

Capturing and Analyzing Bragg Peak Proton Range Data on the Mevion HyperScan



using the XRV-3000 Eagle and LCW-300 multi-chevron wedge

XRV-3000 Eagle Setup



Tallest LCW-300 chevron should be located at the rear of the Eagle facing the handle

The LCW is centered on the target and the Eagle is aligned so the lasers hit the chevron peaks.

Mevion LCW-300 Delivery Plan

> 190 MeV, 9x12 - 15mm pitch



The grid pattern for each energy layer approximates a flat field

Dose for each spot is ~0.2 MU

There should be no beam activity in the capture ROI for ~1 second so the Logos software can detect the change in beam energy

The standard spreadsheet analysis template allows for 35 energy levels

Mevion LCW-300 Delivery Plan

< 165 MeV, 6x8 - 25mm pitch



165 – 190 MeV, 7x9 - 20mm pitch



> 190 MeV, 9x12 - 15mm pitch



Each energy layer is captured as a proton radiograph allowing 2 peak-to-peak measurements







The pristine Bragg Peaks are "quenched" in the scintillator causing the peak-to-peak measurements to be skewed in the proximal direction.

It has been experimentally observed that acrylic and Teflon LCW measurements when adjusted for the WET, correspond closely to the proximal 80% range of protons in water.

Setting up BeamWorks Strata

Launch BeamWorks Strata

		Beam	Works S	trata	
Ready for new beam capture	every Robol Trend Ana	per MDC/PES Trend.	Analysis Script Control 5	elrg:	
Expluse Script Style General Beancenter (Au Capture Images to Week Process Images from Week Real-Time Memory Expl Capture Peak Image (M Capture Peak Image (M) Capture Piak Image (M)	Atomatic) ang Data orking Data Cla anual Proceediate Sec.	ar Working Data		All values in mile × 0.01 Y. 00 Bodesire Distance 1 Dist	refere n arroe 1.2
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Start Script	Bearn: 0	Pass 0	Blank: 0		
Script Step: (Stopp	ped) Elapsed	Time: 0 sec.			

Select "Custom Scripts"

Capture Script Style:

-) Generate Beamcenter (Automatic)
-) Capture Images to Working Data
-) Process Images from Working Data
- Real-Time Memory Capture
- Capture Peak Image [Manual]
- Custom Scripts

Select "Browse"

Setting up BeamWorks Strata

Load BraggPeakCaptureEagle script

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Setting up BeamWorks Strata

🖽 BeamWork:Szata 1.4	- n ×
BA Plan Capture GA Plan Review Robot Trend Analysis NLCA	eamWorks Strata
Update All Scripts with Calibration Parameters Enable Horizontal Scaling (pixels/inn): 3.6563 Vertical Scaling (pixels/inn): 3.6486 Display/Center: % 600.9555 % 600.955 %	New WinCVS Wideo Parameters
New Output Data Folder Erable Bitance C/FalcontEbitData	8 Bits (BMP extension) 16 Bits (TIF extension)
Press F1 for Help	Copyright © 2017 Logos Systems Int

Set the Eagle camera Frame Rate to 2 frames per second and the Gain to 24 dB

Making Measurements

Click on Start Script to launch WinLVS

14 Plan Capture QA Plan Review	Bea	ImWorks	Strata
Ready for new beam capture service			
Capture Script Style: General Beamcenter (Automatic Capture Insigns to Working Dat Process Images from Working D O Real-Time Memory Capture Capture Peak Image (Manual) Custom Scripts	ala ClearWokingDate		All values in nillimeters X: 0.01 Y: 0.01 Bodefine Distance 1 Distance 1.2
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Option 1 Opti	on 2 Option 3	Option 4	
err F1 for Help	100 - 17		Conscient 9 2017 Los



Making Measurements

WinLVS captures images and saves measurements to disk





Tap spacebar to add information windows

Deliver plan



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Click "Option 1"

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Making Measurements

WintUS-1097-3002Eagle BeamWorks - StocLevel 4 of 156 File Edit Script XRV-100/124 XRV-2000/9000/4000 Read Video Image Options Help



Pressing the Option 1 button starts the process of detecting Bragg Peak regions in the captured images and writing peak-to-peak measurements to file in a CSV format that can be easily imported into the template spreadsheet for analysis.

Data is then pasted into the analysis spreadsheet in order to calculate the equivalent proton range in water

	Α	В	С	D	E	F	G	Н	1	J	K
10		Folder 0008						Layer Ener	gy (MeV):	170.9	Snout Adj
11	1	LCW-200/300	R	Center	Peak-to-Pe	eak	Chevron H	eight	Target	Scint. Cove	Wedge
12	Image:	4		Dist (mm)	Dist (mm)		(mm)		(mm)	(mm)	WET
13	Chevron:	А		0	0		170.2		3.4	1.8	1.821
14	Chevron:	^в Peak-	to-pea	ak width	0		150		3.4	1.8	1.821
15	Chevron:	С	•	-12.462	62.3974		130		3.4	1.8	1.821
16	Chevron:	D		14.1868	16.9677		110.1		3.4	1.8	1.821
17	Chevron:	E		0	0		90.1		3.4	1.8	1.821
18	Chevron:	F		0	0		70.2		3.4	1.8	1.821
19											
20		Folder 0006				Delta (Me)	0	Layer Ener	gy (MeV):	170.9	Snout Adj
21	2	LCW-200/300		Center	Peak-to-Pe	eak	Chevron H	eight	Target	Scint. Cove	Wedge
22	Image:	1		Dist (mm)	Dist (mm)		(mm)		(mm)	(mm)	WET
23	Chevron:	А		0	0		170.2		3.4	1.8	1.821
24	Chevron:	В		0	0		150		3.4	1.8	1.821
25	Chevron:	С		-11.9351	60.4817)	130		3.4	1.8	1.821
26	Chevron:	D		13.7981	16.9677		110.1		3.4	1.8	1.821
27	Chevron:	E		0	0		90.1		3.4	1.8	1.821
28	Chevron:	F		0	0		70.2		3.4	1.8	1.821
29											
30		Folder 0008				Delta (Me)	10.5	Layer Ener	gy (MeV):	160.4	Snout Adj
31	3	LCW-200/300		Center	Peak-to-Pe	eak	Chevron H	eight	Target	Scint. Cove	Wedge
32	Image:	3		Dist (mm)	Dist (mm)		(mm)		(mm)	(mm)	WET
33	Chevron:	А		0	0		170.2		3.4	1.8	1.821
34	Chevron:	В		0	0		150		3.4	1.8	1.821
35	Chevron:	С		-11.2606	82.3755		130		3.4	1.8	1.821
36	Chevron:	D		14.9266	40.5036		110.1		3.4	1.8	1.821
37	Chevron:	E		0	0		90.1		3.4	1.8	1.821
38	Chevron:	F		0	0		70.2		3.4	1.8	1.821

Delivery plan MeV values for each energy layer are entered into the spreadsheet

Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL
									LCW-300 (Chevron Da	ata Summary	1
						Plan						
						Layer	Post Snou	t				
(SAD Y)	(SAD X)					Energy	Energy		Chevron		Avg. Energy	
cos(T)	cos(P)		Defined Energies		Layer	(MeV)	(MeV)	Delta	BPD (mm)	Delta	BPD (mm)	Delta
			170.9		1	170.9	167.8		189.8891		190.88674	
			170.9		2	170.9	167.8	0	190.728	0.8389	190.88674	0
0.999869	0.999977		160.4		3	160.4	157.3	-10.5	170.7299	-19.998	170.47672	-20.41
0.99999	0.999971		160.4		4	160.4	157.3	0	170.4918	-0.23816	170.47672	0
			150.5		5	150.5	147.4	-9.9	152.7851	-17.7067	152.14596	-18.3308
			140.1		6	140.1	137	-10.4	134.0345	-18.7506	133.86	-18.286
									Average	-11.1709		
									Std. Dev.	10.51008		
cos(T)	cos(P)											

Parameters for WET (Water Equivalent Thickness) entered into the spreadsheet: 1.821 for Teflon (LCW-300 Chevrons) 1.172 for Acrylic (Eagle support Target)

К	L	М	N	0	Р	Q	R	S
		Global Inp	out Values					
		XRV-3000	SAD X mm:	1850				
		XRV-3000	SAD Y mm:	1850				
		Snout Adj	. MeV:	3.1				
		Nominal V	Vedge WET:	1.821				
)0 Chevrons	C and D.	Nominal T	ARGET WET	1.172				

proximately 20 mm more air to reach each lower Chevron.

Snout Adj	3.1	Final MeV	167.8	Bragg Dep	th (mm):	PSI Equati	on for Prox	imal 80% F
Wedge	PMMA	Trap. Scali	ng	Bragg Pen	etration		Adjusted E	BPD
WET	WET	with SAD >	<	Depth in n	nm		(mm)	
1.821	1.172	0.939081						
1.821	1.172	0.95						
1.821	1.172	0.960811		188.238			188.209	
1.821	1.172	0.971568		191.5767			191.5691	
1.821	1.172	0.982378						
1.821	1.172	0.993135						

Optimization of WET values with the "Hill Climbing" method



Excellent agreement between Mevion and Varian energy layers



Two different LCW units, Two different XRV phantoms, Two different proton delivery systems, Two different facilities. Excellent agreement!

Calculation for depth of 80% energy loss of beam in water converts MeV (black) to millimeters (red)

М	N	0	Р	Q	R	S	Т	U	V	W
Global Inp	ut Values									
XRV-3000	SAD X mm:	1850						The plan l	ies were de	
XRV-3000	SAD Y mm:	1850						The delive	ry was a gr	rid pattern
Snout Adj.	MeV:	3.1						The PSI R8	<mark>0 depth ec</mark>	uation cor
Nominal V	Vedge WET:	1.821						Proximal e	dge R80 is	used beca
Nominal T	ARGET WET	1.172								
		Ch		PSI	Fouatio	n 🥆				
re air to rea	ach each lower	Cnevron.			Lquutt					
Final MeV	167.8	Bragg Dept	th (mm):	PSI Equat	ion for Prox	kimal 80%	Penetratio	n Depth:	190.8867	
Trap. Scali	ng	Bragg Pene	etration		Adjusted I	3PD			\smile	
with SAD >	(Depth in m	ım		(mm)					Y (mm)
0.939081										0
0.95										0
0.960811		188.238			188.209					29.97605
0.971568		191.5767			191.5691					8.242634
0.982378										0
0.993135										0
	Average	189.9073		Average	189.8891					
<mark>Final MeV</mark>	167.8	Bragg Dept	th (mm):	PSI Equat	ion for Prox	kimal 80%	Penetratio	n Depth:	190.8867	
Trap. Scali	ng	Bragg Pene	etration		Adjusted I	BPD				
with SAD >	<	Depth in m	ım		(mm)					Y (mm)
0.939081										0
0.95										0
0.960811		189.9139			189.8865					29.05574
0.971568		191.5767			191.5694					8.242634
0.982378										0
0.993135										0

Proximal depth 80% of Bragg Peak formula (PSI): $D = 0.0244E^{1.75}$

М	N	0	Р	Q	R	S	Т	U	V	W
Global Inp	out Values									
XRV-3000	SAD X mm:	1850						The plan l	ayer energ	ies were de
XRV-3000	SAD Y mm:	1850						The delive	rid pattern	
Snout Adj.	nout Adj. MeV: 3.1							The PSI R8	80 depth eo	uation cor
Nominal V	Vedge WET:	1.821						Proximal e	edge R80 is	used beca
Nominal T	ARGET WET	1.172								
re air to rea	ach each <mark>l</mark> ower (Chevron.		→ PSI	Equatio	on 🔶				
									\frown	
Final MeV	167.8	Bragg Dep	th (mm):	PSI Equat	ion for Prox	imal 80% F	<mark>enetratio</mark>	n Depth: 🌔	190.8867	
Trap. Scali	ing	Bragg Pene	etration		Adjusted E	SPD				
with SAD >	X	Depth in n	nm		(mm)					Y (mm)
0.939081										0
0.95										0
0.960811		188.238			188.209					29.97605
0.971568		191.5767			191.5691					8.242634
0.982378										0
0.993135	•	400.0070		•	100.0001					0
	Average	189.9073	th. (Average	189.8891				100 0007	
Tran Seal	107.8	Bragg Dep	th (mm):	PSI Equat			enetration	n Deptn:	190.8867	
with SAD Y	v	Donth in n			Aujusteu E	DPD				V (mm)
0 030081		Deptirini			(11111)					0
0.555001										0
0.960811		189 9139			189 8865					29 05574
0.971568		191,5767			191,5694					8,242634
0.982378		19119707			10110004					0
0.993135										0
										-

Calculate proton range in water from the LCW measurements using WET and other corrections

WET*[(Scaling ratio)*(Peak to peak)/2)+(Target thickness)]

М	N	0	Р	Q	R	S	Т	U	V	W
Global Inp	ut Values									
XRV-3000	SAD X mm:	1850						The plan la	ayer energi	es were deli
XRV-3000	SAD Y mm:	1850						The delive	d pattern o	
Snout Adj.	MeV:	3.1						The PSI R8	0 depth eq	uation conv
Nominal V	Vedge WET:	1.821						Proximal e	dge R80 is	<mark>used becau</mark>
Nominal T	ARGET WET	1.172								
to reach e	ach lower Chevr	on.								
Final MeV	167.8	Bragg Dept	th (mm):	PSI Equati	<mark>on for Proxi</mark>	imal 80% P	enetration and a set a 	Depth:	190.887	
Trap. Scali	ng	Bragg Pene	etration		Adjusted B	PD				
with SAD	×.	Depth in m	nm		(mm)					Y (mm)
0.93908										0
0.95										0
0.96081		188.238		(188.209	>				29.976
0.97157		191.577			191.569					8.24263
0.98238										0
0.99314										0
	Average	189.907		Average	189.889					
Final MeV	167.8	Bragg Dep	th (mm):	PSI Equati	<mark>on for Proxi</mark>	imal 80% P	enetration	Depth:	190.887	
Trap. Scali	ng	Bragg Pene	etration		Adjusted B	PD				
with SAD 2	x	Depth in m	nm		(mm)					Y (mm)
0.93908										0
0.95										0
0.96081		189.914			189.887					29.0557
0.97157		191.577			191.569					8.24263
0.98238										0
0.99314										0
	Average	190.745		Average	190.728					

Comparing average measurement to equation gives a Δ for that energy layer

AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
<mark>pristine po</mark>	<mark>s</mark> ition in wa	ter.								
				LCW-300 (Chevron Da	ta Summary				
	Plan									
	Layer	Post Snout	t							
	Energy	Energy		Chevron		Avg. Energy		Delta	(Absolute I	Delta
Layer	(MeV)	(MeV)	Delta	BPD (mm)	Delta	BPD (mm)	Delta	BPD (mm)	BPD mm)	
1	170.9	167.8		189.889		190.88674		0.99765	0.99765	
2	170.9	167.8	0	190.728	0.8389	190.88674	0	0.15875	0.15875	
3	160.4	157.3	-10.5	170.73	-19.998	170.47672	-20.41	-0.25322	0.25322	
4	160.4	157.3	0	170.492	-0.23816	170.47672	0	-0.01507	0.01507	
5	150.5	147.4	-9.9	152.785	-17.7067	152.14596	-18.3308	-0.63912	0.63912	
6	5 140.1	137	-10.4	134.034	-18.7506	133.86	-18.286	-0.17448	0.17448	
				Average	-11.1709			Average	0.37305	
				Std. Dev.	10.5101			Std. Dev.	0.37116	
								Max.	0.99765	
								Min.	0.01507	

Find the average Δ for all energy layers

AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
oristine pos	ition in wa	ter.								
				LCW-300 (Chevron Da	ta Summary				
	Plan									
	Layer	Post Snout	Ĭ							
	Energy	Energy		Chevron		Avg. Energy		Delta	(Absolute I	Delta
Layer	(MeV)	(MeV)	Delta	BPD (mm)	Delta	BPD (mm)	Delta	BPD (mm)	BPD mm)	
1	170.9	167.8		189.889		190.88674		0.99765	0.99765	
2	170.9	167.8	0	190.728	0.8389	190.88674	0	0.15875	0.15875	
3	160.4	157.3	-10.5	170.73	-19.998	170.47672	-20.41	-0.25322	0.25322	
4	160.4	157.3	0	170.492	-0.23816	170.47672	0	-0.01507	0.01507	
5	150.5	147.4	-9.9	152.785	-17.7067	152.14596	-18.3308	-0.63912	0.63912	
6	140.1	137	-10.4	134.034	-18.7506	133.86	-18.286	-0.17448	0.17448	
				Average	-11.1709			Average	0.37305	>
				Std. Dev.	10.5101			Std. Dev.	0.37116	
								Max.	0.99765	
								Min.	0.01507	

An automated treatment plan allows fast analysis of 35 energy layers as a proton range constancy check with an accuracy of about 0.5 mm

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34 10 1021 1172 0.9053	0 2000 2000 905 2	3 105.2 103.05 -19 2214 -3.901 222.273 -4.053 0.0759 0.0759	
34 18 1821 11/2 0.9/49	200 210 1014	4 183.3 18115 -19 217.26 -4 196 218.251 -4.022 0.9504 0.9504 5 1814 173.25 -19 213.40 -3.701 218.261 -3.20 0.7611 0.7611	
34 18 1821 1172 0.994	2000 2100 179.5	6 1795 177 35 -19" 2096 -3 882" 210 302 -3.959 0 7044 0 7044	
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nni Inni VET WEF vihS40Y Dephininin (nni)	Yirel SADX SADY costTl costP) 1716	10 1716 163 45 -2 194 32 -3 348 194 194 -4 029 -0 136 0 1362	
34 10 1021 1172 0.9557 224.45 224.38	30 589 2000 2100 0.33 0.3358 %7.5	12 167.6 165.45 -2" 196.09 -4.253" 166.233 -3.967 0.1475 0.1475	
34 16 1821 1172 0.9653 226.22 228.22	95%2 2000 2100 1 1 165.6	13 1656 16345 -2" 18215 -3.938" 182311 -3.522 0.164 0.164	
34 10 1021 1172 0.0749	2000 2000 \$63.5	M 1635 16135 -21' 17621 -3333' 170232 -4.073 0.0233 0.0233 5 1615 16936 -3' 13422 -3938' 174394 -3848 0.026 0.028	
34 10 1021 1172 0394	2000 2000 0005	16 153 157 75 -16" 171 29 -2 203" TT 331 -3 053 0.043 0.043	The second s
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34 16 1821 11/2 0.9557 220.93 230.85	200 210 519 32 525 2000 2100 0 5 69 0 3569 550 5	22 1503 14515 -16 15/16 -2154 156416 -2336 -0144 01434	
34 10 1021 1172 0.9653 22195 22194	11.863 2000 2100 1 1 W8.1	23 MB1 M5 95 -22" 190 05 -3 977" M3 536 -3 967 -0.5M 0.5M5	
34 18 1821 1172 0.949	2000 2000 962	24 N52 N405 -15 N596 -3495 N6 N6 -339 -0.41 0.41	
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nel hel VET VET VINSADY Dephoto (on)	YITE SADX SADY codl (codP)		
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