International Scoping Study
Accelerator Working Group:
Status and Plans

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ISS Plenary Meeting–KEK
January 23-25, 2006

Introduction

- Third time ISS Accelerator Group meets together
  - at CERN, September 2005 (plenary meeting)
  - at BNL, December 2005 (Accelerator Group workshop)
  - at KEK, this week
    - please continue to encourage your colleagues to join the effort
      - subscribe to NF-SB-ISS-ACCELERATOR e-mail list

- We have a full agenda!
  - any interested members of the ISS are welcome to attend and contribute to the Accelerator Group
    - in particular, we welcome input from Detector Group on requirements that impact our design specifications
      - hopefully, discussion takes place at joint session tomorrow

- Accomplishments here and plans for next meeting summarized Wednesday by Rick Fernow

Introduction

- **Accelerator Group will continue after the plenary meeting in "Workshop mode"**
  - **try to make progress on specific tasks ⇒ more work, fewer talks**

Proton Driver

- identify issues for producing short (~1 ns) bunches, e.g., define parameters for suitable bunch compression ring or transport line
- evaluate space-charge issues
- look at implications of pulse structure throughout Neutrino Factory facility (including target, front end, acceleration)

Targetry

- assess minimum acceptable proton beam repetition rate at 4 MW intensity (solid and liquid targets)
- develop realistic solid-target scenario (rod, band, pellets, or granular)
- look at production rate as a function of proton bunch length in the range of 1–5 ns

Front End

- look at thermal implications on absorbers and RF windows of muon beam containing both sign muons at 4 MW proton intensity

Acceleration

- FFAG longitudinal dynamics at large transverse amplitudes

Decay Ring

- develop isosceles triangle ring with ~ 40° apex angle
- develop strawman pairs of sites that could be simultaneously served by a triangle ring
- begin tracking 50+20 GeV and isosceles triangle rings *with errors*

Today's Agenda

Monday, January 23, 2006
Building 4, Seminar Hall

Time	Topic	Speaker	Duration
11:00 - 11:30	COFFEE		30
11:30 - 12:00	Introduction-Detector Working Group	Blondel	30
12:00 - 12:30	Introduction-Accelerator Working Group	Zisman	30
12:30 - 13:00	Introduction-Physics Working Group	Long	30
13:00 - 14:00	LUNCH		60

Building 4, Room 345

Time	Topic	Speaker	Duration
14:00 - 14:30	SPL as a Neutrino Factory Proton Driver	Prior	25+5
14:30 - 15:00	J-PARC Ring as a Neutrino Factory Proton Driver	Tomizawa	25+5
15:00 - 15:15	Gas-filled Cavity Approaches	Neuffer/Fernow	10+5
15:15 - 15:30	DISCUSSION		15
15:30 - 16:00	COFFEE		30
16:00 - 16:15	Scaling FFAG Issues	Berg	10+5
16:15 - 16:30	Non-scaling FFAG Issues	Machida	10+5
16:30 - 16:50	Optimization of Bunching and Phase Rotation	Palmer	15+5
16:50 - 17:10	RLA Optimization Including Errors	Berg	15+5
17:10 - 17:30	Optimization of Cooling vs. Acceleration Acceptance	Palmer	15+5
17:30 - 18:00	DISCUSSION		30

Tomorrow's Agenda

Tuesday, January 24, 2006
Building 4, Seminar Hall

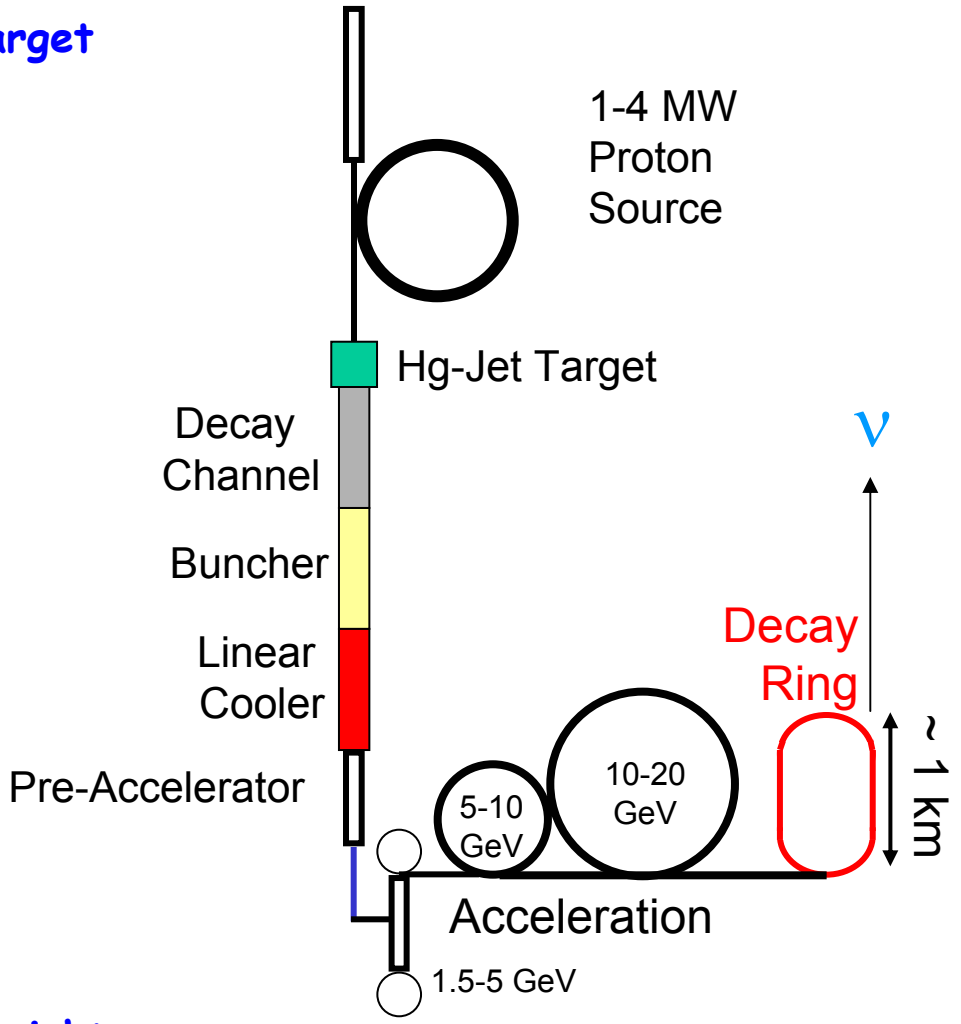
Time	Topic	Speaker	Duration
11:30 - 12:00	Comparison of Proton Driver Approaches	Weng	25+5
12:00 - 12:30	Decay Ring Progress	Johnstone	25+5
12:30 - 13:00	D I S C U S S I O N		30
13:00 - 14:00	**L U N C H**		60

Building 4, Room 345

Time	Topic	Speaker	Duration
14:00 - 14:15	Update on MUCOOL R&D	Bross	10+5
14:15 - 14:35	Update on MERIT	McDonald/Zisman	15+5
14:35 - 14:55	Update on MICE	Yoshida	15+5
14:55 - 15:15	Update on PRISM	Sato	15+5
15:15 - 15:45	Scaling FFAGs - Experimental Results	Mori/Aiba	25+5
15:45 - 16:00	D I S C U S S I O N		15
16:00 - 16:30	**C O F F E E**		30
16:30 - 16:50	Intensity Limitations for Solid Targets	McDonald/Zisman	15+5
16:50 - 17:30	Machine Working Group Summary Talk (Dry Run)	Fernow	30+10
17:30 - 18:00	Discussion of Summary Talk content and future plans	All	30

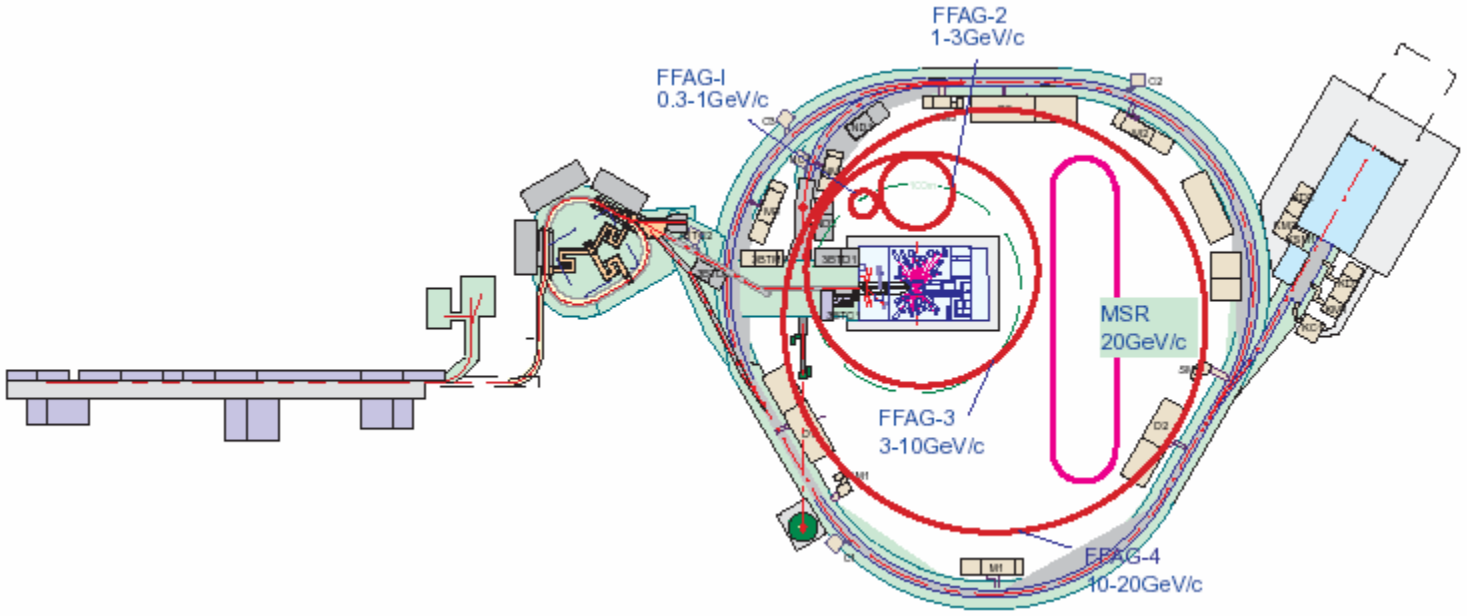
Neutrino Factory Ingredients

- **Proton Driver**
  - primary beam on production target
- **Target, Capture, Decay**
  - create π, decay into μ
- **Bunching, Phase Rotation**
  - reduce ΔE of bunch
- **Cooling**
  - reduce transverse emittance
- **Acceleration**
  - 130 MeV $\rightarrow$ 20 GeV
- **Decay Ring**
  - store for ~500 turns; long straight section



FFAG-Based Neutrino Factory

- **Alternative design concept based on FFAG rings for phase rotation and acceleration is under study in Japan**
  - **this approach is being evaluated and compared with other designs as part of our task**
    - **implications of keeping both sign muons need evaluation**

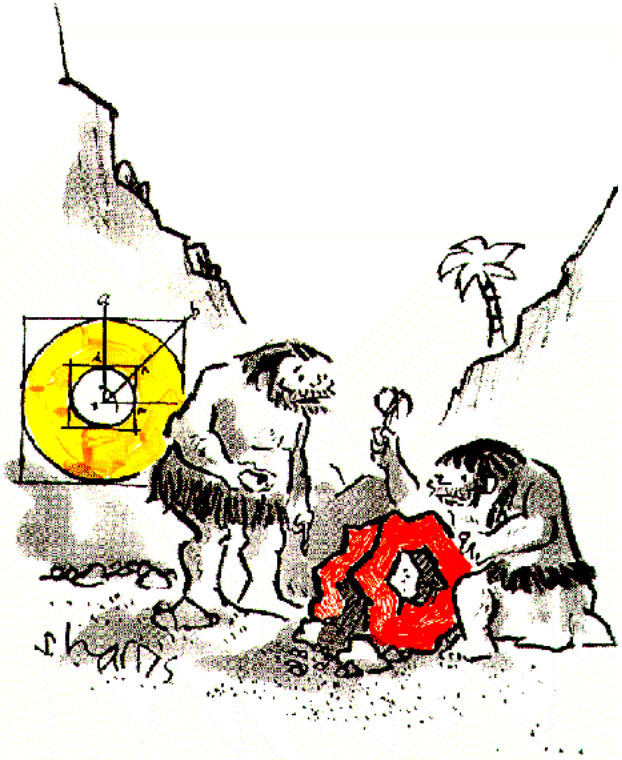


NF Design: Driving Issues

- **Constructing a muon-based NF is challenging**
  - **muons have short lifetime (2.2 μs at rest)**
    - **puts premium on rapid beam manipulations**
      - **requires high-gradient NCRF for cooling (in B field)**
      - **requires presently untested ionization cooling technique**
      - **requires fast acceleration system**
  - **muons are created as a tertiary beam (p→π→μ)**
    - **low production rate ⇒**
      - **target that can handle multi-MW proton beam**
    - **large muon beam transverse phase space and large energy spread ⇒**
      - **high acceptance acceleration system and storage ring**
  - **neutrinos themselves are a quaternary beam**
    - **even less intensity and "a mind of their own"**

Challenges

- **Challenges go well beyond those of standard beams**
  - **developing solutions requires substantial R&D effort**
    - **R&D should aim to specify:**
      - **expected performance, technical feasibility/risk, cost (matters!)**



Accelerator WG Organization

- **Accelerator study program managed by "Machine Council"**
  - R. Fernow, R. Garoby, Y. Mori, R. Palmer, C. Prior, M. Zisman
  - meet (roughly) biweekly by phone conference

- **Aided by Task Coordinators**
  - Proton Driver: R. Garoby, H. Kirk, Y. Mori, C. Prior
  - Target/Capture: J. Lettry, K. McDonald
  - Front End: R. Fernow, K. Yoshimura
  - Acceleration: S. Berg, Y. Mori, C. Prior
  - Decay Ring: C. Johnstone, G. Rees

Accelerator Study Phase 1

- Study alternative configurations; arrive at baseline specifications for a system to pursue
  - examine both cooling and no-cooling options
- Develop and validate tools for end-to-end simulations of alternative facility concepts
  - correlations in beam and details of distributions have significant effect on transmission at interfaces (muons have "memory")
  - simulation effort will tie all aspects together
- Goal: complete this work within 6 months
  - this is going more slowly than I had hoped ☹
- Making choices requires ("top-down") cost evaluation
  - ISS will require engineering resources knowledgeable in accelerator and detector design

Accelerator Study Phase 2

- **Focus on selected option(s)**
  - as prelude to subsequent World Design Study
    - WDS will have more of an engineering aspect than the ISS
  - this is the aspect "at risk" to delays in Phase 1

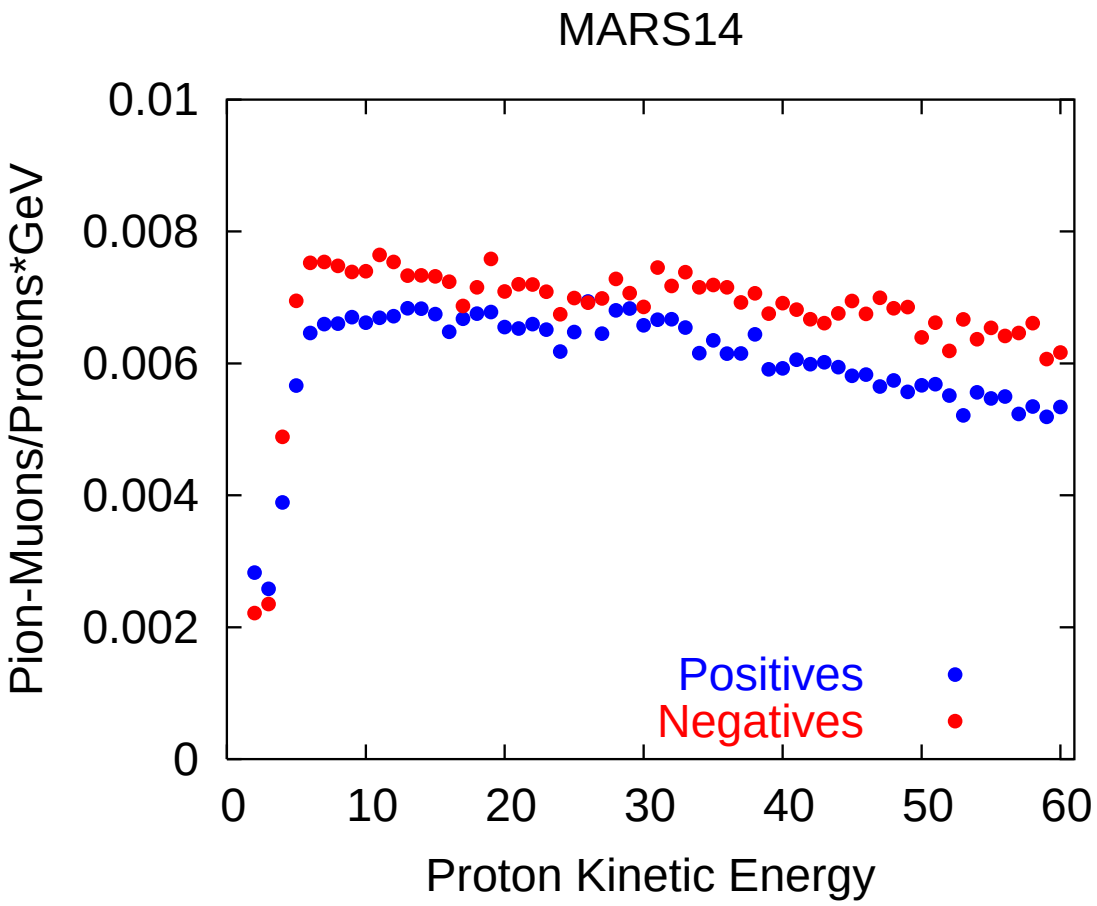
- **Must develop R&D list as we proceed**
  - identify activities that must be accomplished to develop confidence in the community that we have arrived at a design that is:
    - credible
    - cost-effective
  - until construction starts, R&D is what keeps the effort alive

Proton Driver Questions

- **Optimum beam energy** √
  - depends on choice of target
    - consider C, Ta, Hg
- **Optimum repetition rate** (in progress)
  - depends on target and downstream RF systems
- **Bunch length trade-offs** (in progress)
  - need (and approaches) for bunch compression
  - performance implications for downstream systems √
- **Hardware options** (in progress)
  - FFAG, linac, synchrotron
    - compare performance, cost

Optimum Energy

- **Optimum energy for high-Z targets is broad, but drops at low-energy**



μ^-: 6 – 11 GeV

μ^+: 9 – 19 GeV

Proton Driver Phase 1

- **Examine candidate machine types for 4 MW operation**
  - FFAG (scaling and/or non-scaling)
  - Linac (SPL and/or Fermilab approach)
  - Synchrotron (J-PARC and/or AGS approach)

Progress report by Bill Weng tomorrow

    - consider
      - beam current limitations (injection, acceleration, activation)
      - bunch length limitations and schemes to provide 1-3 ns bunches
      - repetition rate limitations (power, vacuum chamber,…)
      - tolerances (field errors, alignment, RF stability,…)
      - optimization of beam energy

- **Compare and contrast Superbeam and Neutrino Factory requirements**
  - required emittance and focusing
  - how do we migrate from one to the other?

Not much progress; need more SB help

Target/Capture/Decay Questions

- **Optimum target material**
  - solid or liquid
    - low, medium, or high *Z*
- **Intensity limitations**
  - from target
    - or from beam dump, which is no easy task either
- **Superbeam vs. Neutrino Factory trade-offs**
  - horn vs. solenoid capture
    - can one solution serve both needs?
  - is a single choice of target material adequate for both?

Target/Capture/Decay Phase 1

- Production rates as *f(E)* for C, Hg, Ta √
  - do reality check with HARP data if possible
- Target limitations for 4 MW operation (in progress)
  - use guidance from FEA and experiments
    - consider bunch intensity, spacing, repetition rate
- Implications of 1 vs. 3 ns bunches on delivered beam √
- Superbeam vs. Neutrino Factory comparisons
  - horn vs. solenoid
  - selected targets

Target Material Comparisons (1)

- **Studied by Fernow, Gallardo, and Brooks**
  - **targets examined: C (66 cm); Hg (25 cm); Ta (20 cm), all with *r* = 1 cm**
    - target aligned with solenoid axis
    - re-interactions included
  - **cases studied: C (4, 40 GeV); Hg (4, 40 GeV); Ta (10 GeV)**
    - Hg (24 GeV) is nominal Study 2 "benchmark" case
  - **proton bunch length 1 ns**
    - performance decreases 10% for 3 ns bunch
  - **accelerator normalized acceptance**
    - transverse: 30 mm
    - longitudinal: 150 mm
    - momentum range: 100–300 MeV/c
  - **work based on MARS output; need experimental check!**

Target Material Comparisons (2)

- **Results**
  - **FS2a FOM is 0.0077 μ^+ per p-GeV**

Target	E_{beam} (GeV)	μ^+ per p-GeV	μ^- per p-GeV
C	4	0.0114	0.0113
C	40	0.0043	0.0046
Hg	4	0.0066	0.0098
Hg	40	0.0068	0.0083
Ta	10	0.0087	0.0108

Front End Questions

- Practical accelerating gradient and cost per GeV at several frequencies (5, 88, 201 MHz)
  - include power sources as well as cavities
- Relative performance of existing schemes (KEK, CERN, U.S.-FS 2b)
- Optimization of cooling vs. acceleration acceptance

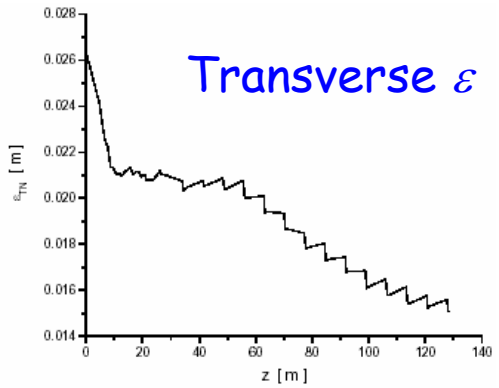
Front End Phase 1 (1)

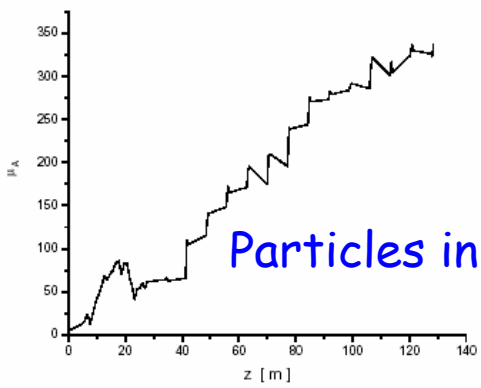
- Compare performance of existing schemes (KEK, CERN, U.S.-FS 2b)
  - use common proton driver and target configuration(s) √
  - consider possibility of both signs simultaneously √
  - conclusions will require cost comparisons, which will come later
- Evaluate implications of reduced V_{RF} for each scheme
  - take V_{max} = 0.75 V_{des} and 0.5 V_{des}
    - re-optimize system based on new V_{max}, changing lattice, absorber, no. of cavities, etc. √
- Optimize U.S. Φ Rotation/Bunching scheme with lower gradients and/or fewer frequencies
  - evaluate performance (started)
  - costs will come later

FS2a-CERN Comparisons (1)

- Looked at both "original" 44+88 MHz version and "improved" 88-MHz-only version
  - accelerator normalized acceptance
    - transverse: 30 mm
    - longitudinal: 300 mm
    - momentum range: 100–500 MeV/c

- Performance of both CERN channels looks much worse than FS2a channel
  - evidence that channel is not long enough or needs tapering





FS2a-CERN Comparisons (2)

- **Results (88-MHz-only channel)**
  - **FS2a FOM is 0.0077 μ^+ per p-GeV**

Target	E_{beam} (GeV)	μ^+ per p-GeV
C	4	0.0015
C	40	0.0007
Hg	4	0.0009
Hg	40	0.0011
Ta	10	0.0014

Front End Phase 1 (2)

- **Evaluate trade-offs between cooling efficacy and downstream acceptance**
  - consider several values of downstream acceptance (longitudinal and transverse) (under way)
    - small, medium, and large (or extra-large?)
    - see how much cooling channel can be simplified
  - develop agreed-upon figure-of-merit (e.g., μ/P_{prot}) √
  - consider need/merits of longitudinal cooling
  - costs will come later
- **Evaluate performance issues and limitations**
  - absorbers (LH_2, LiH, Be or plastic) (start at this meeting)
    - consider implications of both sign muons
  - RF gradient (e.g., due to windows)
  - interactions with Target group recommended for this topic

Acceleration Phase 1

- **Compare different schemes *on an equal footing***
  - RLA, scaling FFAG, non-scaling FFAG (started)
    - consider implications of keeping both sign muons
    - consider not only performance but relative costs
  - need to bring scaling FFAG design to same level as non-scaling design

- **Prepare scenarios for different values of acceptance**
  - transverse and longitudinal
    - small, medium, large (or extra-large?)
      - some acceptance issues have arisen in non-scaling case (Machida)
  - identify cost drivers
    - these will be used later to assess cost vs. acceptance

- **Consider matching between acceleration subsystems**
  - are there simplifications in using fewer types of machines?

Decay Ring Phase 1

- Design implications of final energy (20 vs. 50 GeV) √
- Optics requirements vs. beam emittance √
  - arcs, injection and decay straight sections
- Implications of keeping both sign muons (under way)
  - can there be both injection and decay optics in this case?
- Implications of two simultaneous baselines √
- Radiation issues at 10^{21} useful neutrinos per year
  - liner vs. open-midplane magnets
- Discuss in joint session tomorrow

Summary

- Making progress toward goal of reaching consensus on a single optimized Neutrino Factory scheme
  - first step is to get proper comparisons of competing schemes
    - this is the hard part
- Joint session tomorrow will discuss
  - initial proton driver comparisons
  - decay ring design progress
- Must articulate need for an adequately-funded accelerator R&D program
  - and define its ingredients
- Will hold workshop, Bldg. 4, Room 345 Wed.-Fri.
  - all are welcome to participate