Micromegas Trigger Logic

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Introduction

- Started to try to crystallize several ideas about the trigger processor into a prototype working model

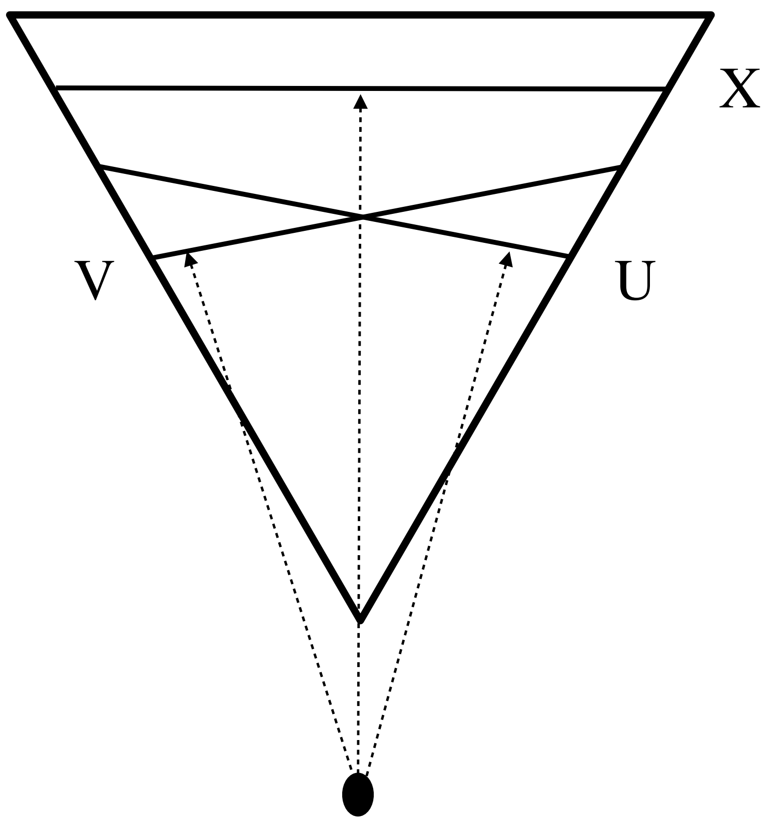
- Try to use these ideas to provide timing estimates

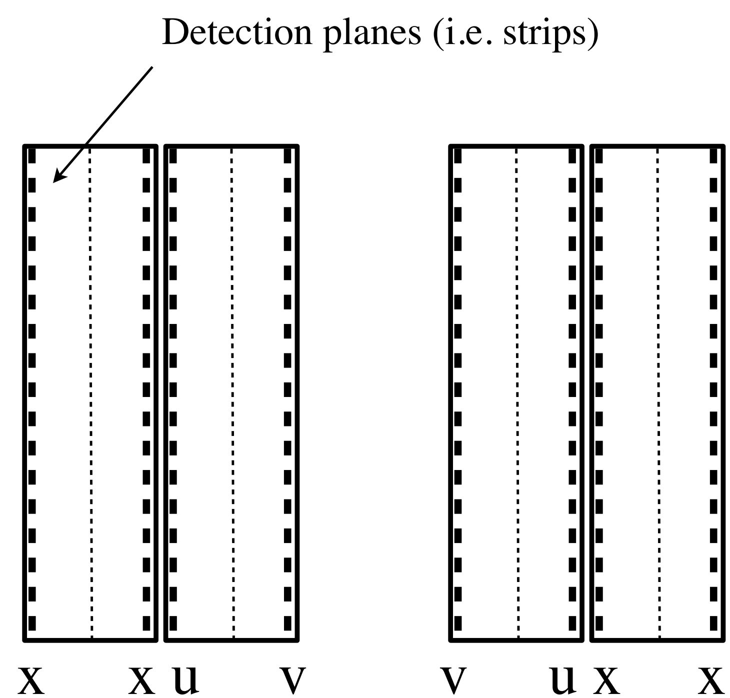
- We have built a trigger processor simulation so that we can test and optimize the configuration of the trigger algorithm with a realistic model

- We will also use it to start building the simulation of the FPGA programming, which should give us better timing estimates

- This is a prototype version: comments and questions are welcomed

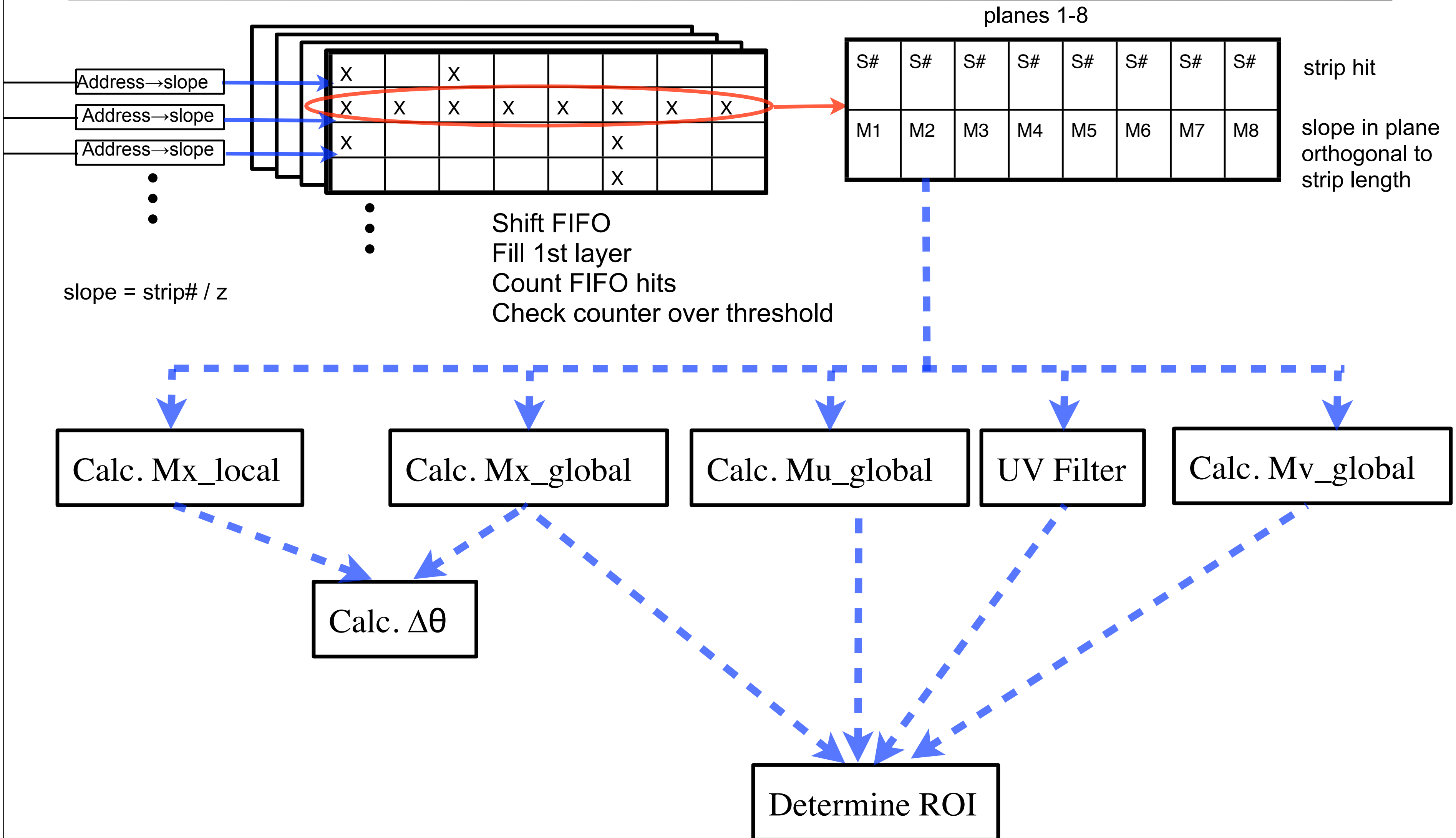
Stereo Plane Layout and Naming



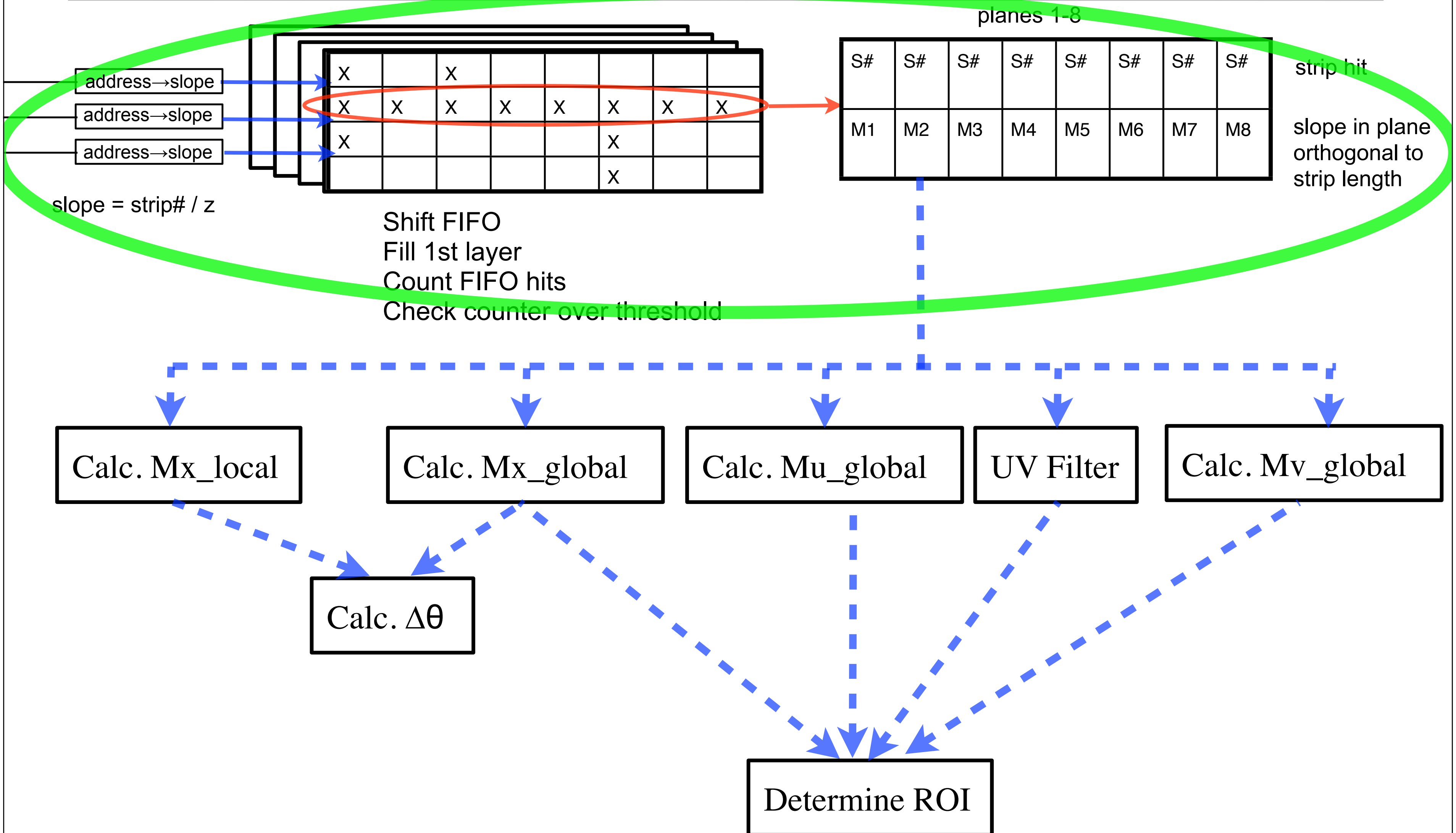


Strip # = (orthogonal distance from beam line) / (strip width)

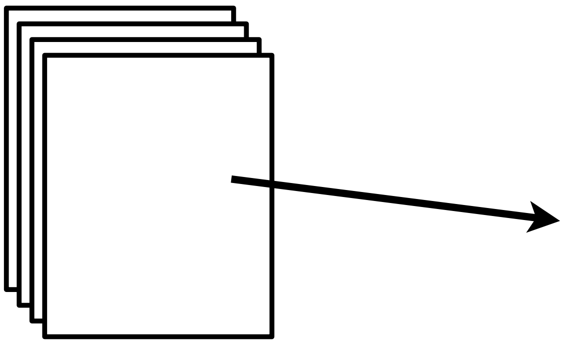
Overall Picture



Examine Coincidence Detection



Track Identification by Coincidence



Planes

	1	2	3	4	5	6	7	8	Hit Counter
M+2ε	X		X	X	X	X			5
M+ε	X	X	X	X	X	X		X	7
M	X	X	X	X	X	X	X	X	8
M-ε		X	X	X	X	X	X	X	7
M-2ε			X	X	X	X	X		5

FIFO 4 layers deep
Each layer shifts forward and updated every BC
After 4 BC a hit is deleted if not removed before to form a track

Stereo planes (3,4,5,6) have a higher slope tolerance b/c the slope is in a different plane

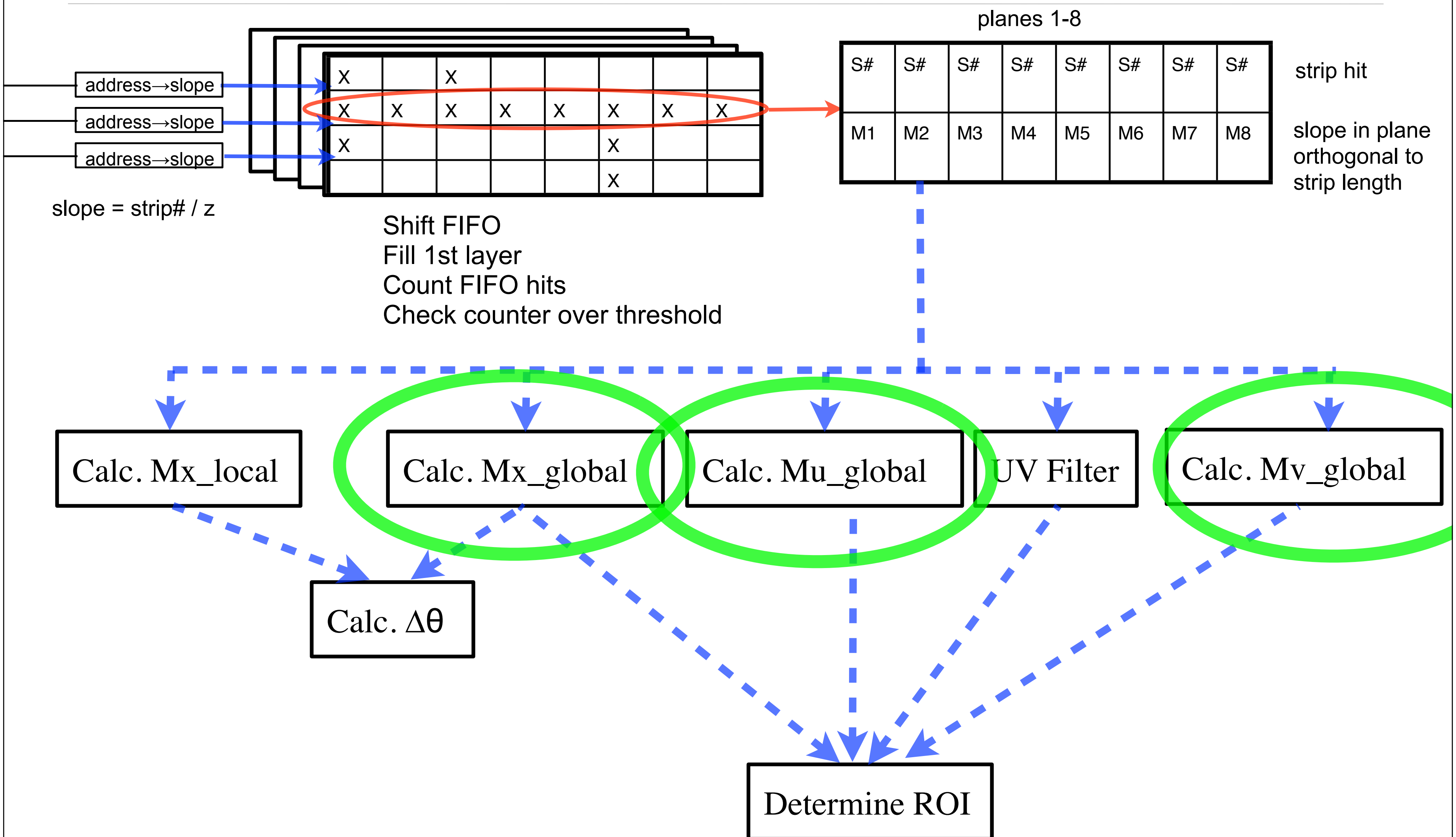
Need to optimize:
1) Slope resolution (i.e. table size)
2) # hits necessary for track

	1	2	3	4	5	6	7	8
Strip #	s#	s#	s#	s#	s#	s#	s#	s#
Slopes	Mx	Mx	Mu	Mv	Mv	Mu	Mx	Mx

When a track is read, the corresponding hit truth tags are set to zero in the FIFO.

		X	X				
X	X	X	X			X	X
X	X			X	X	X	X
				X	X		

Examine Global Slope Calculations



Avg X,U, and V global slope

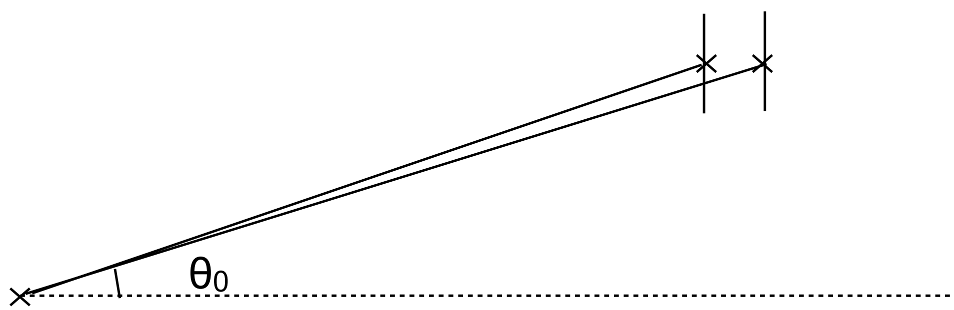
Note: “global” implies that the slope value is anchored to the IP

	1	2	3	4	5	6	7	8	
Strip #	s#	s#	s#	s#	s#	s#	s#	s#	
Slopes	Mx	Mx	Mu	Mv	Mv	Mu	Mx	Mx	slope in plane orthogonal to strip length

Mv_global = AVG(Mv values)

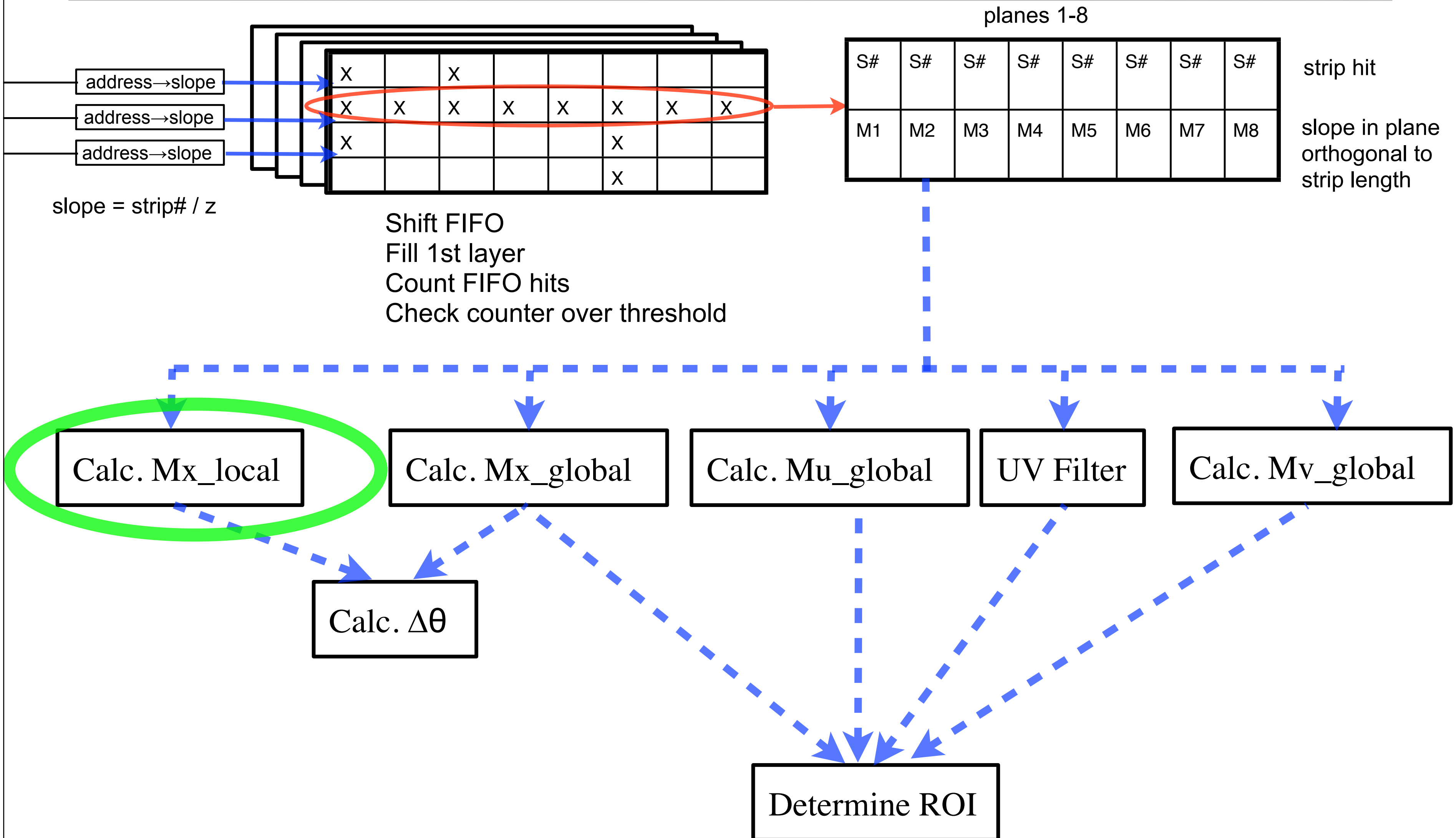
Mu_global = AVG(Mu values)

Mx_global = AVG(Mx values)



IP

Examine Mx_local Calculation



Calculate Local Mx Slope

$$M_{X\_local} = A_k \sum_i z_i y_i - B_k \sum_i y_i$$

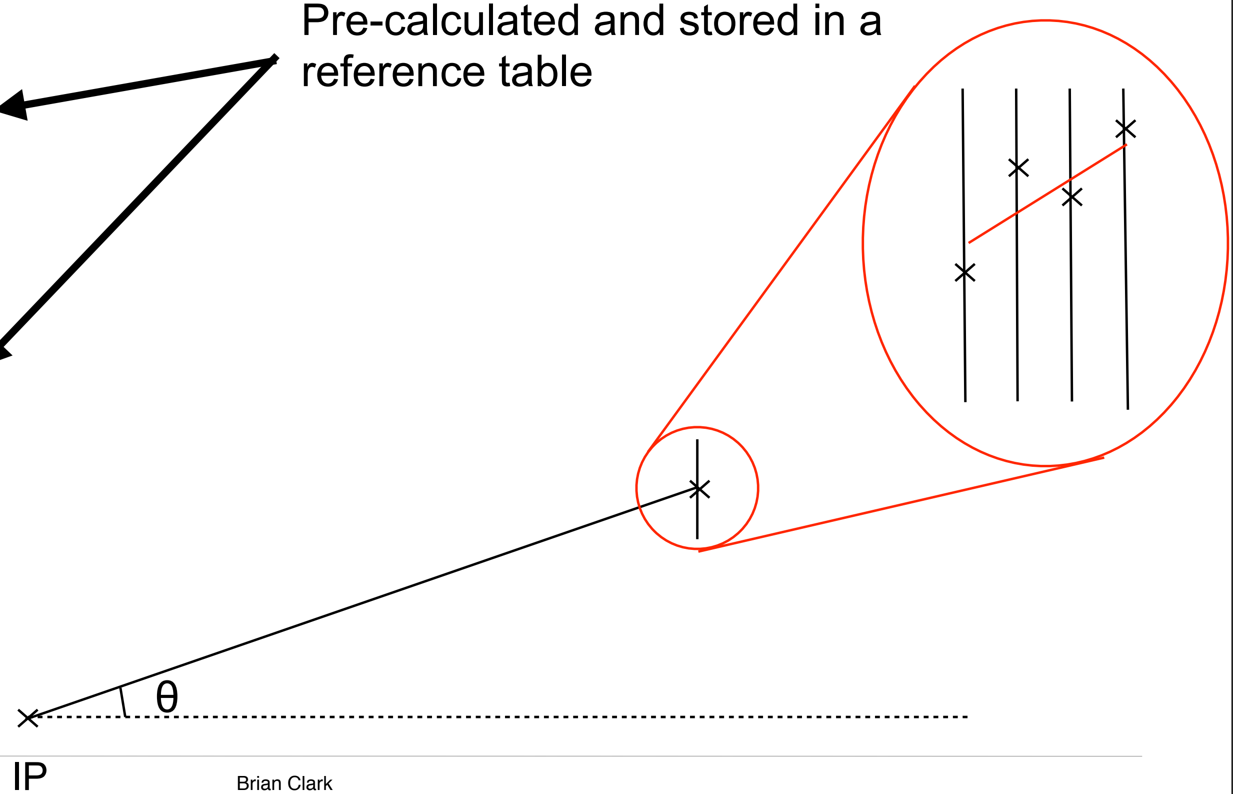
$$A_k = \frac{N}{N\sum_{i=1}^{N} z_i^2 - \left(\sum_{i=1}^{N} z_i\right)^2}$$

$$B_k = \frac{\sum_{i=1}^{N} z_i}{N\sum_{i=1}^{N} z_i^2 - \left(\sum_{i=1}^{N} z_i\right)^2}$$

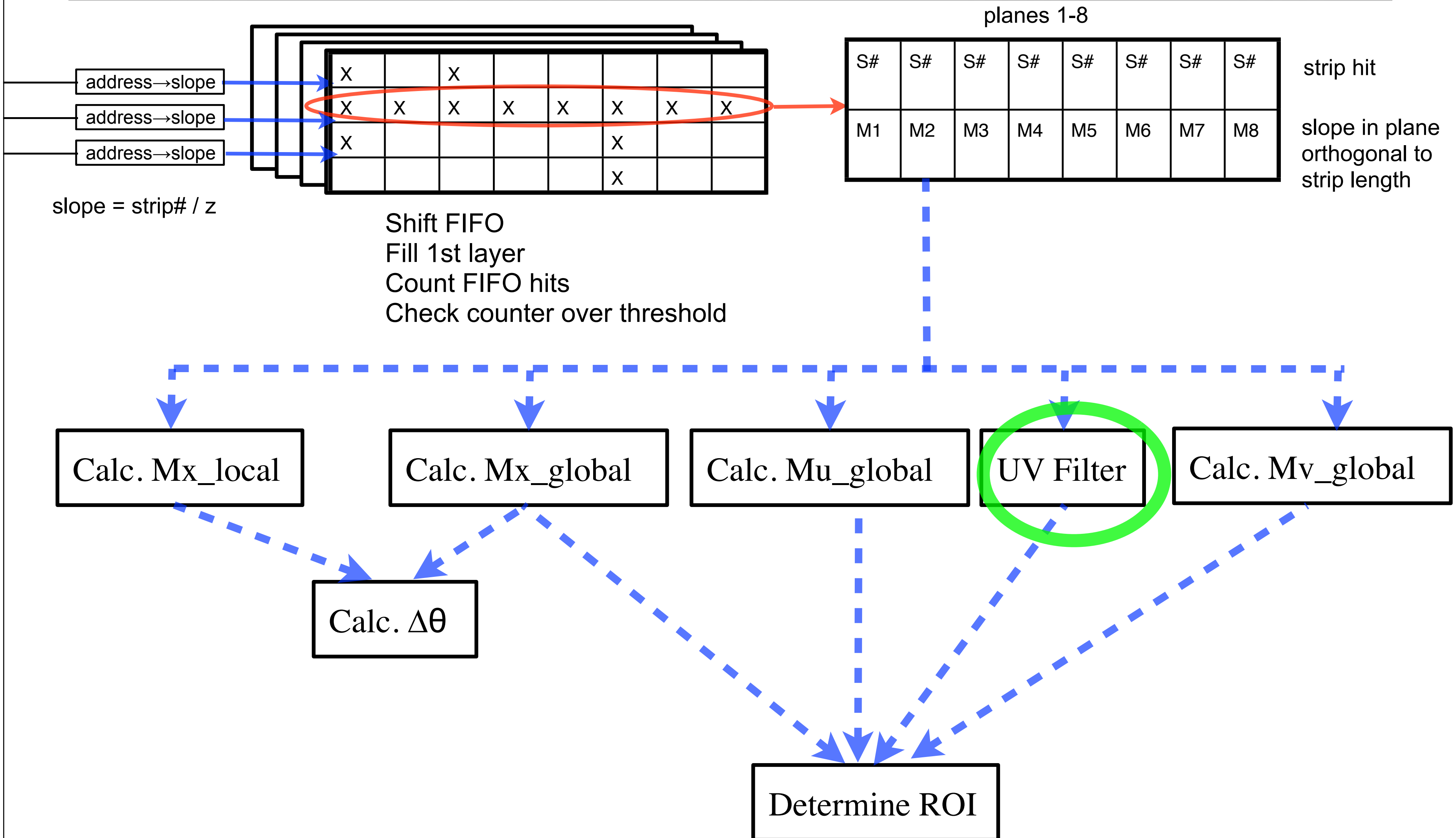
"Local" implies that the fit is not influenced by the IP

Note: Given 4 X-planes, there are 11 hit combinations, assuming N>1

Pre-calculated and stored in a reference table



Examine UV Filter



Filter U V Hits

- The X planes were filtered by the initial coincidence table and delta_theta cut

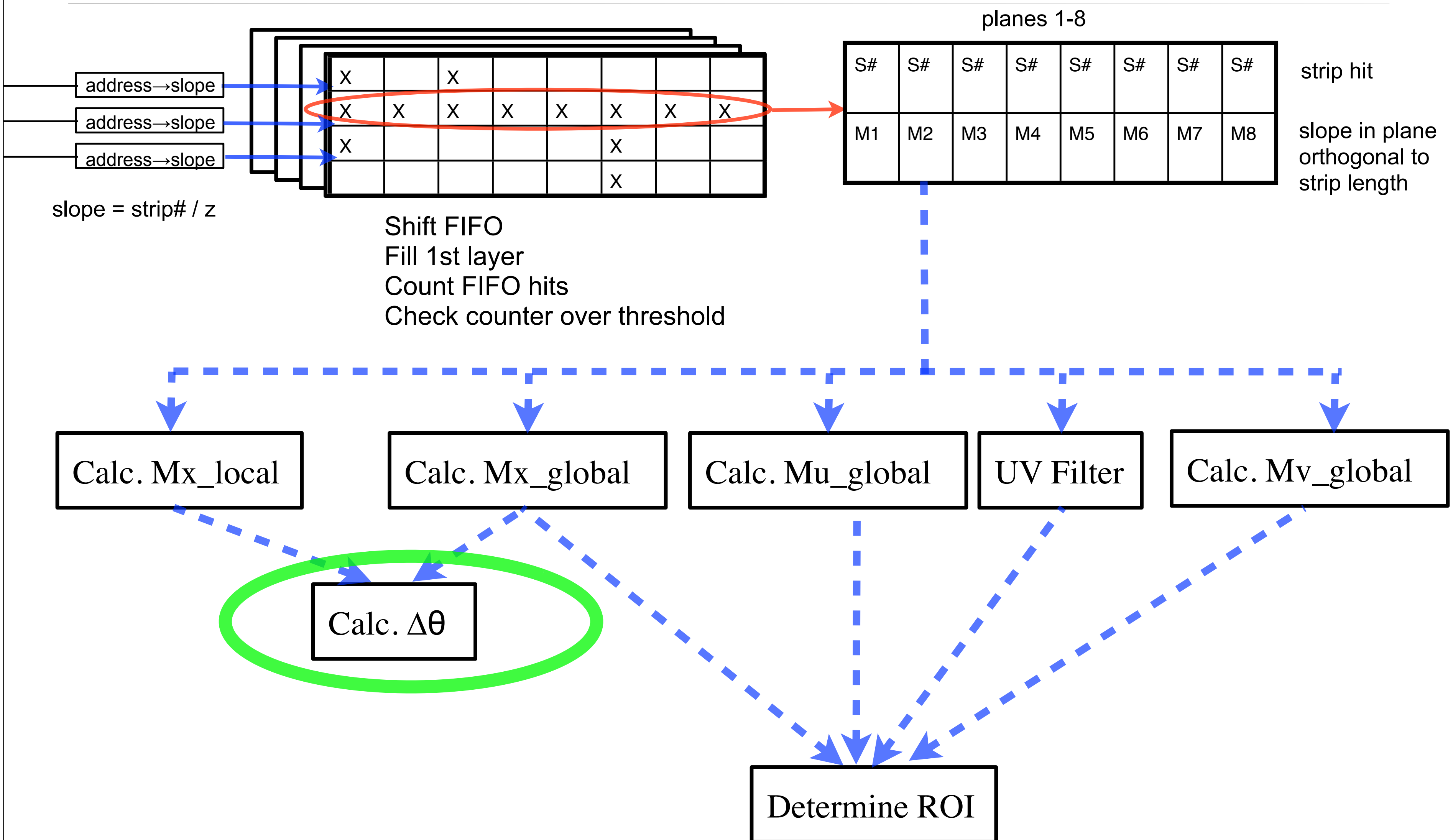
- Filtering is accomplished by comparing U hit slopes and V hit slopes (A finer resolution coincidence filtering than was originally done in identifying a possible track)

- Two U (or V) hits should have a slope coincident within a given tolerance

- This is refining the upfront resolution that was relaxed for the initial coincidence table

- THIS IS THE PORTION OF THE ALGORITHM THAT NEEDS TO BE IMPROVED TO INCREASE PHI FITTING ACCURACY

Examine Delta_theta Calculation



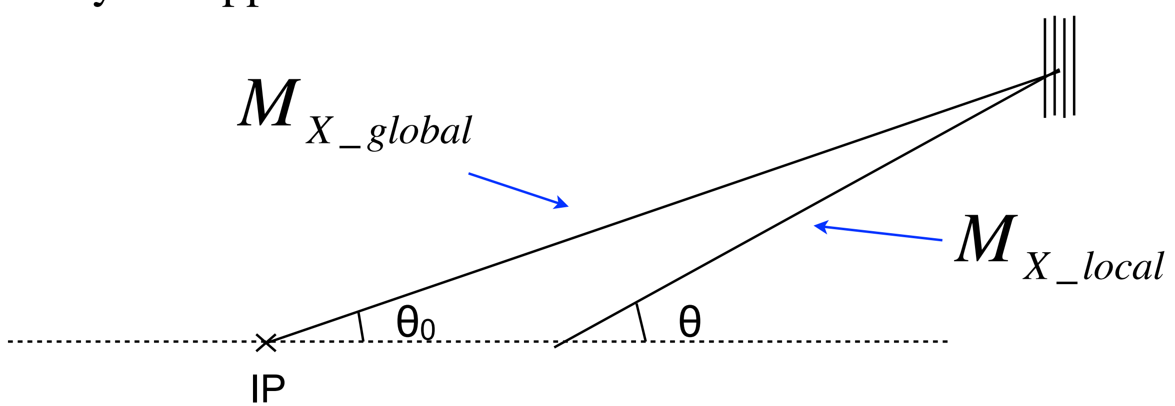
Calculate Delta Theta and Cut

$$\delta\theta = \frac{M_{X\_local} - M_{X\_global}}{\sin(\phi) + \frac{M_{X\_local} M_{X\_global}}{\sin(\phi)}}$$

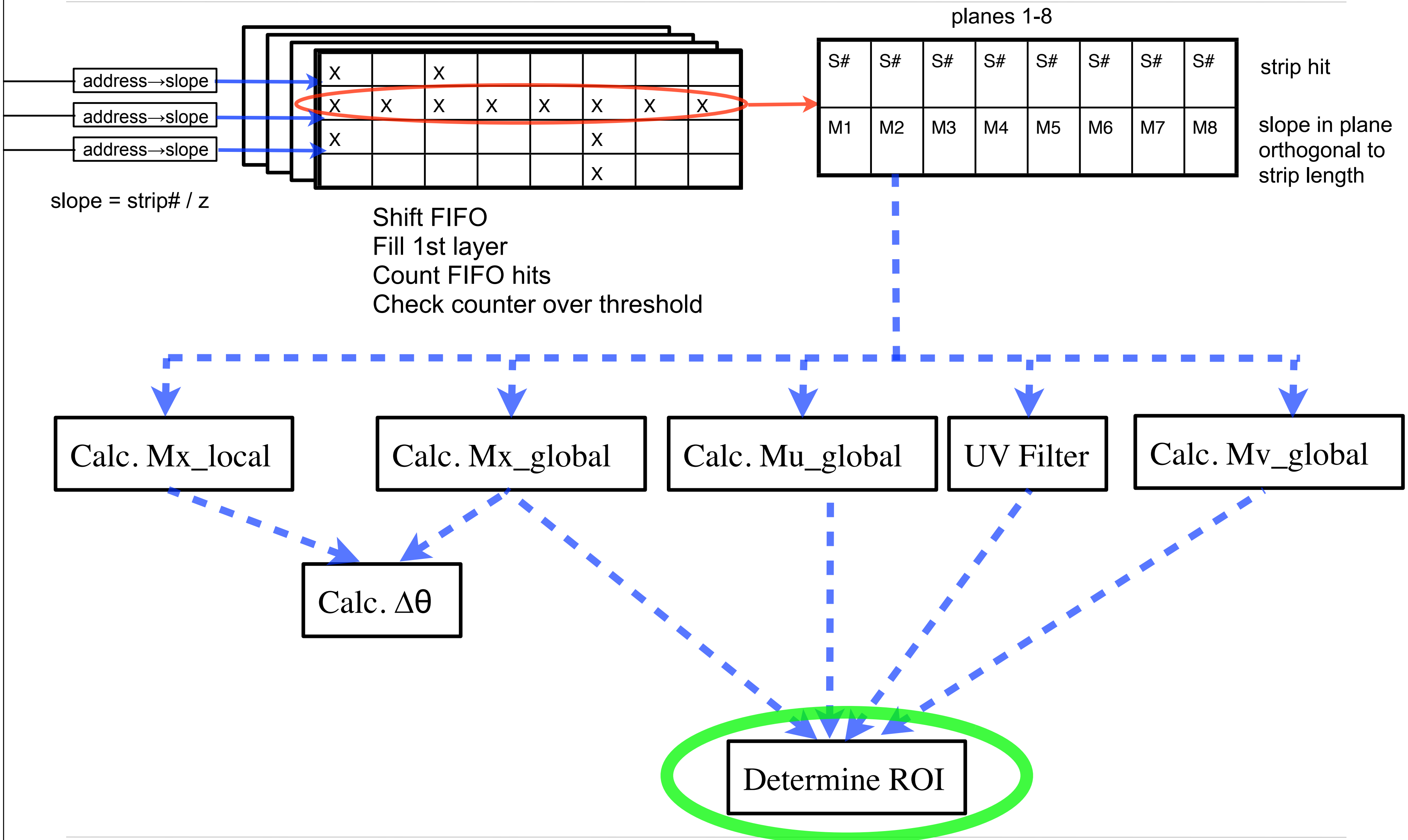
$$\approx \frac{M_{X\_local} - M_{X\_global}}{1 + M_{X\_local} M_{X\_global}}$$

We can now cut on delta_theta to filter out background tracks that are not originating from the vicinity of the IP

The error introduced by the approximation is <4%



Examine ROI Determination



Calc. Cartesian Slope Components

Slope vector: (m_x, m_y, m_z)

$$m_x = AM_U - BM_X \qquad m_x = -AM_V + BM_X \qquad m_y = M_X$$

$A = \csc(3^\circ)$

$B = \cot(3^\circ)$

average

$$m_x$$

ROI

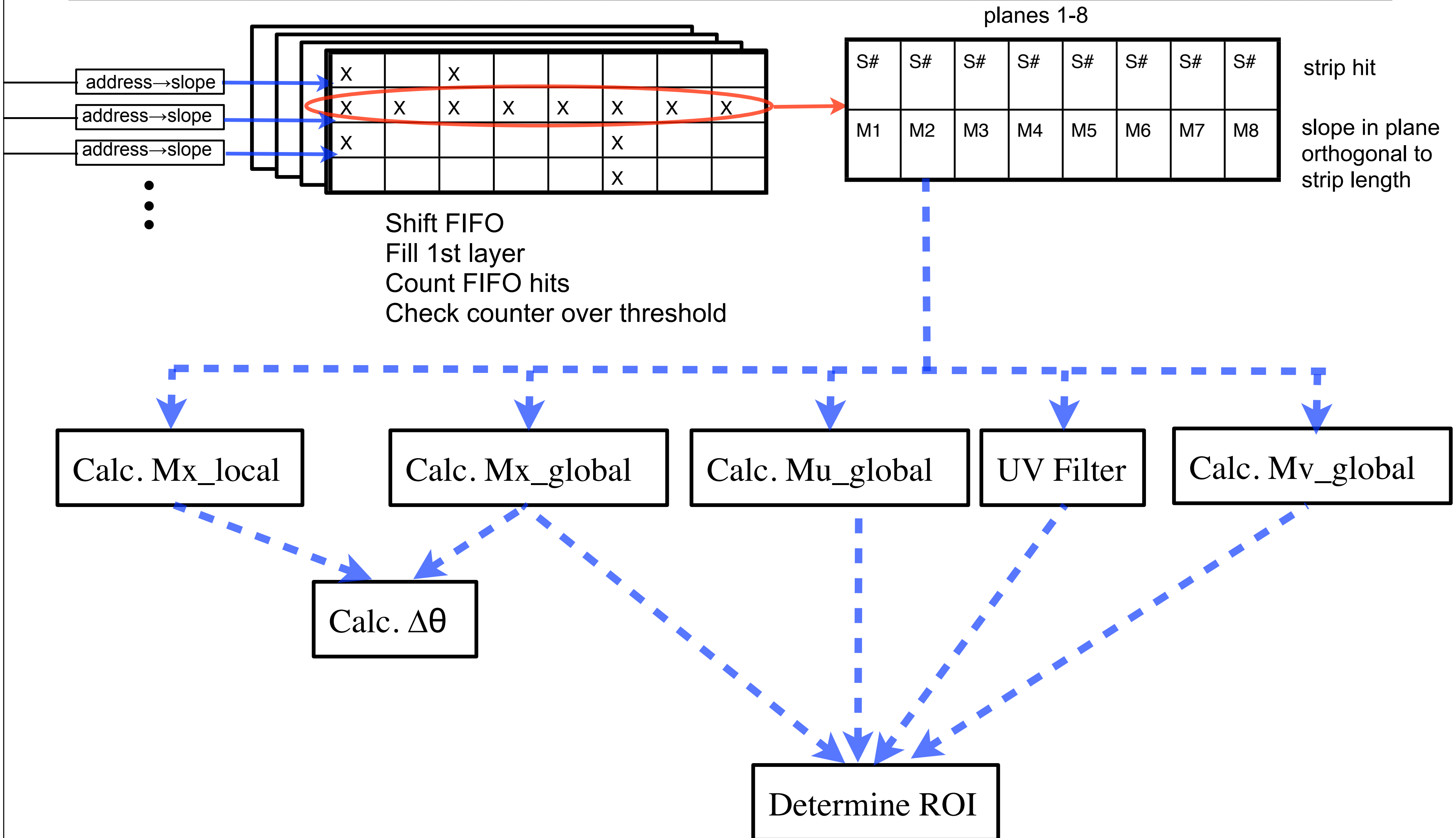
$$\left(m_x, m_y\right) \rightarrow \left(\theta, \phi\right)$$

Reference table

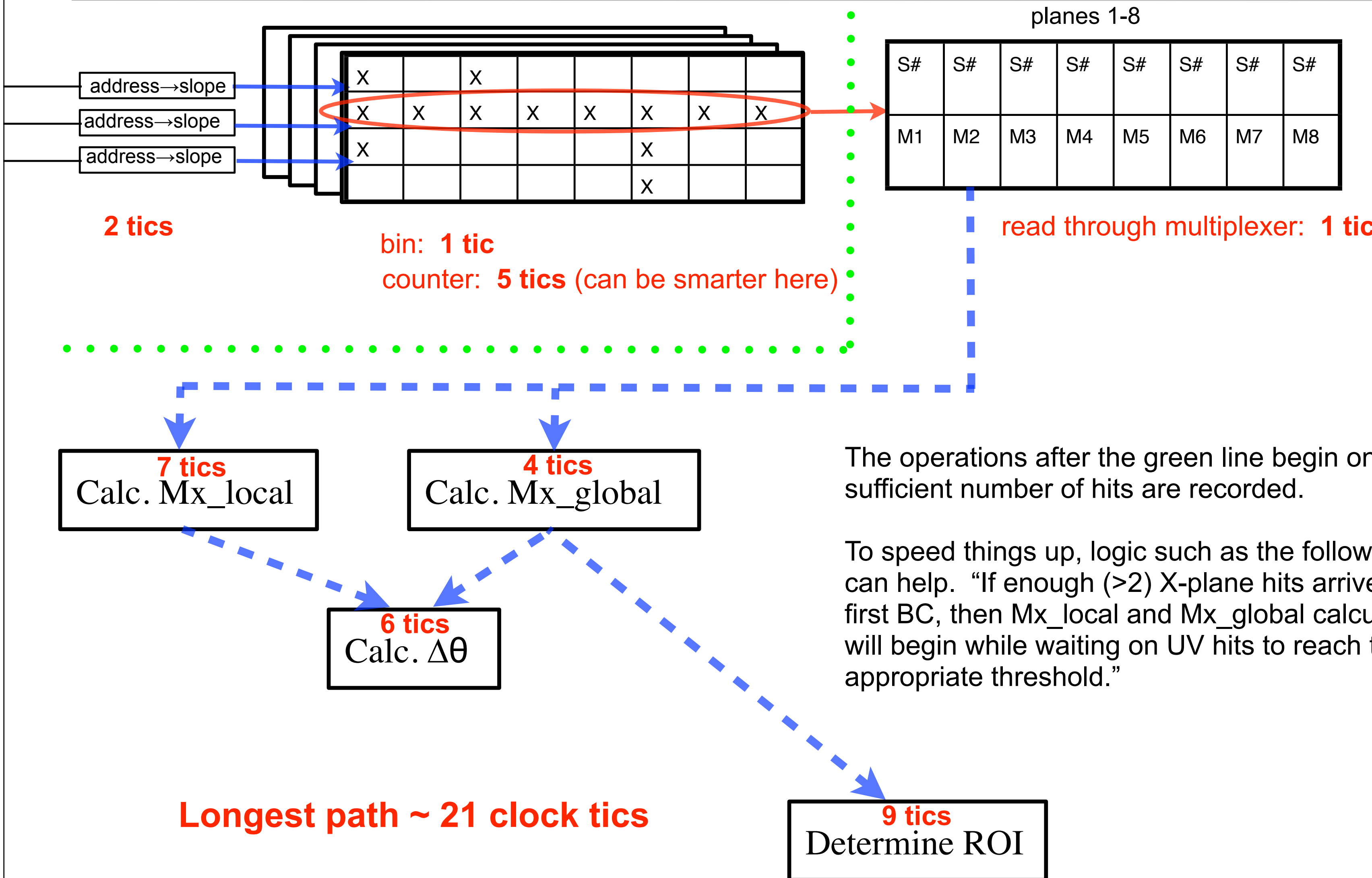
The slope to angles conversion is a 1-1 reference table of size less than ~5000x1700x2 (assuming an additional operation to determine if m_x is +/- and then shift phi; otherwise table is x2 larger)

Note: Actual table can be much smaller and tuned to specified ROI resolution required

Overall Picture



Longest Path



The operations after the green line begin once a sufficient number of hits are recorded.

To speed things up, logic such as the following can help. “If enough (>2) X-plane hits arrive in the first BC, then Mx_local and Mx_global calculations will begin while waiting on UV hits to reach the appropriate threshold.”

Longest path ~ 21 clock tics

Method for Counting Clock Tics

Adding is accomplished in pairs and each addition is 1 clock cycle.

A+B --> 1 tic
A+B+C --> 2 tics
A+B+C+D --> 2 tics
A+B+C+D+E --> 3 tics

Multiplication is accomplished in 2 clock cycles.

A*B --> 2 tics
A*B*C --> 4 tics
A*B*C*D --> 4 tics
A*B*C*D*E --> 6 tics

Reading a reference table is accomplished in 2 clock cycles.

Quick look at performance

Energy = 50GeV, 200GeV, and 1000GeV events were analyzed to determine the fitting performance (~2050 events for each energy)

Recall that the region of interest is determined using a mesh of x,y cartesian slopes superimposed on the wedge. The results that follow use a mesh that is has slope resolution 0.0001. This is finer-grained resolution than needed and can be relaxed.

All tracks fitted had at least 6 hits.

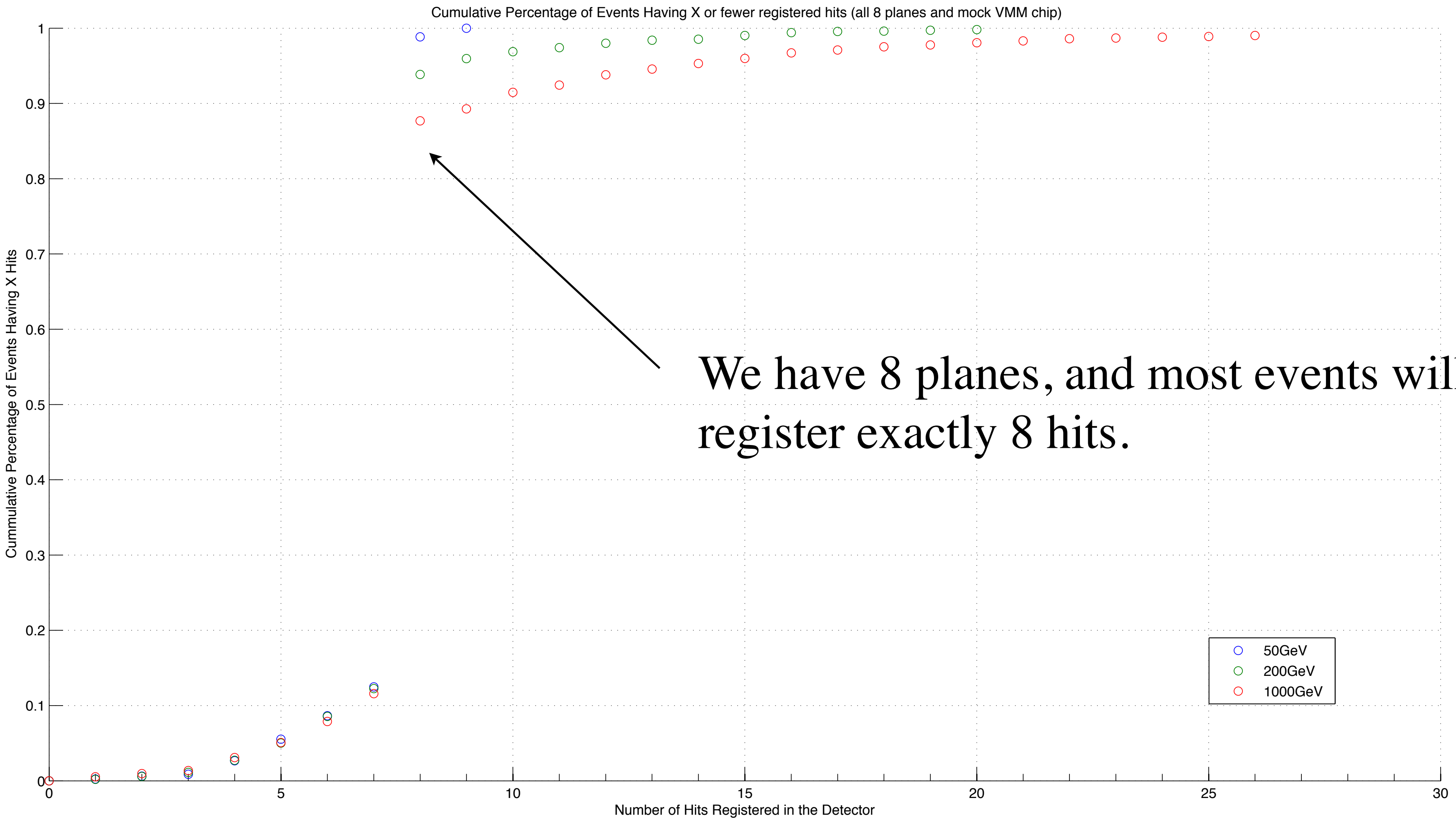
The stereo tilt is 3deg for these studies with xxuvxxuv plane configuration.

Quick look at performance

Events used in this algorithm were generated by Athena. Therefore, true hit and digitized hit information was available.

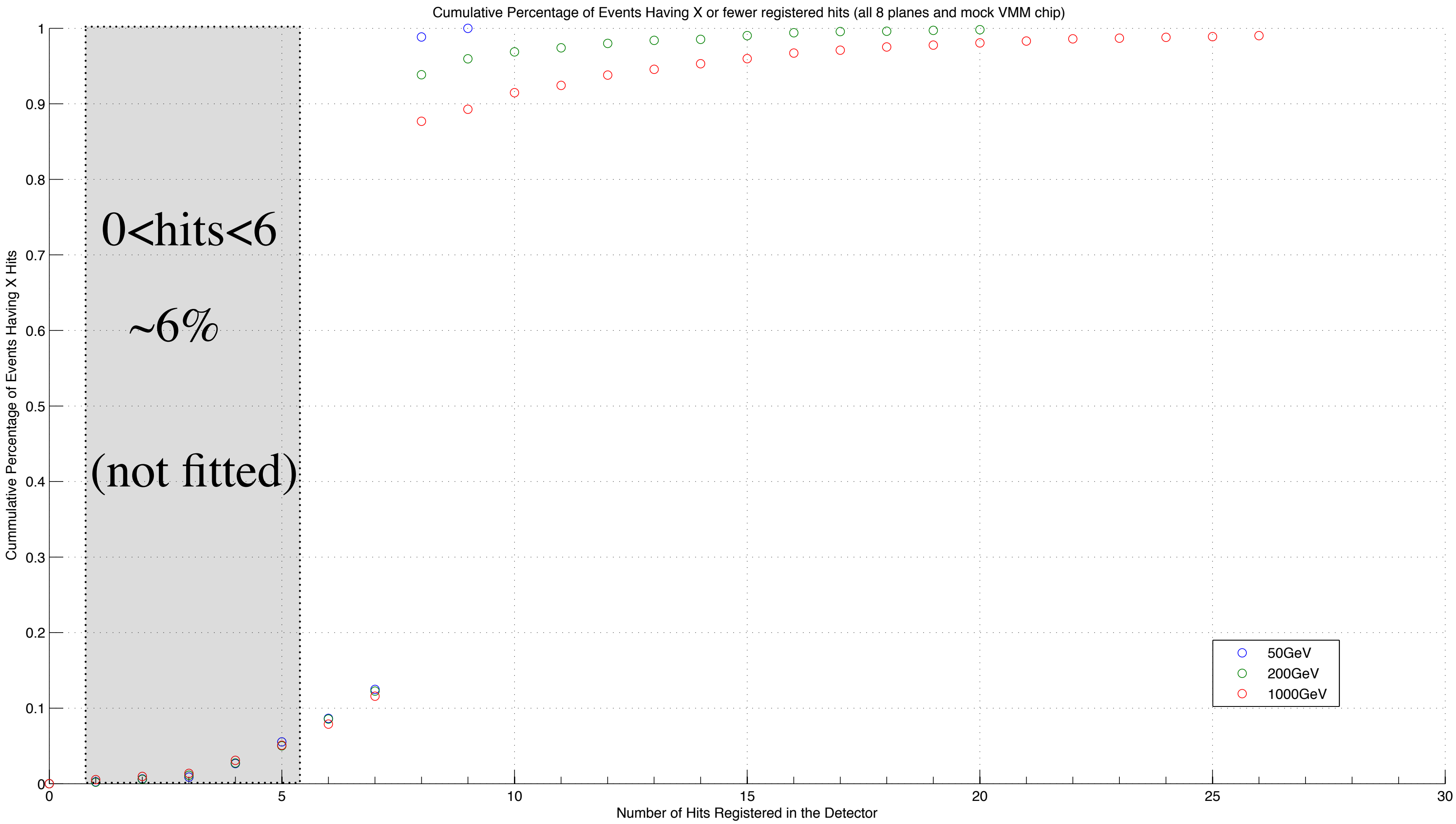
Currently, Athena does not include VMM chips. Therefore, the Athena hits were time-ordered and a mock version of the VMM chip operation was created by grouping sets of 64 sequential strips. The first digitized hit by time of arrival was used and other hits arriving to the same "VMM chip grouping" within 100ns were ignored. (Note: This deadtime is a bit too long for the real VMM chip; however, I did not allow events to pile-up in this analysis as I separated events by more than 4 bunch crossings.)

Number of Hits per Event

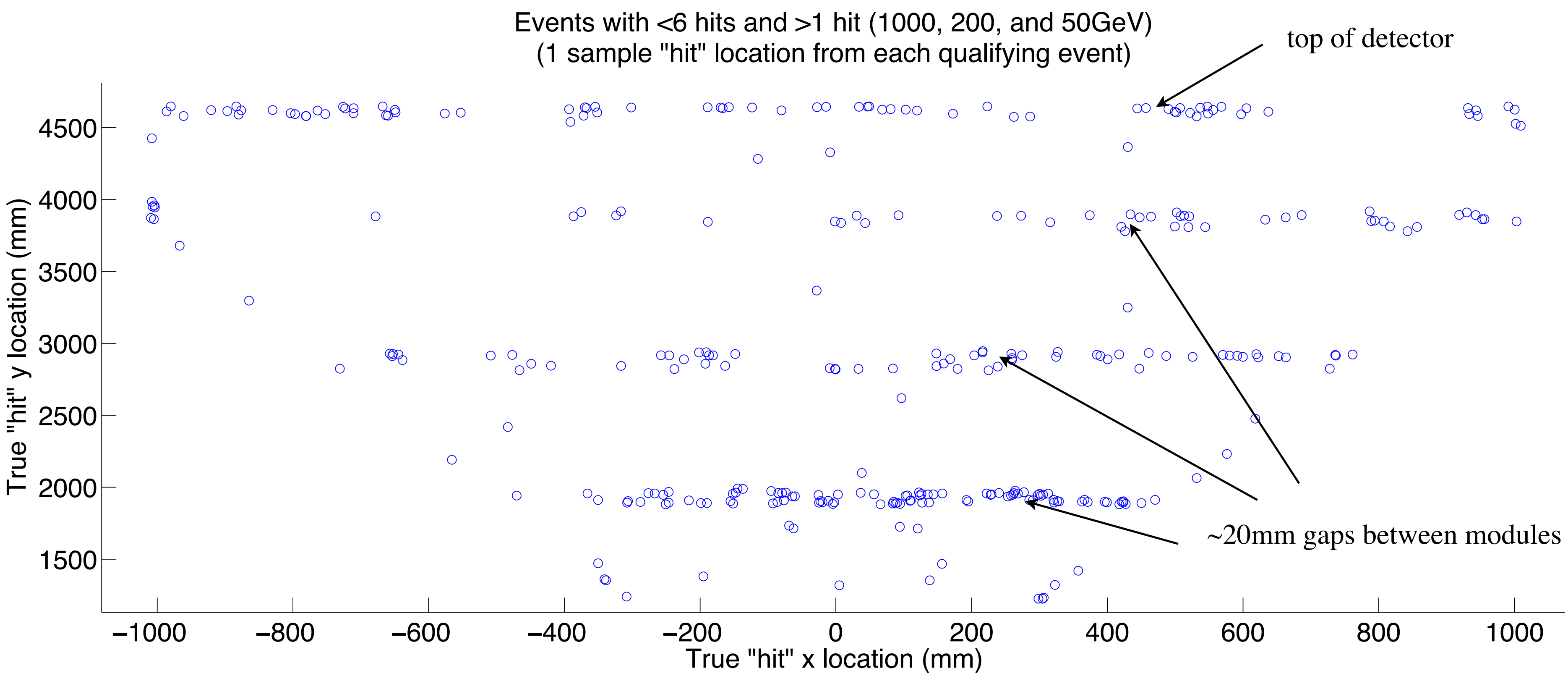


We have 8 planes, and most events will register exactly 8 hits.

Hits per Event

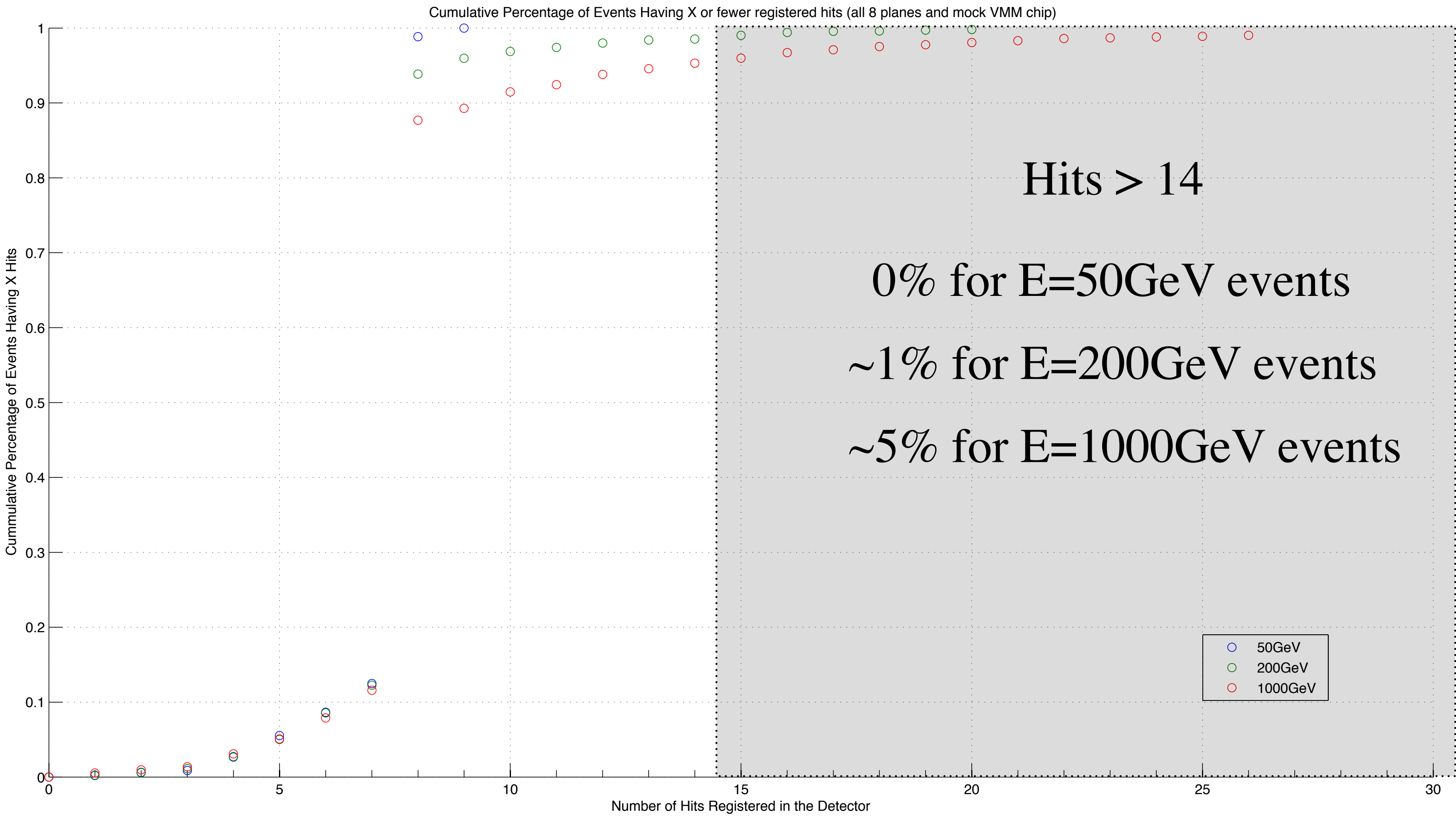


Events with 0<#hits<6



Note: The current Athena geometry used to simulate events for this presentation does not have overlapping gaps call for in the design.

Hits per Event

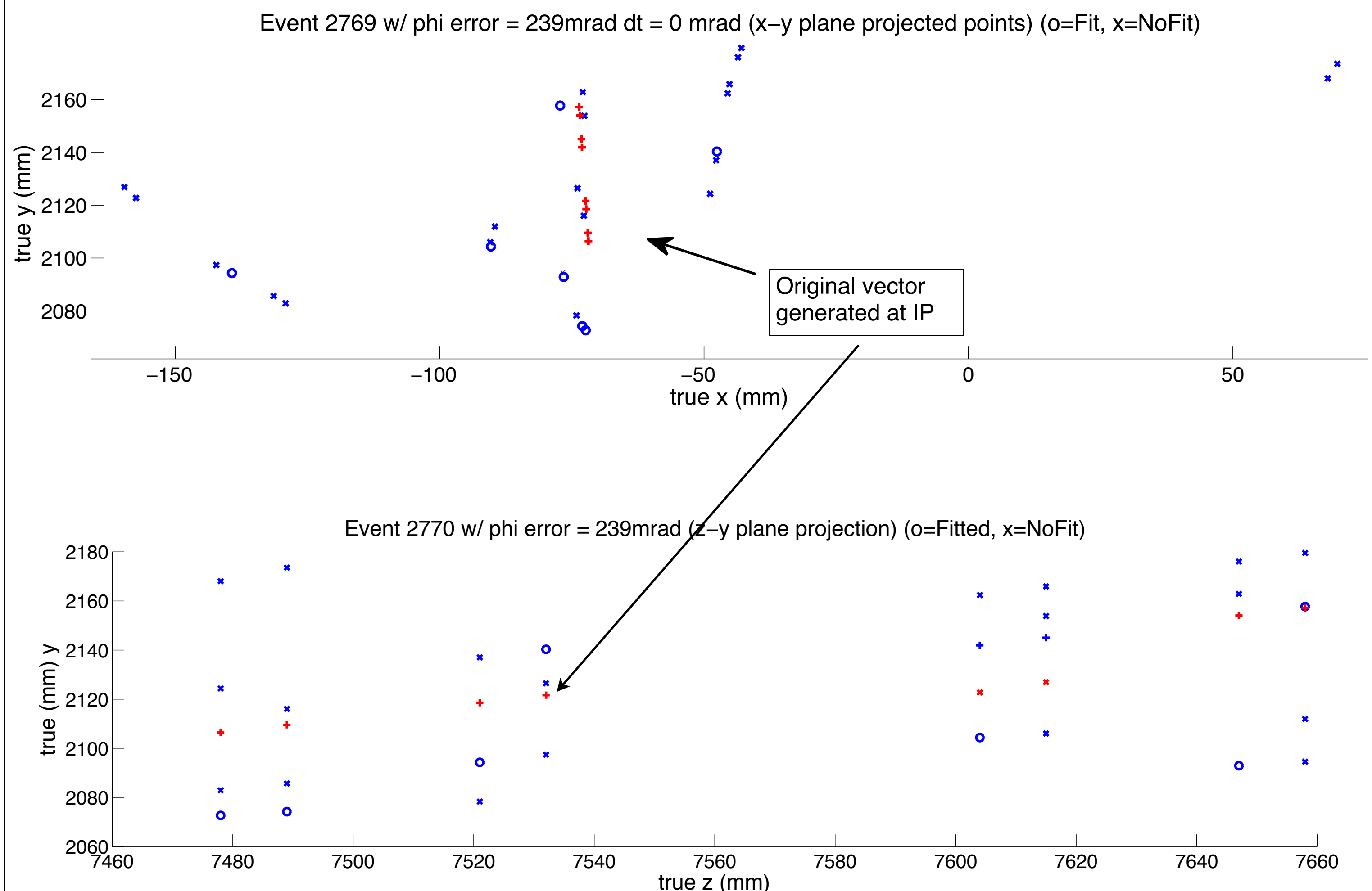


Events with many hits

Events with >8hits involve secondary tracks. (Note that the VMM chips cover 64 strips and only output the first hit followed by >50ns deadtime.)

The fit accuracy decreases as the number of hits increases. This is primarily due to the large tolerance currently assigned to incoming U and V plane hits. An incorrect choice of a U or V hit with respect to the X hits can lead to a poor phi fit result. We are currently considering avenues to reduce this issue without adding to the overall clock time.

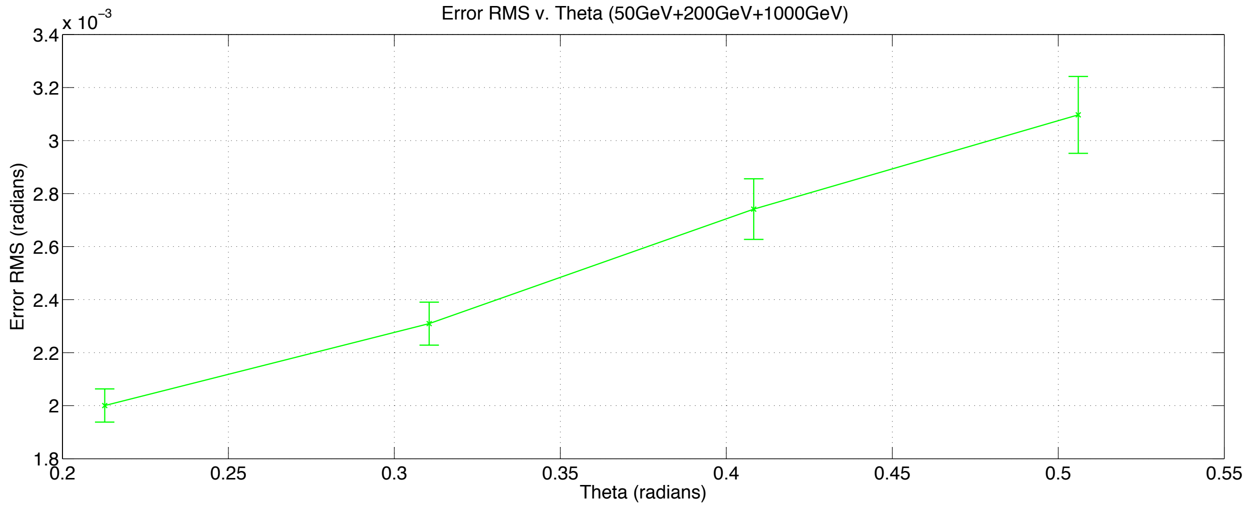
Events with many hits

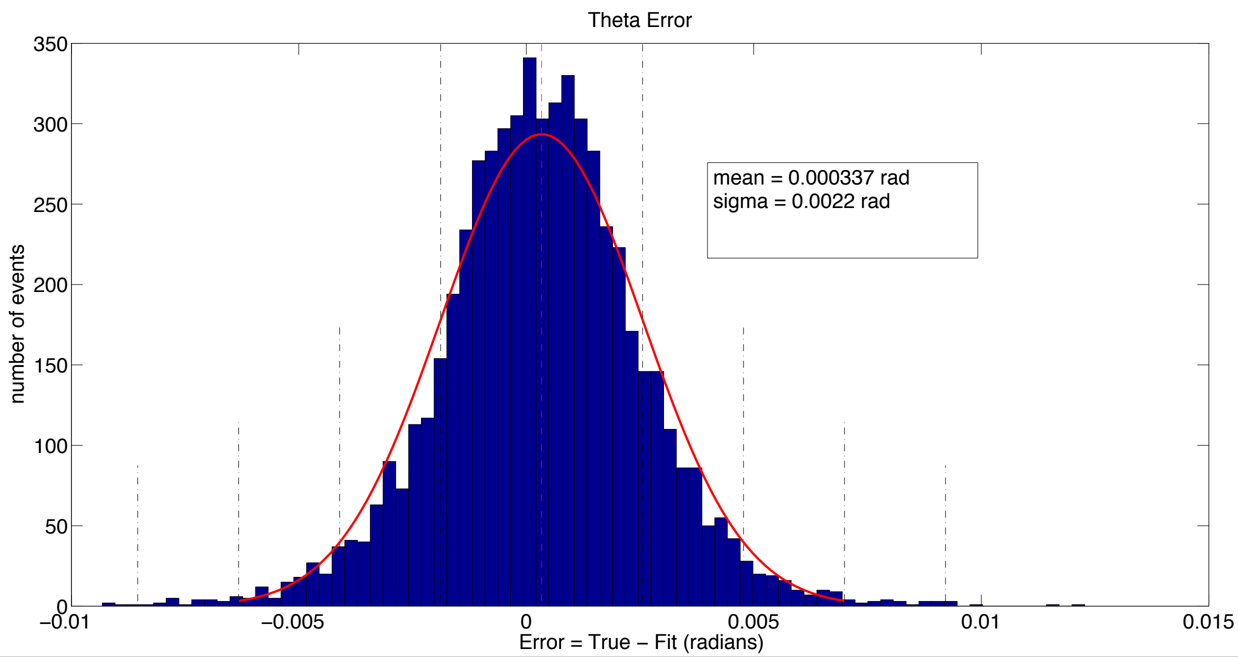


Both plots show the same event which resulted in a fit with phi_error ~239mrad.

The cause of the bad fit is poor choice of U and V hits for the fit.

Theta Resolution

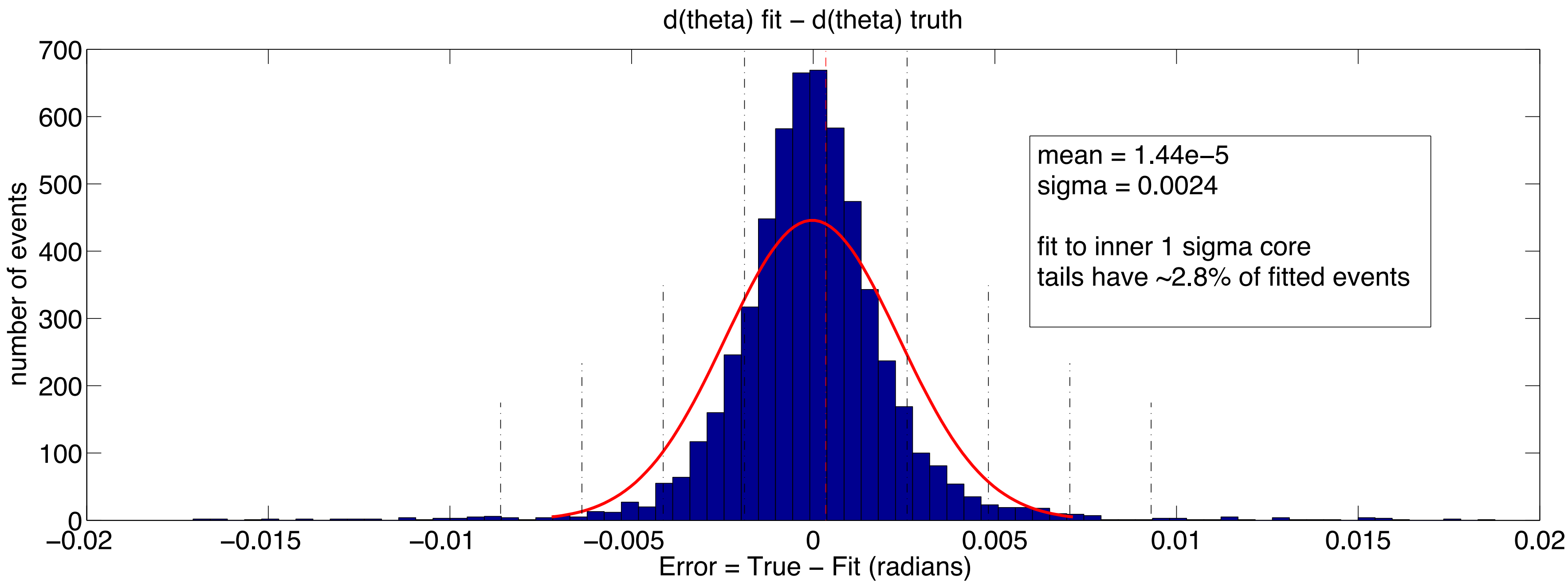




Theta fitting resolution is finer grained than the required 0.02rad.

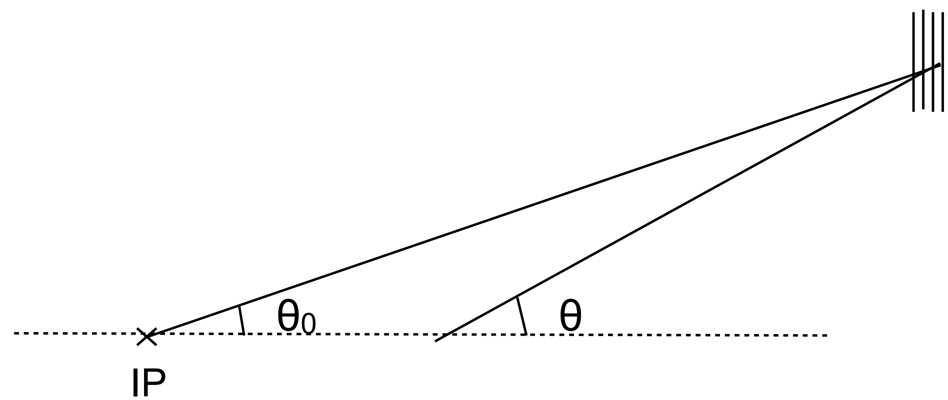
Geometrically, one would expect the resolution to increase with theta; however, multiple scattering effects dominate as the muon travels through additional material as theta increases.

Delta Theta Resolution

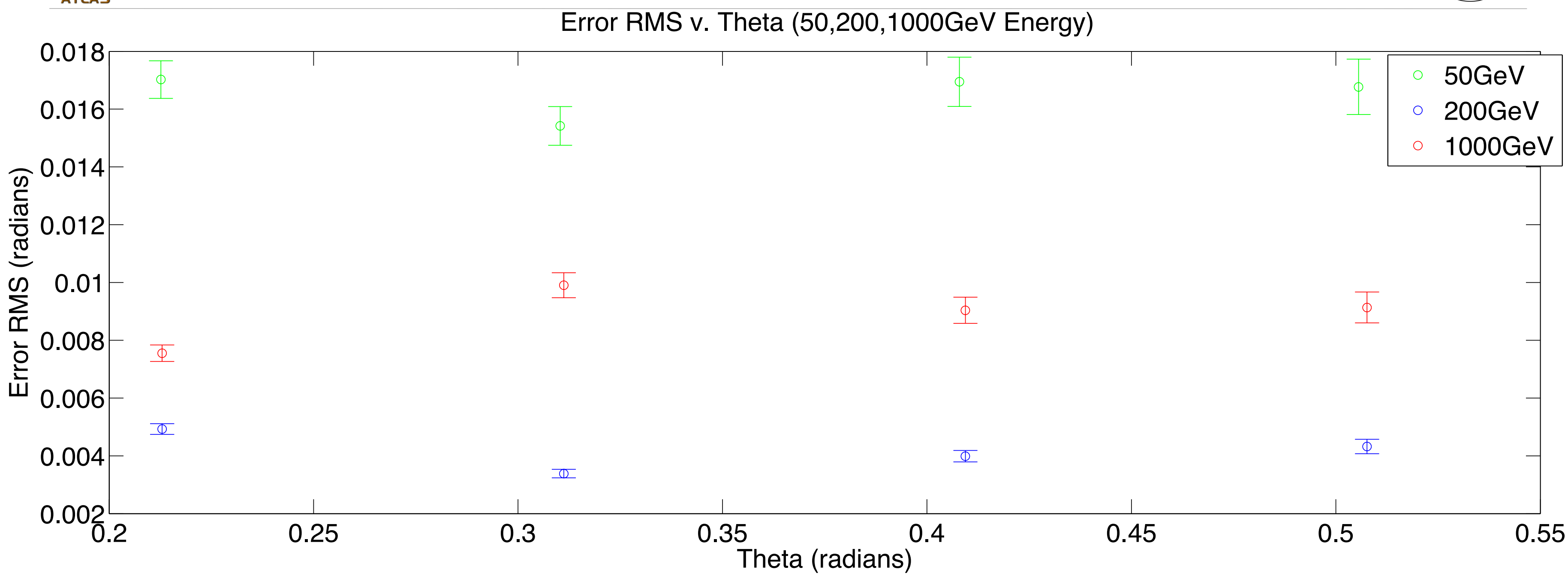


The true delta theta values were calculated using "true" hit locations on the planes before the hits were digitized.

Error = d(theta)_fit - d(theta)_truth



Phi Resolution (all events with >5hits)

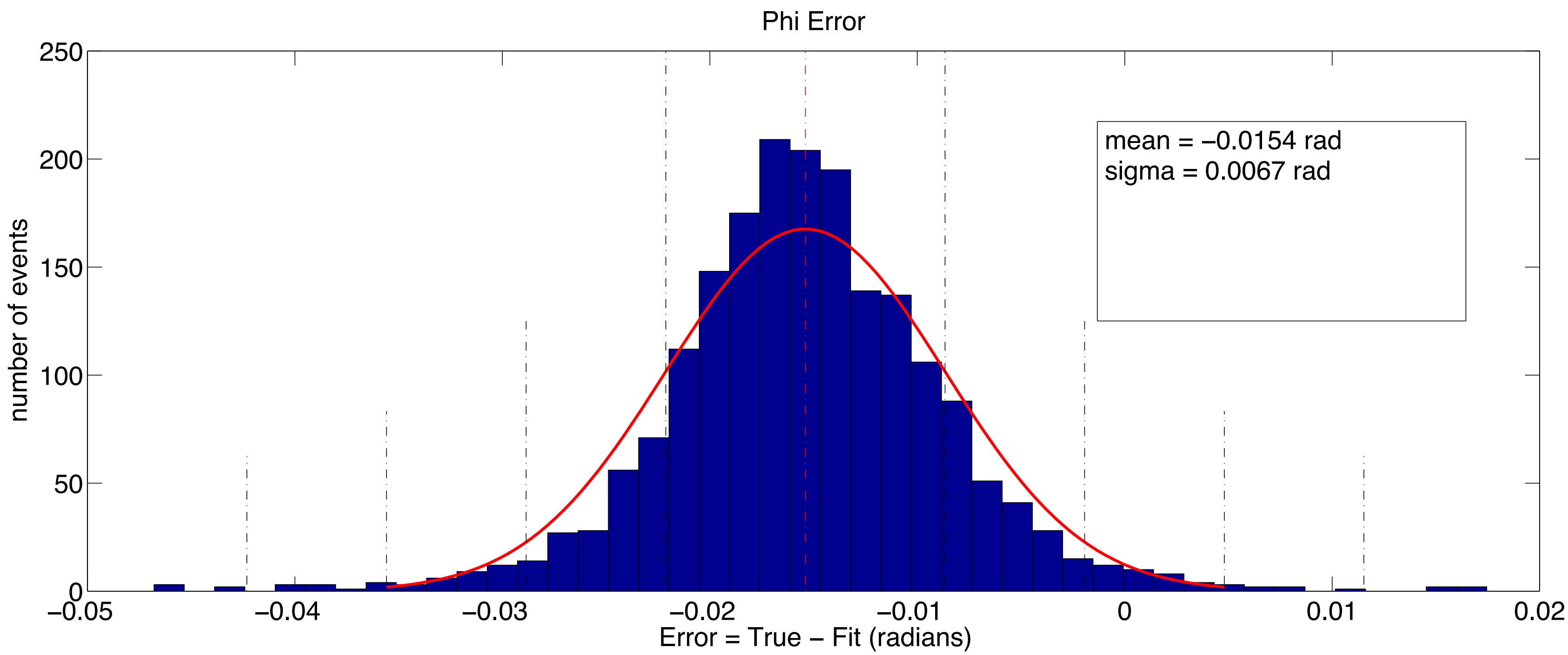


The fits are made using the inner 3sigma core of each energy data set. The tails account for 1.3% (50GeV), 0.8% (200GeV), and 1.7% (1000GeV) of the fitted events.

50GeV fit performance limited by the 15mrad offset likely due to bending solenoid B-field

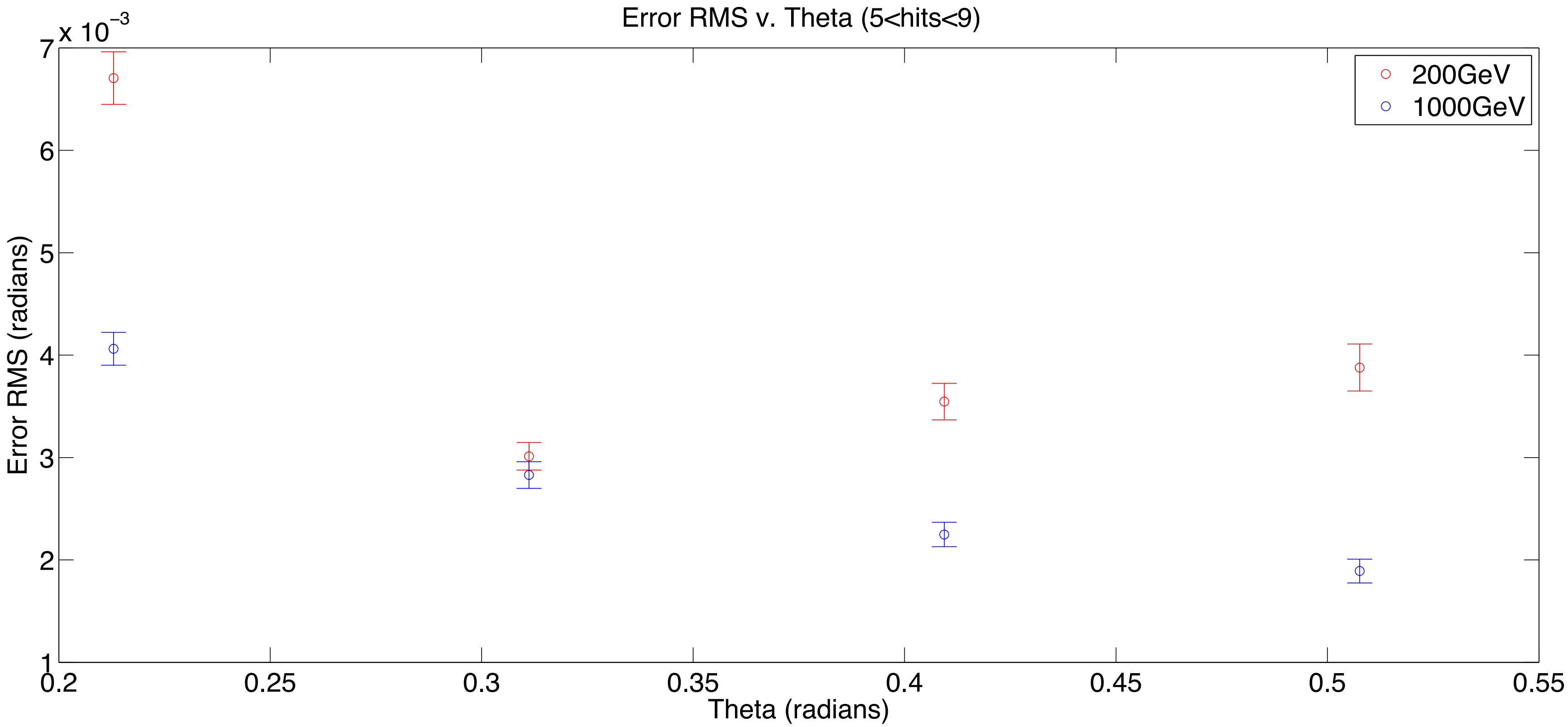
200GeV and 1000GeV fit performance limited by secondary tracks and showers in detector

50GeV Events



50 GeV events show a considerable bias such that the fitted phi is generally greater than the true phi. This bias can be largely attributed to bending of the track in the solenoid.

Fit Resolution (events with 5<hits<9)



Define efficiency as: (Events with error<20mrad) / (Events considered)

Both 200GeV and 1000GeV data were fitted with >99% efficiency for events with 5<hits<9

Performance

Define: Absolute Error = $|(\phi\_true - \phi\_fit)|$

50GeV fit performance limited by the 15mrad offset likely due to bending solenoid B-field

1000GeV fit performance limited by secondary tracks and showers in detector

Percentages are (number of "good fits") / (Number of events considered)

"good fit" with Absolute Error < 20mrad

Energy	Events with > 5 Hits	All Events
50GeV	78.9%	74.5%
200GeV	98.4%	93.4%
1000GeV	94.8%	90.0%

"good fit" with Absolute Error < 30mrad

Energy	Events with > 5 Hits	All Events
50GeV	97.5%	92.1%
200GeV	98.8%	93.8%
1000GeV	95.8%	90.9%

Conclusions/Next Steps

- A first prototype model of the trigger logic has been presented and it seems like it can meet timing constraints and provide ROI and $\Delta\theta$ information as required in the specifications

- We have an algorithmic simulation of the logic and we are tuning operating values for configurable parameters

- We will also start working on a firmware simulation based on this model soon

- This is definitely not the final product, so comments are welcomed, but hopefully it is a reasonable place to start