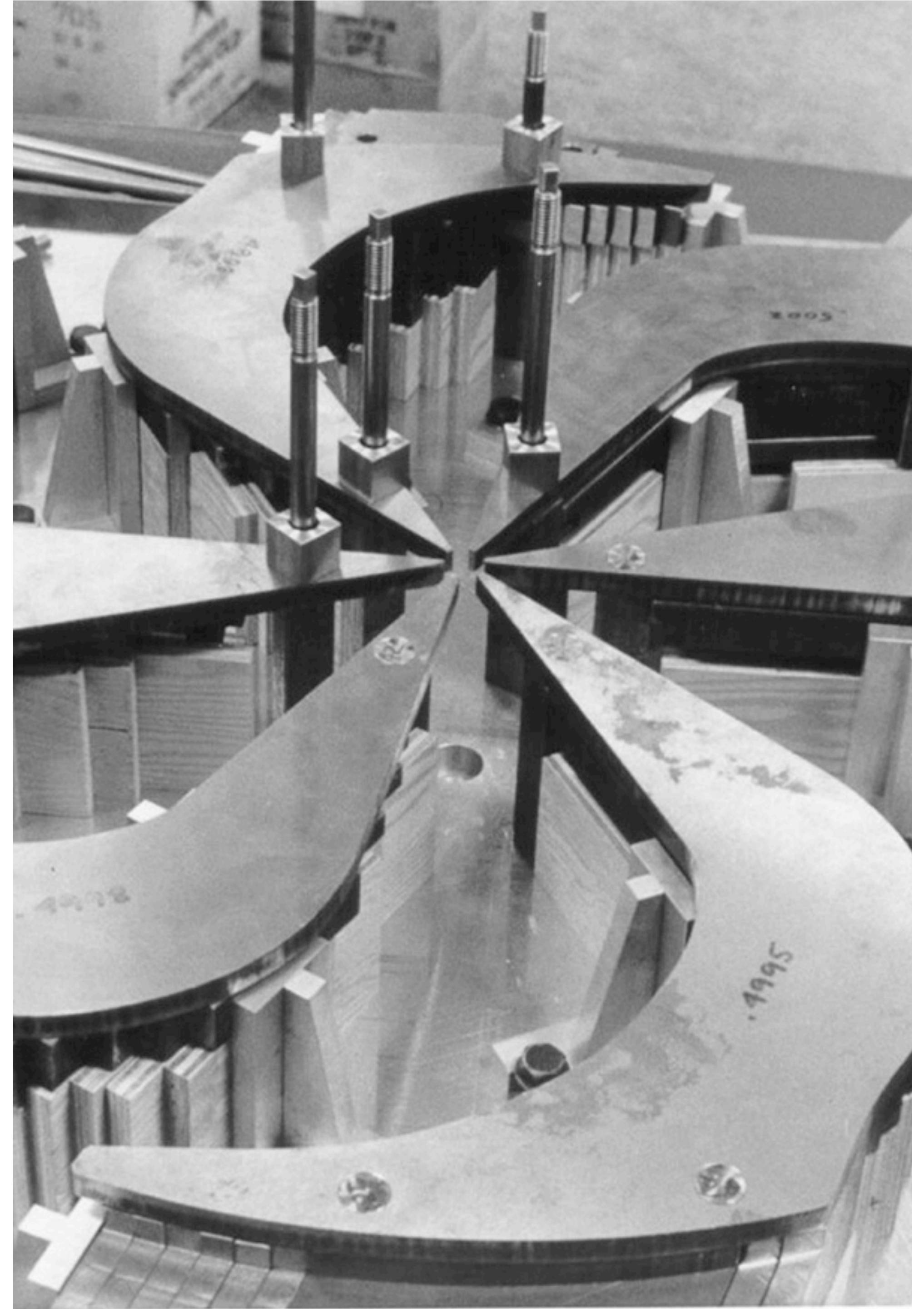


How to install the DarkLight experiment

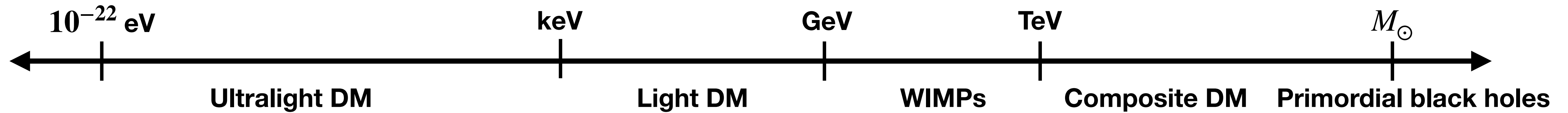
Laura Miller

PSD Mixer
2025-07-18



Background

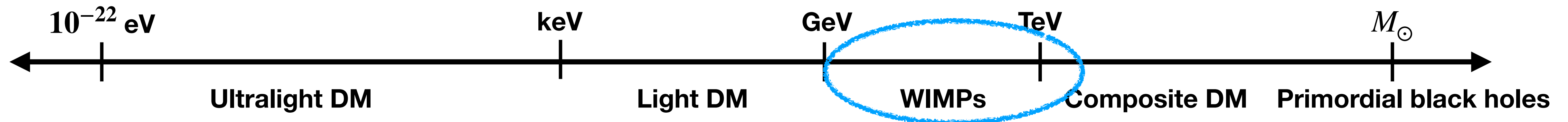
- Dark matter is one of the big unanswered questions of particle physics



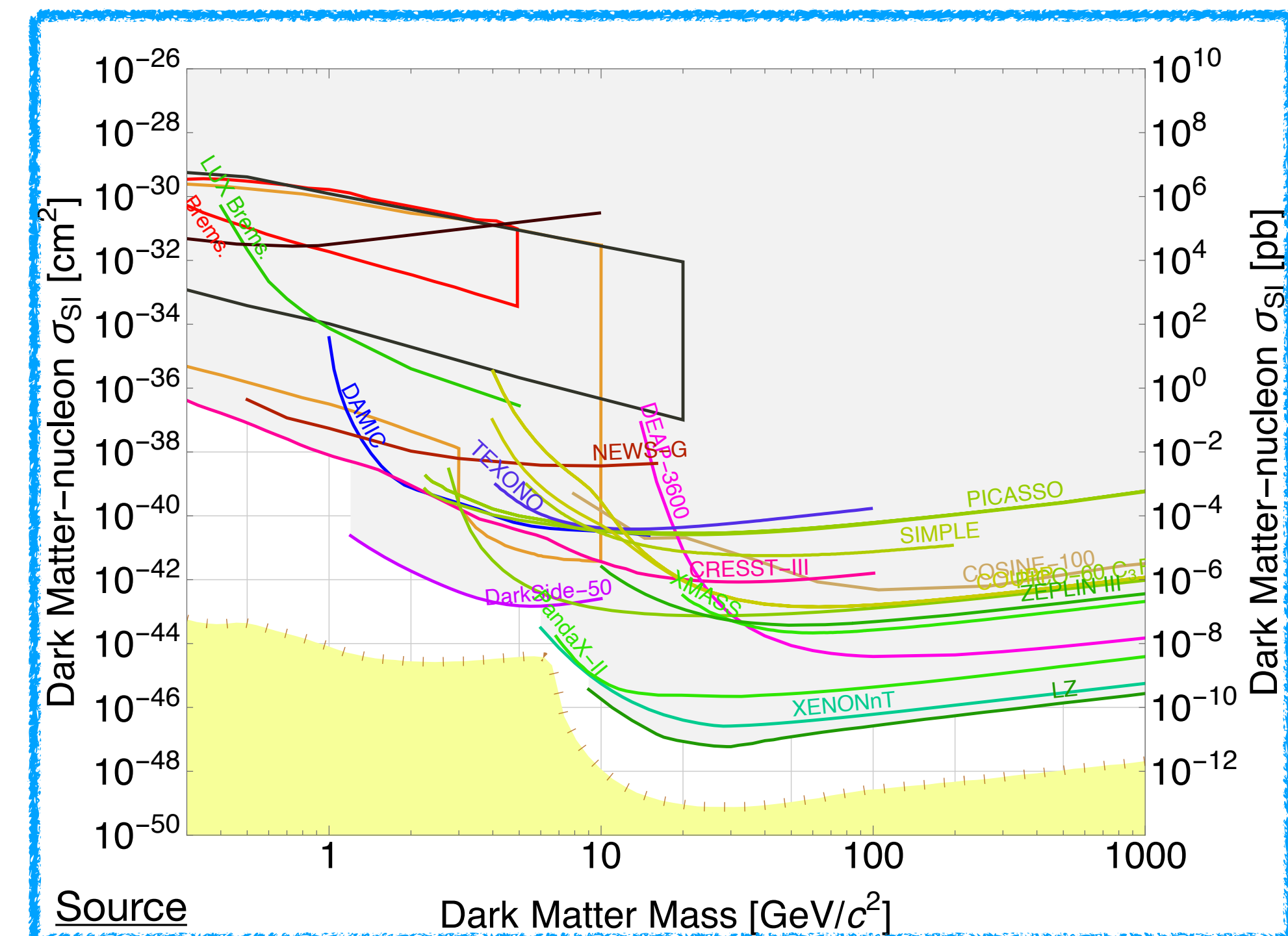
Background

- Dark matter is one of the big unanswered questions of particle physics

2



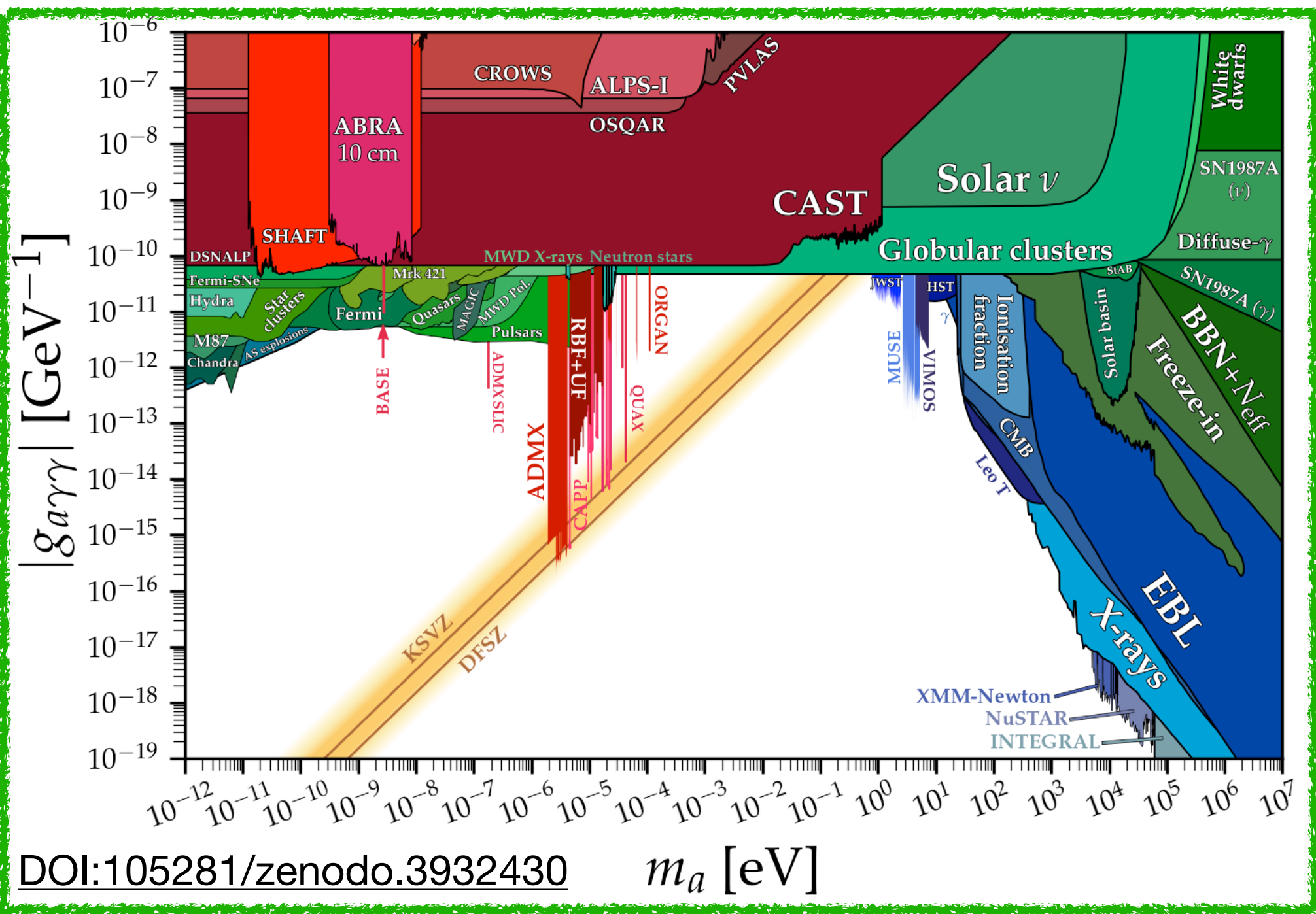
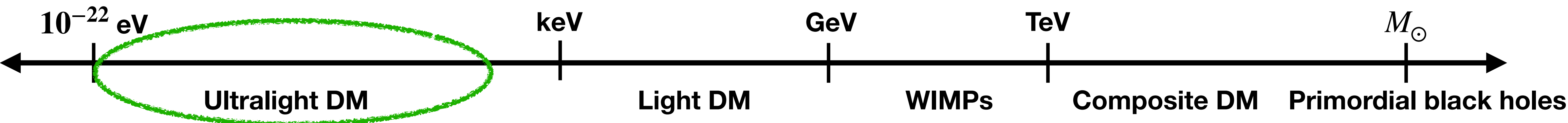
- Weakly interacting massive particles (WIMPs) have been a focus of many past and proposed experiments
- No experimental evidence so far



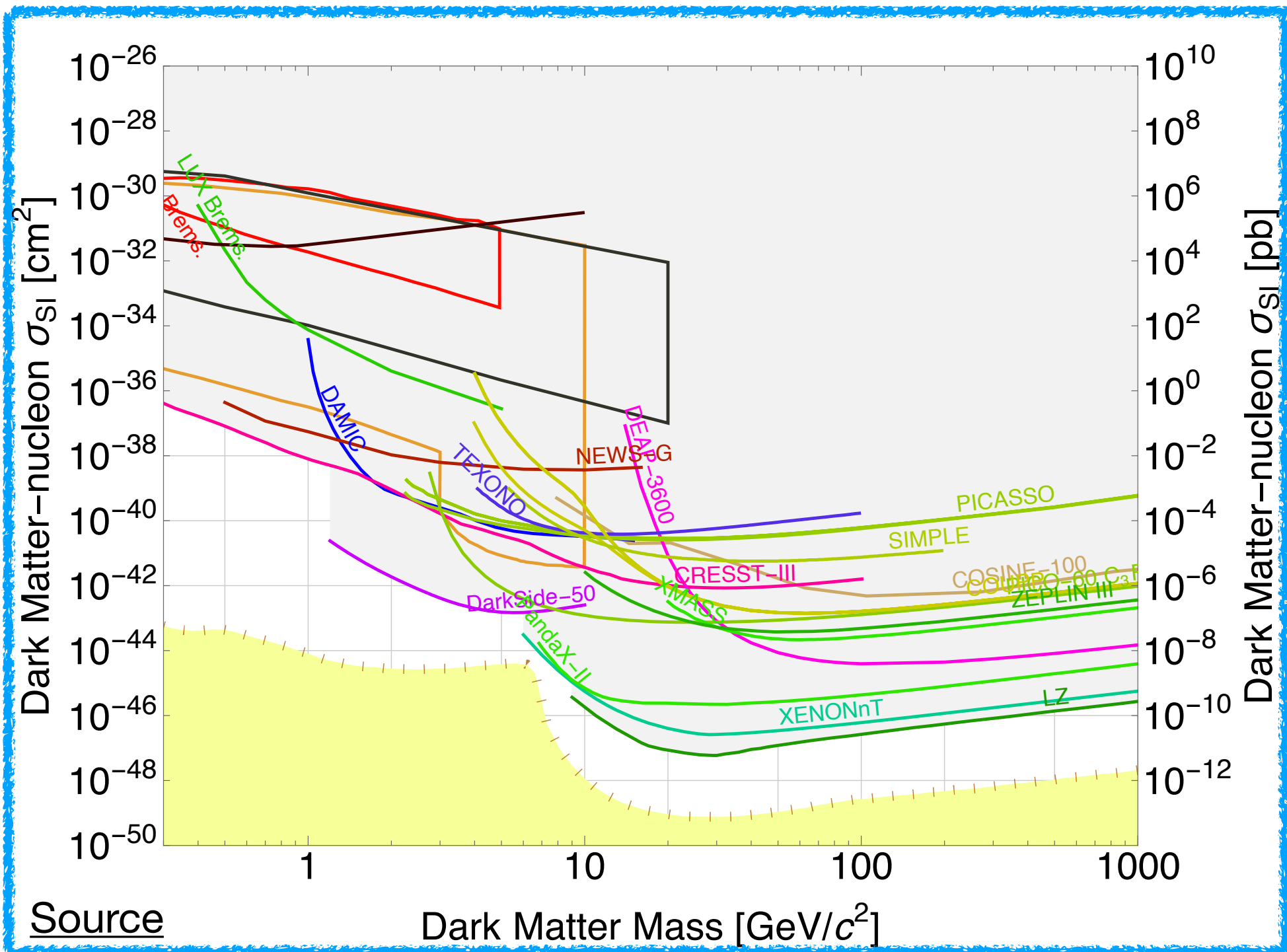
Background

- Dark matter is one of the big unanswered questions of particle physics

2



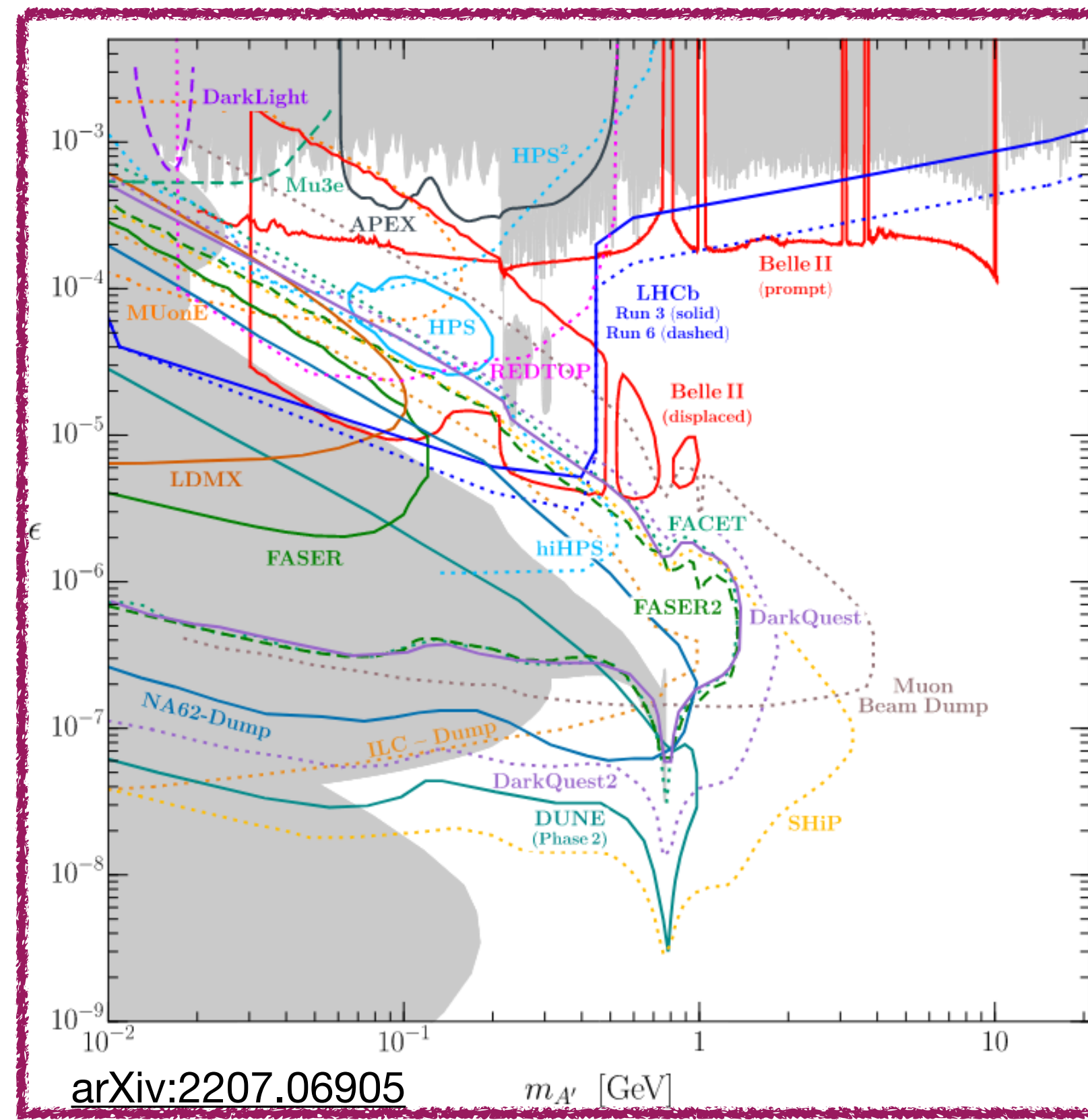
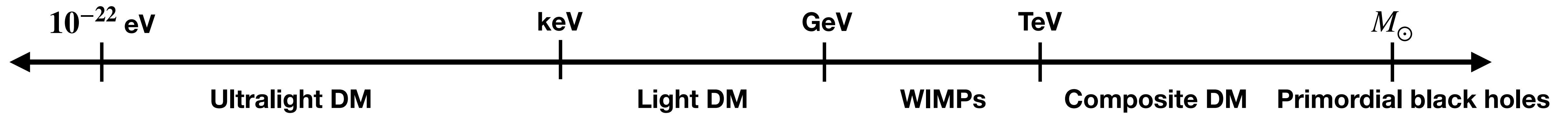
- Axion searches have also failed to produce any experimental evidence of dark matter



Background

- Dark matter is one of the big unanswered questions of particle physics

2

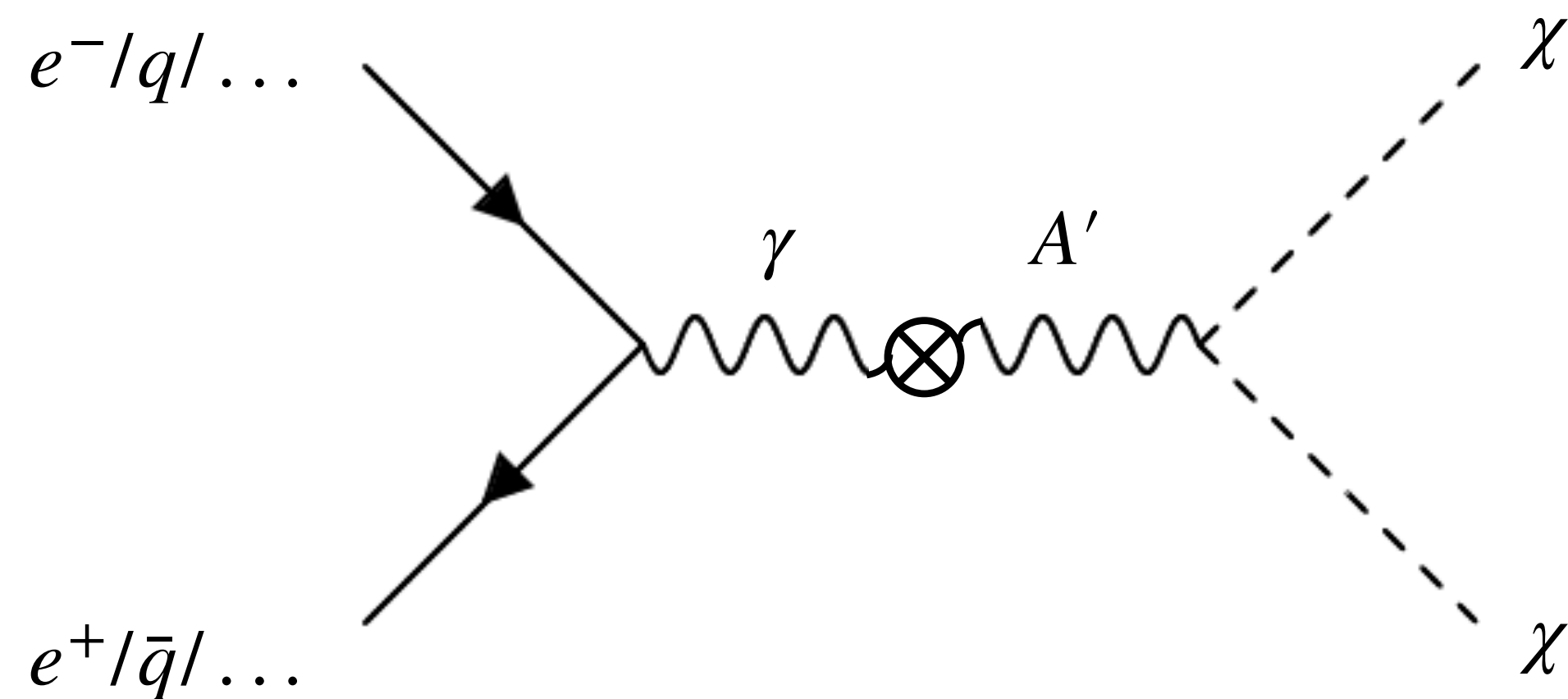


- Recently increased interest in DM candidates on the MeV scale
- Includes dark sector models

Dark Photon

- Posits a dark sector not charged under an SM gauge group, where interactions with the SM are facilitated by an intermediary particle
- Dark photon implies an additional U(1) gauge group
- Most basic model: kinetic mixing with the SM photon

3

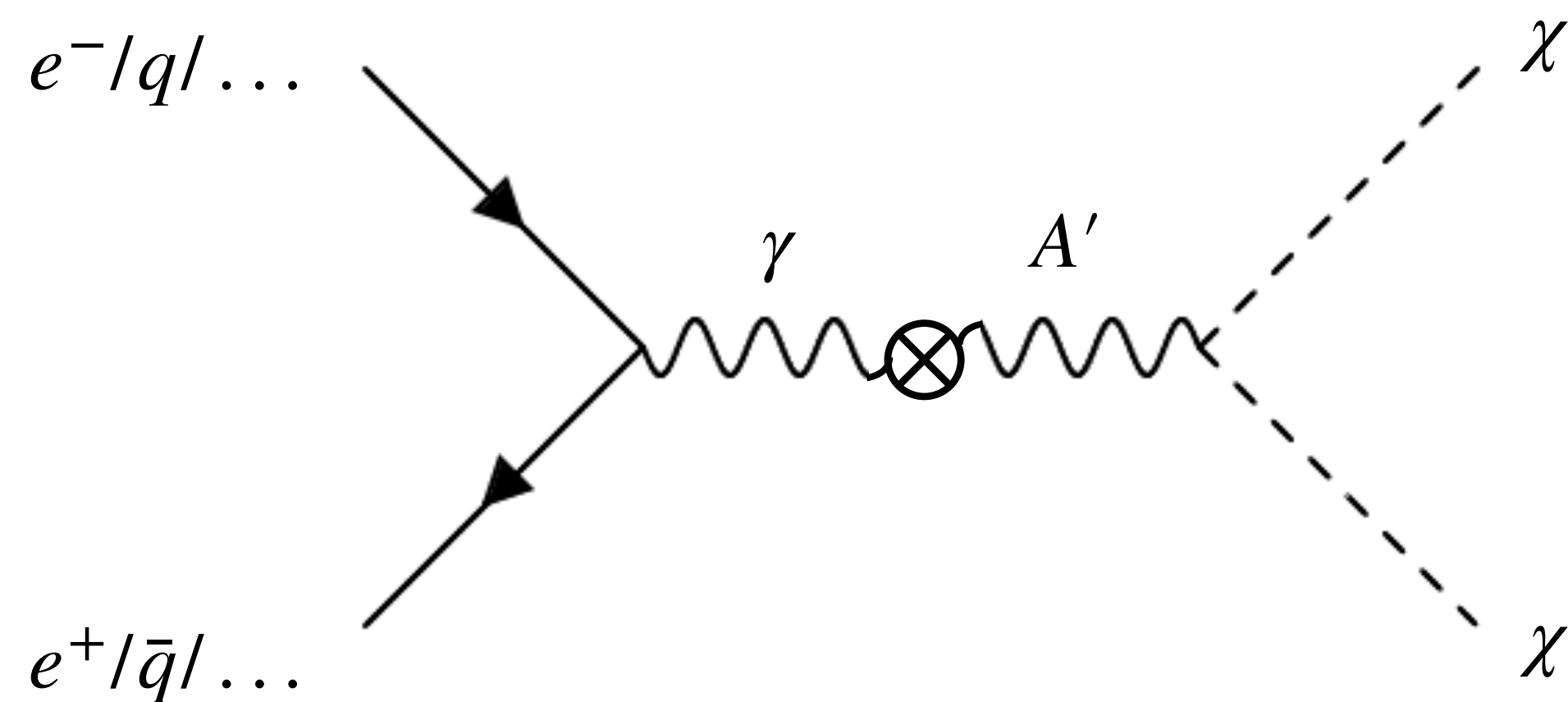


$$\mathcal{L}_{\text{int}} = e\epsilon J_\mu A'^\mu$$

Dark Photon

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3



$$\mathcal{L}_{\text{int}} = e\epsilon J_{\mu} A'^{\mu}$$

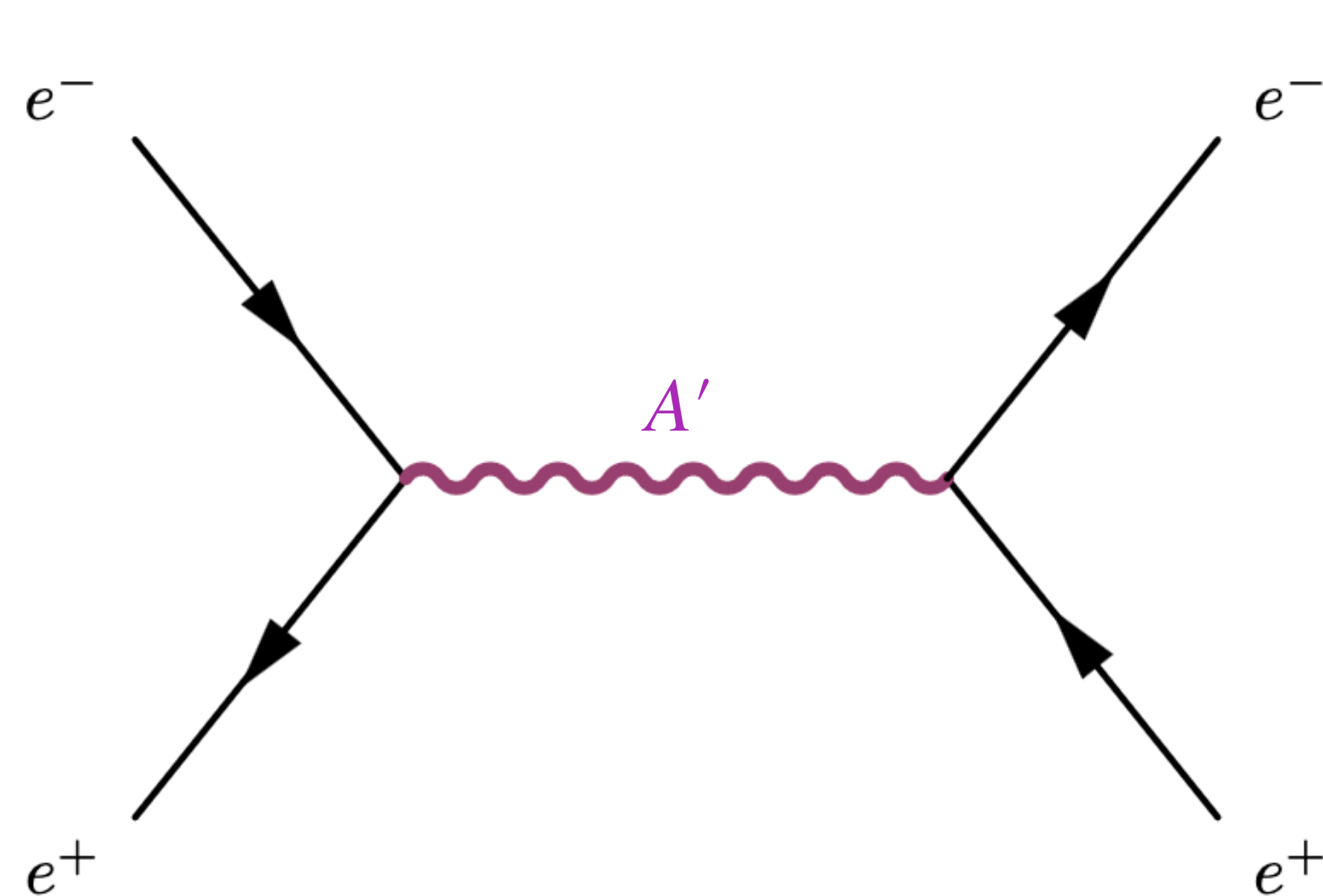
The equation is annotated with three colored arrows pointing to its terms:

- A blue arrow points to ϵ with the label "Kinetic mixing strength".
- A green arrow points to J_{μ} with the label "SM QED current".
- A purple arrow points to A'^{μ} with the label "Dark photon".

Dark Photon

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3



$$\mathcal{L}_{\text{int}} = e\epsilon J_{\mu} A'^{\mu}$$

Kinetic mixing strength

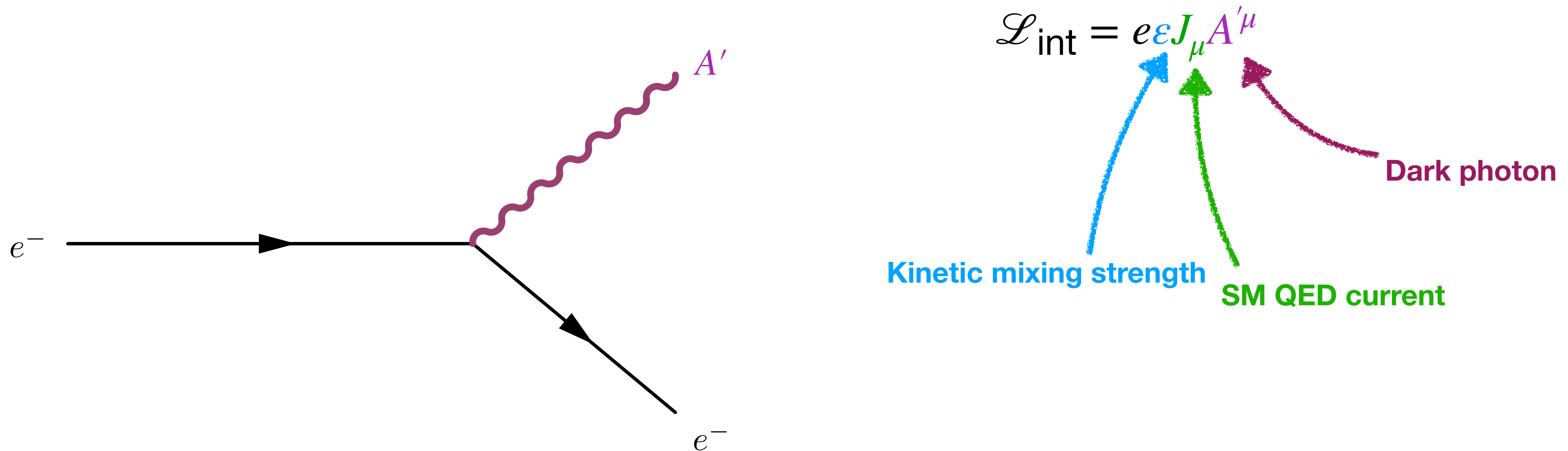
SM QED current

Dark photon

Dark Photon

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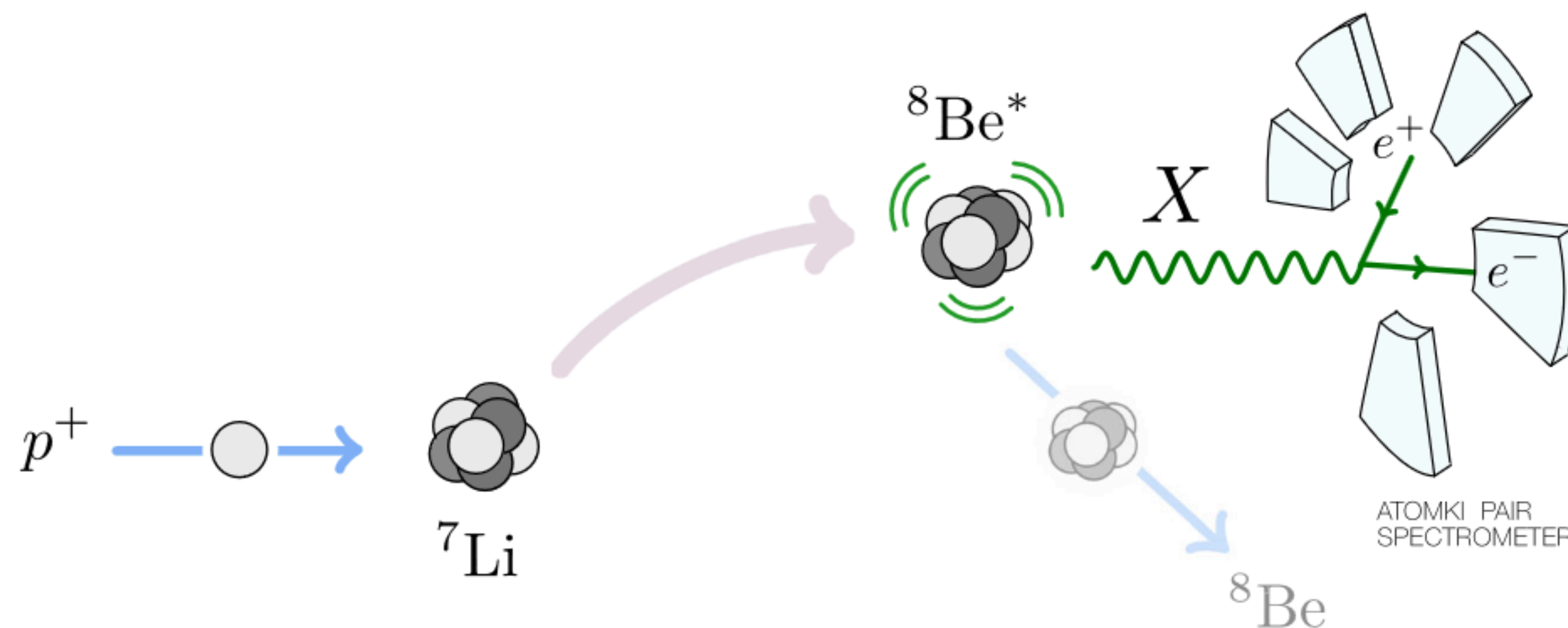
3



Experimental anomalies: X17

- Originally observed by ATOMKI collaboration in excited state decays of ^8Be

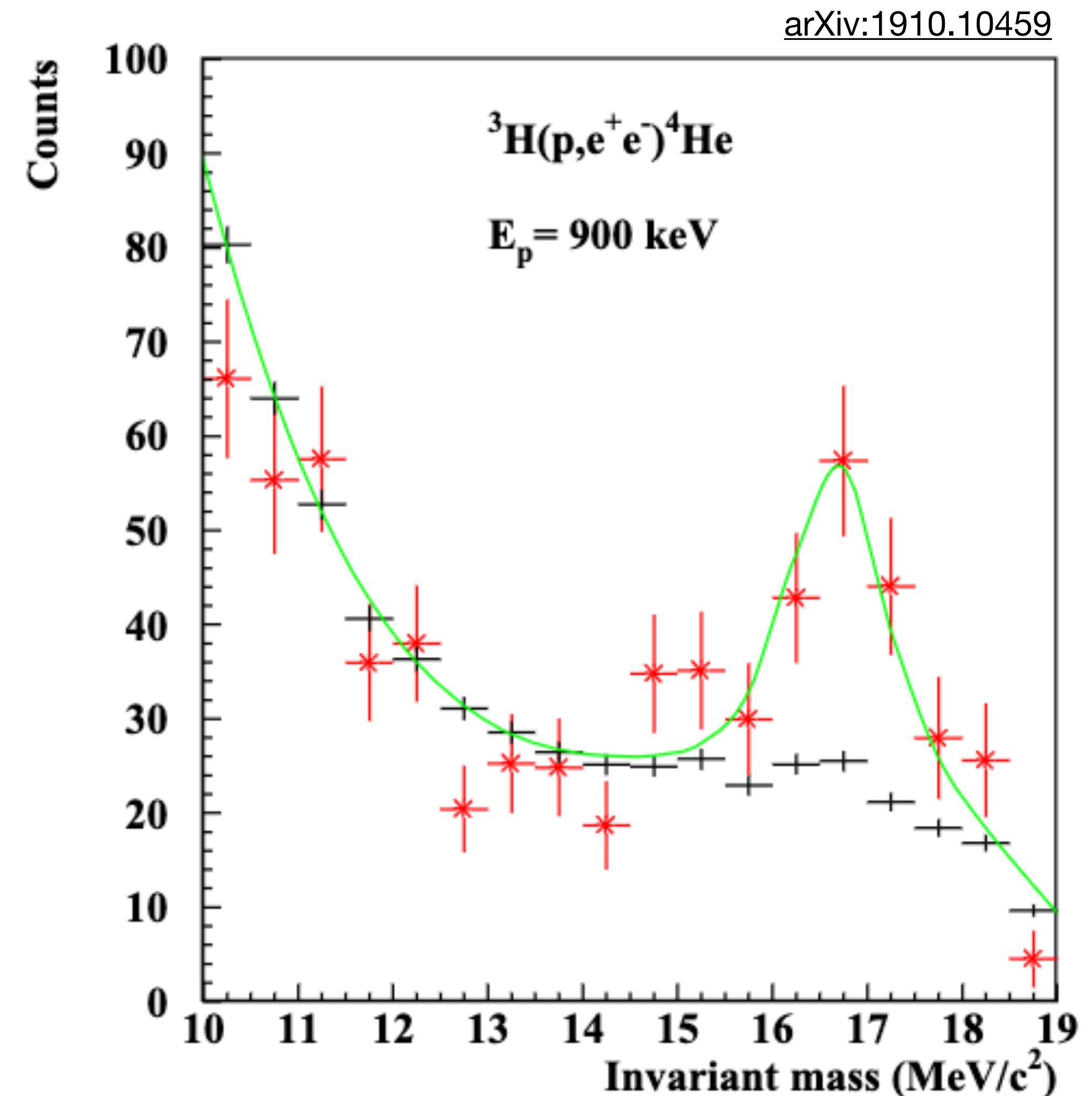
4



Physical Review D 95, 035017 (2017)

Experimental anomalies: X17

- Originally observed by ATOMKI collaboration in excited state decays of ^8Be
- Excess in e^+e^- invariant mass spectrum possibly indicate of a new boson with mass around 17 MeV
- Similar anomaly observed in ^4He , ^{12}C and using an independent apparatus

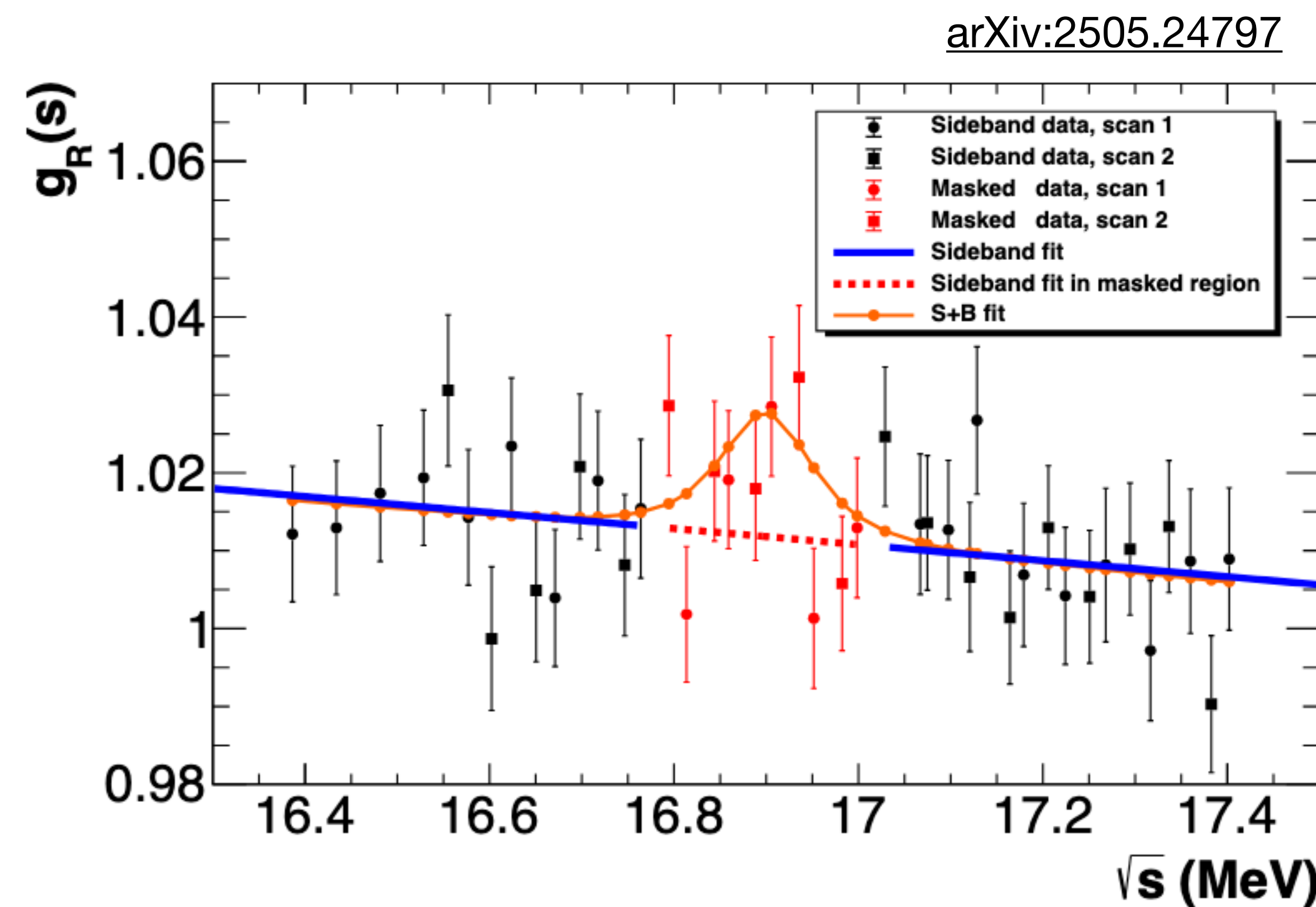


See: [Phys. Rev. Lett. 116, 042501 \(2016\)](#), [arXiv:1910.10459](#), [Phys. Rev. C 104, 044003 \(2021\)](#),

[arXiv:2205.07744](#), [Phys. Rev. C 106, L061601 \(2022\)](#), [arXiv:2308.06473](#), [arXiv:2311.18632](#), [arXiv:2401.11676](#)

Experimental anomalies: X17

- Originally observed by ATOMKI collaboration in excited state decays of ^8Be
- Excess in e^+e^- invariant mass spectrum possibly indicate of a new boson with mass around 17 MeV
- Similar anomaly observed in ^4He , ^{12}C and using an independent apparatus
- Recent PADME result sees slightly less than 2σ deviation from background



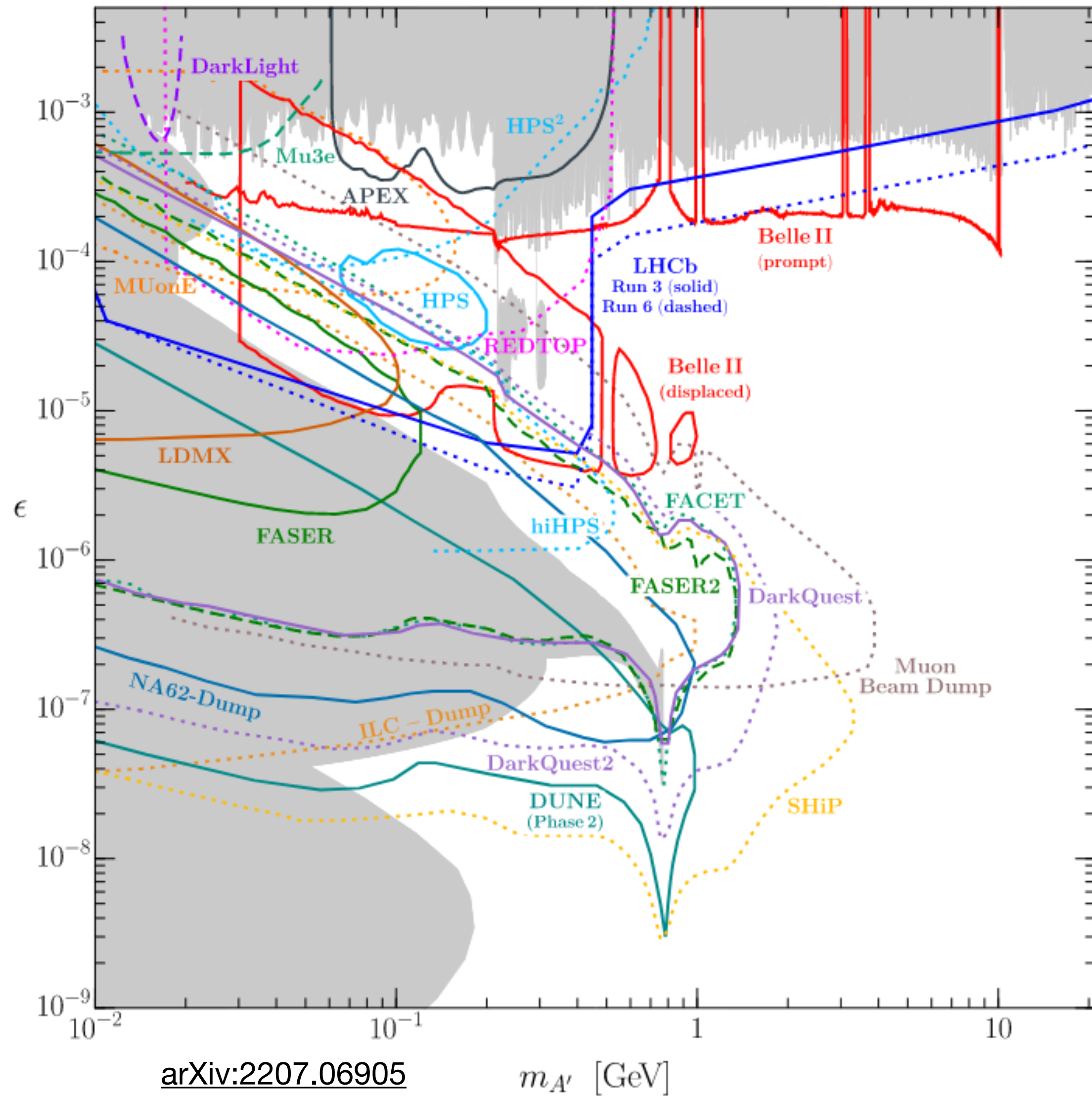
See: [Phys. Rev. Lett. 116, 042501 \(2016\)](#), [arXiv:1910.10459](#), [Phys. Rev. C 104, 044003 \(2021\)](#),

[arXiv:2205.07744](#), [Phys. Rev. C 106, L061601 \(2022\)](#), [arXiv:2308.06473](#), [arXiv:2311.18632](#), [arXiv:2401.11676](#)

Dark photon: current limits

Limits for past (grey) and future dark photon experiments

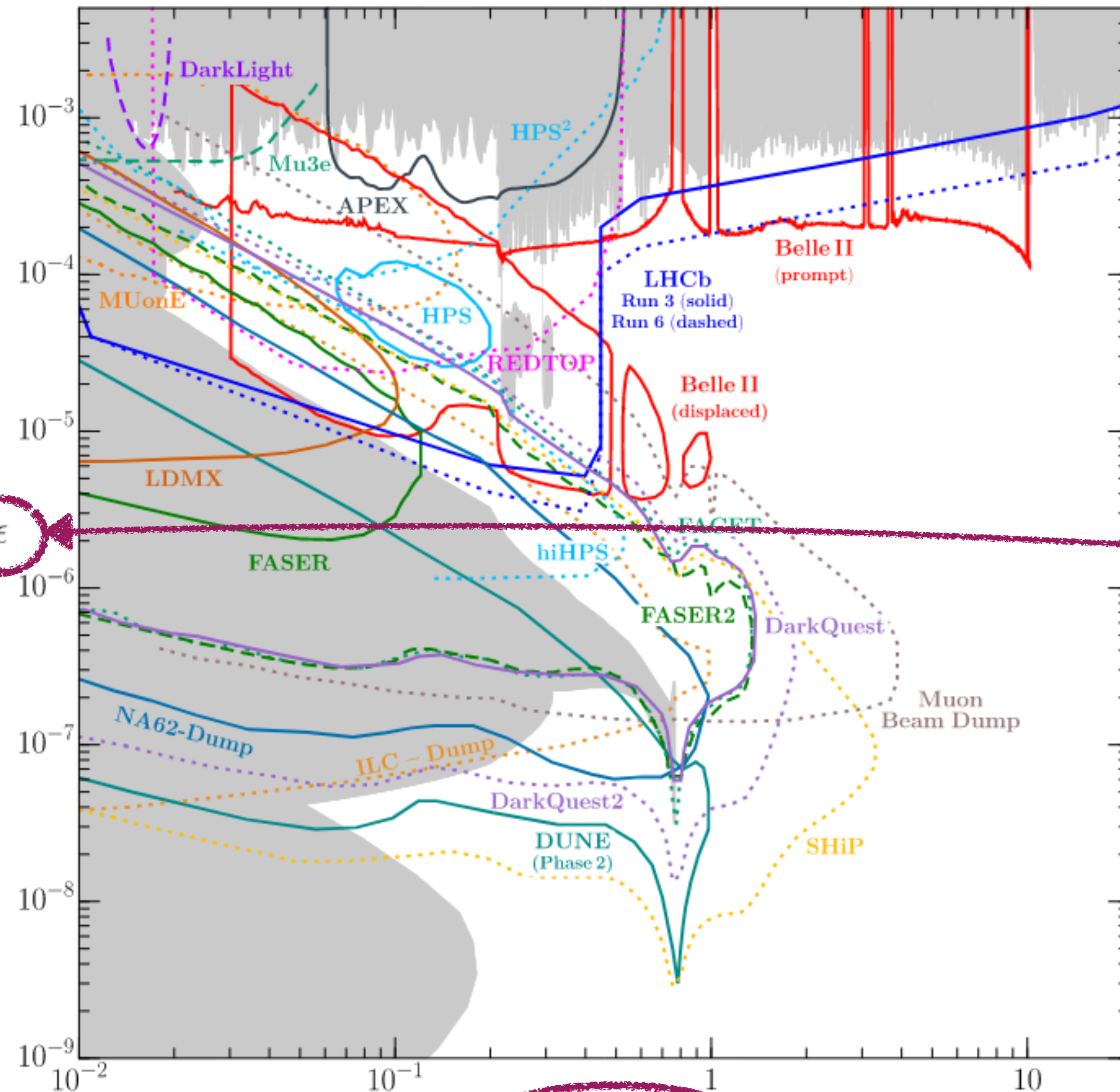
5



Dark photon: current limits

Limits for past (grey) and future dark photon experiments

5



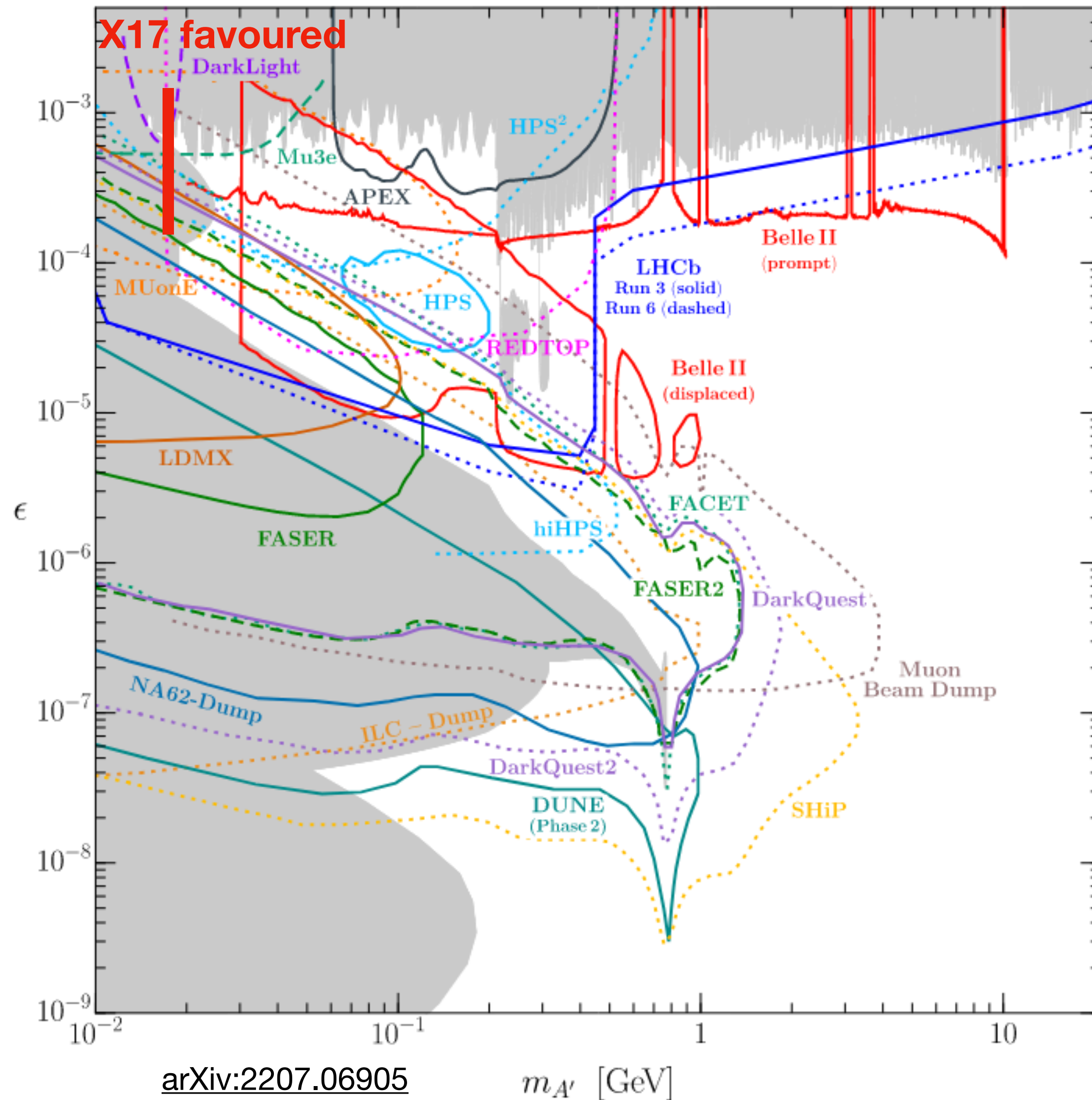
Kinetic mixing strength

Dark photon mass

Dark photon: current limits

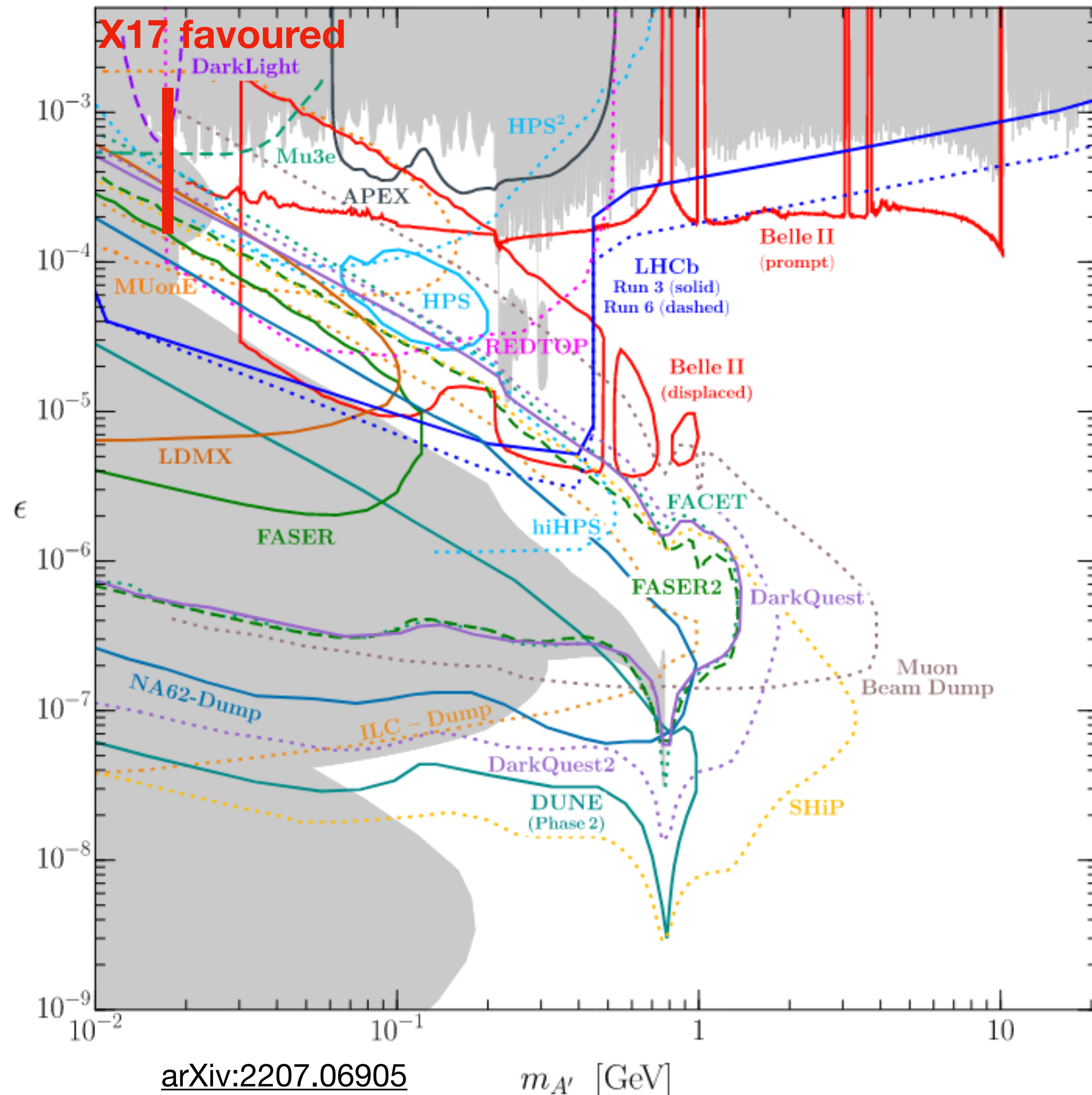
- Unclear exactly what form the coupling ϵ takes

Limits for past (grey) and future dark photon experiments



Dark ~~photon~~: current limits boson

Limits for past (grey) and future dark photon experiments



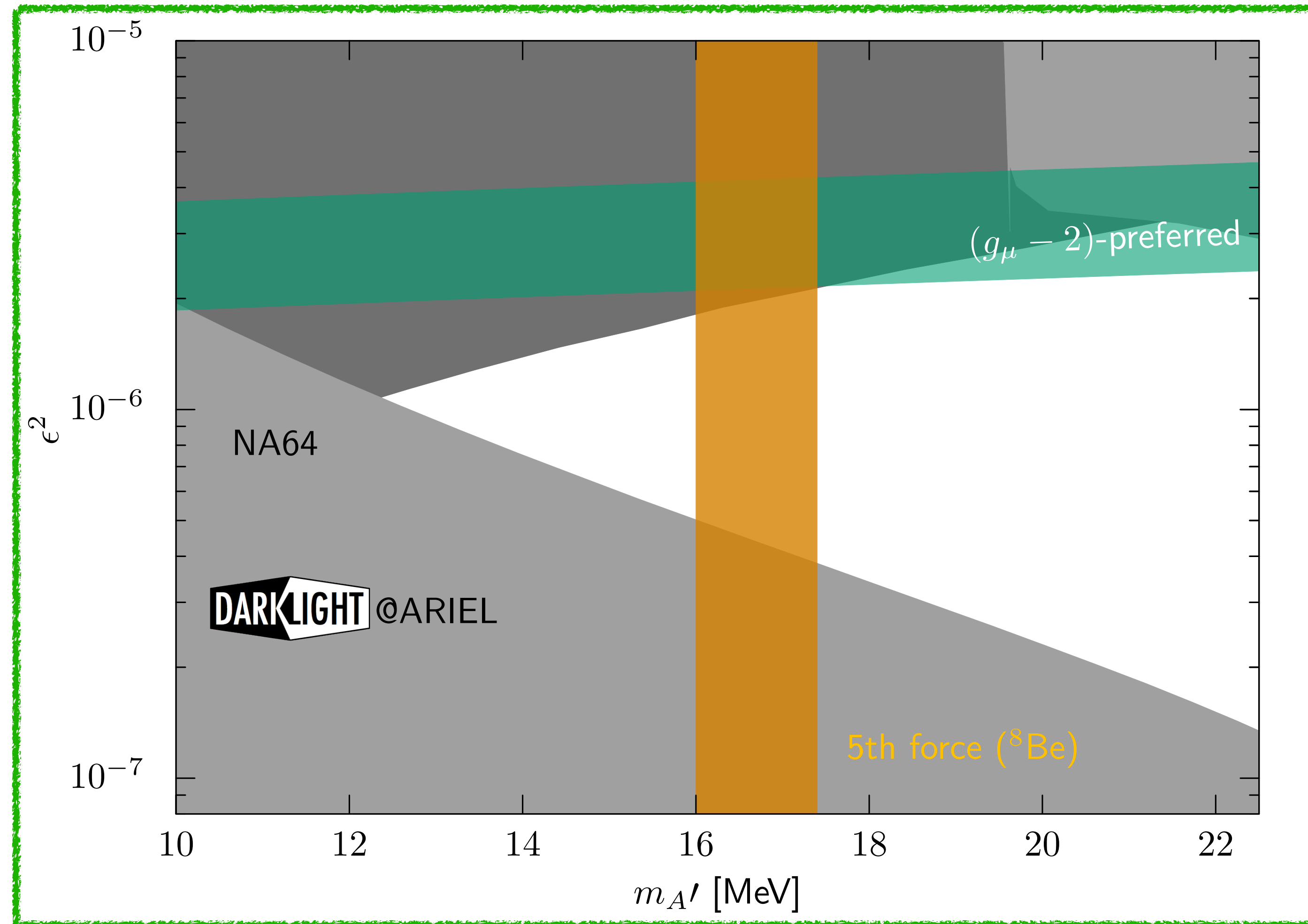
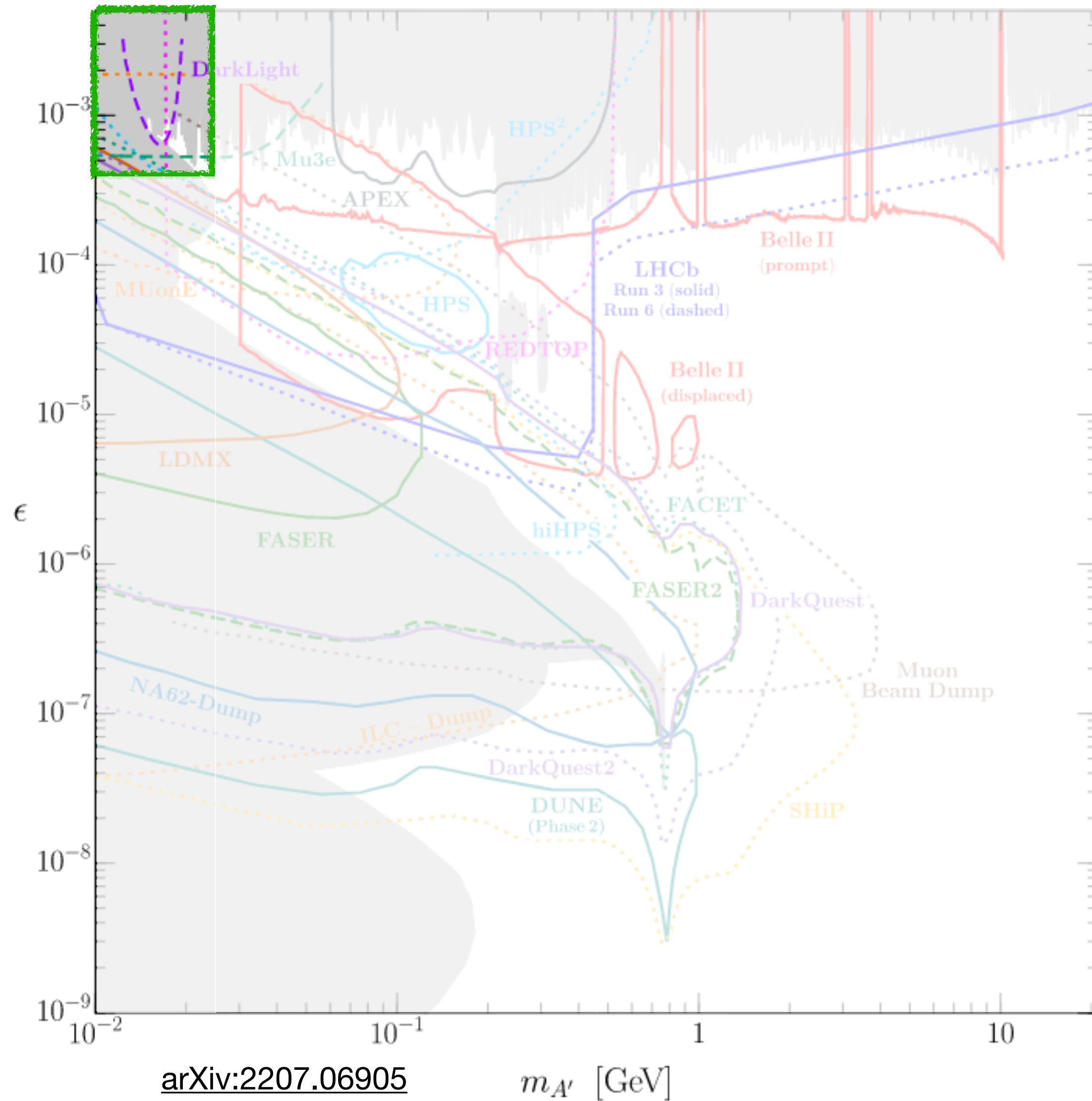
- Unclear exactly what form the coupling ϵ takes
- **Protophobic** coupling (reduced coupling to protons) required by the X17
- Coupling no longer universal to the QED current: $\mathcal{L}_{\text{int}} = e\epsilon J_\mu A'^\mu$
- Instead something more complex, but can still display limits in the same parameter space

For more details see: Feng et. al. [PRL 117, 071803 \(2016\)](#), [Physical Review D 95, 035017 \(2017\)](#), [Physical Review D 102, 036016 \(2020\)](#)

Dark ~~photon~~: current limits boson

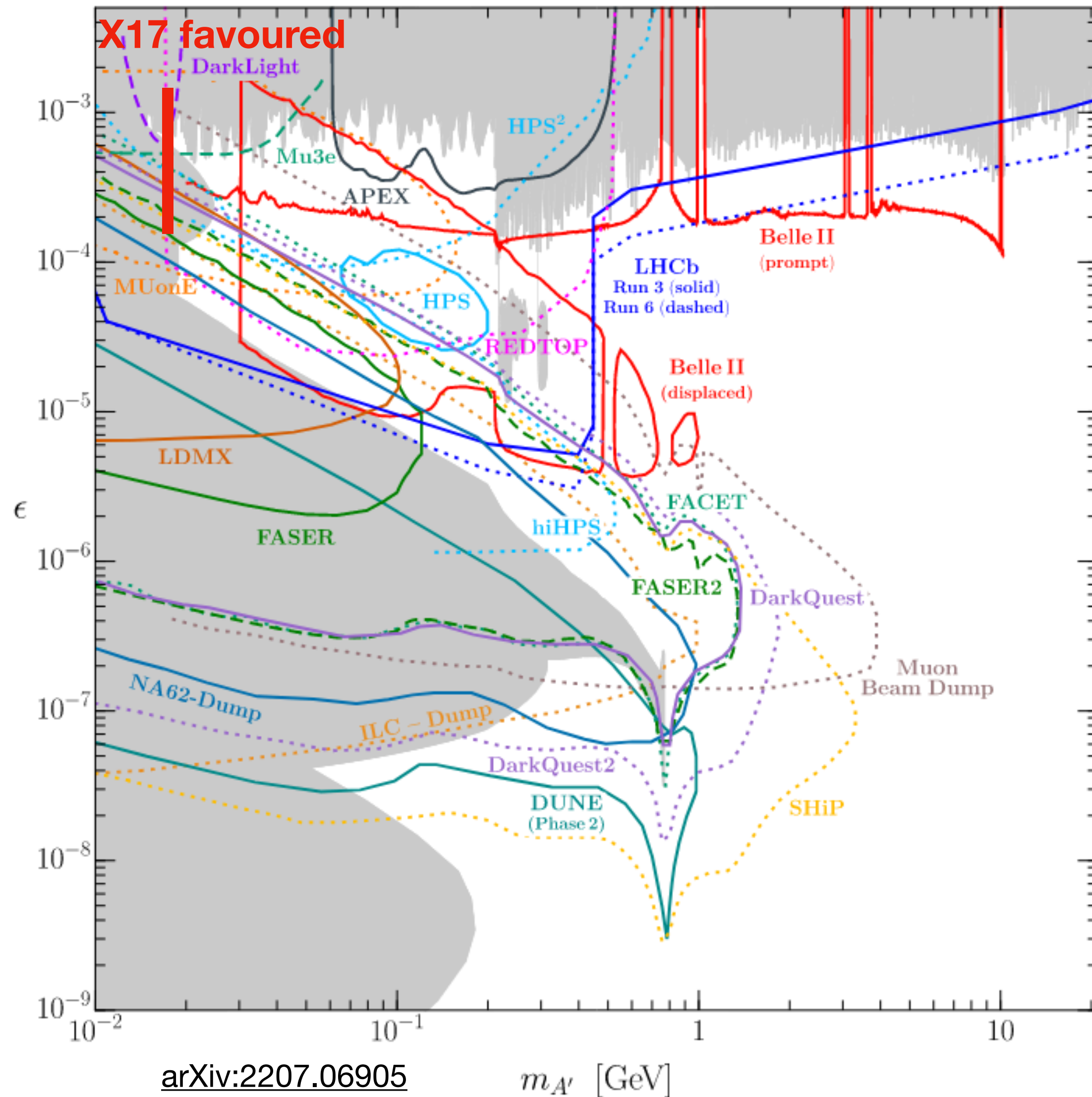
Limits for past (grey) and future dark photon experiments

5



Dark ~~photon~~: current limits boson

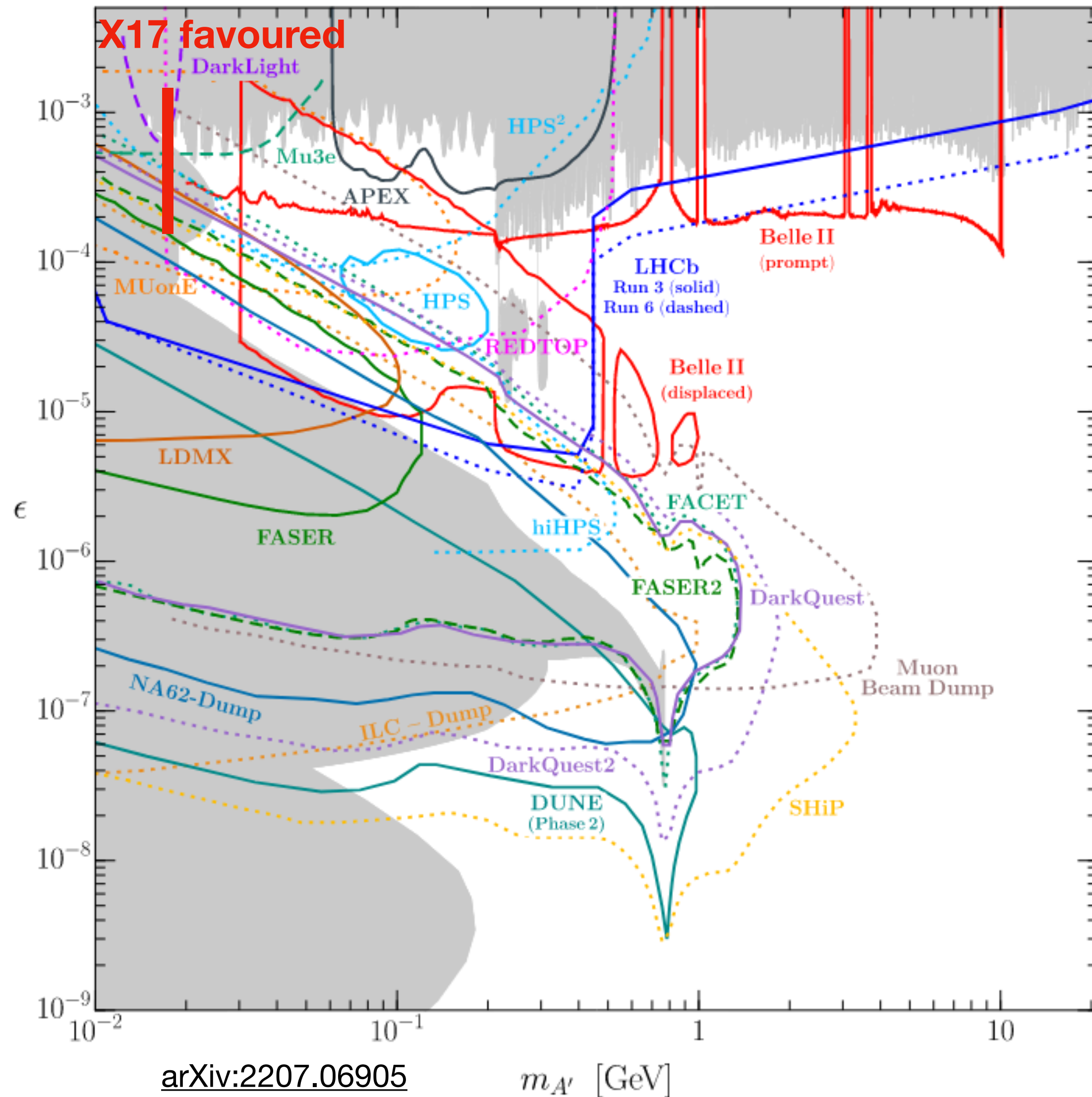
Limits for past (grey) and future dark photon experiments



- Unclear exactly what form the coupling ϵ takes
- **Protophobic** coupling (reduced coupling to protons) required by the X17
- Reopens some previously excluded parameter space
- Can only be probed with a fully leptonic experiment

Dark ~~photon~~: current limits boson

Limits for past (grey) and future dark photon experiments

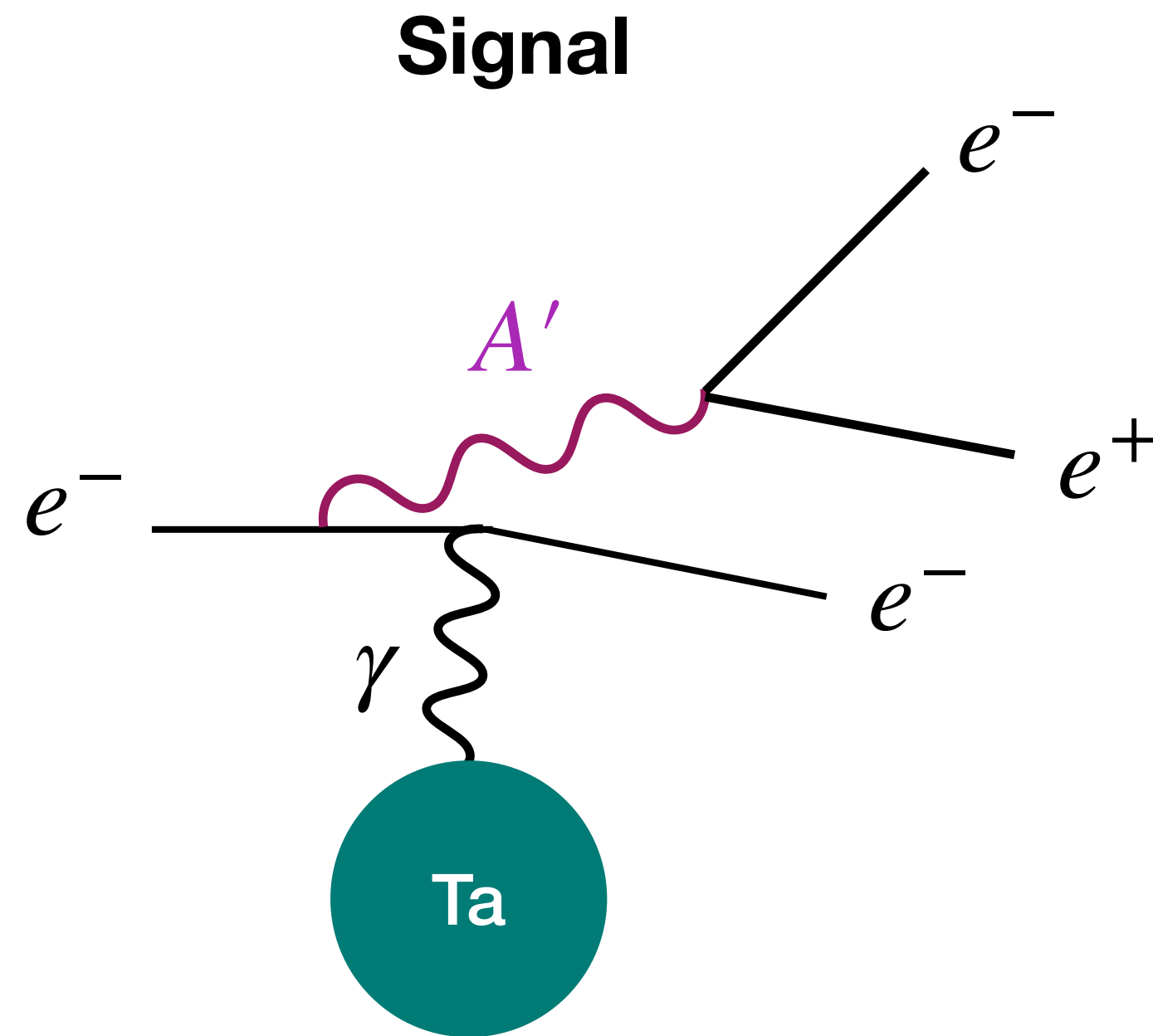


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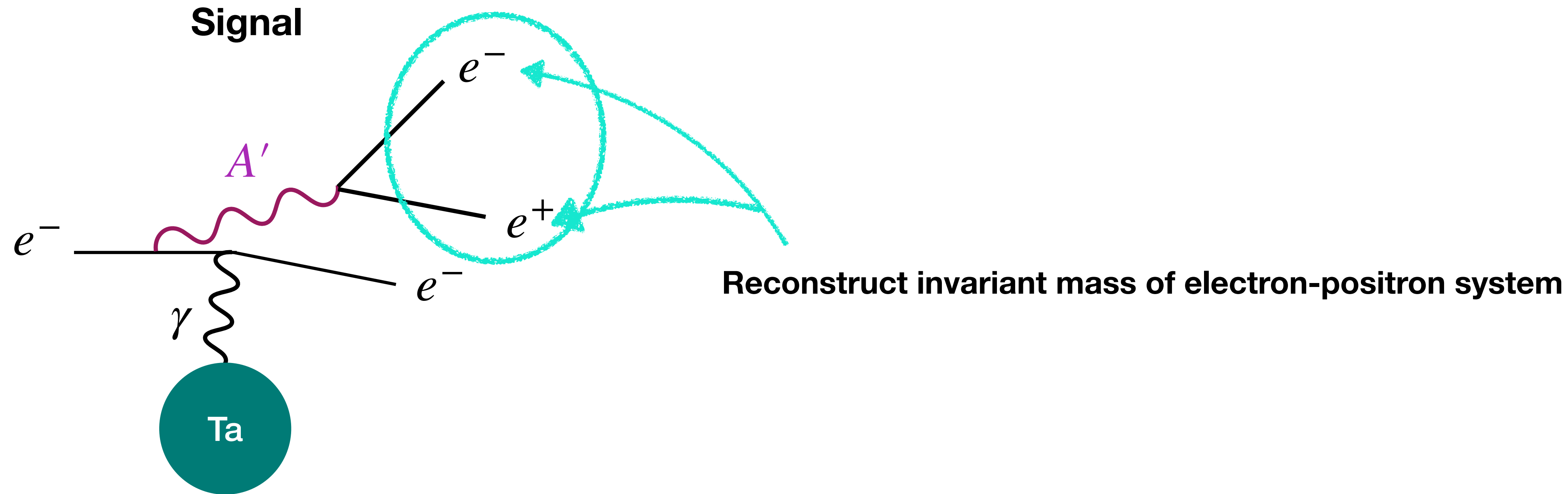
DarkLight@ARIEL

- Bombard fixed high Z target with low energy high intensity electron beam



DarkLight@ARIEL

- Bombard fixed high Z target with low energy high intensity electron beam

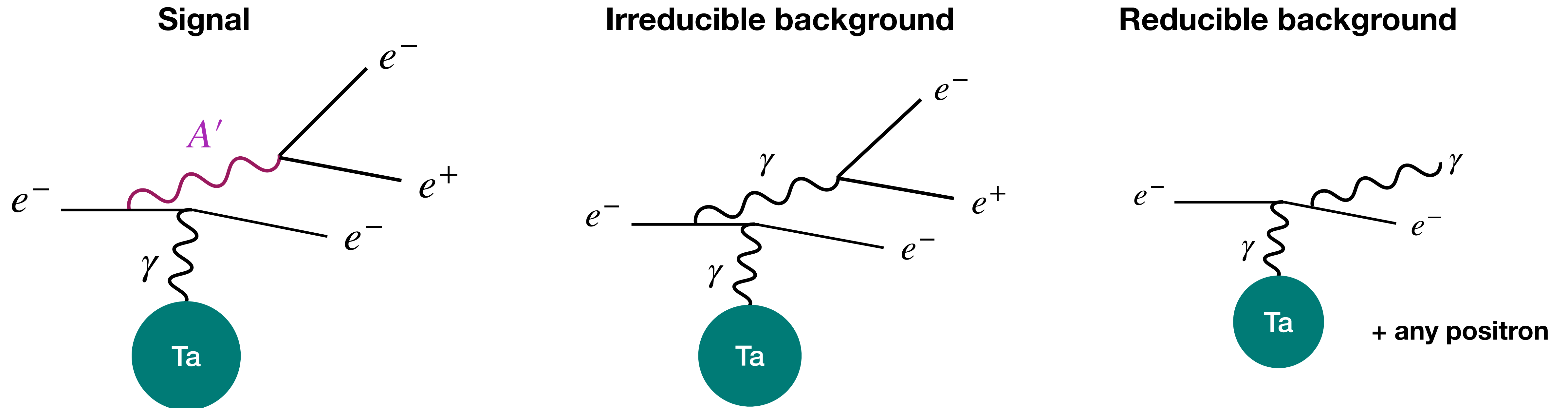


- Low energy allows probe of X17 region, high intensity for lots of statistics

DarkLight@ARIEL

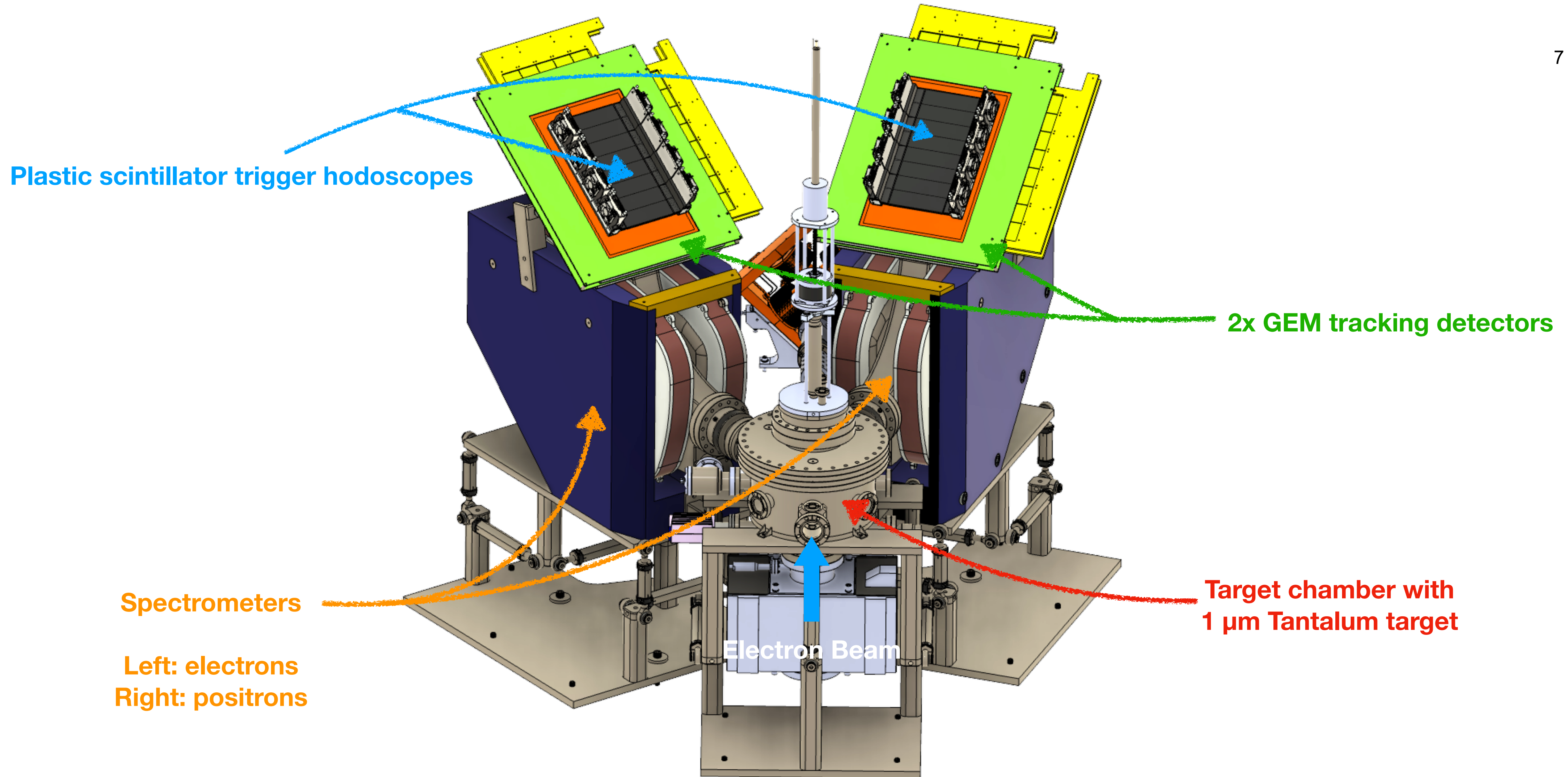
- Bombard fixed high Z target with low energy high intensity electron beam

6



- Low energy allows probe of X17 region, high intensity for lots of statistics

The DarkLight apparatus

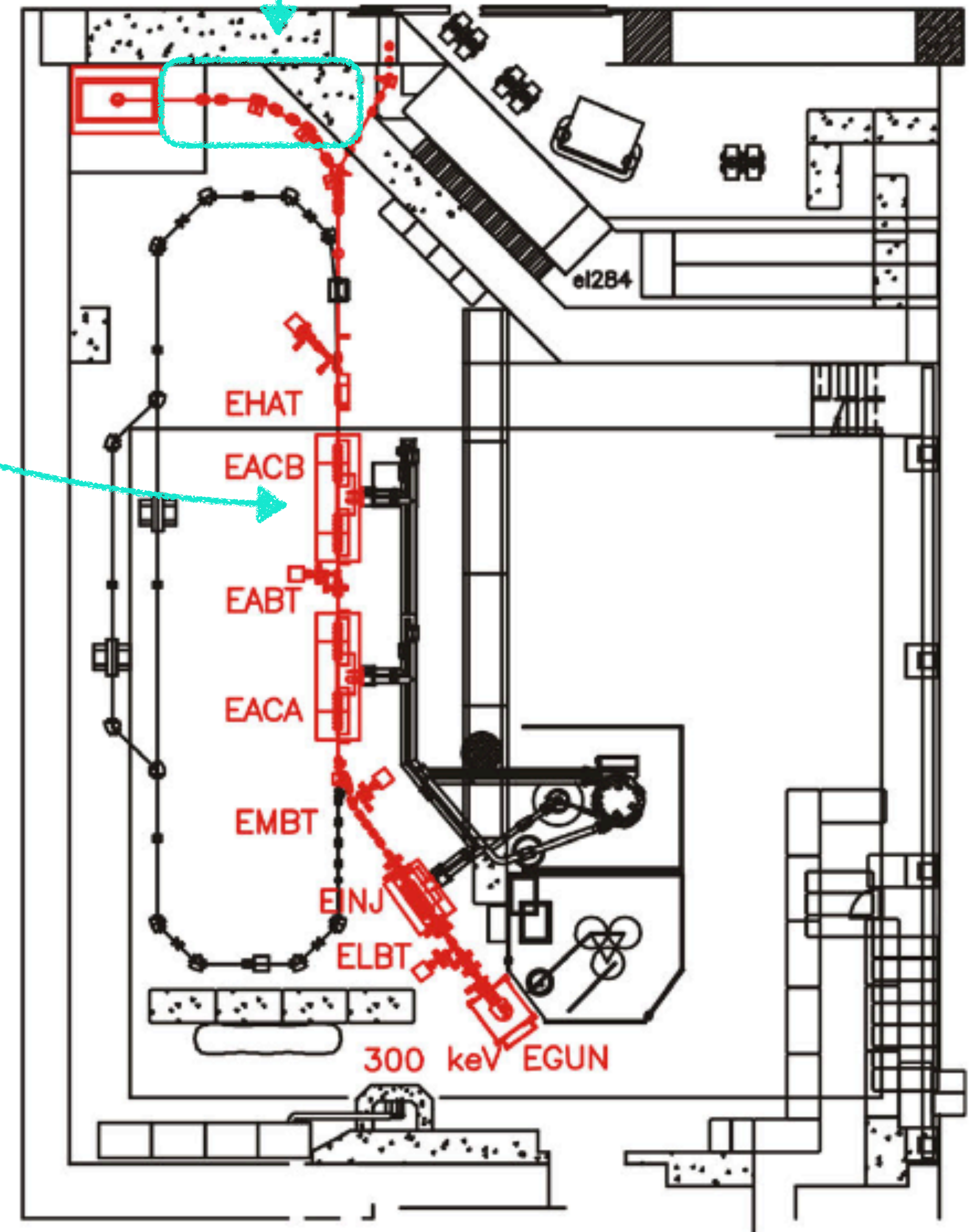


ARIEL eLinac

- 30 MeV electron beam setup
 - Best sensitivity is below 17 MeV
 - Excellent for commissioning
- 50 MeV upgrade: new cryomodule
 - Allows probe of X17 favoured region

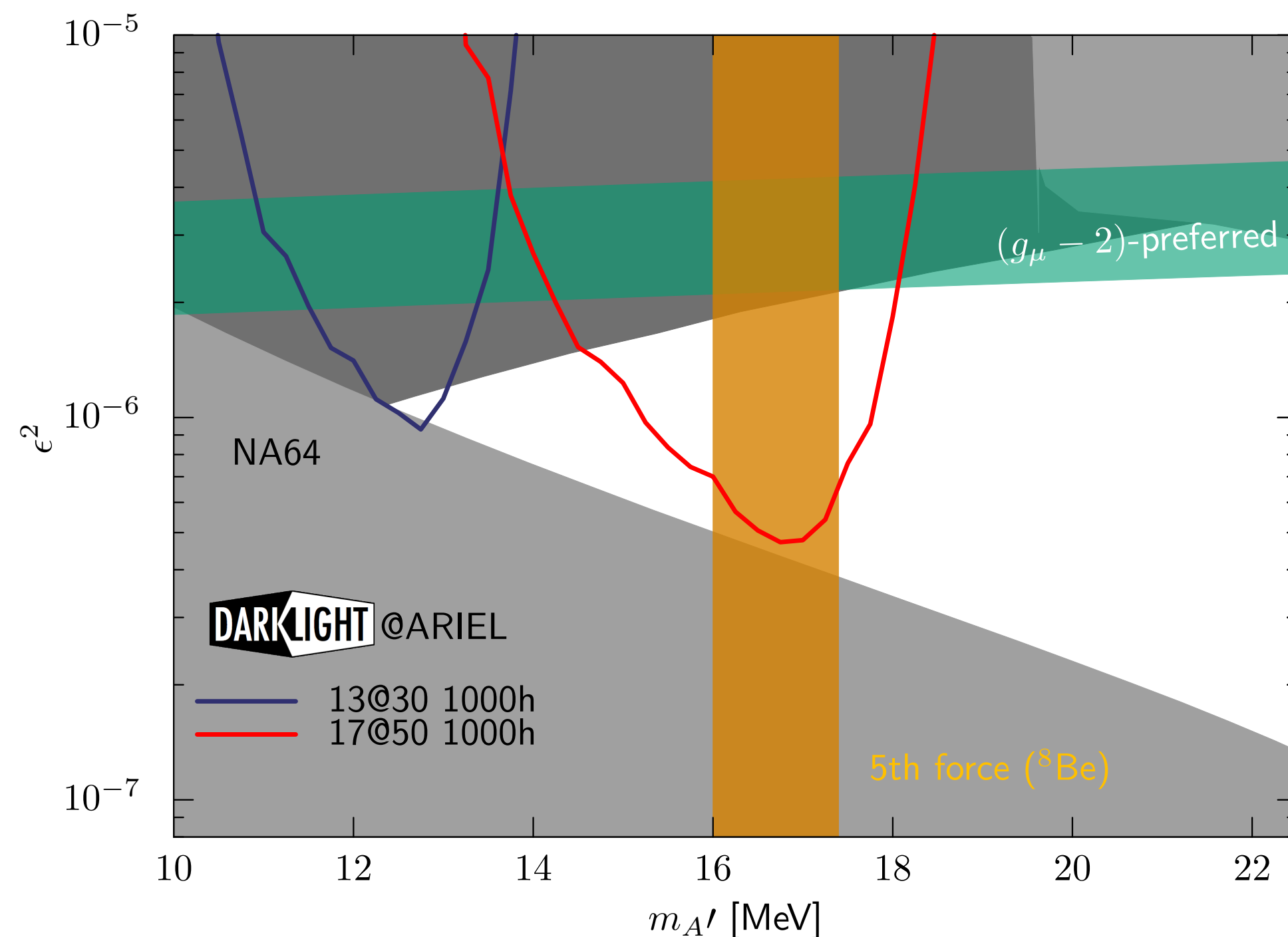


To ARIEL facility



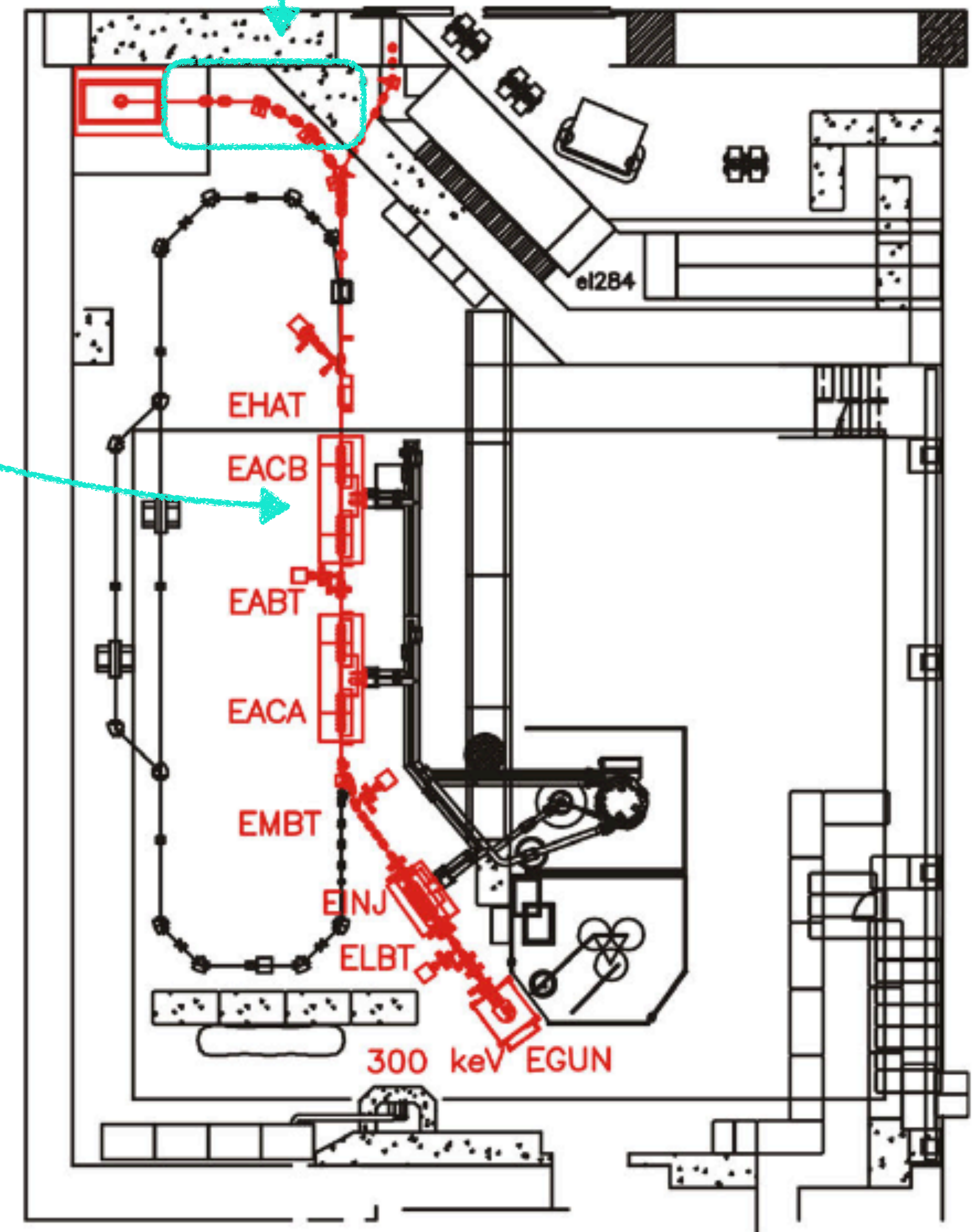
ARIEL eLinac

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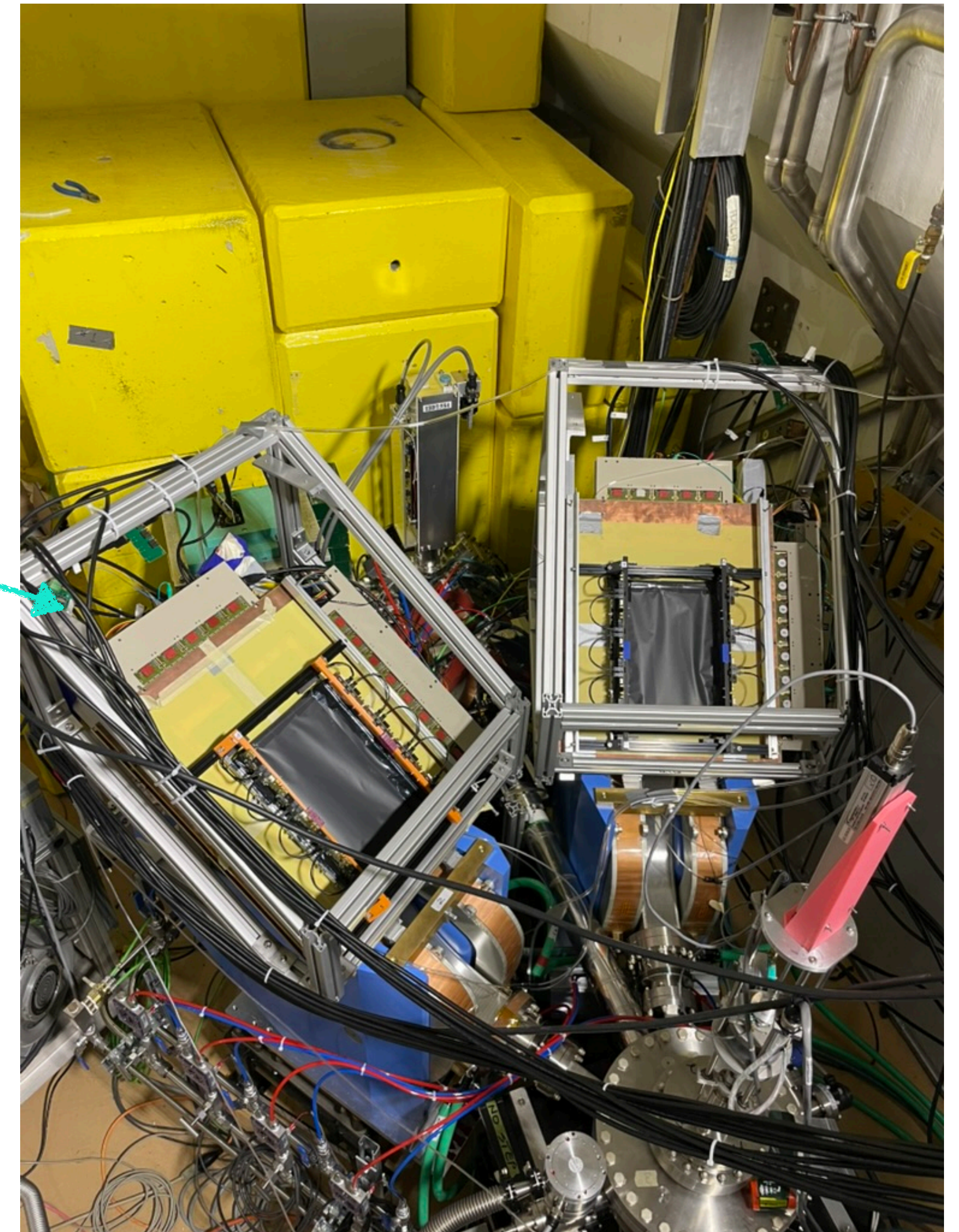
DARKLIGHT

To ARIEL facility



Where are we now?

- Installation done!

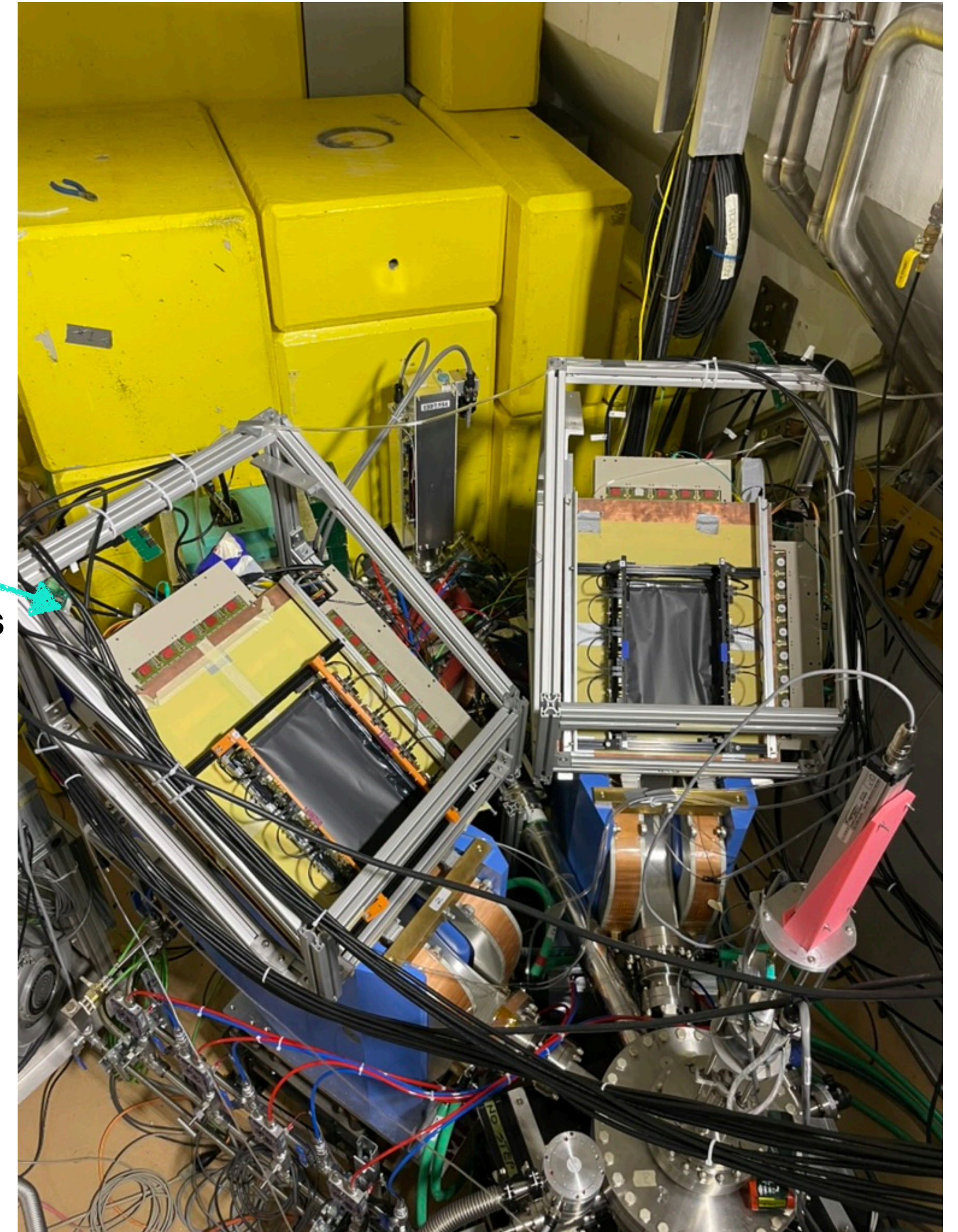


Where are we now?

- Installation done!
- How'd it go?



Blood, sweat and tears



Step 1: Acquire all your bits and pieces



10



Step 2: Get yourself a good team

- Thanks everyone!

11

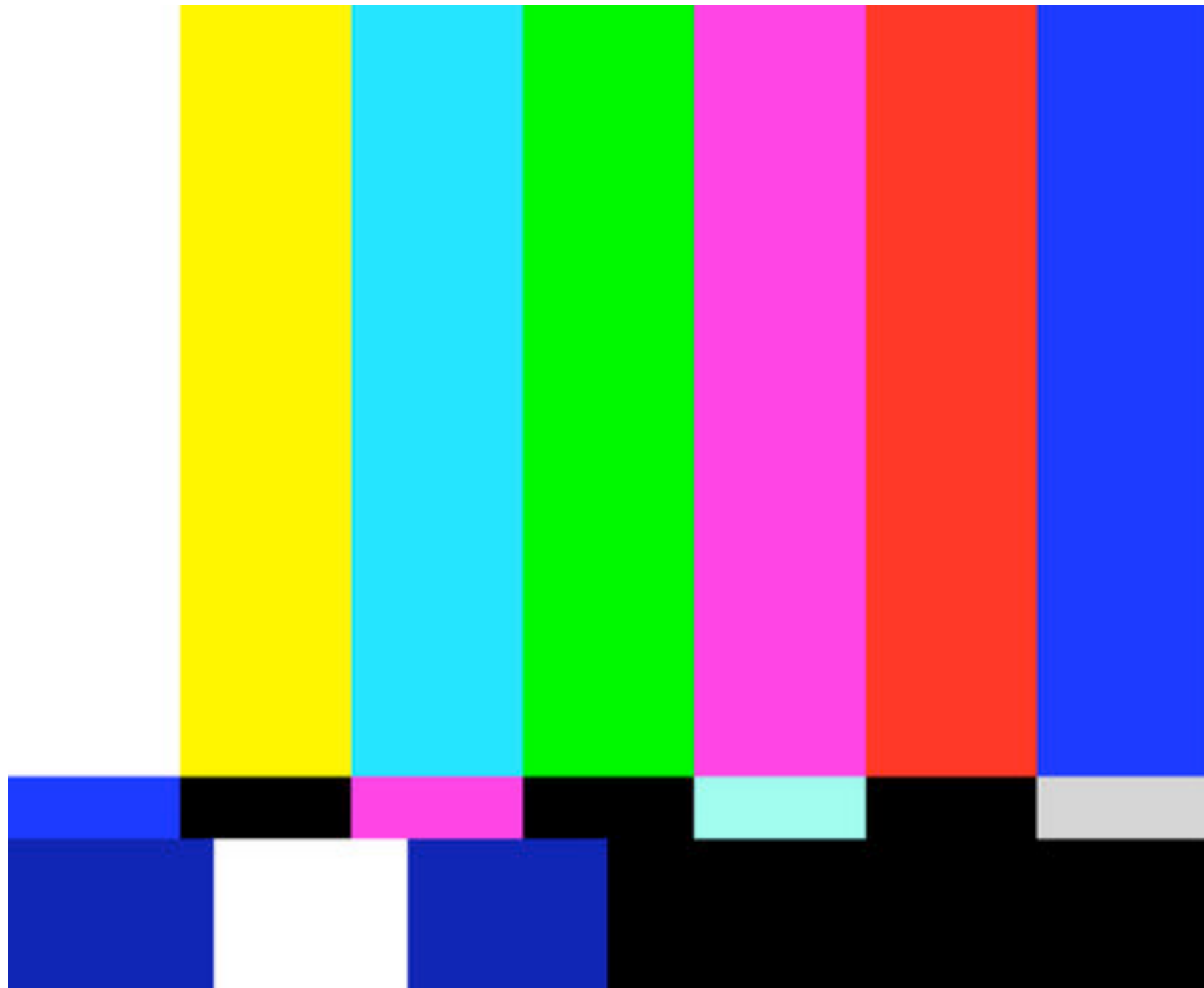
Tony Hessels
Michael Vogel
Anthony Ip
Thomas Yungwirth
Shaquielle Prince
Anton Zelenin
Darren Blom
Marco Marchetto
Doug Preddy
Yehya Mohamed
Roberto Armenta
Mike Rowe
Julie Cho

Derek Orth
Edi Dalla Valle
Ryan Lang
Nagma Mathur
Dimo Yosifov
Randy Boehm
Vivian Jiang
Tim Luechachandej
Max Ridout
Melchor Almario
Arthur Leung
Pierre St. Louis
Ajit Sakar
Peter Hall-Patch
Jason Chak
Max Maitland
Keith Ng

Clayton Handley
Gerry Ibe
Louis Moskven
Yetvart Hosepyan
Devon Lang
Nicolas Massacret
Alec Stockton
Philip Lu
Alex Sorokin
Tristan McLean
Rick Maharaj
Leanne Beet

Scott Kajioka
Alex Faganello
Michael Donohoe
Victor Verzilov
Steve McDonald
Emile Vartanian
Paul Jensen
Alireza Shirazi
Joe Abelseth
Normal Muller
Josh Thompson

Step 3: cleaning and leak checks



Footage not found: Anthony, Derek, Gabby and I trying to get all the detector parts into the ultrasonic cleaner



Step 3: cleaning and leak checks



Footage not found: Anthony, Gabby and I trying to get all parts into the ultrasonic



Step 4: disassemble

- Before:

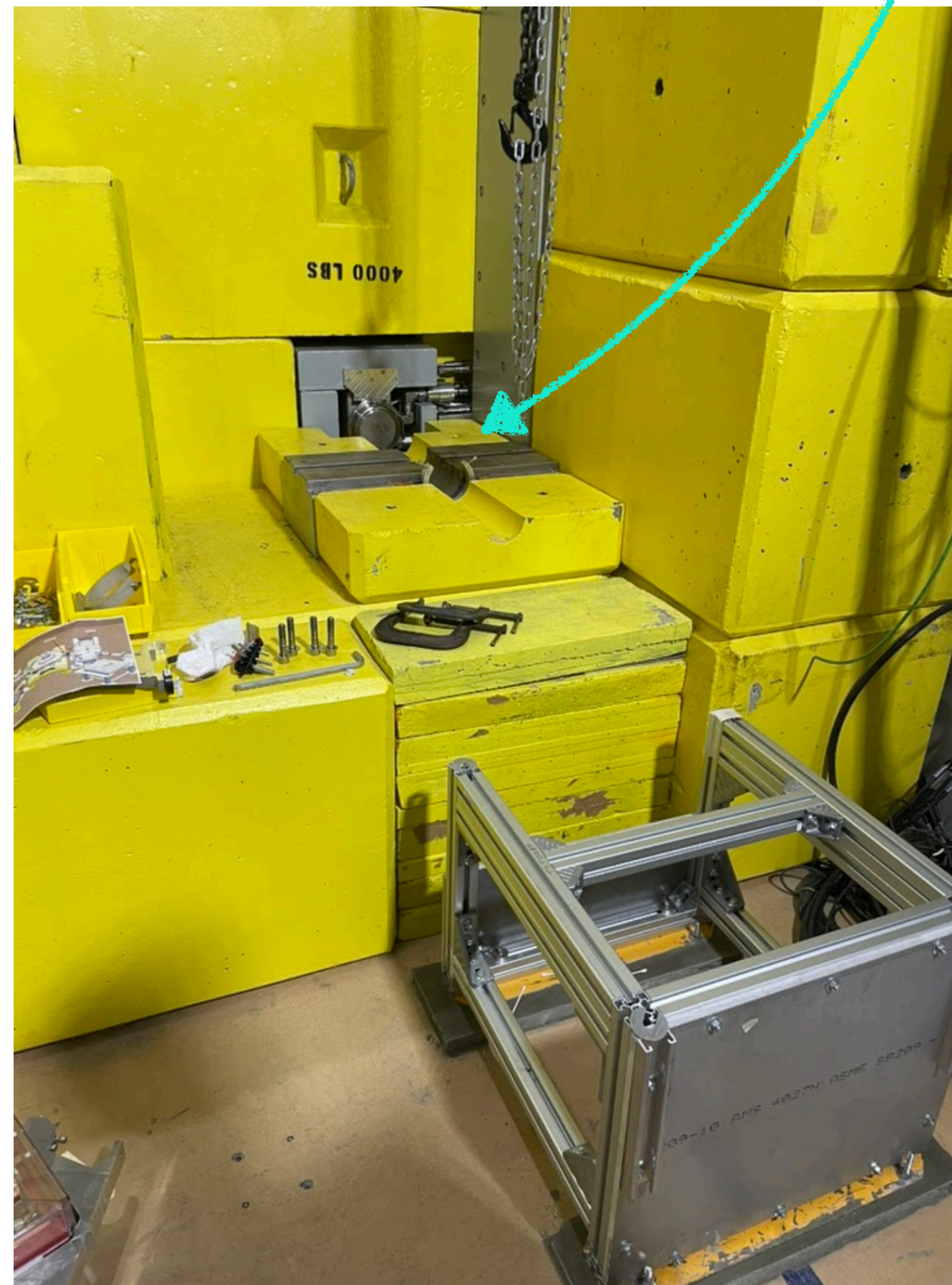


Step 4: disassemble

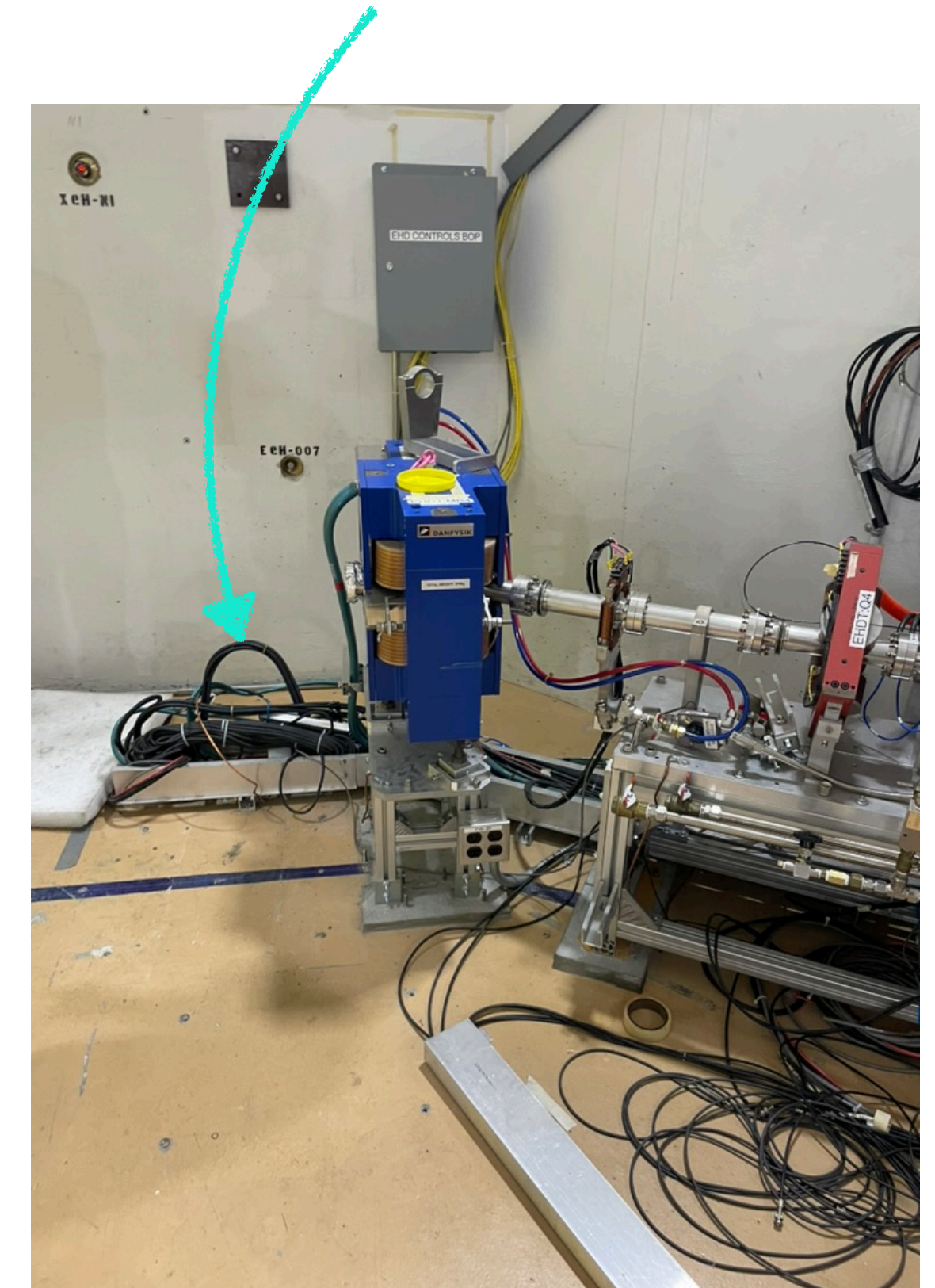
- After:



Future home of collimator



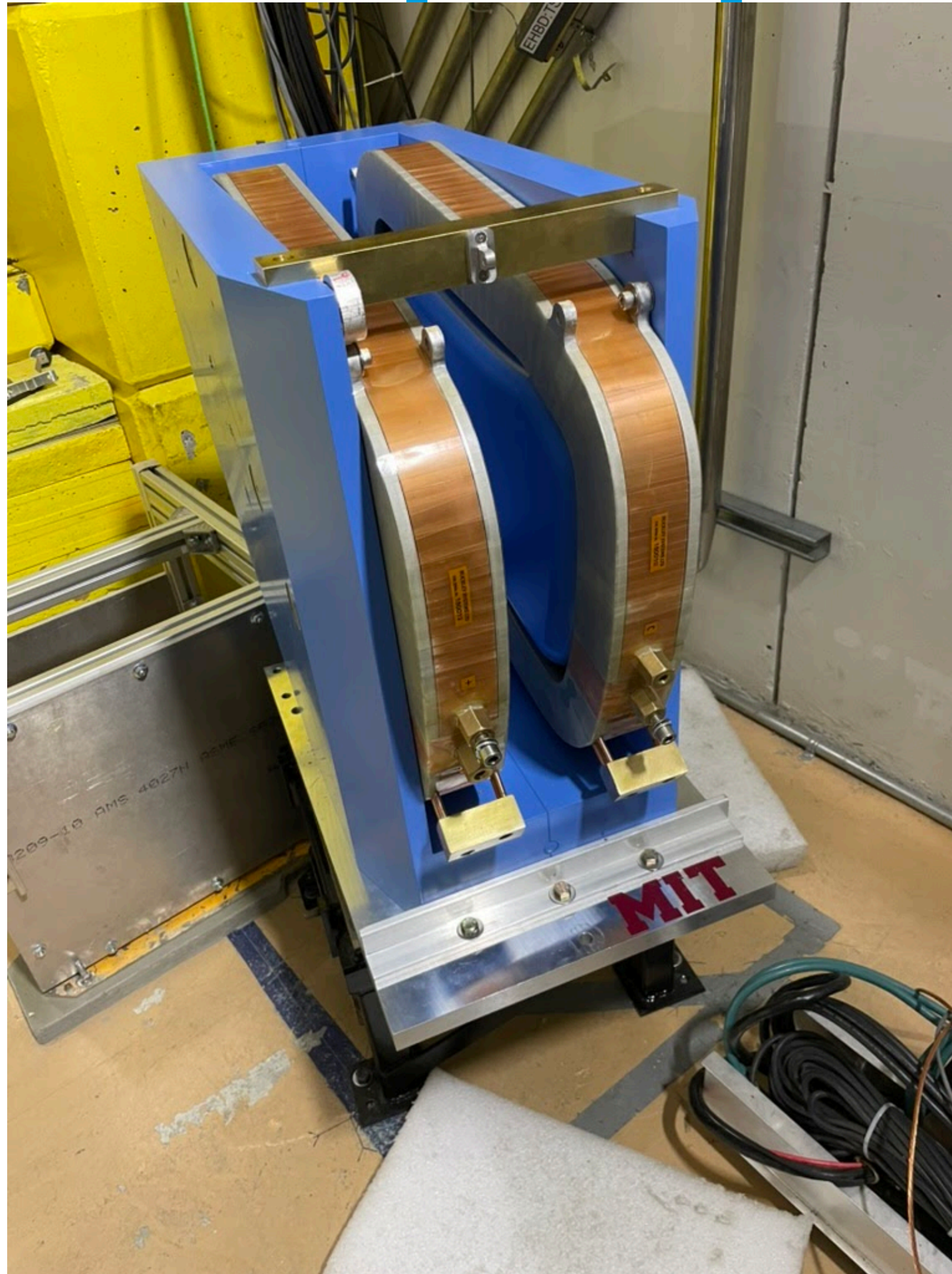
Future home of target chamber



Step 5: put an experiment there



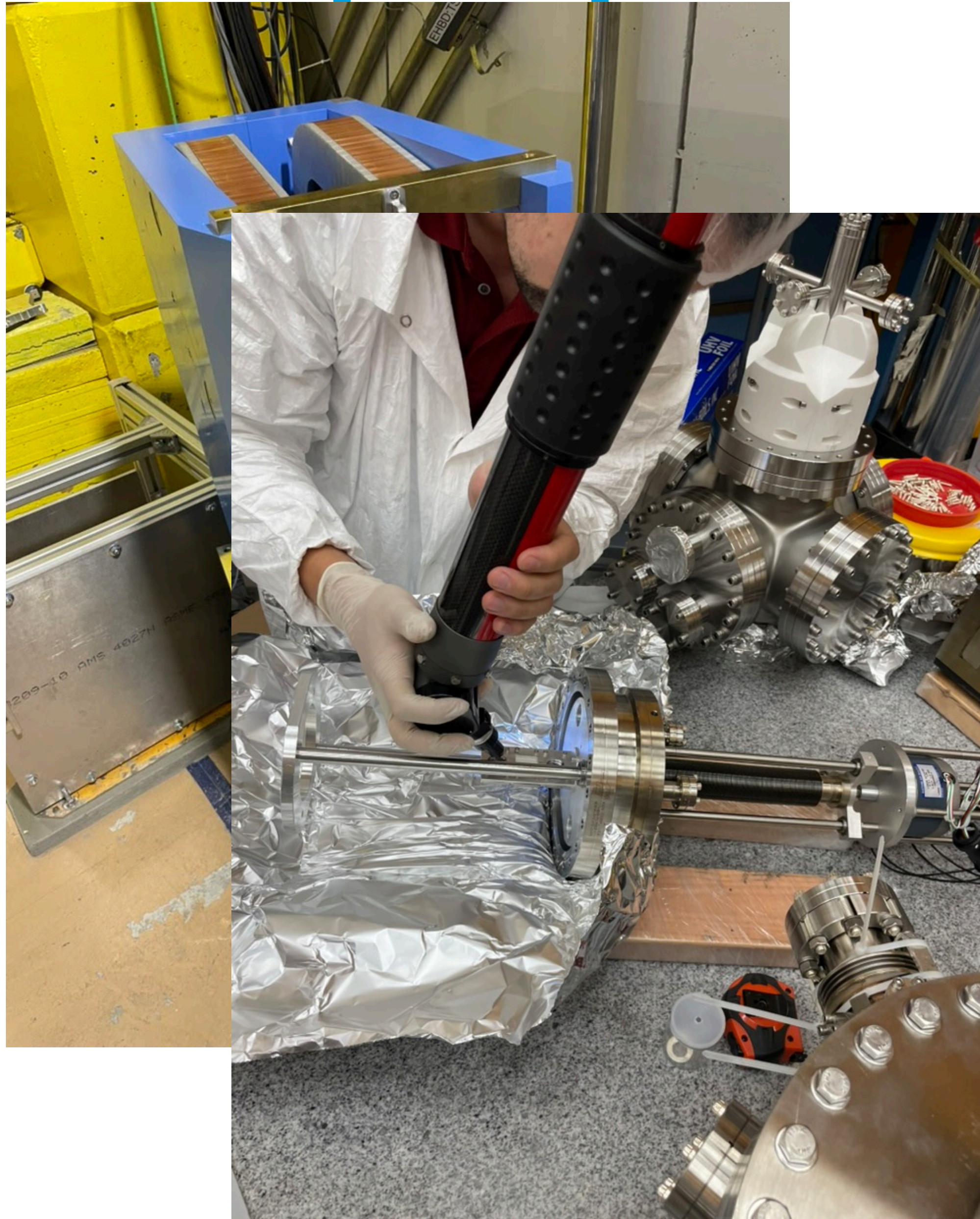
May 12th-23rd



Step 5: put an experiment there



May 12th-23rd



Step 5: put an experiment there



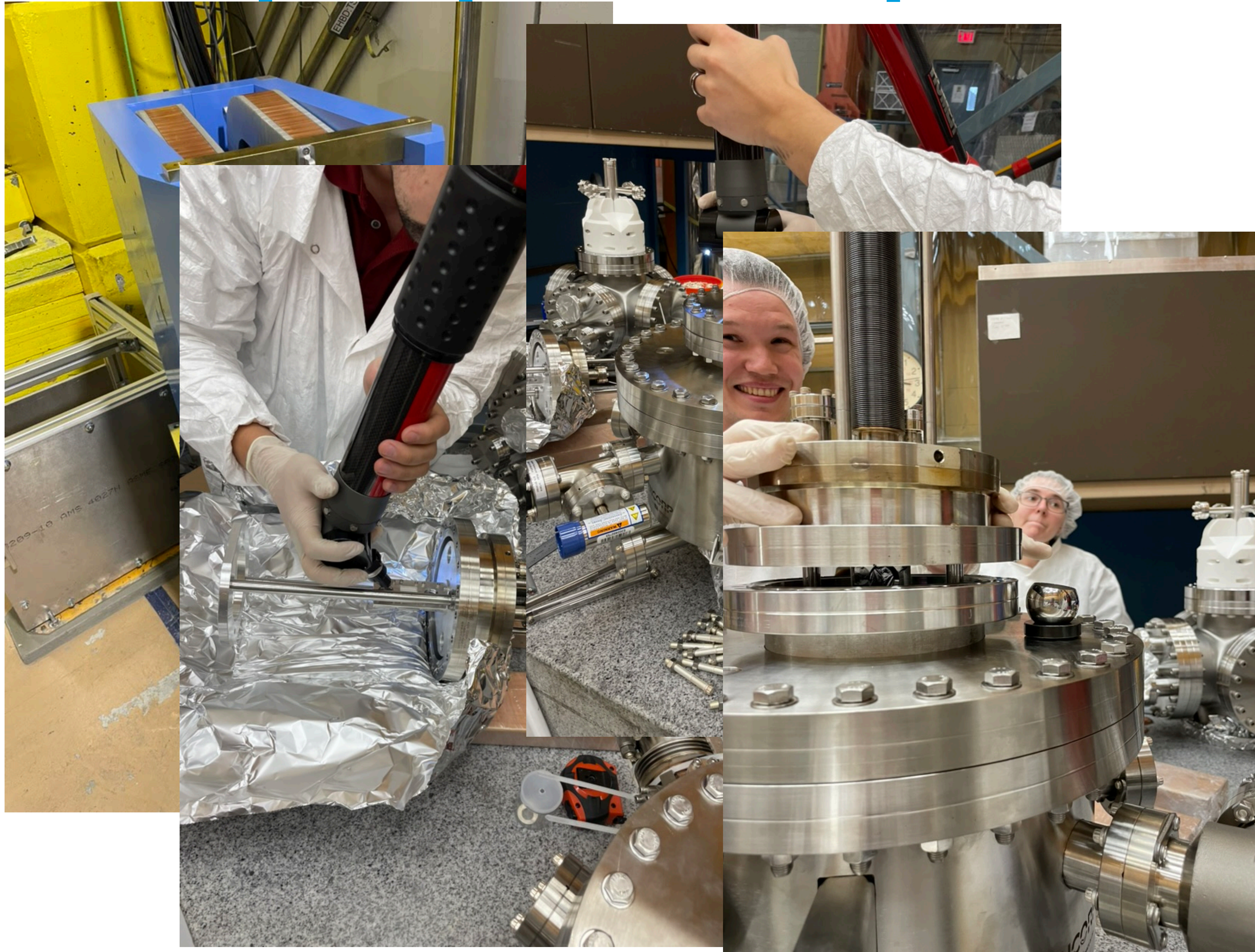
Step 5: put an experiment there



May 12th-23rd

(with some brief interludes)

14



Intermission for machining...

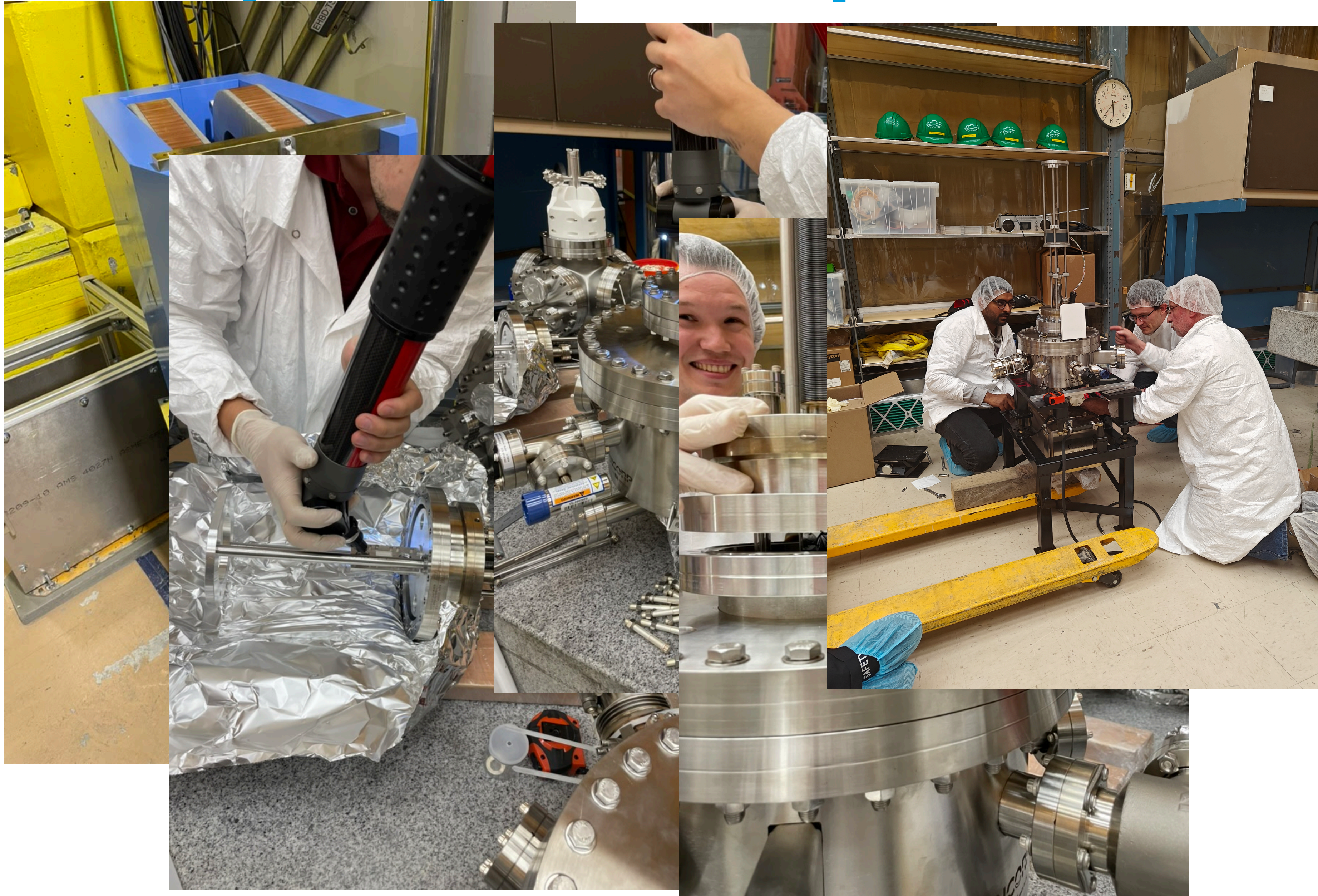
Step 5: put an experiment there



May 12th-23rd

(with some brief interludes)

14



Step 5: put an experiment there



May 12th-23rd

(with some brief interludes)

14



Intermission for welding...



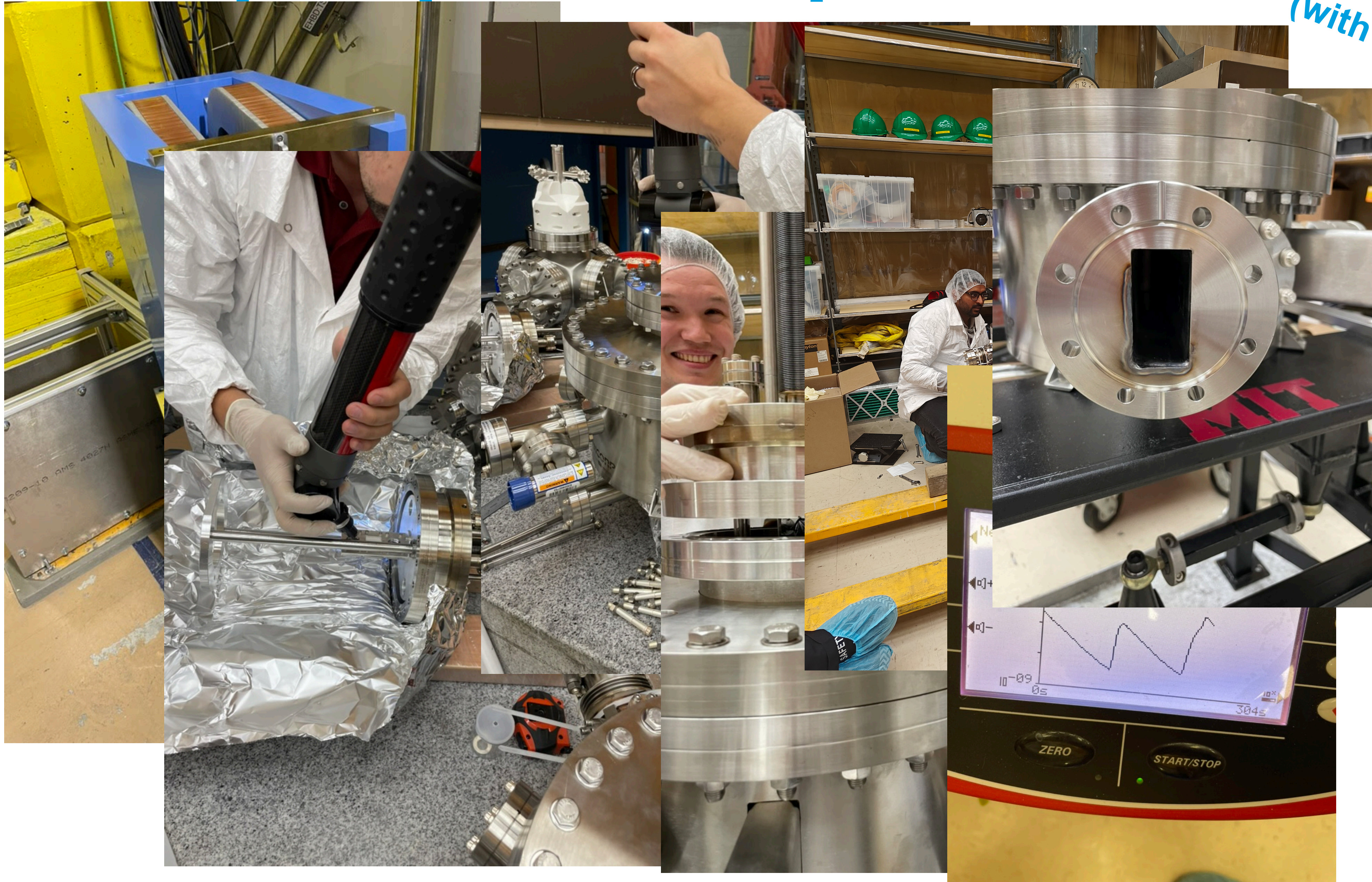
Step 5: put an experiment there



May 12th-23rd

(with some brief interludes)

14



Step 5: put an experiment there



May 12th-23rd

(with some brief interludes)

14



Step 5: put an experiment there



May 12th-23rd

(with some brief interludes)

14



**...except it needs to be
cleaned again**

Step 5: put an experiment there



May 12th-23rd

(with some brief interludes)

14



Step 5: put an experiment there

May 12th-23rd

(with some brief interludes)

14



Pro tip: always use silver plated bolts

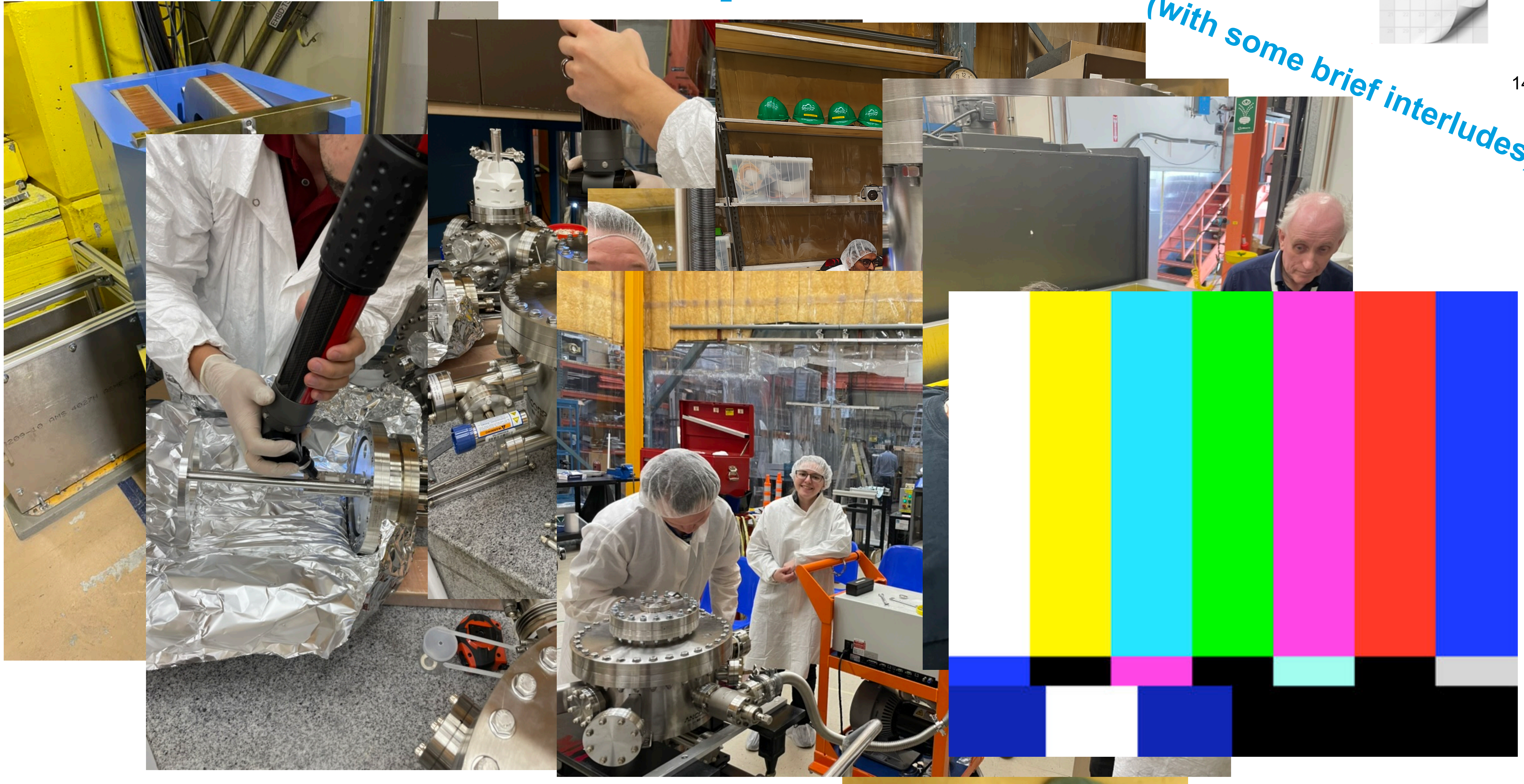
Step 5: put an experiment there



May 12th-23rd

(with some brief interludes)

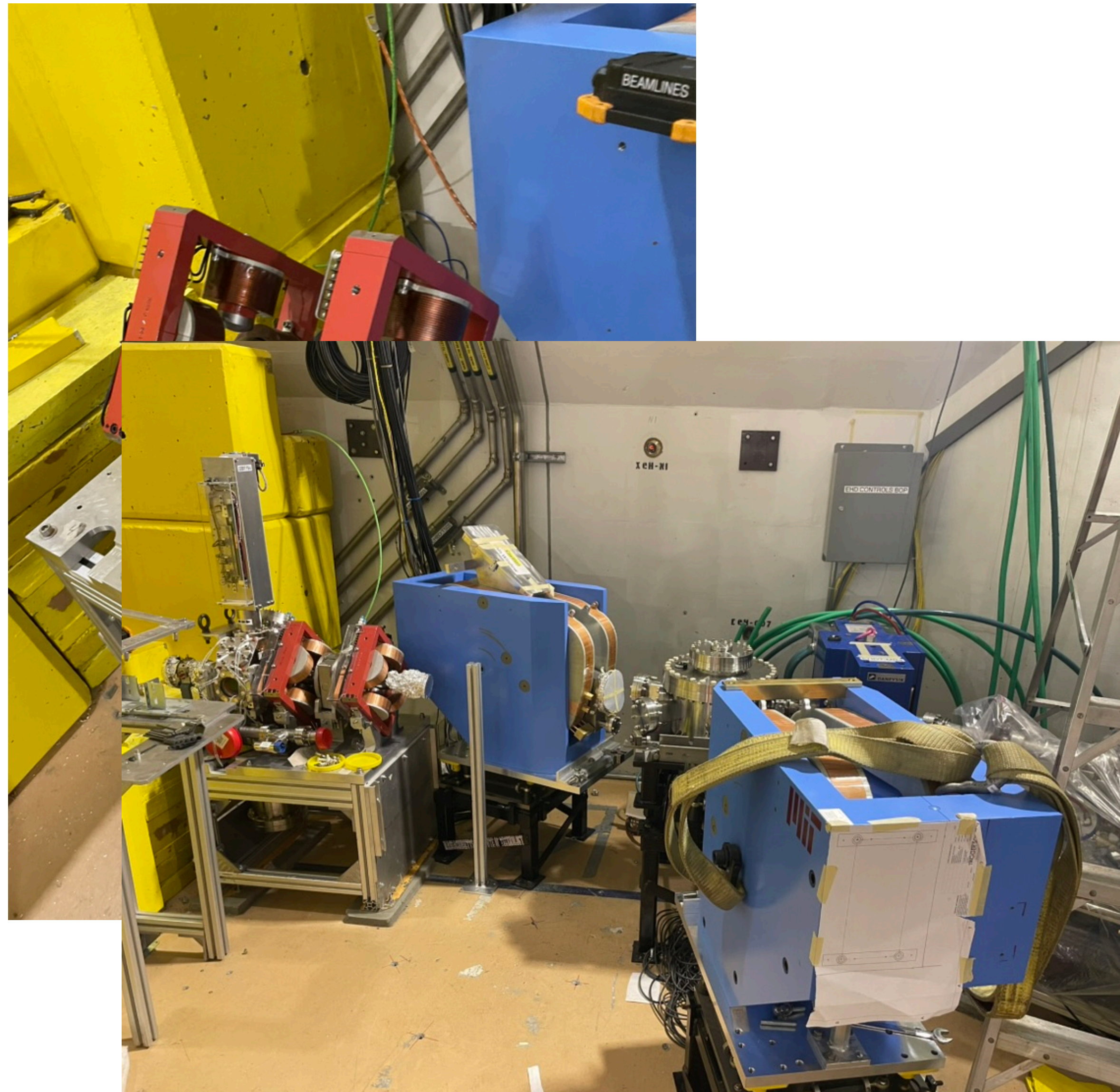
14



Step 5: put an experiment there



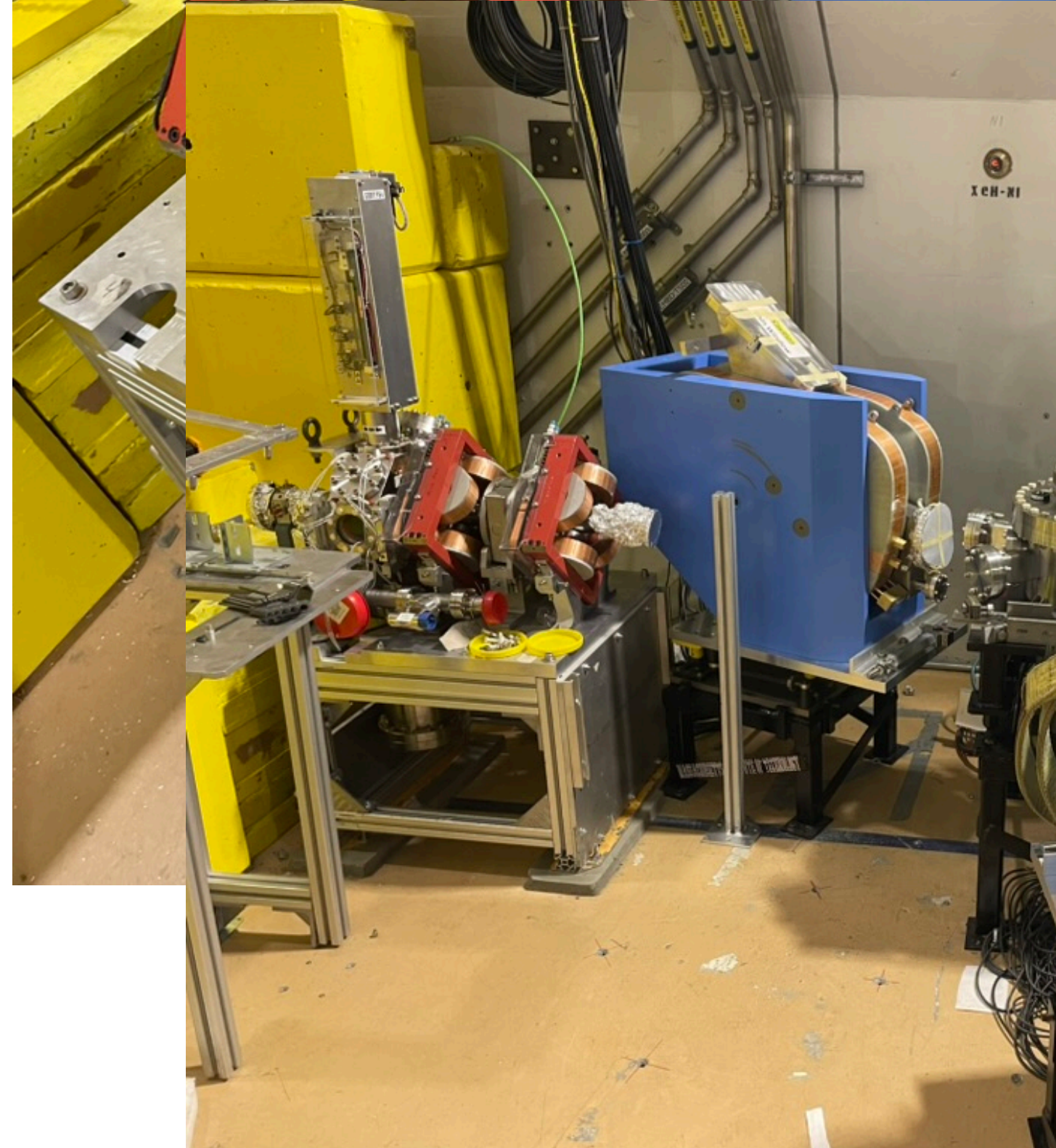
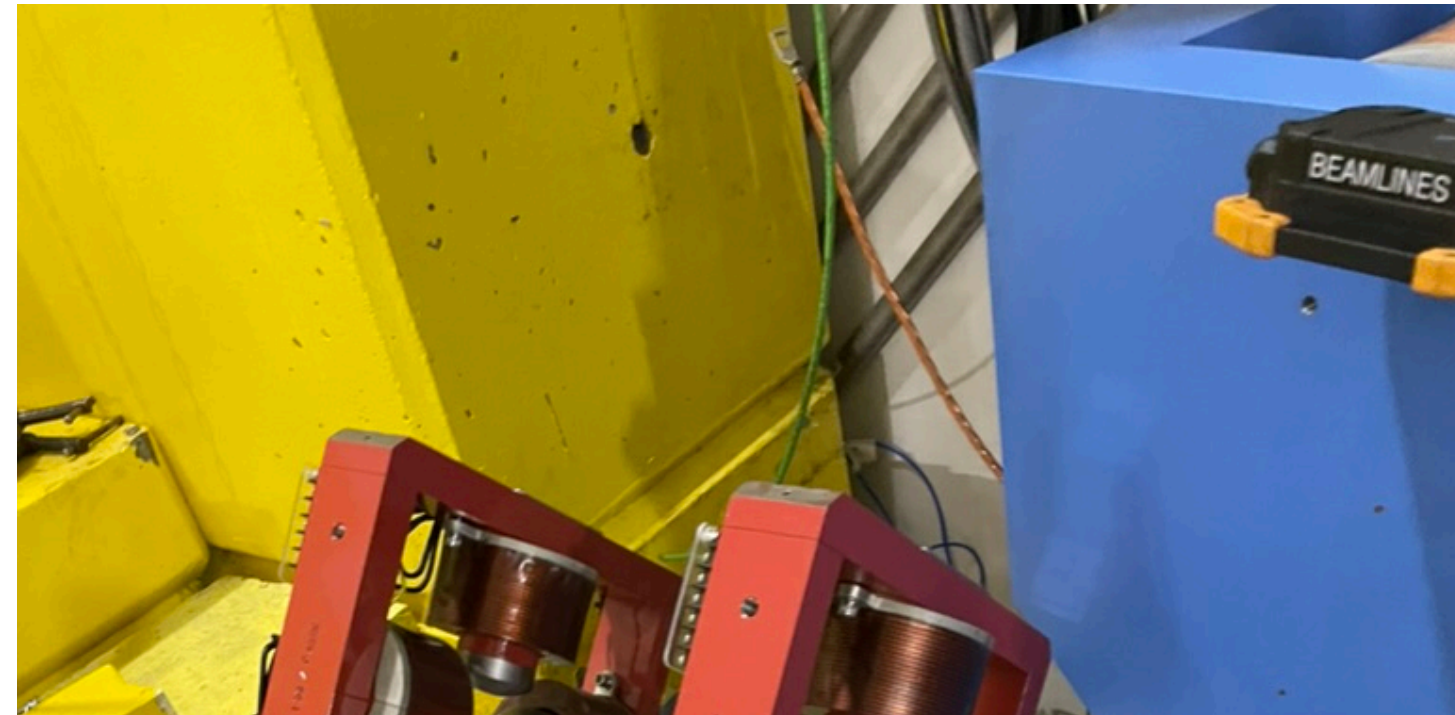
Step 5: put an experiment there



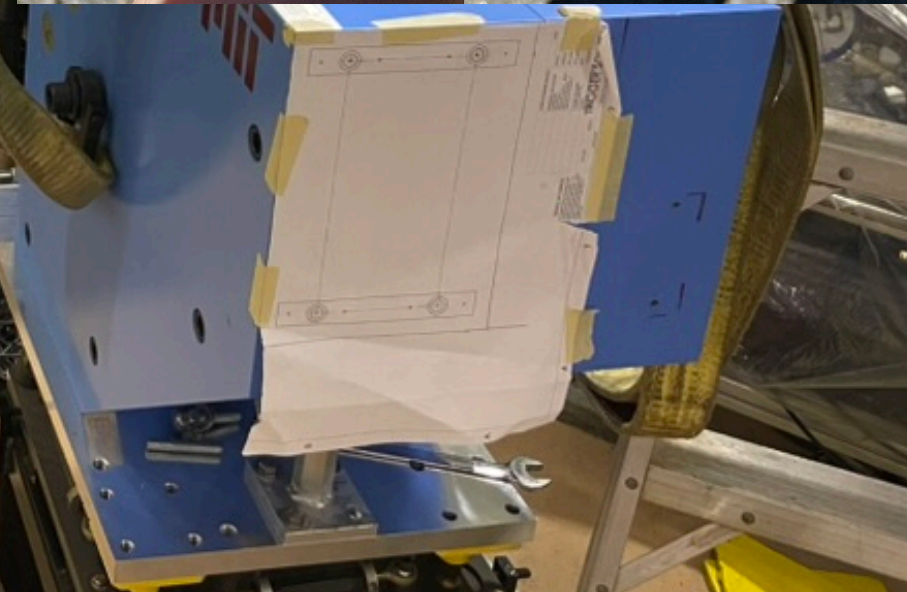
Step 5: put an experiment there



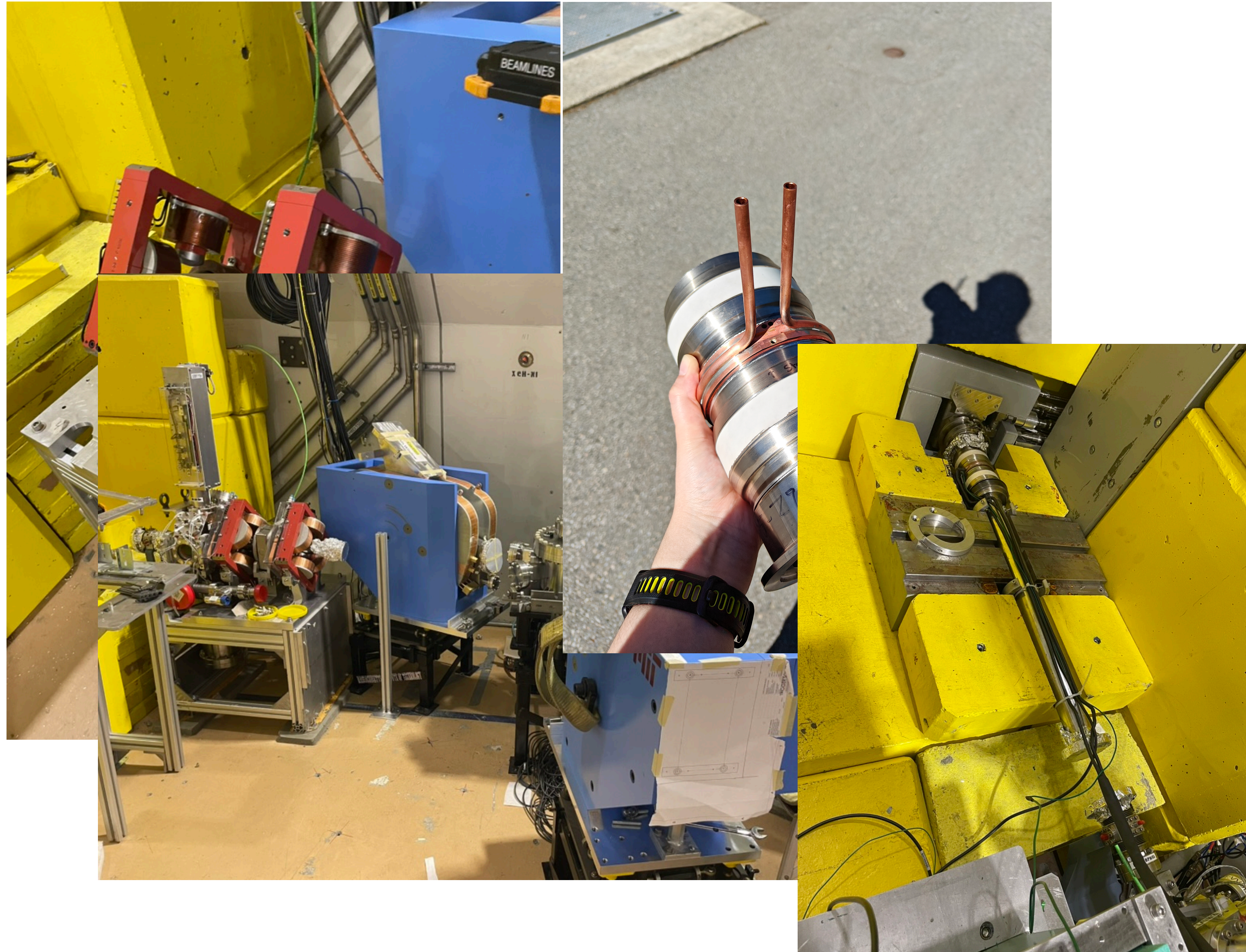
15



Hot off the press collimator!



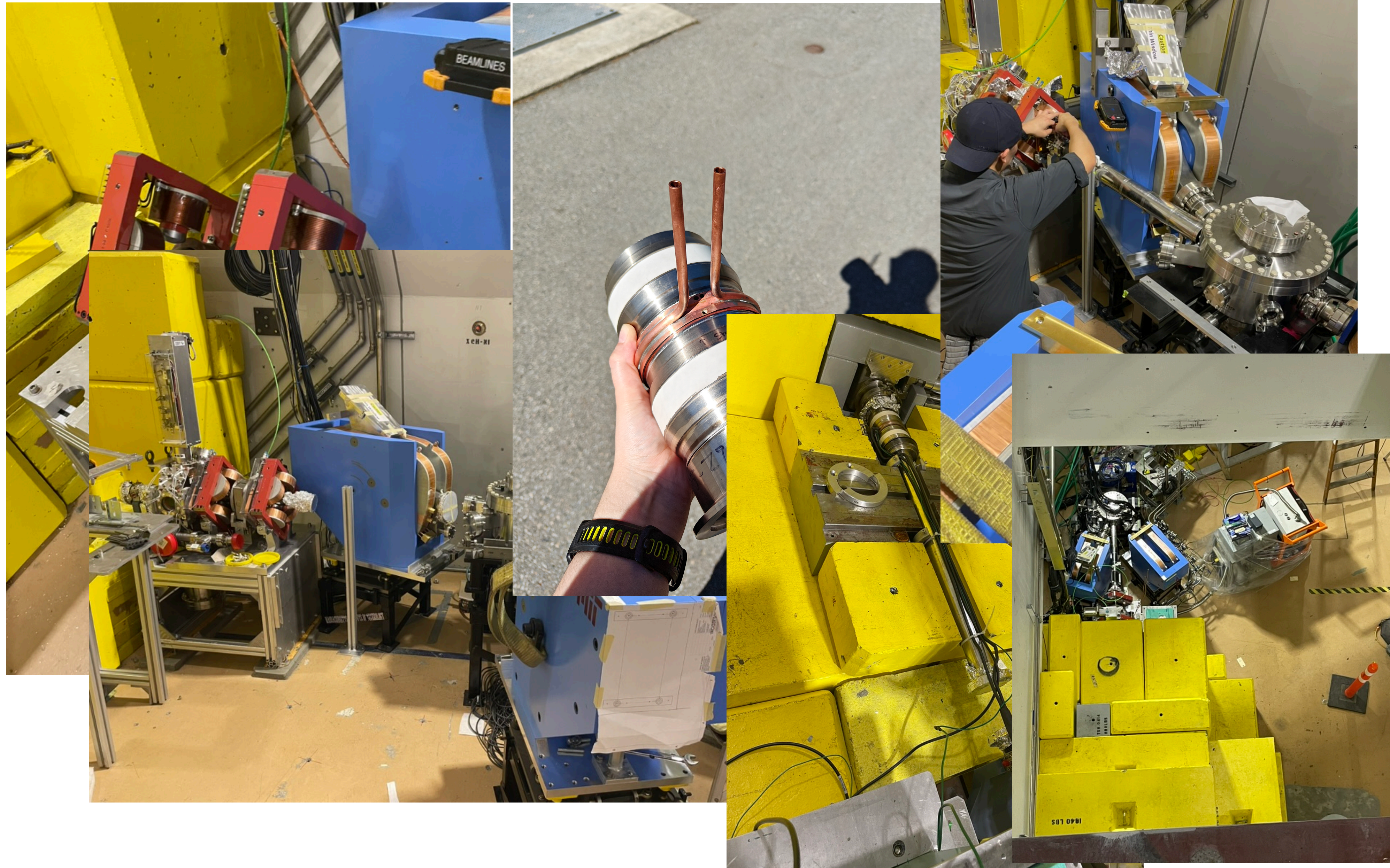
Step 5: put an experiment there



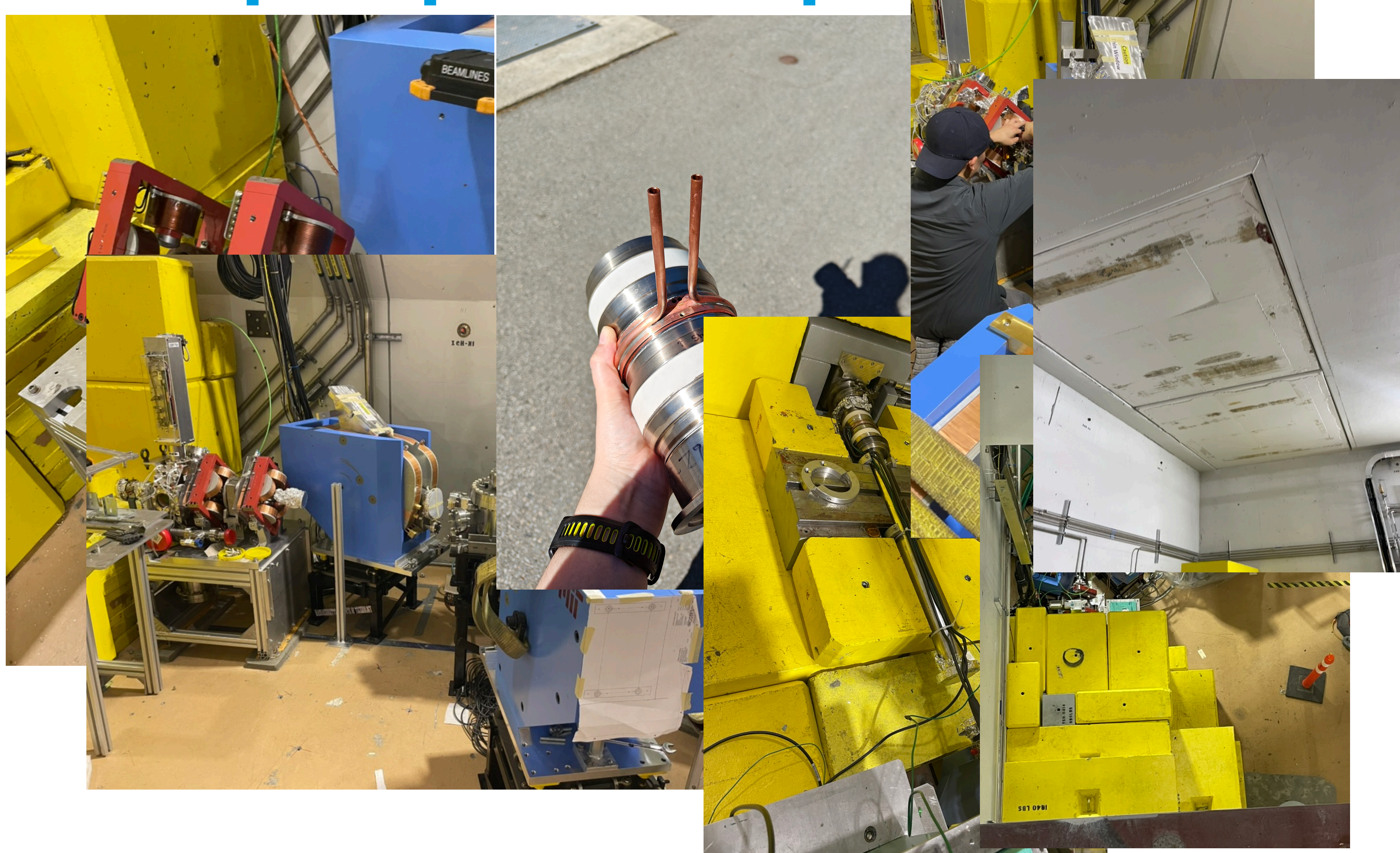
Step 5: put an experiment there



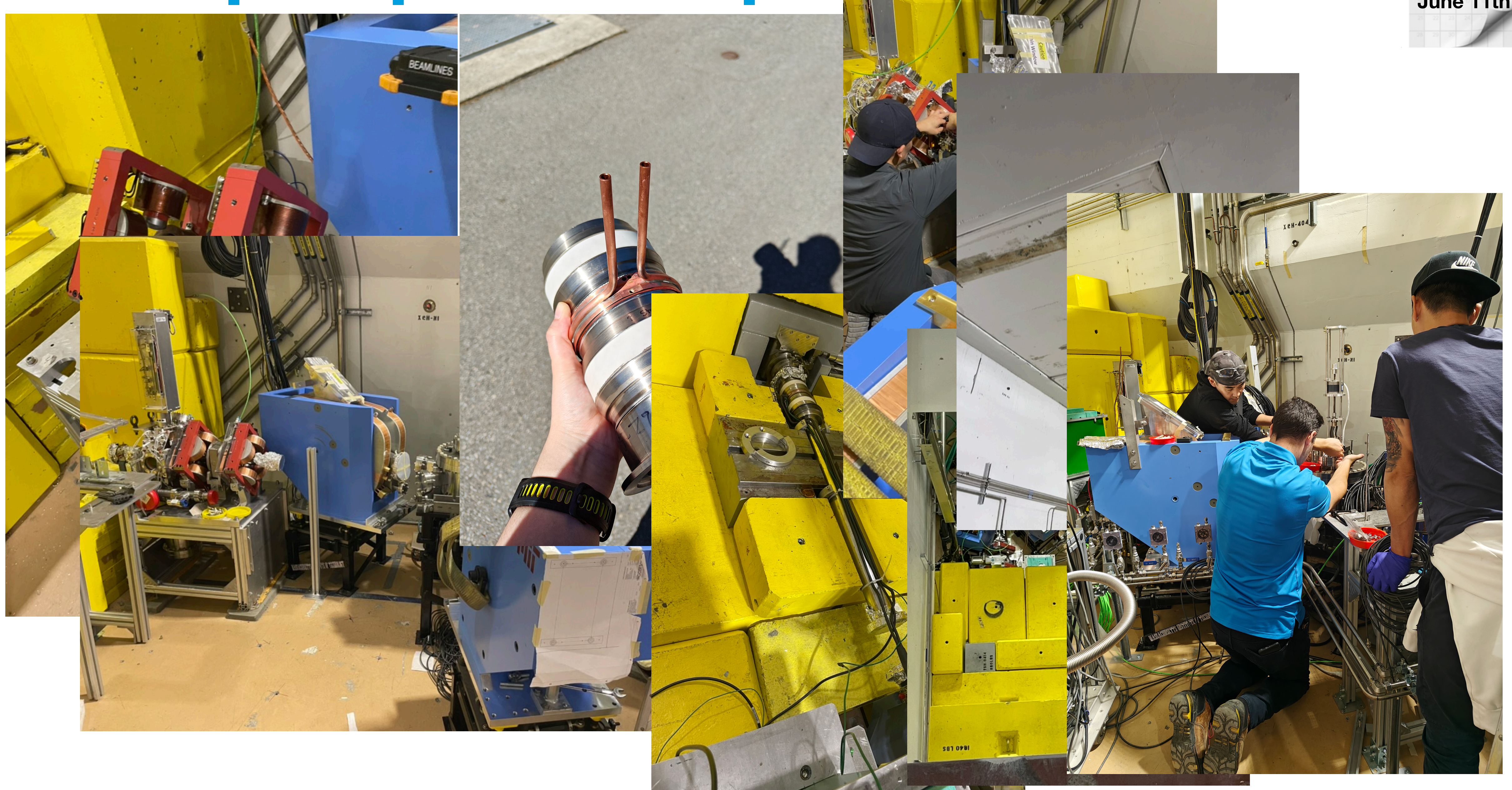
Step 5: put an experiment there



Step 5: put an experiment there



Step 5: put an experiment there



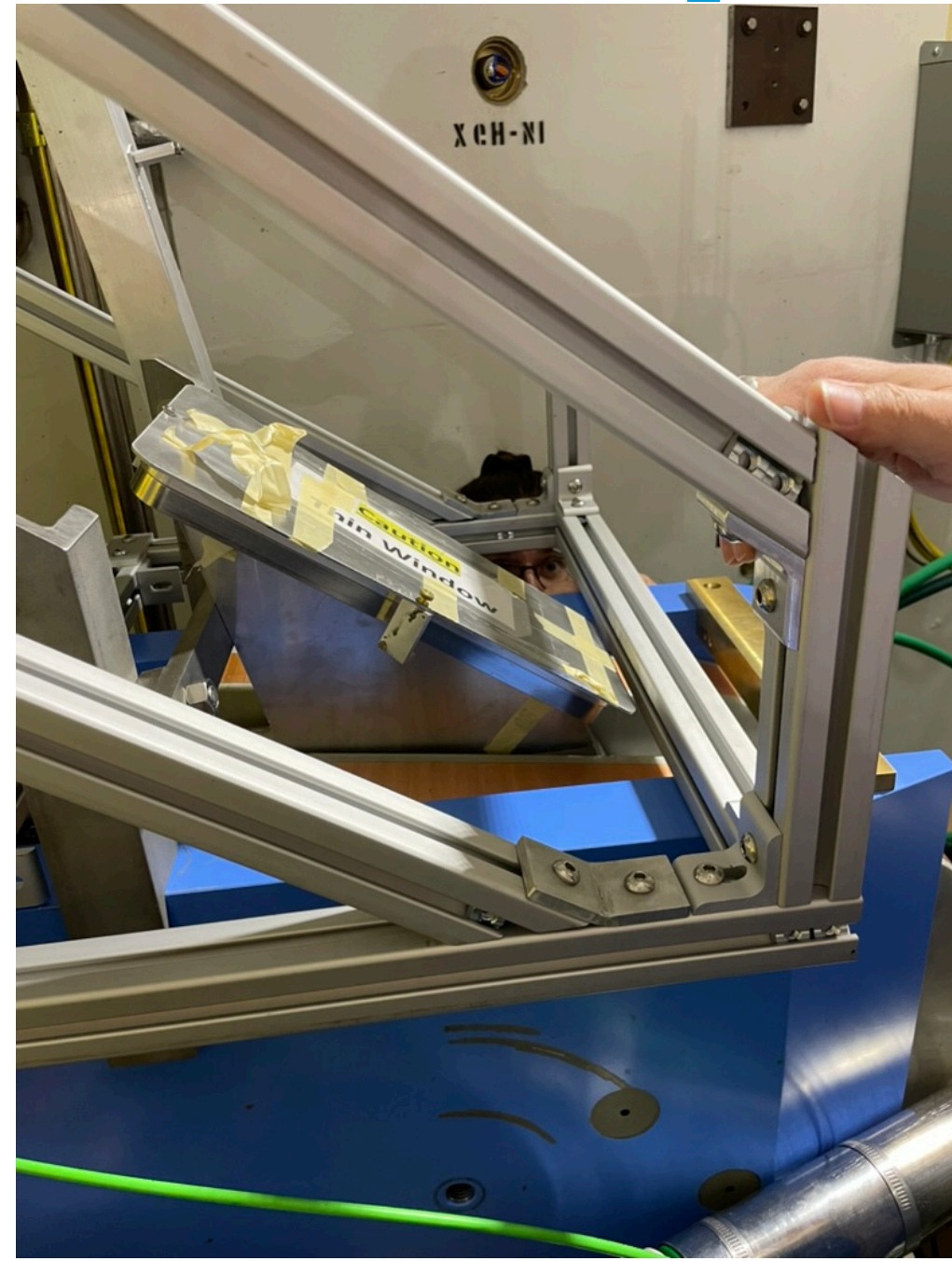
Step 5: put an experiment there



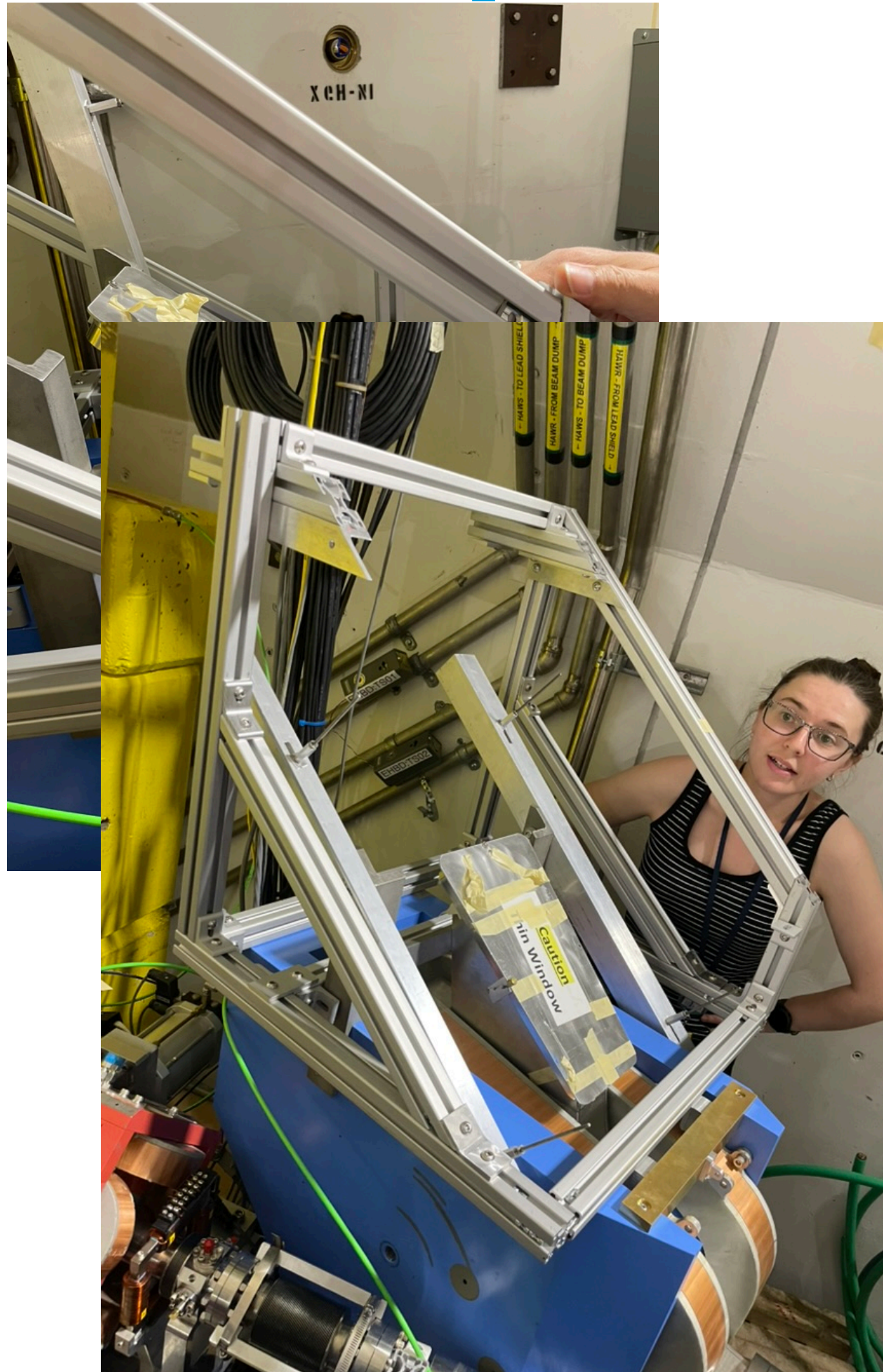
15



Step 6: detector time! (+ misc.)



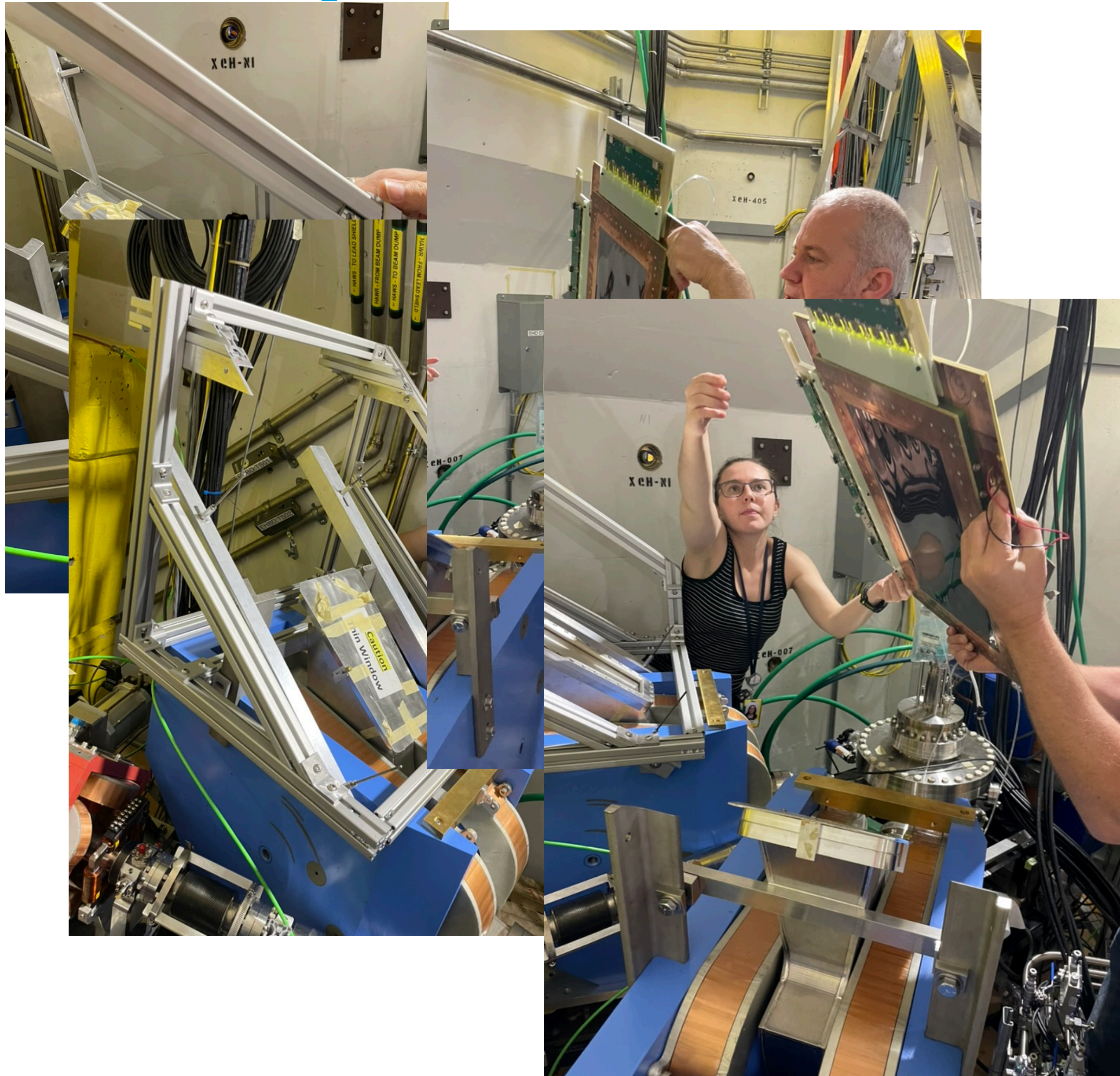
Step 6: detector time! (+ misc.)



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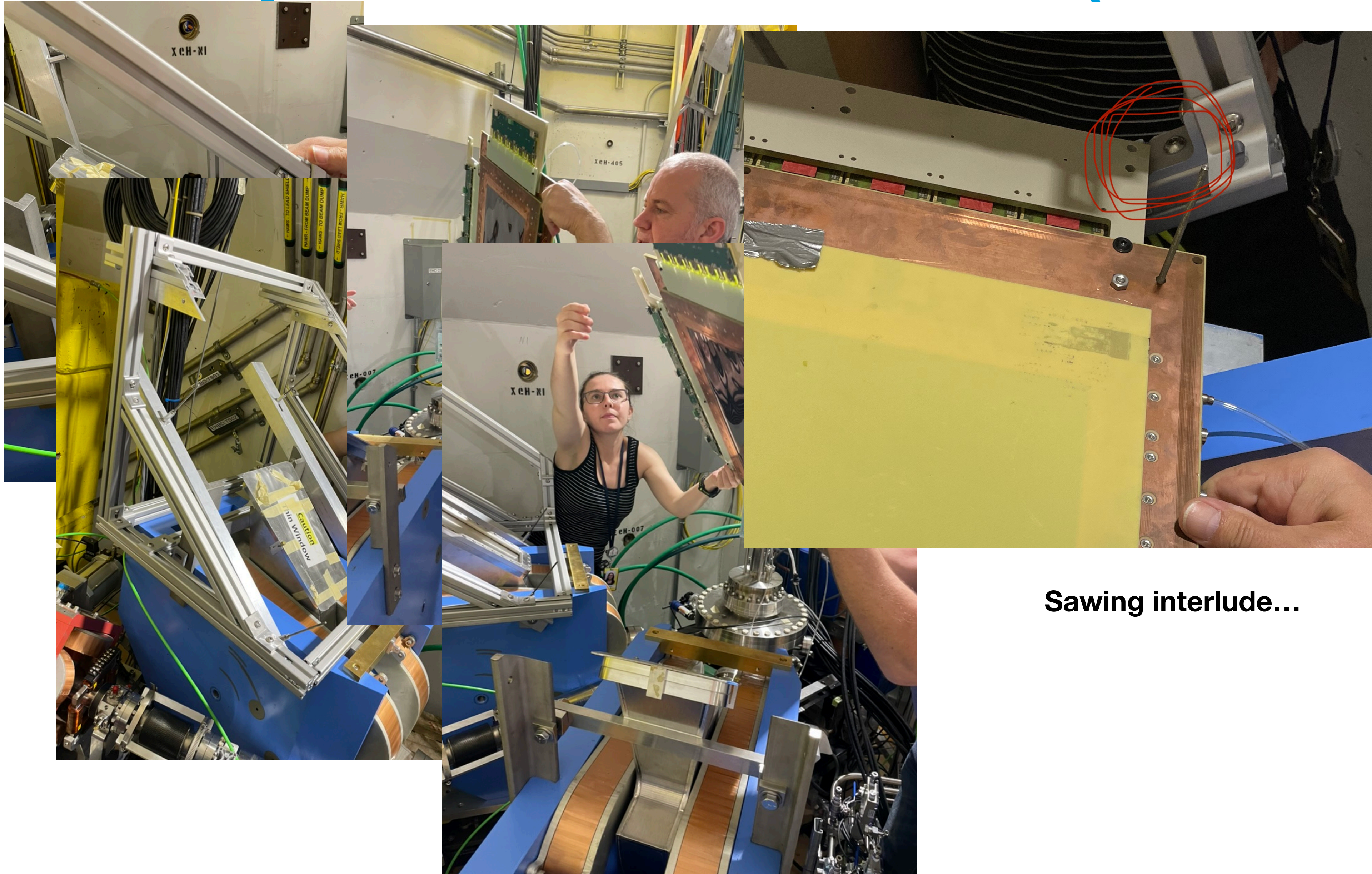
Step 6: detector time! (+ misc.)



Step 6: detector time! (+ misc.)



16

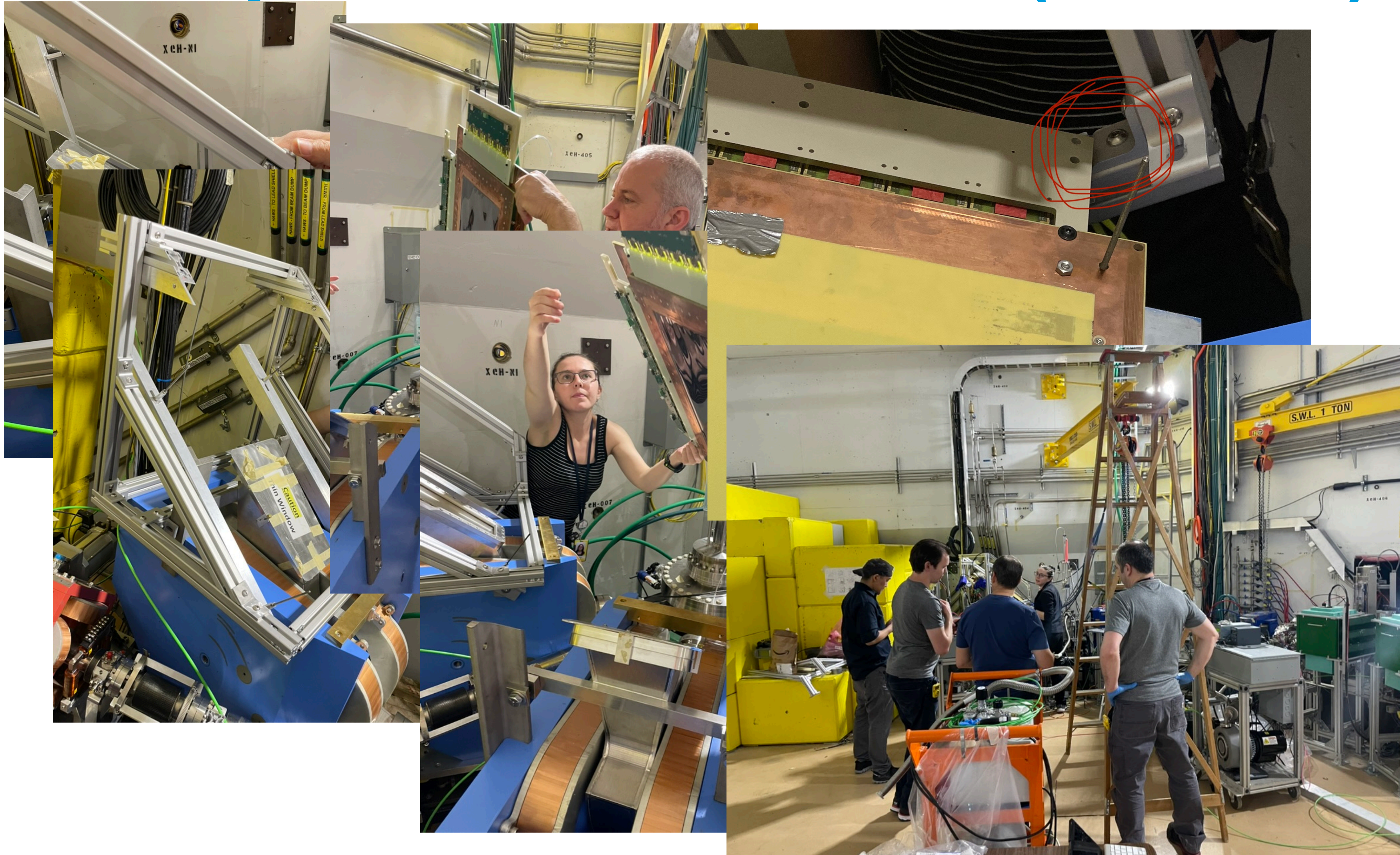


Sawing interlude...

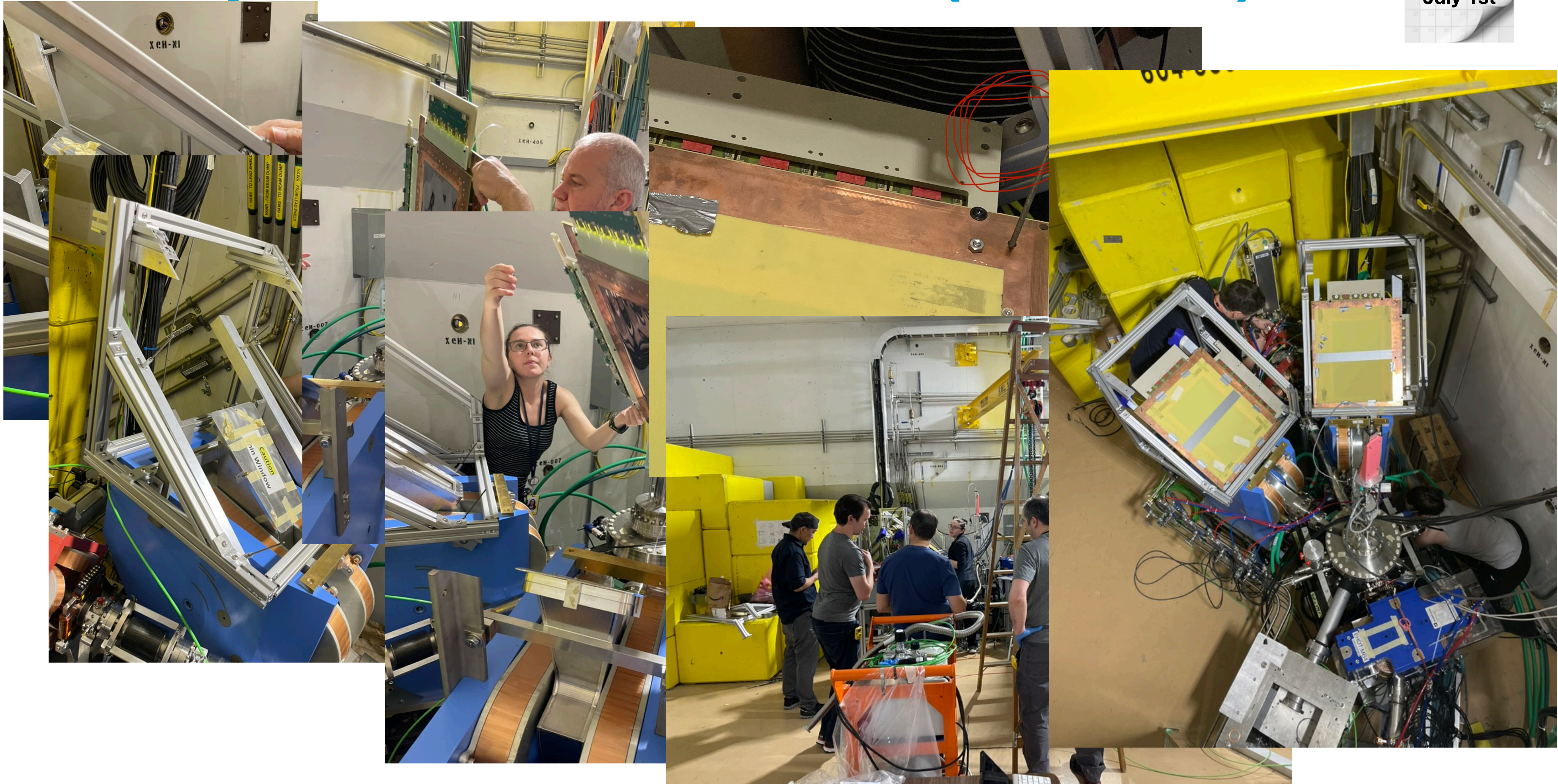
Step 6: detector time! (+ misc.)



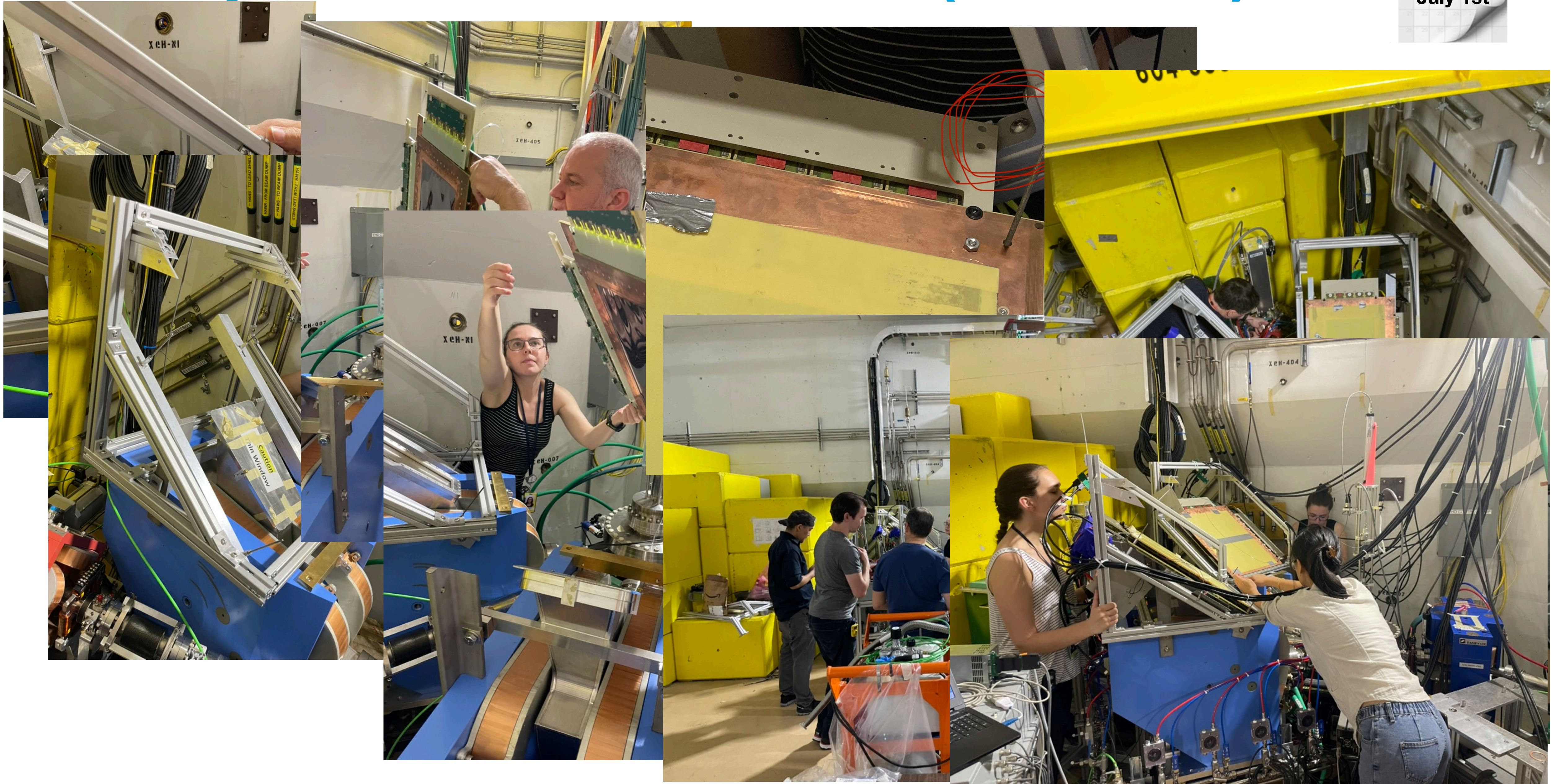
16



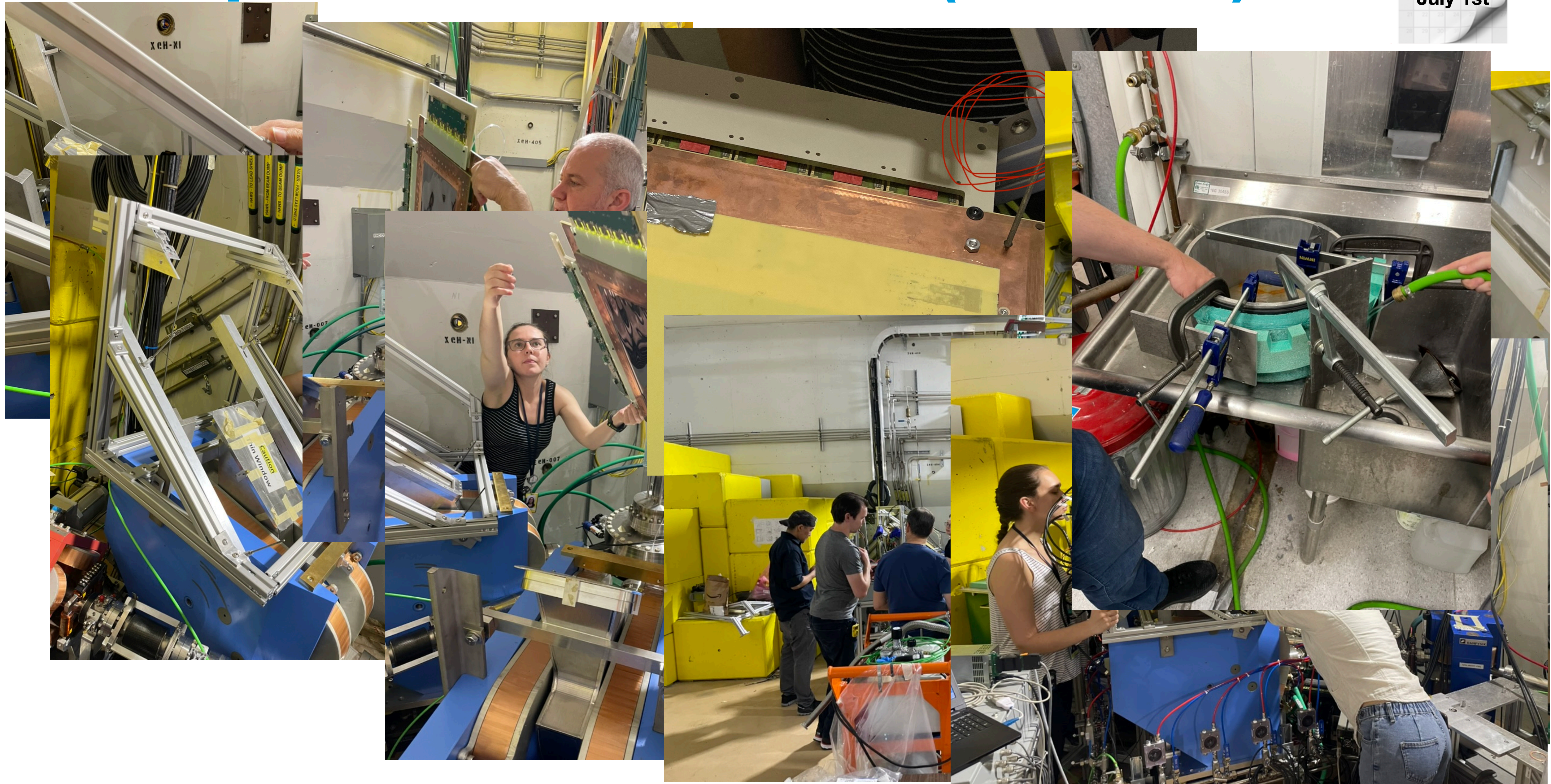
Step 6: detector time! (+ misc.)



Step 6: detector time! (+ misc.)



Step 6: detector time! (+ misc.)



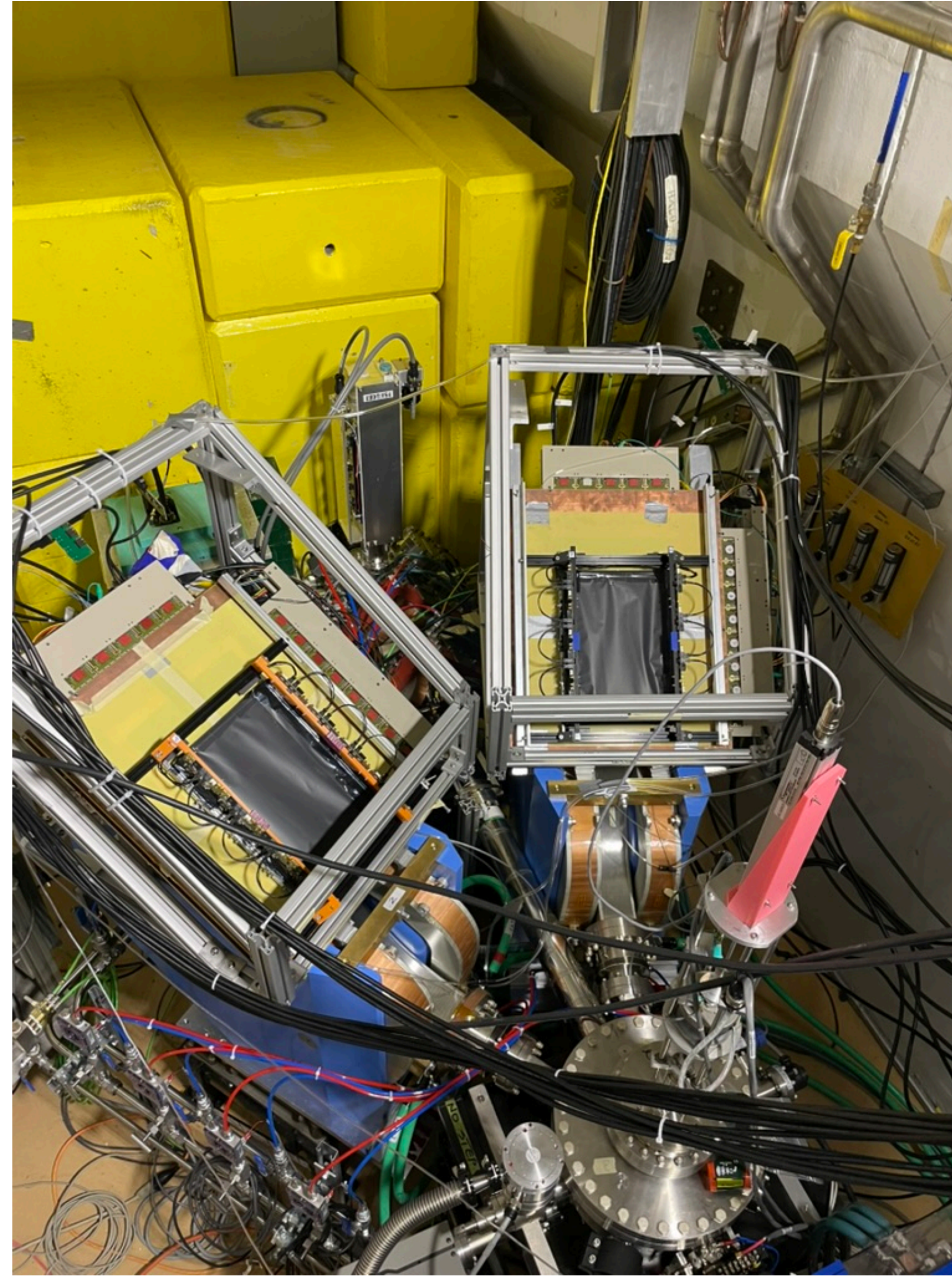
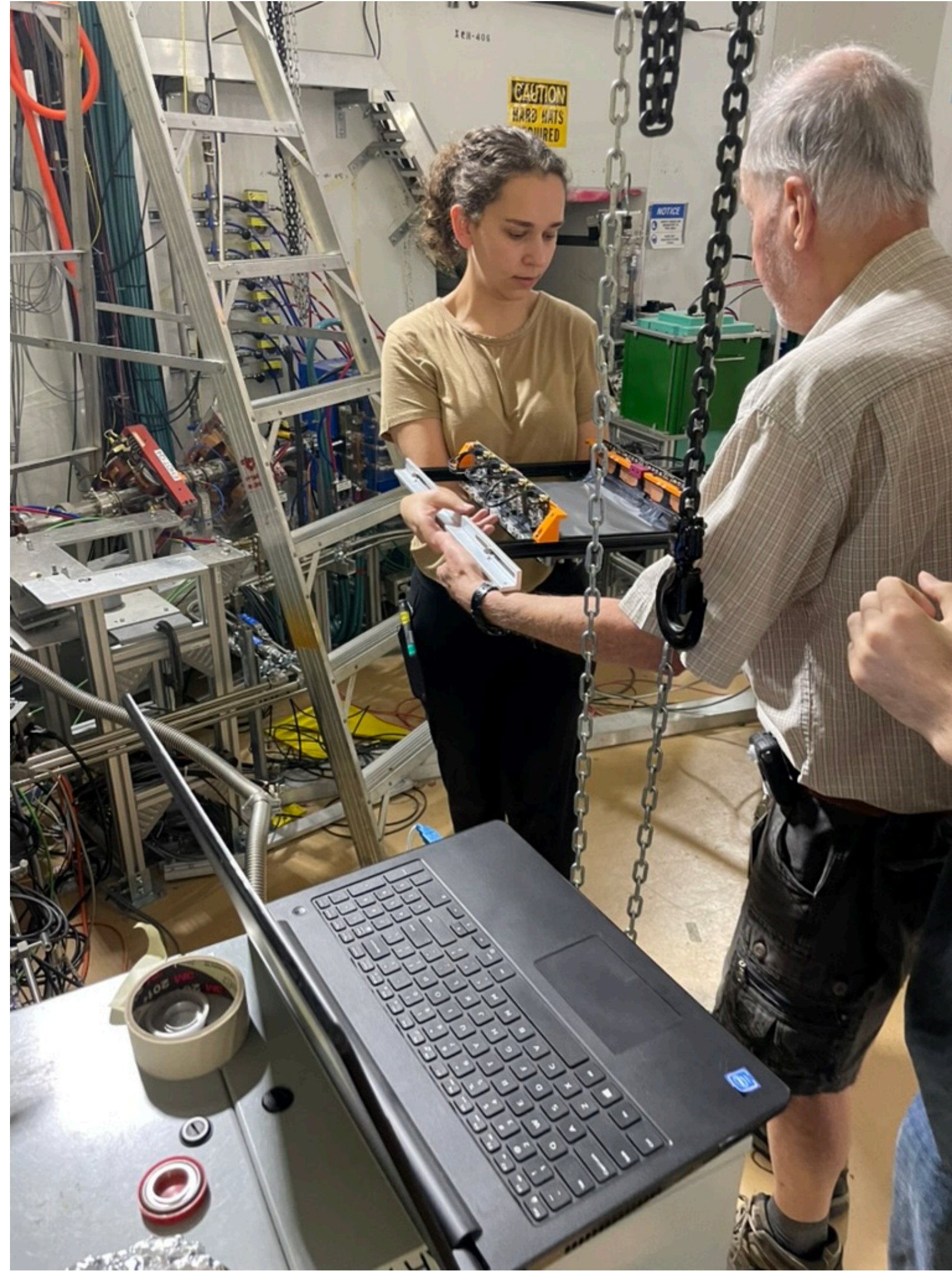
Step 6: detector time! (+ misc.)



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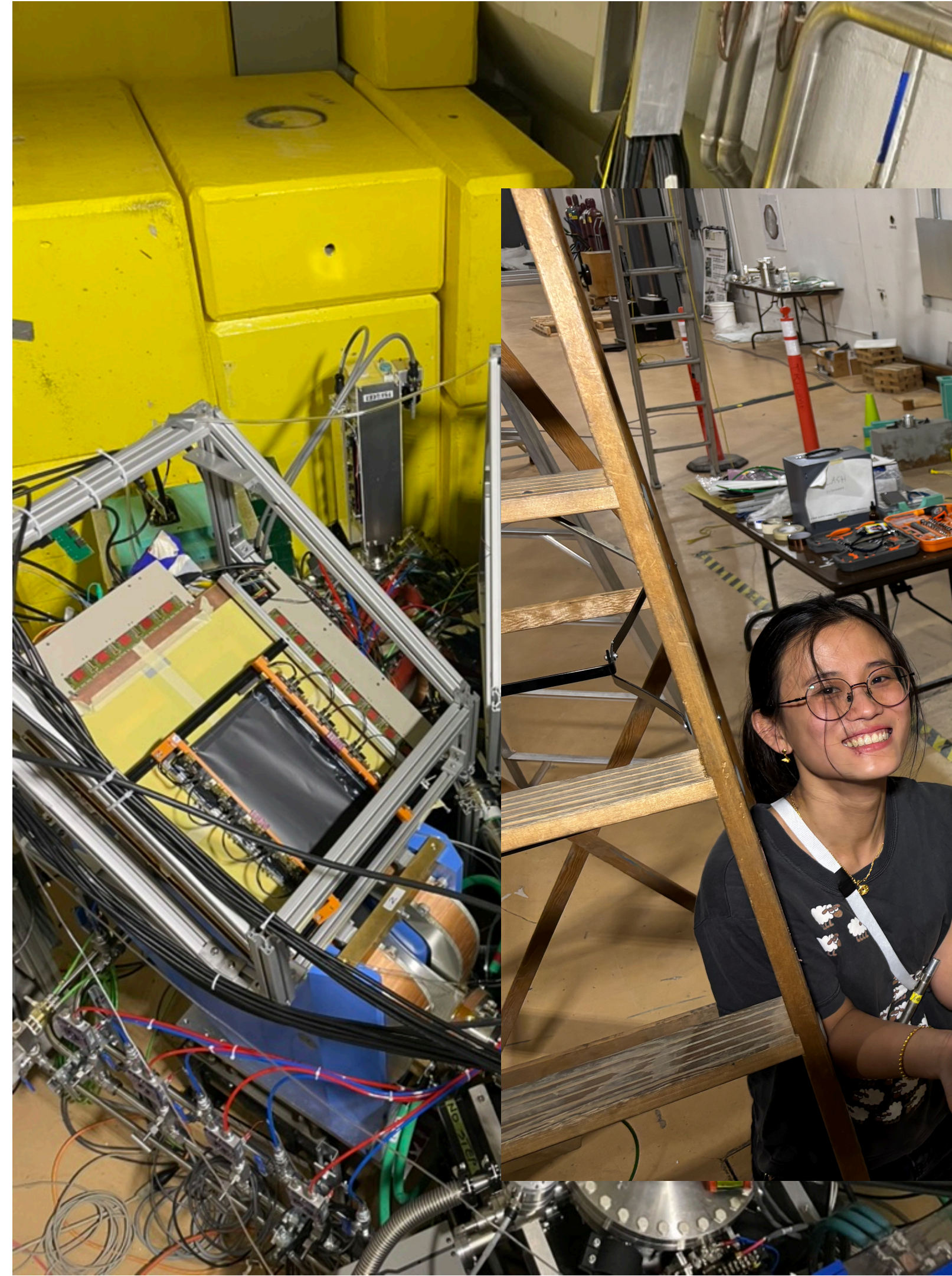
17



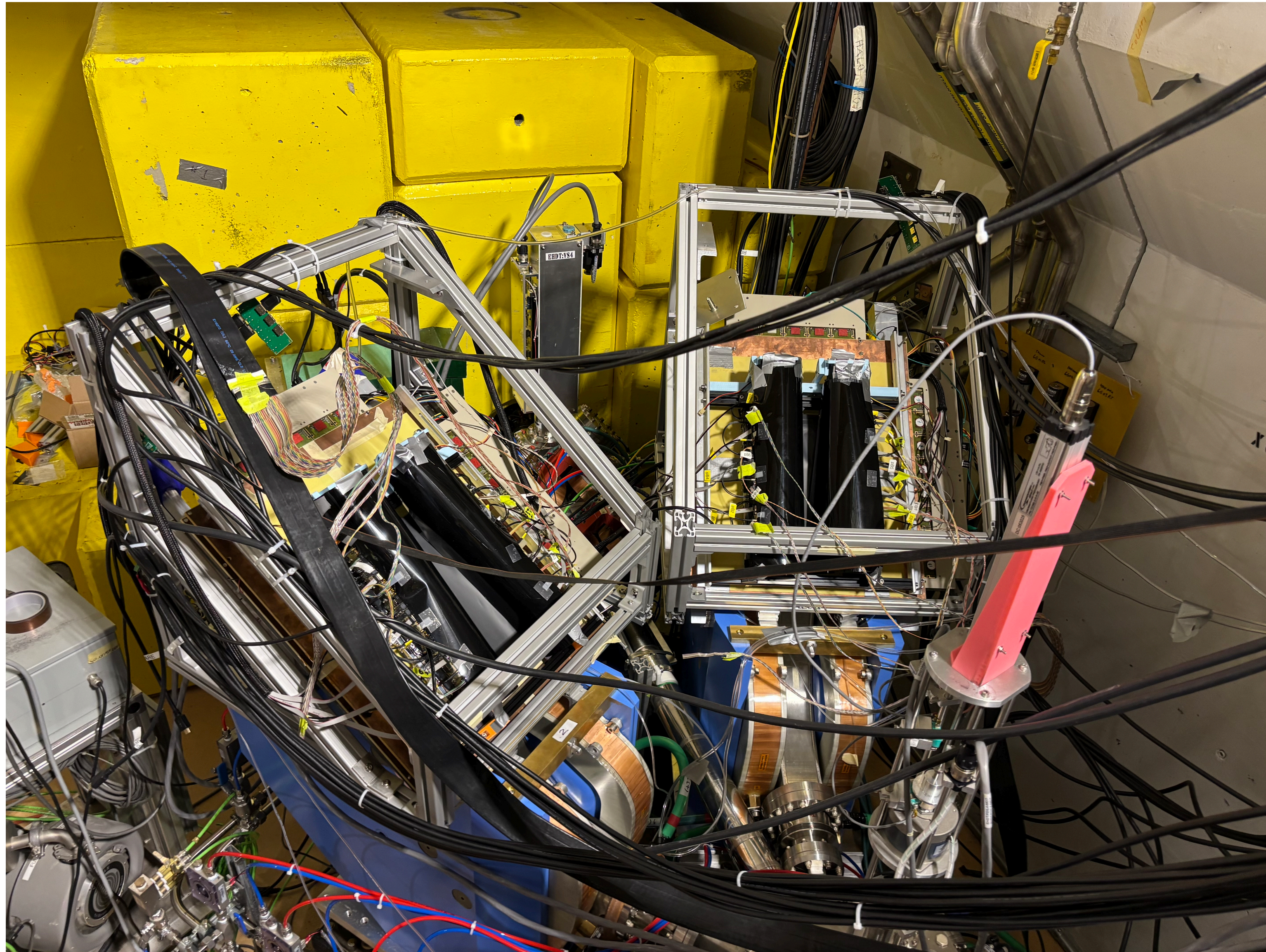
Step 6: detector time! (+ misc.)



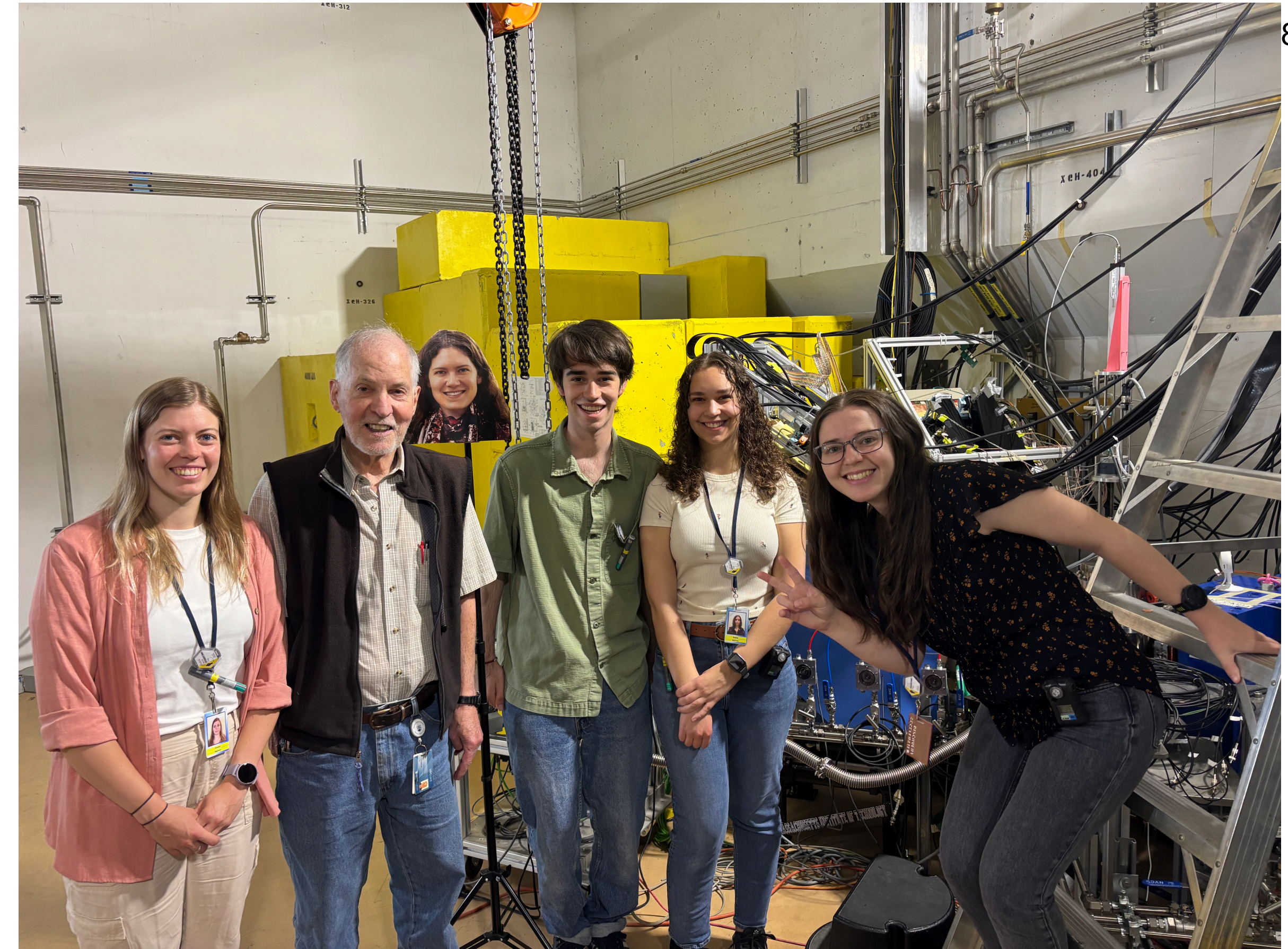
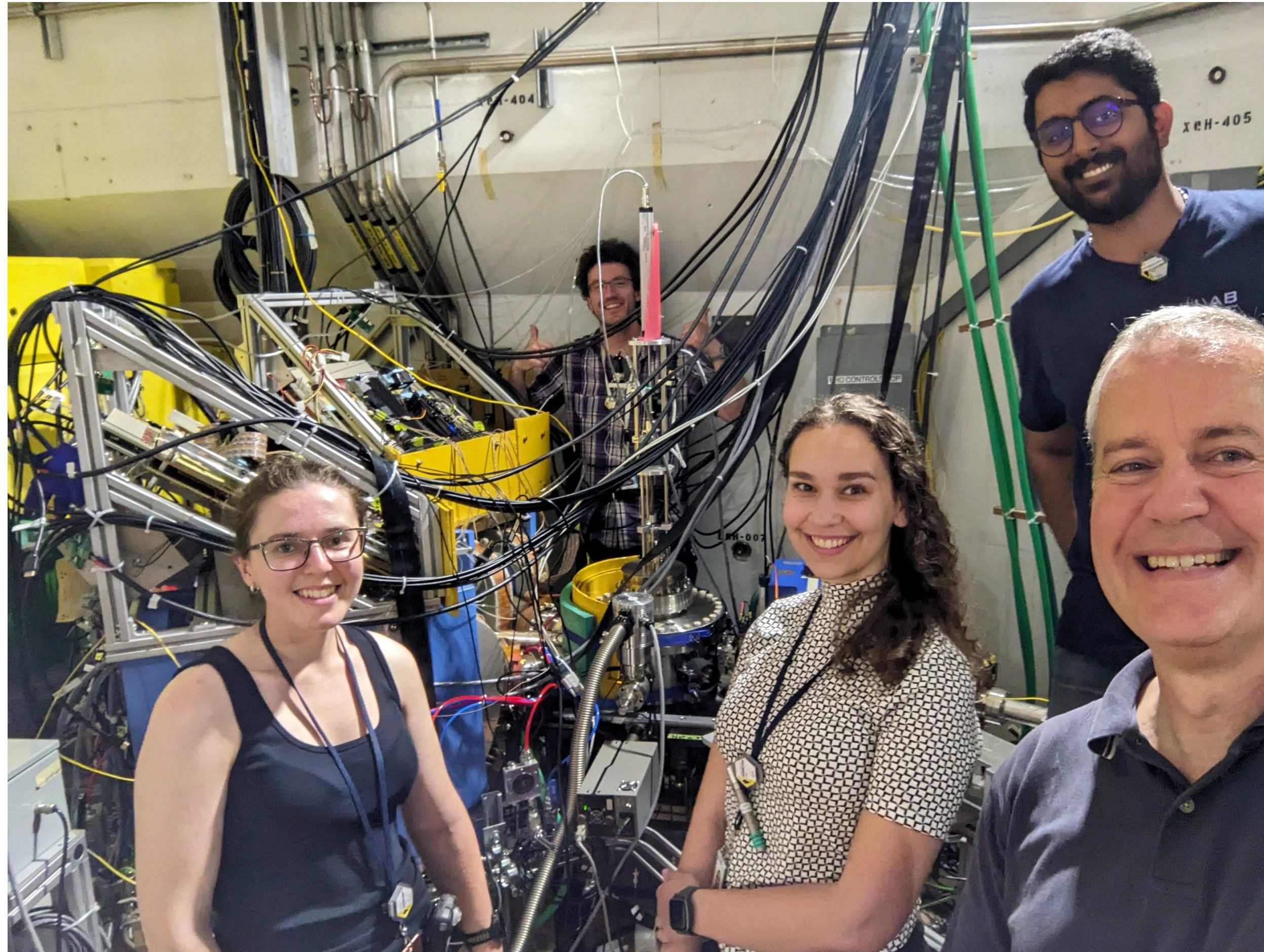
17



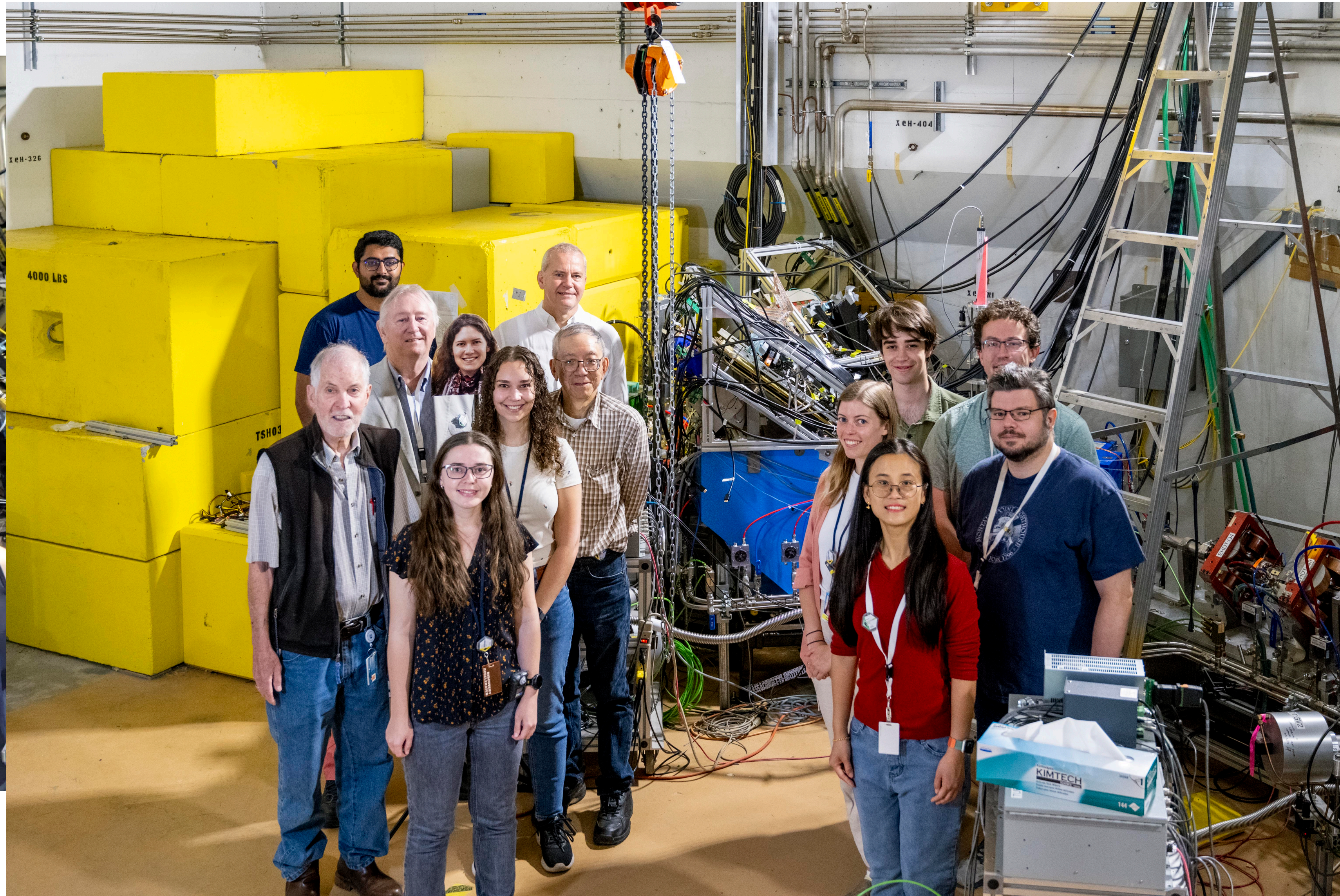
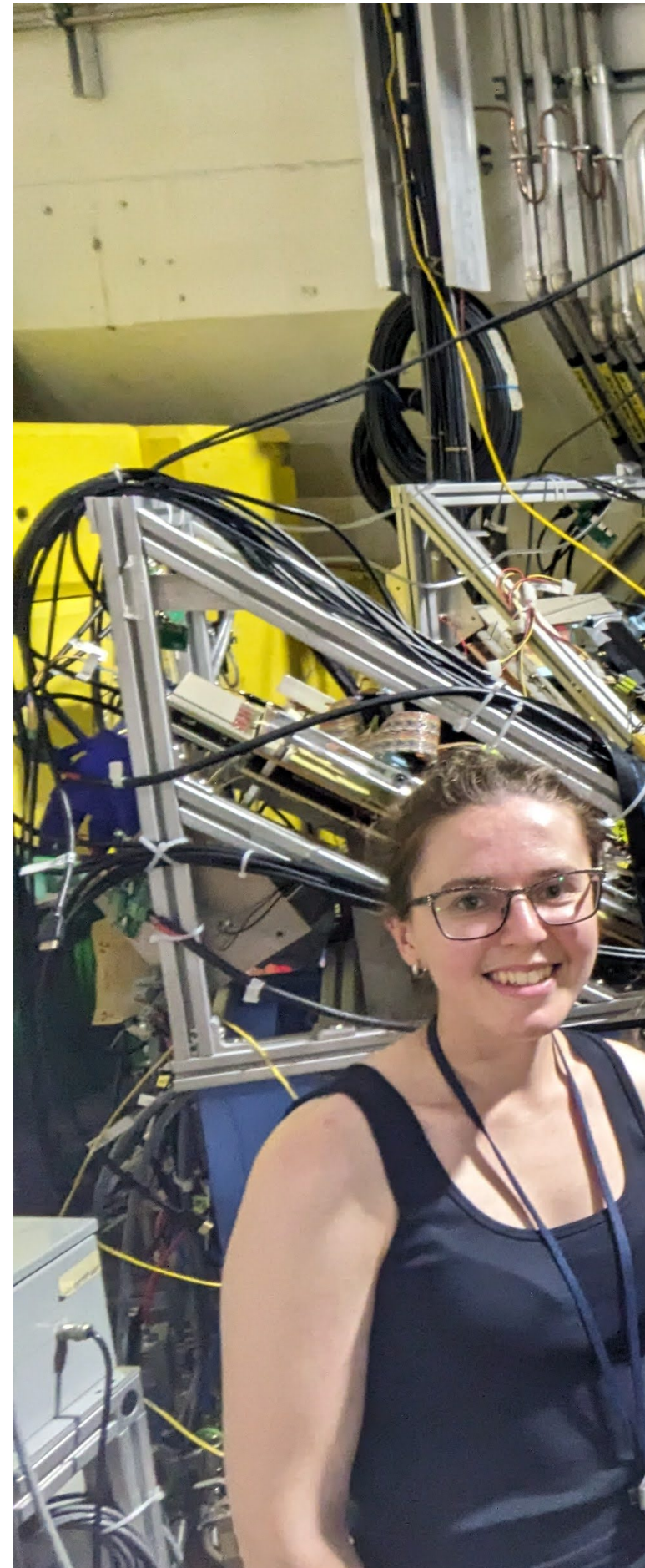
Step 7: celebrate



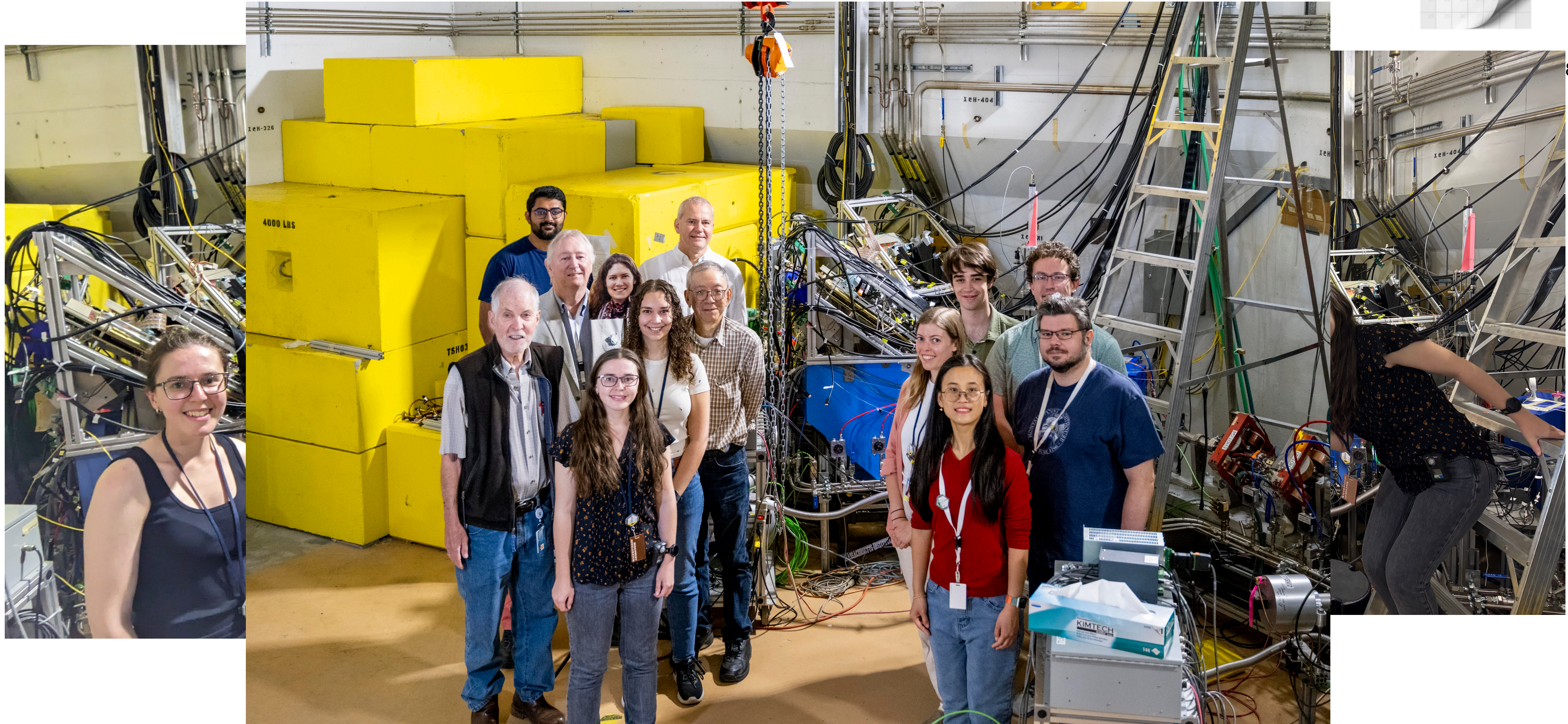
Step 7: celebrate



Step 7: celebrate



Step 7: celebrate



...ignoring all the looming software work

Current status and into the future

- Ready for beam!
- eLinac beginning e-gun conditioning soon
- now - end of December 2025: commissioning followed by physics runs for 30 MeV
- 2027: additional cryomodule added with collaboration from JLAB
- 2028: 50 MeV data-taking
- Big thank you once again to all the technicians!