CNGS Run 2007: Radiation Issues

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On behalf the

CNGS Secondary Beam Working Group

Outline

- CNGS Overview
- Run 2007
- Radiation Issues during the Run
- Expected Radiation Levels
- Summary

CNGS (CERN Neutrino Gran Sasso)

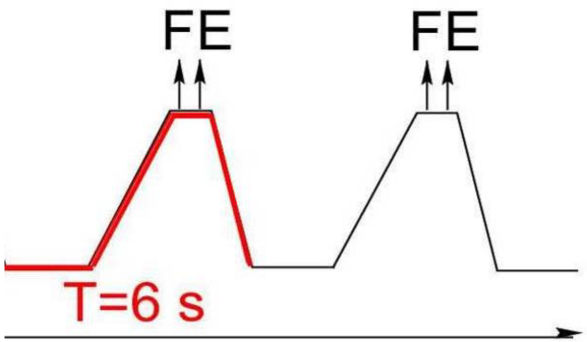
- A long base-line neutrino beam facility (732km)
- send ν_μ beam produced at CERN
- detect ν_τ appearance in OPERA experiment at Gran Sasso

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

Task for CERN: produce intense ν_μ beam 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



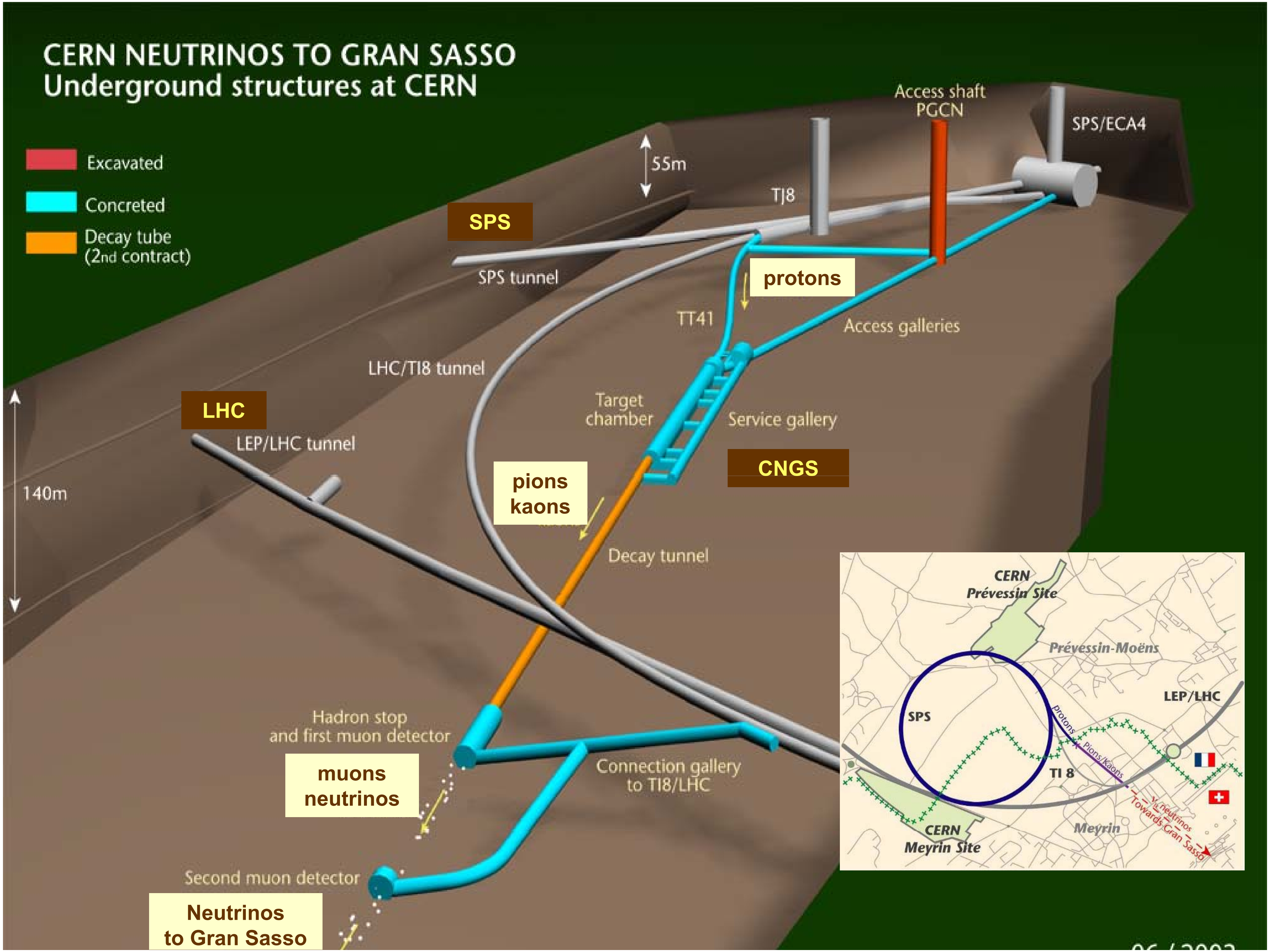
Expected beam performance: 4.5 x 10^{19} protons/year on target

CNGS Challenges

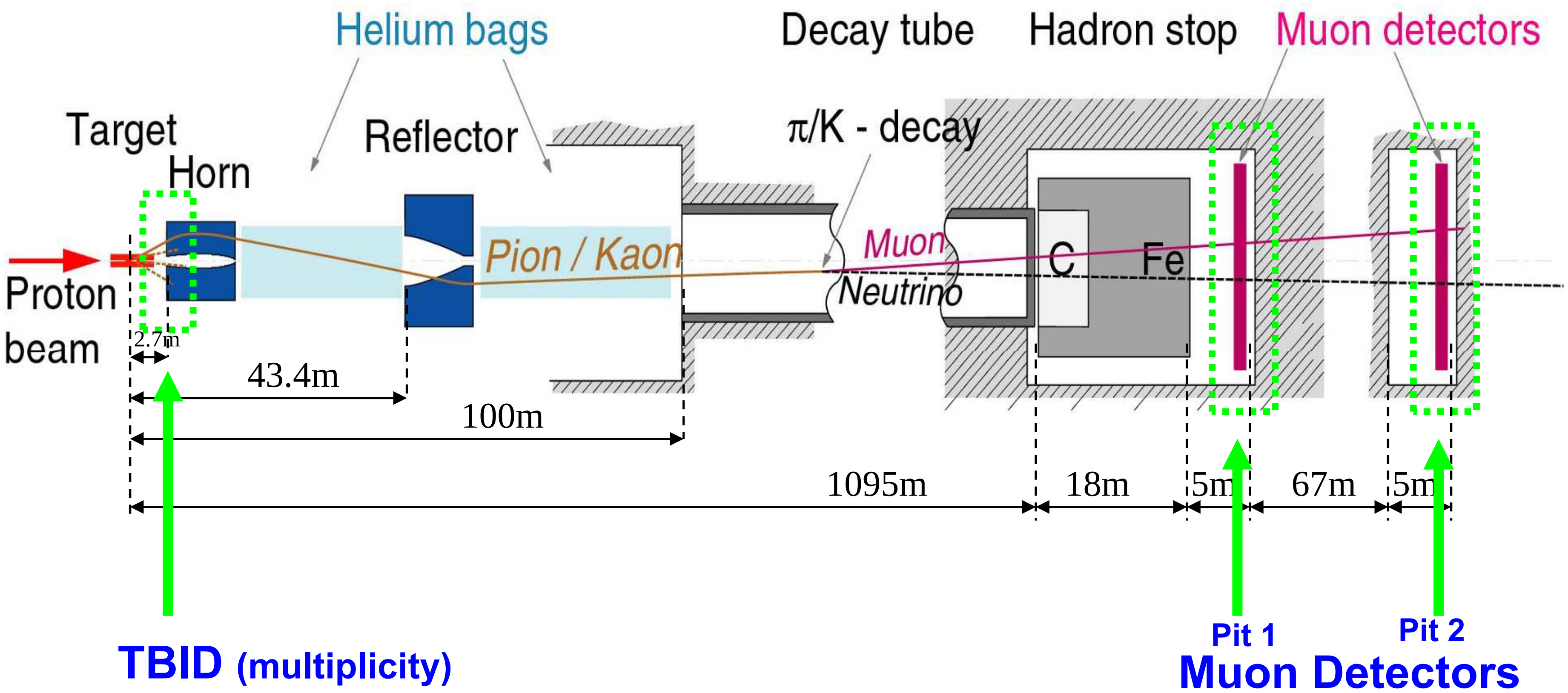
- **High Intensity, High Energy Proton Beam**
  - Tune, tune, tune
  - Induced radioactivity
    - In components, shielding, fluids, etc…
  - Intervention on equipment 'impossible'
    - Remote handling by overhead crane
    - Replace broken equipment, no repair
    - Human intervention only after long 'cooling time'
  - Design of equipment: compromise
    - E.g. horn inner conductor: for neutrino yield: thin tube, for reliability: thick tube

- **Intense Short Beam Pulses, Small Beam Spot**
  - Interlock, interlock, interlock
  - Thermo mechanical shocks by energy deposition (designing target rods, thin windows, etc…)

→ **most challenging zone: Target Chamber** (target–horn–reflector)

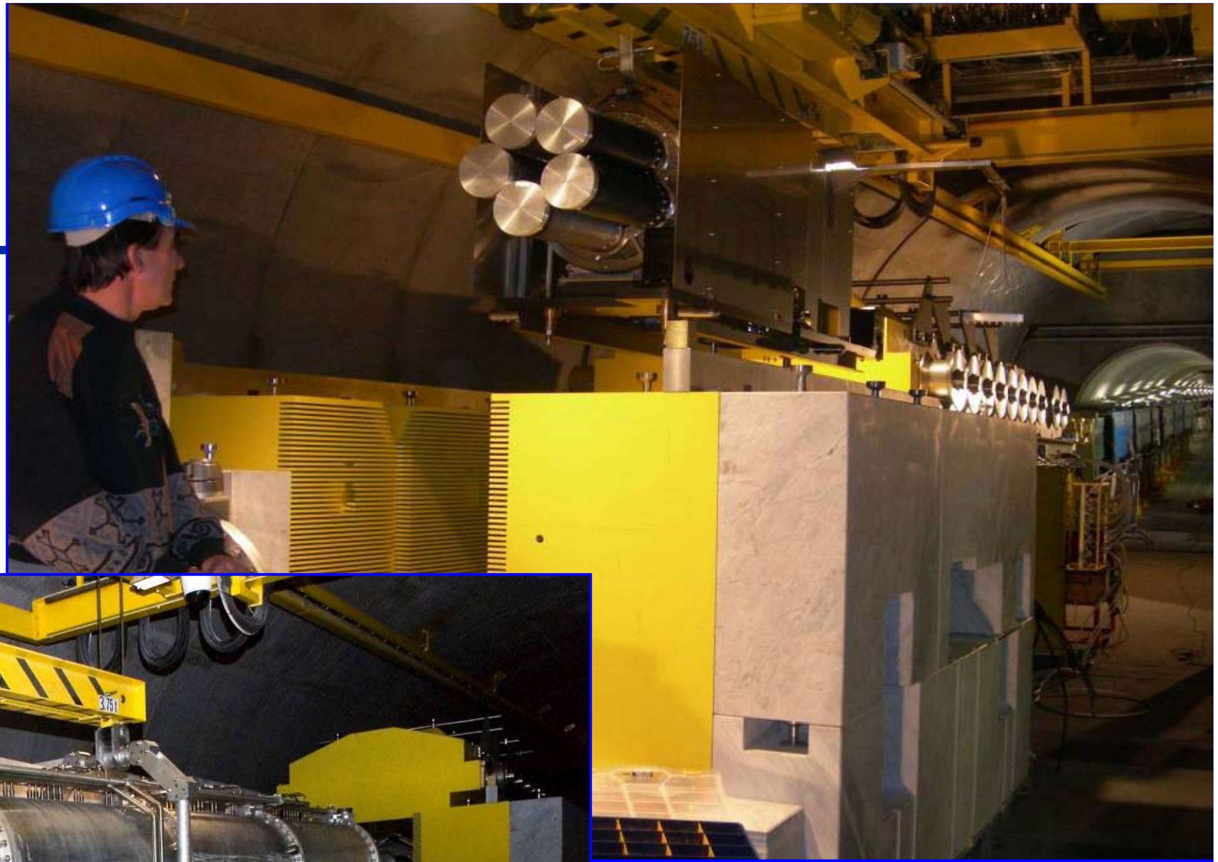

CERN NEUTRINOS TO GRAN SASSO
Underground structures at CERN
Excavated
Concreted
Decay tube
(2nd contract)
SPS
SPS tunnel
55m
TJ8
Access shaft
PGCN
SPS/ECA4
protons
TT41
Access galleries
LHC/TI8 tunnel
Target
chamber
Service gallery
CNGS
LHC
LEP/LHC tunnel
140m
pions
kaons
Decay tunnel
Hadron stop
and first muon detector
muons
neutrinos
Connection gallery
to TI8/LHC
Second muon detector
Neutrinos
to Gran Sasso
CERN
Prévessin Site
Prévessin-Moëns
LEP/LHC
SPS
protons
Pions/Kaons
TI 8
neutrinos
Towards Gran Sasso
CERN
Meyrin Site
Meyrin

CNGS Layout



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

CNGS
Target Chamber



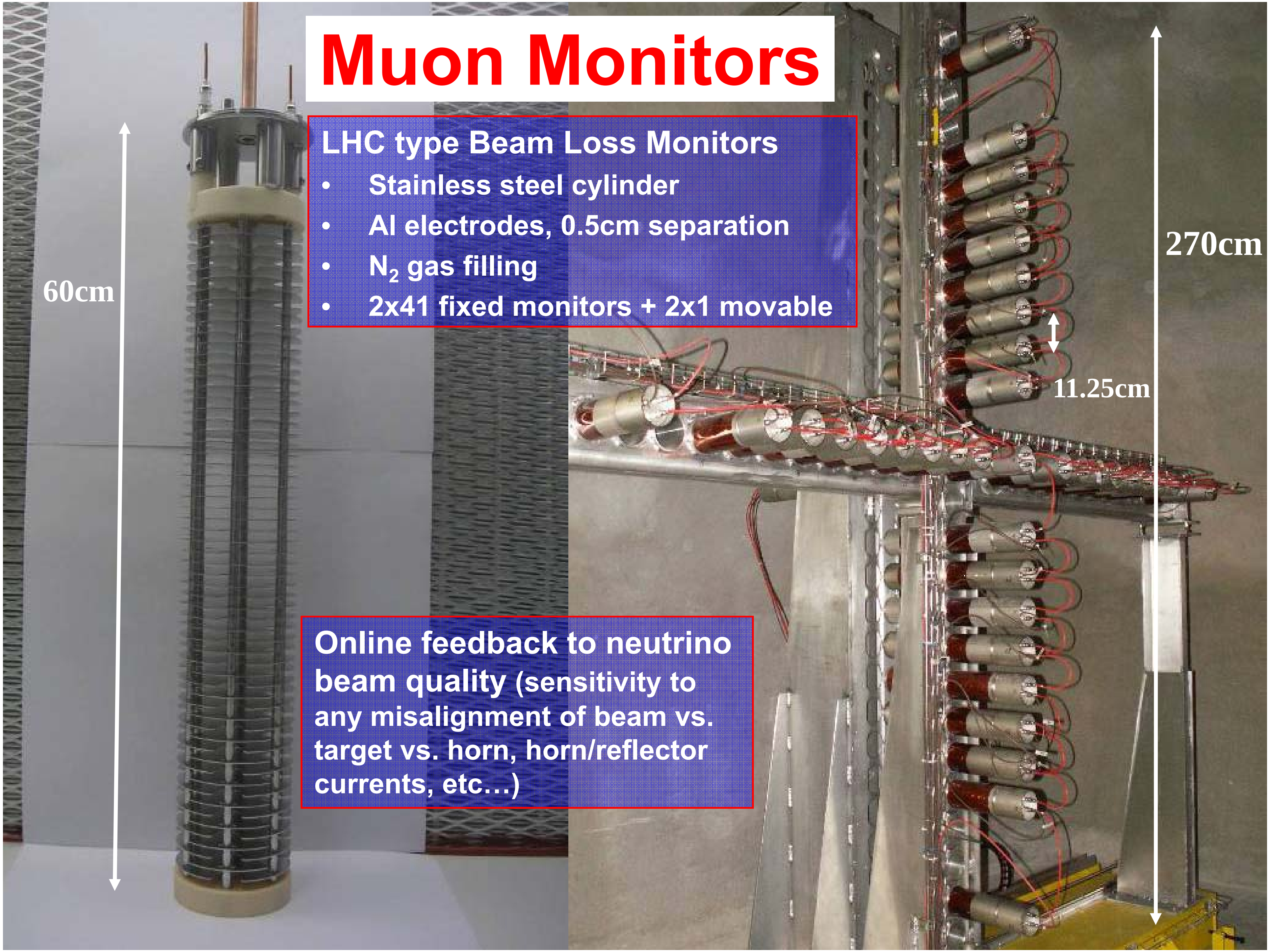
Installation of target magazine (4 in-situ spares)

Installation of Focusing magnet ('Horn')

Muon Monitors

LHC type Beam Loss Monitors

- Stainless steel cylinder
- Al electrodes, 0.5cm separation
- N_2 gas filling
- 2x41 fixed monitors + 2x1 movable

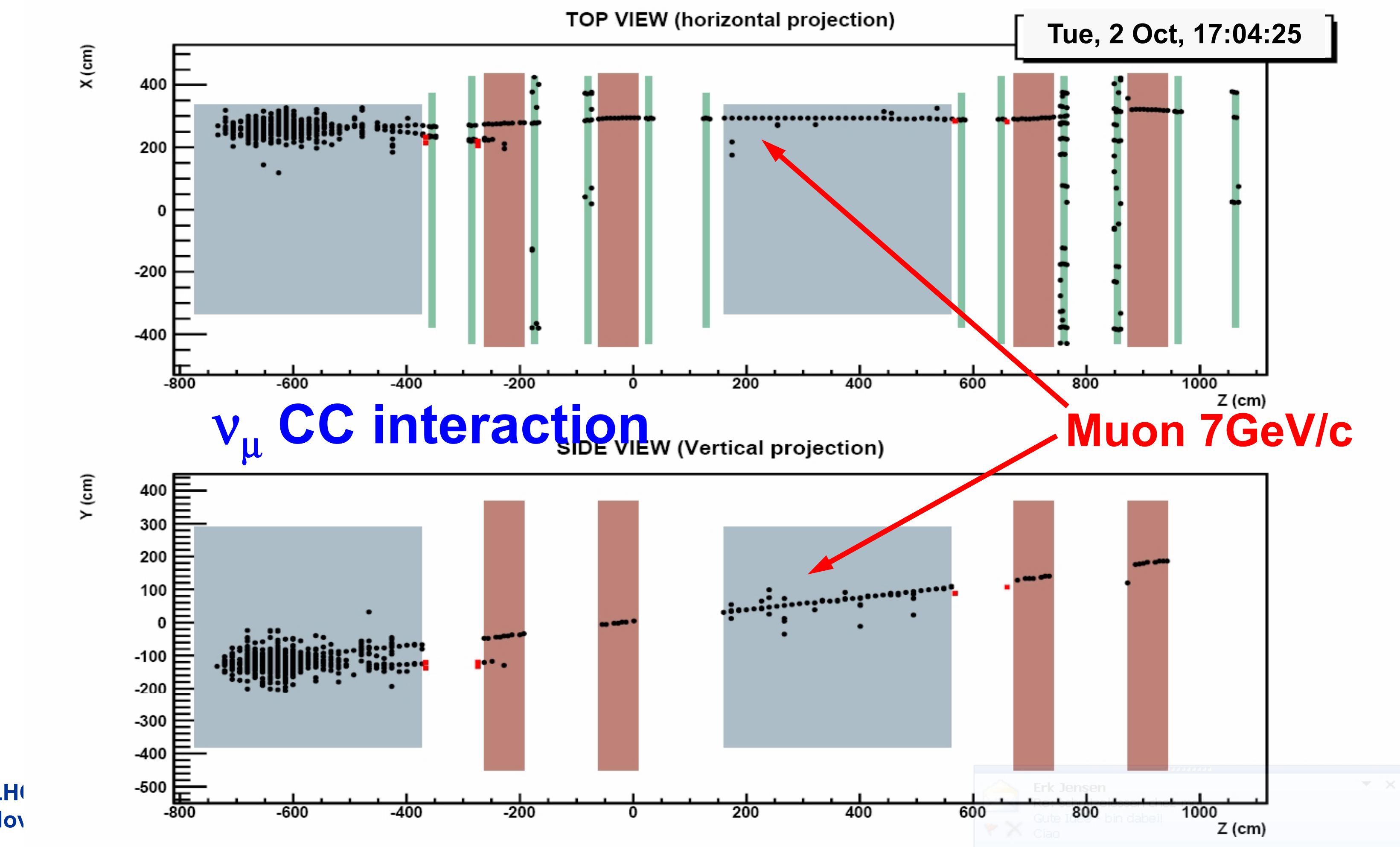


Online feedback to neutrino beam quality (sensitivity to any misalignment of beam vs. target vs. horn, horn/reflector currents, etc…)

CNGS Run 2007 (17/09-22/10/2007)

Smooth start-up, very good beam performance

- 38 OPERA events in bricks
- More than 400 events from interactions outside OPERA detector



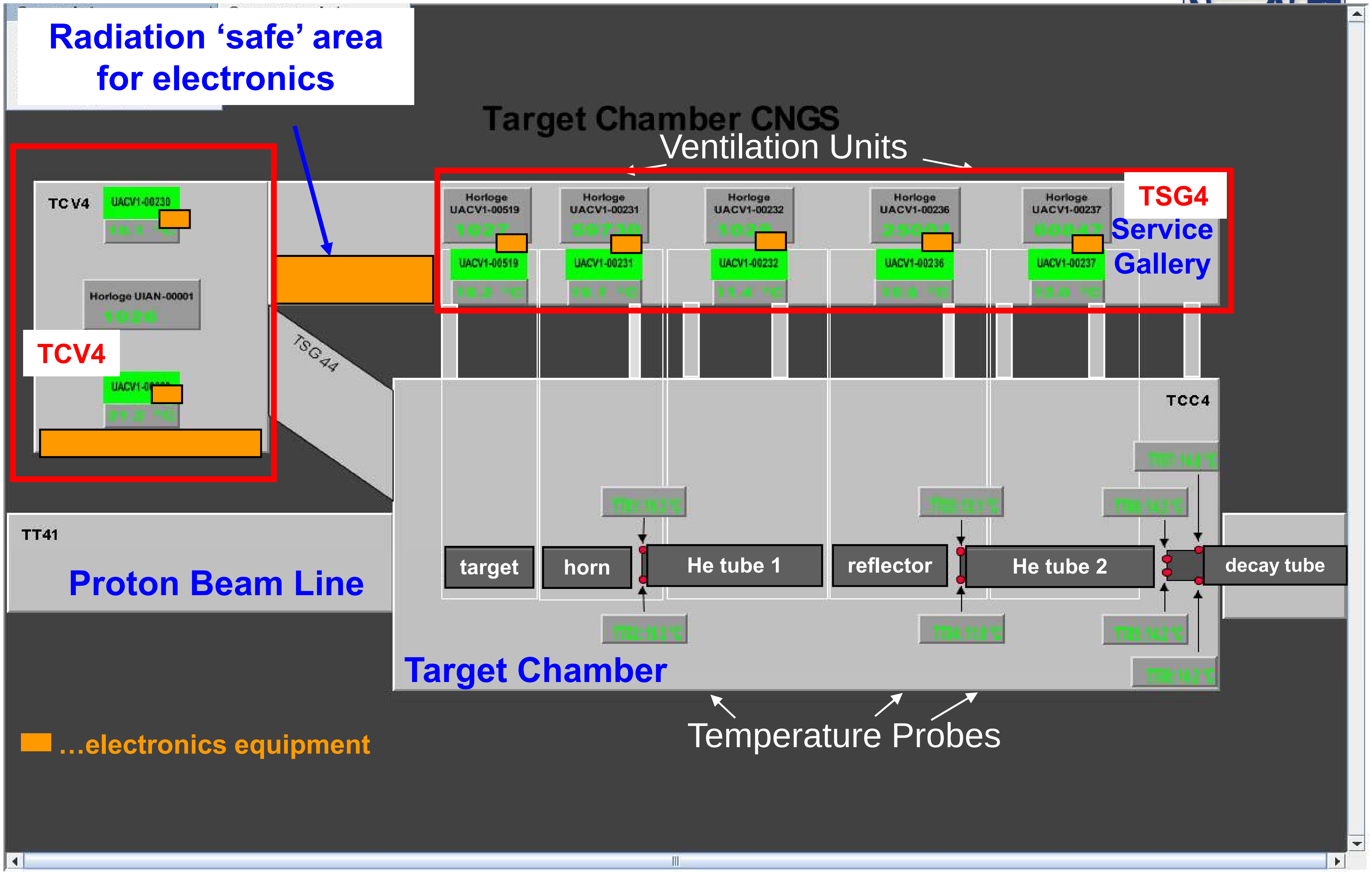
CNGS Run 2007 (17/09-22/10/2007)

- Smooth start-up, very good beam performance
  - 38 OPERA events in bricks
  - More than 400 events from interactions outside OPERA detector

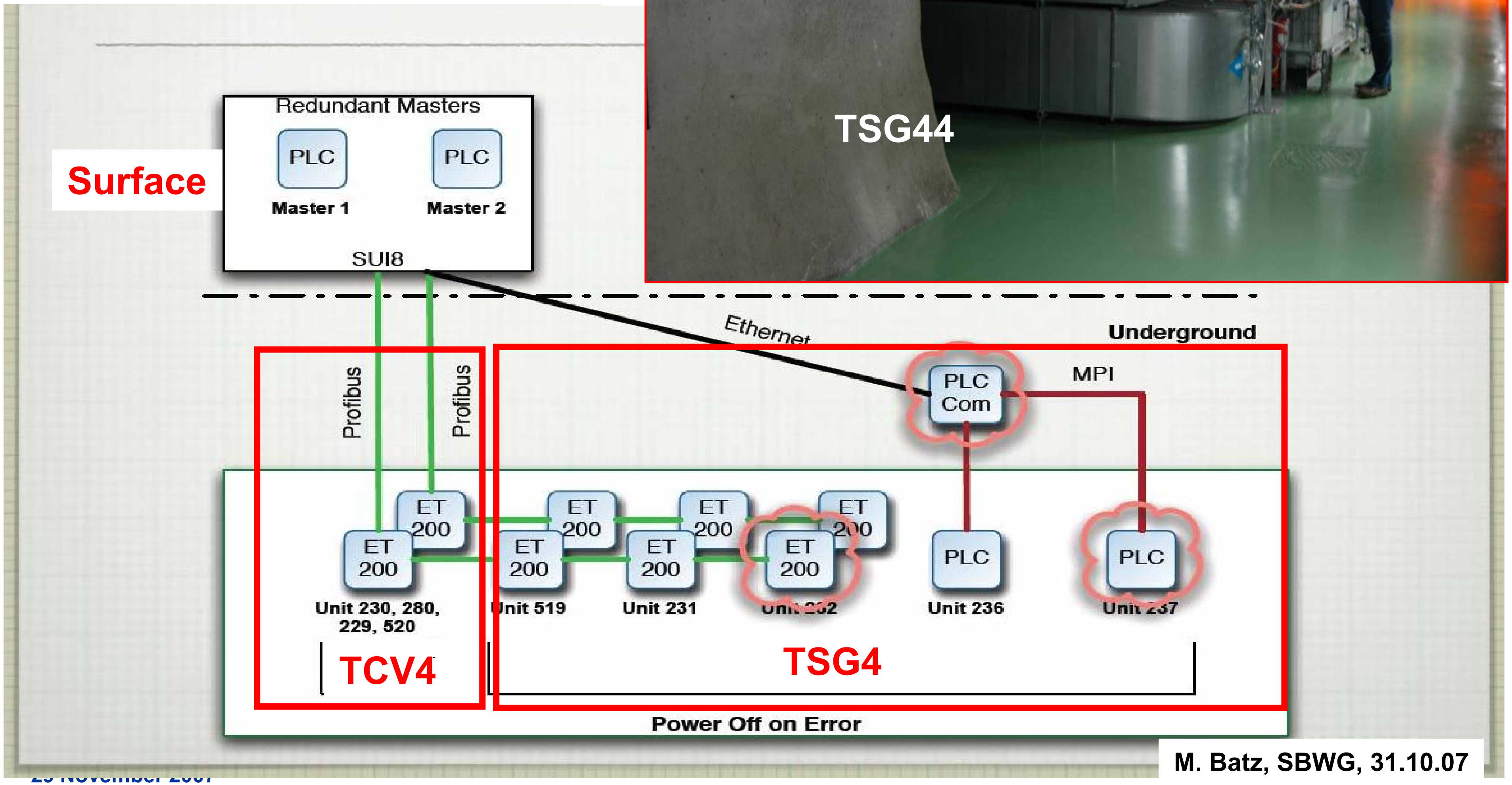
- Successive failures in the ventilation system
  - Strong efforts made by TS/CV to save the situation
- Physics run stopped on Monday 22 October 2007, 5 days ahead of time.
  - Failures in the ventilation system control electronics that blocked switching to access mode in a safe manner

    → intolerable for an INB facility

CNGS Electronics Layout



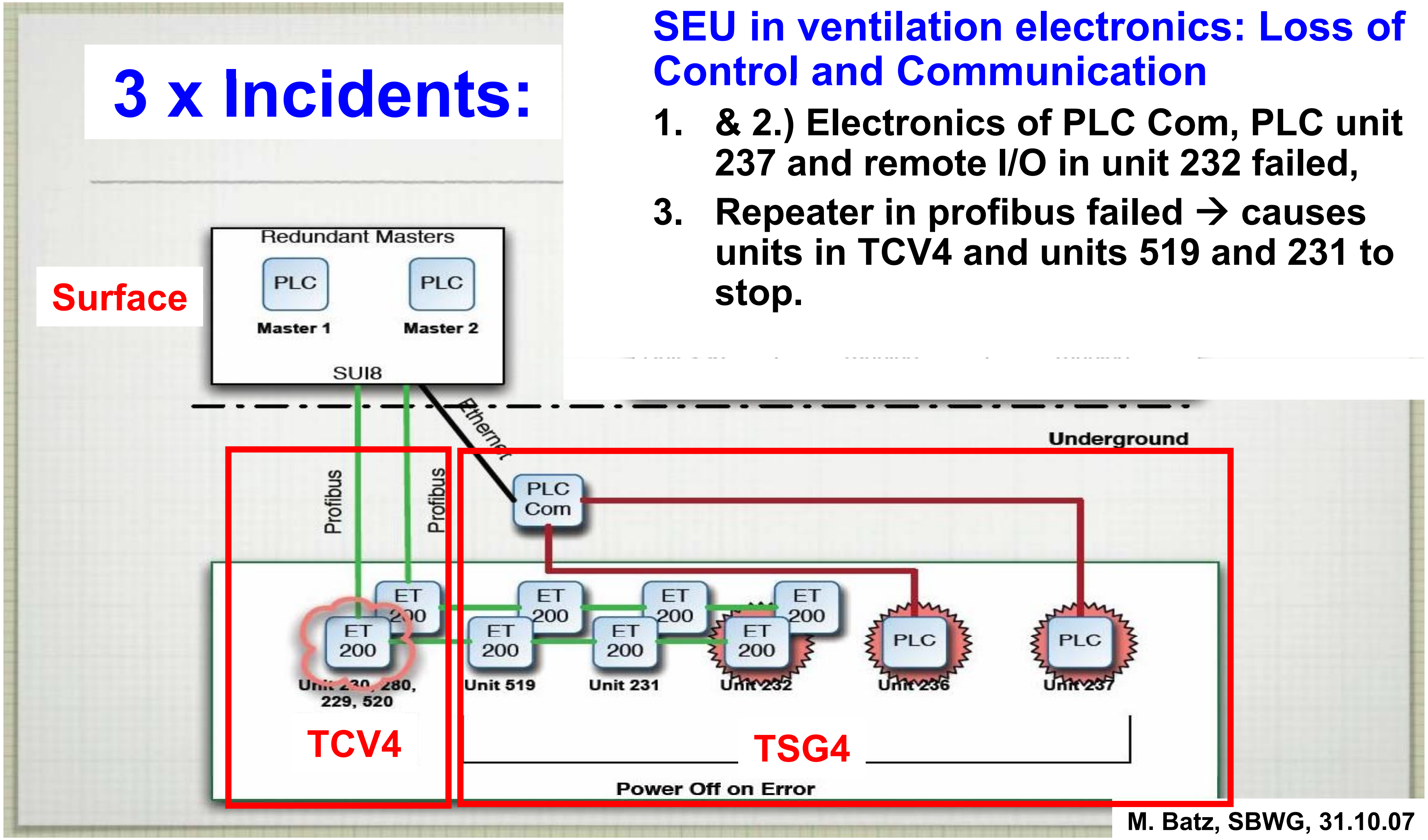
Ventilation System for CNGS



M. Batz, SBWG, 31.10.07

Incidents of CNGS Ventilation System

3 x Incidents:



M. Batz, SBWG, 31.10.07

SEU in ventilation electronics: Loss of Control and Communication

1. & 2.) Electronics of PLC Com, PLC unit 237 and remote I/O in unit 232 failed,
3. Repeater in profibus failed → causes units in TCV4 and units 519 and 231 to stop.

CNGS Radiation Levels Calculations with FLUKA

M. Brugger, A. Ferrari, L.Sarchiapone, AB/ATB

Simulation environment:

- Unified approach for
  - physics (neutrino and muon fluxes),
  - engineering (power deposition),
  - prompt (radiation damage) dose rates
  - residual (maintenance and interventions) dose rates
- Reasonably detailed geometry down to muon pits
  - each BLM simulated in detail
- Service and connection galleries empty
  - no rack, no ventilation unit, no piping, no ducts, no doors, no dividing walls

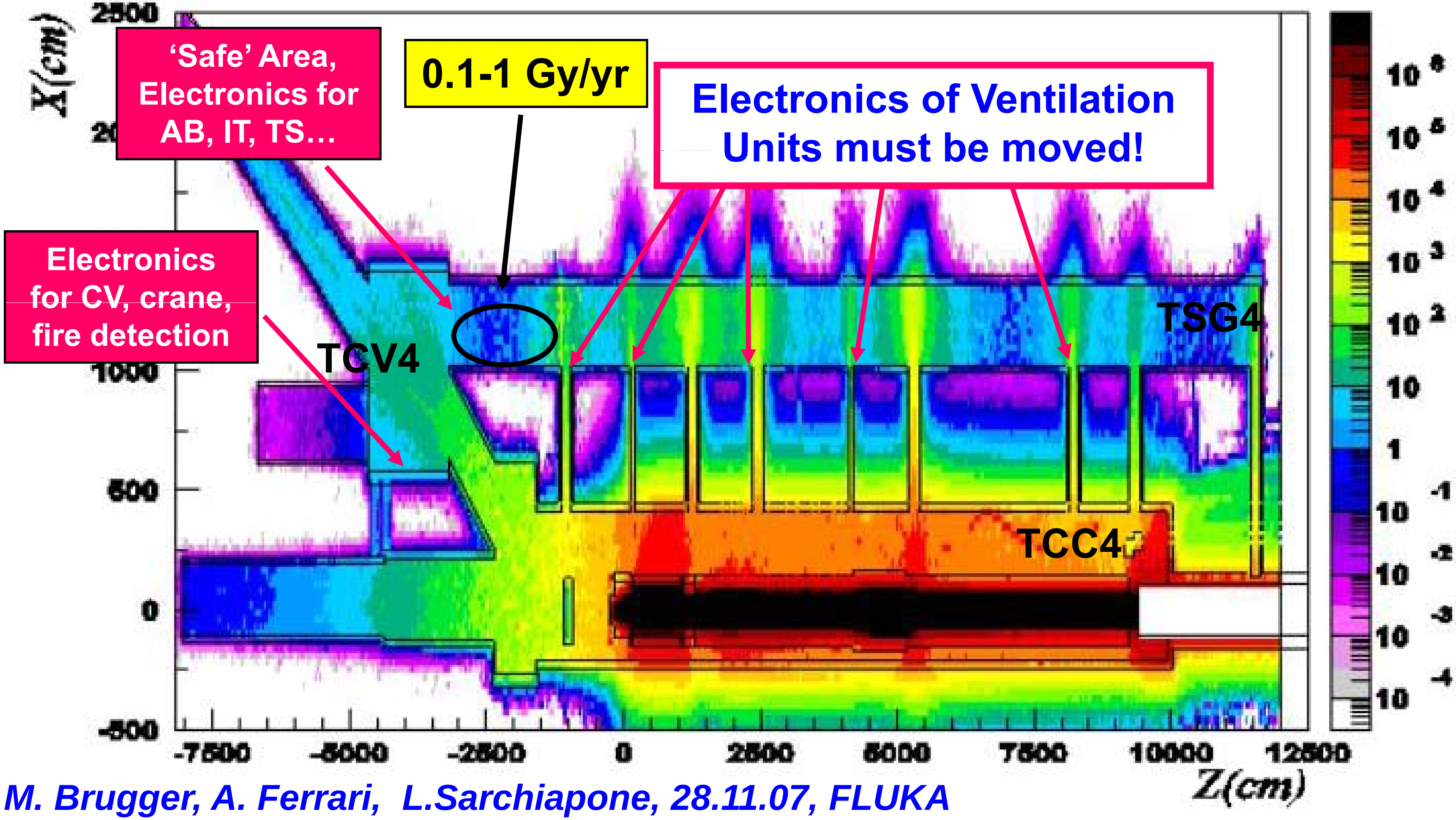
  → should be conservative
- Common effort of AB/ATB, RP, INFN

Available outputs for radiation:

- Absorbed and equivalent dose maps (prompt and residual)
- High energy hadron fluences
- 1 MeV neutron equivalent fluences (for Si damage)
- Particle spectra at several locations

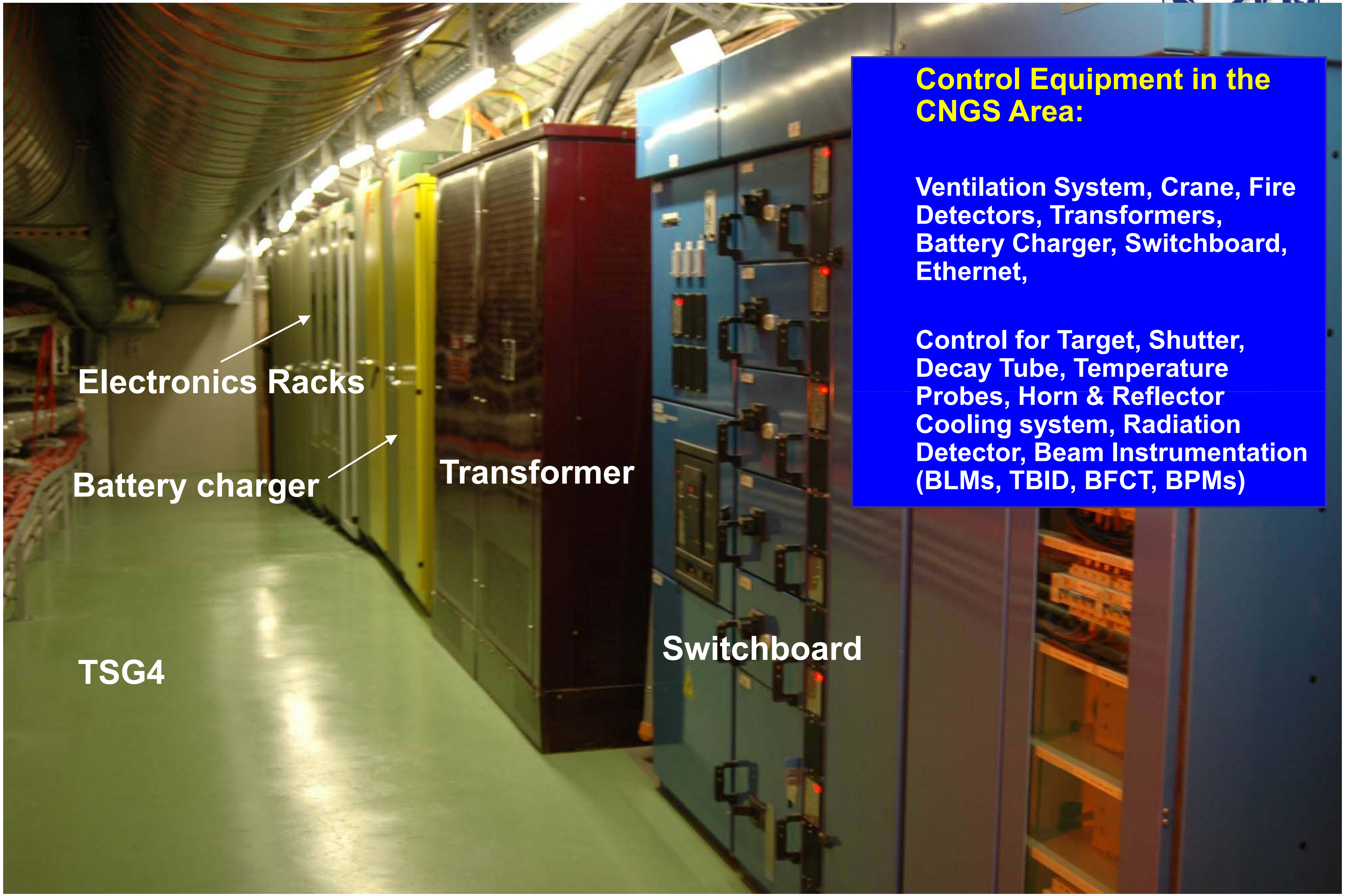
Expected Dose Levels

Gy/yr for a nominal CNGS year of 4.5 10^{19} pot



M. Brugger, A. Ferrari, L.Sarchiapone, 28.11.07, FLUKA

‘Safe’ Area for Electronics



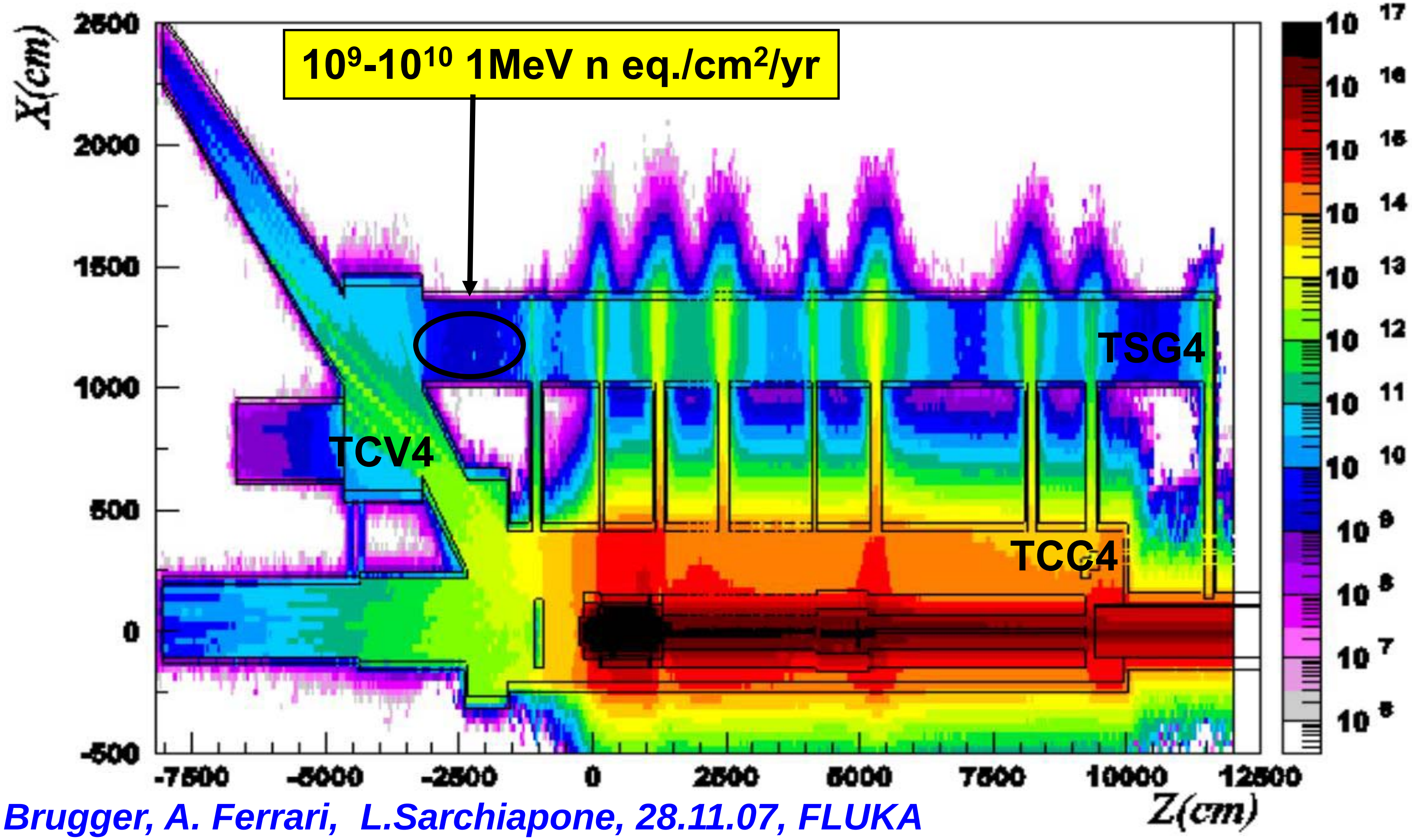
Control Equipment in the CNGS Area:

Ventilation System, Crane, Fire Detectors, Transformers, Battery Charger, Switchboard, Ethernet,

Control for Target, Shutter, Decay Tube, Temperature Probes, Horn & Reflector Cooling system, Radiation Detector, Beam Instrumentation (BLMs, TBID, BFCT, BPMs)

Expected Neutron Fluence

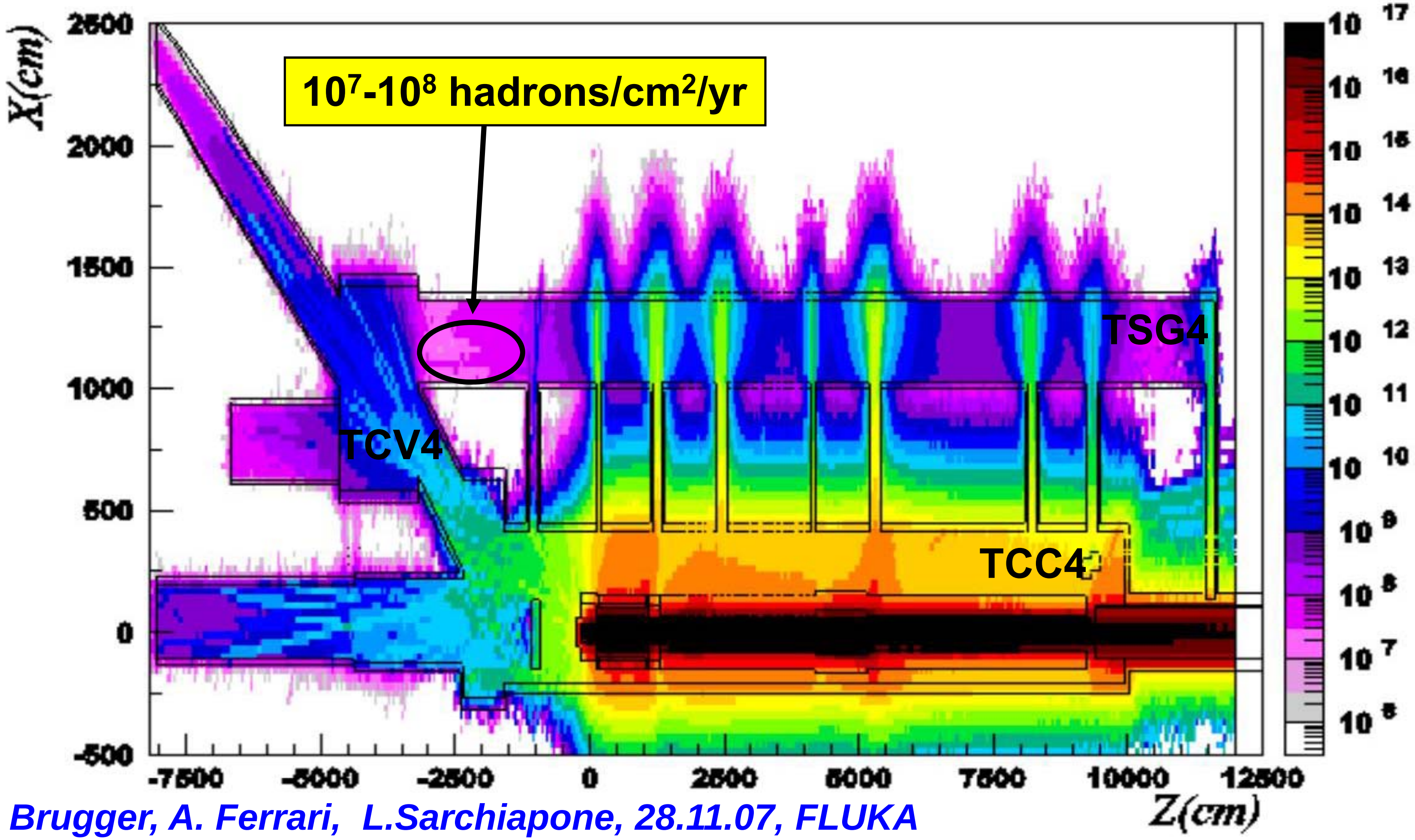
1 MeV eq. neutron fluence (cm^{-2} yr^{-1}) for a nominal CNGS year of 4.5 10^{19} pot



M. Brugger, A. Ferrari, L.Sarchiapone, 28.11.07, FLUKA

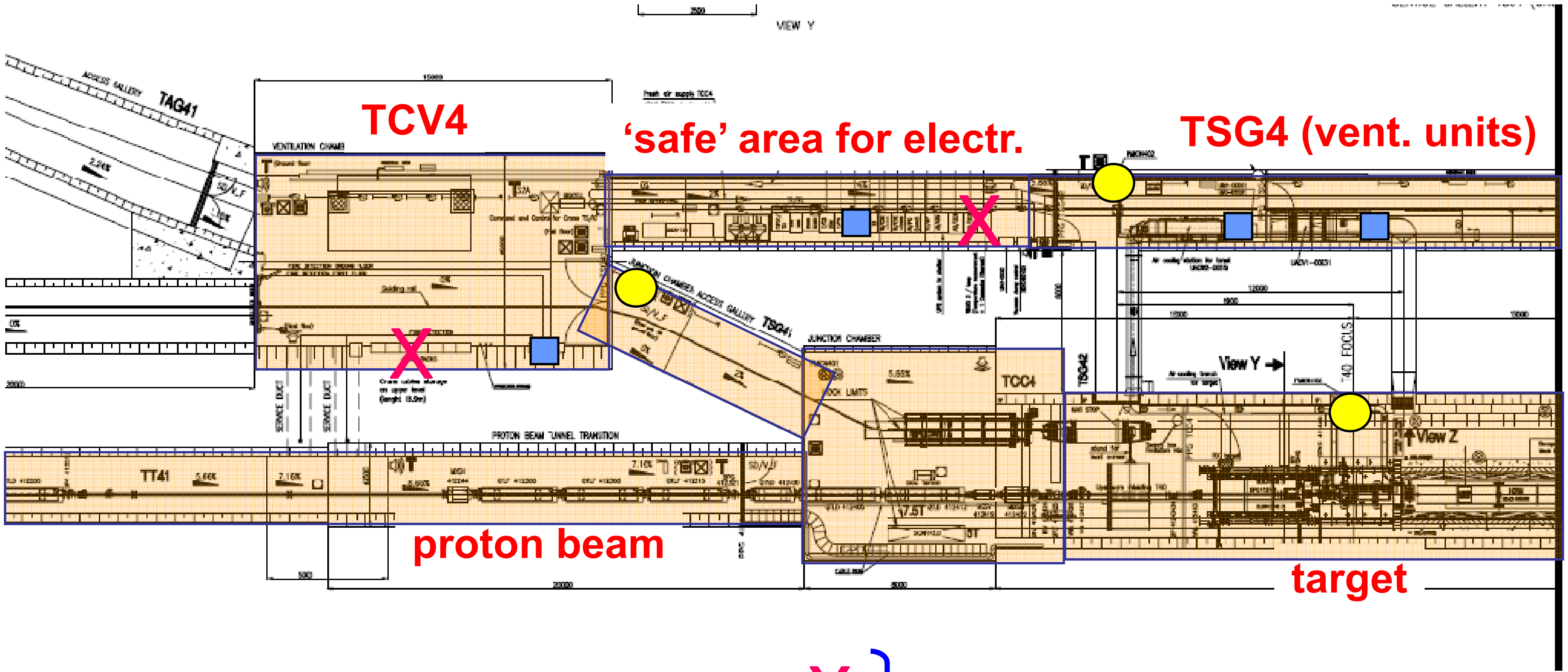
Expected High Energy Hadron Fluence

Energetic (> 20 MeV) hadron fluence (cm^{-2} yr^{-1}) for a nominal CNGS year of 4.5 10^{19} pot



M. Brugger, A. Ferrari, L.Sarchiapone, 28.11.07, FLUKA

Radiation Measurements



- RadMon Monitors (T. Wijnands) X
- TLDs (SC/RP) ■

} Measurements only during last day of operation: $7.2 \cdot 10^{16}$ pot

- PMI detectors (SC/RP) ●

Summary I

- **Detailed analysis and comparison between the simulations and measurements ongoing**
  - **The numbers basically agree:**
    - **Some better understanding of RadMon monitor sensitivity needed.**
- **No major changes in simulations (updated geometry) with respect to previous calculations → confirmed by measurements**

Summary II

- All installed electronics are COTS (most not even rad hard)
- Nearest completely safe area is ~1000m away
- For much of the electronics there are technical reasons to limit the cable lengths to <100m.

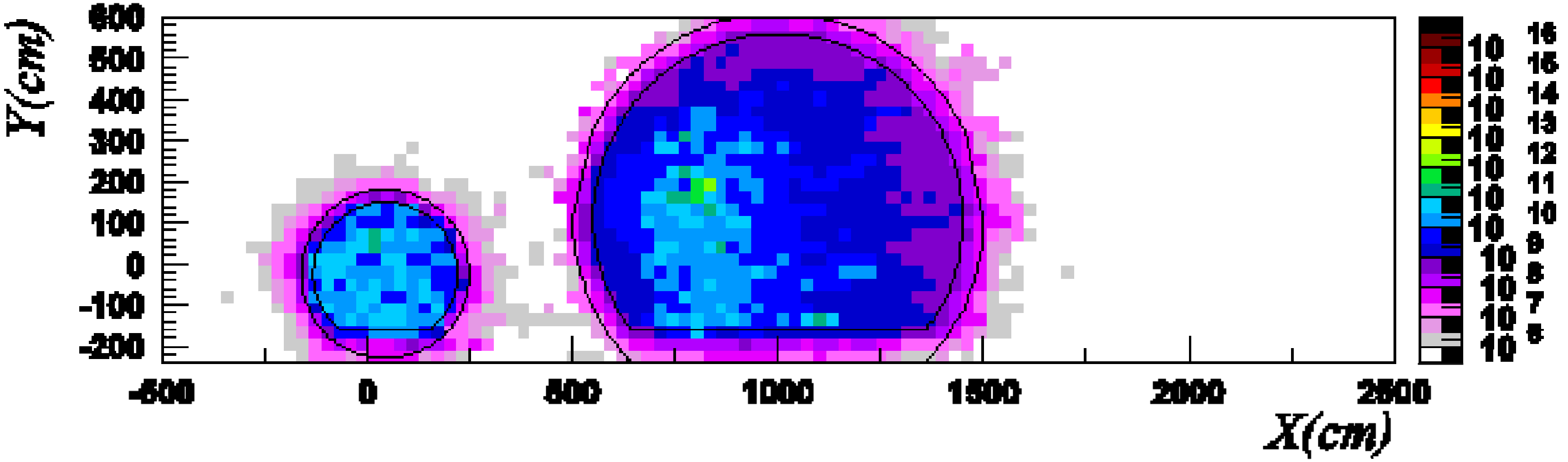
- For MTBF > 1year
  - Area with electronics must be shielded (gain factor >10^4 ?!)
  - Or move electronics to storage area and add shielding
  - For both cases:
    - Critical equipment for access must be moved to the surface (mainly ventilation parts)
    - Redundancy and preventive maintenance and actions
    - Radiation monitoring

→ CNGS must be ready for beam on 28 May 2008

Spare Slides

High energy hadron levels, TCV4

Energetic (> 20 MeV) hadron fluence (cm^{-2} yr^{-1}) for a nominal CNGS year of 4.5 10^{19} pot: vertical cut along TCV4



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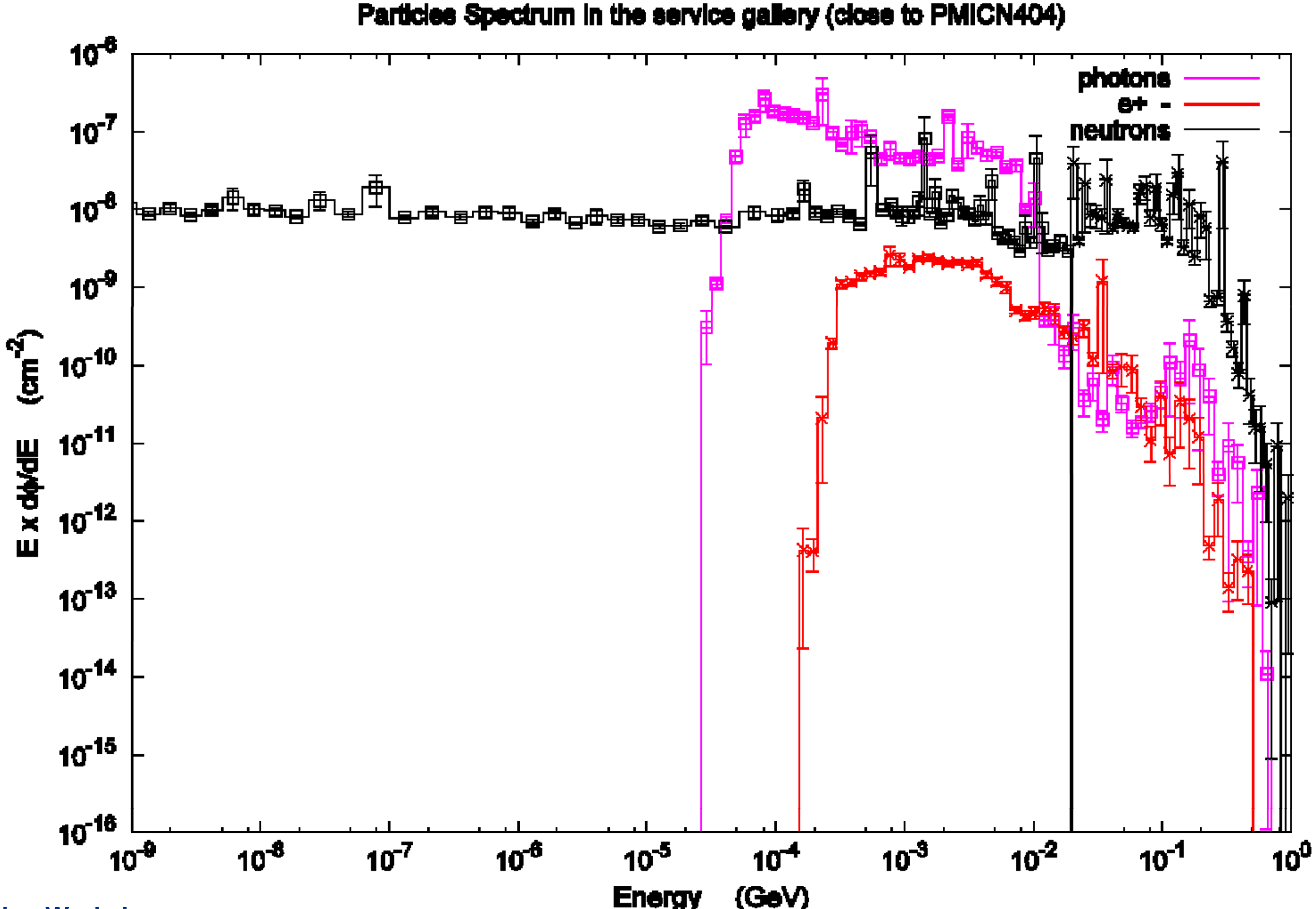
Example Expected Particle Spectra in TSG4

Neutron (black), photon (purple), and electron (red) spectra in the service gallery



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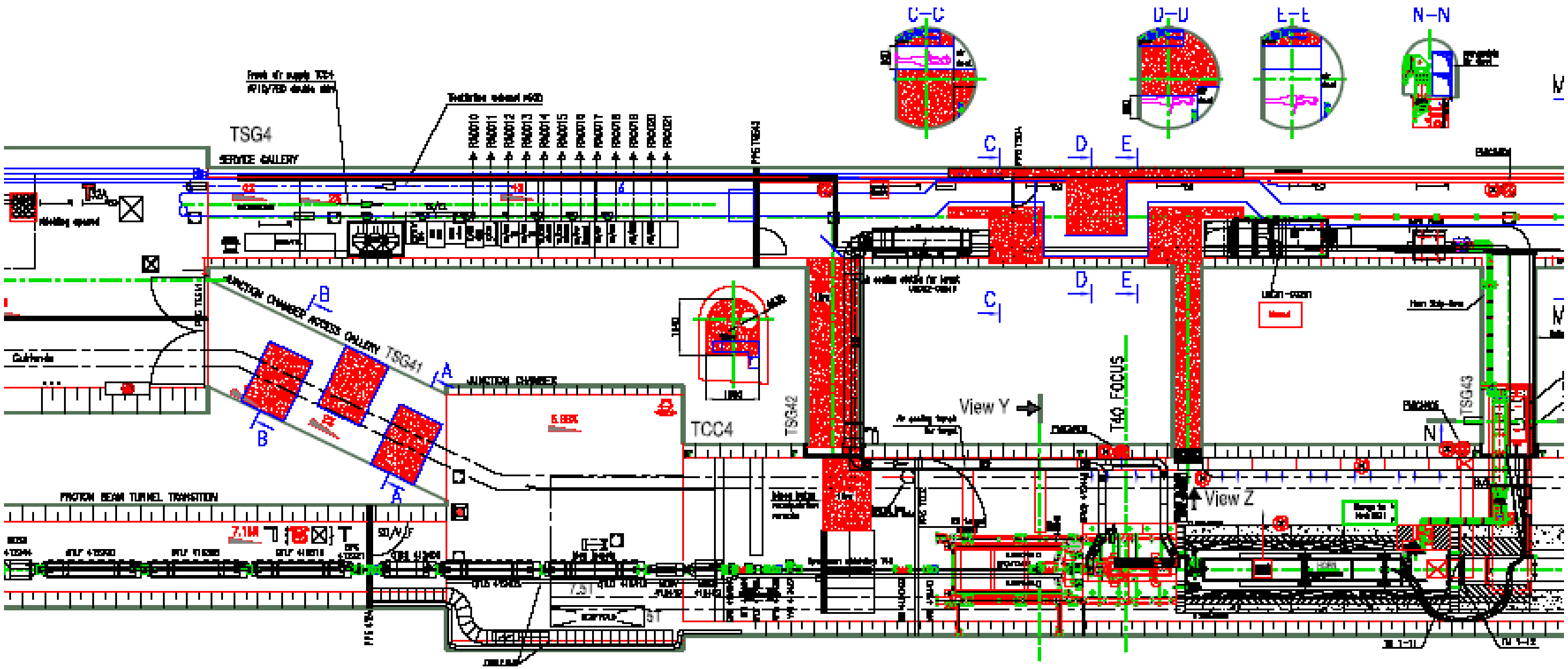
Possible solutions

1) leave electronics in place, add shielding

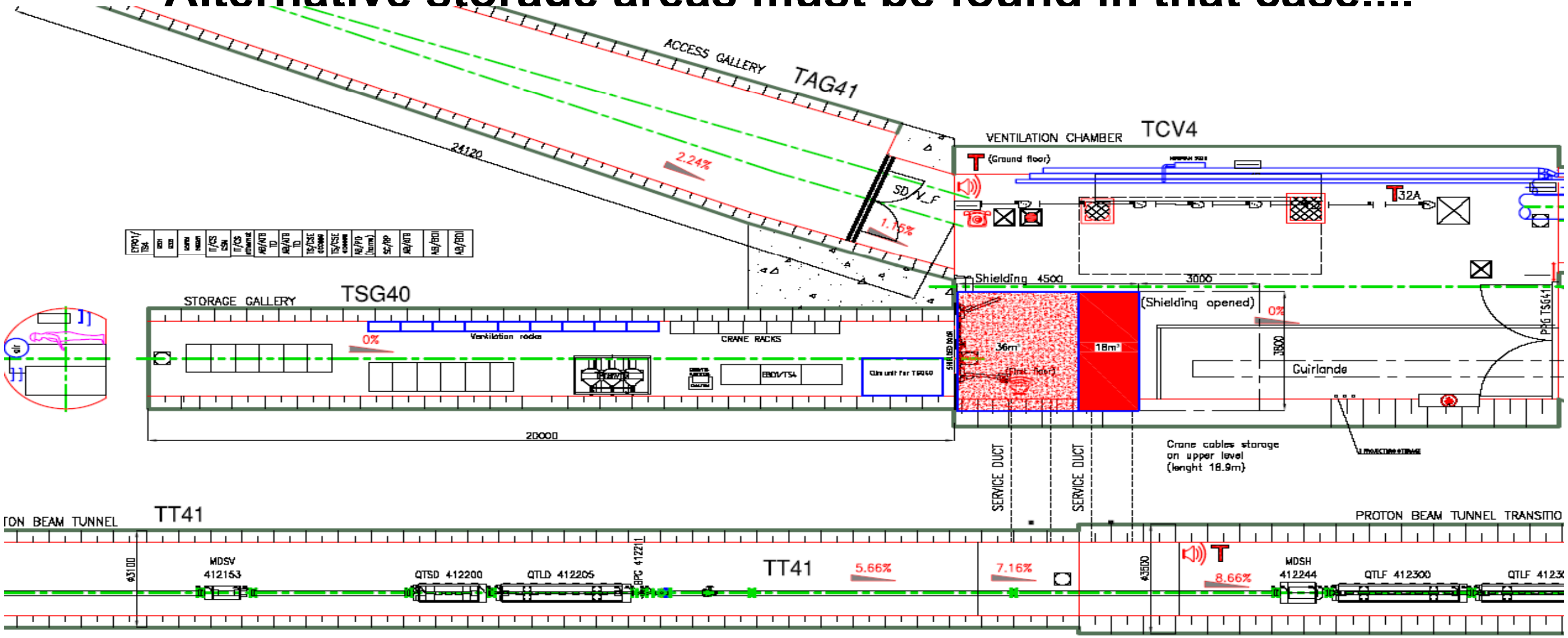
Required reduction factor: ~10^4
Typical shielding: ~1.6m Fe **+** ~1m concrete but hermetic!



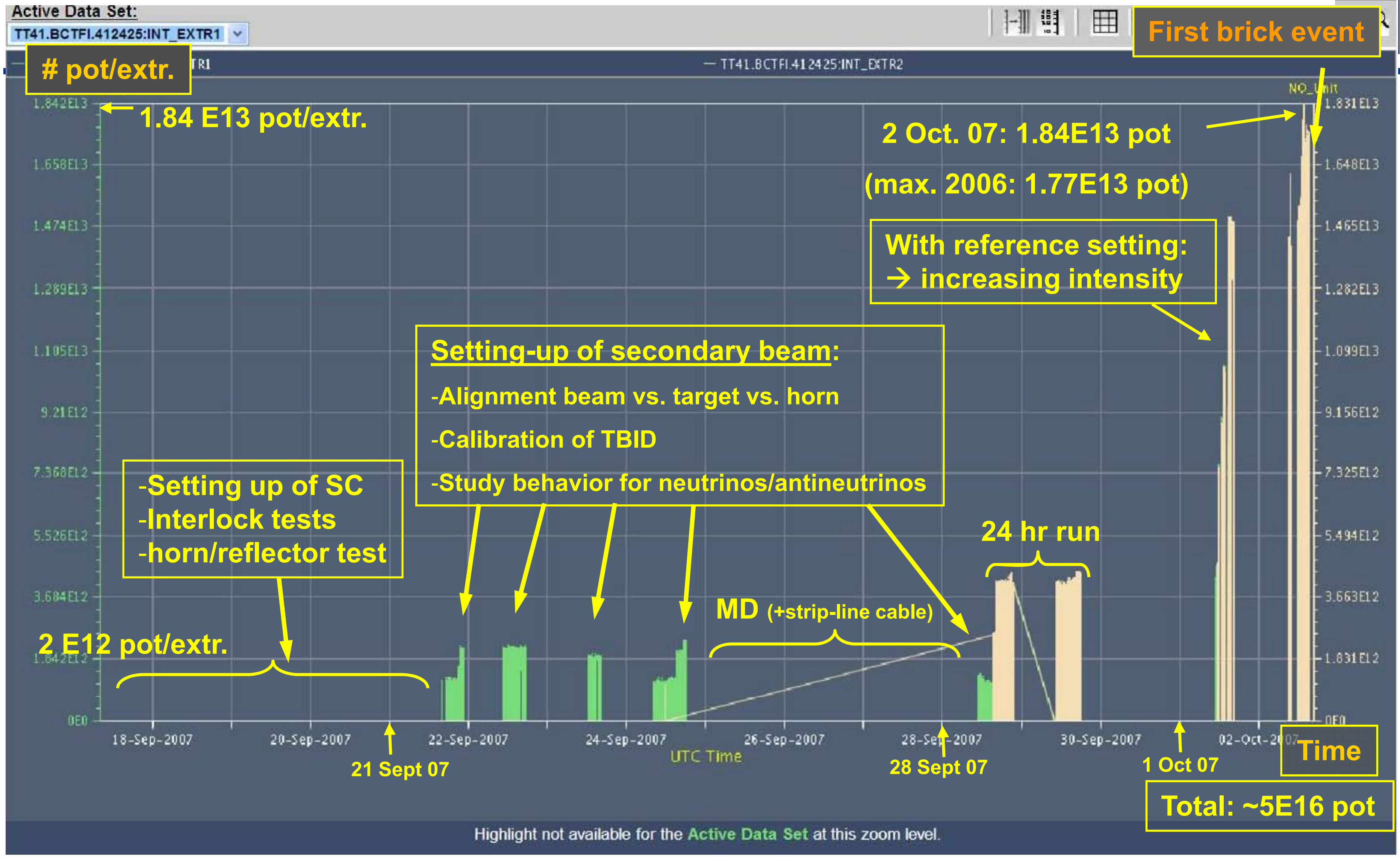
Possible solutions...

2) use existing tunnel (TSG40) to house all the electronics

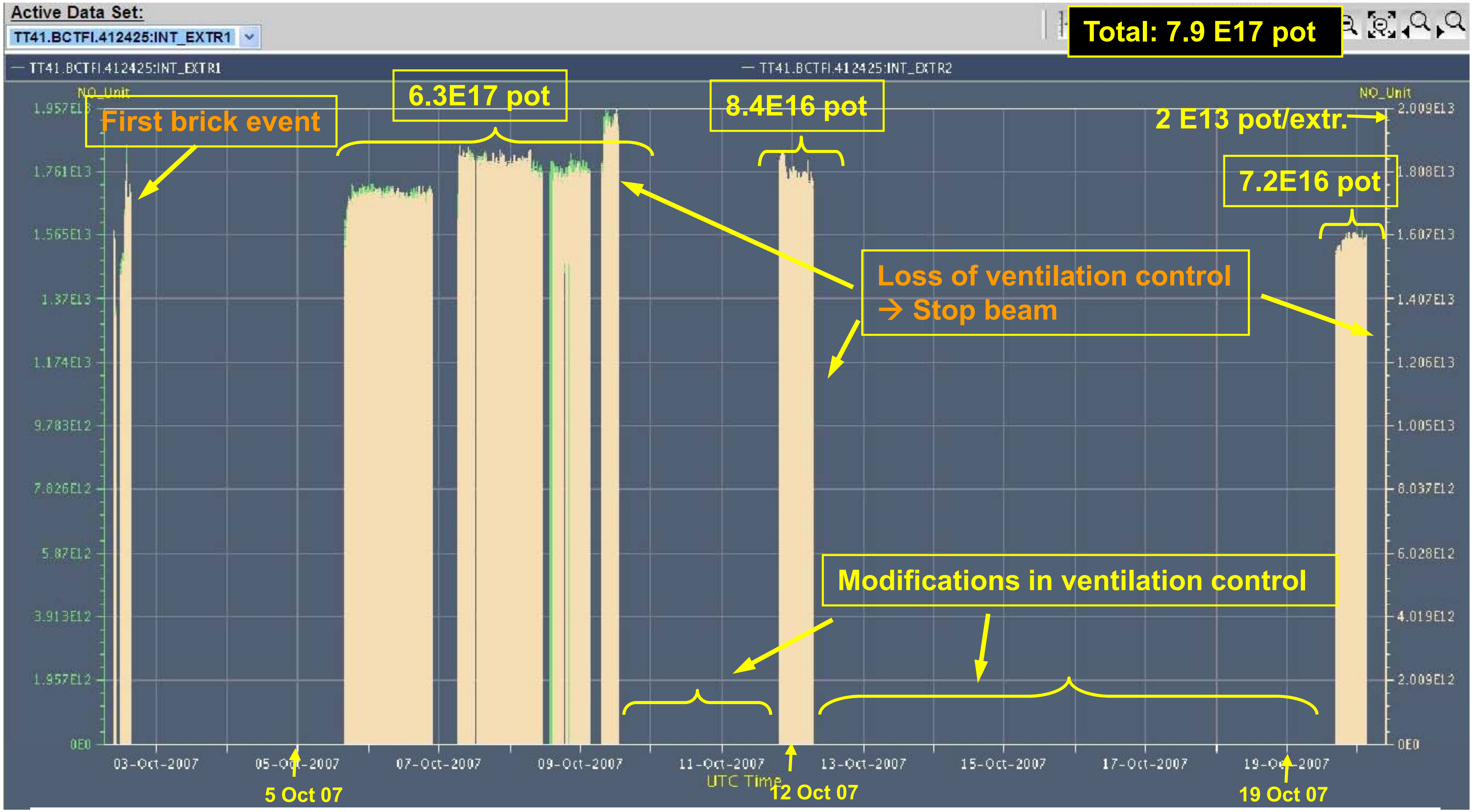
– **TSG40 is foreseen as garage to store broken horn/reflector/target during the lifetime of the facility. Alternative storage areas must be found in that case....**



CNGS 07 Commissioning Week 38-40

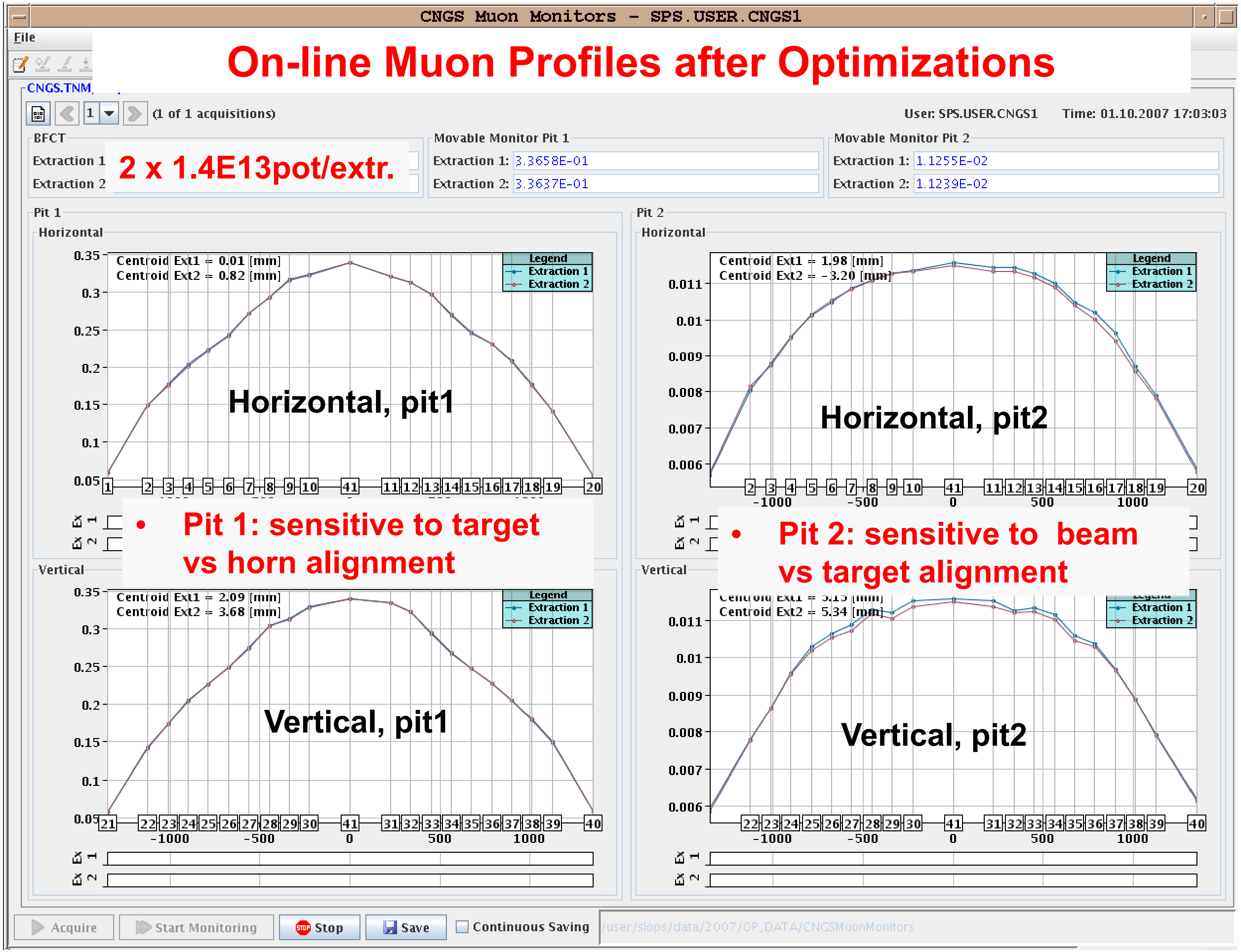


CNGS Physics Run 2007



Stop CNGS: non-standard mode of operation (access) not possible in an INB controlled facility

On-line Muon Profiles after Optimizations



Radiological Issues

- **Beam on:**
  - **< 100Sv/h outside the horn shielding**
  - **< 2Sv/h in service gallery**
- **Beam off immediately afterwards**
  - **100mSv/h**

Access is controlled with 'radiation veto'!

For intervention: dose rate < 2mSv/intervention (CERN rule)

Examples:

- **1 week shutdown to change a motor of the target**
- **1 month shutdown to exchange the horn**
  - **Only possible because most is remotely handled!**