

Possible IIT Experiments at NML

Dan Kaplan



Workshop on
Future Directions for Accelerator R&D at Fermilab
Lake Geneva, WI
11–13 May 2009



Accelerator R&D at IIT

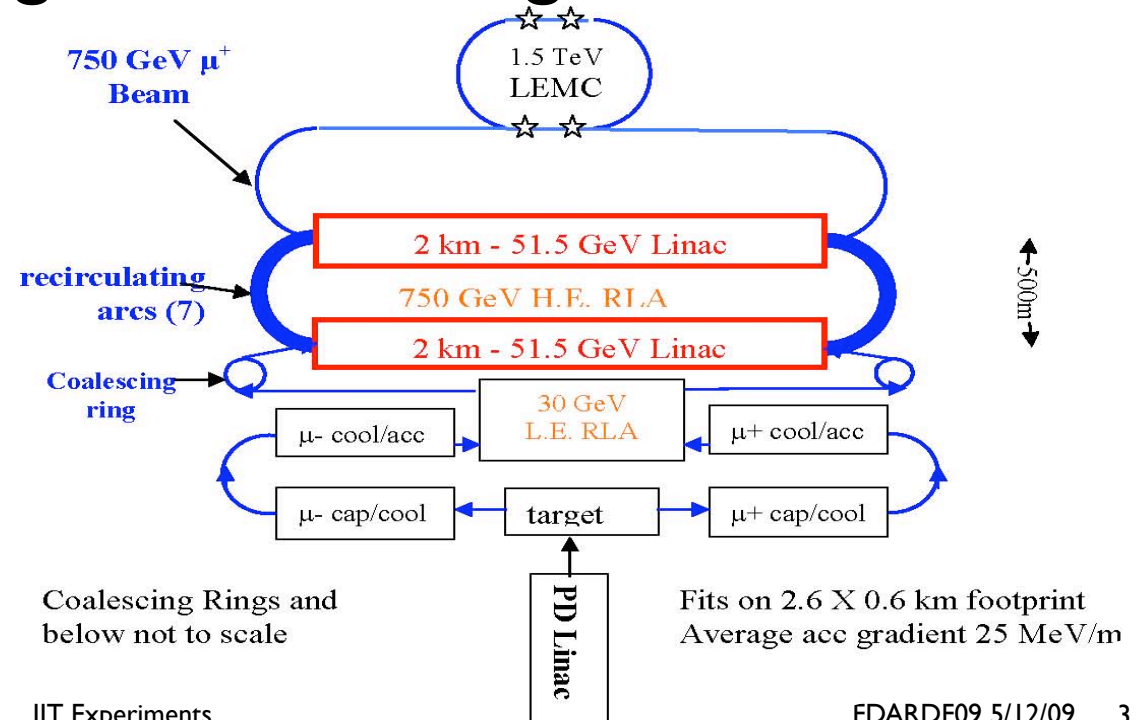
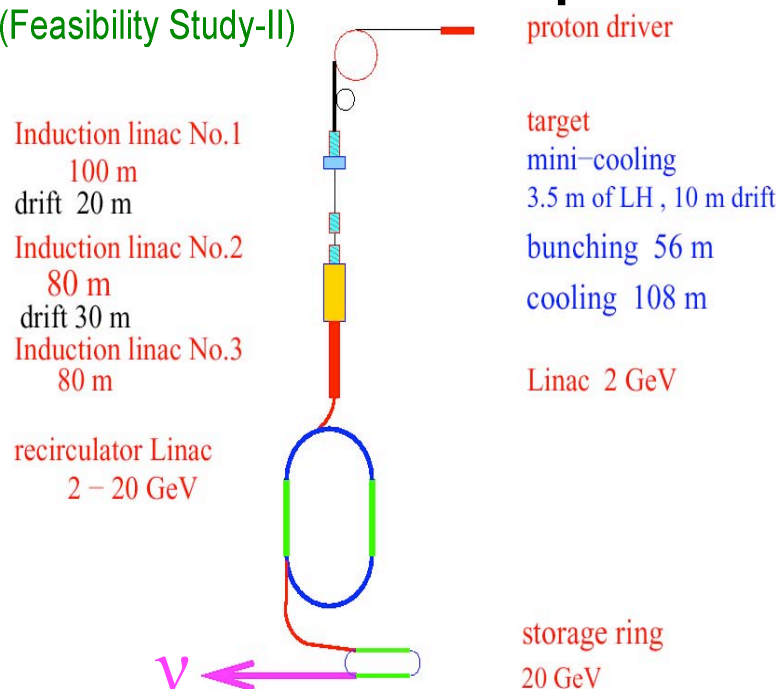


- D. Kaplan, Y. Torun:
 - μ cooling
- L. Spentzouris:
 - high-intensity beams & space-charge
 - novel metamaterials & applications
- \exists interested grad students...

Muon Cooling

- Key enabling technology for neutrino factories (NF) and muon colliders (MC)
- Transverse cooling sufficient for NF
- MC requires longitudinal cooling as well

(Feasibility Study-II)



Muon Cooling



- Only ionization cooling fast enough ($\tau_\mu = 2.2 \mu\text{s}$)
- but:

1. Effect is transverse only

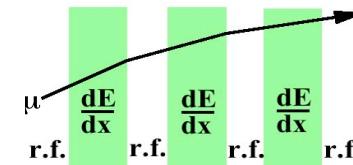
- Might hope to cool longitudinally via dE/dx curve's slight positive slope above ionization minimum
- But dE/dx “straggling” tail leads to heating

2. To optimize cooling requires:

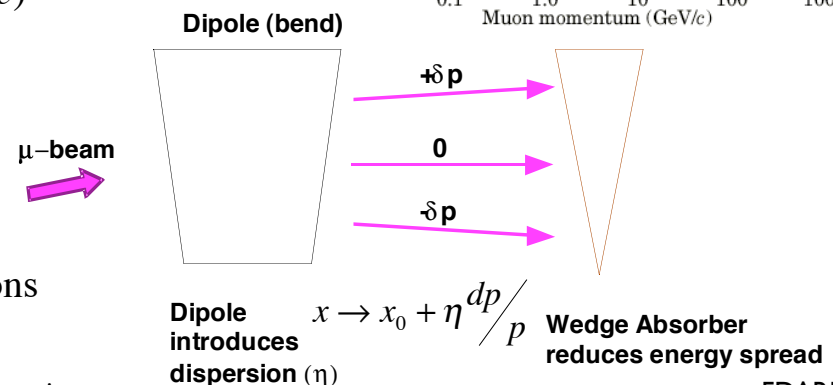
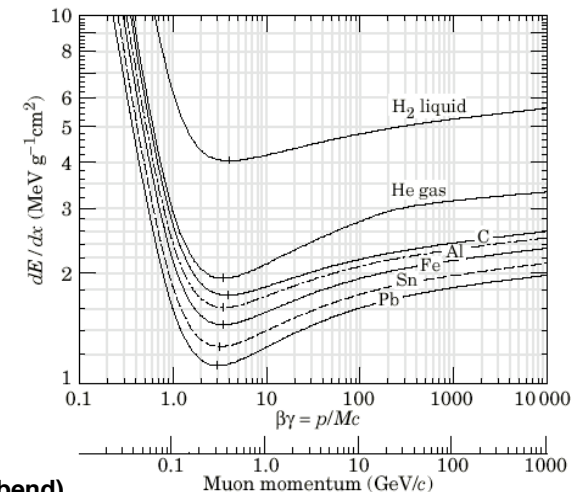
- low β_\perp (strong focusing)
- large X_0 (low Z)
- low E_μ (typ. $150 < p_\mu < 400 \text{ MeV}/c$)

3. Can “rotate” portion of effect into longitudinal phase plane via “emittance exchange”

- Allows all 6 phase-space dimensions to be cooled



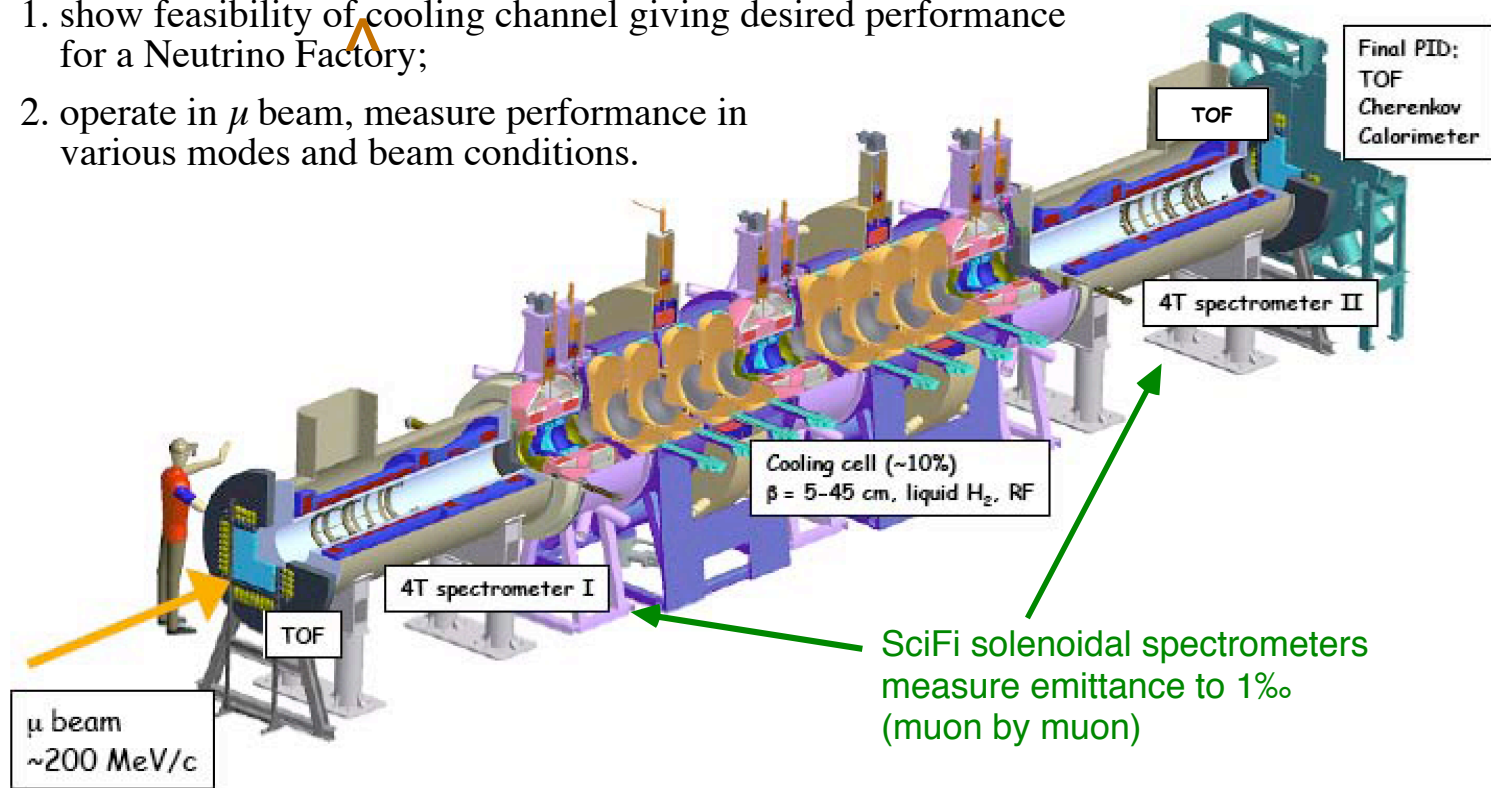
G. I. Budker and A. N. Skrinsky, Sov. Phys. Usp. **21**, 277 (1978)
 A. N. Skrinsky and V. V. Parkhomchuk, Sov. J. Part. Nucl. **12**, 223 (1981)



Muon Ionization Cooling Experiment (MICE)

Goals:

1. show feasibility of **transverse** cooling channel giving desired performance for a Neutrino Factory;
2. operate in μ beam, measure performance in various modes and beam conditions.



- Large international, interdisciplinary collaboration:

- >100 particle and accelerator physicists and engineers from Belgium, Bulgaria, China, Italy, Japan, Netherlands, Russia, Switzerland, UK, USA

- Construction now in progress at Rutherford Lab in UK



Possible Applications at NML

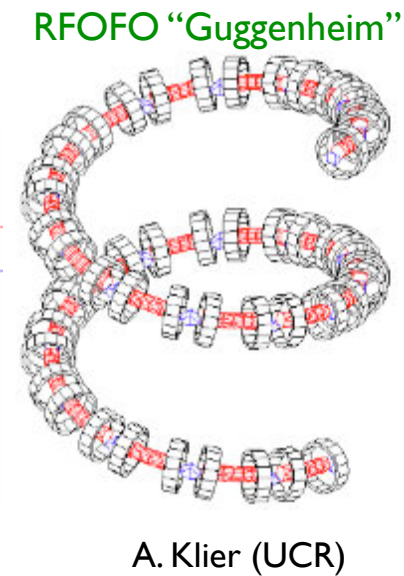
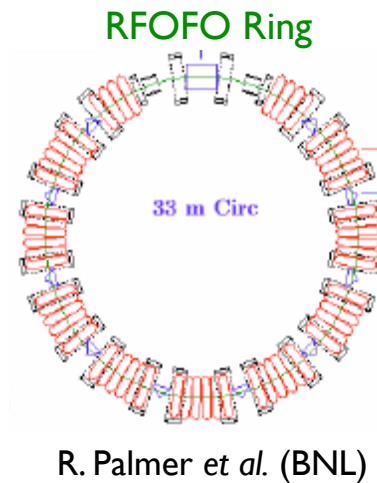
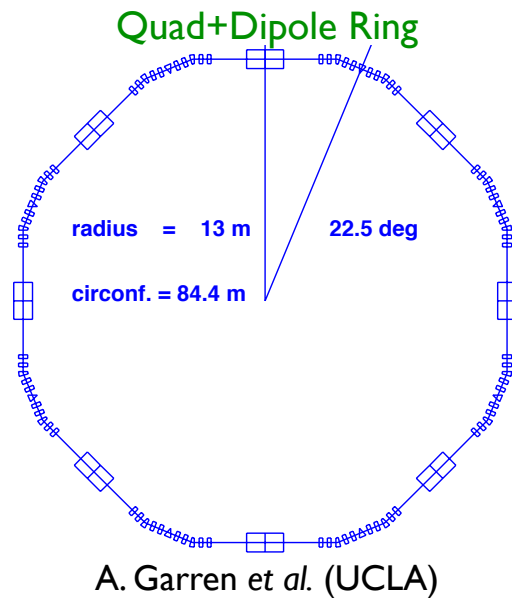


...the Future. www.iit.edu

- Demonstrate 6-dimensional muon cooling
 - 6D μ cooling ring
 - other 6D cooling experiments
- Test optical stochastic cooling?
 - demo in progress at Bates?

6D μ Cooling Rings

- Variety of approaches explored:

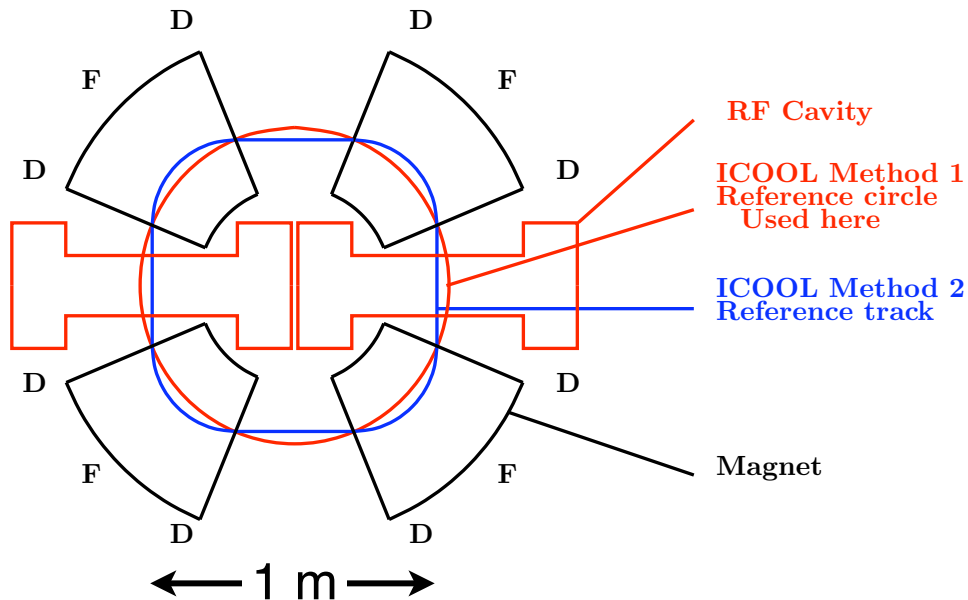


- Large and expensive!

6D μ Cooling Rings

- Also some small, demonstration rings

D. Summers et al.:
 Large-admittance sector
 cyclotron



D. Cline et al.:
 High-pressure dipole ring

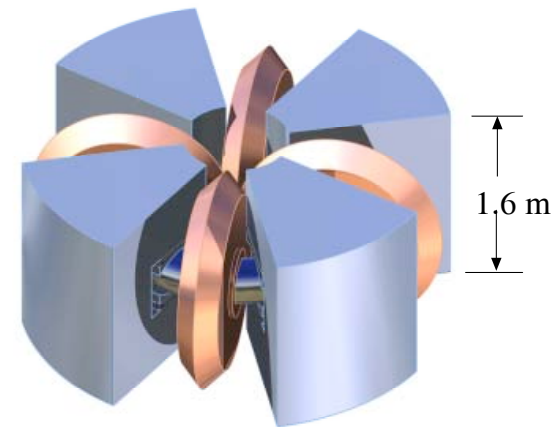
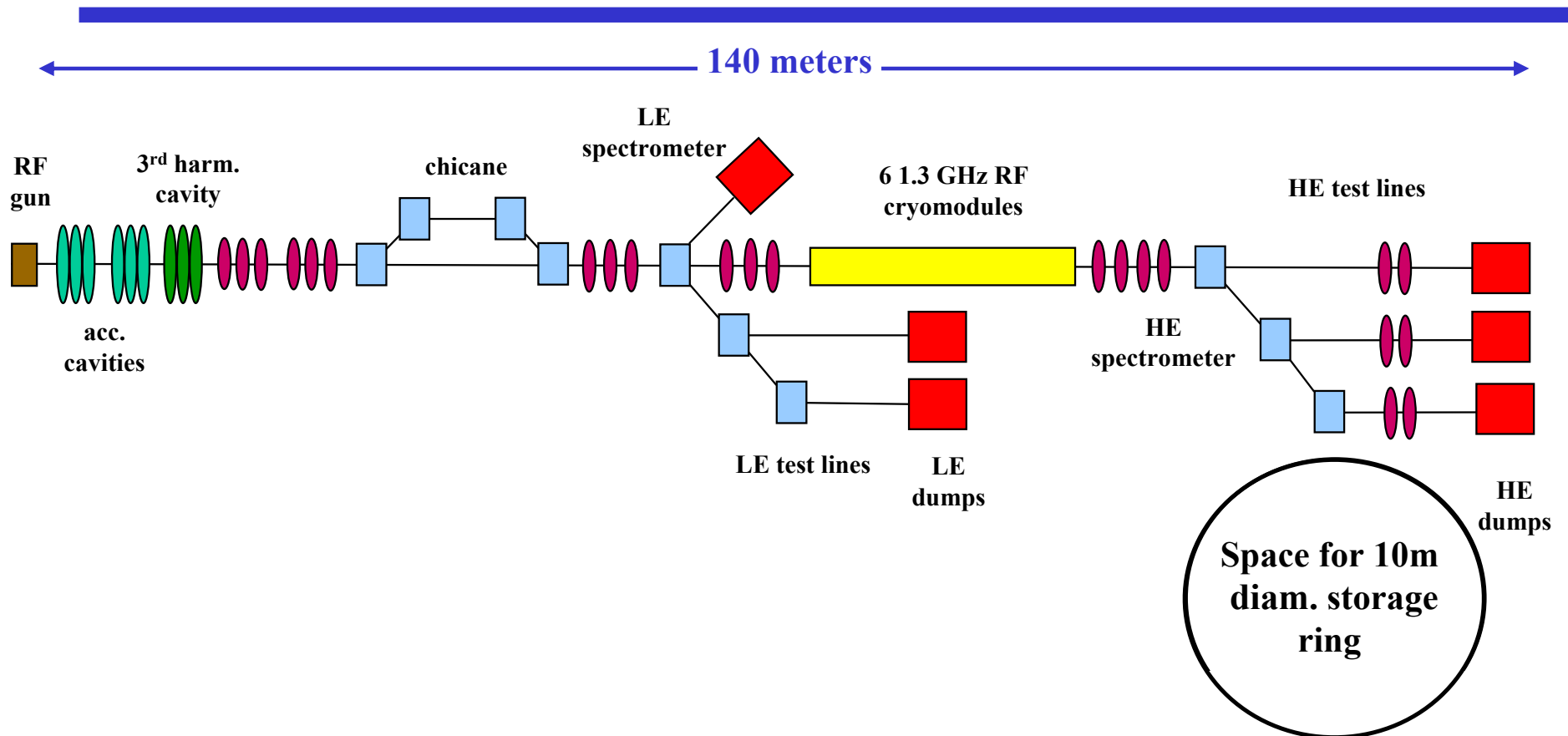


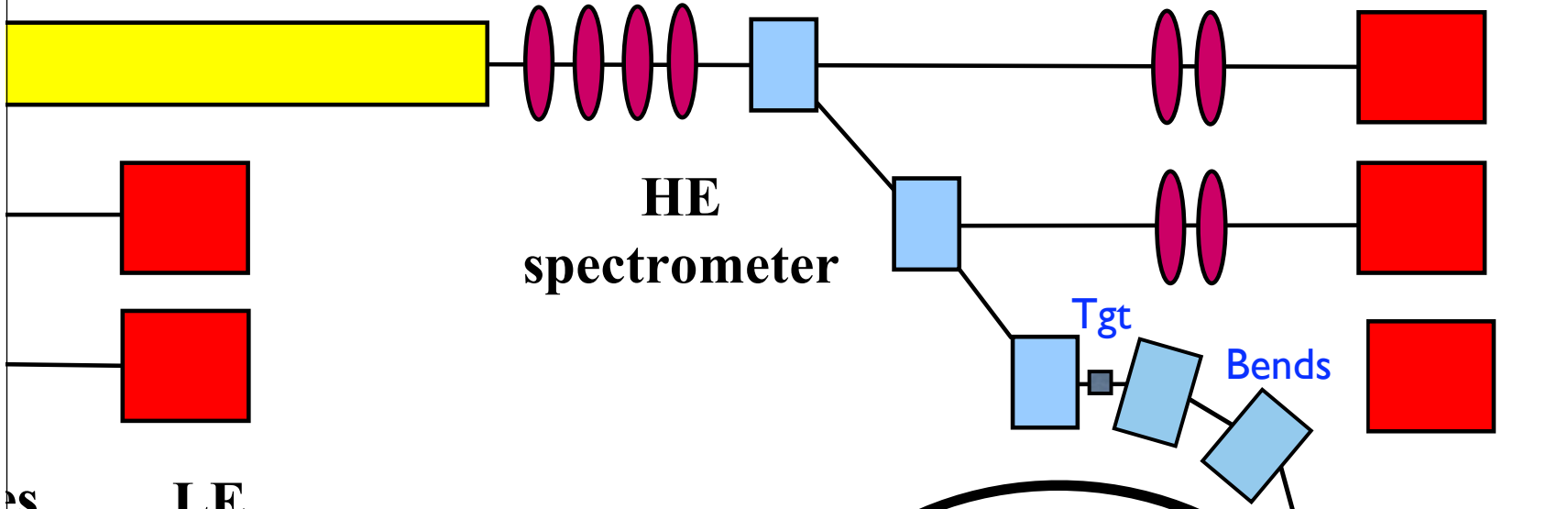
Figure 5: Ring cooler with dipole.

Proposed NML Schematic Layout (not to scale)



6 1.3 GHz RF cryomodules

HE test lines



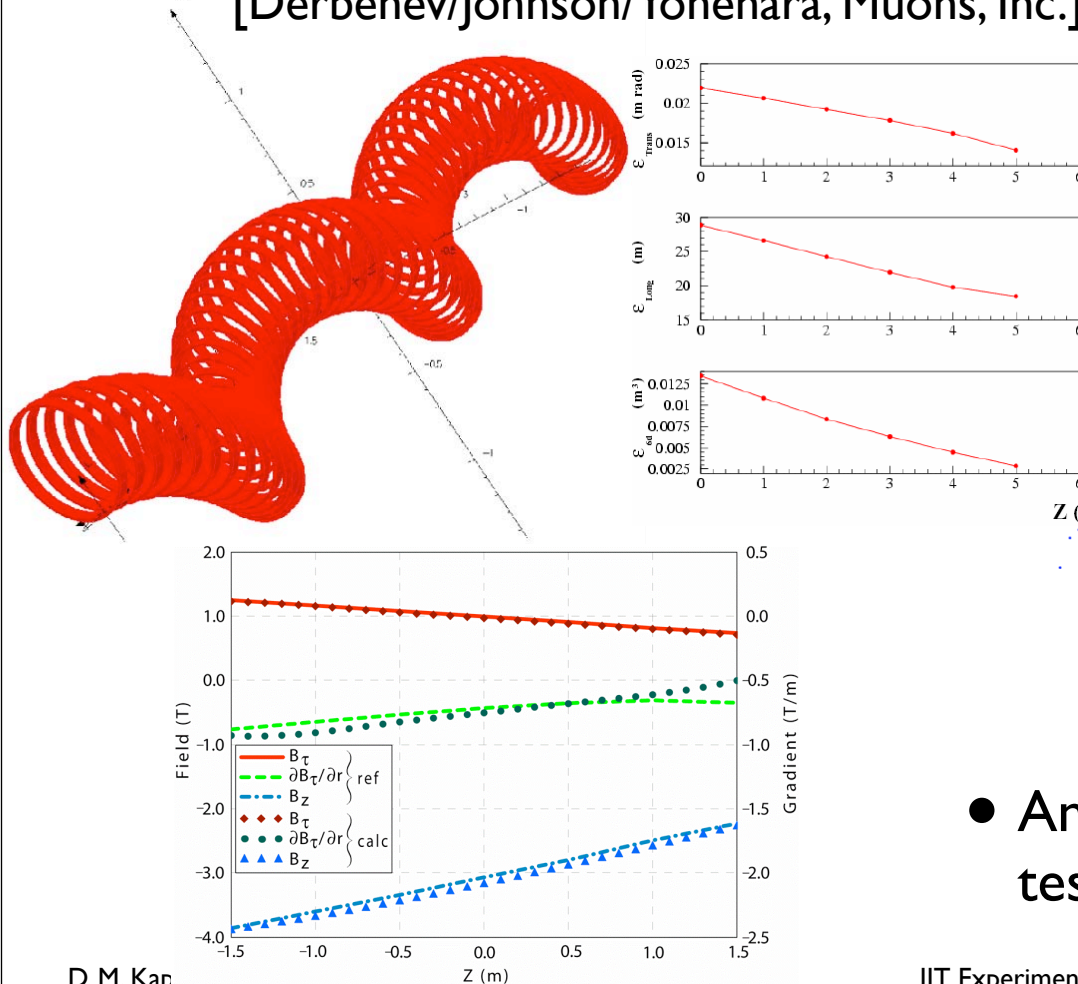
es
LE
dumps

HE
dumps
Cooling ring (or other 6D device)

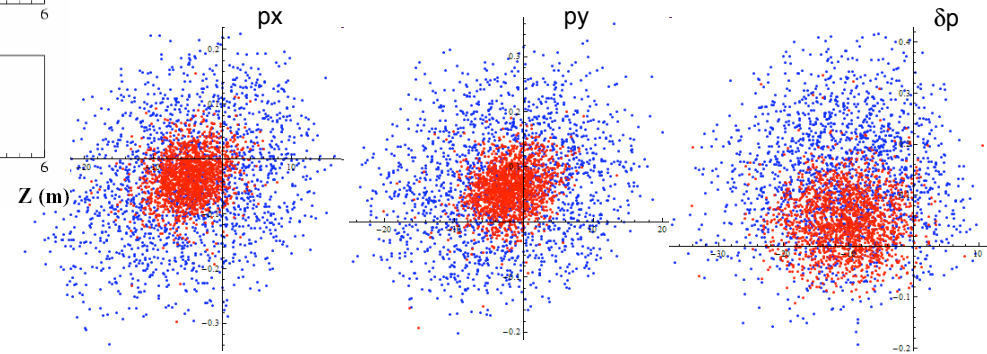
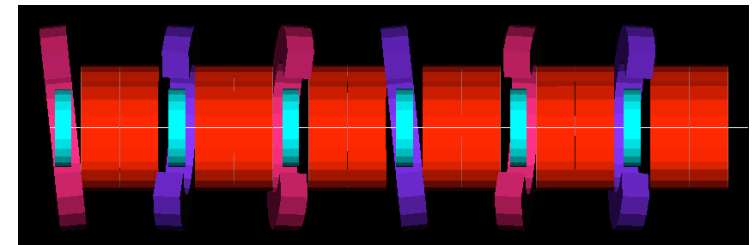
“Ppt engineering”!
 Much omitted:
 – quads
 – injection
 – detectors
 – ...

Other 6D Cooling Approaches

- Helical Cooling Channel (HCC) [Derbenev/Johnson/Yonehara, Muons, Inc.]



- FoFo Snake [Alexahin, MCTF]



blue - initial, red - final

- Any of them might be worth testing in NML (e.g., MANX)

Making Muons

- H.E. e^\pm interacting in target certainly make muon pairs (Bethe-Heitler)

W.A. Barletta, A.M. Sessler / Nucl. Instr. and Meth. in Phys. Res. A 350 (1994) 36-44

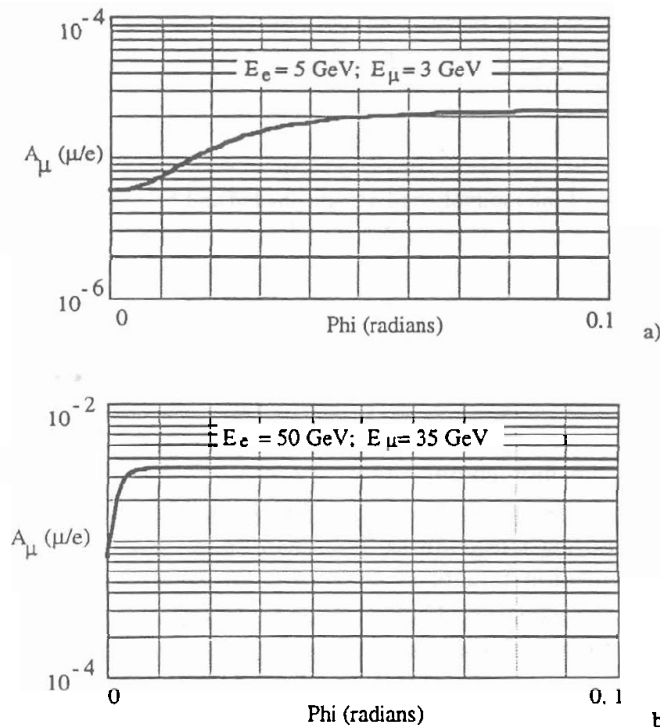


Fig. 2. Number of μ pairs per e^- accepted at an angle $\leq \phi$ for (a) a 5 GeV electron beam with $E_\mu = 3$ GeV and (b) a 50 GeV electron beam with $E_\mu = 35$ GeV.

- for muon cooling, want $KE < 300$ MeV or so
 - need to do rate estimate
 - but $\sim 10^{14}$ e/s available
- \Rightarrow substantial μ rate even if only 10^{-8} μ/e or less



Conclusions



- I suggest we put the “muon” back in New Muon Lab!
- NML may come on-line after MC 5-y plan
- Could test one or more 6D cooling techniques chosen as part of that plan
(+ optical stochastic cooling if still of interest after Bates work)