Neutrino Backgrounds

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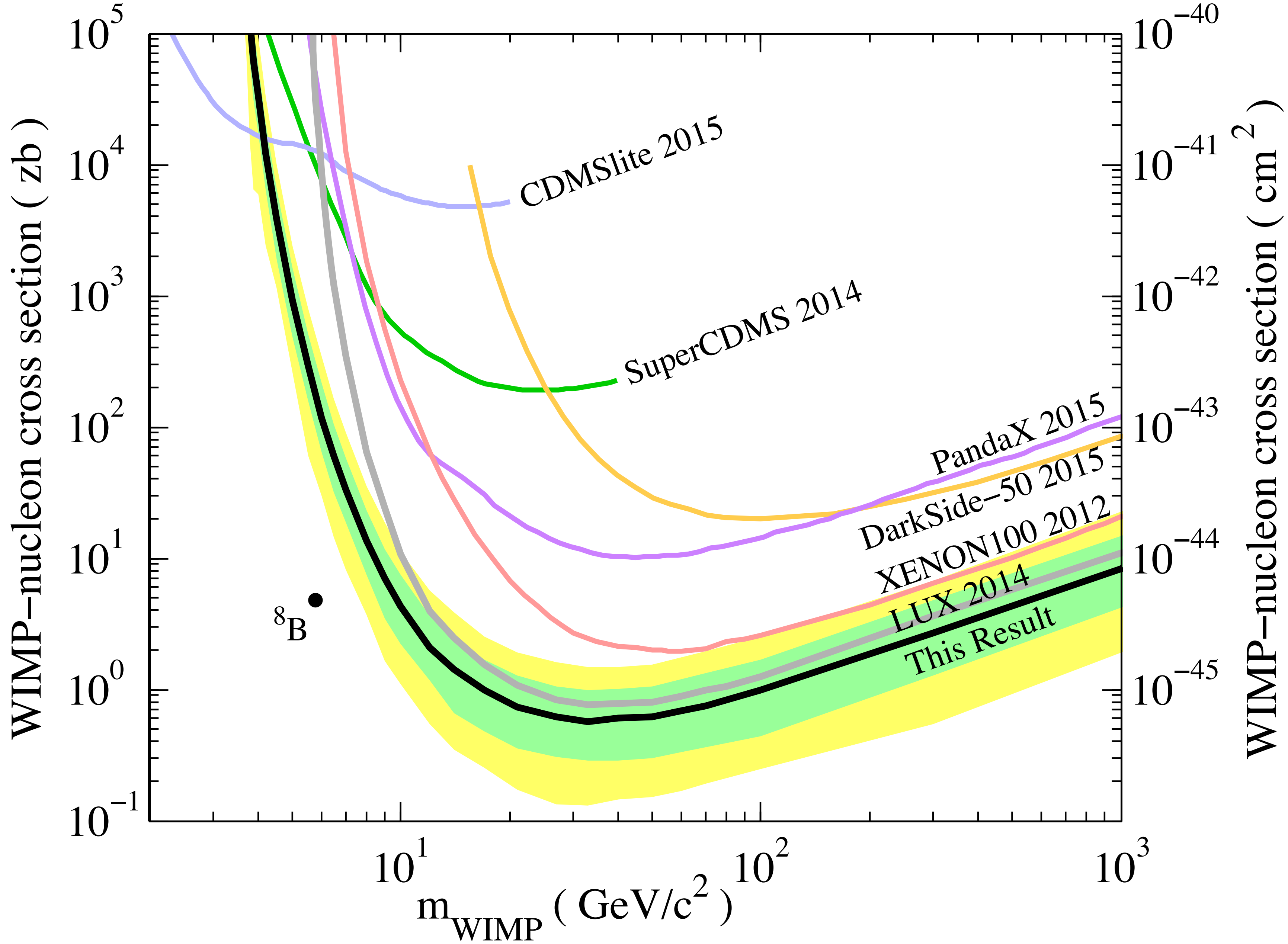
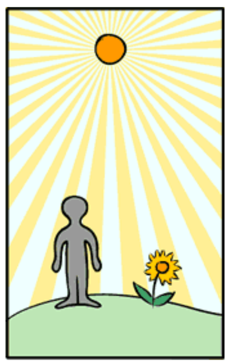
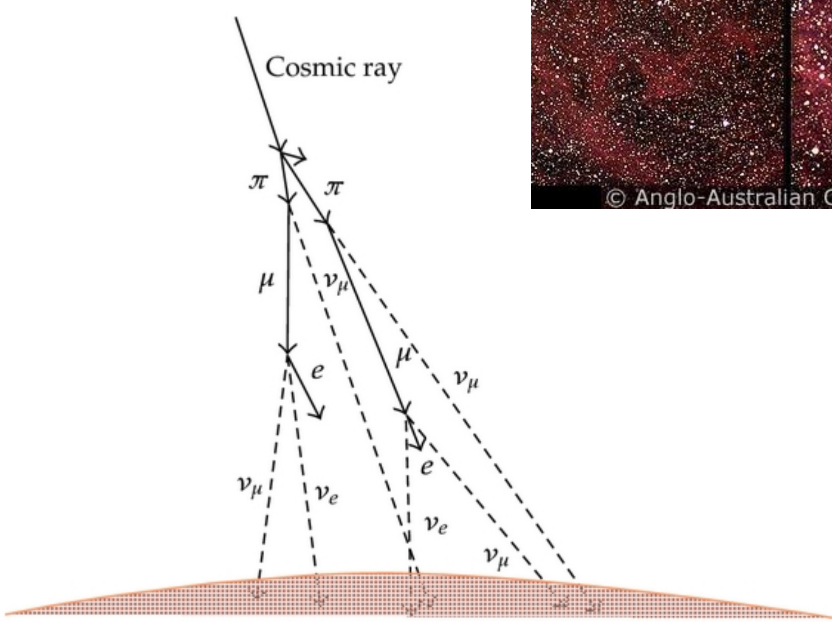
DOE Cosmic Visions, University of Maryland
March 24, 2017

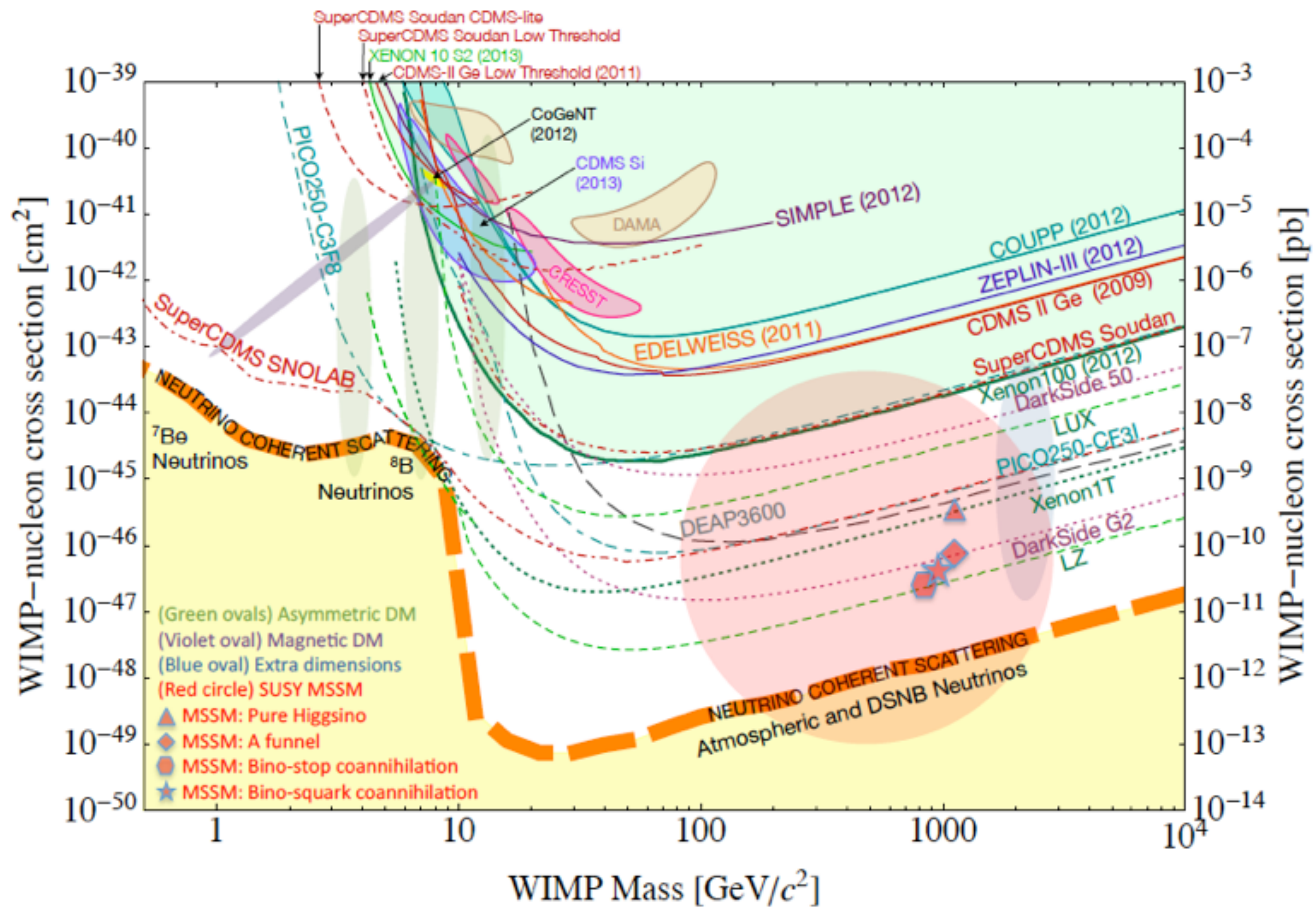
Neutrino backgrounds/signals

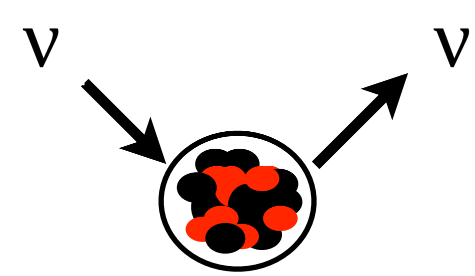


Neutrino backgrounds/signals





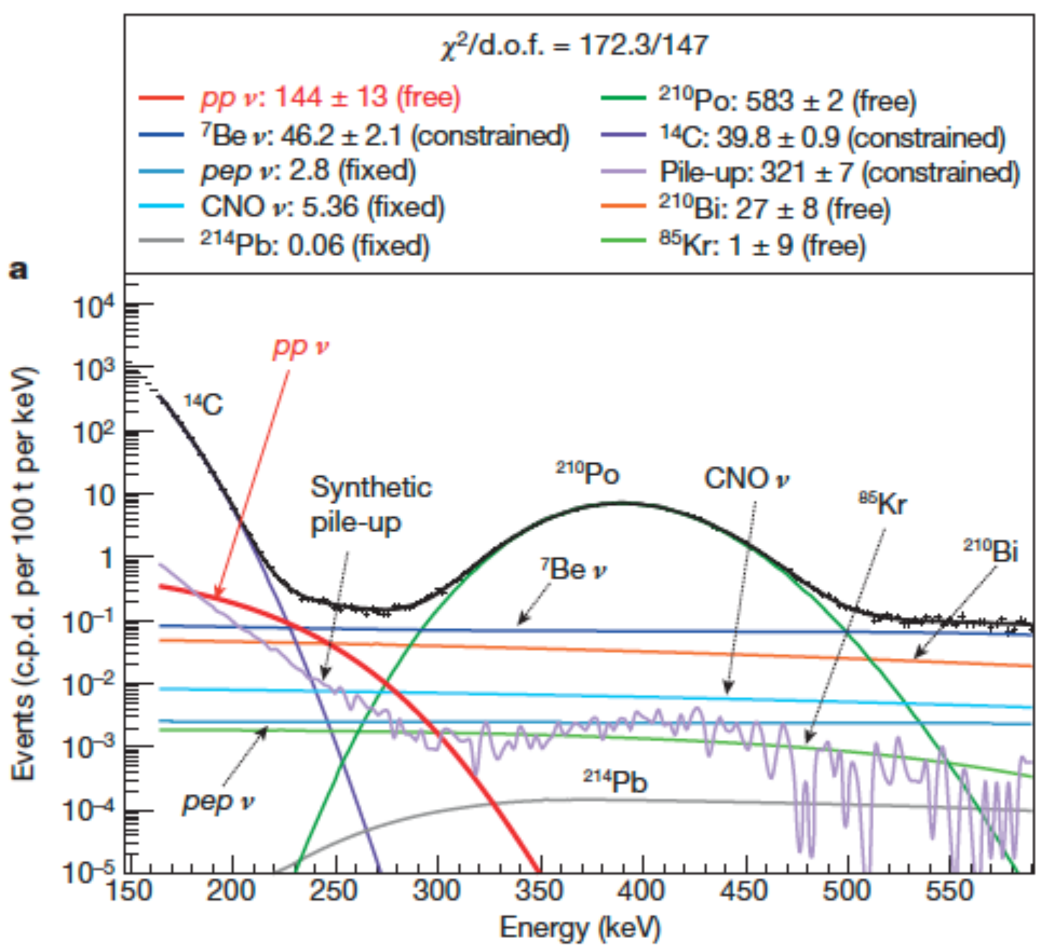




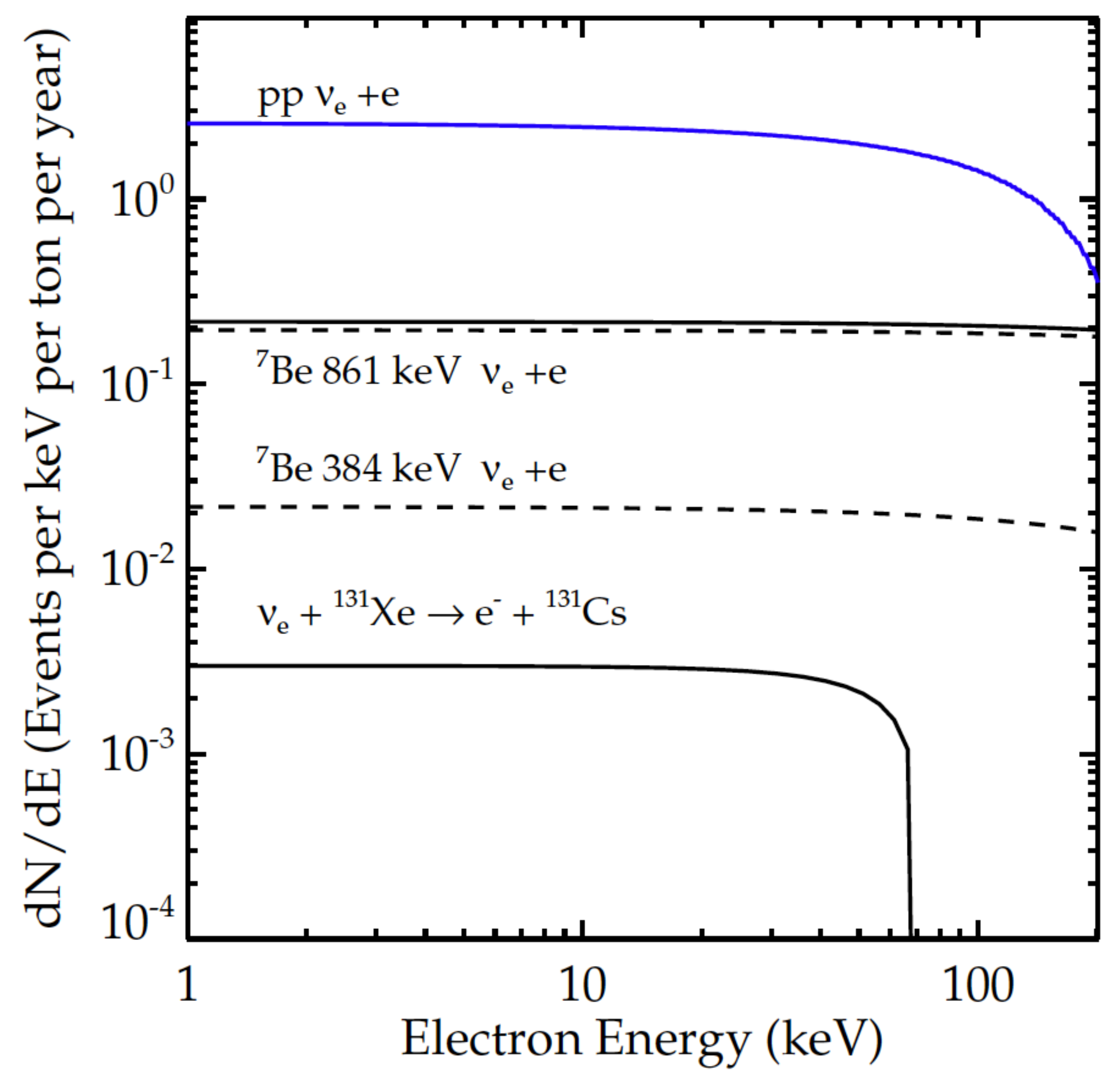
- \`\`Neutrino Floor" from Coherent Neutrino-Nucleus scattering
- Annual modulation/Directionality discrimination (Davis 2014; O'Hare et al. 2015; Grothaus et al. 2015)

Neutrino backgrounds/signals

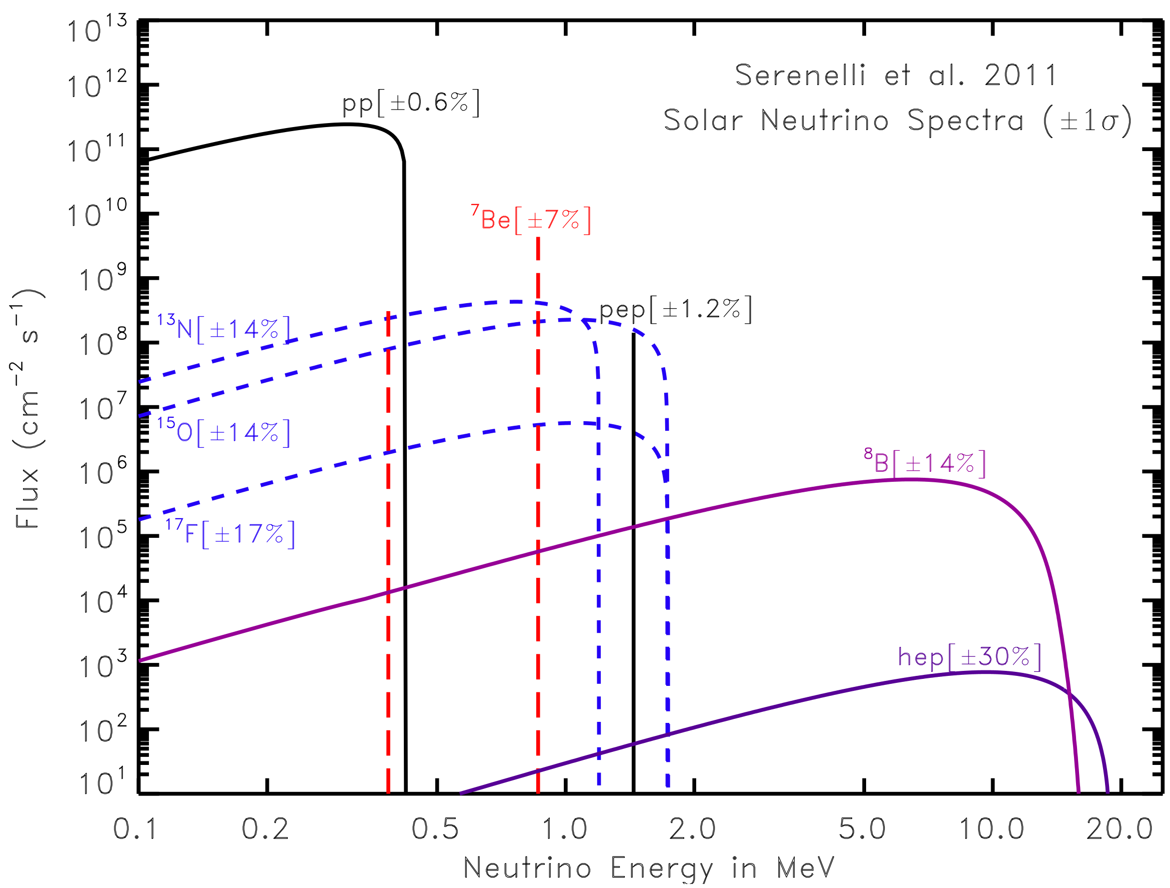
$$\nu + e^- \rightarrow \nu + e^-$$

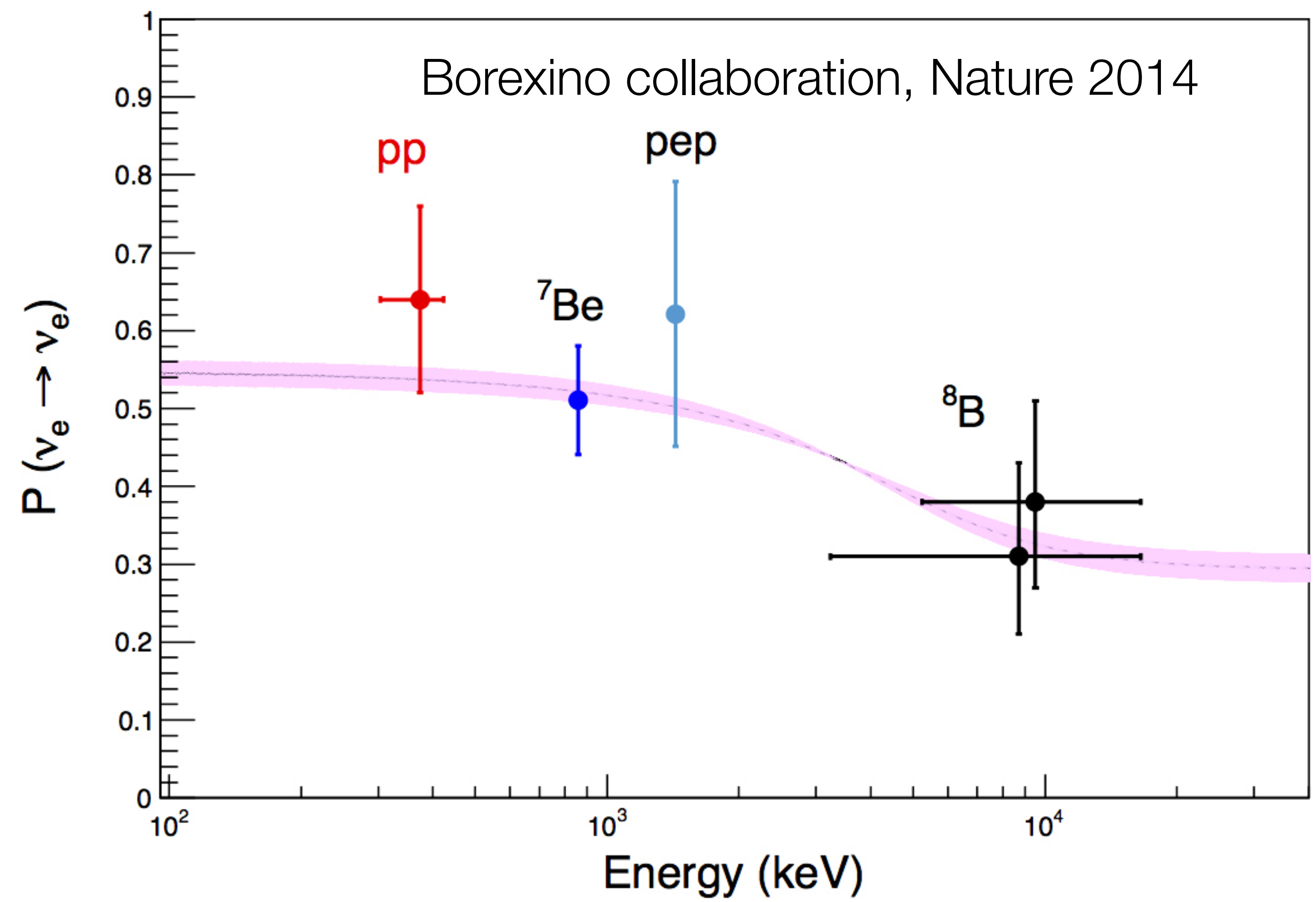


Borexino Collaboration, Nature 2014



Solar neutrinos: Status





Solar Neutrinos: Status and Prospects

W.C. Haxton,[1] R.G. Hamish Robertson,[2] and Aldo M. Serenelli[3]

The program of solar neutrino studies envisioned by Davis and Bahcall has been only partially completed. Borexino has extended precision measurements to low-energy solar neutrinos, determining the flux of ^{7}Be neutrinos to 5%, and thereby confirming the expected increase in the ν_e survival probability for neutrino energies in the vacuum-dominated region. First results on the pep neutrino

Solar neutrinos: Outstanding issue I

- Solar metallicity
  - 3D rotational hydrodynamical simulations suggest lower metallicity in Solar core (Asplund et al. 2009)
  - Low metallicity in conflict with heliosiesmology data
  - SNO Neutral Current measurement right in between predictions of low and high metallicity SSMs

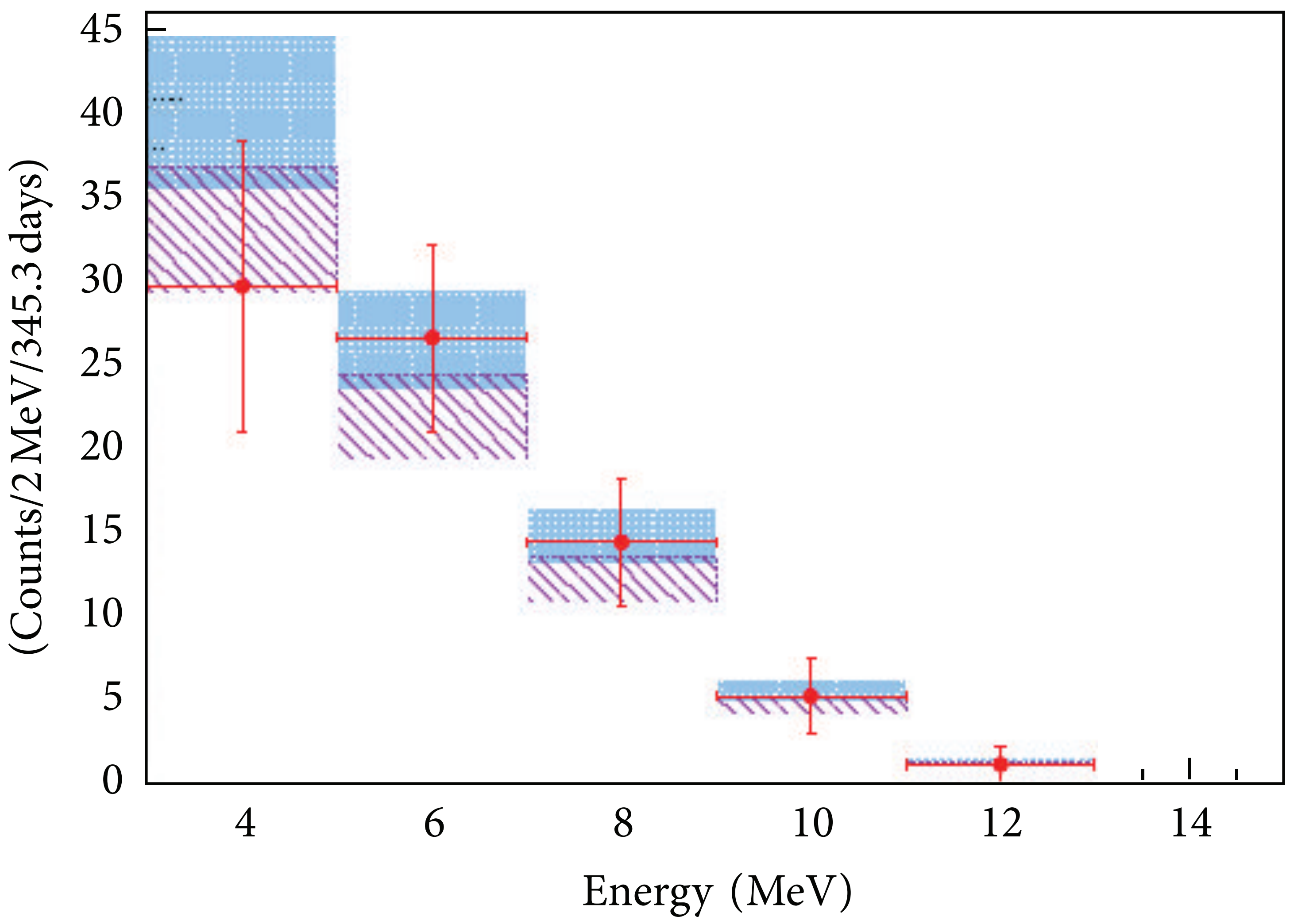
High metallicity — Low metallicity

ν flux	E_ν^{max} (MeV)	GS98-SFII	AGSS09-SFII	Solar	units
p+p→^{2}H+e$^+$+ν	0.42	$5.98(1 \pm 0.006)$	$6.03(1 \pm 0.006)$	$6.05(1^{+0.003}_{-0.011})$	$10^{10}/\mathrm{cm}^2\mathrm{s}$
p+e$^-$+p→^{2}H+ν	1.44	$1.44(1 \pm 0.012)$	$1.47(1 \pm 0.012)$	$1.46(1^{+0.010}_{-0.014})$	$10^8/\mathrm{cm}^2\mathrm{s}$
^{7}Be+e$^-$→^{7}Li+ν	0.86 (90%)	$5.00(1 \pm 0.07)$	$4.56(1 \pm 0.07)$	$4.82(1^{+0.05}_{-0.04})$	$10^9/\mathrm{cm}^2\mathrm{s}$
	0.38 (10%)				
^{8}B→^{8}Be+e$^+$+ν	∼ 15	$5.58(1 \pm 0.14)$	$4.59(1 \pm 0.14)$	$5.00(1 \pm 0.03)$	$10^6/\mathrm{cm}^2\mathrm{s}$
^{3}He+p→^{4}He+e$^+$+ν	18.77	$8.04(1 \pm 0.30)$	$8.31(1 \pm 0.30)$	—	$10^3/\mathrm{cm}^2\mathrm{s}$
^{13}N→^{13}C+e$^+$+ν	1.20	$2.96(1 \pm 0.14)$	$2.17(1 \pm 0.14)$	≤ 6.7	$10^8/\mathrm{cm}^2\mathrm{s}$
^{15}O→^{15}N+e$^+$+ν	1.73	$2.23(1 \pm 0.15)$	$1.56(1 \pm 0.15)$	≤ 3.2	$10^8/\mathrm{cm}^2\mathrm{s}$
^{17}F→^{17}0+e$^+$+ν	1.74	$5.52(1 \pm 0.17)$	$3.40(1 \pm 0.16)$	$\leq 59.$	$10^6/\mathrm{cm}^2\mathrm{s}$
χ^2/P^{agr}		3.5/90%	3.4/90%		

Haxton et al. 2013

Solar neutrinos: Outstanding issue II

- Borexino, SNO, SK indicate the low energy ES data lower than MSW predicts
- More generally, upturn in MSW survival probability not been measure
- May indicate new physics (e.g. Holanda & Smirnov 2011)

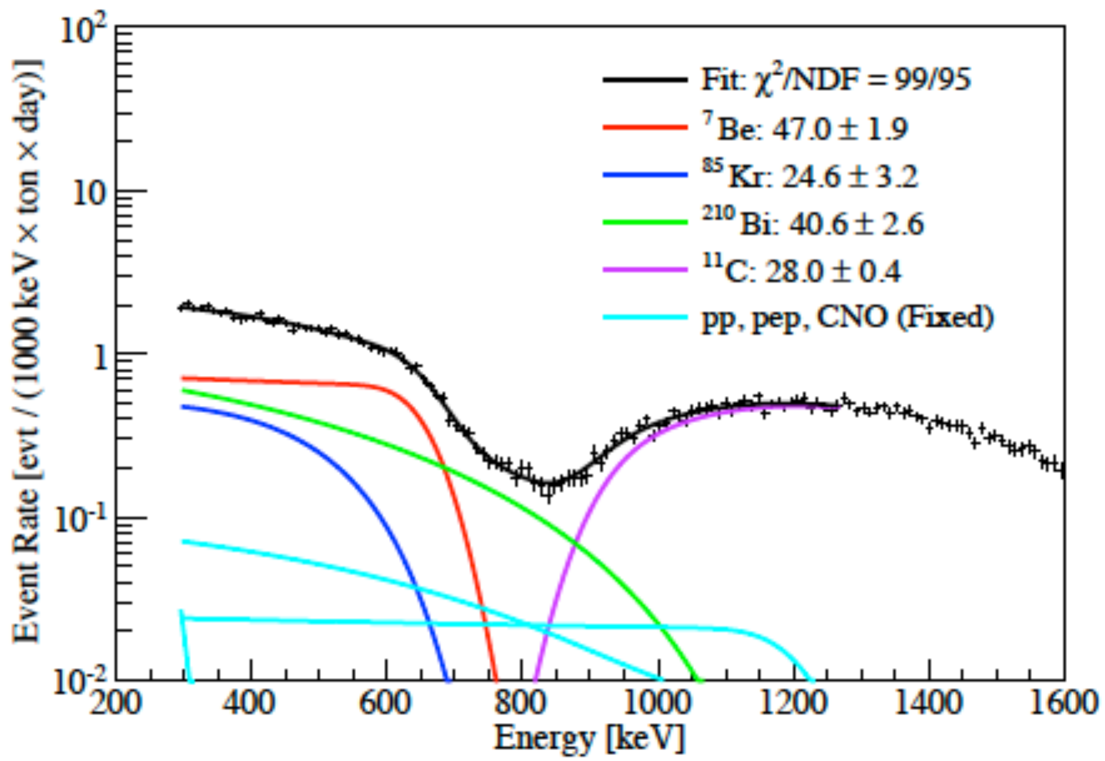


Borexino Collaboration, 2010

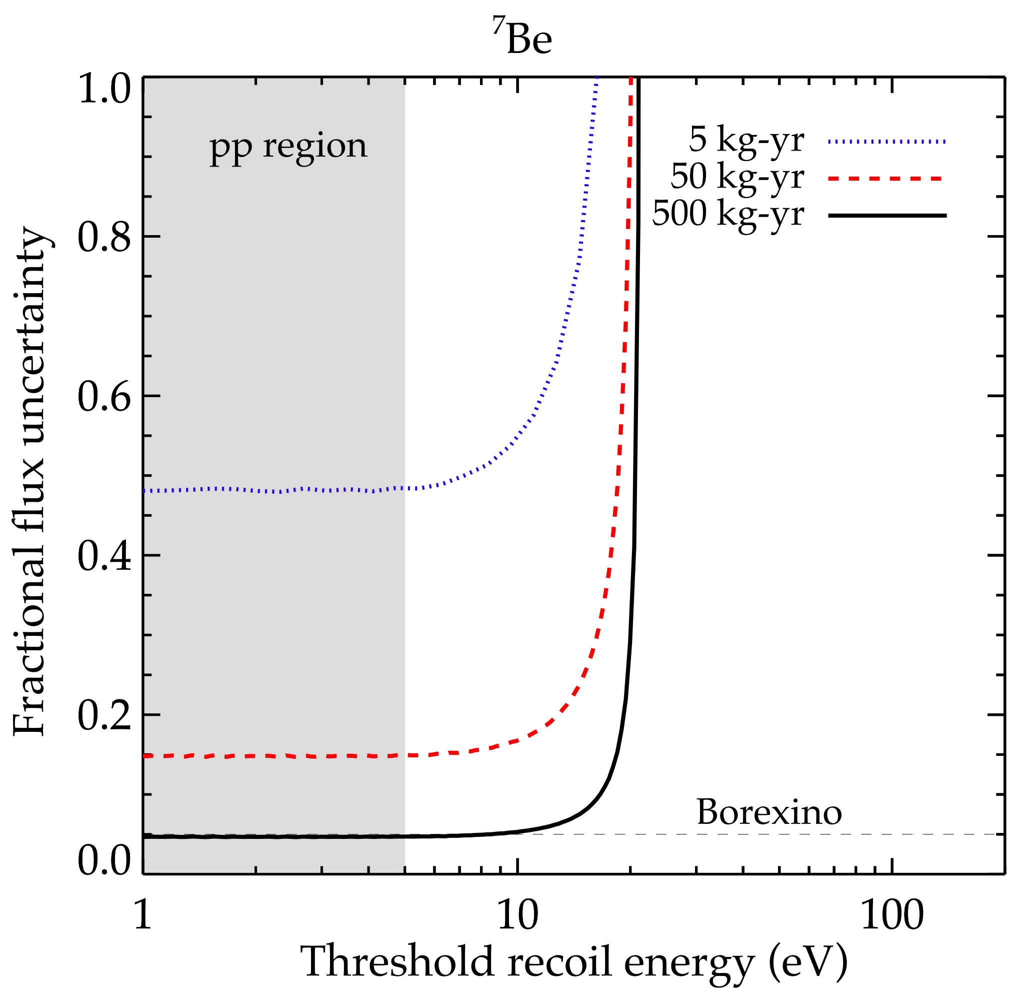
Solar neutrino signals:
Astrophysical goals for dark matter experiments

- First measurement of the 8B neutral current energy spectrum
- First direct measurement of the survival probably for low energy solar neutrinos
- Direct measurement of the CNO flux
- PP flux measurement to ~ few percent will provide most stringent measurement of the ``neutrino luminosity” of the Sun

Low energy solar neutrino survival probability



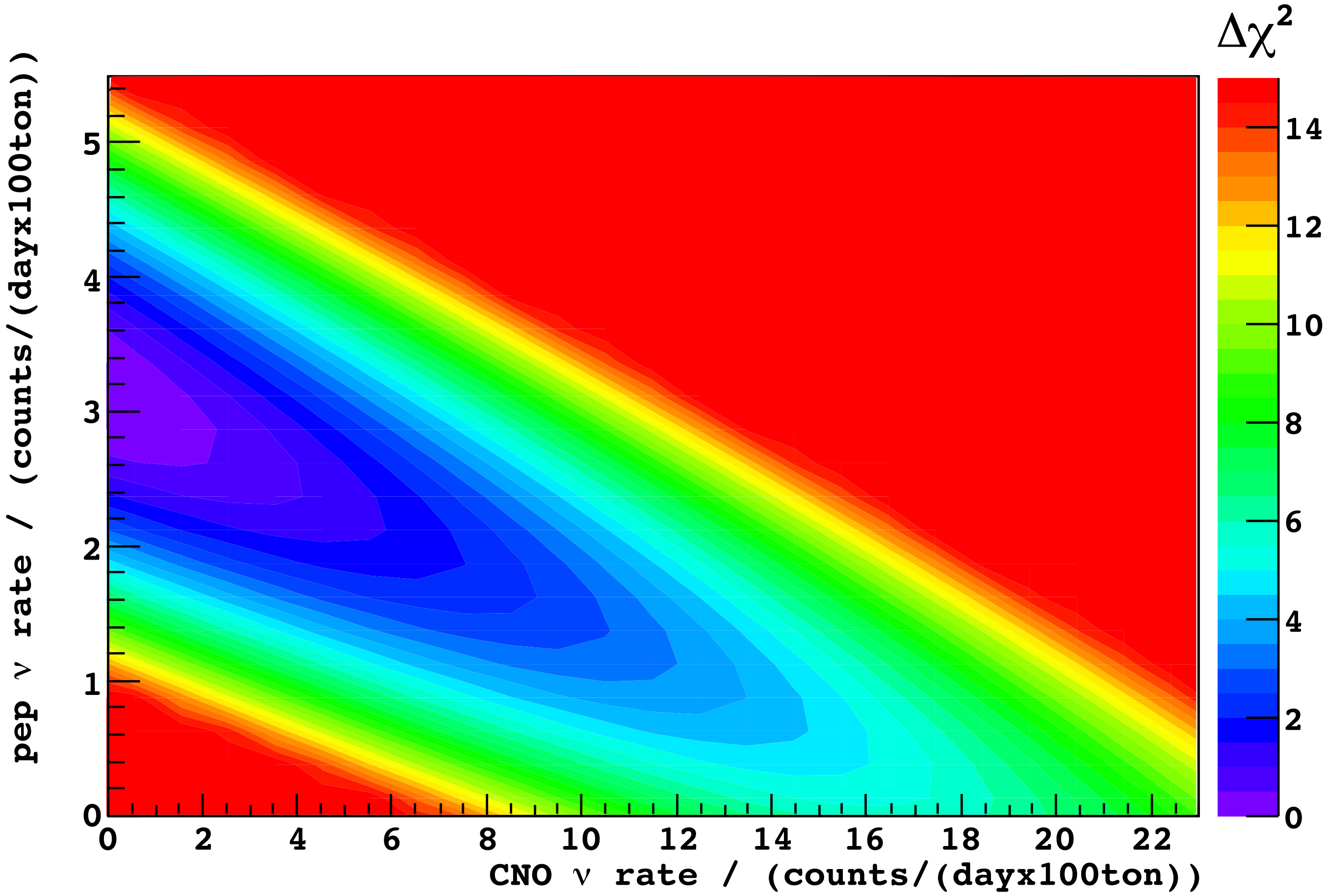
Borexino Collaboration, 2011



LS, PRD 2016

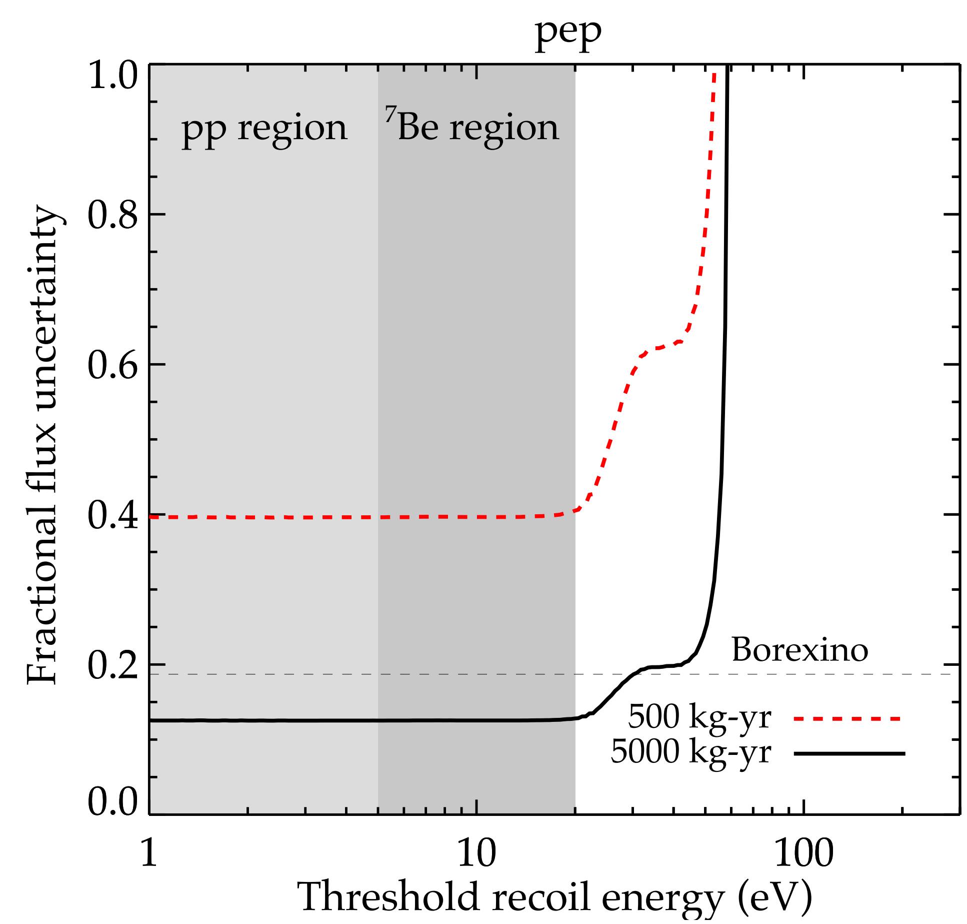
Ultra-low threshold (< 100 eV) detectors will make first neutral current measurement of low energy Solar neutrino fluxes

Neutrino Astrophysics: ultra-low thresholds



First evidence of *pep* solar neutrinos by direct detection in Borexino

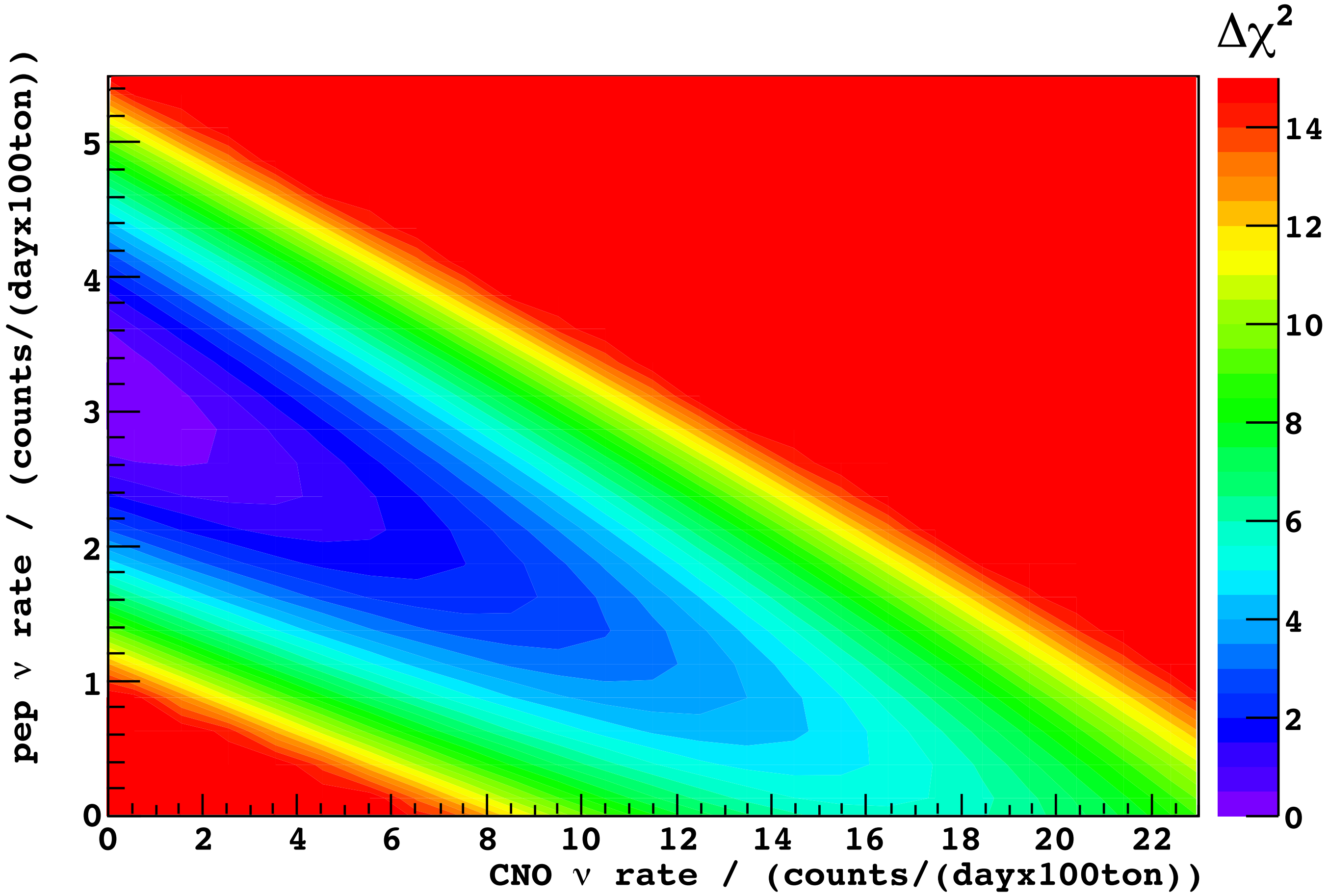
1110.3230



LS, PRD 2016

G3 experiments at low threshold may be able to study the CNO Solar neutrino flux

Neutrino Astrophysics: ultra-low thresholds



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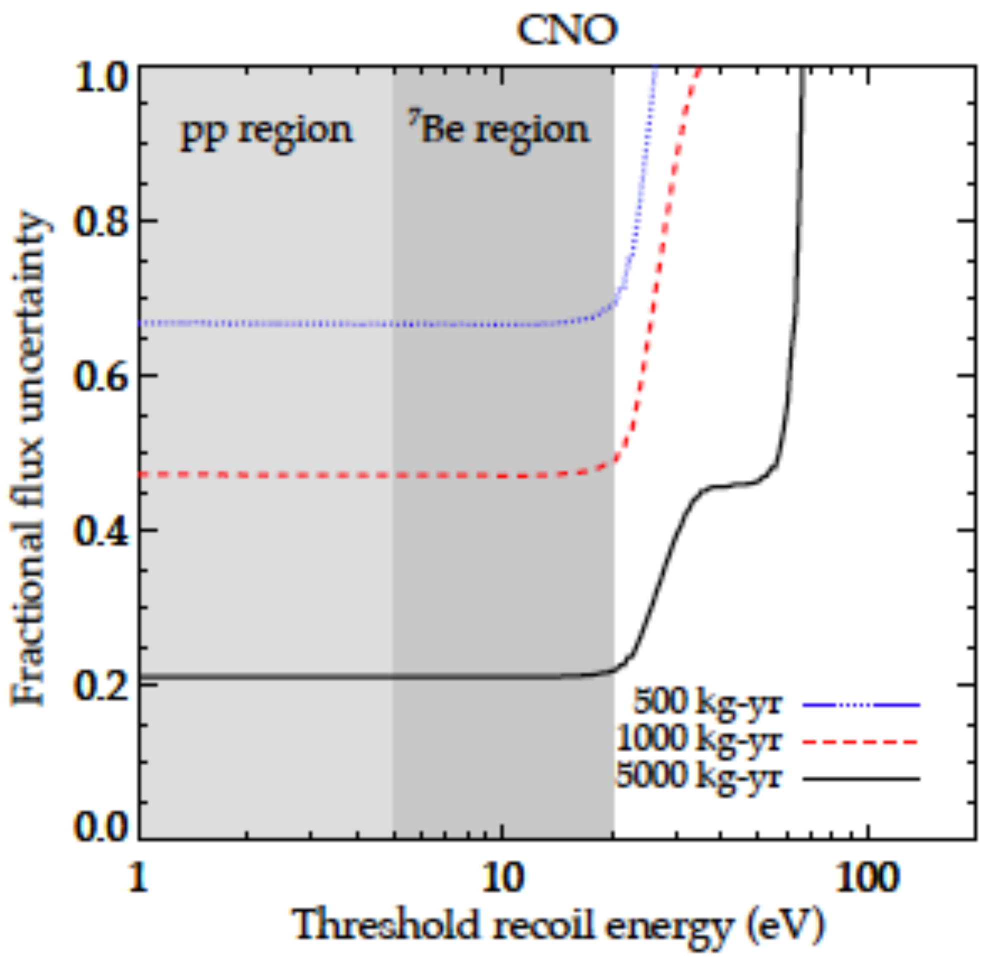


1110.3230

LS, PRD 2016

G3 experiments at low threshold may be able to study the CNO Solar neutrino flux

Neutrino luminosity of the Sun

- Neutrinos can test the idea that the Sun shines because of nuclear fusion
  - Compare the neutrino-inferred luminosity to the Solar luminosity
- Imposing the luminosity constraint gives the share of energy production between PP chain and CNO cycle,

$$\frac{L_{\text{pp-chain}}}{L_\odot} = 0.991^{+0.005}_{-0.004}\,\left[^{+0.008}_{-0.013}\right] \quad \Longleftrightarrow \quad \frac{L_{\text{CNO}}}{L_\odot} = 0.009^{+0.004}_{-0.005}\,\left[^{+0.013}_{-0.008}\right]$$

- Without the luminosity constraint,

$$\frac{L_\odot(\text{neutrino-inferred})}{L_\odot} = 1.04\left[^{+0.07}_{-0.08}\right]\,\left[^{+0.20}_{-0.18}\right]$$

Bergstrom, Gonzalez-Garcia et al. JHEP 2016

- Direct pp measurement (e.g. Xenon) at few percent level can improve this constraint

Radiochemical dark matter experiments

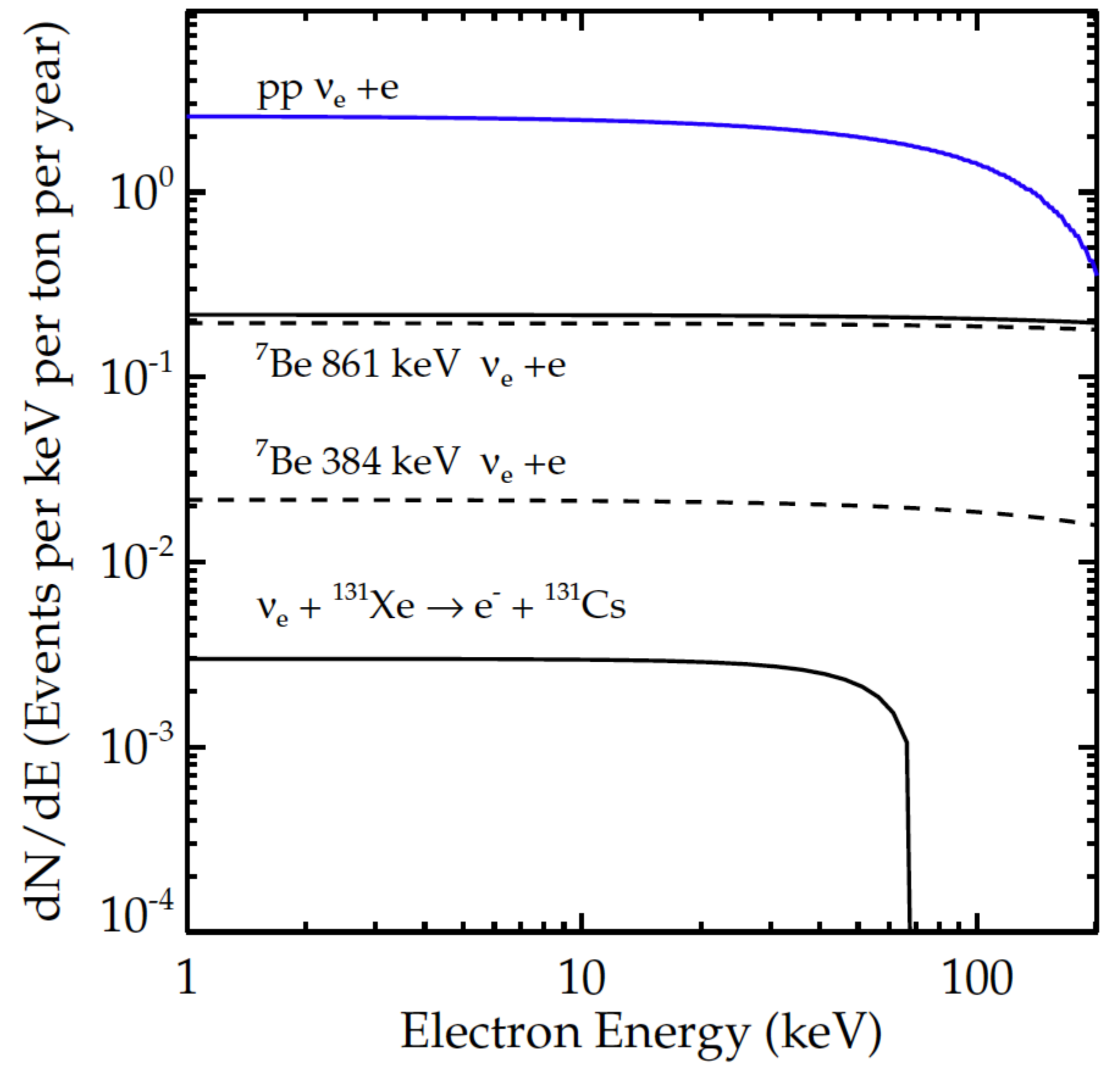
- Ton+ scale Xenon experiments will be sensitive to CC neutrino capture:

A xenon solar neutrino detector

A.Sh. Georgadze[a], H.V. Klapdor-Kleingrothaus[b], H. Päs[b], Yu.G. Zdesenko[a]
[a] *Institute for Nuclear Research, 252028, Kiev, Ukraine*
[b] *Max-Planck-Institut für Kernphysik, P.O. Box 103980, D-69029 Heidelberg, Germany*

Received 22 August 1996; revised 1 January 1997; accepted 3 February 1997

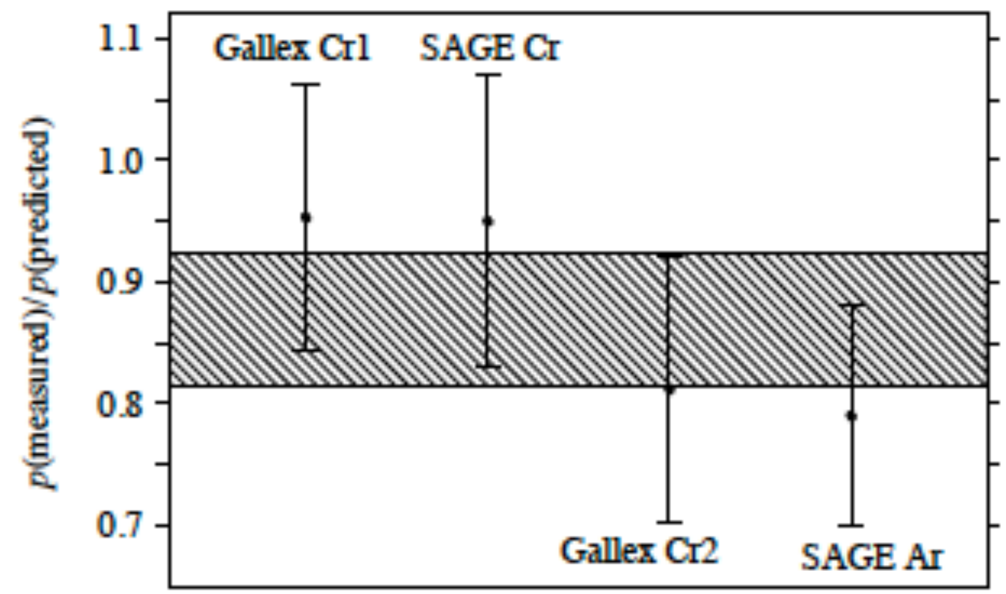
$$\nu_e + {}^{131}\mathrm{Xe} \rightarrow e^- + {}^{131}\mathrm{Cs}$$



- Ground state to ground state transition rate is dominated by pp and is well known; higher energy neutrino capture rate into excited states more uncertain
- First experimental setup to detect outgoing electron, rate is ~ event per ton per year
- Possible coincidence signal with ^{131}Cs decay, with half-life ~ 10 days

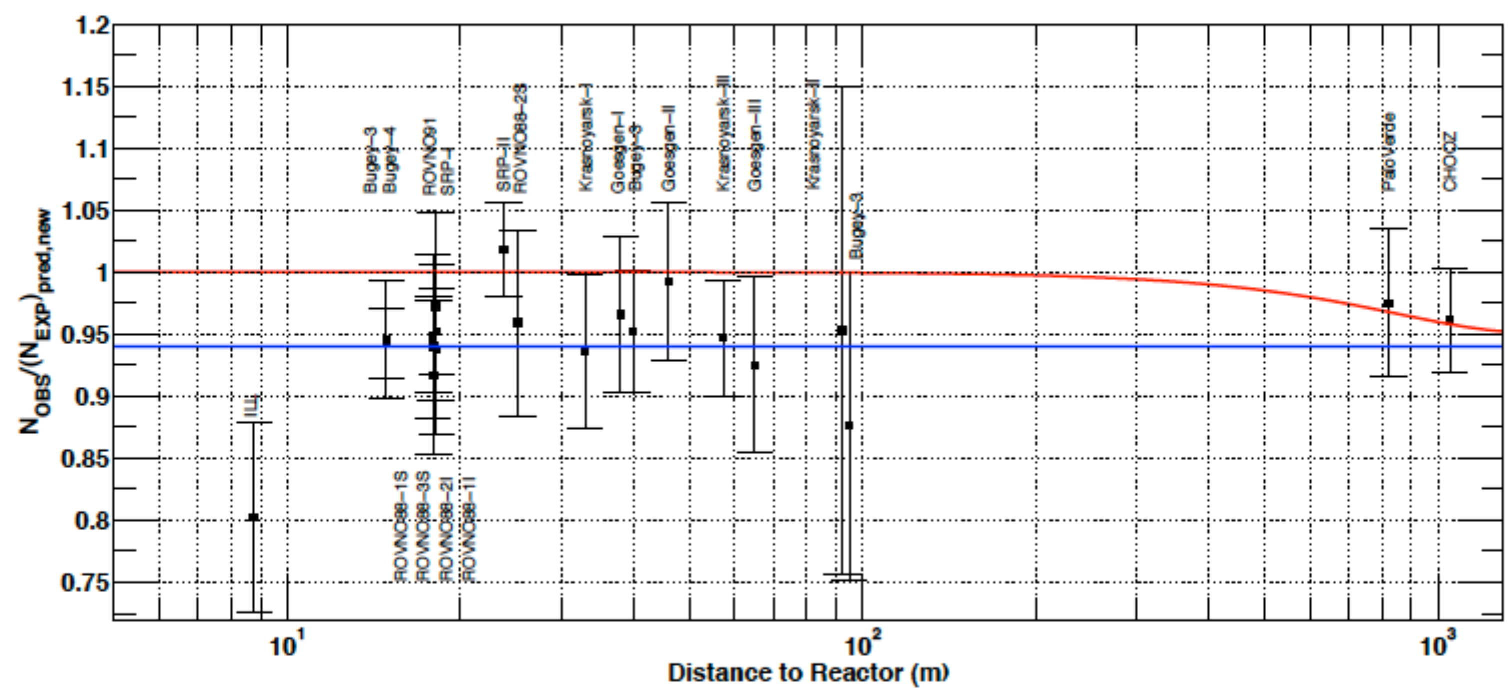
Outstanding issues III

- Gallium calibration experiments check the capture cross section for two excite states not constrained by ^{71}Ge lifetime
- Ratio of measured ^{71}Ge relative to that expected from source strength indicates ~ 2sigma discrepancy



SAGE collaboration, 2009

- Discrepancy may be larger when accounting for uncertainty in cross section (Giunti & Laveder 2010)
- Combined with ‘reactor anomaly’, gallium results may hint at new physics, i.e. ~ eV sterile neutrino



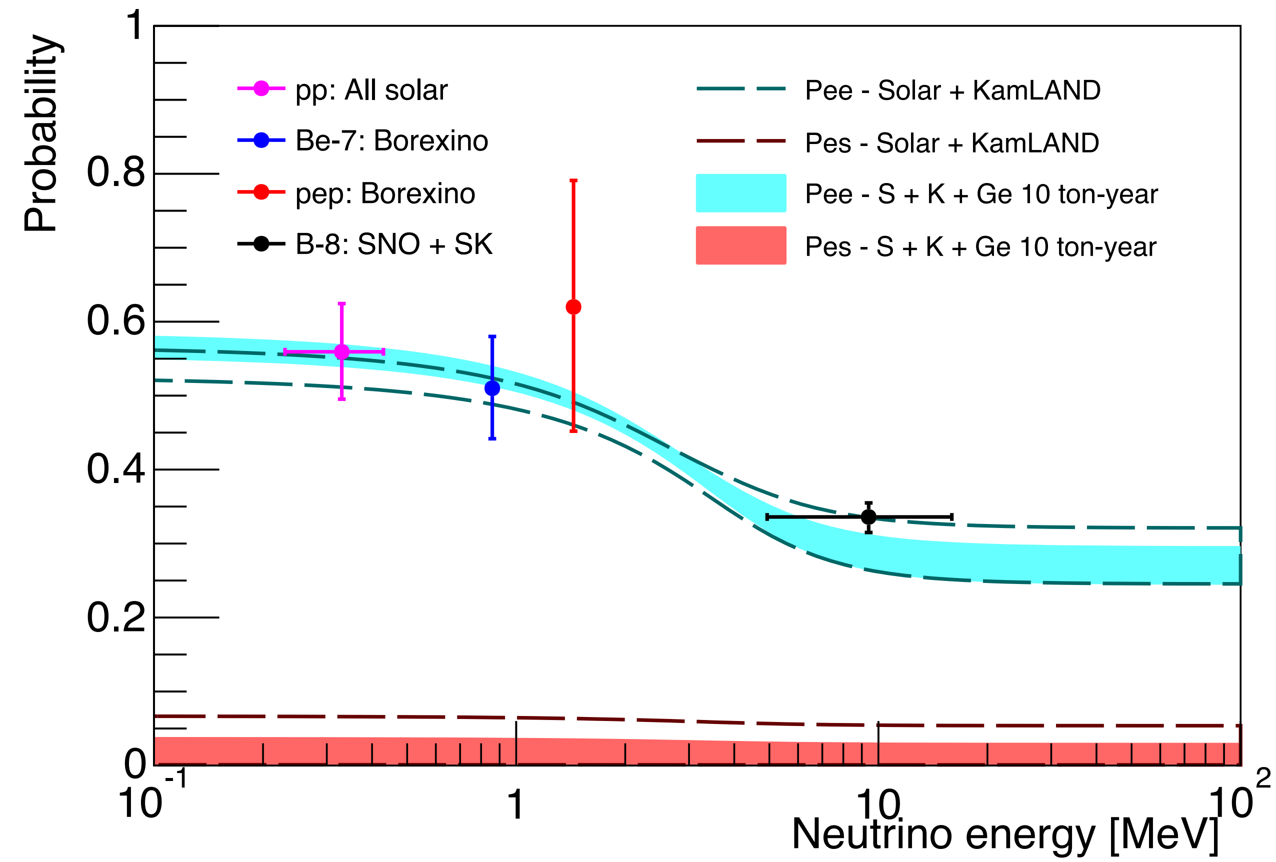
Mention et al. 2011

Neutrino properties: Sterile neutrinos

Super-K, SNO CC, and Borexino may not be seeing the upturn in the MSW survival probability at intermediate energy

- DM experiments provide first measurement of the energy dependence of the survival probability
- Sensitive to oscillation to 4th generation sterile neutrino

Palazzo 2012

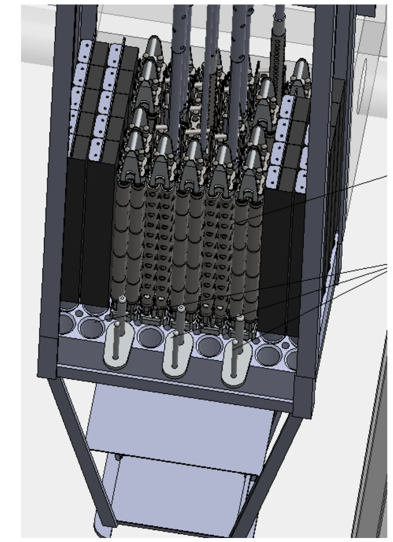


Billard, Strigari, Figueroa-Feliciano, PRD 1409.0050

Mitchell Institute Neutrino Experiment at Reactor

Background Studies for the MINER Coherent Neutrino Scattering Reactor Experiment

G. Agnolet[a], W. Baker[a], D. Barker[b], R. Beck[a], T.J. Carroll[c], J. Cesar[c], P. Cushman[b], J.B. Dent[d], S. De Rijck[c], B. Dutta[a], W. Flanagan[c], M. Fritts[b], Y. Gao[a,e], H.R. Harris[a], C.C. Hays[a], V. Iyer[f], A. Jastram[a], F. Kadribasic[a], A. Kennedy[b], A. Kubik[a], I. Ogawa[g], K. Lang[c], R. Mahapatra[a], V. Mandic[b], R.D. Martin[h], N. Mast[b], S. McDeavitt[i], N. Mirabolfathi[a], B. Mohanty[f], K. Nakajima[g], J. Newhouse[i], J.L. Newstead[j], D. Phan[c], M. Proga[c], A. Roberts[k], G. Rogachev[l], R. Salazar[c], J. Sander[k], K. Senapati[f], M. Shimada[g], L. Strigari[a], Y. Tamagawa[g], W. Teizer[a], J.I.C. Vermaak[i], A.N. Villano[b], J. Walker[m], B. Webb[a], Z. Wetzel[a], S.A. Yadavalli[c]



Mirabolfathi et al. 1510.00999

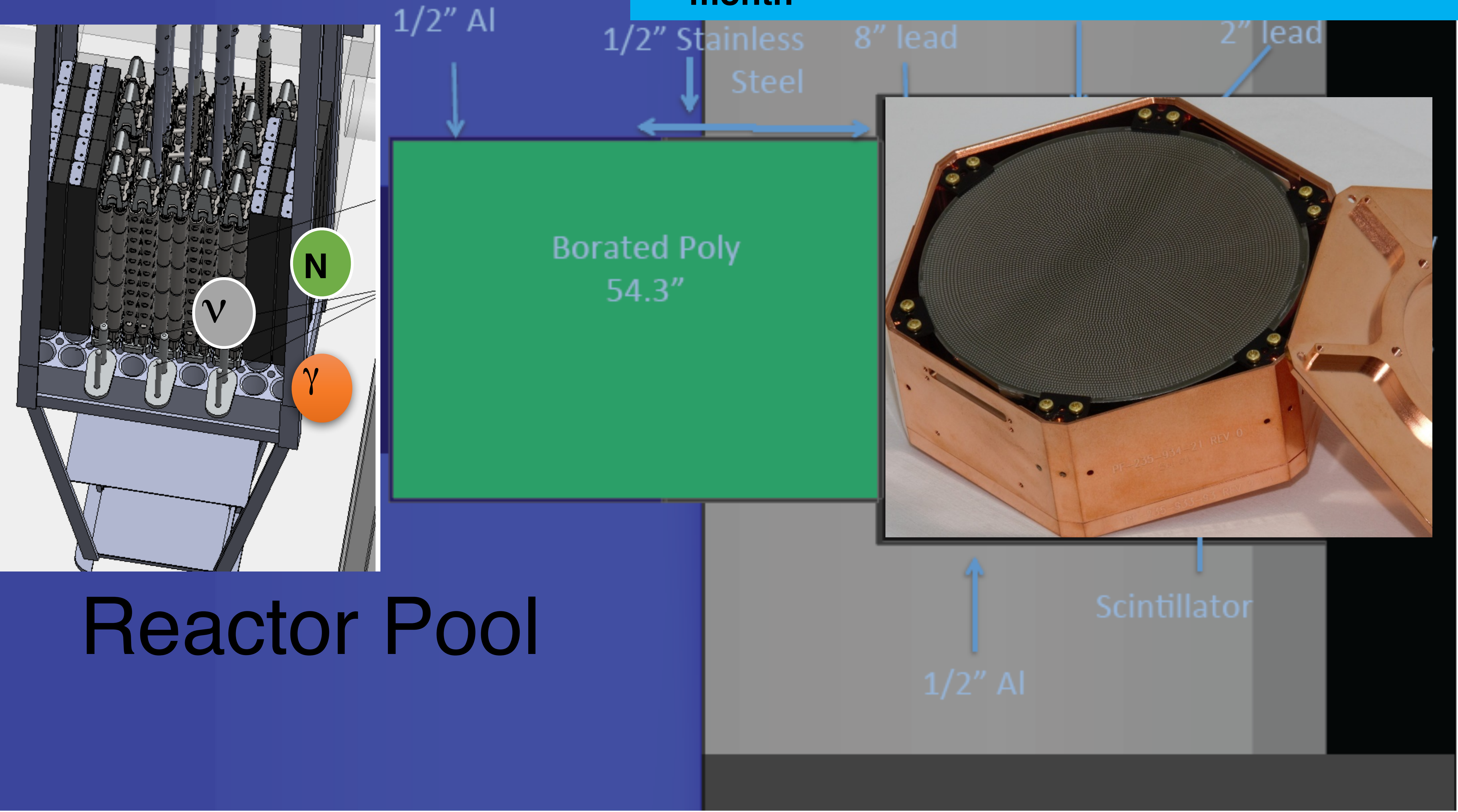
- Reactor-based proposal developed with Nuclear Science Center at Texas A&M University
- Detector technology based on scalable ultra-low threshold Germanium and Silicon arrays
- Close proximity of ~ 1m to MW reactor core
- Equivalent rate to larger detectors at larger distance from core (e.g. TEXONO)
- MW reactor ON/OFF
- Moveable core: Important for sterile neutrino searches

MIνER with Ge/Si

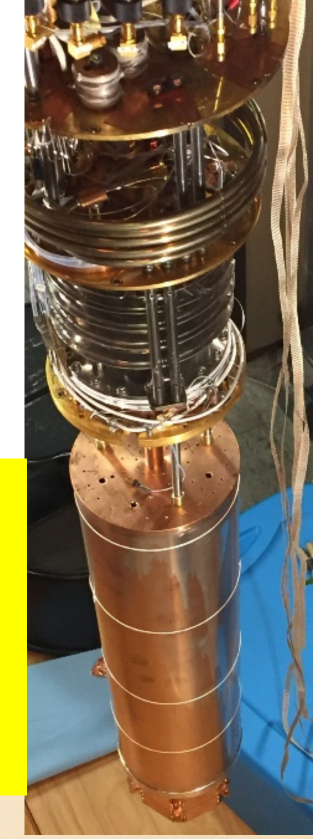
Dilution fridge being commissioned
Shielding construction in progress
Expect engineering data in Fall

Key Features

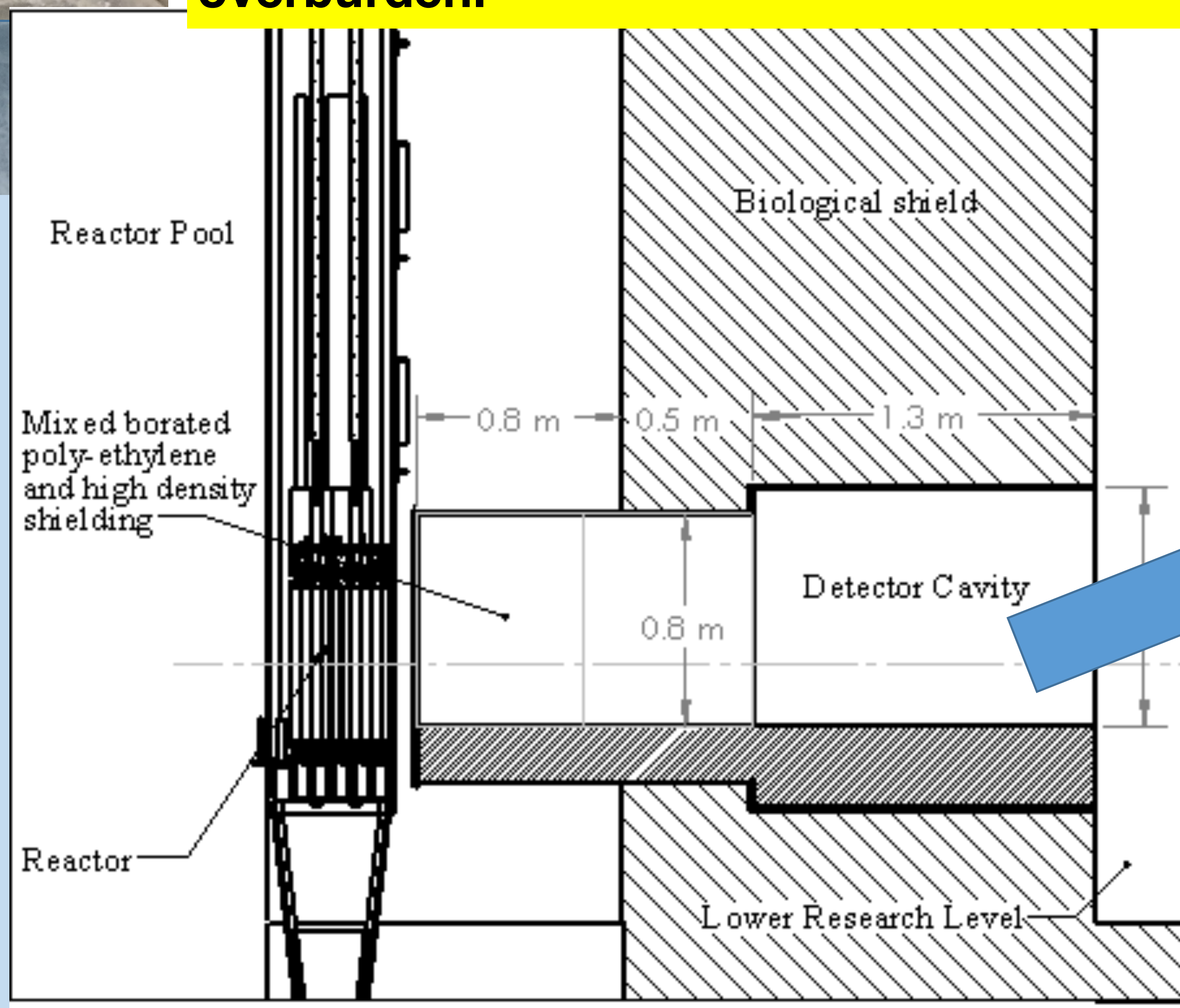
1. **Low-threshold (<100 eV) with sensitivity to CNS**
2. **2m proximity to core (rate enhancement)**
3. **Moveable Core tests short baseline oscillation**
4. **10 kg payload with sensitivity to CNS in a month**

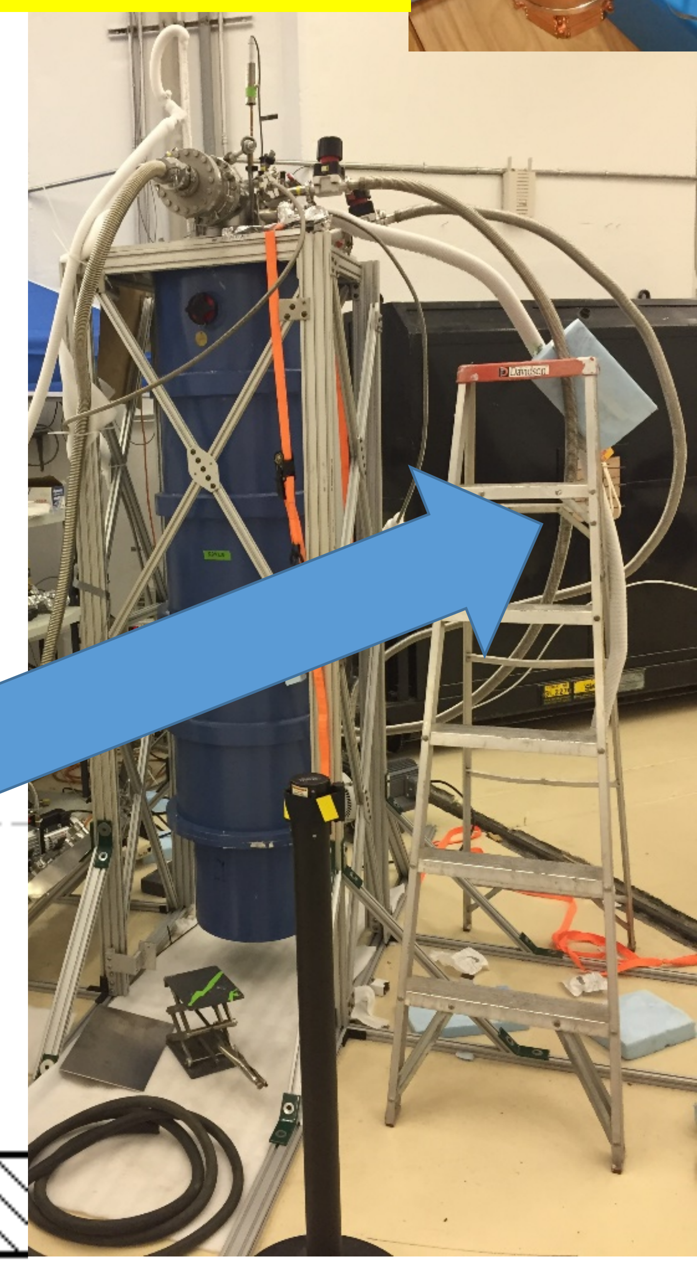


First run may happen outside of thermal cavern with straight hanging detector tower. Distance from core is higher (~4m), but quicker engineering run

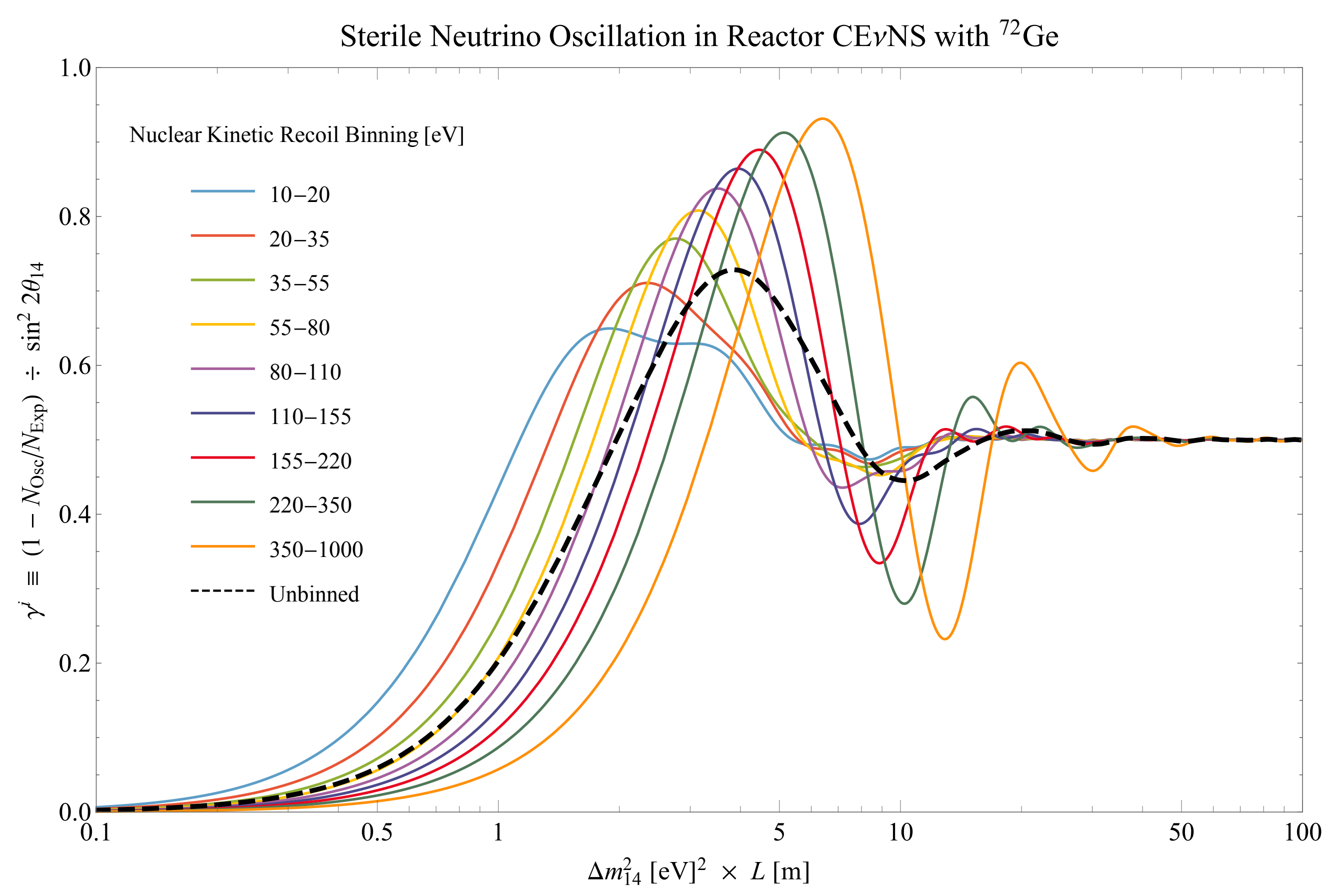


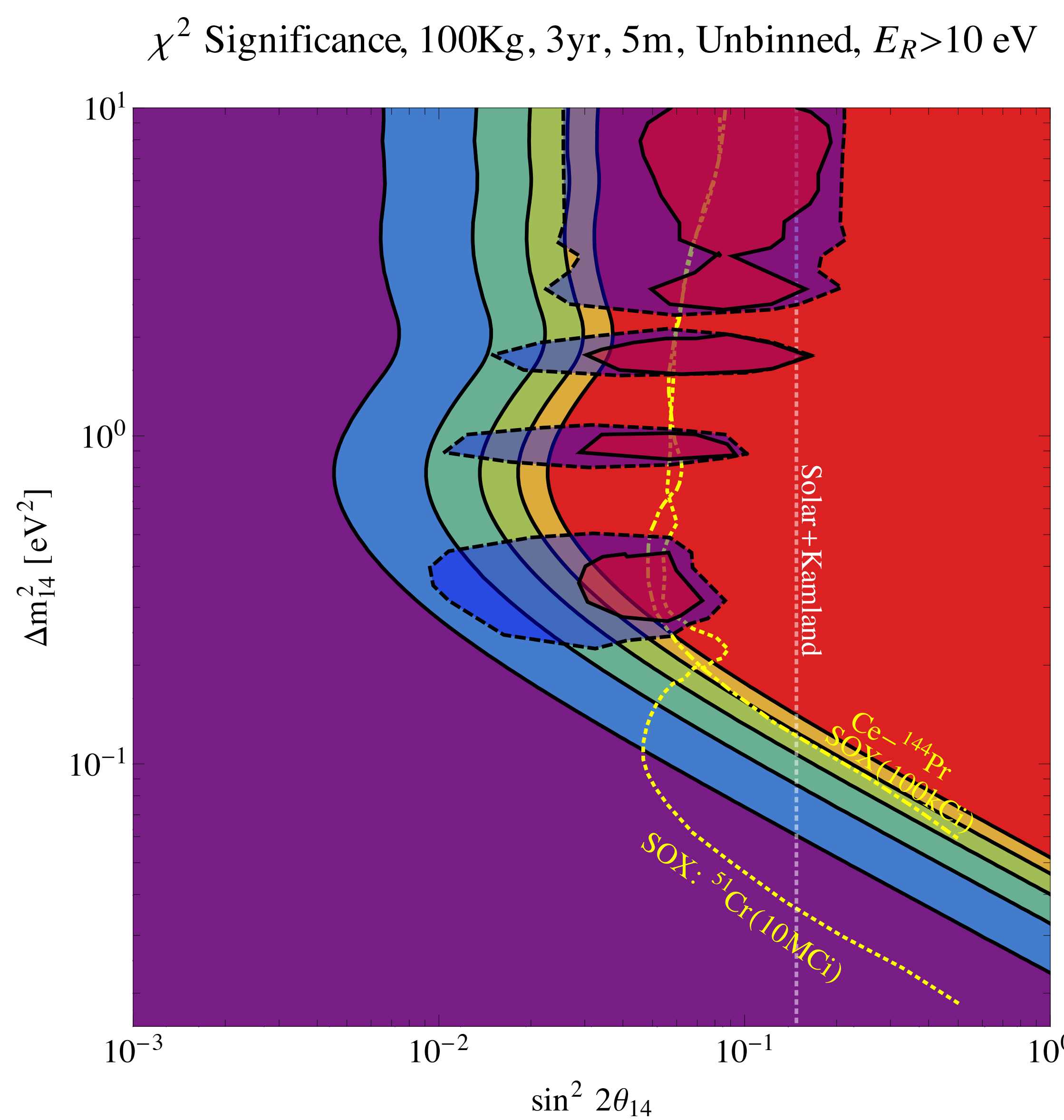
Full run will occur with detectors in Icebox (adapted from SuperCDMS Soudan design) that will reside inside thermal cavern with ~2m proximity and overburden.





Sterile neutrino search at reactors





Dutta et al. 1511.02834

$$P(\nu_\alpha \to \nu_{\not\alpha}) = 4|U_{\alpha 4}|^2(1-|U_{\alpha 4}|^2)\sin^2(1.27\Delta m^2_{41}L/E)$$

Summary: Important physics reach of coherent neutrino-nucleus scattering