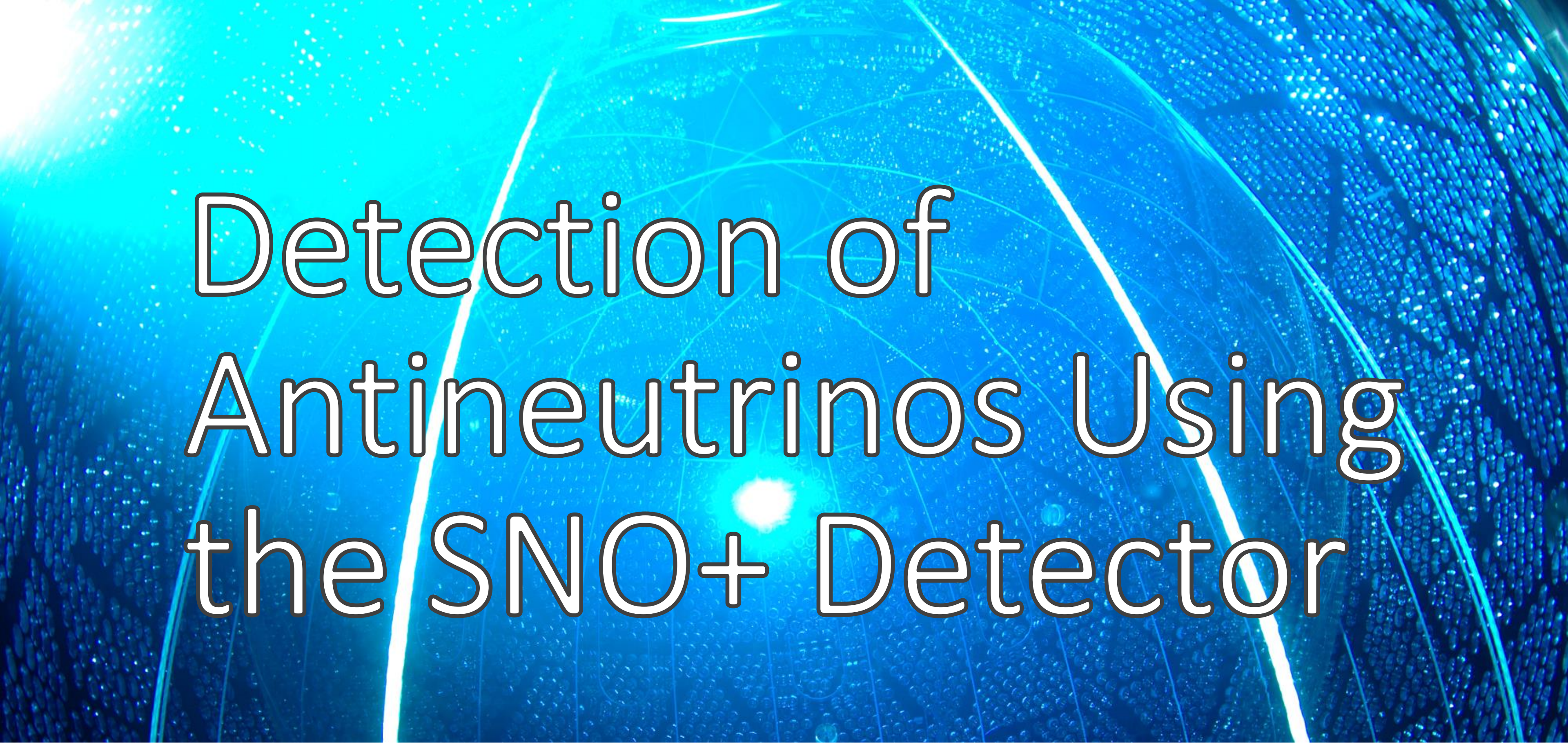
Detection of Antineutrinos Using the SNO+ Detector



PAWEL MEKARSKI

FEBRUARY 17, 2017

WNPPC 2017

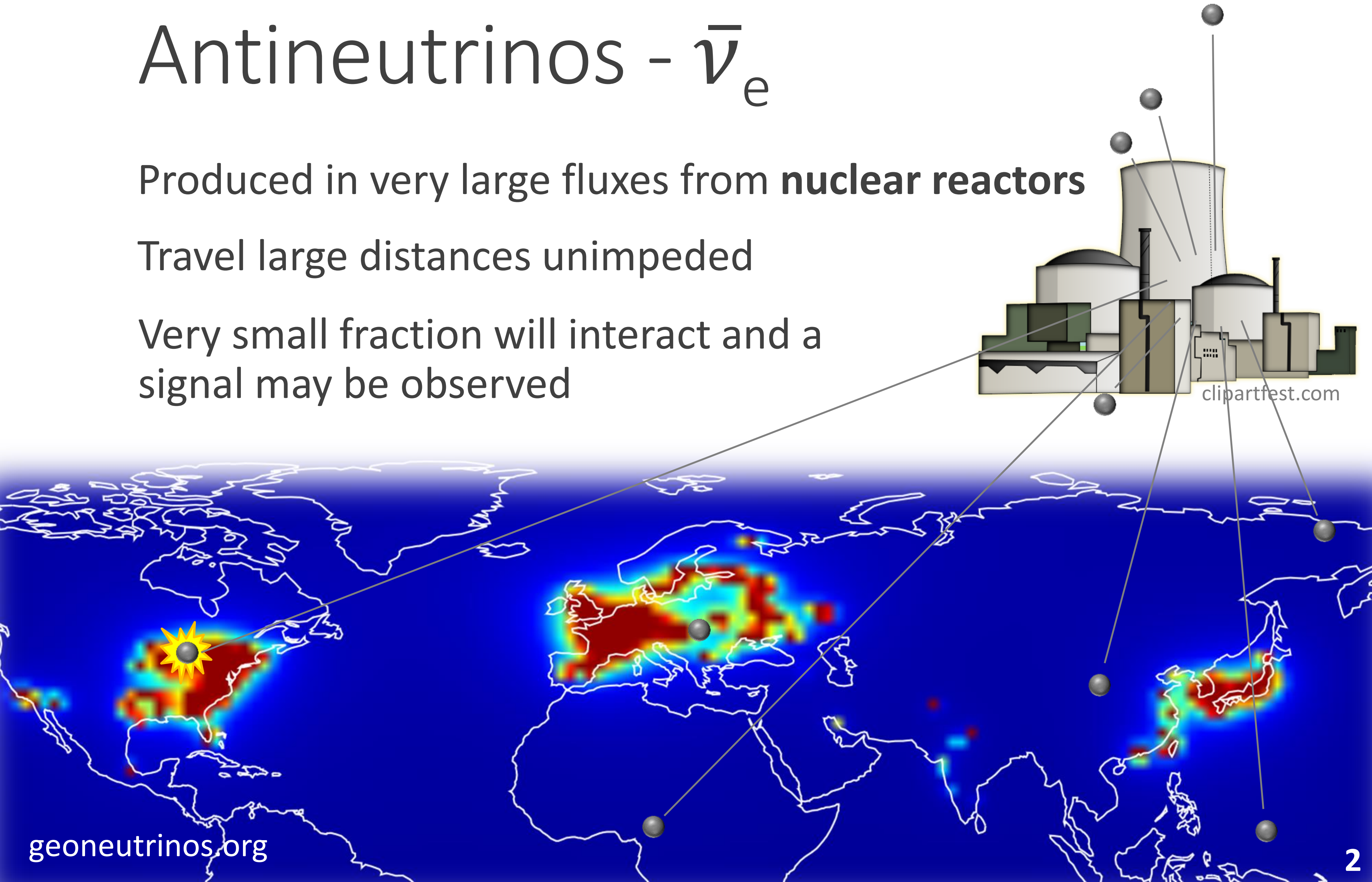
UNIVERSITY OF ALBERTA

Antineutrinos - $\bar{\nu}_e$

Produced in very large fluxes from **nuclear reactors**

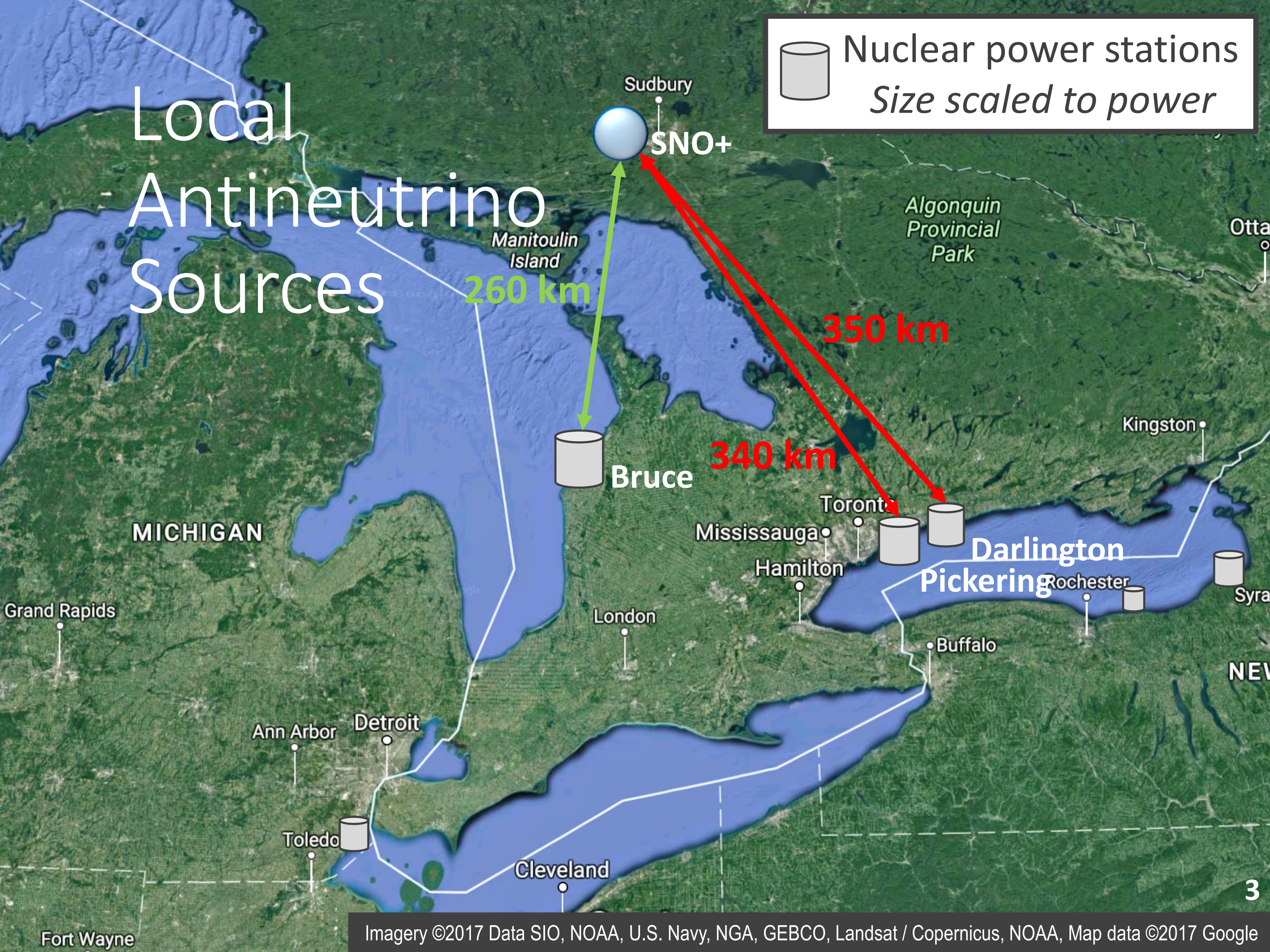
Travel large distances unimpeded

Very small fraction will interact and a signal may be observed



geoneutrinos.org

Local Antineutrino Sources



Antineutrino Oscillation

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Expecting:

On the order of **100 interactions per year**

Antineutrino Interaction

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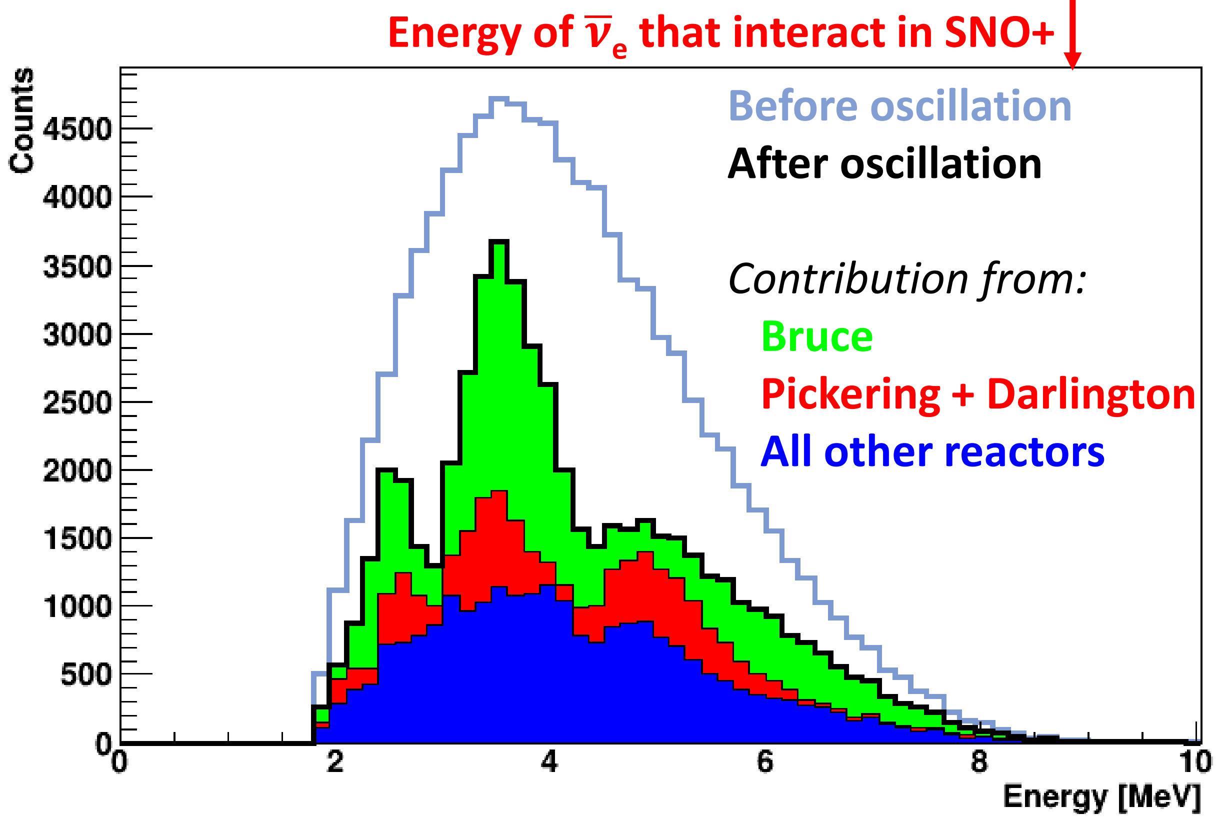
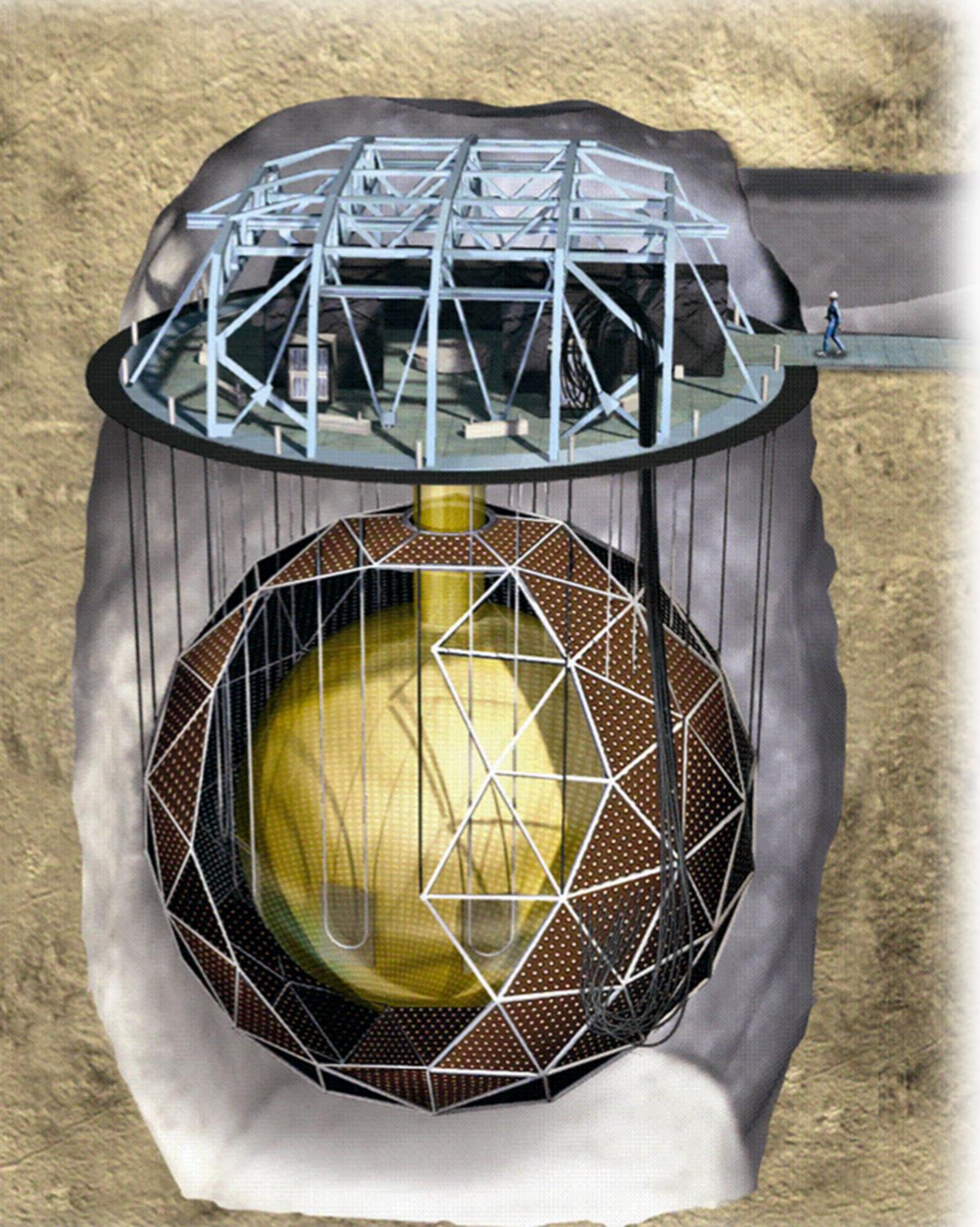
On the order of **100 interactions per year**

Sensitivity to **Δm^2_{12}** of **0.2×10^{-5} eV^2**





SNO+ Detector

Consists of:

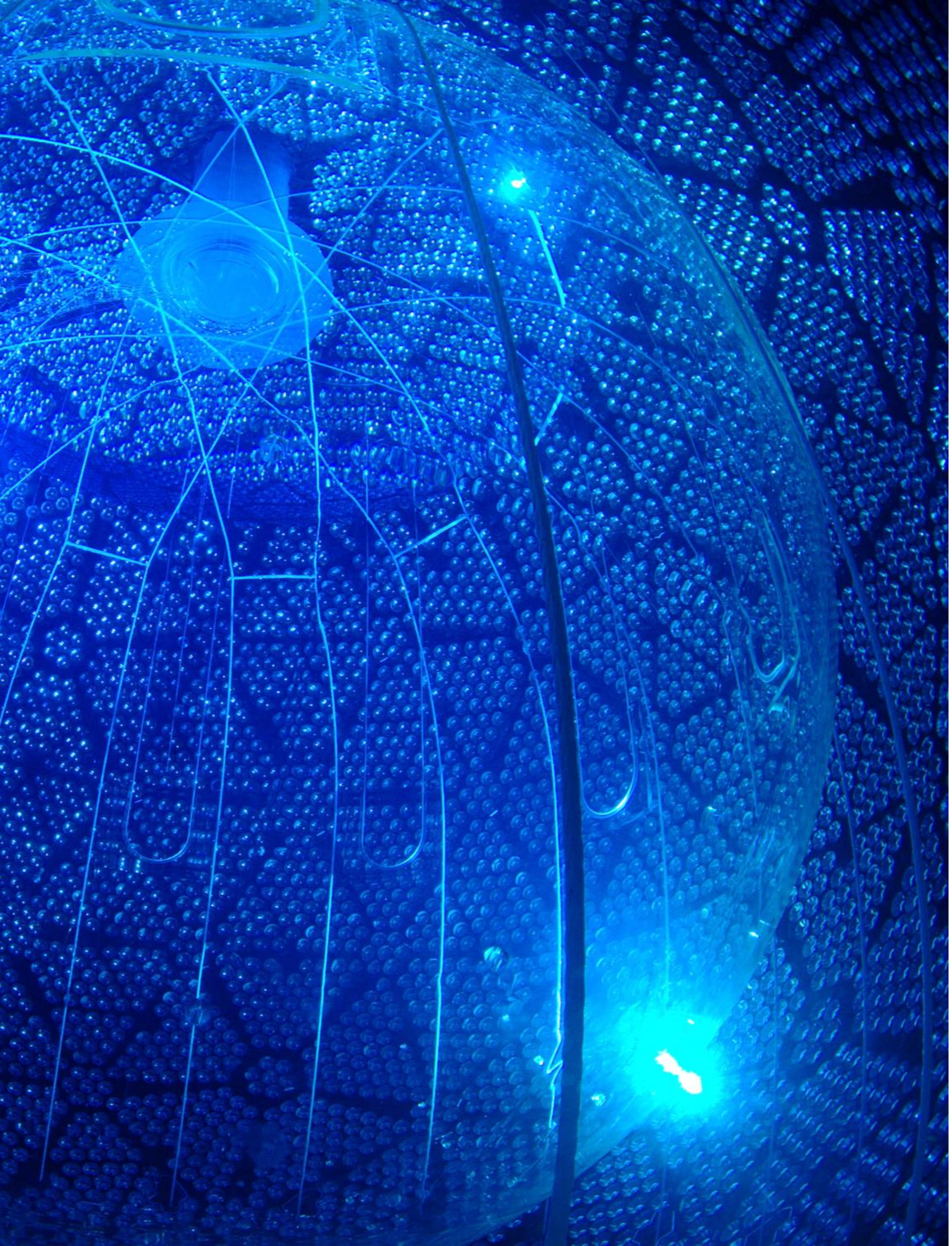
12 m diameter acrylic sphere

9300 photomultiplier tubes (PMTs)

7000 tonnes of surrounding water

Will be filled with **780 tonnes** of liquid scintillator

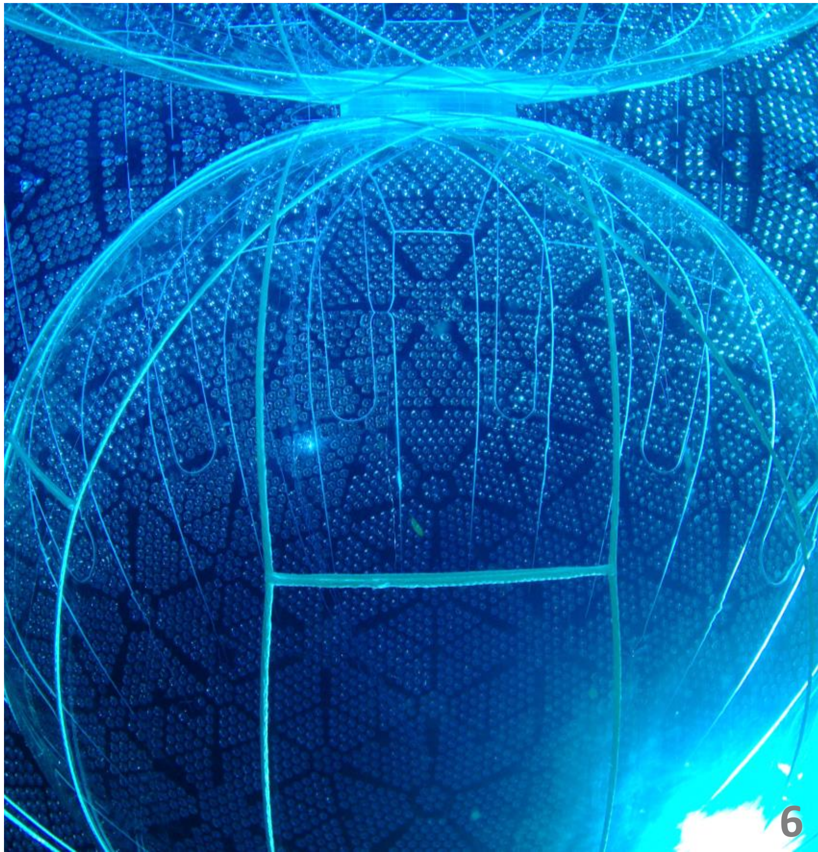
- Also **3.9 tonnes** of natural tellurium



Current Status

Filled with **water**

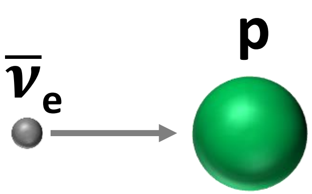
Collecting first **data** sets



Inverse Beta Decay

Antineutrinos may interact in the SNO+ detector via the inverse beta decay (IBD) reaction:

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



t = 0

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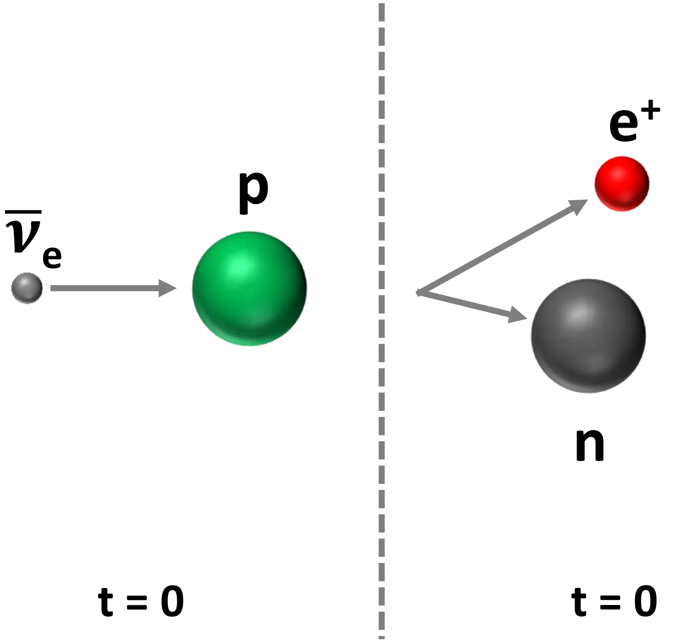

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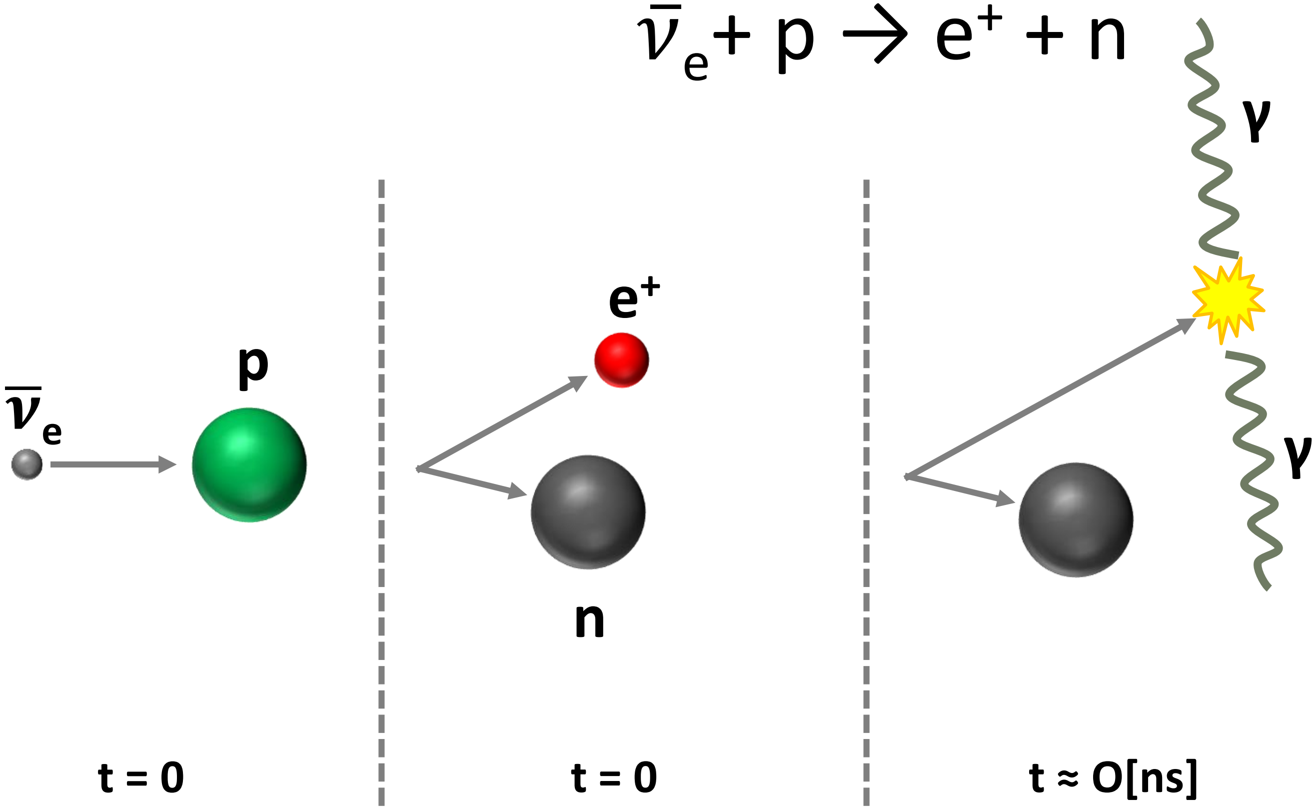

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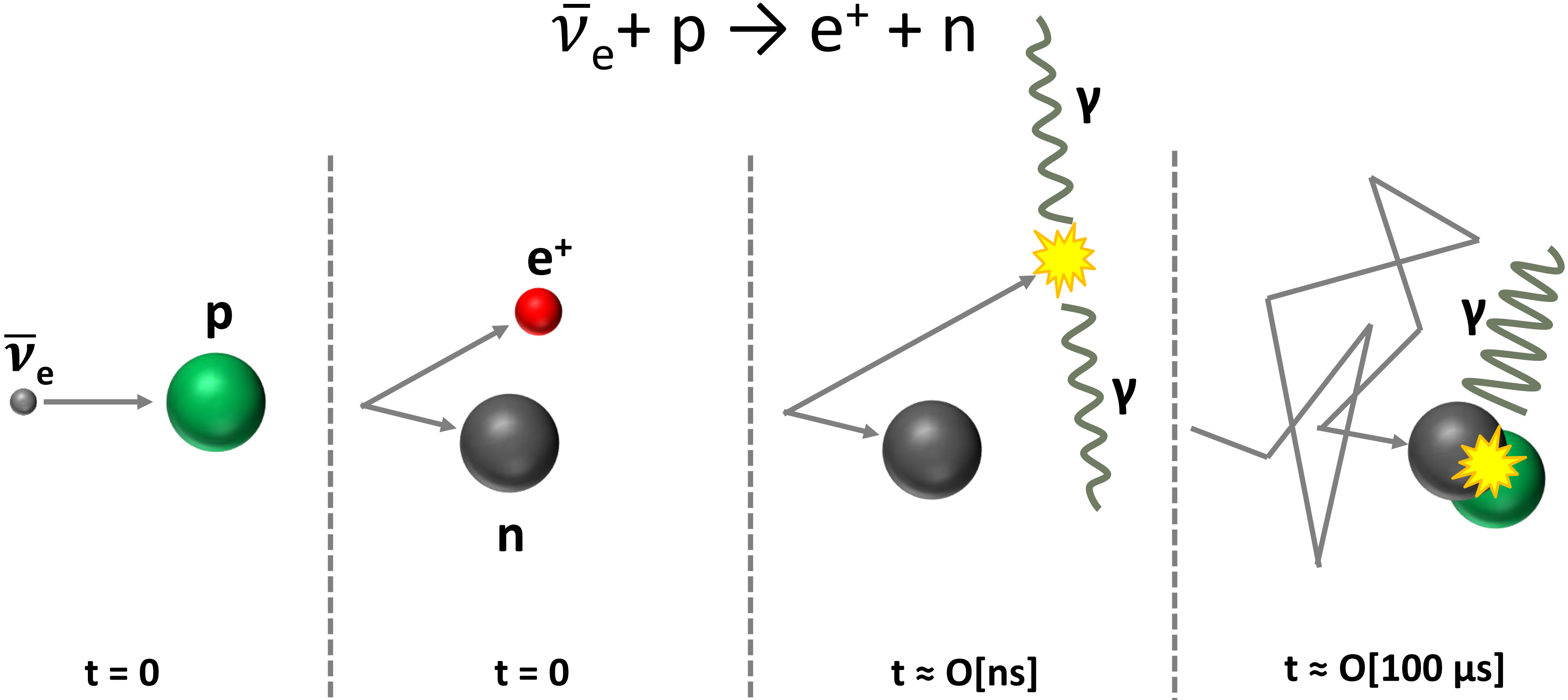
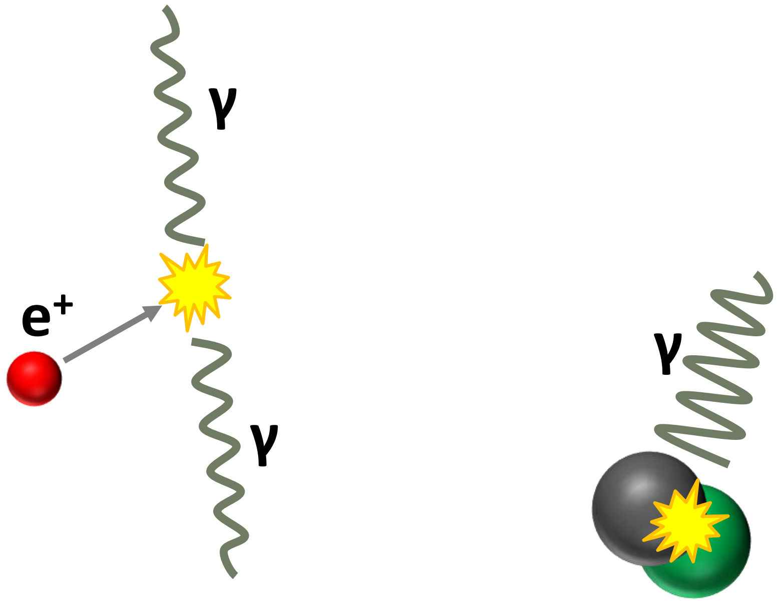


Inverse Beta Decay



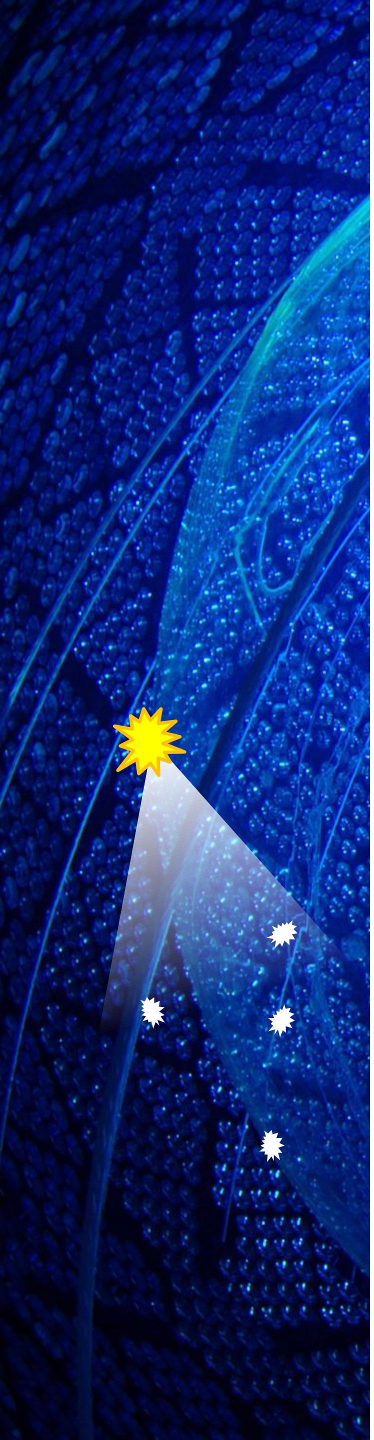

IBD Signal in SNO+
e-
e-
*while the detector is
filled with water

IBD Signal in SNO+

*while the detector is filled with water

IBD Signal in SNO+

*while the detector is filled with water



IBD Signal Search

Perform **Monte Carlo simulations** of the detector

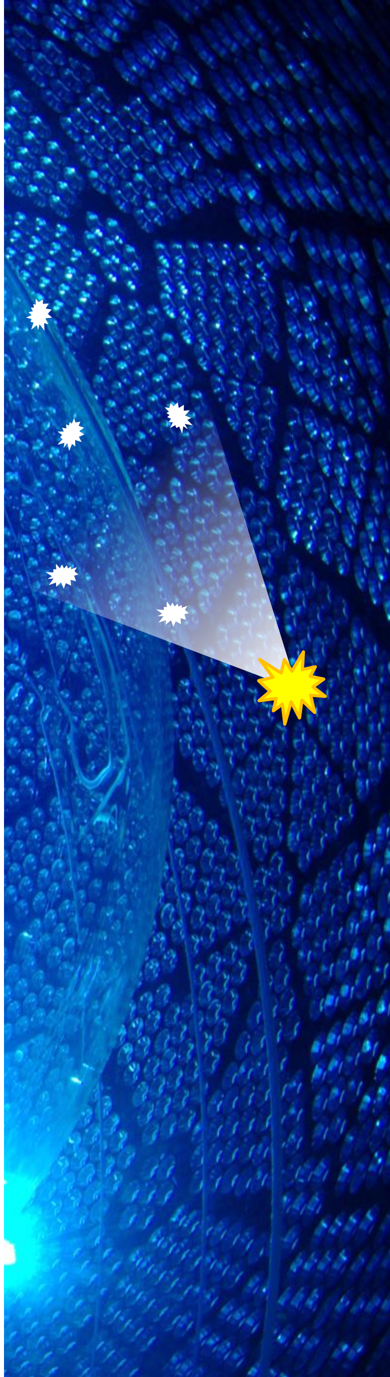
- Determine what signal will look like
- Determine what backgrounds will look like

Design some criteria that can be used:

- The IBD signal will **pass**
- But radioactive backgrounds **will not**

Will be well prepared to search when data arrives

Within a small time interval



Example

Modeled:

IBD signal only

Corresponds to:

5000 years of data taking

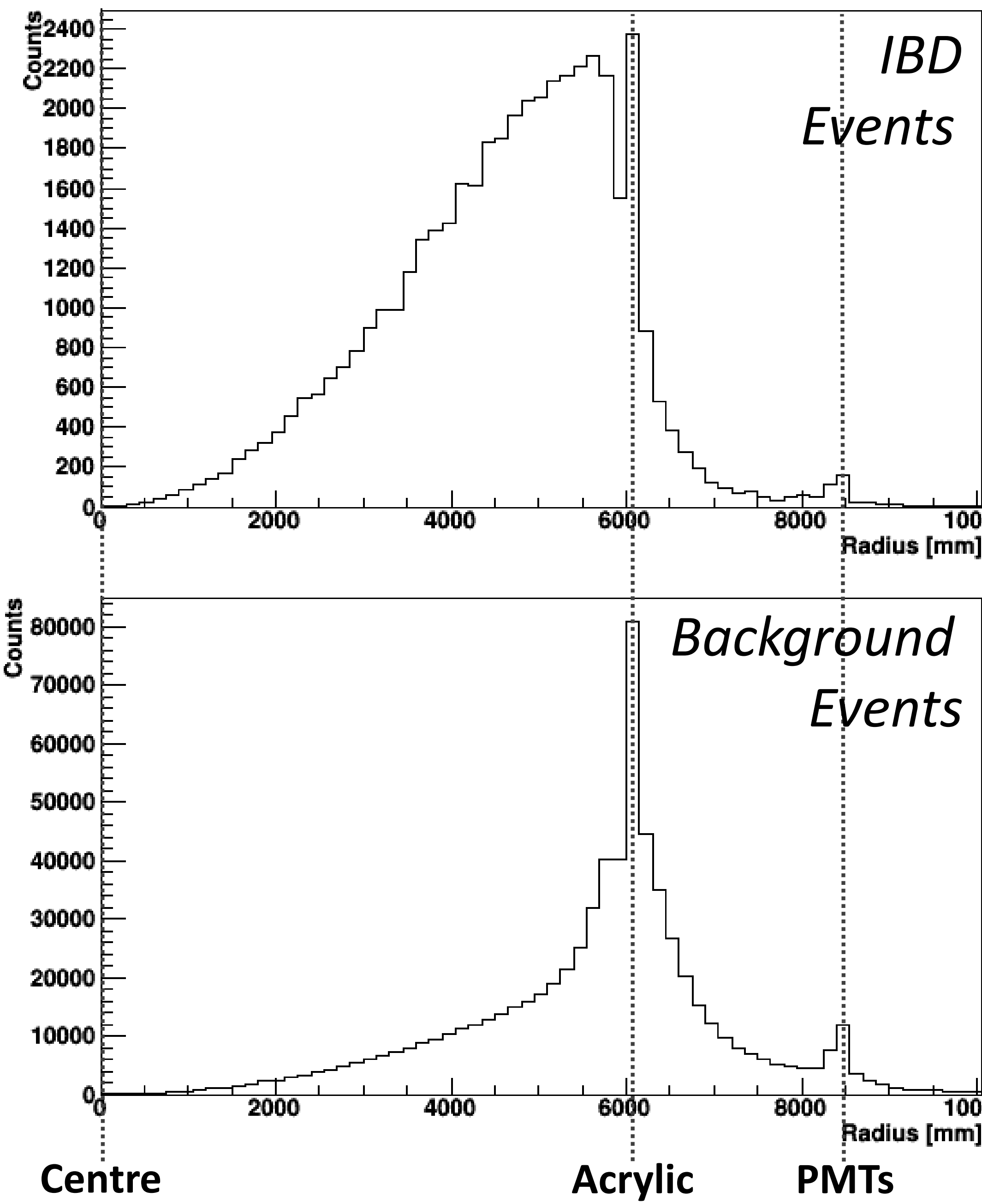
Modeled:

All expected backgrounds (no IBD signal)

Corresponds to:

60 minutes of data taking

Reconstructed position



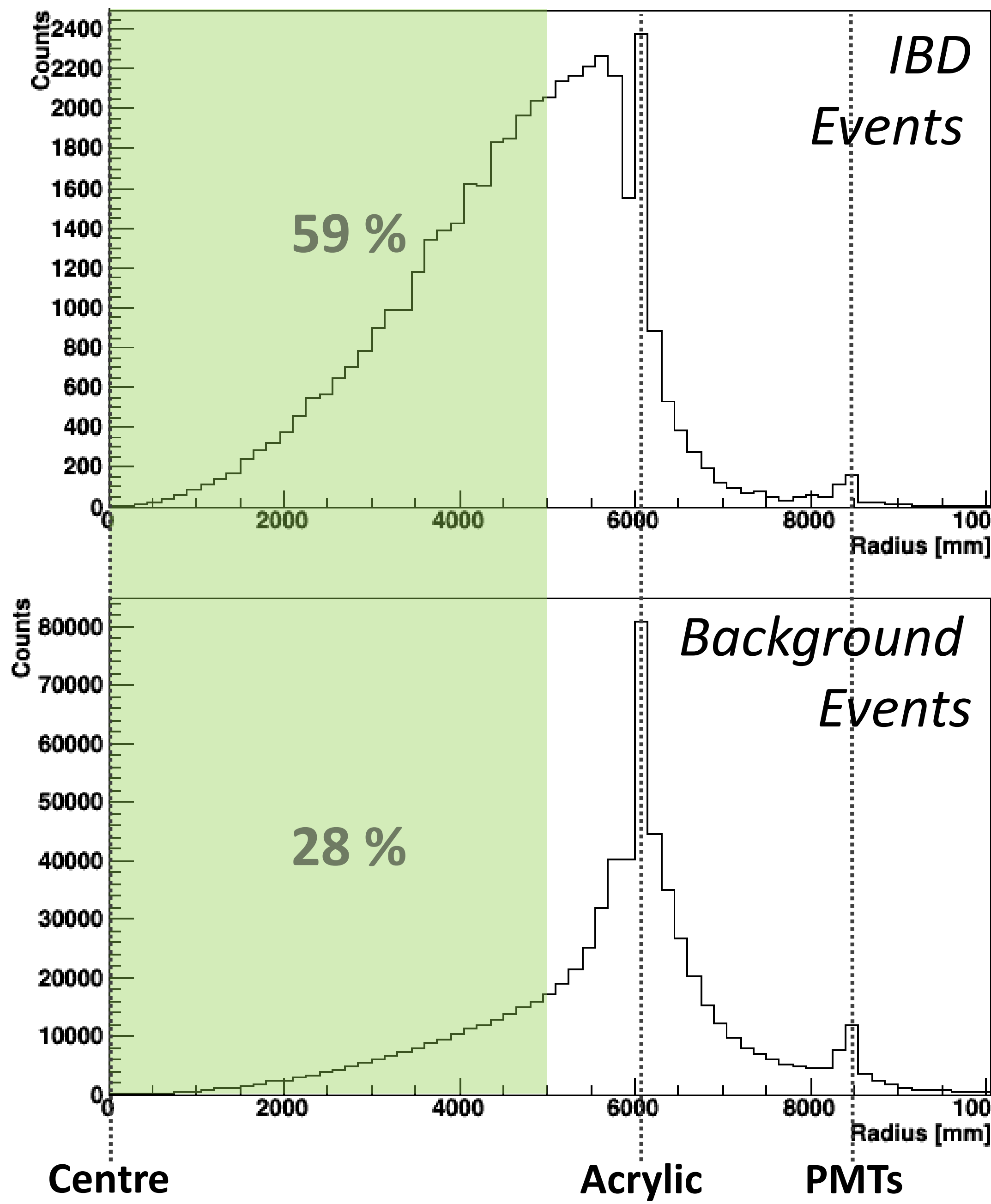
Selection Criteria

First **remove** events that occur near or past the surface of the spherical vessel (more radioactivity here)

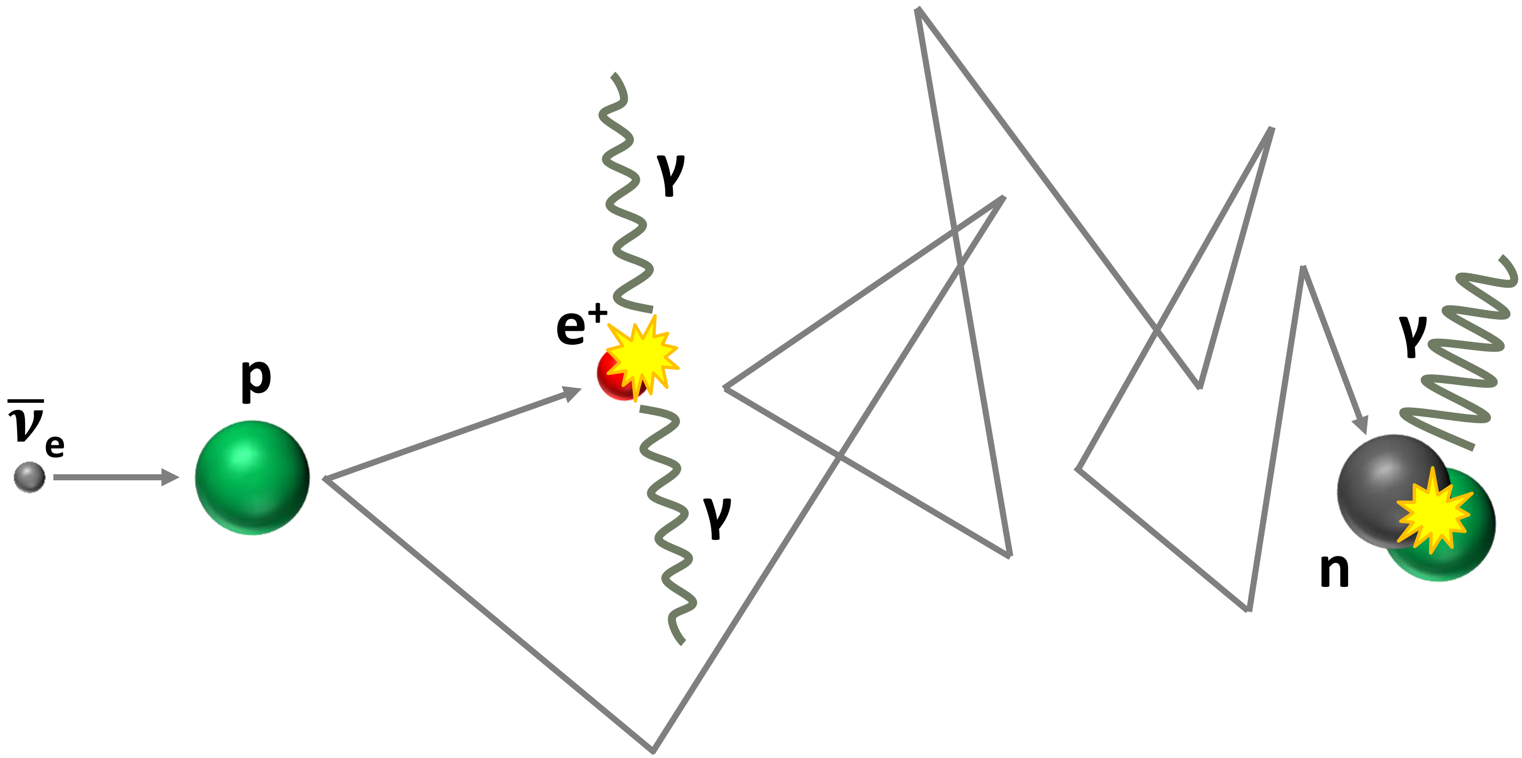
- Impose a fiducial volume cut (FV)

Radius r < 5 m

Reconstructed position

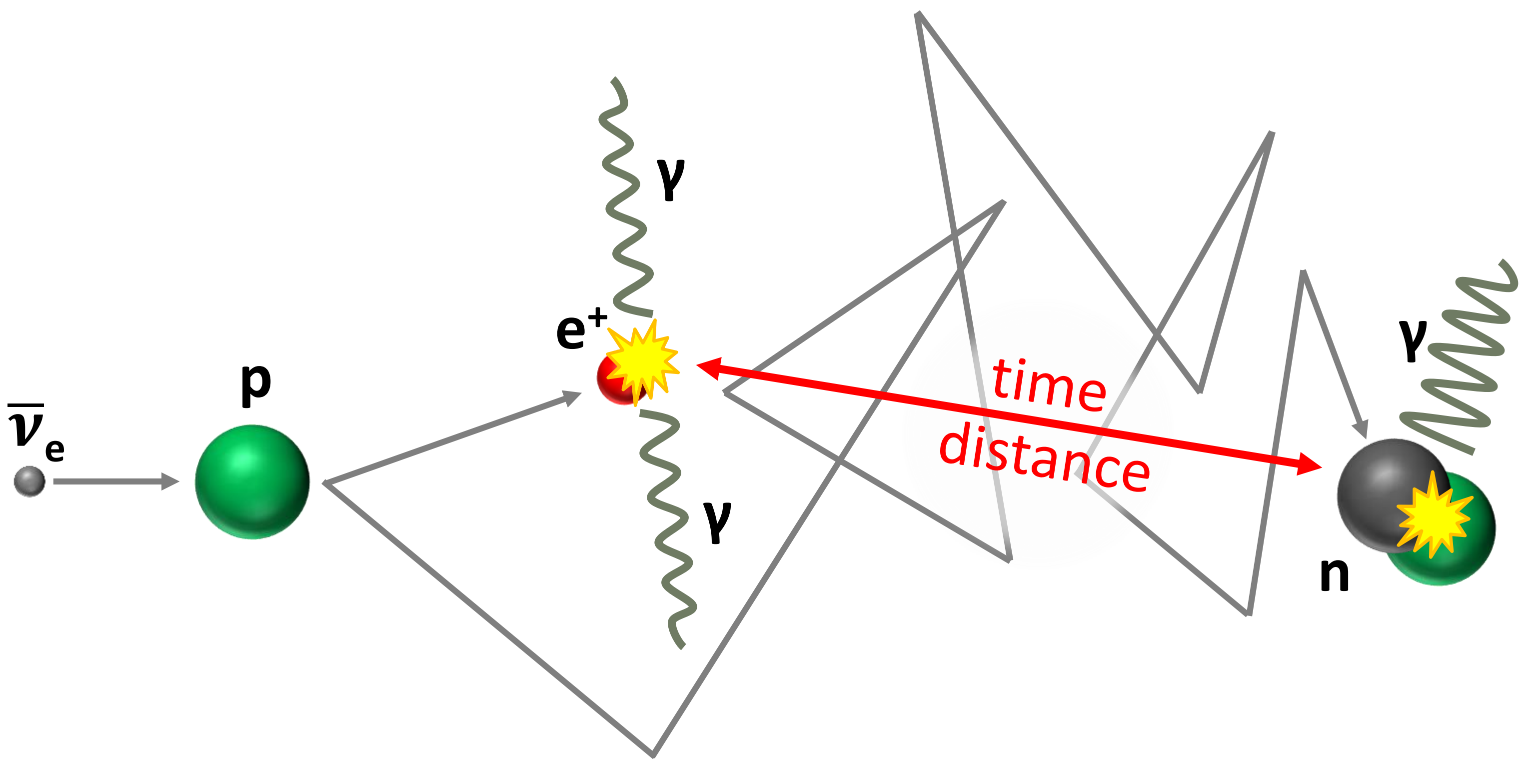


Looking Back



Looking Back

See that these signal events have correlations between them

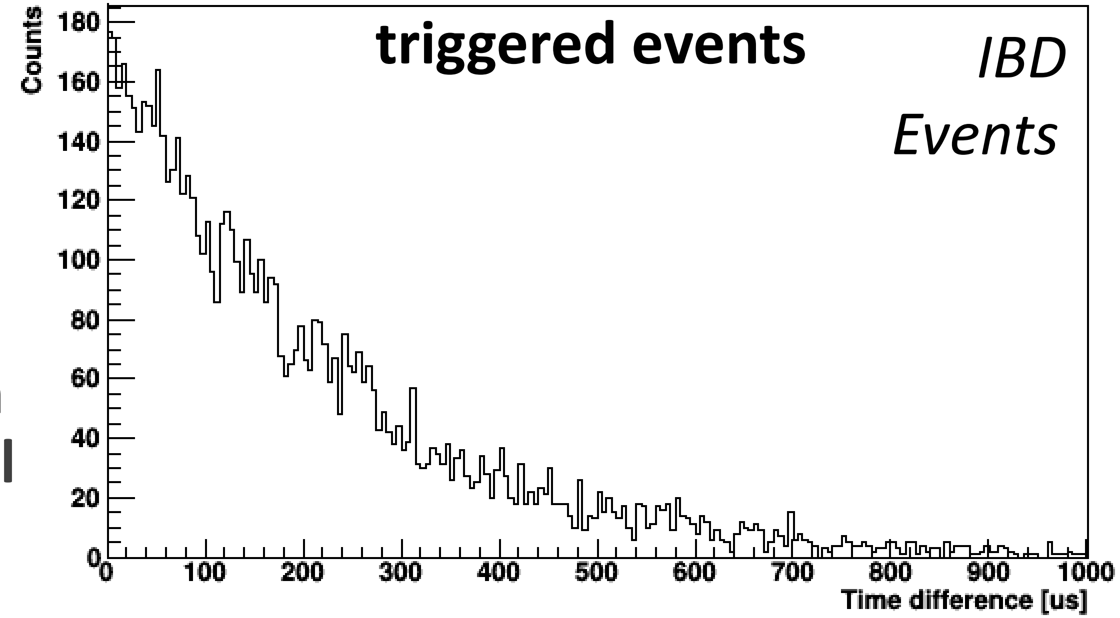


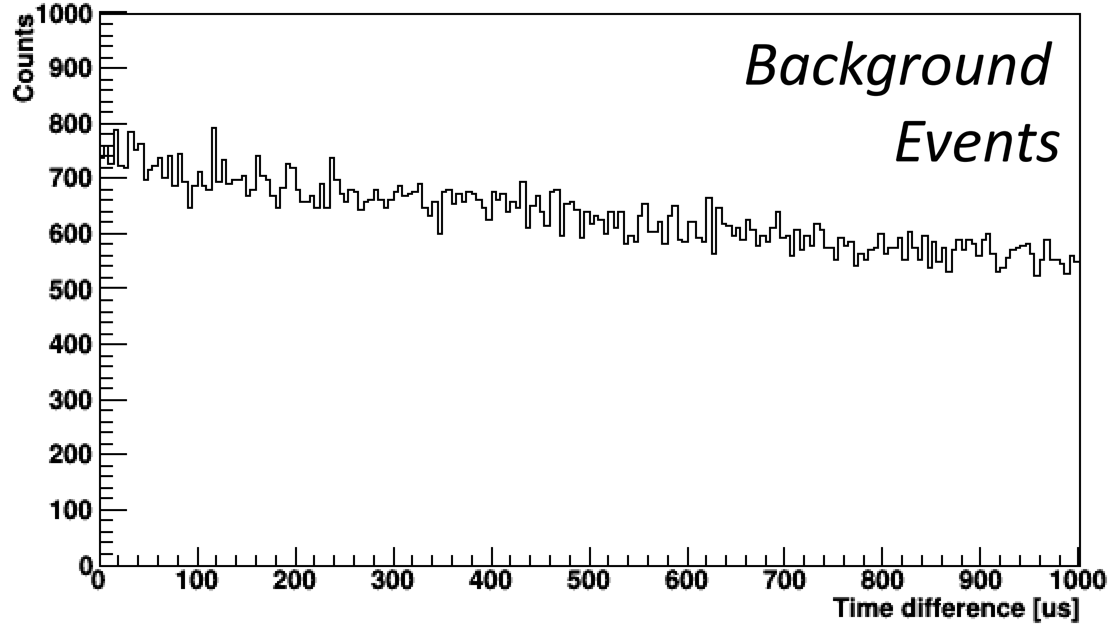
Selection Criteria

Next, **keep** only event pairs that occur within a specific **time interval** of each other

- Coincident events

Time difference between subsequent triggered events





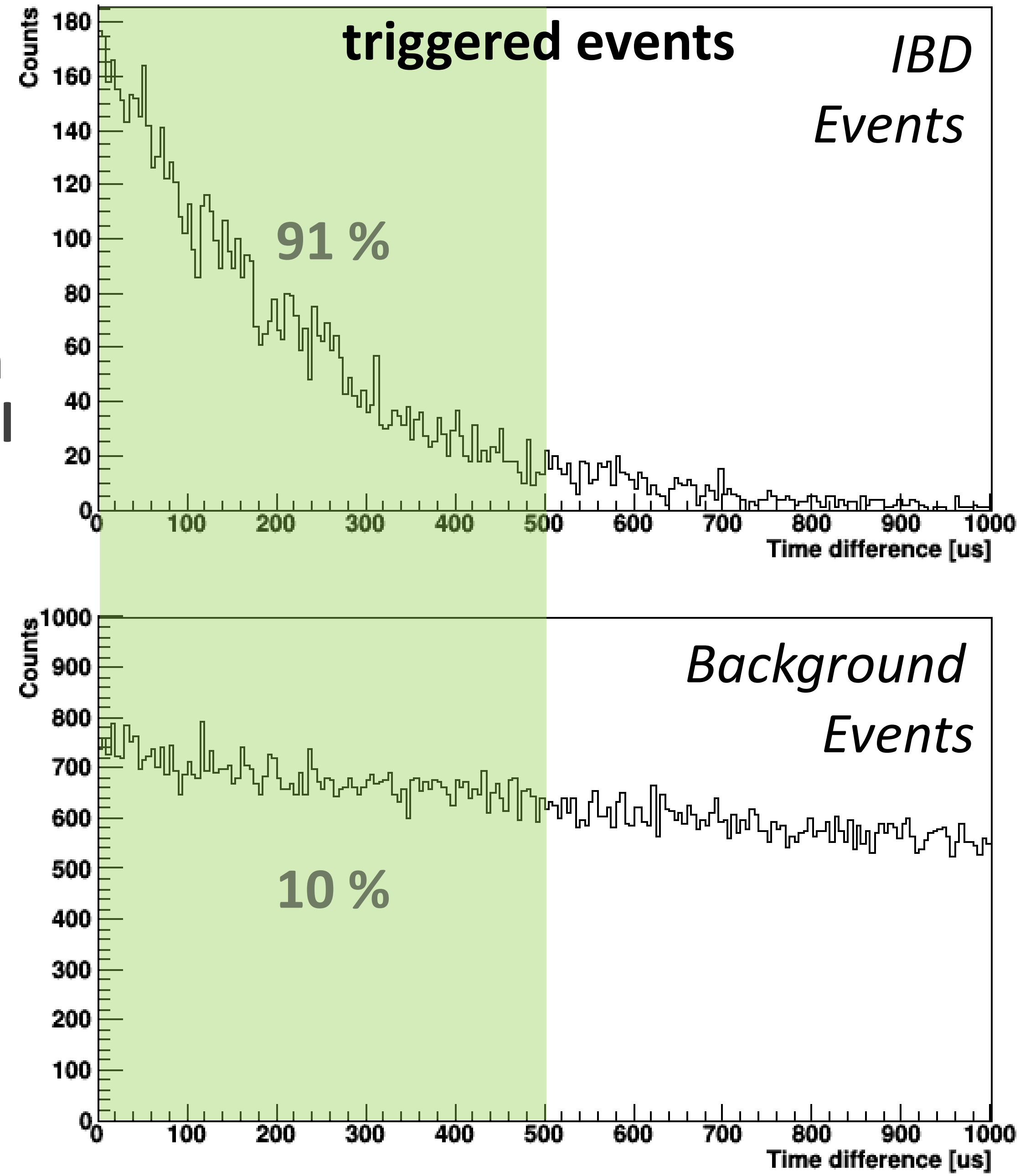
Selection Criteria

Next, **keep** only event pairs that occur within a specific **time interval** of each other

- Coincident events

Time difference
Δt < 500 μs

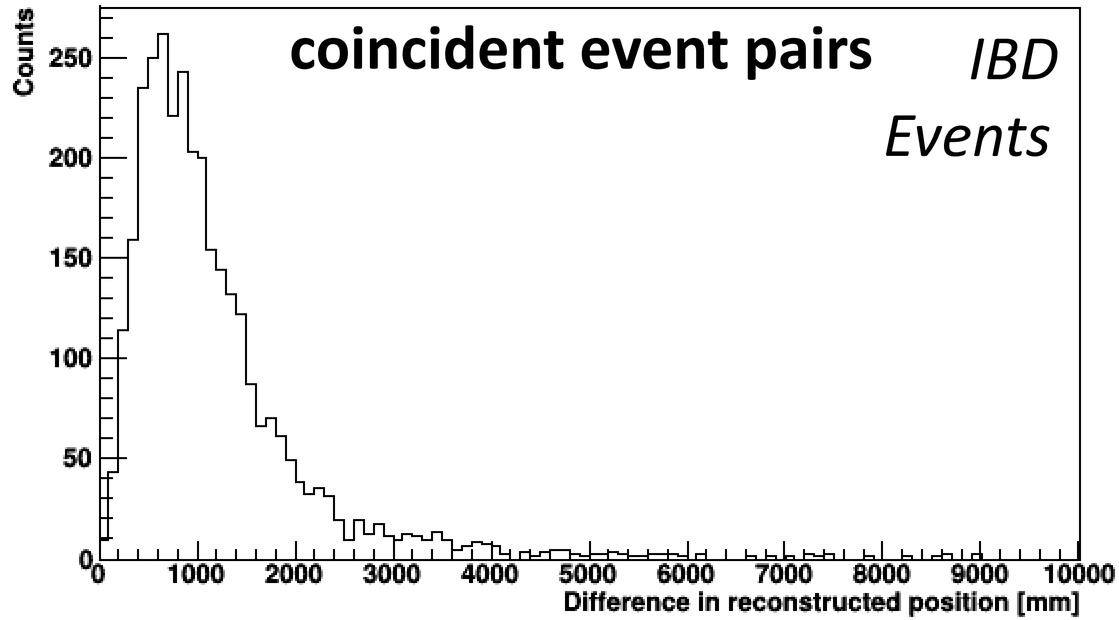
Time difference between subsequent triggered events

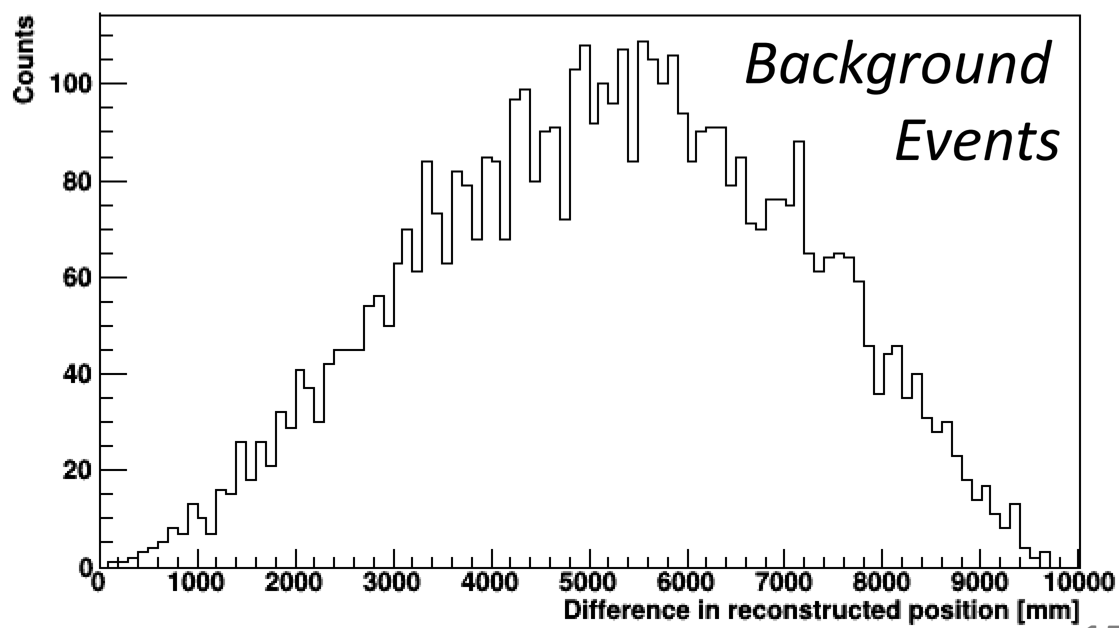


Selection Criteria

Third, **keep** only coincident events that occur within a short **distance** from each other

Reconstructed distance between coincident event pairs



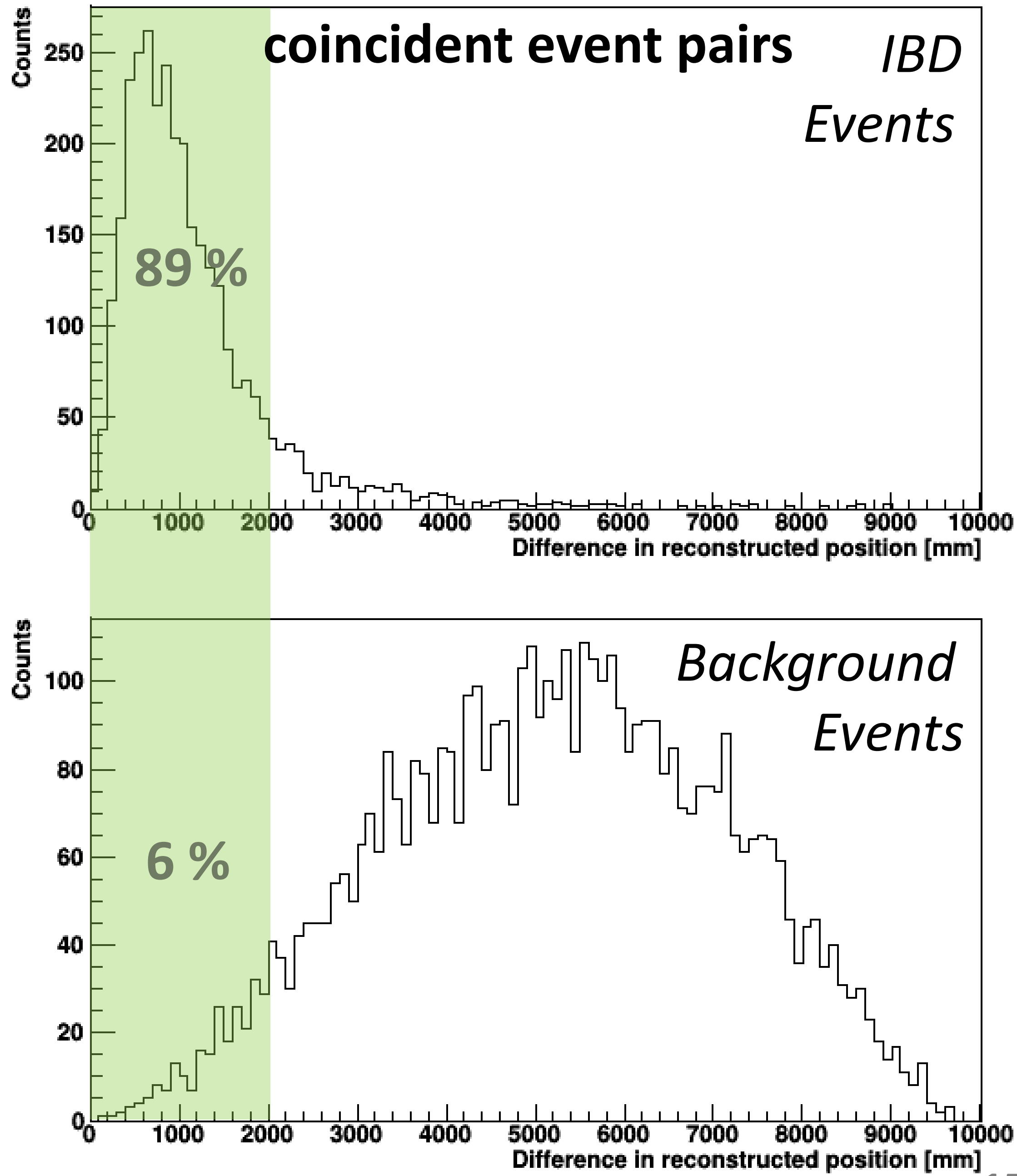


Selection Criteria

Third, **keep** only coincident events that occur within a short **distance** from each other

Position difference
d < 2 m

Reconstructed distance between coincident event pairs



Implications

Imposing this criteria:

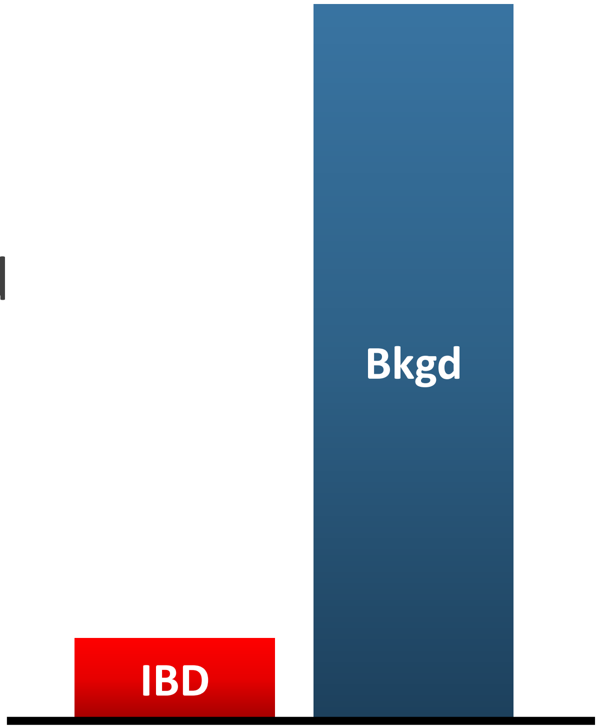
- Reduces signals from IBD events
- But **greatly reduces** signals from radioactive backgrounds

Realistically, only expect to have around **3 IBD decay events** left in our data set after these cuts are applied

- Assuming data collection in water for **6 months**

More than likely, there will be many more background coincidences, drowning the signal

Illustration:
Expected # of events after cuts



Conclusions

But…

By looking at this in Monte Carlo and in ‘water phase’ data:

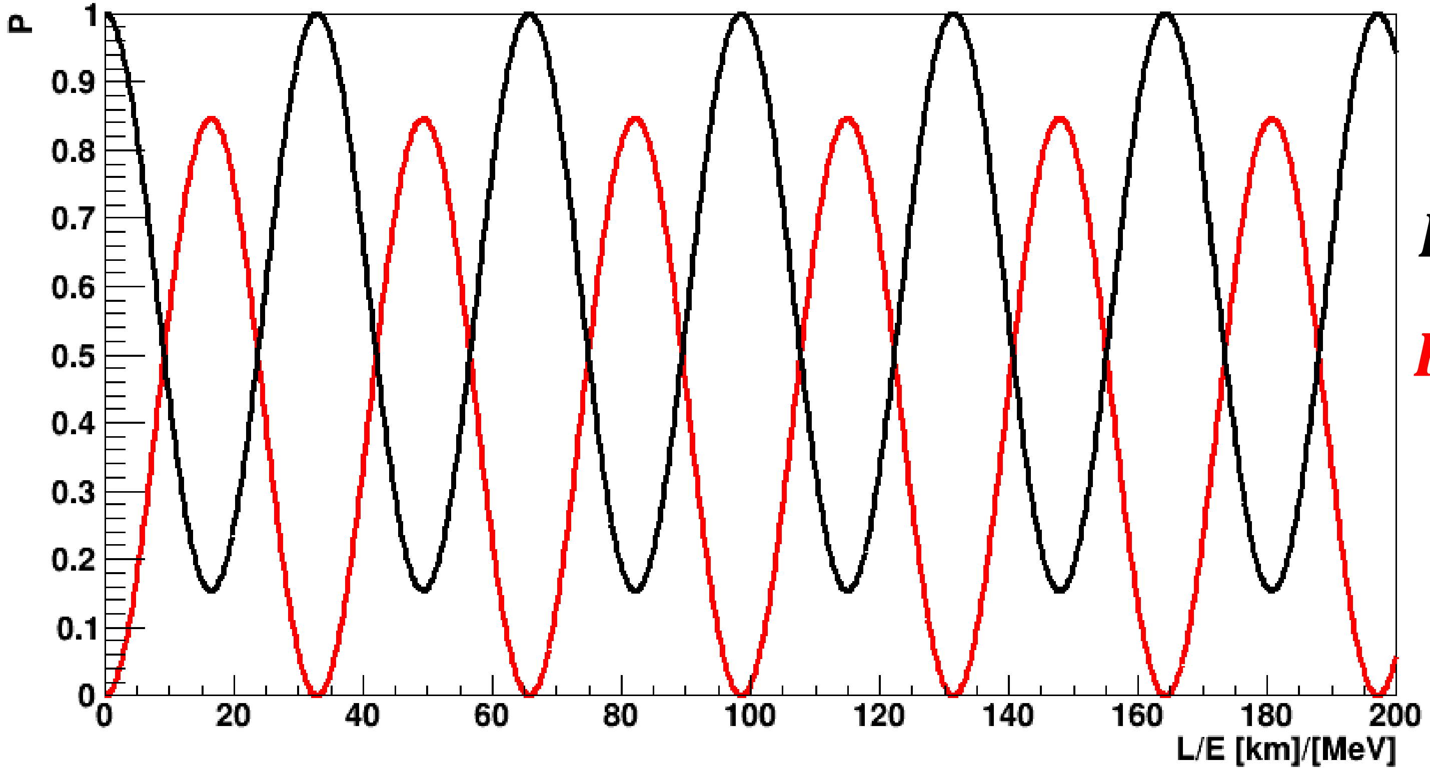
- We can **develop** the tools needed to search for IBD signals
- Begin **optimizing** the techniques that pull out the signal from the data collected
- Better **understand** the backgrounds that mimic this signal

We are set up well for a measurement of antineutrinos when ‘scintillator phase’ begins *(scheduled: Fall 2017)*

Back-up Slides

Neutrino Oscillation

$$P_{\nu_\alpha \rightarrow \nu_\beta} = \sin^2(2\Theta)\,\sin^2(1.27\,\Delta m^2\,[eV^2]\,\frac{L\,[km]}{E\,[GeV]})$$



$P_{\nu_\alpha \rightarrow \nu_\alpha}$

$P_{\nu_\alpha \rightarrow \nu_\beta}$