# Recent results of the CONUS experiment

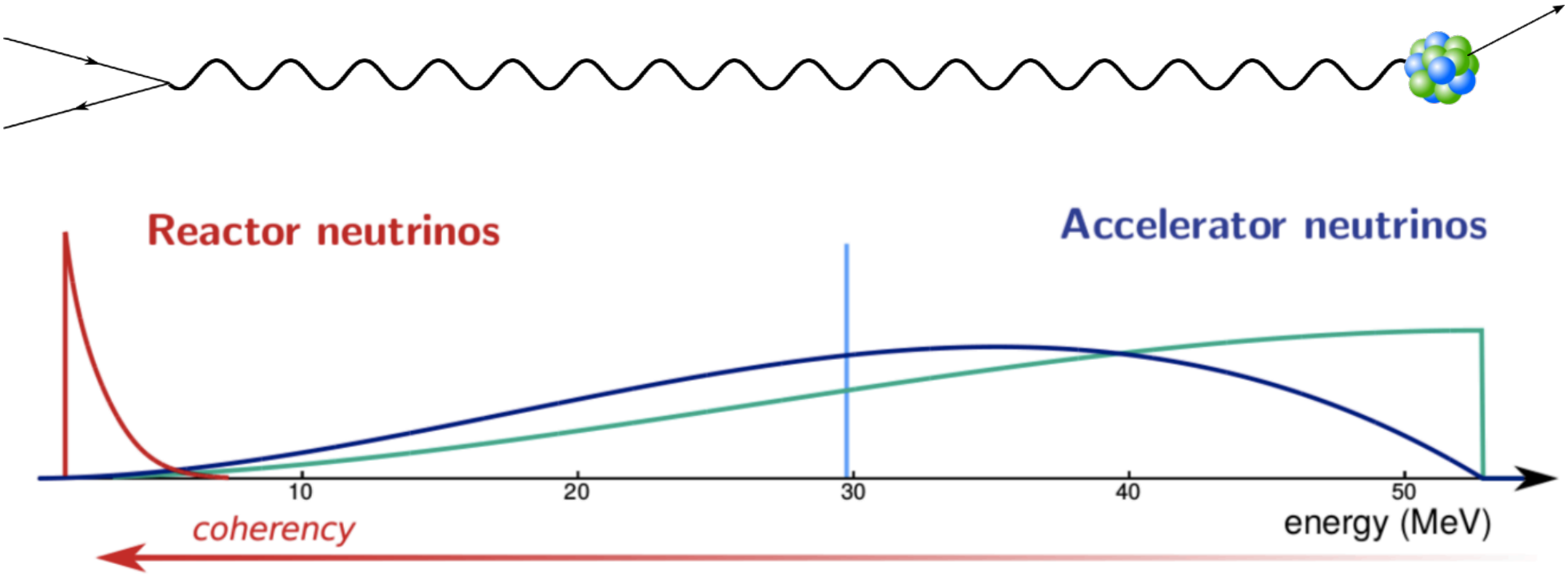
Christian Buck (on behalf of the CONUS collaboration)
Max-Planck-Institut für Kernphysik, Heidelberg
Magnificent CEvNS, Oct 6, 2021

MAX PLANCK GESELLSCHAFT

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK HEIDELBERG

CONUS

# CEvNS at nuclear reactors




*Courtesy of A. Bonhomme*

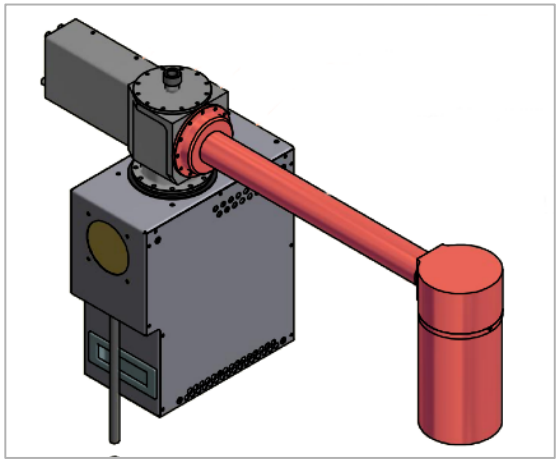
- Pure flux of electron antineutrinos
- E ~ 0 - 10 MeV ==> form factor close to 1 (fully coherent regime)
- Many experiments: CONUS, nuGeN, CONNIE,…

- Different neutrino flavors
- E ~ 20 - 50 MeV ==> form factor < 1
- COHERENT: first observation in 2017

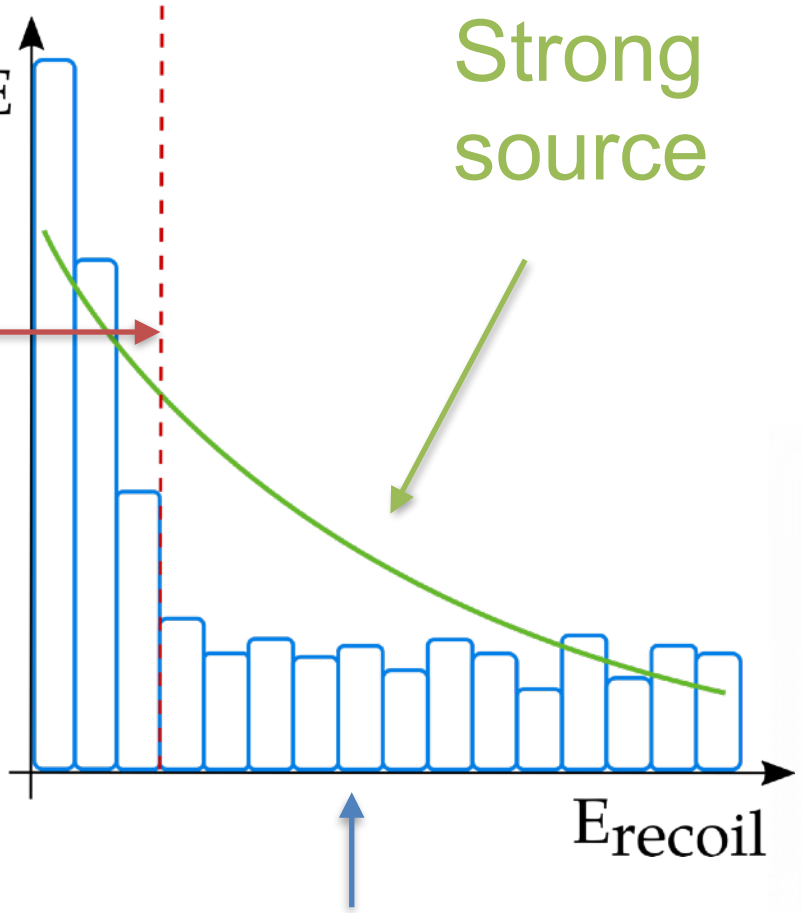
**Complementarity !**

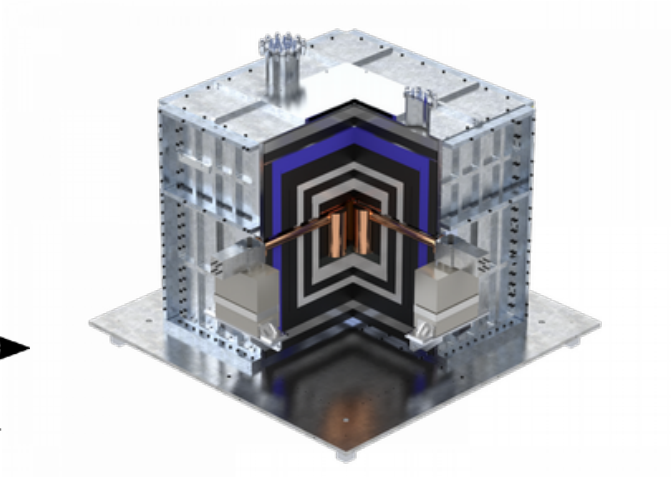
# Requirements

Nuclear power plant
(Brokdorf, KBR)



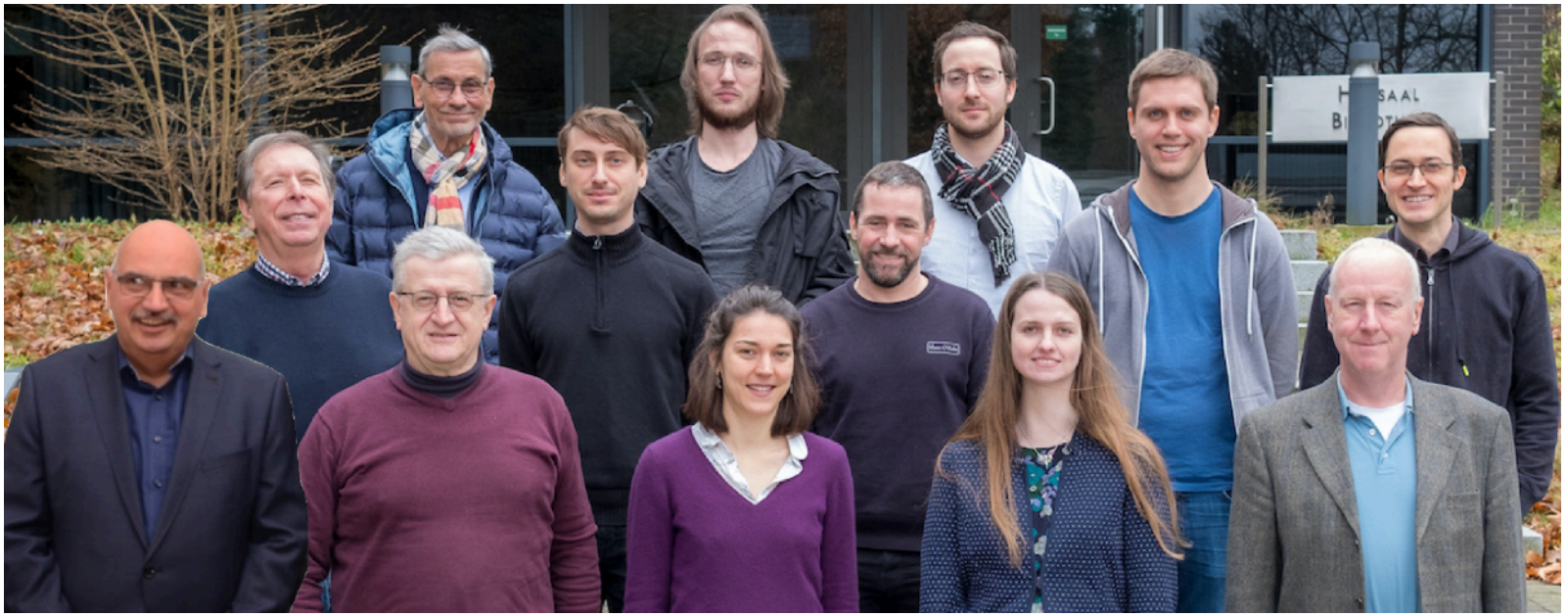
Point contact
HPGe spectrometer



Shield (shallow depth)

# CONUS Collaboration



MAX-PLANCK-INSTITUT FÜR KERNPHYSIK HEIDELBERG

Preussen Elektra

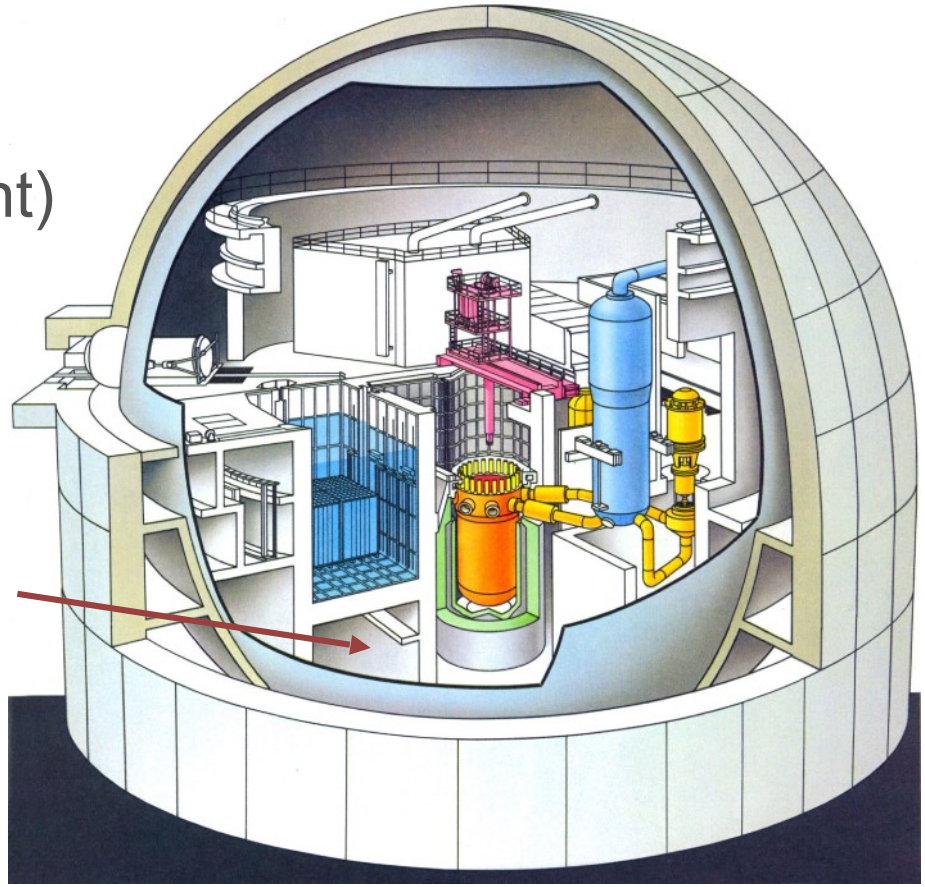
**H. Bonet, A. Bonhomme, C. Buck, J. Hakenmüller, J. Hempfling, J. Henrichs, G. Heusser, T. Hugle, M. Lindner, W. Maneschg, T. Rink, E. Sanchez Garcia, J. Stauber, H. Strecker**
*Max Planck Institut für Kernphysik (MPIK), Heidelberg*

**K. Fülber, R. Wink**
*Preussen Elektra GmbH, Kernkraftwerk Brokdorf (KBR), Brokdorf*

# Experimental Site

Overburden:
10 - 45 m w.e.
(angle-dependent)

CONUS location

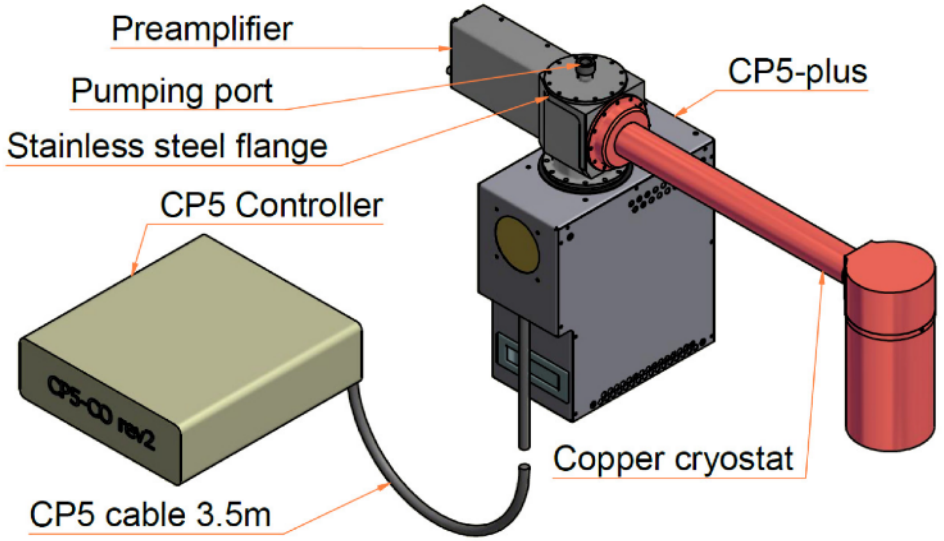


KBR Brokdorf:

- 3.9 GW thermal power
- Distance 17.1 m
- OFF time ~1 m/y
- Operational until end of 2021

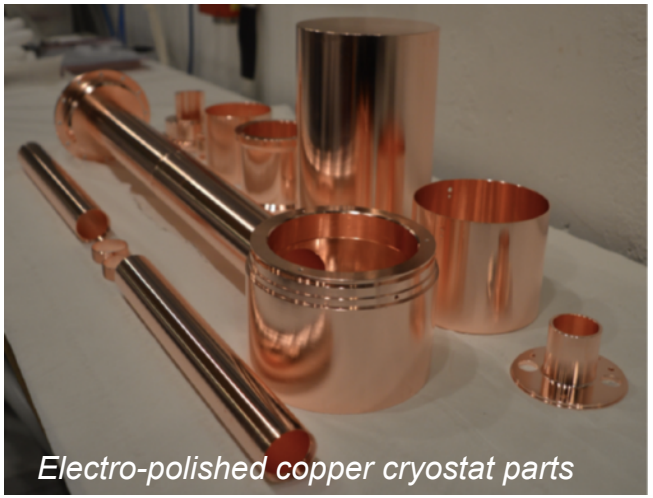
Challenging environment: no remote control, restricted materials, earthquake engineering, access, temperature fluctuations,…

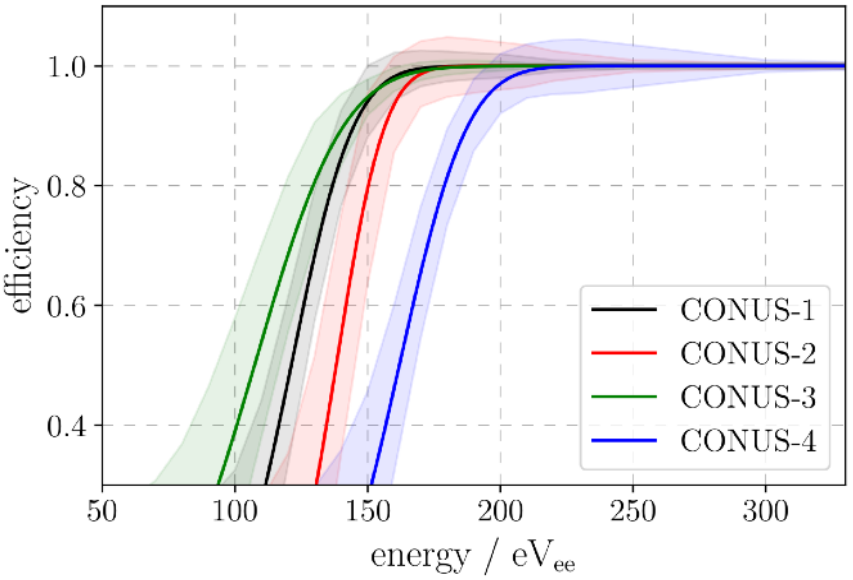
# Detectors




4 p-type HPGe detectors:

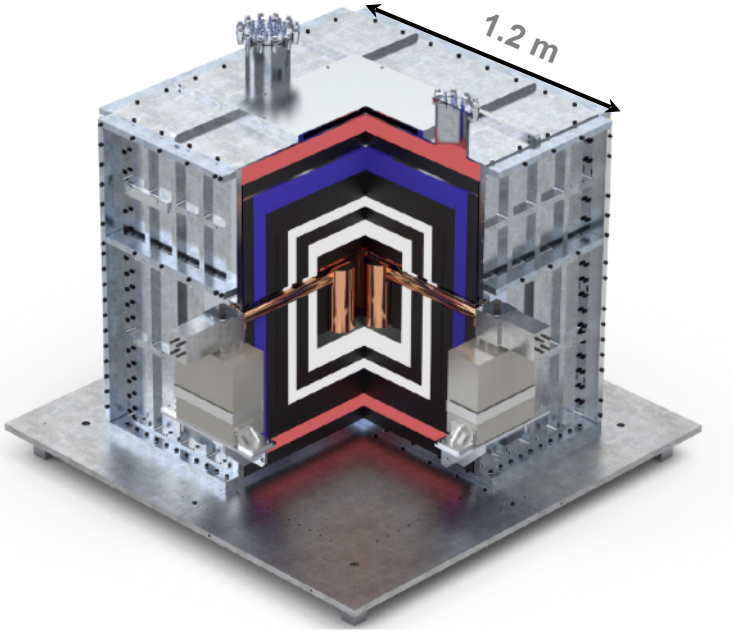
- Total mass: 4.0 kg
- Pulser resolution < 80 eV
- Efficiency ~1 in ROI
- Electrical cooling


*Electro-polished copper cryostat parts*




CONUS, EPJ C (2021) 81:267

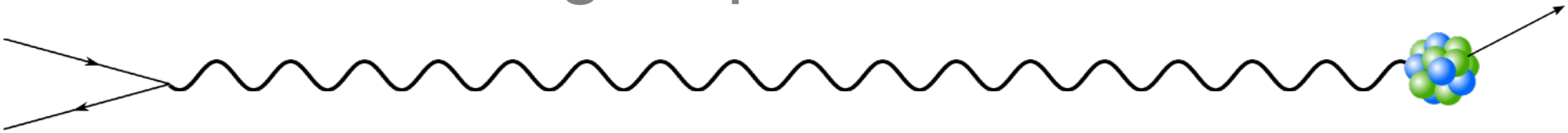
# CONUS setup

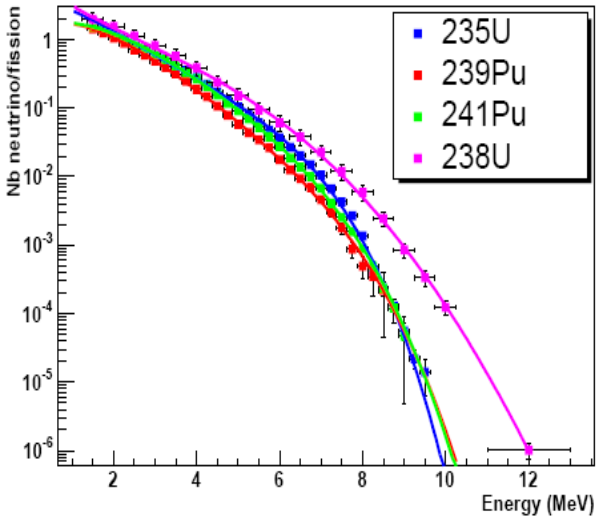



- Design basis: GIOVE (MPIK)
- V = 1.65 $m^3$, m = 11 tons
- Low radioactivity lead (Pb)
- Borated PE (n moderation + capture)
- Active muon veto (~97% rejection)
- Construction, commissioning and installation: ~2y

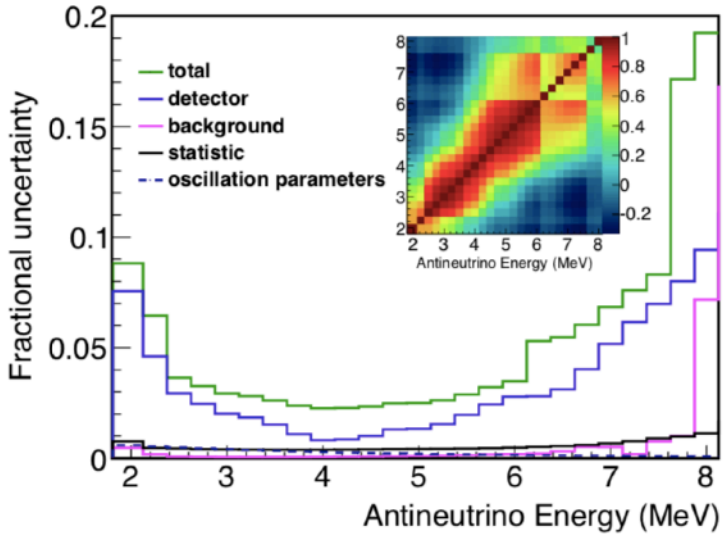
Radon removal:
Flush with air bottles


# Signal prediction

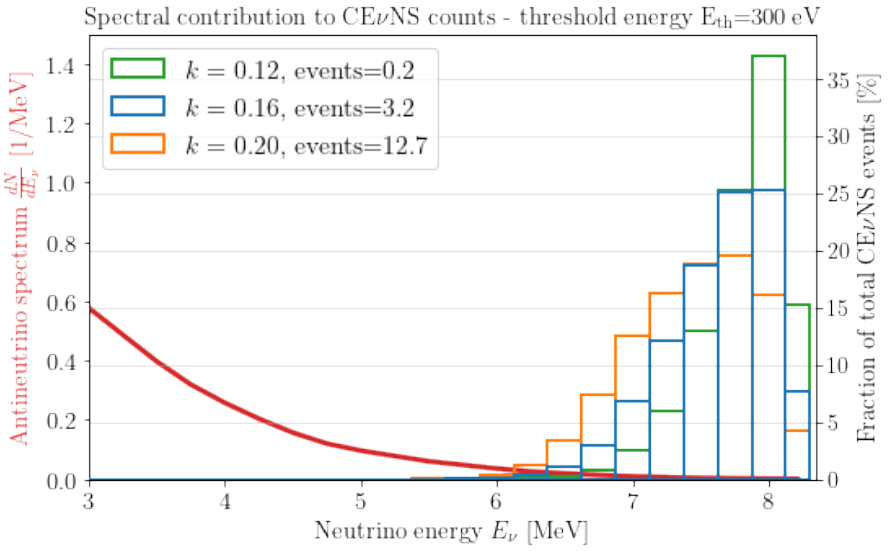





- Thermal power and energy/fission
- Flux at CONUS site: 2.3x10$^{13}$ /(cm$^2$ s)
- Spectra from Huber and Mueller et al.
- Fission fractions (KBR) for combination
- Daya Bay correction
- High quenching factor dependence!



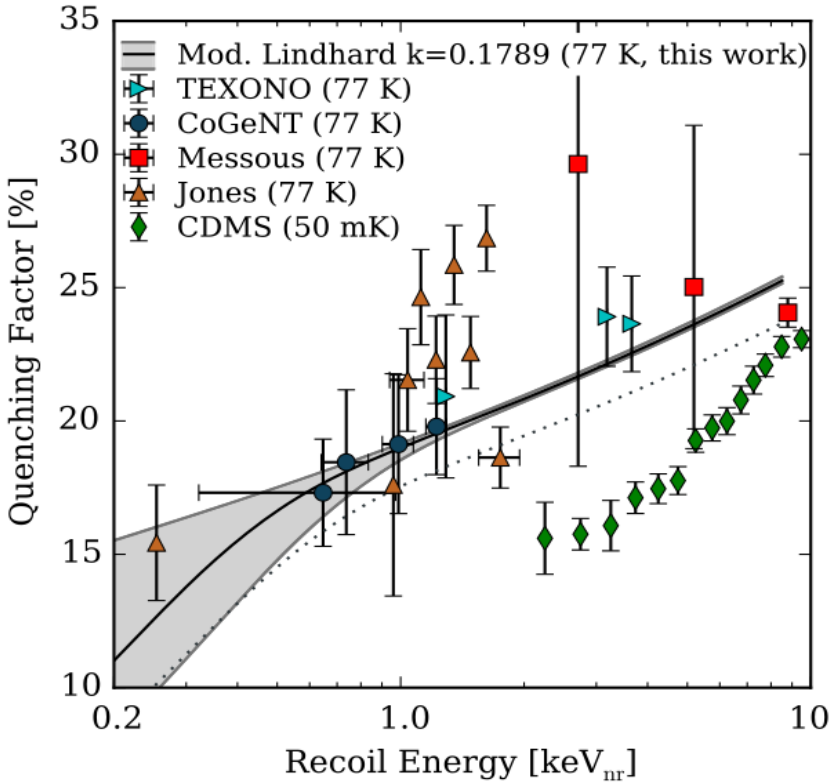

*Daya Bay, CPC 41 (2017) 1, 013002*



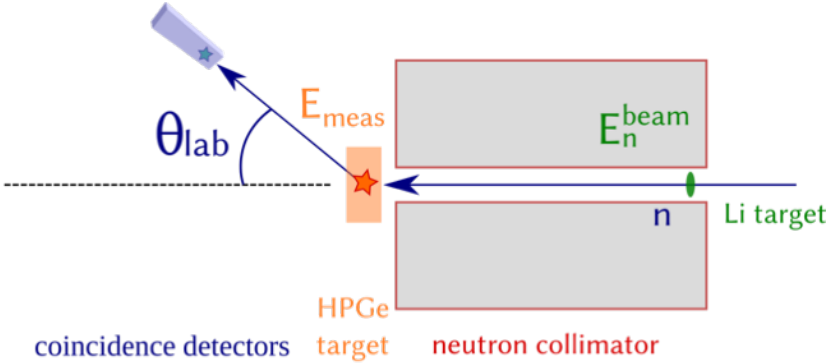

Example for one detector in first phase of data taking

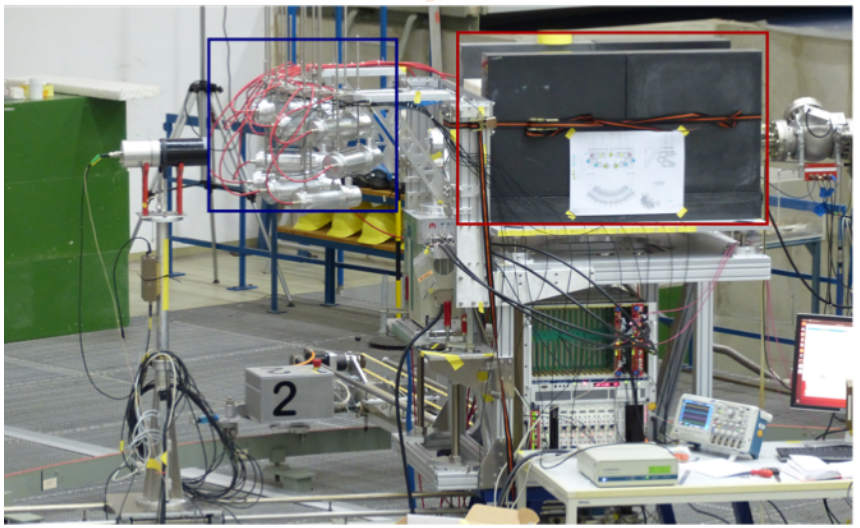
# Quenching measurement

Situation at start of CONUS:




*Scholz et al, PRD 94, 122003 (2016)*



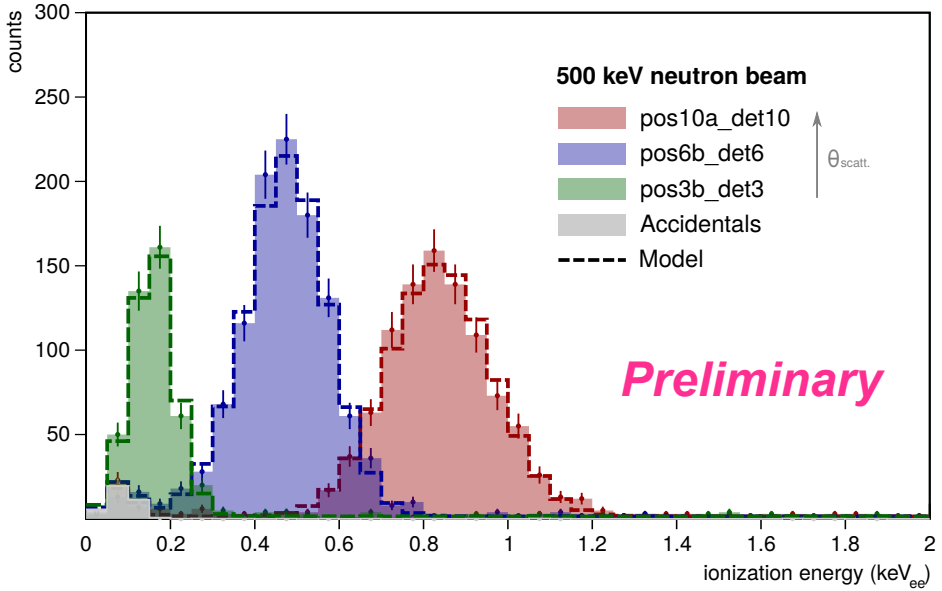

- Large variation of data points
- Lack of data at very low energies

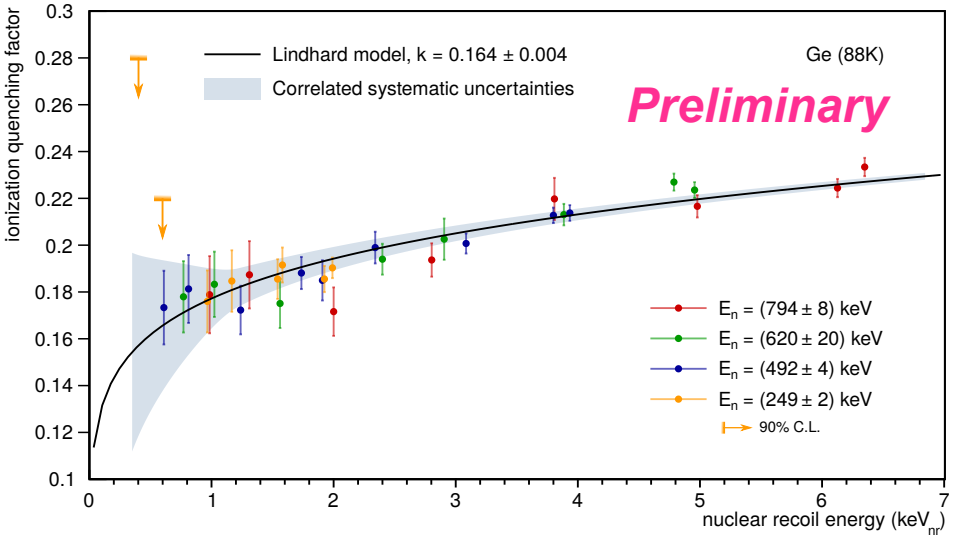
*Cooperation with PTB Braunschweig*

Physikalisch Technische Bundesanstalt
Braunschweig und Berlin

# Quenching results

- Method
  - Model-independent
  - Triple coincidence
  - Beam energy 250 - 800 keV
  - Angles 18-45° (1° precision)
  - Nuclear recoils 0.4 - 6 keV
- Results
  - Good compatibility with Lindhard theory!
  - k = 0.164 ± 0.004 (stat.+syst.)
  - Challenge for CEvNS signal detection with Ge at reactor

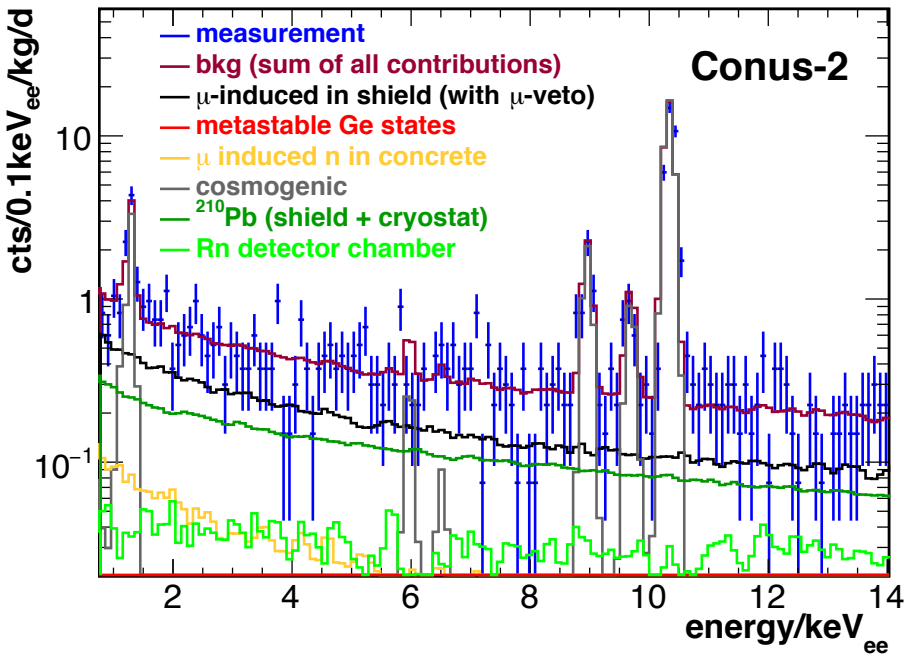


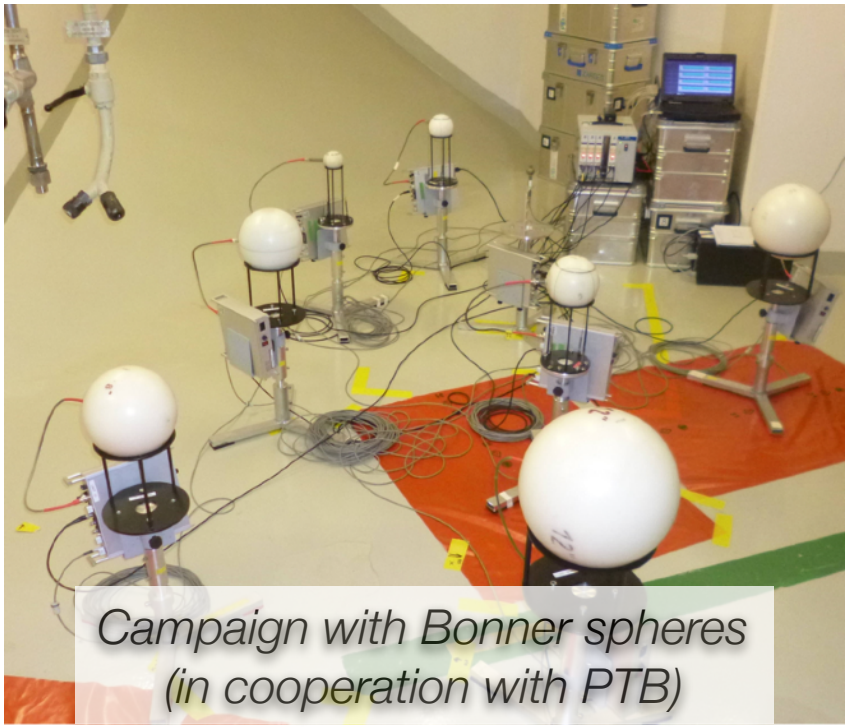
# Background

- Background suppression: ~$10^4$
- Rate 0.5-1 keV: ~10 /(keV d kg)
- Bg spectrum well understood (MC + commissioning @ MPIK)

***Preliminary***



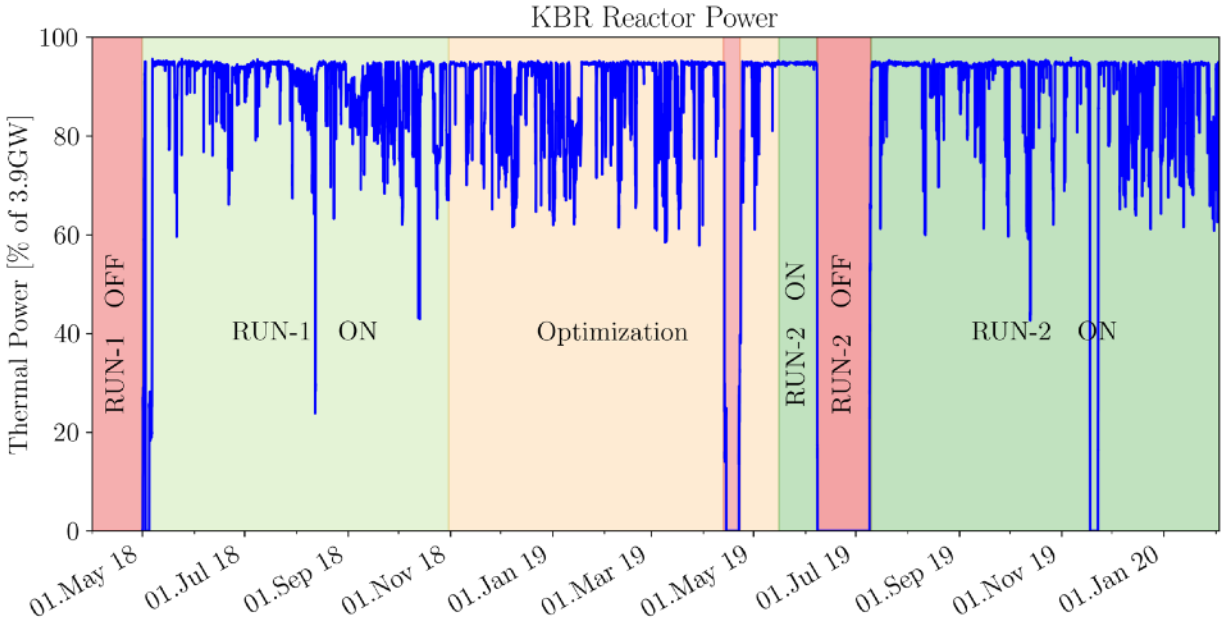

Reactor-correlated: neutrons



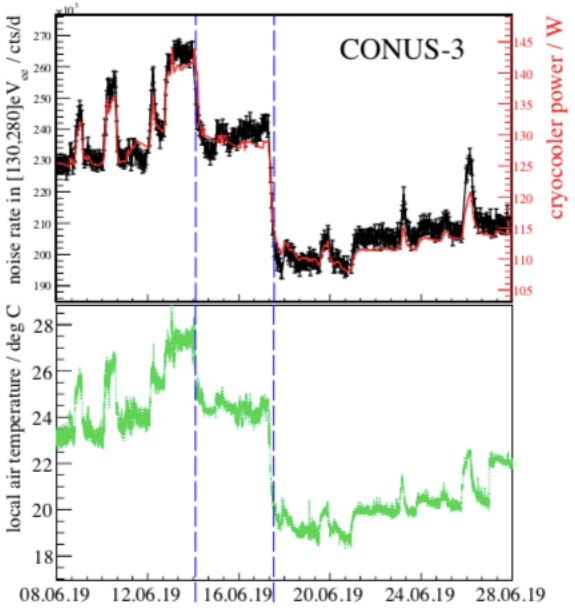

- Neutron flux in CONUS room suppressed by factor >$10^{20}$
- 80% of neutron flux is thermal

CONUS, Eur. Phys. J. C (2019) 79:699

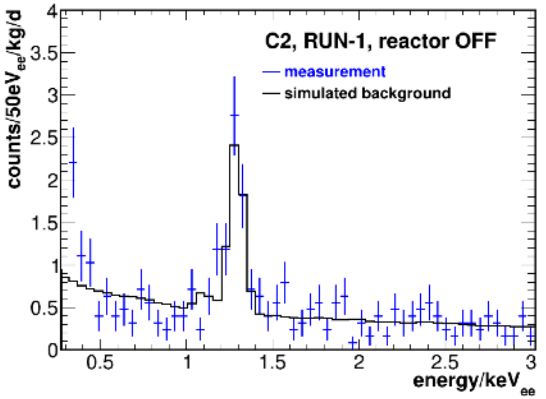
# Data Selection




Temperature, cryocooler power and noise rate correlated




| Det. | RUN | ON [d] | OFF [d] | ROI [keV$_{ee}$] |
|---|---|---|---|---|
| C1 | 1 | 96.7 | 13.8 | 0.296 - 0.75 |
| C2 | 1 | 14.6 | 13.4 | 0.311 - 1.00 |
| C3 | 1 | 97.5 | 10.4 | 0.333 - 1.00 |
| C1 | 2 | 19.6 | 12.1 | 0.348 - 0.75 |
| C3 | 2 | 20.2 | 9.1 | 0.343 - 1.00 |
| total: | | 248.7 | 58.8 | |



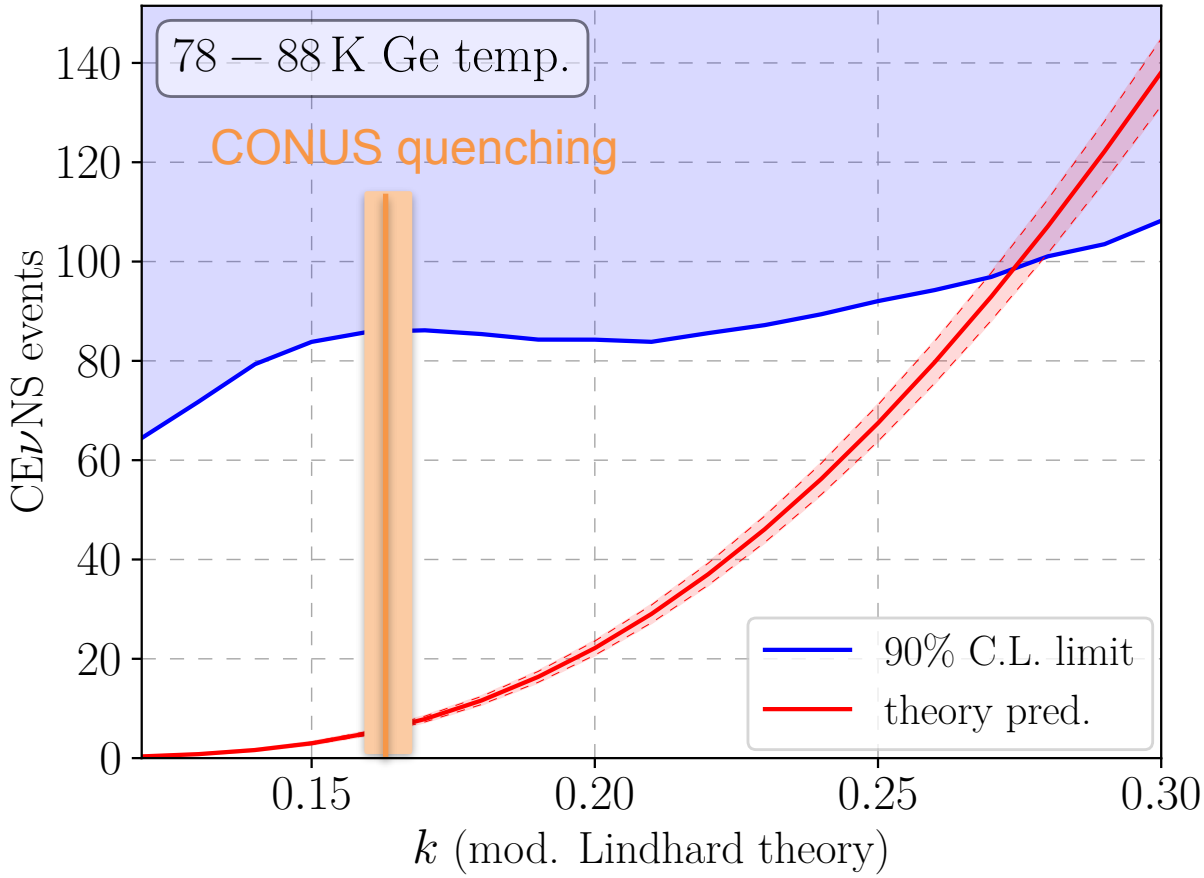
# CEvNS data analysis

Background treatment

- MC modelling
- Free normalization parameter in fit
- Exponential fit for „noise“

Likelihood

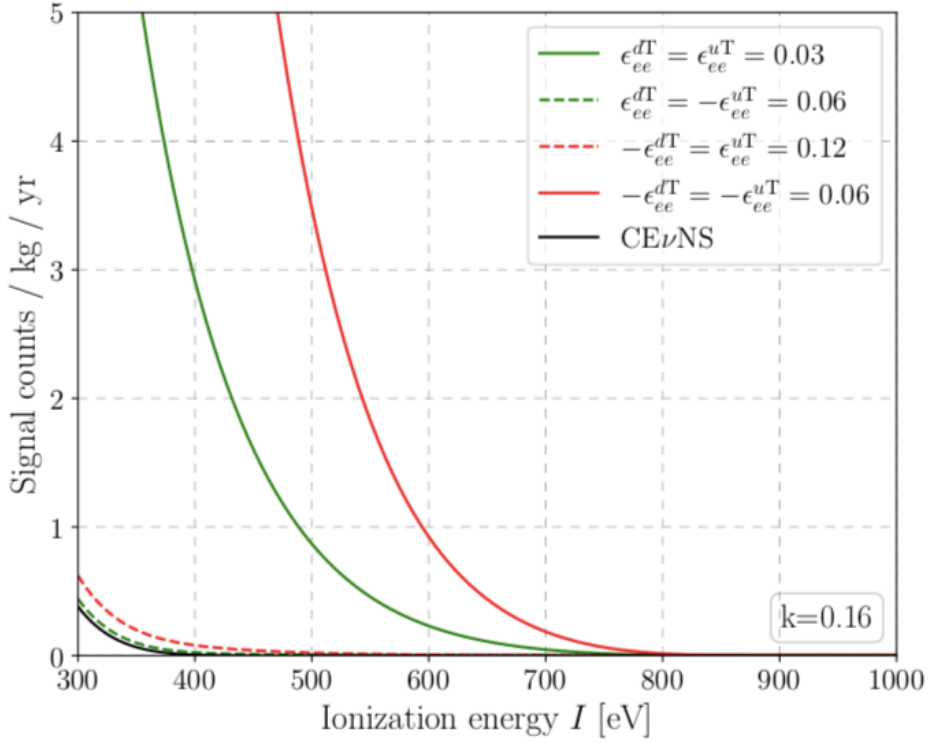
- Simultaneous fit ON/OFF (all detectors and runs)
- Scan over signal parameter
- Systematics via pull terms (energy scale, fiducial mass, efficiency, neutrino flux)

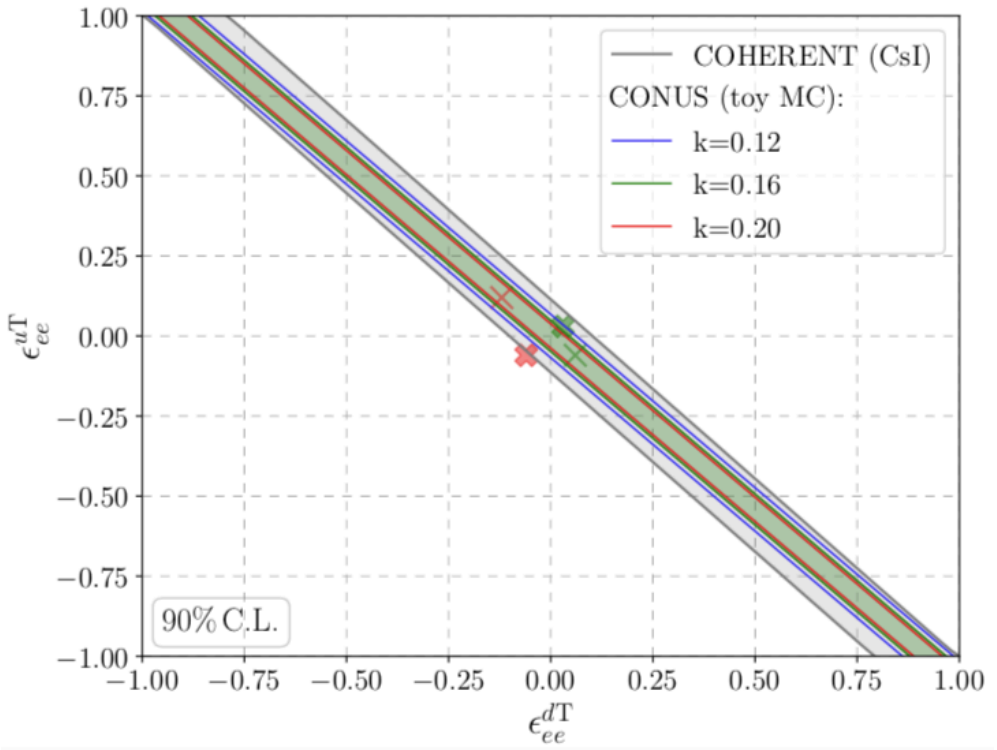



CONUS, PRL 126 (2021) 041804

# BSM: non standard interactions (tensor)

New coupling with nuclear charge term adding to CEvNS cross-section



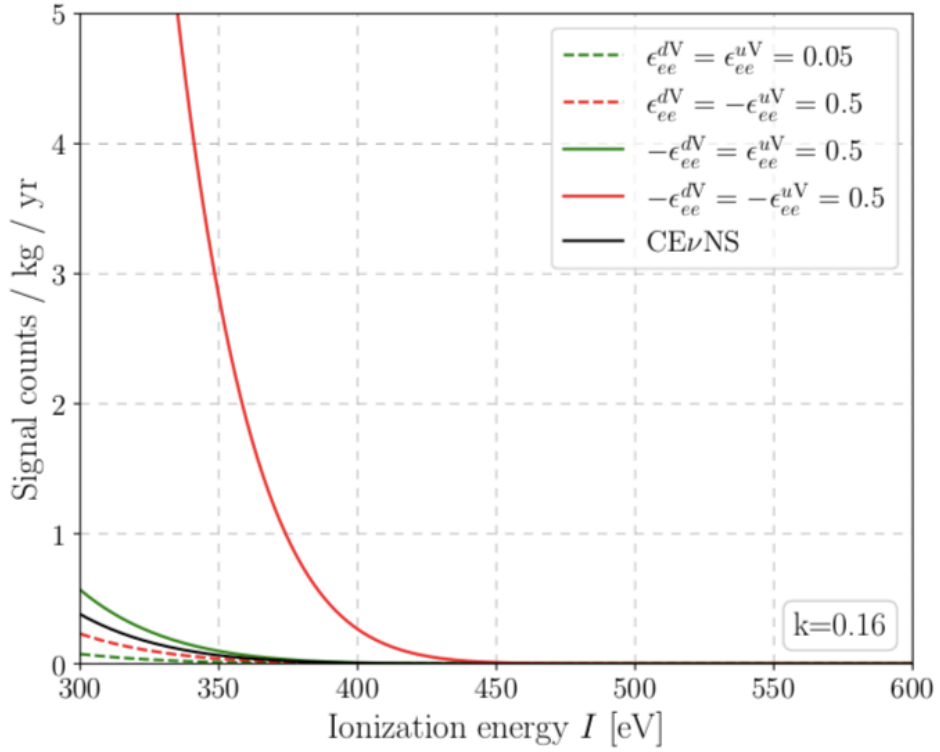



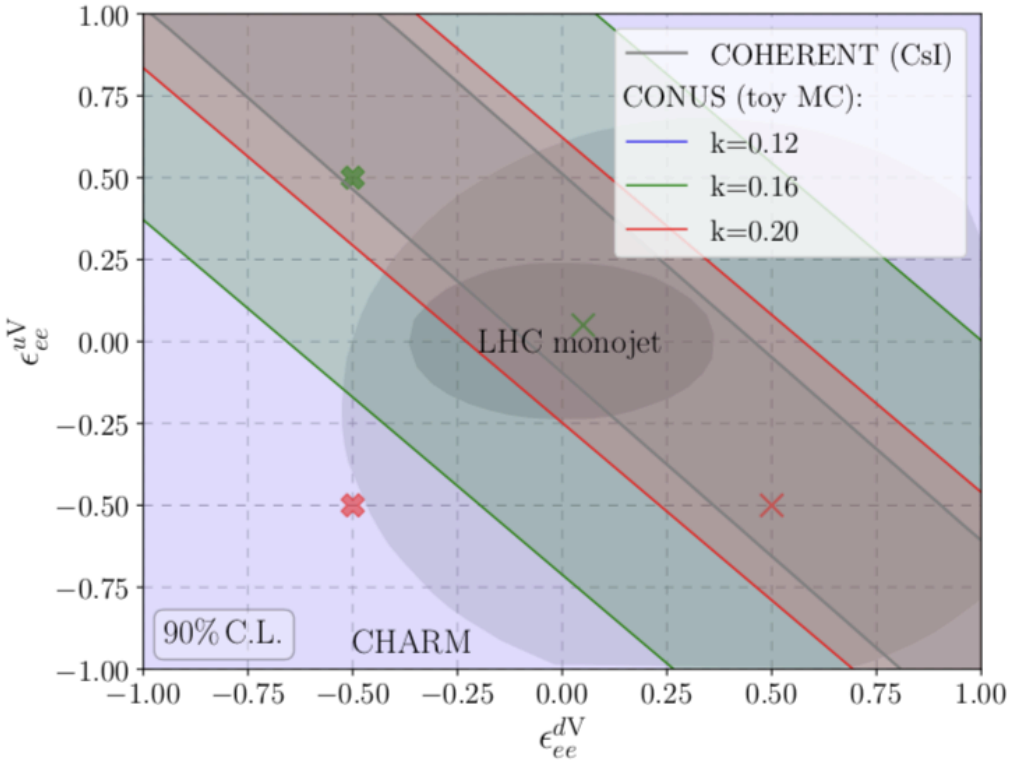

Best limits!

New!!! CONUS, arXiv 2110.02174 [hep-ph]

# BSM: non standard interactions (vector)

New interaction similar to CEvNS (Z-like mediator): Modified weak charge



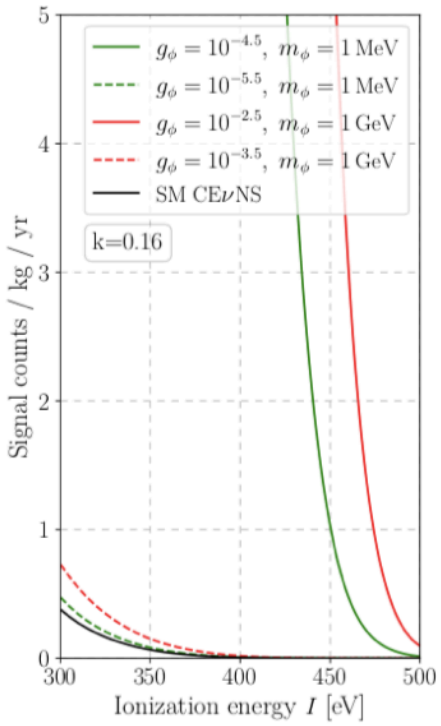



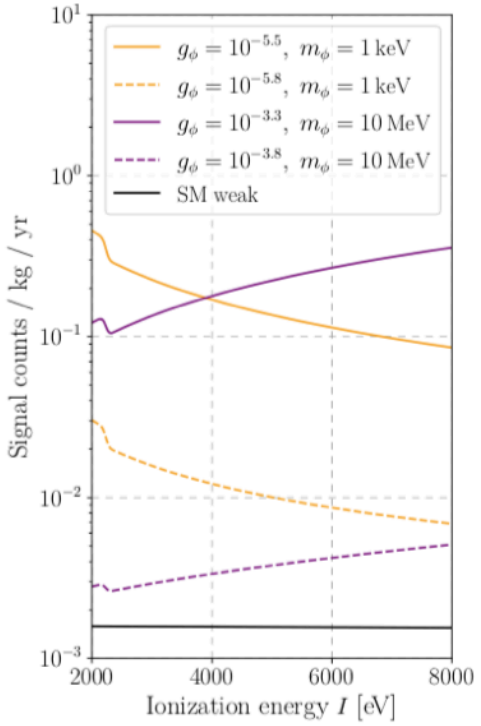

Destructive interference possible

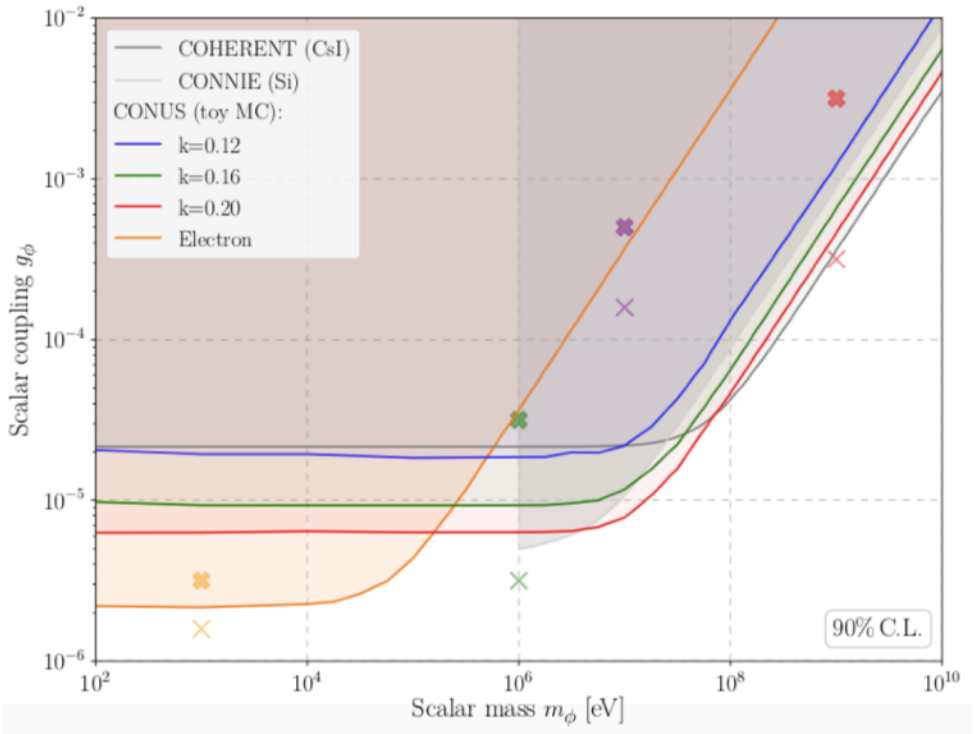
New!!! CONUS, arXiv 2110.02174 [hep-ph]

# BSM: light mediators (scalar)

- Testing simplified models assuming universal couplings
- Nucleus and electron (2-8 keV) channels included



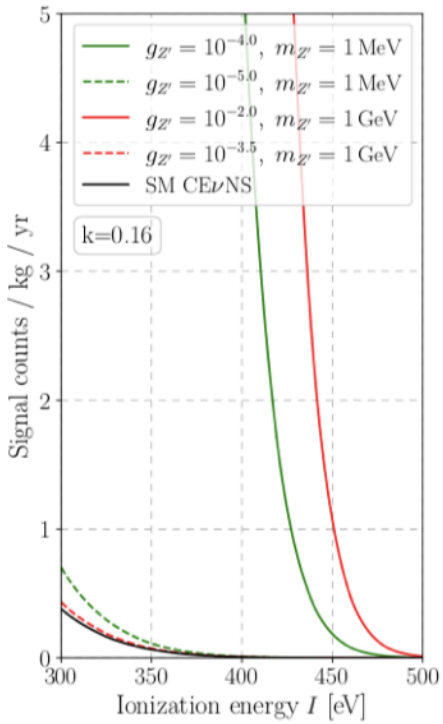



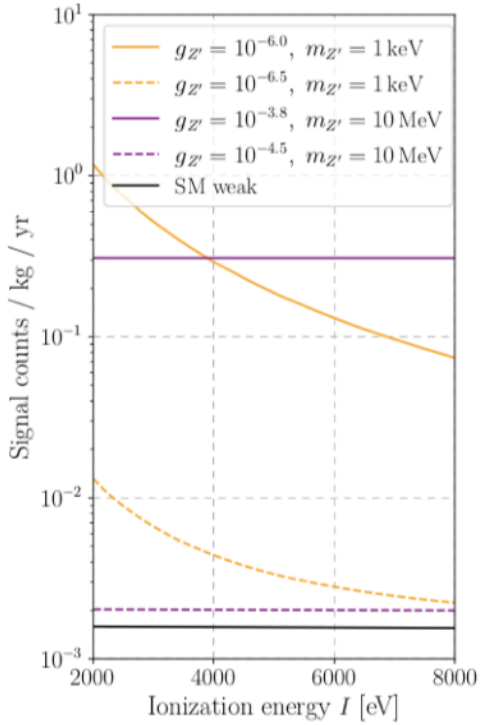



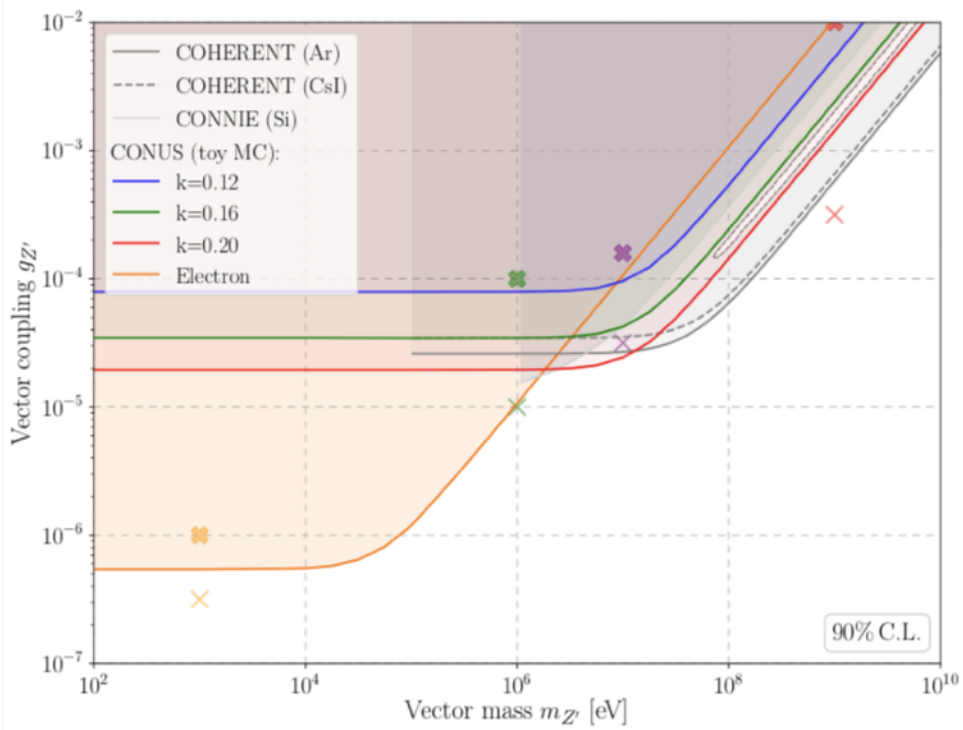

New!!! CONUS, arXiv 2110.02174 [hep-ph]

# BSM: light mediators (vector)

Reactor as source: high sensitivity for mediator masses below the energy of the neutrino (< 10 MeV)




New!!! CONUS, arXiv 2110.02174 [hep-ph]

Next: neutrino magnetic moment analysis (sensitivity < $10^{-10}$ $\mu_B$…)

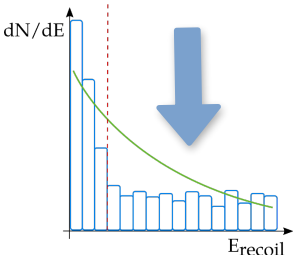
# Outlook

More statistics

Lower threshold, background control

Additional on/ off periods

DAQ/electronics upgrade ==> PSD




Final reactor off end of 2021 ==> 1 y background

Temperature stability (less noise and cuts)

Improved background knowledge (e.g. MC)

# Summary

- Nuclear reactors: intense source of low energy (< 10 MeV) electron antineutrinos ==> CEvNS in fully coherent regime
- CONUS: Low energy threshold HPGe-detectors 17.1 m from reactor core (Brokdorf)

*CONUS, Eur. Phys. J. C (2021) 81:267*

- Good background control/modeling

*CONUS, Eur. Phys. J. C (2019) 79:699*

- First constraints on CEvNS at reactor

*CONUS, PRL 126 (2021) 041804*

- New BSM constraints (NSI and light mediators)!

*arXiv 2110.02174 [hep-ph]*

- Ge-quenching measurement at PTB consistent with Lindhard theory

*CONUS, in preparation (TAUP2021)*