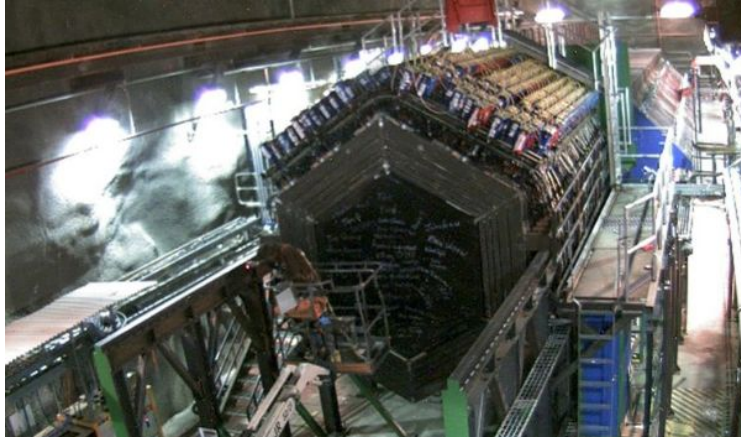


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MINERvA Masterclass Start-up





What is a Masterclass?



High school students are “Particle Physicists for a Day”

- Intro talk(s) on physics and experiment
- Tour of physics lab
- Ramp up and then...
- Analyze authentic (MINERvA) data
- Finish with (Fermilab) videoconference

Key element:

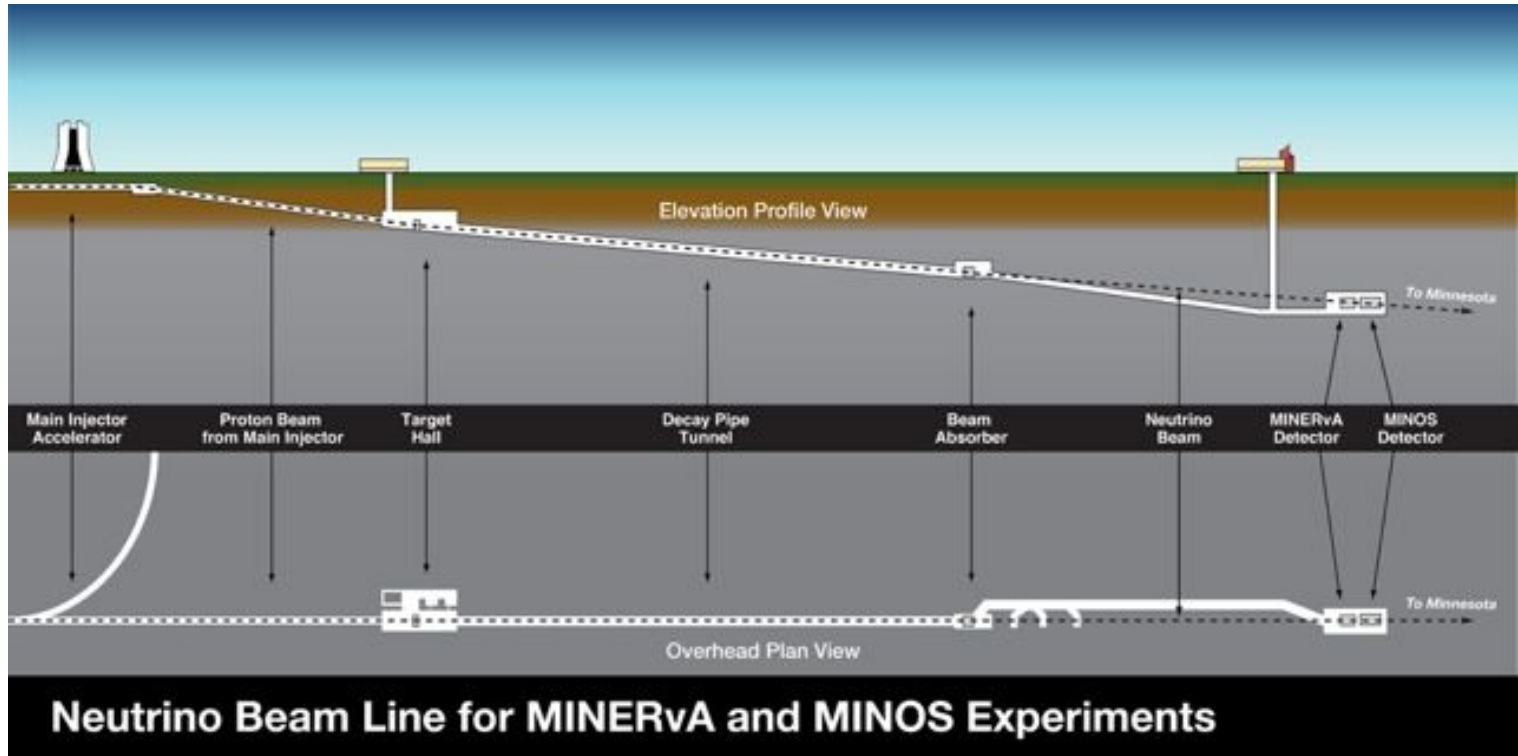
- Student/teacher interaction with physicists

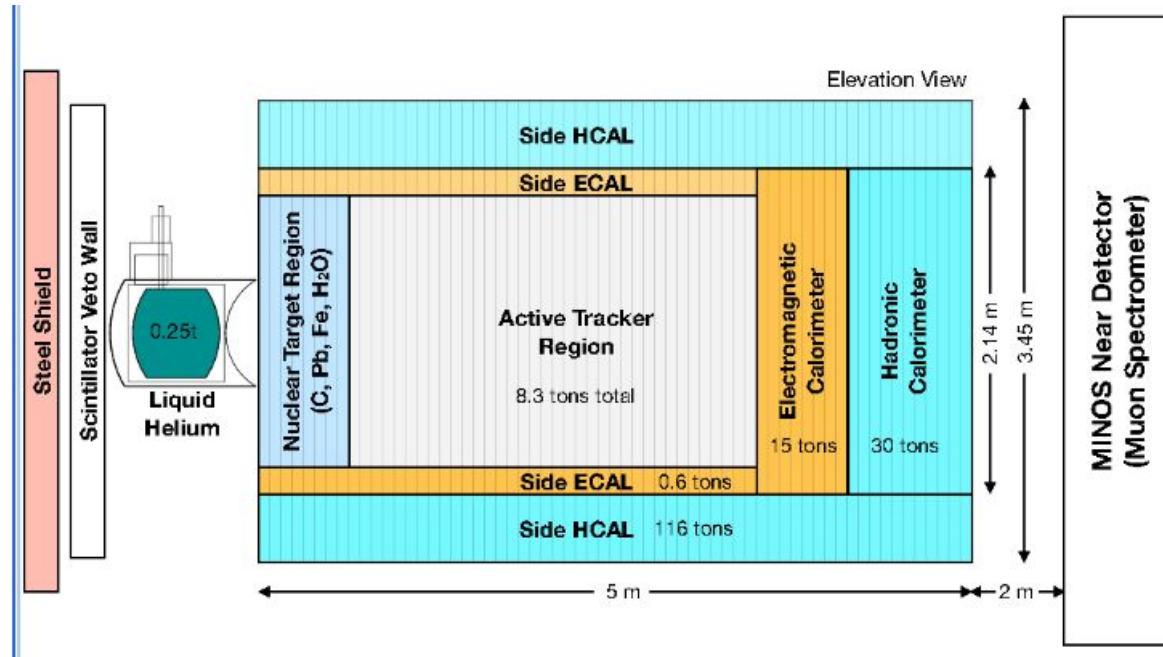




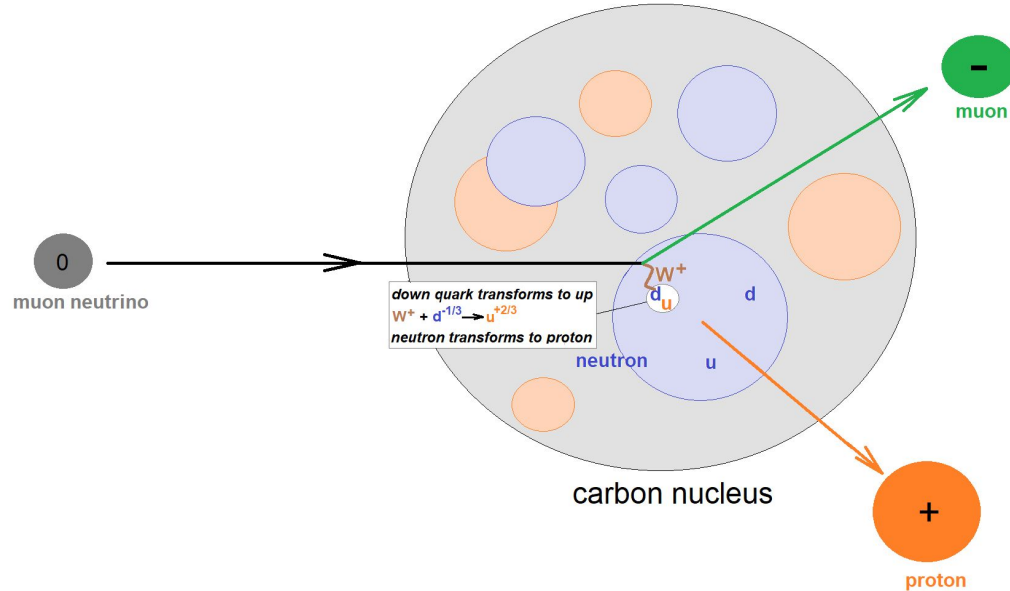
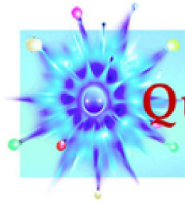
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MINOS and MINERvA

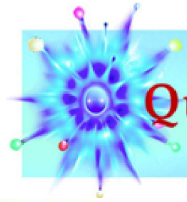




Muon neutrinos hit the carbon target. MINERvA measures the products of the interaction.

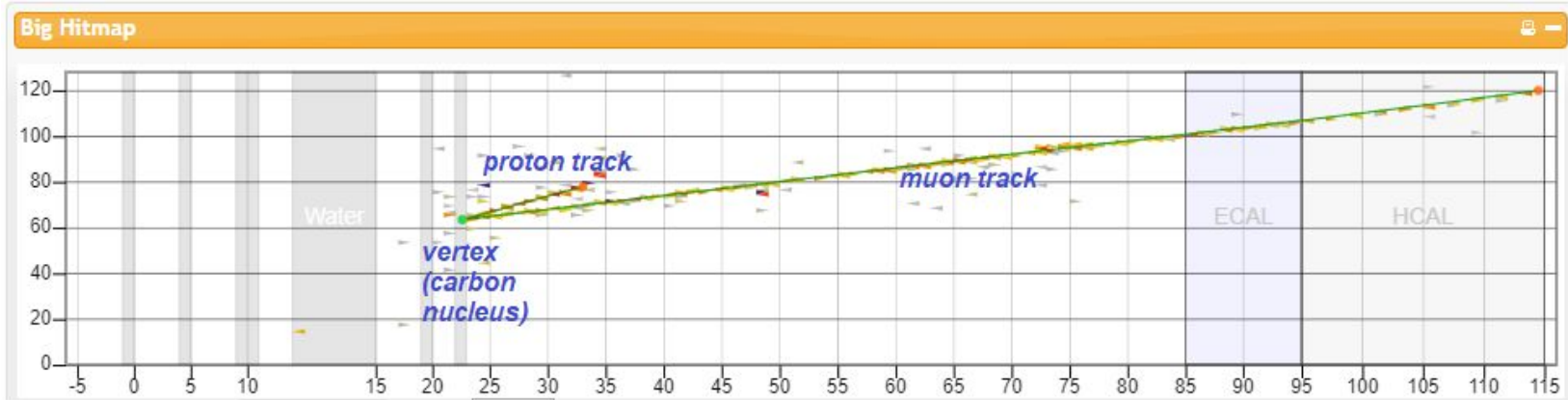


A muon neutrino interacts with a carbon nucleus. A muon and a proton are ejected from the nucleus carrying the neutrino momentum.



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Measurement



This is what MINERvA “sees”. The neutrino comes from the left, undetected. It hits a carbon nucleus and interacts with a neutron. The interaction transforms the neutrino into a muon and the neutron into a proton. MINERvA can measure the momentum of each.

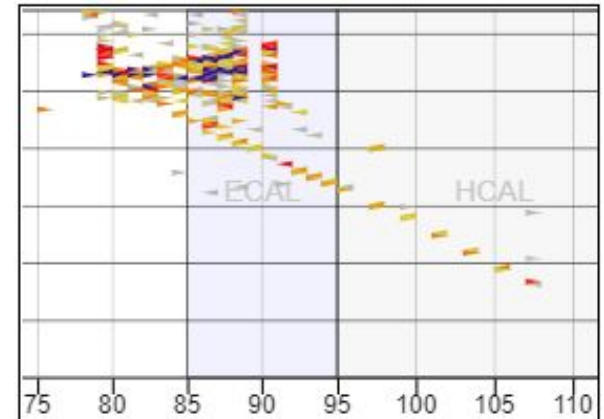
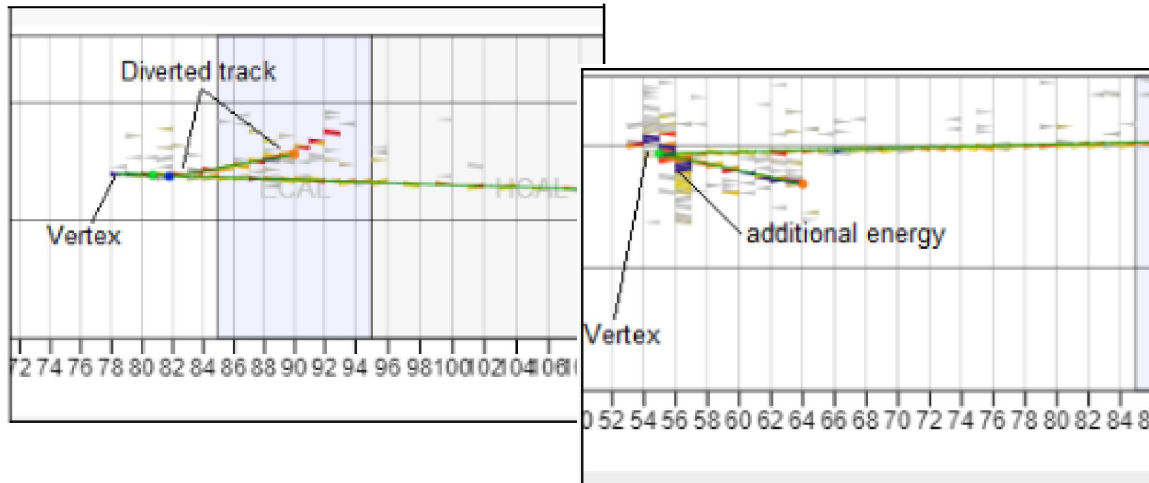


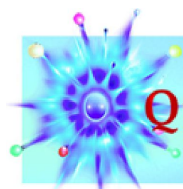
Signal vs. Background



Background events:

- Do not fit signal paradigm of one short proton track, one long muon track, or
- Confound the ability of MINERvA to measure momentum accurately.





QuarkNet Measure signal in Arachne



Arachne

Status: Done!

Data

mergedTuple_79.root

Entry: 5

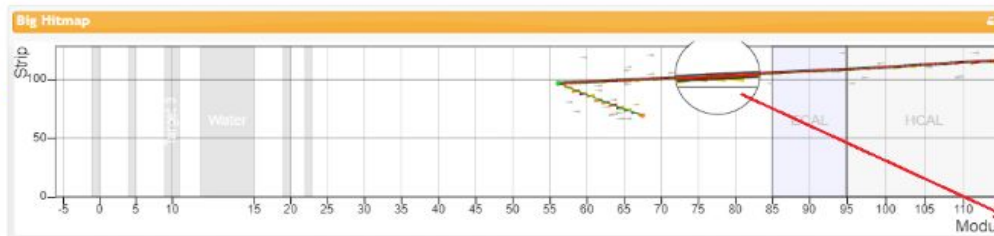
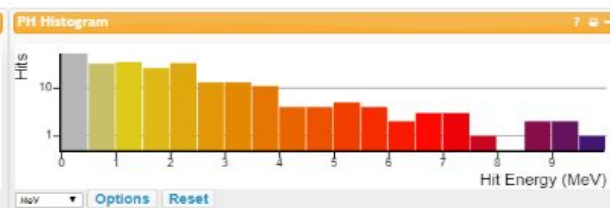
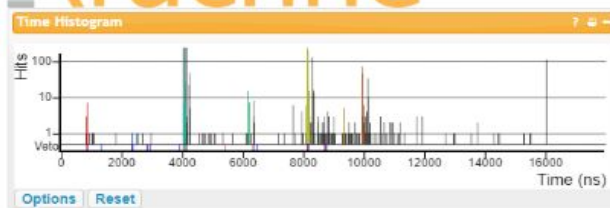
Current slice: Slice 5

Prev Gate p Next Gate n
Prev Slice - Next Slice +
 a

[Link to this event](#)
[Go to the muon decay library](#)

Tracks

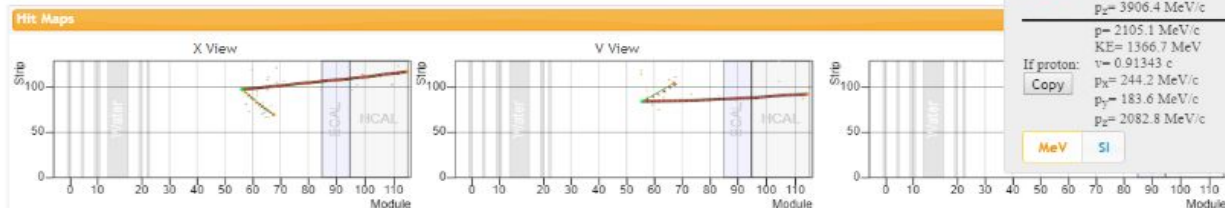
- Show tracks
- Individual Tracks:
 - Track 0
 - Track 1
 - Track 2
 - Track 3

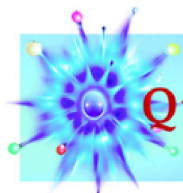


Track Information

Track 0 (Slice 5)

Hits	155
Vis Energy	311.6 MeV
Time	4070 ns
Minos:	$p_{range} = 2730.0 \text{ MeV}/c$ $p_{curve} = -2857.1 \text{ MeV}/c$
	$p = 3948.2 \text{ MeV}/c$ $KE = 3844.6 \text{ MeV}$ $v = 0.99965 c$
If muon:	$p_x = 458.0 \text{ MeV}/c$ $p_y = 344.4 \text{ MeV}/c$ $p_z = 3906.4 \text{ MeV}/c$
	$p = 2105.1 \text{ MeV}/c$ $KE = 1366.7 \text{ MeV}$ $v = 0.91343 c$
If proton:	$p_x = 244.2 \text{ MeV}/c$ $p_y = 183.6 \text{ MeV}/c$ $p_z = 2082.8 \text{ MeV}/c$





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Transfer to spreadsheet



3	merged		Background	Zoo	Muon					Proton					Net
4	Tuple	Entry	(enter a 1)	(enter a 1)	KE (MeV)	w/c	px (MeV/c)	py (MeV/c)	pz (MeV/c)	KE (MeV)	w/c	px (MeV/c)	py (MeV/c)	pz (MeV/c)	px (MeV/c)
154	78	38			2,468.00	0.99917	127.87	-451.51	2,527.66	250.63	0.61	282.26	73.04	669.32	
155	78	39			4,180.98	0.9997	-290.25	322.75	4,262.65	4,180.98	1	-290.25	322.75	4,262.65	
156	78	40			2,783.10	0.99934	-181.33	-468.2	2,842.18	299.54	0.65	40.96	609.33	527.92	
157	78	41													
158	78	42			3,467.68	0.99957	311.9	-624.25	3,502.30	1,219.51	0.9	169.69	-339.63	1,905.48	
159	78	43			6,862.50	0.99989	579.99	-95.45	6,941.86	330.54	0.67	-61.04	308.27	794.1	
160	78	44			70.27	0.80069	56.54	-31.5	124.52	158.34	0.52	228.67	-127.41	503.58	
161	78	45			4,687.34	0.99976	-602.76	-335.44	4,741.27	158.34	0.52	228.67	-127.41	503.58	
162	78	46			2,879.91	0.99938	-369.07	-127.86	2,957.39	1,286.94	0.91	-249.61	-86.47	2,000.18	
163	78	47			3,890.06	0.99965	-295.93	433.85	3,959.00	1,397.32	0.92	-158.47	232.33	2,120.09	
164	78	48			5,784.31	0.99984	370.25	-586.18	5,847.42	189.58	0.53	-246.29	271.65	460.9	
165	78	49			3,074.27	0.99945	-228.59	-303.83	3,154.71	1,432.36	0.92	-156.6	-208.15	2,161.23	
166	78	50			5,756.19	0.99984	326.56	-411.38	5,836.67	5,784.31	1	370.25	-586.18	5,847.42	
167															
168															
169															
170															
171	79	0													
172	79	1			125.64	0.89036	111.97	-12.75	171.66	280.46	0.62	406.75	-46.31	623.59	
173	79	2													
174	79	3			2,745.79	0.99932	-396.07	-157.98	2,816.76	1,493.81	0.92	-311.93	-124.42	2,218.35	
175	79	4			235.04	0.60049	337.93	-438.13	435.93	235.04	0.6	337.93	-438.13	435.93	
176	79	5			3,844.64	0.999646564	457.9591639	344.430018	3,906.44						
177	79	6													
178	79	7													
179	79	8													
180	79	9													
181	79	10													
182	79	11													
183	79	12													
184	79	13													



Build plots



We can find:

- Neutrino beam energy (almost)
- Uncertainty in proton momentum
- Uncertainty in proton position → nuclear radius

Model dependent!

