WG3 Summary

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and D. Li (LBNL)

Nufact09 Workshop

Illinois Institute of Technology, Chicago

July 20 ~ 25, 2009

WG3 Summary

- Many thanks to Session Chairs, WG3 participants and poster presenters
- High quality presentations
  - Very well prepared talks that were presented well
- Good discussions that lead to
  - Future to-do-list in each sub-field
  - Strengthen and develop new collaboration
- Over all impression and possible improvement
  - More discussion time needed, should be favored
  - Balance WG3:
    - Dominated by ionization cooling R&D this time
    - Capture after target (horn) and beta beams not discussed

WG3 Programs

- Nine sessions including three joint sessions with WG4
  - 30 presentations
  - 30 ~ 60+ participants
  - A complete list of the presentations can be found at NUFACT09 Workshop web site, all presentations in WG3 have been uploaded !
- NF related accelerator issues (proposals, status report, experiments and simulations):
  - Proton drivers (Project X at Fermilab, SPL at CERN)
  - Muon production
  - Cooling
  - Acceleration
  - Capture, beta beam discussions missing
- Beta beam: only one plenary session talk

WG3 Summary I

Derun Li

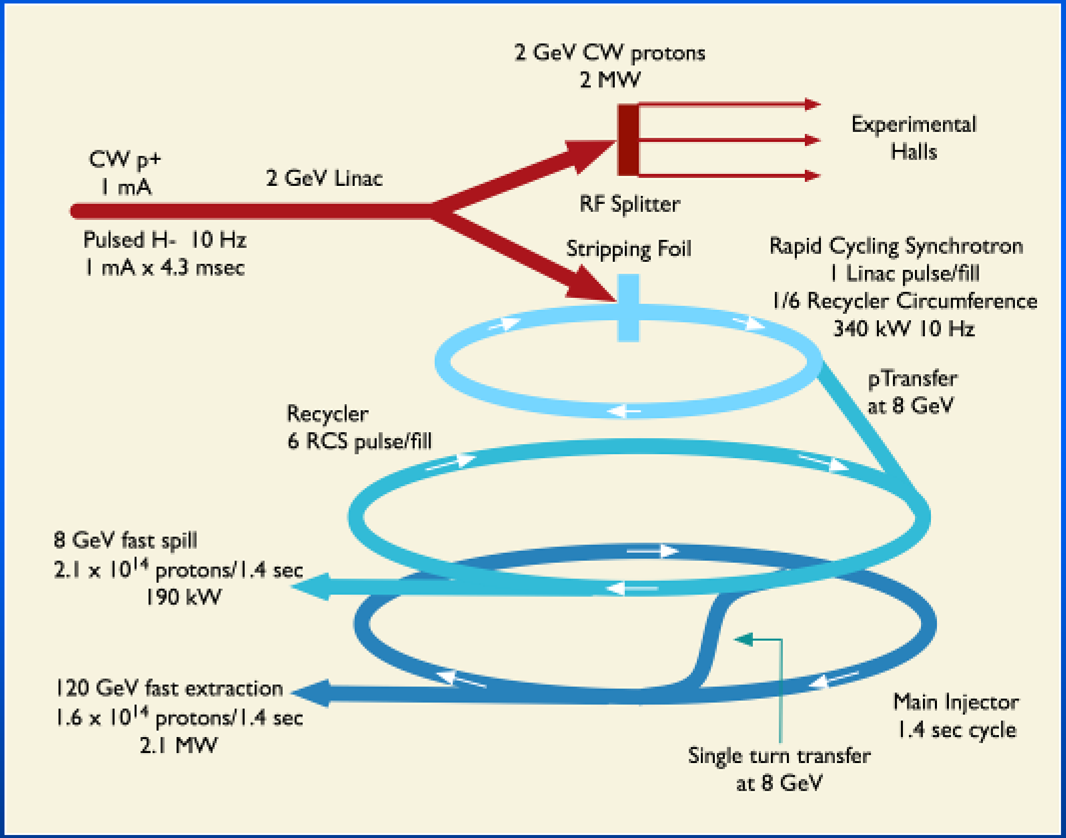
Project X at Fermilab – V. Lebedev

For large project in DOE:

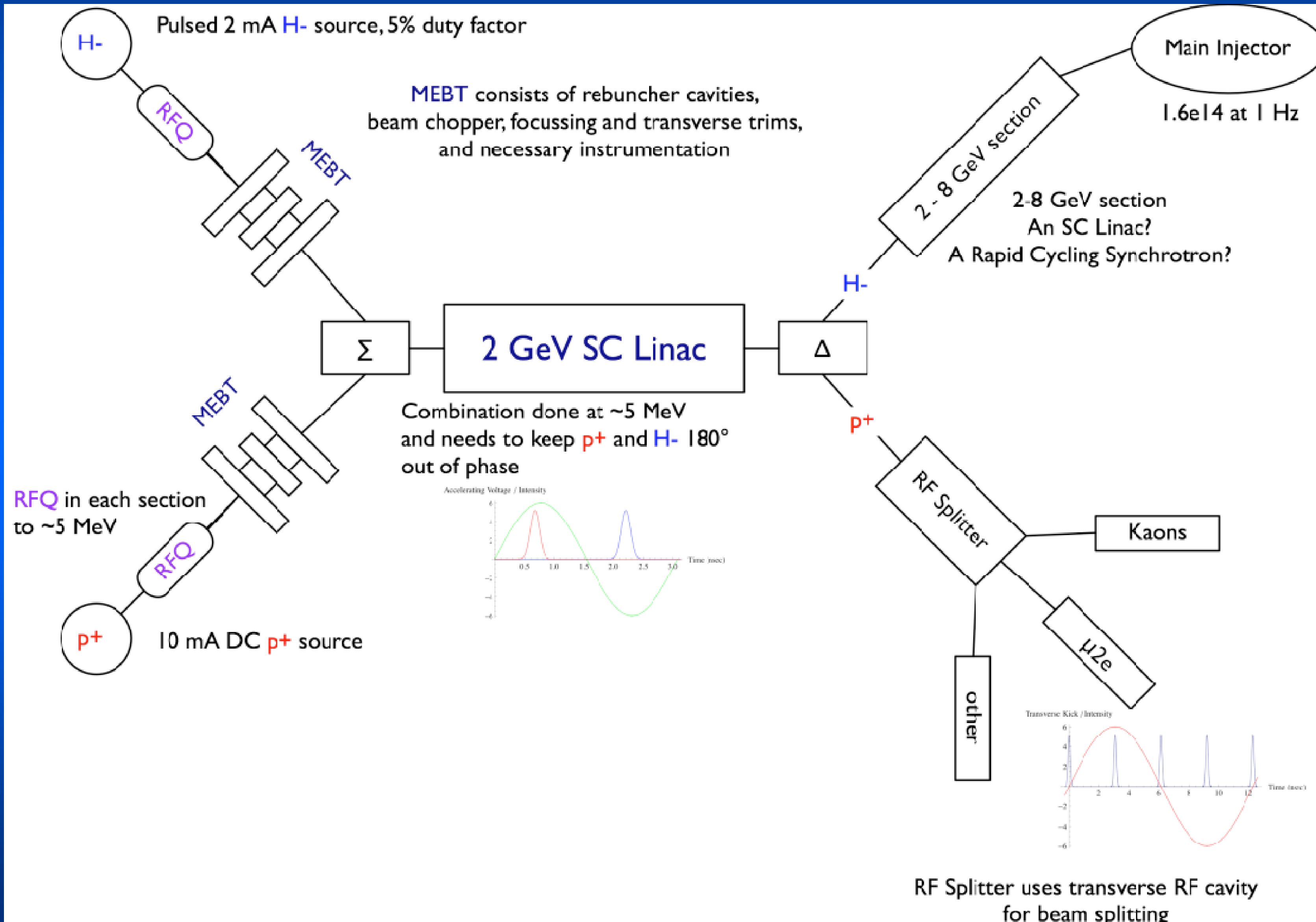
CD0: ICD (Initial Configuration Document)
and ACD (Alternative Configuration Document)

CD1: Project design and construction and commissioning □

ACD now becomes ICD-II



Ingredients in the ICD-II



Evolution of Project X and Physics Programs

- Initial Configuration I (ICD-I)
  - 8 GeV H^- Pulsed SC linac
  - 20mA, 1.25ms, 5Hz
  - ILC type 1.3GHz
- Initial Configuration II (ICD-II)
  - 2 GeV CW H^- and proton SC linac
  - proton beam to service K, μ2e, g-2, etc.
  - H^- into 2-8 GeV RCS or pulsed linac
  - 8 GeV injection into Main Injector (service for Super-beam, N-Factory, MC, etc.)

Issue: Can this new plan support 4MW for a ≥ 8GeV source?

Project X and a Muon Facility at Fermilab, Advantages of the Proposed Plan - M. Popovic

- Experiments can start with Booster beam, then transition to beam from Project X without relocating
- Beam time can be shared flexibly
- Existing infrastructure can be intensely used
- All 1st-round experiments located in one area
- It can be implemented rapidly
- It provides a path back to the energy frontier

A 30 GeV Muon Collider front end to feed a Neutrino Factory - Rolland Johnson

Muon Ionization Cooling R&D

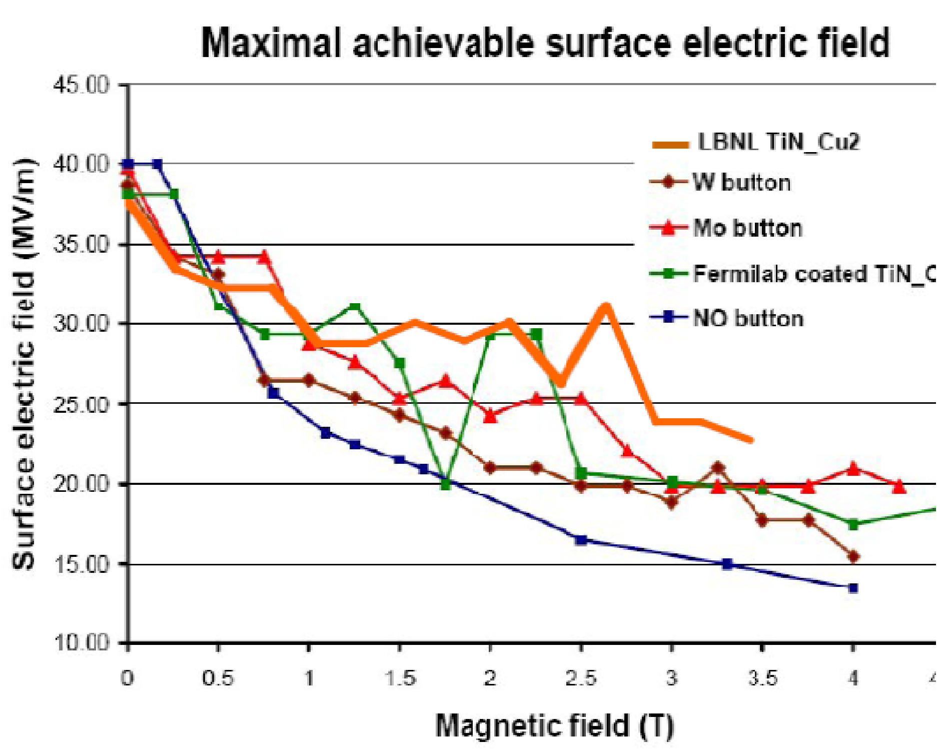
Major technical issue is RF in magnetic field. Is the program receiving enough attention?

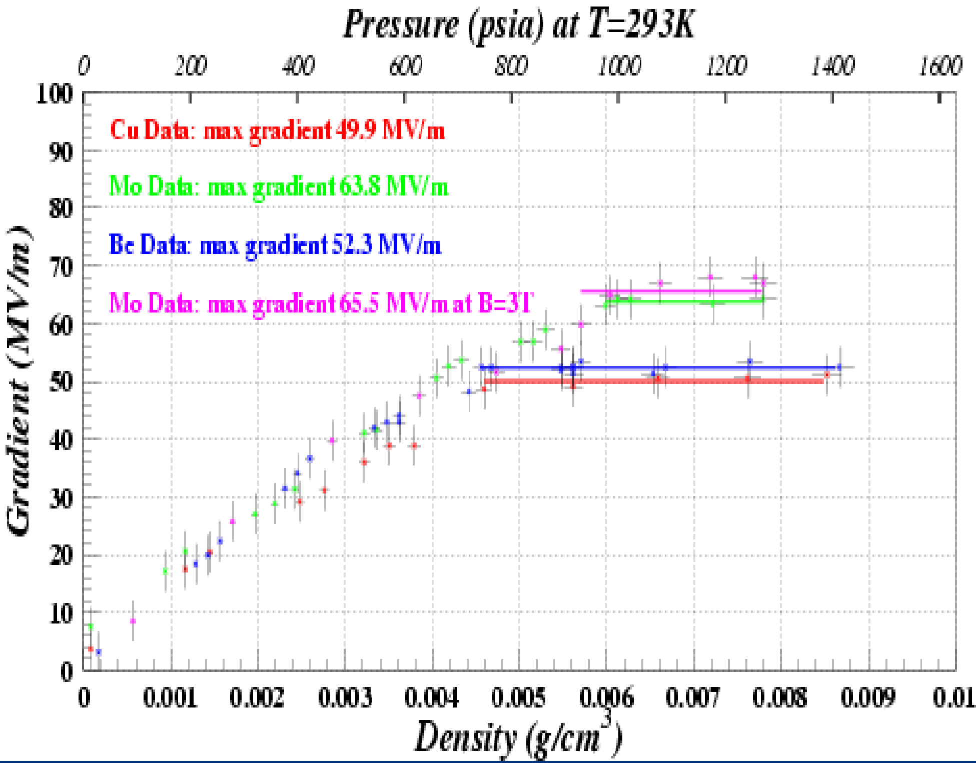
- Be cavity design
  - Robert Palmer
- Effects of external magnetic fields on RF cavity operation (experiments)
  - Diktys Stratakis
- Thoughts on incorporating HPRF in a linear cooling channel
  - Michael Zisman
- The problem of RF gradient limits
  - Jim Norem
- Atomic layer deposition to improve accelerator performance
  - Thomas Proslier
- Shielded RF lattice for the muon front end
  - Chris Rogers

RF Gradients in magnetic fields

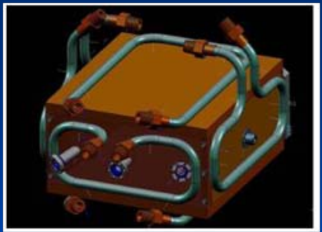
Muon Ionization Cooling Channel requires high gradient RF cavity in strong magnetic field

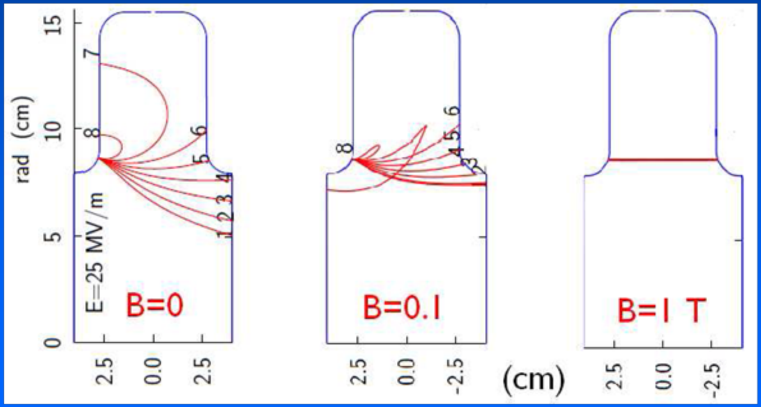
- Electric fields are parallel to magnetic fields: damage was observed in tests
- Achievable RF gradient of vacuum RF cavity decreases as the external magnetic fields increases, but not in high pressurized RF cavity

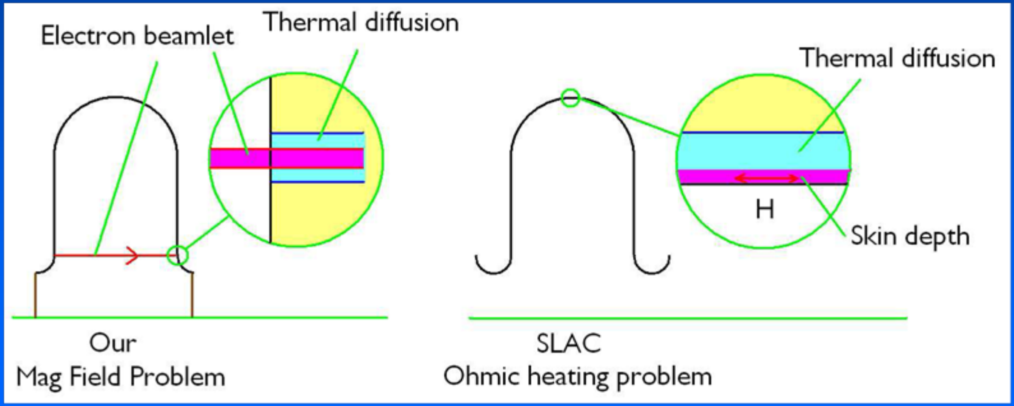


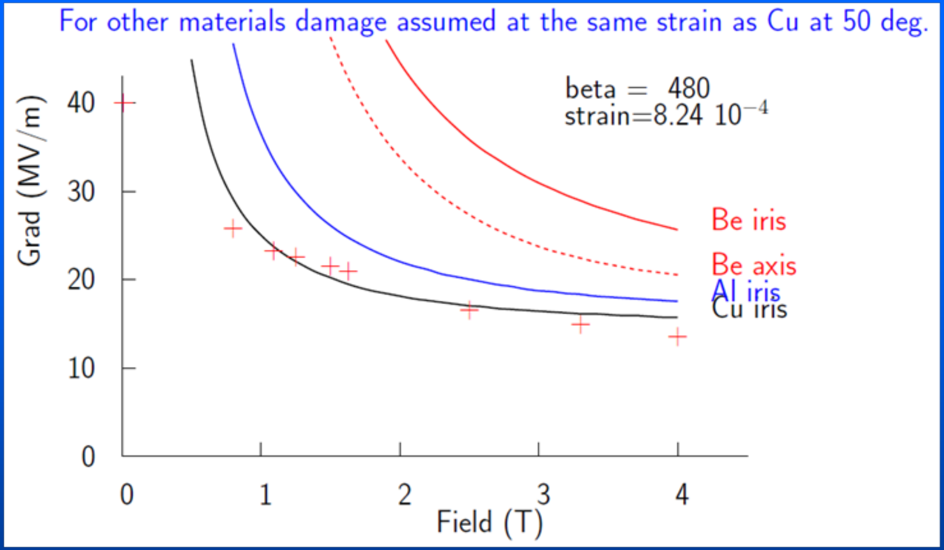


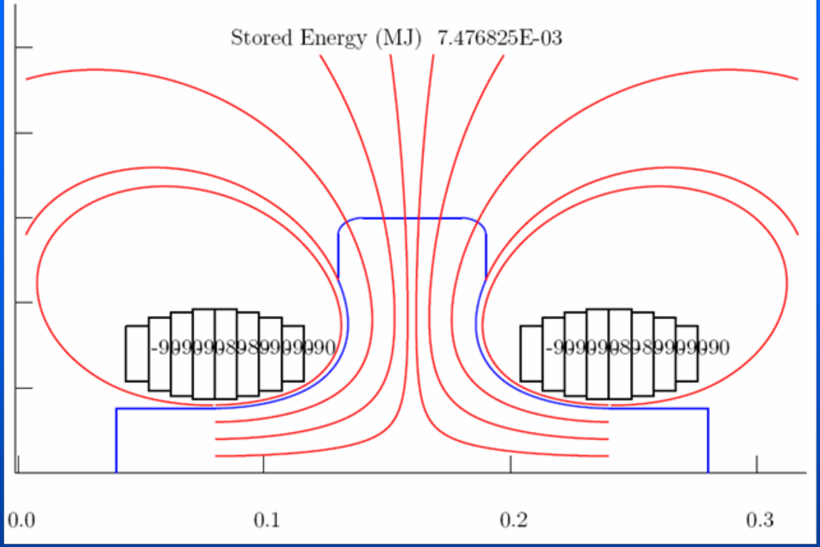
Understanding the RF Problem and Possible Solutions





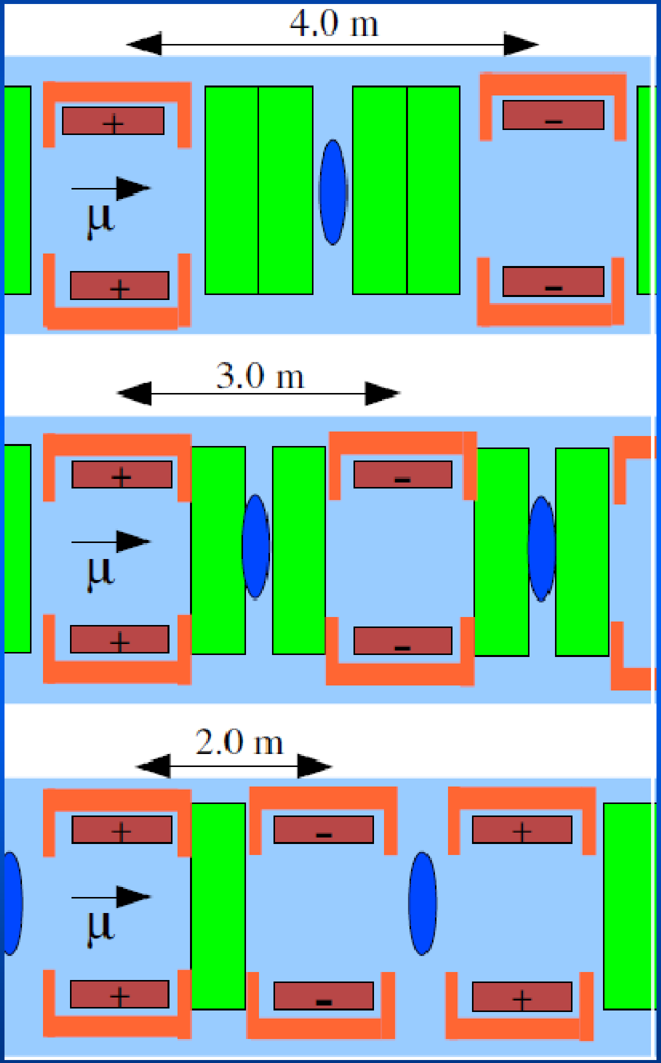


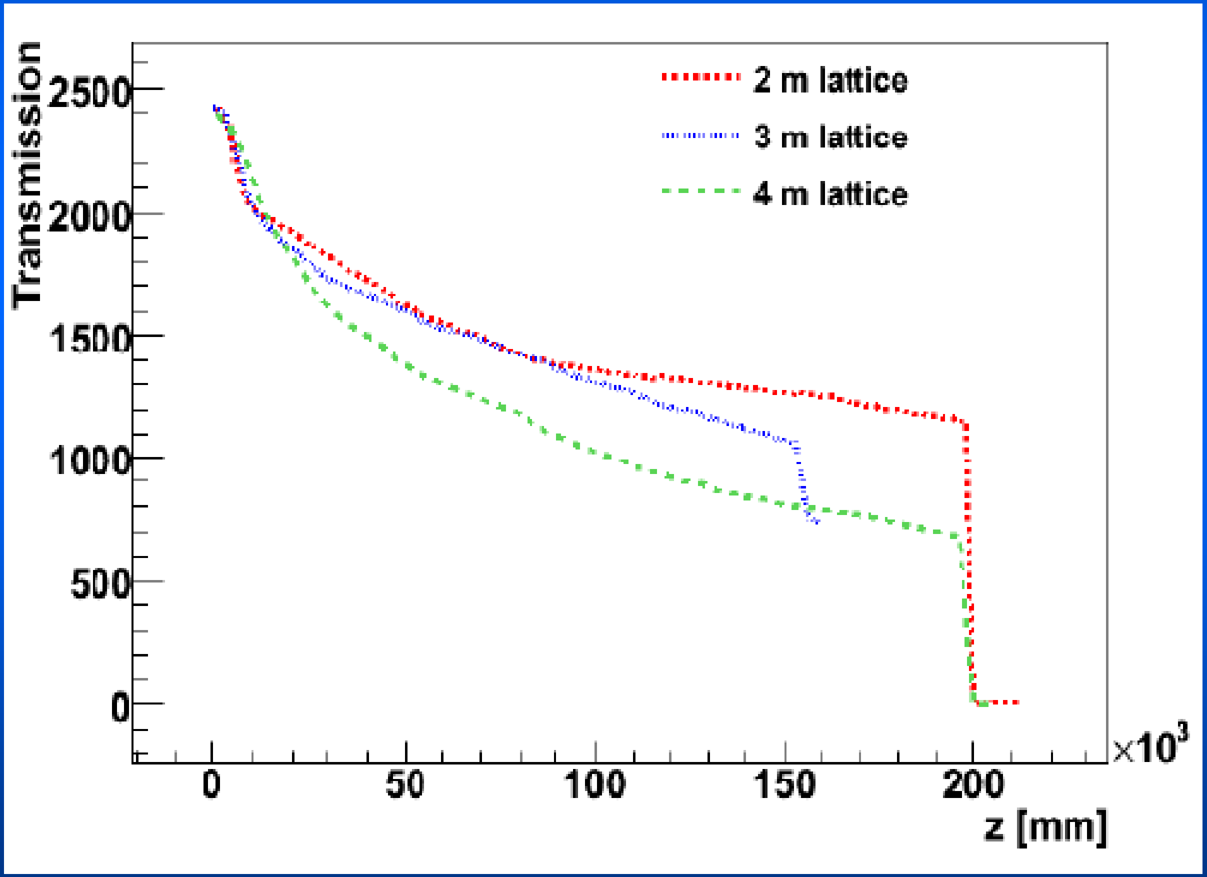




Square box cavity to study EXB effects; Be cavity to theory and RF gradient; Magnetic field shielding to avoid cavity damage by external magnetic fields

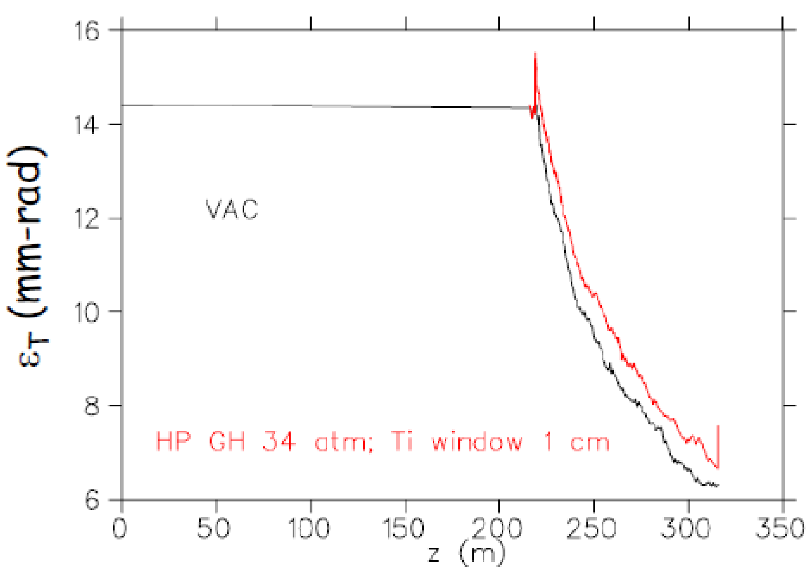
Shielded RF Ionization Cooling Channel - C. Rogers

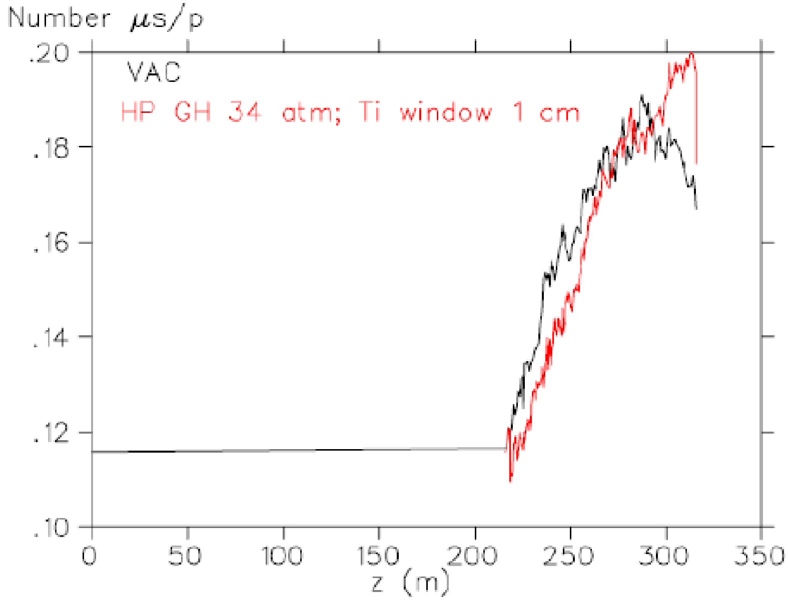




A Hybrid Cooling Channel using HPRF Cavity – M. Zisman

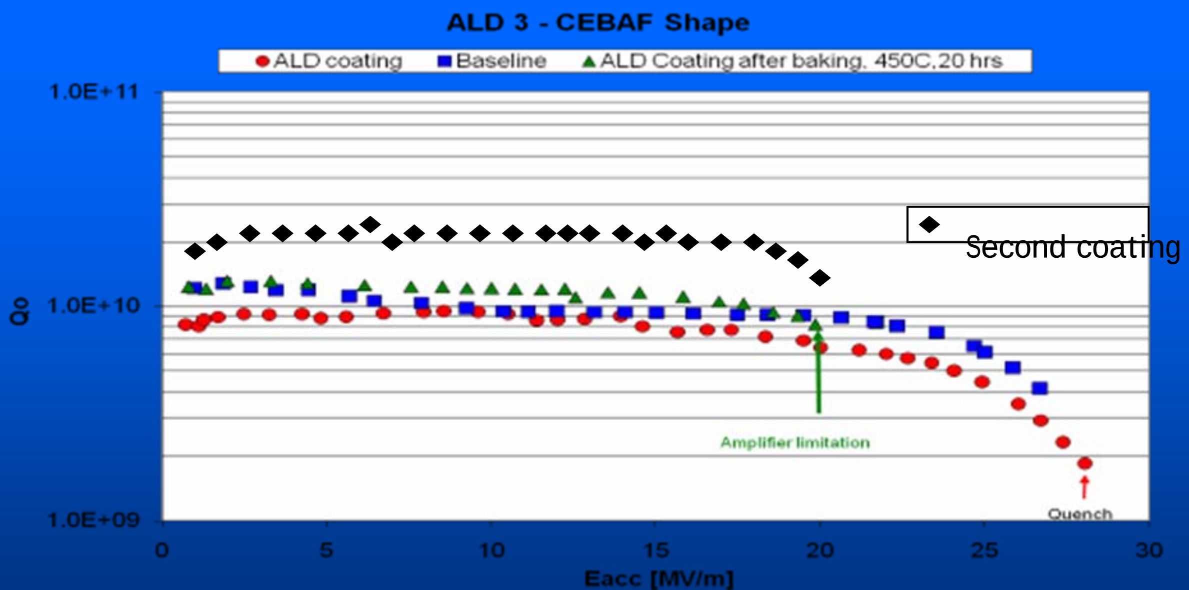
- Primary purpose of HPRF is to avoid degradation from magnetic field
  - use gas only to deal with this task
    - requires much lower pressure than to reach material limit
- For the Study 2a case, we need gradient of ~15 MV/m
  - from HPRF test cavity, expect this to require only ~34 atm at room temperature
    - or ~9 atm at 77 K
  - need eventually to confirm with 201-MHz cavity

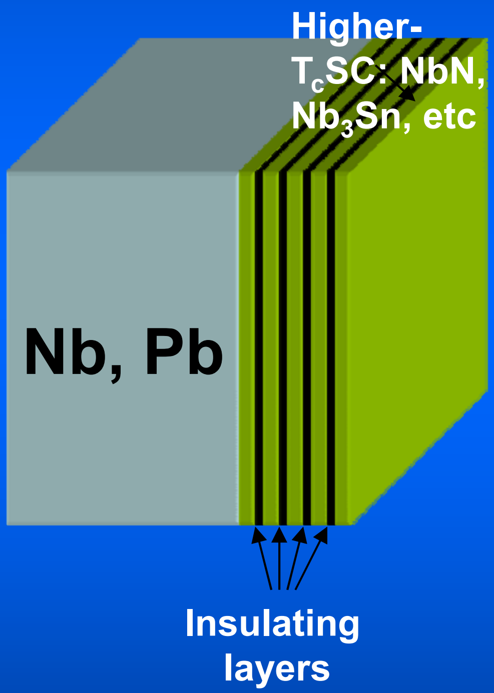




Atomic Layer Deposition (ALD)

- To eliminate field emission: origin of the RF gradient limits by external B fields
- Well controlled Smooth surface
- Tests from SC RF
  - Promising results
    - High accelerating gradient and higher Q



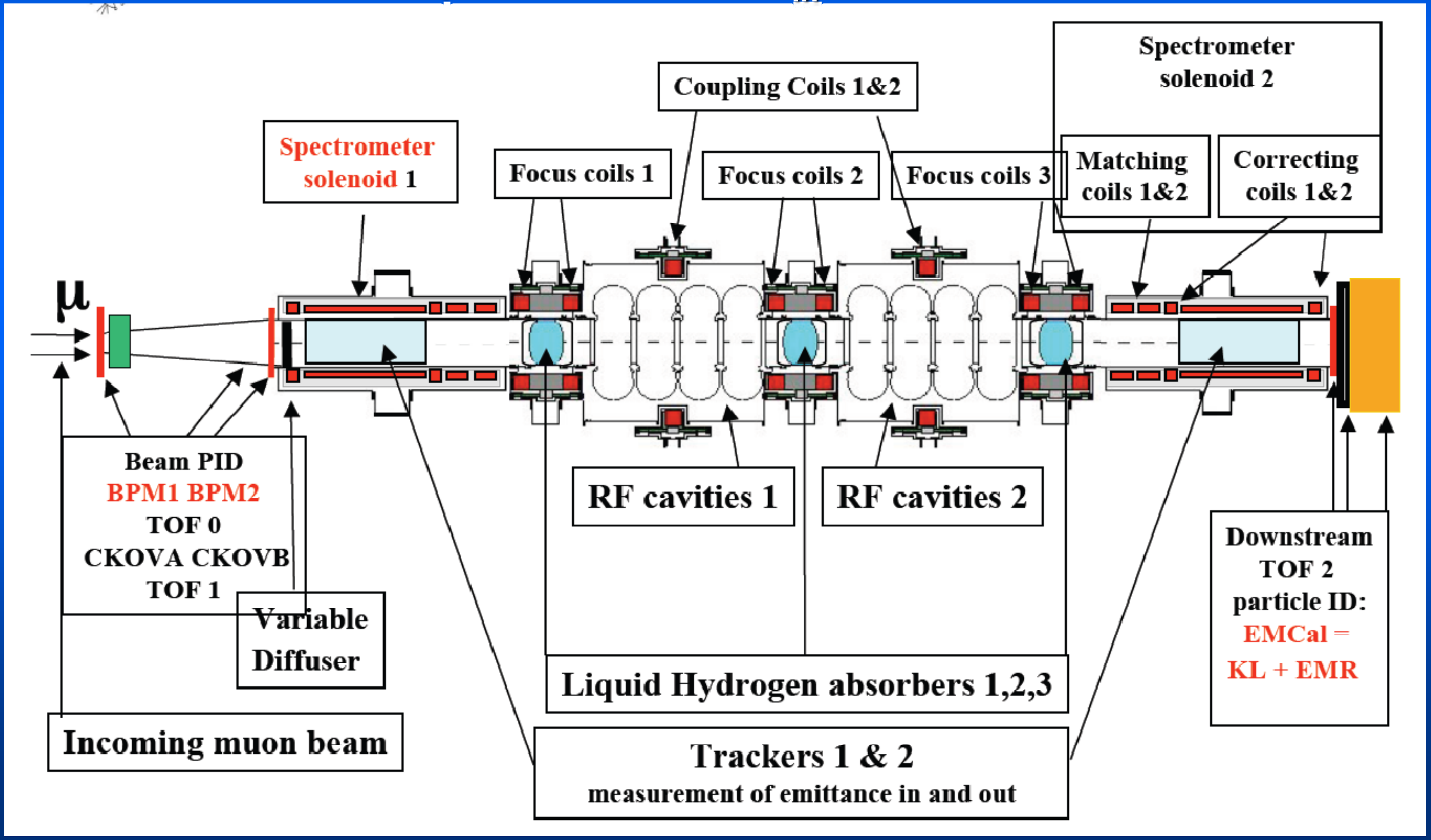


Promising technique and should be followed at next NUFACT

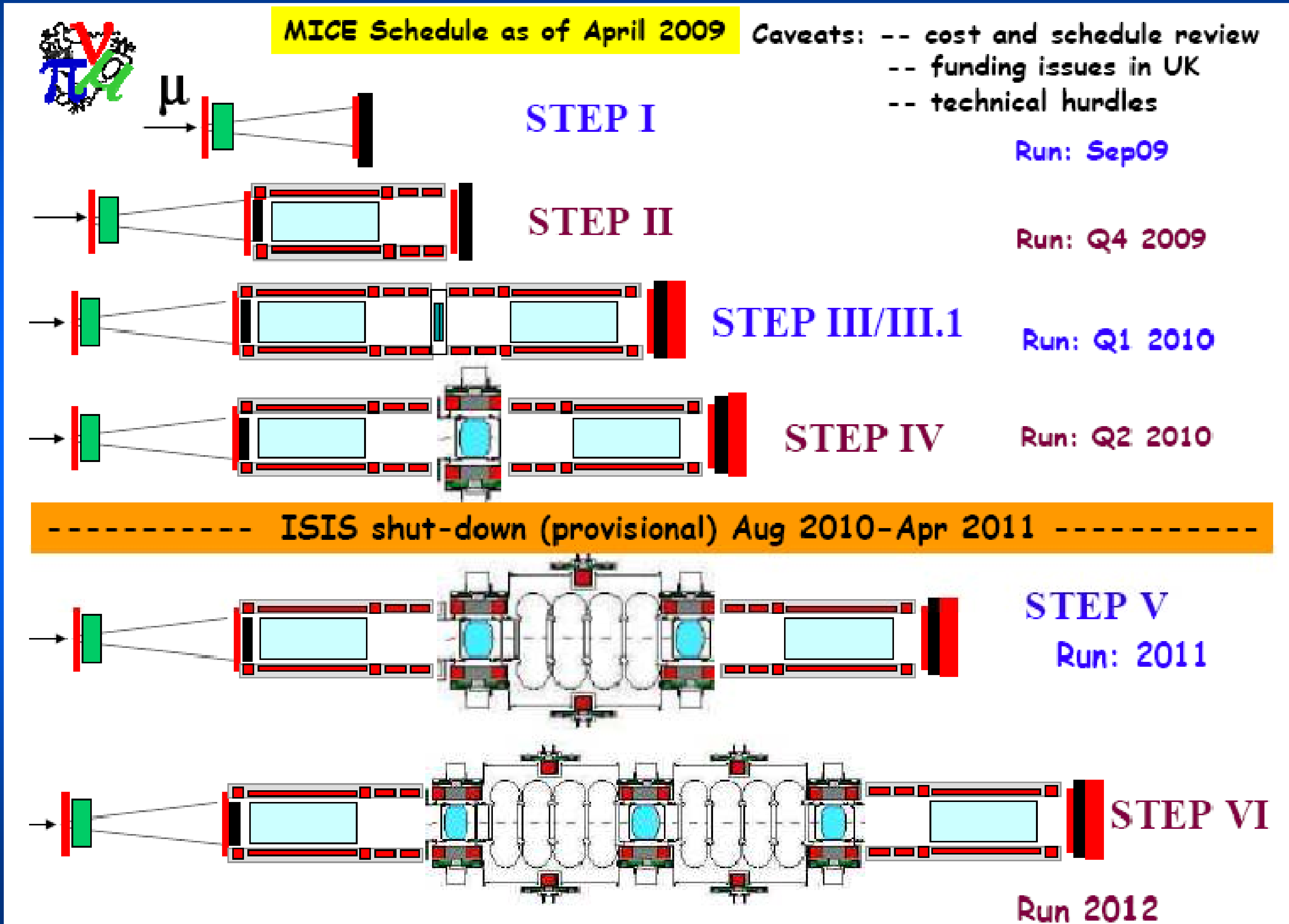
Cooling R&D

- **Physics Processes Missing from our Current Simulation Tools**
  - **Tom Roberts**
    - **List of processes not now included in current simulation software we are using**
    - **To-Do-List (for next NUFACT)**
      - Try to include and implement these physics processes
- **Cooling R&D:**
  - **Cooling scheme summary (Beta Beams, ionization cooling)**
    - **David Neuffer**
  - **Frictional cooling scheme for Muon Collider: demonstration experiment summary**
    - **Daniel Greenwald**
  - **MICE Status**
    - **Paul Soler**

- The **Muon Ionization Cooling Experiment (MICE)** is being built at the Rutherford Appleton Laboratory (RAL) to measure ionization cooling from a beam of muons traversing liquid hydrogen and other low Z absorbers (LiH).
- **The aim of MICE** is to measure ~10% cooling of 140-240 MeV/c muons with a measurement precision of $\Delta\varepsilon/\varepsilon_{in}=10^{-3}$



MICE Schedule



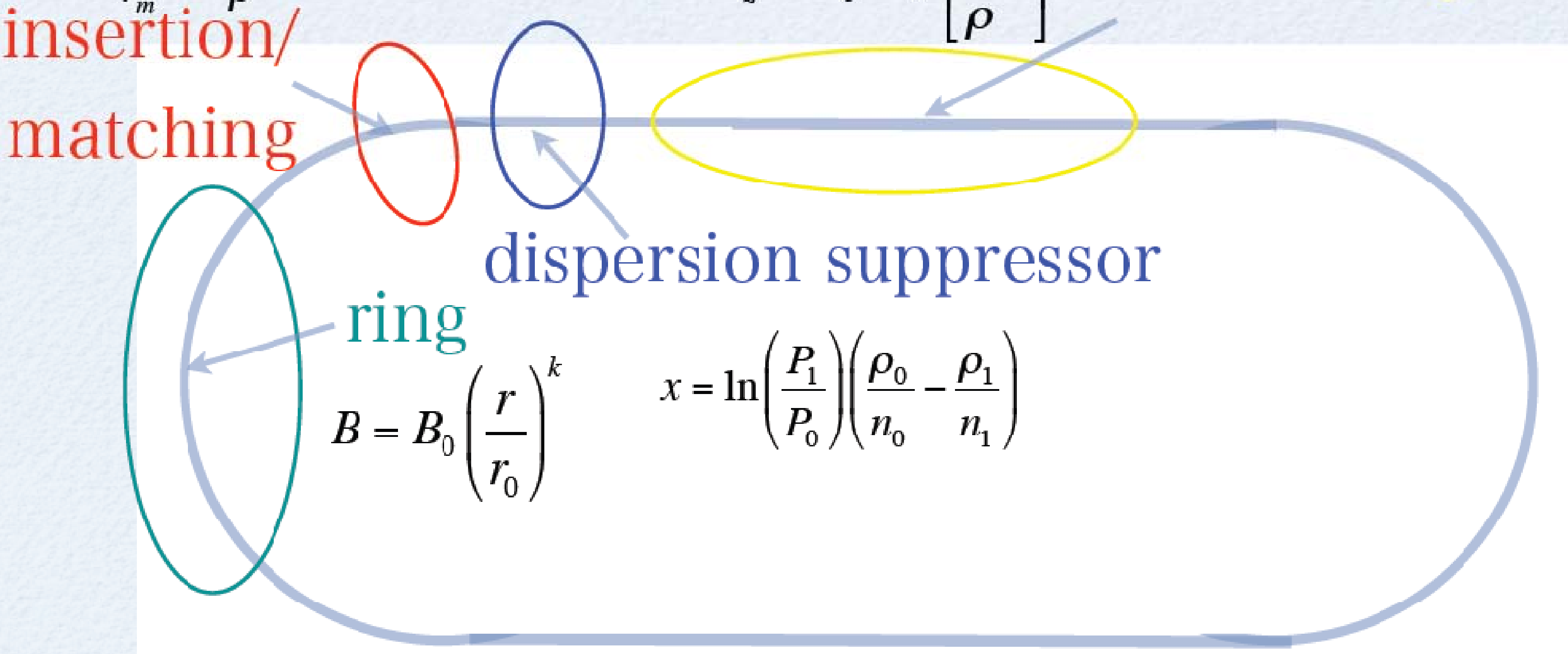
Current Status and Outlook

- Commissioning MICE beam commenced 2008!
- MICE target operated from Mar-Dec 2008.
- Particles observed using TOF/CKOV counters.
- New target, decay solenoid and tracker to be ready in September 2009 → MICE Steps I & II (emittance measurement)
- Steps III/III.1 & IV should occur in 2010.
- Step VI expected 2012.
- On track for observation of ionization cooling by 2012!

Advanced Scaling FFAG – Y. Mori

- A new and advanced scaling FFAG scheme has been developed
- The scaling linear system requires
  - Scaling law
  - Insertion/Matching
  - Dispersion suppressor
- Race-track FFAG ring is in reality now
- Muon acceleration → Neutrino Factory
- option replacing RLA (T. Planche)
- Applications

Advanced scaling FFAG



$$\frac{k+1}{r_m} = \frac{n}{\rho}$$

$$B_z = B_0 \exp\left[\frac{n}{\rho} x\right]$$

$$B = B_0 \left(\frac{r}{r_0}\right)^k$$

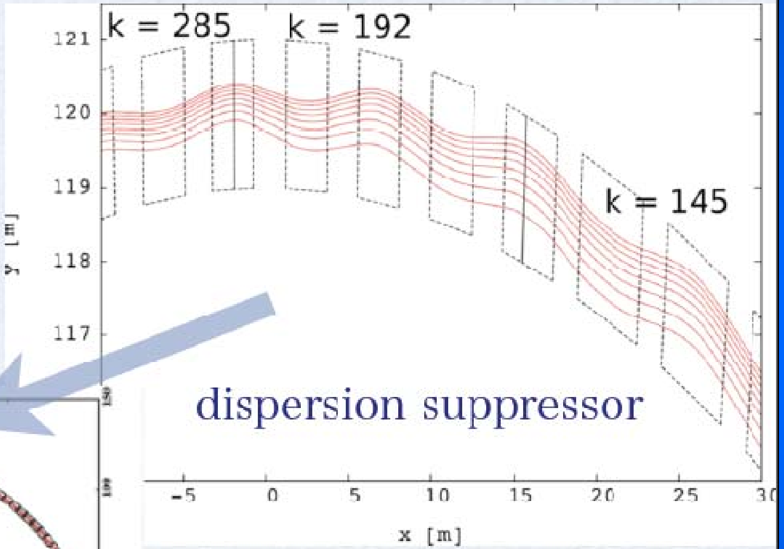
$$x = \ln\left(\frac{P_1}{P_0}\right)\left(\frac{\rho_0}{n_0} - \frac{\rho_1}{n_1}\right)$$

Applied to muon accelerator

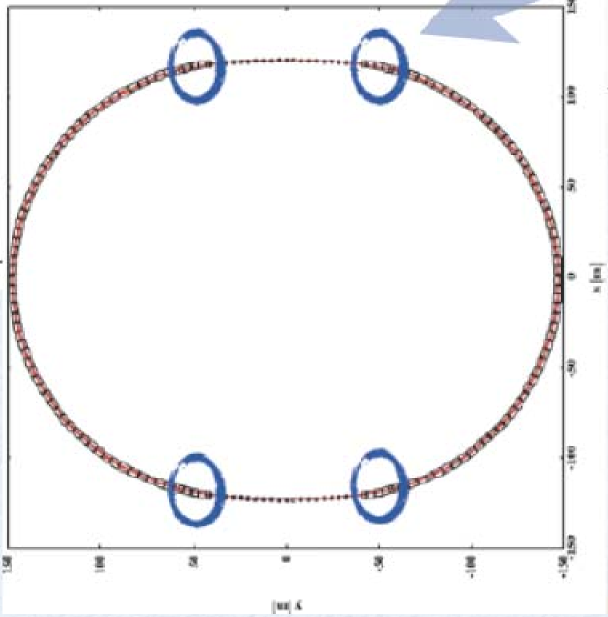
- 3-10 GeV Muon accelerator in Neutrino Factory
  - T.Planche - next talk

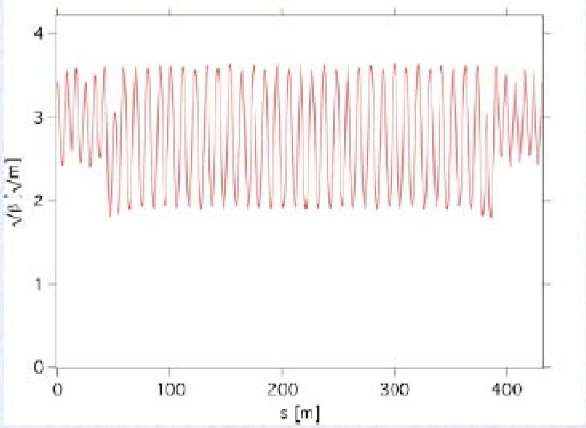
Table 1: 3 to 10 GeV Muon Ring Parameters

Lattice type	scaling FFAG - double beam
Mean radius	120 m
Number of cells	72
Field index k	145
Packing factor	0.7
B_{max}	2.6 T
Horiz. phase adv. per cell	93.2 deg.
Verti. phase adv. per cell	30.2 deg.
Mean RF frequency	~ 400 MHz
RF peak voltage	1.6 GV/turn
Number of RF cavities	72



dispersion suppressor





WG3 Summary II

E. Wildner

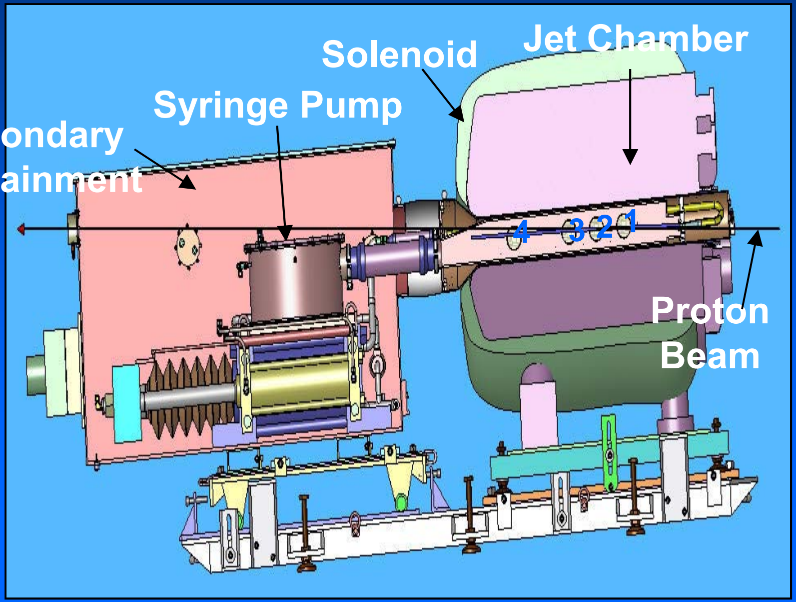
Harp data and min energy for Proton Driver (J. Strait)

- The "abrupt fall-off in pion production" below about 5 GeV appears to be an artifact of the default MARS pion generator.
- Work is nearly complete on a stable LAQGSM option in MARS, thoroughly benchmarked in this region.
- HARP cross-section data show that, normalized to equal beam power, an incident proton beam energy of 4 GeV is comfortably sufficient for the proton driver for a neutrino factory. This conclusion does not depend on whether one uses the data published by the main HARP collaboration, or the HARP-CDP collaboration.

Studies of Muon-Induced Radioactivity at NuMI, David Boehnlein

- JASMIN has measured radio-nuclides produced in aluminum and copper in the muon alcoves
- It's not clear how much of the activity is produced by muons and how much by muon-produced neutrons (for radiation safety, does it matter?)
- MARS15 simulations give good predictions of dose rates and activation.
- Studies will continue in Fall 2009.

MERIT Experiment at CERN – H. Kirk



- Hg jet disruption mitigated by magnetic field 8 MW equivalent demonstrated.
- Need to understand issues for sustained operation.

Pion Production and Tracking for 5–15 GeV Beam for NF Front-End Study – G. Prior

- Fraction of pions surviving is small (7-9%) (can be improved ?)
- Yield/p/GeV increase with beam energy
- Joint efforts are ongoing to understand apparent differences in simulation results. Outcome should be a more robust understanding

Production Simulations from Hg Jet Target – X. Ding

- Target parameters of incident beam below Hg target and KE from 2 to 100 GeV are optimized. Peak yield for 8 GeV protons.
- Beam angles and beam/jet crossing angles vary at low KE due to magnet field.

Initial Commissioning of the T2K Beamline – M. Hartz

- Stability of the extraction beam orbit from Main Ring is confirmed
- Combined function superconducting magnets work as expected
- Beam is transported to center of T2K target
- Next beam commissioning run begins later this year

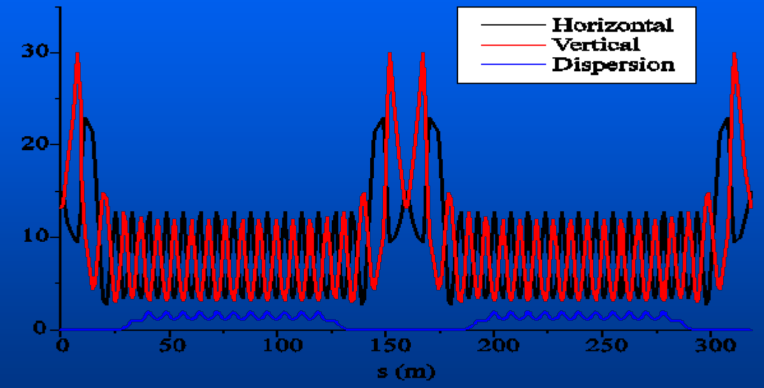
Be ready for physics run by December 2009!

Beam stability in the SPL - Proton Driver accumulator for a Neutrino Factory at CERN – Elena Benedetto

- CERN 4MW 5GeV, 6 bunches (ISS requirement)
- Accumulator isochronous (no RF stabilizing) fast (<400 Ms) instabilities may arise?
- Space Charge OK
- Machine impedance:

  (narrow-band , resistive wall, longitudinal and transverse broadband instabilities no issue)
- e-cloud not an issue

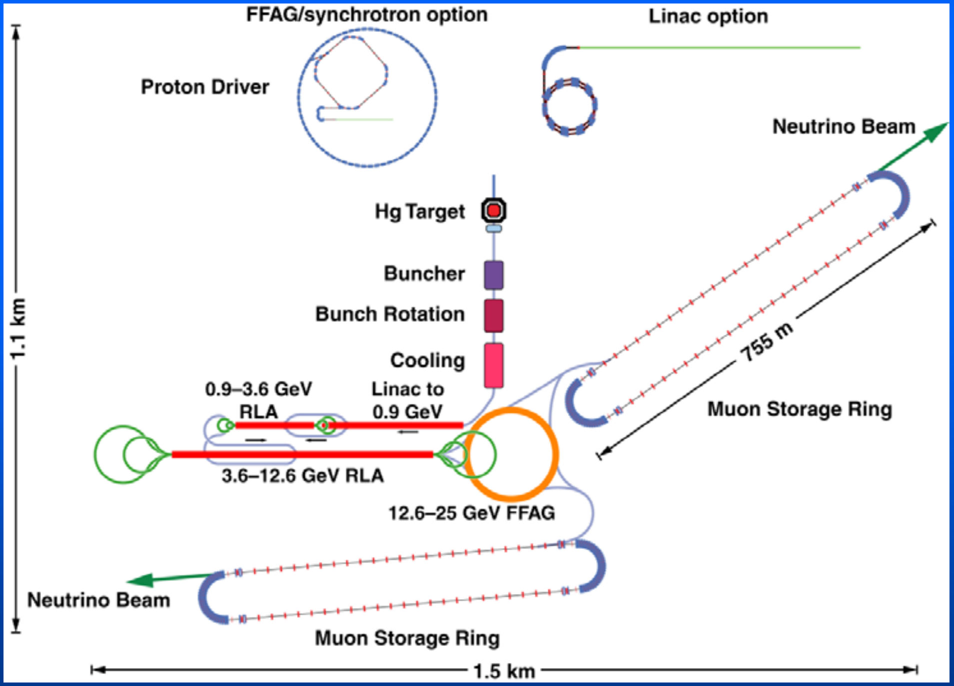
  Works also with 3 bunches option



Status and Plans of the EUROnu Neutrino Factory work-package – Ken Long

- • Euronu started, work to integrate EU partners in IDS

  - Work focuses on problems to be solved for a design report in 2010 /2012, align with IDS
- Baseline to be chosen 2011
- Target work is performed mainly in EUROnu in WP2. Work concentrates on shock studies and solid target and fluidized powder.
- End to end simulation of complex, pre-engineering of magnets and RF and costing as input for comparison (super-beam, beta beam, nu-factory) 2012



EUROnu Super-Beam studies– *Andrea Longhin*

- New forces for SPL-Fréjus project
- comparison nu-factory, beta beams, superbeams 2012 implies also costing
- Solid carbon target option (in association with multiple horns) permits a much reduced energy deposition and neutron fluxes (-X 15)
- Comparable neutrino fluxes and competitive performances at the level of θ_{13} sensitivities even before horn optimization for longer target.

- Optimizing the focusing (dependence on δ of θ_{13} sensitivity)
- Promising horn configurations under test: room for improvement
- Verification of codes and HARP data

Questions from NUFACT08

- Which labs in the world can host a 4+ MW power station?
  - CERN, Fermilab and Asian countries (?)
- Could one combine cooling and phase rotation?
  - Yes, simulations done in gas filled cooling channels (D. Neuffer)
  - Should work in current ionization cooling channel, but requires higher accelerating gradient in RF cavities
- Could one re-use the proton driver to accelerate muons?
  - ?
- Major technical issue is RF in magnetic field. Is the program receiving enough attention?
  - Yes, highest priority in MUCOOL program
  - Progress in theory, simulations and future experimental studies (reported in Summary I by D. Li)

Questions from Nufact08
Beta Beams (i)

- Intensity limitations ?
  - Radiation studies show that we are within manageable limits
  - 6He (2 10^{13} for 6He from experiments 2009) and 8Li (by preliminary considerations) are possible to produce in sufficient quantities
  - 18Ne needs more studies (experiments), however direct production experiments give good results for small targets, can be scaled

Questions from Nufact08
Beta Beams (ii)

- What is the needed power to produce 6He, 18Ne , 8B and 8Li ?
  - Proton drivers of 1 GeV, 200 kW are needed to produce 6He (possibly also 8Li). Other ions have to be produced by direct production or by enhanced direct production (production rings)
- Can proton drivers be used for beta beams ?
  - Yes, converter targets can take high power

Questions from Nufact08 Beta Beams (ii)

- What about near detector stations?
  - With WG1 nufact10
- Approximate cost / timescale
  - Will be discussed nufact10

Outlook

- See you all at Nufact10 with, again, very interesting and encouraging results!

Thank You!

P X

Project X is not a project yet; it's a concept that Fermilab is promoting. To become a construction project, it has to go through several steps mandated by the Department of Energy. That may take a few years. The concept is evolving, so you may hear different things from different people.

There are three purposes:

1) to increase the intensity of the Main Injector to provide ~ 2 MW of beam power from 60 to 120 GeV for long-baseline neutrino expts;
2) to provide beam for precision experiments at the intensity frontier;
3) to provide beam for neutrino factory and/or muon colliders.

The third item might be achieved via an upgrade to the initial configuration
to provide 4 MW of beam power.

P X

There are presently two main ideas for how to achieve the above goals. Both would include a superconducting rf linac operating at 1.3 GHz. ICD1 (Initial Configuration Document 1) is based on an 8-GeV pulsed linac, with a beam structure somewhat like the ILC. For example, maybe 5 Hz, 10 mA, 1 msec or something like that.

ICD2 includes a CW linac up to slightly more than 2 GeV at 1 mA, initially. That might be followed by a rapid-cycling synchrotron to reach 8 GeV for use by the Main Injector after accumulation in the Recycler.

The path to a driver for a muon collider and/or neutrino factory is not very well-defined yet for either of these configurations. I think I know how to use the ICD1 configuration in conjunction with a couple of 8-GeV rings, one to form the right number of bunches and the second to shorten the bunches. ICD2 might be augmented by increasing the energy of the CW linac to ~ 5 or 8 GeV, but it would be harder to accumulate the output to form bunches in a ring.