OAK RIDGE National Laboratory

Reactor Position Reconstruction Study with PROSPECT

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The University of Tennessee Knoxville

On behalf of the PROSPECT collaboration

June 13th – DPF2021 Meeting

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APS | DIVISION OF PARTICLES & FIELDS

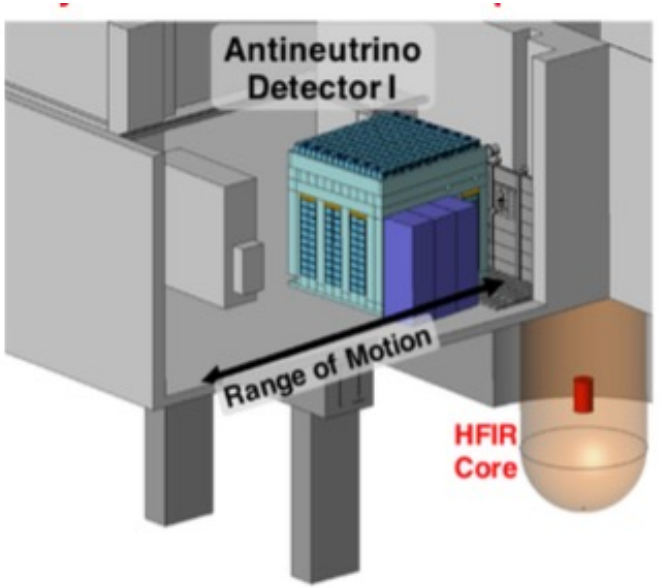
U.S. DEPARTMENT OF ENERGY

PROSPECT

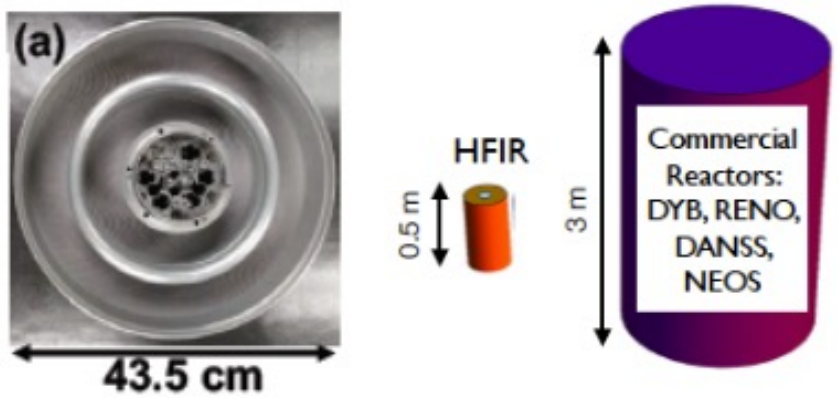
Physics Division

PROSPECT Detector at HFIR

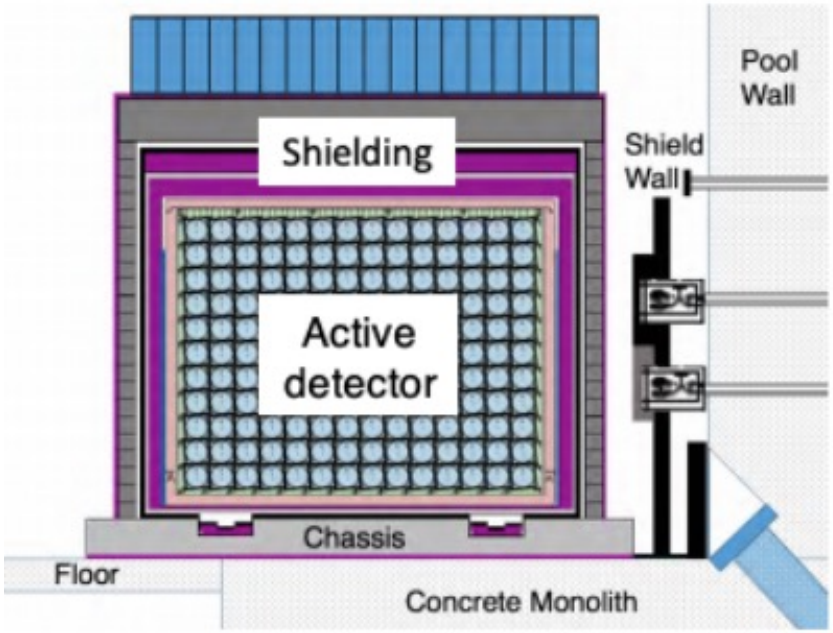
Layout of the PROSPECT experiment



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



Schematic of the active detector volume

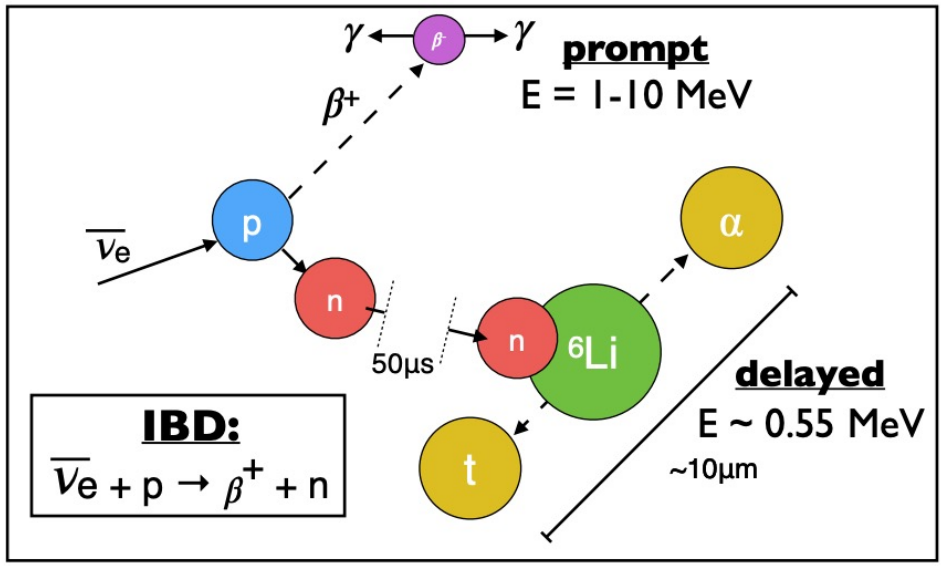


14 x 11 array of 6Li doped liquid scintillator for detecting reactor antineutrinos (6.7-9.2 m from compact highly enriched uranium reactor core)

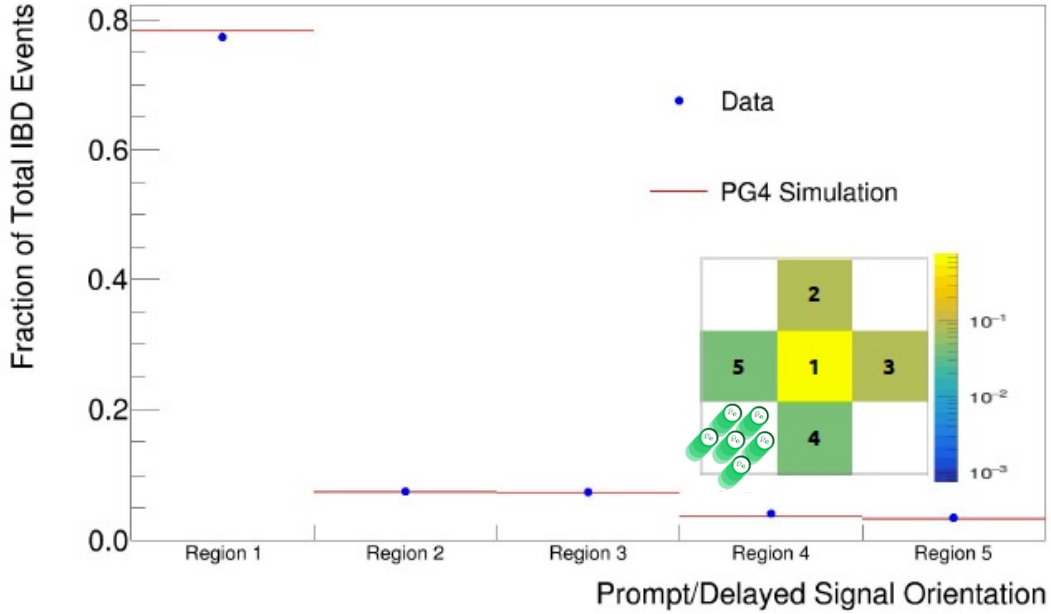
J. Ashenfelter et al. (PROSPECT), Nucl. Inst. Meth. A 922, 287(2019)

Antineutrino Detection and Directionality

- PROSPECT detects antineutrinos via the Inverse Beta Decay (IBD) process.
- IBD signature is characterized by e^+ energy deposition and a localized n-6Li capture
- Kinematics of the IBD interaction allows us to recover directional information, given that the outgoing neutron preserves the direction of the incoming neutrinos.



Schematic of the IBD process

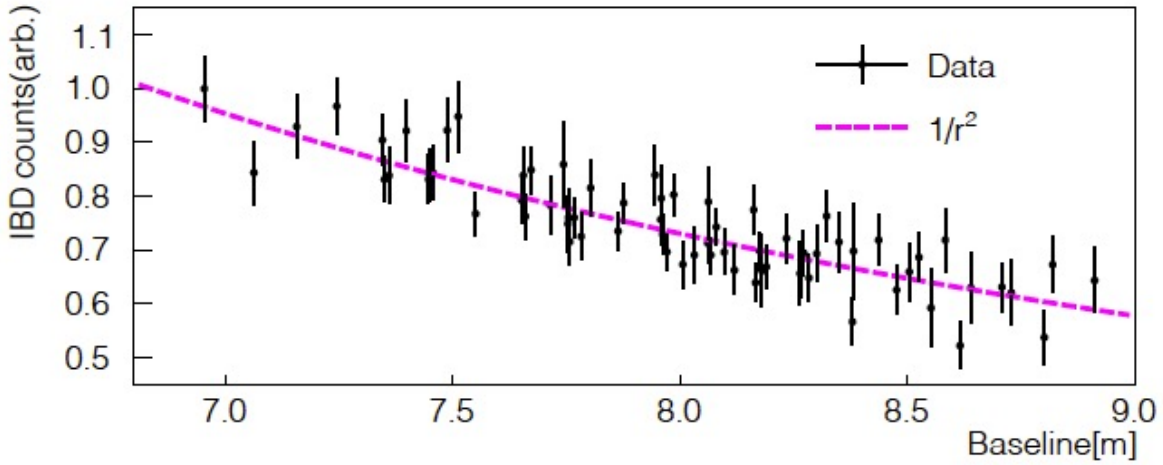


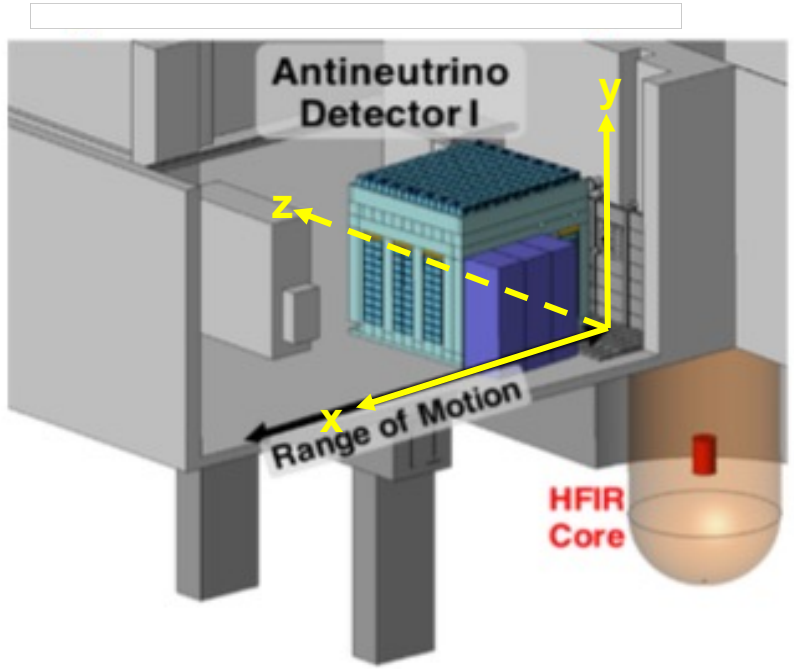
Neutron mobility in the PROSPECT detector

M. Andriamirado et al. (PROSPECT Collaboration), Phys. Rev. D 103, 032001 (2021).

A New Method

- We would like to determine the reactor core position by making use of the $1/r^2$ nature of the IBD signal in our detector
- Currently the position of the reactor core relative to PROSPECT was determined by using HFIR facility mechanical drawings
  - ❖ Test the accuracy of the reactor core coordinates reported in the latest publication (PhysRevD.103.032001) by comparing data and PROSPECT Geant4 (PG4) based simulations with different core positions.





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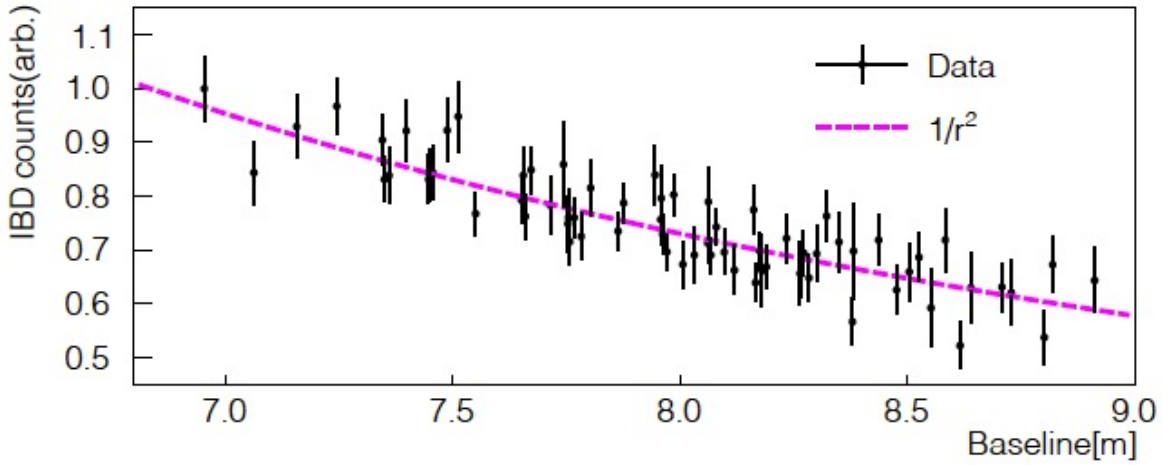
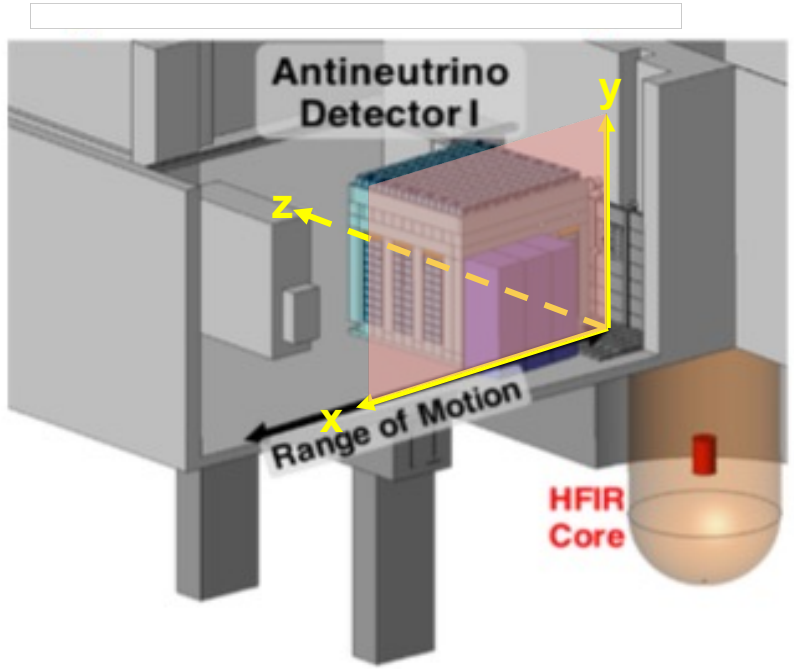
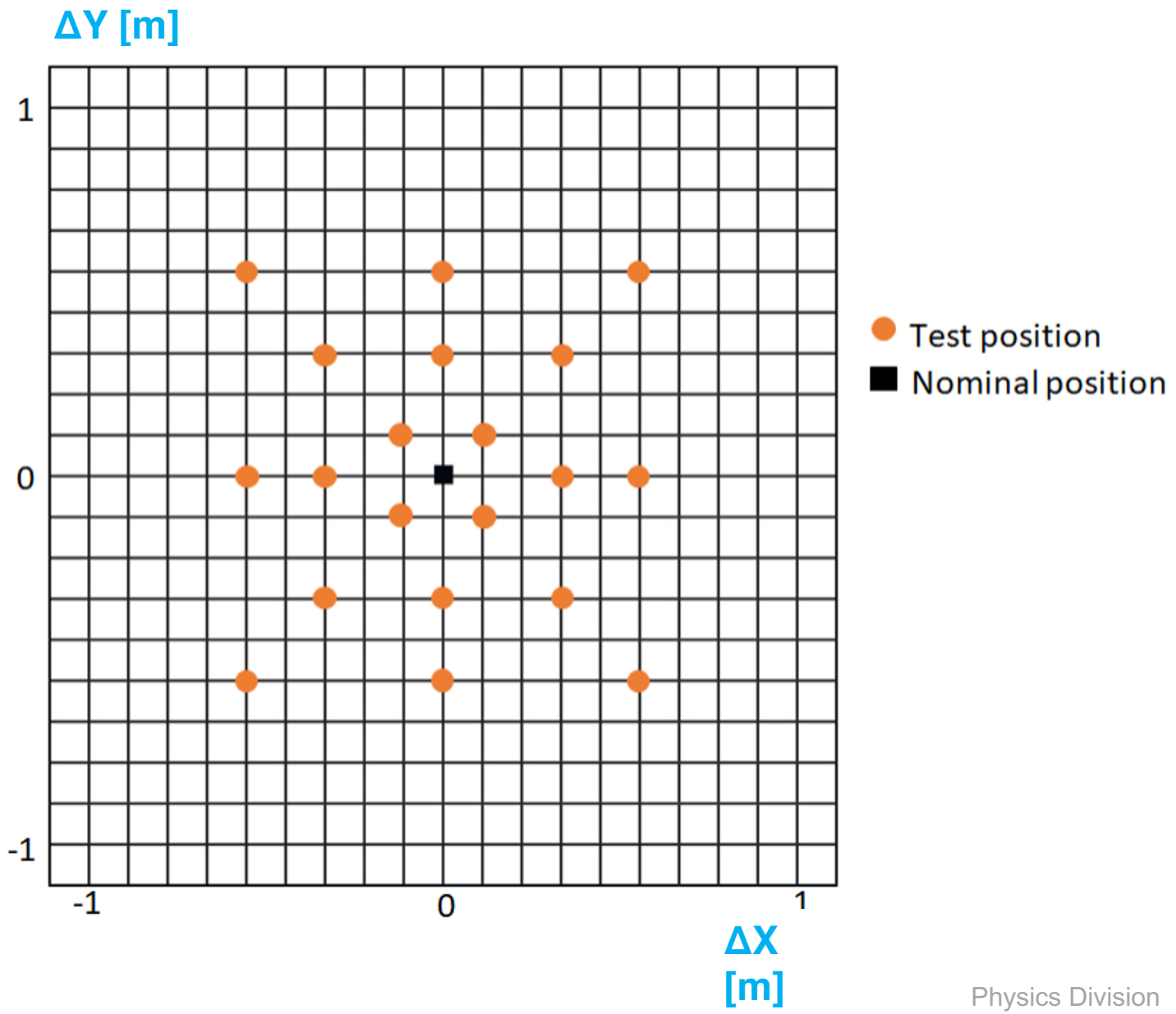




M. Andriamirado et al. (PROSPECT Collaboration), Phys. Rev. D 103, 032001 (2021).

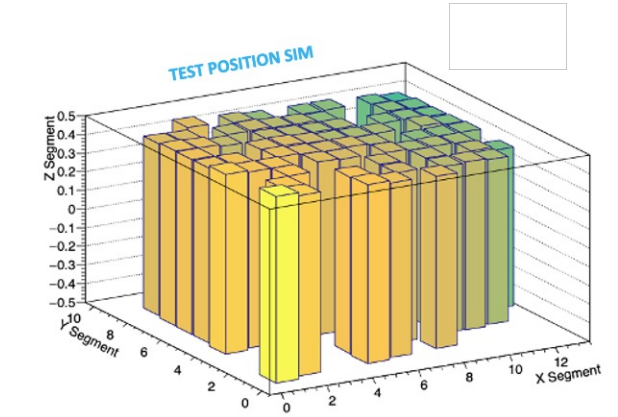
Method

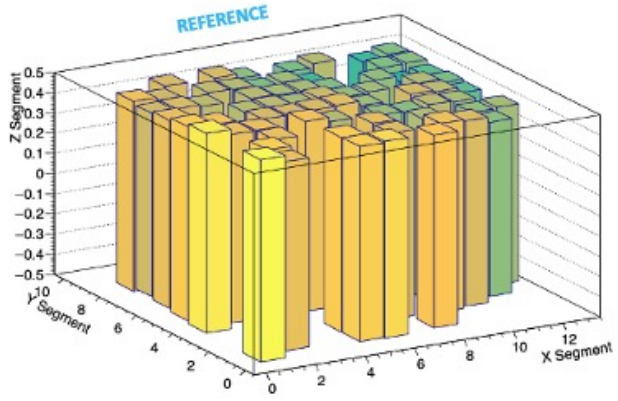
- Nominal z position is left unchanged
  - Δz=0
- Change the position of the core an amount delta along the x-y plane
  - Δx=±1m, Δy=±1m
- Simulate 1 Million events at each position
  - **Test Position**
- Comparison of **Test Position** grid with:
  - **Low Statistics Sim** (~ data IBD counts)
  - **High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

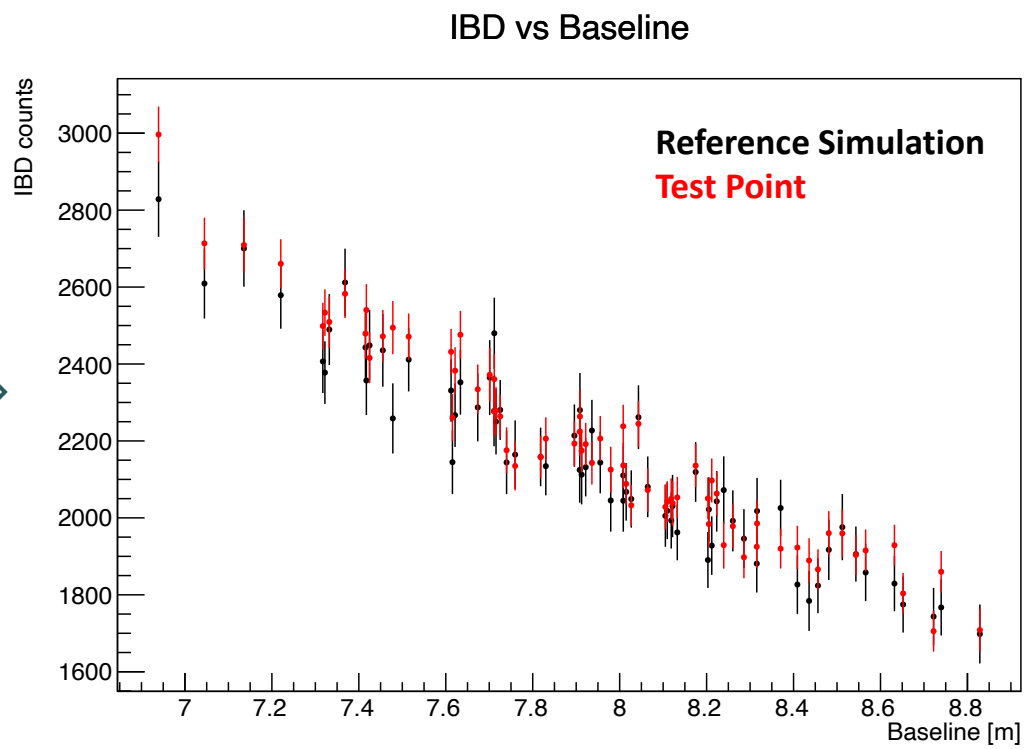


Sensitivity test

We are comparing the IBD counts cell by cell and calculating the corresponding χ2/NDF for each test position.





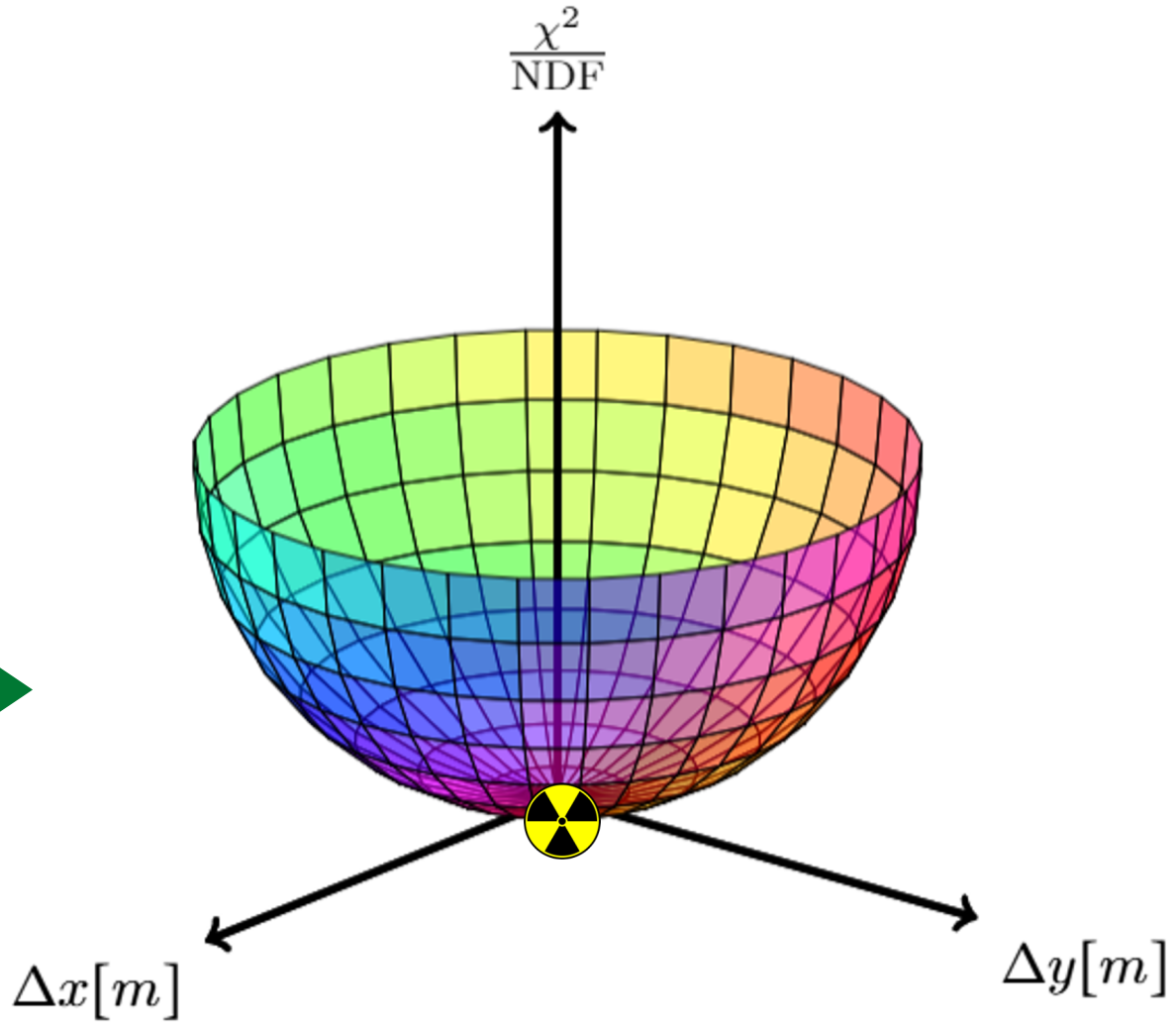


$$\frac{\chi^2}{NDF}$$

Sensitivity test

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

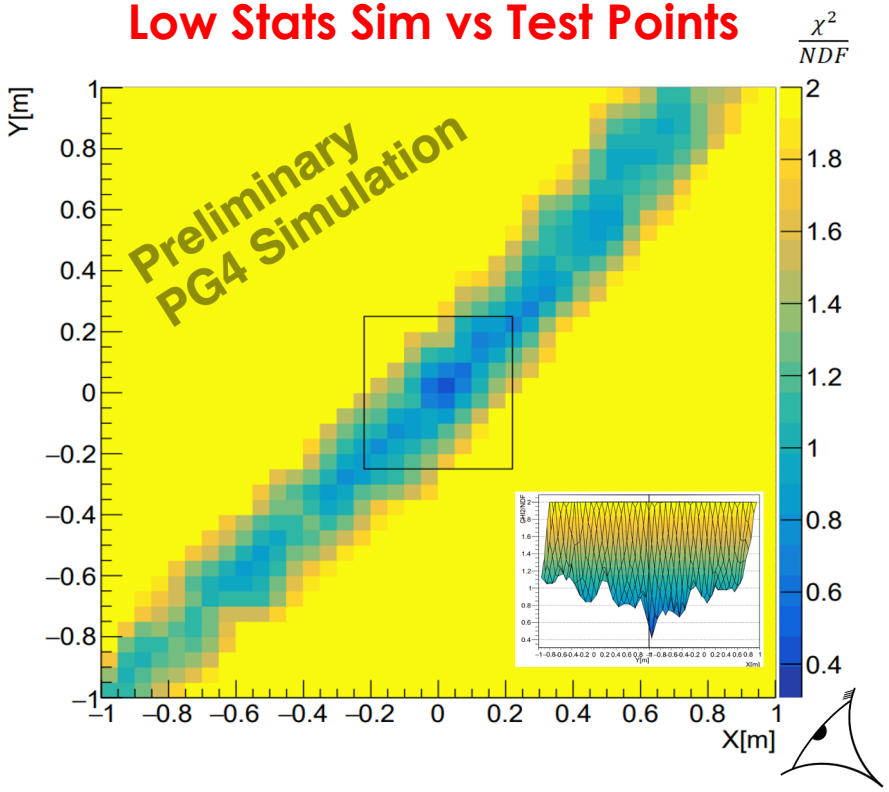
What we would like to see



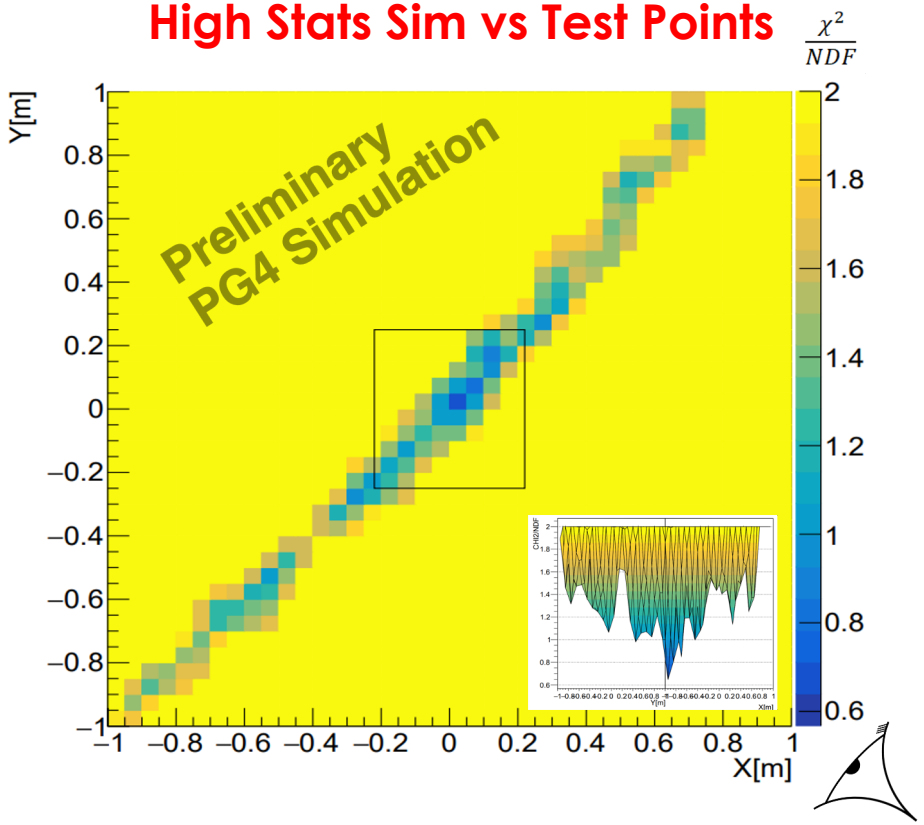
Results

- Preliminary results show that our method is effective at locating the reactor core position, which corresponds to the point of minimum.
- It is observed that certain movements of the core are favored when trying to locate the optimal position.

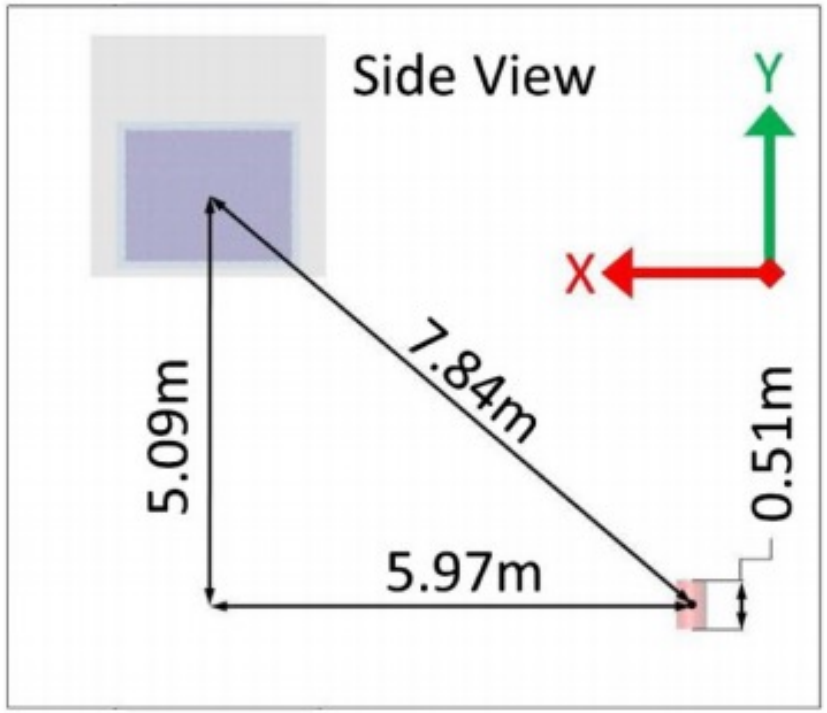
Low Stats Sim vs Test Points



High Stats Sim vs Test Points



Side view of the PROSPECT experimental layout in the HFIR building.



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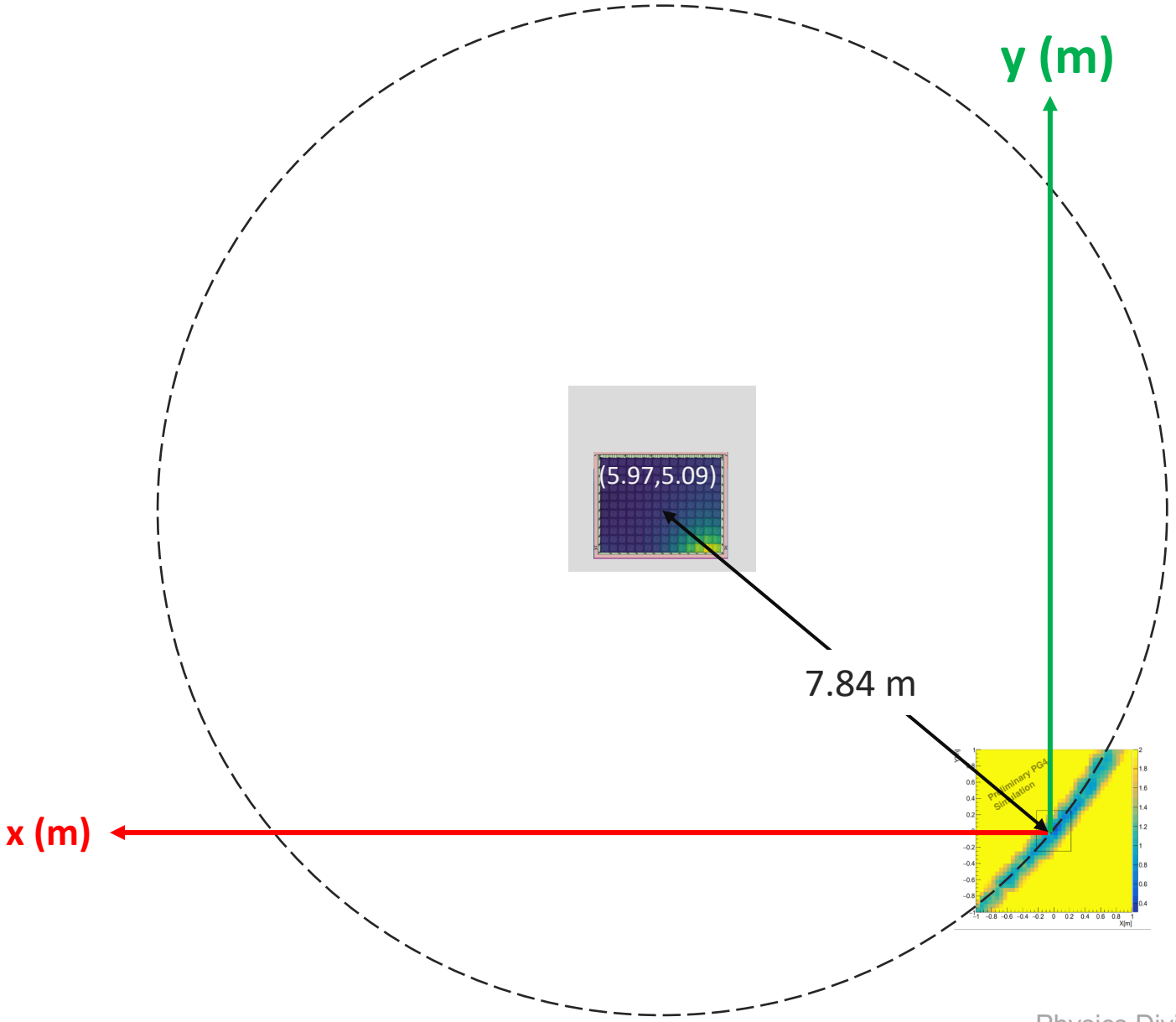
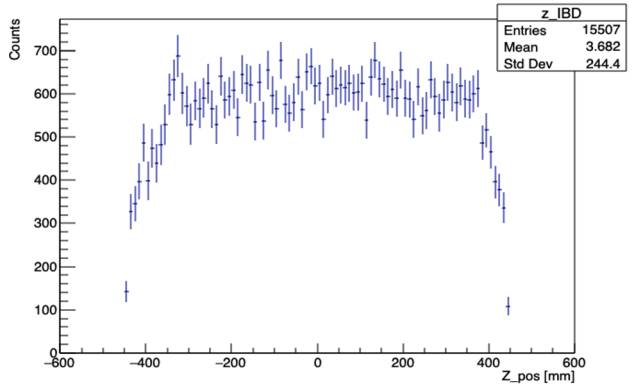


Including information along the z direction

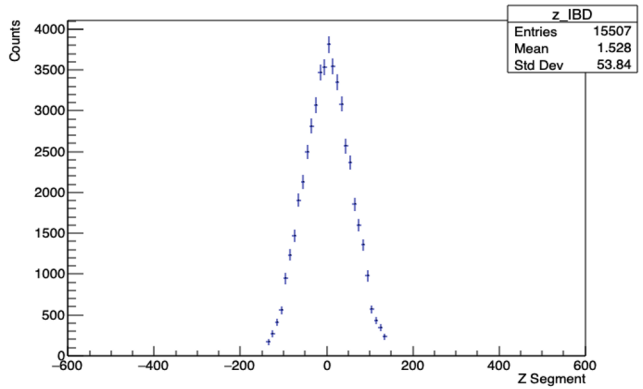
→ In addition to the $1/r^2$ dependence of our signal, we can use the z-reconstruction capabilities from both **Prompt** and **Prompt-Delayed** signals.

→ Recalling that the **Prompt-Delayed** z-position offset preserves the neutrino directionality.

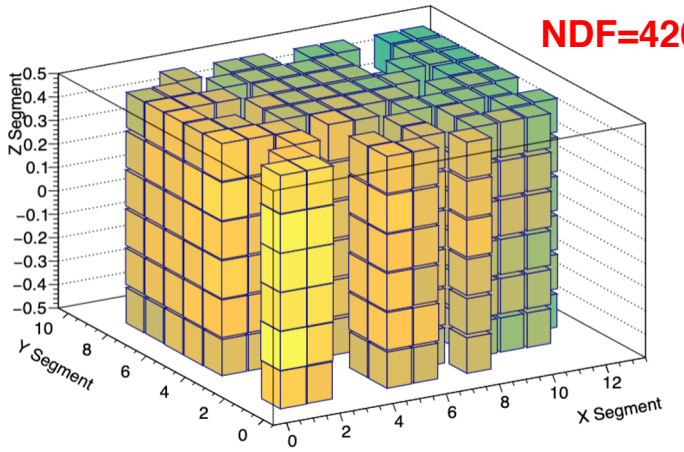
Prompt Signal Z-position



Prompt-Delayed Z-position offset



NDF=420



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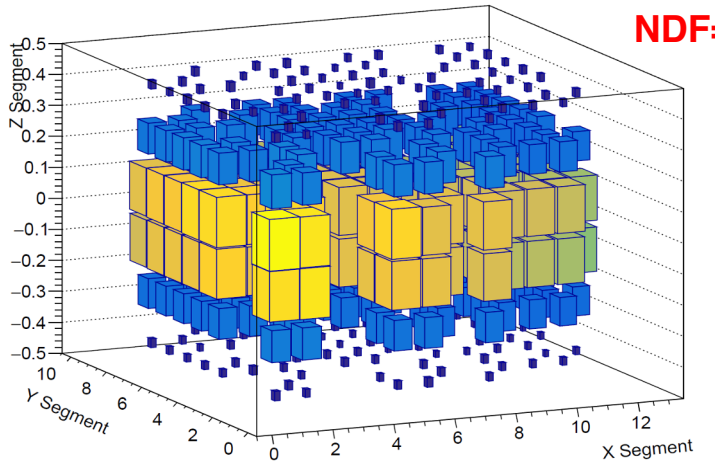

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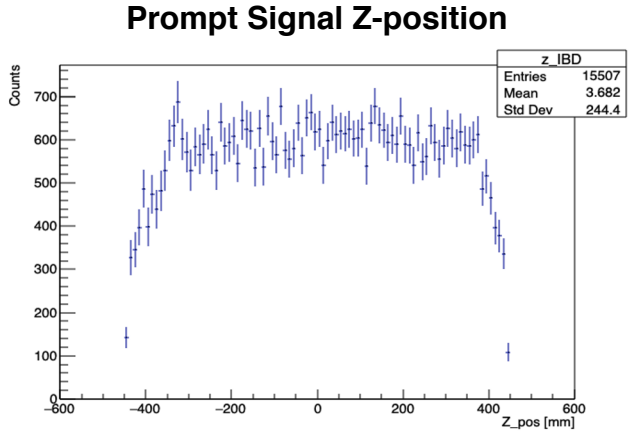
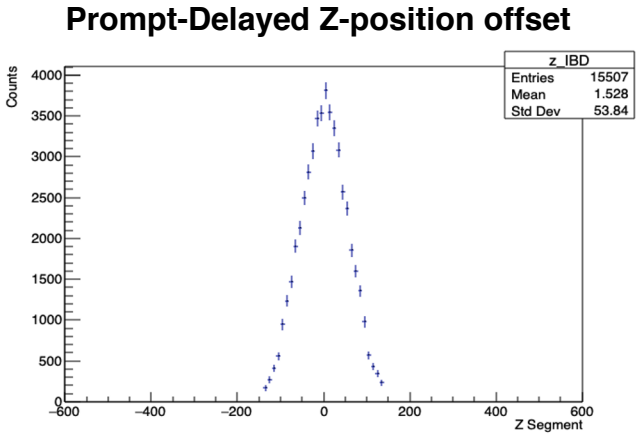
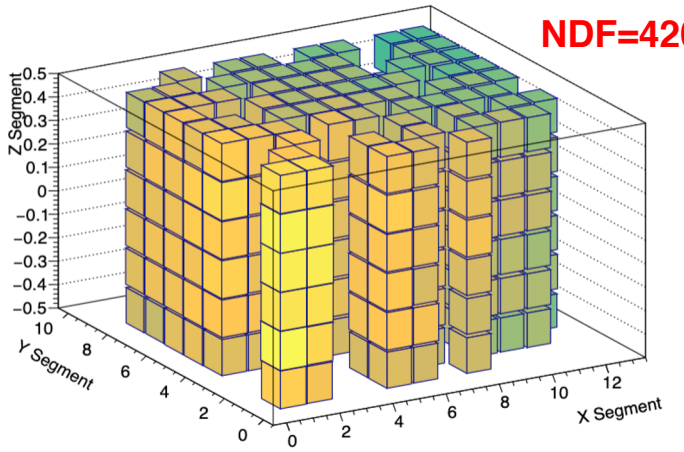
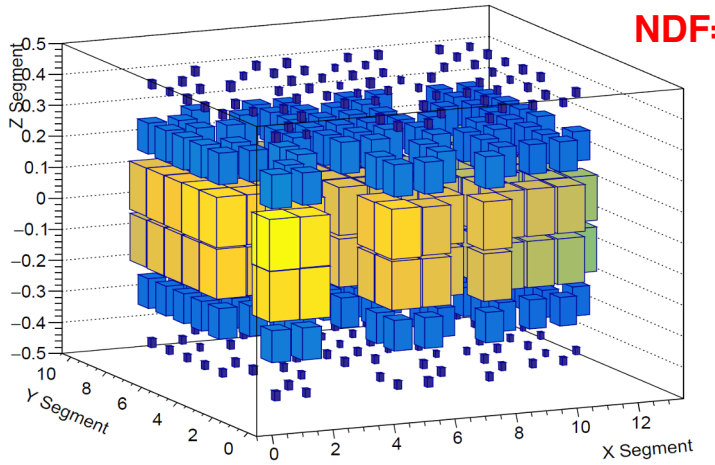
Sensitivity Test including Z-information







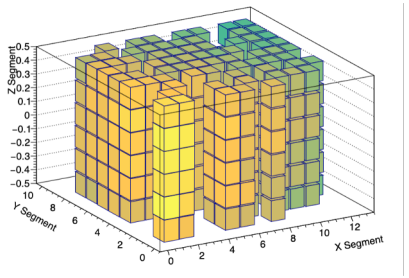


Preliminary Results

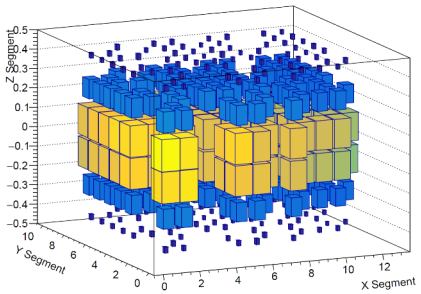
- Both **Prompt** and **Prompt-Delayed** signals preserve the minimum in the nominal position

- The **Prompt-Delayed** signal yields a cleaner band which is in agreement with the directionality argument

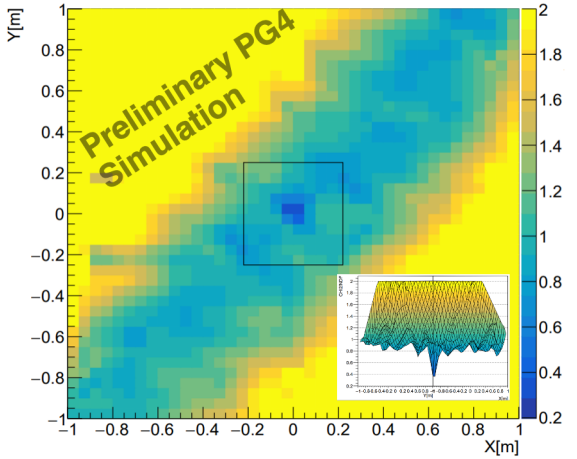
prompt

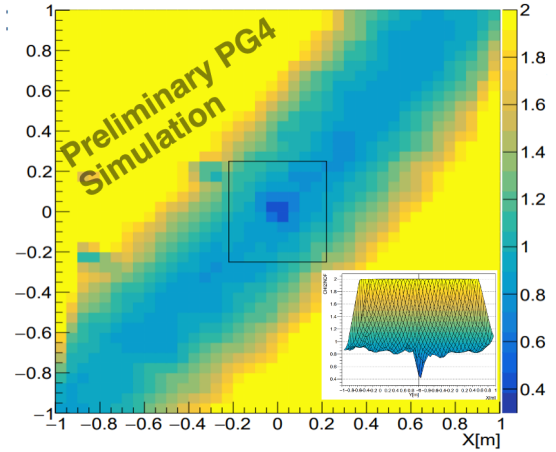


prompt - delayed

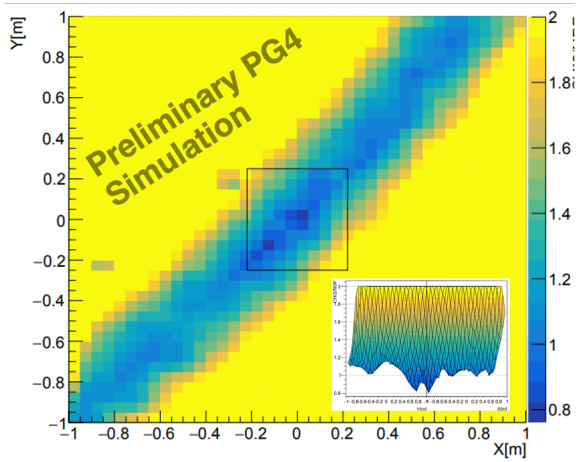


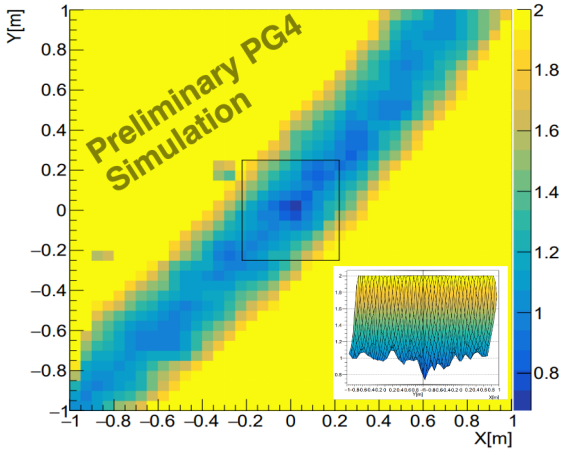
Low Stats





High Stats

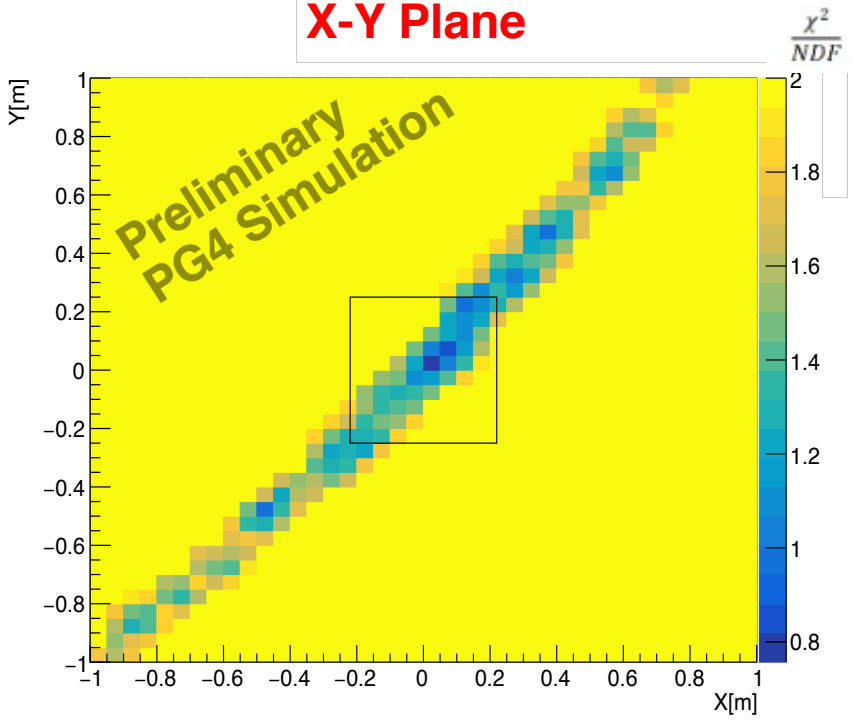




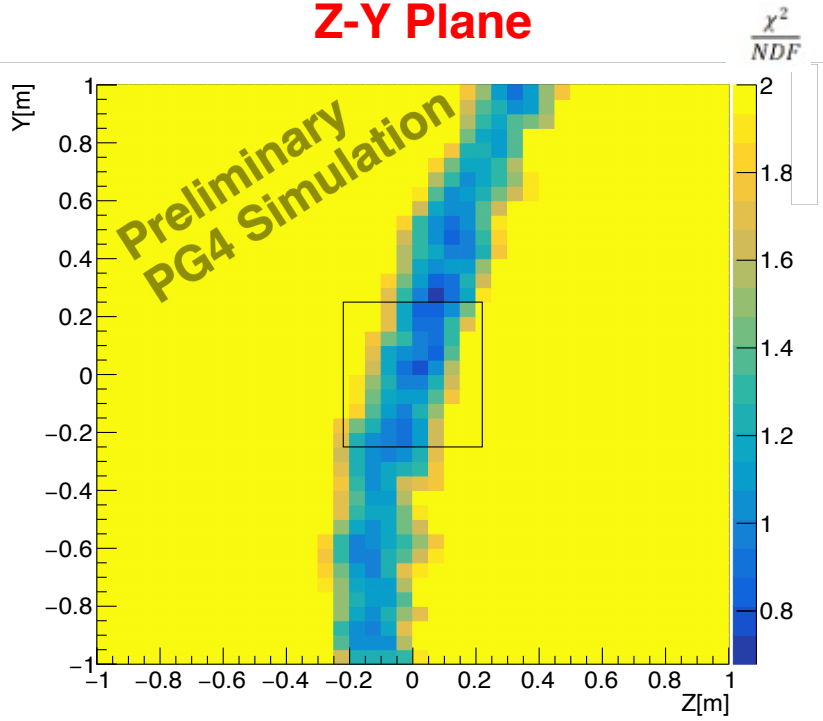
Exploring multiple planes

- Sensitivity studies along different planes of motion for the reactor core seem to prove effective when locating the reactor core position.

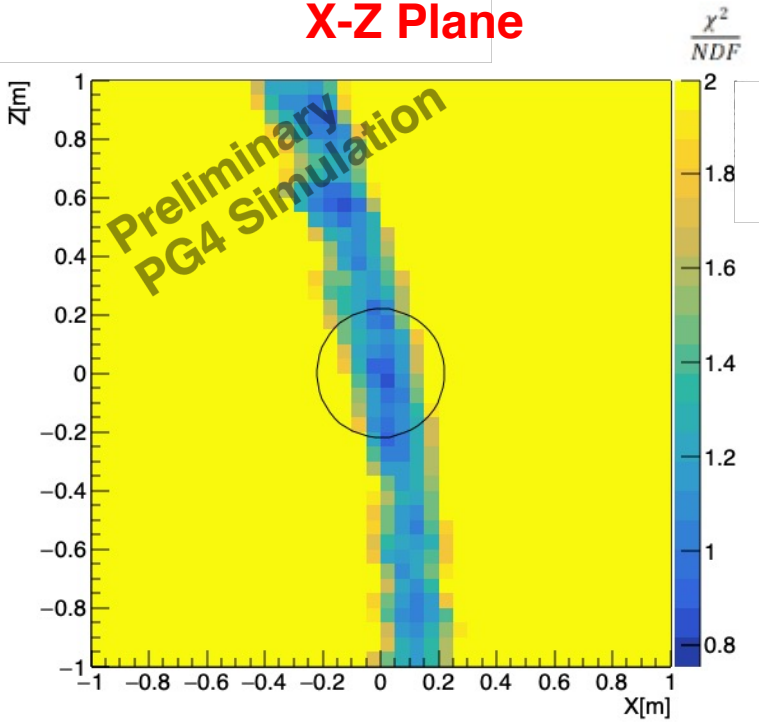
X-Y Plane



Z-Y Plane

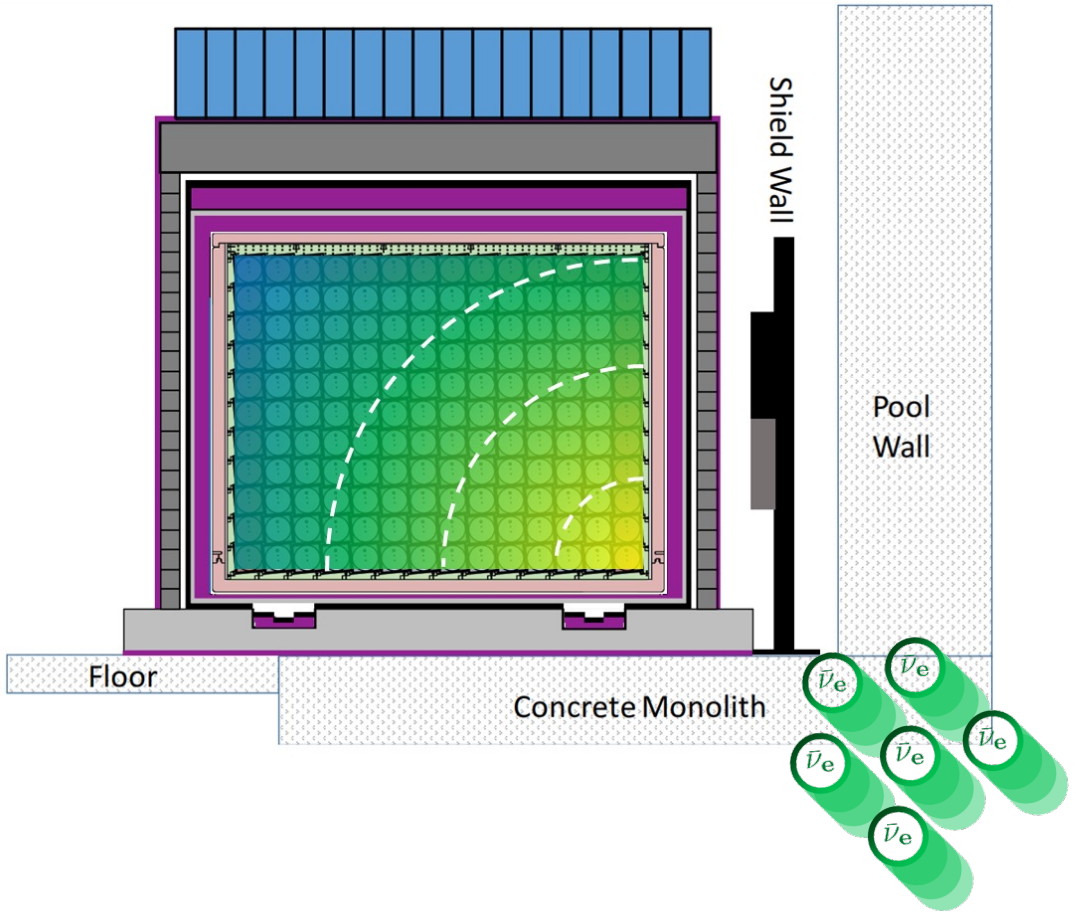


X-Z Plane



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.
- Include z-information coming from cell-offset
- Conduct sensitivity study for test points against real data.



June 2021 Collaboration Meeting, 43 Collaborators

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