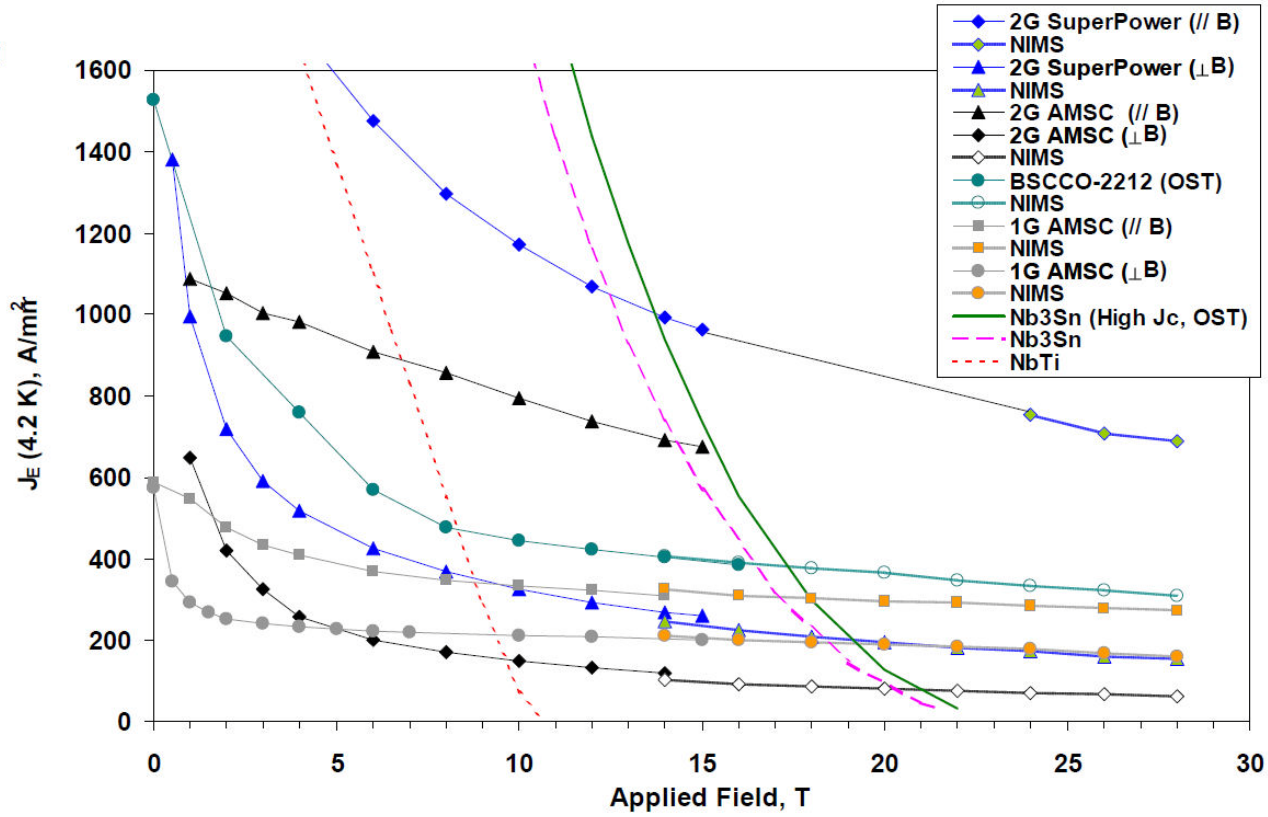
Basic Building Block can be Cavity + Coil




80GeV
Linac
Woodland Hills
mAcceleration
80GeV
Linac
Collider
Ring
mCollisions
μμ
μμ
© 2008 Europa Technologies
© 2008 Tele Atlas
Google
Pointer 41°50'36.14" N 88°14'30.02" W elev 742 ft
Streaming 100%
Eye alt 22823 ft

HTS Wire

New Data within FNAL-NIMS Coll.

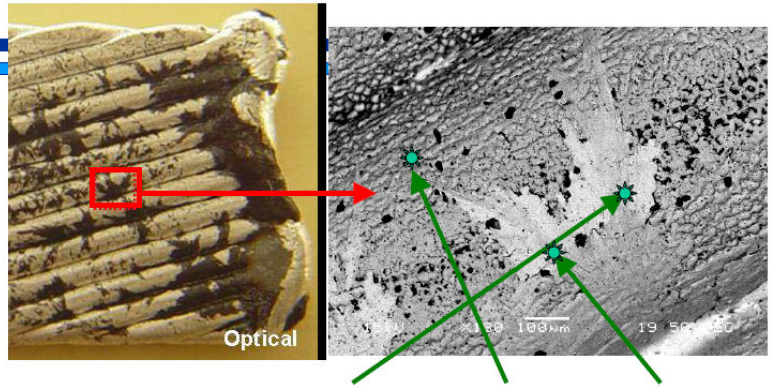


D. Turrioni et al., "Study of HTS Wires at High Magnetic Fields", accepted in IEEE Transactions on Applied Superconductivity

HTS Cable

SEM/EDS Cable Surface Analysis

The surface of all the cables after reaction showed black spots embedded in the silver coating.



Spectrum No.	1	2	3
Element	At. %	At. %	At. %
Ag (L)	0	100	0
Bi (M)	14.91	0	3.59
Sr (L)	9.04	0	2.21
Ca (K)	5.53	0	0.78
Cu (L)	11.49	0	5.80
Mg (K)	0	0	29.33
O (K)	59.03	0	58.28
Totals	100.00	100.00	100.00

Bi-2212? Bi-2212+MgO?

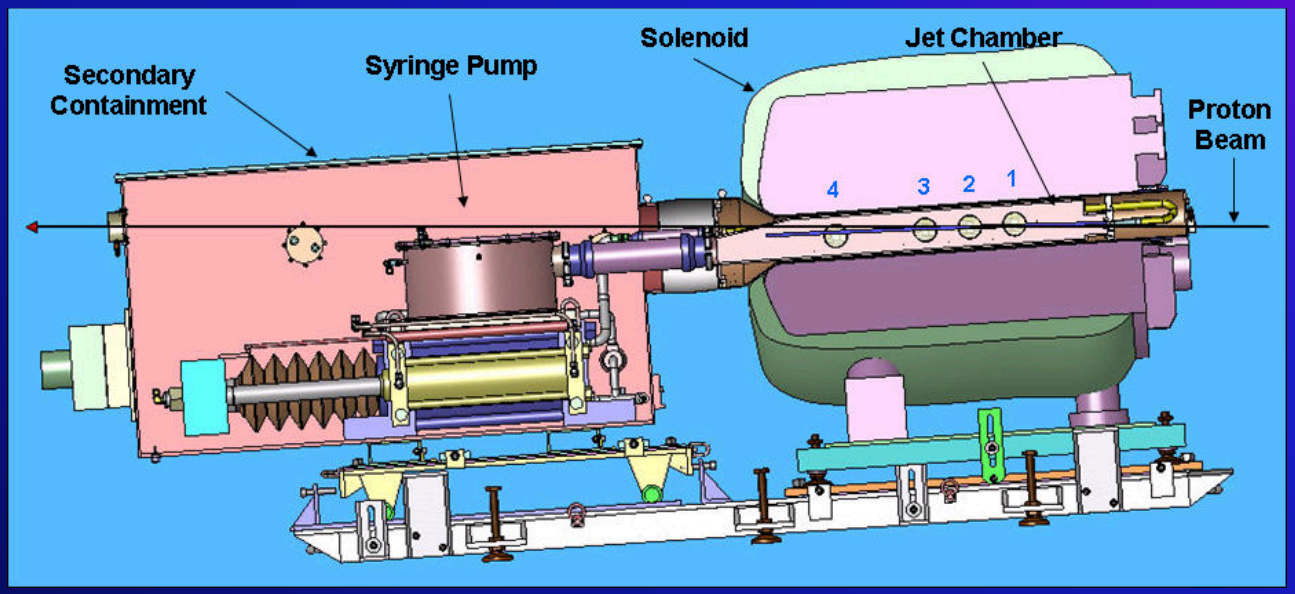
Caused by filament powder leaks

For all the cables, tested at self-fields of 0.1 to 0.3 T, an I_c degradation of about 50% was measured. This was much larger than the reduction found on the extracted strands.

E. Barzi et al., "BSCCO-2212 Wire and Cable Studies", Advances in Cryogenic Engineering, AIP, V. 54, p. 431 (2008)

Targetry

MERIT



- We actually Finished Something!
  - & With Great Success!

2nd Oxford-Princeton Workshop on High-Power Targets, Princeton, 6-7 Nov 2008

Thursday AM

1. McDonald: Introduction
2. Graves: Hg Containment Concepts
3. Ding: Hg Jet Optimization
4. Park. MERIT Results
5. Kadi: Eurisol Liquid Target Studies

Thursday PM

6. Rennich: SNS 3-MW Rotating Target
7. Fitton: T2K Target
8. Rooney: T2K Beam Window
9. Davenne:. Pelletized Target for ISIS
10. Hylen: DUSEL Target Options
11. Bennett: Solid Target Studies
12. Bennett: Absorption in Solid Targets
13. Skoro: Visar Studies for Solid Targets
14. Loveridge: Helmholz Coils for Wheel Target
15. Caretta: Tungsten Powder Jet Target
16. Brooks: Model for Production by Low-Density Targets
17. Brooks: Pion Production Update

Friday AM

18. Bricault: e- Targets
19. Samulyak: Hg Jet Simulations
20. Davenne: Hg Jet/Pool Simulations
21. Skoro: Simulations of Thermal Shock in Solids
22. Simos: Material Irradiation Studies
23. Efthymiopoulos: CERN Target Test Facilities
24. Hurh: Fermilab AP-0 Target Test Facility

Friday PM

25. Long: Discussion (IDS)

http://www.hep.princeton.edu/~mcdonald/mumu/target/index.html#2nd_OP_workshop

EUROnu WP2 Workshop, CERN, 15-17 Dec 2008

EUROnu WP2

from **Monday 15 December 2008 (14:00)**
to **Wednesday 17 December 2008 (16:00)**
Europe/Paris
at **CERN (*14-4-030*)**
chaired by: ***Marco Zito (IRFU-CEA) Marco Zito***
support: marcos.dracos@ires.in2p3.fr

Description: Meetings of Work Package 2 of European Project EUROnu

Monday 15 December 2008 | Tuesday 16 December 2008 | Wednesday 17 December 2008 |

http://indico.in2p3.fr/conferenceDisplay.py?confId=1586

Monday 15 December 2008

top

15:00	Organisation (3h00')	All

Tuesday 16 December 2008

top

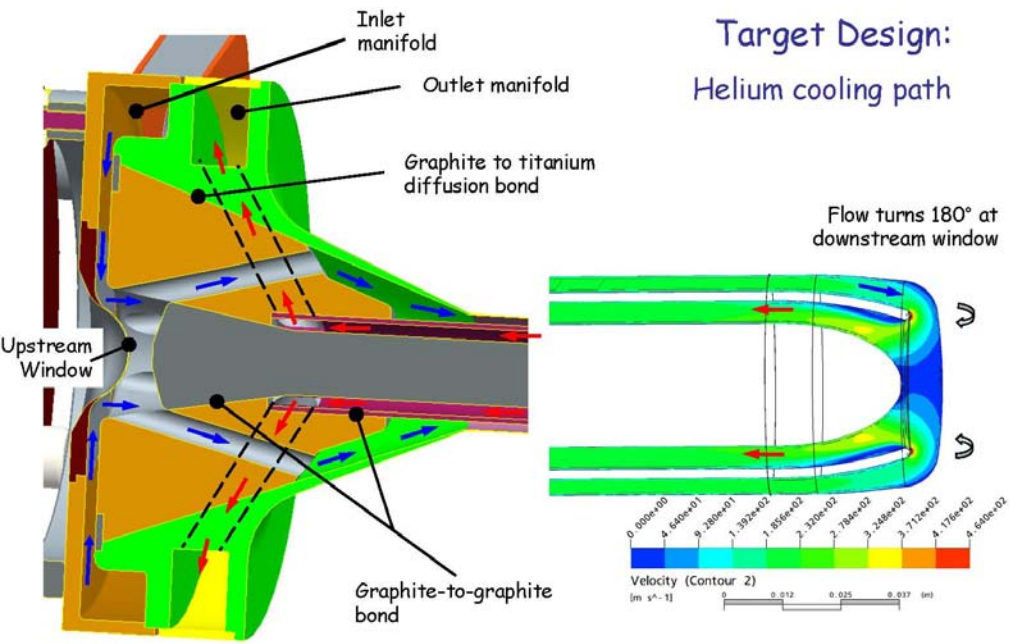
09:00	CERN Proton Drivers (30') (Slides)	M. Martini (*CERN*)
09:30	Beam stability in the SPL-based accumulator: issues and planned studies (30') (Slides)	E. Benedetto
10:00	Harp Results on Hadroproduction (45') (Slides)	G. Catanesi
10:45	T2K neutrino spectra (45')	TBC
11:30	SPL neutrino spectra (30') (Slides)	Antoine Cazes (*IPNL-IN2P3*)
12:00	Discussion (30')	All
14:00	Dusel neutrino spectra (30') (Slides)	M. Bishai
14:30	Princeton/Oxford Meeting (45') (Slides)	Kirk Mc Donald (*Princeton University*)
15:15	CERN Target Test Area (45') (Slides)	Ilias Efthymiopoulos (*CERN*)
16:00	T2K Target (45') (Slides)	Chris Densham
16:45	Solid Target R&D (45') (Slides)	Roger Bennett
17:30	Powder Jet development (45') (Slides)	O. Caretta

Wednesday 17 December 2008

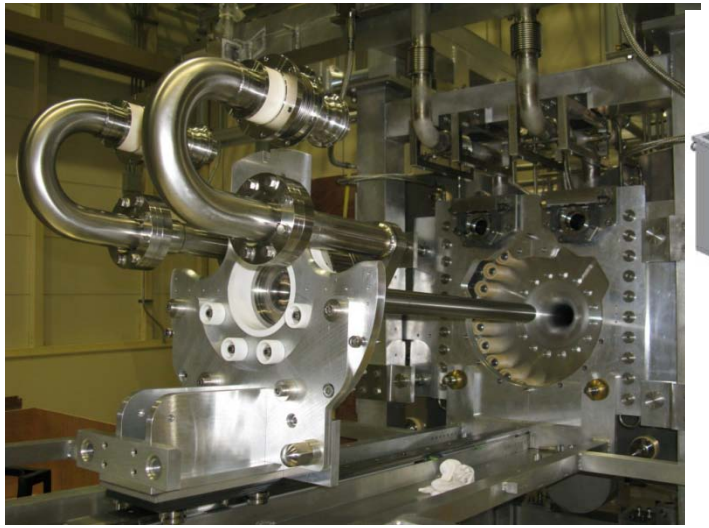
top

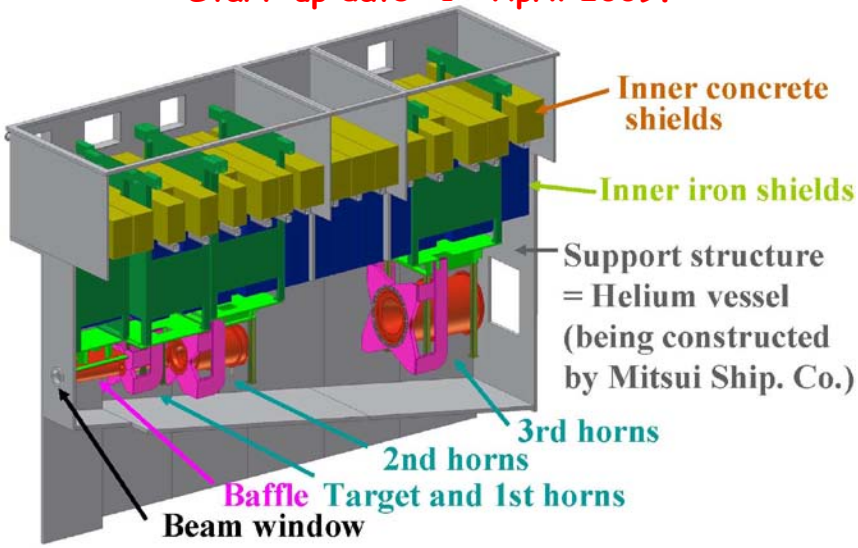
09:00	Target Imbed in Horn (45') (Slides)	Nikolaos Simos (*BNL*)
09:45	SPL Collection system (45') (Slides)	Marcos Dracos (*IPHC-IN2P3/CNRS*)
10:30	Design and Operational Features of a Mercury Target Facility (45') (Slides)	Van Graves
11:15	Hg Beam Dump issues (45') (Slides)	T. Davenne
12:00	Muon Production efficiency (45') (Slides)	Harold Kirk (*BNL*)
14:00	Workplan and summary (2h00') (document ; pictures) (Room 112-R-028 PLEASE note room change !)	All

T2K Target (C. Densham, RAL)

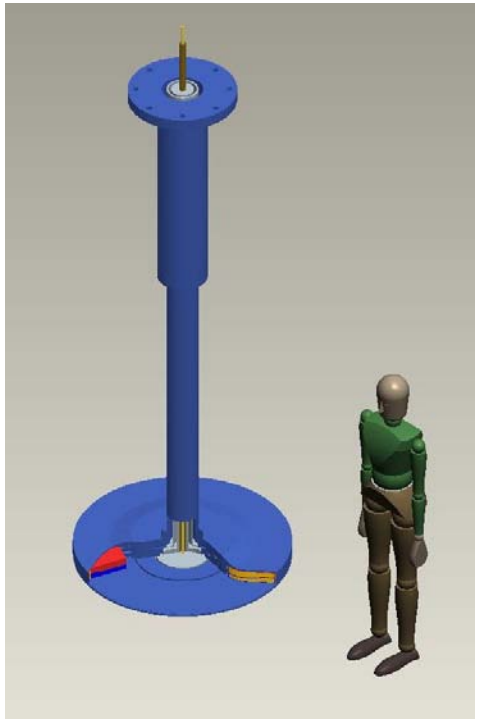


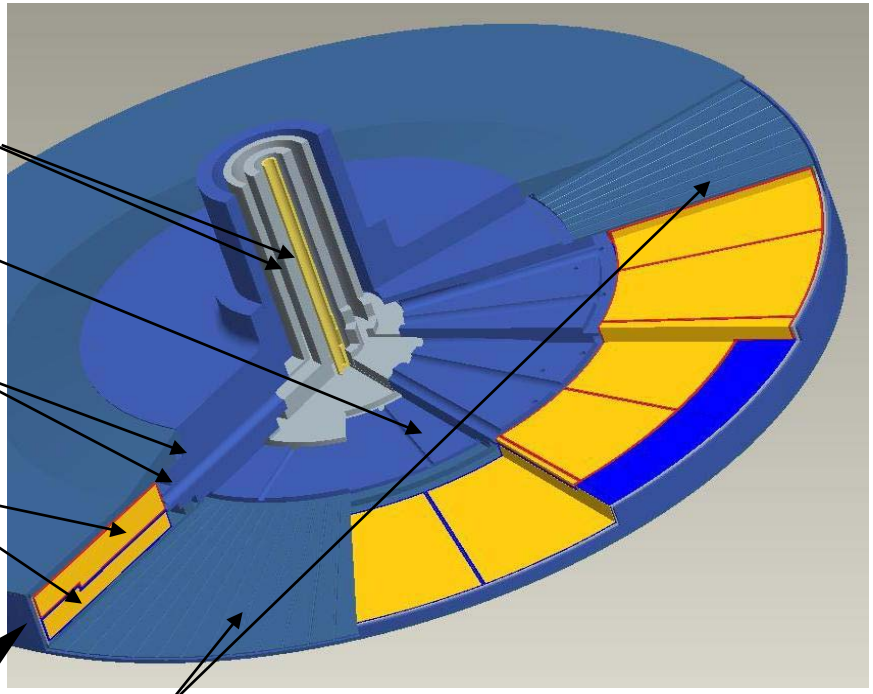
- Graphite rod, 900 mm (2 int.lengths) long, 26 mm (c.2σ) diameter.
- 20 kW of 750 kW Beam Power dissipated in target as heat.
- Helium cooled (i) to avoid shock waves from liquid coolant,s e.g., water and (ii) to allow higher operating temperature.
- Target rod completely encased in titanium to prevent oxidation of the graphite.
- Pressure drop ~ 0.8 bar available for flow rate of 32 g/s.
- Target to be uniformly cooled at ~400°C to reduce radiation damage.
- Can remotely change the target in the first horn.
- Start-up date: 1st April 2009.





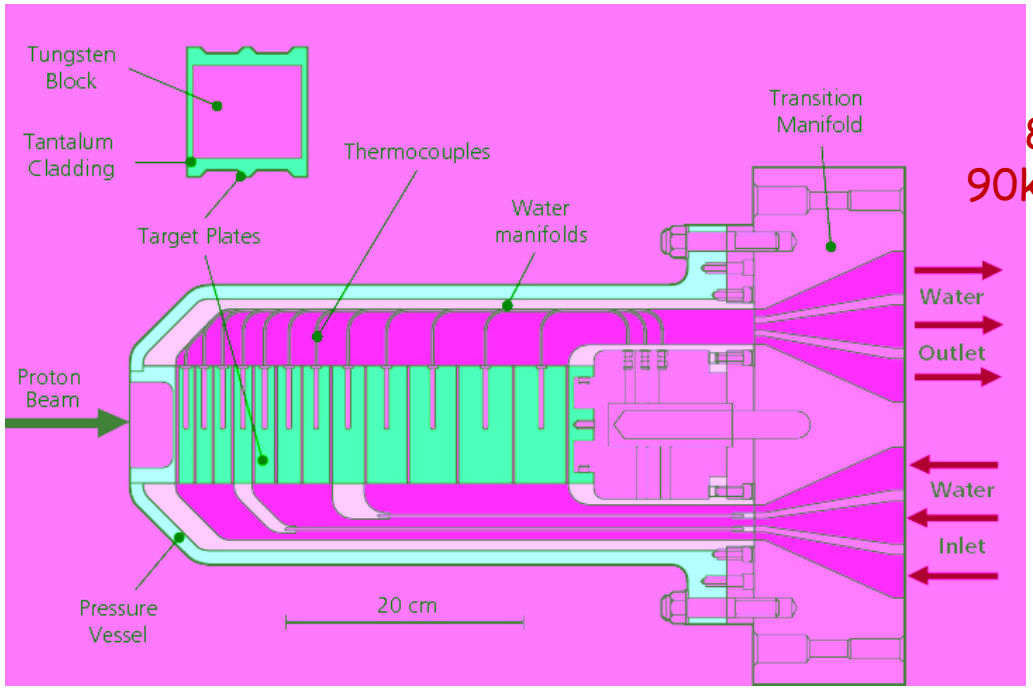
SNS 3-MW Target Option (Rennich, ORNL)





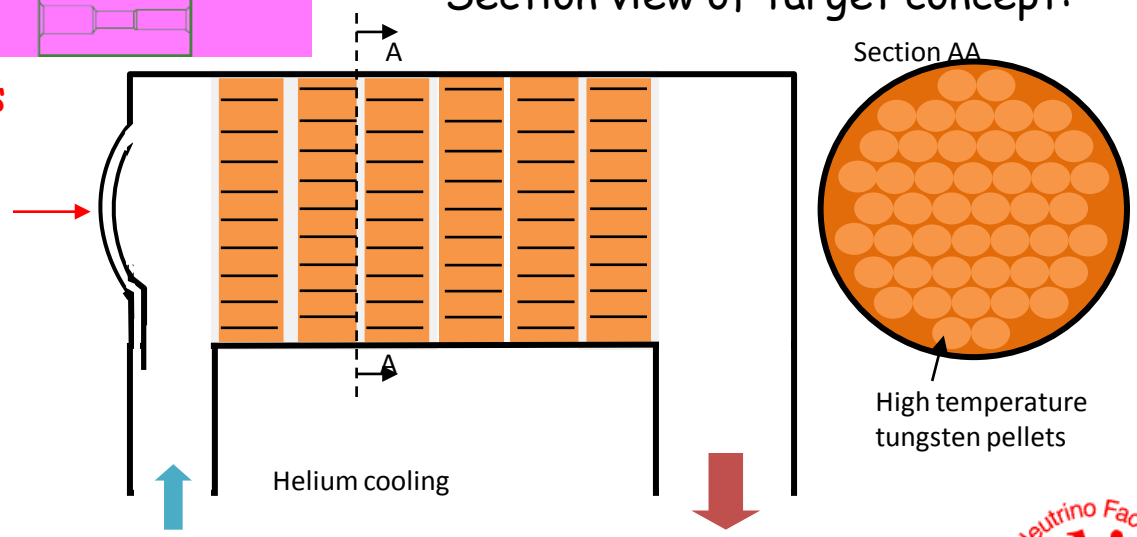
30 rpm with 20-Hz pulse frequency and 1-μs pulse length, 7-cm diameter.
Water cooled by 10-gpm total flow.
Design life: 3 years.

Pelletized Target Option for ISIS (T. Davenne, RAL)



800MeV, 160kW, 50Hz
90kW heat removed in water

Section view of target concept:



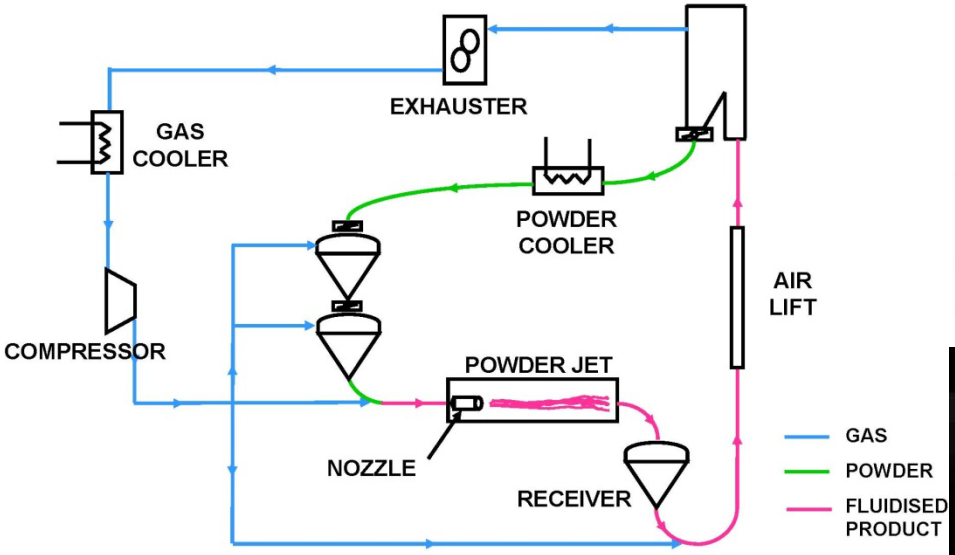
Target being in pellet form allows high temp operation without high stresses

No cooling water to moderate neutron flux

Scope for more than 160kW?
Ref: Sievers (2003)

Fluidized Powder Targets (O, Caretta, RAL)

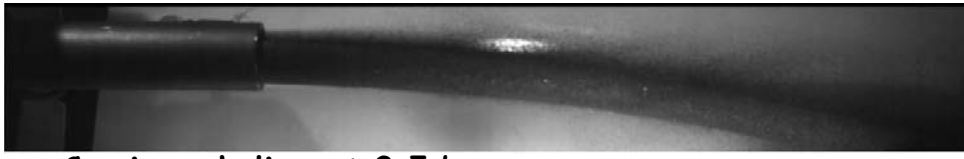
- Powders propelled (fluidized) by a carrier gas flow somewhat like liquids.
- Powder grains largely unaffected by magnetic fields (eddy currents).
- Flowing powder density ~ 30% of solid.



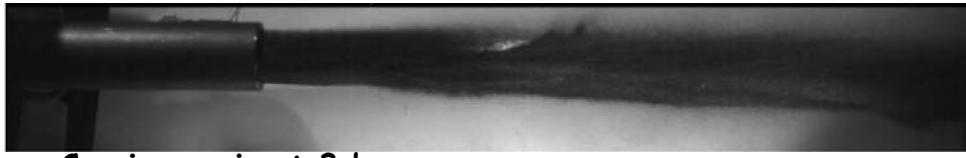
- Mechanics of a quasicontinuous flow system are intricate, but good industry support.
- Erosion a critical issue: ceramic inserts?

Carrier = helium at 1.5 bar

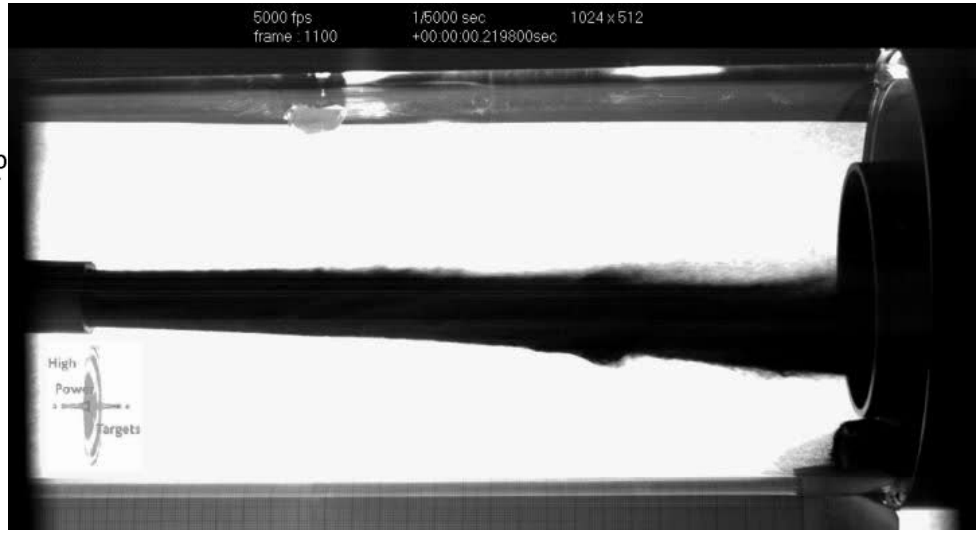
Carrier = helium at 2.5 bar



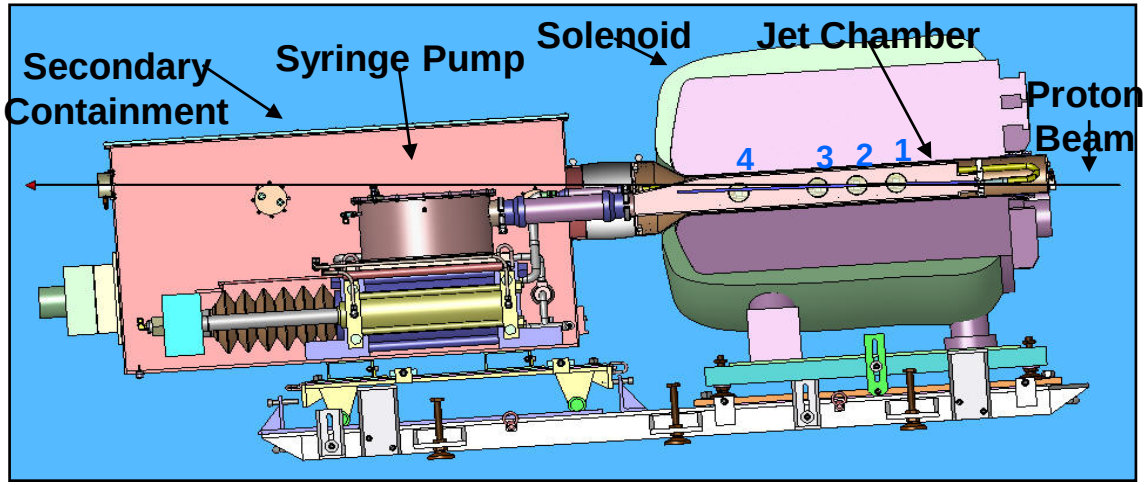
Carrier = helium at 3.5 bar

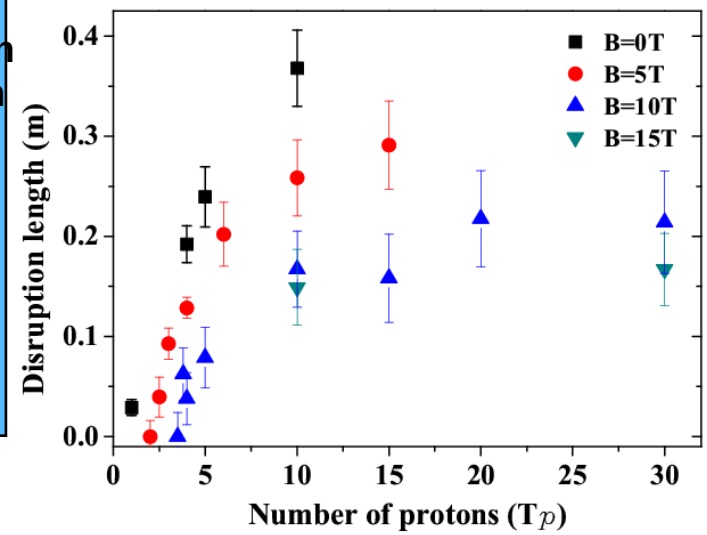


Carrier = air at 3 bar



CERN MERIT Experiment (Park, BNL)

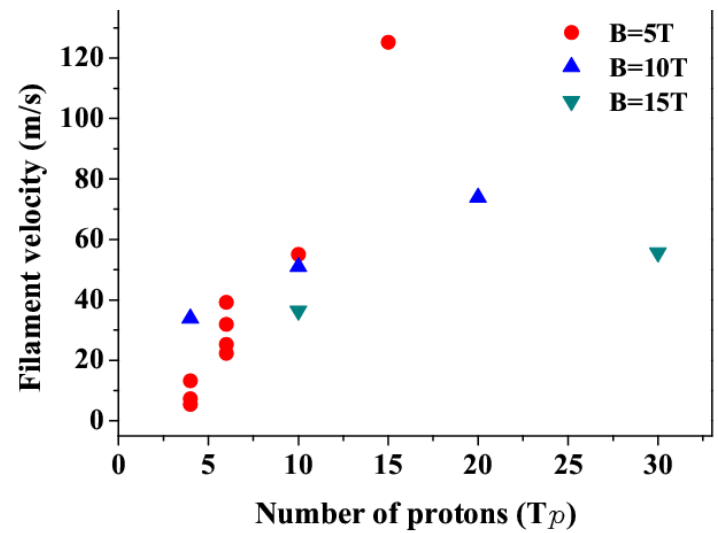




Proof-of-principle demonstration of a mercury jet target in a strong magnetic field, with proton bunches of intensity equivalent to a 4 MW beam.

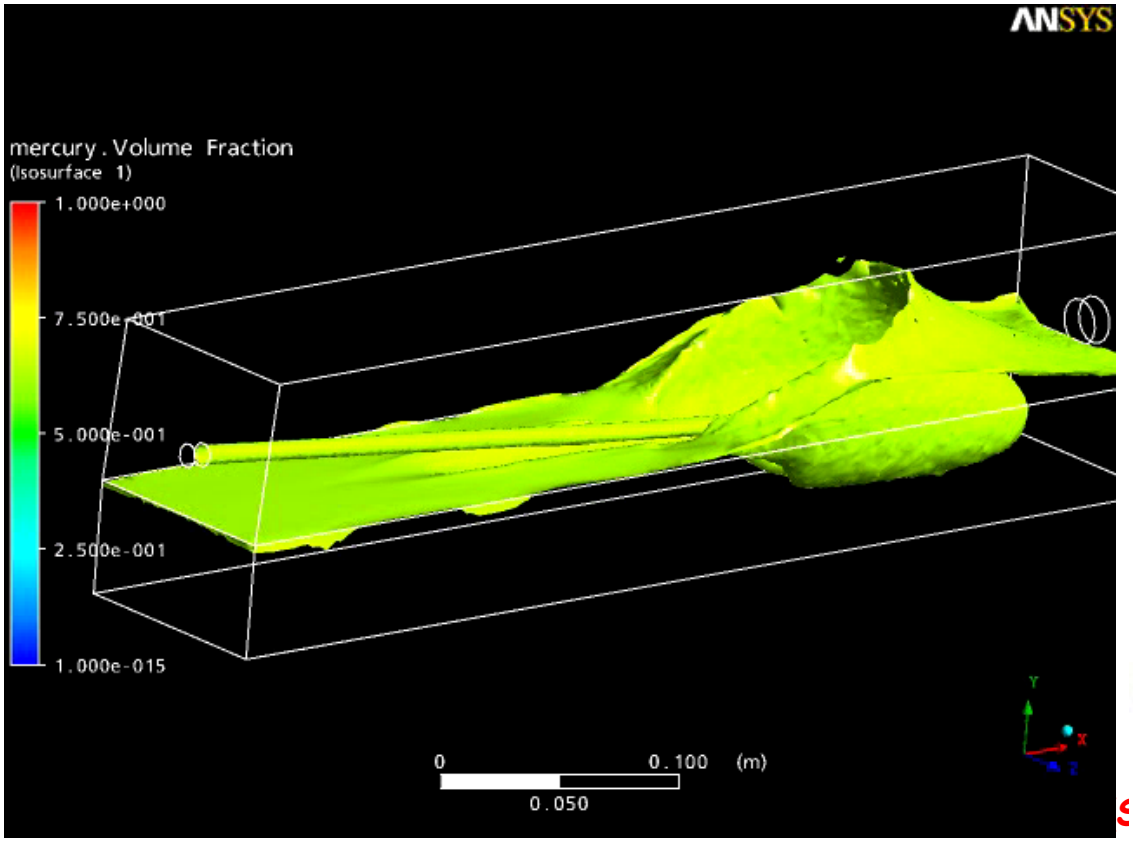
Jet disruption suppressed (but not eliminated by high magnetic field.

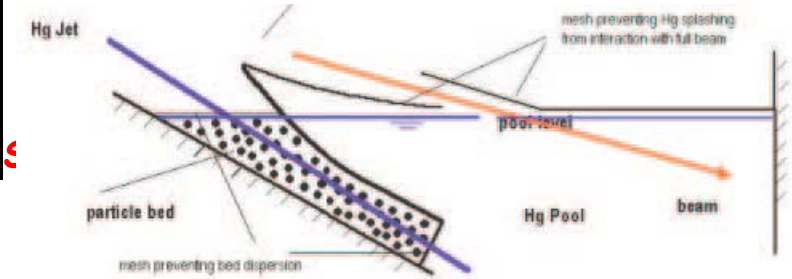
Particle production remains nominal for several hundred μs after first proton bunch of a train.



Mercury Beam Dump Simulations (T. Davenne, RAL)

A 20-m/s mercury jet causes significant agitation as it enters the mercury collection pool.





IDS

IDS

- IDS Goals
  - Specify/compute physics performance of neutrino factory
  - Define accelerator and detector systems
  - Compute cost and schedule
  - Identify necessary R&D items
- IDS Deliverables
  - Interim design report (c. 2010)
    - Engineering designs for accelerator and detector systems
    - Cost and schedule estimates
    - Work plan to deliver reference design report
      - Report production itself
      - Outstanding R&D required
  - Reference design report (c. 2012)
    - Basis for a "request for resources" to get serious about building a neutrino factory

IDS Overview

- **International Scoping Study ν-Factory parameters**
  - ~4MW proton souce producing muons, accelerate to 20+ GeV, long baseline mu decay lines (2500/7500km)
- **International Design study- develop that into an engineering design**
  - cost specification
- **Front end (Target to Linac) is based on ISS study**
  - capture/decay drift
  - μ buncher/rotator
  - ionization cooling

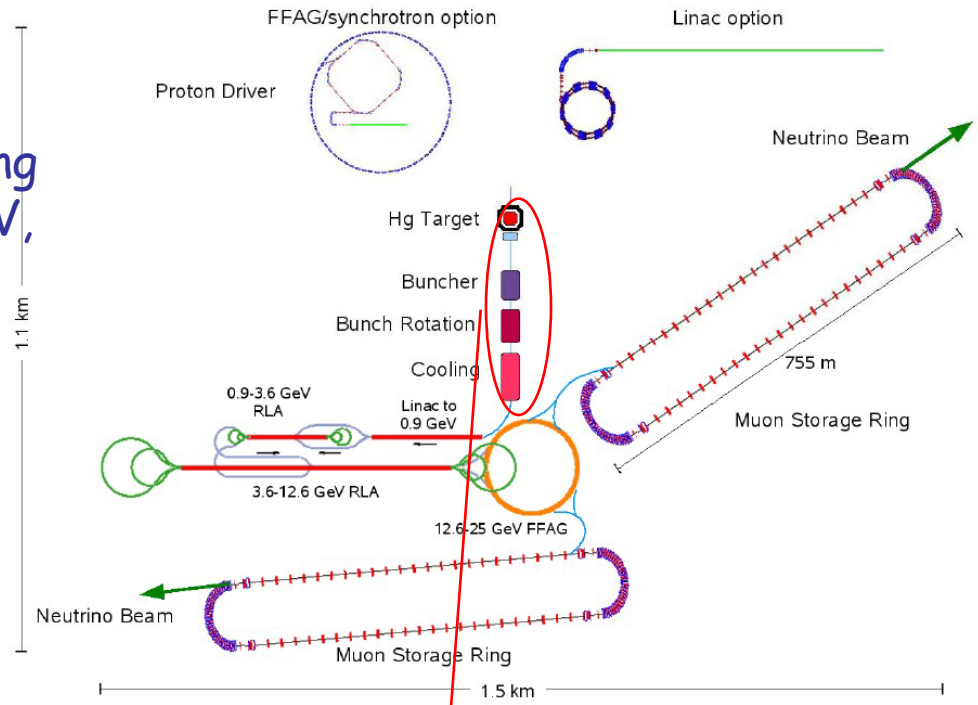
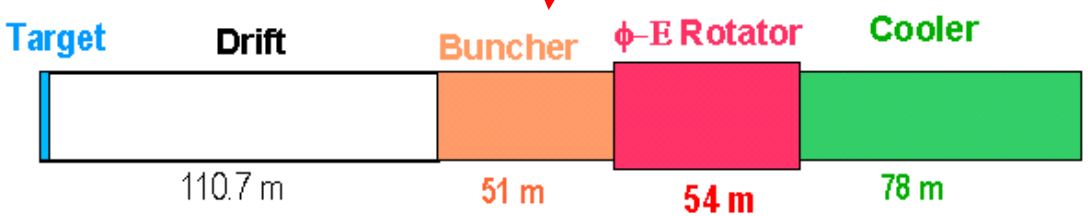
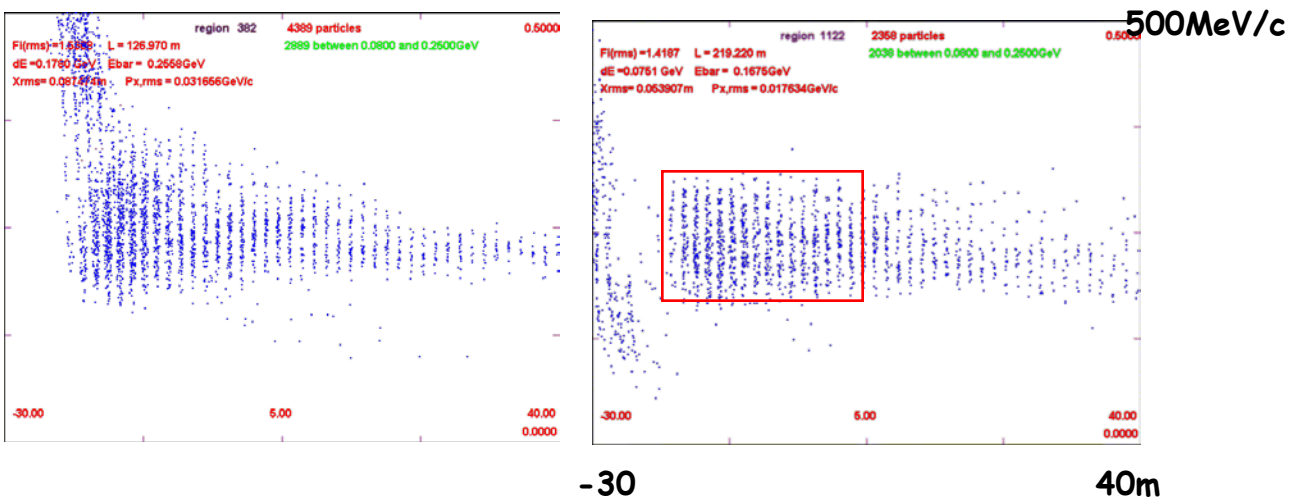


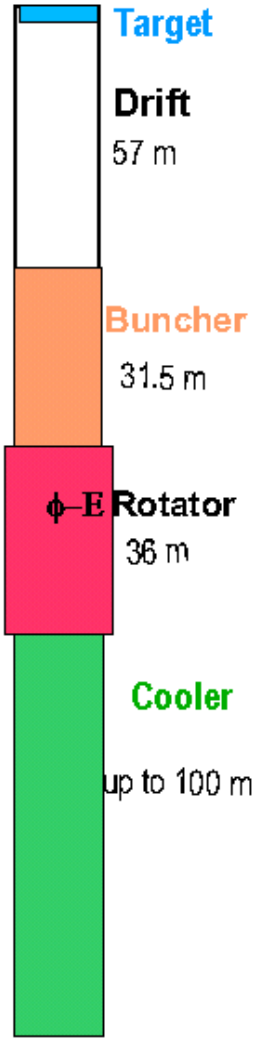
Figure 1: Schematic drawing of the ISS baseline for the Neutrino Factory accelerator complex. The various systems have been drawn to scale.



Try Shorter Buncher

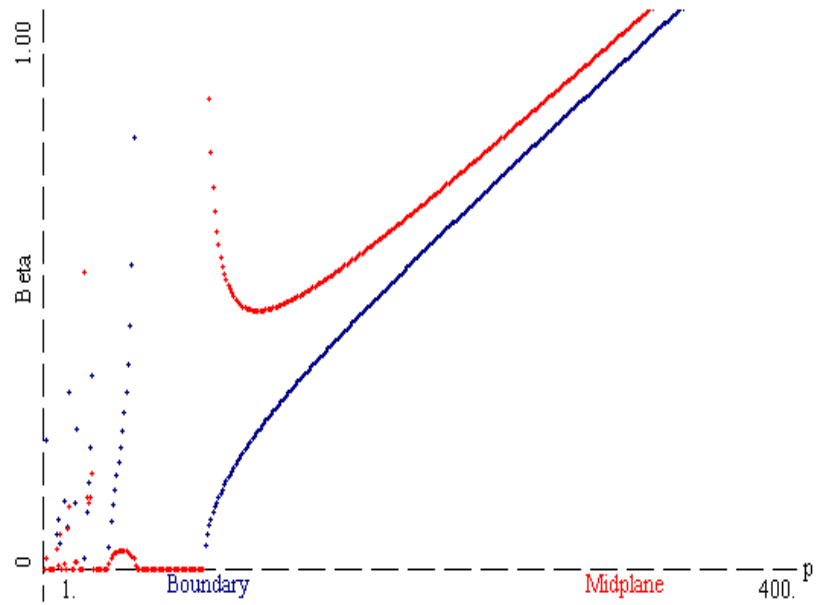
- Reduce drift, buncher, rotator to get shorter bunch train:
  - 217m ⇒ 125m
  - 57m drift, 31m buncher, 36m rotator
  - Rf voltages up to 15MV/m (×2/3)
- Obtains ~0.25 μ/p_{24} in ref. acceptance
- 80+ m bunchtrain reduced to < 50m
  - ΔN_B: 18 -> 10
- More suitable for collider





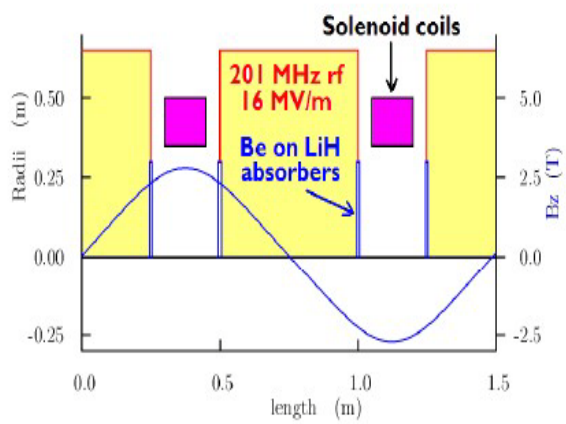
Use ASOL lattice rather than 2T

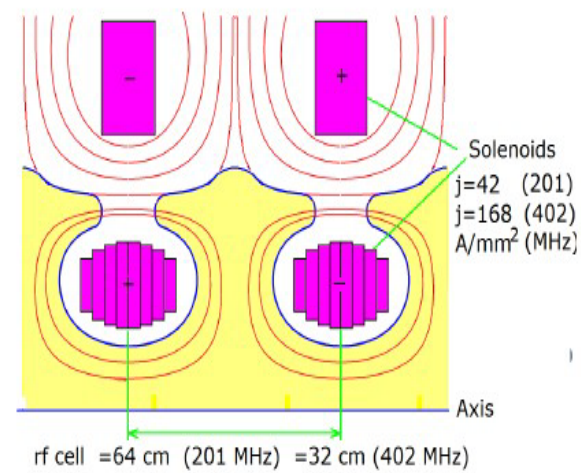
- "magnetically insulated" lattice similar to alternating solenoid



- Study 2A ASOL
  - B_{max}= 2.8T, β^*=0.7m,
  - P_{min}= 81MeV/c
  - 2T for initial drift
  - Low energy beam is lost
    - (P < 100MeV/c lost)
    - Bunch train is truncated
  - OK for collider

- Magnetic focusing similar to magnetically insulated

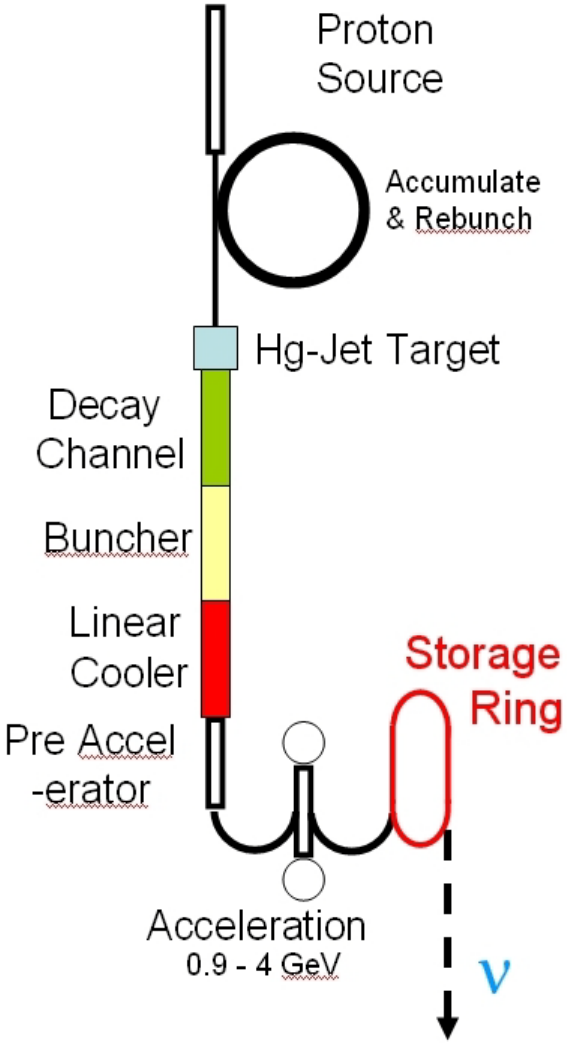




Variation: 4 GeV ν-Factory

- Use magnetized totally active scintillator detector
- 4 GeV muons provide adequate neutrino beam for detector
- Fermilab to DUSEL (South Dakota) baseline -1290km

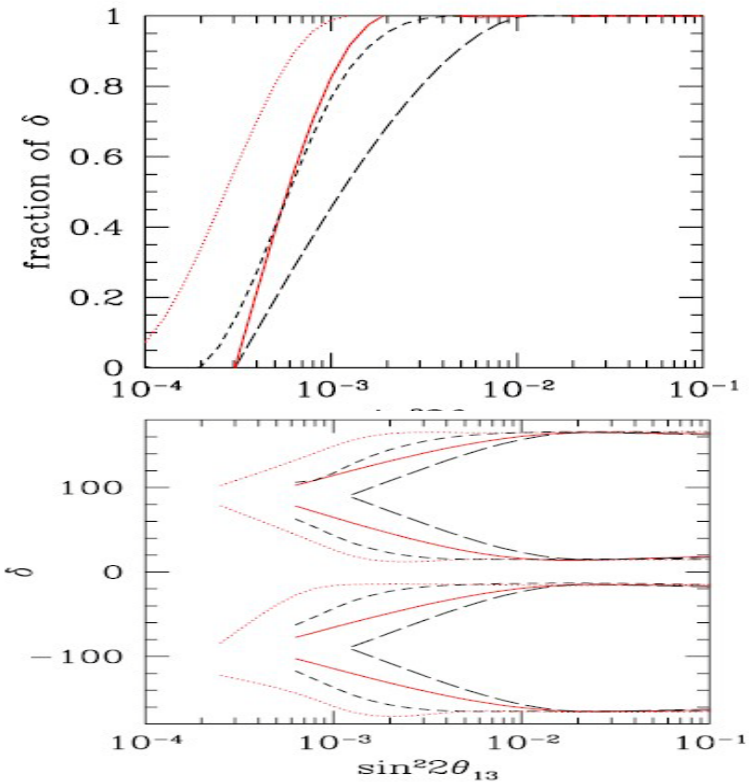
A. Bross et al.
Phys. ReV D 77, 093012 (2008)

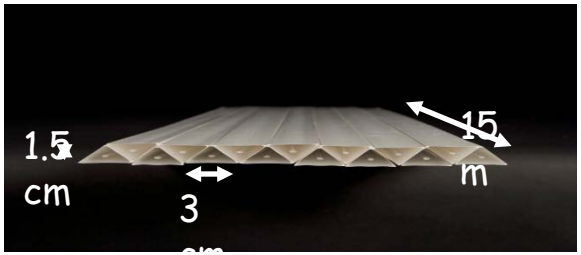


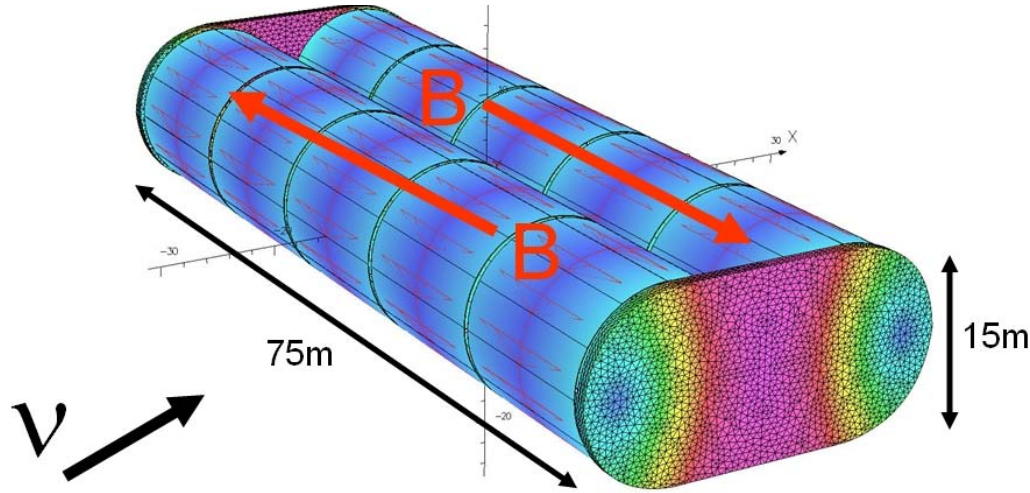
C. Ankenbrandt et al.
Fermilab-Pub-09-001-APC

Detector, Sensitivity

- Factory at Fermilab, Detector at Homestake, SD
  - ~1290km baseline
- Totally Active Scintillator Detector
  - ~20000 m^3
- B=0.5T magnetic field
  - easily identify charge and identify particles
- ν's from 4 GeV μ's
  - ~0.5GeV ν's
  - no charged τ

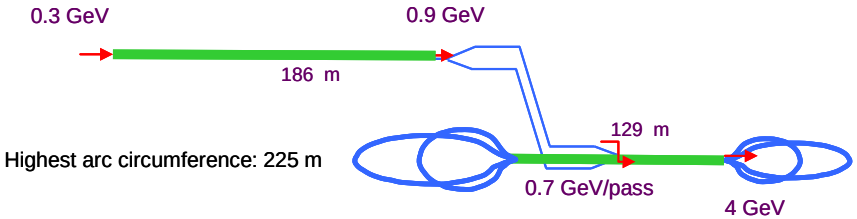




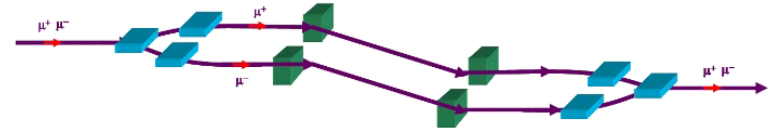


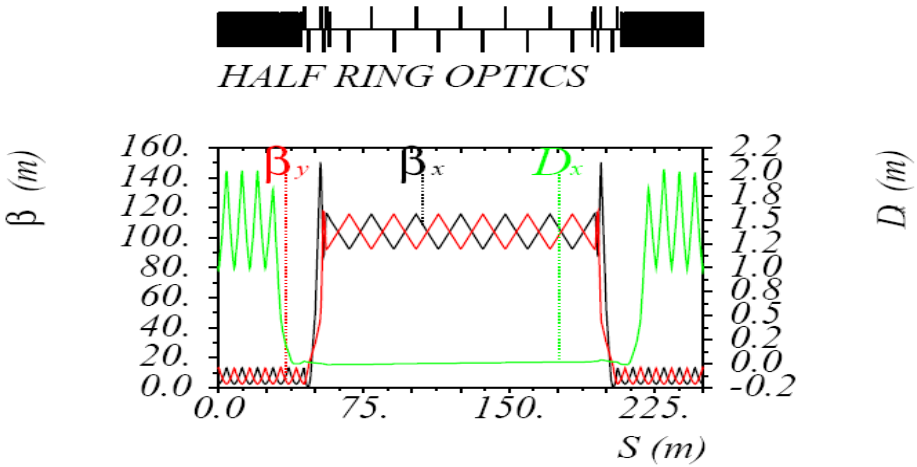
4 GeV Neutrino Factory

- **Acceleration** (A. Bogacz)
  - Linac + RLA ~0.3 GeV to 4 GeV
  - accelerates both μ^+ and μ^-
  - no FFAGs



- **Storage Ring** (C. Johnstone)
  - C = 900m, r = 15cm
    - half the circumference
  - B < ~1T
    - conventional or permane magnet





Design and Simulation

Muon Collider Design Workshop - Summary

Alex Bogacz

Muons, Inc.
Innovation in Research

Muon Collider Task Force

Sponsorship support provided by Muons, Inc.

Motivation & Goals

The annual Muon Collider Design Workshop (previously hosted at BNL) is aimed at bringing together all the groups working on various designs for Muon Colliders. The goal is to **review and assess the current state of the concepts, simulation work and experiments**. We shall examine practical limits on the performance of required technologies in attempt to focus future efforts towards a baseline collider scenario. The workshops will cover topics such as:

- Proton drivers
- Muon cooling and demonstration experiments
- Bunch recombination
- Muon acceleration schemes
- Collider Ring and Interaction region design
- Site boundary radiation
- Detector concepts for energy frontier

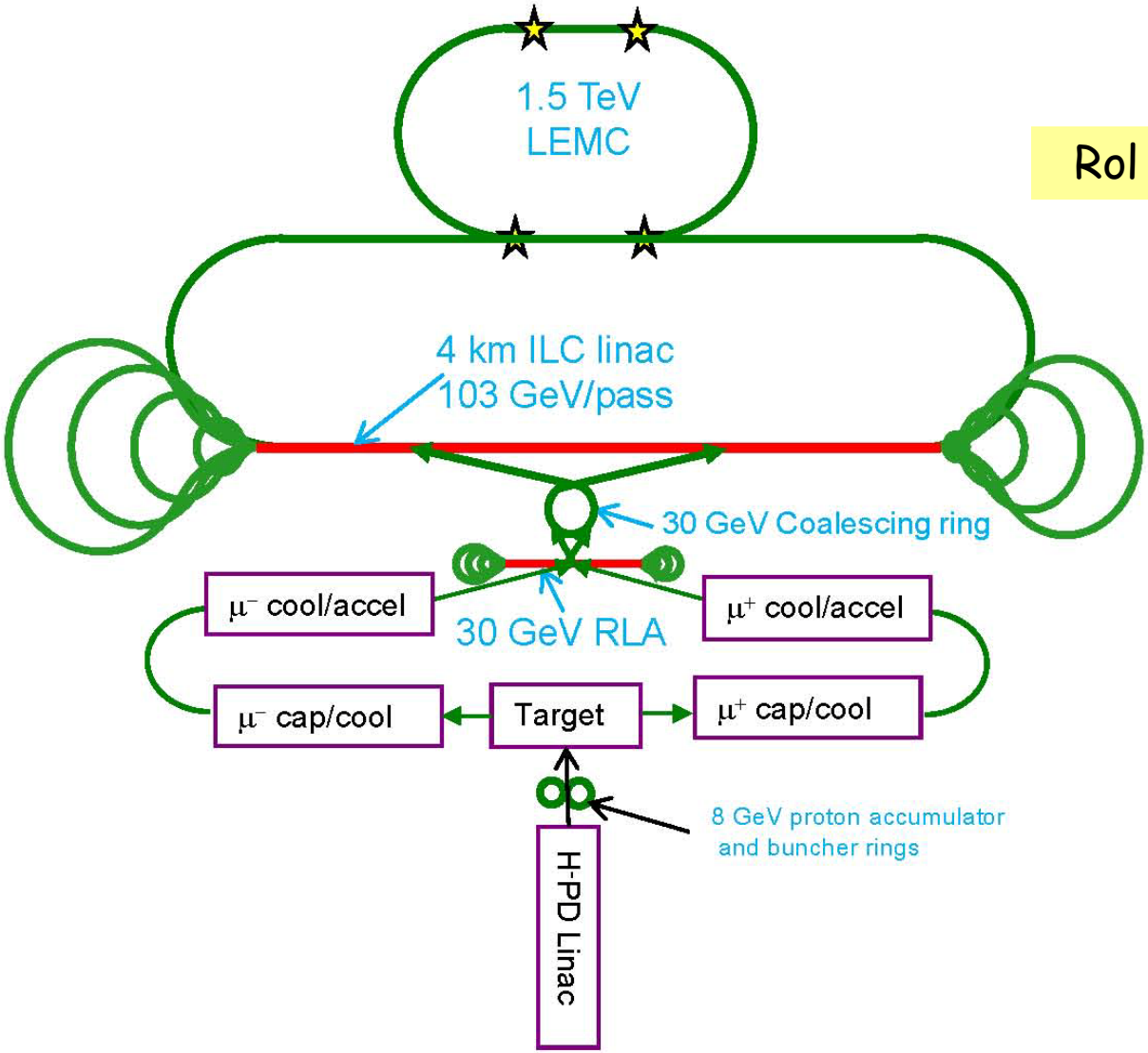
Program - Sessions

- COLLIDER SCENARIOS
- PROTON DRIVER & RF
- COOLING SIMULATIONS
- FINAL COOLING
- ACCELERATION
- INTERACTION REGION
- EXPERIMENTS & PLANS
- SUMMARIES

Participants – *The Usual Suspects*

LEMC Scenario

Rol Johnson

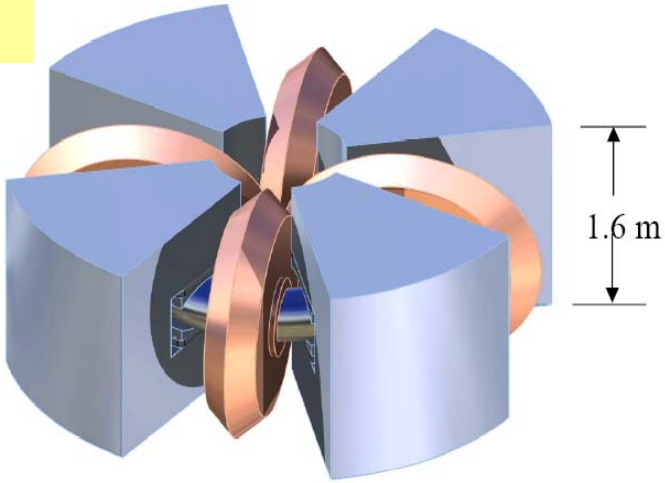


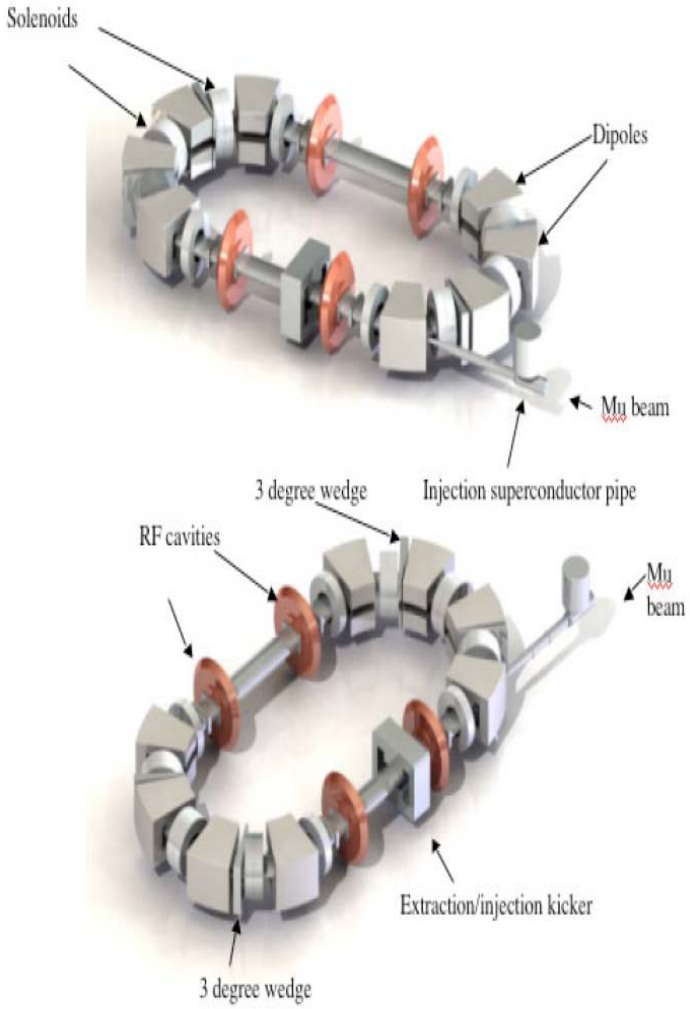
Parameters of Different MC options

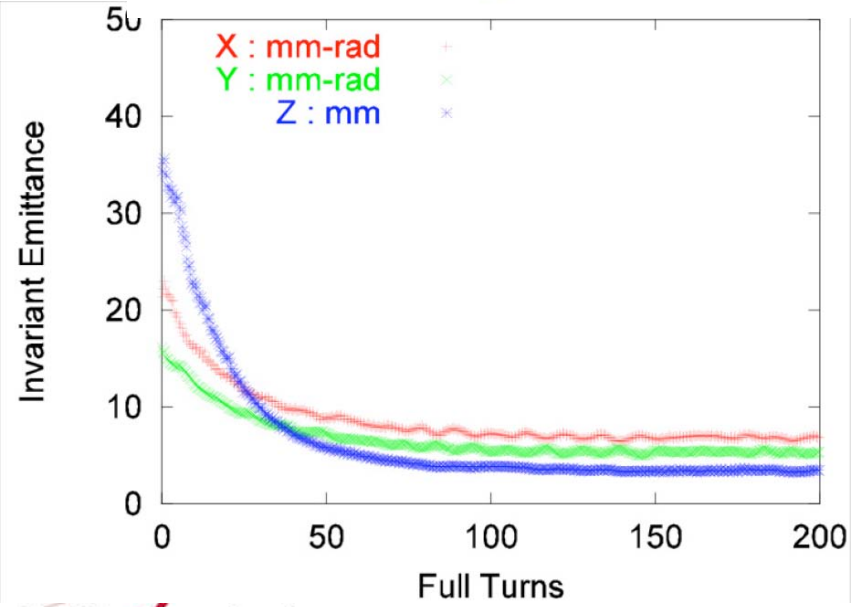
	Low Emit.	High Emit.	MCTF07	MCTF08	
$\sqrt{s}$ (TeV)		1.5			
Av. Luminosity ($10^{34}/cm^2/s$) *	2.7	1	1.33-2		
Av. Bending field (T)	10	6	6		
Mean radius (m)	361.4	500	500 $\Rightarrow$	495	
No. of IPs	4	2	2		
Proton Driver Rep Rate (Hz)	65	13	40-60		
Beam-beam parameter/IP	0.052	0.087	0.1		
β^* (cm)	0.5	1	1		
Bunch length (cm)	0.5	1	1		
No. bunches / beam	10	1	1		
No. muons/bunch (10^{11})	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) at 800MHz		$407\times10^3\alpha_c$	0.21**	0.84** $\Rightarrow$	$0.3^\dagger$
Muon survival $N\mu/N\mu0$		0.31	0.07	0.2	?
μ+ in collision / proton		0.047	0.01	0.03	?
8 GeV proton beam power	3.62***	3.2	1.9-2.8	?	

Study of Ring Coolers for μ+ μ- Colliders

David Cline



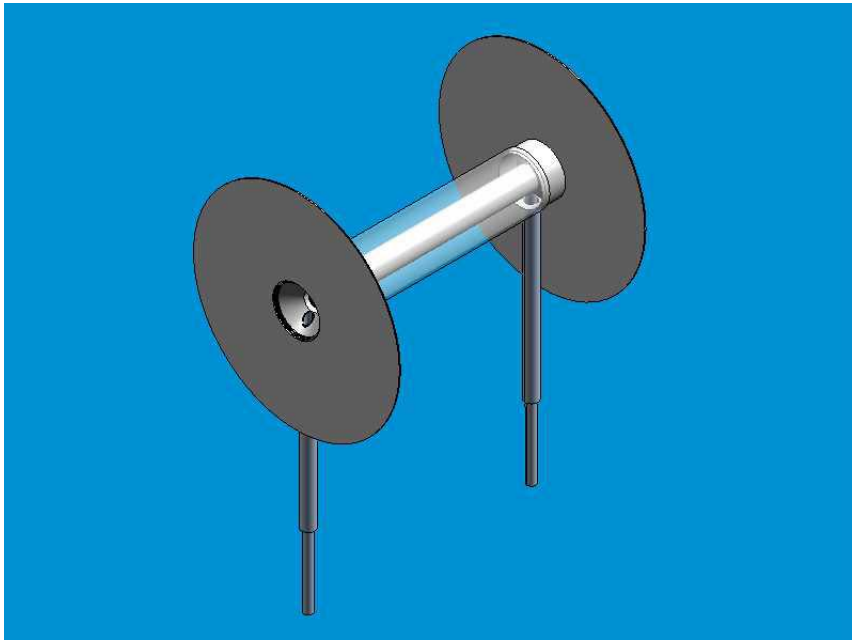


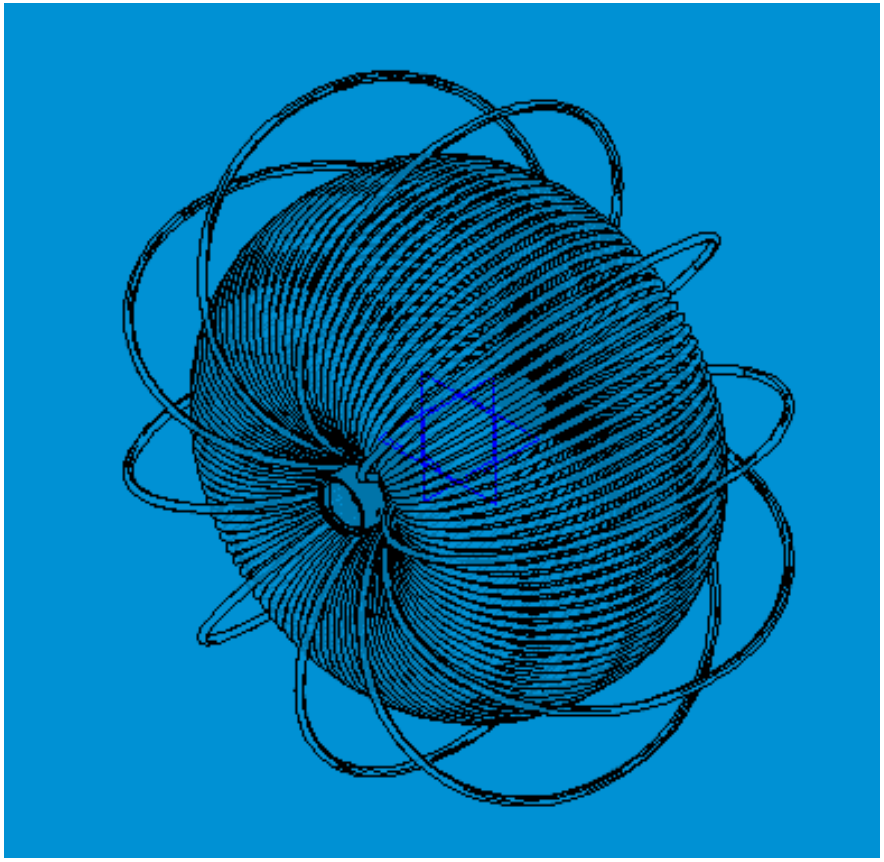


Lithium Lens for Muon Final Cooling

Kevin Lee

Initial Design of Liquid Li Lens



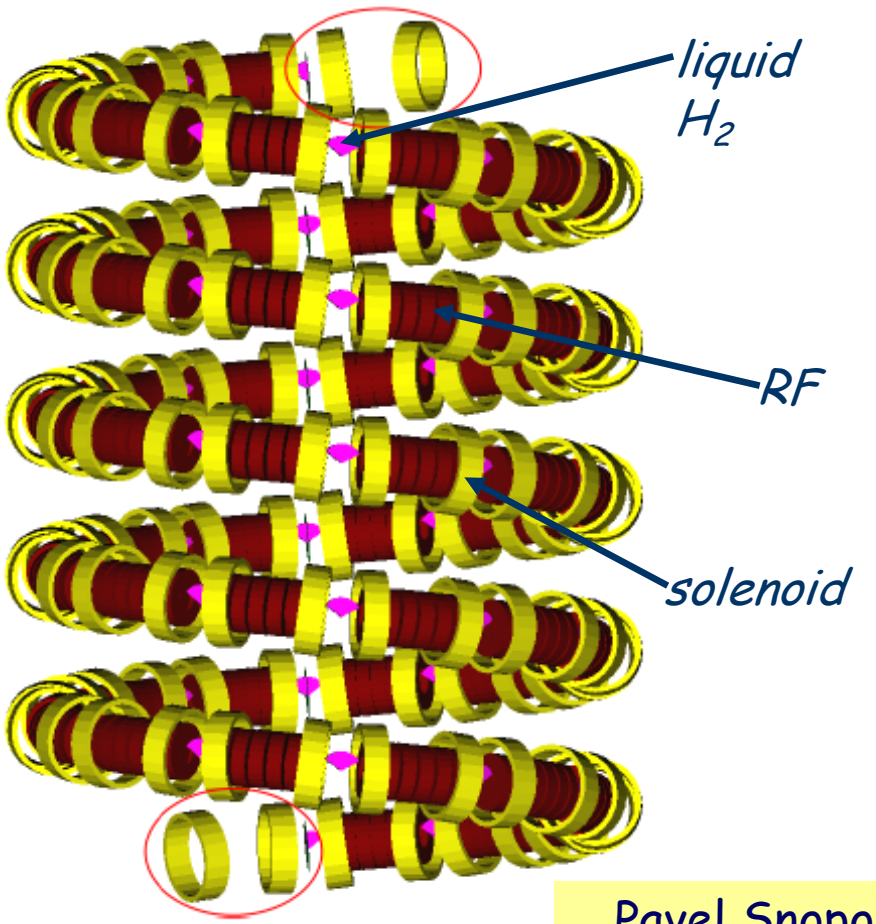


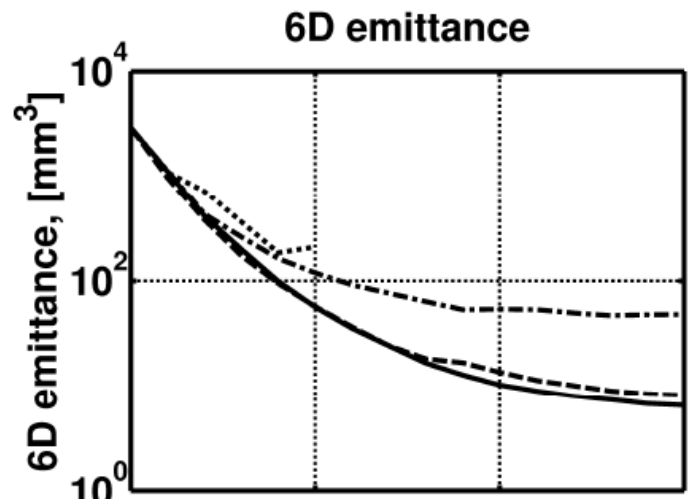
Lens assembly w/ current discs and the primary and secondary coils

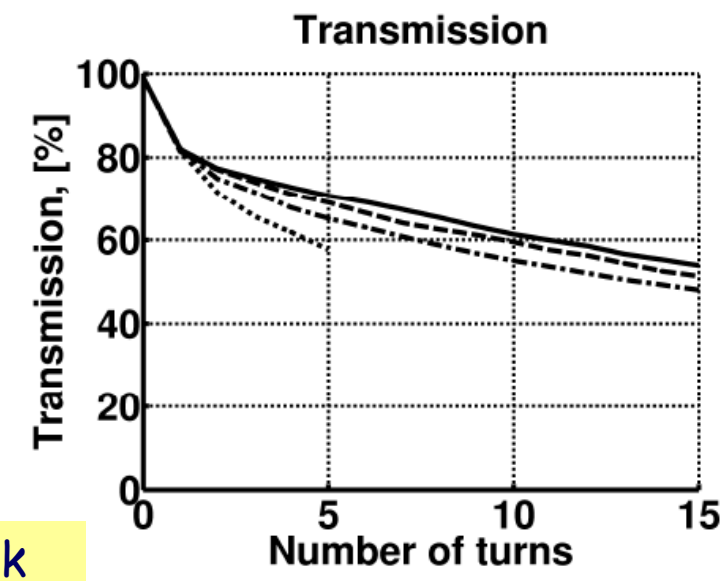
Li D = 2.54 cm; L = 30.0 cm

Progress on Guggenheim RFOFO - Simulations

Multilayer scheme



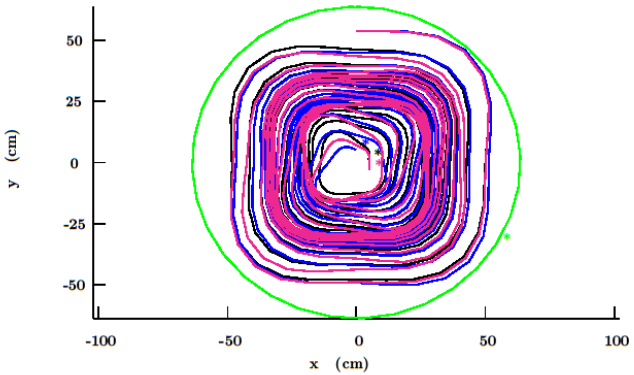




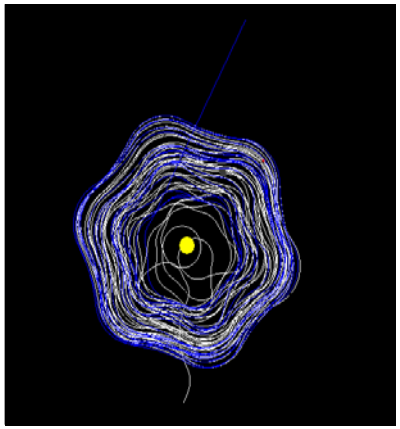
Pavel Snopok

Simulations of Muon Cooling With an Inverse Cyclotron

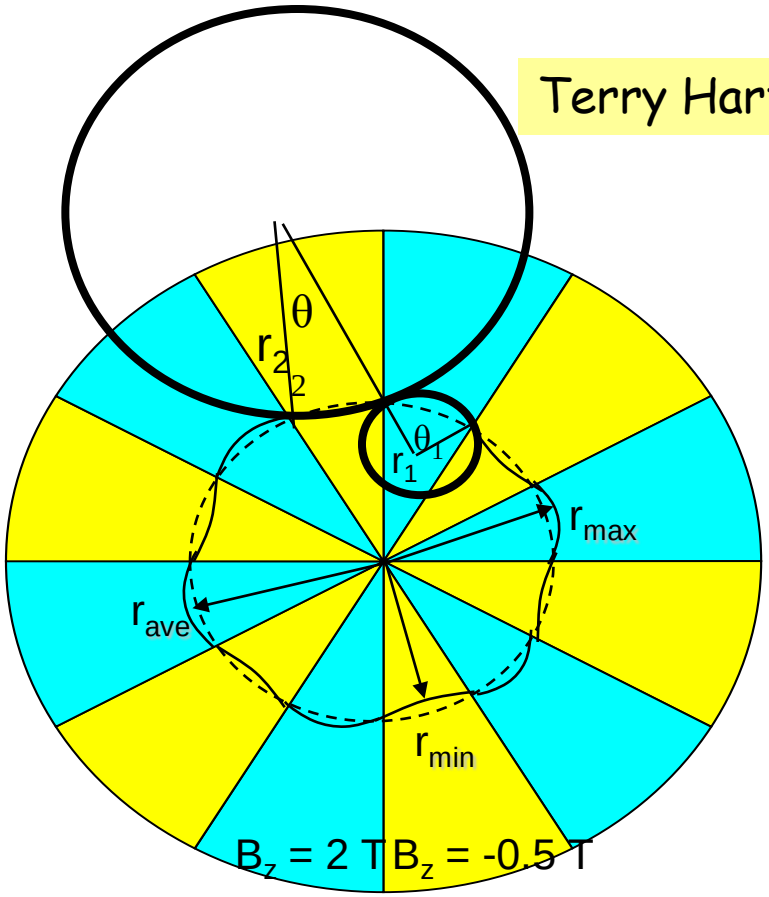
R. Palmer's ICOOL model



G4beamline model



Terry Hart

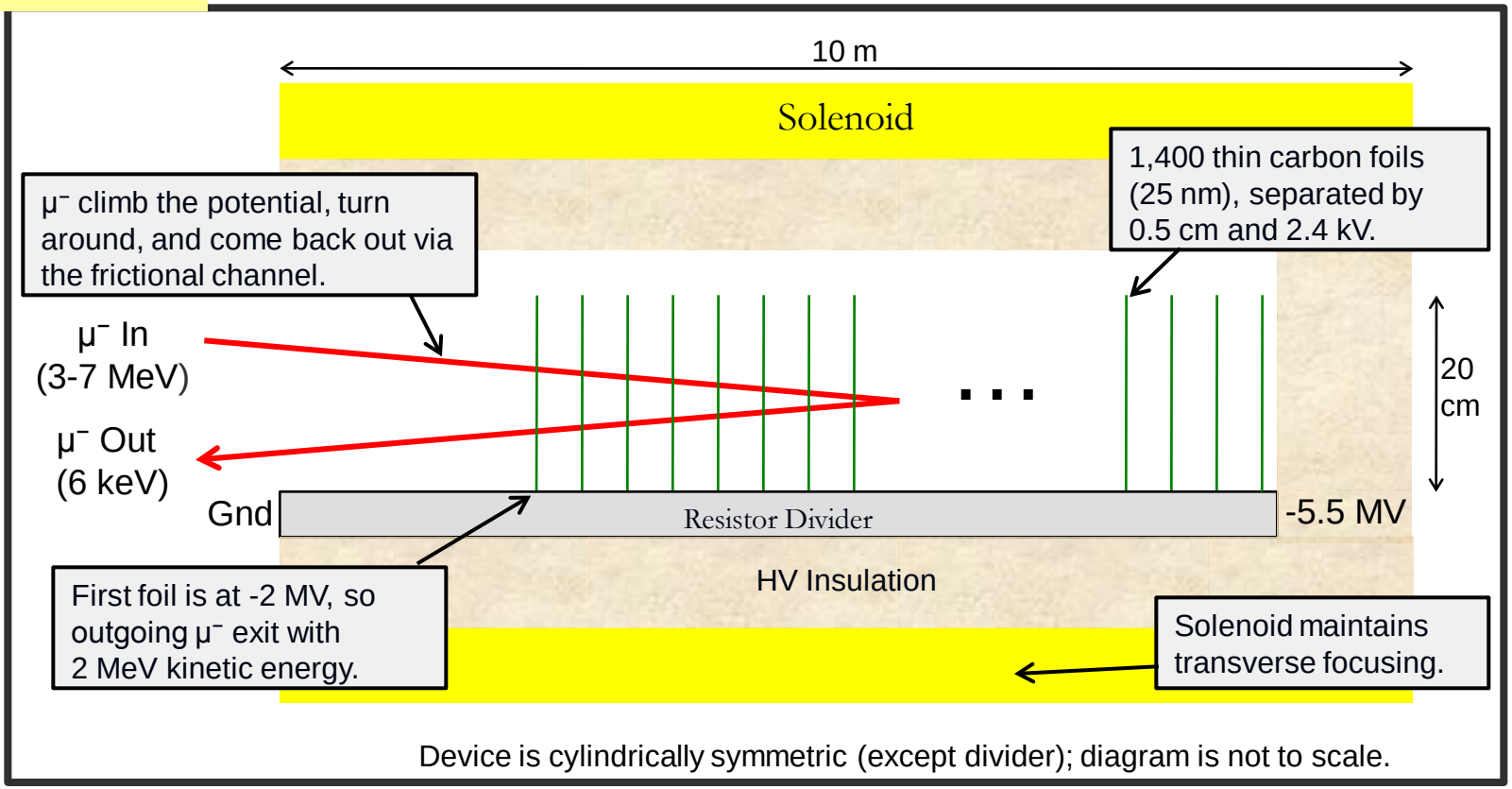


VORPAL 3D Simulations with space-charge

Kevin Paul

Frictional Cooling

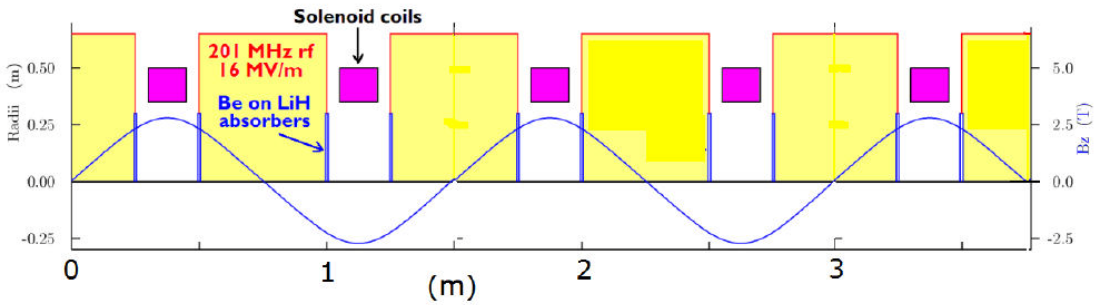
Tom Roberts

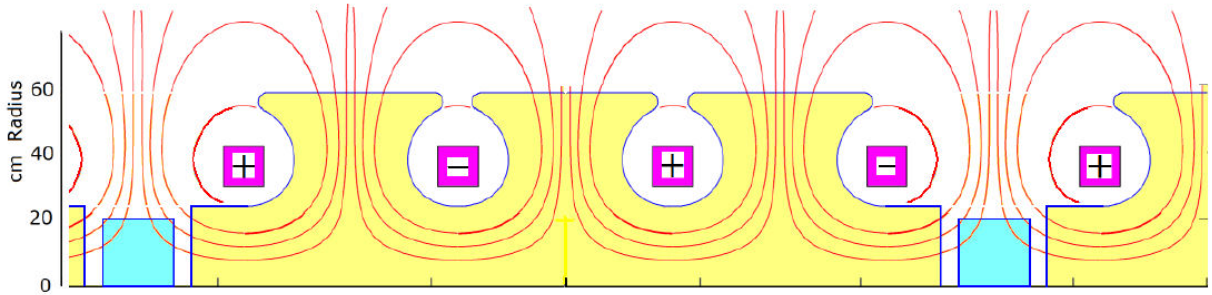


Remember that 1/e transverse cooling occurs by losing and re-gaining the particle energy. That occurs every 2 or 3 foils in the frictional channel.

Magnetic Insulation

Mag insulated Pre-cooling Lattice

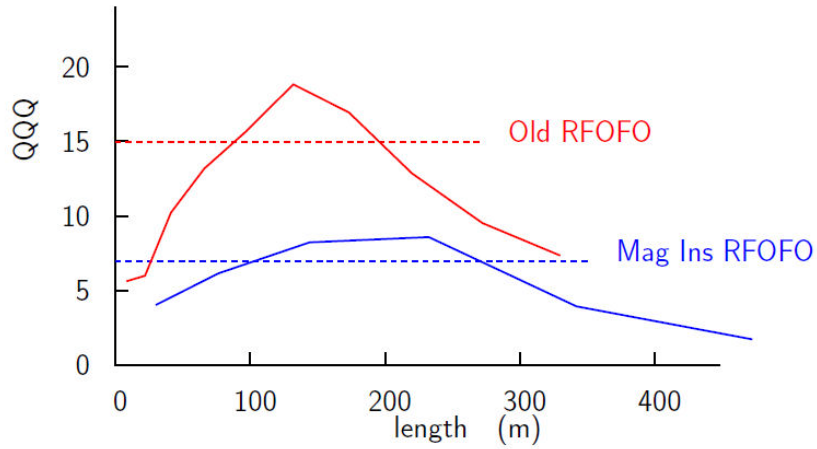




- Fields on axis are identical
- So losses expected to be the same

Magnetic Insulation II

Compare Lattices for 201 & 402 MHz 6D cooling



	freq MHz	Cell m	Bz_{max} T	B_{coil} T	$< \mathcal{E} >$ MV/m	ϵ_{min} π mm rad	Q_{max}	$Q_{assumed}$	Trans %
Old RFOFO	201	2.75	3	5	8.6	2.2	18.5	15	7.5
Mag Ins RFOFO	201	3.0	3.2	6	7.9	3.7	8.6	7	3.3

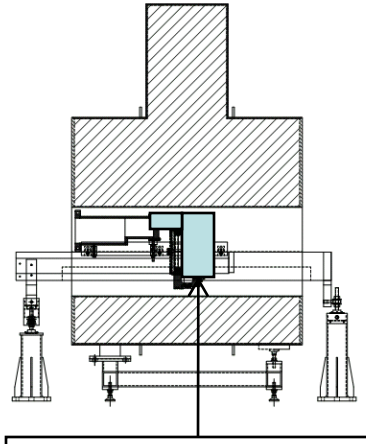
- Poor performance of Mag-Ins could be an ICOOL artifact
- But if real, makes Mag-Ins unsuitable for early 6D Cooling
- Final cooling is another matter

16

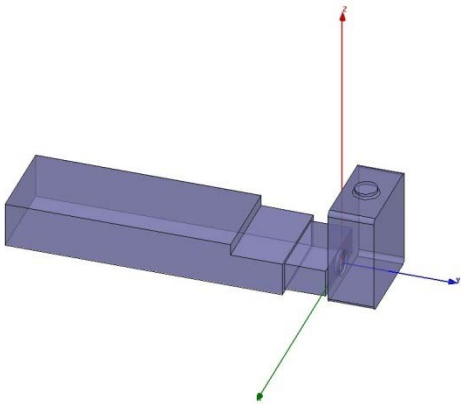
Long-Range Planning

Thinking Ahead

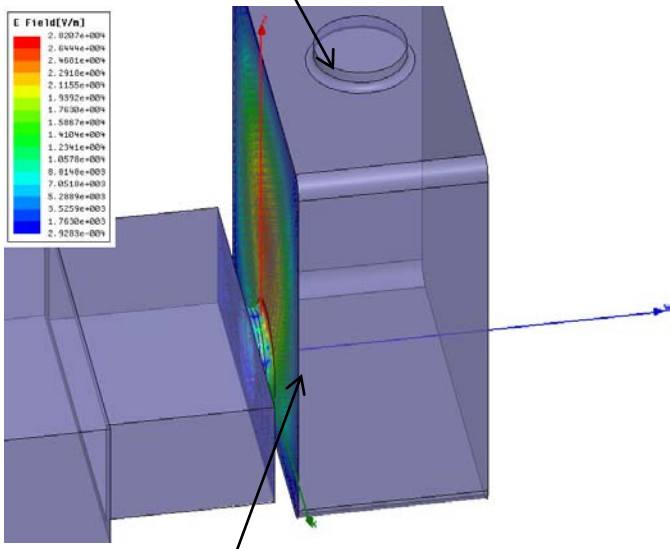
Parallel E and H case



Drawing Not to scale



Not present Final design



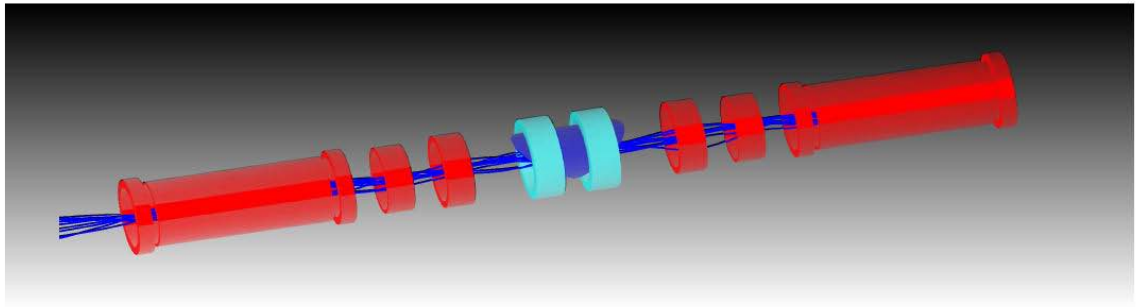
Rectangular aperture final design

A solution exists but with circular apertures. It needs to be calculated with rectangular apertures. The plot shows that the highest peak field is at the radius of the coupling aperture. This is the reason to study the rectangular coupling aperture.

6D Cooling in MICE

Simple Wedge

- Simple wedge
  - Induce dispersion in input beam
  - Measure (reverse) emittance exchange
- To what purpose?
  - "Proof-of-principle" - demo for wider community
  - Test material physics model in a different geometry
- Open questions
  - Which material?
  - What opening angle?
  - Can we measure an effect?



Extensions to MICE

Possible Experimental Goals

	MICE	MICE-IV Wedge	MICE-Tilt	HP Gas	BField-MuScat	MANX	None
Accelerator Demonstration							
Ionisation Cooling Demo							
Emittance Exchange Demo							
Reverse Emittance Exchange Demo							
Physics Processes							
H2 Physics Processes							
He Physics Processes							
LiH Physics Processes							
Be Physics Processes							
Physics Processes in High Bz							
Beam Dynamics							
Straight Solenoid Beam Dynamics							
Tilted Solenoid Beam Dynamics							
Helical Solenoid Beam Dynamics							
Magnetically Insulated Beam Dynamics							
PIC Beam Dynamics							
Energy Recovery							
Longitudinal Dynamics							
Engineering							
Liquid H2 Safety							
Liquid Vessel Window Design/Operation							
High Pressure Gaseous H2 Safety							
Pressure Window Design/Operation							
Be Window Design + Handling							
LiH absorber Design + Handling							
Integration of RF Equipment							
Integration of magnetically insulated RF							
Integration of high pressure RF							
Integration of HCC RF							
HCC Construction							

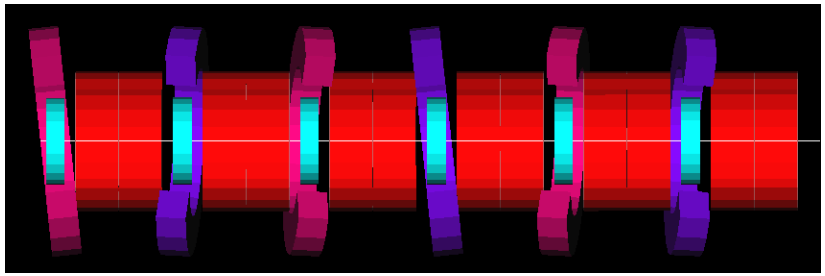
FOFO Snake Test @ MICE?

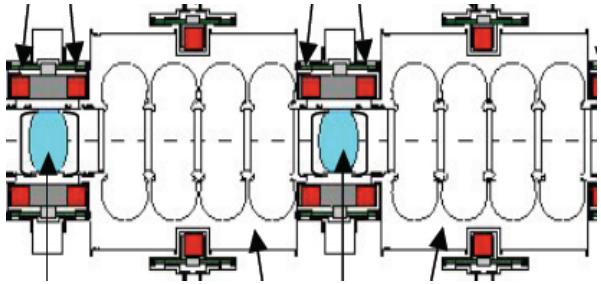
Y. Alexahin

(FNAL)

Or How to give Mike Zisman a Heart Attack
Ed. note

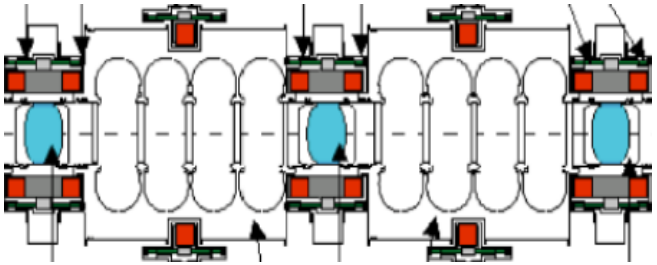
Helical Snake vs MICE

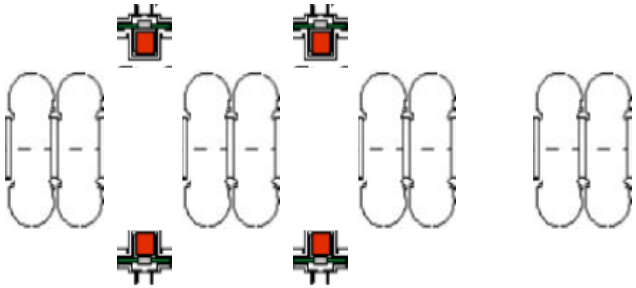




Channel parameters:	Snake	MICE	
201 MHz RF cavities	2x36cm	4x43cm	
# RF cavities / period	6	2	
Max RF gradient	16MV/m	16MV/m	
Solenoids L/ Rin/ Rout, cm	24/60/92	21/26.3/34.7	25/72.5/84.1
Current density, A/mm^2	58	114	96
Integrated current, MA	4.4	2	2.8
# Solenoids / period	6	4	2
LH2 absorbers / period	6x15cm	2x35cm	
Period length, m	6.12	5.5	

How to butcher MICE





To make 1 snake period:

- 4 more RF cavities
- 4 more coupling coils (or 6 new coils with larger cross-section)
- 6 new LH2 absorbers

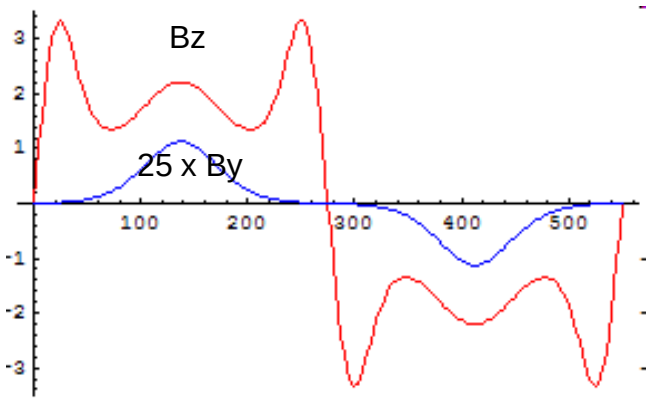
Can 6D cooling be obtained with the present MICE configuration?

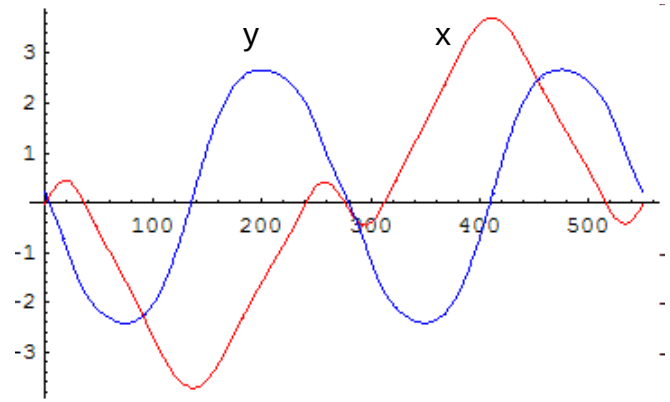
Coupling Coils Tilt

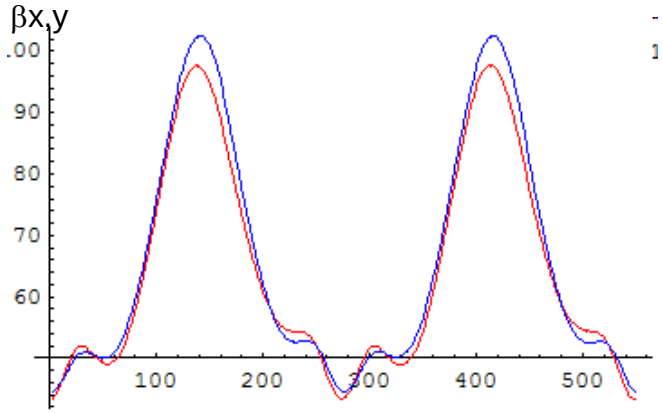
With nominal currents and RF gradient $Q\perp \approx 1.377 + 0.0097i$, $Q|| \approx 0.186 - 0.0028i \Rightarrow$

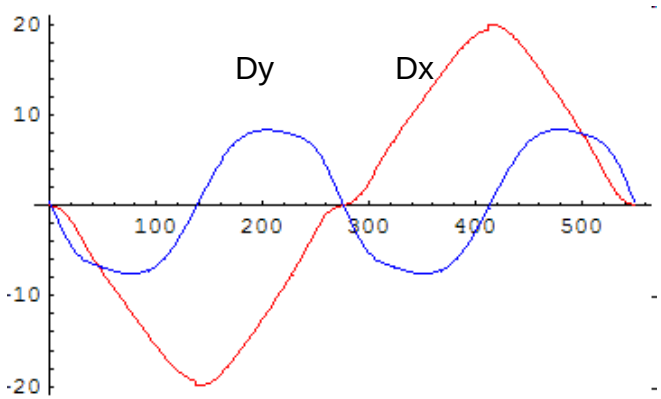
1st harmonic transverse field is required to excite integer resonance

- can be generated by tilting (or displacing) coupling coils in the same direction. With a 20mrad tilt:









Dispersion ≈ 0 at absorbers, maximum in the center of RF linacs

Summary

- It seems possible to test the Helical FOFO Snake at RAL utilizing MICE RF cavities and - probably - the coupling coils
- Converting MICE into a 6D cooling channel by introducing the coupling coils tilts or offsets does not seem a lucky idea due to a significant reduction in the transverse and/or momentum acceptance
- This does not exclude the possiblity to find a better solution with additional magnets

A Mu2e Upgrade Plan for the Project X Era

Chuck Ankenbrandt
Muons, Inc. and Fermilab
January 28, 2009

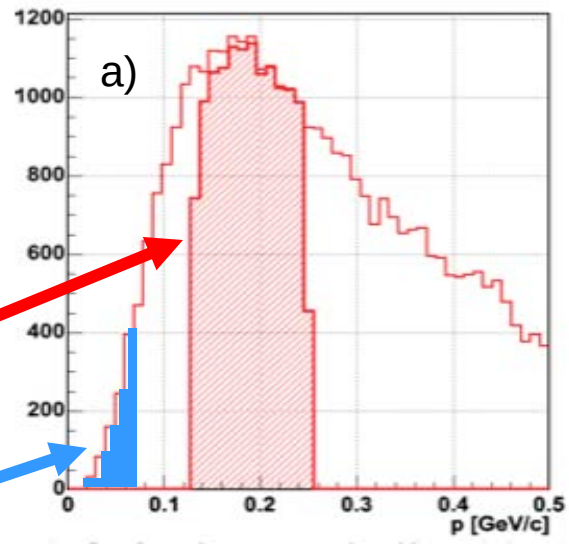
Concepts

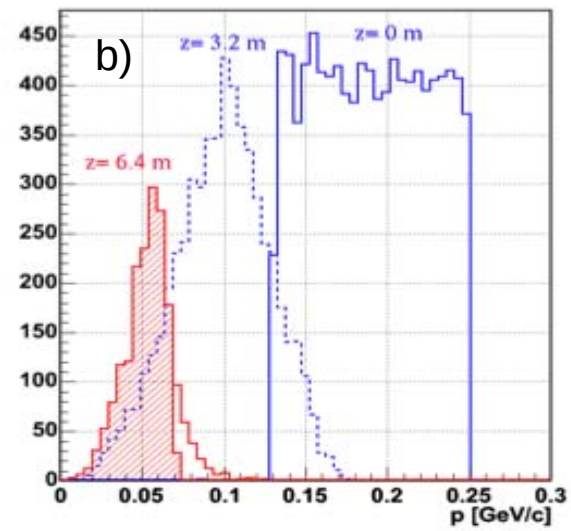
- (a) π/μ production

  (b) momentum evolution

HCC acceptance

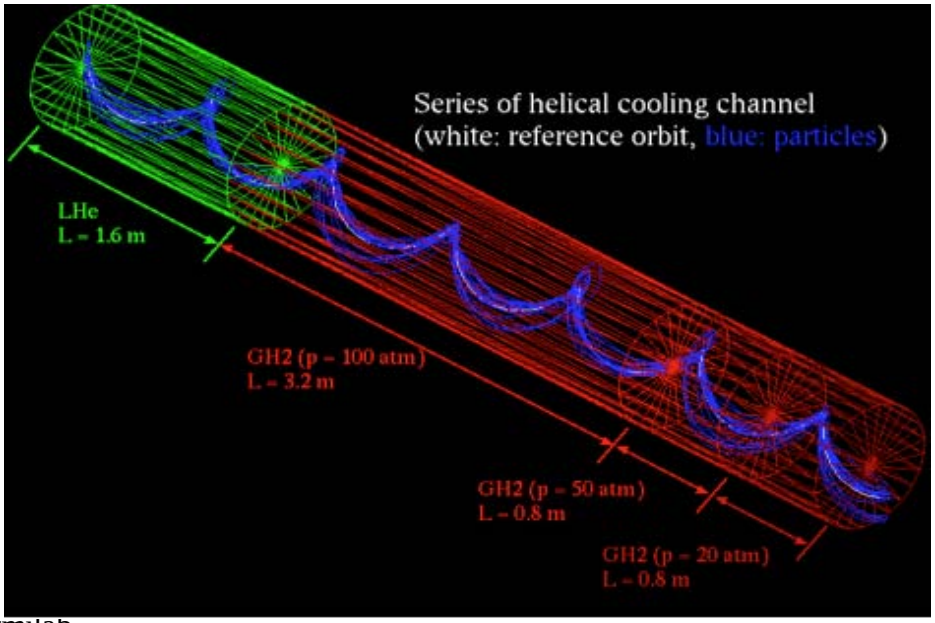
MECO acceptance





- SBIR Cooling Concept:
  - 6D particle density increase
  - Absorber density decrease

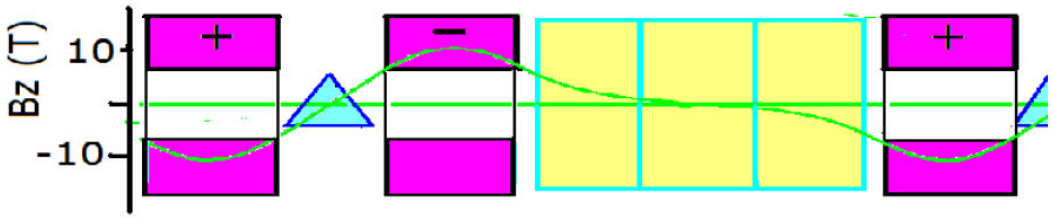
(From Mary Anne Cummings)



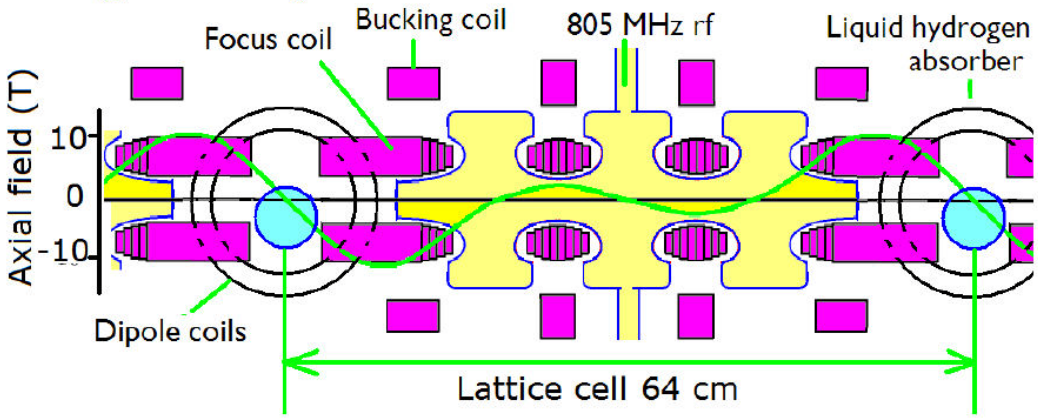
6D Cooling Experiment with Magnetic Insulation

- Experiments have shown damage and reduced gradients in required fields
- Solutions include:
  - Magnetically insulated cavities
  - High pressure gas cavities
- Possible cooling experiments include:
  1. A magnetically insulated experiment at 201 MHz
  2. A section of 201 MHz Guggenheim with high pressure hydrogen
  3. A section of 201 MHz Helical Cooling with hydrogen and integrated rf
  4. A demonstration of 805 MHz final collider 6D cooling
- # 1-3 use much of MICE equipment
- #4 would use somewhat less and requires more new equipment and rf sources

2) Guggenheim at 805 MHz and 12 T
Lattice as simulated in 2006



Magnetically insulated version

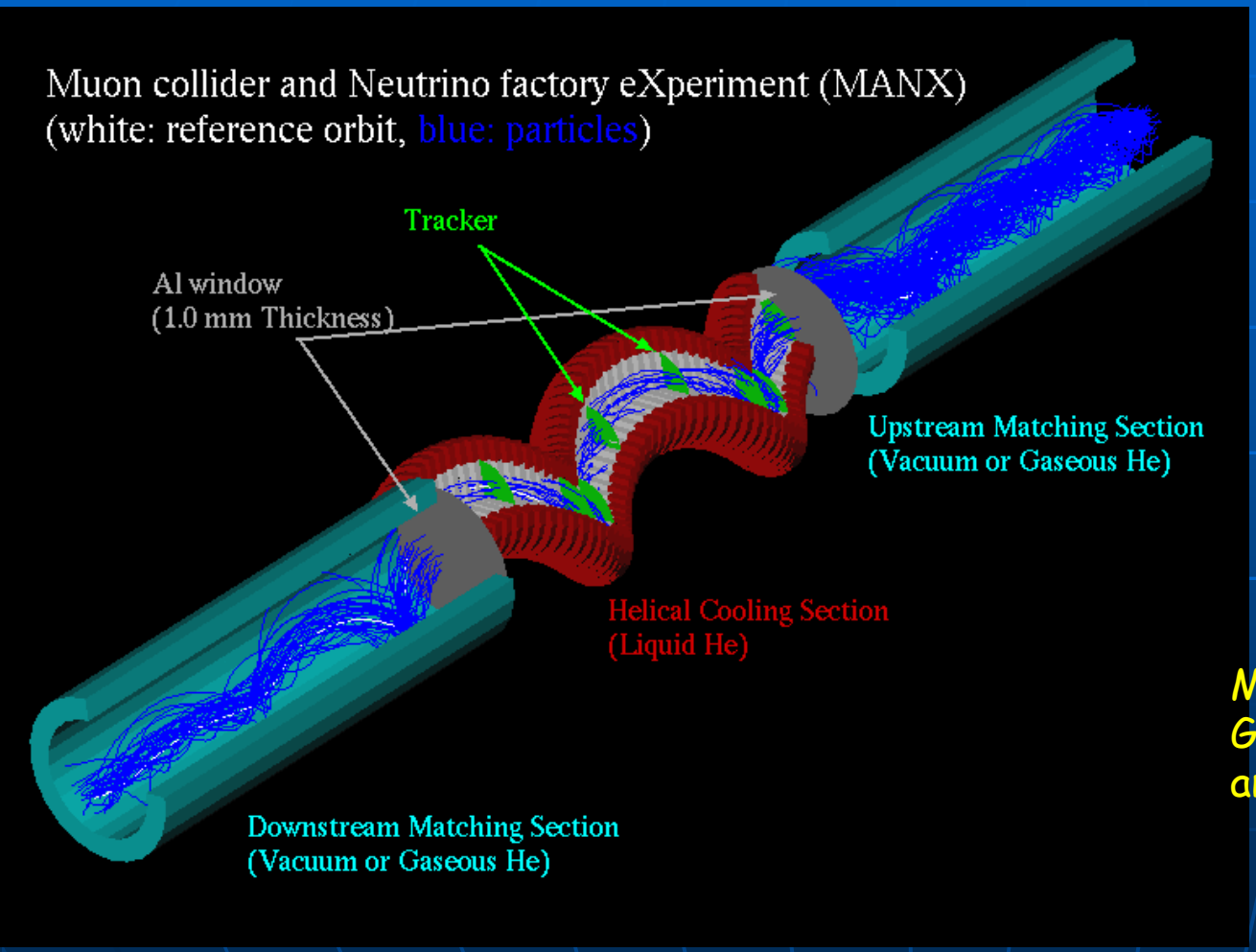


MANX- Toward Bright Muon Beams for Colliders, Neutrino Factories, and Muon Physics

Rolland P. Johnson
Muons, Inc. (http://www.muonsinc.com/)

New inventions are improving the prospects for high luminosity muon colliders for Higgs or Z' factories and at the energy frontier. Recent analytical calculations, numerical simulations, and experimental measurements are coming together to make a strong case for a series of devices or machines to be built, where each one is a precursor to the next. If chosen correctly, each device or machine with its own unique experimental and accelerator physics programs can drive the development of muon cooling and acceleration theory and technology. This strategy can achieve an almost unlimited program of experimental physics based on the cooling and acceleration of muon beams. The very first step of the program is to develop stopping muon beams by using a 6D muon cooling segment (momentum-dependent Helical Cooling Channel with emittance exchange using a homogeneous energy absorber) to test the theory and simulations and to improve the mu2e experiment. http://www.muonsinc.com/

Overview of MANX channel



- Use Liquid He absorber
- No RF cavity
- Length of cooling channel: 3.2 m
- Length of matching section: 2.4 m
- Helical pitch κ: 1.0
- Helical orbit radius: 25 cm
- Helical period: 1.6 m
- Transverse cooling: ~1.3
- Longitudinal cooling: ~1.3
- 6D cooling: ~2

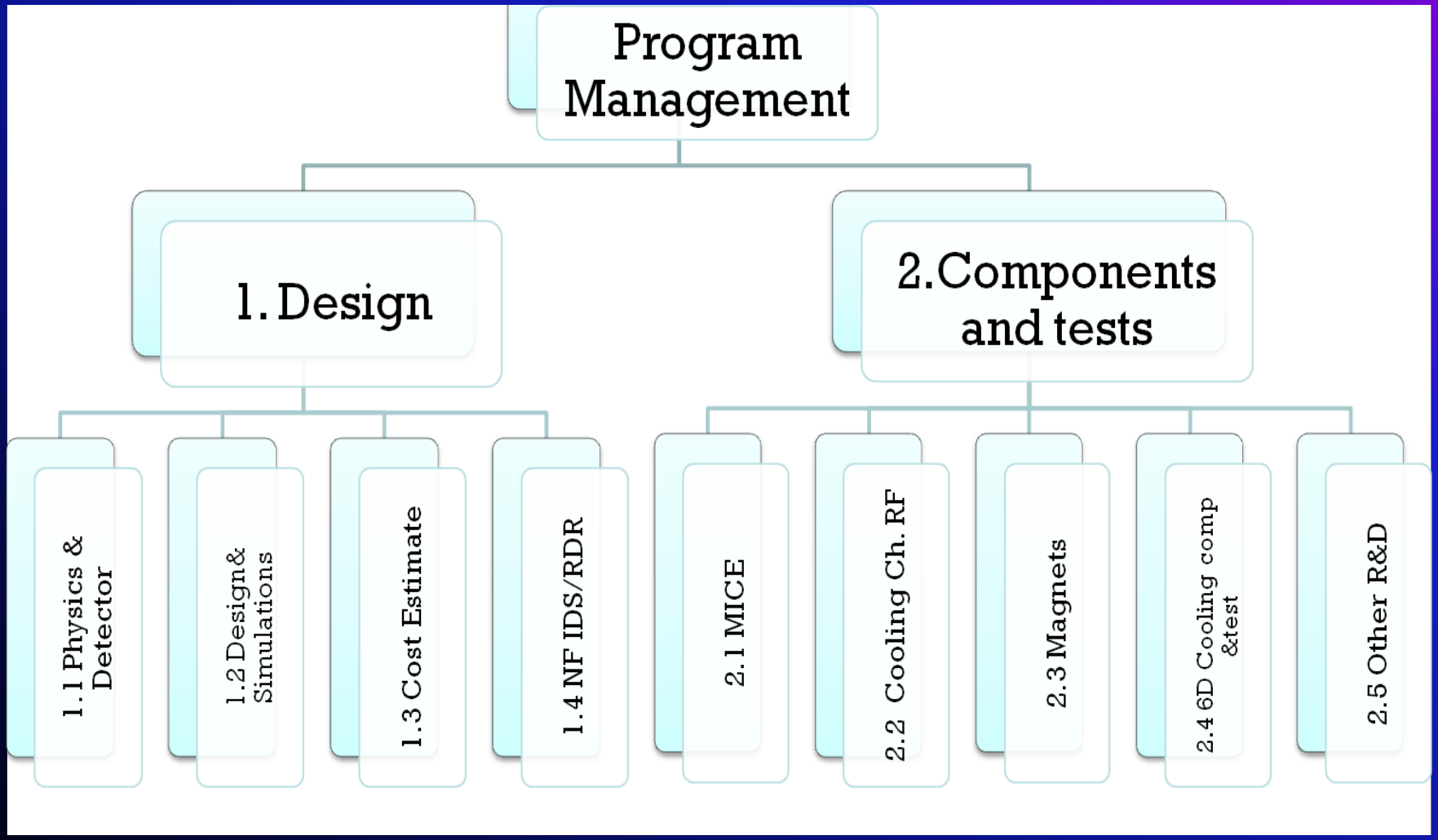
Most Simulations use G4Beamline (Muons, Inc.) and/or ICOOL (BNL)

The 5 Year Plan

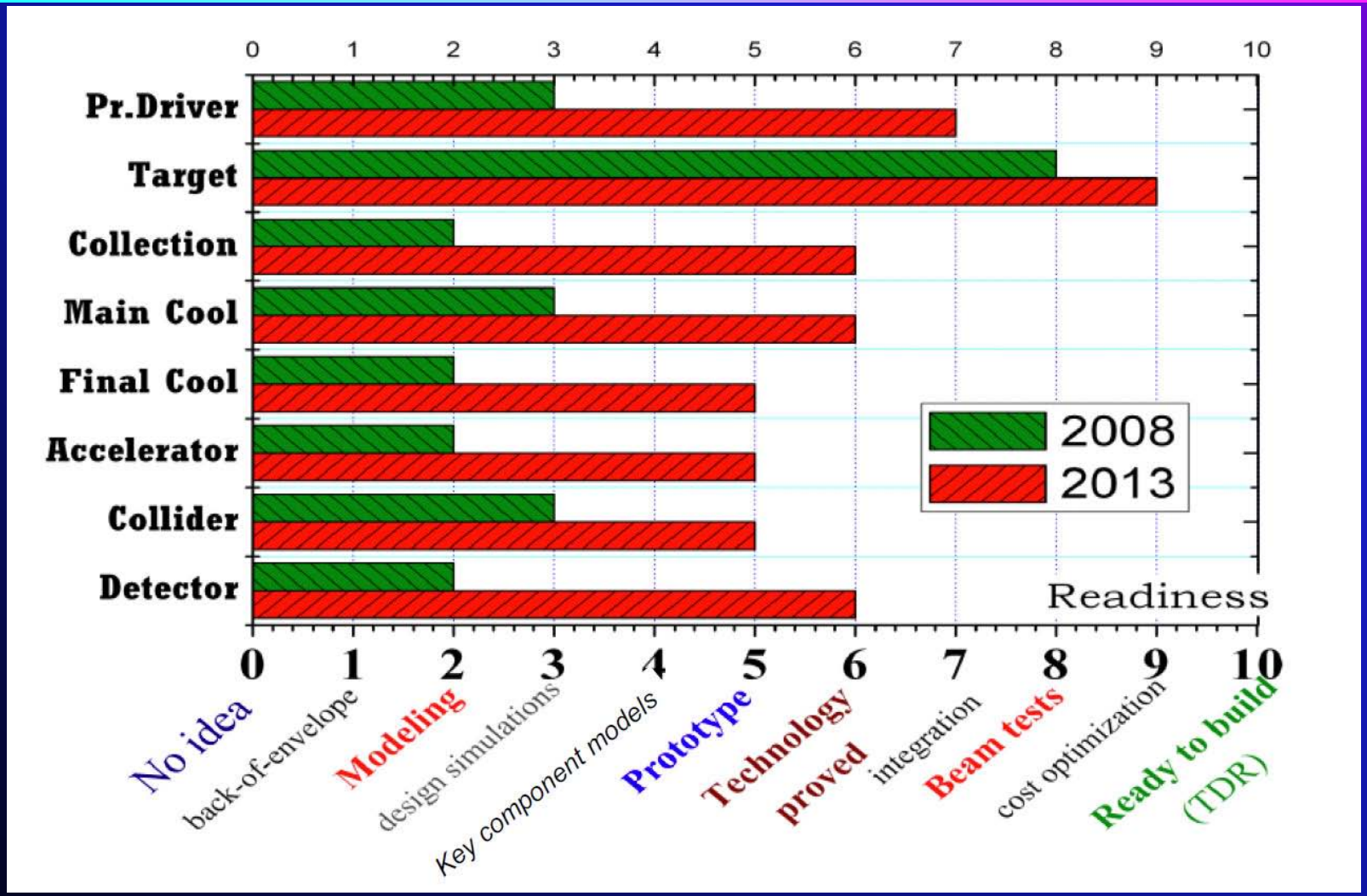
The Proposal Has now been submitted to DOE

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

Elements of the MC R&D Plan



From Here to There



Outlook

- With the Continuing Resolution, it has, so far, been a tight year, but there is reason for some optimism
  - End to CR
  - Supplemental funding
- The submission of our 5 Year Plan Proposal to the DOE is the first step towards an expanded and much broader US effort on NF and MC R&D
- The Muon Acceleration Program will be represented at the DOE budget retreat in March
- Hope for a formal review of the 5 Year Plan proposal this FY