Novel Techniques for the Position Calibration of FAUST

UMASS AMHERST

CYCLOTRON INSTITUTE TEXAS A&M UNIVERSITY

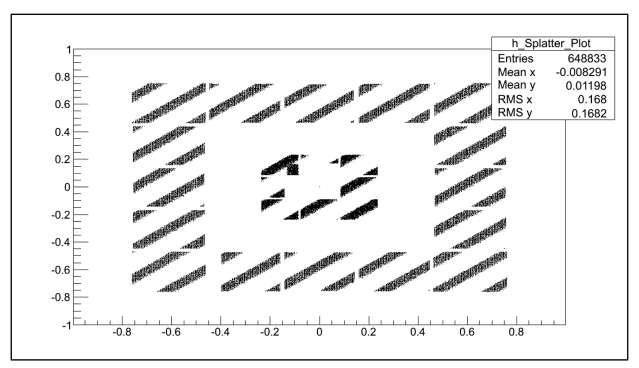
David Balaban, *Cyclotron Institute, Texas A&M University (REU student from University of Massachusetts Amherst)*

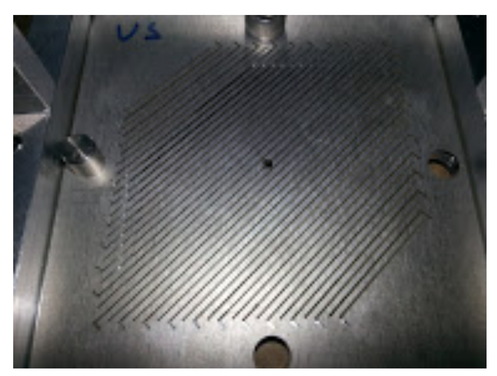
Advisers: Sherry Yennello, Lauren Heilborn, *Cyclotron Institute, Texas A&M University.*

Problem:

The Forward Array Using Silicon Technology (FAUST) consists of 68 detectors, which identify and measure the energy of charged particles. FAUST was recently upgraded to position-sensitive detectors which enable higher resolution in relative momentum. Many different structural tolerances may result in inaccurate relative positioning. This final position must be accurately known for upcoming experiments.

Overview:





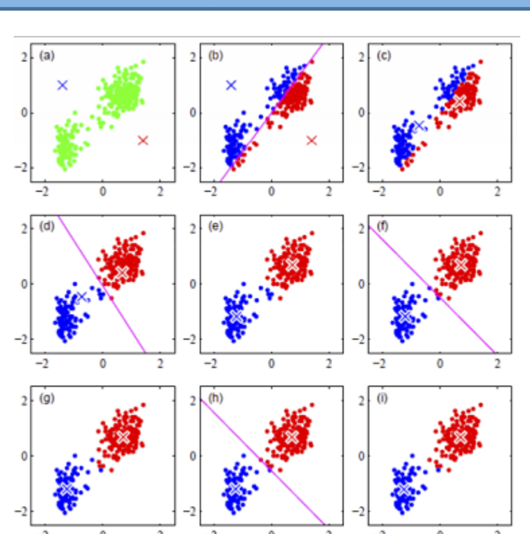
Tungsten mask blocks charged particles and creates striped pattern on detectors. Stripes on detectors will be displaced according to detector placement. Goal is to find how far they are from expected positions

2 phase process:

1.) Identify stripes on detector with the K-means algorithm

2.) Find set of linear transformations applied to detector which will reposition the stripes to the expected values with the Hill Climbing algorithm

Description of K-means:



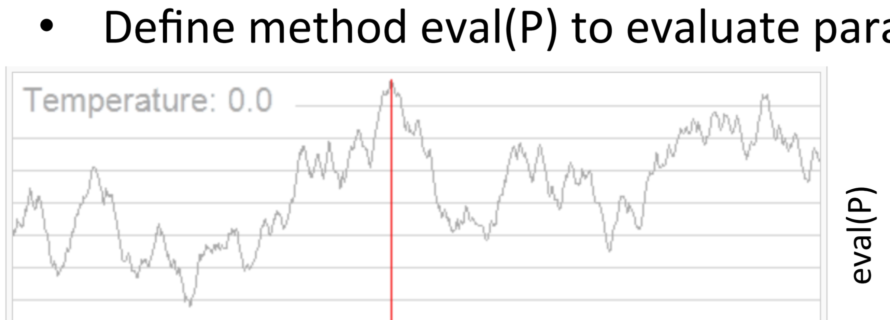
1. Initialize k random points
2. Calculate average position of data associated with each point
3. Reset point to average position
4. Repeat until convergence

will use this method to identify stripes in data

Picture from:
Thomas, Philip. "Midterm Review." Artificial Intelligence 383. University of Massachusetts Amherst, Amherst, MA. 25 Mar. 2014. Lecture.

Description of Hill Climbing (HC):

- Define set of free parameters P
- Define method eval(P) to evaluate parameters to a single value



The picture to the left shows a successful Hill Climb with one free parameter. Local maxima causes difficulty for successful HC.

HC tries to find the global maximum of eval(P) by changing P.

Picture from:
"Hill Climbing." *Wikipedia*. Wikimedia Foundation, 27 July 2014. Web. 03 Aug. 2014.

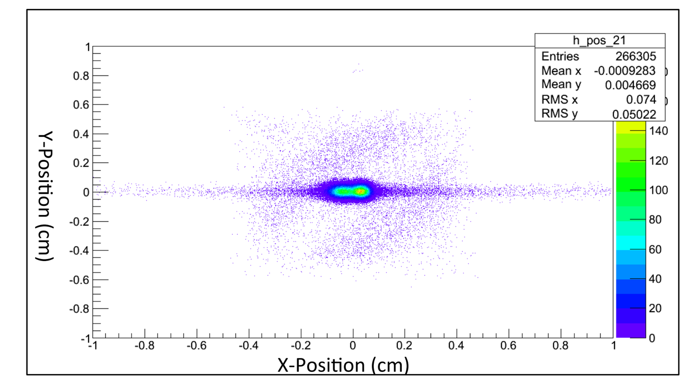
Acknowledgements:

Thank you to the SJY Research Group, the Cyclotron Institute, and Texas A&M University.

This work was supported by the Robert A. Welch Foundation under Grant No. A-1266 and the U. S. Department of Energy under Grant No. DE-FG03-93ER-40773 and the National Science Foundation under Grant No. PHY-1263281.

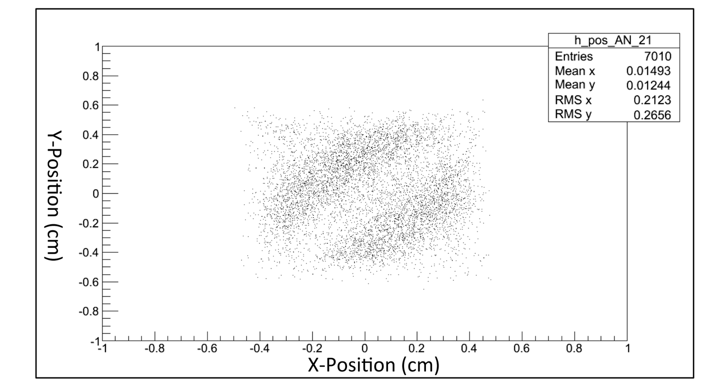
Phase 1, Stripe Identification with K-means:

0. Collect Data



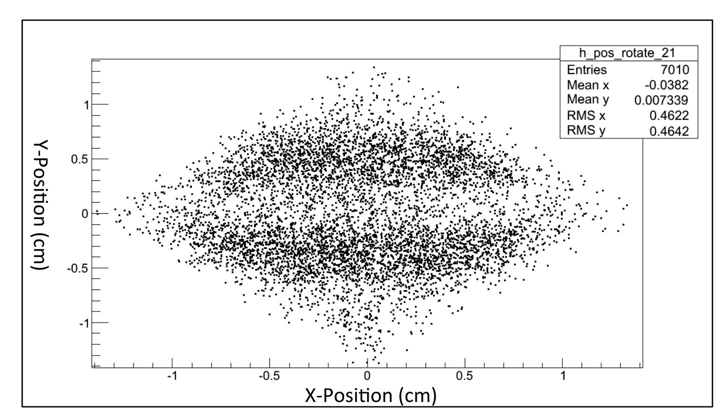
Position plot after raw data collection for detector 21

1. Signal Processing



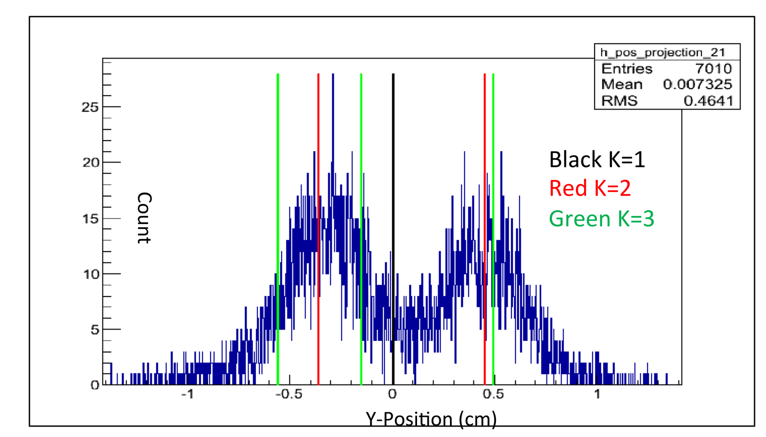
Apply cuts on signal strength to filter out noise levels. The detectors are also stretched so they can fill region.

2. Rotation



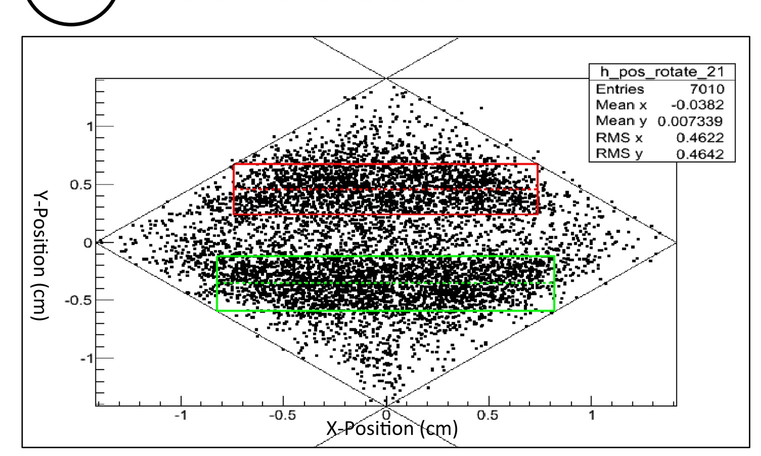
Rotate data by 45 degrees, the expected angle of the slope. This makes projecting and fitting easier.

3. Run K-means Algorithm



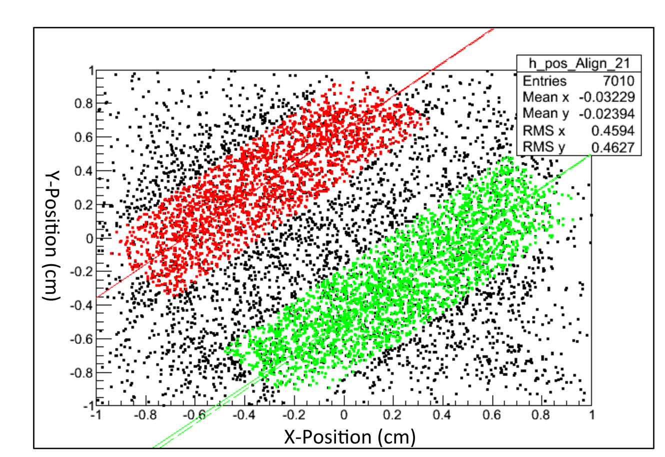
K-Means is used to identify location of stripes. Colors shown are different K-values, best one must be selected.

4. Data Selection

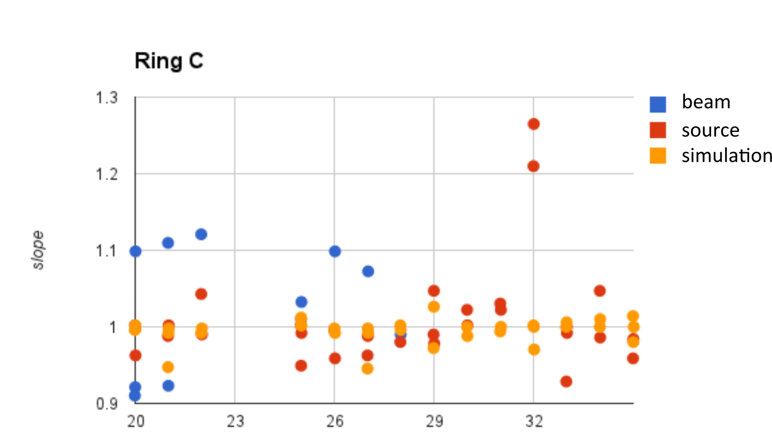


K-means will give approximate location of stripe, can now do a linear fit to data.

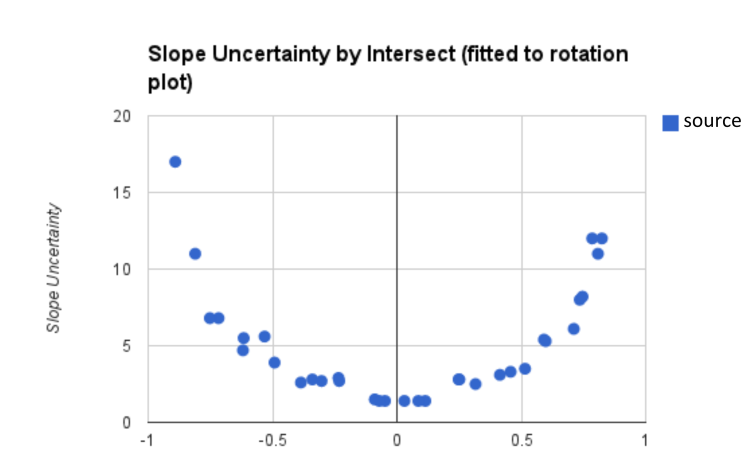
5. Linear Fit



Rotate lines back by 45 degrees. Colors show which points were used in fit

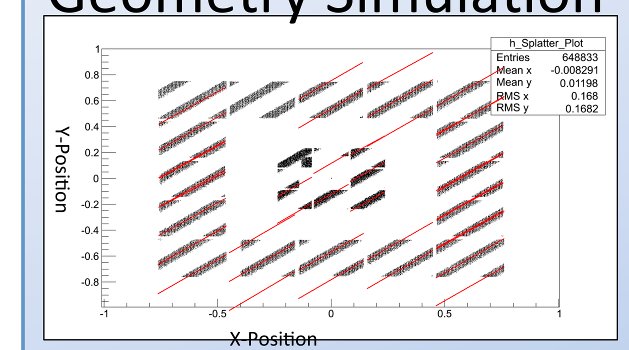


Plot showing the distribution of slopes found by K-means. Blue comes from data obtained from a beam, red from radioactive source, and orange from a simulation.



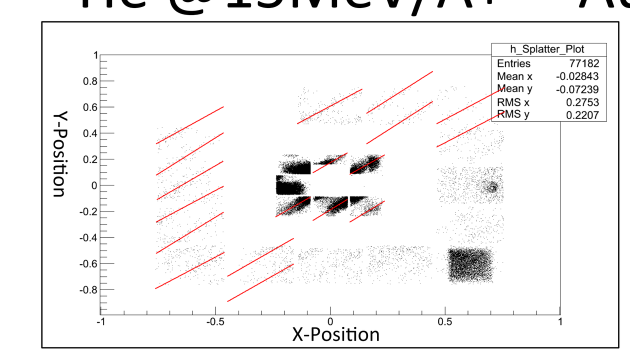
Plot showing the distribution of slope uncertainty. Less centered stripes give worse fits because the data is more square shape than rectangular. Explains deviation from 1 in orange data on plot to the left

Geometry Simulation

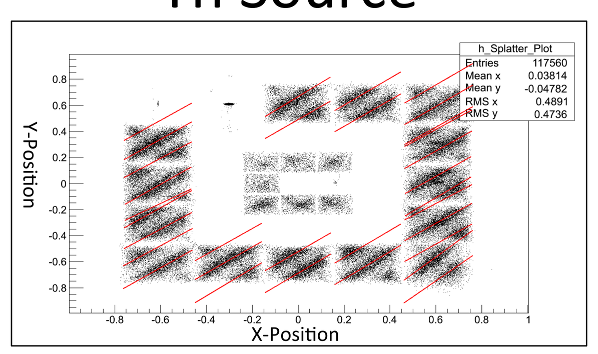


- Geometry Simulation
- "Perfect World" expectation
- Alpha particle simulation perfect elastic scattering

^{4}He @15MeV/A+ ^{nat}Au



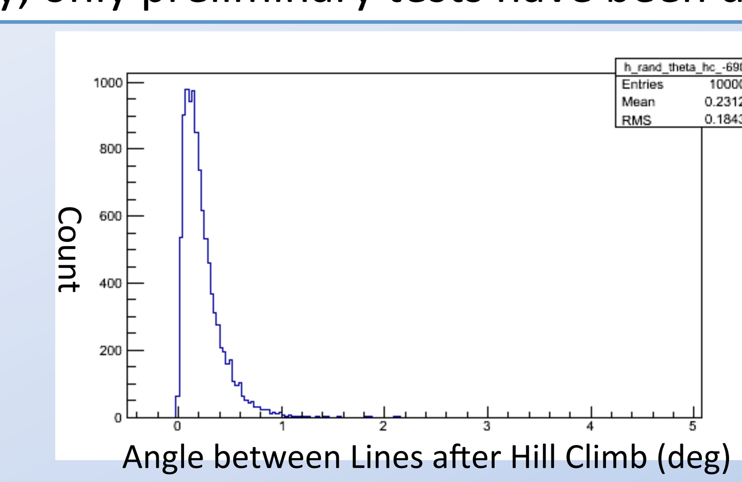
^{228}Th Source



- Beam and source agree closely for detectors with good data
- Significant differences with the Simulation
  - Number of stripes
  - Slope of stripes
- Detectors are in fact moving.

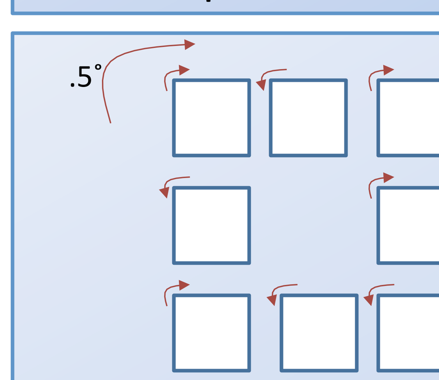
Phase 2, Ideal Detector Alignment with HC:

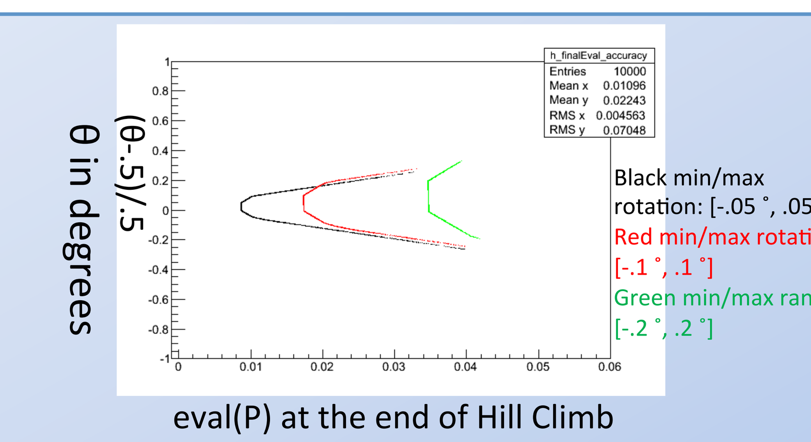
- Use Hill Climbing to find a set of transformations which make beam and source data look more like simulation
- Hill Climbing can be applied to a variety of problems, however it's performance can also be affected by a variety of factors
- Extensive testing must be done to fully understand it
- Presently, only preliminary tests have been done for this algorithm



Setup:

- Two initially parallel lines are rotated randomly
- Hill Climbing is told to make them parallel again through rotations
- 6 free parameters for 3 rotations each





eval(P) at the end of Hill Climb

Setup:

- Ring of detectors rotated by .5 degrees about beam-axis
- Each detector is rotated randomly within a given range
- Hill Climbing is told to rotate ring such that the set of stripes are as close to expected as possible
- 1 free parameter.