Elena Wildner, Alex Bogacz and Makoto Yoshida
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Yes it is; A complete scheme emerged including stripping injection.

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Ongoing, vigorous experimental program under way at MuCool and MTA at Fermi at LBNL (first experimental tests coming out)

3) Does energy deposition pose SC solenoid shielding problem for presently proposed proton drivers?  
Challenging problem, robust engineering solution being worked out.

4) Do we have a working Injection/Extraction scheme for NS-FFAG Rings?  
Working concept under study, specific components being modeled and optimized.

5) Is chromaticity correction sufficient to reduce the TOF problem for NS-FFAG?  
EMMA demonstrated device feasibility. Conceptual solution is being studied.
6) Can Scaling FFAG be used in other-then-ring configurations? Complete prototype lattices designed for new applications e.g. prototype decay ring for VLENF

7) Is there a synergetic path from the Neutrino Factory to MC? A clear path emerged and being developed within MAP. Usage of components and techniques developed for NF-IDS.

8) Target handling for Multi MW targets? 1 MW target handling needs to be addressed

9) Proposed target systems are many, convergence? Multiple designs required; different requirements for various applications

10) Material property evolution with time (from radiation, strain & stress and temperature)? Appropriate material studies under way.
11) Will the Beta Beam be possible in the CERN Complex?
Yes, the baseline beta beam is possible to implement.

12) Verification of the 18Ne production for beta beams?
Tested experimentally.

13) Modeling of pion production complete?
Agreement between two models/codes (MARS and FLUKA) consistent within 10-20% with the HARP data.

14) How serious is power deposition in the structures after/around the target (horn, solenoids...)?
Quite significant. They are modelled accurately; adequate shielding provided.

15) Feasibility of mini-neutrino factory (low energy/intensity storage ring for short baseline measurement of cross-sections)
VLENF conceptual design with large acceptance decay ring, Scaling FFAG option.
8) Target handling for Multi MW targets?
Multi MW targets feasible; two robust designs exist (NF, LBNE)
Example for Frejus Superbeam:

TARGET STATION CONCEPT

Target and horn replacement concept
Requirement: retain functionality with
1 (out of 4) unit failure
1.3 MW each
8) Target handling for Multi MW targets?
Multi MW targets feasible; two robust designs exist (NF, LBNE)

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A few comments on future programme

- **Target technology**
  - main focus of NF/MC target station work since Study II (ie last 10 years)
  - at least 1 ‘champion’ of each of 3/4 target technologies
  - Good to have alternatives (provided does not distract from other work that needs to be done – see below)

- **Solenoid System**
  - Most critical technological issue for NF/MC Target Station?
  - Current baseline appears far from feasible
  - NB ‘Brute force’ solution with extra shielding:
    - Stored energy $\alpha r^2$
    - Only very recently receiving any attention

- **Activation/handling/safety/environmental issues**
  - The other most serious feasibility issue?

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C. Densham

Question will remain till Nufact 12

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9) Proposed target systems are many, convergence? Yes, but multiple designs required; different requirements for various applications

Target options for NF: Hg-jet target is the baseline but energy deposition in the magnet is too-high, magnet shielding need to be improved (under re-design).

Metal-powder target and solid W bars (that can be exchanged between beam pulses) are studied as mitigation options in case the Hg-jet option energy deposition issue turn to be too difficult to solve.

Aim of the feasibility study is to push the Hg-jet option to a realistic design and define if the options under study are a realistic replacement option of the Hg-jet.
Proposed target systems are many, convergence?
Multiple designs required; different requirements for various applications

Superbeam to Frejus

Towards the target baseline

After these studies we have concluded that

- The Titanium pebble bed target appears to be the best candidate (capable of multi-MW) → baseline choice
- The solid static target is feasible, pencil shape solution
- The embedded target is disfavored
10) Material property evolution with time (from radiation, strain & stress and temperature)?
Appropriate material studies under way.

Baseline solenoid system:
Two factors lead to significant technical challenges

1. Demanding Magnet Parameters - High field (14 Tesla) in a large bore (1.3 m)
   - Huge magnetic forces (10,000 Ton)
   - Large stored energy (~600 MJ)
   - Low temperature margin of superconductor
   - Pushing at the limits of present superconductor technology

2. Harsh Radiation Environment - Heating and material damage Issues
   - Heat load from 4 MW pulsed proton beam
     • Total heat load into the cold mass
     • Local Power Density
     • Instantaneous pulsed heating effects
   - Radiation damage to materials
     • Superconductor
     • Stabiliser
     • Turn-to-turn insulation
     • Load bearing elements

C. Densham
3) Does energy deposition pose SC solenoid shielding problem for presently proposed proton drivers?
Challenging problem, robust engineering solution being worked out.

Degradation of superconductor, insulator, thermal conductor, structure etc by irradiation
← some hints from COMET, ITER
Increase inner shielding → 3GJ stored energy
Feasibility?

C, Densham
Alternate target option with Low-Z?
Low-Z → less neutrons
13) Modeling of pion production complete?

Agreement between two models/codes (MARS and FLUKA) consistent within 10-20% with the HARP data

Recent updates from NA61 (talks in WG2).
14) How serious is power deposition in the structures after/around the target (horn, solenoids...)?
Quite significant. They are modelled accurately; adequate shielding provided.

4MW Superbeam Horns

ACTIVITY density in Bq/cm³

- packed Ti target, 65% d_{Ti}
- 4MW beam, 4 horns, 200 days of irradiation

Still >1MGy/year at downstream
need investigation on downstream materials

K. McDonald

4MW NF Solenoids

Deposited Power (MGray/year)

Still >1MGy/year at downstream
need investigation on downstream materials

N. Vassilopoulos

CERN annual activity constraints in molasse (for achieving 0.3mSv for the public through water)

<table>
<thead>
<tr>
<th></th>
<th>SuperBeam, (preliminary)</th>
</tr>
</thead>
<tbody>
<tr>
<td>²² Na</td>
<td>4.2 x 10⁹ Bq</td>
</tr>
<tr>
<td>tritium</td>
<td>3.1 x 10⁹ Bq</td>
</tr>
<tr>
<td></td>
<td>6 x 10⁶ Bq</td>
</tr>
</tbody>
</table>

N. Vassilopoulos
11) Will the Beta Beam be possible in the CERN Complex? Yes, the baseline beta beam is possible to implement

**Existing machines: PS**

Space Charge

- Space-charge induces tune spread (neck-tie)
- Particles can cross betatron resonance lines and
  - either lost
  - either emittance blow-up
- For BBs max. (safe!) 
  $\Delta Q = 0.22$ @ 3.5GeV but 
  e.g. Tof in PS has $|\Delta Q| = 0.30$

- Identify SC limit (max tolerable $\Delta Q$)
- Determine the optimum working point

**Tune scan @ 2GeV**

**E. Benedetto**

**High intensity studies: Started**

- Considered 2 different type of beams:
  - Small emittance, "LHC-type" beam
    - Expected (depending on the WP choice)
      - Beam emittance blow-up (integer crossing)
      - Or losses with bunch shape deformation
  - High intensity, large emittance, "Tof-like" (more similar to BetaBeams)
    - Beam blow-up will translate into losses
    - Aim is to identify different mechanisms...and find a cure!

**Existing machines: SPS**

still needs studies, Less constrained SF helps

2011-08-01
11) Will the Beta Beam be possible in the CERN Complex?
Yes, the baseline beta beam is possible to implement

**DR - Decay Ring**

- For both Baselines:
  - Circumference = 6911.6m & $L_{eff} = 39\%$
  - Bending radii $\rho = 121m \rightarrow B = 4 - 8 \ T$
  - Superconducting $\rightarrow$ Open mid-plane quadrupoles to avoid quenching due to energy depositions from decays

- All ions $\gamma = 100$
- Can only store small part of the DR due to suppression of atmospheric background: $SF \sim 1\%$

Decay Ring optimization good with higher SF, solutions exist for small theta13
11) Will the Beta Beam be possible in the CERN Complex?

Yes, the baseline beta beam is possible to implement.

Efficiencies and beam parameters on the way

T. Lamy
11) Will the Beta Beam be possible in the CERN Complex?
Yes, the baseline beta beam is possible to implement

**Solved DR Limitations**

- $2.48 \times 10^1$ $^6$He/bunch enters DR in 80 bunches!
- 4 times less bunch intensity required
  - Enough intensity can be merged
  - Collective effect no longer problem ($\text{if } R_{\perp}^{\text{DR}} = 1 \text{ M/\Omega m}$)
  - Resistive Wall and Longitudinal to be studied

**Solutions for theta 13 smaller exist**
11) Will the Beta Beam be possible in the CERN Complex? Yes, the baseline beta beam is possible to implement

**Ion Production**

6He ok, operation feasible

Tests done with 1.4GeV p at CERN-ISOLDE (2009)

- 80 porous BeO pellets
- 1+ FEBIAD ion source, cold line for Noble Gases
- >55% released
- Release efficiency, operation temperature, outgassing, materials compatibility, ageing, etc...
- CERN, GANIL, Soreq/Weizman, Bratislava

18 Ne under test

18Ne production target $10^{13}$/s

- 23Na(p, n)22Na requires a yearly salt exchange
- Neutron: $5 \times 10^{13}$ n/cm²/s at target position
- 7.5x25x15cm irradiation cell
- 6mA, 160MeV
- 2L/s pump
- 800 kW pump, 200 kW kW
- $\Delta T=100°C$
- T regulated
- Transfer Line to ion source
- 1MW NaF/ZrF4, @600°C
- T. Mendonça, PJAS-CERN, ESS, Cornelius University
12) Verification of the 18Ne production for beta beams?
Tested experimentally

18Ne Production was a serious show stopper

18 Ne under test

23Na(p,n)22Na requires a yearly salt exchange.
Neutron: 5 $10^{13}$ n/cm²s at target position.

7.5x25x15cm Irradiation cell
6mA 160MeV

$\Delta T=100^\circ$C

NaF/ZrF4 @600°C

$^18$Ne production target $10^{13}$/s

50x15x15cm Psalt = 10mBar 1MW
T. Mendonca PJAS-ORNL ESS, Cornell Universe University
1) Is Project X a suitable proton driver for the Neutrino Factory?
Yes it is; A complete scheme emerged including stripping injection.

Project X: Mission Goals

- A neutrino beam for long baseline neutrino oscillation experiments
  - 2 MW proton source at 60-120 GeV
- High intensity, low energy protons for kaon and muon based precision experiments
  - Operations simultaneous with the neutrino program
- A path toward a muon source for possible future Neutrino Factory and/or a Muon Collider
  - Requires ~4 MW at ~5-15 GeV.
- Possible missions beyond HEP
  - Standard Model Tests with nuclei and energy applications

R. Garoby
1) Is Project X a suitable proton driver for the Neutrino Factory? Yes it is; A complete scheme emerged including stripping injection

**Project X: Reference Design Capabilities**

- 3 GeV CW superconducting H- linac with 1 mA average beam current.
  - Flexible provision for variable beam structures to multiple users
  - CW at time scales >1 μsec, 15% DF at <1 μsec
  - Supports rare processes programs at 3 GeV
  - Provision for 1 GeV extraction for nuclear energy program
- 3-8 GeV pulsed linac capable of delivering 300 kW at 8 GeV
  - Supports the neutrino program
  - Establishes a path toward a muon based facility
- Upgrades to the Recycler and Main Injector to provide ≥ 2 MW to the neutrino production target at 60-120 GeV.
- Day one experiment to be incorporated utilizing the CW linac

⇒ Utilization of a CW linac creates a facility that is unique in the world, with performance that cannot be matched in a synchrotron-based facility.
2) What is the path for solving the problem of operating high gradient RF is strong magnetic field?
Ongoing, vigorous experimental program under way at MuCool and MTA at Fermi (first experimental tests coming out)

1. Better materials: more robust against breakdown (melting point, energy loss, skin depth, thermal diffusion length, etc.)
2. Surface processing: suppress field emission (superconducting RF techniques, coatings, atomic layer deposition)
3. Shielding: iron (Rogers), bucking coils (Alekou, WG3)
4 Magnetic insulation: modified cavity/coil designs to keep $B \perp E$ on cavity surfaces (Palmer)

Loss of x 2 gradient advantage in pillbox geometry

5 High-pressure gas: suppress breakdown by moderating electrons (Muons Inc.) – beam test in progress (Yonehara)
MICE RFCC Module

Each RFCC module has four 201-MHz NC RF cavities and one SC coupling coil (solenoid) magnet; each RF cavity has a pair of curved Be windows and coaxial loop couplers.

RF cavity operation in a few Tesla magnetic field at 8 MV/m

RF Cavity Processing and Testing Plan, M. Zisman, LBNL, NuFact-2011
High Power RF Testing

High power RF measurements with all needed diagnostics and controls

- Cavity conditioning/commissioning
- Frequency variation due to RF heating on beryllium windows and cavity body (may be done initially using the MTA prototype cavity)
- Measurement of cavity frequency shift as a function of average RF power and time
- Repeat above measurement with active tuners on the cavity and measure tuning range and sensitivity

• All above measurements will be conducted using the single cavity vessel
• Repeat the measurements with magnetic fields?
  - Where (MTA or RAL)?
4) Do we have a working Injection/Extraction scheme for NS-FFAG Rings? Working concept under study, specific component being modeled and optimized.

- Septum field was limited to 2 T by the stray fields studies (see next slides).
- Both injection and extraction are in the horizontal plane (minimal additional magnet aperture needed and no generation of the vertical dispersion).
- Larger apertures in the special magnets which are needed have been calculated.
4) Do we have a working Injection/Extraction scheme for NS-FFAG Rings?
Working concept under study, specific component being modeled and
optimized.

Start of engineering design for muon NS-FFAG

- Start of the engineering effort
- Effective drift length reduced to 4m (due to space for the cryostat and flanges).
- Kicker field increased 0.106 T
- Extraction septum field to 1.94 T
- Injection/extraction still feasible!
5) Is chromaticity correction sufficient to reduce the TOF problem for NS-FFAG? EMMA demonstrated device feasibility. Conceptual solution is being studied.
Shinji Machida

with 1.9 MV rf

- Serpentine channel acceleration

\[ P \text{ from H orbit} \quad \text{from H tune} \quad \text{from V tune} \]
5) Is chromaticity correction sufficient to reduce the TOF problem for NS-FFAG? EMMA demonstrated device feasibility. Conceptual solution is being studied.

![Alternative FFAG Ring Designs for PRISM](image)

- **Scaling Superperiodic**
- **Non-Scaling**
- **Reference design**
  - We need to decide about the possible baseline update very soon.
  - The choice is dictated by the performance.
- **Advanced scaling FFAG**
- **Advanced NS-FFAG**

*Under study within the PRISM Task Force.*

04.08.2011, Geneva, nufact'11

J. Pasternak
6) Can Scaling FFAG be used in other-then-ring configurations? Complete prototype lattices designed for new applications e.g. prototype decay ring for VLENF
15) Feasibility of mini-neutrino factory (low energy/intensity storage ring for short baseline measurement of cross-sections)
VLENF conceptual design with large acceptance decay ring, Scaling FFAG option

- 8 GeV protons on 2 λ₁ Be target
- 3 GeV Racetrack ring (M. Popovic)
  - For now, injection is perfect
  - Not defined
- Tuned for μ⁻ with KE = 3.000 GeV
  - 3 GeV chosen primarily for x-section meas.
  - δp/p ≈ 2%
- Detectors (scintillator)
  - Near: 200T @ 20 m
  - Far: 800T @ 600 m

- Running with μ⁻
  \[ \mu⁻ \rightarrow e⁻ + \nu_μ + \bar{\nu}_e \]
- Well defined flavor composition & energy
15) Feasibility of mini-neutrino factory (low energy/intensity storage ring for short baseline measurement of cross-sections)

VLENF conceptual design with large acceptance decay ring, Scaling FFAG option

VLENF: storage ring proposal (Preliminary)

Beam momentum : 1 GeV/c (3 GeV/c)
Momentum acceptance $\sim \pm 50\%$
Transverse acceptance $\varepsilon_N > 30\,000\,\pi\text{ mm.mrad}$
Scallop in the straight part $< 5\text{ mrad}$

$B_{\text{max}} \sim 1.5\text{ T}$
$m \sim 8\text{ m}^{-1}$
$k \sim 2.5$
$r \sim 5\text{ m}$

cf. T. Roberts, VLENF July 2011: 6D acceptance $> 100\times$ bigger
7) Is there a synergetic path from the Neutrino Factory to MC? A clear path emerged and being developed within MAP. Usage of components and techniques developed for NF-IDS.

Muon Collider Scheme: 7+ machines

- 4D cooling
- Phase rotation to 12 bunches
- 20T capture
- Hg target
- Buncher
- Multi-MW Proton Driver
- SC linac
- Synchrotron both

“Front End”~ same as for Neutrino Factory → Idea of staging

μ+

μ−

6D cooling
Merge 12 to 1 bunch
6D cooling

FOFO Snake*
Guggenheim
HCC

40T solenoids*
REMEX
Li lenses

RLA(s)
High Energy Acceleration

Collider Ring

Vladimir Shiltsev / Fermilab
1) What combination of proton beam energy and bunch length is the best compromise for integrated muon beam intensity?

2) Important to update the acceleration system of the beta beams from the source to the decay Ring

3) The PS (space charge, instabilities)

4) The SPS (instabilities and RF)

5) Impact of possible high $\theta_{13}$ on the neutrino facilities, design parameters

6) Operating high gradient normal conducting RF rf cavities in strong magnetic field; gradient degradation, effects of intense ionizing radiation traversing gas? Ongoing, vigorous experimental program under way at LBNL and MTA at Fermi (first experimental tests coming out)
7) Does energy deposition pose SC solenoid shielding problem for presently proposed proton drivers?
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