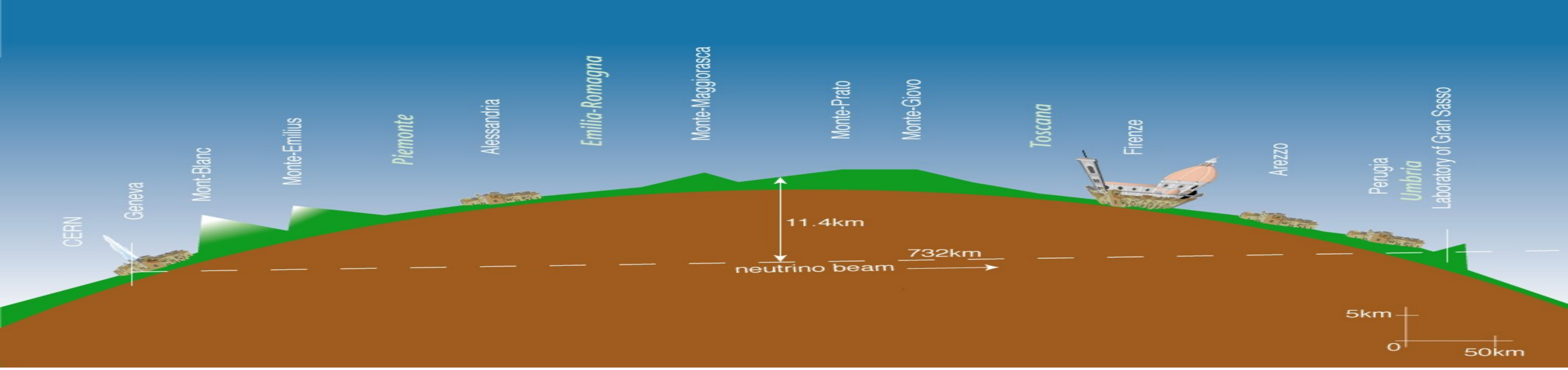


Safety experience from CNGS

CNGS horn exchange procedure

Ans Pardons (EN/MEF) with input from E. Gschwendtner, Hei. Vincke, M.L. Sentis and

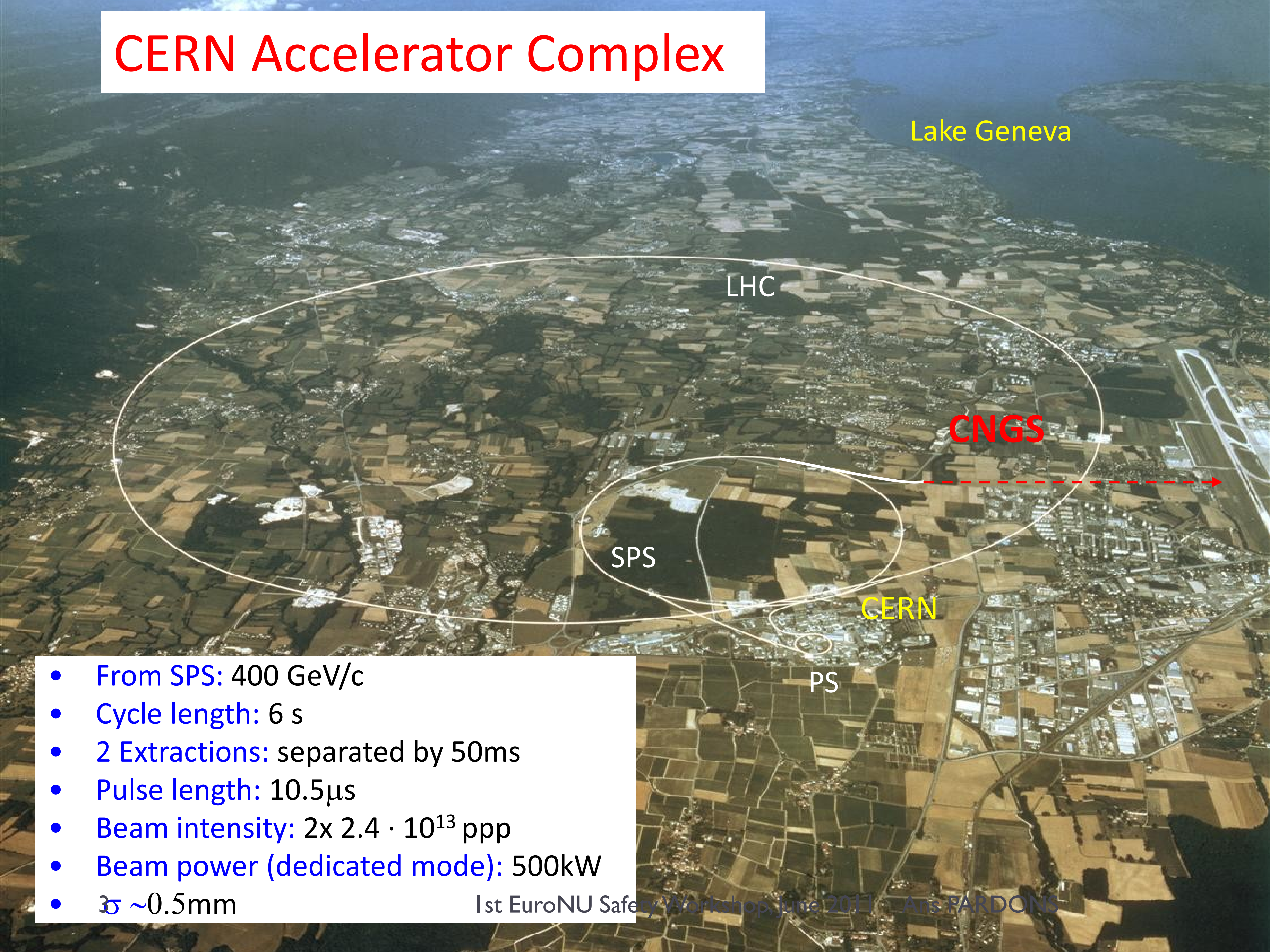
ELECTROWATT-EKONO
Jaakko Pöyry Group

EDMS 1148375

Outline

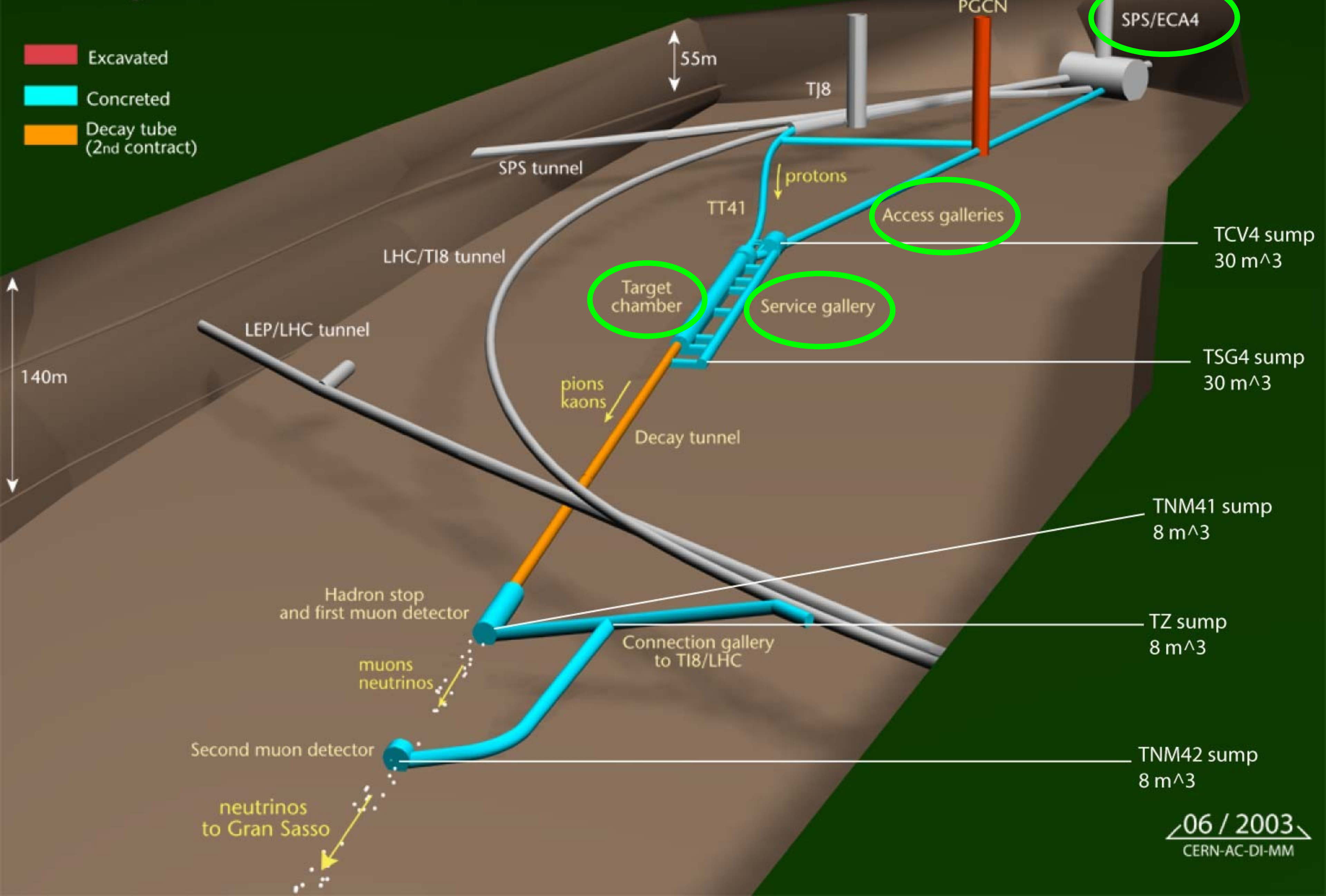
- Introduction to CNGS
- Introduction to CNGS horns
- Horn exchange
  - Remote handling
  - Horn electrical connection
  - Exchange procedure
  - RP optimisation
  - Hazard and operability (HAZOP) study
- 2006 horn repair
- Summary

CERN Accelerator Complex

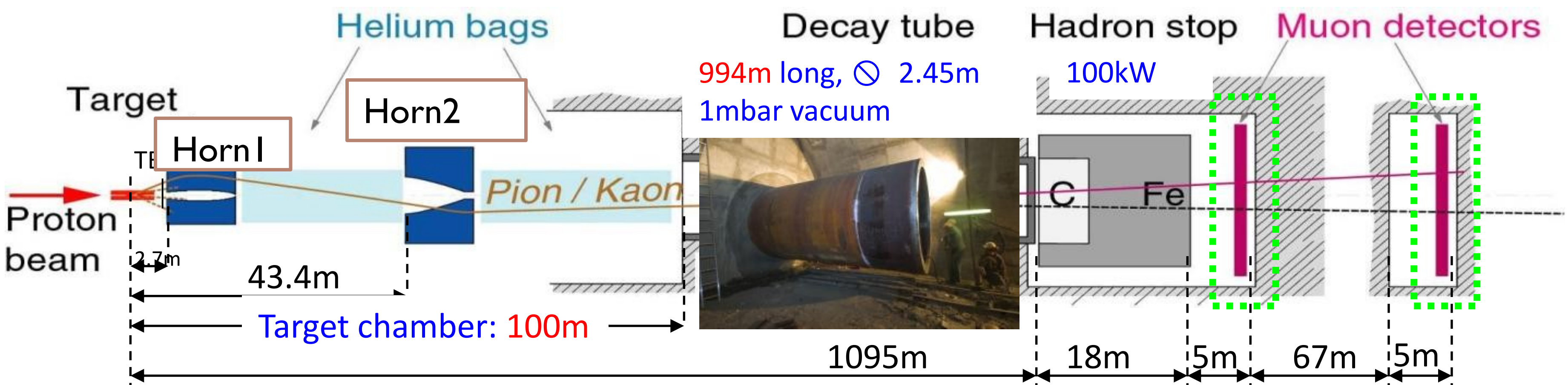


- From SPS: 400 GeV/c
- Cycle length: 6 s
- 2 Extractions: separated by 50ms
- Pulse length: 10.5μs
- Beam intensity: 2x $2.4 \cdot 10^{13}$ ppp
- Beam power (dedicated mode): 500kW
- $3\sigma \sim 0.5$mm

CERN NEUTRINOS TO GRAN SASSO
Underground structures at CERN

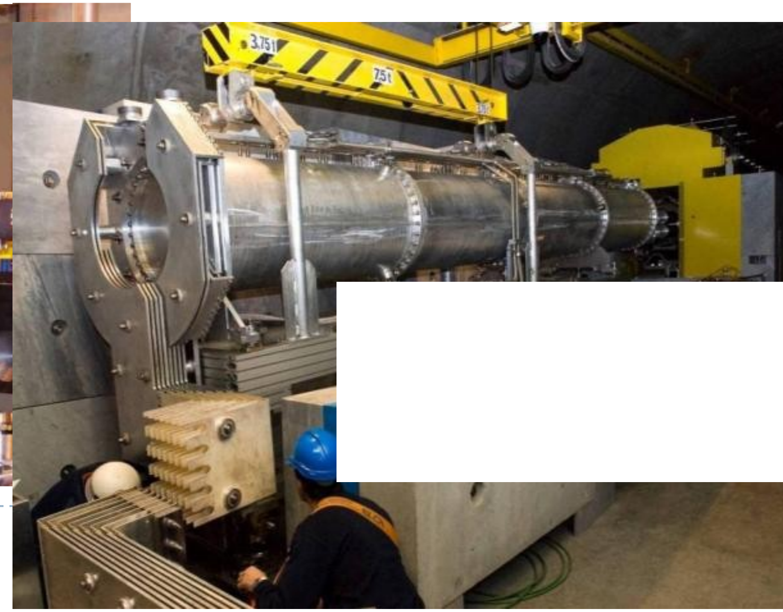


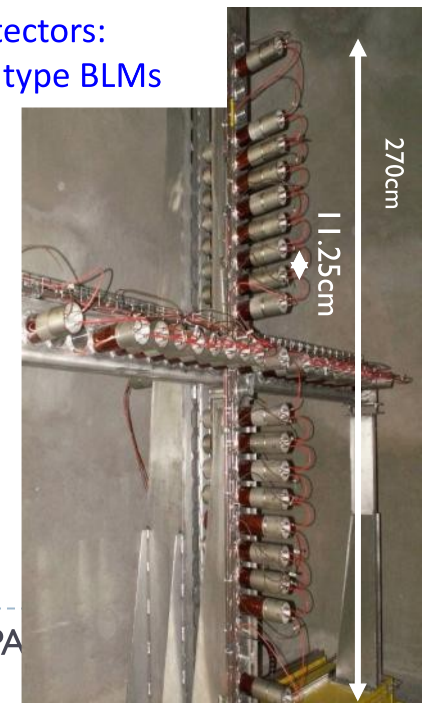
Introduction to CNGS - beamline



1 Target unit: 13 graphite rods 10cm
1 Magazine: 1 unit used, 4 in situ spares

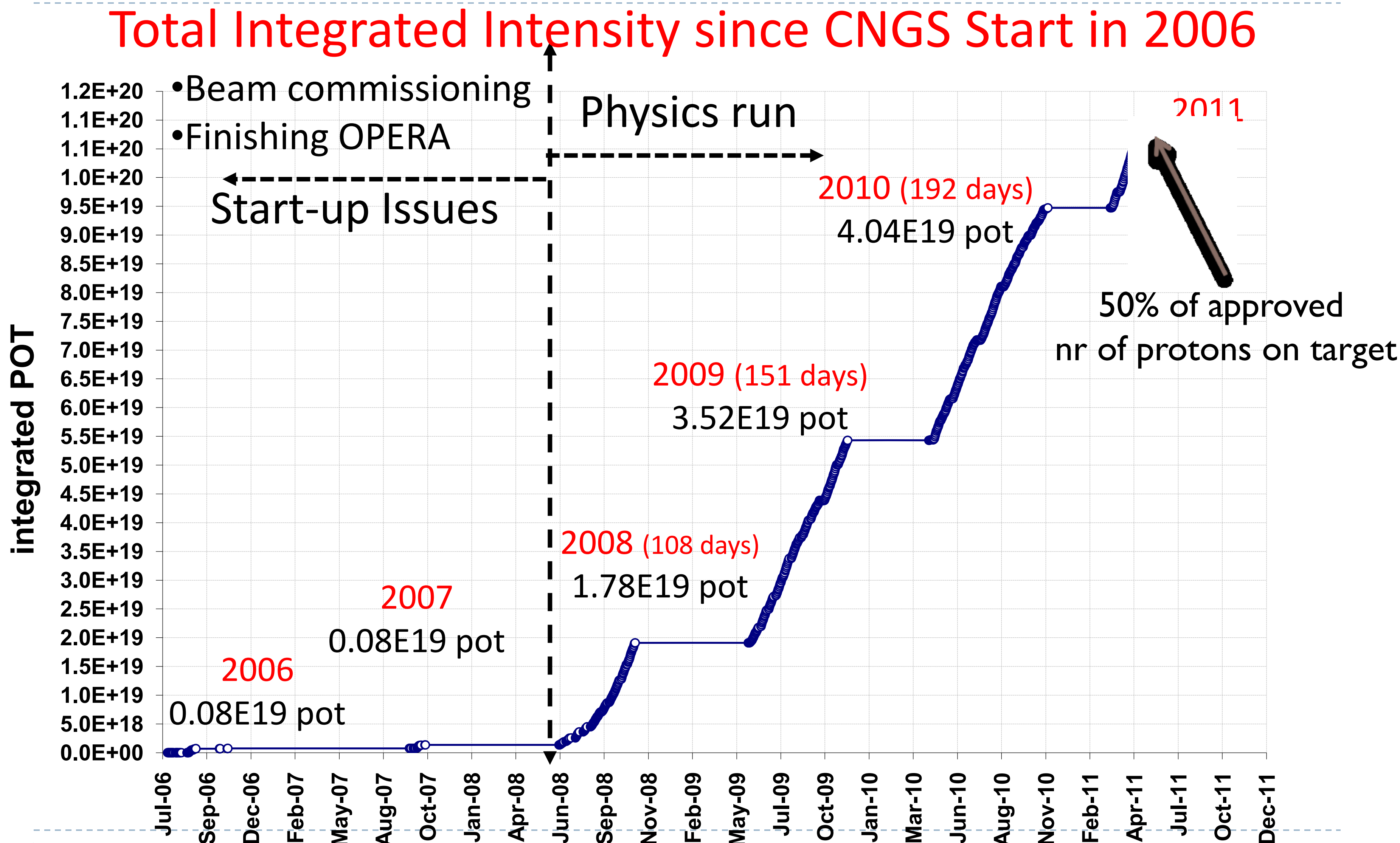
Muon detectors:
2x41 LHC type BLMs



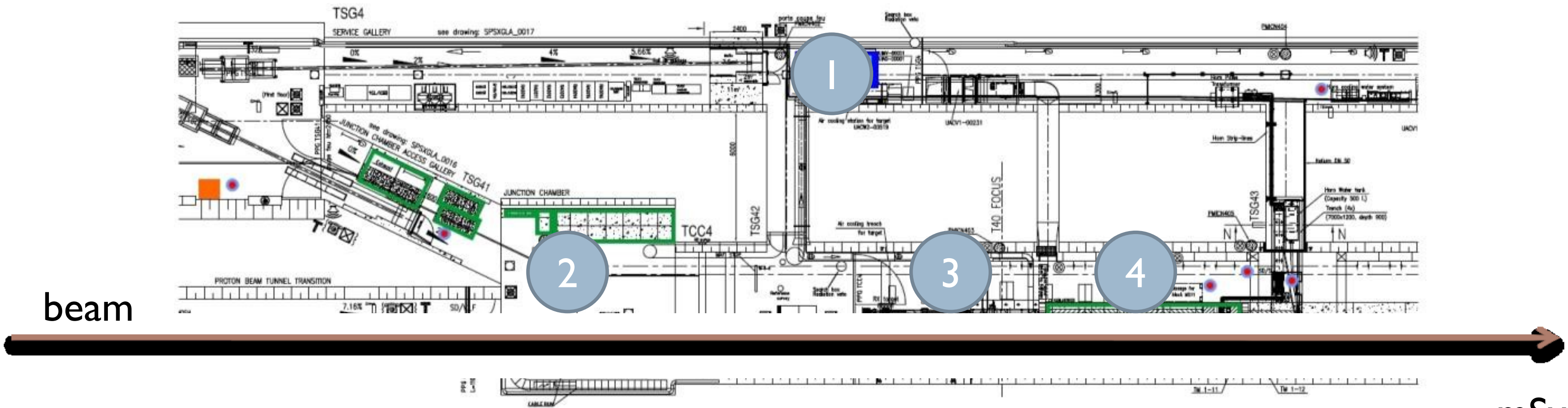


PA

Introduction to CNGS - performance

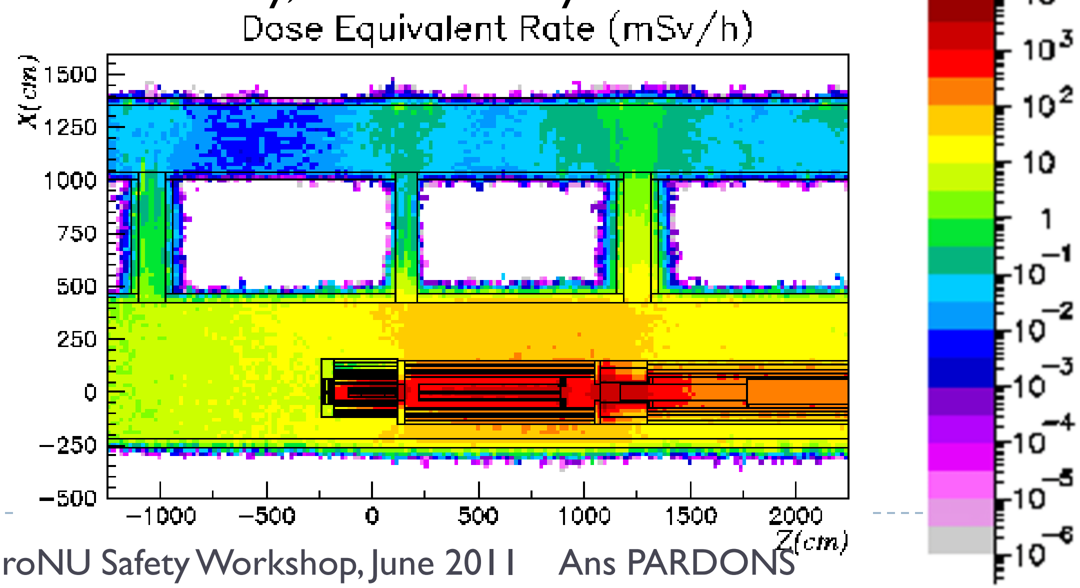


Target chamber lay-out and dose rate

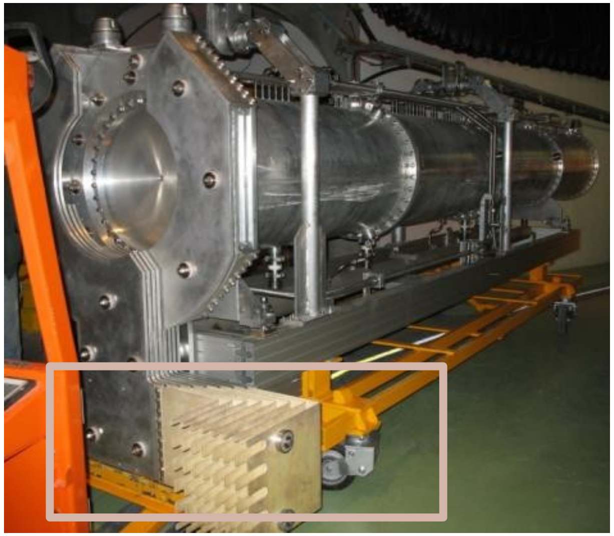


1. Protected service tunnel
2. Upstream part of target hall (crane storage)
3. Target area
4. Horn area

One year continuous operation at 3xnominal intensity, then one day cool-down



CNGS horns


- Length: 7 meters, weight: 1500kg
- Water cooled at 1.5 bar
- Powered at 150/180kA via striplines from service gallery
- In shielding castle
- 2 cradles for remote handling with overhead crane
- Electric Fast Coupling (manual) & water connection (automatic)

Horn exchange

- Design phase: Optimization with respect to dose rate (material choice) and intervention time (remote connections etc.)
- + Experience from past → First draft of procedure
- = Input to RP → minimum waiting time & optimisation of intervention steps → Second draft of procedure
- = Input to HAZOP study

  → main remaining risks identified, modifications proposed and integrated
- New version written with input from study & experts

  (radioprotection, handling, transport, …)
- Tools designed, produced & tested

→ Updated procedure = script for exchange exercise

Remote handling

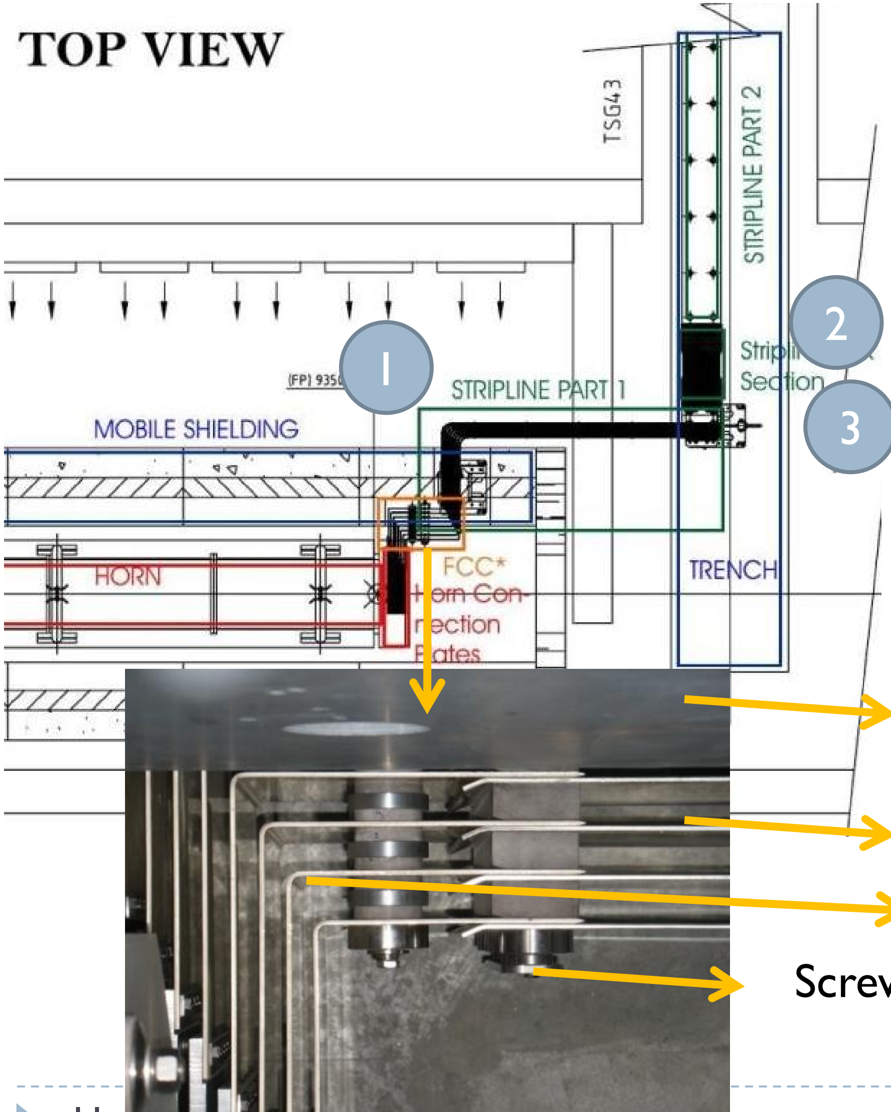
- Design of shielding and beamline elements optimised for remote handling, followed by extensive handling tests
- Overhead crane with coordinate system and cameras







CNGS horns electrical connection



1. Disconnect fast coupling (through shielding block)
2. Remove section of stripline (in trench)
3. Slide disconnected section downstream (in trench)

Custom-made shielding

Sliding section

Section fixed to horn

Screws to disconnect

CNGS horns electrical connection

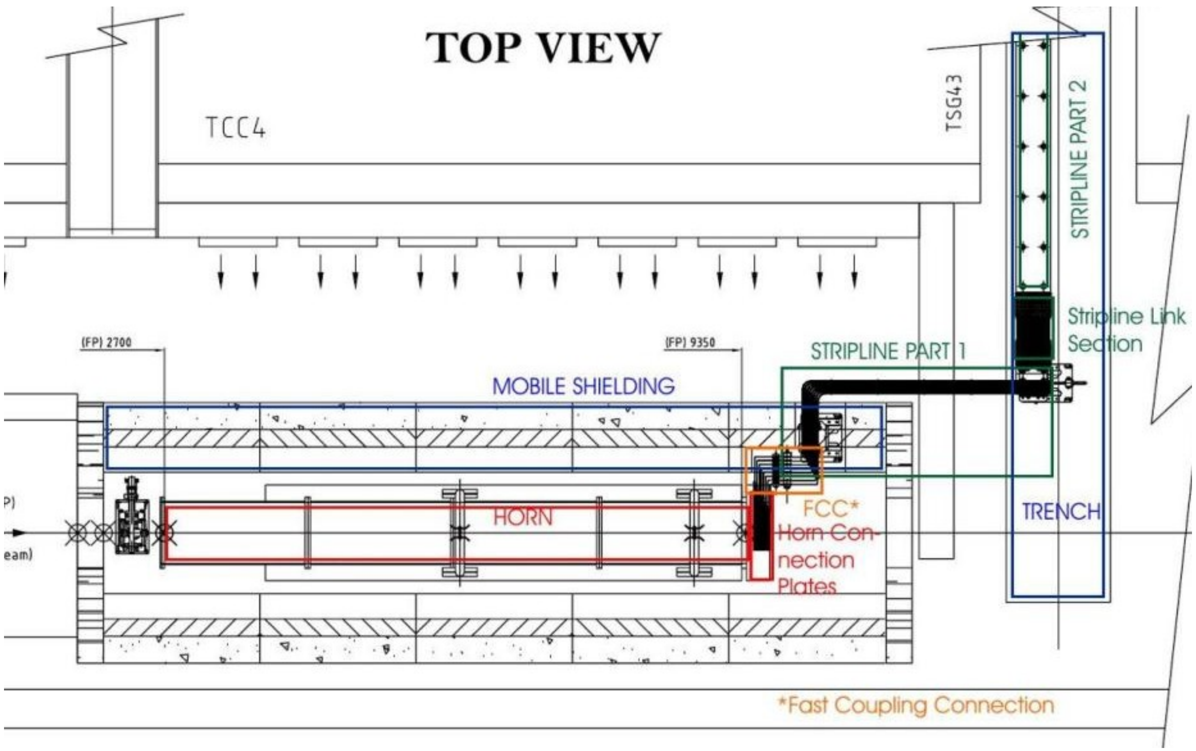
- In pictures:

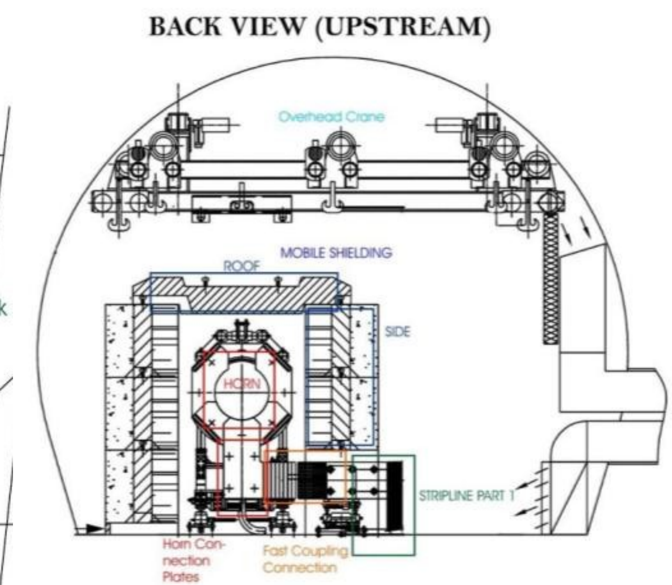







Horn Exchange procedure





- Disconnect Fast Coupling
- Take out Stripline Link
- Move stripline part 1
  (open)
- Remove shielding
  (roof & passage side wall)

→ Exchange
Horn →

- Build up shielding
- Move stripline part 1
  (close)
- Put Stripline Link back
- Connect Fast Coupling

Horn exchange procedure

- Design phase: Optimization with respect to dose rate (material choice) and intervention time (remote connections etc.)
- \+ Experience from past → First draft of procedure
- = Input to RP → minimum waiting time & optimisation of intervention steps → Second draft of procedure
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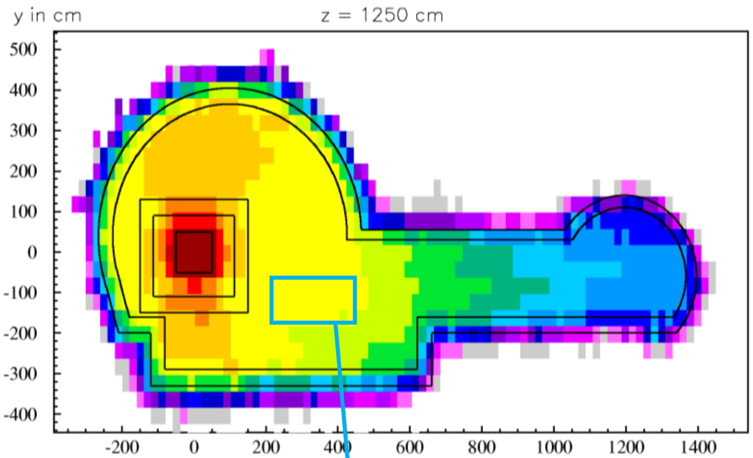
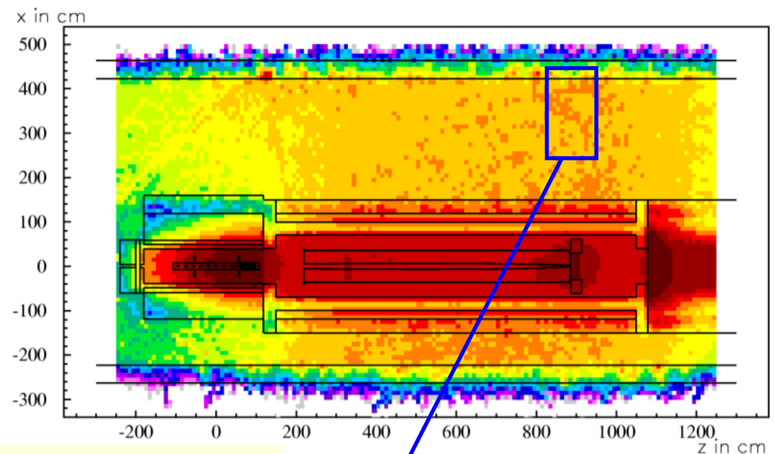
  → main remaining risks identified, modifications proposed and integrated
- New version written with input from study & experts

  (radioprotection, handling, transport, …)
- Tools designed, produced & tested

→ Updated procedure = script for exchange exercise

RP optimisation: FLUKA simulations

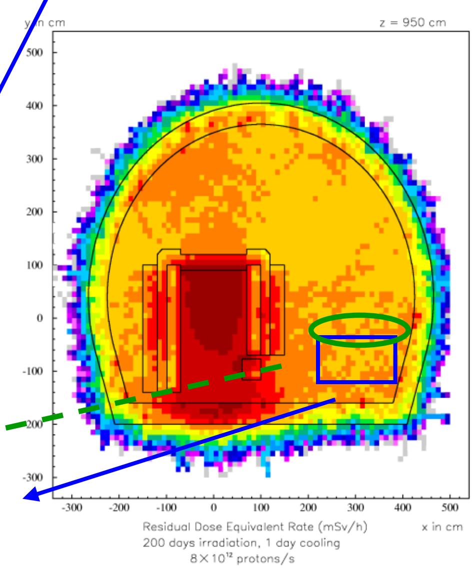


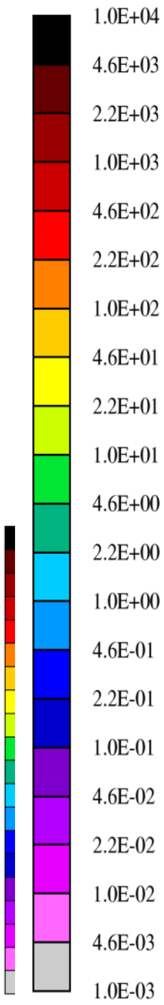


Location	1	2	3
	trench	aisle	aisle
x (cm)	150 .. 400	200 .. 380	200 .. 380
y (cm)	-263 .. -183	-70 .. -20	-160 .. -60
z (cm)	1190 .. 1310	880 .. 1030	880 .. 1030

Dose rate (µSv/h) for different cool-down times

	1	2	3
1 day	24499	94422	96918
1 week	765	2886	3546
1 month	576	1870	2228
2 months	509	1574	1841
4 months	443	1181	1370
6 months	397	1020	1163





mSv/h

RP optimisation: accumulated dose

- Most penalizing steps identified → optimization (design or tools)
- Minimum cool-down time indication (though in-situ RAMSES measurements have the last word)

Intervention Step	Duration (min)	Location	Accumulated dose (µSv) 1 day	1 week	1 month	2 months	4 months	6 months
Install lights	1	2	1573	48	31	26	19	17
Open fast coupling connection	4	3	6461	236	148	122	91	77
Remove stripline link section in trench	14	1	5716	178	134	118	103	92
Slide stripline downstream	3	1	1224	38	28	25	22	19
Slide stripline upstream	6	1	2449	76	57	50	44	39
Close fast coupling connection	6	3	9691	354	222	184	137	116
Take dimensions of new stripline link section	2	1	816	25	19	16	14	13
Install stripline link section in trench	20	1	8166	255	192	169	147	132
Remove lights	1	2	1573	48	31	26	19	17
TOTAL (µSv):			37700	1260	870	740	600	530

Horn exchange procedure

- Design phase: Optimization with respect to dose rate (material choice) and intervention time (remote connections etc.)
- + Experience from past → First draft of procedure
- = Input to RP → minimum waiting time & optimisation of intervention steps → Second draft of procedure
- = Input to HAZOP study

  → main remaining risks identified, modifications proposed and integrated
- New version written with input from study & experts

  (radioprotection, handling, transport, …)
- Tools designed, produced & tested

→ Updated procedure = script for exchange exercise

HAZOP study (from HAZOP report)

- Scope

… The proposed sequence of horn exchange operations was examined using HAZOPs, a **systematic team-based hazard identification method.** This resulted in the **identification of potential hazards and operability problems** which could then be addressed in the development of the detailed method statements which would be produced should replacement of the Horn be needed. This would give confidence that these method statements would **incorporate adequate safety** and that **operator doses** arising from their implementation would be **As Low As Reasonably Achievable** (ALARA). …

HAZOP study (from HAZOP report)

The HAZOP technique

- The HAZOP technique is a structured, systematic and comprehensive examination process of the proposed sequence of operations in order to identify potential hazards and operability problems. The process is carried out by a suitably qualified team of experts familiar with all aspects of the operations undergoing study. This team is led by a team leader qualified in the application of the technique, usually a safety professional. Discussions, conclusions, recommendations and actions are formally recorded by a technical secretary.
- The HAZOP technique is used worldwide throughout the nuclear and chemical process industries as a powerful tool to aid safe design of processes (and operations) and to minimise operability problems associated with the design of a particular process or sequence of operations.
- The HAZOP uses a set of keywords which are essentially potential hazards which direct the team's thinking.
- Each keyword was considered separately in succession and any potential hazards or operability problems recorded.
- The keyword list is presented to the team and agreed before commencement of the study.

HAZOP study

- Performed by specialized company, in close collaboration with CERN experts (radiation protection, safety, handling, horn, horn handling + project leader)

1. Preparation
   - agree on sequences in horn exchange procedure
   - agree on keywords (applicable hazards)
2. HAZOP meeting (2.5 days) 15-17 June 2005
   - visit of tunnels
   - detailed work-through of all the procedure steps, applying each keyword/hazard to each step (see next slide)
3. Follow-up
   1. approve minutes
   2. follow-up on "actions"
   3. review actions (phone conference)
   4. presentation of HAZOP report 2 Sept. 2005

HAZOP study: keywords and procedure steps (from report)

Dose	Spread of activity	Loss of Service	Shielding	Ventilation
Fire / Explosion	Mechanical Handling	Maintainability	Remote Handling	Corrosion / Erosion
Domino	Seismic	Impact/Drop Loads	Conventional	Movement
Timing	Control / Instrument	Contamination		

- ***Preparation:*** *Manned entry to the target chamber to set up the lighting, disconnect the Fast Coupling Connection and physically disconnect the stripline.*
- ***Shielding Removal:*** *Using the overhead crane remotely remove the top and side shielding.*
- ***Removal and Storage of the old Horn:*** *Using the overhead crane remotely remove the old Horn from the target chamber support frame and place on motorised trailer. The motorised trailer is then guided remotely to a chamber where the horn is stored behind shielding.*
- ***Installation of the new Horn:*** *The new Horn, having been brought into the access chamber is picked up by the overhead crane and remotely placed on the target chamber support frame.*
- ***Shielding Replacement:*** *Using the overhead crane remotely replace the top and side shielding.*
- ***Horn Reconnection:*** *Via manned entry, physically re-install the stripline and reconnect the FCC.*
- ***Conclusion:*** *Via manned entry, tidy up target chamber and remove lighting.*

Extract from minutes (from report)

TABLE NO: 7.0 (continued) DOCUMENT REF:

ITEM: Close Horn Shielding

KEYWORD	CONCERN	CONSEQUENCE	COMMENTS	ACTION
Fire / Explosion	No additional considerations.			
Mechanical Handling	Failure to locate shielding blocks in correct location.	Inadequate shielding, excessive shine. Last block may not fit in place.	The shielding blocks have conical receptor for the mushrooms in order to aid locating these. Cameras will be used to ensure visual confirmation of location. The last (lowest, ground level,) layer of shielding will remain in location to provide a good foundation to locate the blocks on.	(no action needed)
NOTE: Shield block replacement needs to be conducted with a good degree of precision.				
Mechanical Handling	Limit / safety switch on crane is activated while moving blocks	Crane stops moving blocks - delay to operation, failure to locate blocks in correct position. Crane needs to be reset.	These switches cannot be overridden from the control panel. Crane needs to be lowered to fix this but there will be blocks located directly underneath this position.	Ensure the limits of the crane are set as such that the crane can complete the fitting of the shield blocks without needing to be reset. Crane needs to be able to operate at its extreme height limit without cutting out.

ACTION NO: 13 ASSIGNED TO: Antonino Calderone

HAZOP study: conclusion (from report)

- A number of hazards and operability concerns were identified together with existing safety measures. Where additional safety measures or other measures to address operability **concerns were** required, they were **addressed through actions raised on team members.** Action **responses were discussed at an action review meeting**; actions were **accepted and cleared**; one recommendation was made. This recommendation is now the subject of a design study.
- As part of pre-active commissioning work the CNGS project intend to **carry out a full trial of the Horn Exchange procedure**. This will take account of issues raised at this study and will result in a complete set of operating instructions for the procedure. In this way the **adequacy of safety measures and the potential for operability problems can be tested** and, depending on the results, **additional measures put in place** prior to the procedure being used during the life of the experiment.

HAZOP study: our conclusion

Was it worth it? Yes.

Frequently Asked Questions & Remarks

"You could have done this yourselves!"

- Yes, but would we have taken the time to do it in enough detail ?
- Would we have done in an officially recognized, traceable manner ?
- An external pair of eyes sheds a new light on "our" topic

"Did you really learn something new?"

(Eh, yes we did (at least I did))

- Even if this could be true for some very experienced persons, having some items pointed out in a clear manner and documented allows no "escape" when it comes to action

Would we do it again?

Yes, this structured exercise is very useful for other, more frequent interventions in "hot" areas at CERN.

Horn exchange procedure

- Design phase: Optimization with respect to dose rate (material choice) and intervention time (remote connections etc.)
- \+ Experience from past → First draft of procedure
- = Input to RP → minimum waiting time & optimisation of intervention steps → Second draft of procedure
- = Input to HAZOP study

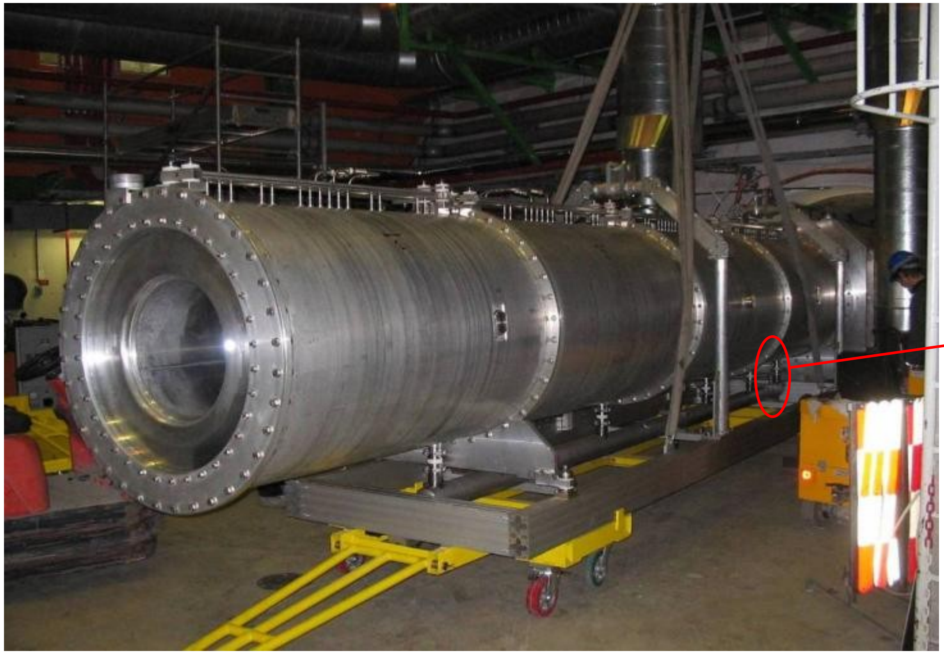
  → main remaining risks identified, modifications proposed and integrated
- New version written with input from study & experts

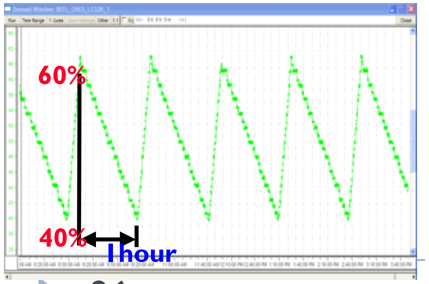
  (radioprotection, handling, transport, …)
- Tools designed, produced & tested
- Third draft = script for exchange exercise (before start-up). From lessons learnt: Final version of procedure

→ Final version of procedure = script for future horn exchange

When reality kicks in: Horn Water Leak

October 2006: Leak in water outlet of cooling circuit of reflector after $4 \cdot 10^5$ pulses





Observation:

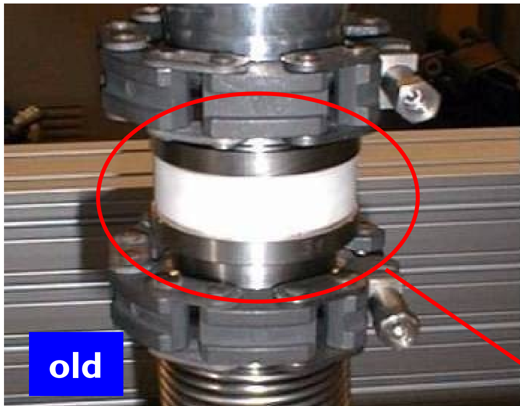
- High refill rate of closed water circuit of reflector cooling system
- Increased water levels in sumps

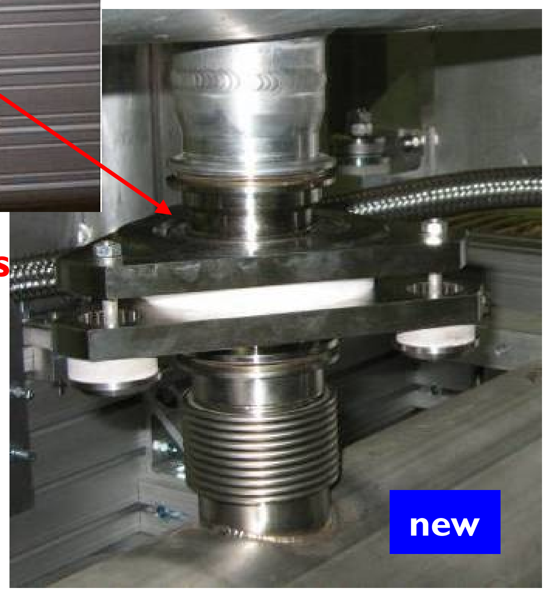
Reason:

- Inadequate design of water outlet connectors (machining, brazing)

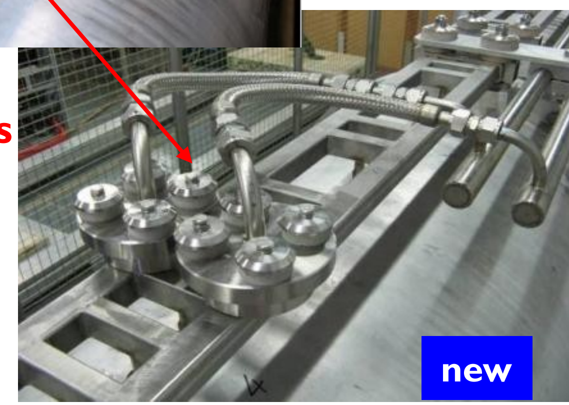
Improvement

Improved design: replace brazed connections by connectors under pressure





Water Outlets



Water Inlets

Stress in ceramic strongly reduced:

- No brazing
- No machined internal edges
- Ceramic under compression only (10 times stronger)

Water & air tight:

- Soft graphite/steel seal (5MPa pre-stress)
- Self-locking nuts

Thorough technical study

- Detailed validation/calculations of the new design
- Additional features optimized

2006 Horn Repair

Work executed in upstream part of target hall

→ Repair includes the removal & reinstallation of both horns according to horn exchange procedure

Dose to personnel minimised thanks to:

- Detailed documentation available on "horn exchange" and additional radiation dose planning and minimization for the rest
- Experience from "horn exchange" available (same team) and practice of the repair work on spare horn
- Each work step executed by up to 4 persons to reduce individual dose
- Additional local shielding

→ total integrated dose: 1.6mSv

(repair plus "horn exchange")

Summary: Guidelines for "smooth" interventions

- Include remote handling from the early design stage on
- Involve RP in the early design stage (many iterations do the trick)
- Invest in an adapted (remote) and reliable lifting device
- Horn exchange procedure received:
  - Mechanical input (experience in deign for remote handling)
  - RP input (FLUKA calculations very helpful, completed with on-site monitoring)
  - General safety input (HAZOP + CERN safety team)
- Practise the procedure on mock-up or on "clean" objects (several weeks and several iterations) and complete documentation with pictures, films, coordinate sheets, ...

For info in next slides

Photos of the horn exchange procedure

Remove old horn

100% Remote

Horn vs. lower frame

from: target chamber
to : radioactive storage

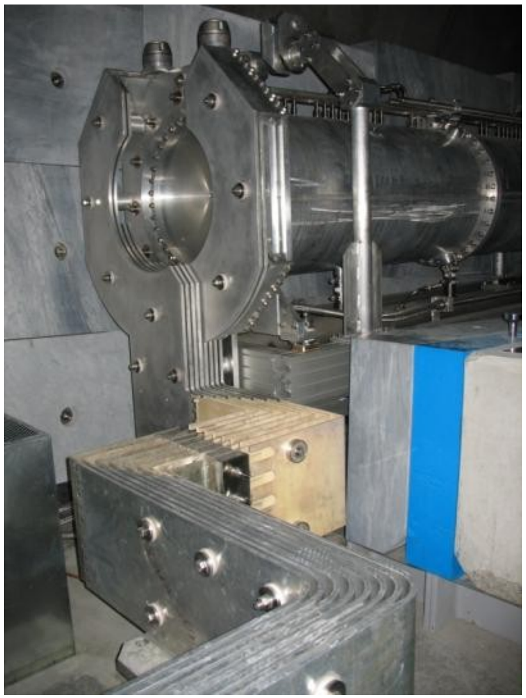
Install new horn

50% Remote

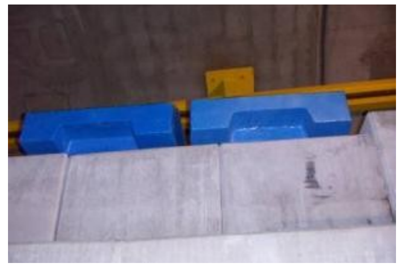
New, « clean » horn

Build up shielding

before



100% Remote



Storage blocks

after

Coordinates recorded during exercise

Beam Parameters CNGS - PSNF

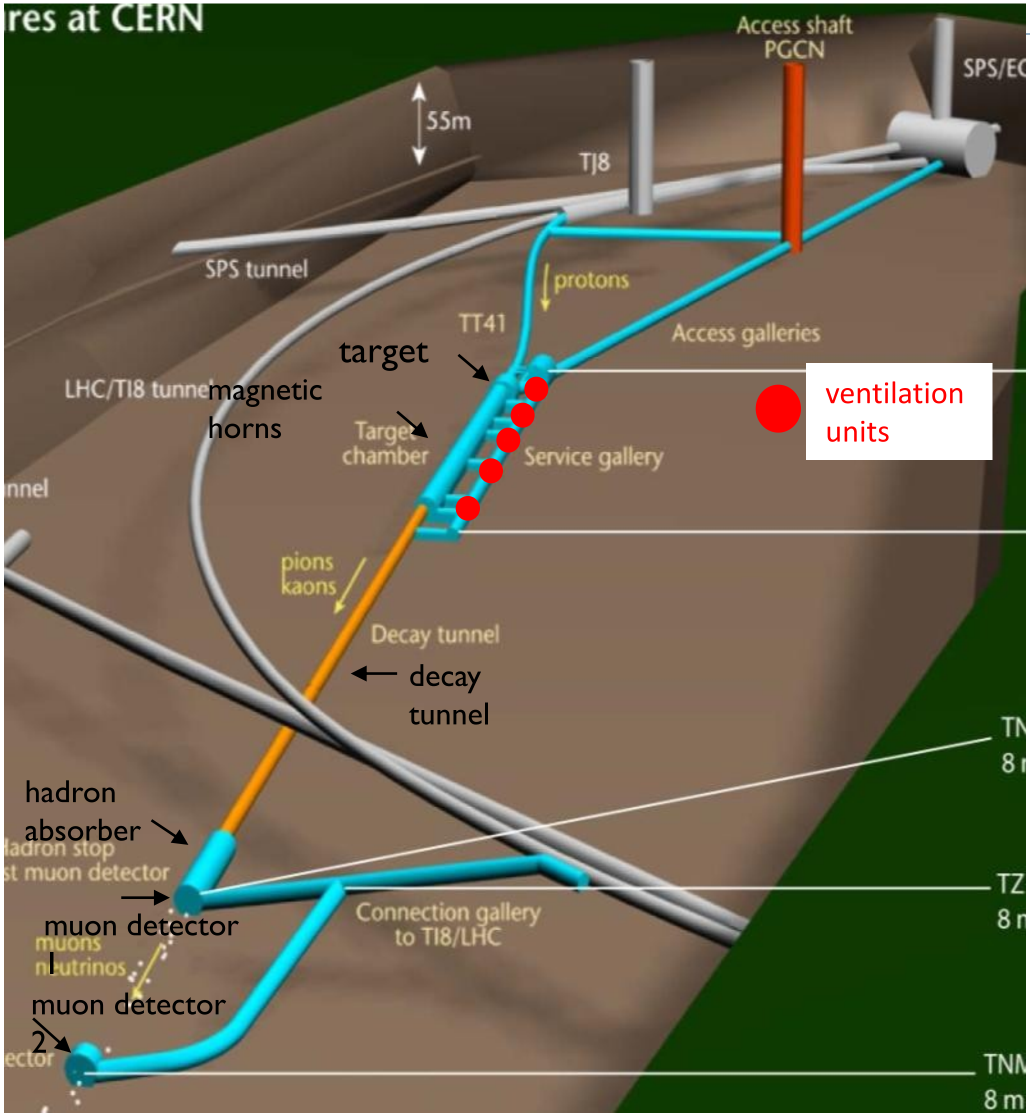
Beam parameters	Nominal **CNGS** beam	Nominal **PSNF** beam
Proton beam delivered from	SPS	PS
Nominal proton energy	400 GeV/c	20 GeV/c
Cycle length	6 s	1.2 s
# extractions per cycle	2 separated by 50 ms	1
Intensity per cycle	$4.8\ 10^{13}$	$3\ 10^{13}$
Extraction length	10.5 μs	2.1μs (dedicated) 1.84μs (parasitic)
Beam power	500 kW	80 kW
Approved total protons on target	$22.5\ 10^{19}$	$25\ 10^{19}$

CNGS Radiation Issues I

(2007-2008)

CNGS: no surface building above CNGS target area

→ large fraction of electronics in tunnel area



Failure in ventilation system installed in the CNGS Service gallery

→ due to radiation effects in electronics

(SEU – Single Event Upsets- from high energy hadron fluence)

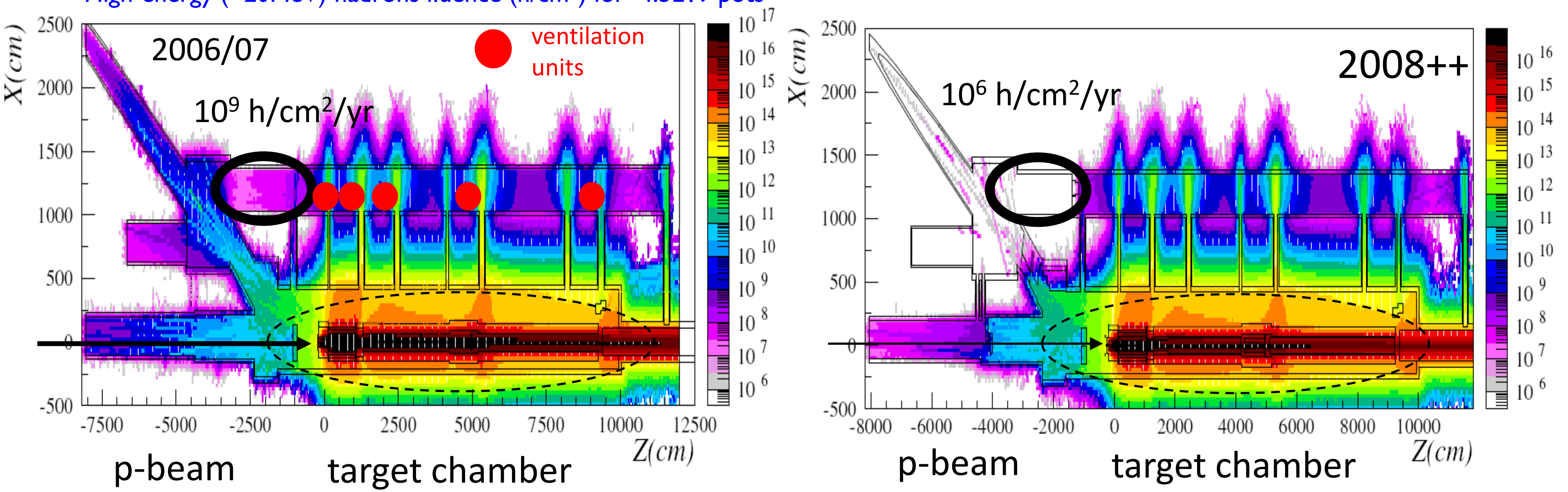
CNGS Radiation Issues II

(2007-2008)

Modifications during shutdown 2007/08:

- Move most of the **electronics out** of CNGS tunnel area
- **Create radiation safe area** for electronics which needs to stay in CNGS
- **Add shielding** → 53m^3 concrete → up to 6m^3 thick shielding walls

High-energy (>20MeV) hadrons fluence (h/cm^2) for 4.5E19 pots

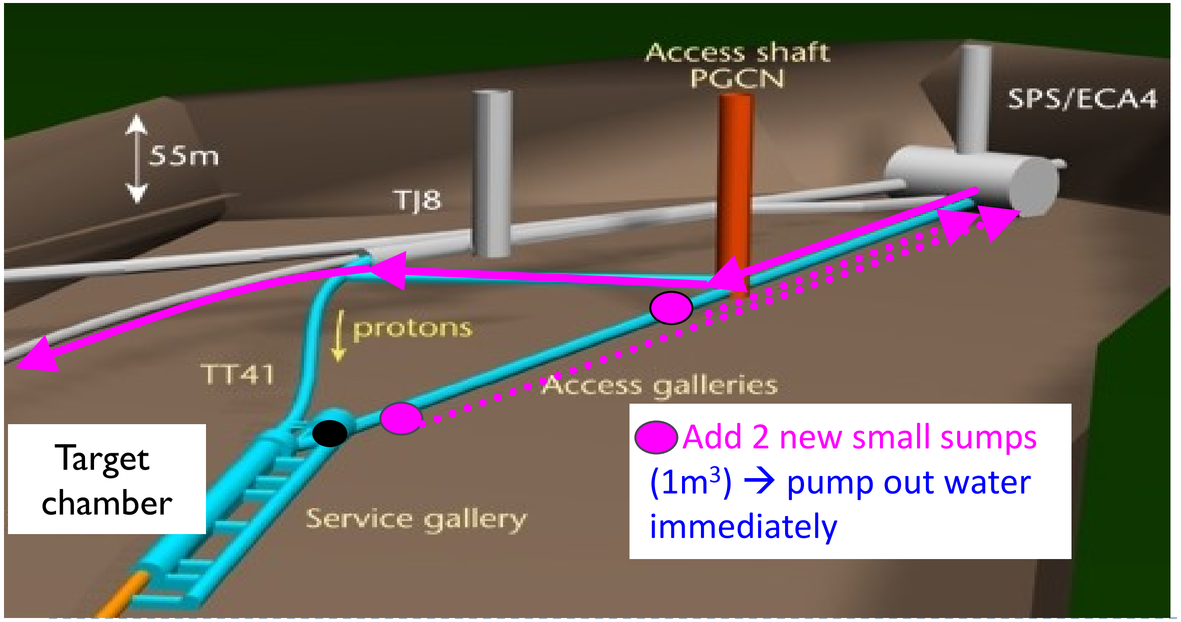


CNGS Sump and Ventilation System

After 1st year of high intensity CNGS physics run: Modification needed for (2009-2010)

- Sump system in the CNGS area
  → avoid contamination of the drain water by tritium produced in the target chamber
  - Try to remove drain water before reaches the target areas and gets in contact with the air
  - Construction of two new sumps and piping work

- Ventilation system configuration and operation
  - Keep target chamber under under-pressure with respect to all other areas
  - Do not propagate the tritiated air into other areas and being in contact with the drain water



Continuous Surveillance and Interlock System