Muon Collider & Neutrino Factory Studies

R B Palmer MUTAC LBNL

- Organization
- Milestones since Last Mutac
- APS Report and Study 2a
- New Ideas for 6D Cooling
- Problem with future of BNL Muon Group

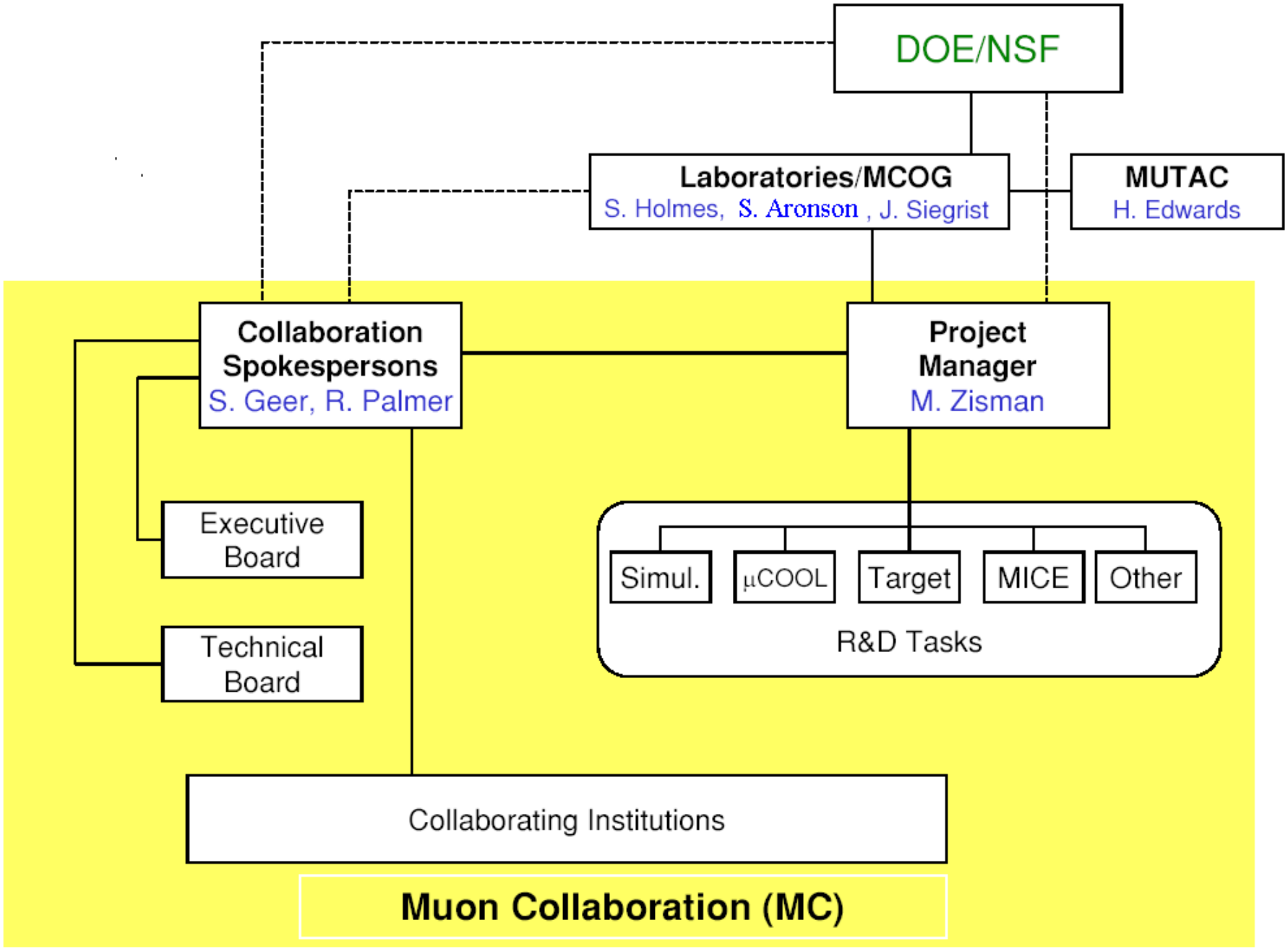
Muon Collaboration (MC) Goals

MC Charter* that defines its goals and organization

The goal of this organization (referred to hereinafter as the Muon Collaboration) is to study and develop the theoretical tools, the software simulation tools, and to carry out R&D on the hardware that is unique to the design of neutrino factories and muon colliders. An important part of the program will be an extensive experimental program to verify the theoretical and simulation predictions and to gather the necessary data for a future facility.

* http://www.cap.bnl.gov/mumu/info/MC_Charter_Final_020903.pdf

National Organization



Members

- 135 Scientists and Engineers
- 6 US Labs
- 17 US Universities
- 14 Foreign Institutions

in Collaboration with

- European Groups
  CERN, RAL (UK), INFN (Italy), Universities
- Japanese Groups
  KEK, Osaka, other Universities
- Russia
  BINP (including Skrinski)
- Annual NuFact International Workshops
  (Rotating: Europe, US, Japan)

Sub-Activity Leaders

- **Targetry**
  - **K. McDonald (Spokesperson)**
  - **H. Kirk (Project Manager)**
- **MUCOOL** **A. Bross (Spokesperson)**
- **US MICE**
  - **D. Kaplan (US Spokesperson)**
- **Simulations/Theory**
  - **R. Fernow (Chair, Simulation/Theory Committee)**
- **Speakers Bureau**
  - **G. Hanson (Chair)**

Funding Sources for All Muon Studies

1. DOE and MICE Funds administered by Project Manager
2. DOE/NSF Support of staff at institutions (Base)
3. NSF Funds Administered by Cornell (now ended)
4. NSF Funds for MICE administered by IIT (now starting)
5. ICAR Funds (now ended)
6. DOE SBIR/STTR Funds (now increasing)
   - Muons Inc
   - Table Top Ring
7. Non-US Funding Sources

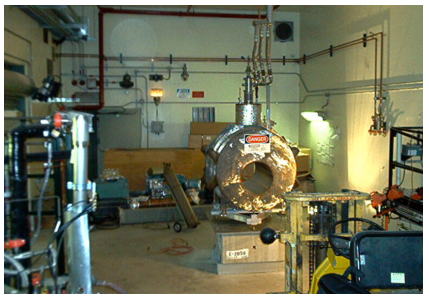
- #1 is under direct control of the Collaboration Organization and forms part of our 5 year Plan
- Many members of the collaboration are involved in activities funded by the other sources

Activities

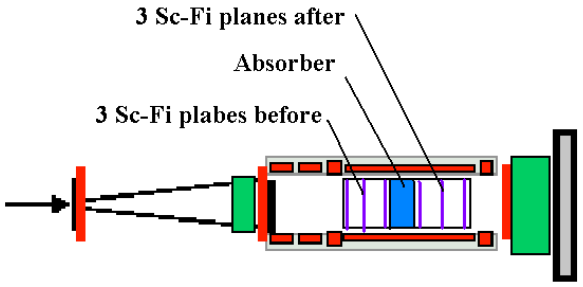
- Feasibility Studies of Neutrino Factory (Fernow)
- Concept studies of Muon Collider (Fernow)
- R&D on Ionization Cooling Components (Bross)
  & Muons Inc (Johnson)
  - 200 MHz Cu RF (Li, Norem)
  - Hydrogen Absorbers (Ishimoto, Cummings)
  - Solenoid Focusing
  - RF in High Pressure Hydrogen (Johnson)
- Demonstrate Ionization Cooling (MICE) (Kaplan, Blondel)
  & Table Top (Fernow)
- R&D on Superconducting Cavities at 200 MHz (Hartill)
- Non-Scaling FFAG Electron Model Ring (UK) (Koscielniak)
- Design a target for 4 MW p beam (McDonald, Samulyak)
- Demonstrate Liquid Mercury Target (Kirk)

magenta = Non Collaboration Funded

Technical Milestones Since Last MUTAC (Mike)

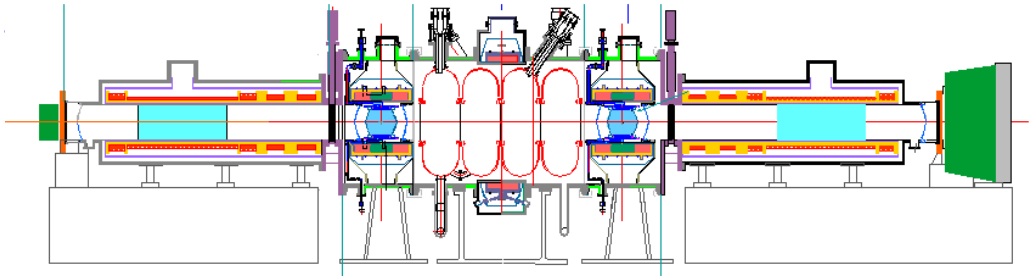


- First Experiment in Muon Test Area (MTA)
  Hydrogen Absorber filled with Liquid H2
  & Near completion of
  first 200 MHz RF Cavity

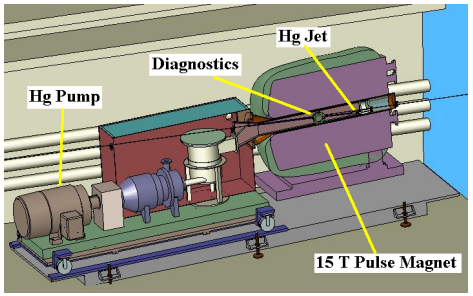


- UK Funding approval for Phase One of Muon Ionization Cooling Experiment (MICE)

  US plan for funding to 'Stage V



- CERN approval of Mercury Target Experiment (NTOF 11)
  & Near completion of Pulsed 15 T Magnet



Theory and Simulation Studies

- History
  - Study I, sponsored by FNAL, Feasibility
  - Study II, Sponsored by BNL, Performance $\times$ 6
  - Study IIa, APS Study Less Cost and both signs (Fernow)

Milestones since last Mutac

- Start of negotiations with Japan and Europe on a 'World Design Study' Sponsored by RAL (Peach)
- Progress in FFAG optimization
- Design of Electron FFAG Model (with Japan & UK)
- New ideas for 6 dimensional Cooling
  Hydrogen Gas in Helical Magnet (Johnson)
  'Desk Top Ring' (Fernow)
  Inverse Cyclotron
- Studies of Muon Colliders (Fernow, Johnson)

APS Study of Neutrino Physics

(Conveners of Neutrino Factory Group: S. Geer, M. Zisman)

"A high-intensity neutrino factory or a beta beam facility is the ultimate tool in neutrino physics for the long term, and may be the only facility capable of definitively addressing some of the physics issues."

"The neutrino factory R&D program needs increased levels of support if the facility is to be realized in the long term."

Study 2a

- Maintained performance per muon of given sign
- Allows use of both signs
- 40 % Lower cost

Main Innovations

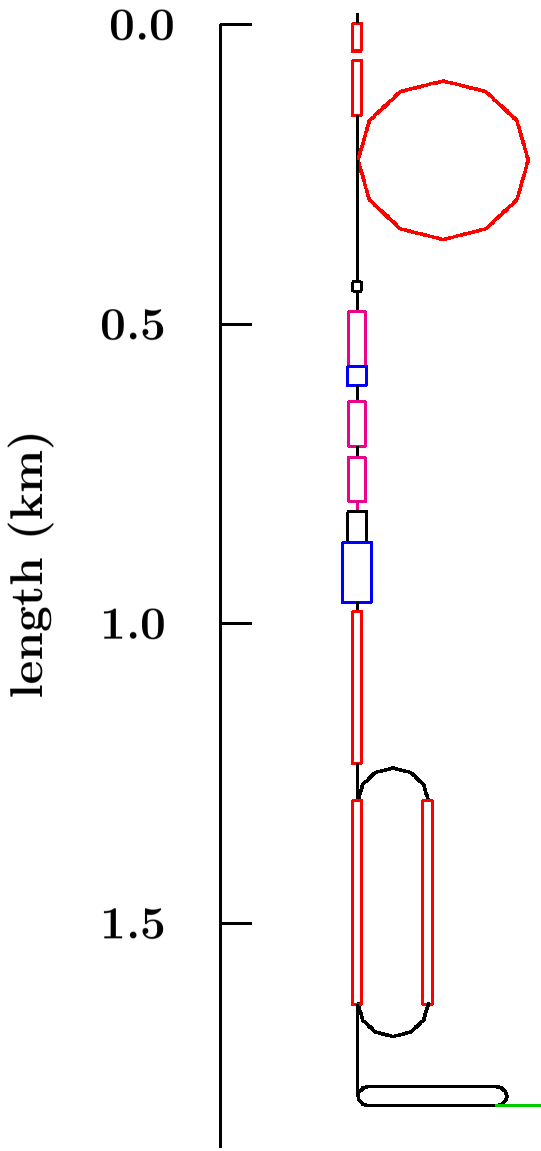
1. Bunching before RF Phase Rotation
2. Less Cooling
3. Larger Acceptance Acceleration including FFAG's

Work Continuing (Study 2b)

World Design Study (Study 3)

- Sponsored by RAL (UK)
- Europe, US,Japan
- Study choices of frequency, amount of cooling, energy etc.

Study 2a Schematic of 20 GeV Factory



p Driver

Hg Target

Phase Rotation

Cooling

Pre-Acceleration

RLA

Storage Ring

Neutrino Beam

	% of 1.0 B$ Cost (no EDIA etc) without driver
Acceleration	(42 %)
	(10 %)
	(17 %)
	(21 %)
	(8 %)

1) Phase Rotation (Reduce dp/p prior to Cooling)

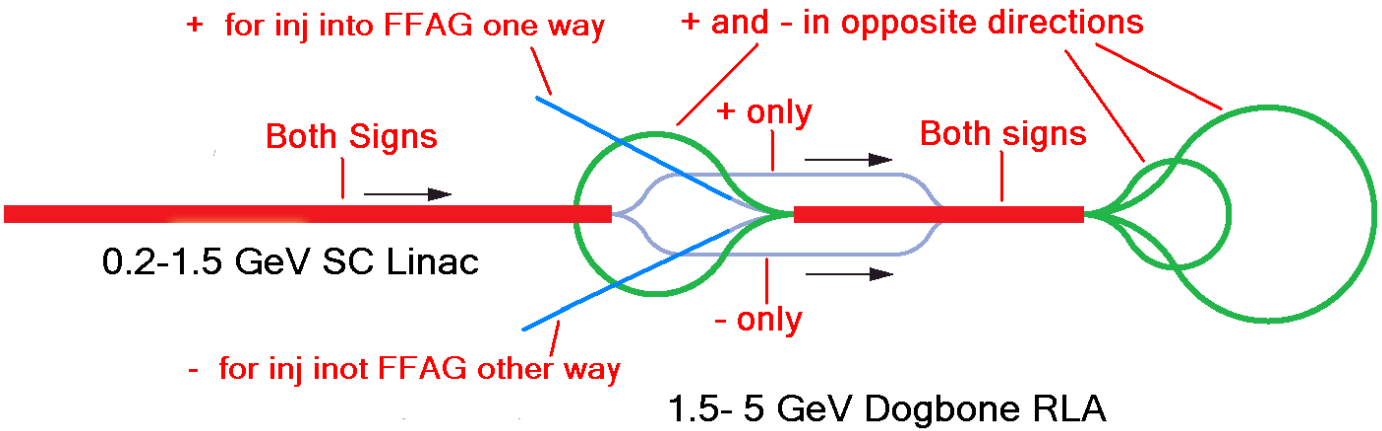
- Bunching before RF Rotation (Neuffer)
  vs. Induction Linac Rotation First
- 200 MHz RF is cheaper than Induction Linacs
- But RF frequency must vary along bunching channel (high mom. bunches move faster than low)

2) Cooling (Fernow)

- Use Larger Acceptance in Acceleration (c.f. Japan)
- Simpler Lattice than Study 2
- LiH instead of Liquid Hydrogen
- Achieves same muon per proton as Study 2
- Preserves both signs

3) Acceleration

Linac and RLA'(0.2 TO 5 GeV)



- 30 pi mm Acceptance (c.f. 15 pi mm in Study 2)
- Both signs are accelerated
- Switchyards are easier in Dog Bone RLA

Non-Scaling FFAG (5 to 20 GeV)

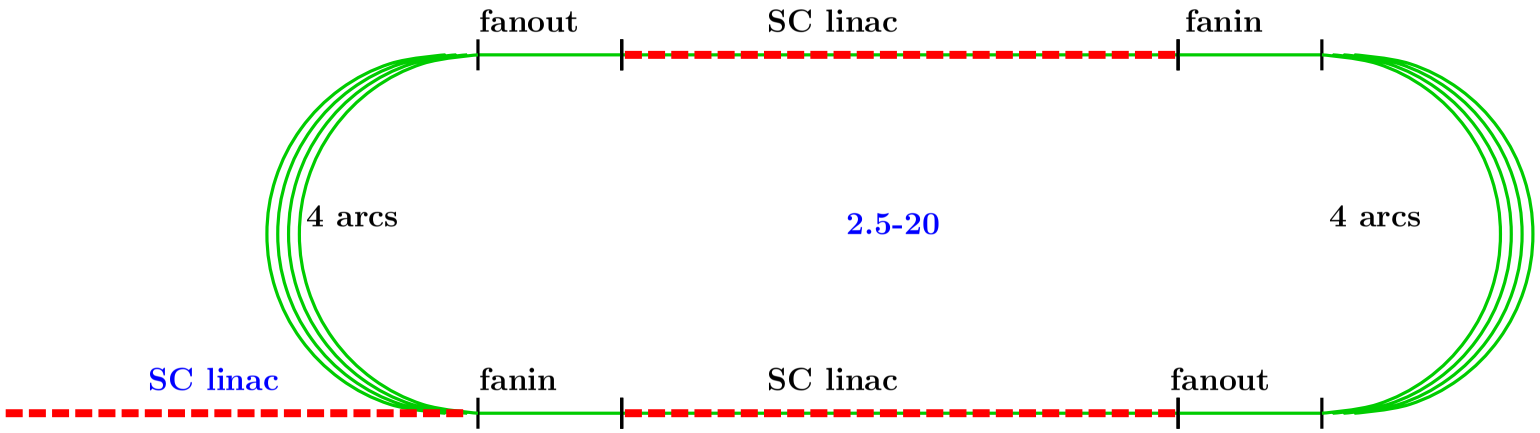
(Proposed by Carol Johnstone & Dejan Trbojevic)

- Orbits are not similar, as in scaling
- They are closer together than in scaling
  $\longrightarrow$ smaller apertures
  $\longrightarrow$ more isochronous

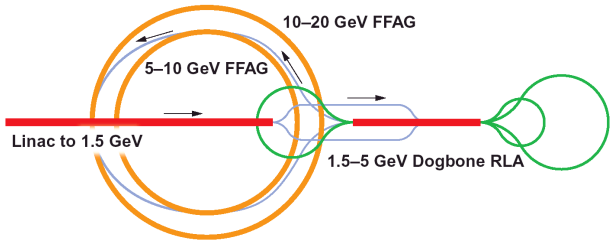
e.g. Compare IIa Acceleration with Study II

Use of Fixed Field Alternating Gradient (FFAG) Acceleration

Study II Linac + RLA



Study IIa Linac + RLA + 2 FFAG's



- **FFAG also under study as high intensity p Source**

Summary of Cost Reductions

	Study 2 M$	2a/2 %
Target and Capture	97	100
Rotation	394	37
Cooling	310	59
Acceleration	544	67
Storage Ring	82	100
	1427	61

- Costs of technical items and conventional construction
- Without controls, missing items, Escalation or EDIA
- Mostly by scaling from Study 2
- Base Technical cost now less than 1B$
- Not a Bottoms up costing

New Ideas for 6 D Ionization Cooling

- Energy loss in light medium in strong focusing → Transverse Cooling
- Two methods to exchange longitudinal and transverse to get 6D cooling:
- Needed for a Muon Collider

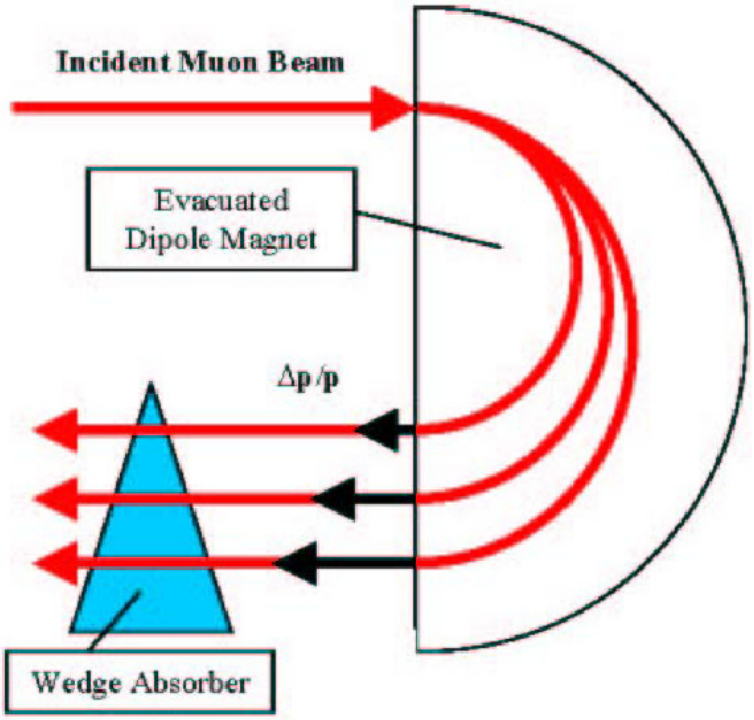


Figure 1. Use of a Wedge Absorber for Emittance Exchange

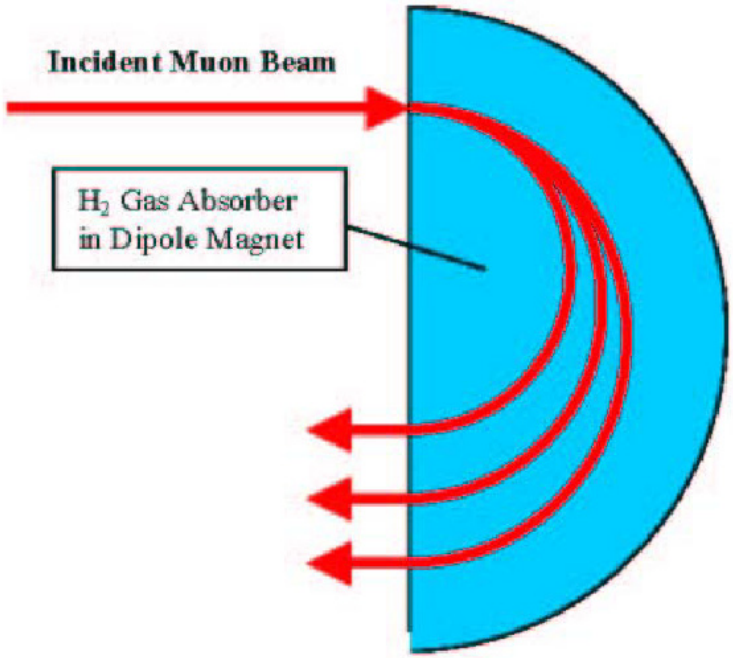
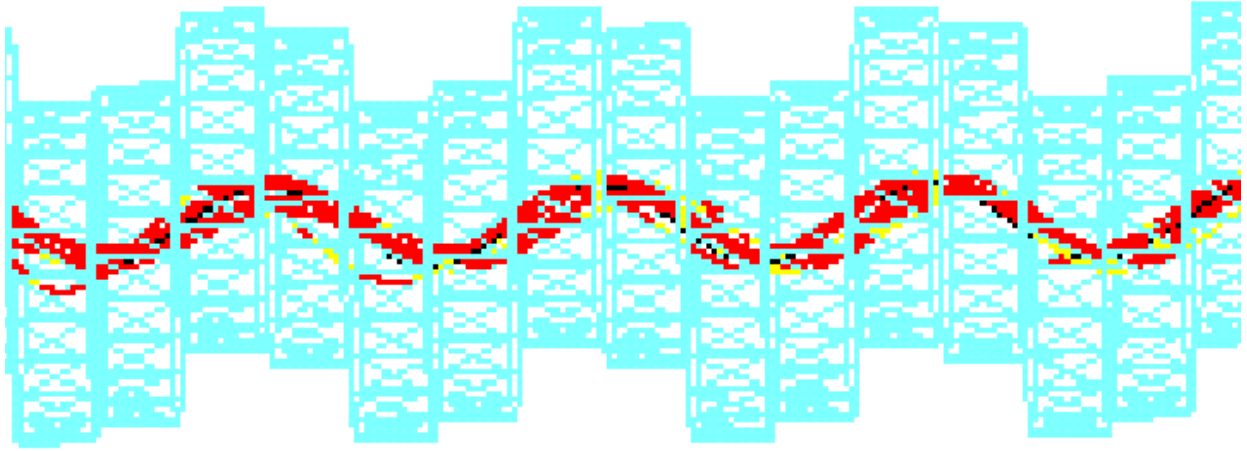
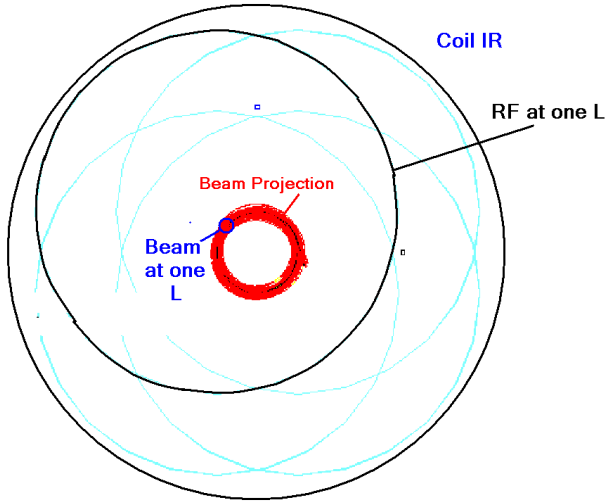


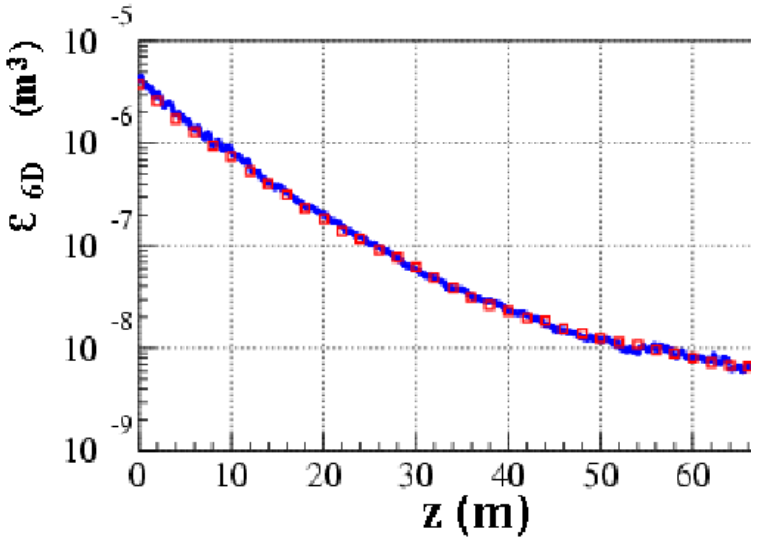
Figure 2. Use of Continuous Gaseous Absorber for Emittance Exchange

e.g. with Hydrogen Gas: Helical Channel
(Derbenev, Rol Johnson, Muons Inc.)



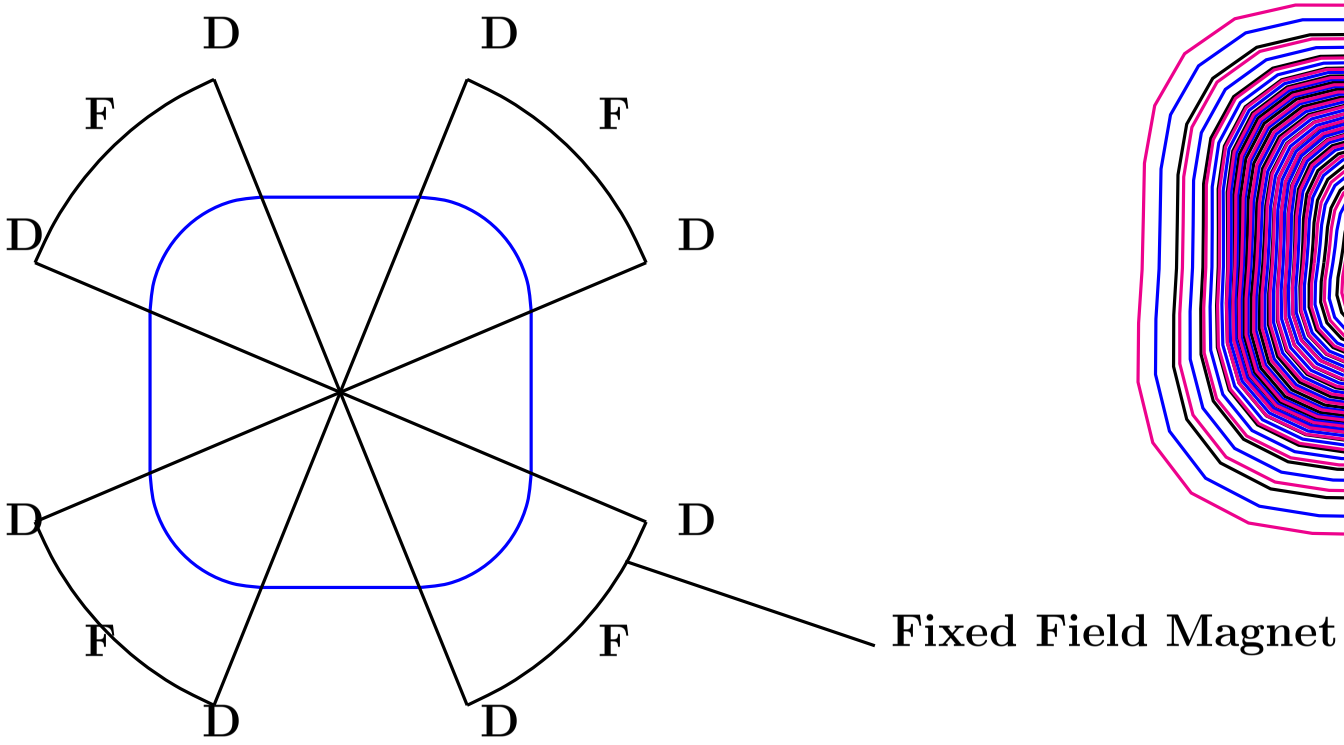


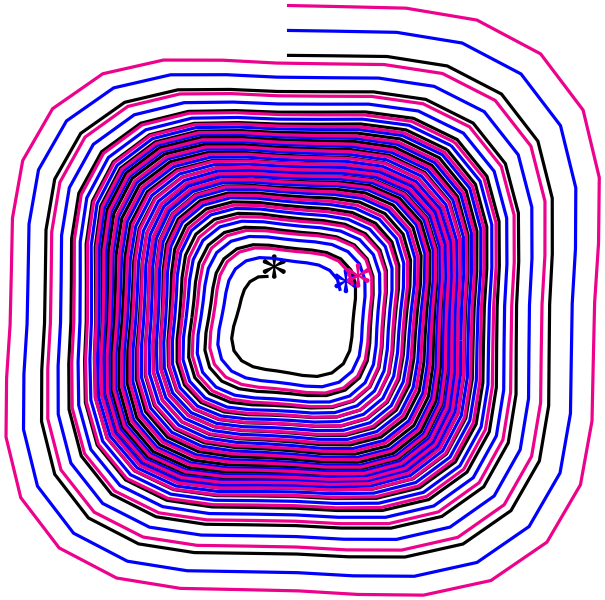
- Cooling in all dimensions of order 300
- Moderate fields at beam Bz=3.5 T. Br=1T
- But Very High Fields at Coils
- Exploring Other Solutions
- But Fields Remain High



e.g. With Gas and Wedges: Inverse Cyclotron

D Summers, A Garren, H Kirk





- Pole angles ≡ D focus
- fine wedges and gas give graded density with radius
- 6D cooling could be of order 1000,000
- Work In progress

Problem with future of BNL Muon Group

- Problems in funding for BNL Physics Groups
  Leading to
- Probable loss of one member of Muon Group now
- Intent to eliminate group in 6 months time
- Requests to DOE to reprogram accelerator funds

Consequences

- A reduction by more than 50% of the DOE "base" support
- Probable cancelation of the approved
  CERN Target Experiment
- Effective loss of the program ICOOL, resulting in:
  - Serious Damage to Simulations Studies, including the potential "World Design Study"
  - Risk to MICE design effort

Conclusion: Exciting Program

- Simulation and Design Studies
  - Cost Reductions
  - Performance improvement
  - "World Design Study"
  - New ideas
- Ionization Cooling R&D
  - First Experiment in MTA
  - 200 MHz RF near
  - H2 Target under test
  - Muon Ionization Cooling Experiment (MICE) Funded
- Liquid Mercury Target
  - Run approved Target Experiment at CERN (NTOF 11)
  - 15 T Pulsed Magnet near
- Threat to Base Program with Grave Consequences