CNGS Project: Status report

OUTLINE

1. Project Overview
2. Civil Engineering work
3. Proton beam line studies
4. Equipment design, procurement and installation progress
5. Outlook

1. Project Overview

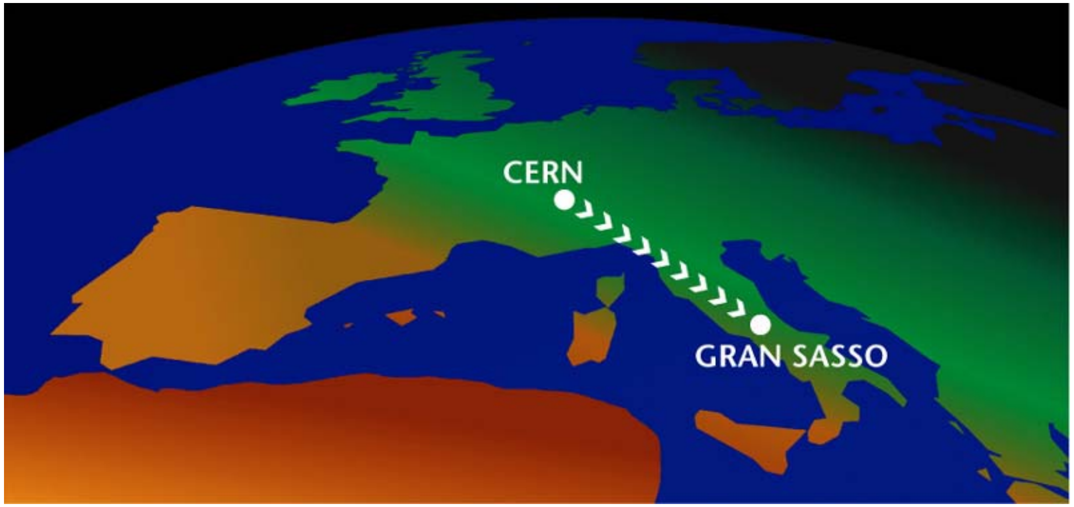
(see http://cern.ch/cngs)

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

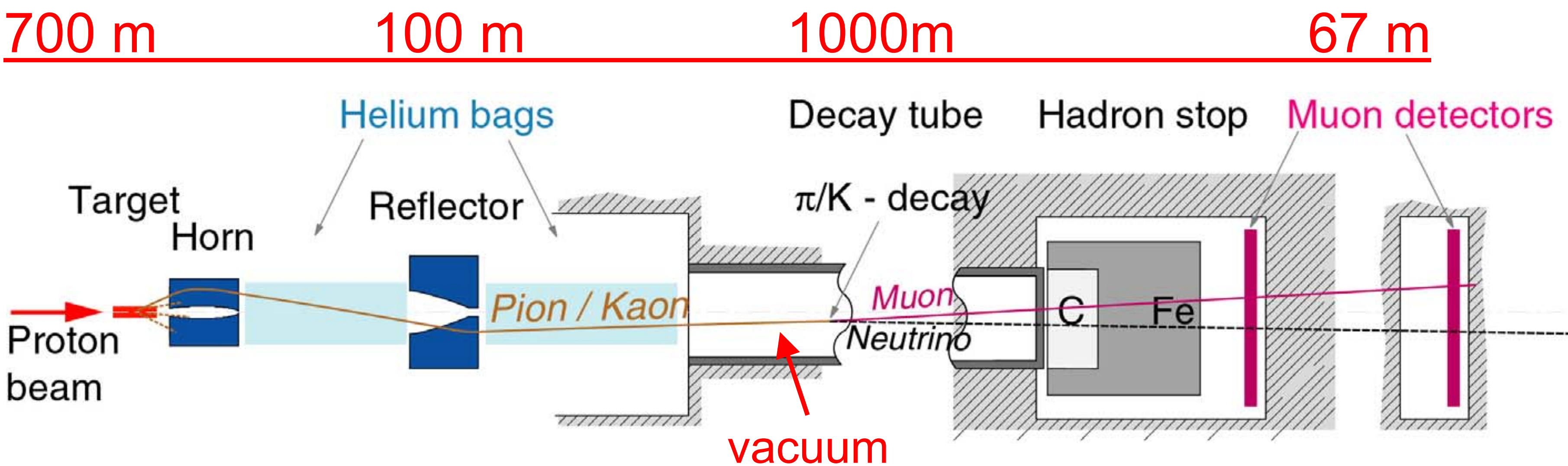
using protons from the existing accelerator chain



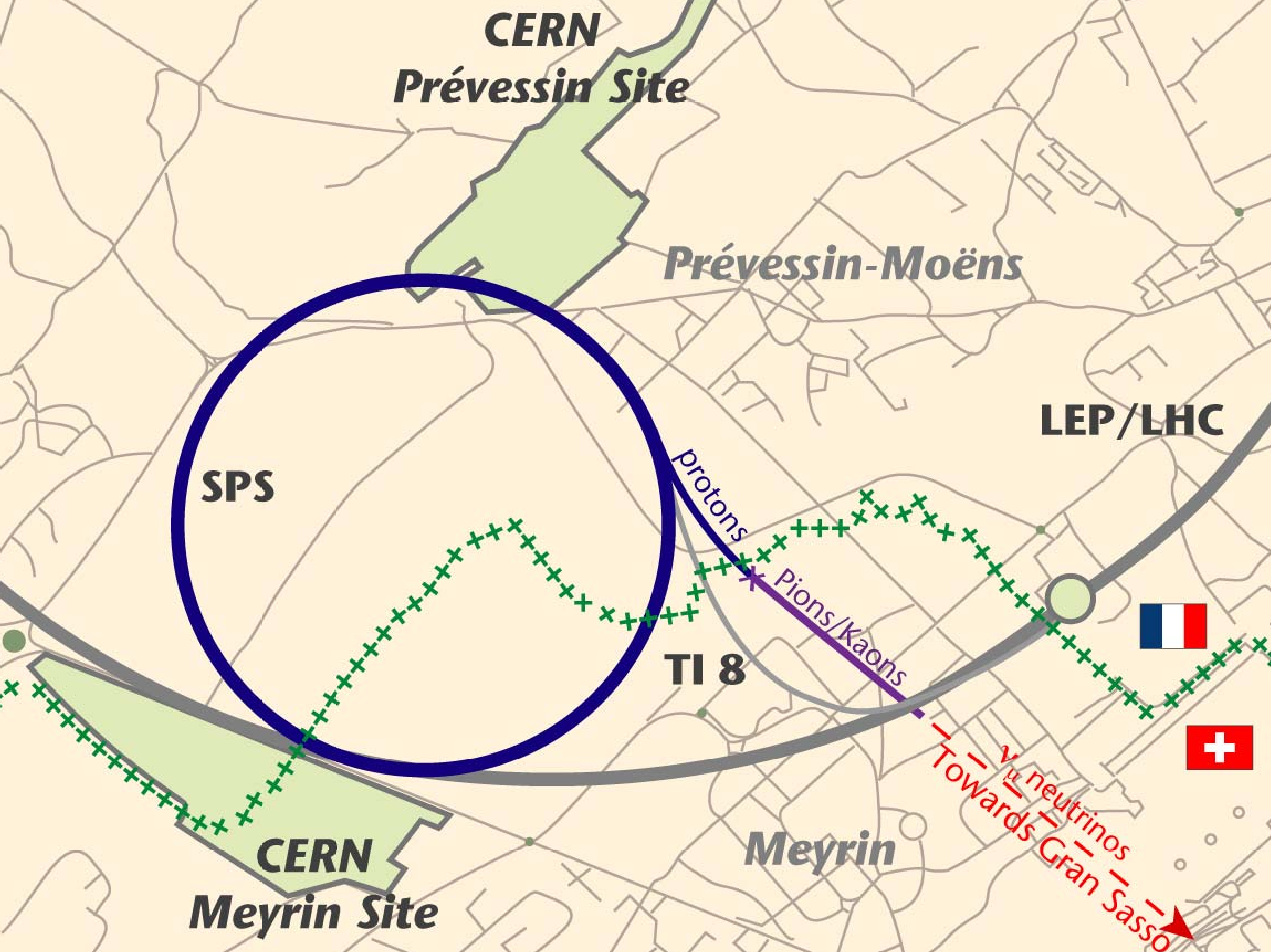
ICARUS

OPERA

CNGS: the main components

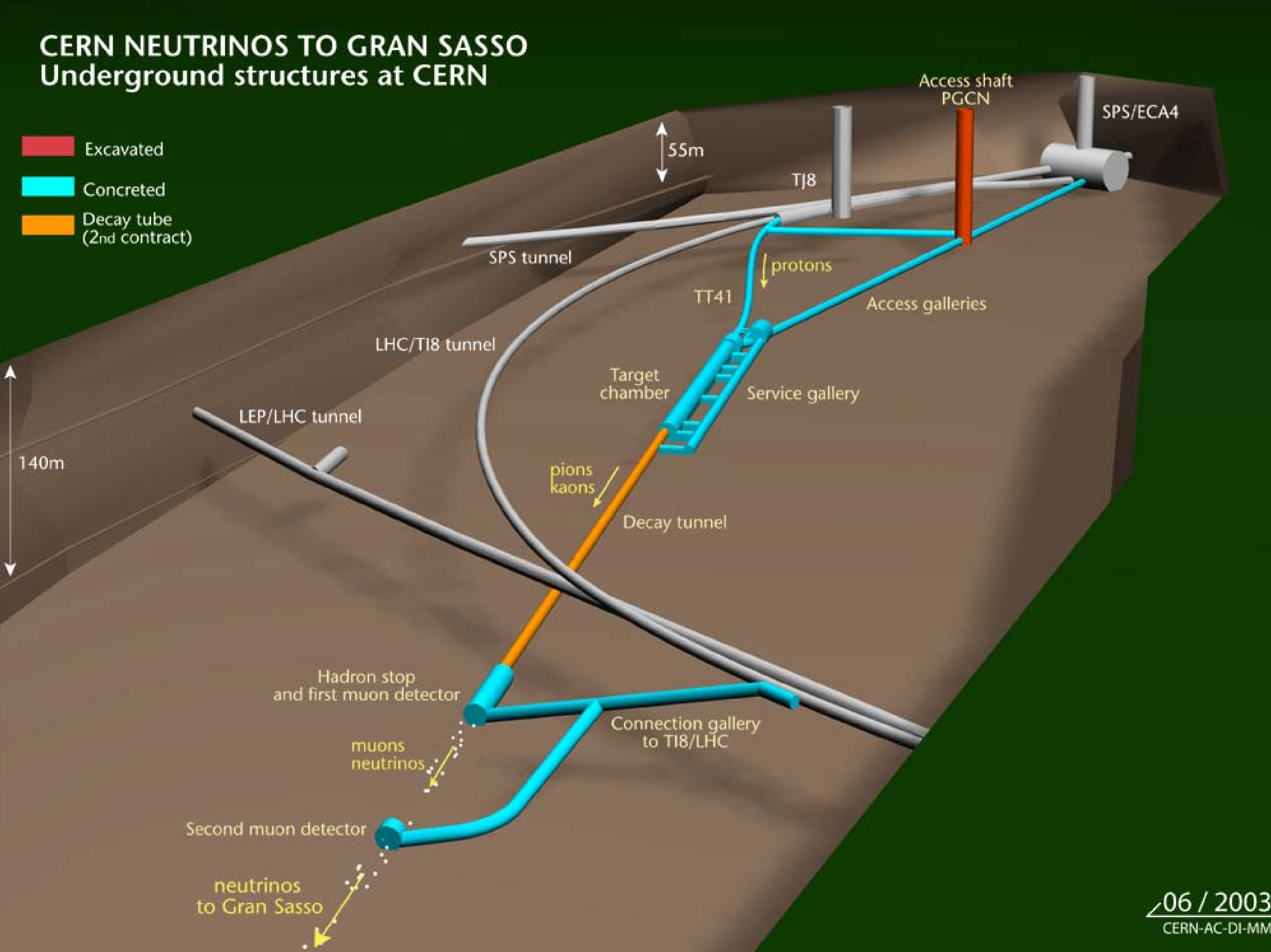


p + C → (interactions) → π^+, K^+, (μ^+) → (decay in flight) → $\mu^+ + \nu_\mu$


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

2. Civil Engineering work

Under the responsibility of N. Lopez, TS/CE


CERN NEUTRINOS TO GRAN SASSO
Underground structures at CERN
Excavated
Concreted
Decay tube
(2nd contract)
55m
Access shaft
PGCN
SPS/ECA4
TJ8
SPS tunnel
protons
TT41
Access galleries
LHC/TI8 tunnel
Target
chamber
Service gallery
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

Proton beam tunnel – April 2003


Target Chamber, June 2003

survey of tunnels (TS-SU):

106 survey points sealed in all of CNGS

- all points measured in vertical plane (altimetry)
  (2mm absolute accuracy)

- 2/3 of all points measured in XY plane
  (5mm absolute accuracy)

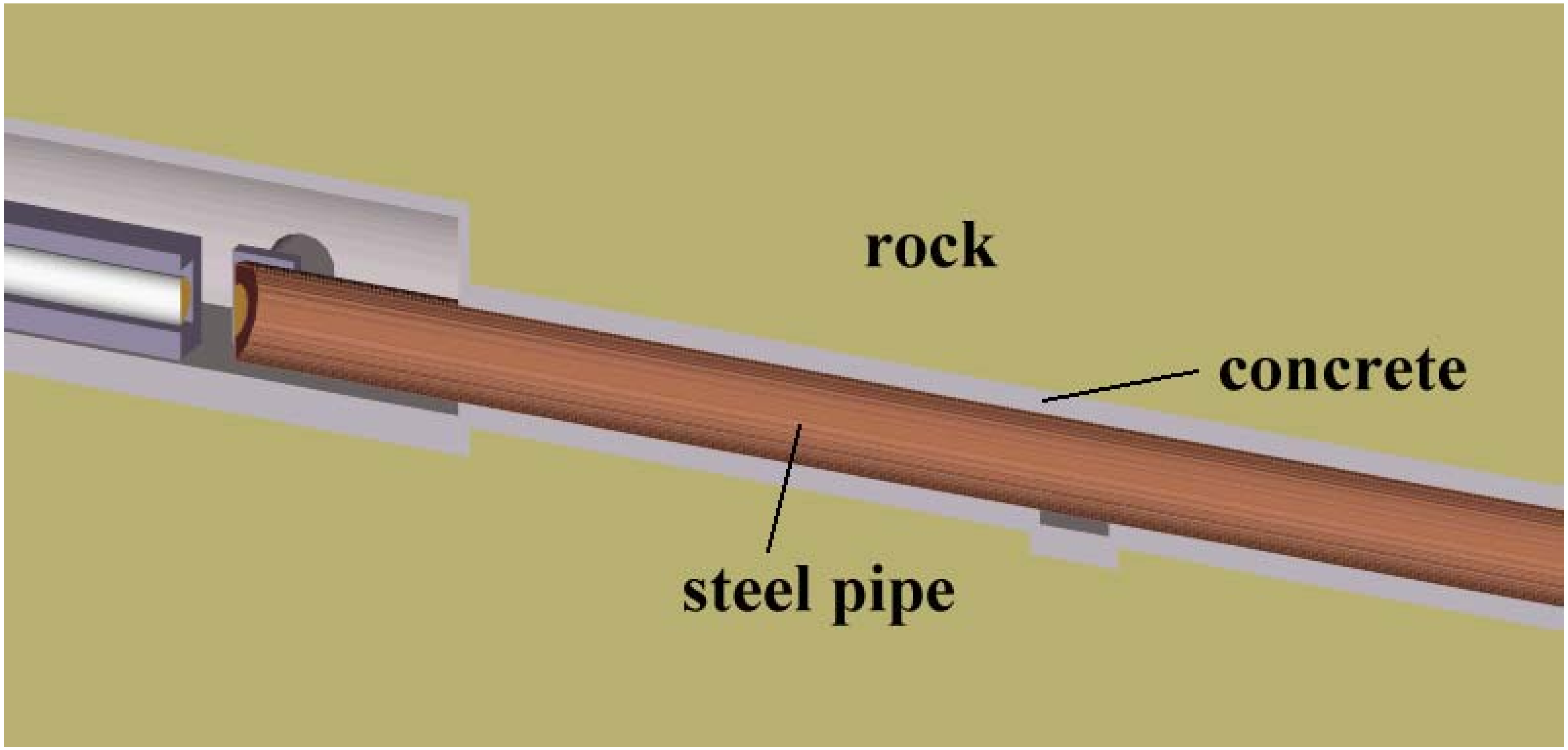
Pointing accuracy to Gran Sasso from CERN surveyors : < 50m
Beam size at Gran Sasso: 1 σ about 1km

M. Chambardon
D. Missiaen

Decay tube

TS seminar on 21st April 2004
by Natacha Lopez

CNGS Decay tunnel



998 m long, evacuated 1-2 Torr
2.45 m diameter
18 mm thick

Steel sleeves of 6m to target chamber
18m steel sleeves down the decay tunnel

decay tube sleeves fully produced, keep arriving

target chamber: assembling the 18m long section


Welding inside decay tube

Inside decay tube
View towards hadron stop

Decay tube outlook:

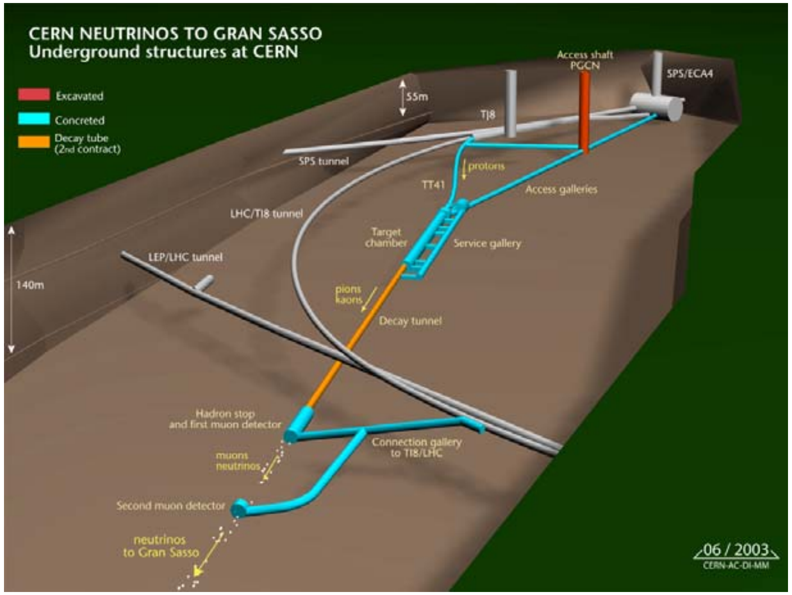
11 Feb. 2004: 57% completed – 576 metres installed.
Alignment re-checked by TS/SU

Decay tube installation expected end: mid-March 2004
-> followed by vacuum tests (by the contractor)

What's next for the Civil Engineering ?

Last civil engineering phase: May –July 2004

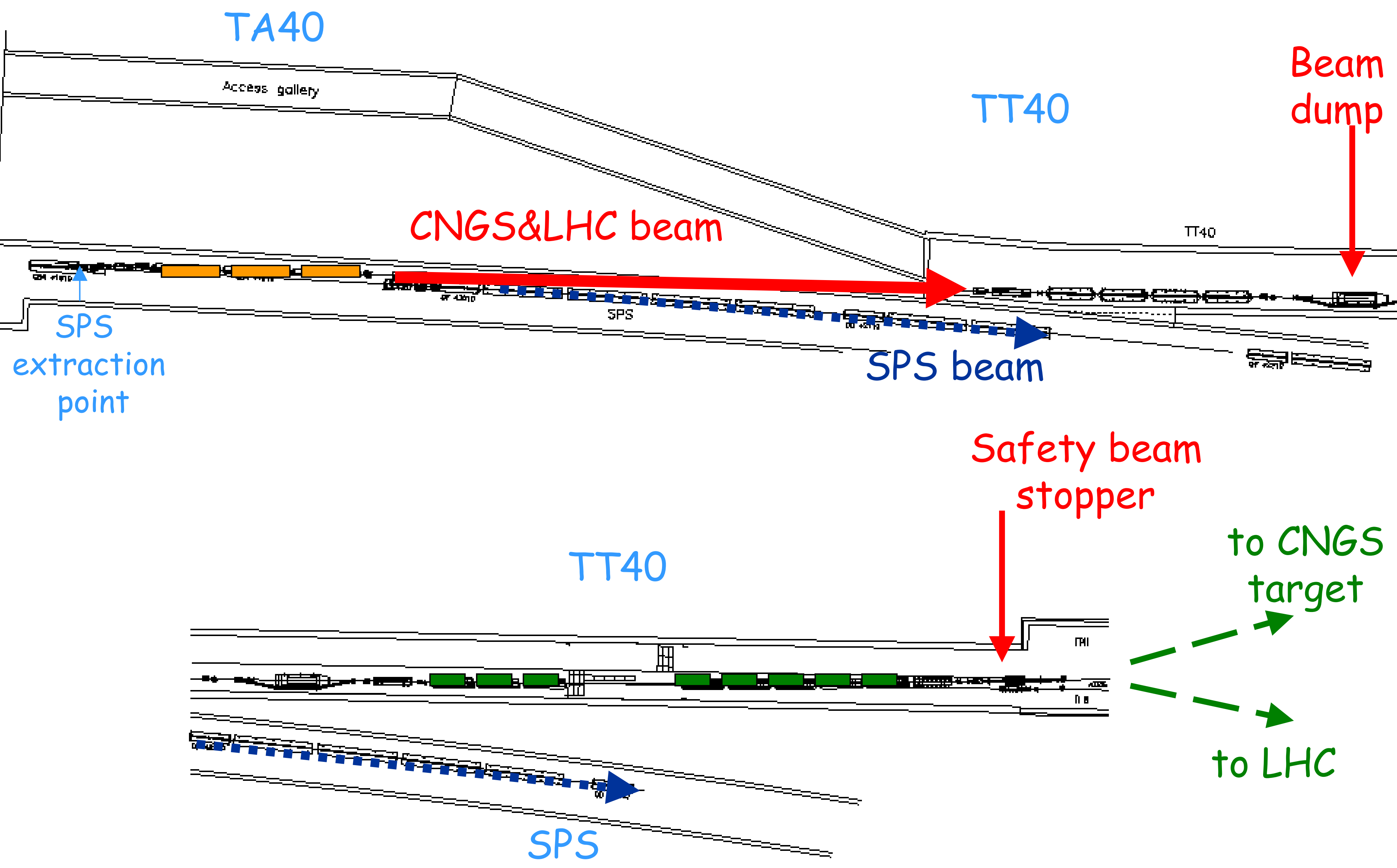
- finishing concrete floors,
- closing off the PGCN pit,
- various minor work



3. Proton beam line studies

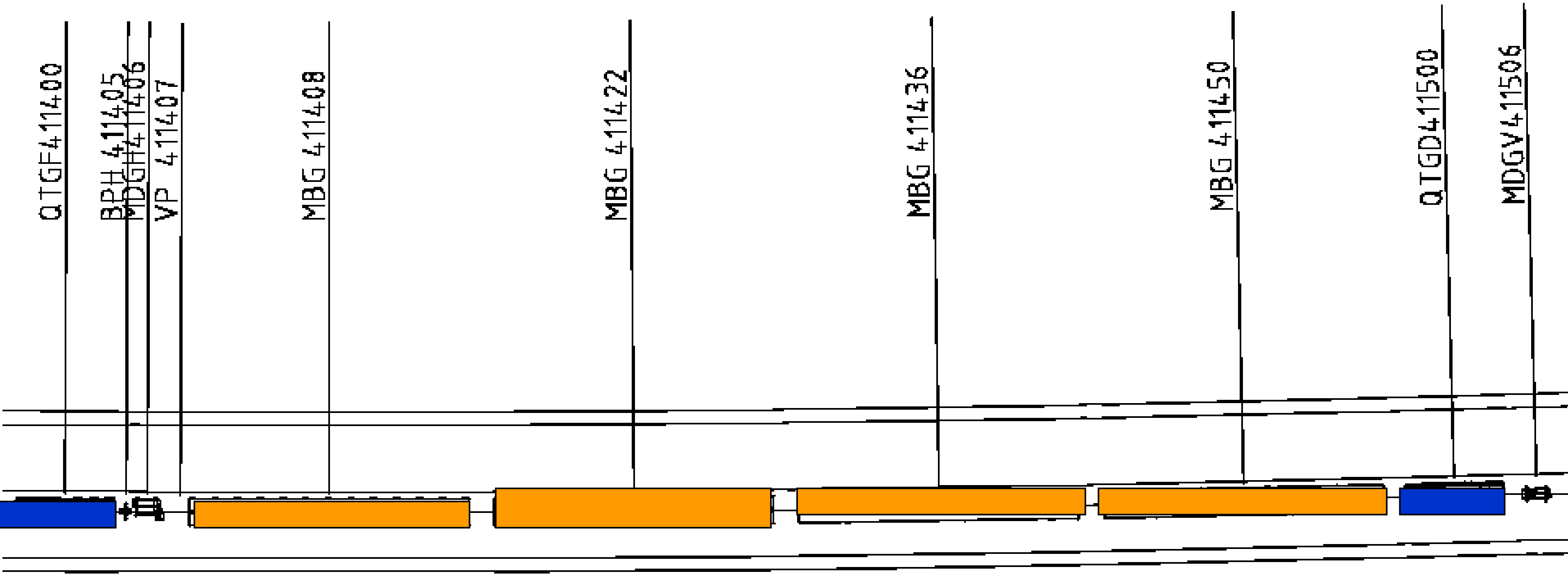
- Layout
- Parameters
- Optics
- Trajectory correction scheme
- Beam stability

Collaboration with W. Herr, AB/ABP

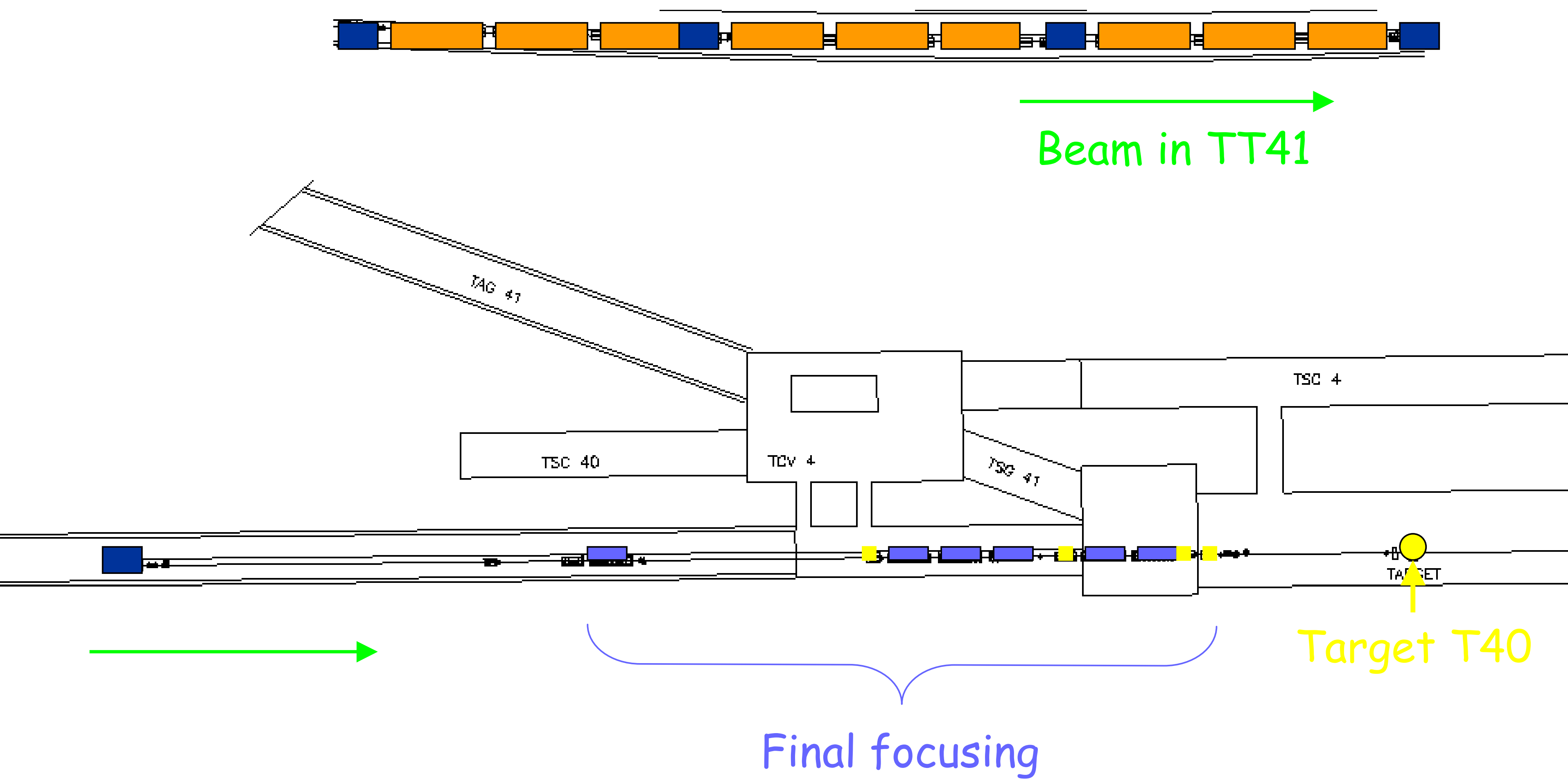


TA40
Access gallery
TT40
Beam dump
CNGS&LHC beam
TT40
SPS
SPS extraction point
SPS beam
Safety beam stopper
TT40
to CNGS target
to LHC
SPS

Transfer line layout: half cell



Last 200m

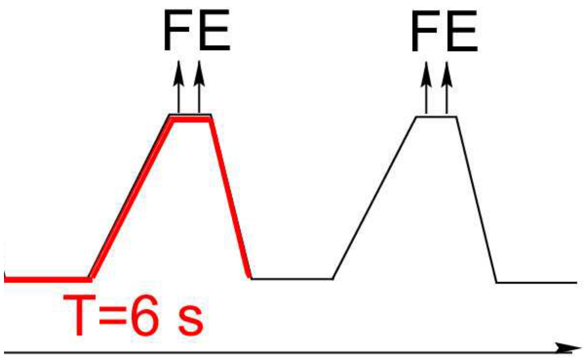


Beam in TT41
TAG 41
TSC 40
TCV 4
TSG 41
TSC 4
Target T40
Final focusing

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] (4σ)	2
Bunch spacing [ns]	5

Upgrade phase: 3.5 10^{13} p



Expected number of protons delivered on CNGS target:

For 1 year of CNGS operation (200 days):

4.5×10^{19} protons on target / year ("nominal")

based on 1998 performance:
4.8×10^{13} protons in SPS, 55% overall efficiency;
(+ mixed cycles with LHC and other fixed target experiments)

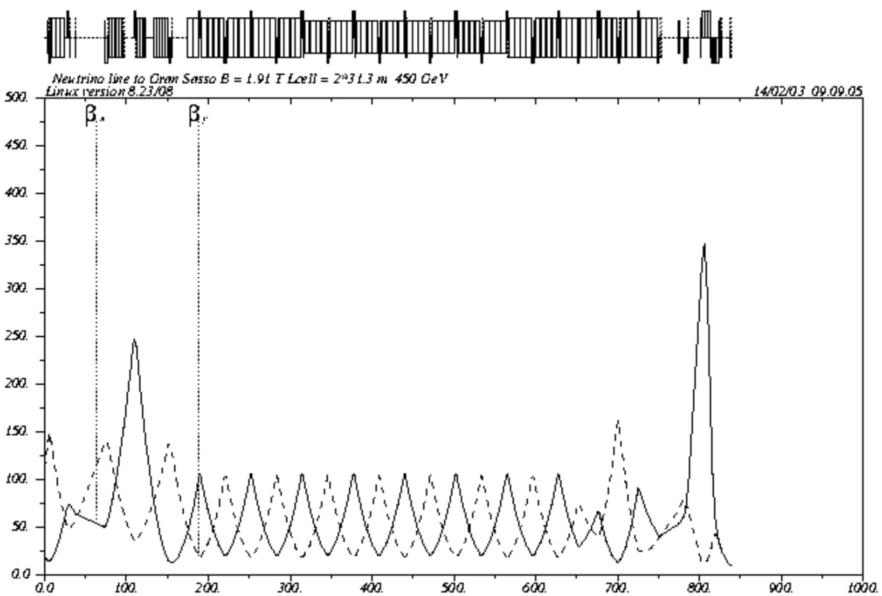
higher proton intensities (very much requested by OPERA and ICARUS):

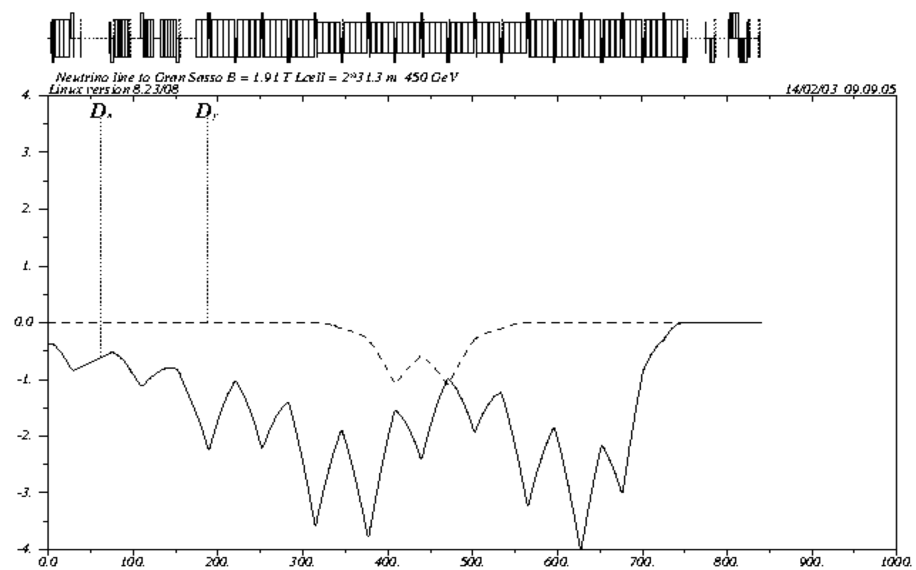
High Intensity Protons Working Group	AB/RF
Machine studies	AB/ABP

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 mrad

Possible to increase beam size to 0.7





Trajectory correction scheme

AIM:

- Is the proposed scheme sufficient?
- Can we save some correctors or monitors?
- What happens if something goes wrong (w.r.t. faulty correctors or monitors)

Took into account:

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

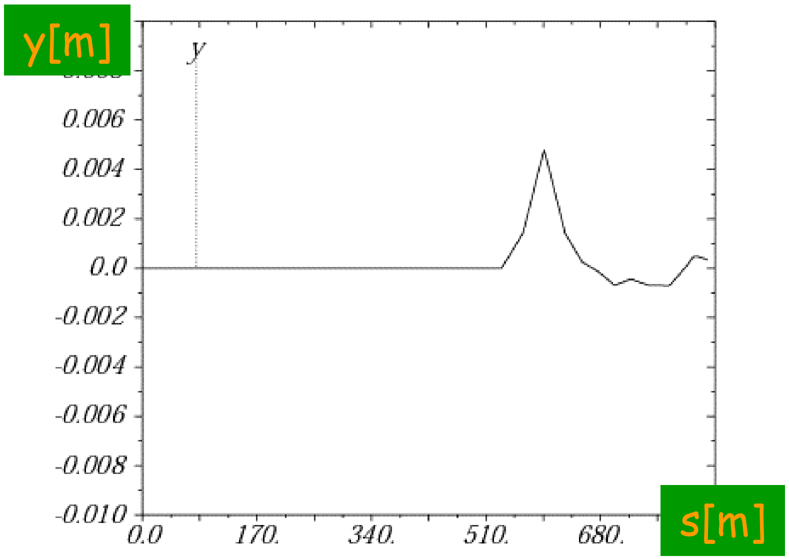
Trajectory correction scheme

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

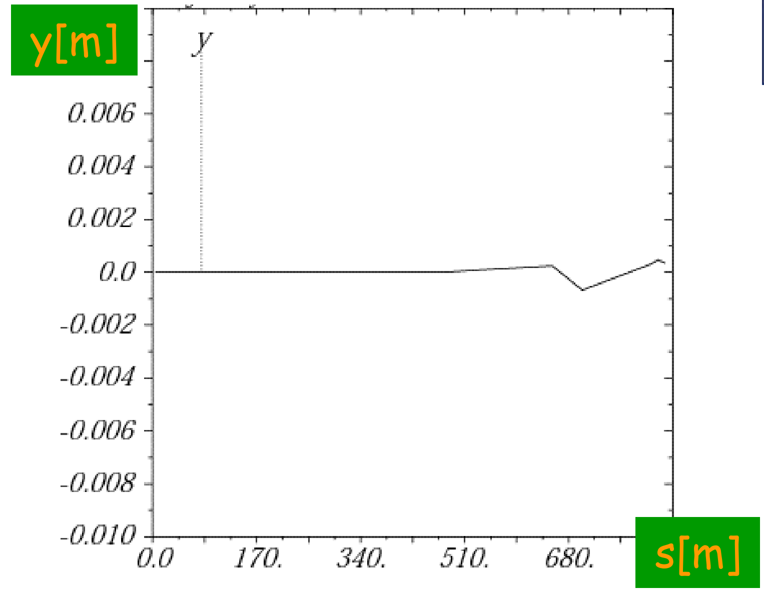
Phase advance per cell: $\pi/2$

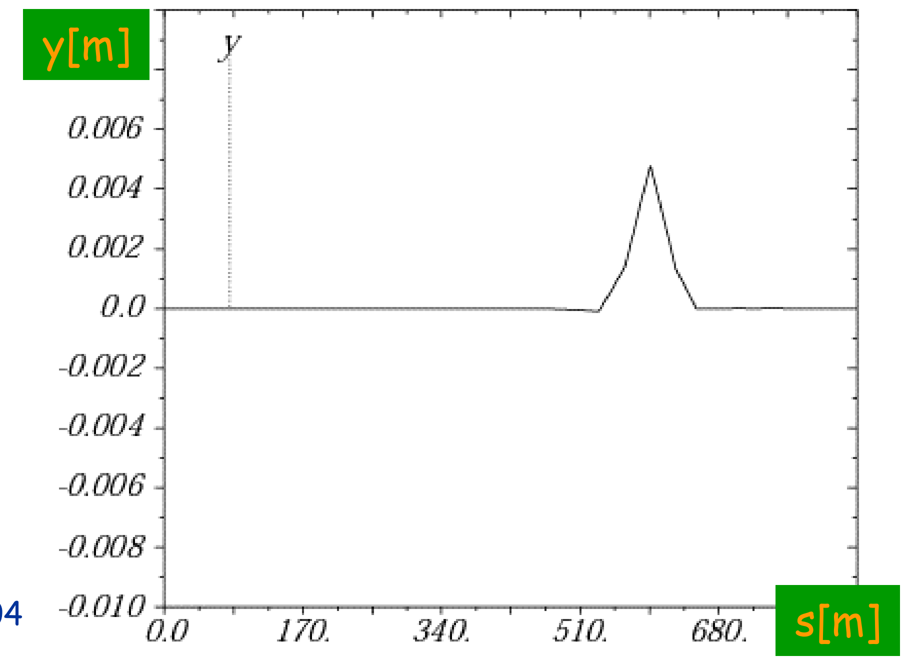
Produce π bumps which may not be visible as the trajectory is heavily under-sampled.
Problem worse when some BPMs are malfunctioning

Vertical bump along beam line



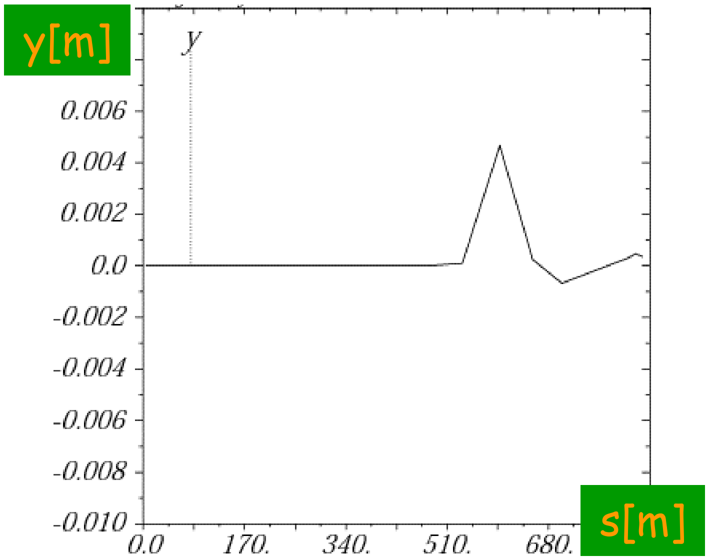
Vertical bump as seen on BPMs



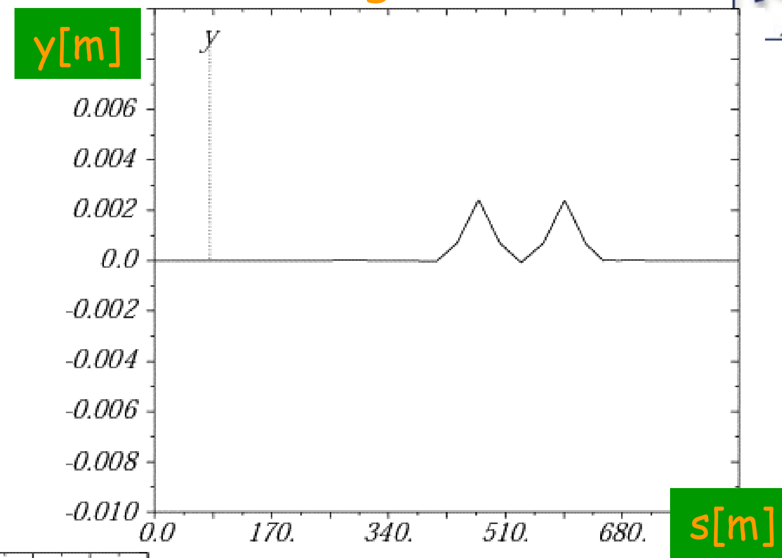


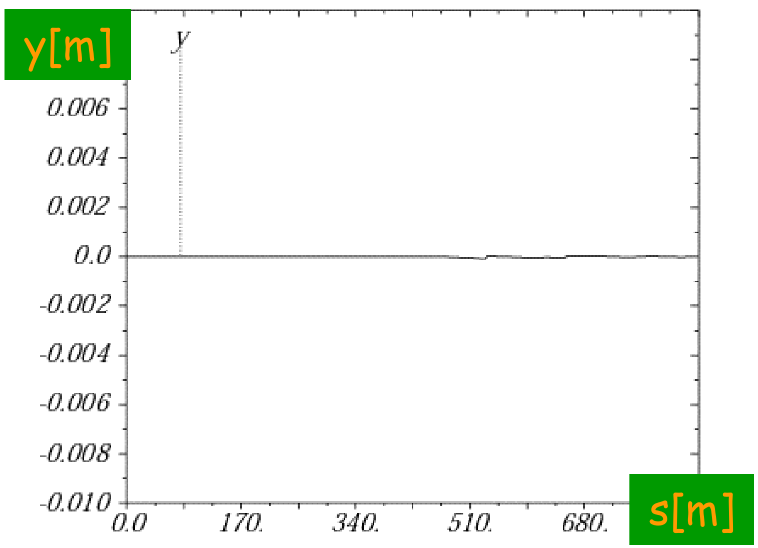
Vertical bump after correction along beam line

Vertical bump before correction
as seen on BPMS (+ 1 BPM)



Same, after correction
along beam line





Same, after correction
with additional corrector

- Reading of the positions in both planes (X, Y) for all BPMs

Trajectory correction scheme

	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 proposed correction scheme is sufficient

Beam stability at the target

AIM:

Investigate the beam spot stability at the target
→ Target resistance to non-centered beam

Took into account:

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

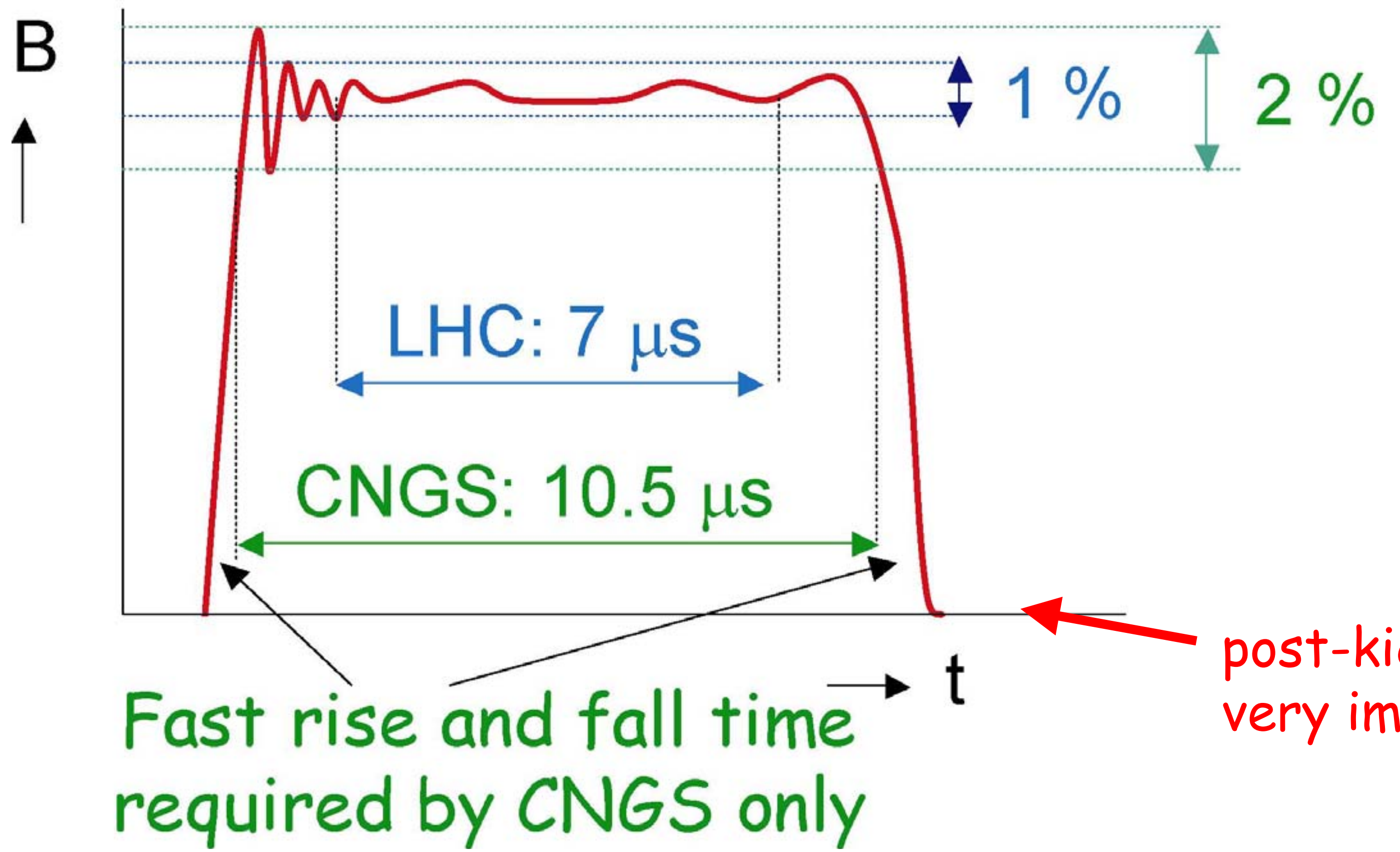
Result:

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, AB/BT



post-kick ripple also very important !!

L. Ducimetière
E. Gaxiola
J. Uythoven

(**Note:** two such pulses are needed, 50 ms apart)

Magnet and extraction errors

	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
± 2% MKE field ripple	0.32	16	0.64
± 3% MKE field ripple	0.48	24	0.96

Margin on the target rods:

Nominal beam size = 0.53 mm

± 1.5% MKE field ripple (v.s. ± 1%):

On target rods (4 mm diameter) :

$2.0\text{ mm} - (3\sigma_{beam} + 0.48\text{mm}) = -0.07\text{mm}$

0.40mm -0.01mm

Going beyond:

- loose in particle production
- induce more activation in target and shielding
- increase rod stresses

Non centered beam on target

- Beam eccentricity is critical as it induces large transversal oscillations
- Second pulse hits when thermal equilibrium from first pulse is not reached yet, hence building up overall stresses.
- Problem arises from one shot
- Eccentricity must remain below admissible stress i.e. < 0.4mm (graphite, ultimate intensity)
- For nominal intensity: marginal with 0.5 mm

L. Bruno, AB/ATB
A. Bertarelli, TS/MME

What really matters in terms of accurate alignment and tuning:

Beam hits the target within the requested specs

Small effect at Gran Sasso from
- proton beam lateral displacement (0.5mm)
- Proton beam angular displacement (0.5 mrad)
- Horn lateral displacement (3mm)
- Reflector lateral displacement (10mm)

More results in

Aperture and Stability studies for the CNGS proton beam line*
AB-Note 2003-20 ABP, W. Herr and M. Meddahi
https://edms.cern.ch/document/383852/1

Trajectory correction studies for the CNGS proton beam line
SL-Note 2002-015 AP, W. Herr and M. Meddahi
https://edms.cern.ch/document/355912/1

* Fraction of particles lost for different aperture misalignments and momentum offsets studied:

For nominal parameters no particle losses are observed.

Equipment design, procurement and installation progress

Magnet production

Proton beam instrumentation (Target region)

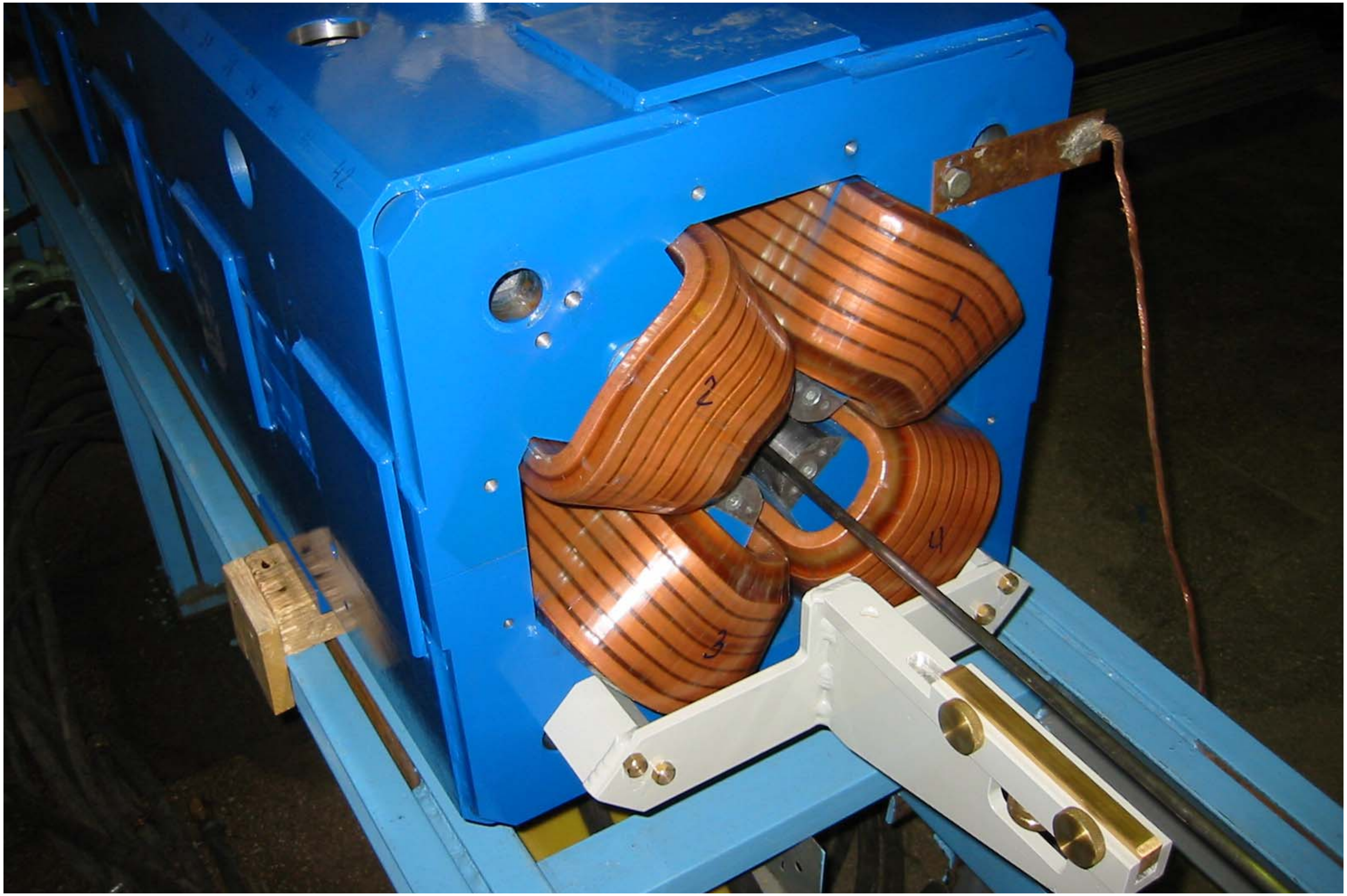
Target

Horns

On going installation

Muon detectors

MBG magnet production – 50 out of 78 have arrived at CERN



QTG series being produced at Novosibirsk

T. Zickler, AT/MEL

Corrector magnets

Price enquiry launched
Contract will be placed in March 2004
All magnets delivered by end 2004

17 magnets
Bending angle:
80 μrad
Gap height: 45 mm

T. Zickler, AT/MEL

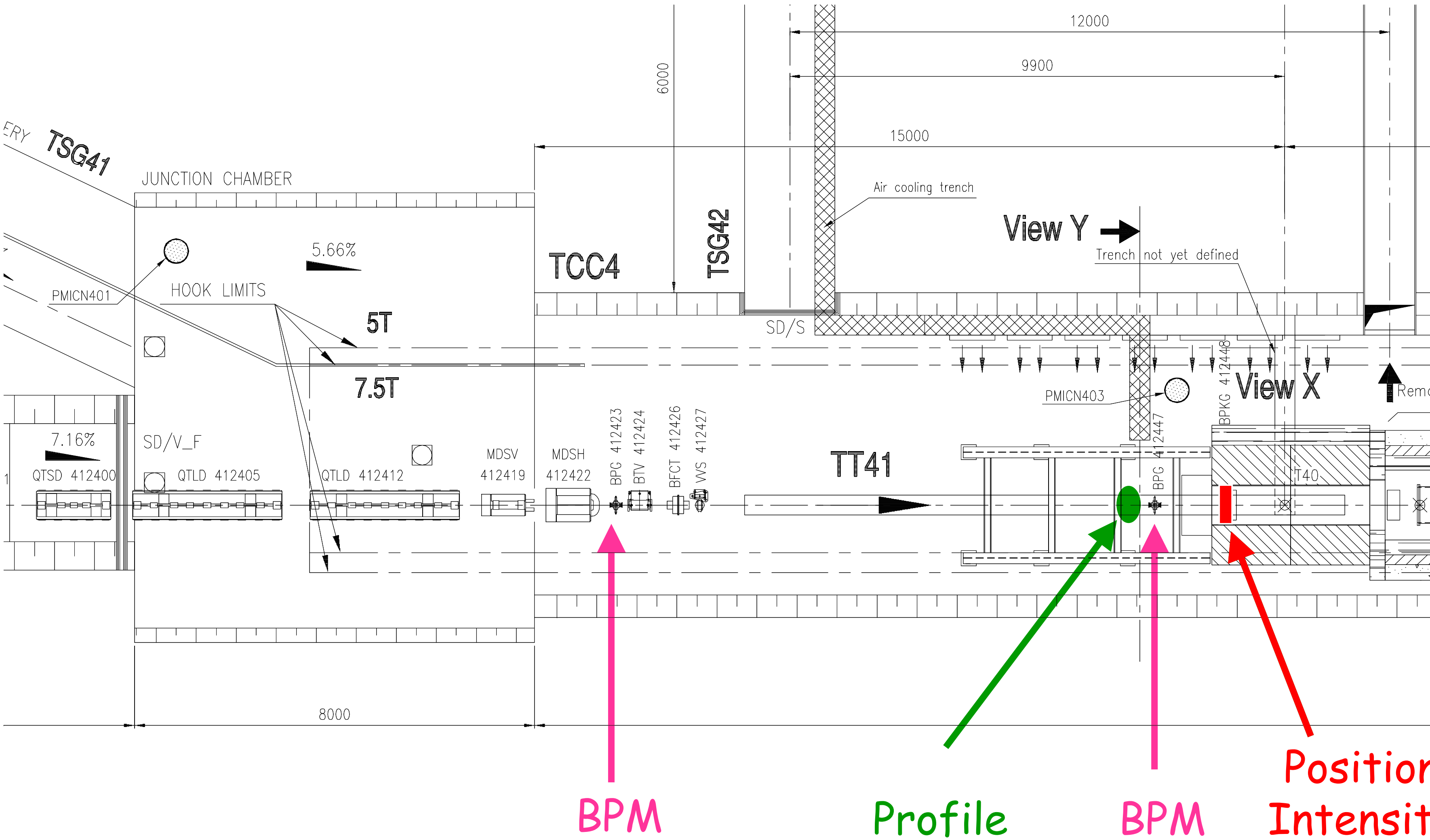
Refurbishment of recuperated magnets

D. Smekens, AT/MEL

Magnet accessories

S. Koczorowski, AT/MEL

TT41 last 100m



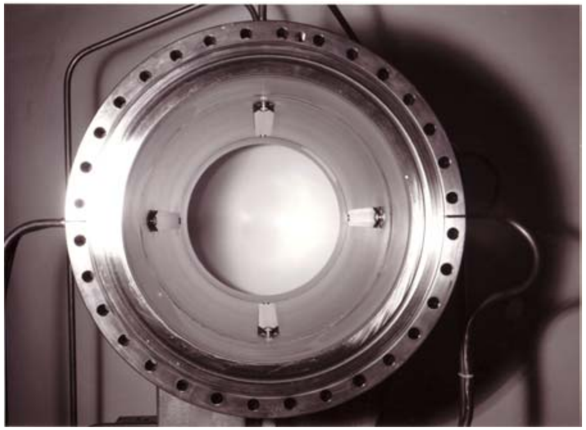
Beam monitoring (AB/BDI)

Problem: fast extracted, very intense proton beam, focused into a very small beam spot is too hot for standard Ti windows

→ SEM monitors don't work

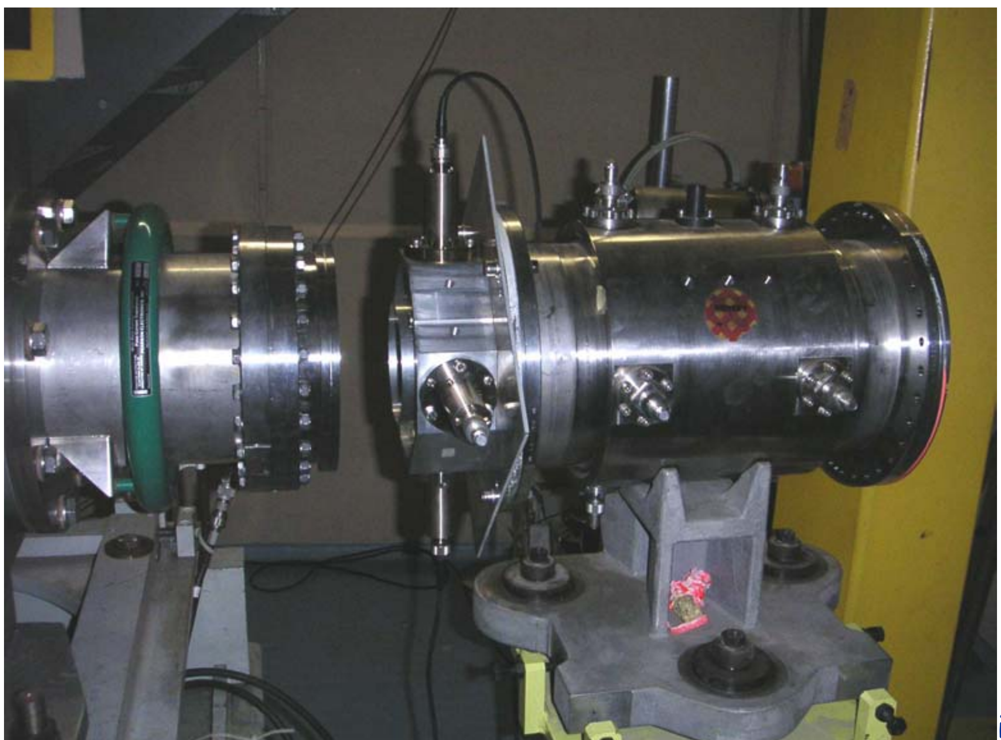
Question: beam position monitor **operated in air** ?

→ a challenge for AB / BDI



Electromagnetic Stripline Coupler Pick-up

Electrostatic Button Pick-up



Test Set-up at PS Booster

T. Bogey
R. Jones

Preliminary Results

Button Electrode Monitor

⇒ *Very sensitive to air ionisation*

Stripline Coupler Monitor

⇒ *less sensitive to air ionisation than button*

⇒ *Position measurement possible BUT work still required*

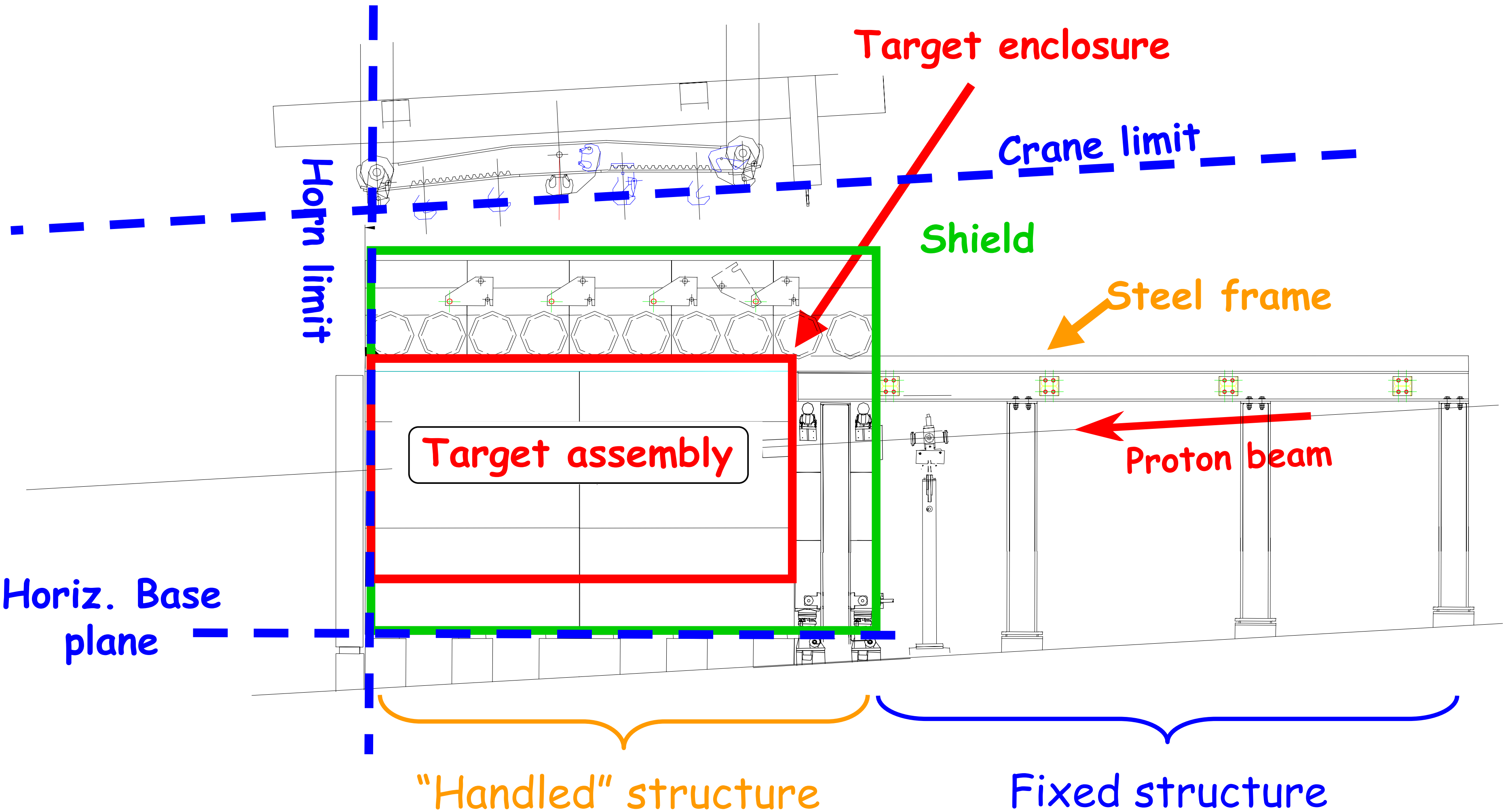
Target Station

Target Team, led by L. Bruno (AB/ATB)

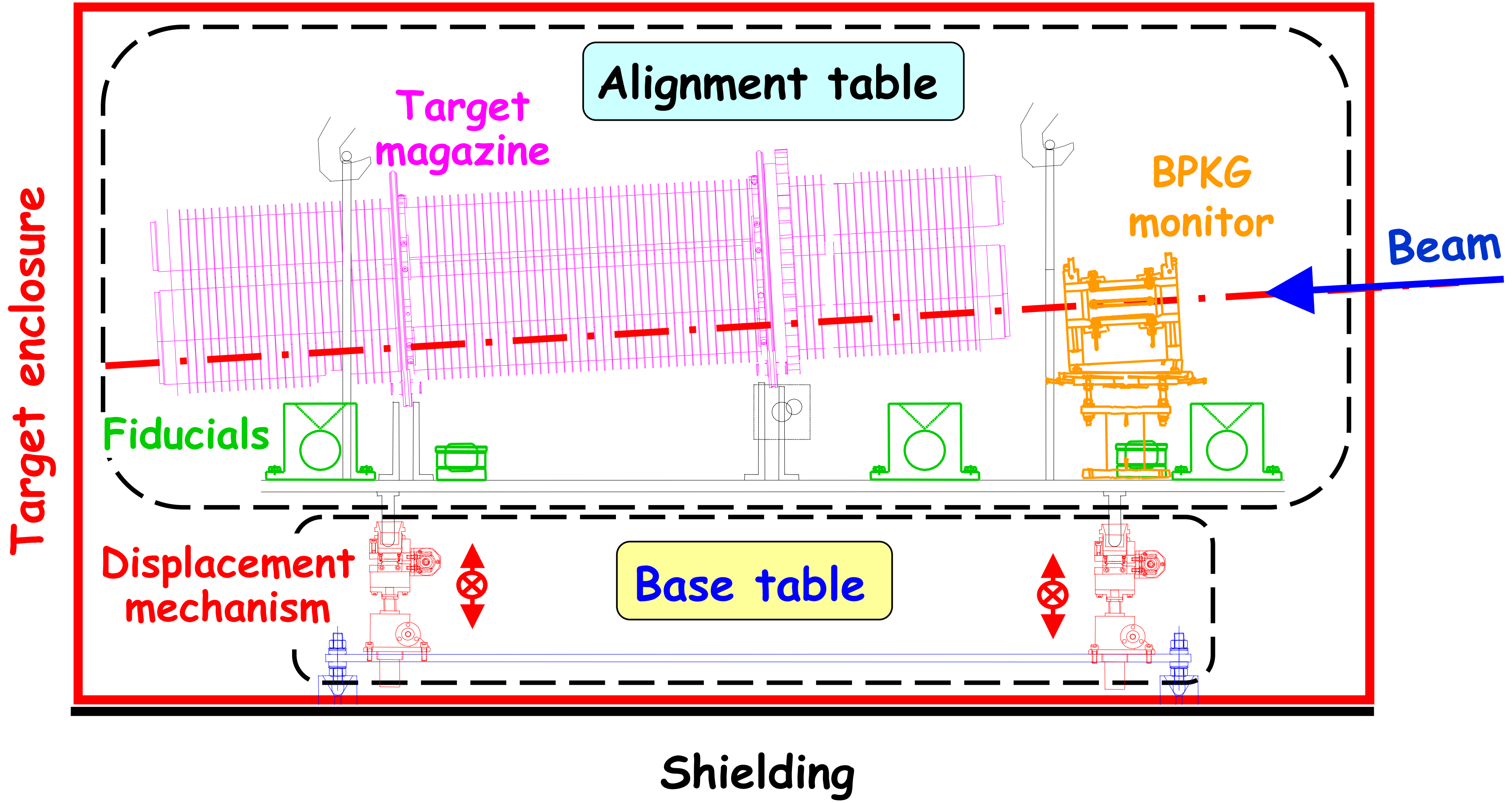
TS/MME, led by G. Patti

All target slides courtesy of L. Bruno, G. Patti

T40 Layout
Schematic Vertical view



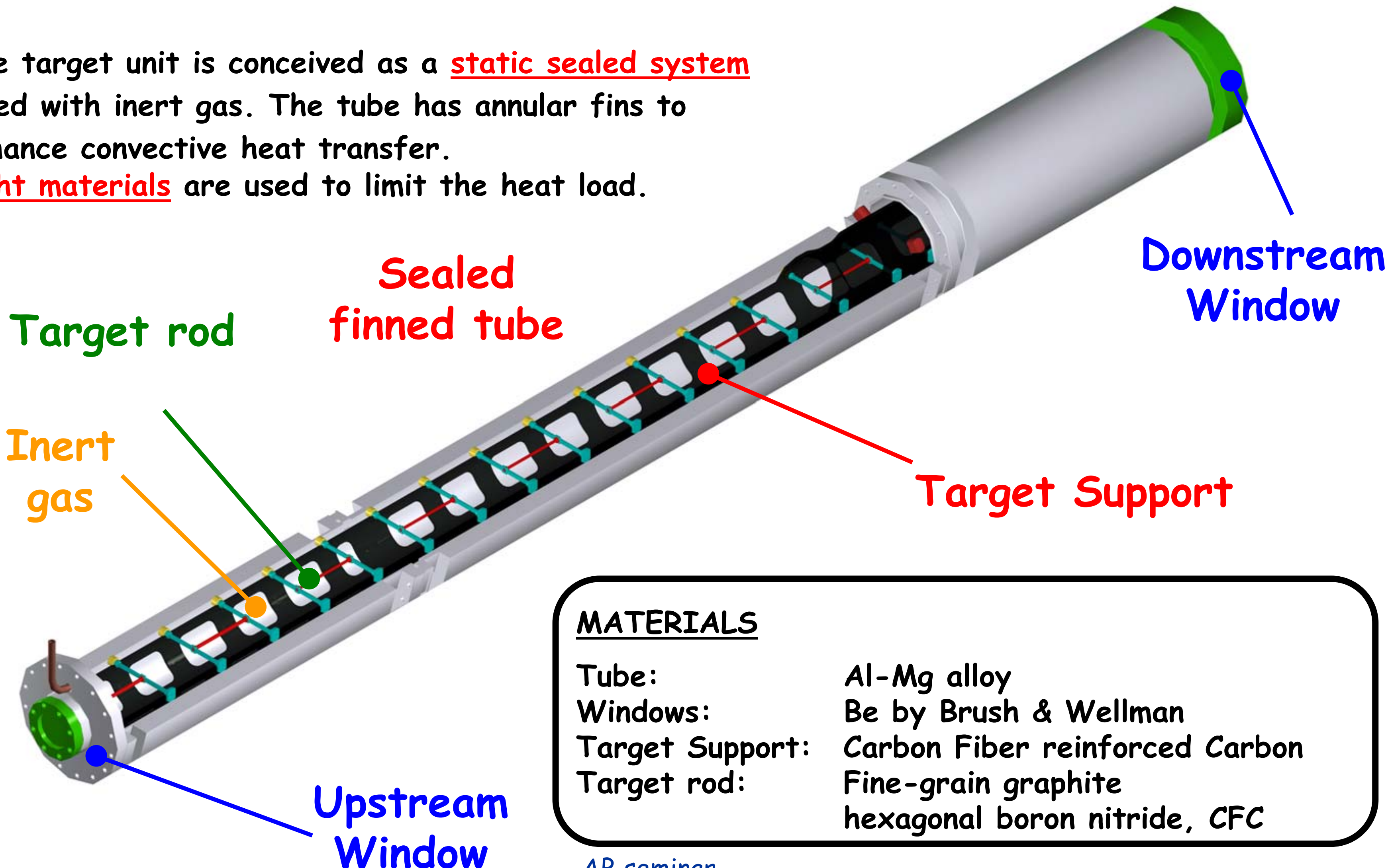
Target Assembly



The target magazine is mechanically coupled to the BPKG monitor. They are aligned in the lab and are remotely handled as a single component (the « alignment table »). They rest on the « base table », bearing the displacement mechanisms.

Target unit

The target unit is conceived as a static sealed system filled with inert gas. The tube has annular fins to enhance convective heat transfer.
Light materials are used to limit the heat load.



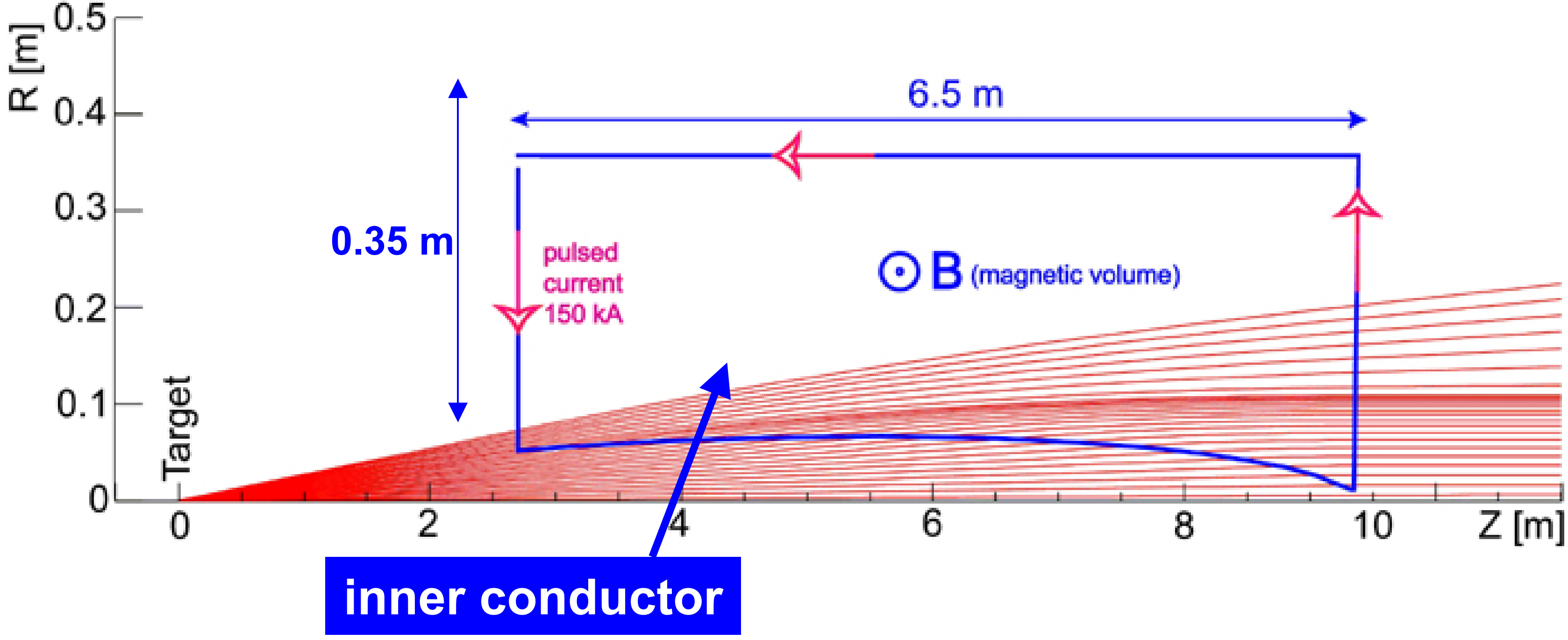
MATERIALS

Tube:	Al-Mg alloy
Windows:	Be by Brush & Wellman
Target Support:	Carbon Fiber reinforced Carbon
Target rod:	Fine-grain graphite
	hexagonal boron nitride, CFC

- Engineering design of the Target station
- Study of alternative target materials (boron nitride)
- Laboratory tests, beam tests for both graphite and boron nitride are under way
- Revolving target magazine (4 in-situ spares)

Magnetic Horn : Principle of focusing

35 GeV positively charged particles leaving the target



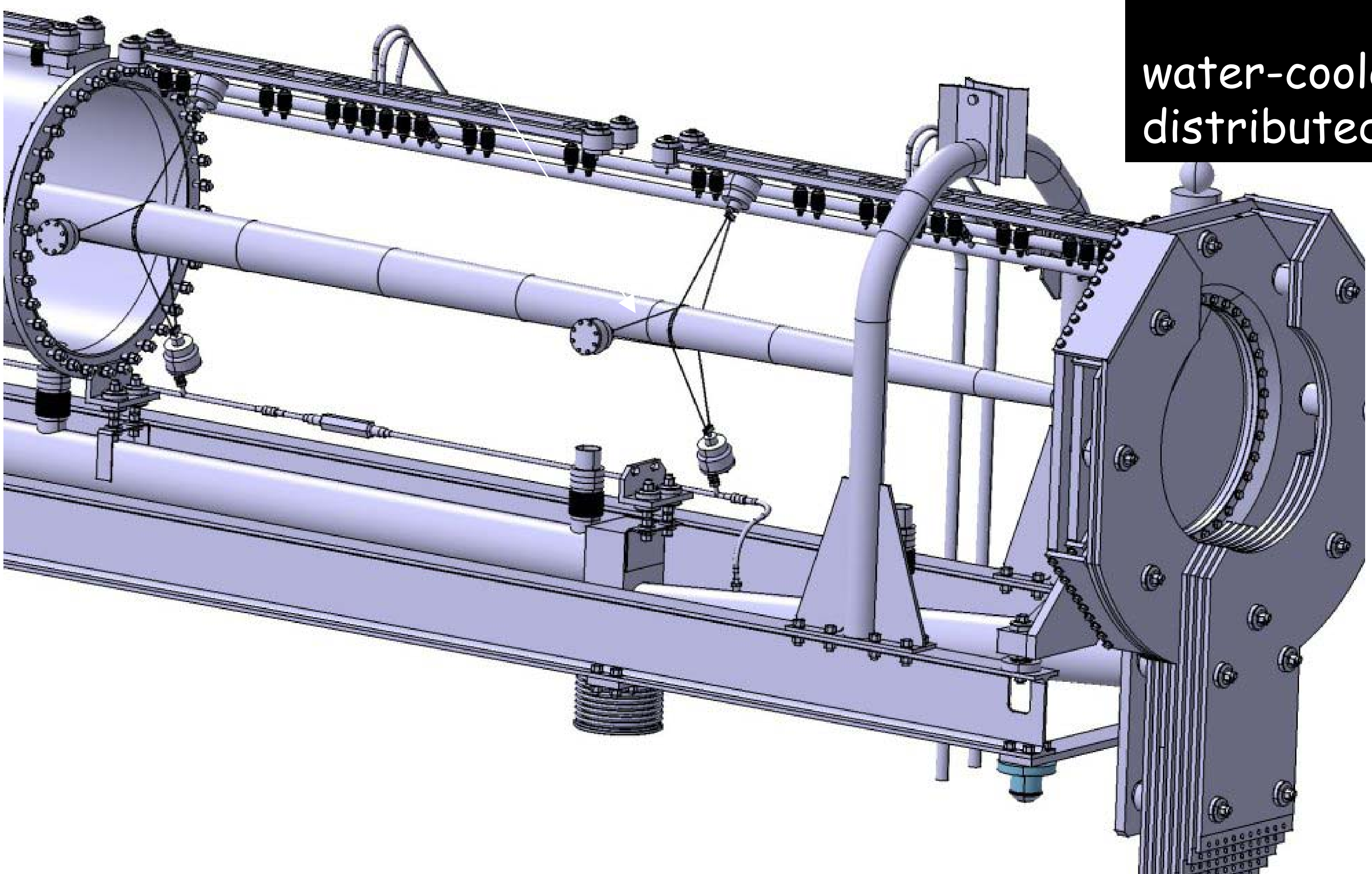
CNGS -- focusing devices

(S. Rangod, PH/TA3
collaboration with LAL, IN2P3, Paris)

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

Pulsed devices:
150kA / 180 kA, 1 ms

water-cooled:
distributed nozzles

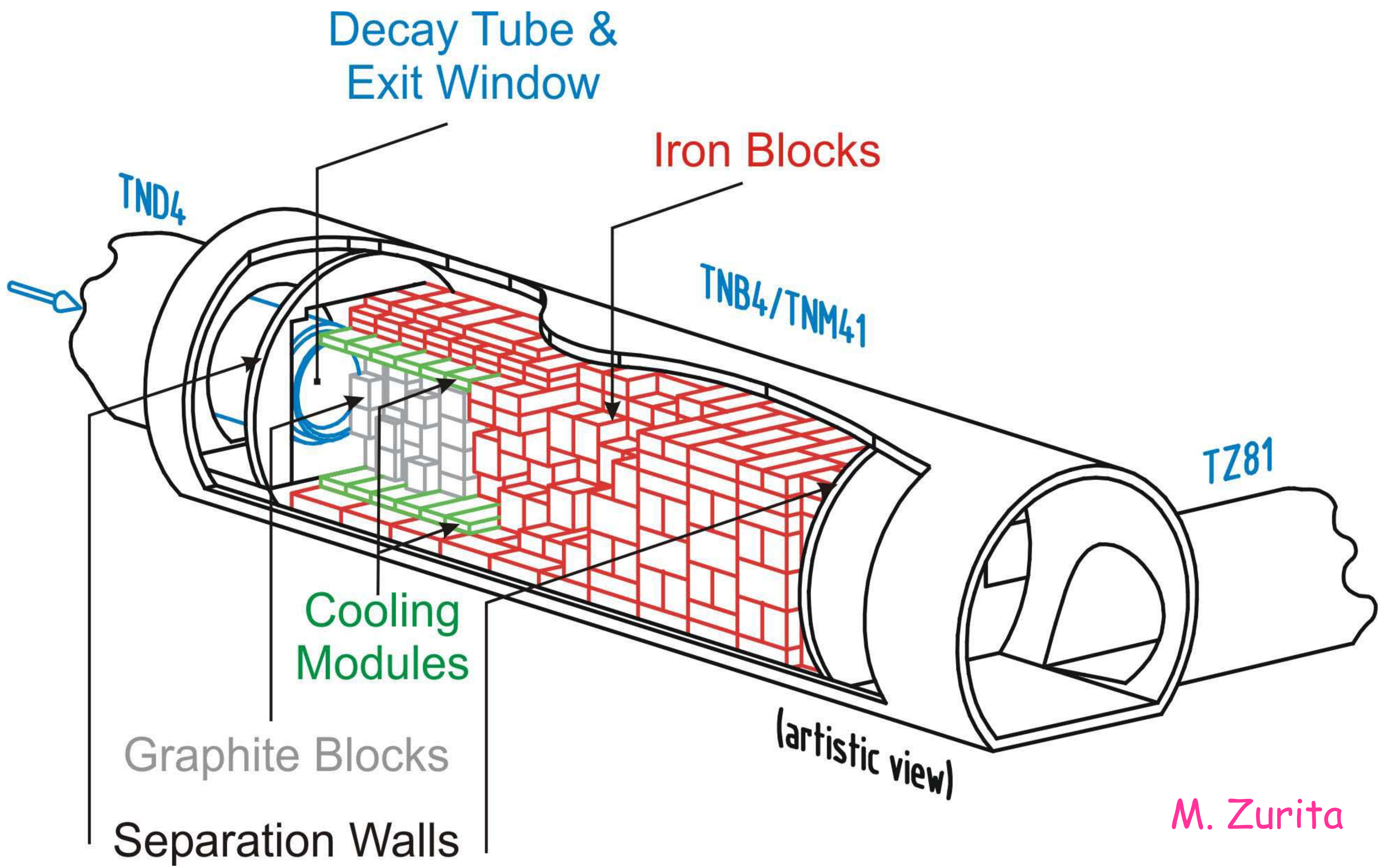


New power transformer

New capacitor bank

G. Maire, PH/TA3

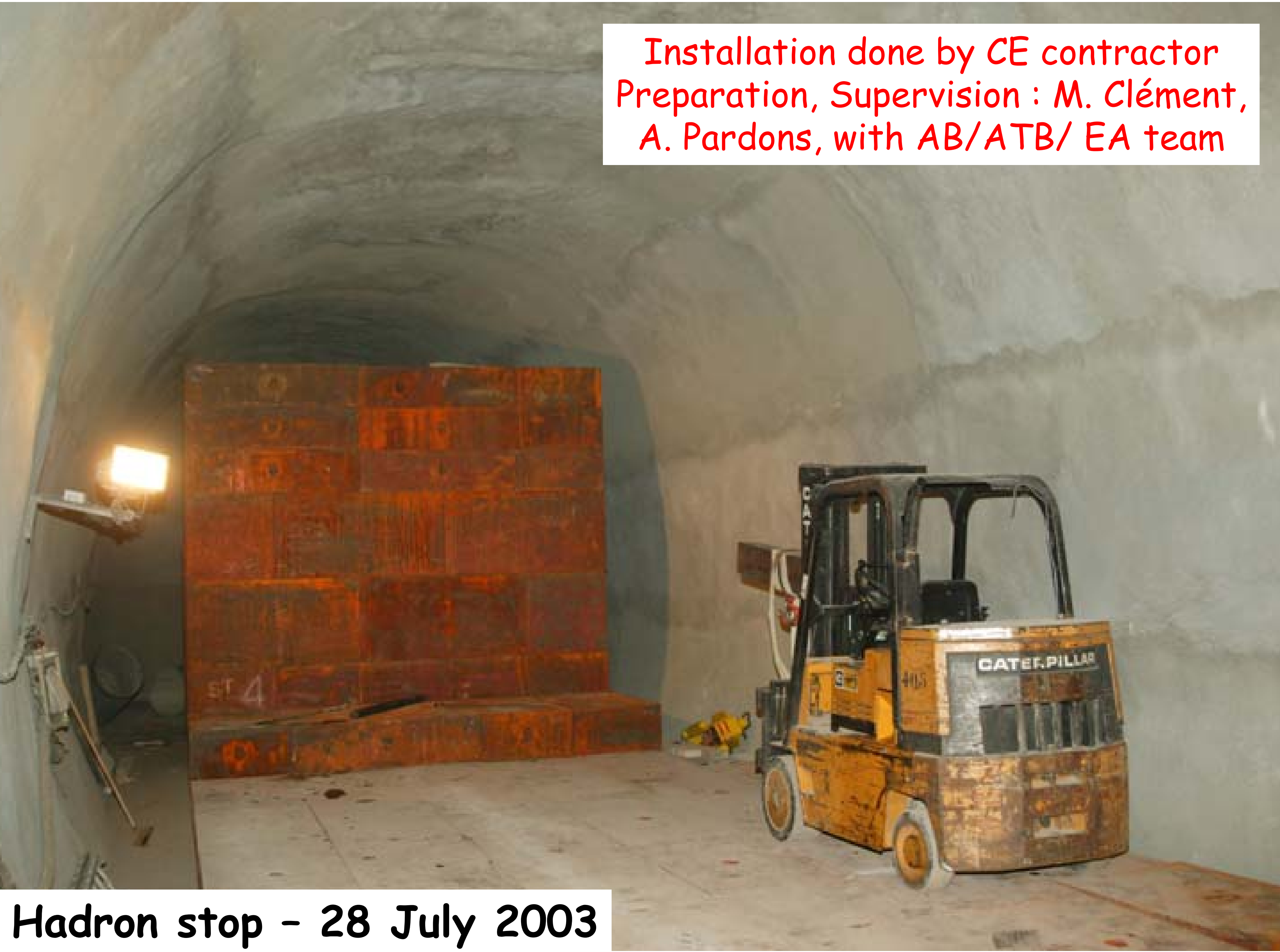
Hadron stop – artistic view



M. Zurita


graphite
cooling modules
11 July 2003 – near the CE shaft

Installation done by CE contractor
Preparation, Supervision : M. Clément, A. Pardons, with AB/ATB/ EA team

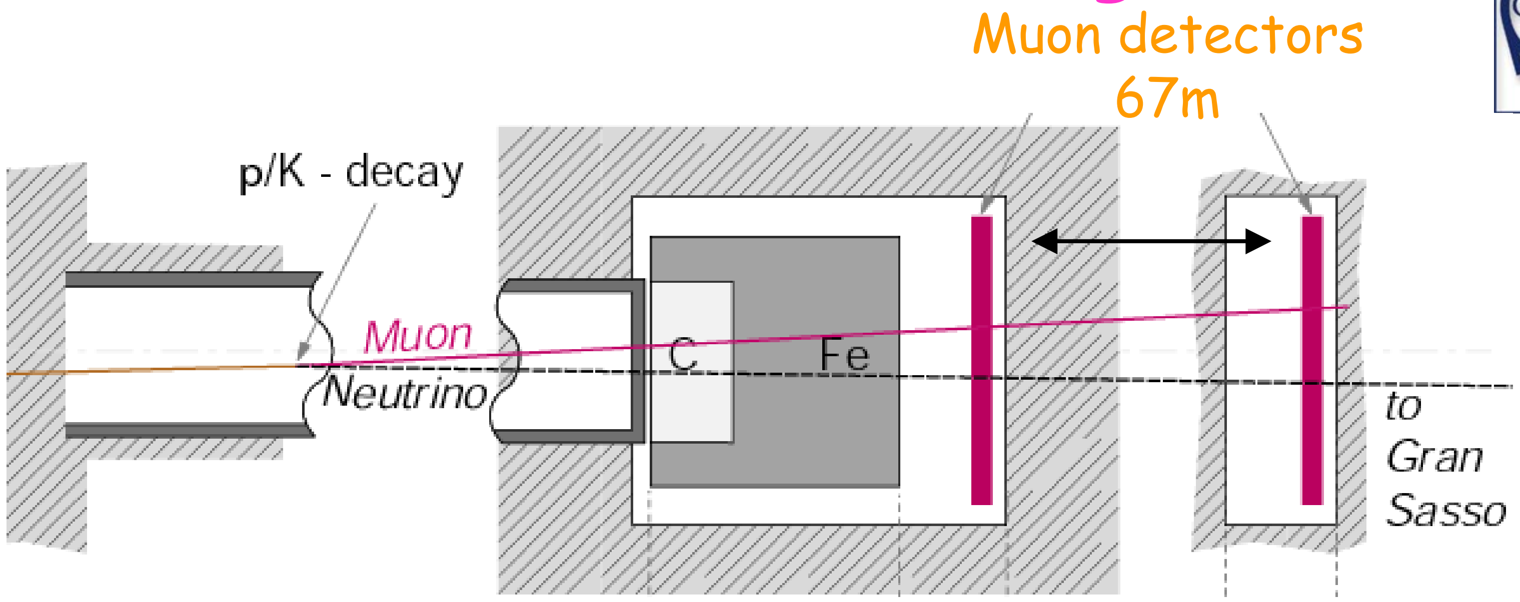


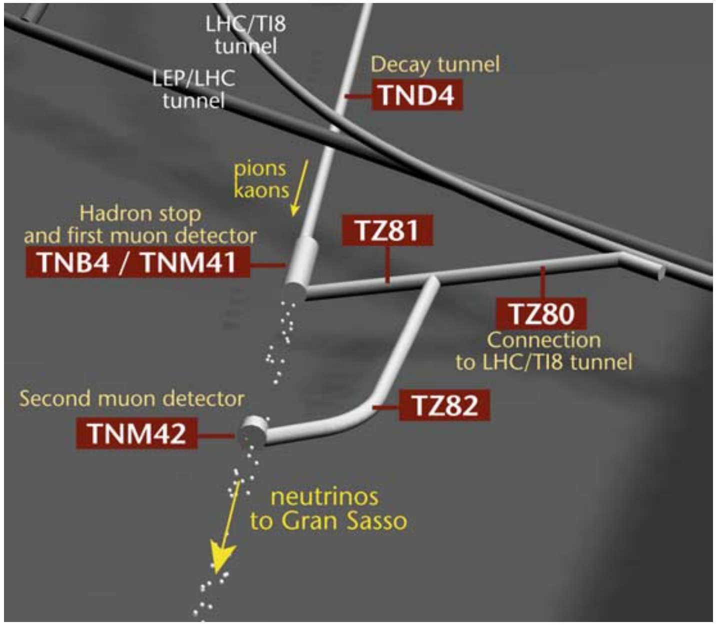
Hadron stop – 28 July 2003

Hadron stop – 2 Sept 2003

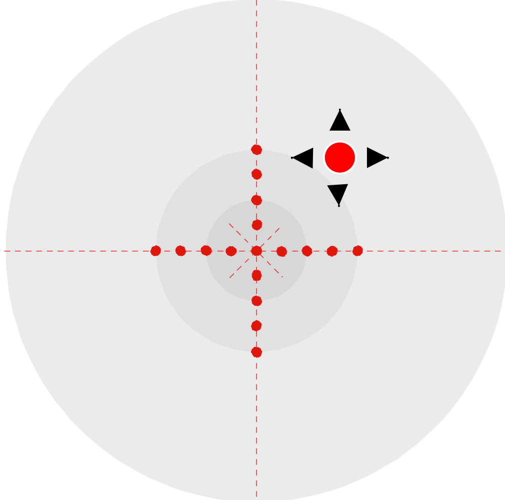
Access gallery TZ80 to muon chambers
TS/EL, TS/CV

CNGS Muon Monitoring





Access very rare



17 BLM (fixed cross centered on beam axis)
1 moveable monitor

SPS Type Beam Loss Monitor

Ionisation Chamber

PS Booster Beam Loss Monitor Tests

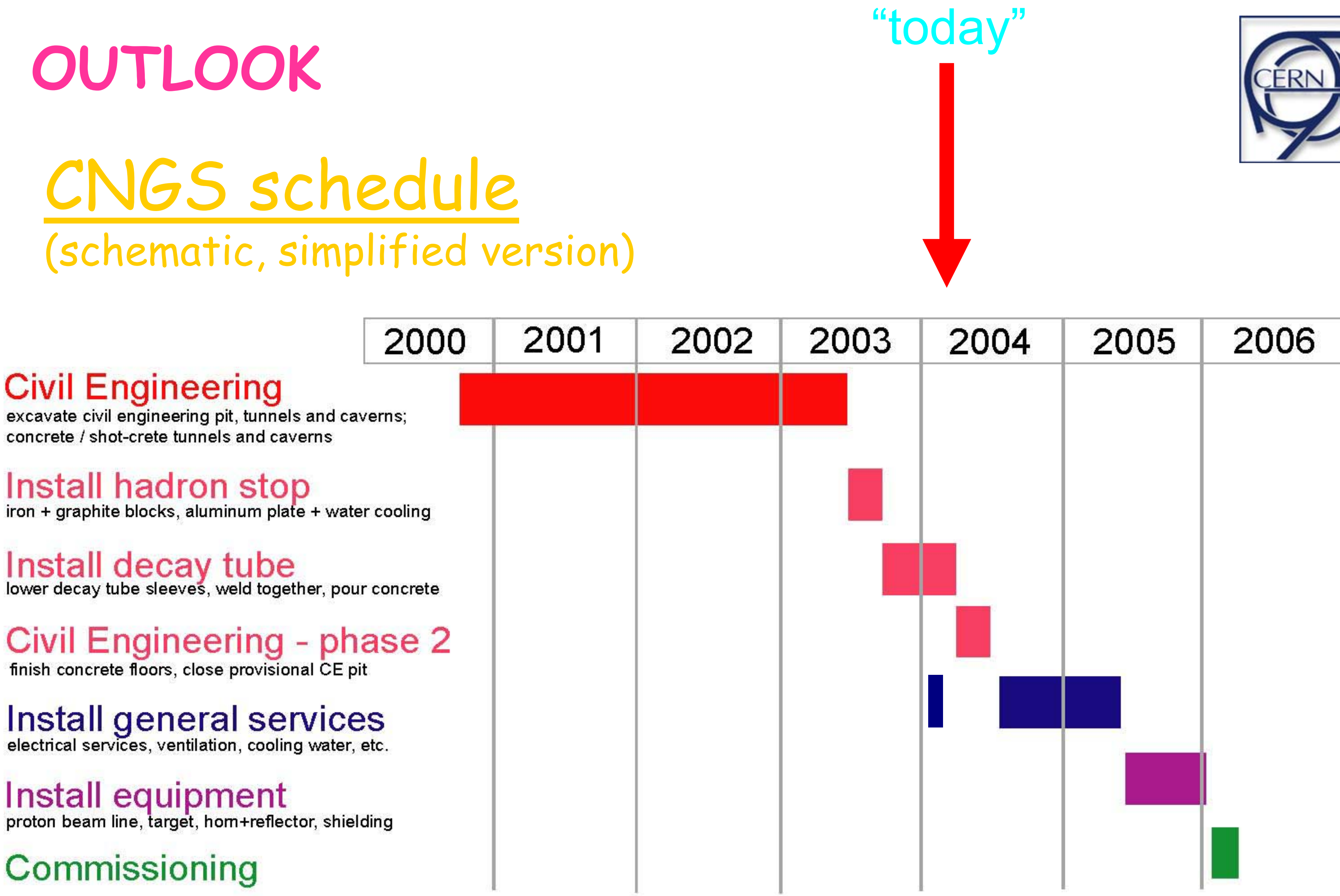
Confirmed that response time not an issue for CNGS (50ms between trains)
More experiments and theoretical work required

B. Dehning, AB/BDI
G. Ferioli, AB/BDI

OUTLOOK

CNGS schedule

(schematic, simplified version)



First beam to Gran Sasso: May 2006

On behalf of the CNGS Project Team

THANK YOU

to the many colleagues who are contributing to the CNGS project