CERN Neutrinos to Gran Sasso, CNGS: Commissioning and First Operation

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CERN

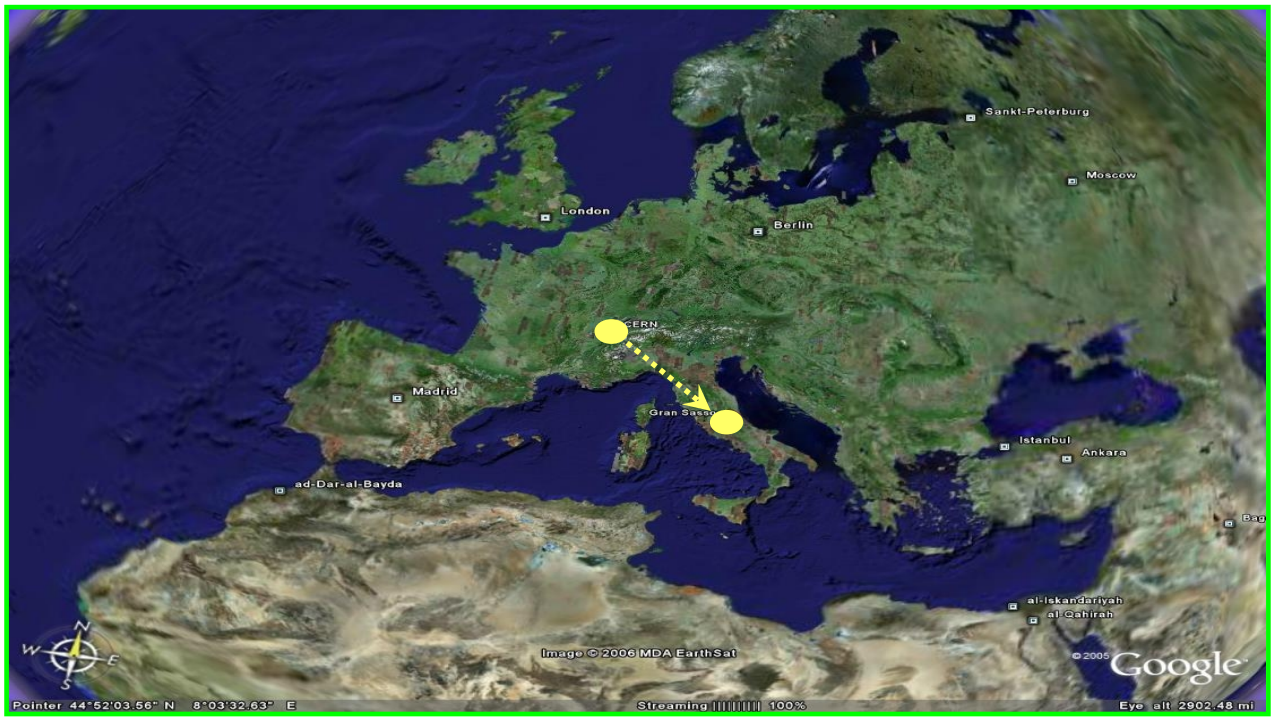
on behalf of the CNGS project and commissioning teams

1. **Introduction**
2. **CNGS Commissioning**
3. **CNGS Operation**

CNGS Project

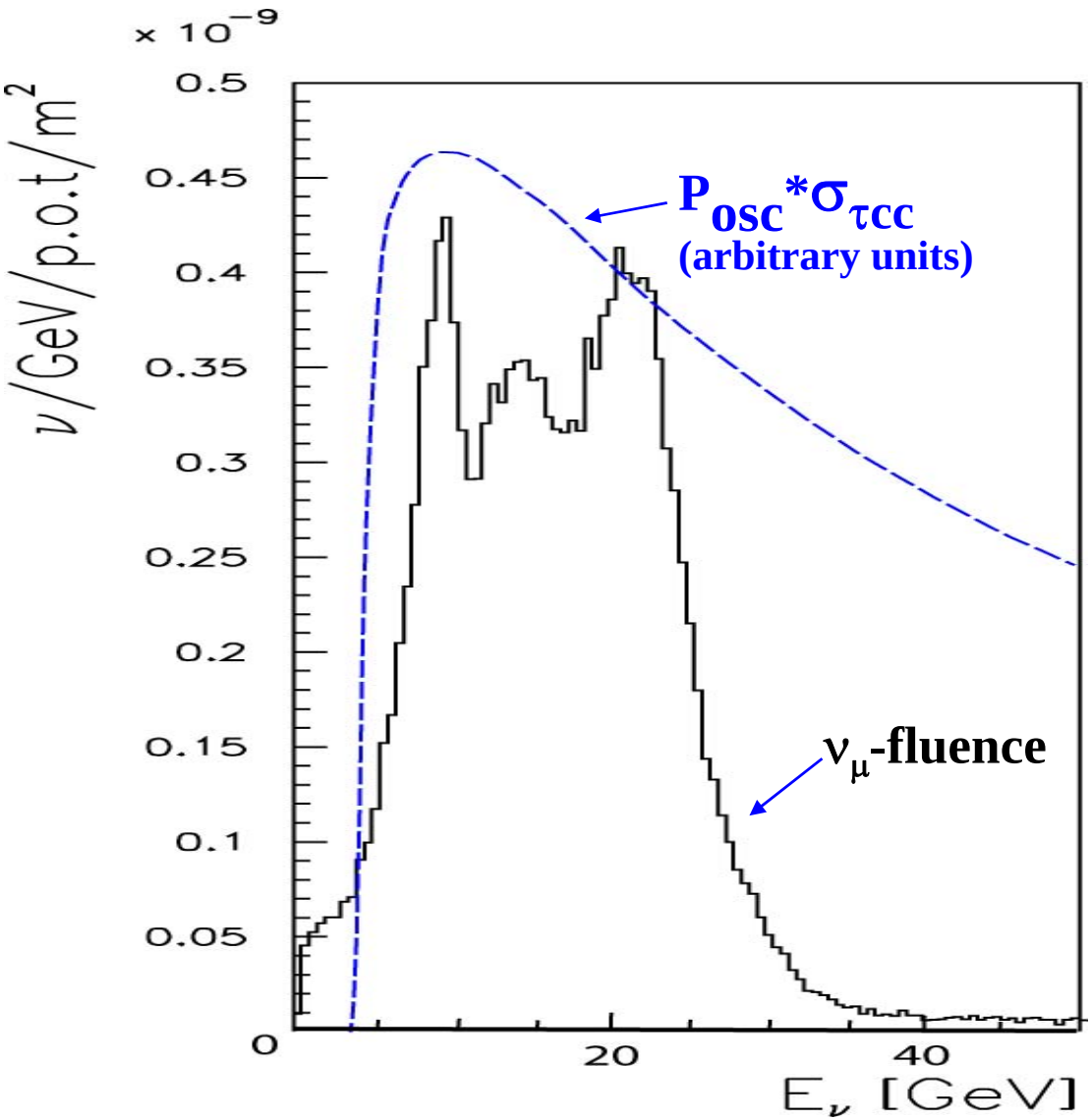
CNGS (CERN Neutrino Gran Sasso)

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



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

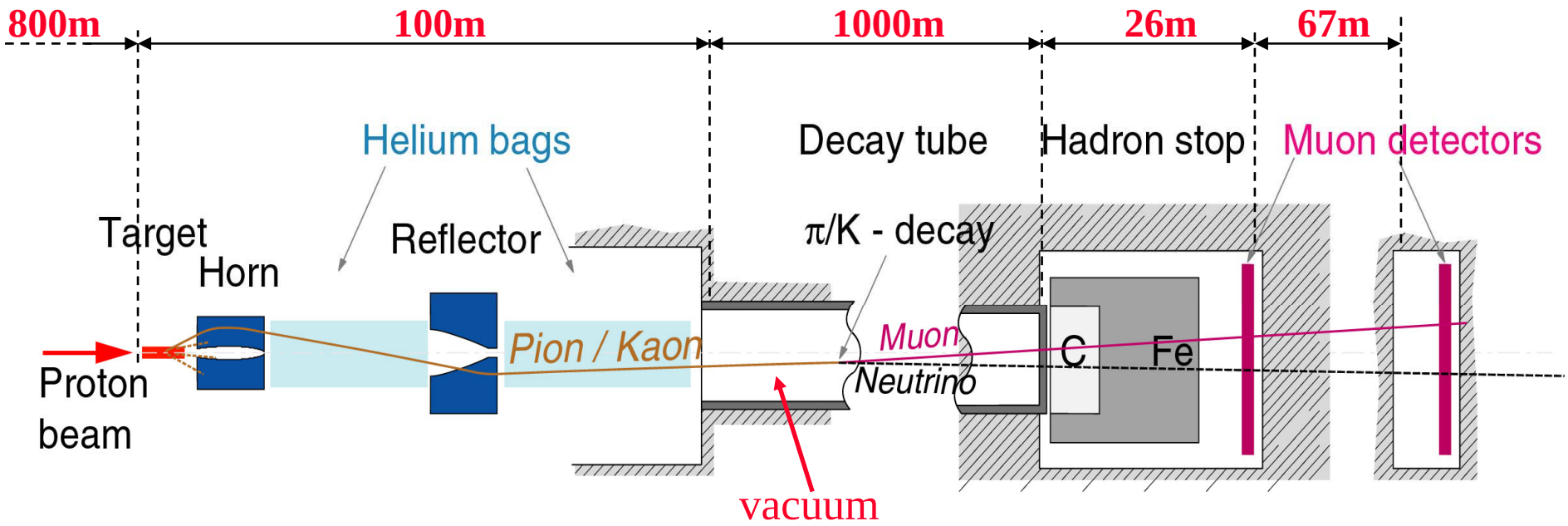
ν_τ – Appearance Experiment



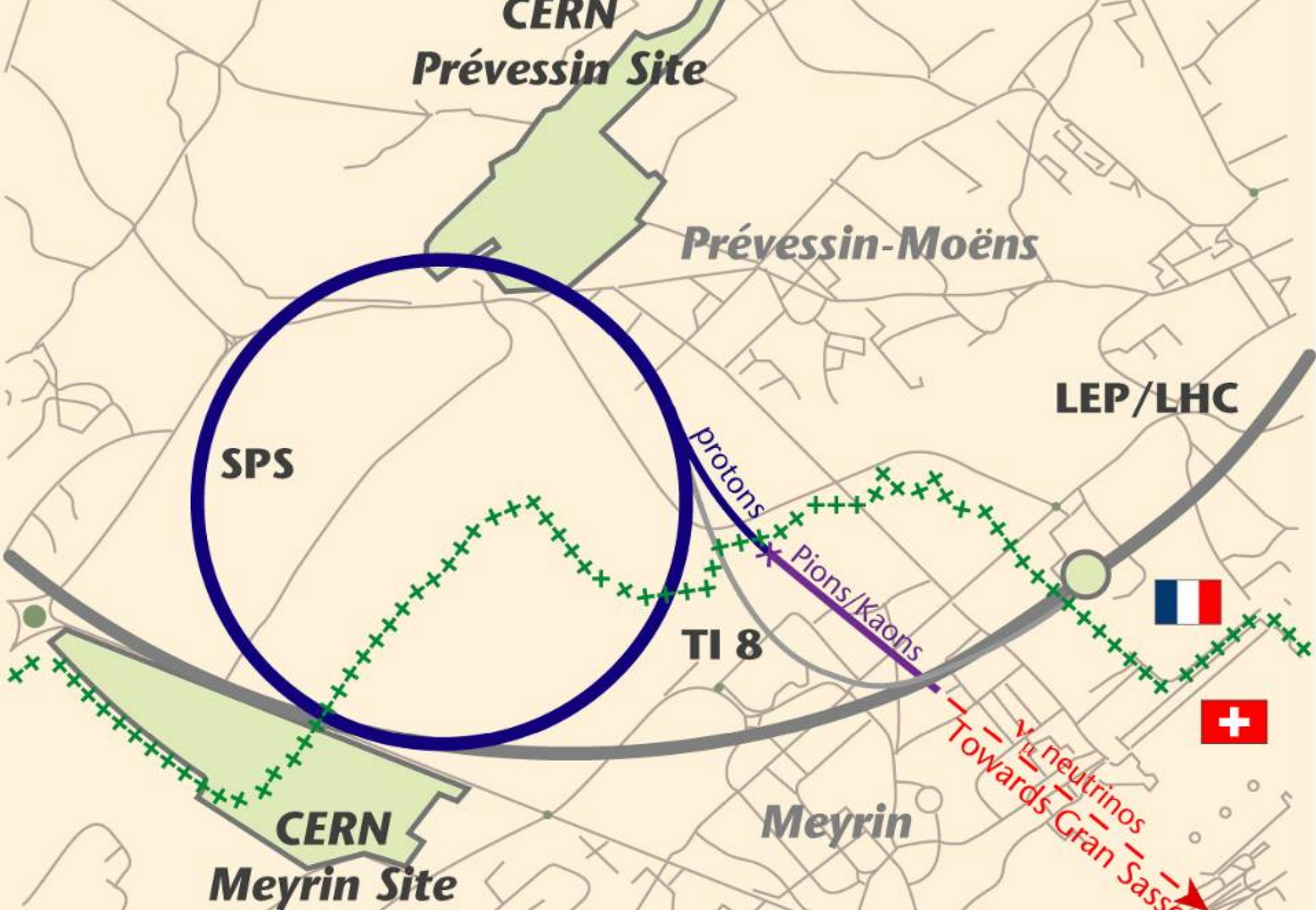
- **Beam optimization:**
  - ➔ **Intensity: as high as possible**
  - ➔ **Neutrino energy: matched for ν_μ-ν_τ appearance experiments**
- **Product of**
  1. **Oscillation probability ν_μ– ν_τ**
  2. **Production cross-section ν_τ with matter**
  3. **ν_μ –fluence(E)**

     + Detection efficiency in the experiment

CNGS Layout



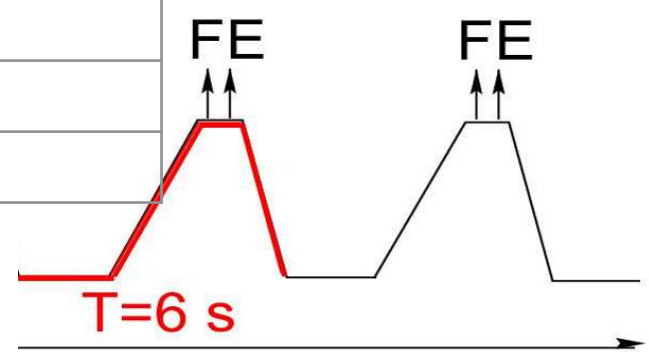
$$p + C \rightarrow \text{(interactions)} \rightarrow \pi^+,\ K^+ \rightarrow \text{(decay in flight)} \rightarrow \mu^+ + \nu_\mu$$


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

CNGS Proton Beam Parameters

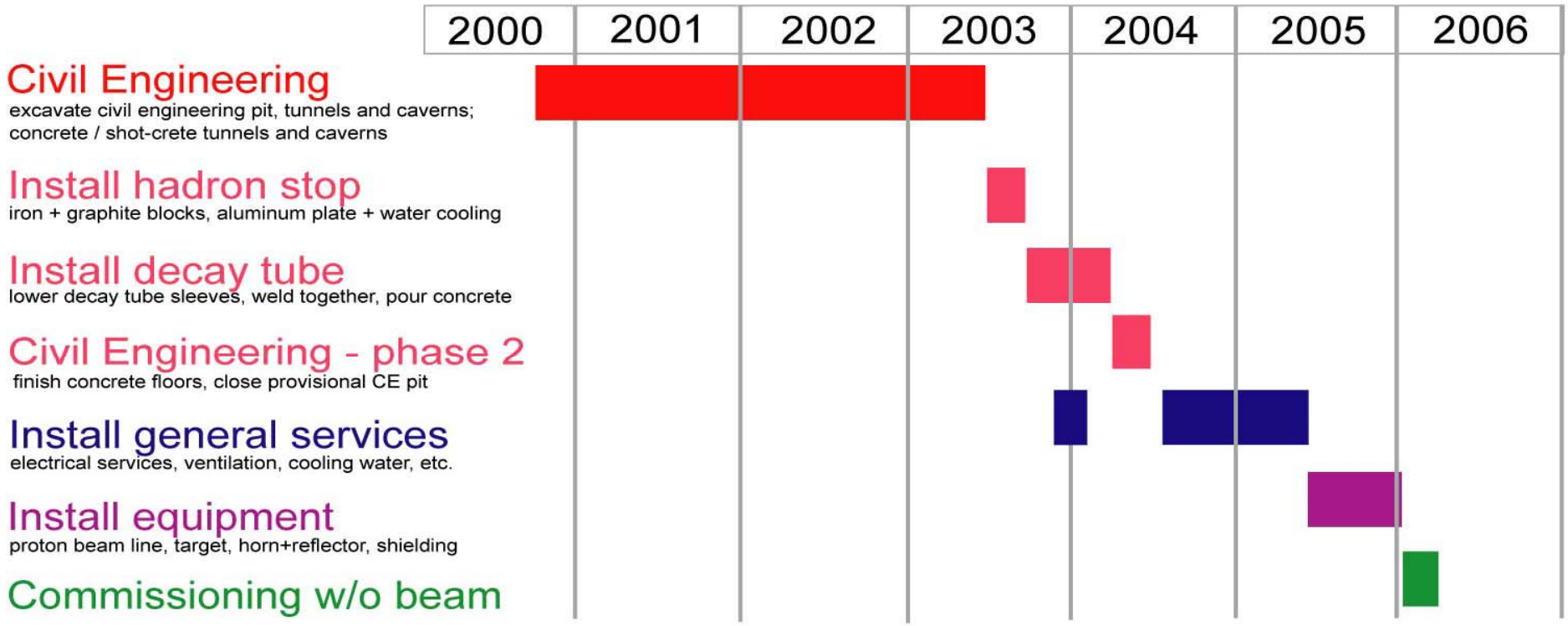
Beam parameters	Nominal CNGS beam
Nominal energy [GeV]	400
Normalized emittance [μm]	H=12 V=7
Emittance [μm]	H=0.028 V= 0.016
Momentum spread Δp/p	0.07 % +/- 20%
# extractions per cycle	2 separated by 50 ms
Batch length [μs]	10.5
# of bunches per pulse	2100
Intensity per extraction [10^{13} p]	2.4
Bunch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



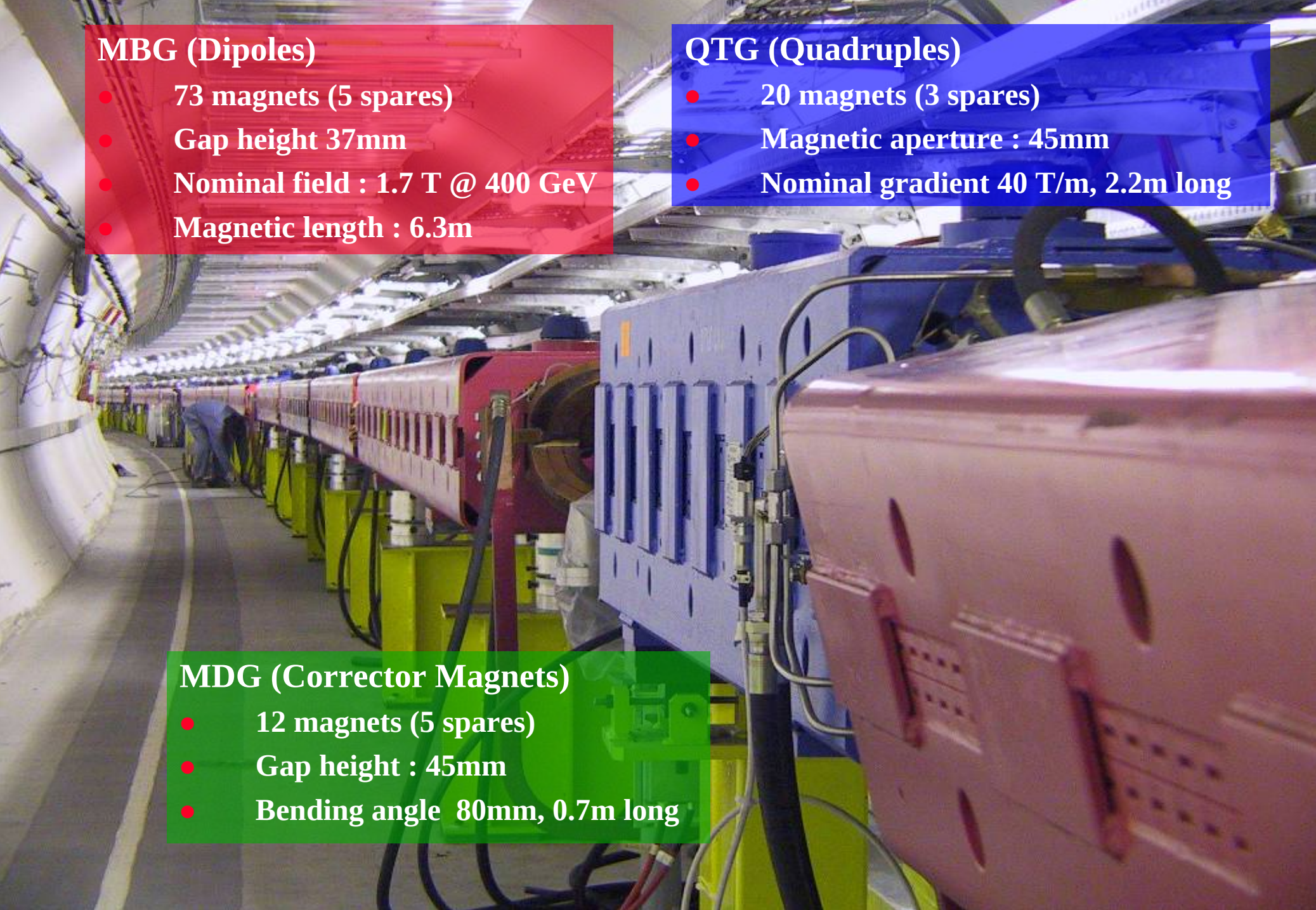
Expected beam performance: 4.5 x 10^{19} protons/year on target

Schedule



First beam:

10 July 2006



MBG (Dipoles)

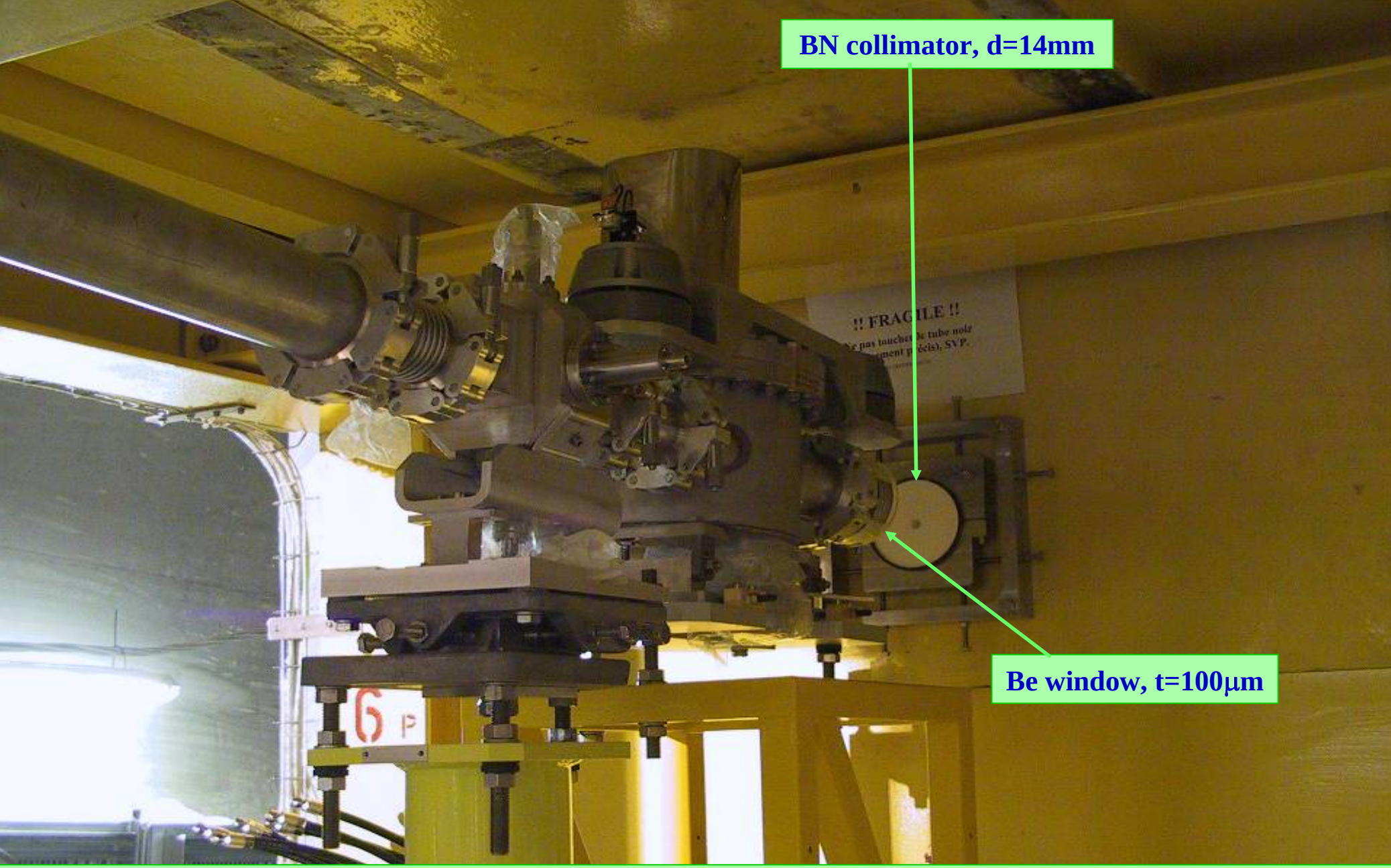
- 73 magnets (5 spares)
- Gap height 37mm
- Nominal field : 1.7 T @ 400 GeV
- Magnetic length : 6.3m

QTG (Quadruples)

- 20 magnets (3 spares)
- Magnetic aperture : 45mm
- Nominal gradient 40 T/m, 2.2m long

MDG (Corrector Magnets)

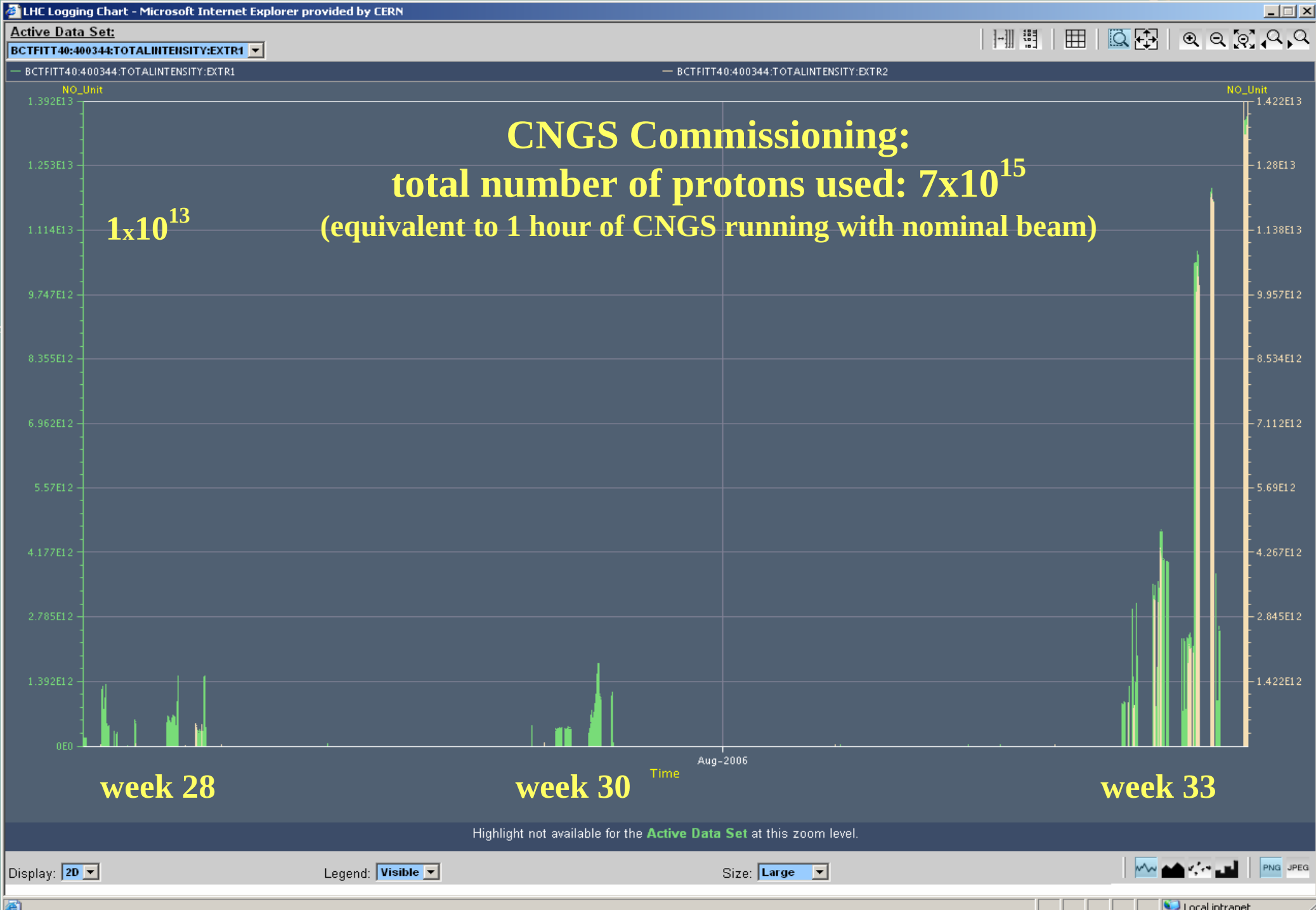
- 12 magnets (5 spares)
- Gap height : 45mm
- Bending angle 80mm, 0.7m long



Proton beam: last beam position / beam profile monitors upstream of the target station collimator and shielding

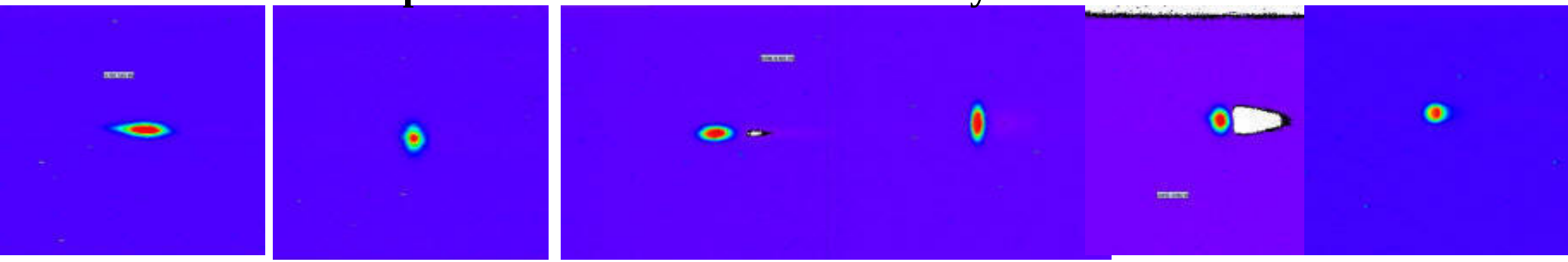
Commissioning Plan

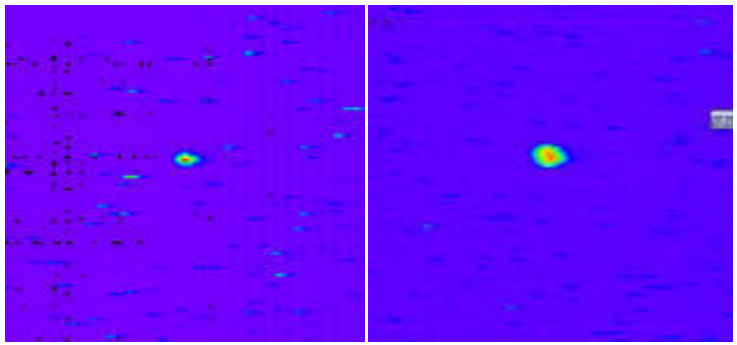
- **Hardware commissioning** **Feb. – April 2006**
  - ➔ **Beam instrumentations**
  - ➔ **Power supplies**
  - ➔ **Magnets (polarities)**
  - ➔ **Vacuum system**
  - ➔ **(April / May: Target / Horn exchange excercises 'real')**
- **'Dry runs' from CCC** **April – May 2006**
  - ➔ **Timing**
  - ➔ **Controls**
  - ➔ **Interlocks**
  - ➔ **Beam permit**
  - ➔ **Magnets (currents & polarities)**
- **Commissioning with beam** **2006: weeks 28, 30 and 33**

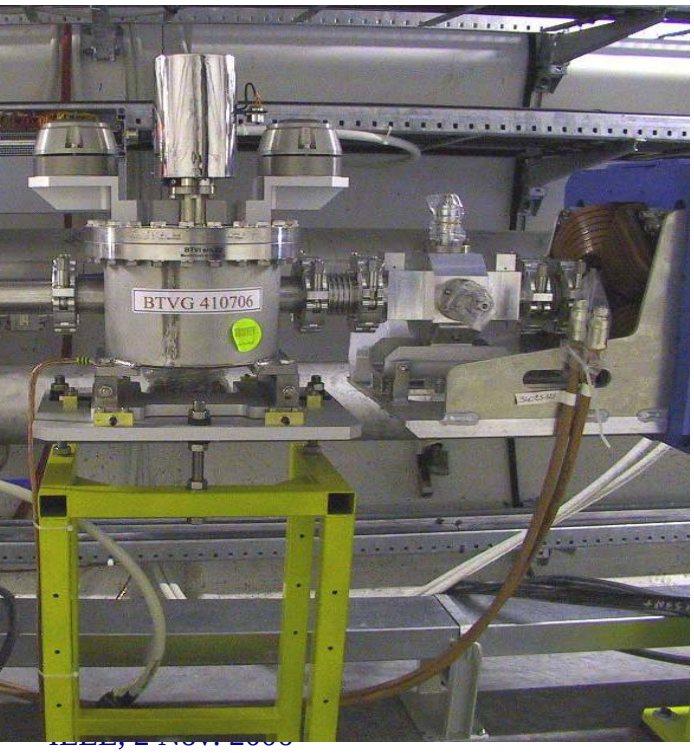

LHC Logging Chart - Microsoft Internet Explorer provided by CERN
Active Data Set:
BCTFITT40:400344:TOTALINTENSITY:EXTR1
BCTFITT40:400344:TOTALINTENSITY:EXTR1
BCTFITT40:400344:TOTALINTENSITY:EXTR2
NO_Unit
NO_Unit
1.392E13
1.253E13
1.114E13
9.747E12
8.355E12
6.962E12
5.57E12
4.177E12
2.785E12
1.392E12
0E0
1.422E13
1.28E13
1.138E13
9.957E12
8.534E12
7.112E12
5.69E12
4.267E12
2.845E12
1.422E12
CNGS Commissioning:
total number of protons used: 7x10^15
1x10^13
(equivalent to 1 hour of CNGS running with nominal beam)
Aug-2006
Time
week 28
week 30
week 33
Highlight not available for the Active Data Set at this zoom level.
Display: 2D
Legend: Visible
Size: Large
PNG
JPEG
Local intranet

FIRST SHOT 11 July 2006

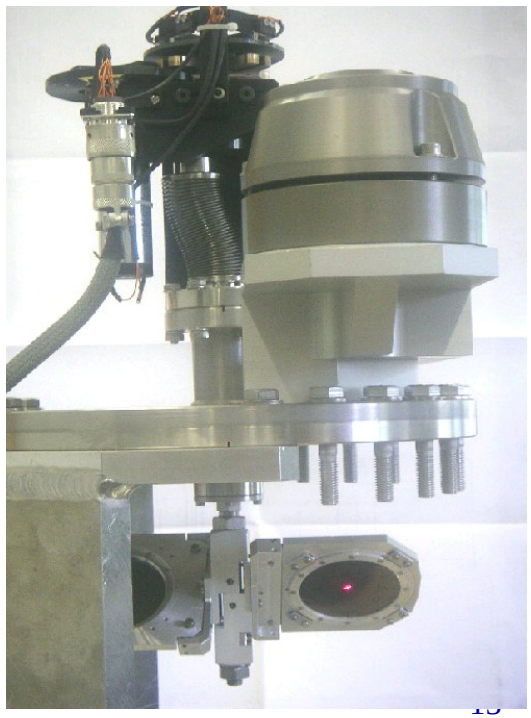
1st shot down proton beam line: beam is already well centered on screens





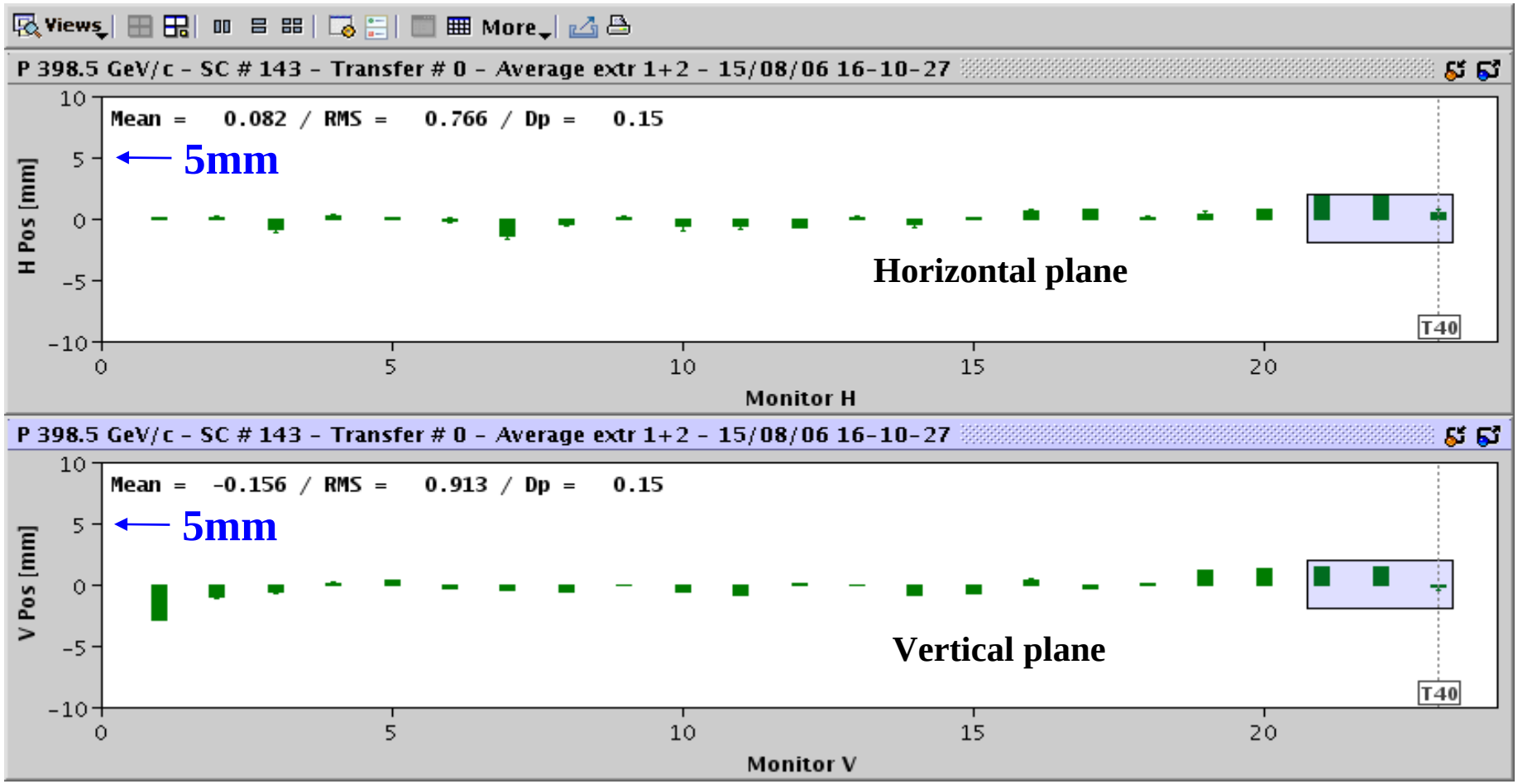


8 profile monitors (BTVG):
Optical Transition Radiation screens:
- **75 μm carbon**
- **12 μm titanium screens**



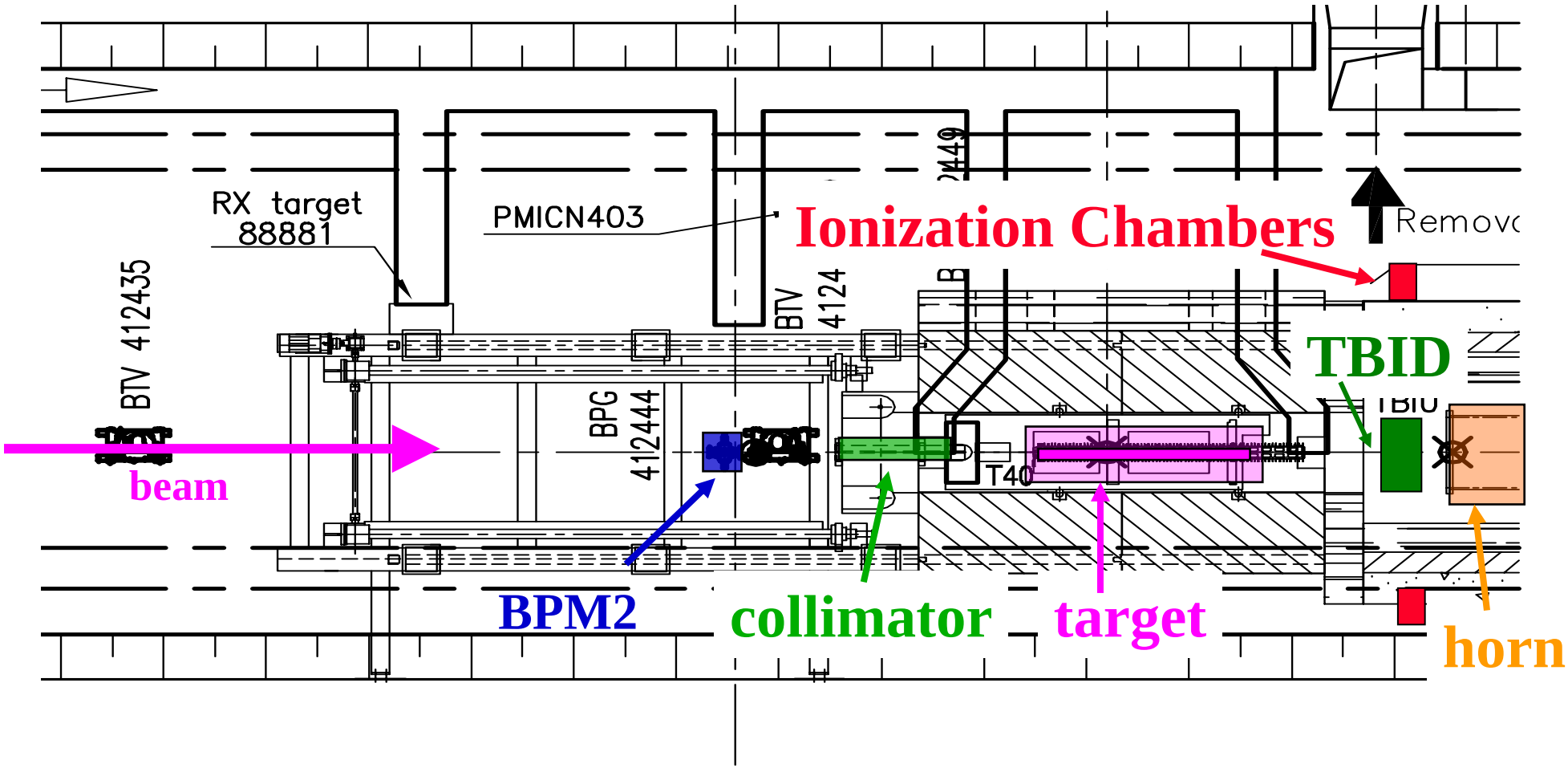
Trajectory along the Beam Line

Average of two extractions. 1E13 protons per batch



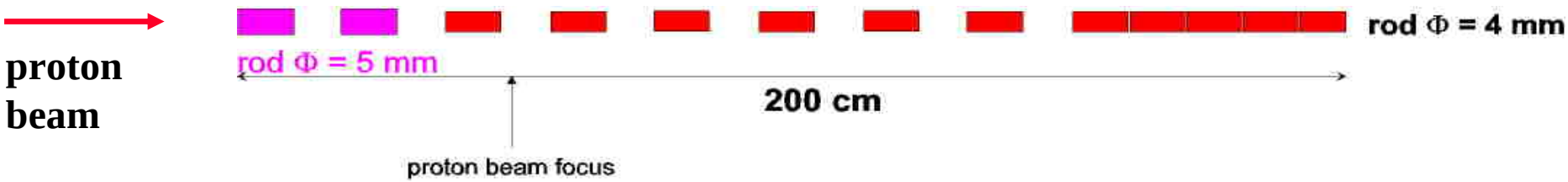
➔ **Beam position stability onto the target over the 3 first days: ~50 μm rms**

Proton Beam Scans across the Target



CNGS Target Elements

10 cm long graphite rods, Ø = 5mm and/or 4mm



Note: **- target rods thin / interspaced to "let the pions out"**

- target shall be robust to resist the beam-induced stresses

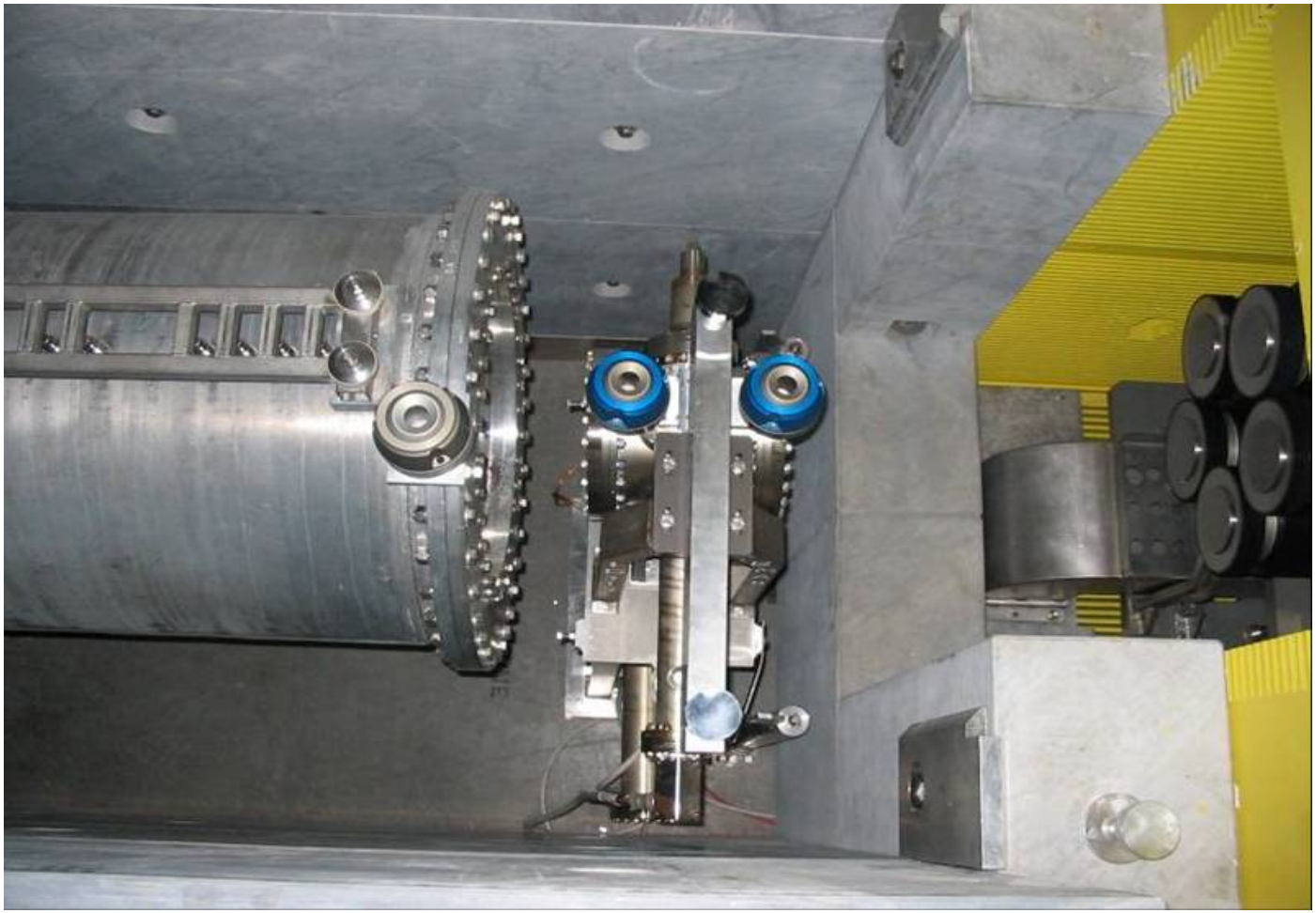
- target is air-cooled (particle energy deposition)

Target Magazine

indexing finger

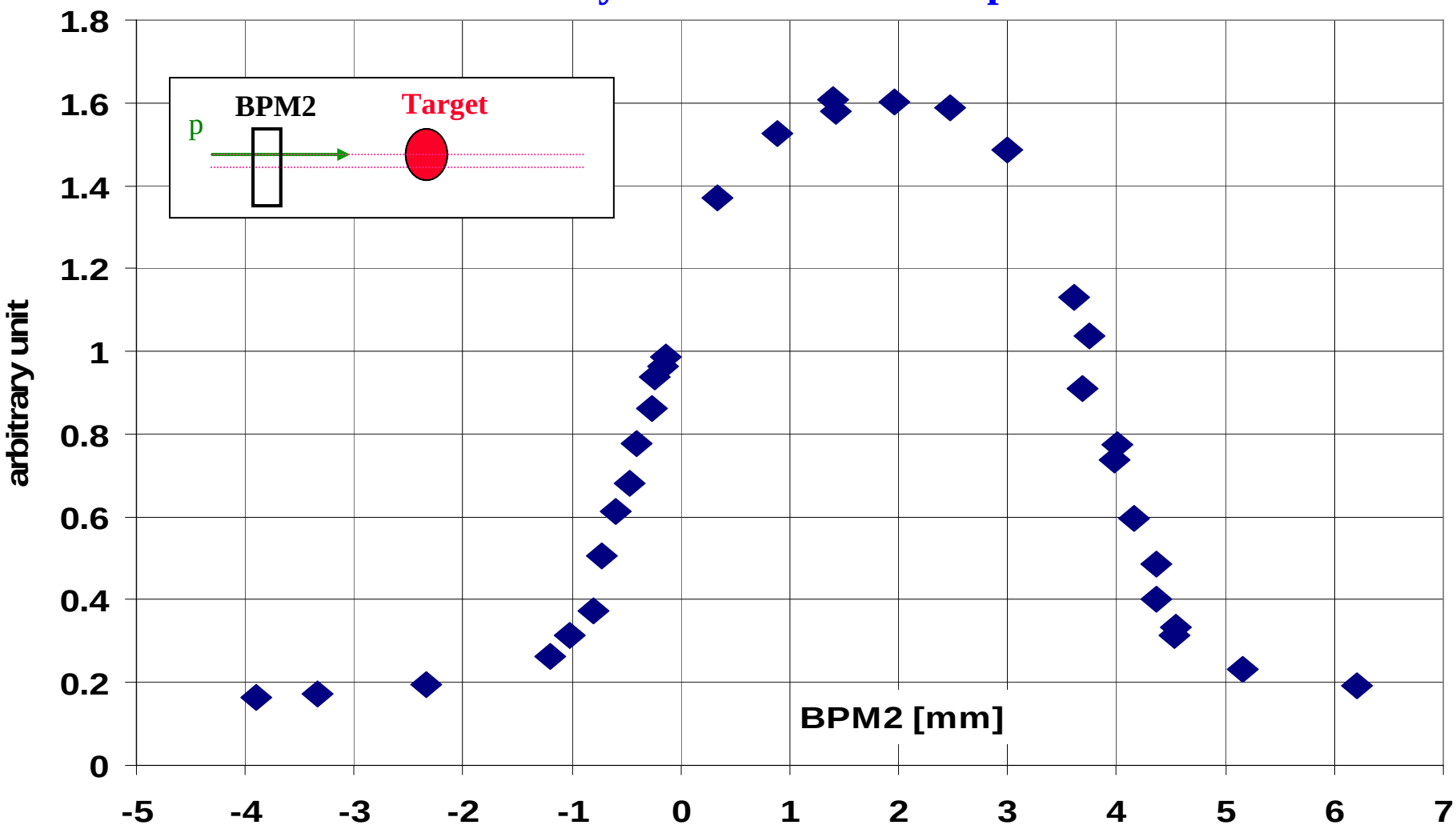
TBID (Target Beam Instrumentation Downstream)

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



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

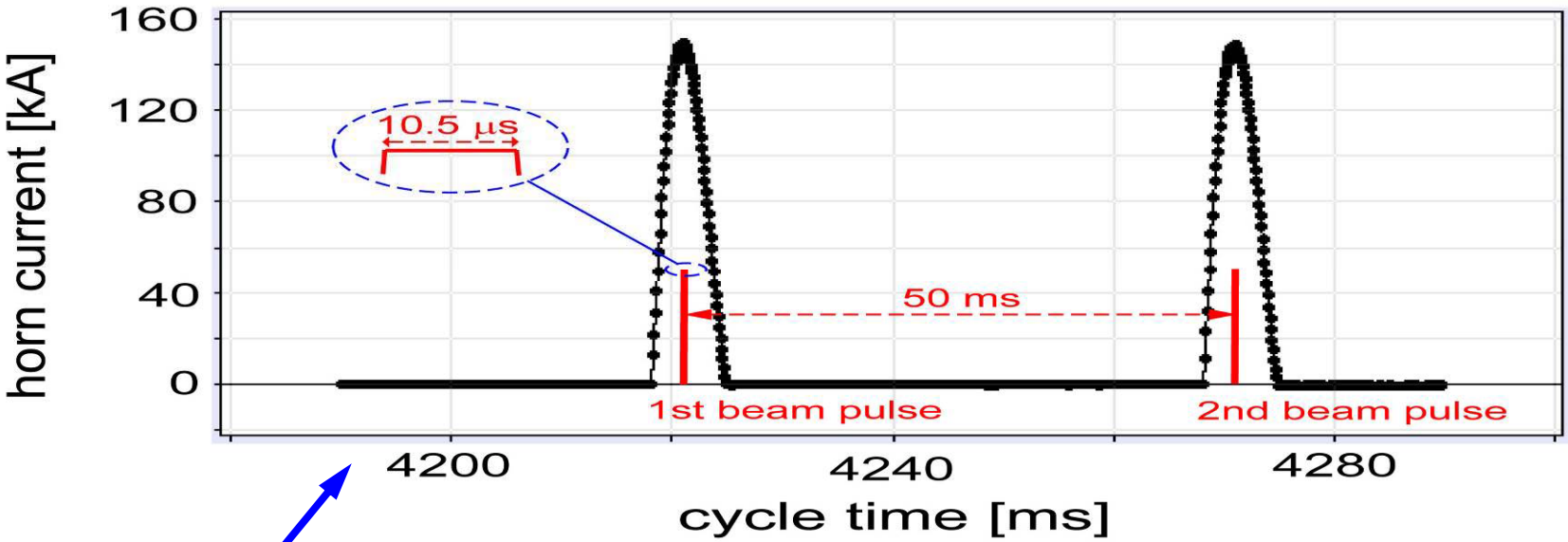
Horizontal Beam Scan, Target IN



Horn

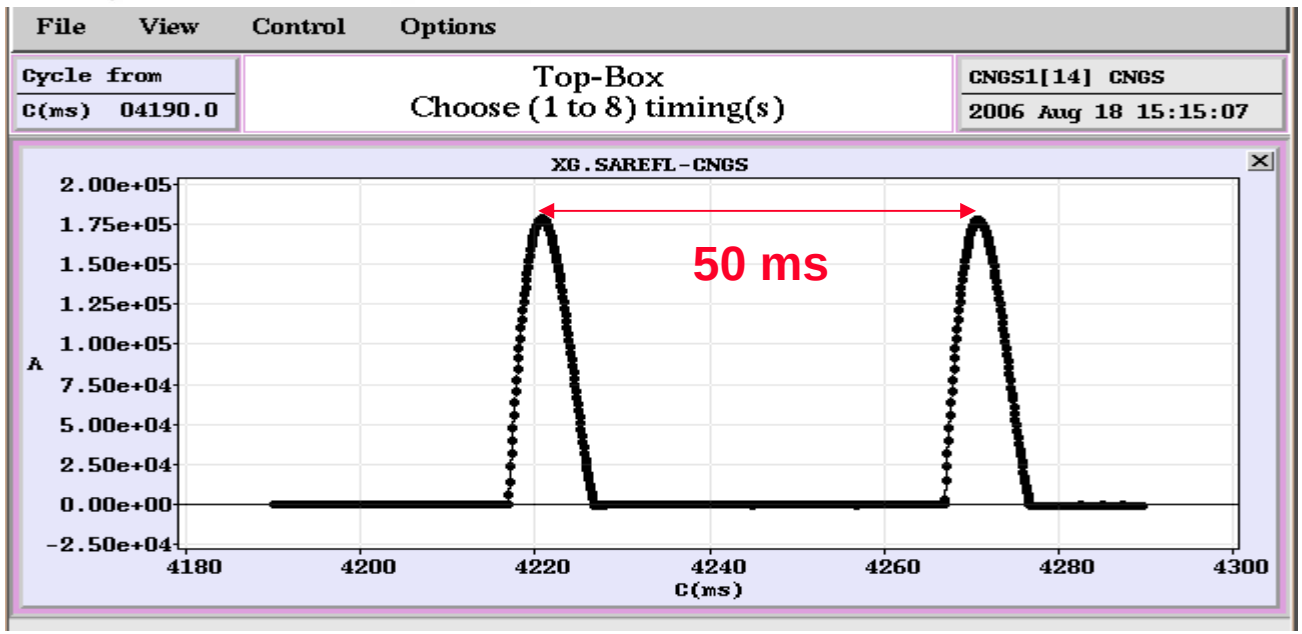
Installation of the horn in the target chamber

Horn/Reflector Power System



Horn
150kA

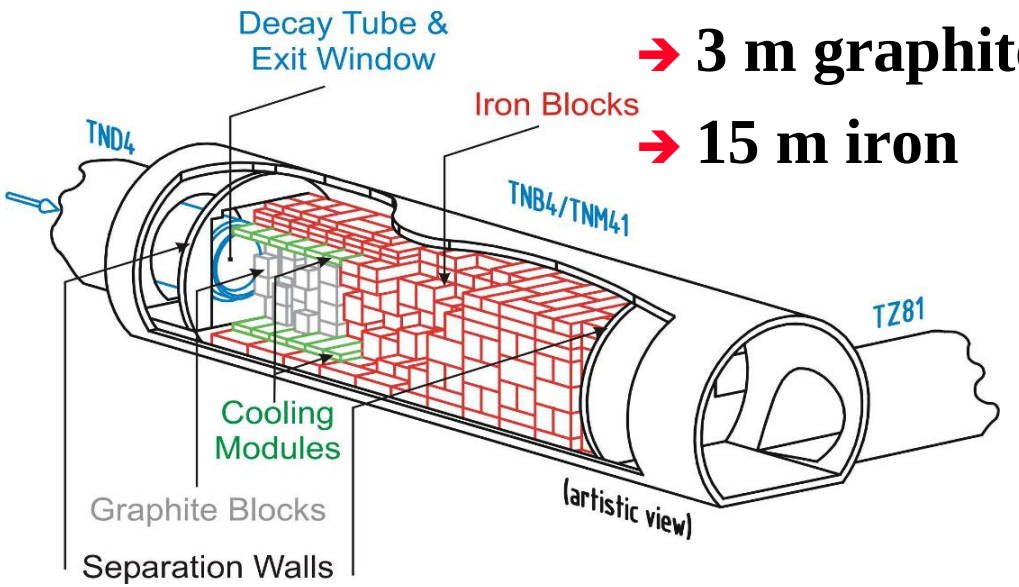
Reflector
180kA



Decay Tube

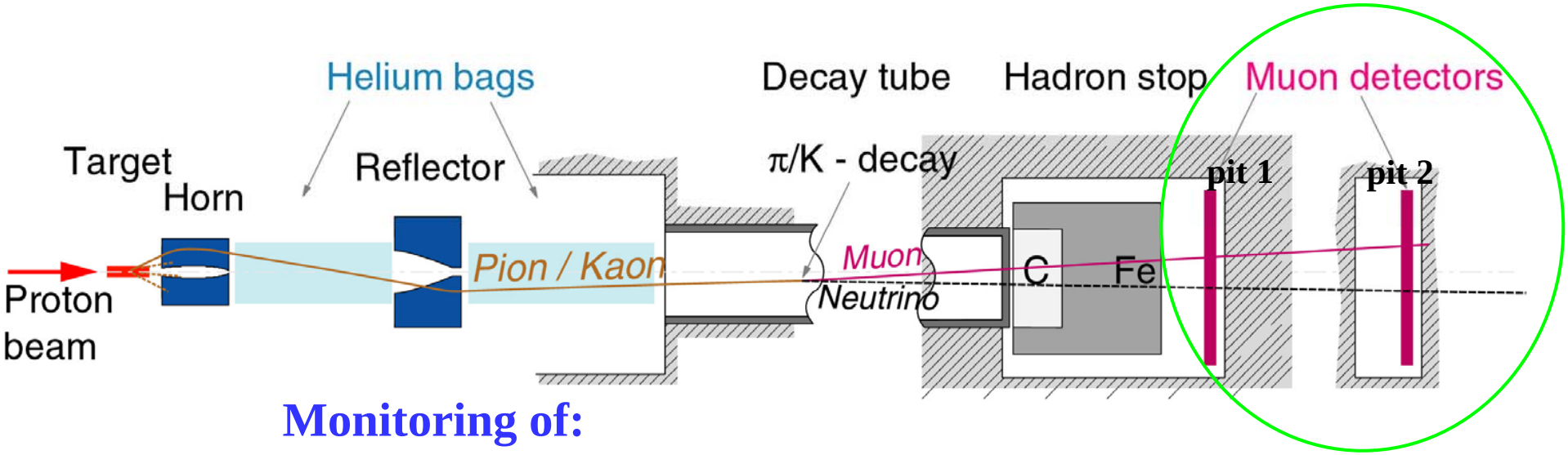
- steel pipe
- 1mbar
- 994m long

Hadron Stop



- 3 m graphite
- 15 m iron

Muon Monitors



Monitoring of:

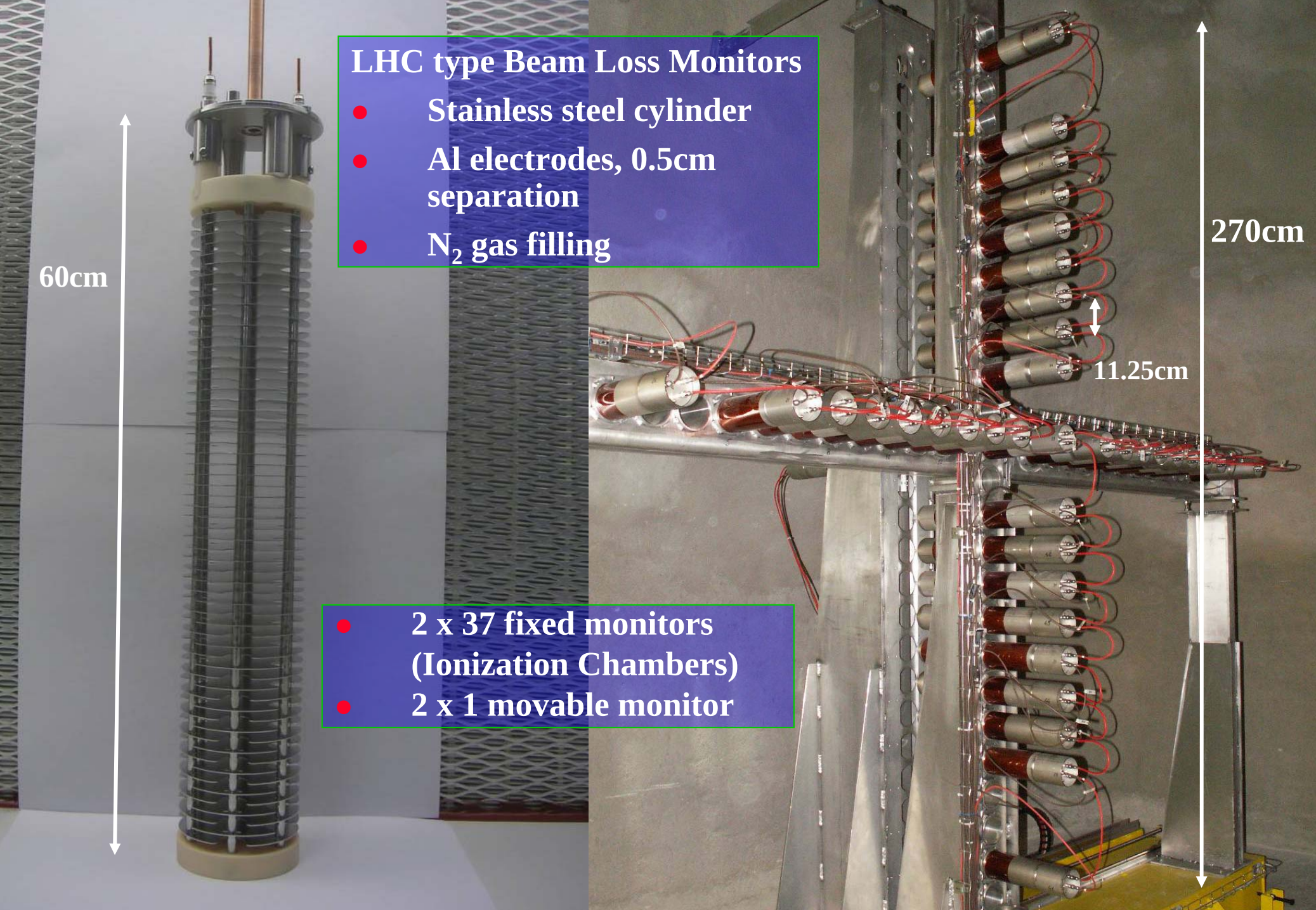
- ➔ **muon intensity**
- ➔ **muon beam profile shape & centre**

Muon energy filter due to 67m rock in between pit 1 and pit 2.

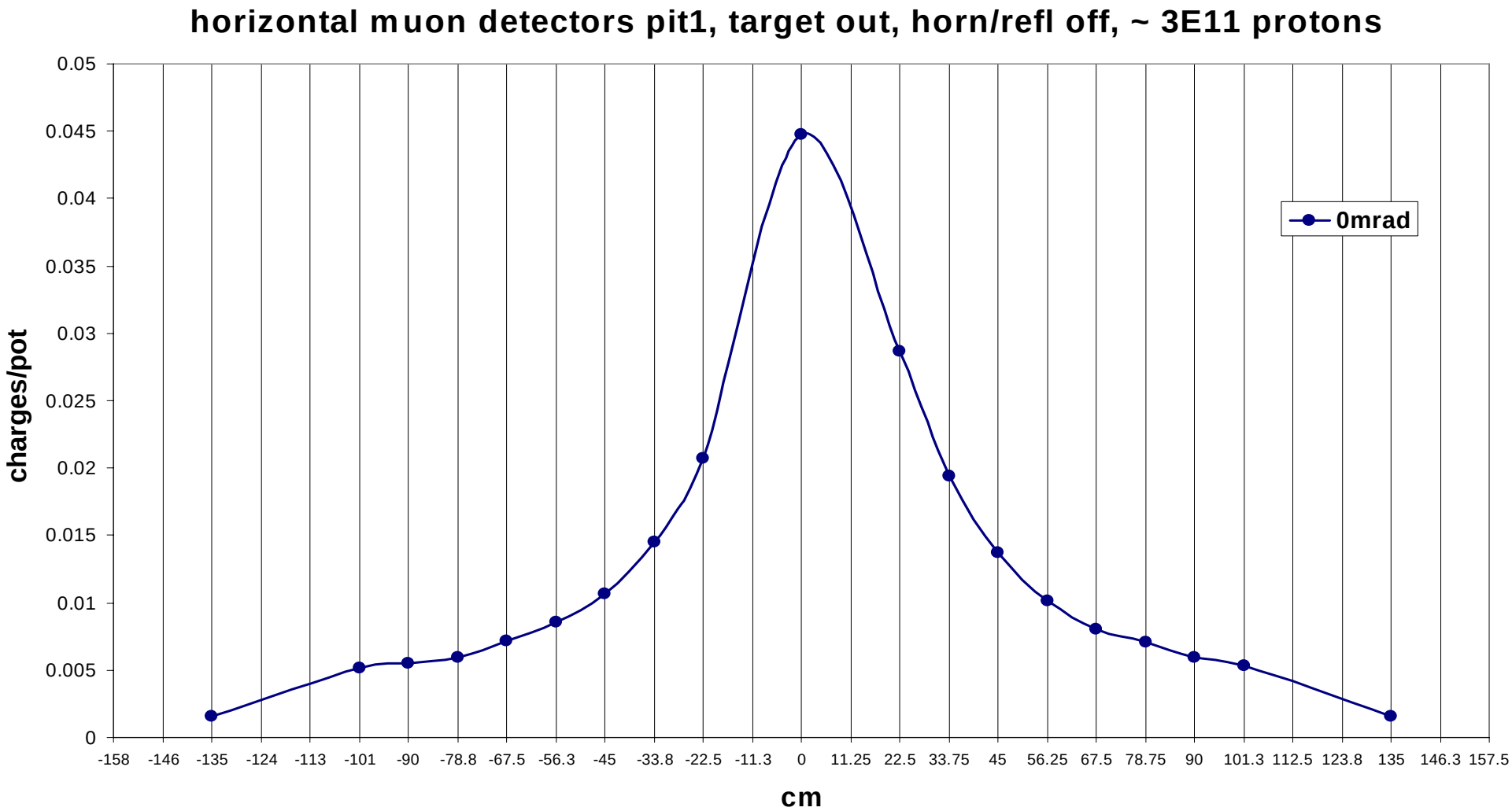
Muon intensity:

Up to ~8x10^7 per cm^2 and 10.5μs

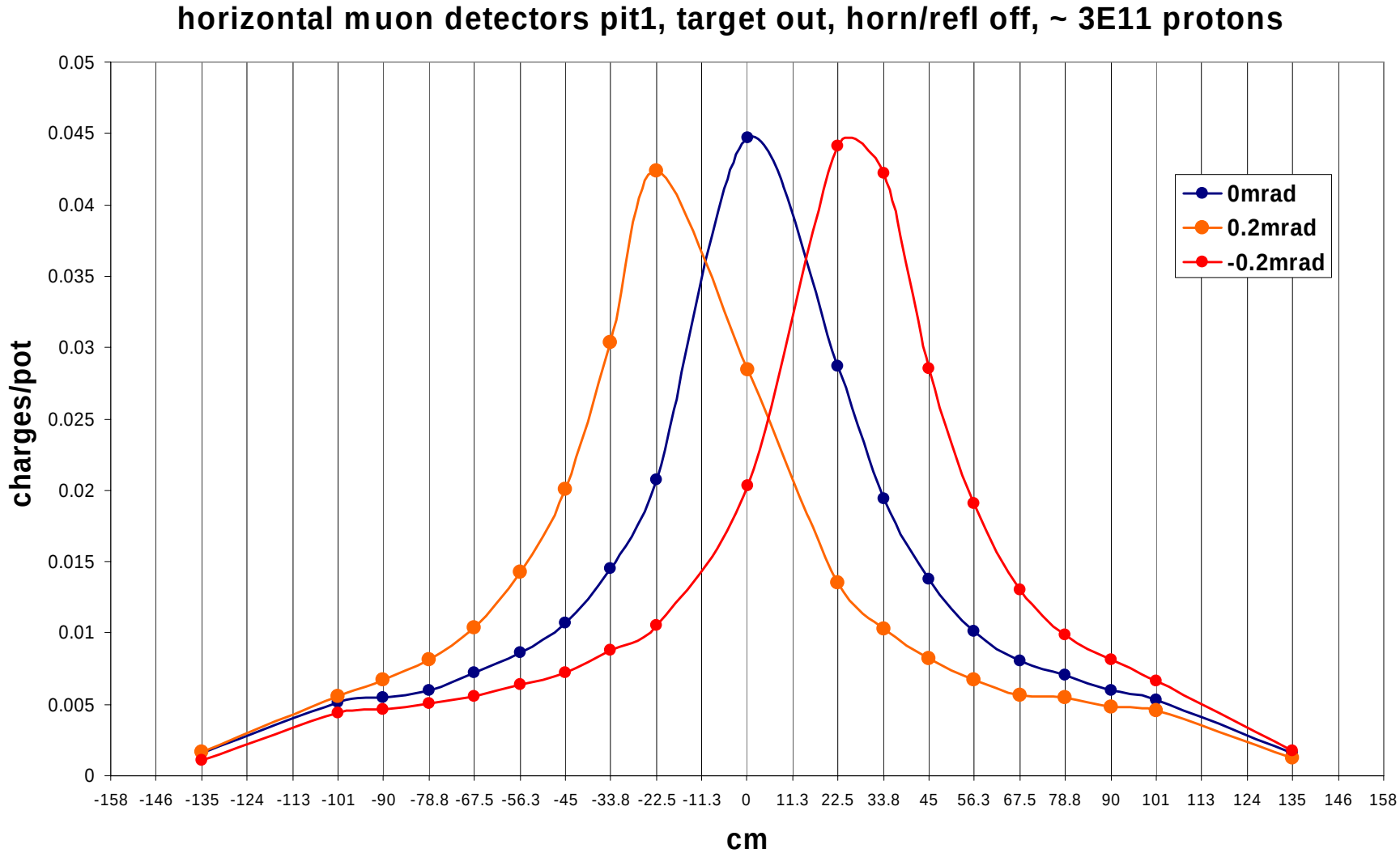
→ Detector choice: ionization chambers


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

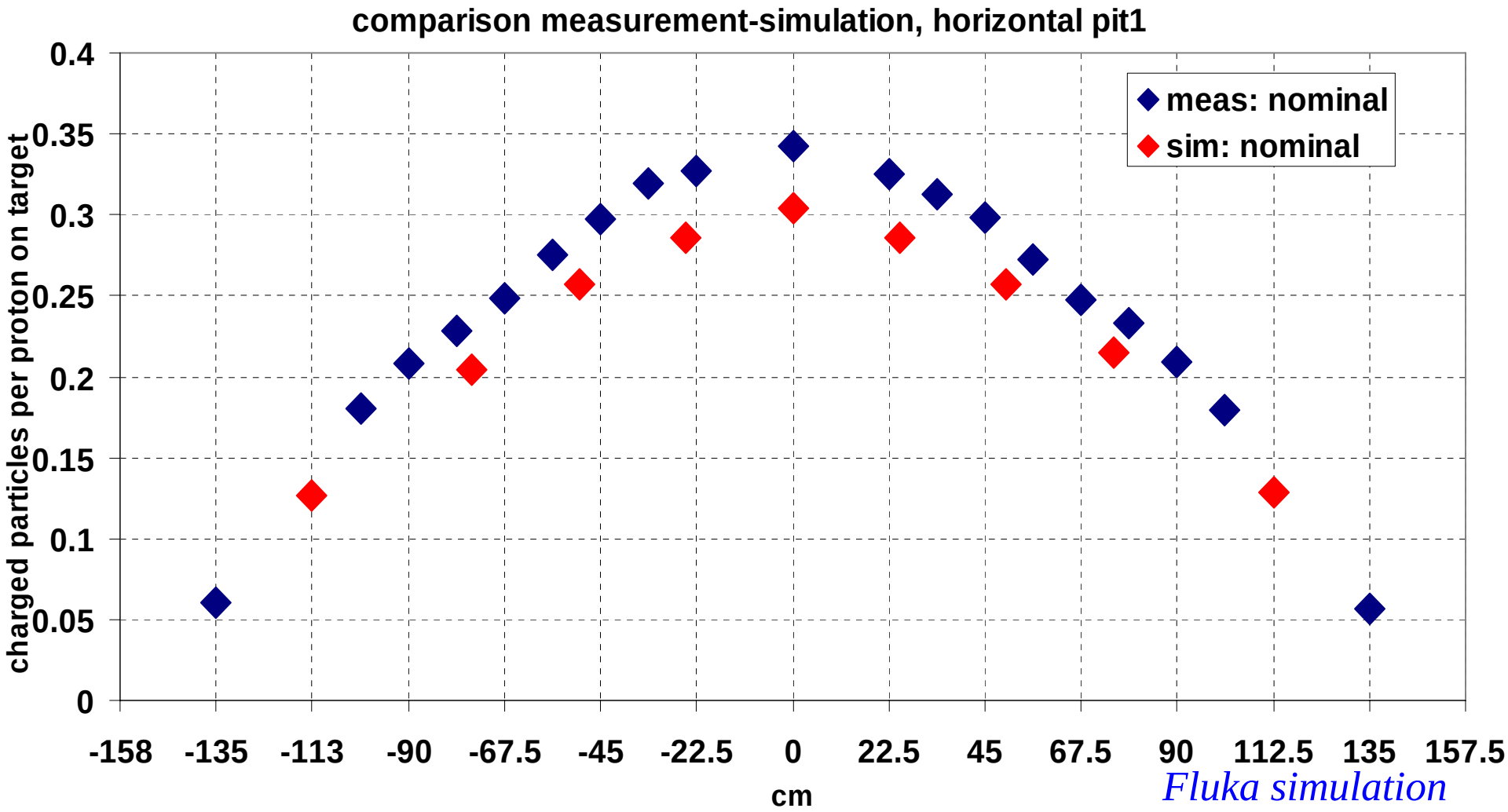
Horizontal Muon Profile, Target Out



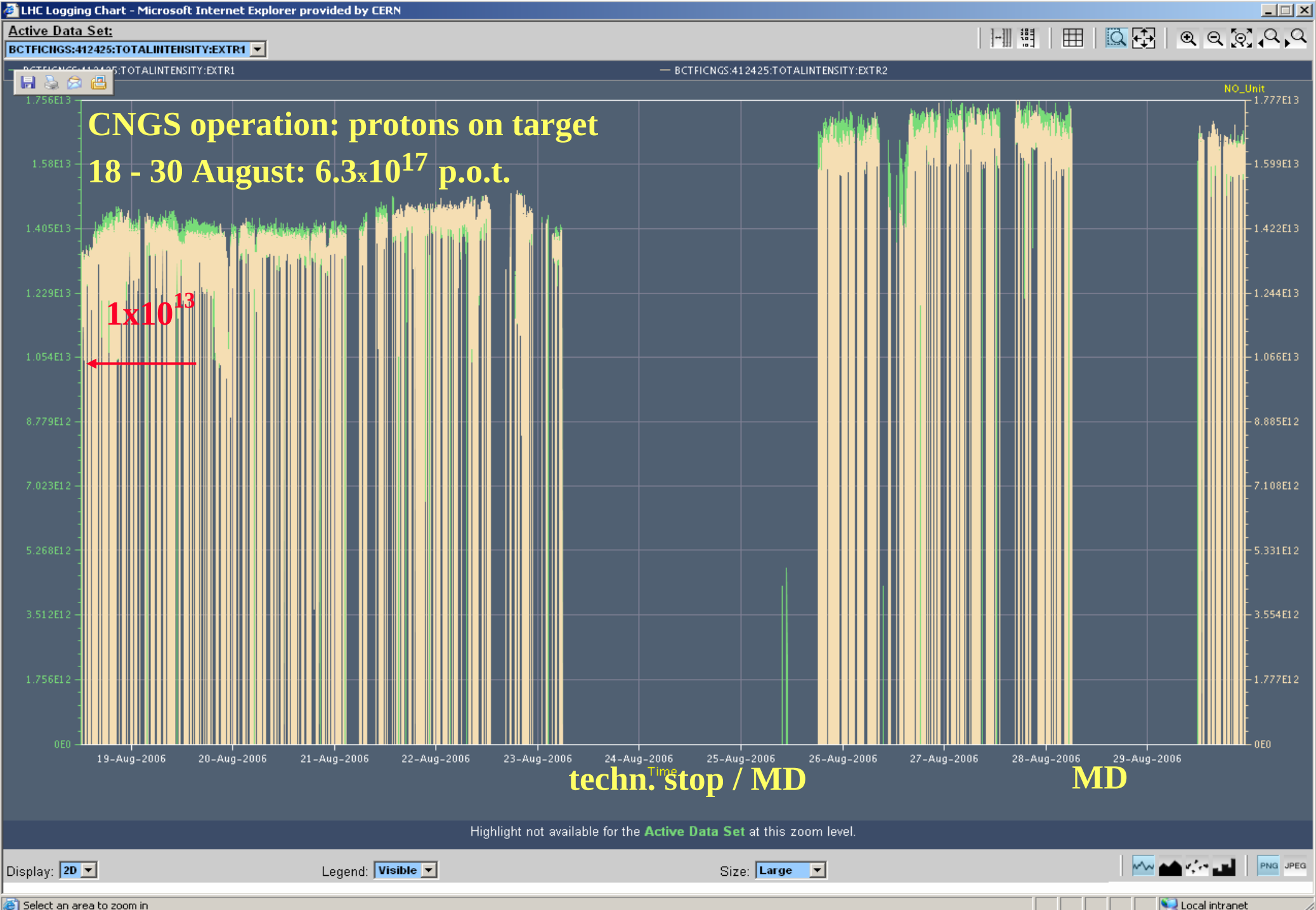
Horizontal Angular Scan, Target Out



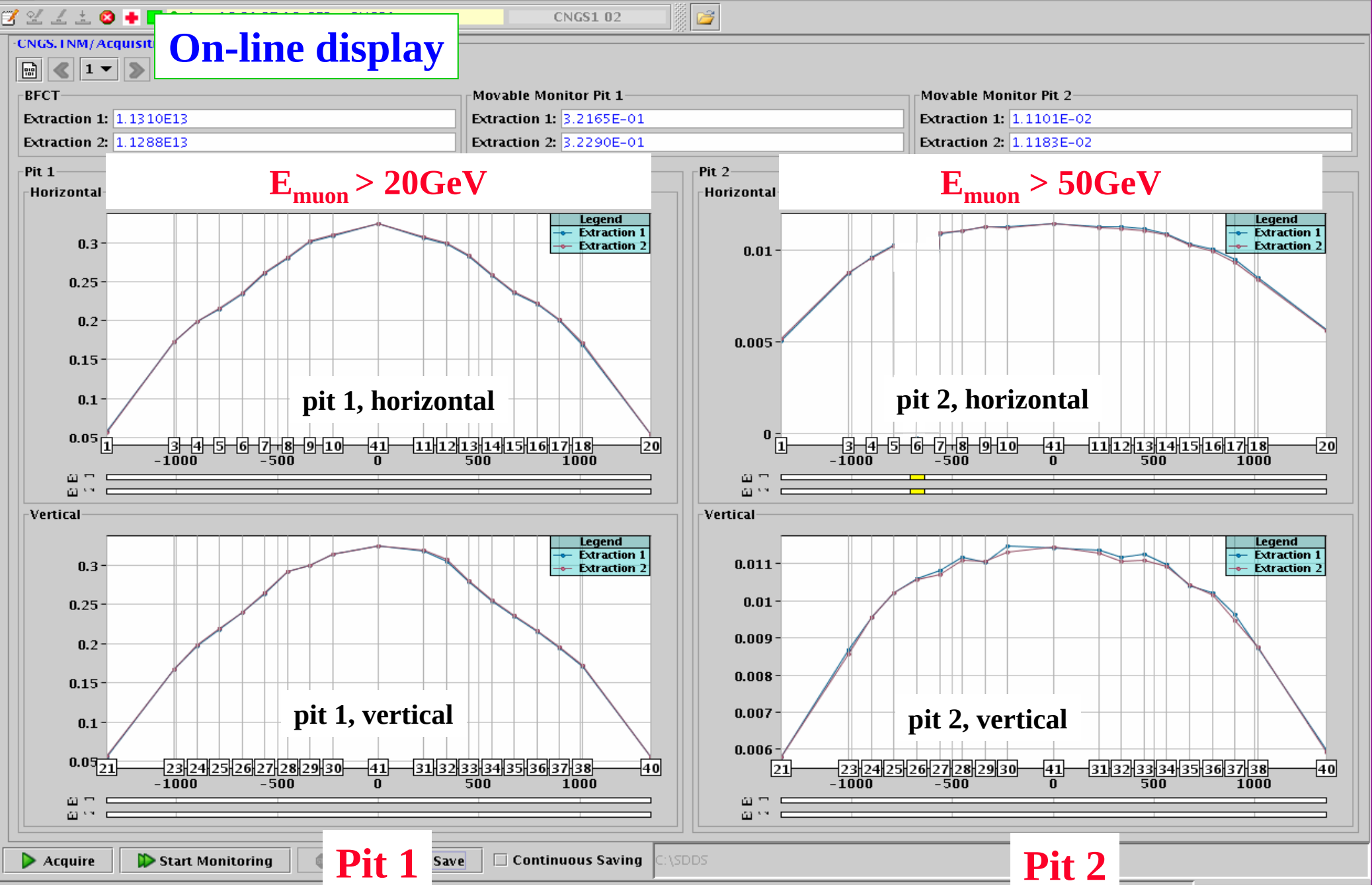
Muon Monitors, Horizontal Pit 1



Fluka simulation


LHC Logging Chart - Microsoft Internet Explorer provided by CERN
Active Data Set:
BCTFICNGS:412425:TOTALINTENSITY:EXTR1
BCTFICNGS:412425:TOTALINTENSITY:EXTR1
BCTFICNGS:412425:TOTALINTENSITY:EXTR2
NO_Unit
CNGS operation: protons on target
18 - 30 August: 6.3x10^17 p.o.t.
1x10^13
1.756E13
1.58E13
1.405E13
1.229E13
1.054E13
8.779E12
7.023E12
5.268E12
3.512E12
1.756E12
0E0
1.777E13
1.599E13
1.422E13
1.244E13
1.066E13
8.885E12
7.108E12
5.331E12
3.554E12
1.777E12
0E0
19-Aug-2006
20-Aug-2006
21-Aug-2006
22-Aug-2006
23-Aug-2006
24-Aug-2006
25-Aug-2006
26-Aug-2006
27-Aug-2006
28-Aug-2006
29-Aug-2006
Time
techn. stop / MD
MD
Highlight not available for the Active Data Set at this zoom level.
Display: 2D
Legend: Visible
Size: Large
PNG
JPEG
Select an area to zoom in
Local intranet

On-line display



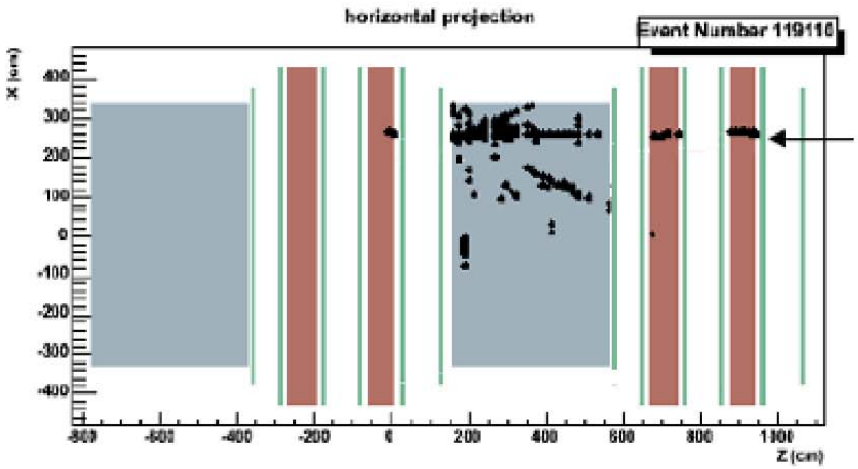
$E_{muon} > 20GeV$

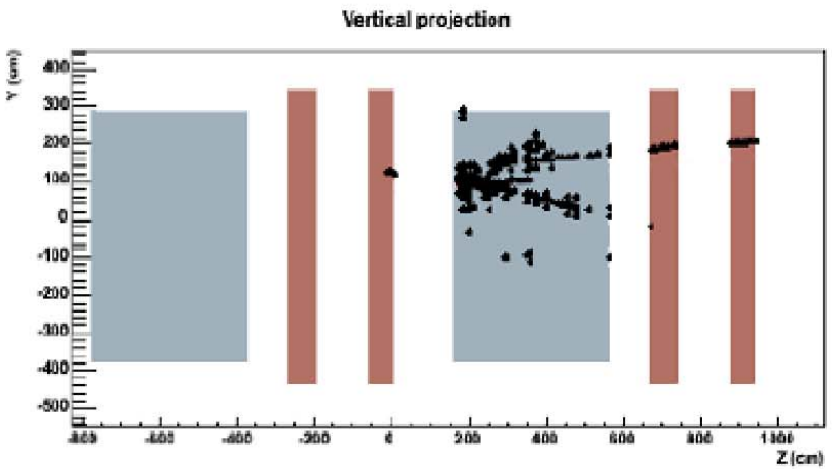
$E_{muon} > 50GeV$

Pit 1

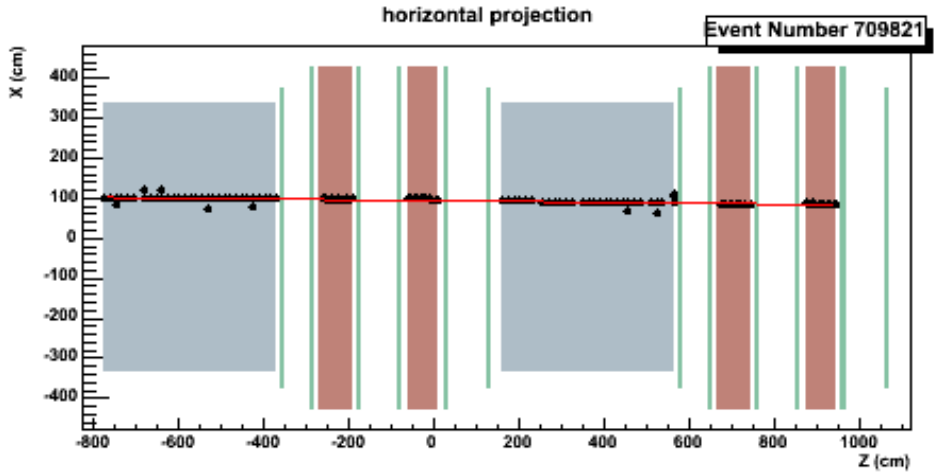
Pit 2

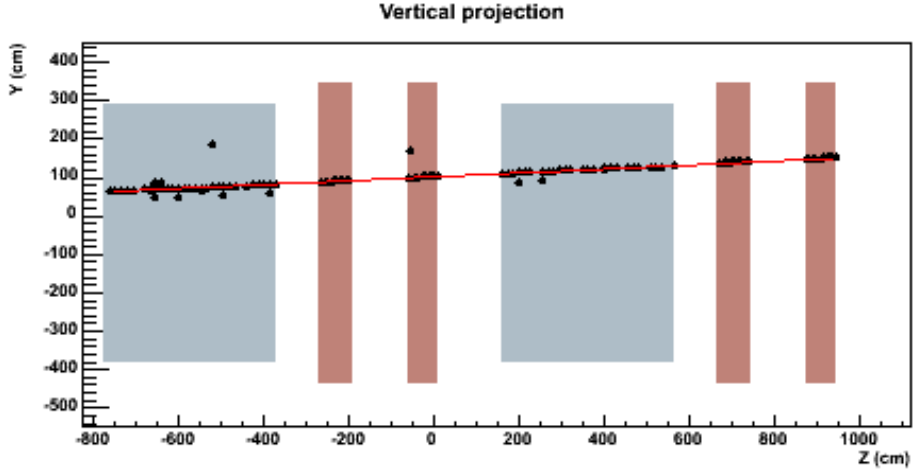
Beam Events at Gran Sasso





CC event in the first magnet





Muon from CC interaction in the material in front of the detector (BOREXINO, rocks)

Summary

- CNGS construction started 2000
- Installation finished beginning 2006
- Detailed hardware commissioning
- 'Dry runs'
  - ➔ **Allowed early debugging of all systems**

→ CNGS has been successfully commissioned

- **The challenging part (high intensity operation) starts now**
  - ➔ **Very high radiation levels**
  - ➔ **Fatigue from beam impact (shocks) on equipment**
    - ➔ First surprise last Friday: Water leak on external cooling circuit of the reflector