SoLid: Recent Results and Future Prospects

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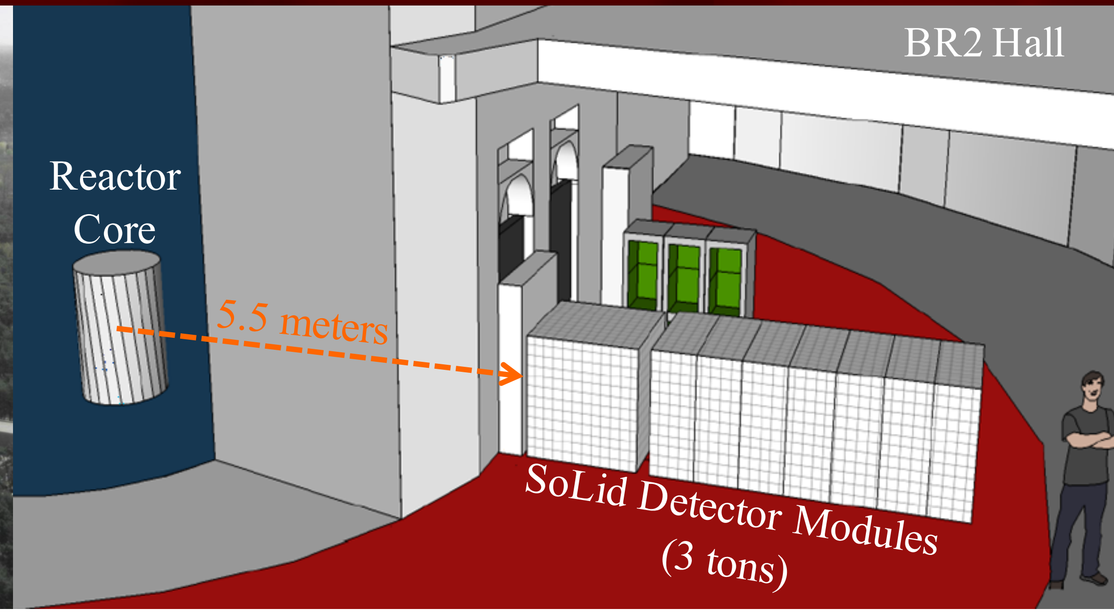
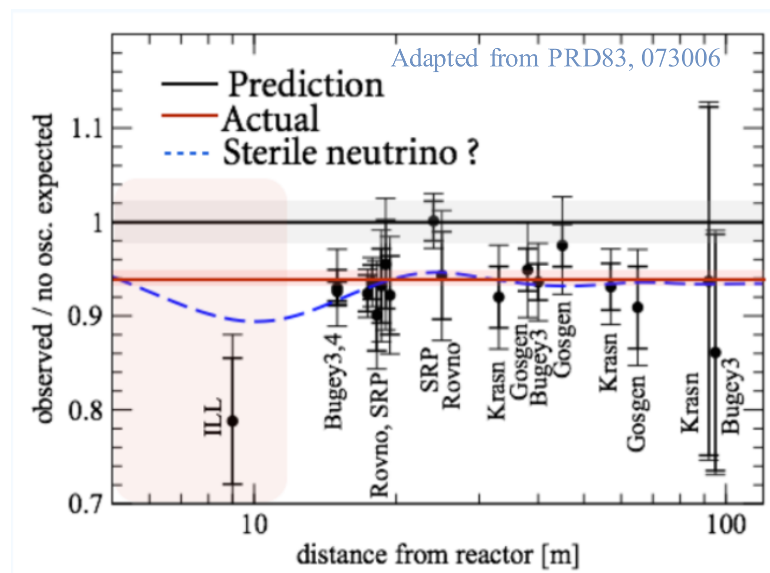
The SoLid Experiment

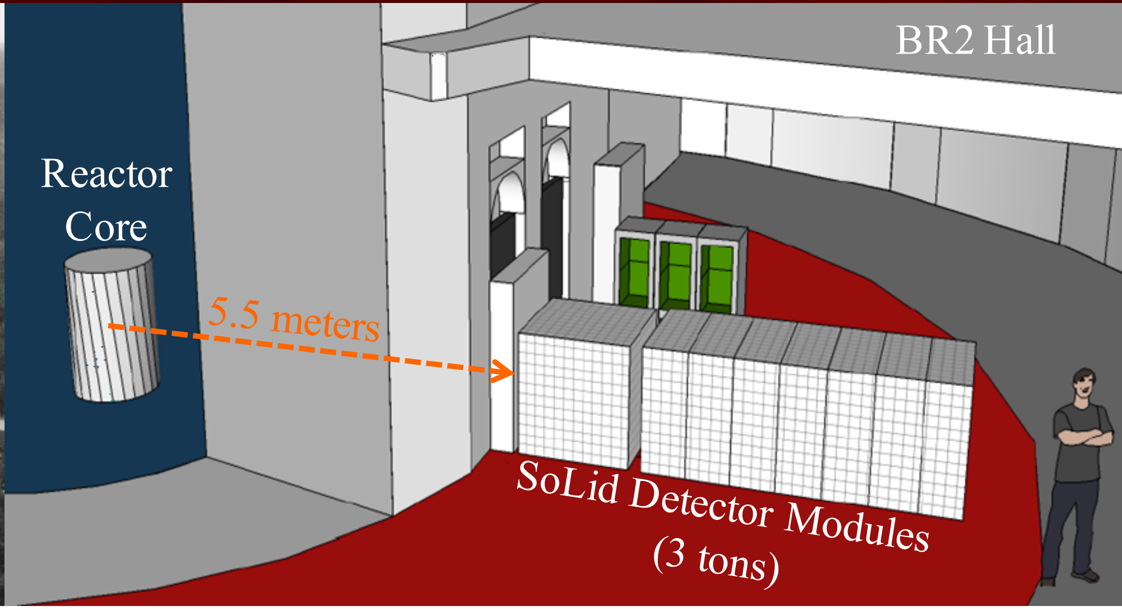


Uses a novel detector technology to

- Search for evidence $\bar{\nu}_e$ disappearance at short-baseline, possibly induced by sterile neutrinos,
- Measure the ^{235}U fission neutrino flux to improve flux predictions, and
- Demonstrate reactor neutrino safeguards for non-proliferation.



The SoLid Experiment



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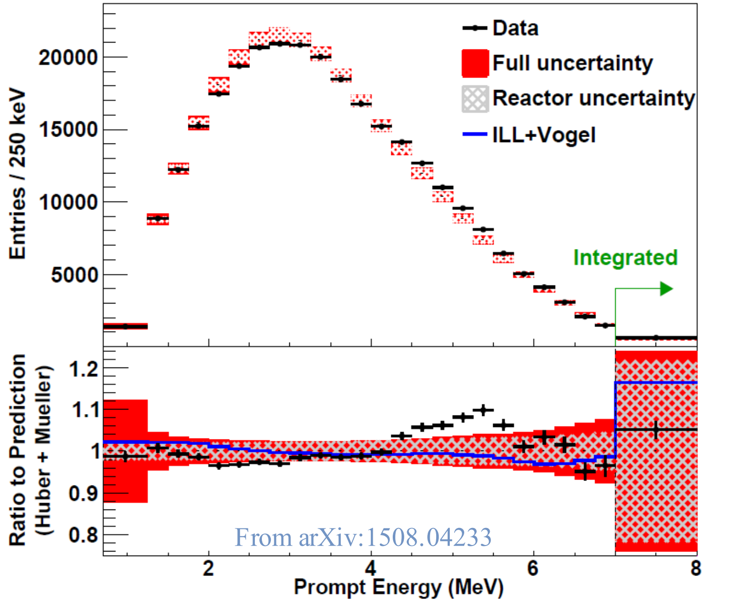


Reactor Neutrino Detection and Backgrounds

Reactors antineutrinos ($\bar{\nu}_e$) interact via the inverse beta-decay process:

$$\bar{\nu}_e + p \rightarrow e^+ + n$$

The positron makes a prompt signal, while the neutron thermalizes and is captured, giving a delayed response.

The coincidence in space and time of the positron and neutron capture helps to reject most radioactive and cosmogenic backgrounds.

Correlated backgrounds include fast neutrons, spallation produced β/n emitters (^{9}Li and ^{8}He), and random coincidences.

Random coincidences dominate in surface experiments, especially in the radioactive environment close to a running reactor.

Good spatial resolution and high purity neutron detection are essential to reduce this background.

The Novel SoLid Detector Concept

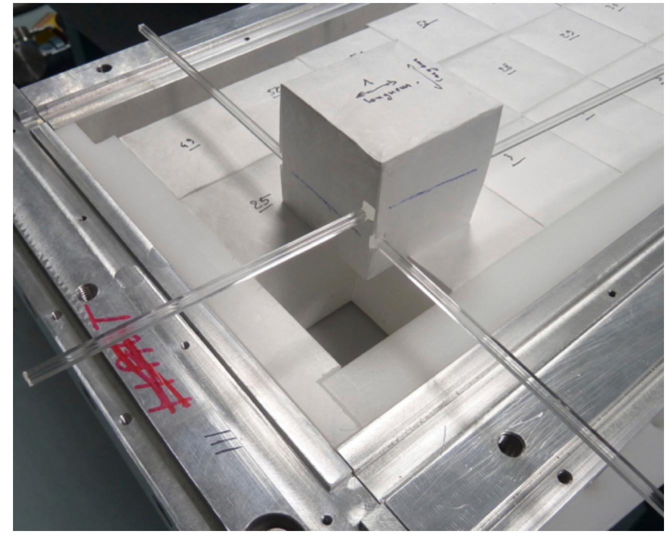
Primary neutrino interactions are detected in 5 cm, optically isolated cubes of plastic scintillator, which are read out by wavelength shifting fibers in two dimensions.

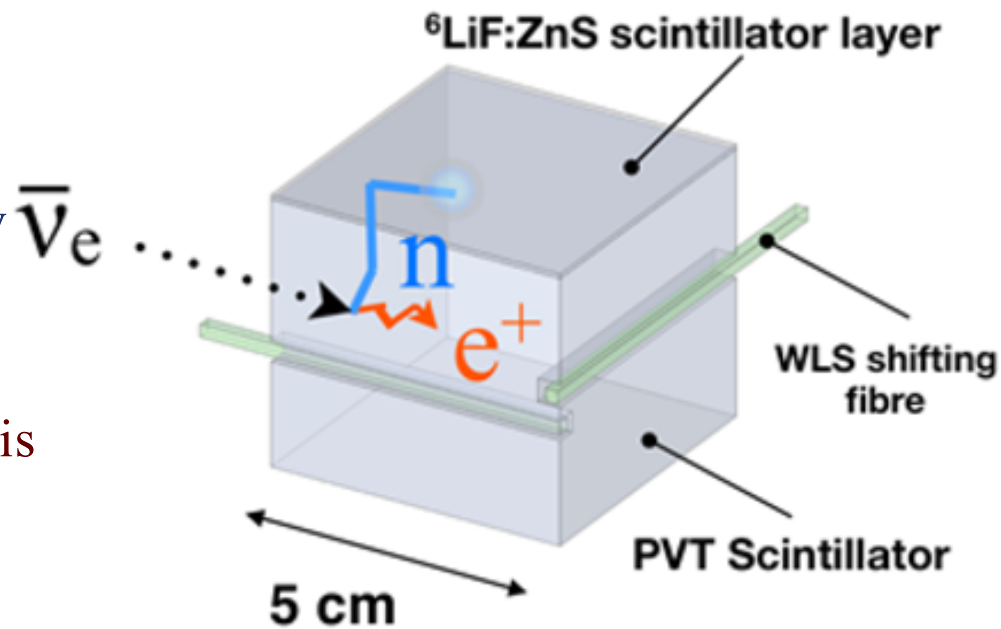
Neutrons are tagged in thin sheets of ^{6}Li-loaded, silver activated zinc sulfide scintillator: ^{6}LiF:ZnS(Ag).

$$^{6}\mathrm{Li} + \mathrm{n} \rightarrow {}^{4}\mathrm{He} + {}^{3}\mathrm{H}$$

ZnS(Ag) releases light with a 200 ns mean emission time which forms a very pure, high efficiency neutron tag.

The cube segmentation results in unprecedented spatial resolution which is used to significantly reduce random coincident backgrounds.





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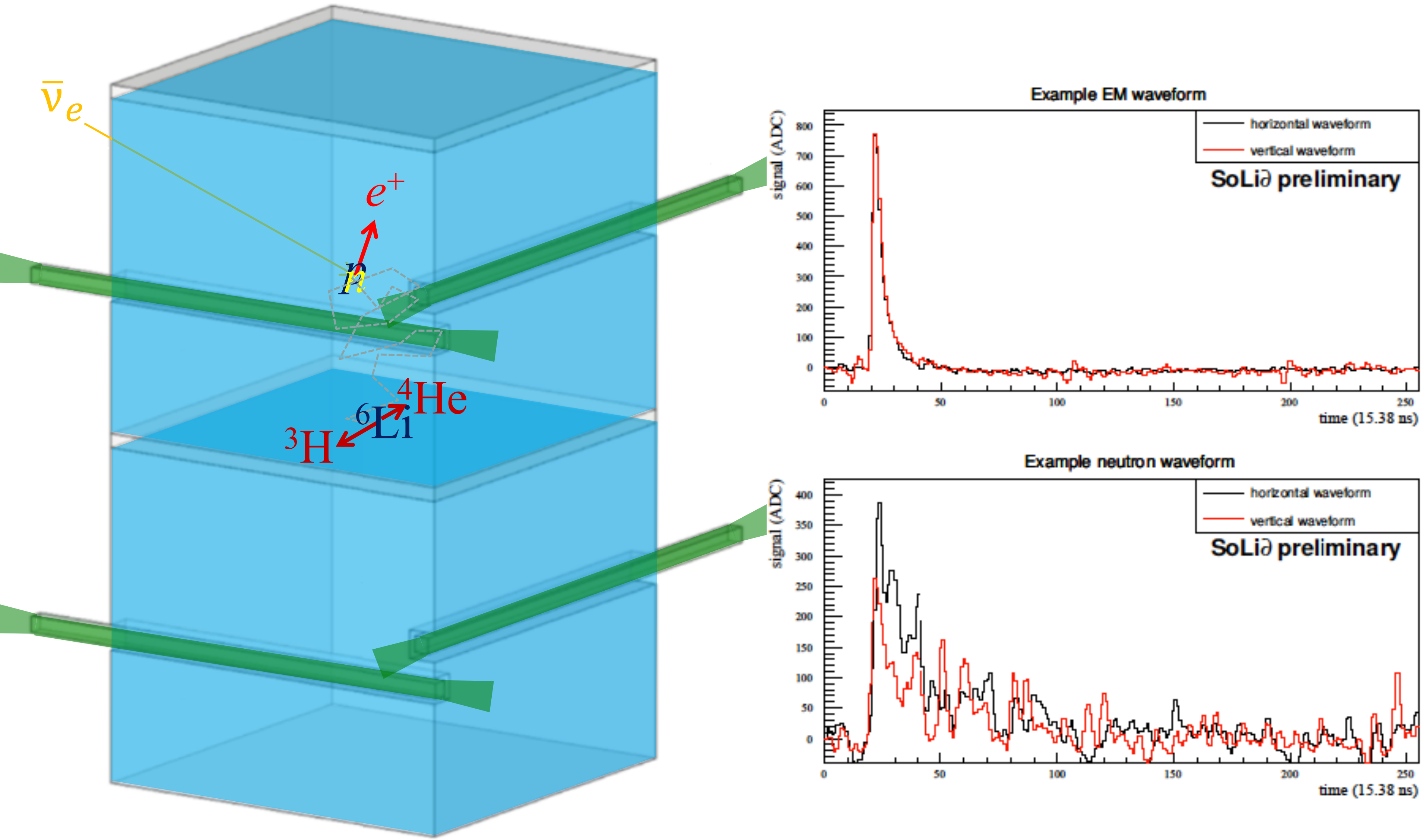
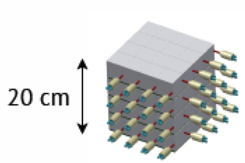


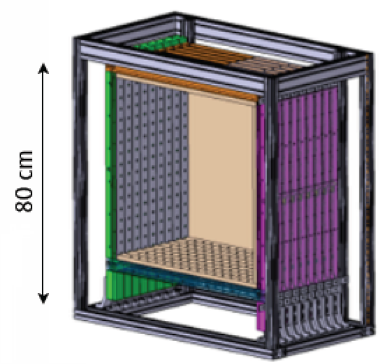
SoLid Detector Development

2013



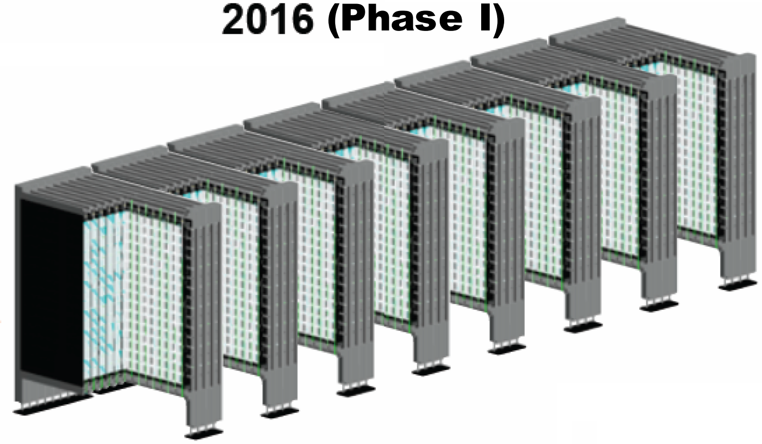
20x

2014-2015



8x

2016 (Phase I)



- NEMENIX
8kg, 64 cubes
and 32 channels

- SoLid Module 1 (SM1)
288kg, 9 detector planes of
16×16 cubes

- 8 SoLid Modules
2 tons, 11,520 cubes
2592 channels

Proof of Concept

1. Demonstrate neutron PID
2. Measure Backgrounds
3. Measure Coincidence Rate

Real Scale Systems Test

1. Demonstrate scalability
2. Test Production (schedule & procedures)
3. Demonstrate Power of Segmentation

Real Scale Systems Test

1. Implement Neutron Trigger
2. Optimize Production
3. Optimize Performance
4. Do Initial Oscillation Search

> 40 days Reactor on Data
(~3 reactor cycles)

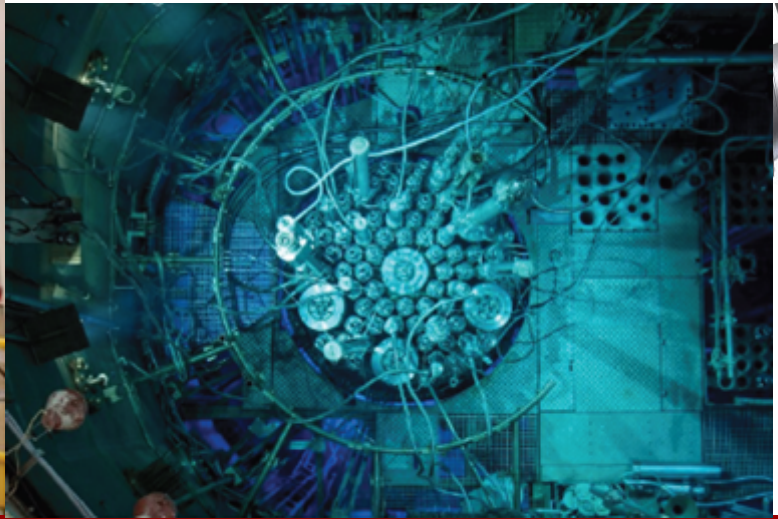
1 week Reactor on Data
2 months Reactor off

Anticipate 1 year of Phase I Data

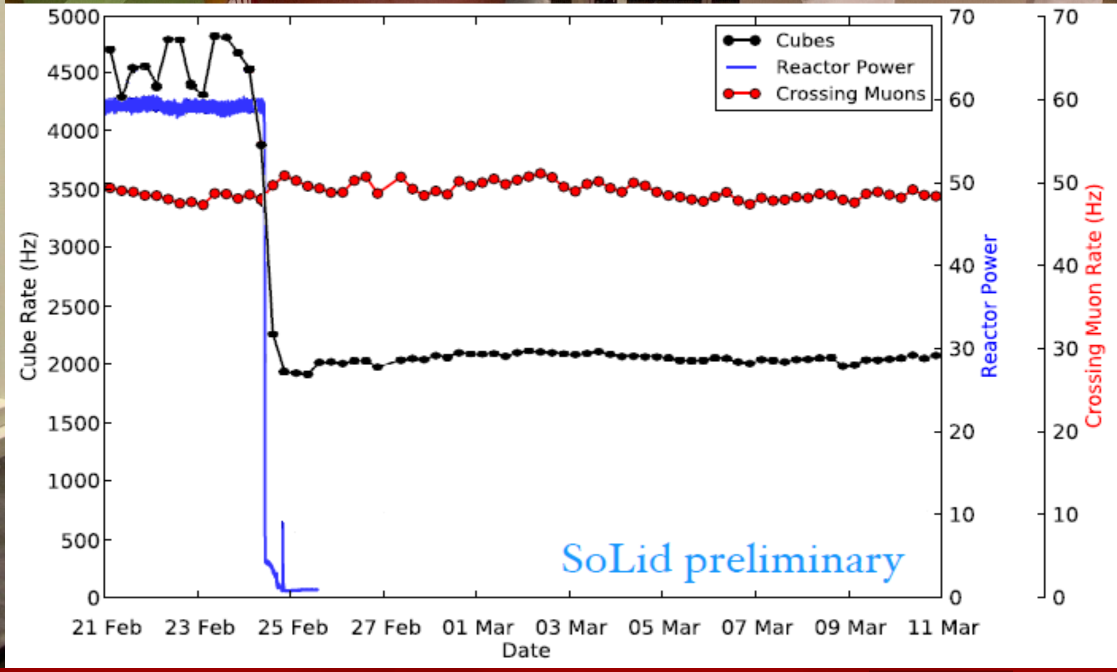
The BR2 Reactor at SCK•CEN (Mol, Belgiun)

Large available floor space covering baselines of 5.5 to 12 meters.

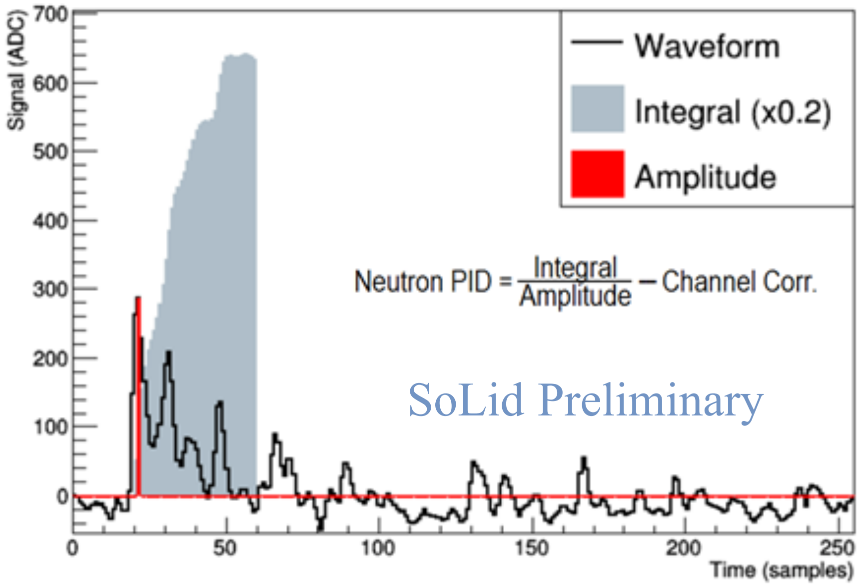
- Compact Source (50 cm effective core diameter)
- High Power (40-80) MW typical operating range)
- Highly Enriched ^{235}U Core
- 150 days/year Duty Cycle
- Low reactor correlated neutron and gamma rates

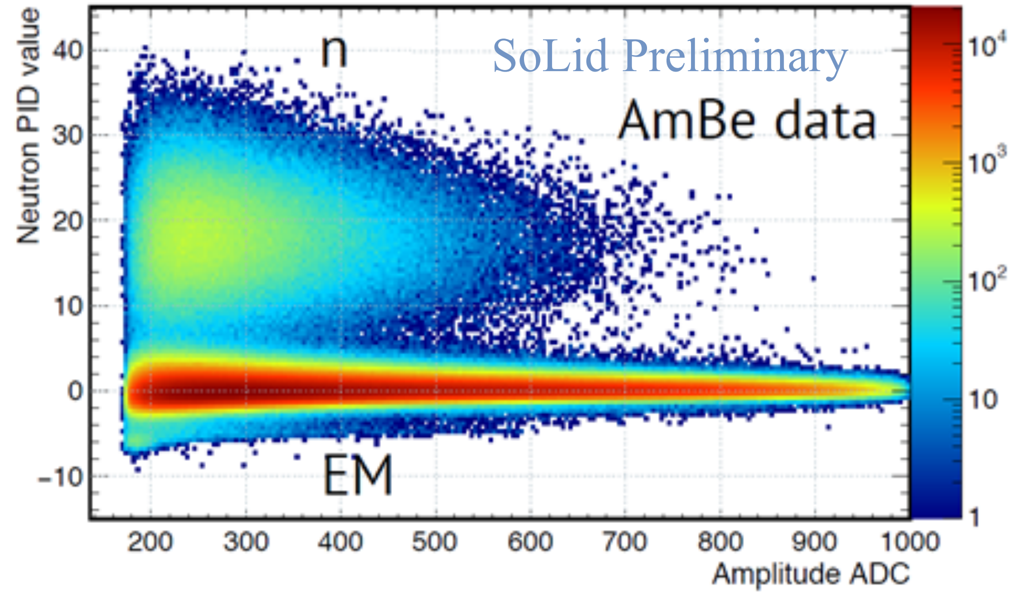


SM1 Test Run at BR2



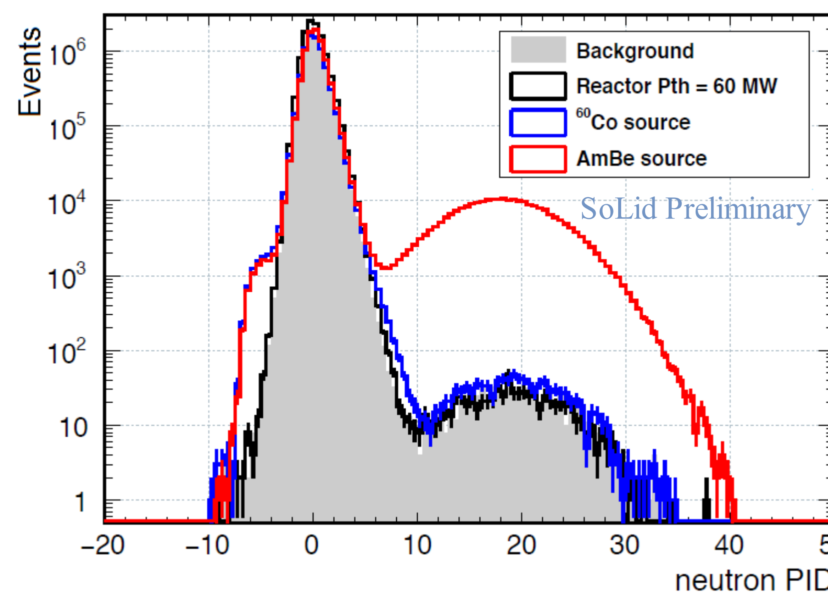
Neutron Identification in SM1





Neutron ID is based on the ratio of signal pulse integral to its amplitude.

Neutron source data confirms a clear separation between neutron and electromagnetic events.



Inverse Beta Decay Analysis

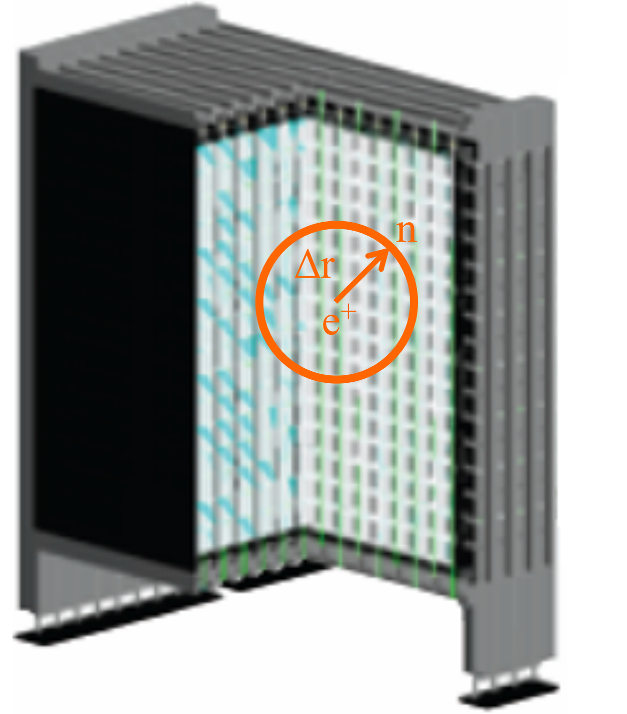
First data processing completed:
  Data reduction, filtering, calibration and reconstruction

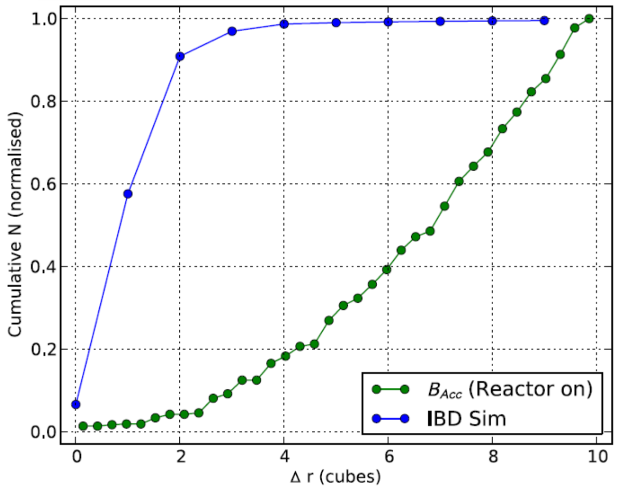
SM1 MC response tuning is ongoing

Study of background events and selection cuts has started

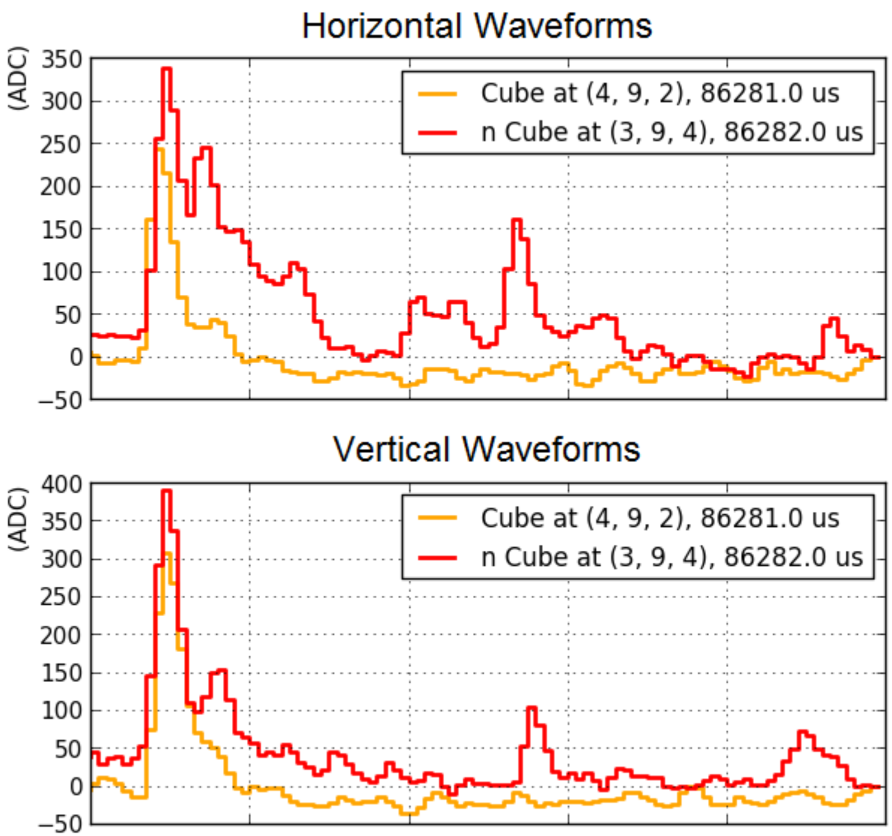
With cube segmentation we expect a signal/background of about 2

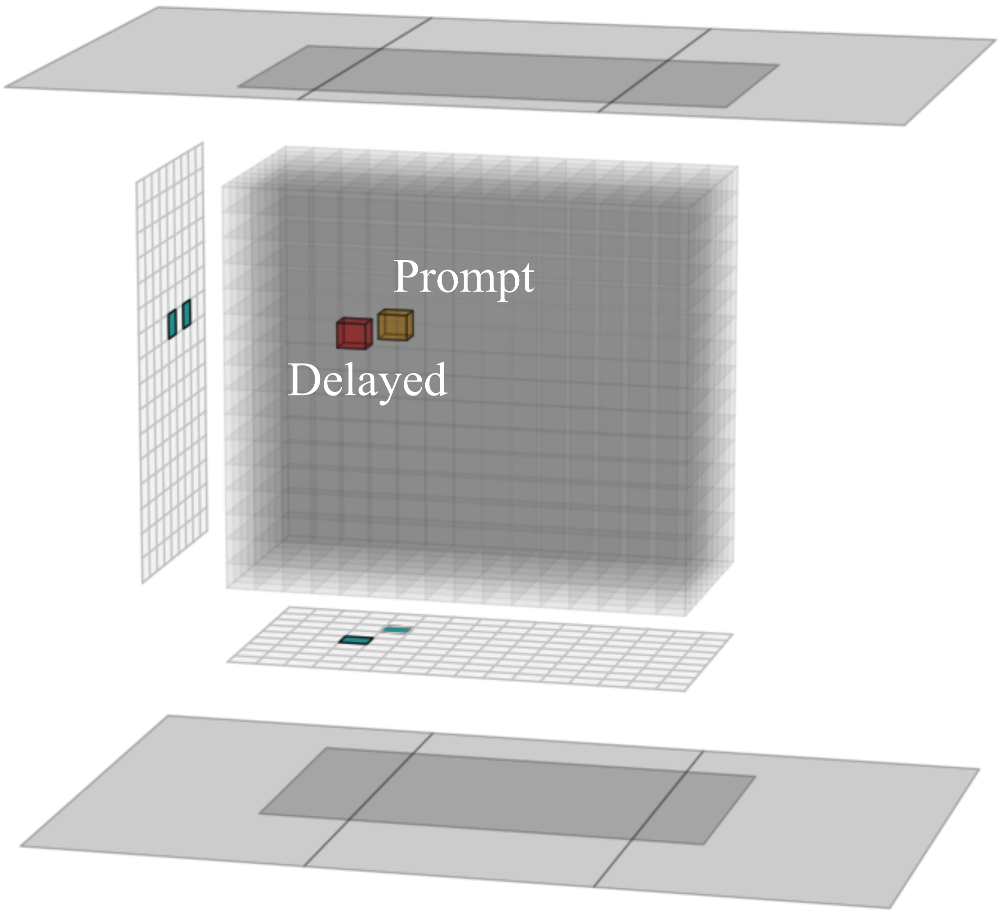
Aim for result early this year





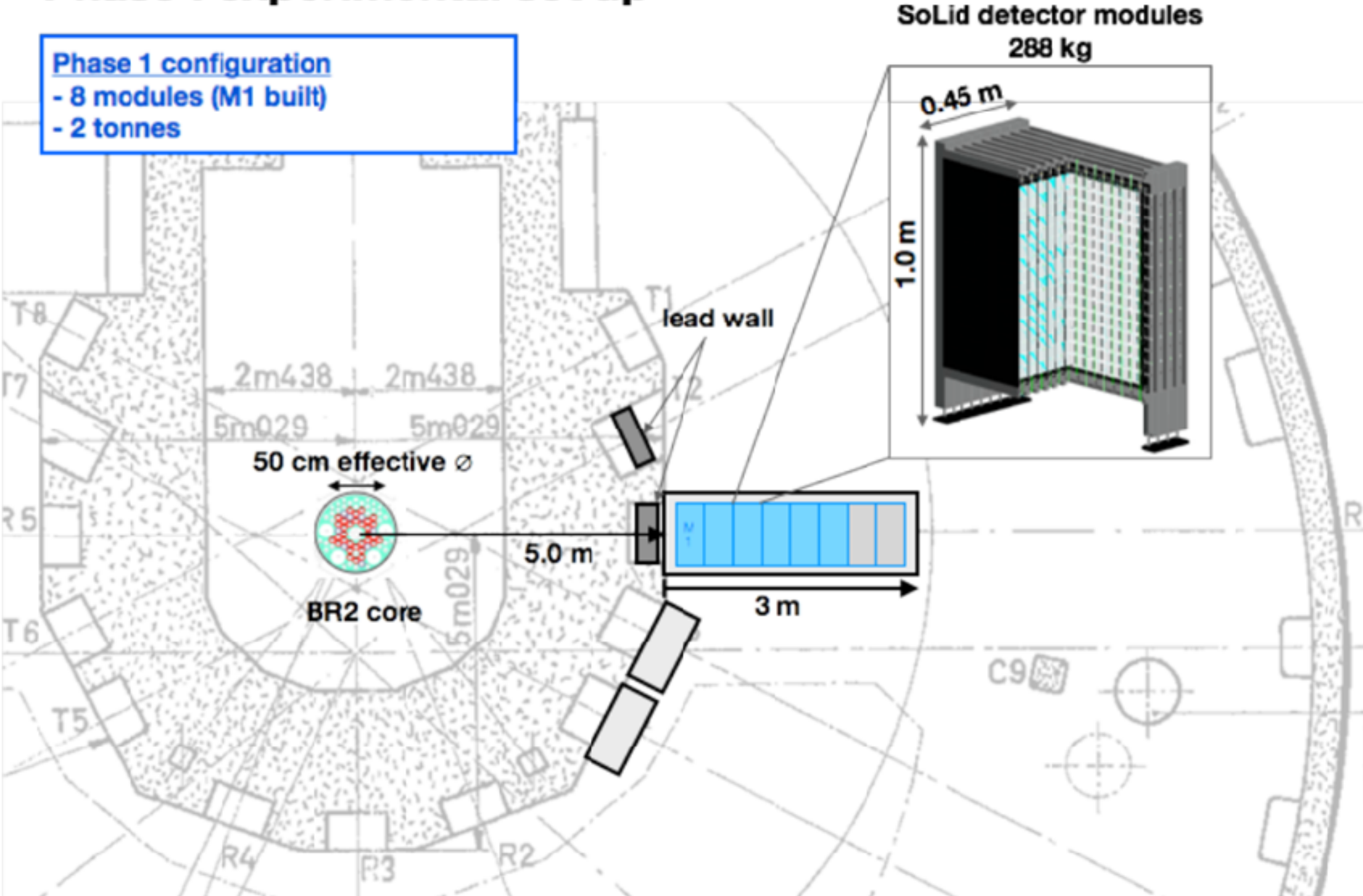
Antineutrino IBD Candidate Event





SoLid Run Plan (2016)

Phase I experimental set up



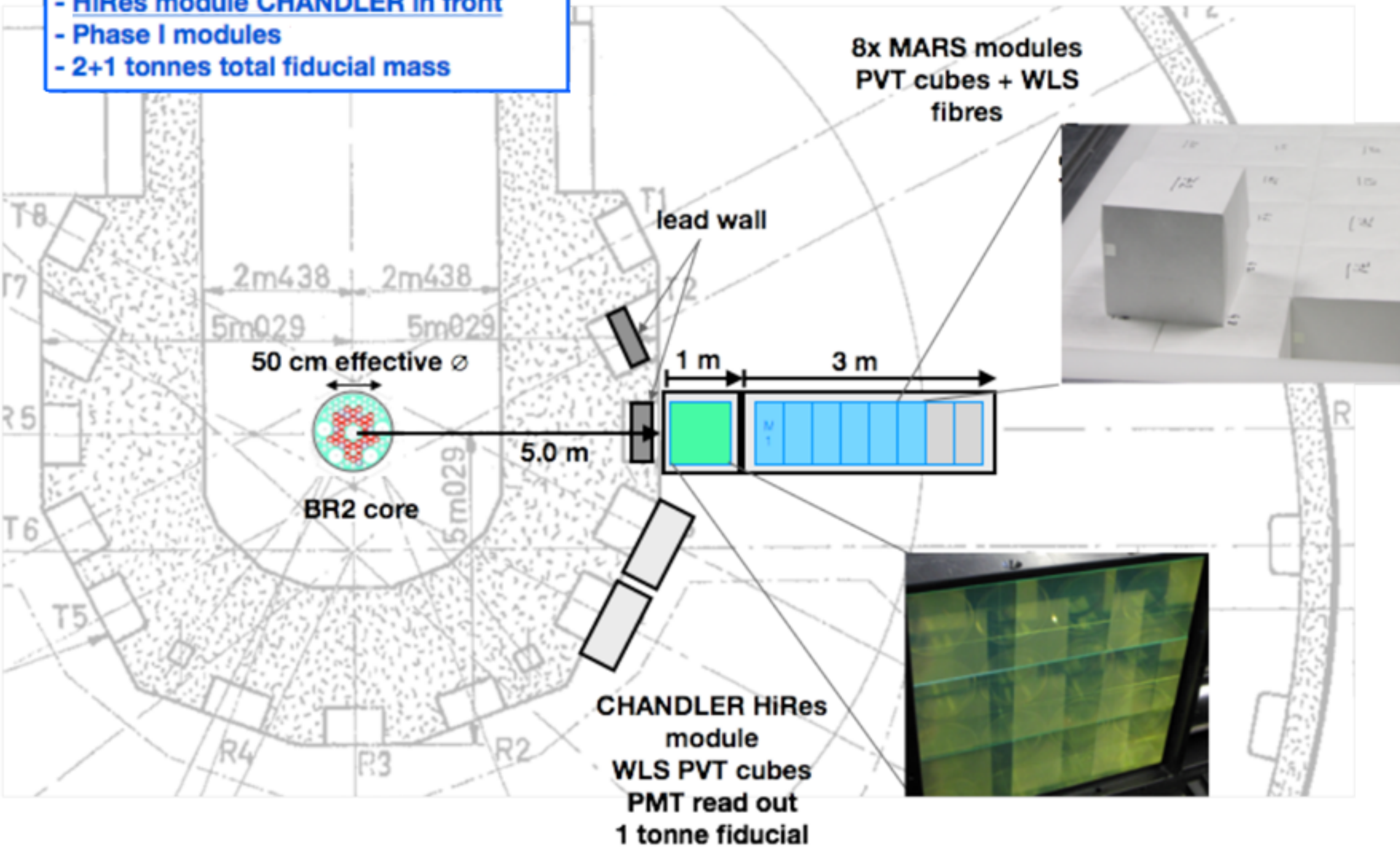
150 Days of Reactor on

SoLid Run Plan (2017-2020)

Phase II experimental set up

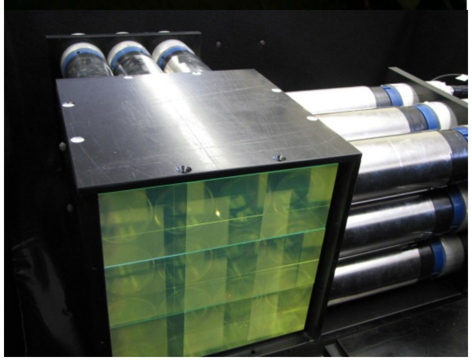
450 Days of Reactor on

Configuration:
- HiRes module CHANDLER in front
- Phase I modules
- 2+1 tonnes total fiducial mass

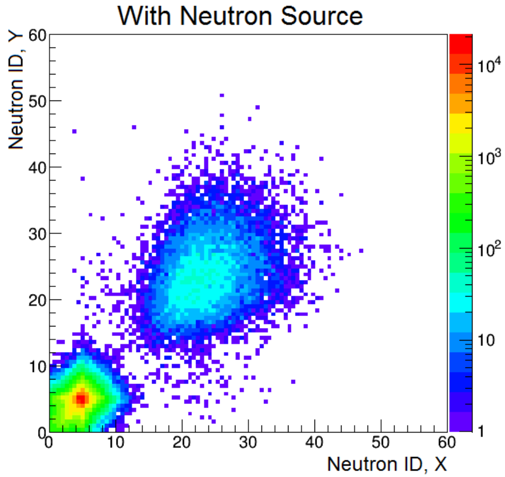


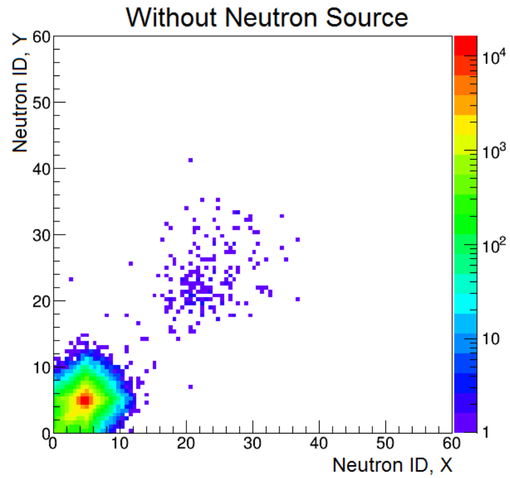
CHANDLER R&D Effort

Cube String Studies have been used to study light production, light collection, light attenuation, energy resolution and wavelength shifter concentration.



MicroCHANDLER is a 3×3×3 prototype which we are using to test our full electronics chain, develop the data acquisition system, study neutron capture identification and measure background rates.





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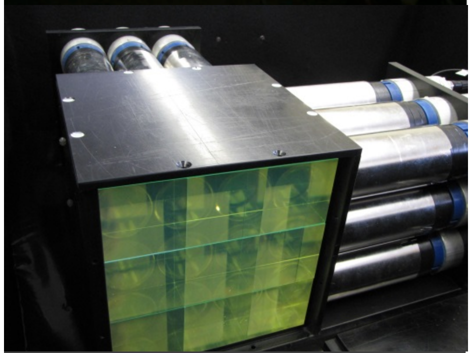

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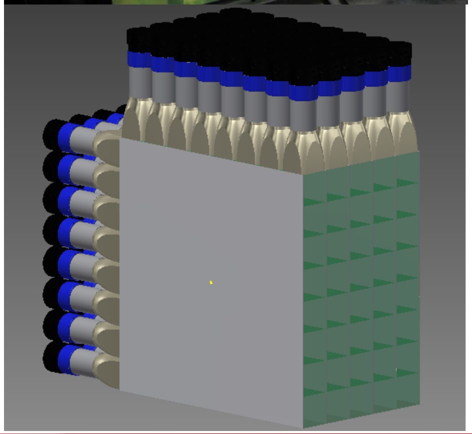


MiniCHANDLER is a **fully funded** systems test (8×8×5) which is currently under construction and will be deployed at a commercial nuclear power plant. It will be operational winter 2016.

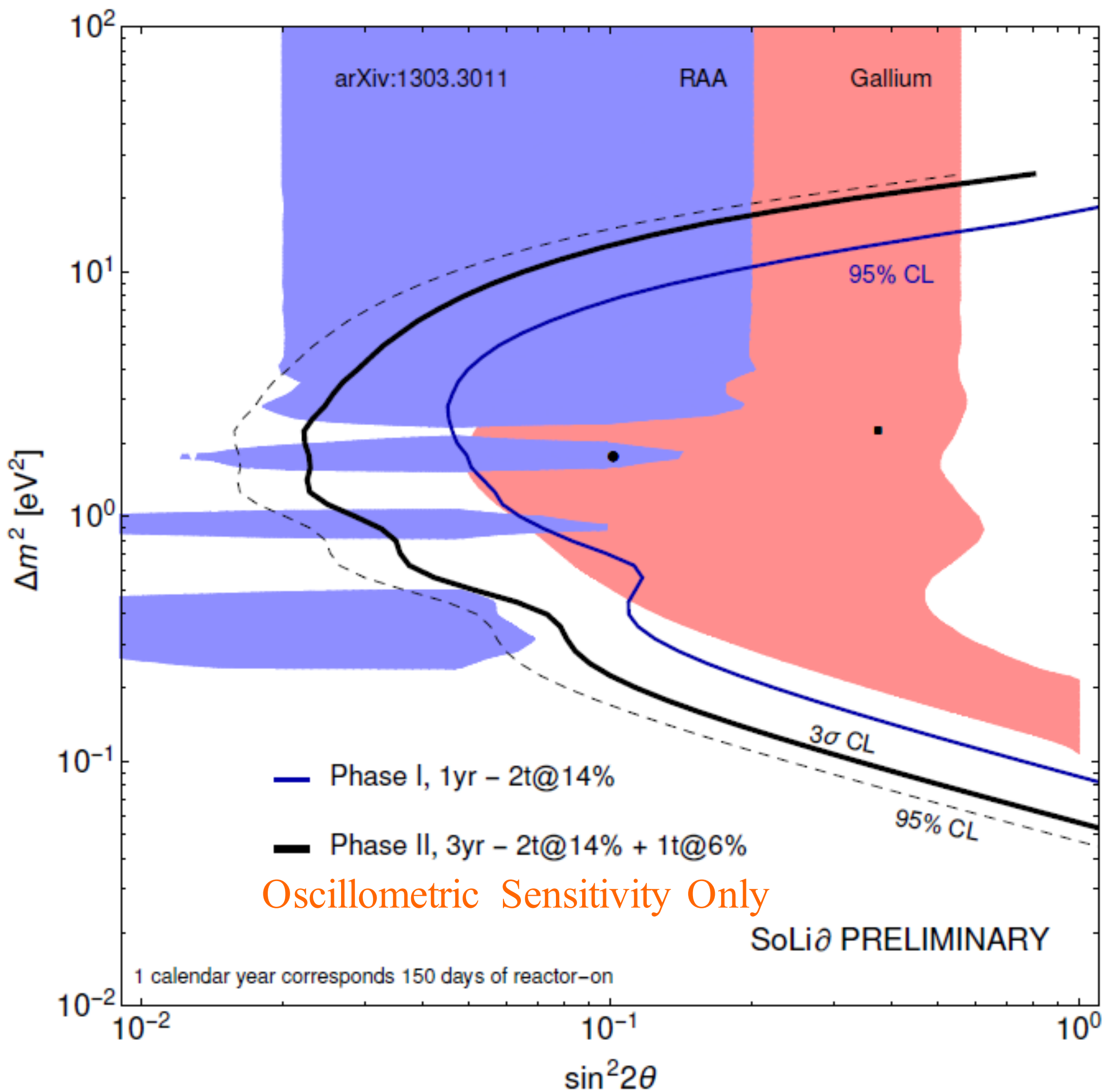
SoLid and CHANDLER Sensitivity

The combined sensitivity for the SoLid/CHANDLER deployment at BR2 is compared to the Gallium and Reactor Anomalies.

The one-year, Phase I SoLid deployment covers most of the low Δm^2 part of the Gallium Anomaly at 95% CL.

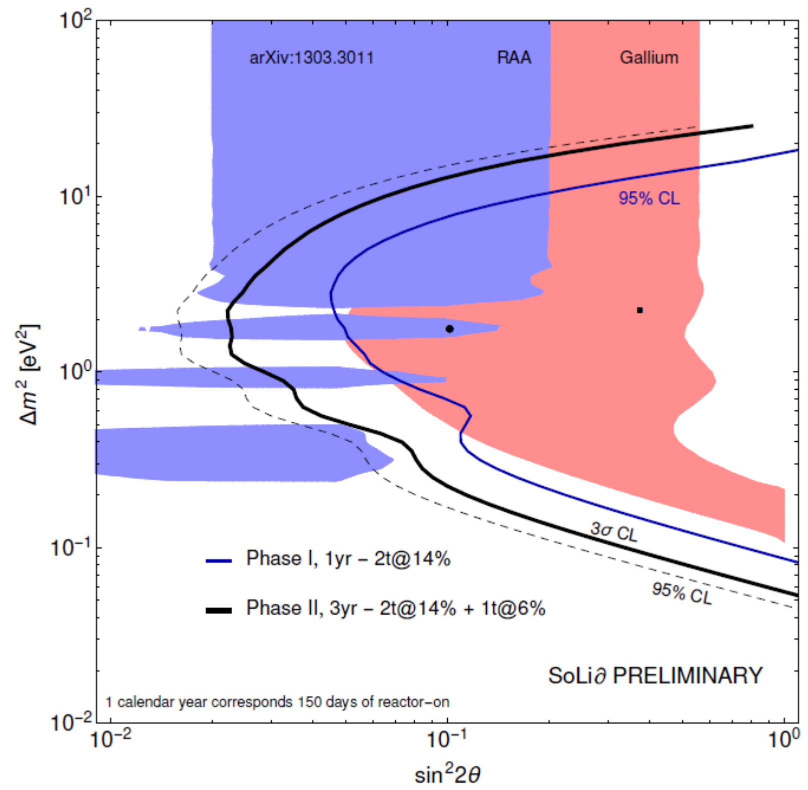
Adding CHANDLER to the three-year Phase II extends the coverage to higher Δm^2 and pushes the reach well into the Reactor Anomaly.

These sensitivities are purely oscillometric, based on energy spectrum and baseline information alone.

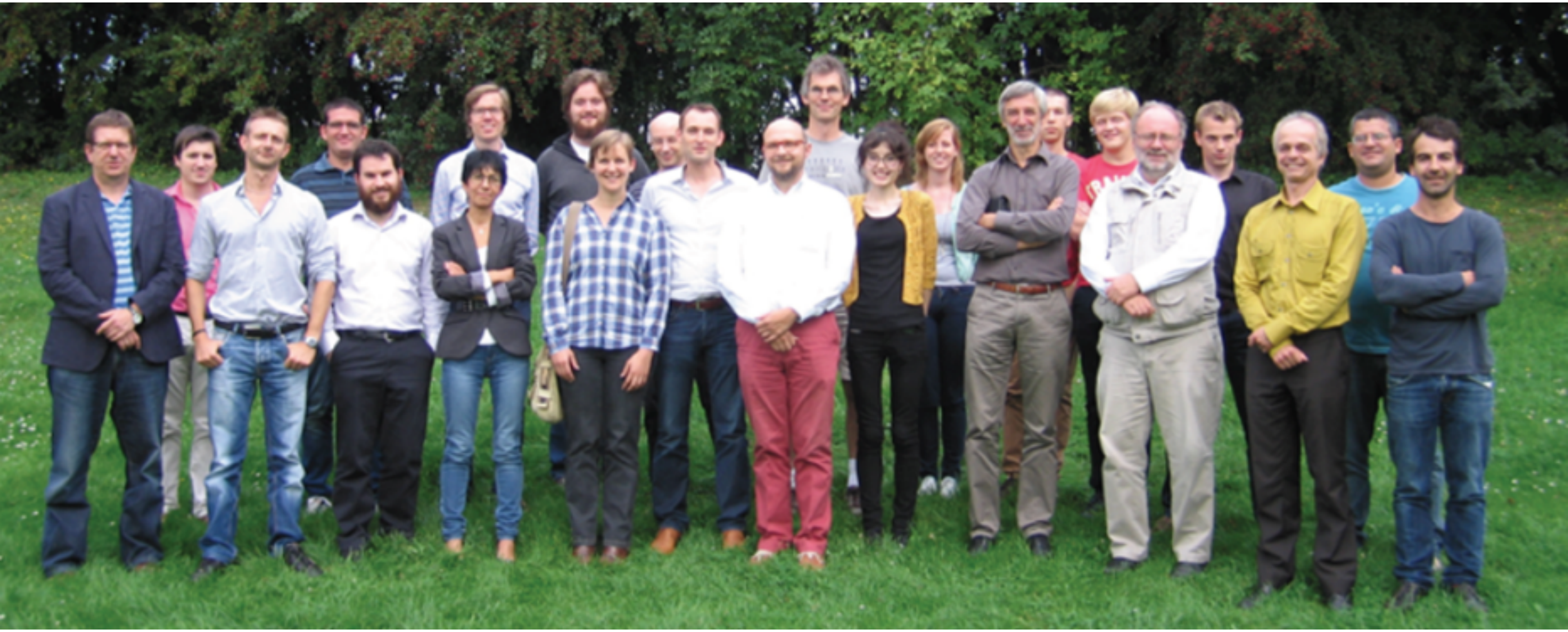


Conclusions

1. The SoLid experiment will make a very sensitive search for reactor antineutrino disappearance using a novel compact detector.
2. The high spatial resolution and pure neutron tag are designed to significantly reduce background rates.
3. The SM1 run was a success and data analysis is progressing. The excellent neutron identification has been demonstrated.
4. CHANDLER is an extension of the SoLid concept with significantly improved energy resolution.
5. The combined CHANDLER/SoLid run will cover most of the allowed $\bar{\nu}_e$ disappearance space.



The SoLid Collaboration



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