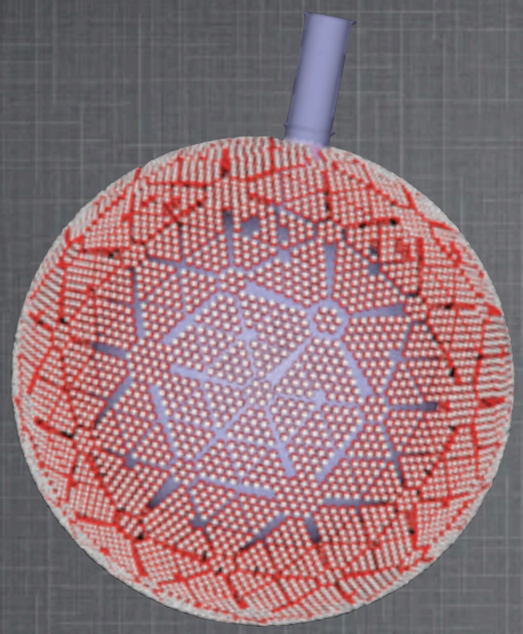


SNO+

"We recommend a targeted program of experiments to investigate neutrino properties and fundamental symmetries"

-- NSAC long-range plan, 2007

1. *A neutrinoless ββ program (p80)*
2. *Precision determination of oscillation parameters (p84)*
3. *Solar neutrinos (p90)*
4. *Reactor antineutrinos (p85)*
5. *Geoneutrinos (p90)*
6. *Neutrino probes of supernovae (p91)*

Gabriel D. Orebi Gann
for the SNO+ Collaboration
Fundamental Symmetries workshop
Chicago Aug 10th 2012

US COLLABORATORS

Reuses > $10M US investment in SNO

Universities

Penn
University of Pennsylvania

University of Washington 1861

The University of California 1868

University of North Carolina Chapel Hill

AASU
Armstrong Atlantic State University

Norwich University 1819

Black Hills State University

National Labs

Berkeley Lab

Brookhaven National Laboratory

INTERNATIONAL COLLABORATORS

Queen's University
Laurentian University
University of Alberta
TRIUMF
SNOLAB

Brookhaven National Lab
University of Pennsylvania
University of Washington
Black Hills State University
Armstrong Atlantic University
University of North Carolina
UC Berkeley and LBNL
Norwich University

Oxford University
Sussex University
Leeds University
Liverpool University
Sheffield University
QMUL

LIP Lisboa and Coimbra

Techniche Universität Dresden

SNO+ Collaboration Meeting, Lisbon, Portugal, June 2010

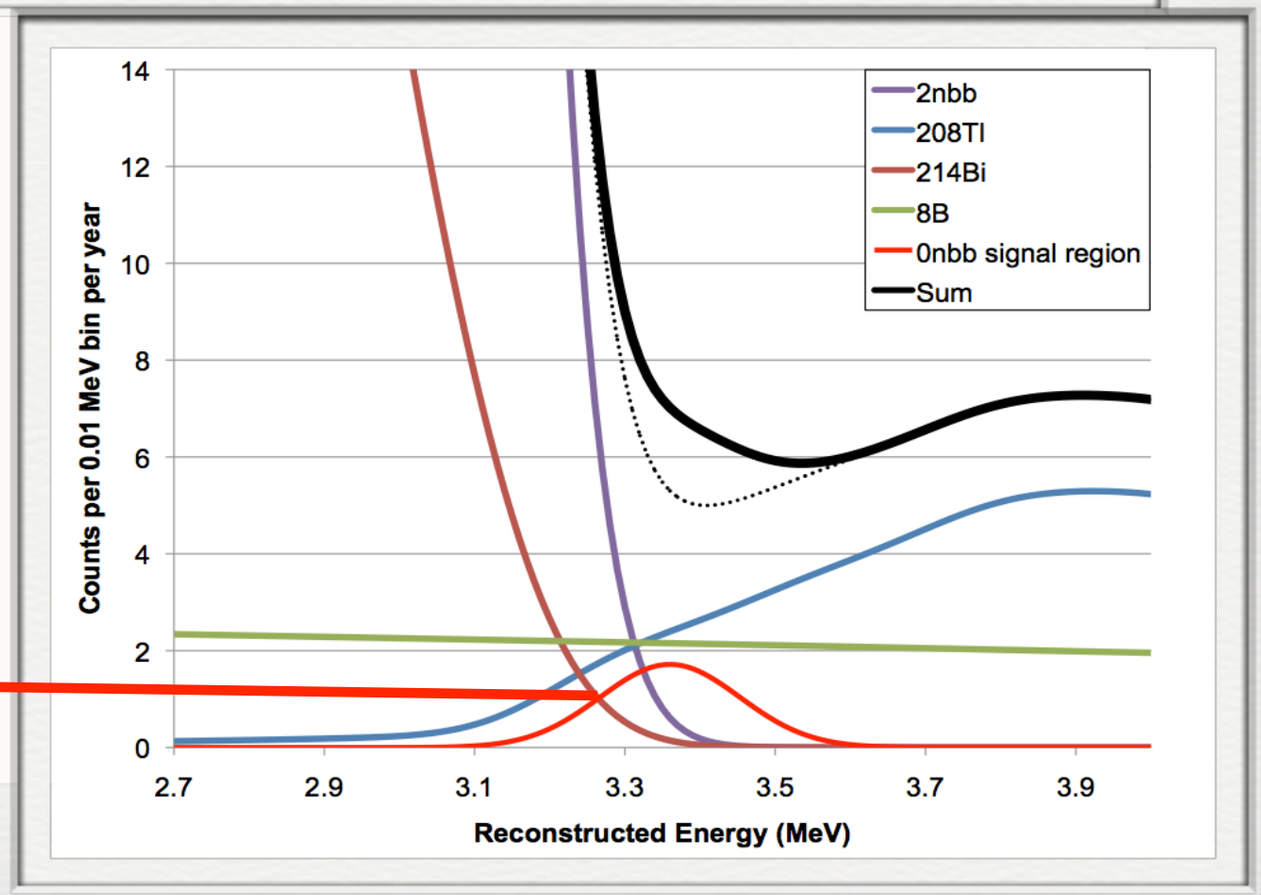
0νββ WITH SNO+

$$\Gamma = (T_{\frac{1}{2}})^{-1} = G_{0\nu}|M_{0\nu}|^2\langle m_\nu\rangle^2$$

Isotope	$Q_{\beta\beta}$	Natural abundance	$\lvert M_{0\nu}\rvert$	$\lvert G_{0\nu}\rvert^{-1}$ (10^{25} y eV^2)	$T^{0\nu}_{1/2}$ (10^{27} y)	$N_{0\nu}$ / $N_{0\nu}$(Ge)
^{150}Nd	**3.37 MeV**	**5.6%**	**1.85 ± 0.55**	**0.13**	**0.15**	**3.3**

Sense and Sensitivity of ββ expts: arxiv/1010.5112

- **Large**
- **Low bkg (deep, clean)**
- Source in / source out
- Well defined background model



0νββ signal

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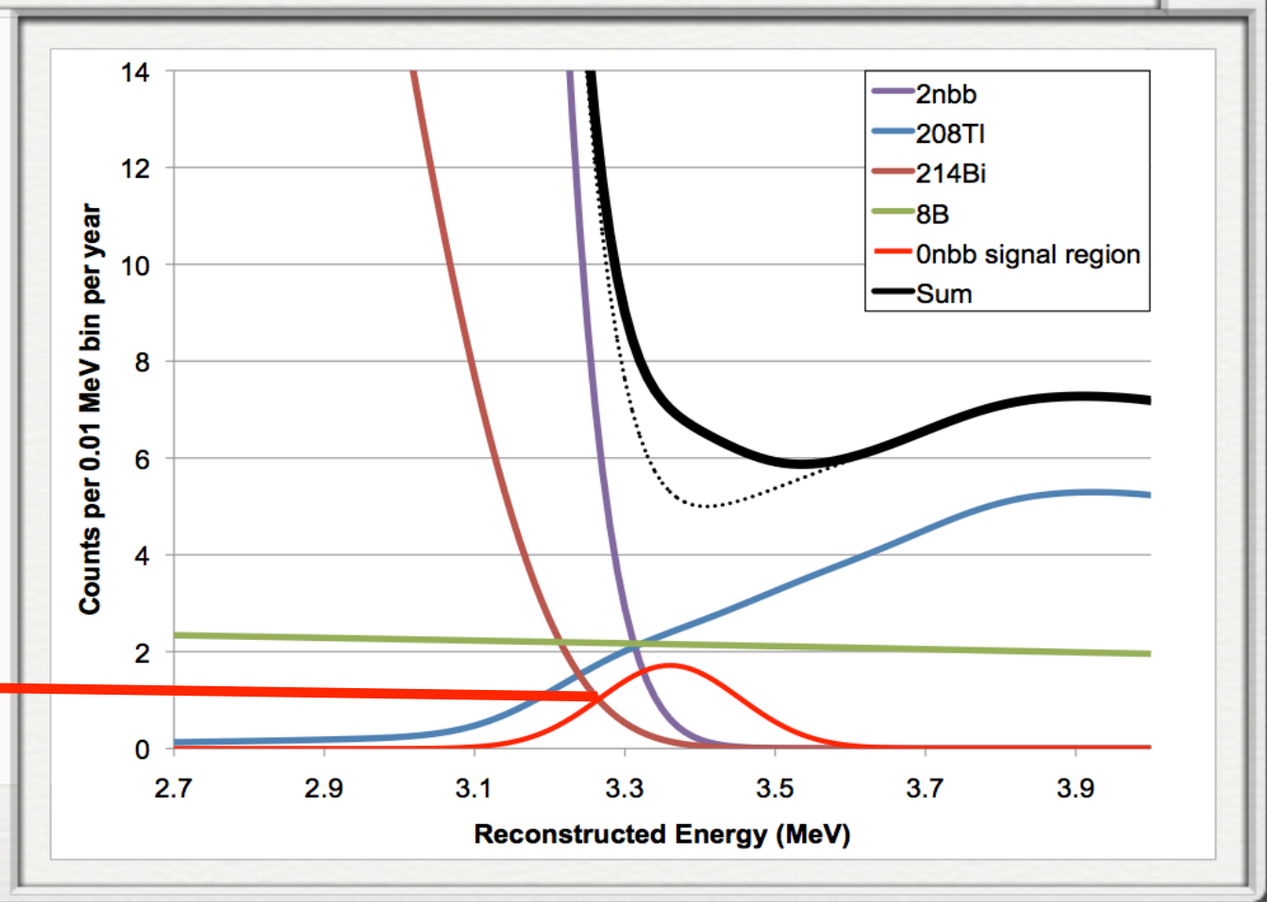
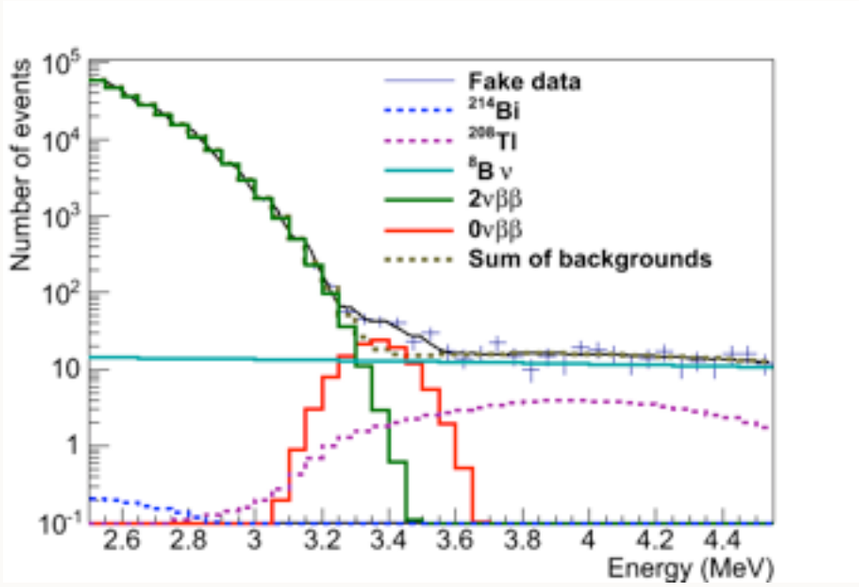
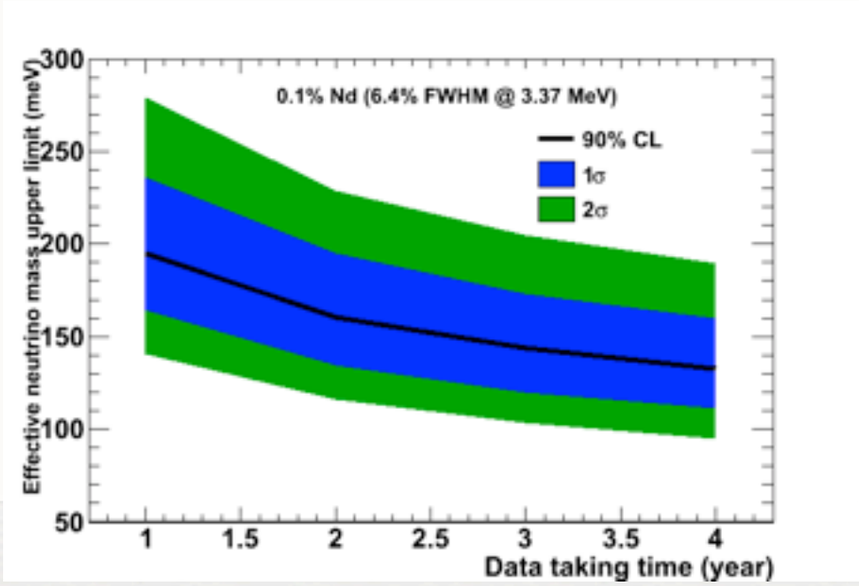


0νββ signal

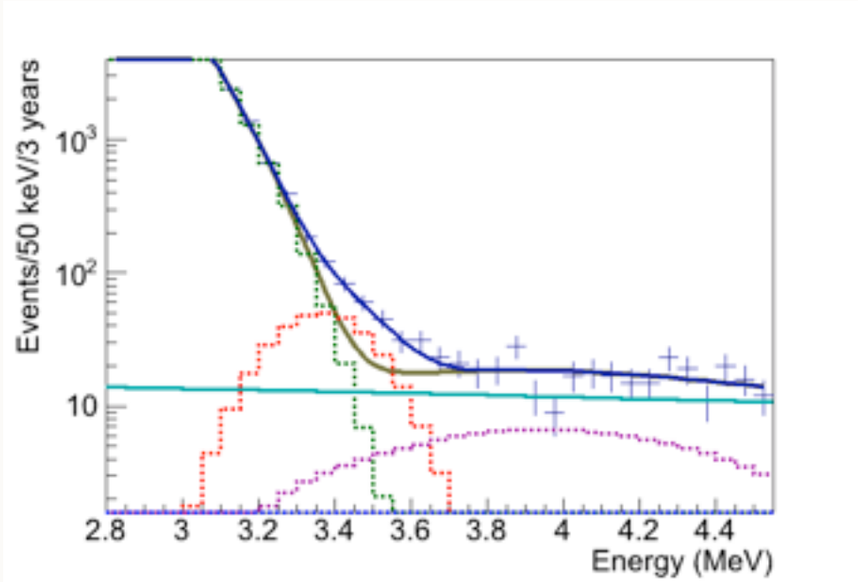
SNO+ 0νββ SENSITIVITY

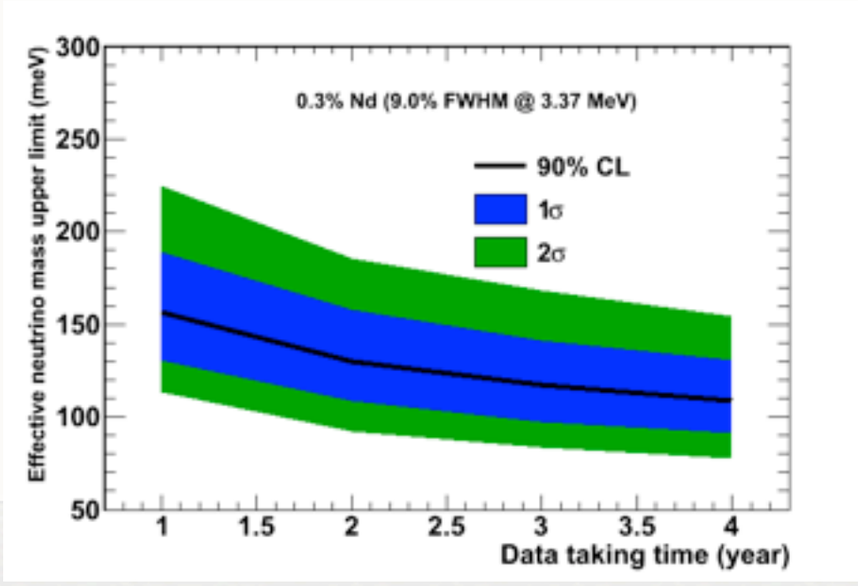
- **0.1% Nd**: 400 hits/MeV
  44kg



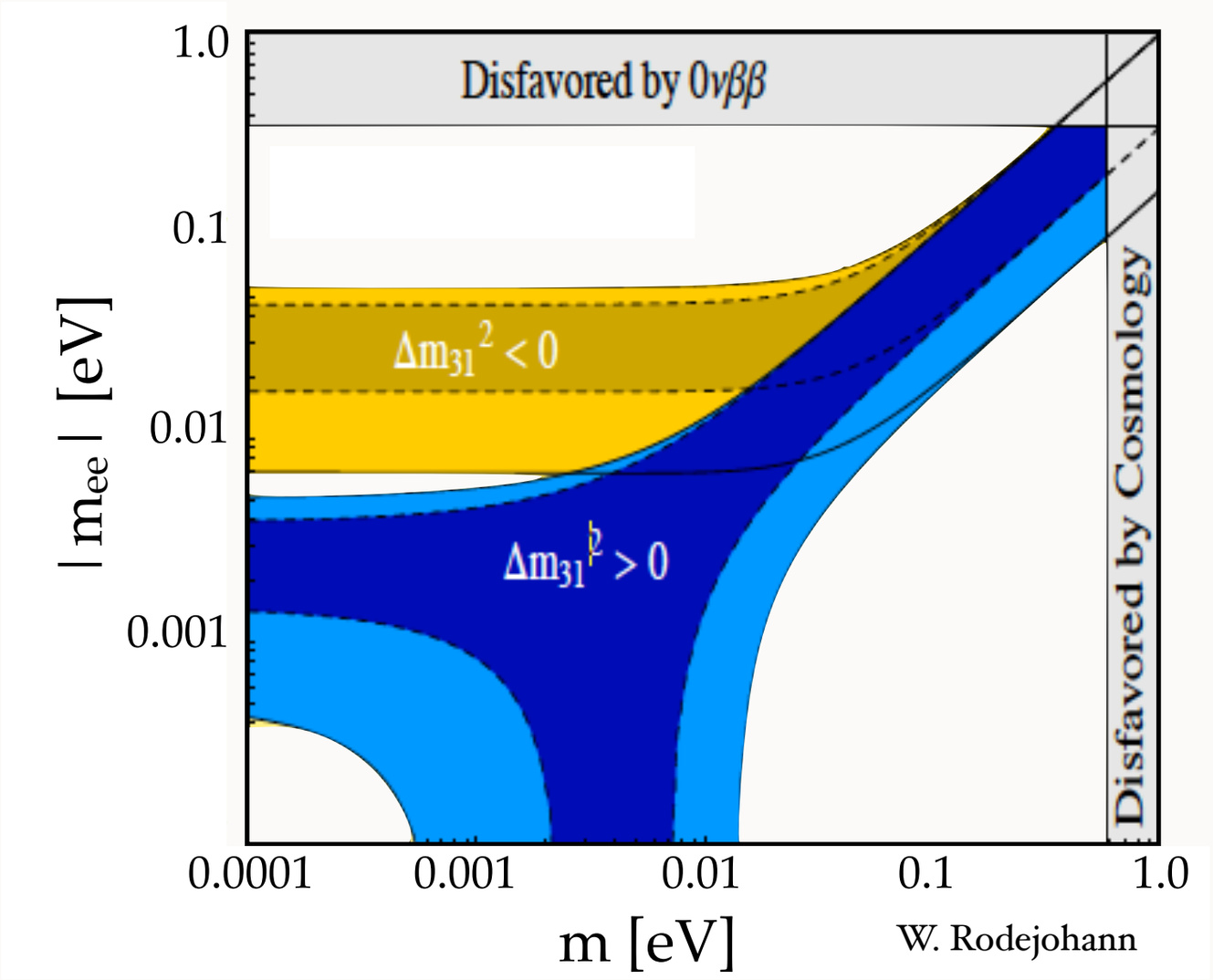


- **0.3% Nd**: 200 hits/MeV
  132kg





STATUS OF THE FIELD



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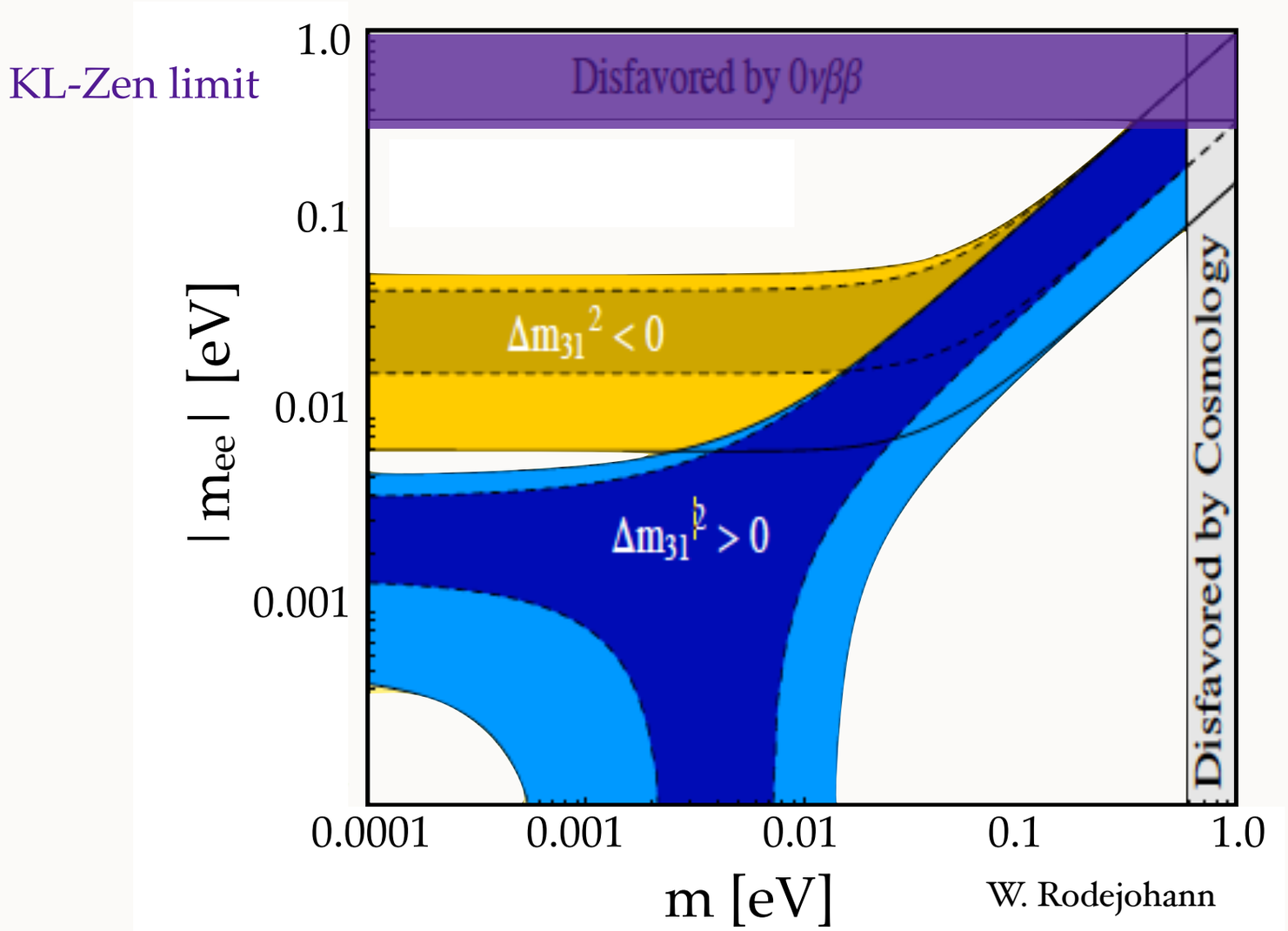

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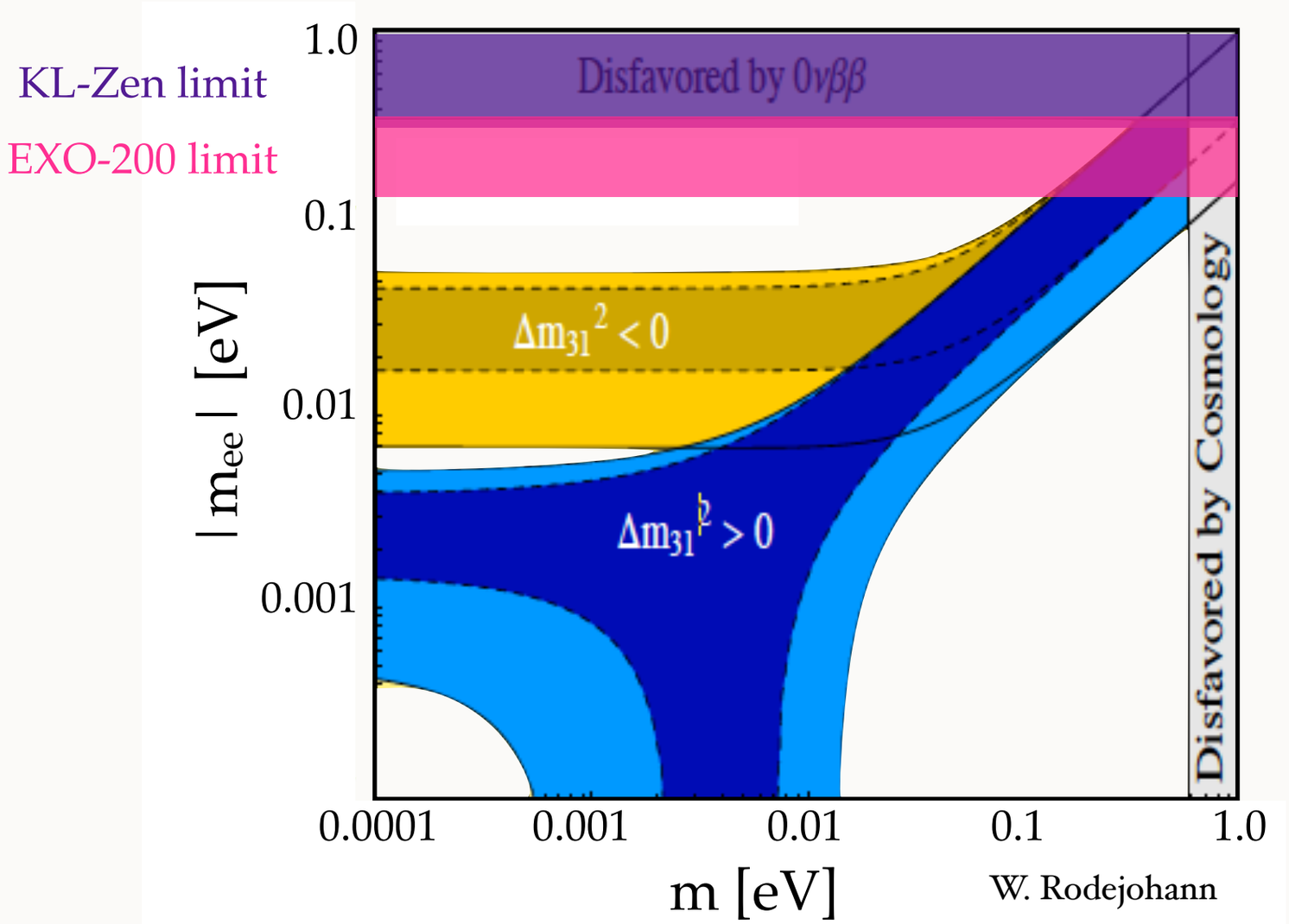

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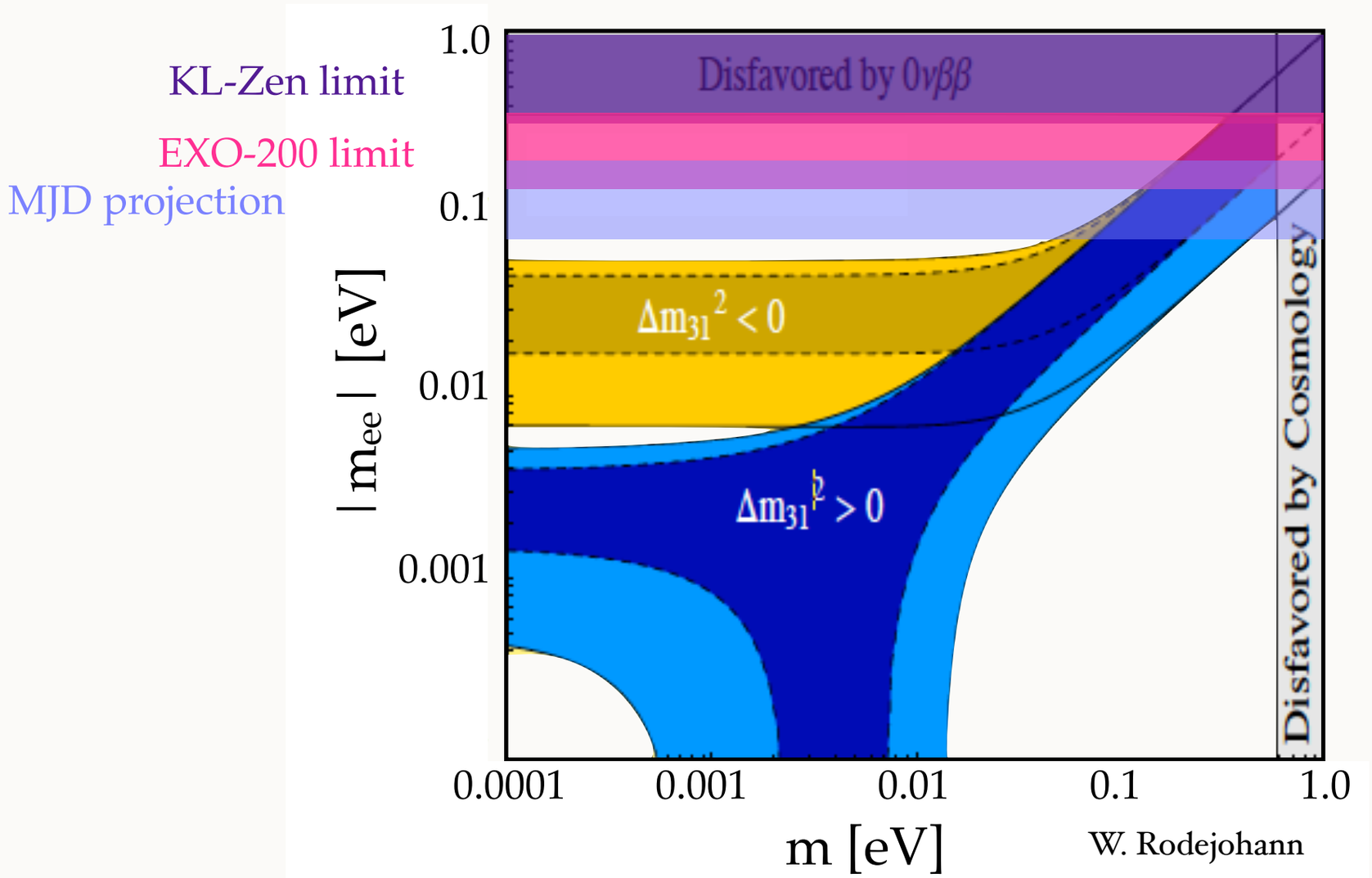

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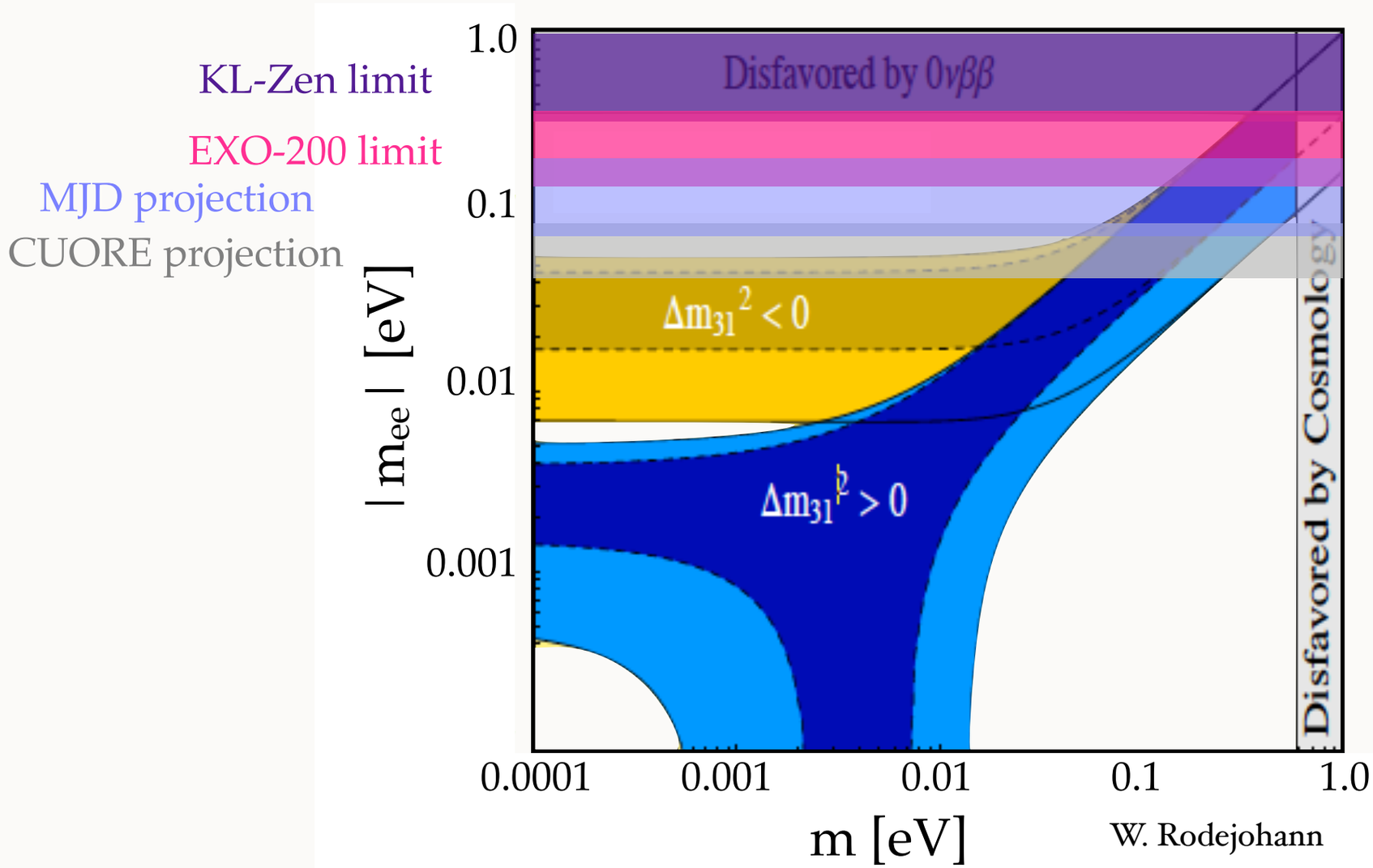

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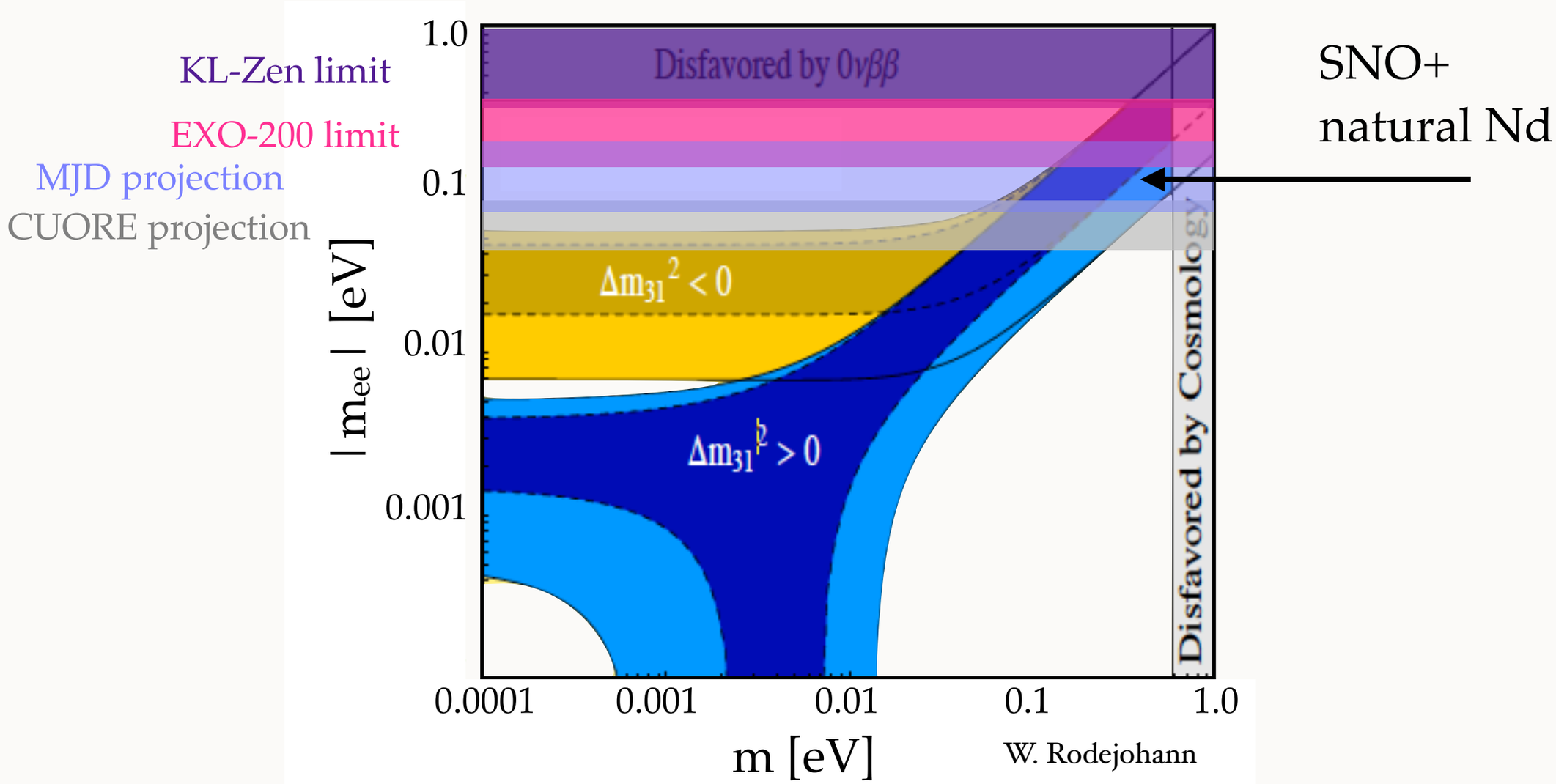

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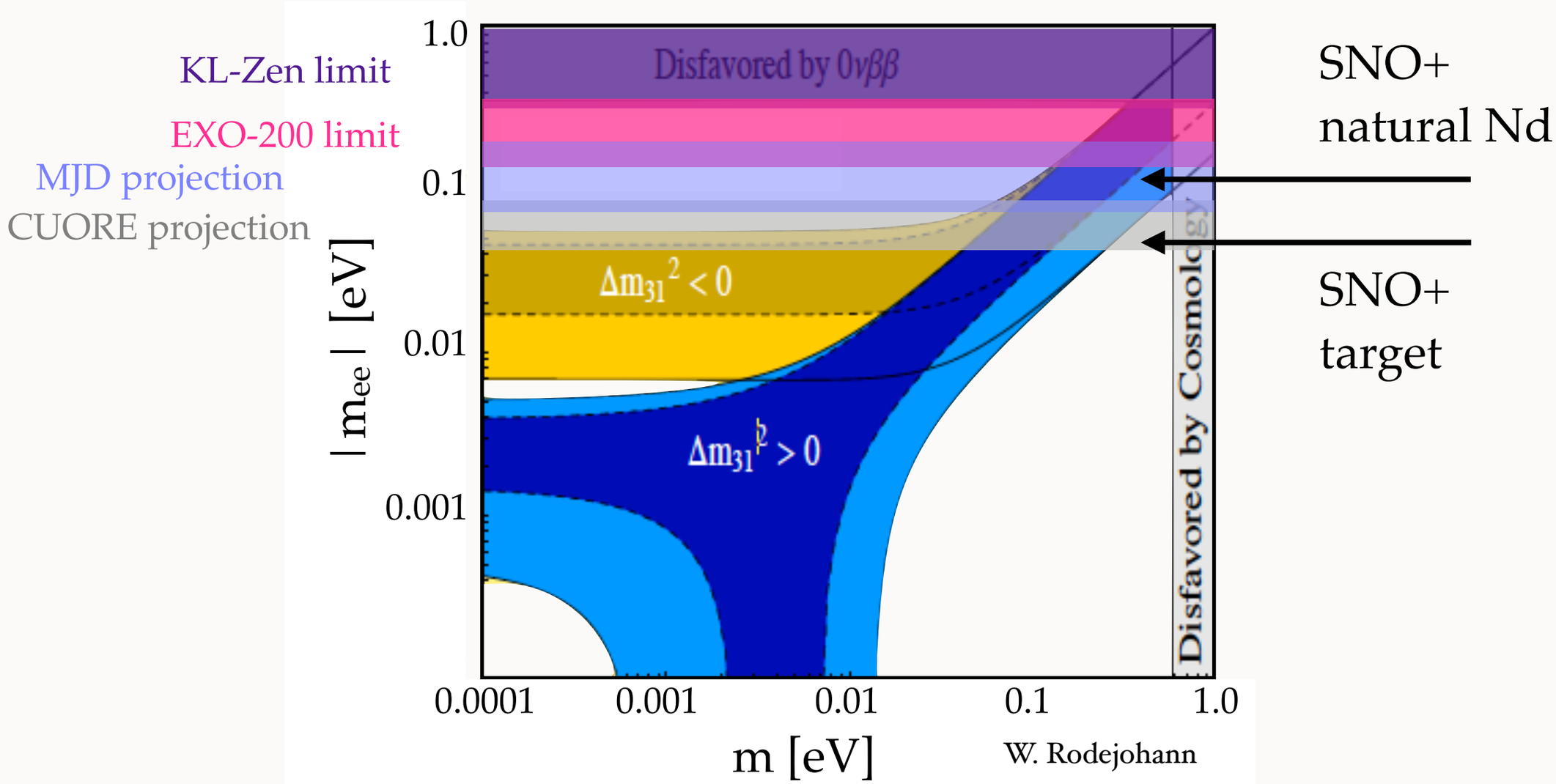
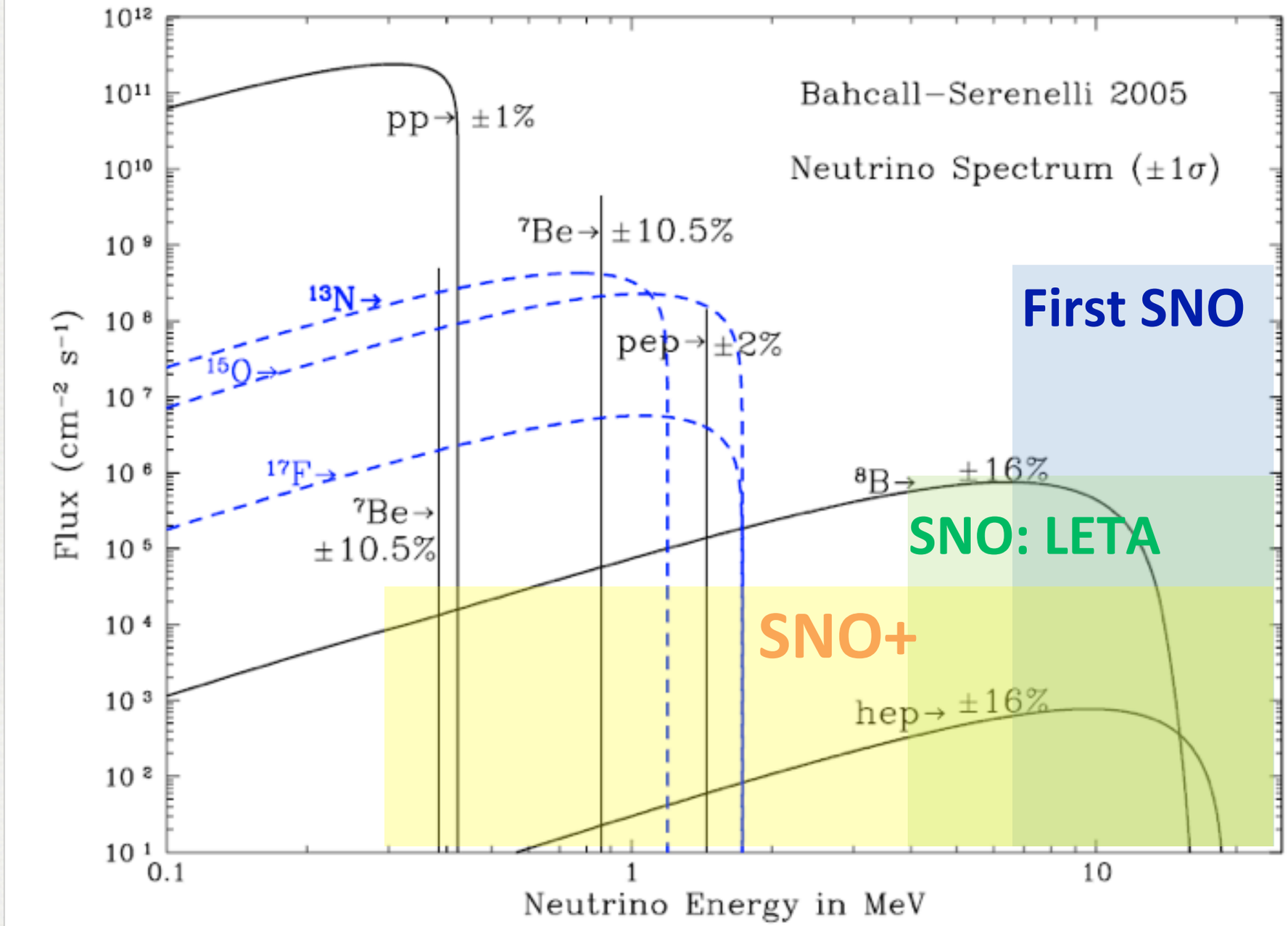


2. Precision determination of oscillation parameters (p84)
3. Solar neutrinos (p90)

SOLAR ν WITH SNO+



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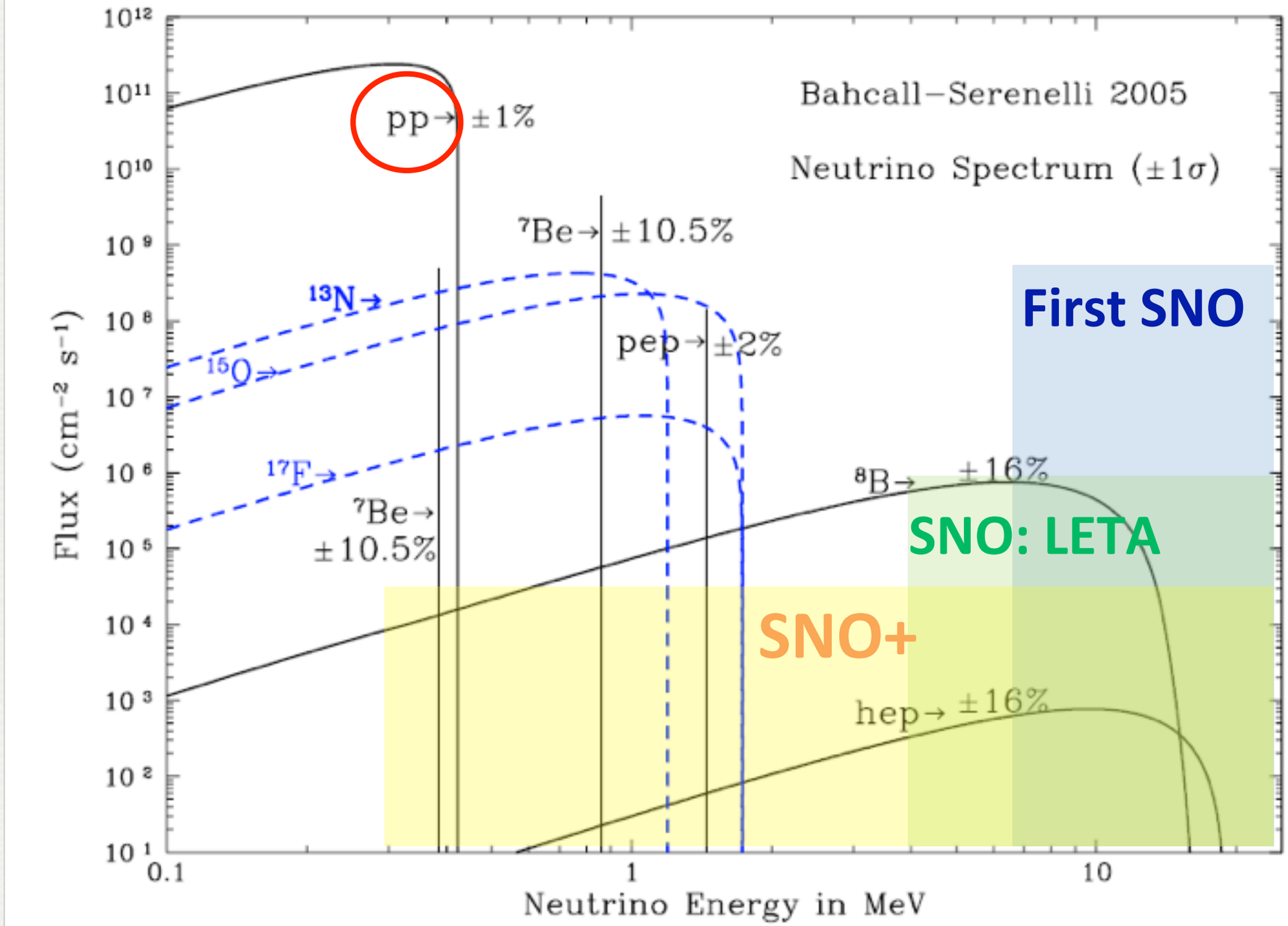
SOLAR ν WITH SNO+

Luminosity constraint



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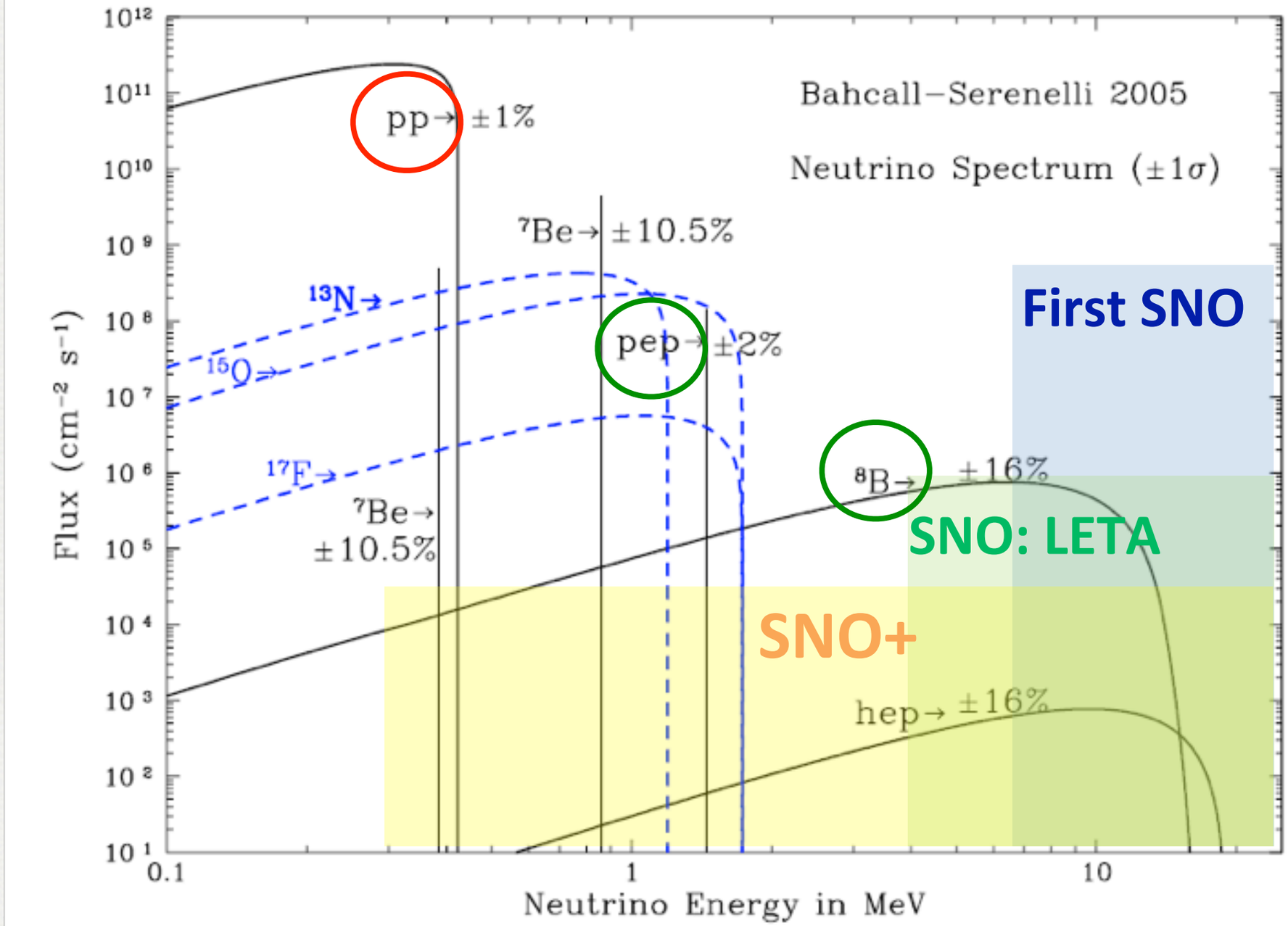
SOLAR ν WITH SNO+

Luminosity constraint

Test MSW / new physics



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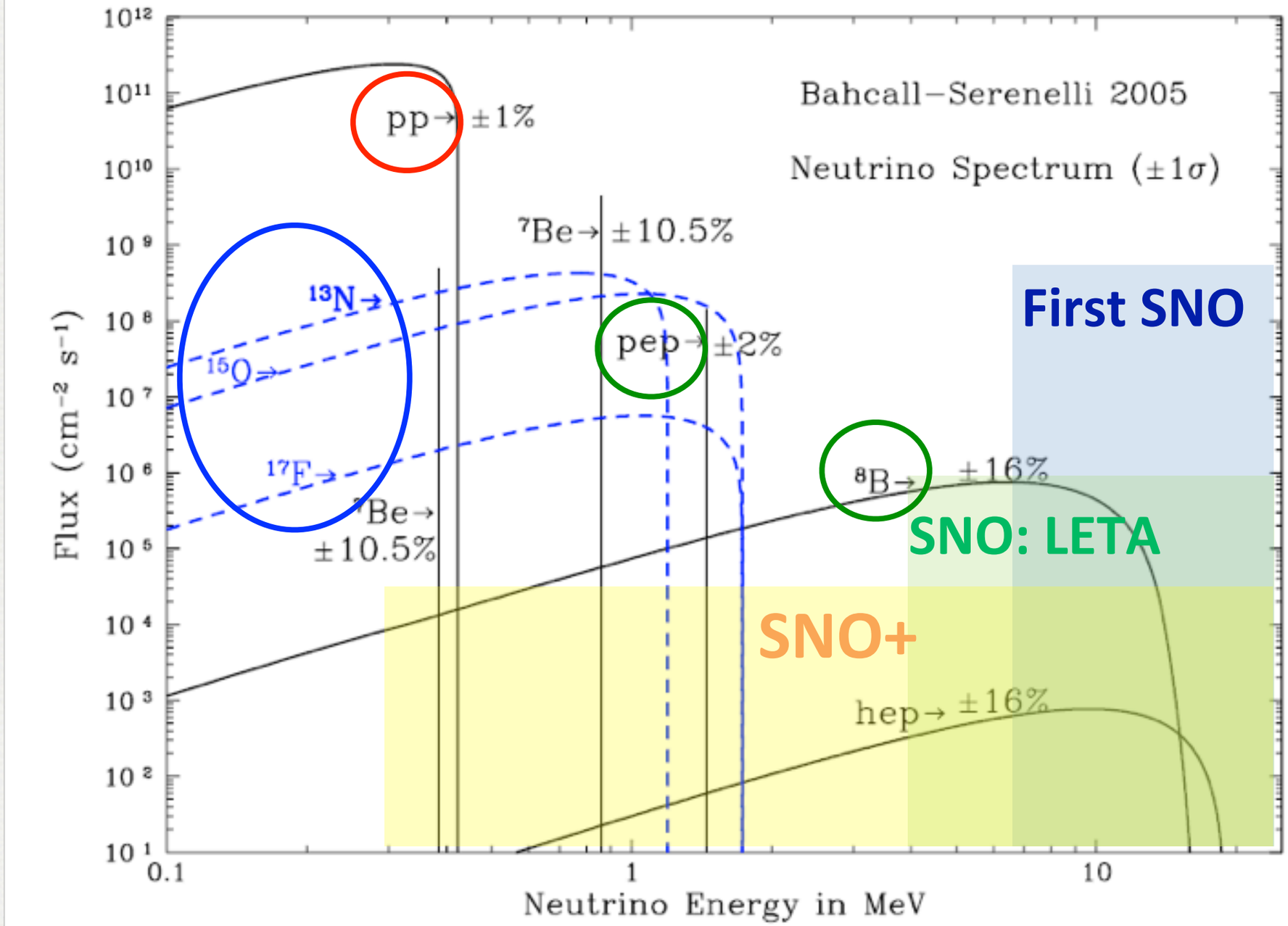
SOLAR ν WITH SNO+

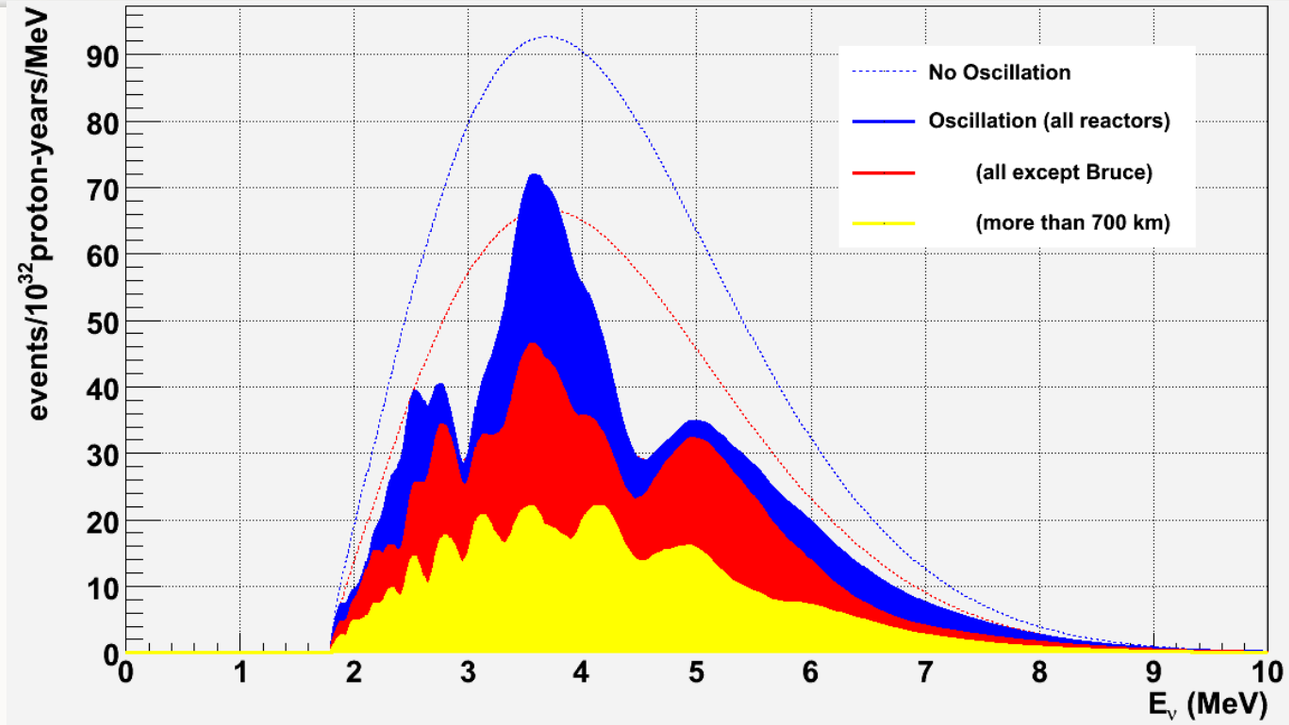
Luminosity constraint

Test MSW / new physics

Solar metalicity



OTHER PHYSICS WITH SNO+



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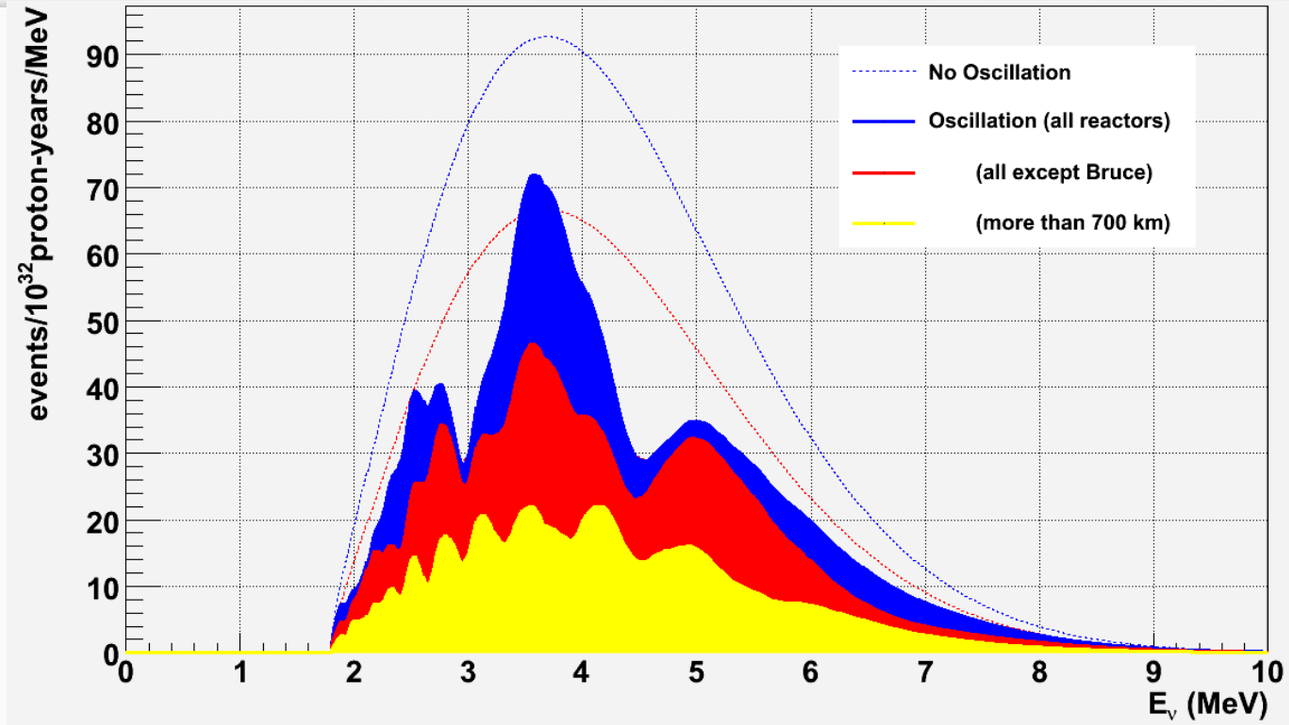
OTHER PHYSICS WITH SNO+



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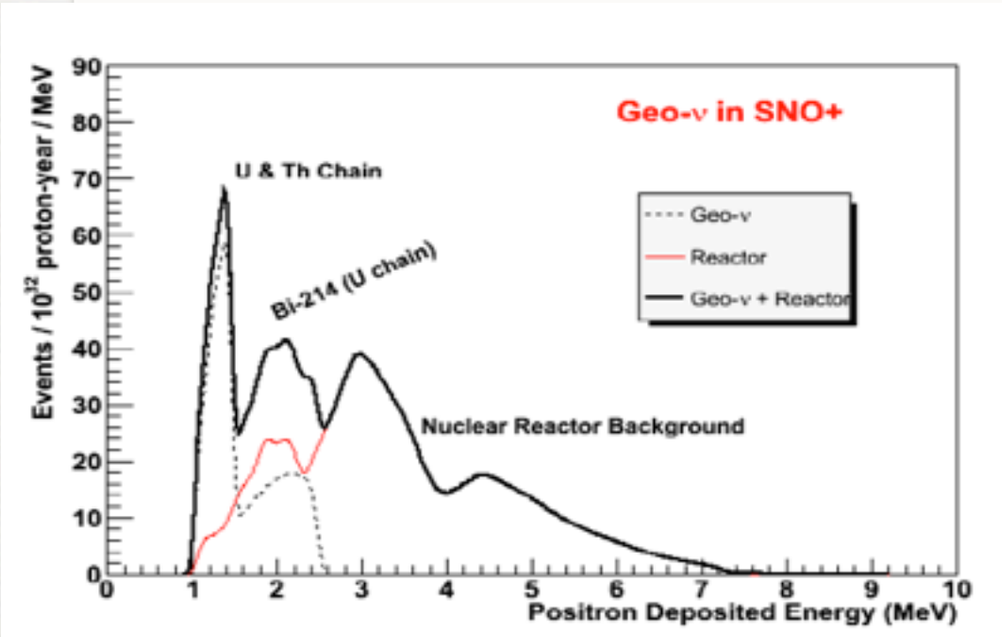

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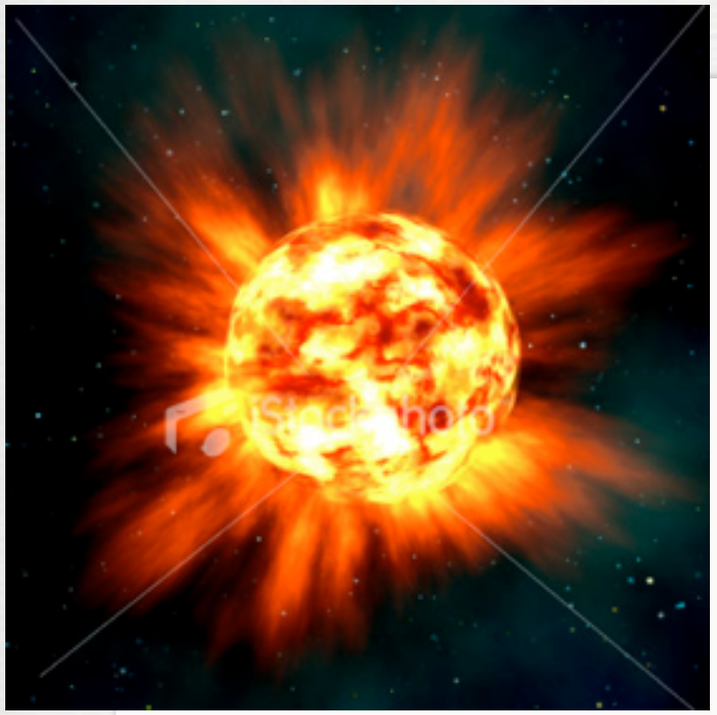

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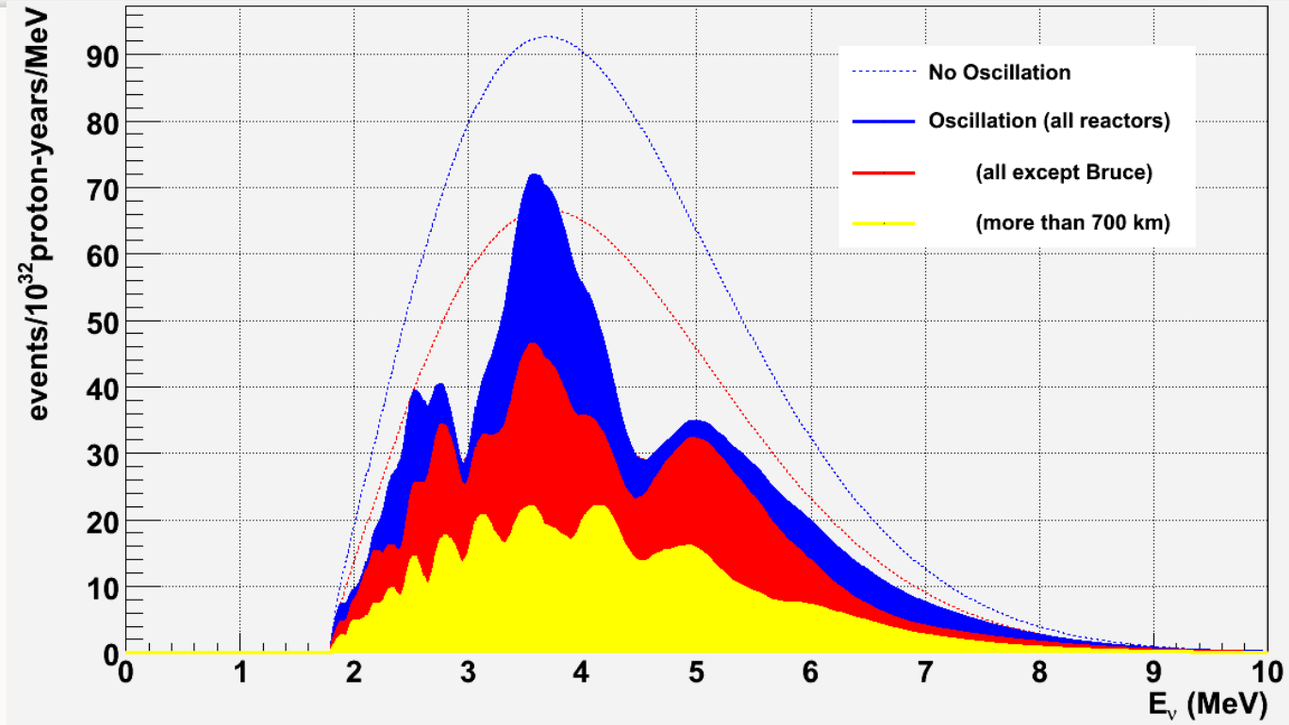

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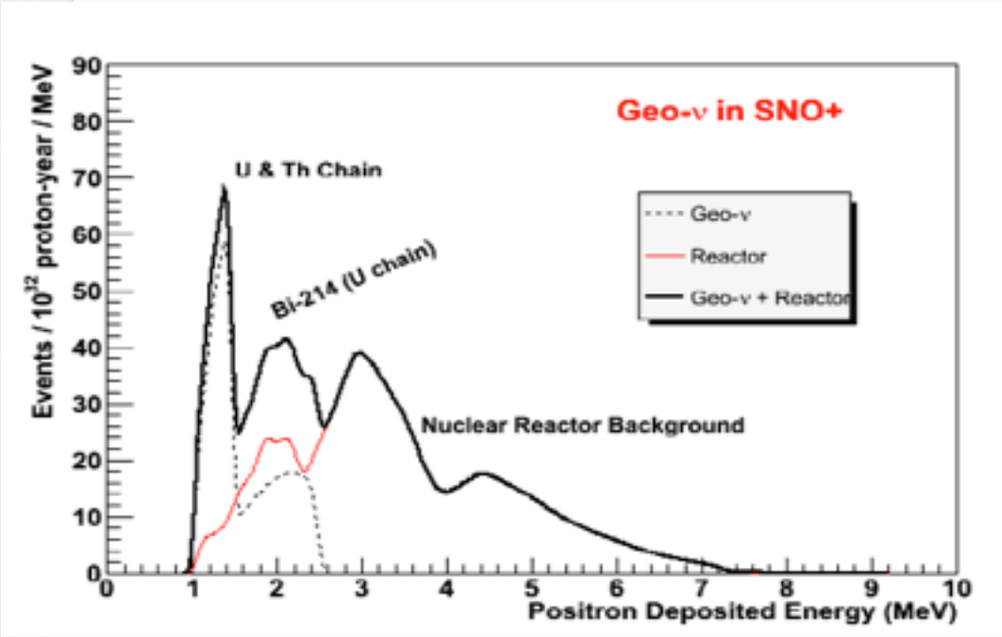

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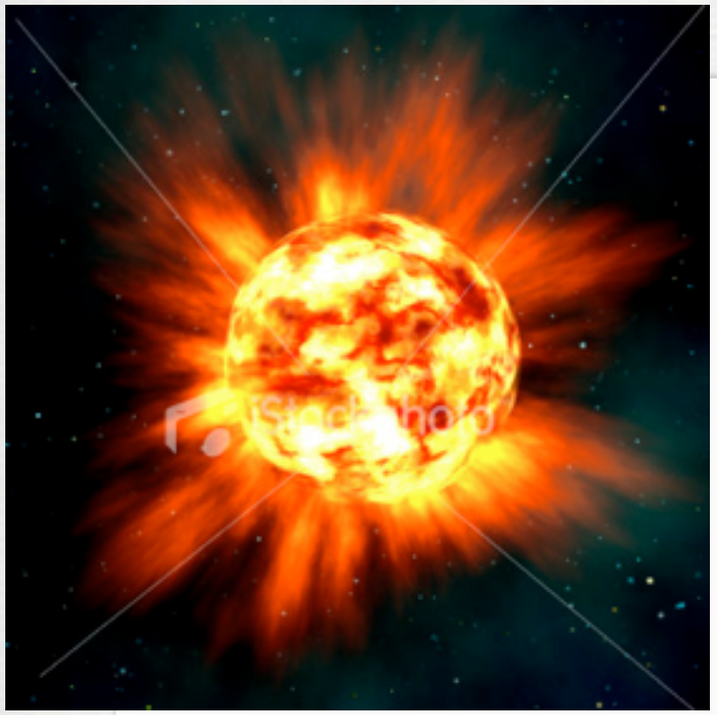

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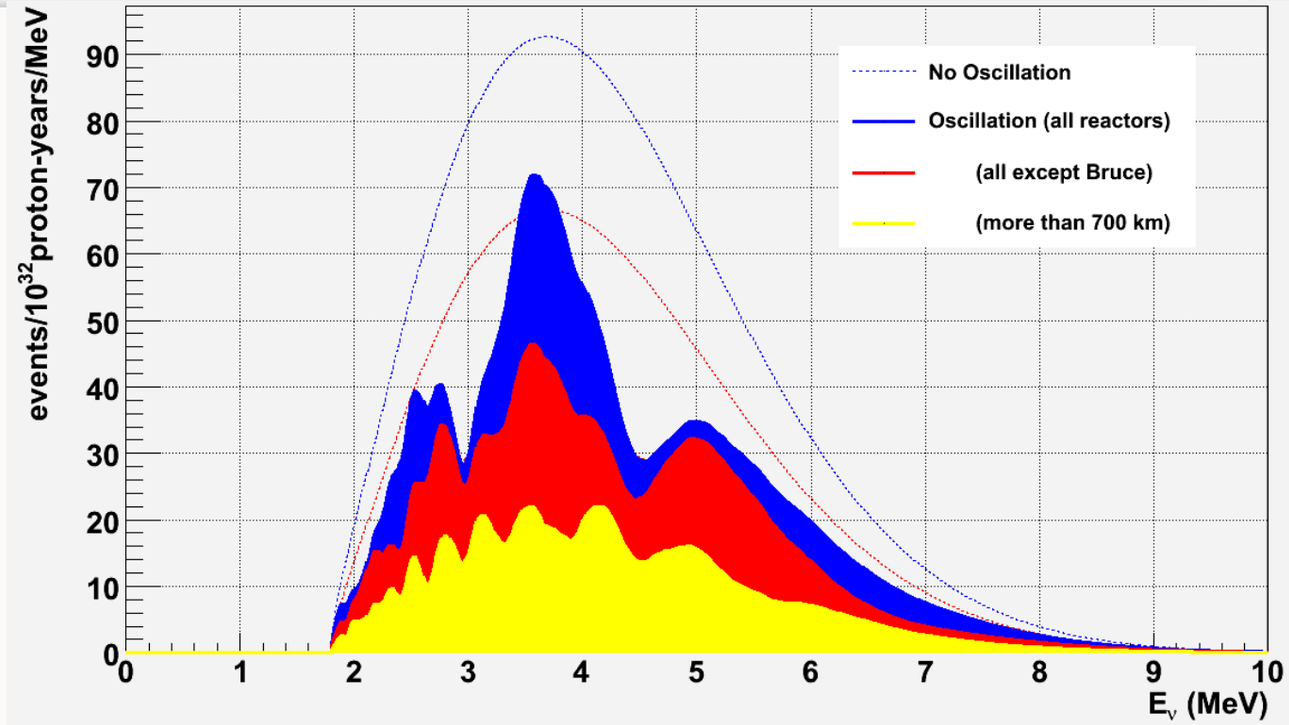

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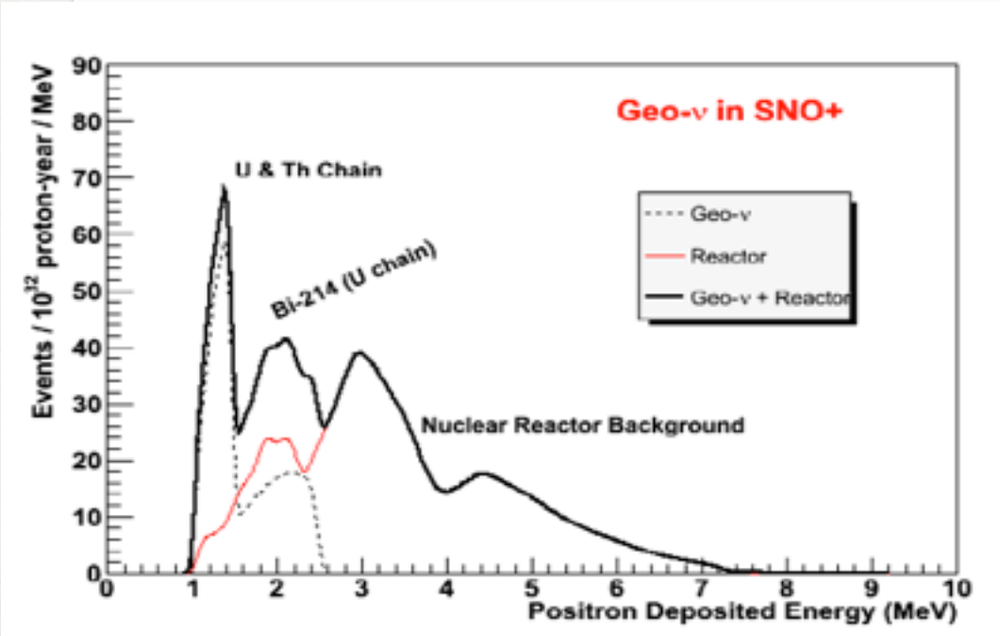
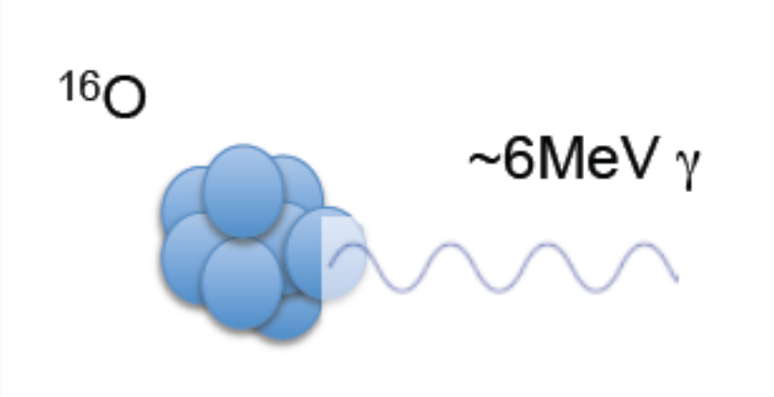




Invisible modes of nucleon decay

US CONTRIBUTIONS

- Leadership Roles
- Scintillator Development
- Electronics and DAQ
- Calibrations
- Monte Carlo simulation
- Analysis

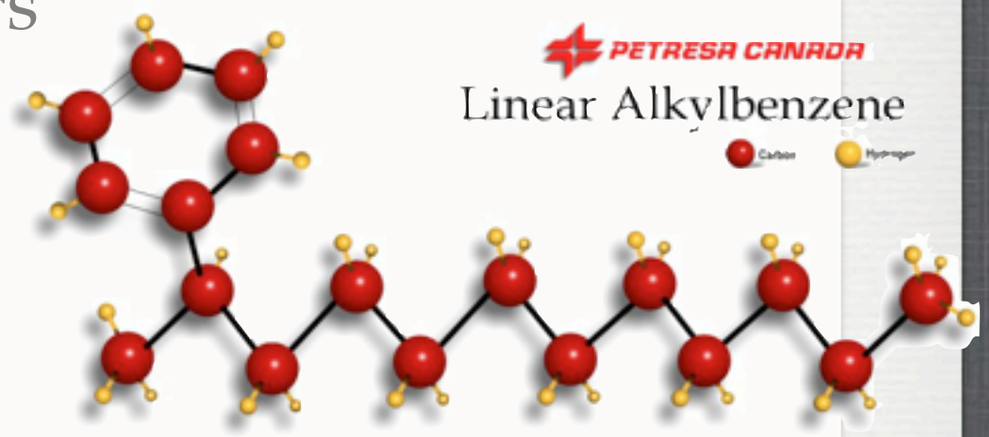
US LEADERSHIP ROLES

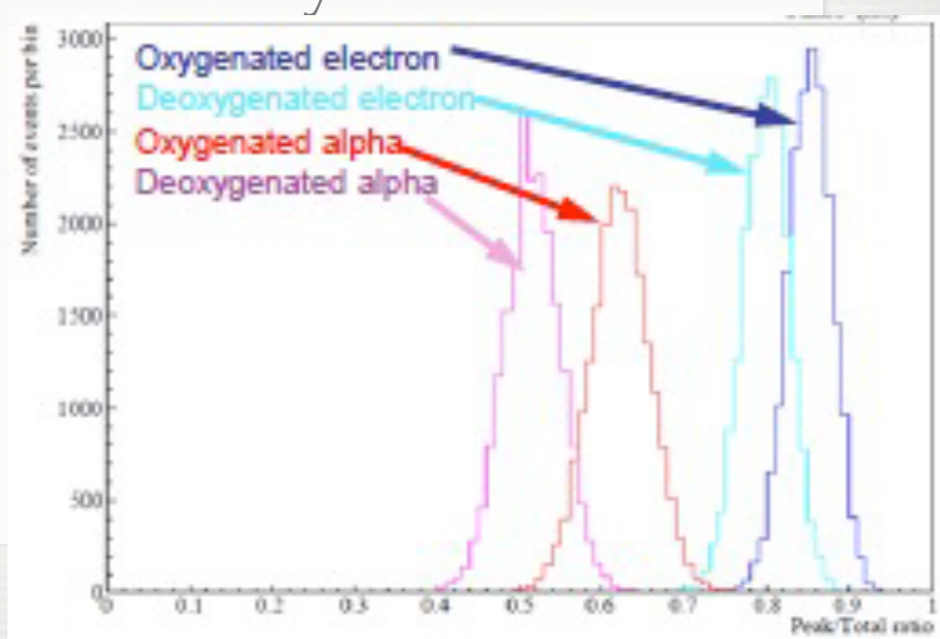
- Outgoing SNO+ Executive Committee Chair
- SNO+ Executive Committee Members
- Analysis Coordinator
- Multiple WG leaders
  - *Electronics & DAQ*
  - *PMT Calibrations*
  - *Solar Neutrinos*
  - *Data Cleaning*
  - *Database*

SCINTILLATOR DEVELOPMENT

- First developed by SNO+ collaborators
- In use in reactor & other experiments
- Chemically compatible with acrylic
- High flash point, low toxicity
- Readily available (used in detergent production)
- Loading of metallic ions to few %, stable for 3+ yrs

  NIM A 578 (2007) 329-339
- High light yield (10,000 γ / MeV)
- Decay times: α-β separation



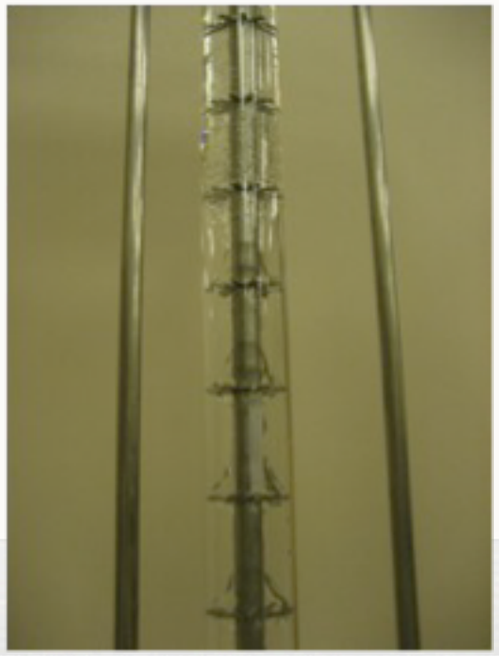


SCINTILLATOR PURIFICATION PLAN

- Multi-stage distillation
  - *Removes heavy metals*
  - *Improves UV transparency*
  - *Dual-stream PPO distillation*

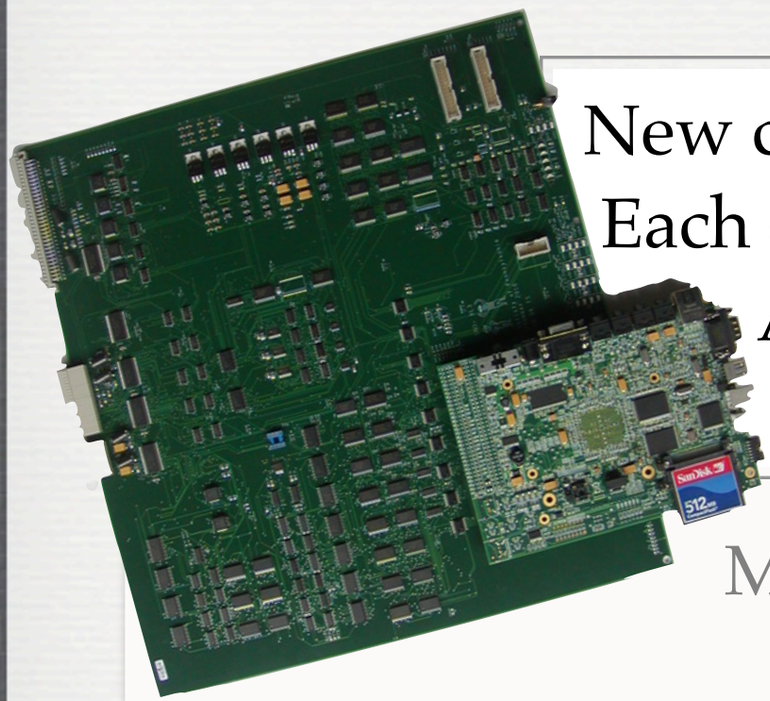
Distillation

Water extraction



- N_2 / steam stripping
  - *Removes Rn, Kr, Ar, O_2*
- Water extraction
  - *Removes Ra, K, Bi*
- Metal scavenging
  - *Removes Bi, Pb*
- Microfiltration
  - *Removes dust*

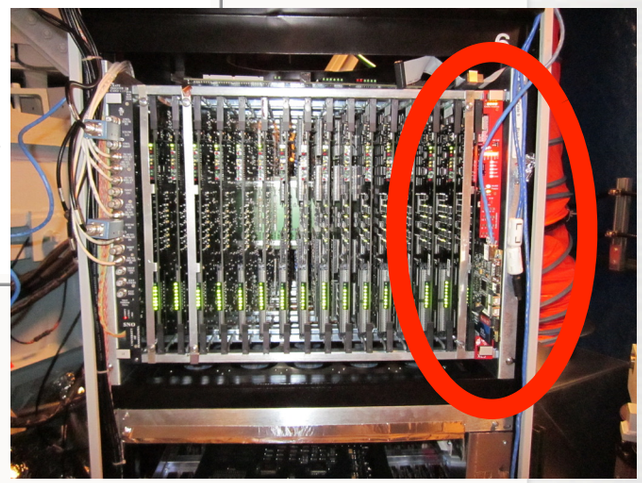
ELECTRONICS & DAQ



New custom crate-readout cards in each crate

Each crate now has **local** intelligence

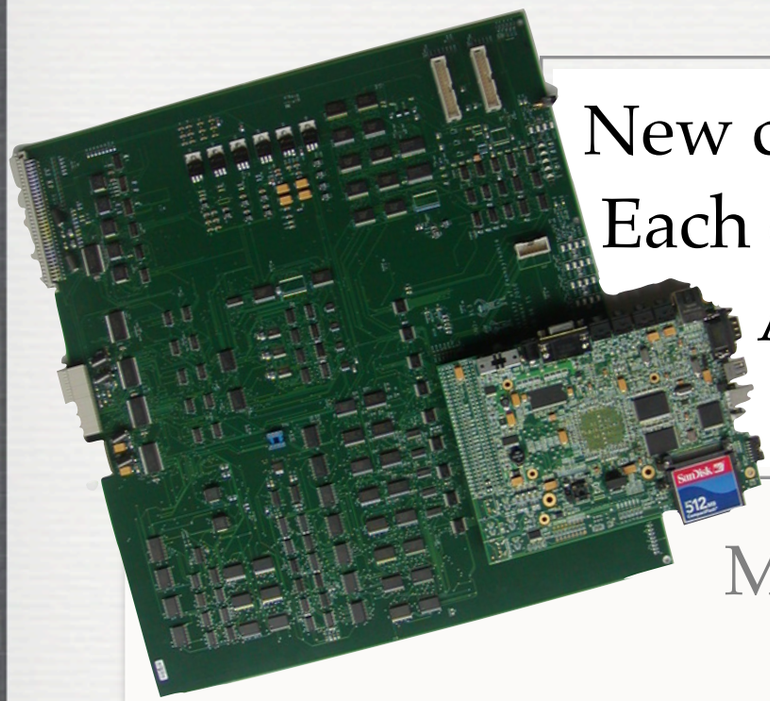
- Autonomously push data to central switch via TCP/IP



Max data rate for SNO: 2.4MBits/s

SNO+: **250** MBits/s

ELECTRONICS & DAQ



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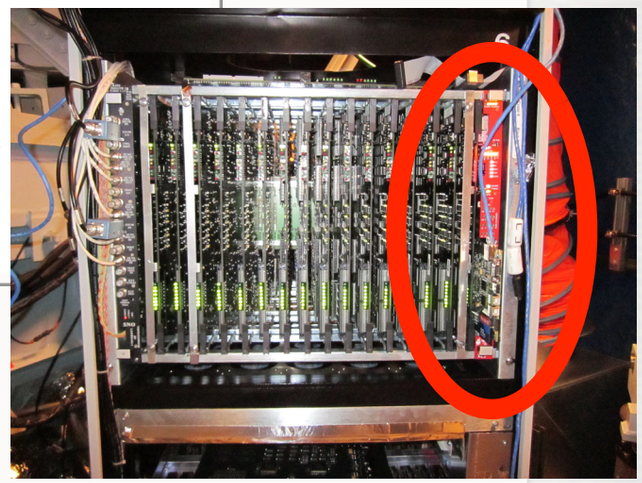

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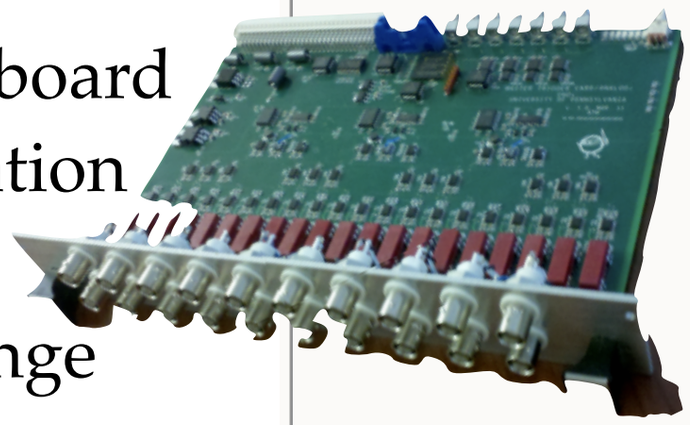
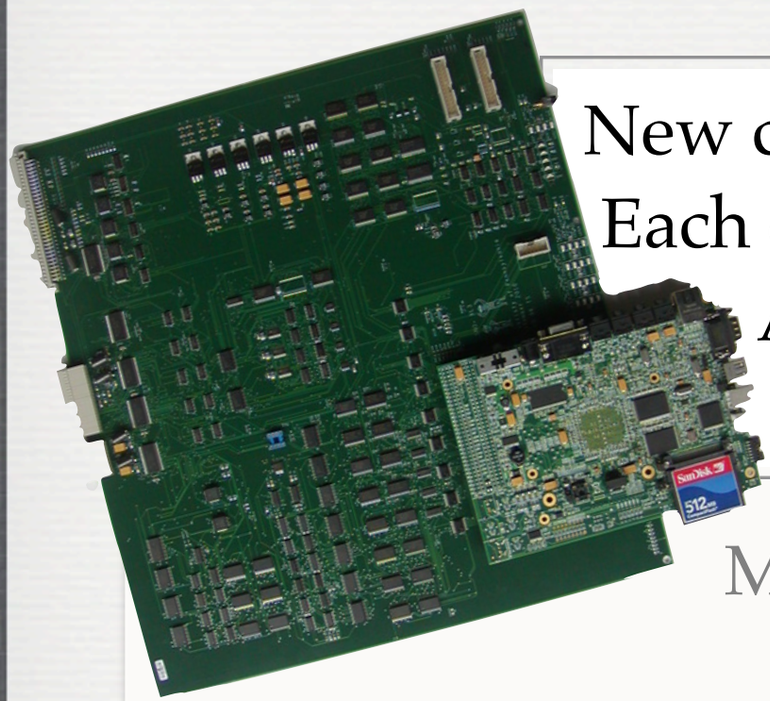
High rate/occupancy
=> need new trigger board
Low power dissipation
Reduce deadtime
Larger dynamic range
+ Auto retrigger
+ Remote crate disconnects



ELECTRONICS & DAQ



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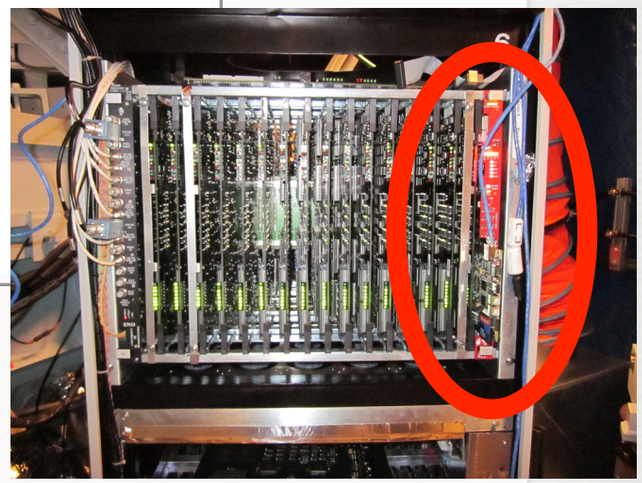

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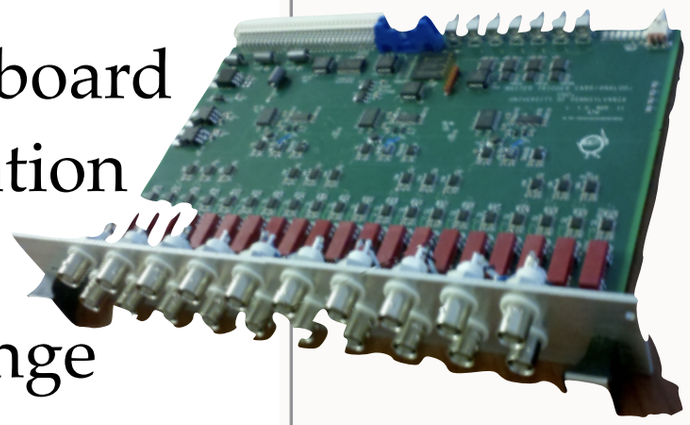
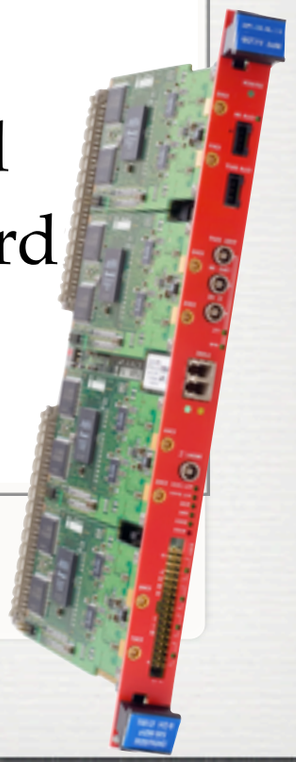
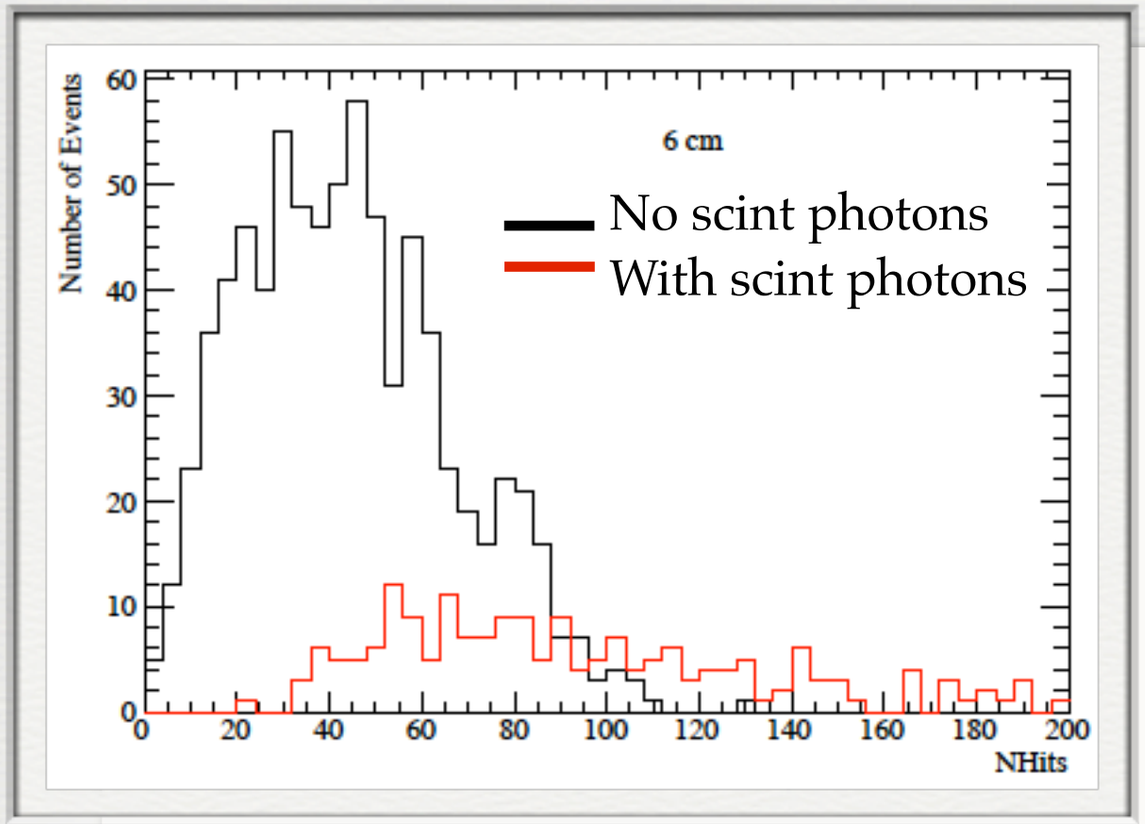


Plus:
New interface board
CAEN digitizer board
New GPS receiver



CALIBRATIONS

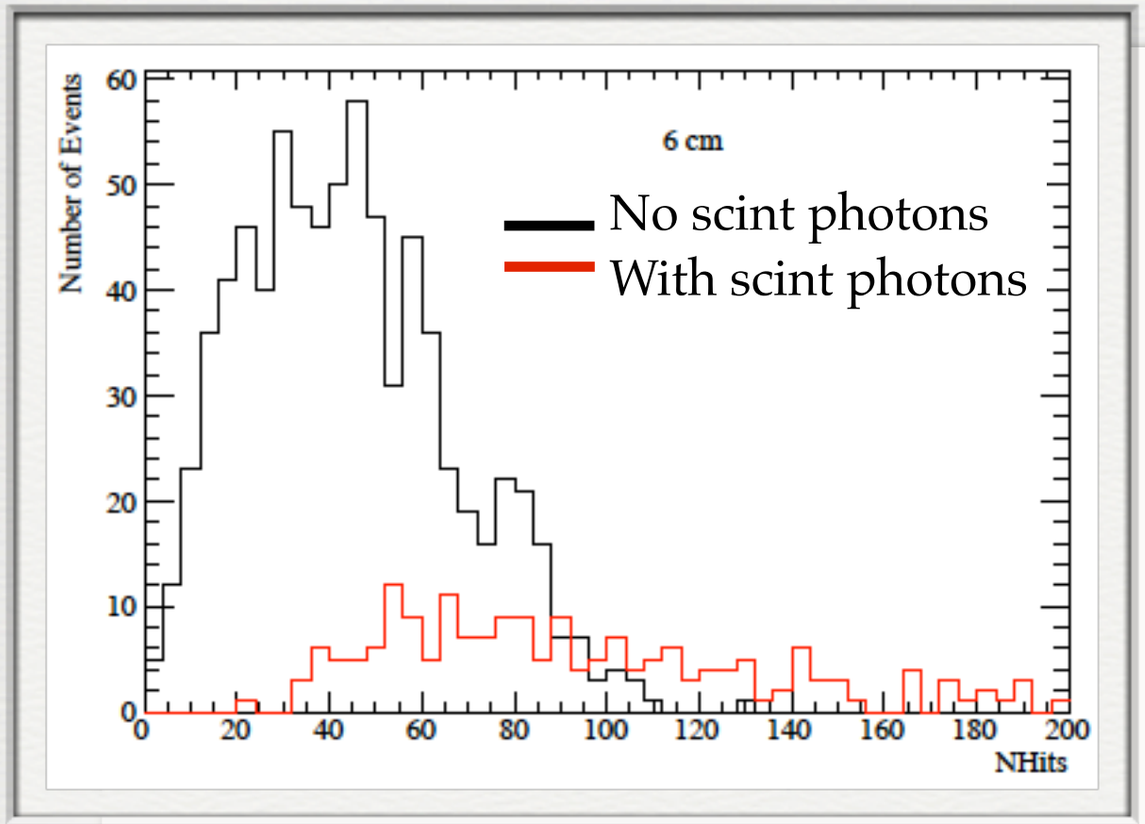


Cerenkov source design

Enables disentangling of
scint light yield vs PMT efficiencies

Designed to maximise fraction of
Cerenkov-only light reaching PMTs

CALIBRATIONS



Cerenkov source design

Enables disentangling of
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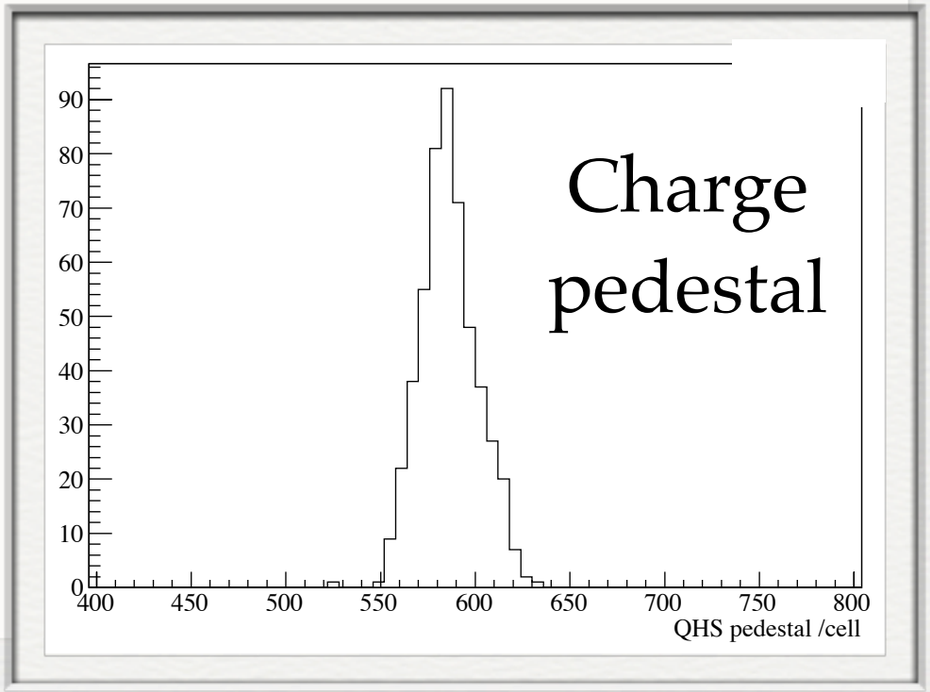
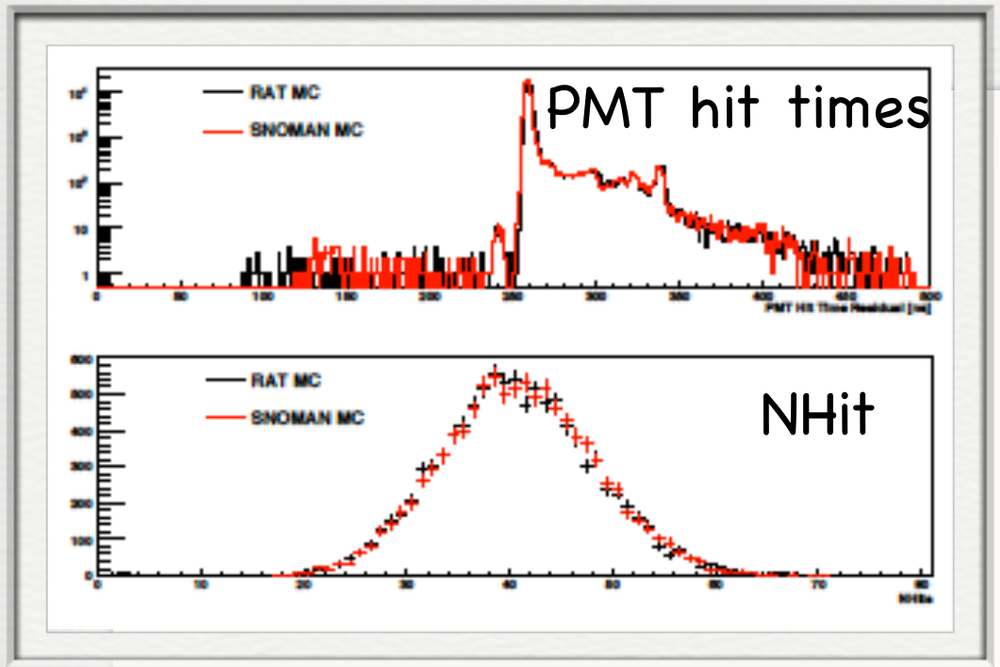
Electronics Calibrations

Charge pedestals
PMT hit time
PMT gain
Discriminator walk

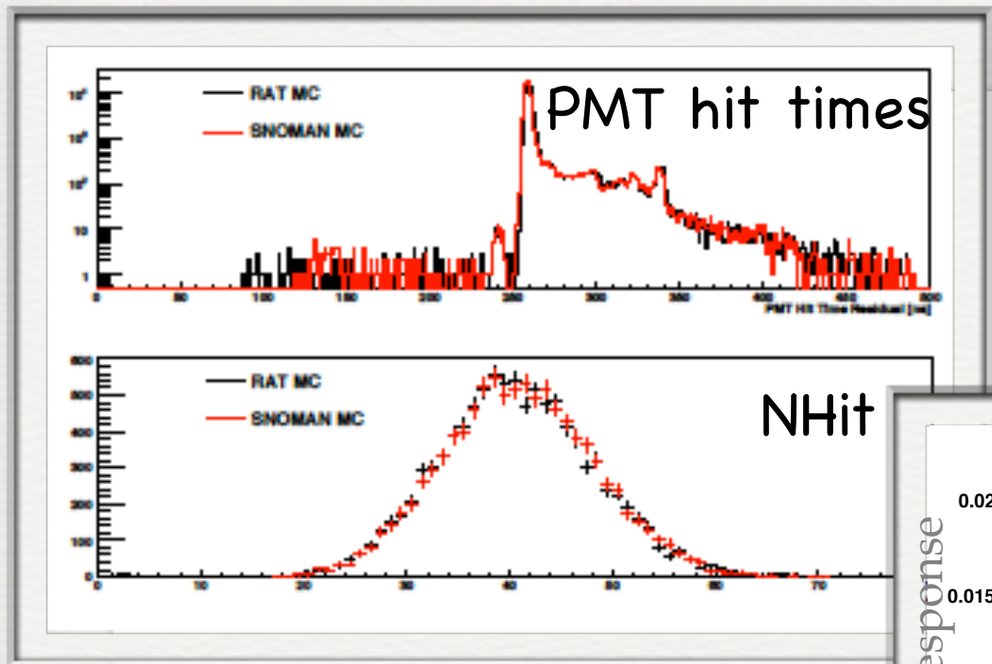


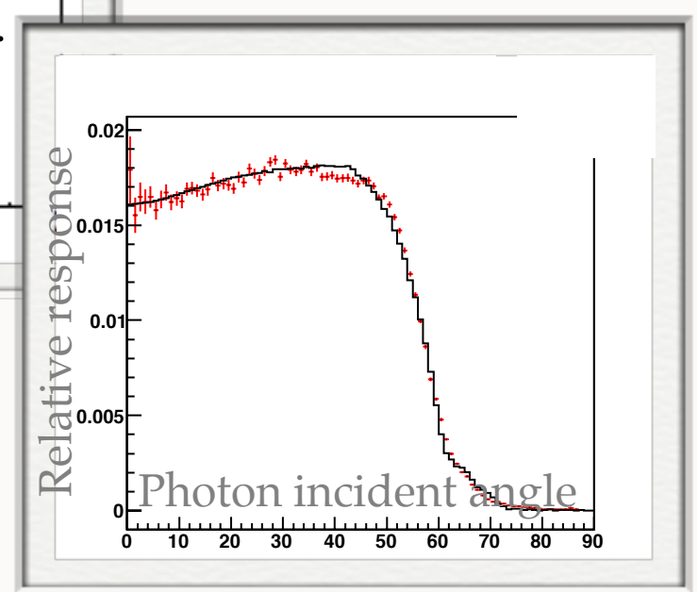
MONTE CARLO / ANALYSIS



- Verification using SNO MC

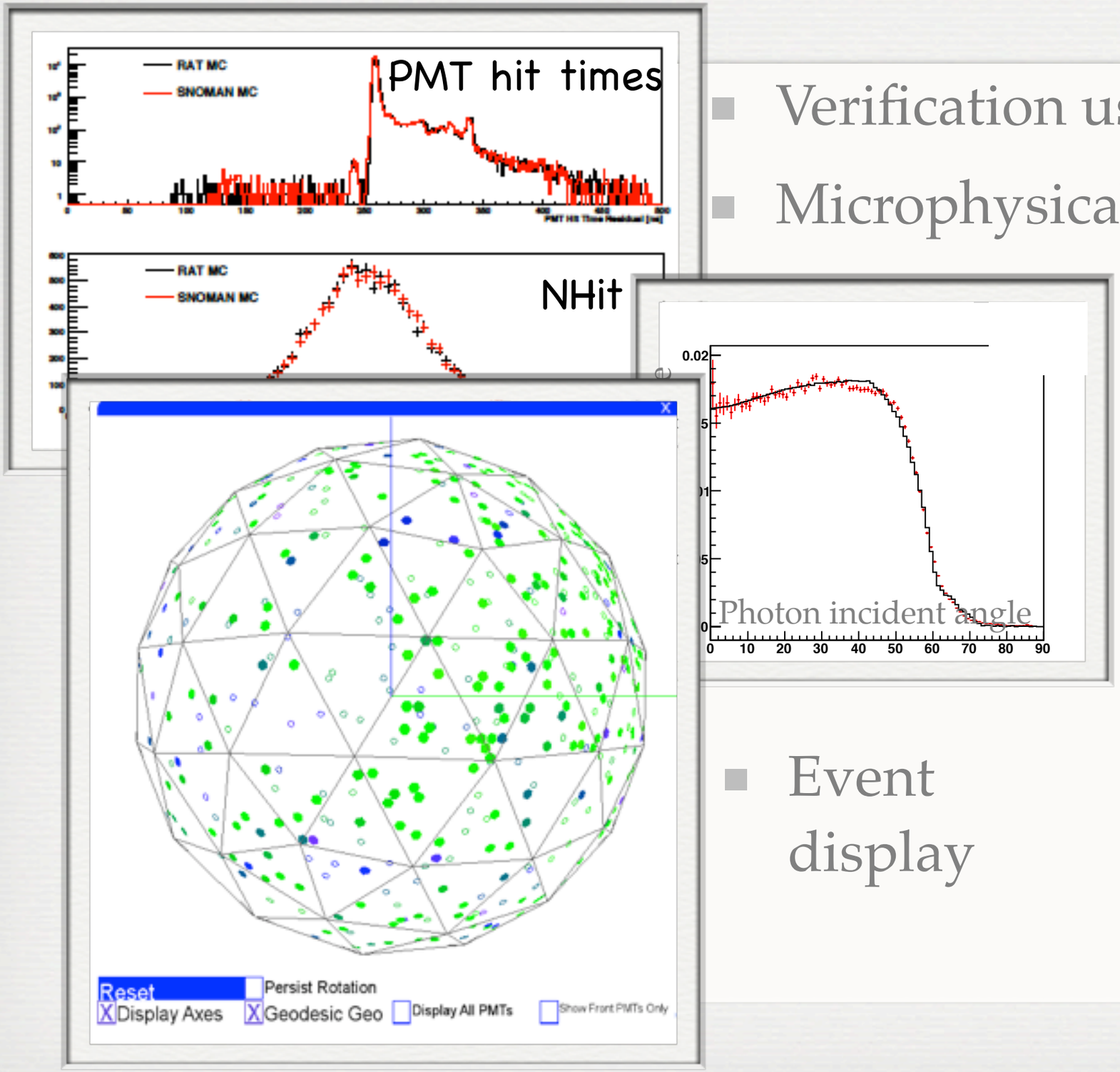
MONTE CARLO / ANALYSIS





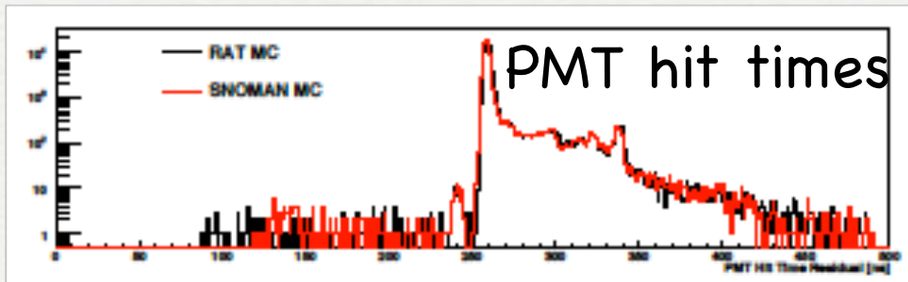
- Verification using SNO MC
- Microphysical detector response model

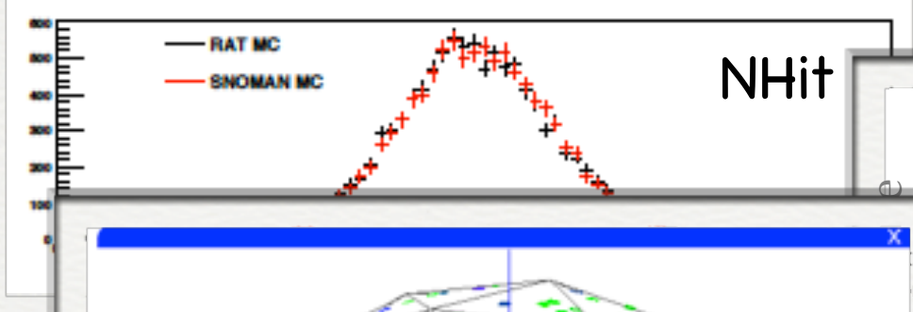
MONTE CARLO / ANALYSIS

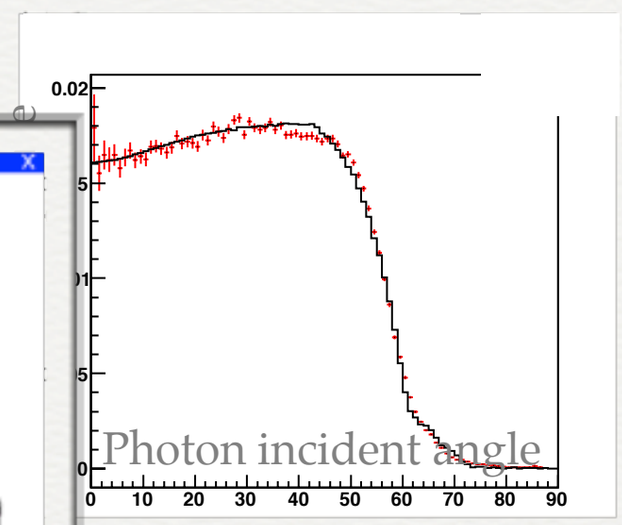


- Verification using SNO MC
- Microphysical detector response model
- Event display

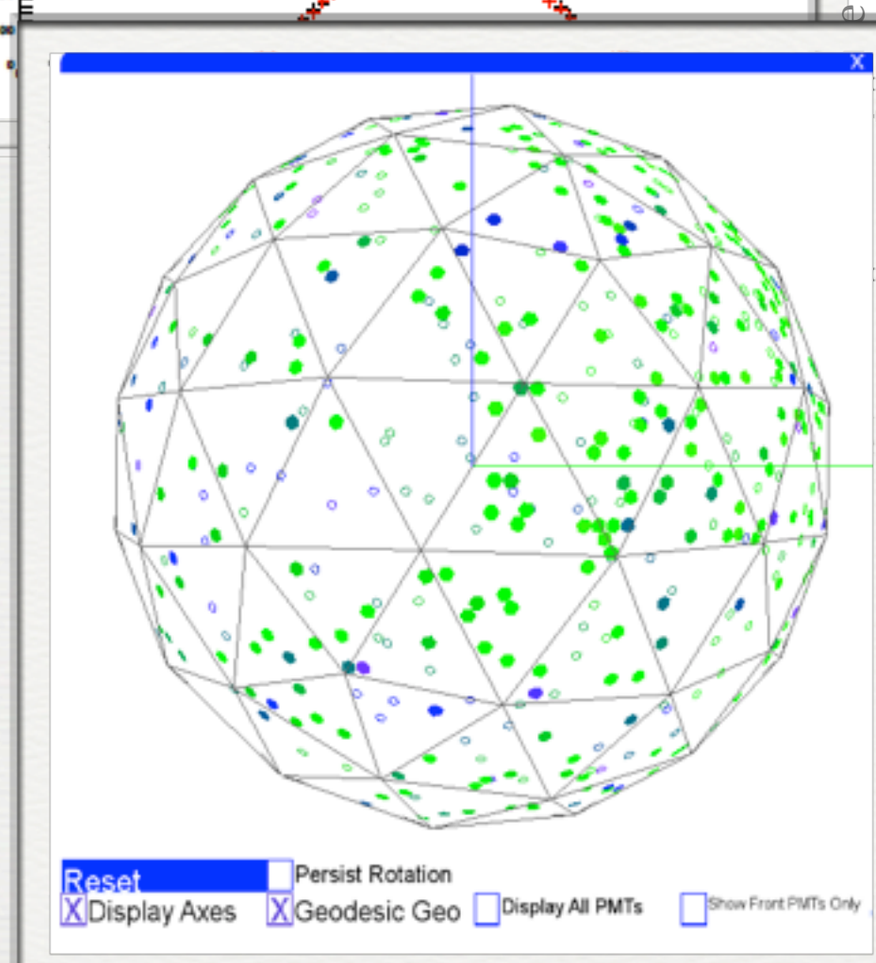
MONTE CARLO / ANALYSIS



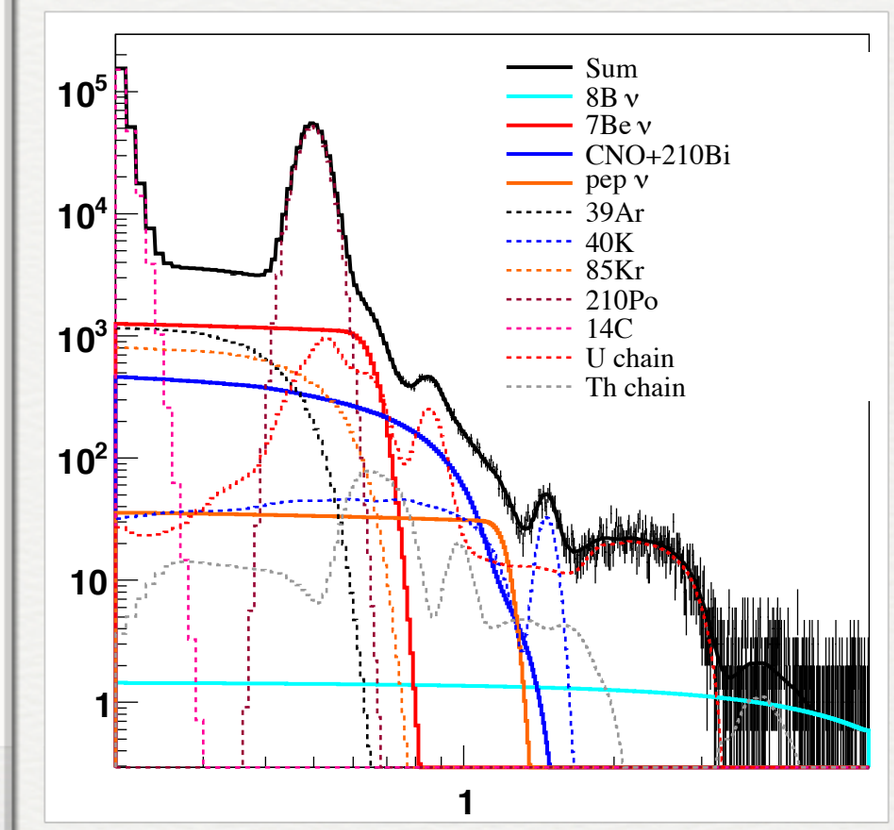




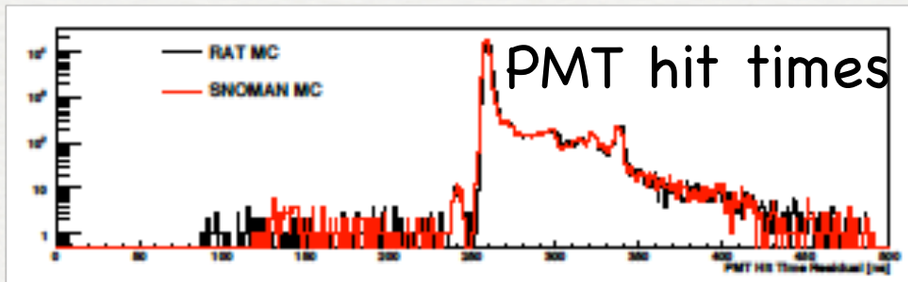
- Verification using SNO MC
- Microphysical detector response model
  - Solar ν Analysis

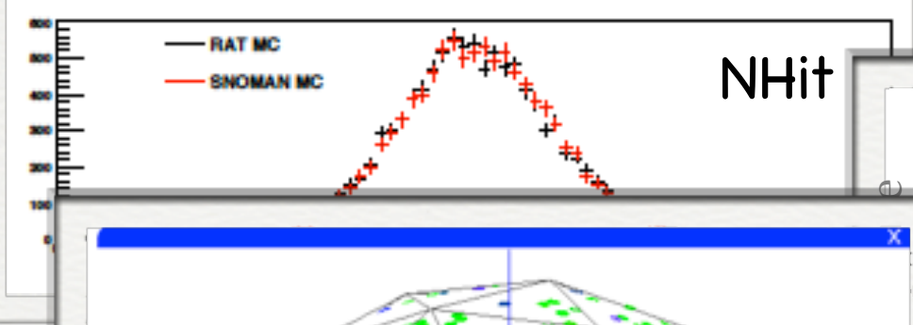


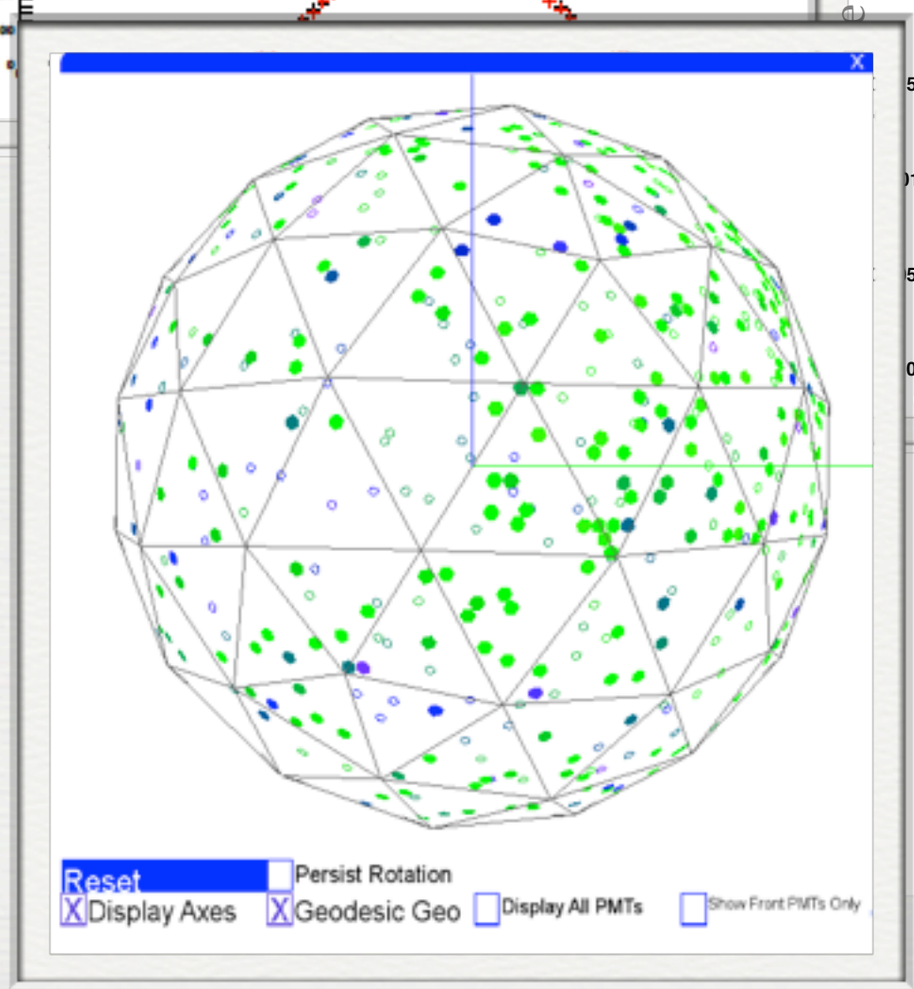
- Event display

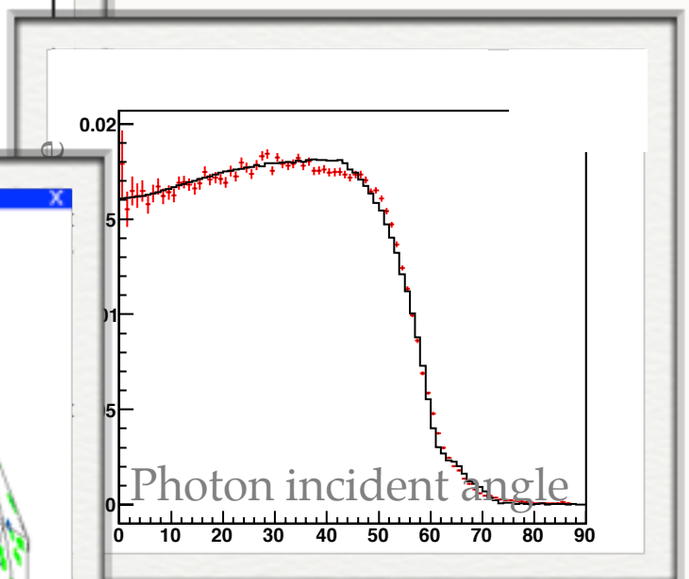


MONTE CARLO / ANALYSIS









- Verification using SNO MC
- Microphysical detector response model
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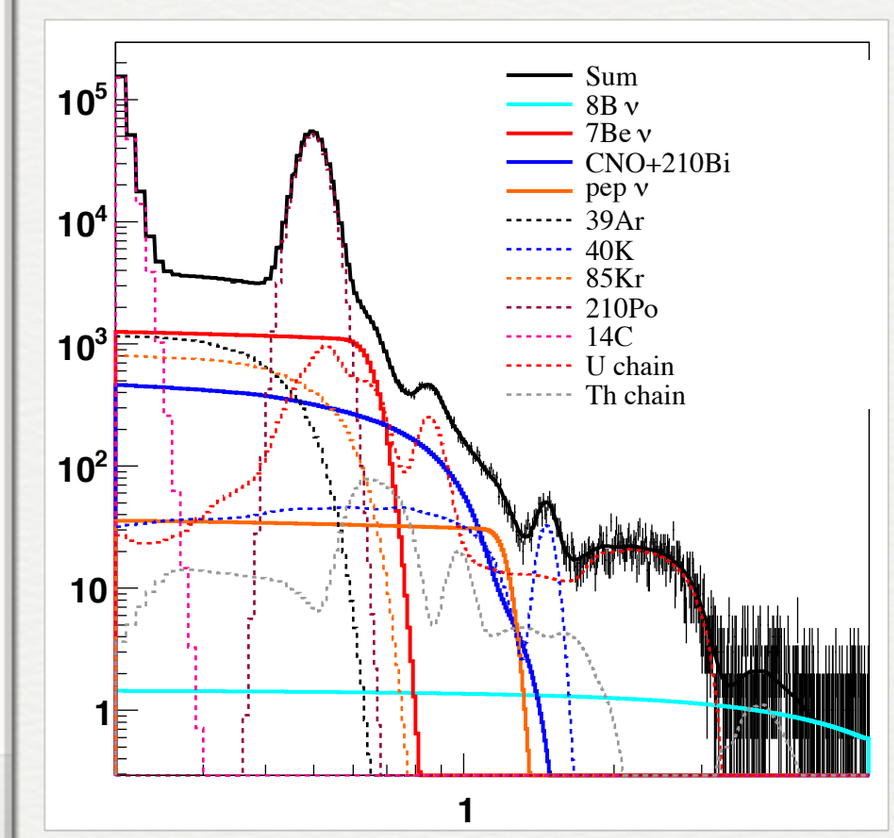
10% pep in 1 year



- Event display

SNO+ SCHEDULE

- **2011/2012 (completed)**

  Detector Upgrades:

  Cavity work

  Install hold-down ropes

  Upgrade electronics

  Commissioning:

  First "air-fill" data taking

- **2013**

  Detector Upgrades:

  Install process systems

  Physics:

  Water-phase data (March)

  Start scintillator fill (Oct)

- **2014**

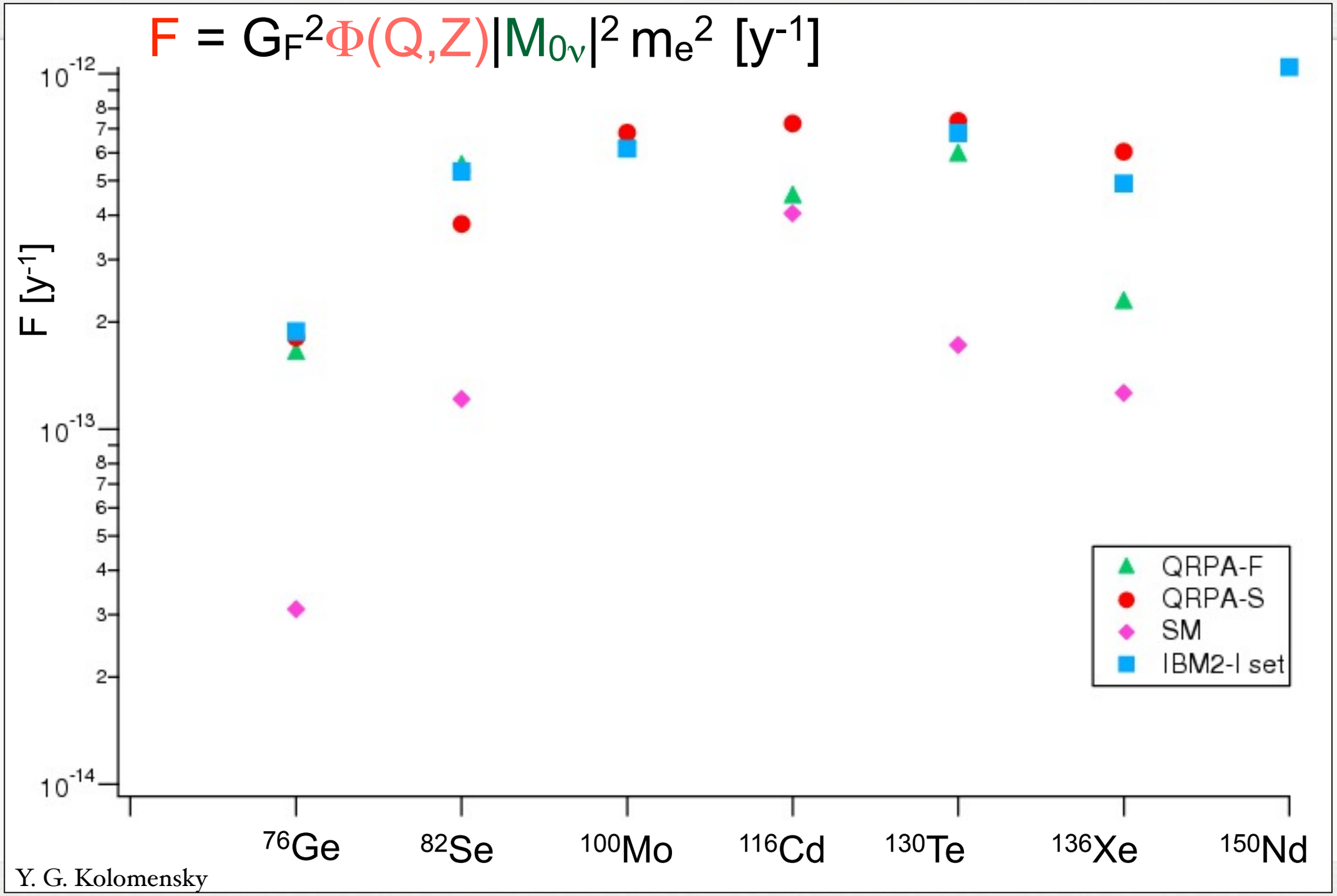
  Physics:

  Scintillator data (March)

Thank you for your attention

Back-up slides

ISOTOPE CHOICE



Y. G. Kolomensky

Current DBD Experiments

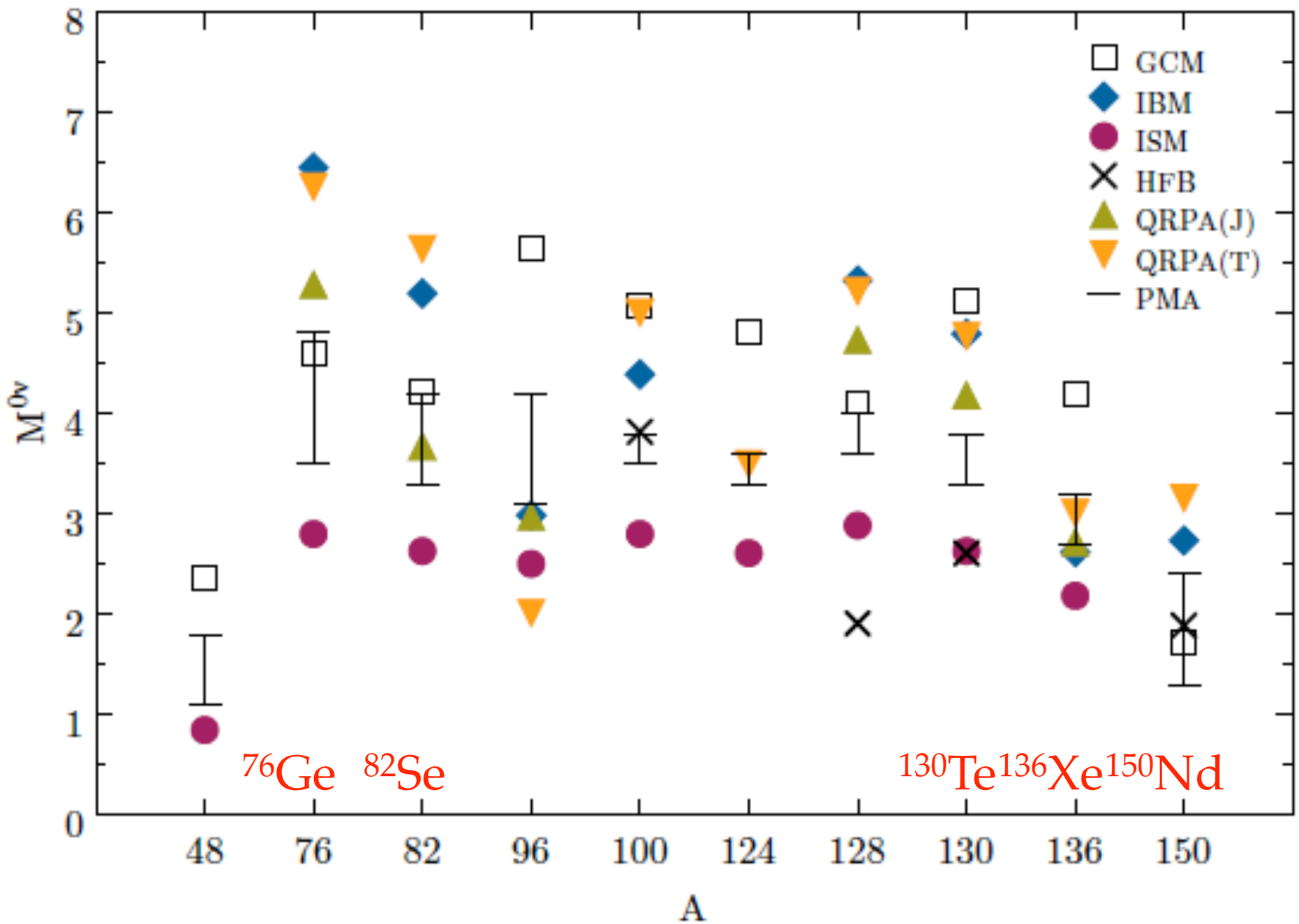
Experiment	Isotope	Mass [kg]	$\tau^{0\nu}_{1/2}$ [y]	$m_{\beta\beta}$ [meV]	When
CUORE	^{130}Te	200	2×10^{26}	35-80	2014-2019
GERDA	^{76}Ge	17 40 1000	3×10^{25} 2×10^{26} 6×10^{27}	180-500 70-200 10-40	2010-2012 2012-2014 2015-2025
MAJORANA	^{76}Ge	33 1000	1.5×10^{26} 6×10^{27}	70-200 10-40	2012-2013 2015-2025
EXO	^{136}Xe	200 1000	6×10^{25} 8×10^{26}	130-190 30-60	2010-2012 2015-2025
SuperNEMO	^{82}Se	100-200	$(1\text{-}2)\times10^{26}$	40-140	2013-2019
KamLAND-Zen	^{136}Xe	400 1000	4×10^{26} $\sim10^{27}$	40-80 25-50	2011-2013 2014-2016
SNO+	^{150}Nd	44-120 500	5×10^{24} 3×10^{25}	80-130 40-100	2013-2016 2016-2020

After A.S.Barabash, Phys.Atom.Nucl. **73**, 162 (2010)

Approved R&D

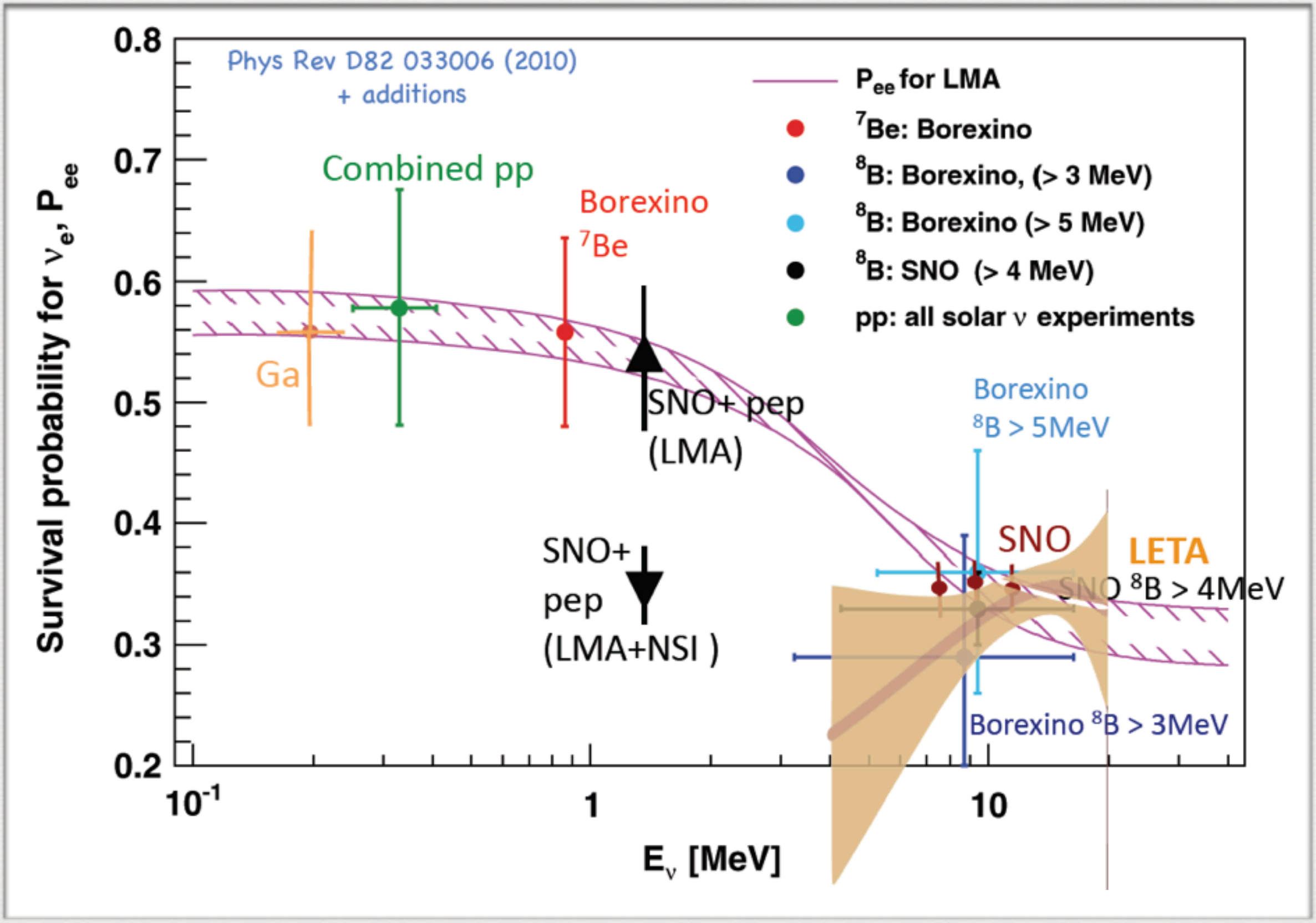
NUCLEAR MATRIX ELEMENTS

Different techniques can give quite different results for NME values:



Sense and Sensitivity of ββ expts: arxiv/1010.5112

SNO+ Potential



Isotope Choice

Isotope	$Q_{\beta\beta}$	Natural abundance	$\lvert M_{0\nu}\rvert$	$\lvert G_{0\nu}\rvert^{-1}$ (10^{25} y eV^2)	$T^{0\nu}_{1/2}$ (10^{27} y)	$N_{0\nu}$ / $N_{0\nu}$(Ge)
^{76}Ge	2.04 MeV	7.8%	4.15 ± 0.65	4.09	0.95	1.0
^{82}Se	3.00 MeV	9.2%	3.75 ± 0.45	0.93	0.26	3.3
^{130}Te	2.53 MeV	34.5%	3.65 ± 0.15	0.59	0.18	3.1
^{136}Xe	2.46 MeV	8.9%	2.95 ± 0.25	0.55	0.25	2.1
^{150}Nd	**3.37 MeV**	**5.6%**	**1.85 ± 0.55**	**0.13**	**0.15**	**3.3**

Sense and Sensitivity of ββ expts: arxiv/1010.5112

Isotope Choice

Isotope	$Q_{\beta\beta}$	Natural abundance	$\lvert M_{0\nu}\rvert$	$\lvert G_{0\nu}\rvert^{-1}$ (10^{25} y eV^2)	$T^{0\nu}_{1/2}$ (10^{27} y)	$N_{0\nu}$ / $N_{0\nu}$(Ge)
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^{136}Xe	2.46 MeV	8.9%	2.95 ± 0.25	0.55	0.25	2.1
^{150}Nd	**3.37 MeV**	**5.6%**	**1.85 ± 0.55**	**0.13**	**0.15**	**3.3**

Sense and Sensitivity of ββ expts: arxiv/1010.5112