AD Briefing to Roger Dixon on the MTA and Muons, Inc.

The Bottom Line

1) 6D muon beam cooling is the key to muon colliders and perhaps Fermilab's future.
2) Hydrogen-filled RF cavities are essential for the best plan we have for this 6D cooling.
3) We desperately need to demonstrate that these cavities will work in the conditions of a cooling channel, with high radiation and strong B fields.

GOAL: Higgs Factory at Fermilab using new muon beam cooling ideas

- μ cooling technique
  - Initial Precooling implies
  - 6D cooling in helix
    - Needs HPRF
  - Parametric resonance Ionization Cooling
  - Reverse emittance exchange (next SBIR proposal)

- ε_N transverse (mm-mr)

  10^4

  10^2 (usual IC limit)

  6D cooling is 10^6

  10

  1

Smaller ε_T means fewer μ

$$\mathscr{L} \approx \frac{N_{\mu^+} N_{\mu^-}}{\beta_\perp \varepsilon_N}$$

Factor of 100 lower emittance means factor 10 fewer muons needed.
Then, proton driver needs 400kW, not 4MW on target (new Linac * MI)
Neutrino radiation problem reduced.
Detector backgrounds reduced.
Take advantage of $(m_\mu/m_e)^2$=40,000 s-channel Higgs production cross-section.
Needs Booster sized ring.

After the Higgs factory, the next step is an energy frontier muon collider using Tesla cavities (perhaps with recirculation) to feed a 2 (or more) TeV ring.

High Pressure, High Gradient RF Cavities for Muon Beam Cooling

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Muons, Inc.

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Jefferson Lab

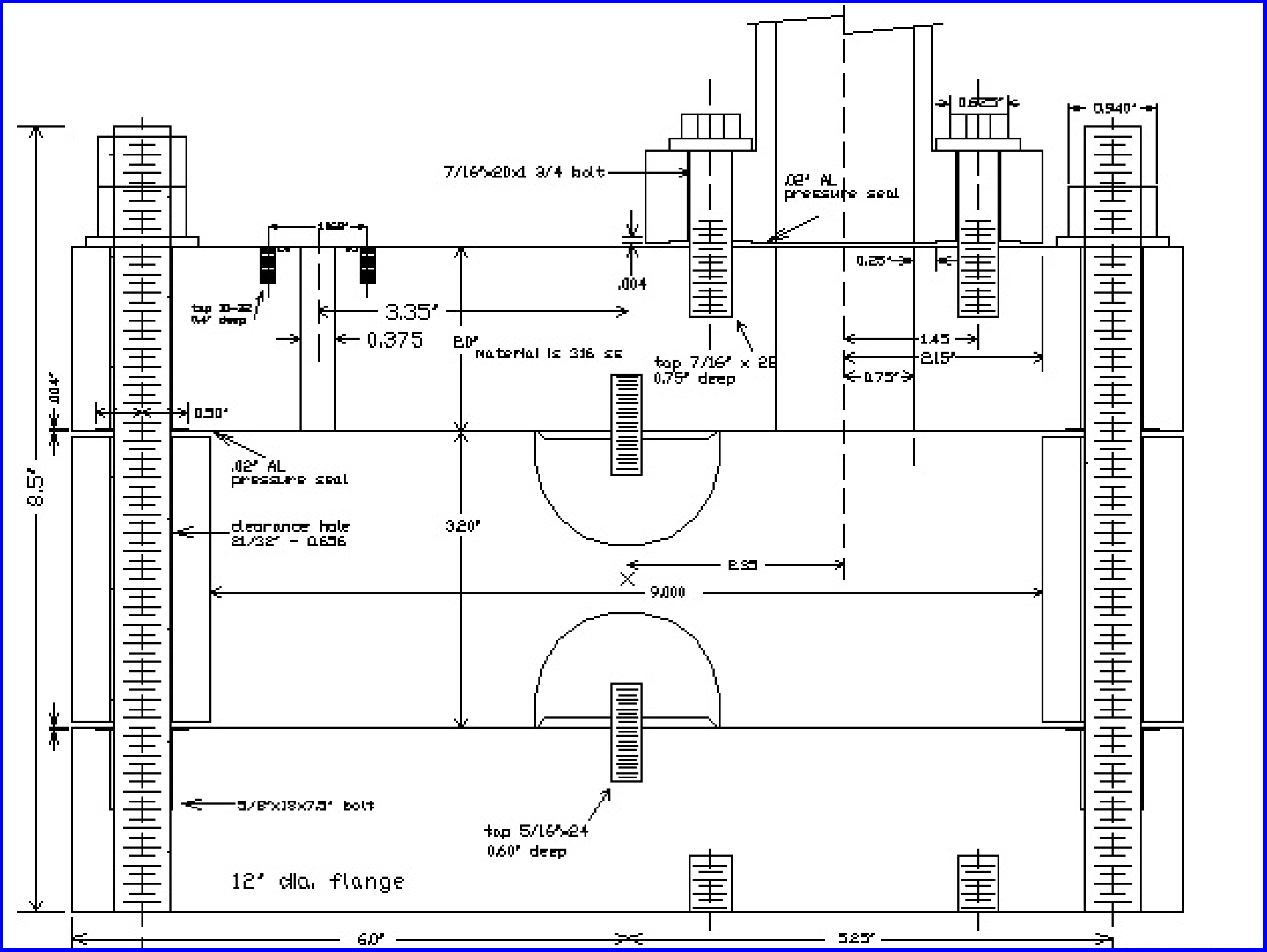
Pressurized RF for Muons

- Only works for muons
  - –No strong interaction scattering like protons
  - –More massive than electrons so no showers
- •Dense GH_2 suppresses high-voltage breakdown
  - –Small MFP inhibits avalanches (**Paschen's Law**)
- •Gas acts as an energy absorber
  - –Needed for ionization cooling

Hardware Development

- To develop RF cavities, pressurized with dense hydrogen, suitable for use in muon cooling.
- Measurements of RF parameters (e.g. breakdown voltage, dark current, quality factor) for different temperatures and pressures in magnetic and radiation fields to optimize the design of prototypes for ionization cooling demonstration experiments
- *First results presented at LINAC2004 last week; posted on www.muonsinc.com MuCool Note 285 has details*

Mark II 805 MHz RF test cell



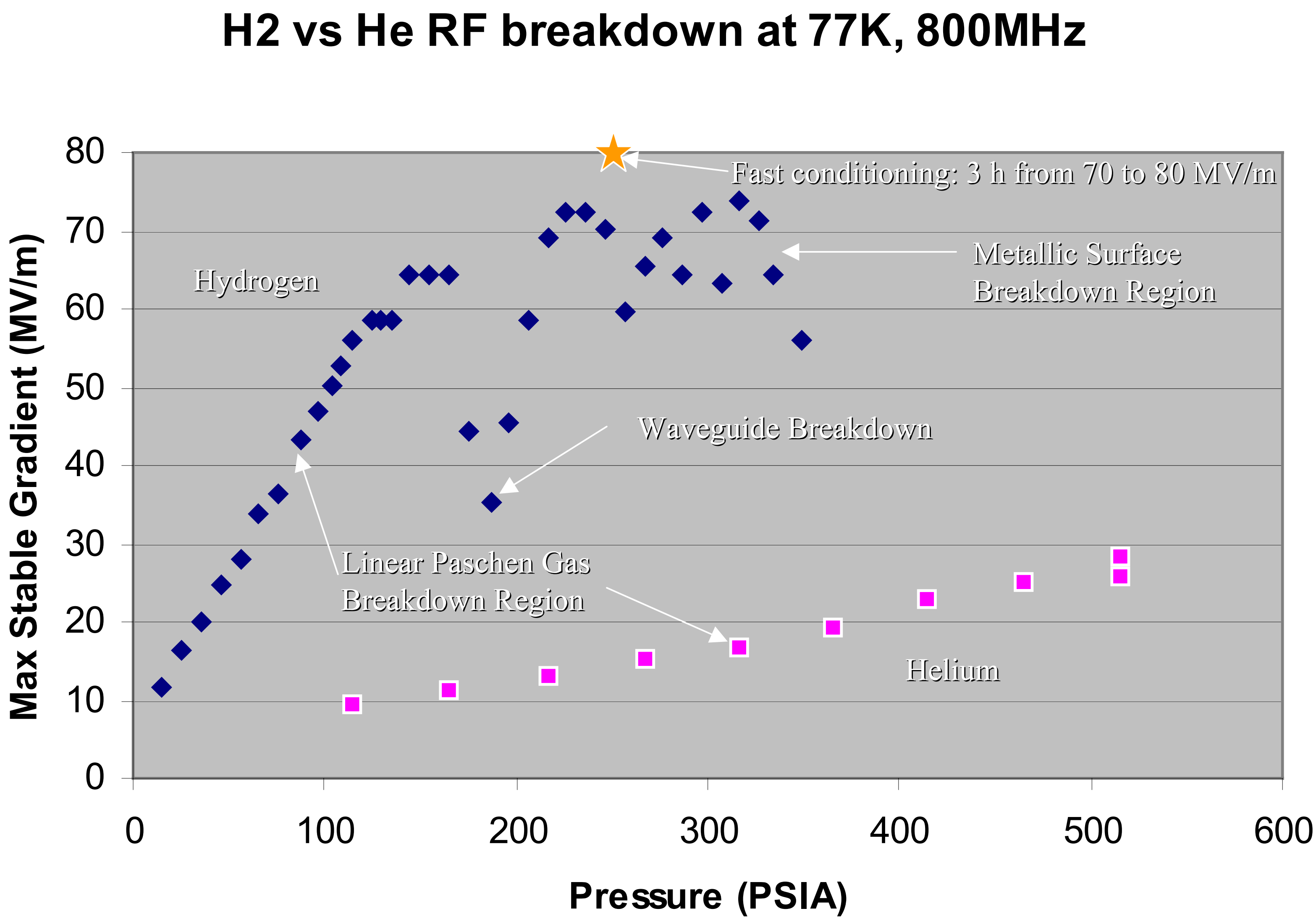
New TC; 1600PSI @ 77K


4/9/2003

RF probe signal

The probe signal taken during the last hours of operation at 250PSI and 77K. The pulse time of 20 μs corresponds to the rising part of the 800MHz envelope. The required pulse length is a few microseconds for a neutrino factory, while a collider may only require a few nanoseconds.

11/19/03 Lab G Results, Molybdenum Electrode



Gas density and dielectric increase with pressure causing frequency to decrease

Hydrogen Gas Virtues/Problems

- Best ionization-cooling material
  - $(X_0 * dE/dx)^2$ is figure of merit
- Good breakdown suppression
- High heat capacity
  - Cools Beryllium RF windows
- Scares people
  - But much like CH_4

Hopes for HP GH2 RF

- Higher gradients than with vacuum
- Less dependence on metallic surfaces
  - Dark currents, x-rays diminished
  - Very short conditioning times already seen
- Easier path to closed-cell RF design
  - Hydrogen cooling of Be windows
- Use for 6D cooling and acceleration
  - Homogeneous absorber concept
  - Implies HF for muon acceleration (1.6 GHz)

Example of HP RF Linac Design: Emittance Exchange With GH2

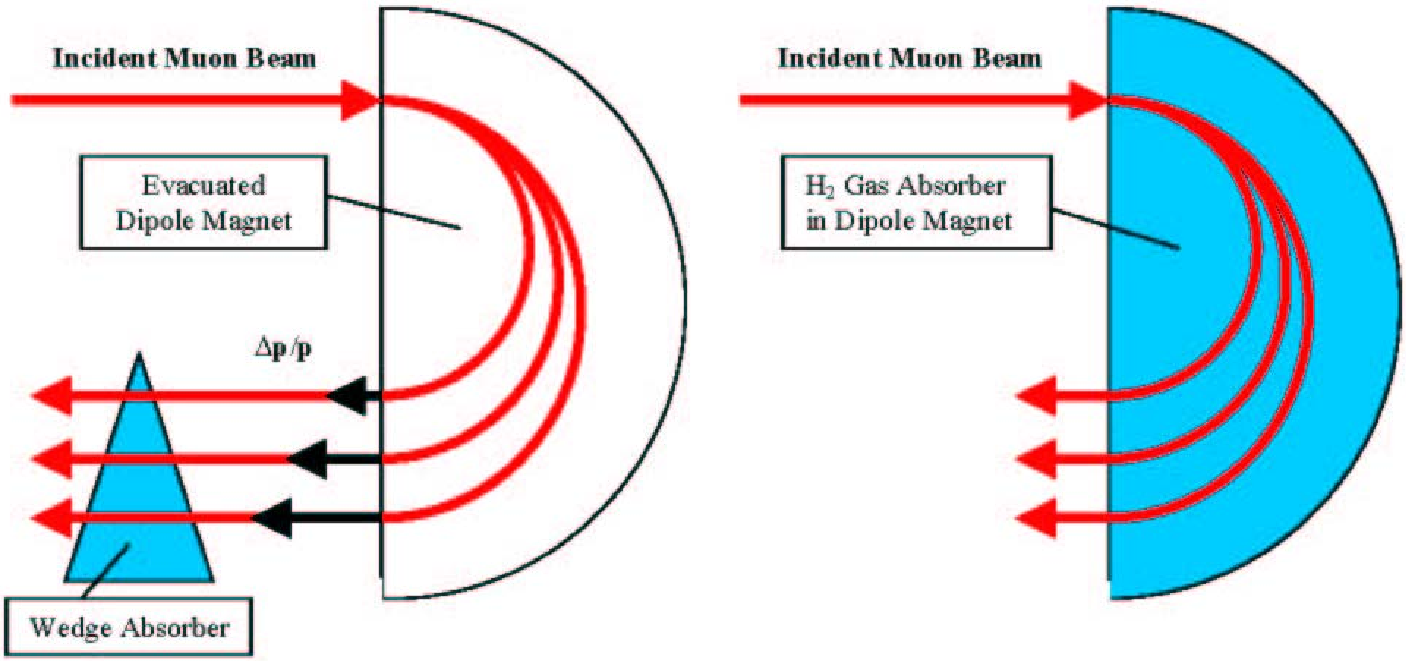
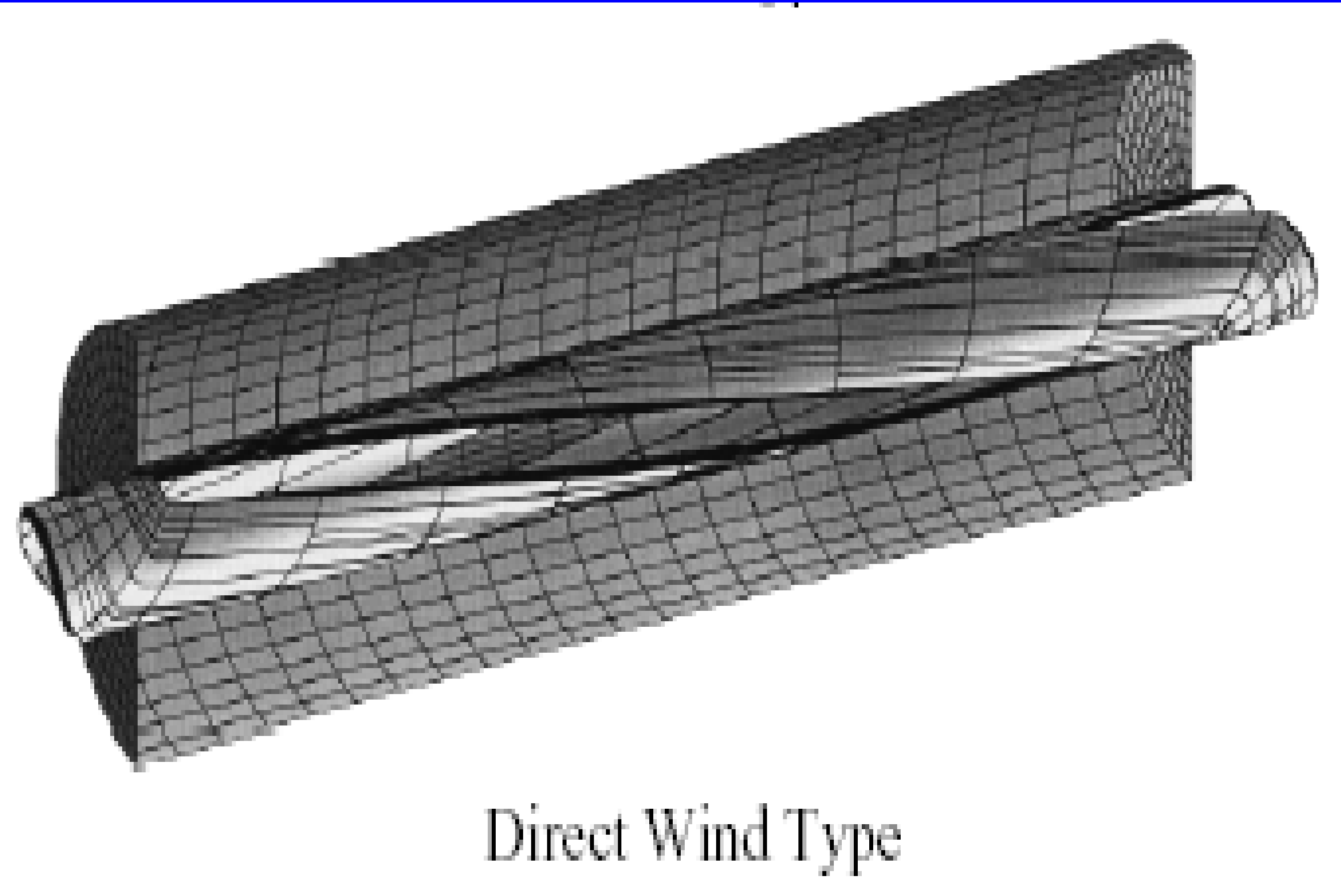


Figure 1. Use of a Wedge Absorber for Emittance Exchange

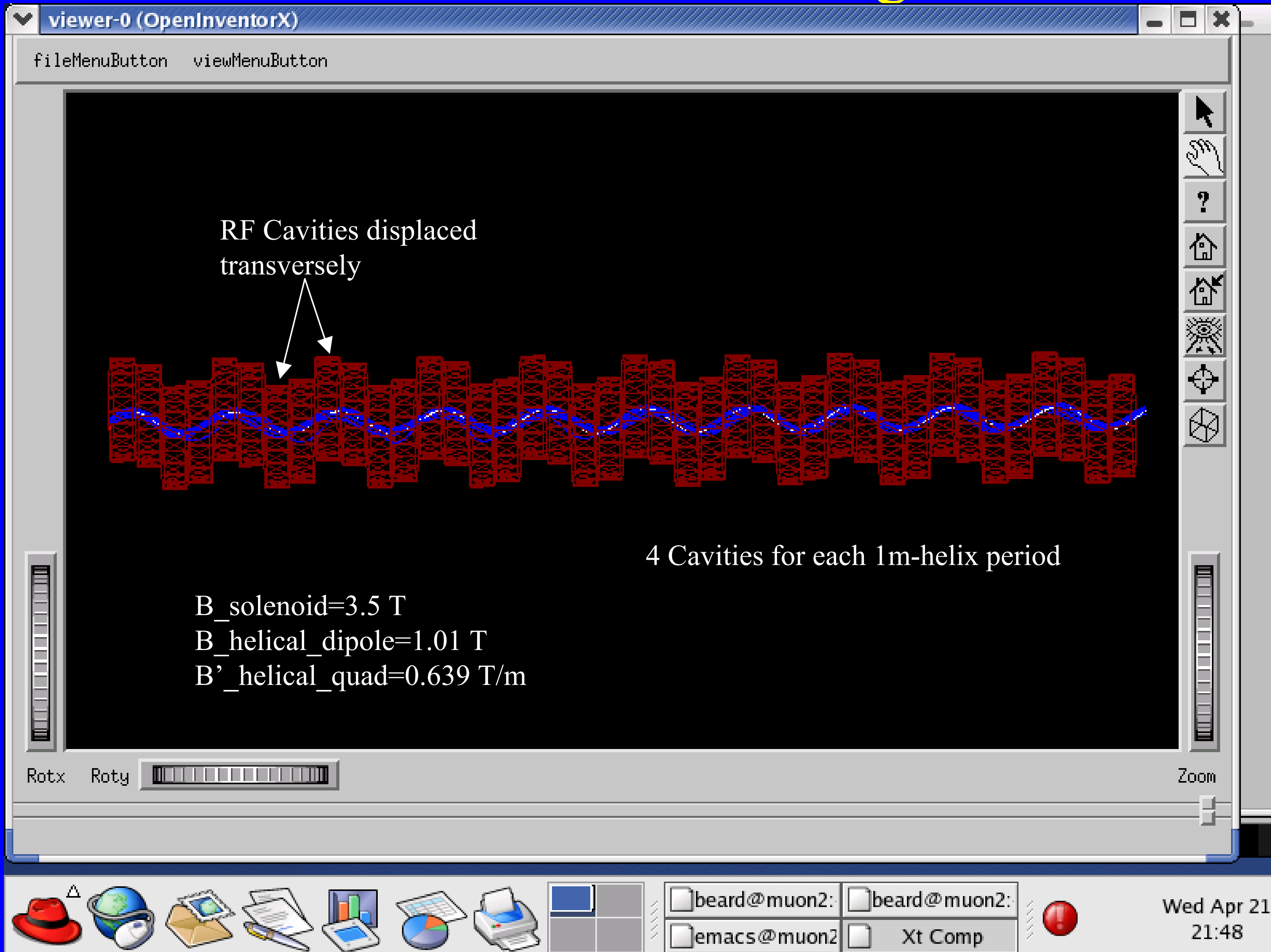
Figure 2. Use of Continuous Gaseous Absorber for Emittance Exchange

This concept of emittance exchange with a homogeneous absorber first appeared in our 2003 SBIR proposal!

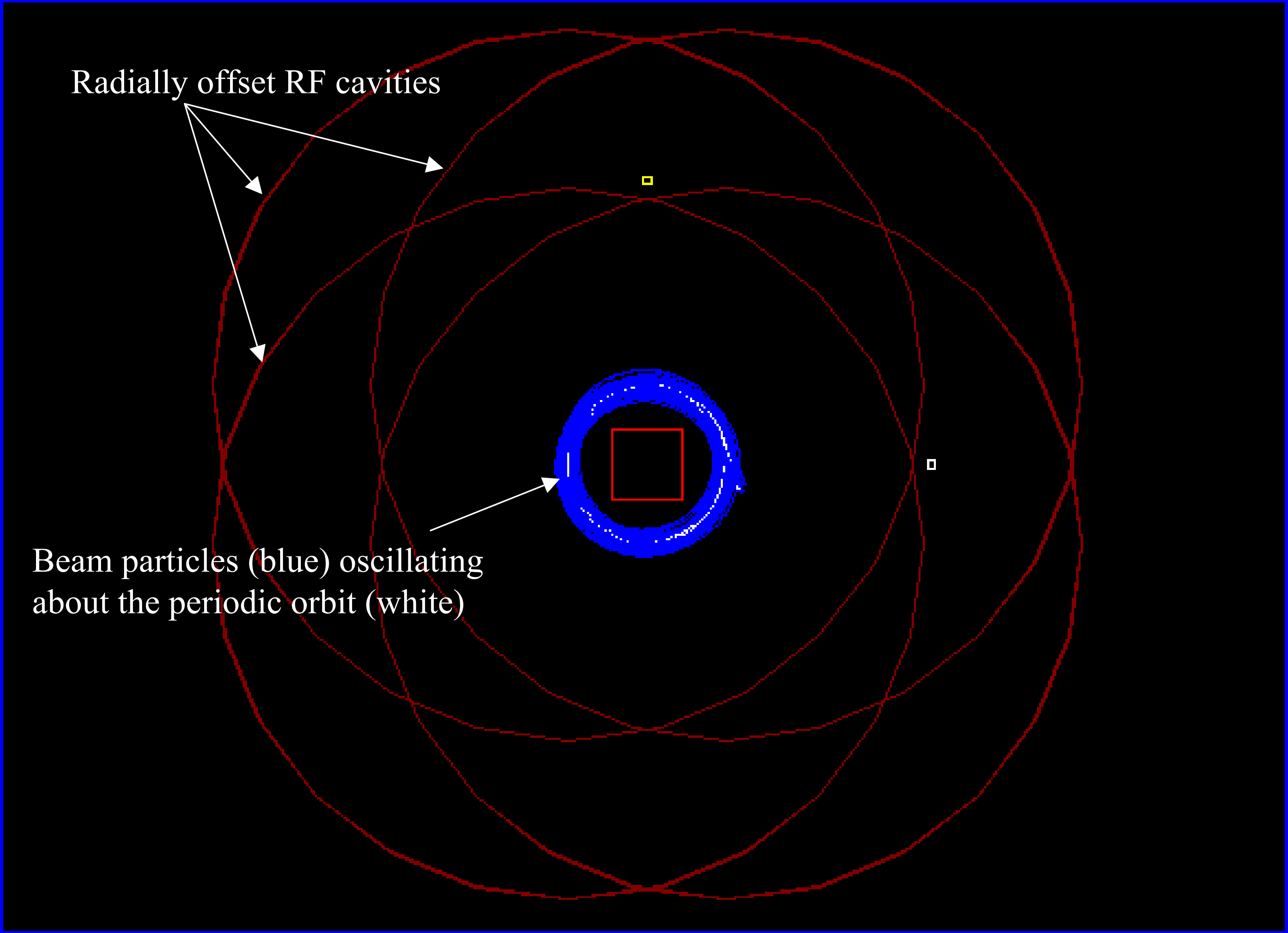
Helical Dipole Magnet (c.f. Erich Willen at BNL)



G4BL 10 m helical cooling channel



G4BL End view of 200MeV HCC



Present Hardware Activities

- Moving from Lab G to MTA
- Studying RF breakdown with cu, mo, cr, be electrodes 50:85:112:194 (Perry Wilson)
- Planning Test Cell for Operation in the LBL 5 T solenoid at 1600 PSI and 77K
- Working on MTA Beam Line
  - Want radiation test of GH2 RF in 2005

Status

Muons, Inc., IIT, Fermilab, and Jefferson Lab under the DOE SBIR program are developing new muon beam cooling concepts. The funded projects:

1) high-pressure, high-gradient RF cavities,
2) six-dimensional beam cooling using a helical dipole magnetic channel and GH2 absorber,
3) a plan for a demonstration muon beam cooling experiment using gaseous absorber,
4) a cryostat for muon cooling that incorporates high-T SC magnets and a hydrogen refrigerator,
5) a new method of ionization cooling using parametric resonances.

But the whole scheme requires that hydrogen-filled RF cavities work in strong magnetic and radiation fields!

Exactly what the MTA is designed to verify!