CERN Neutrinos to Gran Sasso (CNGS): Results from Commissioning

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1. Project Overview
2. CNGS beam line
3. Results from commissioning
1. Project Overview

(see http://cern.ch/cngs)

$\nu_\mu$ beam

$\rightarrow$ detect $\nu_\tau$ appearance

$p + C \rightarrow \pi^+, K^+, (\mu^+) \rightarrow \text{(decay in flight)} \rightarrow \mu^+ + \nu_\mu$
2. CNGS beam line

Nominal beam parameters

<table>
<thead>
<tr>
<th>Beam Parameters</th>
<th>Nominal values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalised emittance [$\mu$m]</td>
<td>H=12 V=7</td>
</tr>
<tr>
<td>Physical emittance [nm]</td>
<td>H=28 V=16</td>
</tr>
<tr>
<td>Momentum spread $\Delta p/p$</td>
<td>0.07% ± 20%</td>
</tr>
<tr>
<td>Number of extractions per cycle</td>
<td>2 (50ms apart)</td>
</tr>
<tr>
<td>Batch length [$\mu$s]</td>
<td>10.5</td>
</tr>
<tr>
<td>Number of bunches per batch</td>
<td>2100</td>
</tr>
<tr>
<td>Intensity per extraction (protons)</td>
<td>2.4 (10^{13})</td>
</tr>
<tr>
<td>Bunch length [ns] ((4\sigma))</td>
<td>2</td>
</tr>
<tr>
<td>Bunch spacing [ns]</td>
<td>5</td>
</tr>
<tr>
<td>Beta at focus [m]</td>
<td>H=10 V=20</td>
</tr>
<tr>
<td>Beam sizes at (400\ GeV) [mm]</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Target

Courtesy of L. Bruno and D. Grenier
Horn and Reflector

length: 6.5 m
diameter: 70 cm
weight: 1500 kg

Pulsed devices:
150kA / 180 kA
water-cooled:
distributed nozzles

Courtesy of A. Pardons
3. Commissioning

Importance of complete hardware commissioning and dry runs (as if beam but without beam)

- **Hardware commissioning**  Feb. - April 2006
  - Beam instrumentations
  - Power supplies
  - Magnets (polarities)
  - Vacuum system

- **“Dry runs”**  April - May 2006
  - Timing
  - Controls
  - Interlocks
  - Beam permit
  - Magnets (current & polarities)

- **Commissioning with beam**  2006: weeks 28, 30 and 33
  Upper limit of protons of $1 \times 10^{17}$ for the 3 weeks.
Proton beam along the 8 screens of transfer line

1st shot down proton beam line: beam is already well centered

Screens:
75 μm carbon
12 μm titanium

Courtesy of E. Bravin, G. Burtin
Beam position monitors (BPM) checked

2 μs, for $I \sim 2 \times 10^{11}$
Trigger at 1 μs, 400ns gate

10.5 μs for $I > 2 \times 10^{12}$
Trigger at 1 μs, 8 μs gate
or trigger at 2 μs, 400ns gate

<table>
<thead>
<tr>
<th>source</th>
<th>rms uncertainty</th>
<th>tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPM (global accuracy)</td>
<td>0.25 mm</td>
<td>± 0.5 mm</td>
</tr>
<tr>
<td>Alignment</td>
<td>0.20 mm</td>
<td>± 0.4 mm</td>
</tr>
<tr>
<td>Total</td>
<td>0.32 mm</td>
<td>± 0.6 mm</td>
</tr>
</tbody>
</table>

System is very sensitive to batch structure and intensity. However for nominal beam parameters, system is reliable.

Malika Meddahi
PAC’07, 25-29 June
for the CNGS commissioning team
Trajectory along beam line

2 extractions, $\sim 10^{13}$ protons per batch

Horizontal plane

Vertical plane

Malika Meddahi
PAC’07, 25-29 June
for the CNGS commissioning team
Trajectory difference between the 2 extractions on BPMs

Energy difference of $6 \times 10^{-5}$
Beam position stability onto the target over 3 first days: ~50 \( \mu \text{m} \) rms
Optics checks

Good agreement with theory

Beta beat of less than 10%

"Beam stability and Optics studies of the CNGS transfer line"
by J. Wenninger et al, AB-Note-2007-008 OP

Dispersion measurements

Horizontal plane

vertical plane

 Courtesy of J. Wenninger
Special beam position monitor on target table:

Stripline coupler Pick-up operated in air

<table>
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<th>rms uncertainty</th>
<th>tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPM (global accuracy)</td>
<td>0.1 mm &amp; 0.15 mm</td>
<td>± 0.2 mm &amp; 0.3 mm</td>
</tr>
<tr>
<td>Alignment</td>
<td>0.10 mm</td>
<td>± 0.2 mm</td>
</tr>
<tr>
<td>Total</td>
<td>0.14 mm</td>
<td>± 0.35 mm</td>
</tr>
</tbody>
</table>

-> very reliable position reading
Downstream Target Beam Instrumentation (TBID)

Secondary emission monitor
12 µm Ti foils
in vacuum

Measures all charged particles downstream the target
-> check efficiency of particle production in the target
Horizontal beam position scan – Target IN beam

Intensity on TBID vs. BPM position

Charged particles per proton (un-calibrated)

BPM reading [mm]

Courtesy of E. Gschwendtner
The CNGS commissioning with beam proved the importance of

- detailed hardware commissioning
- complete “dry” commissioning
- having screens along extraction channel and proton line for the first beam passages
- save protons used during commissioning
Summary - Outlook

CNGS project was approved on December 1999

Civil Engineering– Equipment design– Production– Installation– Commissioning phases lasted 6 years: CNGS handed over to operation on 18 August 06

Project completed within budget and on schedule.

Proton beam line and secondary beam line were successfully commissioned. First shot down the line reached the target at about center. Beam is very stable and parameters are within specification. Experiments at Gran Sasso saw signals correlated to the CERN-CNGS beam.

Let’s run the facility for physics with nominal beam intensity!

Thank you to all the colleagues from CERN and laboratories all over the world who contributed to the project’s success.
Two posters related to CNGS:

E. Gschwendtner, TUPAN095
on CNGS Secondary Beam Results and Simulations, incl. experience from short 2006 physics run

V. Kain, TUPAN096
on Extraction Channel from SPS towards CNGS beam-line