n_TOF Phase-2 Operation in 2009

Outline

- n_TOF operation untill 2004
- New target construction
- Commissioning
- Facility Upgrade
- Beam Requests

ATOP Days 2009
Vasilis.Vlachoudis@cern.ch
CERN 06.03.2009

Concept of n_TOF

ADS Developments:

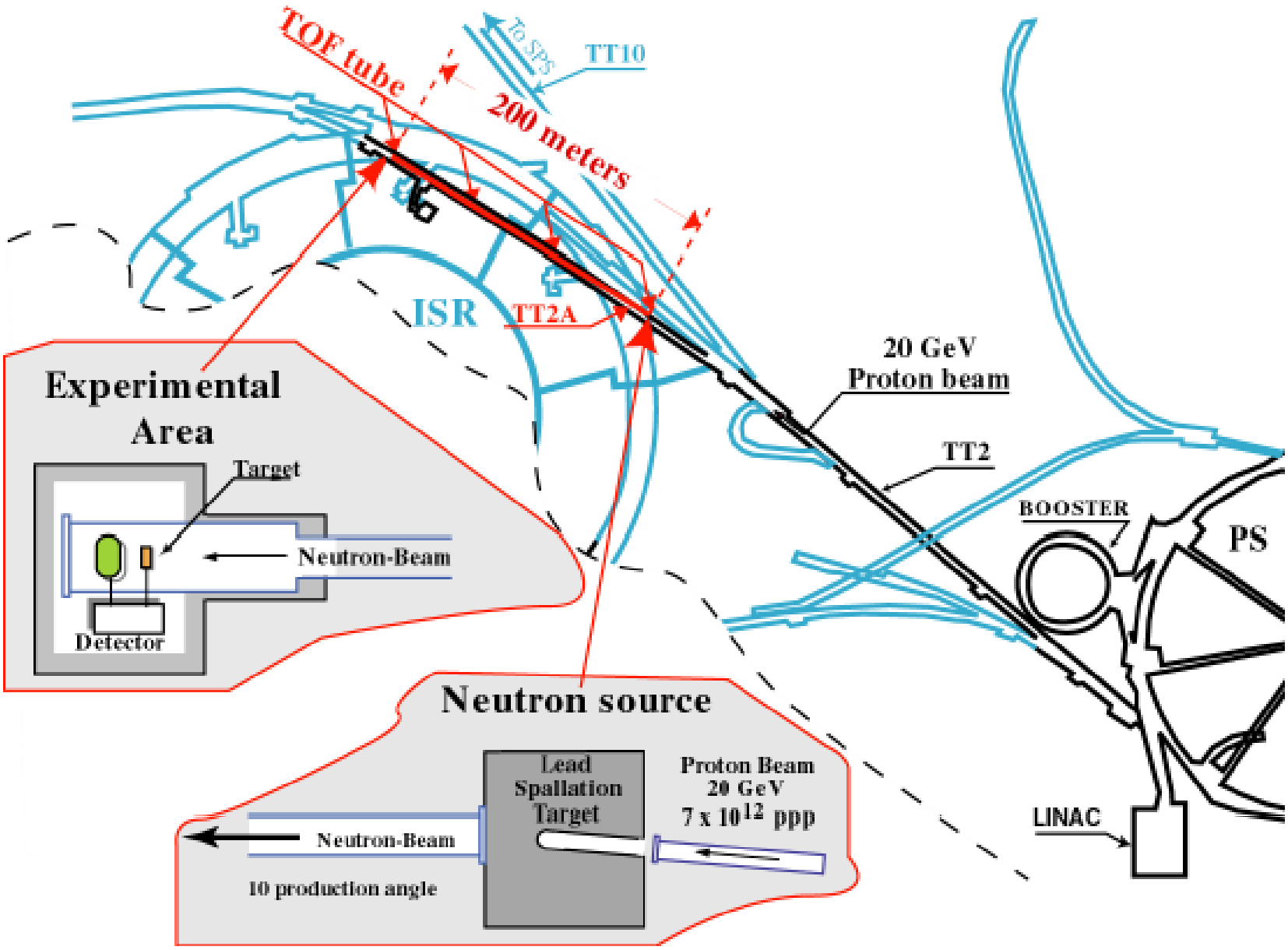
- Nuclear Waste Transmutation
- Medical Isotopes Production
- Cleaner Energy Production
- Boron Neutron Capture Therapy [BNCT]

⇨ **Require the complete and precise knowledge of neutron cross sections**

Idea:

- Knowledge acquired from TARC (PS-211)
- PS of CERN [26 GeV/c, 3 10^{13} pr]
- Spallation target Pb, to produce neutrons
  [1 proton 24 GeV/c ⇒ ~700 neutrons]
- Long flight path ~200 m

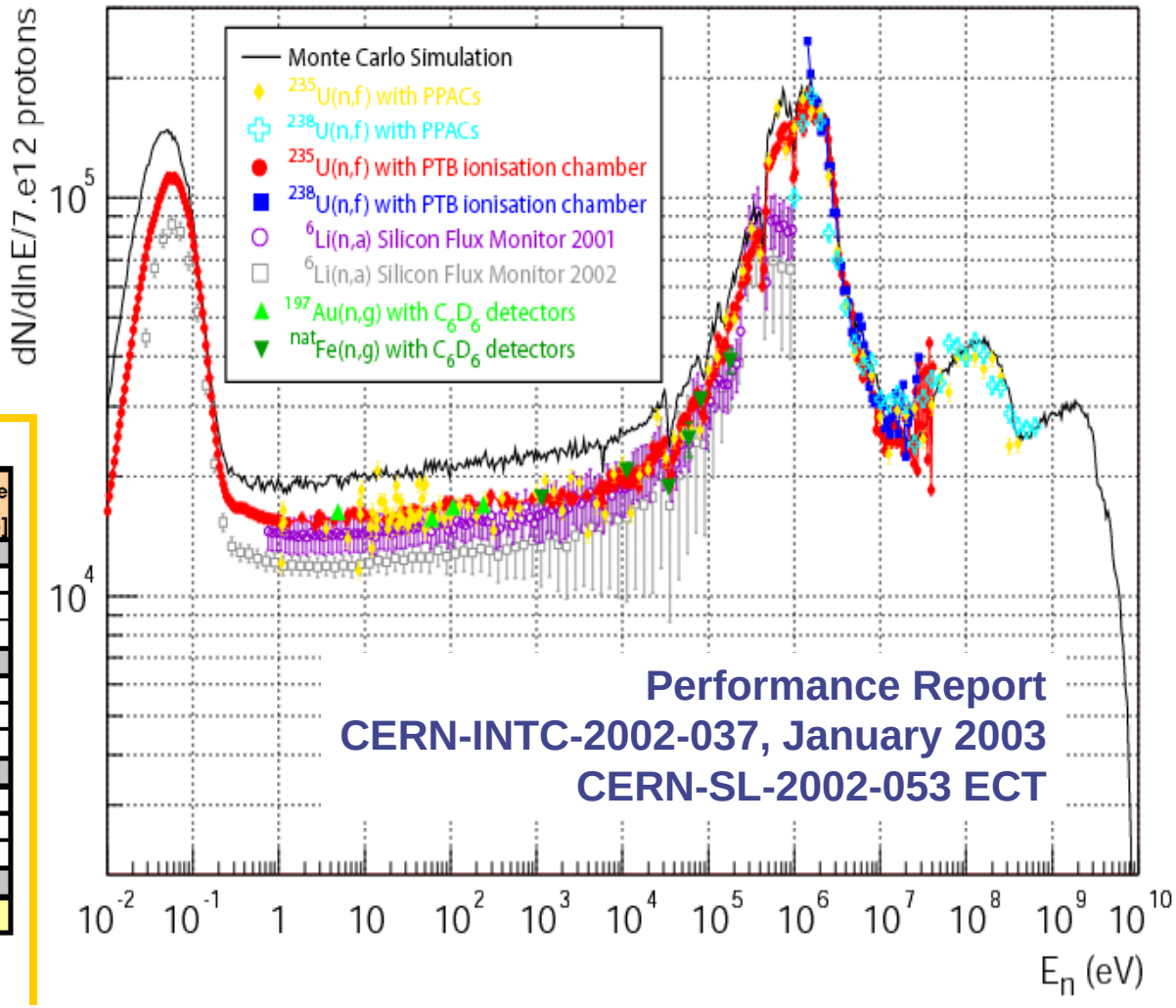
n_TOF Facility



n_TOF beam characteristics

- Wide energy range
- High instantaneous neutron flux
- High resolution
- Low ambient background
- Low repetion frequency
- Favorable duty cycle for radioactive samples.

2nd collimator ϕ=1.8 cm (capture mode)



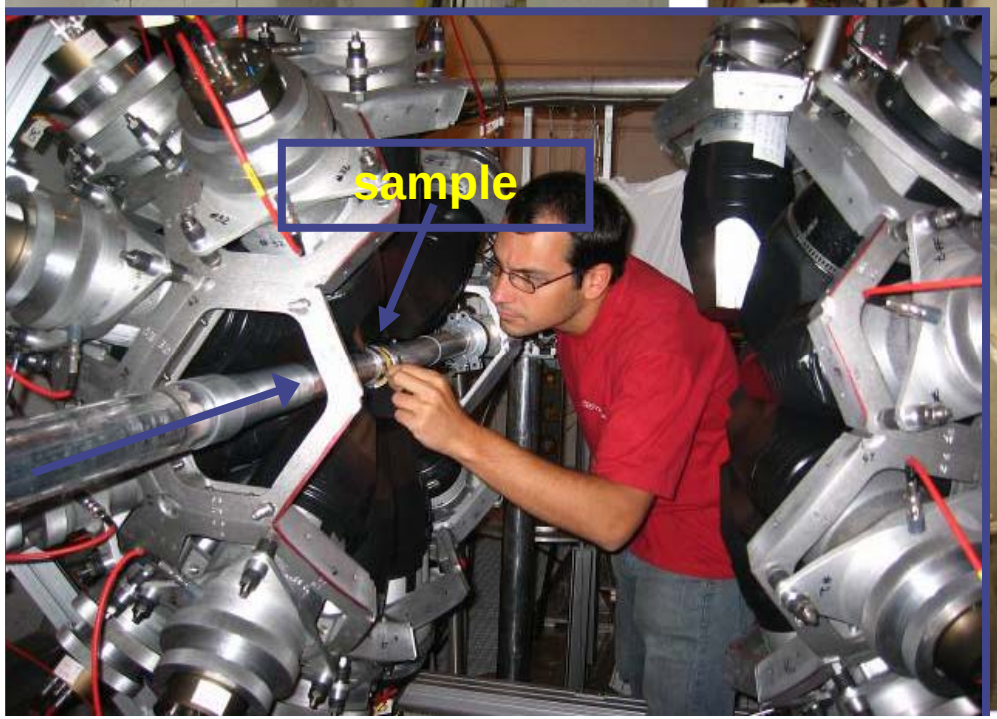
The neutron fluence in EAR-1

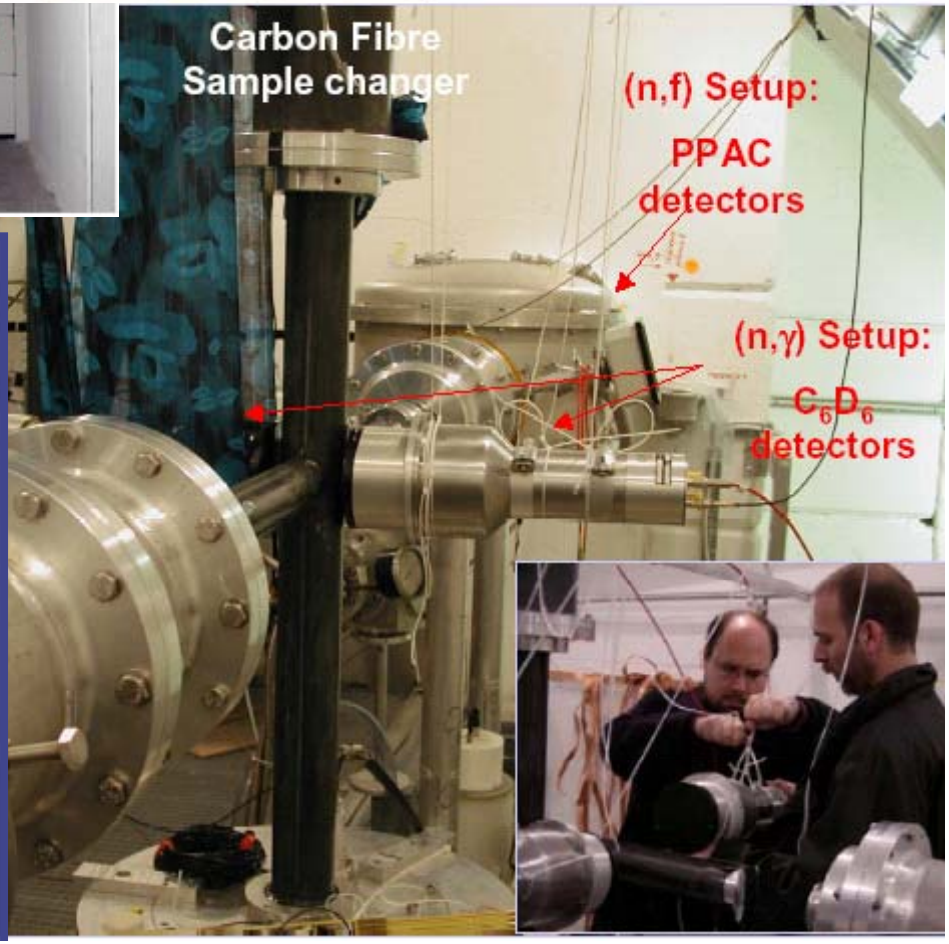
Energy range	Uncollimated [n/pulse/cm2]	Capture mode [n/pulse]	Fission mode [n/pulse]
< 1 eV	**2.0E+05**	**3.1E+05**	**2.0E+06**
1 eV - 10 eV	2.7E+04	4.5E+04	2.9E+05
10 eV - 100 eV	2.9E+04	4.7E+04	3.1E+05
100 eV - 1000 eV	3.0E+04	5.1E+04	3.3E+05
1 eV - 1 keV	**8.6E+04**	**1.4E+05**	**9.3E+05**
1 keV - 10 keV	3.2E+04	5.4E+04	3.6E+05
10 keV - 100 keV	3.9E+04	7.1E+04	4.7E+05
100 keV - 1000 keV	1.1E+05	2.3E+05	1.5E+06
1 keV - 1 MeV	**1.8E+05**	**3.5E+05**	**2.3E+06**
1 MeV - 10 MeV	8.3E+04	2.4E+05	1.7E+06
10 MeV - 100 MeV	2.8E+04	7.2E+04	5.1E+05
> 100 MeV	4.4E+04	1.2E+05	5.6E+05
1 MeV - > 100 MeV	**1.6E+05**	**4.4E+05**	**2.7E+06**
Total	**6.2E+05**	**1.2E+06**	**8.0E+06**

Note: 1 pulse is 7E+12 protons. Collimated fluence (fission and capture modes) is integrated over the beam surface.

The real world

- n_TOF commissioned in 2001-2002





n_TOF experiments 2002-4

Capture

^{151}Sm

^{204,206,207,208}Pb, ^{209}Bi

^{232}Th

^{24,25,26}Mg

^{90,91,92,94,96}Zr, ^{93}Zr

^{139}La

^{186,187,188}Os

^{233,234}U

^{237}Np,^{240}Pu,^{243}Am

Fission

^{233,234,235,236,238}U

^{232}Th

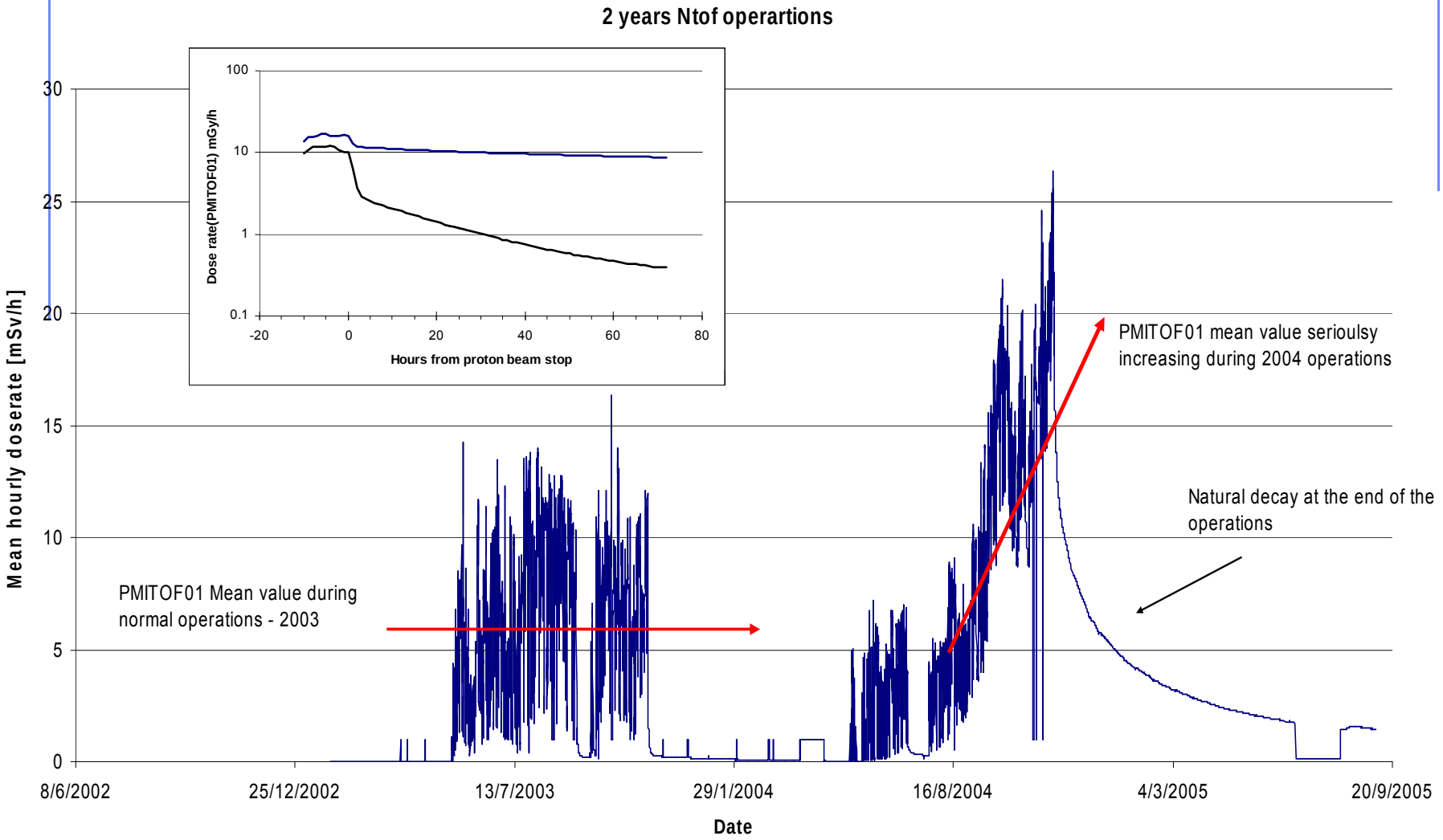
^{209}Bi

^{237}Np

^{241,243}Am, ^{245}Cm

- **M**easurements of neutron cross sections relevant for Nuclear Waste Transmutation and related Nuclear Technologies
  - Th/U fuel cycle (capture & fission)
  - Transmutation of MA (capture & fission)
  - Transmutation of FP (capture)
- **C**ross sections relevant for Nuclear Astrophysics
  - s-process: branchings
  - s-process: presolar grains
- **N**eutrons as probes for fundamental Nuclear Physics
  - Nuclear level density & n-nucleus interaction

SC/RP: Cooling circuit activation in 2004



Info: CERN-SC-2005-034-RP-TN

SC/RP: Cooling circuit activation in 2004

Isotope	Activity concentration 11.11.2003 (Bq g^{-1})	Activity concentration 12.10.2004 (Bq g^{-1})	Activity concentration 16.11.2004 (Bq g^{-1})	Ratio Nov. 2004/ Nov. 2003
^{7}Be	99.6	84.4	74	0.74
^{65}Zn	4.49 10^{-2}	1.63	6.6	
^{88}Y	2.88 10^{-2}	4.51	18	
^{172}Hf/Lu	3.6 10^{-2}	6.44	23	
^{183}Re	7.27 10^{-2}	8.83	73	
^{185}Os	3.46 10^{-2}	25.9	120	
^{195}Au	9.02 10^{-2}	59.0	360	

Isotope	Exemption Limit L_E (Bq g^{-1}) or (Bq)	Activity concentration a 16.11.2004 (Bq g^{-1})	Multiple of L_E	Total activity A in 700 l	Multiple of 100 L_E
^{7}Be	400	74	0.19	51800	1.3
^{65}Zn	3	6.6	2.2	4620	
^{88}Y	8	18	2.25	12600	
^{172}Hf/Lu	8	23	2.88	16100	
^{183}Re	10	73	7.3	51100	
^{185}Os	20	120	6	84000	
^{195}Au	40	360	9	252000	

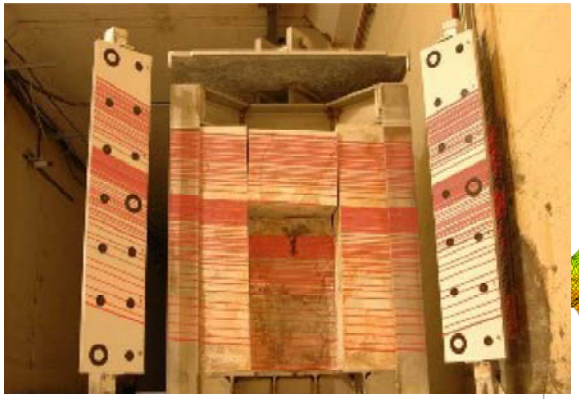
Total Exemption Limit 100 L_E

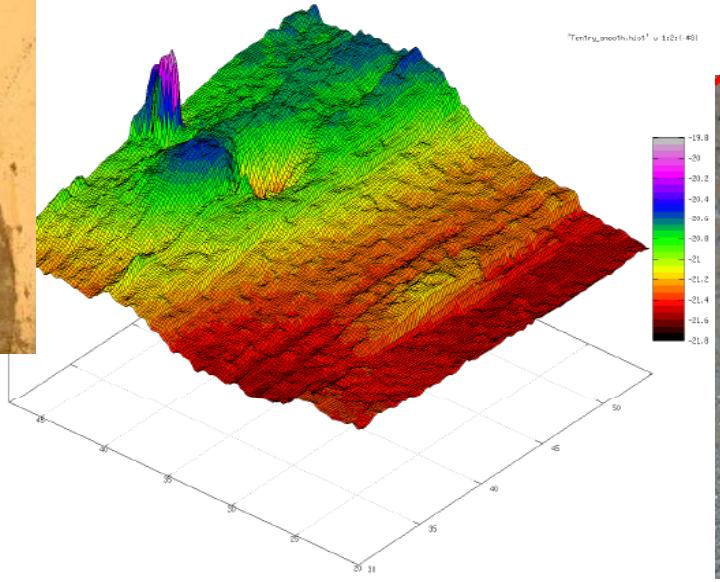
Target Interventions

- Target removal was performed at the 27.09.2007
- Target visual inspection & photography
- Pit & pool inspection (web camera)
- First dose rate measurements of the target and pit
- Measurement of hole at the beam impact location
- Samples taken from the target to be analyzed
- FLUKA simulations of the target activation, as well as detailed maps for pit and pool
- Target surface inspection using a dedicated custom-built (and developed) laser system
- Detailed dose rate measurement of the target and pit (November 2007)
- Extensive study of the target corrosion mechanism

Target Inspection

- Pitting corrosion caused a hole at the proton impact location
- Important surface oxidation due to rupture of protection layer when the drying was performed (flush)
- Target shape didn't allow for a correct water flow at the entrance face
- Modular assembly lead to a mechanical instability and deformation

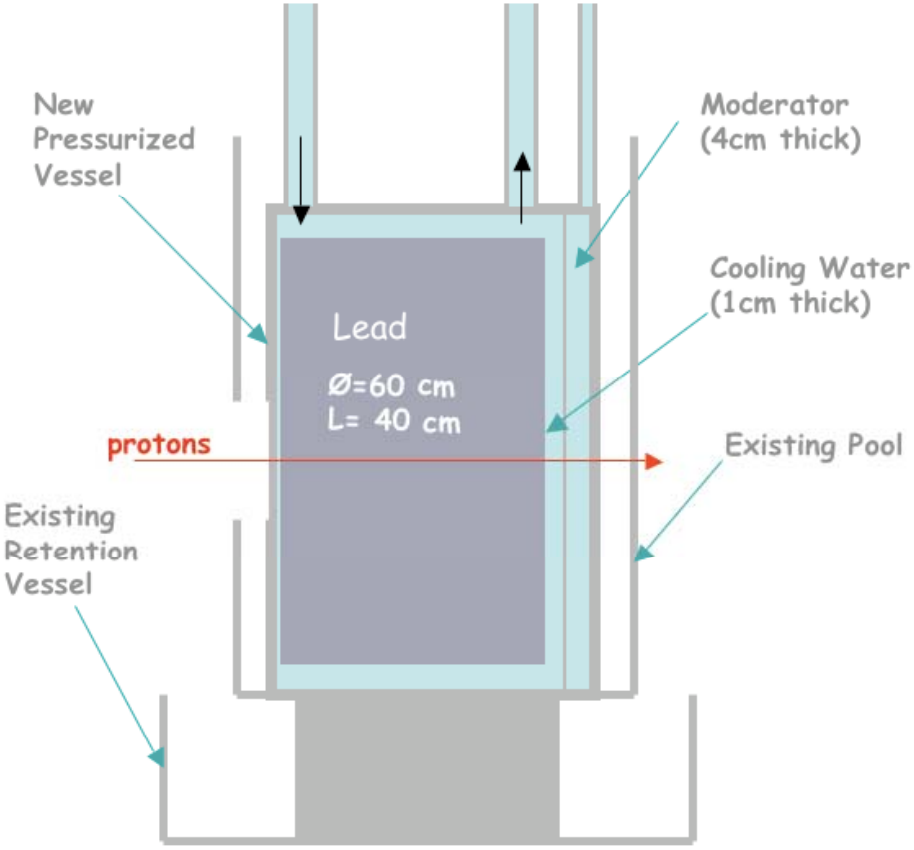


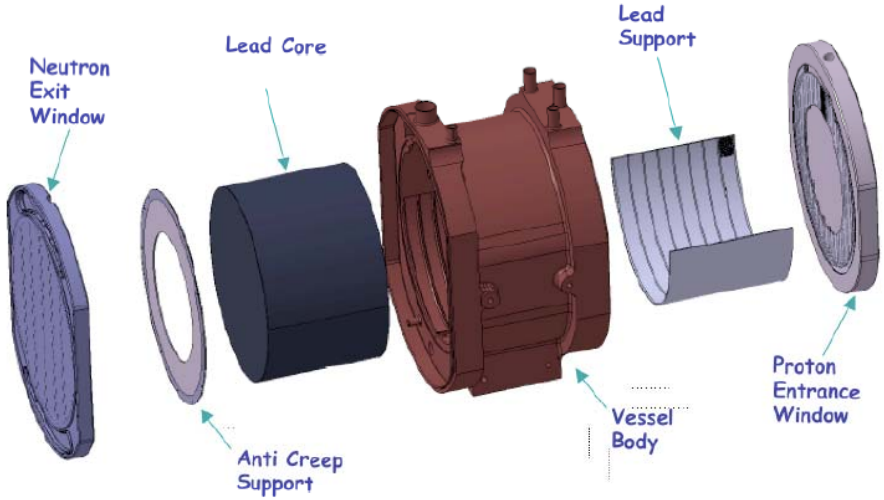


Milestones towards restart of nTOF

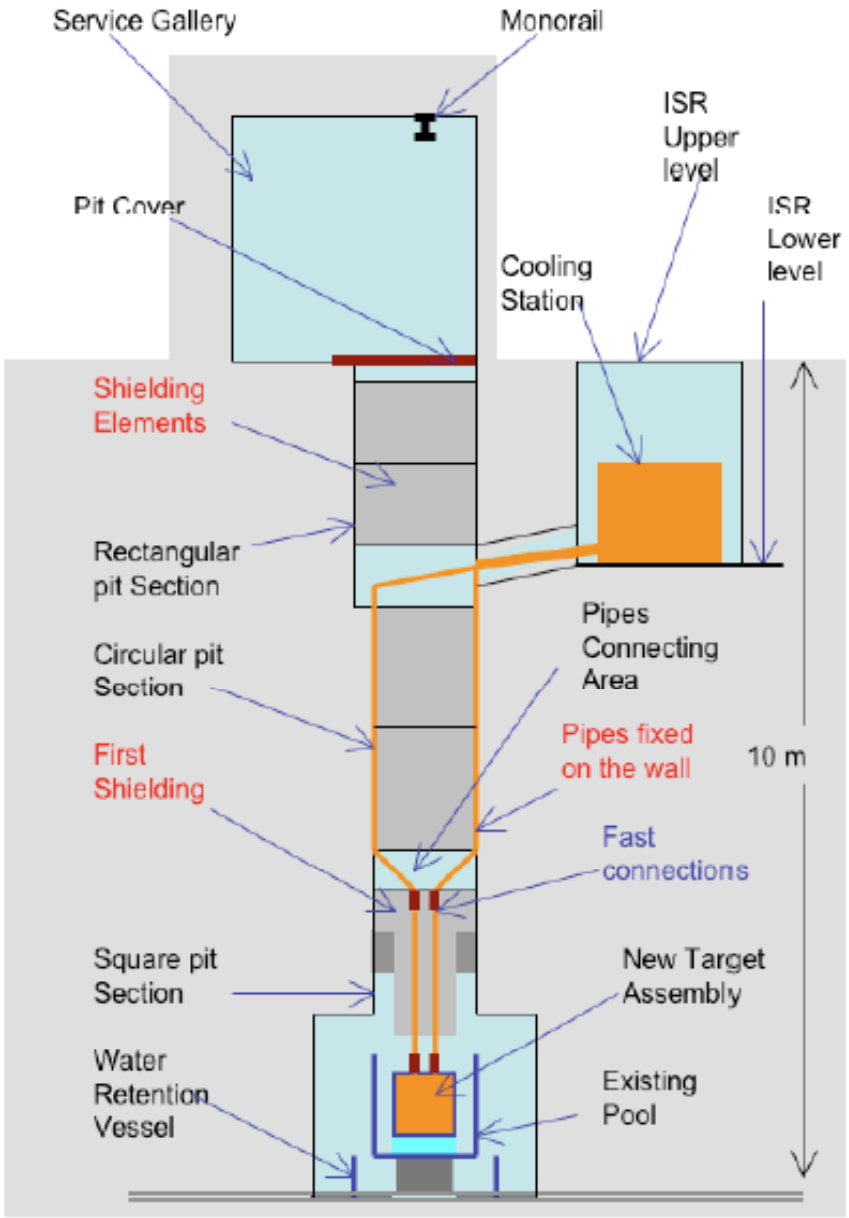
14.07.2007	Presentation to the First External Panel Review
27.09.2007	Old Target removal
	Study of possible solutions
14.02.2008	Presentation to the Second External Panel Review
14.03.2008	Decision to build the New Target
	Target Design and Construction
	Preparation of the Safety File
12.11.2008	Short commissioning of new target
15.04.2009	Installation of the new cooling system
	Ventilation of primary area
	Air-tight technical gallery
	Alignment of FTN line and last collimator
18.05.2009	Commissioning of the new Target

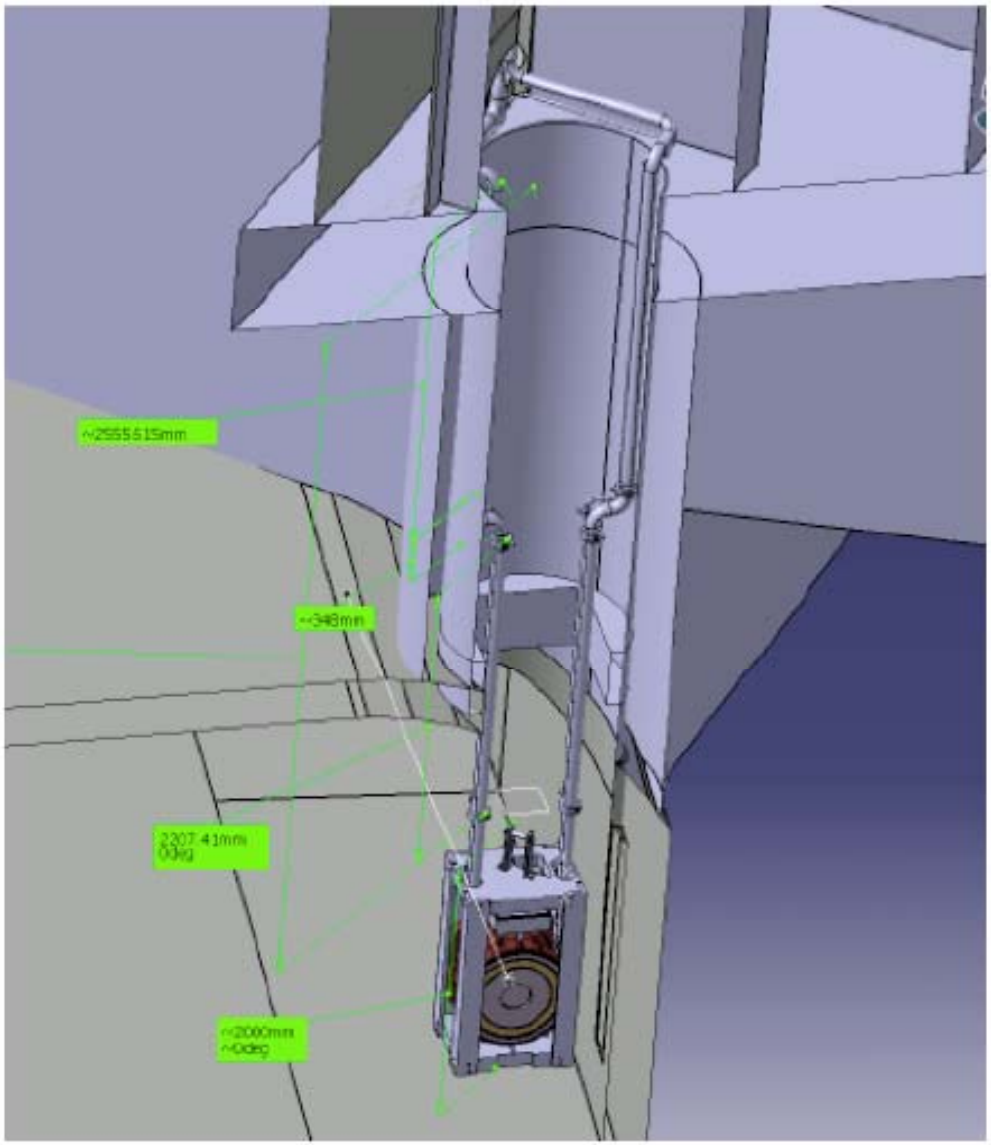
New Target: Conceptual Design



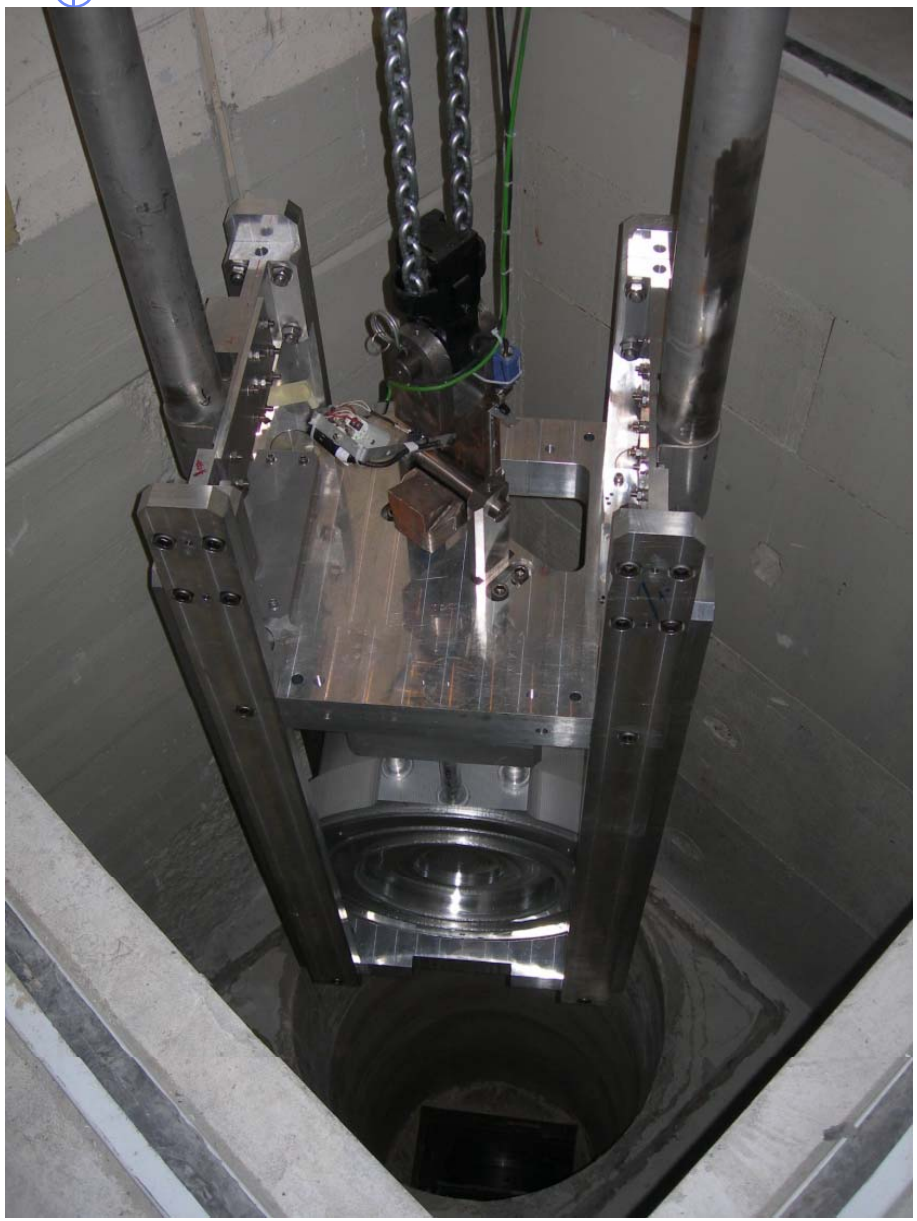


Pit layout


Service Gallery
Monorail
ISR
Upper
level
Pit Cover
ISR
Lower
level
Cooling
Station
Shielding
Elements
Rectangular
pit Section
Pipes
Connecting
Area
Circular pit
Section
Pipes fixed
on the wall
10 m
First
Shielding
Fast
connections
Square pit
Section
New Target
Assembly
Water
Retention
Vessel
Existing
Pool


~2555.515mm
~348mm
2207.41mm
0deg
~2000mm
~0deg

Facility Status 17.10.2008



2008 Short Commissioning

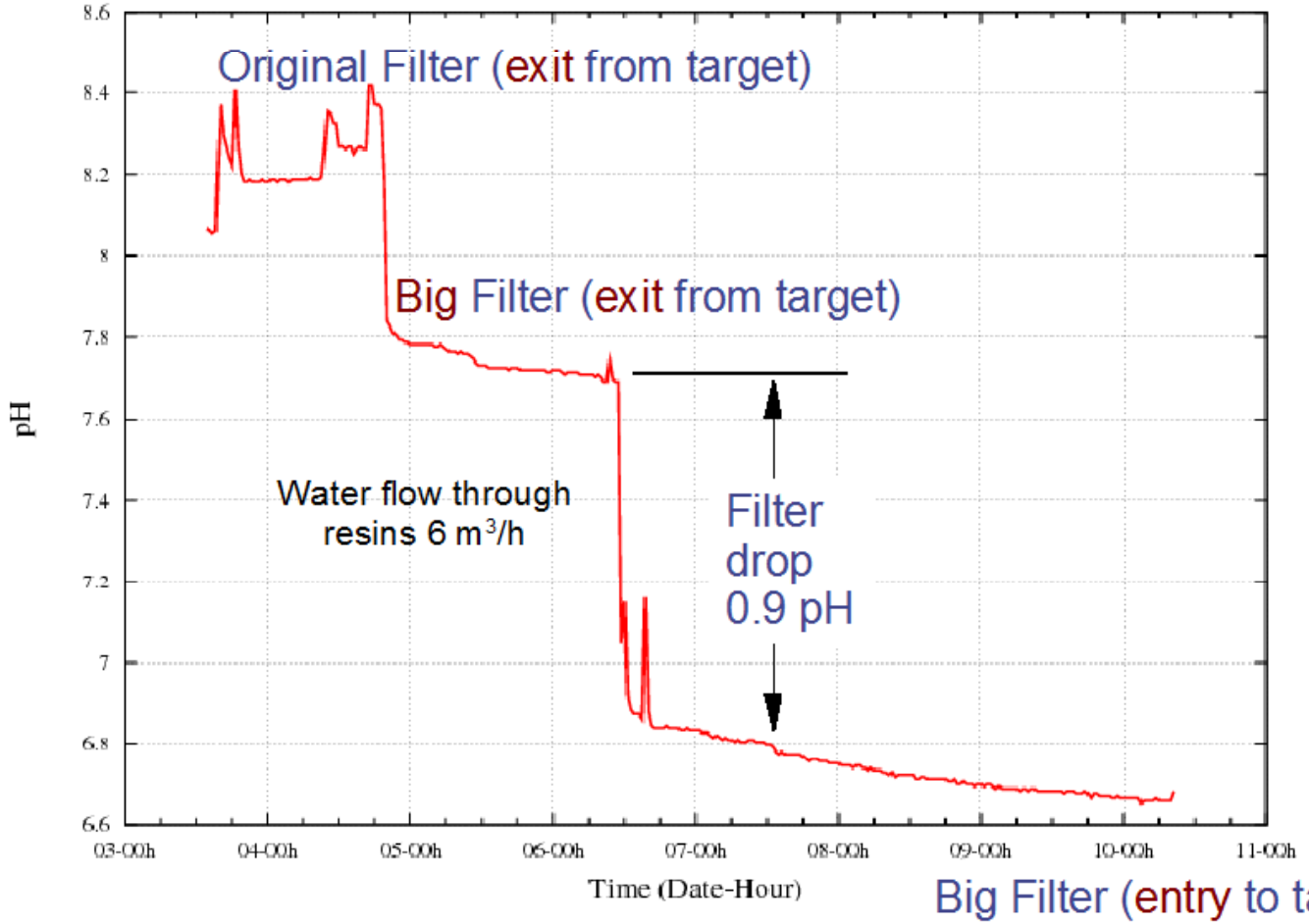
We asked for an exceptional authorization from SC/RP to start in 2008 with a reduced cooling circuit and no ventilation.

Conditions:

- The specific activity should not exceed 1% of the exemption limit LE for the concentration (Bq/kg)
- The absolute activity released per month (Bq) should not exceed the exemption limit
- The above are calculate based on the past experience and the corrosion/erosion test performed at CERN
- Start: Monday 3 Nov 2008
- Stop: 13 Nov 2008
- Duration: 10 days
- Total number of protons: 2×10^{17} pot (1% of a years beam)
- Max. Power accepted: ~3kW
- Super cycle: 40s – 48s

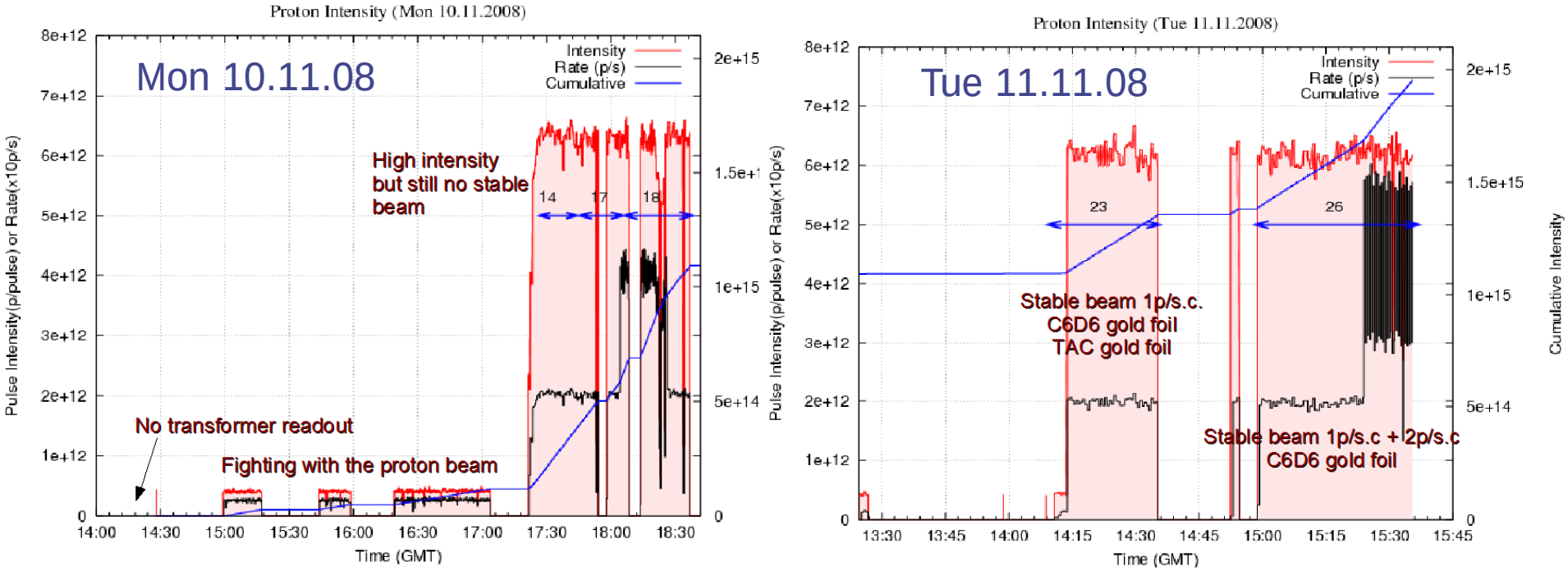
Problems

- pH of cooling circuit too high. Installed a big filter that slowly decreased the level
- ARCON system failure: We developed a pseudo-ARCON system that was able to fulfill the requirements of SC/RP



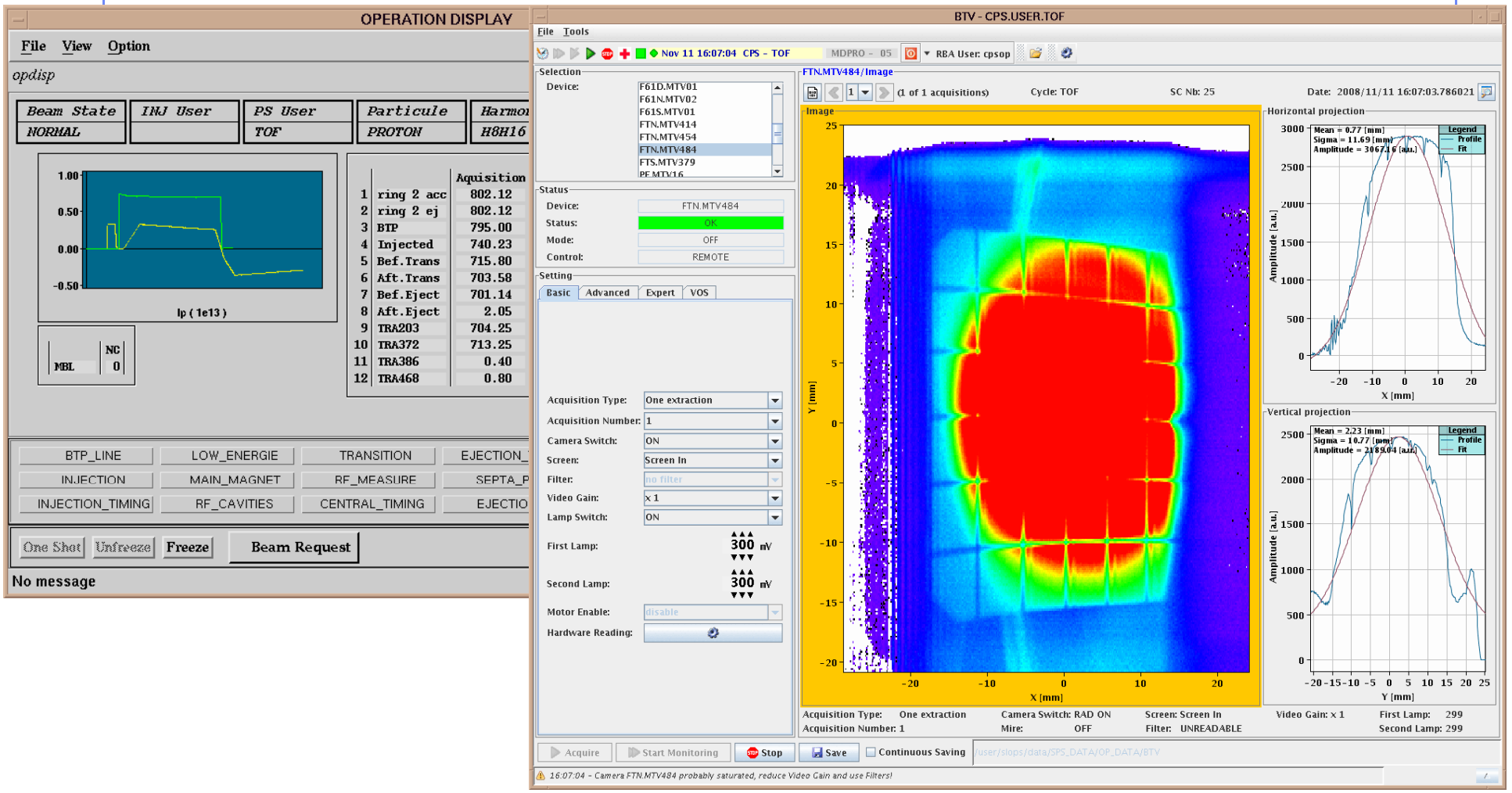
Big Filter (entry to target)

Proton Beam



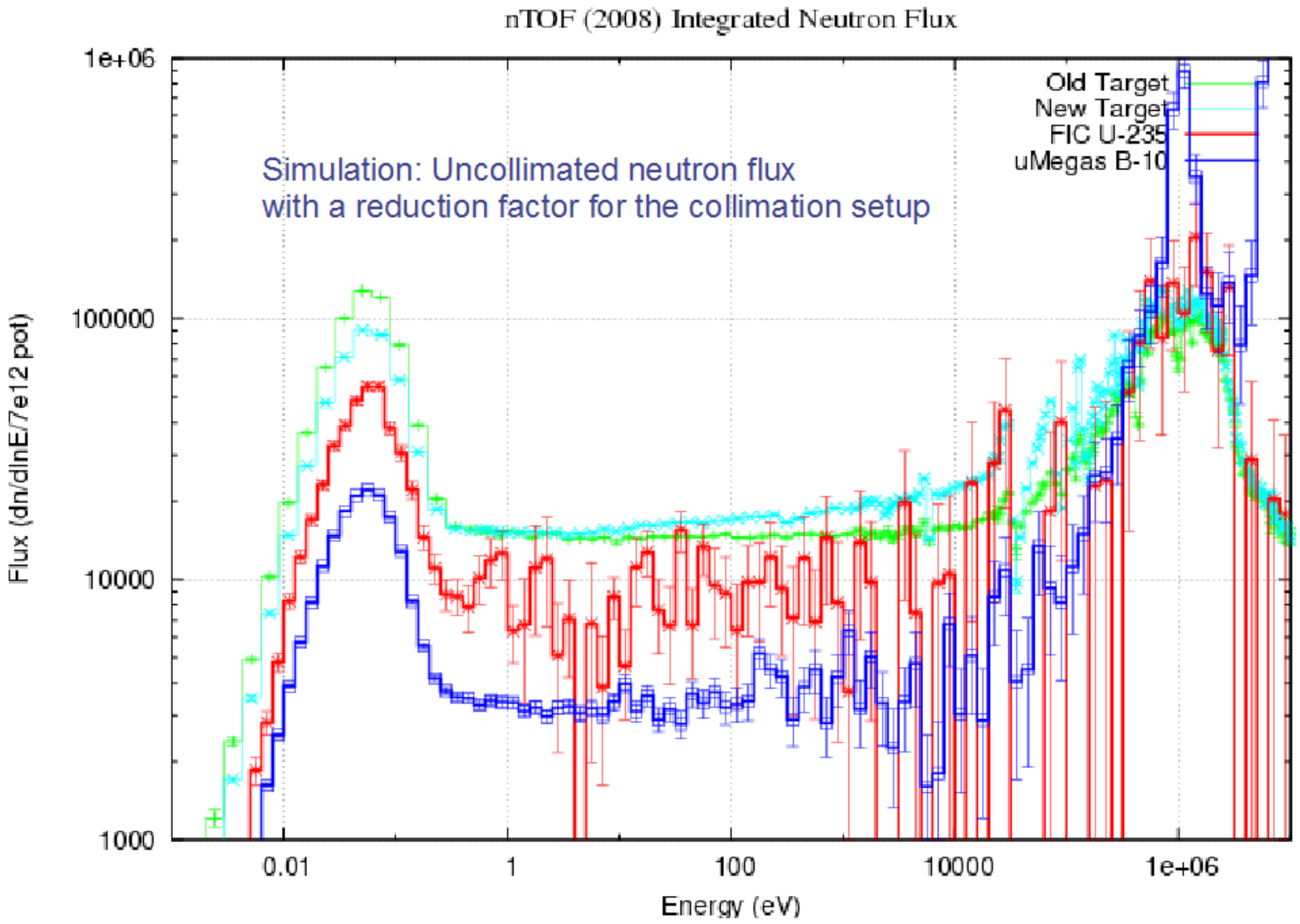
- Most of the time was spent on tuning the beam and detectors
- We've got the authorization to run with 300 pulses of high intensity
- Triggering alarms on PAXTOF01 and PAXTOF04

Beam characteristics on 12.11.2008



Beam spot ~6x6 cm²

Neutron Fluence

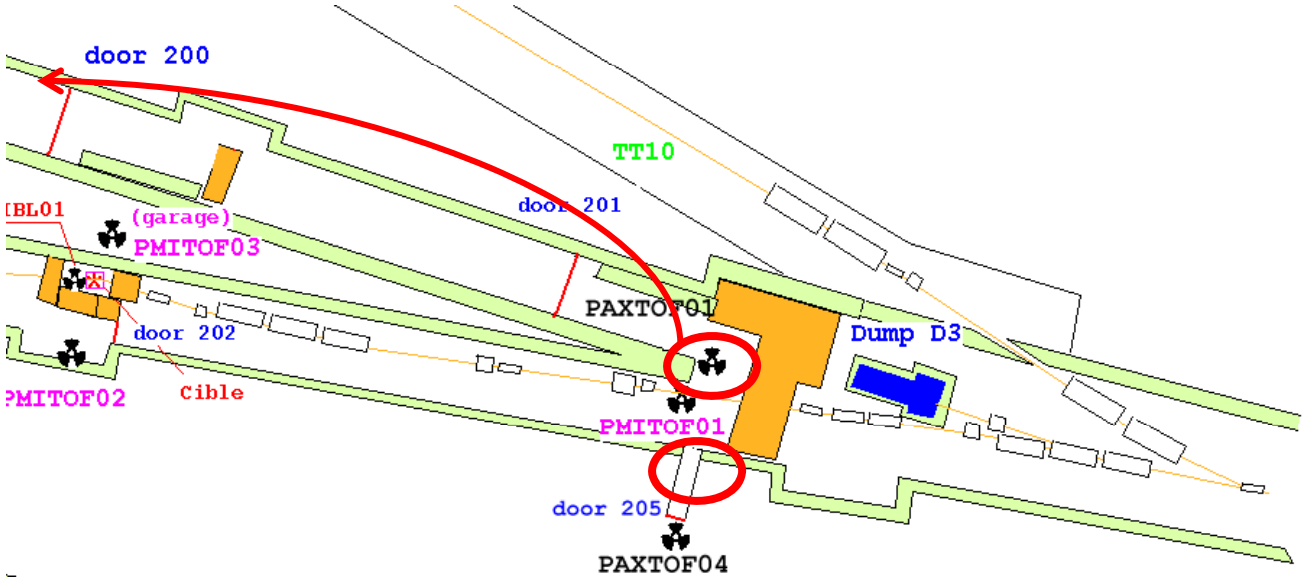


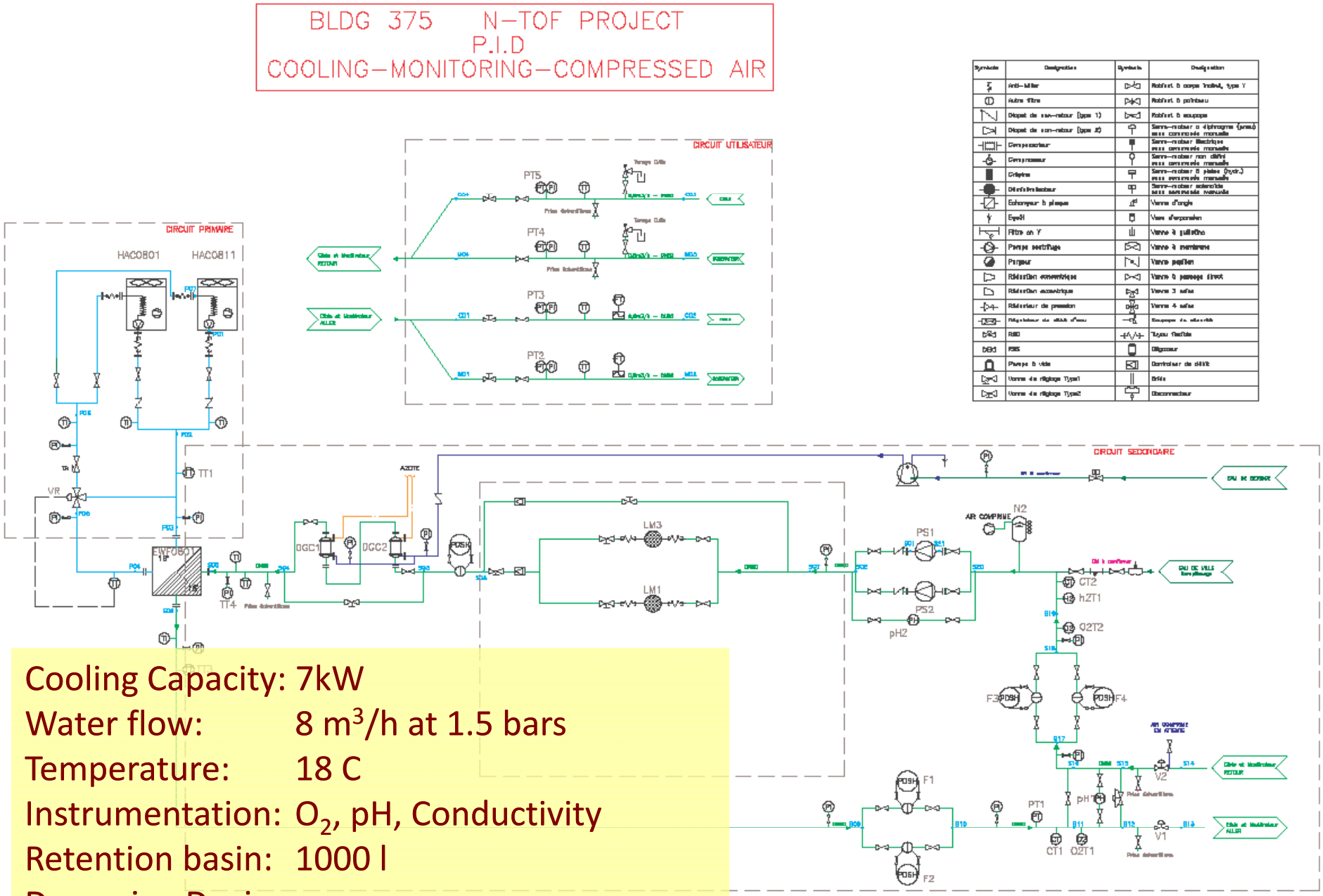
Problems

- Our transformer worked for the 50 last pulses
- Part of the beam was intercepted by the quadrupole magnet
  - Generating alarms on PAXTOF1, and PAXTOF4
  - Above 2.5 µSv/h in the ISR tunnel

Proposal:

- Air Tight the auxiliary gallery
- Move the PAXTOF01 to the level of the 200 door.





Cooling Capacity: 7kW

Water flow: 8 m^3/h at 1.5 bars

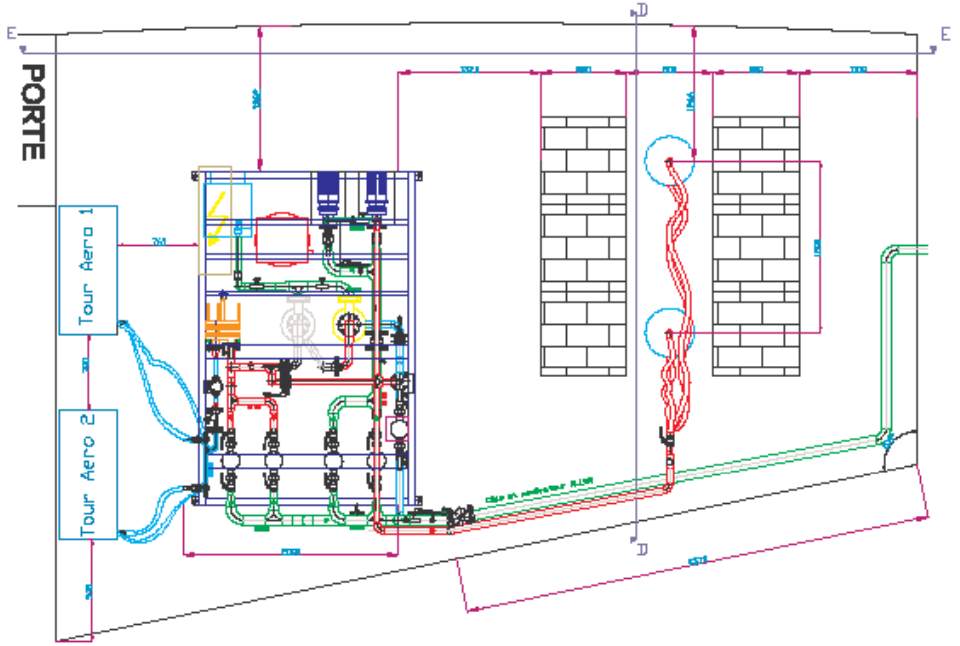
Temperature: 18 C

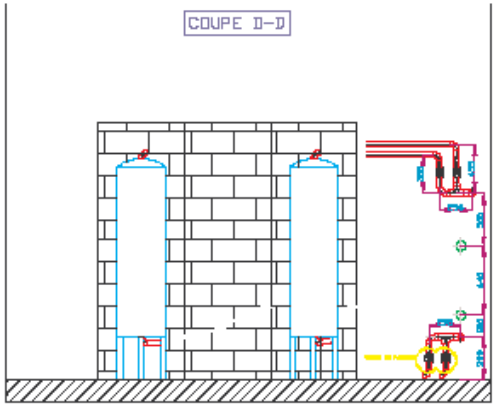
Instrumentation: O_2, pH, Conductivity

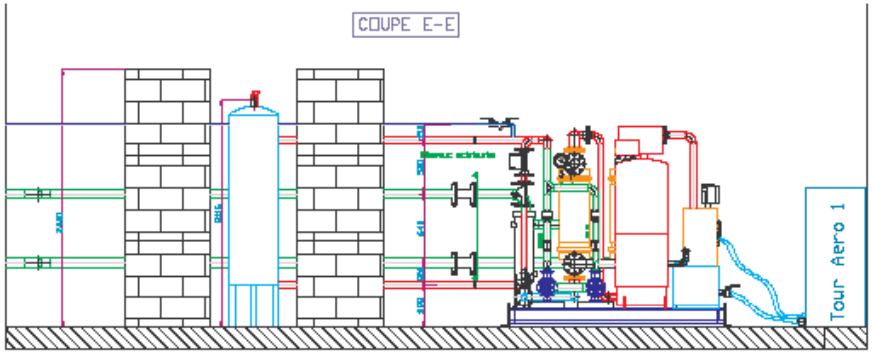
Retention basin: 1000 l

Degassing Device

BLDG 375 N-TOF PROJECT
IMPLANTATION
COOLING-MONITORING-COMPRESSED AIR







BLDG 375 n-TOF PROJECT
COOLING-MONITORING-COMPRESSED AIR

PLAN D'IMPLANTATION

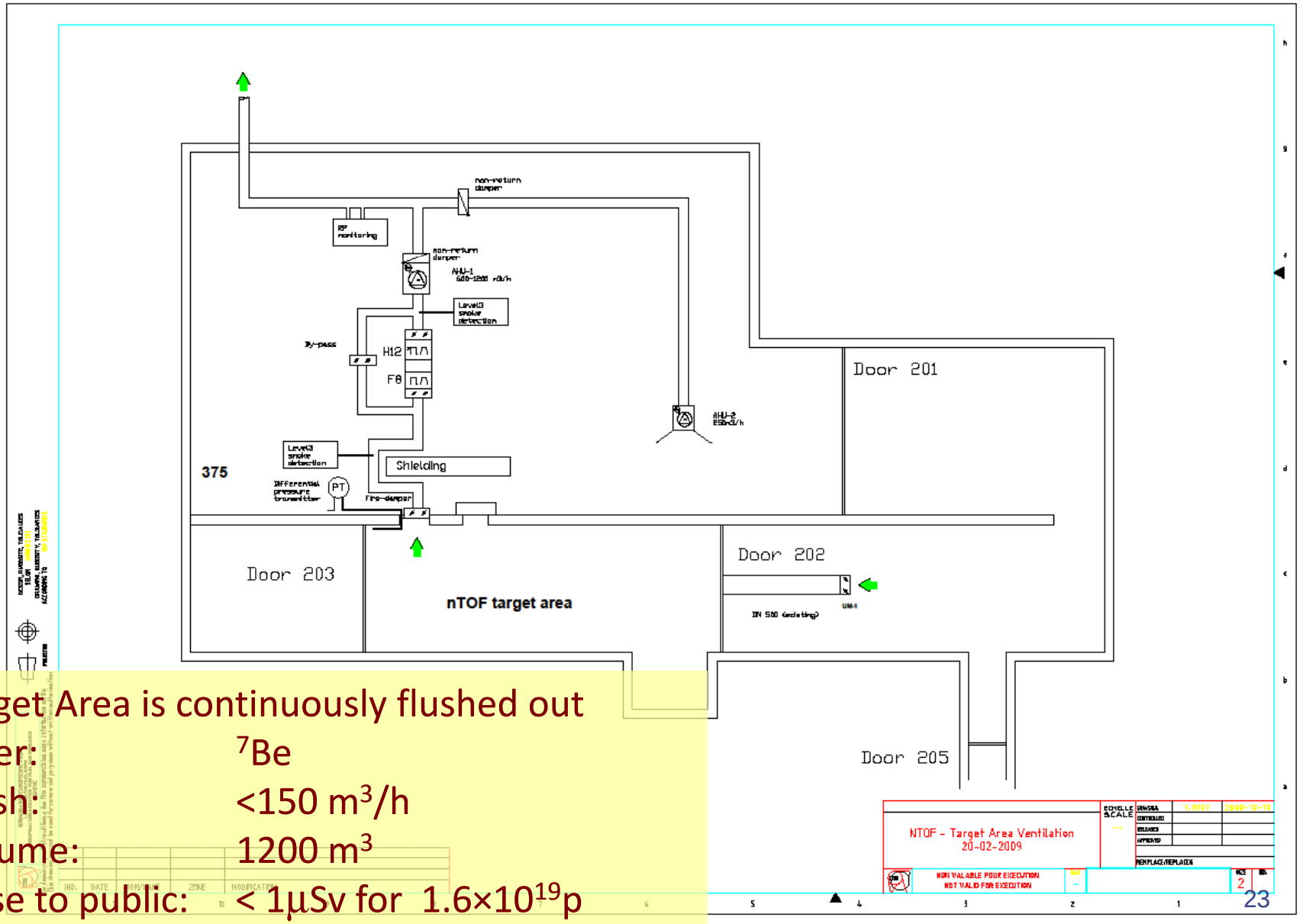
Echelle : 1/20 Format : A0

Date indice courant : 02/03/09

Intitulé du lot :

Lot CVC

Ventilation



Target Area is continuously flushed out

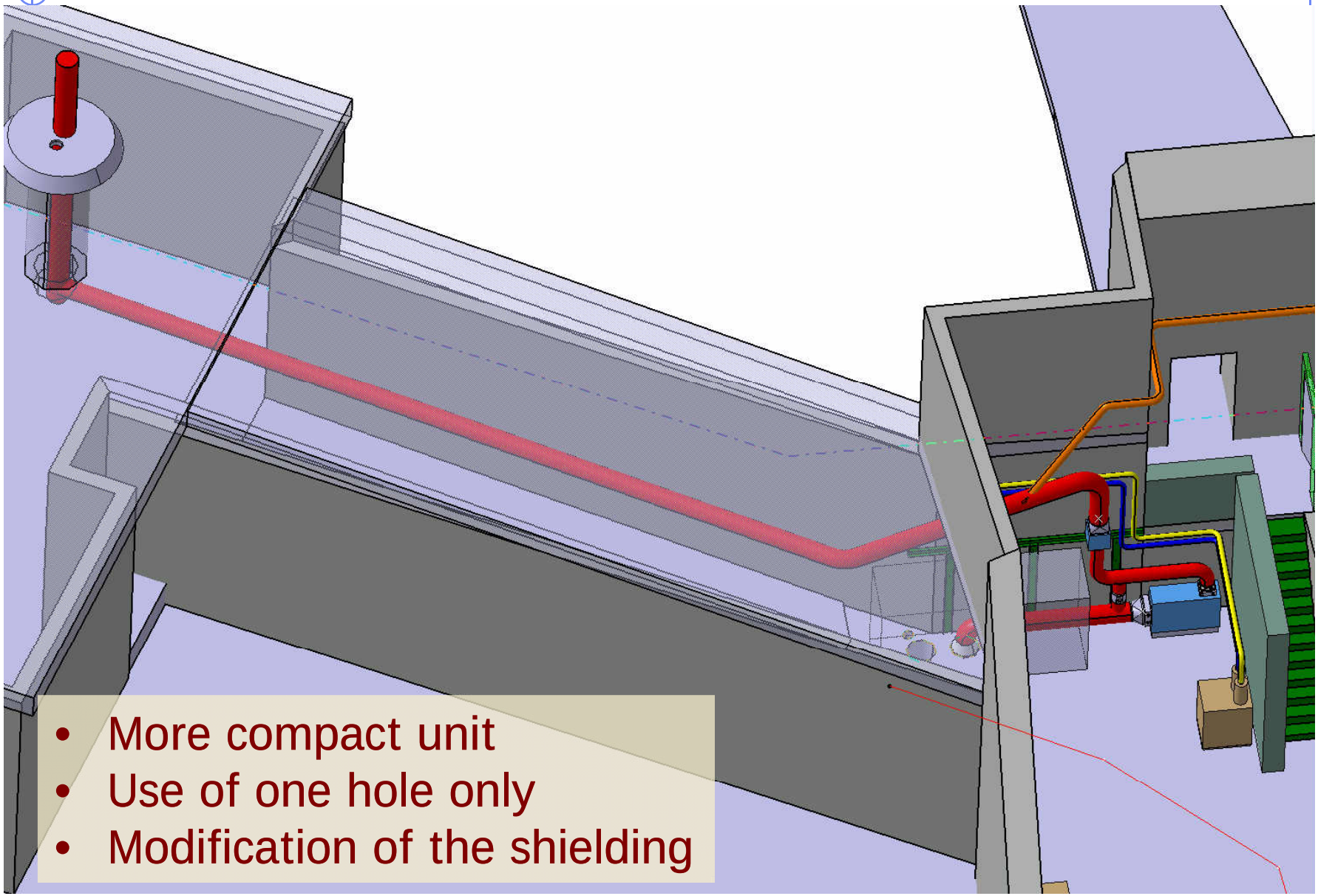
Filter: ^{7}Be

Flush: <150 m^3/h

Volume: 1200 m^3

Dose to public: < 1µSv for 1.6×10^{19}p

Ventilation



- More compact unit
- Use of one hole only
- Modification of the shielding

The n_TOF-Ph2 experiments

Capture measurements	
Mo, Ru, Pd stable isotopes	r-process residuals calculation isotopic patterns in SiC grains
Fe, Ni, Zn, and Se (stable isotopes) ^{79}Se	s-process nucleosynthesis in massive stars accurate nuclear data needs for structural materials
A≈150 (isotopes varii)	s-process branching points long-lived fission products
^{234,236}U, ^{231,233}Pa	Th/U nuclear fuel cycle
^{235,238}U	standards, conventional U/Pu fuel cycle
^{239,240,242}Pu, ^{241,243}Am, ^{245}Cm	incineration of minor actinides

(*) approved by CERN Scientific Committee (planned for execution in 2009)

The n_TOF-Ph2 experiments

Fission measurements	
MA	ADS, high-burnup, GEN-IV reactors
^{235}U(n,f) with p(n,p')	new ^{235}U(n,f) cross section standard
^{234}U(n,f)	study of vibrational resonances at the fission barrier
Other measurements	
^{147}Sm(n,α), ^{67}Zn(n,α), ^{99}Ru(n,α) ^{58}Ni(n,p), other (n,lcp)	p-process studies gas production in structural materials
Al, V, Cr, Zr, Th, ^{238}U(n,lcp)	structural and fuel material for ADS and other advanced nuclear reactors
He, Ne, Ar, Xe	low-energy nuclear recoils (development of gas detectors)
n+D_2	neutron-neutron scattering length

Accepted Proposals

CERN-INTC-2006-012:

The role of Fe and Ni for s-process nucleosynthesis in the early Universe and for innovative nuclear technologies
Number of protons approved: 1.8×10^{19}

CERN-INTC-2006-006:

Proposed study of the neutron-neutron interaction at the CERN n_TOF facility.
Number of protons accepted: 0.2×10^{19}

CERN-INTC-2006-016:

Angular distributions in the neutron-induced fission of actinides.
Number of protons approved: 0.15×10^{19}

CERN-INTC-2008-035:

n_TOF: New target commissioning and beam characterization.
Number of protons accepted: 2.45×10^{18}

Conclusions

- Experience gained from the previous target help on the construction of the new target
- Short commissioning in Nov'08, Showed values consistent with simulations
- Work on progress:
  - Cooling system
  - Ventilation of primary area
  - Air tight the technical gallery and relocate PAXTOF01
  - Alignment of FTN line and neutron line
- Measurements:
  - 4 Accepted proposals, 2 of them will be performed in 2009
    Beam Request: ~2.5×10^{19} p
  - Expected constant use of 2.0×10^{19} p/year
- Future:
  - Heavy water
  - Disposal of old target