CNGS Operation Summary

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Outline

• Introduction
• CNGS Performance
• Highlights since last NBI 2010 in Japan
• Issues
• Summary
CNGS Beam at CERN

- From SPS: 400 GeV/c
- Cycle length: 6 s
- 2 Extractions: separated by 50 ms
- Pulse length: 10.5 μs
- Beam intensity: 2 × 2.4 × 10^{13} ppp
- Beam power: up to 500 kW
- Beam spot size: ~0.5 mm

P_{osc} * \sigma_{T_{CC}} (arbitrary units)

ν_{μ}-fluence

<17 GeV>
target
magnetic horns
decay tunnel
hadron absorber
muon detector 1
muon detector 2
CNGS Secondary Beam Line

Target unit: 13 graphite rods 10cm
1 Magazine: 1 unit used, 4 in situ spares

Target chamber: 100m

Decay tube: 994m long, 2.45m 1mbar vacuum

Hadron stop: 100kW

Muon detectors: 2x41 LHC type BLMs

2 HORNS: 7m long, 150/180kA pulsed
Water cooled
Remote polarity change
1.8mm inner conductor

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CNGS Timeline until Today

2006
Commissioning
Leak in the reflector cooling circuit, damaged stripline cable

2007
Beam commissioning with high intensity
Radiation effects in ventilation system electronics

2008
Physics run
MTE tests, Tritium issue

2009
Physics run
MTE tests, Tritium issue

2010
Physics run
MTE, Tritium issue

2011
Physics run
MTE, bunched beam

2012
Physics run, MTE, bunched beam
Total Integrated Intensity since CNGS Start in 2006

CNGS approved for 22.5E19 pot \( \rightarrow \) i.e. 5 years with 4.5E19 pot/yr
\( \rightarrow \) Expect \( \sim 10 \nu_\tau \) events in OPERA \( \rightarrow 2 \nu_\tau \) candidates published

<table>
<thead>
<tr>
<th>Year</th>
<th>Protons on target/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>0.08 E19</td>
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<tr>
<td>2007</td>
<td>0.08 E19</td>
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<tr>
<td>2008</td>
<td>1.78 E19</td>
</tr>
<tr>
<td>2009</td>
<td>3.52 E19</td>
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<tr>
<td>2010</td>
<td>4.04 E19</td>
</tr>
<tr>
<td>2011</td>
<td>4.84 E19</td>
</tr>
<tr>
<td>2012</td>
<td>3.47 E19</td>
</tr>
</tbody>
</table>

Total (today) 17.81 E19

By end 2012:
\( \rightarrow \) Expect \( \sim 18.3 \)E19 protons on target
\( \rightarrow \) 81% of approved pot

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SPS Efficiencies for CNGS

- **2008**
  - Integrated efficiency: 60.94%

- **2009**
  - Integrated efficiency: 72.86%

- **2010**
  - Integrated efficiency: 79.55%

- **2011**
  - Integrated efficiency: 78.89%

- **2012**
  - Integrated efficiency: 81.78%

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Different CNGS Duty Cycles

CNGS duty cycle: 100%

CNGS duty cycle: 54%

CNGS duty cycle: 66%

CNGS duty cycle: 24%

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CNGS Performance

Beam Position on Target

- Excellent position stability; ~50 (90) μm horiz (vert) over entire run.
- No active position feedback is necessary
  - 1-2 small steerings/week only

Power on Target

- Maximum: 480kW
- Sustained Maximum during 1 day (dedicated CNGS running): 330kW
- With LHC, Fixed Target, MDs...: 156kW

Muon Monitors: Online Feedback

- Offset of target vs horn at 0.1mm level → Muon profiles Pit 1
- Offset of beam vs target at 0.05mm level → Muon profiles Pit 2

See NBI2010 CNGS presentation:
http://kds.kek.jp/getFile.py/access?contribId=5&sessionId=5&resId=0&materialId=slides&confId=5611
Highlights of CNGS Activities since NBI2010

Consequence of the OPERA Results on the Neutrino Velocity Measurements

CERN GPS

LNGS GPS

10500ns

waveforms

time shift by TOF

data

CNGS nominal beam is 10500ns long

– A lot of statistics needed for time of flight analysis

– Many possible systematic effects along the secondary beam line

Activities:

1. Install new muon detectors
   – Measurement of the GPS timing signal at CERN independently from the BFCT
   – Measure time structure of the muon spill

2. Send LHC type bunched beam to CNGS
   – Precise timing of each neutrino interaction
   – Many systematic effects excluded

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2011/2012: Installation of New Additional Muon Detectors

- Use kicker extraction signal to trigger the scope (like done for BCFT)
- Measure the time structure of muon spills with $\sim 1$GS/s
- Perform cable delay measurements

Detector challenge:
- Pit 1: $\sim 1$ THz/cm$^2$
- Pit 2: $\sim 10$-$100$ GHz/cm$^2$

Diamond Detectors
GPS timing measurement is consistent between the BFCT and the diamond monitors.
Nominal CNGS Beam

- Bunch intensity: \( \sim 1 \times 10^{10} \) p
- Bunch separation: 5ns
- 2100 bunches
- 2 extraction/cycle
- Cycle length: 6s

\[ \Rightarrow \sim 35 \text{ neutrino-events/day} \]
2011/2012: LHC Type Bunched Beam to CNGS

21 October to 6 November 2011:

- Bunch intensity: \( \sim 2.5 \times 10^{11} \) p
- Bunch separation: 524 ns
- 4 bunches/batch, 1 batch
- 1 extraction/cycle
- **Cycle length**: 6 s
→ 1 neutrino-event/day

**Issue**: BPMs didn’t work
→ For steering use muon detectors
→ Magnet HW interlock
→ Beam position at exit of SPS extraction

10 – 24 May 2012:

- Bunch intensity: \( \sim 1.25 \times 10^{11} \) p
- Bunch separation: 100 ns
- 16 bunches/batch
- 4 batches, Batch separation: \( \sim 300 \) ns
- 1 extraction/cycle
- **Cycle length**: 13.2 s
→ 4 neutrino-events/day
Nominal beam size on target T40 is **0.53 mm** for the ultimate intensity of **7×10^{13} p / cycle**. Emittance assumed to be ~10 mm.

Since 2006 we are operating at a maximum of **4.2×10^{13} p / cycle**, but with smaller emittances of **4-5 µm**.

- The resulting beam sizes on CNGS target are ~**0.3/0.4 mm** (H/V).
- But the beam density is similar as the brightness ~constant.

Following some worries last year about the state of the target → rematch a new optics that would restore a beam size of ~**0.53 mm**.

- Optics changes are limited to matching section in front of T40.
- Target β on CNGS target was set to **30 m** instead of **10/20 m** (H/V).
Vacuum Be-Window

• Be-window (0.25mm thick, diameter 70mm on 114mm flange) at the downstream end of the proton beam-line, just in front of the target had to be exchanged twice:
  – March 2011 before startup (after 14.34E19 pot)
  – April 2012 after ~2 weeks of beam (after 4.9E19 pot)

• Due to high radiation level no study on reason of window-breaking done yet
Summary

• CNGS is still running fine.
  – BUT: Operating and maintaining a high-intensity facility is very challenging
    • Tritium issue, fatigue, corrosion,…

• Exciting two years since the last NBI2010 in Japan
  – Proton delivery record in 2011
  – LHC type bunched beam
  – Installation of new detectors

• CNGS will stop on 3rd December 2012
  – Not yet decided/requested whether CNGS will continue after LS1 in 2015
CNGS Talks during NBI2012

- We, 16:15-16:30:
  - Experience with CNGS Primary Beam Line Instrumentation, Lars Jensen
- We, 17:45-18:00:
  - Diamond Detectors for CNGS, Hendrik Jansen
- Thu, 9:40-10:00:
  - CNGS Target Operation and Modified Design, Marco Calviani
- Thu, 13:30-13:40:
  - CERN Horn Experience, Ans Pardons
- Fr, 8:45-9:05:
  - CNGS Operation and Environmental Issues, Heinz Vincke
- Sa, 10:10-10:30:
  - Remote Handling Activities at CERN, Jean-Louis Grenard