TRIUMF UCN Source Concept

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Nov. 6, 2007

1 Introduction

This is a summary of recent discussions on UCN source concepts. The starting point for these discussions is the conceptual sketch provided by Masuda (Fig. 1), which displays the important parts and some of the relative sizes of the UCN source.

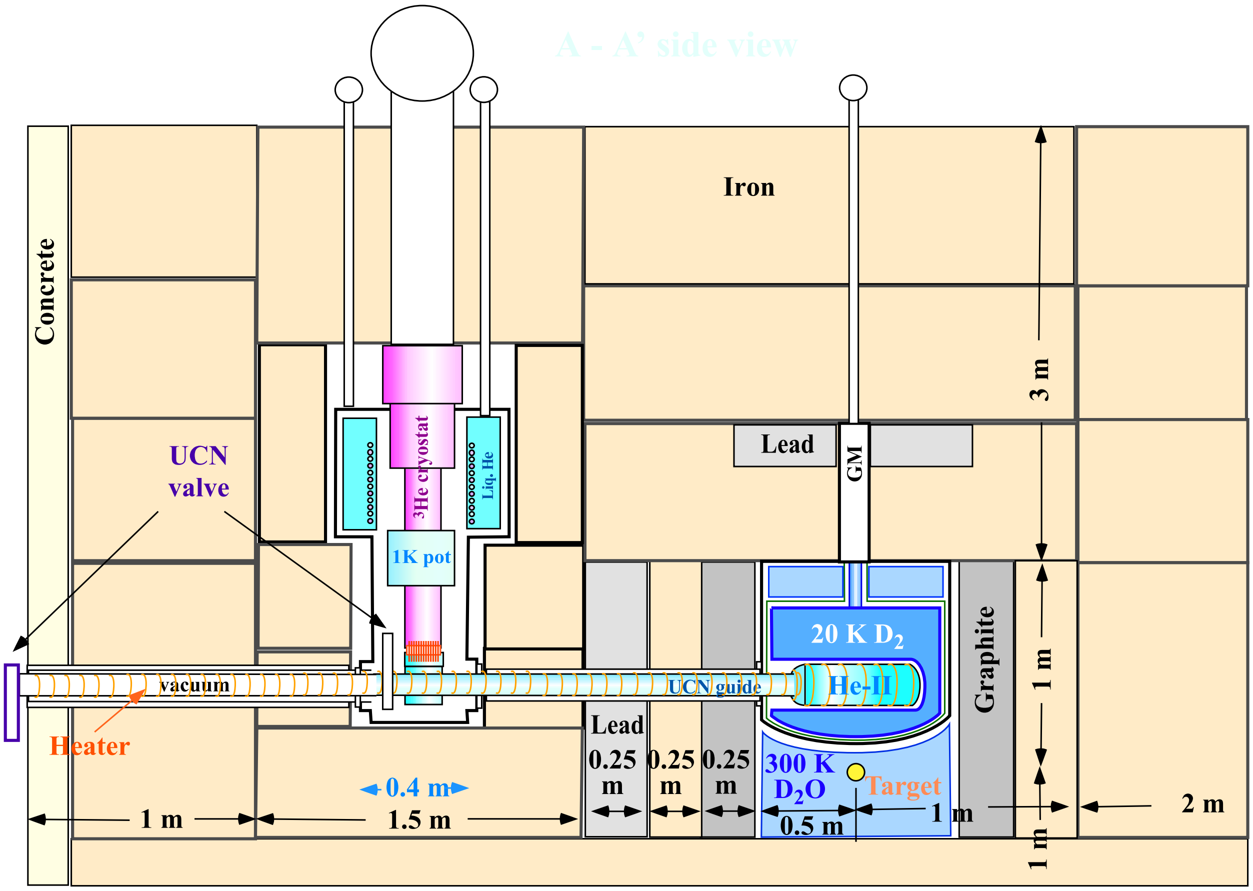

Figure 1: Masuda's conceptual sketch.

2 Beam Requirements

In the following discussion, we assume that the beam is a 40 uA proton beam at 500 MeV, representing instantaneous power of 20 kW. We further assume that the beam is pulsed in a 1 minute on / 3 minute of (25% duty cycle) fashion. In the final section, we comment on how this pulsing could be achieved.

3 Radiation Shielding, Target, and Remote Handling Requirements

The requirements for radiation shielding, target, target cooling, and remote handling are based on predominantly on experience from the LANL UCN source. They are in fair agreement with estimations based on comparison with RCNP, KEK, ISIS.

A revised schematic showing the radiation shielding requirements is shown in Fig. 2.

The target would be a 2 cm diameter, 10 cm long tungsten (W) target. The target would be cooled by flowing either gaseous helium or liquid water.

The target would be shielded on all sides by 3 m of steel, followed by 2 m of concrete.

After continuous operation at full beam current, the target would become too radioactive and would be disposed of. At Los Alamos, this was intended to occur once or twice per year, based on the acceptable activation level in the target to avoid onerous liscensing requirements. In such an instance, the target would be removed by remote handling. This would be accomplished by removing the concrete shielding blocks, then pulling a custom-made target assembly out through a hole in the steel shielding by crane. The activated section of the target handling assembly would then be placed into a cask for safe removal from the area.

No other remote handling would be required for other parts of the assembly, for example the cryostat. (At least this is the case for Los Alamos.) During commissioning, the UCN source would be run at a lower beam current, or in short runs, to avoid unnecessary activation, in the event that problems with the internal elements would be discovered.

Based on these requirements, we envision that a UCN source, constructed in an area free of existing shielding walls, would require a floor space of 12 x 12 m^2, as depicted in Fig. 2.

4 Cryogenics: He-II and D_2O

According to Masuda's Monte Carlo simulations and his estimations, the neutron flux, heat loads at a proton beam power of 12 kW are:

- 0.45 X 10^{12} n/cm^2/s in He-II,
- 2.3 W in He-II,
- 30-60 W in 20 K D2O,
- 1.7 kW in 300 K D2O,
- 12 kW in spallation target,

for his vertical source as it currently exists at RCNP, Osaka. The latent heat and saturated vapor presser of 3He at 0.8 K are: 34.5 J/mol, and 3 Torr, respectively.

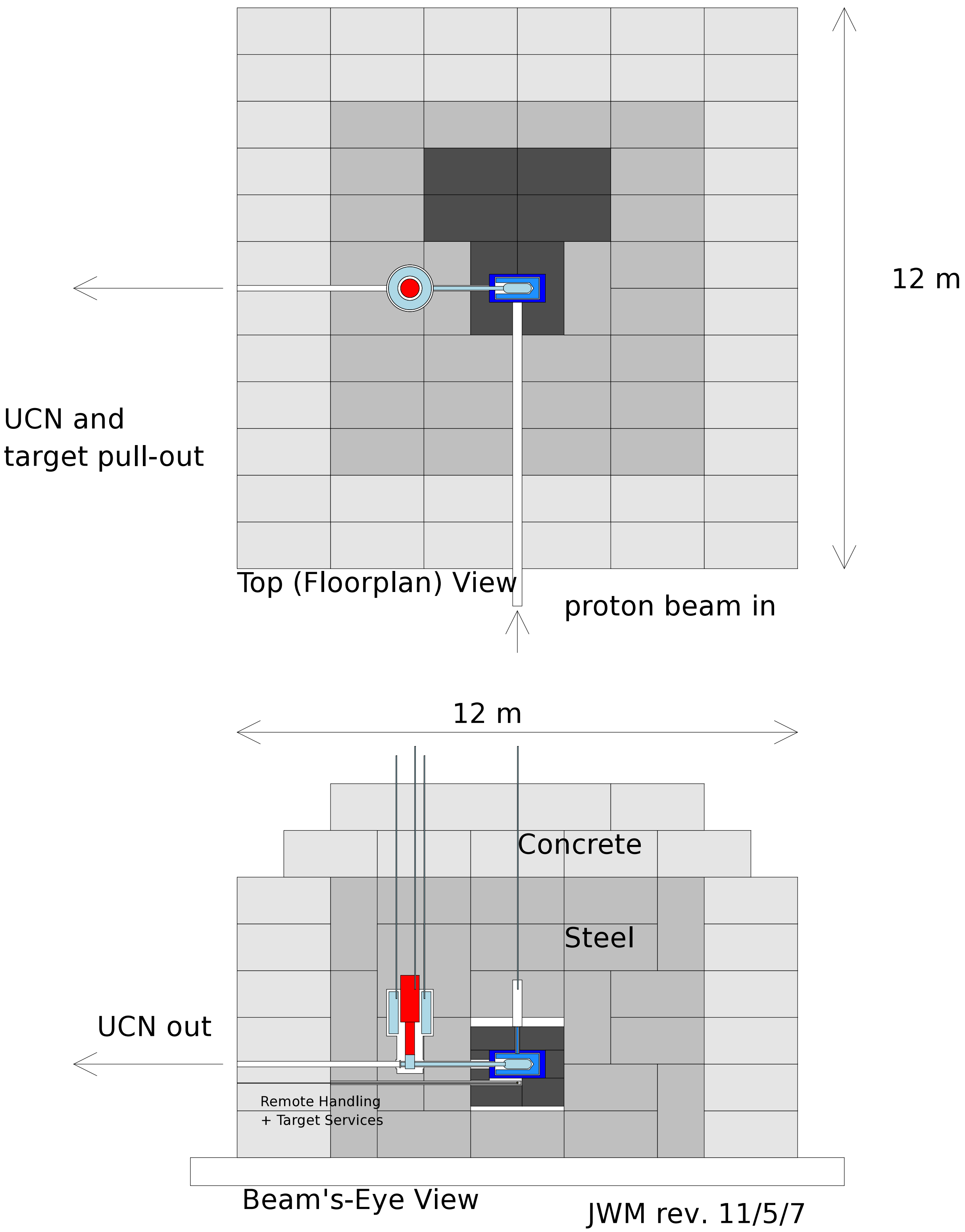

Figure 2: Revised sketch based on shielding and remote handling requirements consistent with the LANL UCN project. For labels of various items in this figure, refer to Fig. 1

Assuming a 3He gas pumping power of 5000 m^3/h, a cooling power of 8 W would be obtained. The pressure difference between the cryostat and the pump head has been neglected. If it becomes an issue, the gamma heating in He-II can be reduced by placing a gamma shield of ^{2}08Pb around the He-II. The gamma flux can be decreased by a factor 10 and neutron by 5 at a shield thickness of 5 cm. Cold neutrons, which are used for UCN production, pass through the Pb because of the Bragg cut off.

Therefore, we estimate that the instantaneous heat loads expected for 20 kW beam power are well within hand for TRIUMF.

5 Space Requirements

Based on the considerations above, the floorspace requirement for the UCN source is 12 x 12 m^2. Additionally, space is required to conduct the low-background physics experiments. We maintain our estimate of 6 x 12 m^2 for this space, consistent with previous estimates by Masuda.

Note that in order to remove the target by remote extraction, in this model, the EDM apparatus would have to be moved, as well, to give sufficient space for the extraction.

Beam pulsing (1 minute on / 3 minutes off) would be achieved by periodically diverting the proton beam to a well-shielded beam dump. The pulsing would be achieved using a fast kicker and septum magnet. Space requirements for those beamline elements have not been addressed at this time. Space requirements for the beam dump would likely be consistent with the size of the proposed UCN source. However, we hope that use can be made of alternate beam dumps, such as the one proposed for ISAC+.

6 Potential Layout at TRIUMF

A potential layout at TRIUMF is sketched in Fig. 3.

In this siting option we have attempted to include space for:

- UCN source, cryogenic elements, shielding, and remote handling of target
- space for two UCN experiments:
  - either a beta-decay (lifetime) or UCN gravity experiment
  - space for developments towards a future n-EDM experiment
- kicker magnet and septum magnet to achieve beam pulsing,
- "achromatic bend" for ISAC+,
- Electron Linac space.

The beam dump to which the beam would be diverted is assumed to exist on BL4N in the future ISAC+ target hall. It is proposed that this scheme should in principle allow for simultaneous running of ISAC+ and UCN, through various kicker/ion source manipulations on the kHz timescales acceptable to ISAC+ production targets.

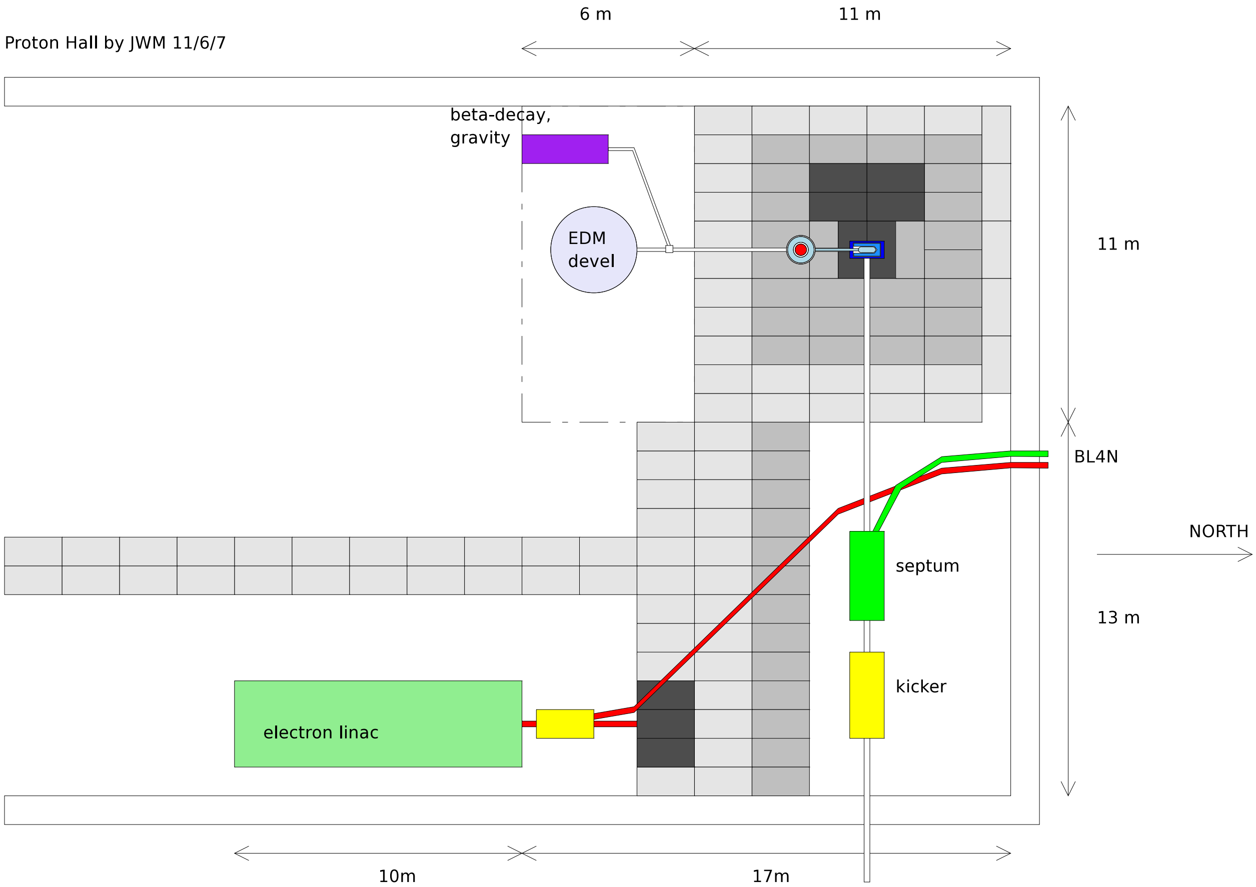

Figure 3: Potential layout in Proton Hall option. For figure description see text.

Note that in Fig. 3, there is a great potential for a common shielding design for the ISAC+ achromatic bend in BL4N and for UCN. The current conceptual design does not attempt to take this into account (for example on the upstream side of the UCN source). We therefore regard the space requirements for shielding in that region as an overestimate.

All other cryogenic supplies and facilities (for example, compressors and helium liquefier) are assumed to be located elsewhere, such as outside the Hall.

Other siting options that have been considered are:

- ISAC+ target hall
- BL1 area (Meson Hall)
- additional BL5 port

Each possibility has various advantages and disadvantages.

For example, the ISAC+ target hall option would increase the relationship of the UCN project to ISAC+, and would potentially make the use of the ISAC+ dump more natural. However, it would potentially necessitate a corresponding increase in the size of the ISAC+ target station hall.