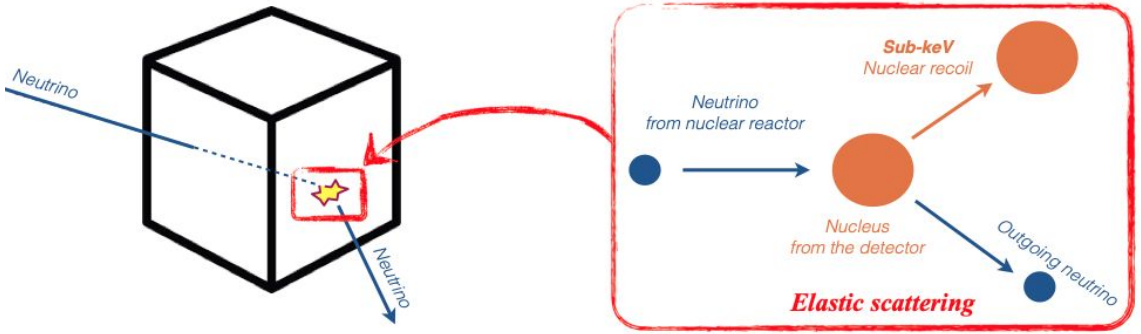
Search of new physics in the neutrino sector with the Ricochet experiment at ILL

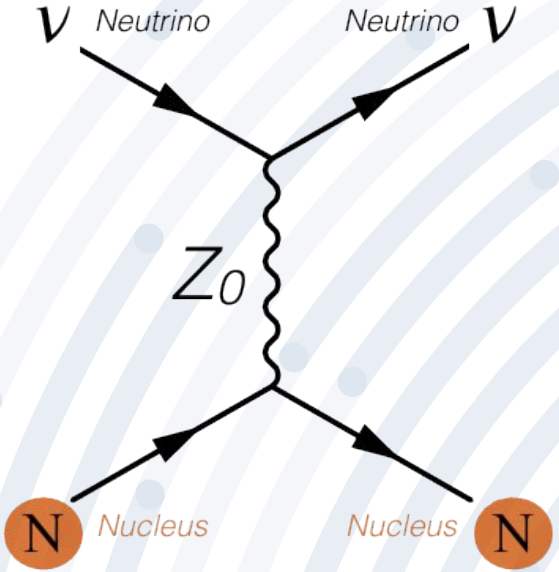
16/04/2024

Nicolas MARTINI, 2nd year PhD student
Supervised by Julien BILLARD

Context : CENNS in the Standard Model

Coherent **E**lastic **N**eutrino-**N**ucleus **S**cattering



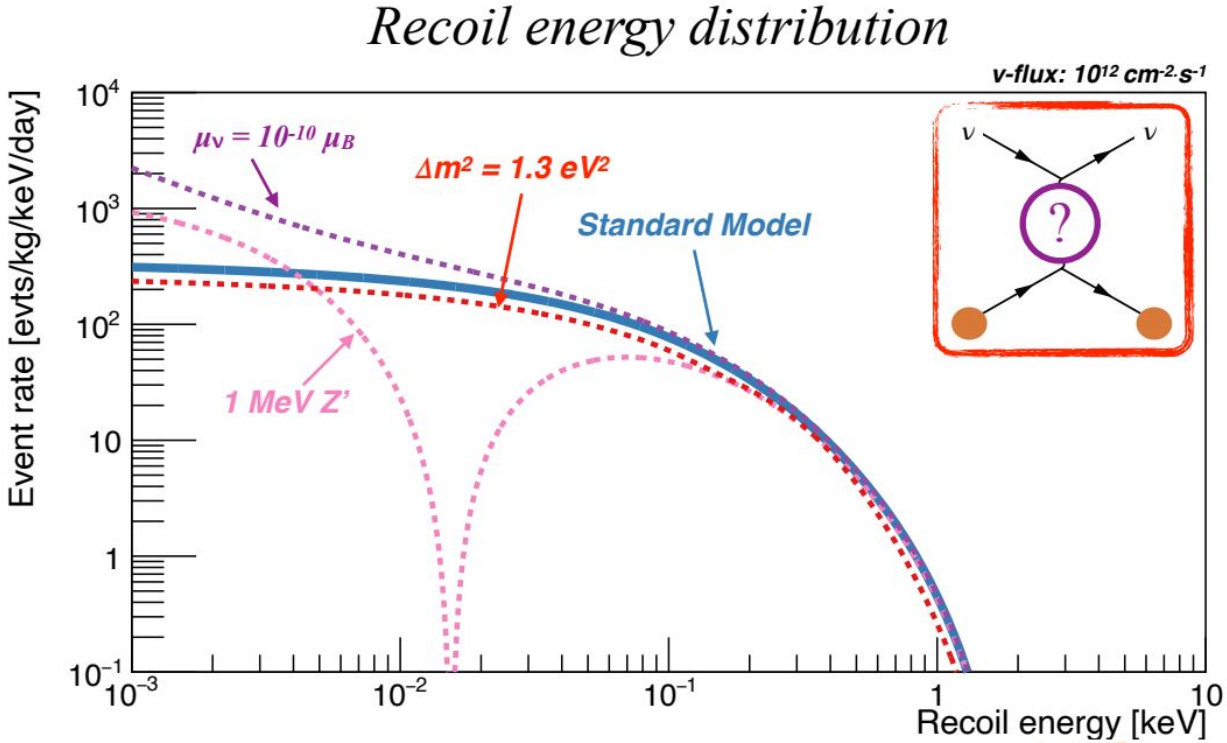


For a recent and detailed review:
M. Abdhulla et al., « Coherent elastic neutrino-nucleus scattering: Terrestrial and astrophysical applications », arXiv:2203.07361

$$\frac{d\sigma(E_\nu, E_r)}{dE_r} = \frac{G_f^2}{4\pi} Q_W^2 m_N \left(1 - \frac{m_N E_r}{2E_\nu^2}\right) F^2(E_r)$$

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

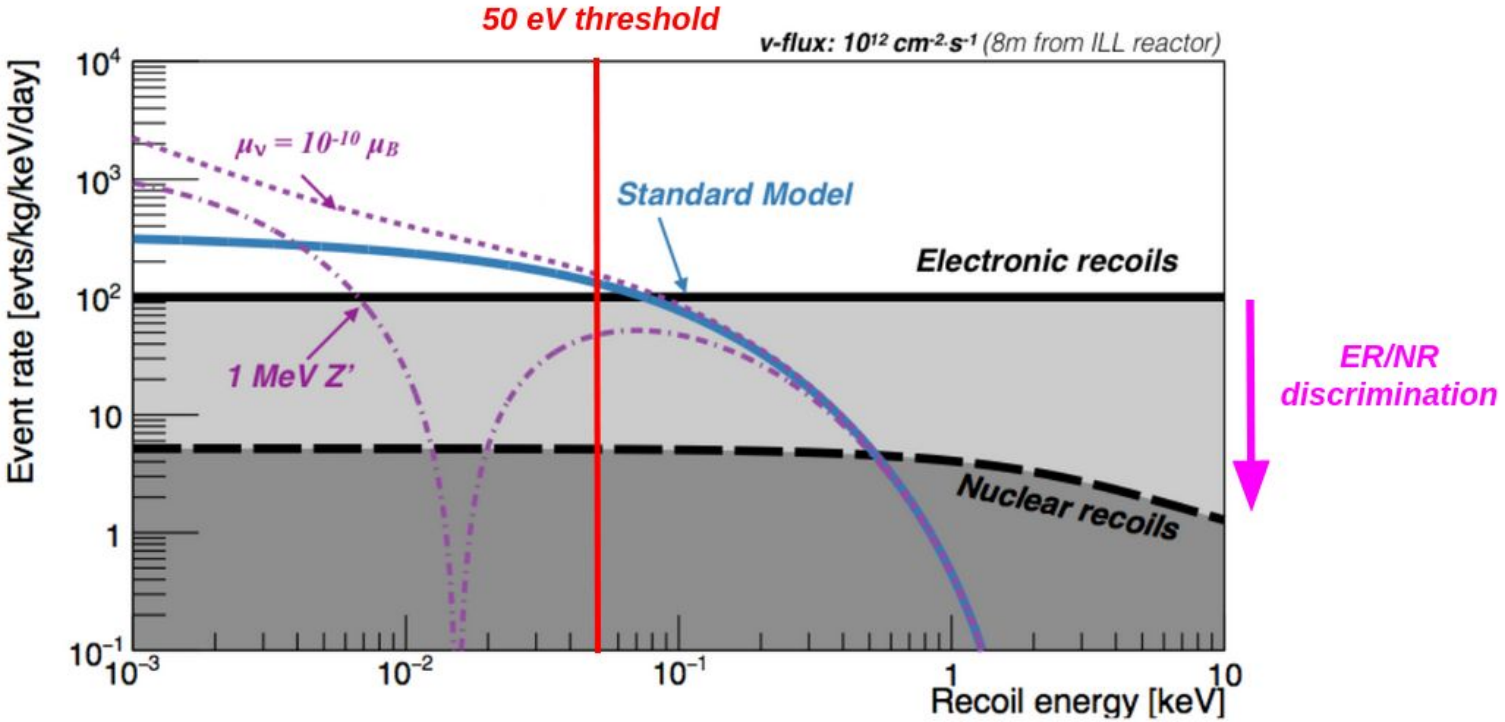
Context : CENNS, a new physics probe



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

Excellent probe for new physics beyond the Standard Model

Context : CENNS, a new physics probe



Excellent probe for new physics beyond the Standard Model

Context : The Ricochet experiment

Neutrino source : Nuclear reactor at Institut Laue-Langevin (ILL) in Grenoble (8,8m)

CryoCube : 18 Ge bolometers

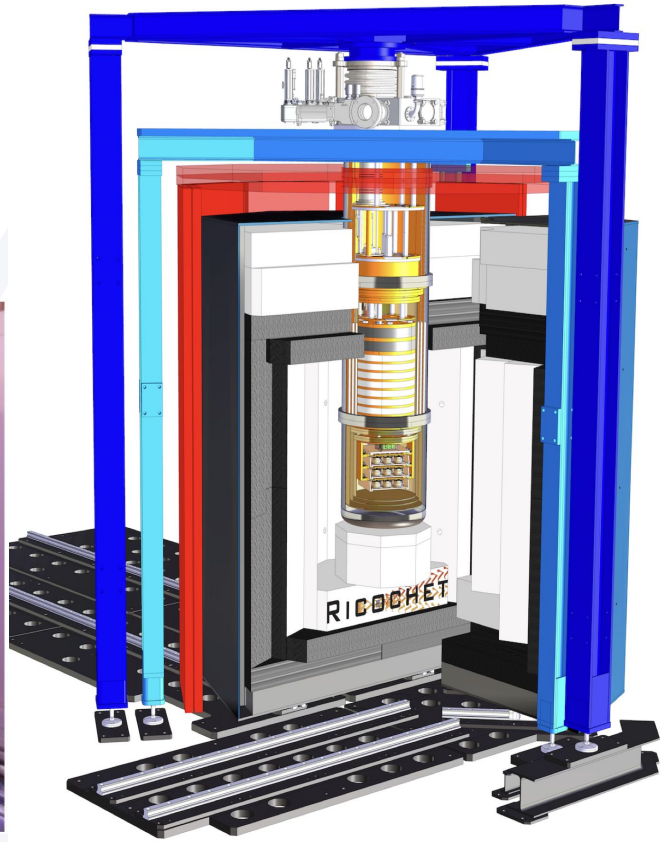
Cryostat : about 10 mK

Background noise :

- Cosmogenic
- Reactogenic
- Radiogenic

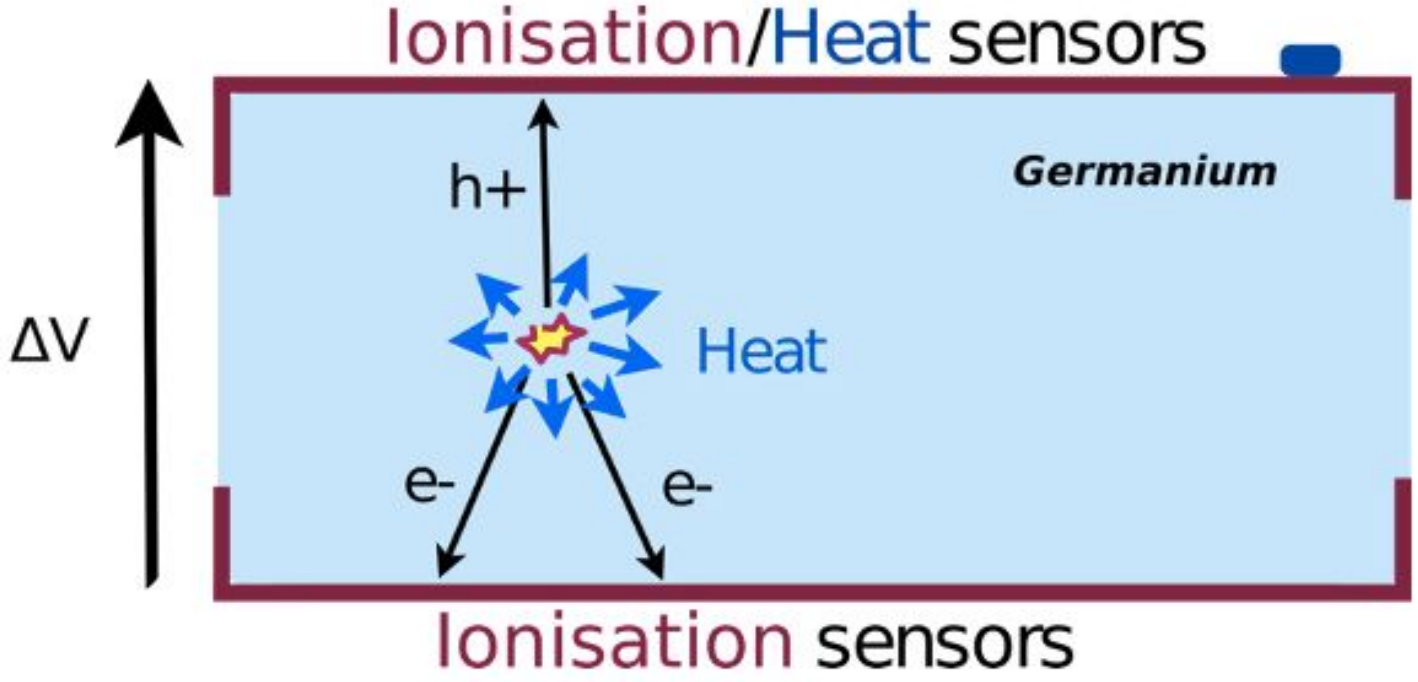
Shielding :

- Muon-veto
- Lead (20 t)
- Polyethylene (4 t)
- Water channel (15 m.w.e)



Started commissioning in February 2024

Context : Working principle of bolometers



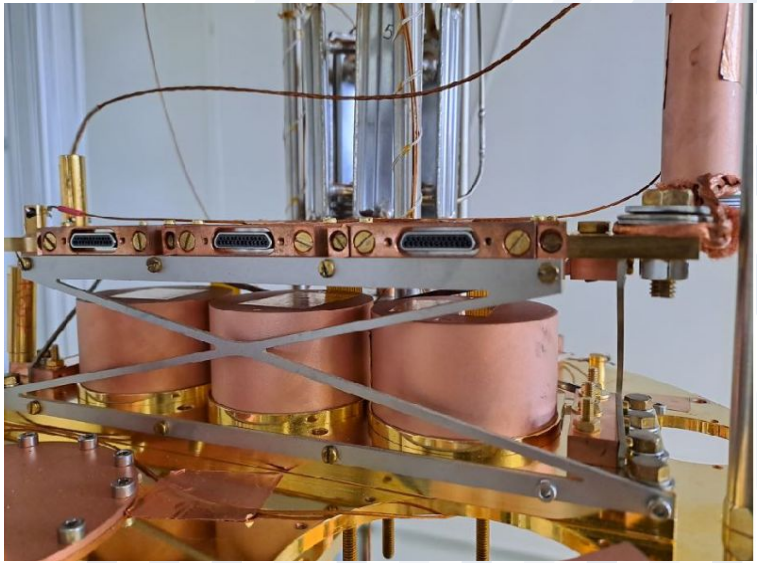
Context : The CryoCube and its components

CryoCube :

38g detectors (18 => 0.7 kg)

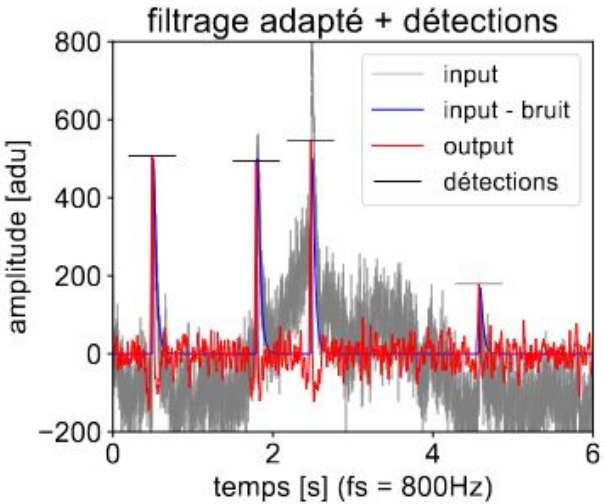
Mini-CryoCube :

CryoCube's part (3 bolometers) tested during my PhD : world record in ionisation resolution (30 eVee) [1]



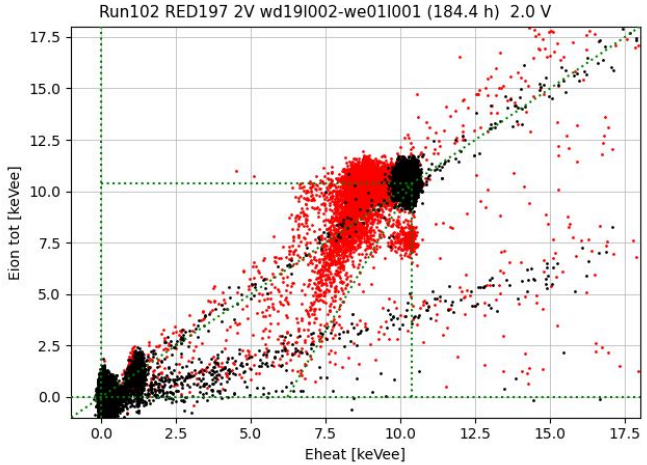
Context : Processing and analysis tools

MPS Processing :



- Adapted filtering
- Event fitting
- Obtaining observables

BALT :



- Calibration
- Cuts
- Analysis

My PhD : What have I been doing?

Goal : A first CEvNS measurement with RICOCHET at ILL

R&D objectives before going at ILL:

- Assembling CryoCube detectors
- 30eVee HEMT common source analysis [1]
- Tests of Ricochet acquisition boards

RICOCHET installation and commissioning:

- Ricochet commissioning at IP2I
- Ricochet installation and commissioning at ILL

Data analysis pipeline development:

- One of two main developers of BALT
- MPS Efficiency

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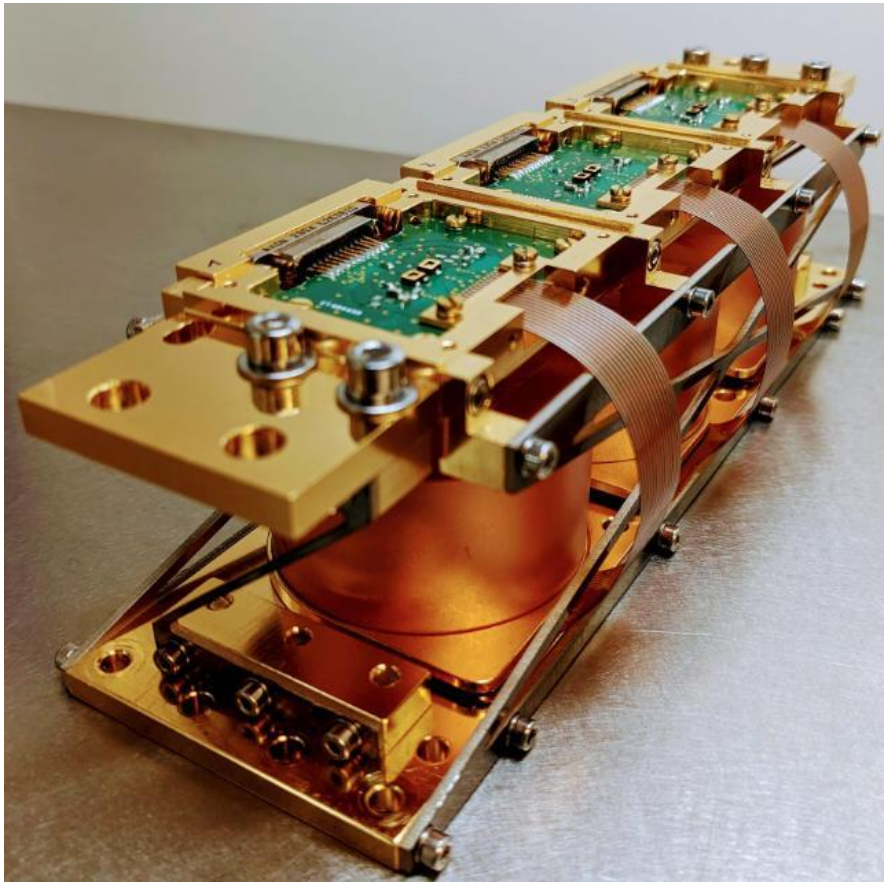
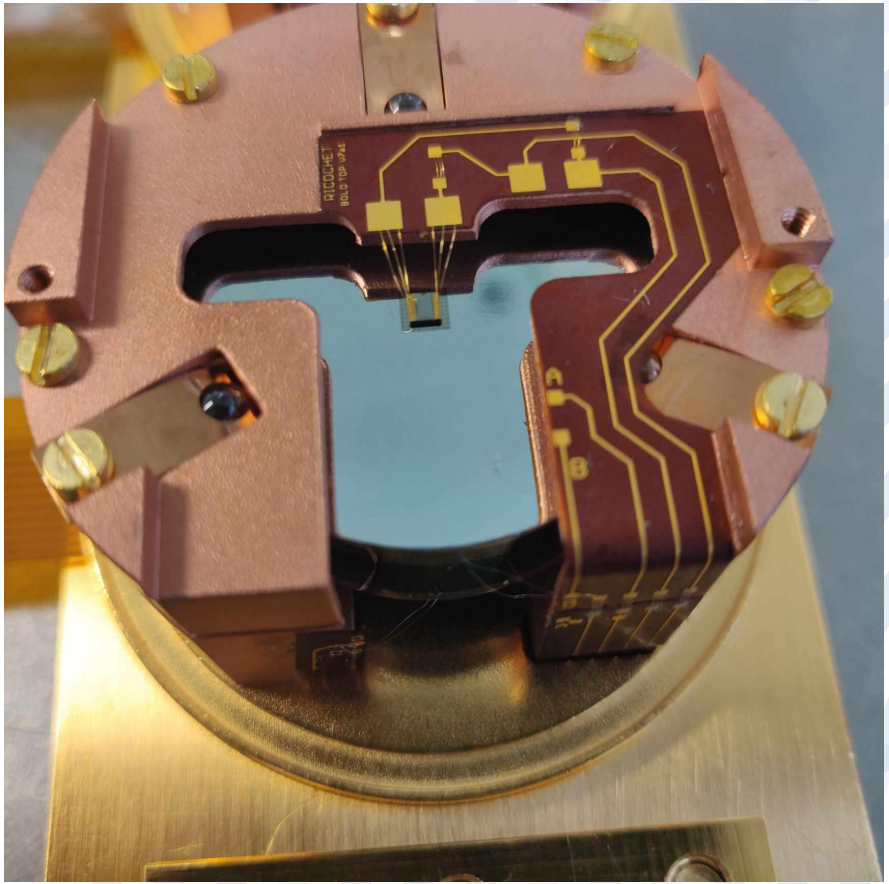
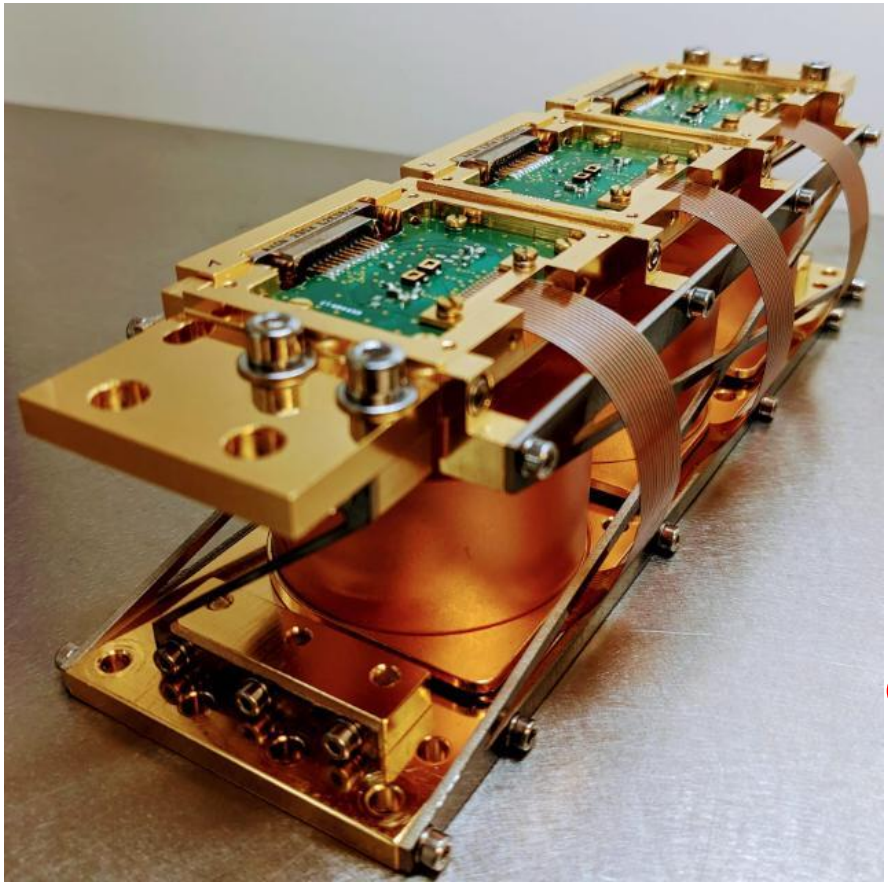
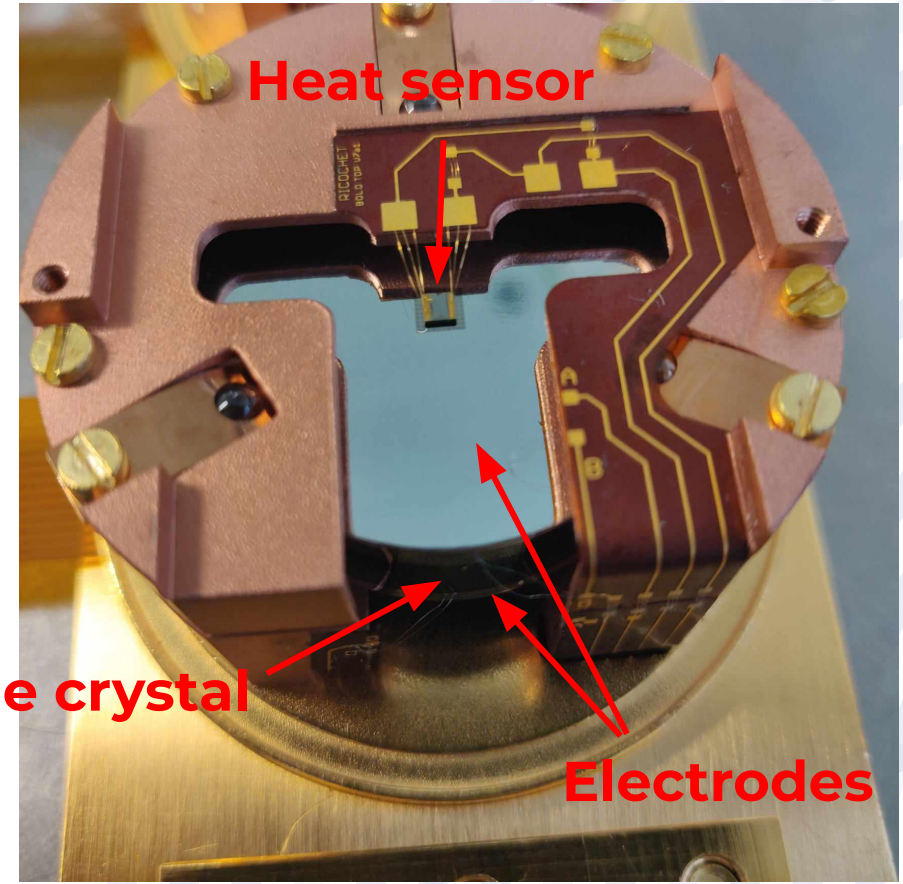




Assembling CryoCube detectors





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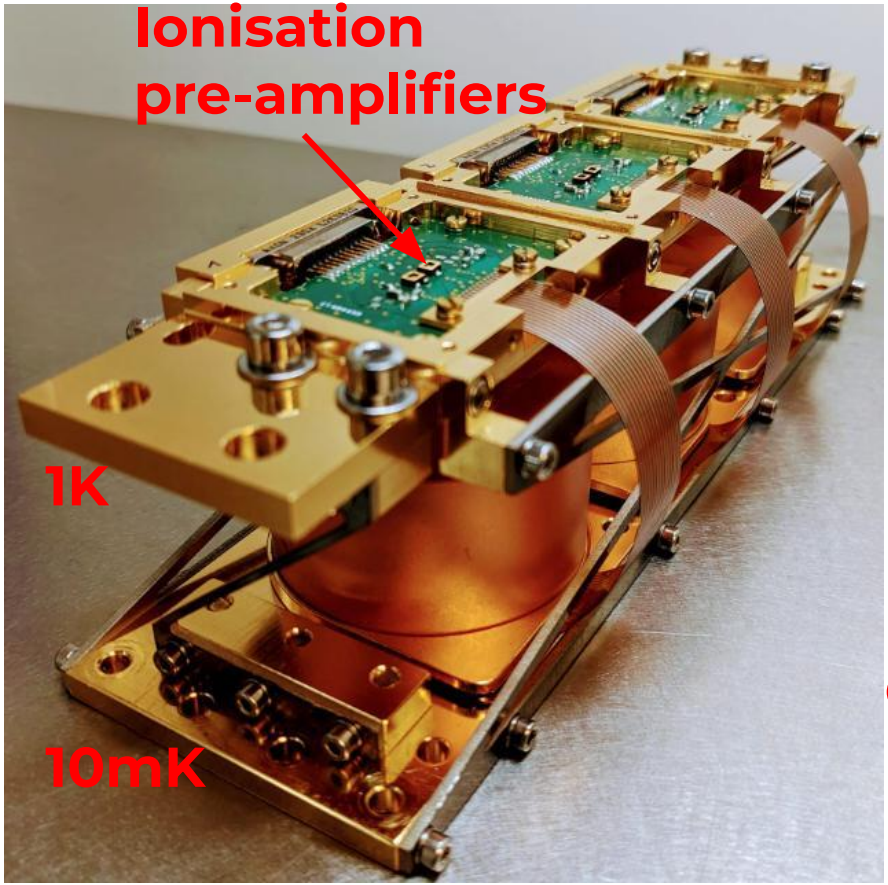
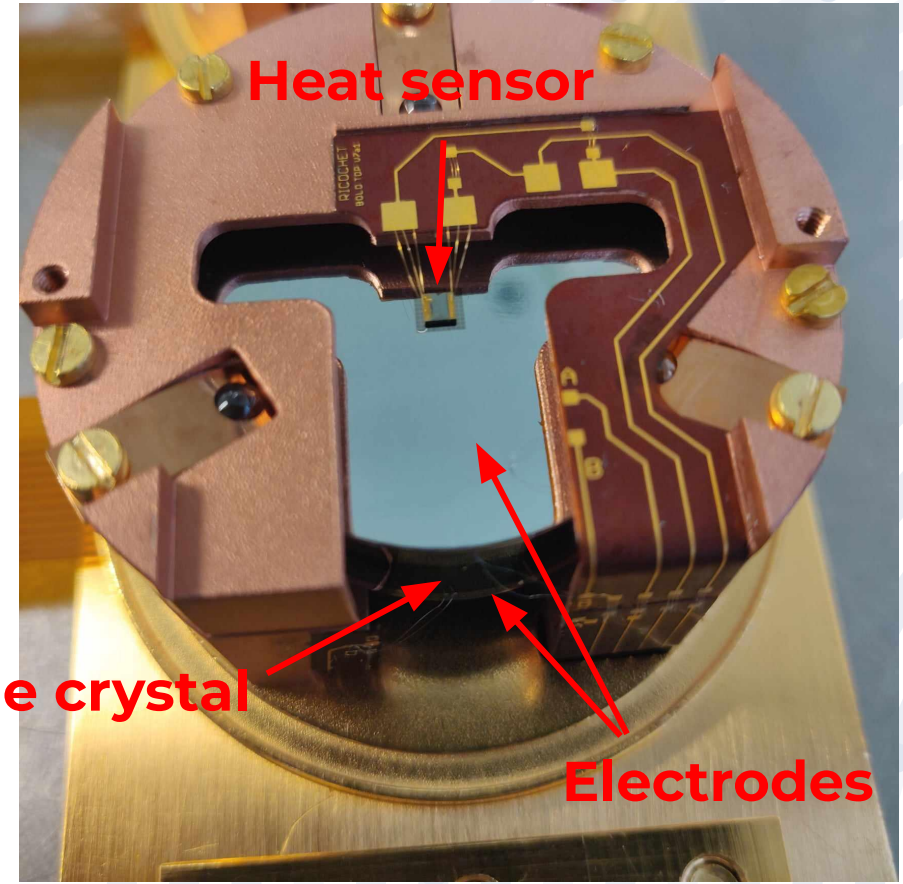
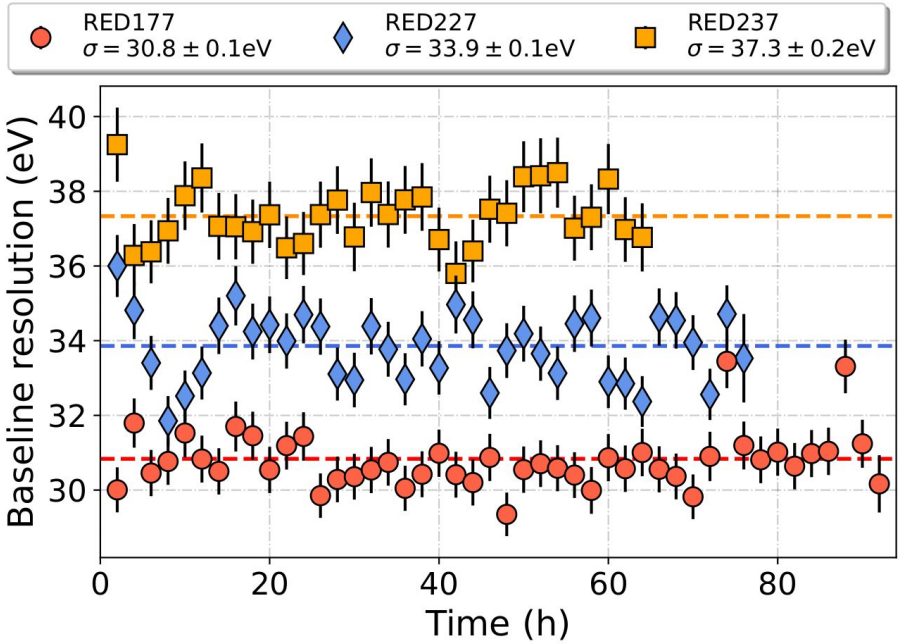
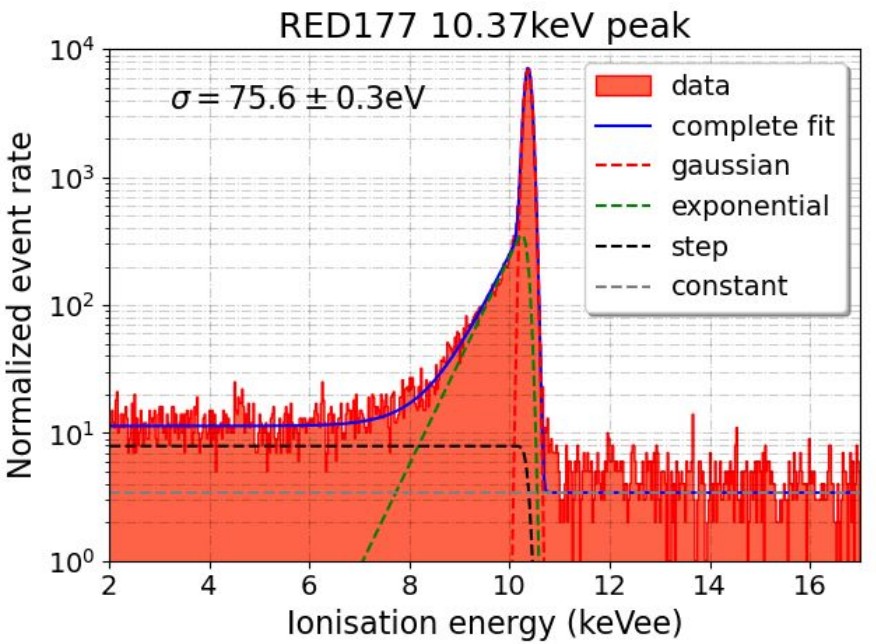




30 eVee HEMT common source [1]

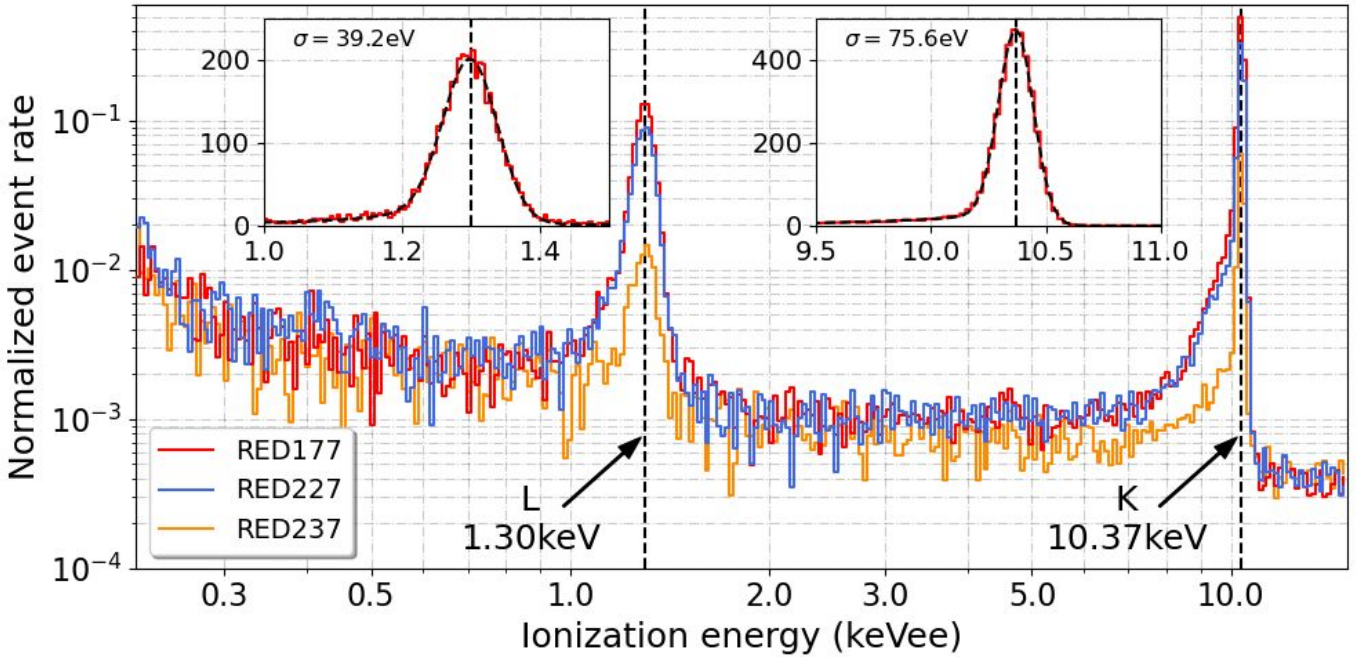




- 30.8 eVee mean resolution on RED177
- Stability

- Impact of calibration peaks on ionisation spectra
- Precise calibration

30 eVee HEMT common source [1]



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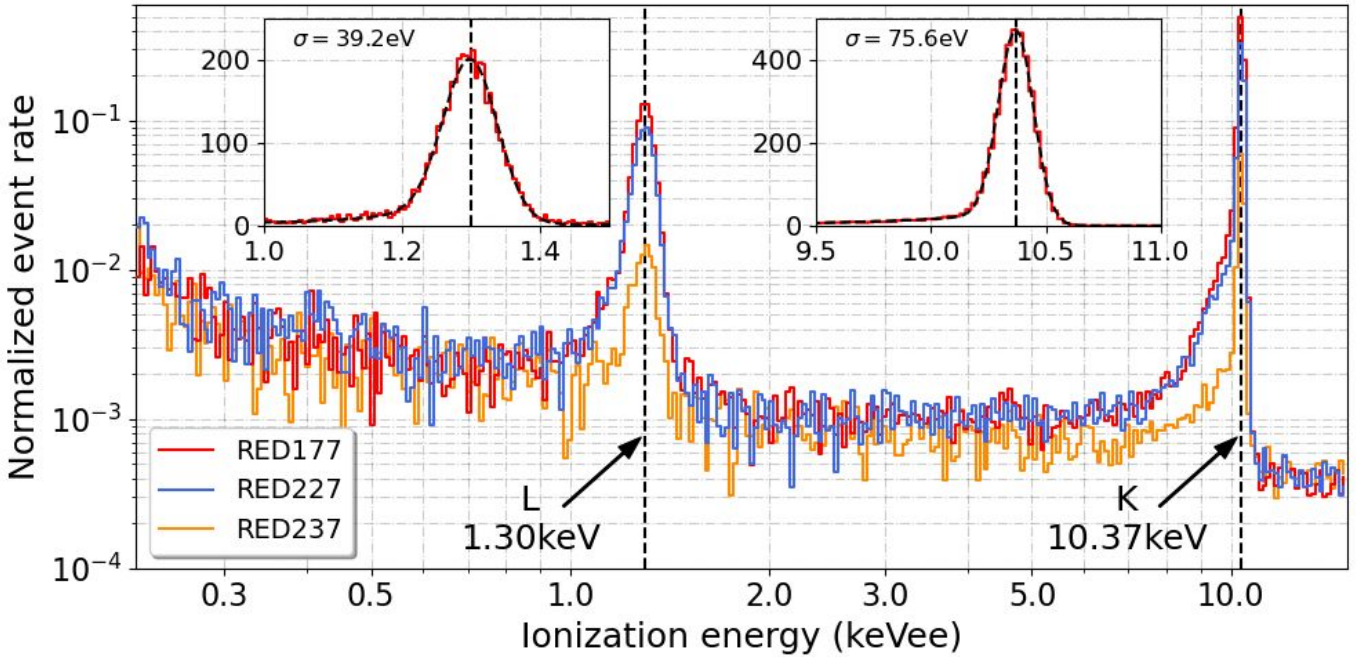
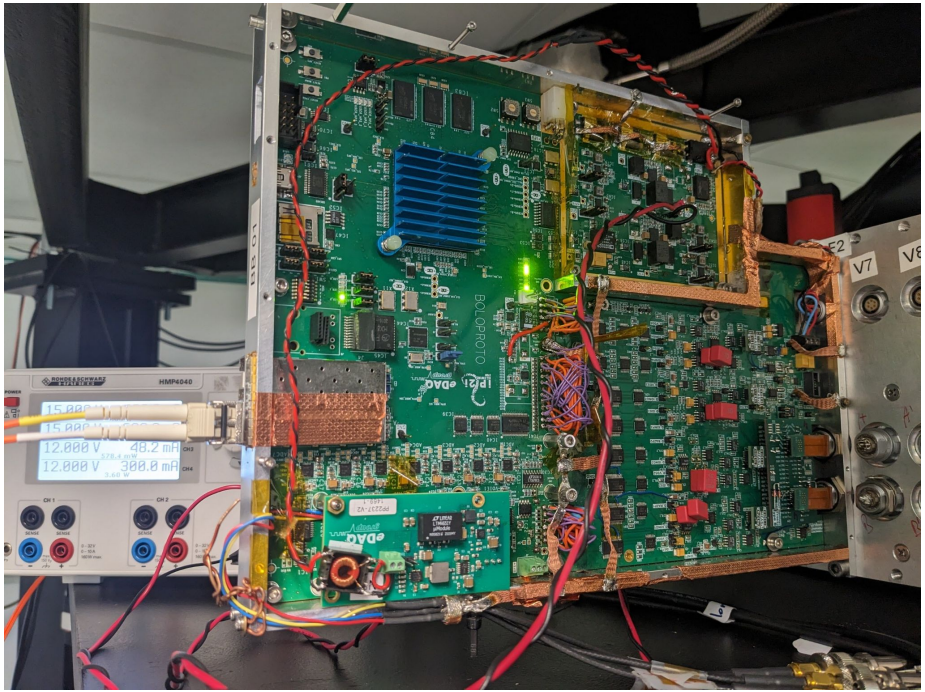
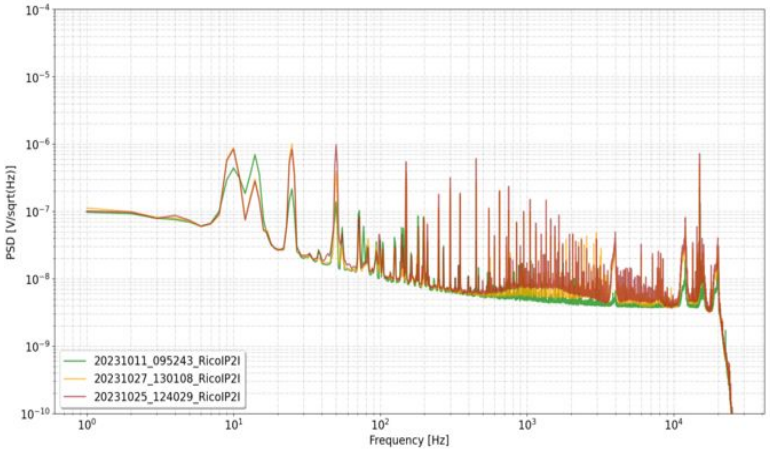


Ionisation performances are good enough to go at ILL

Ricochet acquisition boards





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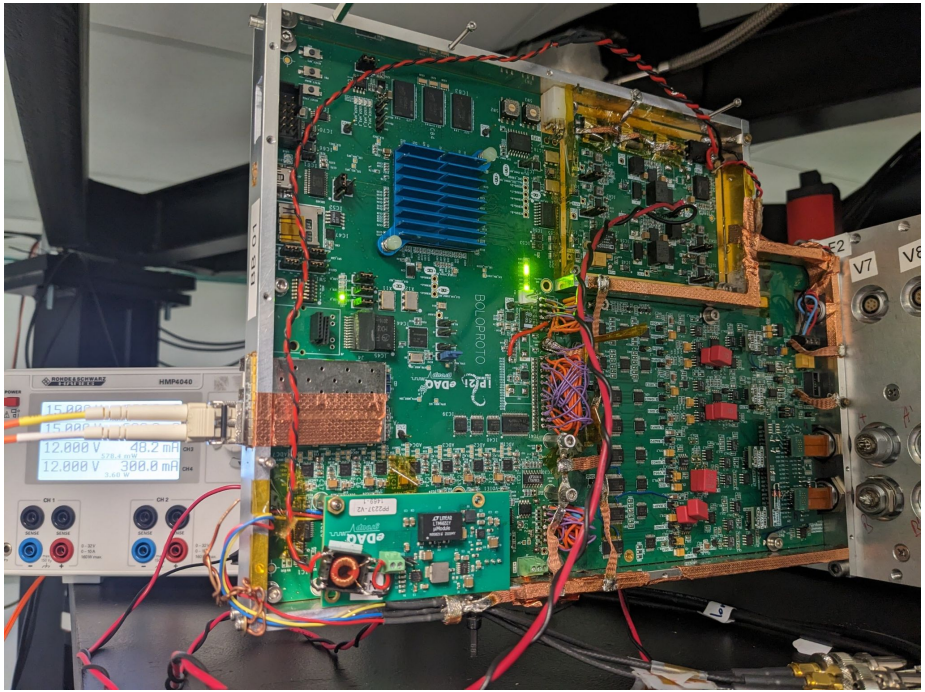

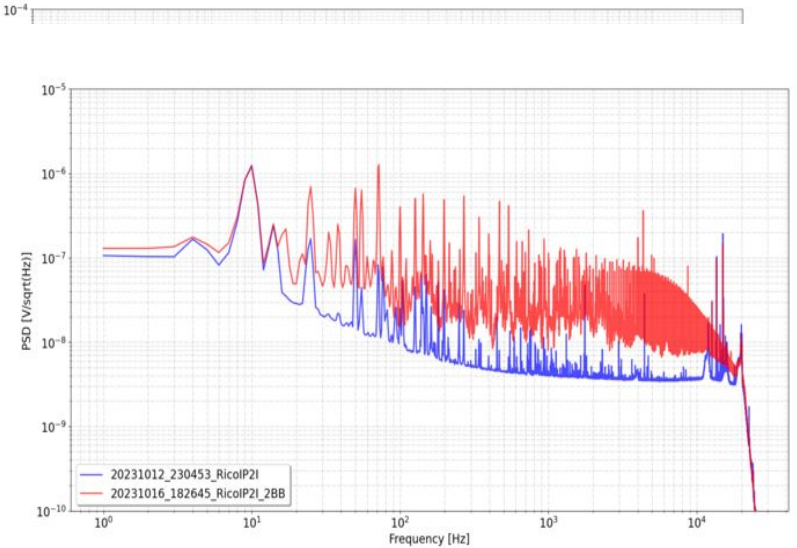

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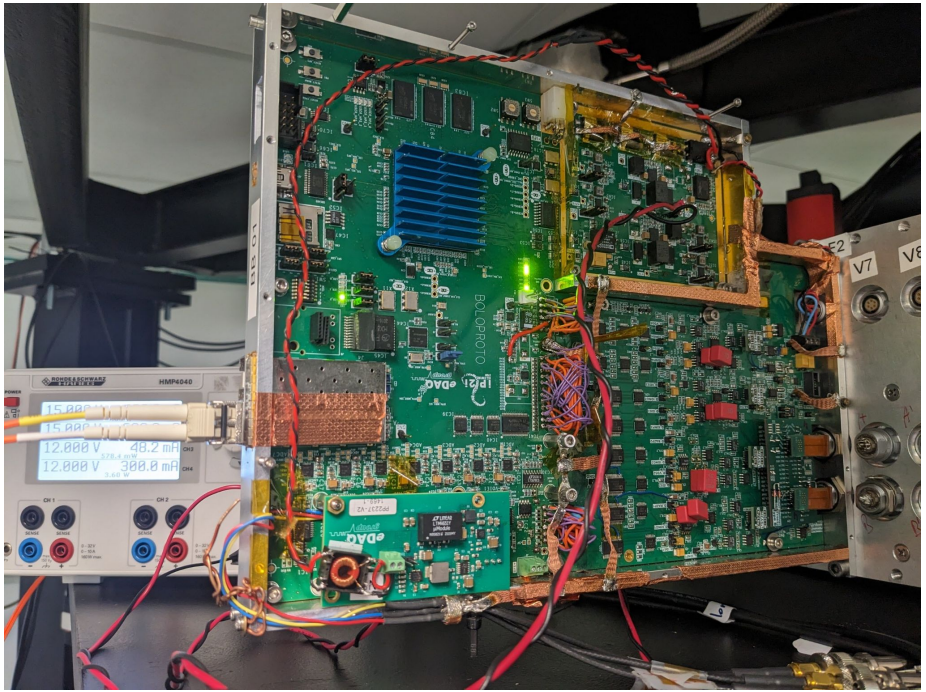
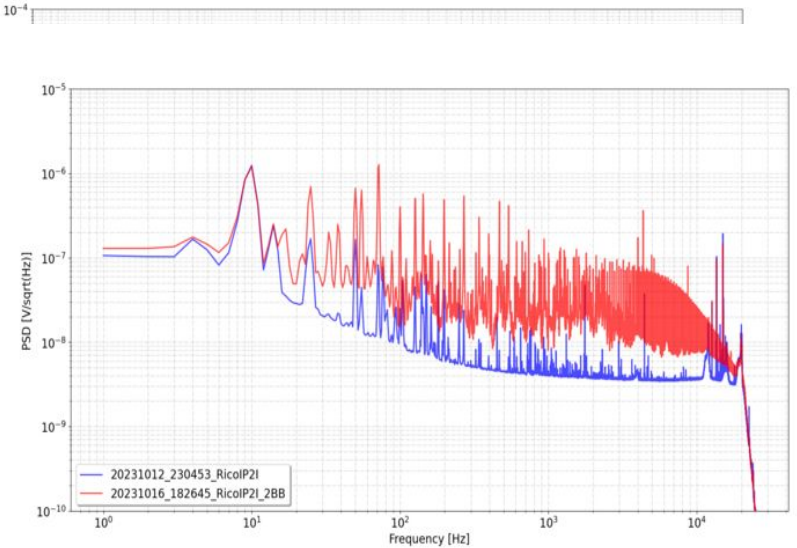
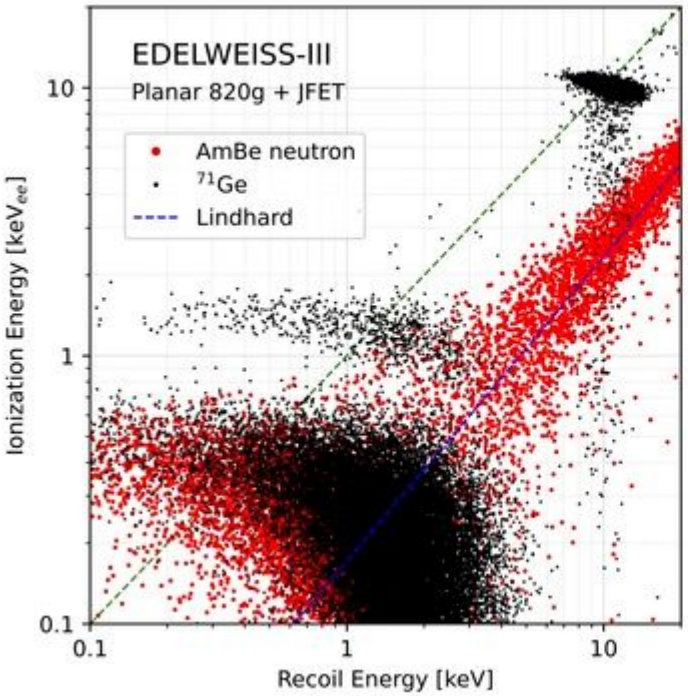


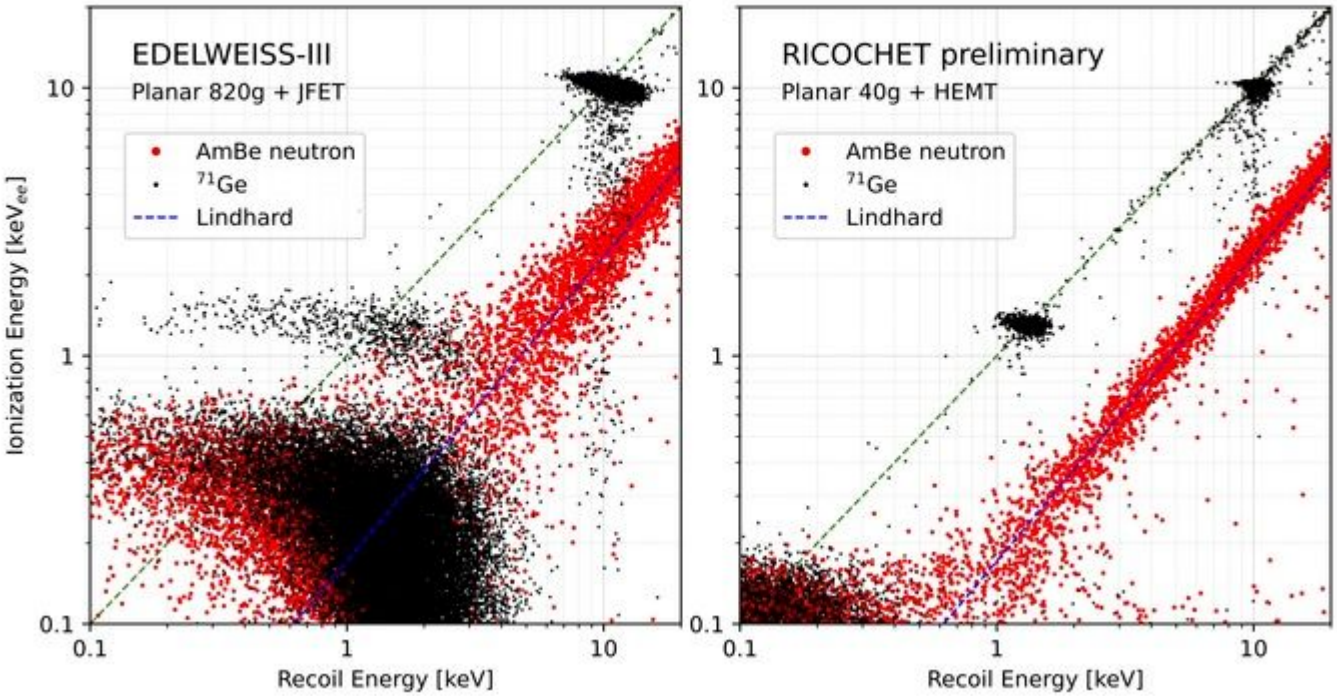


Noise performance is good enough to bring the Ricochet acquisition boards at ILL

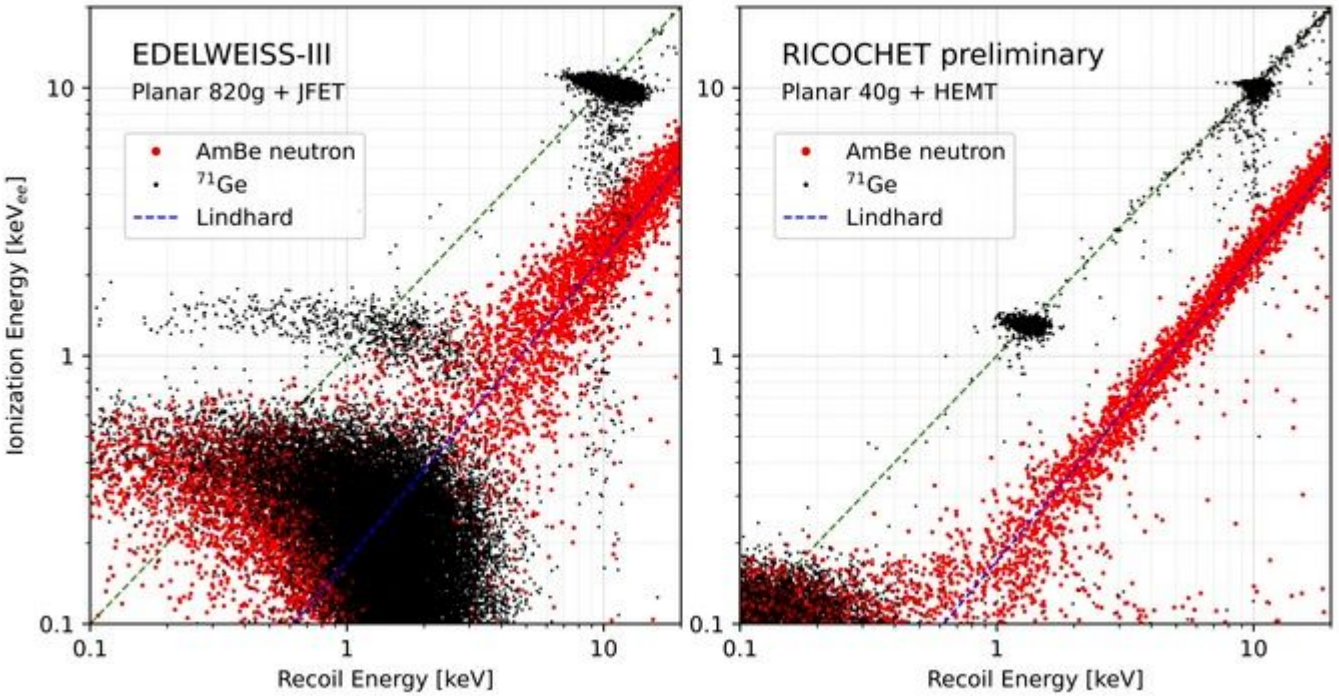
Ricochet acquisition boards



Ricochet acquisition boards



Ricochet acquisition boards



Green light to go at ILL

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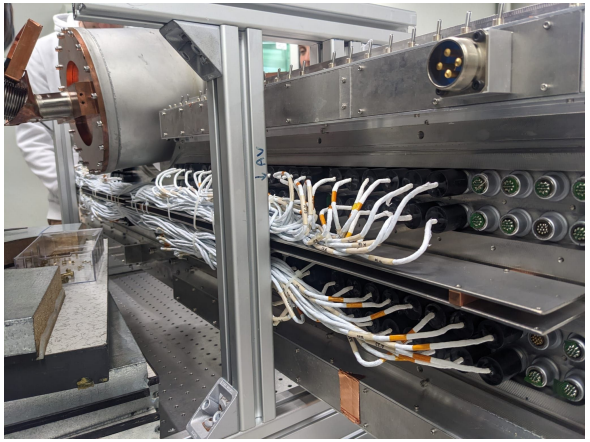
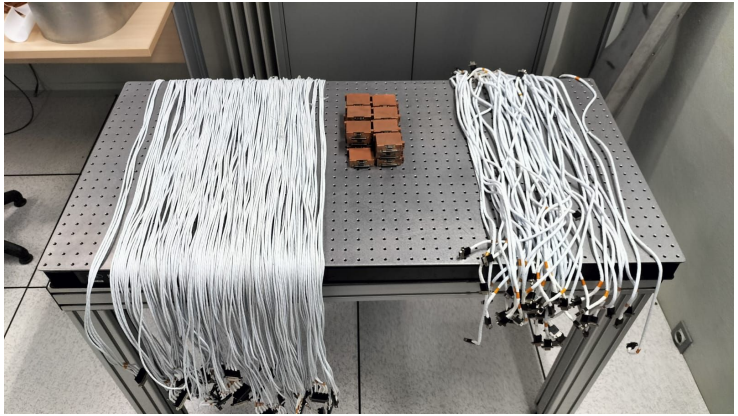
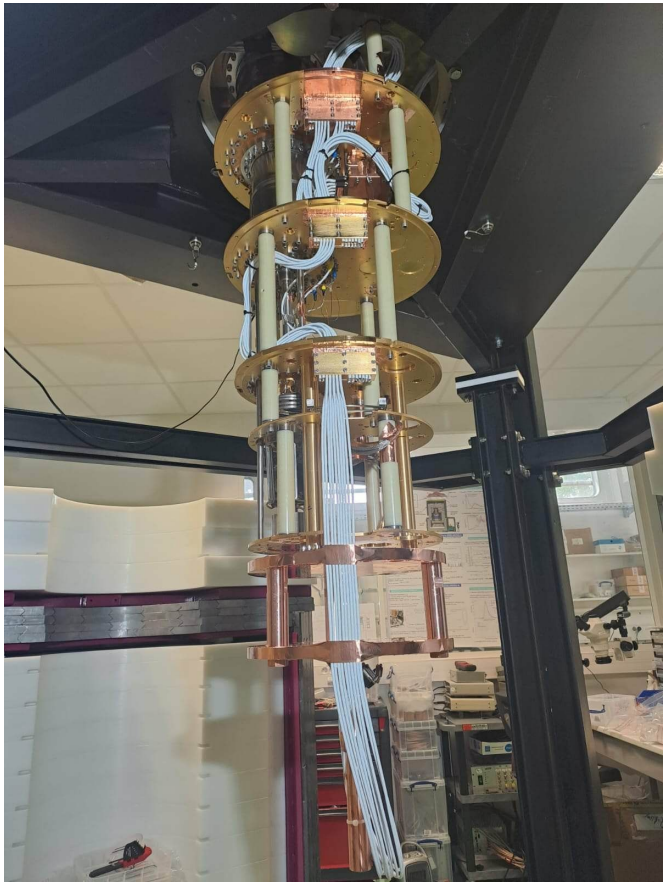
Ricochet commissioning at IP2I





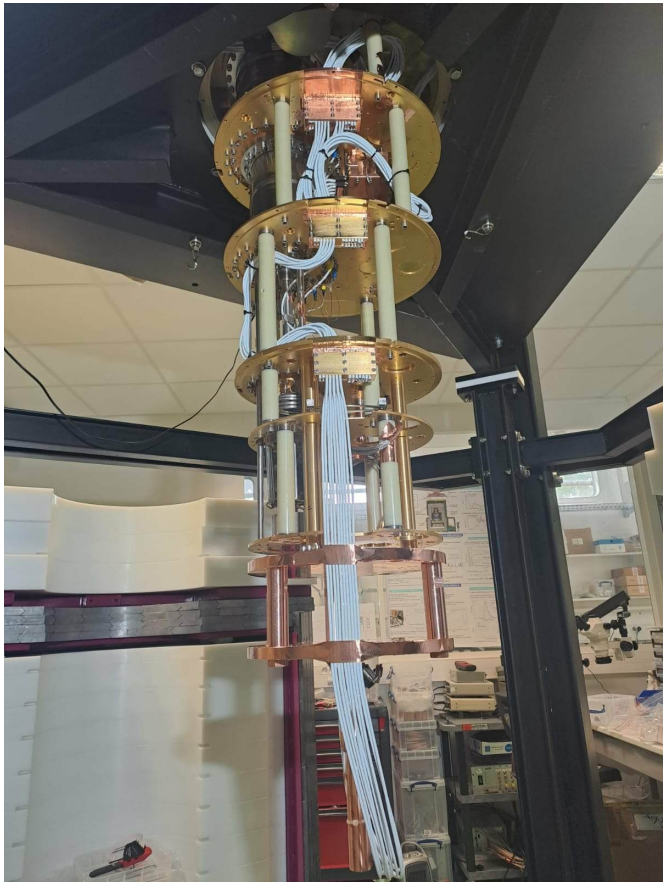
- **Retrieve EDW-III cabling**

Ricochet commissioning at IP2I



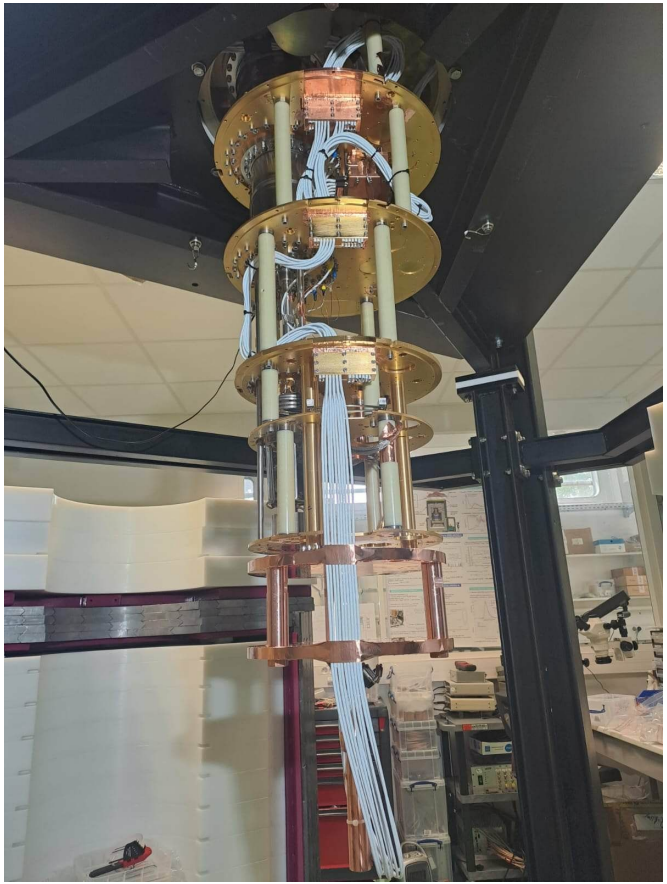
- **Retrieve EDW-III cabling**
- **Install and validate Ricochet cabling**

Ricochet commissioning at IP2I



- Retrieve EDW-III cabling
- Install and validate Ricochet cabling
- Install and validate thermometry

Ricochet commissioning at IP2I



- Retrieve EDW-III cabling
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- IR isolation between cryostat stages

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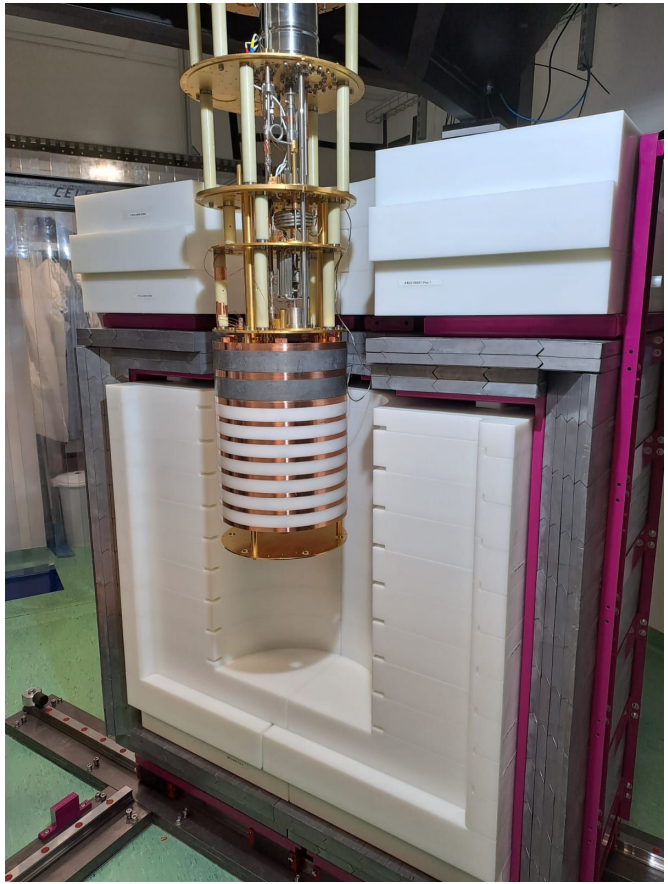

- Retrieve EDW-III cabling
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- Install and validate thermometry
- IR isolation between cryostat stages
- External shielding installation

Ricochet commissioning at IP2I

- Retrieve EDW-III cabling
- Install and validate Ricochet cabling
- Install and validate thermometry
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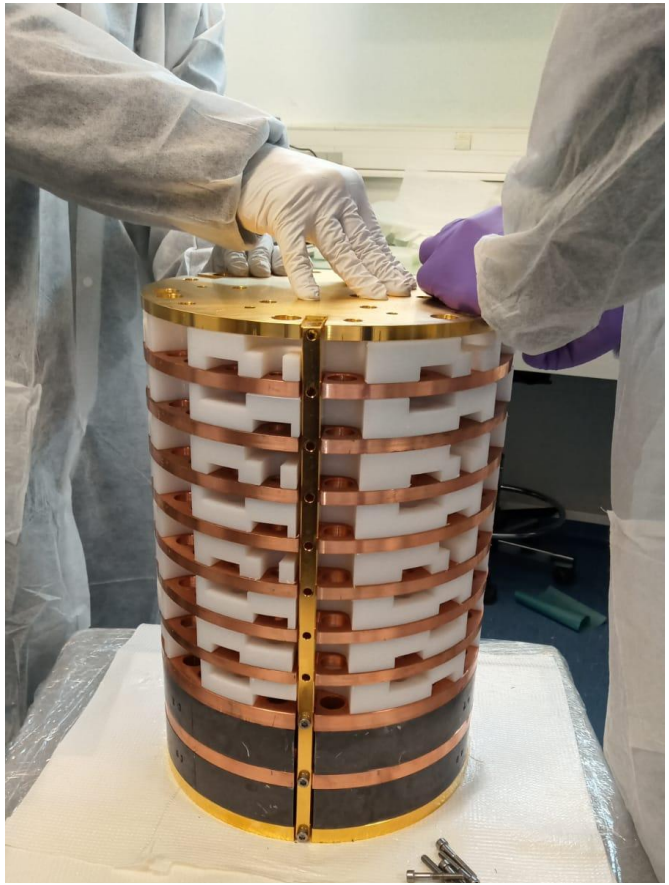
- External shielding installation
- Investigate dilatation problems with the internal shielding and solutions

Ricochet commissioning at IP2I



- Retrieve EDW-III cabling
- Install and validate Ricochet cabling
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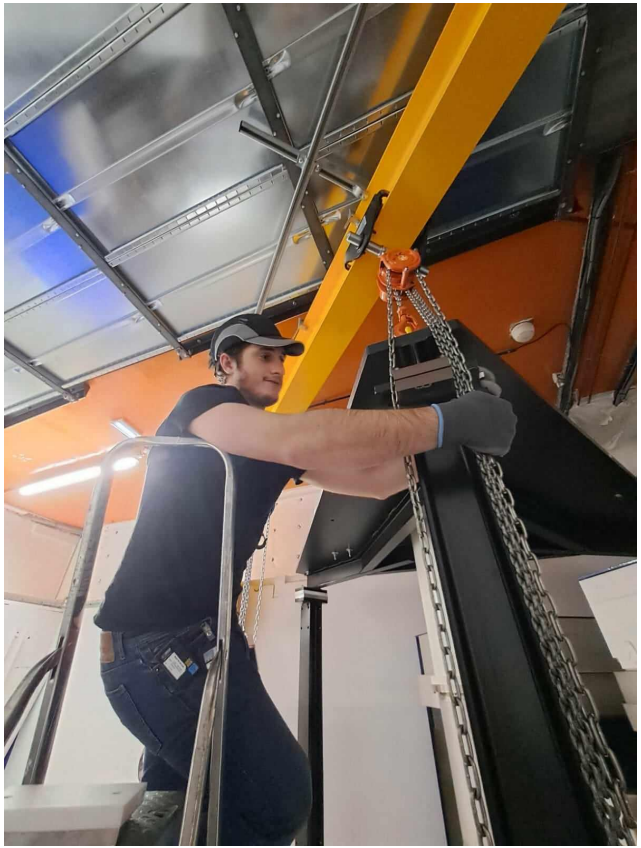
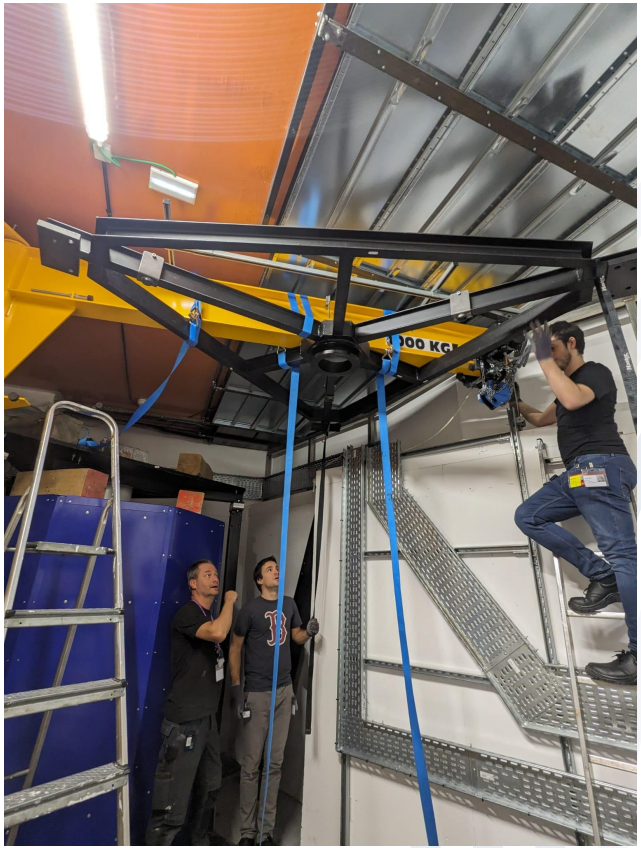
- External shielding installation
- Investigate dilatation problems with the internal shielding and solutions
- New internal shielding assembly

Ricochet installation at ILL





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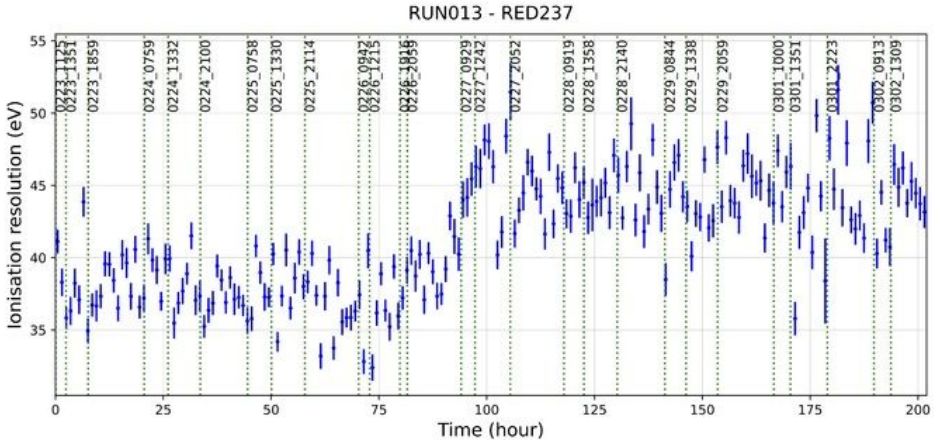

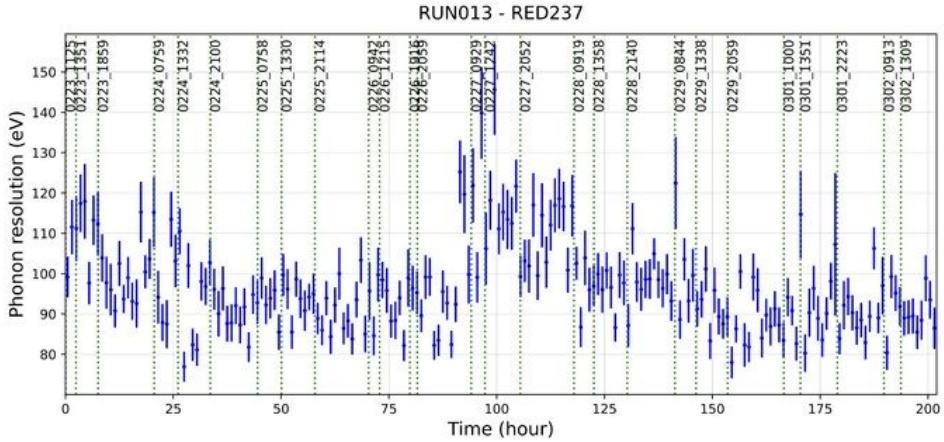

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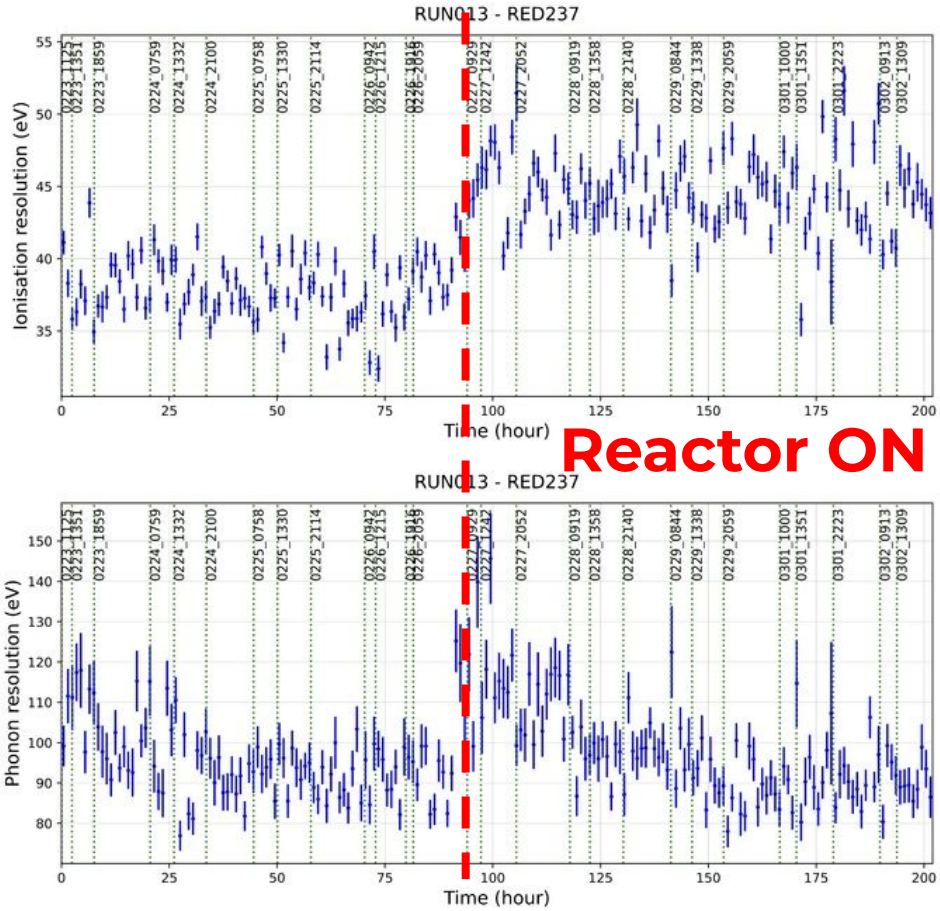

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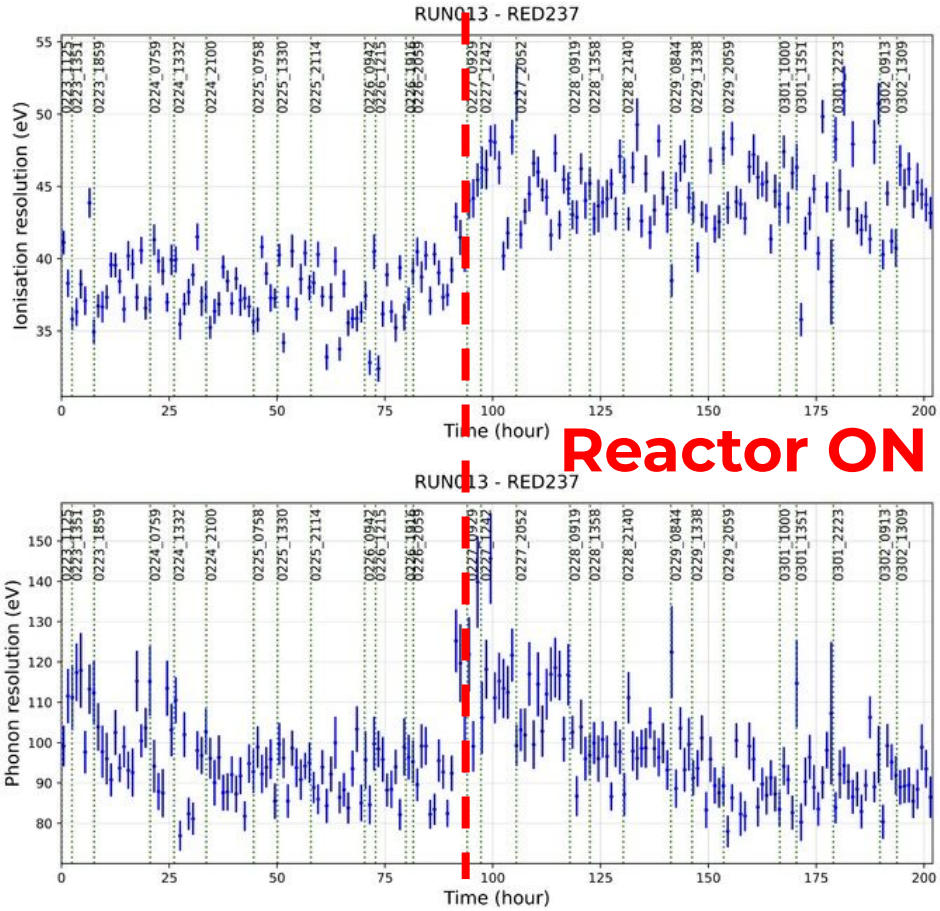

Lots of analysis ongoing:

- Reactor ON impact
- Vibrations damping
- Stability of resolution
- Background noises
- Processing optimisation
- Origin of electronic noises
- Synchronisation
- etc…

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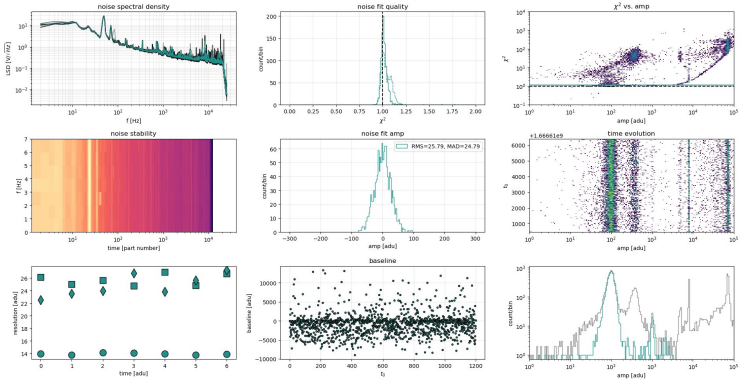
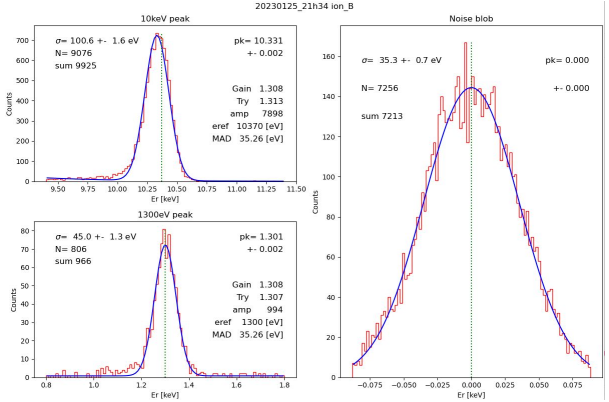
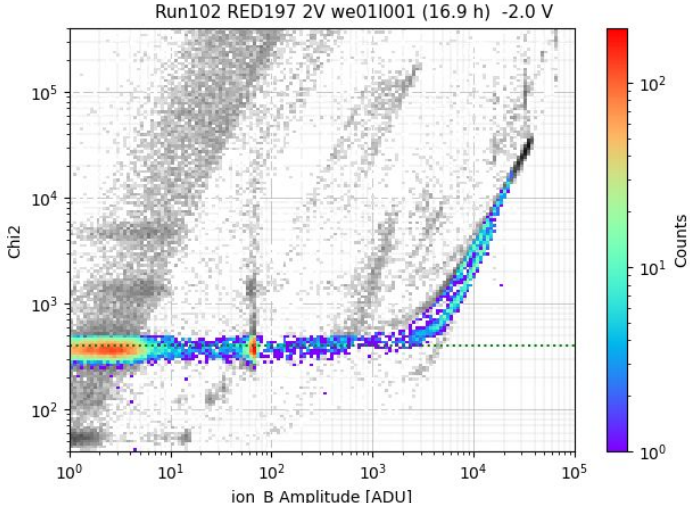
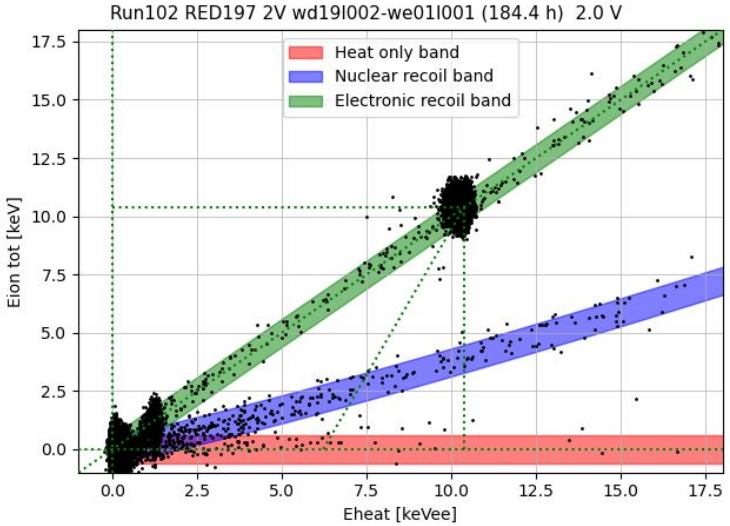
BALT

443 Commits 28 Branches







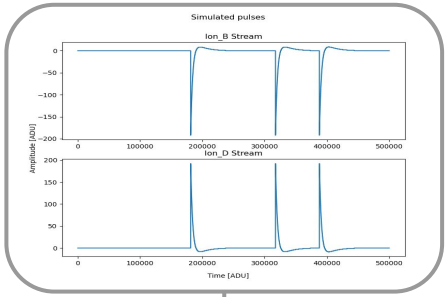


MPS Efficiency

Goal : Estimate CENNS signal detection efficiency to % level

MPS Efficiency

Goal : Estimate CENNS signal detection efficiency to % level

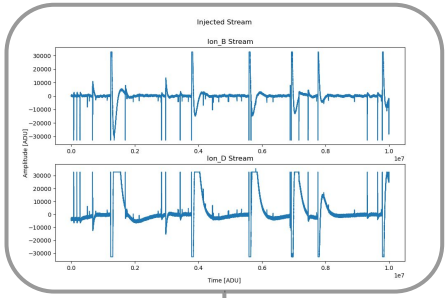


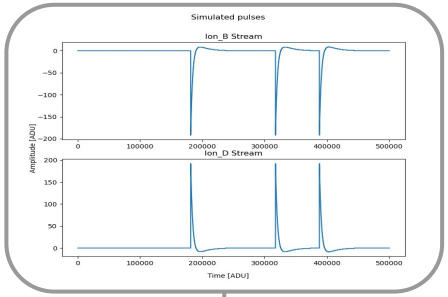
Configurations

MPS Simulation

MPS Efficiency

Goal : Estimate CENNS signal detection efficiency to % level





Configurations

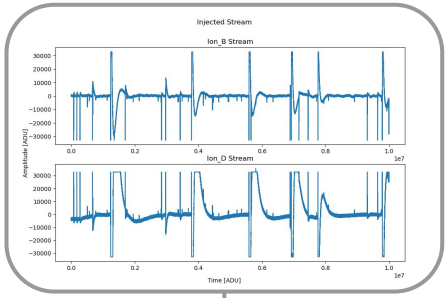
MPS Simulation

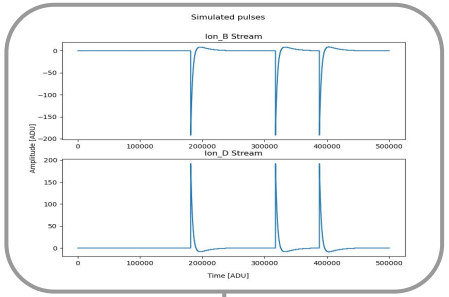
MPS Processing

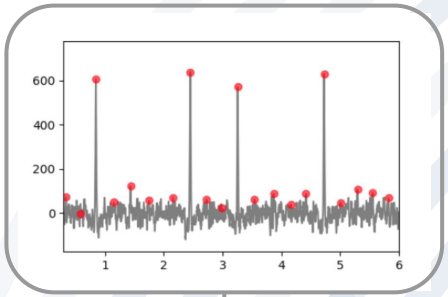
Raw data

MPS Efficiency

Goal : Estimate CENNS signal detection efficiency to % level







Configurations

Raw data

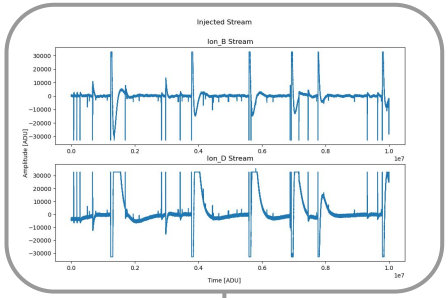
MPS Simulation

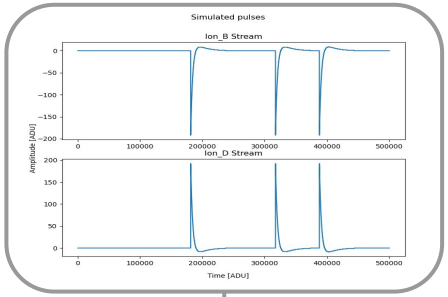
MPS Processing

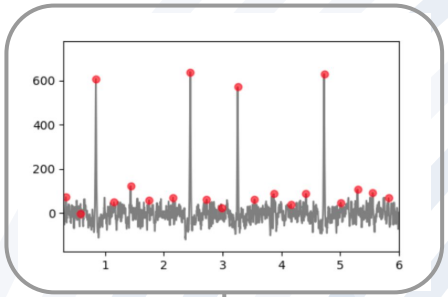
BALT Compare

MPS Efficiency

Goal : Estimate CENNS signal detection efficiency to % level







Configurations

Raw data

N x Injected and processed simulation

MPS Simulation

MPS Processing

N x simulated data sets

N x processed data sets

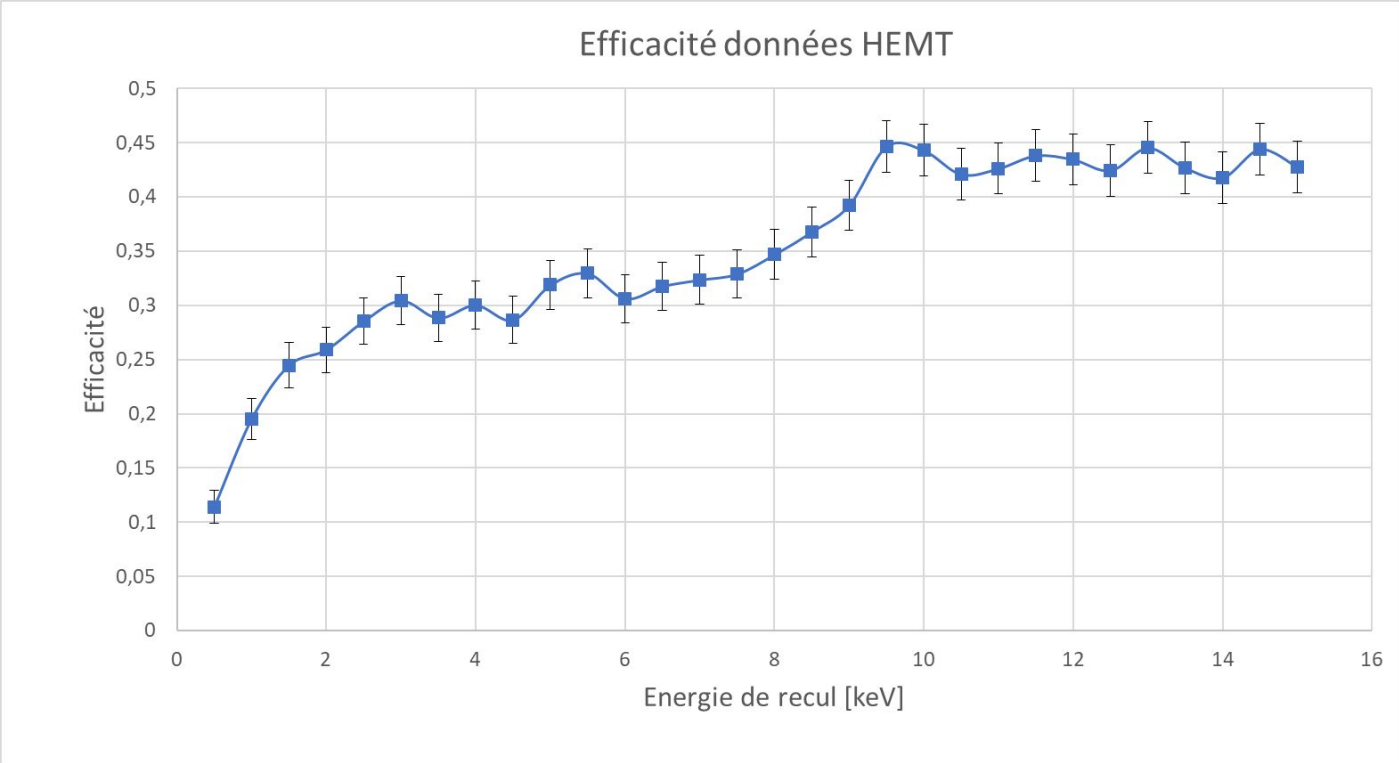
BALT Compare

Efficiency curve

MPS Efficiency

MPS Efficiency

Goal : Estimate CENNS signal detection efficiency to % level



My PhD : What have I been doing?

Goal : A first CEvNS measurement with RICOCHET at ILL

R&D objectives before going at ILL:

- Assembling CryoCube detectors
- 30eVee HEMT common source analysis [1]
- Tests of Ricochet acquisition cards and softwares

RICOCHET installation and commissioning:

- Ricochet commissioning at IP2I
- Ricochet installation and commissioning at ILL

Data analysis pipeline development:

- One of two main developers of BALT
- MPS Efficiency

Thanks!

Any questions?

Publications / Conférences

Contribution majeure

[1] Ricochet Coll. et al., First demonstration of 30 eVee ionization energy resolution with Ricochet germanium cryogenic bolometers, EPJC 2023 (under reviewing, minor revisions), epjc/s10052-024-12433-1

Contribution mineure

EDELWEISS Coll. et al., Tagging and localisation of ionizing events using NbSi transition edge phonon sensors for Dark Matter searches, arXiv:2303.02067

Poster / Talk

Présentations de BALT et du résultat des 30eVee ionisation au Ricochet Collaboration Meeting à Grenoble en Mars 2023 (talk)

Présentation du résultat des 30 eVee ionisation à la conférence Magnificent CEvNS à Munich en Mars 2023 (poster)

My PhD : What have I been doing?

Learning to assemble detectors, work on a cryostat and take data

Development of new analysis tools in BALT

Equipment of the Ricochet cryostat

First year

Study of a way to improve ionisation resolution (quartz)

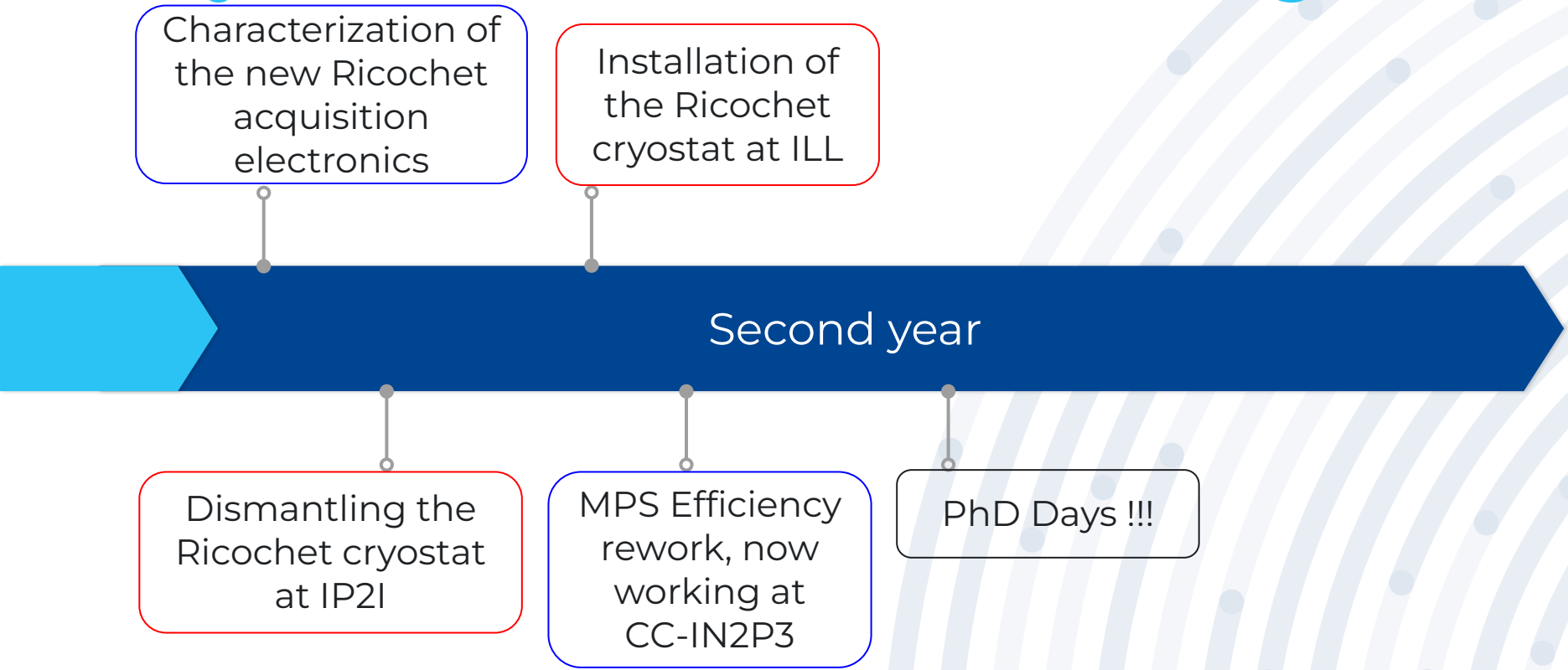
Study of performances of a Mini-CryoCube in common source [1]

MPS Efficiency

Testing of the new Ricochet acquisition electronics

2 work axes : Instrumentation and Data Analysis

My PhD : What have I been doing?



2 work axes : Instrumentation and Data Analysis

Context : The CryoCube and its components

CryoCube :

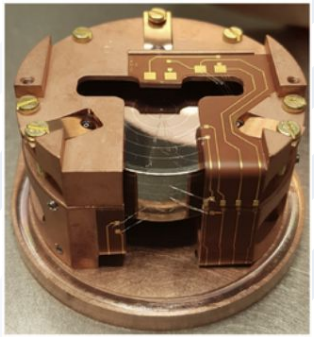
38g detectors (18 => 0.7 kg)

Two topologies :

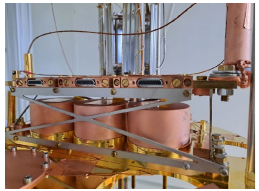
Planar :

Better acceptance

FID :



Better discrimination



Mini-CryoCube : CryoCube's part (3 bolometers) tested during my PhD : world record in ionisation resolution (30 eVee) [1]

Ricochet acquisition software

acquisition_BB02-RicoIP2I.ipy | acquisition_BB03-RicoIP2I.ipy | acquisition_BB01-RicoIP2I_de

Code

```
await bb.usr_hemts_config(polar_hemt)
await bb.usr_offset_heat_config(offset=heat_offset) # -5nA
print(f"going to apply +/- {u/2} V")
await bb.usr_polar_heat_config(p_neg=-u/2-42e-3, p_pos=+u/2-47e-3)
await bb.usr_polar_ion_config(**polar_electrode)
for f in filters:
    await bb.usr_filters_config(**f)
```

Acquisition longue

Start

```
from acquisition_tools import acquisition_longue
await acquisition_longue(bb, descr)
```

Stop

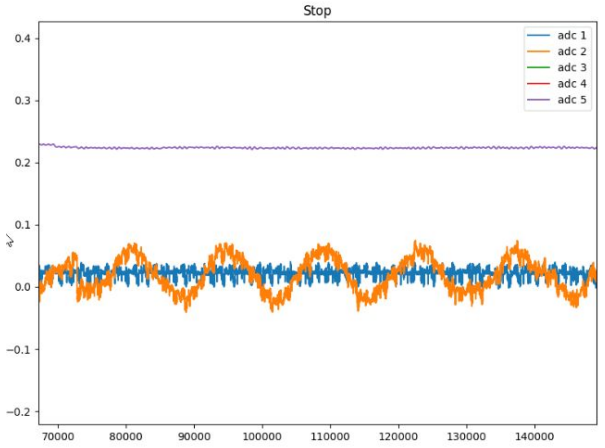
```
# stop acq. and create tar file
await bb.acq_stop()
from sferriol.zarr import create_tar
create_tar(fpath, dpath)
```

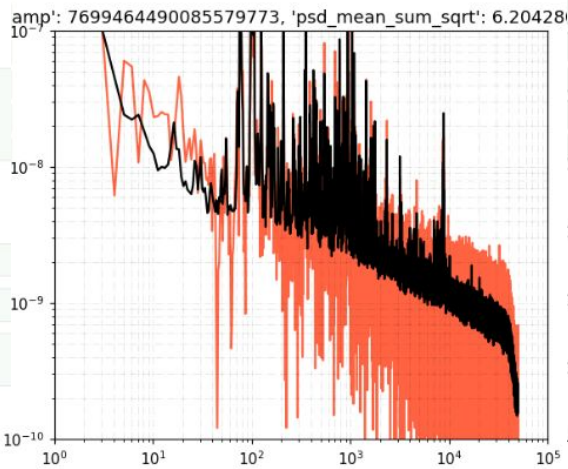
Commandes manuelles

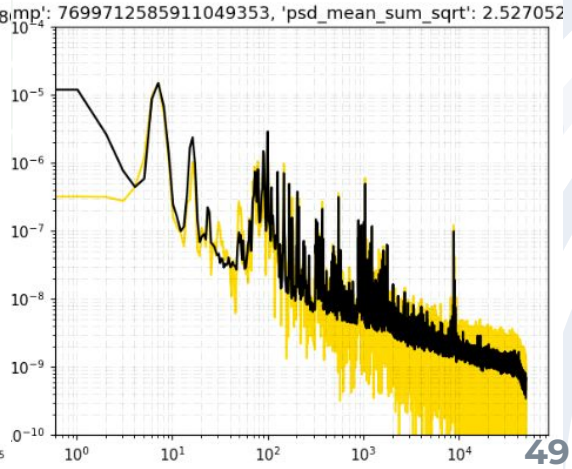
```
await bb.acq_info()
```

```
await bb.acq_stop()
```

```
await bb.acq_stop()
await bb.acq_start()
```

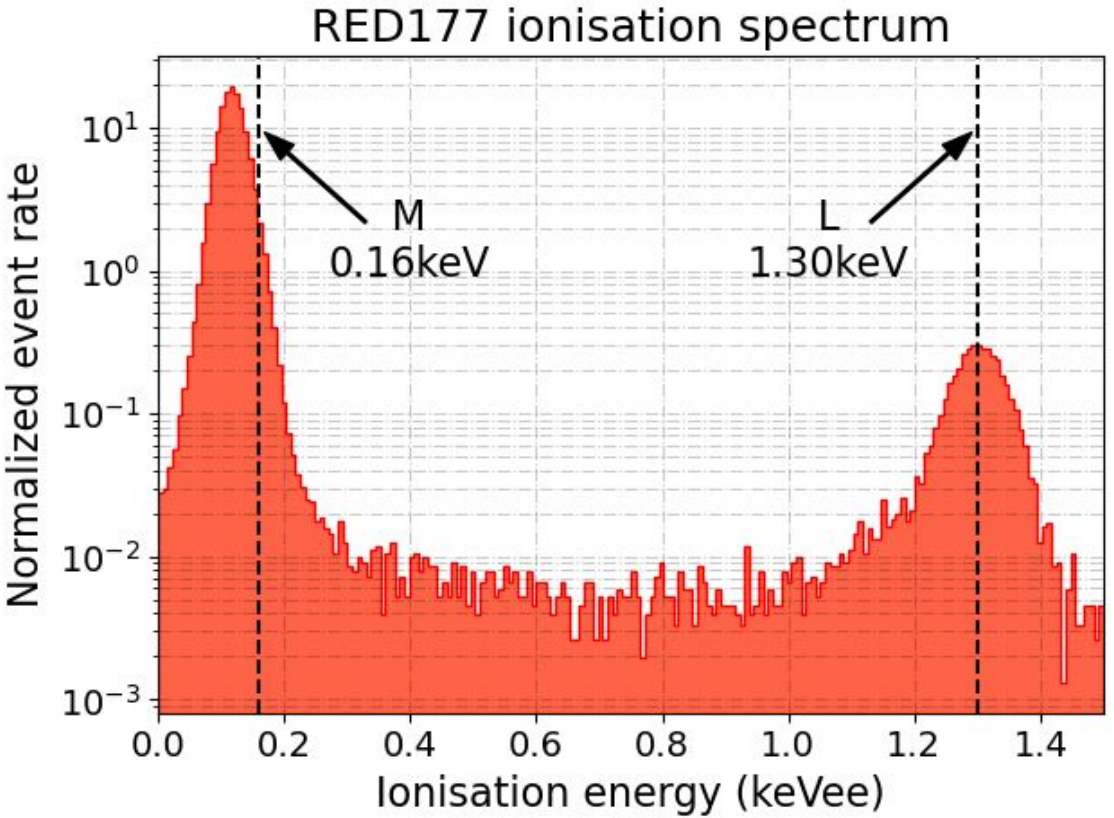




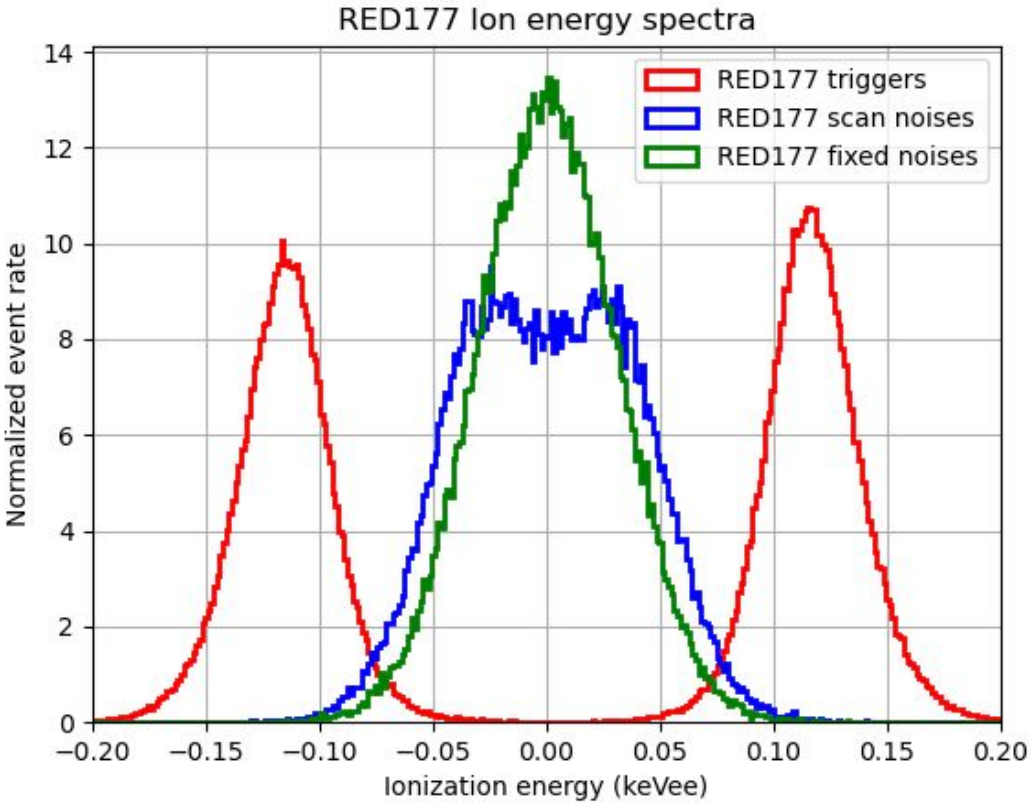


Trigger wall

Peut-on voir la couche M du Ge à 160 eV?

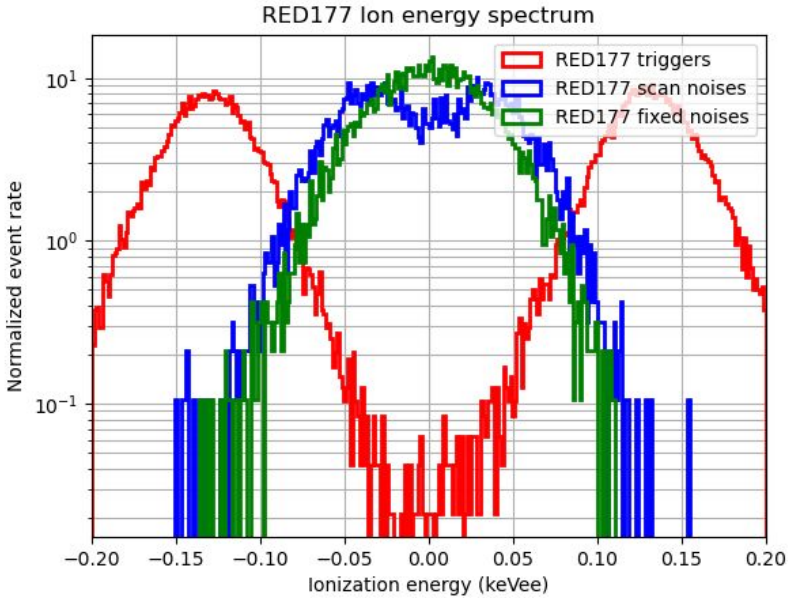


Trigger wall

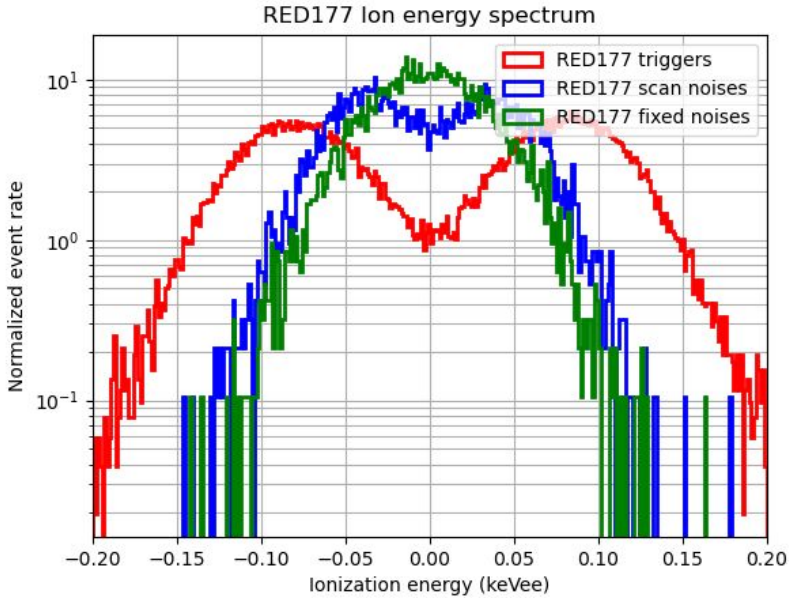


Trigger wall

Détection d'évènements réalisée sur la voie d'ionisation que l'on regarde



Détection d'évènements réalisée sur l'autre voie d'ionisation



BALT

- Nouvelles coupures
- Nouveaux graphiques
- Implémentation de iMinuit
- Nouvelle commande de suivi de RUN, avec une première fonction pour extraire toutes les résolutions d'un RUN
- Gestion des partitions "mortes"
- Gestion du nouveau format d'acquisition Ricochet
- Création de tutoriels et d'un package BALT pour diffuser le programme à la collaboration Ricochet
- Maintenance générale du code
- MPS Efficiency...

MPS Efficiency

- Code propre, plus facile à améliorer
- Capable de traiter différents types de données
- De nombreux paramètres avec lesquels jouer
- Implémentation au CC-IN2P3
- Graphes de vérification du bon fonctionnement de l'algorithme
- Interface en ligne de commande pour les deux parties du programme (MPS et BALT)
- Encadrement d'un stagiaire pour aller plus loin (Test, amélioration des performances, automatisation du fonctionnement au CC-IN2P3...)

Formations

Scientifique

Magnificent CEvNS 2023 School (18h)

DLMI 2023 : Cours théoriques Deep Learning (18,5h)

(prévu : IN2P3 School Of Statistics 2024 ~ 20h)

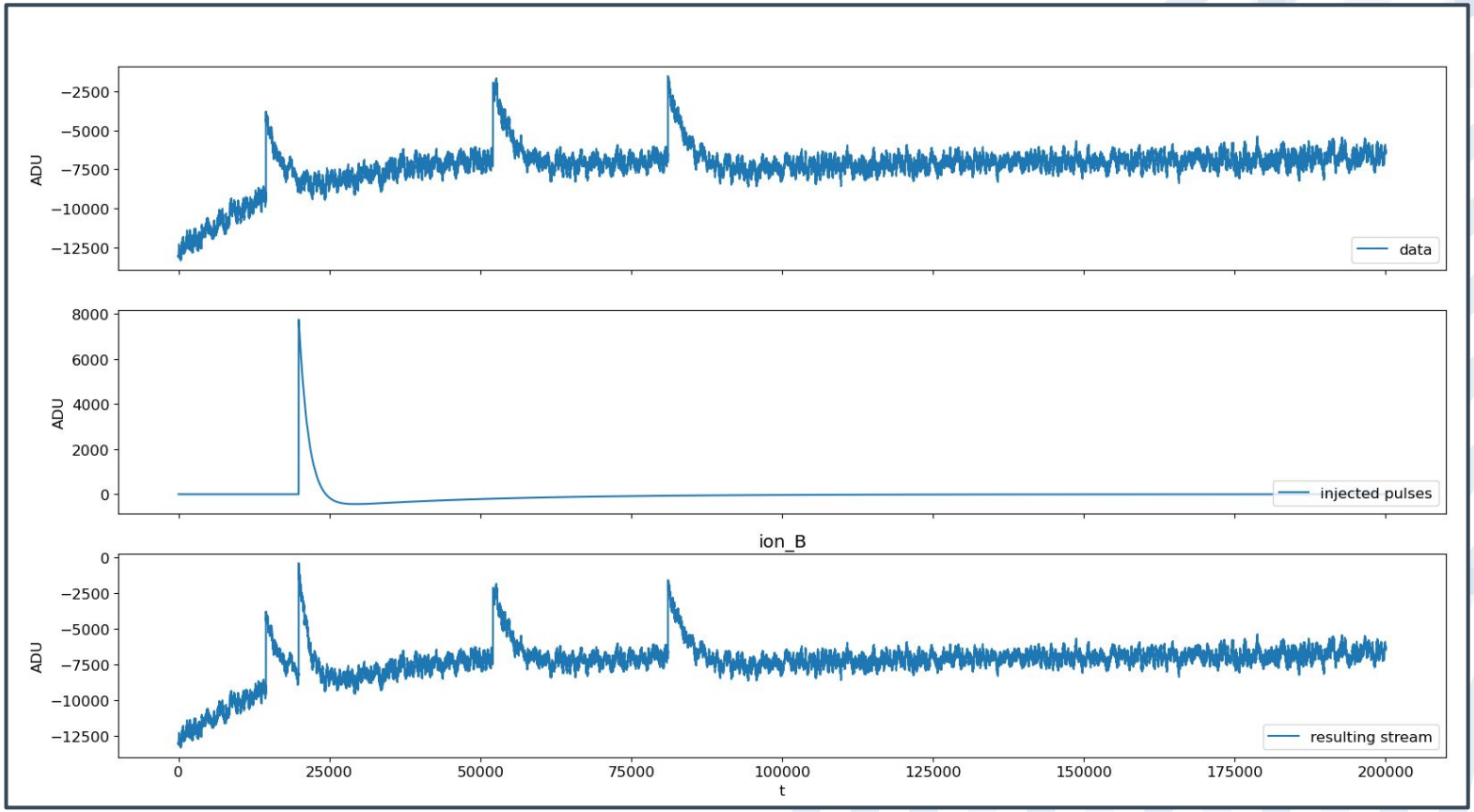
Professionelle

Participation au Festival Particules (5h?)

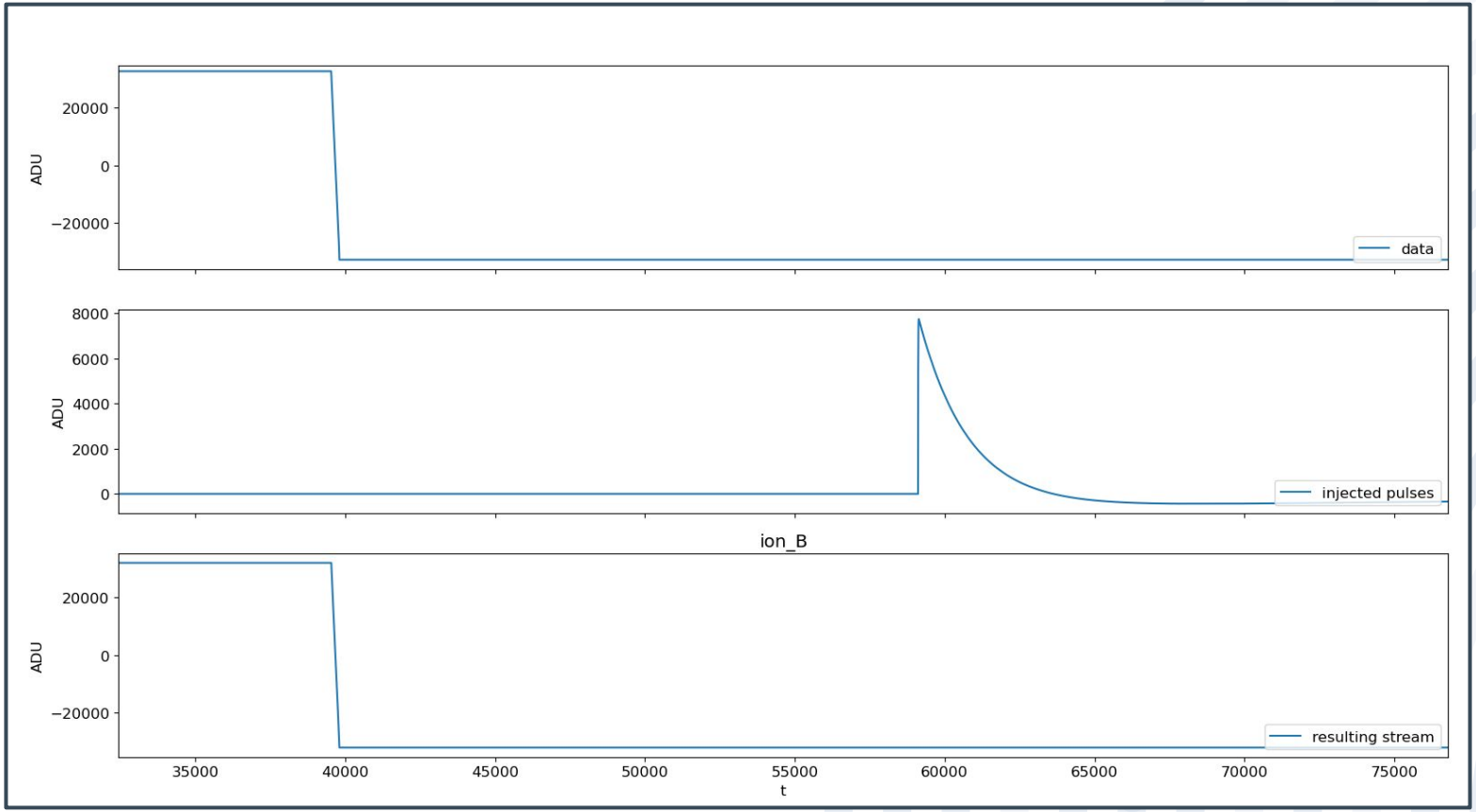
Encadrement d'un stagiaire de L3 (20h ou 10h?)

(prévu : Colles de Physiques à l'ECAM Lyon ~30h ?)

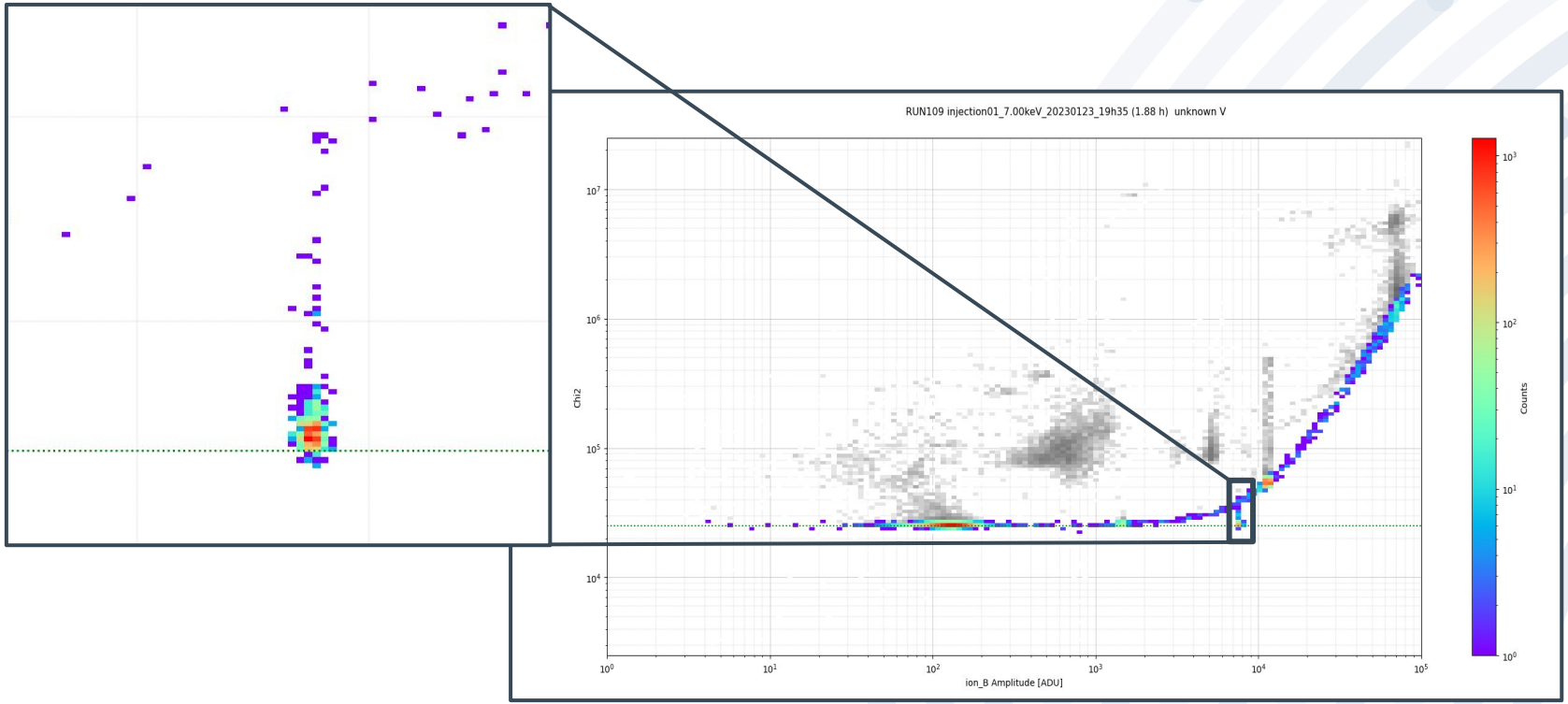
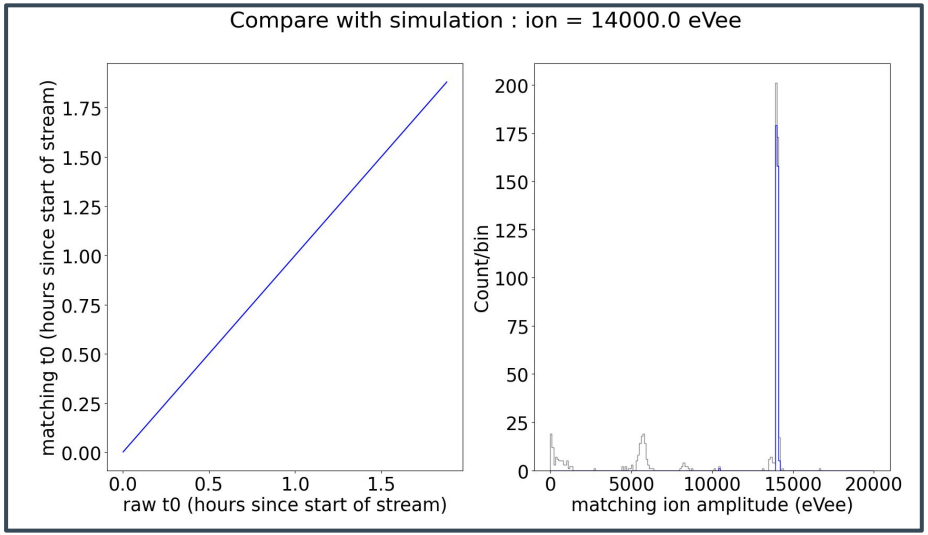
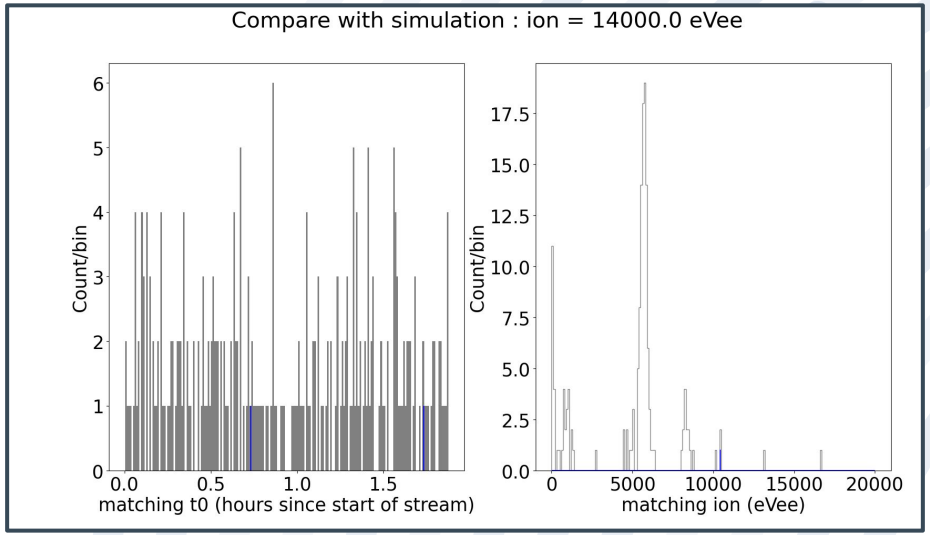
MPS Efficiency



MPS Efficiency



MPS Efficiency



MPS Efficiency