BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: Friday, March 29, 1996

TO: ESRC and RSC Sub-Committees minutes

FROM: E. Lessard ETL

SUBJECT: Uranium Foil Target Information

Attached are the uranium foil containment specifications and heat transfer calculations. Please review the information prior to the next meeting. A meeting will be scheduled as soon as the Users have prepared the pertinent electrical wiring sketches and window diagrams.

Experimental Safety Review
Sub-Committee

Foley, K.
Levesque, J.
Thern, R.

Radiation Safety Sub-Committee

Miltenberger, R.
Reece, K.
Schaefer, C.

Copy to:

Bunce, G.
Hackenberg, R.
Scaduto, J.

BNL E910

MEMORANDUM

Date:	3/27/96
To:	E. Lessard chairman ESRC/RSC Sub Committee
From:	E.P.Hartouni (E910/LLNL)
Subject:	E910 Uranium Foil Target

This memo addresses the concerns numbered 3. and 5. addressed in your memo of 3/18/96; specifically about the Uranium target container and heat transfer calculations, respectively.

The container design is pictured on the three attached sheets entitled "*E910 depleted* ^{238}U *target & holder*". This container is assembled by gluing the various components together, thus preventing the ^{238}U material from contact with any part of the experimental apparatus in E910. This particular target configuration should also allow the experimenters to separate interactions in the container's Al windows. An empty target holder will also be manufactured to allow for "target out" runs in which the ^{238}U is absent.

The heat transfer calculations use the following physical properties of ^{238}U:

heat capacity	27.665 J/K/mol (298.15K)
thermal conductivity	27.6 W/m/K (300K)
coefficient of linear expansion	12.6×10^{-6} /K
density	18.950 g/cm^3
melting point	1405.5 K
boiling point	4018 K

(taken from *The Elements* 2nd edition, John Emsley, Claredon Press, Oxford, 1993)

The target dimensions are 6.35 cm × 6.35 cm × 0.1 cm. The calculations proceed as follows: estimate the energy loss of beam protons in the interaction volume defined by a cylinder with diameter equal to the beam diameter and length equal to the target thickness, us the heat capacity of the target to estimate the rate of temperature increase of the interaction volume, then estimate the rate of temperature increase if the volume is taken to be the entire target.

The beam is no less then 1 mm in diameter, and has a maximum intensity of 1×10^6 protons/second. The beam momentum ranges from 10 to 20 GeV/c. At these energies, the target has an interaction length of:

$$\ell=\lambda_{int}/\rho$$

where λ_{int} is given as 199 g/cm^2 (taken from the Review of Particle Properties), which gives ℓ a value of 10.5 cm. Thus we expect roughly only 1% of the incident beam to interact (by the strong interaction) in the target. The average multiplicity of interactions at these energies is low (typically a few particles per inelastic interaction), thus we shall neglect the energy deposited by secondaries created in interactions. The proton beam deposits energy in the target by ionization energy loss, the dE/dx for a minimum ionizing particle is 1.082 MeV/(g/cm^2). There is a 7% increase in this number due to the fact that 20 GeV/c protons are not minimum ionizing, the ionization is increased due to the relativistic rise (see the Review of Particle Properties for a more detailed description). To estimate the total energy lost by a single proton traversing the target:

$$\Delta E = dE/dx \times \rho \times l = 1.082\ \text{MeV/(g/cm}^2) \times 1.07 \times 18.95\ \text{g/cm}^3 \times 0.1\ \text{cm} = 2.2\ \text{MeV}.$$

Recalling that 1 MeV = 1.6×10^{-13} J, this gives $\Delta E = 3.5 \times10^{-13}$ J. At the maximum beam intensity the power deposited into the target is:

$$P = \Delta E \times \text{Beam Intensity} = 3.5 \times10^{-13}\ \text{J/proton} \times 1\times10^{6}\ \text{protons/sec} = 3.5 \times 10^{-7}\ \text{W}.$$

To calculate the rise in temperature of the target the specific heat must be converted to a volumetric measure:

$$C_v = C_p \times \rho / A = 27.665\ \text{J/K/mol} \times 18.95\ \text{g/cm}^3 / (235\ \text{g/mol}) = 2.23\ \text{J/K/ cm}^3$$

The interaction volume is given by:

$$V = \pi \times (0.05\text{cm})^2 \times 0.1\ \text{cm} = 7.85 \times 10^{-4}\ \text{cm}^3$$

The rate of change of the temperature in the interaction volume alone will be:

$$\Delta T/\Delta t = P / (C_v \times V) = 3.5 \times 10^{-7}\ \text{W} / (2.23\ \text{J/K/ cm}^3 \times 7.85 \times 10^{-4}\ \text{cm}^3) = 0.0002°\ \text{C/s}$$

(recall that changes in temperatures in absolute [K] are the same as in centigrade [C]). Thus for a two day run at 50% duty cycle the interaction volume would increase in temperature by 86400 s × 0.0002° C/s = 17.28° C. **NOTE** that this calculation does not take into account the total target volume, into which the heat will disperse nor the thermal coupling of the target to the target holder, nor the heat radiated by the target, nor the convective heat transfer to the gas in the holder. If the heat did not transfer to the rest of the target then the increased temperature of the interaction volume alone would be quite reasonably within safe limits.

The total target volume is 4.03 cm^3 which would give $\Delta T/\Delta t = (3.89 \times 10^{-8})°$ C/s for the entire target, and a 0.003° C rise in target temperature over the 48 hour beam exposure. Once again, this does not take into account the fact that the target is in thermal contact with the target holder, etc.

In conclusion, the heating of the target due to the beam under the worst case exposure condition would not change the target temperature noticeably above its ambient temperature.

BROOKHAVEN NATIONAL LABORATORY

M E M O R A N D U M

DATE:	Monday, March 18, 1996
TO:	ESRC and RSC Sub-Committees
FROM:	E. Lessard
SUBJECT:	ESRC/RSC Sub Committees on Proposed Use of U Foil at E910

On Friday, March 15, 1996, two sub-committees met to review a proposal by E910 touse a 1 mm thick U foil inside the EOS TPC. E. Lessard, R. Thern, E. Hartouni, K. Foley, K. Reece, J. Scaduto, R. Hackenberg, J. Levesque, C. Schaefer and R. Miltenberger were present.

Facts Presented

1. A uranium-238 foil 1 mm thick and about 2.5 inches by 2.5 inches will be mounted inside a re-entrant volume being assembled inside the EOS TPC.
2. The re-entrant volume will contain: the U-238 foil, pre-amps, phototube bases, wiring, scintillating fibers and scintillator plastic. Thus, the volume will contain an ignition source plus combustible items.
3. The re-entrant volume will have mylar windows separating the P10 counting gas from the re-entrant volume.
4. P10 counting gas inside the EOS TPC is argon and 10% methane.
5. Uranium is pyrophoric; that is, fine pieces will spontaneously ignite. Uranium is highly toxic if inhaled and 250 mg is lethal. U-238 is naturally radioactive at about 0.4 mCi per gram. Additionally, about 1 mCi of spallation products may be produced during irradiation from 1x106 p/s for two weeks.
6. The smallest beam size estimated to be possible is 1 mm [Note that this number is different from the original memo and reflects additional information from *G.Bunce*].

Concerns

1. The uranium is accountable nuclear material. Prior to bringing it to BNL, the *Users* shall contact *K. Dahms* (x4051).
2. A 'material custodian' shall be assigned. This person shall be the responsible authority in order to ensure contamination checks are performed and to ensure the target is moved on and off site according to the rules. (*Users*)
3. There is concern regarding the potential for contamination, both in a fire or if the target should become broken and dispersible. A containment should be placed around the target; a 0.004 inch or more thick can with Al walls may be acceptable. The 'material custodian'chosen by the *Users* shall ensure the target is not removed from its containment while it is at BNL. Contact *E. Lessard* (x4250) when the containment design is ready for review. (*Users*)
4. Dry nitrogen should be flowed through the re-entrant volume while the target is in place. (*J. Scaduto, Users*)

5. Heat transfer calculations for beam on U-238 metal should be performed for the worst case beam size, worst case spill length, and worst case proton intensity possible for this beam line.
6. *AGS HP* (x4660) shall be notified with regard to all on-site movement of this target. (*Users*)
7. Smears of the containment shall be taken before and after irradiation, and the re-entrant cavity shall be checked for contamination. (*Users, HP*)
8. The fusing for the wiring leading to detector components that are inside the re-entrant cavity shall be reviewed by the *ESRC*. Contact *E. Lessard* (x4250) when the wiring diagrams or sketches are ready. (*Users*)
9. Windows for the interface between P10 gas and the re-entrant cavity shall be reviewed by the *ESRC*. Contact *E. Lessard* when ready. (*Users*)