CERN Neutrino beam to Gran Sasso

Konrad Elsener, CERN

- → Overview of CNGS
- → Expected performance / Challenges
- → Cost / Schedule / Status
- → Summary

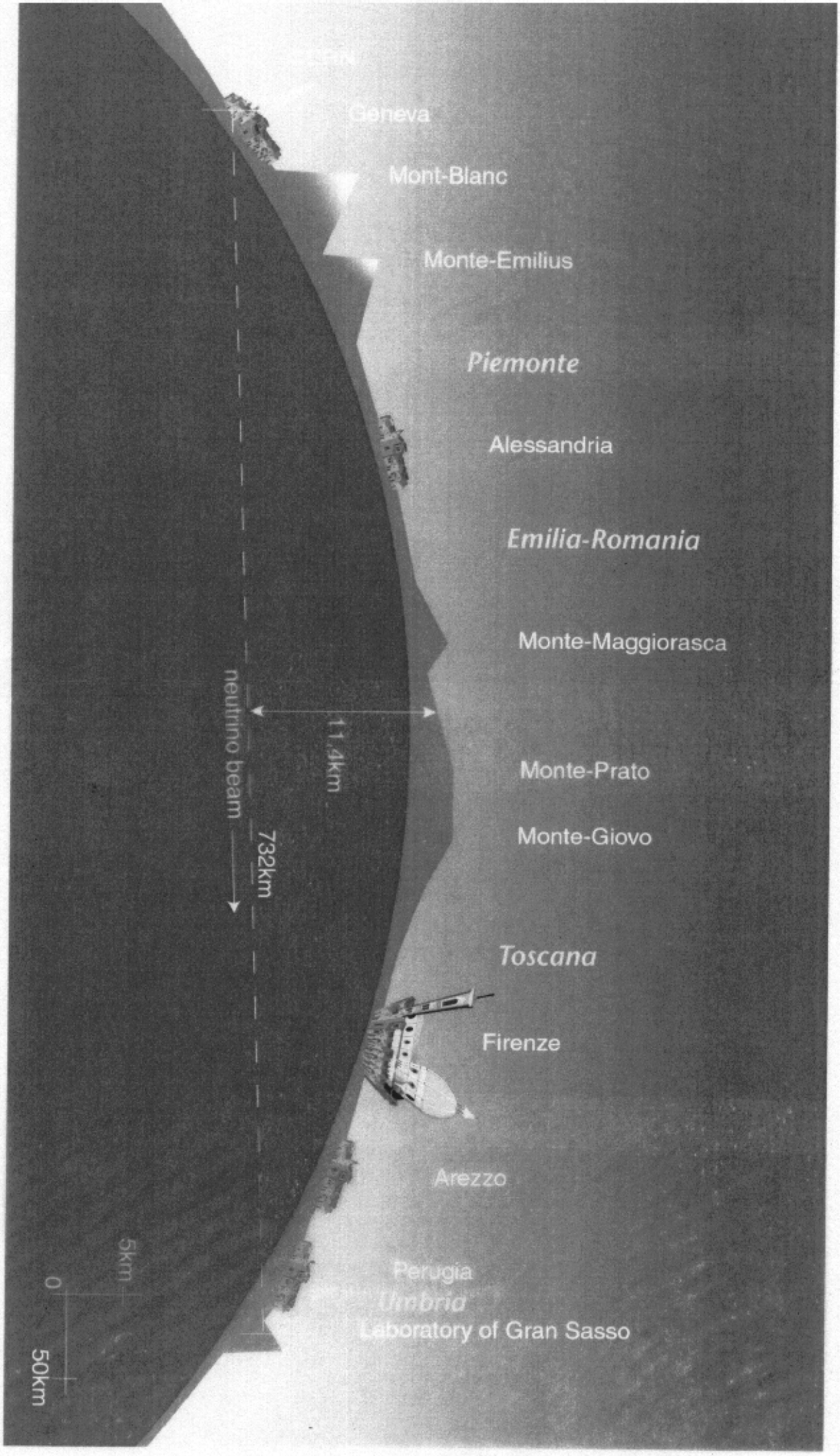
Overview

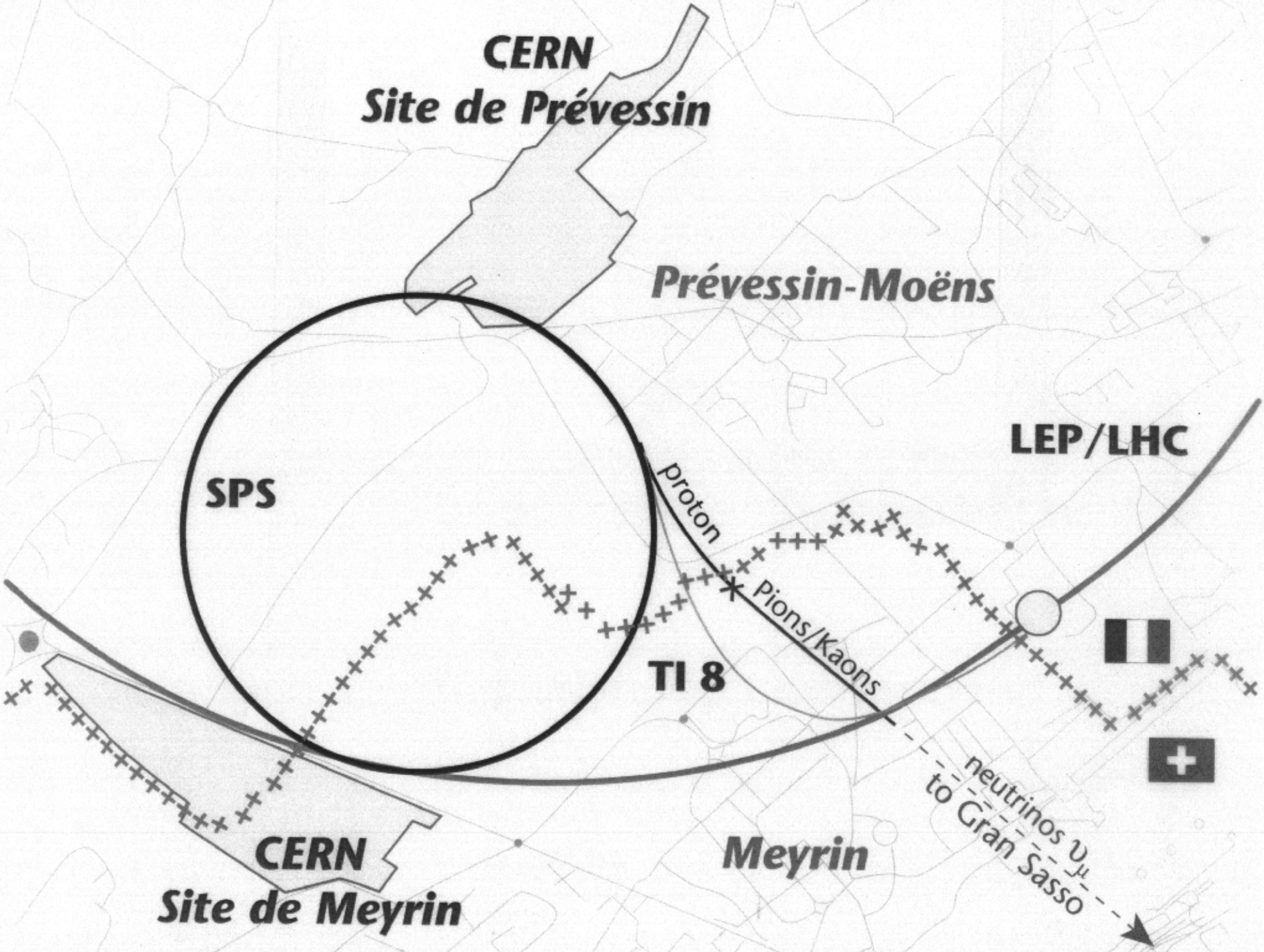
Aim: detect ν_τ **appearance** in a ν_μ beam sent from CERN to Gran Sasso (**732 km**)

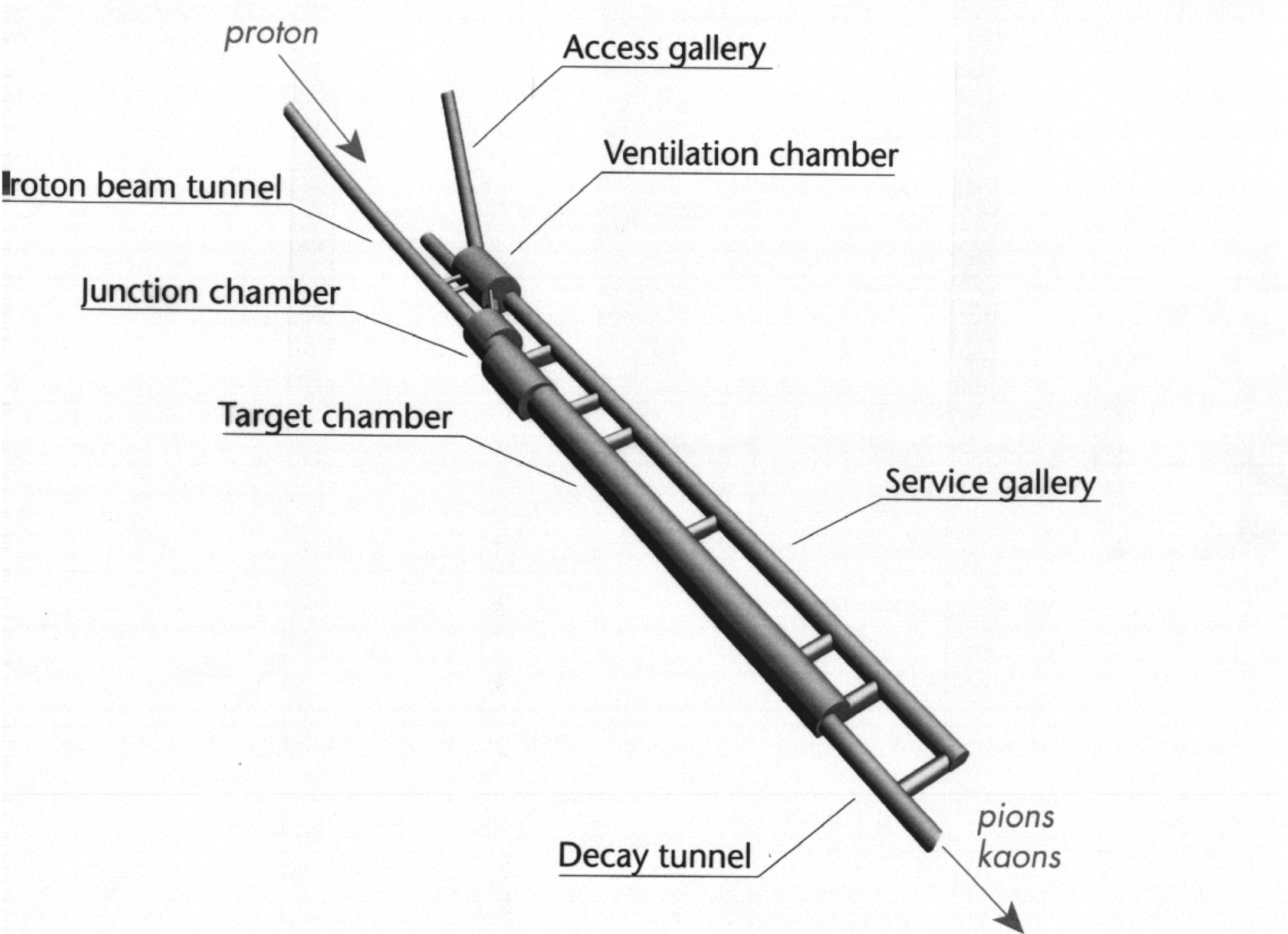
$\rightarrow$ **detect ν_μ—ν_τ oscillation**

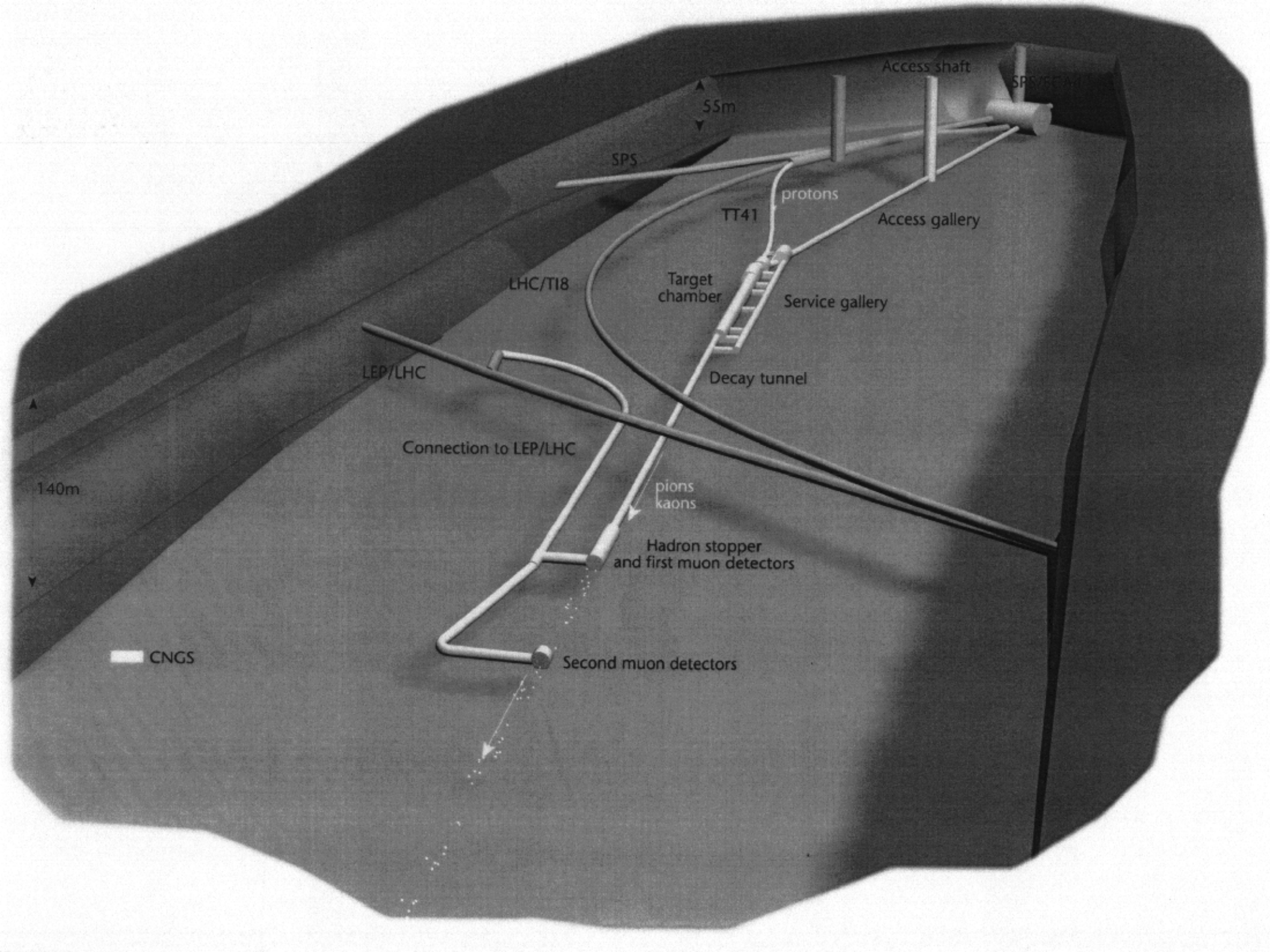
Method:
- "classical" neutrino beam: protons on target + 2 horns to direct π^+ / K^+ towards Gran Sasso
- detector(s) at Gran Sasso: ν_τ detection efficiency + background suppression (ICARUS, OPERA)

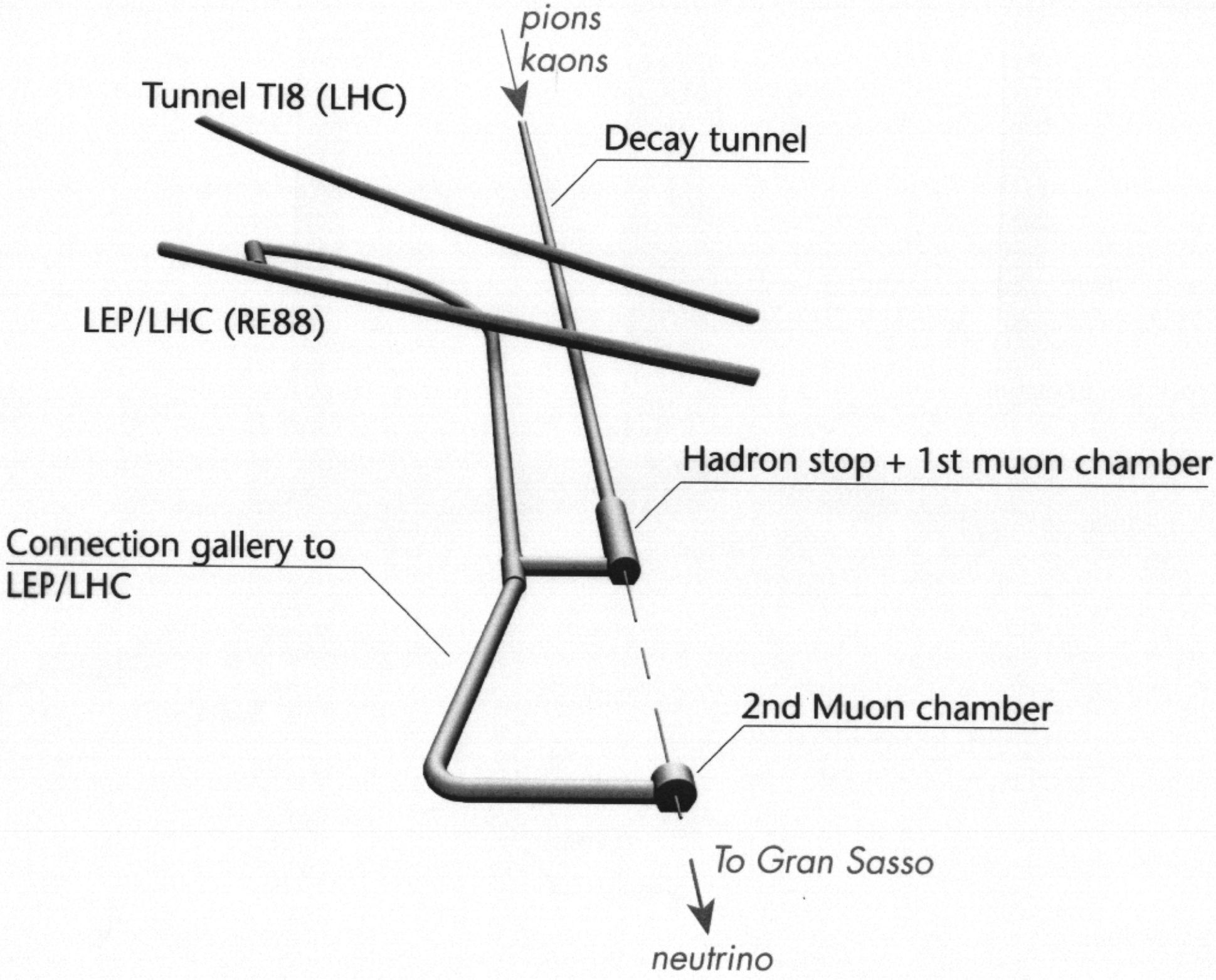
Boundary Conditions:
- use existing accelerators and equipment, e.g. Items under construction for LHC…
  in particular: SPS extraction towards TI8→LHC
- …but do not interfere with LHC !
- **no new surface building !!!**

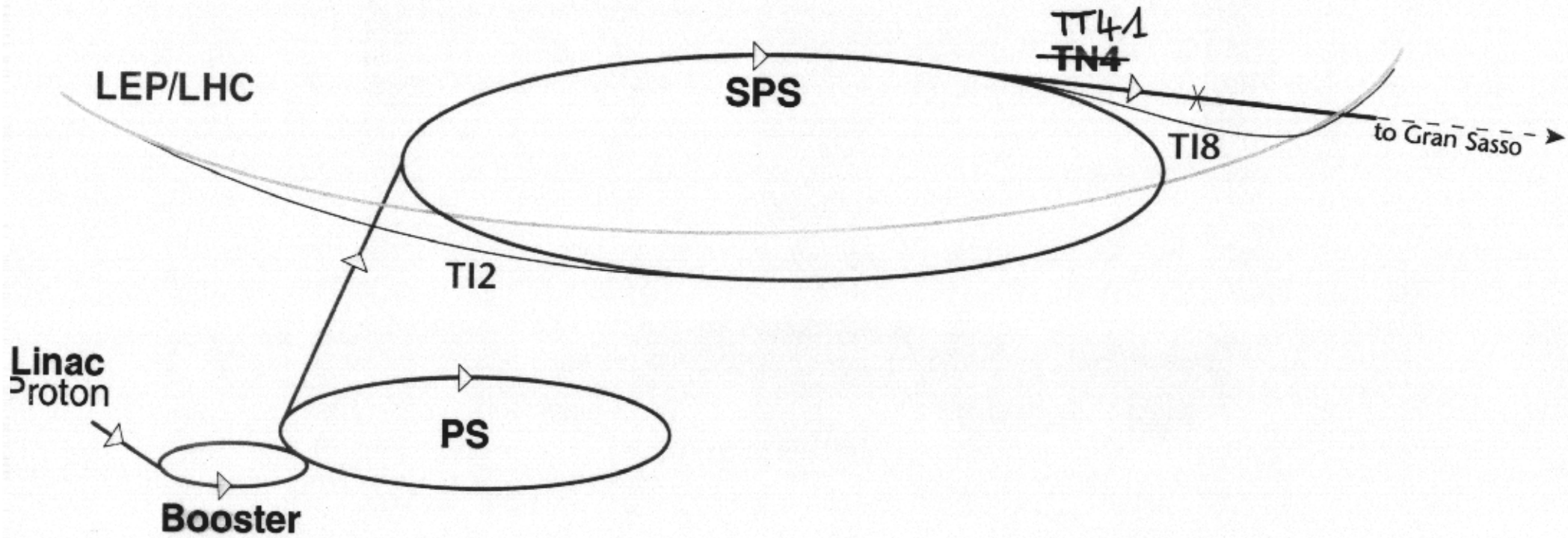

Geneva
Mont-Blanc
Monte-Emilius
Piemonte
Alessandria
Emilia-Romania
Monte-Maggiorasca
neutrino beam
11.4km
732km
Monte-Prato
Monte-Giovo
Toscana
Firenze
Arezzo
Perugia
Umbria
Laboratory of Gran Sasso
5km
0
50km


CERN
Site de Prévessin
Prévessin-Moëns
SPS
LEP/LHC
proton
Pions/Kaons
TI 8
neutrinos υ_μ
to Gran Sasso
CERN
Site de Meyrin
Meyrin


proton
Access gallery
Ventilation chamber
roton beam tunnel
Junction chamber
Target chamber
Service gallery
Decay tunnel
pions
kaons

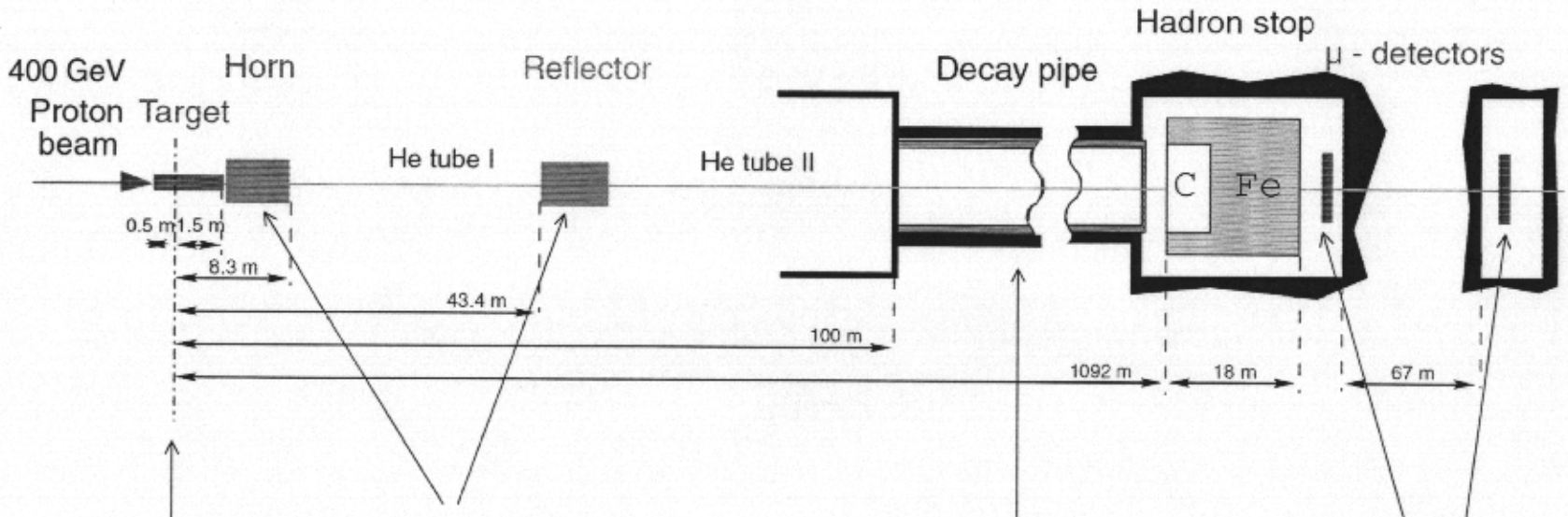

Access shaft
55m
SPS
protons
TT41
Access gallery
LHC/TI8
Target
chamber
Service gallery
LEP/LHC
Decay tunnel
Connection to LEP/LHC
140m
pions
kaons
Hadron stopper
and first muon detectors
CNGS
Second muon detectors


pions
kaons
Tunnel TI8 (LHC)
Decay tunnel
LEP/LHC (RE88)
Hadron stop + 1st muon chamber
Connection gallery to
LEP/LHC
2nd Muon chamber
To Gran Sasso
neutrino



S : Proton Synchrotron
PS : Super Proton Synchrotron
HC : Large Hadron Collider

Overview (2)



graphite cylinders
ϕ=4 mm, L=10 cm;
Δz: variable;
total length: 2 m;
helium gas cooled

150 kA

L=1 km, ϕ=2.45 m
(concrete: t=0.5 m)
entrance window: 2 mm Ti
exit window: 50 mm steel

Arrays of
silicon detectors

Expected Performance

Proton beam performance

(based on SPS performance in 1997)

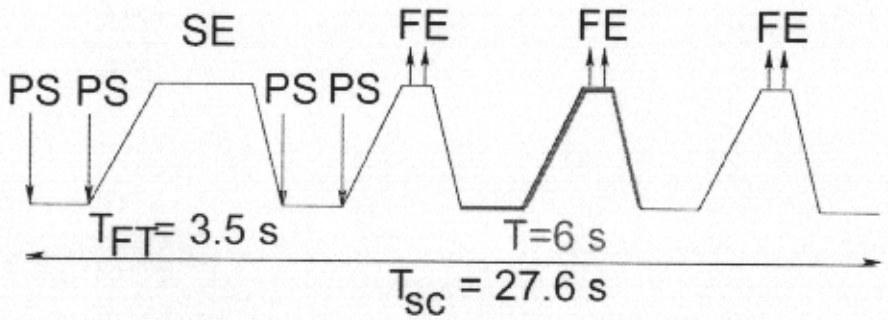
- intensity in the SPS **4.8×10^{13}**
- intensity per extraction **2.4×10^{13}** (10 μs, 2 FE, Δt =50ms)
- protons on target **per year** **4.5×10^{19}**
  (SPS operation shared with other fixed target physics, testbeams,
  LHC pilot or filling, machine development sessions, etc.)

"**1 year**": **200 days** SPS operation, **55%** overall efficiency

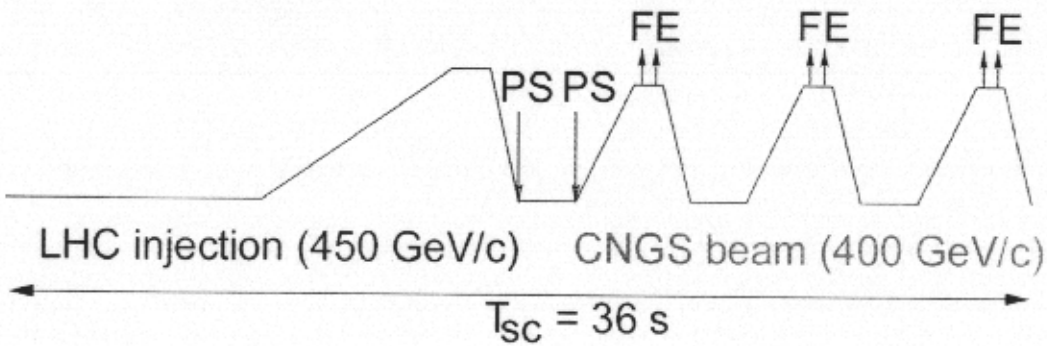
SPS operational modes

CNGS cycle: 6 s (⇔2 injections)

SPS operating for CNGS and standard fixed target physics (e.g. testbeams, experiments)



SPS operating for CNGS while filling LHC



Expected Performance (2)

Neutrino beam performance

No oscillation:

2450 ν_μ cc. events per kt per year

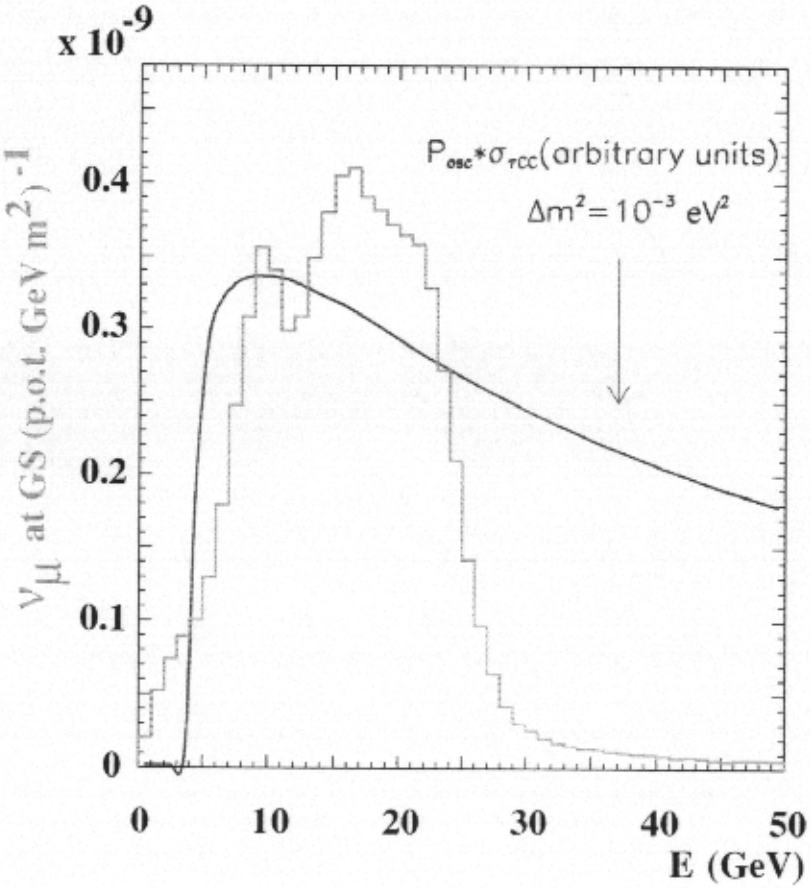
Assume $\sin^2(2\theta)=1$ and $\nu_\mu - \nu_\tau$ is the correct hypothesis:

$\Delta m^2 = 5\times10^{-3}eV^2$: **56** ν_τ

$\Delta m^2 = 3\times10^{-3}eV^2$: **21** ν_τ

$\Delta m^2 = 1\times10^{-3}eV^2$: **2.3** ν_τ

cc. events per kt per year



-- Intermezzo --

CNGS project is still in an early phase …

→ … based on calculations / simulations ...

→ … based on experience...(e.g. WANF - West Area neutrino facility)

⟶ will present many ideas

→ will show **few** approved technical designs

- **excellent moment for a workshop !**

A preliminary impression ...

To do ν_τ appearance experiment implies

-> maximize the neutrino beam intensity in E-"window"

-> "less problems" with beam stability / monitoring

-> "more problems" with detectors at Gran Sasso

Challenges

High intensity proton beam

→ accelerator issues / beam transport / beam losses / monitoring / "routine" operation
(existing p accelerator chain + new CNGS proton beam-line)

→ radiological issues

→ **present** design: **4.8×10^{13} p circ. in SPS** (achieved in 1997)

→ **future:** **7×10^{13} ??**

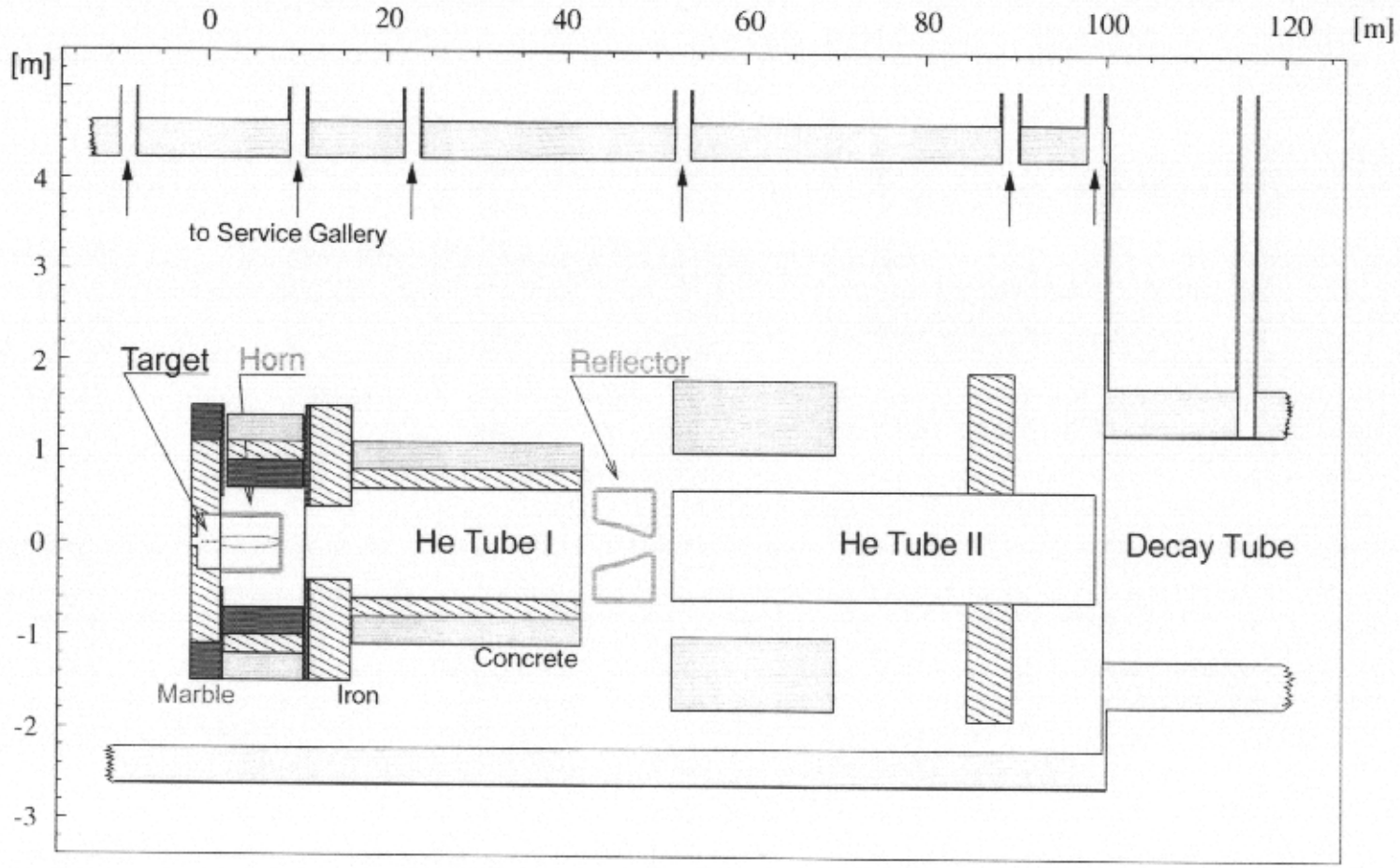
(due to investments made for SPS as LHC injector !)

→ **3 fast extractions** per cycle instead of 2 (3 injections from PS to SPS) ??

Challenges (2)

Shielding: under study

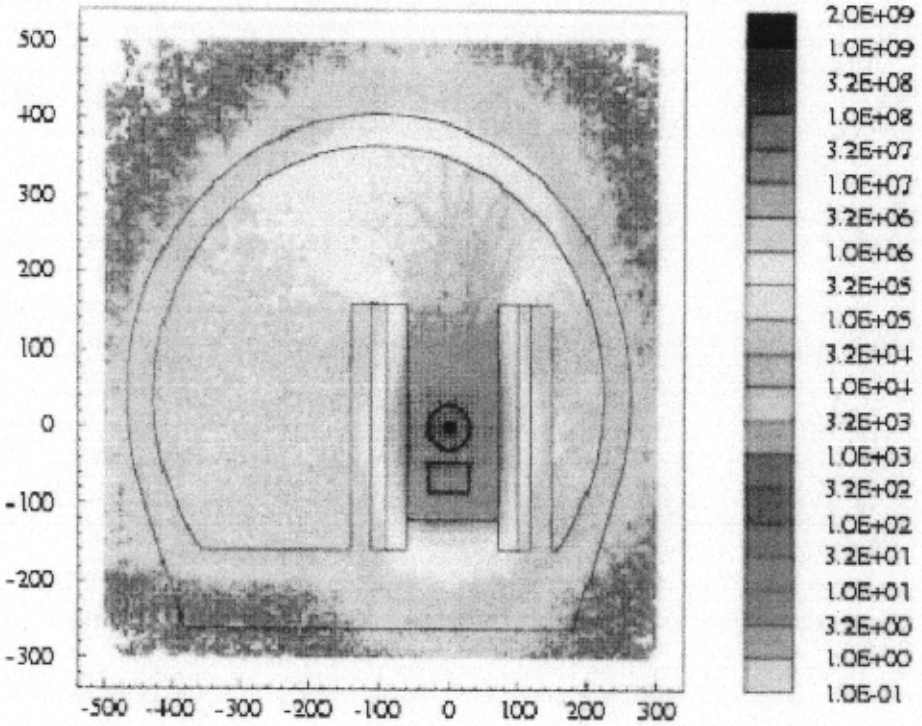
Note the x,y scales!



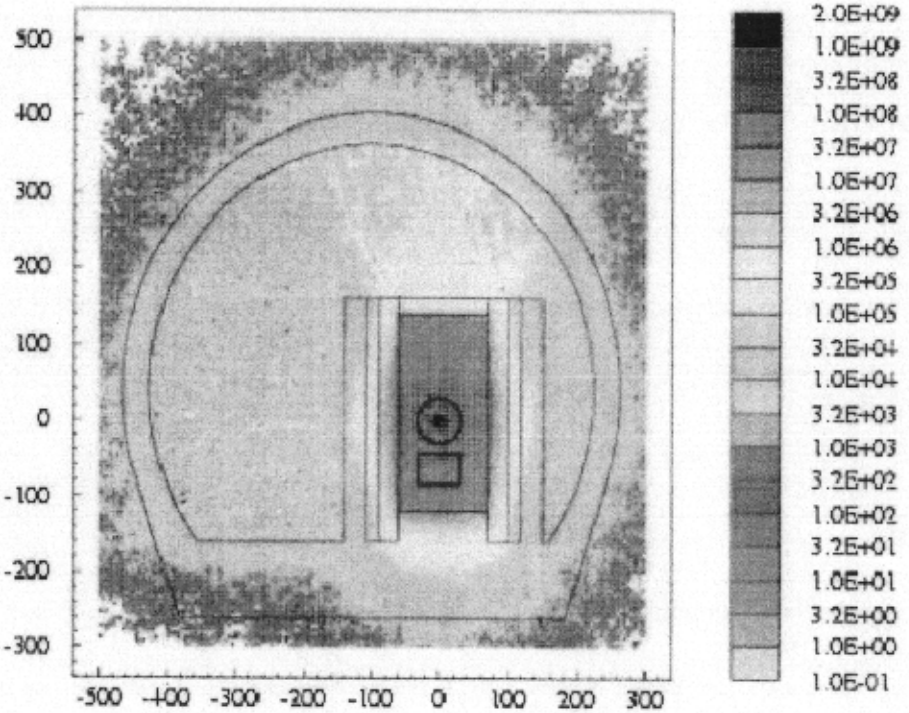
Dose in the neutrino cavern

Heinz Vincke
CERN-TIS/RP

No iron roof



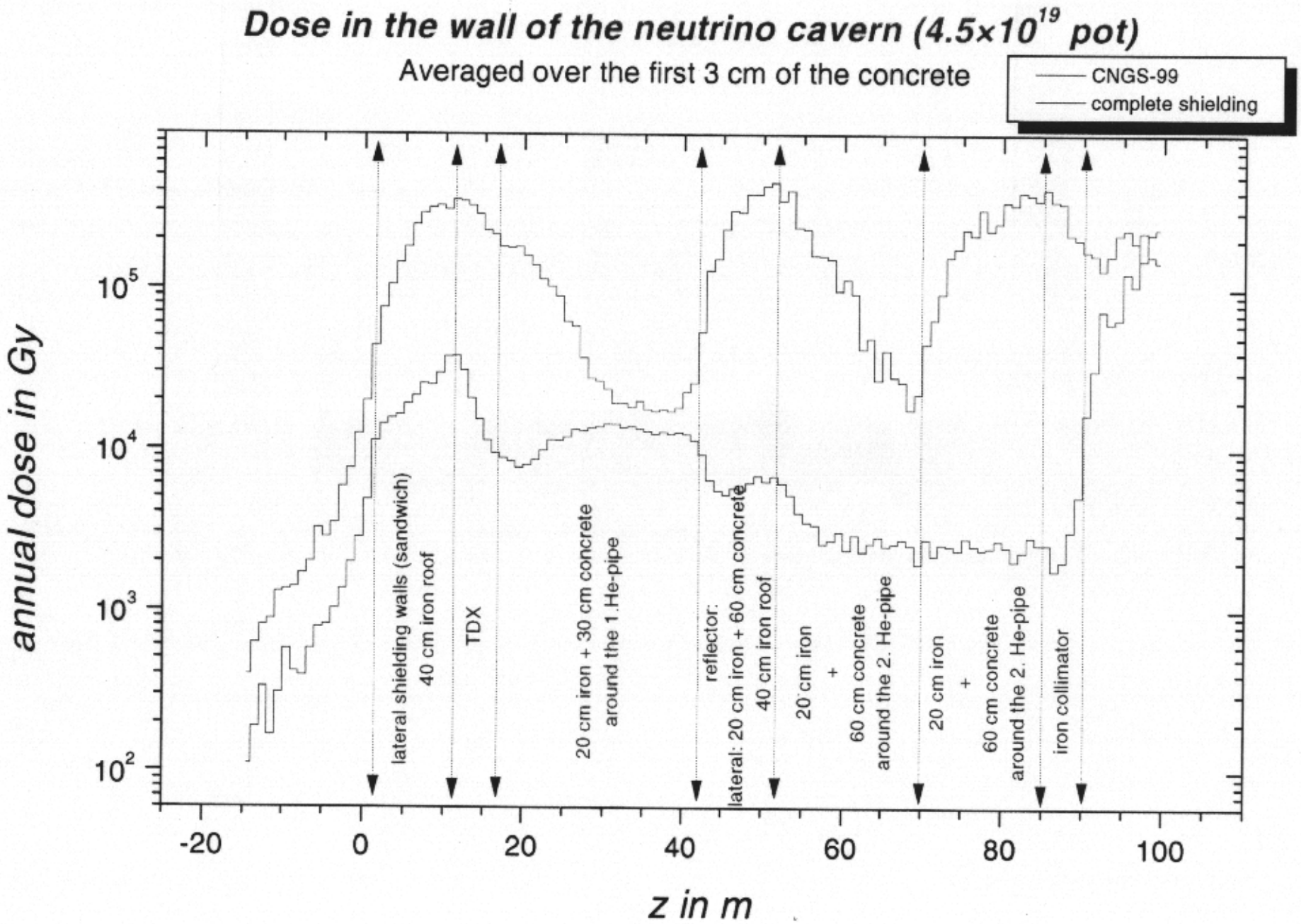
20 cm iron roof



Remark: annual dose in Gy per 4.5×10^{19} pot

$7m < z < 10m$

$z = 0m$…target focal point


Dose in the wall of the neutrino cavern (4.5x10^19 pot)
Averaged over the first 3 cm of the concrete
CNGS-99
complete shielding
annual dose in Gy
z in m
lateral shielding walls (sandwich)
40 cm iron roof
TDX
20 cm iron + 30 cm concrete
around the 1.He-pipe
reflector:
lateral: 20 cm iron + 60 cm concrete
40 cm iron roof
20 cm iron
+
60 cm concrete
around the 2. He-pipe
20 cm iron
+
60 cm concrete
around the 2. He-pipe
iron collimator

Challenges (3)

Target design

→ thermo-mechanical shock
→ heating / cooling
→ handling / shielding

Note: very difficult already for present design values,
i.e. 2.4 x 10^{13} protons per fast extraction

→ **future: 3.5 x 10^{13} p per FE ??** 2 or 3 FE per cycle?

Challenges (4)

Horn + Reflector

→ **150 kA:**

- minimize material (ν_μ fluence!)
- fatigue issues
- handling / replacement

→ **future:**

180 kA ??

3 pulses instead of 2 ???

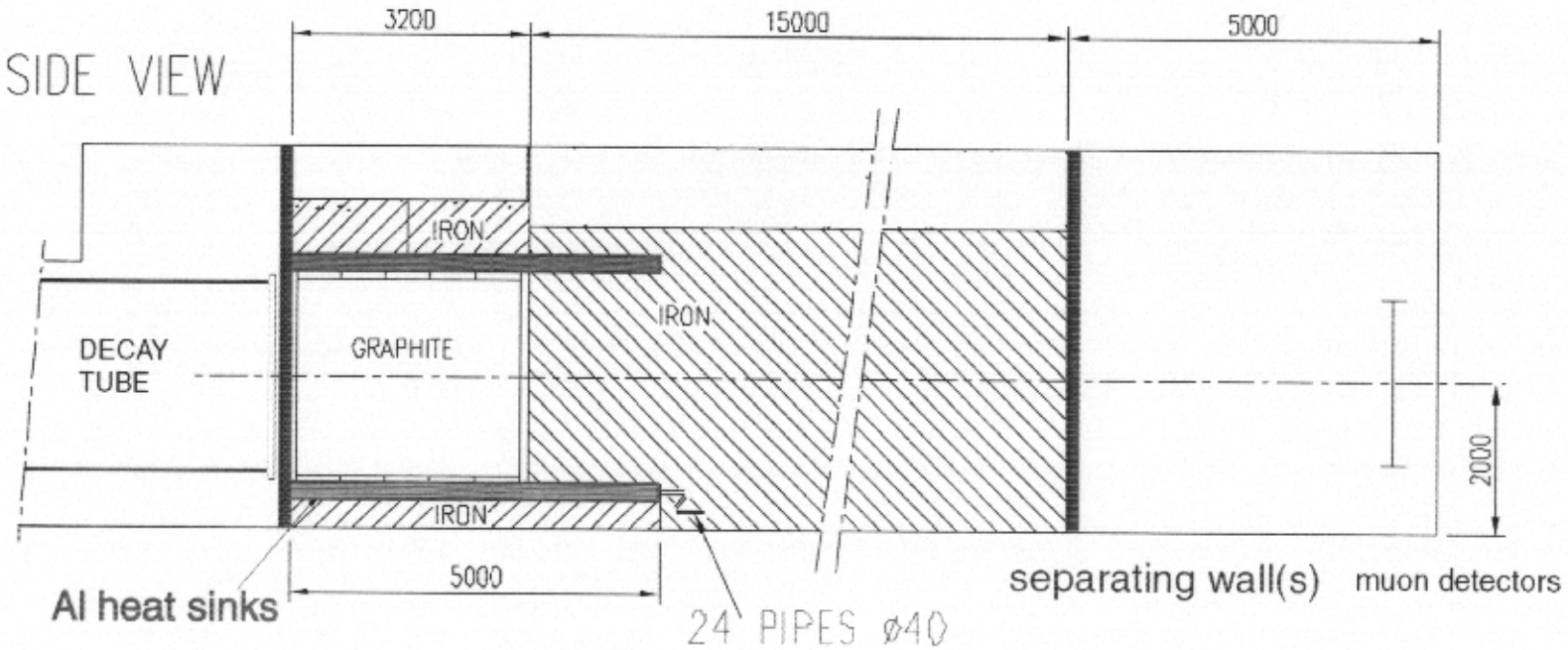
(cf. proton beam extraction)

→ sensitivities to horn / reflector alignment:

abandon motorization of horns ??

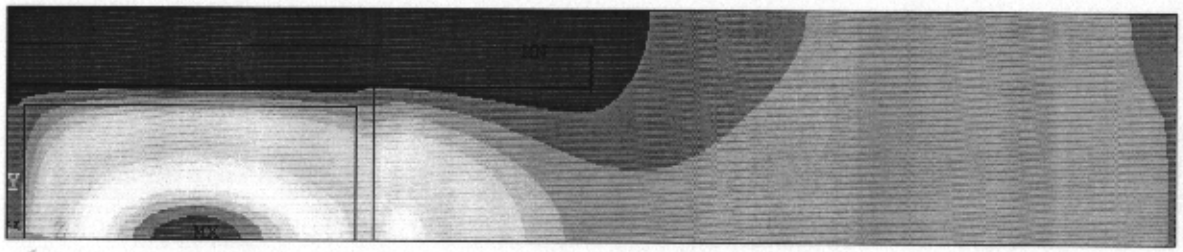
Challenges (5)

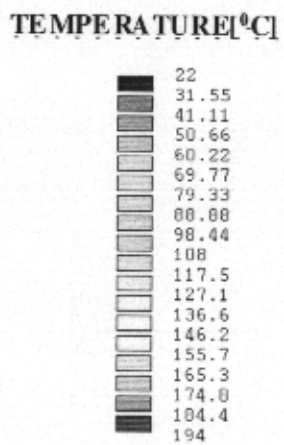
Decay tube and "Hadron Stopper"



B. Calcagno, 5 April 2000: "worst case" scenario, 13.8 x 10^{19} p.o.t. / year

LONGITUDINAL Temperature Profile related to the maximum temperatures in iron and in graphite





COMPONENT	2 COOLING SYSTEM TEMP.MAX [^{0}C]	1 COOLING SYSTEM TEMP.MAX [^{0}C]
Graphite	194	298
Aluminum	108	211
Cast-iron	137	256

Challenges (6)

Neutrino Beam Monitoring

- "hadron monitor" immediately after the target
  (**secondary emission monitor**) ?
- "hadron monitor" upstream of the decay tunnel
  (**ionisation chambers**) ?
- muon detection system - **silicon counters**: required absolute and relative accuracy ?

How much of this is really needed -

is "all protons are hitting the target" good enough ?

→ redundant fault detection system ...

Cost of the CNGS facility*

*without detectors at Gran Sasso

Civil Engineering (including decay tube)	41.6 MCHF
Equipment	19.6 MCHF
Infrastructure	7.3 MCHF
Contingency	2.5 MCHF
Total	**71 MCHF**

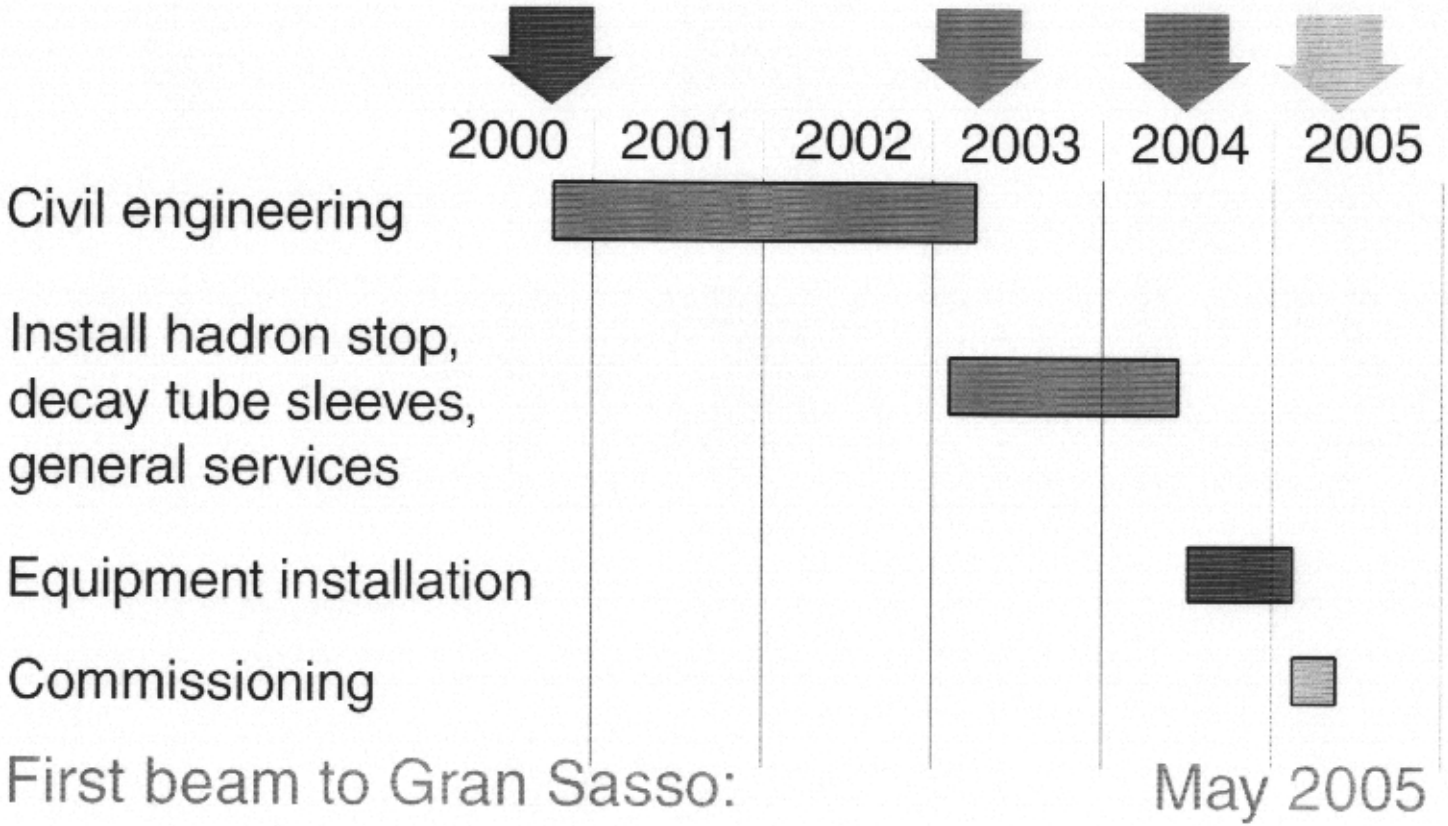
+ the value of recuperated equipment and investment for LHC:

estimated 22 MCHF

<u>Voluntary contributions</u> announced:

Belgium	1 MCHF
France	1 MCHF
Germany	5 MCHF
Italy	47 MCHF
Comp. S. Paolo (Italy)	1.6 MCHF
Spain	4 MCHF
Total	**59.6 MCHF**
Switzerland	??.? MCHF

CNGS schedule / status



CNGS schedule / status

Approval of the CNGS facility by CERN Council:	December 1999
Civil engineering contract signed (within budget)	August 2000
Start civil engineering works	4 Sept. 2000
Presentation ICARUS and OPERA proposals	5 Sept. 2000
End civil engineering works	April 2003
Installation hadron stop / decay tube until…	June 2003
Installation general services until…	July 2004
Start equipment installation	**July 2004**
First beam to Gran Sasso	**May 2005**

Summary

- Following the approval of CNGS in Dec. 1999, construction has now started.
- First CNGS beam for the ν_τ appearance search is expected in May 2005.
- Work is under way to optimize many aspects of the CNGS facility.
- This workshop is an excellent opportunity to discuss our present ideas - thanks to the organizers and Fermilab !