Neutrino Signals in Dark Matter Detectors

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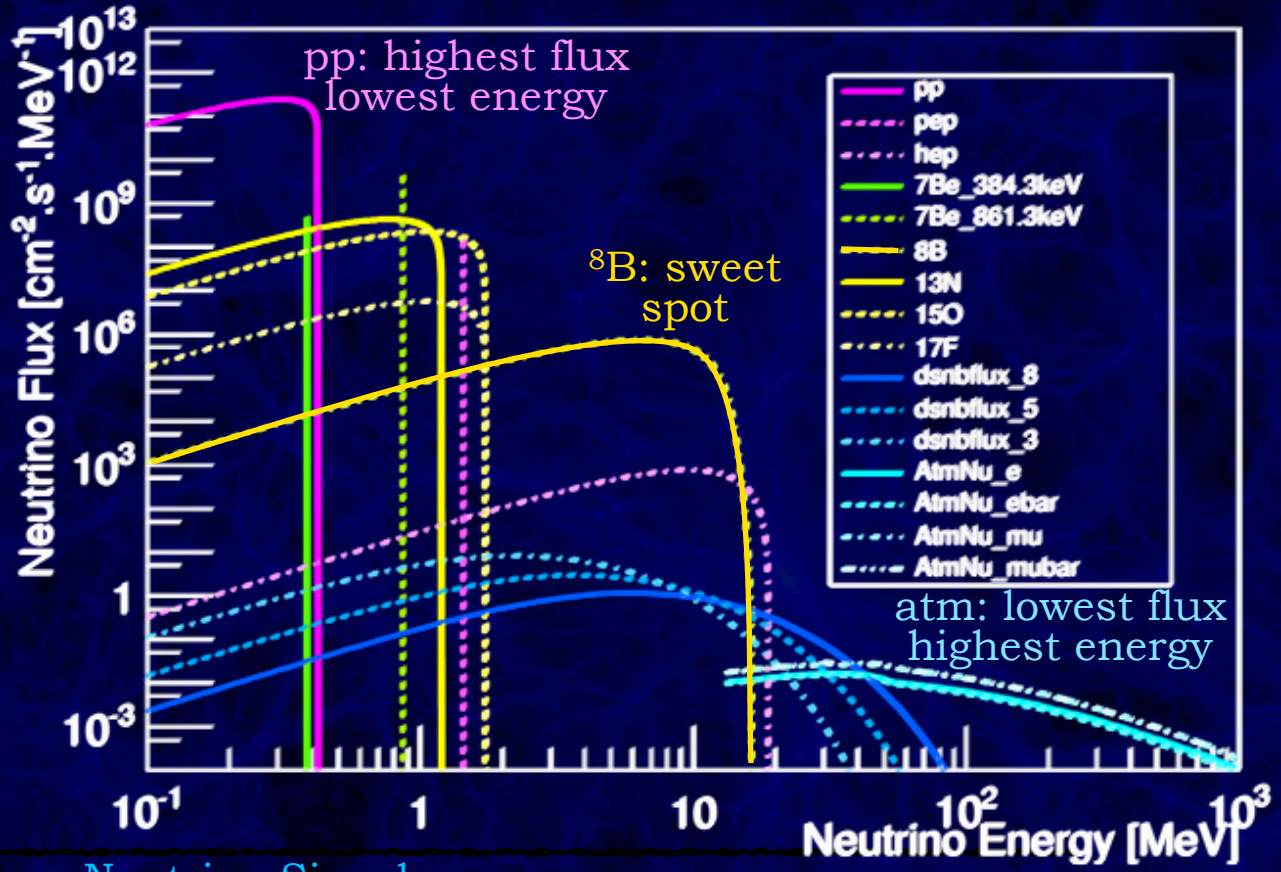
Relevant Neutrino Fluxes



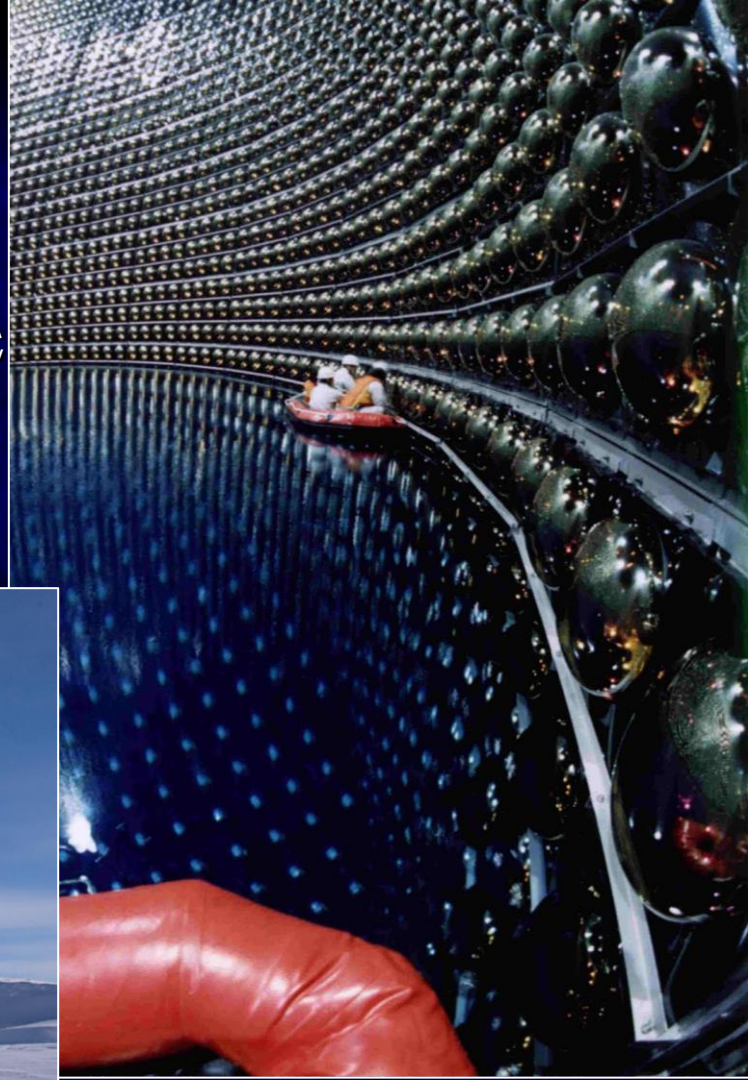
Billard, Strigari & Figueroa-Feliciano 1307.5458

Neutrino Detectors

BOREXINO
17m, 280t

Super-KamiokaNDE
40m, 50kt

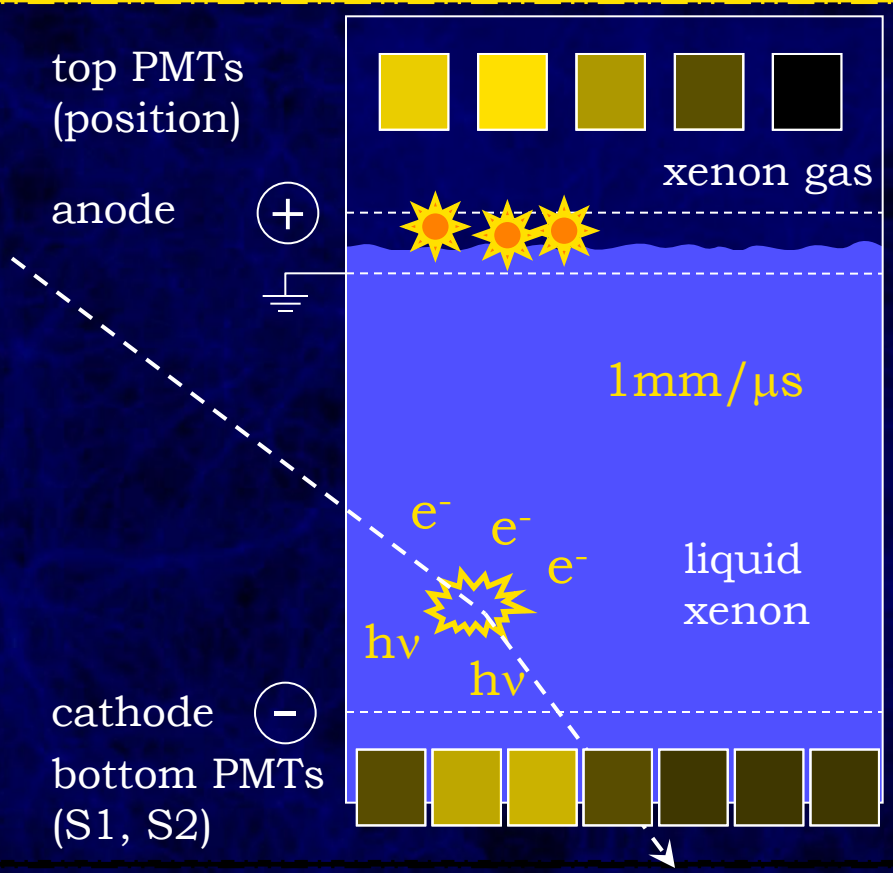
IceCube
1km^3, 1Gt



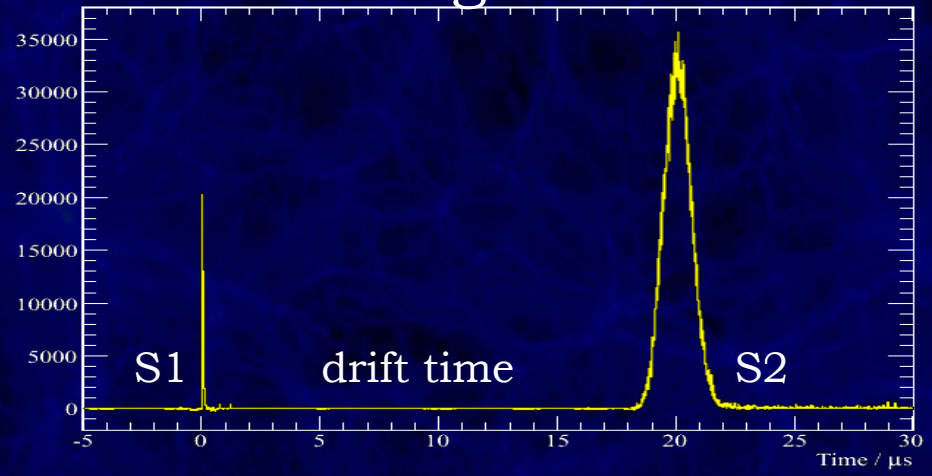
Rafael Lang:

XENON1T, 1m^3, 2t, running since summer

Dual-Phase Xenon TPCs



Built-in amplification for S2 signal



XENON1T Electronic Recoil Background

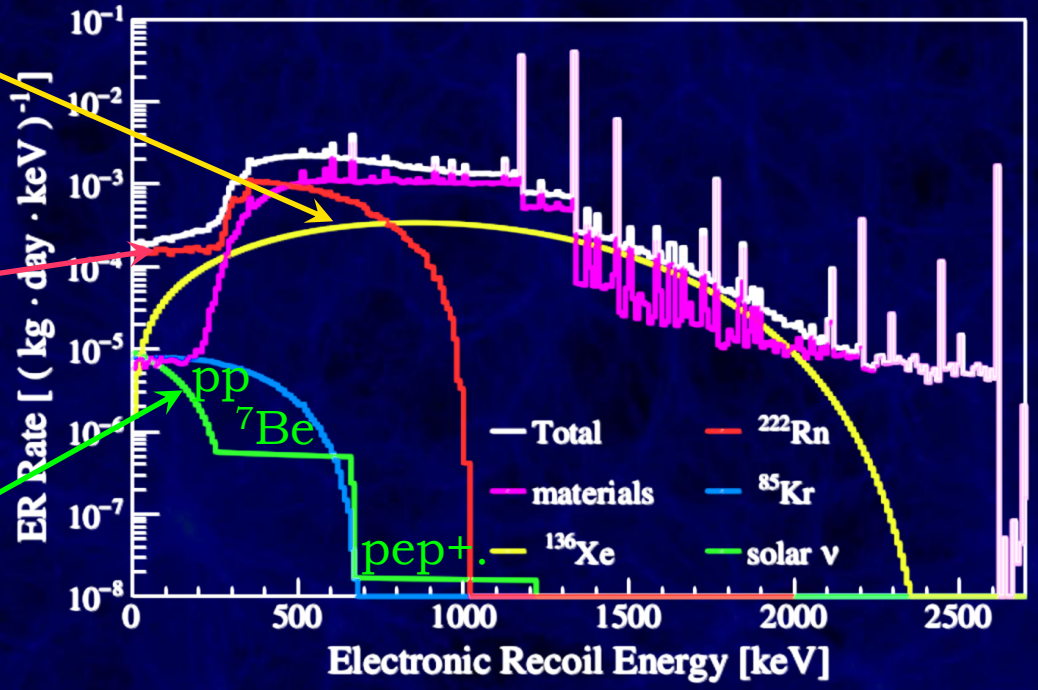
Overall, 2ν2β dominates ($t_{1/2}$~10^{21} years!)

^{222}Rn a technological challenge

sensitivity to pp solar ν elastic scattering

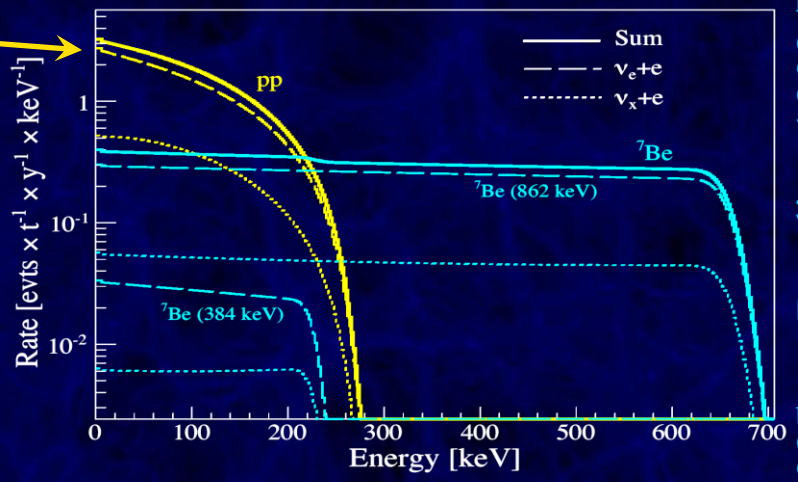
$\nu_e + e^- \rightarrow \nu_e + e^-$

first measurement possible with a couple months



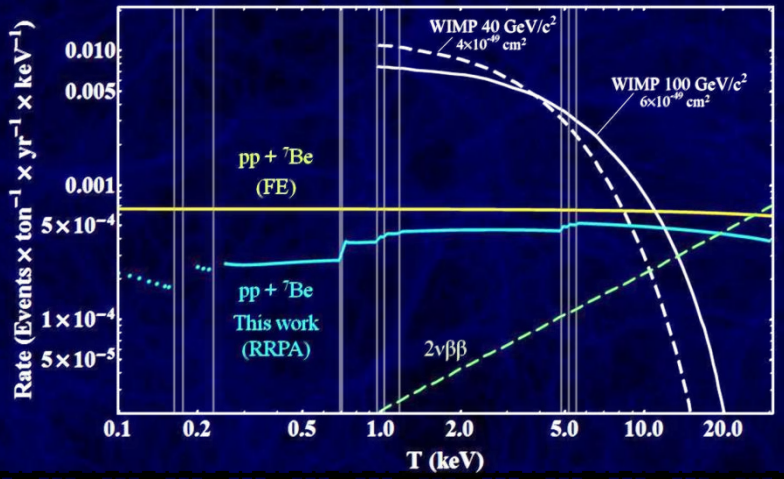
Solar Neutrino Elastic Scattering

92% from pp $\nu_e + e^- \rightarrow \nu_e + e^-$



Baudis+ 1309.7024

flux known to 2% but free electron approximation bad:



Chen+ 1610.04177

DARWIN/ARGO:

- Refine solar models
- Measure $\sin^2\theta_W$ to ~1%
- Measure ^{7}Be ν flux

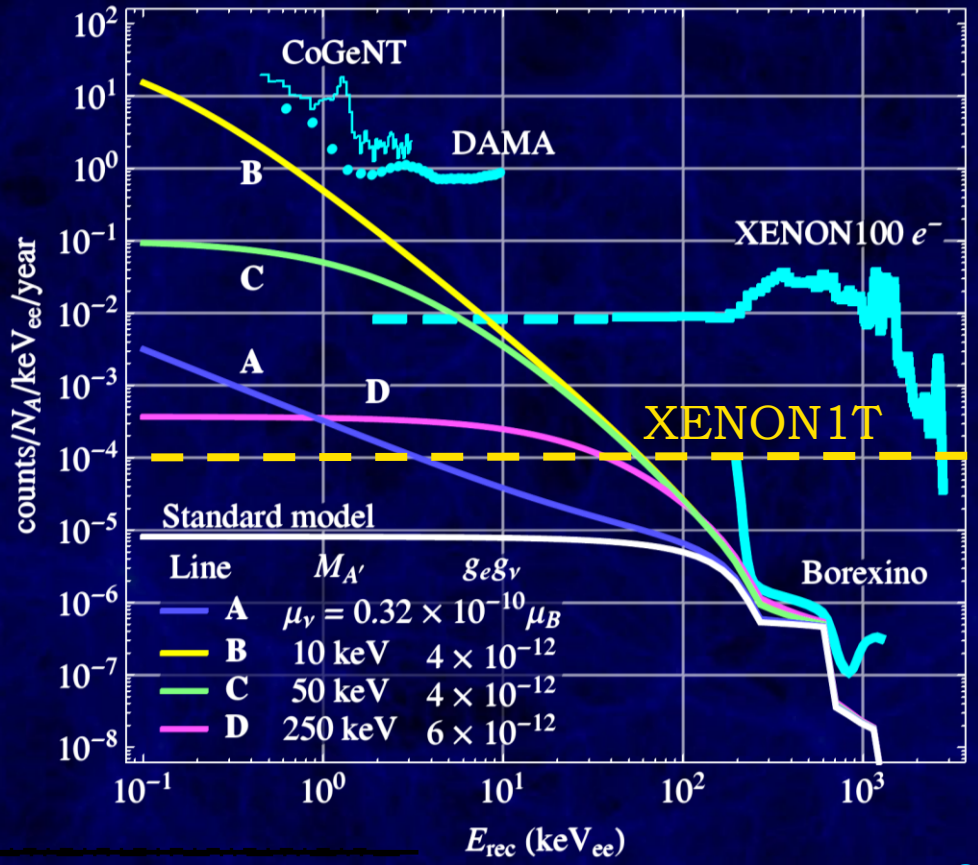
Cerdeno+ 1604.01025

New Physics: Add μ_ν or A'

Modified predictions for neutrino elastic scattering

$$\nu_e + e^- \rightarrow \nu_e + e^-$$

- Magnetic dipole moment of neutrino $\mu_\nu = 3 \times 10^{-11}\ \mu_B$?
- Additional U(1)' vector boson A' of some mass?



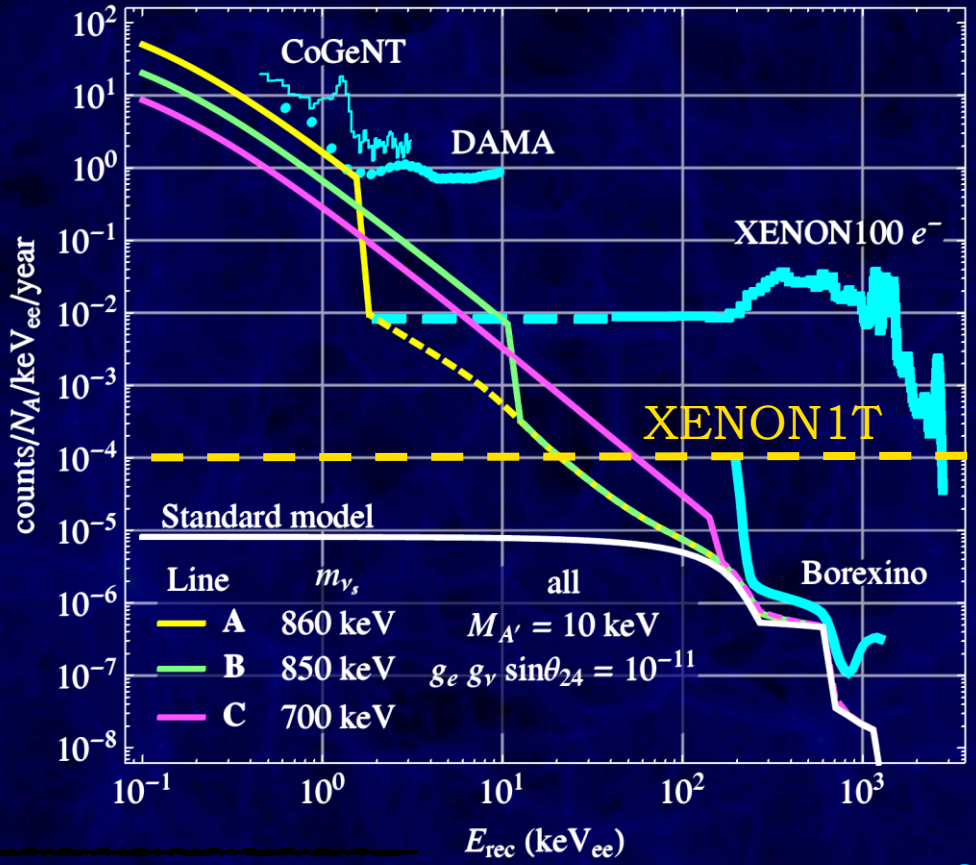
Harnik, Kopp & Machado 1202.6073

New Physics: Heavy Sterile Neutrinos

Modified predictions for neutrino elastic scattering

$\nu_e + e^- \rightarrow \nu_e + e^-$

- Might enhance rates below some threshold



Harnik, Kopp & Machado 1202.6073

Coherent Neutrino-Nucleus Scattering

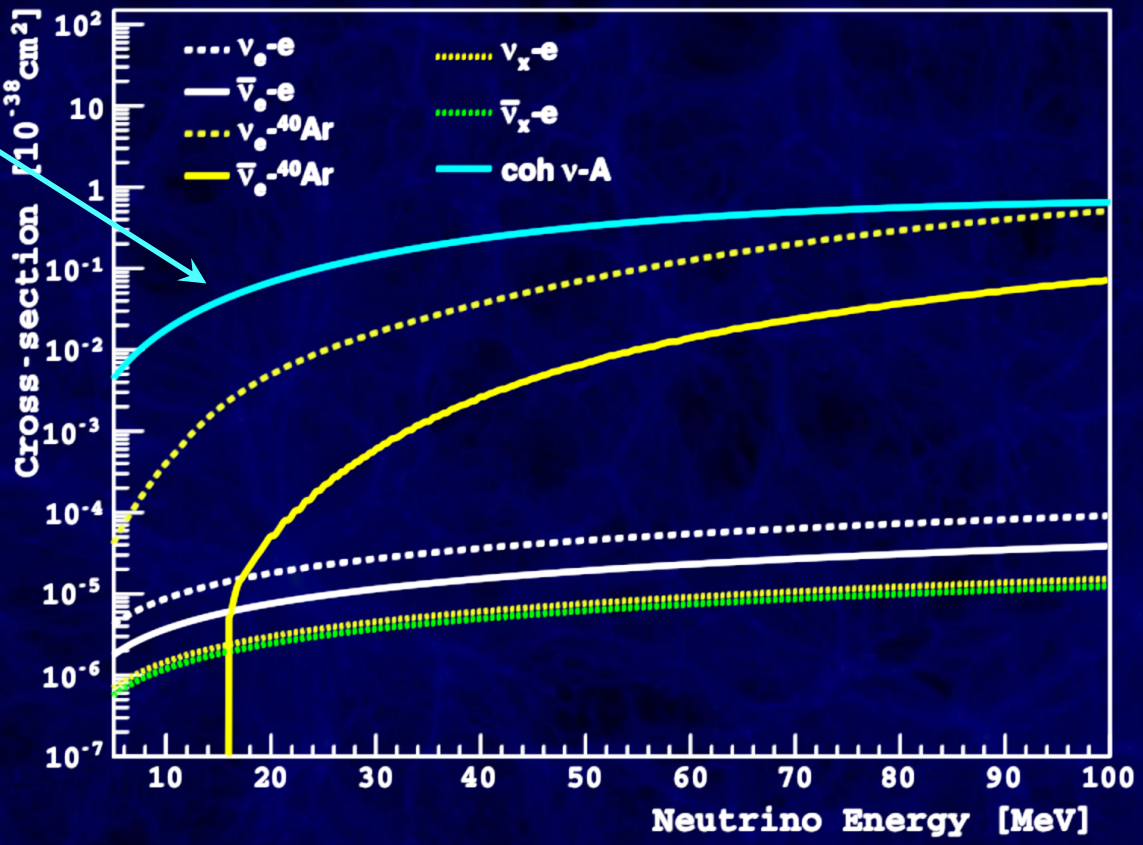
$\nu_x + N \rightarrow \nu_x + N$

once transferred momentum

$p > \hbar / r_{\text{nucleus}}$

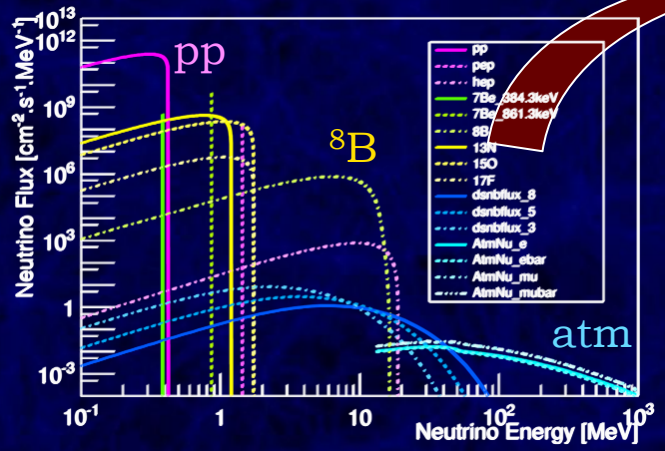
get same coherence effect as for WIMPs:

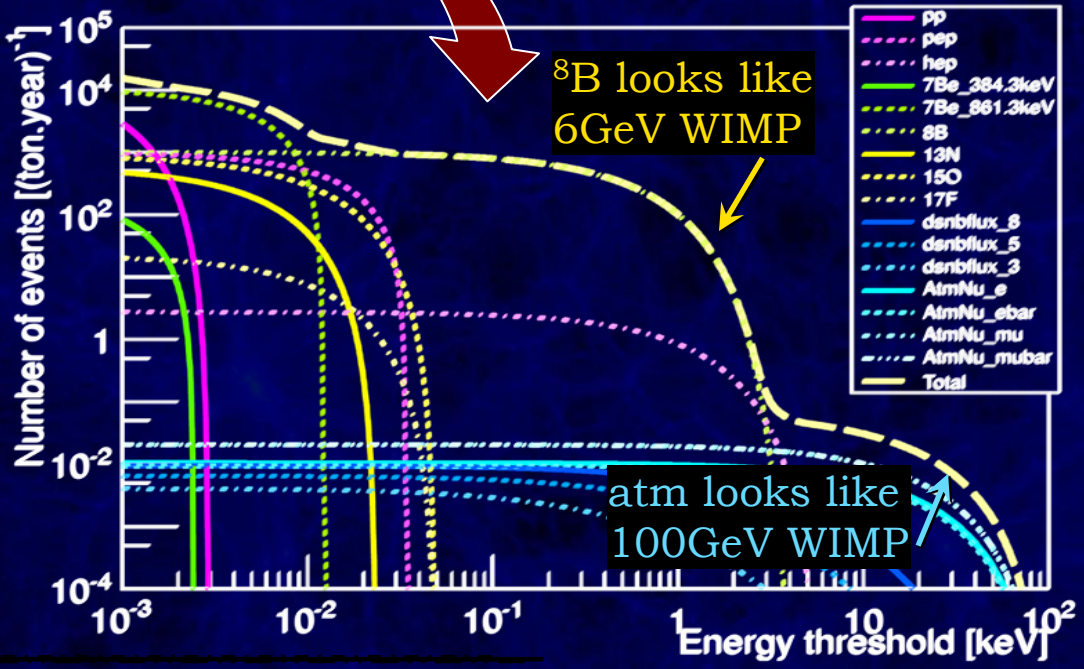
$\sigma \propto A^2$



Brice+ 1311.5958

From Flux to Recoil $\nu_x + N \rightarrow \nu_x + N$

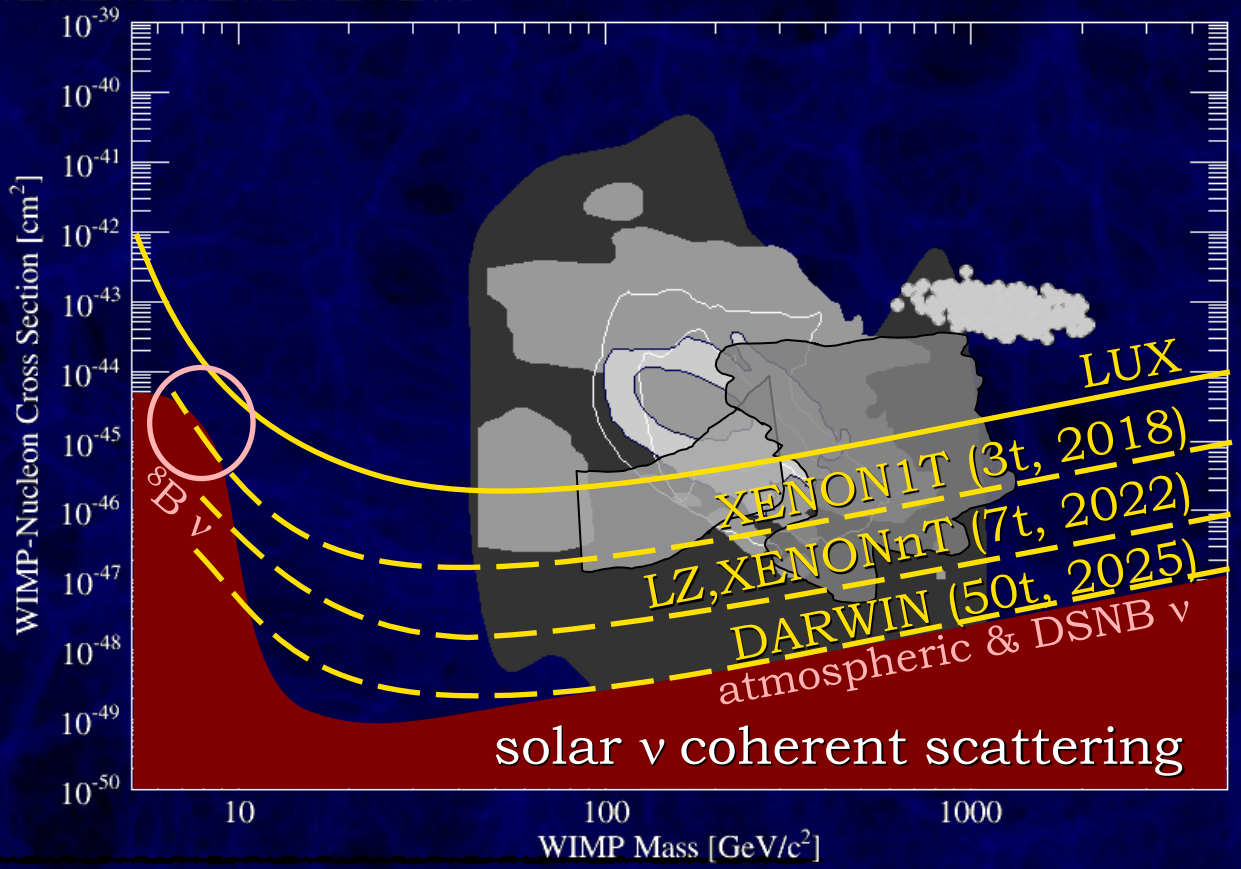




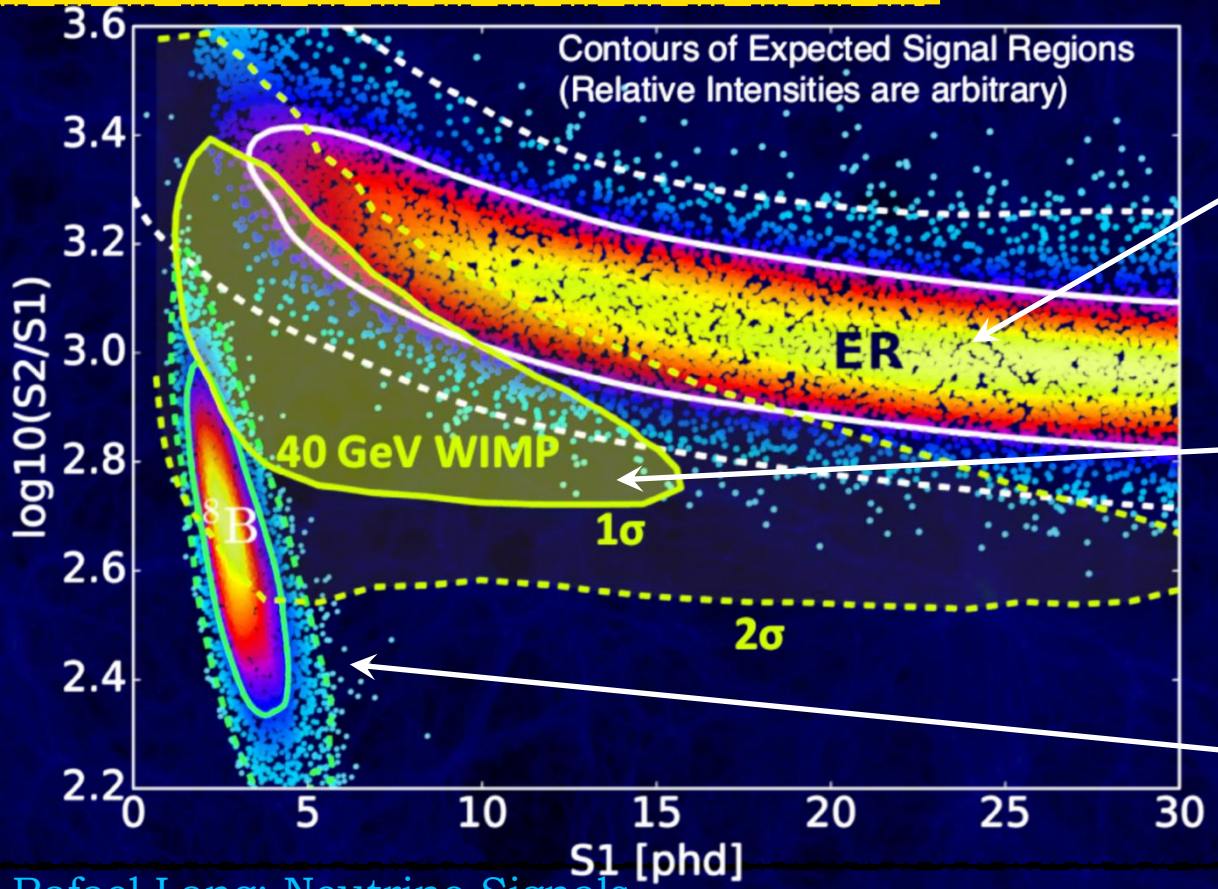
Billard, Strigari & Figueroa-Feliciano 1307.5458

^{8}B around the corner, atm not so much

discovery potential for XENON1T



S2/S1 Discrimination



background electronic recoils

dark matter nuclear recoils

^{8}B solar neutrino nuclear recoils

LZ Collaboration

Clarify Solar Metallicity with ^{8}B ν

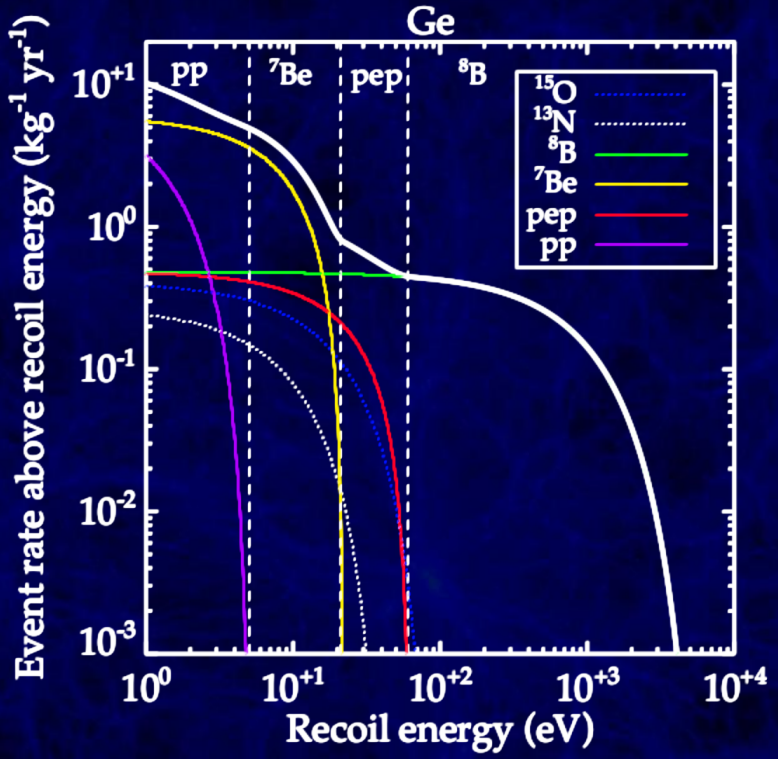
- Helioseismology suggests high metallicity in Solar core; predict $(5.6 \pm 0.8)\times10^6$ ^{8}Bν/cm^2/s

- 3D hydrodynamical simulations suggest lower metallicity in Solar core;
  predict $(4.6 \pm 0.6)\times10^6$ ^{8}Bν/cm^2/s

- best estimate from measurement (BOREXINO, SNO): $(5.0 \pm 0.2)\times10^6$ ^{8}Bν/cm^2/s

Haxton 1208.5723

CNNS at Ultra-Low Threshold



Strigari 1604.00729

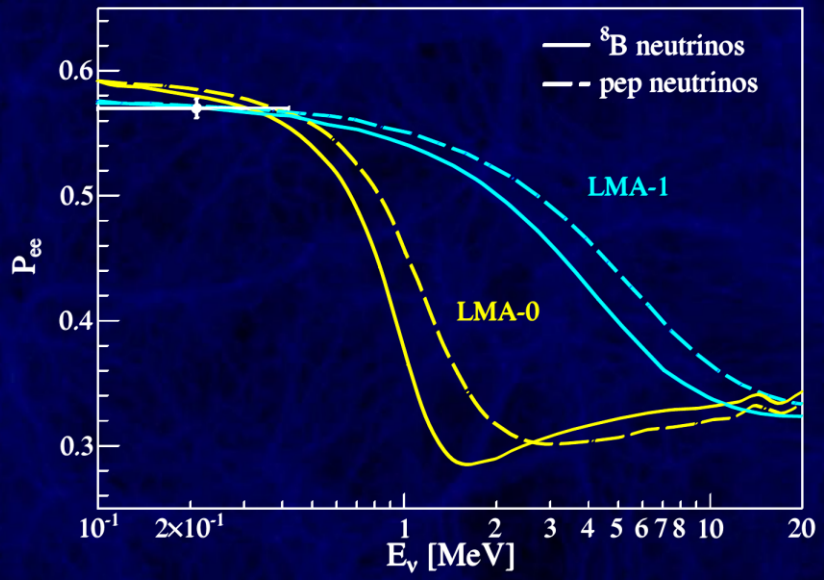
Even conceivable to study Solar CNO neutrino flux

Neutrino Oscillations

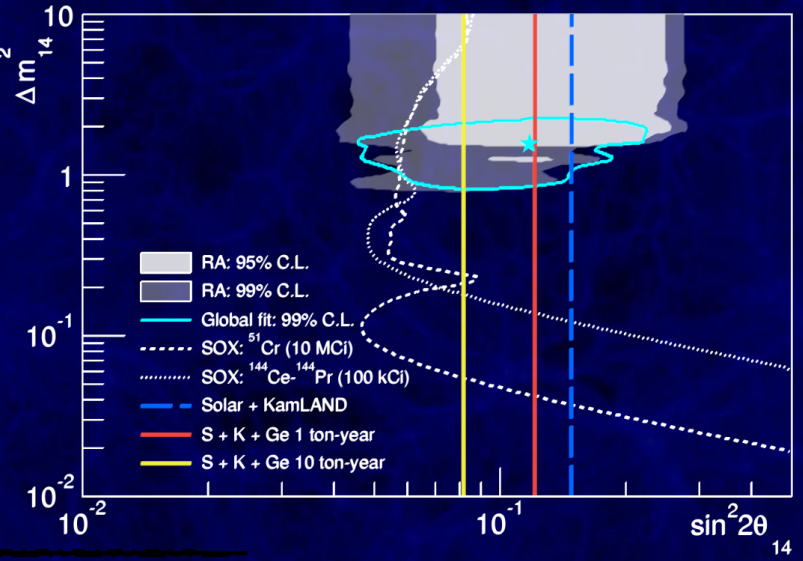
$\nu_{e,\mu,\tau} + \mathrm{Xe} \rightarrow \nu_{e,\mu,\tau} + \mathrm{Xe}$

Distinguish neutrino oscillation scenarios?
Requires >10 ton years

Baudis+ 1309.7024



Coherent scattering is flavor-insensitive: Check for neutrino disappearance
Here: Ge, 0.1keV threshold

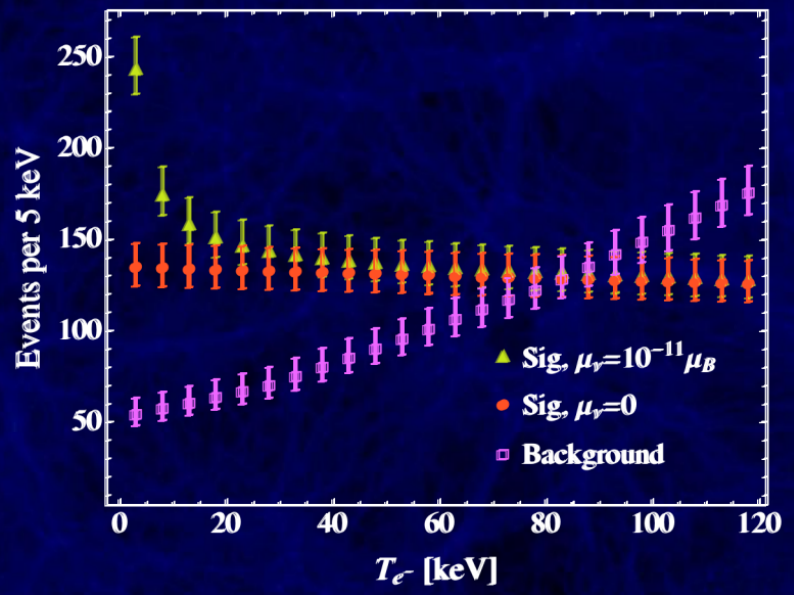


Billard,Figueroa-Feliciano&Strigari 1409.0050

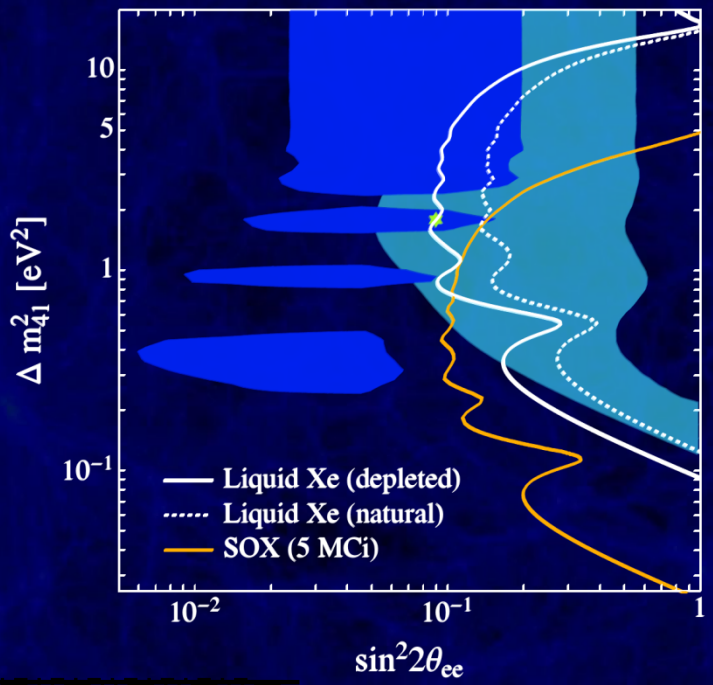
200PBq ^{51}Cr Anyone?

$\nu_e + \mathrm{Xe} \rightarrow \nu_e + \mathrm{Xe}$

Sensitivity to neutrino magnetic moment



Complementary sterile ν sensitivity with LZ/XENONnT?



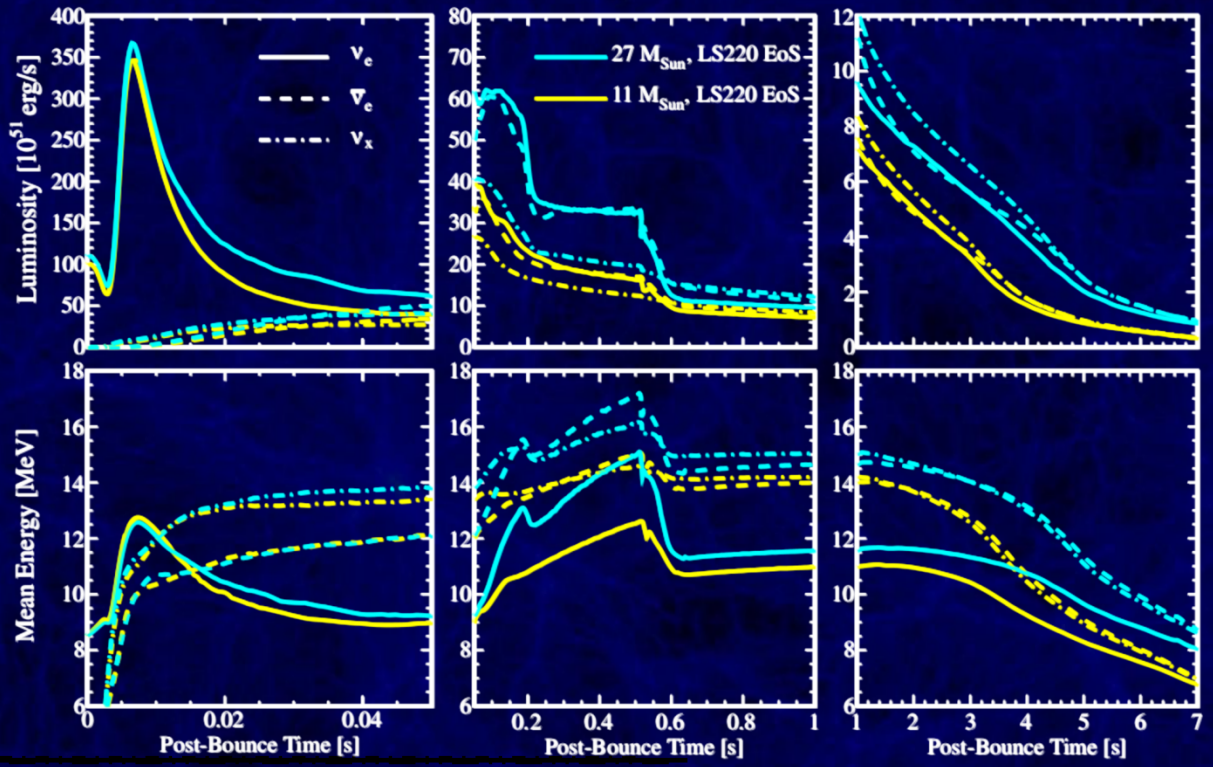
Coloma, Huber & Link 1406.4914

CNNS from Supernova ν

$$\nu_{e,\mu,\tau} + \mathrm{Xe} \rightarrow \nu_{e,\mu,\tau} + \mathrm{Xe}$$

- few seconds
- ~10 MeV
- all ν flavors

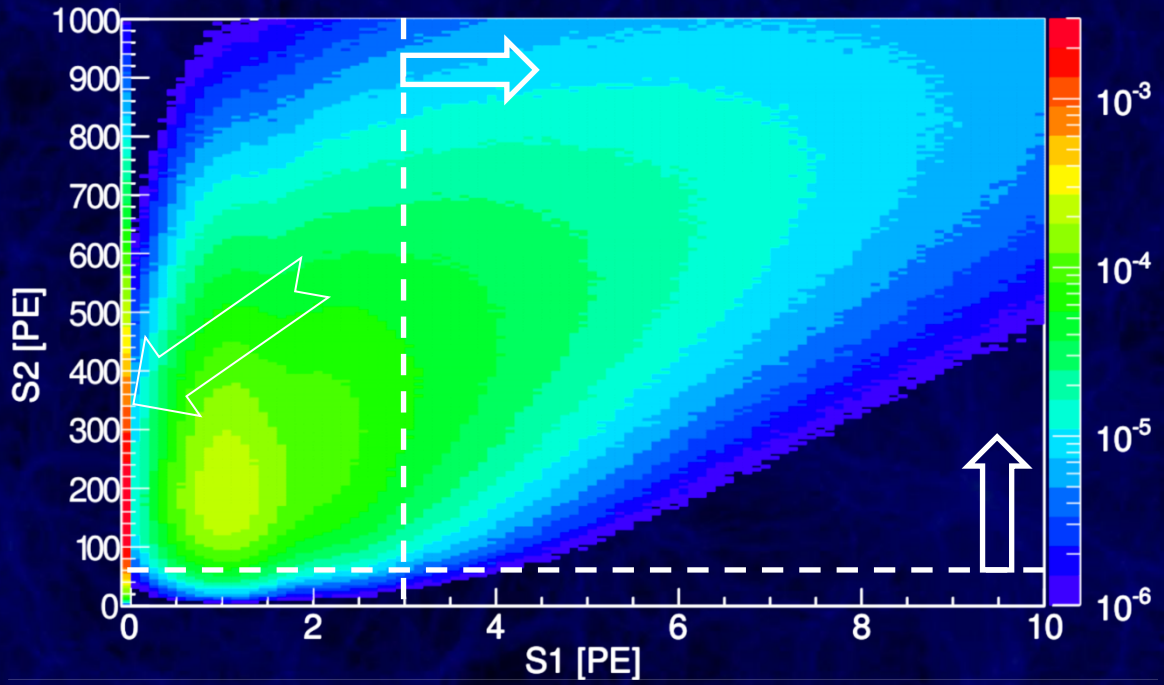
CC: $\mathcal{O}(0.1)\bar{\nu}_e$ /ton
CNNS: $\mathcal{O}(10)$ /ton

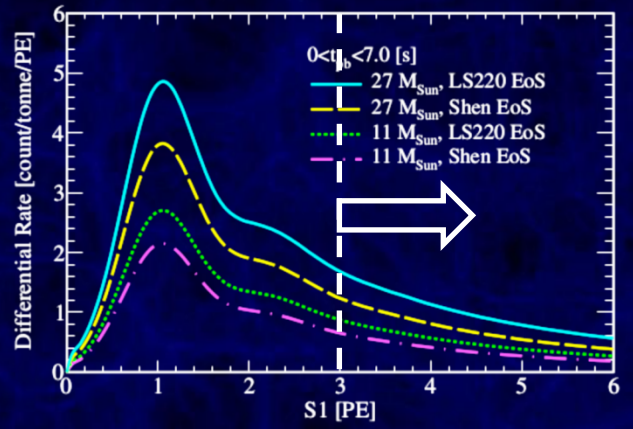


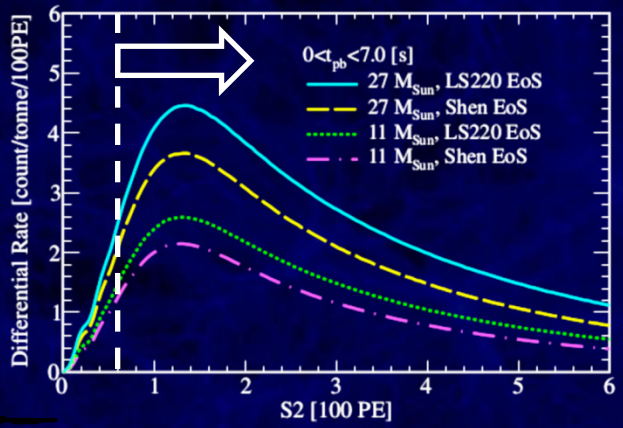
RFL, McCabe, Reichard, Selvi, Tamborra 1606.09243

Supernova Signals in Xenon

Detailed XENON1T simulation:





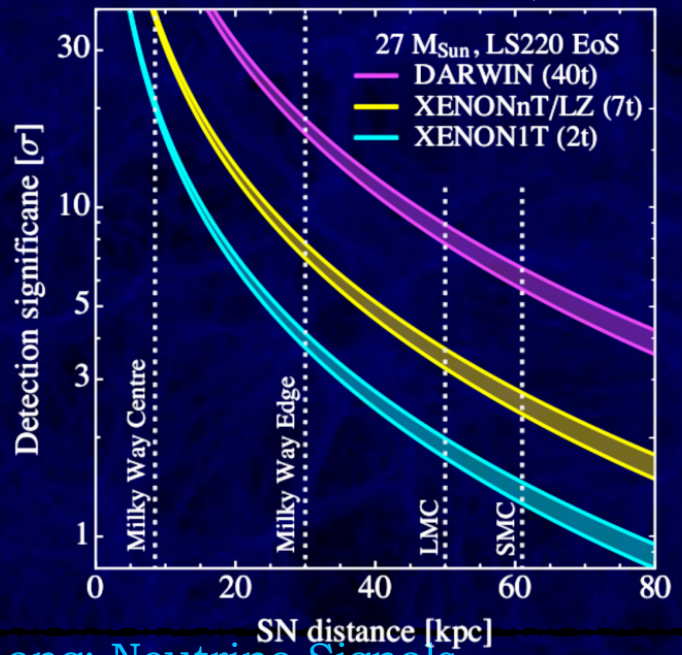


"S2-Only" analysis! bckgrnd ~10^{-2}/t/s

RFL, McCabe, Reichard, Selvi, Tamborra 1606.09243

Supernova!

XENON1T sensitive across entire Milky Way (once trigger implemented…)



flavor-independent: complementary information

- contribute to SNEWS

DARWIN:

- out to LMC & SMC
- measure total energy in ν
- distinguishing accretion phase from Kelvin-Helmholtz cooling phase

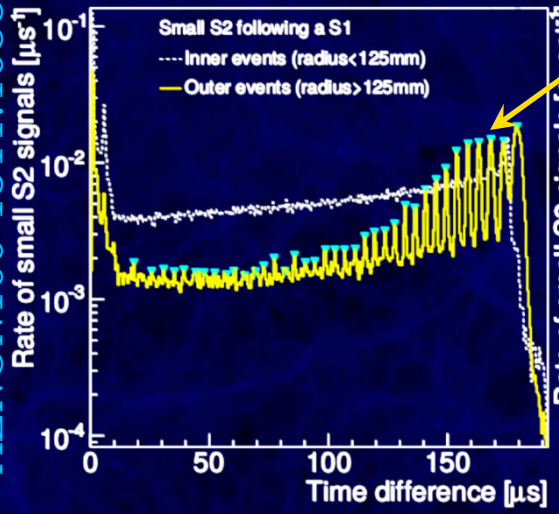
RFL,McCabe,Reichard,Selvi,Tamborra1606.09243

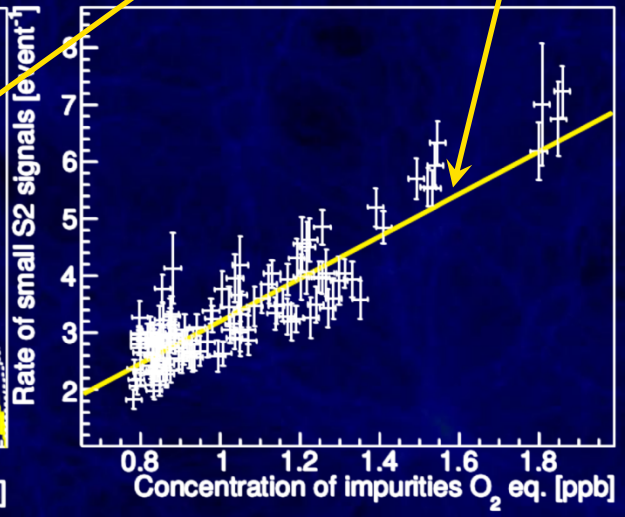
Homework: Understand "S2-Only"

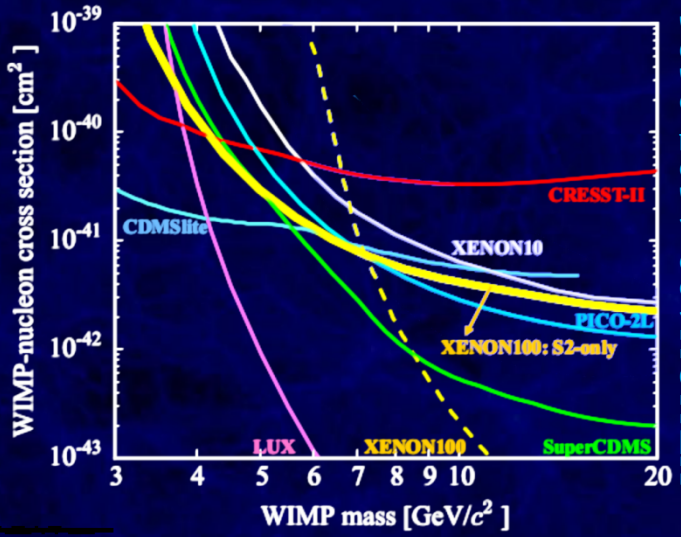
Background poorly understood; Xenon light 175nm=7eV

- Photoionization: metals, impurities, xenon

XENON100 1311.1088







XENON100 1605.0626

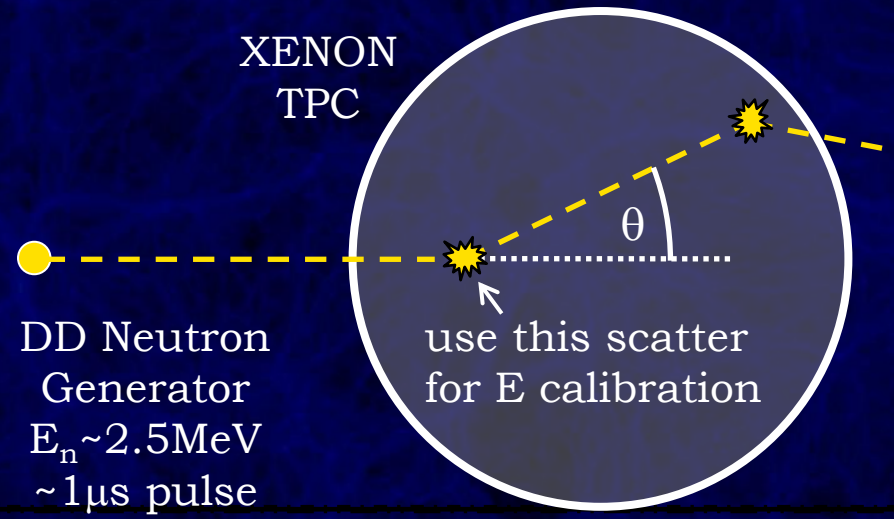
- Delayed extraction?
- Something else?

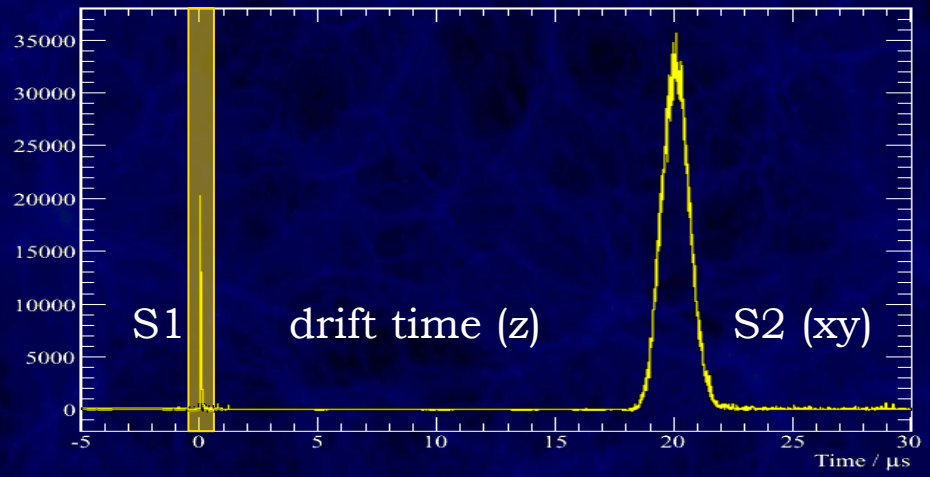
Homework: Understand "S2-Only"

Energy & acceptance calibration

Instead of S1, use ~μs neutron pulse from DD generator:

- Get vertex and scattering angle
- Reduce backgrounds





Conclusions

- Running DM detectors sensitive to ν
- pp $\nu_e + e^- \rightarrow \nu_e + e^-$ from pp ν:
  Solar models, $\sin^2\theta_W$, BSM
- ^{8}B CNNS $\nu_x + N \rightarrow \nu_x + N$
  Solar metallicity
- Atm. CNNS $\nu_x + N \rightarrow \nu_x + N$
  background to dark matter after 2025
- Supernova CNNS $\nu_x + N \rightarrow \nu_x + N$
  complementary, total E_ν, SN physics
- Requires "S2-only" calibration