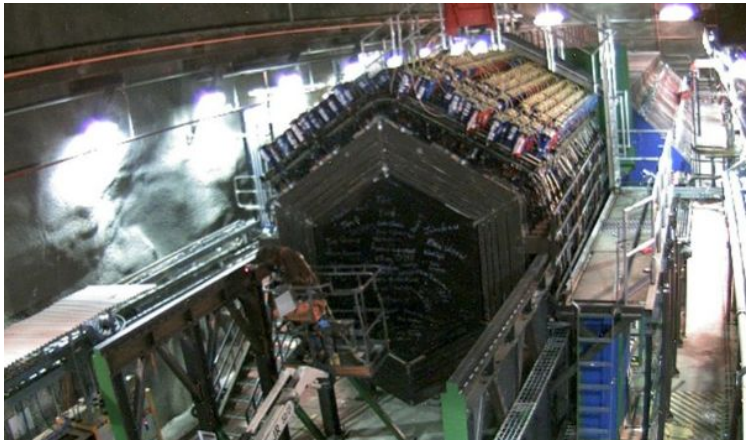
QuarkNet

Fermilab

Neutrino Masterclasses



MINERvA

Fermilab

INTERNATIONAL MASTERCLASSES
hands on particle physics

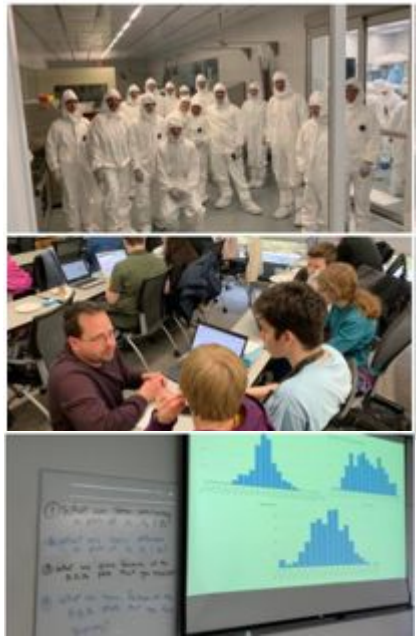
What is a Masterclass?

High school students are “Particle Physicists for a Day”

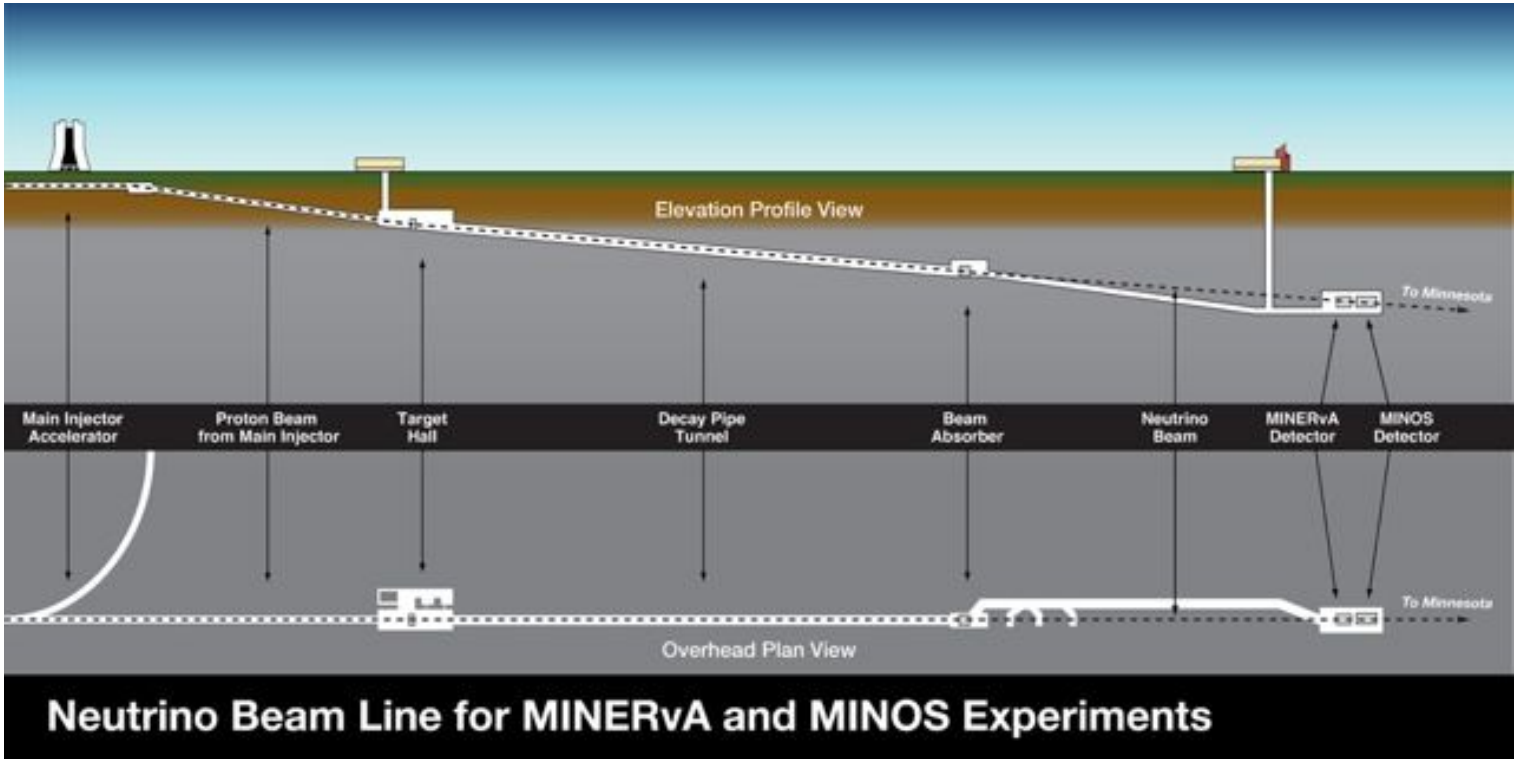
- Intro talk(s) on physics and experiment
- Tour of physics lab
- Ramp up and then...
- Analyze authentic (MINERvA) data
- Finish with (Fermilab) videoconference

Key element:

- Student/teacher interaction with physicists



MINOS and MINERvA



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MINERvA

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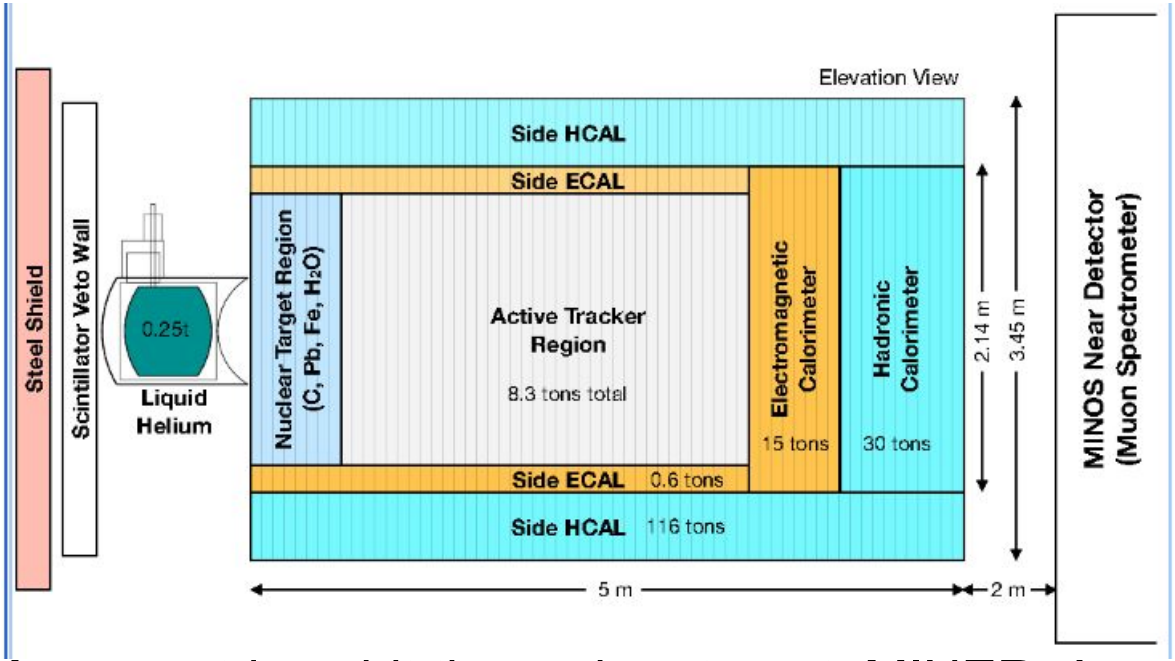
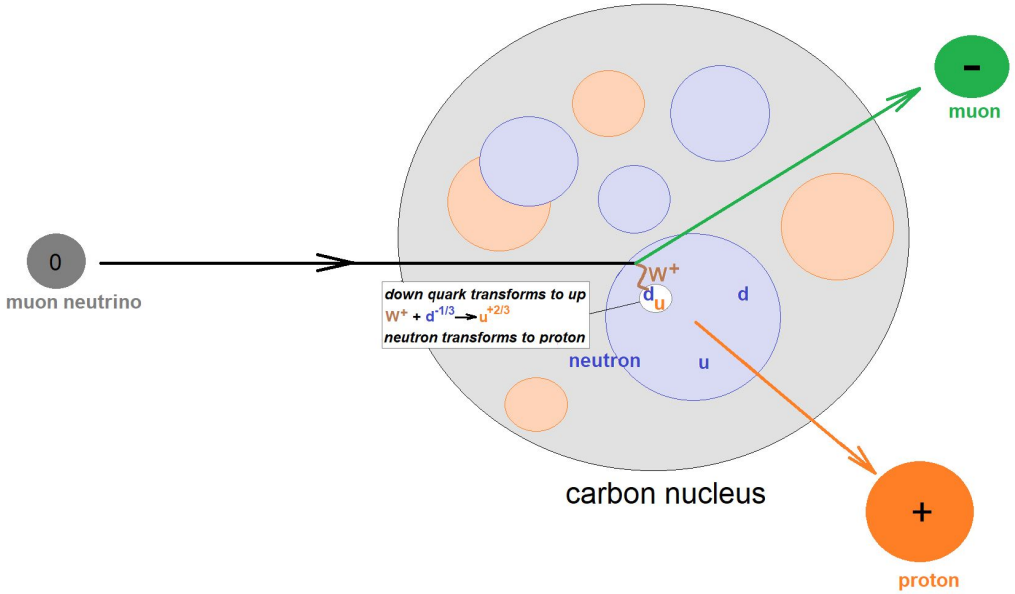


Muon neutrinos hit the carbon target. MINERvA measures the products of the interaction.

The Interaction



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

QuarkNet Student Measurement

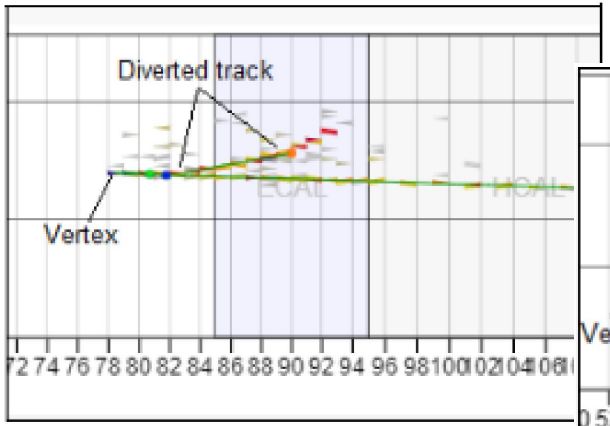
Fermilab

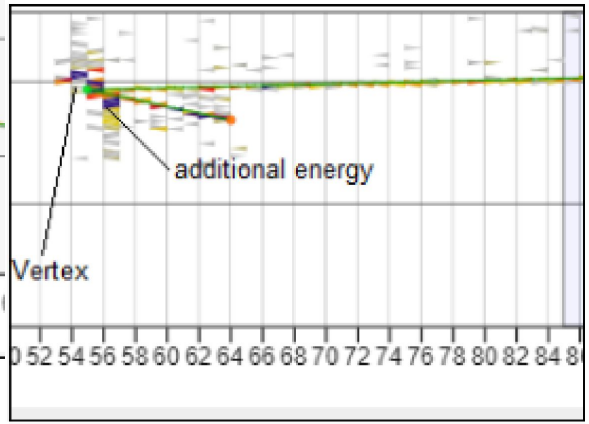
This is what MINERvA “sees” (and what students are looking for). The neutrino comes from the left, undetected. It hits a carbon nucleus and interacts with a neutron. The interaction transforms the neutrino into a muon and the neutron into a proton. MINERvA can measure the momentum of each.

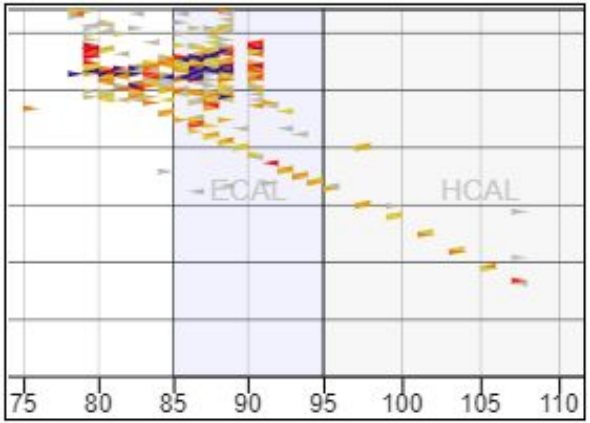
Signal vs. Background

Background events:

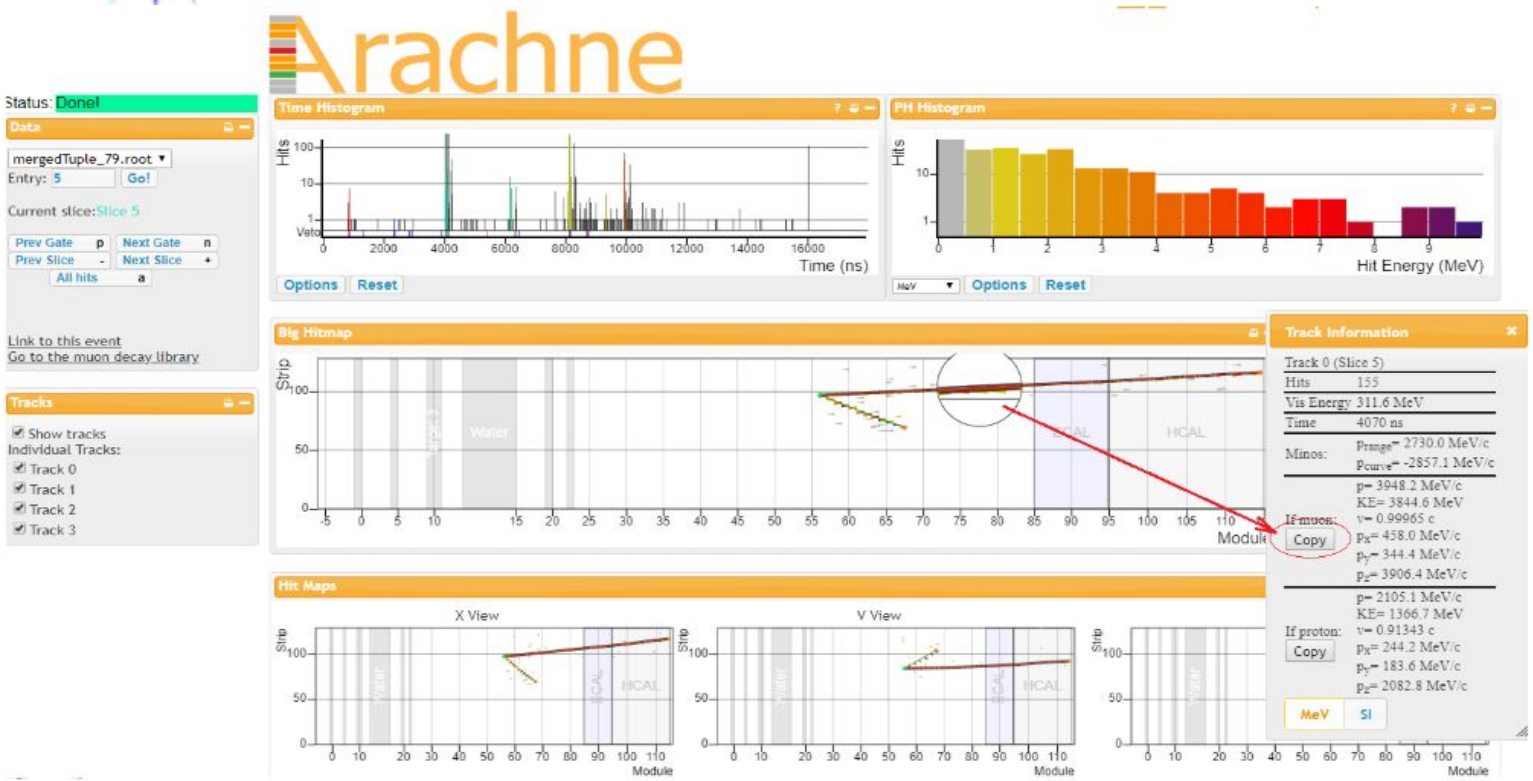
- Do not fit signal paradigm of one short proton track, one long muon track, or
- Confound the ability of MINERvA to measure momentum accurately.







Measure signal in Arachne



Transfer to spreadsheet

	merged		Background	Zoo	Muon					Proton					Net
	Tuple	Entry	(enter a 1)	(enter a 1)	KE (MeV)	v/c	px (MeV/c)	py (MeV/c)	pz (MeV/c)	KE (MeV)	v/c	px (MeV/c)	py (MeV/c)	pz (MeV/c)	px (Me
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	169.58	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	260.46	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													

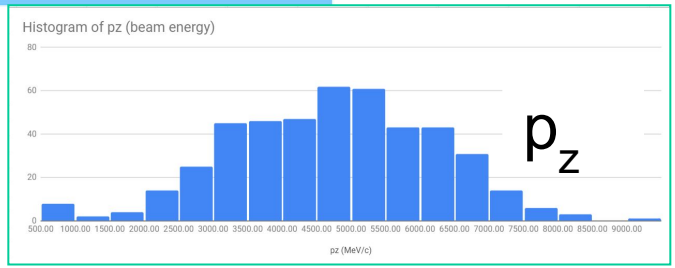
mergedTuples1to25 | mergedTuples26to50 | Copy of mergedTuples51to100 | videocon plots

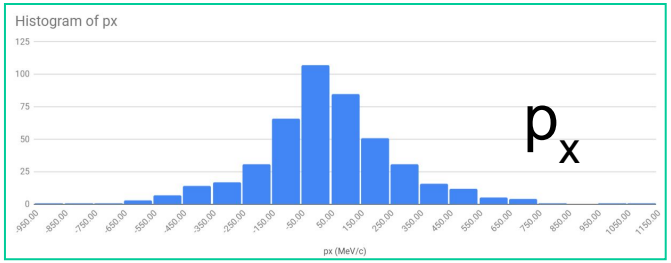
Build plots

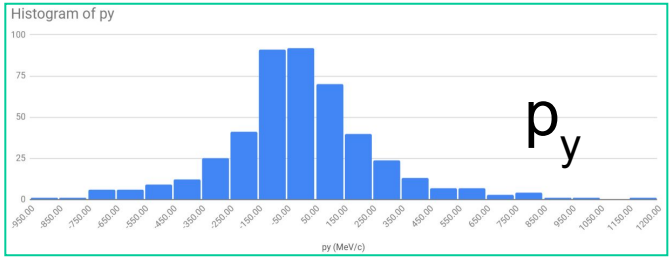
We can find:

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

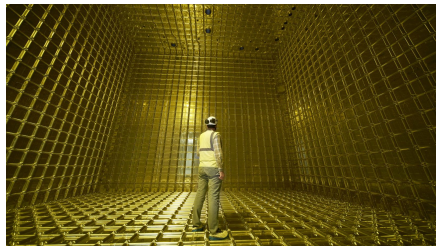
Model dependent!







The future



DUNE

DEEP UNDERGROUND NEUTRINO EXPERIMENT

μBooNE