Candidate Event Formation and Readout Dead Time Accounting

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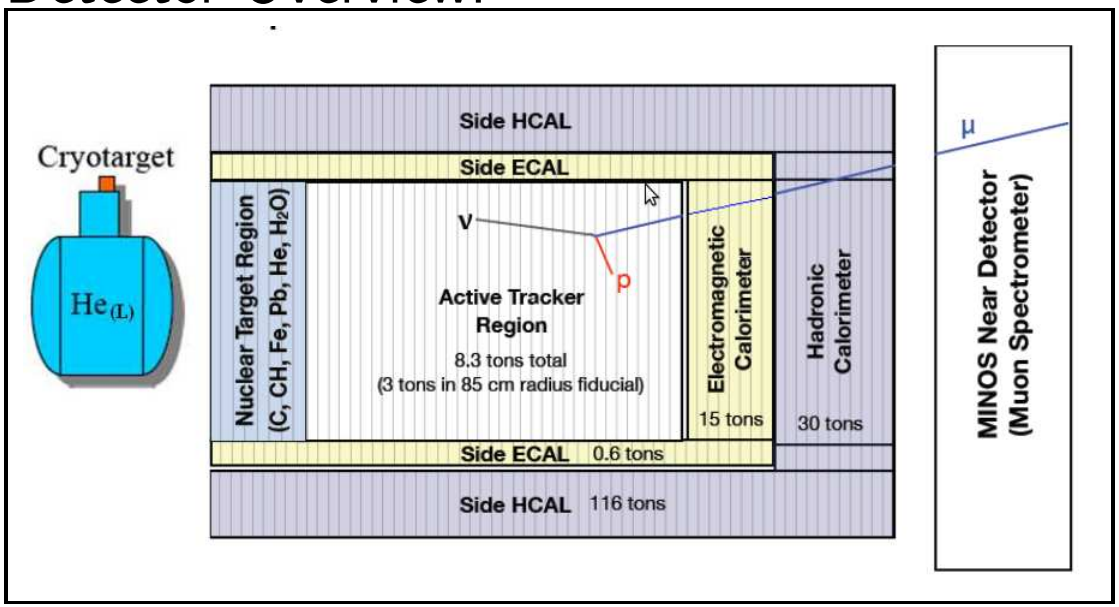
Main INjector ExpeRiment ν-A

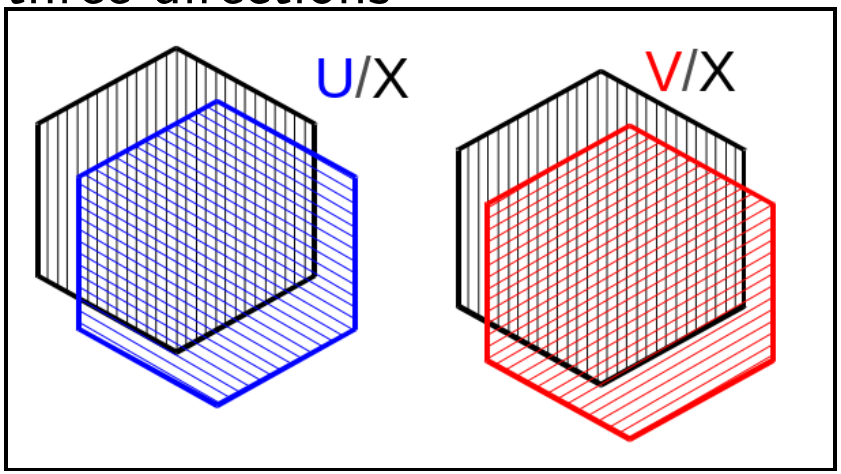
Physics Goals

- Inclusive and exclusive ν-A interaction cross sections (range of A.)
- Form factors and structure functions.
- Nuclear effects on the ν-A interactions.

Detector Overview:



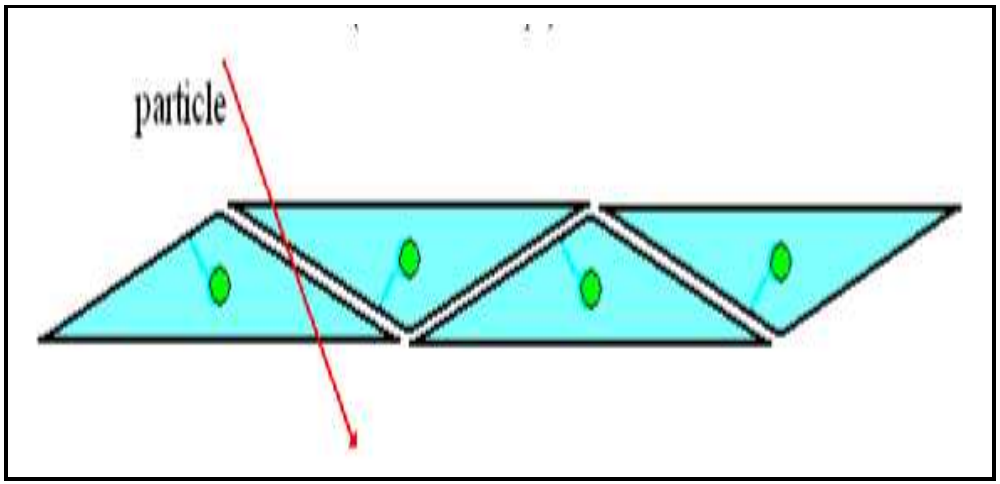
Scintillator planes made of scintillator strips are oriented in three directions

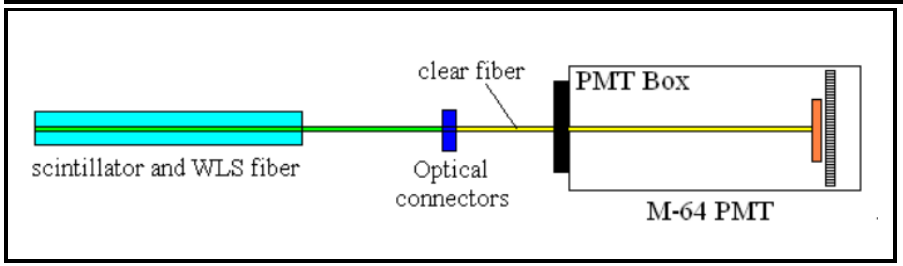


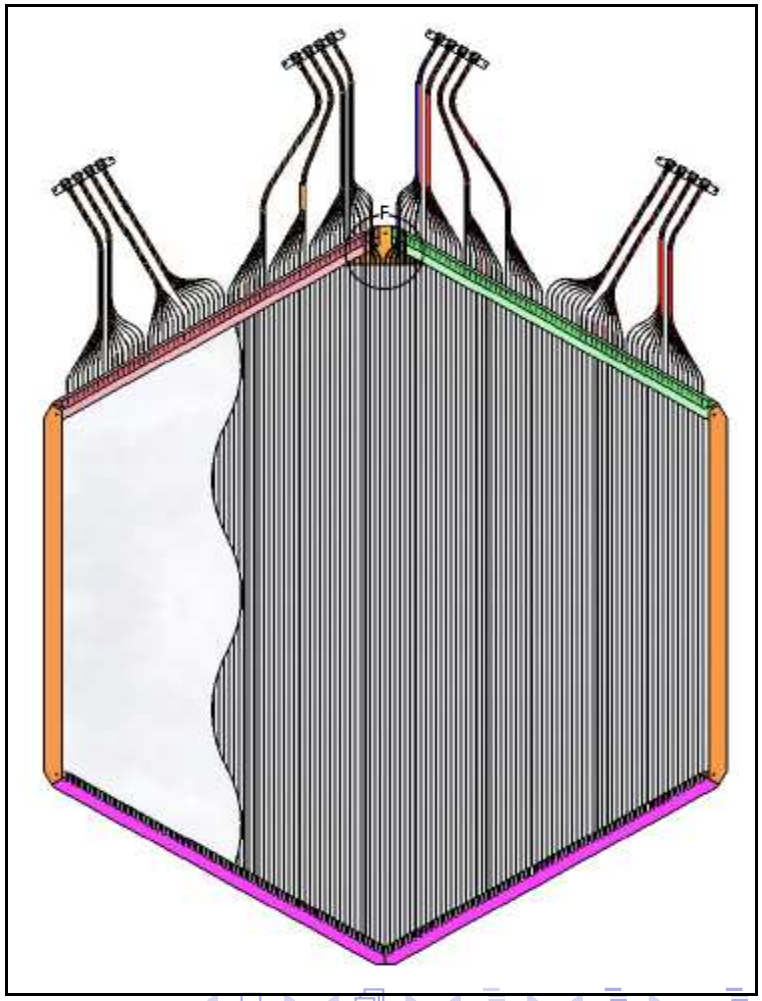
MINERνA Detector

Every strip has a WLS fiber that collects the light which is transmitted to the PMT

MINERνA has $\sim$ 32k readout channels in total.



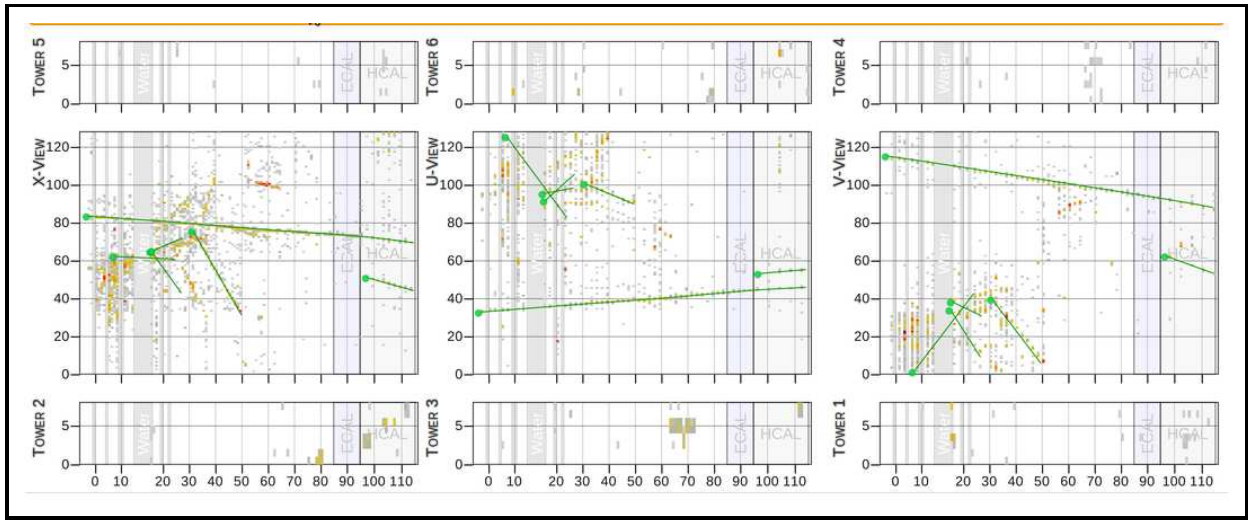




Time slices

- MINERνA receives a neutrino beam spill of 10μs every 2.2 s.
- Hits are bunched into event candidates, a.k.a.xx **"Time Slices"**.
- A time slice is a collection of hits occuring in the same time windows.
- Time slices are typically $\sim$100 ns wide.

The MINERνA event display for a gate (35e12 POT/spill)looks like:

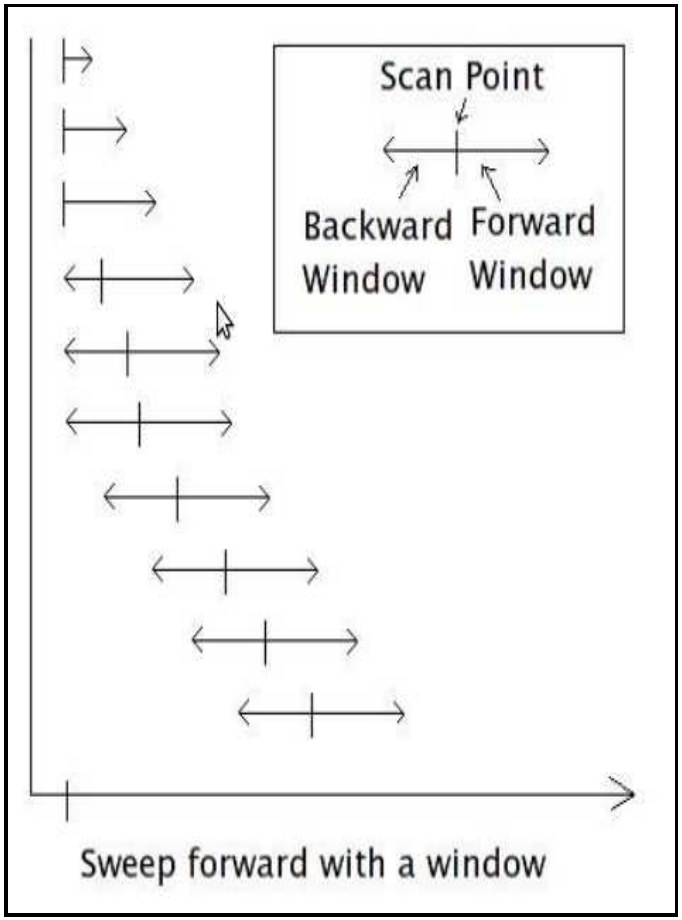


These represent 3 views: X (view from above), U(-60°) and V(60°).

Time Slicing strategy

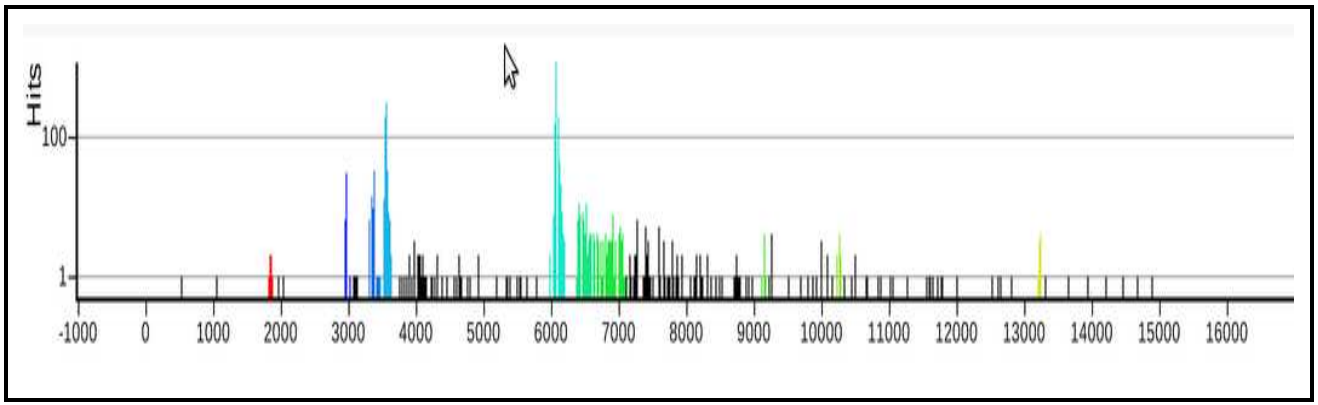
Method:

- Make a sweep over all hit times to looking for a minimum number of photo electrons(PE) in a set time window.
- Start a slice when minimum PE (10 PE's) is found in sweeping window.
- Stop a slice when minimum PE is no longer found in sweeping window.
- For every scan point, we use a forward window (50 ns) to find the final point of the slice.

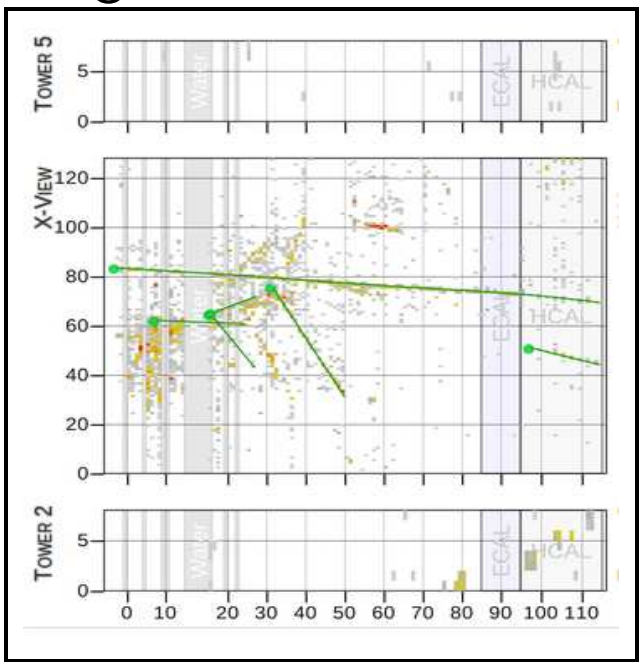


Time Slicing example

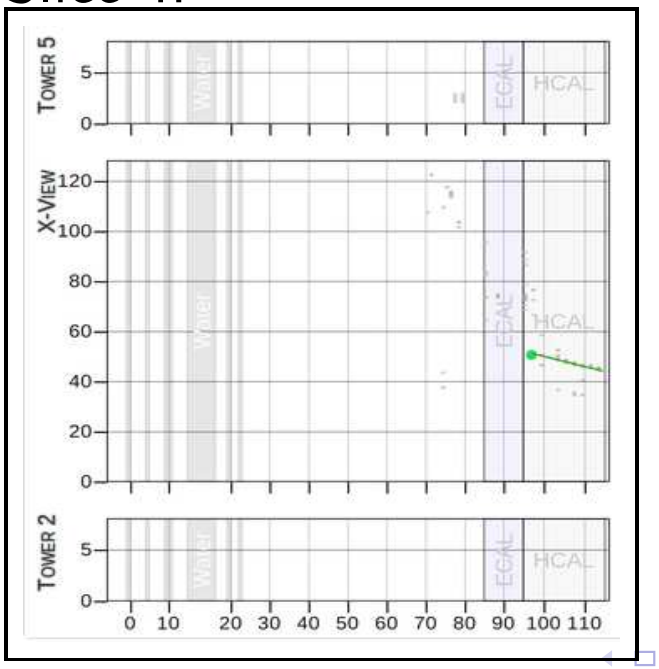
After this, we can separate different interactions.



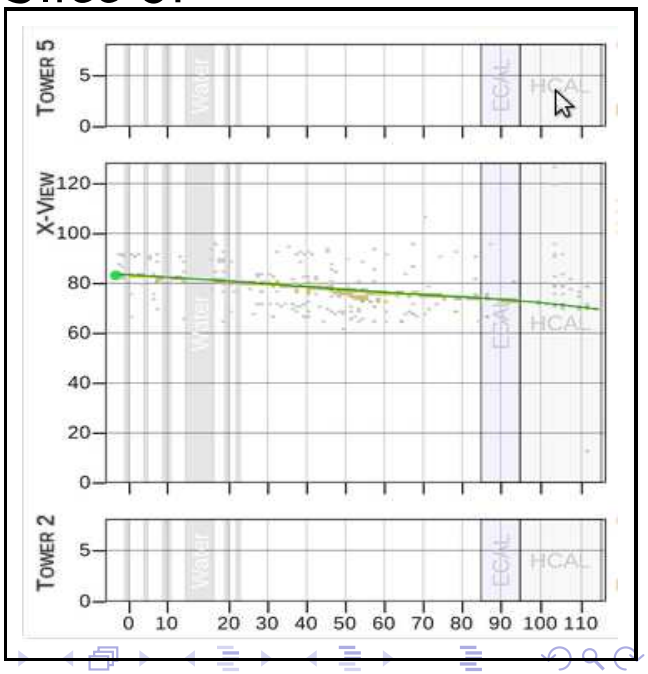
All gate:



Slice 4:

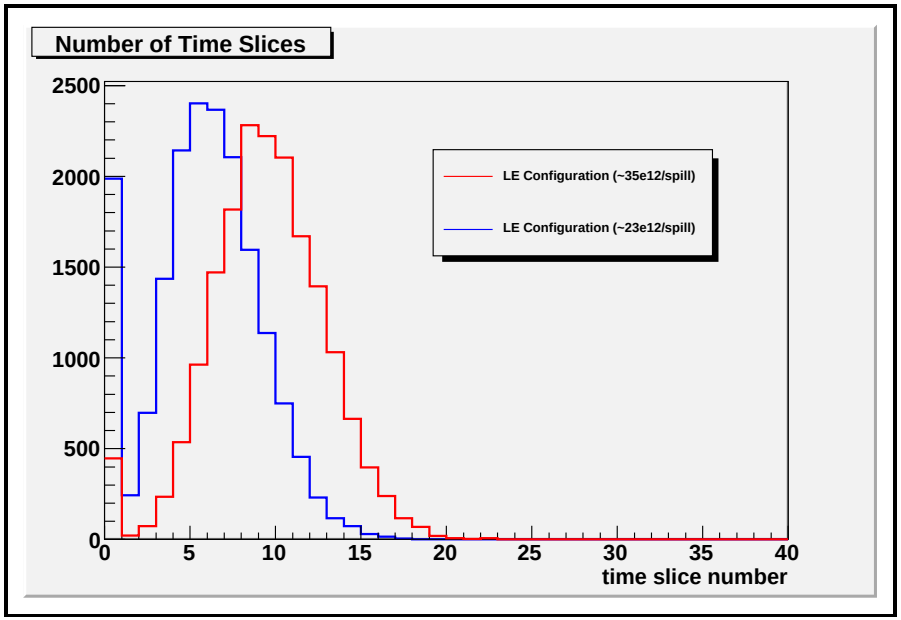


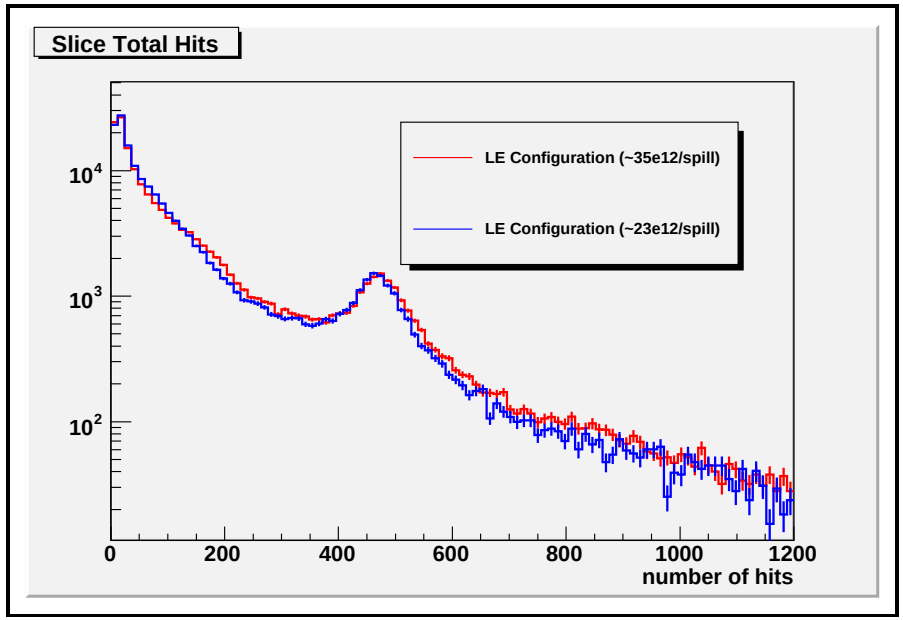
Slice 5:



Time Slicing plots

- Number of time slices and hits per slice for MINERνA data.
- We show two curves below. Both curves are from MINERνA data in Low Energy NuMI beam configuration and they are area normalized.
- The red curve represents the result from an average of 35e12 POT/spill intensity of NuMI beam and the blue one represents the result from a lower intensity NuMI beam, 23e12 POT/spill.

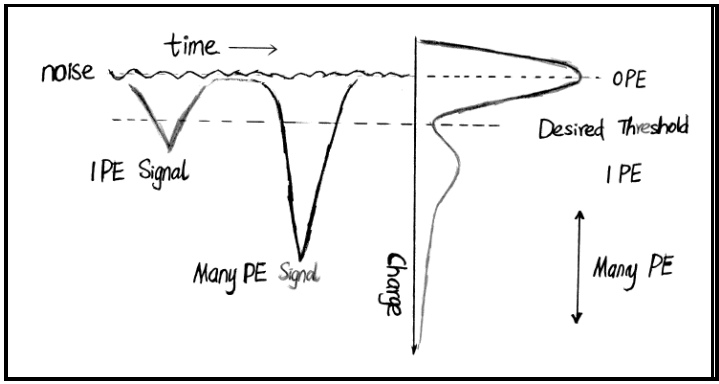


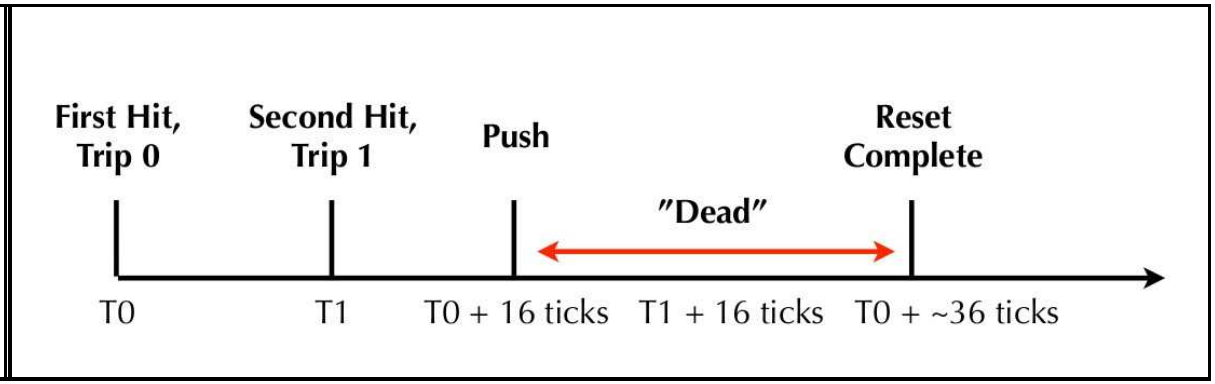


Readout dead times

A few words about MINERνA timing

- A discriminator produces a flag when the charge is over a threshold.
- A TRIP chip serves 16 channels of the PMT.
- The TRIPs are group in pairs to readout purposes, that is, when a discriminator fires, all the 32 channels of this group are read.





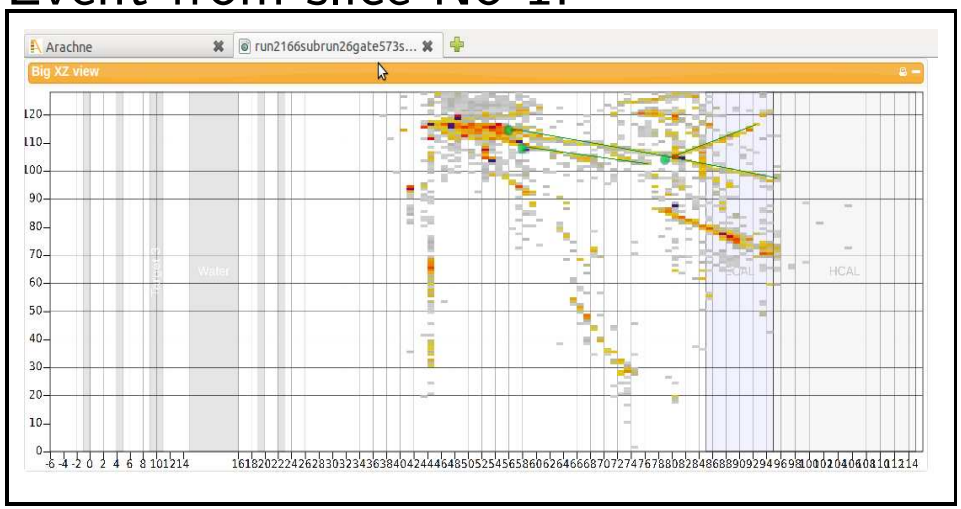
- The first hit set a timestamp shared by the "Trip Group" and open a window to read hits. for $\sim$150 ns.
- If discriminator fires, this 32 channels are read and effectively dead to new signal for $\sim$188 ns.

We need to know the effects of the dead time in the reconstruction.

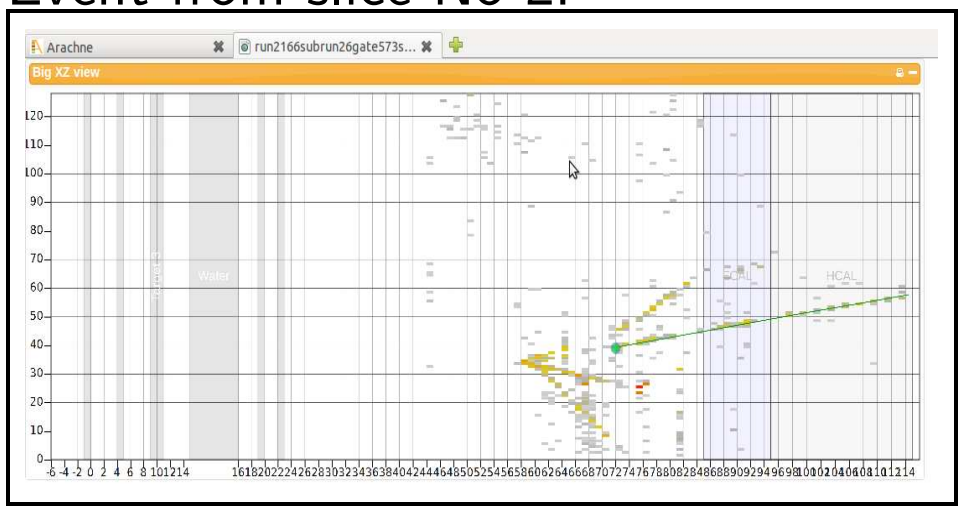
Motivation 1

The readout of the information in one time slice could affect the reconstruction of the event in the next time slice.
For example, in this event, the possible vextex in slice No 2 is not reconstructed.

Event from slice No 1:



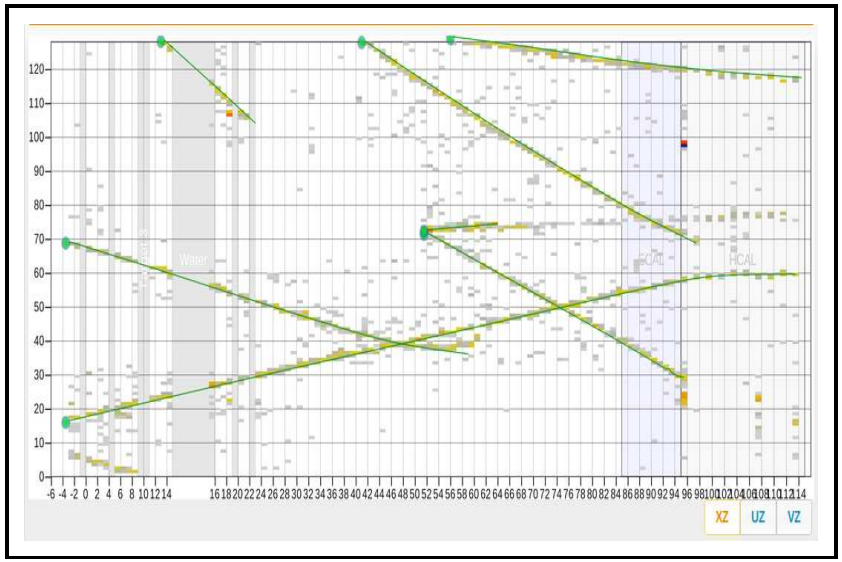
Event from slice No 2:



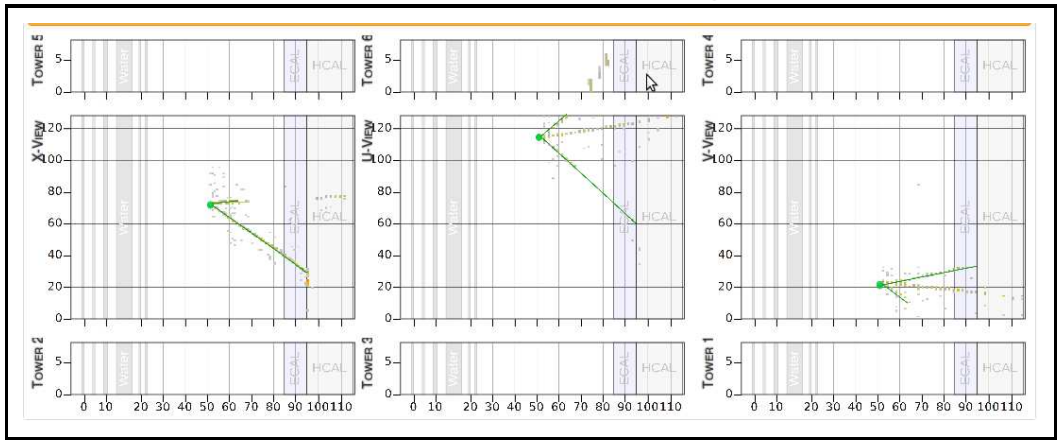
Motivation 2

Another example:

- We know there is a muon found in MINOS by the time of MINERνA time slice No 4 that likely come from MINERνA .
- However the muon track in MINERνA has not been reconstructed.



There is not muon track in MINERνA that goes to MINOS for slice No 4:



Dead times strategy

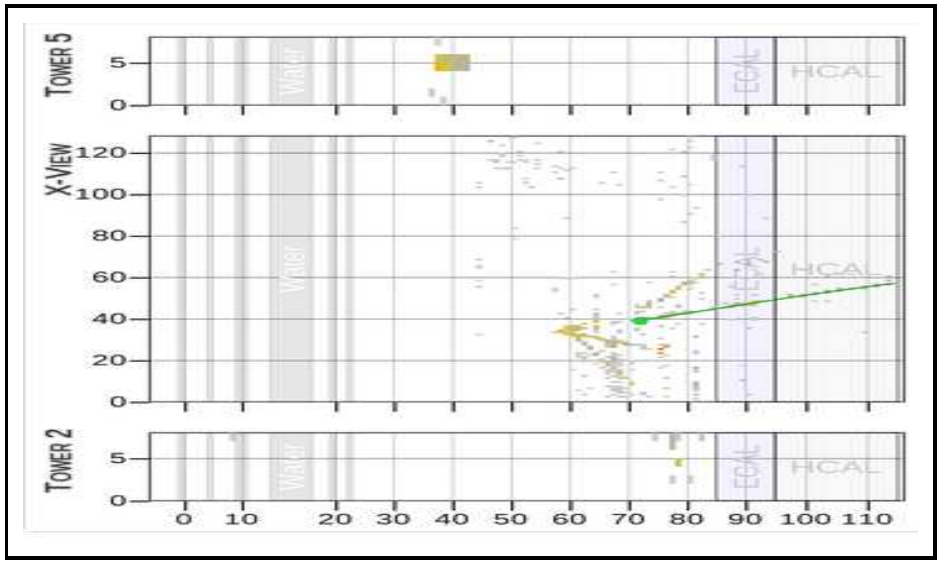
- Group all channels that share the discriminator pair and assign a unique ID (DiscrPairID).
- Save the initial time of the discriminator window for every DiscrPairID during the data processing.
- Retrieve this information and set a table (1 indicates dead time) like:

DiscrPairID N	0	0	1	1	1	...0	0	1	...	0
...	0	0	0	0	0	...0	0	1	...	0
DiscrPairID 2	1	1	1	1	1	...0	0	1	...	1
DiscrPairID 1	0	0	0	0	0	...0	0	1	...	0
time (clock ticks)	**1**	**2**	**3**	**4**	**5**	**...0**	**0**	**1**	**...**	**1600**

- Find the time of the initial reconstructed track and find the number of DiscrPairIDs looking two modules before(tdead) and after(ddead) the track as well as along (dead) the track.

Quantifying readout dead times

For the event that we show in the motivation (run 2166, sub-run 26 gate 455). The slice No 2 indicates tdead= 11, dead = 124 and ddead=0.



Quantifying readout dead times

To see the impact of the readout dead time we see:

- The fraction of dead discriminator pairs for initial track time for charge current interactions per module number.
- In the upper plot, we compare the results between two different intensities for low energy beam configuration (Red: 23e12 POT and Blue: 35e12 POT).
- In the lower plot, we compare the results among different energy configuration of NuMI.