LAr TPC Monte Carlo

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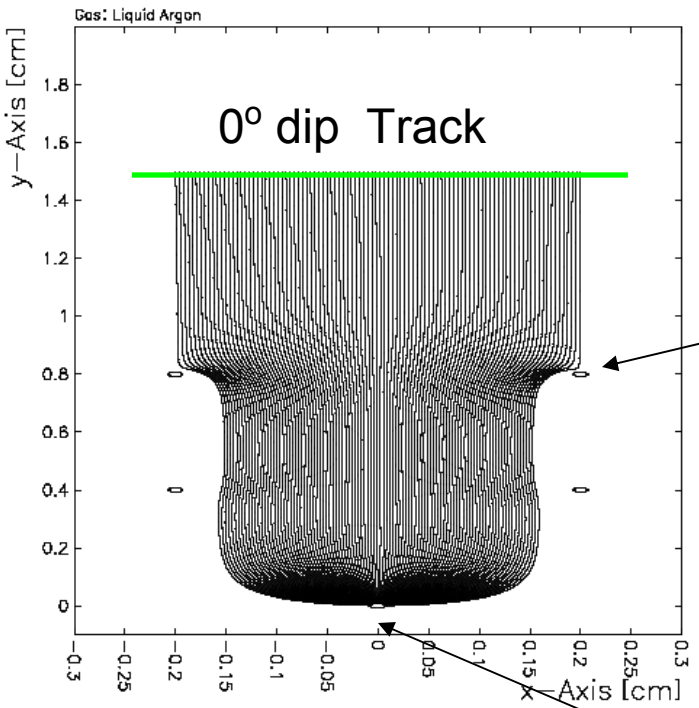
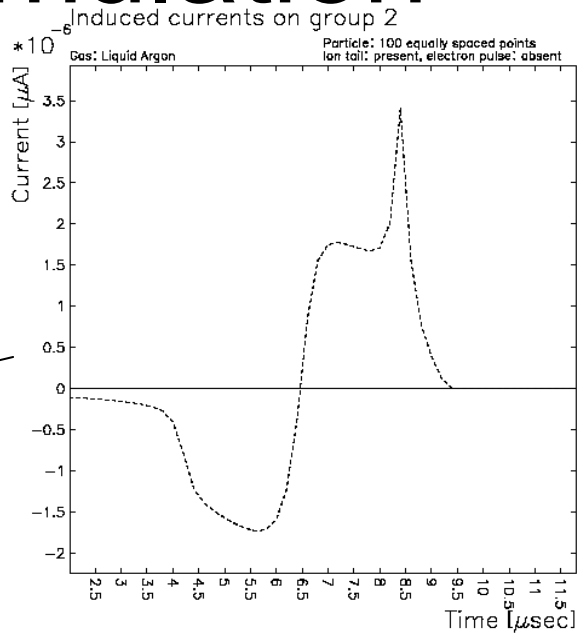
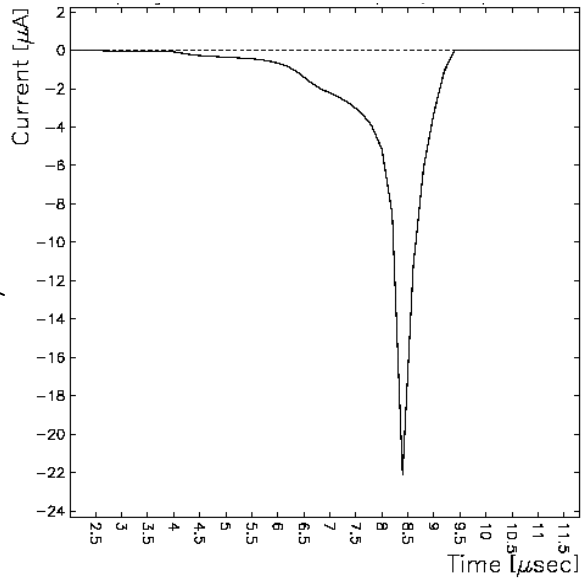
Methodology

- Use Geant for
  - Tracking
  - Simulating ionization & interaction processes
- Use Garfield simulation to determine time dependence of induction & collection plane signals
  - Requires knowledge of the bias voltages and sampling time
  - Garfield signal shapes are stored in text files
- Use home-grown code for
  - Electron diffusion, lifetime, electronics convolution, etc

Garfield Simulation

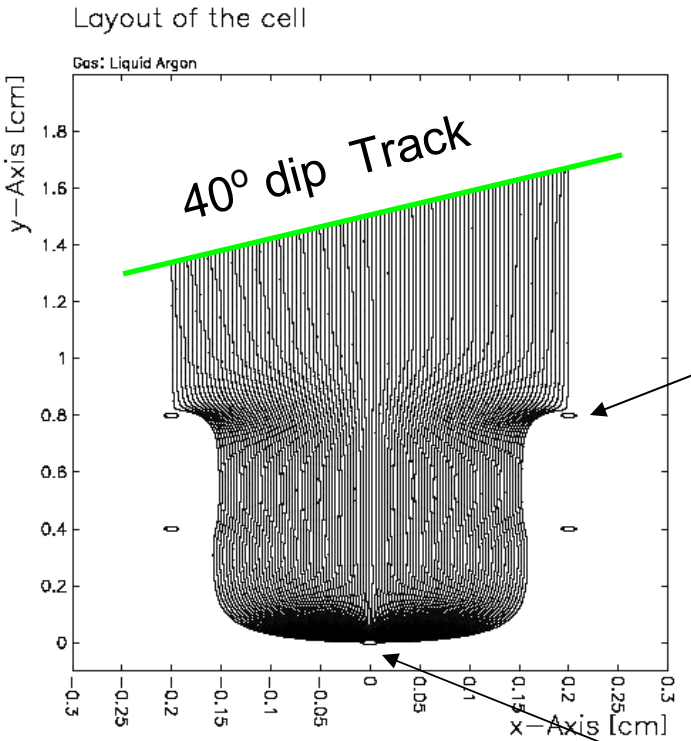


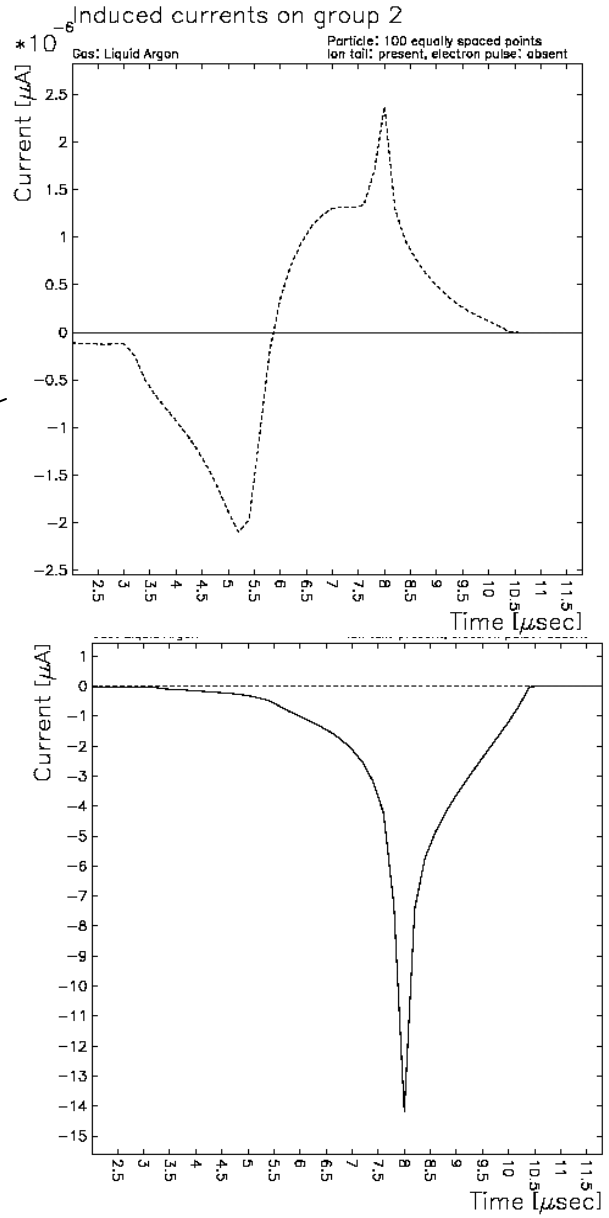




E_{drift} = 500 V/cm
V_{ind1} = -300V
V_{ind2} = 0V
V_{coll} = 400V

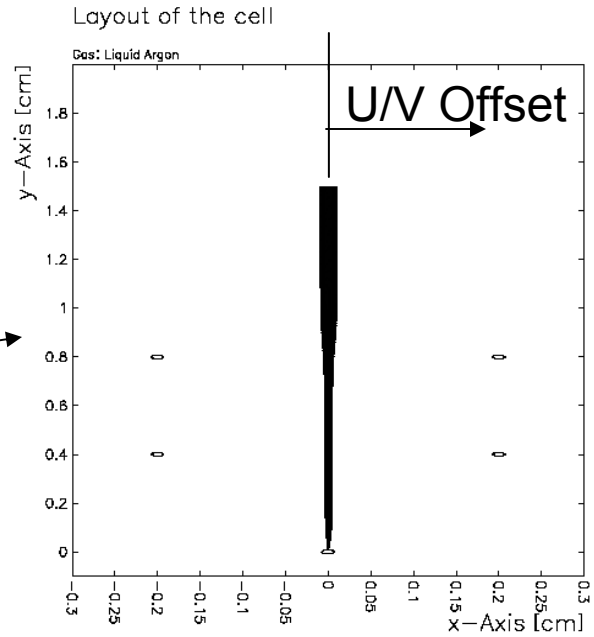
Garfield Simulation

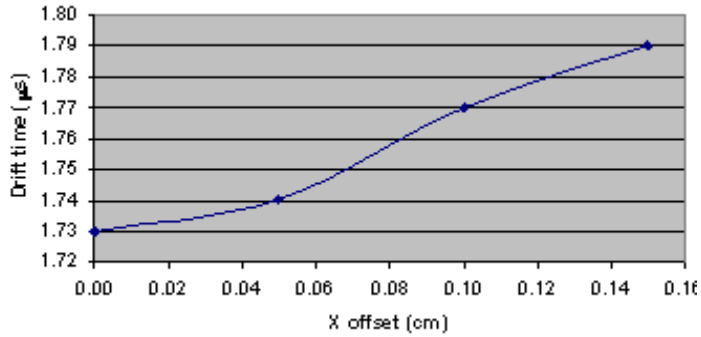




Garfield Simulation

- Simulate tracks of all dip angles
  - Use “stubby” 100 μm track pulse shape
  - Apply correction for drift time vs U/V offset
  - Ignore pulse shape variations wrt U/V offset





Electronics Simulation

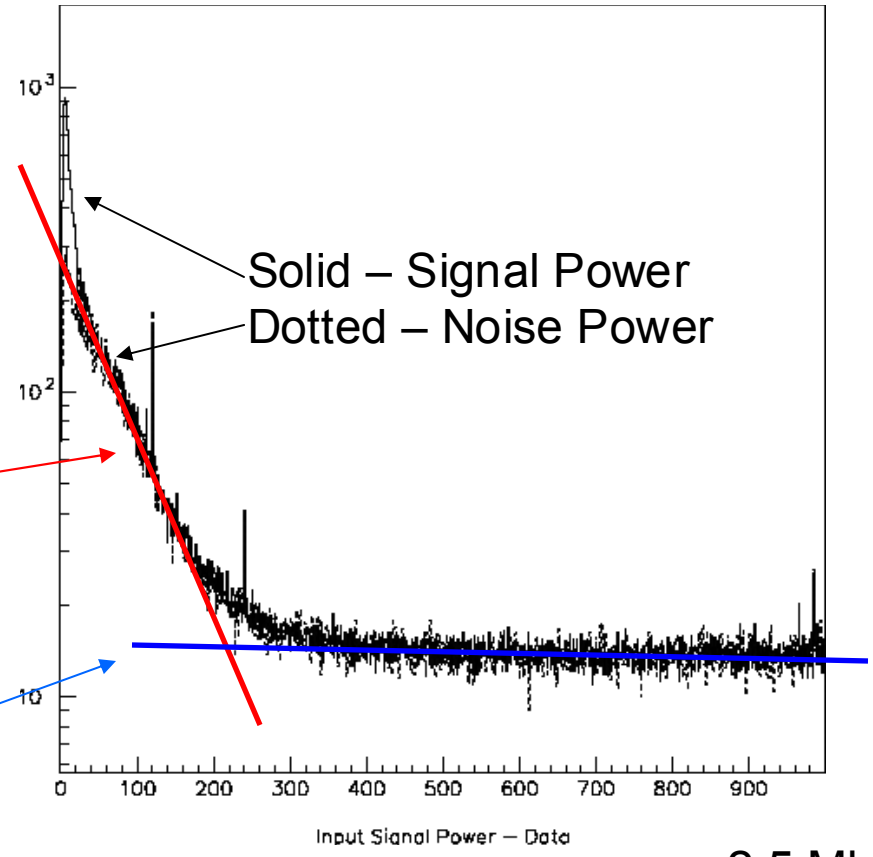
- ArgoNeut
  - Hard coded preamp response
  - Shaper delta function response derived from bench measurements
    - Text file
- ICARUS-like preamp & shaper
  - Shaping times scaled w sample time
    - τ_1 = 3 μs, τ_2 = 0.9 μs

    for 0.4 μs sample time
  - Hard coded

$$\frac{e^{-t/\tau_1}}{1+e^{-t/\tau_2}}$$

Electronics Noise Simulation

- Use ArgoNeut cosmic ray data
  - After filtering…
- Electronics noise matches exponential
- White noise due to digitization error (ignore)



2.5 Mhz

Electronics Noise Simulation

- For each frequency bin (0 - 1024)
  - Calculate power amplitude
  - Randomize within ±10%
  - Apply high pass filter (>7.5 kHz)
  - Pick a random phase angle
  - Fill complex array: Work(i) = (Re(Amp), Im(Amp))
  - Reflect the power Work(2048-i) = Work(i)
- ADC noise = $\mathrm{Re}(\mathrm{FFT}^{-1}(\mathrm{Work}))$
    - Re-use noise sample if ADC array size > 2048

Job Initialization

- Force Geant step size = 100 μm
- Set max number of tracking steps large
- Set tracking thresholds to the minimum
  - KE = 100 keV
- Define geometry, noise level, sample time, electronics shaping model
- Convolute ArgoNeut preamp & shaper with delta function input
- Determine appropriate ADC offset
  - 50% of full scale for bi-polar signals (induction)
  - 10% of full scale for mono-polar signals (collection)

Tracking at each 100 μm step

- If new track
  - Create new MC truth track
  - Determine sampling frequency for MC truth trajectory
    - Frequency ~ momentum * number of tracking steps
      - At least one MC truth sample/wire space
  - MC truth trajectory = X,Y,Z position
    - Should have included momentum…
  - Zero the ADC array

Tracking at each 100 μm step

- If old track
  - Add trajectory to MC truth track buffer?
  - Accumulate true energy lost in the last step (destep)
  - Determine X distance from track to the induction plane
  - Apply gaussian diffusion in X, Y, Z
  - Apply electron lifetime factor
  - Rotate (Y,Z) position into wire coordinates (U,V)
    - U = Induction plane, V = collection plane
  - Determine which wires will receive the charge
  - Determine U(V) offset and apply drift time correction
  - Determine which 2 ADC bins in U(V) will receive charge (linear interpolation)
  - Accumulate destep in ADC bins

End of Event

- Generate electronics noise and add to ADC
- Convolute ADC with combined Garfield/preamp/shaper response
- Scale by electronics gain and recombination factor (70%)

Calibration Event

- The first MC event is a small angle muon
  - Resolves the t_0 problem
  - Corrects for time offsets caused by convolution, unknown inter-plane drift velocity, etc
    - Determine the hit X difference between the true track trajectory and the reconstructed hit position
  - Provides development of code for calibration
    - Determine the position resolution for a straight track
- Should generate a large dip angle track to determine the electron lifetime
  - Needed to make pulse height correction → MIP's

Output Options

- Schemes
  - ICARUS compression (Full ADC)
    - Write 4 bit difference
  - Hit blocks (ADC bins in hit regions)
- Reconstructed hits