Overview of current status and prospects on CEvNS

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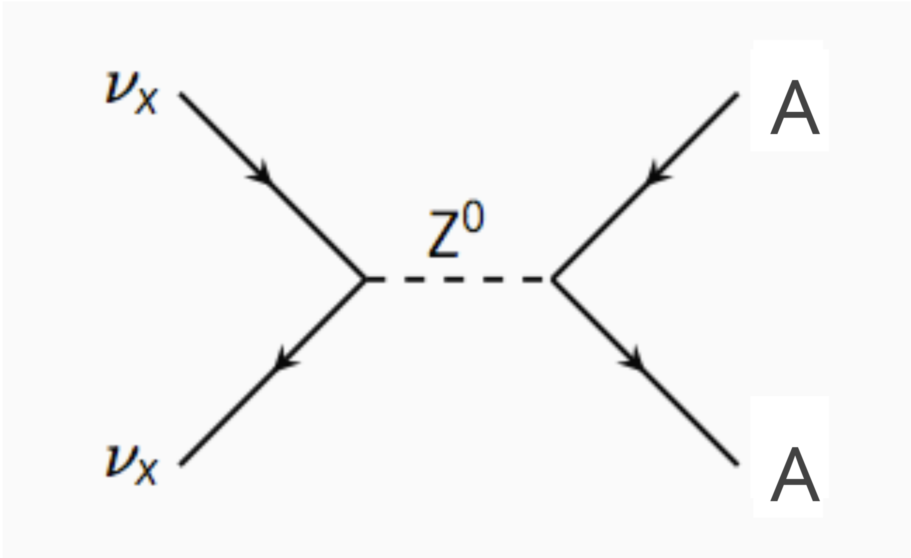
ICAS

Universidad Nacional de San Martín

What is CEνNS?



Coherent Elastic
Neutrino-Nucleus Scattering

is a process in which neutrinos scatter off a nucleus acting as a single particle

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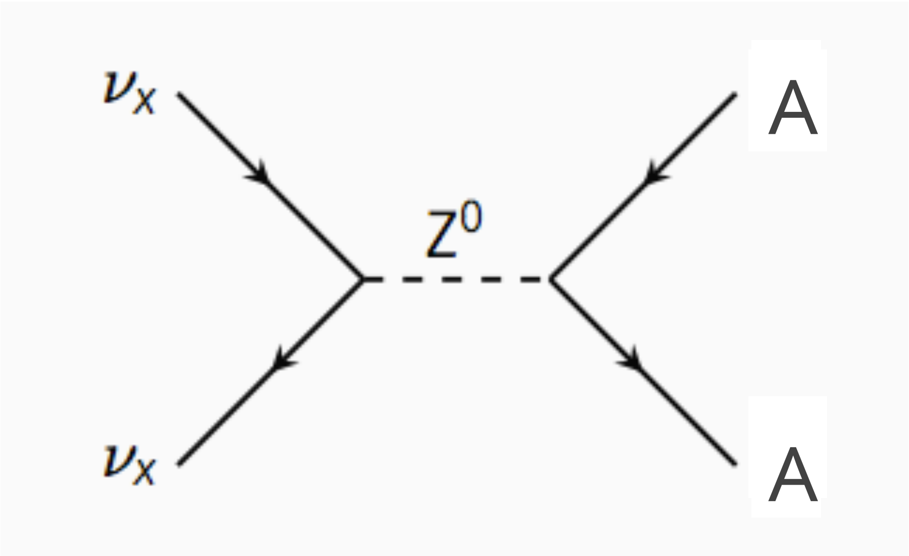

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D. Freedman, Phys.Rev. D 9 1389 (1974)

PHYSICAL REVIEW D VOLUME 9, NUMBER 5 1 MARCH 1974

Coherent effects of a weak neutral current

Daniel Z. Freedman†
National Accelerator Laboratory, Batavia, Illinois 60510
and Institute for Theoretical Physics, State University of New York, Stony Brook, New York 11790
(Received 15 October 1973; revised manuscript received 19 November 1973)

If there is a weak neutral current, then the elastic scattering process $\nu + A \to \nu + A$ should have a sharp coherent forward peak just as $e + A \to e + A$ does. Experiments to observe this peak can give important information on the isospin structure of the neutral current. The experiments are very difficult, although the estimated cross sections (about 10^{-38} cm^2 on carbon) are favorable. The coherent cross sections (in contrast to incoherent) are almost energy-independent. Therefore, energies as low as 100 MeV may be suitable. Quasi-coherent nuclear excitation processes $\nu + A \to \nu + A^*$ provide possible tests of the conservation of the weak neutral current. Because of strong coherent effects at very low energies, the nuclear elastic scattering process may be important in inhibiting cooling by neutrino emission in stellar collapse and neutron stars.

There is recent experimental evidence[1] from CERN and NAL which suggests the presence of a neutral current in neutrino-induced interactions. A primary goal of future neutrino experiments is important to interpret experimental results in a very broad theoretical framework.[4] We assume a general current-current effective Lagrangian

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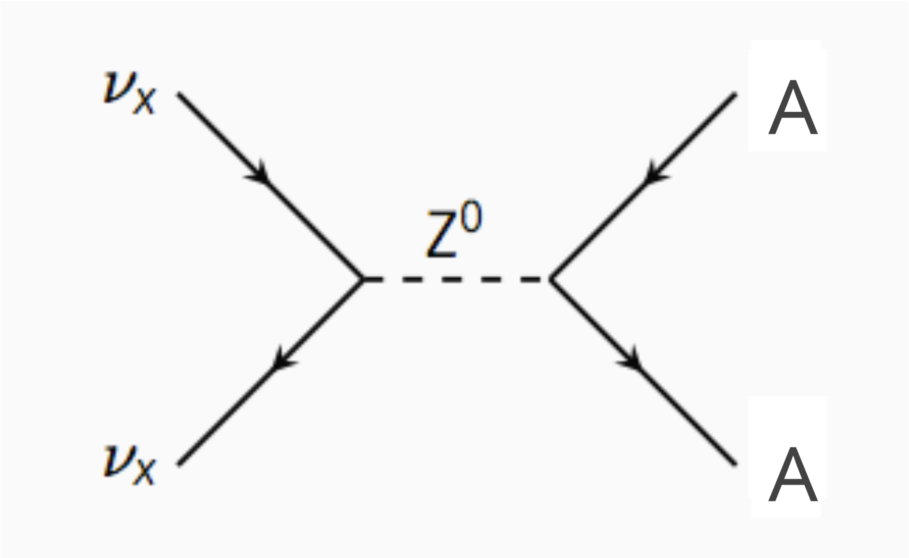

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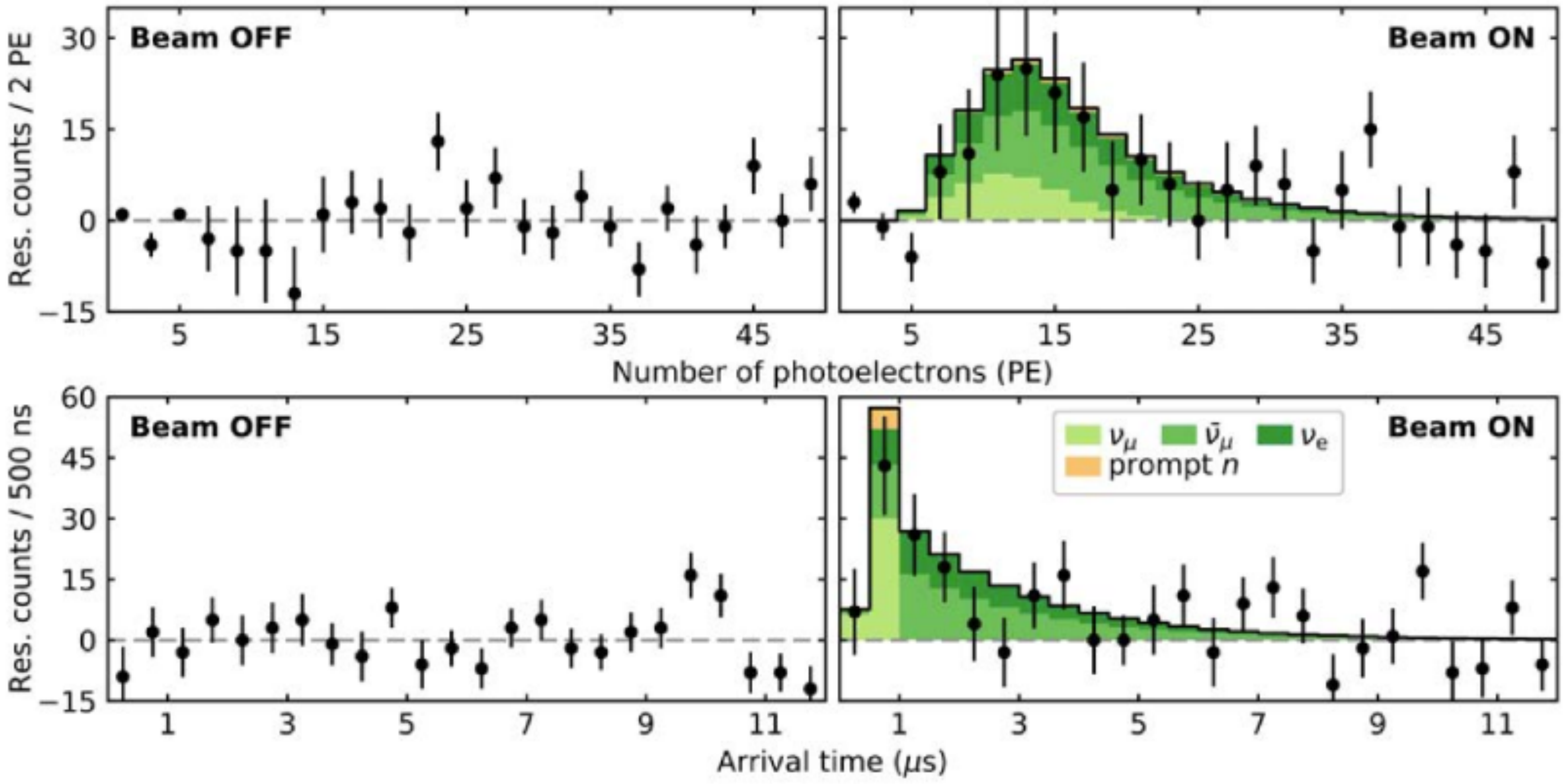

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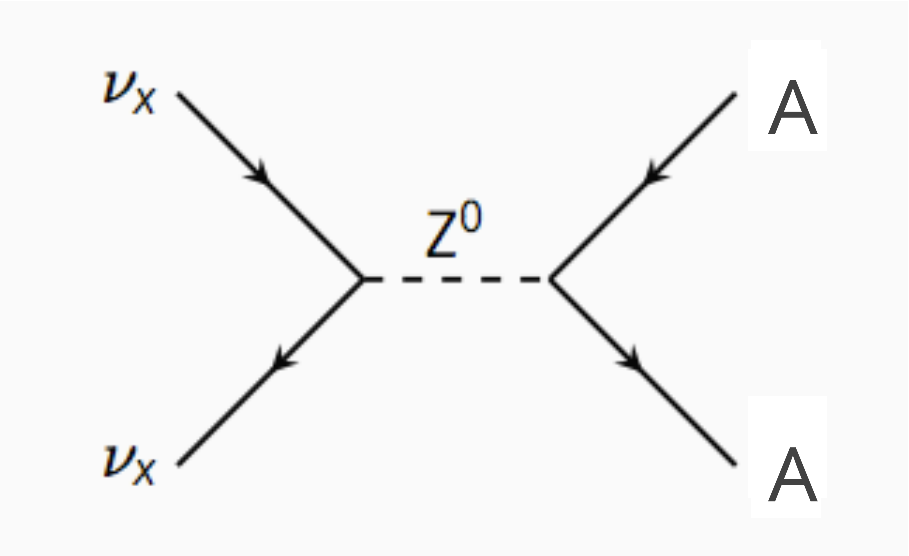

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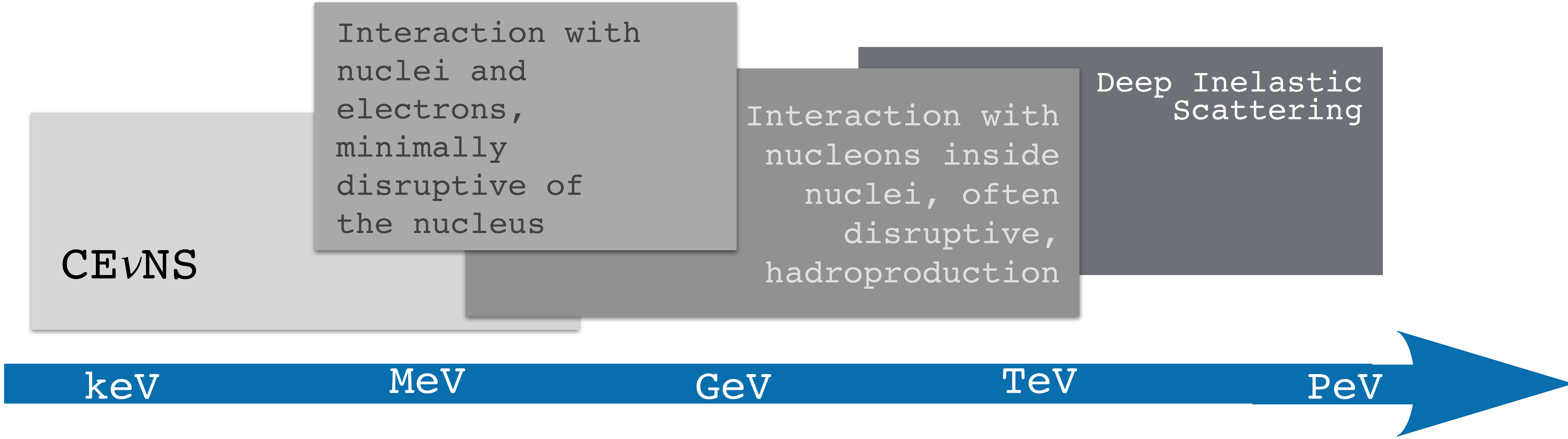

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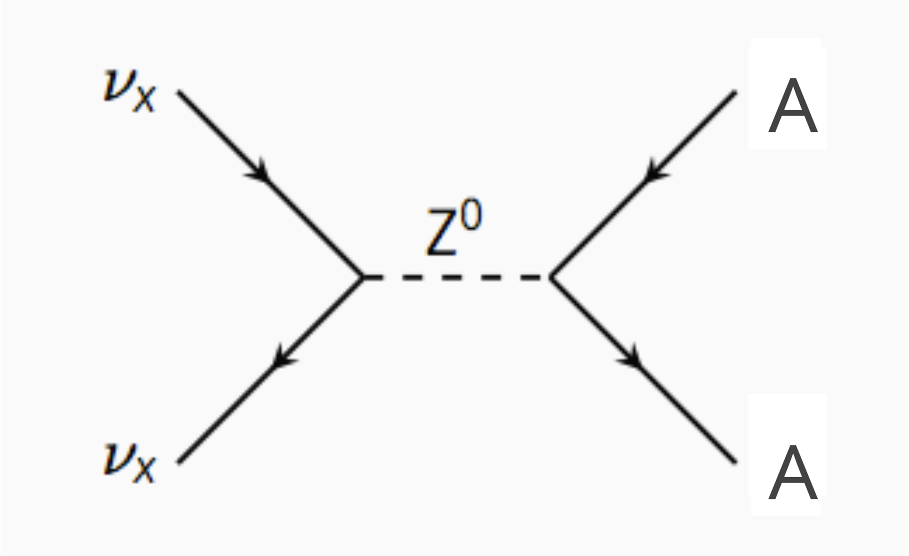

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- Dominant process for $E_\nu \lesssim 50$ MeV
- Cross section increases as N^2

For:
$q \cdot R << 1$

q = three-momentum transfer
R = nuclear radius

$$q = \sqrt{2ME_r}$$

$$\frac{d\sigma_{SM}}{dE_R}(E_{\bar{\nu}_e}) = \frac{G_F^2}{8\pi} Q_W^2 \left[2 - \frac{2E_R}{E_{\bar{\nu}_e}} + \left(\frac{E_R}{E_{\bar{\nu}_e}}\right)^2 - \frac{ME_R}{E_{\bar{\nu}_e}^2} \right] M|F(q)|^2$$

$$Q_W = N - (1 - 4\sin^2\theta_W)Z$$

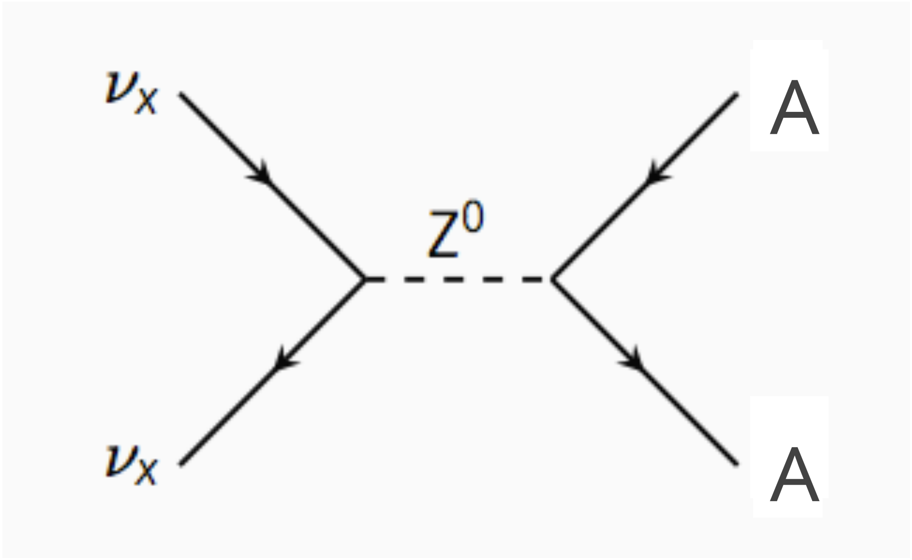
for: $\sin^2\theta_W \sim \frac{1}{4} (\approx 0.22)$

G_F = Fermi coupling constant
Z = atomic number of the nucleus
N = neutron number of the nucleus

E_ν = neutrino energy
θ_W = weak mixing angle
Q_W = weak charge

F(q) = form factor
M = mass of the nucleus

What is CEνNS?



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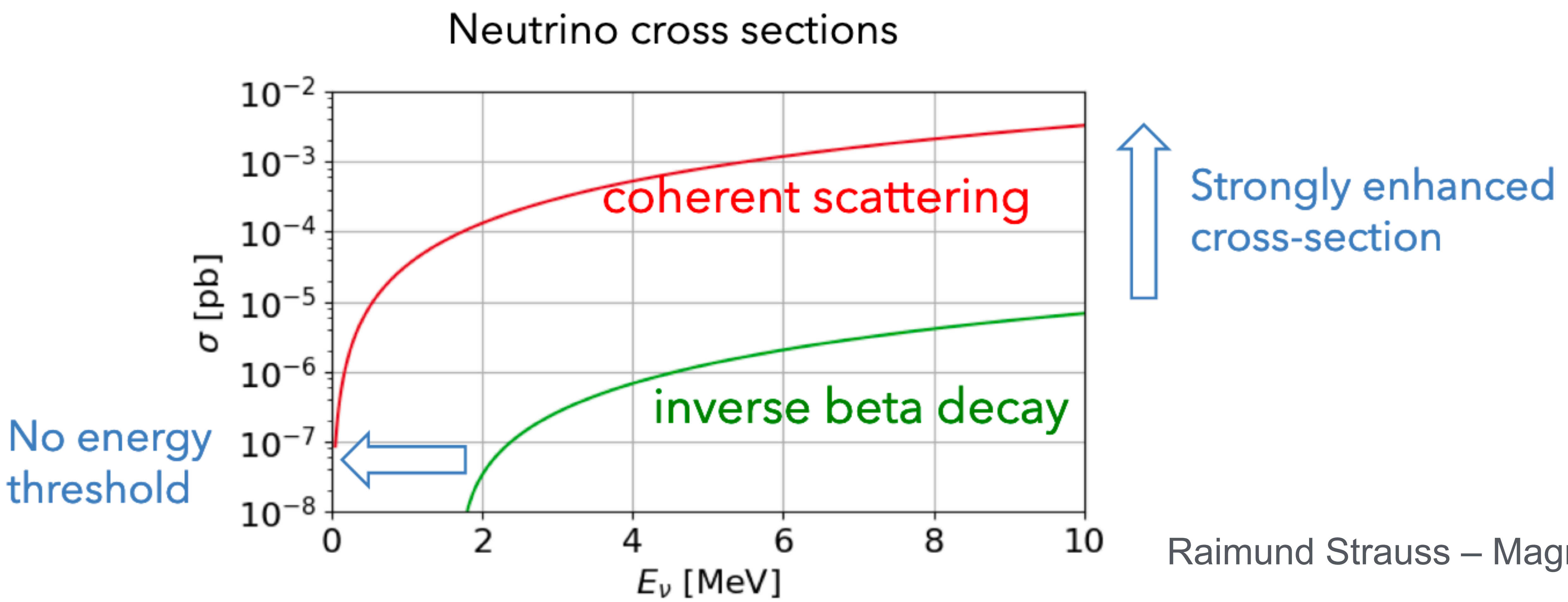
$$\sigma_{SM} \sim \frac{G_F^2}{4\pi} N^2 E_\nu^2$$



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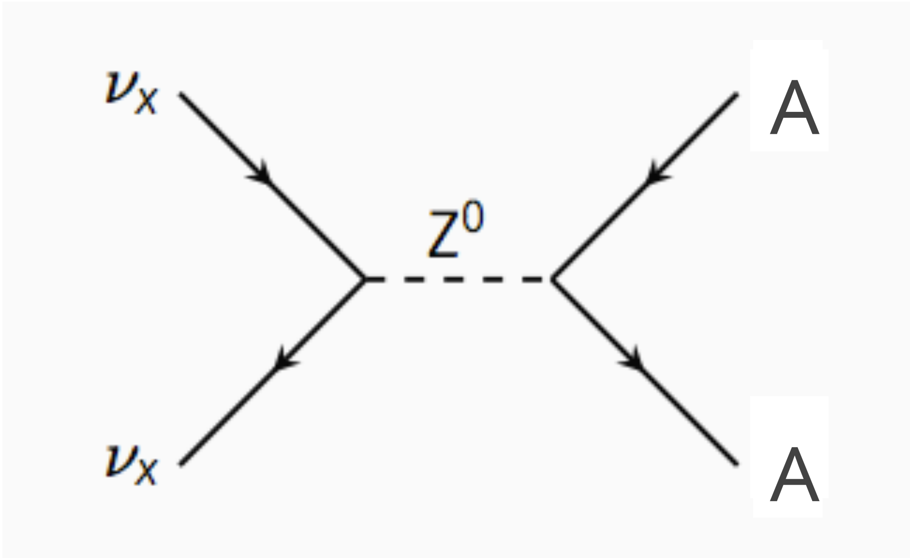

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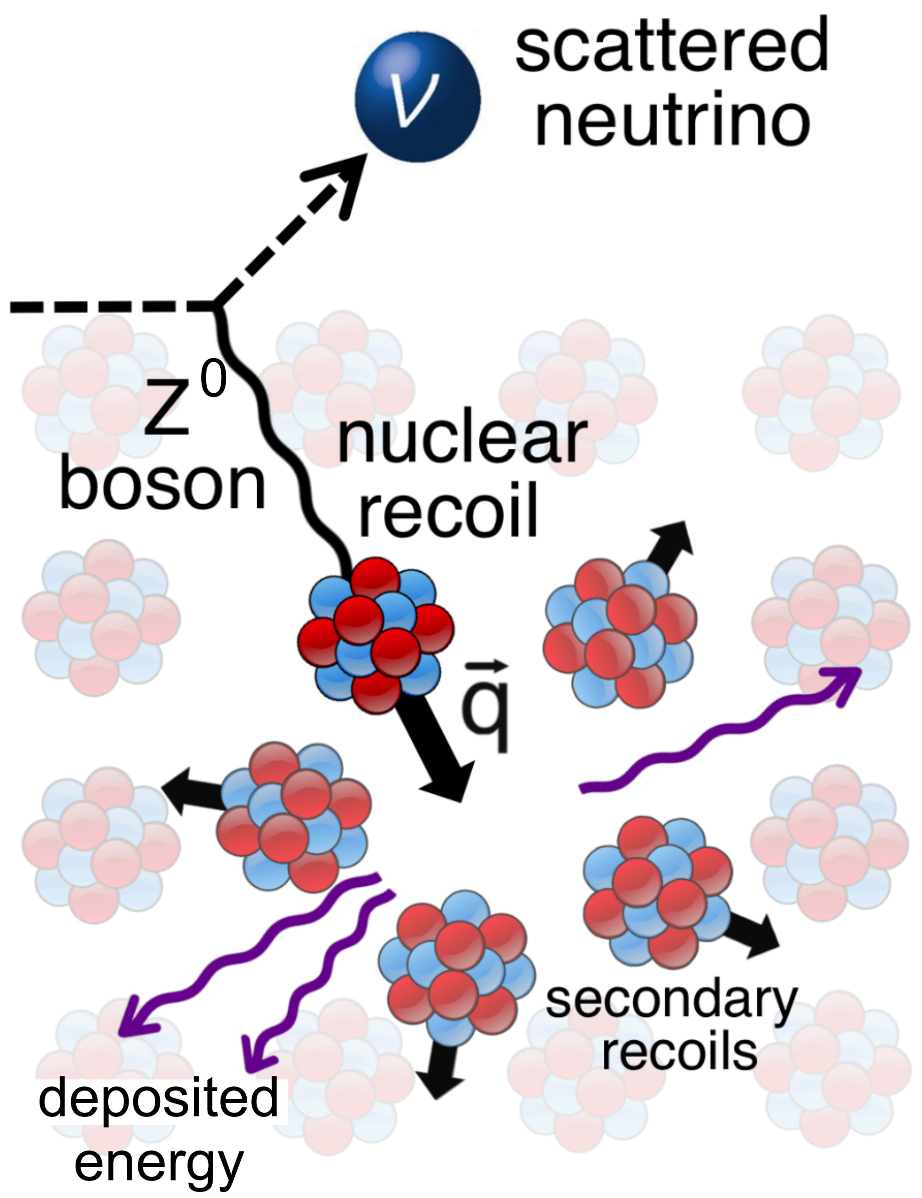
Large cross section...

...but hard to observe due to tiny nuclear recoil energies:

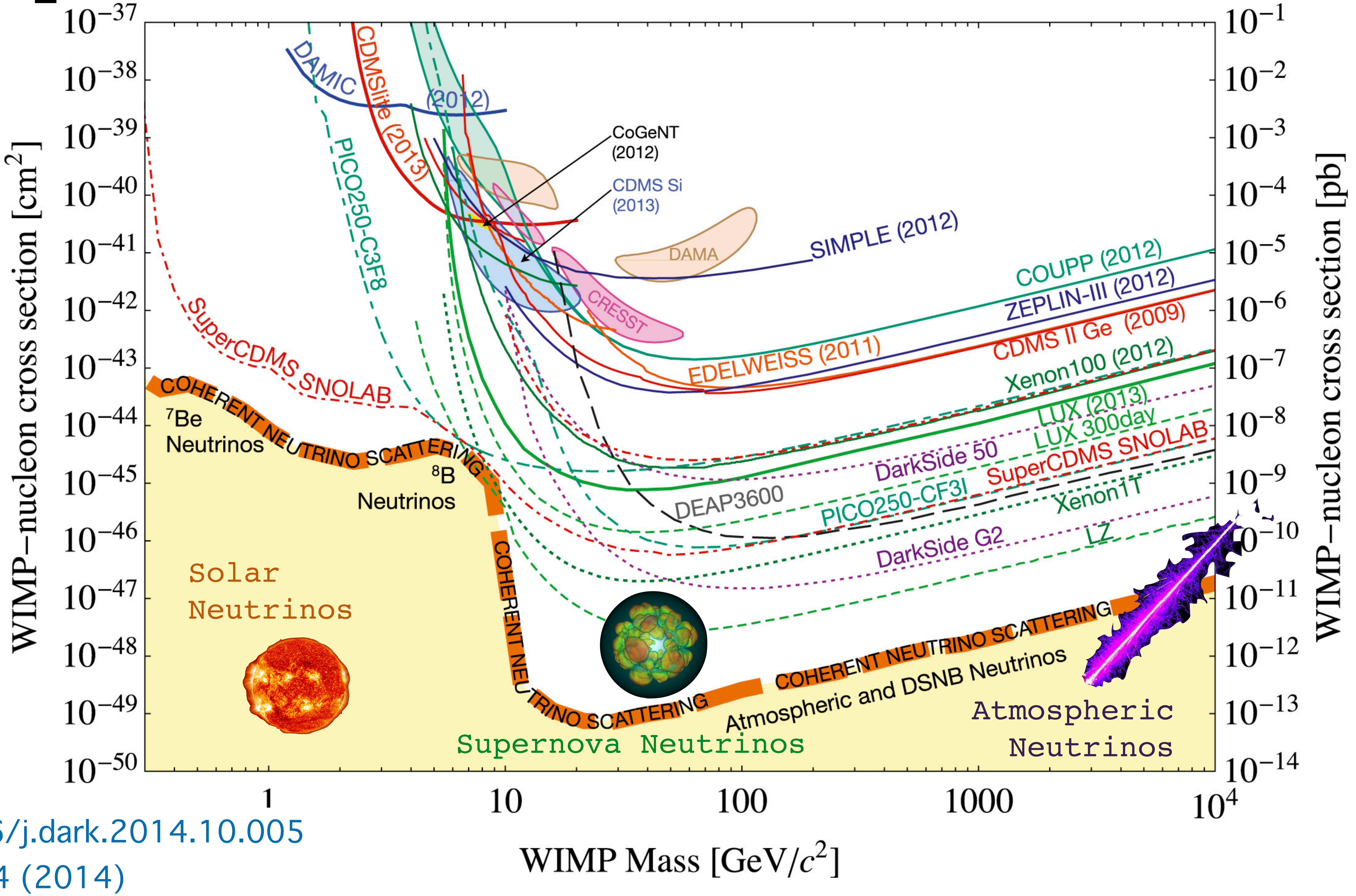


$$< E_r >= \frac{2}{3}\frac{(E_\nu/\mathrm{MeV})^2}{A}\mathrm{keV}$$

- Energies below the typical detection threshold of conventional neutrino experiments
- Now low threshold and background detectors available thanks to the efforts done for dark matter experiments.

Why CEνNS?

Background for DM experiments



https://doi.org/10.1016/j.dark.2014.10.005
Phys. Rev. D 89, 023524 (2014)

What is CEνNS good for?

Fundamental neutrino interactions

- Precision test of SM
- Beyond SM physics

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Nuclear physics

- Nuclear form factor
- Neutron distribution radius (Rn)

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Nuclear physics

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Supernova neutrinos

- Energy transport in supernovae: all neutrino flavors with E ~ tens-of-MeV
- To detect SN neutrinos (tonne-scale DM detectors)

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Supernova neutrinos

- Energy transport in supernovae: all neutrino flavors with E ~ tens-of-MeV
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Reactor physics

- Reactor fluxes & monitoring (below IBD threshold)
- Application for non-proliferation

Neutrino Sources

for CEνNS

Requirements:

- High flux
- Neutrino production well understood
- Low background rates
- Multiple flavors
- etc

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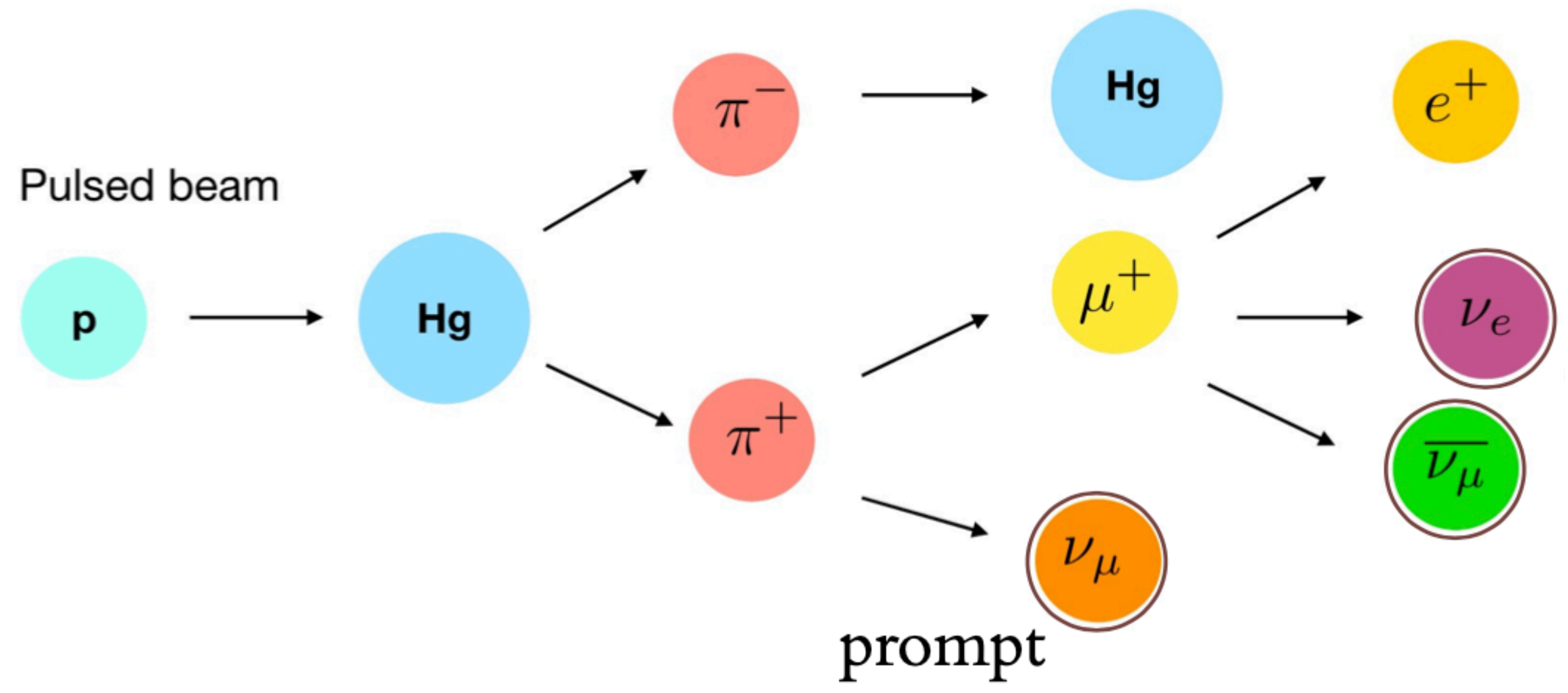


- Stopped-pion beams

Pion-decay-at-rest neutrino source:
neutrinos are produced from the decay of pions and muons

- intermediate neutrino energies (~ 30 MeV)
- slightly incoherent
- pulsed beam for background rejection

Neutrino Sources

for CEνNS

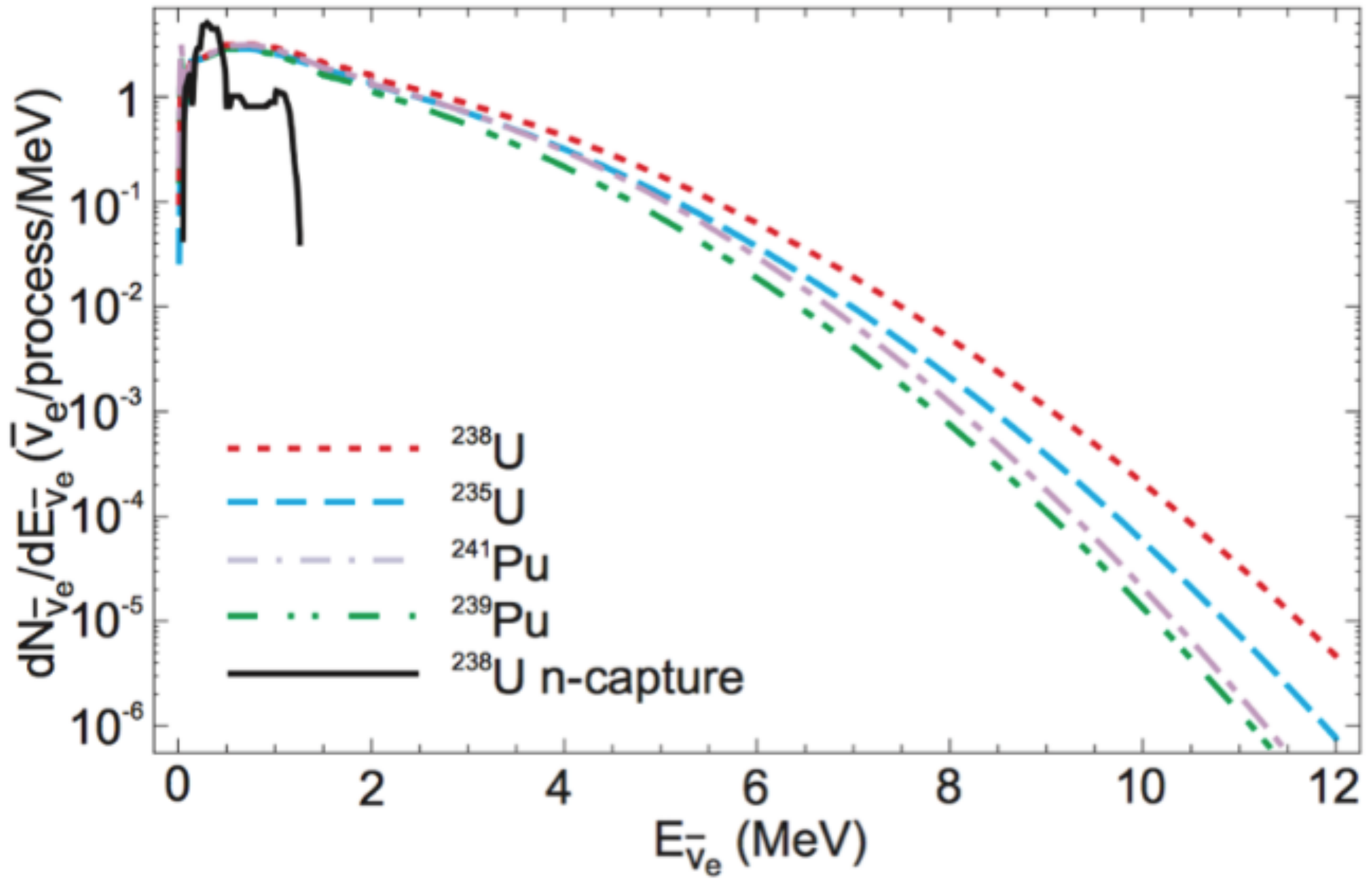
Requirements:

- High flux
- Neutrino production well understood
- Low background rates
- Multiple flavors
- etc

Nuclear reactors

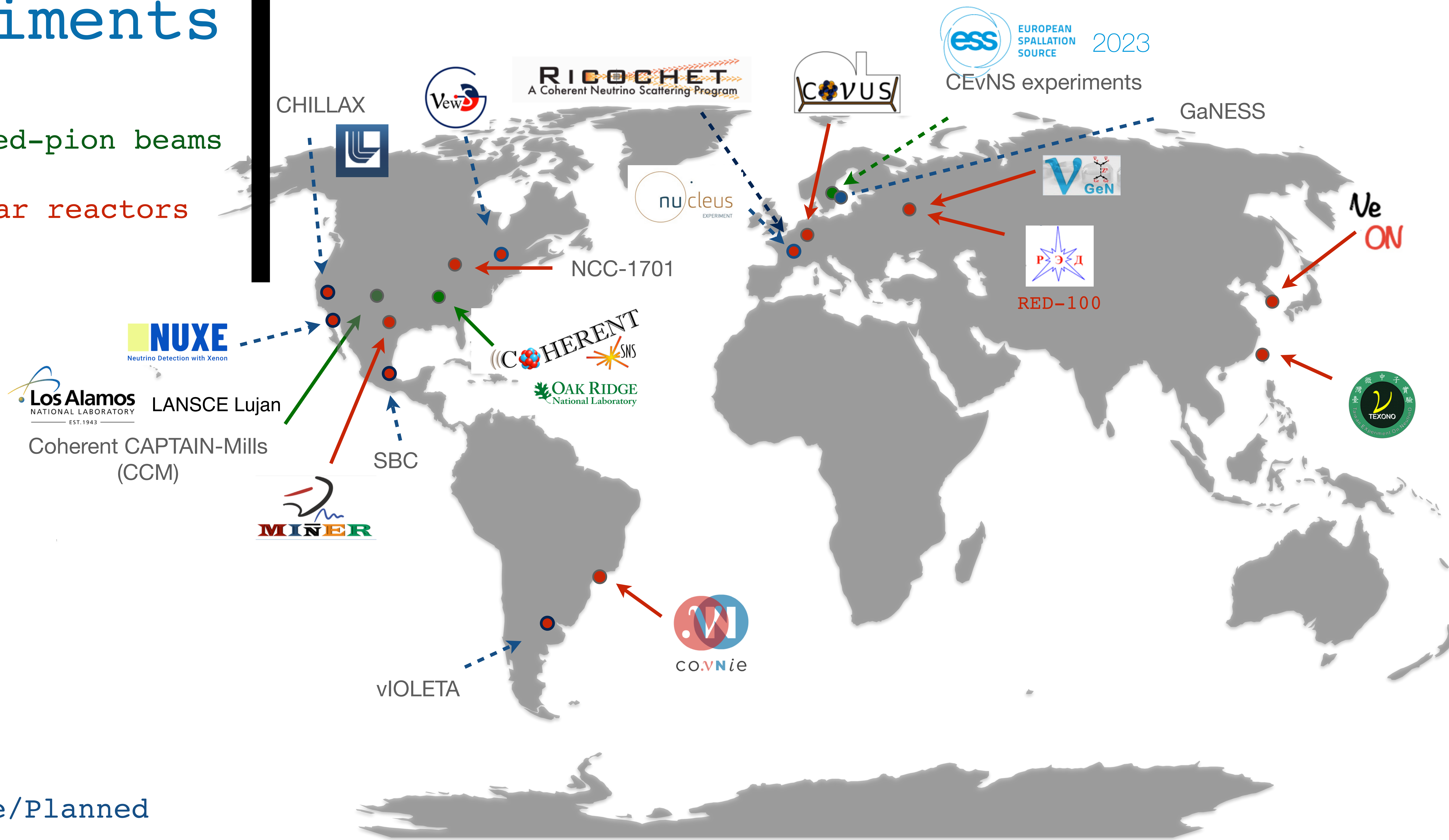
Neutrinos are produced in beta decays of fission fragments

- high flux ~ 10^{20} ν/s (power reactors)
- Intense @ MeV energies (up to 10 MeV)
- Clean in background, active and passive shielding



Experiments

- Stopped-pion beams
- Nuclear reactors



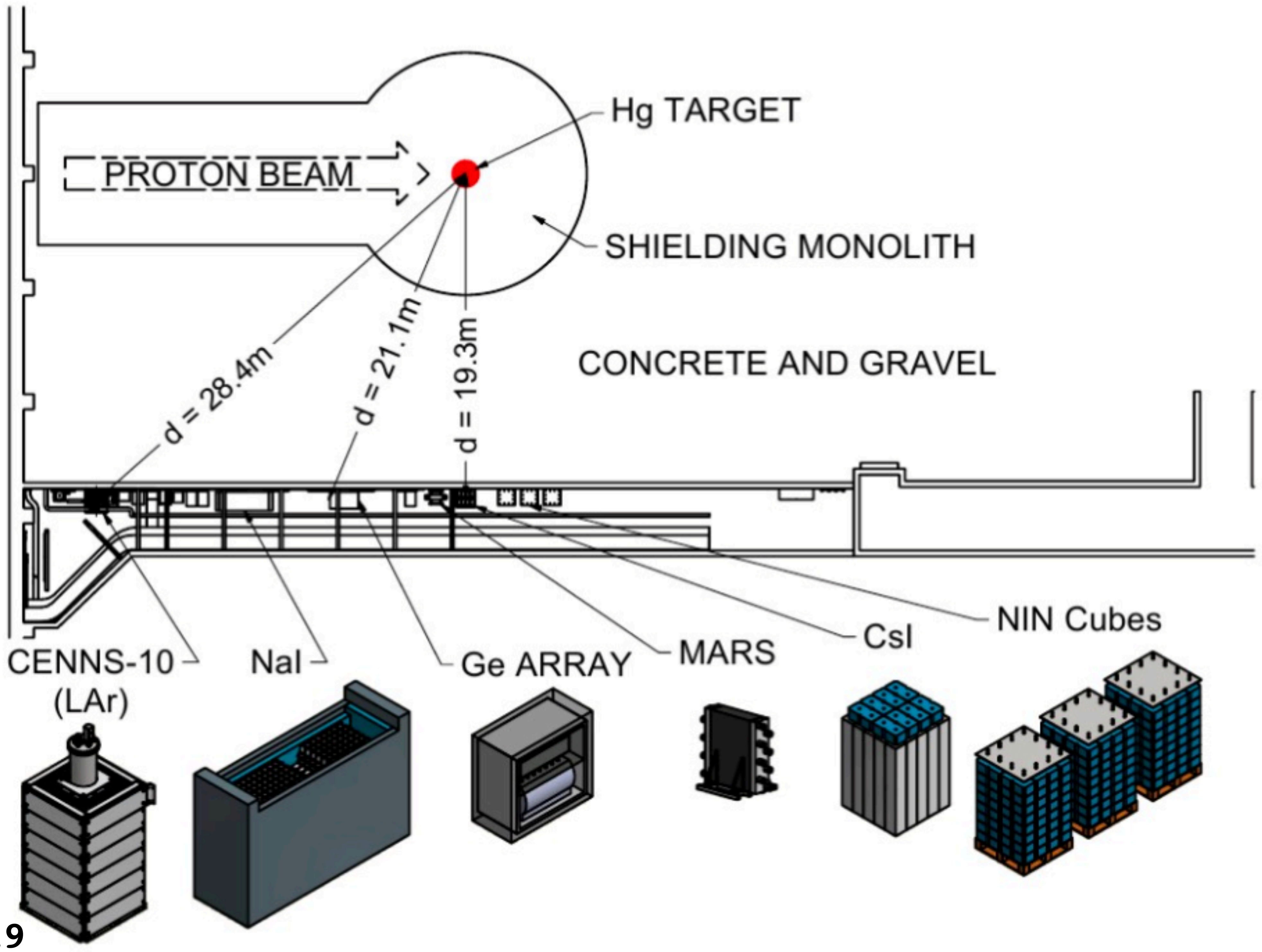
- Future/Planned

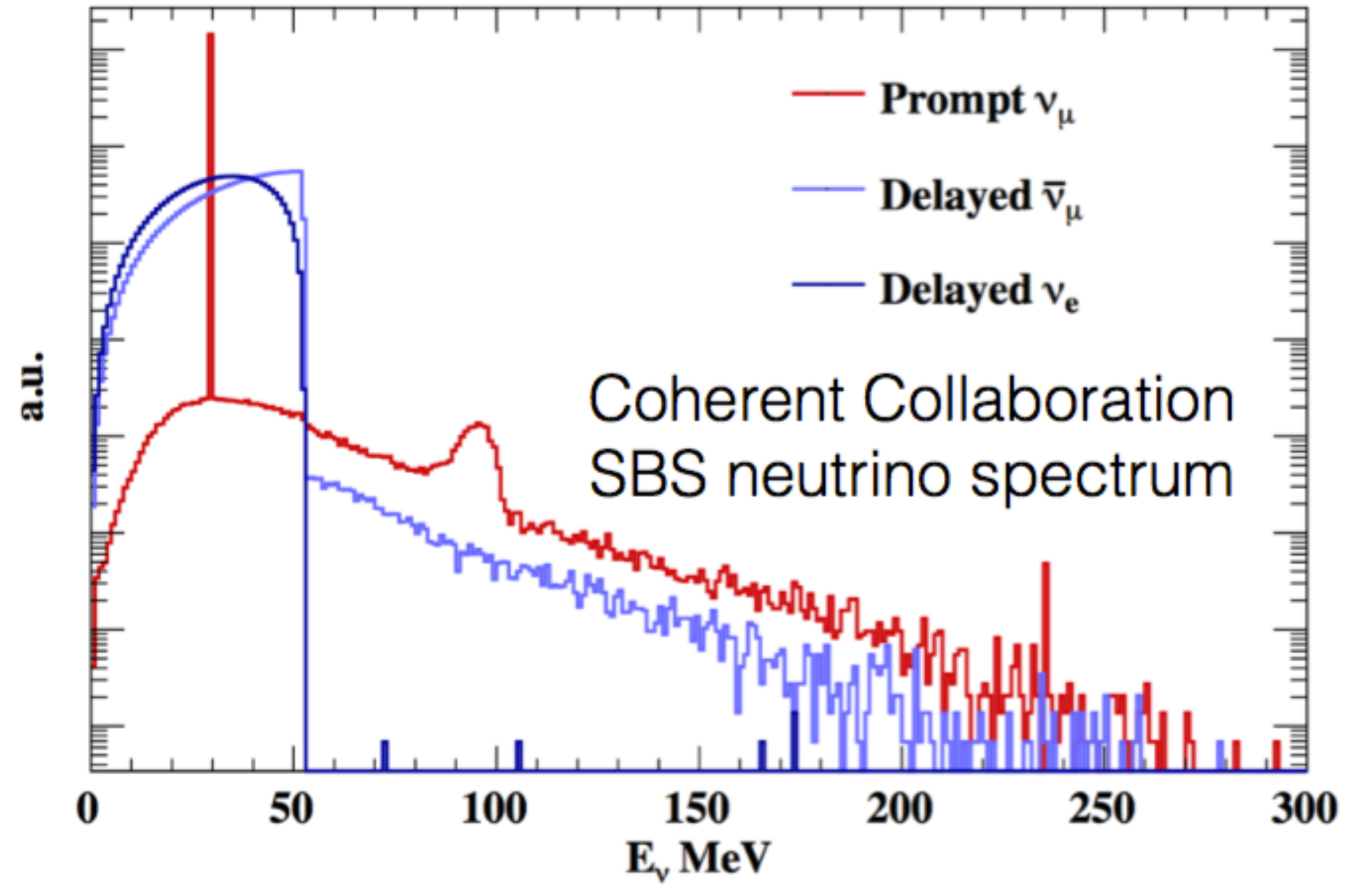
Stopped-pion beam experiments

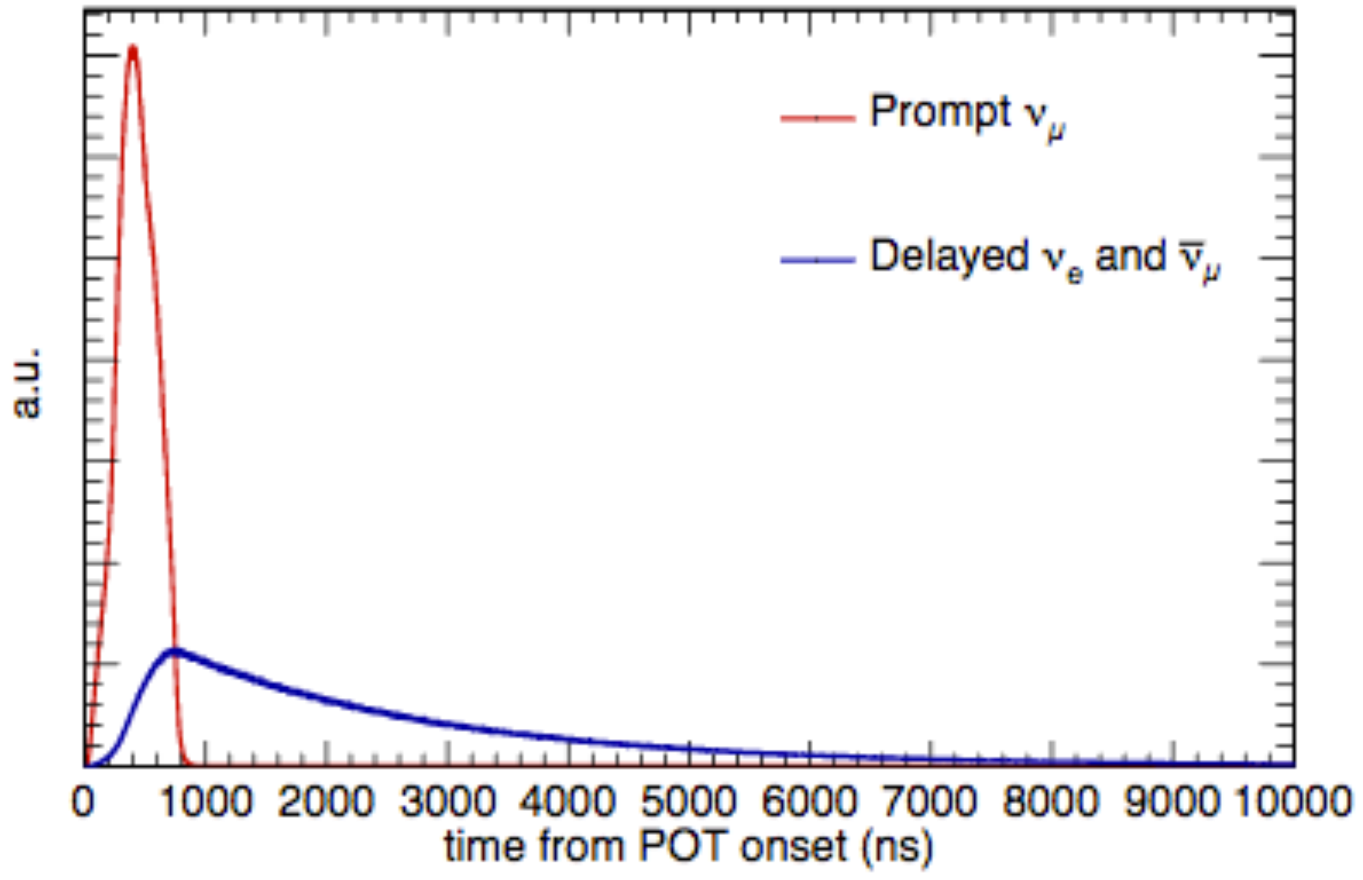
Stopped-pion beam experiments

COHERENT Experiment — SNS

- Spallation Neutron Source – 1 GeV proton beam
- Pion-decay-at-rest neutrino source
  - prompt monochromatic ~ 30 MeV
- Pulsed beam @ 60Hz for background rejection (factor ~ 10^4)
- Multi-target program to measure N^2 dependence



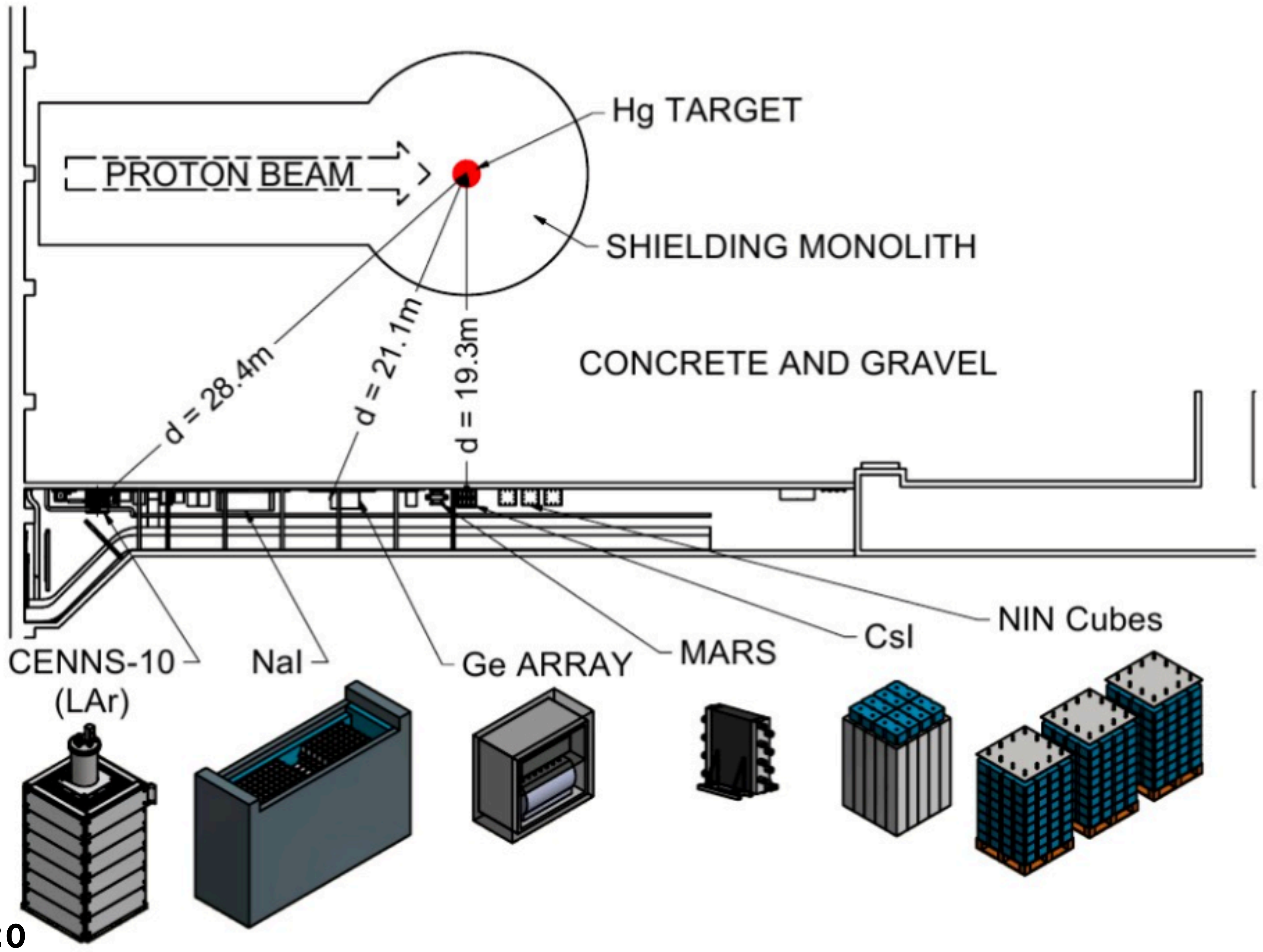


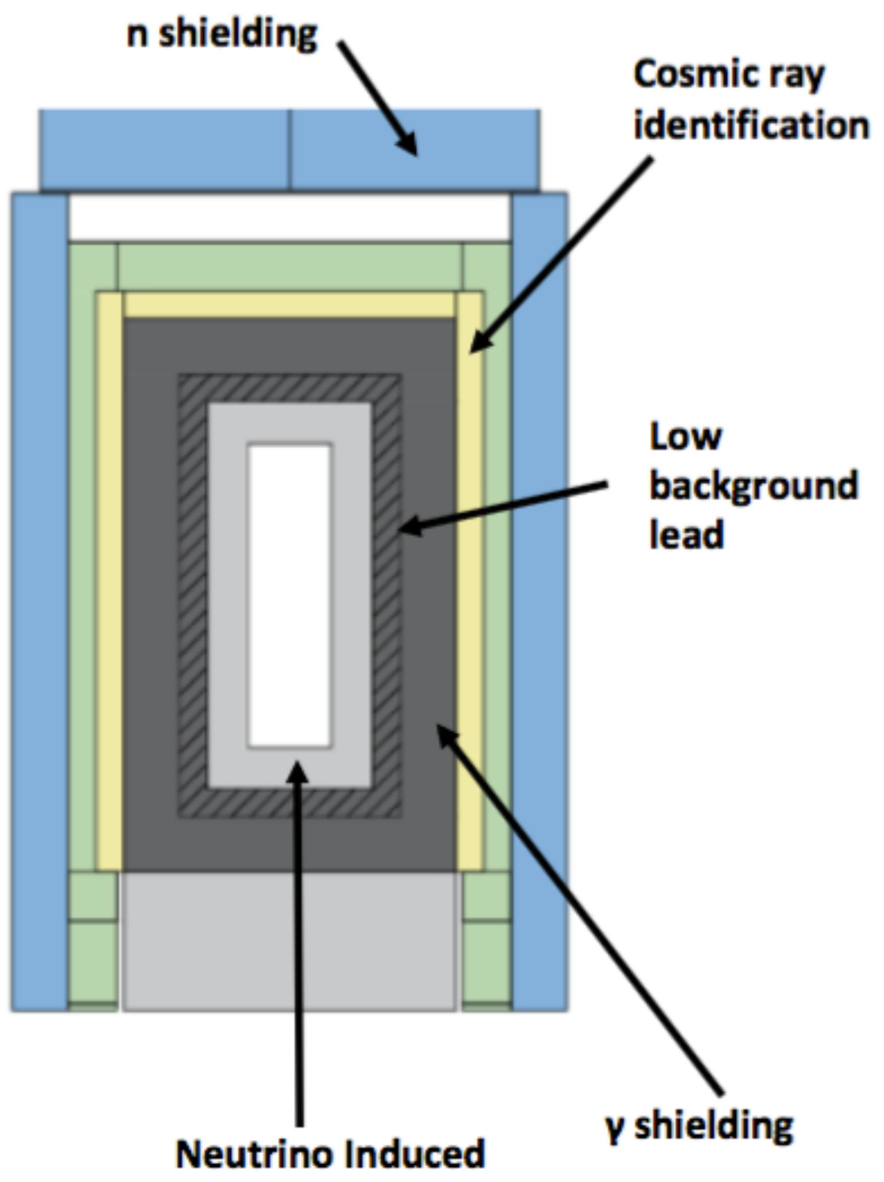


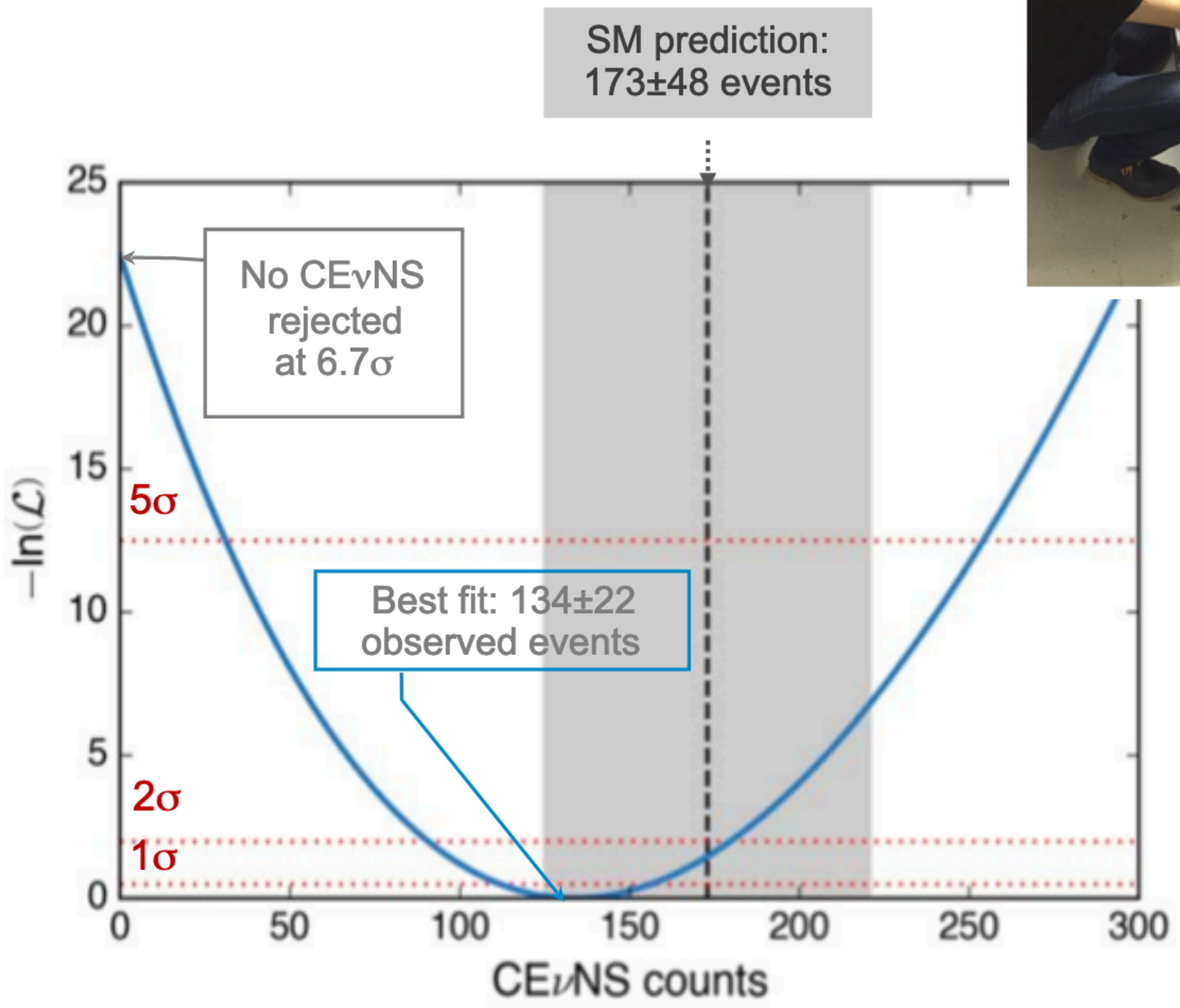
Stopped-pion beam experiments

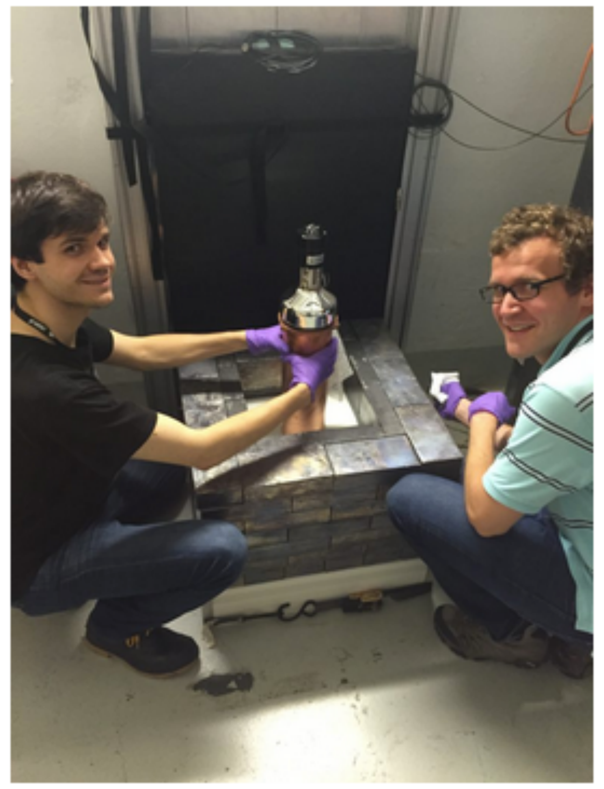
COHERENT CsI

- 2017 First CEνNS detection
- 14.6 kg CsI scintillating cristal
- 19.3 m from the source
- 134 ± 22 events observed (173 ± 48 predicted)
- 6.7σ significance







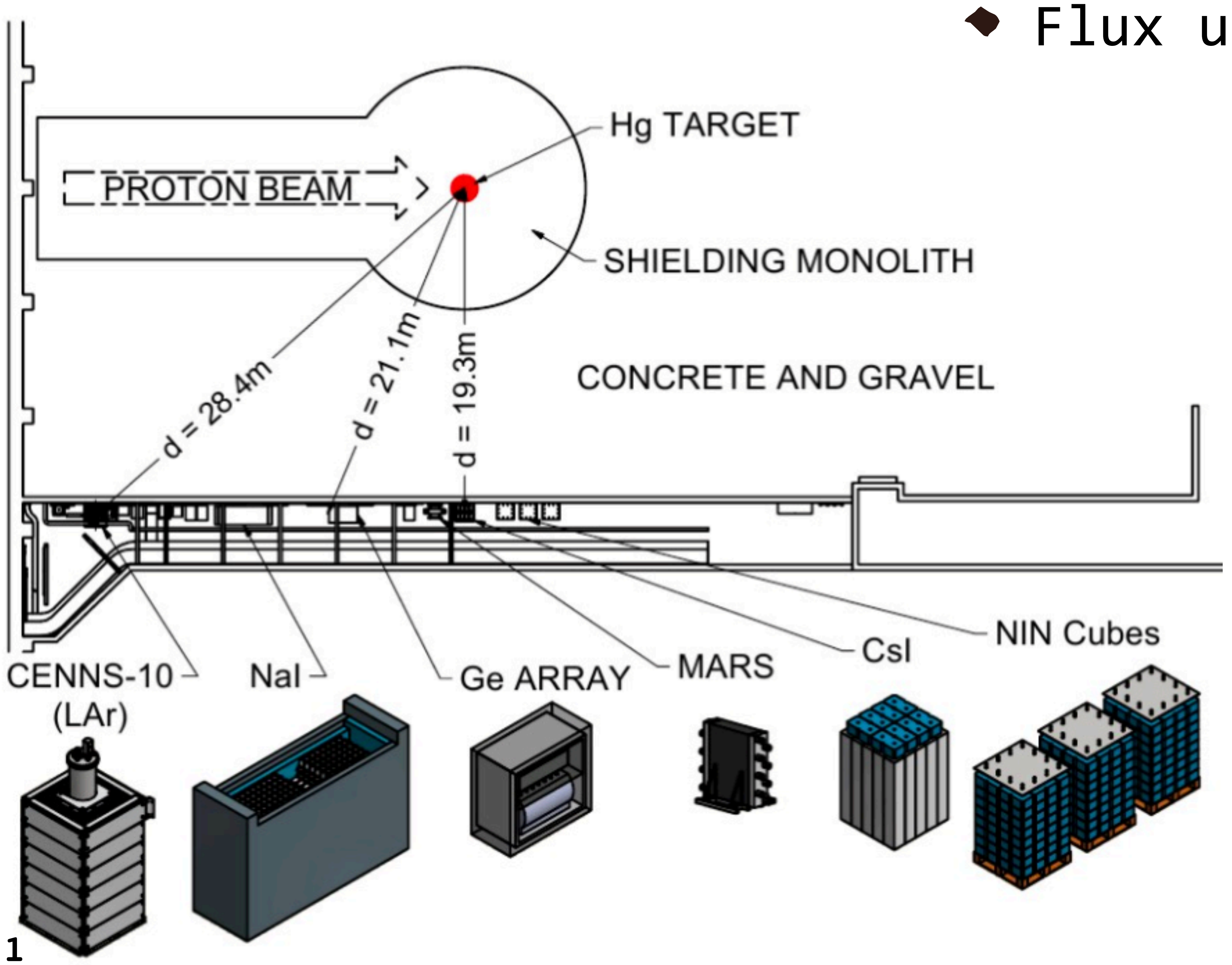


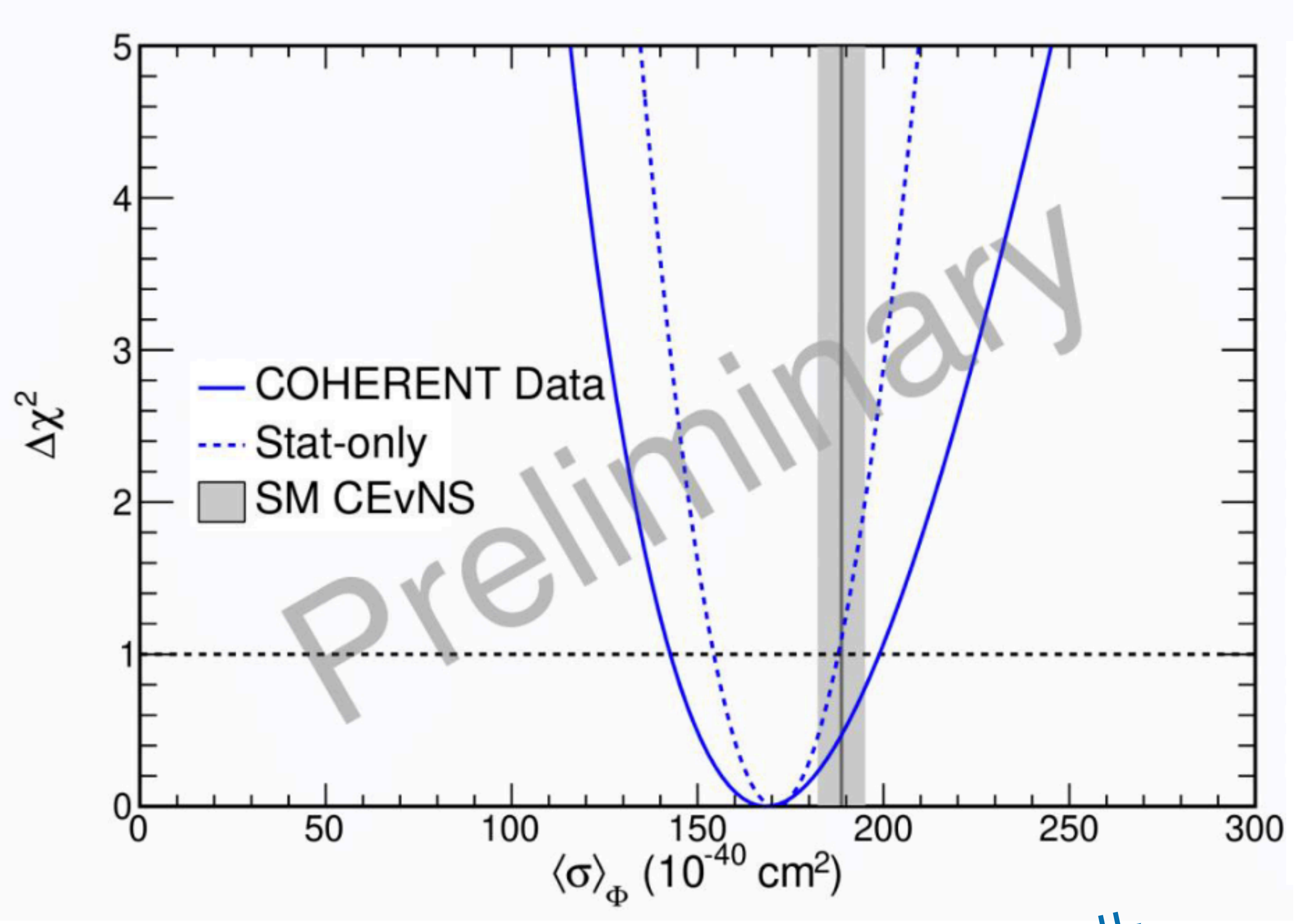
M. Green @ Magnificent CEvNS 2019

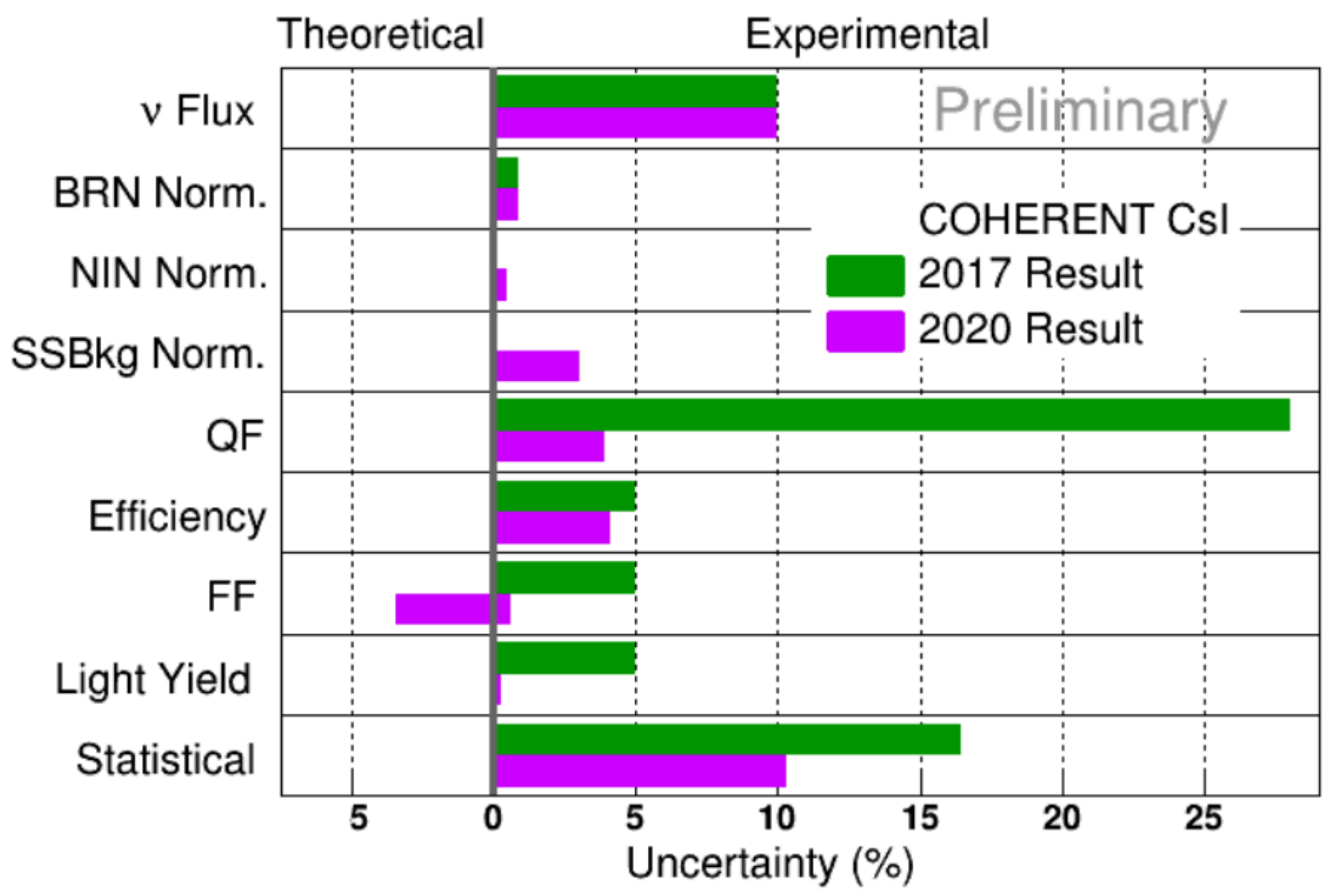
Stopped-pion beam experiments

COHERENT CsI 2020

- 2020 More statistics! +2x
- Better signal reconstruction
- 306 ± 20 events observed (333 ± 11 (th) ± 42 (ex) predicted)
- No CEνNS rejection: 11.6σ
- Result consistent with SM prediction at 1σ
- Flux uncertainty dominates the systematic uncertainties (13%)







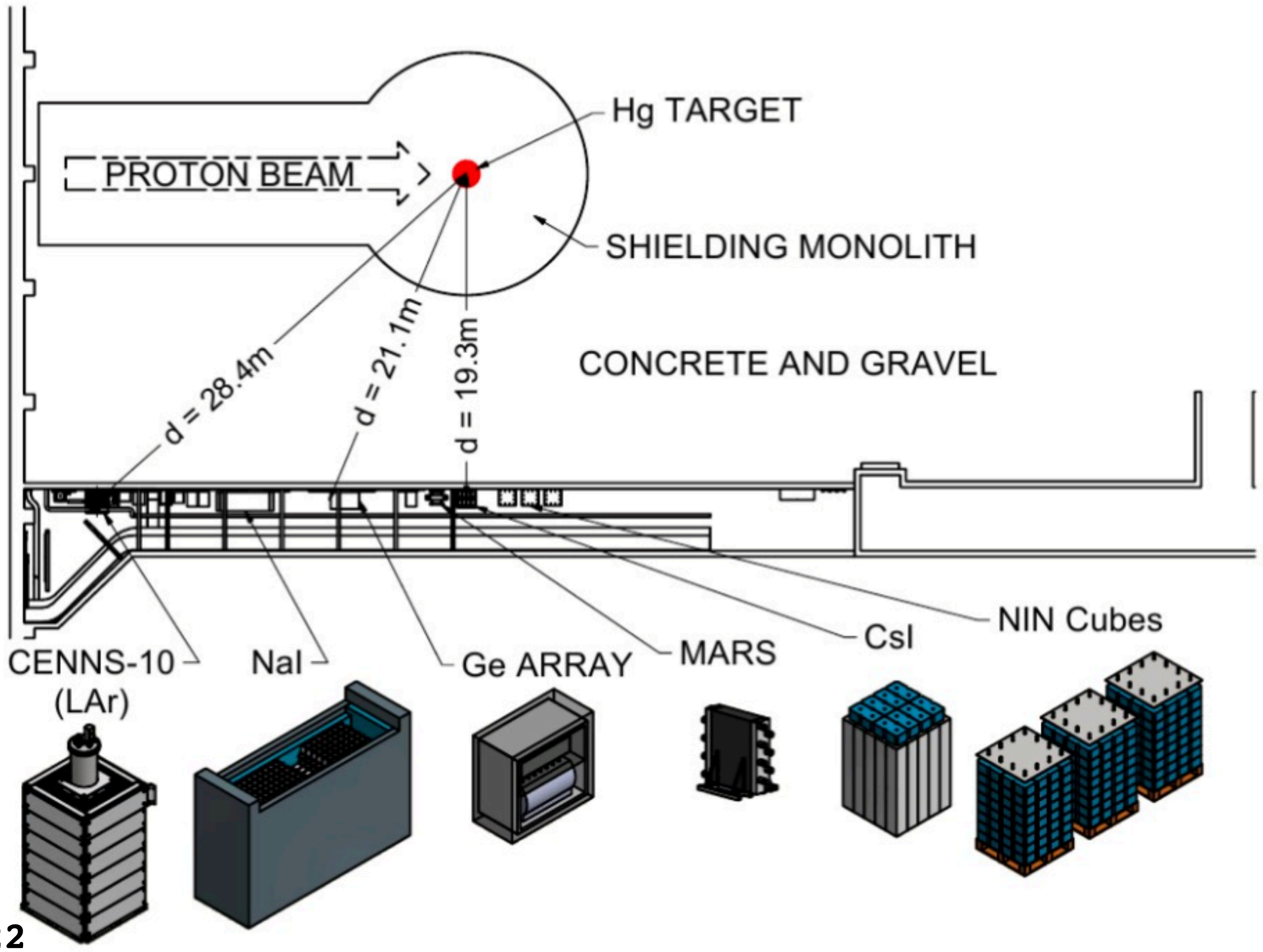
See Daniel Pershey's talk
New results from COHERENT

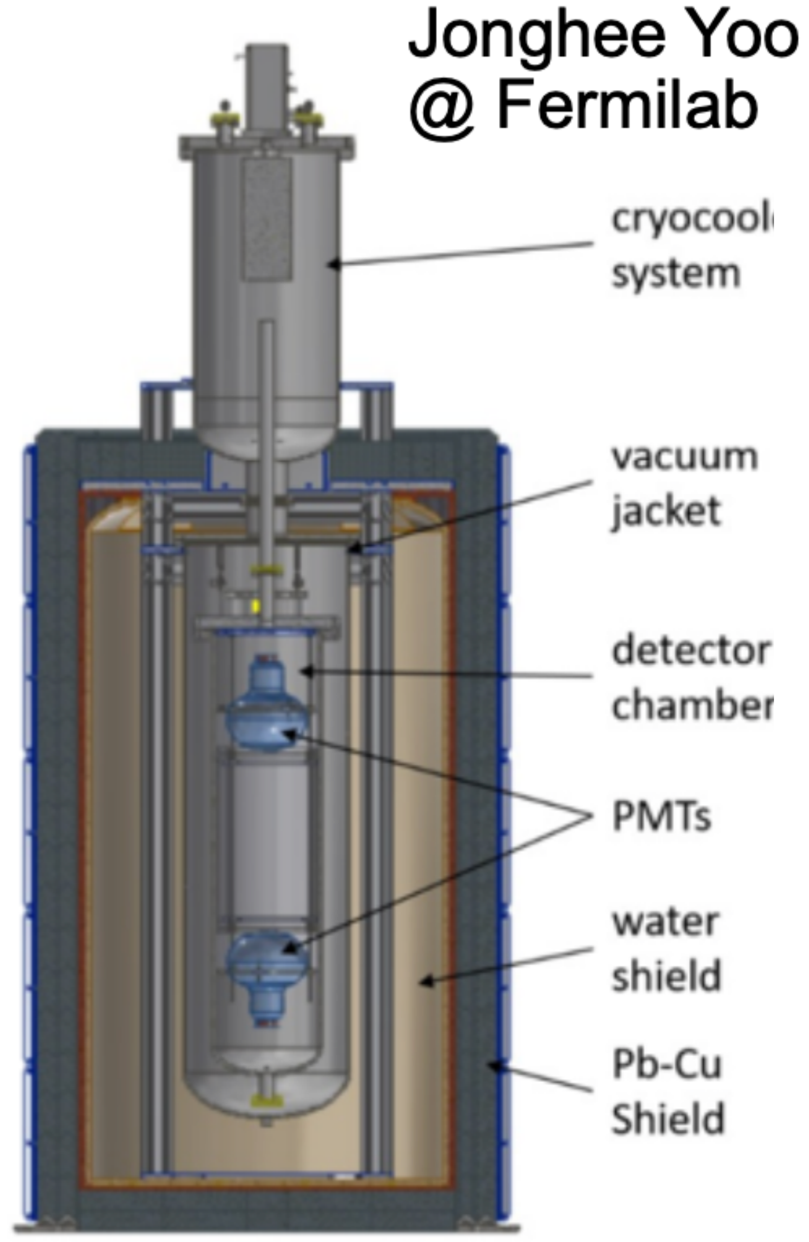
D. Pershey @ Magnificent CEvNS 2020

Stopped-pion beam experiments

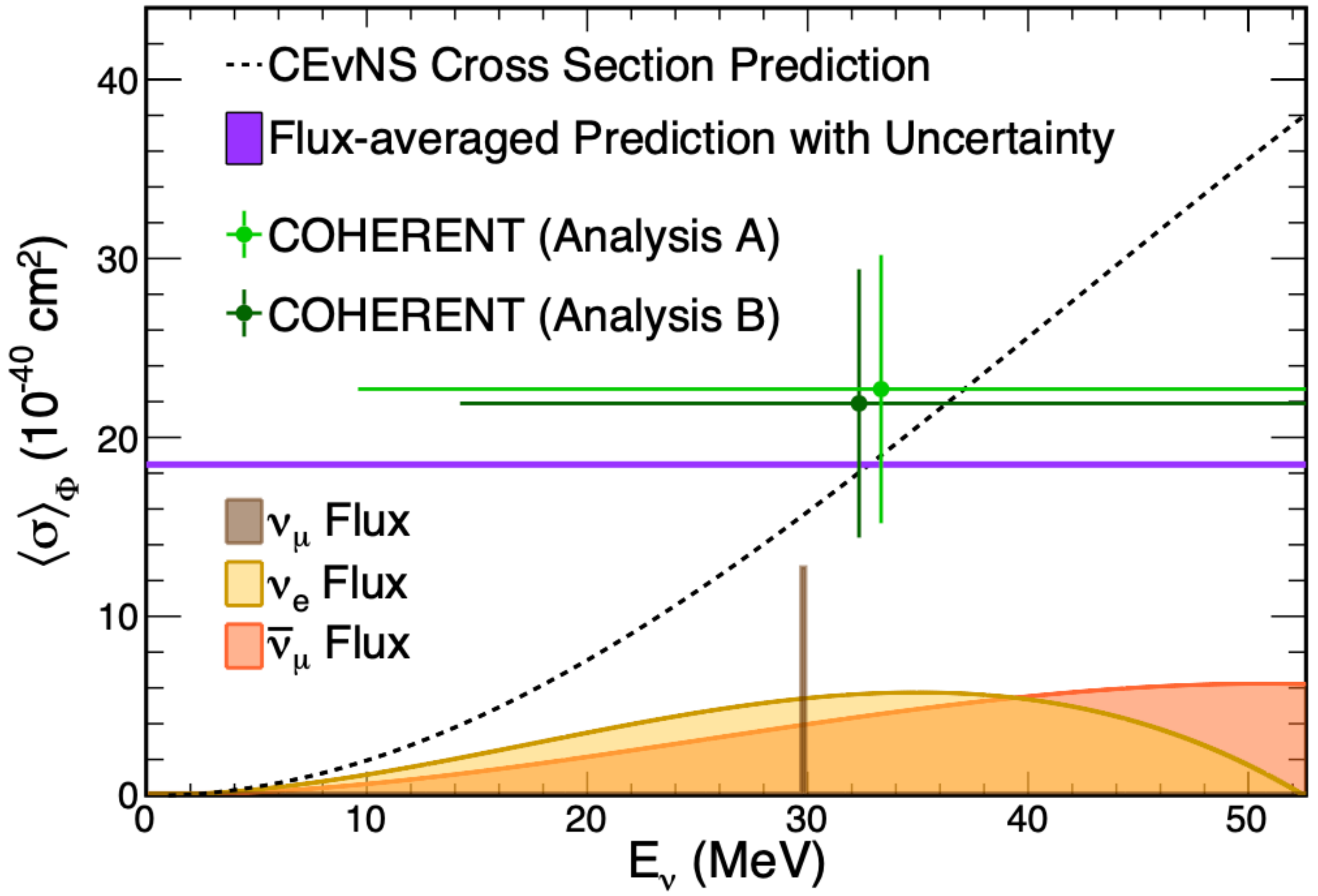
COHERENT in Argon

- 2020 first results with he CENNS-10 detector
- Active mass 24 kg at 27.5 m from the source
- Single phase only (scintillation) with a threshold at 20 keV_{nr}
- 2 independent blind analyses
- 3σ CEνNS detection significance





Cross section = $(2.3 \pm 0.7)10^{-39}$ cm^2



COHERENT, Phys. Rev. Lett. 126, 012002 (2021)

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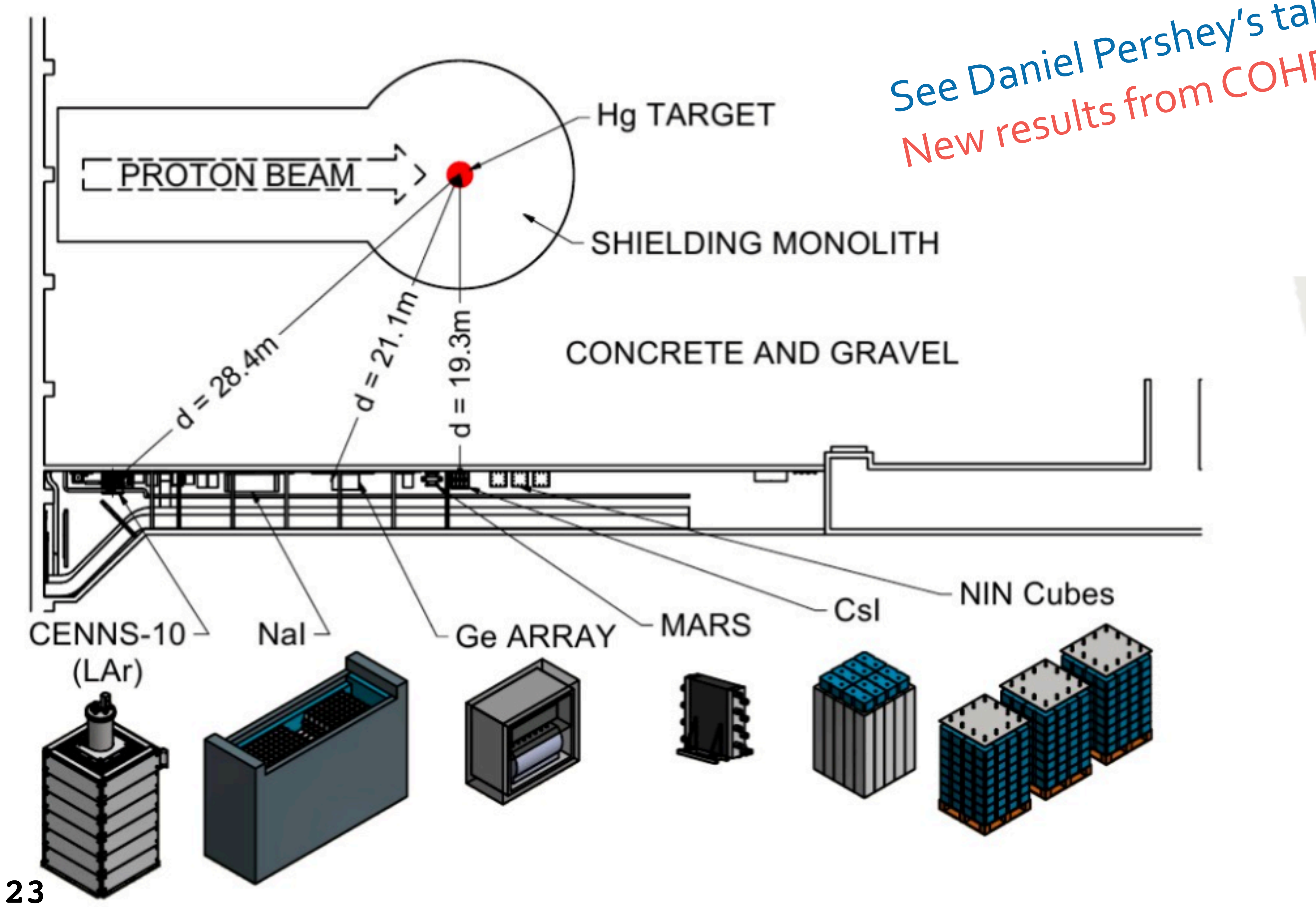

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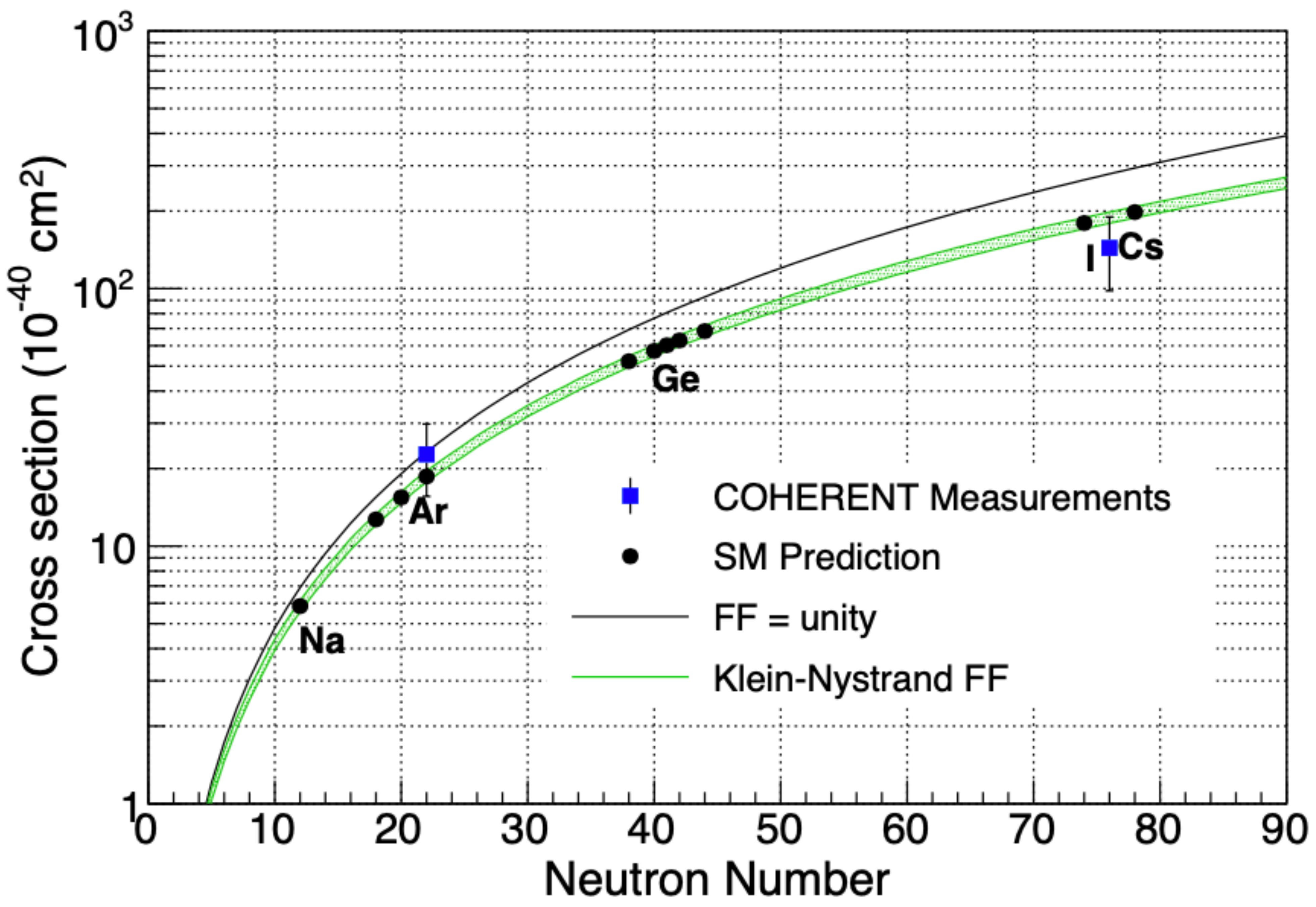
New results from COHERENT

First confirmation of SM prediction of N² dependence !



J. Newby @ Neutrino2020

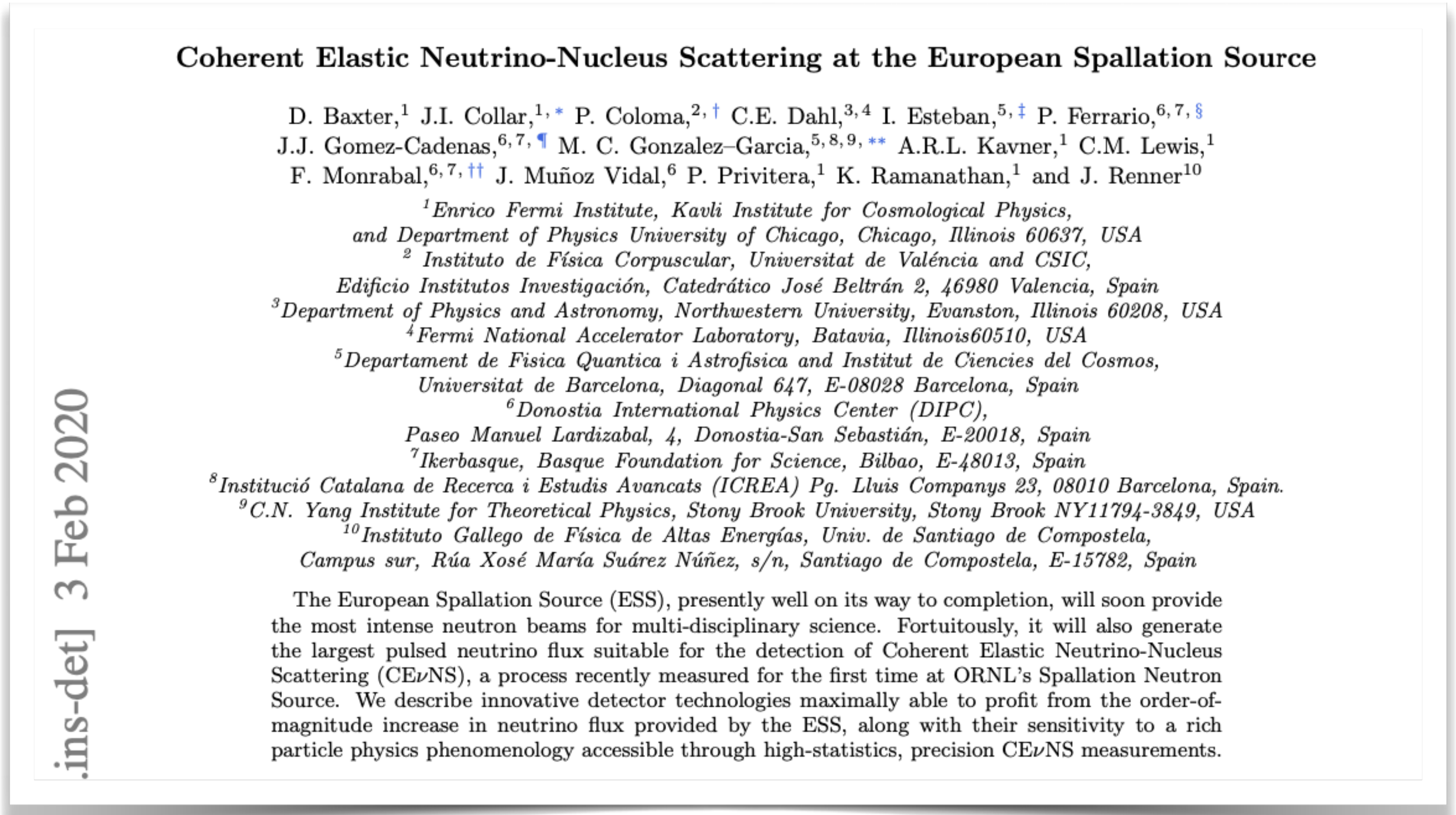
Stopped-pion beam experiments

Ongoing and new experiments

European Spallation Source

- Gaseous detector for Neutrino physics at the ESS (GaNESS)

- Other proposed projects
  ex: JHEP 2020,123 (2020);
  arXiv:1911.00762



Coherent Elastic Neutrino-Nucleus Scattering at the European Spallation Source

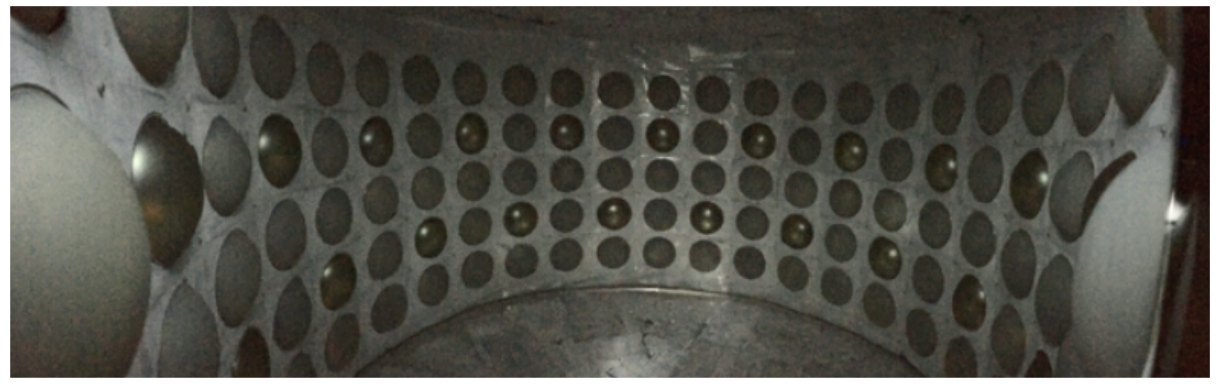
D. Baxter,[1] J.I. Collar,[1,*] P. Coloma,[2,†] C.E. Dahl,[3,4] I. Esteban,[5,‡] P. Ferrario,[6,7,§] J.J. Gomez-Cadenas,[6,7,¶] M. C. Gonzalez–Garcia,[5,8,9,**] A.R.L. Kavner,[1] C.M. Lewis,[1] F. Monrabal,[6,7,††] J. Muñoz Vidal,[6] P. Privitera,[1] K. Ramanathan,[1] and J. Renner[10]

[1]Enrico Fermi Institute, Kavli Institute for Cosmological Physics, and Department of Physics University of Chicago, Chicago, Illinois 60637, USA
[2] Instituto de Física Corpuscular, Universitat de Valéncia and CSIC, Edificio Institutos Investigación, Catedrático José Beltrán 2, 46980 Valencia, Spain
[3]Department of Physics and Astronomy, Northwestern University, Evanston, Illinois 60208, USA
[4]Fermi National Accelerator Laboratory, Batavia, Illinois60510, USA
[5]Departament de Fisica Quantica i Astrofisica and Institut de Ciencies del Cosmos, Universitat de Barcelona, Diagonal 647, E-08028 Barcelona, Spain
[6]Donostia International Physics Center (DIPC), Paseo Manuel Lardizabal, 4, Donostia-San Sebastián, E-20018, Spain
[7]Ikerbasque, Basque Foundation for Science, Bilbao, E-48013, Spain
[8]Institució Catalana de Recerca i Estudis Avancats (ICREA) Pg. Lluis Companys 23, 08010 Barcelona, Spain.
[9]C.N. Yang Institute for Theoretical Physics, Stony Brook University, Stony Brook NY11794-3849, USA
[10]Instituto Gallego de Física de Altas Energías, Univ. de Santiago de Compostela, Campus sur, Rúa Xosé María Suárez Núñez, s/n, Santiago de Compostela, E-15782, Spain

The European Spallation Source (ESS), presently well on its way to completion, will soon provide the most intense neutron beams for multi-disciplinary science. Fortuitously, it will also generate the largest pulsed neutrino flux suitable for the detection of Coherent Elastic Neutrino-Nucleus Scattering (CEνNS), a process recently measured for the first time at ORNL's Spallation Neutron Source. We describe innovative detector technologies maximally able to profit from the order-of-magnitude increase in neutrino flux provided by the ESS, along with their sensitivity to a rich particle physics phenomenology accessible through high-statistics, precision CEνNS measurements.

.ins-det] 3 Feb 2020

Lujan Center @ LANSCE



- Coherent CAPTAIN-Mills (CCM)
  - 10-ton liquid Argon detector
  - Energy threshold ~ 50 keV
  - To be improved to 20-30 keV by LAr purification
  - Data taking since 2021

Nuclear Reactor experiments

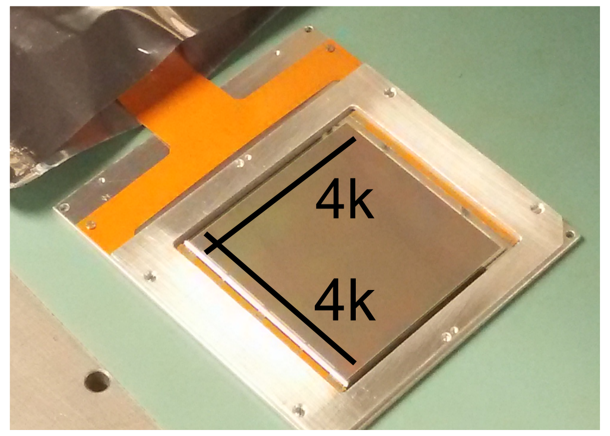
Silicon
Charge Coupled Devices (CCDs)

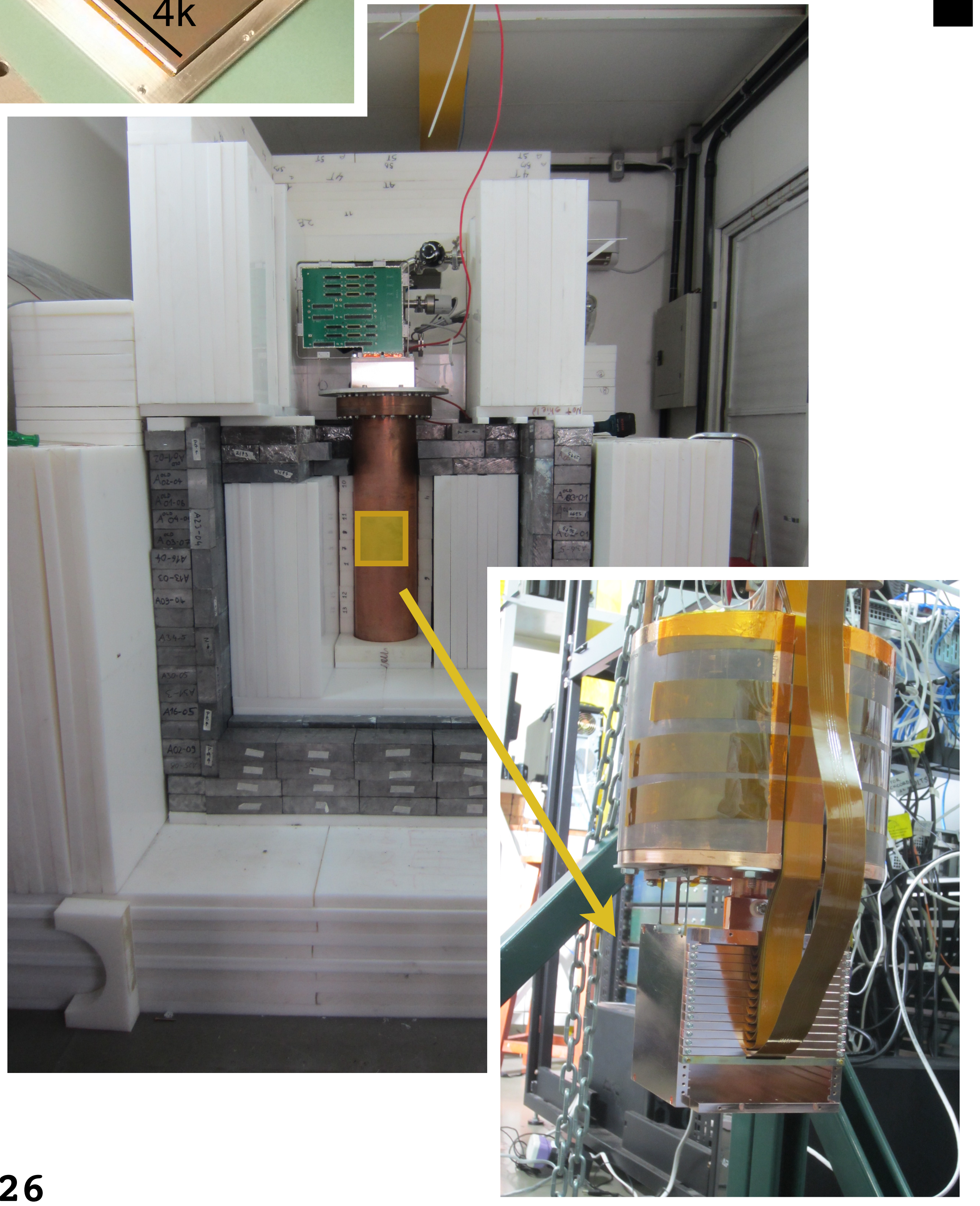
Nuclear reactors

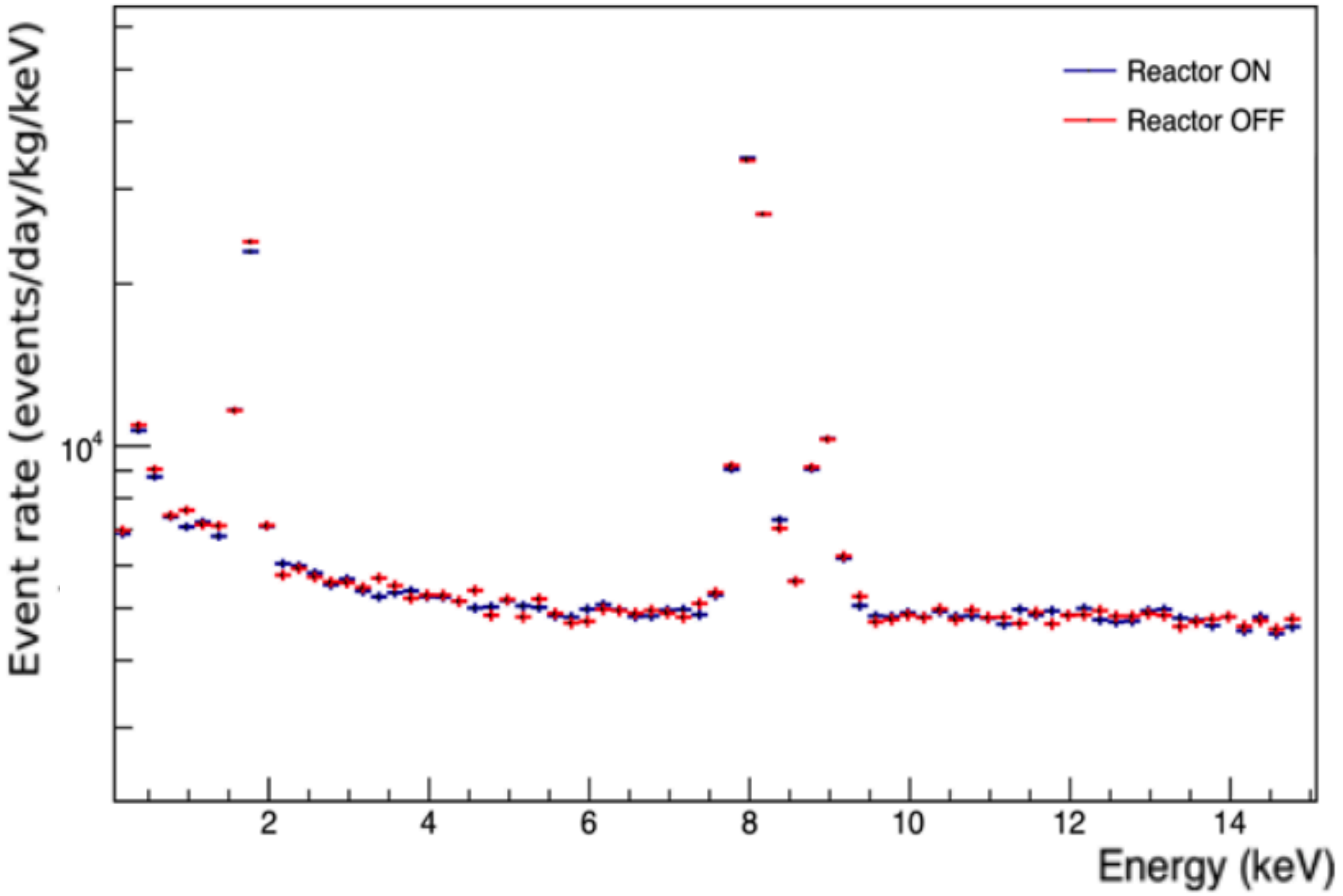
COherent Neutrino-Nucleus Interaction Experiment

CONNIE

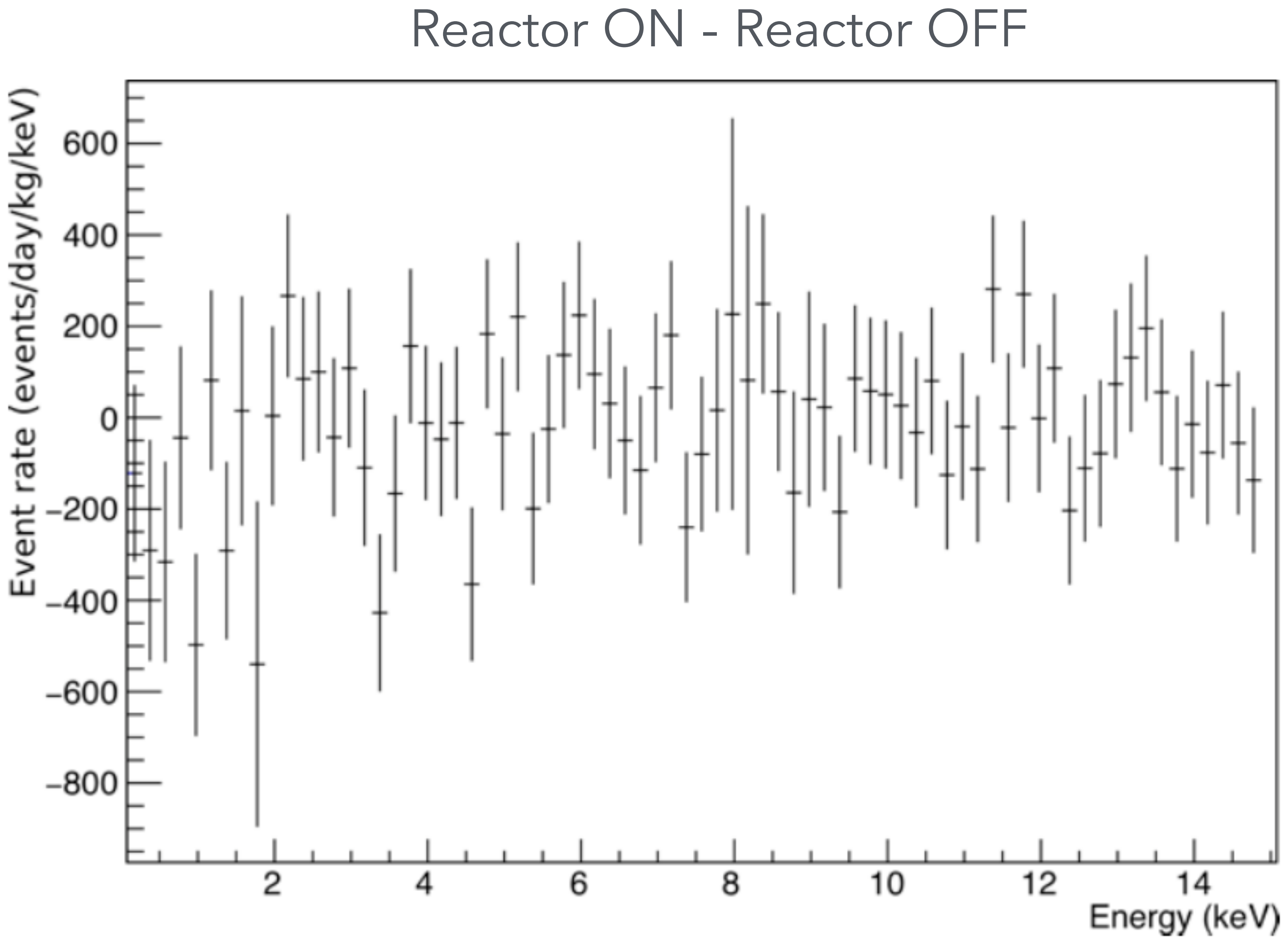
- Experiment @ 30 m from the 3.9 GW reactor core
- Reactor-OFF periods (~1/14 months) for background measurements
- Flux: $\sim 10^{12}\ \bar{\nu}_e\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$
- 14 CCDs of 6 g each
- Passive shield (Lead + polyethylene)
- Energy threshold ~ 50-70 eV_{ee}







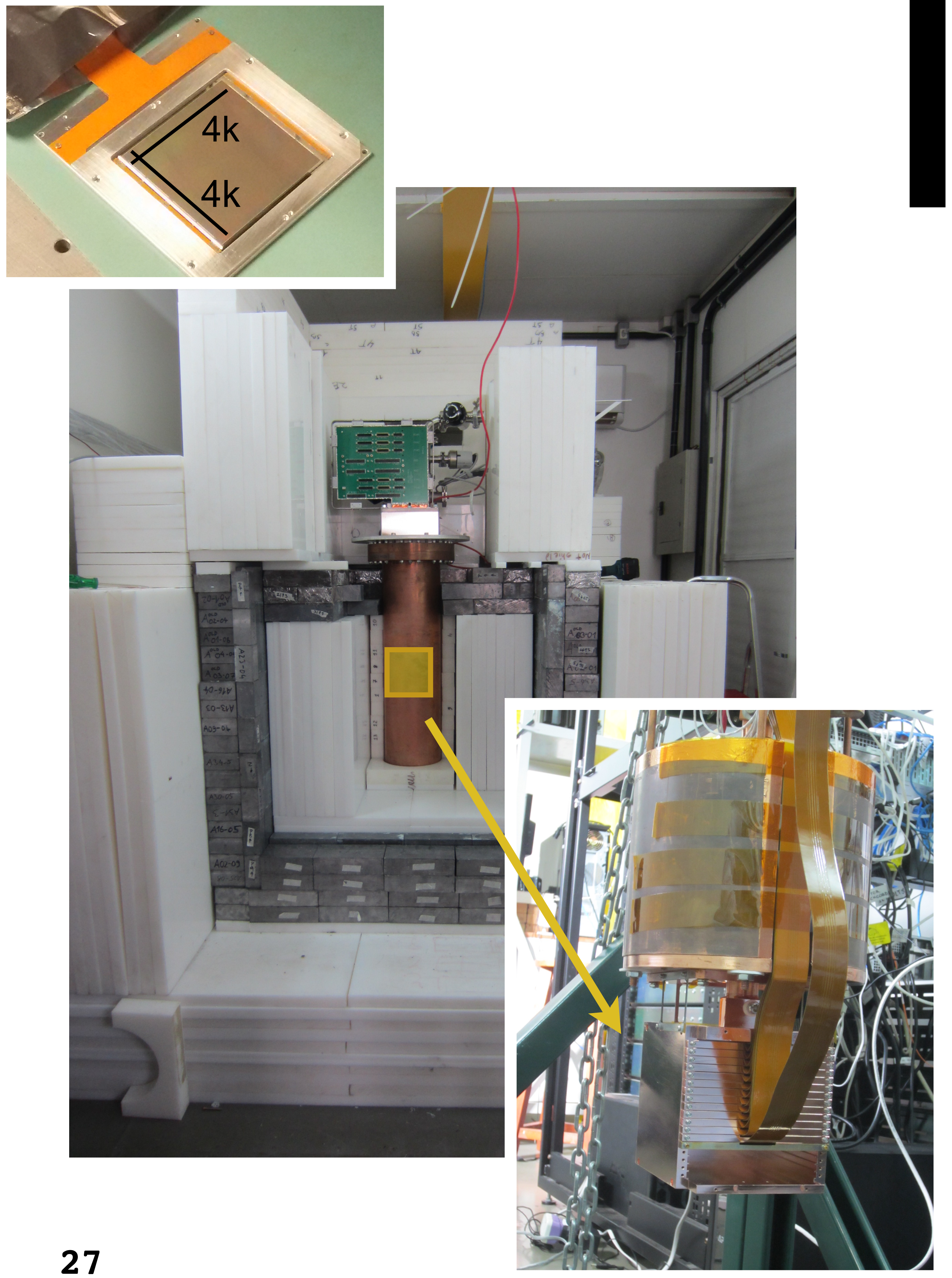
CONNIE, PRD 100, 092005 (2019)

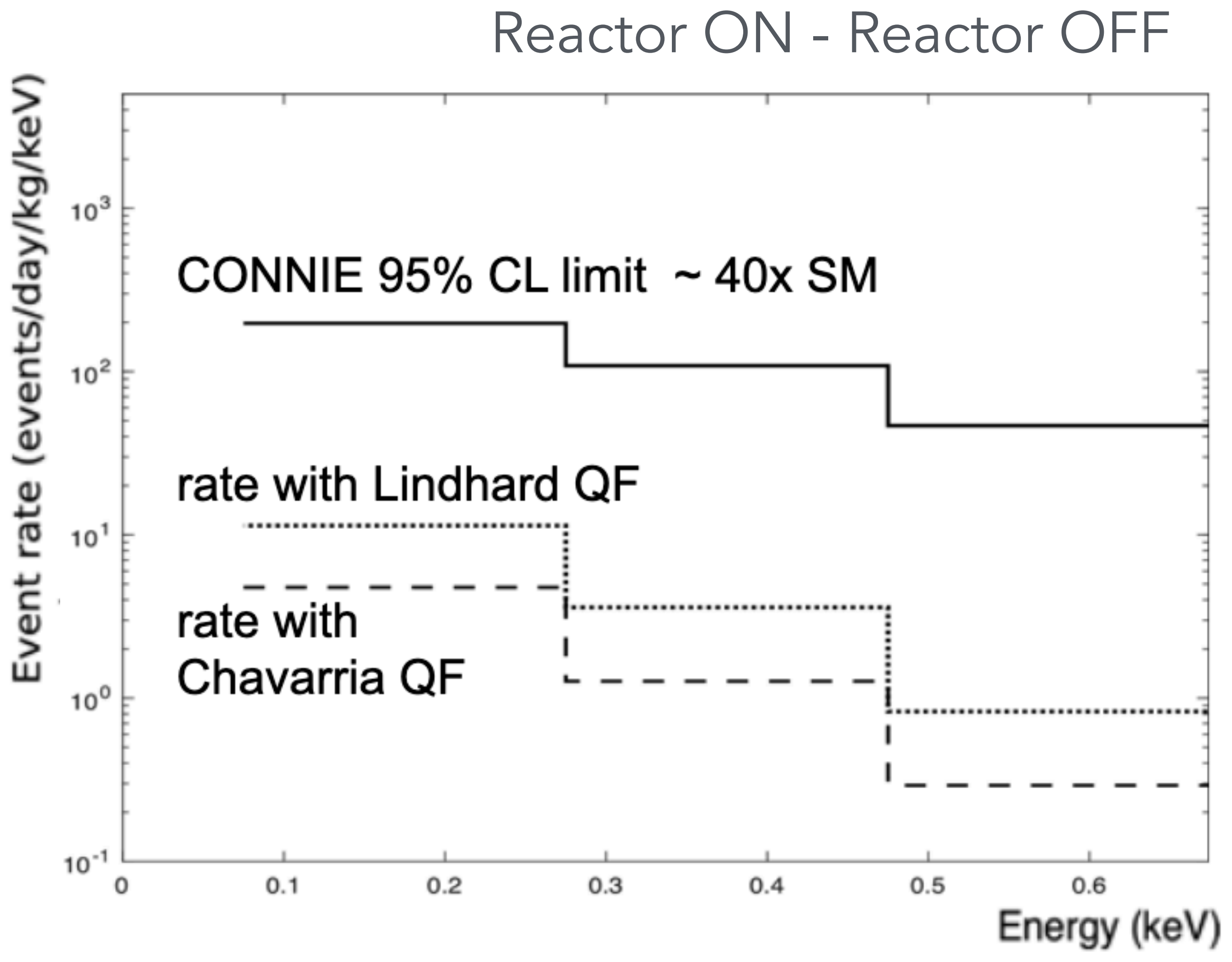


Nuclear reactors

CONNIE — 2016-2018

co.νNie





CONNIE, PRD 100, 092005 (2019)

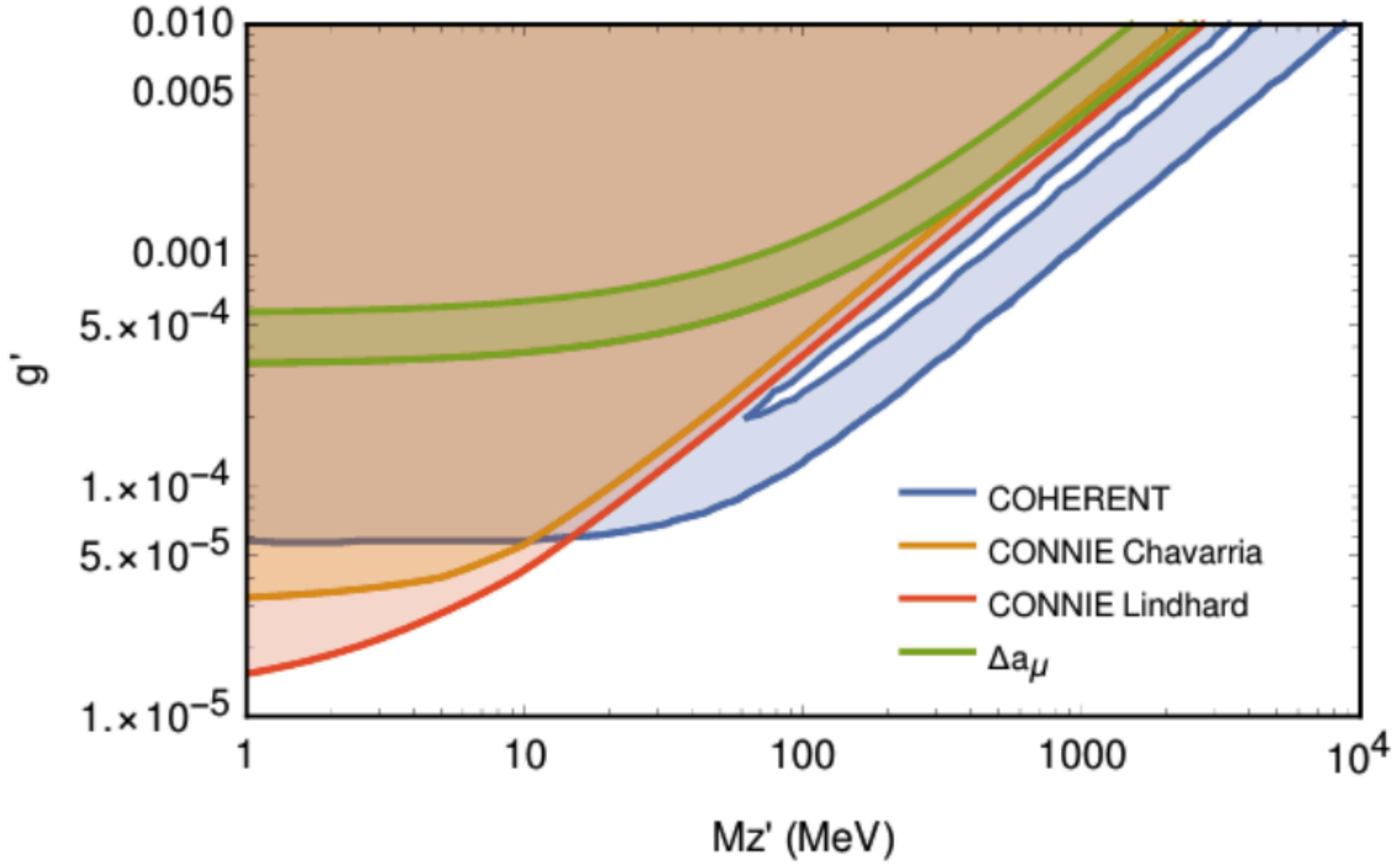
- Active mass 47.6 g.
- Reactor ON (2.1 kg-day) vs Reactor OFF (1.6 kg-day).
- Event rates in the lowest-energy bin yield limits on non-standard neutrino interactions

NEUTRINO 2022
XXX International Conference on Neutrino Physics and Astrophysics
May 30 - June 4, 2022
Virtual Seoul

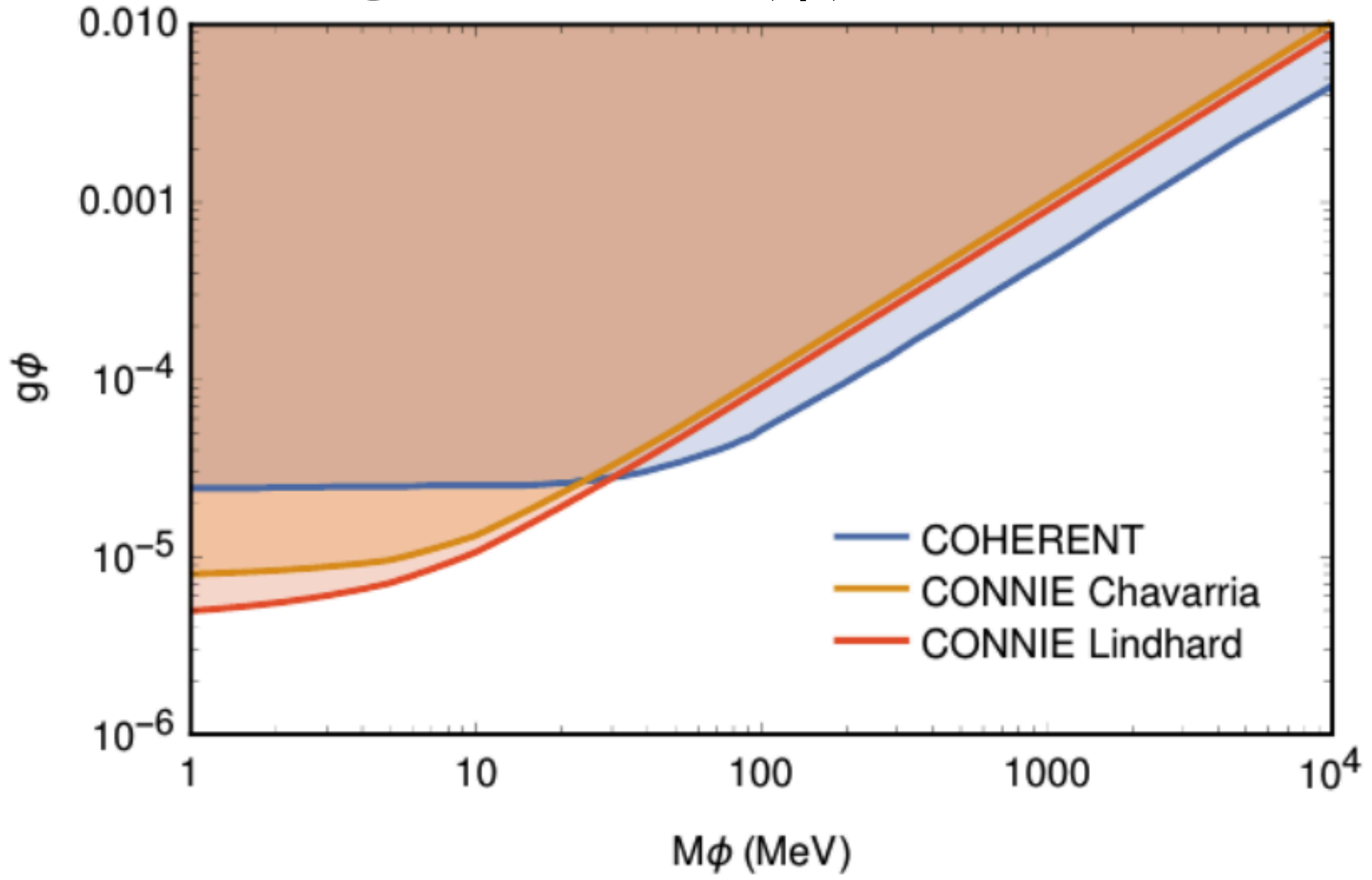
6F Dirac, DT06-556

- First competitive BSM constraints from CEvNS at reactors

Light vector (Z') mediator



Light scalar (ϕ) mediator

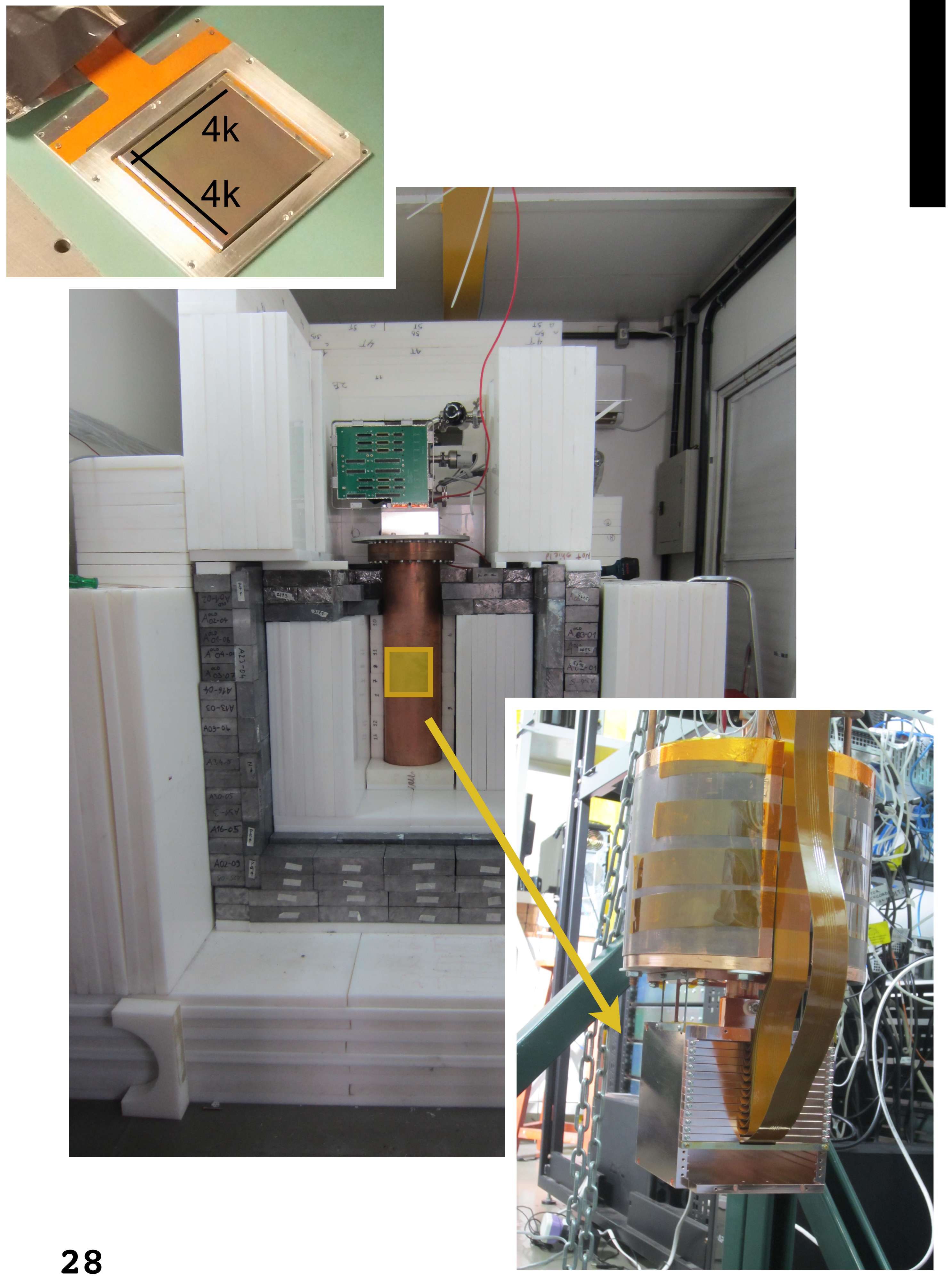


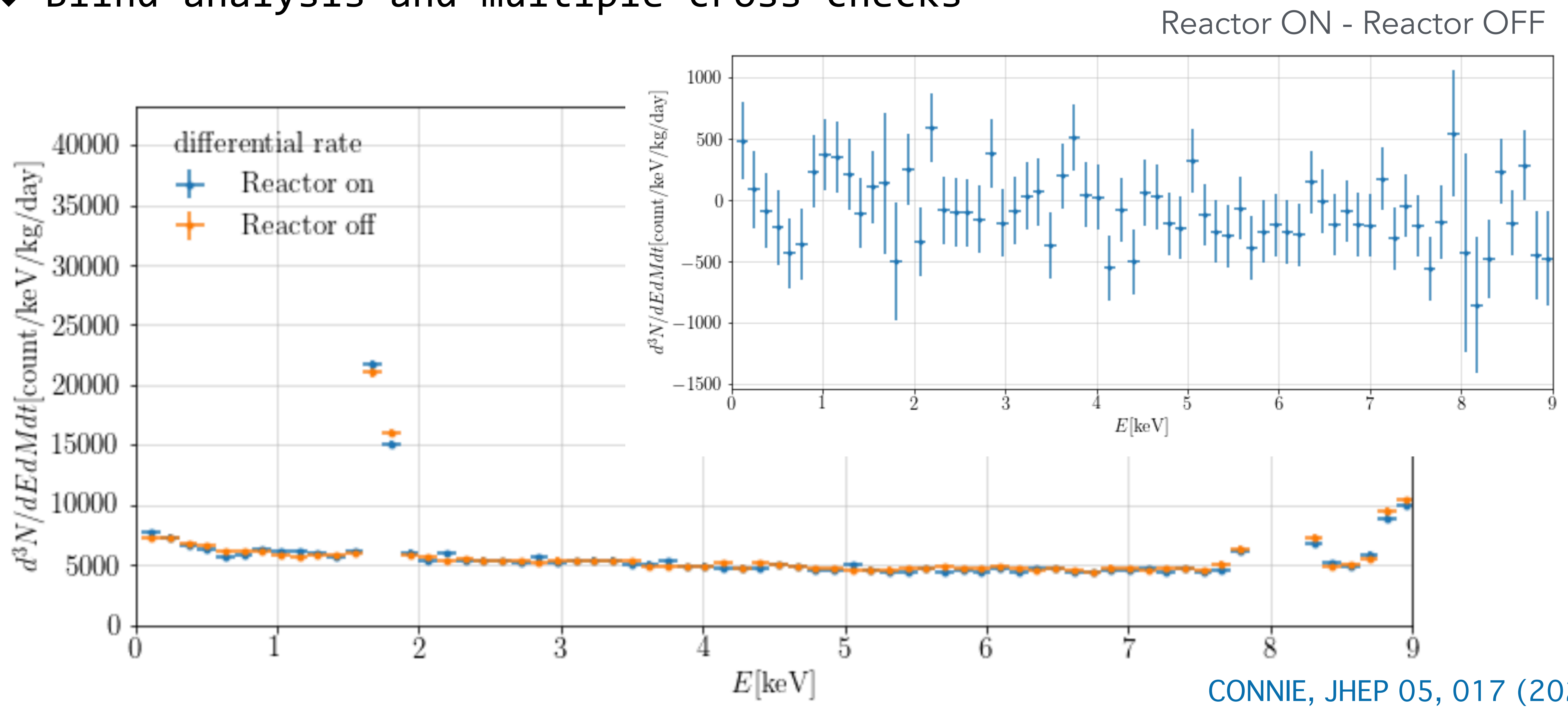
CONNIE, JHEP 04, 054 (2020)

Nuclear reactors

CONNIE — 2019

- 1x5 pixel hardware re-binning to improve acceptance and selection efficiency at low energy
  - Full efficiency reached at 100-150 eV
- Low-energy background reduction
  - 3 times lower image exposure to reduce the single electron rate
  - Improved size-depth calibration (Large low-energy events and partial-charge-collection layer)
- Blind analysis and multiple cross-checks



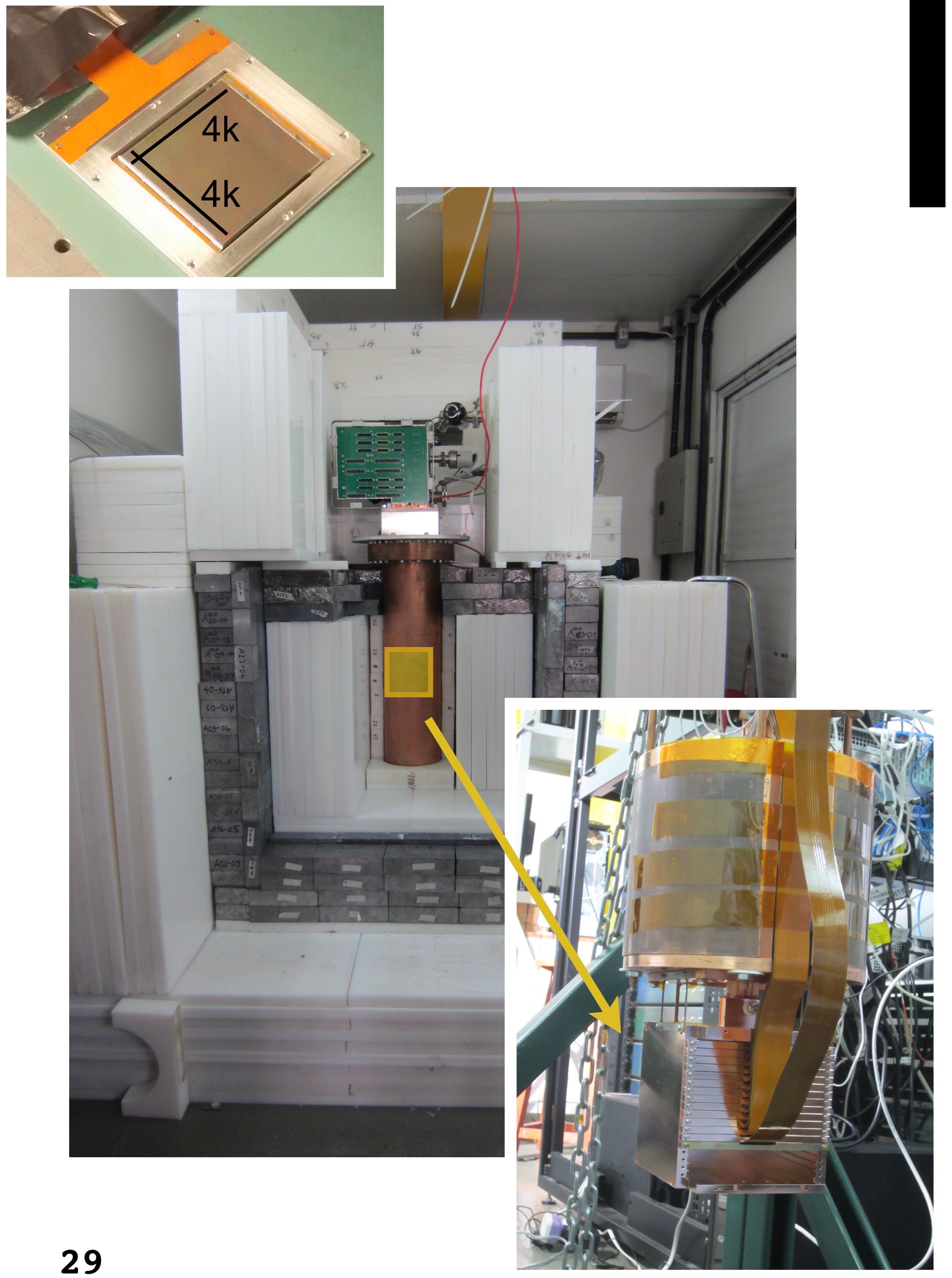


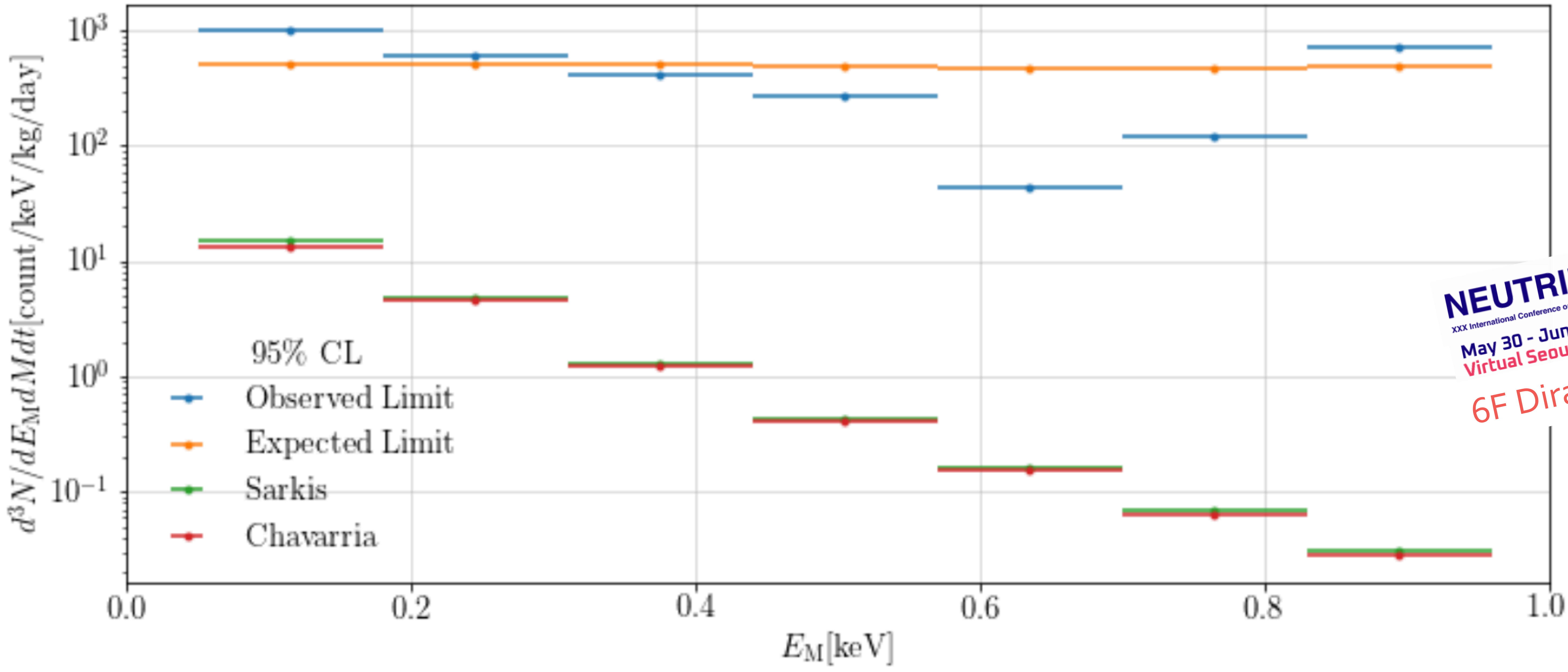
CONNIE, JHEP 05, 017 (2020)

Nuclear reactors

CONNIE — 2019

- Rate difference at low energies yields upper limits at 95% CL on the measured neutrino rate





CONNIE, JHEP 05, 017 (2020)

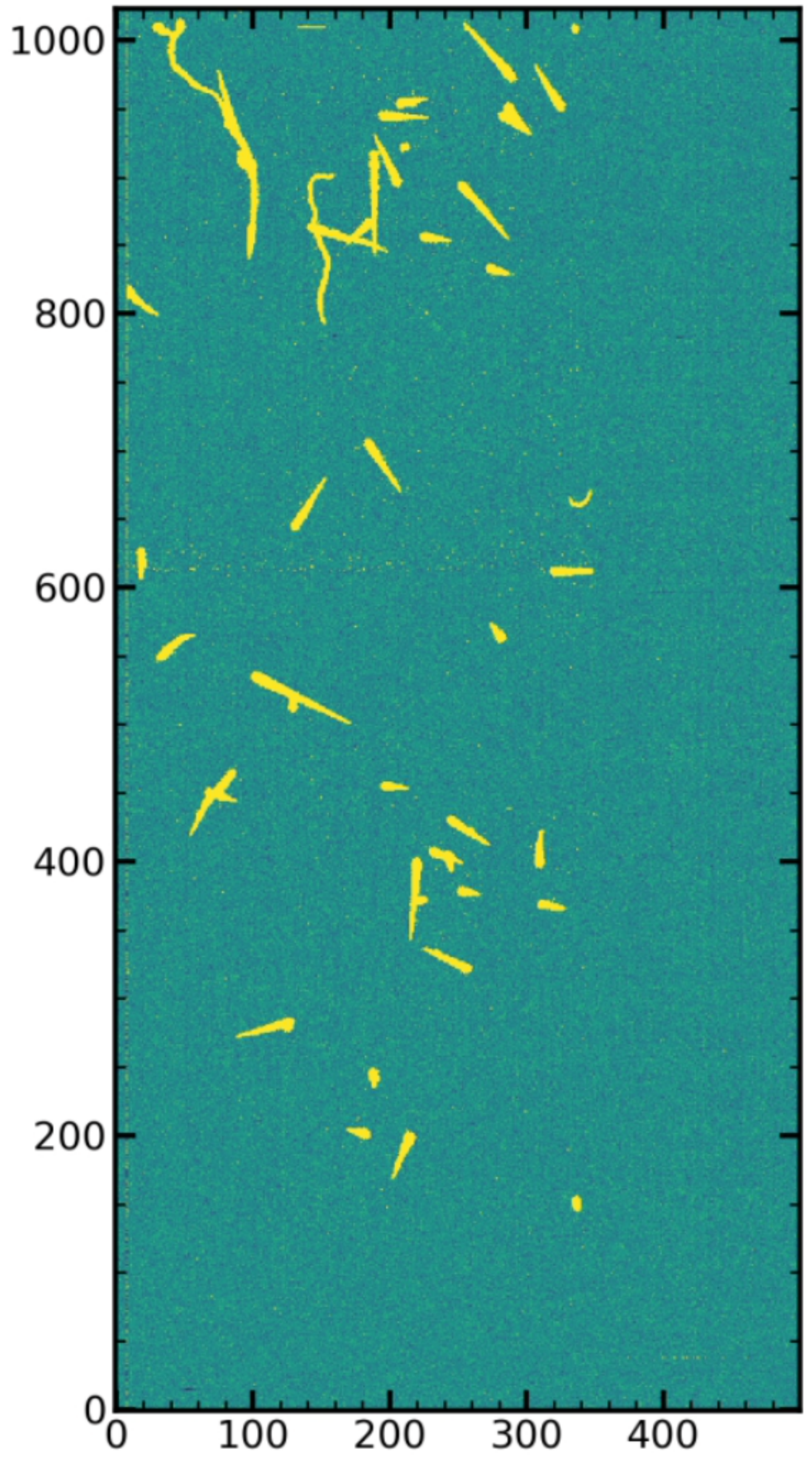
- Results compatible with previous analysis
  - Expected limit in in the lowest-energy bin ~35 times the SM prediction (agains ~ 65 times in previous analysis)

Nuclear reactors

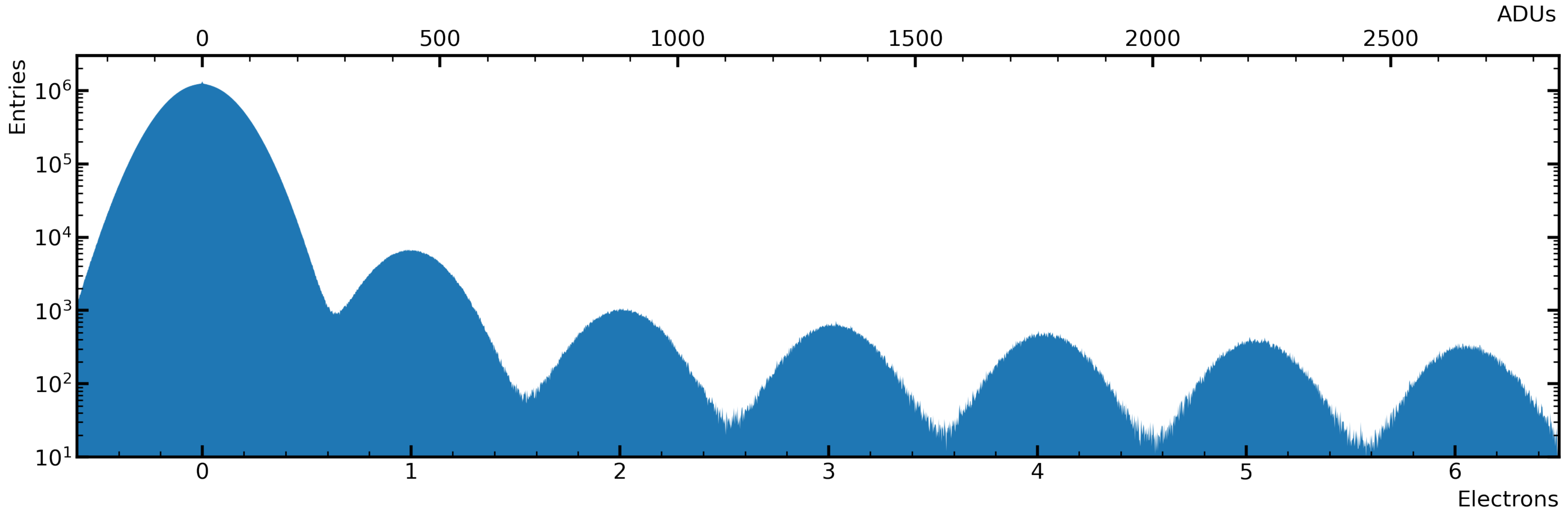
CONNIE – Skipper-CCDs

- Skipper-CCD technology
  - Allow multiple non-destructive charge measurements of each pixel
  - Significant readout noise reduction reaching single-electron resolution!
    - Reduce detection threshold
    - Improve efficiency at low energy

PRL 119 (2017)



- Skipper-CCDs @ CONNIE since July 2021
  - 2 skipper-CCDs (1022 x 682 pixel each)
  - new Low Threshold Acquisition (LTA) readout electronics
  - Data taking in ongoing
    - Readout noise: ~0.15e- RMS
    - Single electron rate: ~ 0.05 e-/pix/day



Nuclear reactors

CONNIE — Skipper-CCDs

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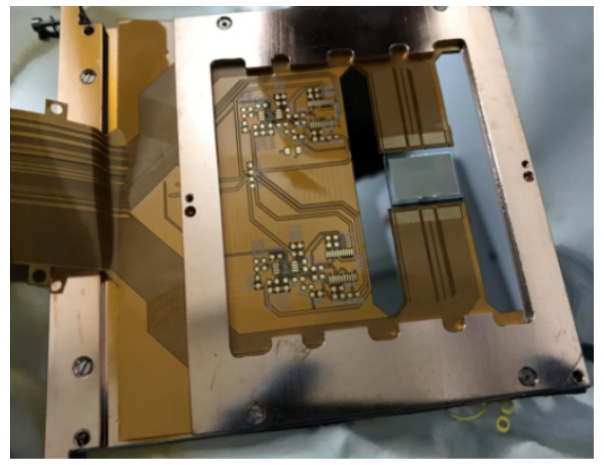
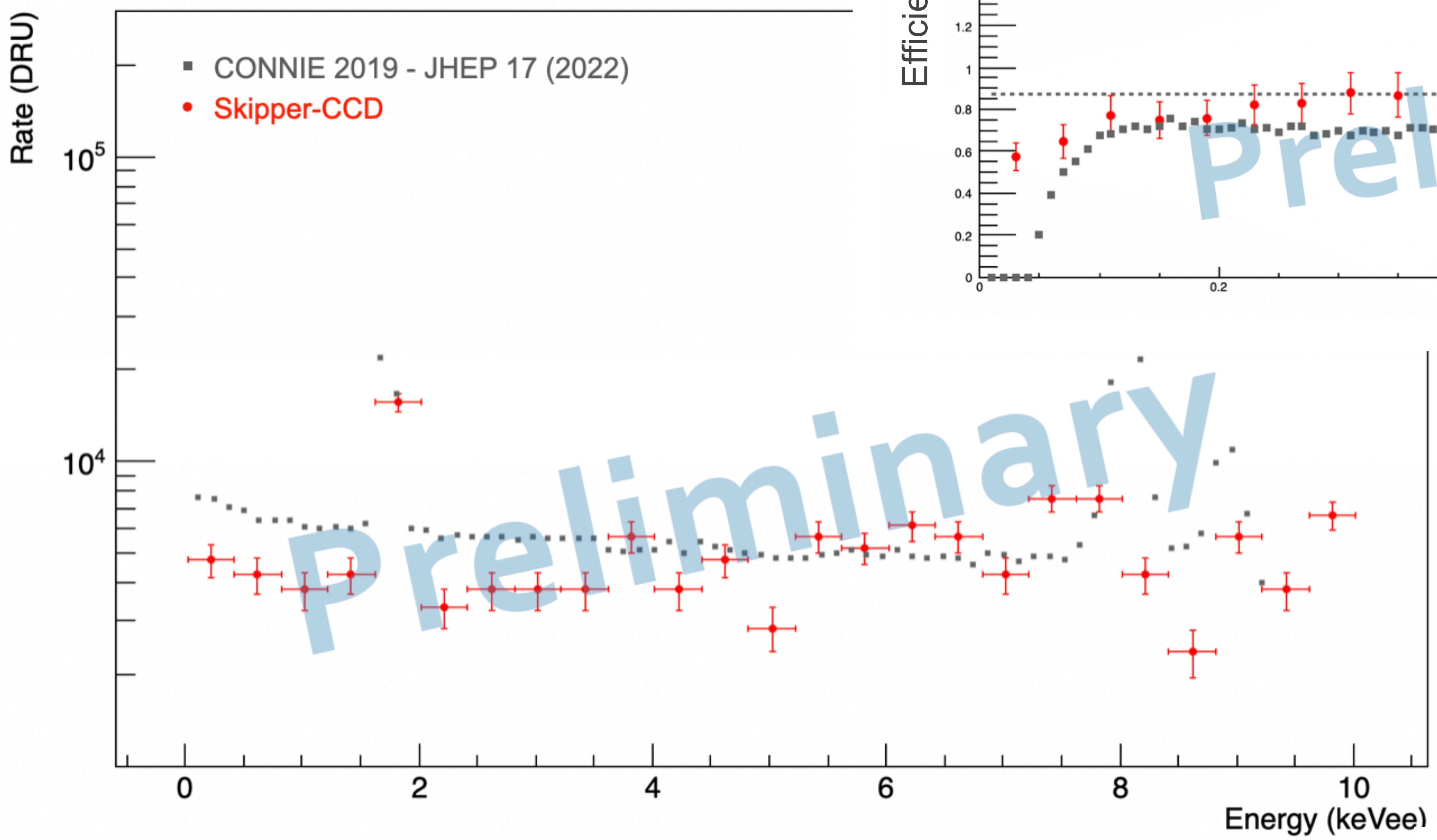
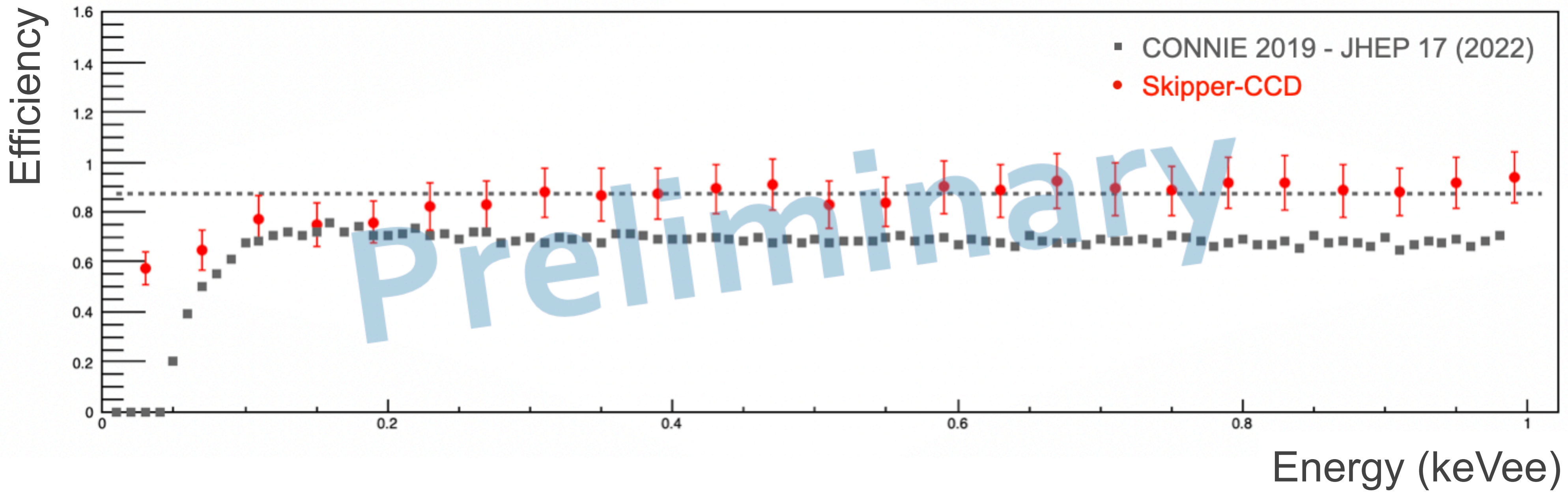
6F Dirac, DT06-556



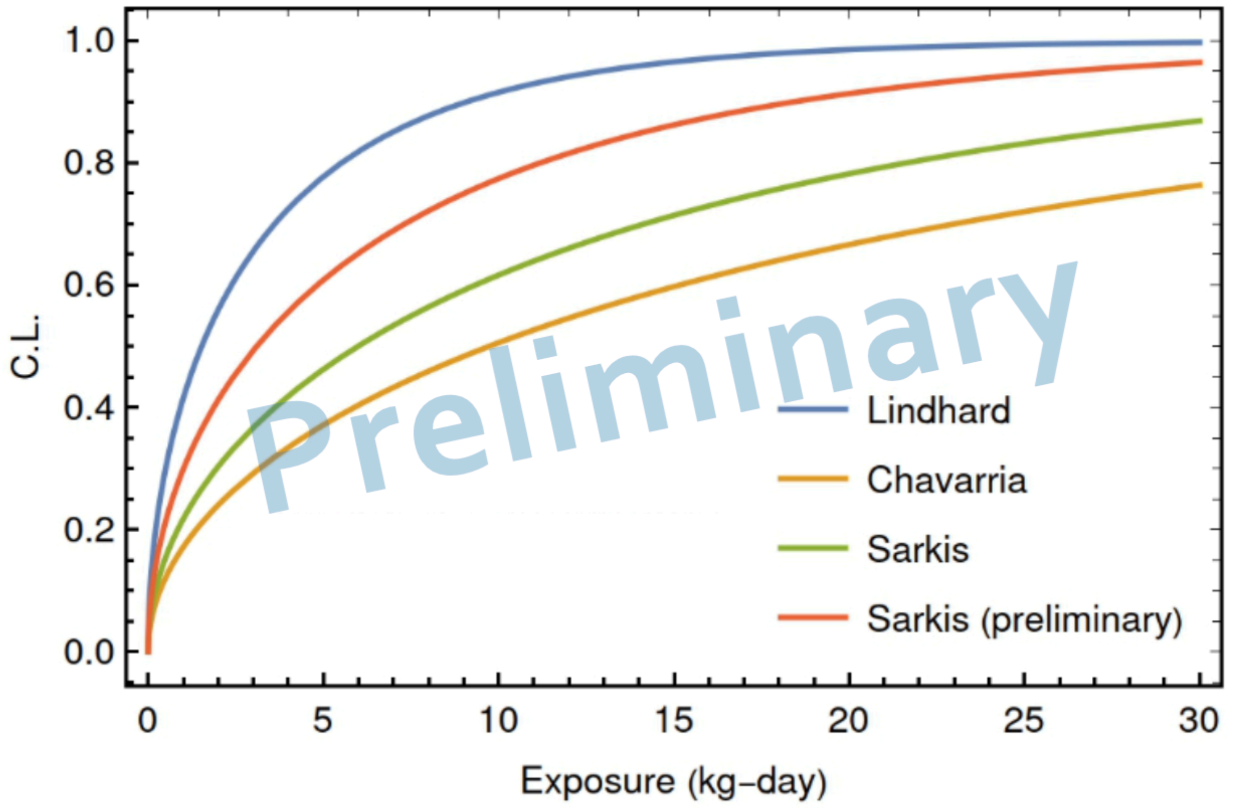
- Background and efficiency





- Energy threshold 15 eV
- CEvNS rate increase 2.2 times compared to CONNIE 2019 run

- Considering 4 kdru of background and a future detector of 1 kg at the CONNIE site, it should run for 9 days (if Lindhard) or 2 months (Chavarria) to observe CEvNS at 90% C.L.

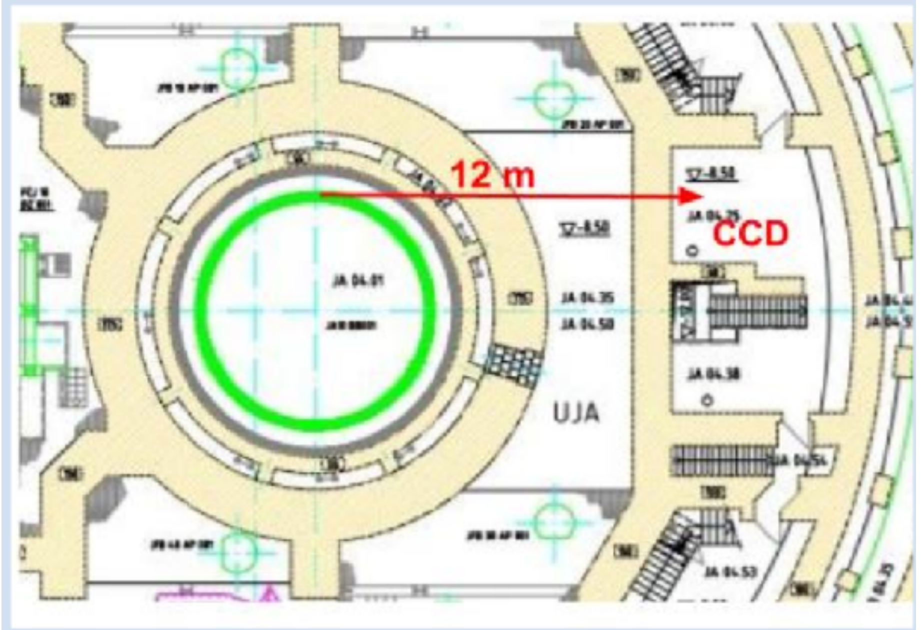


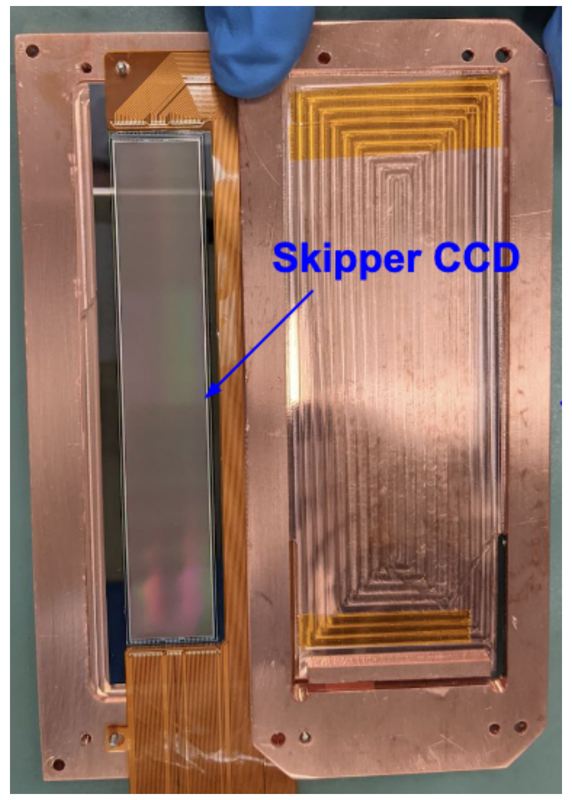
Nuclear reactors

Skipper-CCD @ Atucha

- 1 skipper-CCD ~ 0.68 g
  - 6144 x 1024 pixels of 15 μm size
  - 675 μm width
- Detector threshold ~15 eV
- Installed at 12 m of a 2GW nuclear reactors
- Flux: $2 \cdot 10^{13}\ \bar{\nu}_e\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

Atucha II plant in Argentina





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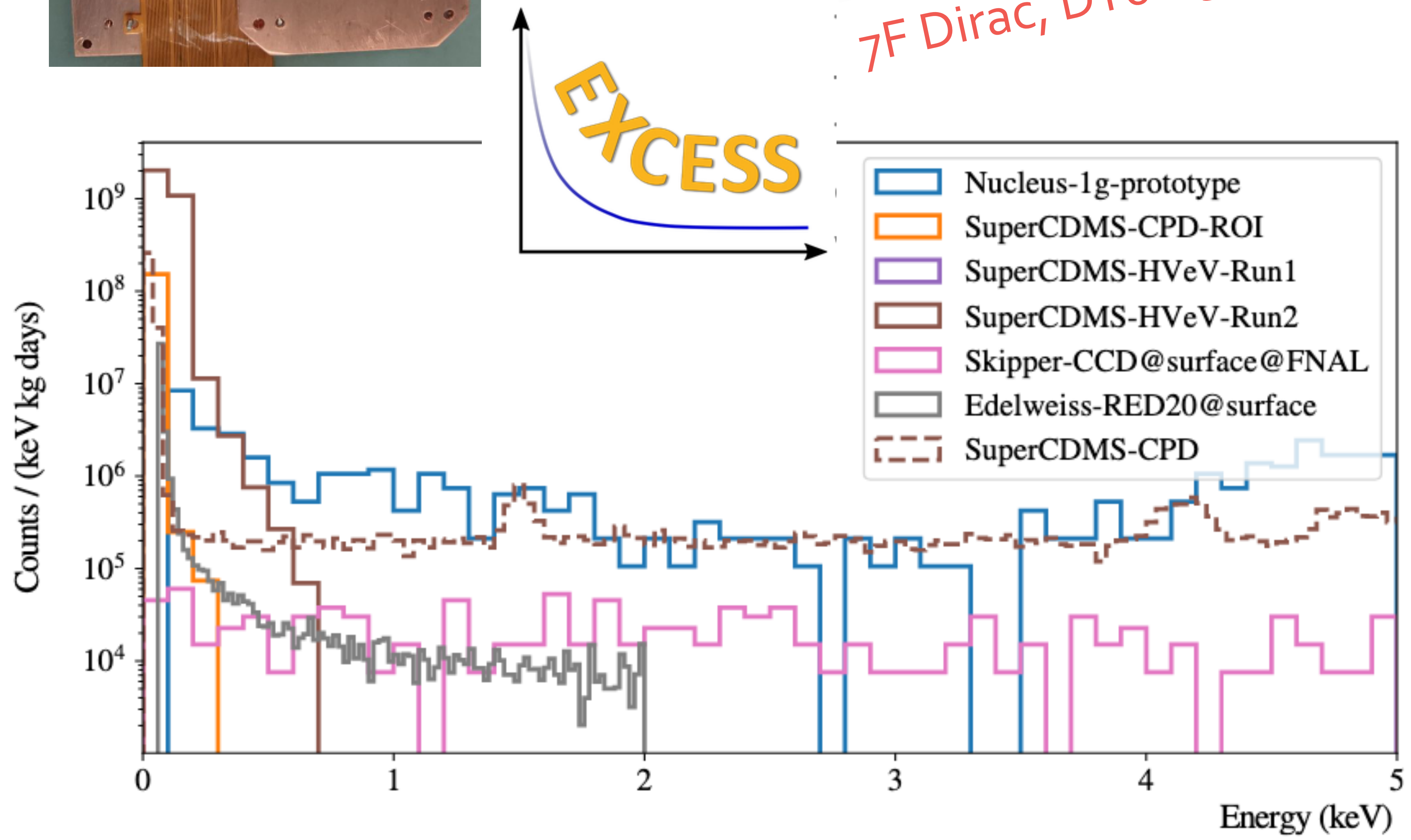
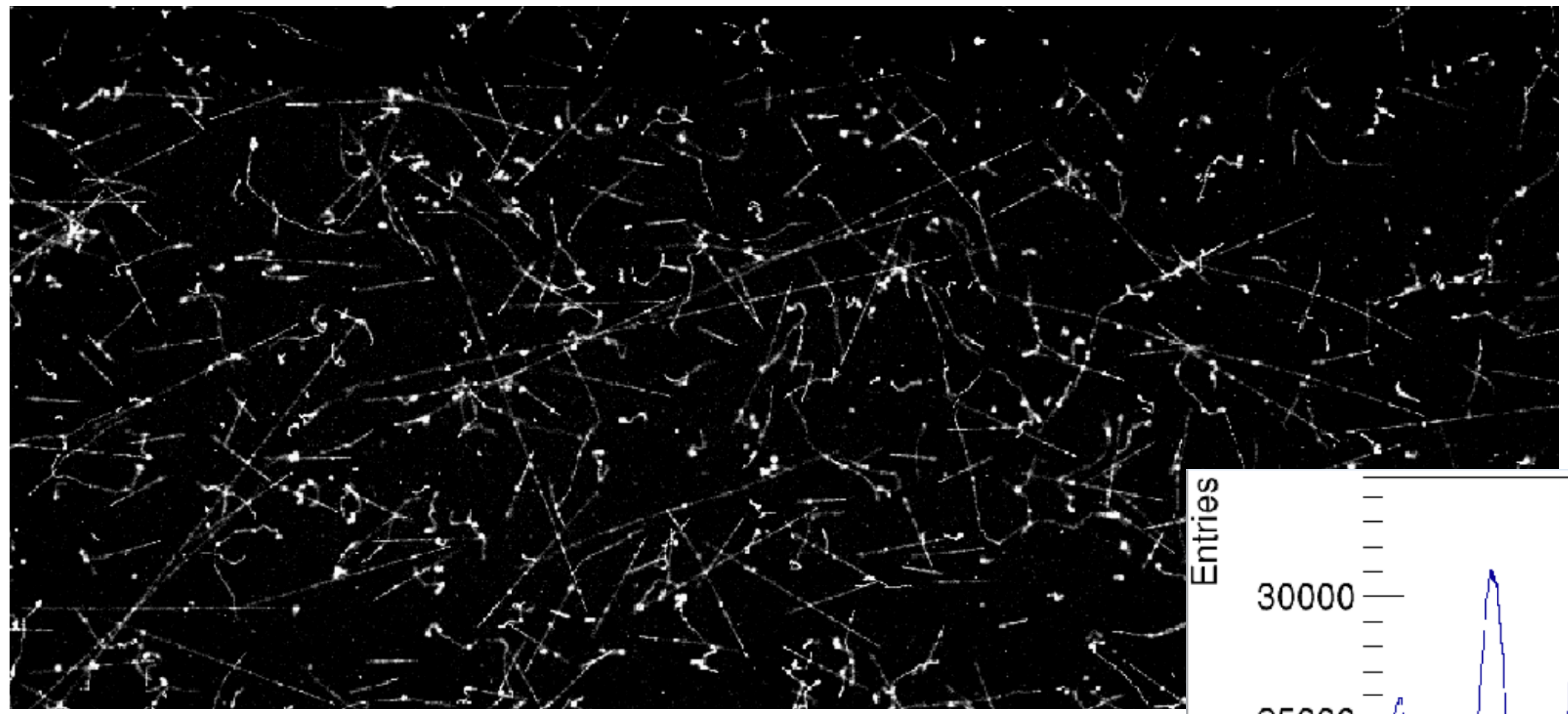
7F Dirac, DTo6-399



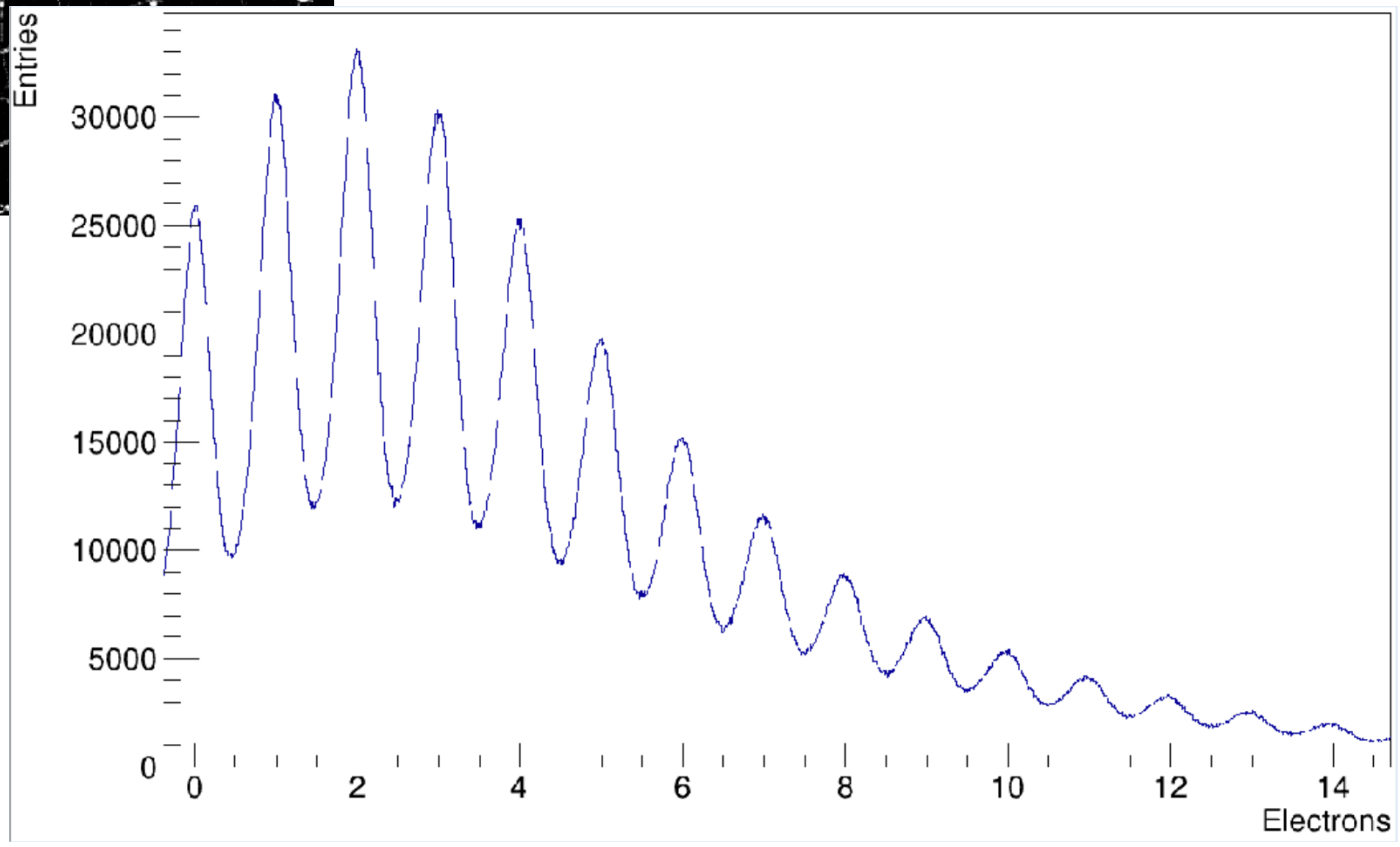
G. Fernandez-Moroni, et al, arXiv:2107.00168



Detector image @ Atucha

- Readout noise 0.17e-
- Horizontal binning of 10 columns

Single electron resolution



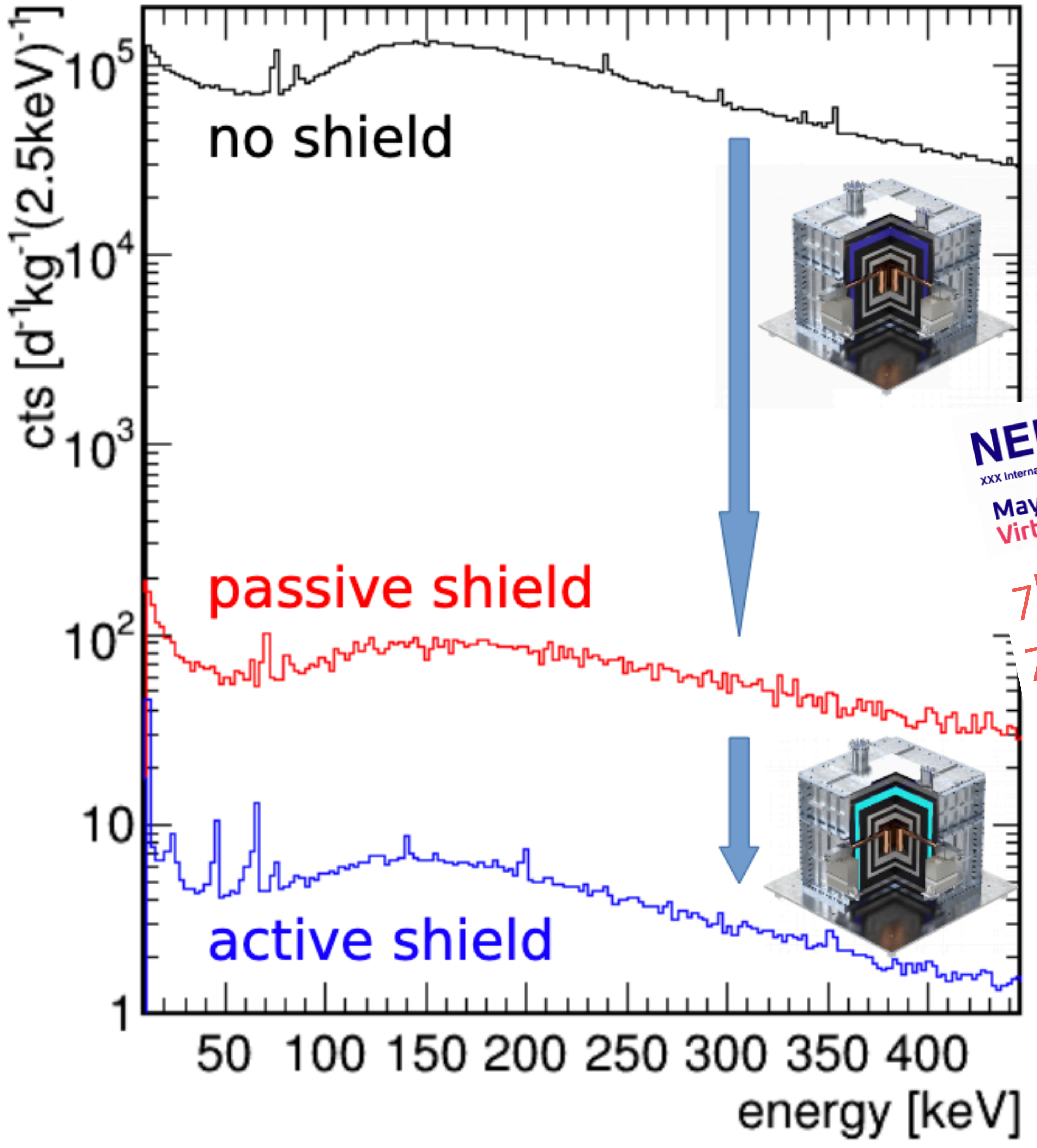
Nuclear Reactor experiments

P-type High Purity Germanium

Nuclear reactors

CONUS

- Experiment @ 17 m from the 3.9 GW reactor core
- 24 m.w.e overburden, muon reduction ~ 3.5 times
- Flux: $2 \cdot 10^{13}\ \bar{\nu}_e\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$
- Four 1kg-HPGe detectors (low-background crystals)
- Passive and active shield (10^4 fold suppression)
  - Lead + polyethylene
  - Active muon-veto (plastic scintillators)
- Energy threshold ~ >200 eV_{ee} (full efficiency)



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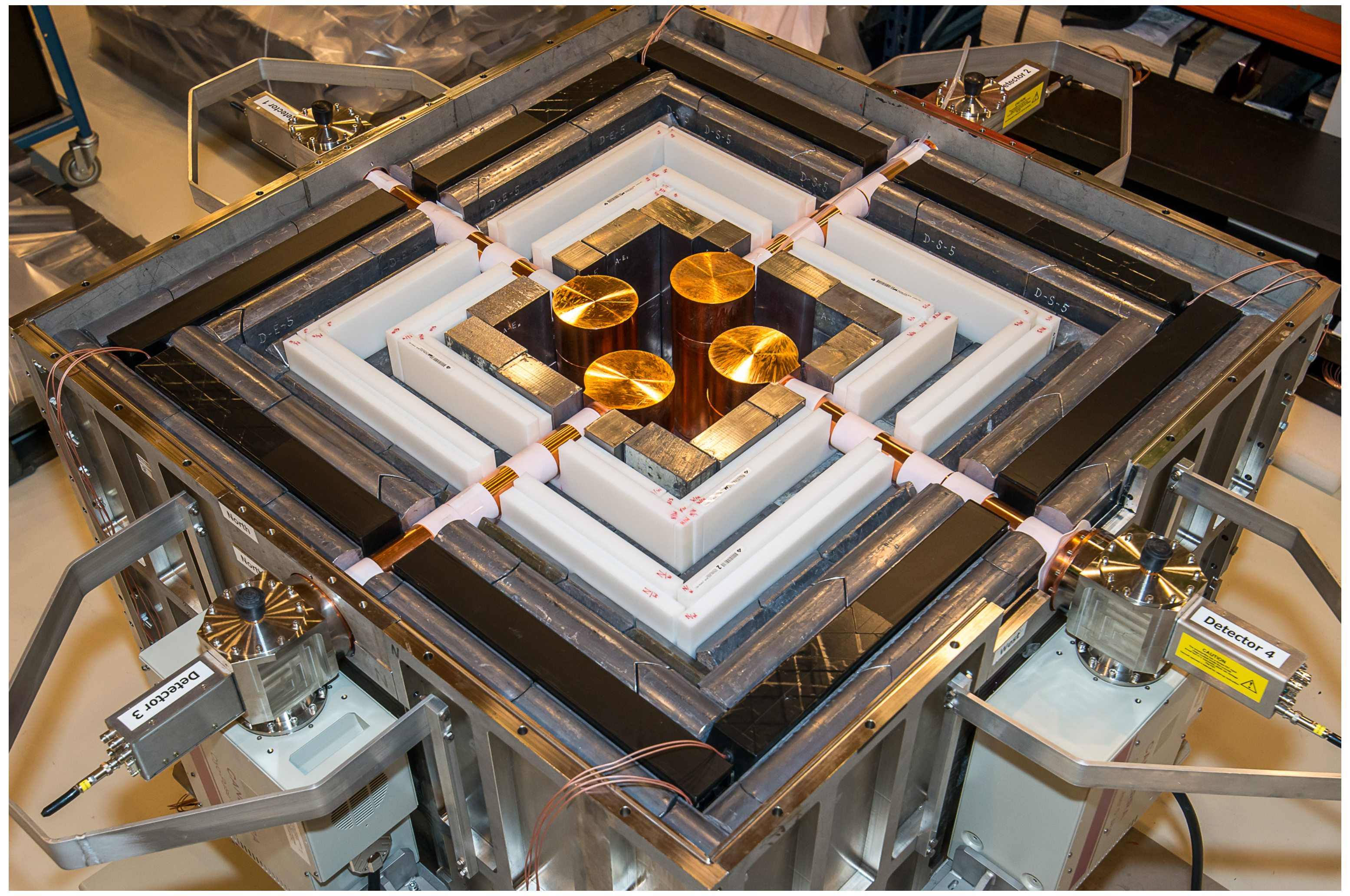
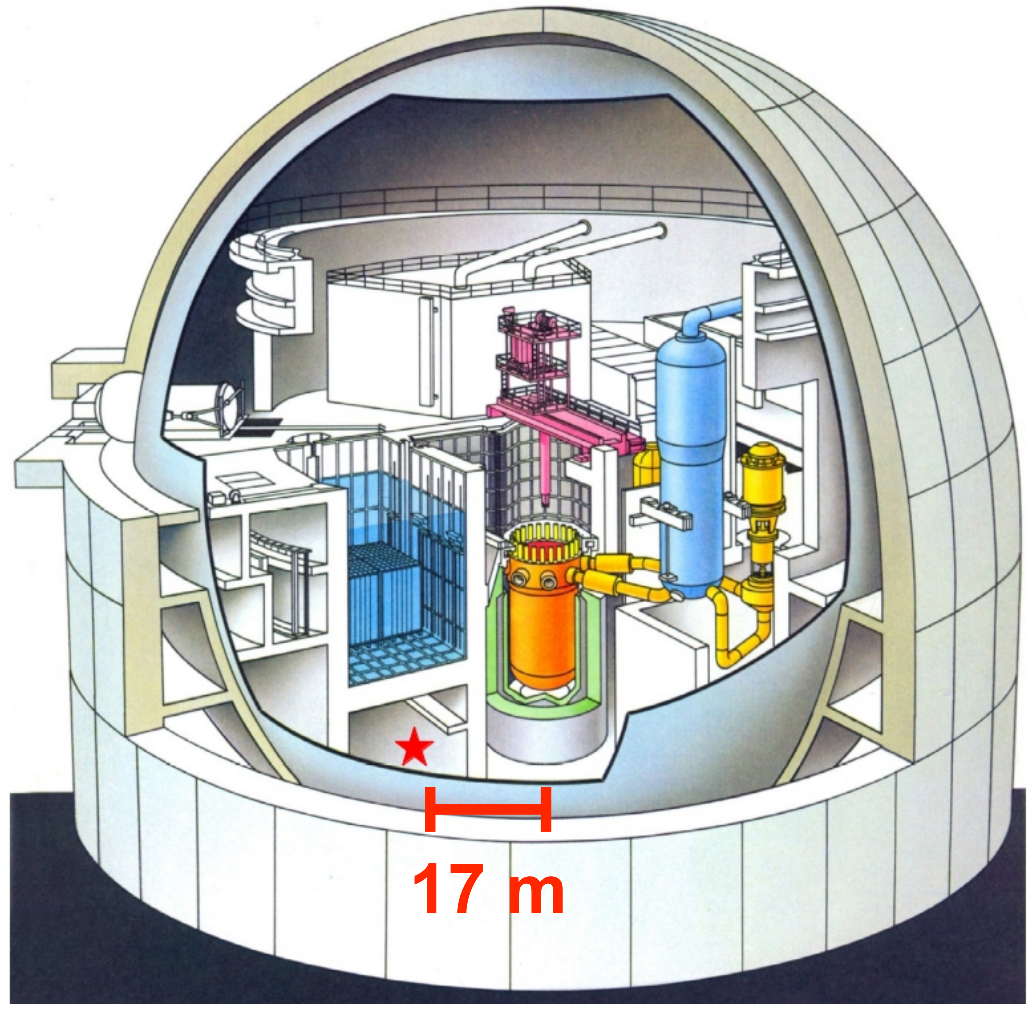
7F Majorana, MT05-206
7F Majorana, MT05-179
5F Dirac, DT15-345





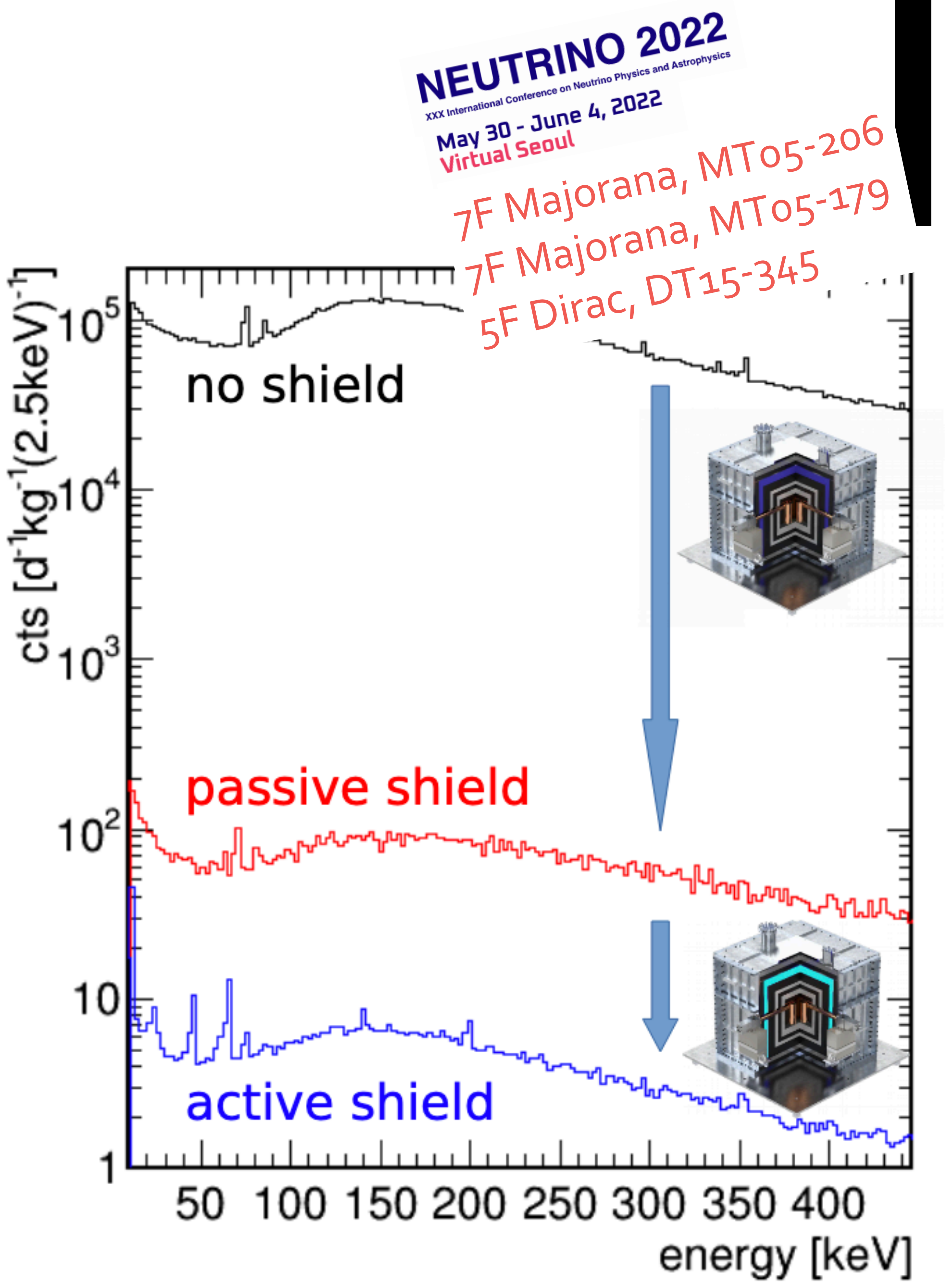
Brokdorf nuclear power plant in Germany

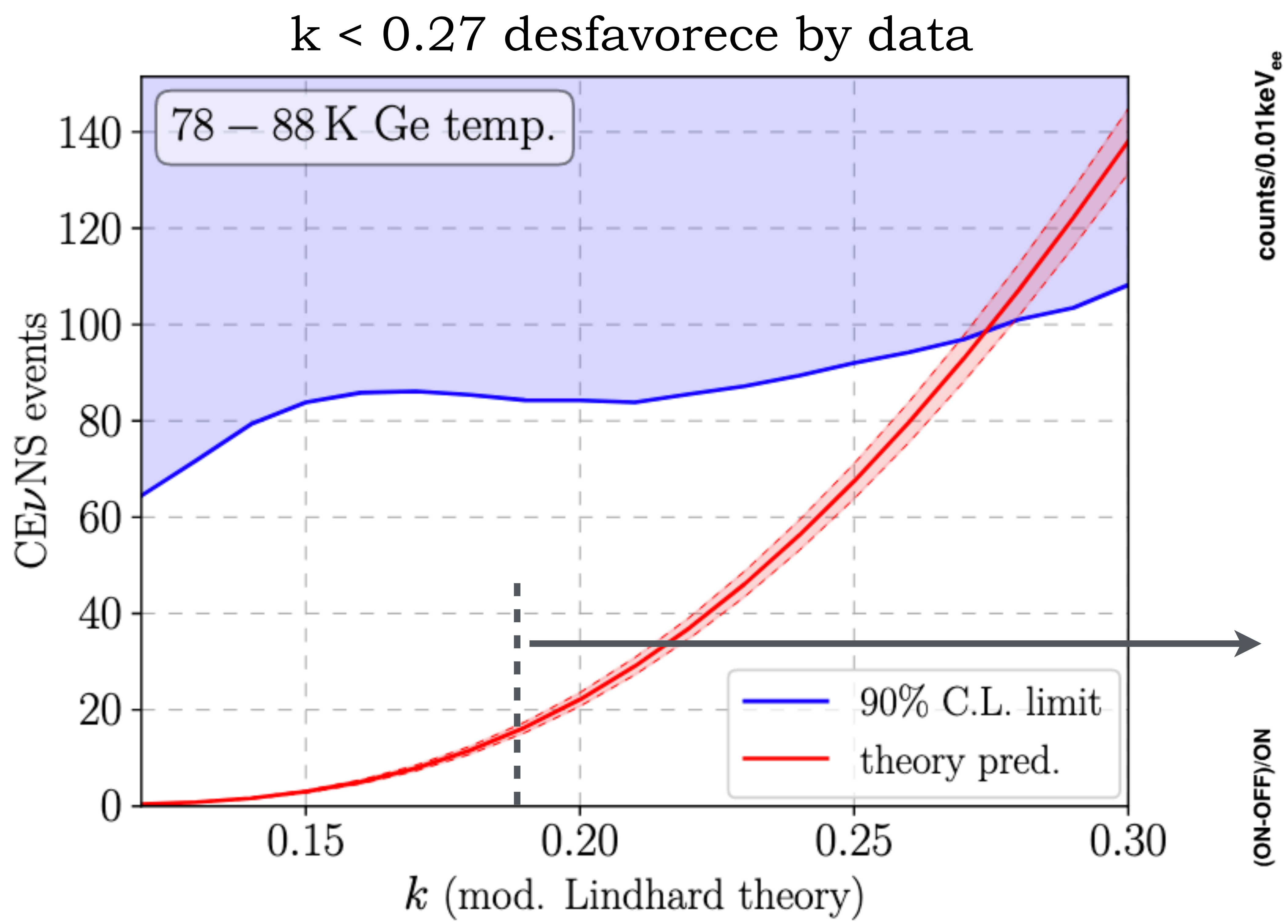
J. Hakenmüller @ Magnificent CEvNS 2020

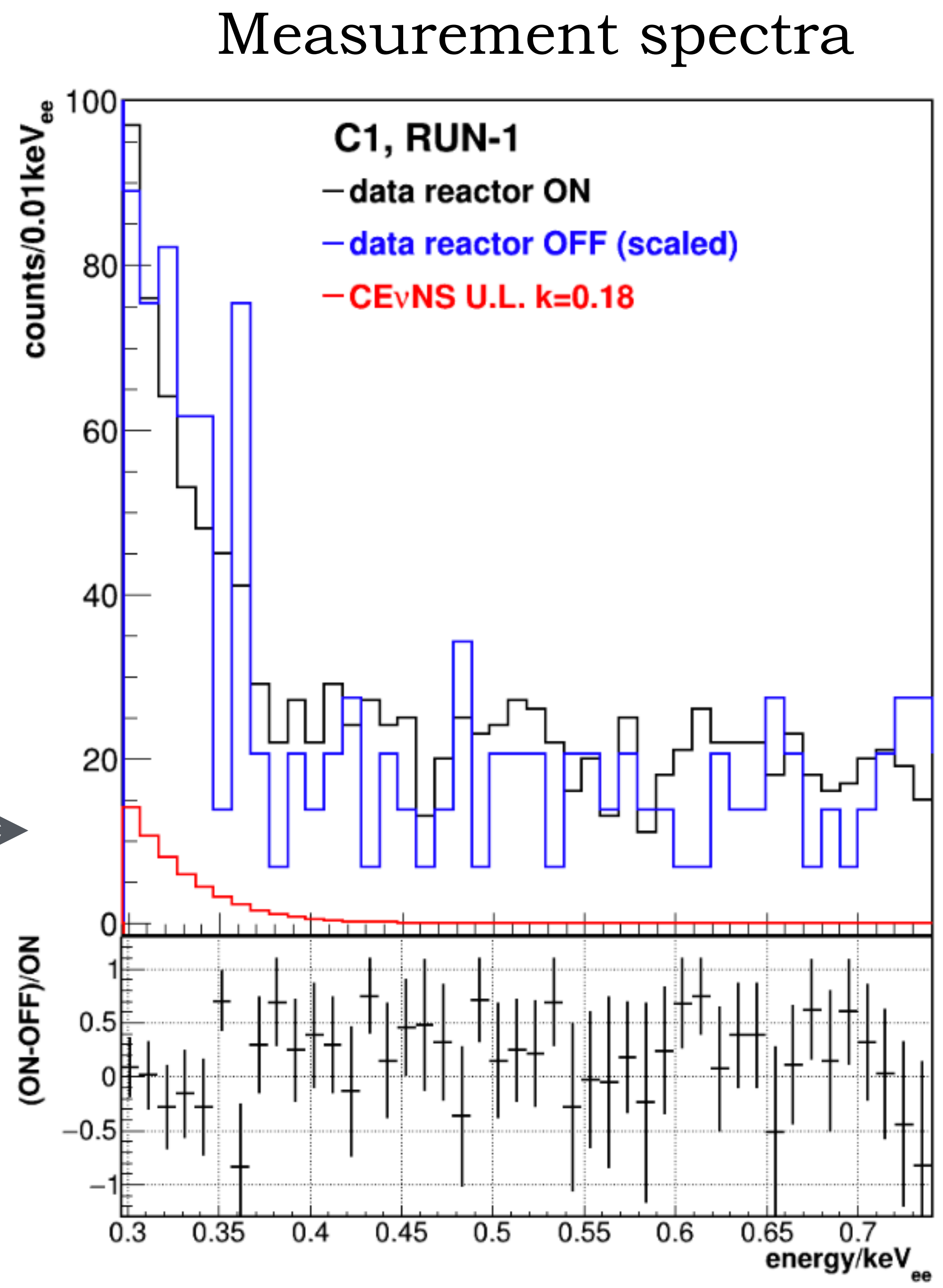
Nuclear reactors

CONUS

- Best limit on CEνNS in the fully coherent regime as a function of the quenching factor parameter k
- Quenching factor: k = 0.162 ± 0.004



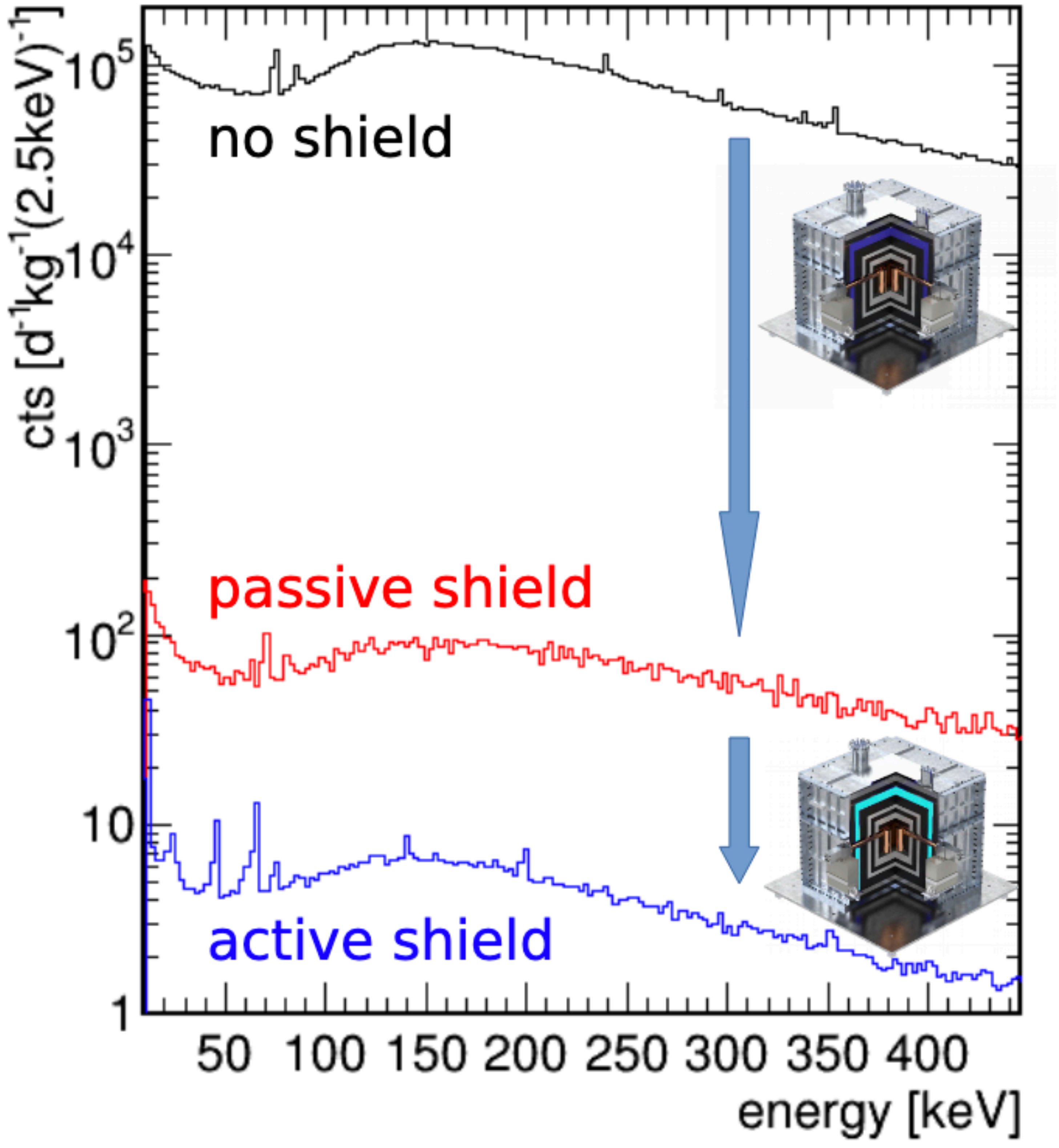




CONUS, PRL 126, 041804 (2021)

J. Hakenmüller @ Magnificent CEvNS 2020

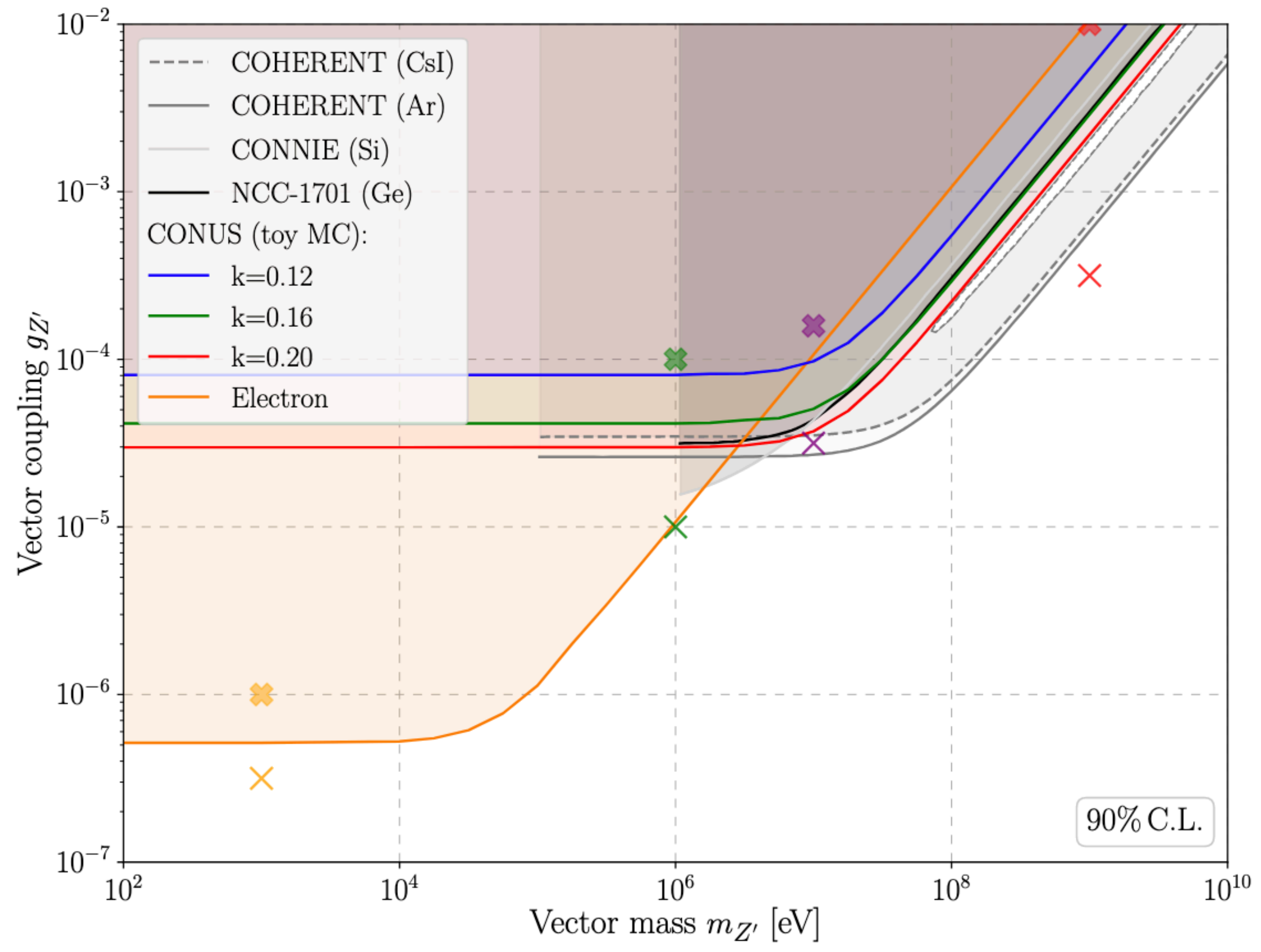
Nuclear reactors



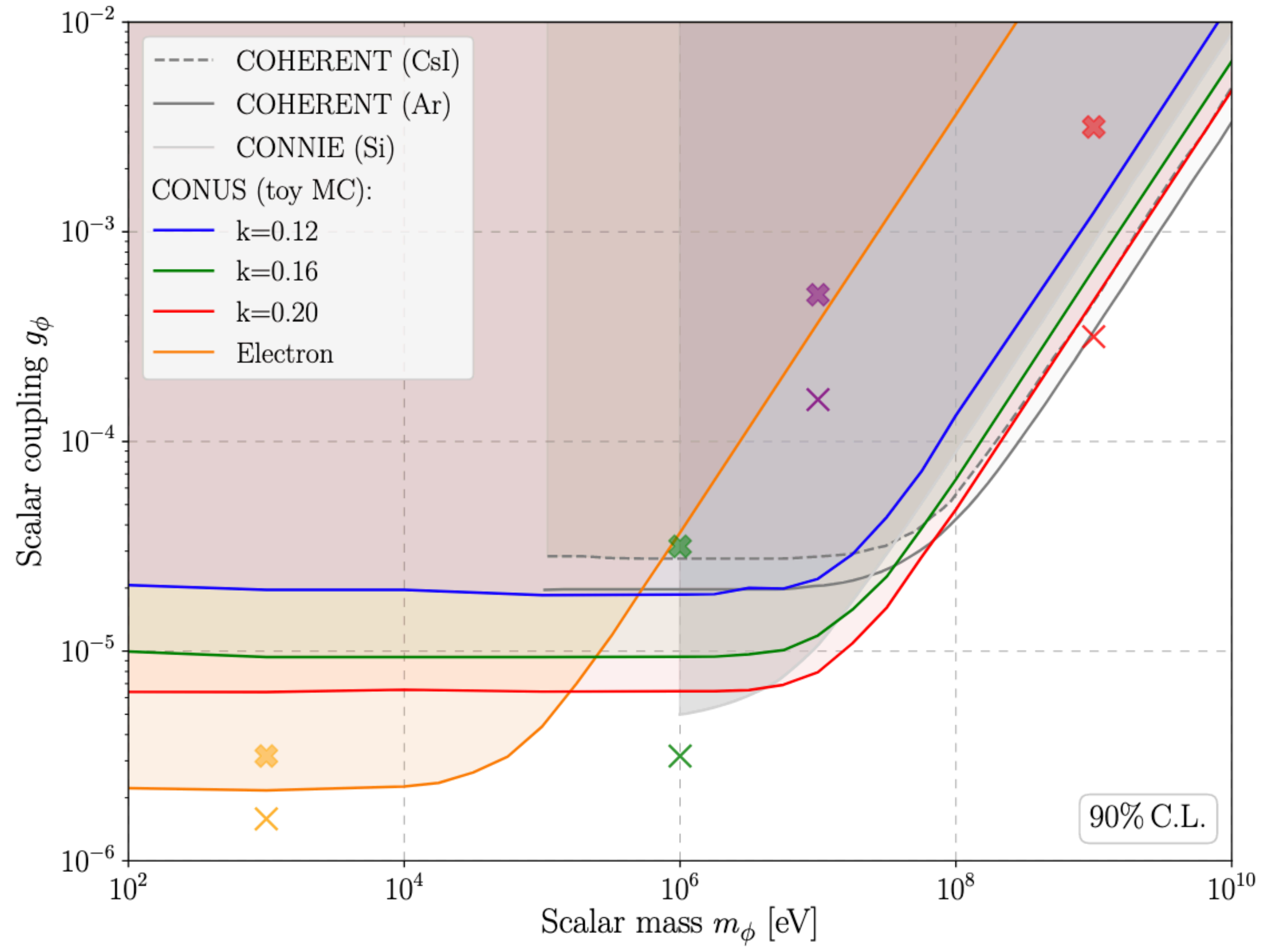
CONUS

- Constrains on neutrino physics beyond SM

Light vector (Z') mediator



Light scalar (ϕ) mediator



CONUS, JHEP 05, 085 (2022)

- First limits on neutrino electromagnetic properties

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7F Majorana, MT05-206
7F Majorana, MT05-179
5F Dirac, DT15-345

- Background measurements (2022)
- 20% reduction of the background @ sub-keV
  - PSD (pulse shape discrimination) that selects events via shape of readout pulse

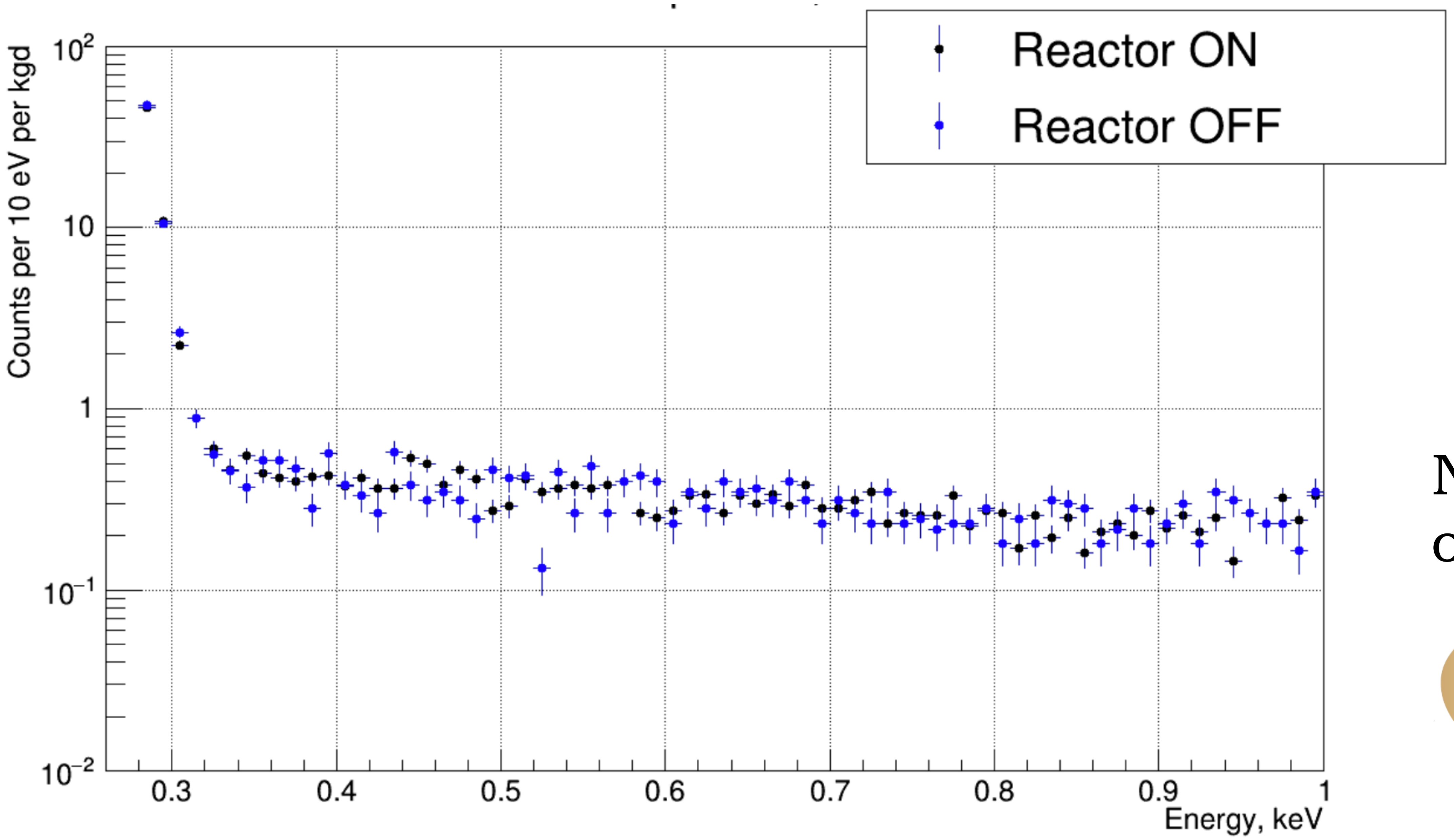
J. Hakenmüller @ Magnificent CEvNS 2020

Nuclear reactors

Kalinin Nuclear Power Plant in Rusia

nuGeN

- 1.5 kg HPGe detector
- ~ 10-11 m of the 3.1 GW reactor core (distance can change)
- Flux: $5 \cdot 10^{13}\ \bar{\nu}_e\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$
- Reactor-OFF periods (~2/18 months) for background measurements
- Overburden ~ 50 m.w.e
- Passive and active shield
  - Copper + B-polyethylene + lead + B-polyethylene
  - Active muon-veto

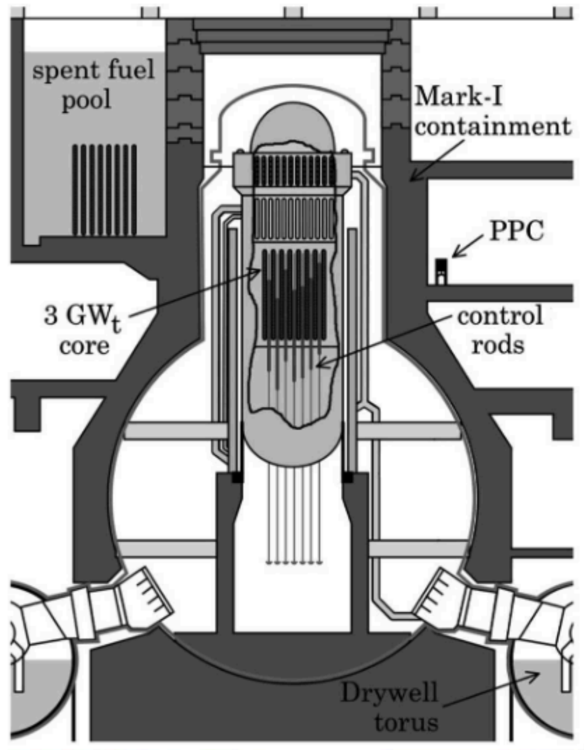


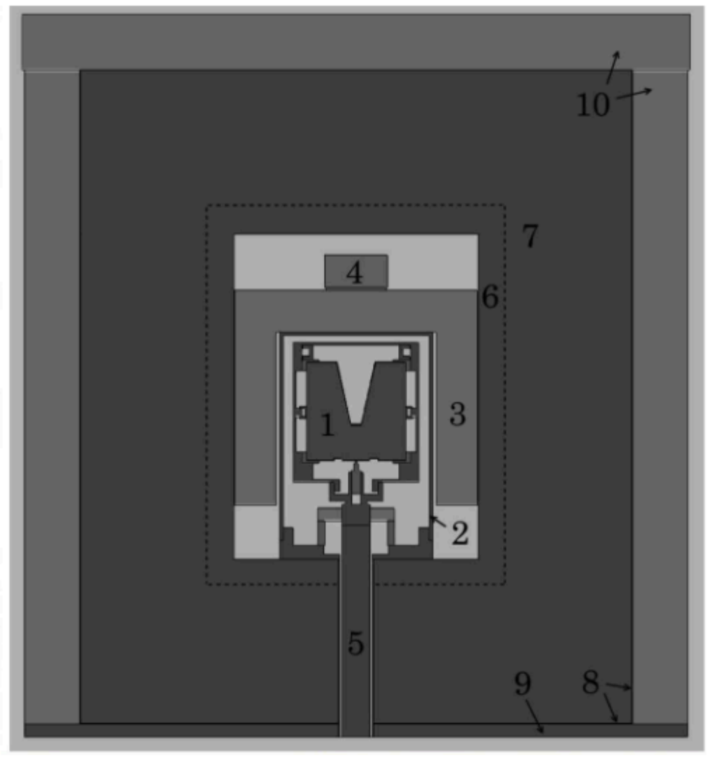
No signal excess observed

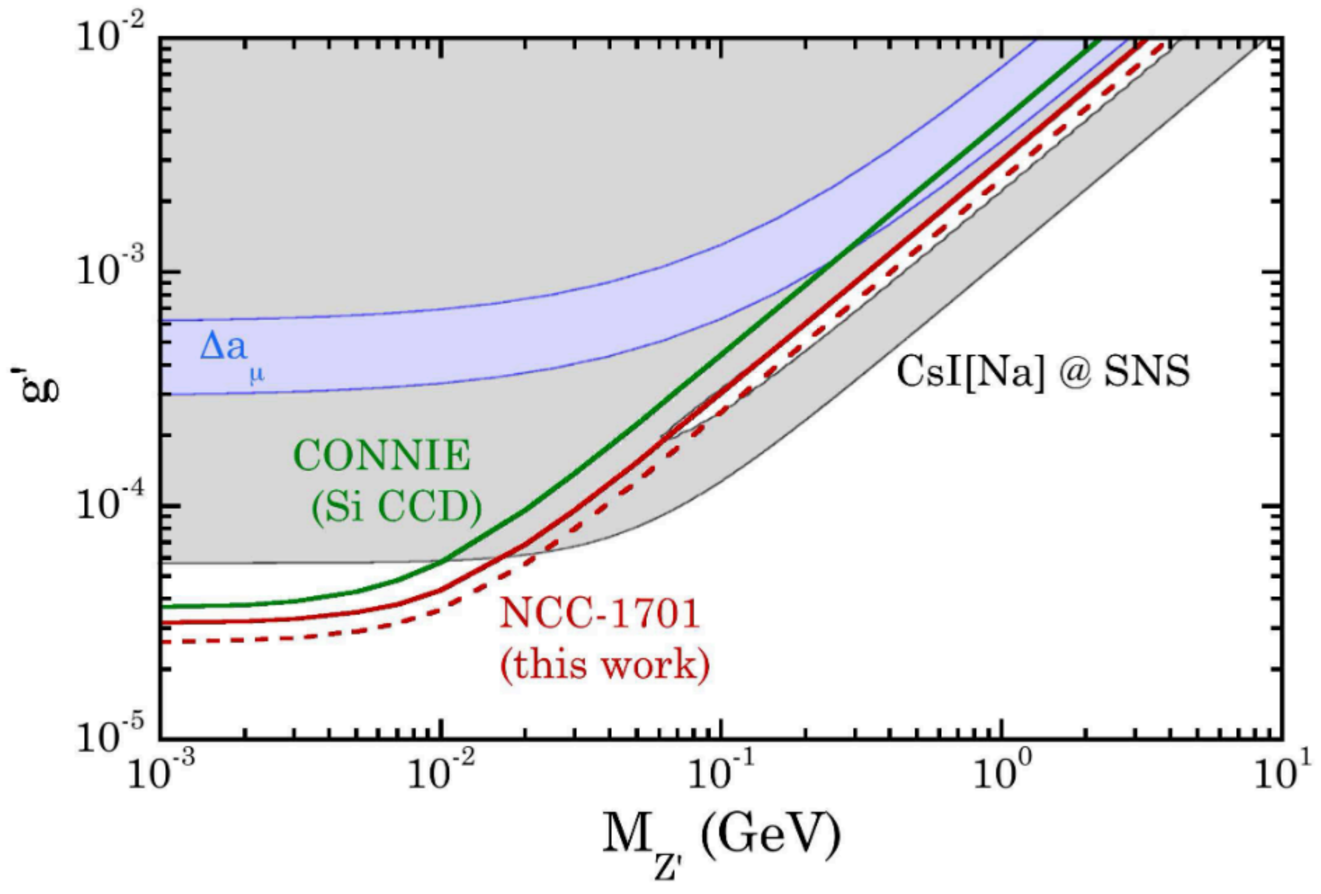
Nuclear reactors

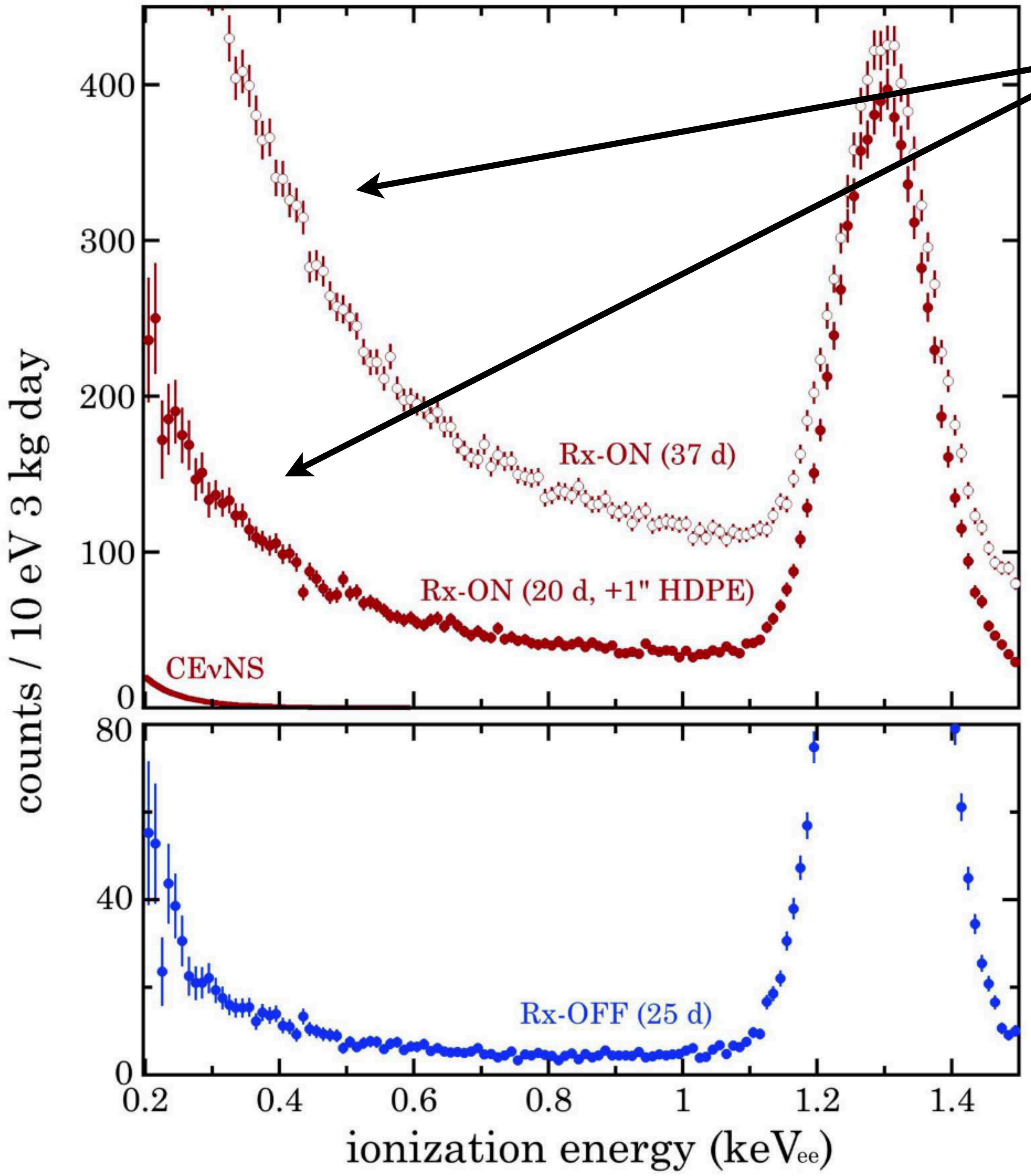
CEνNS @ Dresden-II

- 3 kg of P-type point contact (PPC) Ge detector
- Located @ 8 m of 2.96 GW (BWR) boiling water reactor
- Flux: $8.1 \cdot 10^{13}\ \bar{\nu}_e\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$
- Detector threshold: 0.2 $\mathrm{keV_{ee}}$
- Passive (lead + cadmium sheet) and active (scintillator) shield



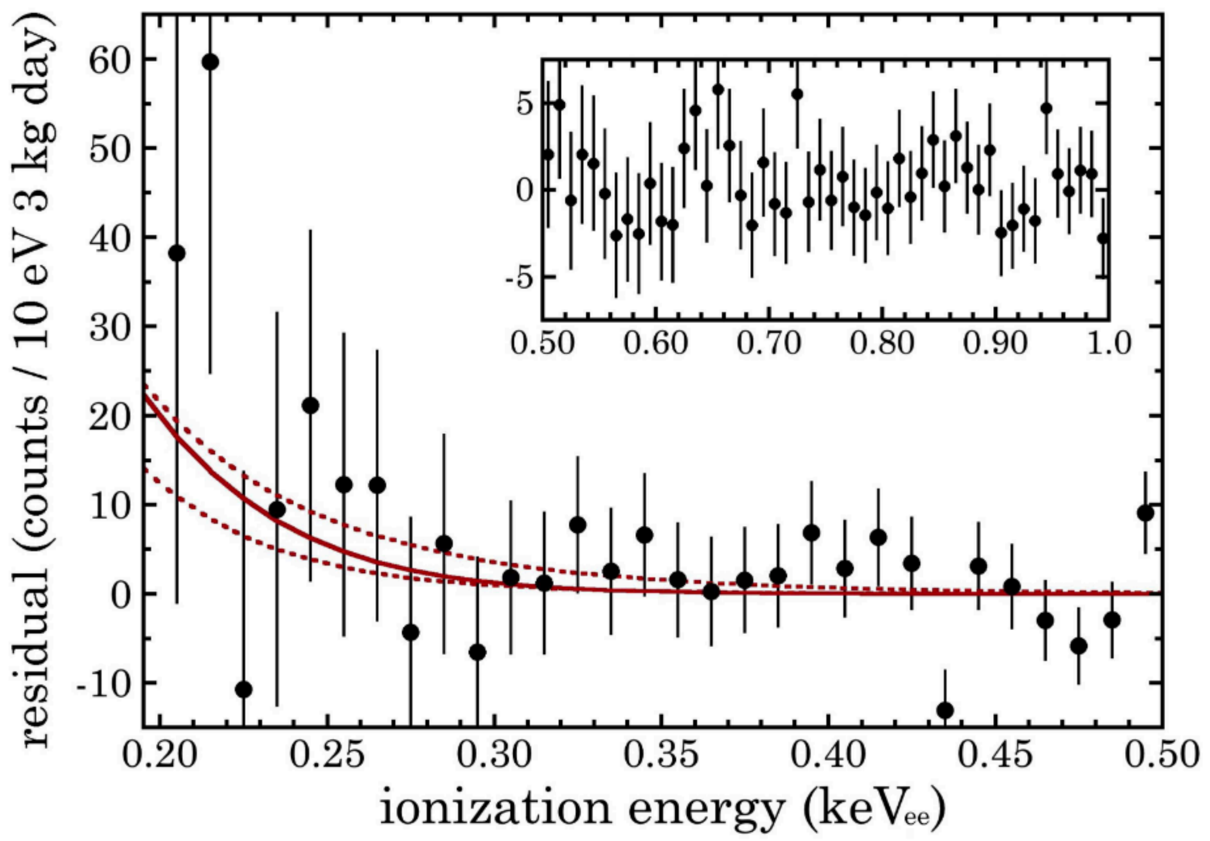






Dominant background: epithermal neutrons

Best-fit epithermal neutron background (model)



Lower background and threshold needed !!

J. Colaresi, et al, arXiv:2108.02880

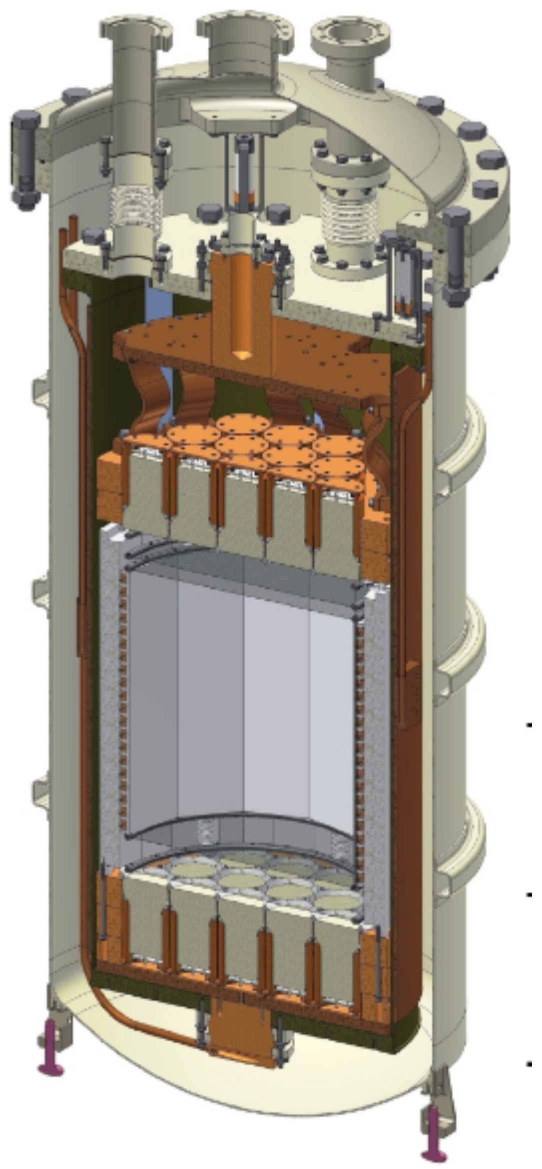
Nuclear Reactor experiments

Noble Element Detectors

Nuclear reactors

RED100

- Two-phase Xe emission detector ~ 100 kg
  - sensitive to single ionization electrons (SE)
- 19 m of the 3.1 GW reactor core
- 160 kg detector with passive shield
  - building & infrastructure for muons
  - water tank for neutrons
  - 5 cm of Cu for gamma
- Veto after muon or gamma signal
- Multi-electron events (ME) are the main instrumental background of a two-phase emission detector



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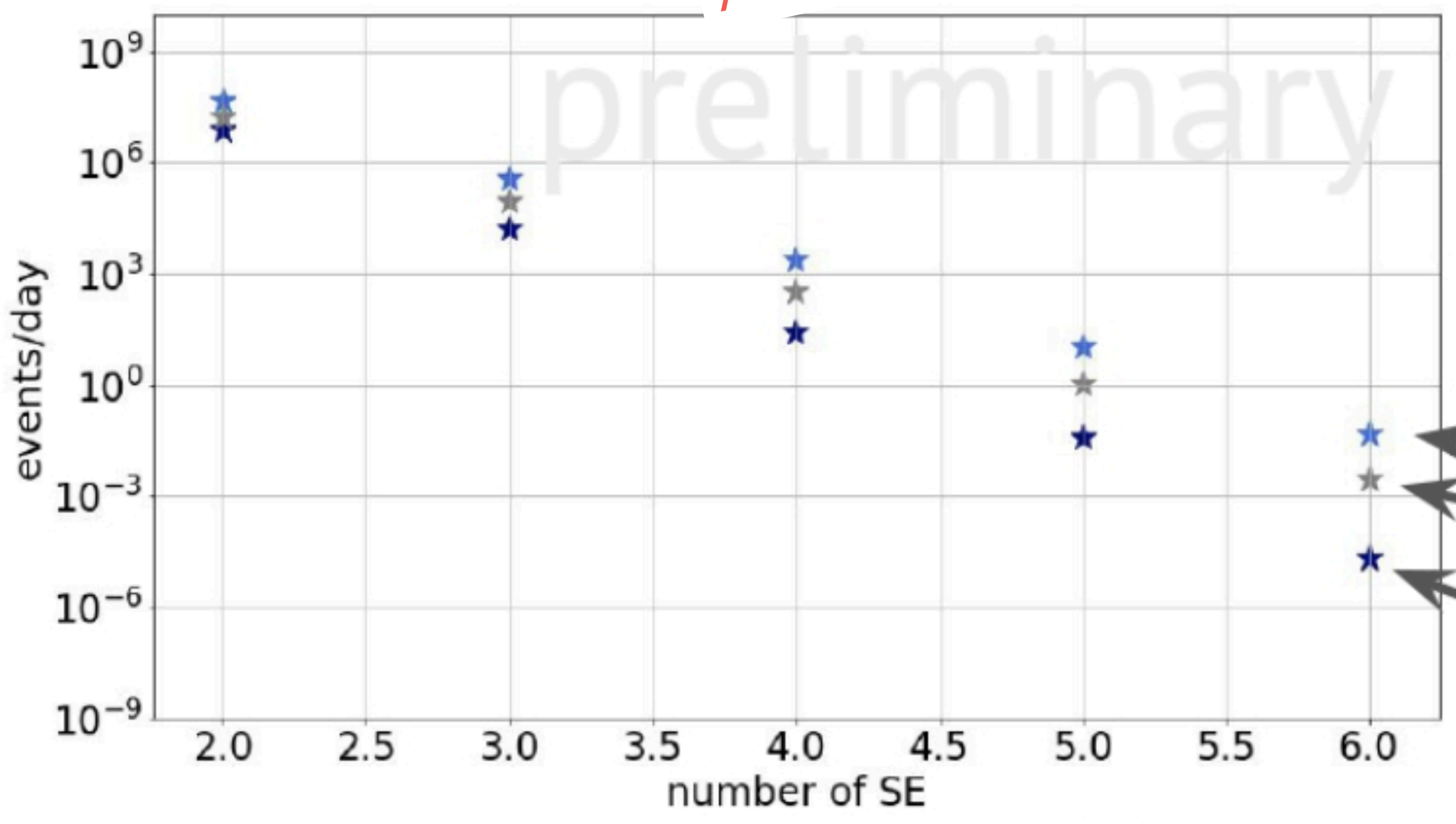
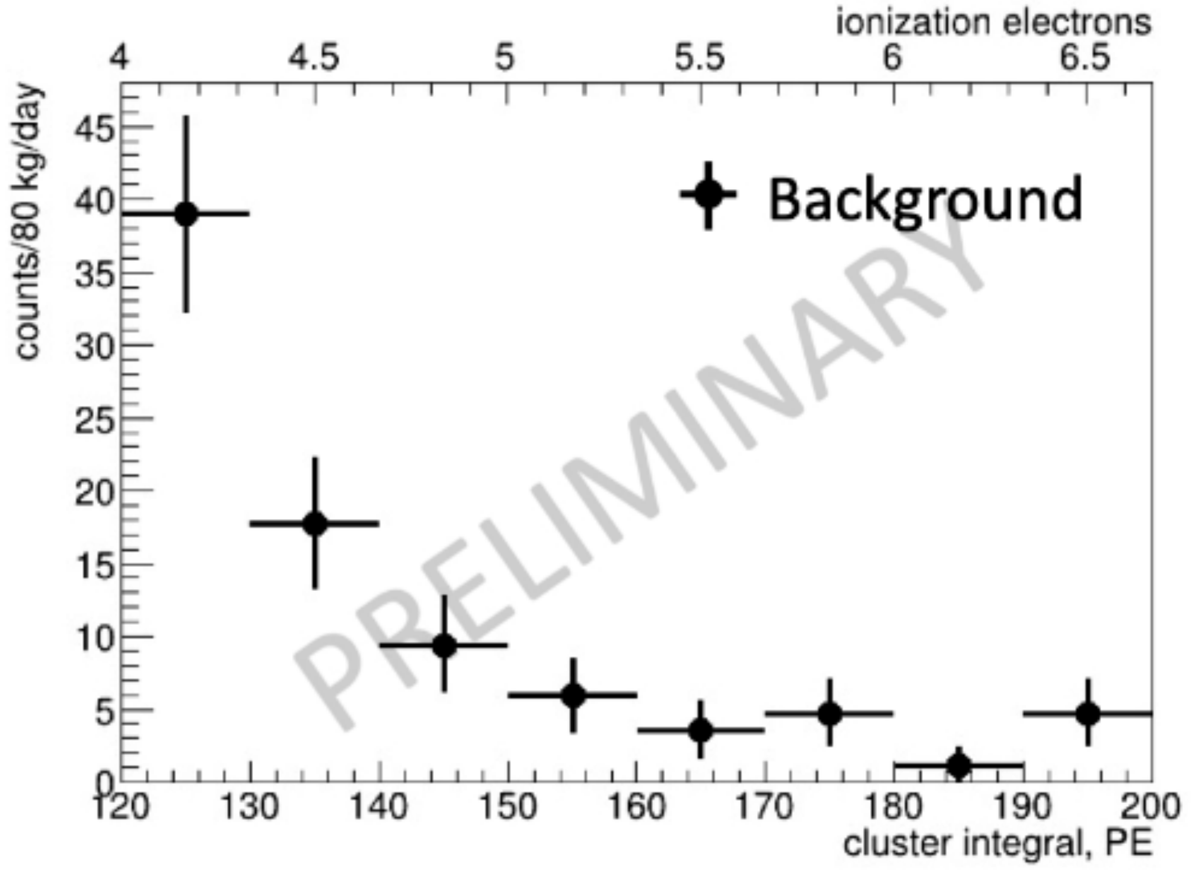
6F Dirac, DT06-231
7F Dirac, DT06-619

Kalinin Nuclear Power Plant in Rusia



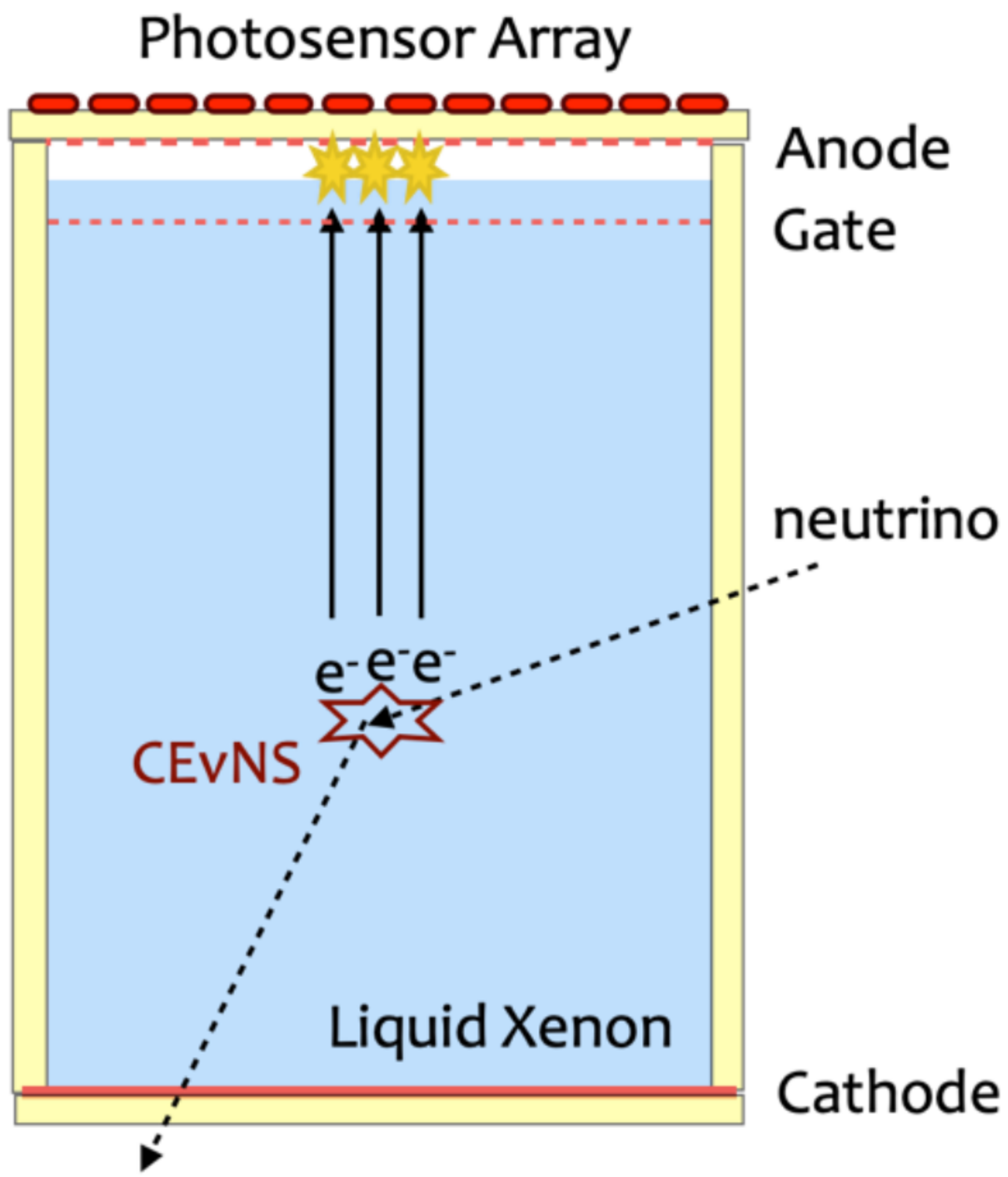
- Data until: March 2022
- CEvNS: 3-6 SE region
- Analysis in progress
- Preliminary: No reactor correlated background

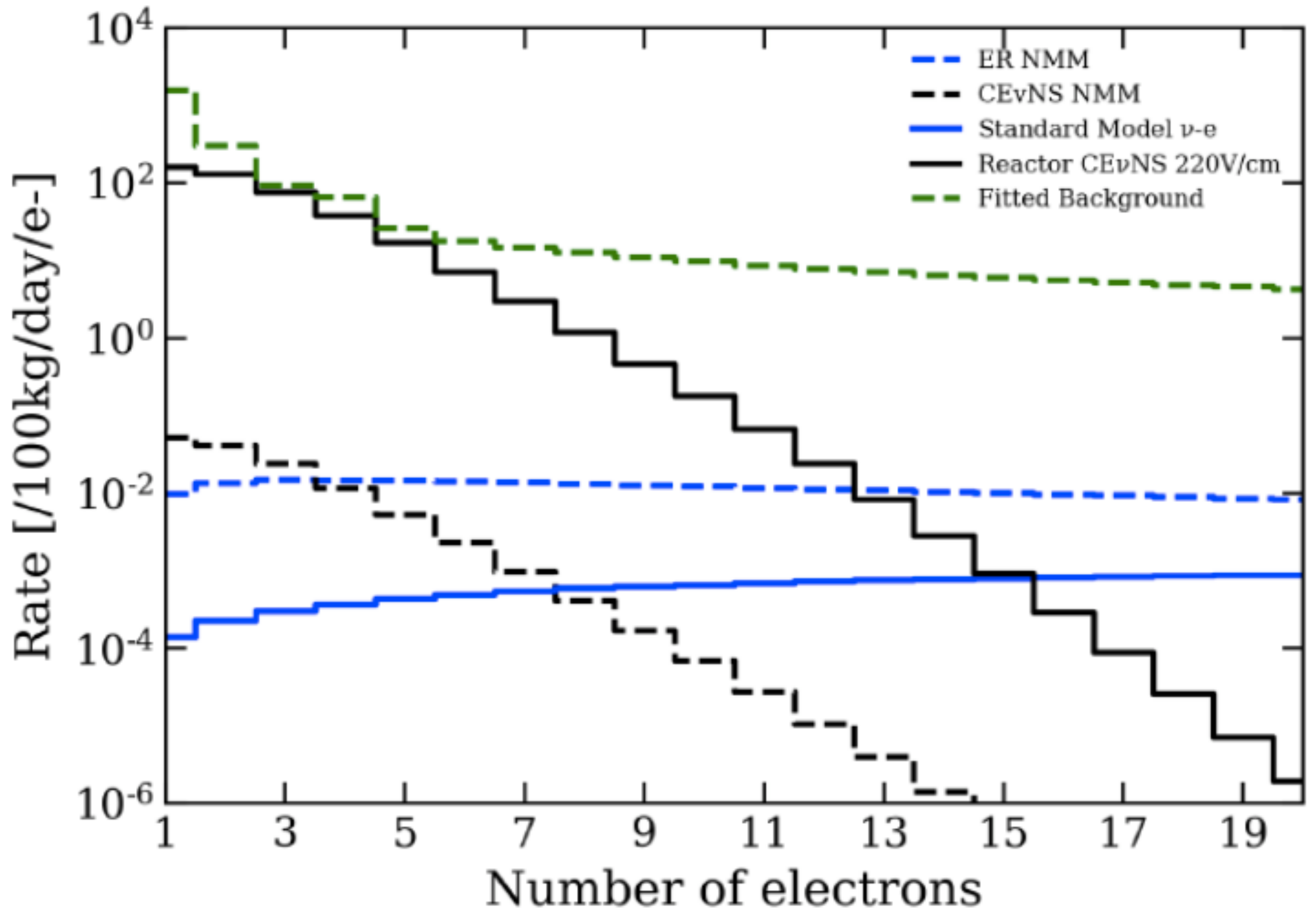


Nuclear reactors

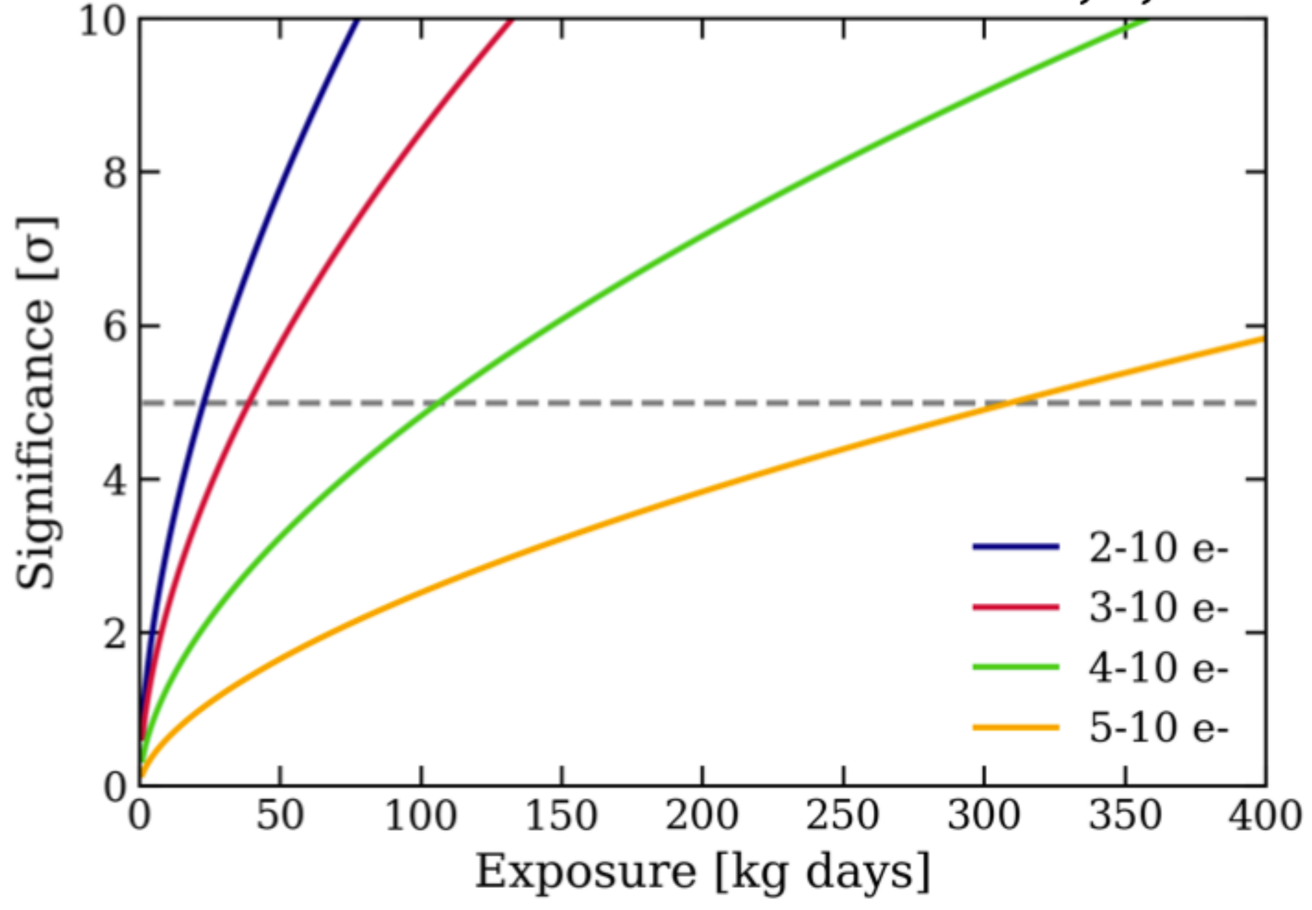
NUXE

- Single-Electron Sensitive Liquid Xenon Detector
  - Produce: prompt scintillation & delayed ionization
- Ionization-only: single electron sensitive
  - Nuclear recoil threshold ~300 eV
- Detector system under construction at UCSD
  - R&D efforts to reduce the single-and-few electrons background
- Background estimation based on Xenon10/Xenon100
  - 10-kg active LXe detector is expected to achieve 5σ CEvNS detector





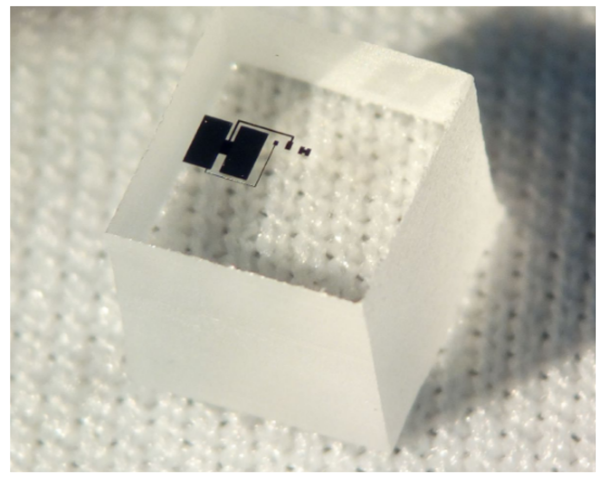
Universe 2021, 7, 54

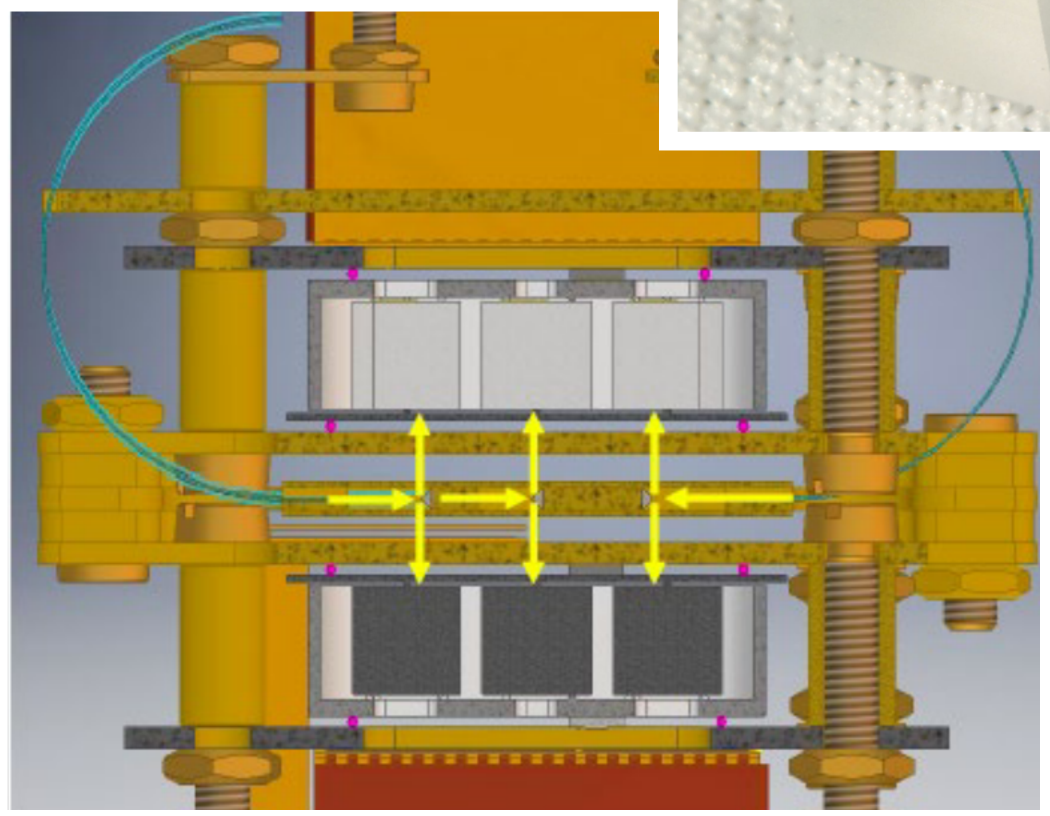


Nuclear Reactor experiments

Bolometers

Nuclear reactors





NUCLEUS

- g-scale $CaWO_4$ (CEvNS) and Al_2O_3 (Bkg) crystals @ mK temperatures
  - 2 arrays of 3 x 3 cryogenic crystals (gram scale)
- Detector threshold ~ 20 eV
- Target background 100 events/kg/day/keV
- 102 m & 72 m of 2 reactors of the Chooz-B plant of 4.25 GW each
- Flux: $1.7 \cdot 10^{12}\ \bar{\nu}_e\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

- Multi-layer passive shield + active vetos
  - Muon veto with plastic scintillators
  - 20 cm 5%-borated polyethylene
  - 4 cm boron carbide
  - Cryogenic outer veto (COV) – HPGe crystals (4 kg)

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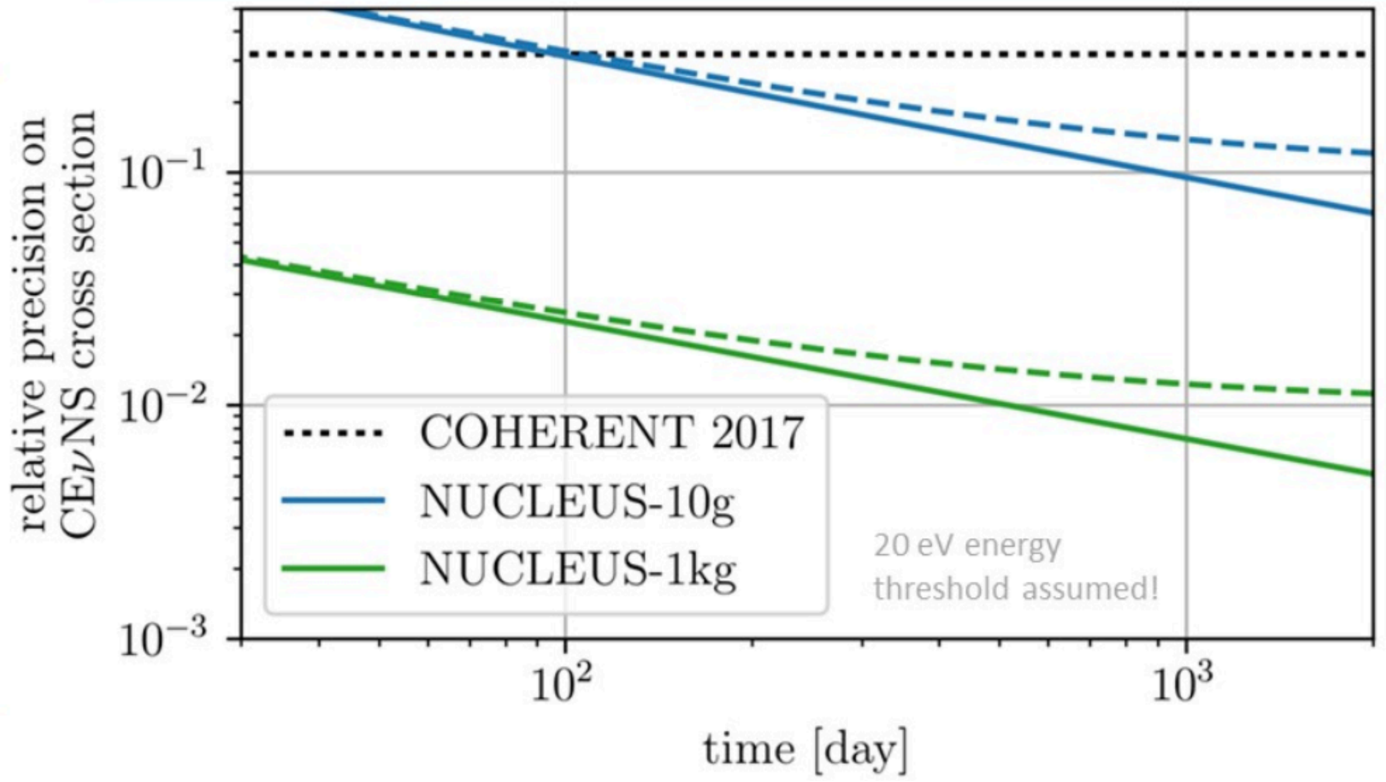
3F Majorana, MT16-158
6F Dirac, DT06-166
7F Dirac, DT06-738



- NUCLEUS 10 g 5σ observation of CEvNS in < 1 year

Background contribution Rates in $kg^{-1}\ d^{-1}$ ***(Preliminary)***	$CaWO_4$ array			Al_2O_3 array		
	10-100 eV	100 eV – 1 keV	1 keV – 10 keV	10-100 eV	100 eV – 1 keV	1 keV – 10 keV
Ambient gammas	1.7 ± 0.2	5.3 ± 0.4	≈ 45	3.9 ± 0.4	10.4 ± 0.6	≈ 90
Atmospheric muons	< 1.9	< 1.9	< 1.9	< 2.9	< 2.9	0.4 – 2.8
Atmospheric neutrons *(with a factor 5 from VNS building)*	≈ 7	≈ 23	≈ 64	≈ 1.5	≈ 15	≈ 44
Total	**≈ 10**	**≈ 30**	**≈ 110**	**≈ 6**	**≈ 30**	**≈ 140**
CEνNS signal	≈ 30	≈ 9	-	≈ 2	≈ 4	-

Nuclear reactors

Ricochet

RICOCHET
A Coherent Neutrino Scattering Program

- Cryogenic phonon detectors with an energy threshold < 100 eV
  - Neutron-Transmutation-Doped (NTD) thermistors
  - Transition-Edge Sensors (TES)
- 8 m of the 58.3 MW ILL reactor core @ Grenoble, France
- 15 m.w.e of overburden, muon reduction 2-3 times
- Flux: $1.2 \times 10^{12}\ \bar{\nu}_e \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Cycles of 50 days with time for background characterization

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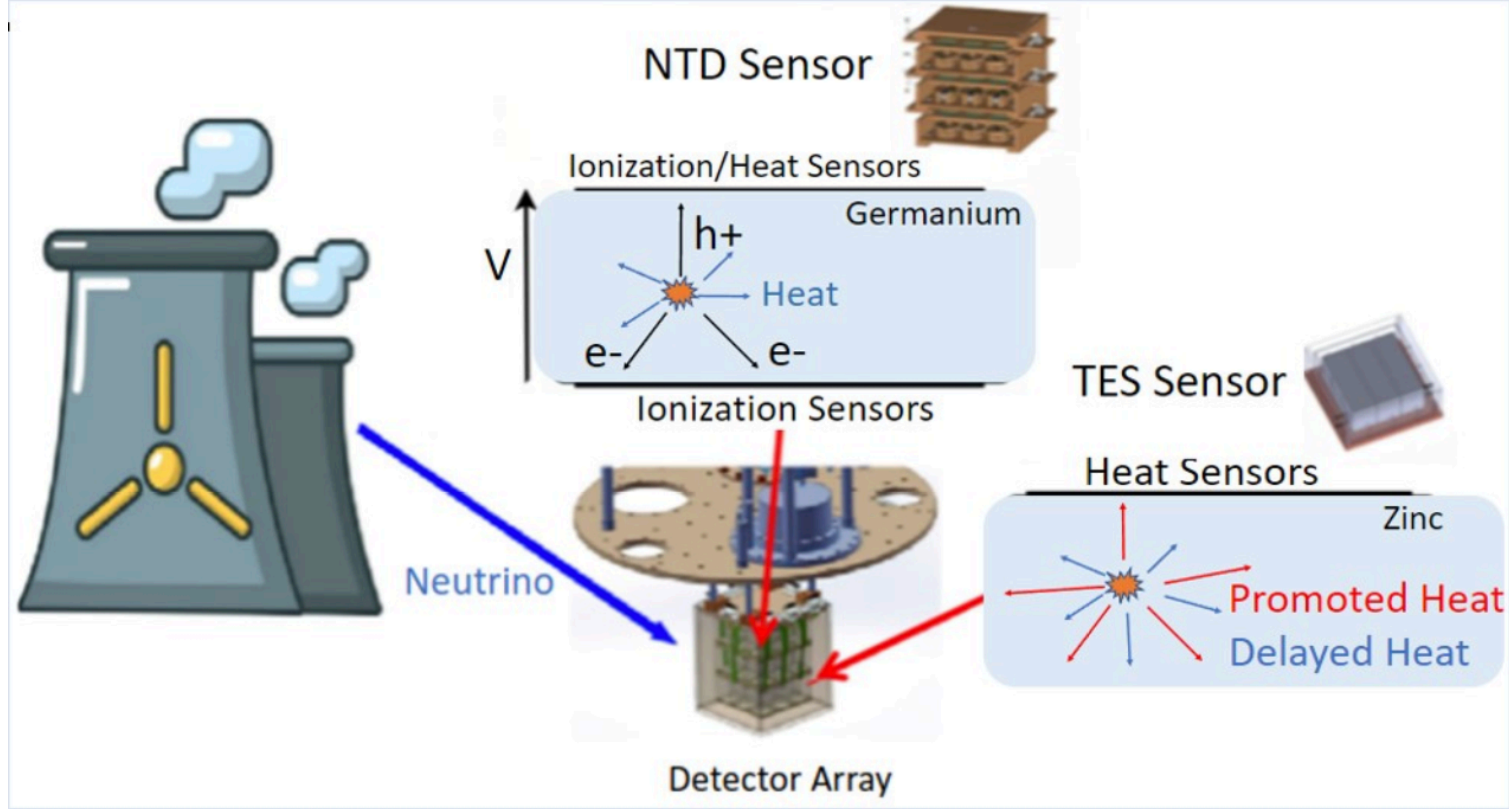
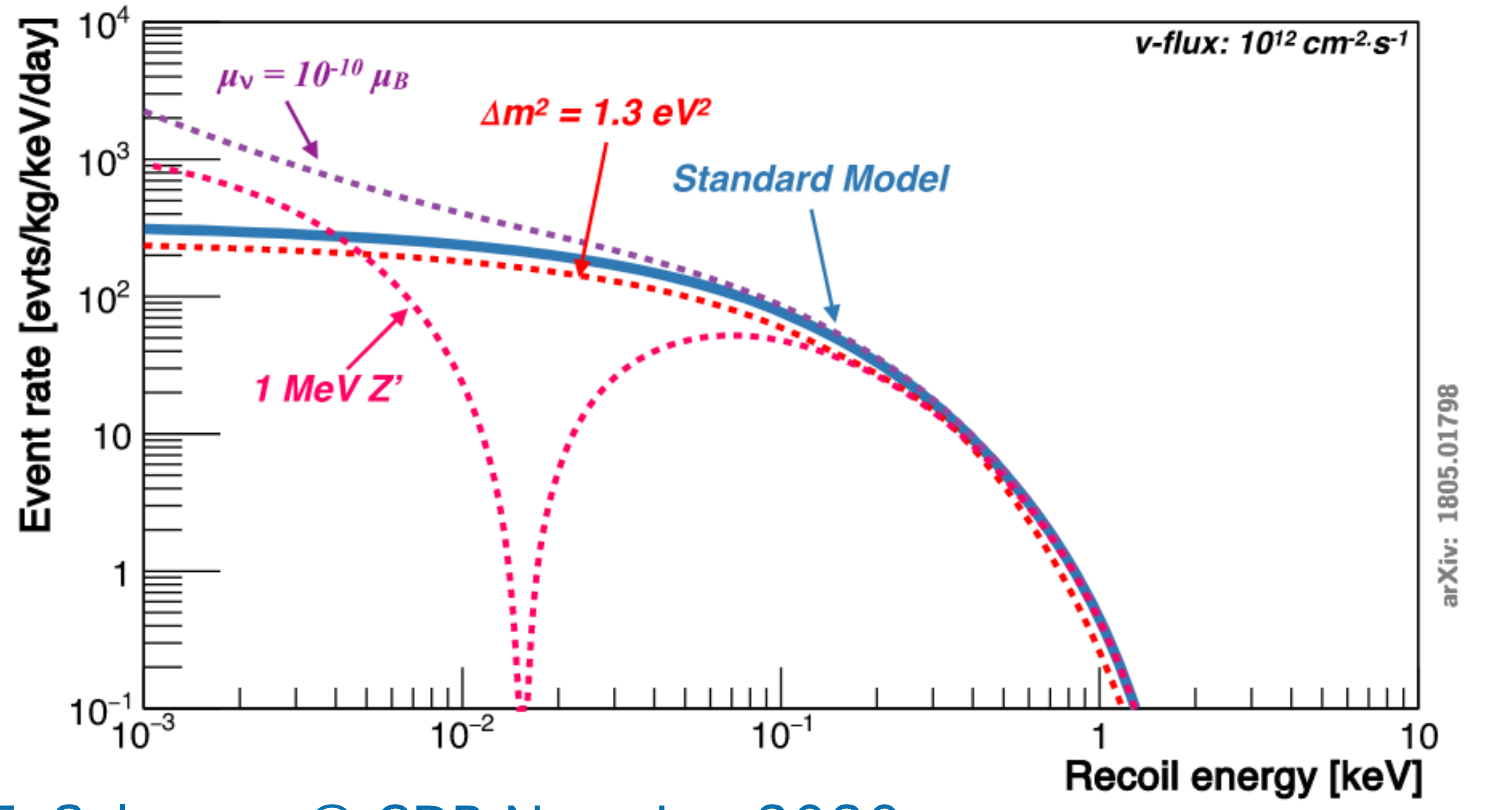
4F Majorana, MT06-632



Example: Nuclear recoil spectrum inside 1kg Ge target at ~ 8 m of the 58 MWth ILL reactor



T. Salagnac @ GDR Neutrino 2020

Nuclear Reactor experiments

Crystal Scintillator Detectors

Nuclear reactors

NeON

- Neutrino Elastic-scattering Observation with NaI
- Detector threshold < 0.3 keV
- 13.5 kg (comercial detectors: 3x 1.6 kg & 3x 3.4 kg)
- Located @ 23.7 m of a 2.8 GW nuclear reactor
- Flux: $7.1 \cdot 10^{12}\ \bar{\nu}_e\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Passive shield (polyethylene, B-polyethylene and lead)
- Active shield (liquid scintillator)

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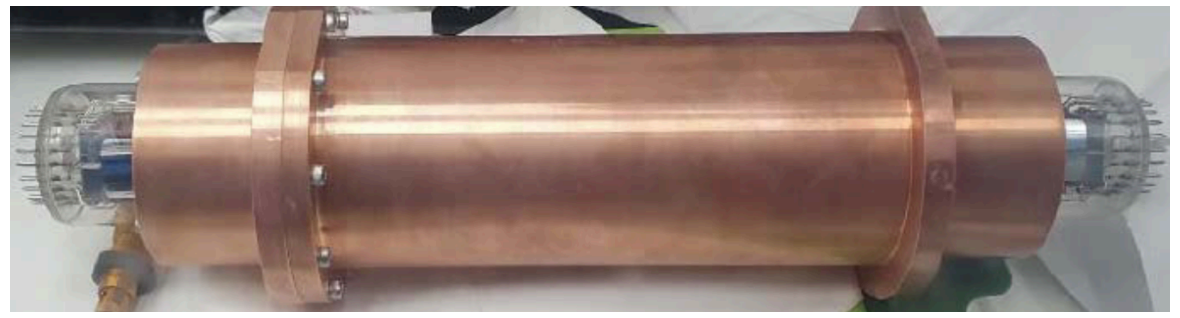
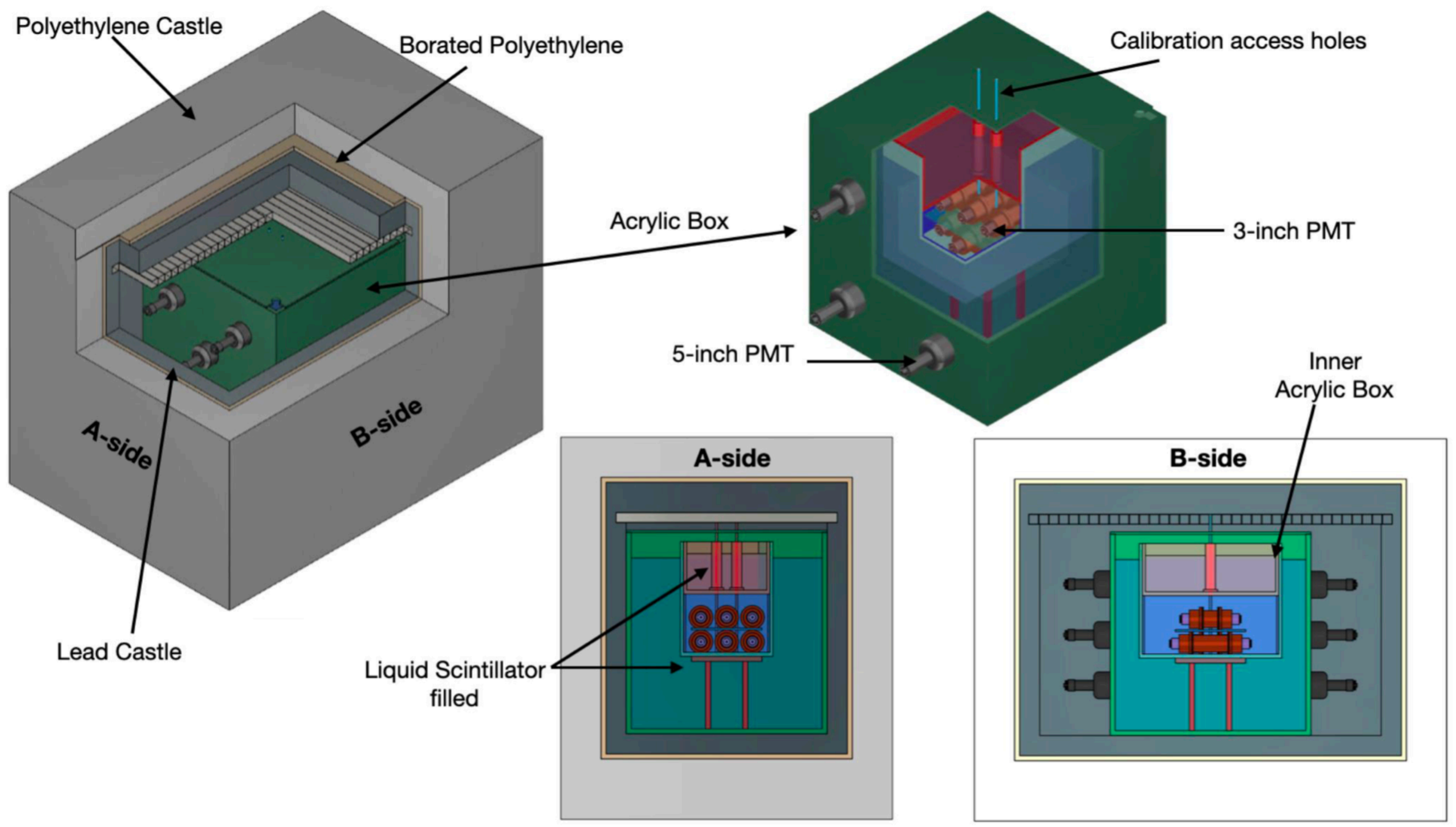
7F Dirac, DT06-789
7F Dirac, DT06-630





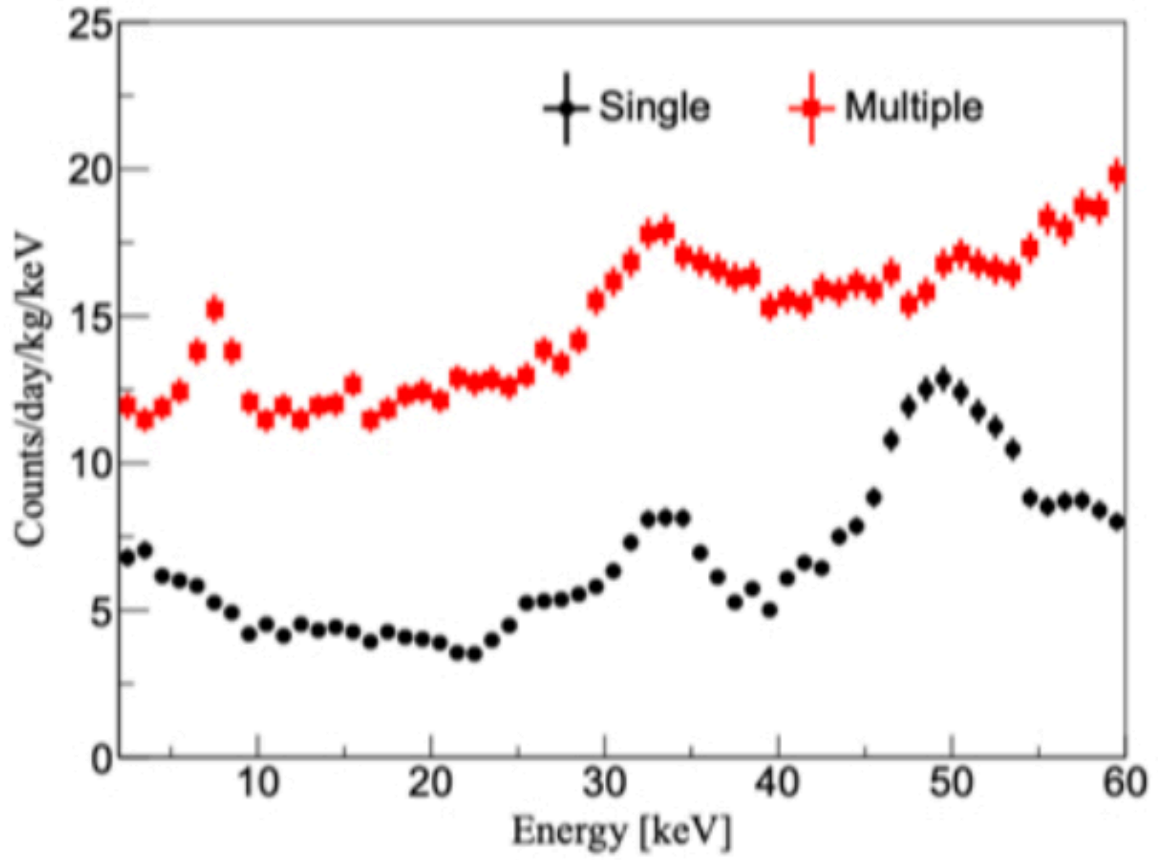
arXiv:2204.06318

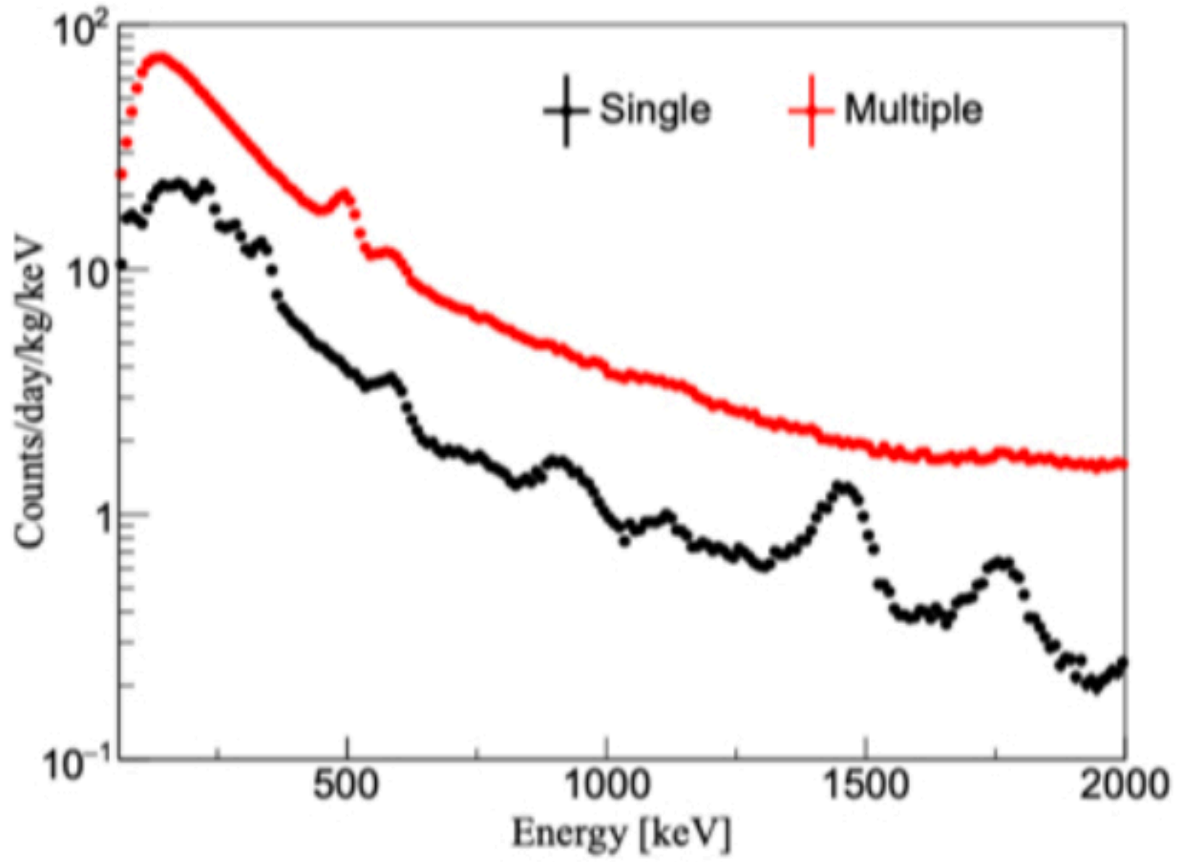
- Sensitivity:

  Background of ~ 7 dru (thanks to the veto)

  Light yield of 22 NPE/keV

  Threshold 5 NPE (200 eV)





Nuclear reactors

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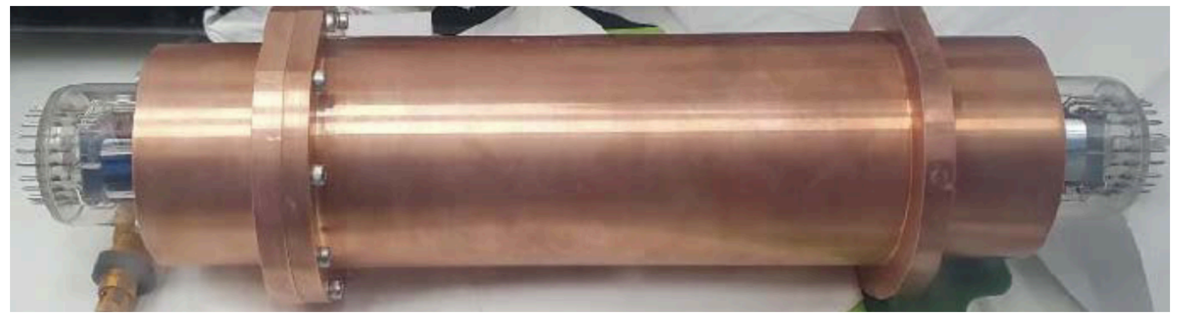
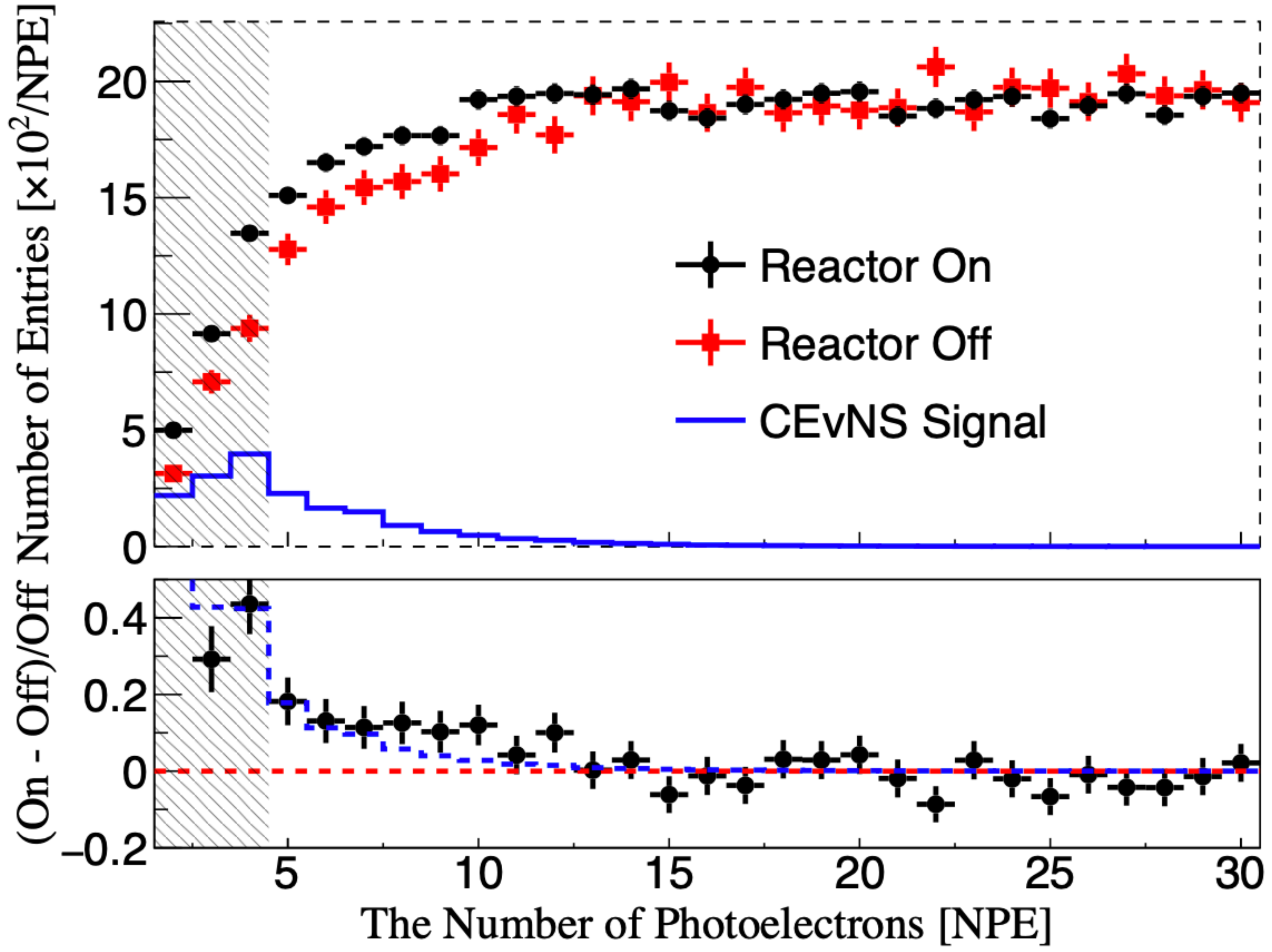
7F Dirac, DT06-630

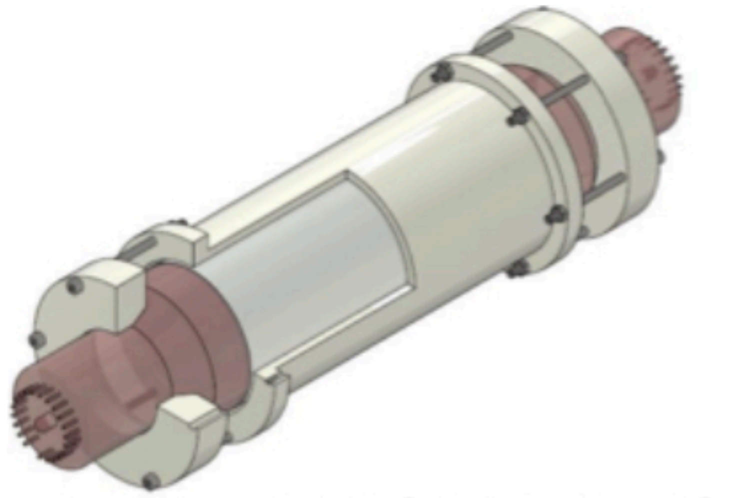


arXiv:2204.06318

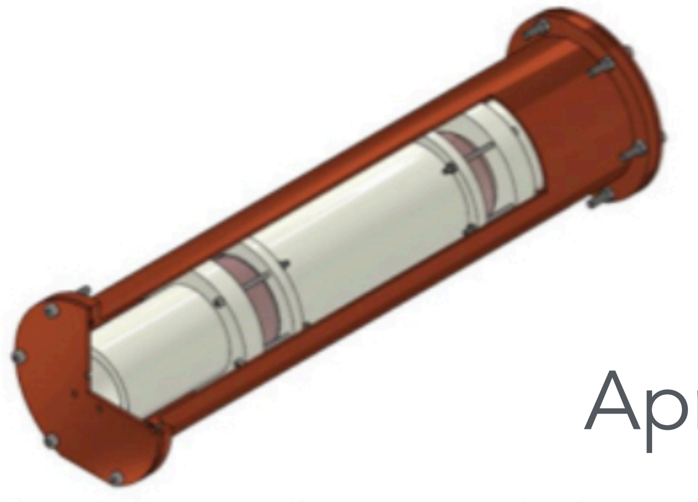
- CEvNS detection significance 4 ± 1 σ
  - Background of ~ 7 dru (thanks to the veto)
  - Light yield of 22 NPE/keV
  - Threshold 5 NPE (200 eV)
  - 1 year Reactor ON data
  - 100 days Reactor OFF data



- Phase-2
  - New encapsulation



Inside of copper(Teflon frame)



Copper shield with crystal

April 2022

Nuclear Reactor experiments

Color Center Passive Detectors

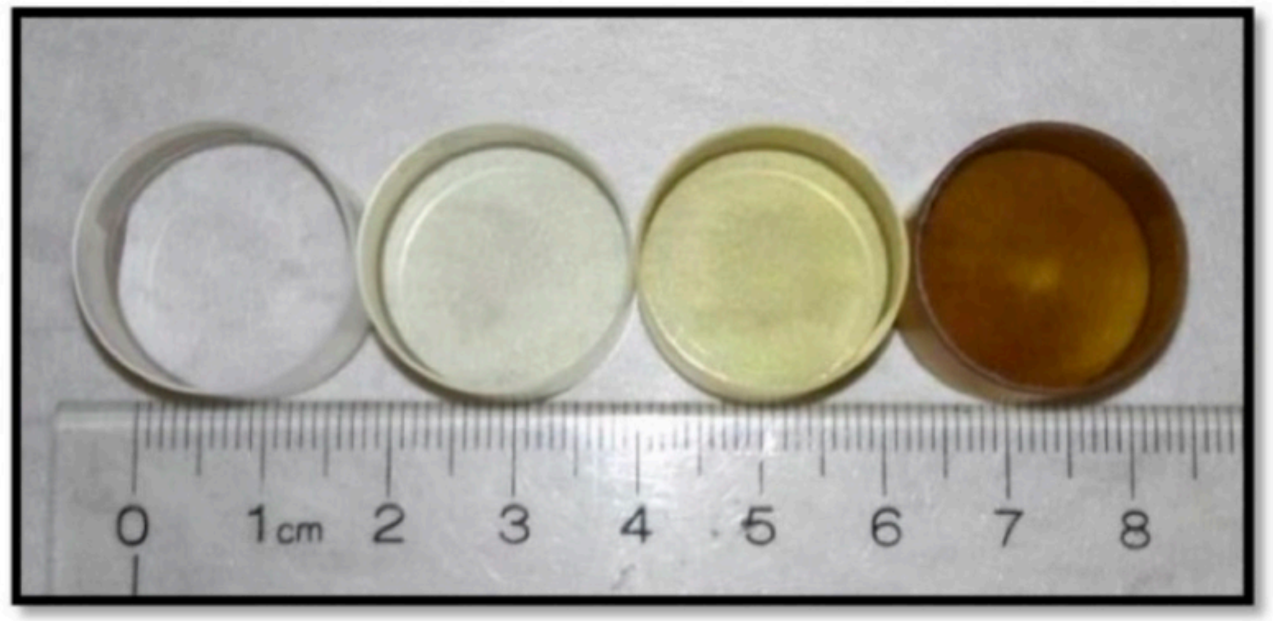
Nuclear reactors

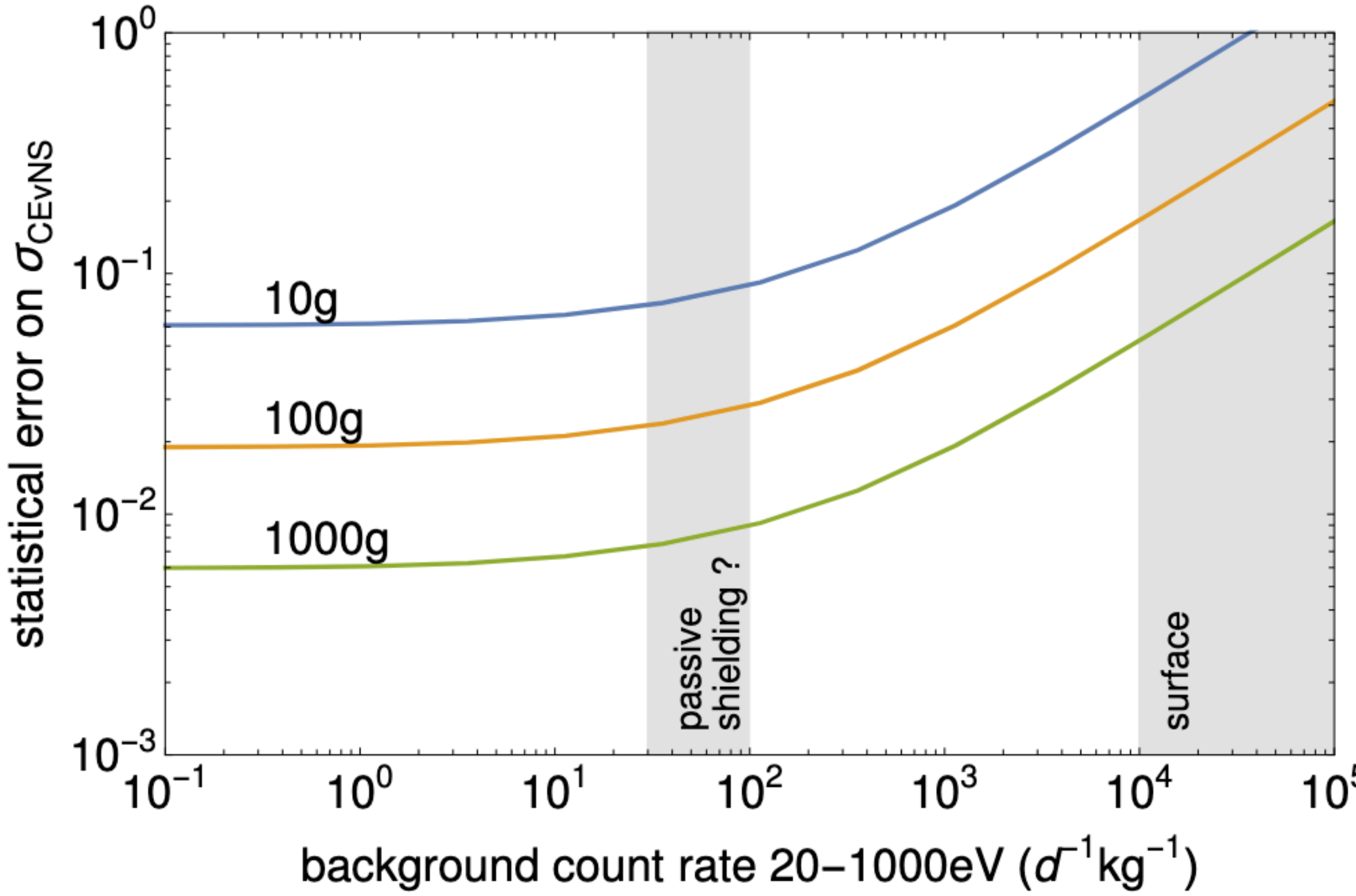
PAssive Low Energy Optical Color CEnter Nuclear rEcoil

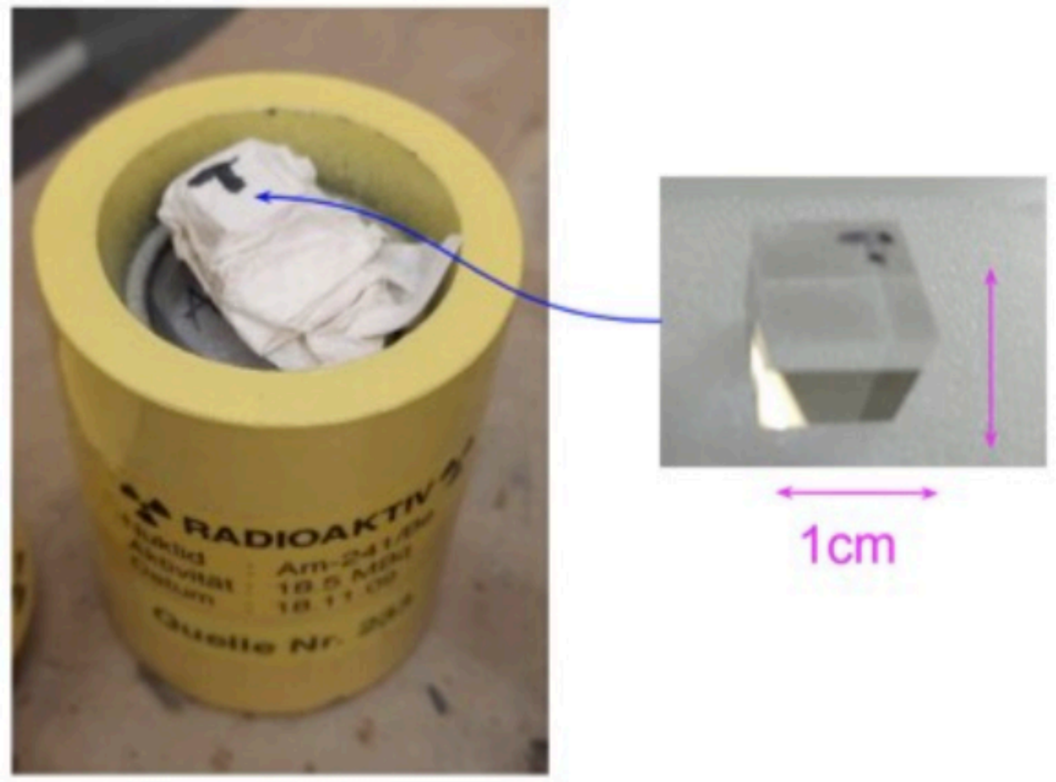
PALEOCCENE

- Room-temperature, passive and robust detectors
  - gram-kilogram range detectors
- Nuclear recoils result in damage to the crystal lattice and some of these damage sites can become optically active
  - Few tens of eV
  - Optical detection of the fluorescence of single color centers
- R&D efforts to investigate the feasibility of this concept
- CEvNS detection at 30 of a 3 GW nuclear reactor during 1 year

CaF$_2$ crystal with different radiation doses







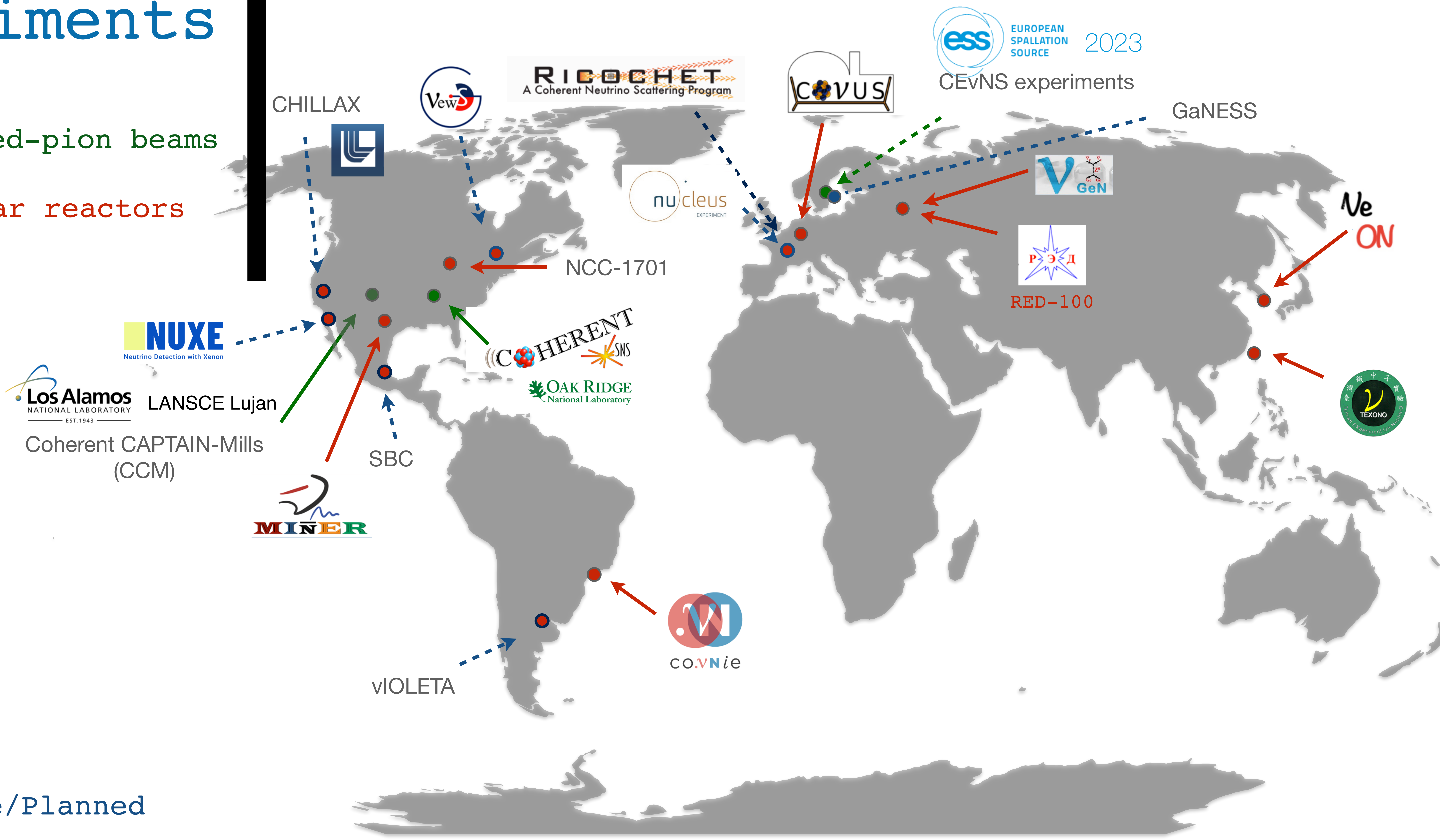
CaF$_2$ crystal irradiated by AmBe source

NEUTRINO 2022
XXX International Conference on Neutrino Physics and Astrophysics
May 30 - June 4, 2022
Virtual Seoul

3F Majorana, MT16-226

Experiments

- Stopped-pion beams
- Nuclear reactors



- Future/Planned

Summary

- CEνNS: very active field
- Exciting moment: new results from different experiments and new techniques expected soon
- New facilities and next generation experiments being designed
- Synergy between experiments and theory

More in Carlo Giunti's talk
New physics search w/ CEνNS

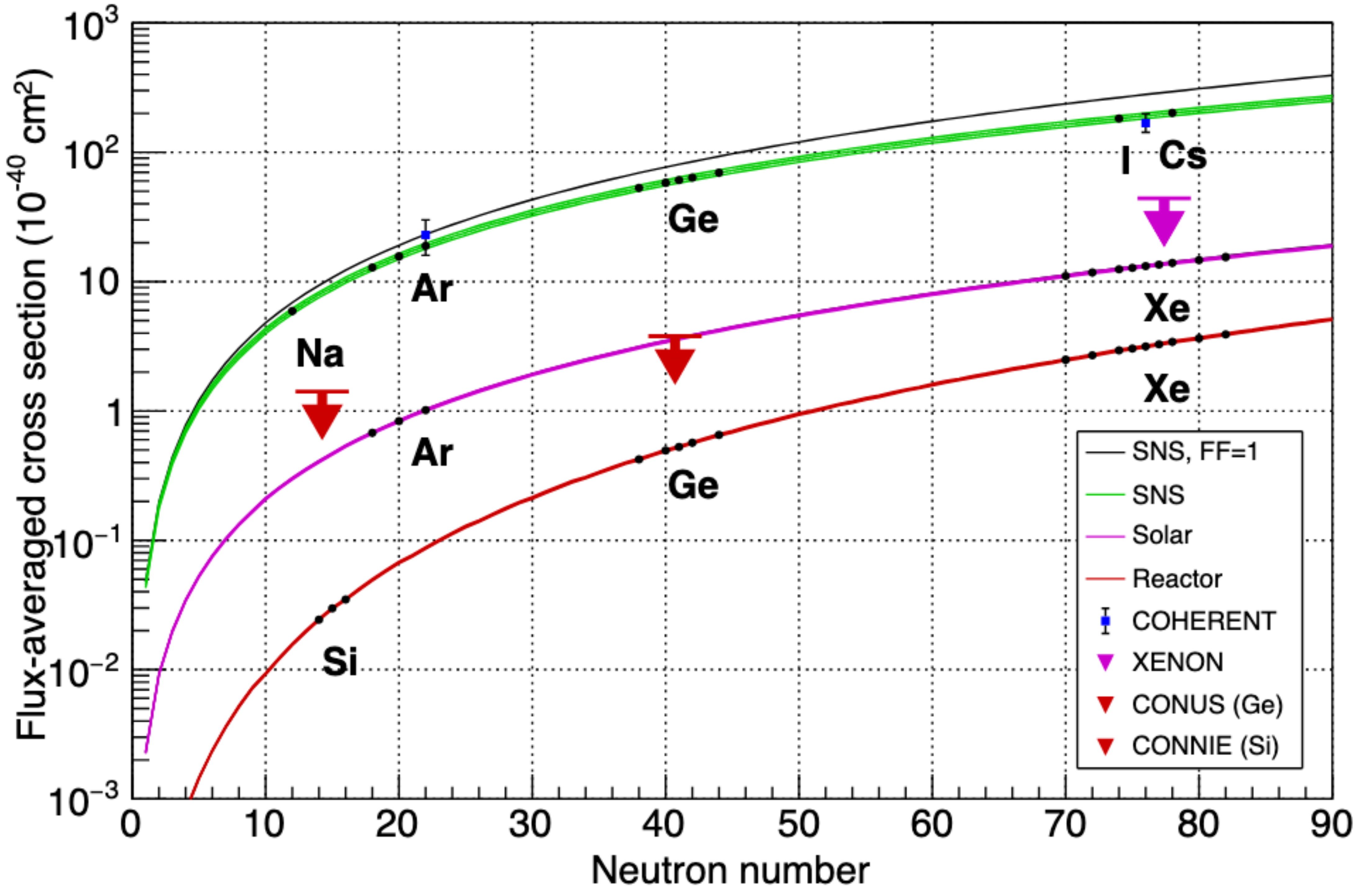


Figure: Kate Scholberg

It's just the beginning....

Thank you !!