# Scientific overview of the future RICOCHET experiment

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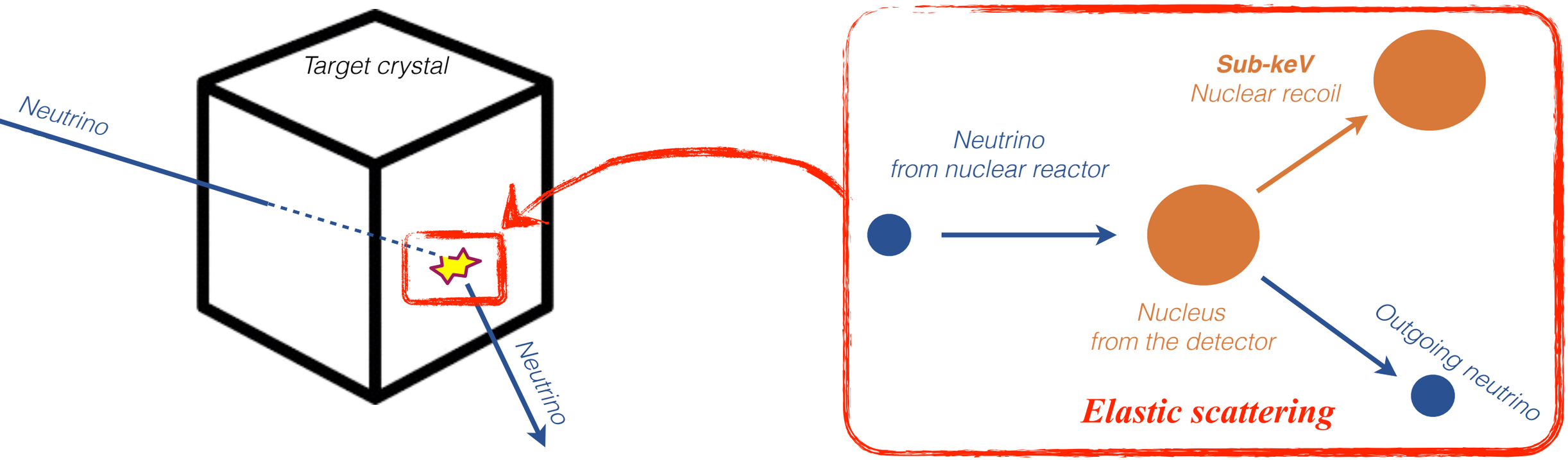
Joint JINR-IN2P3 meeting, May 18th, 2021

# Ricochet: *Searching for new physics with CENNS*

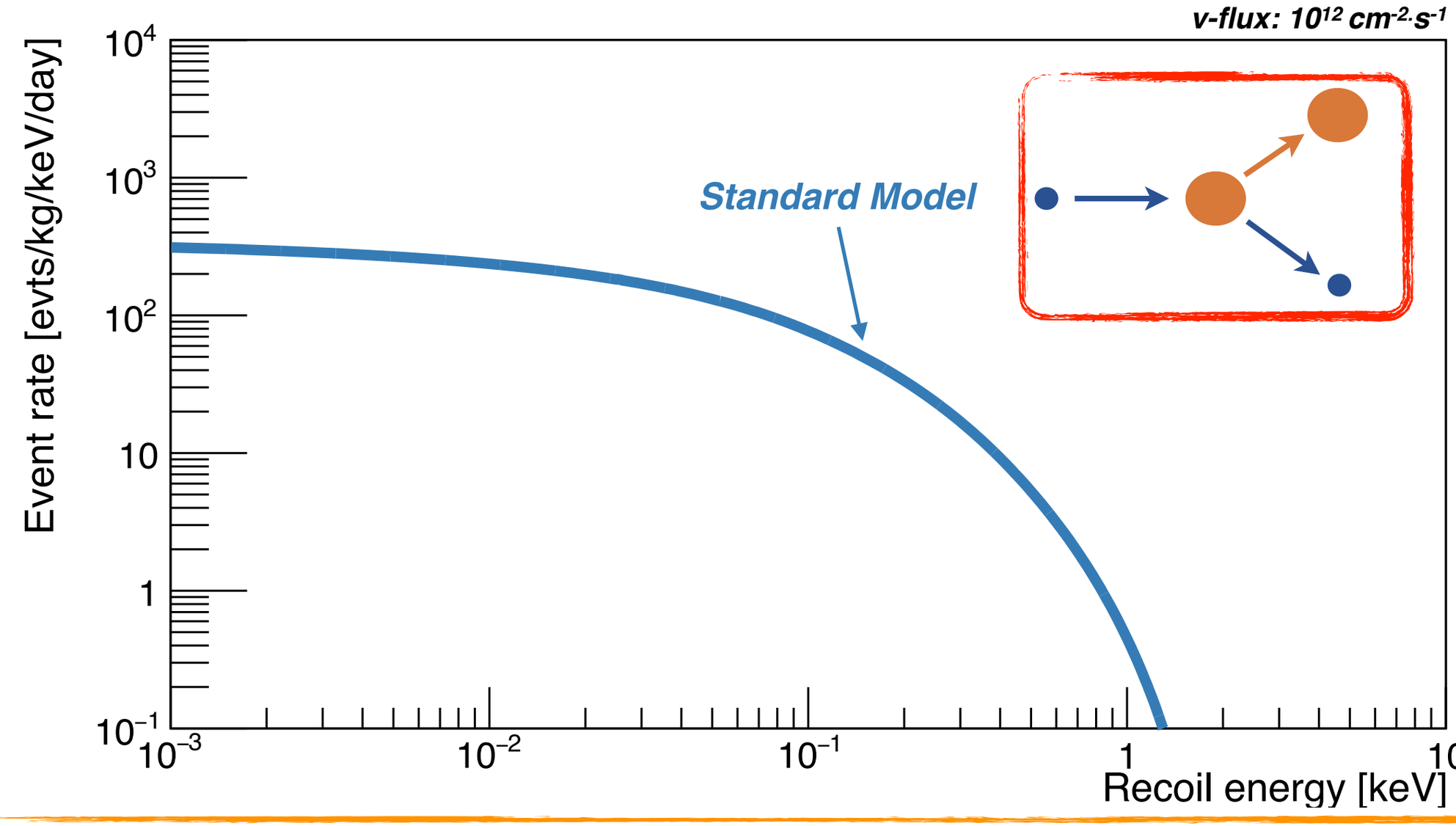
## **C**oherent **E**lastic **N**eutrino-**N**ucleus **S**cattering (CENNS)




- CENNS cross-section ***1000 times larger*** than that of IBD considered in most neutrino experiment
- Elastic scattering — ***No neutrino energy threshold***
- From ton-scale to kg-scale neutrino detector payloads with complementary scientific potential

# Ricochet: *The CENNS process*

*Recoil energy distribution*



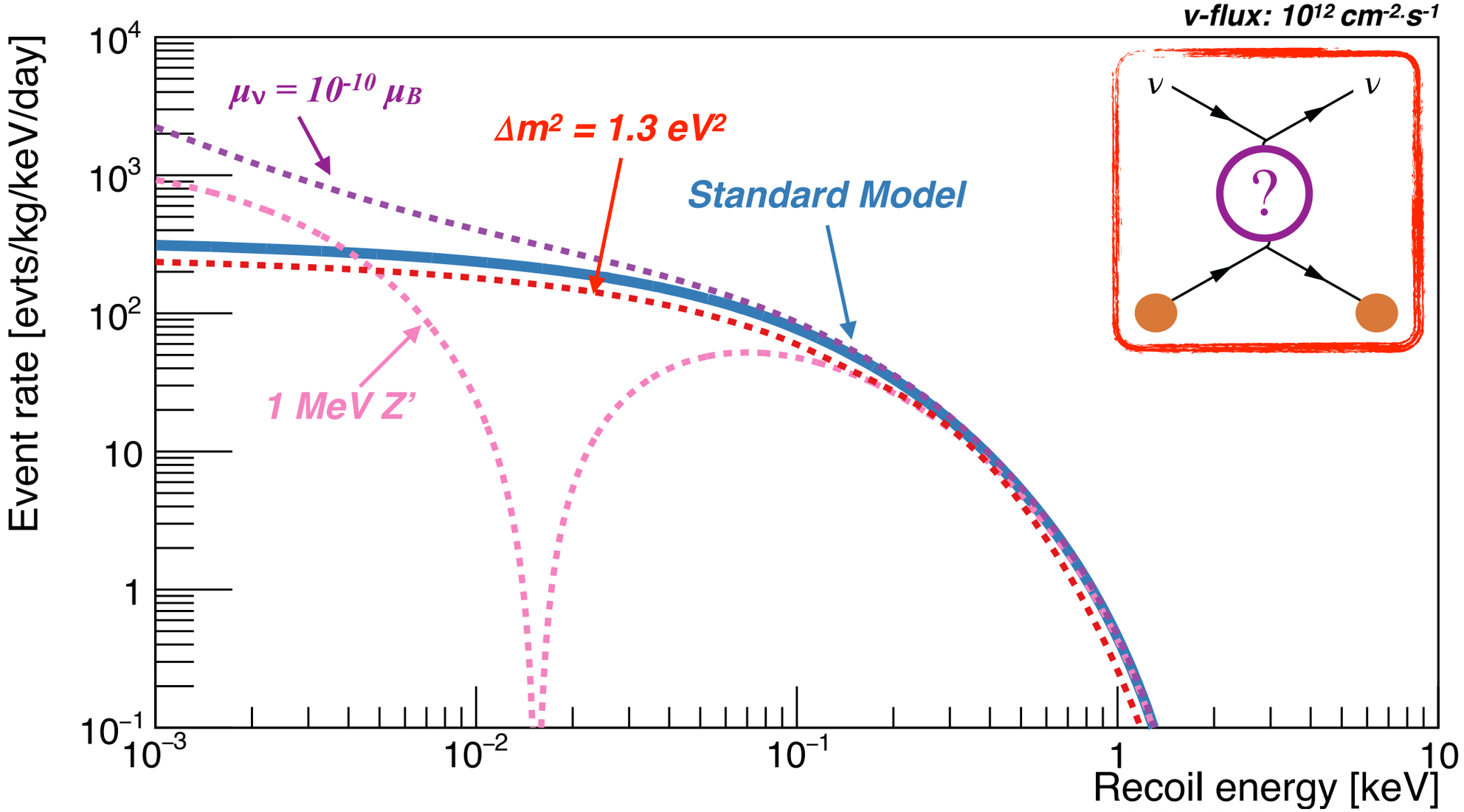

*J. Billard, J. Johnston and B. Kavanagh*, JCAP (2018)

*We expect a few tens of events per day and per kg of detector material*

***Calls for small total detector mass to reach high-precision: kg-scale with sub-100 eV threshold***

# Ricochet: *searching for new physics*

## *Recoil energy distribution*

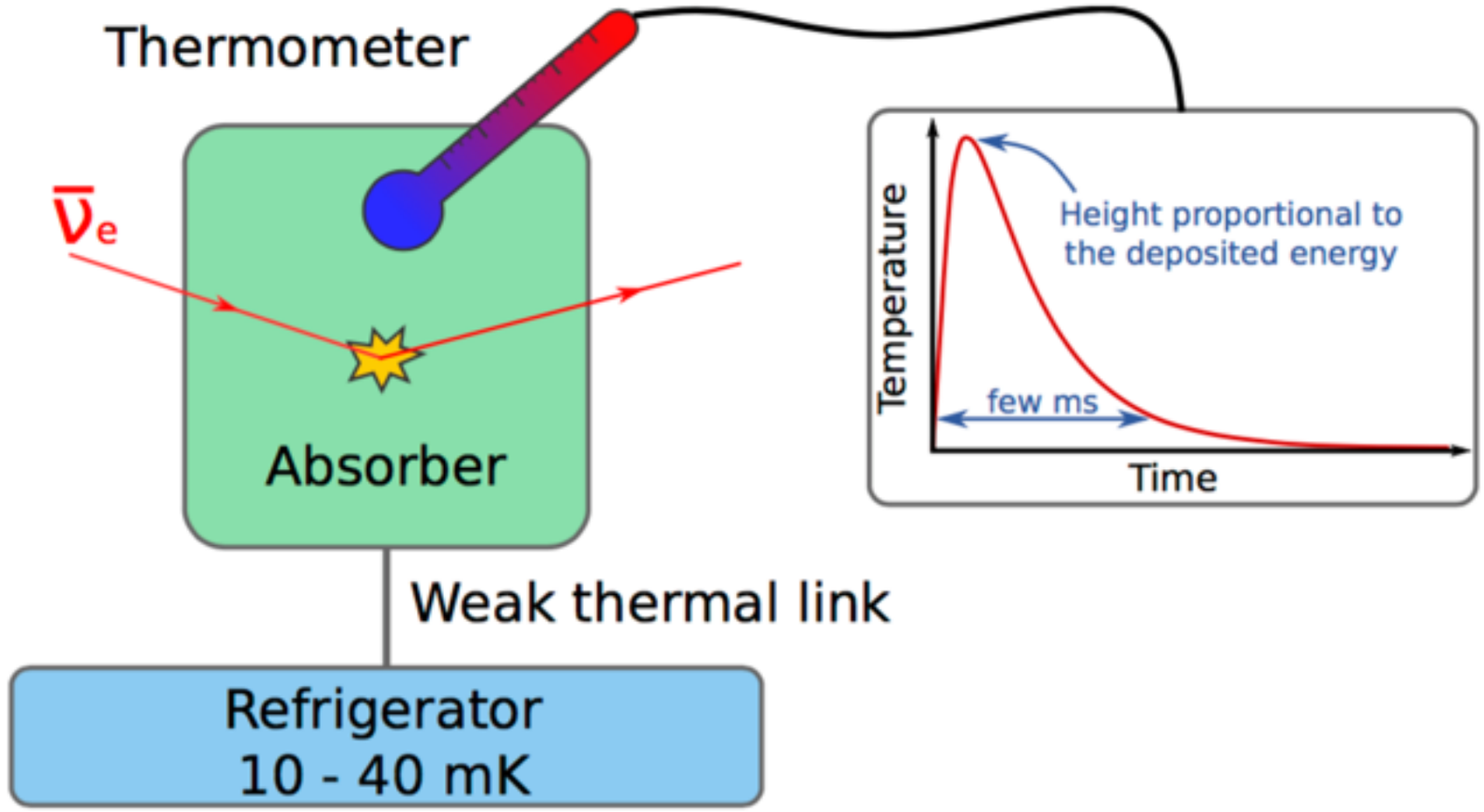



J. Billard, J. Johnston and B. Kavanagh, JCAP (2018)

*New physics signatures will arise at the lowest energies*

***Calls for very low-energy thresholds: O(10) eV***

# RICOCHET: *Cryogenic detectors for CENNS*

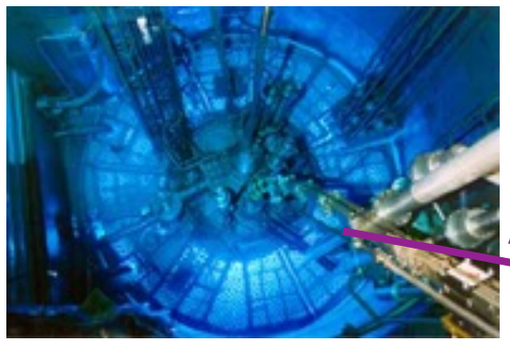



***Advantages of a cryogenic phonon readout:***

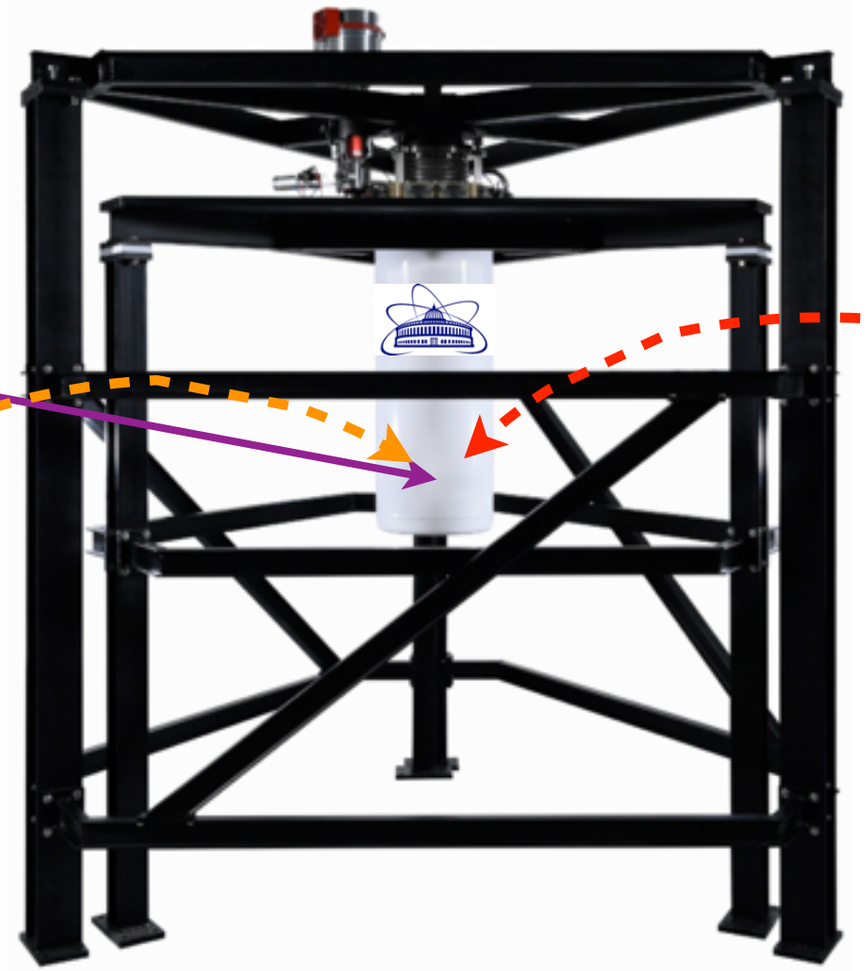
- Direct measurement of the recoil energy, *no quenching involved*
- Almost 100 % of the recoil energy is sensed, *allowing for low-thresholds*
- From thermodynamics, ultimate energy resolution is: **~eV (RMS) for ~ 10 g detectors**
  - ***Calls for the construction of arrays of 10g-scale cryogenic detectors***

# RICOCHET: *A future low-energy neutrino observatory*

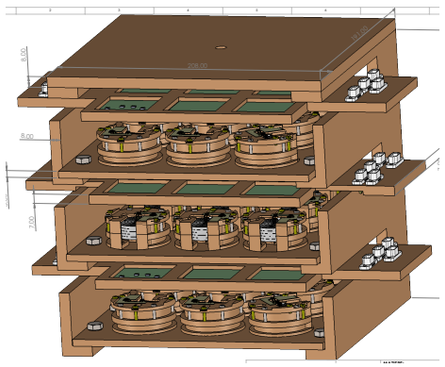
RICOCHET is a **France, USA and Russia** wide collaboration accounting for about 50 physicists, engineers, and technicians, aiming at building the **first low-energy neutrino observatory**



Neutrino



**CRYOCUBE**
Ge (& Si?)



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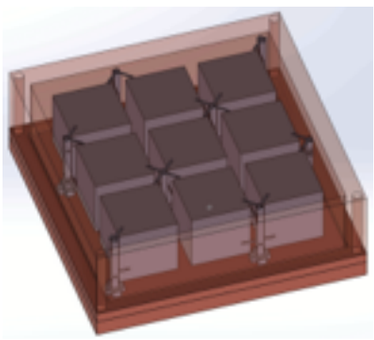
**Q-ARRAY**



HEISING-SIMONS FOUNDATION

# RICOCHET
## A Coherent Neutrino Scattering Program

Northwestern University

LPSC Grenoble

CSNSM

iPNL

MIT

NÉEL

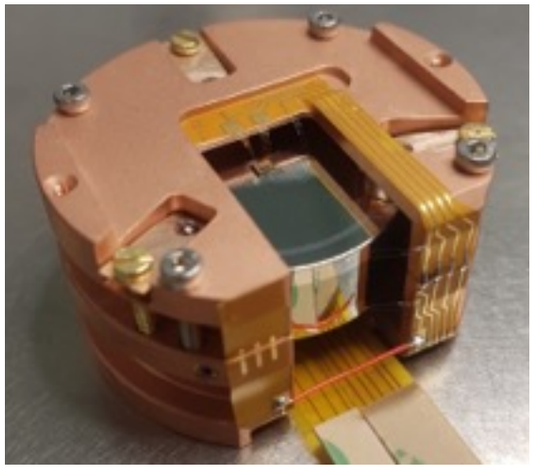
THE UNIVERSITY of WISCONSIN MADISON

UMASS AMHERST

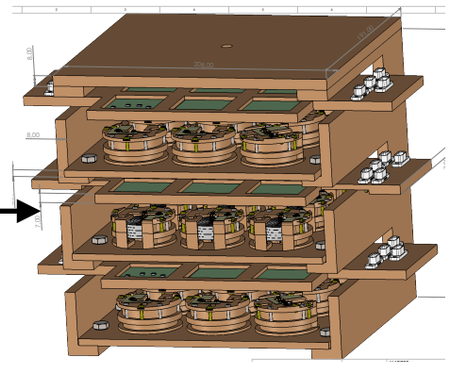
# Ricochet: *Detector technology innovation*

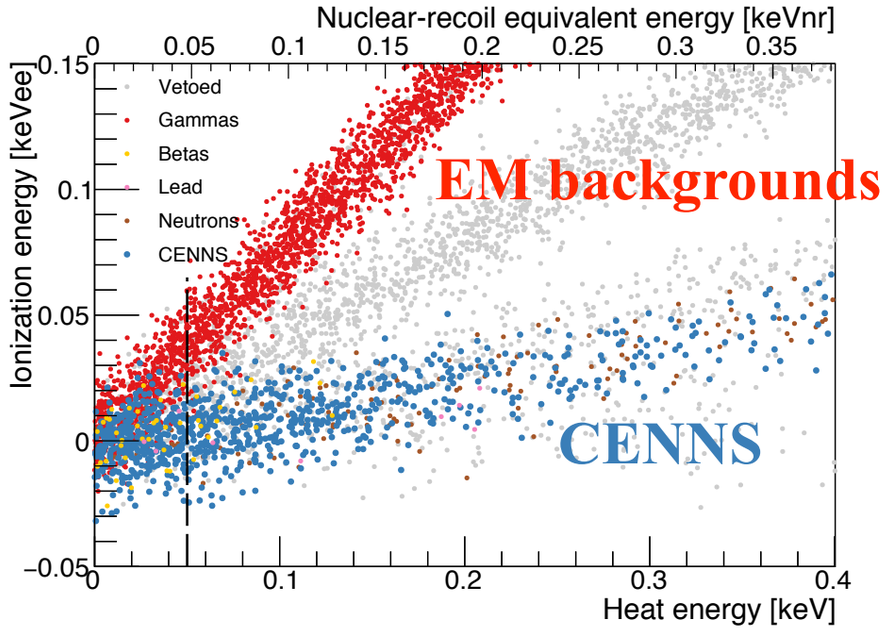
**Technological key features of RICOCHET: Particle Identification down to sub-100 eV**

## *Germanium semicondutor*



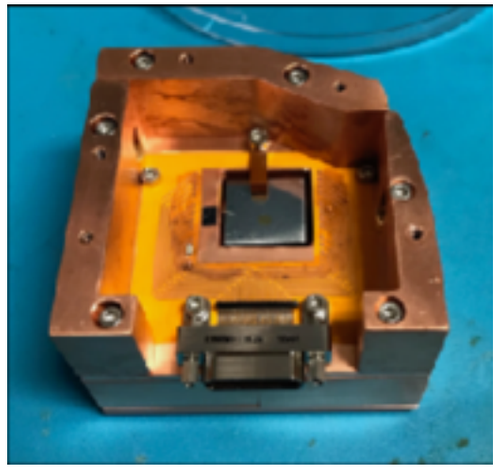
*Array of 27 38-g Ge detectors (~1 kg)*



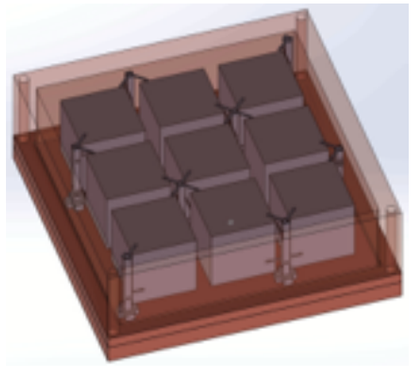


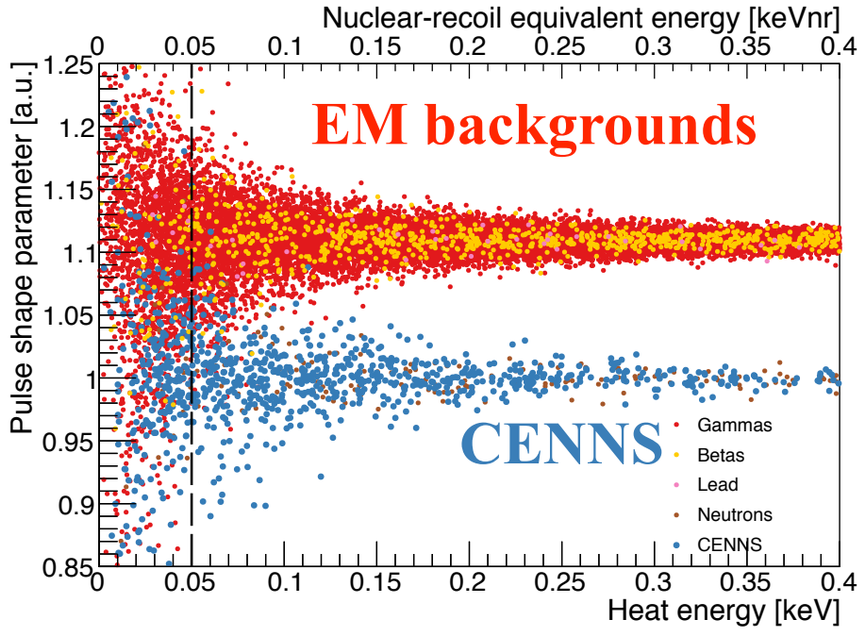

Particle ID based on **Ionization / heat** ratio

## *Zinc superconducting metal*



*Array of 9 32-g Zn detectors (300 g)*






Particle ID based on **Prompt / delayed** heat signals

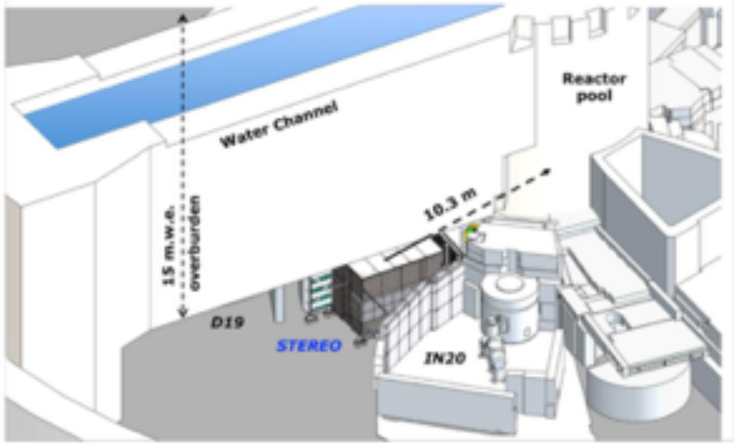
# Ricochet: *The competition*

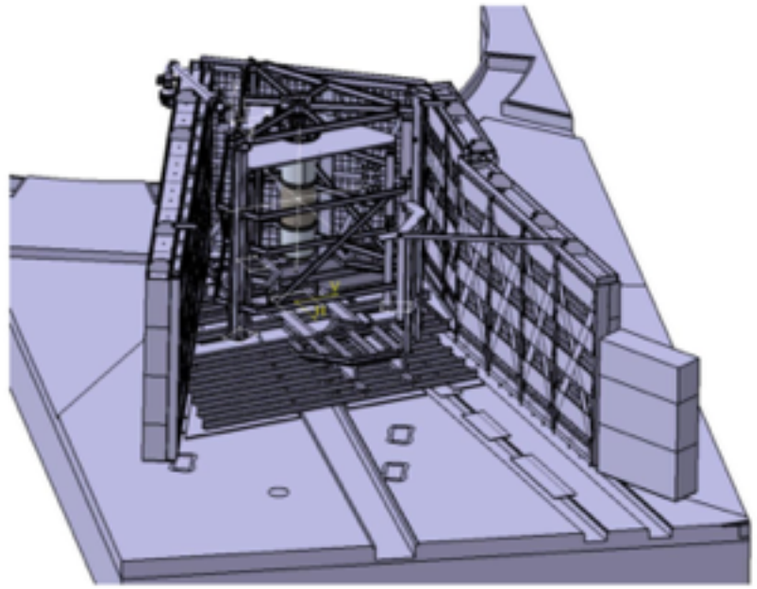

*credits: A. Konovalov*

- Highly competitive field with about 20 experiments worldwide considering various type of neutrino sources
- MINER, NuCLEUS and RICOCHET are the only ones aiming for a ***sub-100 eV CENNS measurement at reactors***
  - **Ricochet is the only one with Particle Identification to unambiguously identify the CENNS signal**

# RICOCHET: *ILL-H7 nuclear reactor site (phase 1)*

- 58 MW nominal thermal power
- Large neutrino flux: ~1x$10^{19}$ ν/s
  - 8m from core: 15.5 evts/day/kg *(1.6x$10^{12}$ ν/s/cm$^2$)*
- 3 to 4 cycles per year: ***excellent ON/OFF modulation to subtract uncorrelated backgrounds***
- Significant overburden (~15 m.w.e)
- Ricochet will make use of STEREO casemate following its dismantling end-2020 and benefits from its strong experience of running at ILL
- Background simulation studies based on onsite characterization suggest that the **science potential at ILL-H7 is excellent**
- **Ricochet mechanical design is ongoing**
  - **Fully funded:** cryogenic detectors (ERC + NSF), Cryostat (JINR), shielding (ANR), DT Calibration (DOE)
  - **Deployment at ILL planned by the end-2022**



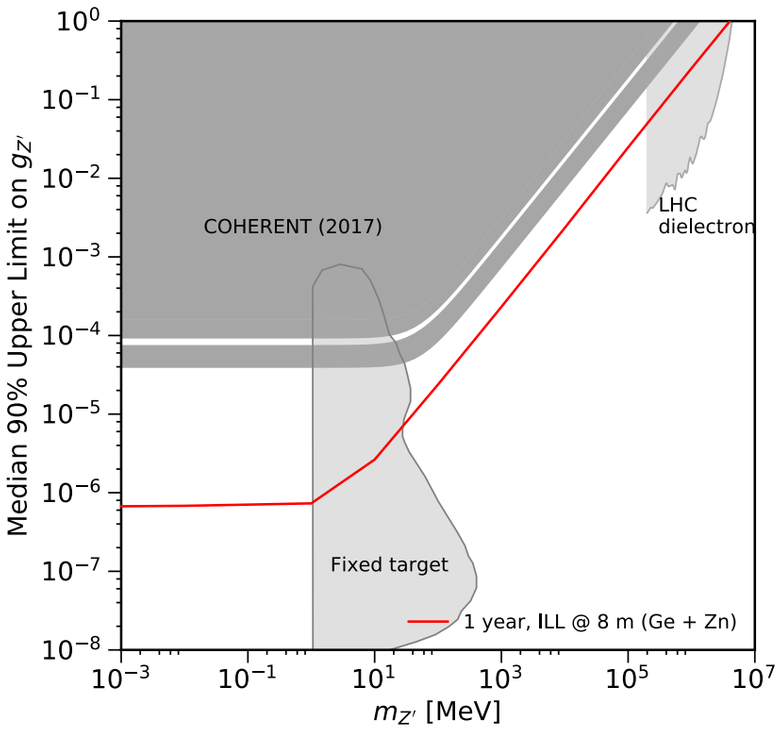



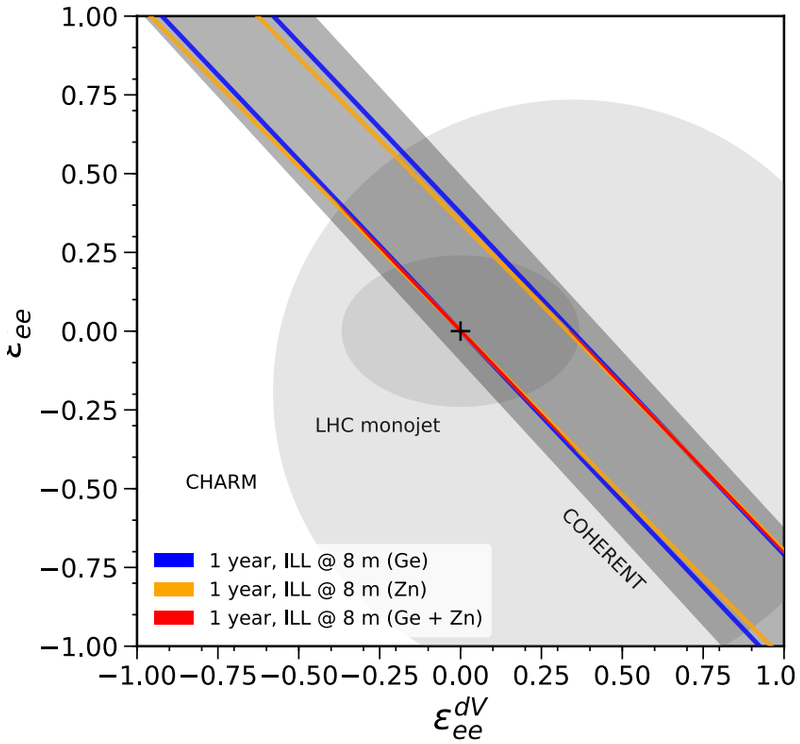
# RICOCHET: *Novovoronezh NPP (phase 2 ?)*

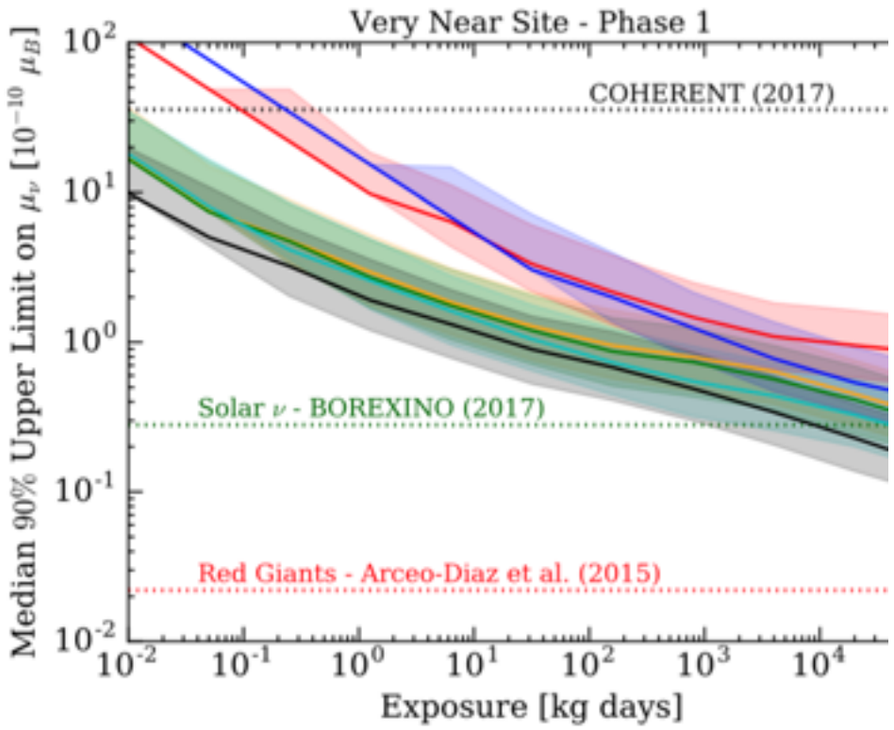
- 3200 MW nominal thermal power
- Large neutrino flux: ~5.3x$10^{20}$ ν/s
  - 25m from core: 84.6 evts/day/kg (~6 times more than at ILL)
- Almost continuous running as per energy production constraints
- Excellent overburden (~50 m.w.e) such that cosmogenic backgrounds should be negligible — *contrarily to at ILL*
- Ongoing onsite investigations by the RICOCHET JINR group performing background studies:
  - Muon flux 7 times smaller than at sea level (50 m.w.e)
  - Fast neutron background 25 times smaller than at ILL (reactor ON)
- **Scientific potential of RICOCHET at NVNPP expected to be one-to-two orders of magnitude higher than at ILL**
  - **Ongoing discussions for a possible hosting of RICOCHET for a second phase.**
  - **RICOCHET would benefit from the long lasting JINR experience in working at NPP (NuGEN, GEMMA, DANSS, …)**


# RICOCHET: *Searching for new physics*

*J. Billard, J. Johnston and B. Kavanagh*, JCAP 11 (2018) 016




The scientific goal of RICOCHET is to deliver a low-energy and high precision CENNS measurement at the **percentage level to:**

- Measure the Weinberg angle with a %-precision from 1 to 10 MeV in momentum transfer
- Search for new bosons with a sensitivity **up to two orders of magnitude better than current limits**
- Further constrain the existence of NSI by two orders of magnitude
- Reach a world-leading CENNS-based NMM limit of $\mu_\nu \sim 10^{-11}\ \mu_B$ **at the 90% C.L.**

# RICOCHET: *A new JINR-IN2P3 collaborative project*

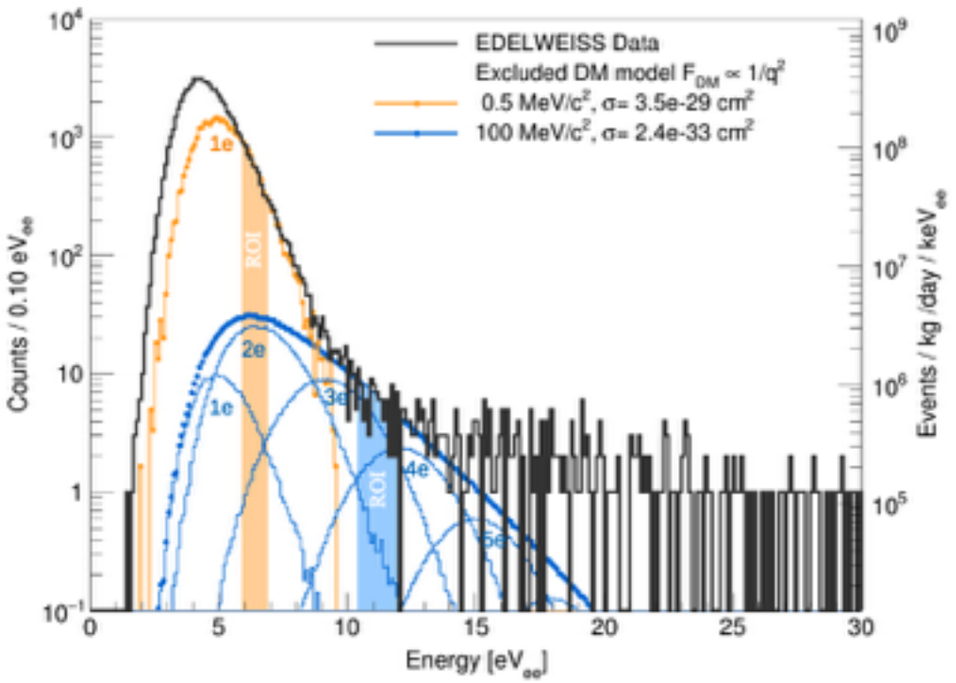
***RICOCHET is a product of the long lasting collaboration of the JINR and IN2P3 in the context of low-energy and rare event searches with bolometers hosted at LSM:***

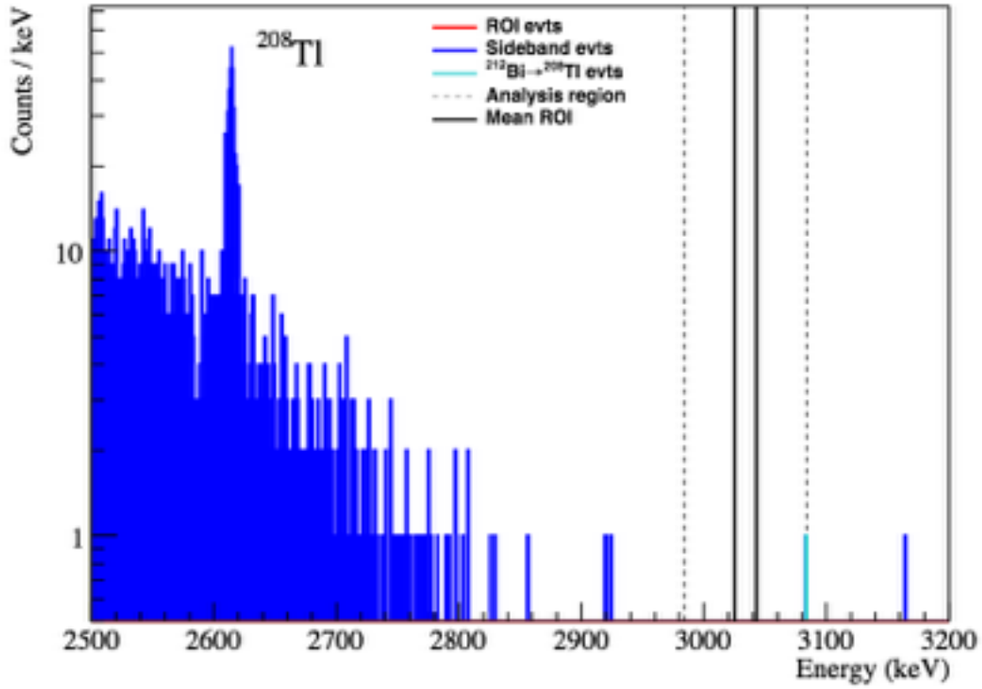
## *EDELWEISS*

First Ge-based constraints on sub-MeV/$c^2$ DM particles interacting with electrons, as well as on dark photons down to 1 eV/$c^2$.
***[PRL 125, 141301 (2020)]***

## *CUPID-MO*

New world leading limit for 0νββ decay of $^{100}$Mo of 1.4x$10^{24}$ y.
***[PRL 126, 181802 (2021)]***




RICOCHET will also have tremendous implications in the fields of: ***1)*** low-mass DM searches, and ***2)*** nuclear monitoring and the non-proliferation of nuclear fuels to be developed in the next decades