Reactor Position Reconstruction Study with PROSPECT

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On behalf of the PROSPECT collaboration
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PROSPECT Detector at HFIR

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

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)

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 $n$-$^6$Li 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

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.

![Graph showing IBD counts vs. baseline with data and $1/r^2$ line]

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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 x data IBD counts)
Sensitivity test

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

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

What we would like to see
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.
Side view of the PROSPECT experimental layout in the HFIR building.

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.
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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.
Exploring multiple planes

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