ADC Stuck Code Feature

Jonathan Insler

LSU

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ADC Stuck Code Issue

- Linearity study of 35t ADC ASICs found that 6 LSBs frequently "stick" at 000000 (0x00) or 111111 (0x3F)

- Brian Kirby presented these slides at LAr-FD Cold Electronics meeting last week, in DocDB 11328

- Currently working to simulate stuck codes in DetSim and interpolate over stuck codes in reconstruction (CalWire)
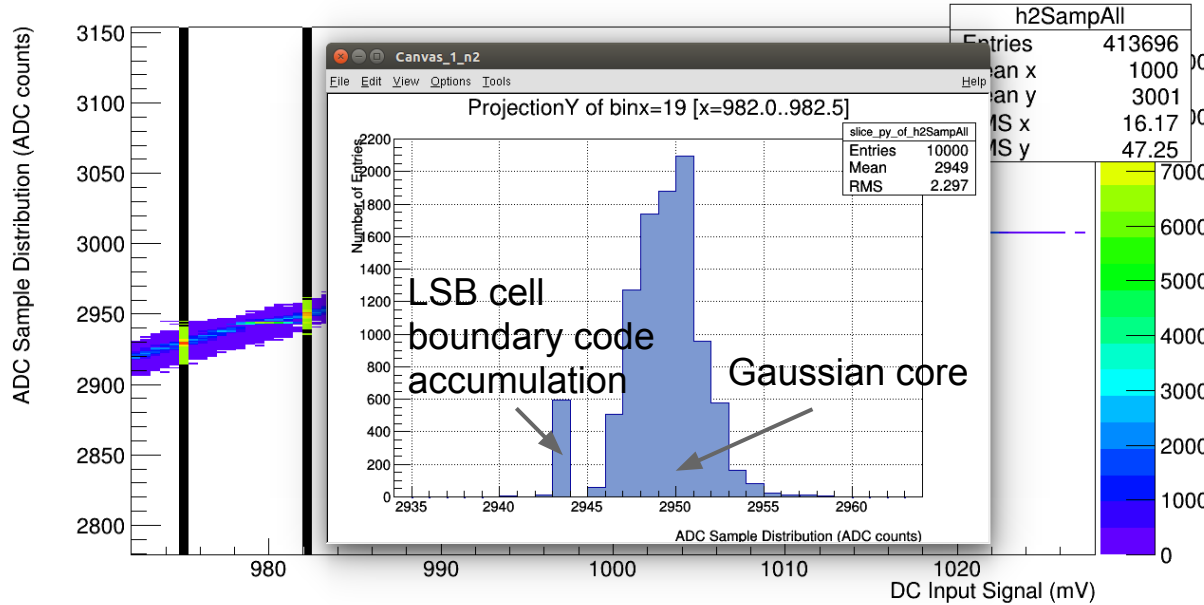
DC Signal Scan Data

ADC Sample Distribution vs Input Signal
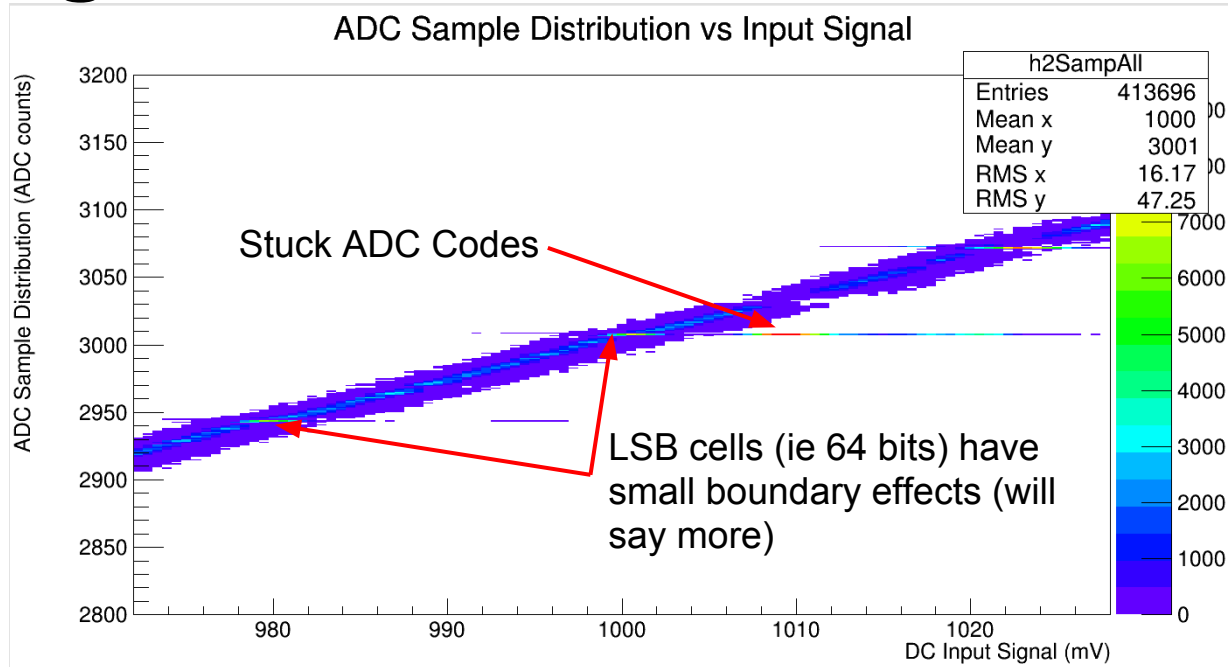
- DC signal injected directly into ADC test input
- Range of DC signals tested, 10000 samples recorded at each voltage level

ADC Sample Value Probability

ADC Sample Distribution vs Input Signal

- For given input signal, have probability distribution for measured samples
  - Core of distribution, approximately Gaussian with ~1bit DNL
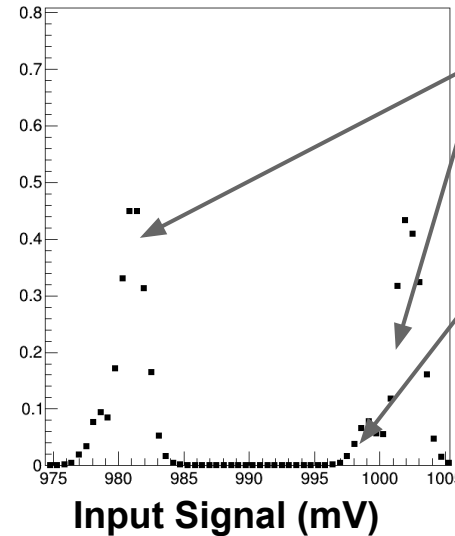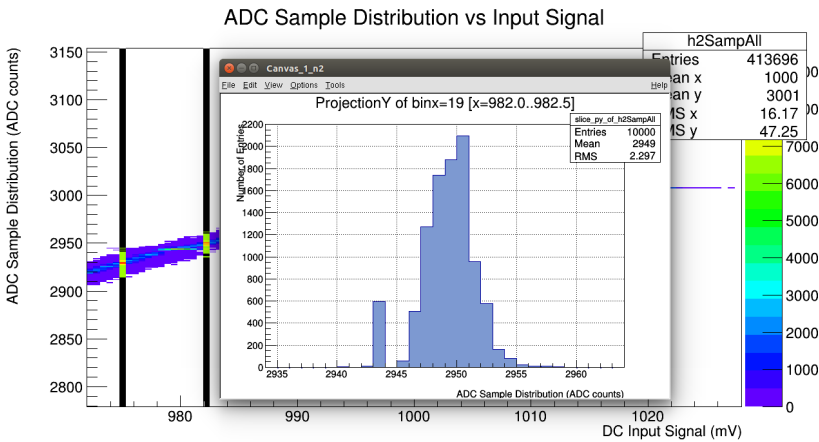 - Sample accumulation at LSB cell boundaries ie. "stuck ADC codes"

What Are Stuck ADC Codes?

ADC Sample Distribution vs Input Signal
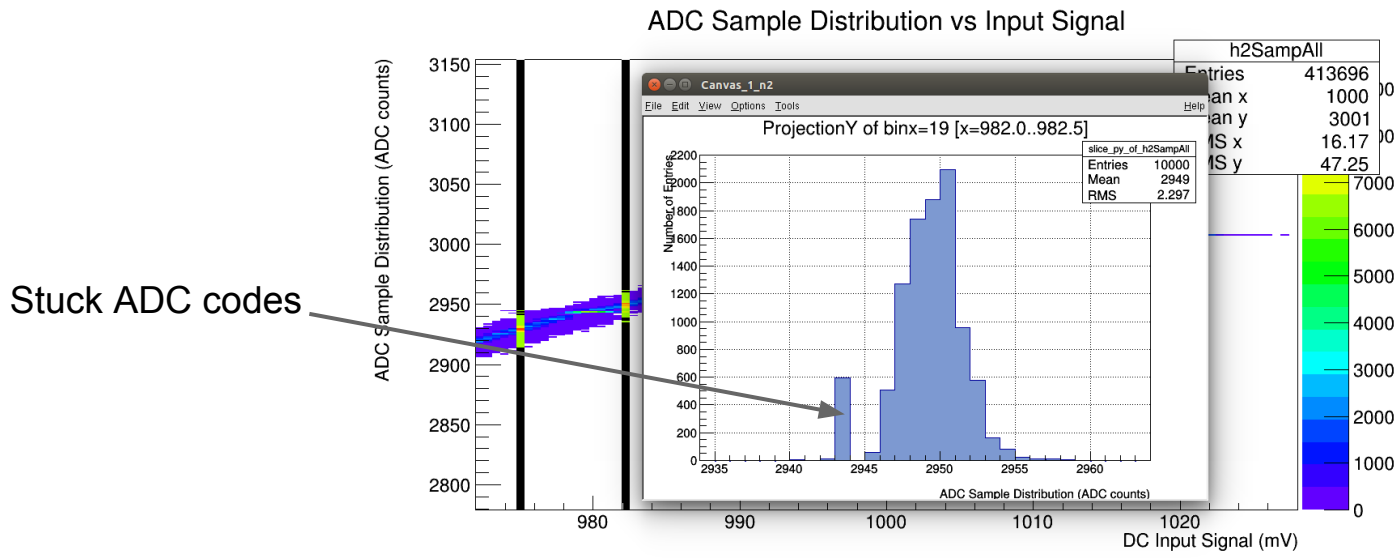
- Ideally a given input signal voltage would be converted to a single ADC value according to a roughly Gaussian probability distribution
- Stuck code issue: there is some probability for 35t ADCs to convert the input signal to an ADC code at the boundary of 6-LSB range
  - This is equivalent to saying the 6-LSB have some probability to erroneously all be 0 or 1
  - These are "stuck codes": the 6-LSBs of the sample are "stuck" at the LSB cell boundary
  - This does not affect the 6 MSBs in ADC samples

Stuck ADC Code Probability

Probability 6 LSBs = 0x00 OR 0x3F

Input signals near boundaries of 6-LSB range, these should result in ADC codes with 6 LSBs = 0x00 or 0x3F

Stuck ADC codes: input signals not near 6-LSB range boundary have some chance to convert to ADC codes with 6 LSBs = 0x00 or 0x3F
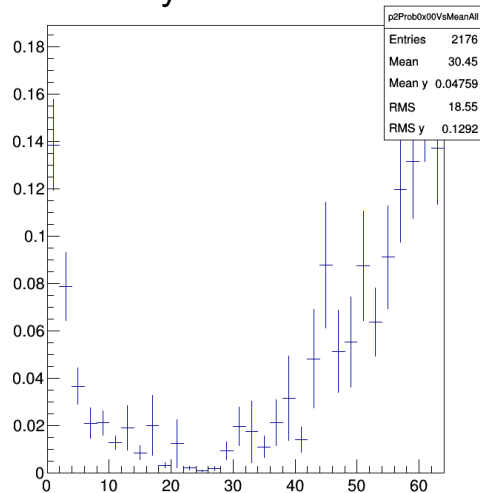
- Measure probability of getting LSB cell boundary samples at various inputs
- Inputs close to cell boundaries have high probability of boundary samples (this is expected)
- See in addition elevated probability of getting LSB cell boundary samples/stuck ADC codes for other input signal ranges
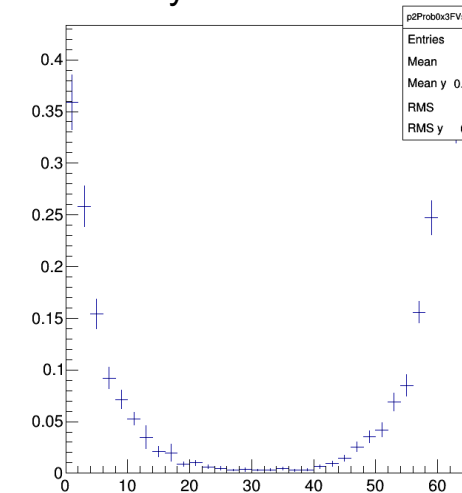
Stuck ADC Code Probability Vs Input Signal

Room Temperature Stuck ADC Probability   **Cryogenic Stuck ADC Probability**
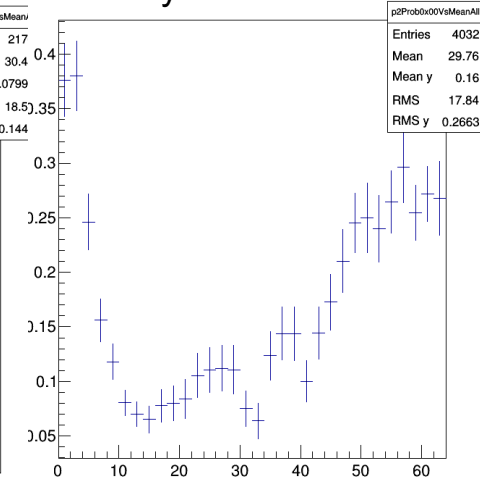
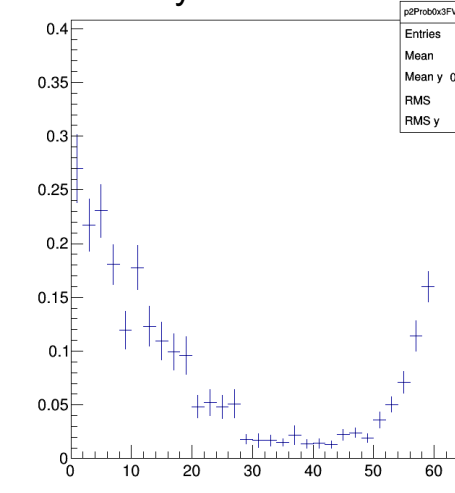Probability 6 LSBs = 0x00   Probability 6 LSBs = 0x3F   Probability 6 LSBs = 0x00   Probability 6 LSBs = 0x3F

Input Signal in Equivalent # of ADCs Modulo 64   **Input Signal in Equivalent # of ADCs Modulo 64**

- Measure mean probability to get a stuck ADC code for a given input signal
  - Converted input signal to corresponding ADC code value, averaged over all 6-LSB cells
- **Stuck ADC code probability at 77K is ~2-3 higher than 300k**

Simulating Stuck Codes

- Each ADC vector entry has some probability of getting stuck at 0x00 or 0x3F, proportional to input signal siz

- SimStuckBits Boolean fcl parameter added to detsimmodules_lbne.fcl

- For each entry, use random number generator to determine if it sticks to either 0x00 or 0x3F

- Flip 6 LSBs with bitwise operators:
  - 0x00: set ADC value adcvec_a[i] = adcvec_a[i] & 0xffc0
  - 0x3f: set ADC value adcvec_a[i] = adcvec_a[i] | 0x003f

Next Steps

- Complete stuck bits simulation in DetSim with probabilities dependent on signal size, channel number

- Implement interpolation over stuck bits in CalWire

  - Identify ADC codes ending in 0x3F, make linear extrapolation from non-stuck neighbors
  - Ignore bits stuck at 0x00? At least for all-zero entries