Trigger simulation studies

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Triggering strategy overview

Fast trigger implemented in hardware:

1. identify the activity within the BNB and NuMI beam gates
   (1.6 µs and 8.6 µs respectively)
2. tag optical activity as signal-like or background-like
   (background includes cosmic rays, optical detector noise, radioactivity...)
3. cross with Cosmic Ray Tagger data to veto cosmogenic background
4. resolve to the bunched substructure of the neutrino spill?
   (BNB: 81 1 ns-wide bunches, 19 ns apart)
   $\rightarrow$ optical timing resolution of $\mathcal{O}(1\text{ ns})$ should allow it

Rates in a nutshell

- beam gate opening: 5 Hz (BNB), 0.53 Hz (NuMI)
- expected neutrino interactions: 0.03 Hz (BNB), 0.007 Hz (NuMI)

The goals

The studies may be divided in two stages:

pure simulation studies, targeted to...

... inform aspects of the design of the trigger system

- → discrimination thresholds
- → pattern for consolidation of pairs of channels

... predict trigger rates for selected physics processes

→ define target efficiency and data rate

first data studies measuring trigger efficiency from data

→ provide tools that collaborators can use for their signal

The plan

In this first stage (pure simulation), we focus on trigger design:

1. validate the optical simulation using single signal-like muon events
   $\rightarrow$ learn about timing structure, amount of collected light, optical detector noise, topology of the response
2. study pure signal events
   $\rightarrow$ learn how our target events look like
3. study empty events
   $\rightarrow$ learn how noisy is the noise
4. study cosmic ray background samples
   $\rightarrow$ learn about resolution between different physics events, time-wise and space-wise
5. develop discrimination and test it on signal+background samples
6. parametrise trigger efficiency for key signals (ν_μ, ν_e) and tune it
7. study other relevant processes (e.g. NuMI neutrino events)

The effort will be documented into an internal note.

The input

The two stages of study have different prerequisites:

trigger simulation (for design and prediction of efficiency):

- → generated samples (μ, ν_μ, ν_e, cosmic rays, ...)
- ✓ decent parametrisation of PMT noise
- ✓ simulation of the PMT readout output
- → understanding of the CRT data and its flow

trigger validation on data (commissioning analyses):

- zero-bias data
- validated noise model
- full detector simulation (PMT, TPC, CRT)
- full reconstruction of time ("t_0"), tracks and showers

The status

- the simulation study effort has just started!
- we need to produce or enrich all the relevant simulated samples:
  - available: single muons, single electrons, BNB neutrino interactions
  - in progress: cosmic rays, with and without signal overlaid
  - not started: empty events, NuMI neutrino events, single protons
  - → need to add simulated noise to PMT waveforms
- the optical simulation in the new samples needs to be validated
  - → both amount of light and arrival time distributions
- PMT readout simulation is in place
  - noise model is based on a completed measurement with our PMTs, uncoated and in LAr
  - the current test stand at CERN may inform us further
  - *this is the input to the trigger logic*
- some simple code simulating the trigger response is in place

Timeline and action items

- planning to be done:
  - now: develop a plan to take advantage of CRT
  - next: consider the possibility of utilising TPC information
  - soon: develop a plan for testing on the first data
    (and make sure we and DAQ stay on the same page)
- work to be done:
  - Thanksgiving present: thresholds and topology of signal events
  - Christmas present: time resolution
  - St. Patrick clover: tuning for muon signal, and trigger primitive recommendation
  - Easter egg surprise: efficiency and rate expectations

$\Rightarrow$ coordination with: PMT, CRT, DAQ, reconstruction, SBN[-ND]

Thank you for your attention

Discussion and ideas: 3... 2... 1... go!

Highlight on our unique roles and expertise:

Animesh Chatterjee at Fermilab, contact with CRT development

Andrea Falcone optical simulation expert

Gianluca Petrillo software expert

Yun-Tse Tsai data acquisition expert

<YOUR NAME HERE> lot of work to do! helping this effort, you'll...

... learn a lot about trigger and optical systems
... get experience in simulation
... learn a bit of every other subsystem and of DAQ

Expected event rates

- expected exposure: $\approx 6 \cdot 10^{20}$ protons on target
- expected data size: $\approx$ 100 MB/event

	BNB	NuMI	CNGS
p.o.t. per spill	$5 \cdot 10^{12}$	$4 \cdot 10^{13}$	
spill width	1.6 µs	8.6 µs	10.5 µs
extraction rate	5 Hz	0.53 Hz	
ν interactions (T600)	1 every 180 spills	1 every 150 spills	
beam-related (halo, ...)	1 every 210 spills	n/a	
in-spill cosmic rays	1 every 55 spills	1 every 10 spills	
total expected rate	1 every 35 spills	1 every 9 spills	

Source: DocDB 5505