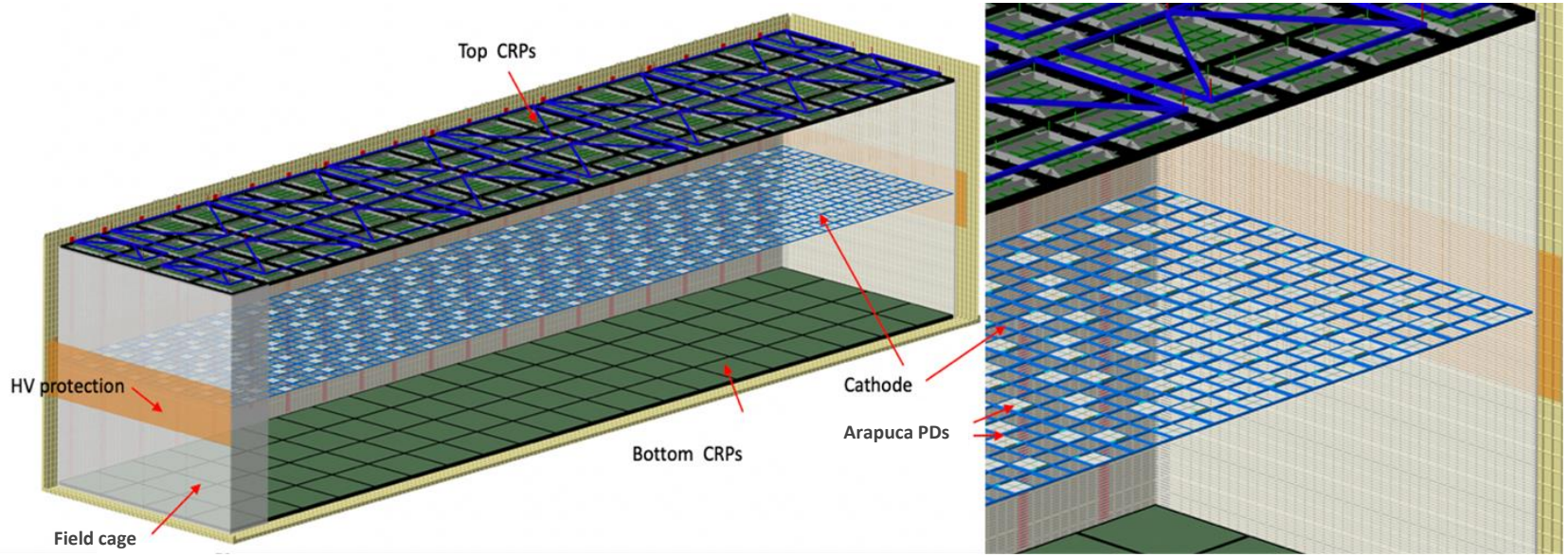
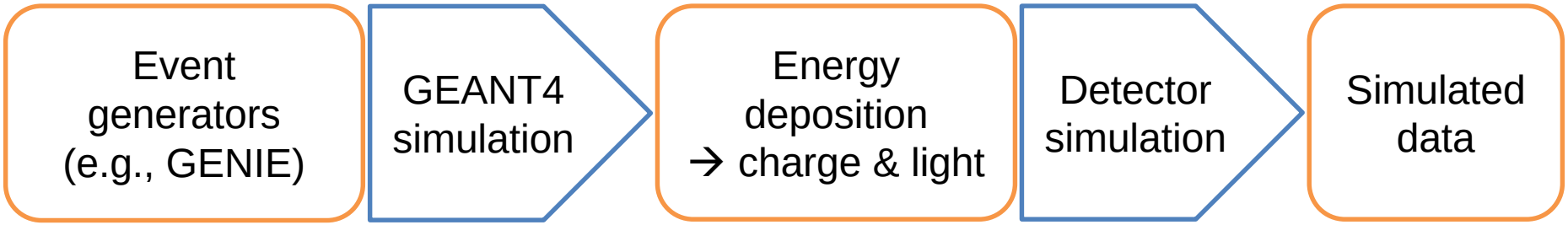
Vertical Drift Detector Simulation Chain



Vyacheslav Galymov
IP2I Lyon

10 May 2021

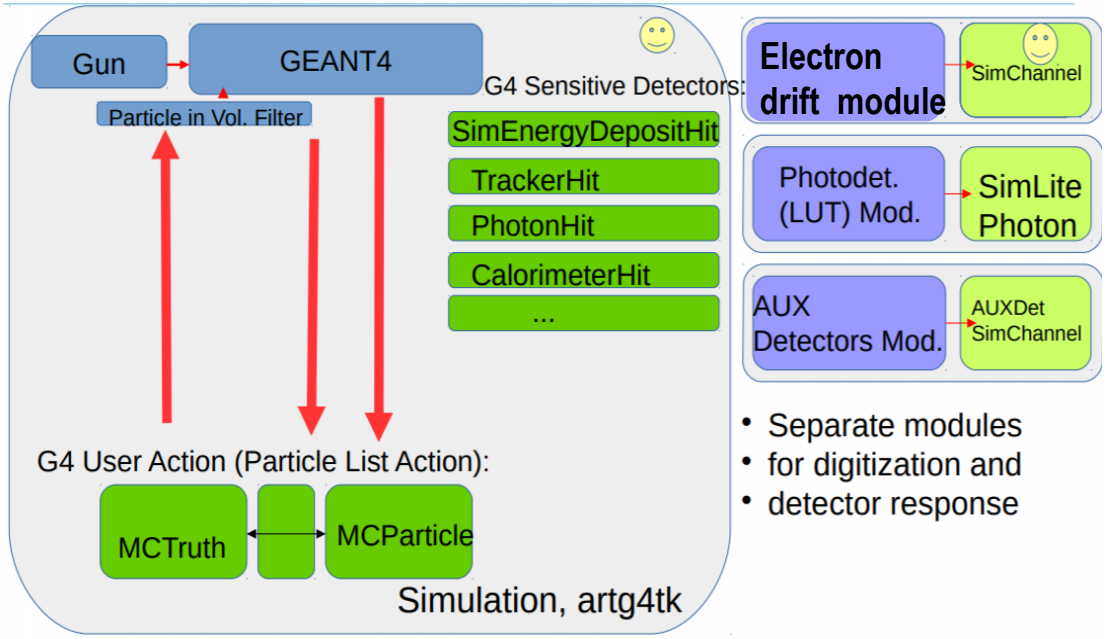
Simulation flowchart



- Simulation implemented within common LArSoft framework
- GEANT4 tracks primary particles and their daughters through the detector geometry → energy depositions → number of ionization electrons and scintillation photons
- Detector simulation :
  - Ionization electron absorption and diffusion during drift
  - Signal induction of anode strips from modelled anode field response
  - Convolution with amplifier pulse shaping + noise → digitized waveforms
  - Photon hits in PDS according to “visibility” of the given volume element + convolution with electronics → digitized waveforms

Refactored workflow

Refactored (larg4)



W. Gu "Simulation Improvements", LBNC, Dec 3/2020

- Use refactored larg4 framework from the start
- Has been extensively tested and adopted within ProtoDUNE SP
  - Cleanly separates physics simulation from detector response
  - Flexible configuration
  - Ability to include several scintillating materials (e.g., Xe)

Detector geometries

- To assess impact of different anode stack / strip layouts configurations three “workspace” detector geometry layouts have been prepared:
  1. 2-view geometry from the original proposal
  2. CDR reference 3-view geometry
  3. Additional 3-view layout with +/- 30 deg induction views

- Workspace dimensions:
  - Single 6.5 m drift cell
  - Total active volume, 6.5 (*X*) x 10 (*Y*) x 9 (*Z*) m^3, sufficiently large to contain events

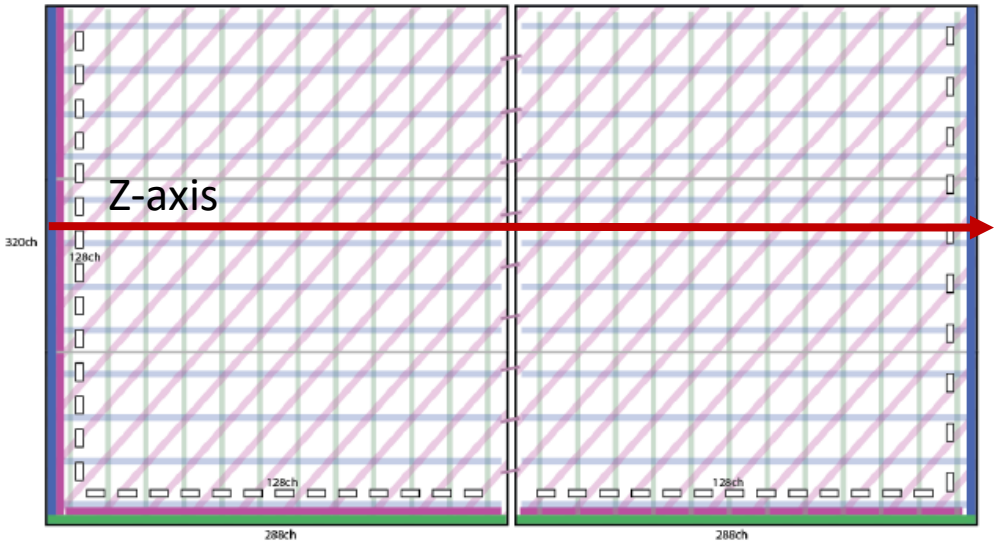
Anode reference design : 3-views

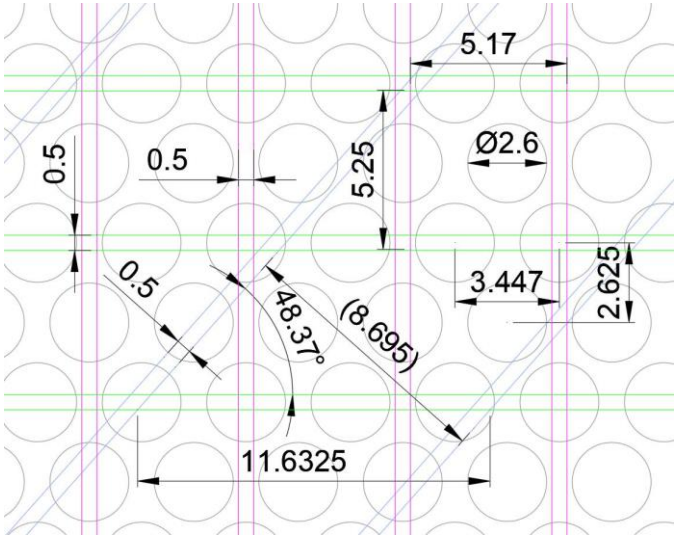
M. Nessi, Vertical Drift Detector Overview, LBNC April 28/21

- ✓ We are confident that the 3-views and the 2-views anode layout are both technically implementable without any problem. The 2021 cold box test will prove this
- ✓ *For the needs of the CD-1RR review, which must be based on conservative cost estimations, we focus on the description and costing of the 3-views layout, having about 30% larger costs and some implementation complexity compared to a 2-views geometry*
- ✓ The final configuration of the anodes layout will be definitively defined in 2022 prior to CD-2, with no practical perturbations to the project aside the possibility for further economies, based on the prototype results and on the simulation work in progress. This optimization effort will also touch the relative angle between the two induction planes

3-view CDR reference

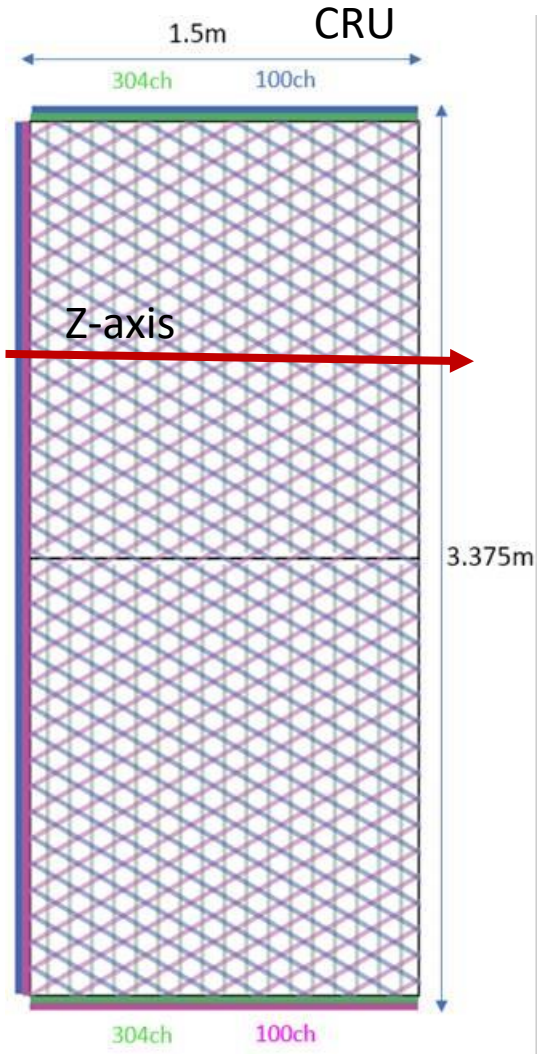
Top anode CRU

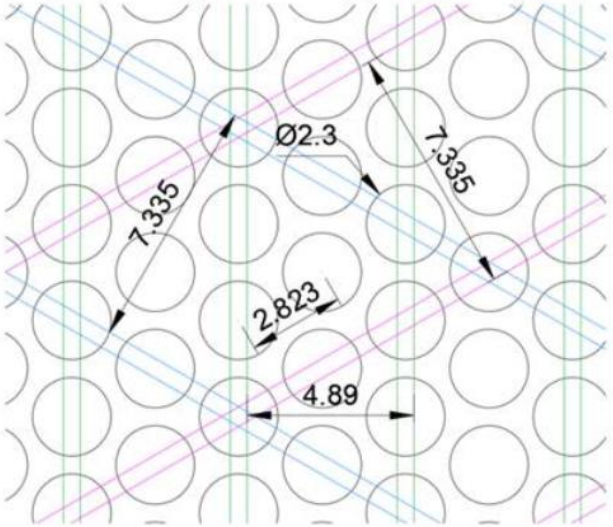




- 1st induction at 48 deg and pitch 8.695 mm
- 2nd induction at 0 deg and pitch 5.25 mm
- Collection at 90 deg and pitch 5.17 mm

Alternative 3-view “30 deg”





- The two induction views at +/- 30 deg and 7.335 mm pitch
- Collection at 90 deg and 4.89 mm pitch

TPC response simulation

- TPC response is done with WireCell Toolkit
  - Following the same approach as ProtoDUNE SP and recent updates for FD HD simulations
- Propagation of ionization electrons though drift volume:
  - Attachment to impurities / transverse & longitudinal diffusion
- Signal induction in anode strips
  - Calculation of the anode stack field response includes signal induction on neighboring anode electrodes
- Convolution with electronics response
- Addition of expected intrinsic noise based predicted strip capacitance

Anode Field Response (FR)

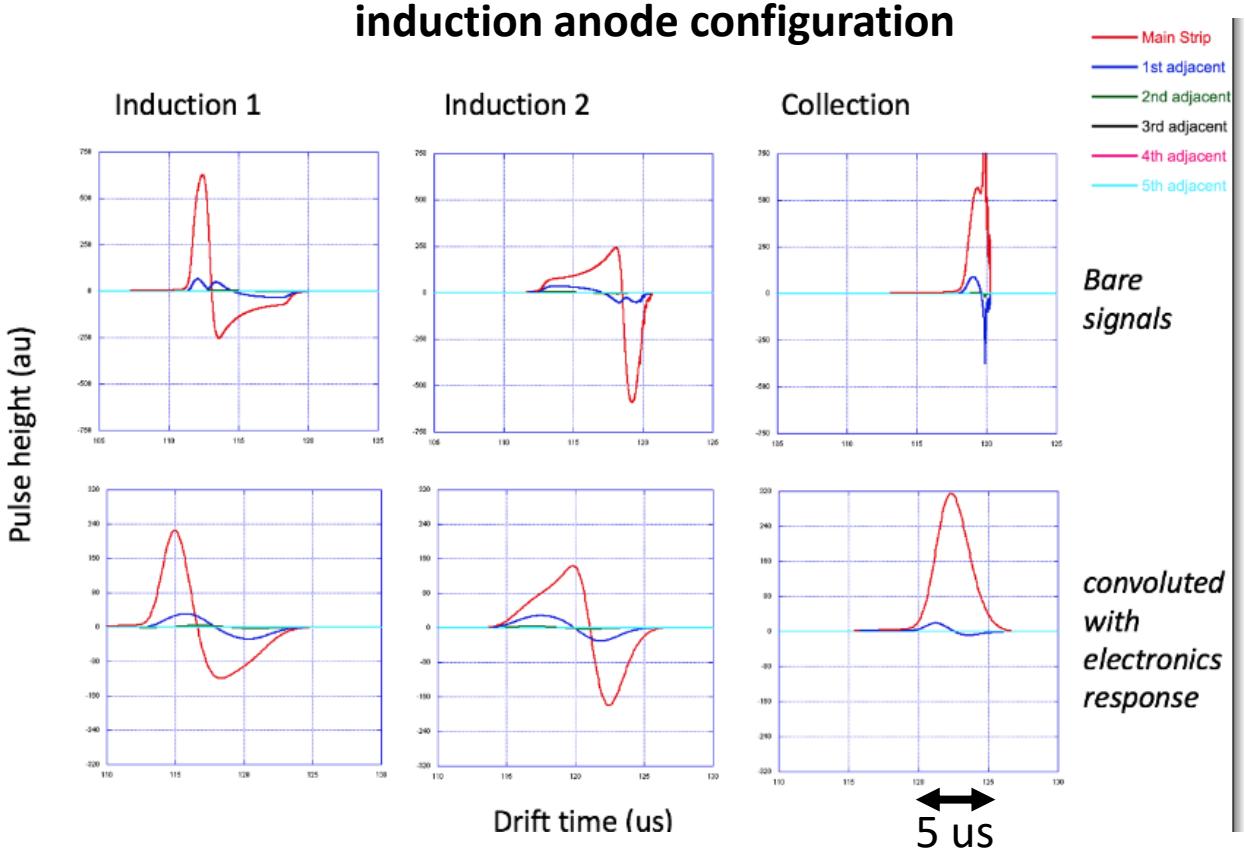
Models for:

- 50L 2-view prototype
- 3-view 30 deg configuration

Field response model for CDR reference anode design is computationally more challenging

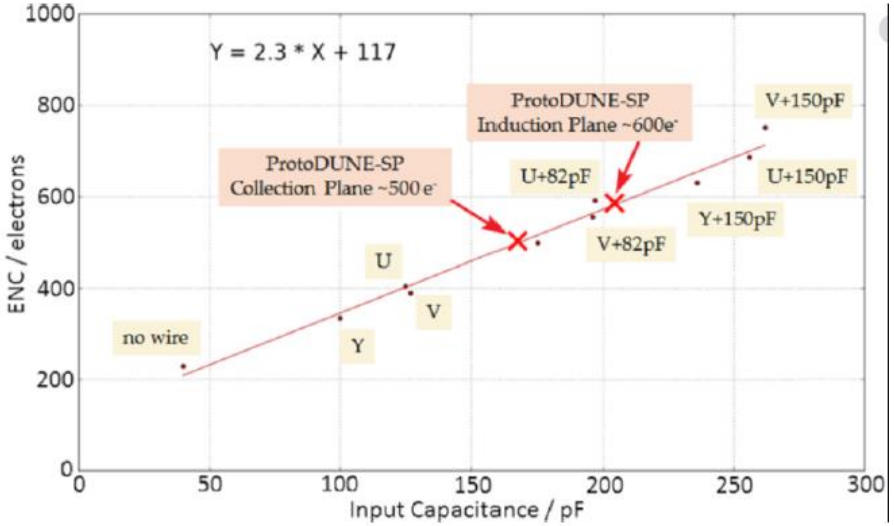
- Using “3-view 30 deg” FR model as a placeholder
- Data from upcoming cold-box test campaign should help to understand validity of possible approximate solutions

Average current signals for 3-view +/- 30 deg induction anode configuration

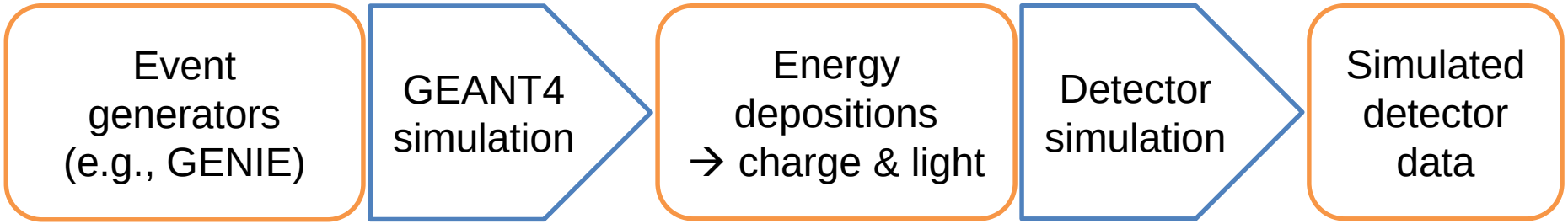


Noise model

- Measured noise spectra as function of input capacitance from ProtoDUNE – SP and MicroBooNE
- Strip lengths (different lengths between views and strips at angle) converted to expected capacitance
- By design anode strip capacitance is similar as for wire planes
  - For CDR ref anode: <250 pF for 1st induction / 125 pF for 2nd induction / 150 pF for collection

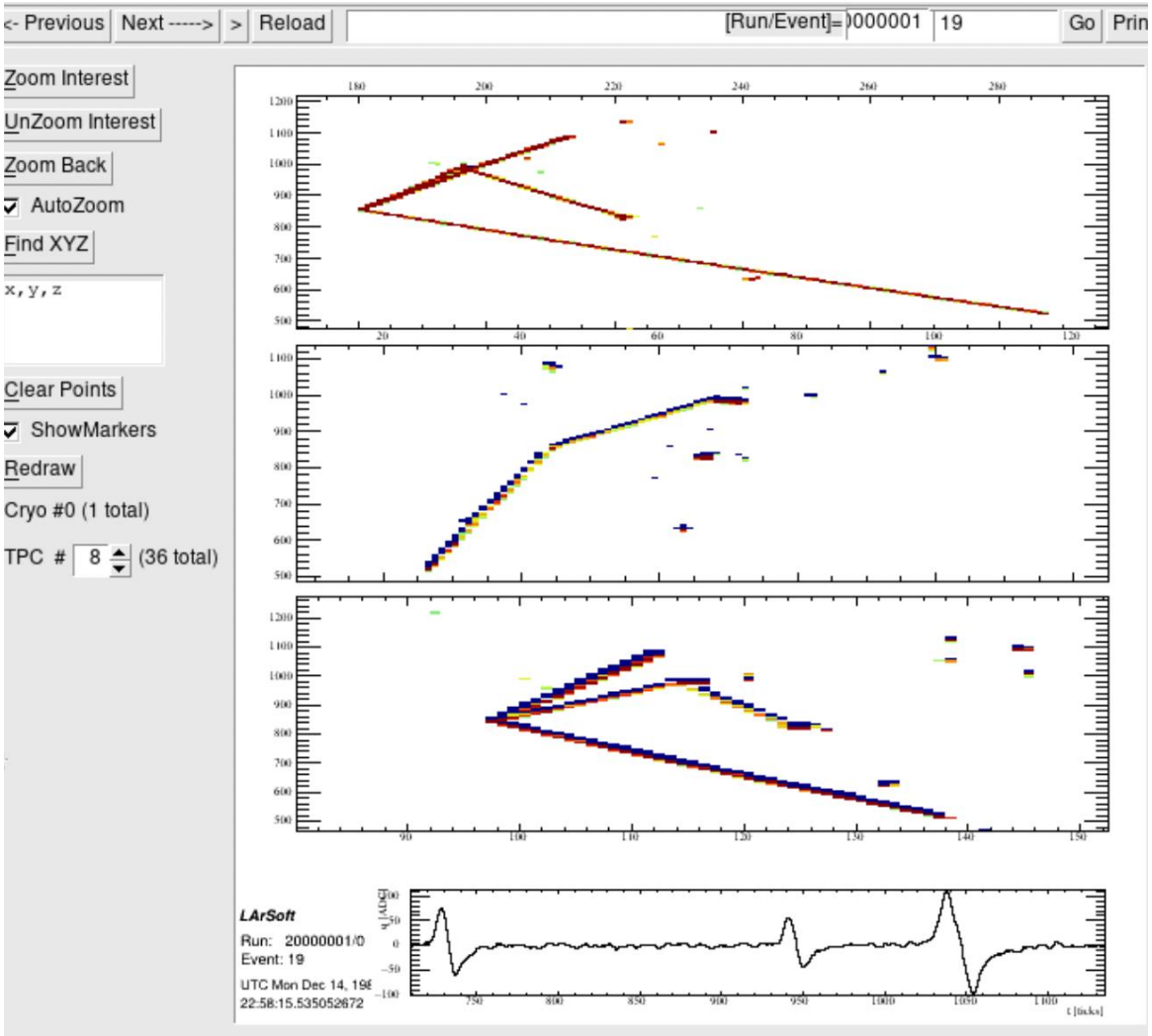


Complete chain



- ✓ Detector model for GEANT 4 simulation
- ✓ TPC response:
  - Anode field response
  - Electronics response + intrinsic noise
- ✓ Machinery in place to run complete simulation chain

GENIE-simulated ν_μ CC event in 3-view CDR reference design



Collection @ 90 deg

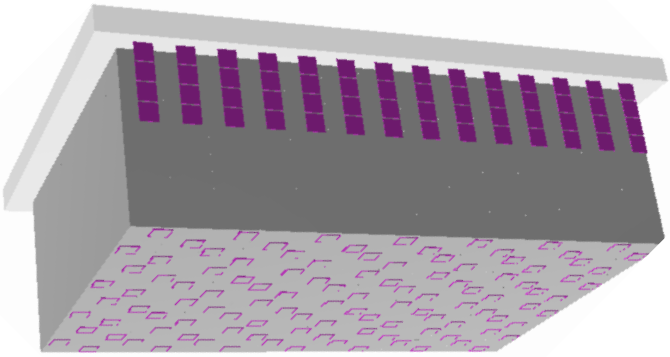
2nd induction @ 0 deg

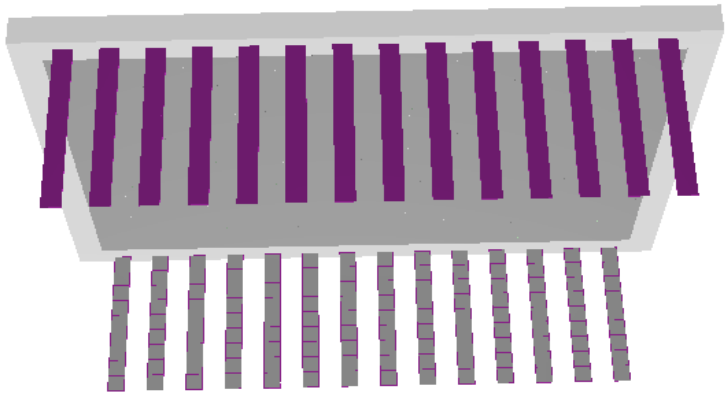
1st induction @ 48 deg

One of induction view channels illustrating generated waveforms with bi-polar signals

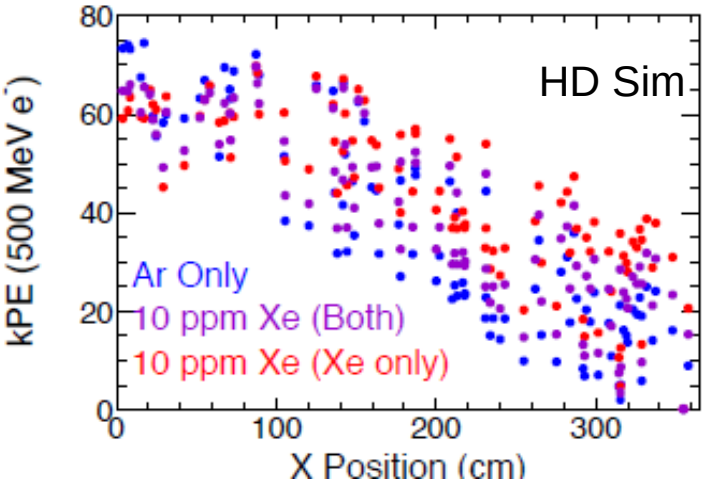
Vertical Drift PDS in LArSoft

- PDS layout for reference and backup designs (top volume)



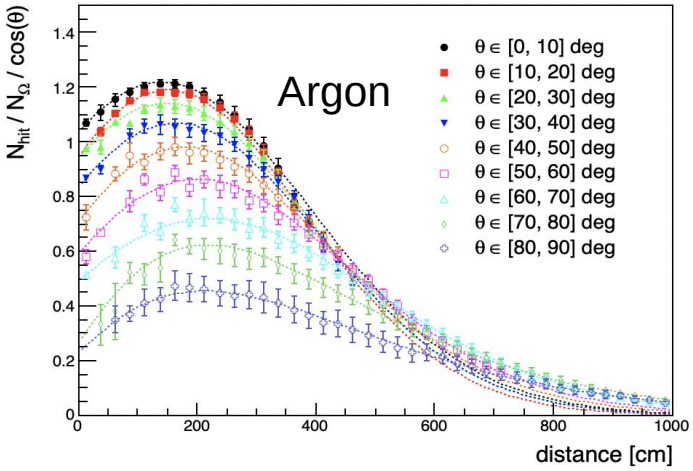


- Simulation of Xe-doped Light:
  - Ar and Xe light in the same job with separate light yields stored

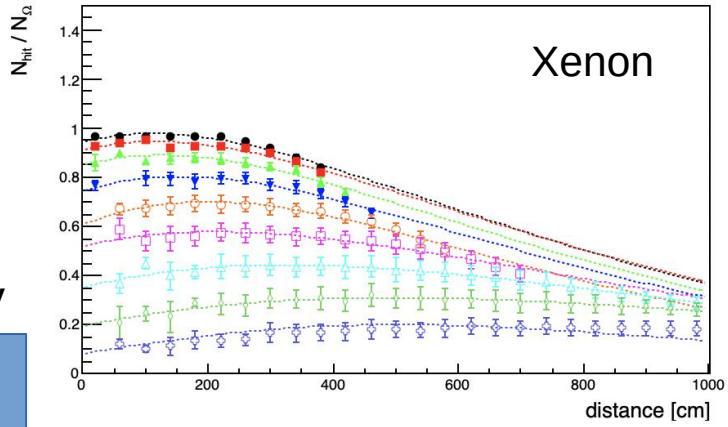


Vertical Drift PDS in LArSoft

- Fast light simulation done with a semi-analytic model → parameterization as a function of source-PD distance and relative angle
  - **on the way** for the vertical drift far detector simulation

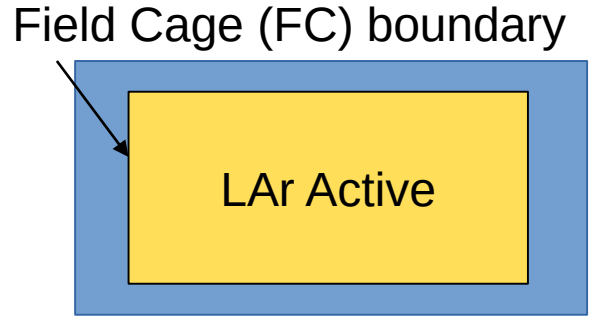


- Hybrid model will be needed to also handle volume outside FC



HD Sim

-Semi-analytic:
Inside active volume
-Photon Library:
Outside active volume
(Electric Field ~ 0)

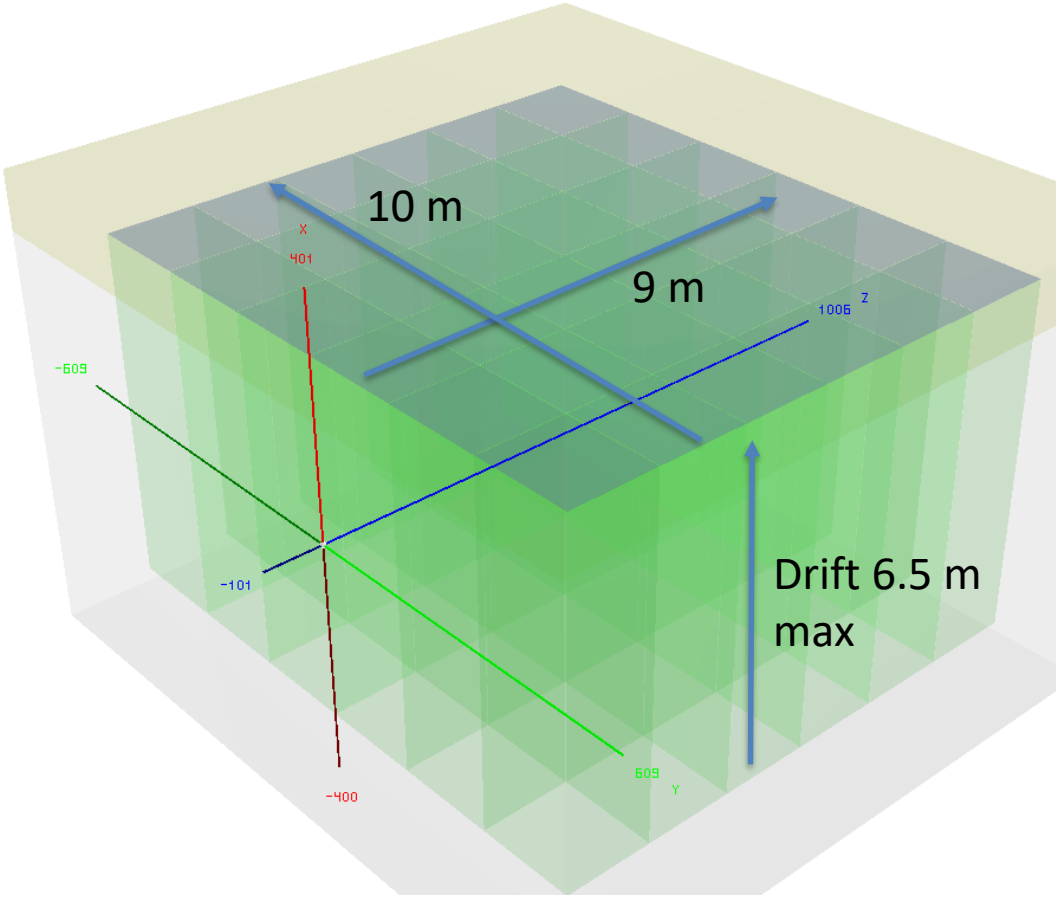


Summary

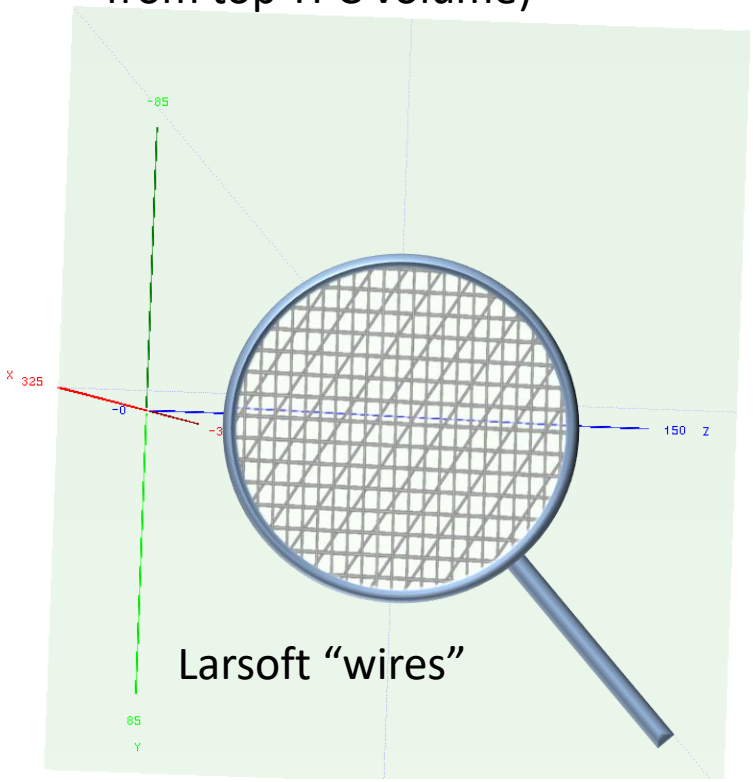
- Detector geometries for several choices of views / anode strip angles have been produced
- The necessary pieces for a complete simulation workflow (event generator → raw data) have been prepared and appear to be functional
- Work on-going to integrate PDS simulation within framework

Extra

Workspace volume



View from top (upper anode from top TPC volume)

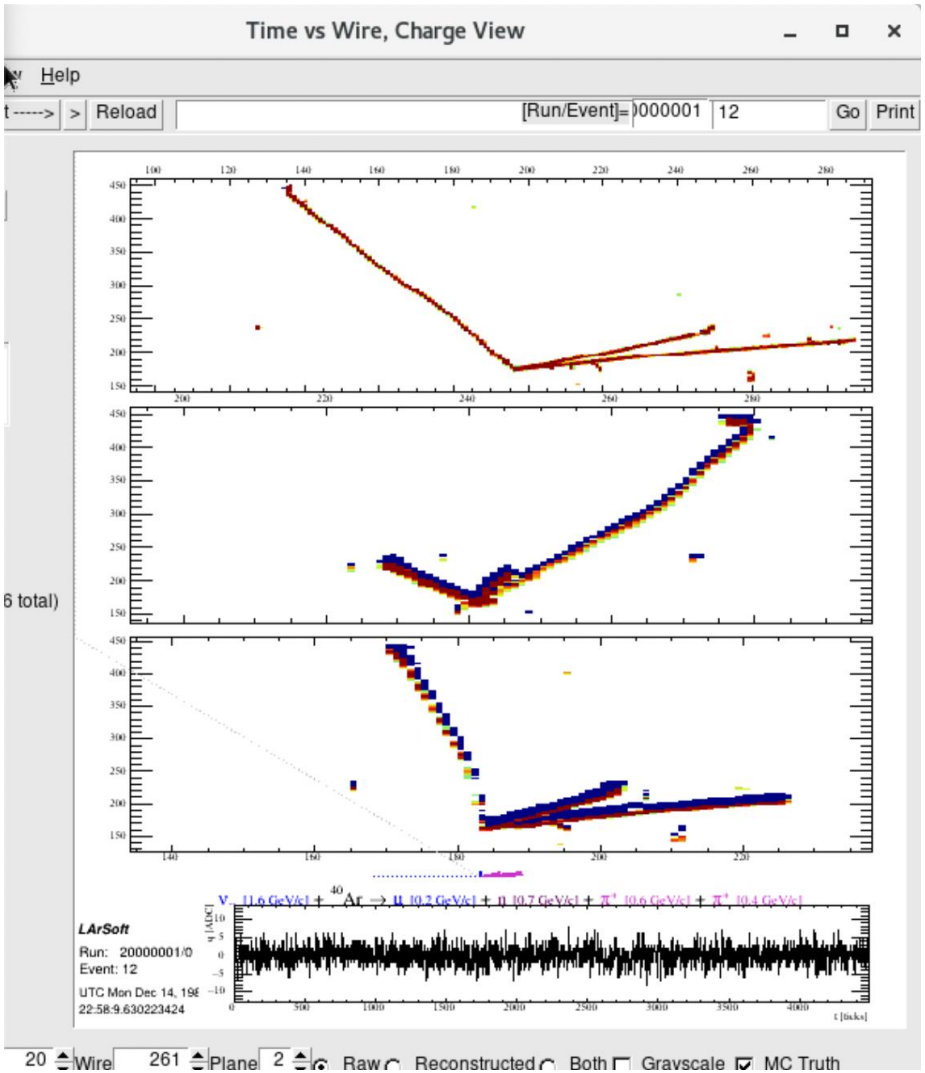


Key Anode Parameters

D. Duchesneau, LBNC, 04/24/21

	3-v anode, initial cold box			3-v anode, 60° ind. between views		
Parameters	**1st view**	**2nd view**	**3rd view**	**1st view**	**2nd view**	**3rd view**
Strip length [m]	≤ 2.24	1.49	1.68	≤ 1.72	≤ 1.72	1.68
Strip pitch [mm]	8.70	5.25	5.17	7.365	7.365	4.91
Strip gap [mm]	0.5	0.5	0.5	0.5	0.5	0.5
Unit capacitance [pF/m]	109	80	91	100	100	79
Total capacitance [pF]	≤ 250	125	153	≤ 172	≤ 172	133
Number of strips per CRU	384	640	576	496	496	608
Strip angle w.r.t. beam [°]	48	0	90	30	-30	90
Nominal bias voltage [V]	-500	0	+1000	-500	0	+1000

Backward scattered muon



Collection @ 90 deg

2nd induction @ 0 deg

1st induction @ 48 deg