$H(e,e'p)$ **Study**

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Proton absorption

- The proton absorption is the percentage of protons that fail to form a coincidence trigger.

Table 4.8: List of cuts used in proton absorption estimate.

Variables	Cut
HMS PID	H.cer.npeSum>1 && 0.90 < H.cal.etottracknorm && H.cal.etottracknorm < 1.10
E_{miss}	-0.02 < P.kin.secondary.emiss && P.kin.secondary.emiss<0.04
δ_{HMS}	-6.0 < H.gtr.dp && H.gtr.dp < 8.0
x'_{tar},y'_{tar}	Graphical cut on HMS xptar and yptar shown in Fig 4-20
z_{tar}	abs(H.react.z)<3
y_{tar}	abs(H.gtr.y)<2
x_{fp}	-25<H.dc.x[0] && H.dc.x[0]<30
y_{fp}	-10<H.dc.y[0] && H.dc.y[0]<25
W	0.85 < H.kin.W && H.kin.W < 1.04

Courtesy to John Matter

A_{pred} = 8.56%

A_{exp} = 9.03 ± 0.71%

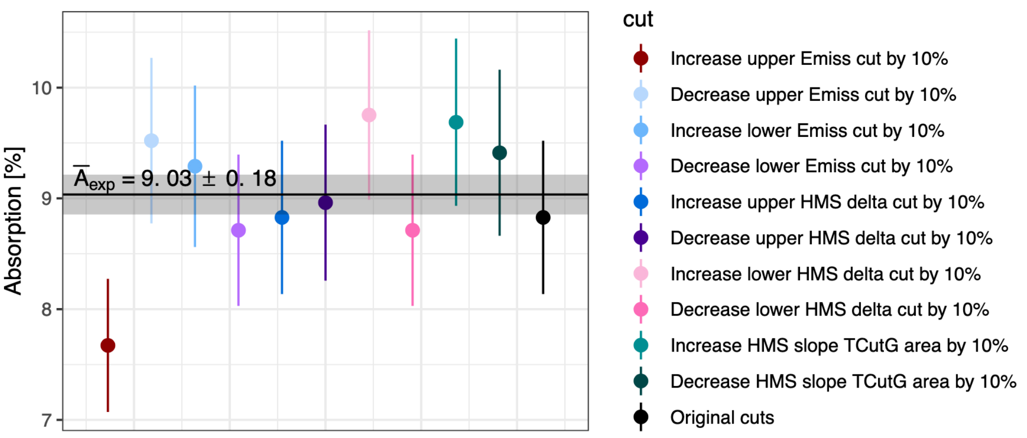


Figure 4-21: Values of absorption estimated with 10% variations on cuts used to select $H(e, e'p)$ events.

Proton absorption

	Component	Material	Thickness (inch)	Thickness (cm)	Density (g/cm^3)	X (g/cm^2)	T (g/cm^2)	_I (g/cm^2)	lambda_avg (g/cm^2)	X/lambda	% of total		% total for item
Target and spectrometer	LH2 (after scattering in 10cm loop)	LH2		5.00	0.070	0.35000	42.80	52.00	47.40	7.38E-03	9.29%		
	Scattering exit window	Al	0.005	0.01	2.700	0.03429	69.70	107.20	88.45	3.88E-04	0.49%		
	Air	Air		30.00	0.001	0.03675	61.30	90.10	75.70	4.85E-04	0.61%		
	HB entrance	Al	0.010	0.03	2.700	0.06858	69.70	107.20	88.45	7.75E-04	0.98%		
	Dipole exit	Al	0.020	0.05	2.700	0.13716	69.70	107.20	88.45	1.55E-03	1.95%		
													13.32%
NGCER	Entrance window	Tedlar	0.002	0.01	1.300	0.00660	61.70	90.30	76.00	8.69E-05	0.11%		
http://www.peopl	Gas	CO2 @ 1.0 ATM		200.00	0.002	0.39600	60.70	88.90	74.80	5.29E-03	6.66%		
	Mirror	SiO2		0.30	2.200	0.66000	65.20	97.80	81.50	8.10E-03	10.19%		
	Mirror support	Rohacell		1.80	0.110	0.19800	-	-	70.00	2.83E-03	3.56%		
	Exit window	Tedlar	0.002	0.01	1.300	0.00660	61.70	90.30	76.00	8.69E-05	0.11%		
DC	Entrance window	Mylar	0.001	0.0025	1.390	0.00353	58.90	84.90	71.90	4.91E-05	0.06%		
	Gas	50/50 Ethane/Ar	1.500	3.81	0.002	0.00587	68.60	101.00	84.80	6.92E-05	0.09%		
	Field Wire	W		0.00483	2.700	0.01303	69.80	108.00	88.90	1.47E-04	0.18%		
	Sense Wire	Be/Cu		0.00030	19.300	0.00582	110.00	185.00	147.50	3.95E-05	0.05%		
	Cathode	5 mil kapton	0.070	0.18	1.420	0.25248	59.20	85.50	72.35	3.49E-03	4.39%		
https://hallcweb.jla	Exit window	Mylar	0.001	0.0025	1.390	0.00353	58.90	84.90	71.90	4.91E-05	0.06%		
													4.84%
HODO	Scintilator plane (x2.25 [pe	PVT		1.13	1.032	1.16100	57.30	81.30	69.30	1.68E-02	21.08%		
HGCER	Entrance window	Al		0.10	2.700	0.27000	69.70	107.20	88.45	3.05E-03	3.84%		
	Gas	CO2 @ 1.0 ATM		104.44	0.002	0.20679	60.70	88.90	74.80	2.76E-03	3.48%		
	Mirror	SiO2		0.30	2.200	0.66000	65.20	97.80	81.50	8.10E-03	10.19%		
	Exit window	Al		0.10	2.700	0.27000	69.70	107.20	88.45	3.05E-03	3.84%		
													21.35%
AERO	Entrance window	Al		0.13	2.699	0.35086	69.70	107.20	88.45	3.97E-03	4.99%		
	Aerogel	Aerogel		9.00	0.200	1.80000	65.00	97.30	81.15	2.22E-02	27.92%		
	Air	Air		17.10	0.001	0.02103	61.30	90.10	75.70	2.78E-04	0.35%		
	Exit window	Al		0.16	2.700	0.43200	69.70	107.20	88.45	4.88E-03	6.15		
									SUM	7.95E-02			
									ABSORPTIC	7.64%			

3.8 and 4.9 GeV

n = 1.030, density = 0.14

7.02%

6.2 and 10.6 GeV

n = 1.015, density = 0.07

6.30%

8.2 GeV

n = 1.011, density = 0.05

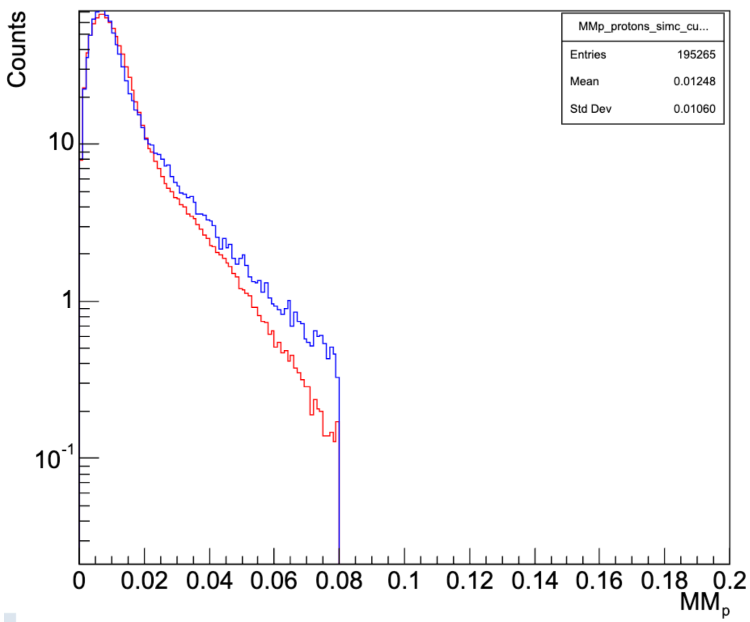
6.09%

HeeP Yield Ratio

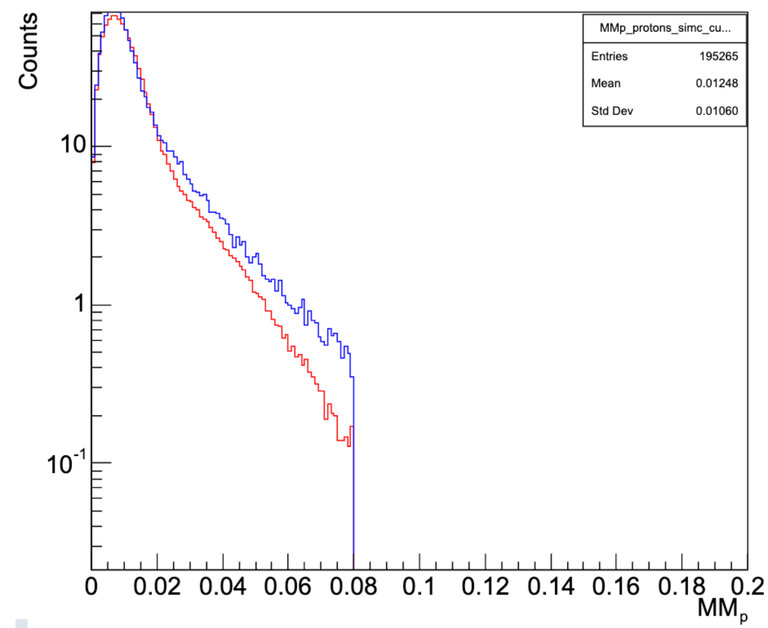
Beam Energy (GeV)	3.8	4.9	6.2	8.2	10.6
Without Proton absorption	1.023 +/- 0.007	1.017 +/- 0.007	1.048 +/- 0.007	1.056 +/- 0.007	1.048 +/- 0.006
With Proton absorption	1.100 +/- 0.008	1.094 +/- 0.008	1.119 +/- 0.008	1.124 +/- 0.008	1.119 +/- 0.006
With Proton absorption + MMp<0.02	1.054 +/- 0.008	1.040 +/- 0.007	1.078 +/- 0.008		0.894 +/- 0.006

$H(e, e'p)$ Data vs. SIMC 3.8 GeV

Without proton absorption



With proton absorption

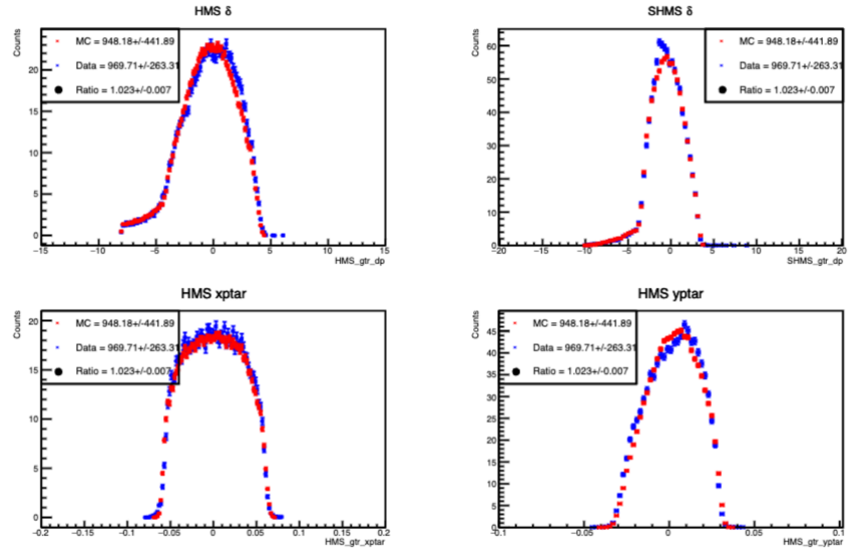


$H(e, e'p)$ Data vs. SIMC 3.8 GeV

Without proton absorption

HeePCoin Setting
Beam Energy = 3.834
Q^2 = 3.366
HMS_p = 2.026
HMS_theta = 38.600
SHMS_p = 2.583
SHMS_theta = 29.305
Red = SIMC
Blue = DATA

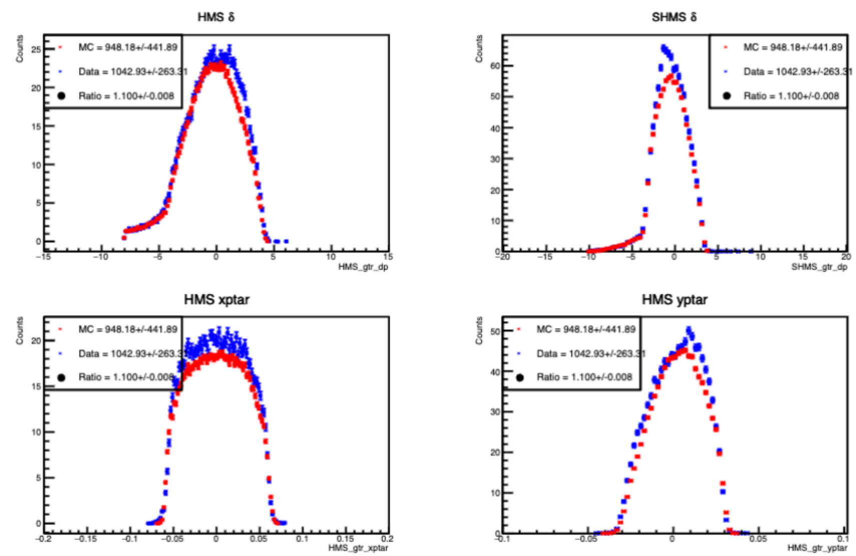
Data/SIMC Ratio = 1.023 +/- 0.007



With proton absorption

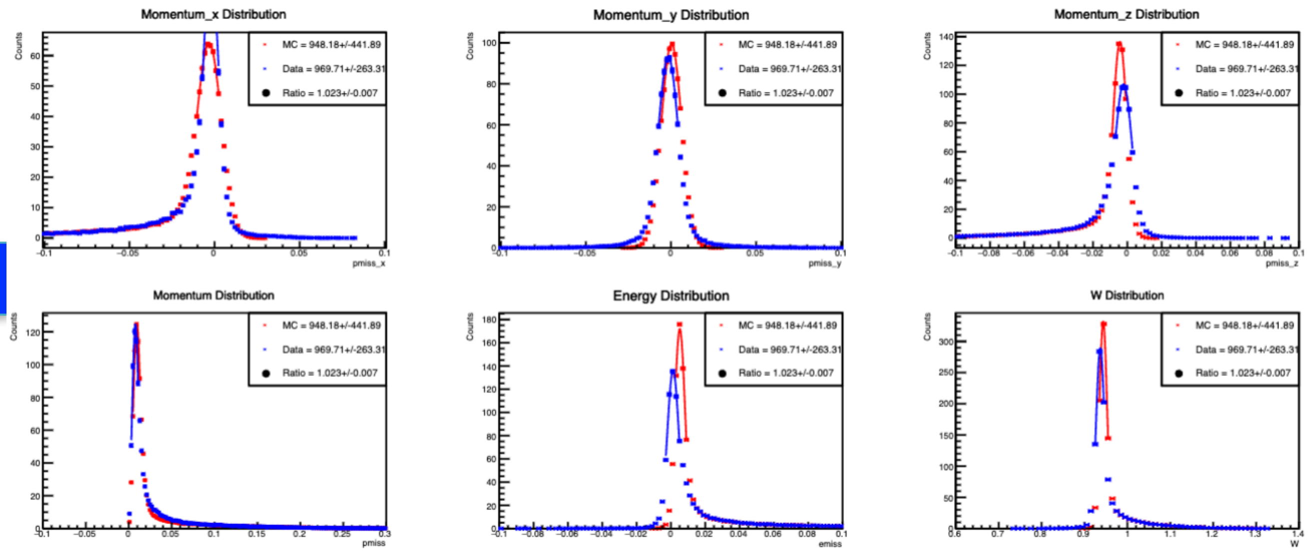
HeePCoin Setting
Beam Energy = 3.834
Q^2 = 3.366
HMS_p = 2.026
HMS_theta = 38.600
SHMS_p = 2.583
SHMS_theta = 29.305
Red = SIMC
Blue = DATA

Data/SIMC Ratio = 1.100 +/- 0.008

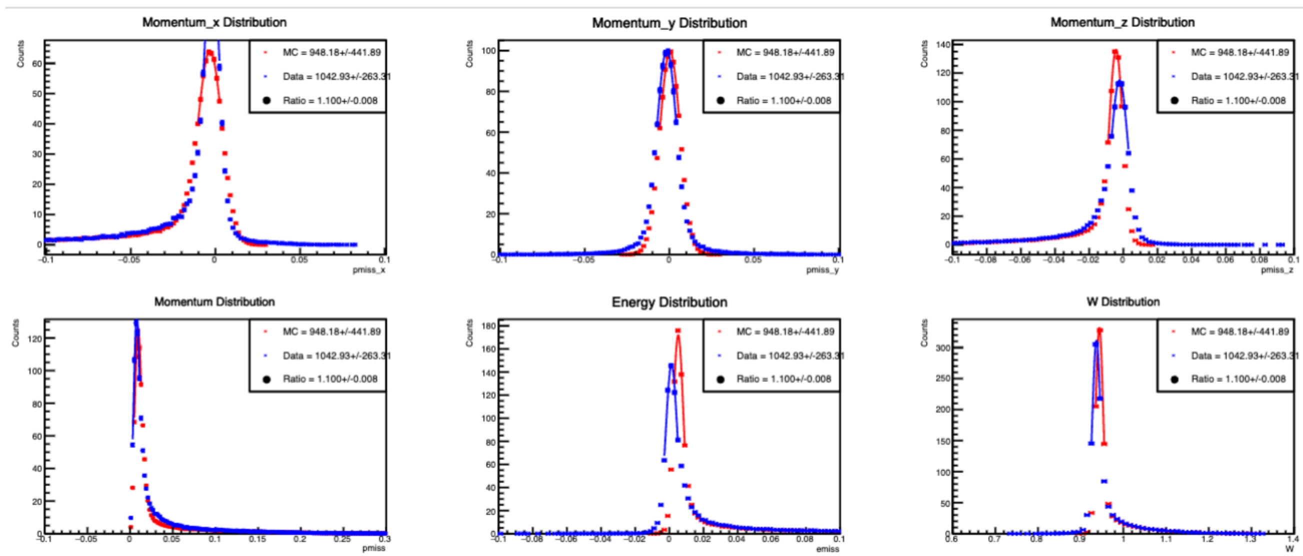


$H(e, e'p)$ Data vs. SIMC 3.8 GeV

Without proton absorption

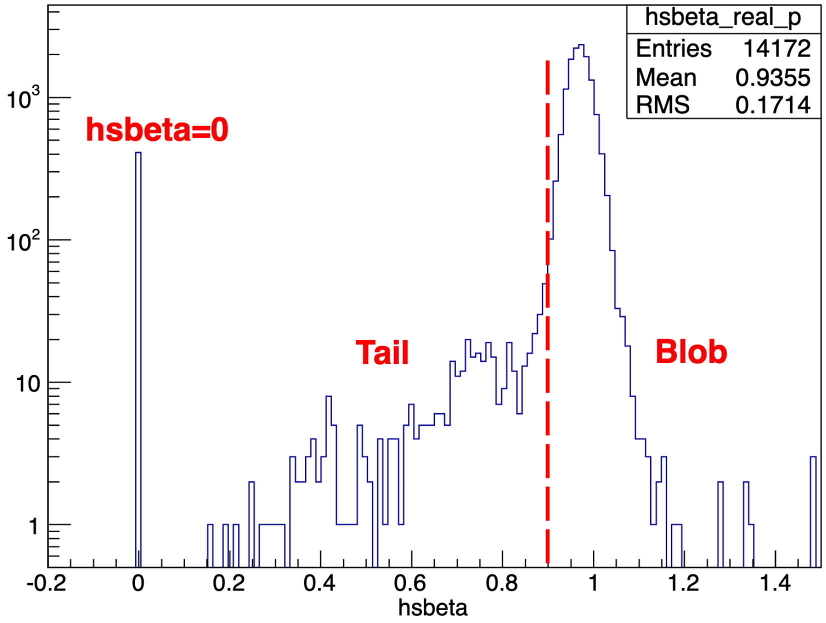


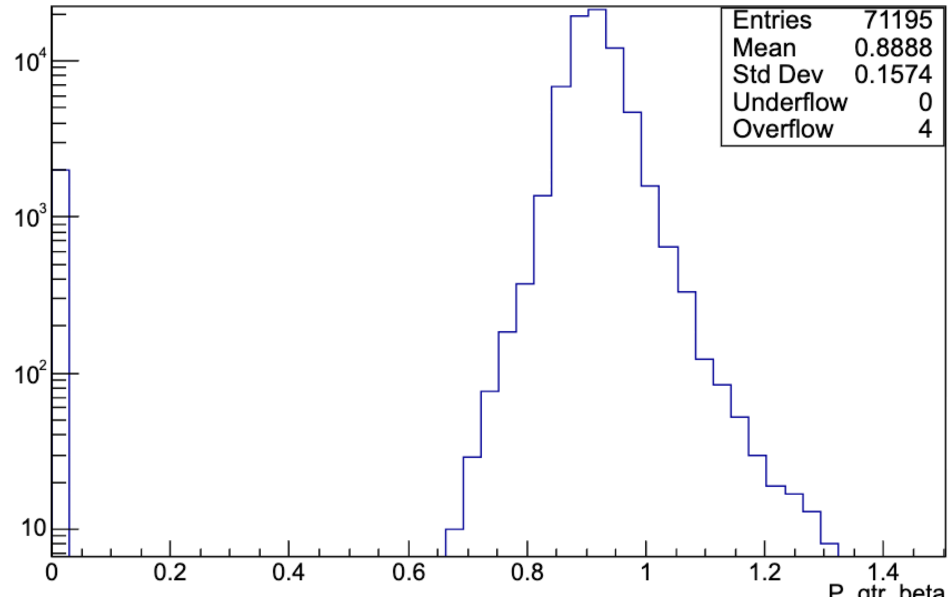
With proton absorption



Proton absorption Overestimate

- The proton absorption is the percentage of protons that fail to form a coincidence trigger.
- But, recoil protons could also produce another proton, while interacting with detector material, to form a good coincidence trigger.
- The events added to cover back the absorbed protons lead to over-counting





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HeeP Cuts

(H_gtr_dp > -8) & (H_gtr_dp < 8)

(P_gtr_dp > -10) & (P_gtr_dp < 20)

(H_gtr_xp > -0.08) & (H_gtr_xp < 0.08)

(H_gtr_yp > -0.045) & (H_gtr_yp < 0.045)

(P_gtr_xp > -0.06) & (P_gtr_xp < 0.06)

(P_gtr_yp > -0.04) & (P_gtr_yp < 0.04)

(H_cer_npeSum > 2.0) & (H_cal_etottracknorm > 0.7)

Missing Mass < 0.08 GeV/c^2

The event selection criteria (cuts) used to analyze the Heep data are listed below, many of these conditions are similar to the ones used in the previous analysis efforts [55, 75, 76]. Note that the same cuts are used for the ω analysis.

HMS Acceptance Cut: $abs(hsytar) \leq 1.75$ && $abs(hsdelta) \leq 8.0$ && $abs(hsxptar) \leq 0.080$ && $abs(hsyptar) \leq 0.035$.

SOS Acceptance Cut: $ssytar \leq 1.5$ && $abs(ssdelta) \leq 15.$ && $abs(ssxfp) \leq 20.$ && $abs(ssxptar) \leq 0.04$ && $abs(ssyptar) \leq 0.065$.

Partial PID Cut: $hsbeta > -0.1$ && $hsbeta < 1.5$ && $hcer\_npe < 2$ && $ssshtrk > 0.70$ && $scer\_npe > 0.50$.

ACD Threshold Cut: Depending on the HMS central momentum setting, a different Aerogel Cherenkov threshold is required. See detail in Sec. 5.3.7.

Full PID Cut: Partial PID Cut && ACD Threshold Cut.

Missing Mass (M_m) and Energy Cut (E_m): $Em < 0.10$ && $M_m > -0.032$ && $M_m < 0.018$.

Bill's Proton Absorption

Table 5.8: HMS spectrometer material table modified from similar table recreated by Henk Blok, which was originally produced during the F_π-2 analysis [55]. Original version of the table was documented in Ref. [84]. t shows the material thickness; ρ is the material density; λ is the nuclear collision length at $\sigma = 38.4$ mb; $X = t \times \rho$; rescaled nuclear collision length at $\sigma = 43$ mb: $\lambda' = \lambda \times 43/38.4$; X/λ' denotes the proton interaction probability as it travel through the each spectrometer component.

Absorber	Material	t	ρ	λ	X	X/λ'	Partial Sums
		cm	g/cm^3	g/cm^2	g/cm^2	%	%
Target	LH_2	1984	0.072	43.3	0.143	0.370	
Target Window	Al	0.013	2.700	70.6	0.035	0.056	
Chamber Window	Al	0.0406	2.700	70.6	0.110	0.174	
Chamber Gap	Air	15	0.001	62.0	0.018	0.033	
Entrance Window	Kevlar	0.0381	0.740	60.0	0.028	0.052	
Idem	Mylar	0.0127	1.390	60.2	0.017	0.032	
Exit Window	Titanium	0.0508	4.540	79.9	0.231	0.324	
	Target - Exit Window Sum						1.04
Dipole-DCGap	Air	35	0.001	62.0	0.042	0.076	
DC Windows	Mylar	4×(0.0025)	1.390	60.2	0.014	0.026	
DC Gas	Ar/C6H6	12×(1.8)	0.002	65.0	0.033	0.057	
DC Sensewires	W	2×(5.89E-06)	19.30	110.3	0.001	0.001	
DC Fieldwires	Be/Cu	36×(0.00018)	5.400	70.0	0.035	0.056	
Airgap DC-S2X	Air	83.87	0.001	62.0	0.101	0.182	
ACD Entrance	Al	0.15	2.700	70.6	0.405	0.642	
Aerogel	SiO2	9	0.04-0.06	66.5	0.450	0.758	
ACD Airgap	Air	16	0.001	62.0	0.019	0.034	
ACD Exit	Al	0.1	2.700	62.0	0.270	0.488	
S1X	polystyrene	1067	1.030	58.5	1.100	2.106	
S1Y	polystyrene	1067	1.030	58.5	1.100	2.106	
	Dipole-DCGap - S1 Sum						6.53
Cer Windows	Al	2×(0.102)	2.700	70.6	0.550	0.872	
Cer Gas	C4F10	135	0.002	63.0	0.332	0.590	
Cer Mirror	Support	1.8	0.050	53.0	0.090	0.190	
Cer Mirror	SiO2	0.3	2.200	66.5	0.660	1.111	
S2X	polystyrene	1.067/4	1.030	58.5	0.275	0.526	
	Cer Windows - S2X Sum						3.29

Bill's Proton Absorption

- For the protons interacting from the drift chambers to S1 (6.53%), it was assumed that a fraction f1 of protons were lost triggers, while the remaining fraction (1 − f1) of protons would successfully generate a trigger. These non-lost protons would either end up in the 'zero' or in the 'tail' section of the hsbeta distribution.

- Finally, for the interactions from the front window of the HGC detector through the first 1/4 thickness of S2 (corresponding to approximately the deposition which is necessary to generate a trigger), it was assumed that a fraction f2 resulted in a low β value ('zero' and 'tail'), while the remaining (1 − f2) were indistinguishable from those protons that did not undergo nuclear interactions ('blob').

- The implementation of the proton interaction correction is to divide the yield by 0.953±0.01, and is combined with other corrections when computing scaler information for each data run. In the early stage of HMS commissioning, a proton interaction study was performed and a correction of 0.945±0.02 was determined.