CNGS Project: Status report

1. Project Overview
2. Proton beam layout and equipment status
3. Proton beam dynamics
4. Target and secondary beam equipment readiness
5. Commissioning preparation
6. Outlook

1. Project Overview

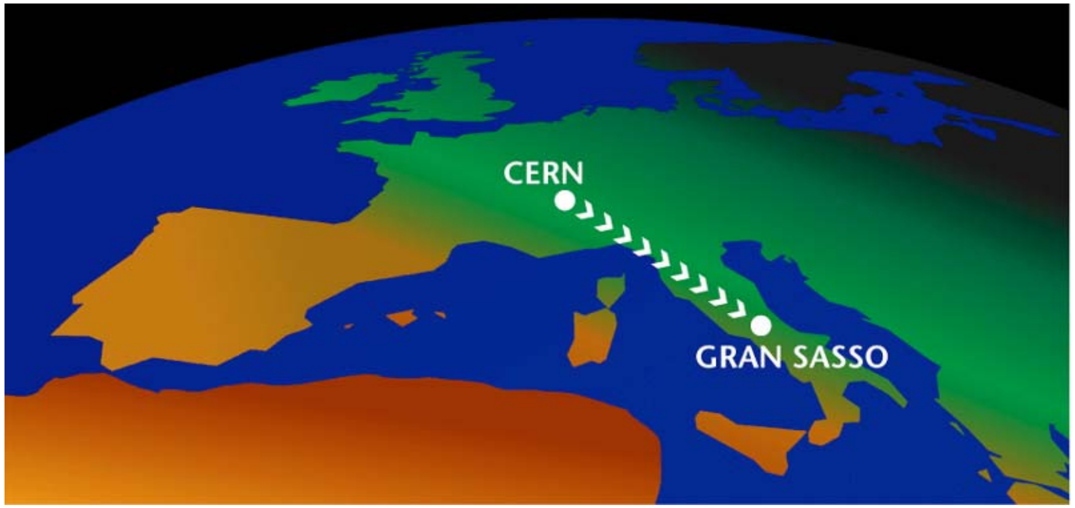
(see http://cern.ch/cngs)

CNGS - a long base-line neutrino beam facility (732 km)

send ν_μ beam -> detect ν_τ appearance

CNGS project at CERN: production of the ν_μ beam

using protons from the existing accelerator chain

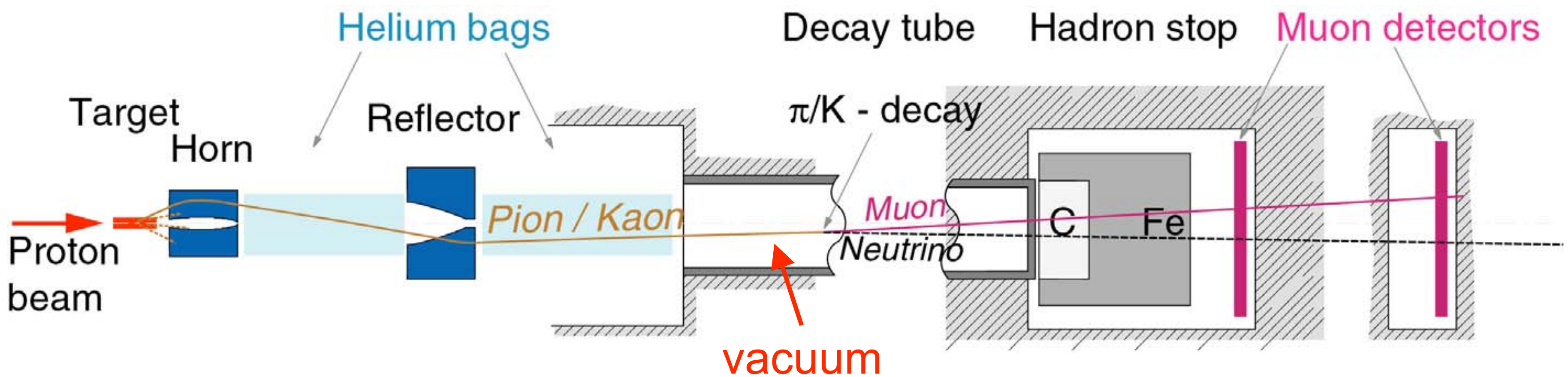


At Gran Sasso:

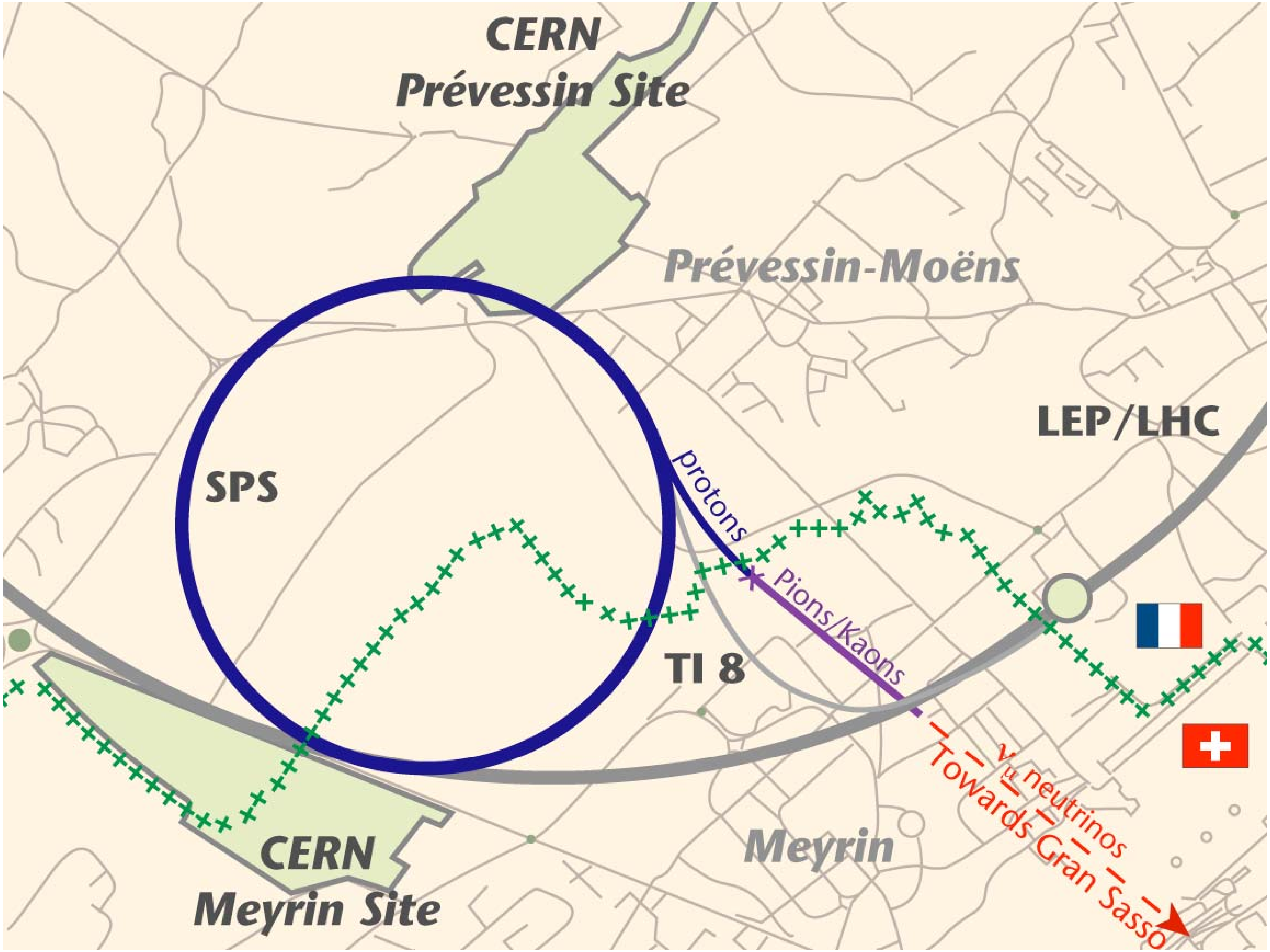
OPERA detecting ν_τ

CNGS: the main components

700 m 100 m 1000m 67 m

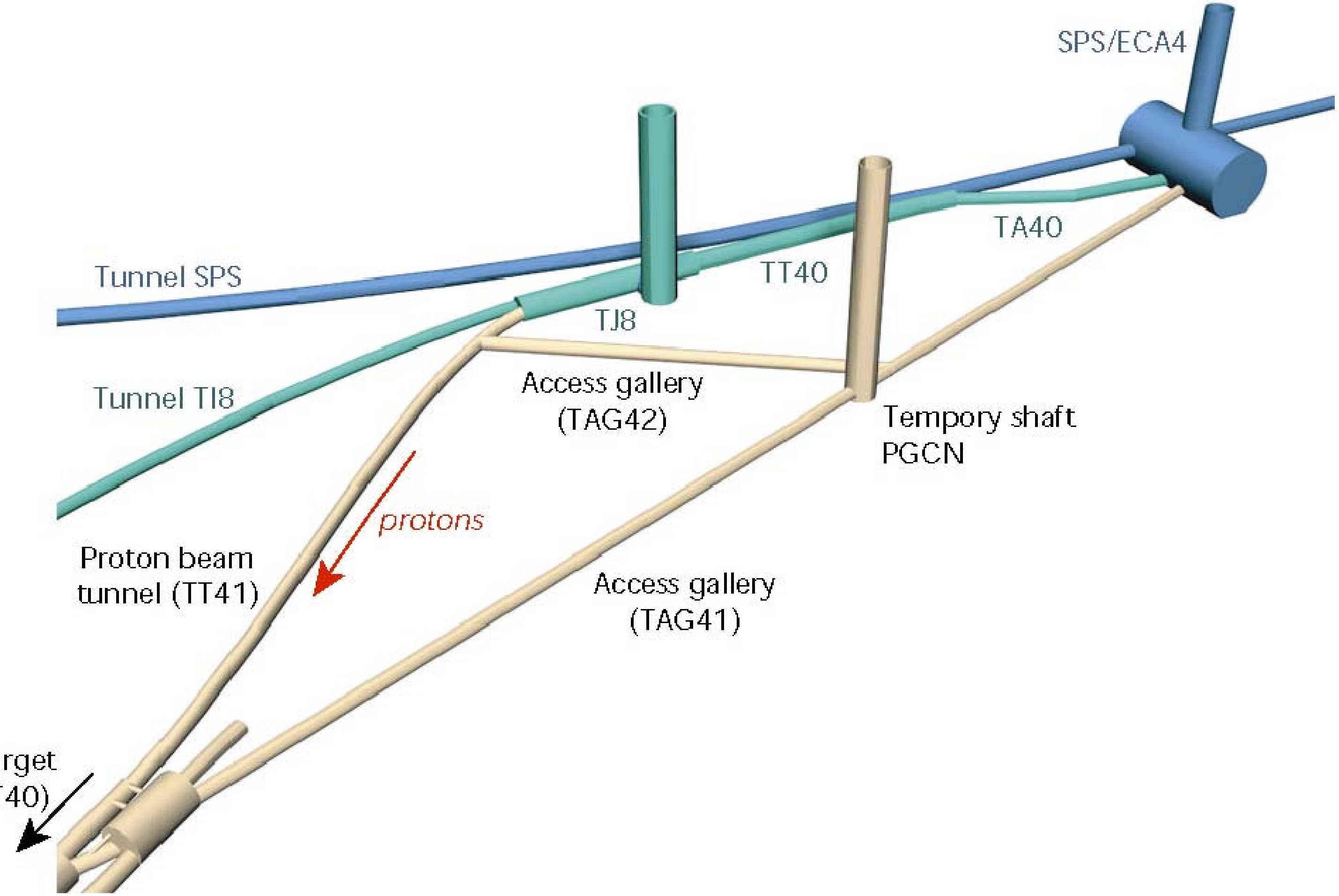


$$p + C \rightarrow \text{(interactions)} \rightarrow \pi^+, K^+, (\mu^+) \rightarrow \text{(decay in flight)} \rightarrow \mu^+ + \nu_\mu$$

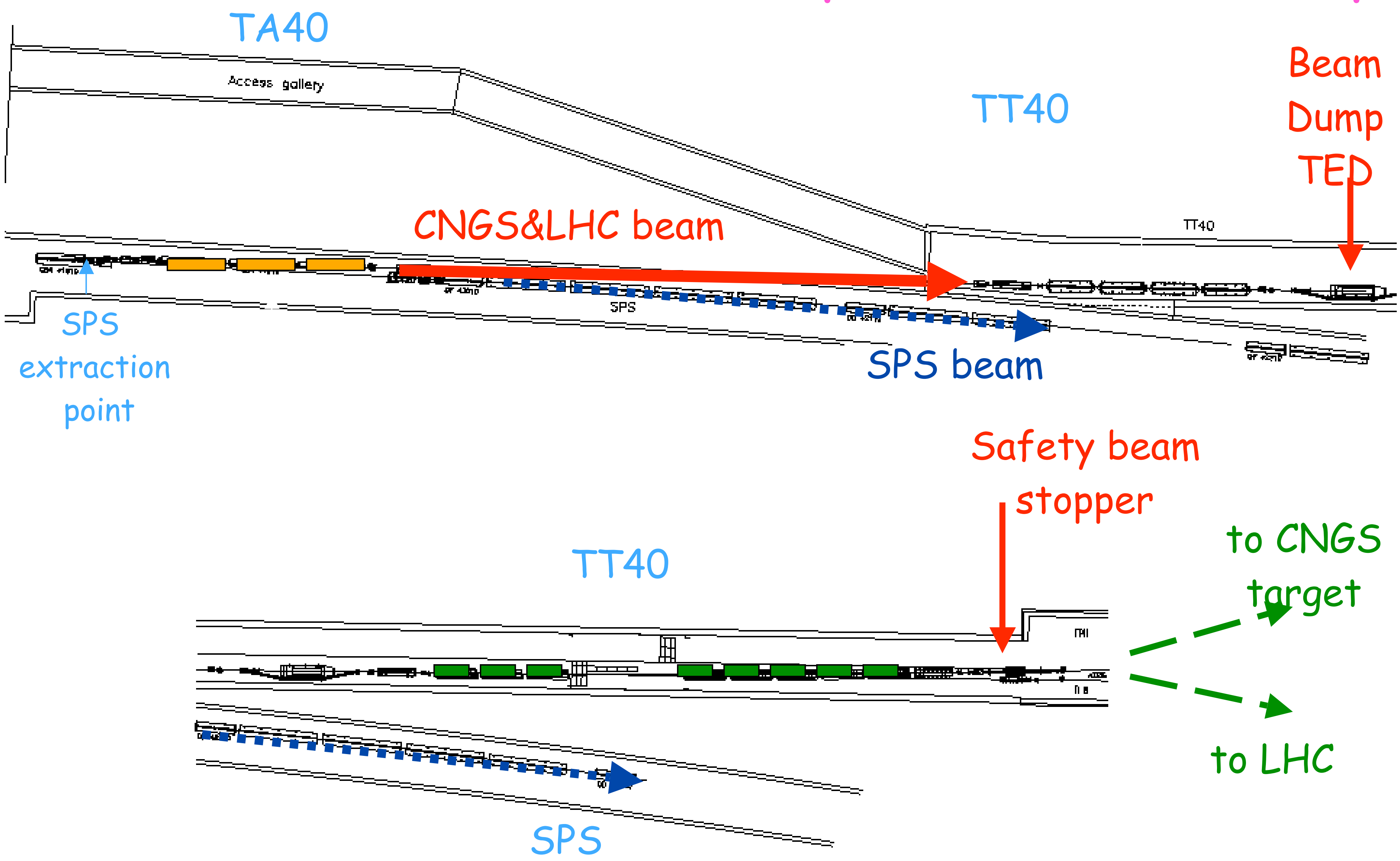

CERN
Prévessin Site
Prévessin-Moëns
LEP/LHC
SPS
protons
Pions/Kaons
TI 8
ν_μ neutrinos
Towards Gran Sasso
CERN
Meyrin Site
Meyrin

2. Proton beam line layout and equipment status

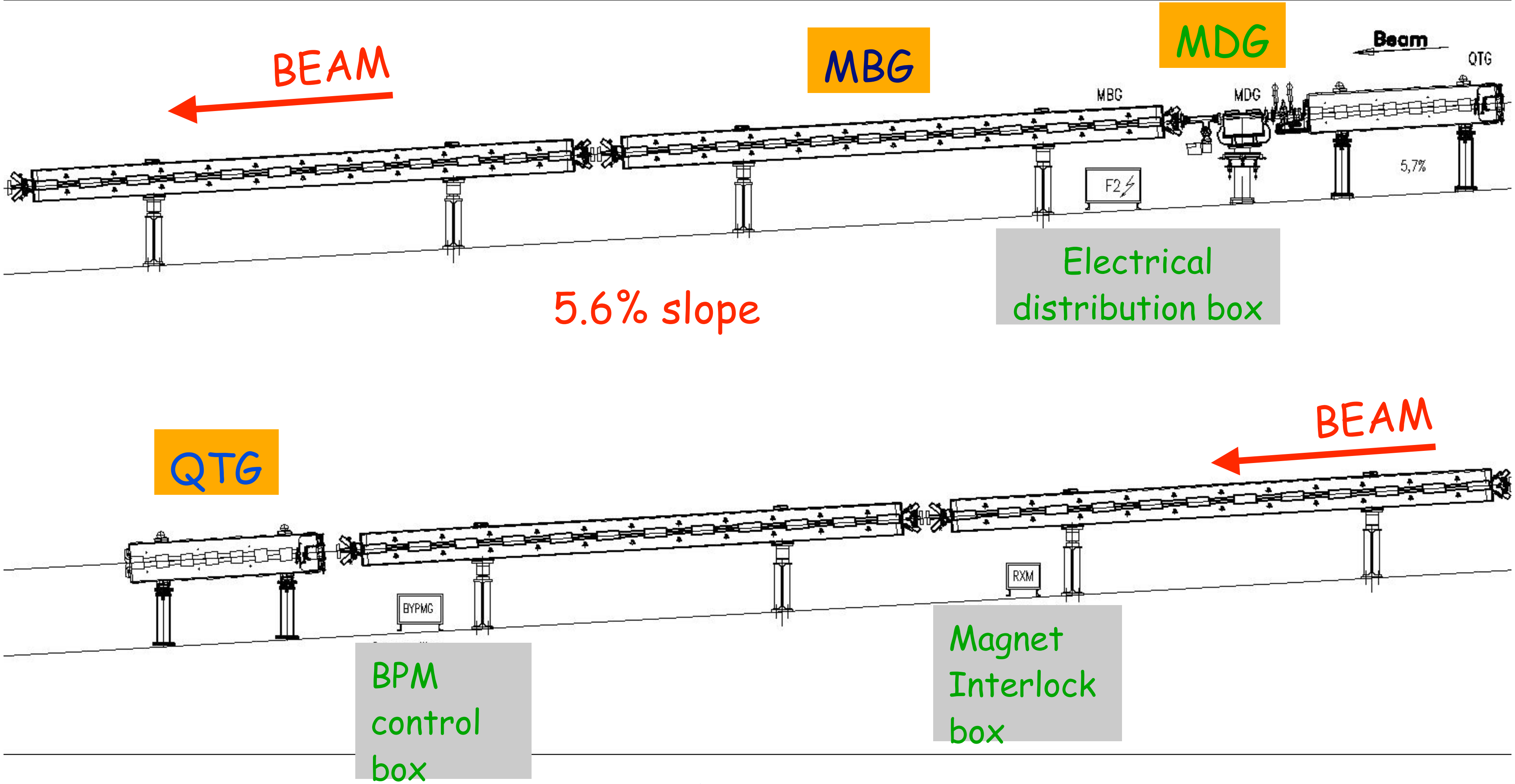
Proton beam line overview



TT41 extraction point to beam dump



Transfer line layout: half cell



Main dipole magnet status

MBG

73 magnets (78 ordered)

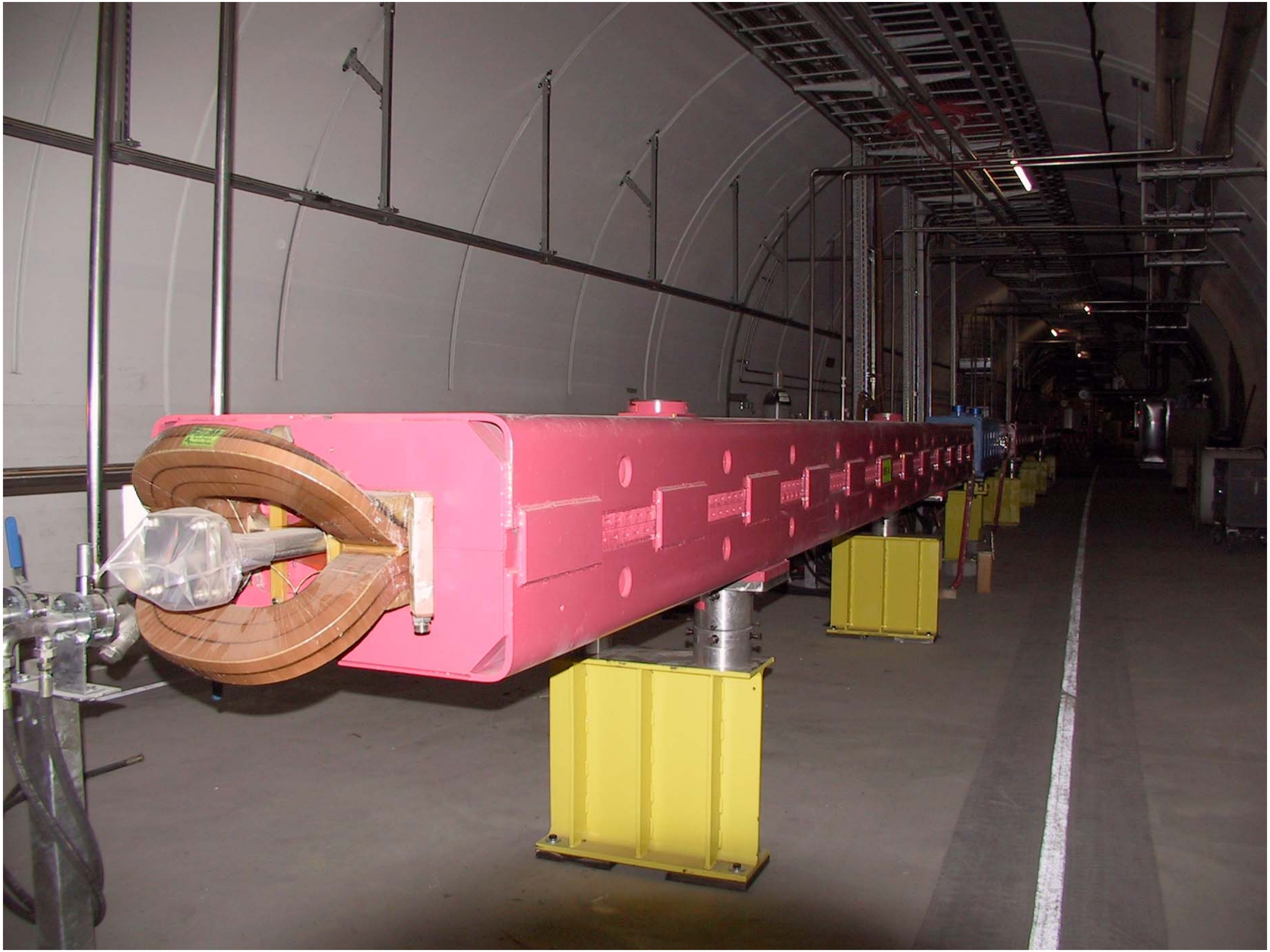
Nominal field : 1.7 T @ 400 GeV

Magnetic length : 6.3 m

Gap height 37 mm

ALL RECEIVED and stored

TT41 mock-up



Main quadrupole magnet status

QTG 20 magnets (23 ordered)

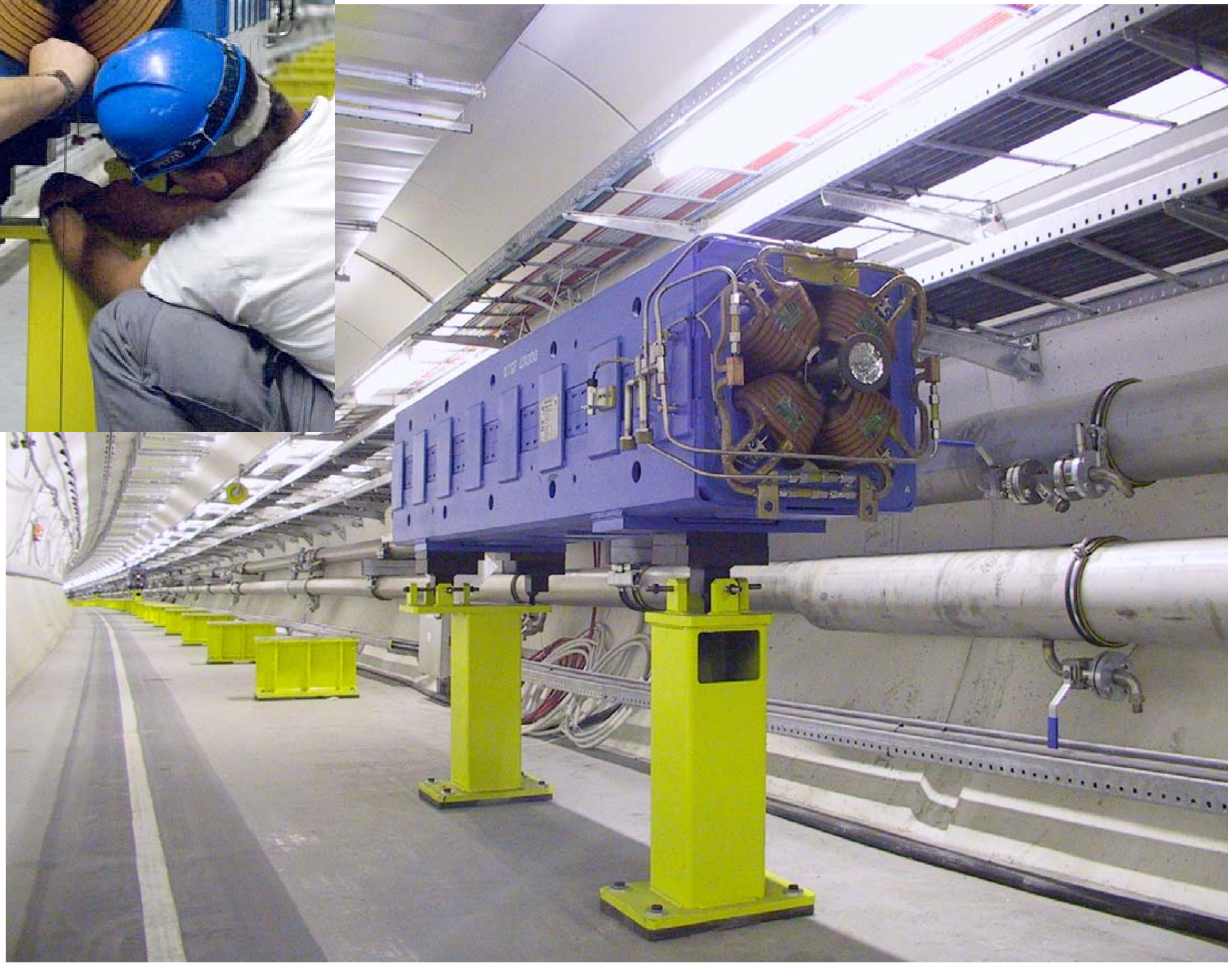
Magnetic aperture : 45 mm

Nominal gradient 40 T/m, 2.2 m long

All QTG received

All QTG installed in TT41 and aligned

Quadrupole installation in TT41



23 August 2005

Dipole corrector magnet status

MDG 12 magnets (17 ordered)

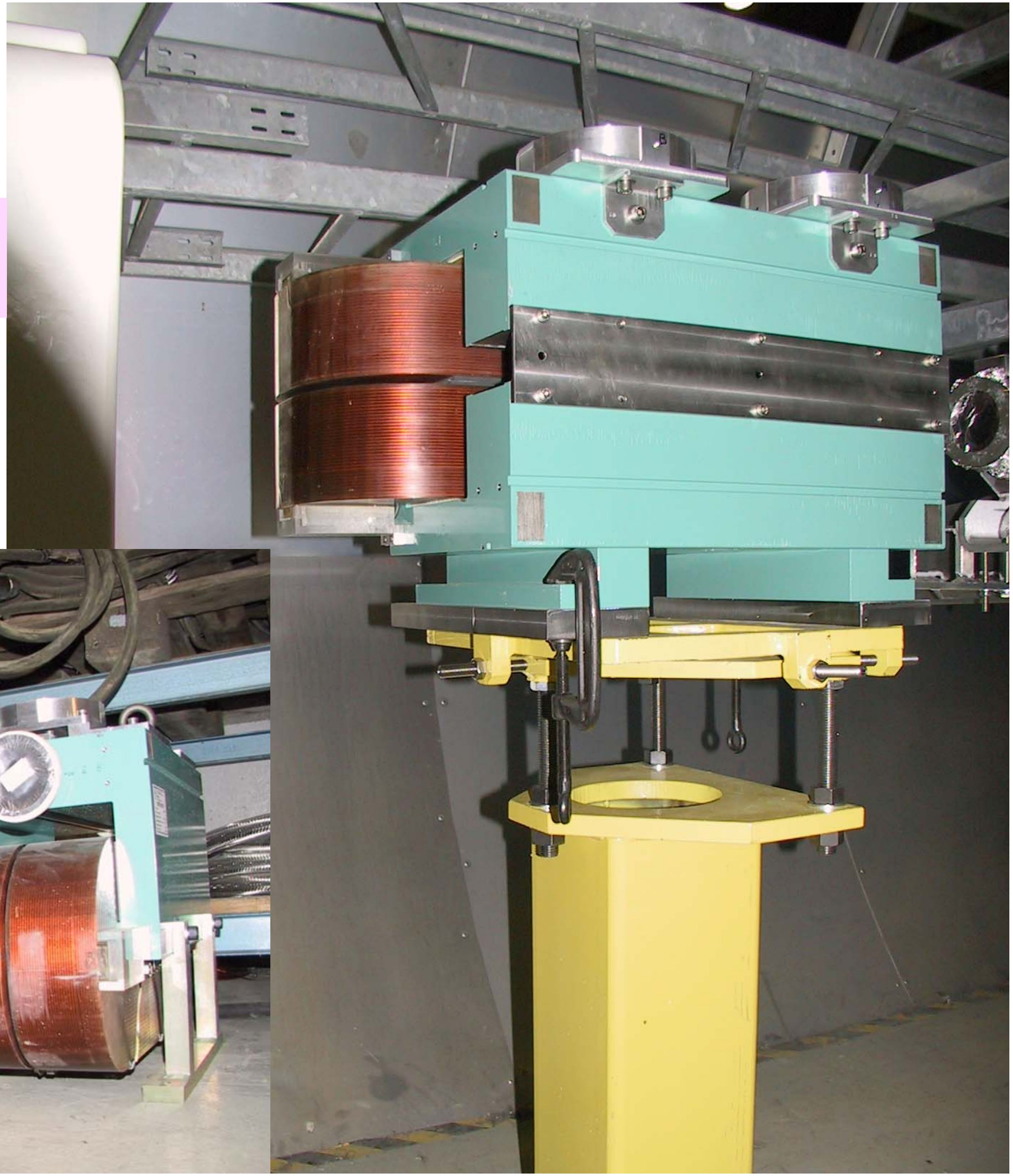
Gap height : 45 mm

Bending angle 80 μrad, overall length: 700mm

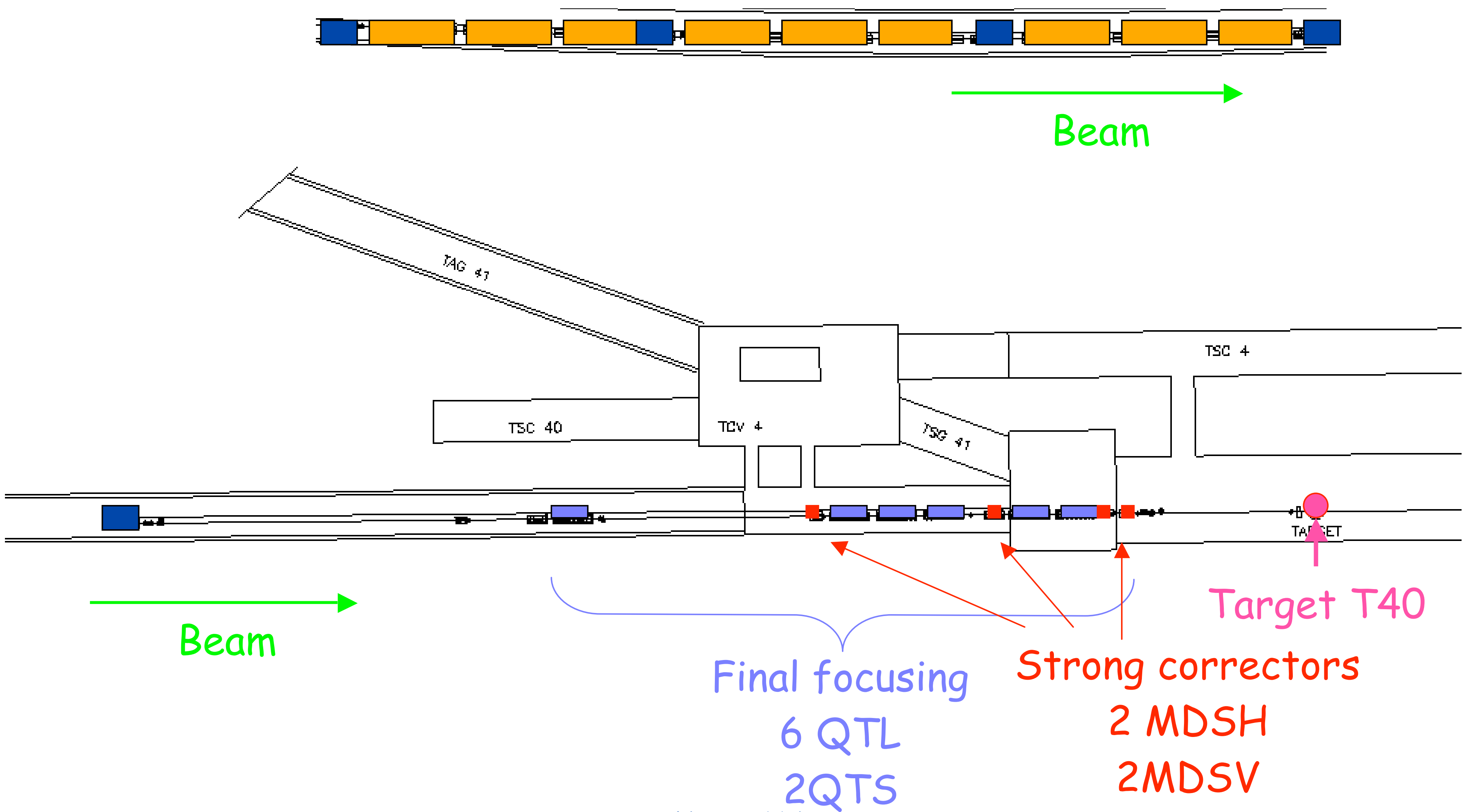
All MDG magnets received

Chambers to be inserted in 4 MDGH (at CERN)

MDGH and MDGV
Dipole corrector magnets



Last 200m



Beam
TAG 41
TSC 4
TSC 40
TCV 4
TSG 41
TARGET
Beam
Target T40
Final focusing
6 QTL
2QTS
Strong correctors
2 MDSH
2MDSV

Beam line instrumentation

- **18** beam position monitors in proton beam line (BPG) + 4 in common line with LHC (BPK)
- **1** coupler in air on target table (BPKG)
- **8** proton beam profile monitors (BTVG)
- **18** beam loss monitors (BLM)
- **1** beam current transformer (BFCT) (+1 BFCT in common line with LHC

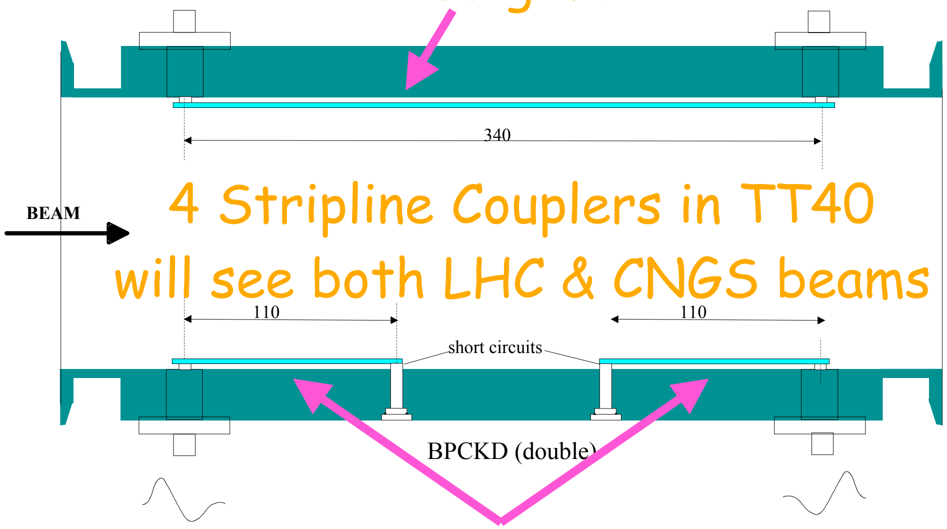
Beam Position Monitoring

Beam Position Measurement Requirements

source	*rms uncertainty*	*tolerance*
BPM (global accuracy)	0.25 mm	± 0.5 mm
Alignment	0.20 mm	± 0.4 mm
Total	0.32 mm	± 0.6 mm

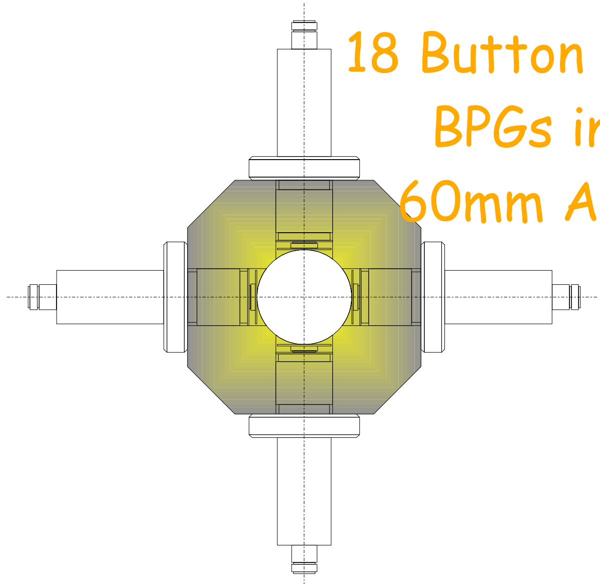
Intensity Range:
1×10^{12} to 3.5×10^{13}

Original



4 Stripline Couplers in TT40
will see both LHC & CNGS beams

Modified



18 Button Electrode
BPGs in TT41
60mm Aperture

Target Beam Position Monitor

Target Beam Position Measurement Requirements

Final standard BPG of the proton beam line & target BPKG

⇒ *used to provide position at the target*

⇒ *setting up performed using final beam line BPG*

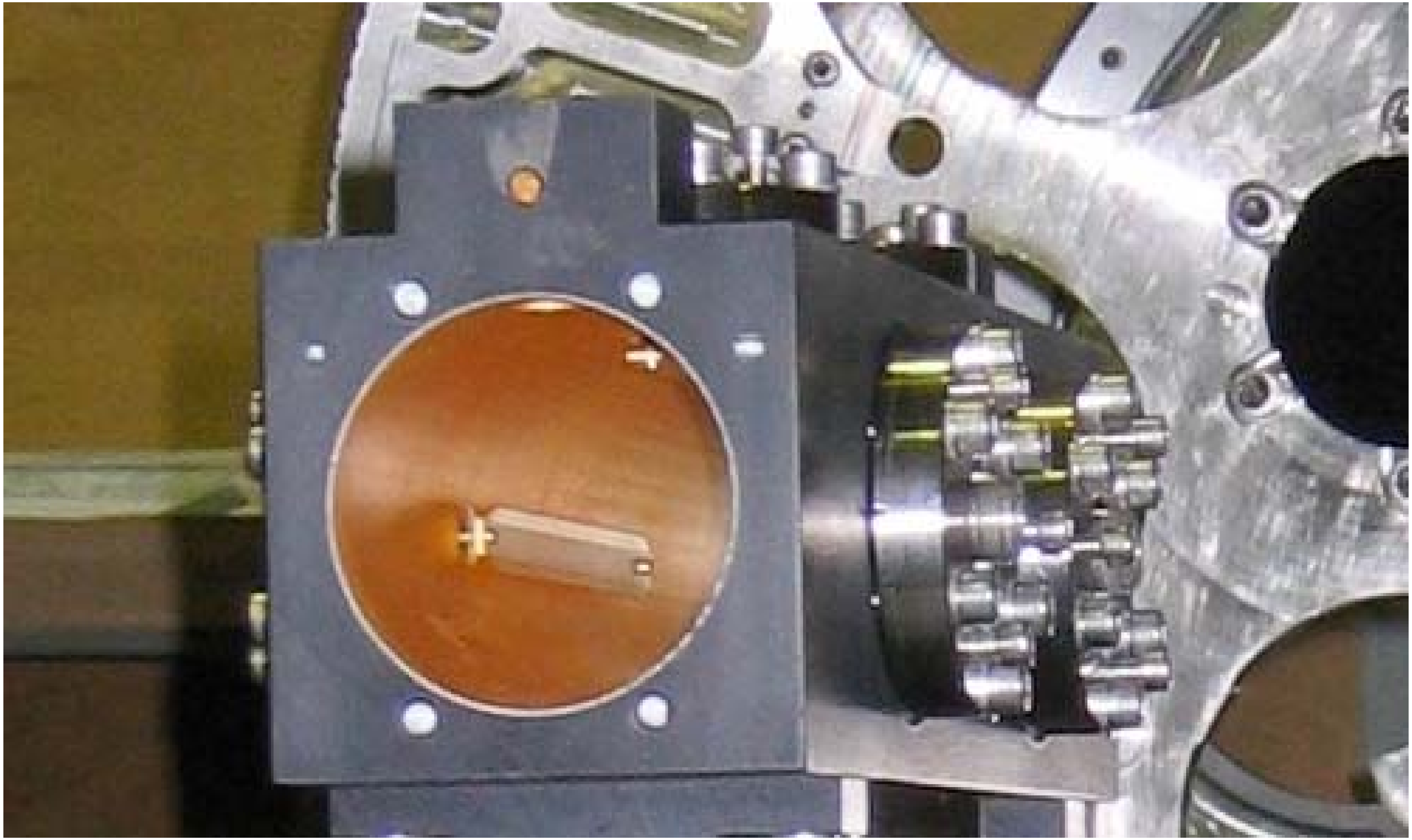
⇒ *aiming at target rods verified & tracked using target BPKG*

⇒ *accuracy of measurement ±0.2mm in ±2mm central region.*

⇒ *accuracy of measurement ±0.5mm outside ±2mm central region.*

error source	*rms uncertainty*	*tolerance*
BPM (global accuracy)	0.1 mm & ≤± 0.15 mm	± 0.2 mm & ≤± 0.3 mm
Alignment	0.10 mm	± 0.2 mm
Total	0.14 mm	≤± 0.35 mm

BPKG – special beam position monitor on target table
Stripline Coupler Pick-up operated in air



Beam Profile monitors

75 μm carbon and 12 μm titanium screens

5 to 10 % precision requested

Beam Loss Monitoring

Beam losses will be detected using:

- ⇒ 18 standard 1 litre, SPS, nitrogen filled ionisation chambers
- ⇒ 30 parallel plates with 5mm separation - ionisation length of 19cm
- ⇒ efficiency of ~1250 pairs per primary charge

Beam Current Transformers

Two Monitors _ one at the beginning & one at the end of the line
Absolute Accuracy of 1% for the Intensity Range: 1×10^{12} to 3.5×10^{13}

First BCT sees both LHC & CNGS beams

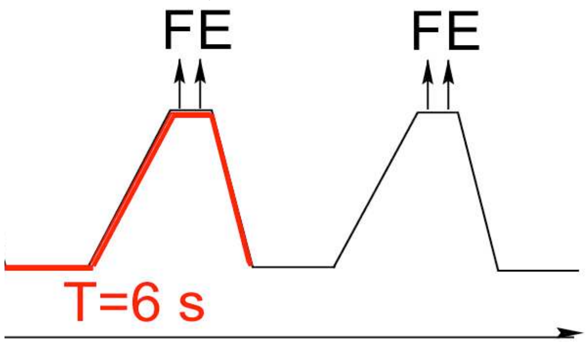
- *Has to fulfill additional requirement of LHC bunch by bunch capability (i.e. 25ns resolution)*

3. Proton beam dynamics

Nominal beam parameters

Beam parameters	Nominal CNGS beam
Nominal energy [GeV]	400
Normalized emittance [μm]	H=12 V=7
Emittance [μm]	H=0.028 V= 0.016
Momentum spread Δp/p	0.07 % +/- 20%
# extractions per cycle	2 separated by 50 ms
Batch length [μs]	10.5
# of bunches per pulse	2100
Intensity per extraction [10^{13} p]	2.4
Bunch length [ns] (4 σ)	2
Bunch spacing [ns]	5

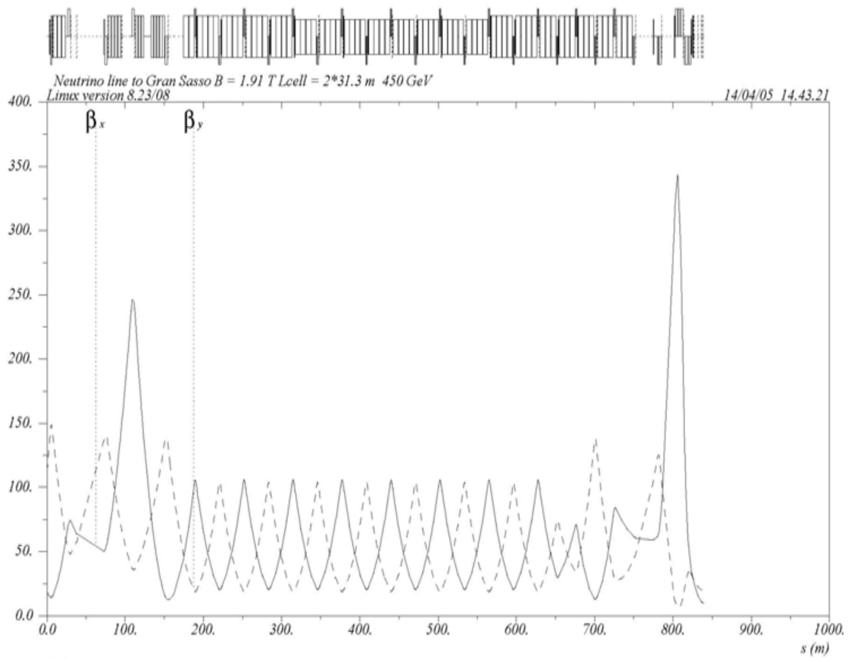
Upgrade phase: $3.5\ 10^{13}$ p

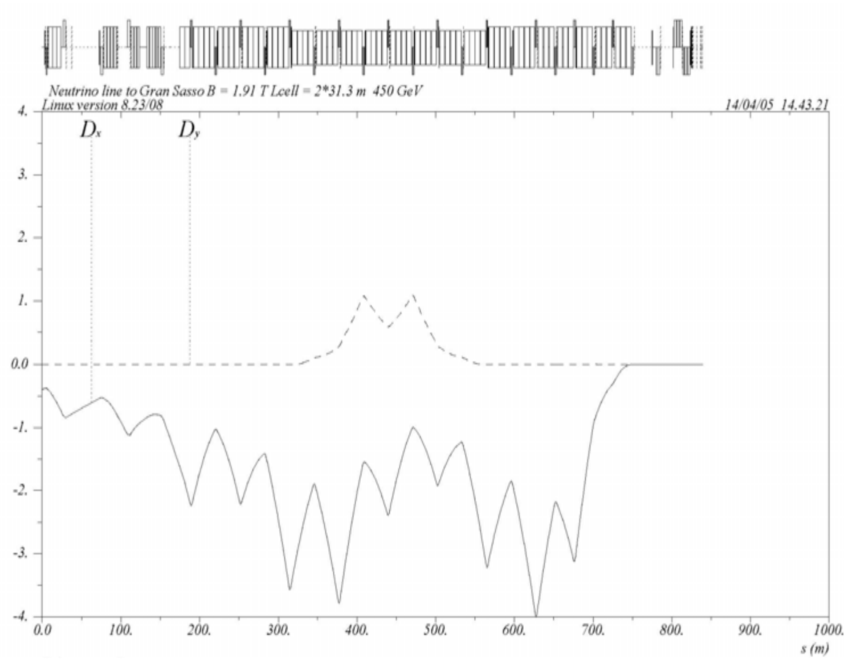


Optics at Target

Nominal parameters :
- Beta at focus : 10 m, 20m
- Beam size σ at 400 GeV : 0.5 mm
- Beam divergence σ' at 400 GeV : 0.05, 0.03 mrad

Possible to increase further the beam size





Trajectory correction scheme

2-in-3 scheme: 2 consecutive half cells per plane out of 3 are equipped with Beam Position Monitors (BPMs) and correctors.

Phase advance per cell: $\pi/2$

Beam line errors (quad displacement, beam position monitor, dipole field and tilt, extraction from SPS)

	Max. RMS	Max. Excursion (mm)
X before trajectory. Correction	3.6	15.
X after trajectory correction	0.7	2.7
Y before trajectory. Correction	3.2	8.
Y after trajectory correction	0.6	2.5

Note: max. trajectory excursion allowed: 4 mm

The implemented correction scheme is sufficient

Beam stability at the target

→ Target resistance to non-centered beam

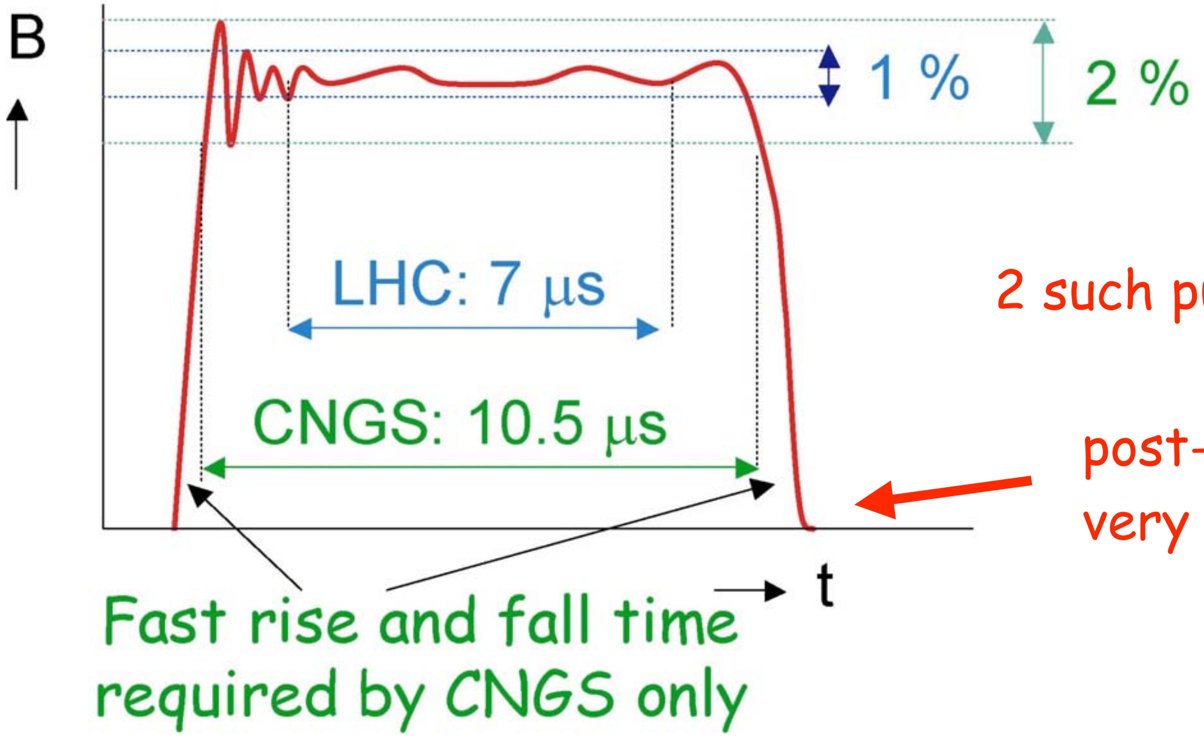
Beam line imperfections (quad displacement, beam position monitor, main dipole field and tilt, extraction, power supply precision)

Horizontal spot size is dominated by extraction errors

Vertical spot size is not increased, vertical beam position is determined by trajectory errors.

Type of error	Error magnitude	Horizontal σ_x at target (mm)	Horizontal σ'_x at target (μrad)
Magnet errors	As in specs.	0.12 mm	11 μrad
Horizontal extraction angle	10 μrad r.m.s.	0.11mm	5 μrad
Horizontal extraction position	0.5 mm r.m.s.	0.32 mm	21 μrad
Nominal beam [r.m.s.]		0.53 mm	53 μrad
Effective beam [r.m.s.]		0.64 mm	57 μrad

MKE – extraction kicker



2 such pules needed, 50ms apart

post-kick ripple also very important !!

	σ_x at target(mm)	σ'_x at target (μrad)	$2\sigma_x$ at target(mm)
± 1% MKE field ripple	0.2	8	0.4
± 1.5% MKE field ripple	0.24	12	0.48

Aperture studies

For nominal beam parameters and expected errors

-> no beam loss is expected.

For the most critical parameters

-> a margin of a factor 2 found

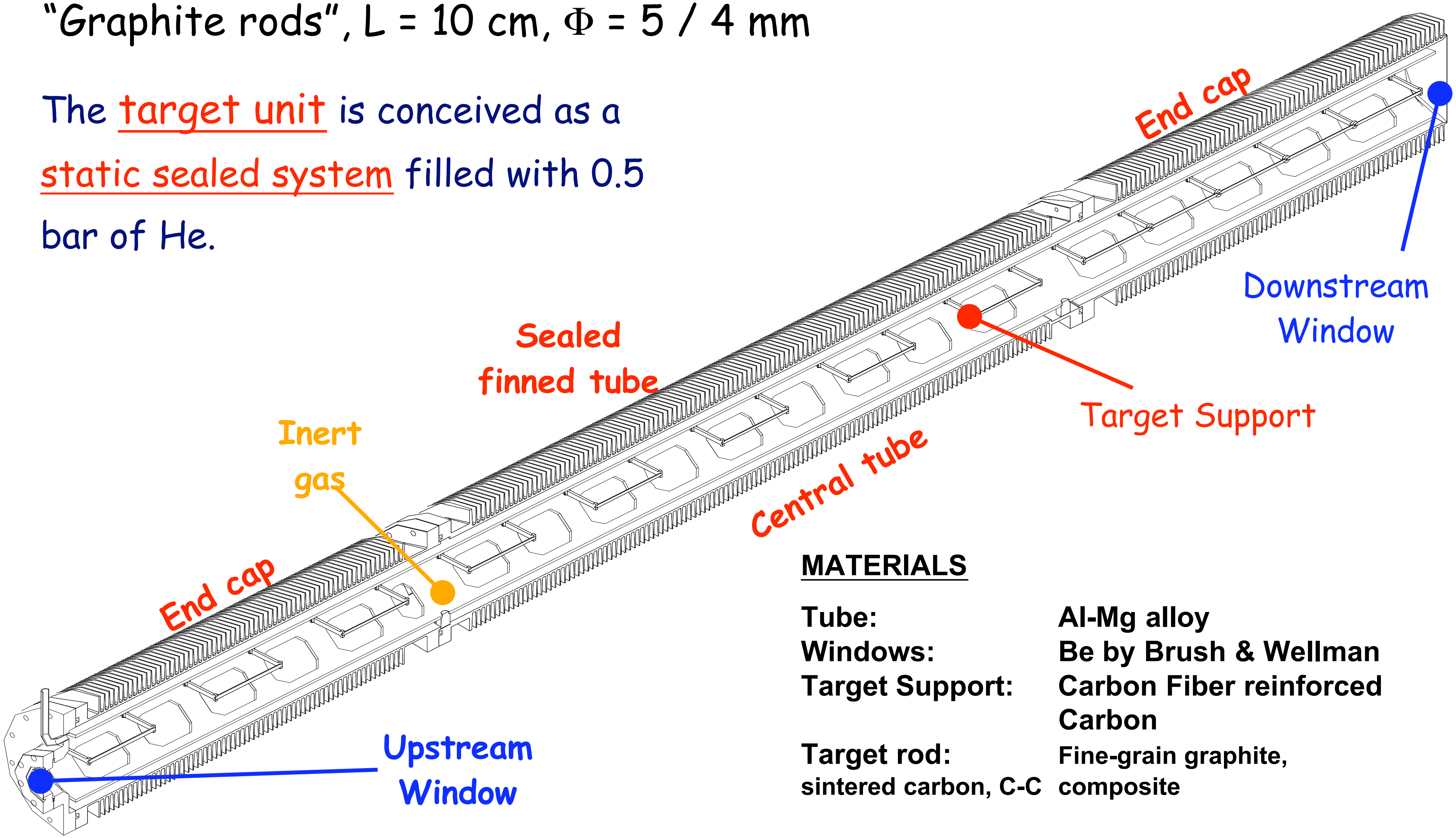
Upper limits for possible injection errors have been established.

4. Target and secondary beam equipment readiness

Target Station

"Graphite rods", L = 10 cm, Φ = 5 / 4 mm

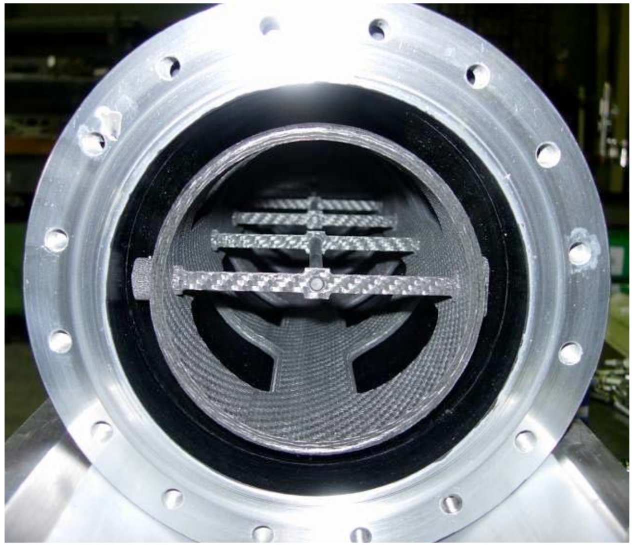
The target unit is conceived as a static sealed system filled with 0.5 bar of He.



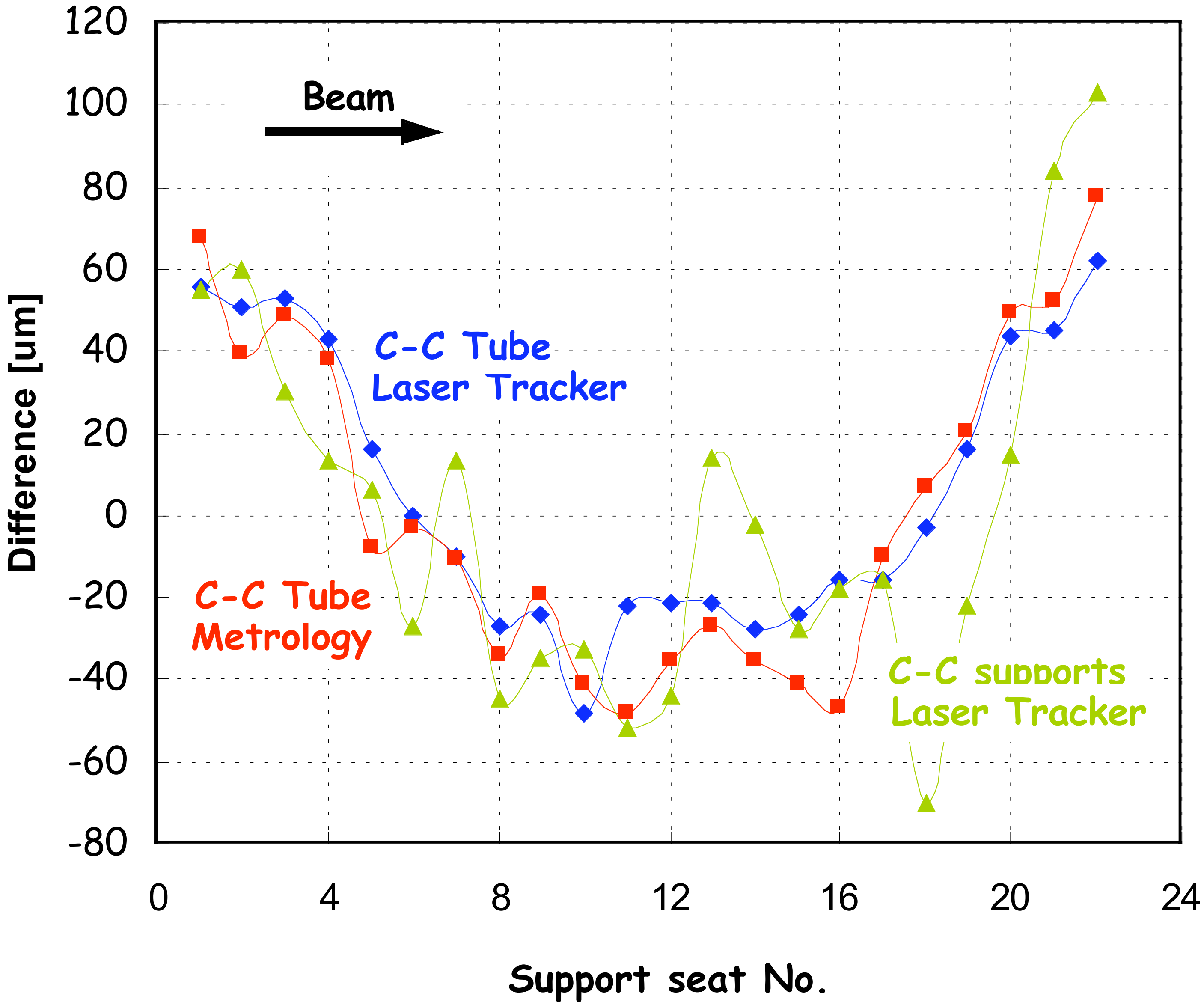
MATERIALS

Tube:	**Al-Mg alloy**
Windows:	**Be by Brush & Wellman**
Target Support:	**Carbon Fiber reinforced Carbon**
Target rod:	**Fine-grain graphite, sintered carbon, C-C composite**

The target units

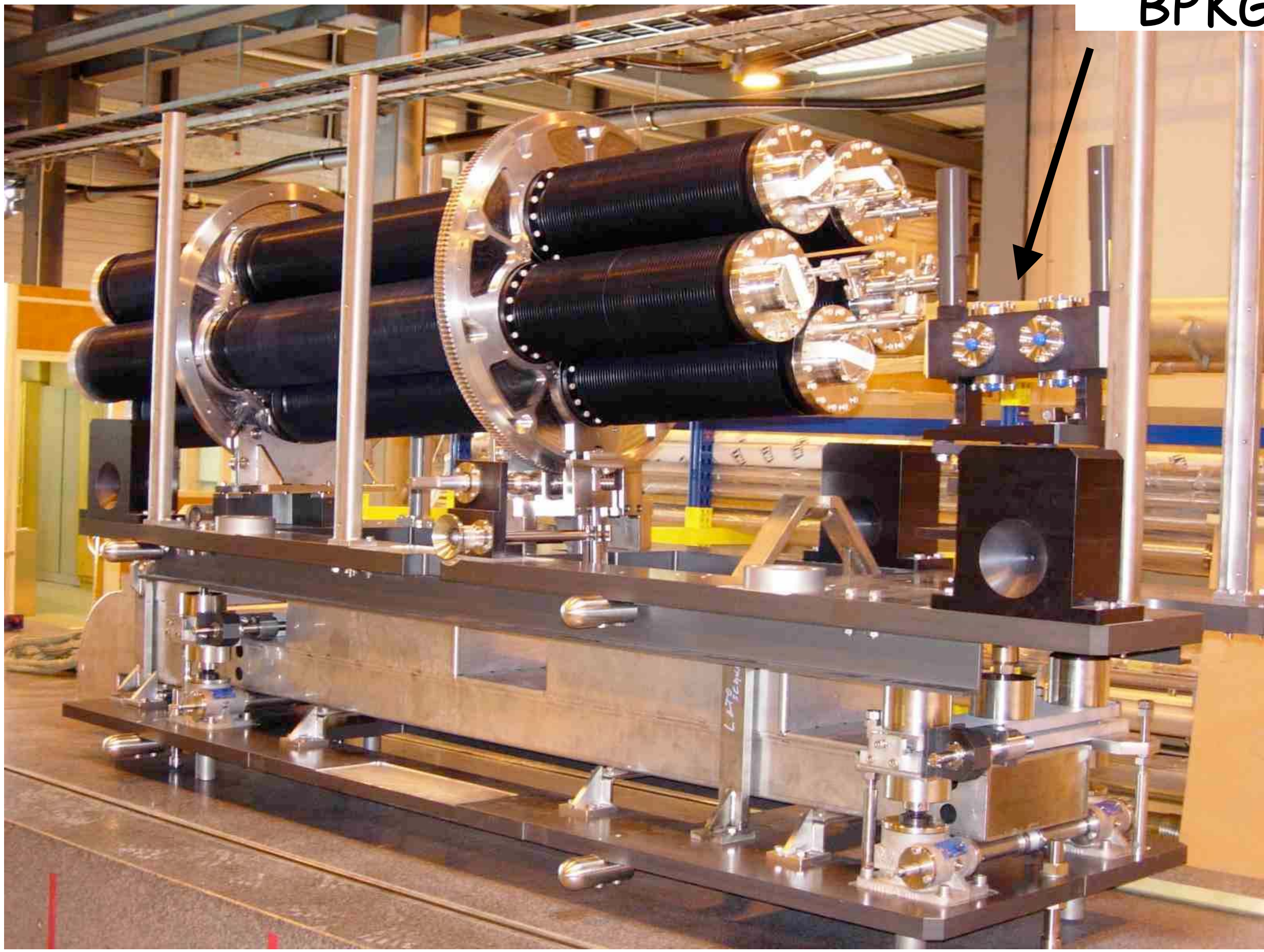


Target rods: alignment



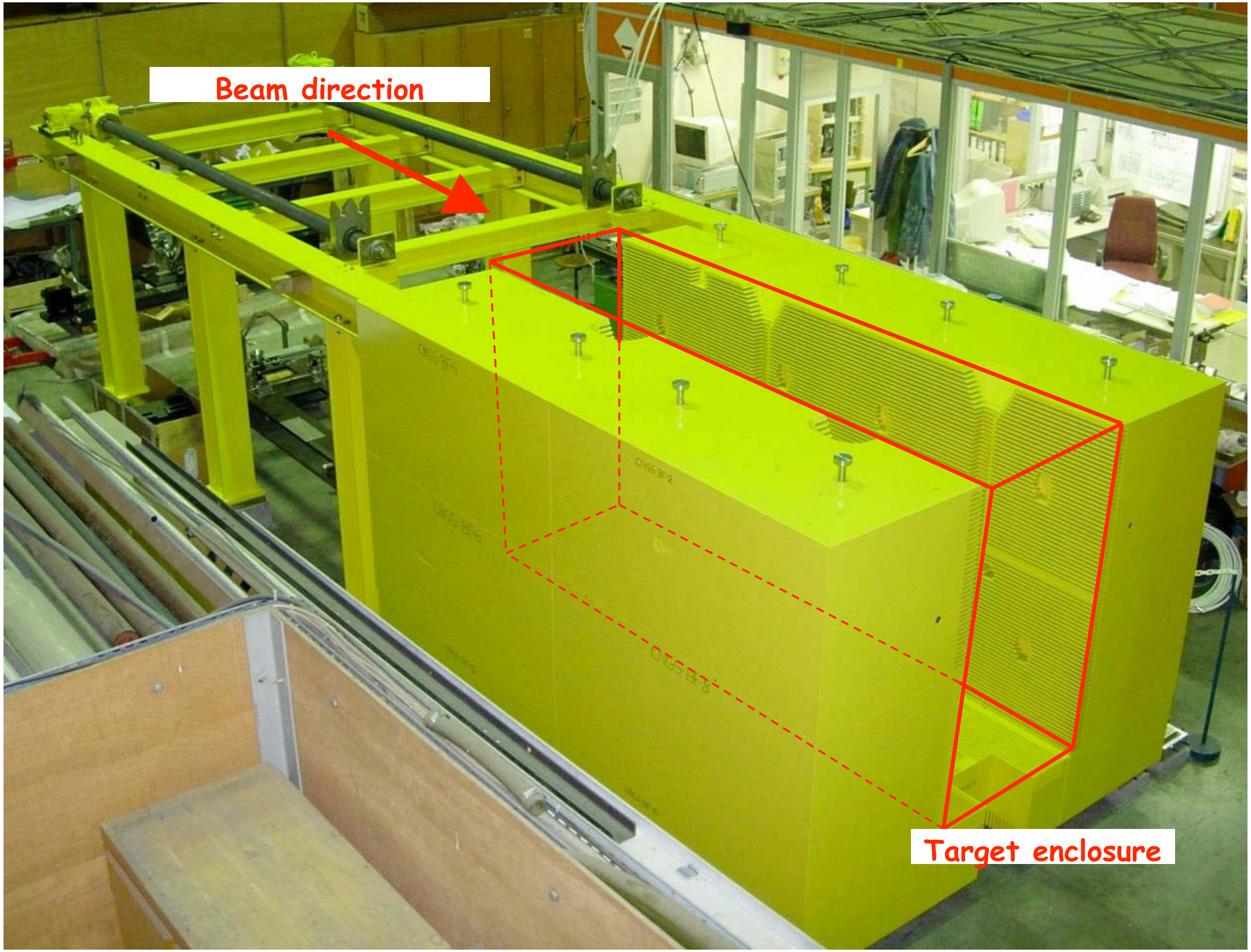
Target Magazine + BPKG

BPKG



Indexing finger

Target Station - Shielding




CNGS-BF-8

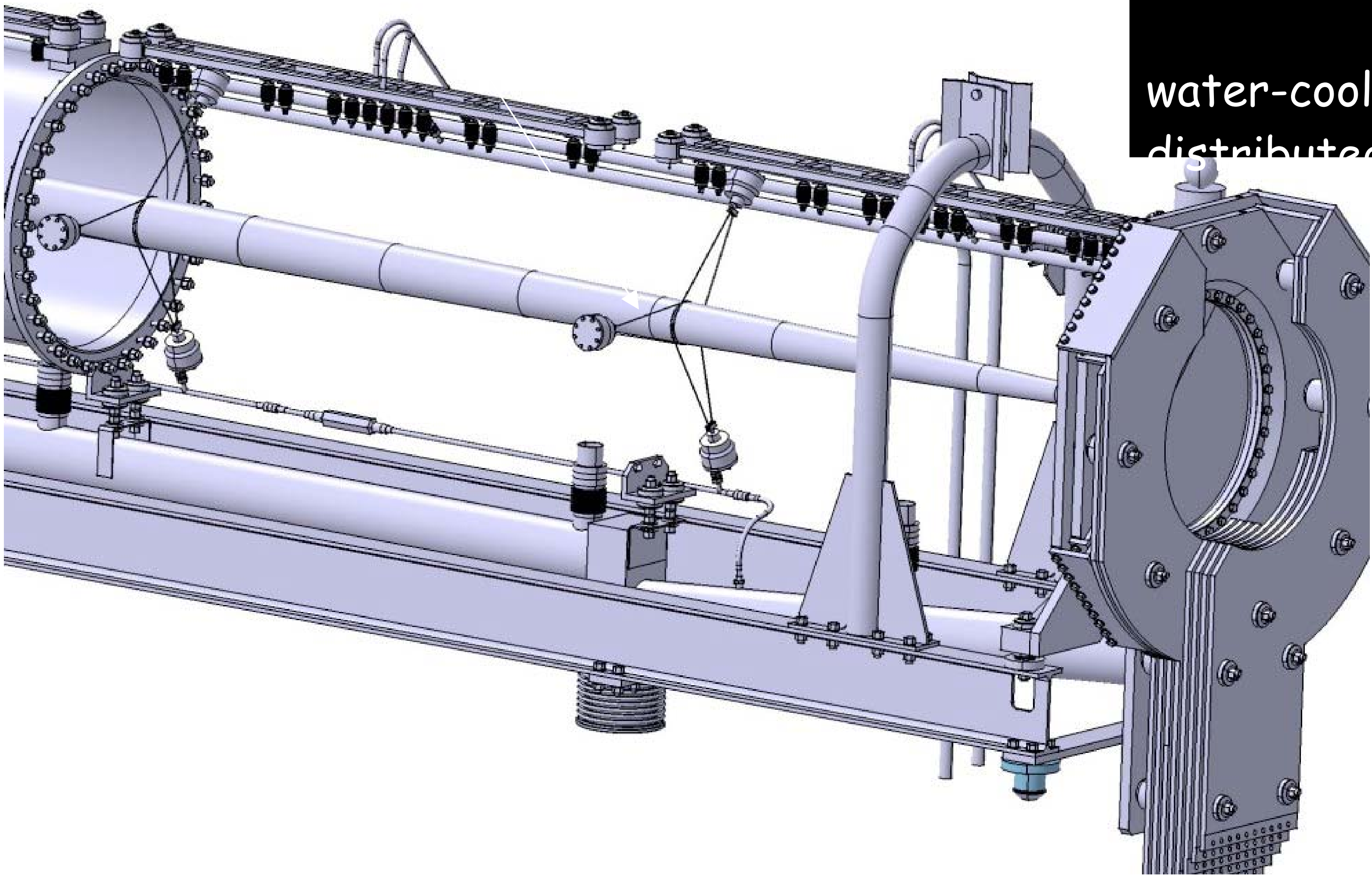
Horn system

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

Pulsed devices:
150kA / 180 kA, 1 ms

water-cooled:
distributed nozzles

Design criteria:
>95% probability to work for 5×10^7 pulses




ATTENTION:

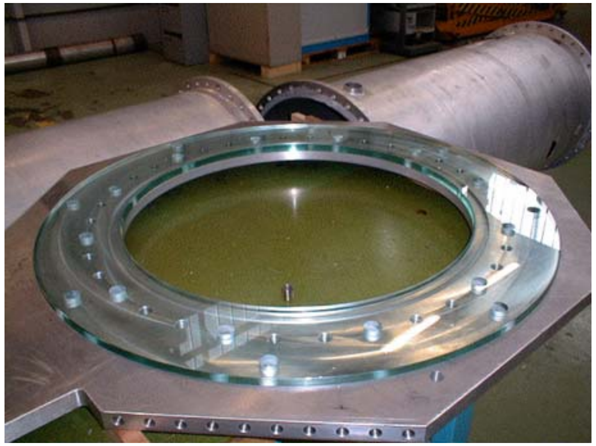
The CNGS horn“today”

Glass Disk - the remaining big issue

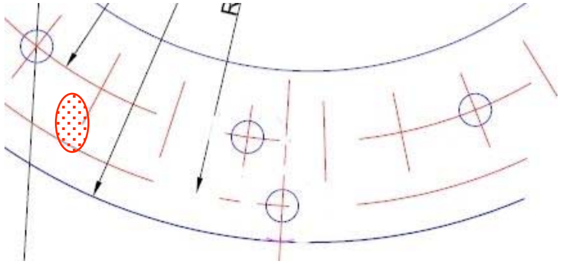
Received from LAL

Glass plate broken
Problem = conceptual

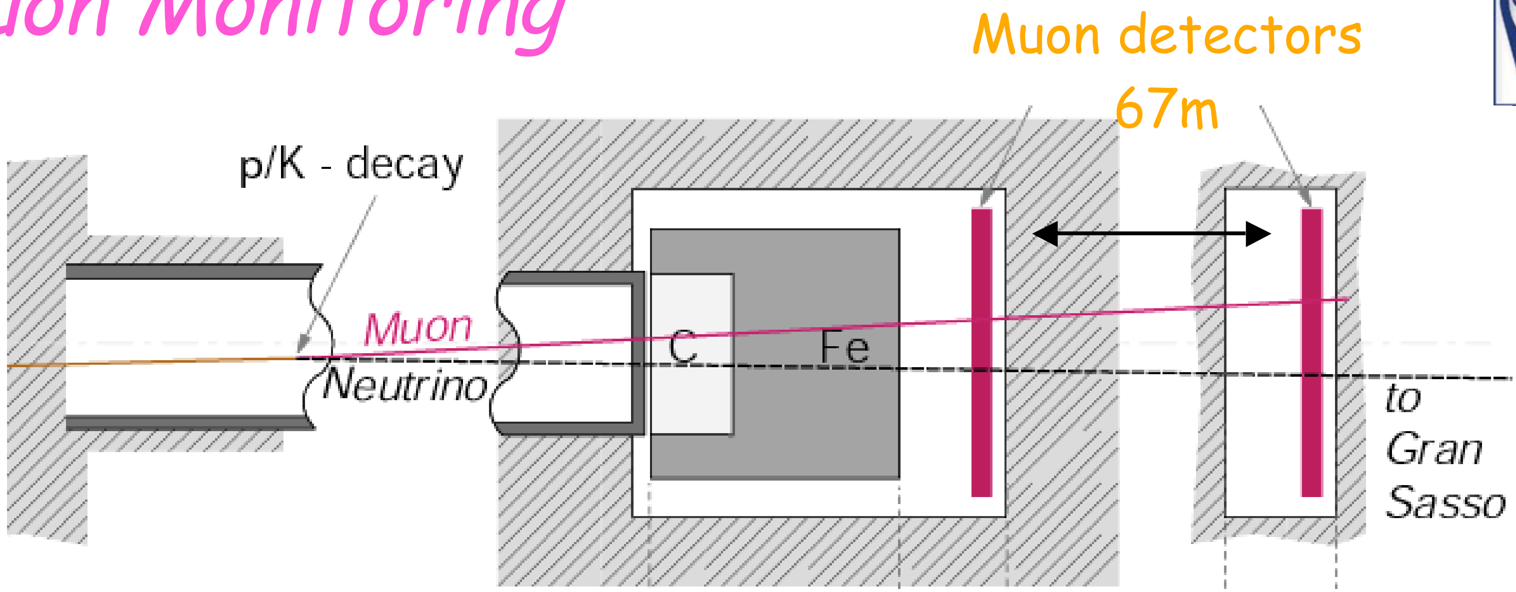
After modification

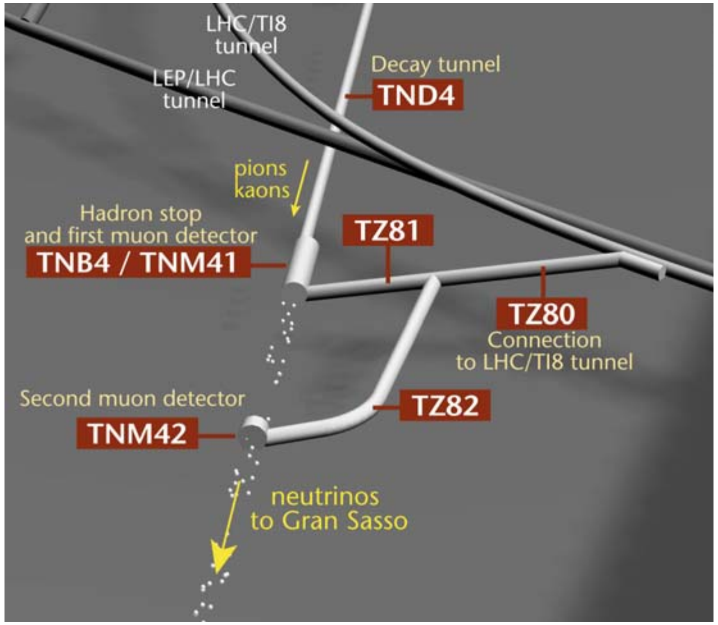


Cracks discovered ~weeks
after electrical tests



Muon Monitoring

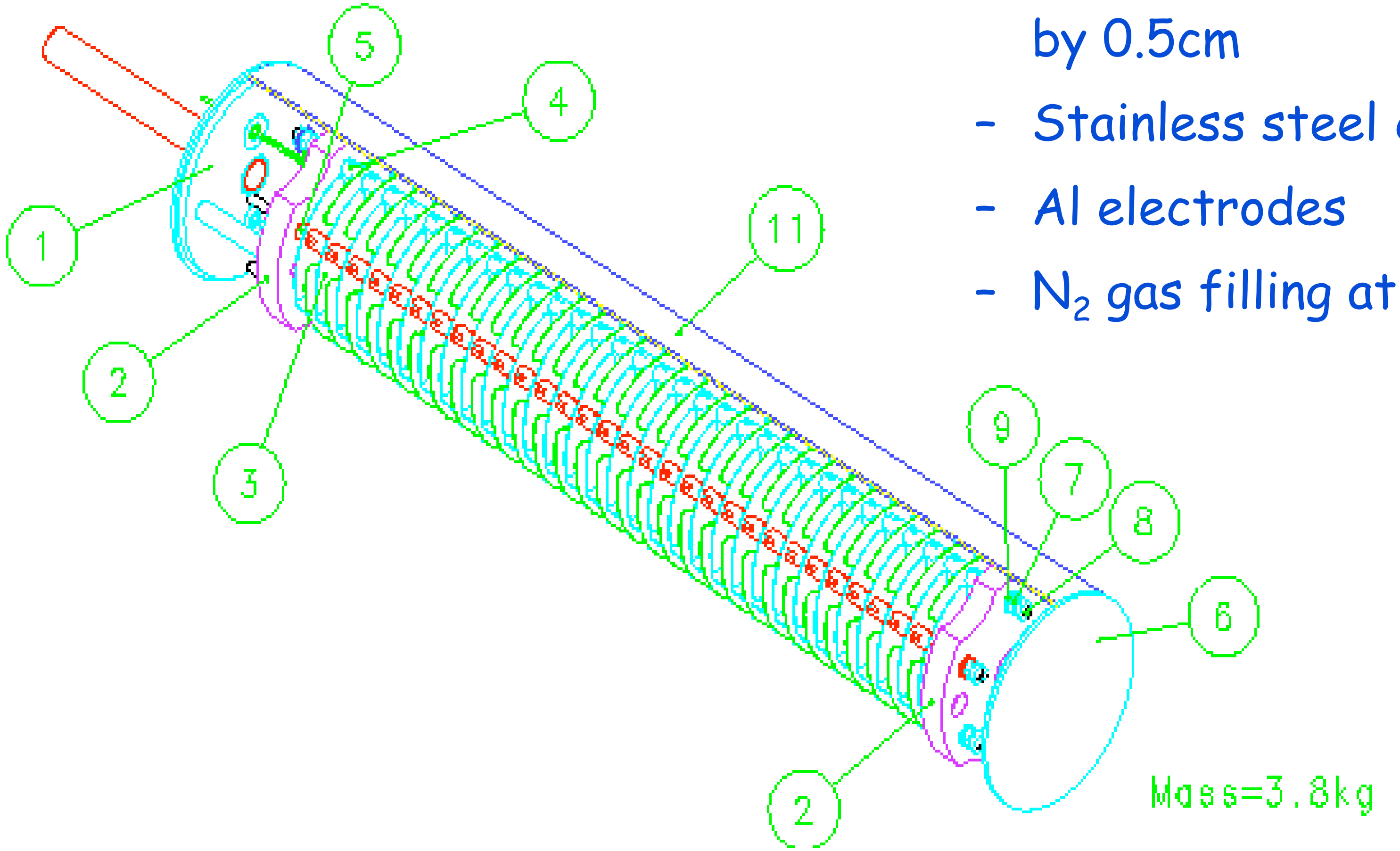




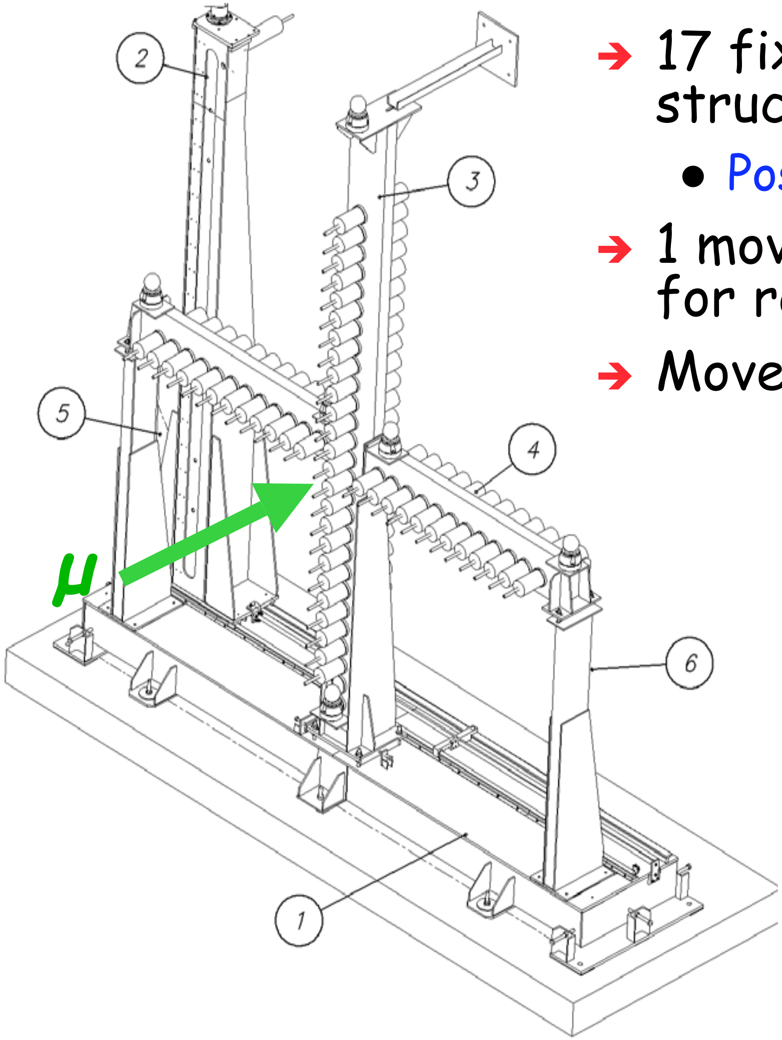
Access very rare

LHC type beam loss monitor

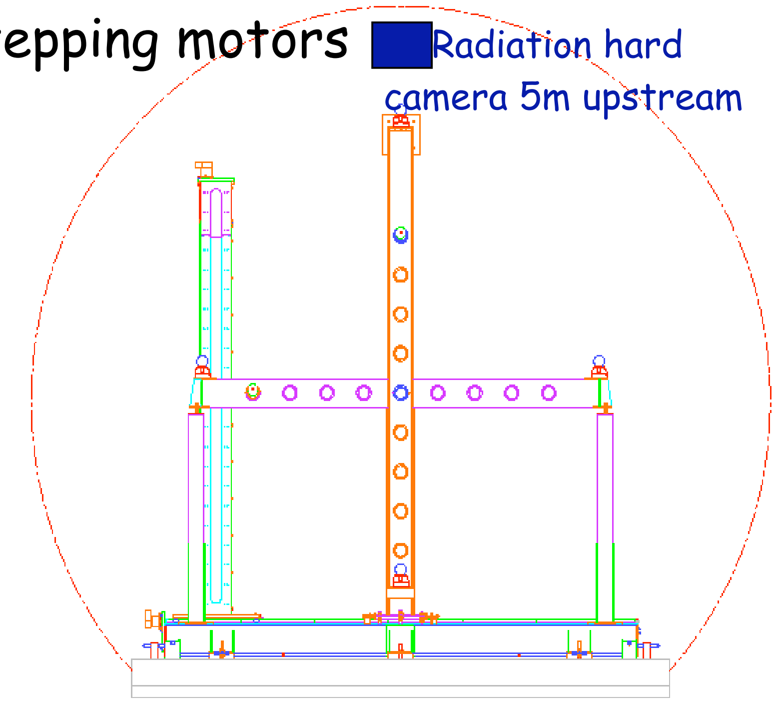
- Parallel electrodes separated by 0.5cm
- Stainless steel cylinder
- Al electrodes
- N_2 gas filling at 1-1.1 bar



Monitor Layout



- 17 fixed monitors mounted on cross shaped structure (Al)
  - Possibility to double number of monitors
- 1 movable chamber behind fixed monitors for relative calibration
- Movement by stepping motors

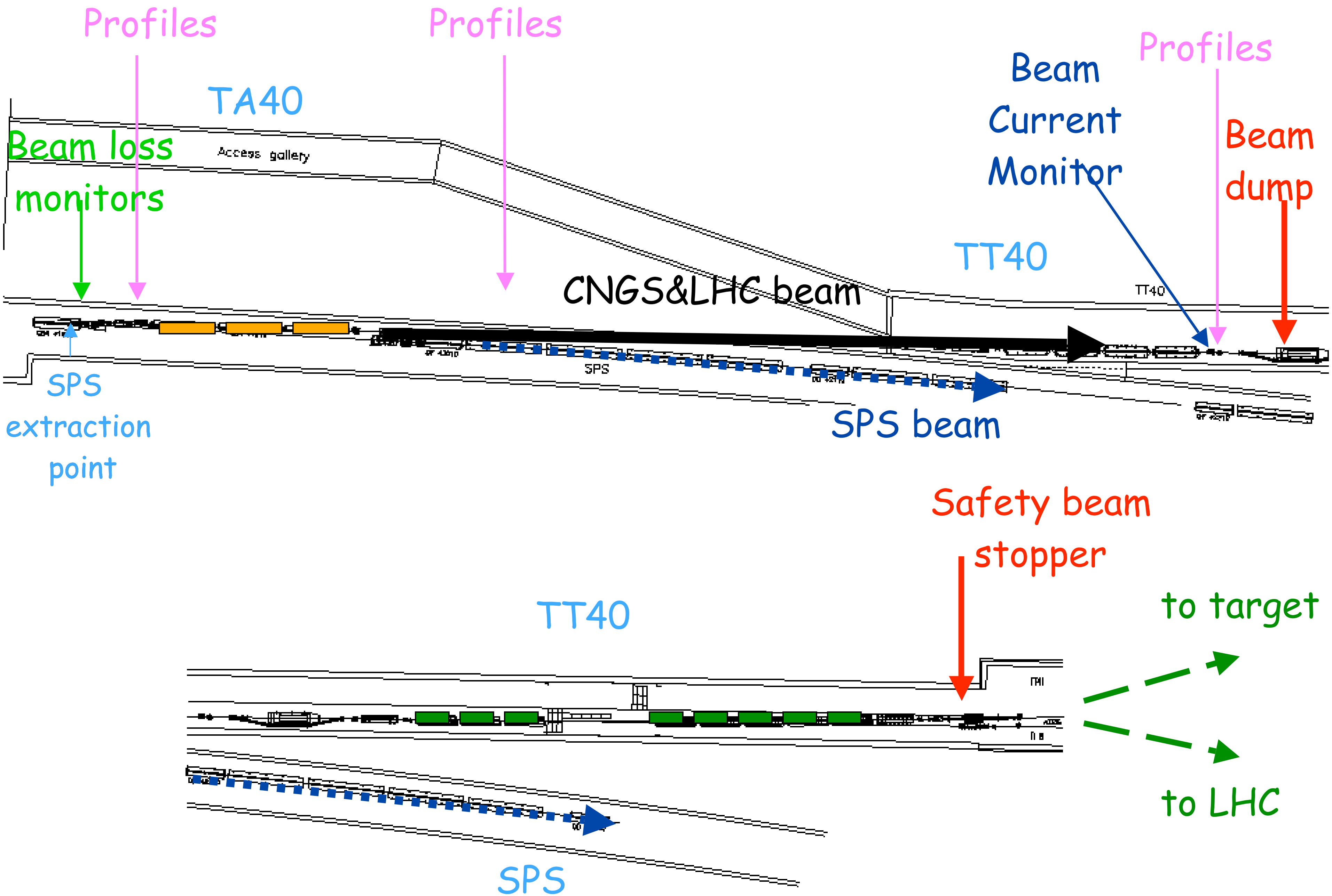


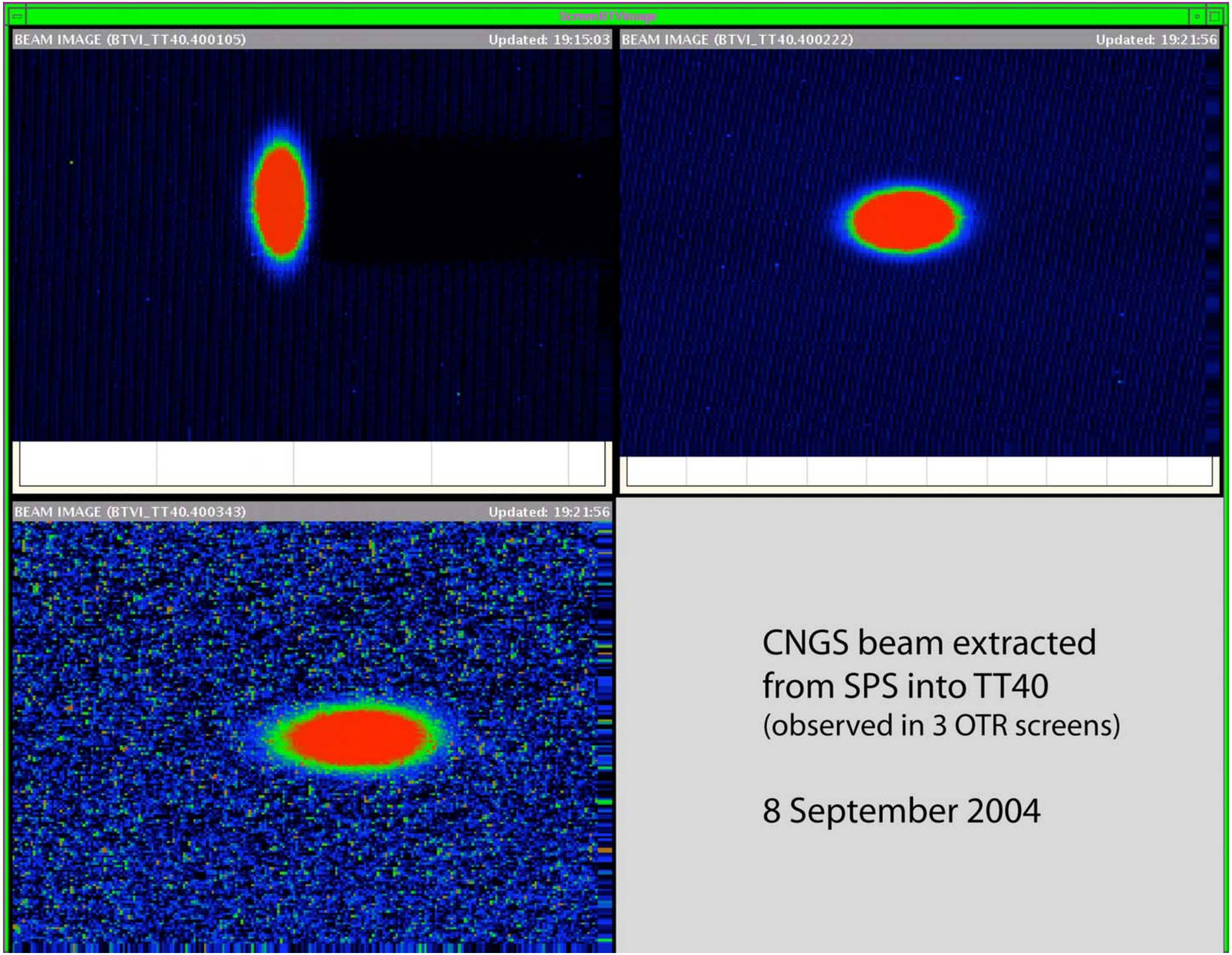
5. Commissioning preparation

First checks of CNGS beam extraction done in September 2004

First and last opportunity to check the CNGS beam extraction before the start up in May 2006

- Tests the extraction channel with CNGS beam and double pulse extraction
- MKE kicker magnets & circulating SPS beam
- BPKG test in air


Profiles
Profiles
Profiles
TA40
Beam loss
monitors
Access gallery
Beam
Current
Monitor
Beam
dump
TT40
CNGS&LHC beam
TT40
SPS
SPS
extraction
point
SPS beam
Safety beam
stopper
to target
TT40
to LHC
SPS



CNGS beam extracted
from SPS into TT40
(observed in 3 OTR screens)

8 September 2004

High intensity test in the SPS

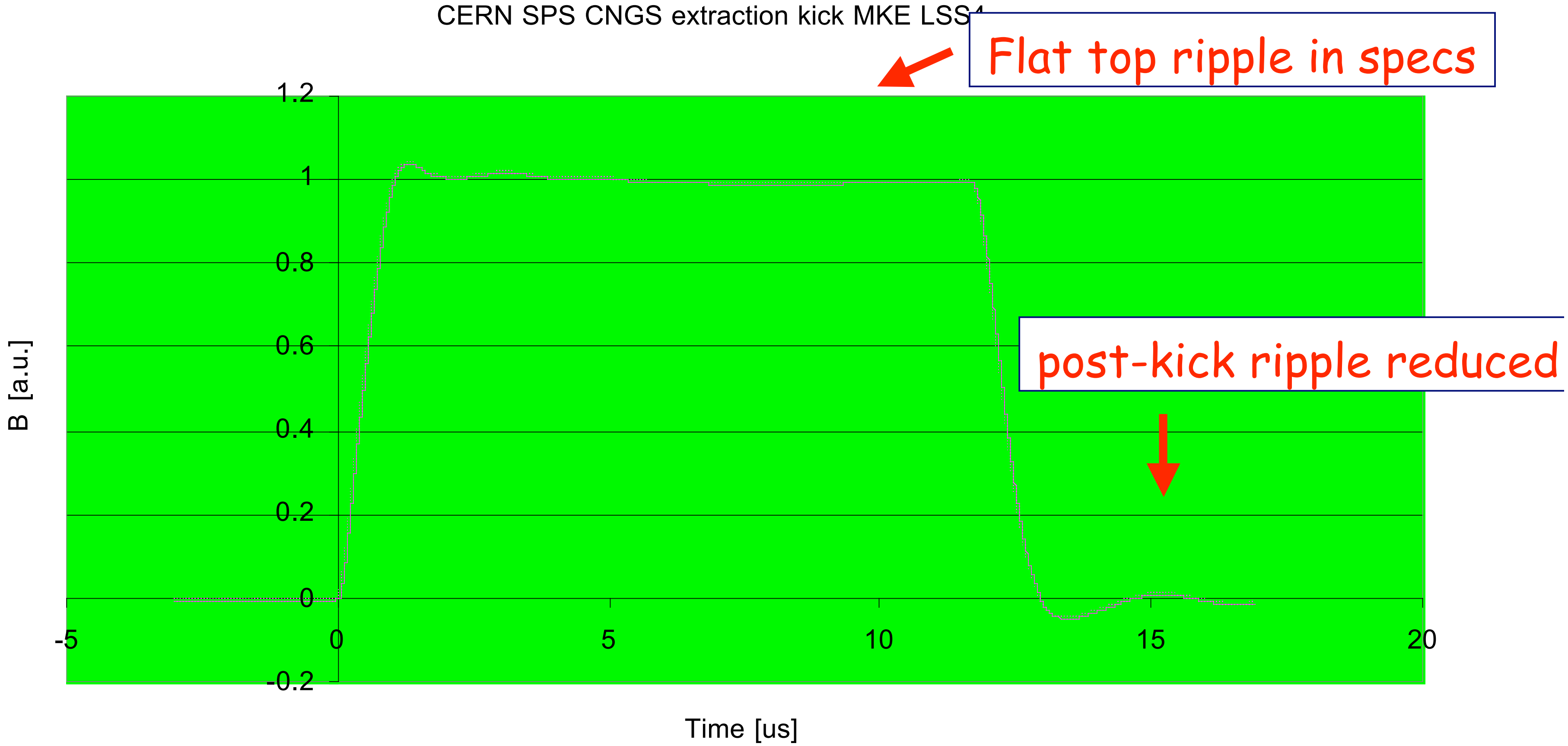
During 2004, high intensity tests allow to reproduce the previous 1996 record in terms of intensity per cycle : 4.8 10^{13} protons, with record value of 5.3 10^{13} protons

Beam losses and induced radiation are the most critical issues for the whole complex (extraction in the PS, low energy losses in the SPS, SPS extraction losses)

Reduction of the beam losses is the operation goal in order to deliver the committed number of protons in a reliable and sustainable way

MKE - extraction kicker, AB/BT

Measured extraction kicker field



Extraction kick pulse parameters

	Requested	Achieved No damper	Achieved with damper
Rise time	1.05 μs	1.05 μs	1.05 μs
Fall time	1.05 μs	1.05 μs	1.05 μs
Usable batch length	2x10.5μs	2x10.4μs	2x 10.5μs
Flat top field ripple	< 2%	< 2%	< 2%
Post kick pulse ripple	< 2%	< 4%	< 2%

Commissioning schedule

- Hardware commissioning Feb. – April 2006

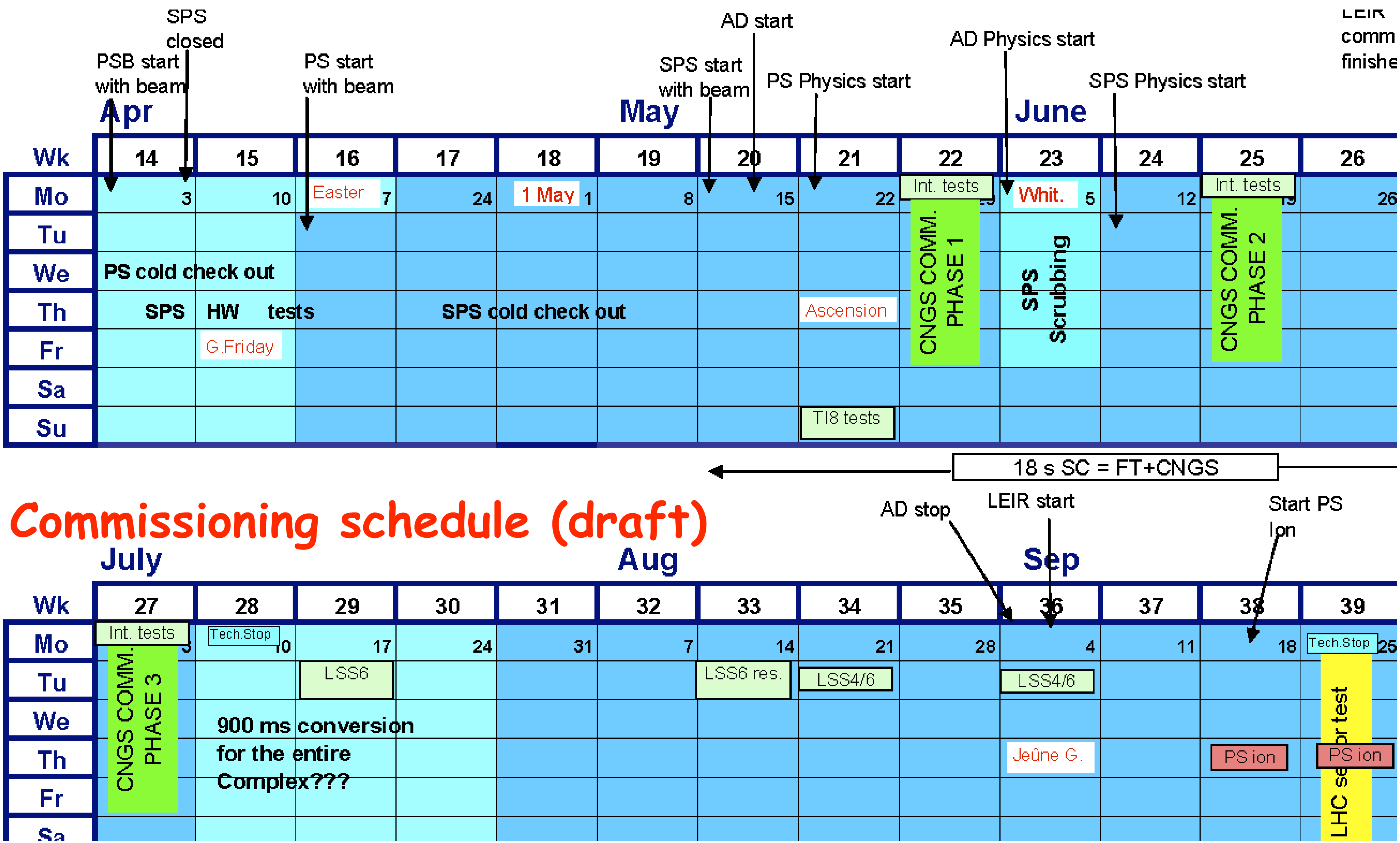
    Beam instrumentations
    Power supplies
    Magnets (polarities)
    Vacuum system

- "Dry runs" April – May 2006

    Timing
    Controls
    Interlocks
    Beam permit
    Magnets (current & polarities)

- Commissioning with beam 2006: weeks 22, 25 and 27

Commissioning schedule (draft)



Week 22 : low intensity, up to target

Week 25 : low to medium intensity, secondary beam

Week 27 : high intensity, full facility

Commissioning team, mandate, list of subjects to be addressed were defined

CNGS COMMISSIONING GOALS

GOAL	PARAMETERS	Beam instrumentation	Commissioning Goal
1	Proton beam parameters on target	Proton beam intensity monitor BFCT412425	Intensity : 2.4 E13 per extraction or maximum available from injectors
		Proton beam profile monitor BTVG412445	Beam sizes : 0.45 mm < $\sigma_{x,y}$ < 0.7 mm for nominal target unit
		Proton beam position monitor at BPKG412449	Proton beam position stability better than +/- 0.5 mm (upper value)
2	Proton beam direction on target	Proton beam positon monitors BPG412424 and BPG412444	Proton beam direction established within better than 0.2mr of the known direction to Gran Sasso detectors
3	Proton beam position along TT41	Proton beam positon monitors along TT41	Trajectory excursion less than +/- 4 mm
5	Muon detector parameters	Muon monitors in TNM41 and TNM42	Intensity per proton and Profile within xx% (TBA by SBWG) of simulated values
6	Proton beam losses	Beam loss monitors	No more than 1E-3 at extraction. None along TT41 beam line
7	Proton beam tails	Proton beam profile monitors	tbd

Commissioning with beam

Step1:

Low intensity : 10^{12} p/extraction, 1 extraction per cycle then 2

High intensity :10^{13} p/extraction, 2 extractions per cycle, few batches

a. Target OUT – Horns OFF – TED IN

b. Target OUT – Horns OFF – **TED OUT**

Setp2: Low intensity : 10^{12} p/extraction, 2 extractions per cycle

c. **Target IN** – Horns OFF – TED OUT

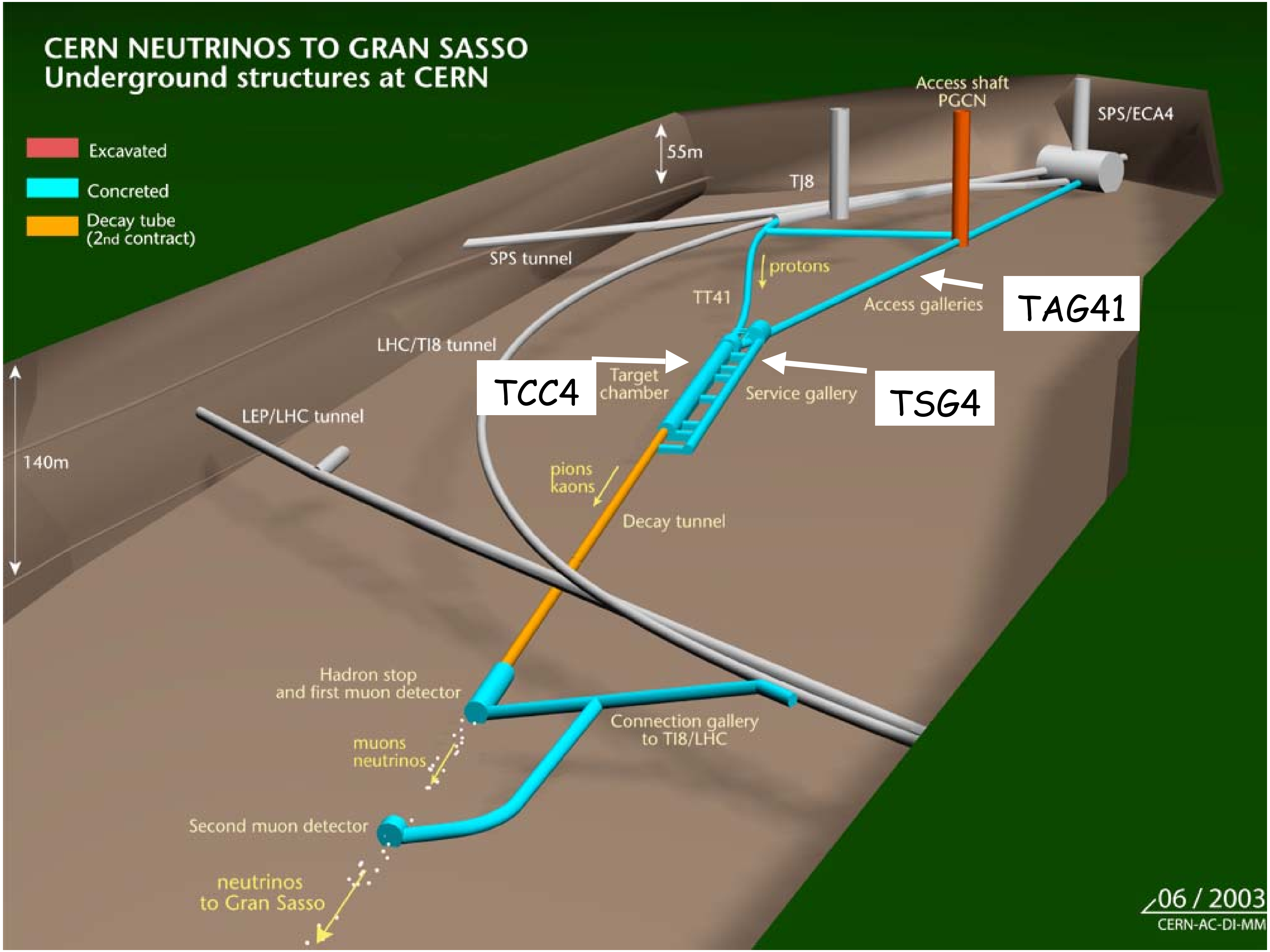
d. Target IN – **Horns ON** – TED OUT

e. Combination of Horn **ON/OFF**, Reflector **ON/OFF**, Horn+Reflector **ON/OFF**

Step: High intensity :10^{13} p/extraction, 2 extractions per cycle:

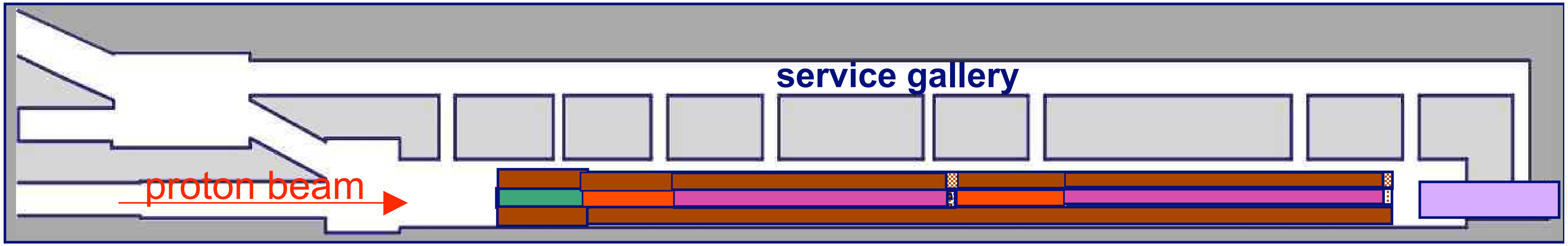
f. All parameters at optimized values, high intensity

6. Outlook


CERN NEUTRINOS TO GRAN SASSO
Underground structures at CERN
Excavated
Concreted
Decay tube
(2nd contract)
55m
TJ8
Access shaft
PGCN
SPS/ECA4
SPS tunnel
protons
TT41
Access galleries
TAG41
LHC/TI8 tunnel
TCC4
Target
chamber
Service gallery
TSG4
LEP/LHC tunnel
140m
pions
kaons
Decay tunnel
Hadron stop
and first muon detector
Connection gallery
to TI8/LHC
muons
neutrinos
Second muon detector
neutrinos
to Gran Sasso
06 / 2003
CERN-AC-DI-MM

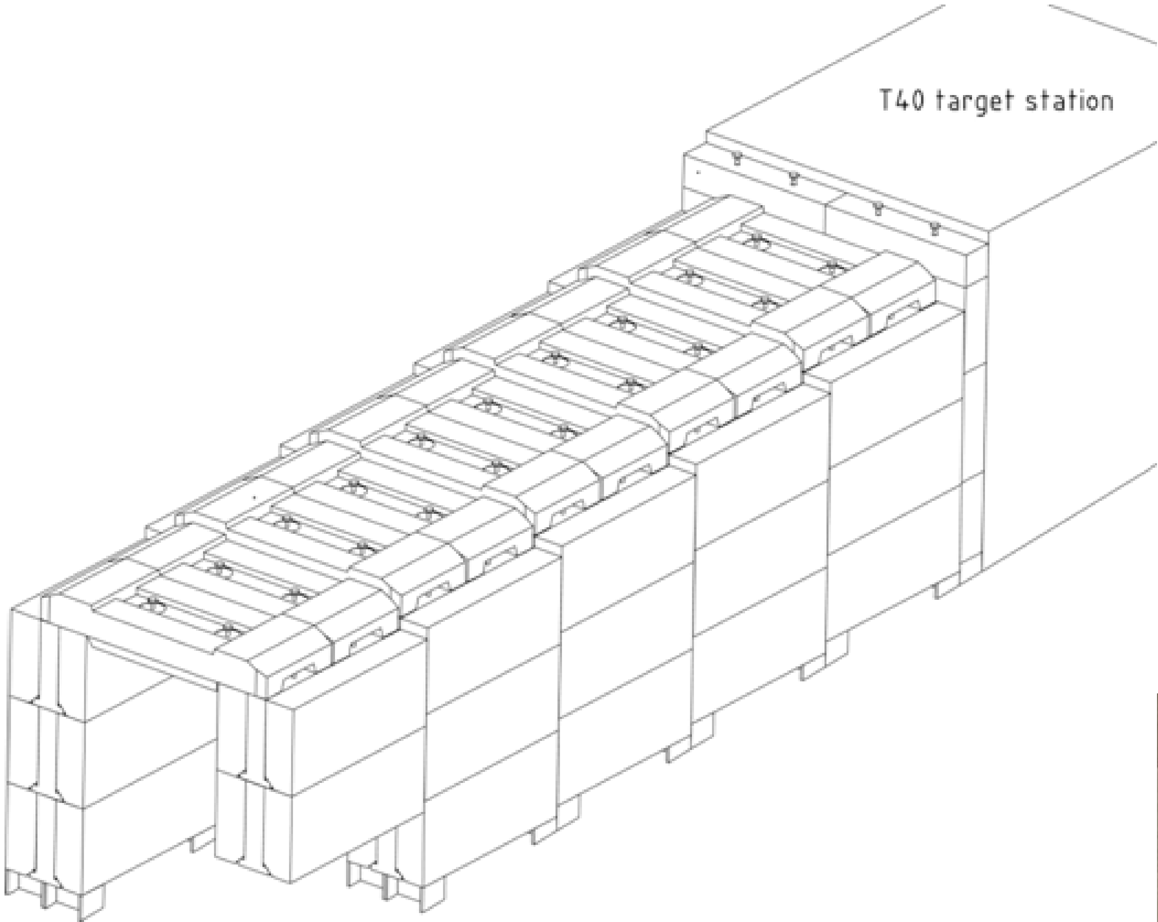

TAG41 Access Gallery

Target Chamber: Shielding



Target chamber July 2004

Target chamber August 2005



23 August 2005

Target Chamber: Helium Tanks

Alu Helium tube sleeve

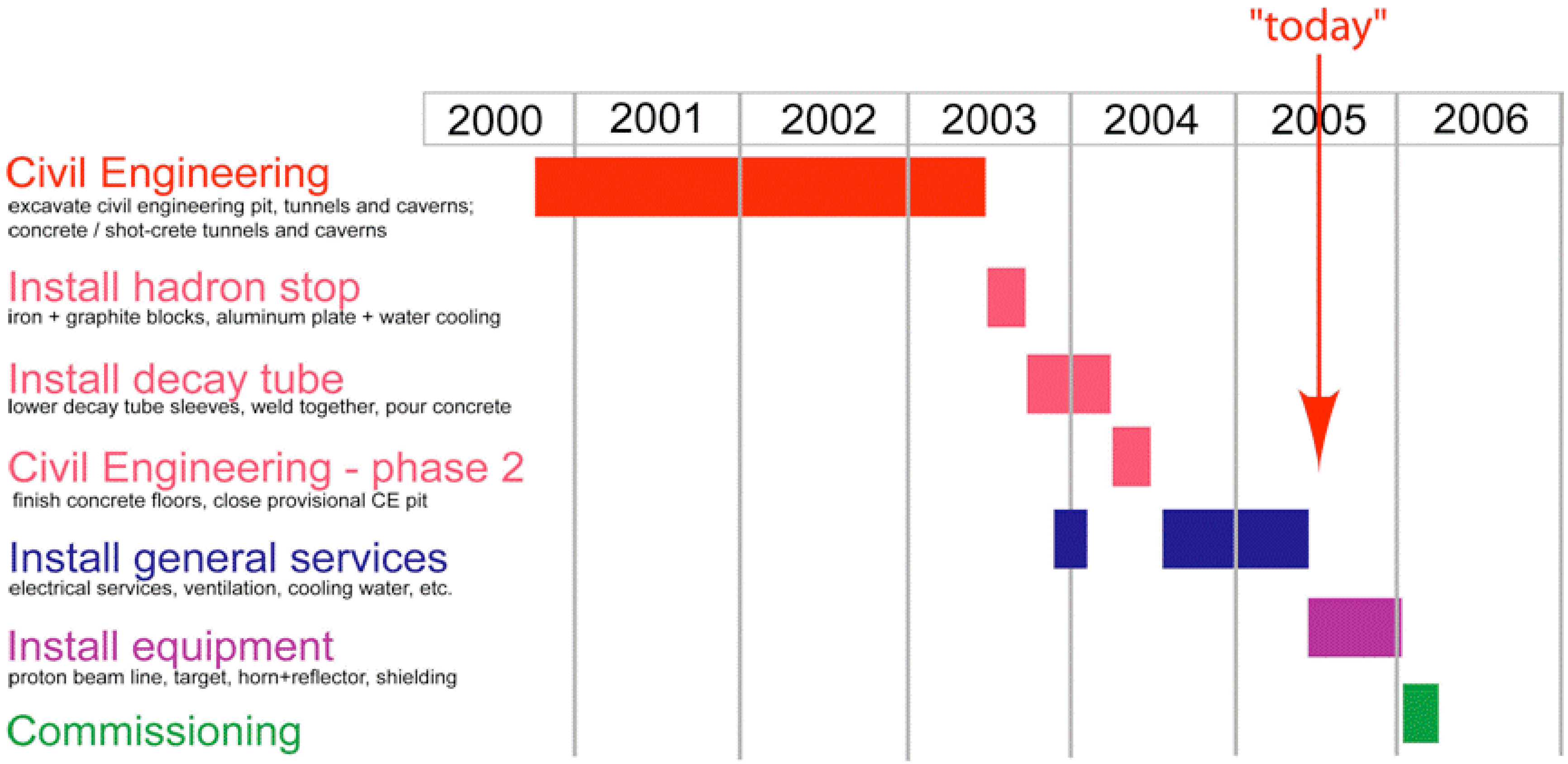
20 July 2005:
last element
of He tube
installed

23 August 2005

23 August 2005

TSG4 Service Gallery

CNGS schedule



First beam to Gran Sasso*: May 2006

* pending details in SPS schedule for 2006

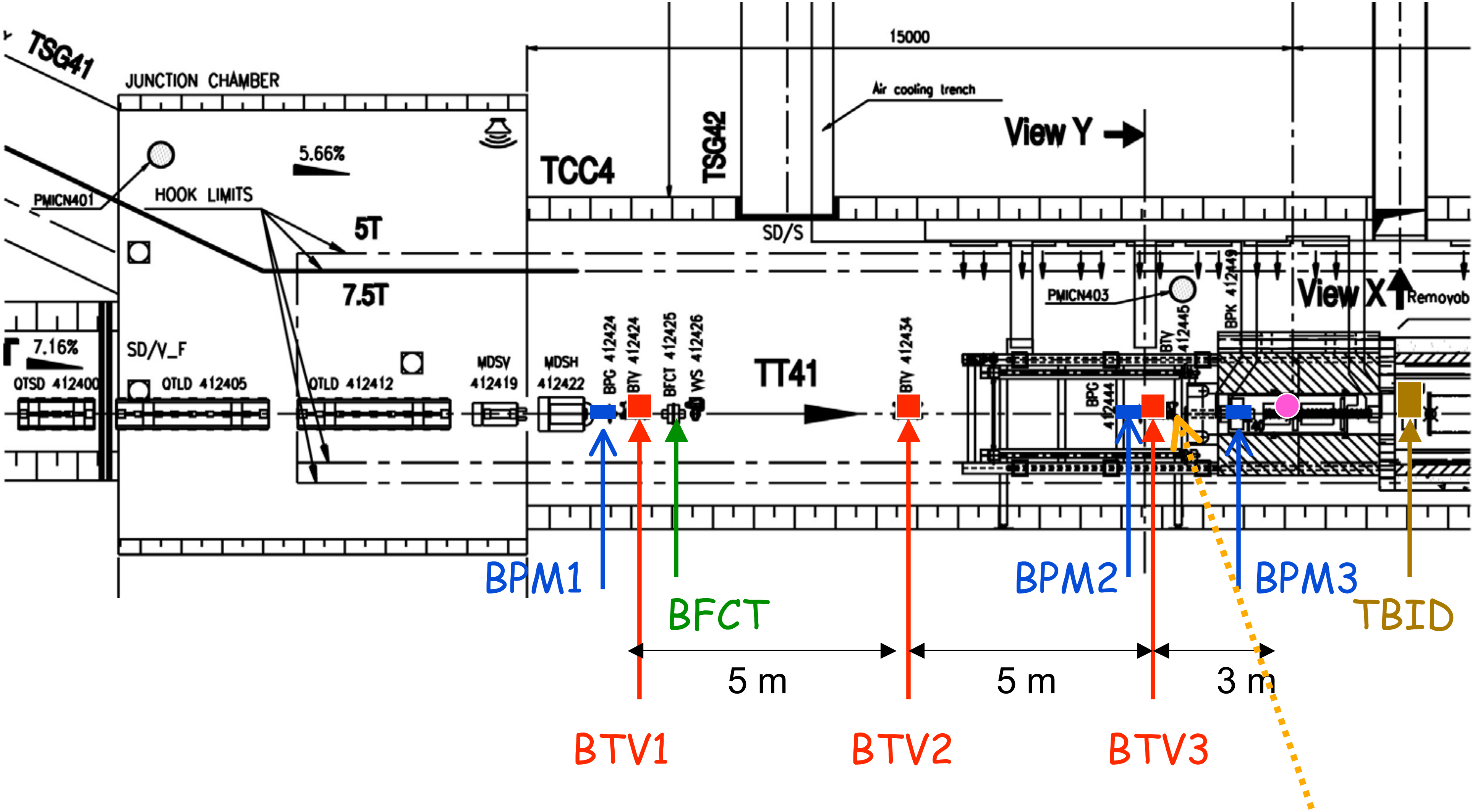
Summary

-> Procurement of last equipment is being complete

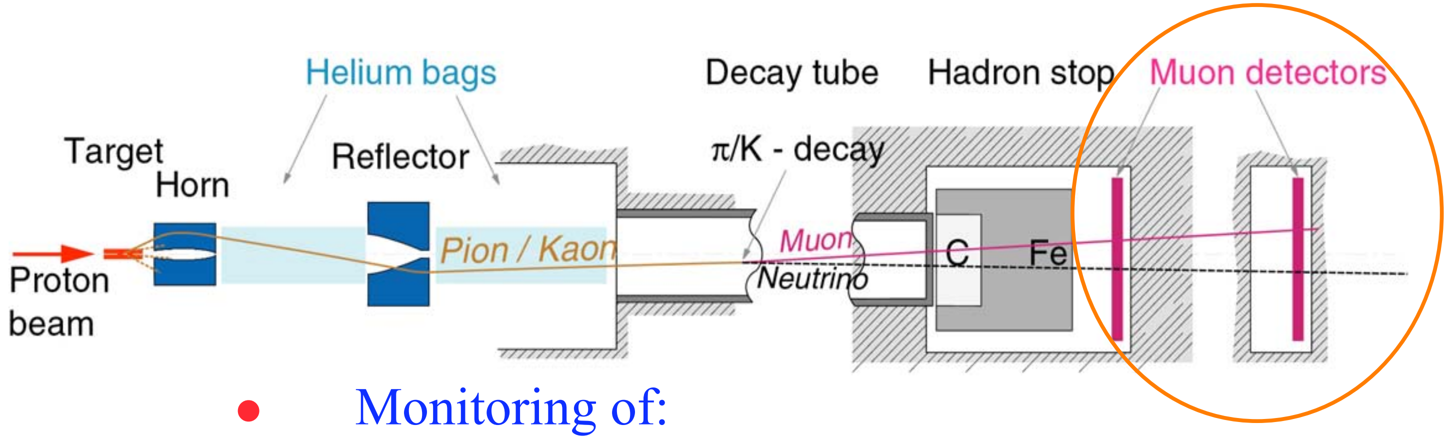
-> Installation is well underway

-> Commissioning with beam:
to start week 22 (29 May 2006)

-> CNGS beam operational after week 27 (July 2006)


TSG41
JUNCTION CHAMBER
PMICN401
HOOK LIMITS
5.66%
5T
7.5T
TCC4
TSG42
SD/S
15000
Air cooling trench
View Y
PMICN403
View X
7.16%
SD/V_F
QTSD 412400
QTLD 412405
QTLD 412412
MDSV 412419
MDSH 412422
BPG 412424
BTV 412424
BFCT 412425
WS 412426
TT41
BTV 412434
BPG 412444
BTV 412445
BPK 412449
BPM1
BFCT
BPM2
BPM3
TBID
5 m
5 m
3 m
BTV1
BTV2
BTV3
2 BLMs

Muon Monitors

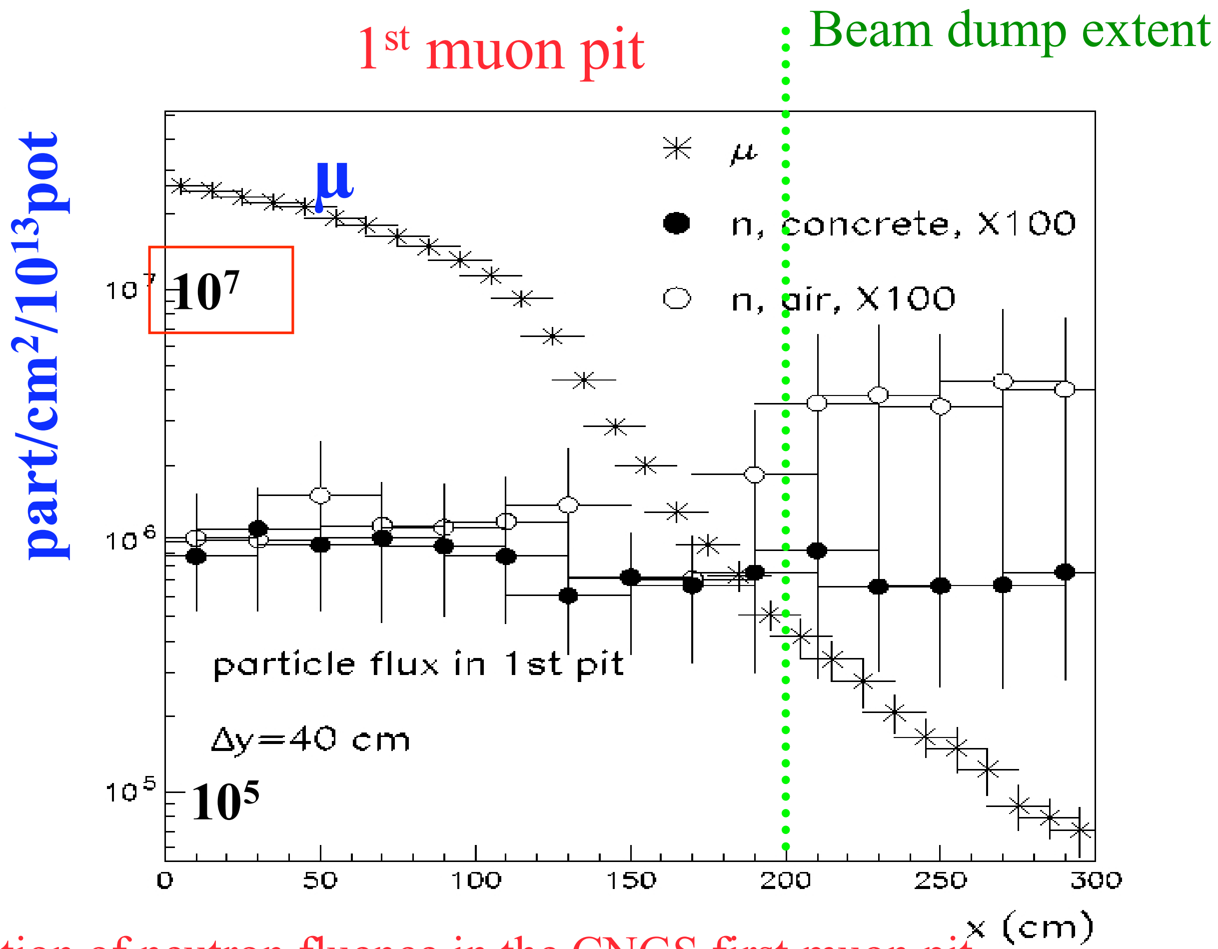


- Monitoring of:
  - ➔ muon intensity
  - ➔ muon beam profile shape
  - ➔ muon beam profile centre
- Muon intensity:
  - ➔ Up to 7.7×10^{7} per cm^{2} and 10.5 µs
- Dynamic range: 10^{5}
- Accuracies:
  - ➔ absolute 10 %
  - ➔ relative 3 %
  - ➔ reproducibility: cycle to cycle 1%, one year 5%

Muon Monitors

Muon Profiles in Pit 1

FLUKA simulations



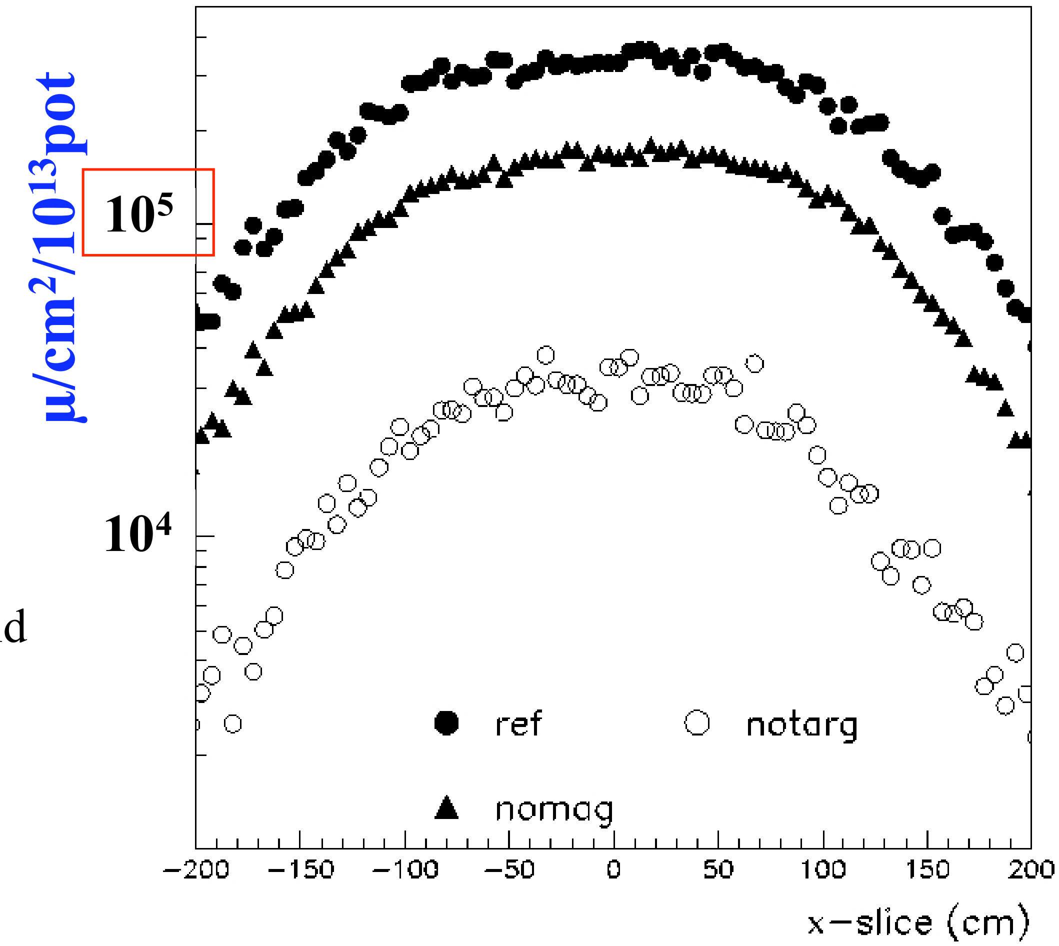
An updated calculation of neutron fluence in the CNGS first muon pit, A. Ferrari, A. Guglielmi, P.R. Sala

Muon Monitors

Muon Profiles in Pit 2

FLUKA simulations
(P. Sala, not published)

2^{nd} muon pit



_ target in, magnetic field
▲ target in, no magnetic field
○ no target

Muon Information from Gran Sasso

- With sufficient beam intensity
  - ➔ measure muons from _ interactions in Gran Sasso rock
  - ➔ later: receive time stamp of muons

- Expected muon fluence for the nominal CNGS beam intensity (FLUKA)
  - ➔ **43.6μ/m^2/10^{19} pot**
  - ➔ **0.98μ/m^2/day or**
  - ➔ **196μ/m^2/y**

  - ➔ Muon spectrum peaks at low energies: <p> = **16.2GeV/c.**