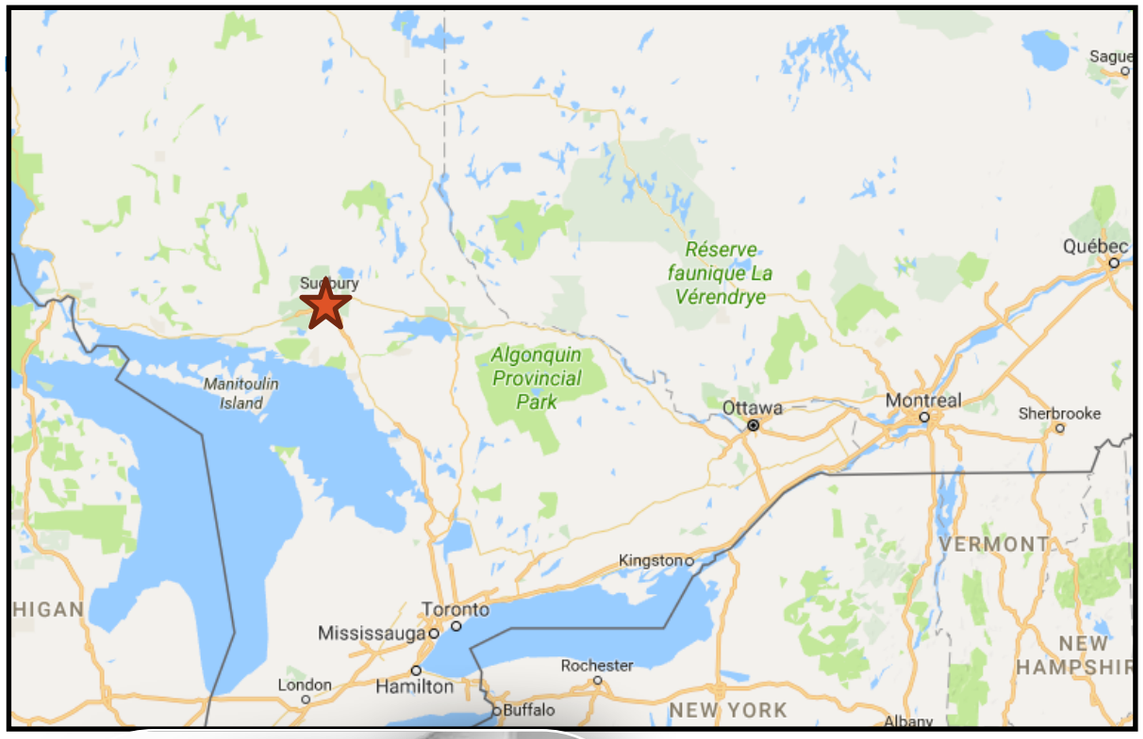
30 January, 2020

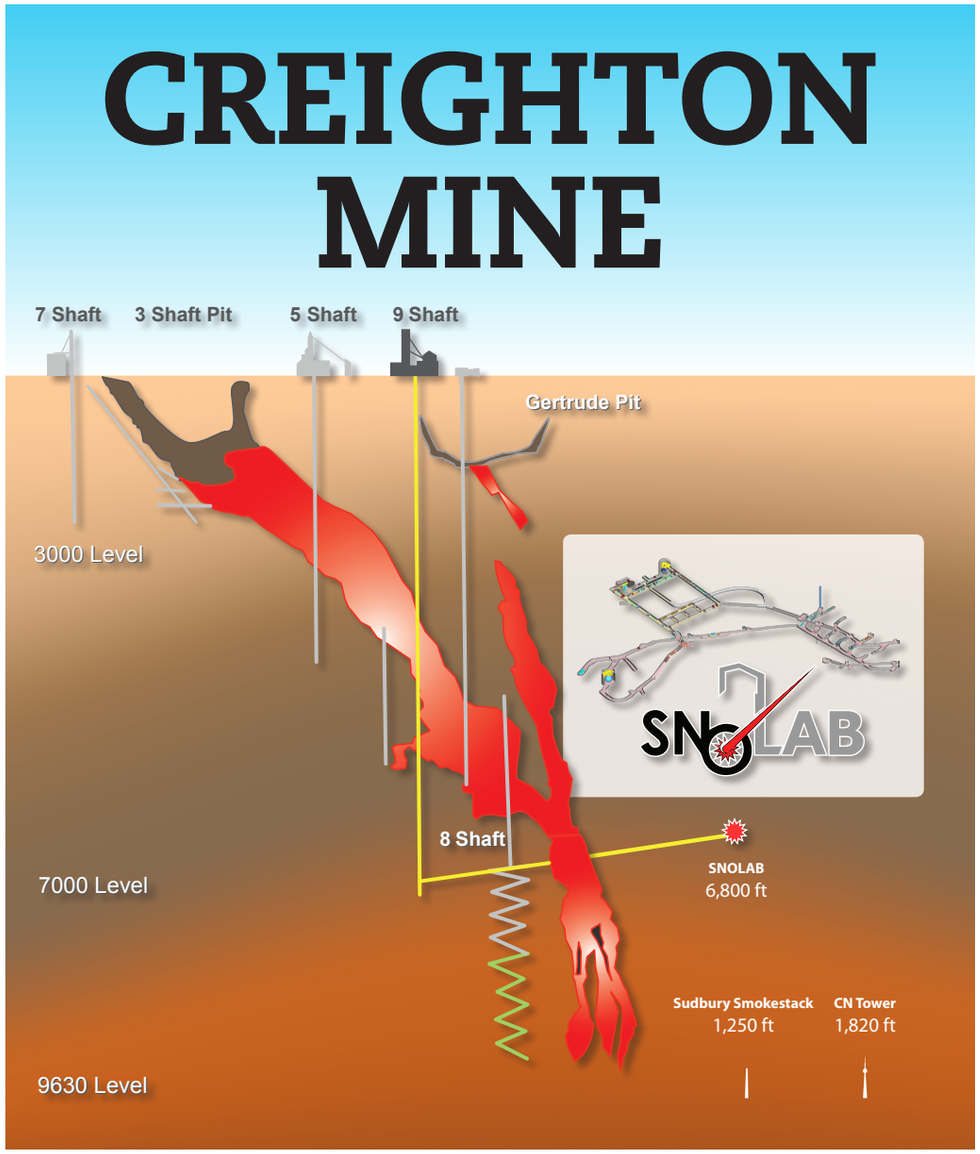
Canadian Multi-Messenger
Astrophysics Workshop

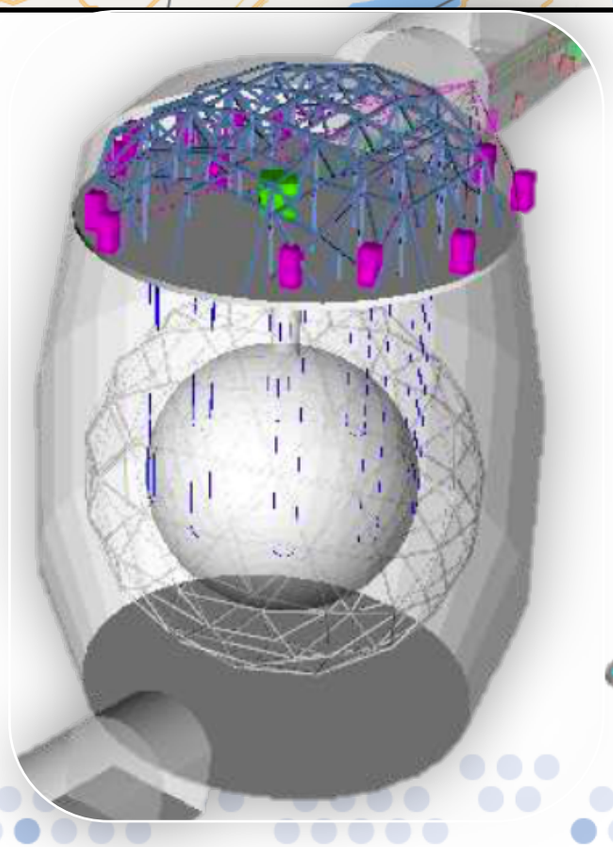
SNO+ & Supernova Detection

Erica Caden
Research Scientist
ecaden@snolab.ca

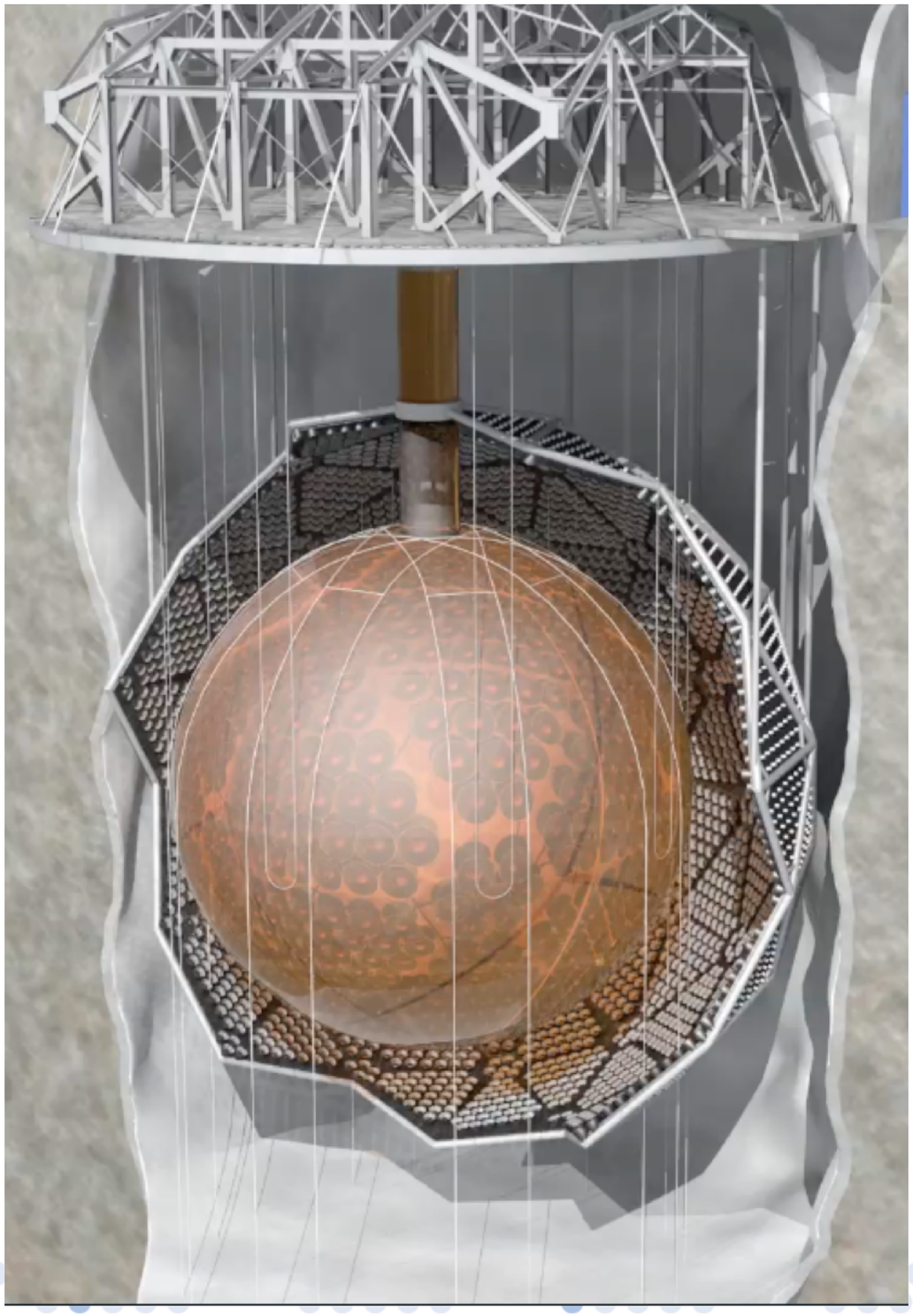
SNO+ @ SNOLAB


Sague
Québec
Réserve faunique La Vérendrye
Sudbury
Algonquin Provincial Park
Manitoulin Island
Ottawa
Montreal
Sherbrooke
VERMONT
Kingstono
HIGAN
Toronto
Mississauga
Rochester
NEW HAMPSHIR
London
Hamilton
Buffalo
NEW YORK
Albany


CREIGHTON MINE
7 Shaft
3 Shaft Pit
5 Shaft
9 Shaft
Gertrude Pit
3000 Level
SNOLAB
8 Shaft
7000 Level
SNOLAB
6,800 ft
Sudbury Smokestack
1,250 ft
CN Tower
1,820 ft
9630 Level

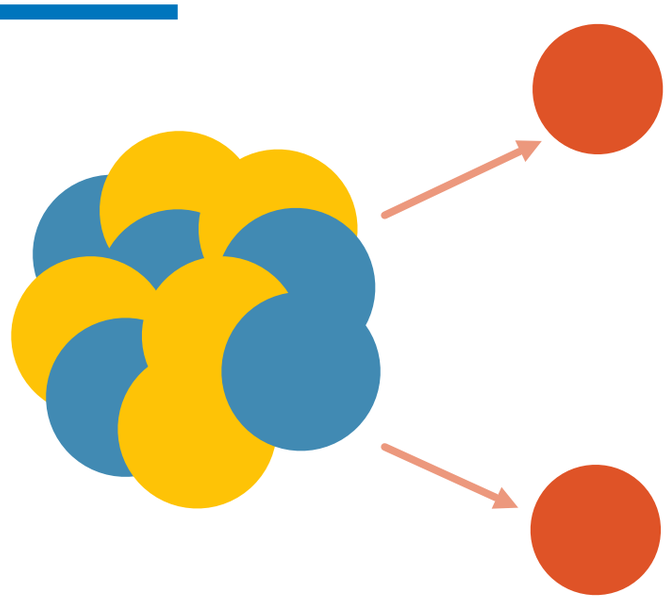


SNO+ Detector

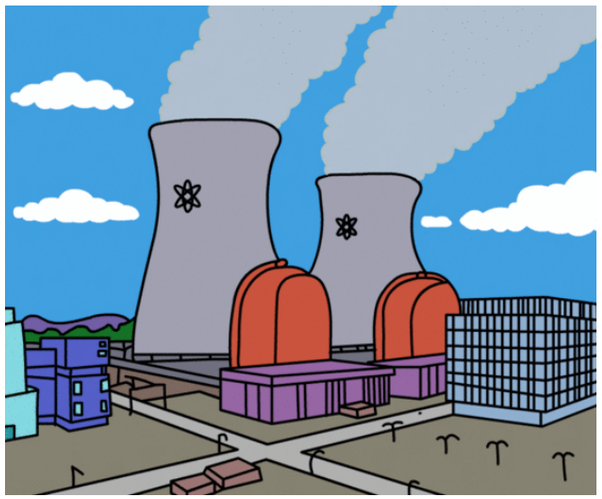


- Floating Deck with upgraded DAQ and calibration system
- Urylon liner: Rn seal
- Replaced Hold Up Ropes
- Optical Monitoring System
- Hold Down Rope Net
- Acrylic Vessel
  - Φ 12 m
  - 5 cm thick
- Water shielding
  - 1700 t inner
  - 5300 t outer
- ~9300 PMTs, 50% coverage
- 2070 km rock overburden

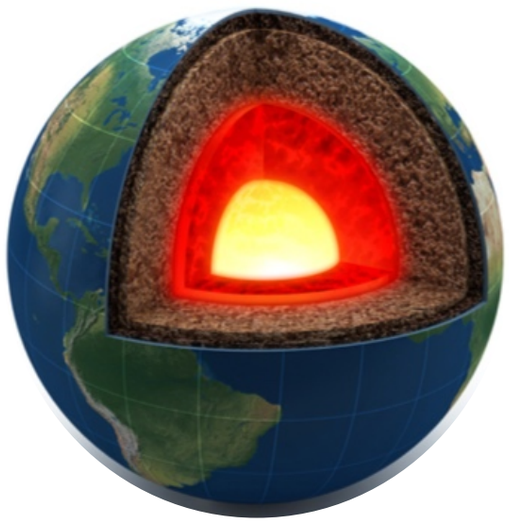
SNO+ Physics Program



Double Beta Decay

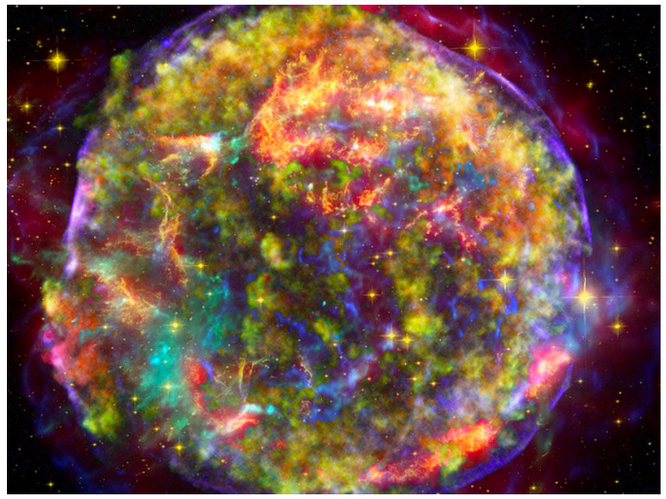


Reactor Antineutrinos

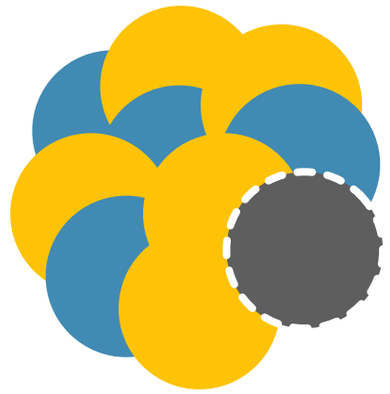


Geo Antineutrinos

Solar Neutrinos



Supernovae

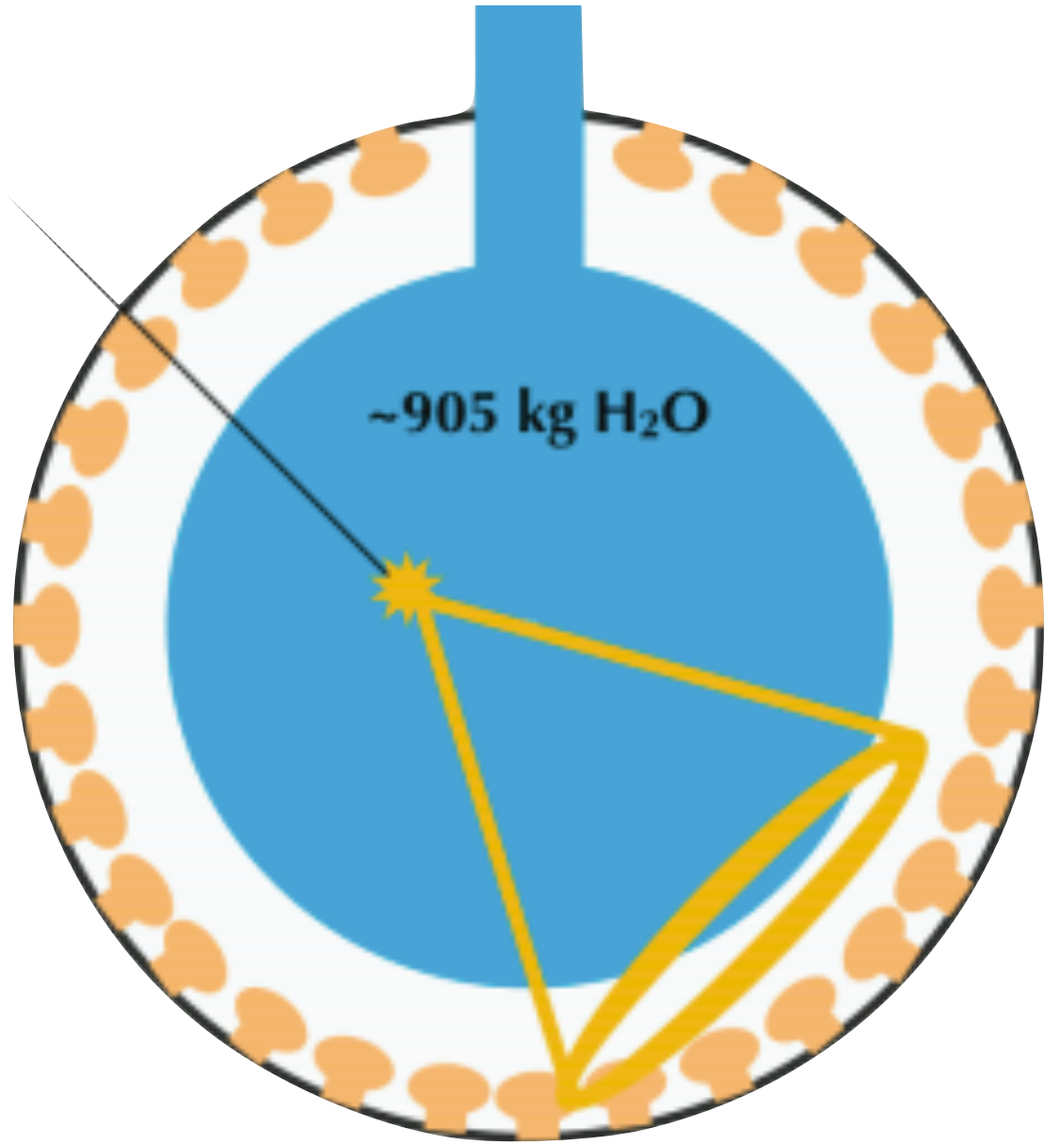


Nucleon Decay

SNO+ Timeline

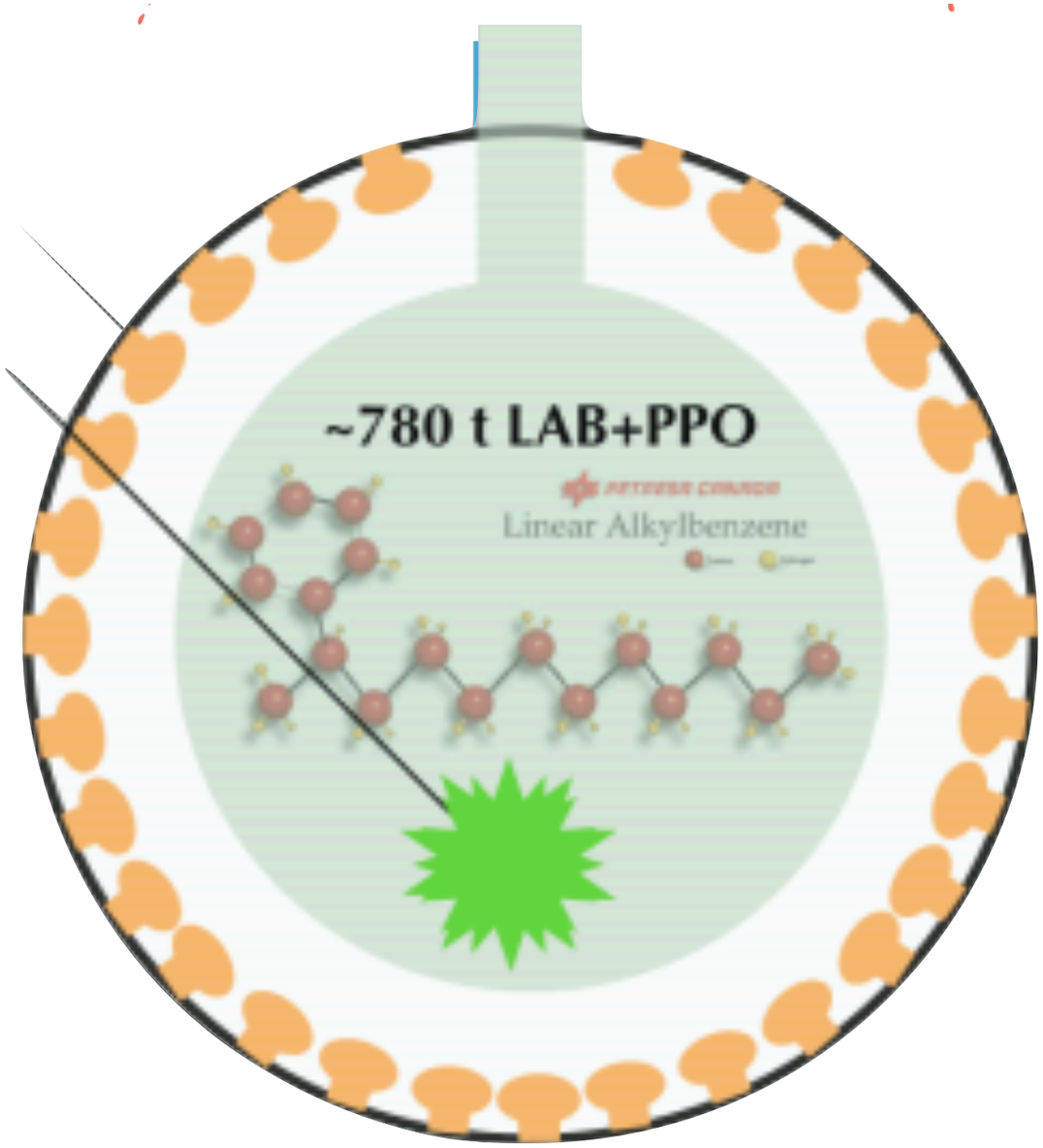
SNO+ Timeline

1. Water Phase (May 2017-July 2019)
    - Detector Calibration
    - Backgrounds Measurement
    - Solar 8B Flux
    - Invisible Nucleon Decay



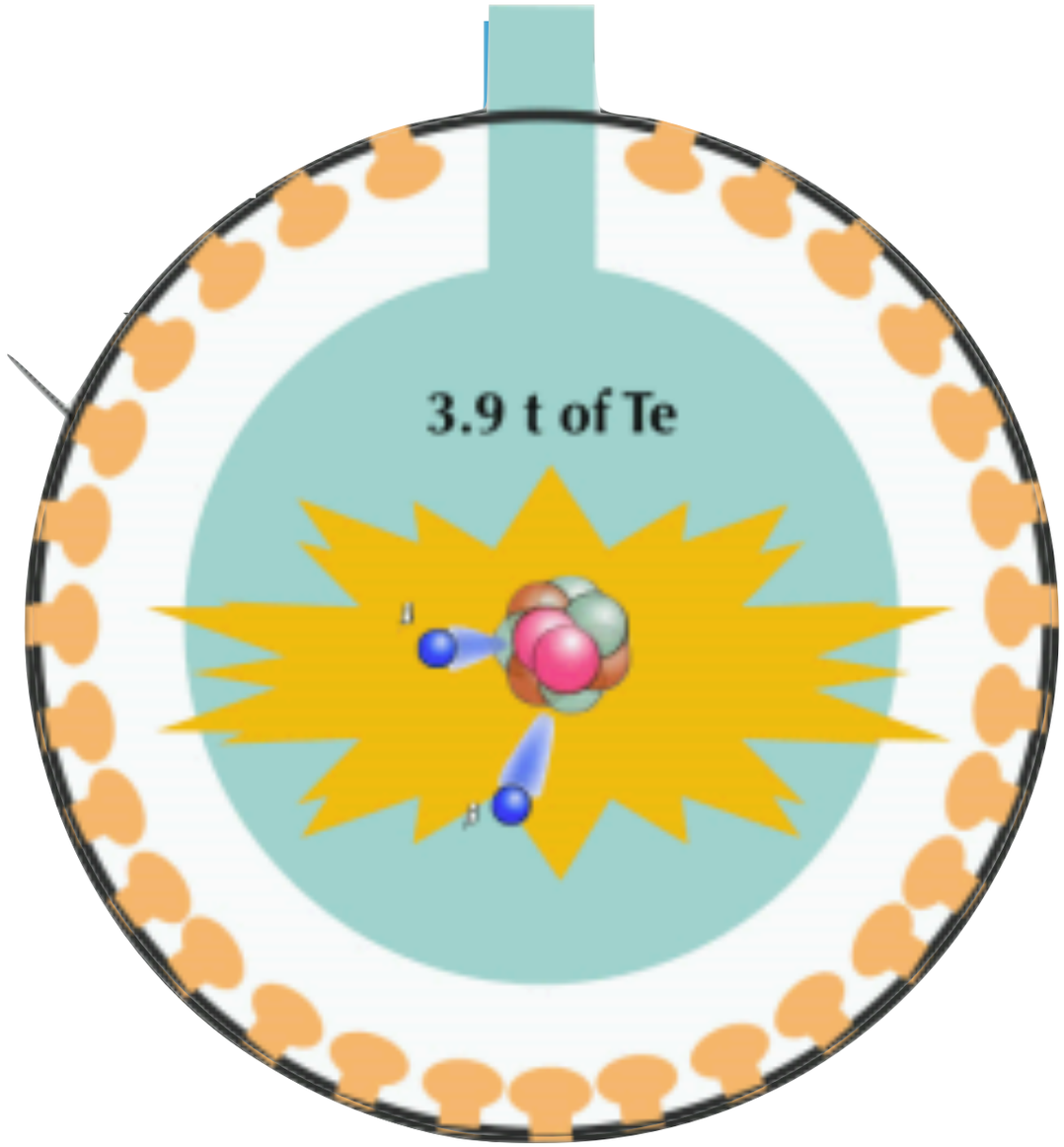
SNO+ Timeline

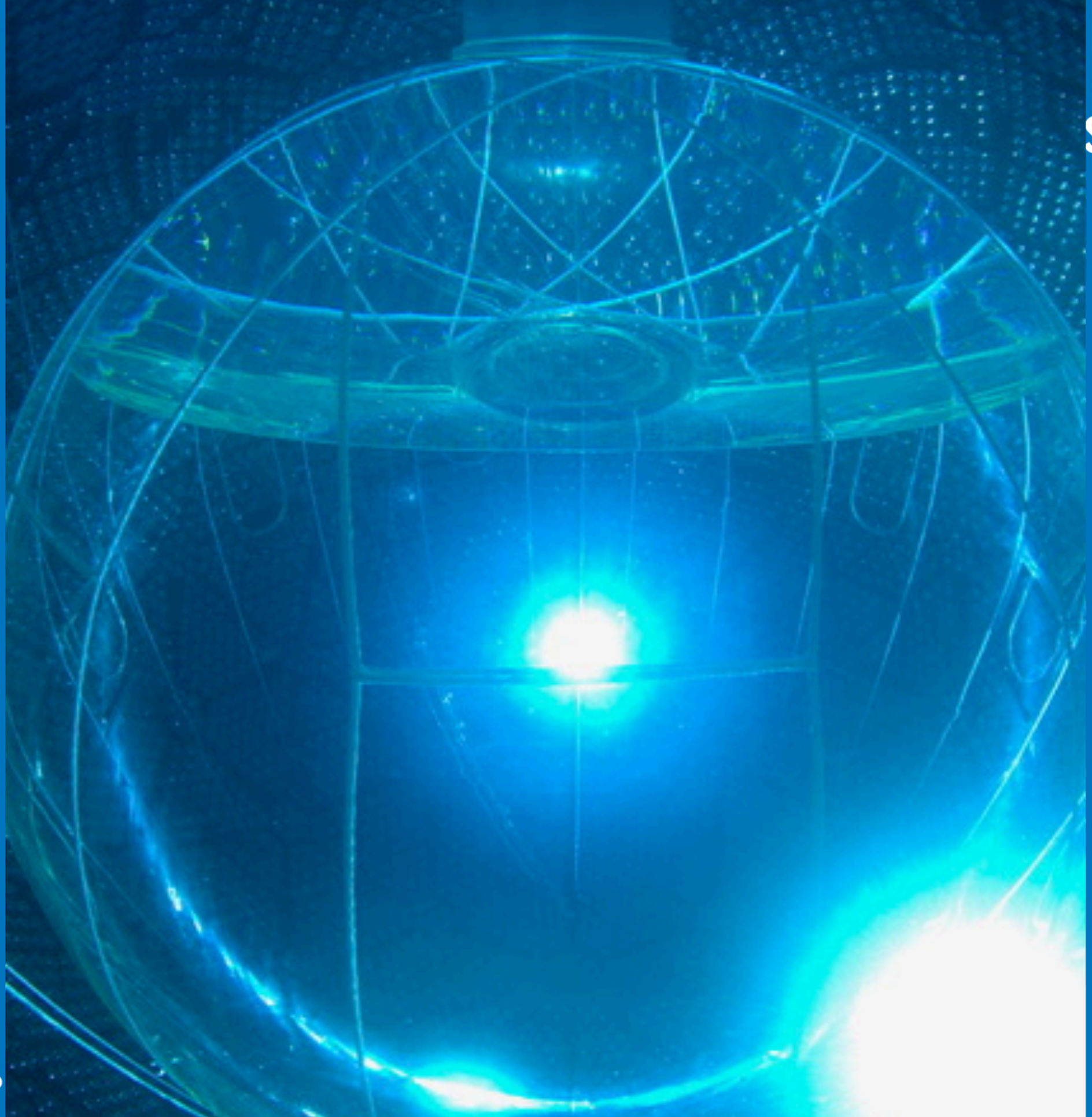
1. Water Phase (May 2017-July 2019)
   - Detector Calibration
   - Backgrounds Measurement
   - Solar 8B Flux
   - Invisible Nucleon Decay
2. Scintillator Phase
   - Detector Calibration
   - Background Measurements
   - Antineutrino Measurements
   - Supernova Neutrinos



SNO+ Timeline

1. Water Phase (May 2017-July 2019)
   - Detector Calibration
   - Backgrounds Measurement
   - Solar 8B Flux
   - Invisible Nucleon Decay
2. Scintillator Phase
   - Detector Calibration
   - Background Measurements
   - Antineutrino Measurements
   - Supernova Neutrinos
3. Te-loaded Phase
   - Neutrinoless Double Beta Decay
   - 130Te (34% nat.ab.)
   - 0.5% loading by mass (1.3t of 130Te)





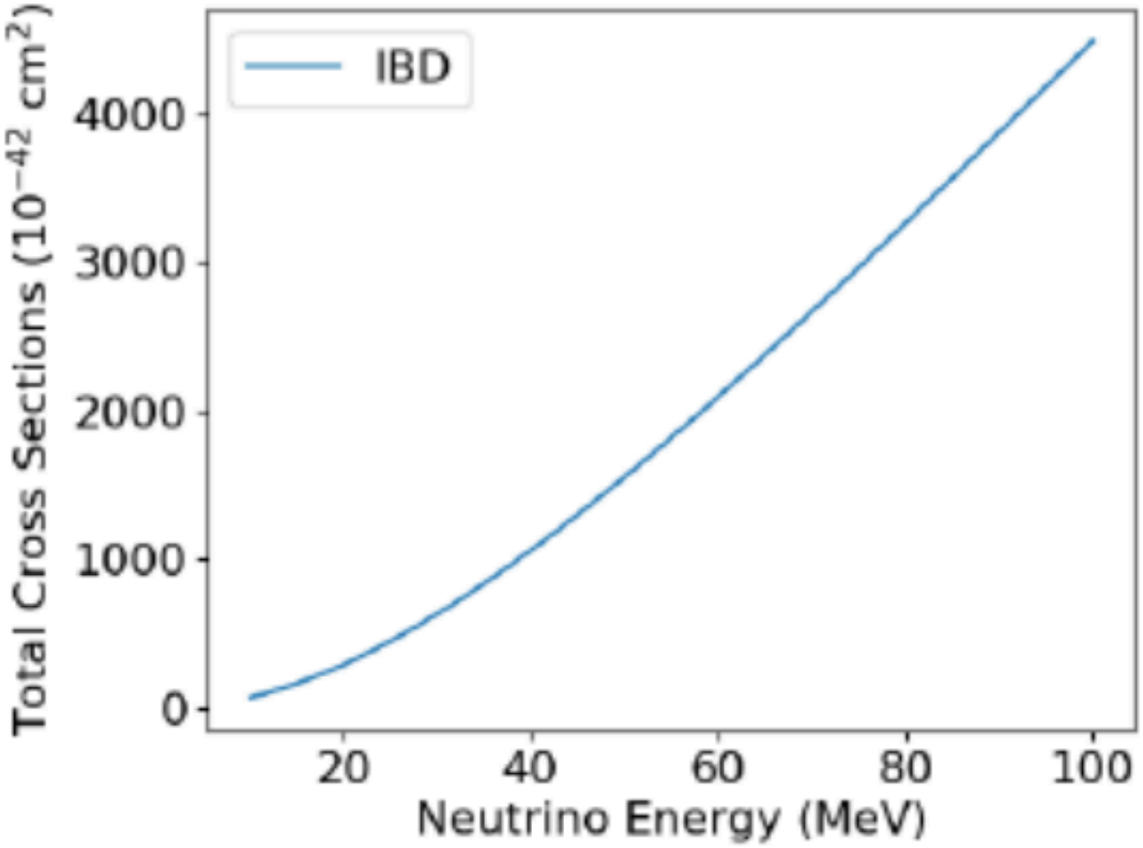
SN Detection Channels in SNO+ (LAB)

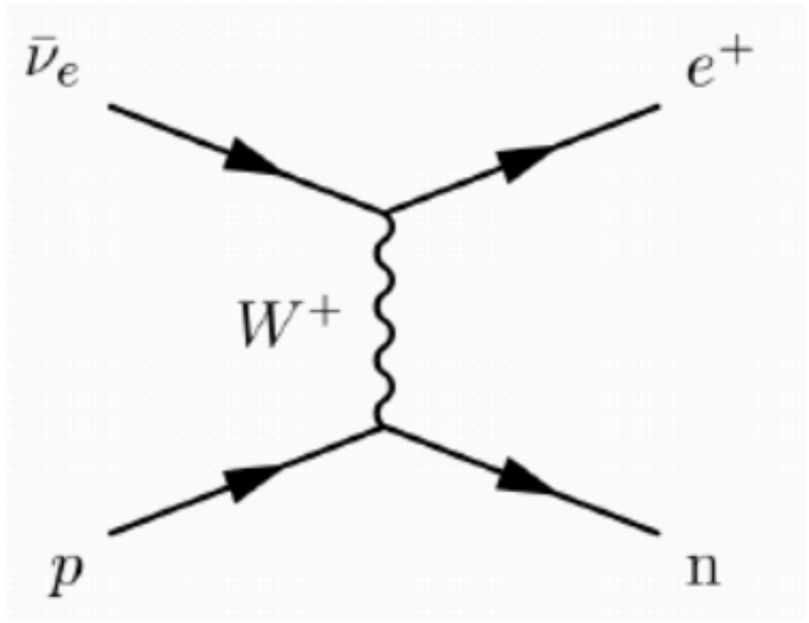
CC:	$\bar{\nu}_e + p \rightarrow n + e^+$	41%
	${}^{12}C(\nu_e, e){}^{12}N$	4.7%
	${}^{12}C(\bar{\nu}_e, e^+){}^{12}B$	1.5%
NC:	${}^{12}C(\nu_x, \nu_x){}^{12}C^*$	9.3%
	$\nu_x + p \rightarrow \nu_x + p$	42%
ES:	$\nu_x + e \rightarrow \nu_x + e$	1.9%

Inverse Beta Decay

- Sensitive to electron anti-neutrino
- Large Cross section
- Tagged reaction
- 1.8 MeV threshold

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

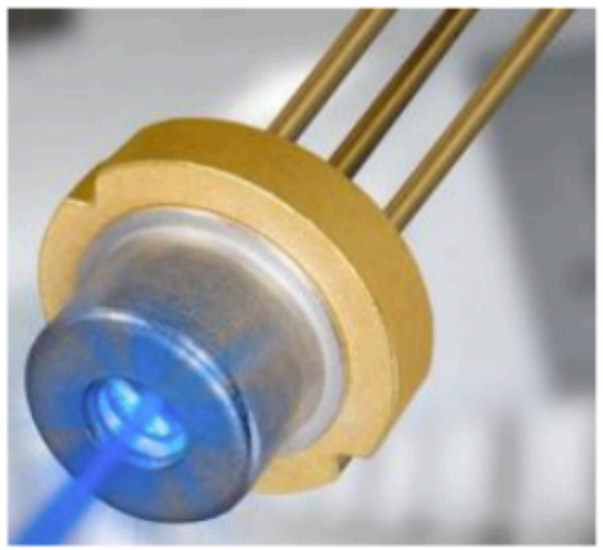




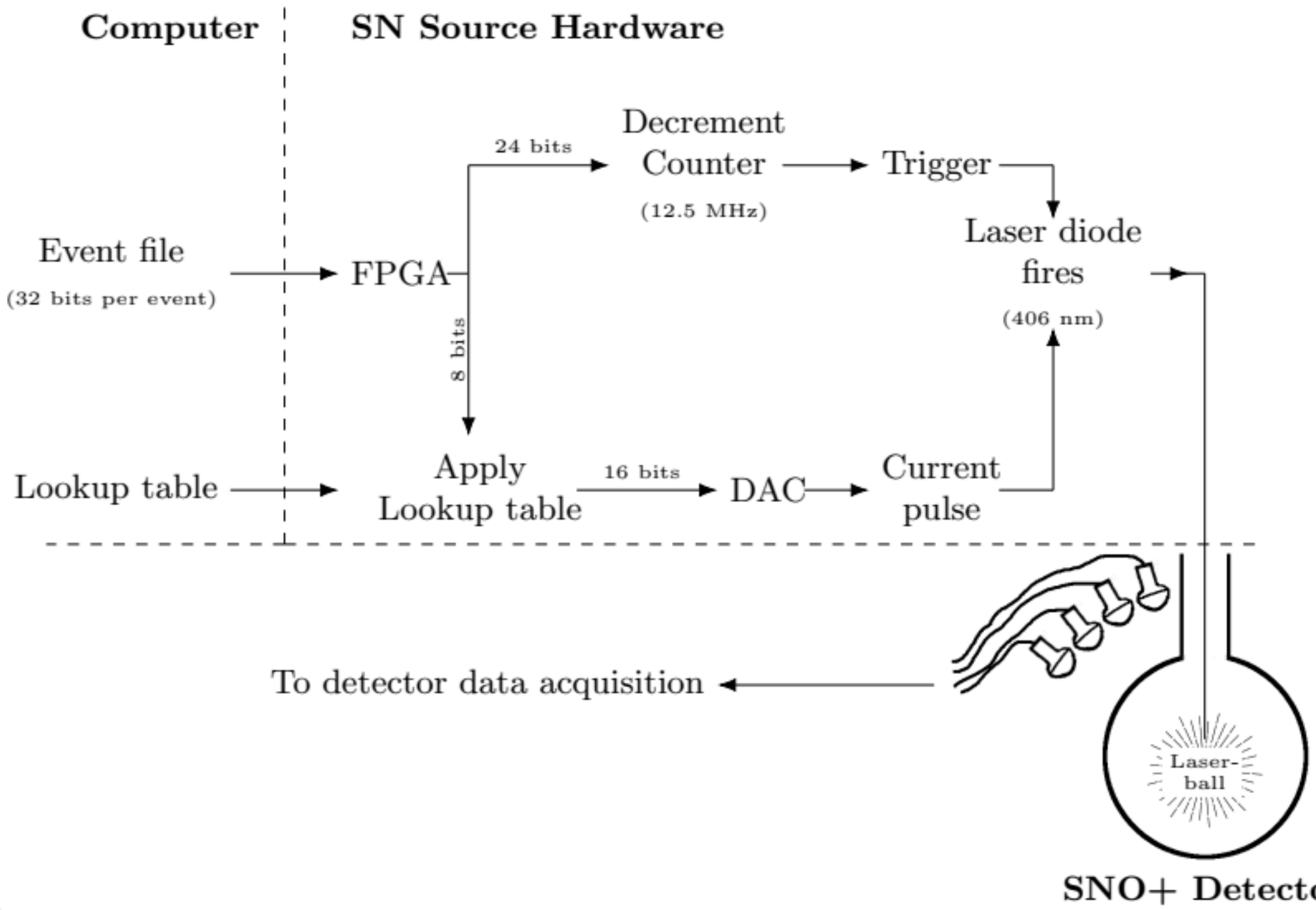
(M.Rigan)

Supernova Calibration Source

- Developed at Laurentian University
- High-rate, high-occupancy optical calibration to stress-test DAQ and electronics
- Dynamic frequency range, variable energy pulse
- Simulates realistic SN neutrino bursts

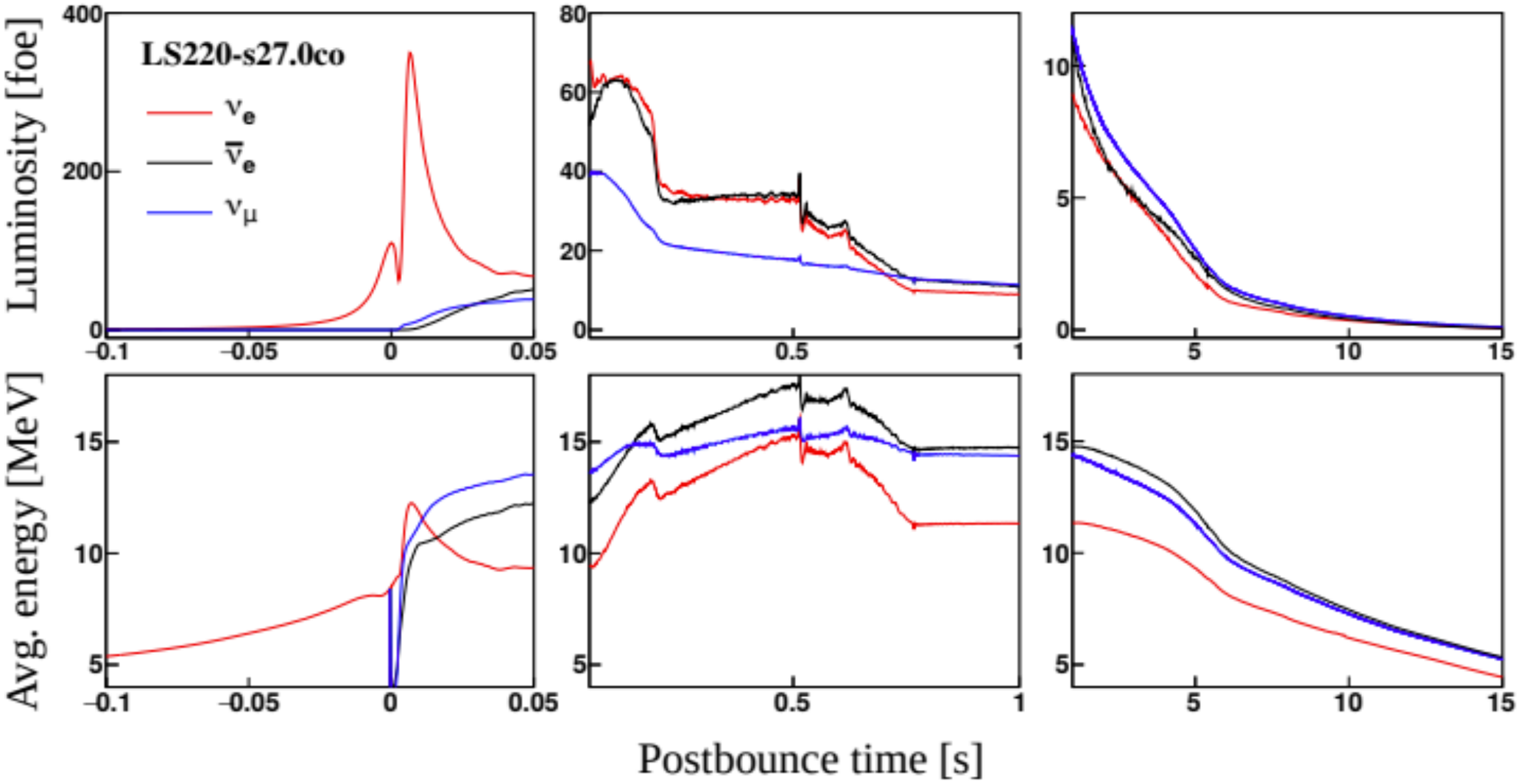


Supernova Calibration Source



(J. Rumleskie)

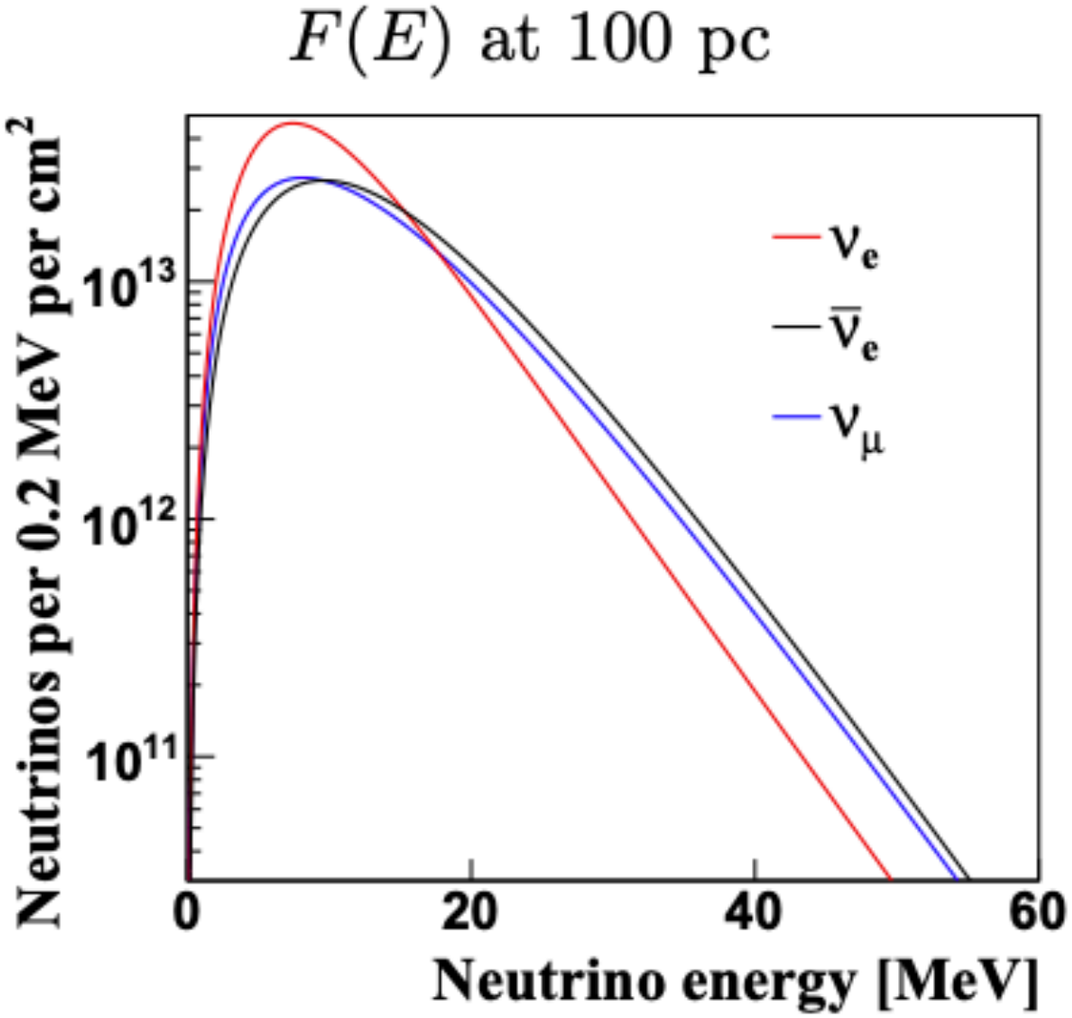
Supernova Models

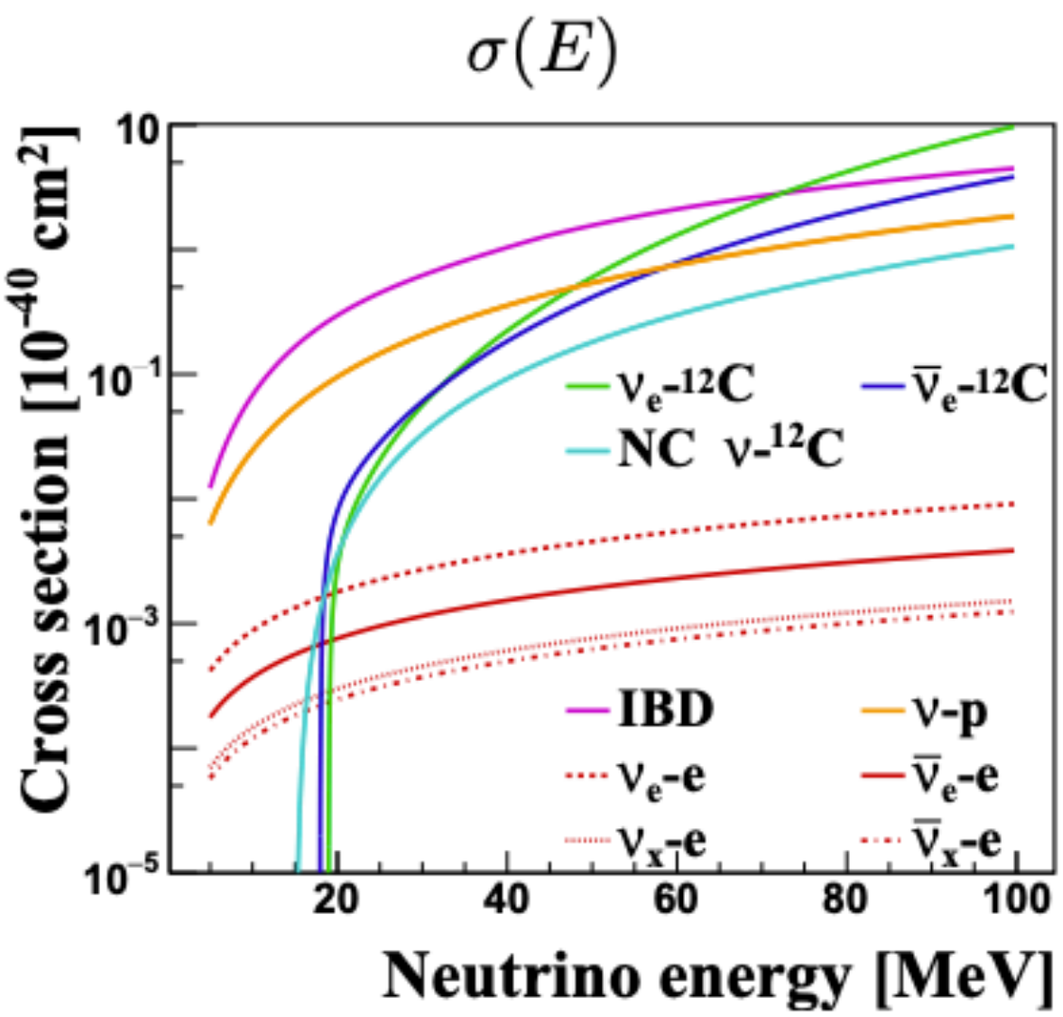


- Calculate neutrino flux using a modified Fermi-Dirac expression (d = 100 pc)
- SN models provided by the Garching group (A. Mirizzi et al. Rivista del Nuovo Cimento Vol. 39 N. 1-2 (2016))

(J. Rumleskie)

Convolve flux and cross sections

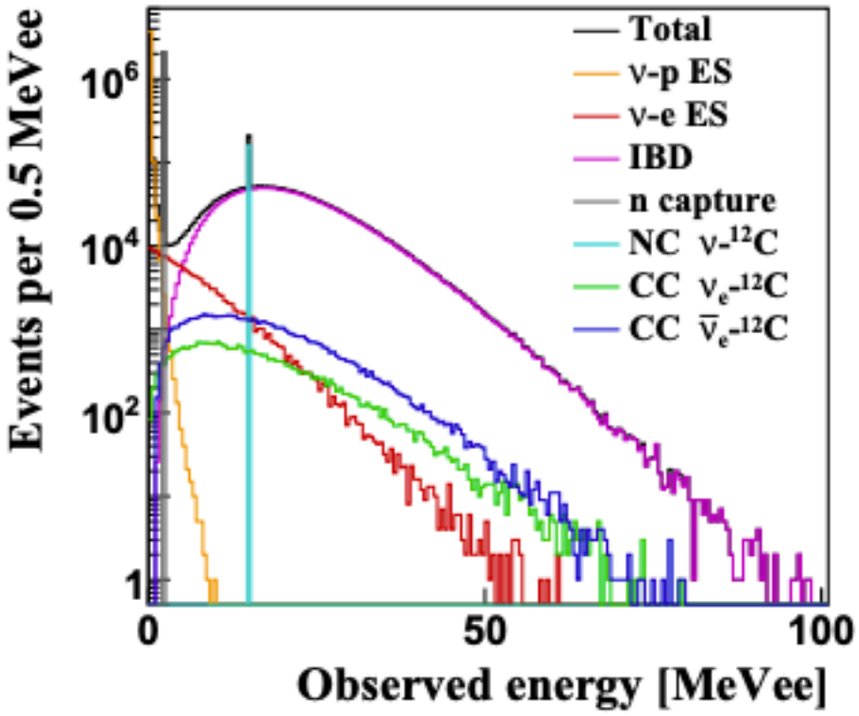


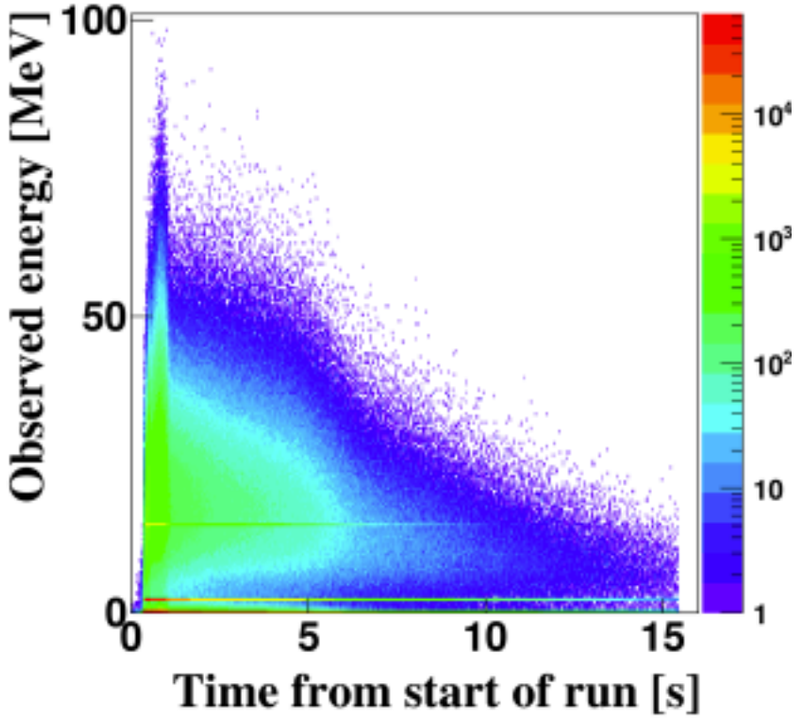


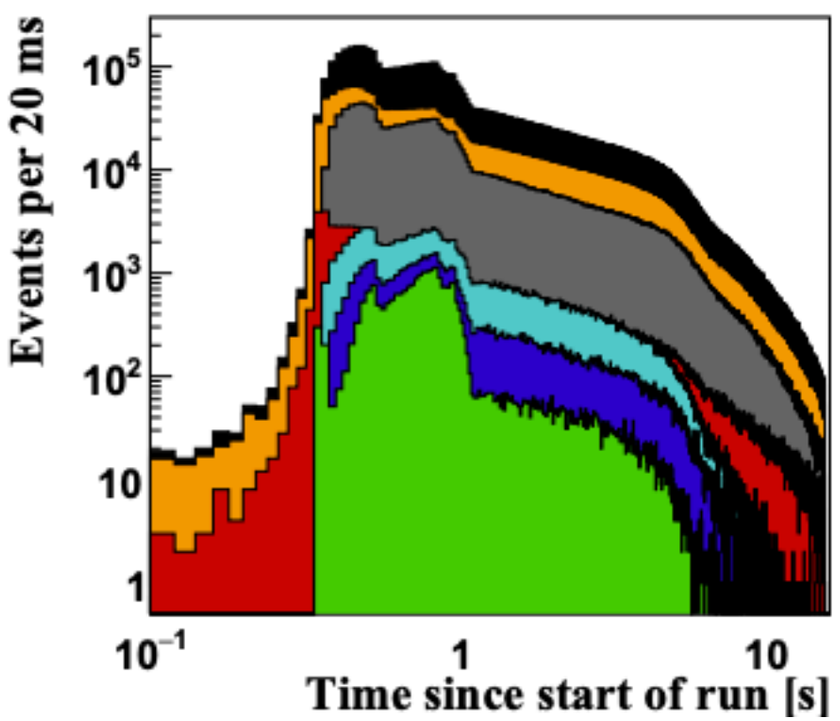
$$N = N_{targets} \int_0^{E_{max}} \int_{t_1}^{t_2} F(E)\sigma(E)\ dt\ dE$$

(J. Rumleskie)

Master File Events (100pc)





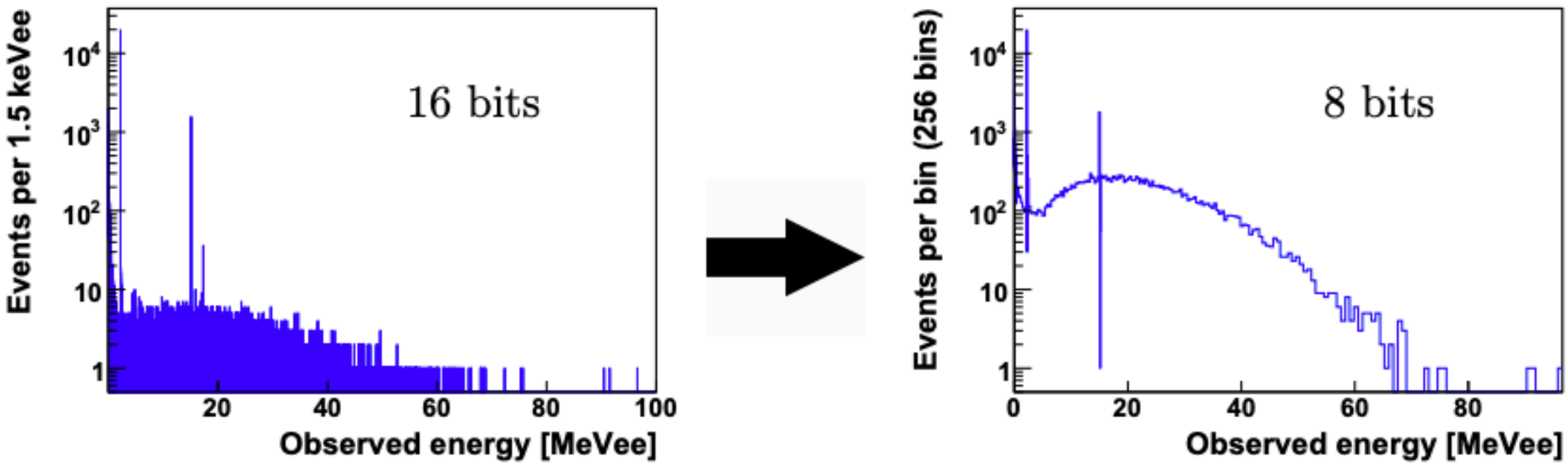


- Features of supernova visible in interaction channels
- ν – p events at low energy (quenched)
- ~8 400 000 events in 15 seconds
- Sample file for various distances

(J. Rumleskie)

SN Source Data Files

- Create time/energy file for the SN source.
- Dynamic time scaling to manage pile up in event window
- Non-linear transformation to retain low energy and high energy features



(J. Rumleskie)

Supernova Burst Trigger

- Trigger to recognize Supernova burst, works in 3 levels
  - L1: generate burst file
  - L2: analyse basic patterns
  - L3: clean the data
- Water Burst definition:
  - 30 events in 2s over 35 PMTs hit
- Circular buffer
- Search for specific signs:
  - flat distribution of hits
  - almost exponential time distribution
- To Integrate with the SNEWS system

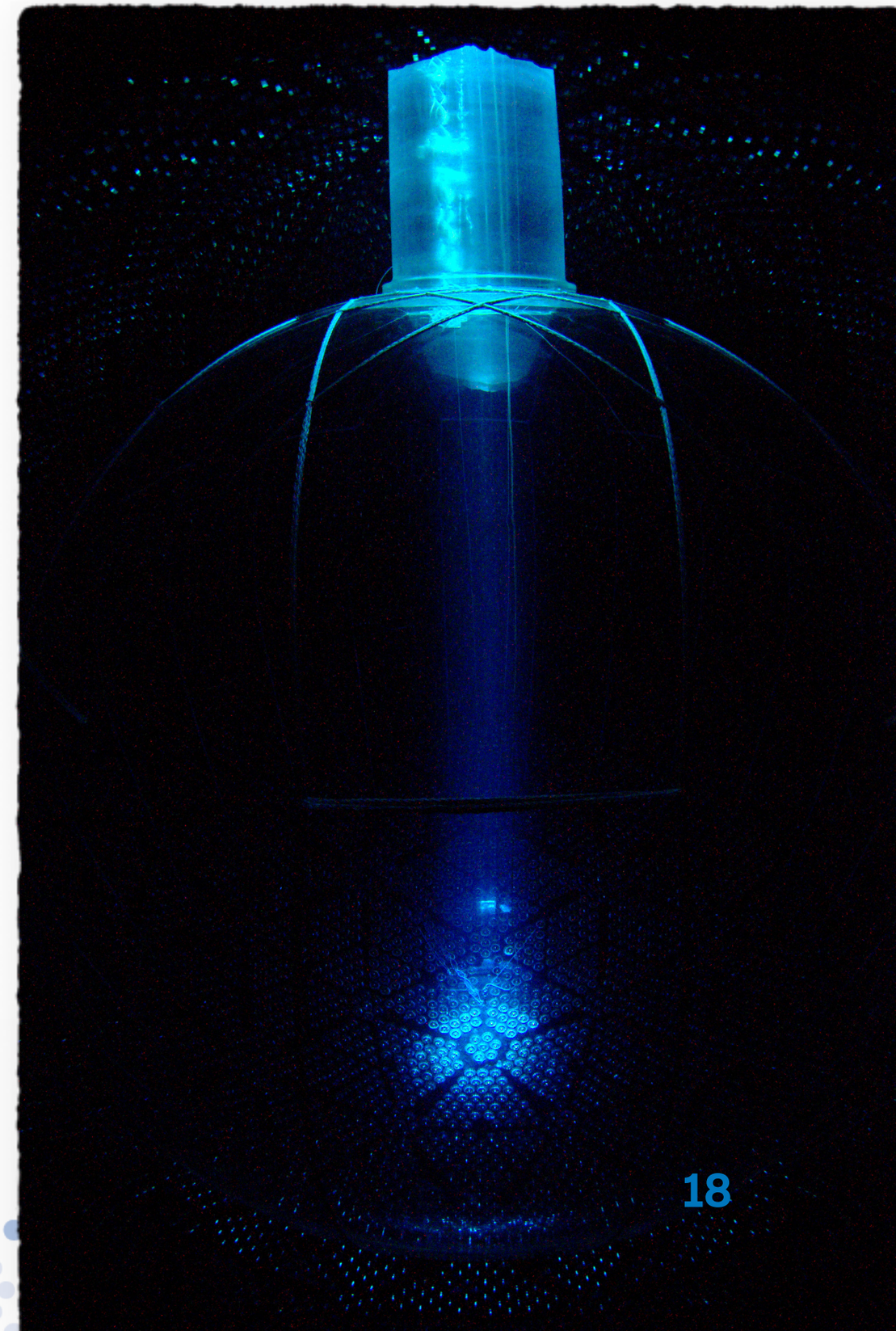
Frederick REINES and Clyde COWAN
Box 1663, LOS ALAMOS, New Mexico

Thanks for message. Everything comes to him who knows how to wait.

Pauli

Summary

- SNO+ is a multipurpose neutrino experiment
- Well understood backgrounds from initial water phase analyses
- Sensitive to Supernovae in all phases
- Dedicated calibration source to prepare for a supernova
- Source Event files have been generated:
  - Distances
  - Neutrino oscillations
  - Supernova progenitors
- Deploy when SNO+ is filled with scintillator
- Dedicated Trigger implemented for initial analysis of "burst" events



SNO+ Collaboration

🇨🇦 U of Alberta, Laurentian U, Queen's Univ, SNOLAB, TRIUMF

🇩🇪 TU Dresden

🇲🇽 U National Autonoma de Mexico

🇵🇹 LIP Lisbon & Coimbra

🇬🇧 Lancaster U, U of Liverpool, King's College London, U of Oxford, Queen Mary U of London, U of Sussex

🇺🇸 UCBerkeley/LBNL, Boston U, Brookhaven National Lab, UChicago, UCDavis, Norwich U, U of Pennsylvania