n_TOF facility

EFNUDAT Final Scientific Workshop

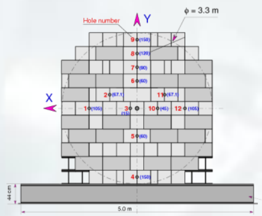
CERN, Aug 30-Sep 2 2010

Vasilis.Vlachoudis@cern.ch

for the n_TOF collaboration

n_TOF timeline

1996 — **2010**



1995-**1997** **TARC** experiment

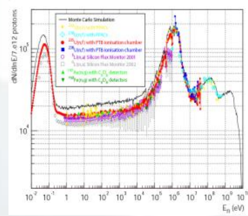
1997 **Concept** by C.Rubbia CERN/ET/Int. Note 97-19

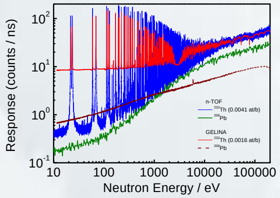
May **1998** **Feasibility** CERN/LHC/98-02+Add

Aug **1998** **Proposal** submitted

1999 **Construction** started

2000 **Commissioning**



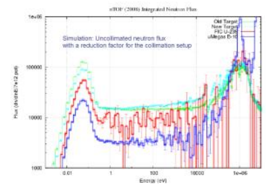


2001-**2004** **Phase I**
Isotopes
Capture: 25
Fission: 11
Papers: 21
Proc.: 51
Doc: 150

2005-**2007** **Problem** Investigation

2008 **New Target** construction

May **2009** **Commissioning**



2009 **Phase II**

2010 **Upgrades:**
Borated-H_2O
Class-A

1997: n_TOF concept

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} p/pulse]
- Spallation target Pb, to produce neutrons
  [1 proton 24 GeV/c $\Rightarrow$ ~700 neutrons]
- Long flight path ~200 m

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

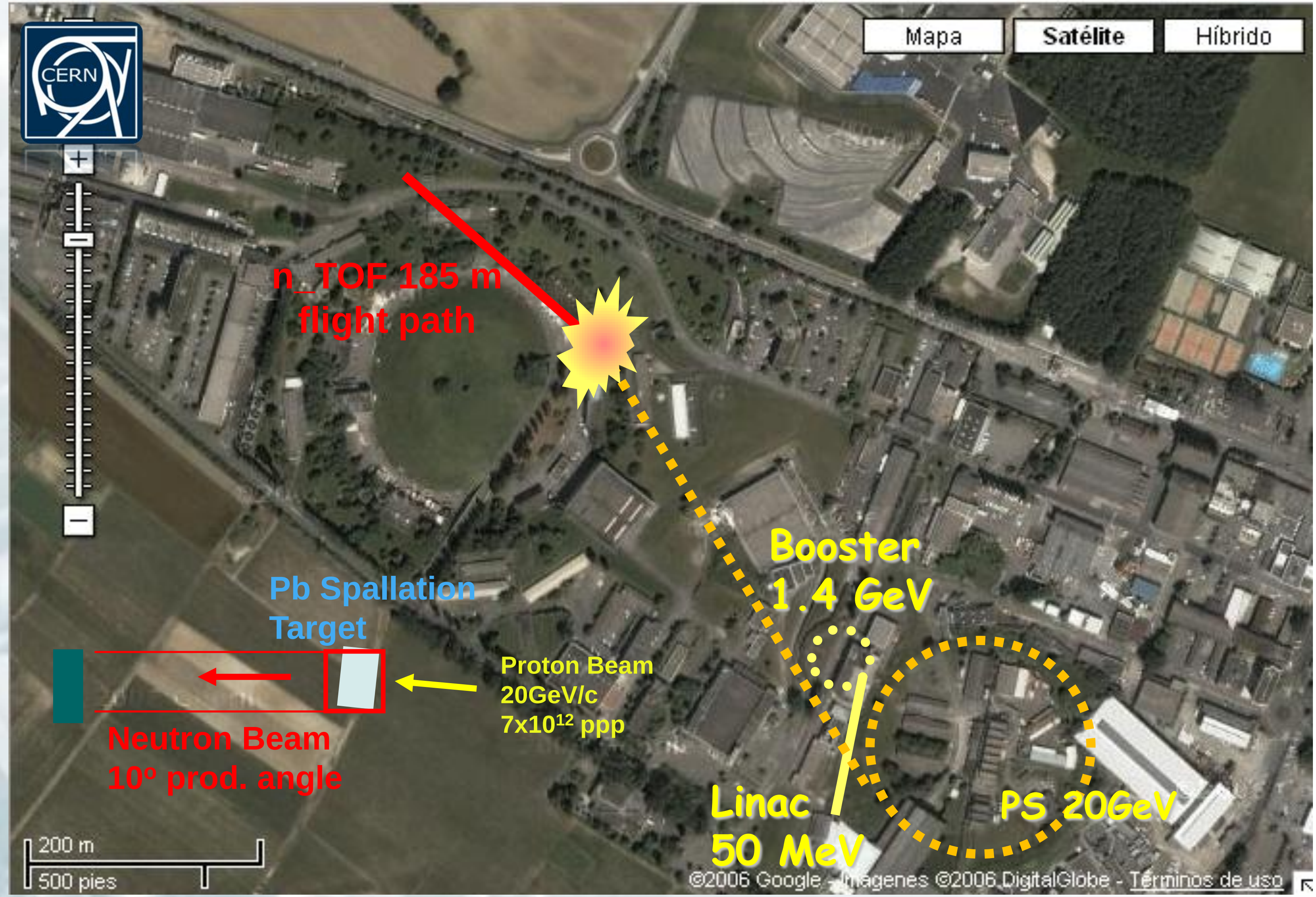
1999: The n_TOF Collaboration

U.Abbondanno[14], G.Aerts[7], H.Álvarez[24], F.Alvarez-Velarde[20], S.Andriamonje[7], J.Andrzejewski[33], P.Assimakopoulos[9], L.Audouin[5], G.Badurek[1], P.Baumann[6], F. Bečvář [31], J.Benlliure[24], E.Berthoumieux[7], F.Calviño[25],D.Cano-Ott[20],R.Capote[23],A.Carrillo de Albornoz[30],P.Cennini[4], V.Chepel1[7], E.Chiaveri[4], N.Colonna1[3], G.Cortes[25], D.Cortina[24], A.Couture[29], J.Cox[29], S.David[5], R.Dolfini[15], C.Domingo-Pardo[21], W.Dridi[7], I.Duran[24], M.Embid-Segura[20], L.Ferrant[5], A.Ferrari[4], R.Ferreira-Marques[17], L.Fitzpatrick[4], H.Frais-Koelbl[3], K.Fujii[13], W.Furman[18], C.Guerrero[20], I.Goncalves[30], R.Gallino[36], E.Gonzalez-Romero[20], A.Goverdovski[19], F.Gramegna[12], E.Griesmayer[3], F.Gunsing[7], B.Haas[32], R.Haight[27], M.Heil[8], A.Herrera-Martinez[4], M.Igashira[37], S.Isaev[5], E.Jericha[1], Y.Kadi[4], F.Käppeler[8], D.Karamanis[9], D.Karadimos[9], M.Kerveno[6], V.Ketlerov[19], P.Koehler[28], V.Konovalov[18], E.Kossionides[39], M.Krtička[31], C.Lamboudis[10], H.Leeb[1], A.Lindote[17], I.Lopes[17], M.Lozano[23], S.Lukic[6], J.Marganiec[33], L.Marques[30], S.Marrone[13], P.Mastinu[12], A.Mengoni[4], P.M.Milazzo[14], C.Moreau[14], M.Mosconi[8], F.Neves[17], H.Oberhummer[1], S.O'Brien[29], M.Oshima[38], J.Pancin[7], C.Papachristodoulou[9], C.Papadopoulos[40], C.Paradela[24], N.Patronis[9], A.Pavlik[2], P.Pavlopoulos[34], L.Perrot[7], R.Plag[8], A.Plompen[16], A.Plukis[7], A.Poch[25], C.Pretel[25], J.Quesada[23], T.Rauscher[26], R.Reifarth[27], M.Rosetti1[1], C.Rubbia[5], G.Rudolf[6], P.Rullhusen[16], J.Salgado[30], L.Sarchiapone[4], C.Stephan[5], G.Tagliente[13], J.L.Tain[21], L.Tassan-Got[5], L.Tavora[30], R.Terlizzi[13], G.Vannini[35], P.Vaz[30], A.Ventura[11], D.Villamarin[20], M.C.Vincente[20], V.Vlachoudis[4], R.Vlastou[40], F.Voss[8], H.Wendler[4], M.Wiescher[29], K.Wisshak[8]

33 Research Institutions

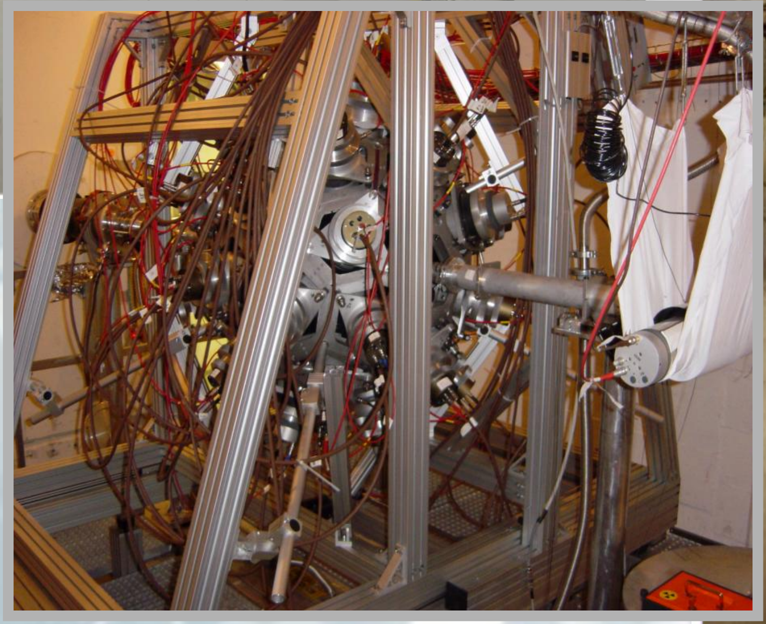
120 researchers

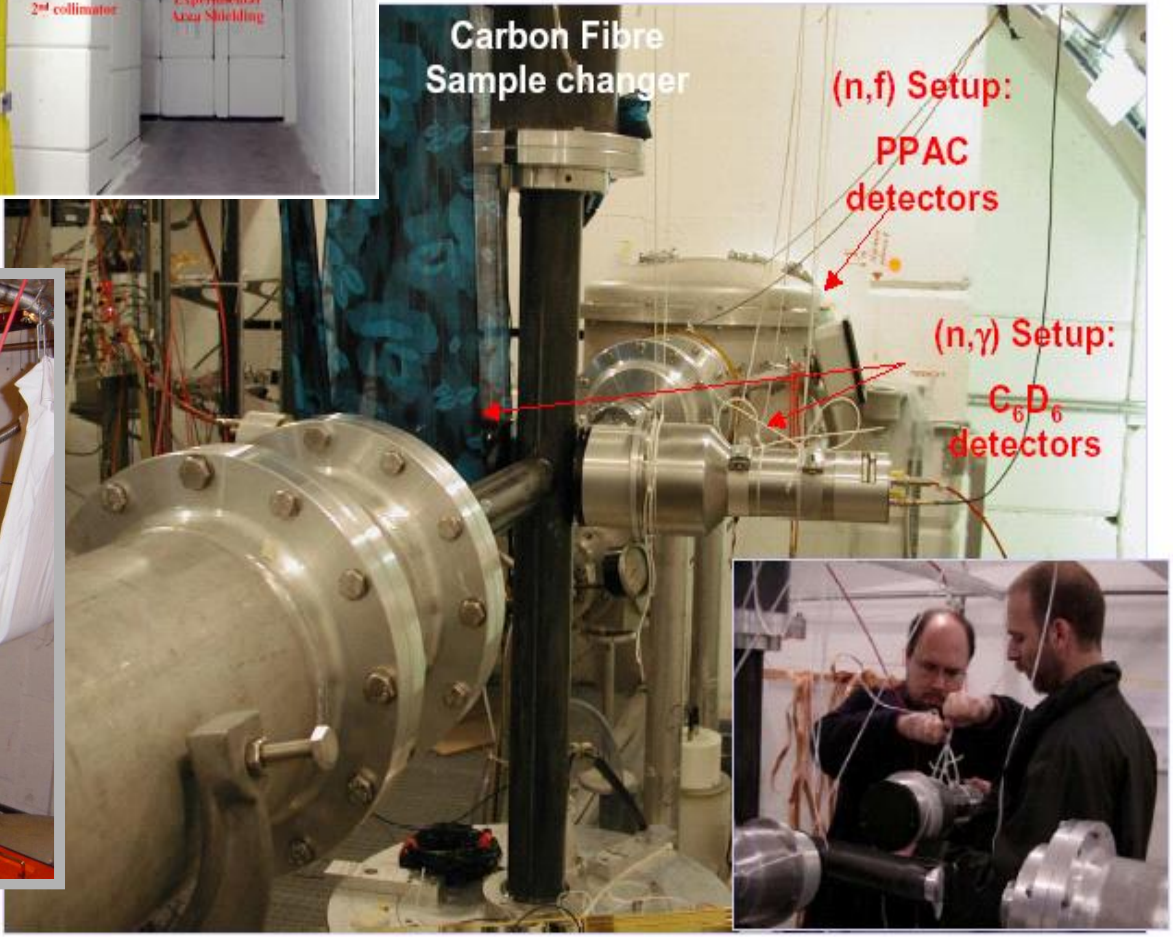
2000: A Google™ view of n_TOF



2001: The real world

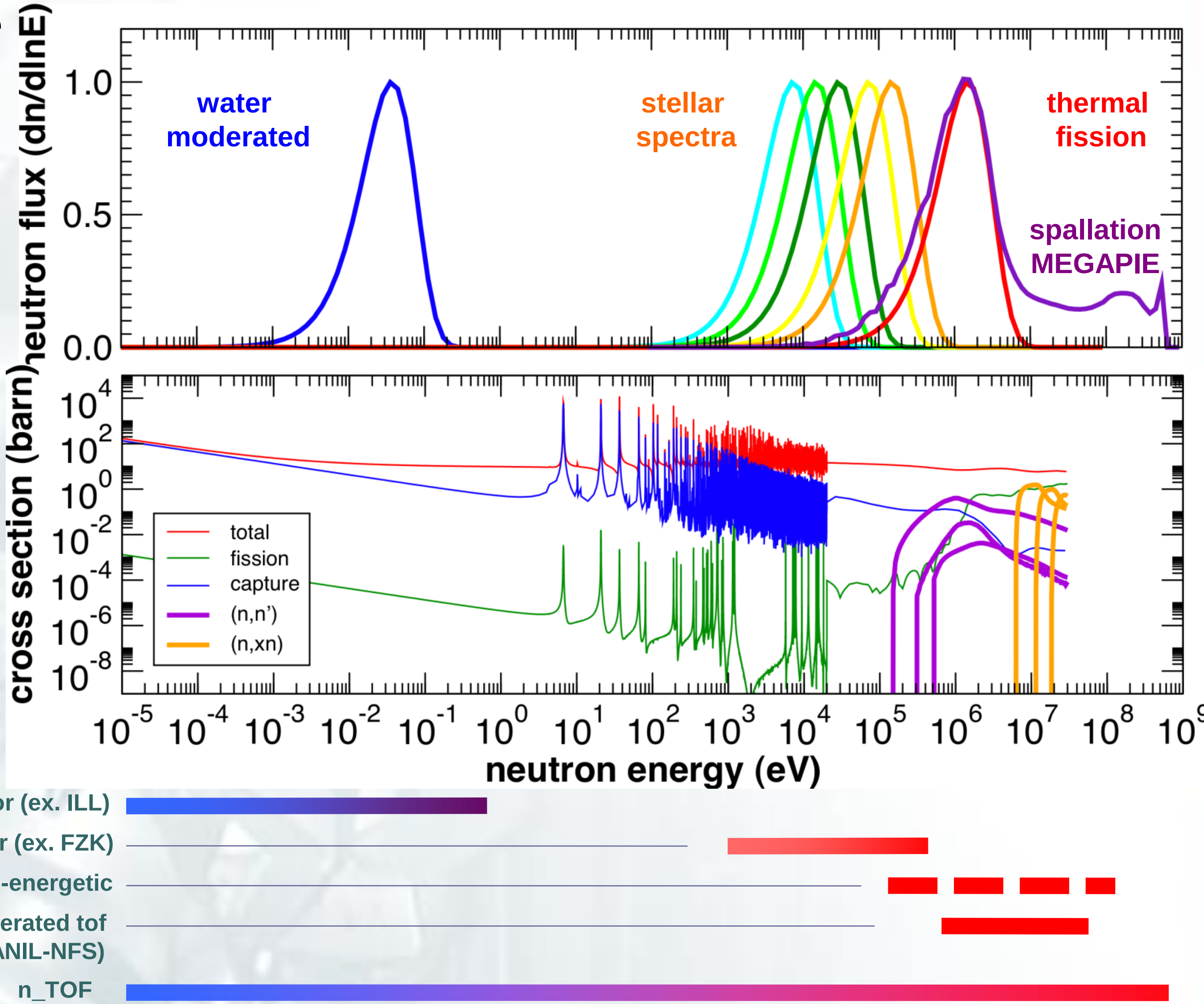
- n_TOF commissioned in 2001-2002





2002-4: n_TOF basic characteristics

- wide energy range

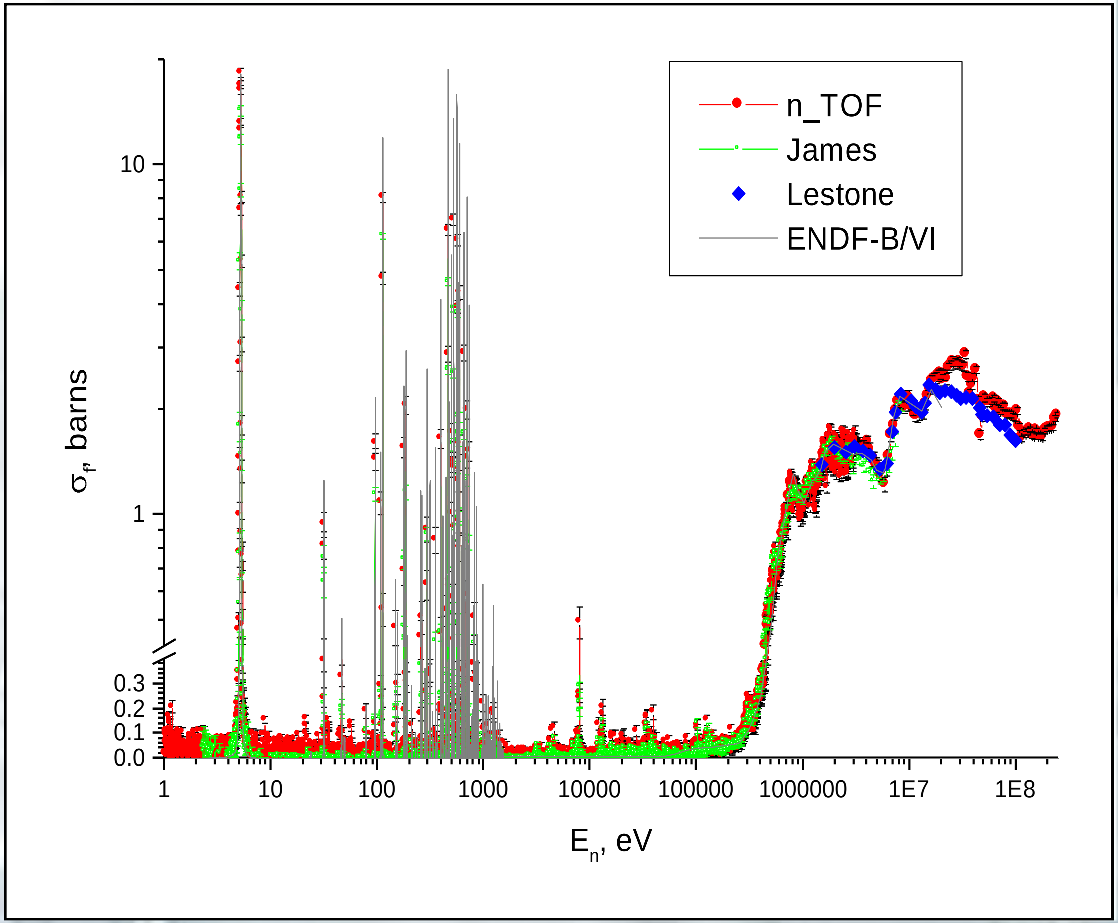


2002-4: n_TOF basic characteristics

- wide energy range

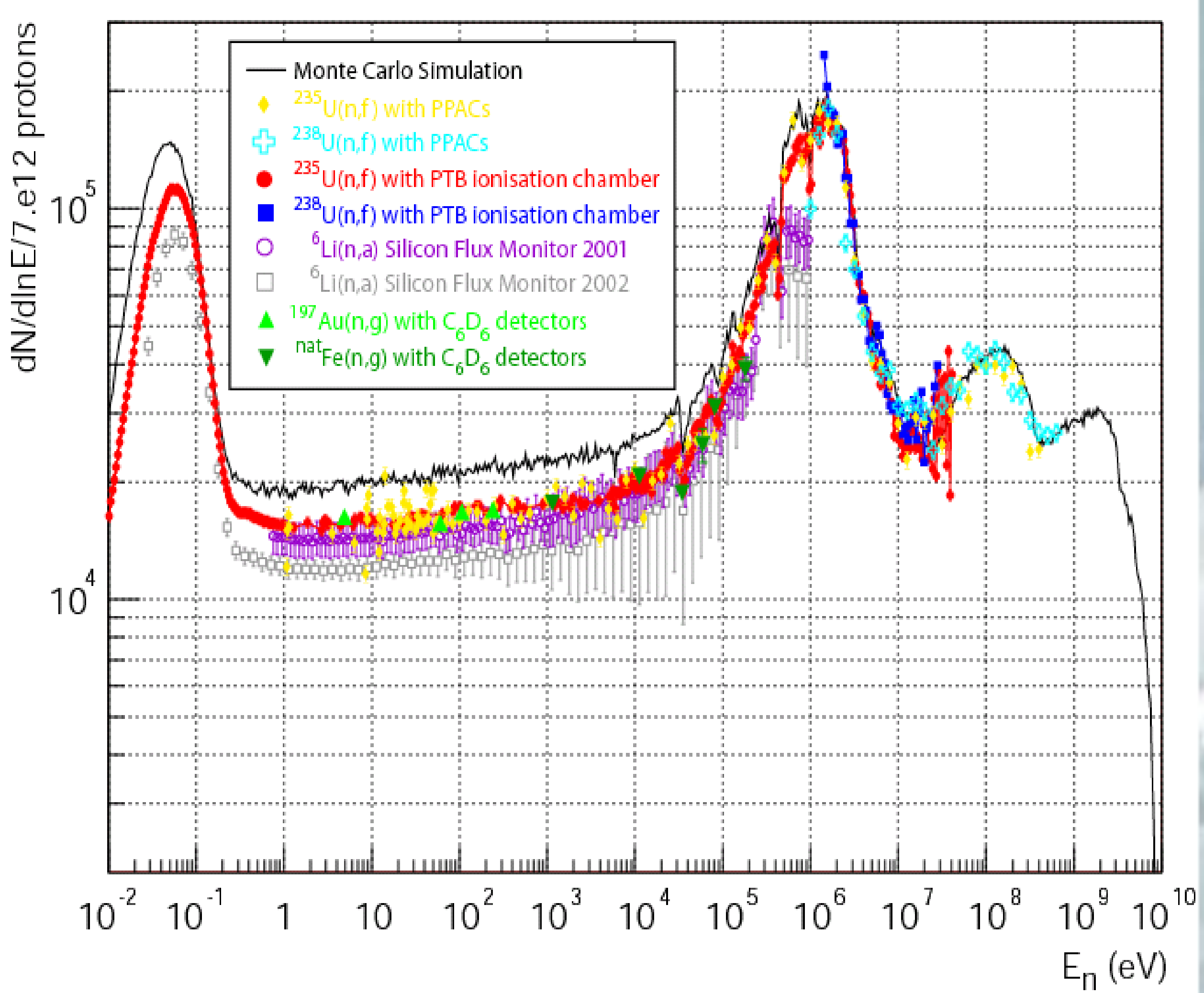
FIC-0 & PPACs (2003)

$^{234}U(n,f)$



2002-4: n_TOF basic characteristics

- wide energy range
- high neutron flux

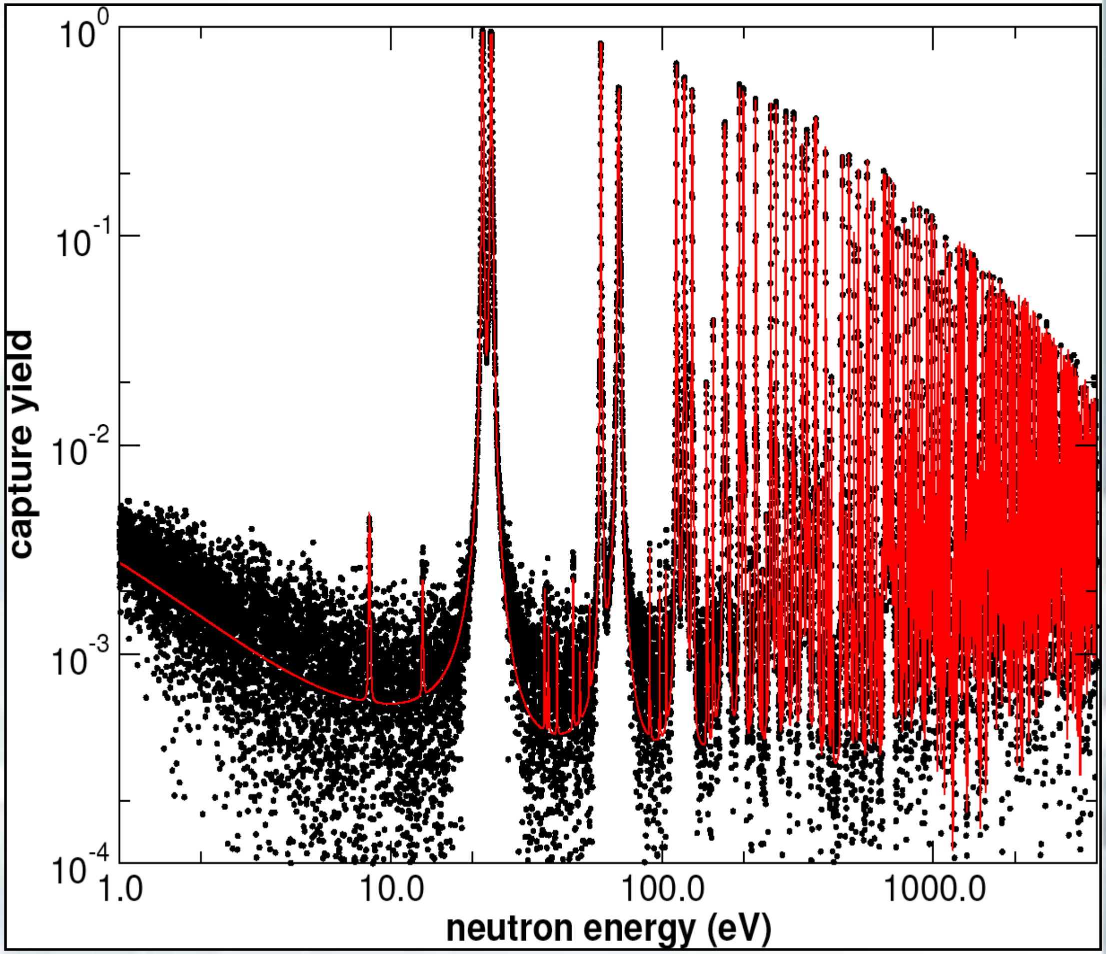


2002-4: n_TOF basic characteristics

- wide energy range
- high neutron flux
- high resolution

$^{232}Th(n,\gamma)$

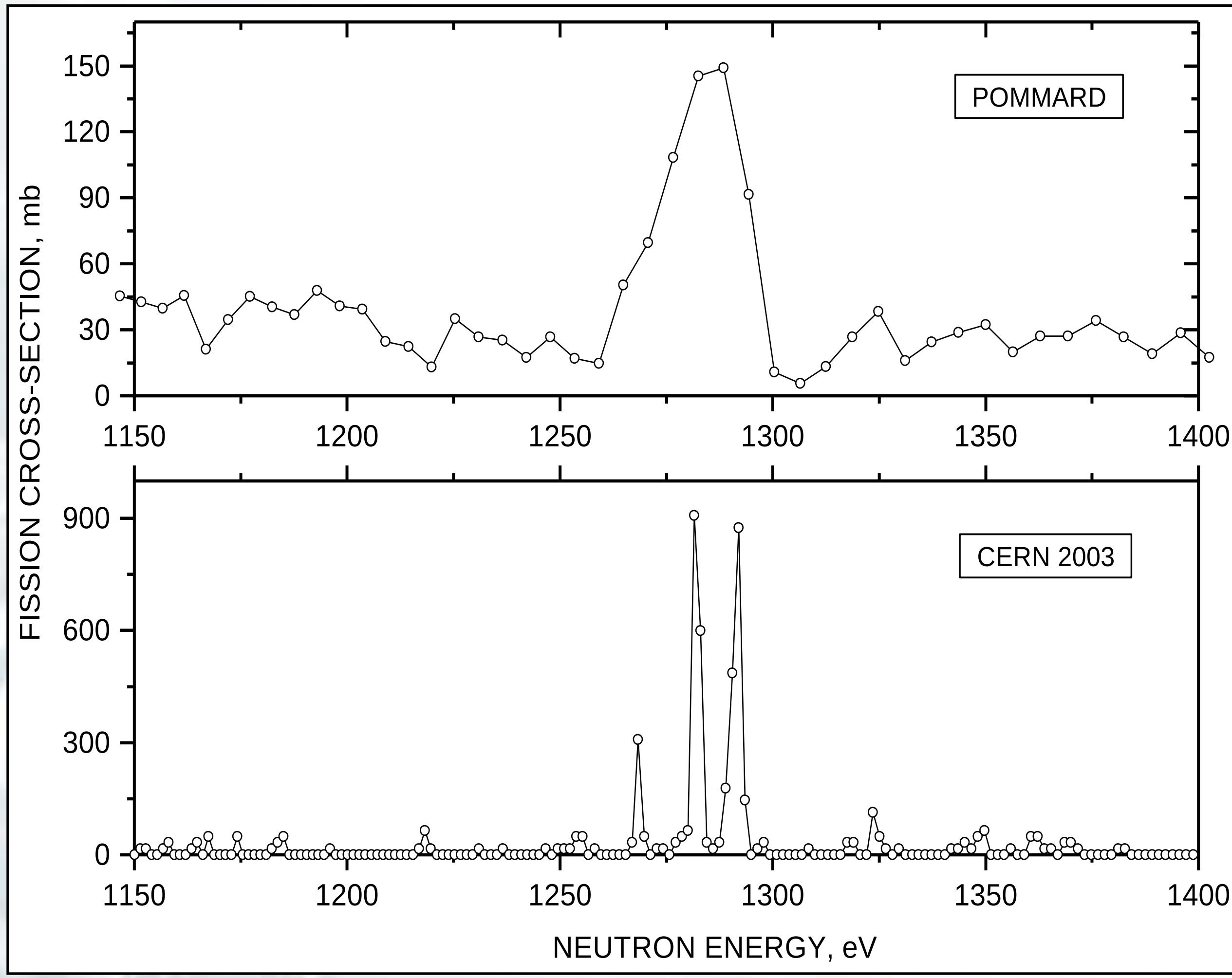
small samples



2002-4: n_TOF basic characteristics

- wide energy range
- high neutron flux
- high resolution

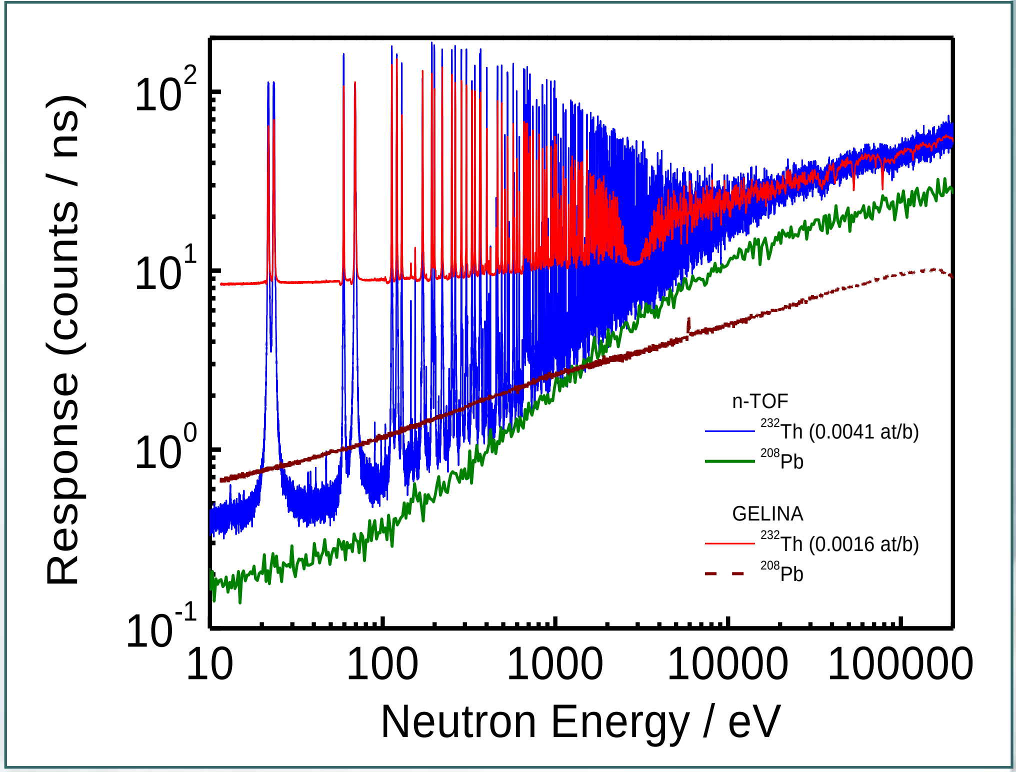
$^{236}U(n,f)$



2002-4: n_TOF basic characteristics

- wide energy range
- high neutron flux
- high resolution
- low repetition rate of the proton driver

$^{232}Th(n,\gamma)$



source: P Rullhusen (GELINA)

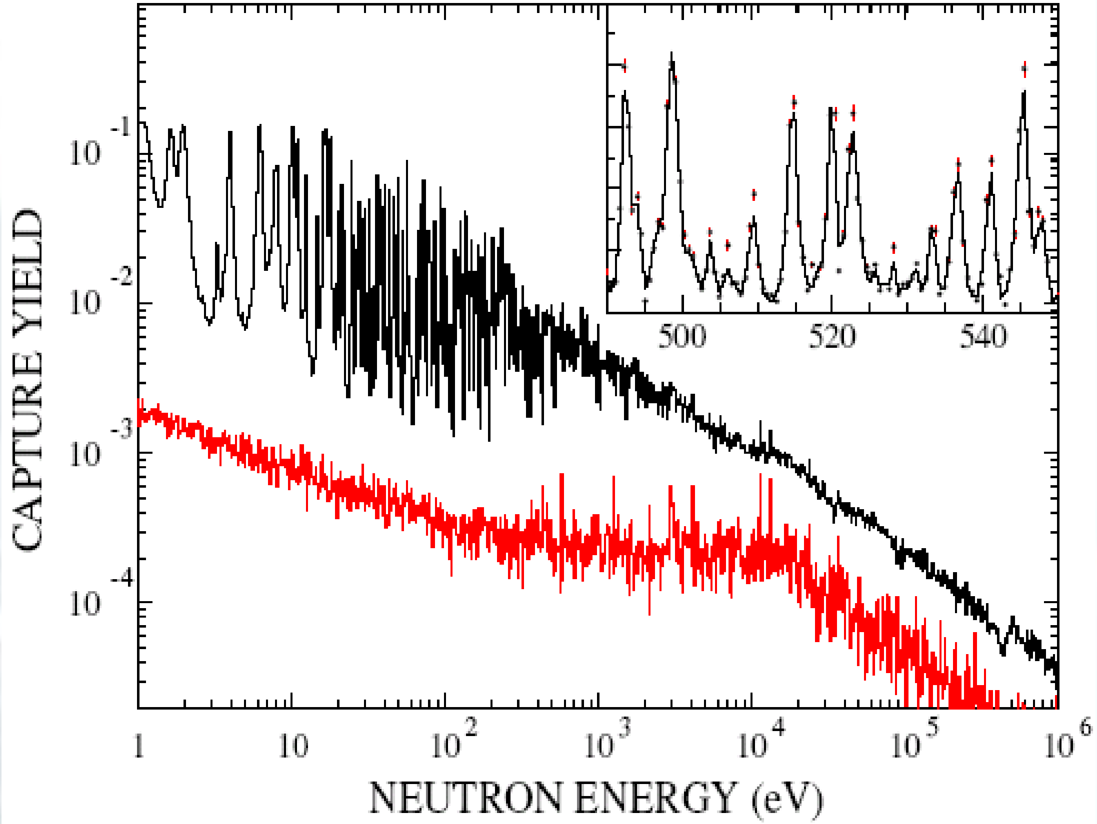
comparison with GELINA (~ same average flux at 30m)

2002-4: n_TOF basic characteristics

- wide energy range
- high neutron flux
- high resolution
- low repetition rate of the proton driver
- low background conditions

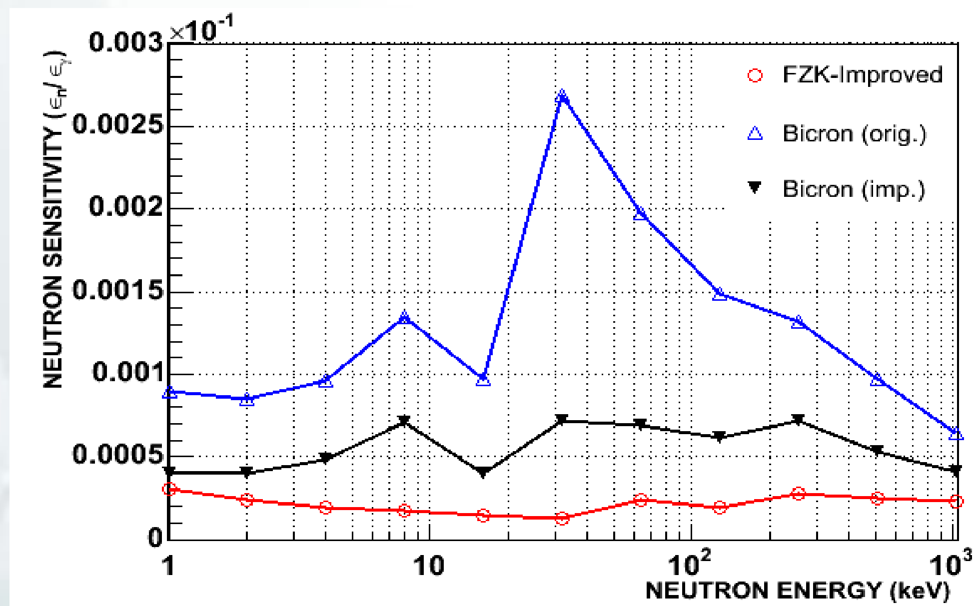
U Abbondanno et al. (The n_TOF Collaboration) Phys. Rev. Lett. **93** (2004), 161103
&
S Marrone et al. (The n_TOF Collaboration) Phys. Rev. C **73** 03604 (2006)

$^{151}Sm(n,\gamma)$



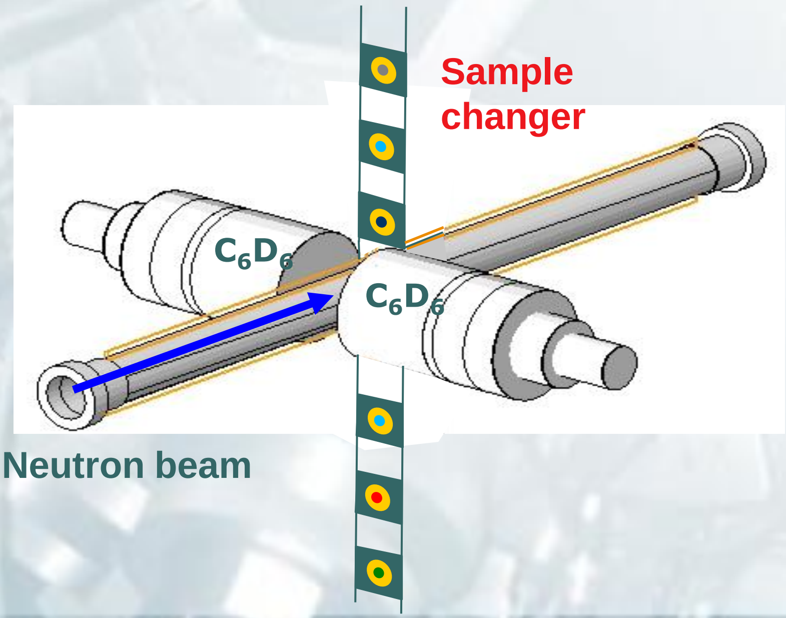
2002-4: n_TOF basic character

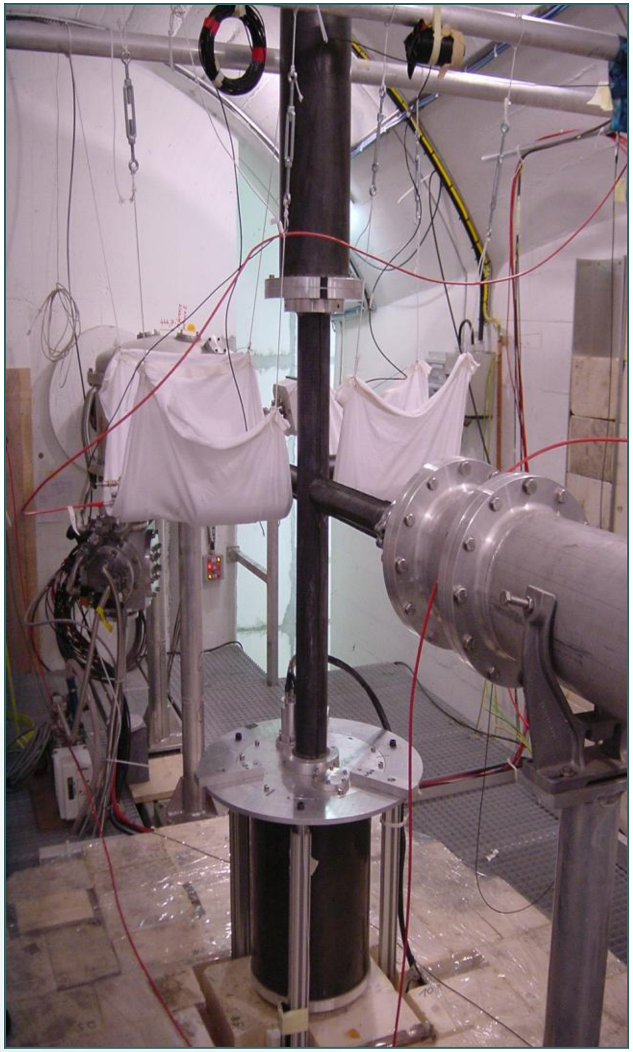
- wide energy range
- high neutron flux
- high resolution
- low repetition rate of the proton driver
- low background conditions
- detectors with extremely low neutron sensitivity



2002-4: n_TOF basic characteristics

- wide energy range
- high neutron flux
- high resolution
- low repetition rate
  of the proton driver
- low background conditions
- detectors with extremely
  low neutron sensitivity



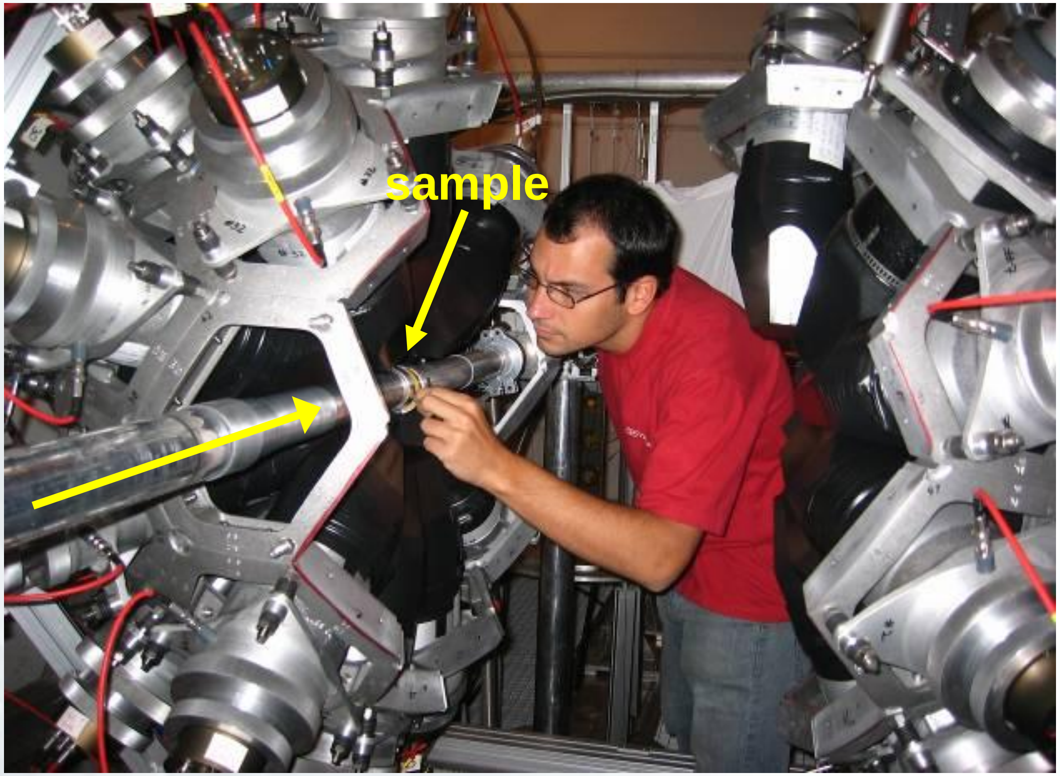


sample changer and beam pipe
made out of carbon fiber

2002-4: n_TOF basic characteristics

- wide energy range
- high neutron flux
- high resolution
- low repetition rate
  of the proton driver
- low background conditions
- detectors with extremely
  low neutron sensitivity
- high efficiency detectors (TAC)

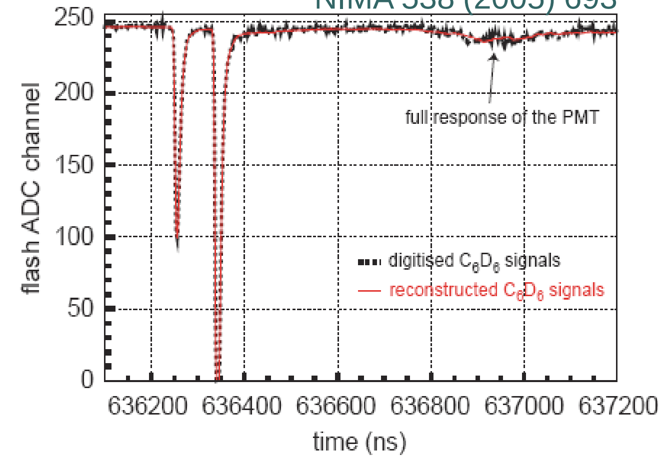
- 40 BaF_2 crystals
- high detection efficiency ≈100%
- good energy resolution
- so far, only used for (n,γ) measurements in 2004

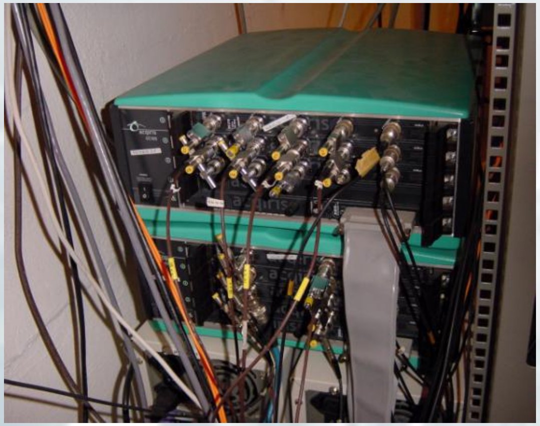


2002-4: n_TOF basic characteristics

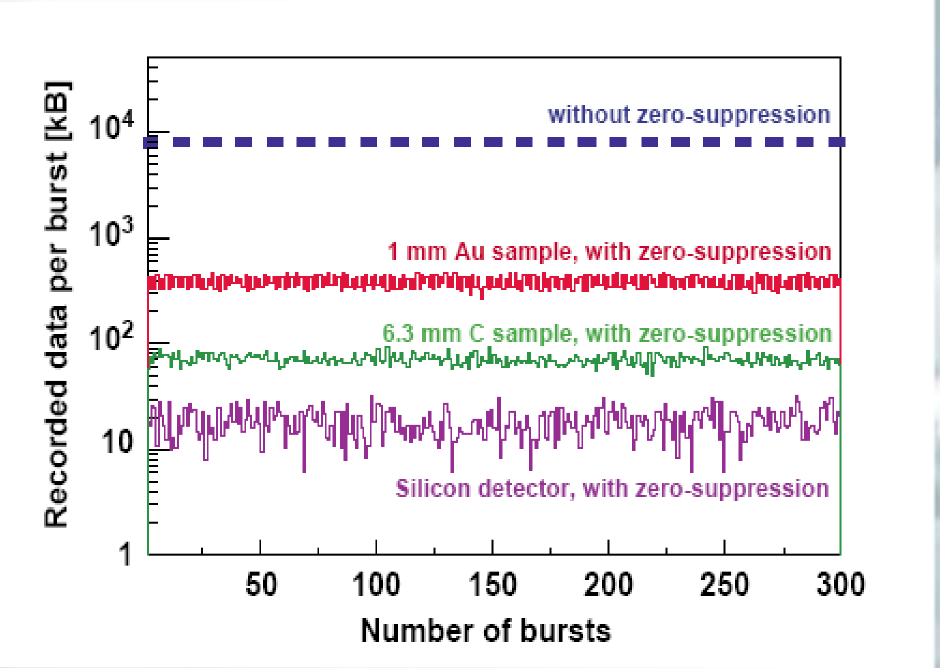
- wide energy range
- high neutron flux
- high resolution
- low repetition rate of the proton driver
- low background conditions
- detectors with extremely low neutron sensitivity
- high efficiency detectors (TAC)
- advanced DAQ system

R Plag et al. (The n_TOF Collaboration) NIMA 538 (2005) 693





Acqiris FADC



2002-4: n_TOF experiments

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

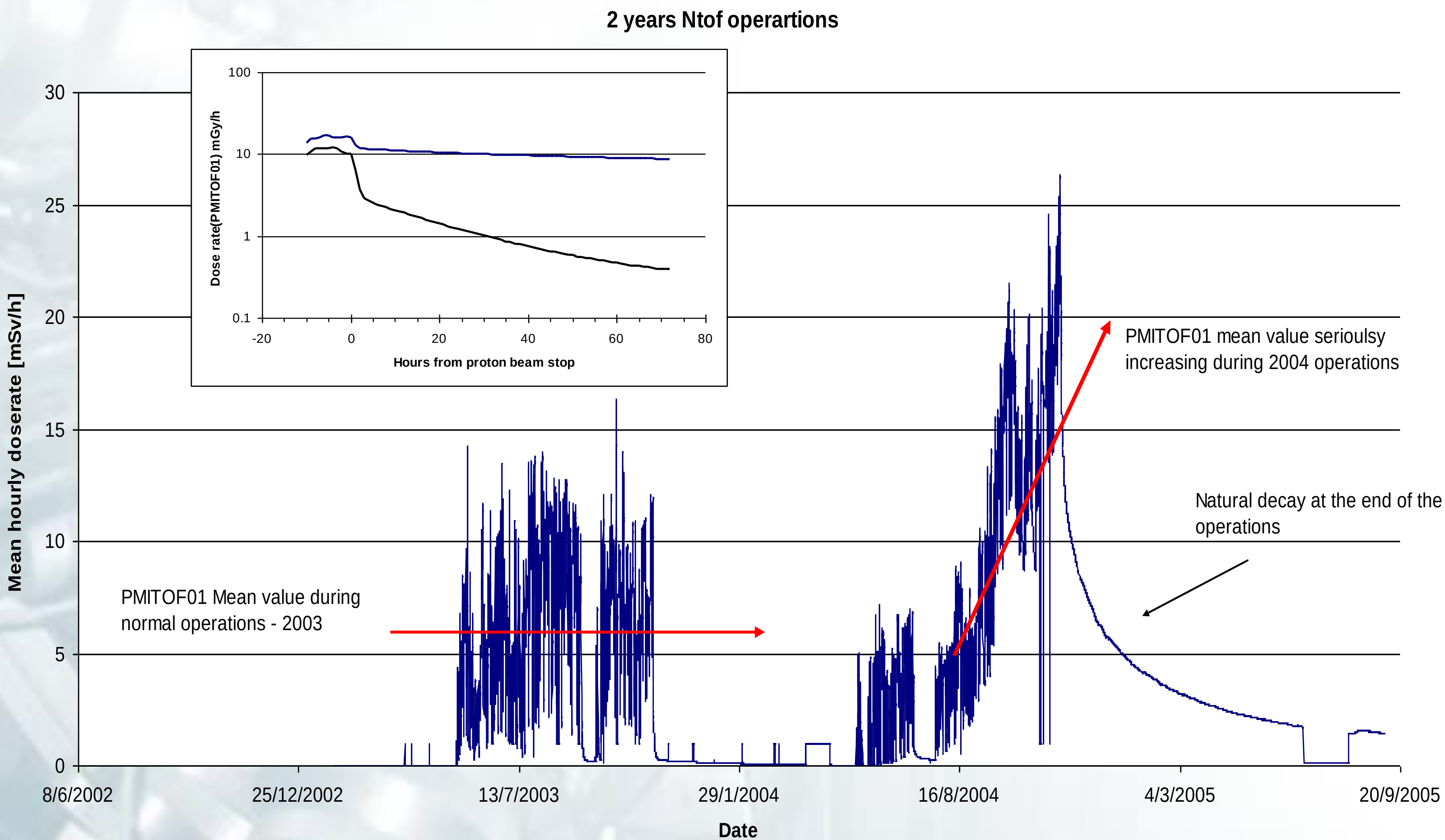
^{209}Bi

^{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

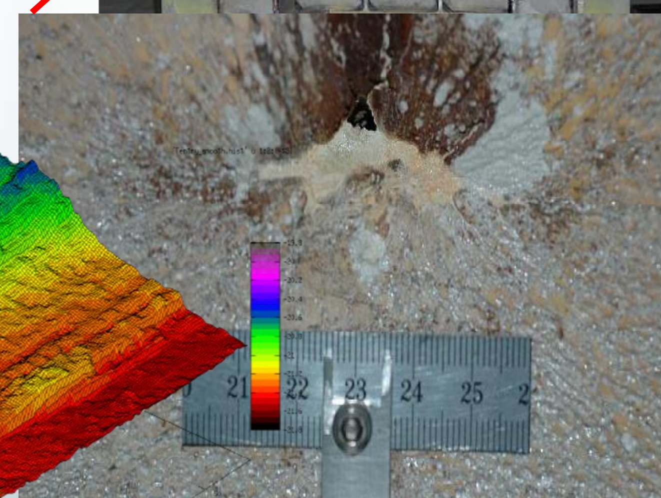
2004: Cooling circuit activation

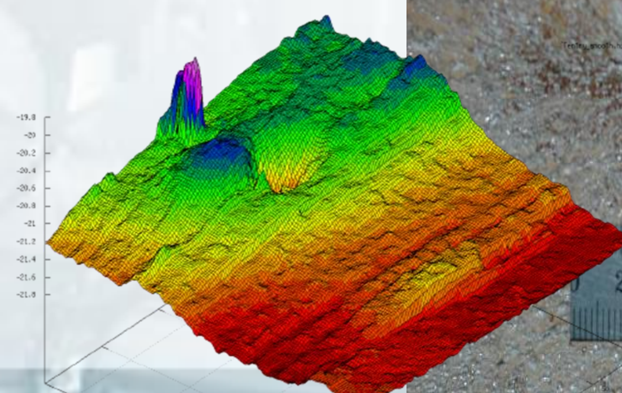


Info: CERN-SC-2005-034-RP-TN

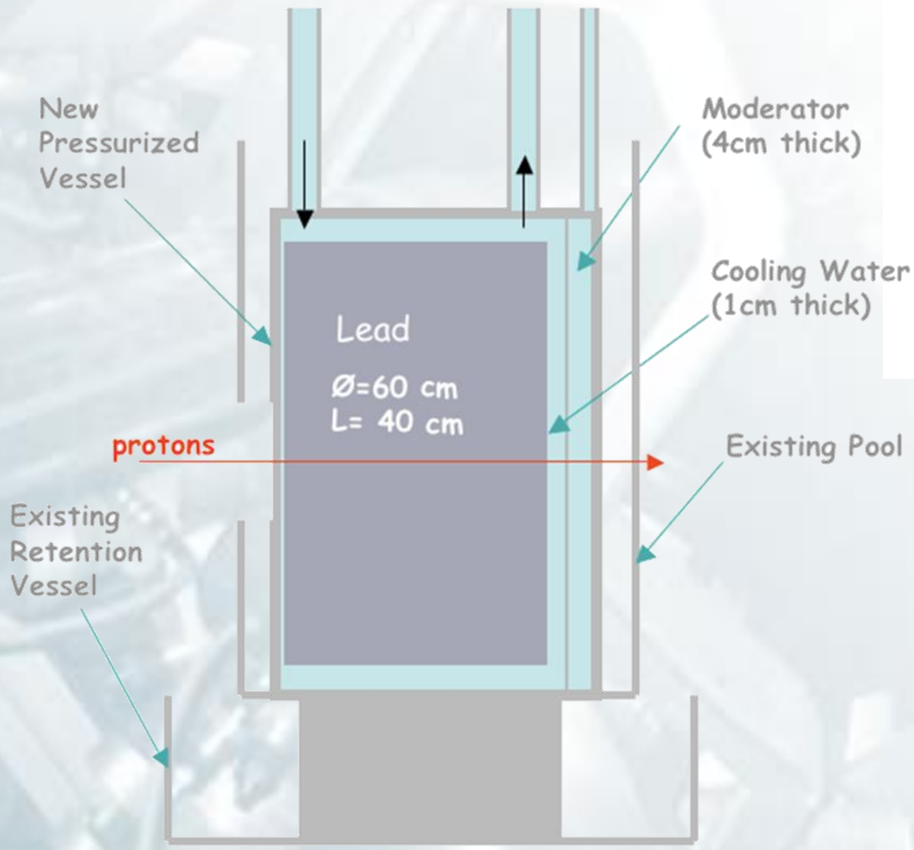
2005-7: Target investigation

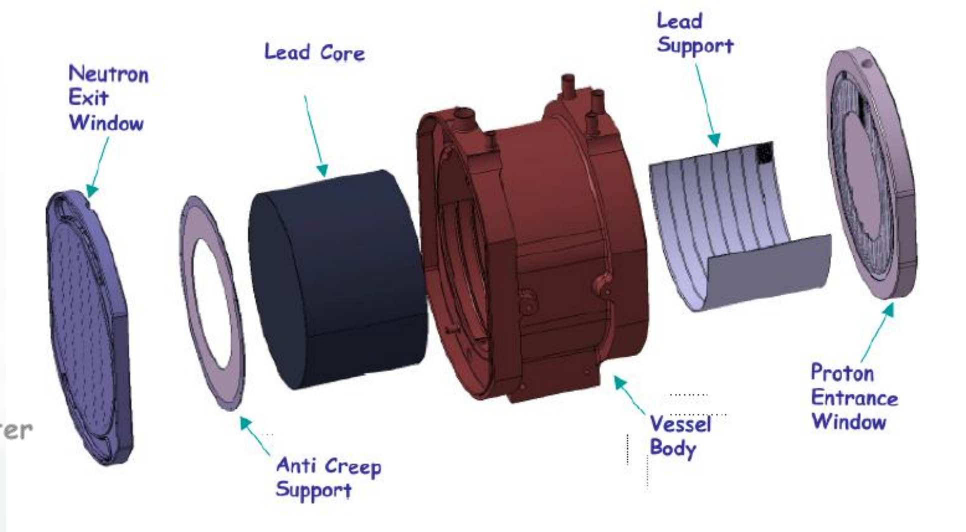
- 27.09.2007: Target removal
- Target visual inspection & photography, RC-camera
- Dose rate measurements of target
- Measurement of hole at the beam impact location
- Analysis of lead Samples taken
- FLUKA simulations of the target activation, as well as detailed maps for pit and pool
- Target surface inspection using a dedicated custom-built (and developed) laser system
- Extensive study of the target corrosion mechanism
- 2 External reviews verified the concept of the new target
    - Water cooled lead target
    - Improved cooling
    - New cooling system



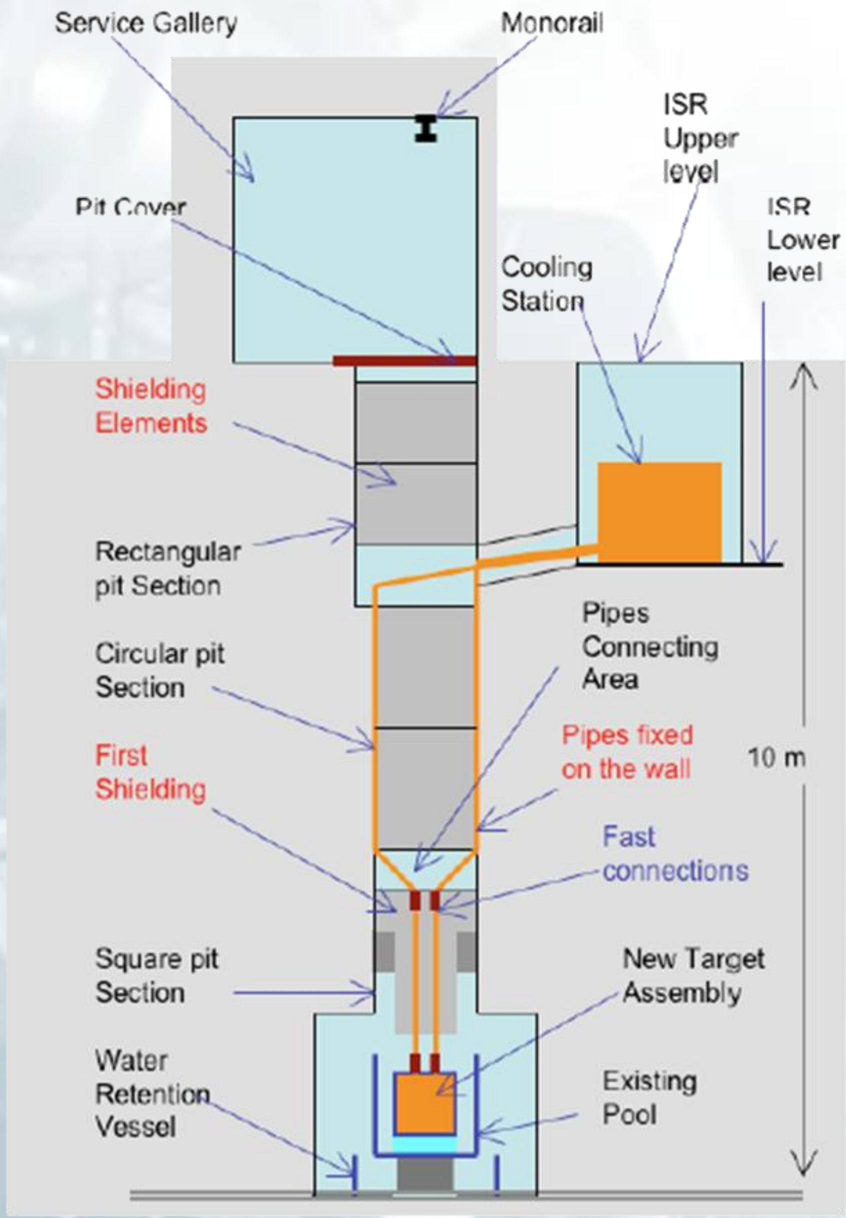


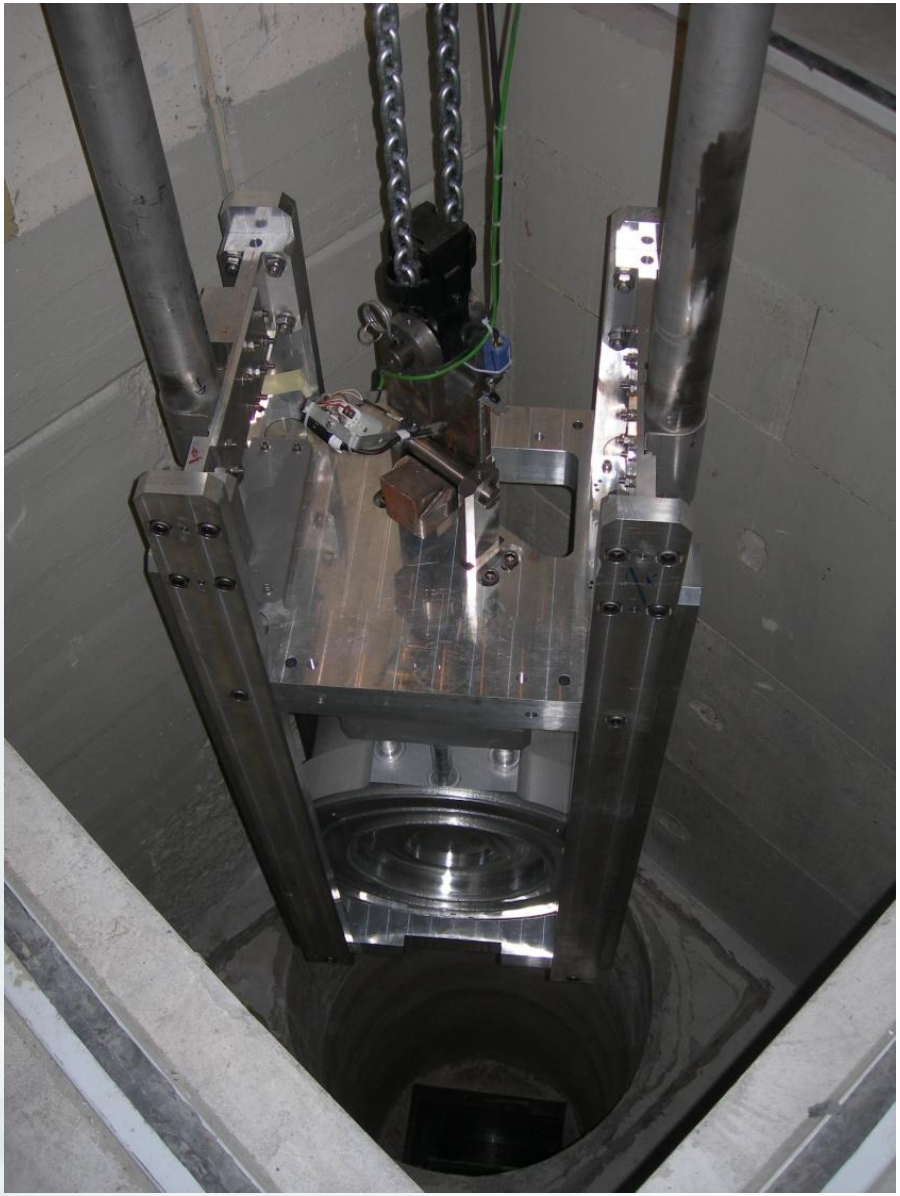
2008: New spallation target





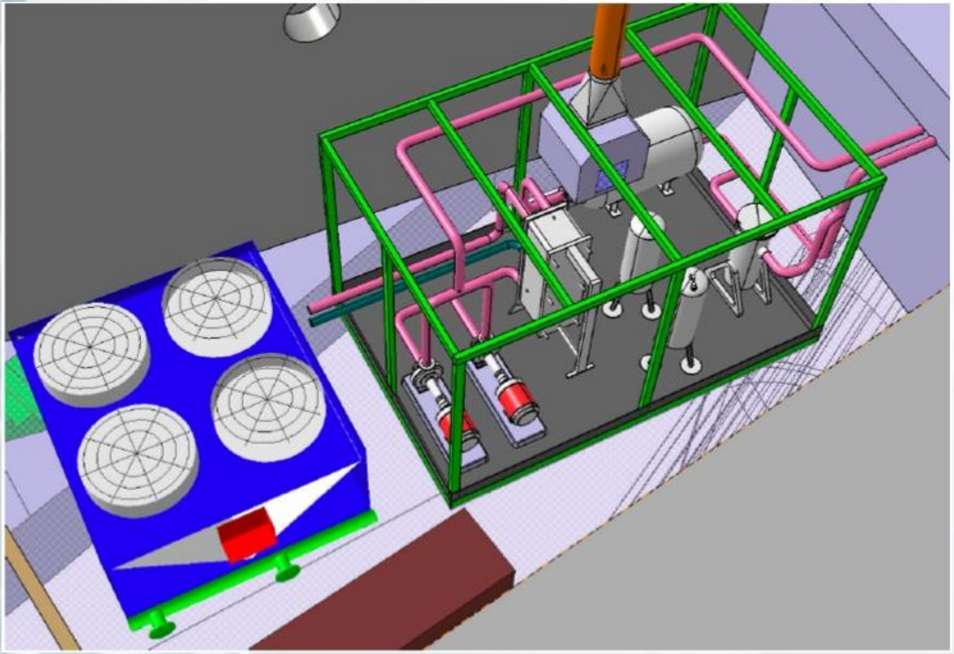
2008: Pit lay-out





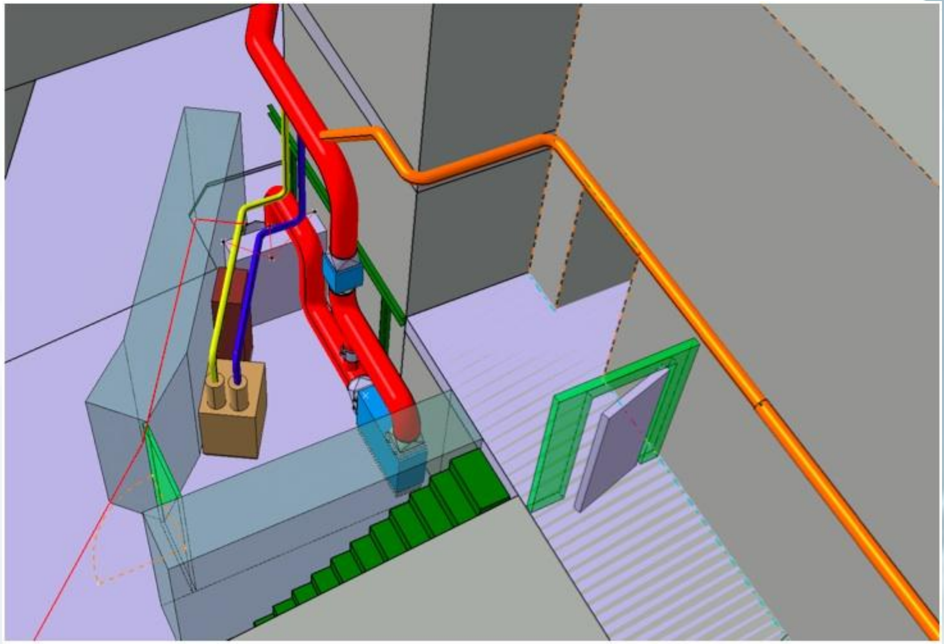
2008-9: Stations lay-out

Target cooling 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
Resin filters:	2
Degassing Device	O_2 level < 80ppb

Ventilation system



Target Area is continuously flushed out	
Filter:	^7Be
Flush:	<150 m^3/h
Volume:	1200 m^3
Dose to public:	< 1μSv for 1.6×10^{19}p

Requirements for Work Sector Type-A

- *Fire resistance*
  - Walls F90 and doors T60
  - Detection system in the area and ventilation ducts
  - Isolation of Work Sector in case of fire
- *Ventilation system*
  - Under pressure in the Work Sector (higher hazard) – 60 Pa
  - > 5 air renewal/hour (500 m^3/h)
  - Under pressure secured in case of power failure (CERN Safety Network or dedicated UPS)
- *Floor and walls*
  - Continuous and impermeable coating (floor coating raised 10 cm to wall)
- *Access protocol specification*
  - Material and personnel (“hot” and “cold” changing room)
  - RP detectors
- *Decontamination system*
  - Wash basin (with water container retention vessel)

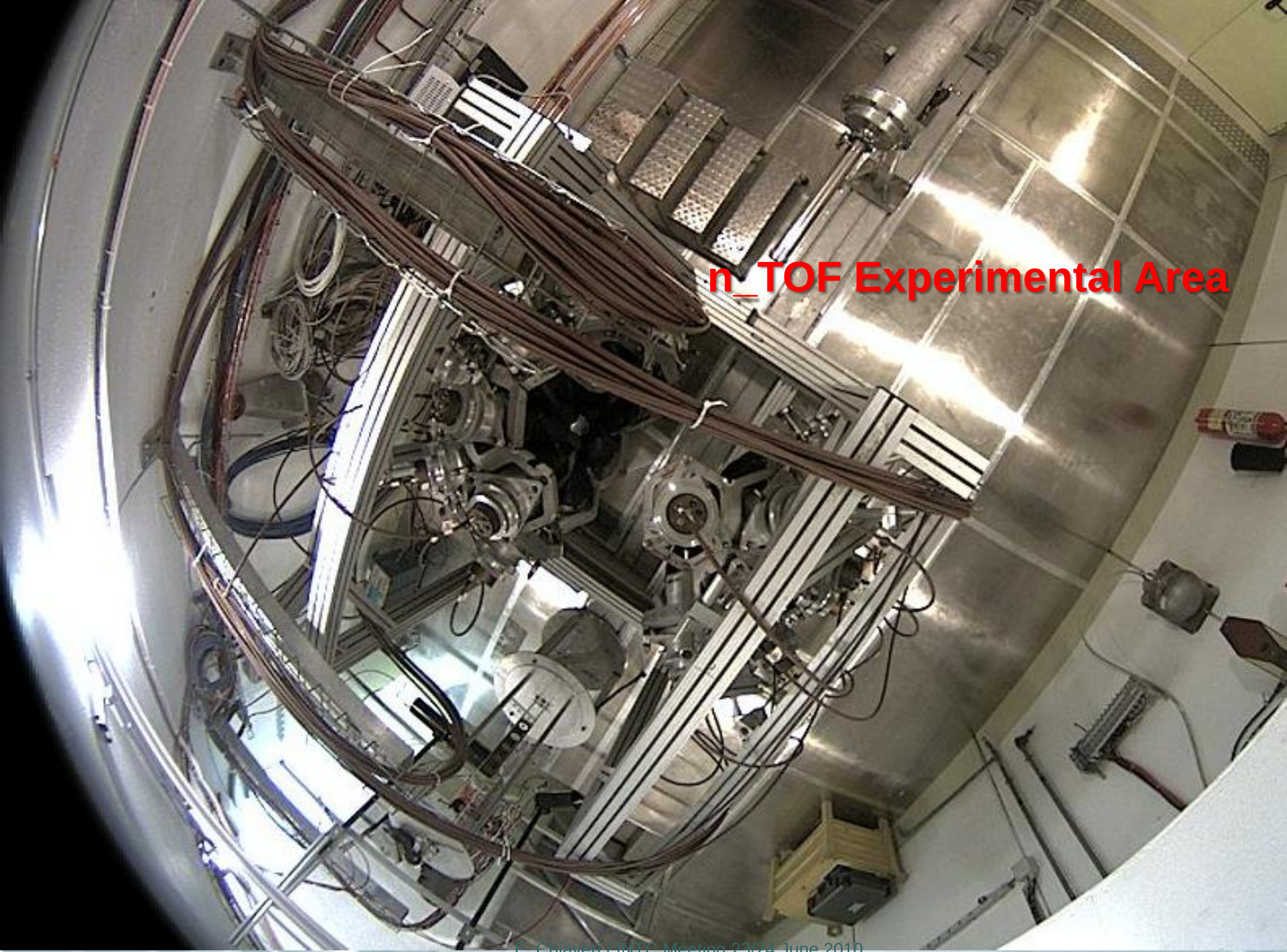

Entrance of n_TOF beam line
IN CASE OF ALARM
DO NOT ENTER
EN CAS D'ALARME
NE PAS ENTRER
RADIATION
LIMITED STAY
SÉJOUR LIMITÉ
TIREZ
PULL
RADIATION


RADIATION
ZONE CONTRÔLÉE
CONTROLLED AREA
LIMITED STAY
SÉJOUR LIMITÉ
Material entrance
Entrée matériel
Changing room
Vestiaire
Material entrance
Changing room


n_TOF changing room
RADIATION
ZONE CONTRÔLÉE
CONTROLLED AREA
LIMITED STAY
SÉJOUR LIMITÉ
Dosimeters obligatory
Dosimètres obligatoires

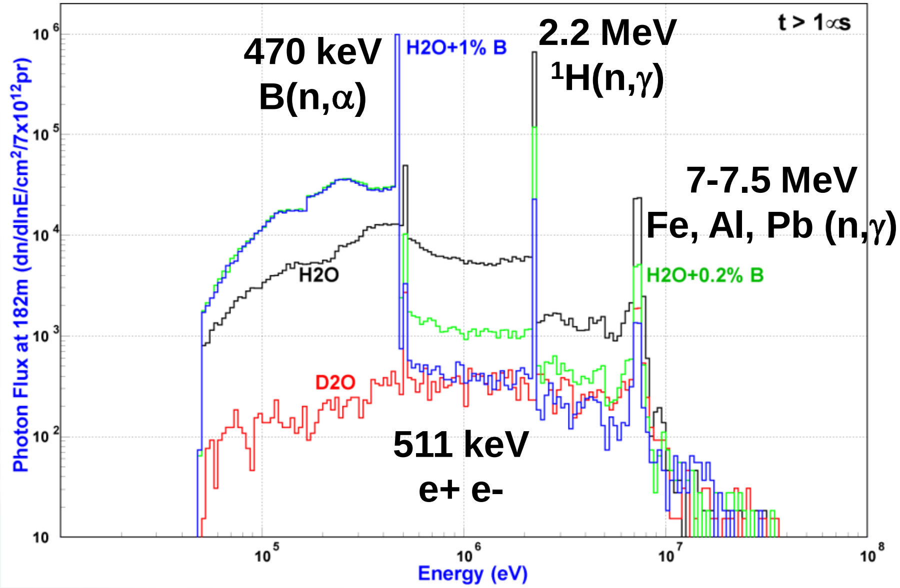

Escape line

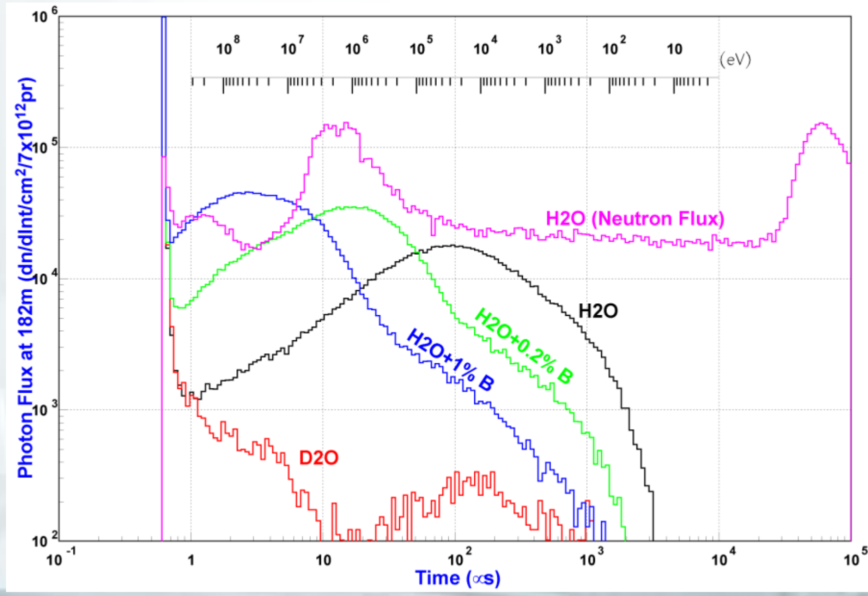
n_TOF Experimental Area



Borated Water Circuit

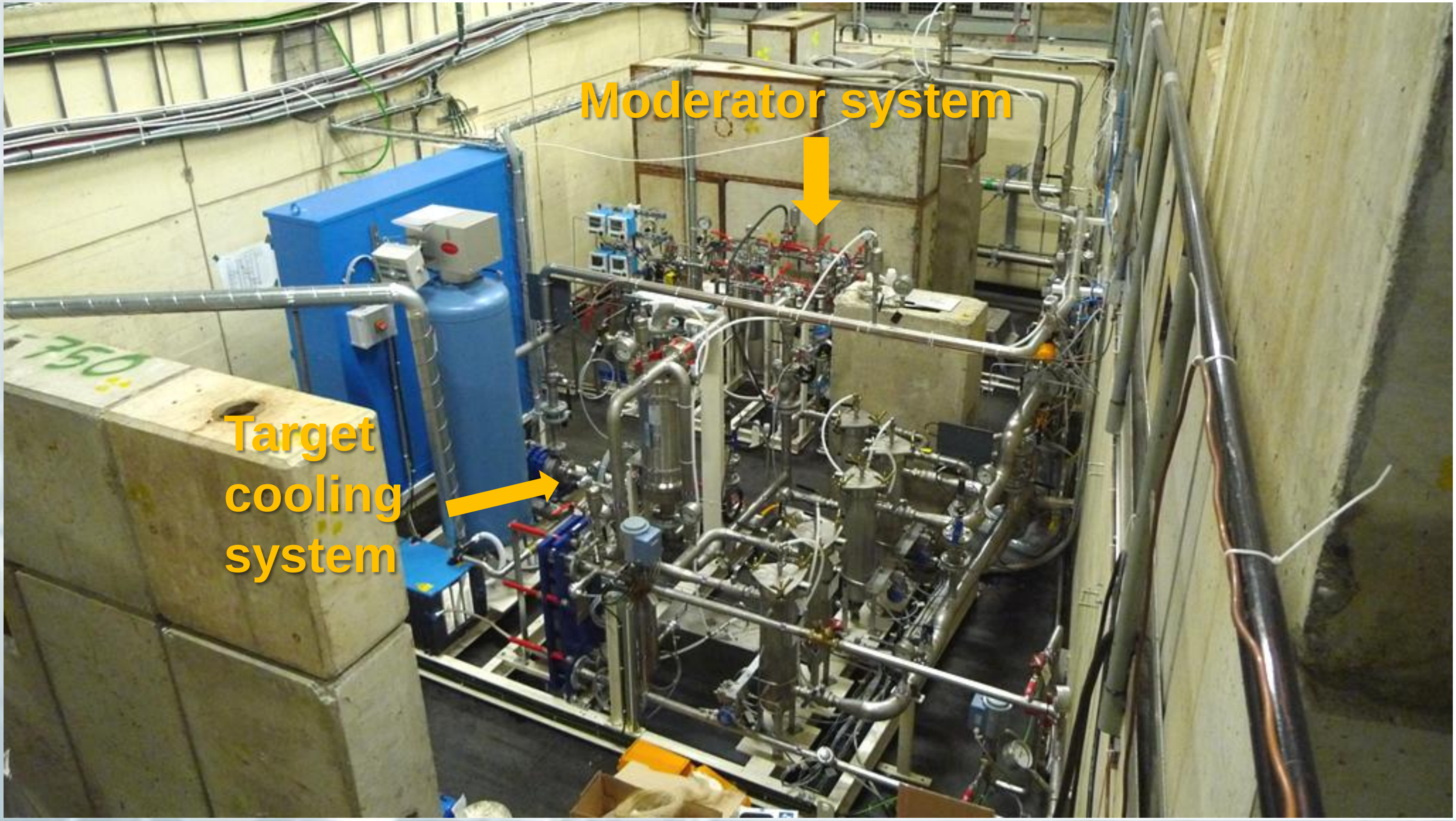
- Main contribution of γ background was the 2.2 MeV $^{1}H(n,\gamma)$
- Solutions to replace water moderator with
  - borated water
    - **+** unaffected fluence and energy resolution >1eV
    - **-** 470 keV photons
  - heavy water
    - **+** increase fluence
    - **-** worse energy resolution
- Installed Separated circuit using enriched boric acid in saturation mode (44g/l @18°C) ~1.28% of H_3BO_3





Cooling and Moderator station

- The target and moderator circuits are **decoupled** and **work independently**



2008-9: Commissioning

Beam characteristics:

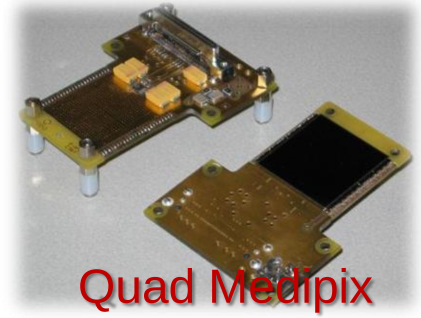
- Neutron fluence:
  PTB Fission Chamber ^{235}U
  uMegas: ^{235}U & ^{10}B
  SiLi, Gold foils
- Spatial distribution:
  Medipix with LiF & polyethylene
- Resolution function:
  C6D6 with $^{54,56}Fe$
- Background:
  CR-39, TLD, BaF_2 and C6D6

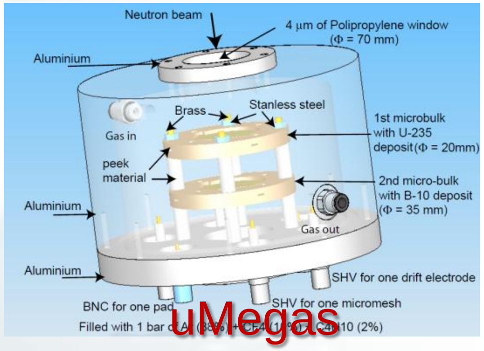
Cooling station:

- Monitor Performance
- Control O_2 level

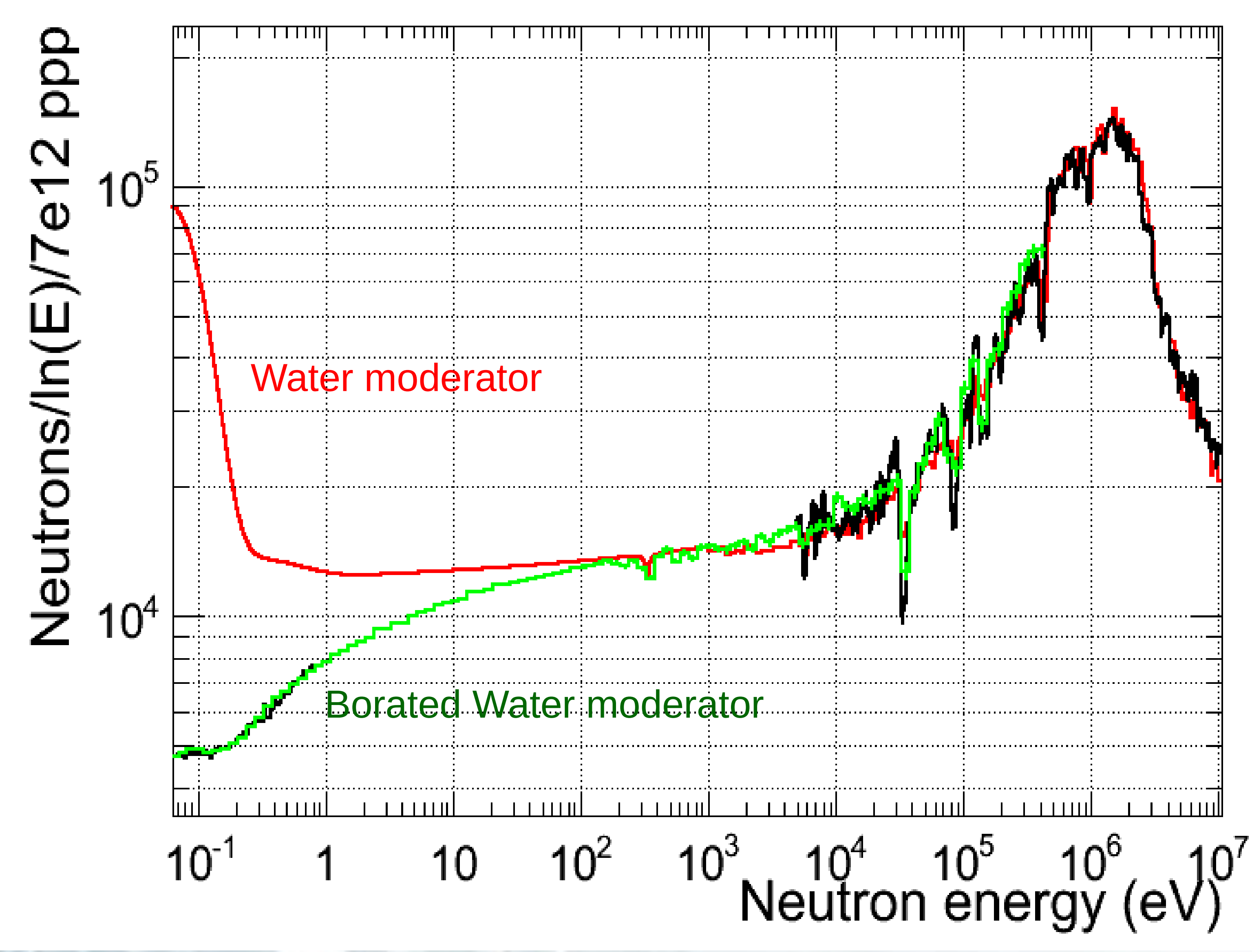
Requirements

- 2.5×10^{18} p
  ~1 month of beam time

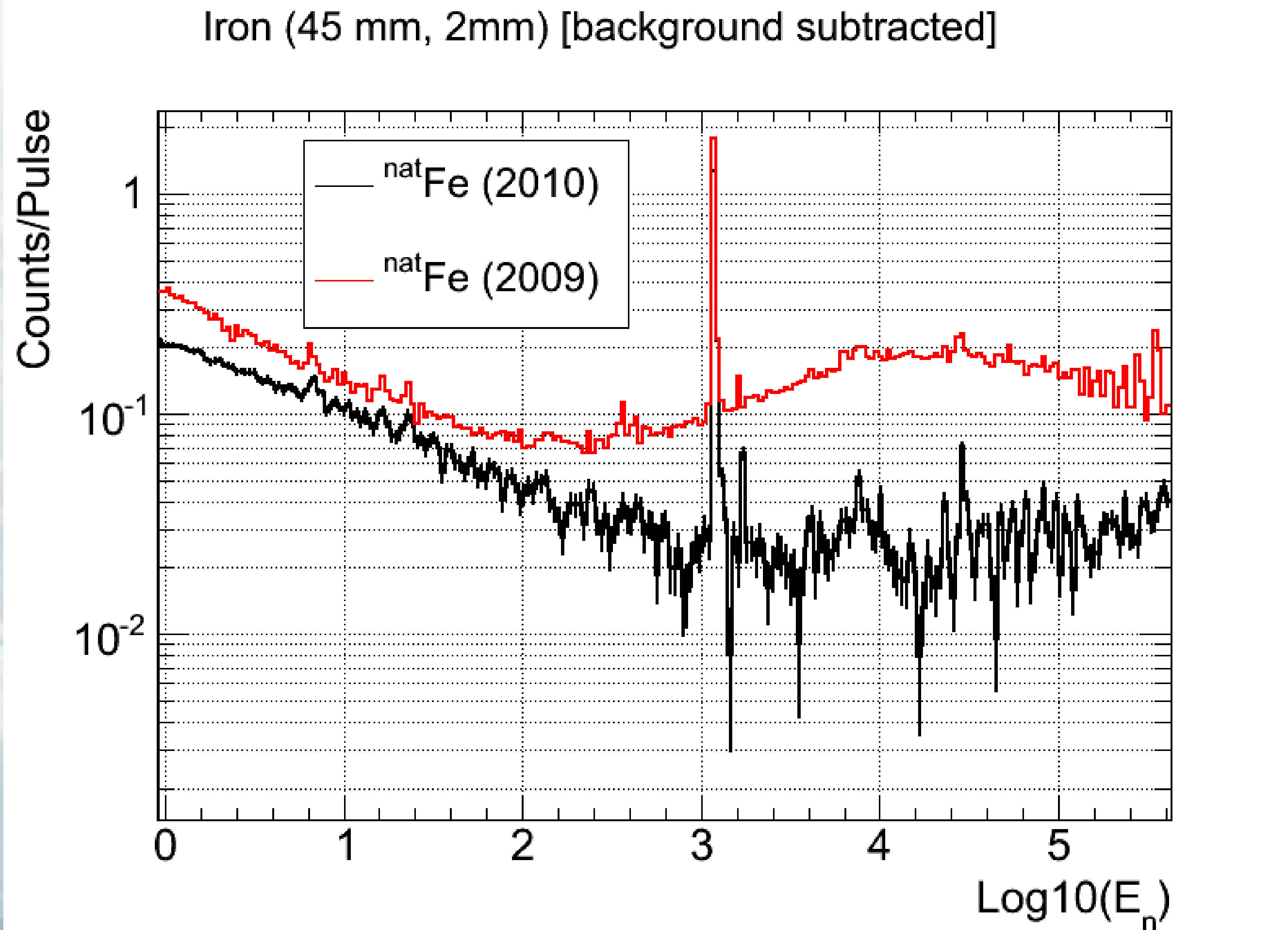




Neutron Fluence



Background



Iron (45 mm, 2mm) [background subtracted]
Counts/Pulse
1
10-1
10-2
natFe (2010)
natFe (2009)
0
1
2
3
4
5
Log10(En)

2009-2015: Phase II program

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)

2009-2015: Phase II program

Fission measurements	
MA $^{240,242}Pu$, ^{245}Cm, $^{241,243}Am$	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	
$^{147}Sm(n,\alpha)$, $^{67}Zn(n,\alpha)$, $^{99}Ru(n,\alpha)$ $^{58}Ni(n,p)$, 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~~

n_TOF facility Summary

Spallation Target

- New spallation target more robust than the past, with equal physics performarnces
- Borated water moderation system
  Elimination of the $^{1}H(n,\gamma(2.2\ MeV))$ → further improved signal-to-background conditions

Work Sector Type A experimental area

- → no major restrictions on radioactive samples measurement
- Significant improvement in measurement capabilities

2010-2015 experimental campaign

- Angular distribution of fission fragments with PPACs
- Capture measurements with C6D6 (Fe,Ni,^{241}Am)
- Capture measurements on actinides with TAC (^{241}Am)
- Commissioning with borated water moderator
- Validation of simultaneous measurement of capture and fission reactions
- Measurement of the fission cross-section of ^{240}Pu and ^{242}Pu