CNGS:
First Year of Operation

E. Gschwendtner AB/ATB on behalf of the CNGS team
Outline

• Introduction
• CNGS Timeline
• CNGS Facility
  – Layout and Main Parameters
  – Startup Issues
  – 2008 Performance
• Highlights from the OPERA Experiment
• Outlook for 2009
• Summary
Neutrino Parameter Status: July 2008 Review of Particle Physics

Direct measurement of neutrino masses: still compatible with Zero:
- $\nu_e < 2\text{eV}$
- $\nu_\mu < 0.19\text{MeV}$
- $\nu_\tau < 18.2\text{MeV}$

If flavor eigenstates and mass eigenstates are different (mixing) and if masses are different $\rightarrow$ neutrino oscillation

Mass states: $|\nu_1\rangle$, $|\nu_2\rangle$, $|\nu_3\rangle$

$\Delta m_{12} = m_2 - m_1$, $\Delta m_{23} = m_3 - m_2$

Mixing of the three neutrinos: unitary 3x3 matrix $\rightarrow$ 4 parameters like the CKM matrix for Quarks.

CP violating phase not yet accessible $\rightarrow$ currently 3 mixing angles $\theta$.

$$P_{\mu \rightarrow \tau} = \sin^2(2\theta_{23}) \sin^2 \left( \frac{\Delta m_{23}^2 L}{4E} \right)$$

$$\Delta m_{21}^2 = 8 \pm 0.3 \times 10^{-5} \text{eV}^2$$
$$\Delta m_{32}^2 = 2.5 \pm 0.5 \times 10^{-3} \text{eV}^2$$

$\Delta m_{21}$ = solar and reactor Neutrinos
$\Delta m_{32}$ = Atmospheric and long Baseline

$$\sin^2 2\theta_{21} = 0.86^{+0.03}_{-0.04} \rightarrow \theta_{21} = 34.1 \pm 1.6 \text{ degrees}$$
$$\sin^2 2\theta_{23} > 0.93 \rightarrow \theta_{23} = 35.3 \text{ degrees compatible with max. mixing } \theta = 45 \text{ degrees}$$
$$\sin^2 2\theta_{13} < 0.19 \rightarrow \theta_{13} < 13 \text{ degrees compatible with min. mixing } \theta = 0 \text{ degrees}$$
Neutrino Introduction

→ $\Delta m^2_{32}$… governs the $\nu_\mu$ to $\nu_\tau$ oscillation

→ Up to now: only measured by disappearance of muon neutrinos:
  • Produce muon neutrino beam, measure muon neutrino flux at near detector
  • Extrapolate muon neutrino flux to a far detector
  • Measure muon neutrino flux at far detector
  • Difference is interpreted as oscillation from muon neutrinos to undetected tau neutrinos
→ K2K, NuMI

→ CNGS (CERN Neutrinos to Gran Sasso):
  long base-line appearance experiment:
  • Produce muon neutrino beam at CERN
  • Measure tau neutrinos in Gran Sasso, Italy (732km)
→ Very convincing verification of the neutrino oscillation
How to Detect a Tau Neutrino?

→ $\nu_\tau$ interaction in the target produces a $\tau$ lepton.
→ $\tau$ lepton: very short lifetime

→ Identification of tau by the characteristic ‘kink’ on the decay point.

First direct measurement of $\nu_\tau$ only in 2000 by DONUT (Detector for Observation of Tau Neutrino) at Fermilab → Emulsion target

**CNGS:**
- tau: lorenzboost of ~10:
- Tau tracklength: ~1mm

- Need high resolution detector to observe the kink
- Large mass due to small interaction probability

**Gran Sasso:**
→ OPERA (1.2kton) emulsion target detector: ~146000 lead-emulsion bricks
→ ICARUS (600ton) liquid argon TPC

**Introduction**

Tau lifetime: $2.9 \times 10^{-13} s$

→ $c^*\text{lifetime}: 87 \ \mu m$
CERN Neutrinos to Gran Sasso

Experiments: OPERA (1200 ton), ICARUS (600 ton)

4.5 \times 10^{19} \text{ pot/year (200 days, nominal intensity)}

\rightarrow 2.2 \times 10^{17} \text{ pot/day}

\rightarrow \sim 10^{17} \nu_\mu /\text{day}

\rightarrow \sim 10^{11} \nu_\mu /\text{day at detector in Gran Sasso}

\rightarrow 3600 \nu_\mu \text{ interactions/year in OPERA}

\text{(charged current interactions)}

\rightarrow 2-3 \nu_\tau \text{ interactions detected/year in OPERA}

\sim 1 \nu_\tau \text{ observed interaction with } 2 \times 10^{19} \text{ pot}

\text{CNGS Run 2008: } 1.78 \times 10^{19} \text{ pot}
### CNGS Timeline

<table>
<thead>
<tr>
<th>Date/Event</th>
<th>Activity Description</th>
<th>Location</th>
<th>POT</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 July-27 Oct 2006</td>
<td>Beam Commissioning</td>
<td>CERN</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Detector electronics commissioning</td>
<td>Gran Sasso</td>
<td>0.08\cdot 10^{19}$pot</td>
</tr>
<tr>
<td>ShUTDOWN 2006-2007</td>
<td>Reflector Water Leak Repair/Improvement</td>
<td>CERN</td>
<td></td>
</tr>
<tr>
<td>17 Sept-20 Oct 2007</td>
<td>Beam Commissioning at high intensity</td>
<td>CERN</td>
<td>0.08\cdot 10^{19}$pot</td>
</tr>
<tr>
<td></td>
<td>Detector commissioning with 60000 bricks</td>
<td>Gran Sasso</td>
<td></td>
</tr>
<tr>
<td>ShUTDOWN 2007-2008</td>
<td>Additional shielding and electronics re-arrangement</td>
<td>CERN</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finishing OPERA bricks</td>
<td>Gran Sasso</td>
<td></td>
</tr>
<tr>
<td>18 June-3 Nov 2008</td>
<td>CNGS Physics Run</td>
<td>CERN</td>
<td>1.78\cdot 10^{19}$pot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gran Sasso</td>
<td></td>
</tr>
</tbody>
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Introduction
CNGS Layout and Main Parameters
CERN NEUTRINOS TO GRAN SASSO
Underground structures at CERN

- Excavated
- Concreted
- Decay tube (2nd contract)

- Target
- Magnetic horns
- SPS tunnel
- LHC/T18 tunnel
- T18/LHC tunnel
- Access galleries
- Protons
- Pions
- K0s
- Neutrinos
- Hadron absorber
- Hadron stop and first muon detector
- Second muon detector
- Muon detector pit 1
- Muon detector pit 2
- Decays tunnel
- TCV4 sump 30 m^3
- TSG4 sump 30 m^3
- TNM31 sump 8 m^3
- TZ sump 8 m^3
- TNM42 sump 8 m^3

CNGS: Conventional Neutrino Beams

\[ p + C \rightarrow (interactions) \rightarrow \pi^+, K^+ \rightarrow (decay in flight) \rightarrow \mu^+ + \nu_\mu \]

Produce pions and Kaons to make neutrinos
## CNGS Proton Beam Parameters

<table>
<thead>
<tr>
<th>Beam parameters</th>
<th>Nominal CNGS beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal energy [GeV]</td>
<td>400</td>
</tr>
<tr>
<td>Normalized emittance [μm]</td>
<td>H=12 V=7</td>
</tr>
<tr>
<td>Emittance [μm]</td>
<td>H=0.028 V=0.016</td>
</tr>
<tr>
<td>Momentum spread $\Delta p/p$</td>
<td>0.07 % +/- 20%</td>
</tr>
<tr>
<td># extractions per cycle</td>
<td>2 separated by 50 ms</td>
</tr>
<tr>
<td>Batch length [μs]</td>
<td>10.5</td>
</tr>
<tr>
<td># of bunches per pulse</td>
<td>2100</td>
</tr>
<tr>
<td>Intensity per extraction [10^{13} p]</td>
<td>2.4</td>
</tr>
<tr>
<td>Bunch length [ns] (4σ)</td>
<td>2</td>
</tr>
<tr>
<td>Bunch spacing [ns]</td>
<td>5</td>
</tr>
<tr>
<td>Beta at focus [m]</td>
<td>hor.: 10 ; vert.: 20</td>
</tr>
<tr>
<td>Beam sizes at 400 GeV [mm]</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Beam divergence [mrad]</td>
<td>hor.: 0.05; vert.: 0.03</td>
</tr>
</tbody>
</table>

**Expected beam performance:** 4.5 x 10^{19} protons/year on target
CNGS Primary Beam Line
100m extraction together with LHC, 620m long arc to bend towards Gran Sasso, 120m long focusing section

Magnet System:
• 73 MBG Dipoles
  – 1.7 T nominal field at 400 GeV/c
• 20 Quadrupole Magnets
  – Nominal gradient 40 T/m
• 12 Corrector Magnets

Beam Instrumentation:
• 23 Beam Position Monitors (Button Electrode BPMs)
  – recuperated from LEP
  – Last one is strip-line coupler pick-up operated in air
  – mechanically coupled to target
• 8 Beam profile monitors
  – Optical transition radiation monitors: 75 μm carbon or 12 μm titanium screens
• 2 Beam current transformers
• 18 Beam Loss monitors
  – SPS type N₂ filled ionization chambers
Proton beam: last beam position / beam profile monitors upstream of the target station collimator and shielding

BN collimator, d=14mm

Be window, t=100μm
Air cooled graphite target
- Target table movable horizontally/vertically for alignment

- Multiplicity detector: TBID, ionization chambers

- 2 horns (horn and reflector)
  - Water cooled, pulsed with 10ms half-sine wave pulse of up to 150/180kA, remote polarity change possible

- Decay pipe:
  - 1000m, diameter 2.45m, 1mbar vacuum, 3mm Ti entrance window, 50mm carbon steel water cooled exit window.

- Hadron absorber:
  - Absorbs 100kW of protons and other hadrons

- 2 muon monitor stations: muon fluxes and profiles
CNGS Target

13 graphite rods, each 10cm long, Ø = 5mm and/or 4mm
2.7mm interaction length

Ten targets (+1 prototype) have been built. → Assembled in two magazines.
CNGS Horn and Reflector

- 150kA/180kA, pulsed
- 7m long, inner conductor 1.8mm thick
- Designed for $2 \times 10^7$ pulses
- Water cooling to evacuate 26kW
- 1 spare horn (no reflector yet)

Design features
- Water cooling circuit
  - In situ spare, easy switch
    - $<1$ mSv total dose after 1y beam, 1w stop
  - Remote water connection
- Remote handling & electrical connections
  - $<1$ mSv total dose after 1y beam, 1m stop
- Remote and quick polarity change
Muon Monitors

- 2 x 41 fixed monitors (Ionization Chambers)
- 2 x 1 movable monitor

LHC type Beam Loss Monitors

- Stainless steel cylinder
- Al electrodes, 0.5cm separation
- N₂ gas filling

Muon Intensity:
- Up to $8 \times 10^7 \text{ /cm}^2/10.5 \mu\text{s}$
Startup Issues

- **2006-2007**
  - Reflector water leak
- **2007-2008**
  - Horn and Reflector stripline improvement
  - Radiation problems and solutions
- **2007-2008 beam**
  - Polarity puzzle
  - Non-linearity puzzle
Reflector Water Leak

October 2006: Leak in water outlet of cooling circuit of reflector after $4 \cdot 10^5$ pulses

Observation:
- High refill rate of closed water circuit of reflector cooling system
- Increased water levels in sumps

Reason:
- Inadequate design of water outlet connectors (machining, brazing)
Reflector and Horn Repair/Improvement

Improved design: replace brazed connections by connectors under pressure

Stress in ceramic strongly reduced:
- No brazing
- No machined internal edges
- Ceramic under compression only (10 times stronger)

Water & air tight:
- Soft graphite/steel seal (5MPa pre-stress)
- Self-locking nuts

Thorough technical study:
- Detailed validation/calculations of the new design
- Additional features optimized
Horn and Reflector Repair

- Repair and exchange
  - Detailed radiation dose planning and minimization
  - Practice of repair/improvement work on the spare horn in order to reduce exposure time
  - Each work step executed by up to 4 persons to reduce individual dose
  - Additional local shielding

  → total integrated dose: 1.6 mSv
Horn & Reflector Stripline Improvement

Aug 2007: Cracks in stripline flexible connection of reflector

Old design (WANF extrapolation):
• clamped plates, twisted cables, brazed.
• Large displacement from magnetic forces between plates (vibration of 2mm measured) → caused cracks → reflector cable broke due to fatigue

New design:
• No brazing, semi-flexible fully clamped plates
• vibration during pulsing reduced to 0.2mm
• no change in the impedance or current flow properties
• modify the flexible striplines of both horn & reflector
Radiation Issues - 2007 CNGS Run

CNGS: no surface building above CNGS target area
→ large fraction of electronics in tunnel area

- During CNGS run 2007:
  - Failure in ventilation system installed in the CNGS Service gallery due to radiation effects in electronics (SEU – Single Event Upsets- due to high energy hadron fluence)
  → radiation levels predicted by simulations too high for off the shelf components -COTS

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Ventilation units in the service gallery

High-energy (>20MeV) hadrons fluence (h/cm²) for 4.5E19 pots

A. Ferrari, L. Sarchiapone et al, FLUKA simulations 2008
Modifications in Shutdown 2007/08 due to Radiation Issues

1. Move as much electronics as possible out of CNGS tunnel area
2. Create radiation safe area for electronics which needs to stay in CNGS
3. Add shielding: concrete walls up to 6m thick, in total ~53m³ concrete
   - Movable shielding plugs in TSG4 and TSG41 remotely controlled, connected to access system
     → will be opened before any access to CNGS is granted
   - Bypass of ventilation ducts
     → decrease radiation by up to a factor $10^6$

→ Side effect:
   - CNGS triggered a large campaign for rad-hardness for LHC
   - CNGS serves as test bed for parasitic irradiations of LHC and others
CNGS Radiation Simulations

Dose in Gray for a nominal year (4.5 E19 pot)

2007 no shielding

\(~10 \text{ Gr/y}\)

\(F \ 10^6\)

\(< 10 \mu\text{Gr/y}\) 2008++

High-E (>20 MeV) hadron fluence for a nominal year (4.5 E19 pot)

2007 no shielding

\(~10^{10} \text{ h/cm}^2/\text{yr}\)

\(F \ 10^4\)

\(< 10^6 \text{ h/cm}^2/\text{yr}\) 2008++

A. Ferrari, L. Sarchiapone et al, FLUKA simulations 2008

E. Gschwendtner, AB/ATB

AB Seminar, 20 Nov. 2008
Photo Gallery- Motorized Shielding Plugs

PPP-TSG4: 15 tons, moves on 6% slope

PPP-TSG41: 20 tons, moves on flat surface

Plugs connected to access system and remotely controlled
Open before an access to CNGS is granted
Service Gallery

Radiation Safe Area:
Electronics reshuffled
→ 4 racks removed to make space for control cubicle of ventilation systems
Junction to Target Chamber

View from ventilation chamber into target chamber
Junction to Target Chamber
Shielding in TT41 Proton Beam Line
CNGS Polarity Puzzle

Muon detectors very sensitive to any beam change – give online feedback for neutrino beam quality!!

- Observation of asymmetry in horizontal direction between
  - Neutrino (focusing of mesons with positive charge)
  - Anti-neutrino (focusing of mesons with negative charge)
CNGS Polarity Puzzle

Explanation: Earth magnetic field in 1km long decay tube!
- calculate B components in CNGS reference system
- Partially shielding of magnetic field due to decay tube steel

→ Results in shifts of the observed magnitude
→ Measurements and simulations agree very well (absolute comparison within 5% in first muon pit)

![Neutrino flux graph](image)

**Neutrino**
- Focusing on positive charge

**Anti-neutrino**
- Focusing on negative charge

**Lines:** simulated μ flux
**Points:** measurements
Normalized to max=1

FLUKA simulations, P. Sala et al 2008
Muon Detector Non-Linearity Puzzle

2007: observation: non-linear muon detector signal in horizontal profile of pit 1 (not in vertical profile, neither in profiles of pit 2)

Looks like saturation effect
But:
Check:
Timing?
Electronics cards?
Beam intensity?

A. Marsili et al, AB-2008-044-BI
Muon Detector Non-Linearity Puzzle

Wire topology:
All detectors are connected to readout card via a 750m long twisted multi-wire cable.
→ Horizontal profile detectors are inside the multi-wire cable
→ See different capacitances!

Remedy:
Increase capacitance of all wires to a fixed value:
→ adding 220nF capacitor between each wire and shielding.
CNGS 2008 Performance

• Primary and Secondary Beam
• Experiences gained in operating a 500kW high intensity facility
CNGS Run 2008

18 June – 3 November 2008

→ 1.78·10^{19} protons on target

Excellent performance of the CNGS Facility:

→ CNGS modifications finished successfully:
  • no radiation problems/effects in the electronics during the entire run 2008
  • excellent horn/reflector performance during 2008 run

→ Beam line equipment
  • Working well and stable (target, horns, detectors…)

OPERA experiment:
  – 10100 on-time events
  – 1700 candidate interactions in bricks
Supercycle

48s supercycle:
North Area, 3 CNGS, 1 LHC, 1 MD
→ 37.5% CNGS duty cycle

50.4s supercycle:
7 CNGS, 1 LHC
→ 83% CNGS duty cycle
CNGS Run 2008: 18 June- 03 Nov 2008

Total: $1.78 \cdot 10^{19}$ pot

Nominal: $4.5 \cdot 10^{19}$ pot/yr for 5 years

CNGS Facility – Performance 2008

- SPS timing fault: vacuum leak & magnet exchange
- PS magnet exchange, septum bakeout
- 18kV cable repair
- MD
- SPS extraction line: Magnet ground fault
- CNGS maintenance
- MD

E. Gschwendtner, AB/ATB
SPS Efficiency for CNGS

Integrated efficiency: 60.94%
Protons on Target per Day

Beam to CNGS, North Area, LHC

CNGS duty cycle: 37.5%, 54%

37.5%, 43%

37.5%, 45%, 54%

56%-83%

3.5E17

integrated pot
Beam Intensity

Number of extractions during 2008 run:

Almost 1 million - 995000!

Intensity limits:
- Losses in the PS
- SPS RF

Typical transmission of the CNGS beam through the SPS cycle ~ 92%.
Injection losses ~ 6%.
Primary Beam

- Extraction interlock in LSS4 modified to accommodate the simultaneous operation of LHC and CNGS
  - Good performance, no incidents
- No extraction and transfer line losses
- Trajectory tolerance: 4mm, last monitors to +/-2mm and +/- 0.5mm (last 2 monitors)
  - Largest excursion just exceed 2mm
- Total trajectory drift over 2008 is ~1mm rms in each plane

![Graph showing Horizontal and Vertical plane performance](graph.png)
Target Beam Position

- Excellent position stability; ~50 microns over entire run.
- No active position feedback is necessary
  - 1-2 small steerings/week only

Horizontal beam position on the last BPM in front of the target
On-line Muon Profiles

Centroid for each profile and extraction
Beam Stability seen on Muon Monitors

- Position stability of muon beam in pit 2 is ~3cm rms
- Beam position correlated to beam position on target.
  - Parallel displacement of primary beam on T40
Muon Monitors

Very sensitive to any beam changes!

- Offset of beam vs target at 0.05mm level

CNGS Facility – Performance 2008

Muon Profiles Pit 2

- Centroid of horizontal profile pit2

→ 5cm shift of muon profile centroid
→ ~80μm parallel beam shift

- Offset of target vs horn at 0.1mm level
  - Target table motorized
  - Horn and reflector tables not
Muon Monitors: Measurements vs. Simulations

→ Excellent agreement!

E. Gschwendtner, AB/ATB

AB Seminar, 20 Nov. 2008
Experience from Operating a 500kW Facility
Target Region Layout

- alignment with beam to be done during every start-up

Horizontal Beam Scan across target and collimator

Intensity on **TBID** vs BPM

Intensity on **Ionization Chambers** vs BPM

14mm collimator opening

5mm target

50mm target

BPM [mm]
Target Region

- TBID detector break-down on 19 July 2008 (after $0.12 \cdot 10^{19}$ pot), fault is on detector side

→ Ionization chambers still running fine, can be used as back-up for beam line setting up
Helium Tube Entrance Window

- 0.3mm thick
- 0.8m inner diameter
- Clamped with seal between flanges

Titanium Grade (Ti-6Al-4V)
- Ultimate stress:
  - @20°C: >900MPa
  - @100°C: >870MPa
  - @150°C: >850MPa

From calculations:
- When ventilation vs. beam is such that temp. at flange = 66°C:
  → Window: Temp. <100°C & Stress <250MPa → Safety factor 3 ensured.

From temperature measurements during operation (extrapolate):
- If temp. measured < 85°C
  → Window: Temp. <150°C & Stress <300MPa → Safety factor 2.5 ensured.

Courtesy of A. Pardons
Helium Tube Entrance Window Temperature

CNGS duty cycle: 37.5%, 54%
37.5%, 43%
37.5%, 45%, 54%
56%-83%
OPERA
Tau Neutrino Detection Principle

Detection of tau lepton: identification of a ‘kink’ or ‘trident’ topology

- Large mass due to small interaction probability \(\rightarrow\) lead target
- Micrometric and milliradian resolution to observe the kink \(\rightarrow\) photographic emulsion
- Select neutrino interactions \(\rightarrow\) electronic detectors
- Identify muons and their charge to reduce charm background \(\rightarrow\) electronic detectors

Key elements: bricks

- 146621 bricks, each 8.3kg
- Per brick:
  - 56 (1mm) Pb sheets
  - 57 (300\(\mu\)m) FUJI emulsion layers
  - 2 (300\(\mu\)m) changeable sheets (CSd)
The OPERA Detector

- Total target mass:
  - 1.2 kton

- 2 super modules:
  - Spectrometer: 22 RPC planes in magnetic field (1.5T), 6 Drift tube planes
  - Target: 27 lead emulsion brick walls, alternated with scintillator planes
Bricks

- Brick filling finished on 14 July 2008
- 146621 bricks in total ~ 8 millions of nuclear emulsions
- 5000 bricks more will be added at the end of 2008 once additional lead will be delivered

BMS: Brick Manipulating System
Drum loader
(1 drum = 234 bricks)
OPERA Working Chain

→ Trigger on ‘on-time’ event
→ Find brick with electronic detector information
→ Remove brick by BMS
→ Separate changeable sheets (CS) from brick, develop (LNGS, Japan)
→ Expose to X-rays and cosmic rays for sheet alignment if track is found
→ Disassemble brick, develop films, send to scanning labs
→ Labs look for particle in CS and follow until neutrino interaction is found
→ Volume scan around the neutrino interaction, neutrino vertex is confirmed

→ Scanning labs in Europe and Japan
  → ~40 scanning stations
  → high-speed automated scanning systems 20-60cm²/h.

→ Informations into local DB and to one of two synchronized central DB
→ Events are analyzed off-line, access DB to search for tau
OPERA Results 2008

- 10100 on-time events
- 1700 candidate interactions in bricks

**Brick handling activity per week in 2008**

Handling of 100 bricks/week

Up to ~65 CSd scanned/week

**CS delivered to the Scanning Stations**

CS scanned
CS with a positive results
3 prong vertex in the bottom layer of the emulsion
Backward going charged particle (interesting as will allow to benchmark the MC simulation of backscattering)
Event Gallery

Other particles with very short life-time:
Charmed mesons produced by $\nu_\mu$ interactions
$\rightarrow$ Can contribute to background in case the muon from charm decay is missed.

2.1 expected charm events during 2007-2008
Seen: 2 charm-like topologies
Outlook 2009

- 2009 Schedule: CNGS physics start on 7 May 2009 → total 175 days
Protons on Target CNGS Run 2009

2009: 175 days

Estimated with $2.0 \cdot 10^{13}$ pot/extr:

- Total 2009: $2.8 \cdot 10^{19}$ pot
- Total 2009: $3.7 \cdot 10^{19}$ pot
- Total 2009: $4.8 \cdot 10^{19}$ pot
Multi-Turn-Extraction

- Novel extraction scheme from PS to SPS:
  - Beam is separated in the transverse phase space using
    - Nonlinear magnetic elements (sextupoles and octupoles) to create stable islands.
    - Slow (adiabatic) tune-variation to cross an appropriate resonance.
  - Beneficial effects:
    - No mechanical device to slice the beam → losses are reduced
    - The phase space matching is improved
    - The beamlets have the same emittance and optical parameters.

MTE extracted beam has been provided to the SPS for the last night of CNGS run.
2009: Start with classical extraction, parallel prepare MTE, provide first SFTRPO, then CNGS
Summary

• Start-up issues of CNGS have been overcome
  – a lot of work!

• CNGS 2008 run was very successful
  – $1.78 \times 10^{19}$ p.o.t.
  – 1700 candidate events in OPERA
  – exploring limits of CNGS facility

• 2009
  – full year of high intensity operation
  – First tau neutrino events!
Thank You!!

to all the colleagues for their effort to make CNGS a success this year!

AB Department, TS Department, SC/RP, CNGS Secondary Beam Working Group, MTE Project Team