Charge Collection Efficiency (CCE) Measurements of MSSD Sensors

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Outline

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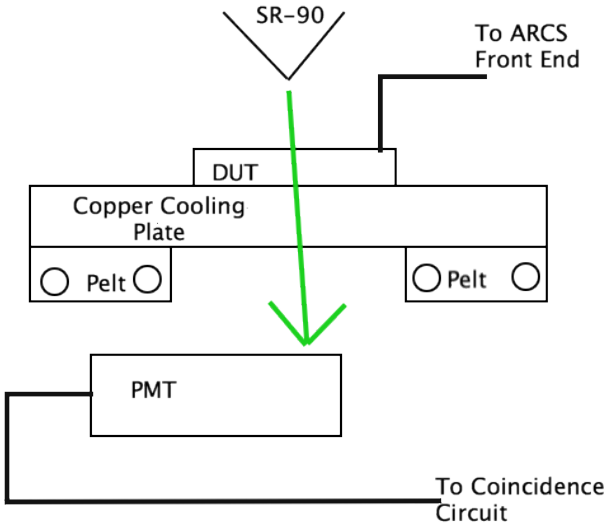
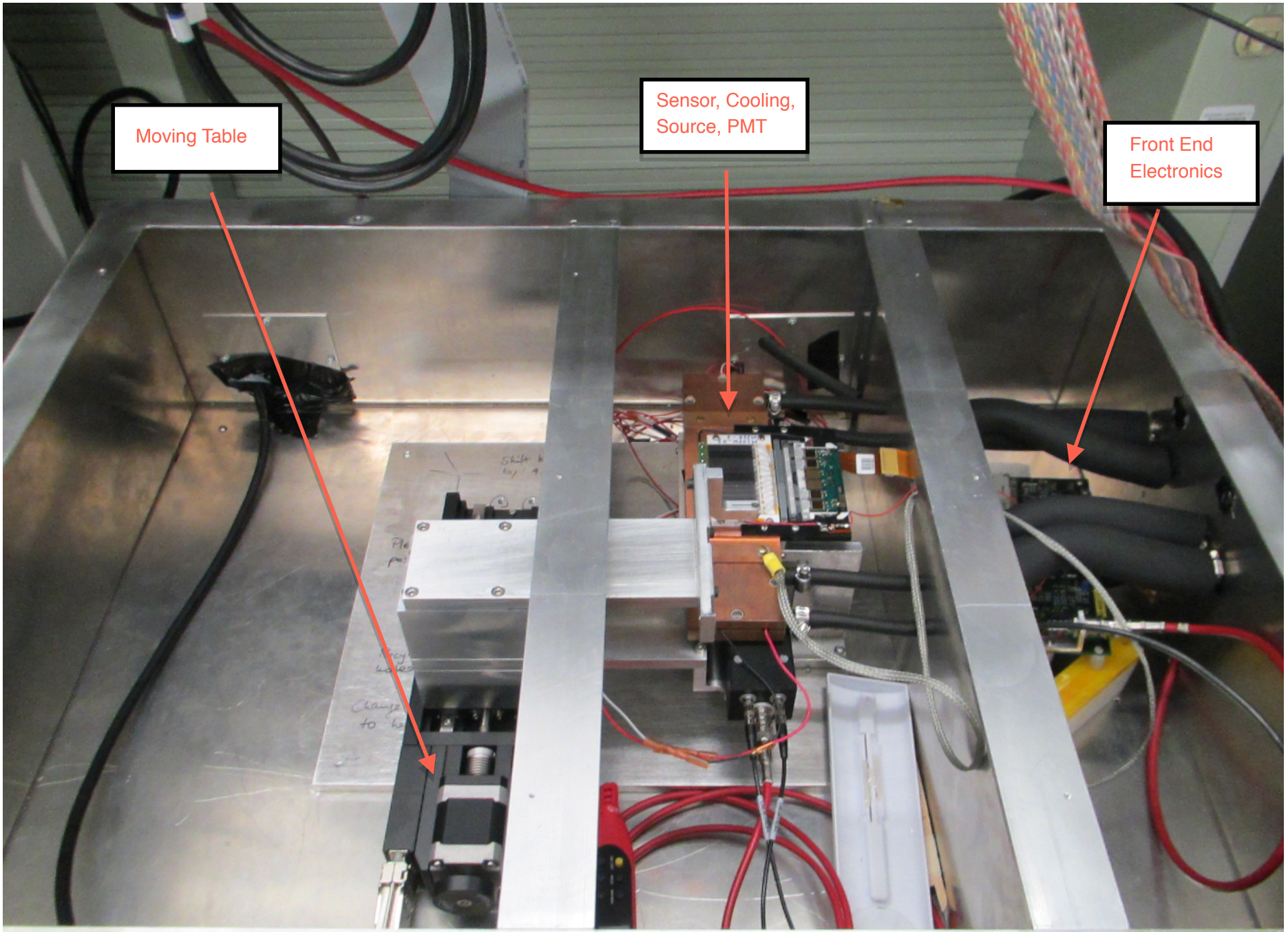
Goals

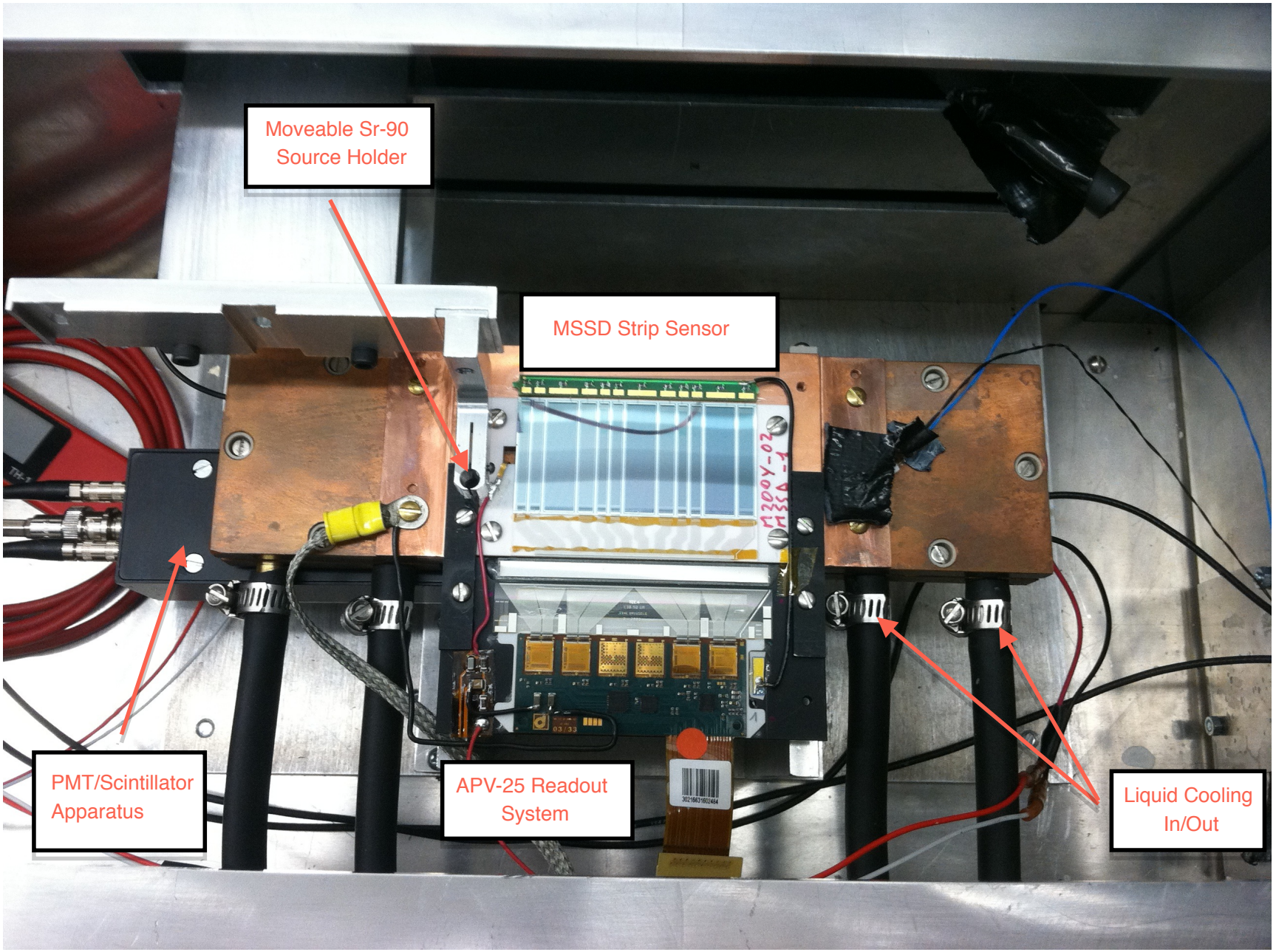
- Characterize sensors before and after irradiation to identify optimal type/geometry to use in the outer tracker at CMS during HL-LHC runs
- Expect radiation induced defects to affect sensor CCE and depletion voltage
- Measure Charge Collection Efficiency in Hammamatsu strip sensors with different properties (production type, polarity, geometry) before and after irradiation.
- Measure long term stability of continually biased sensors.
- Measure depletion voltage
- Currently using APV Readout Controller (ARC) hardware and software for processing APV-25 chip signals. Will soon have the capability to compare/cross-check with the Alibaba system

Brown APV Readout Controller (ARC) Setup - Highlights

- Sensor, moving table, and front end electronics housed in light-tight Aluminum box
- Moving table holds Sr-90 β-source which can be placed over different regions of the sensor
- Sensor can be cooled:
  - Detector is placed on a copper plate above two Peltier Elements for quick responsive cooling (using PID controller)
  - Liquid Coolant is pumped across hot side of Peltier Elements to achieve lower temps.
- Pair of PMTs and scintillating material placed below sensor for triggering, designed to filter out lower energy electrons.

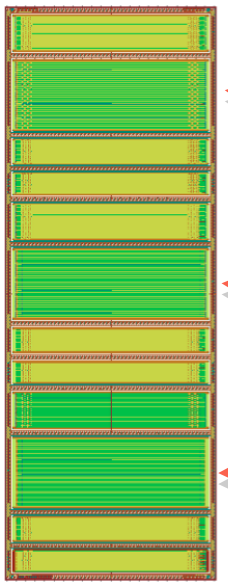



Moving Table
Sensor, Cooling, Source, PMT
Front End Electronics


Moveable Sr-90
Source Holder
MSSD Strip Sensor
PMT/Scintillator
Apparatus
APV-25 Readout
System
Liquid Cooling
In/Out

Sensor Sample Layout

- 12 regions with 32 channels each = 384 connected channels.
- Each region has unique implant width/pitch ratio.
- 2 MCz sensors, 200μm thick, n-type, p-type spray)



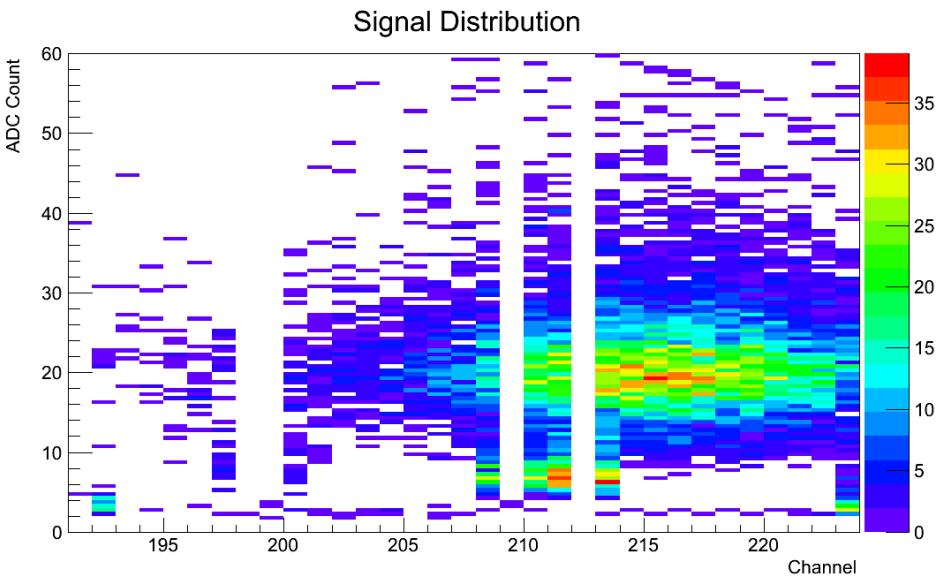
name	pitch	implant width	alu width	w/p
1-120	120	16	29	0,133
2-240	240	34	47	0,142
3-80	80	10	23	0,125
4-70	70	8,5	21,5	0,121
5-120	120	28	41	0,233
6-240	240	58	71	0,242
7-80	80	18	31	0,225
8-70	70	15,5	28,5	0,221
9-120	120	40	53	0,333
10-240	240	82	95	0,342
11-80	80	26	39	0,325
12-70	70	22,5	35,5	0,321

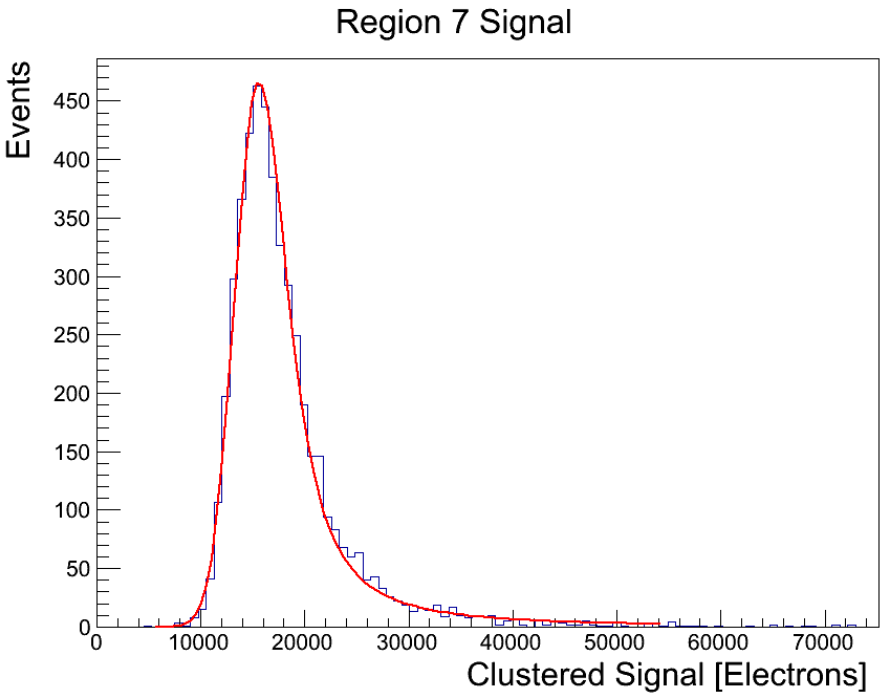
Analysis Chain

- Cool non-irradiated sensor to 0°C, Take 10k events with source over single region
- Calculate and subtract pedestal
- Locate and Mask Bad Channels
- Locate center of signal (seed) w/ Bad Channel rejection
- Cluster side channels
- Calculate and subtract Common Mode w/o signal channels
- Fill histogram with subtracted ADC values from seed and cluster channels

Signal

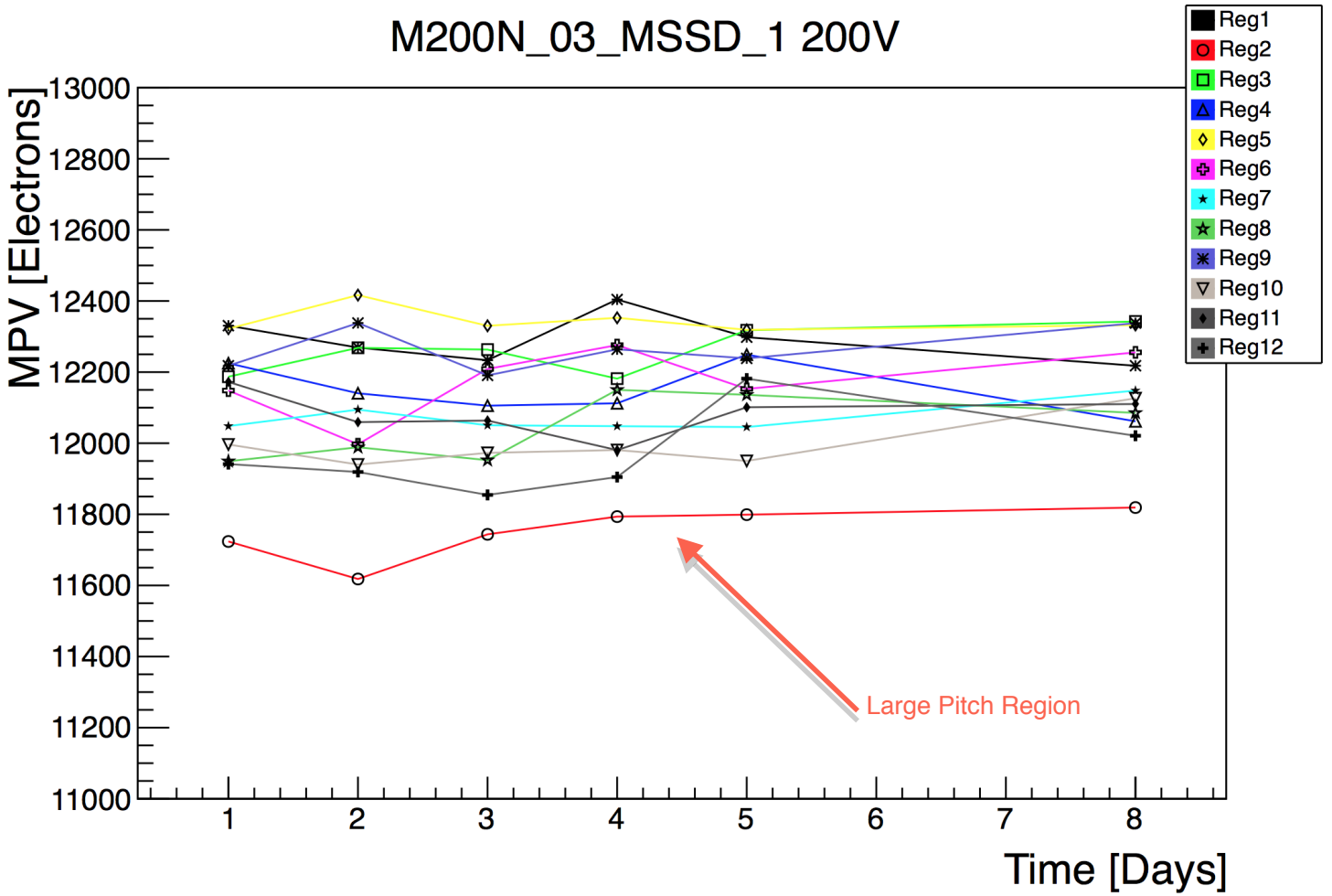
- Classify and Calculate Total Signal: seed $> 5\sigma$, side $> 2\sigma$
- Fit with Landau convoluted with a Gaussian





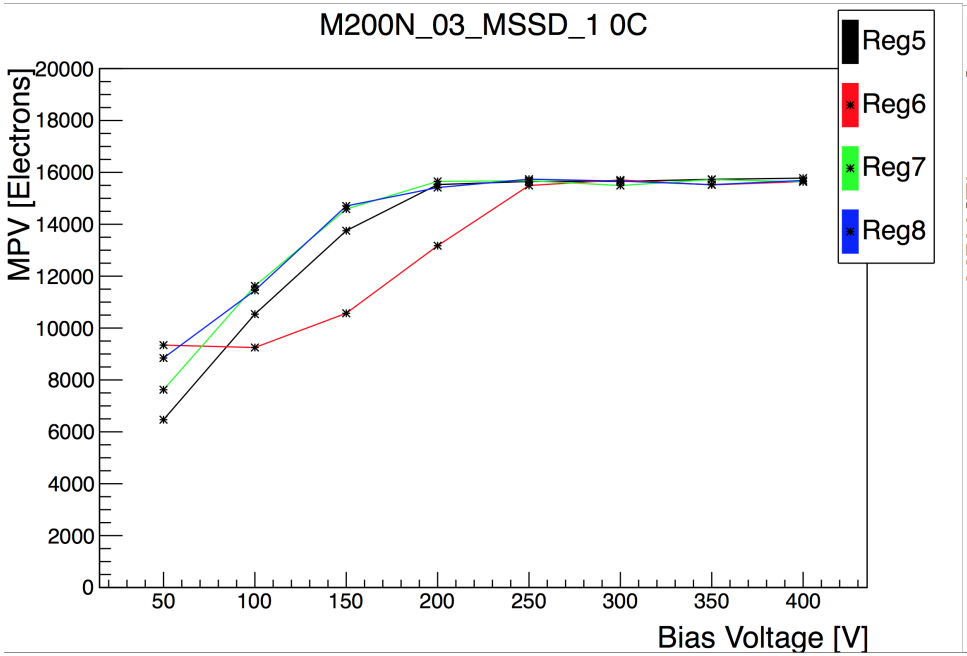
Long Term

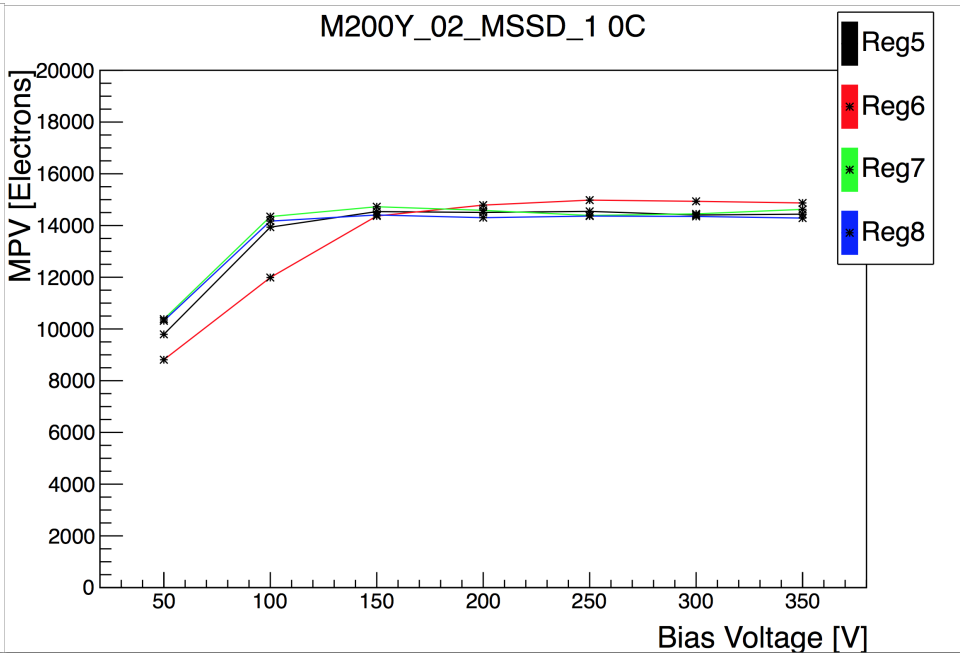
- 10k events with source over each region
- 1 per day for 6 out of 8 days (break on weekend)
- Plot MPV vs Time



Voltage Ramp

- 10k events with source over set of 4 regions
- for range of bias voltages 50-500V, 50V steps (or until breakdown)
- Plot MPV vs Voltage, important reference measurement





Outline

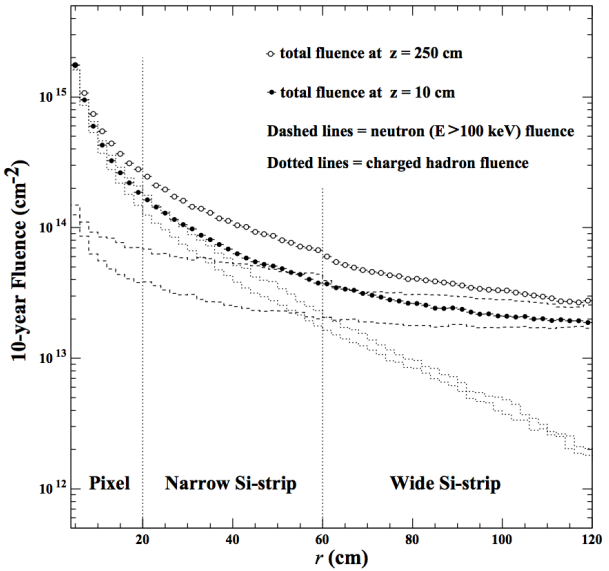
Summary

- Current Results
  - Build setup/Developed analysis to characterize properties of potential sensors to be used in future CMS tracker upgrades
  - Long term stability of CCE observed in non-irradiated sensor (n-type MCz)
  - Observed differences in CCE and depletion voltage possibly caused by sensor geometry
  - Obtaining good reference measurements for comparison after irradiation
- Additional Data Soon
  - Repeat at -20°C
  - Cross-Check with Alibaba readout system
  - Irradiate (Los Alamos, 800MeV protons)

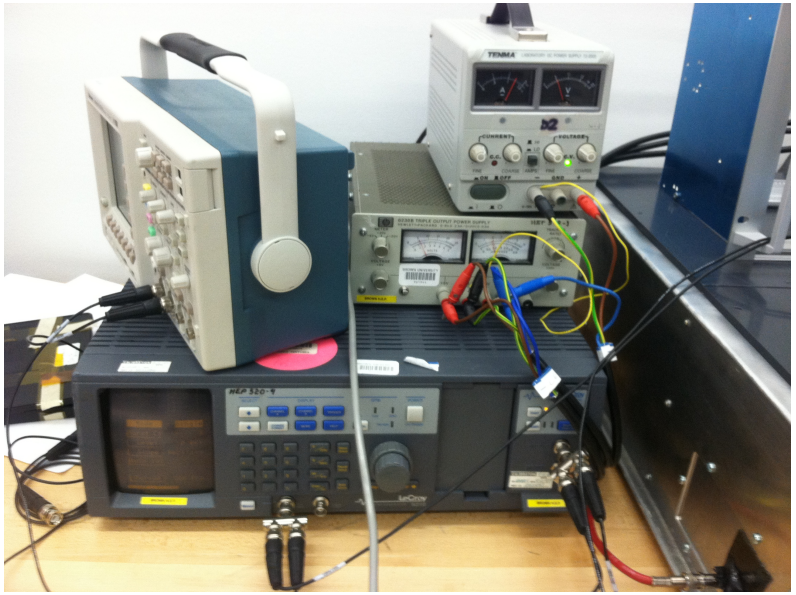
Outline

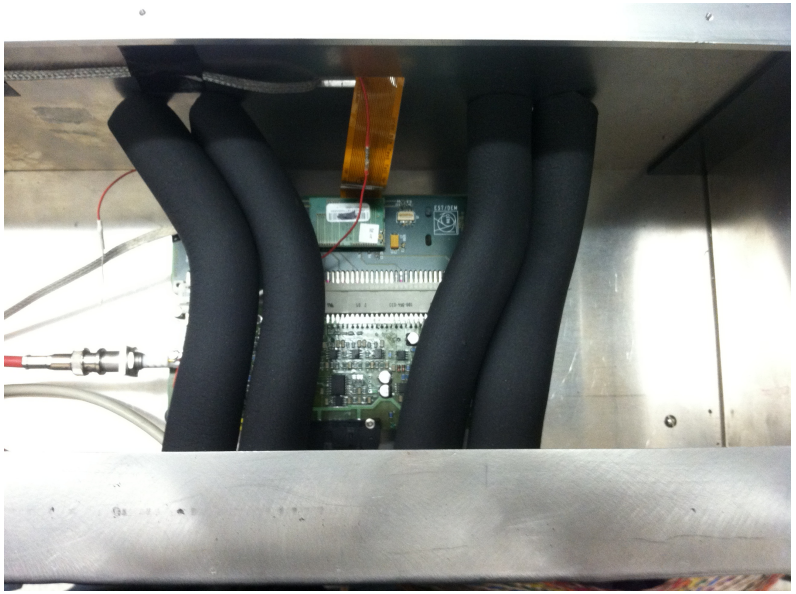
HPK Campaign

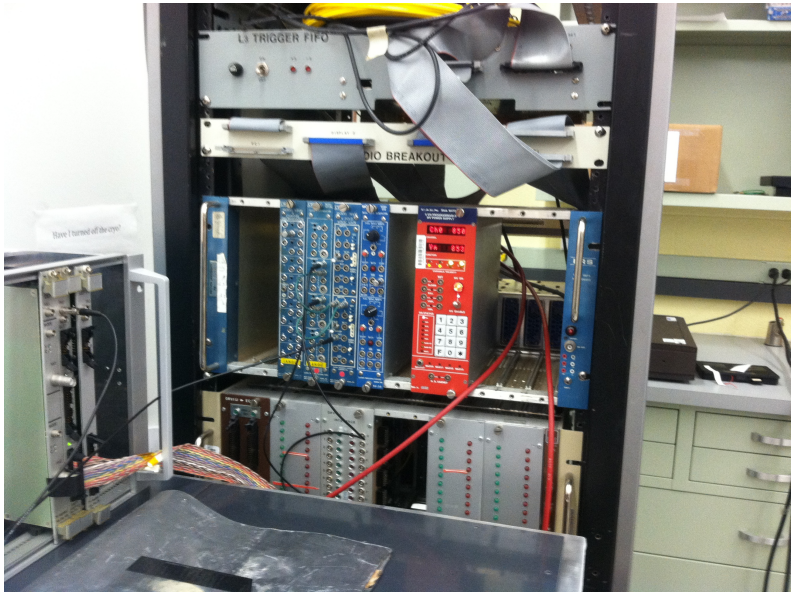
- Goal: Find appropriate sensors for future upgrades to the Si tracker which survive the high radiation environment of an upgraded LHC
- L increased: $10^{32} cm^{-1} s^{-1} \rightarrow \ > 10^{35} cm^{-1} s^{-1}$
- Increased energy: 8TeV $\rightarrow$ 14TeV
- More particles, more frequently $\rightarrow$ Higher rate of radiation damage
- Quantities to test: S/N, degradation due to irradiation
- Determine how these values relate to: Si growth procedure (FZ, MCz, Epitaxy), sensor width/pitch/thickness and sensor bulk polarity.

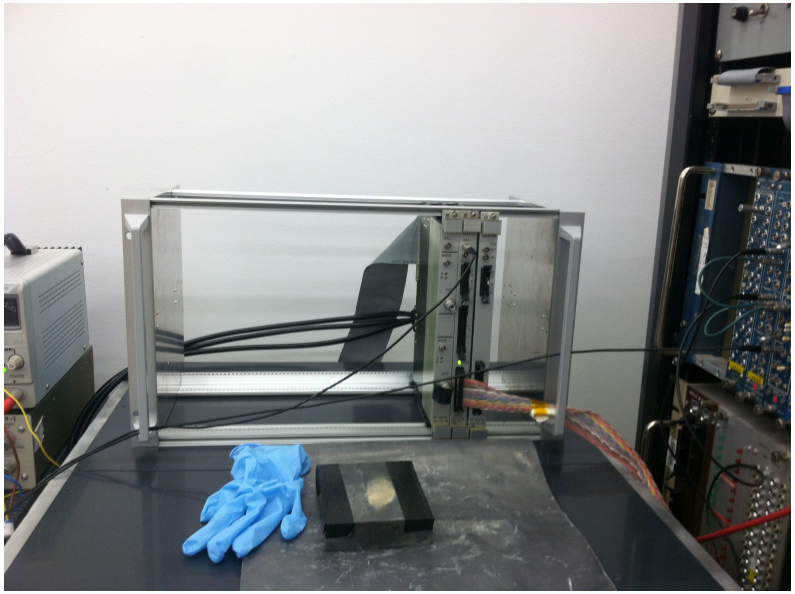


More Pictures



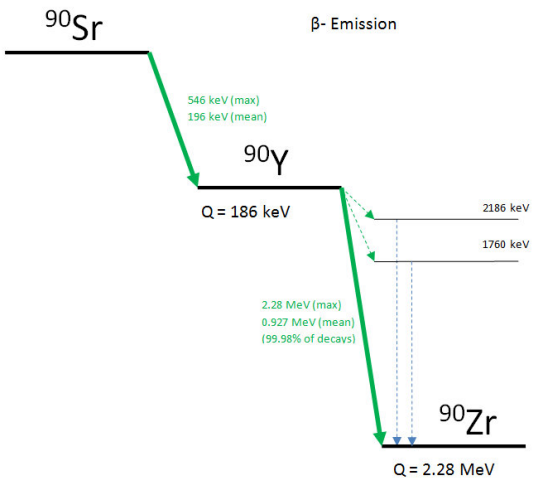


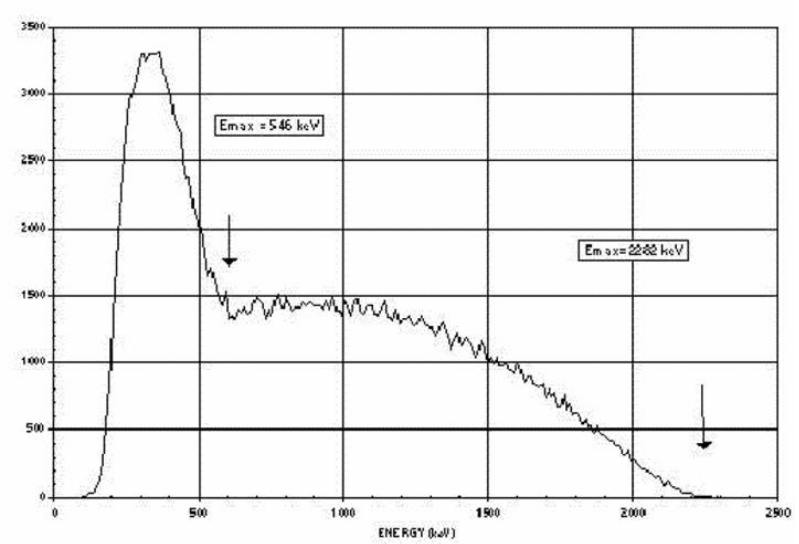




Strontium-90

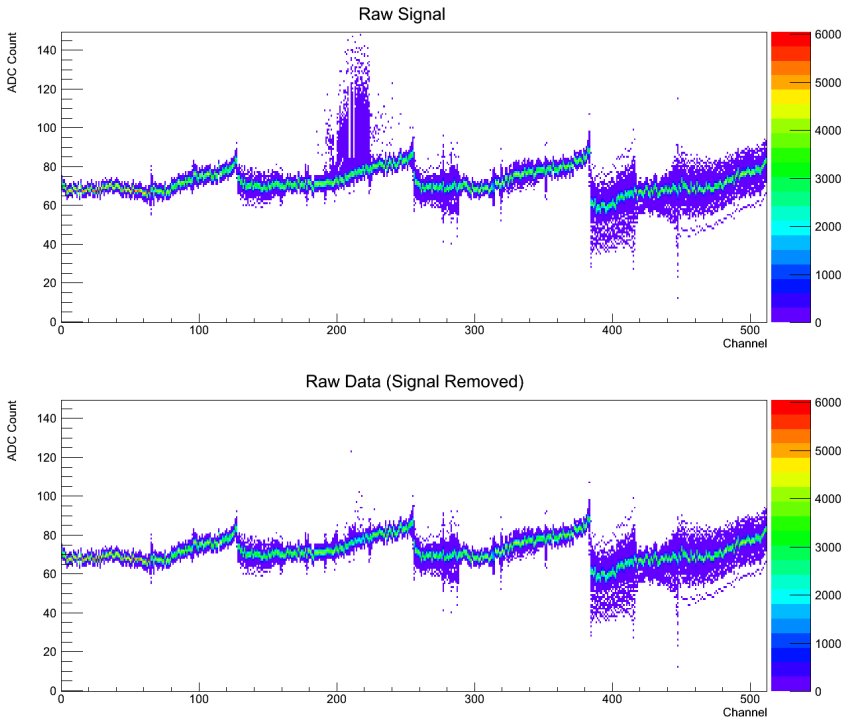
- β-decay to yttrium-90 followed by β-decay to zirconium-90
- Interested in second, higher energy decay
- PMTs designed to filter lower energy electrons

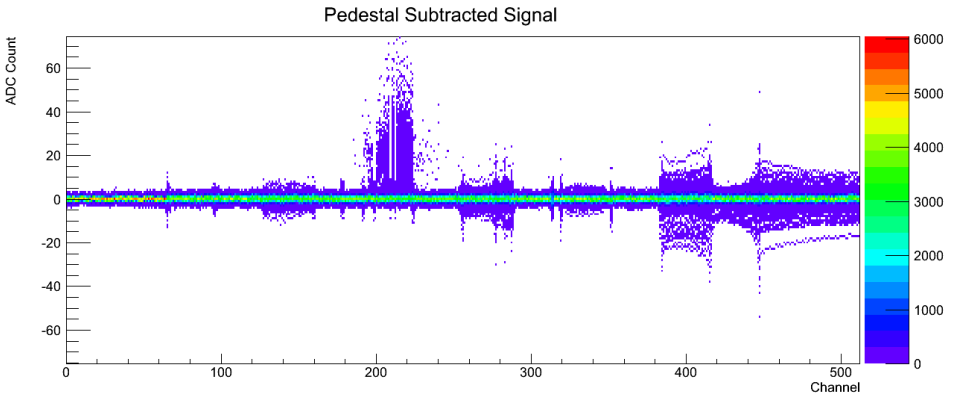




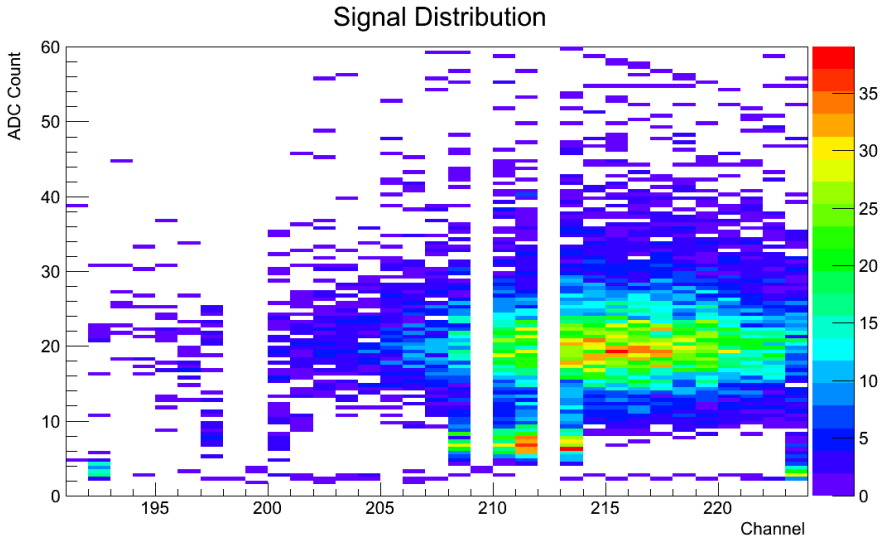
Pedestal Calculation

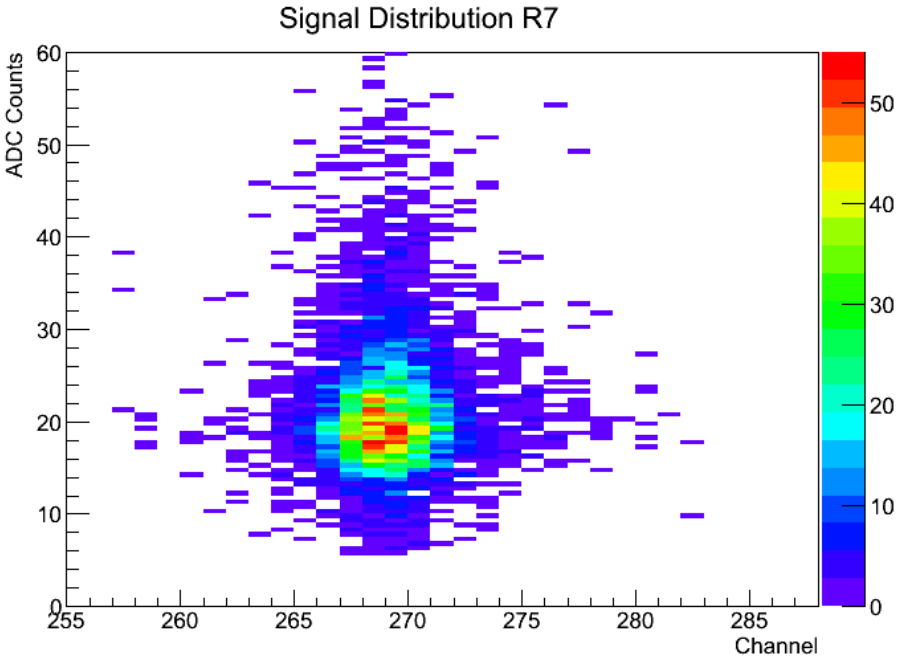
- Calculate Pre-Pedestal with no-source run
- Using Pre-Pedestal find and remove signal channels from source run
- Create pedestal from signal-subtracted source run



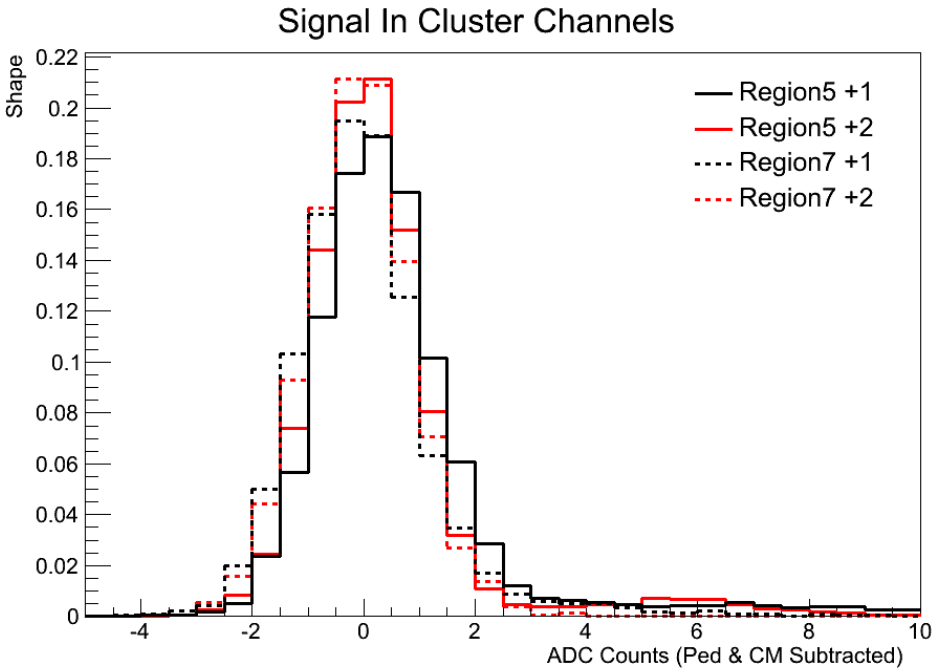


Clustering





- Signal appears in more than 1 channel
- Difference in region width (wire spacing) affects clustering
- Test for best conditioning of when to include a side channel



Common Mode Calculation

- Definition: Average fluctuation above or below pedestal across APV

$$\frac{1}{128}\sum_{i=1}^{128}(x_i - p_i)$$

- Calculated for each APV for each event, Modify to exclude signal