Feasibility Study-II

Technical and Engineering Issues

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Neutrino Factory and Muon Collider Collaboration Meeting–BNL
February 1, 2001

Outline

- Introduction
- Progress
- Issues
- Plans
- Schedule
- Summary

Introduction

- Study-II has been under way in earnest for about 4 months
  - Study Leaders are R. Palmer (Simulations), M. Zisman (Technical and Costing), S. Ozaki (Site Specific, Detector/Physics, and ES&H)
    - Editors have met twice in person
      - and weekly via teleconferences
- Initially, main focus was simulation work, with Technical Group providing guidance
  - after parameter list settled down, technical design work proceeded
    - iterating with the simulations group as technical parameters became fixed and problems or conflicts developed
- Some items unchanged from Study-I (e.g., RF power source)
  - most were revisited in view of new design parameters
    - target, induction linacs, buncher and cooling channel, acceleration system, storage ring, detector

Introduction

- Here I will summarize
  - technical progress in design of the various systems
  - presently unresolved issues and plans to resolve them
  - schedule
- Team has worked well together in finding solutions to difficult issues
  - solenoids, RF cavities, and absorbers coexist in cooling channel

Introduction

- **Editors for Study-II**

Conceptual Parameters & Simulations
Leader: R. Palmer (BNL)

Topic	Editor
Target & Capture	K. McDonald (Princeton)
Phase Rotation	Harold Kirk (BNL)
Cooling	Bob Palmer (BNL)
Acceleration	V. Lebedev (Jlab)
Alternative Accel.	Scott Berg (BNL)

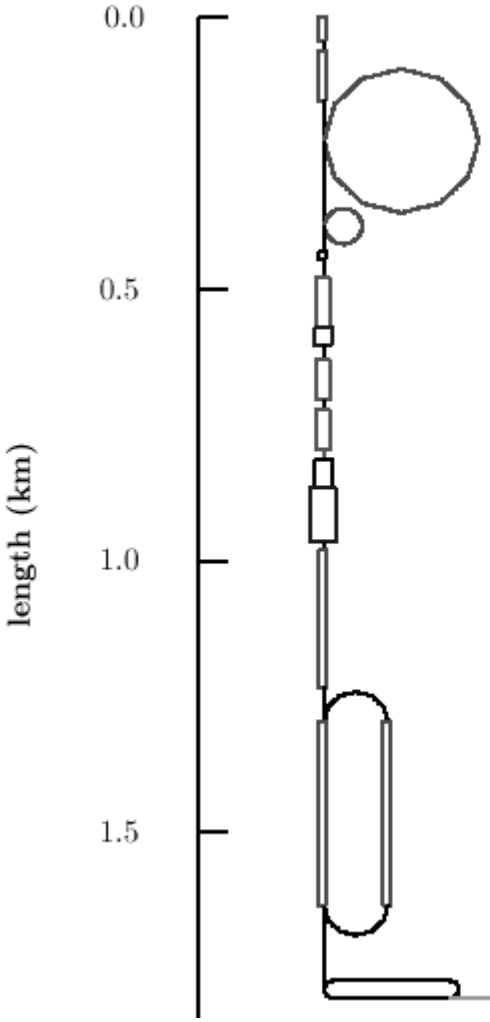
Site Specific & ES&H
Leader: S. Ozaki (BNL)

Topic	Editor
Detector	Ed O'Brien (BNL)
Physics	R. Shrock (BNL/SUNYSB)
Proton Driver	T. Roser (BNL)
Layout	tbd
ES&H	tbd

Technical & Costs
Leader: M. Zisman (LBNL)

Topic	Editor
Target	Helge Ravn (CERN)
Solenoids (Target, matching, drift, cooling)	Mike Green (LBNL)
Induction Linac	Simon Yu (LBNL)
Absorbers (Cooling, Minicooling)	Dan Kaplan (IIT)
NCRF (Cooling, Bunching, Acceleration)	Bob Rimmer (LBNL)
SCRF (Acceleration, Storage Ring)	Don Hartill/H. Padamsee (Cornell)
Magnets (Acceleration, Storage Ring)	Brett Parker (BNL)
Lattice (Storage Ring)	Ramesh Gupta (BNL)
Diagnostics	Jim Norem (ANL)
RF power source	tbd
Vacuum	D. Hseuh (BNL)
Acceleration	V. Lebedev (Jlab)

Introduction



Warm Linac	200 MeV
SC Linac	1 GeV
AGS	24 GeV
Bunch compressor	rms 3 ns
Hg Target	(.45 m)
Induction #1	(100 m)
Mini Cooling	(3.5 m H_2)
Induction #2	(80 m)
Induction #3	(80 m)
Buncher	(55 m)
Cooling	(108 m)
Linac	(2.3 GeV)
Recirculating Linac	(2.3-20 GeV)
Storage Ring	(20 GeV)

Introduction

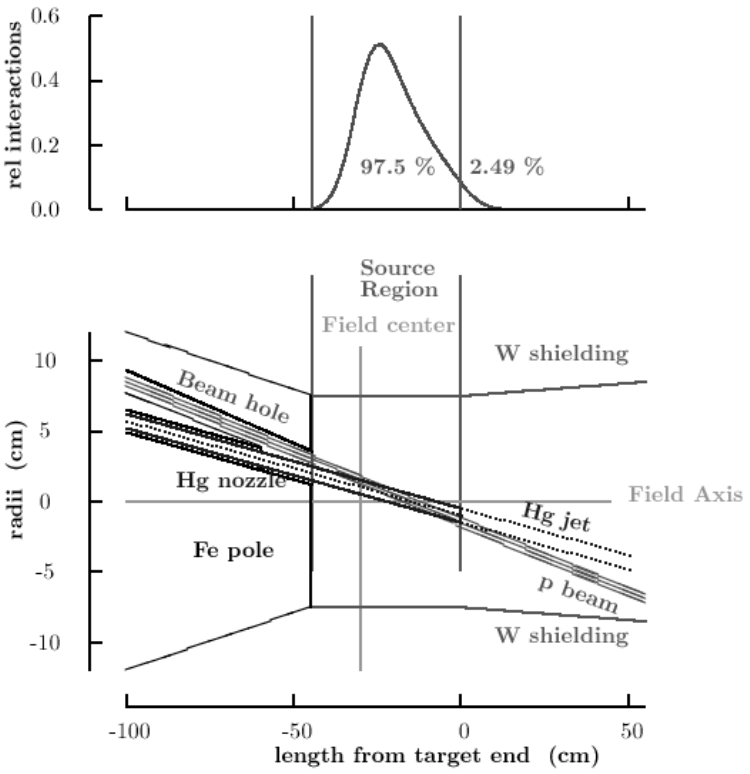
	length m	totals m
target	0.45	0
taper	17.6	17.6
drift	18	35.6
Induction 1	100	135.6
Drift	5	140.6
Mini-Cool	10	150.6
Drift	35	185.6
Induction 2	80	265.6
Drift	20	285.6
Induction 3	80	365.6
Match to Super FOFO	17.5	383.1
Buncher	$20 \times 2.75 = 55$	428.1
cooling part 1	$16 \times 2.75 = 44$	472.1
match	4.4	476.5
cooling part 2	$36 \times 1.65 = 59.4$	535.9
Linac	275	
RLA arcs	270	
RLA Linacs	2×366	
Storage Ring Arcs	2×53	
Storage ring Straights	2×216	

Introduction

Energy	24	GeV
protons per bunch	$\approx 1.7\ \ 10^{13}$	
bunches per fill	6	
time between extracted bunches	≈ 20	ms
repetition rate	2.5	Hz
rms bunch length	≤ 3	ns
beam power	≥ 1	MW
normalized emittance (95%)	mm mrad	100
normalized emittance (rms)	mm mrad	17

Progress

- Target
  - design has evolved to put nozzle well into solenoid field
  - bunch spacing increased from 15-20 ms, making jet parameters easier



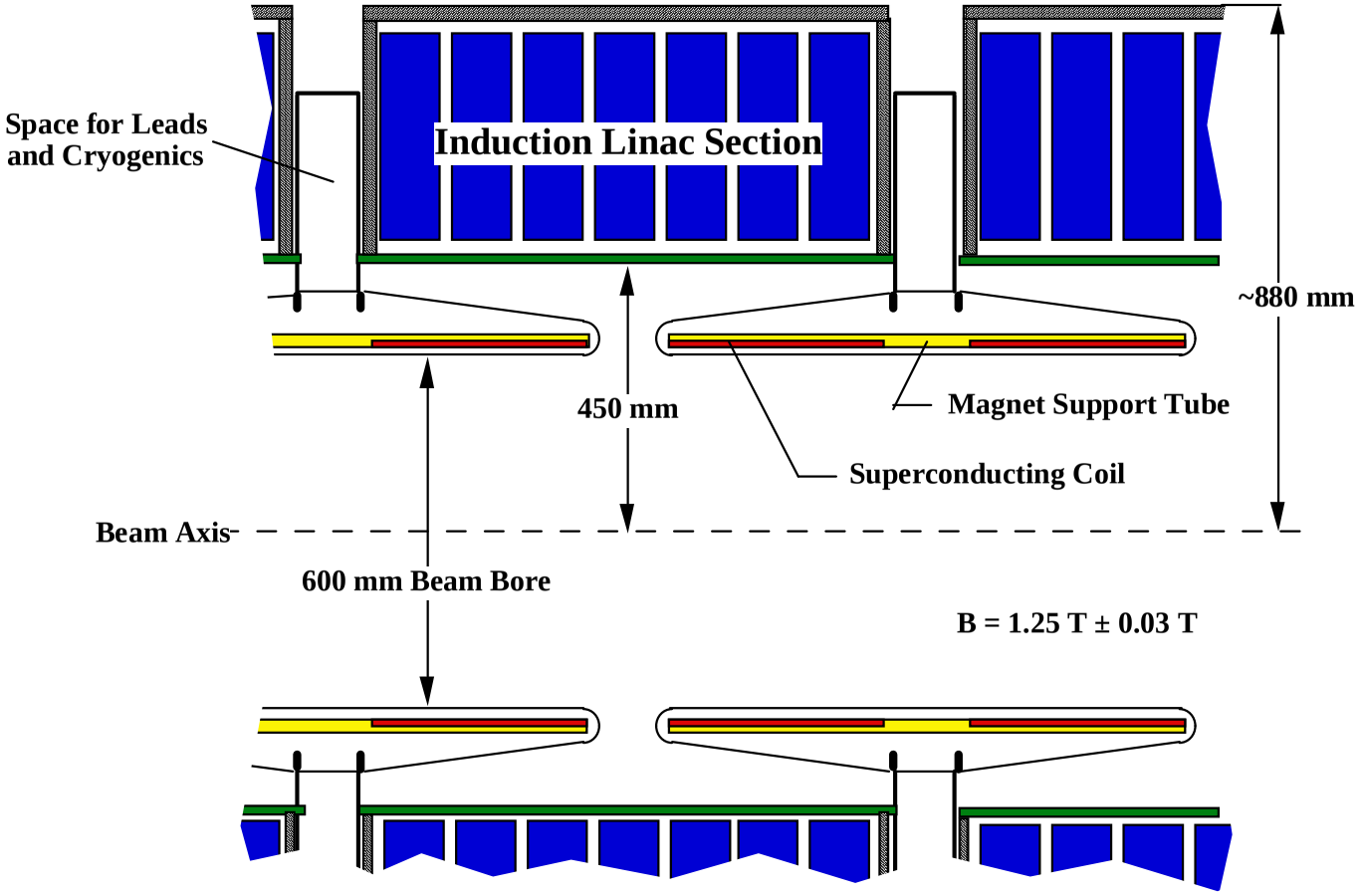
Progress

- radiation levels predicted to be lower than for Study-I
- considering both hollow-conductor and Bitter magnet inserts for target solenoid

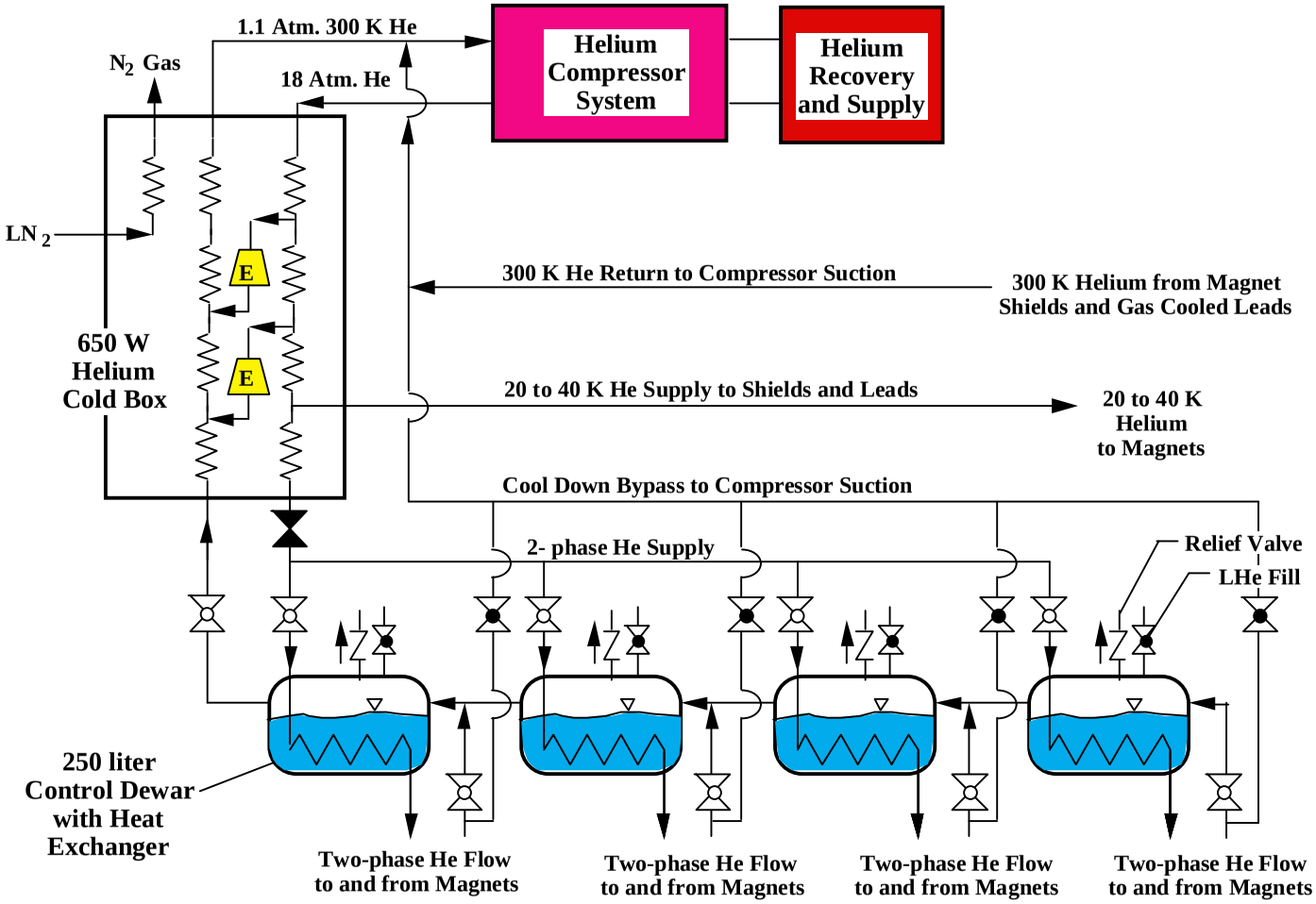
Progress

- Phase rotation
  - compared with Study-I, we have less distortion in the phase rotation
    - but this requires more induction linac and a bipolar waveform
    - our implementation uses three IL units, all unipolar
      - cost optimization favors length over gradient
  - solenoid periodicity is 0.5 m (validated by simulations)

Cross-section Through a Typical Induction Linac Cell

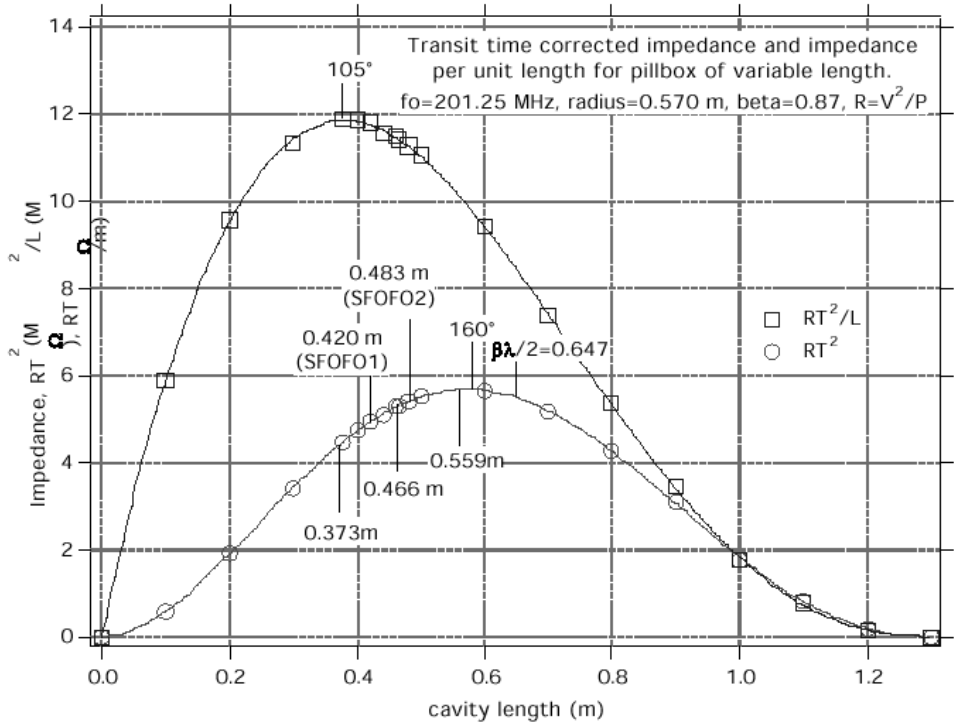


Cryogenic Cooling System for One Hundred Phase Rotation Solenoids



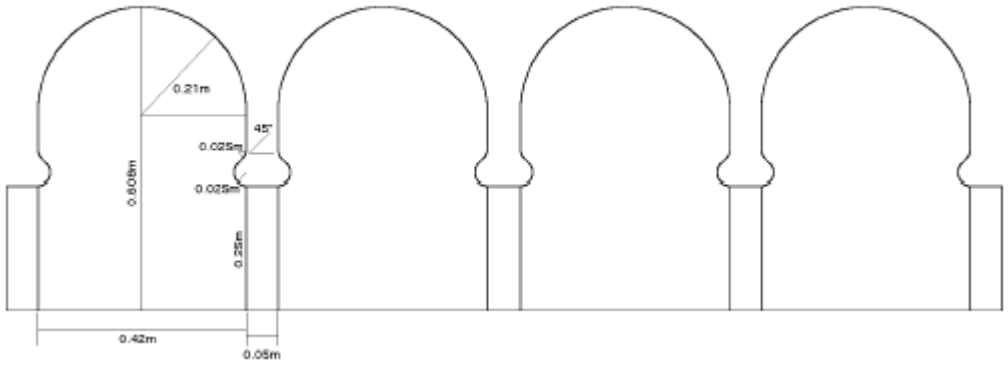
Progress

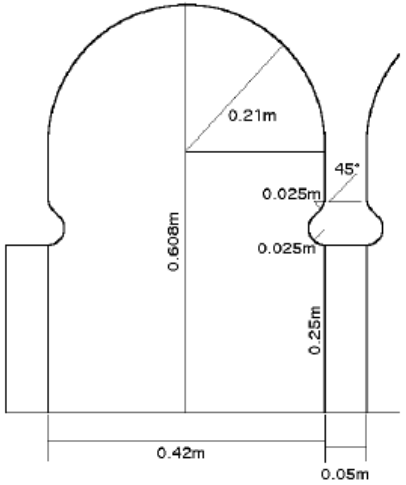
- Buncher and cooling channel
  - cavities based on Be-window design
  - rough optimization of power consumption has been considered
    - peak power consumption of cooling channel RF ≈700 MW



Progress

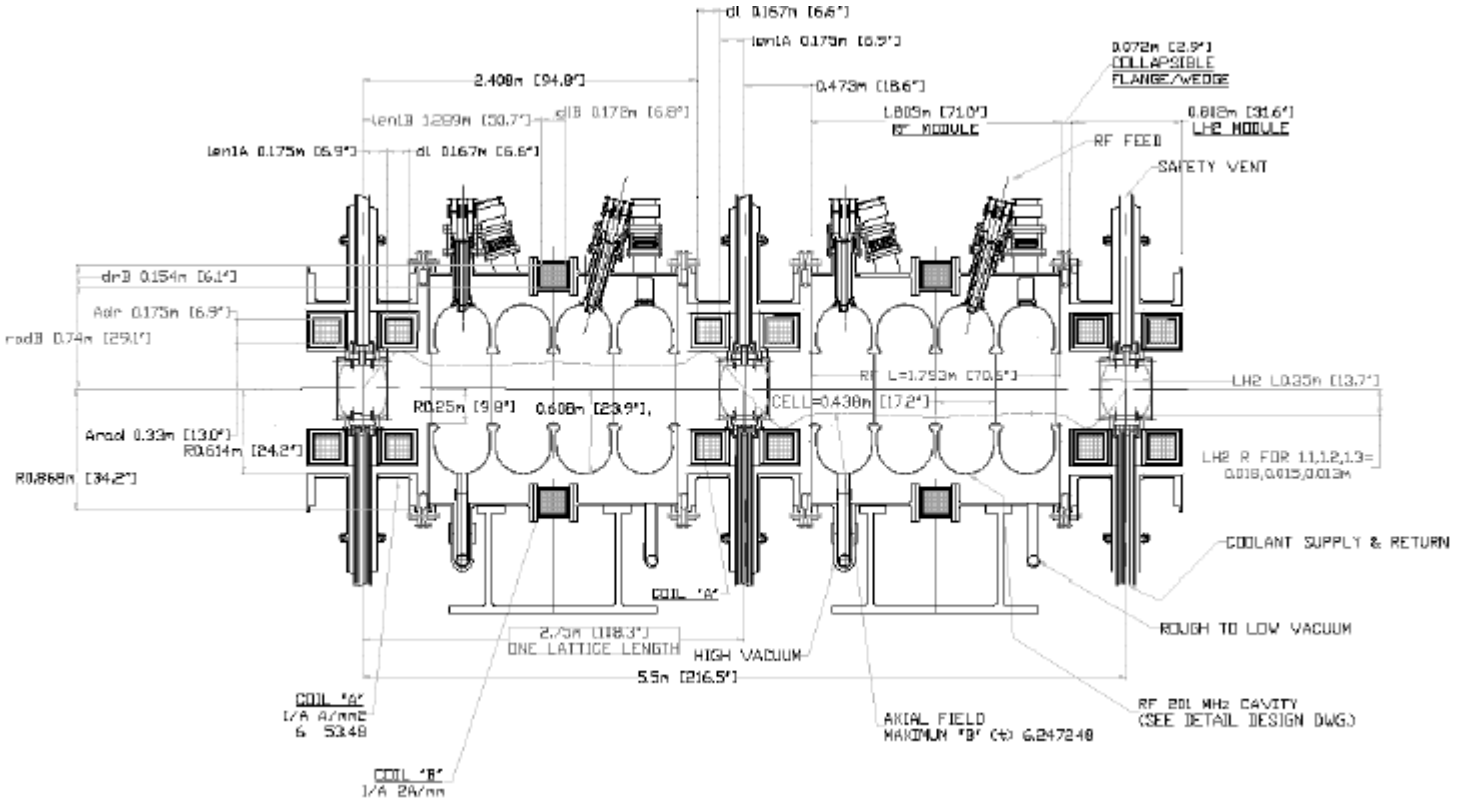
- cavities accommodate stepped foils (thicker at the outside)
  - these are included in the simulations





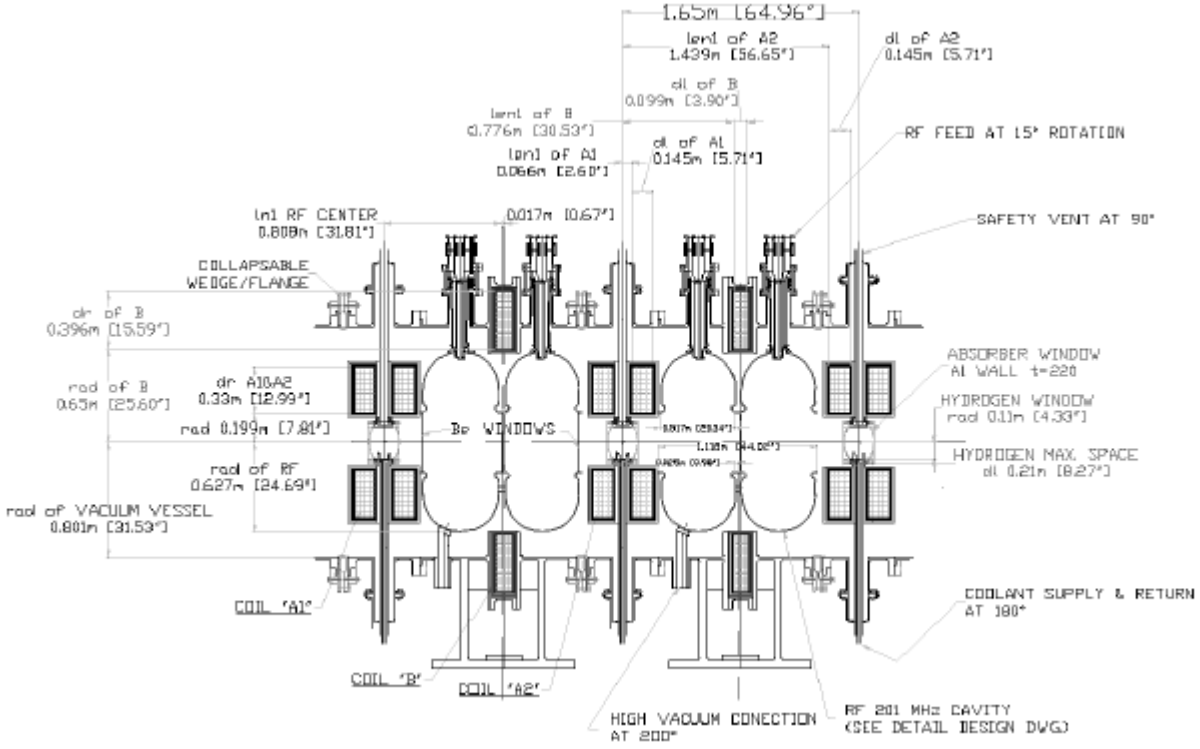
Progress

- it all fits in cooling channel lattice 1 (2.75 m)



Progress

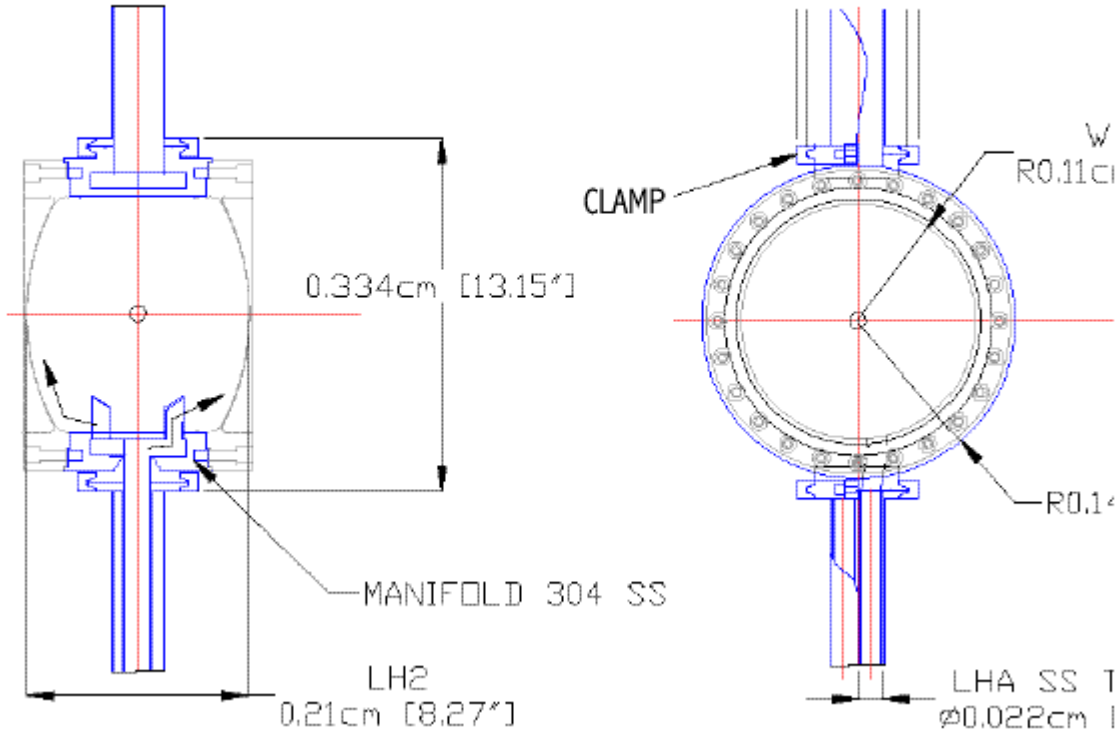
- it's a bit more cheek by jowl in lattice 2 (1.65 m)



Progress

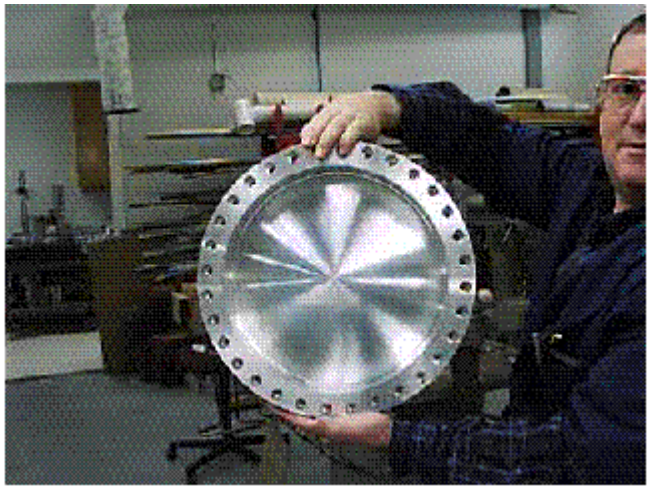
- LH_2 absorber mechanical design has been worked out
  - a tight fit in lattice 2

SFOFO 2 Absorber Assembly:



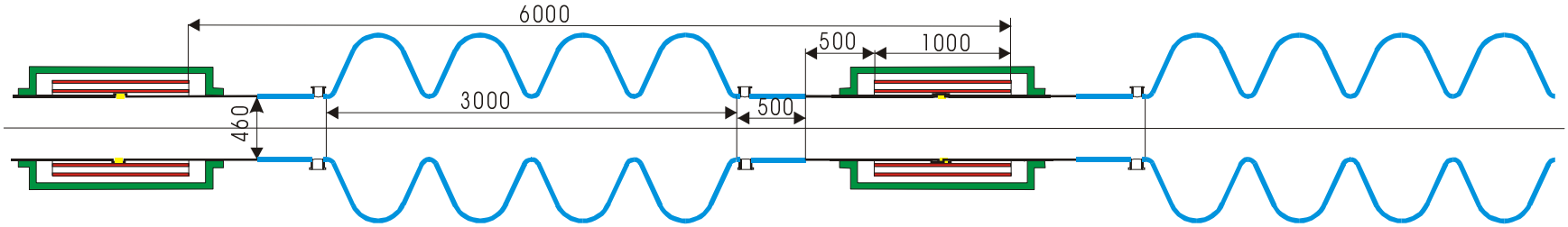
Progress

Prototype Al window (from U-Miss) to be tested at FNAL

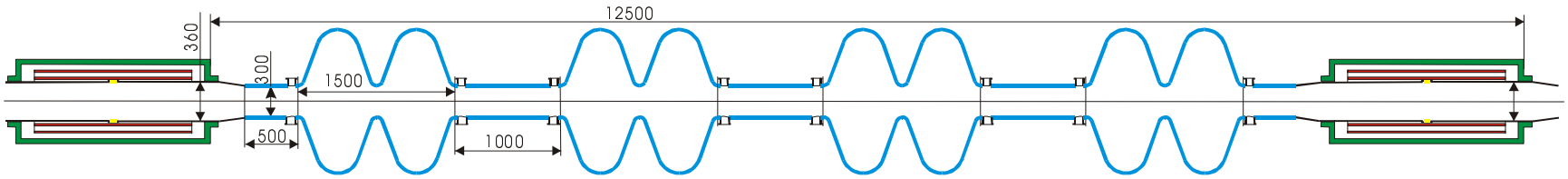


Progress

- Acceleration
  - preacceleration linac (130→2350 MeV) has adopted SCRF and solenoidal focusing
    - use short cryomodules for first 1/3, long modules for the rest
      - short cryomodule

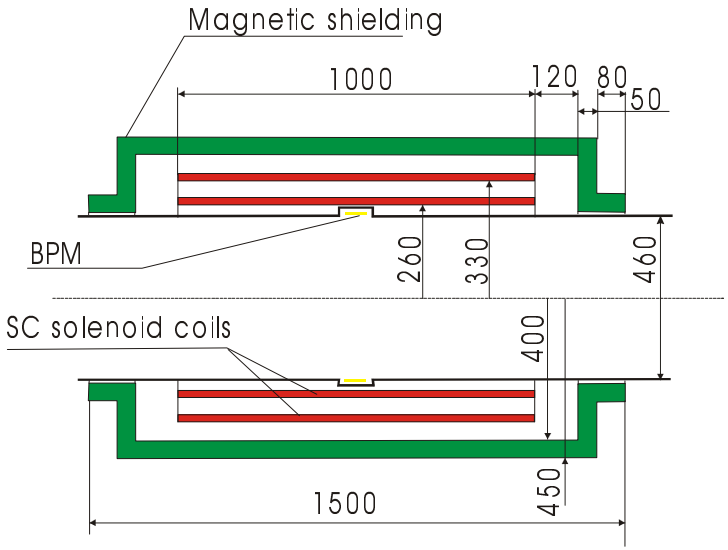


      - long cryomodule



Progress

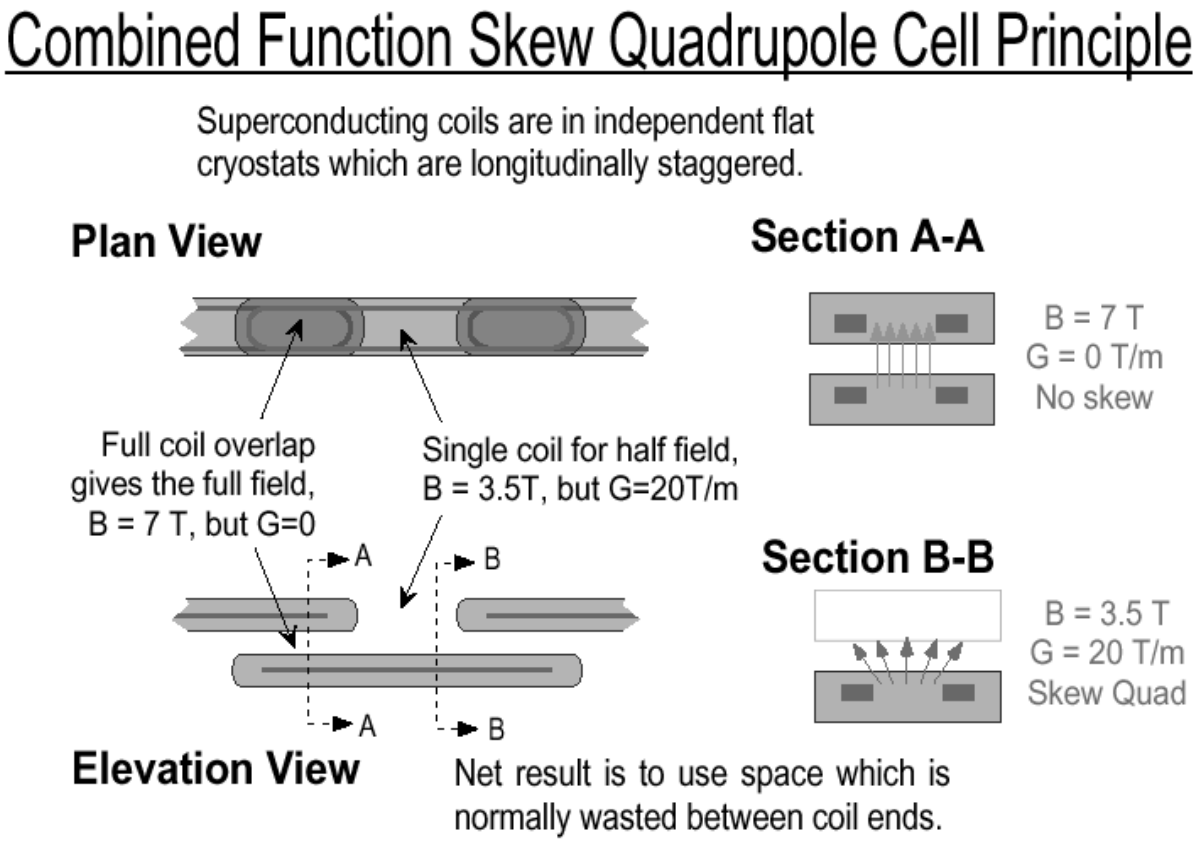
- minimize fringe field on SC cavities with compensated coil design along with shielding



- RLA is a 4-pass system with horizontal separation
  - optics is triplet focusing with 3 sextupole families
  - SCRF is 201 MHz operating at high gradients
    - gain is 4.4 GeV/turn

Progress

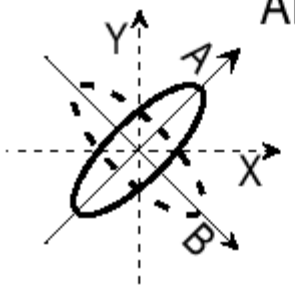
- Storage ring
  - lattice based on skew-quad design with magnet coils off of midplane



Progress

- lattice for nominal parameters is worked out

Skew Combined Function Ring Lattice

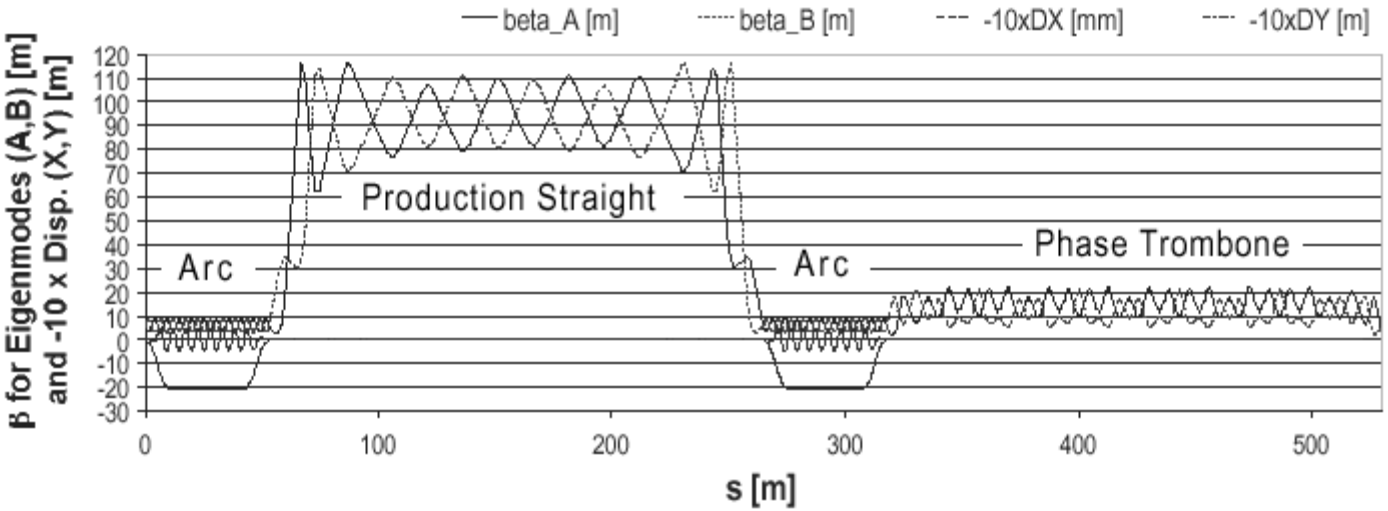


Arc Cell Parameters:

$\beta_{max}^{(A,B)}$ = 8.80 m $\eta_x = (\eta_A+\eta_B)/\sqrt{2}$ $\eta_Y = (\eta_A-\eta_B)/\sqrt{2}$

$\beta_{min}^{(A,B)}$ = 3.16 m $\eta_{Long}^{(A,B)}$ = 1.782 m η_{max}^{X} = 2.066 m

$\Delta\phi$ = 60° $\eta_{Short}^{(A,B)}$ = 1.141 m η_{max}^{Y} = 0.484 m



Issues

- Loss of NHMFL involvement late in the game requires last-minute adjustment of plans
  - involving MIT and Everson for design work, and augmenting LBNL and BNL effort
  - goal is to design SC solenoid compatible with either hollow-conductor or Bitter insert
- Mini-cool absorbers are large and must handle "challenging" amounts of power
  - need to evaluate alternatives (e.g., water-cooled Be or LiH)
- Cell length in lattice 2 is tight
  - for now, we think we can make everything fit, but the next iteration should increase the cell length
- Diagnostics space in cooling channel is very limited
  - consider having empty (or partially empty) diagnostics cells

Issues

- Tracking of the non-standard SR lattice needs to be done
  - proper tools for this purpose need to be identified
  - the multipole content of the field needs to be evaluated
- Present design has no allowance for "hot spares" in RF system
  - need to evaluate this issue during error studies
    - seems unlikely that so many highly stressed RF systems will always operate at design parameters
    - must accommodate this in cooling and acceleration sections

Plans

- Results from this week's meeting will permit us to identify and resolve remaining issues and discrepancies
- Thereafter
  - embark on error studies
  - prepare written report
  - prepare cost estimate
    - draft WBS is prepared and being evaluated
  - prepare R&D plan to address Study-II issues
- Discussion of alternative technical approaches and phased implementation will appear in Appendices to main report

Schedule

- Initial write-ups are due in mid-February
- Final write-ups due in early March
- Cost estimate due in early March
- Draft report ready for perusal by MC in late March
- Final report complete in mid-April
- Expect closeout session with BNL management at end of April
  - meeting later today to discuss this

Summary

- Building on Study-I design, we have worked on a higher performance Neutrino Factory design
- We're in the home stretch
- Study Leaders (Palmer, Ozaki, MZ) are very appreciative of the efforts that have gone into the Study, and the support from the *MC*
  - we are confident that we will have a result we can all be proud of
- This is not "the Study to end all studies"
  - there will be more
  - a detailed look at Balbekov's double-flip channel and a study of a cooling ring should be considered
  - and, someday, emittance exchange!