Proposed Trigger Scheme for the ICAL Detector of India-based Neutrino Observatory

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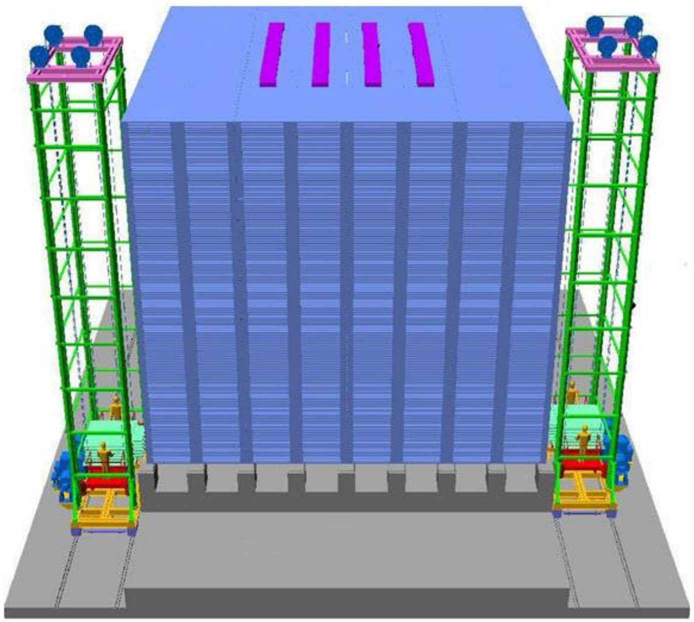
Outline

1. The ICAL Detector
2. Proposed Trigger Scheme
3. Chance Coincidence Rates
4. Simulation Framework & Results

The ICAL Detector

Modules	3
Module dimension	16 m x 16 m x 14.5 m
Detector dimension	48 m x 16 m x 14.5 m
Iron layers	151
Iron plate thickness	56 mm
RPC layers	150
Gap for RPC units	40 mm
RPC dimension	1840 mm x 1915 mm x 20 mm
RPC units/ layer/ module	64
RPC units/ module	9600
Total RPC units	28,800
Magnetic field	1.3 Tesla



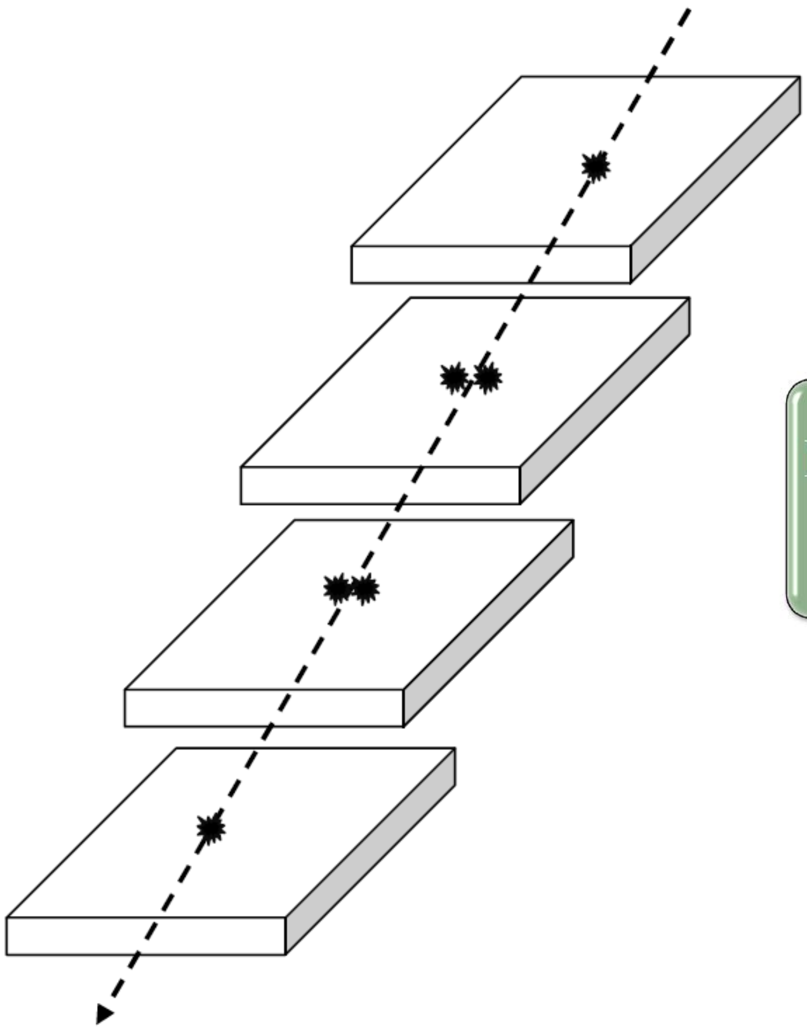
Neutrino Interactions in ICAL

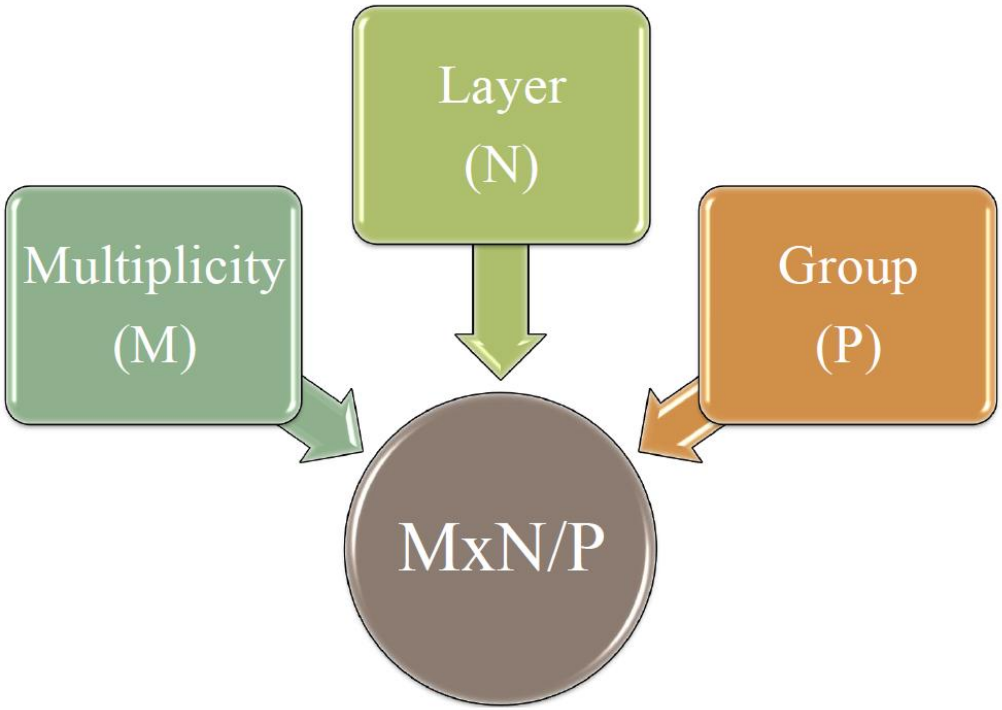
- Neutrino interactions in iron produce muon and/ or hadrons.
- Muon produces long track inside the detector, traversing many layers.
- Hadrons give rise to showers, confined within a few layers.
- The neutrino energy can be estimated from the muon momentum and the hit distribution of hadrons.

Design Goals of Trigger System

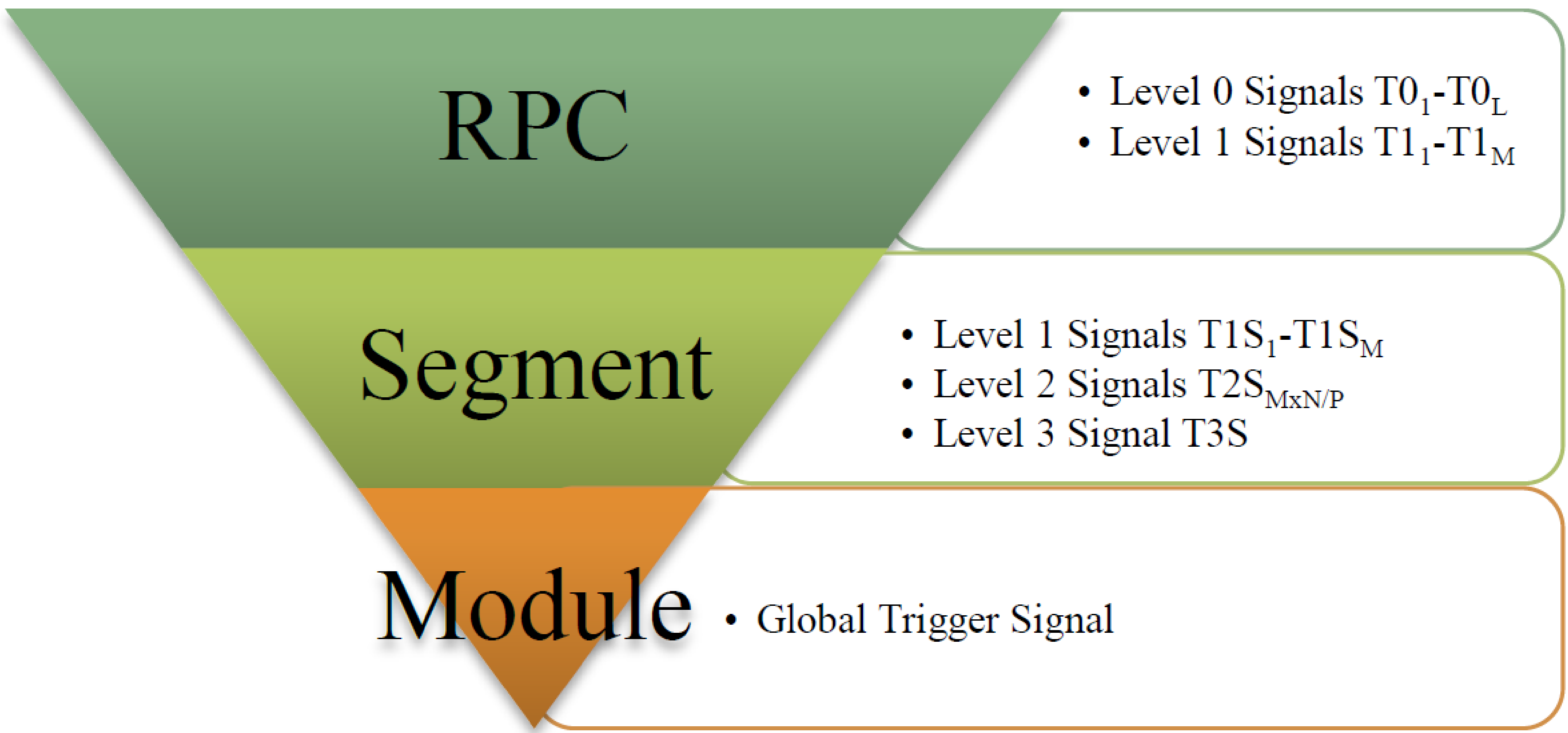
- High detection efficiency
- Admissible chance trigger rate
- Feasibility of hardware implementation

Trigger Criteria

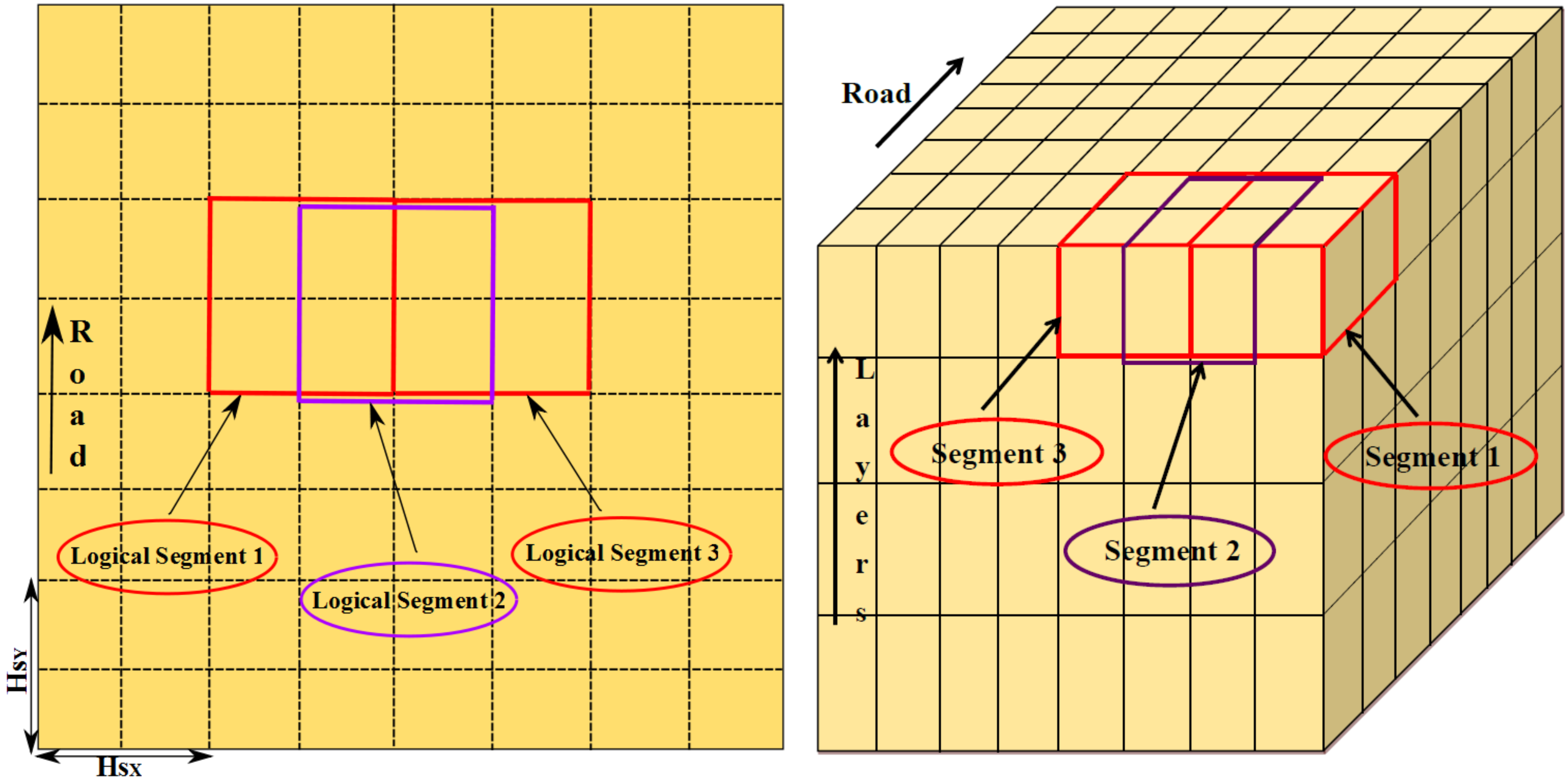




The Trigger Pyramid



Segmentation



Hierarchy of Trigger Scheme

Level0 Signals

- $T0_1 = S_{00} + S_{08} + S_{16} + S_{24} + S_{32} + S_{40} + S_{48} + S_{56}$
- $T0_2 = S_{01} + S_{09} + S_{17} + S_{25} + S_{33} + S_{41} + S_{49} + S_{57}$
  :
- $T0_8 = S_{07} + S_{15} + S_{23} + S_{31} + S_{39} + S_{47} + S_{55} + S_{63}$

Level1 Signals

- $T1_1 = T0_1 + T0_2 + \ldots + T0_8$
- $T1_2 = T0_1.T0_2 + T0_2.T0_3 + \ldots + T0_8.T0_1$
- $T1_3 = T0_1.T0_2.T0_3 + T0_2.T0_3.T0_4 + \ldots + T0_8.T0_1.T0_2$
- $T1_4 = T0_1.T0_2.T0_3.T0_4 + \ldots + T0_8.T0_1.T0_2.T0_3$

Level2 Signals

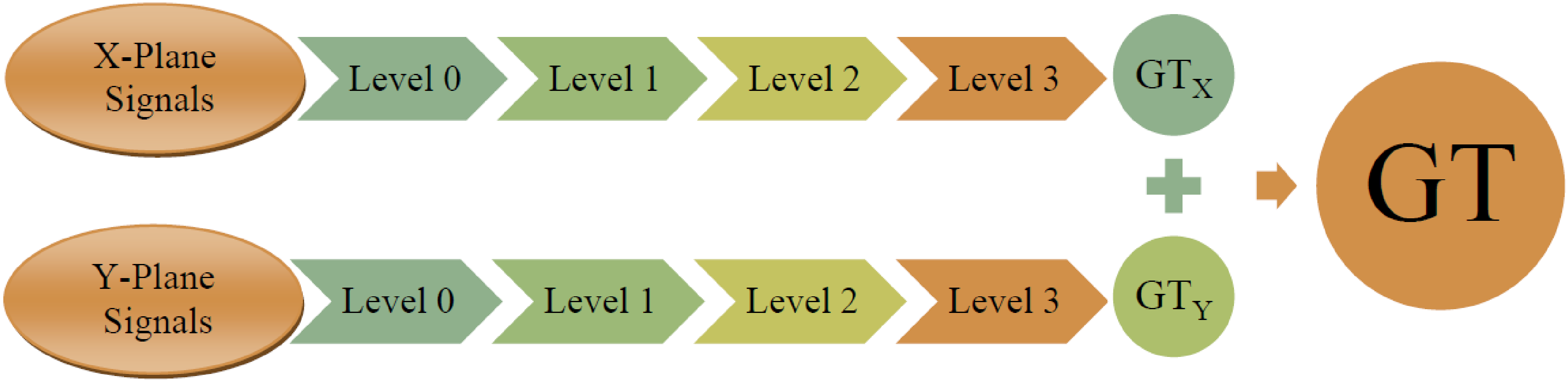
- $T1S_M = \Sigma\, T1_M$
- $T2S_{MxN/P}$

Level3 Signals

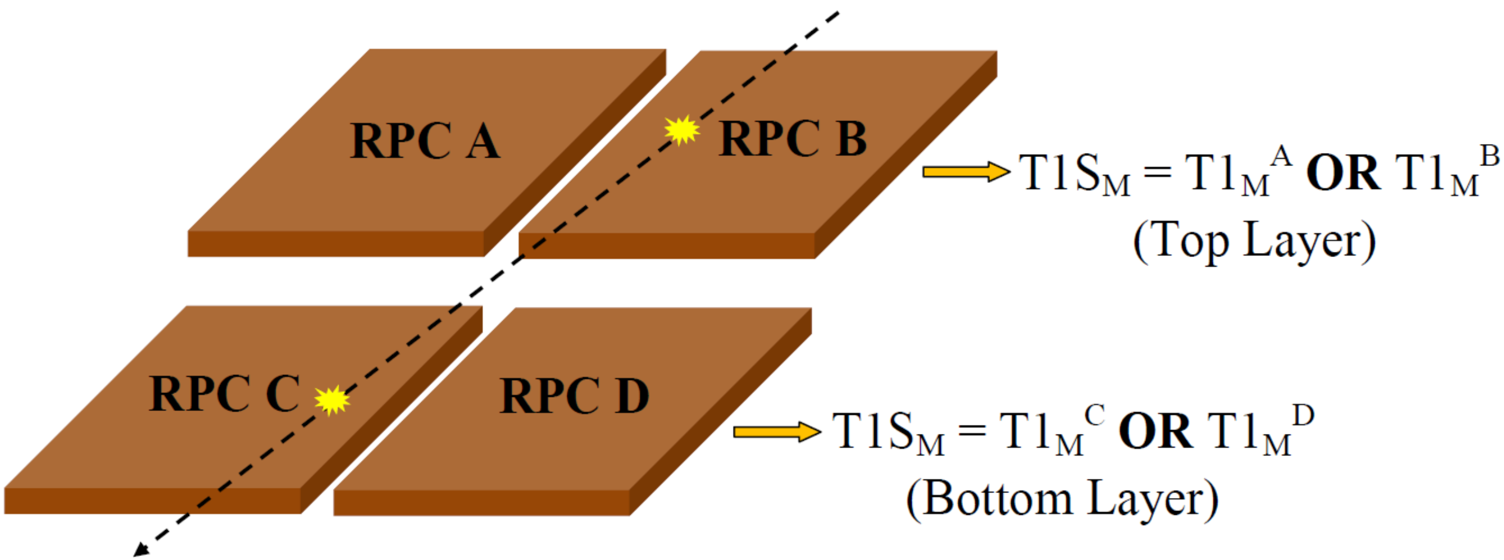
- $T3S = \Sigma\, T2S_{MxN/P}$

Global Trigger

- $GT_X = \Sigma\, T3S_X$, $GT_Y = \Sigma T3S_Y$
- $GT = GT_X$ OR GT_Y



X-Plane Signals
Level 0
Level 1
Level 2
Level 3
GT_X
Y-Plane Signals
Level 0
Level 1
Level 2
Level 3
GT_Y
GT



RPC A
RPC B
RPC C
RPC D
$T1S_M = T1_M^A$ **OR** $T1_M^B$
(Top Layer)
$T1S_M = T1_M^C$ **OR** $T1_M^D$
(Bottom Layer)

Chance Coincidence Rates

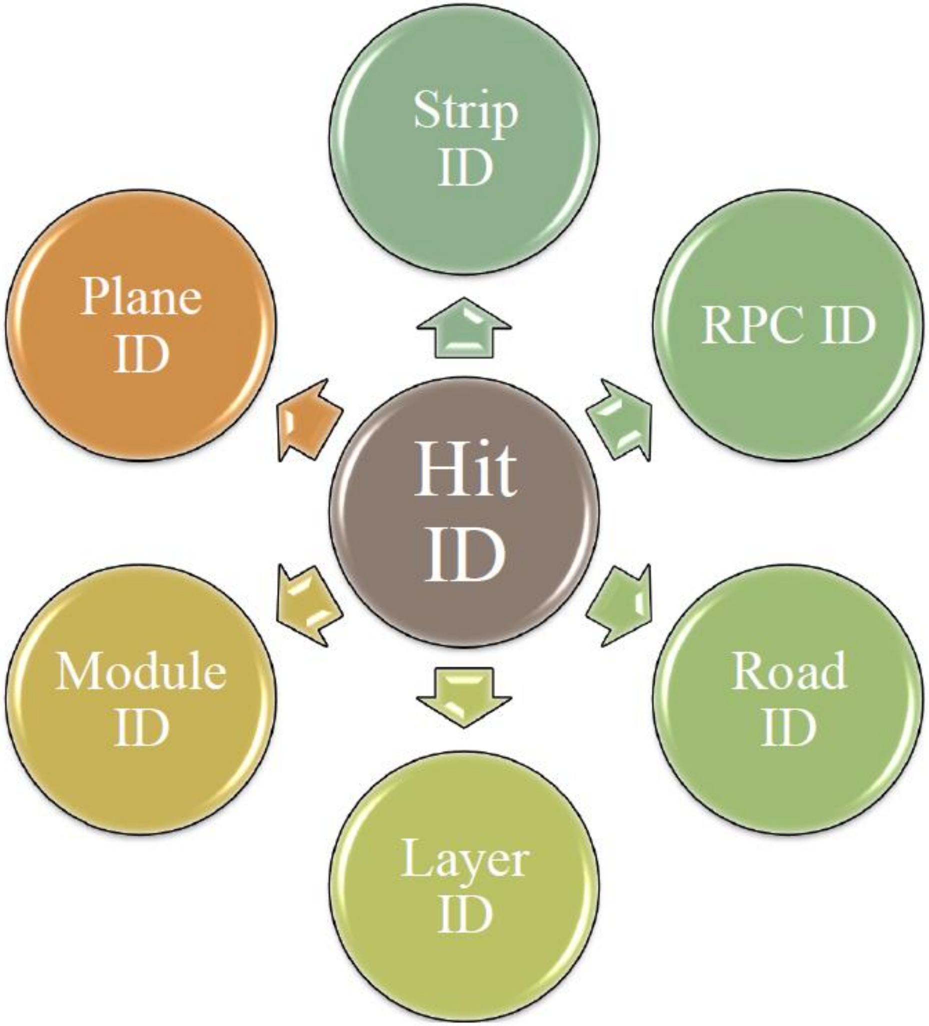
Average noise rate/ RPC strip (200 cm x 3 cm)		Coincidence Window (ns)
Surface Rate (Hz)	**Underground Rate (Hz)**	
200	10*	100

Set 1
- 1x5/8
- 2x4/8
- 3x3/8
- 4x2/8

Set 2
- 1x4/8
- 2x3/8
- 3x2/8

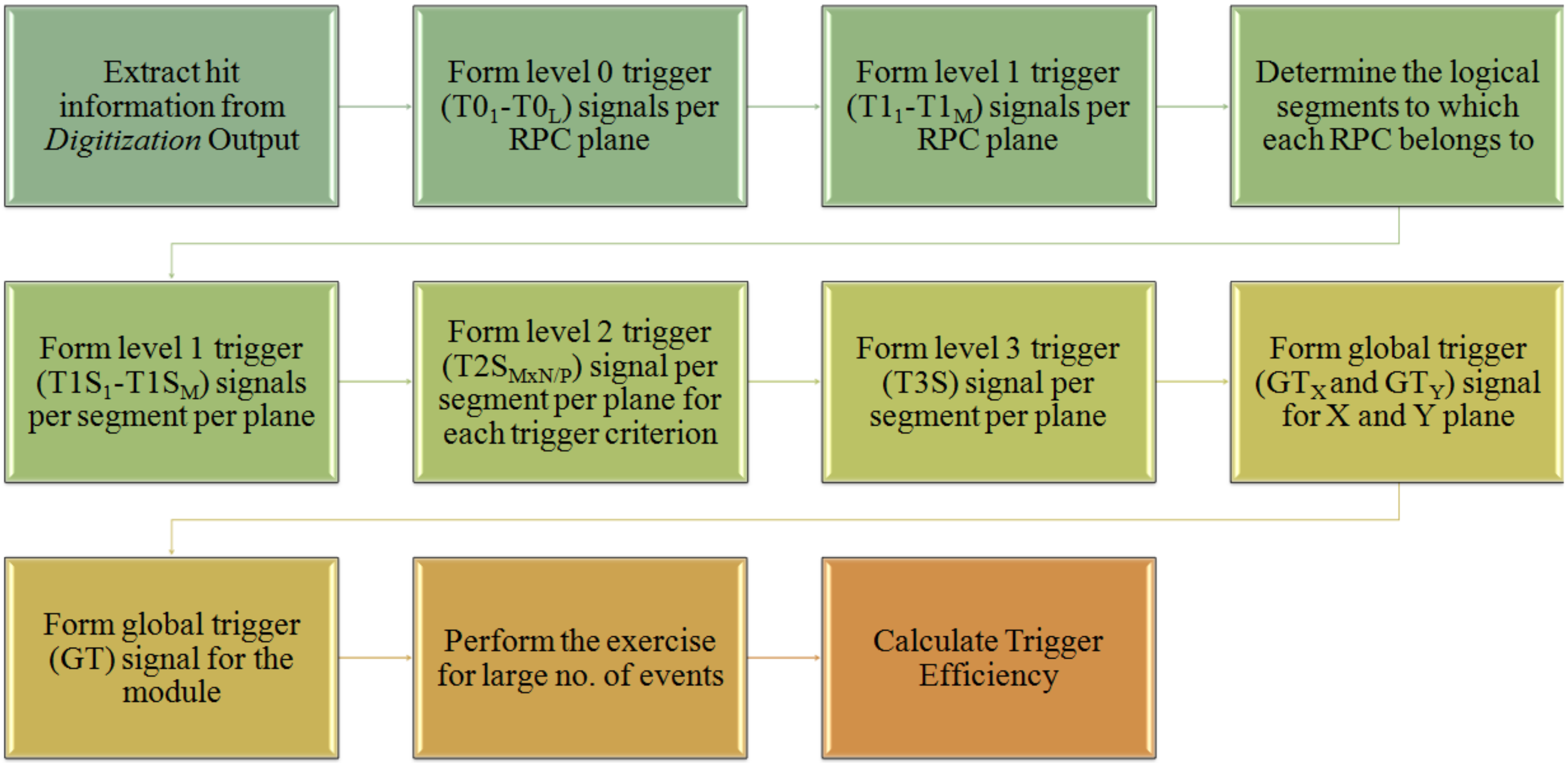
H_S	V_S	Segment Dimension	Total Segments	Trigger Criteria Set 1		Trigger Criteria Set 2	
				Surface Rate (Hz)	**Underground Rate (Hz)**	**Surface Rate (Hz)**	**Underground Rate (Hz)**
4 (2x2)	10	4 m x 4 m x 1 m	735	87	2.7×10^{-5}	1.4×10^{4}	8.5×10^{-2}
	20	4 m x 4 m x 2 m	392	87	2.7×10^{-5}	1.4×10^{4}	8.5×10^{-2}
	40	4 m x 4 m x 4 m	196	87	2.7×10^{-5}	1.4×10^{4}	8.5×10^{-2}
9 (3x3)	30	6 m x 6 m x 3 m	180	3.7×10^{3}	1.1×10^{-3}	2.6×10^{5}	1.6
	40	6 m x 6 m x 4 m	144	3.7×10^{3}	1.1×10^{-3}	2.6×10^{5}	1.6
	60	6 m x 6 m x 6 m	108	3.7×10^{3}	1.1×10^{-3}	2.6×10^{5}	1.6
16 (4x4)	40	8 m x 8 m x 4 m	100	4.5×10^{4}	1.4×10^{-2}	1.8×10^{6}	11.1
	60	8 m x 8 m x 6 m	75	4.5×10^{4}	1.4×10^{-2}	1.8×10^{6}	11.1
	80	8 m x 8 m x 8 m	50	4.5×10^{4}	1.4×10^{-2}	1.8×10^{6}	11.1

Analysis Input



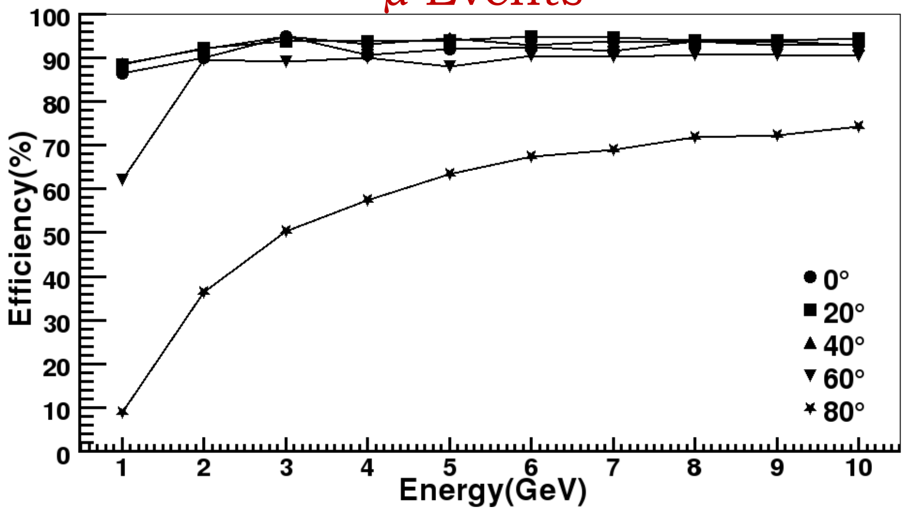
Algorithm

$$\eta = \frac{N_E}{N_T}$$



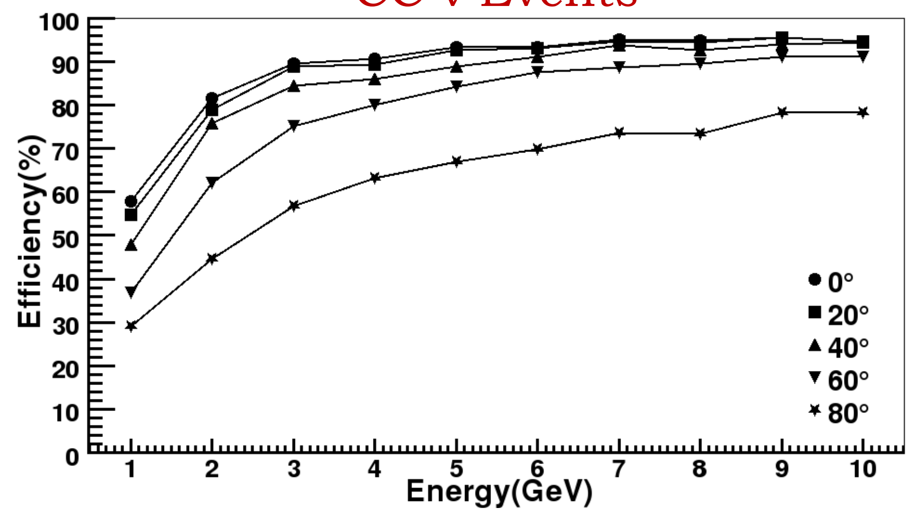
Trigger Efficiency Vs. Event Parameters

μ Events



- Trigger efficiency increases with increase in energy of the incident particle.

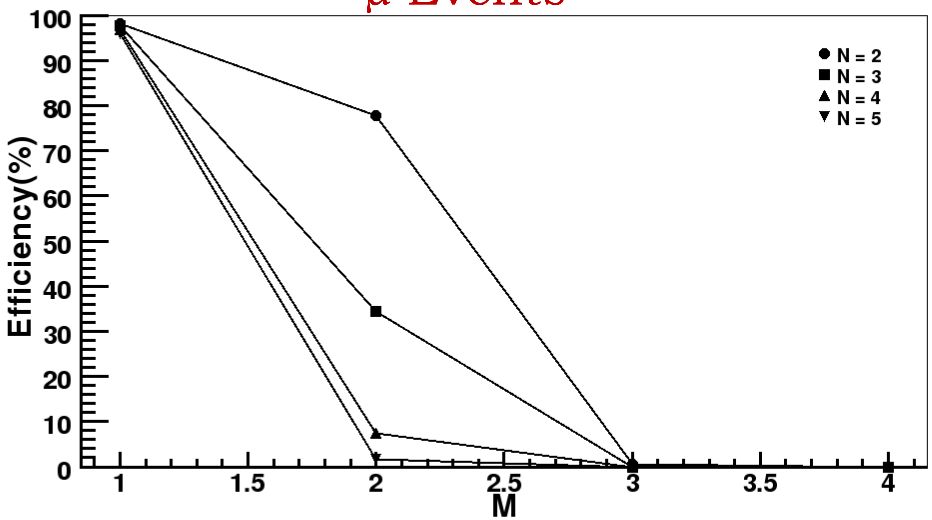
CC ν Events



- Trigger efficiency decreases with increase in the angle of incidence.

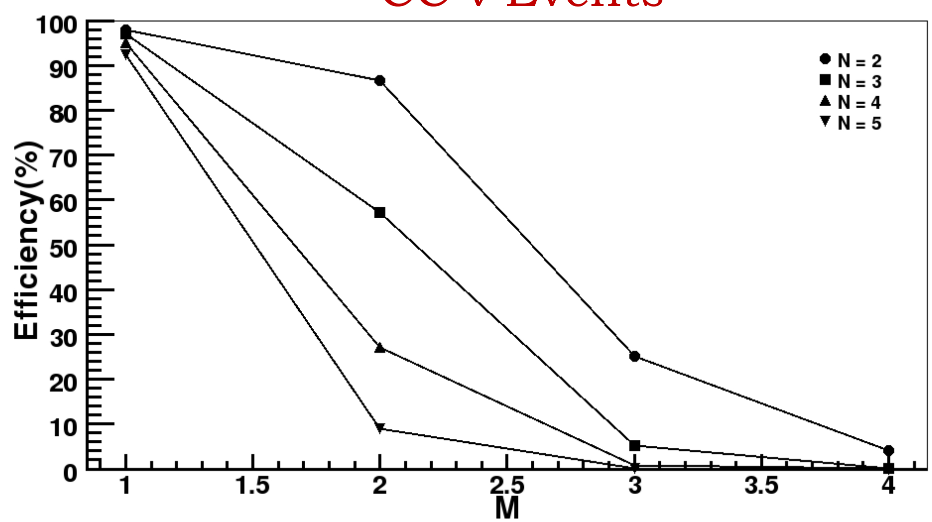
Trigger Efficiency Vs. Trigger Parameters (M, N)

μ Events



- Trigger efficiency is dominated by the 1-Fold and the 2-Fold criteria for muon events.

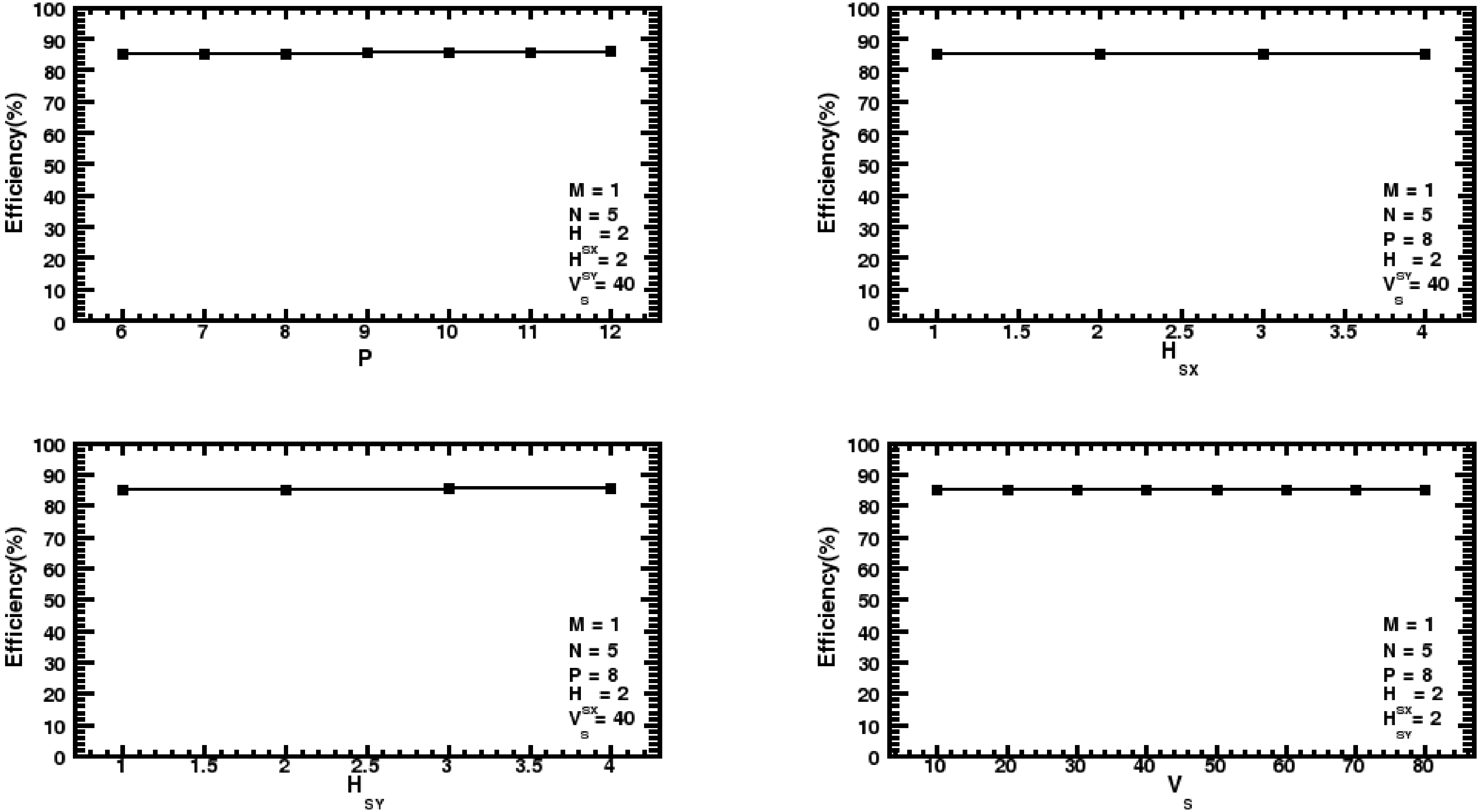
CC ν Events



- Trigger criteria with M>2 is significant for neutrino events compared to muon events.

Trigger Efficiency Vs. Trigger Parameters (P, H_{SX}, H_{SY}, V_S)

μ Events



Summary

- An architecture for the trigger scheme of the ICAL detector has been developed.
- Associated chance trigger rates are found to be acceptable for an optimal combination of the trigger parameters.
- The simulation results provide a good assessment of the detection efficiency of the trigger scheme.
- The nature of variation of trigger efficiency as a function of different trigger parameters are also understood.
- Validation of the scheme motivates to proceed towards the subsequent implementation phase.

References

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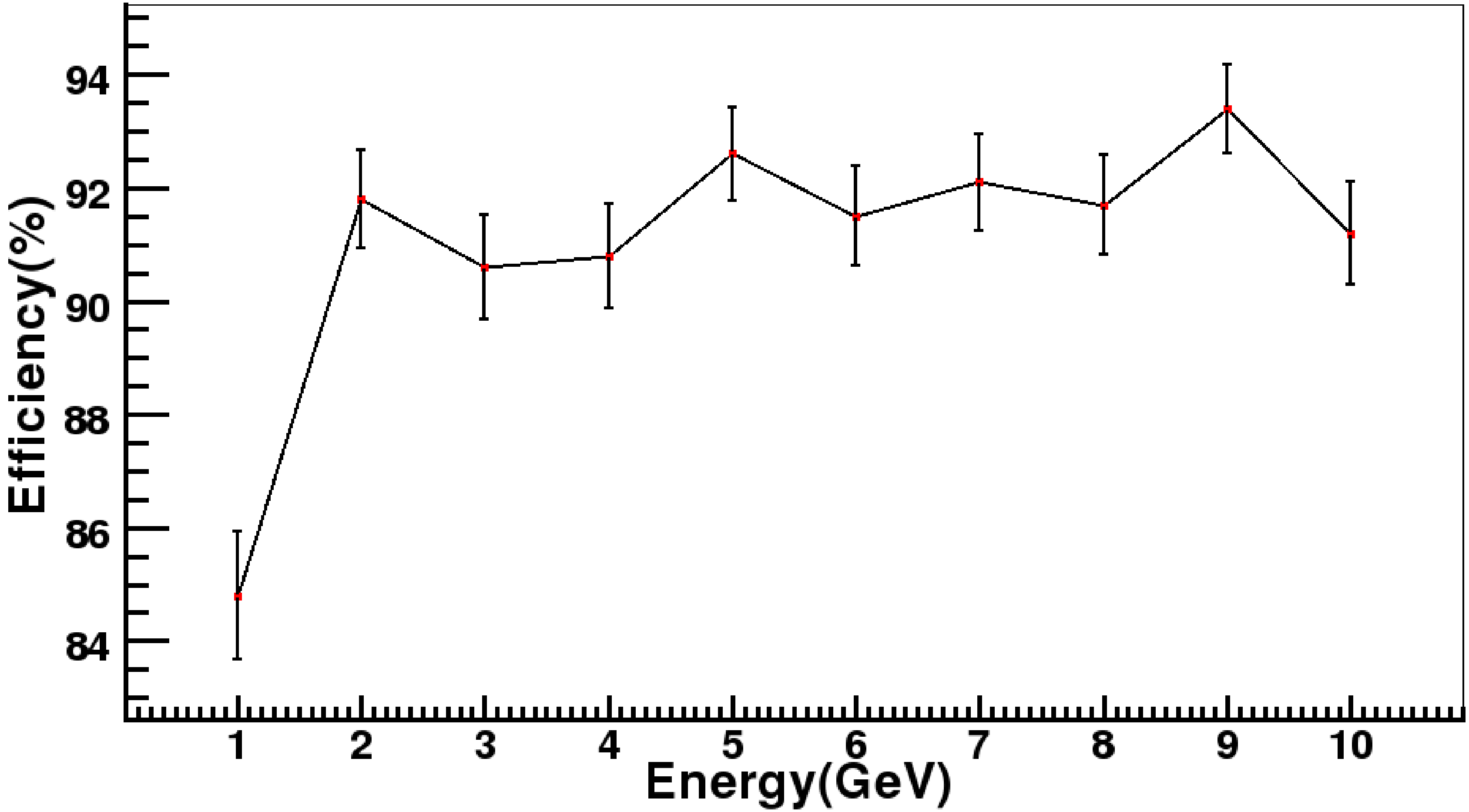
Back-up Slides

μ Events



Efficiency Vs. Trigger Criteria

Set 1	Set 2	Set 3
1x5/8	1x5/8	1x4/8
2x4/8	2x3/8	2x3/8
3x3/8	3x2/8	3x2/8
4x2/8		

CC ν Events