Trigger and Optimization Studies

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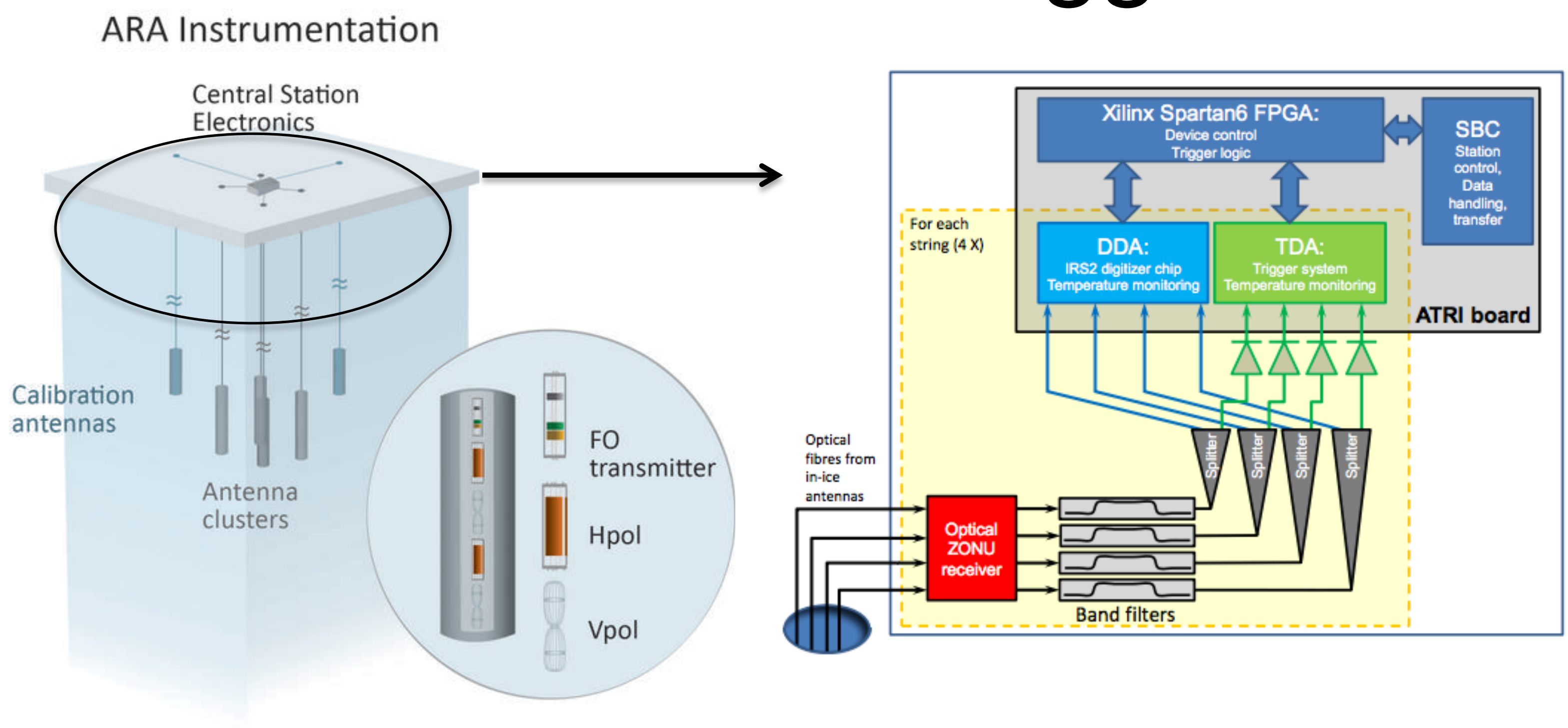
ARA Collaboration Meeting

Outline

- Intro to ARA trigger
- What we know –
  Trigger optimization
  Event N-chan
  Station size study
- Discussion –
  Smarter trigger + station design

Intro to ARA Trigger

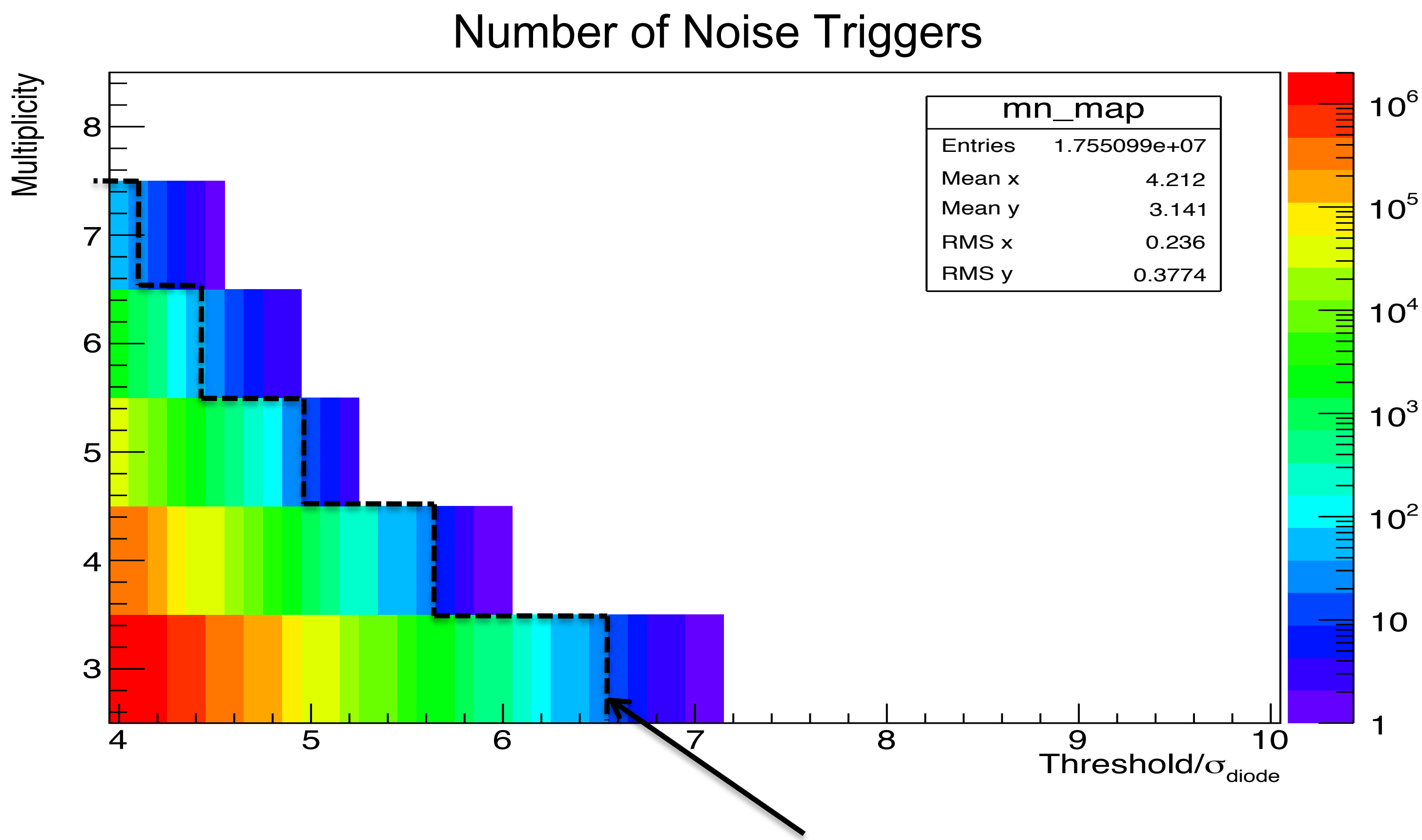


- Trigger scalars are defined and combined by ATRI
- Default trigger is a simple multiplicity trigger - 3 out of 8 Vpol/Hpol channels have power excursions over threshold in a preset time frame
- Thresholds are set so that station rate stays ~5Hz
- Thermal noise dominates trigger (>99%). Threshold is noise floor limited. Detection energy threshold at 1km is ~ 5PeV*

*E. Zas, F. Halzen, T. Stanev Phys.Rev.D 45, 362

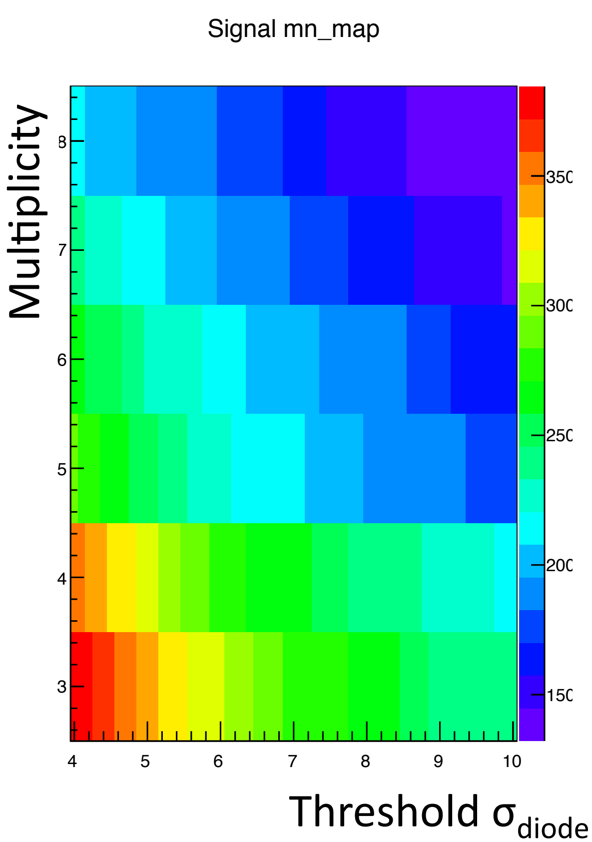
Trigger Optimization

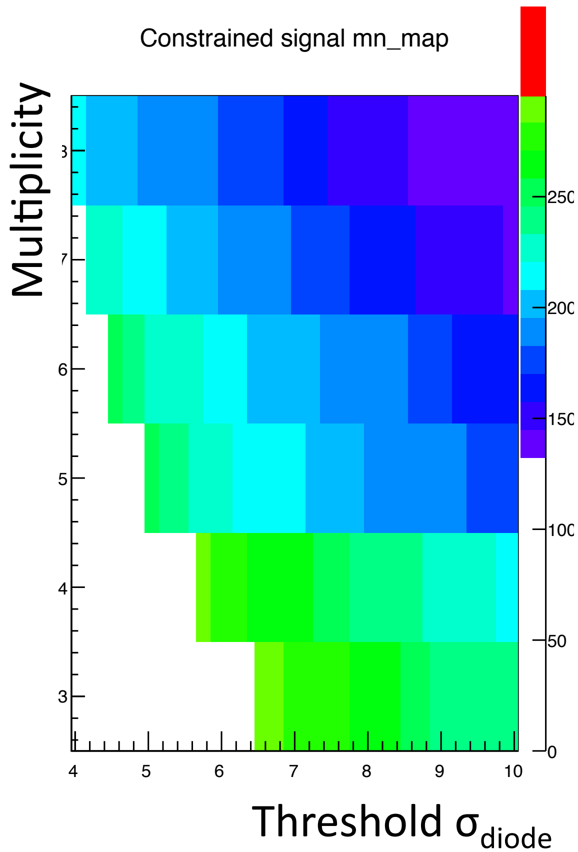
- Start from the simple: Explore combinations of multiplicity m (m/8 Hpol/Vpol) and threshold n (in unit of noise diode sigma) to optimized neutrino trigger efficiency assuming specific spectrum.



Benchmark = current operation RF rate 5Hz

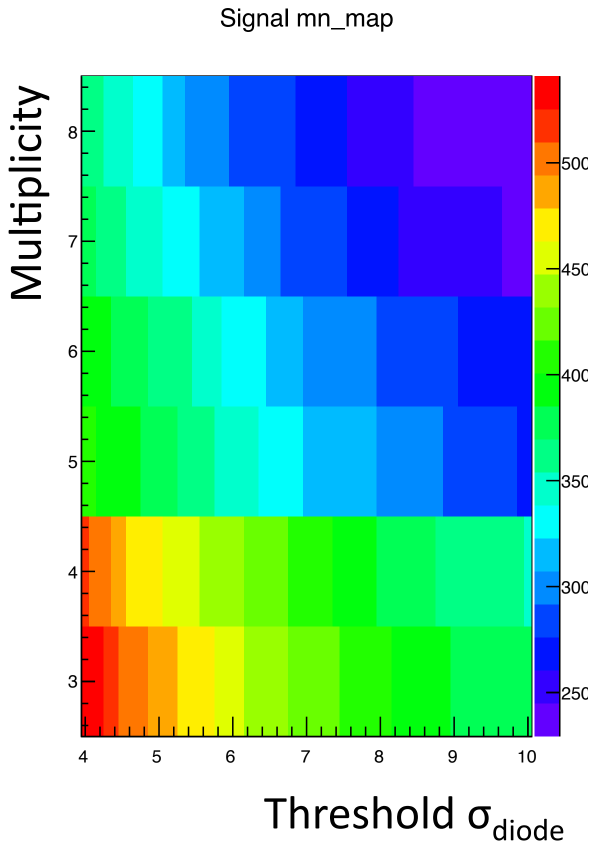
Simulated E^{-2} signal

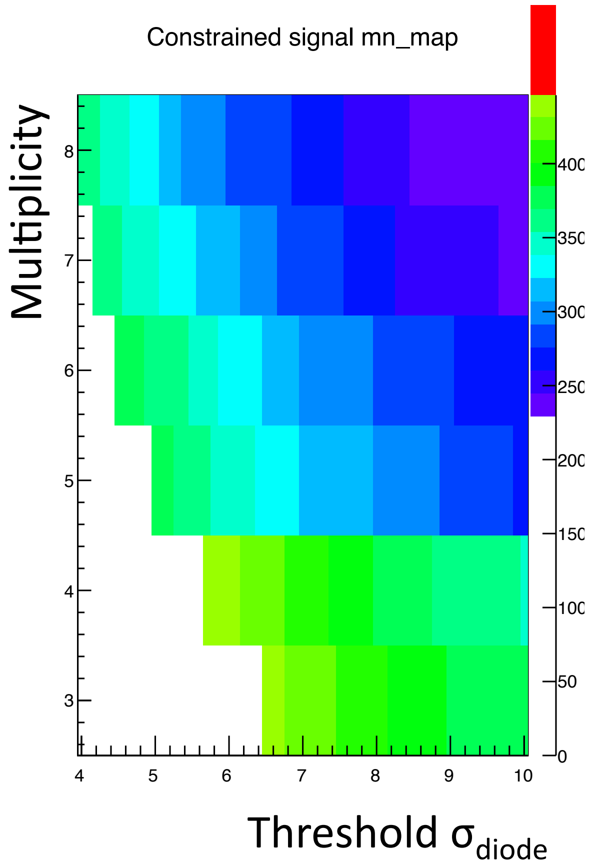




m	n	Event #	Ratio to benchmark
3	6.5	295.42	1.00
3	6.6	291.63	0.99
4	5.7	289.52	0.98

Simulated Kotera signal

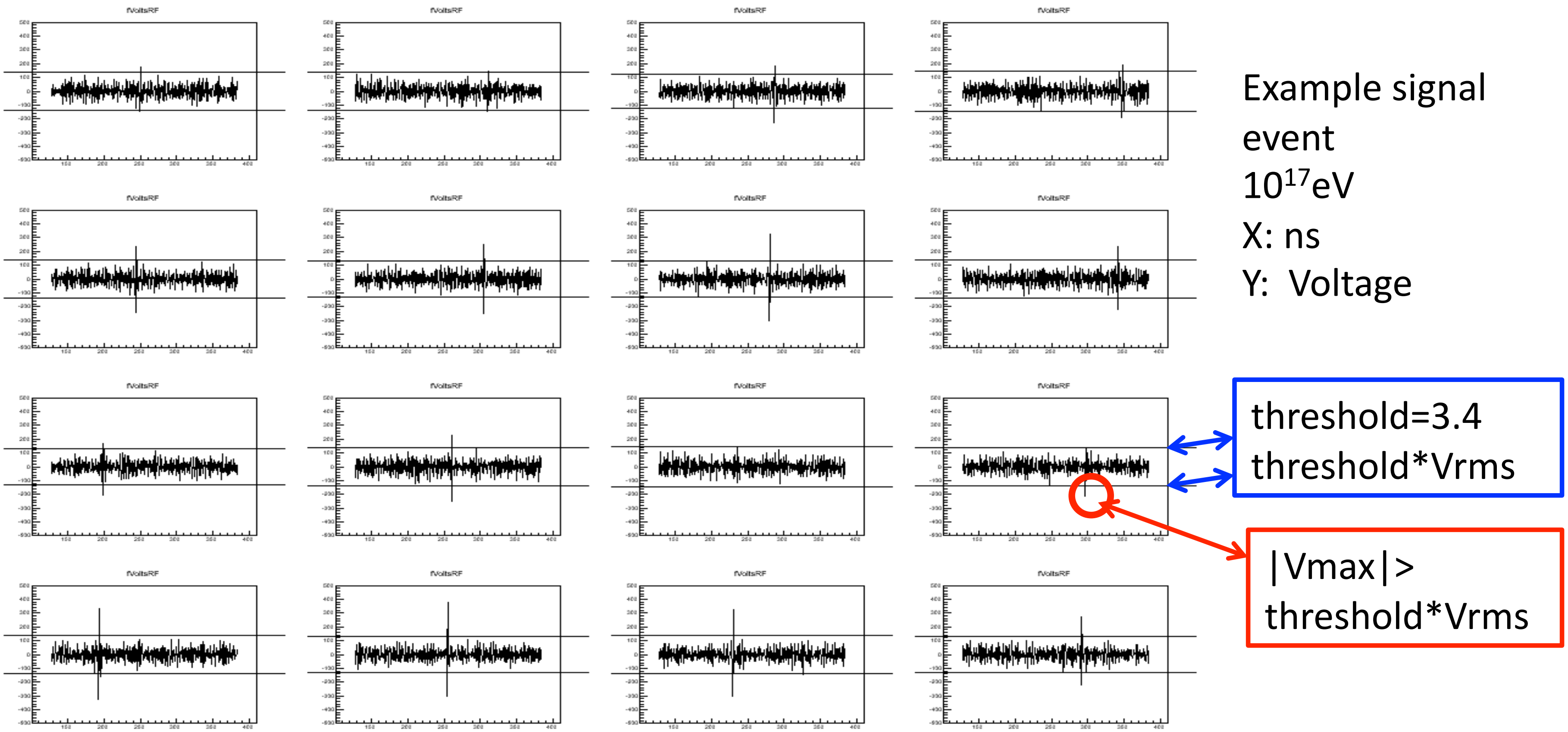




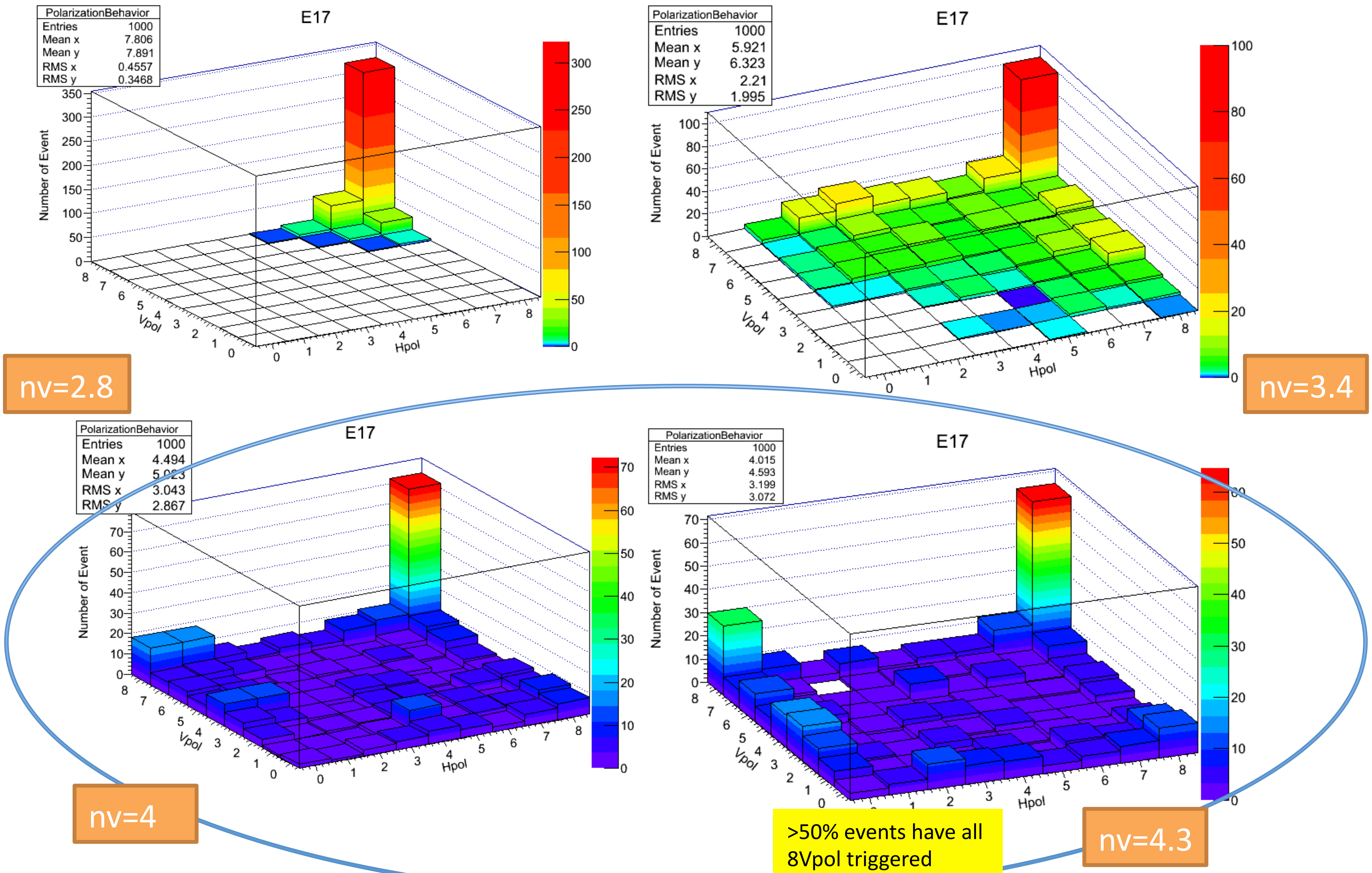
m	n	Event #	Ratio to benchmark
4	5.7	446.29	1.02
4	5.8	442.81	1.01
3	6.5	436.67	1.00

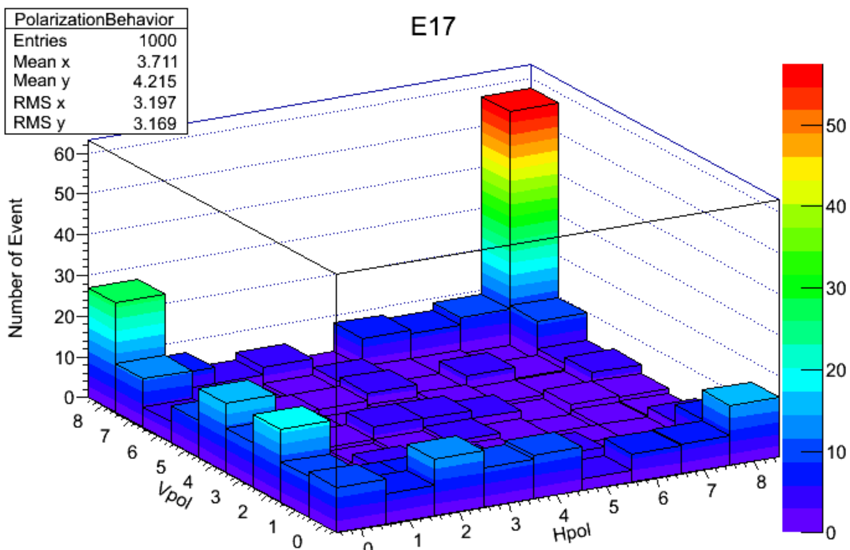
Event Waveform N-chan

- Vrms is computed for each channel (take ½ wf w/o Vmax)
- Nchan = number of channels with |Vmax| > threshold * Vrms

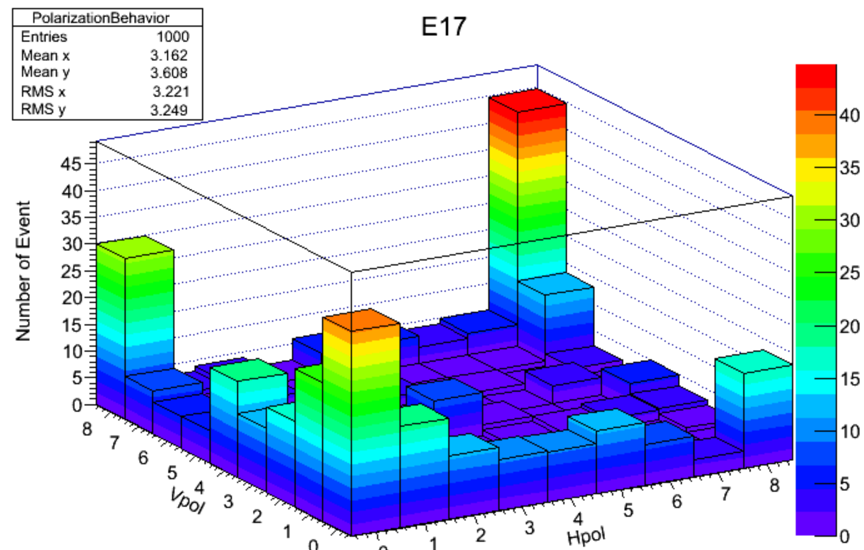


10^{17} eV 1000 triggered events, waveform Nchan




PolarizationBehavior
Entries 1000
Mean x 3.711
Mean y 4.215
RMS x 3.197
RMS y 3.169
E17
Number of Event
Vpol
Hpol

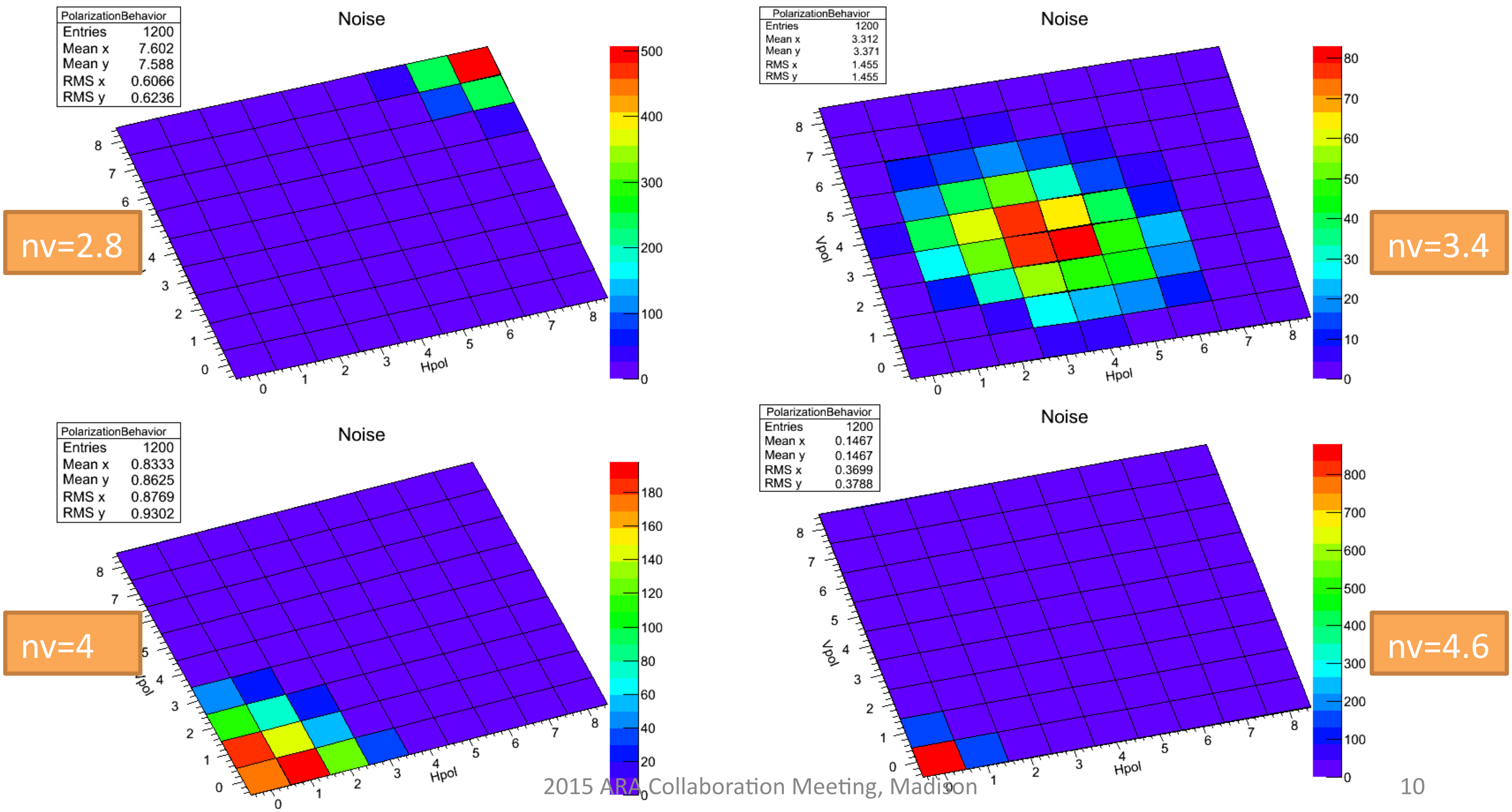
nv=4.6


PolarizationBehavior
Entries 1000
Mean x 3.162
Mean y 3.608
RMS x 3.221
RMS y 3.249
E17
Number of Event
Vpol
Hpol

nv=5.2

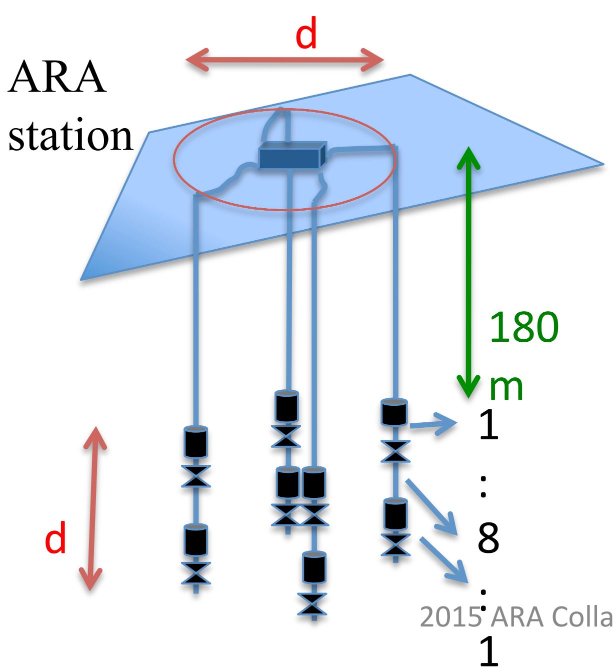
Pure noise N-chan

- Simulated with n_{pwr}=4.9
- Low statistics (~1k events)



Station Size Study

- Study single ARA station sensitivity with various station sizes at constant noise rate
- Larger size -> better reconstruction
- Larger size -> higher threshold to restrain noise trigger -> loss of sensitivity ?
- “Size” d= Horizontal distance between opposite strings = Vertical distance between top and bottom antenna in a string
- d = {5,10,15,20,30,40,50,60,70,80,90,100,110,120,130,140,150} meters
- Benchmark: constant 5Hz noise rate. For each d the threshold is re-adjusted to reach this benchmark.

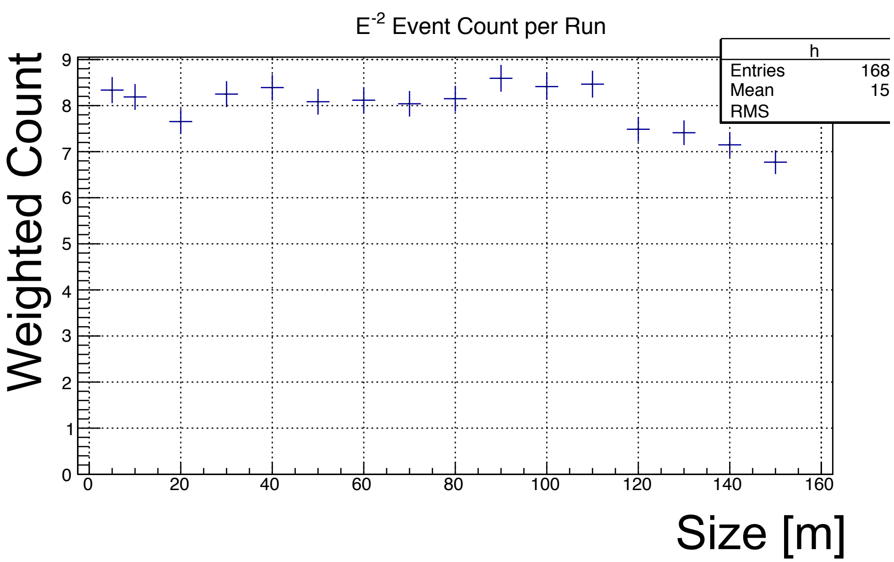


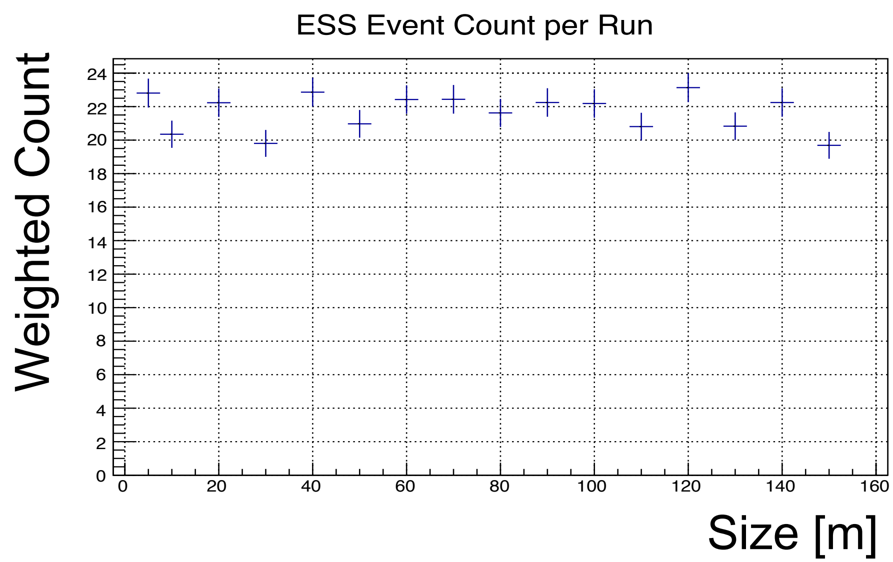
- Bottom antenna is always kept at 200m deep
- Spacing between same-string adjacent Hpols & Vpols: 1:8:1

Simulation result:

Signal event rate vs station size at trigger level

- Count the weighted number of events for each size simulation at trigger level. Forced interaction in ice in cylinder around station
- Each run 10k interactions

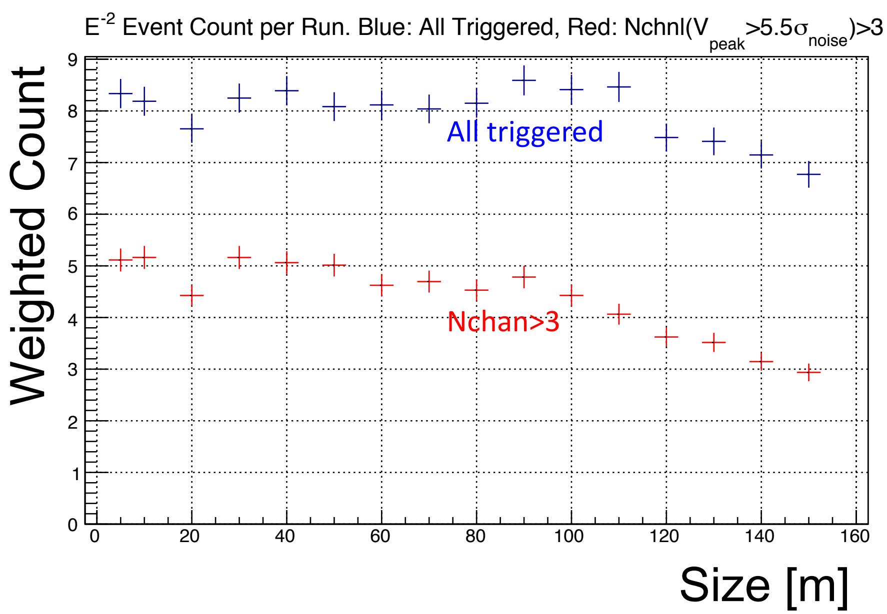


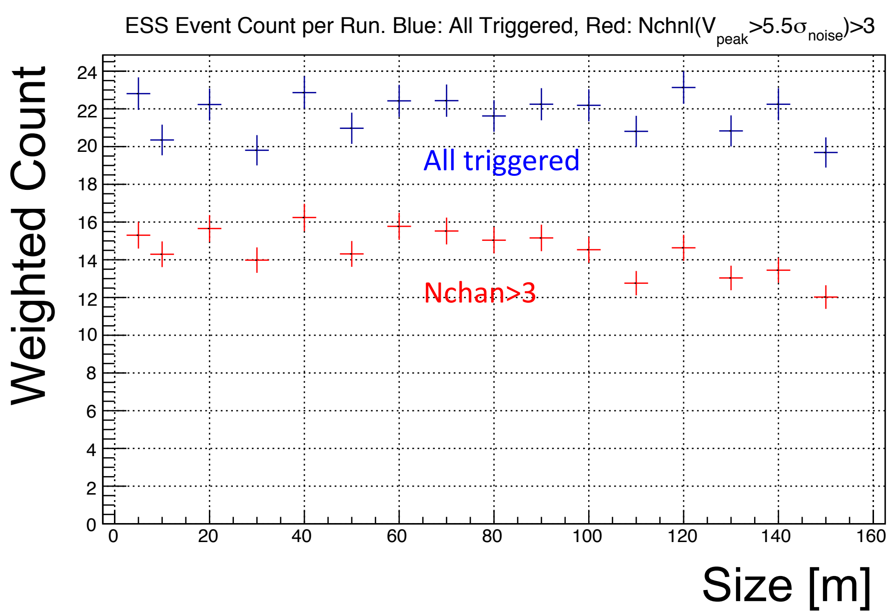


Simulation result:

Signal event rate vs station size – Nchan>3

Waveform Nchan > 3 : event must have at least 4 channels of the same polarization above threshold to survive.
This is intended to be a simple cut for event reconstructability





Discussion

- Current station size (20m) unable to revolve vertex distance unless with ~<O(100ps) timing uncertainty

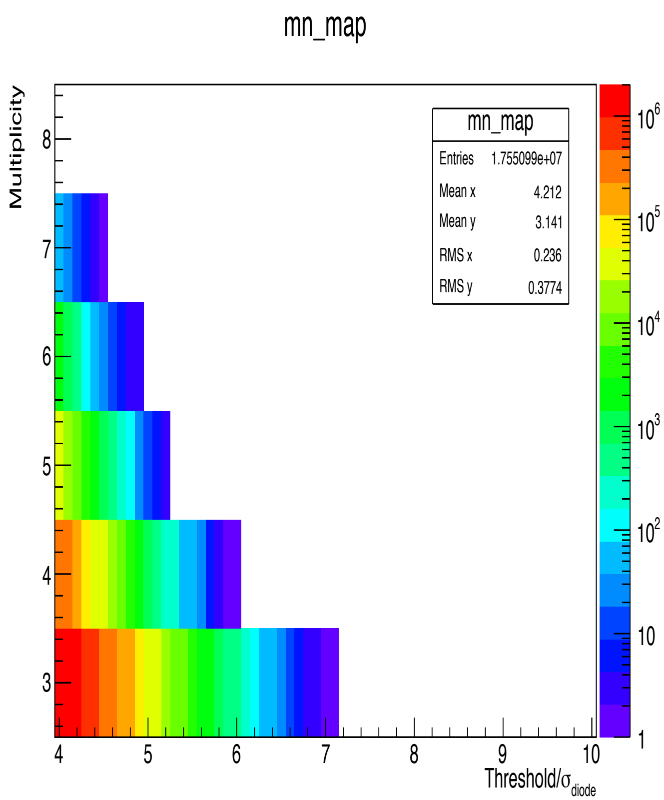
- Increasing station size by 2~3 times has no negative impact on trigger-level sensitivity, but will help reconstruction (need O(ns) timing resolution)

- The fact that a significant amount of events have high n-chan also implies room for a bigger station. This also suggests inter-string trigger may be overkill

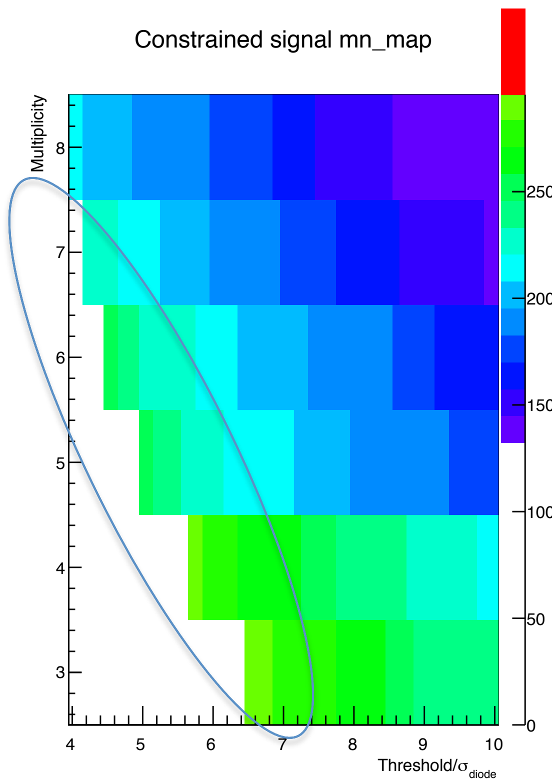
Backup slides

Applying t-sequence to certain (m,n) simulation

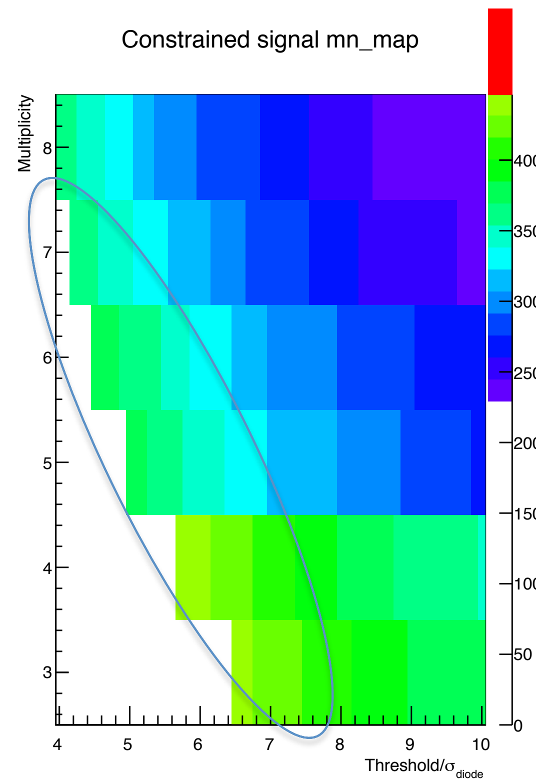
noise



E^-2



Kotera



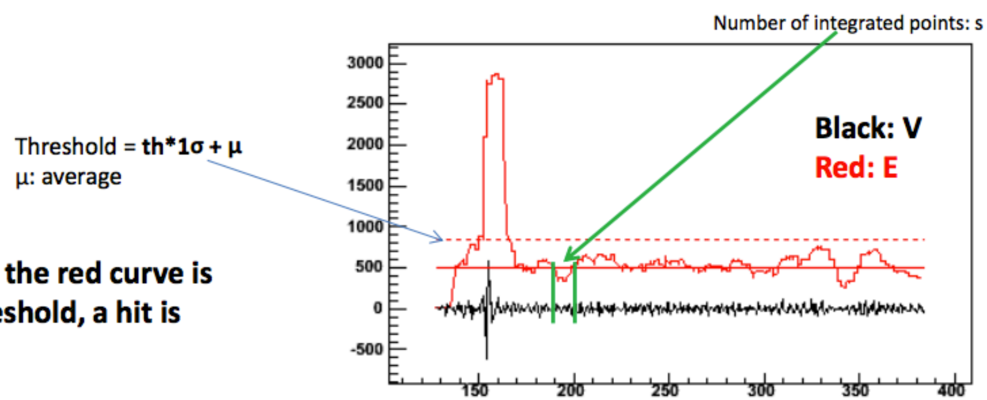
Specifically, the “border” trigger combinations

Threshold factor in T-Seq algorithm

1. Calculate an envelope for each waveform (a sliding integration of squared samples):

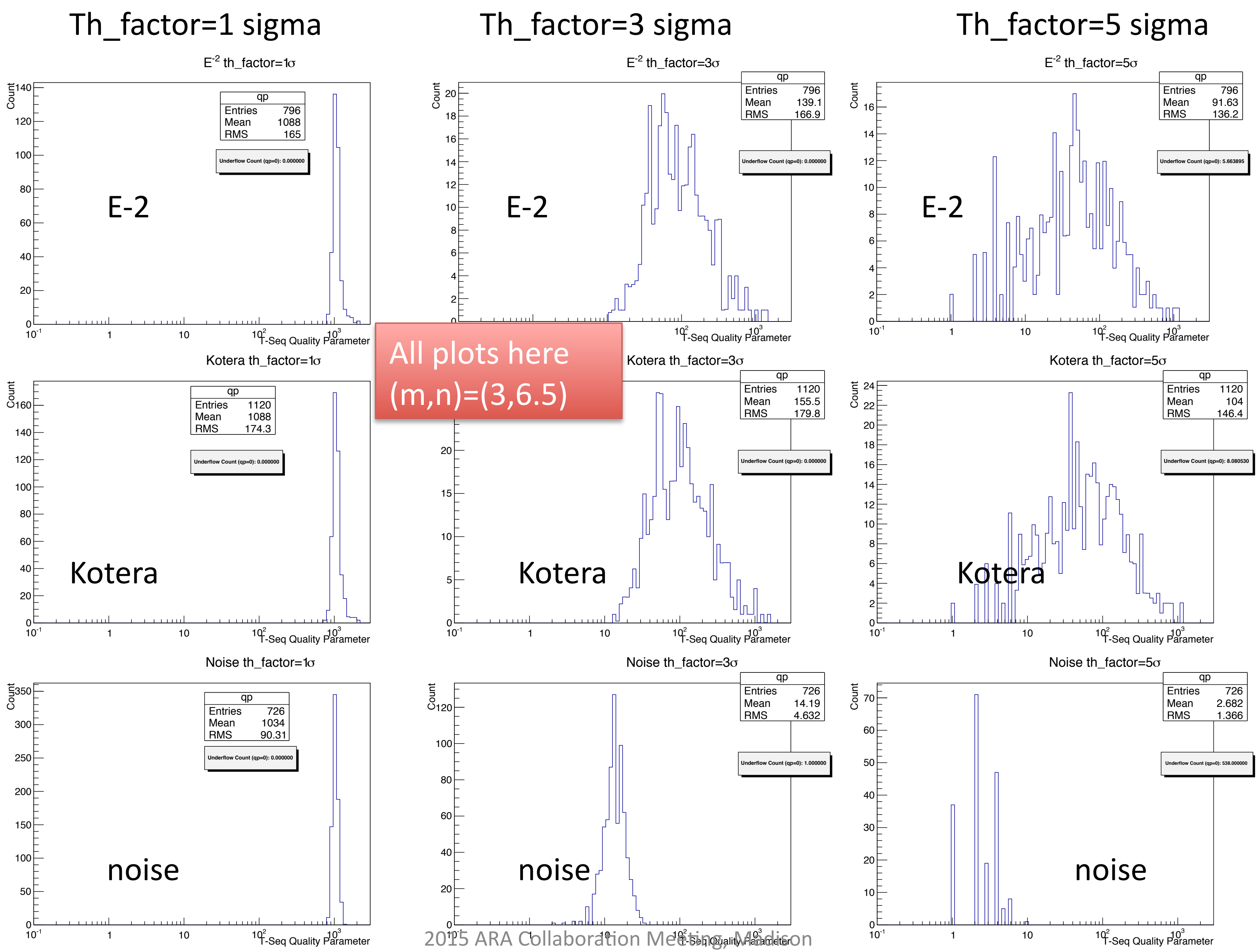
$$E_j = \sqrt{\sum_{i=j-s}^{j} V_i^2}$$

   with i,j=sample number, s=number of samples over which is integrated
2. Calculate average μ and standard deviation σ for this
3. **Generate threshold** as multiples of the standard deviation: $TH = \mu + th * \sigma$



Whenever the red curve is above threshold, a hit is recorded!

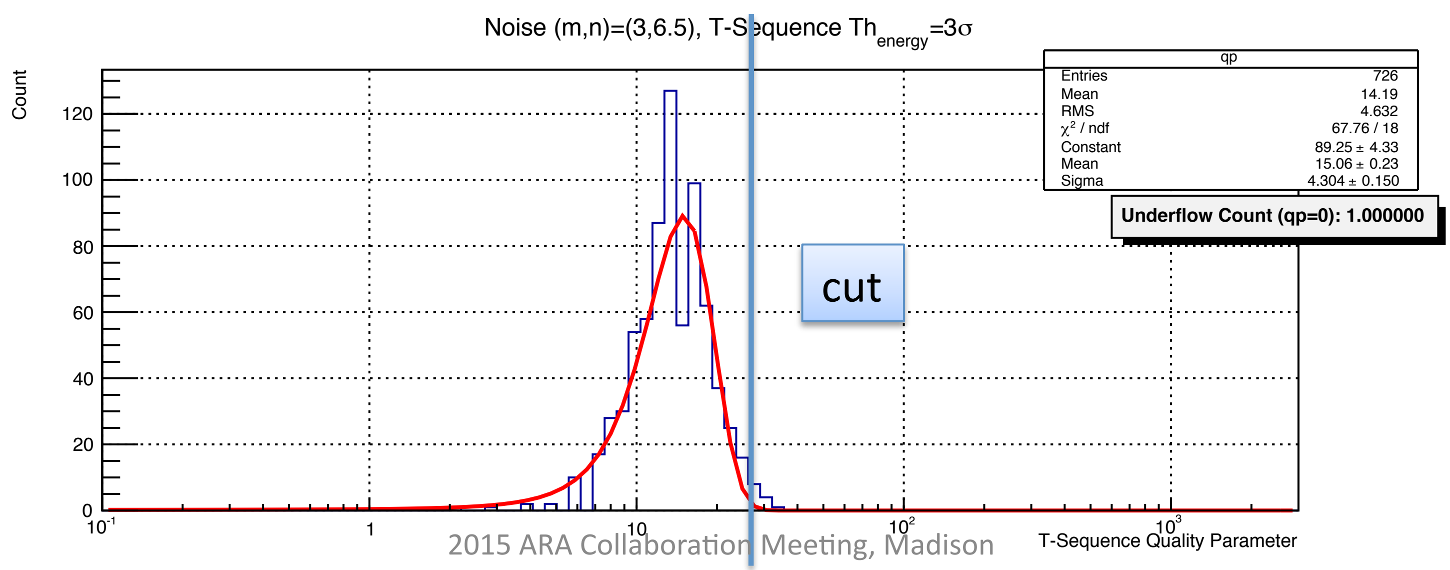
- With the version of filter code I got, the threshold is tuned for actual data.
- Did a simple threshold scan to and look for optimal signal/noise separation
- Noise simulated at (m,n)=(3,6.5)



Th_factor=1 sigma
Th_factor=3 sigma
Th_factor=5 sigma
E-2
Kotera
noise
All plots here
(m,n)=(3,6.5)
T-Seq Quality Parameter
Count

Cutting on T-Seq quality parameters

1. Noise: threshold scan -> for each threshold a Gaussian is fit to noise and a cut will be selected equal the 3σ deviation value in the positive end.
2. Signal @ each (m,n): threshold scan && make corresponding cut -> compute number of passed events at each threshold
3. For each (m, n), pick the threshold that gives max passed events
4. For all border (m,n), compare their individual max passed events, and see which (m,n) gives the most passed events



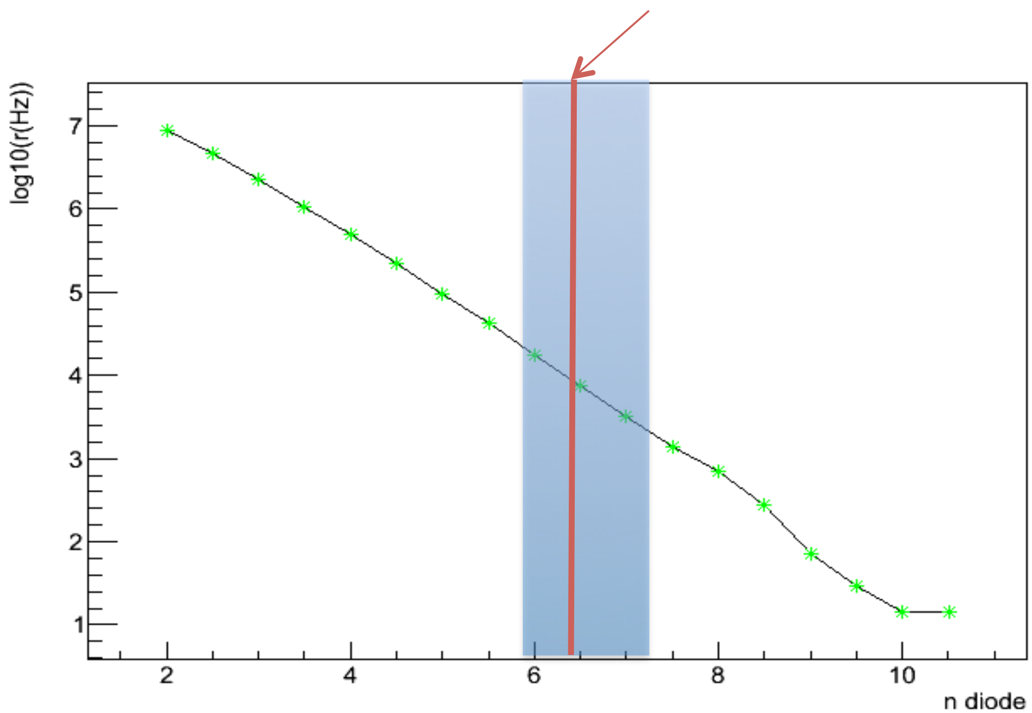
Max number of passed events

(m,n)	E-2			Kotera		
	Trigger Count	Pass Rate (%)	Passed Count	Trigger Count	Pass Rate (%)	Passed Count
(3,6.5)	336.00	92.89	1	438.21	94.57	1
(4,5.7)	323.70	93.91	0.97	424.54	97.16	0.995
(5,5.0)	274.11	94.67	0.83	386.02	95.51	0.89
(6,4.5)	238.26	97.81	0.75	391.19	96.57	0.91
(7,4.2)	225.30	97.93	0.71	358.27	96.19	0.83
(8,4.0)	205.98	98.06	0.65	327.90	99.05	0.78

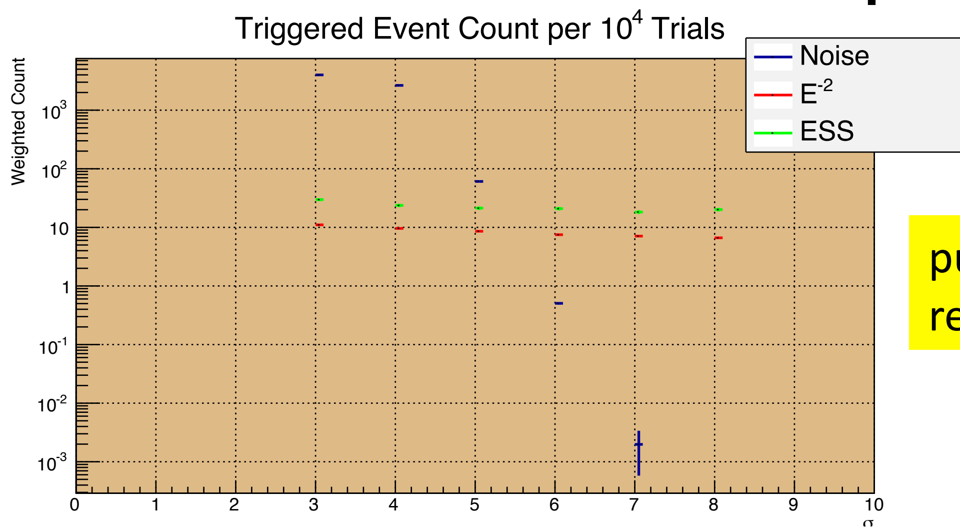
Conclusion: after passing through T-Seq filter for reco-ability estimate, the current trigger configuration remains optimal

Trigger threshold variation

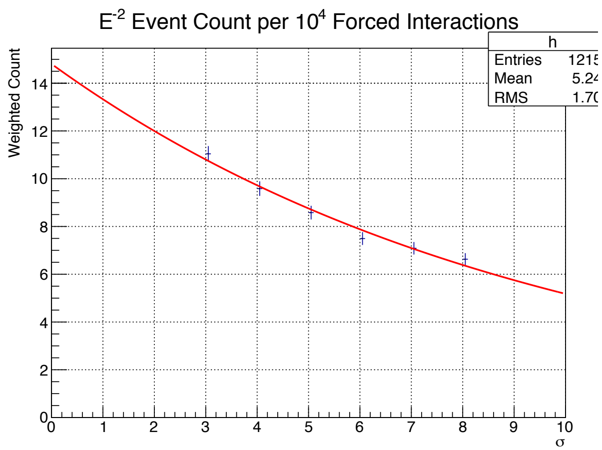
- To fix noise rate, the sizes correspond to a range of -8.5~12.1% difference from the regular operating value 6.47 sigma



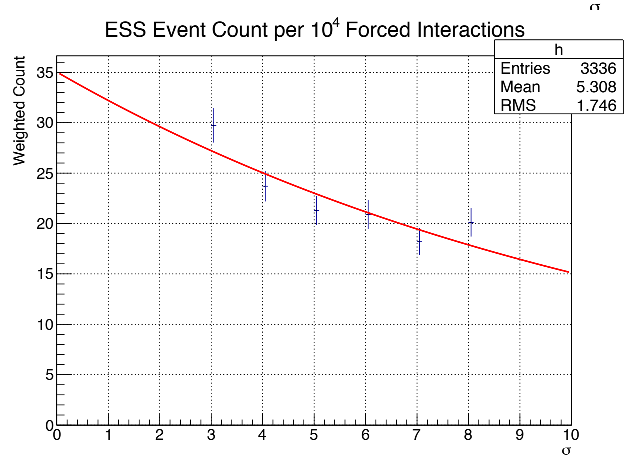
Threshold effect and compensation



pure signal
regular station size



$\ln(y) = -0.105x+2.69$

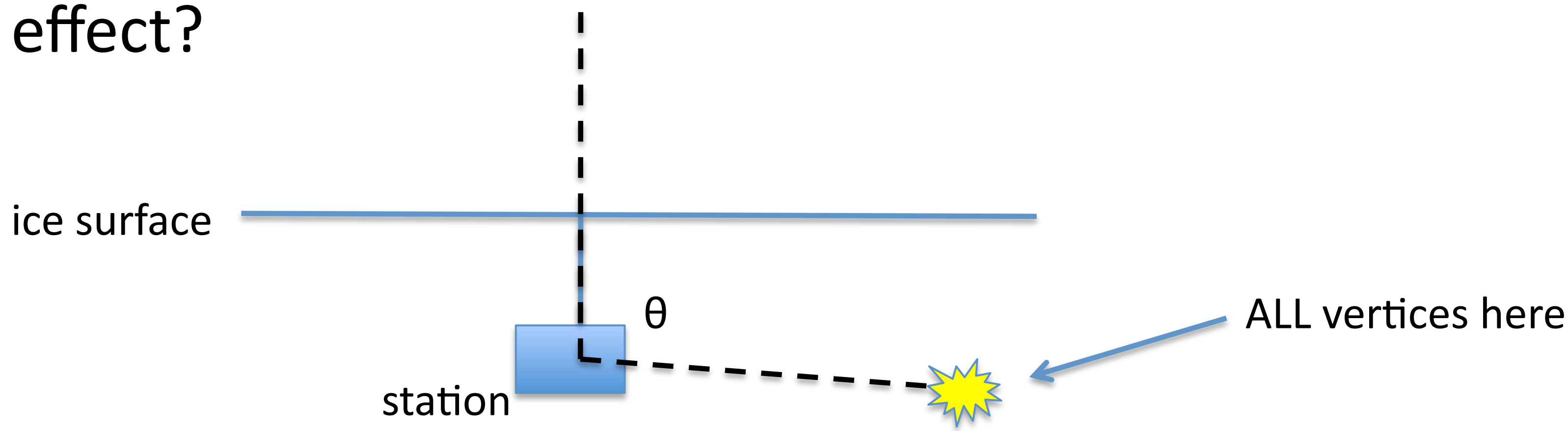


$\ln(y) = -0.084x+3.56$

Ratio to 20m	E^{-2}	ESS
40m	97.3%	97.8%
80m	94.7%	95.7%
150m	92.1%	93.7%

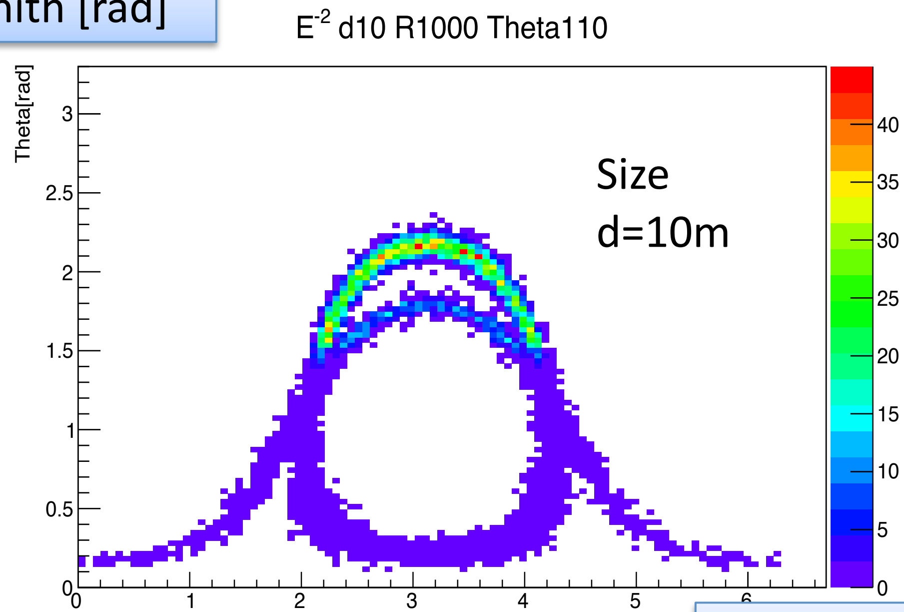
Threshold effect and compensation

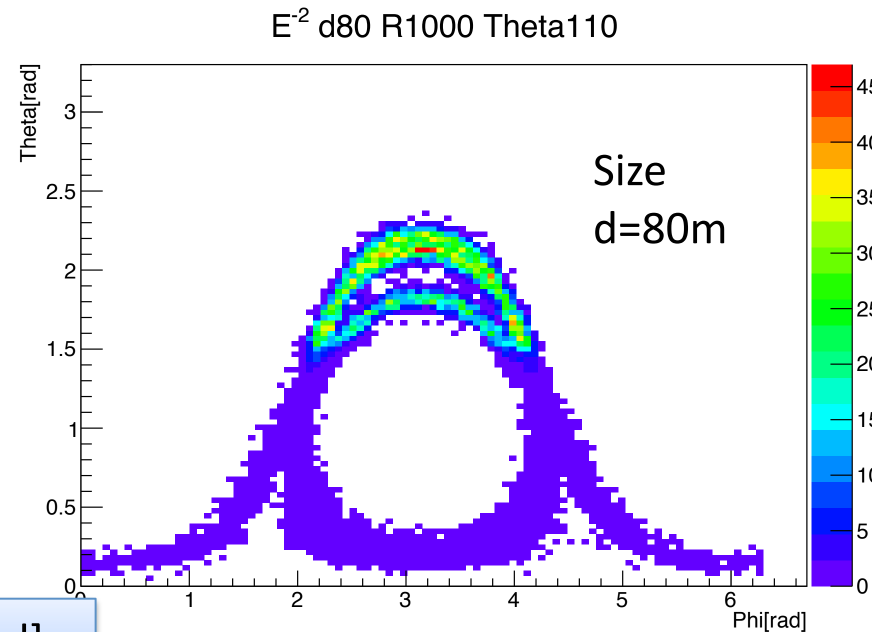
How do larger stations compensate for threshold effect?



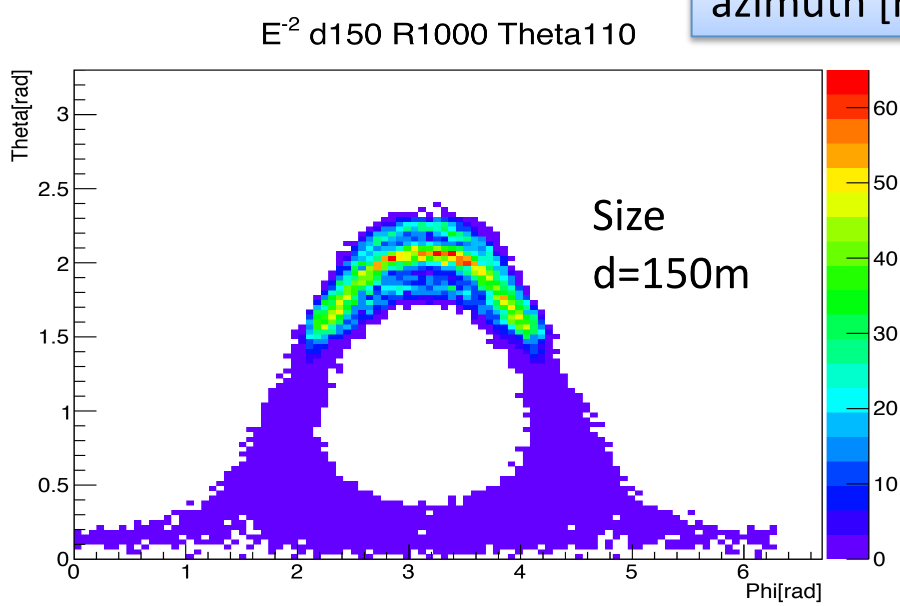
Fix vertex positions
Distance to station center: 1km
Zenith angle: 110°
Azimuth: 0°
Isotropic neutrino flux
Plot triggered neutrino travel direction

zenith [rad]



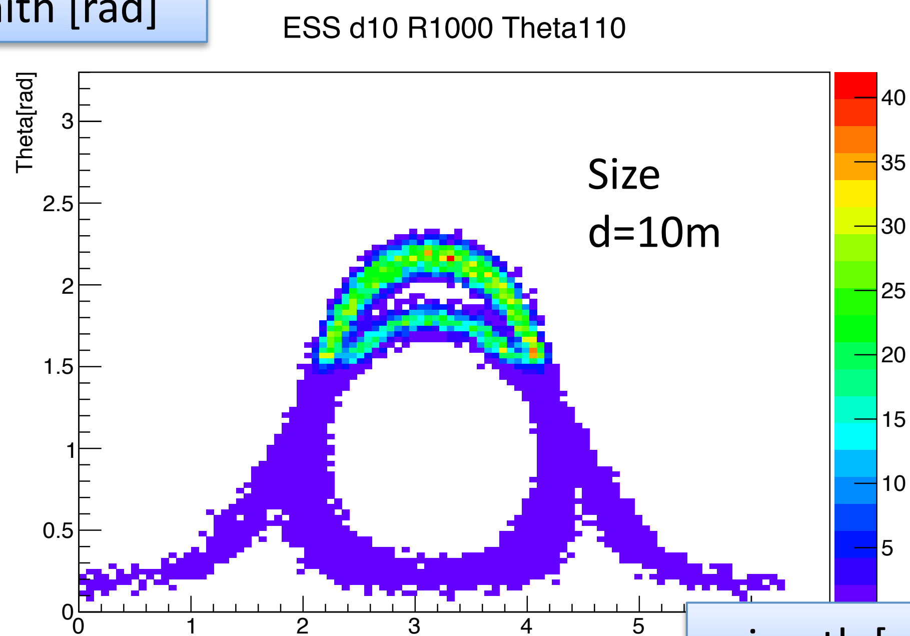


azimuth [rad]

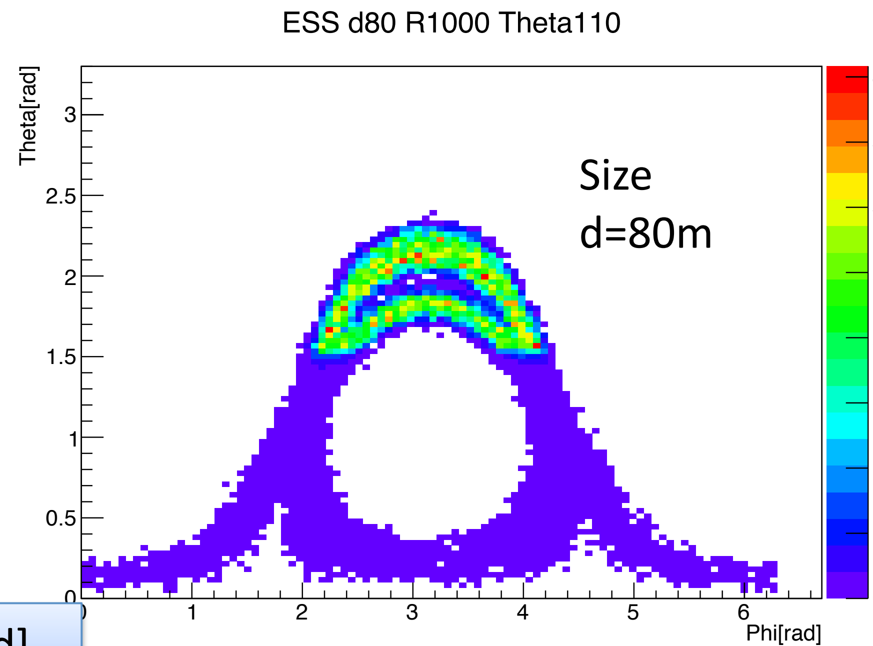


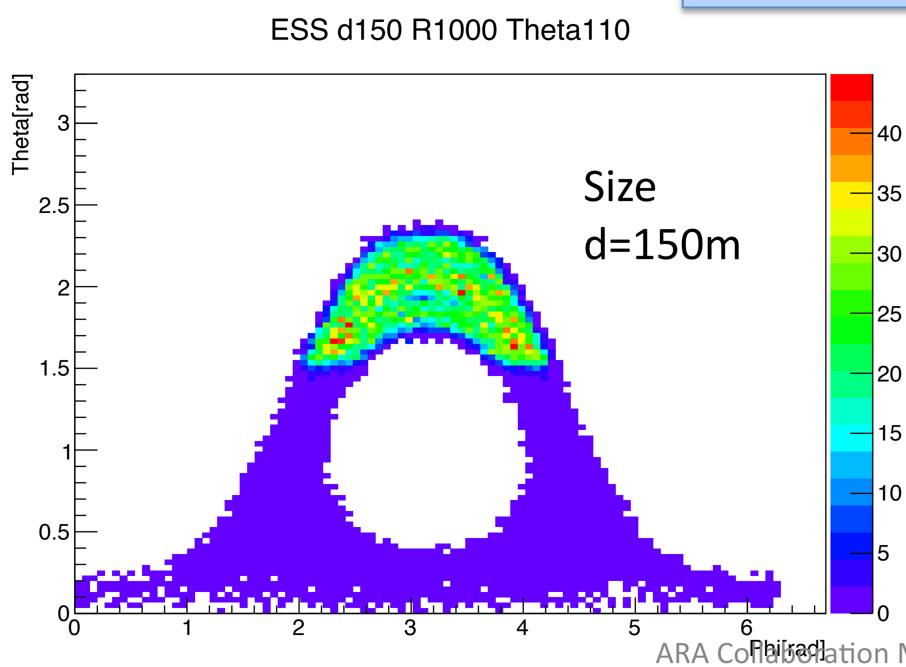
A scaled-up station allows for a wider "spread" of neutrino directions to trigger the station.

zenith [rad]



azimuth [rad]





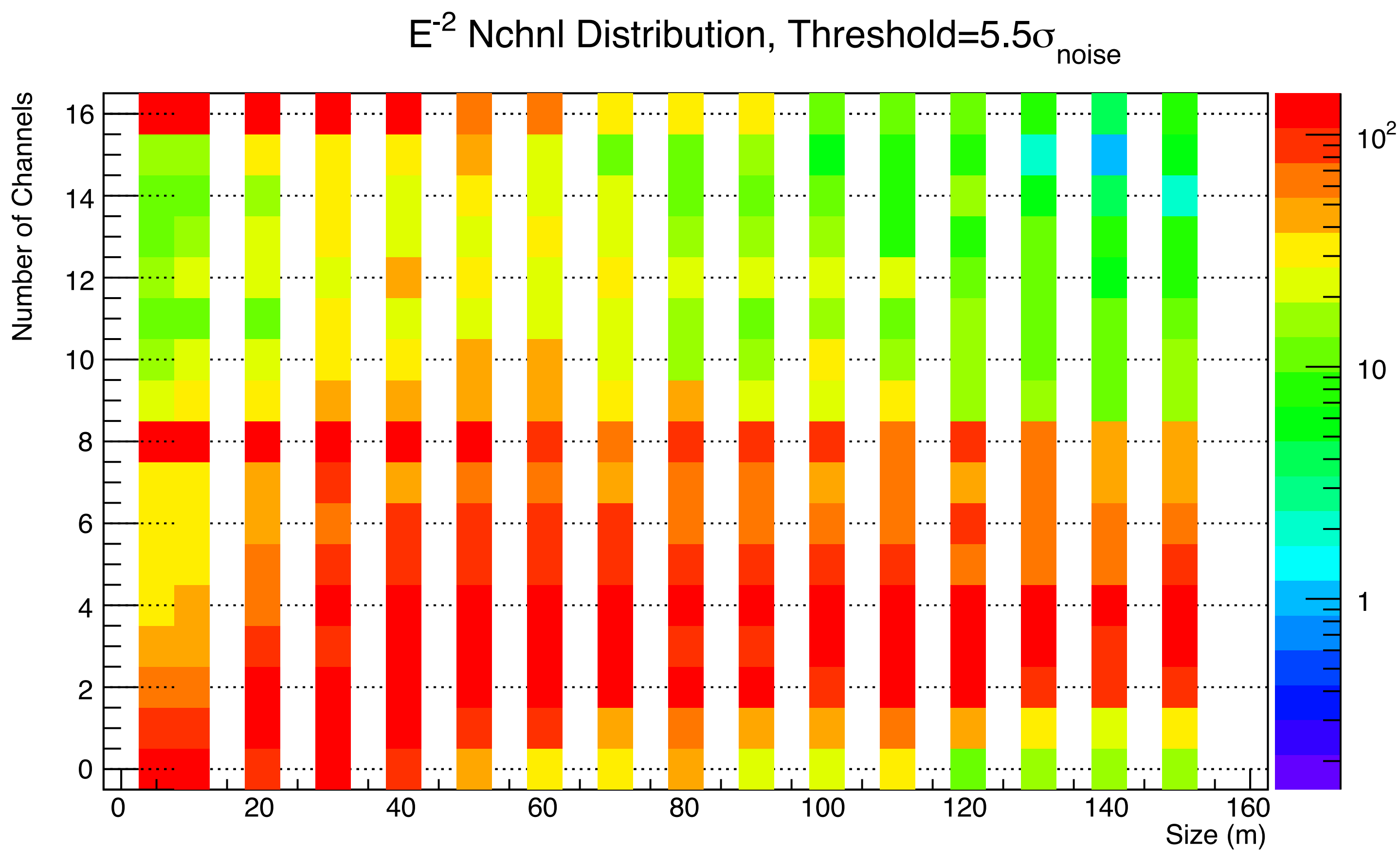
A scaled-up station allows for a wider "spread" of neutrino directions to trigger the station.

Reconstruction capability

- Larger size already implies longer baselines and better reconstruction resolution
- But a sparse spacing may partly “miss” the Cherenkov cone -> less baselines to do reconstruction
- Run n-channel filter, and set a cut on the number of channels

Size Simulation and N-channel cut

- Plane wave reconstruction at UW - usually don't converge with n-channel < 4



Size Simulation and N-channel cut

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