n_TOF Experimental Area 2 (EAR2) preliminary feasibility study

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1. INTRODUCTION

The unique features of the n_TOF neutron beam are the very high instantaneous neutron flux, the excellent TOF resolution, the low intrinsic backgrounds and the wide range of neutron energies, from thermal to some GeV.
These characteristics provide a unique possibility to perform neutron-induced cross-section and angular distribution measurements, for applications in nuclear astrophysics, nuclear reactor technology and basic nuclear physics.

The overall efficiency of the experimental program and the range of possible measurements could be significantly improved with the construction of a 2nd Experimental Area (EAR2), vertically located 20 m on top of the n_TOF spallation target (see Fig.1)
This possibility, already evocated in the past during the first phase of n_TOF was recently analysed in detail within the framework of an interdepartmental working group. During the last year, this group has considered in details the feasibility of the project and in particular clarification and better definition of the scientific case, expected characteristics of the neutron beam, civil engineering challenges and radiation protection issues. The present document is a brief and preliminary summary of the work and of the conclusions reached to date.

The configuration of the presently designed n_TOF Experimental Area 2 allows to measure neutron-induced reactions with the following advantages:
Reduction of γ-flash: Since most of the relativistic particles produced in spallation process and which generate the so-called "γ flash" are emitted in the forward direction, placing an experimental area at an angle of 90 degrees with respect to the primary beam axis strongly reduces the related background effects. The strong reduction of these signals, which for some detectors are masking the signal from neutron reaction for the first μs, opens the possibility to extend - in those cases - the measurement of neutron induced reactions up to higher energies with respect to what is presently achievable in EAR1.
Higher neutron flux: Being closer to the spallation target (flight path of 20 m) the configuration provides a higher instantaneous neutron flux with respect to the present neutron fluence in EAR1 (flight path of 185m from the spallation target); this is a clear advantage for the measurement of reactions on samples with very small masses or reactions with very small cross sections. The reduced energy resolution important for resolved resonances due to the smaller distance does not affect the measurements at high neutron energies (E_n> 100 keV).

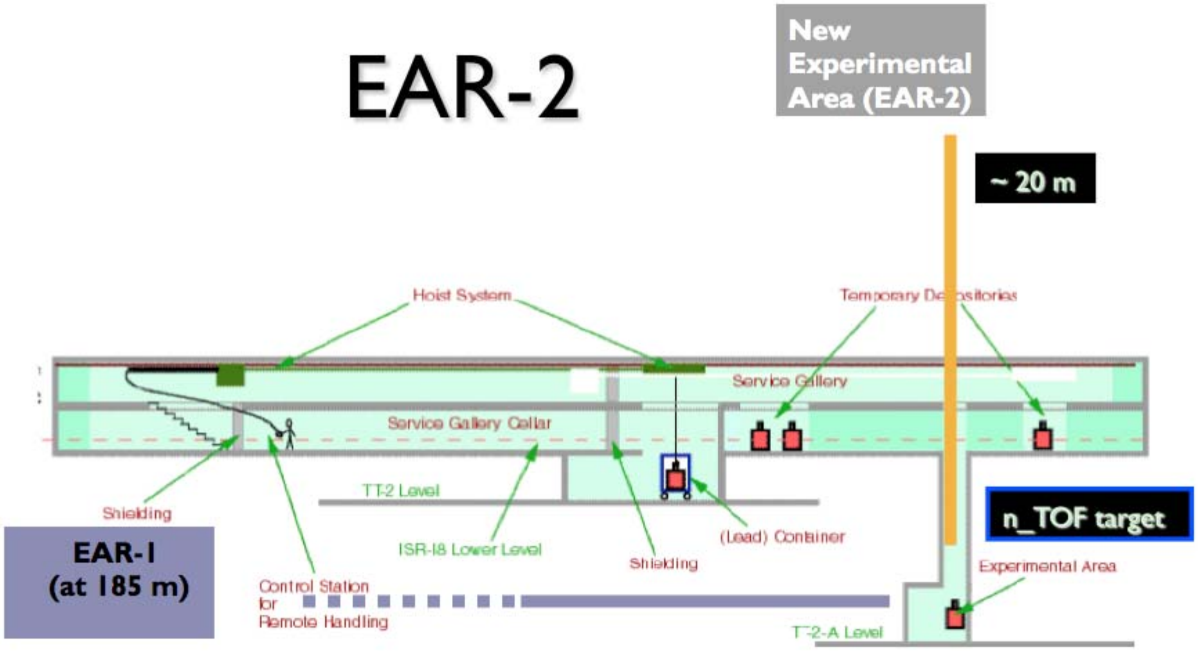

Fig.1 Experimental Area 2 (EAR2) schematic view

2. SCIENTIFIC CASE

The realization of the 2nd Experimental Area, with its short flight path, will contribute to a substantial improvement in experimental sensitivities and will open a new window to stellar nucleosynthesis, technological issues (such as transmutation or design of safety of future nuclear energy systems) and basic nuclear physics by allowing to measure neutron-induced reactions which are not accessible so far .

The main advantages of the 2nd Experimental Area are the following:

- Neutron-induced reaction measurements can be performed on very small mass samples. This feature is crucial to reduce the activity of unstable samples and in cases where the available sample material is limited.(ex. ^{238}Pu, ^{241}Pu ^{243}Cm, ^{244}Cm, ^{245}Cm, ^{242}mAm, ^{231}Pa, ^{233}Pa)
- Measurement can be performed on isotopes with very small cross sections for which the optimization of the signal/background ratio is an essential prerequisite.(ex. ^{86}Kr, ^{138}Ba, ^{140}Ce, ^{208}Pb)
- Measurement can be performed on much shorter time scales. Repeated runs with modified conditions are essential to check corrections and to reduce systematic uncertainties.
- Measurements of neutron-induced cross sections at high energies (E_n>10-100 MeV), which are not possible in the existing EAR-1, will benefit from largely reduced the γ-flash. This will be particularly important for measurements of (n, charge particle)

reactions at high energies because Si and Ge detectors are most strongly affected by the γ-flash.

3. CIVIL ENGINEERING STUDY

The function of the so-called bunker (see Fig.2 and Fig.3) is to house the Experimental Area 2 (EAR2). The bunker is envisaged to be approximately 7.9 m long 7.8 m wide.
The EAR2 will be located partly on top of the TT2 tunnel and partly on top of the ISR building (see Fig. 2). Due to the foreseen weight of the bunker of the Experimental Area, support pillars of roughly 12 meters will have to be built with the feet located on the concrete structure of the TT2 target foundations. This will require the opening of a trench of roughly 8 meters from the ground (at the maximum point), while the rest of the trench would be sitting on top of the ISR building. A venting chimney on top of the TT2 tunnel will have to be partly dismantled.

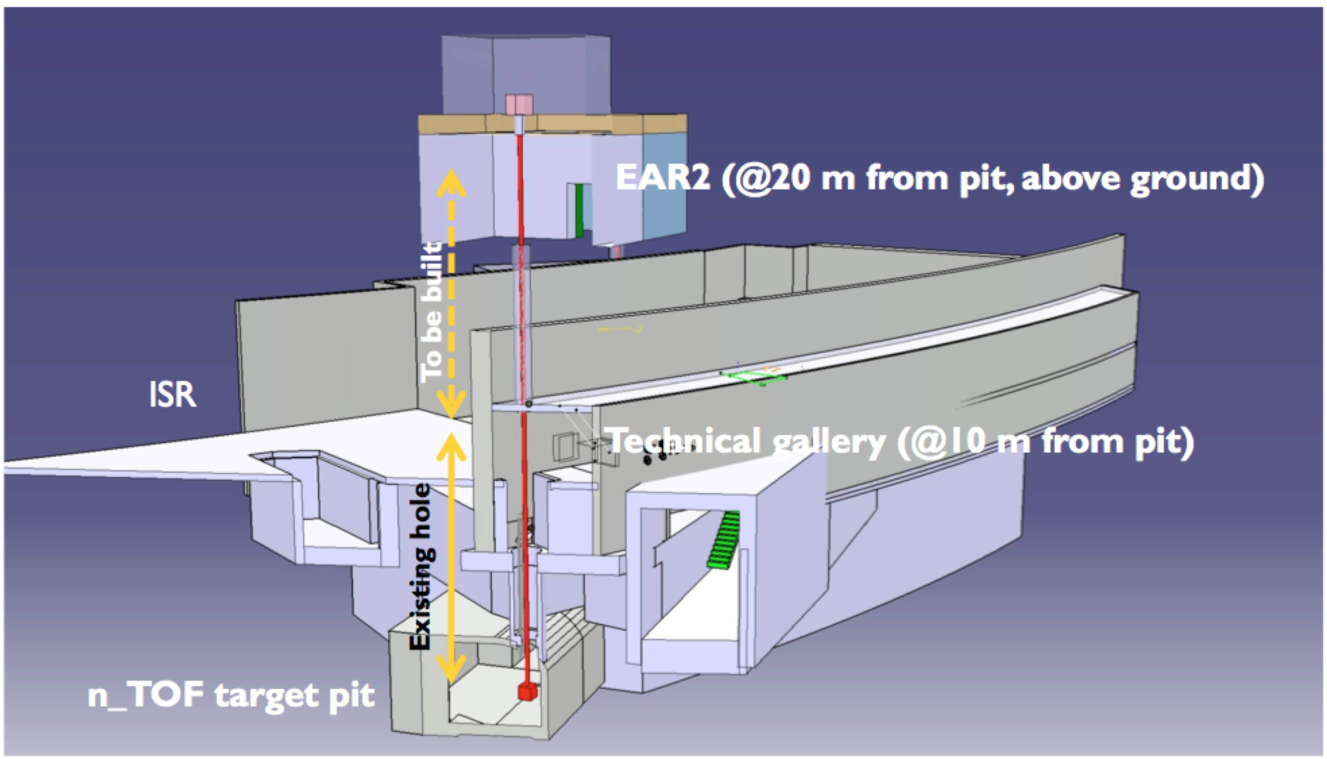

Fig. 2: Overview of n_TOF spallation target area

The walls and roof of the bunker will be made of concrete with a minimum thickness of 50 cm.
This design is optimized for n_TOF measurements, for which also a collimator will be put in place, and meets the requirements for radioprotection of the surrounding area during physics measurements.
A shield made of prefabricated blocks will be placed on the roof, surrounding the beam dump.
The bunker will be connected with the n_TOF underground facilities, in the TT2A tunnel, via a duct of 60cm in diameter.

Additional shielding for an upgrade of the facility for testing electronics components or material tests, which will be done without collimator can be implemented in a second building stage by adding a baseplate around the building and by positioning concrete shielding blocks as a wall around the facility as sketched in figure 3.

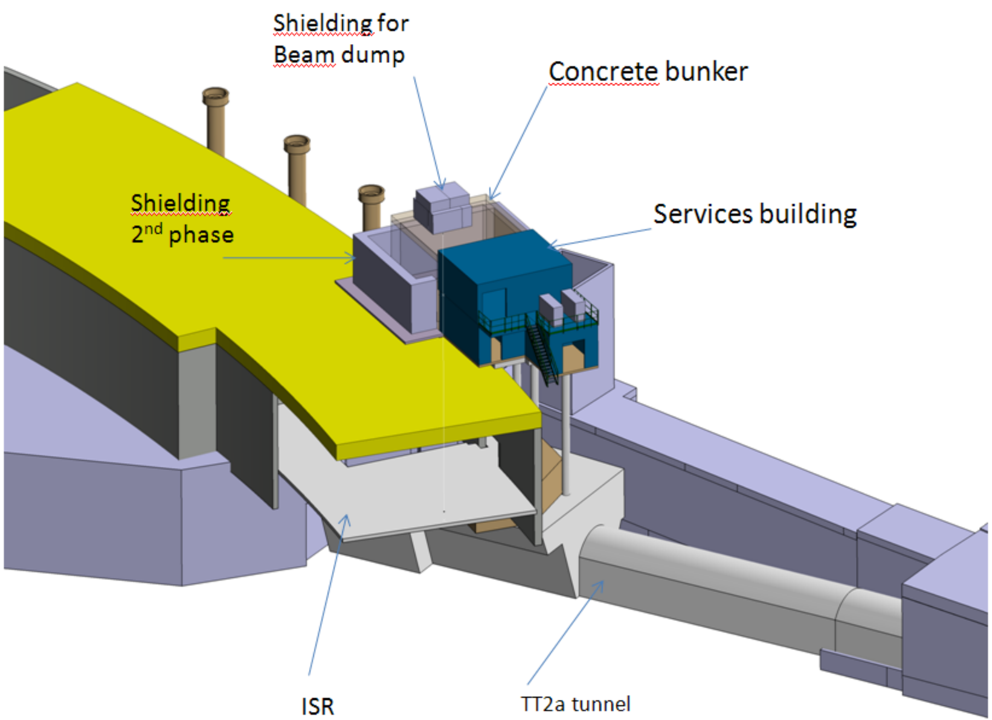

Fig. 3: n_TOF EAR2 surface and underground installations

4. MONTE-CARLO SIMULATIONS

In order to quantitatively assess the improvement with respect to the fluence achievable in the Experimental Area 1, a FLUKA Monte Carlo simulation has been performed. The geometry of the facility was set up according to the preliminary plans discussed with civil engineering (GS Department). A realistic neutron collimation system has been also implemented, in order to be representative of the foreseen experimental configuration at n_TOF.

The implemented collimator has a conical shape, with an inner diameter of 8 cm at the entrance to the experimental area, similar to the collimation used before the Experimental Area 1 during fission cross section measurements.
The results of the simulations for the neutron fluence per cm^2 of the facility (EAR2), in comparison with the existing n_TOF Experimental Area (EAR1) are shown in Figure 4.

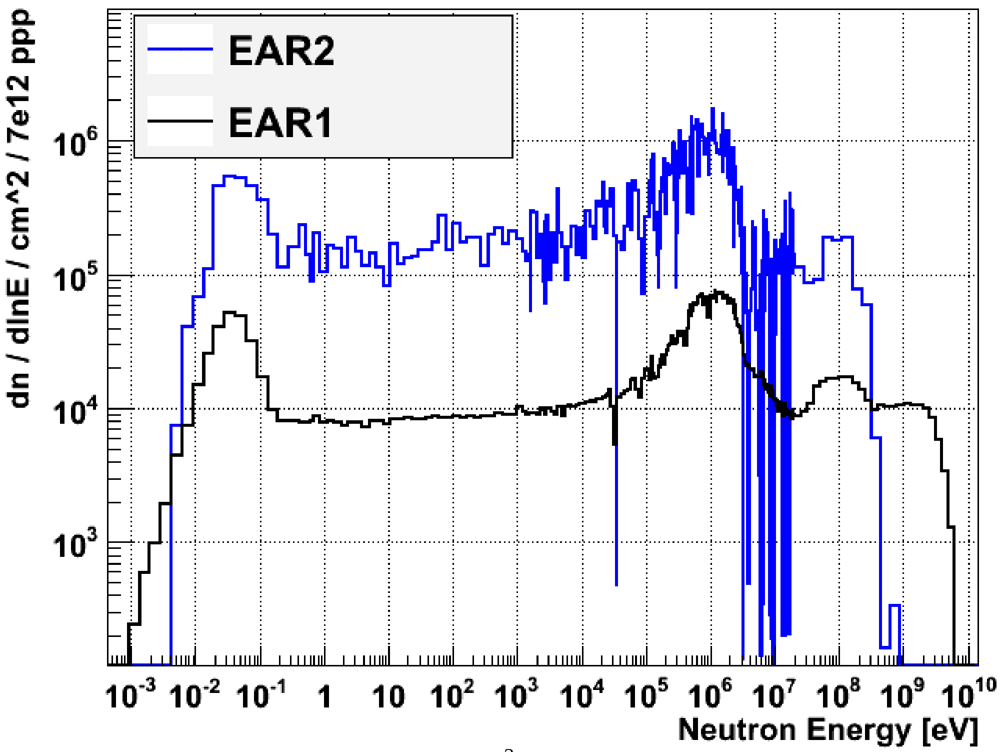

Figure 4: Simulated neutron fluence per cm^2 in the existing n_TOF experimental area (EAR1, black line) and in the proposed facility above the n_TOF target (EAR2, blue line).It is worth noticing that while the neutron spectrum extends up to several GeV for the EAR1, there is a sharp cut at ~300 MeV in EAR2.

The integrated neutron fluence per cm^2 in EAR1 and EAR2 for different energy intervals is listed in table 1.

Energy Interval	EAR2 n / cm^2 / pulse	Statistical uncertainty [%]	EAR1 n / cm^2 / pulse	Statistical uncertainty [%]	Gain
0.1 – 10 eV	7.11e5	3.4	5.11e4	0.3	13.8
10 eV – 1 keV	8.37e5	2.7	4.06e4	0.3	13.9
1 keV – 100 keV	1.03e6	2.7	5.03e4	0.2	20.6
0.1 – 10 MeV	2.52e6	1.6	1.77e5	0.1	20.5
10 – 100 MeV	3.48e5	3.8	2.64e4	0.3	14.3
Total range	6.47e6	1.19	4.68e5	0.08	13.2

Table 1: Integrated neutron fluence for EAR1 and EAR2. The fluence gain in EAR2 is between 13 and 20 with respect to the fluence available in EAR1.

The high dose and neutron fluence suggest to qualify the upgraded facility also for material irradiation tests in the neutron beam at 1.5 m close to the target. According to the simulations, a neutron fluence of 6.22e15 [neutrons/ cm^2 / week] is obtained 1.5 m above the target center, assuming a repetition rate of 1 pulse every 2.4 s for n_TOF.

5. RADIATION PROTECTION ANALYSIS

An analysis has been performed to determine the shielding requirements for the construction of the new experimental area at 90 degree from the n_TOF target (as regard to the proton beam direction) using the Monte-Carlo code FLUKA.
The experimental area is a shielded enclosure connected to the target by a new collimation system (entering the floor of the experimental area) which will be implemented inside the plug used to shield the pit presently dedicated to the target handling. The collimated neutrons will be absorbed inside a shielded beam dump which will be installed on the roof of the experimental area.

For the shielding design, it is either considered that all neutrons are intercepted inside the beam dump or that the neutrons are scattered in a thick target located inside the experimental area. It should be noted that when the facility will be used for experiments dedicated to cross section measurement, the majority of the neutrons will be intercepted inside the beam dump as the neutron absorption and scattering on the sample will be very small. The shielding criteria used for the determination of the experimental area wall thickness and the shielding necessary around the dump are based on a dose rate of 2.5 μSv/h considering that no permanent workplace is present in the vicinity. This dose rate value corresponds to a non-designated area; nevertheless as radioactive material will be used for experiments the area will still be classified from a radiological point of view.

The preliminary results show no major Radiation Protection problem has been encountered for the possible construction of the EAR2.

6. CONCLUSION

A new measuring station, so-called Experimental Area 2 (EAR2), has been proposed for construction at n _TOF. The project consists of a vertical flight path of 20 m from the lead spallation target and the EAR2 itself, where experiments would be performed. An interdepartmental working group was established 6 months ago and the preliminary outcome has been presented.

The neutron beam in the EAR2 will benefit from an increase of more than one order of magnitude in neutron fluence and a strong reduction of the γ-flash. These characteristics will enhance the capabilities of the facility and allow, among others,

a) the measurement of samples with very low mass or very high activity,
b) the measurement of neutron induced reactions up to higher neutron energies, and
c) the use of very thin samples suited for (n, charged particle) reactions, again to higher energies that in EAR1.

The radiation protection studies are ongoing and detailed results regarding shielding and the beam dump design have been already discussed. No show-stoppers have been identified so far. The irradiation of electronics components has also been envisaged and could further increase the range of possible application of the at n_TOF neutron beam.

The studies on the construction are carried out by the Civil Engineering group. A feasibility study has been performed and discussed along with a construction plan.

The working group continues working and a complete report is due in December 2011.

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