CERN Super-Beam (SPL)
Conceptual design of the SPL II

A high-power superconducting H⁻ linac at CERN
# CERN Super-Beam (SPL)

## Possible energy upgrade to 5 GeV could be the subject of a 3rd CDR (CDR3)

**Table 2.2: Main linac parameters and changes from CDR1 to the revised design (CDR2)**

<table>
<thead>
<tr>
<th></th>
<th>CDR1</th>
<th>CDR2 (neutrino)</th>
<th>CDR2 (ISOL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy [GeV]</td>
<td>2.2</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Length [m]</td>
<td>690</td>
<td>430</td>
<td>430</td>
</tr>
<tr>
<td>Average beam power [MW]</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Average RF power(\dagger) [MW]</td>
<td>24</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td>Average cryogenics power [MW]</td>
<td>9.6</td>
<td>3.6</td>
<td>4.4</td>
</tr>
<tr>
<td>Repetition rate [Hz]</td>
<td>75</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Beam pulse length [ms]</td>
<td>2.2</td>
<td>0.57</td>
<td>0.71 + 0.014</td>
</tr>
<tr>
<td>Average pulse current (after chopping) [mA]</td>
<td>11</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Peak bunch current (after 3 MeV) [mA]</td>
<td>18.4</td>
<td>64</td>
<td>40</td>
</tr>
<tr>
<td>Beam duty cycle (after chopping) [%]</td>
<td>16.5</td>
<td>2.9</td>
<td>3.6</td>
</tr>
<tr>
<td>Injection turns (into ISR)</td>
<td>660</td>
<td>176</td>
<td>–</td>
</tr>
<tr>
<td>Peak RF power [MW]</td>
<td>32</td>
<td>162</td>
<td>162</td>
</tr>
<tr>
<td>No. of 352.2 MHz tetrodes (0.1 MW)</td>
<td>79</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>No. of 352.2 MHz klystrons (1 MW)</td>
<td>44</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>No. of 704.4 MHz klystrons (5 MW)</td>
<td>–</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Cryo-temperature [K]</td>
<td>4.5</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

\(\dagger\) Without 30% margin for Lorentz detuning.

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**ISS/Irvine, August 21 2006**

Marcos Dracos
CERN Super-Beam (SPL)

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Beams for European Neutrino Experiments (BENE)
Midterm scientific report

Edited by the (extended) BENE Steering Group

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ISS/Irvine, August 21 2006

Also a lot of information inside the BENE Midterm scientific report
Collection system for future neutrino beams
horn and target integration

- 2 LoI's in BENE (CARE)
  - CERN
  - Strasbourg
CERN Lol

• Target R&D
• Horn and solid target integration

1. Improve existing infrastructure (at BA7) to allow realistic tests of a NuFact prototype horn at nominal conditions. Analysis of fatigue tests and possible corrective actions.

2. Investigation of the material structure of the existing NuFact horn (480 k€, available) with a 50 Hz power supply (300 kA, 5 kV, <100 µs). The investigation will be based on laser vibrometer (100 k€, available) measurements of the horn’s resonance frequencies and of their damping constants with increasing number of cycles. A mechanical analysis (mechanical engineers from Poland/Krakow via T. Kurtyka) should be derived to assess the fatigue of the system (horn and strip line) and its life time (expected to be few month of operations at nominal parameters).

3. Development of a test bench using the NuFact horn and the 50Hz power supply to validate multi-physics simulations in order to reduce the experimental working load and costs (collaboration with Strasbourg).

4. Address the integration issues of the horn. Complete the design of the existing horn including possibly the studies for a target station located in the inside. Investigate the cooling issues involved. (collaboration with BNL).

total cost for the collector: 1.35 M€
Power Supply for horn pulsing (major issue)

Values considered by CERN

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_o$</td>
<td>7 kV</td>
</tr>
<tr>
<td>$I_M$</td>
<td>300 kA (14.5 rms)</td>
</tr>
<tr>
<td>$\tau_0$</td>
<td>100 $\mu$s</td>
</tr>
<tr>
<td>$L$</td>
<td>0.6 (0.4 Horn) $\mu$H</td>
</tr>
<tr>
<td>$R$</td>
<td>500 (180 Horn) $\mu$Ω</td>
</tr>
<tr>
<td>$C$</td>
<td>1500 $\mu$F</td>
</tr>
</tbody>
</table>

Plateau de quelques $\mu$s

50Hz thyristors

Commutation

Charge

Recuperation 1.0 m

Recuperation 20 $\mu$f

Thyristors main

$m$ = milli
$u$ = micro

Electrical equivalent circuit
Due to the high price go to a modular system and increase small by small the current.
"Physics" studies to be restarted

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Marcos Dracos
Previous Studies

• S. Gilardoni: Horn for Neutrino Factory and comparison with a solenoid
  • [http://newbeams.in2p3.fr/talks/gilardoni.ppt](http://newbeams.in2p3.fr/talks/gilardoni.ppt)

• A. Cazes: Horn for SPL
Focusing system: magnetic horn

Current of 300 kA

To decay channel

$B \propto \frac{1}{R}$

$B = 0$

Protons

Hg Target
Horn prototype ready for tests
Proposed design

Particle at target

Total momentum

2.2 GeV protons

Entries

2500

2000

1500

1000

500

0

0

0.2

0.4

0.6

0.8

1

1.2

1.4

1.6

1.8

GeV/c

π^+

π^−

π^−

π^−

In collaboration with LAL

ECT- Trento

Simone Gilardoni

21 Oct. 2004
New Geometry

- 2.2 GeV proton beam:
  - $<p_\pi> = 405\text{MeV/c}$
  - $<\theta_\pi> = 60^\circ$

- 3.5 GeV proton beam:
  - $<p_\pi> = 492\text{MeV/c}$
  - $<\theta_\pi> = 55^\circ$
Reflector

- A reflector has been included
- It is not optimized yet
- diameter: 2m
- length: 1.5m
- I = 600kAmp
### Flux summary, 2.2 GeV

<table>
<thead>
<tr>
<th>Decay tunnel: 20m</th>
<th>Decay tunnel: 80m</th>
<th>( \nu_\mu )</th>
<th>3.89 ( 10^{13} ) (+8%)</th>
<th>( \nu^- ) (99%)</th>
<th>5.06 ( 10^{12} ) (-0.4%)</th>
<th>( \pi^+ ) (99%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \overline{\nu}_\mu )</td>
<td>3.19 ( 10^{12} ) (+6%)</td>
<td>( \pi^- ) (99%)</td>
<td>3.18 ( 10^{13} ) (+8.5%)</td>
<td>( \pi^+ ) (100%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \nu_e )</td>
<td>1.77 ( 10^{11} ) (+50%)</td>
<td>( \pi^+ \rightarrow \mu^+ ) (90%)</td>
<td>3.09 ( 10^{10} ) (+8.5%)</td>
<td>( \pi^+ \rightarrow \mu^+ ) (40%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \overline{\nu}_e )</td>
<td>1.24 ( 10^{10} ) (+14.5%)</td>
<td>( K^0 ) (55%); ( \pi^- \rightarrow \mu^- ) (45%)</td>
<td>1.14 ( 10^{11} ) (+40%)</td>
<td>( \pi^- \rightarrow \mu^- ) (95%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>( \nu_\mu )</th>
<th>4.21 ( 10^{13} ) (+8%)</th>
<th>( \pi^+ ) (99%)</th>
<th>5.08 ( 10^{12} ) (-0.4%)</th>
<th>( \pi^+ ) (99%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \overline{\nu}_\mu )</td>
<td>3.18 ( 10^{13} ) (+8.5%)</td>
<td>( \pi^- ) (99%)</td>
<td>3.09 ( 10^{10} ) (+8.5%)</td>
<td>( \pi^+ ) (37%); ( K^+ ) (35%); ( K^0 ) (25%)</td>
</tr>
<tr>
<td>( \nu_e )</td>
<td>2.66 ( 10^{11} ) (+50%)</td>
<td>( \pi^+ \rightarrow \mu^+ ) (90%)</td>
<td>2.85 ( 10^{10} )</td>
<td>( \pi^+ \rightarrow \mu^+ ) (38%); ( K^+ ) (37%); ( K^0 ) (25%)</td>
</tr>
<tr>
<td>( \overline{\nu}_e )</td>
<td>1.42 ( 10^{10} ) (+14.5%)</td>
<td>( K^0 ) (50%); ( \pi^- \rightarrow \mu^- ) (50%)</td>
<td>8.14 ( 10^{10} )</td>
<td>( \pi^- \rightarrow \mu^- ) (90%)</td>
</tr>
</tbody>
</table>
# Flux summary, 3.5 GeV

<table>
<thead>
<tr>
<th>Decay tunnel: 20m</th>
<th>Decay tunnel: 80m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decay tunnel</td>
<td>Flux (/100m²/γ)</td>
</tr>
<tr>
<td></td>
<td>Majoritary composition</td>
</tr>
<tr>
<td>νμ</td>
<td>7.82 \times 10^{13}</td>
</tr>
<tr>
<td>νμ</td>
<td>1.10 \times 10^{13}</td>
</tr>
<tr>
<td>νe</td>
<td>4.07 \times 10^{11}</td>
</tr>
<tr>
<td>νe</td>
<td>5.34 \times 10^{10}</td>
</tr>
<tr>
<td>νμ</td>
<td>8.32 \times 10^{13} (+6%)</td>
</tr>
<tr>
<td>νμ</td>
<td>1.19 \times 10^{13} (+8%)</td>
</tr>
<tr>
<td>νe</td>
<td>5.60 \times 10^{11} (+38%)</td>
</tr>
<tr>
<td>νe</td>
<td>5.93 \times 10^{10} (+11%)</td>
</tr>
</tbody>
</table>
$\theta_{13}$ Sensitivity

- Use Mauro Mezzetto code.
- Detector:
  - Water Cerenkov
  - 440 kt
  - at Fréjus (130 km from CERN)
- Run:
  - 2 years with positive focusing.
  - 8 years with negative focusing.
- Computed with $\delta_{CP}=0$ (standard benchmark) and $\theta_{13} = 0$
- Parameter...
  - $\Delta m_{23} = 2.5 \times 10^{-3} eV^2$
  - $\Delta m_{12} = 7.1 \times 10^{-5} eV^2$
  - $\sin^2(2\theta_{23}) = 1$
  - $\sin^2(2\theta_{12}) = 0.8$
Sensitivity 2.2GeV

Minimum: \( \theta_{13} = 1.6^\circ \) (90%CL)

ECFA/Bene meeting - 24th of May 2004

Antoine Cazes
Sensitivity 3.5GeV

Minimum: $\theta_{13} = 1.2^\circ$ (90%CL)
Other reflector design (S. Gilardoni Thesis)

- Reflector length 3.5m
- Reflector inner conductor cylindrical length : 2.5m
- Proton Beam 2.2GeV

![Graph showing values of \( \Delta m^2_{23} \) and \( \sin^2 2\theta_{13} \) for 90%, 95%, and 99% CL with a minimum at \( \theta_{13} = 1.3^\circ \) (90% CL)]
Conclusion

- New CDR for SPL
- Restart hardware activity around the:
  - collector
  - power supply
  - target integration
- Restart optimization studies of the collector
- Strengthen the collaboration with other super-beams
- Be ready for FP7