

Reactor Position Reconstruction Study with PROSPECT

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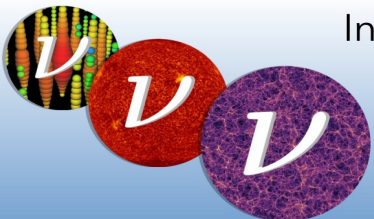
On behalf of the PROSPECT collaboration

June 8th - NBIA PhD School 2021

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International PhD Summer School on Neutrinos
Here, There & Everywhere

July 5-9, 2021
Niels Bohr Institute, Copenhagen



U.S. DEPARTMENT OF
ENERGY

Physics Division

Reactor Neutrino Physics

- Nuclear reactors are the largest human-made source of neutrinos
- First neutrino detection took place at a reactor antineutrino experiment.
- First observation of a non-zero θ_{13} mixing angle

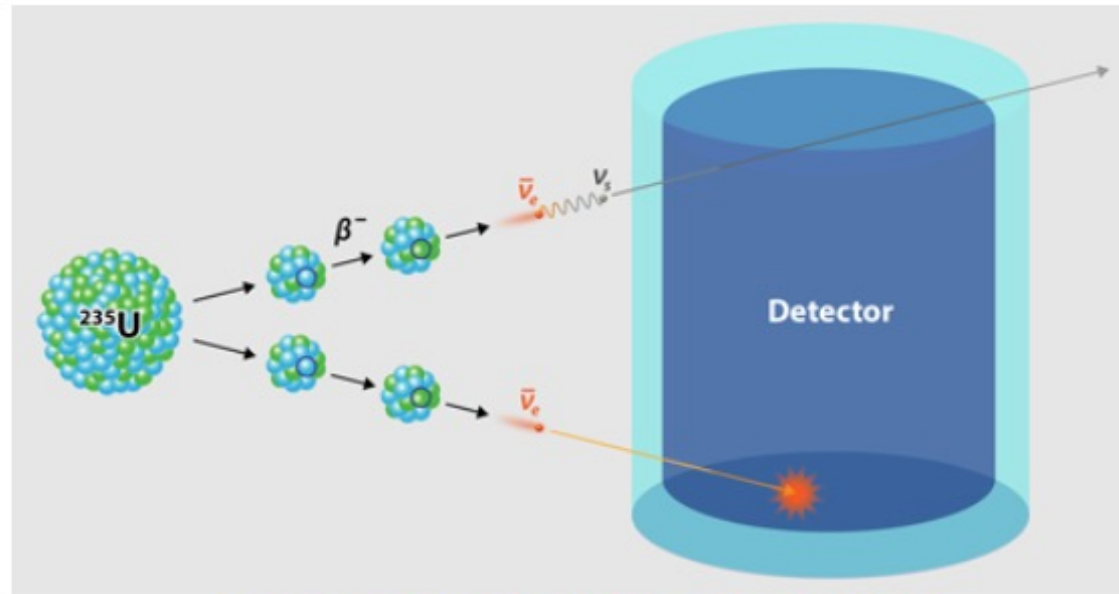
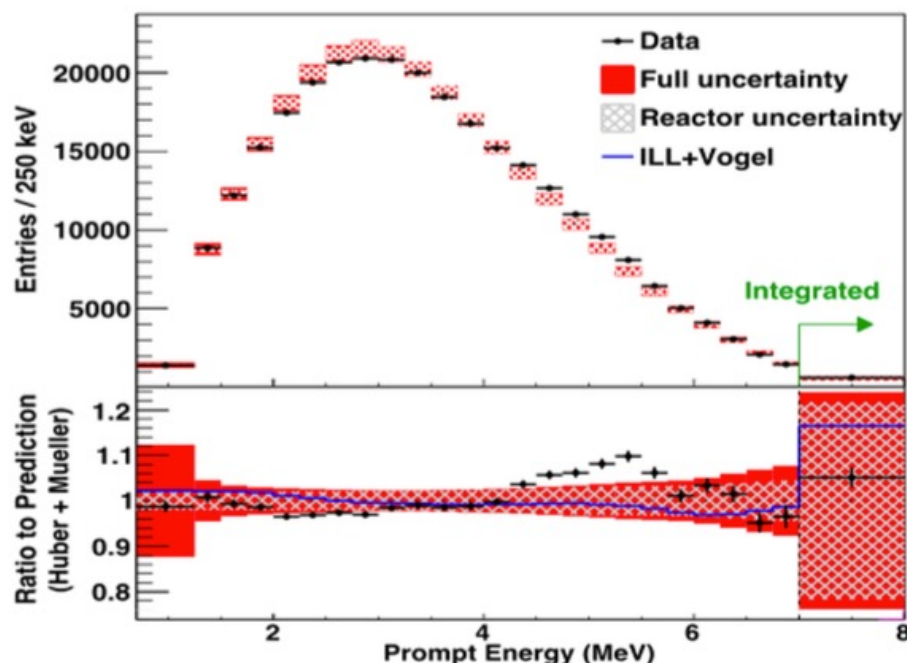


Image source: <https://physics.aps.org/articles/v10/66>

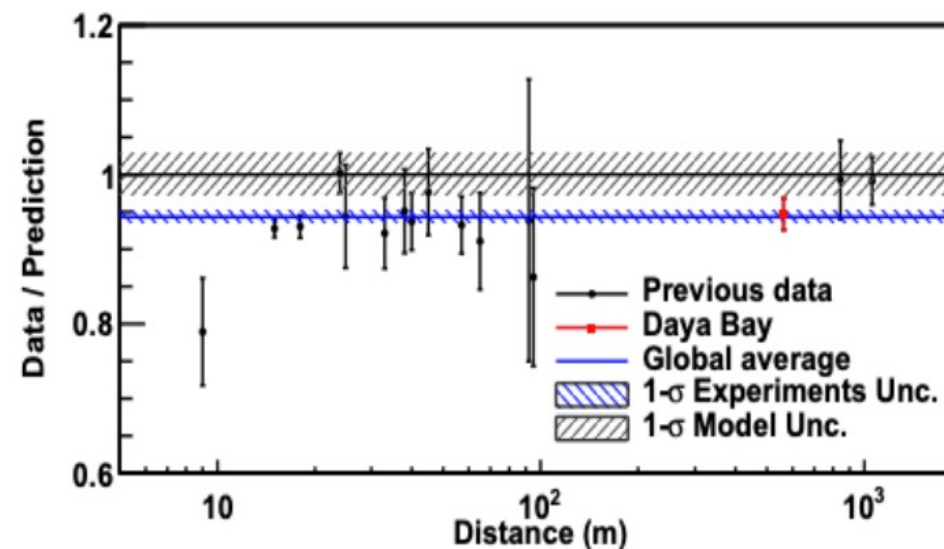
Reactor Antineutrino Anomaly, a motivation for PROSPECT

- Short-baseline reactor experiments have reported a deficit of the measured antineutrino rate when compared to theoretical predictions

Antineutrino anomaly bump in 4-6 MeV

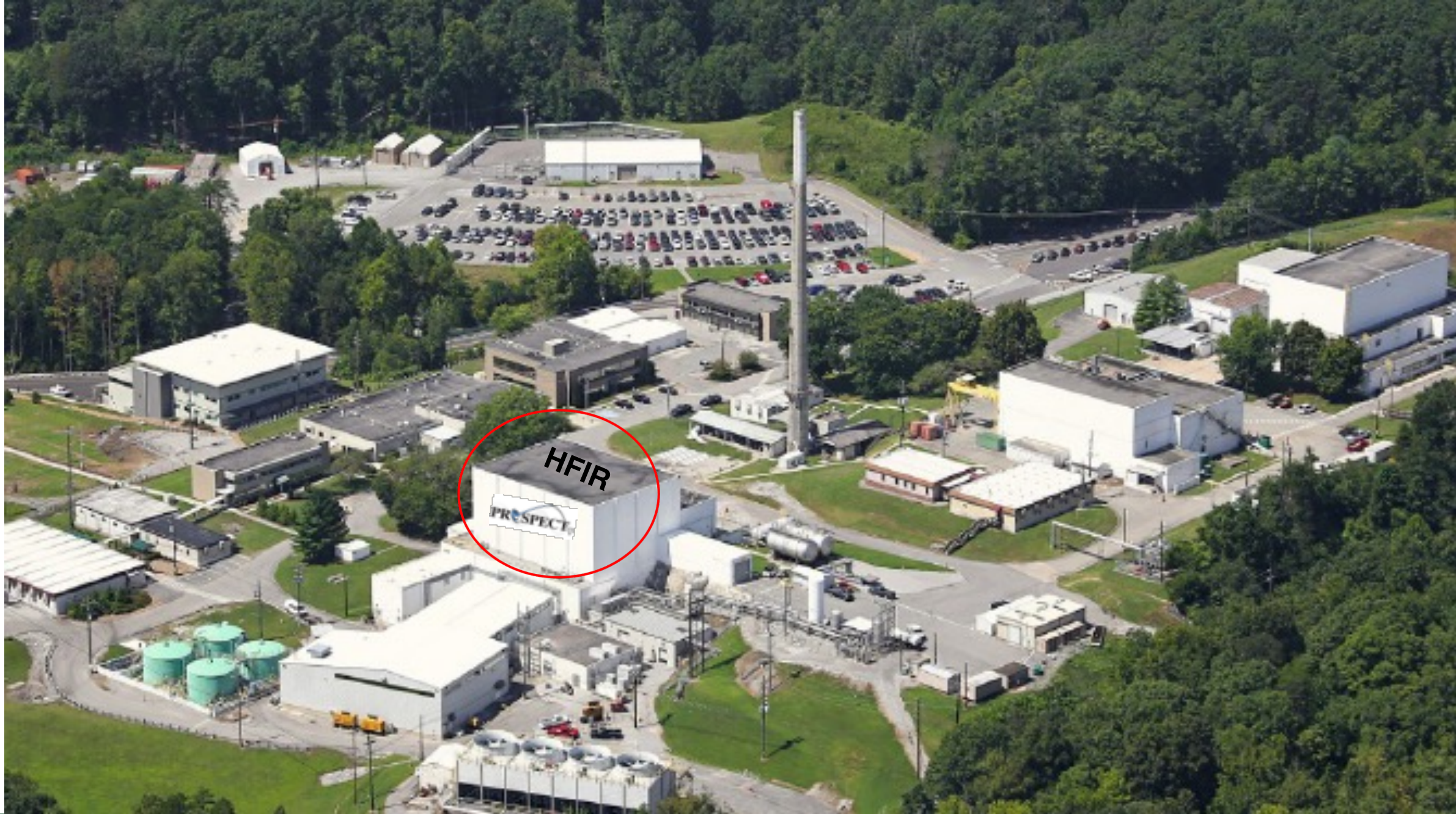


Observed flux deficit of about 6%



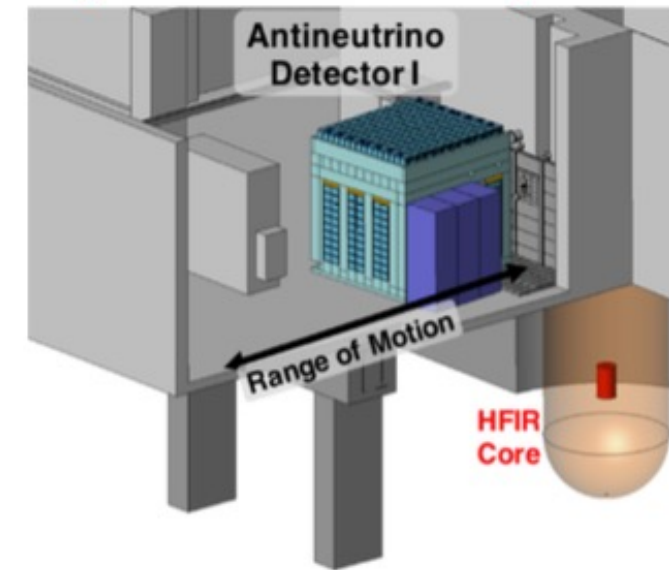
Feng Peng An et al. Measurement of the Reactor Antineutrino Flux and Spectrum at Daya Bay. Phys. Rev. Lett., 116(6):061801, 2016, 1508.04233.



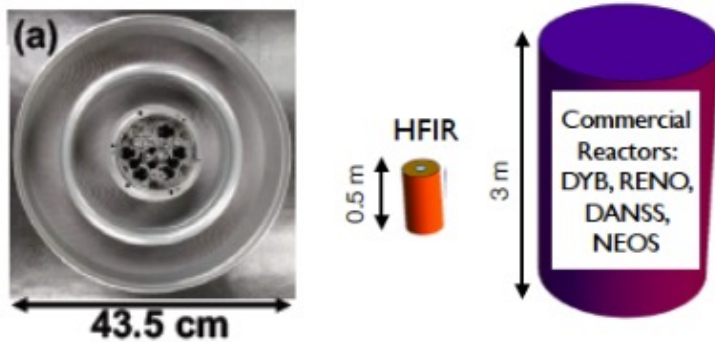


PROSPECT Detector at HFIR

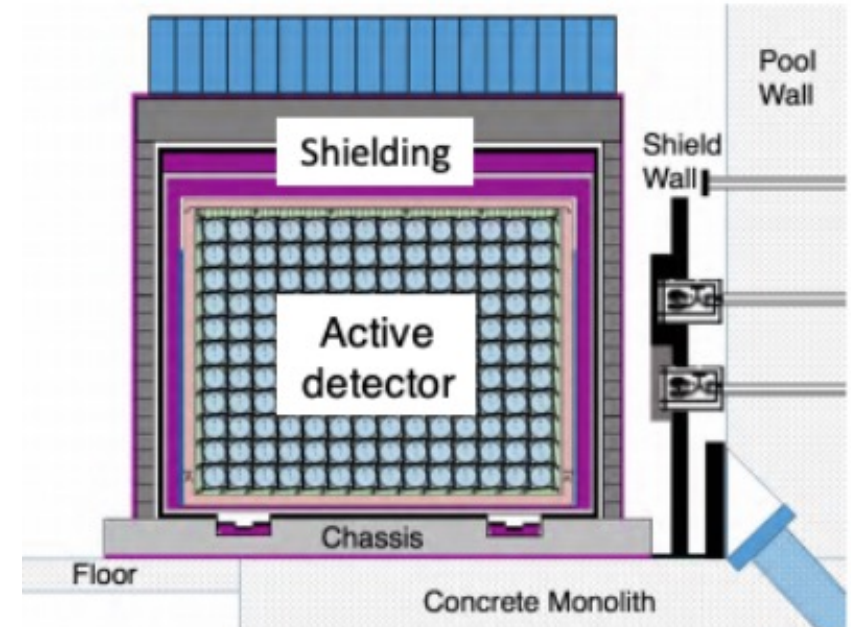
Layout of the PROSPECT experiment



- 93% ^{235}U Fuel
- 85 MW thermal power
- Compact core
- Huge flux in the few MeV range



Schematic of the active detector volume

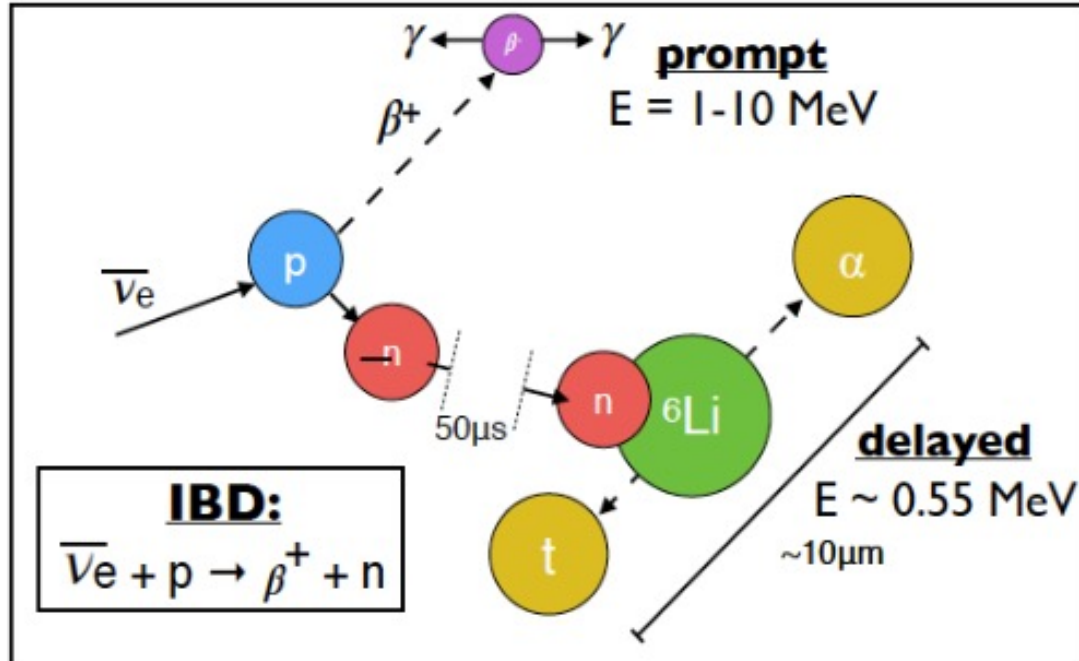


14 x 11 array of ^6Li doped liquid scintillator for detecting reactor antineutrinos (6.7-9.2 m from compact highly enriched uranium reactor core)

J. Ashenfelter et al. (PROSPECT), Nucl. Inst. Meth. A 922, 287(2019)

Antineutrino Detection

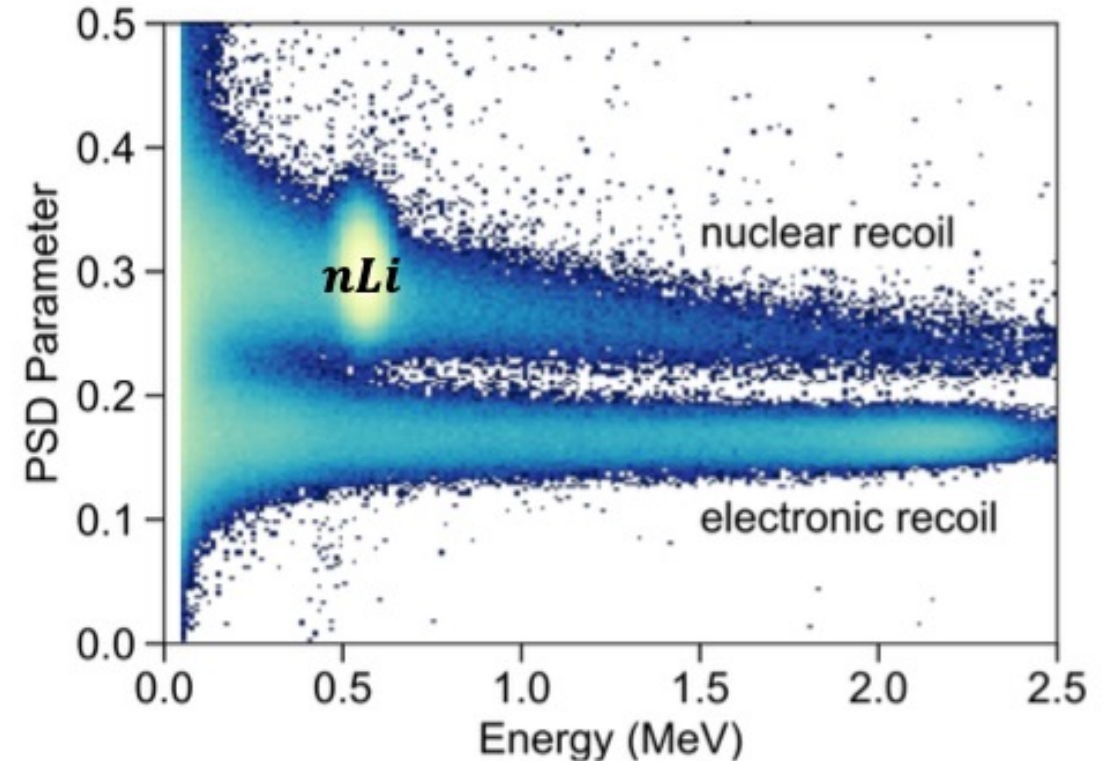
Schematic of IBD interaction in 6LiLS



- PROSPECT detects antineutrinos via the Inverse Beta Decay (IBD) process
- Prompt signal (e^+) provides a good energy estimate of incoming ν
- Localized delayed (n - 6Li) signal

PROSPECT Collaboration, arXiv:2006.11210 (2020)

Prompt energy/PSD distribution for IBD-like events

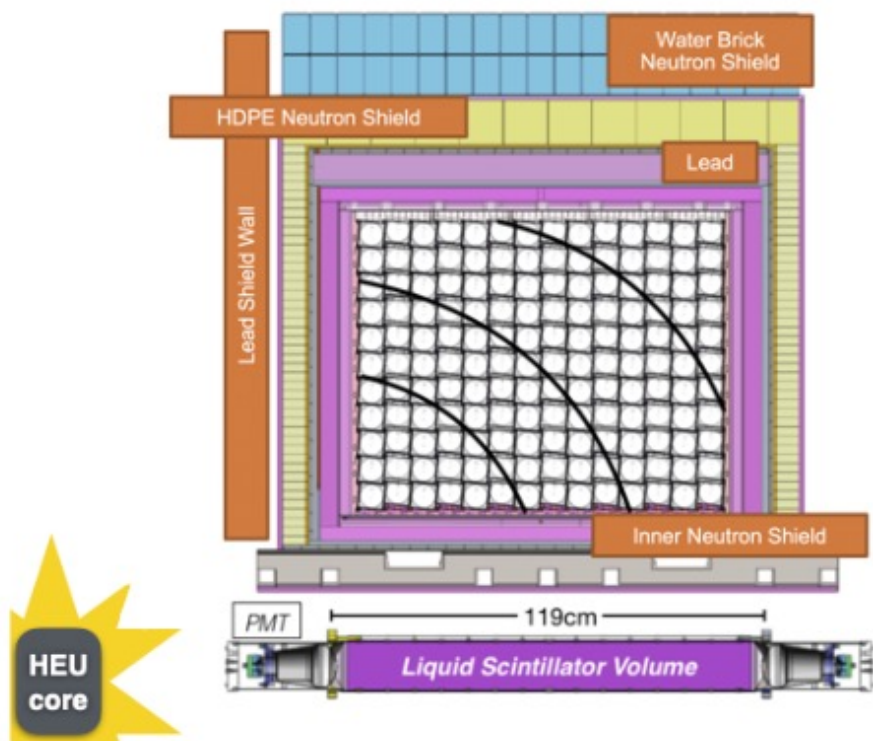


- PSD-energy correlation is used to discriminate between prompt and delayed signal events

J. Ashenfelter et al. (PROSPECT), JINST 13, P06023 (2018).

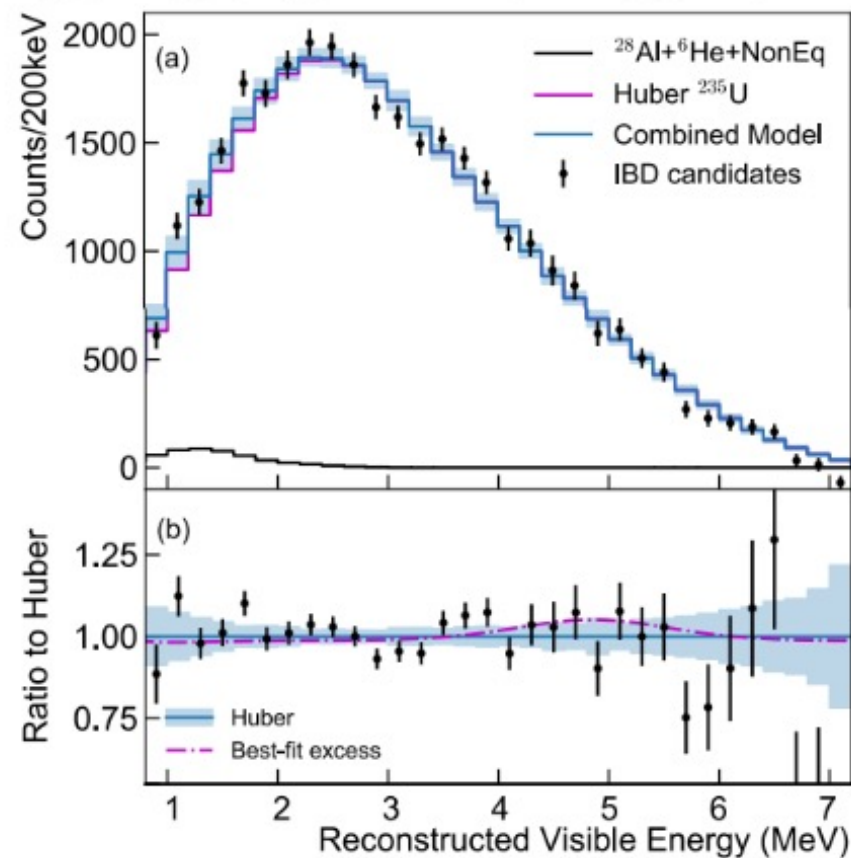
PROSPECT-FIRST Results

First search for short-baseline neutrino oscillations at HFIR with PROSPECT



J. Ashenfelter et al. (PROSPECT), Phys. Rev. Lett. 121, 251802 (2018).

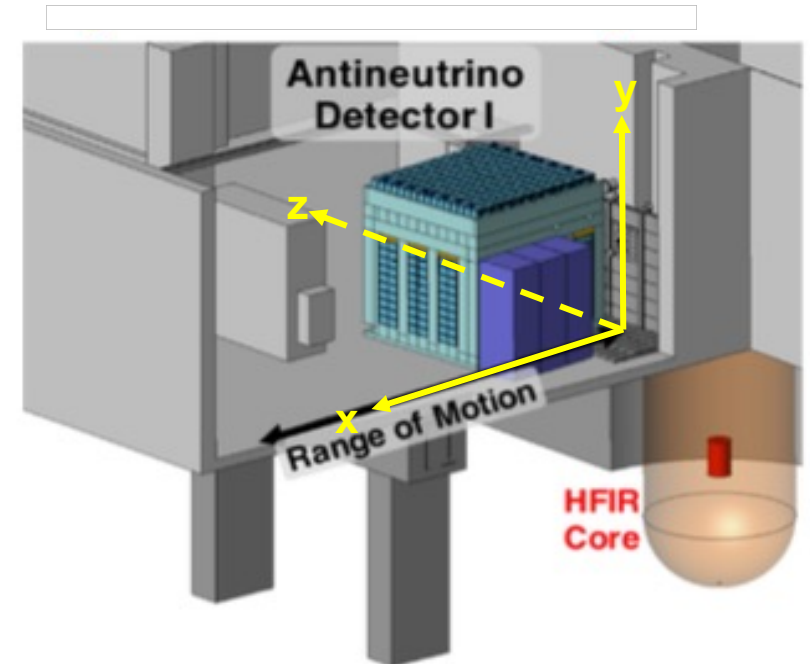
Measurement of the Antineutrino Spectrum from ^{235}U Fission at HFIR with PROSPECT



J. Ashenfelter et al. (PROSPECT), Phys. Rev. Lett. 122, 251801 (2019).

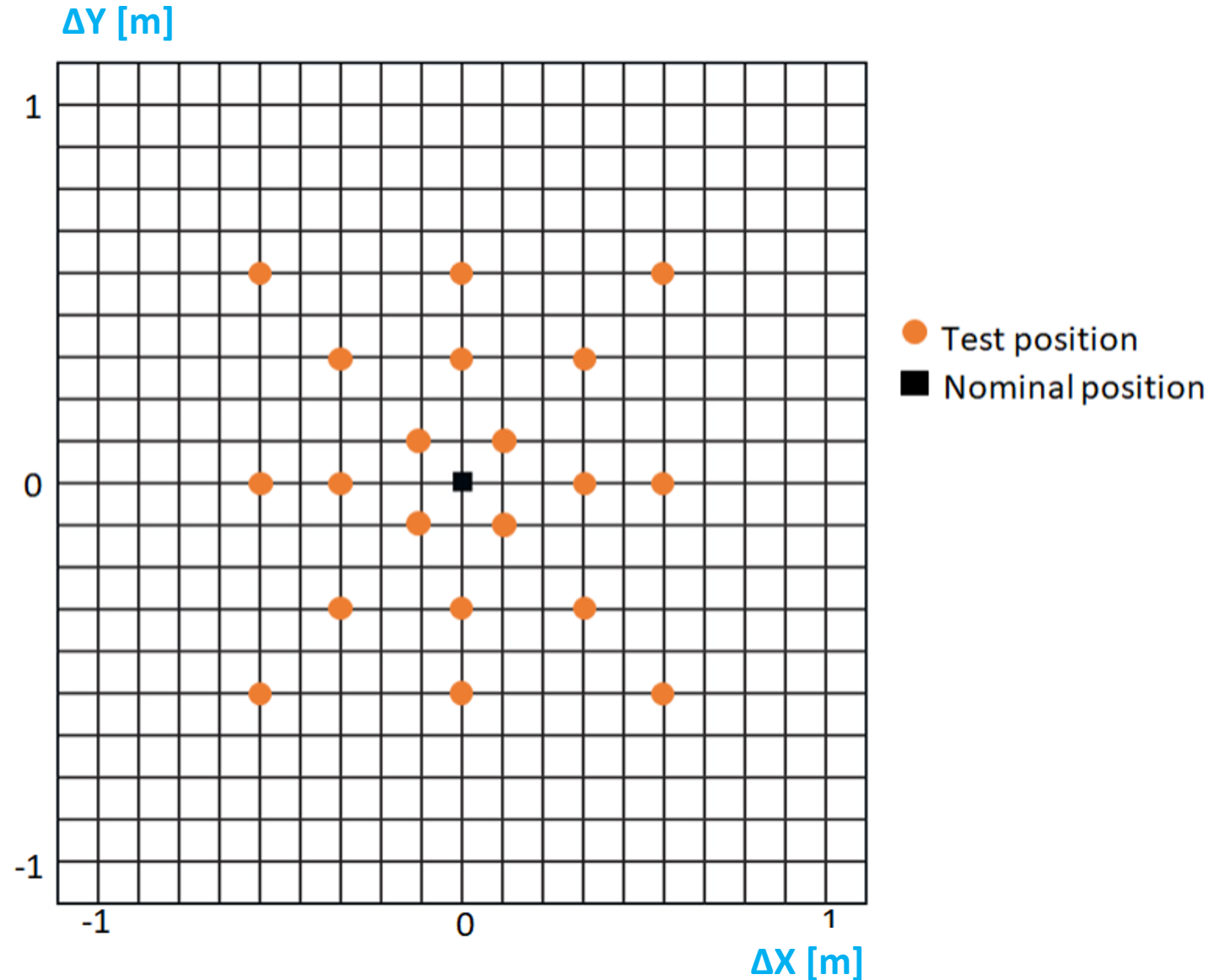
Study Description

- We would like to determine the reactor core position. To do so:
- ◆ Test the accuracy of the reactor core coordinates reported in the latest publication ([PhysRevD.103.032001](#)) by comparing data and PROSPECT Geant4 (PG4) simulations with different core positions.
 - PG4 models the reactor core as a point source.
 - We expect the comparison between data and simulation with the best χ^2/NDF value to correspond to the true position of the reactor core.
 - ◆ Use the known detector's response to include z-dependence



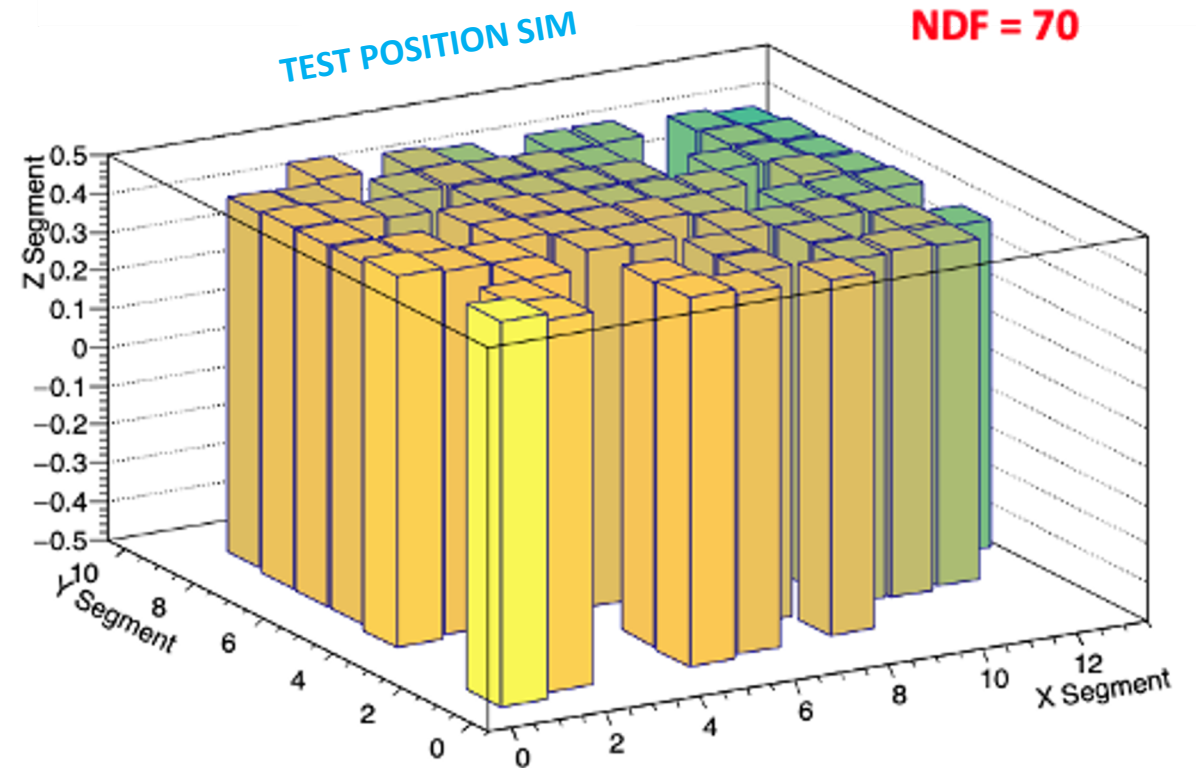
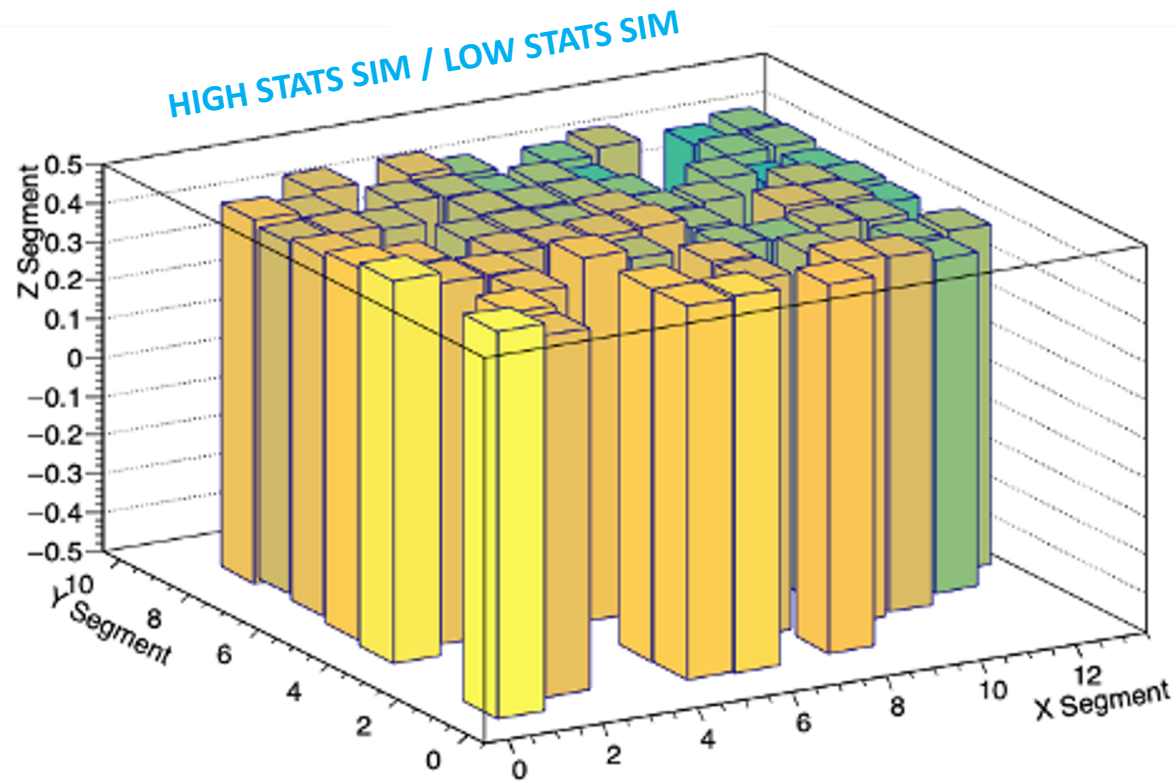
Method

- Nominal z position is left unchanged
 - $\Delta z=0$
- Change the position of the core an amount delta along the x-y plane
 - $\Delta x=\pm 1\text{m}, \Delta y=\pm 1\text{m}$
- Simulate 1 Million events at each position
 - **Test Position**
- Comparison of **Test Position** grid with:
 - **Low Statistics Sim**
(~ data IBD counts)
 - **High Statistics Sim**
(~14 data IBD counts)



Sensitivity test

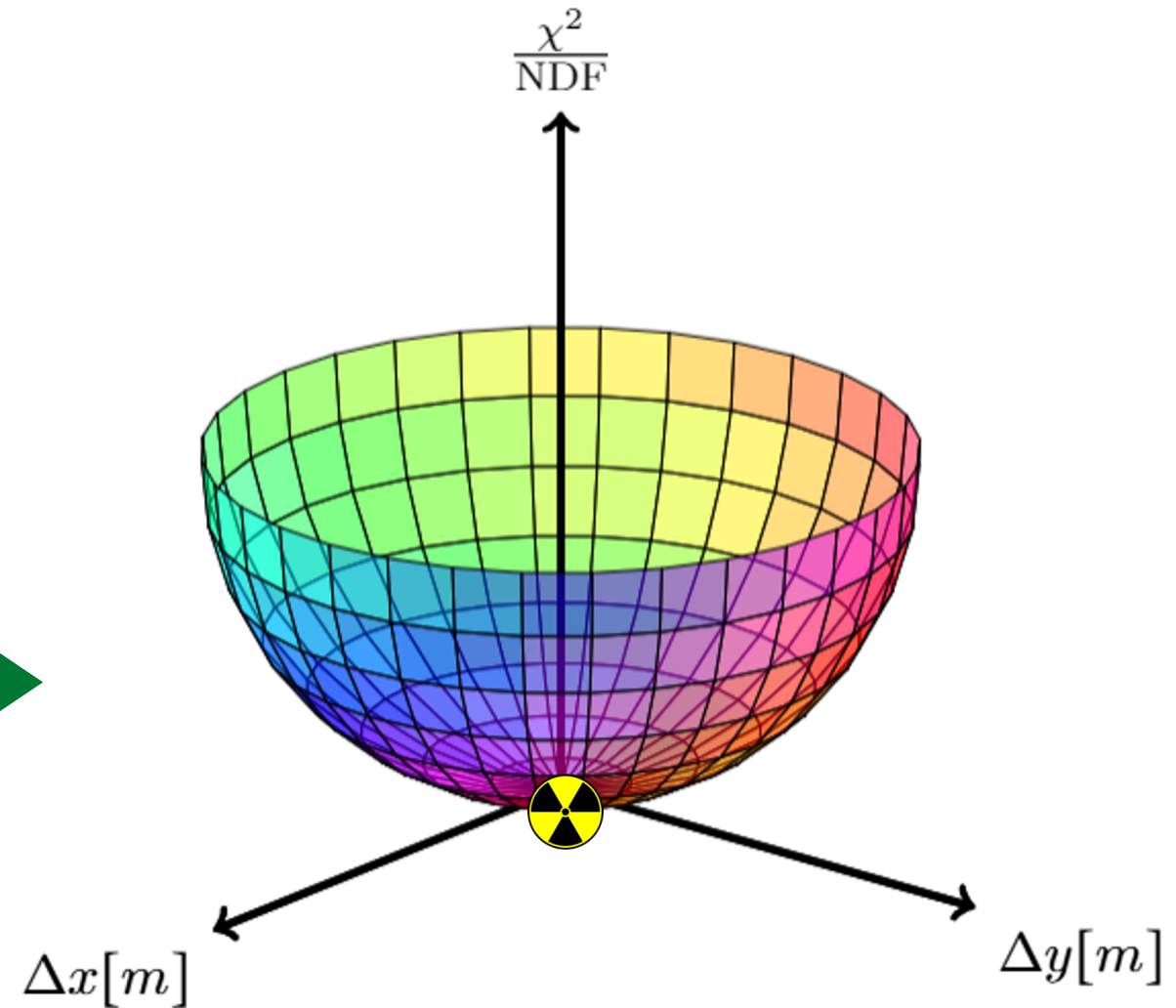
We are comparing the IBD counts cell by cell and calculating the corresponding χ^2/NDF for each test position.



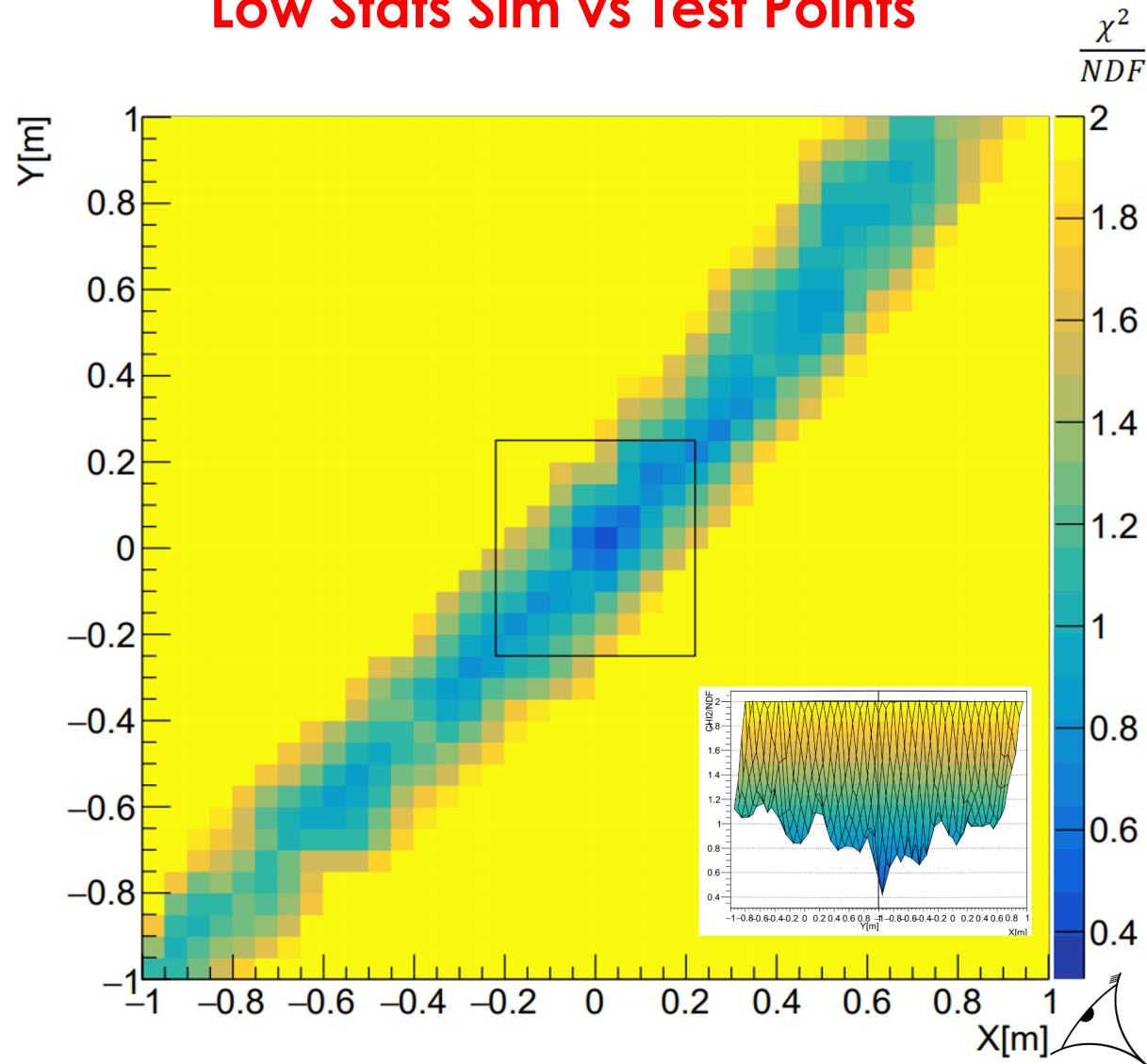
Sensitivity test

- High Statistics Sim vs. Test Points
- Low Statistics Sim vs. Test Points

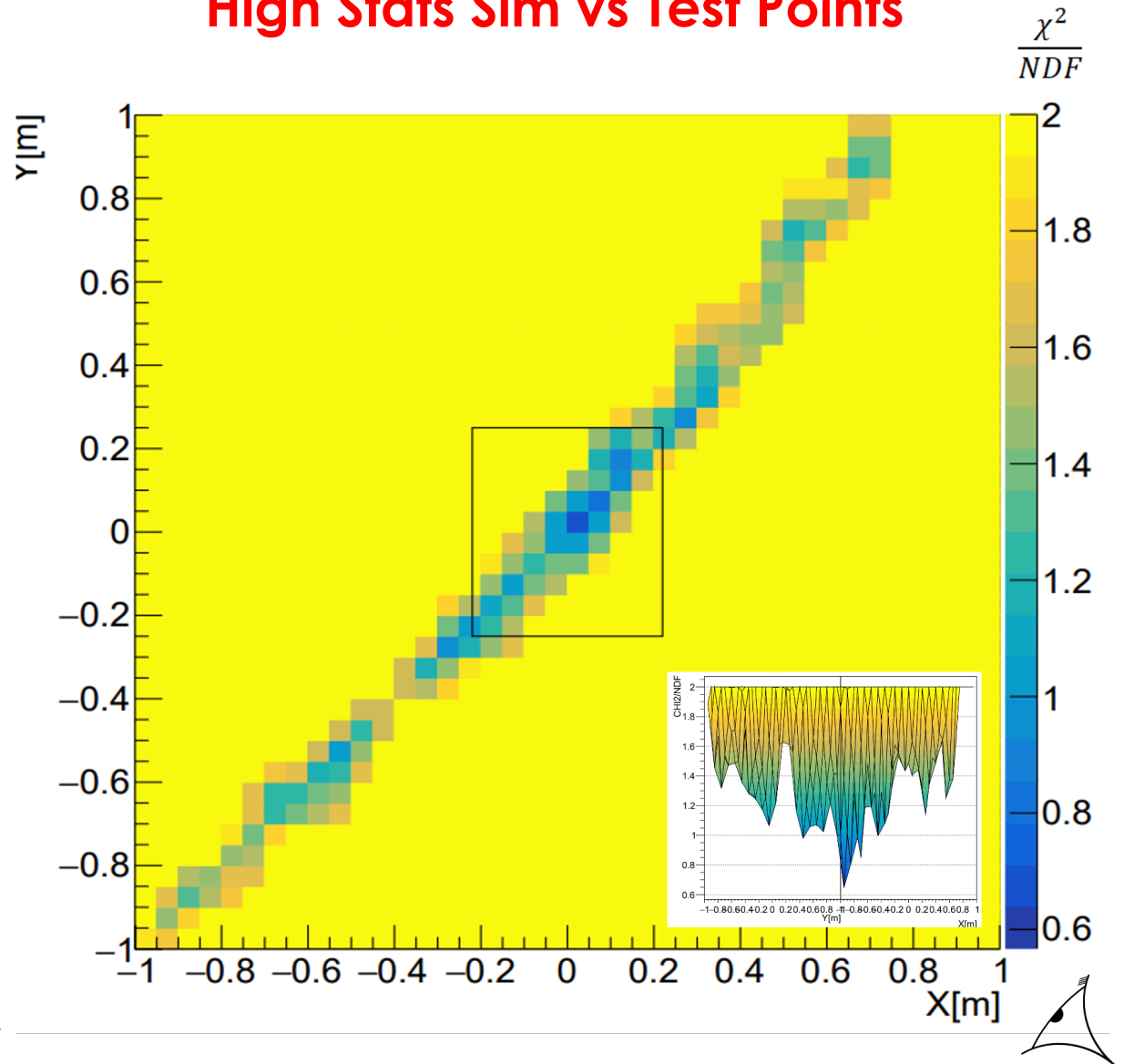
What we would like to see



Low Stats Sim vs Test Points

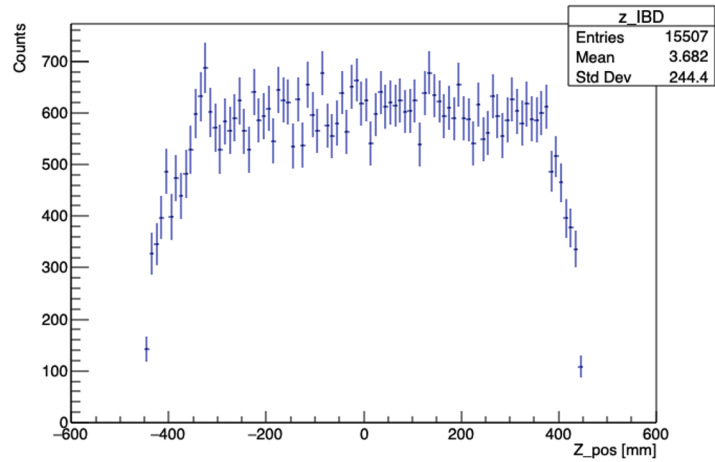


High Stats Sim vs Test Points

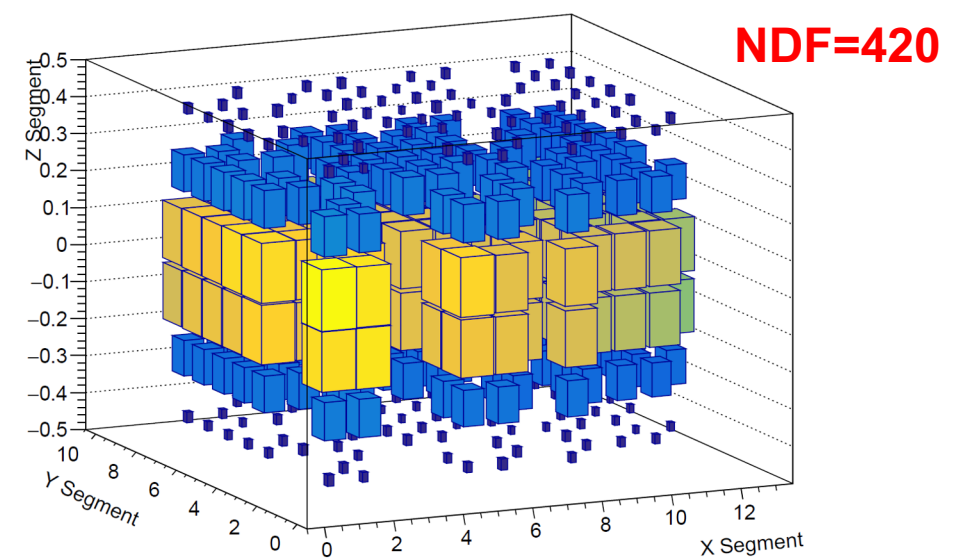
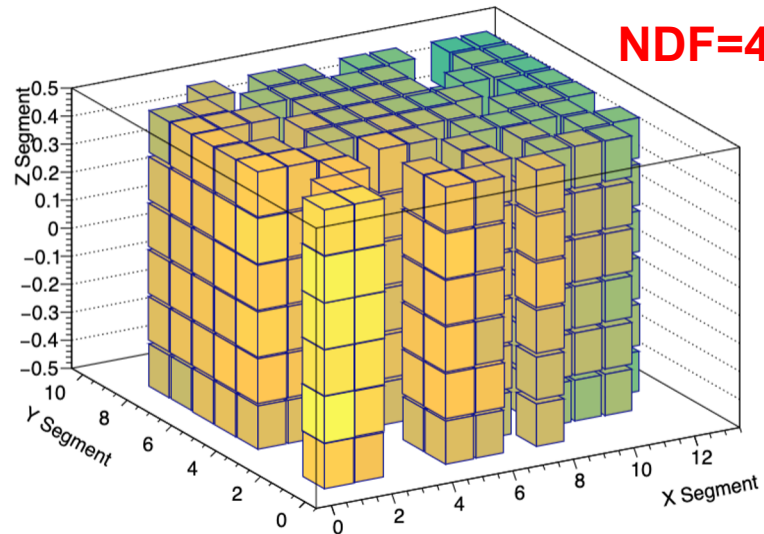
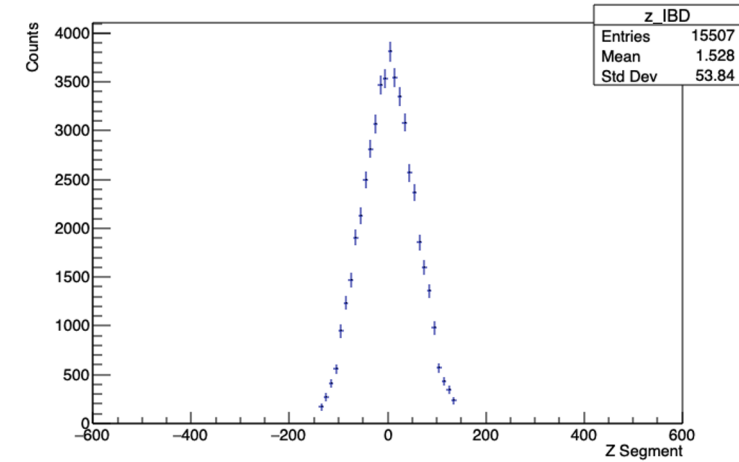


Including z-cuts

Prompt signal

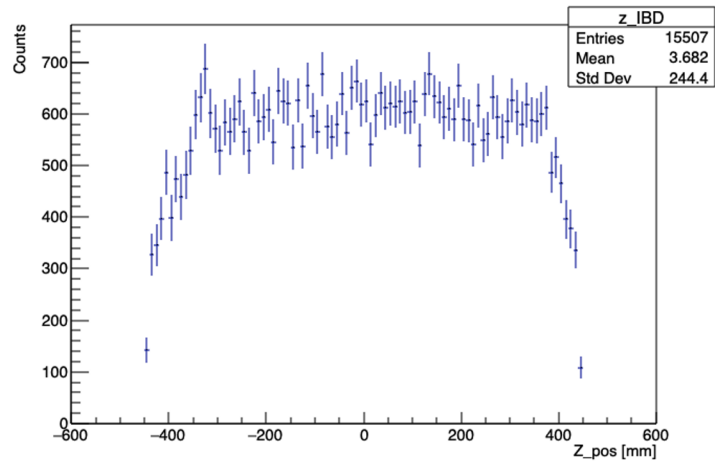


Prompt-Delayed signal



Including z-cuts

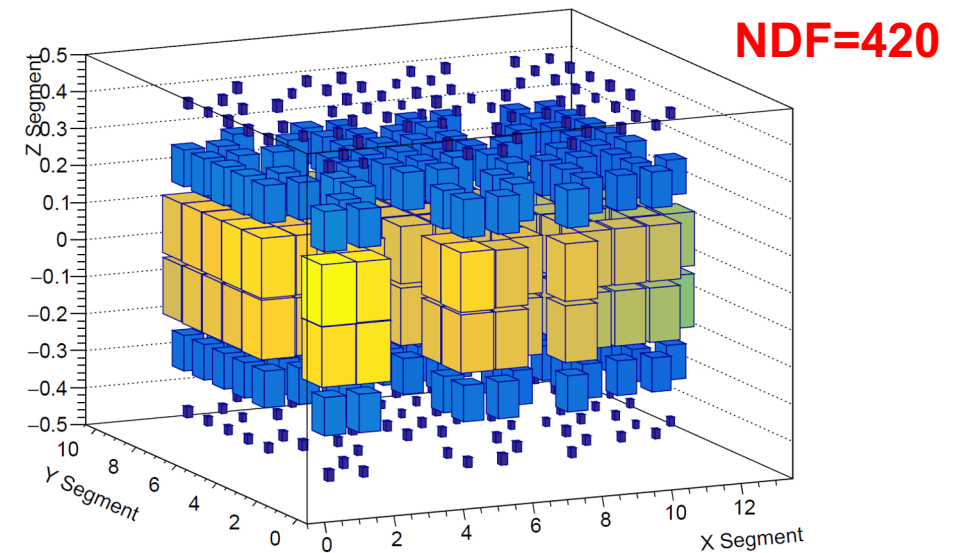
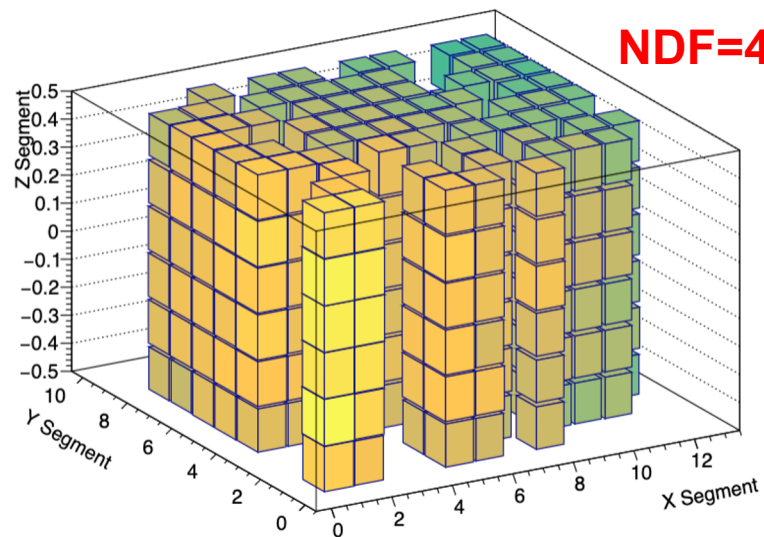
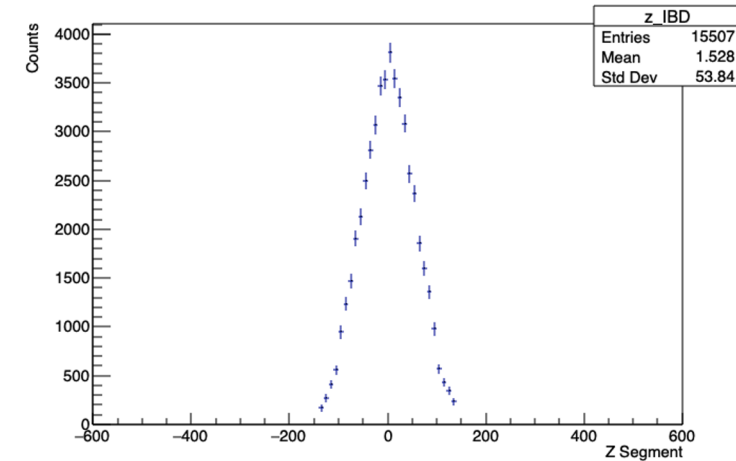
Prompt signal



Sensitivity
Test

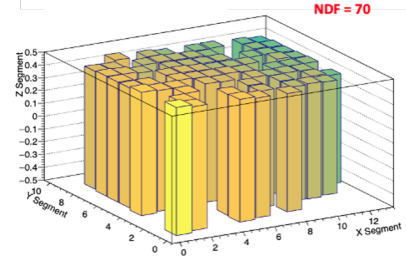
High Stats Sim
Low Stats Sim

Prompt-Delayed signal

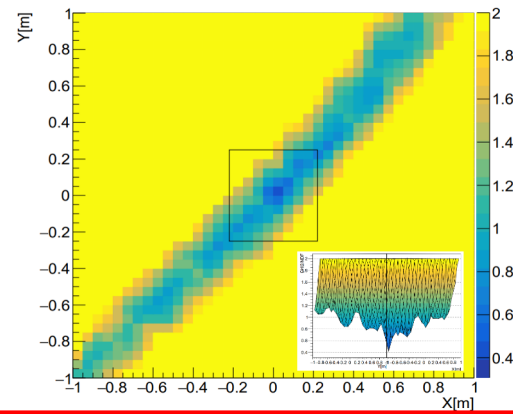


Preliminary Results

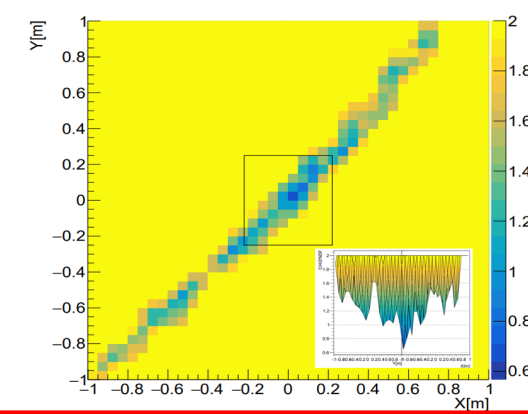
no z-cut



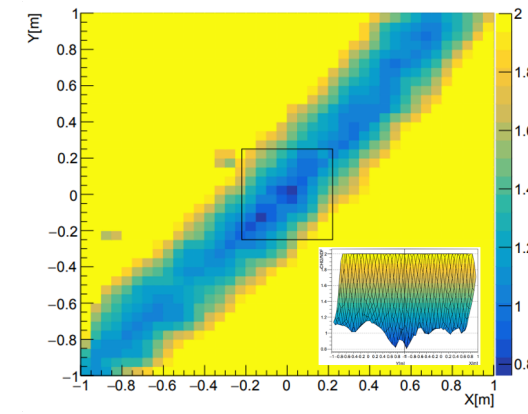
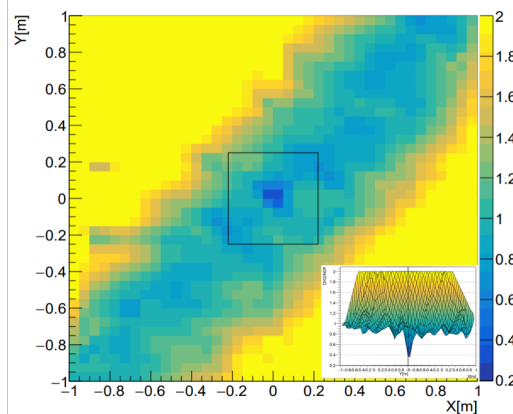
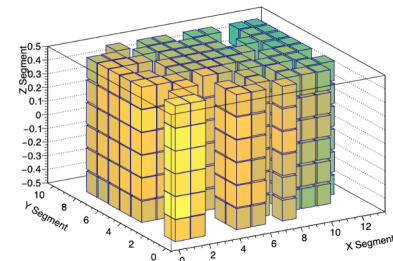
Low Stats



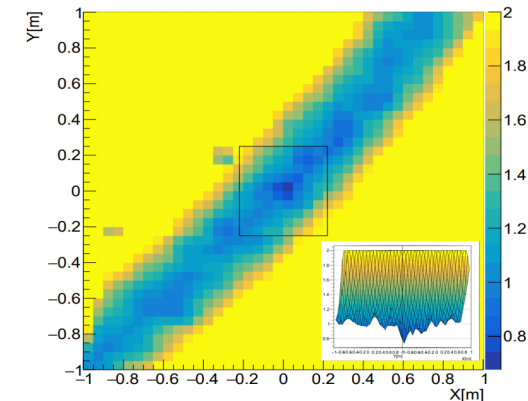
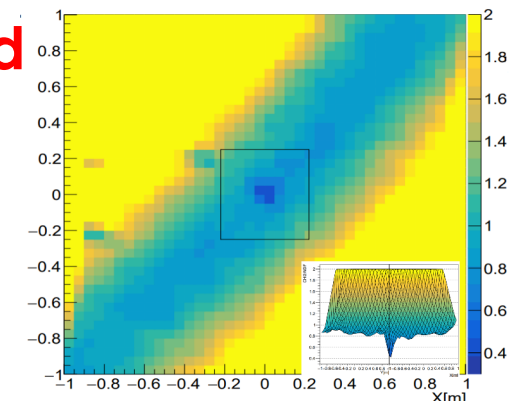
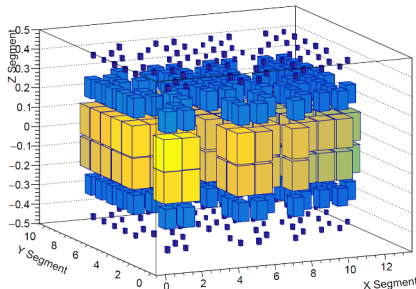
High Stats



prompt

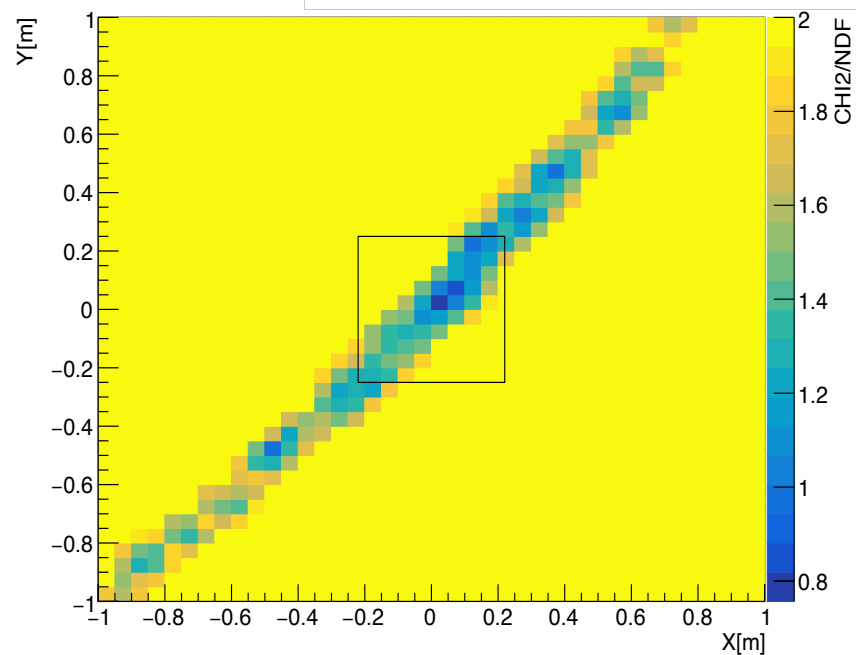


prompt - delayed

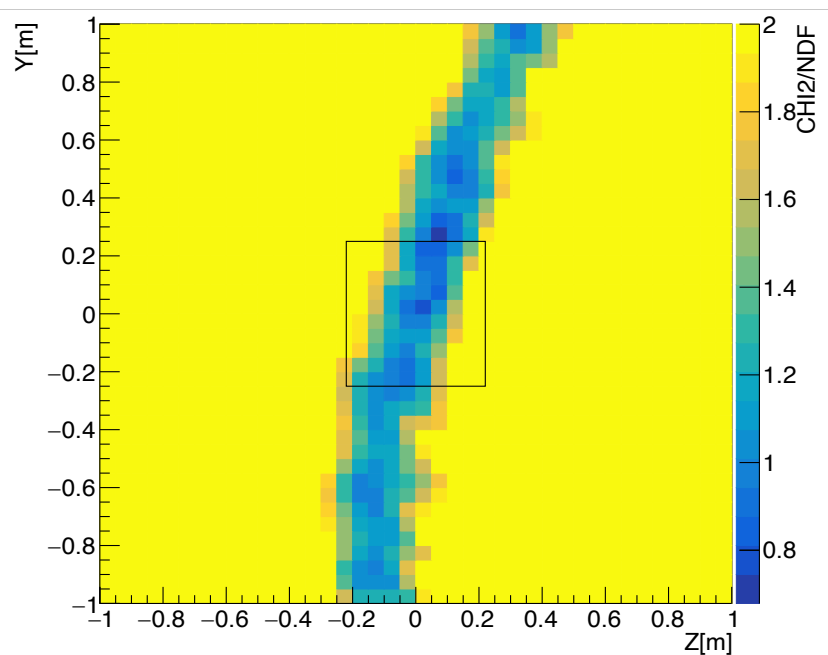


Exploring multiple planes

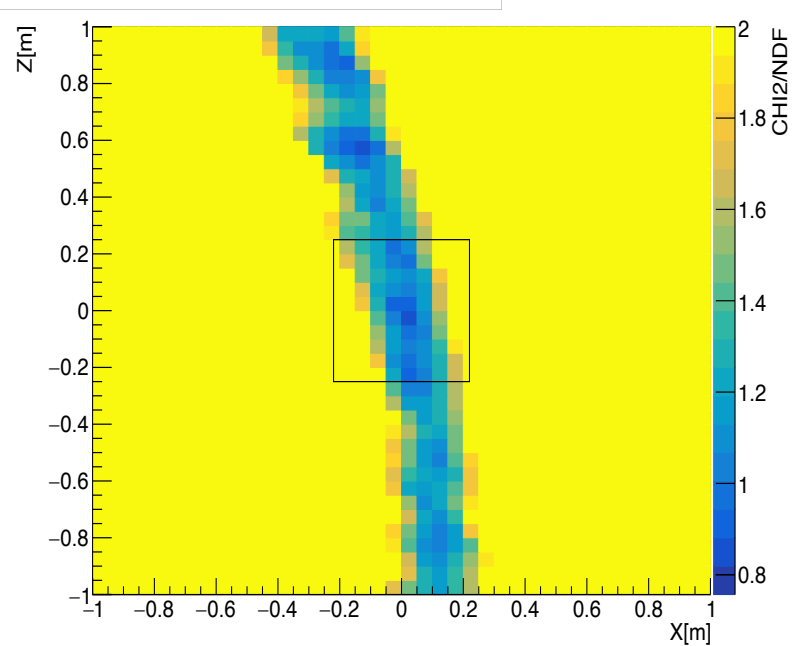
X-Y Plane



Z-Y Plane

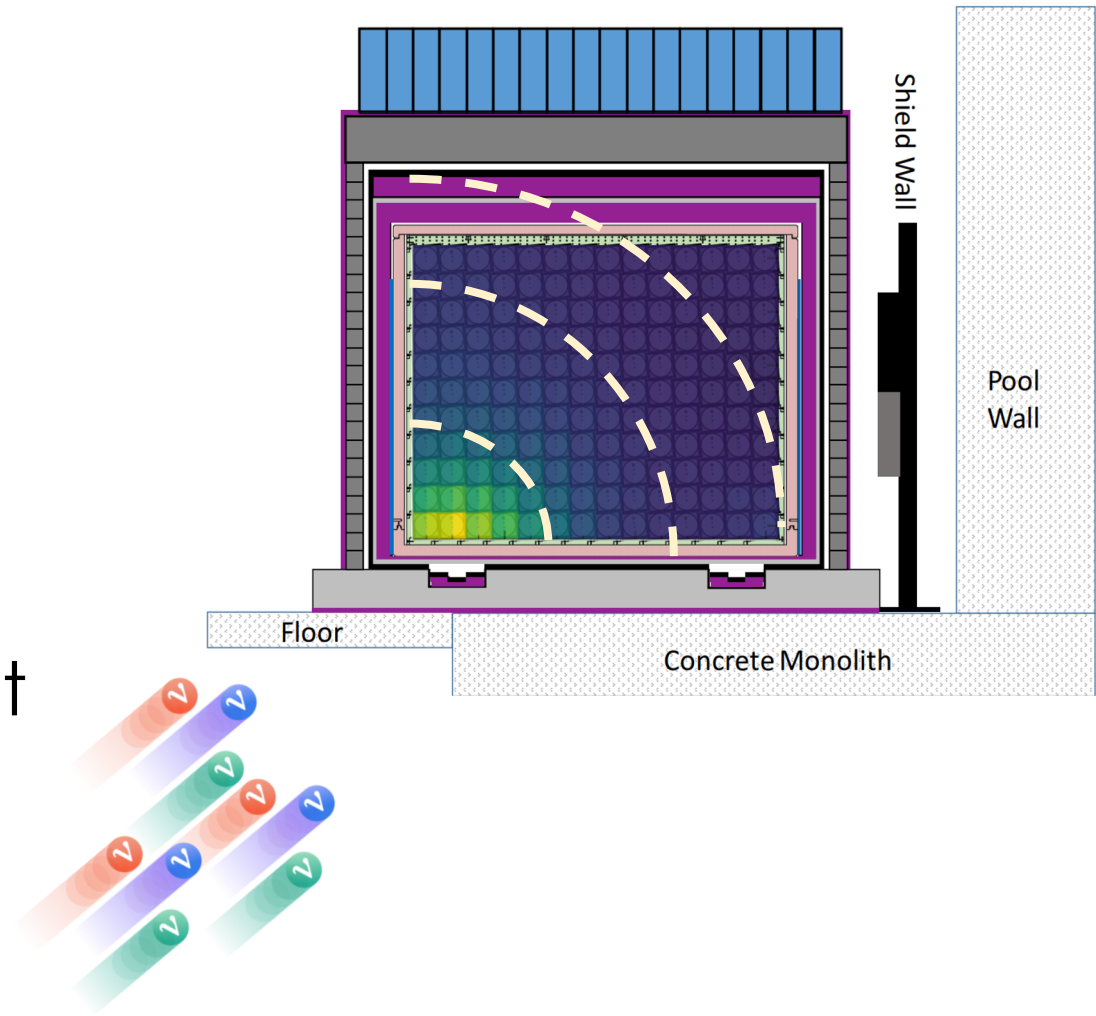


X-Z Plane



Summary and future work

- First exploration using PG4 simulations appears to be effective when locating the reactor core position.
- Investigate effect of finite size source in PG4 on the results.
- Conduct sensitivity study for test points against real data.





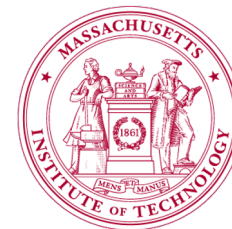
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