The Front End

MAP Review

Fermi National Accelerator Lab

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Harold G. Kirk
Brookhaven National Laboratory
Outline

Define Front End

Major Sub-systems

Key Challenges

Milestones
The Muon Collider/Neutrino Factory Front End

The Front End is that portion of the facility after the proton driver which is common to both the Muon Collider and the Neutrino Factory. The proton source will have different bunch structures and possibly beam power.

**Neutrino Factory**

**Muon Collider**
The Major Front End Sub-Systems

Target/Capture Drift ($\pi \rightarrow \mu$) Buncher/Rotator Cooler

- Target/Capture Drift ($\pi \rightarrow \mu$)
- Buncher/Rotator
- Cooler

Diagram:
- Target: 18.9 m
- Drift: $\sim 40$ m
- Buncher: $\sim 33$ m
- Rotator: 34 m
- Cooler: $\sim 80$ m
The Target Concept

Maximize Pion/Muon Production

- Soft-pion production
- High-Z materials
- High-magnetic field

Meson Production - 16 GeV $p + W$

Graph showing the production of pions ($\pi^+$ and $\pi^-$) as a function of pion kinetic energy (in GeV). The graph plots the differential cross section ($dN/dKE$) in units of 1/GeV/interacting proton against pion kinetic energy, with a peak around 0.5 GeV for $\pi^-$ and decreasing for $\pi^+$. The graph also includes a feasibility study showing particle tracks with $B > 20$ MeV.
All insertion/extraction from upstream end

Locating & supporting features not shown – will require additional space
The Key Target Parameters

Proton Driver

- 4 MW Beam power
- 5-15 GeV KE (8 GeV is currently favored)
- NF: 50 Hz / MC: 15 Hz
- NF: 3 bunch structure (320 μs total) / MC: 1 bunch

Target System

- 20-T solenoid magnet
- Liquid metal jet
- 20 m/s flow rate (“new” target every pulse @ 50 Hz)
- High-Z (Hg favored)
**Key Buncher/Rotator Parameters**

**Buncher**
- 37 rf cavities
- 320 to 233.6 MHz (13 frequencies)
- 8 MV/m Peak rf gradient
- 24 MW Peak rf power (NF: 0.7 MW avg)
- 1.5T Peak magnetic field
- 33 m total length

**Rotator**
- 56 rf cavities
- 230 to 202.3 MHz (15 frequencies)
- 12 MV/m Peak rf gradient
- 140 MW Peak rf power (MF: 4 MW avg)
- 1.5 T Peak magnetic field
- 42 m total length
The Buncher/Rotator

Target

Drift

Buncher

Rotator

Pion/Muon Kinetic Energy

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Key Parameters of the Cooler

- 100 rf cavities
- 201.25 MHz
- 15 MV/m Peak rf gradient
- 400 MW Peak rf power (NF: 12 MW avg)
- 2.8 T Peak magnetic field
- 75 m Total length
Front End Challenges

Target

• Shielding of the SC coils
• Thermal Management
• Containment of Hg
• Delivery of stable 20 m/s Hg jet

Buncher/Rotator/Cooler

• Performance of rf cavities in magnetic field
• Shielding of beam line components
• Proof-of-principle cooling demonstration (MICE)
Front End Challenges: RF

Machine performance reduced

- $\mu/p$ ratio reduced with rf gradient limitations

Mitigation Strategies: Alan Bross, D. Li rf talks

- Beryllium cavities
- High pressure (GH$_2$ filled) rf cavities
- Atomic Layer Deposition
- Magnetic insulation cavities

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Front End Challenges: Beamline Shielding

Mitigation Strategies

- Upstream bent solenoid
- Beryllium “beam stop” plugs

Electron beam power (kW)

Proton beam power (kW)
Front End Challenges: Target Shielding

Mitigation Strategies:

- Increase SC IDs
- Replace Cu resistive insert with HTS insert
- Design and engineer thermal management solution

25 KW of Energy deposition In SC1

~3 MW in Shielding

X. Ding
Front End Challenges: Hg Nozzle

Hg Jet

• 8 mm OD
• 20 m/s for 50Hz operations
• Hg jet performance in MERIT not optimal

Mitigation Strategies

• MHD simulations of jet/magnet/proton interactions
• Design and engineer nozzle delivery system
• Fabricate and test prototypical nozzle design
Mercury

- Low vapor pressure
- Toxic
- Disperses easily upon spilling

Mitigation Strategies

- Design and engineer double containment Hg system
- Explore alternatives:
  - PbBi eutectic
  - Tungsten powder flow
Front End Challenges: Pion Production

Current pion production modeling based on MARS15 simulations
HARP data does not support sharp falloff of pion production for proton KE < 8 GeV

Mitigation Strategies

• Incorporate HARP (and MIPP) results into MARS (underway Mokhov, et al)
• Contribute high-Z target for production experiment at 5 and 8 GeV (MIPP proposal, Torun, et al.)
Front End Milestones

FY10  Initial target configuration
FY10  IDS-NF IDR
FY11  Establish initial FE configuration
FY12  Down selection of 201 rf cavity design
FY12  Engineering design of Front End
FY13  Complete costing of Front End
FY14  IDS-NF RDR
FY14  Interim MC DFS
Summary

• A Front End baseline has been established
• Optimization studies have resulted in a 0.08 μ/p throughput ratio for 8 GeV incoming protons
• Key Front End challenges
  – Performance of rf cavities in magnetic field
  – Shielding of superconducting solenoids
• Mitigation strategies have been developed to address these challenges