CYGNUS Simulation Group Report

Sven Vahsen (U. Hawaii)

Overview

- Goals and activities of the Simulation Group
- Meetings
- Recent work on simulation comparing TPC readout technologies

Activities of Group

- Current focus:
  - Write paper on conceptual design of large directional nuclear recoil observatory
  - Goal: submit to journal approx. end of May 2017, in support of next round of funding proposals
- Longer-term goal
  - Develop shared simulation infrastructure
  - Develop detailed technical design

Meetings

- Every few months in 2016
- Approx. once a month in 2017
- Slides from past meetings available at: https://indico.phys.hawaii.edu/categoryDisplay.py?categId=34
- Next meeting: Wed. February 22nd

Paper Status

- Outline resides in Git repository https://uhhepvcs.phys.hawaii.edu/cygnus/recoil-observatory-paper
- Some, but not much text exists
- Simulation work is ongoing
  - see following slides
  - see talk by Frederic Mouton (Sheffield)

Feasibility of a Nuclear Recoil Observatory with Directional Sensitivity to WIMPs and Solar Neutrinos

F. Author[1]

Abstract

Now that conventional WIMP dark matter searches are approaching the neutrino floor, there has been a resurgence of interest in the possibility of introducing recoil direction sensitivity into the field. Such directional sensitivity would offer the powerful prospect of reaching below this floor, introducing both the possibility of identifying a clear signature for dark matter particles in the galaxy below this level but also of exploiting observation of coherent neutrino scattering from the Sun and other sources with directional sensitivity. We survey the experimental status of all technologies proposed to date, and perform a cost-benefit analysis to identify the optimal choice in different WIMP and neutrino scenarios. Based on our findings, we propose a large-scale directional nuclear recoil observatory with directional WIMP sensitivity below the neutrino floor and capability to explore Solar neutrino coherent scattering with direction sensitivity

Keywords: keyword1, keyword2

Contents

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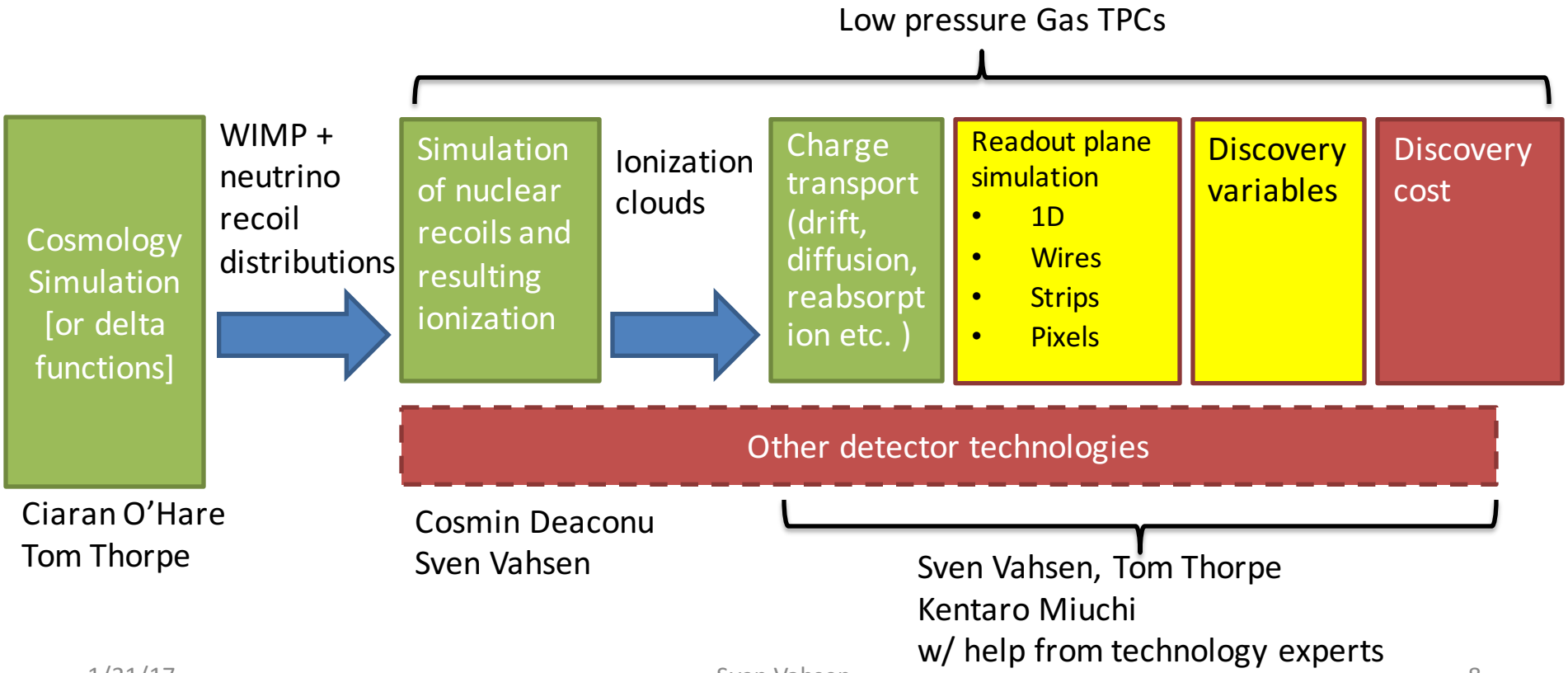
Please write Sven and chapter editors (names in blue) to join the fun!

S. Vahsen & K. Miuchi

Directional Technology Comparison

- Goal: Estimate cost-to-discover WIMP physics scenarios with different directional detection technologies
  - Assume zero background can be reached
  - Focus on TPCs first, then other approaches
- Warm-up exercise: compare "directionality" versus recoil-energy for different TPC readout technologies
  - Specifically: how many recoils required to distinguish a recoil angle distribution that's a 3d-delta function from an isotropic distribution?
  - Expect TPC w/ highly segmented 3D-pixel readout to require the fewest recoils, especially at lowest recoil energies
  - But less segmented readouts are much less expensive.
  - What is the optimal tradeoff?
- The final result will factor in (relative or absolute) cost

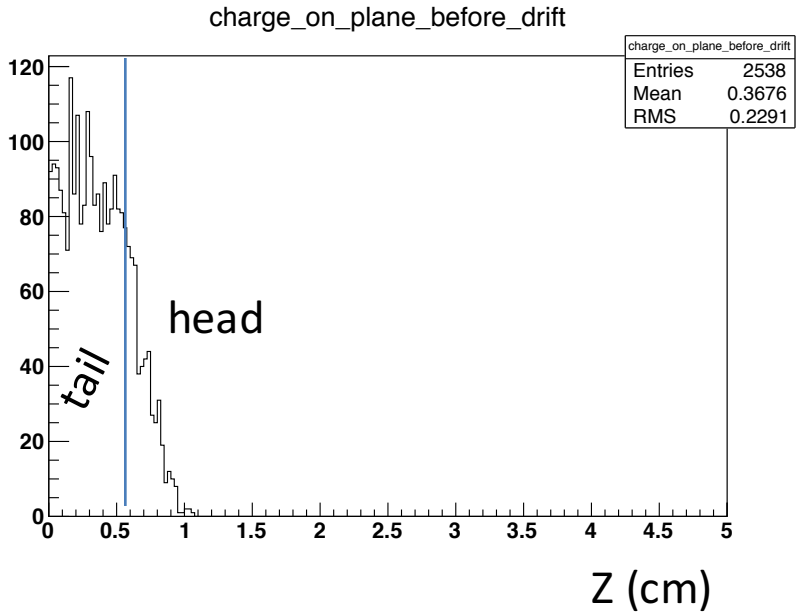
Overview of Simulation Steps

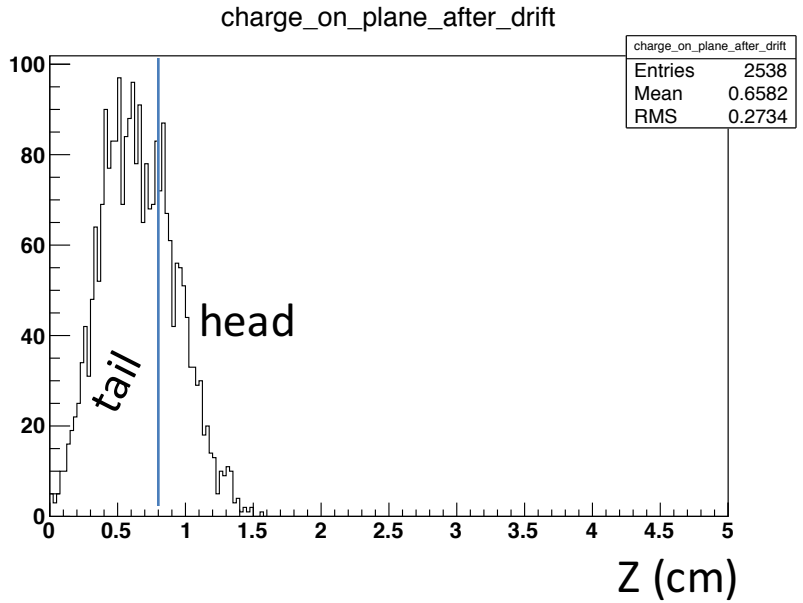


Example 1

- **Simulating TPC with 20 torr SF_6 gas**
  - <=1 m drift (flat recoil distribution in drift direction)
  - 1D readout plane, wires, x/y strips, pixels
  - how many recoils required to reject isotropy at three sigma?
  - Interesting in itself, and validates simulation steps
- Disclaimers: Following results are *highly* preliminary
  - All non-ideal detector effects (noise, thresholds etc) turned off
  - Only diffusion and readout segmentation is enabled
  - Statistical treatment is very handwaving

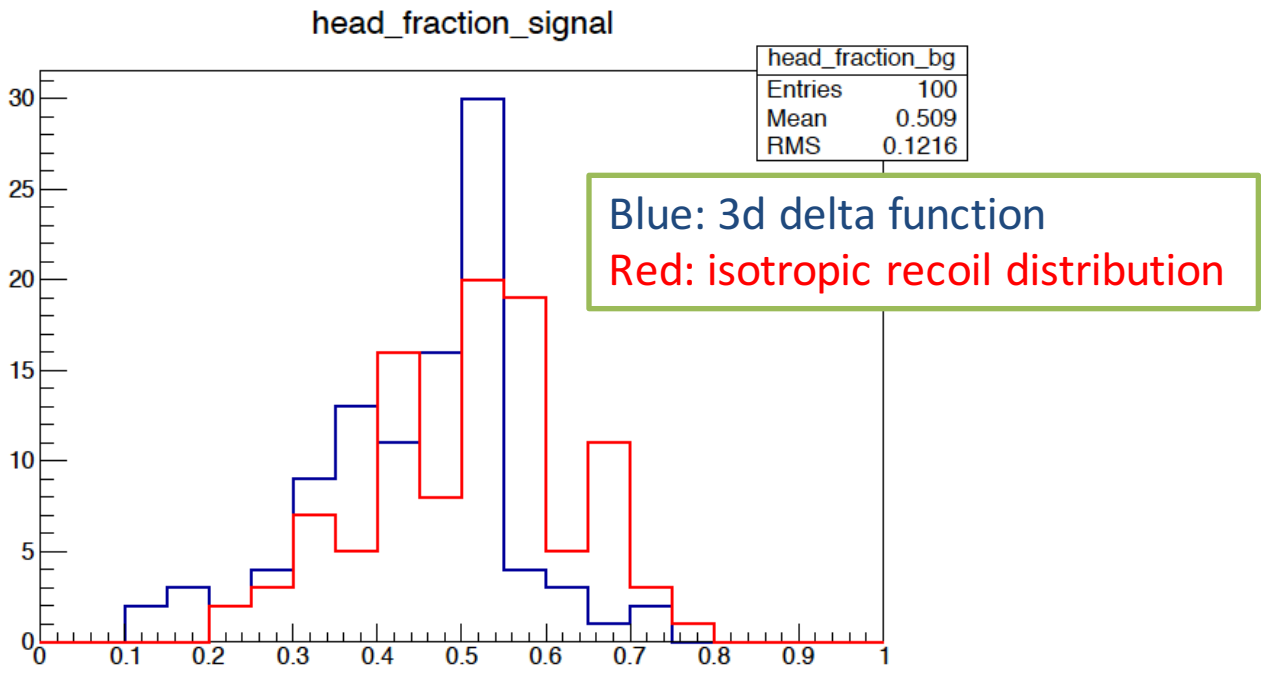
90 keV F-Recoils: Head/Tail effect





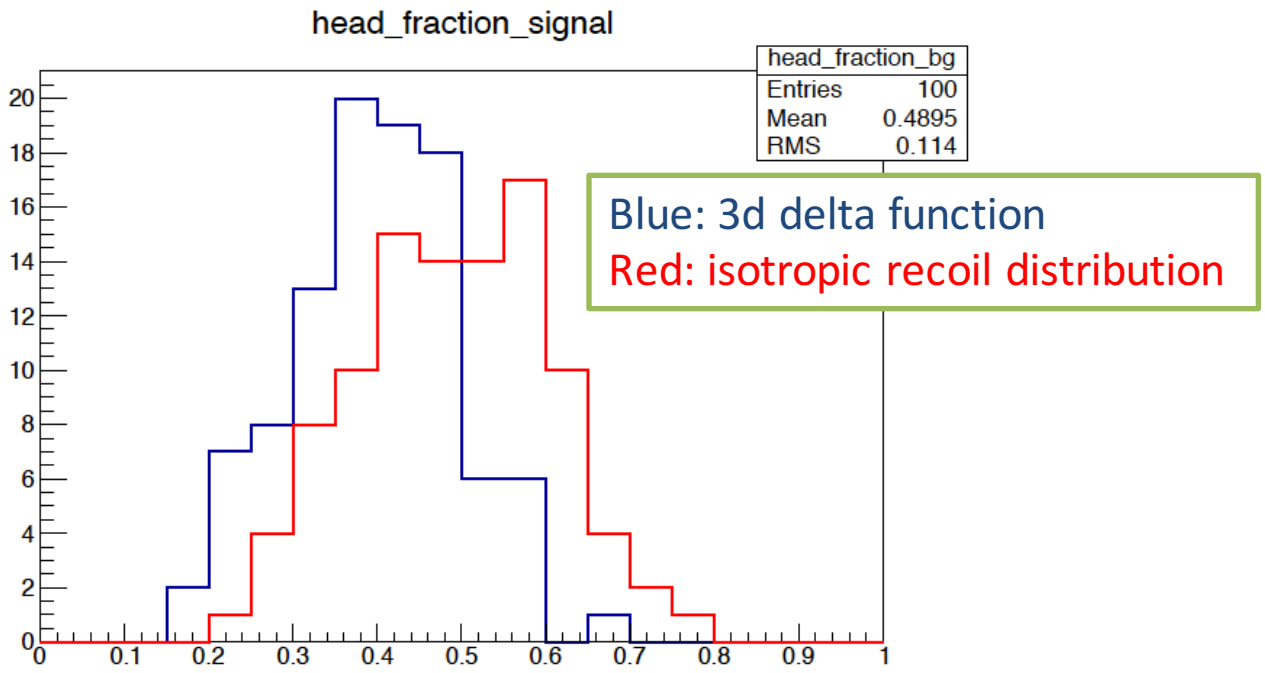
Higher charge density in tail than head. Effect reduced by diffusion during drift in the TPC.

10 keV F-Recoils: Head/Tail effect



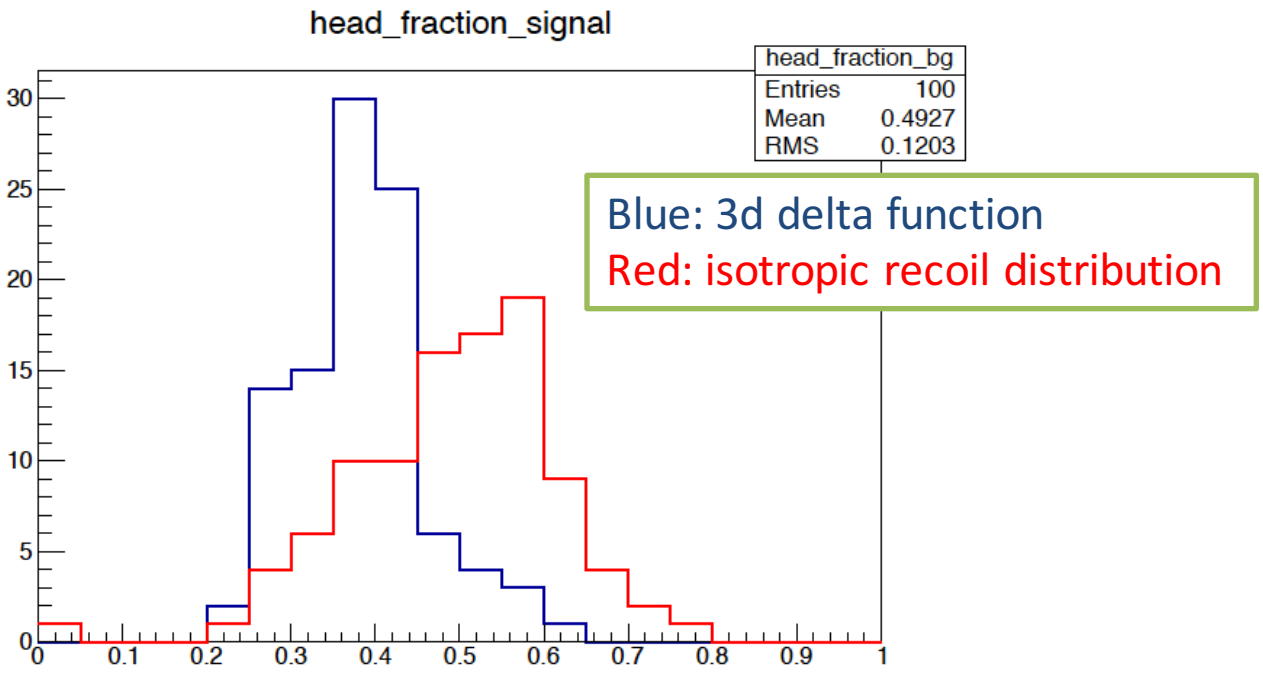
Head tail effect at 10 keV masked by diffusion.

30 keV F-Recoils: Head/Tail effect



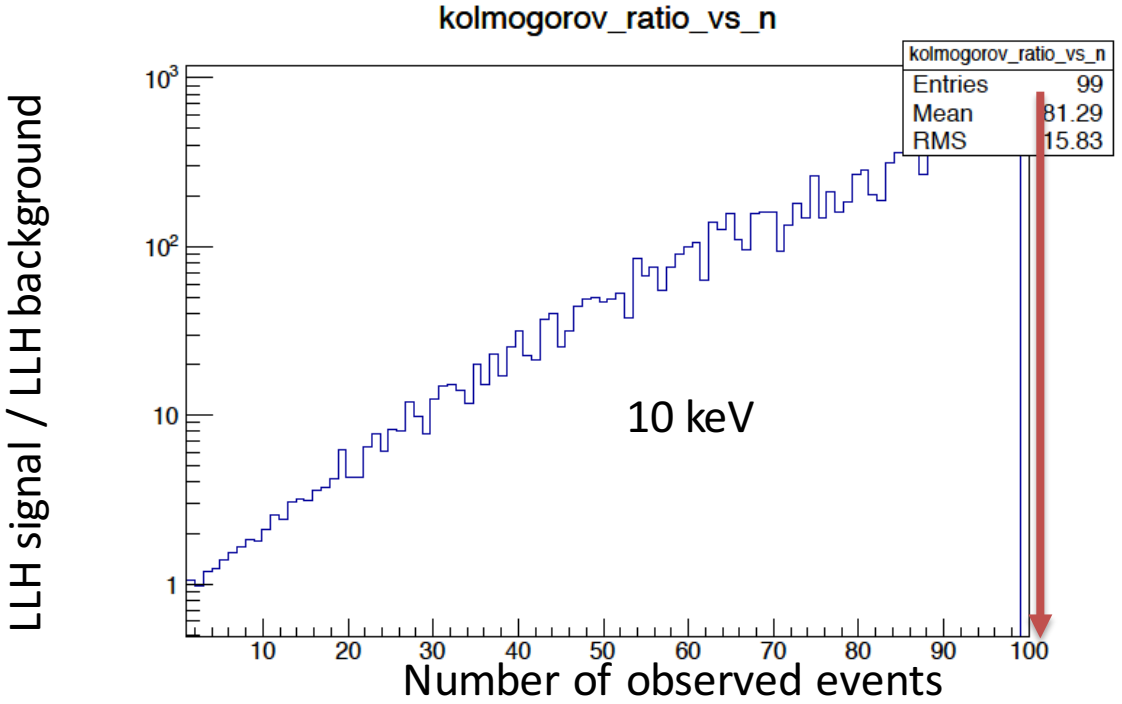
Head tail effect emerging

80 keV F-Recoils: Head/Tail effect



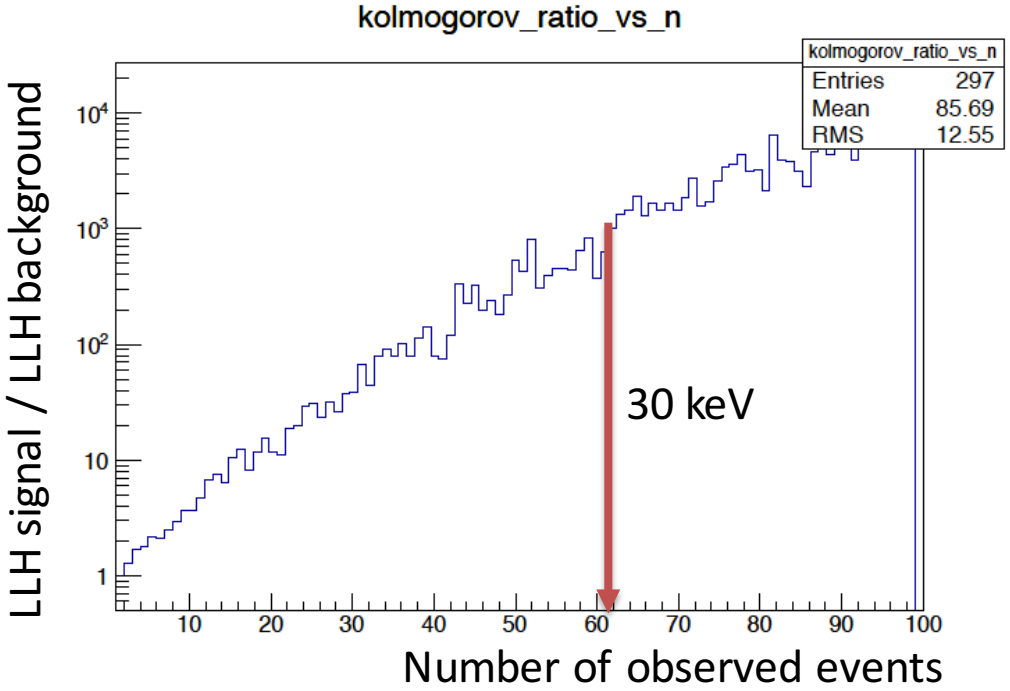
Head tail effect getting strong

How strong is the 1D head/tail signature at different recoil energies?



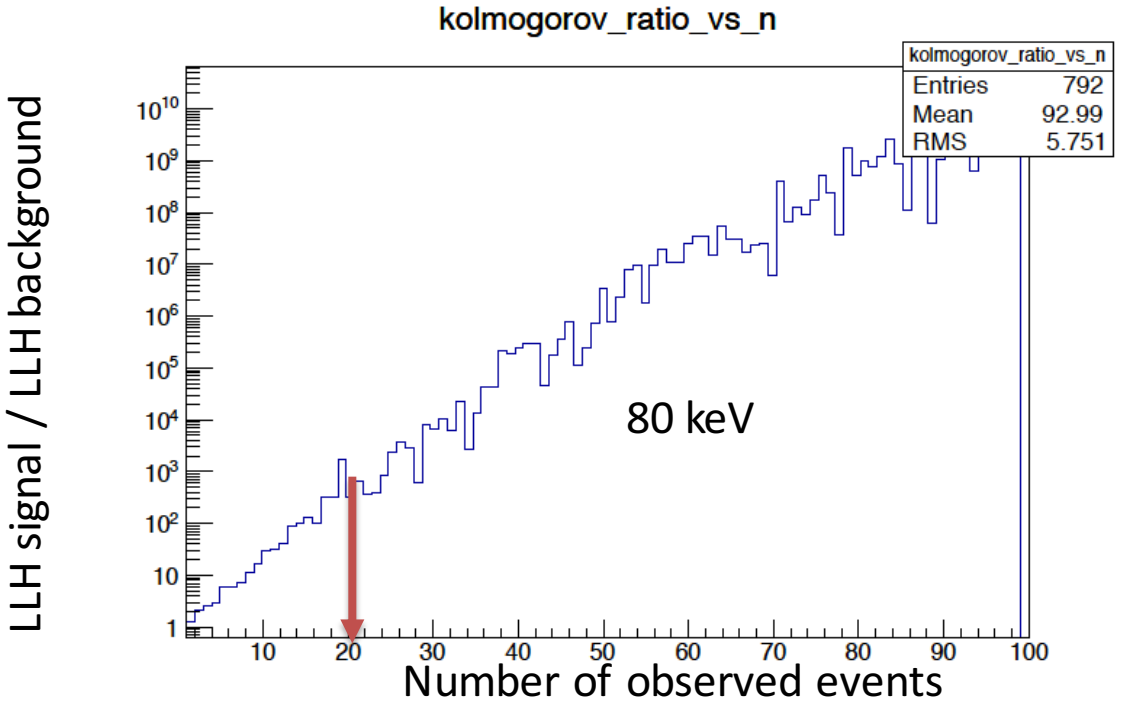
>100 events for “3-sigma” discovery

How strong is the 1D head/tail signature at different recoil energies?



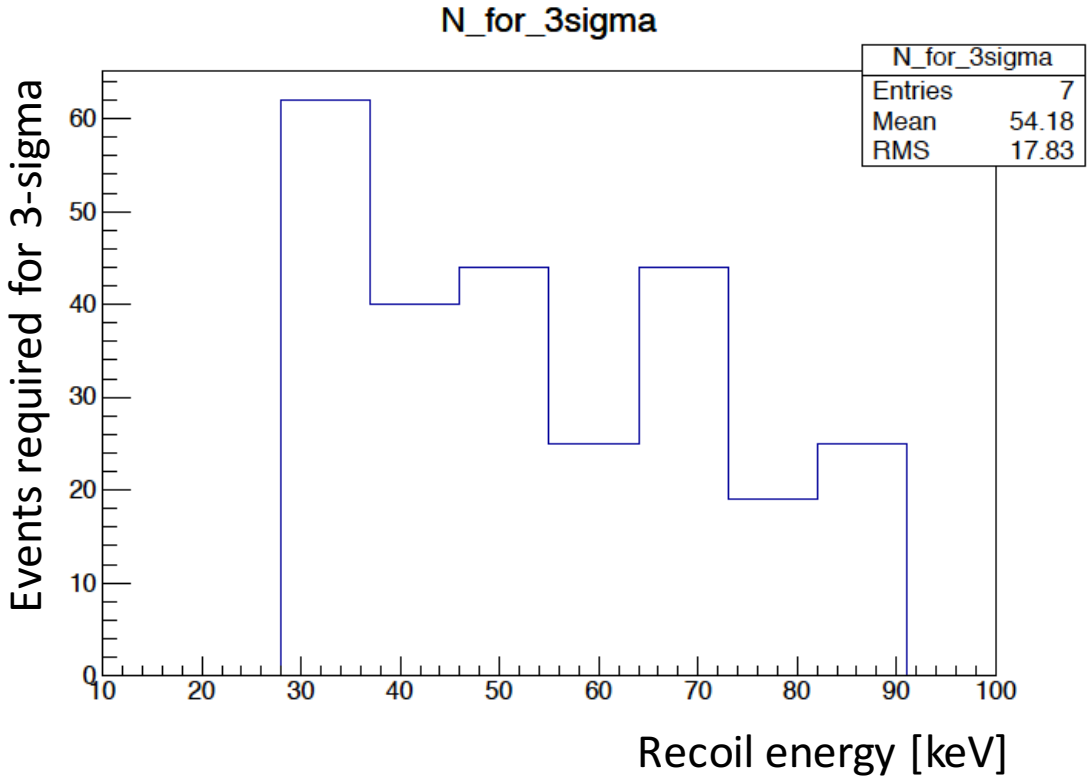
~60 events for "3-sigma" discovery

How strong is the 1D head/tail signature at different recoil energies?



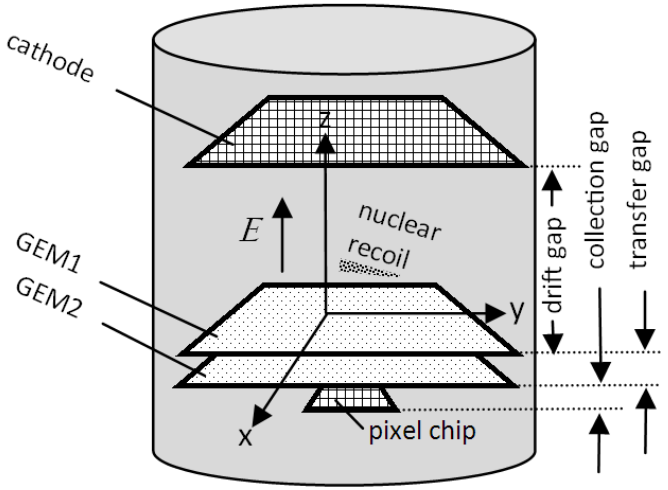
~20 events for “3-sigma” discovery

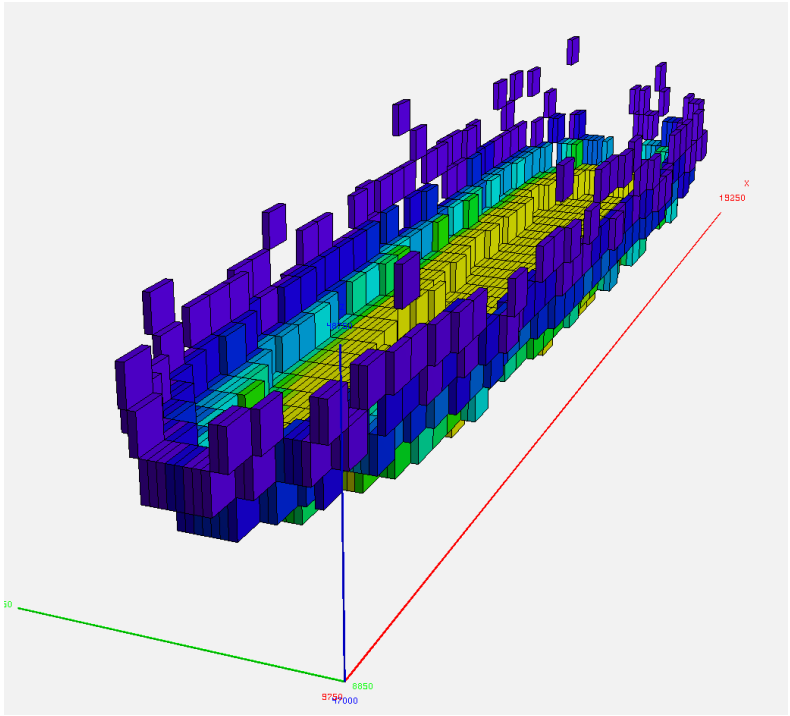
“Directionality” VS recoil energy

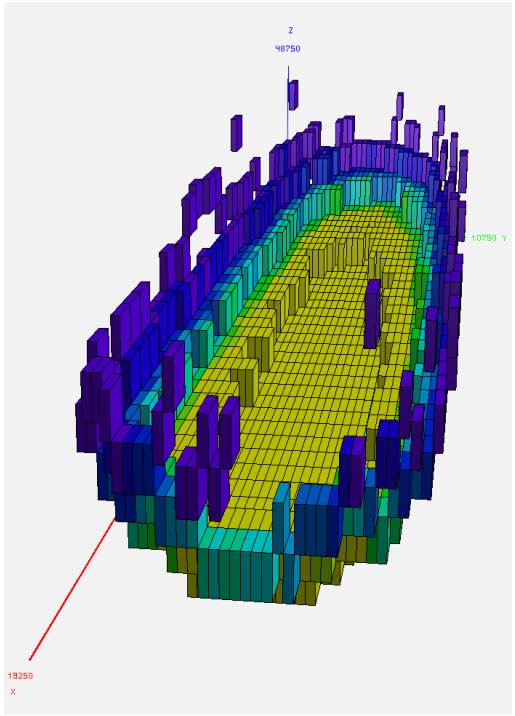


Example 2: HD TPC simulation

- Double GEM pixel TPC
- 750 keV He-recoil in $HeC0_2$
- Drift: 5 cm
- gain = 900 per GEM




X
19250
9750
8850
47000


Z
48750
10750 Y
19250
X

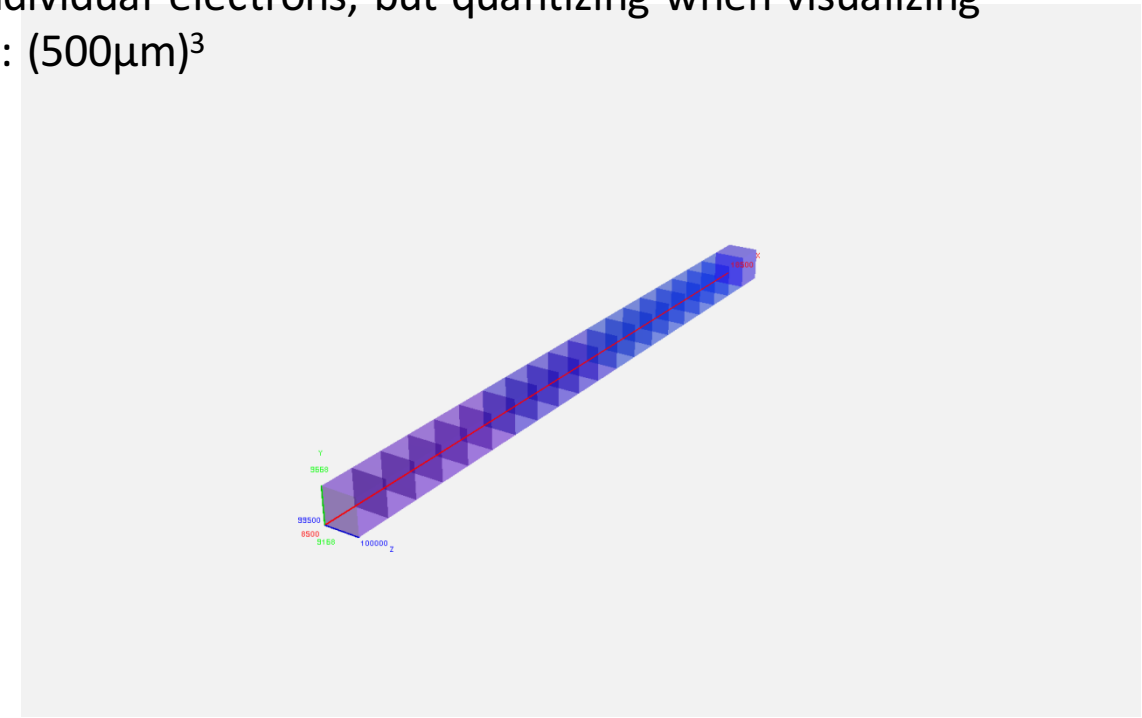
Conclusion

- To propose a large recoil observatory, and engage the community and the funding agencies…
- We need a conceptual design that establishes
  - Physics case and reach
  - Technical Feasibility
  - Cost scale
- Work has started and is ramping up.
- We welcome additional manpower!

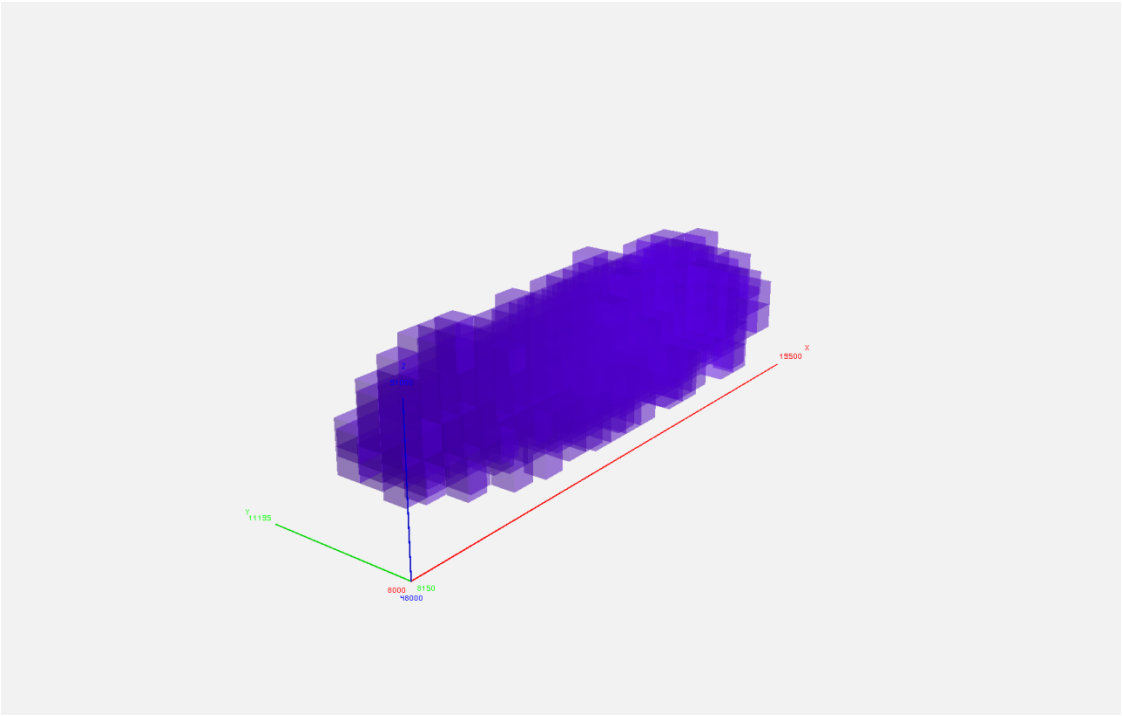
BACKUP SLIDES

generated

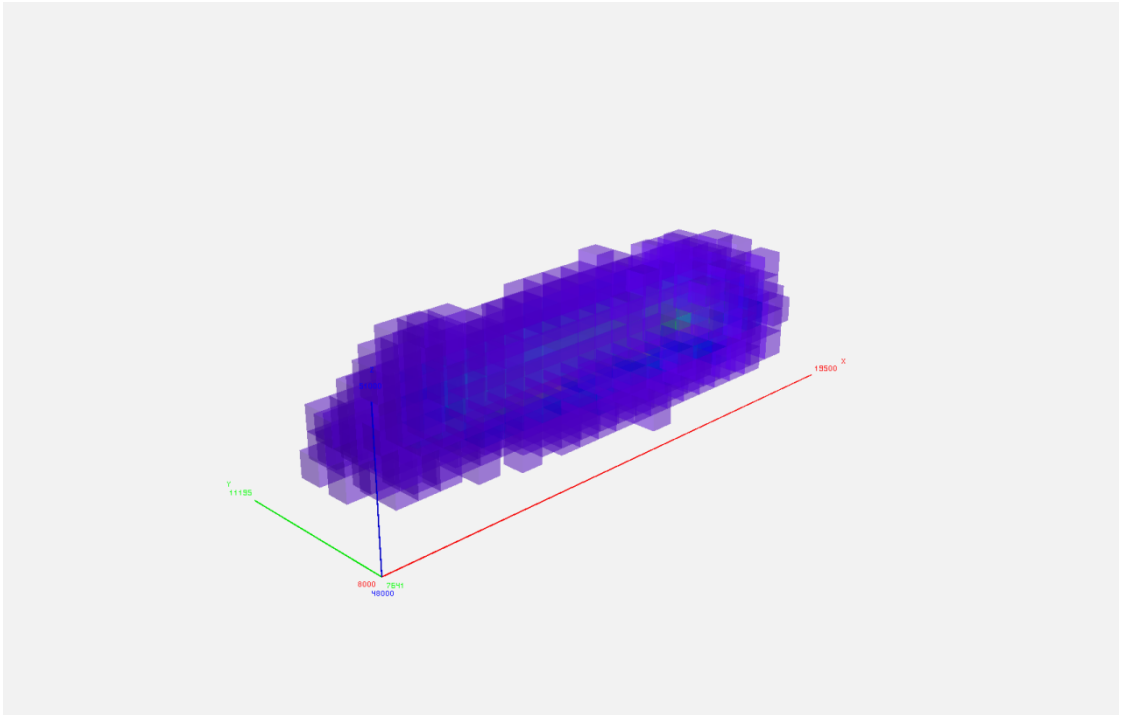
- Simulating individual electrons, but quantizing when visualizing
- Quantization: $(500\mu m)^3$



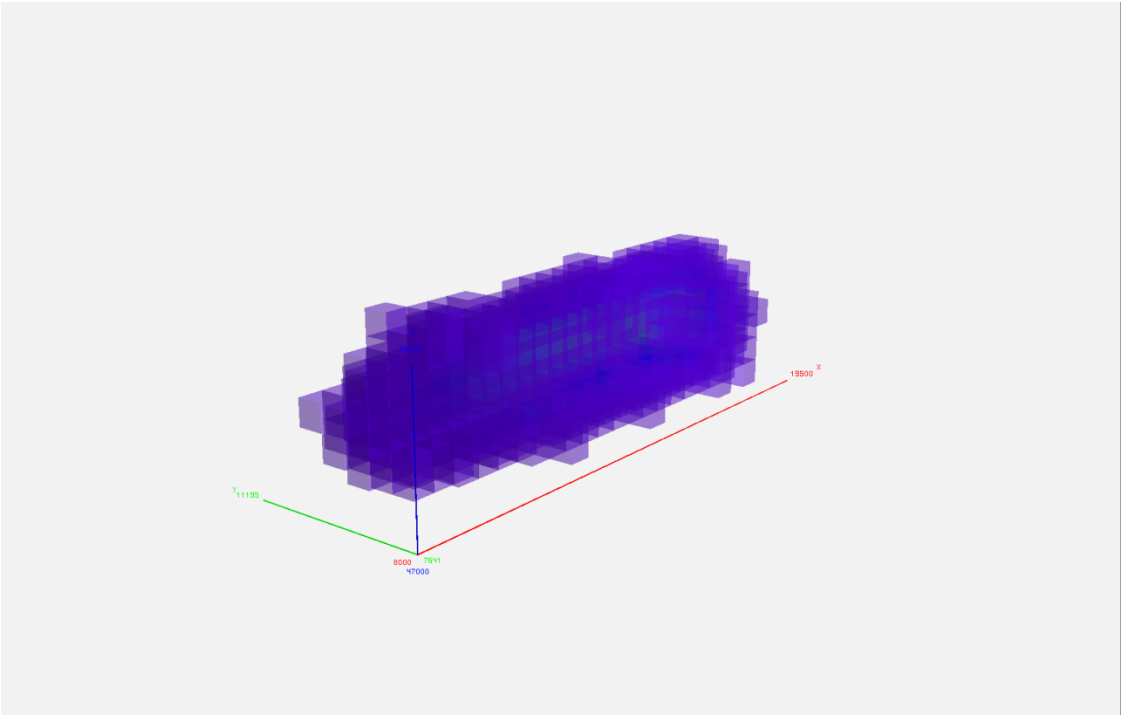
post drift



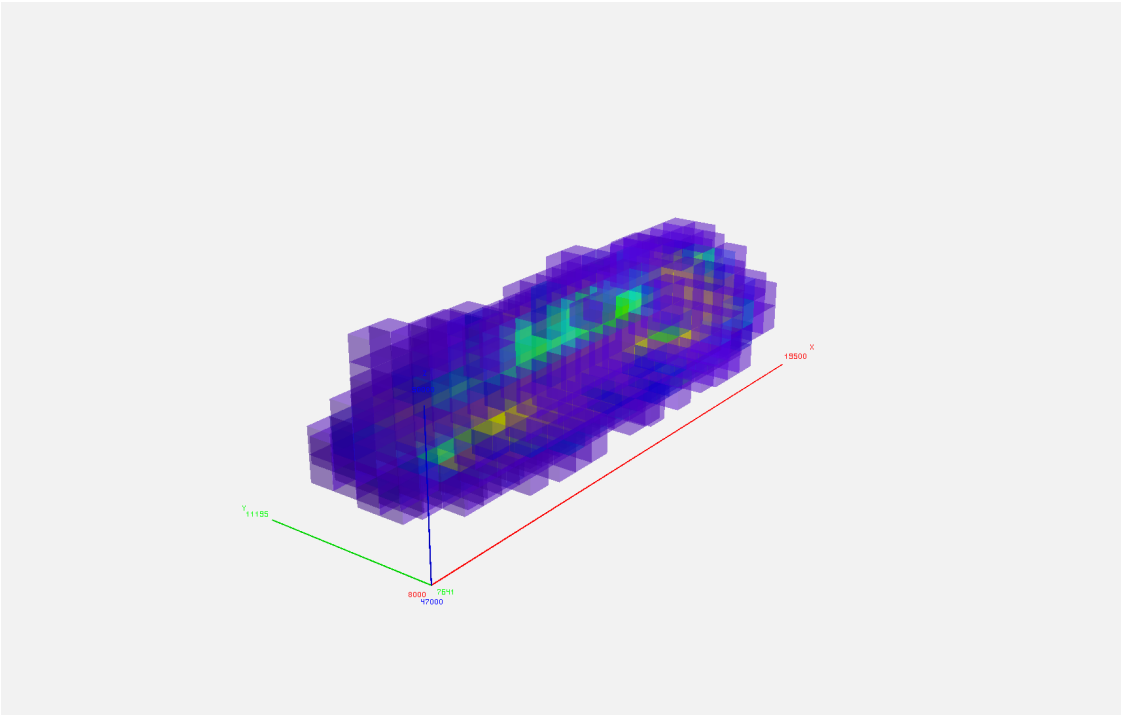
post GEM1



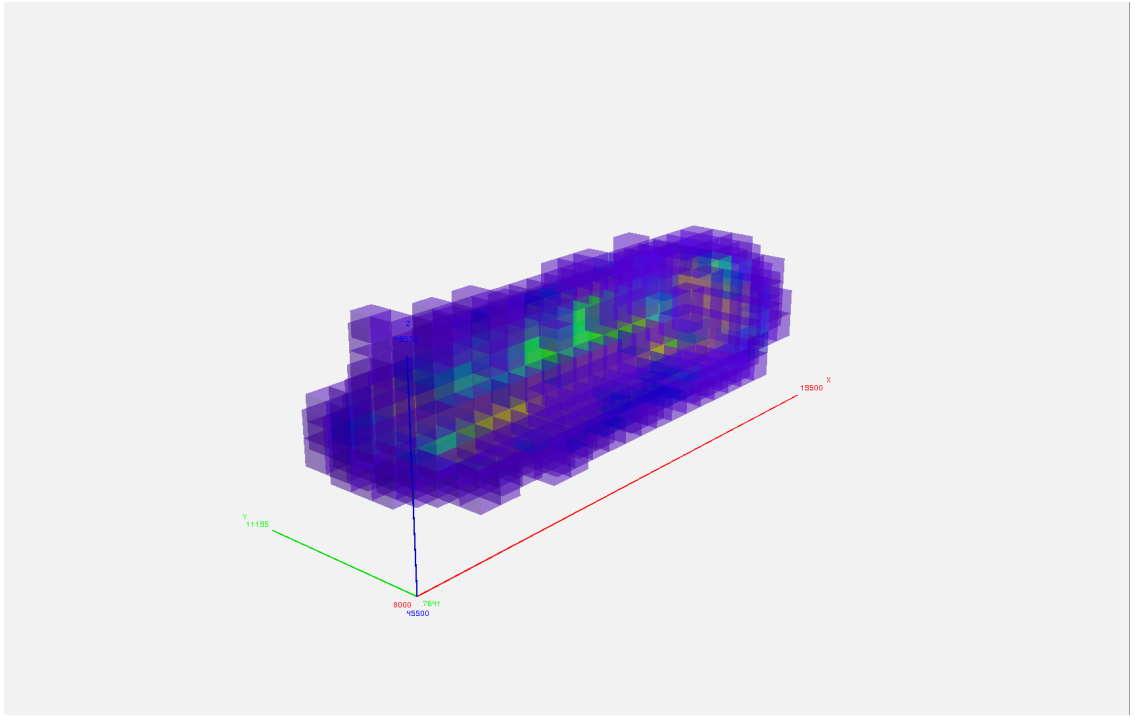
post transfer gap



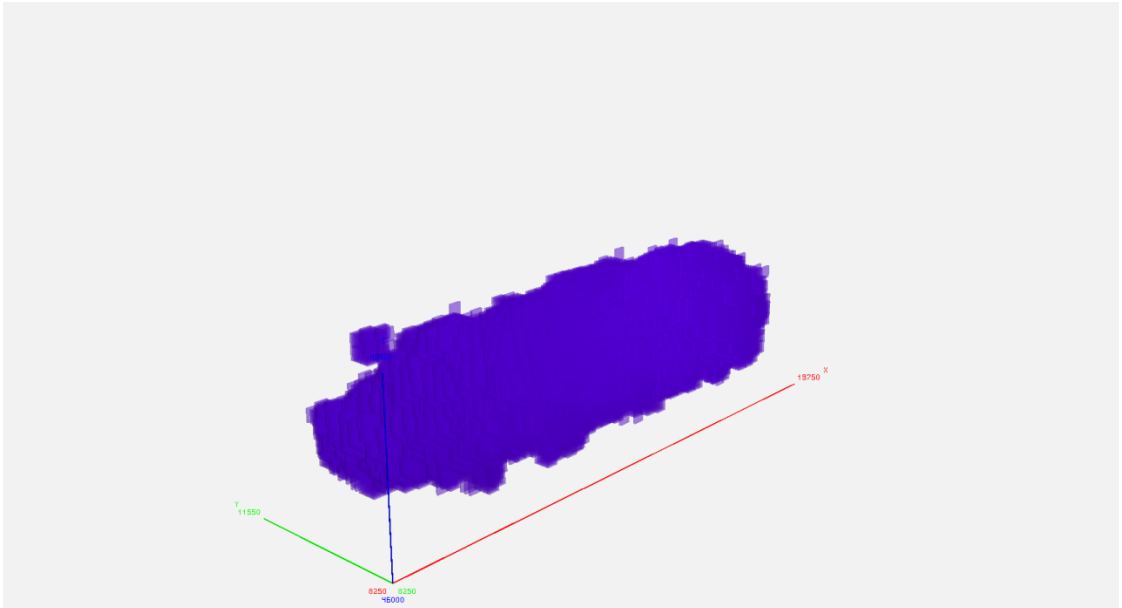
post GEM2



post collection gap



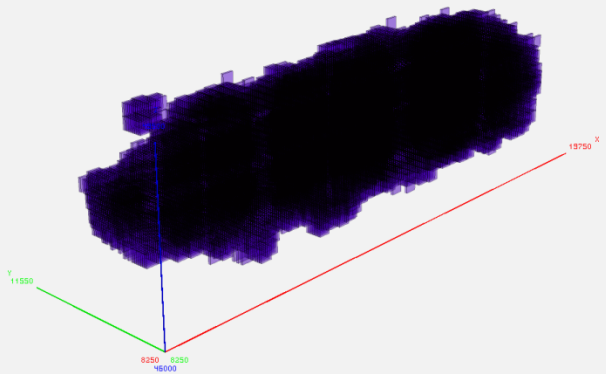
above threshold



now with finer quantization - equal to that of pixel chip

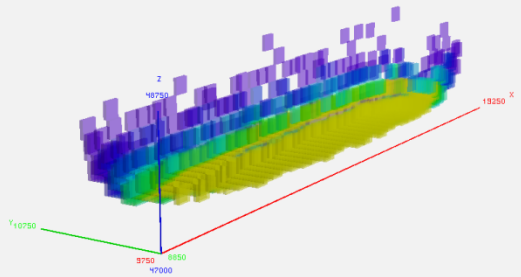
npoints = 17443

above threshold



rendering of box edges turned on

fully digitized



npoints= 1211

fully digitized (non transparent)