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EA Renovation Day, 14 December 2000

CNGS secondary beam
(configuration for neutrino oscillations search)

(CNGS = CERN Neutrinos to Gran Sasso facility)

Talk overview

1. **How to build a beam for neutrino oscillations search**
2. **CNGS beam line in general**
3. **Secondary beam line elements**
4. **Summary**

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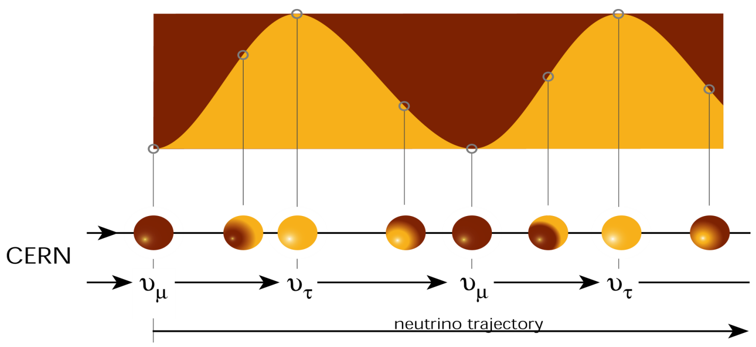
Neutrino oscillation

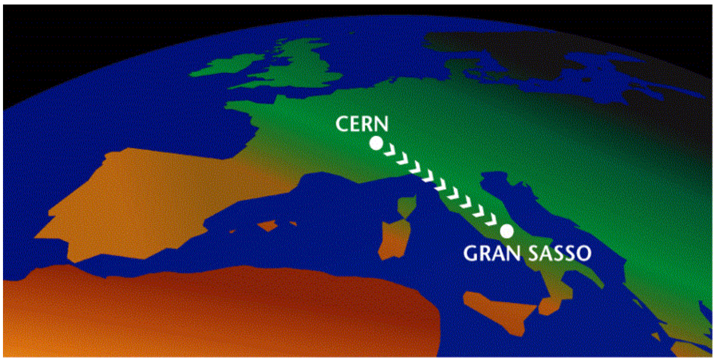
The results of Kamiokande, Superkamiokande and Soudan on atmospheric neutrino and the null result of the CHOOZE experiment can be interpreted in the terms of ν_μ - ν_τ oscillation.



A year ago CERN Council took the decision to build a neutrino beam for neutrino oscillation search

The aim of the project:

detect ν_τ appearance in a ν_μ beam sent from CERN to Gran Sasso (732 km)



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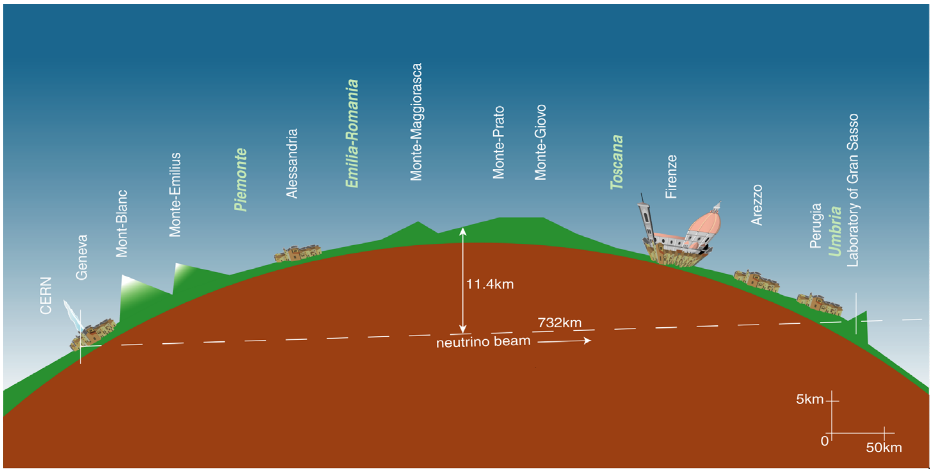


CERN neutrino beam to Gran Sasso

‘Parallel’ ν_μ beam

A 400 Gev proton interacted in a graphite target produces in average 2.36 positive pions and .25 positive kaons (E>2Gev)

Then the pions and kaons decay into:

$\pi^+ \rightarrow \mu^+ + \nu_\mu$ **100 %**

$K^+ \rightarrow \mu^+ + \nu_\mu$ **63.4 %**

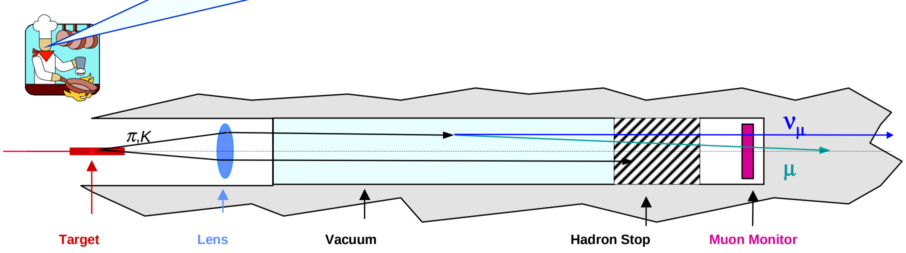
$K^+ \rightarrow \pi^0 + \pi^+$ **21 %**

$\hookrightarrow \mu^+ + \nu_\mu$

Production of the ν_τ is negligible.

A recipe for a ‘parallel’ ν_μ beam :

- **‘Parallel’ pion and kaon beam toward the detector**
- **Conditions for pions and kaons decays**



CNGS at CERN site

- The beam line starts at BA4, cross the boundary and stops under Meyrin
- Vertical slope 5.6%
- Service gallery for equipment and personnel
- Equipment is about 1km away from the nearest building

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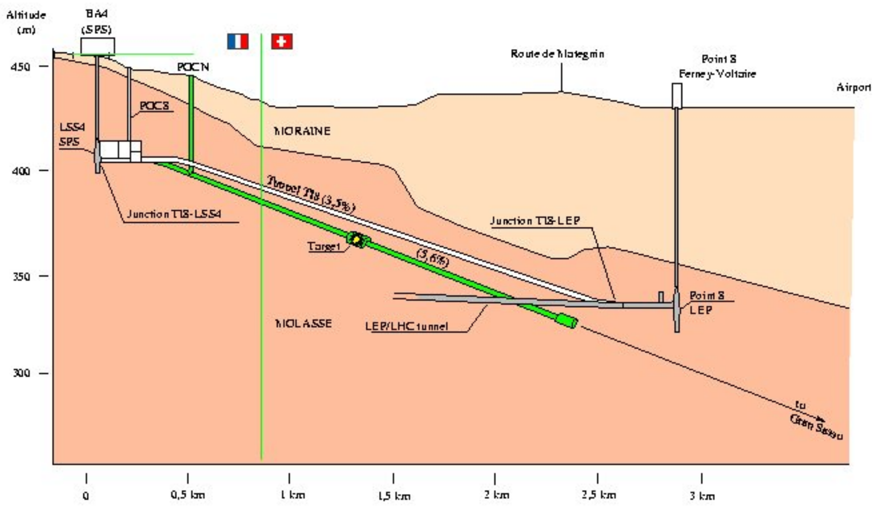

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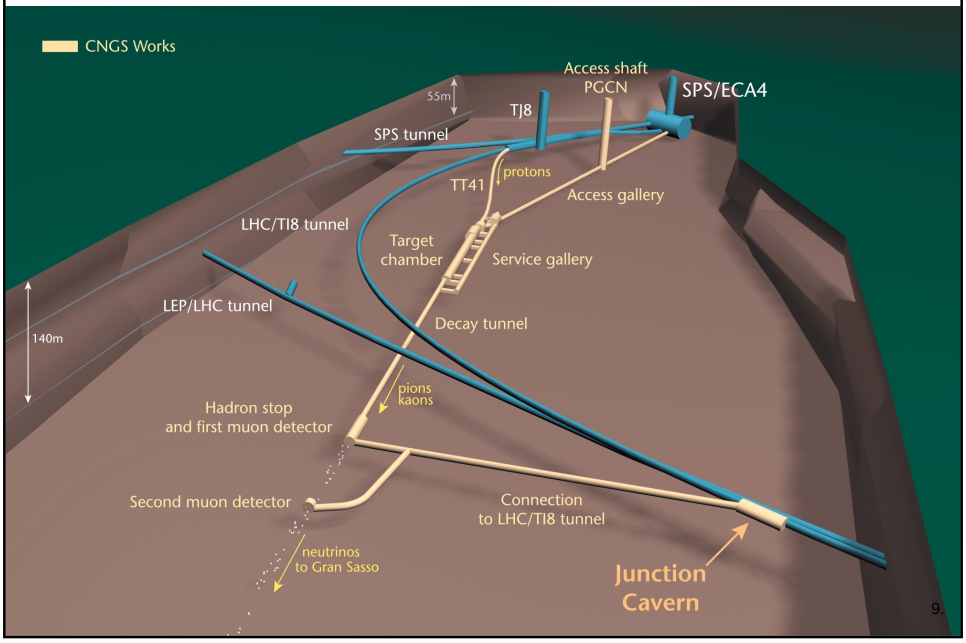

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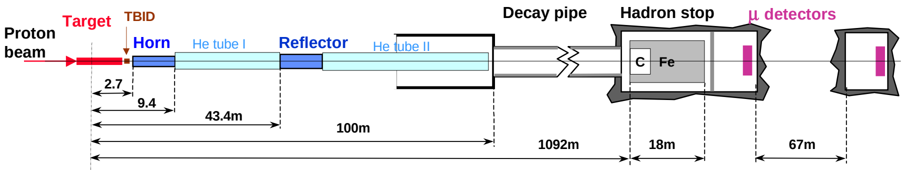
Secondary beam line elements



- Horn and Reflector
- He tubes
- Decay pipe
- Hadron stop
- Muon monitoring station
- Collimators, shielding, etc...

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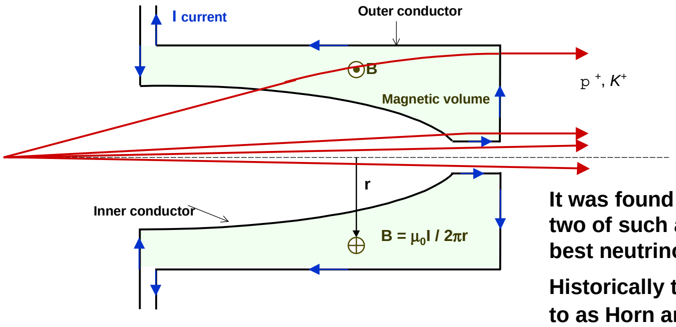
Focusing of charged particles by Horns



Inner conductor - paraboloid of revolution

Outer conductor - cylinder

It was found the combination of two of such a lens produces the best neutrino beam.

Historically the first lens is referred to as Horn and second as Reflector.

To create a strong magnetic field the Horn and Reflector currents should be high:

I(Horn) = 150 kA, I(Reflector)=180kA

As it is inefficiently to keep such a current permanently, the Horn and Reflector are pulsing devices

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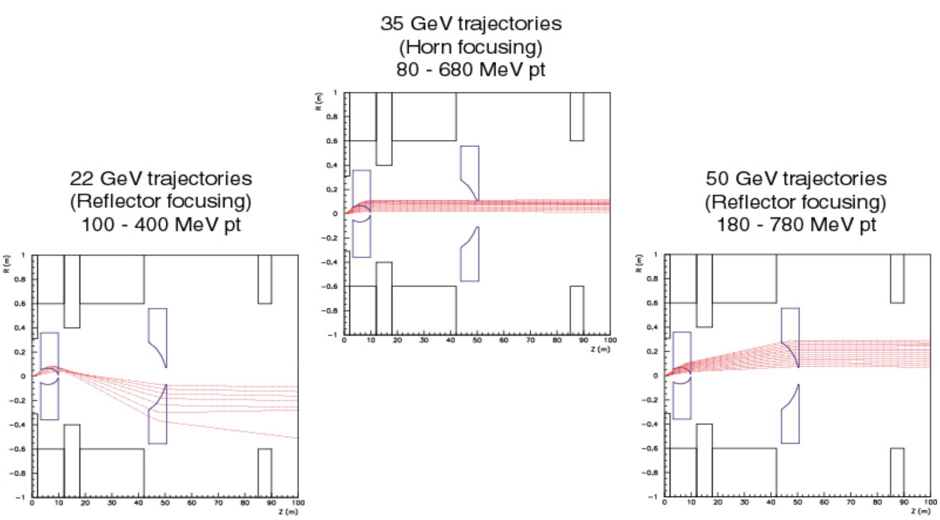
CNGS focusing optics (positive sign particle trajectories)



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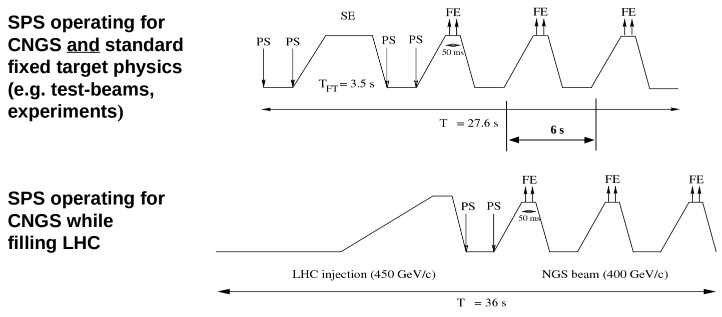
CNGS timing



- Two 10µs fast extractions with 50ms interval between them.
- 6 seconds CNGS cycle.

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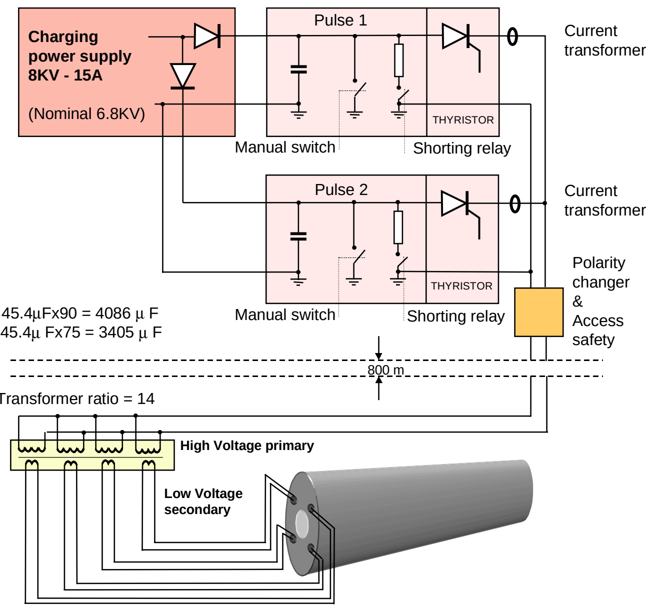
Horn/Reflector Electrical Layout



HORN C= 45.4µFx90 = 4086 µ F
Reflector C= 45.4µ Fx75 = 3405 µ F

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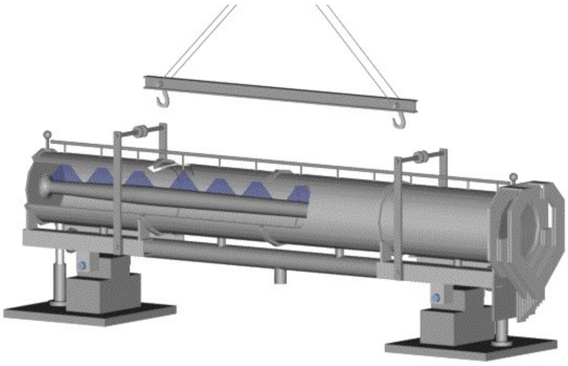
Horn/Reflector Cooling

Important amount of energy dissipated in the Horn/Reflector by electrical current and beam is evacuated by water cooling.



Items to control:

- ***Primary and strip lines currents (each pulse)***
- ***PS's and discharge circuits***
- ***Temperatures and water flows***
- ***Timing***

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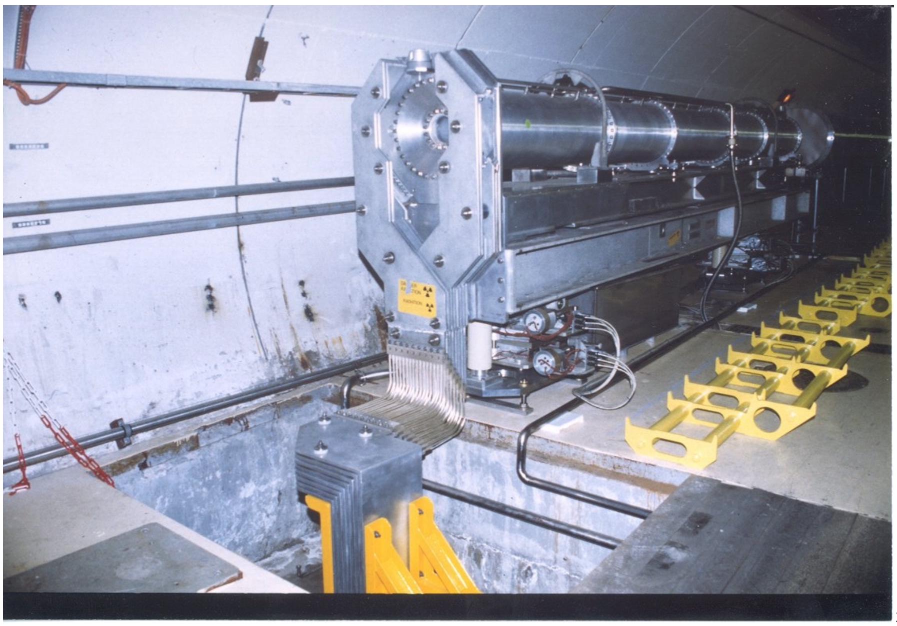

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He tubes Reduce probability of particle interaction with air before decay. $83m^3$ of He
Items to control: ***He flow rate and purity***

Decay pipe 992m length, 1mbar pressure, ϕ 2.45m
2mm thick titanium window on target chamber side

Shutter in front of the titanium window to protect personnel and equipment during an access

Items to control: ***pressure, shutter movement***

Hadron stop

- 3.2m of graphite + 15m of iron
- water cooling
- up to 170 ºC at the hottest point after 200 days of running

Items to control: ***temperature, water flow***

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Muon monitoring station

2 muon chambers (5 x 6 x 6 m each) separated by 67m of 'molasse'

Maximal muon fluxes :

5×10^7 particles/cm^2/10µs in muon chamber 1

7×10^5 particles/cm^2/10µ s in muon chamber 2

Current proposal is a system based on the solid state detectors like one which was used for a WANF (West Area Neutrino Facility) muon monitoring.

Silicon detector as flux measurement device

- About 10^4 electrons-holes pairs/particle independent on particle nature and energy
- The detector is not counting the particles, but measuring the total charge.
- Integrated charge is proportional to the particles flux.

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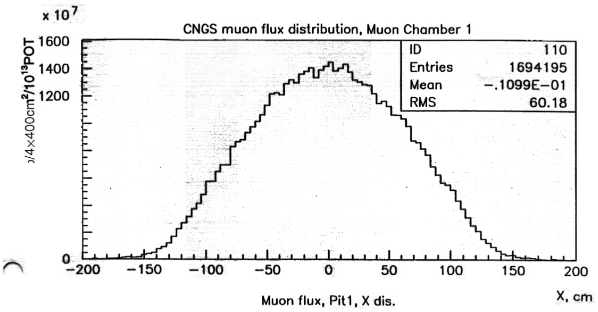

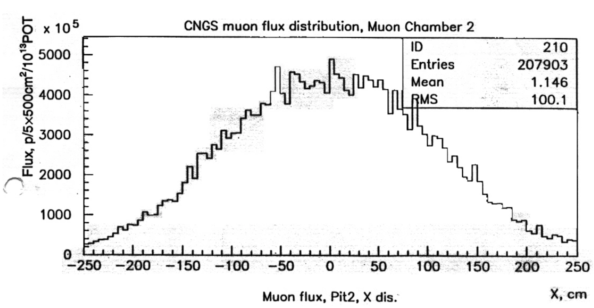

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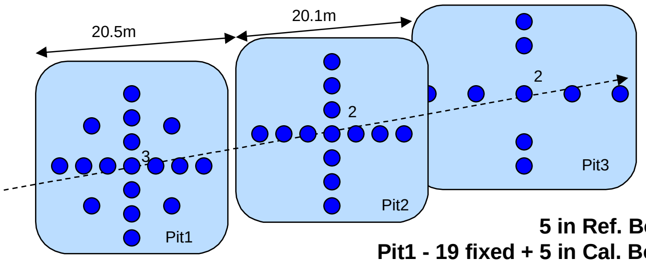
Neutrino Flux Monitor of WANF (94-98)

43 detectors mounted inside of the water-tight boxes and installed on the support plates



5 in Ref. Box
Pit1 - 19 fixed + 5 in Cal. Box
Pit2 - 14 fixed + 5 in Cal. Box
3 muon pits, 63 detectors : Pit3 - 10 fixed + 5 in Cal. Box

A remotely controlled girder ("lift") equipped with a calibration box was able be positioned in front of any point of support plate. There was a space on each lift to transport at the same time a second box of the same type (reference box)

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Some silicon detectors used in the WANF

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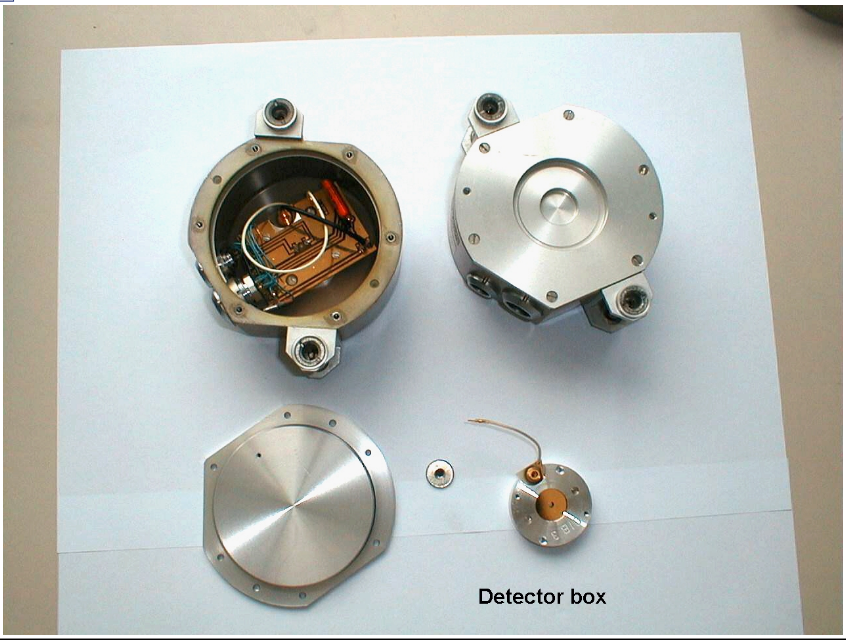

Detector box

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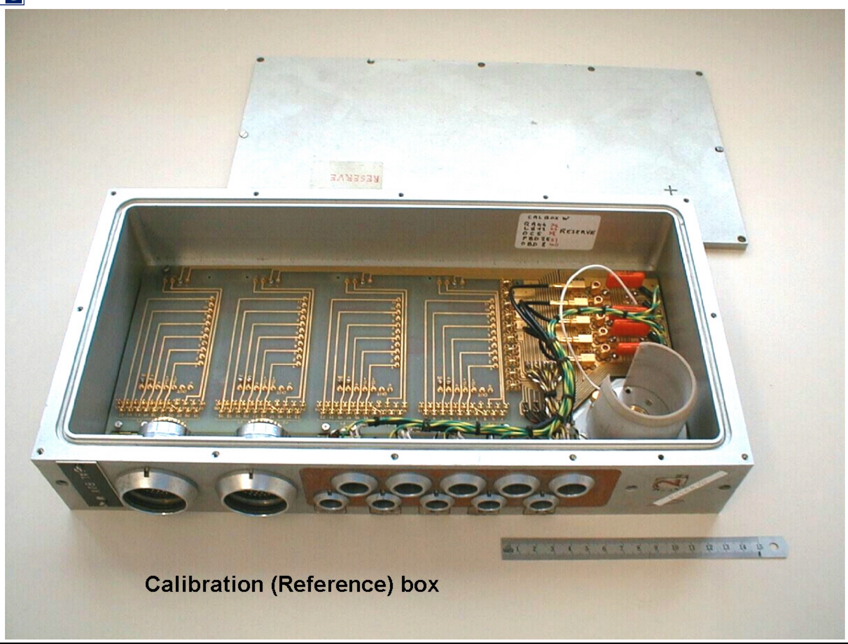

Calibration (Reference) box

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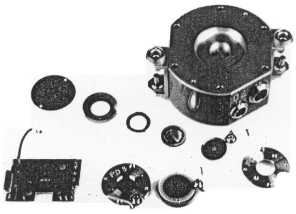
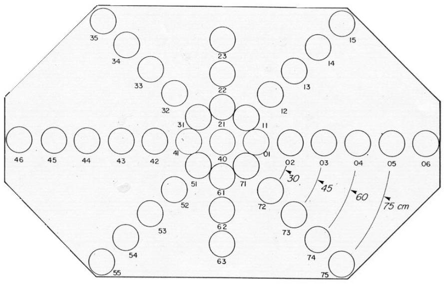


The disassembled detector mounting together with the tight box. The detector shown here, has an active area of 2 cm^2.



Geometry of the detector support plate. The numbers are the position indicators.

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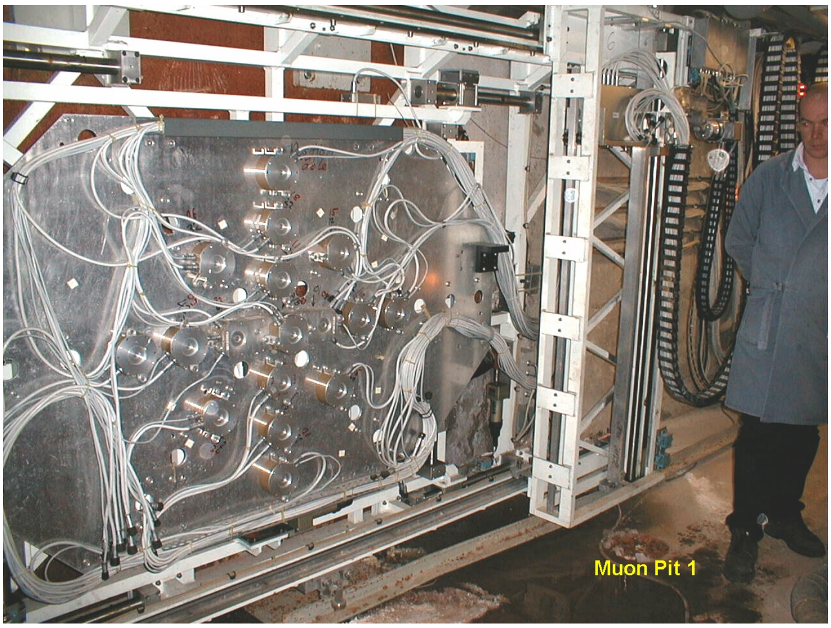

Other main features of the system

- Individual bias voltages
- Charge sensitive amplifiers with variable gain (the gain changed from 1 to 500) with direct coupling to the detectors
- Permanent leakage current compensation (automatically each 15 min) up to the 10 μA maximum current. Changing of the detectors with higher current.
- Permanent detector calibration, which allowed to keep flux measurement resolution of individual detectors in range of 1%
- A good electronics linearity and resolution (better than 0.5% in average)
- Adaptation of the detector size to the measured flux

Muon flux profiles

- The beam centre and width were determined by the fixed detectors for each spill with a precision of ±2mm for pits 1 and 2, and ±3mm for pit 3.
- Independent beam profile scans were done by calibration boxes moved either horizontally or vertically.

Advantage: independent on the relative SSD calibrations
Disadvantage: average flux only
Precision: ± 1mm

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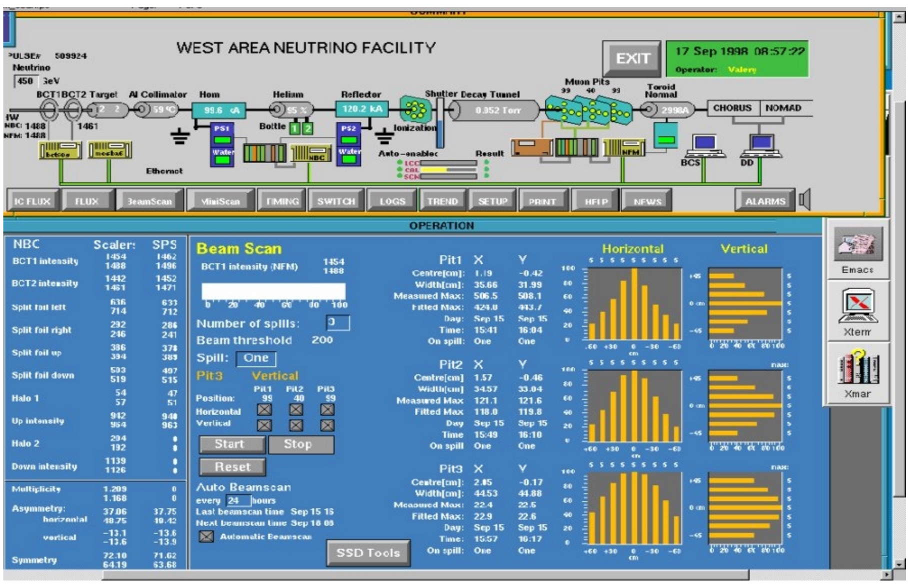
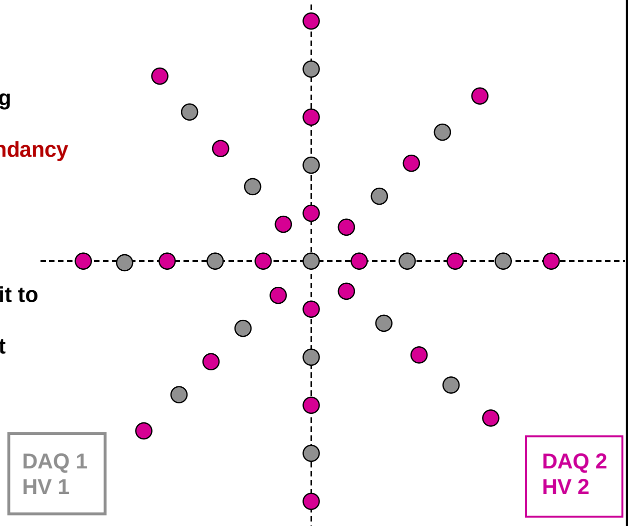


Features of CNGS muon monitoring

Access to the equipment is very difficult. The challenge is to build a system which don't need any access during 200 days run.

⇒ High reliability and redundancy

For example one possibility it to split the monitoring system into two independent ones



Detector performance (first estimation)

Muon Chamber 1

Step	Individual SSD precision	Precision at nominal position
20 cm	1%	1.5 mm
	2%	3.0 mm
40 cm	1%	2.5 mm
	2%	4.0 mm

Muon Chamber 2

Step	Individual SSD precision	Precision at nominal position
30 cm	1%	2.5mm
	2%	4.0mm
60 cm	1%	3.5mm
	2%	5.0mm

Final number and positions of the detectors is under study.

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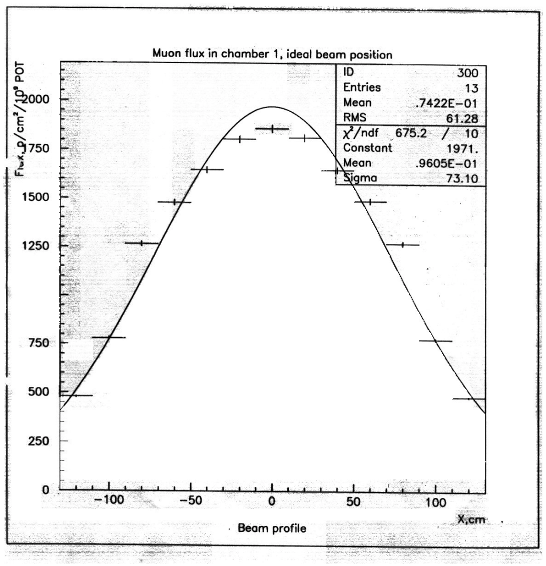

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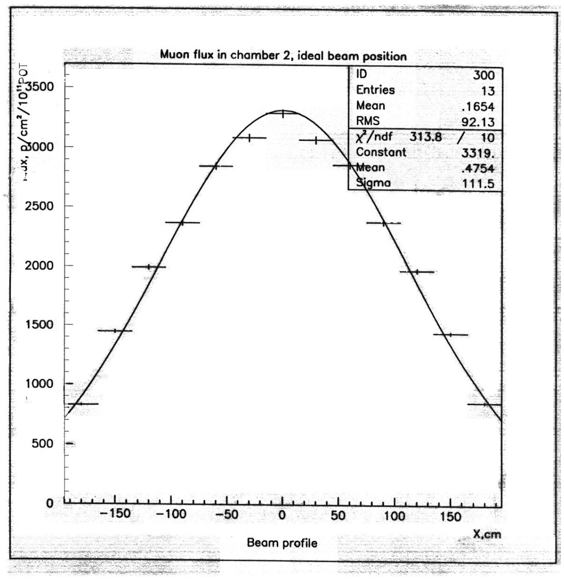

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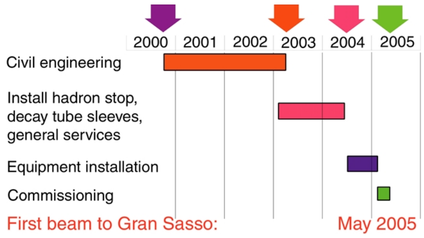
Items not included in this presentation

- Control system, including synchronised with the beam DAQ
- Timing distribution, etc...

CNGS schedule/status



Summary

The main elements of the CNGS secondary beam line are:

- **Horn and Reflector**
- **He tubes**
- **Decay tunnel**
- **Muon monitoring station**

All these elements should be designed, constructed, tested and installed before the beginning of 2005.