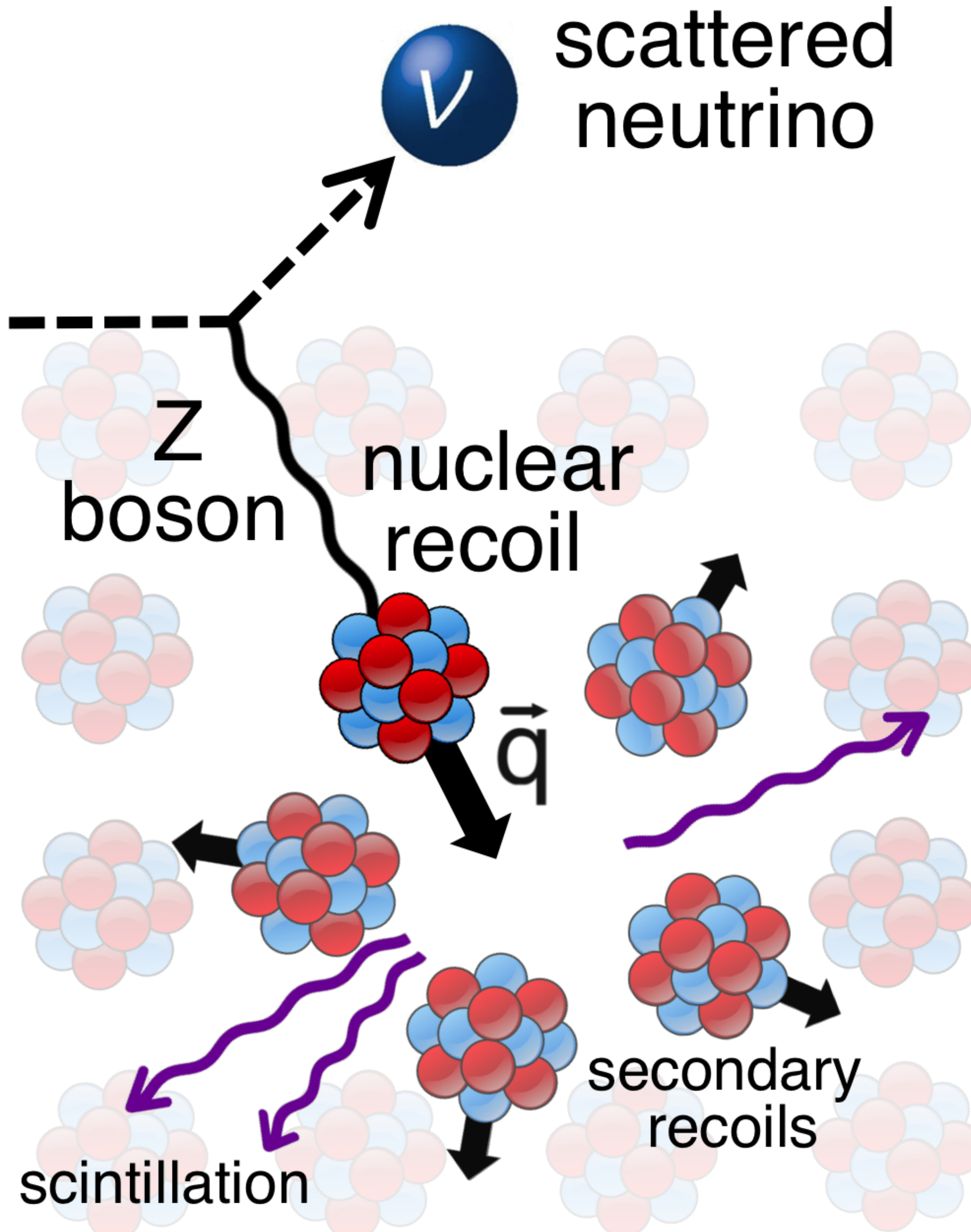
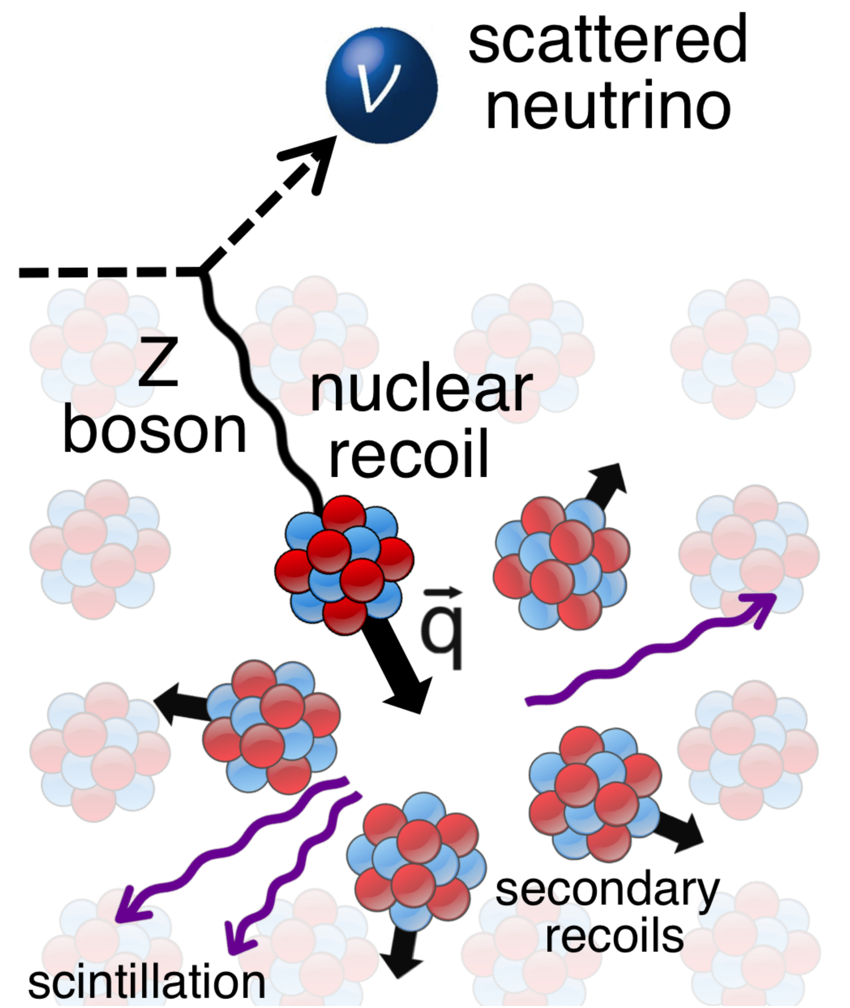


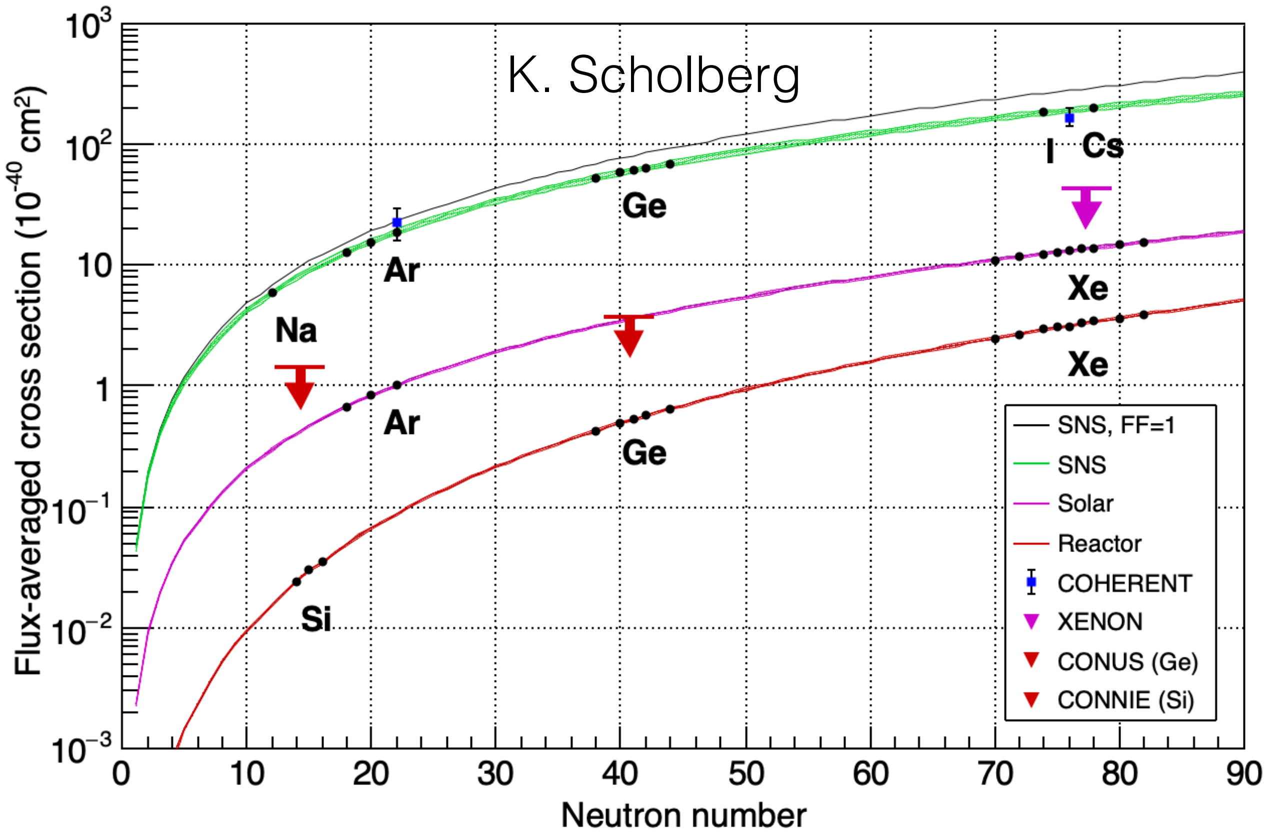
CEvNS Signal

Phil Barbeau
(he/him/his)

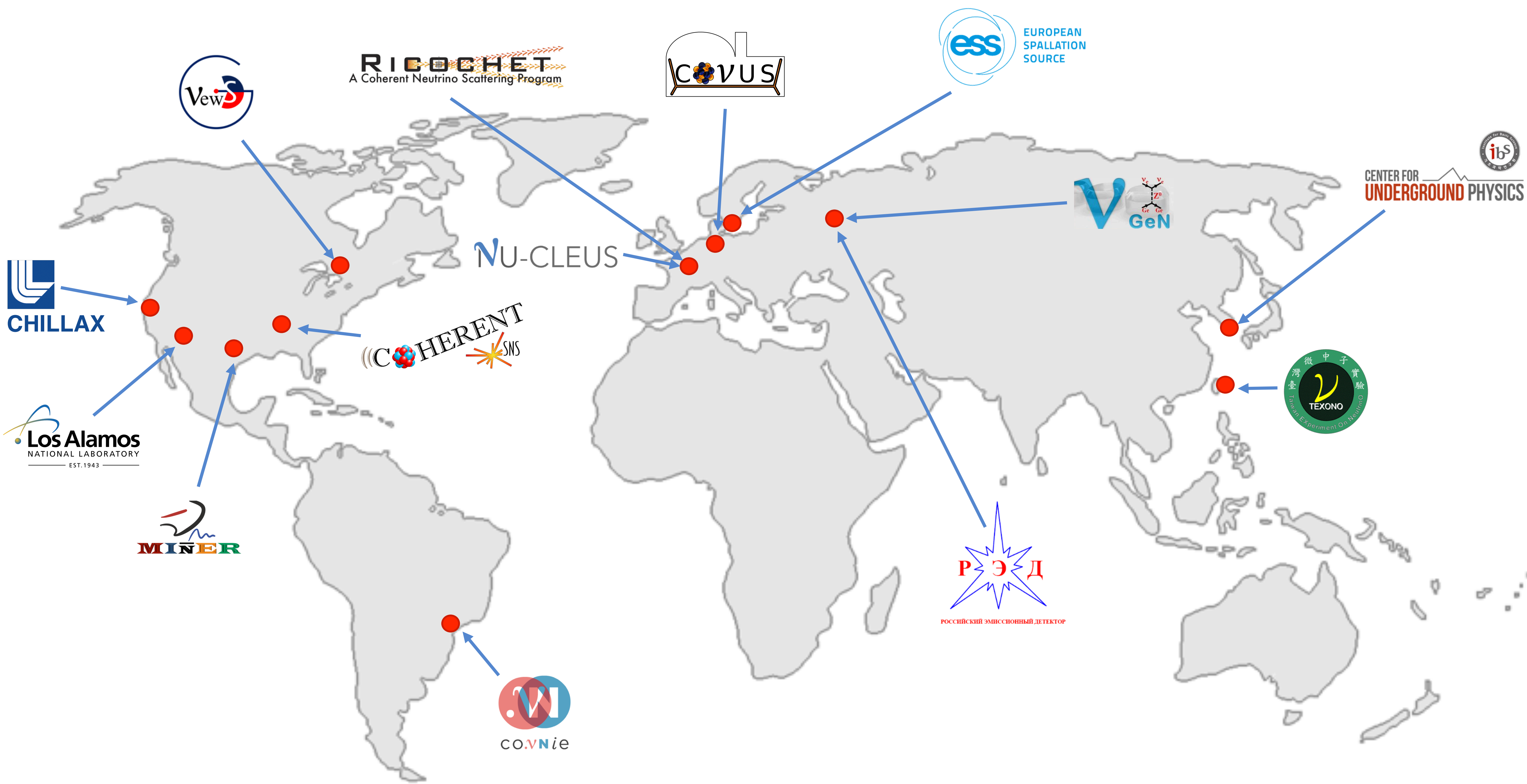
Coherent **ν**-Nucleus Scattering



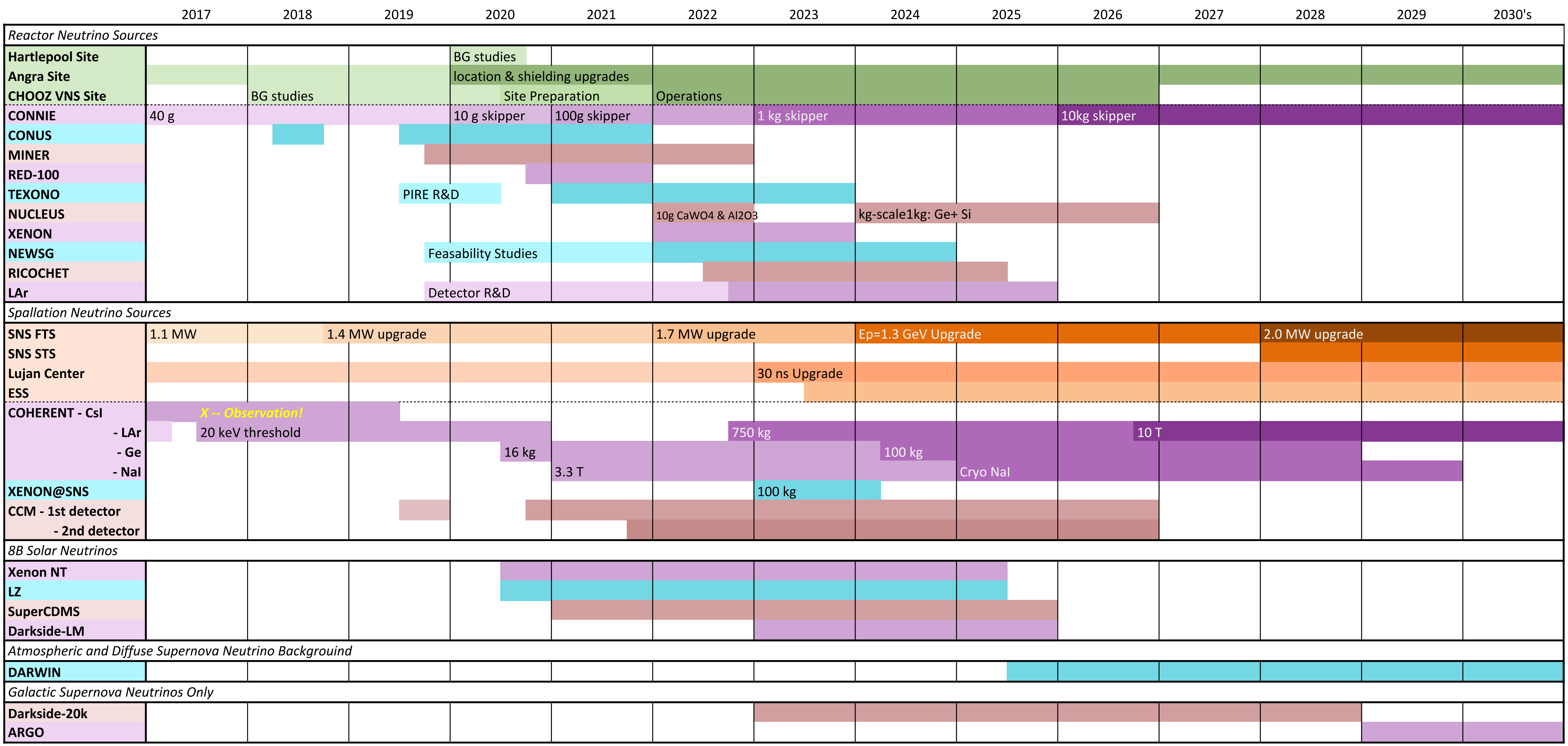
- 47 years ago, Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) was predicted with the realization of the neutral weak current.
  D. Z. Freedman, PRD 9 (5) 1974
- Neutrino scatters coherently off all Nucleons → cross section enhancement: $\sigma \propto$ **N²**
- Initial and final states must be identical: Neutral Current elastic scattering
- Nucleons must recoil in phase →low momentum transfer qR <1 → ***very low* energy nuclear recoil**



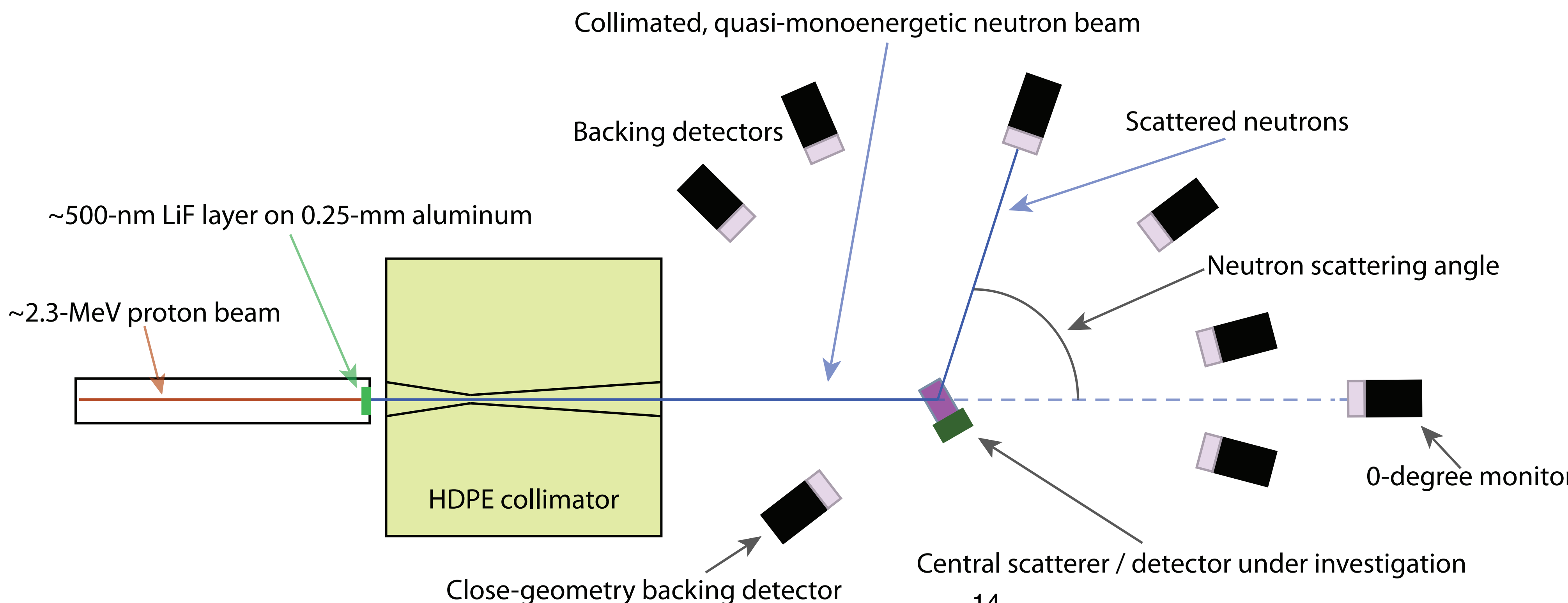
CEvNS: A collaborative community

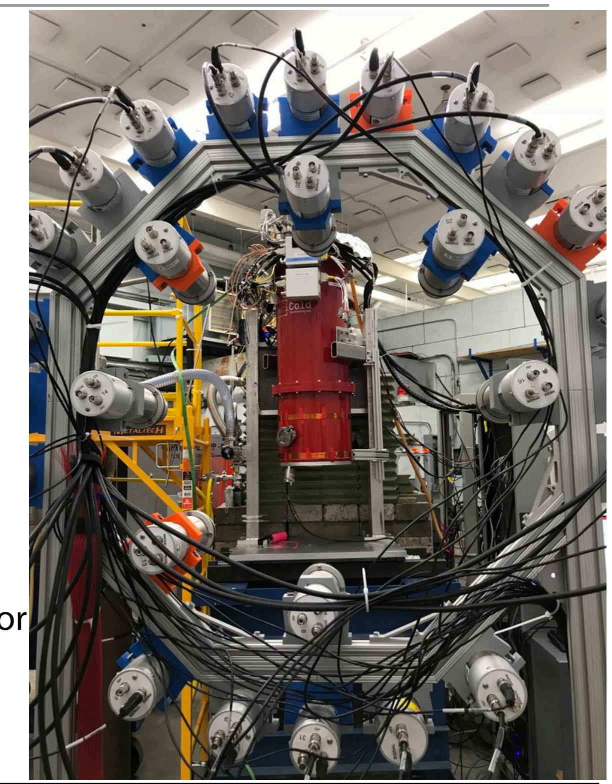


CEvNS: Exciting Decade ahead of us

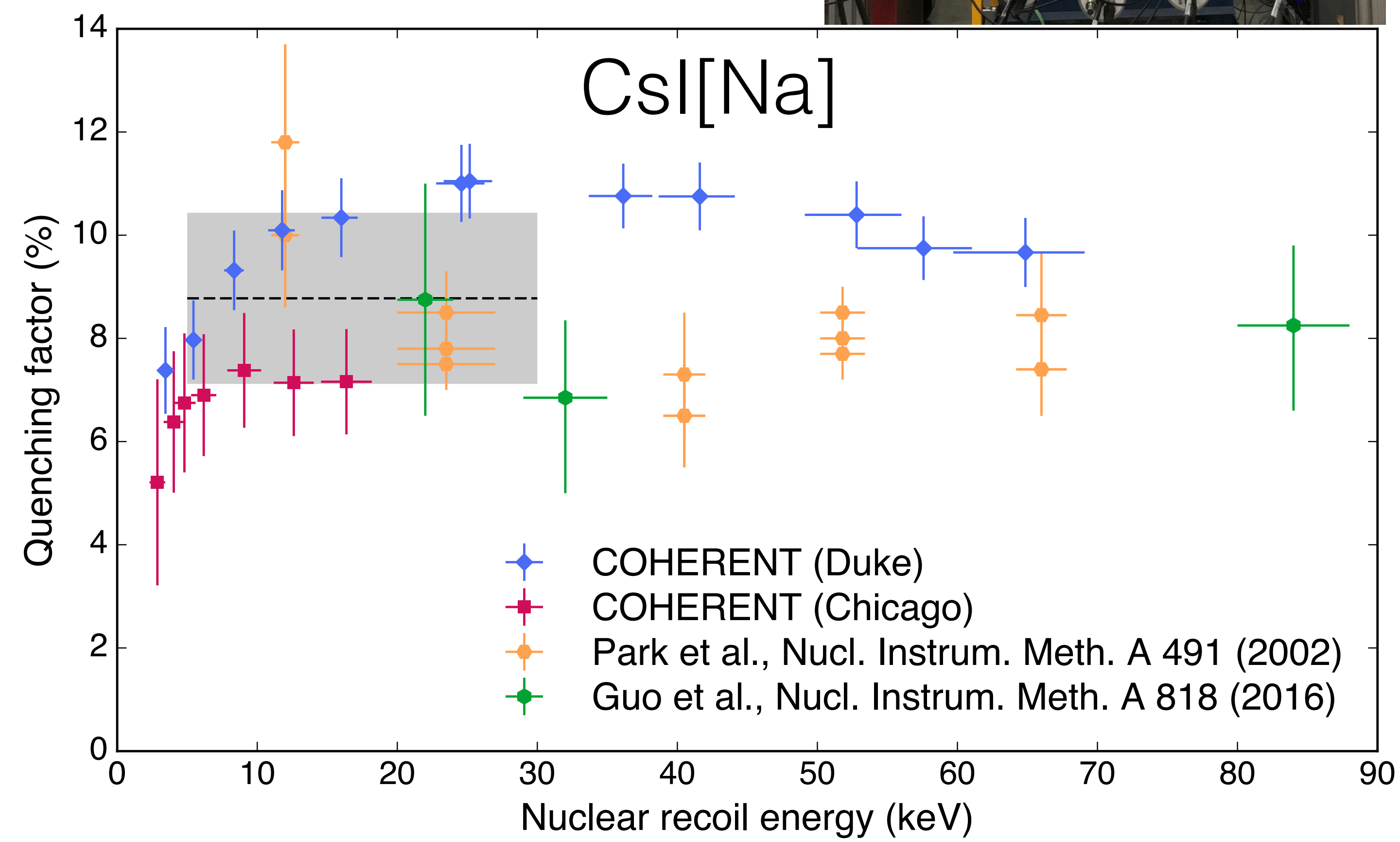


Measuring the recoil: Quenching Factor



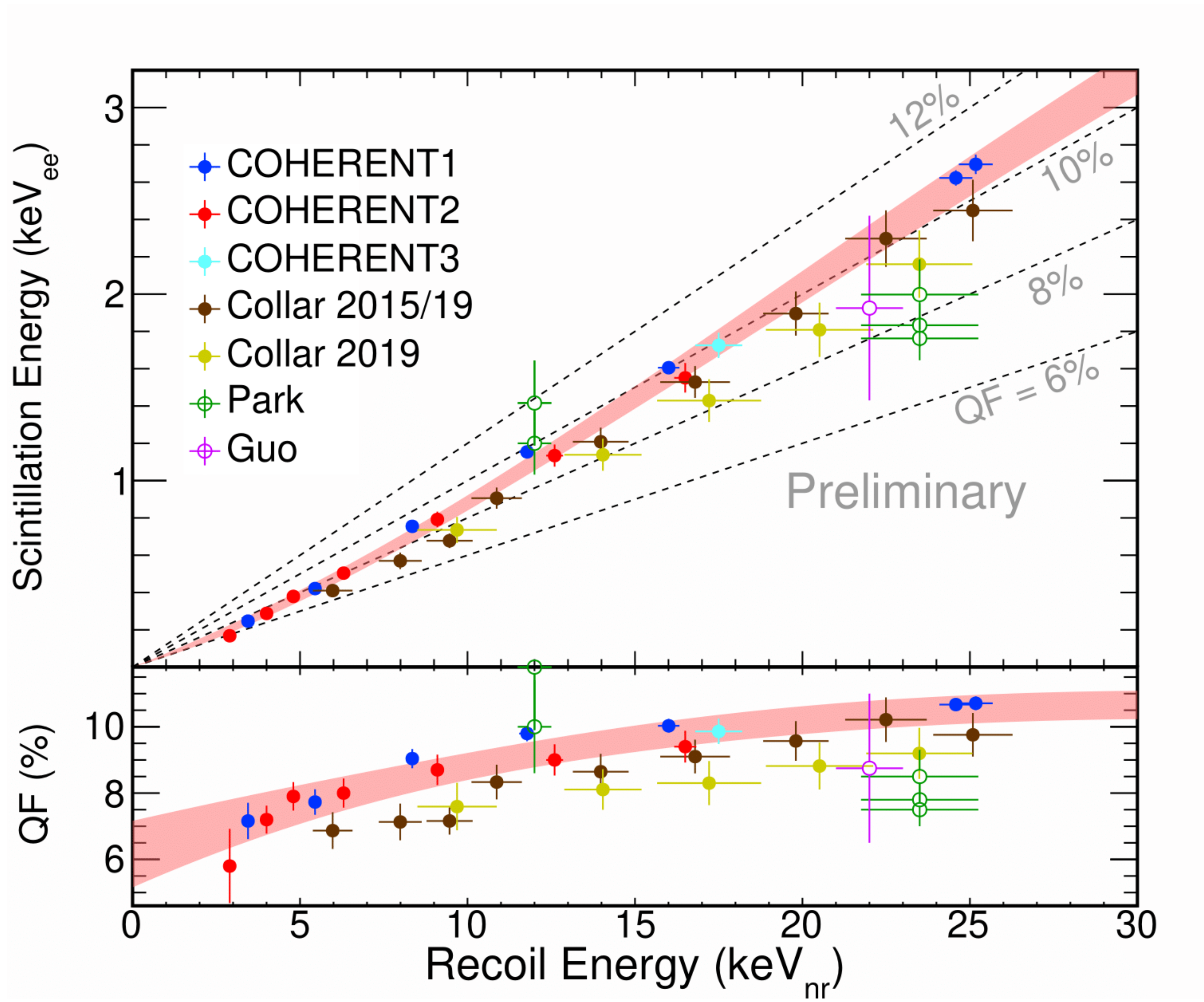


- Facility also used for:
- CsI[Na], CeBr, Ge, Si, LXe, GNe, GHe, NaI(Tl), EJ-301, Stilbene, MicroCHANDLER



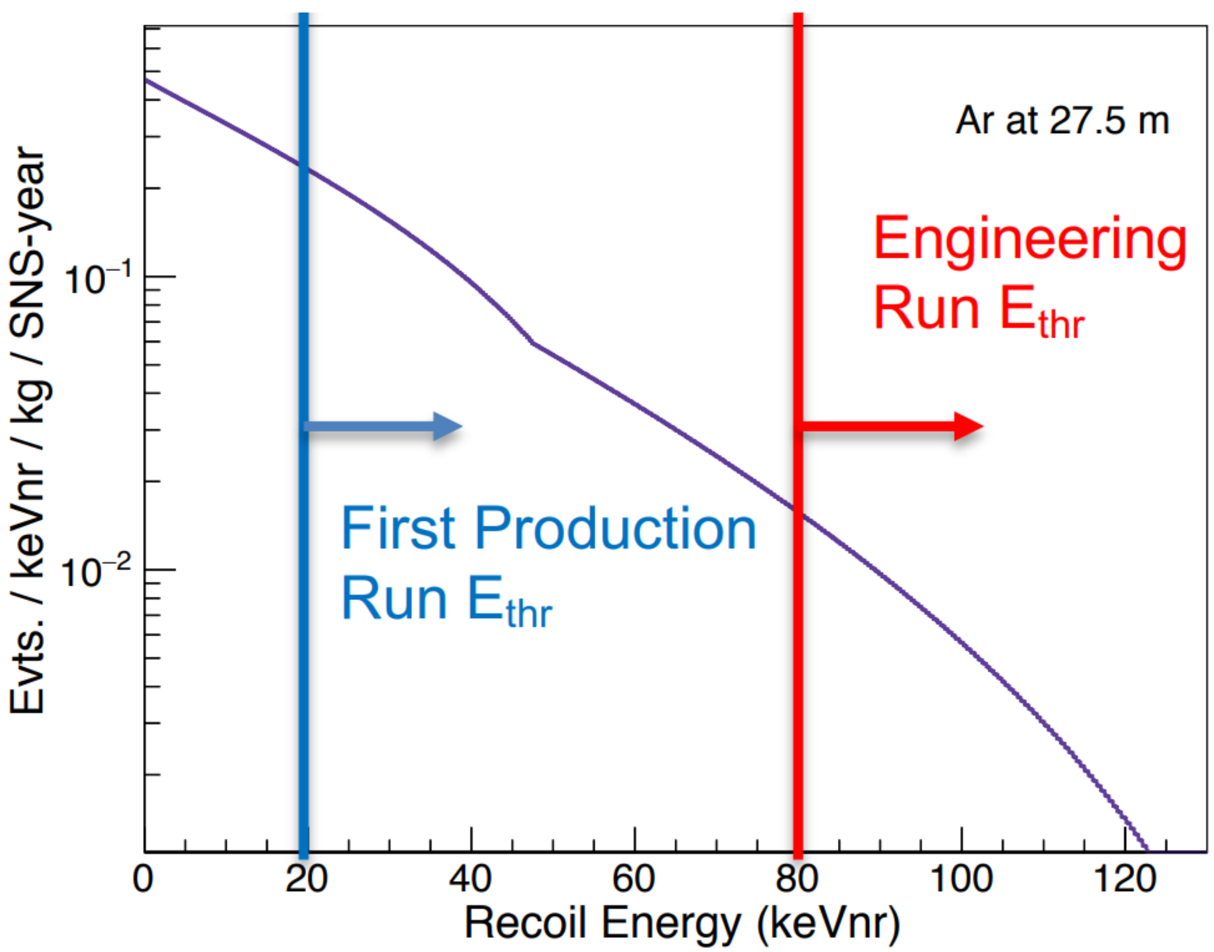
Improving the Precision for COHERENT CsI: New Quenching Factor

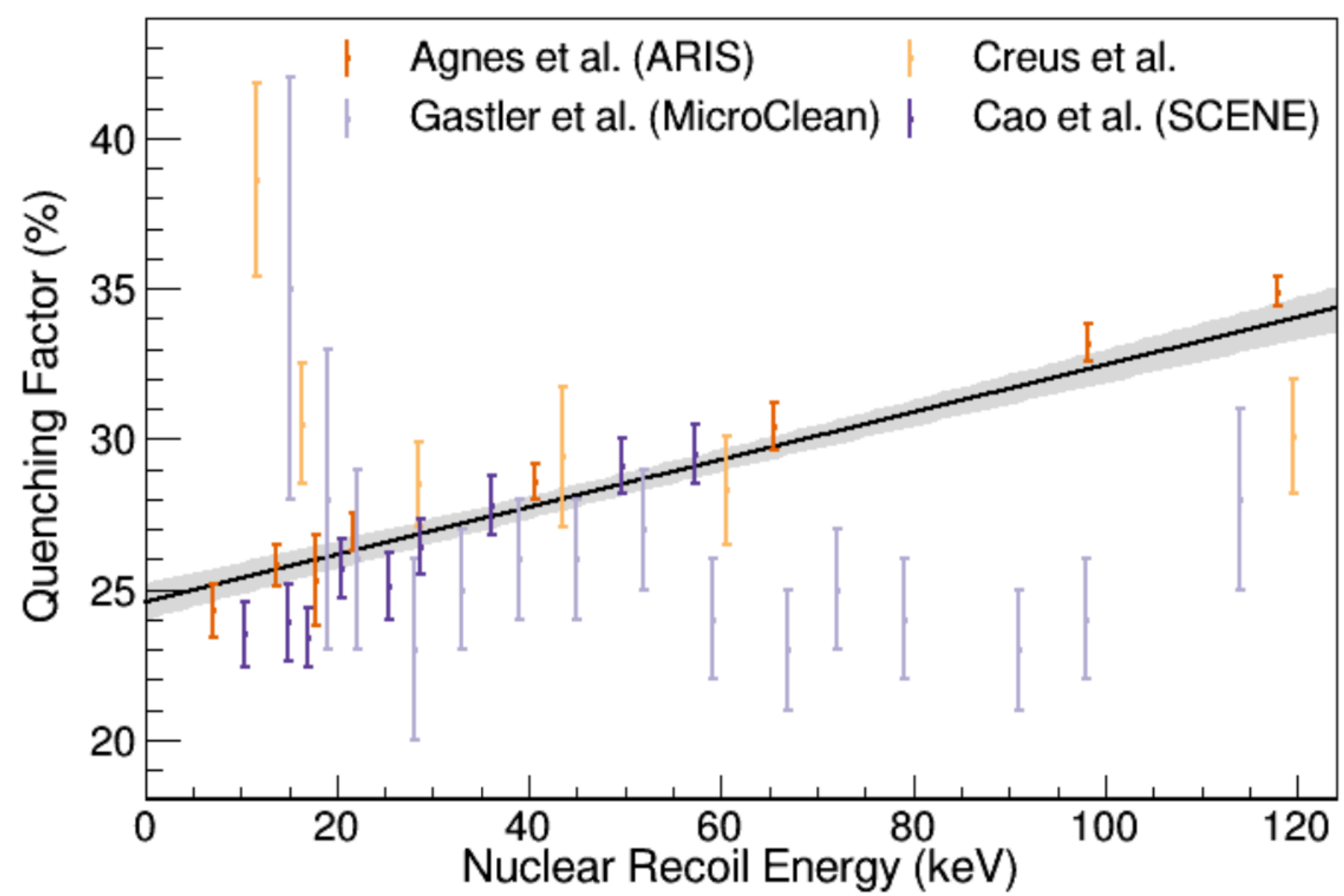
- Uncertainty on CEvNS rate improved from 25% to 4%
- Situation even more challenging for lower energy neutrinos at reactors



Another high energy example: COHERENT LAr

- Global analysis of world data
- Parametric model fit according to PDG prescription
- 2% uncertainty on CEvNS in ROI





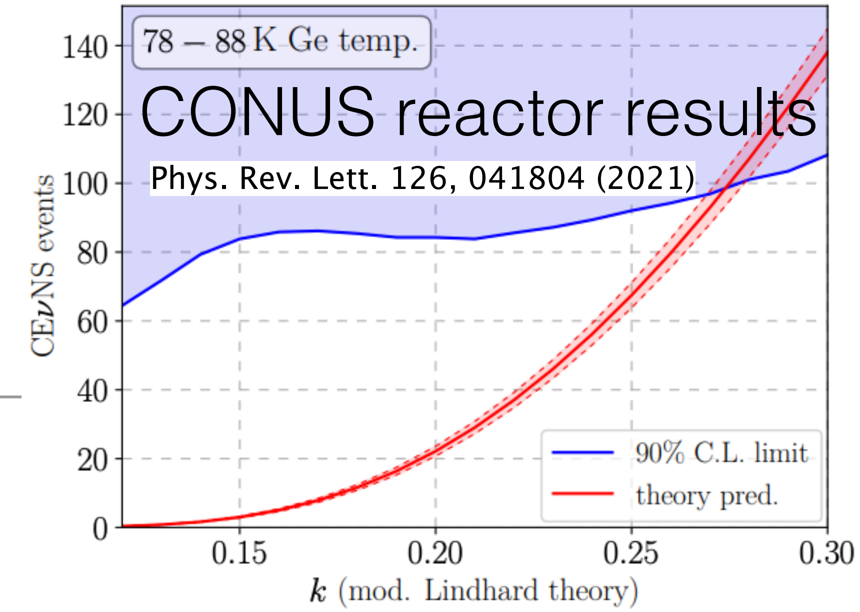
Lowering thresholds can counteract QF uncertainty

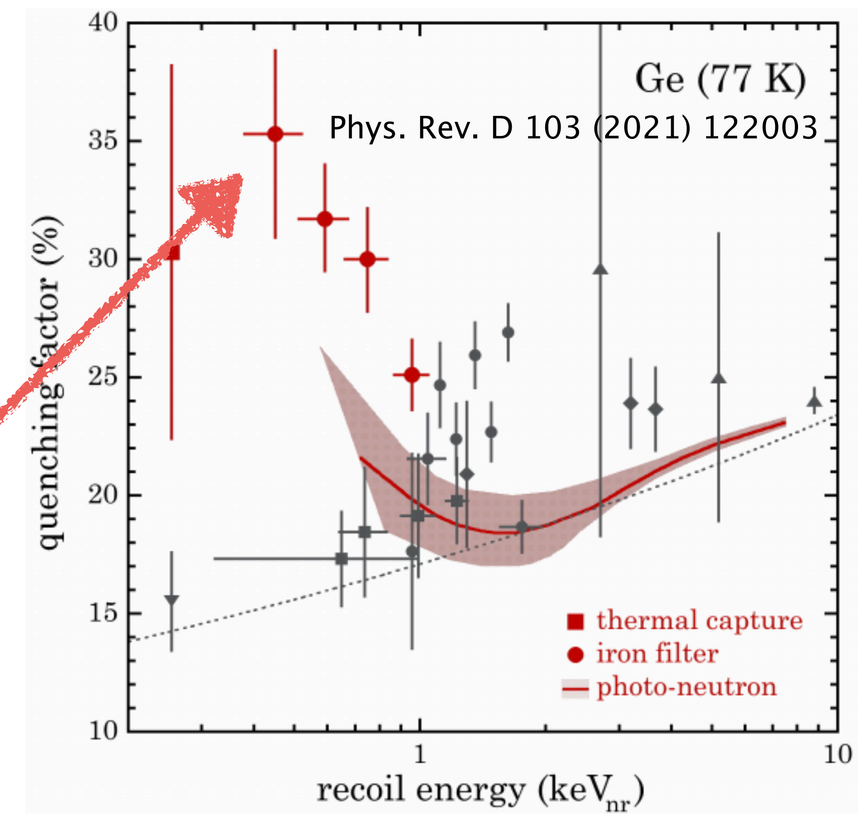
Example: Germanium

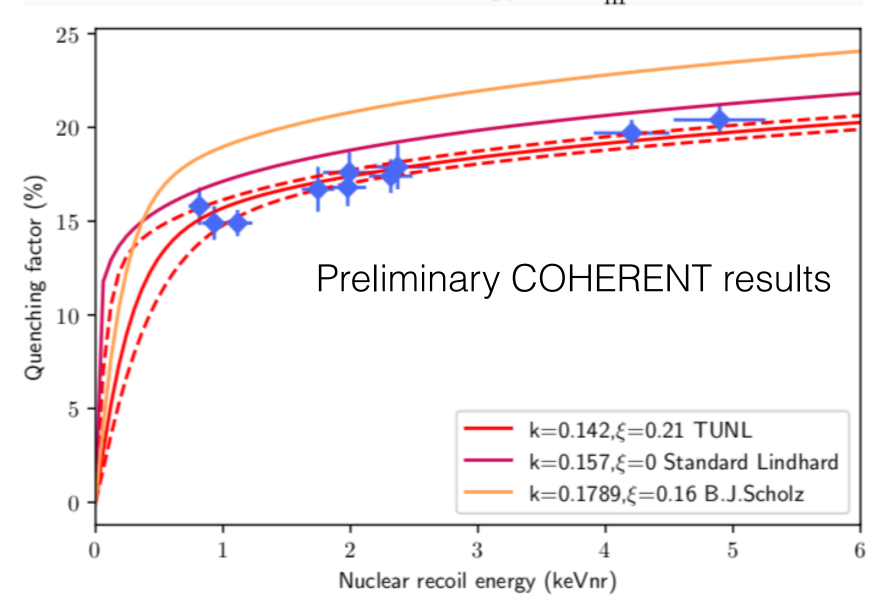
- CONUS Rx Ge experiment producing data
- Growing confusion as to low-energy QF, with a major impact on expected rate above threshold

Is this the Migdal effect?

TUNL Campaign

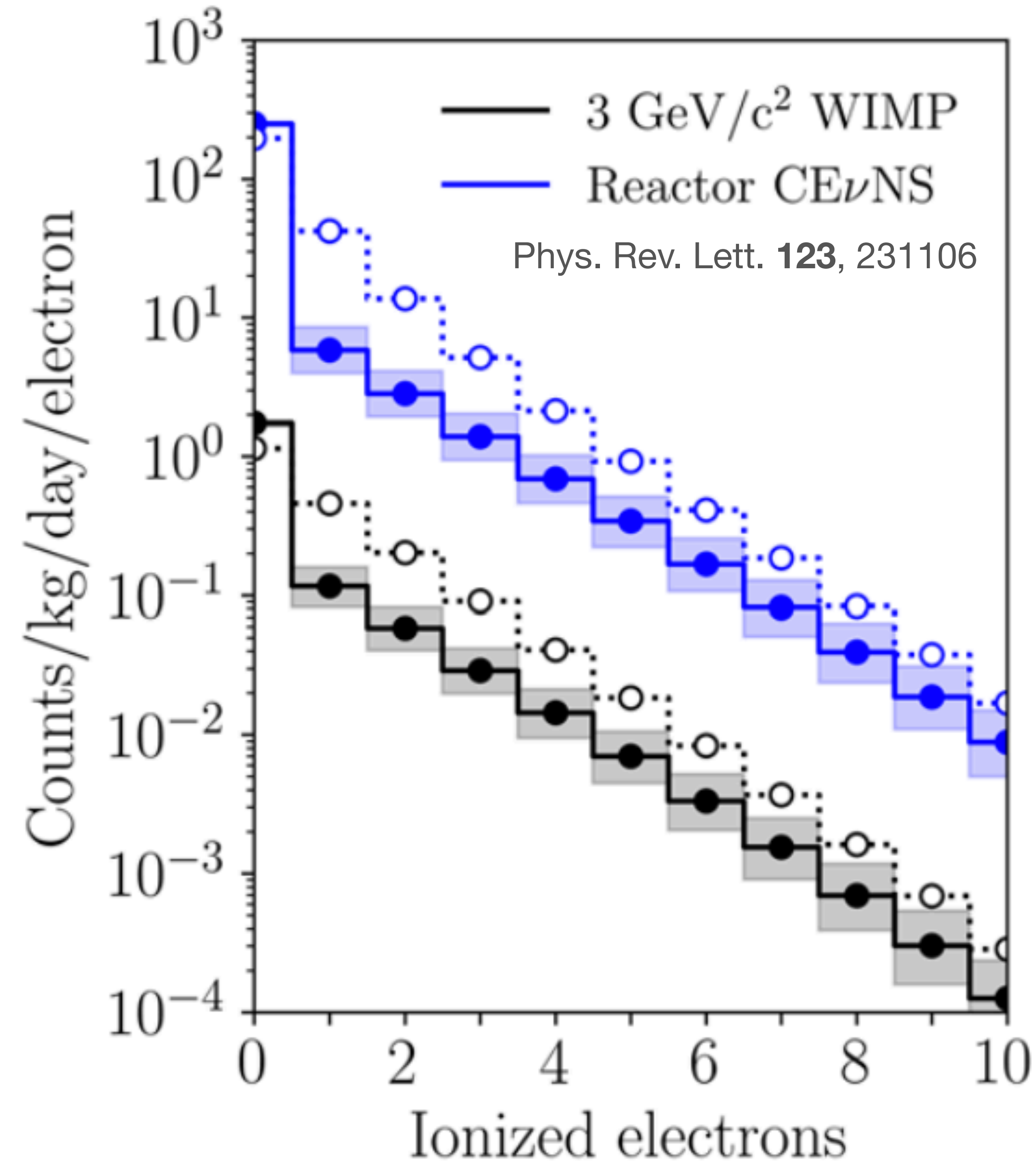


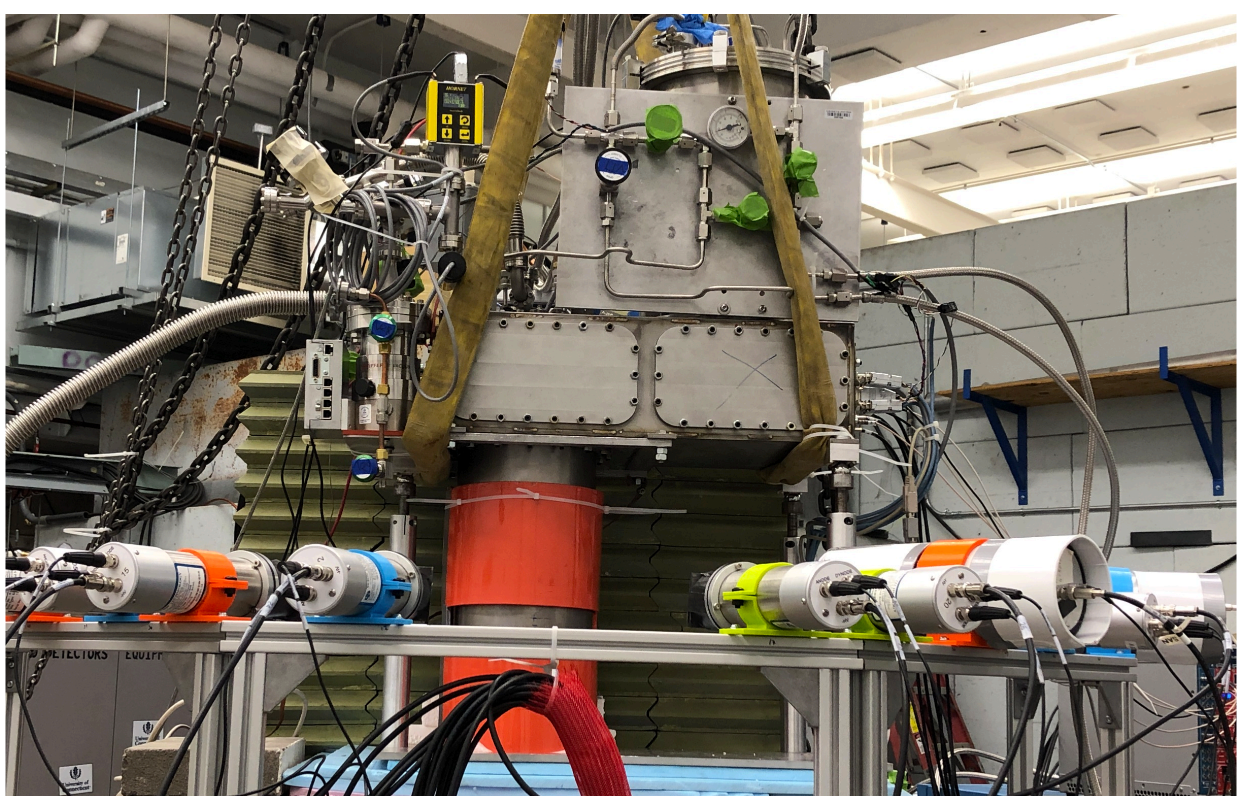


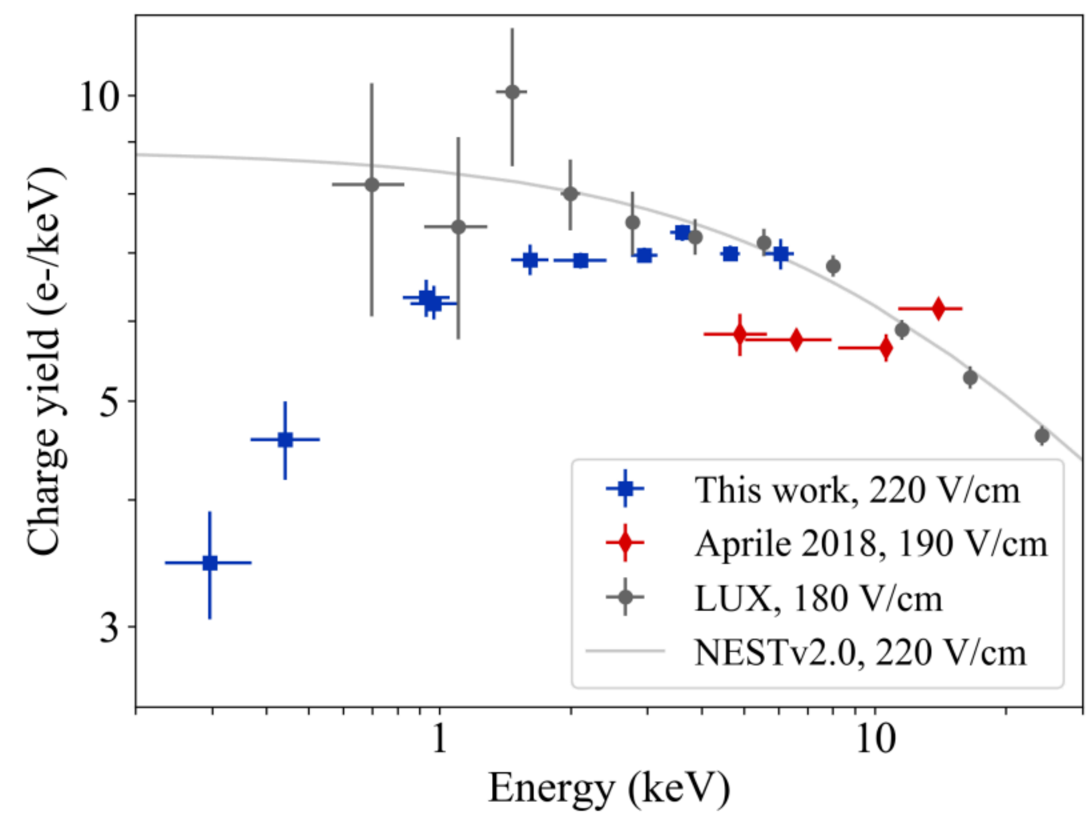


Example: Liquid Xenon

- LUX/LZ measurements at TUNL had dramatic impact on predicted Rx CEvNS signal
- Measurements continuing in LXe and LAr with CHILLAX



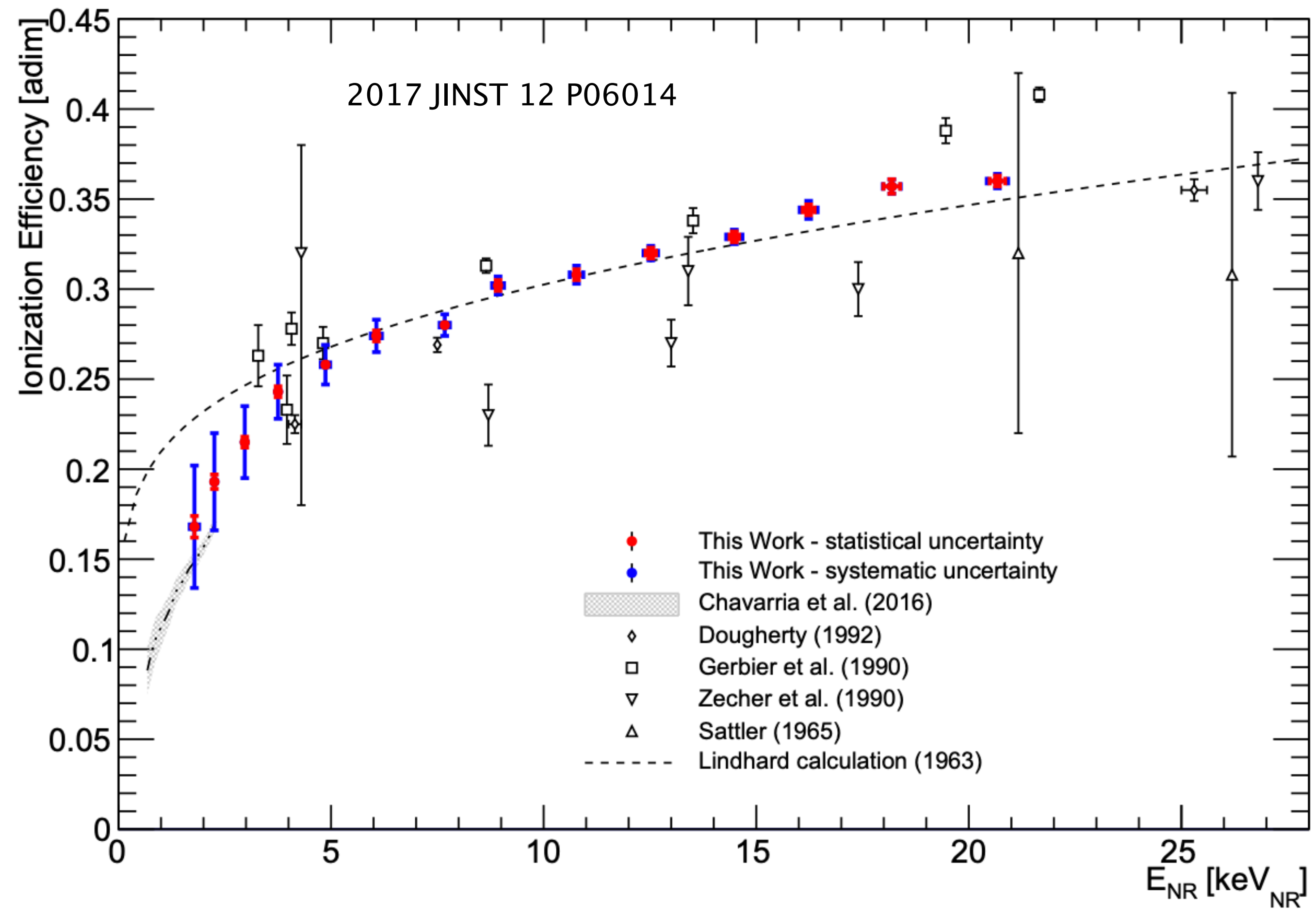


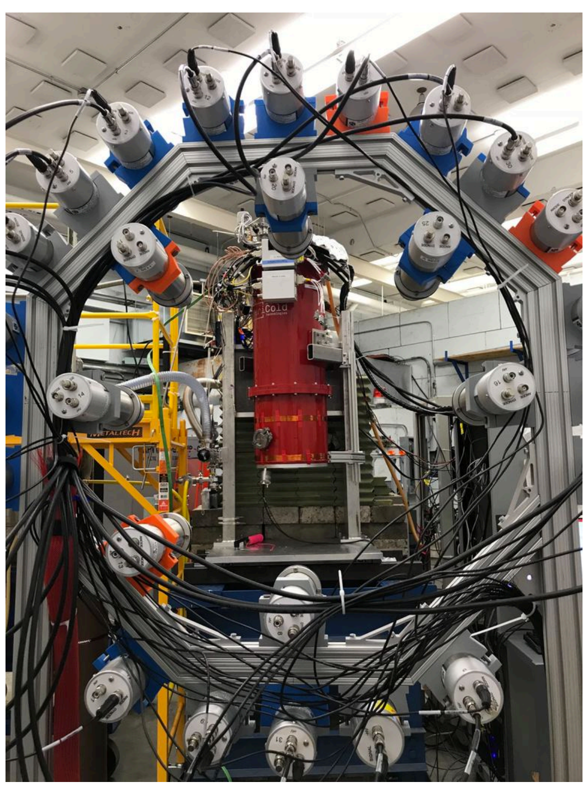


Example Silicon

- Dramatic drop below model prediction observed in silicon semiconductors. Implies significant impact

- Challenging measurement campaign to confirm with SuperCDMS Si detectors at TUNL with 55 keV ± 1 keV neutron beam





Energy range (keV)	CEνNS-rate Lindhard	CEνNS-rate Chavarria	95% C. L. from data
0.075–0.275	11.4	4.8	197
0.275–0.475	3.6	1.3	109
0.475–0.675	0.8	0.3	47

TABLE I. Expected rate from CEνNS, in events/day/kg/keV, assuming quenching factors from Lindhard [57] and Chavarria [52] together with the 95% CL limit from the data presented in this paper.

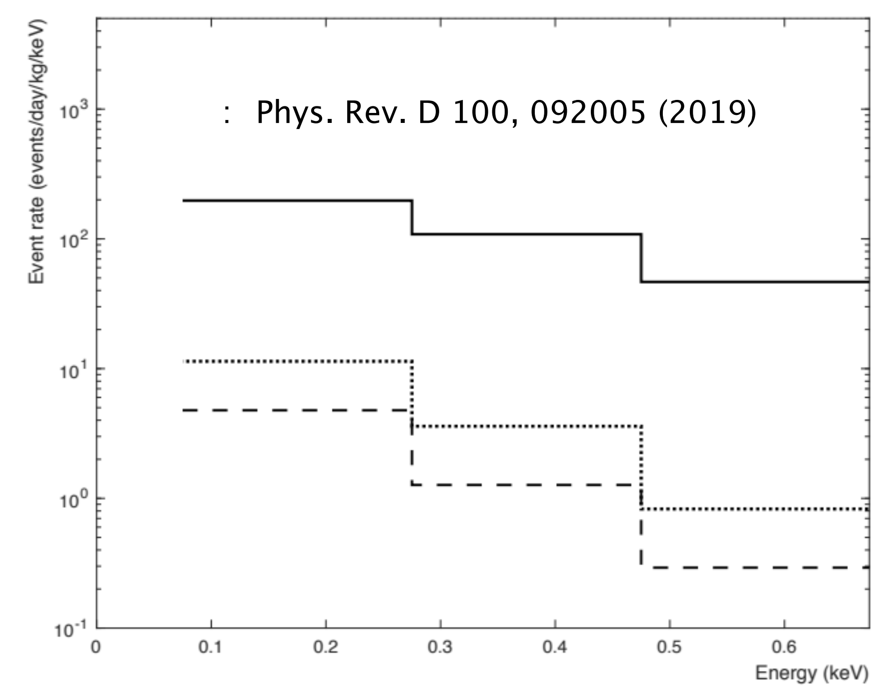
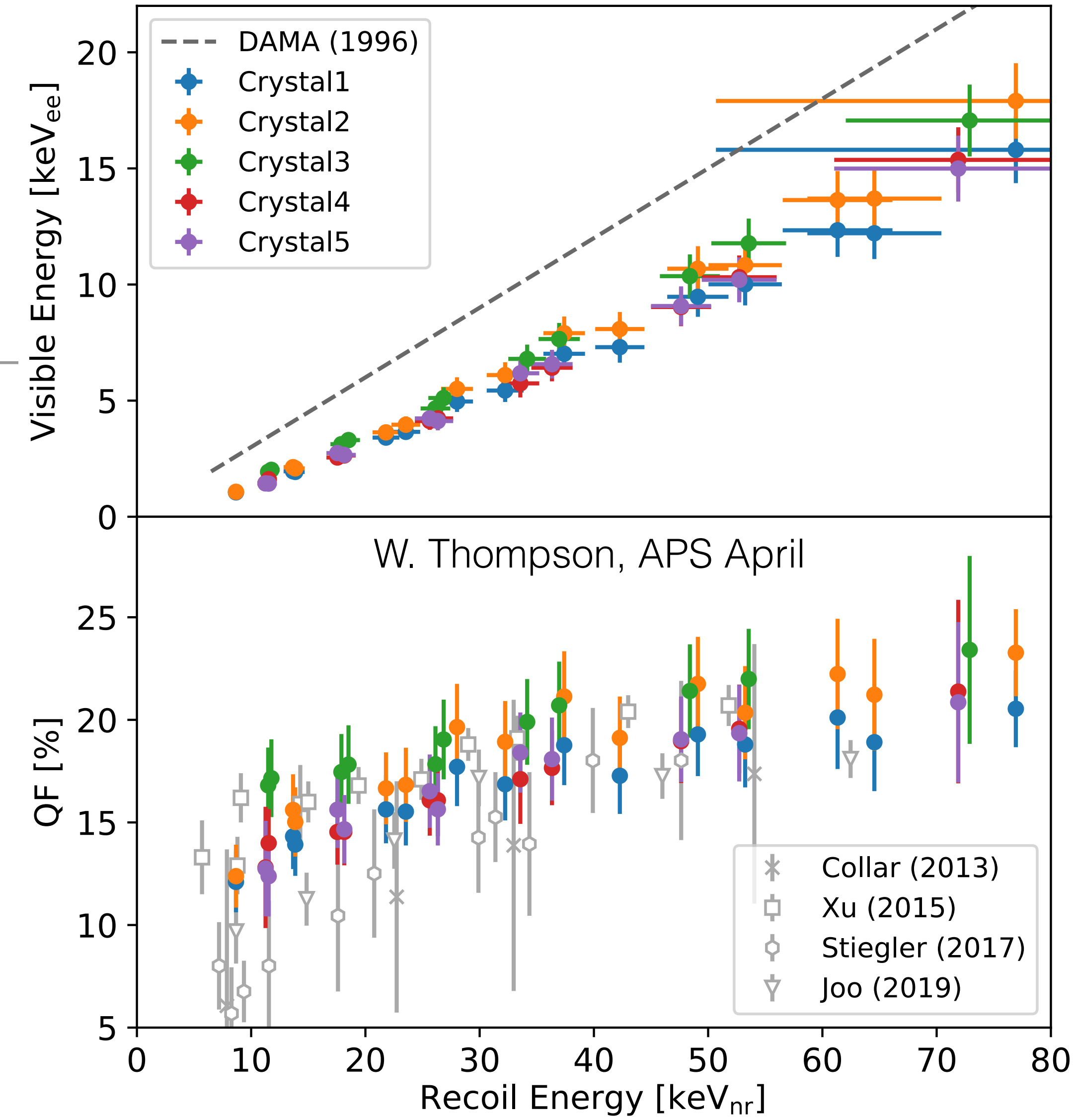
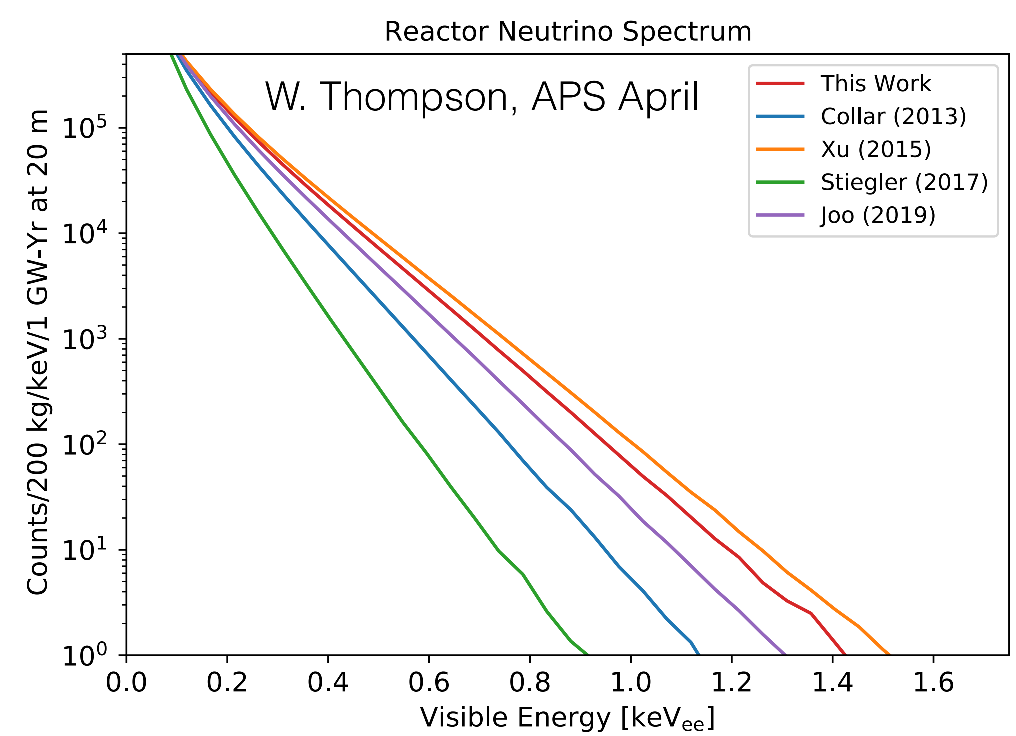


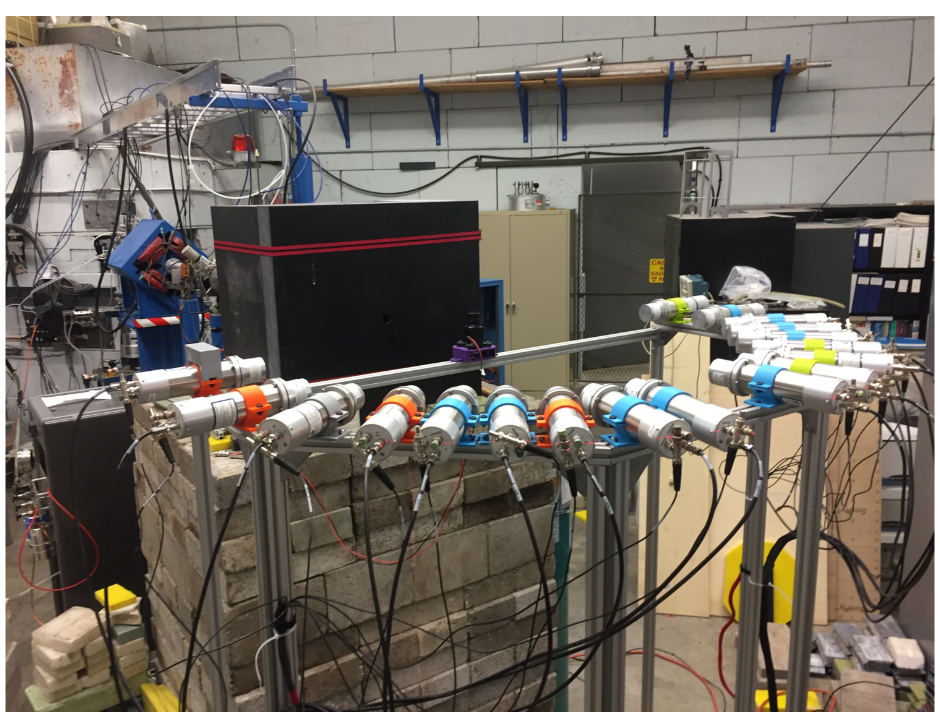
FIG. 20. CEνNS event rate: 95% confidence level limit from the reactor on - off measurement (solid line) and neutrino signal expected from the Lindhard [57] (dotted line) and Chavarria [52] (dashed line) quenching factors.

Example: NaI[Tl]

- Long history of NaI[Tl] QF measurements
- Still a lot of variance
- Now testing variance across crystal manufacture technique (ANAIS and COSINE)
- Next up: varying dopant concentration & temperature



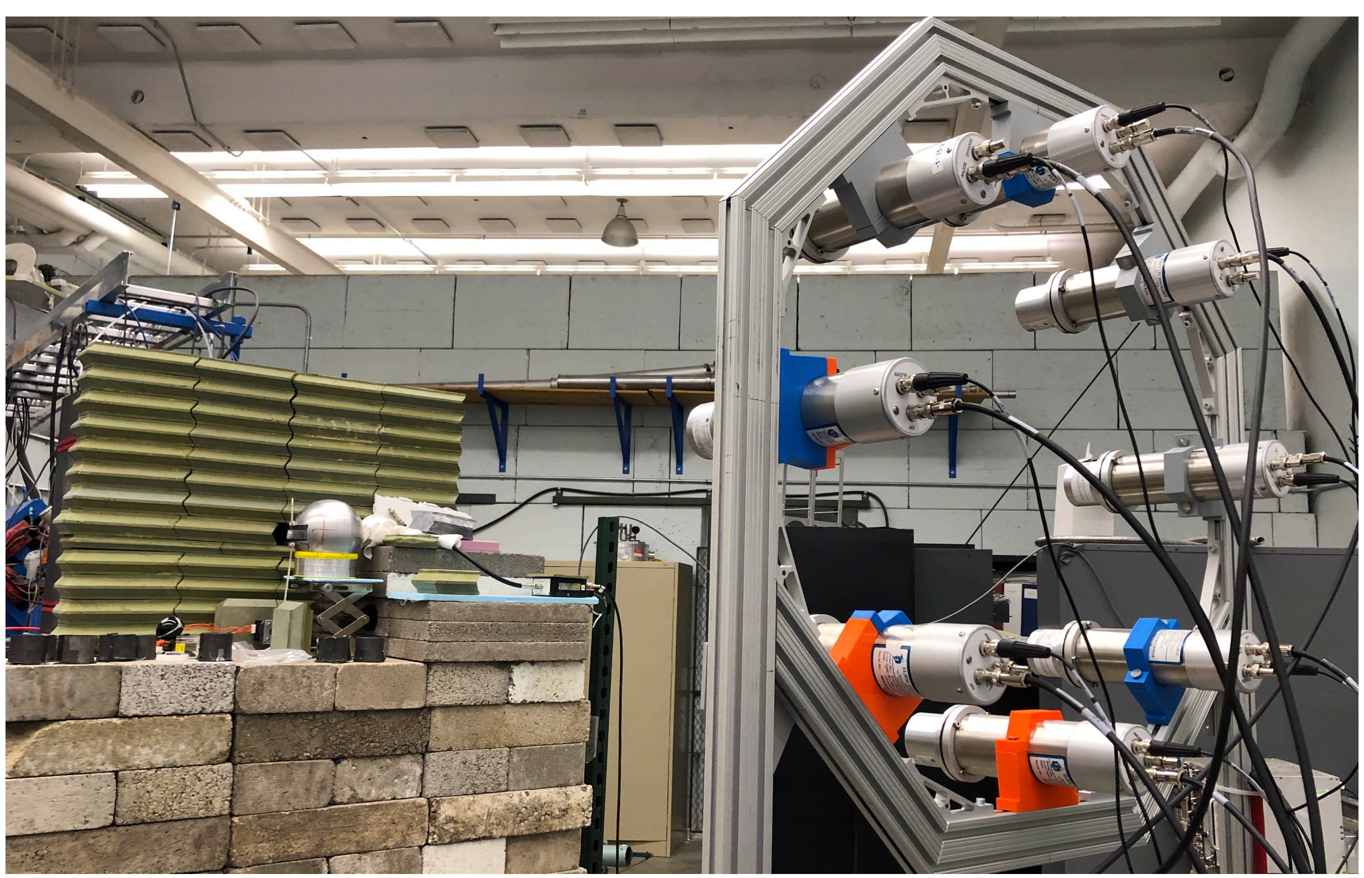


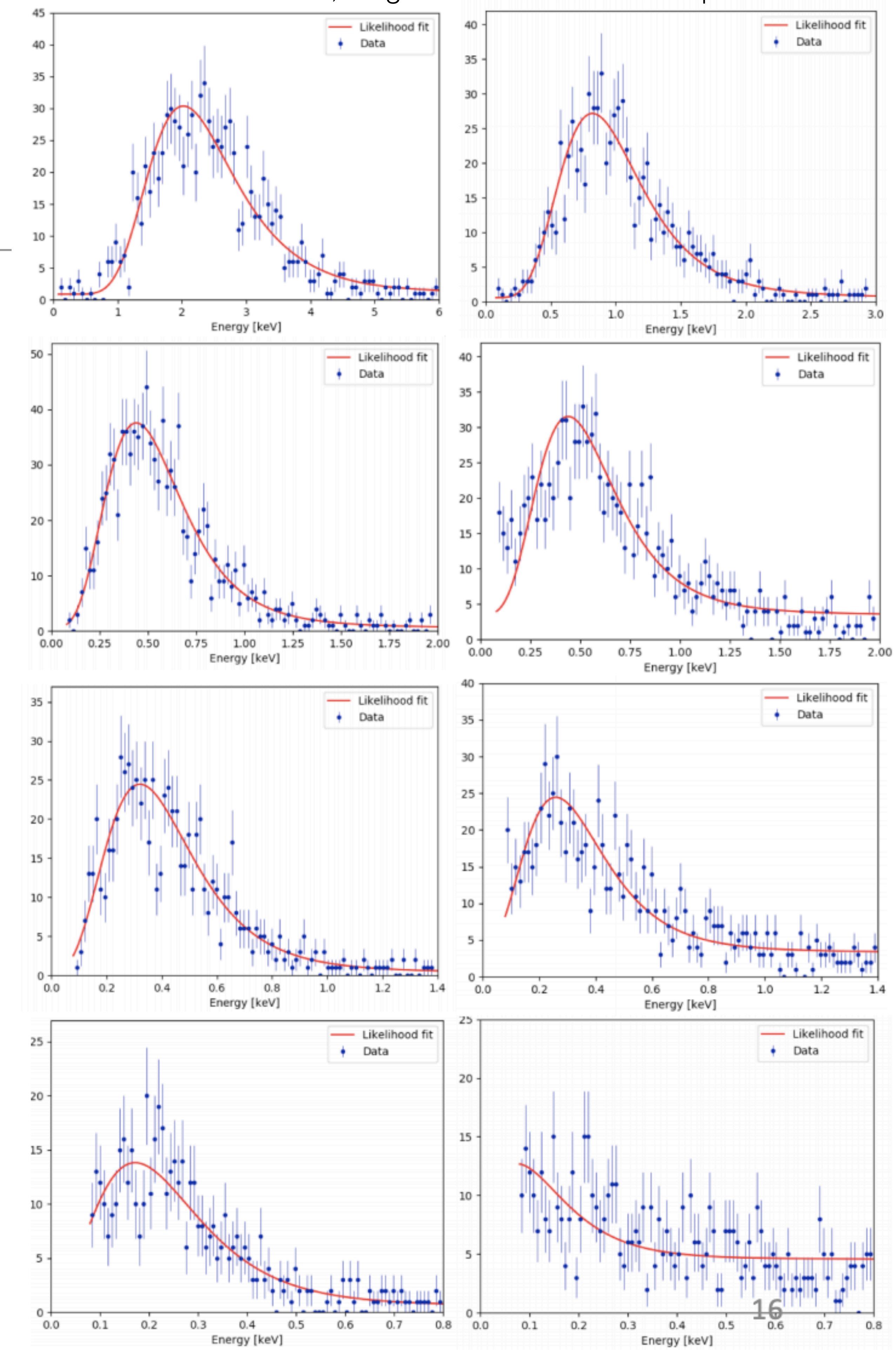


M. Vidal, Magnificent CEvnS Workshop 2020

Example: Gaseous Ne

- Never before measured, so CEvNS signal unknown
- NEWS-G measurement at TUNL
- Challenge: scattering neutrons on gas



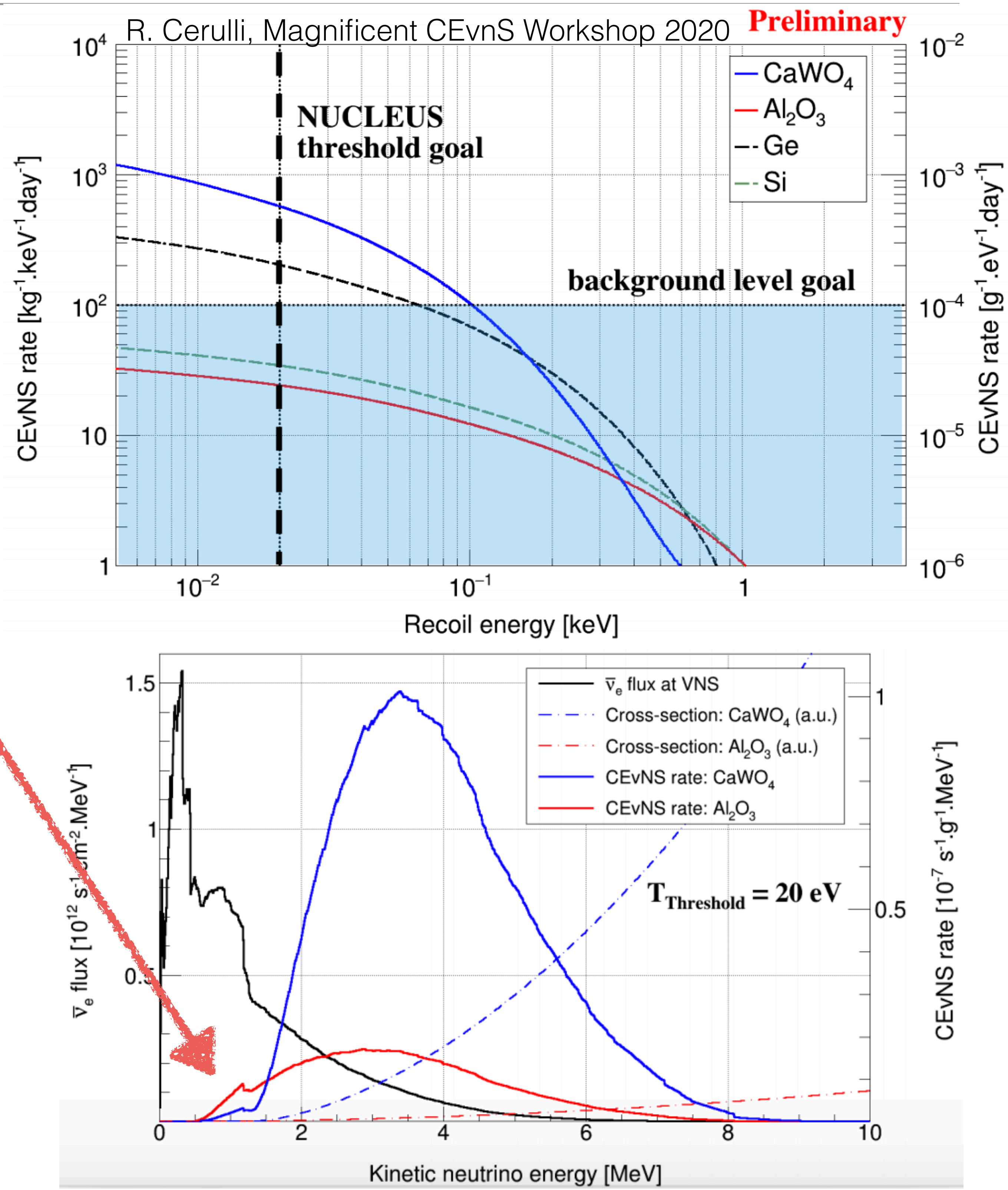


A Caveat: Bolometric Detectors

- Bolometric detectors (NUCLEUS, RICOCHET) do not suffer from QF loss of signal. Many of these also have extremely low thresholds

- Such detectors optimally suited to measure neutrinos <1.8 MeV IBD threshold

- Detector response should still be demonstrated



Actionable next steps

- More thorough measurement campaigns needed across all detector systems
- Unified approach to evaluating new and existing data
- Modeling remains a challenging (and perhaps unattainable) goal. Empirical measurements preferred
- Possible scoping study: should a decision be made on bolometric vs calorimetric detector systems? Do we avoid QF's all together? Such a study seems unlikely to be effective.

Trade-offs towards improved precision

- Small, purpose built detectors required to reduce multiple scattering.
- More beam-time needed at more facilities, but these facilities are not often run by agencies interested in this problem.
- Beam-time can be reduced with larger backing detector arrays, which also improve fidelity of results.
- But reduction of systematic uncertainties likely requires tuning of beam energy, as well as scanning over detector characteristics (e.g. doping concentration). Will require more beam time.
- Can move to higher neutron flux, but often this is also controls the neutron energies (e.g. 55 keV SuperCDMS run).
- Control of kinematics via neutron collimation, energy tuning, monochromaticity and beam pulsing will burn down systematic uncertainties.