Status of the n-TOF experiment

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On behalf of n_TOF collaboration
ITEMS

✓ Experimental campaign 2010

✓ Experimental campaign 2011

✓ EAR2 (experimental Area 2)

✓ Summary
Experimental campaign 2010: HIGHLIGHTS

The campaign 2010 has been excellent in terms of beam efficiency and innovation:

✓ First experimental campaign making use of the $^{10}$B-water moderation circuit

✓ First experimental campaign making use of the Work Sector Type-A (WSTA)

✓ Successful measurements of $^{54}$Fe $\sigma$(n,\(\gamma\))

✓ Successful measurement of $^{241}$Am (4GBq) combining TAC (4\(\pi\) BaF$_2$) + C$_6$D$_6$

✓ First test at n_TOF for measuring (n,lcp) with diamond (xCVD) detectors

✓ First n_TOF experiment for simultaneous (n,\(\gamma\))+(n,f): TAC+MGAS

✓ First n_TOF experiment for Angular Distributions of fission fragments (PPAC)

Results of ongoing analysis from 2009/10 campaigns already presented in several International Conferences /Workshops: ND-2010, EFNUDAT-2010, NPA-V, …
# Summary of the n_TOF-Ph2 experimental campaign 2010

<table>
<thead>
<tr>
<th>Document No</th>
<th>Proposal</th>
<th>Measurement</th>
<th>Detectors</th>
<th># Protons</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>-</td>
<td>Start Up</td>
<td>All</td>
<td>1.0E+17</td>
<td>18/5-21/5</td>
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<tr>
<td>CERN-INTC-2008-035</td>
<td>n_TOF-12: New target commissioning and beam characterization</td>
<td>$^{10}$B water commissioning</td>
<td>PTB, SiMon, MGAS, XY-MGAS, C6D6</td>
<td>2.1E+18</td>
<td>22/5-27/6</td>
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<tr>
<td>CERN-INTC-2006-012</td>
<td>n_TOF-13: The role of Fe and Ni for s-process nucleosynthesis ...</td>
<td>$^{54}$Fe(n,g)</td>
<td>C6D6</td>
<td>2.0E+18</td>
<td>28/6-2/8</td>
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<tr>
<td>-</td>
<td>Start up of the $^{241}$Am measurements: RP issues, high activity on detectors, etc.</td>
<td>$^{241}$Am(n,g)</td>
<td>C6D6</td>
<td>1.0E+18</td>
<td>3/8-18/8</td>
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<tr>
<td>CERN-INTC-2009-025</td>
<td>n_TOF-15: Neutron capture cross section measurements of $^{238}$U, $^{241}$Am and $^{243}$Am at n_TOF</td>
<td>$^{241}$Am(n,g)</td>
<td>C6D6</td>
<td>1.3E+18</td>
<td>19/8-7/9</td>
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<tr>
<td>-</td>
<td>Start up of the $^{241}$Am measurements: RP issues, high activity on detectors, etc.</td>
<td>$^{241}$Am(n,g)</td>
<td>TAC</td>
<td>4.0E+17</td>
<td>8/9-14/9</td>
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<tr>
<td>CERN-INTC-2009-025</td>
<td>n_TOF-15: Neutron capture cross section measurements of $^{238}$U, $^{241}$Am and $^{243}$Am at n_TOF</td>
<td>$^{241}$Am(n,g)</td>
<td>TAC</td>
<td>2.1E+18</td>
<td>15/9-10/10</td>
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<tr>
<td>CERN-INTC-2010-037</td>
<td>LOI: Validation of simultaneous measurement of capture and fission reactions at n_TOF</td>
<td>$^{235}$U(n,g), $^{235}$U(n,f)</td>
<td>TAC + MGAS</td>
<td>6.0E+17</td>
<td>11/10-18/10</td>
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<tr>
<td>CERN-INTC-20106-016</td>
<td>n_TOF-14: Angular distributions in the neutron-induced fission of actinides</td>
<td>$^{232}$Th(n,f), $^{235,238}$U(n,f)</td>
<td>PPAC</td>
<td>2.0E+18</td>
<td>19/10-23/11</td>
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<tr>
<td><strong>TOTAL 2010</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>1.16E+19</strong></td>
<td><strong>18/5-23/11</strong></td>
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</table>
Experimental campaign 2010: $^{62}\text{Ni}(n,\gamma)$

The unprecedented accuracy of the nTOF measurements solves the contradiction between different Cross Section Evaluations.
Experimental campaign 2010: Simultaneous \((n,\gamma)/(n,f)\)

- Fission tagging chamber fabricated at CERN
- Test experiment performed during a 7 days campaign

Fission tagging: TAC+MGAS

![](image1)

![Graph](image2)

(n,γ) dominated
Experimental campaign 2010: $^{241}\text{Am}(n,\gamma)$

✓ First ever measurement recording data from thermal to 1 MeV in a single shot!

$^{241}\text{Am}(n,\gamma)$ at n_TOF (100 BPD, $E_{\text{thr}}=280$ keV)

Counts/Pulse

$10^2$

$10$

$1$

$10^{-1}$ $1$ $10$ $10^2$ $10^3$ $10^4$ $10^5$ $10^6$

Neutron energy (eV)

$^{241}\text{Am}$

Dummy ($\text{Al}_2\text{O}_3$)

$\text{Al}$ Canning

Nothing in beam

$^{241}\text{Am}$ activity
Experimental campaign 2010: Ang. Distr. Of Fission Fragments

- PPAC with 10 parallel plate detectors tilted 45 degrees with respect to the beam.
- 9 samples: $^{235}$U, $^{238}$U, $^{237}$Np and 6x$^{232}$Th.
nTOF is planned to get 1.55E19 protons on target in 2011 for 1.6E19 requested.

Integrated Planned Intensity for the 2011 nTOF Run

(1.55x10^{19} foreseen for 1.6x10^{19} requested, based on inj. schedule V1.1)

Start of nTOF beam setting up in PS: Friday 11 March 2011
Start of nTOF beam delivery for physics: Friday 18 March 2011
Experimental campaign 2011: PLANS

The campaign 2011 will provide finally a total of $1.55 \times 10^{19}$ protons/year, which will allow to advance in most of the approved proposals.

Some innovations:
- First use of MGAS for measuring $^{33}\text{S} \sigma(n,\alpha)$: isotope for possible medical application
- First use of a large area pCVD diamond for $\sigma(n,\alpha)$ beyond the MeV frontier
- First use of MGAS for measuring $\sigma(n,f)$ at high energy: $^{240,242}\text{Pu}$
- First ever measurement of the radioactive $^{63}\text{Ni} \sigma(n,\gamma)$

The challenges will mainly come from:
- the use of new (or combinations) of detection systems
- the unprecedented aimed accuracy for the $^{238}\text{U}(n,\gamma)$ measurement:
  - 2-3% overall accuracy between thermal and 1 MeV!!

The n_TOF Collaboration will benefit from the arrival of new members:
- Oak Ridge National Laboratory (USA)
- IRMM Geel (Belgium)
- University of Zagreb (Croatia)
- University of Manchester
- University of York
- University of Thessaloniki

2/3 February 2011
## Preliminary n_TOF measurement plan for 2011

<table>
<thead>
<tr>
<th>INTC Reference</th>
<th>Measurement</th>
<th>Detector</th>
<th>Expected dates</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start Up</td>
<td>Varii</td>
<td>17/3 - 22/3</td>
<td></td>
</tr>
<tr>
<td>CERN-INTC-2006-012</td>
<td>$^{57}\text{Fe}(n, \gamma)$</td>
<td>C6D6</td>
<td>22/3 – 10/4</td>
<td></td>
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<tr>
<td>CERN-INTC-2010-067</td>
<td>$^{63}\text{Ni}(n, \gamma)$</td>
<td>C6D6</td>
<td>10/4 – 20/5</td>
<td></td>
</tr>
<tr>
<td>CERN-INTC-2010-037</td>
<td>$^{240,242}\text{Pu}(n,f)$</td>
<td>MGAS</td>
<td>10/4 – 20/5</td>
<td>In parallel with $^{63}\text{Ni}$ Splitted in half: 2011-2012</td>
</tr>
<tr>
<td>CERN-INTC-2009-025</td>
<td>$^{238}\text{U}(n, \gamma)$</td>
<td>TAC+C6D6</td>
<td>20/5 – 5/9</td>
<td></td>
</tr>
<tr>
<td>CERN-INTC-2010-065</td>
<td>$^{236}\text{U}(n,\gamma)$</td>
<td>TAC+C6D6</td>
<td>5/9 – 3/11</td>
<td></td>
</tr>
<tr>
<td>CERN-INTC-2010-061</td>
<td>$^{10}\text{B}(n, \alpha)$</td>
<td>pCVD</td>
<td>3/11 – 13-11</td>
<td></td>
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<tr>
<td>CERN-INTC-2006-016</td>
<td>FF Ang. Dist.</td>
<td>PPAC</td>
<td>13/11 - 23/11</td>
<td>Pending 5e17 p. from 2010</td>
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<tr>
<td>CERN-INTC-2010-023</td>
<td>$^{33}\text{S}(n,\alpha)$</td>
<td>MGAS</td>
<td>12/11 - 22/11</td>
<td>In parallel with PPAC</td>
</tr>
</tbody>
</table>

The total of $1.55 \cdot 10^{19}$ protons will be allocated in order to carry out a total of 8 measurements using:

- 11 different samples
- 5 detection systems
- 2 different collimator configurations
**EAR-2**

**New Experimental Area (EAR-2)**

~ 20 m

**EAR-1**
(at 185 m)

Flight-path length: ~20 m
at 90° respect to p-beam direction
expected neutron flux enhancement
drastic reduction of the $t_0$ flash

INTC Meeting 2/3 February 2011
Next generation neutron time of-flight facilities such as n_TOF2 … with unsurpassed neutron fluxes are necessary to perform such measurements [neutron capture cross sections … for unstable nuclei [which are] still not known with sufficient accuracy]. Pag.142

Europe has to date been well provided for in terms of neutron beams for neutron capture studies, with a number of active facilities and the recently upgraded n-TOF facility at CERN. However […] there is a need for a new generation of such facilities with greatly increased neutron fluxes and better TOF measuring capability Pag.146

Support to […] installations at large scale facilities that are unique to provide high quality nuclear data essential for nuclear energy applications should be guaranteed [as in the case of the] n_TOF at CERN with the construction of the short flight path … Page 179
Overview of the n_TOF spallation target area

EAR2 (@20 m from pit, above ground)

Technical gallery (@10 m from pit)

n_TOF target pit

ISR

Existing hole

To be built
Neutron Fluence
Experiments in EAR-2 can be performed:

- on very small samples
  (important to reduce mass of unstable samples and in cases where sample material is limited)

- on isotopes with very small cross sections
  (where signal/background ratio is crucial)

- in much shorter time
  (measurements can be eventually repeated to reduce systematic uncertainties)
From the transmutation projects (or future generation nuclear energy systems), the EAR2 would allow to measure the fission cross-section of Pu isotopes and minor actinides with half lives of a few tens of years.

Although short lived, it may be convenient to burn those actinides in future systems (either ADS or Gen IV fast reactors), together with their neighboring long-lived isotopes.

Important Candidates:
Fission Cross Section: $^{238}$Pu (87.7 y)/$^{241}$Pu (14.1 y) $^{244}$Cm (18.1 y)
Capture Cross Section: $^{242}$Am (141 y)/ $^{243}$Cm (29.1 y) and $^{231}$Pa (32400 y)
Nucleosynthesis by the slow neutron capture process represents a unique tool for studying the related abundances through the tight correlation with the experimental \((n, \gamma)\) cross sections.

The EAR-2 options for measurements of so far inaccessible reaction rates will provide a boost for our understanding of neutron capture nucleosynthesis during the He burning phases of stellar evolution, which played a crucial role in the history of the Universe, because they contributed half of the abundances between Fe and Bi.

**Important candidates for EAR-2:**

\(^{79}\text{Se}, \ ^{90}\text{Sr}, \ ^{93}\text{Zr}, \ ^{107}\text{Pd}, \ ^{135}\text{Cs}, \ ^{147}\text{Pm}, \ ^{163}\text{Ho}, \ ^{171}\text{Tm}, \ ^{182}\text{Hf}, \ ^{204}\text{Tl}\)
1. **Neutron fluence for neutron-induced fission and/or capture measurement on small masses**
   @ 20 m
   • 7-8*10^6 n/cm^2/pulse
   • >20 MeV 8-9*10^5 n/cm^2/pulse

2. **Testing of active electronic equipments for LHC and other applications.**
   @20 m
   >20 MeV 8-9*10^5 n/cm^2/pulse
   1 Pulse every 3 sec 5-10*10^10 n/cm^2/week

3. **Passive irradiation of (small) equipment in high fluence environment (ITER, IFMIF,...)**
   @1.5 m
   1-2*10^10 n/cm^2/pulse
   1 Pulse every 3 sec ⇒ ~ 3*10^15 n/cm^2/week
n_TOF Facility Summary

✓ Work Sector Type A experimental area
   Converted the actual experimental area to a Work Sector Type A → no major restrictions on radioactive samples measurement
   Significant improvements in measurement capabilities

✓ Operation of a borated water moderation system
   Improvements of $\gamma$ background conditions

✓ 2010 experimental campaign
   Program completed and analysis ongoing

✓ 2011 experimental campaign
   Official schedule under preparation

✓ EAR-2 (Experimental Area 2)
   Feasibility study ongoing

✓ Platform for n_TOF data dissemination in collaboration with the European Nuclear Data Evaluation Team (JEFF-NEA)