Commissioning of the New Spallation Target for the n_TOF facility at CERN

Outline

- n_TOF operation until 2004
- New target construction
- Commissioning of the new target
- Facility Upgrade
- Measurements programme

AccApp2009 Vienna 4-8 May 2009

Samuel Andriamonje

European Organization for Nuclear Research (CERN), Geneva, Switzerland

Concept of n_TOF

ADS Developments:

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

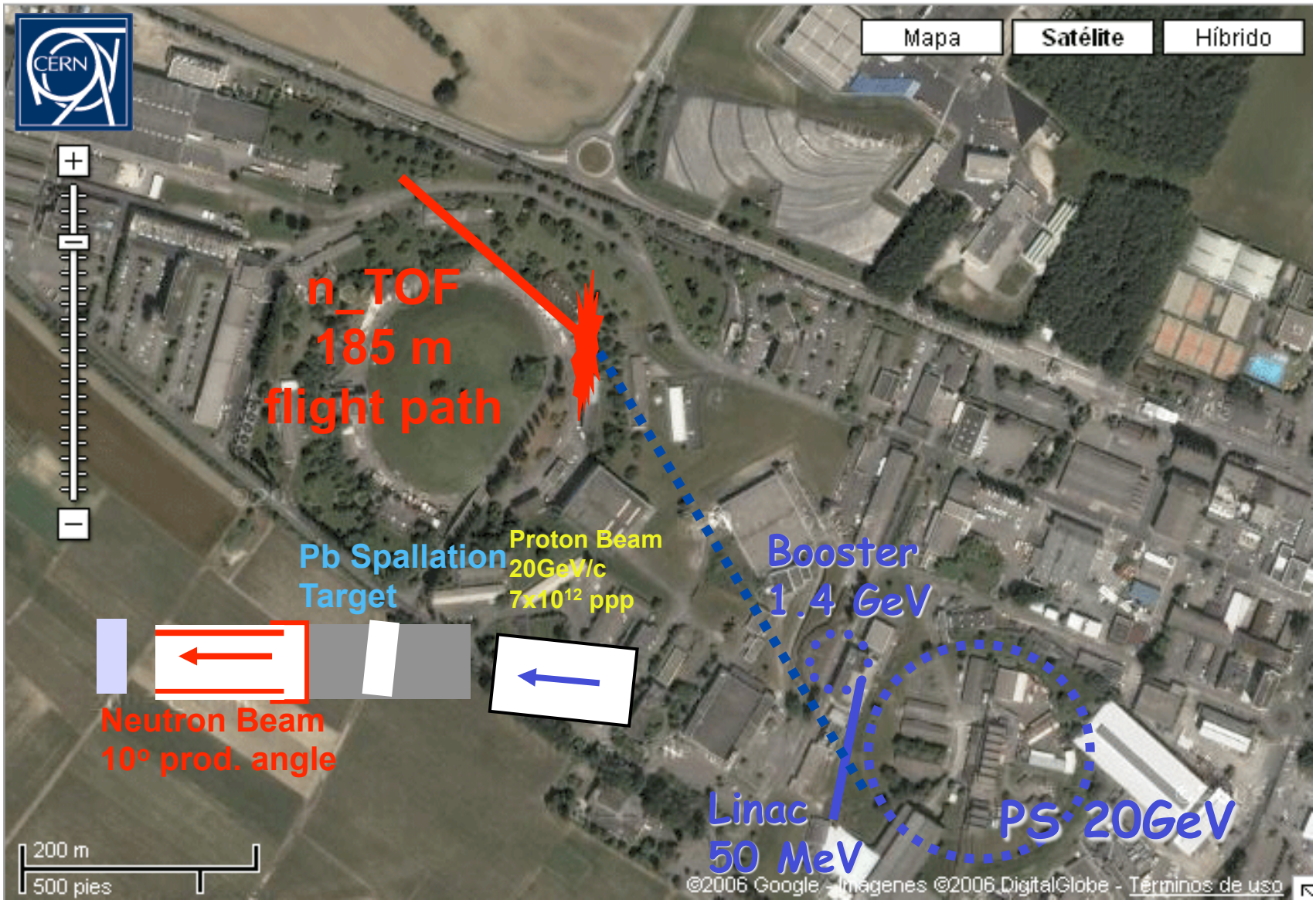
Require the complete and precise knowledge of neutron cross sections

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

CERN/ET/Int. Note 97-19
http://proj-ntof.web.cern.ch/proj-nTOF

(A Google-view of) The n_TOF facility at CERN



n_TOF beam characteristics

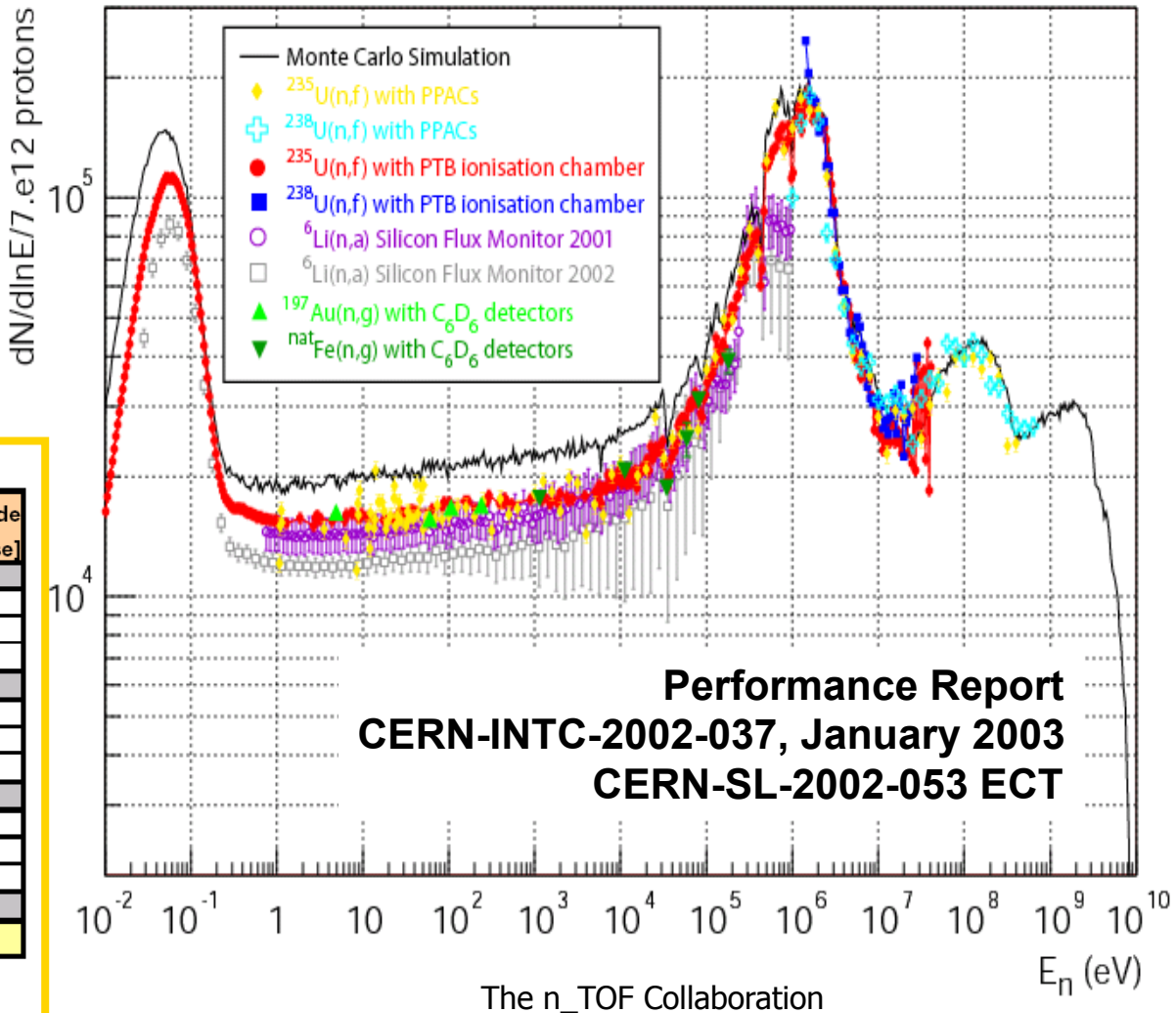
- Wide energy range
- High instantaneous neutron flux
- High resolution
- Low ambient background
- Low repetion frequency
- Favorable duty cycle for radioactive samples.

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.

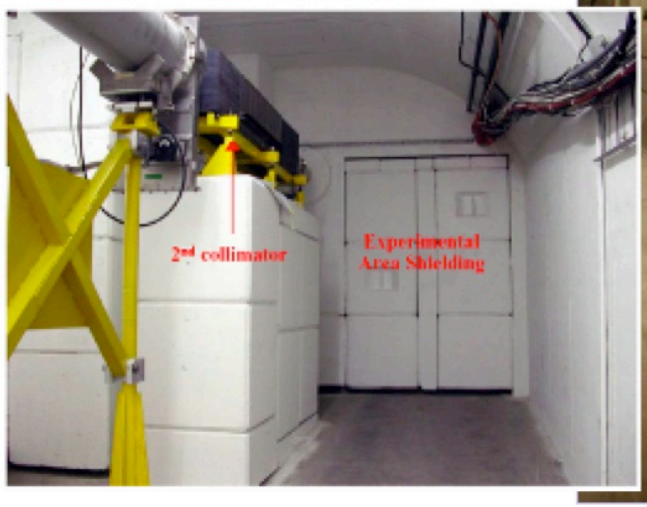
2nd collimator ϕ=1.8 cm (capture mode)

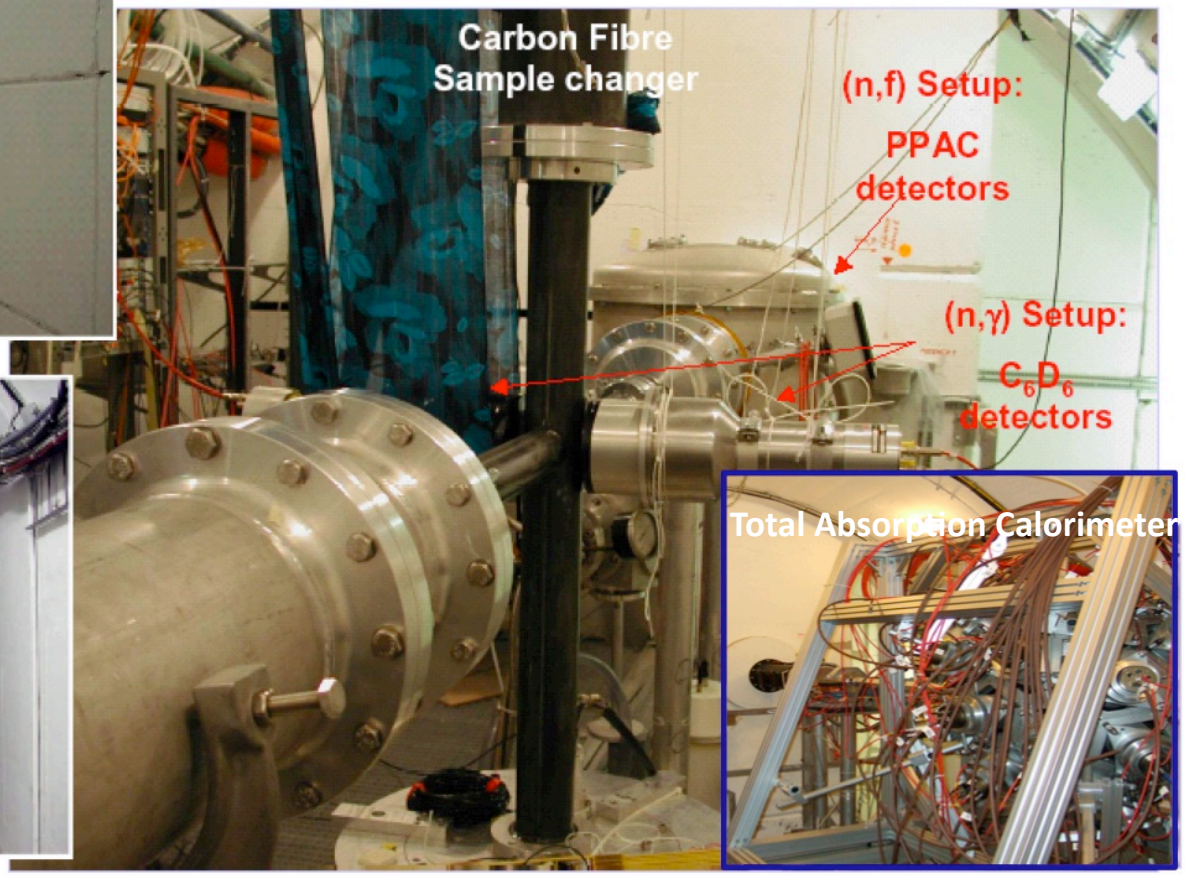


The n_TOF Collaboration

CERN n_TOF overview

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: branching
  - 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 (CERN-SC-2005-034-RP-TN)

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	147
^{88}Y	2.88 10^{-2}	4.51	18	625
^{172}Hf/Lu	3.6 10^{-2}	6.44	23	639
^{183}Re	7.27 10^{-2}	8.83	73	1004
^{185}Os	3.46 10^{-2}	25.9	120	3468
^{195}Au	9.02 10^{-2}	59.0	360	3991

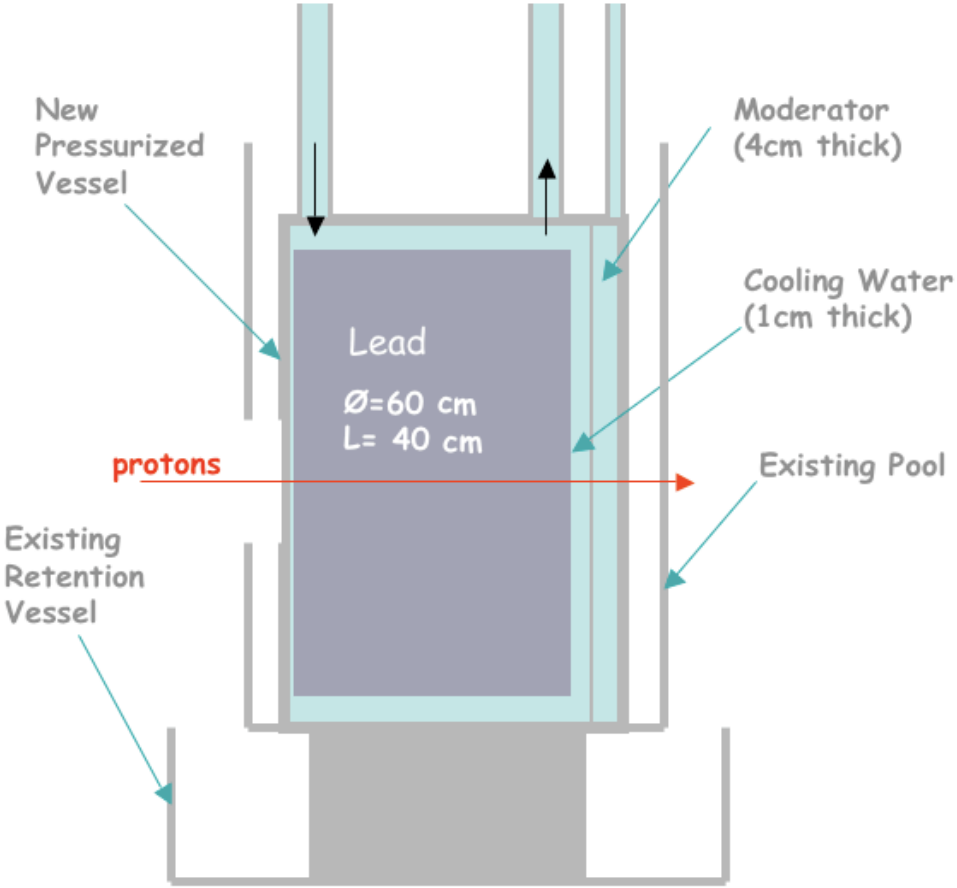
Isotope	Exemption Limit L_E (Bq g^{-1}) or (Bq)	Activity concentration a 16.11.2004 (Bq g^{-1})	Multiple of L_E	Total activity A in 700 l	Multiple of 100 L_E
^{7}Be	400	74	0.19	51800	1.3
^{65}Zn	3	6.6	2.2	4620	15.4
^{88}Y	8	18	2.25	12600	15.75
^{172}Hf/Lu	8	23	2.88	16100	20.13
^{183}Re	10	73	7.3	51100	51.1
^{185}Os	20	120	6	84000	42
^{195}Au	40	360	9	252000	63

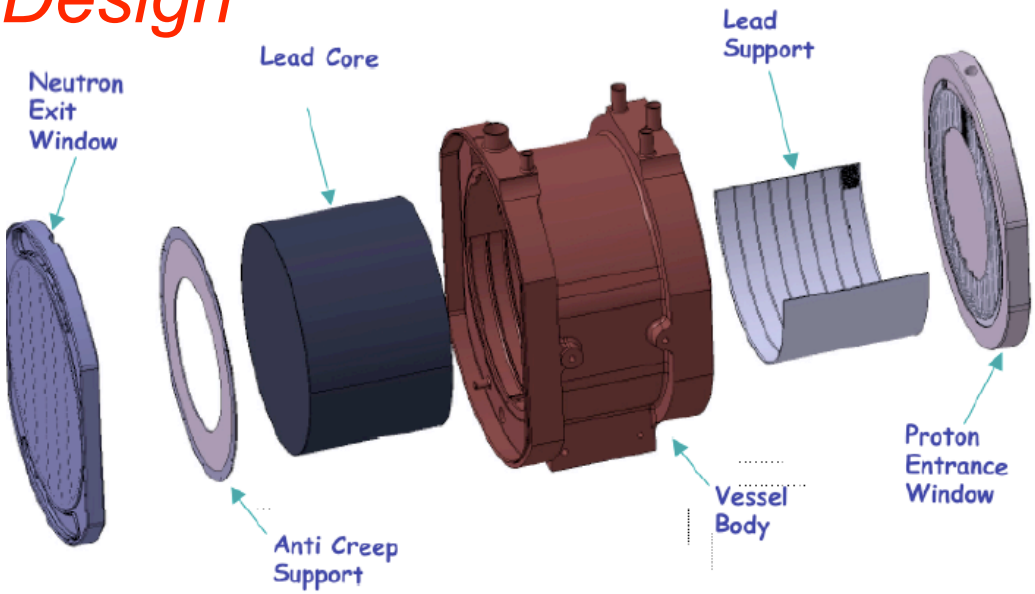
Total Exemption Limit 100 L_E

Target Interventions

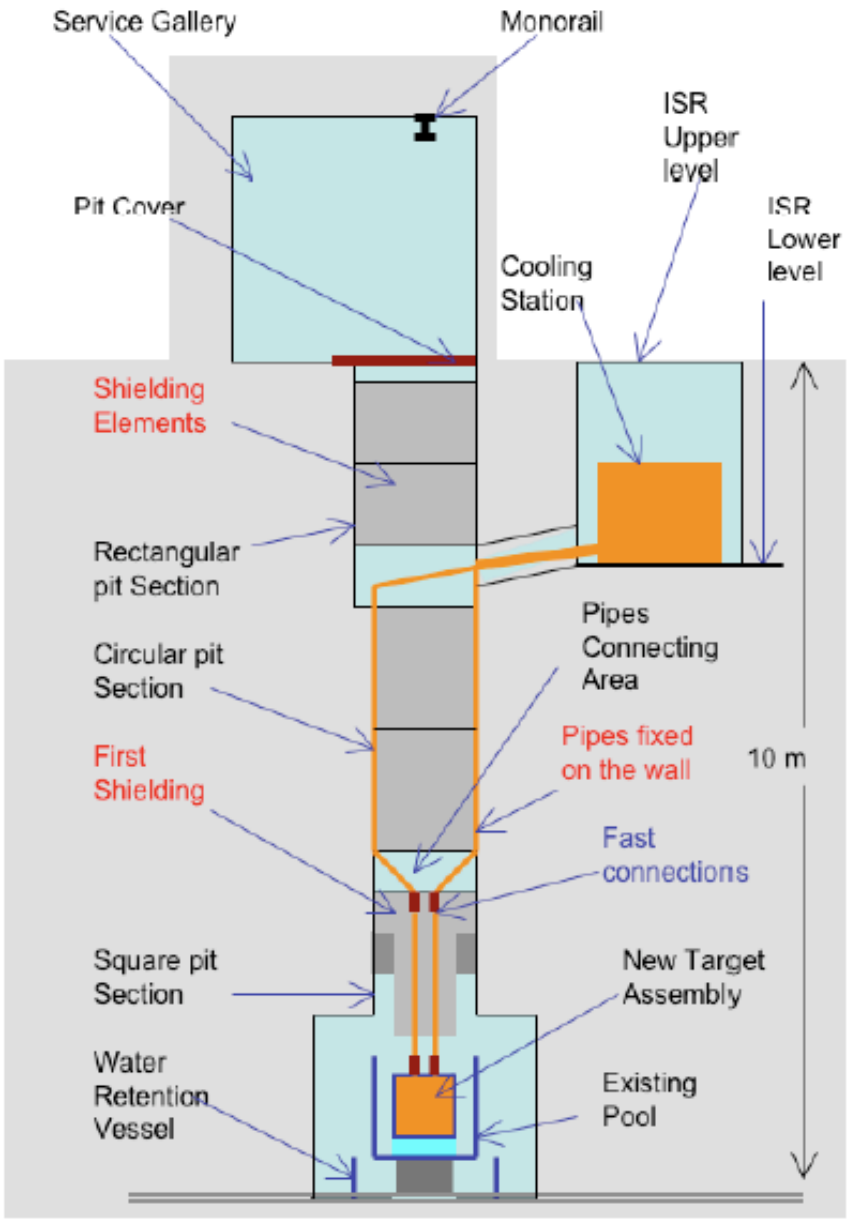
- Target removal was performed at the 27.09.2007
- Target visual inspection & photography
- Pit & pool inspection (web camera)
- First dose rate measurements of the target and pit
- Measurement of hole at the beam impact location
- Samples taken from the target to be analyzed
- FLUKA simulations of the 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

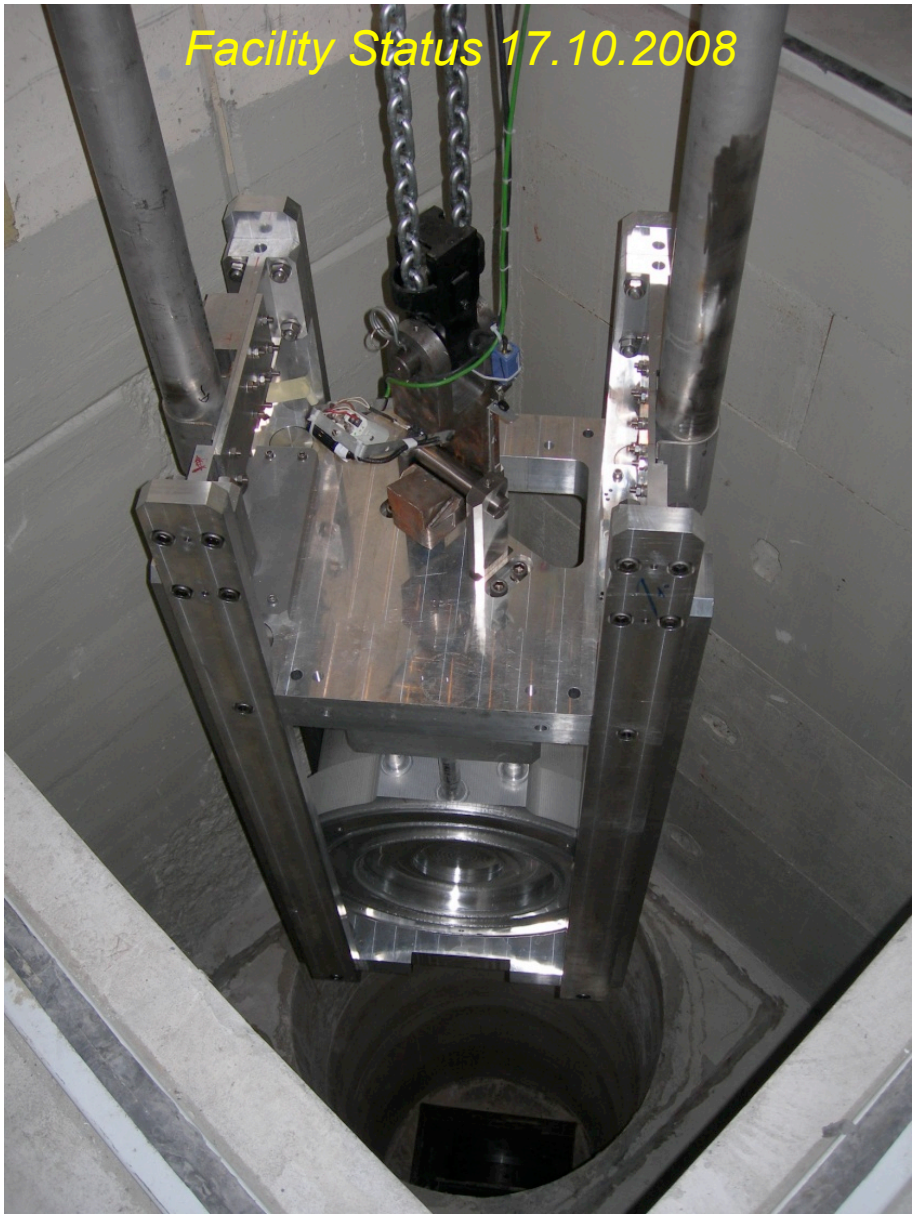
New Target: Conceptual Design



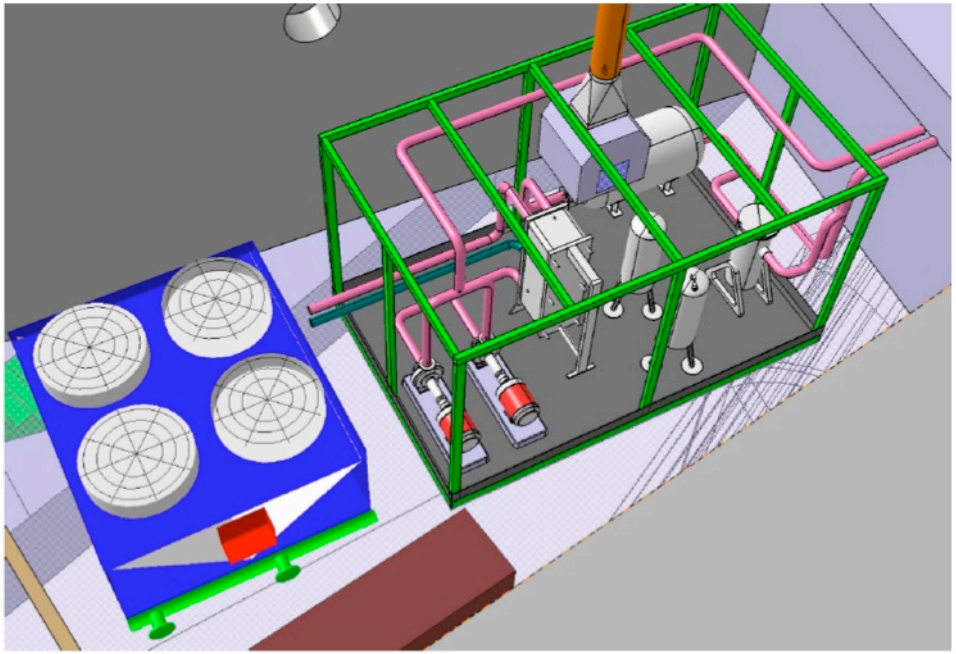


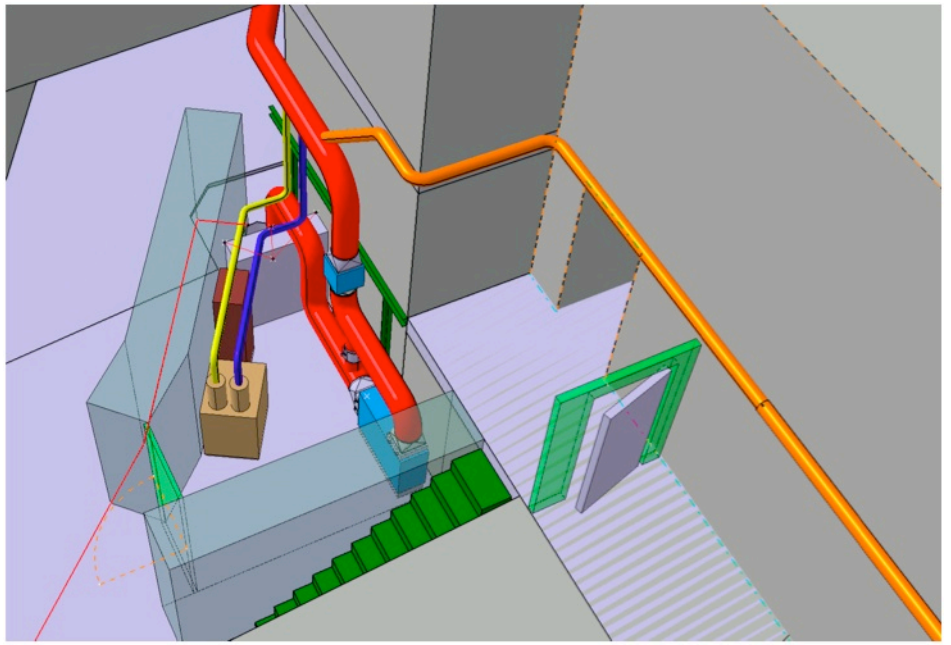
Pit lay-out


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


Facility Status 17.10.2008

Target Cooling System (Stations Lay-out) Ventilation System





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

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

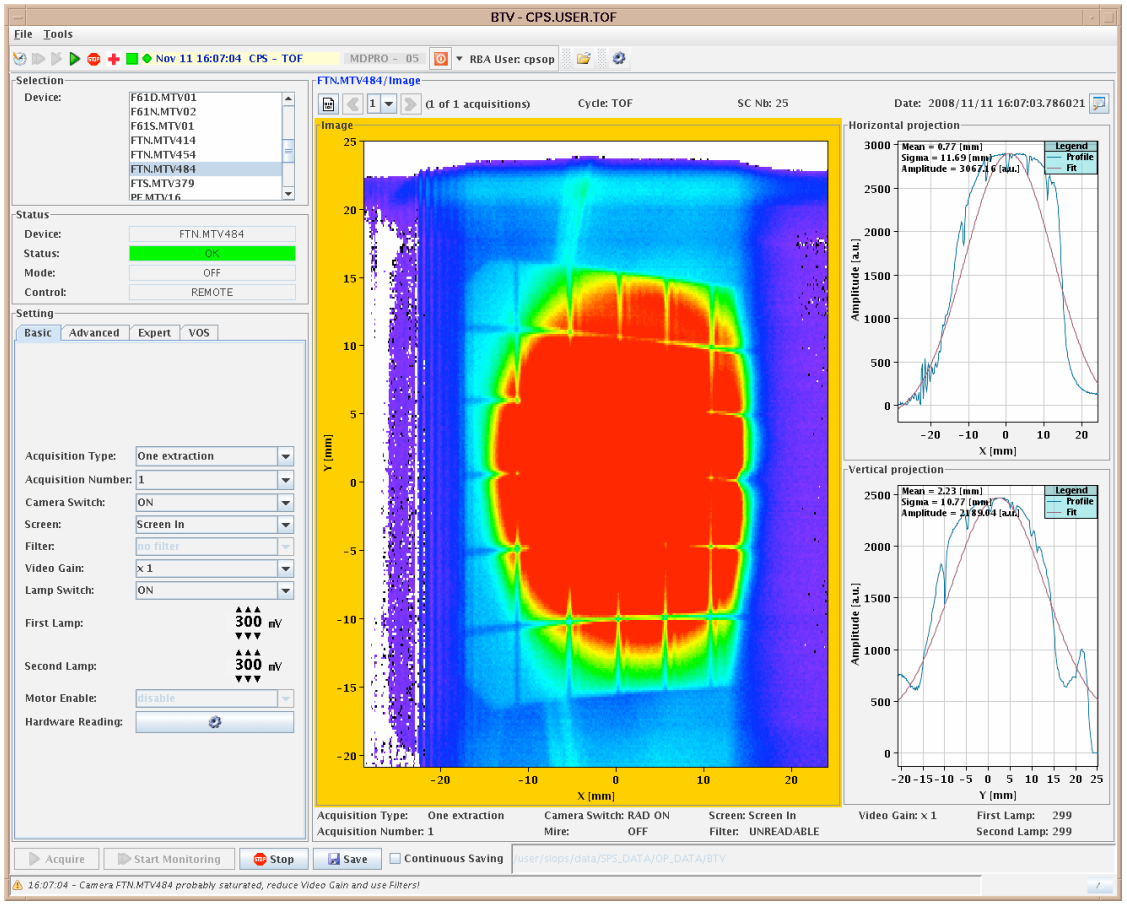
2008 Short Commissioning of the new Target

Exceptional authorization from CERN SC/RP to start in 2008 with a reduced cooling circuit and no ventilation.

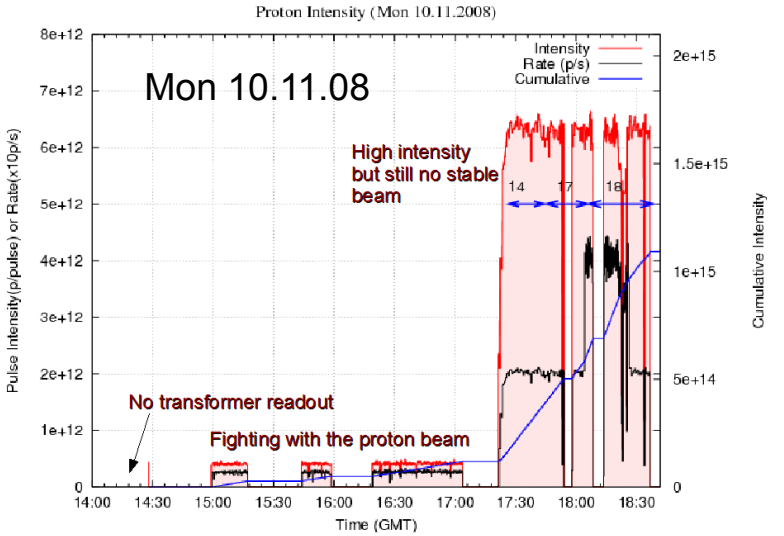
Conditions:

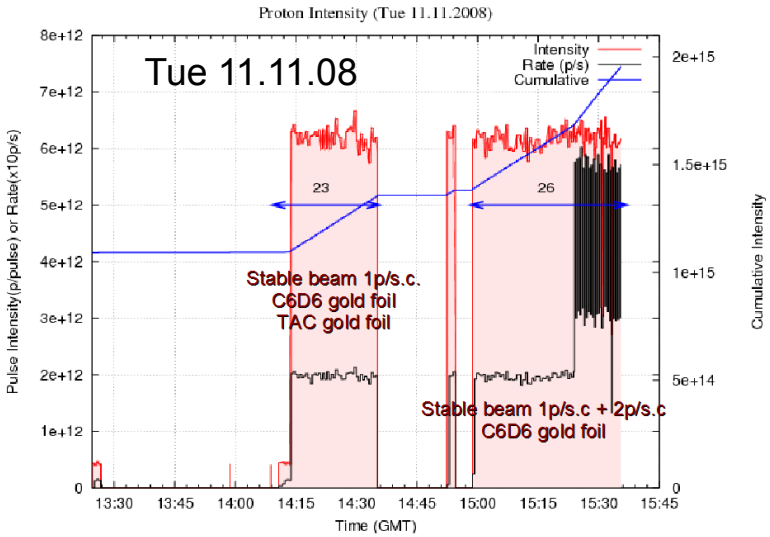
- The specific activity should not exceed 1% of the exemption limit LE for the concentration (Bq/kg)
- The absolute activity released per month (Bq) should not exceed the exemption limit
- The above are calculate based on the past experience and the corrosion/ erosion test performed at CERN
- Start: 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

Beam characteristics



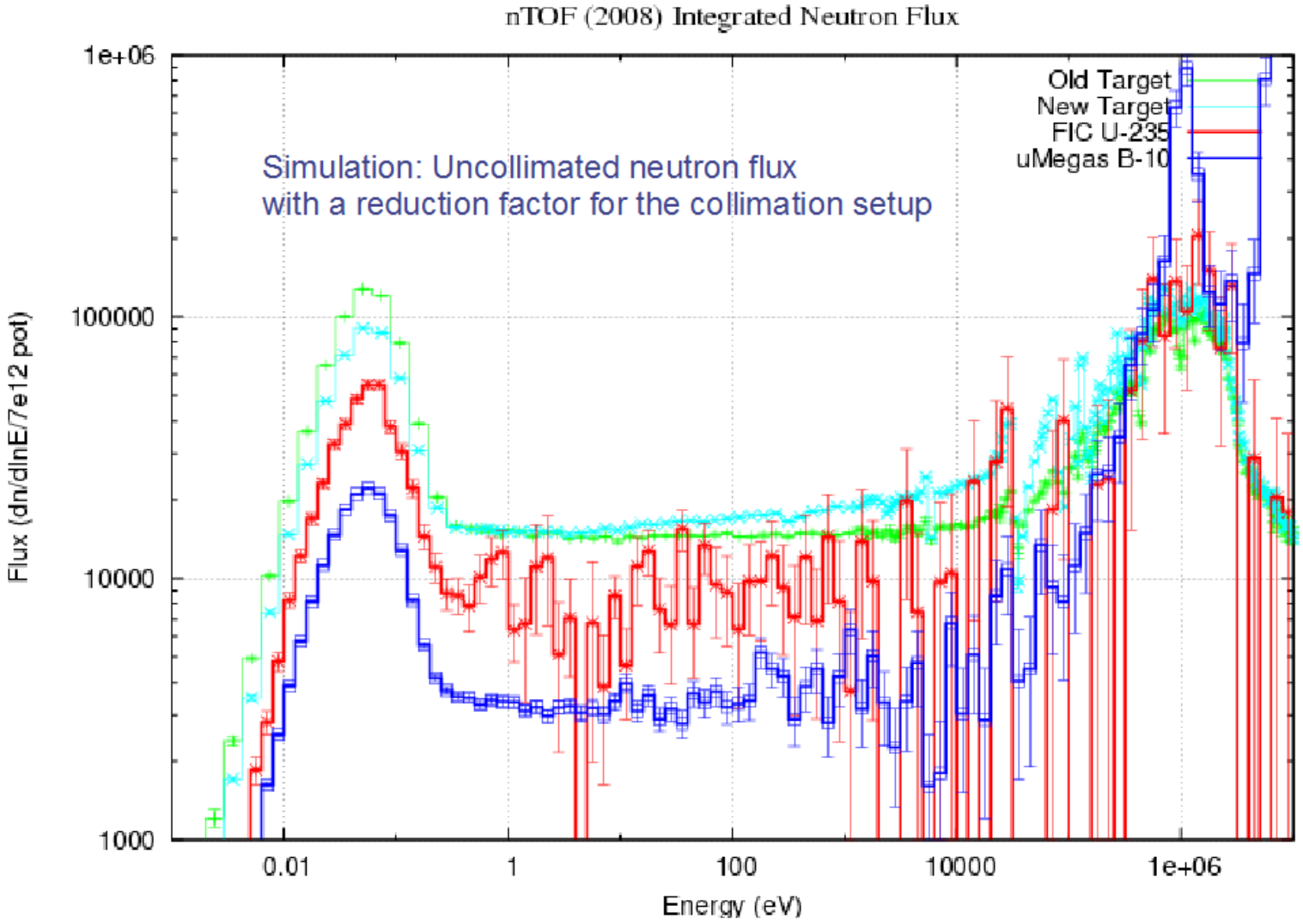
Beam spot ~6x6 cm²





- 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

Neutron Fluence



Preliminary results

obtained with:
Micromegas detector
and
Fission Ionization
Chamber (FIC)
detector

- Uncertainty of the ^{10}B mass
- Rather poor statistics
- Bad alignment of the collimator

Φ= 1.8 cm
(cf. AT/OC-02 presentation)

The n_TOF-Ph2 experiments (1)

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

The n_TOF Collaboration n_TOF-Ph2

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

The n_TOF-Ph2 experiments (2)

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 for dark matter research)
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} (start 18 of May 2008)

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 and finished before 18 of May 2009
  - Cooling system
  - Ventilation of primary area
  - Air tight the technical gallery
  - Alignment of proton beam 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:
  - Borated water
  - Heavy water
  - Disposal of old target