

# An Update on Target Window Backgrounds and Runtime Requirements

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August 26, 2009

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## **Abstract**

This technical note updates the target window background estimates and beamtime requirements based on a new GEANT3 target geometry and new information about realistic target window thicknesses. The two geometries compared in this note are an all Aluminum scenario with a 4 mil upstream window and a 5 mil downstream window, and a Beryllium-Aluminum hybrid scenario with a 15 mil Beryllium upstream window and a 5 mil Aluminum downstream window. This differs from previous notes in which upstream windows of 5 mils for Aluminum and 10 mils for Beryllium were used. A “worst case” scenario for the Aluminum target window backgrounds is also discussed which assumes the background from Aluminum target windows is twice what is simulated due to inelastic transitions and high-Z contamination of the Aluminum alloy that are not currently taken into account. At the current nominal Lower X = 319 cm, the backgrounds for the two cases are 30.9% (all Aluminum) and 26.0% (hybrid). With an error budget of 0.7% for backgrounds the time requirements to reach the needed statistical accuracy for these cases are 20.3 beam days (all Aluminum) and 15.8 beam days (hybrid). In the worst case scenario, the time requirements increase to 40.2 beam days and 23.3 beam days for the all Aluminum and hybrid cases, respectively. The results still support the hybrid geometry being a better option if it can be machined and pass safety reviews.

# 1 Introduction

Target window background estimates were updated based on new information regarding realistic target window thicknesses. The downstream Aluminum window remains a 5 mil thick Aluminum window. Two options for the upstream target window are presented: a 4 mil Aluminum window and a 15 mil Beryllium window. Previously, a 5 mil Aluminum window and a 10 mil Beryllium window were considered. For the background estimates and beam time requirements based on the old geometries, see [1], [2], and [3]. Detailed descriptions of the methods used to calculate the background estimates and runtime requirements can be found in the above references.

Another change in the GEANT3 geometry since the previous results were presented in [1] and [2] is the shape of the target cell. Before, a simple LH<sub>2</sub> filled cylinder of radius 2.5146 cm that was surrounded by 0.0254 cm of Aluminum was used. The geometry has since been updated to reflect a more realistic representation of the target cell. The target is now a LH<sub>2</sub> filled cone with an upstream radius of 1.56 cm and a downstream radius of 9 cm. The shape of the LH<sub>2</sub> filled volumes of these two geometries are shown in Fig. 1.

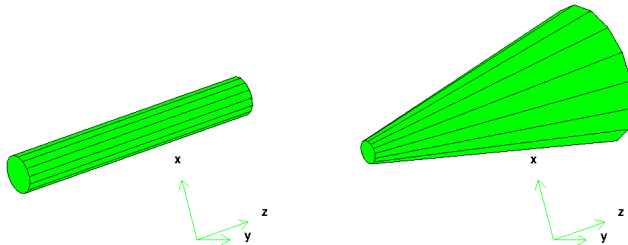


Figure 1: Comparing old (cylinder, left) and new (cone, right) target geometries.

An Aluminum cylinder of radius 15.24 cm encases the target cell. The geometry of the downstream window was updated to reflect a 5 mil Aluminum nipple of radius 0.75 cm (through which the scattered electrons pass) with 20 mil thick Aluminum extending from  $R = 0.75$  to 9 cm. Lastly, the downstream vacuum exit window was updated in both position and more importantly thickness, as the old geometry used 10 mils while the actual thickness is 30 mils.

# 2 Backgrounds

The target window backgrounds are presented for different “Lower X” values: this corresponds to the inner radius of the Čerenkov bar. The nominal location is currently Lower X = 319 cm, a value chosen for the factor  $BFIL = 1.04$ . Backgrounds from the “all Aluminum” scenario are shown in

Table 1 and backgrounds from the “hybrid Beryllium-Aluminum” scenario in Table 2.

In the previous report [2], it was found that using a 10 mil Beryllium window compared to a 5 mil Aluminum window reduced the total target window background by 41% (31%) for Lower X = 319 cm (324 cm). In the updated geometries the Beryllium window is 50% thicker while the upstream Aluminum window is 20 % thinner. Therefore, the overall reduction is now only 16% (12%) for Lower X = 319 cm (324 cm). However, recall the concerns raised in [1] about the uncertainty in the estimate of elastic scattering from Aluminum. The GEANT3 simulation does not include inelastic transitions, nor does it account for the high-Z contaminants present in the Aluminum alloy: namely 5.1-6.1% Zinc (Z=30) and 1.2-2.0% Copper (Z=29) [4, 1]. In a possible worst case scenario the backgrounds from Aluminum target windows may be twice the size of what is simulated currently.

Table 1: Target window backgrounds from a 4 mil upstream Aluminum window and a 5 mil downstream Aluminum window for different Lower X values.

Lower X (cm)	Upstream Window (%)	Downstream Window (%)	Total(%)
319	19.3	11.6	30.9
320	18.6	11.6	30.2
321	17.5	11.6	29.1
322	15.8	11.7	27.5
323	13.6	11.8	25.4
324	10.5	12.1	22.6
325	7.5	12.6	20.1

Table 2: Target window backgrounds from a 15 mil upstream Beryllium window and a 5 mil downstream Aluminum window for different Lower X values.

Lower X (cm)	Upstream Window (%)	Downstream Window (%)	Total(%)
319	14.4	11.6	26.0
320	13.9	11.6	25.5
321	13.1	11.6	24.7
322	12.0	11.7	23.7
323	10.3	11.8	20.1
324	7.9	12.1	20.0
325	5.6	12.6	18.2

### 3 Beamtime Requirements

The values of  $dA_{bkgd}/A_{bkgd}$  and corresponding runtime requirements presented in this note assume that the total background error budget has been raised to 0.7%. Recall from [3] that this error budget is split between the target window backgrounds and all other backgrounds, and further split between statistical and systematic uncertainties. These time requirements represent the beam time needed to achieve the statistical accuracy goal; whether or not the required systematic uncertainty can be achieved is another, very important, question.

A beam current of 60  $\mu\text{A}$  is assumed on dummy targets that are 4% radiators. If a different beam current can be used, then the times presented in these tables should be multiplied by 60  $\mu\text{A}$  divided by the beam current being used. The beam time requirements for the all Aluminum geometry and the hybrid Beryllium-Aluminum geometry are presented in Table's 3 and 4, respectively.

Table 3: Time requirements for the all Aluminum scenario assuming 60  $\mu\text{A}$  beam current and a 0.7% error budget constraint.

Lower X (cm)	$f_{up}$	$dA_{up}/A_{up}(\%)$ (statistical)	$\text{Time}_{up}$ (days)	$f_{down}$	$dA_{down}/A_{down}(\%)$ (statistical)	$\text{Time}_{down}$ (days)	Total Time (days)
319	0.0170	1.32	10.8	0.0107	2.05	9.5	20.3
320	0.0162	1.37	10.2	0.0107	2.08	9.2	19.4
321	0.0154	1.44	9.7	0.0107	2.09	9.0	18.7
322	0.0140	1.57	9.0	0.0107	2.11	8.7	17.7
323	0.0120	1.79	8.0	0.0108	2.13	8.4	16.4
324	0.0093	2.23	6.8	0.0111	2.15	8.2	15.0
325	0.0067	2.95	5.7	0.0116	2.14	8.4	14.1

For the current nominal Čerenkov location of Lower X = 319 cm, the time requirement for the all Aluminum case is 20.3 beam days compared to 15.8 beam days for the hybrid case. Moving the bars out radially by 5 cm to Lower X = 324 cm changes these times to 15.0 beam days for the all Aluminum case and 12.3 beam days for the hybrid case.

As mentioned in the previous Section, we can not rule out that the background from the Aluminum target windows could be twice the size as currently simulated. Under this situation, the beam time requirements for the Aluminum windows double and the required statistical uncertainty  $dA_{bkgd}/A_{bkgd}$  decreases. The results under this scenario are presented in Table 5 and Table 6 for the all Aluminum case and the Beryllium-Aluminum hybrid case, respectively.

Table 4: Time requirements for the Beryllium-Aluminum hybrid scenario assuming 60  $\mu\text{A}$  beam current and a 0.7% error budget constraint.

Lower X (cm)	$f_{up}$	$dA_{up}/A_{up}(\%)$ (statistical)	$\text{Time}_{up}$ (days)	$f_{down}$	$dA_{down}/A_{down}(\%)$ (statistical)	$\text{Time}_{down}$ (days)	Total Time (days)
319	0.0110	1.67	7.4	0.0107	2.19	8.4	15.8
320	0.0106	1.73	7.0	0.0107	2.20	8.2	15.2
321	0.0101	1.80	6.8	0.0107	2.21	8.0	14.8
322	0.0092	1.96	6.2	0.0107	2.23	7.8	14.0
323	0.0080	2.20	5.7	0.0109	2.23	7.7	13.4
324	0.0061	2.77	4.8	0.0111	2.26	7.5	12.3
325	0.0044	3.64	4.1	0.0116	2.23	7.7	11.8

Table 5: Time requirements for the all Aluminum scenario assuming 60  $\mu\text{A}$  beam current, a 0.7% error budget constraint, and Aluminum backgrounds that are twice what is currently simulated.

Lower X (cm)	$f_{up}$	$dA_{up}/A_{up}(\%)$ (statistical)	$\text{Time}_{up}$ (days)	$f_{down}$	$dA_{down}/A_{down}(\%)$ (statistical)	$\text{Time}_{down}$ (days)	Total Time (days)
319	0.0333	0.66	21.4	0.0211	1.03	18.8	40.2
320	0.0321	0.68	20.4	0.0211	1.04	18.4	38.8
321	0.0302	0.72	19.2	0.0211	1.05	17.9	37.1
322	0.0275	0.79	17.8	0.0212	1.06	17.4	35.2
323	0.0237	0.90	15.9	0.0215	1.06	17.0	32.9
324	0.0184	1.05	15.3	0.0220	1.12	15.1	30.4
325	0.0133	1.48	11.3	0.0229	1.07	16.7	28.0

The time required for the all Aluminum worst case scenario at Lower X = 319 cm is approaching half of the total beam time of the experiment at 40.2 beam (80.4 calendar) days. The requirements on  $dA_{bkgd}/A_{bkgd}$  for this case are also undesirable. If the bar is moved out by 5 cm to Lower X = 324 cm, then  $dA_{bkgd}/A_{bkgd}$  increases to 1% and the beam time requirement decreases to 30.4 beam (60.8 calendar) days. The Beryllium-Aluminum hybrid geometry is clearly better under the worst case scenario since only the downstream window is affected. The beam time requirements for the hybrid scenario are 23.3 beam (46.6 calendar) days and 19.2 beam (38.4 calendar) days for Lower X = 319 cm and Lower X = 324 cm, respectively.

Table 6: Time requirements for the Beryllium-Aluminum hybrid scenario assuming 60  $\mu\text{A}$  beam current, a 0.7% error budget constraint, and Aluminum backgrounds that are twice what is currently simulated.

Lower X (cm)	$f_{up}$	$dA_{up}/A_{up}(\%)$ (statistical)	$\text{Time}_{up}$ (days)	$f_{down}$	$dA_{down}/A_{down}(\%)$ (statistical)	$\text{Time}_{down}$ (days)	Total Time (days)
319	0.0110	1.51	9.0	0.0211	1.18	14.3	23.3
320	0.0106	1.56	8.7	0.0211	1.19	14.0	22.7
321	0.0101	1.63	8.3	0.0211	1.19	13.7	22.0
322	0.0092	1.77	7.6	0.0215	1.20	13.5	21.1
323	0.0080	1.98	7.0	0.0215	1.20	13.4	20.4
324	0.0061	2.48	6.0	0.0220	1.20	13.3	19.2
325	0.0044	3.23	5.2	0.0229	1.18	13.7	18.9

On a final note, the effect of target window background runtimes on the  $Q_{weak}$  figure of merit (the error on  $dQ_W^p/Q_W^p$ ) is shown in Fig. 2. The total beam time for the experiment is 2544 hours (106 days), with the typically quoted FOM value assuming all 106 days are on LH<sub>2</sub>. For the worst case all Aluminum scenario at the current nominal Lower X = 319 cm, 40 beam days on Aluminum dummy targets leads to an increase in the FOM from 4.1% to 4.8%.

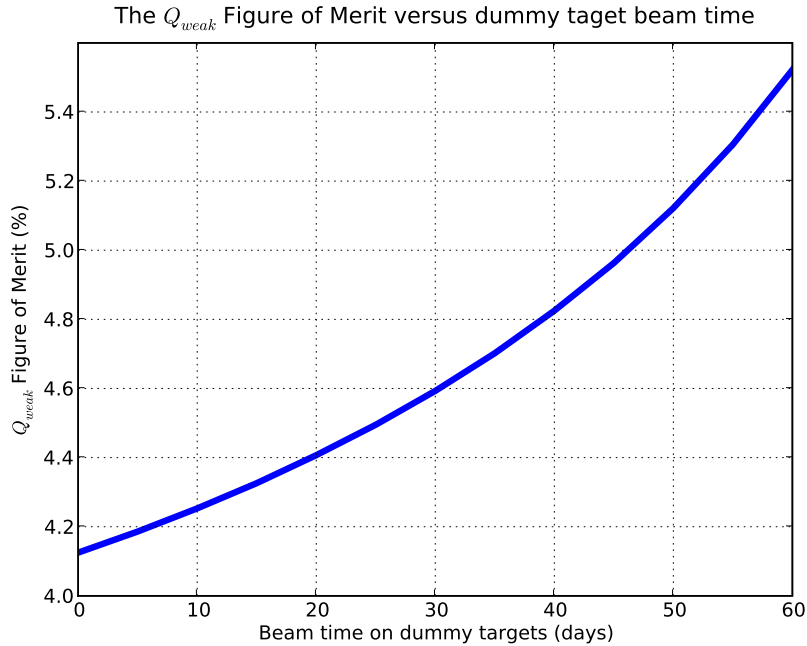


Figure 2: The  $Q_{weak}$  figure of merit versus target window beam time requirement.

## References

- [1] K.E. Myers, *The Aluminum Target Window Background in GEANT3*, Qweak-doc-947 (2009).
- [2] K.E. Myers, *The Beryllium Target Window Background in GEANT3 and a Comparison to Aluminum*, Qweak-doc-950 (2009).
- [3] K.E. Myers, *Target Window Background Runtime Requirements*, Qweak-doc-961 (2009).
- [4] G. Smith, S. Covrig, J. Mammei, and D. Meekins, *Qweak Target Cell: Exit Window Design Specs*, Qweak-doc-748-v2 (2008).