CNGS Status: Neutrino Beam to OPERA

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Outline

- CNGS Commissioning and Physics Operation 2006
- Perspectives 2007
- Maximum Possible Number of Protons on CNGS

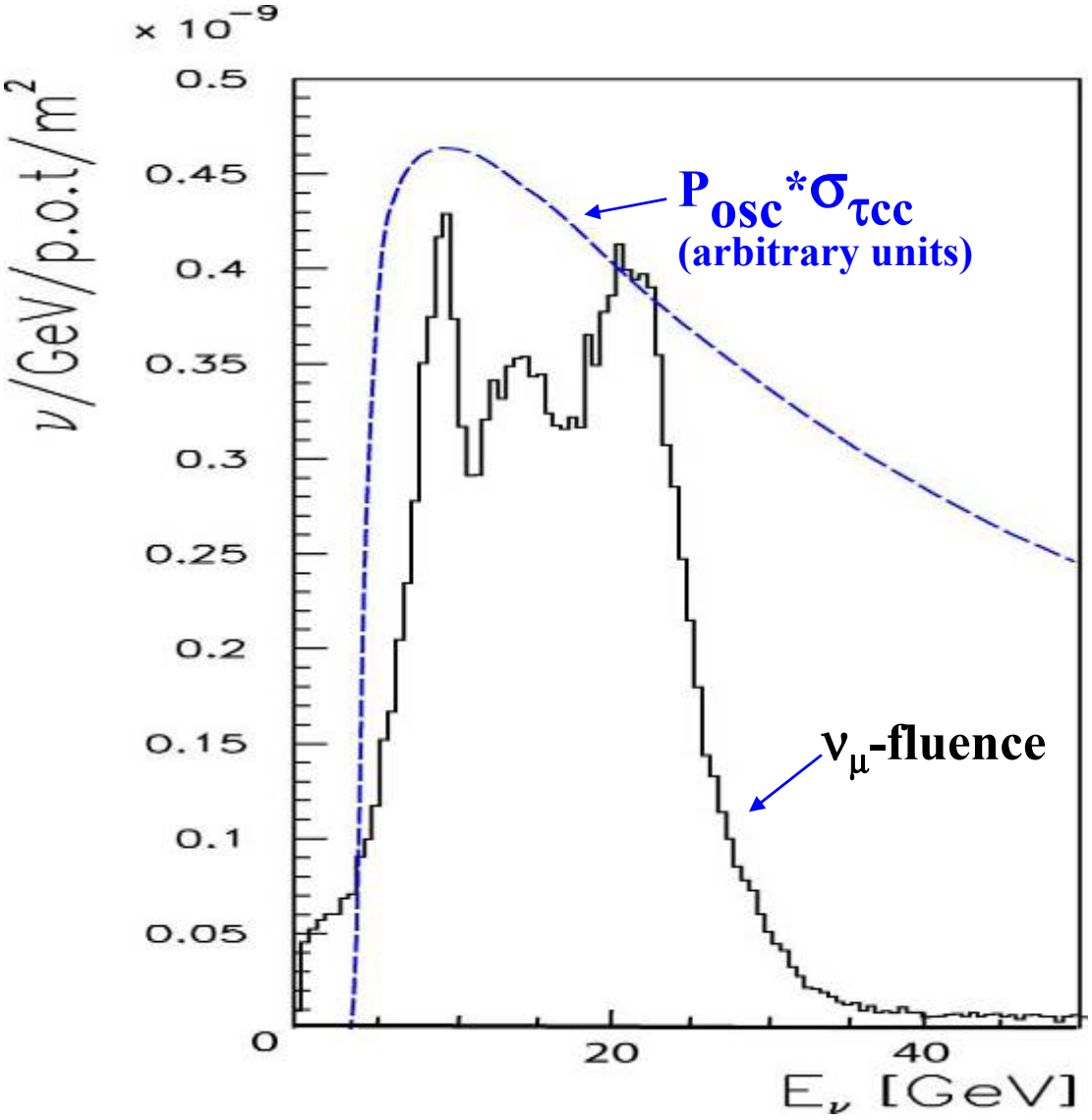
CNGS Project

CNGS (CERN Neutrino Gran Sasso)

- A long base-line neutrino beam facility (732km)
- send ν_μ beam produced at CERN
- detect ν_τ appearance in OPERA experiment at Gran Sasso

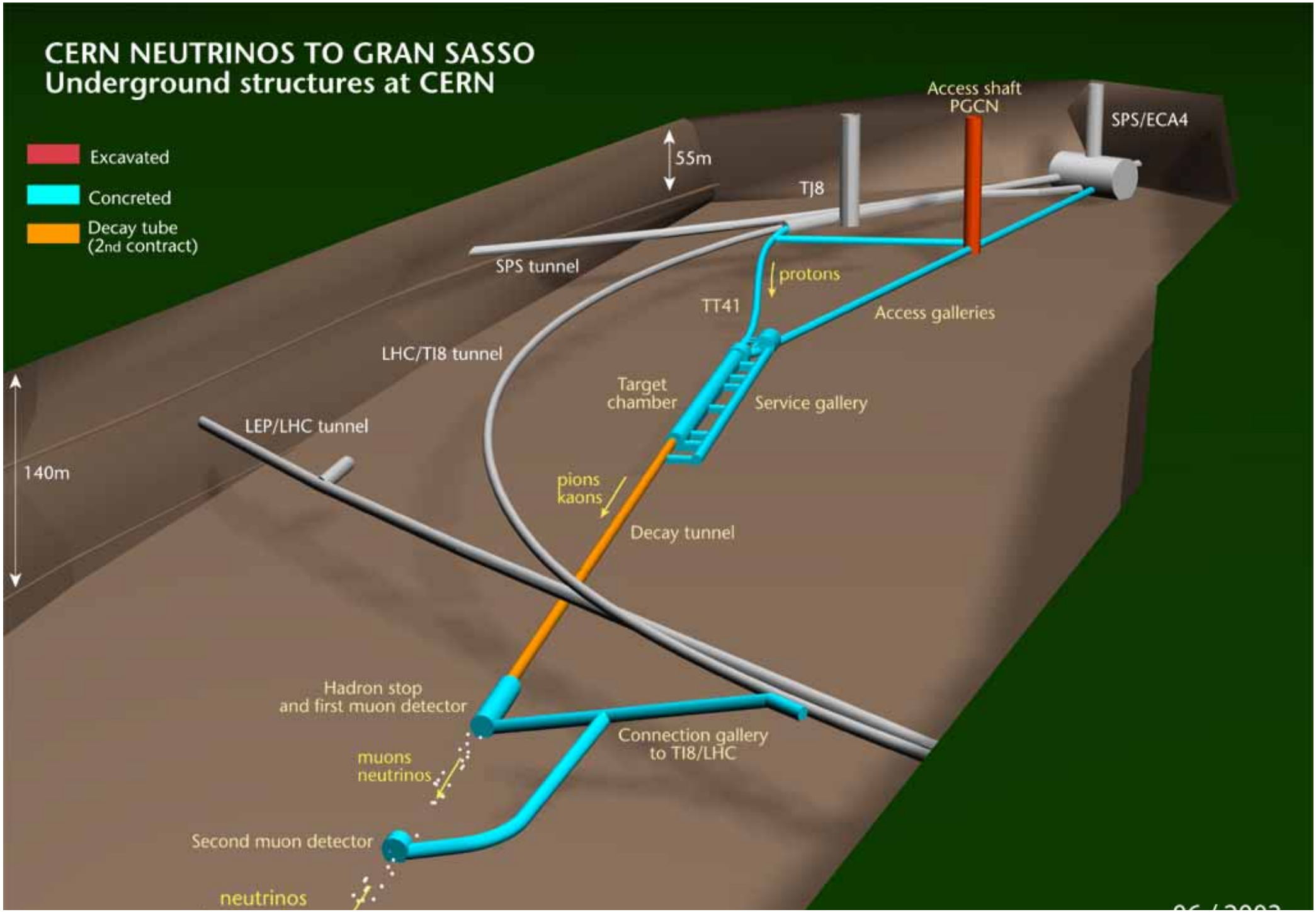
➔ direct proof of ν_μ - ν_τ oscillation (appearance experiment)

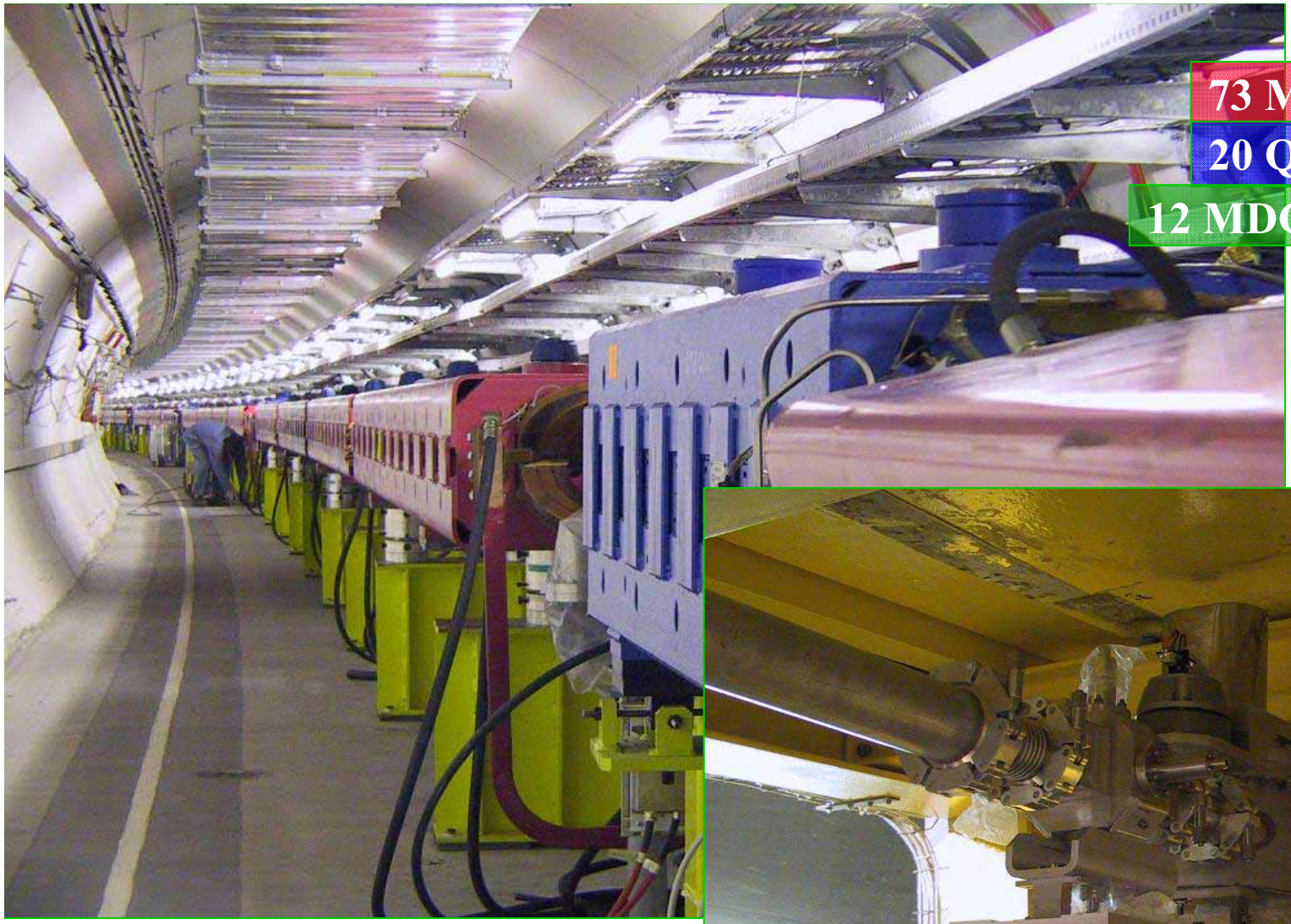
ν_τ – Appearance Experiment



- **Beam optimization:**
  - ➔ **Intensity: as high as possible**
  - ➔ **Neutrino energy: matched for ν_μ-ν_τ appearance experiments**
- **Product of**
  1. **Oscillation probability ν_μ– ν_τ**
  2. **Production cross-section ν_τ with matter**
  3. **ν_μ –fluence(E)**

     + Detection efficiency in the experiment

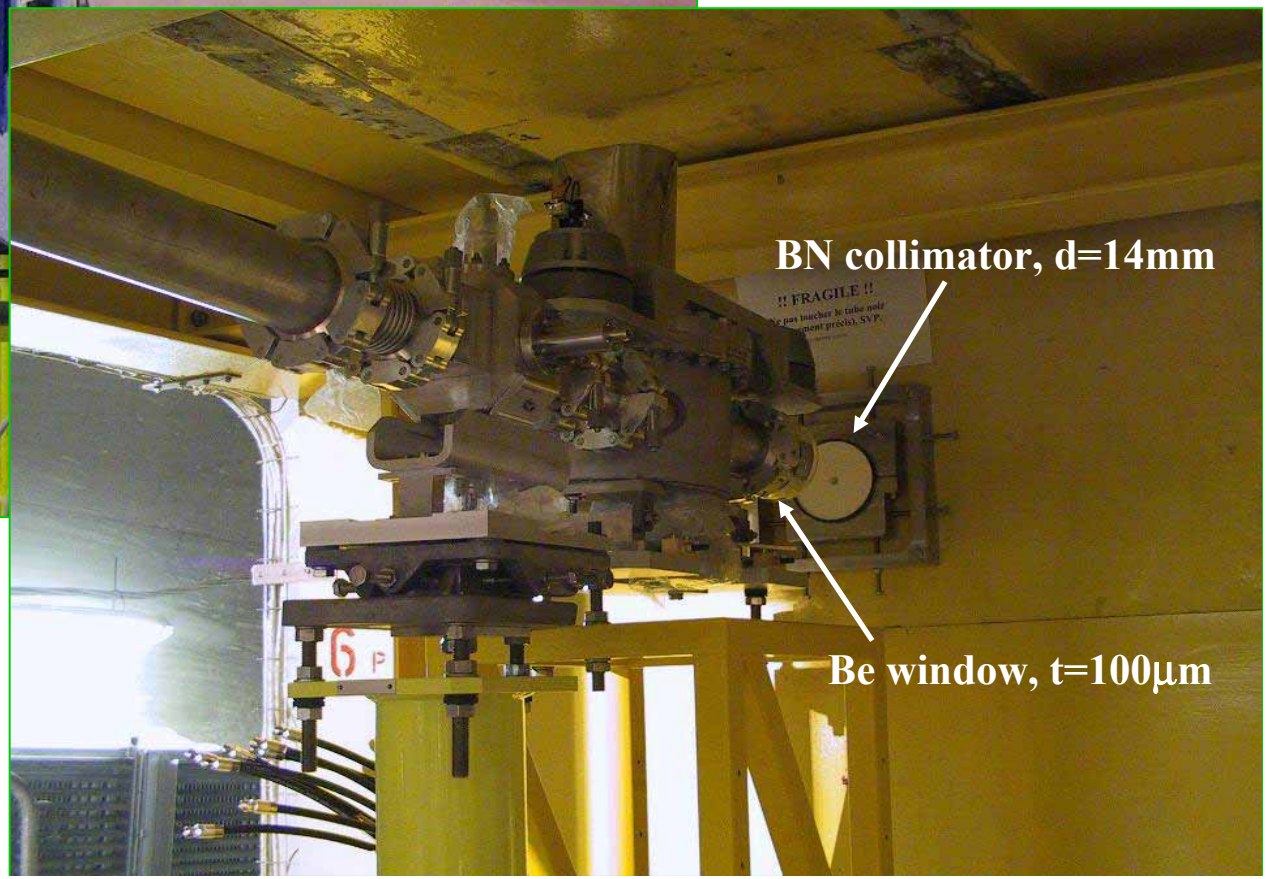

CERN NEUTRINOS TO GRAN SASSO
Underground structures at CERN
Excavated
Concreted
Decay tube
(2nd contract)
55m
Access shaft
PGCN
SPS/ECA4
TI8
SPS tunnel
protons
TT41
Access galleries
LHC/TI8 tunnel
Target
chamber
Service gallery
LEP/LHC tunnel
140m
pions
kaons
Decay tunnel
Hadron stop
and first muon detector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



73 MBG (Dipoles)

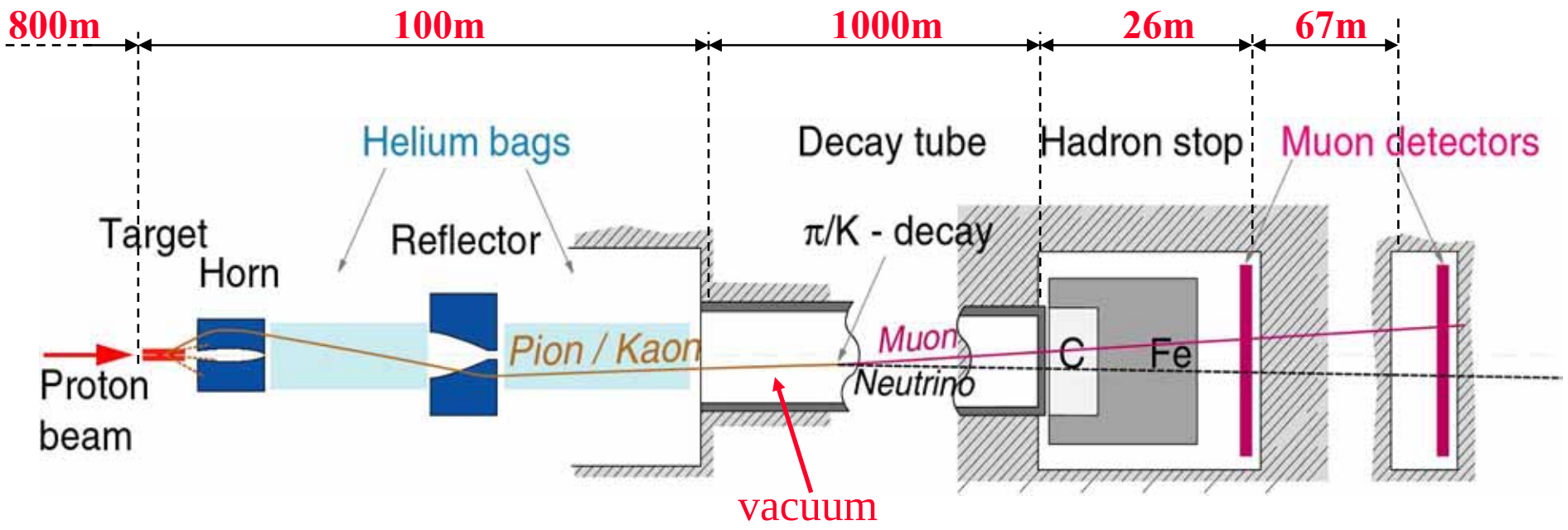
20 QTG (Quadruples)

12 MDG (Corrector Magnets)



Proton Beam Line

CNGS Layout

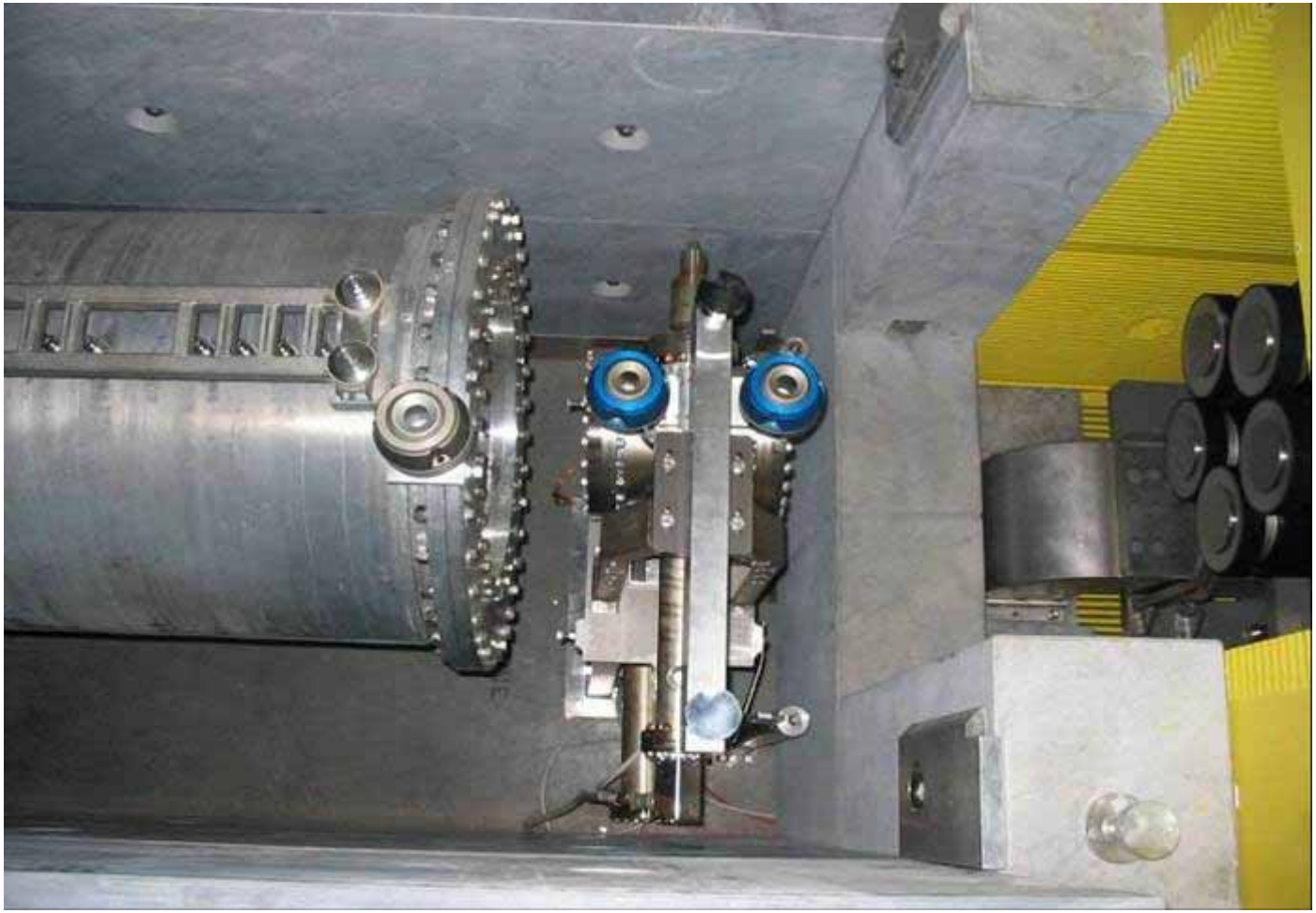


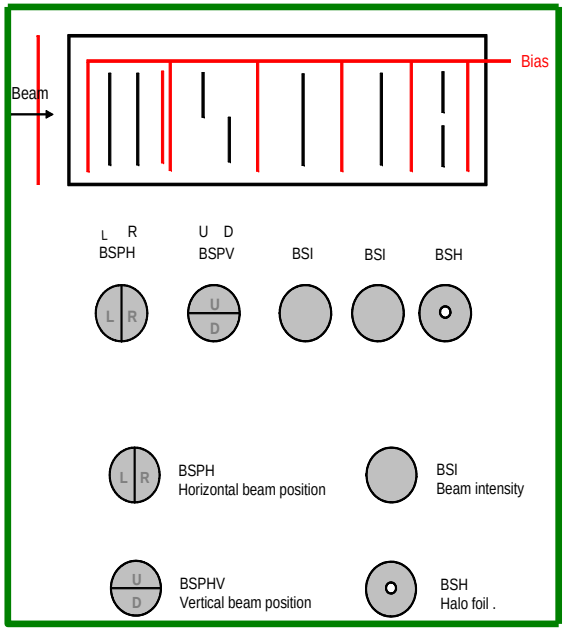
$$p + C \rightarrow \text{(interactions)} \rightarrow \pi^+,\ K^+ \rightarrow \text{(decay in flight)} \rightarrow \mu^+ + \nu_\mu$$

CNGS Target

TBID (Target Beam Instrumentation Downstream)

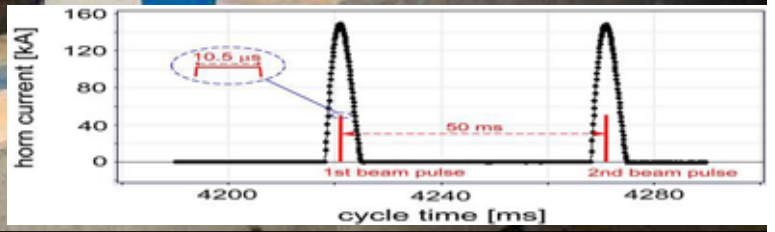
Secondary emission monitor, 12 µm Ti foils, diameter = 145mm





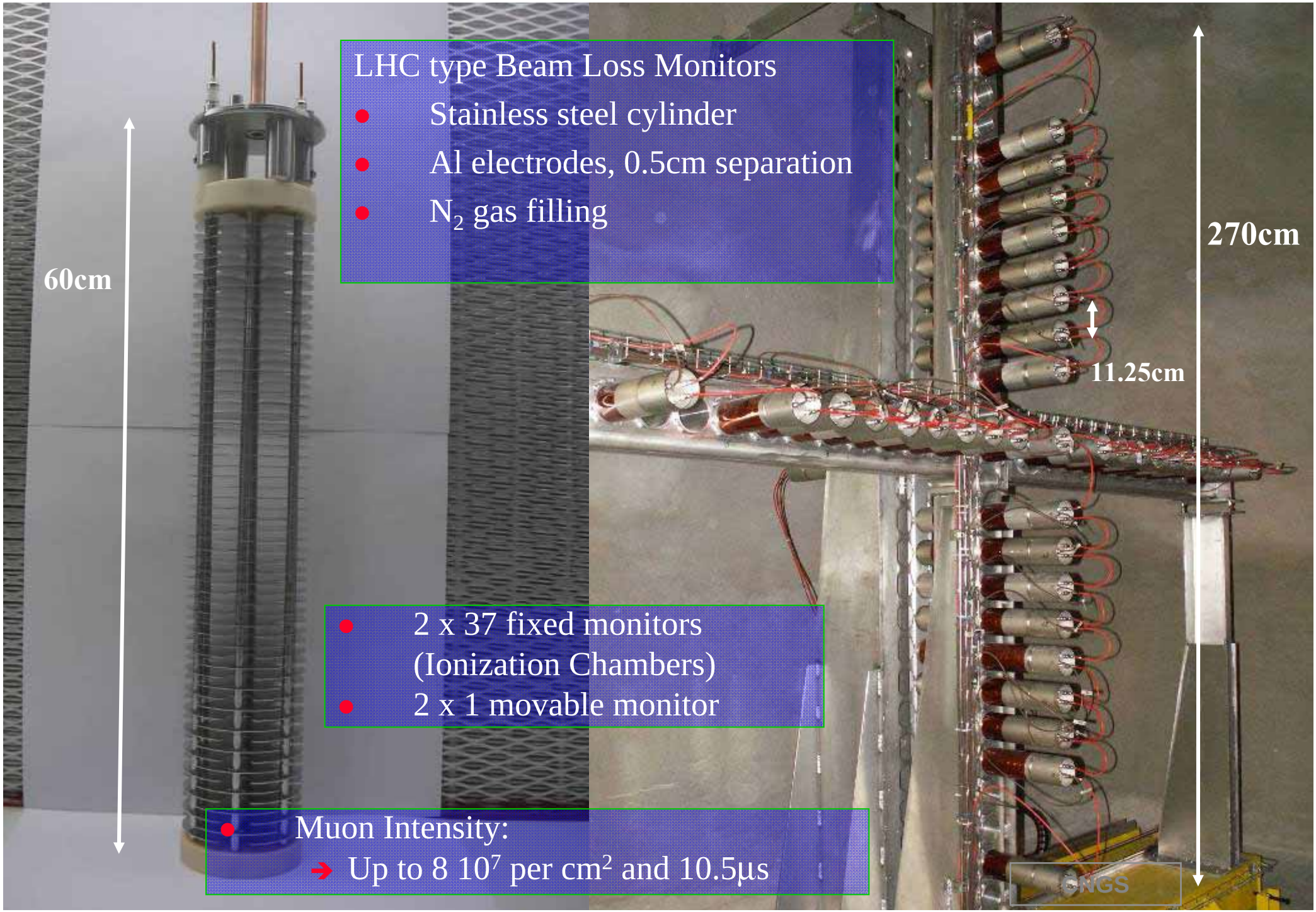
- **Measures all charged particles downstream the target**
  - ➔ **Check efficiency of particle production in the target**

Horn



	Unit	HORN System	REFL. System
Load Peak current	kA	150	180
Pulse duration	ms	6.5	9.8
Water flow for delta T=5C	l/min	50	50
Pressure	bar	1.2	1.2

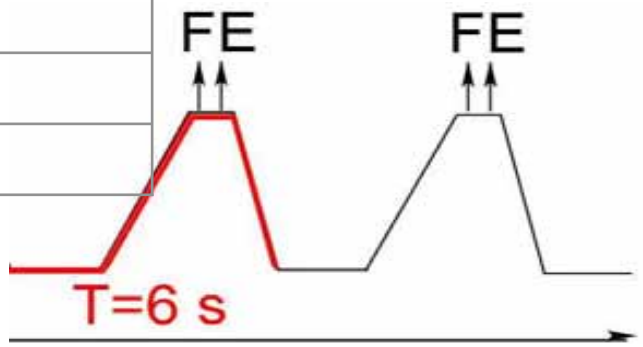
Installation of the horn in the target chamber


LHC type Beam Loss Monitors
Stainless steel cylinder
Al electrodes, 0.5cm separation
N_2 gas filling
60cm
270cm
11.25cm
2 x 37 fixed monitors (Ionization Chambers)
2 x 1 movable monitor
Muon Intensity:
→ Up to 8 10^7 per cm^2 and 10.5µs
CNGS

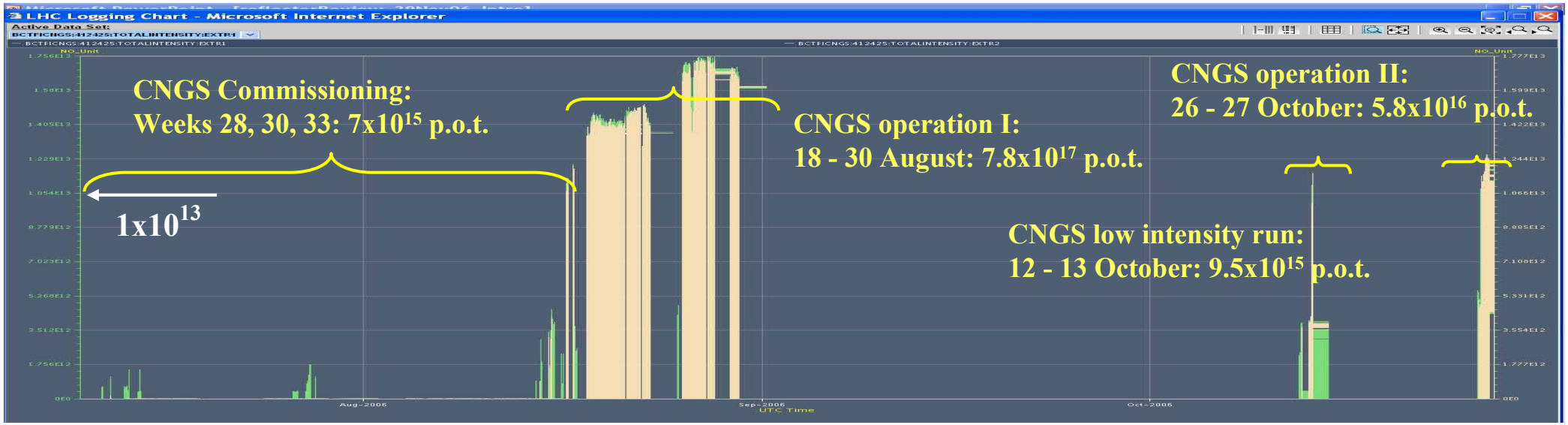
CNGS Proton Beam Parameters

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
Beta at focus [m]	hor.: 10 ; vert.: 20
Beam sizes at 400 GeV [mm]	0.5 mm
Beam divergence [mrad]	hor.: 0.05; vert.: 0.03

~500kW beam power



Expected beam performance: 4.5 x 10^{19} protons/year on target

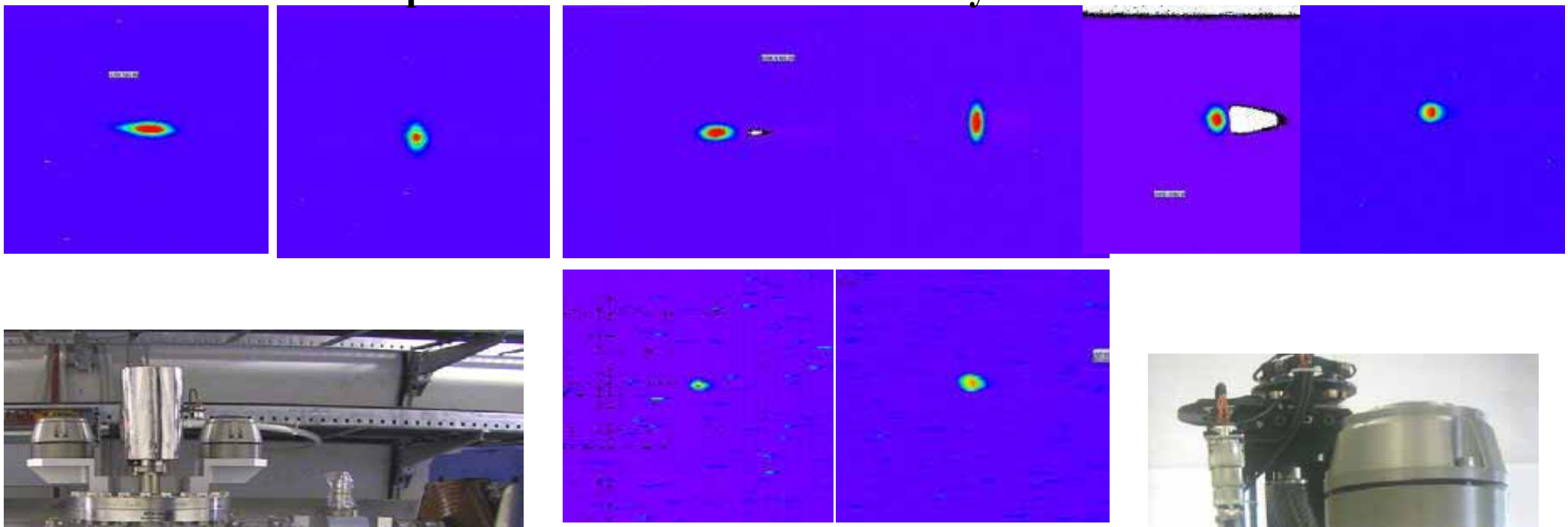


	Date	Extractions	Protons
Commissioning W28	10 – 14 Jul. 2006	300	1.3 E14
Commissioning W30	31 Jul. – 4 Aug. 2006	500	2.4 E14
Commissioning W33	14 – 18 Aug. 2006	1300	6.5 E15
Physics Operation I	18 – 30 Aug. 2006	53000	7.8 E17
Low Intensity Tests	12 – 13 Oct. 2006	2500	9.5 E15
Physics Operation II	26 – 27 Oct. 2006	8300	5.8 E16

- Maximum proton intensity reached in 2006: 3.5 $\cdot 10^{13}$/cycle at 400GeV
- While setting up high intensities for all 3 cycles, reflector leak appeared

FIRST SHOT 11 July 2006

1st shot down proton beam line: beam is already well centered on screens



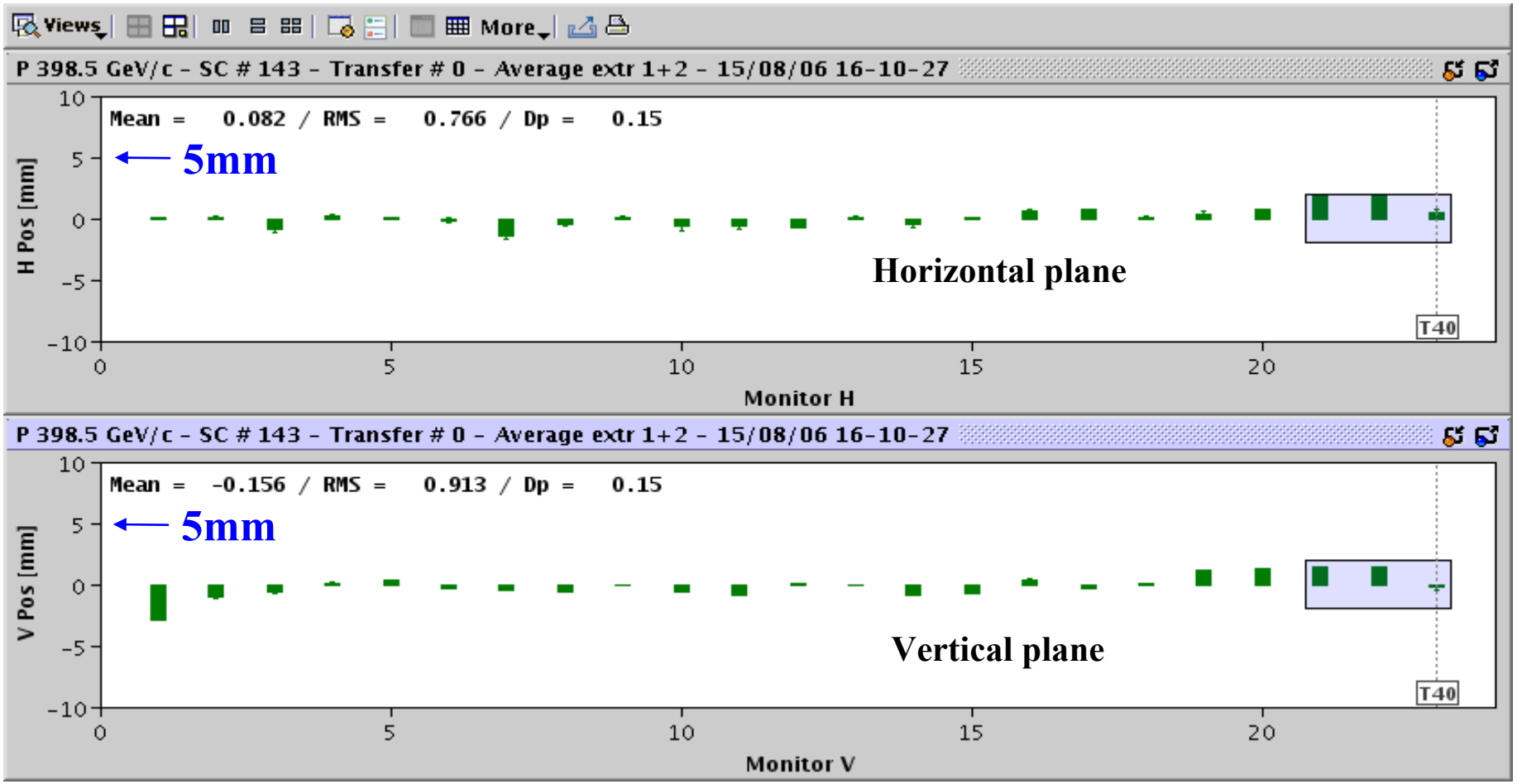
8 profile monitors (BTVG):

Optical Transition Radiation screens:

- **75 μm carbon**
- **12 μm titanium screens**

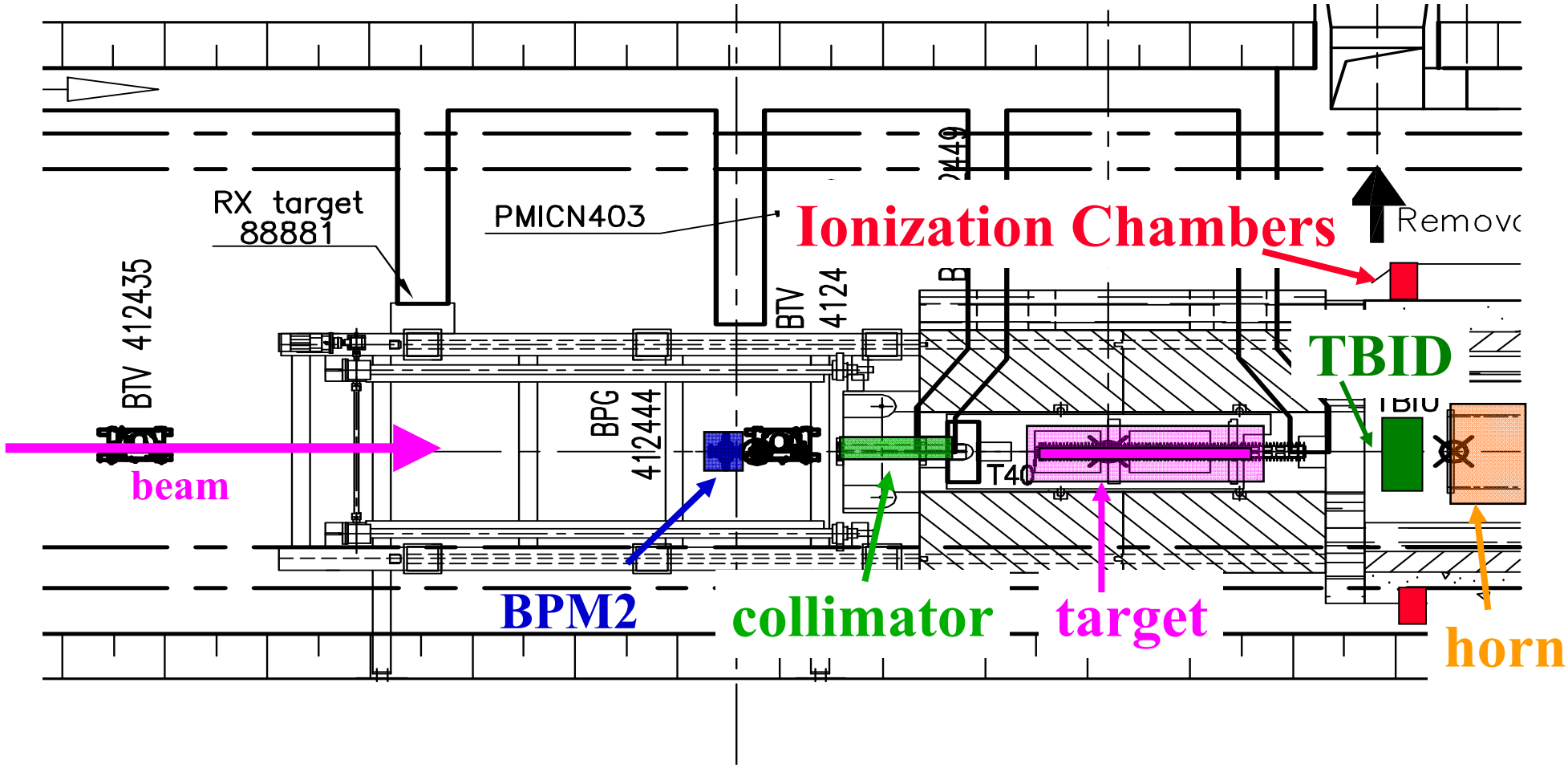
Trajectory along the Beam Line

Average of two extractions. 1E13 protons per batch



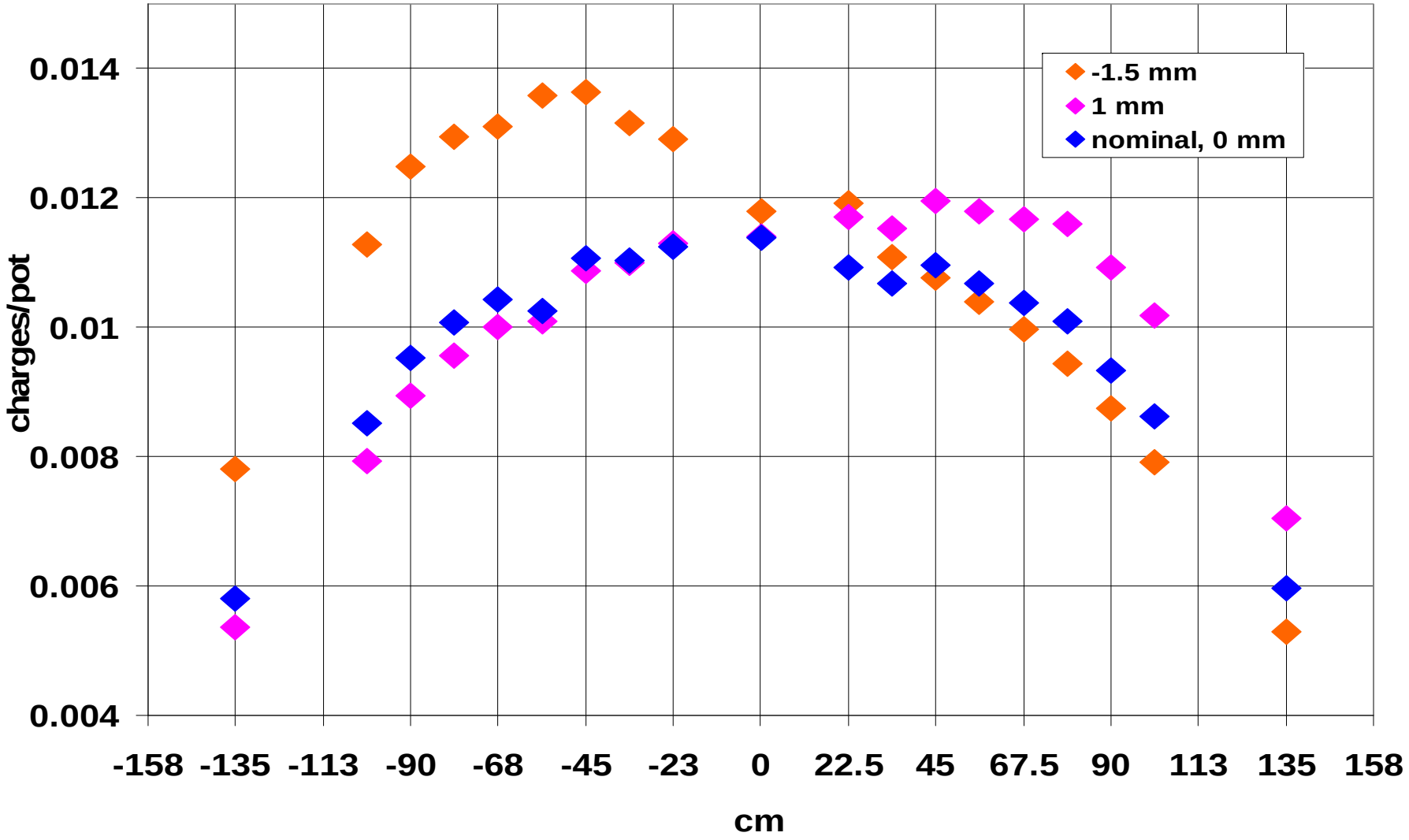
➔ **Beam position stability onto the target over the 3 first days: ~50 μm rms**

Proton Beam Scans across the Target

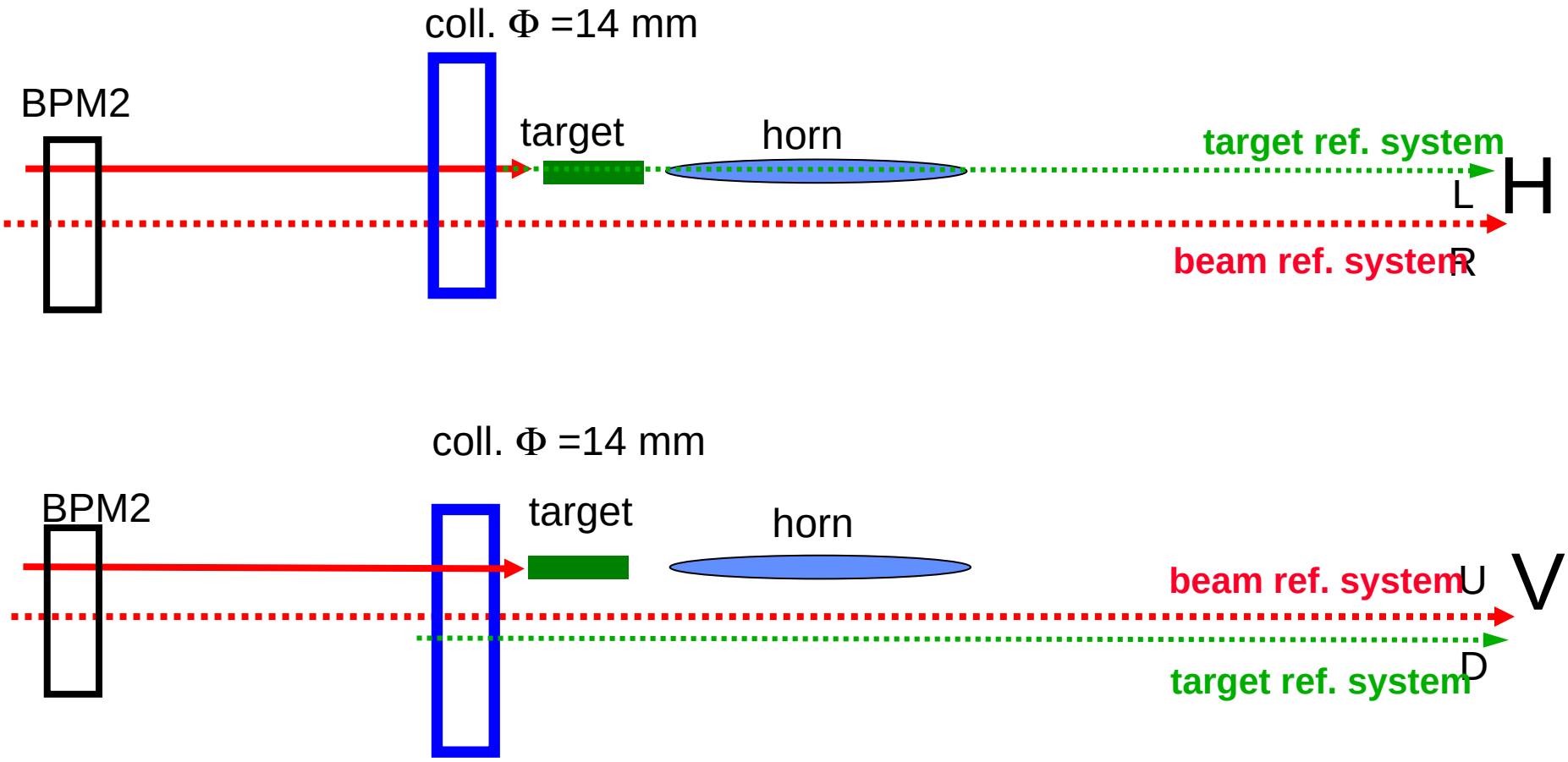


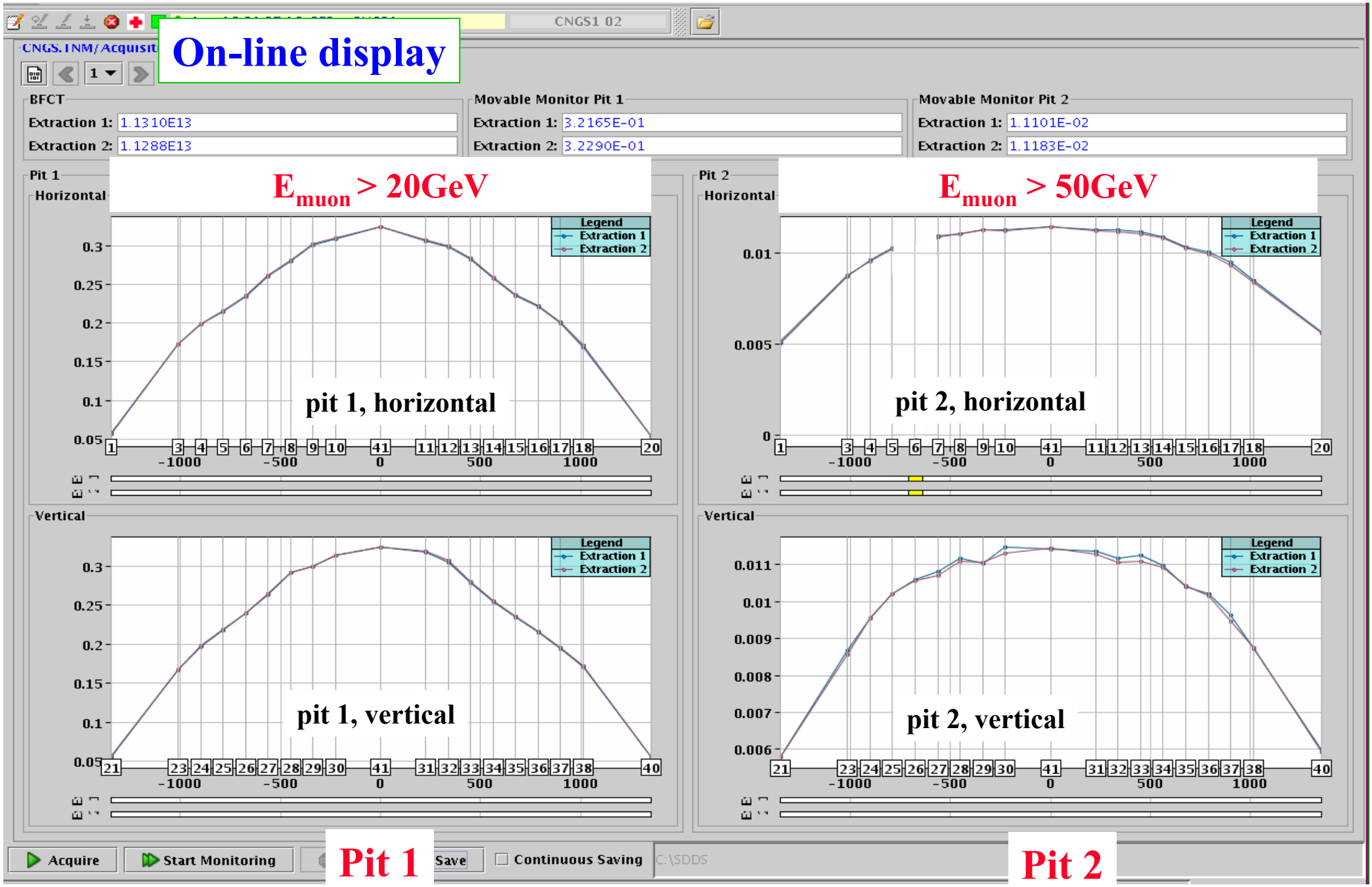
Vertical Beam vs. Target Alignment

Muon pit 2: sensitive to beam vs. target alignment



CNGS Final Alignment




On-line display
CNGS1 02
CNGS.TNM/Acquisit
BFCT
Extraction 1: 1.1310E13
Extraction 2: 1.1288E13
Movable Monitor Pit 1
Extraction 1: 3.2165E-01
Extraction 2: 3.2290E-01
Movable Monitor Pit 2
Extraction 1: 1.1101E-02
Extraction 2: 1.1183E-02
Pit 1
Horizontal
E_muon > 20GeV
pit 1, horizontal
Vertical
pit 1, vertical
Pit 2
Horizontal
E_muon > 50GeV
pit 2, horizontal
Vertical
pit 2, vertical
Legend
Extraction 1
Extraction 2
Acquire
Start Monitoring
Save
Continuous Saving
C:\SDDS
Pit 1
Pit 2

Summary of 2006 Run

- **Commissioning was very successful**
  - ➔ **Detailed hardware commissioning**
  - ➔ **'Dry runs'**
    - **Allowed early debugging of all systems**
- **Smooth start-up**
  - ➔ **Beam interlock system very good**
  - ➔ **Extraction channel well tuned**
  - ➔ **Beam well centered along beam line**
    - **Beam position stability: 50 μm rms**
    - **Beam spot at target: 0.5 mm rms.**
  - ➔ **Centering of beam vs. target and horn important**
  - ➔ **Muon monitors: very sensitive to any beam changes**
    - **Used as on-line feedback for quality control of neutrino beam.**

Radiation Protection Issues

Radiation Protection constraints to CNGS operation

- **Cool down limit for starting access into CNGS**
  - ➔ **2hr + 4hr (i.e. 4 hr ventilation on)**
- **RP inspection mandatory before any access is granted:**
  - ➔ **Takes ~1/2 day (surveys, taking samples, etc.)**
- **Dose planning mandatory for any interventions**

Perspectives for 2007

- **OPERA has asked for 1 E19 pot at the end of the run 2007.**
  - ➔ **Subject to experimental status.**
  - ➔ **To be decided in the next SPSC.**

- **Meanwhile: repair work for the CNGS horn and reflector is ongoing.**

Maximum Possible Number of Protons delivered to CNGS
(M. Meddahi and E. Shaposhnikova for PAF members)

CNGS design values

- CNGS committed to deliver 4.5 E19 pot/year for 5 years

- I=3.5 E13 per batch, I=7E13 per cycle
  - ➔ assumed in the design phase for the equipment for which the instantaneous intensity is important (target)

- 1.38 E20 pot/year
  - ➔ assumed (unrealistic scenario) for the design of equipment, for which long term effects are relevant (equipment exchange)

Intensity Limitations from the CNGS Facility

Intensity limitation	Protons per batch	Protons per cycle	POT per year
Radiation Protection calculation and optimization	3.5E13		Soil/concrete activation: 4.5E19 Air/water activation: 7.6E19
Target design	3.5E13	1.4E14	2E20
Horn design	3.5E13	7E13	1.38E20
Shielding, Decay Tube, Hadron stop design			1.38E20
Kicker system	3.5E13	1E14	
Instrumentation	3.5E13		

- **Intensity limitations from the injectors**
  - ➔ **Intensity limitations from accelerator chain injectors and for various scenarios are being evaluated. More results for end March 2007.**

Spare Slides

CNGS Performance

For CNGS performance, the main issues are

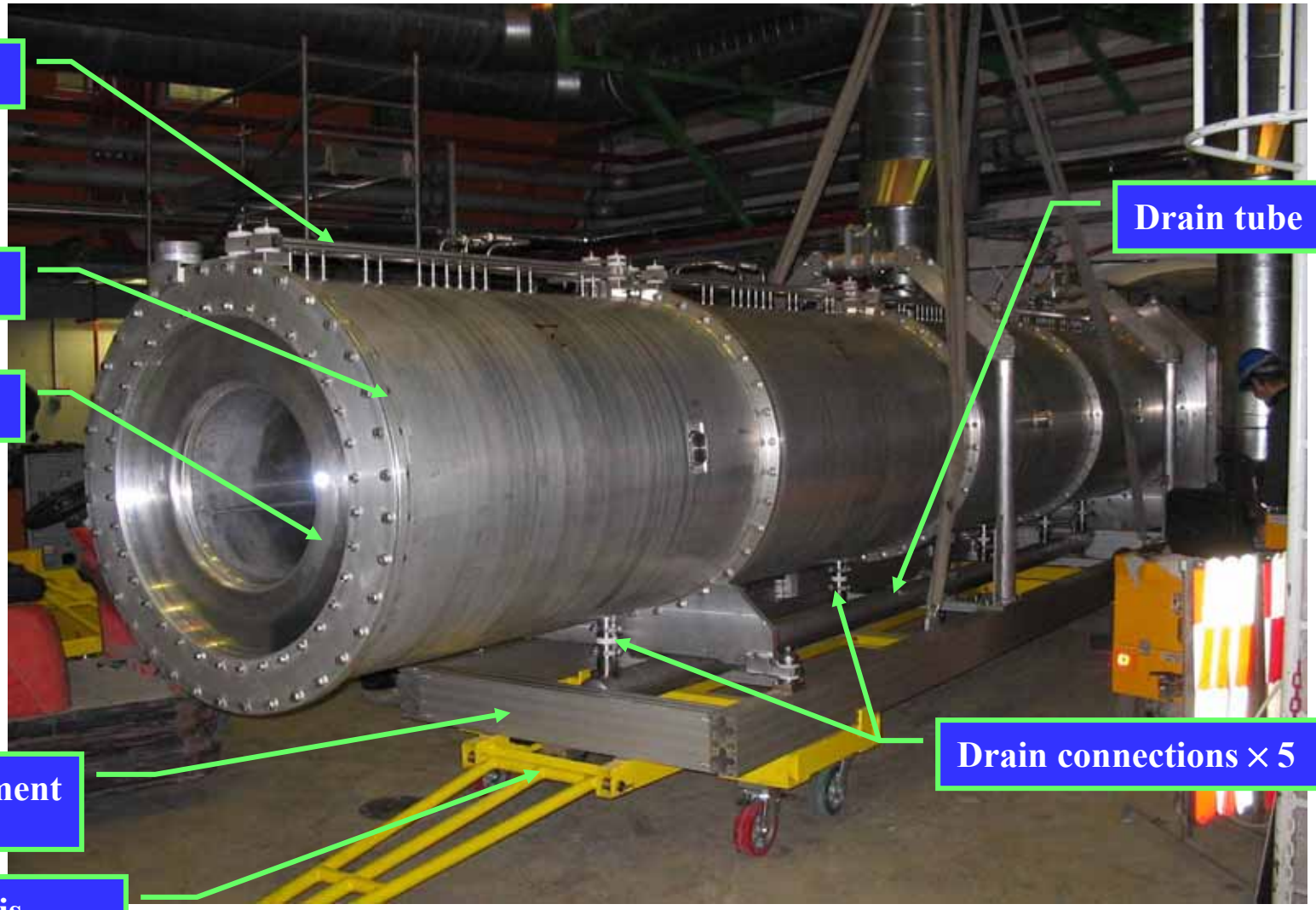
➔ **the geodesic alignment wrt. Gran Sasso**

Examples:	effect on ν_τ cc events
horn off axis by 6mm	< 3%
reflector off axis by 30mm	< 3%
proton beam on target off axis by 1mm	< 3%
CNGS facility misaligned by 0.5mrad (beam 360m off)	< 3%

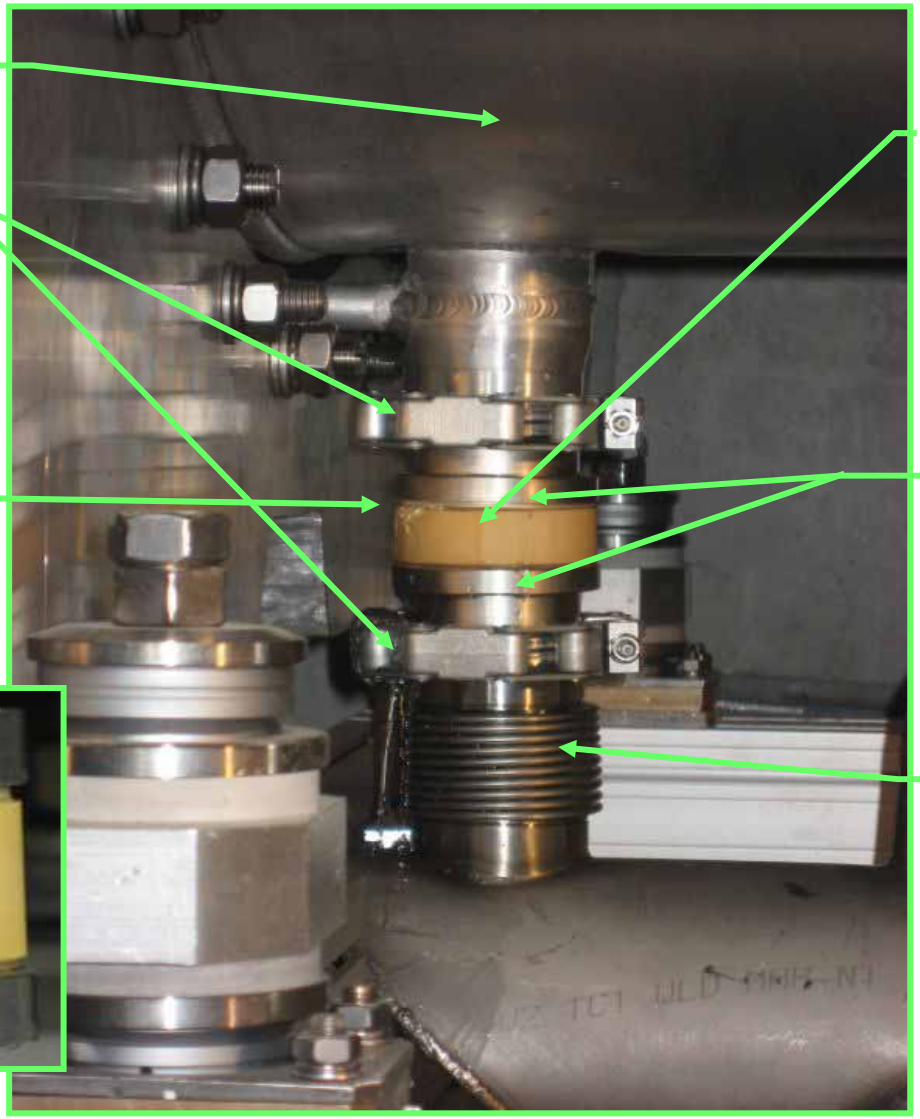
➔ **the beam must hit the target very accurately**

➔ **horn and reflector tables NOT motorized**

The CNGS Reflector



Leaking Drain Connection



Outer conductor (Al)

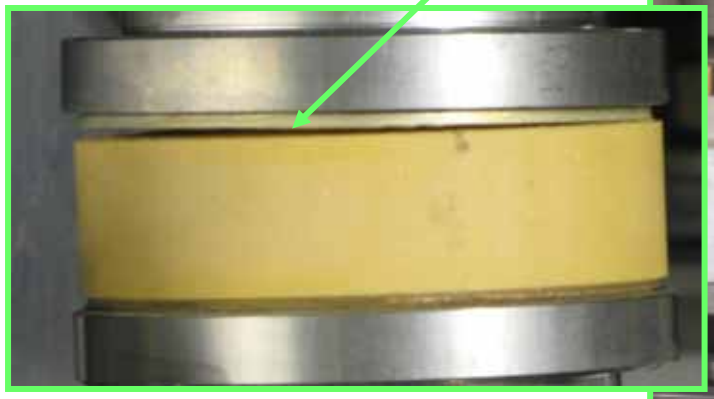
Clamps for vapor tightness

Rupture point – leak!!

Ceramic insulator (500V)
(brazed to the Ti joints)

Titanium joints

Bellows to give (some) flexibility



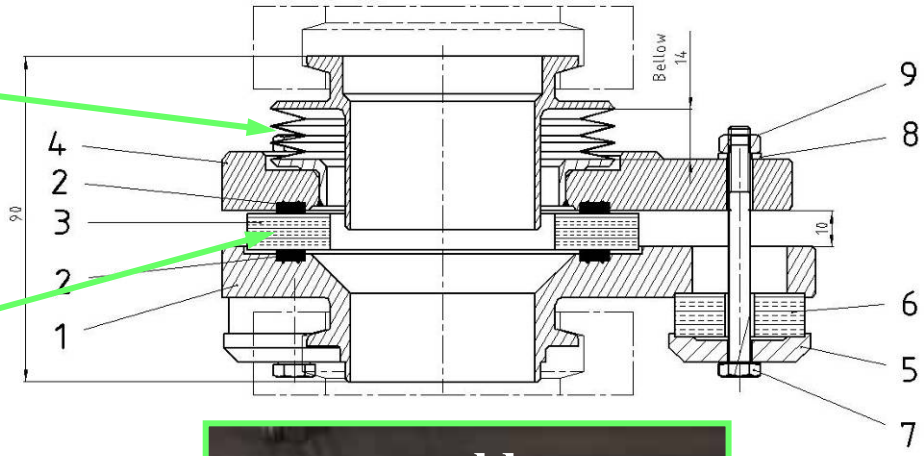
New Design for Drain Connection

CNGS Reflector Leak Review Meeting with AB, TS and RP experts, held on 29 Nov 06

Improvements of new design:

- **Second welded bellows**
  - ➔ **Absorb better any misalignment errors**
- **Water and vapour tightness maintained**
  - ➔ **tightening the ceramic between flanges with bolts**
- **Brazing is avoided**
- **Rigorous QA during assembly**
  - ➔ **Tracing of equipment and record history**

new



Next Steps

Tests

- Mounting first prototype on spare horn
- Perform tests with spare horn in BA7
  - ➔ Electrical tests
  - ➔ Vibration measurements on old drain connection
  - ➔ Vibration measurements on new drain connection

Repair

- Radiation Issues
  - ➔ Careful dose planning needed

- Repair is not trivial

Repair Location