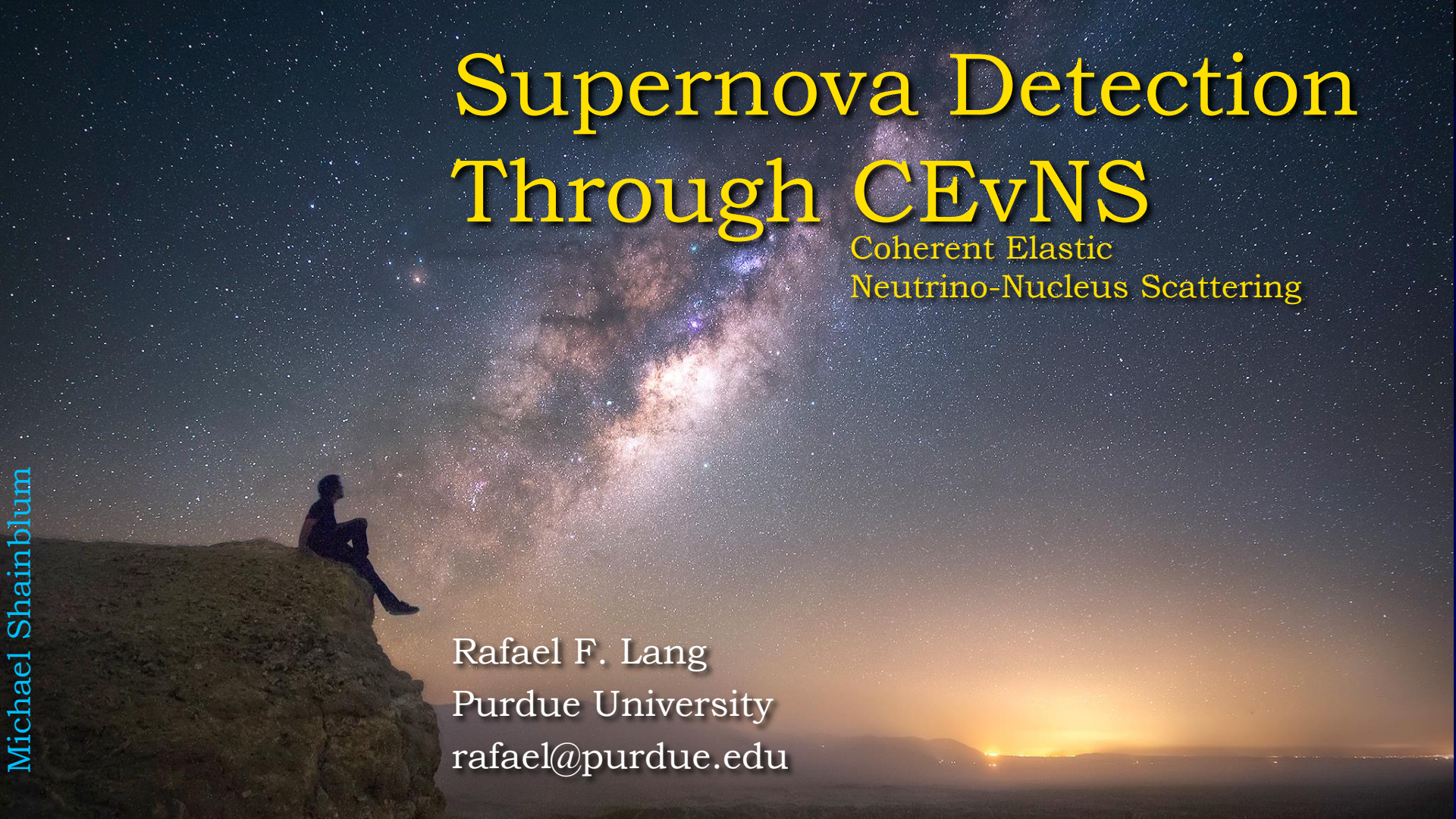
Supernova Detection Through CEvNS

Coherent Elastic
Neutrino-Nucleus Scattering



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Michael Shainblum

Coherent Elastic ν-Nucleus Scattering

Supernova neutrino wavelength:

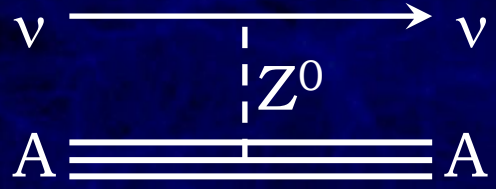
$$\frac{\lambda_{\mathrm{deBroglie}}}{2\pi} = \frac{\hbar}{p} \sim \frac{197\,\mathrm{MeV\ fm}}{10\,\mathrm{MeV}} > r_{\mathrm{nucleus}}$$

Thus ν interact with entire nucleus and $\sigma \propto A^2$

Dark matter detectors now approaching ~10 ton targets.
With A~100 that's ~1000-ton-equivalent

→ Many potential new contributors to SNEWS

Provide flavor-independent measurement

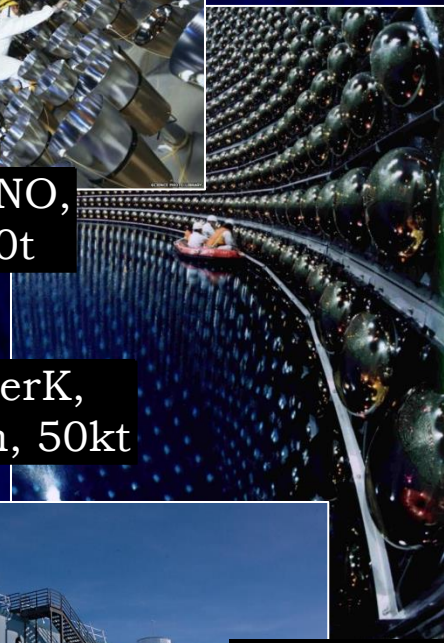


Just to be clear…

XENON1T,
1m^3, 2t

Won't achieve SuperK/IceCube statistics but will give complementary & flavor-independent information

BOREXINO,
17m, 280t



SuperK,
40m, 50kt

IceCube,
1km^3, 1Gt

Some Notable/Near-Term Detectors

XENON1T	finished	2t Xe	1606.09243
PANDAX-4t	construction	3t Xe	1806.02229
XENONnT	construction	6t Xe	see Ricardo's poster
LZ	construction	7t Xe	1801.05651
Gen3/DARWIN	mid-2020s	>40t Xe	1606.09243
DEAP-3600	running	3.3t Ar	also astro-ph/030207
DarkSide-20k	soon	20t Ar	1707.08145
ARGO	late 2020s	>200t Ar	1905.09283
DUNE	construction	40kt Ar	see Adryanna's poster
PICO-500	construction	1t C_3F_8	1806.01417
CUORE	running	0.7t TeO_2	PoS Neutel 2013 070

see also 1309.4492

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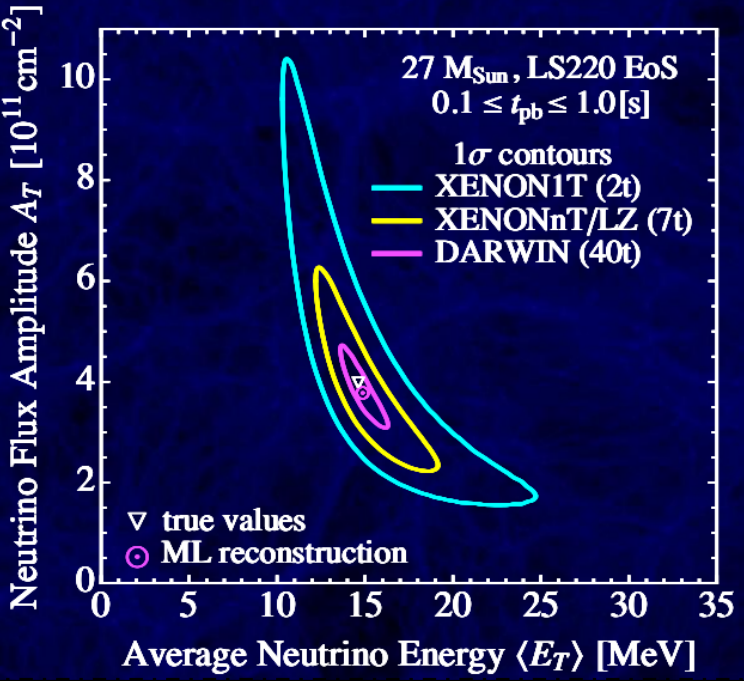
Supernova CEvNS Is A Thing Already

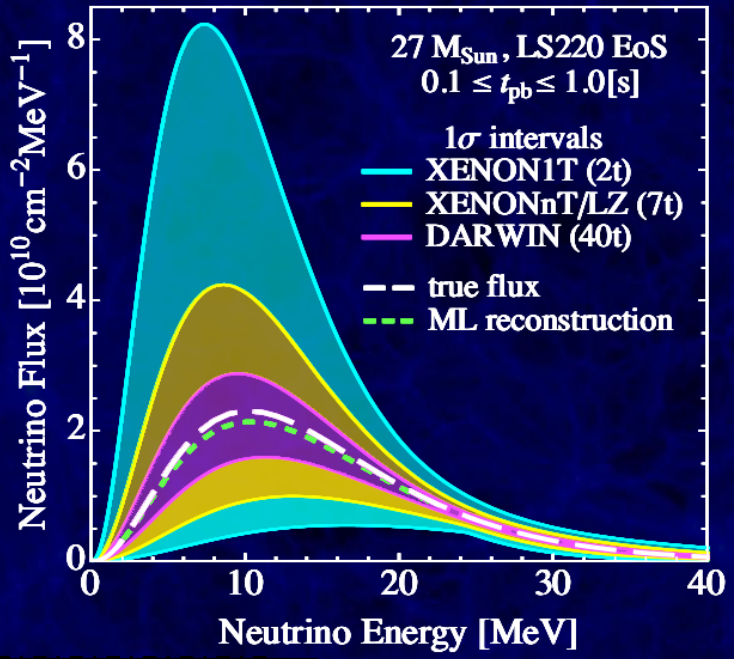
see also 1309.4492

Complementary Information

Sensitive to all flavors (including sterile neutrinos)

"Calorimetric" measurement of energy in neutrinos





Rafael+ 1606.09243

Is there Strength in Numbers?

- Many additional detectors
- Plus, all those detectors come with ~kt active muon vetos, which are sensitive to CC interactions…

see Soud's & Ricardo's posters

- But each with relatively low statistics

Does that help with triangulation at all?

We usually think about a 10kpc supernova. Could be much closer…

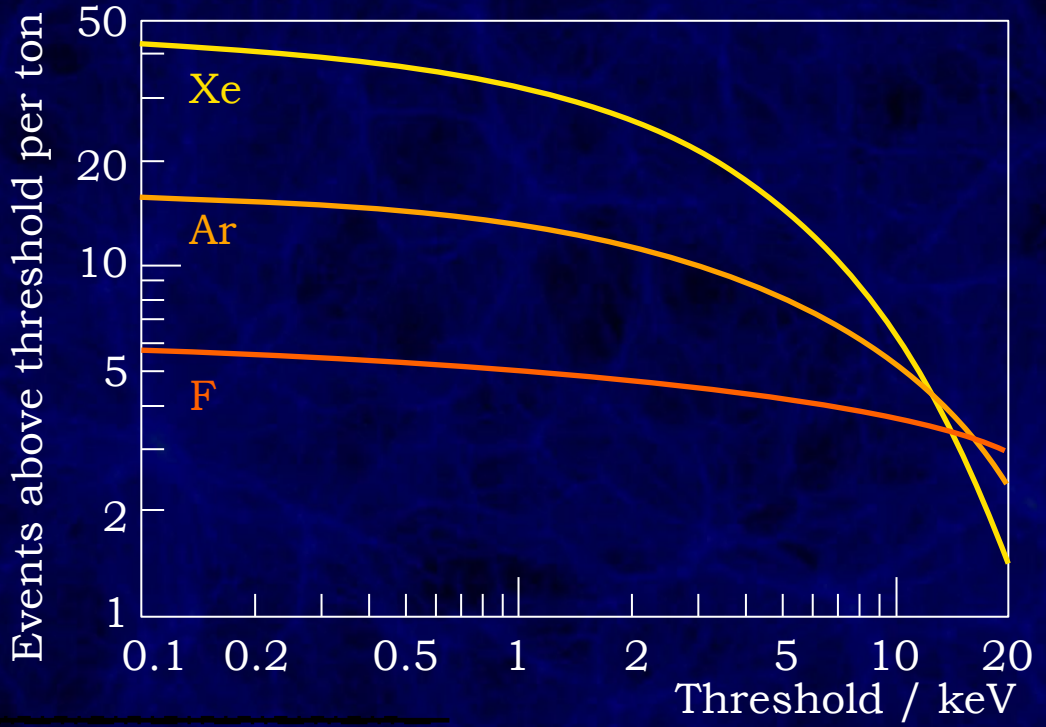
Challenge: Low recoil energies

- For MeV neutrinos, get keV recoils:

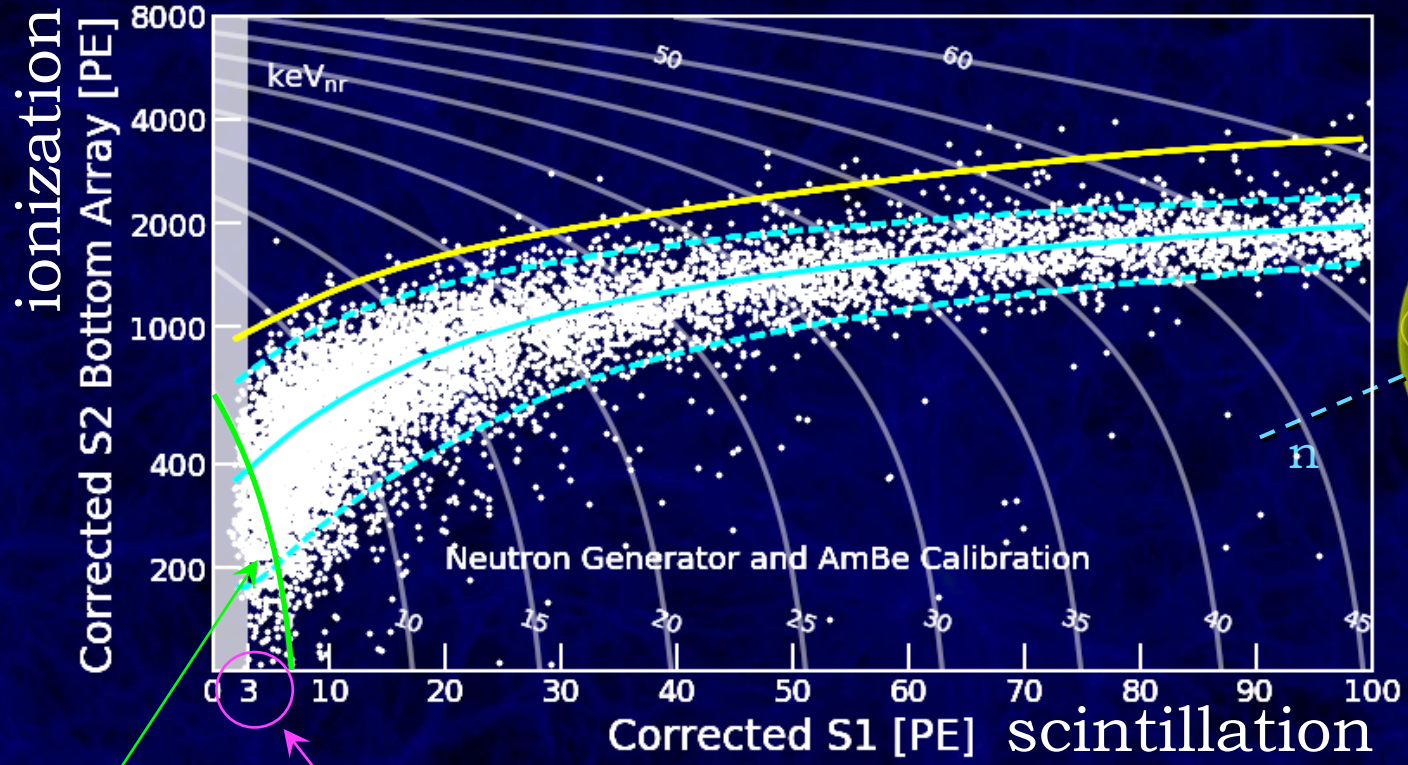
- For Ar & Xe, achieve lower threshold by giving up scintillation: encounter additional backgrounds

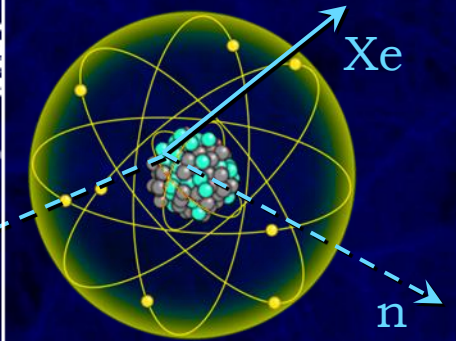
- Even more important for pre-supernova

see Volodymyr's talk



Lowering Energy in Two-Phase TPCs



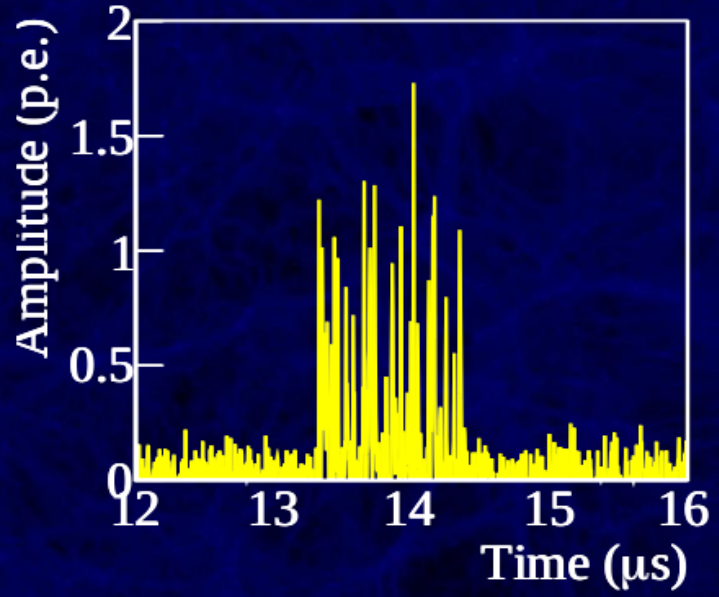


5keV

Limited by PMT Dark Counts

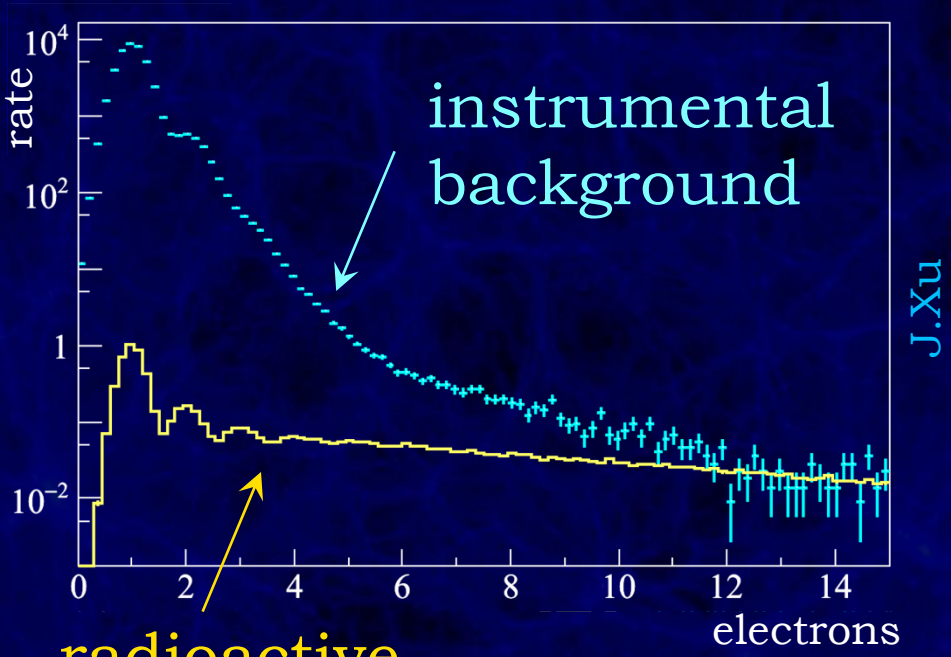
Push LXe to Single e^-

- Scalable to 10s of tons
- Whopping signal:



Xu+ 1904.02885

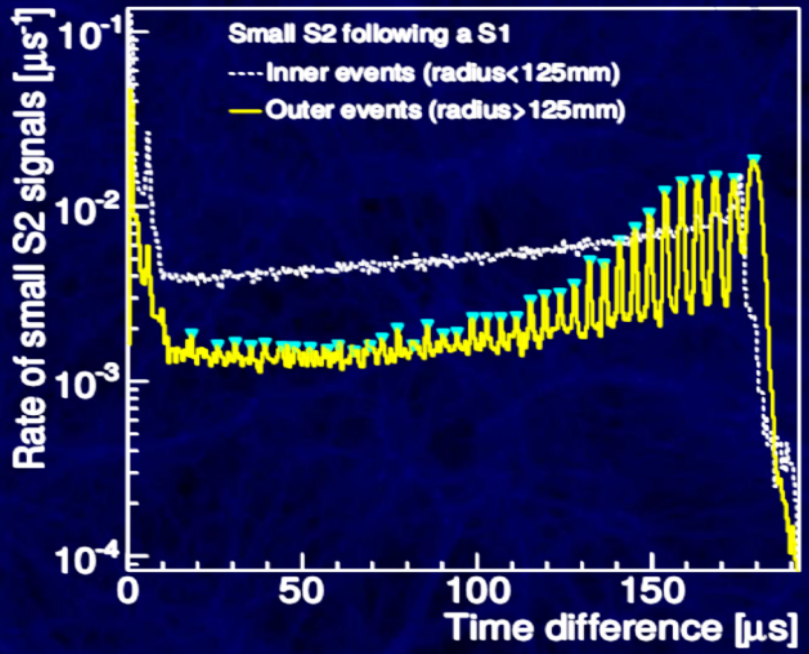
- But: Backgrounds

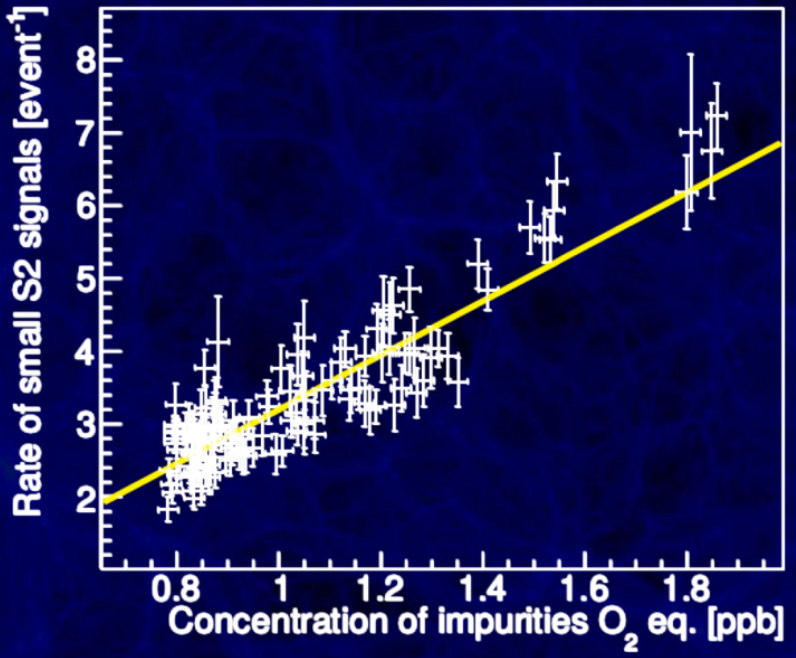


J.Xu

Background: Photoionization

Xenon light 175nm=7eV photoionizes metals & impurities

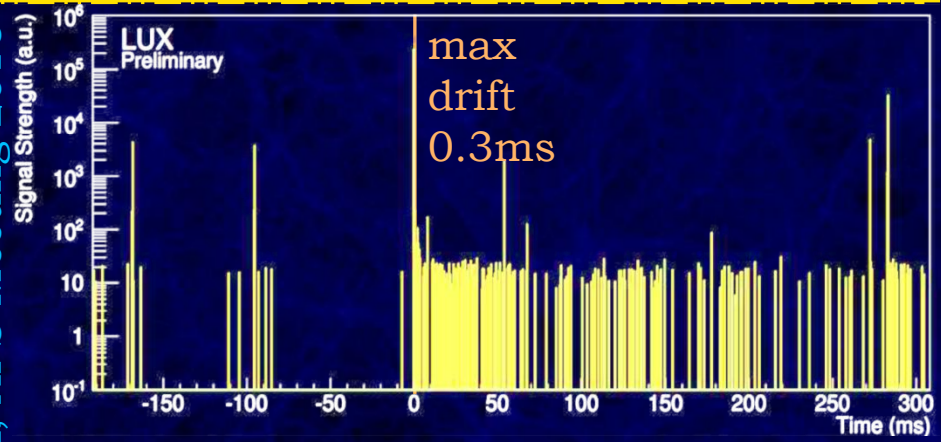




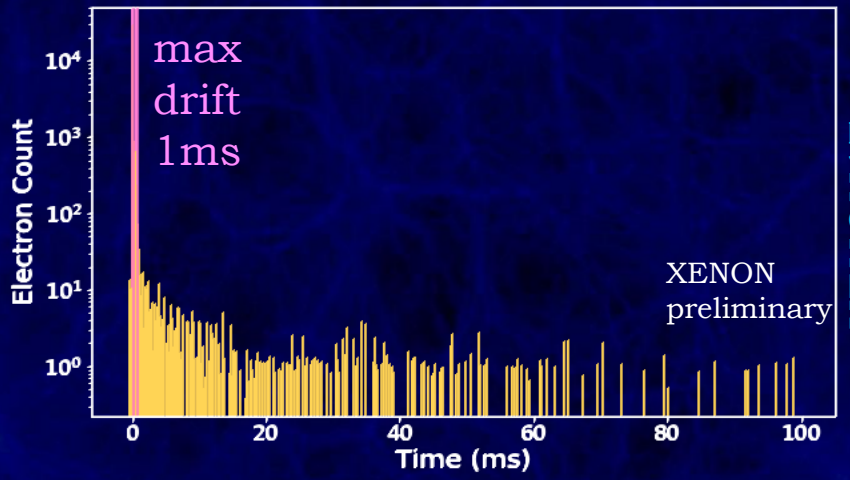
XENON100 1311.1088

Not a huge worry: simply veto away

Long Timescales



J.Xu/LUX, APS Meeting 2016



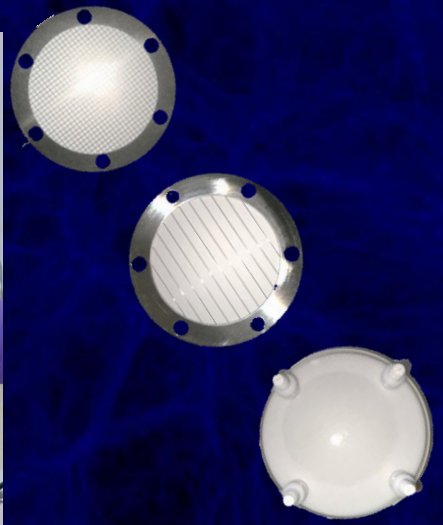
- Long-lived impurity states?
  Sorensen&Kamdin 1711.07025
- Delayed extraction?
  Sorensen 1702.04805
- Self-Organized Criticality?
  Pereverzev in prep.

The LBECA Project

1) Characterize backgrounds
2) Mitigate backgrounds
3) Build dedicated LXe detector

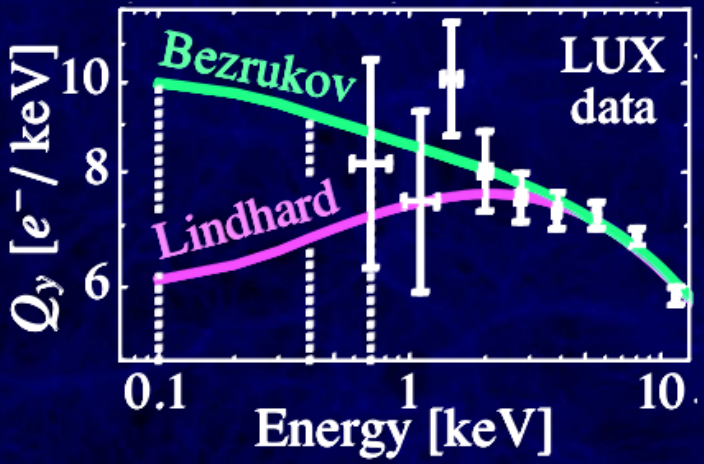
U.S. DEPARTMENT OF ENERGY
Office of Science

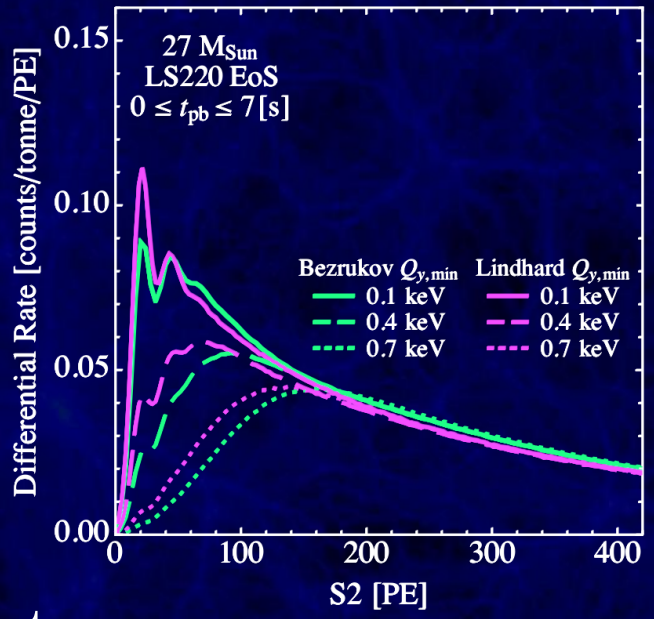
LLNL: J.Xu, A.Bernstein, S.Pereverzev;
LBNL: P.Sorensen; UCSD: K.Ni; Stony Brook: R.Essig, M.Fernandez-Serra;
Purdue: Rafael



Improve Calibrations

- Requires some dedicated, challenging measurements
- e.g. in Xe: expected count varies by ~10%





- some such data already on tape

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Fire Drill Please

New detectors will particularly benefit from this

- Joint effort to run our detector-specific Monte Carlos. See what CEvNS experiments really can contribute; What data is or isn't useful.
- Try triangulation given the many detectors
- Consider dedicated CEvNS-only SNEWS alert. Nothing expected from that… but of course you can only find sterile neutrinos if you search for them.