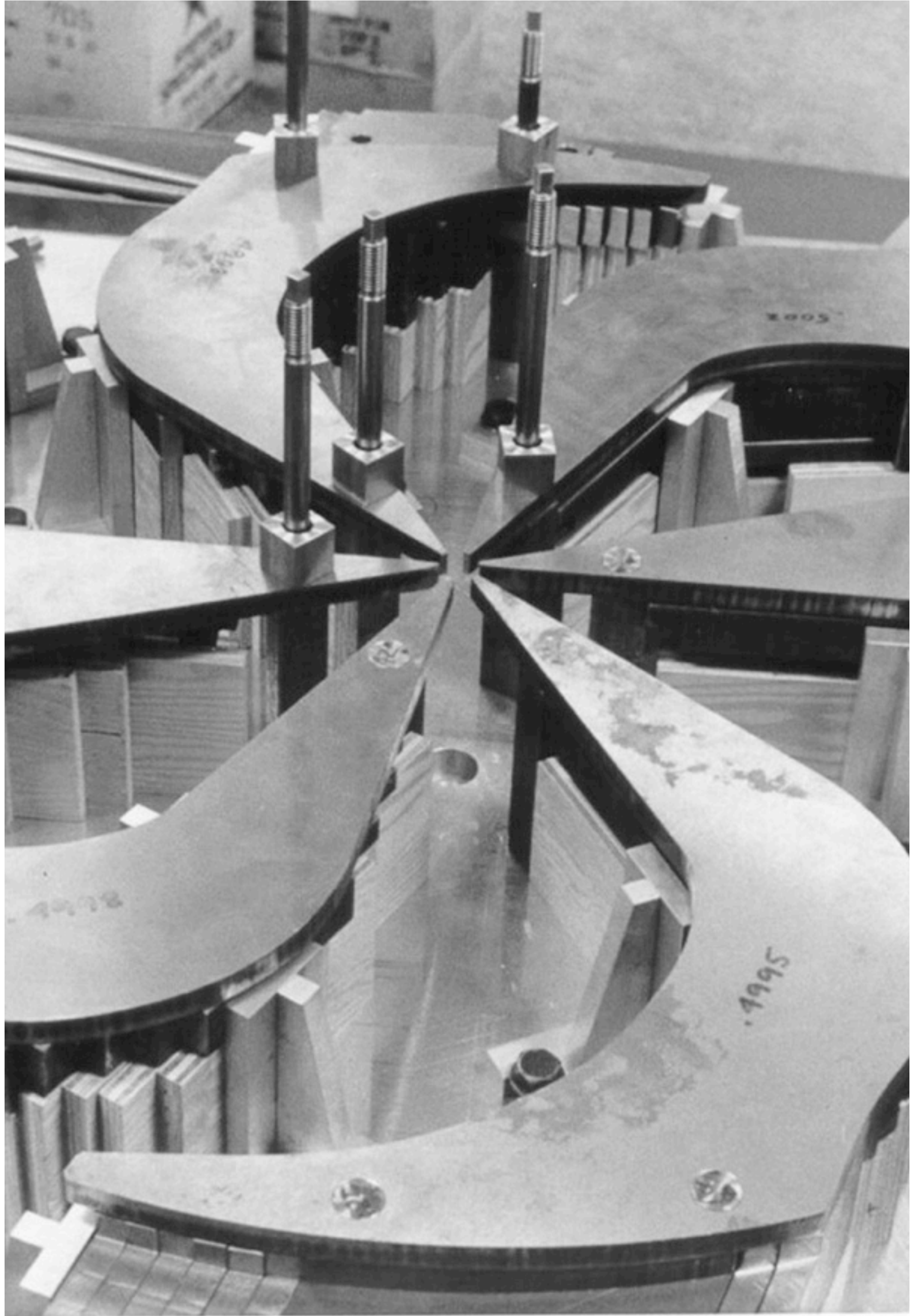
TRIUMF

Conceptual design review: Darklight @ ARIEL

Kate Pachal
Science technology

On behalf of the DarkLight Collaboration



Discovery, accelerated

Today's goals

- First: thank you for being here!
- We are reviewing the DarkLight experiment, which will be installed at TRIUMF next year, primarily in the context of its interaction with and effects on the lab and the ARIEL e-linac
- Many relevant groups at TRIUMF, as this experiment will interface with beamlines, vacuum, controls, shielding, and require support from mechanical and building services, among others
- Will go briefly through the experiment and its impact on the above areas, then have ample time for discussion
- Goal is to progress to a Gate 2/3 review as soon as possible after this: now is a good time to raise relevant points so we can address them all!

Relevant links

- Technical design report: link
- Beam optics report: TBC, but find diagram of proposed optics here
- STEP file with subset of experiment design: link
- Gate 1 documents
  - Final report
  - Top-level requirements
  - Hazards & safety
- Special CFI review (more up-to-date than Gate 1): report

Who?

- International collaboration, mostly Canadian + American institutions
- 3 experiment spokespeople: Richard Milner (MIT), Ross Corliss (Stony Brook), Jan Bernauer (Stony Brook)
- Canadian contingent of collaborators led by Mike Hasinoff (UBC)
- (Internal) TRIUMF project leader: Kate Pachal (that's me)
- (Internal) TRIUMF project manager: Stephanie Rädel
- TRIUMF support & contributions from accelerator division and lab leadership
- Engineering & design support from MIT/Bates Research and Engineering Center

Who?

Task	Lead institutions
Magnetic spectrometers	MIT, Mainz
Target and scattering chamber	MIT
GEM detectors	Hampton University
Data acquisition	Stony Brook & TRIUMF
Trigger hodoscopes	TRIUMF, UBC, UM, UW, and SMU
Software & simulation	Stony Brook, TRIUMF, MIT
Integration with ARIEL	TRIUMF & UM

The DarkLight@ARIEL Collaboration

Arizona State University, Tempe, AZ, USA

University of British Columbia, Canada

Hampton University, Hampton, VA, USA

TJNAF, Newport News, VA, USA

Massachusetts Institute of Technology, Cambridge, MA, USA

St. Mary's University, Halifax, Nova Scotia, Canada

Stony Brook University, NY, USA

TRIUMF, Vancouver, British Columbia, Canada

University of Manitoba, Canada

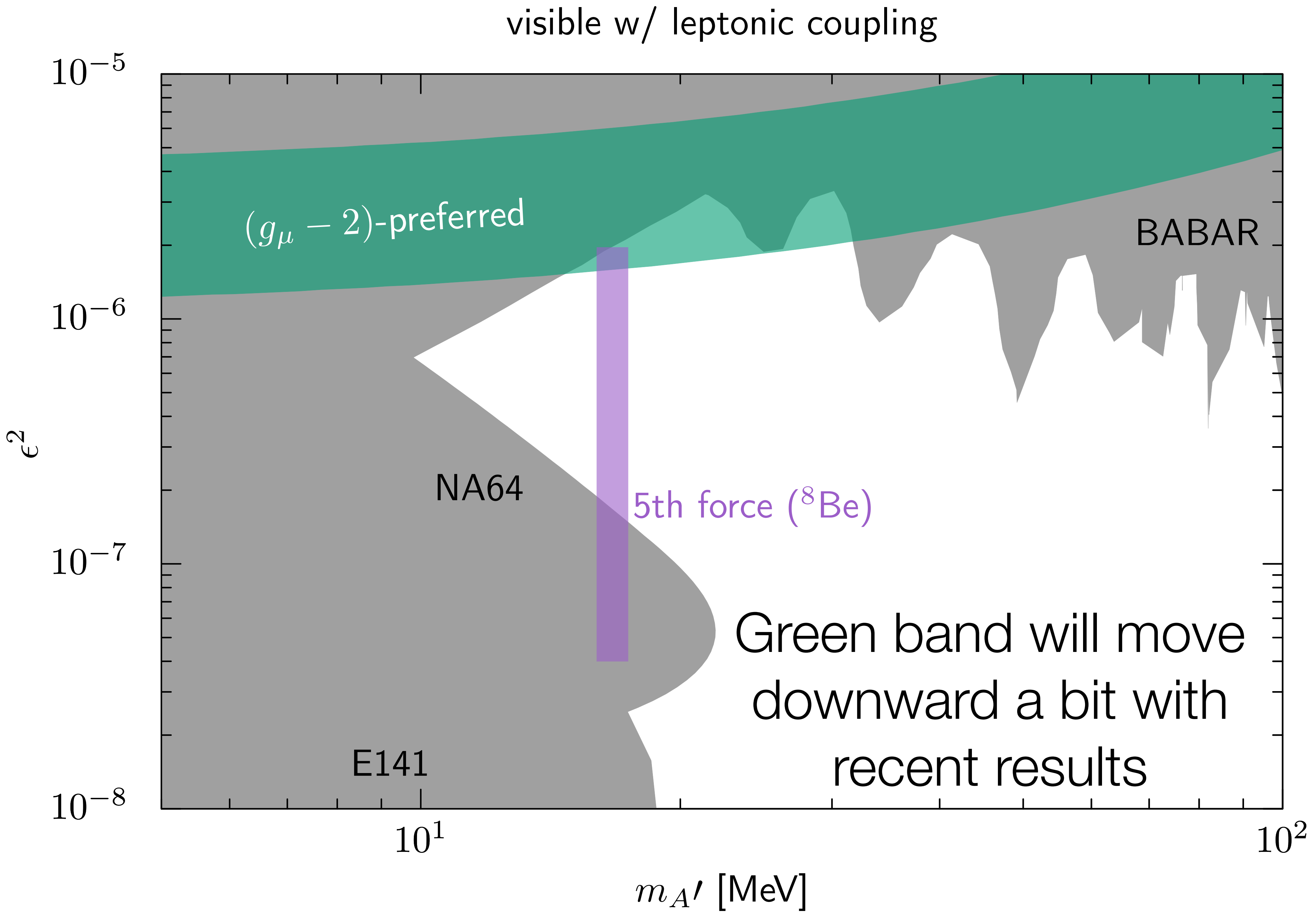
University of Winnipeg, Manitoba, Canada

What?

- Small fixed target experiment to be placed in ARIEL e-linac in front of existing beam dump
- Thin (0.5 - 1 μm) tantalum foil target will intersect e- beam. Two dipole magnets either side of the beamline select e- and e+; tracking detectors record their positions.
  - Target chamber and dipole magnets will form part of vacuum system
- Various electronics serving tracking and trigger detectors, along with shielding around them
- Five new quadrupoles between experiment and dump, plus a collimator
- A second phase, discussed in the TDR, is planned for later after extensive accelerator modifications in order to run at 50 MeV. Today’s review is **not** concerned with this. We are talking only about an initial 30 MeV phase of the experiment.

Why?

This plot: limits on possible new bosons from e+e- interactions only



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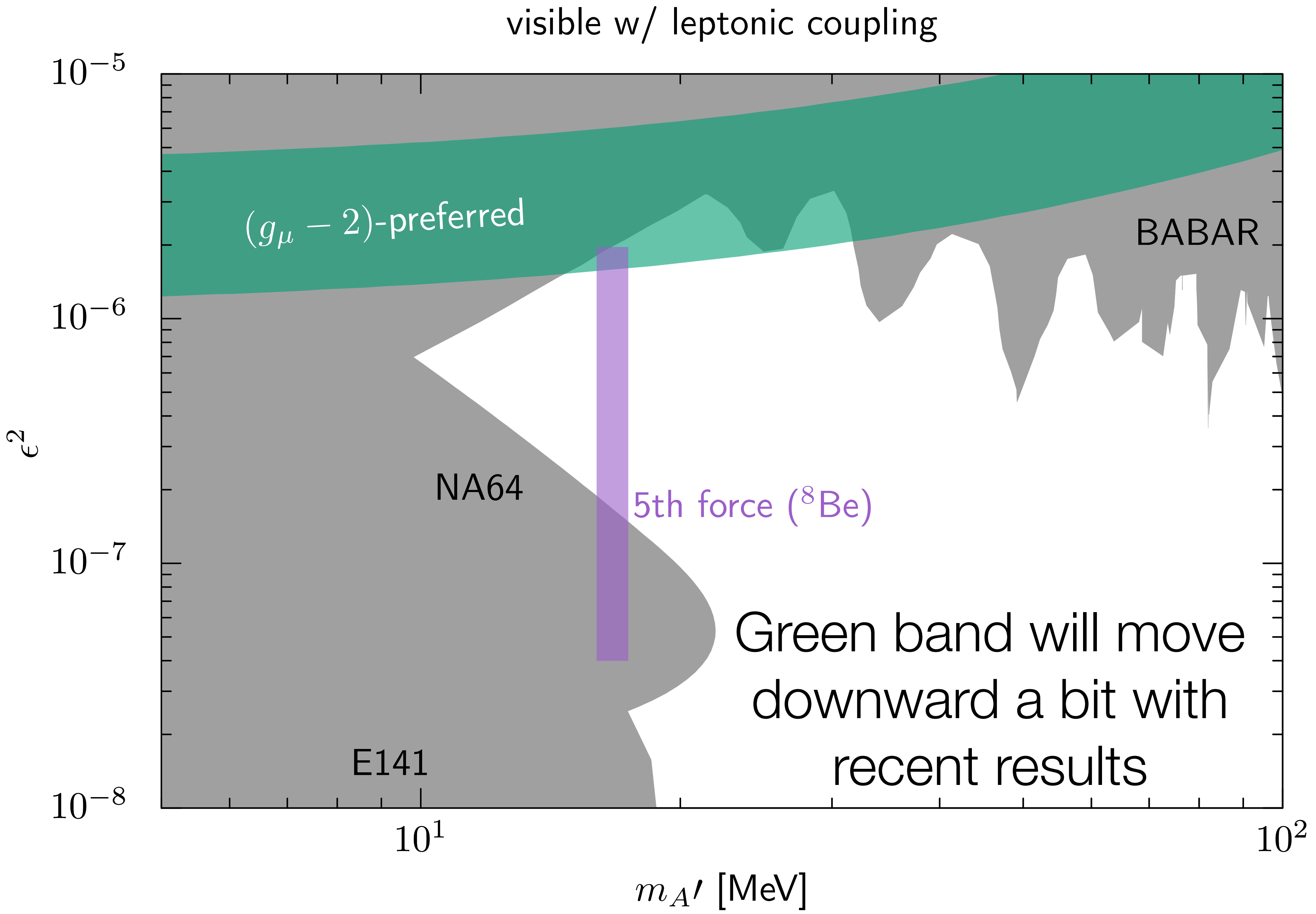

Green band will move downward a bit with recent results

X17 and **muon g-2** anomalies both appear in lepton interactions. “Protophobic” new boson would avoid constraints from pion interactions but can be cleanly probed at e- machine.

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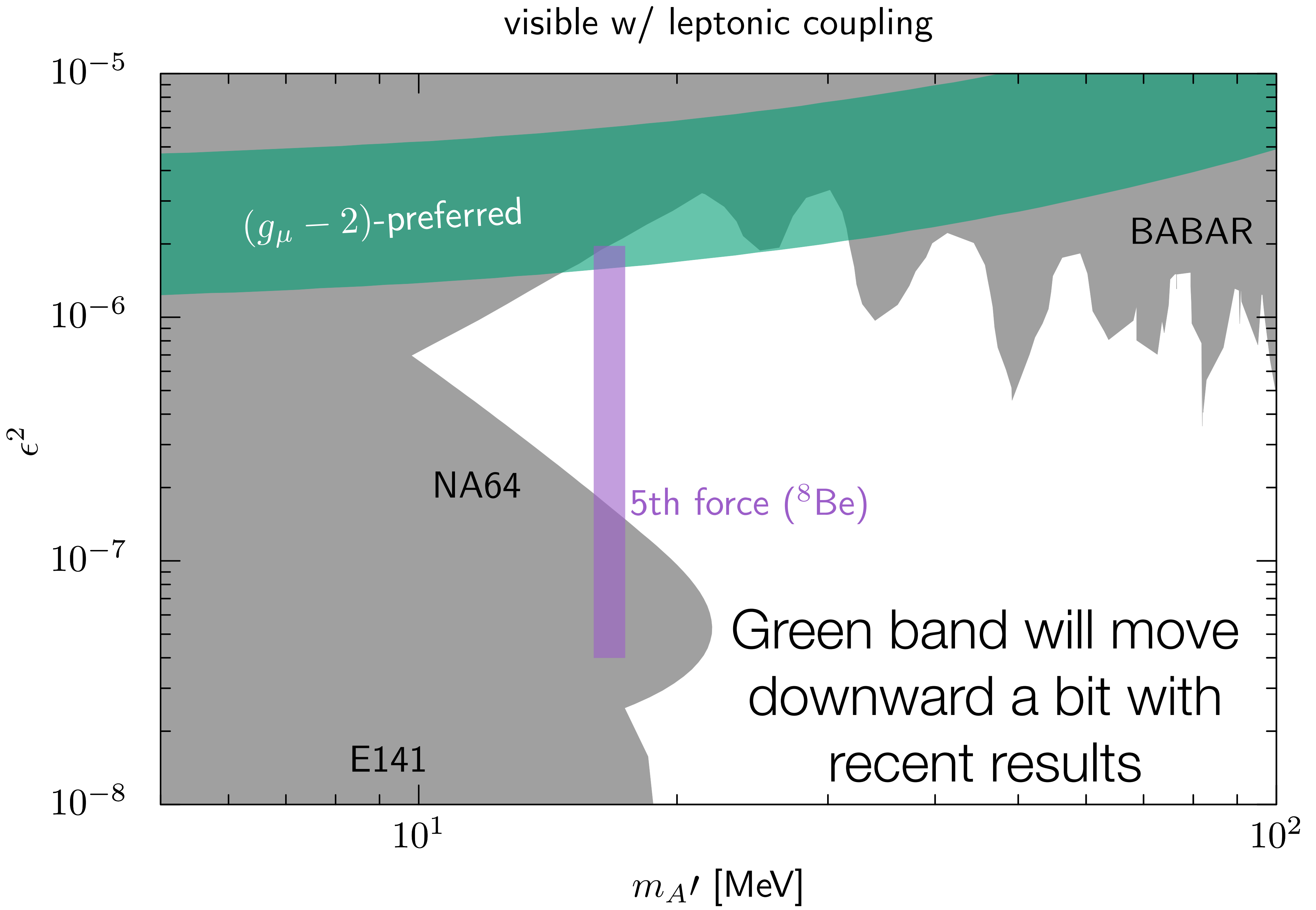

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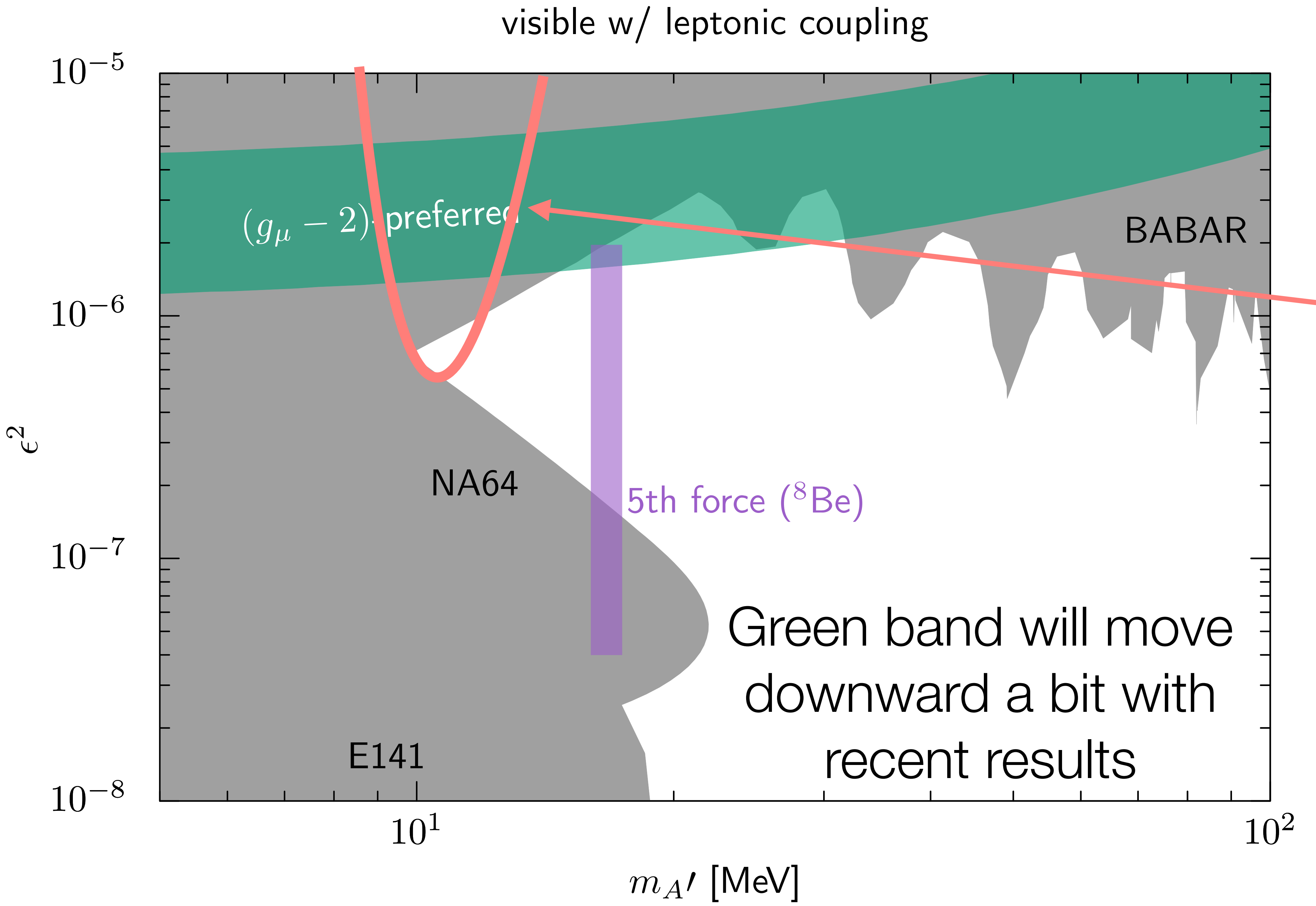

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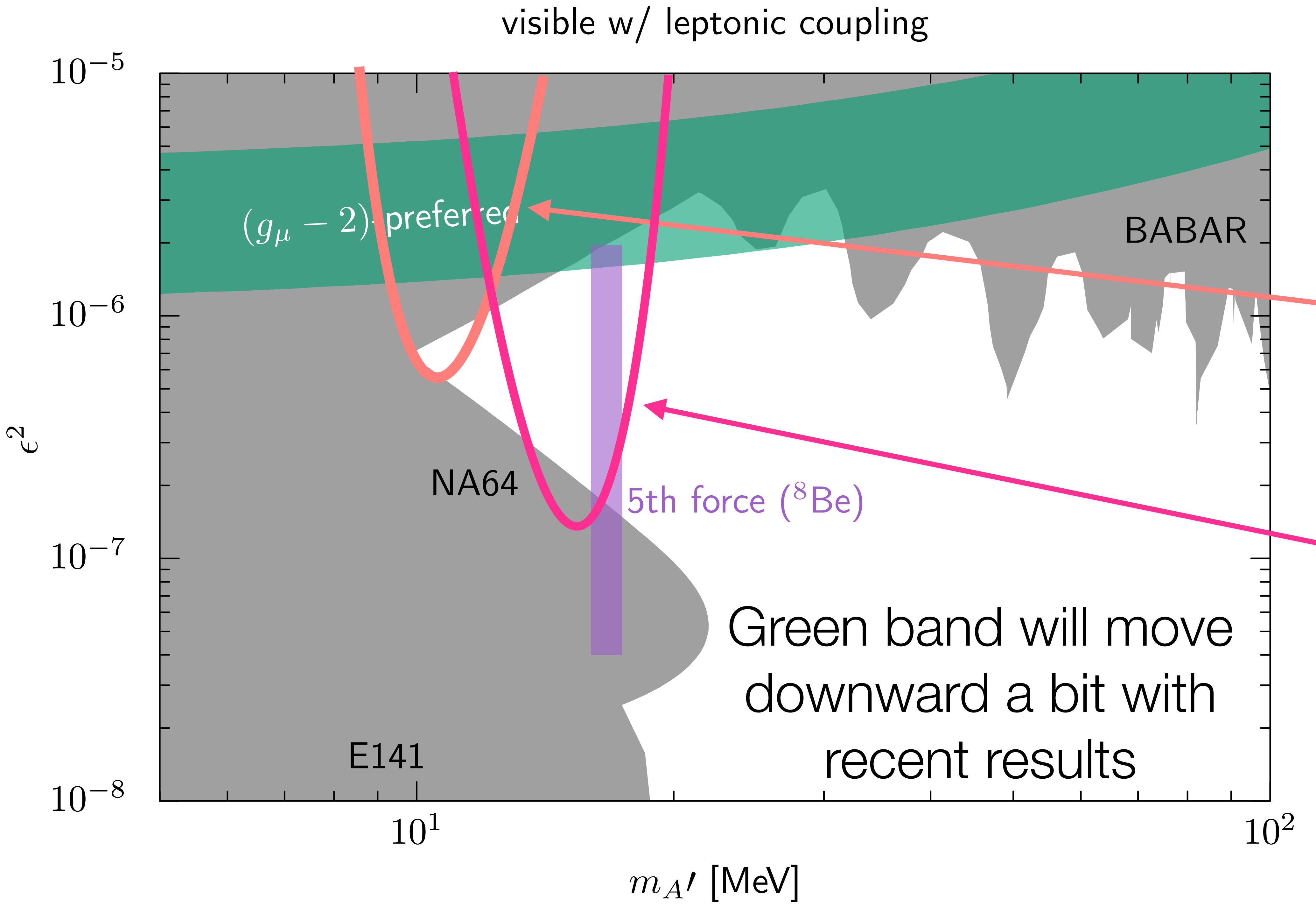

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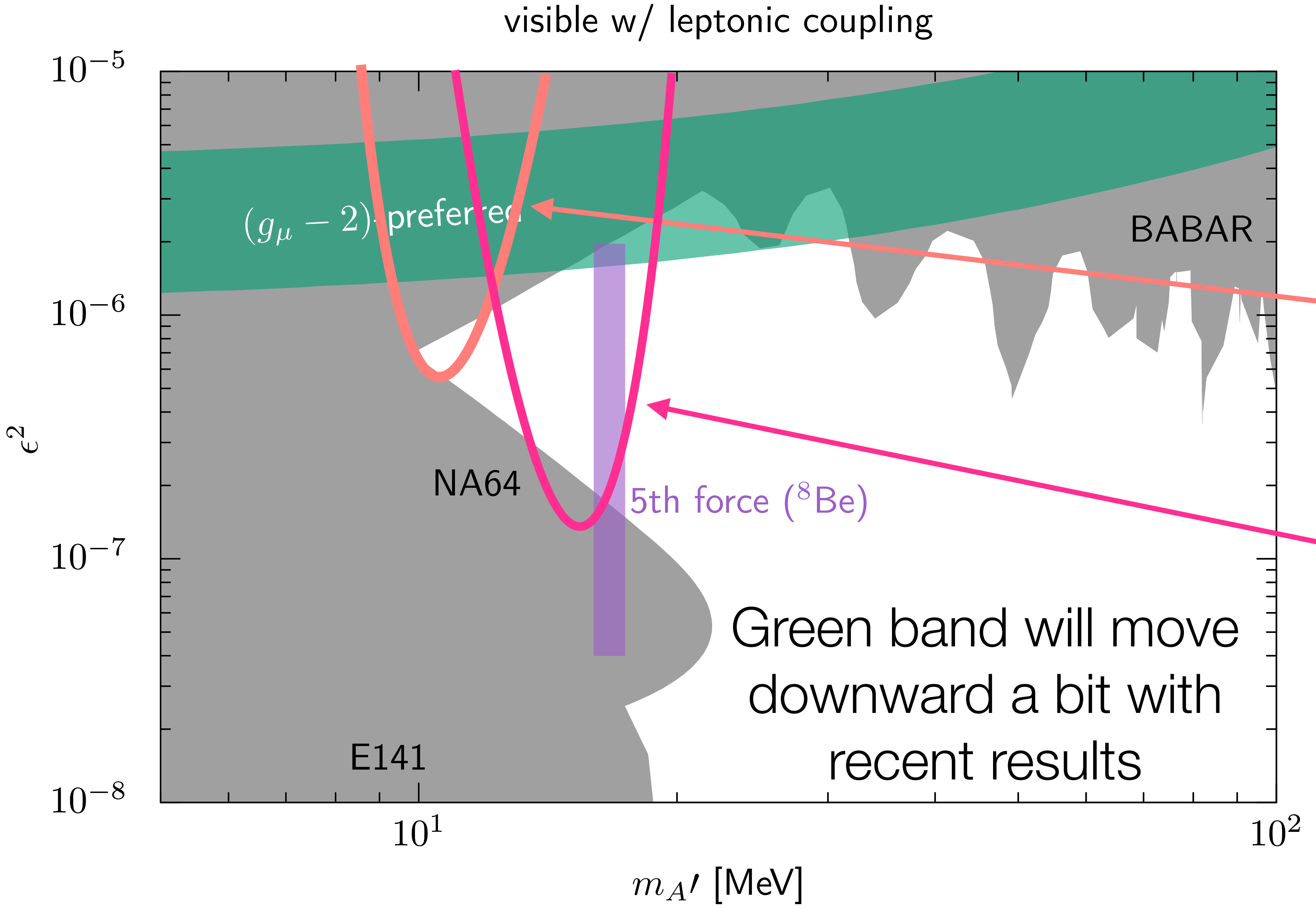

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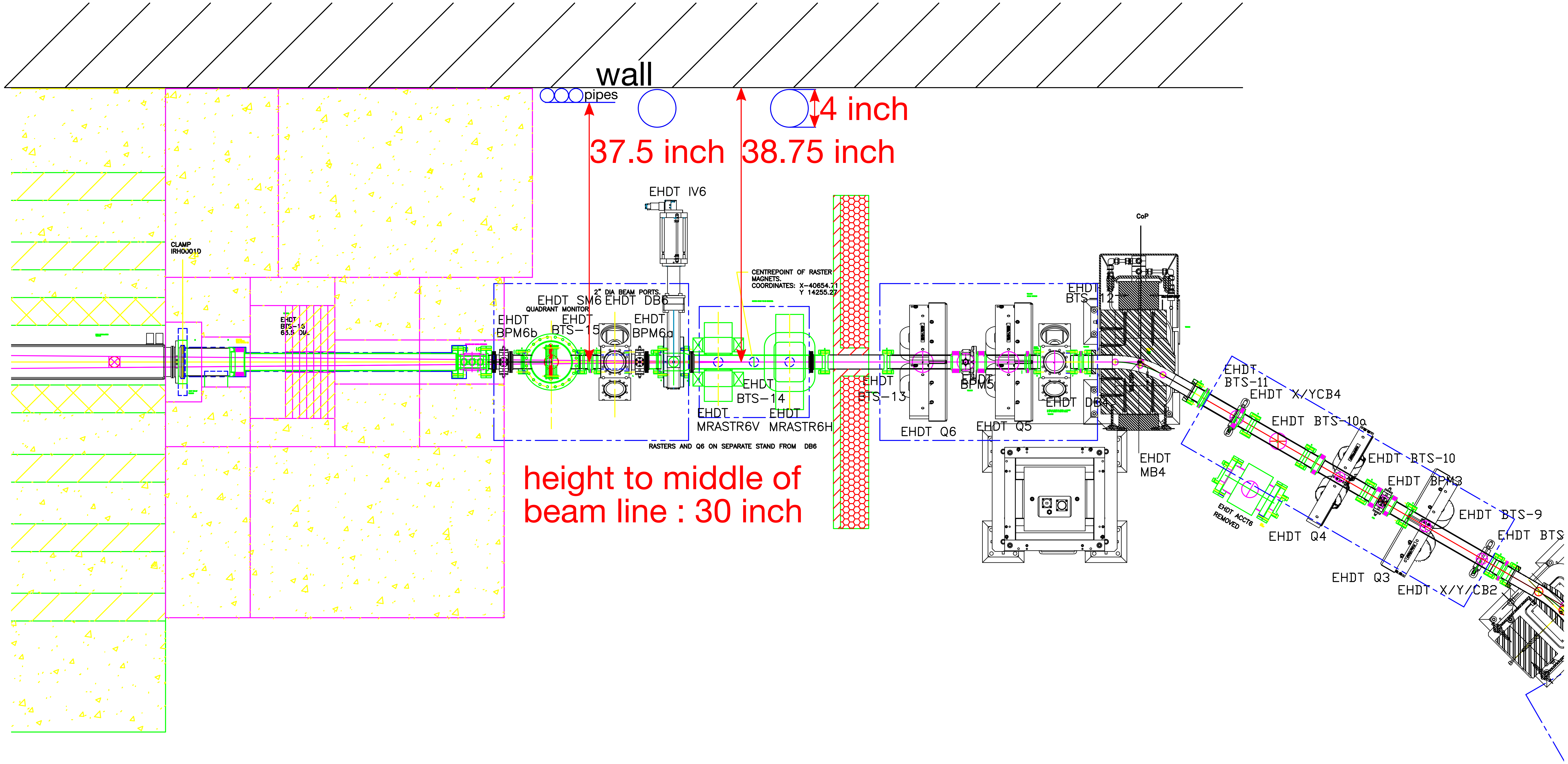
Especially with an eventual energy upgrade (not up for approval today)

ARIEL e-linac's low energy and high current make it appealing accelerator to do this search

Where?

- Directly in front of existing beam dump to minimise distance over which lower quality beam must be transported



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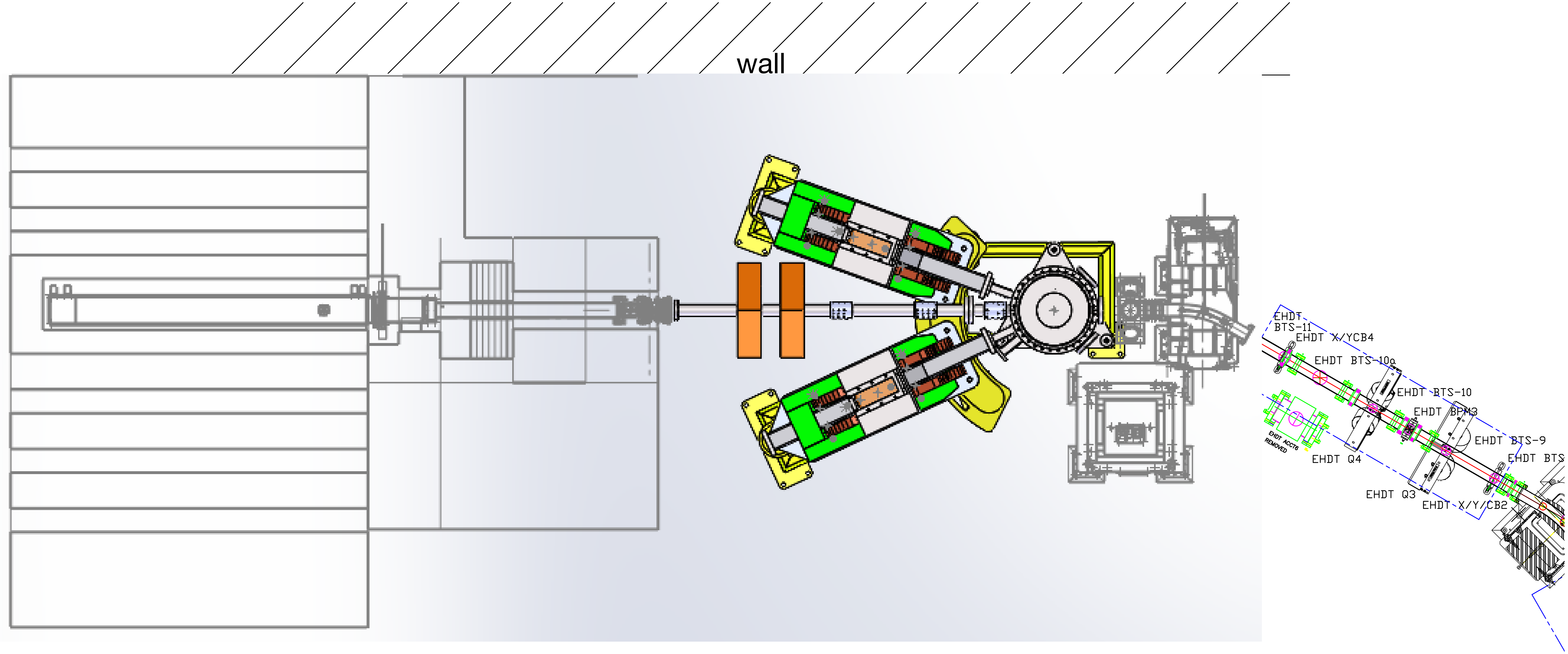

When?

Note: Hampton already completed GEM detectors; being commissioned

Needs TRIUMF help or leadership

MIT can do alone

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*** TRIUMF DarkLight team needs help with FLUKA**

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This meeting

All design finished

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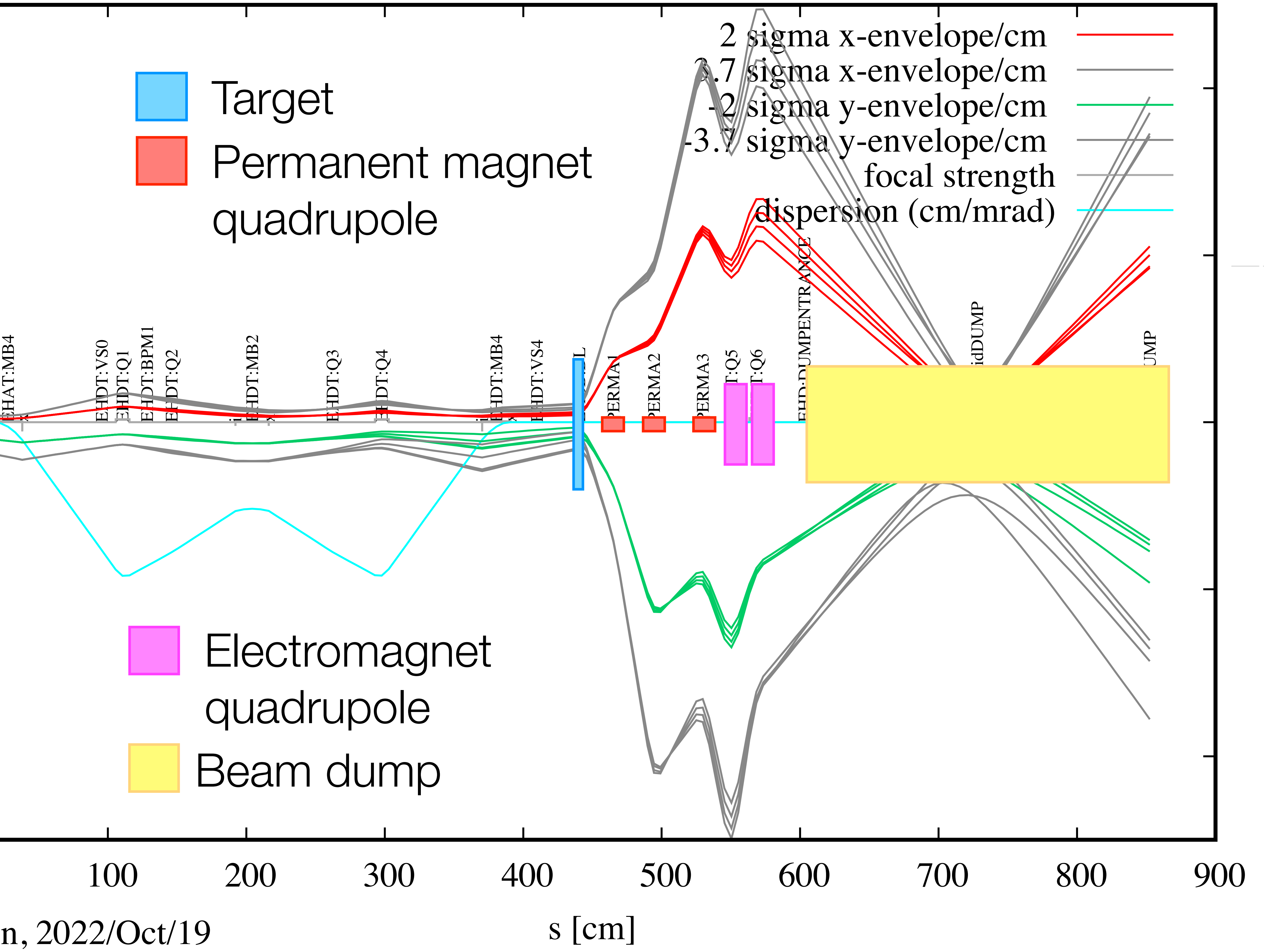
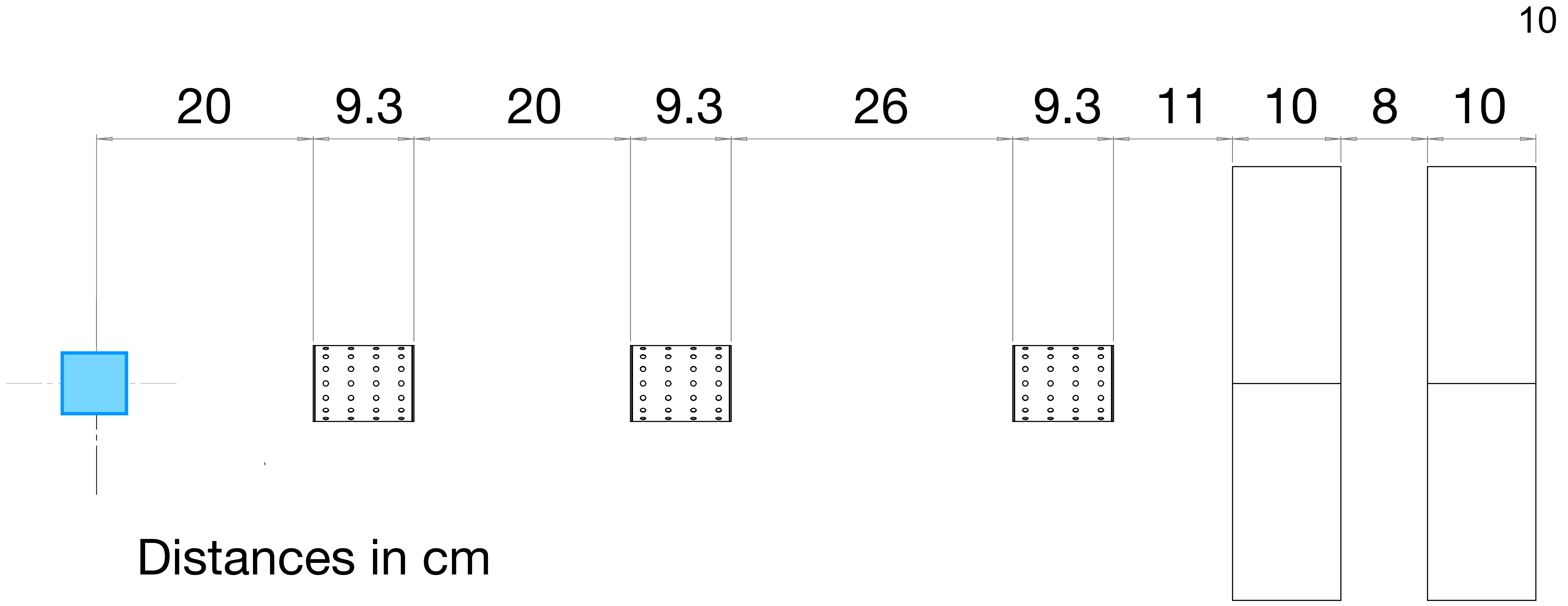
Layout and beam optics





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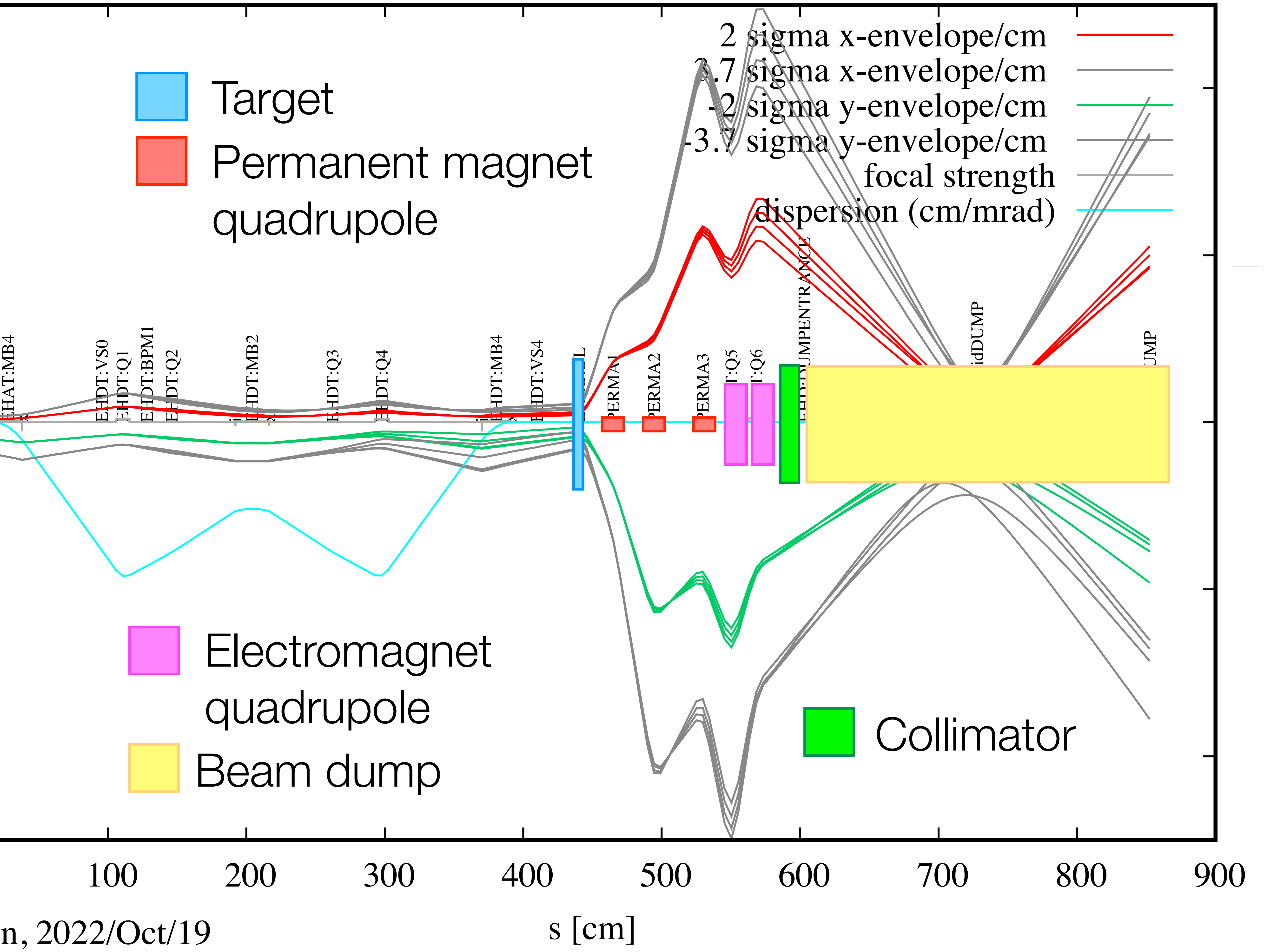
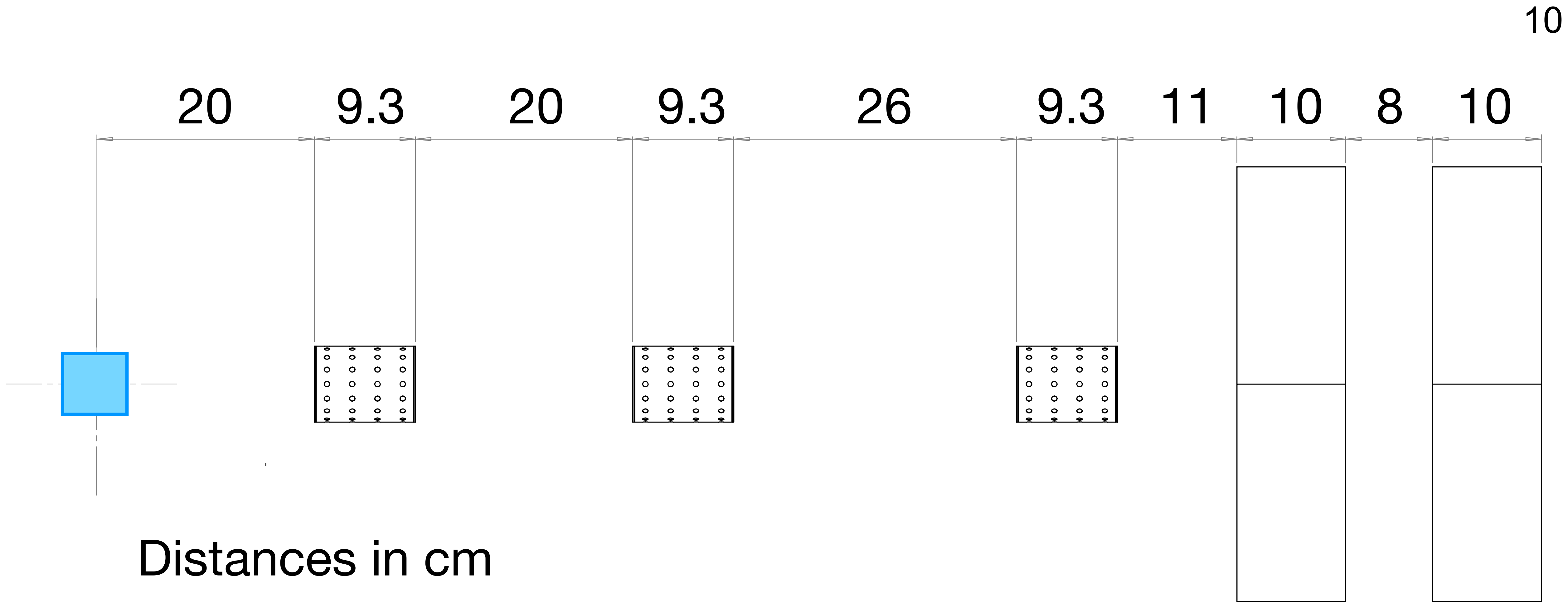


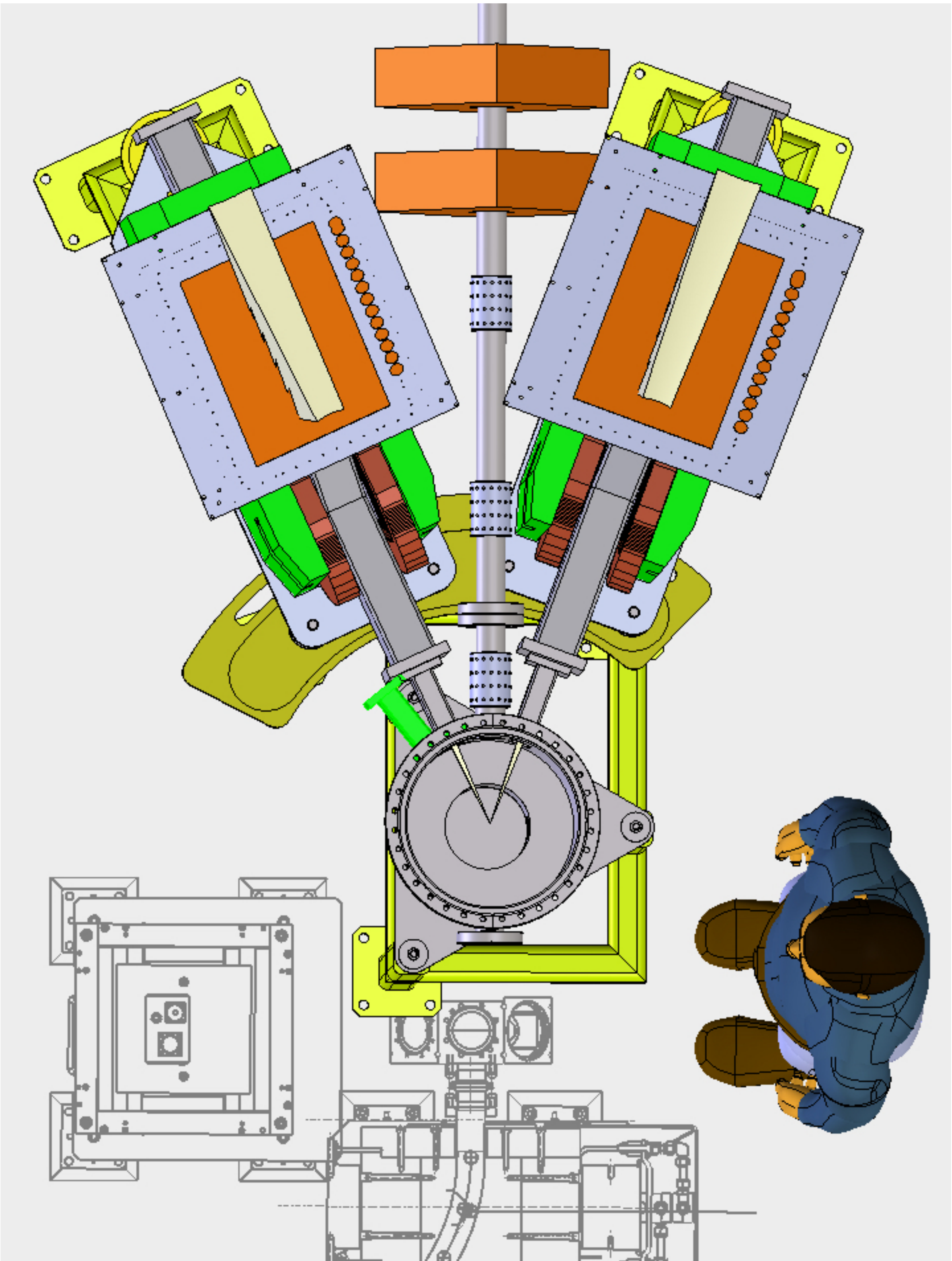


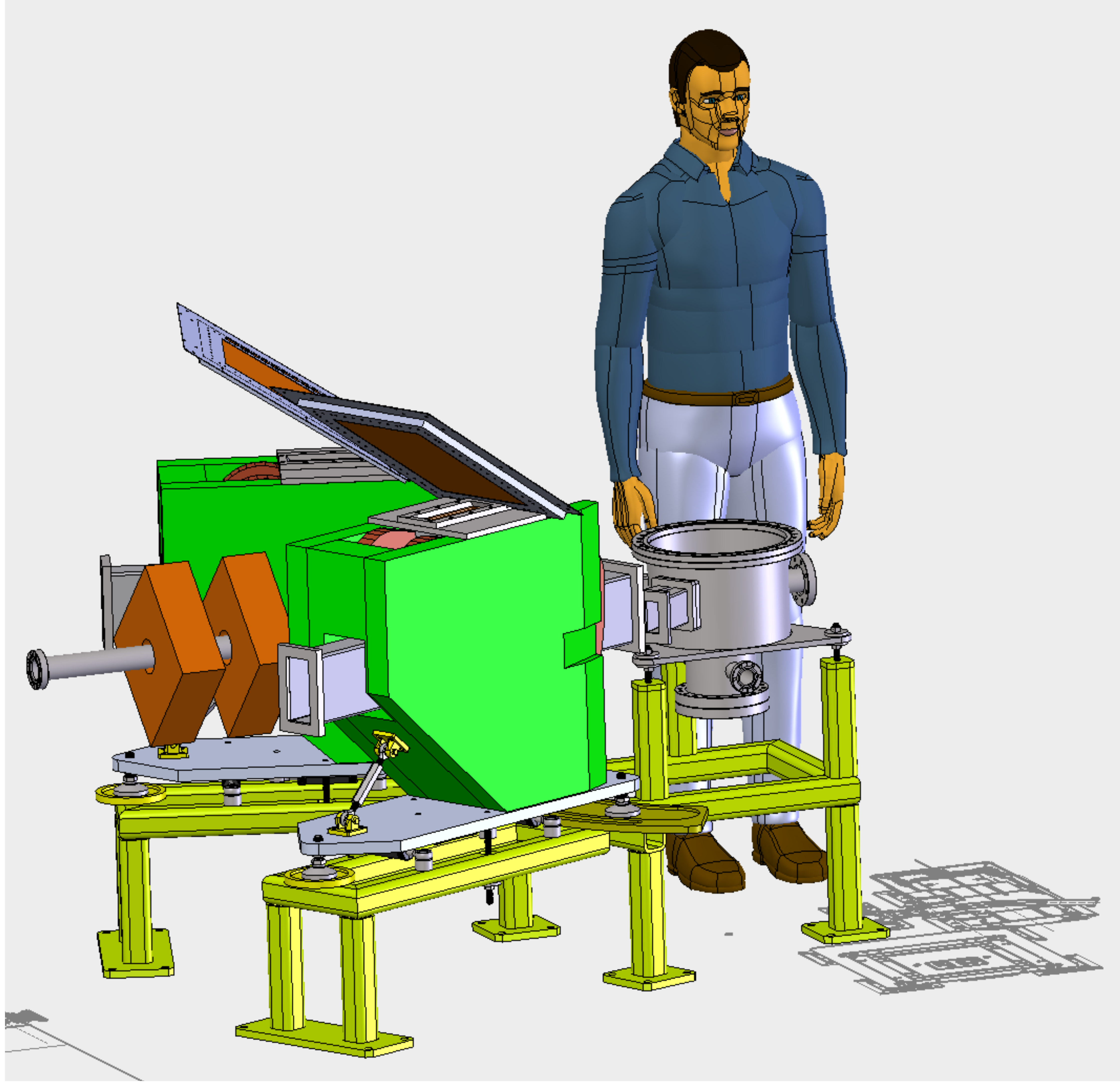
Additionally, require collimator directly in front of dump entrance to protect dump from scattered beam. Not yet designed; currently working on requirements.

Plan to handle design via TRIUMF SciTech engineers

The experimental apparatus

Drawings: Chris
cvidal@mit.edu





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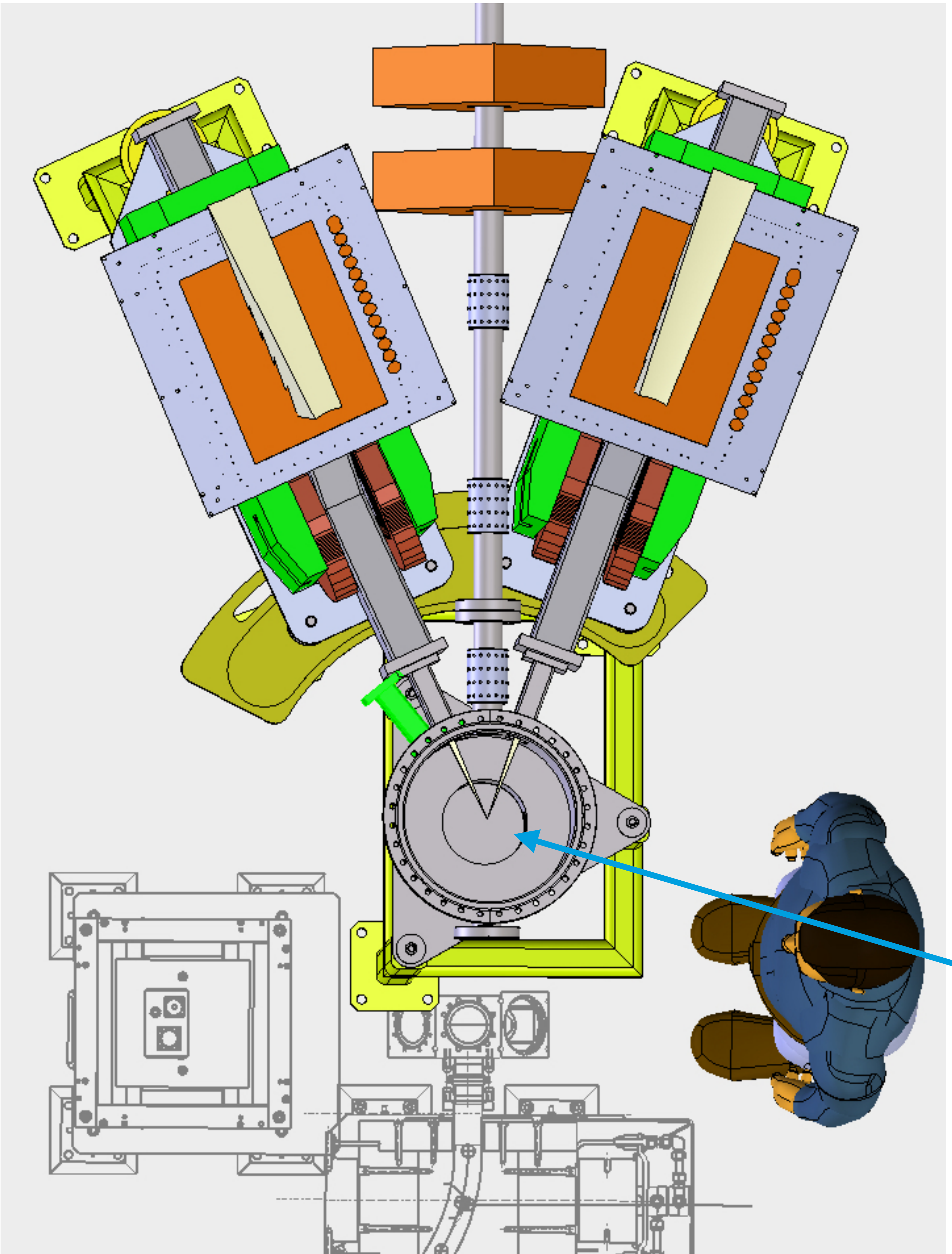
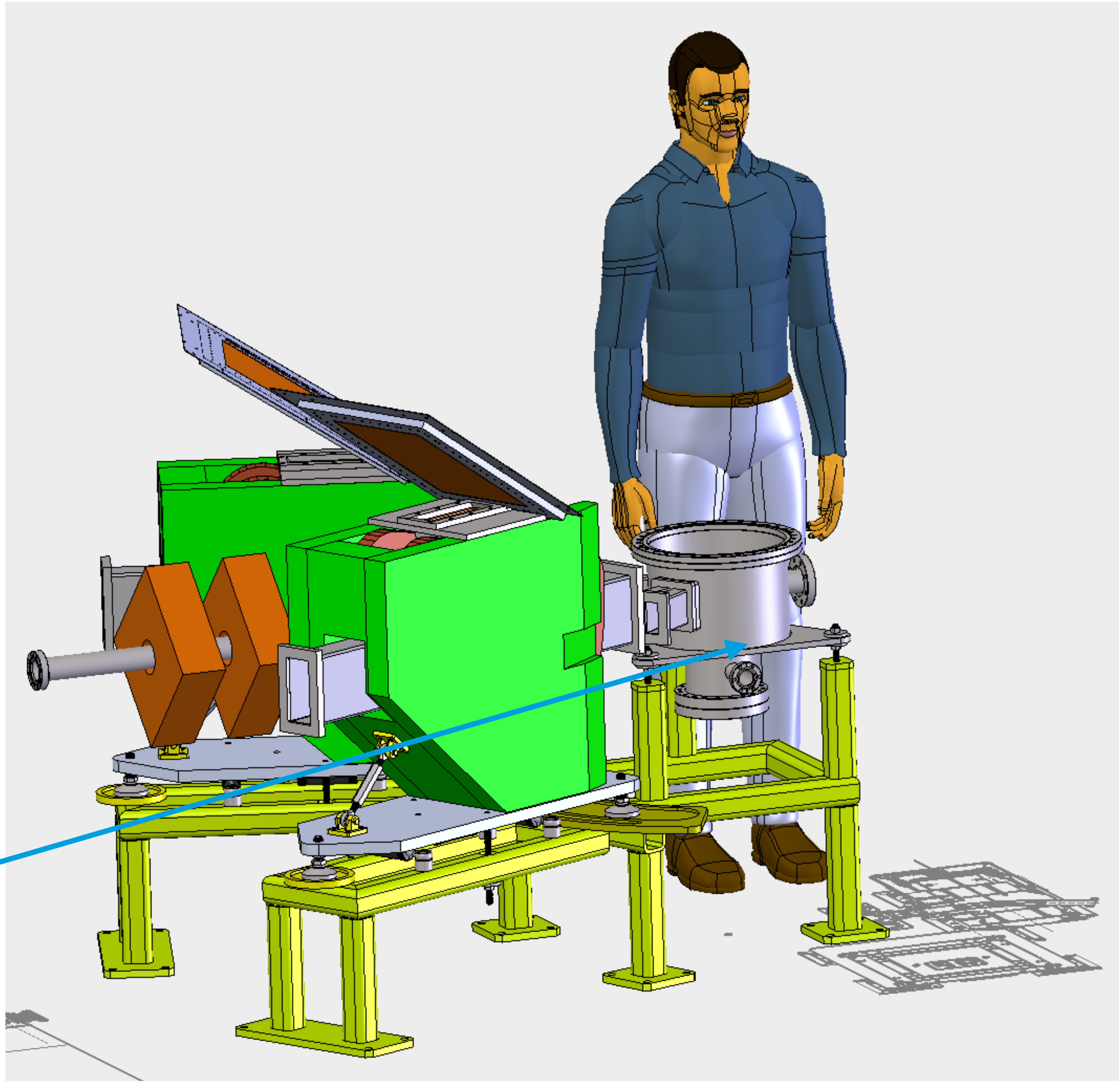


Target chamber



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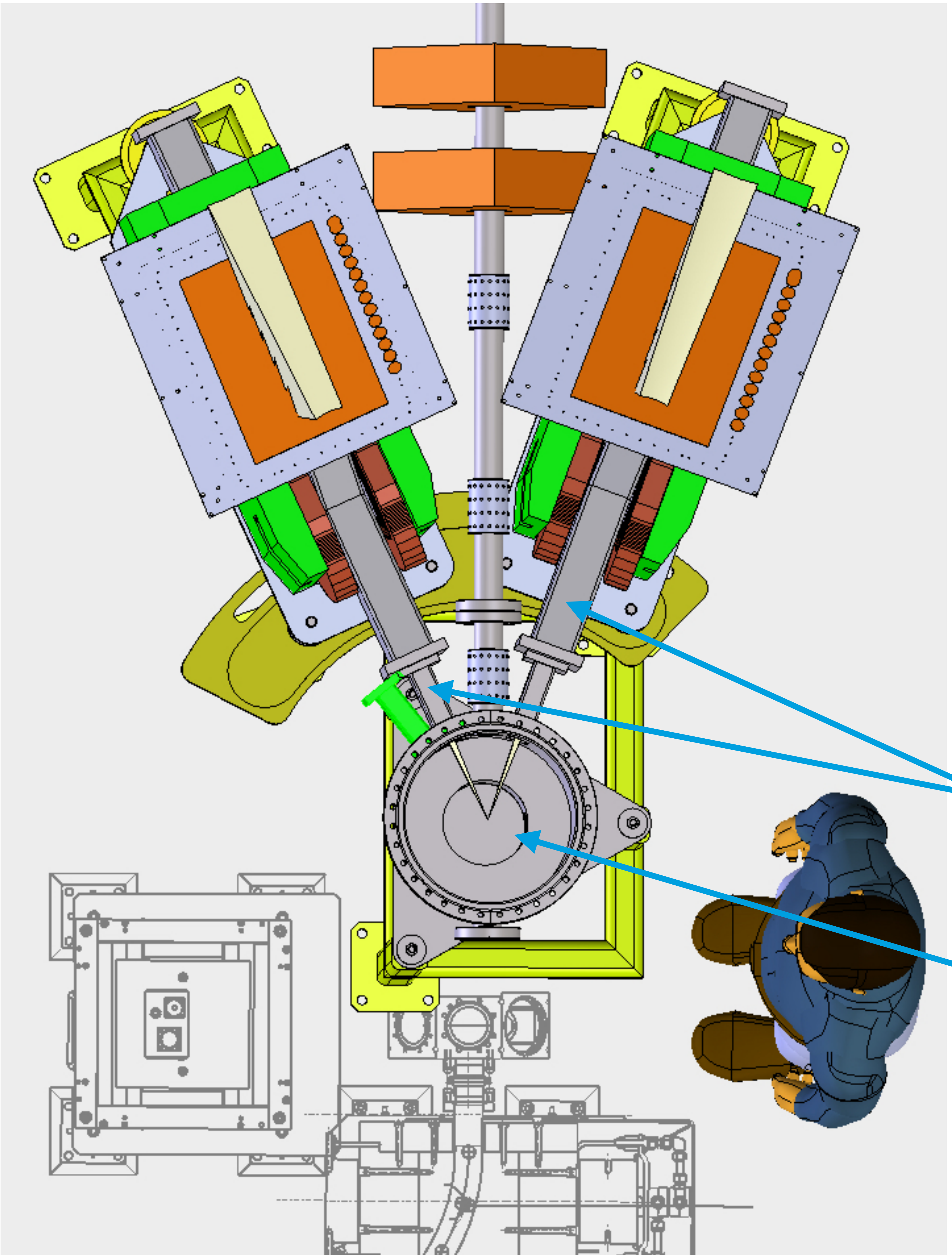
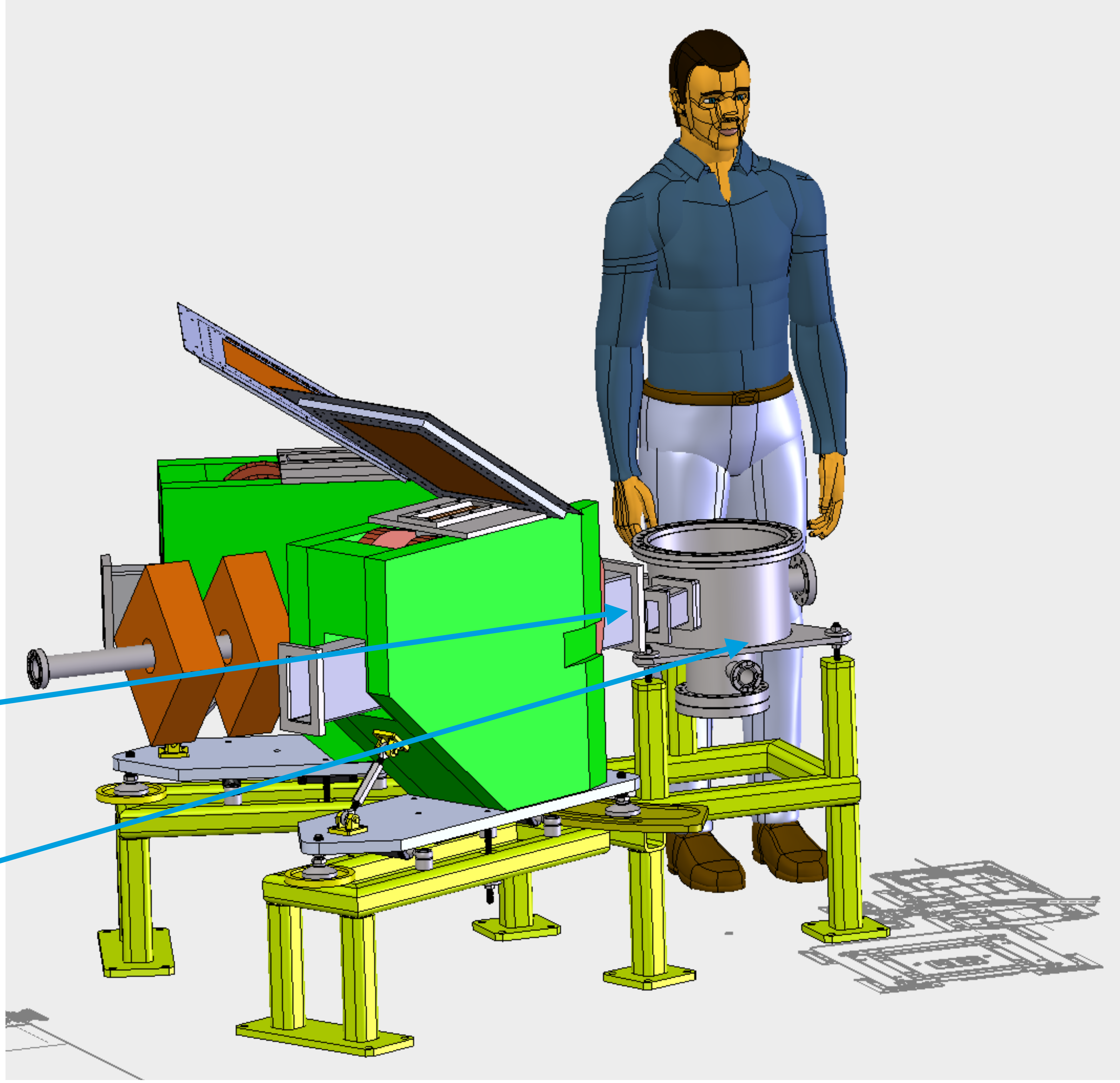


One fixed arm; one with two angles

Target chamber



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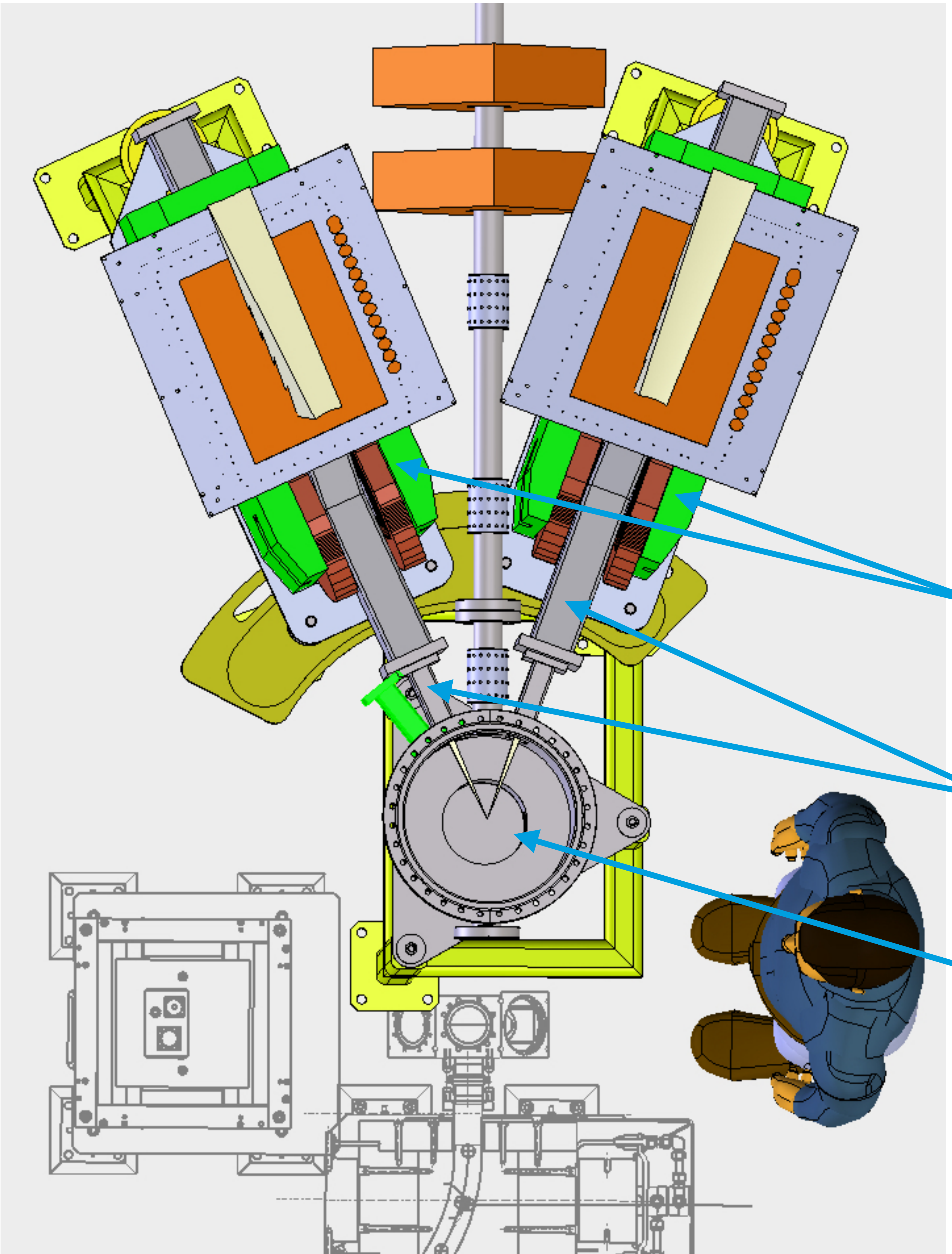

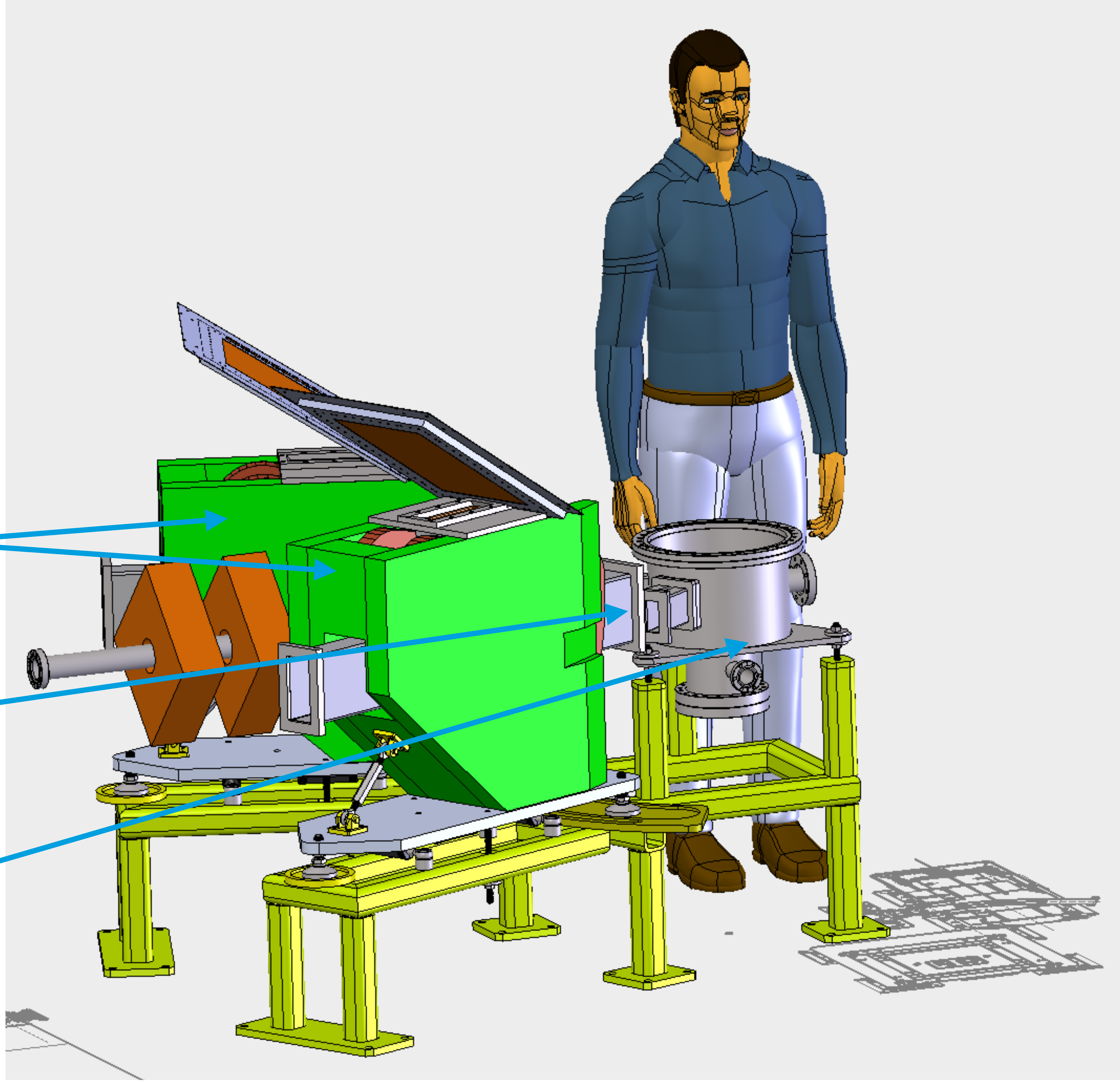

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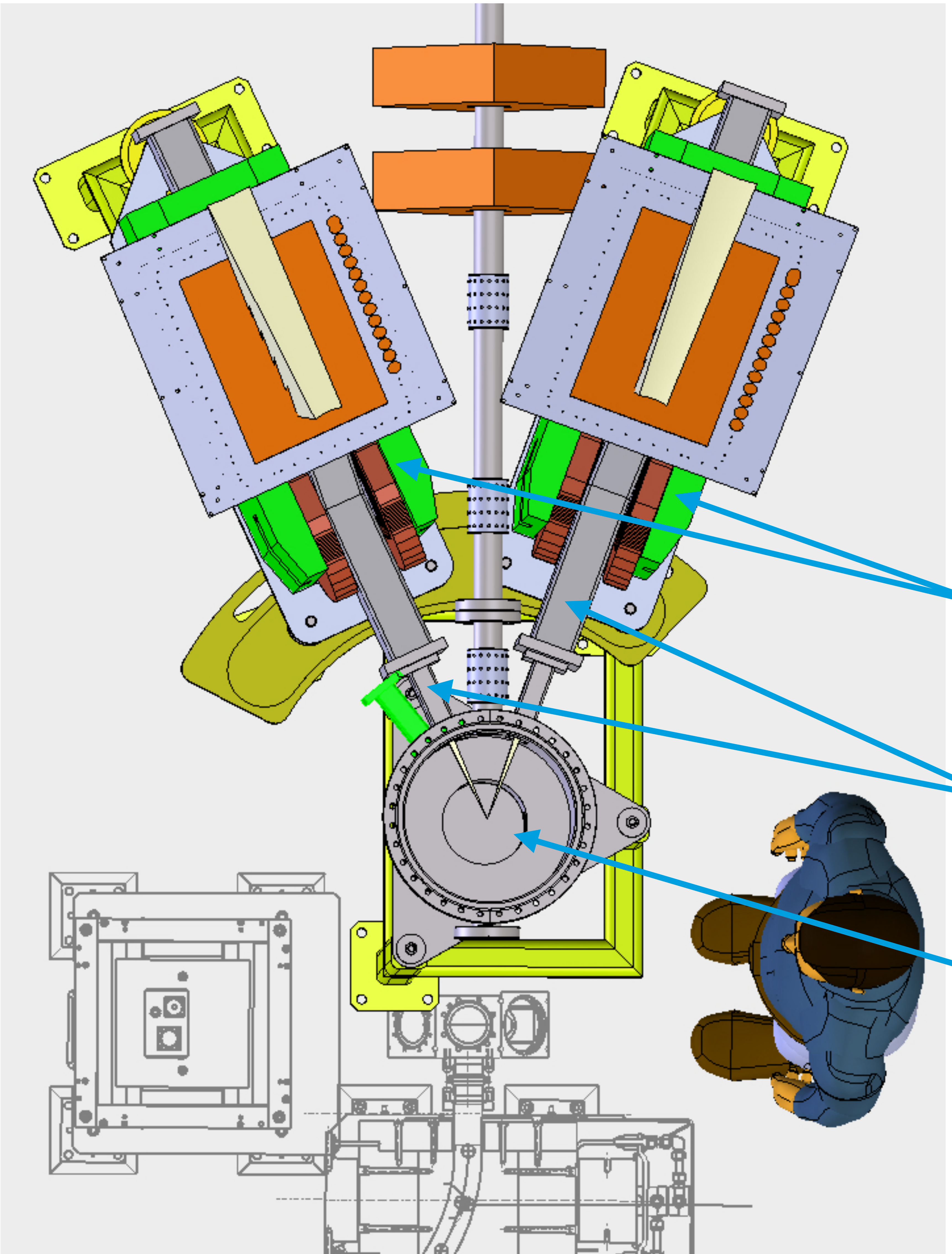

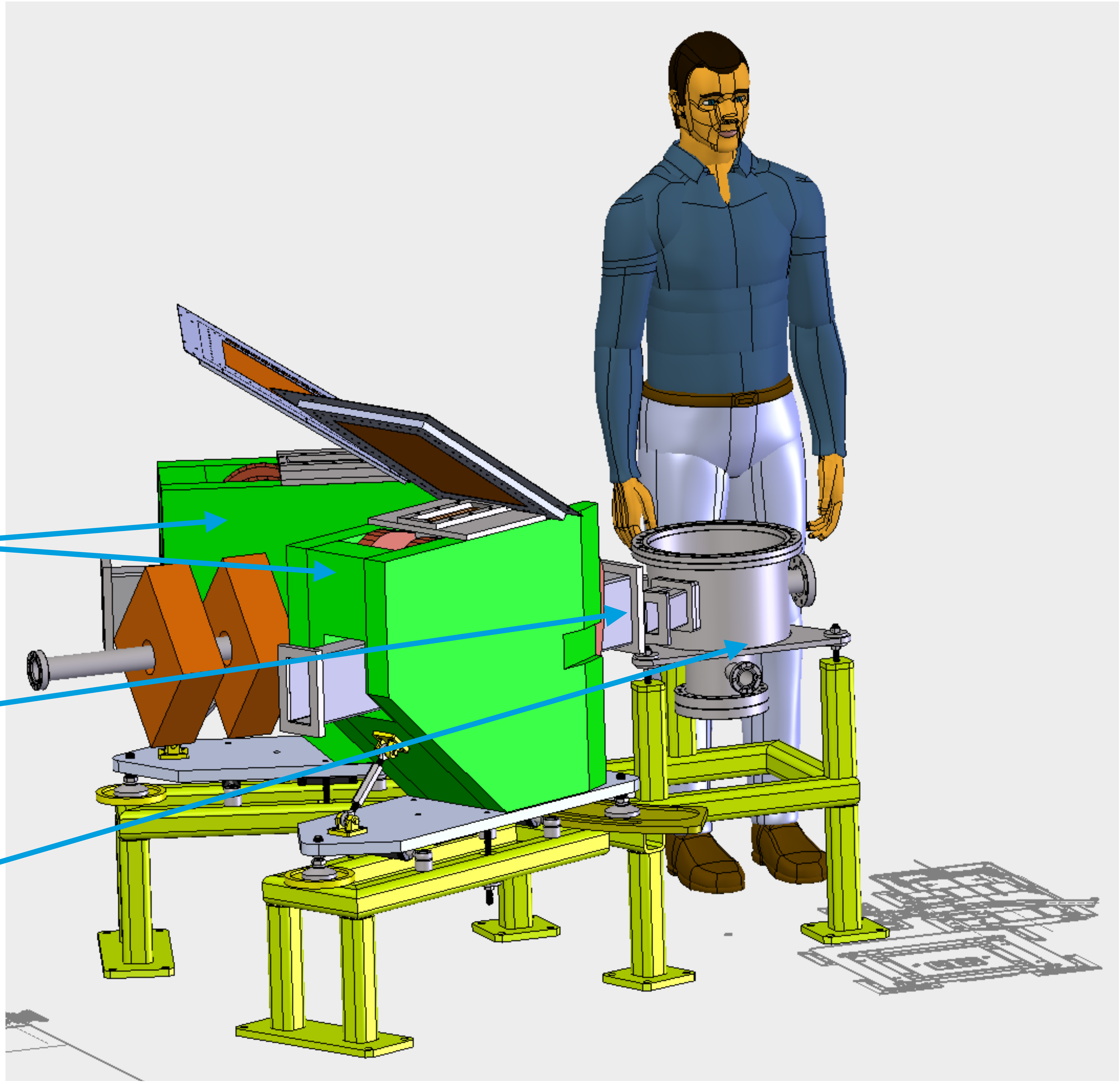

Dipole magnets

One fixed arm; one with two angles

Target chamber

Part of vacuum system

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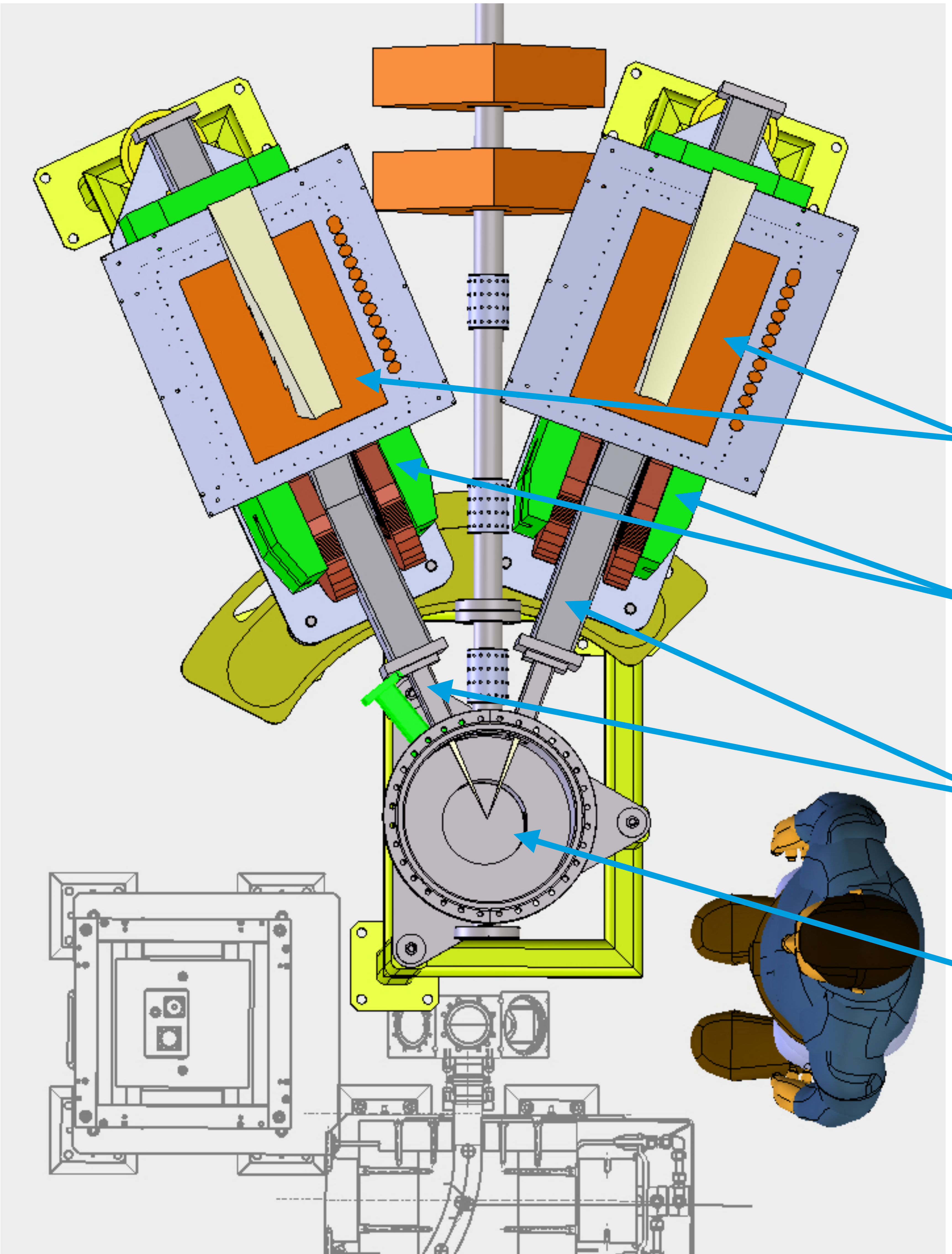

Tracking detectors

Dipole magnets

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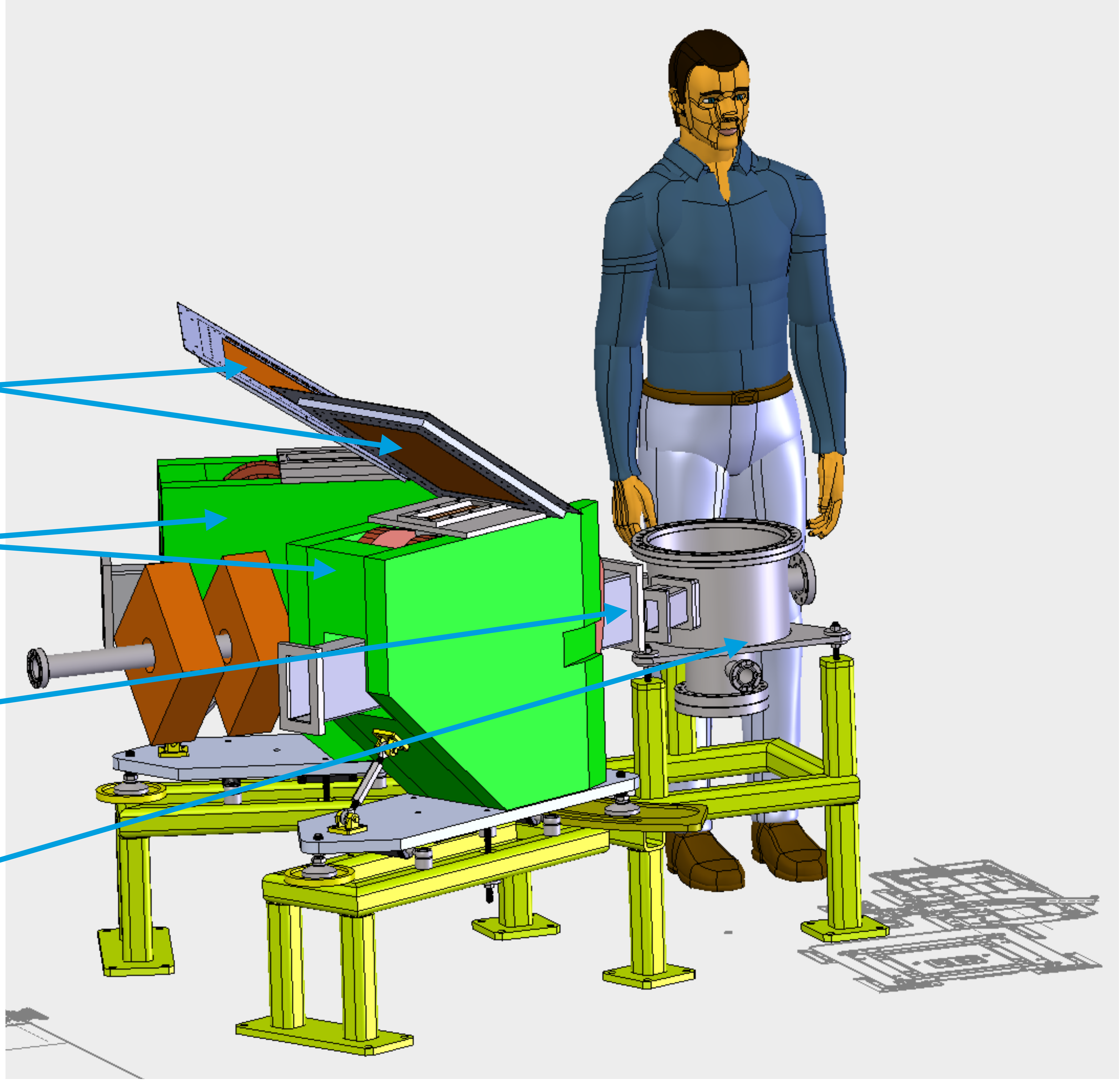

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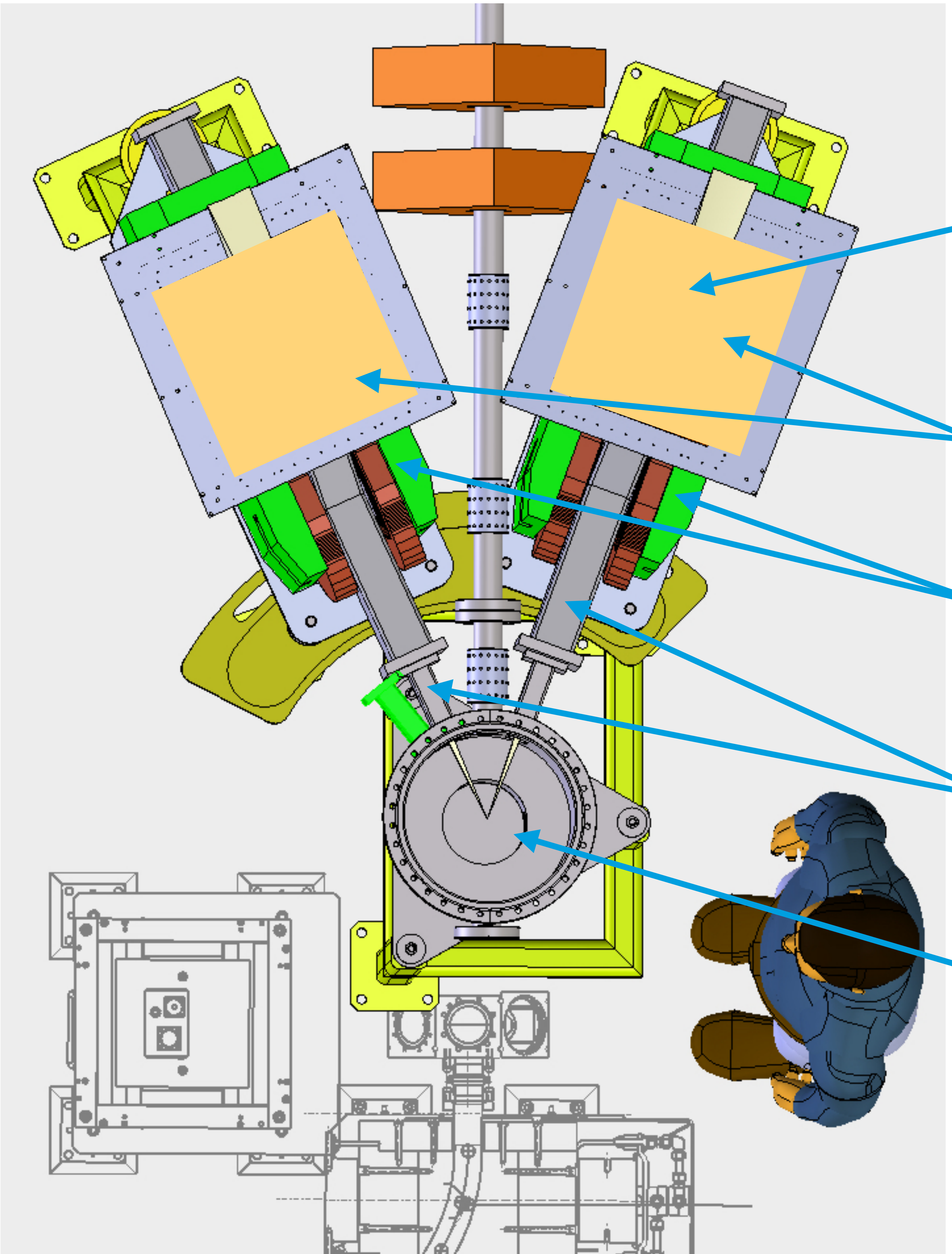

(Not in drawing)
Trigger detectors

Tracking detectors

Dipole magnets

One fixed arm; one with two angles

Target chamber

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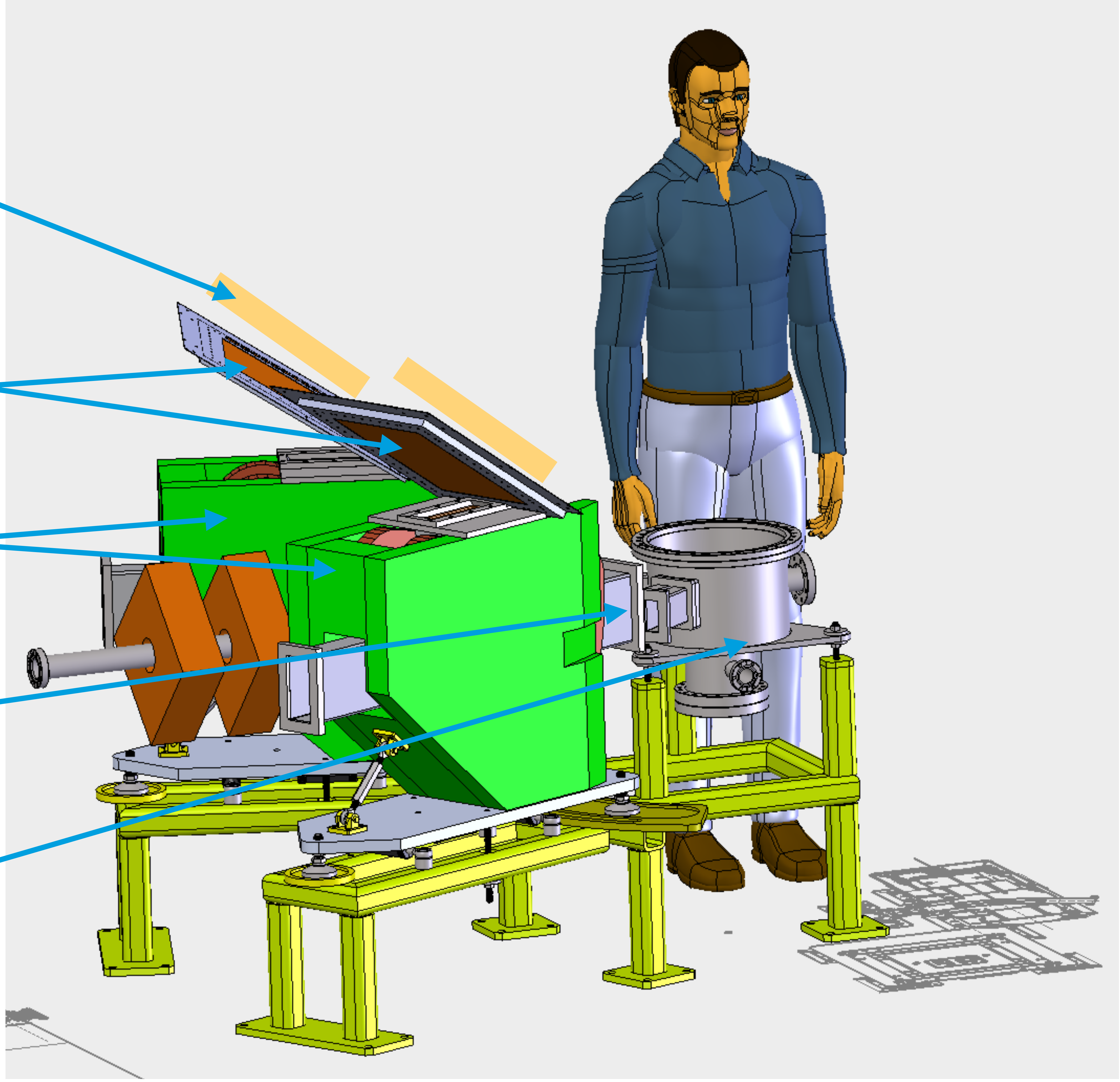
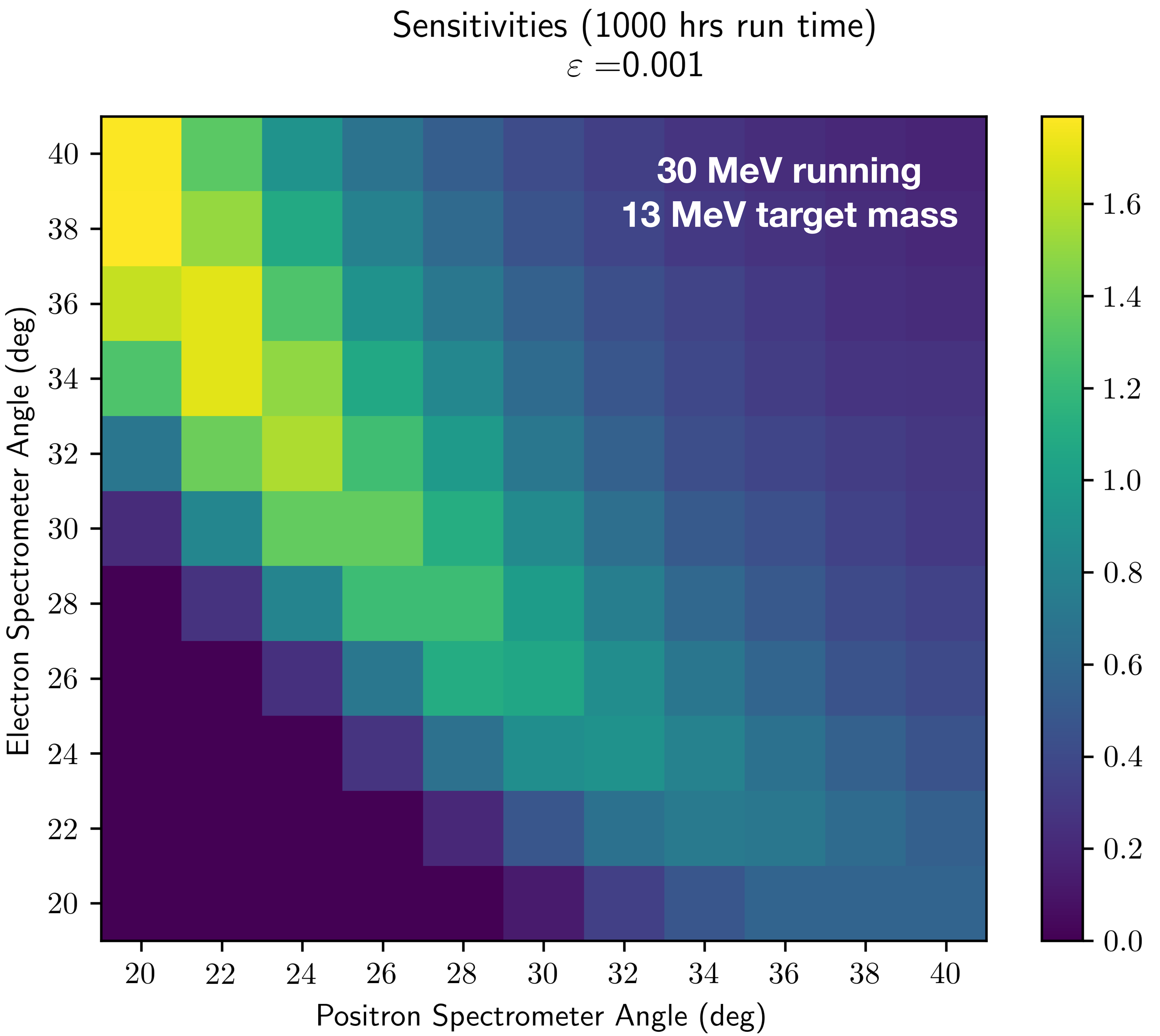


Physical constraints of experiment

- Sensitivity dependents on proximity of the positron spectrometer to the beam line.
  - This means that we need the first magnets as small as possible, hence pursuing a permanent magnet solution (see later)
- Second arm of spectrometer will be ~ 39 degrees for this experiment, with additional opening on target chamber for planned later 50 MeV run
- Additional constraint from need to shield electronics on both arms (see later)



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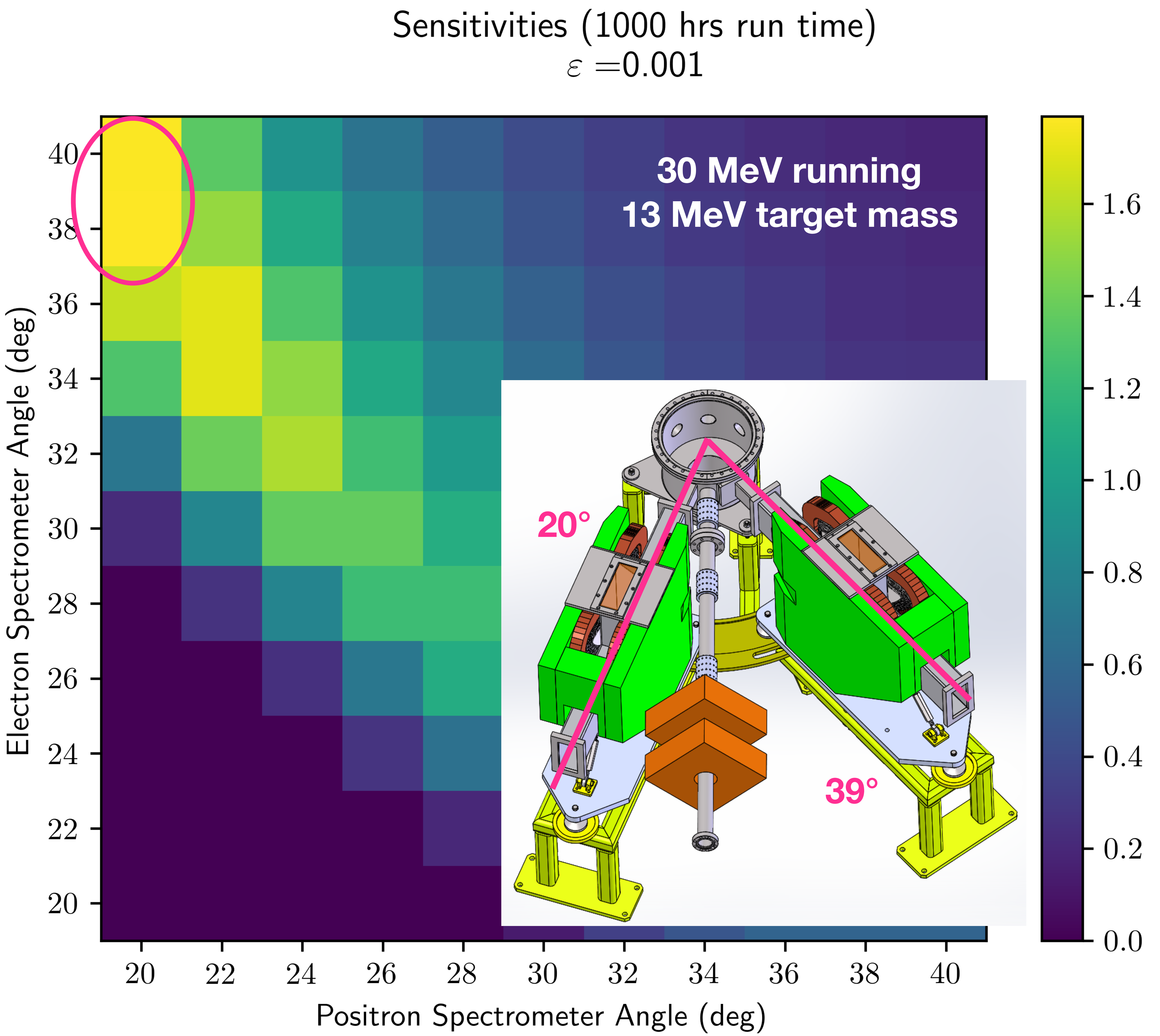


Target heating estimates

- Estimated amount of target heating using approximations available for tungsten (similar to tantalum)

- Found that for currents of 0.3 mA (larger than projected currents for 30 MeV running), spot radius 1.6 mm, and a 1 μm foil, temperature at edge of beam spot is ~ 600 C compared to tantalum melting temperature of 3020 C.

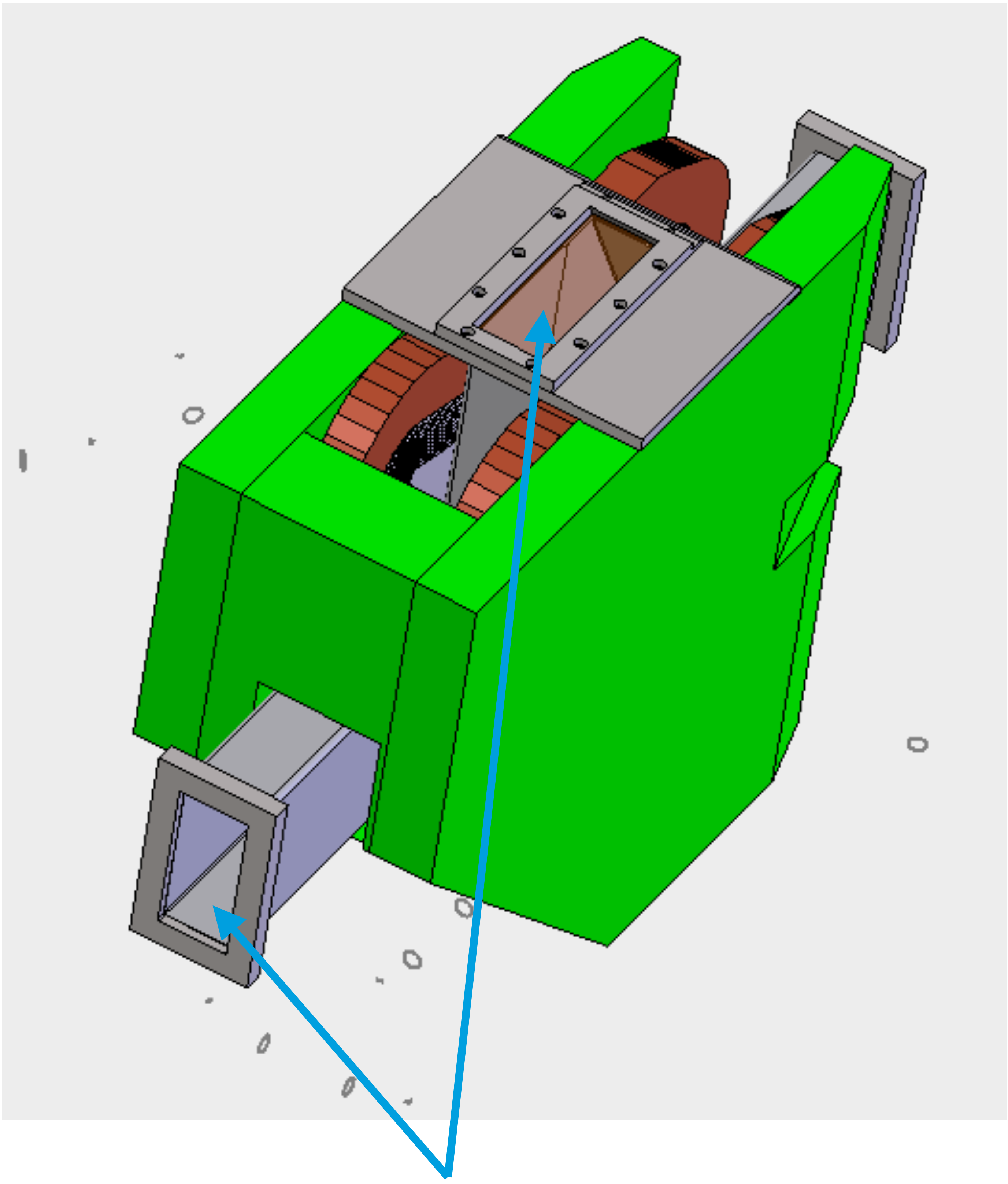
- This is for purely radiative cooling with no movement of the foil target

Bottom line: believe there is no likelihood of target disintegration due to heat with current design

- Foils are mechanically fragile, however: plan to study stability and backgrounds as a function of foil thickness, current, and beam spot size.

Vacuum requirements/compatibility

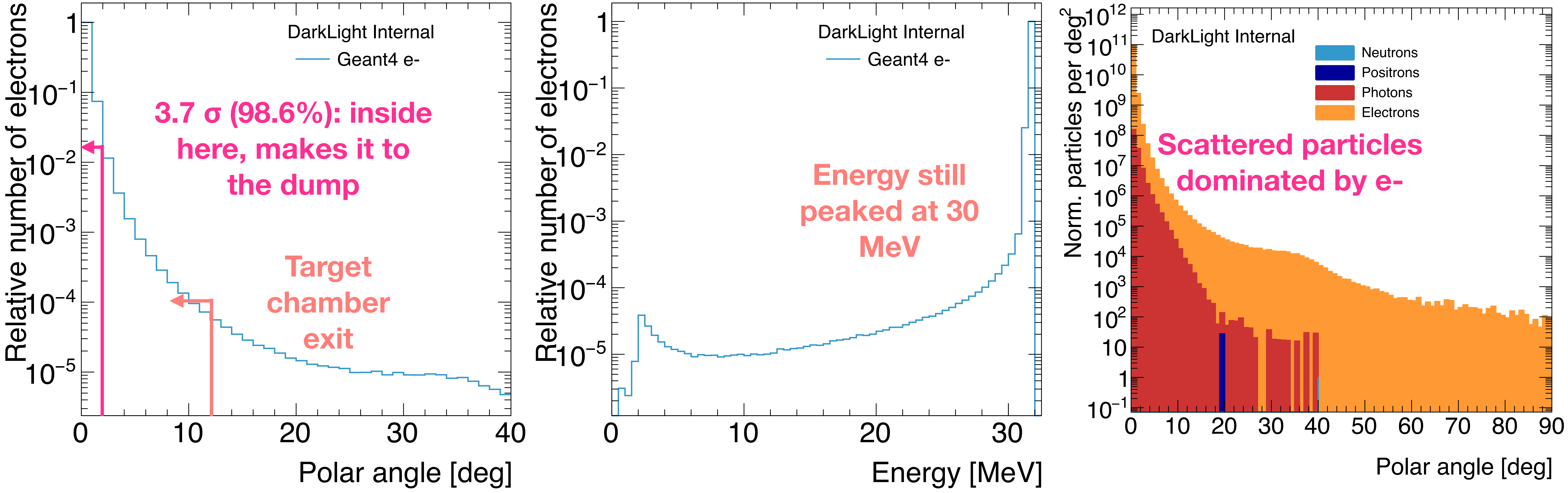
- Target chamber, arms, and inside surfaces of spectrometer magnets will be part of vacuum system
- Design established with intention of adding a pump underneath the target chamber
  - Compatible with turbo pump or NEG pump, happy to do either and open to suggestions from TRIUMF
- All surfaces except for windows out of spectrometers are standard (steel?) and MIT has worked with them many times before. Fine for vacuum to 10^{-9}.
- Windows out of spectrometer must be thin to minimise multiple scattering. Still debating exact material but most likely will use a thin piece of aluminum. Again, opinions welcome.



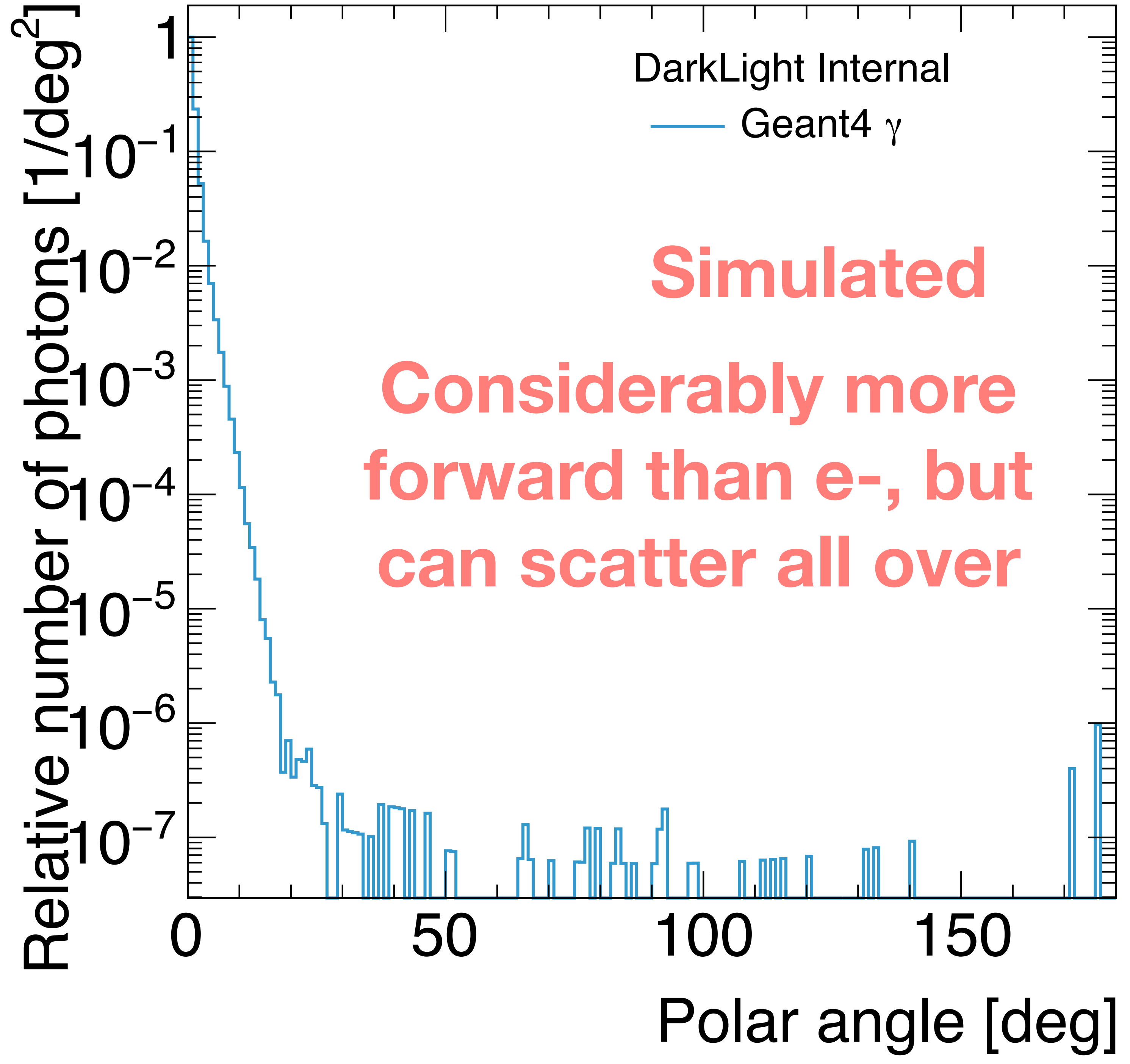
Beam spread from target

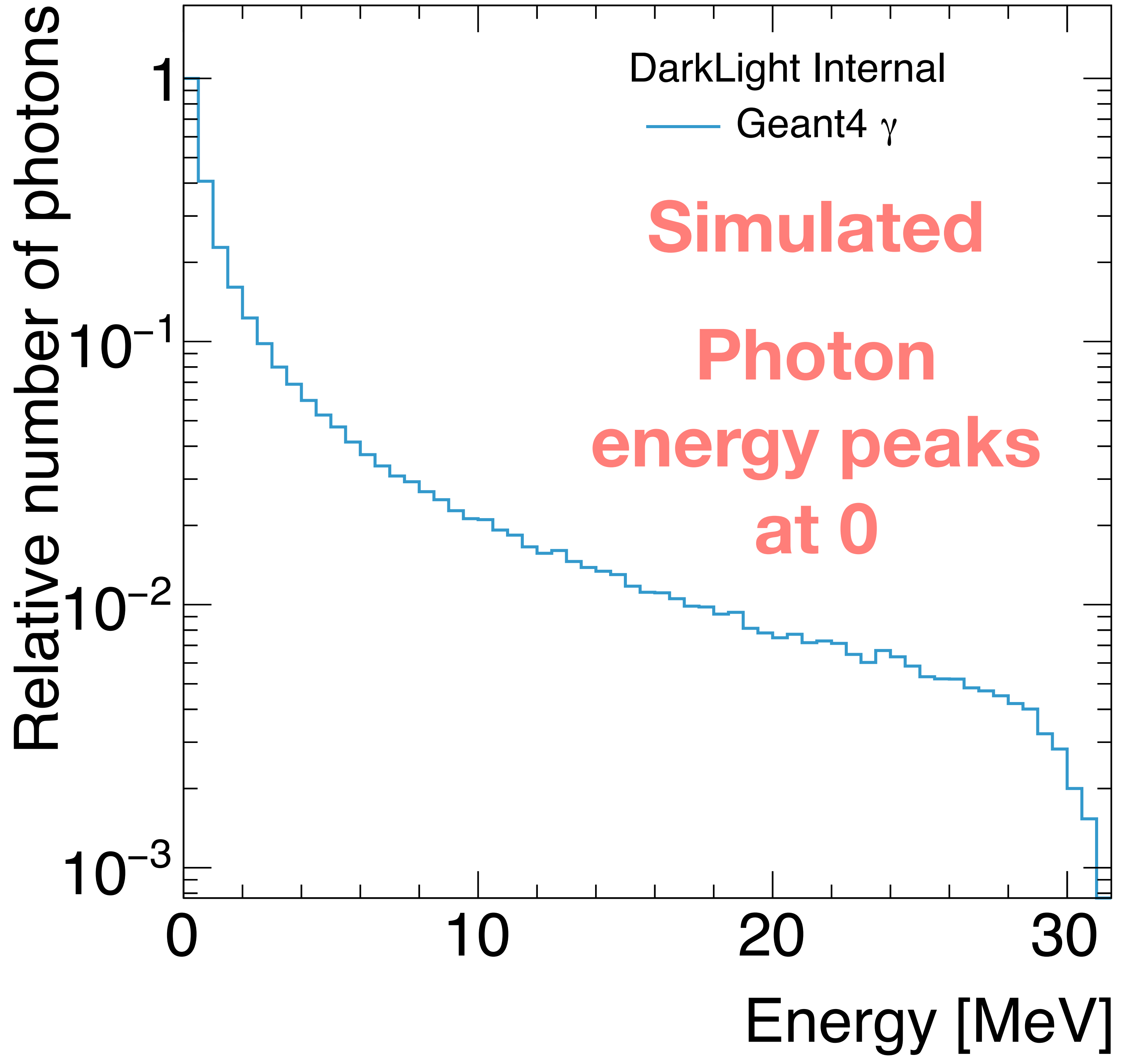
- Primary consequence of adding foil target is scattered electrons. Some will strike target chamber walls, others will make it into beam pipe but be lost before the dump.

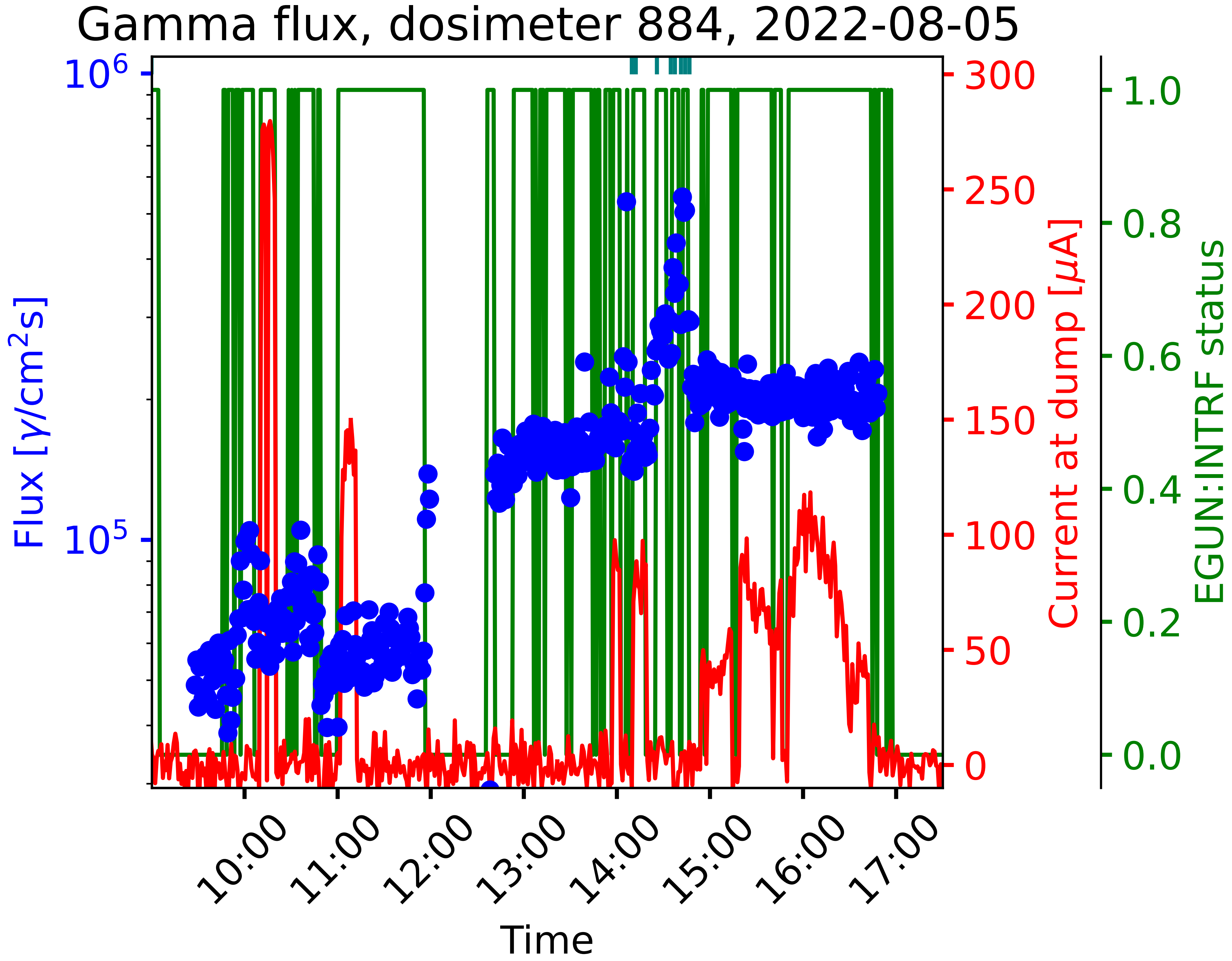
- **Very** basic Geant model gives some guidelines for what to expect: energies, angles, and rates



Other target radiation: photons







- Top right: measured photon flux ~1 m from target during August beam tests, estimated from dose assuming 1 MeV photons
- Also measured total dose immediately downstream of target: got ~ 100 Gy in 24 hours of running
- Ongoing measurements of photon flux near dump in absence of target as well

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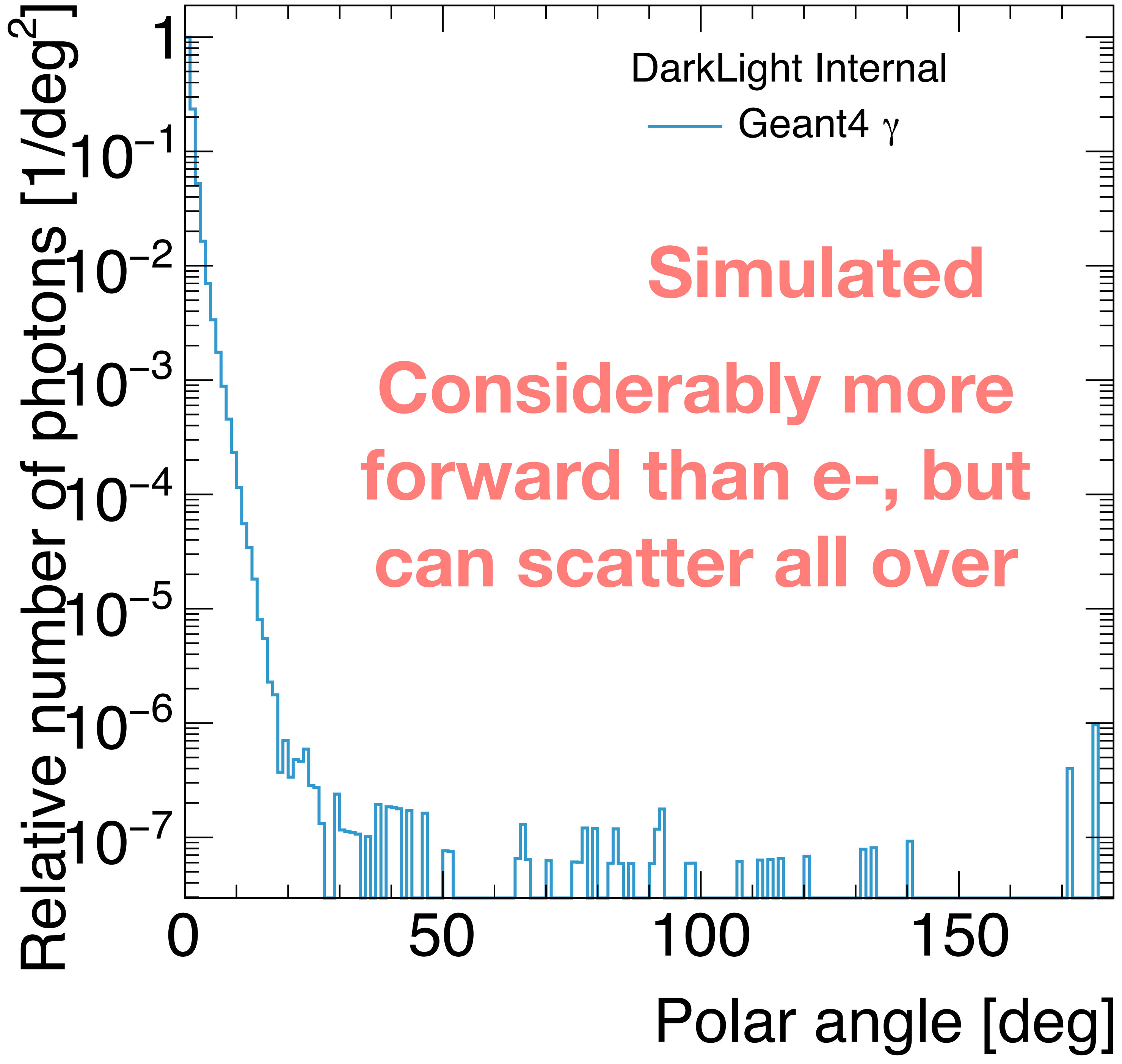

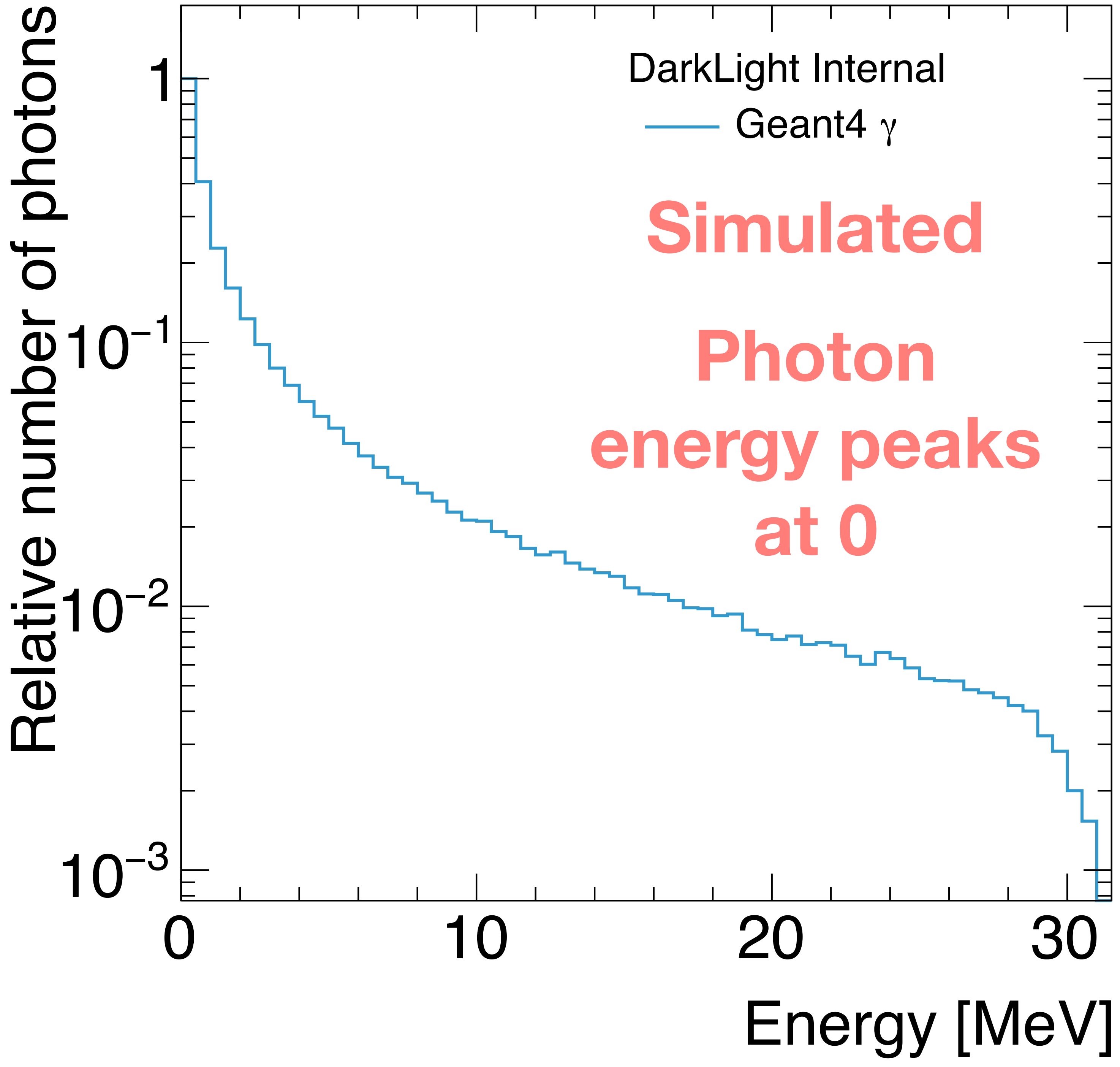

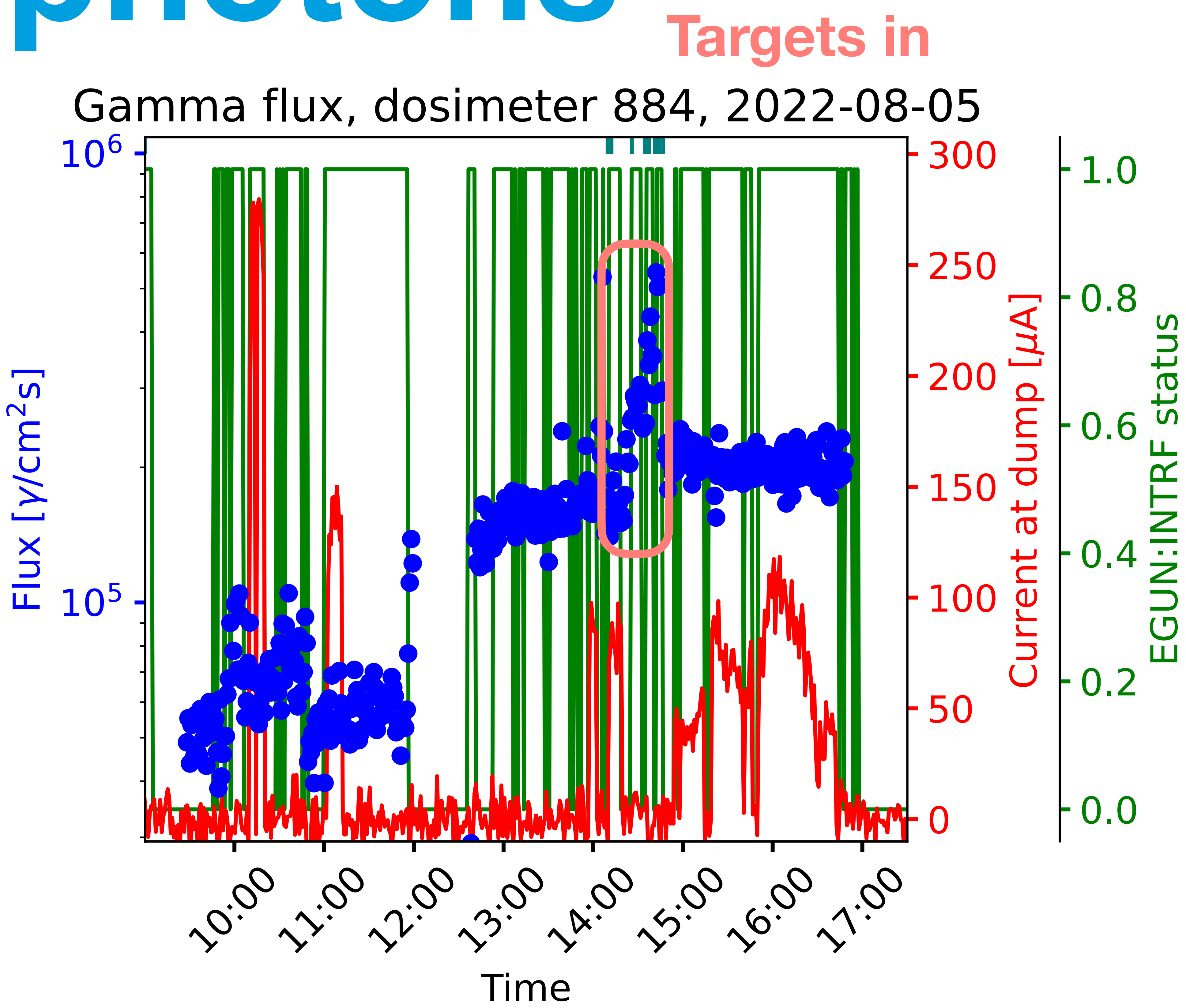

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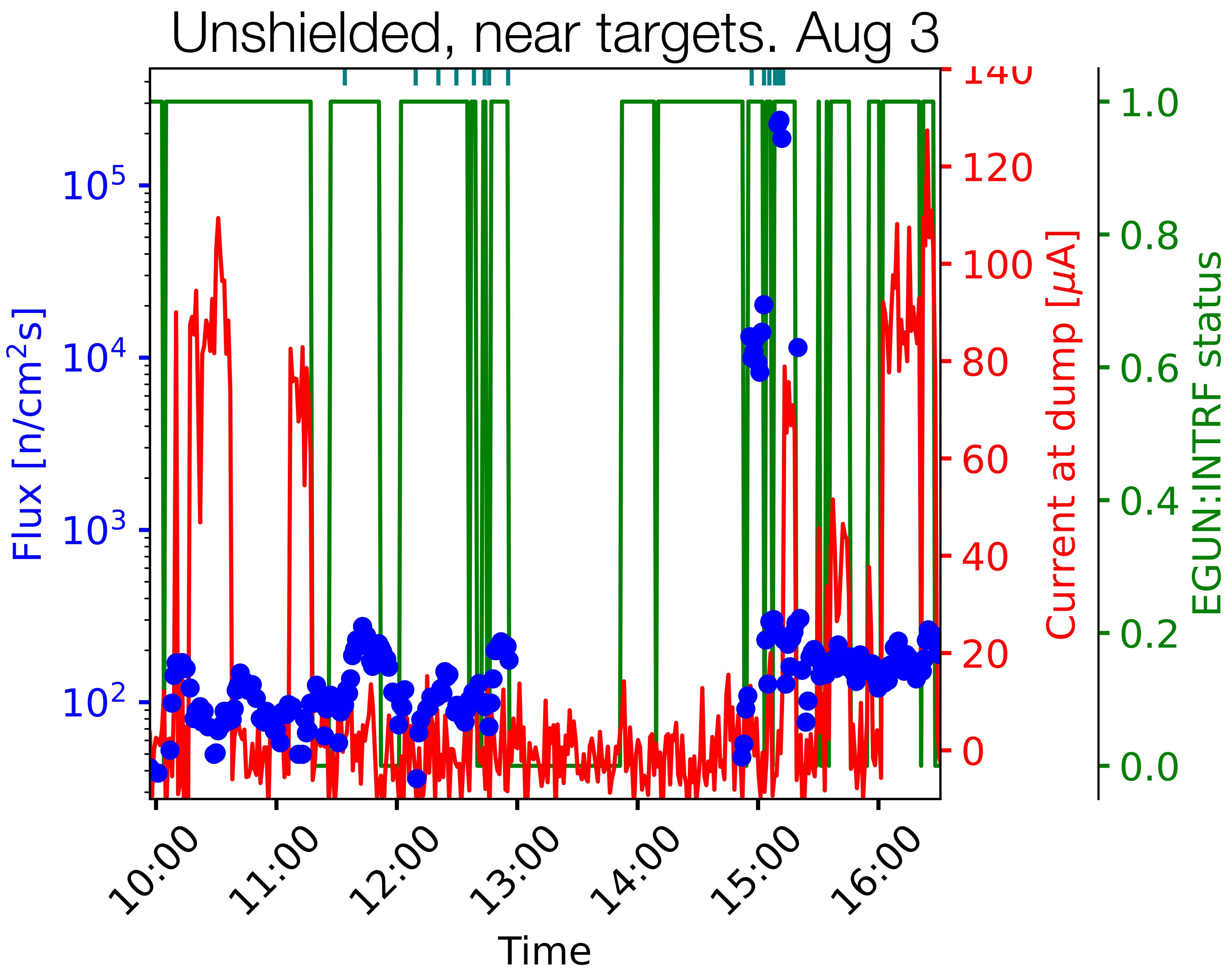
Neutrons in the hall

- No reliable simulation of neutrons right now (Geant is not great at this).
- Estimate shown in technical design report is 7.2 x 10^6 neutrons/s/MeV total at 150 μA current, with evaporation neutrons isotropic and direct emission forward-peaked
- Measurements made in e-hall with dosimeters during beam-on-target tests (again, 1 MeV used in estimate)



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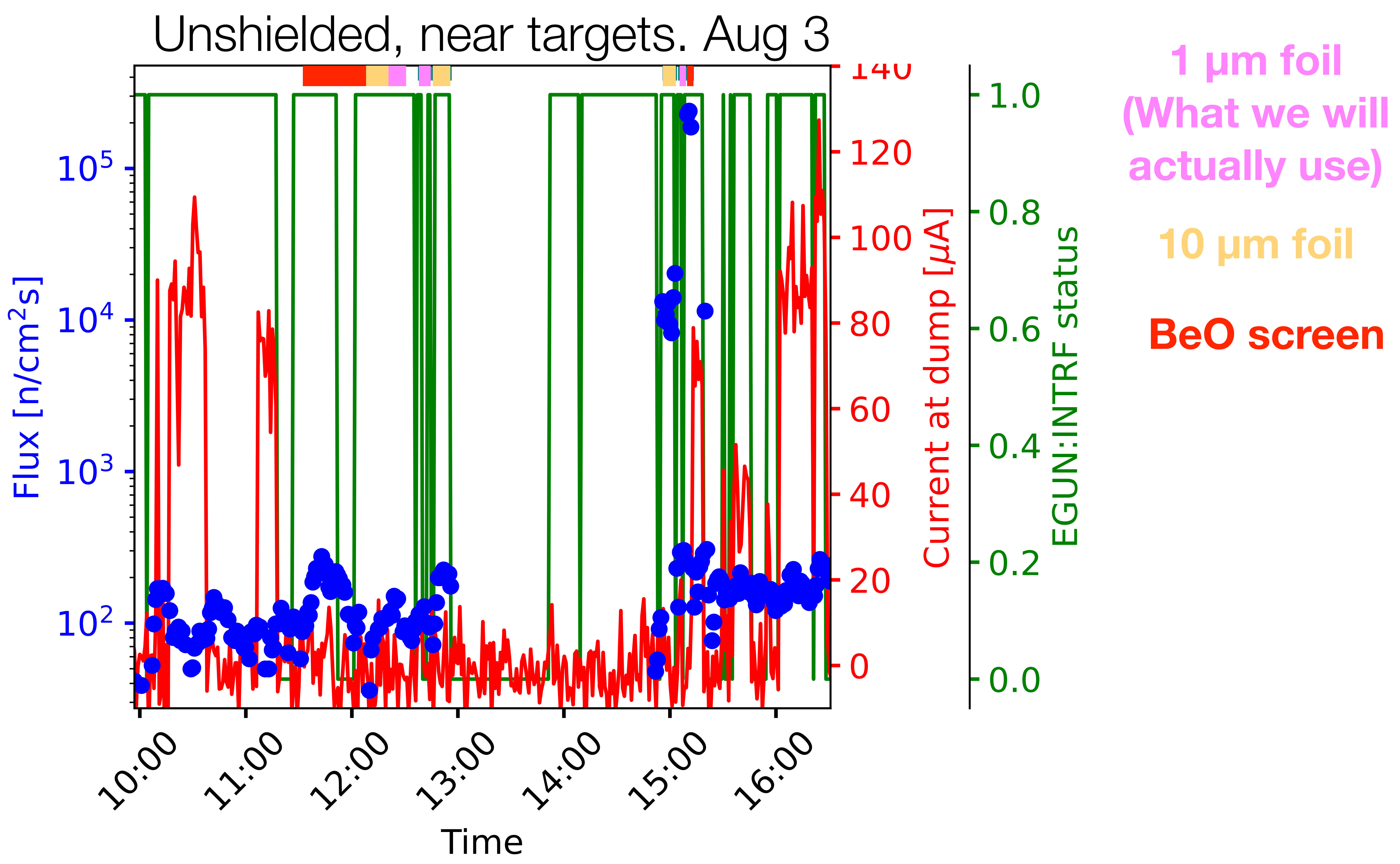

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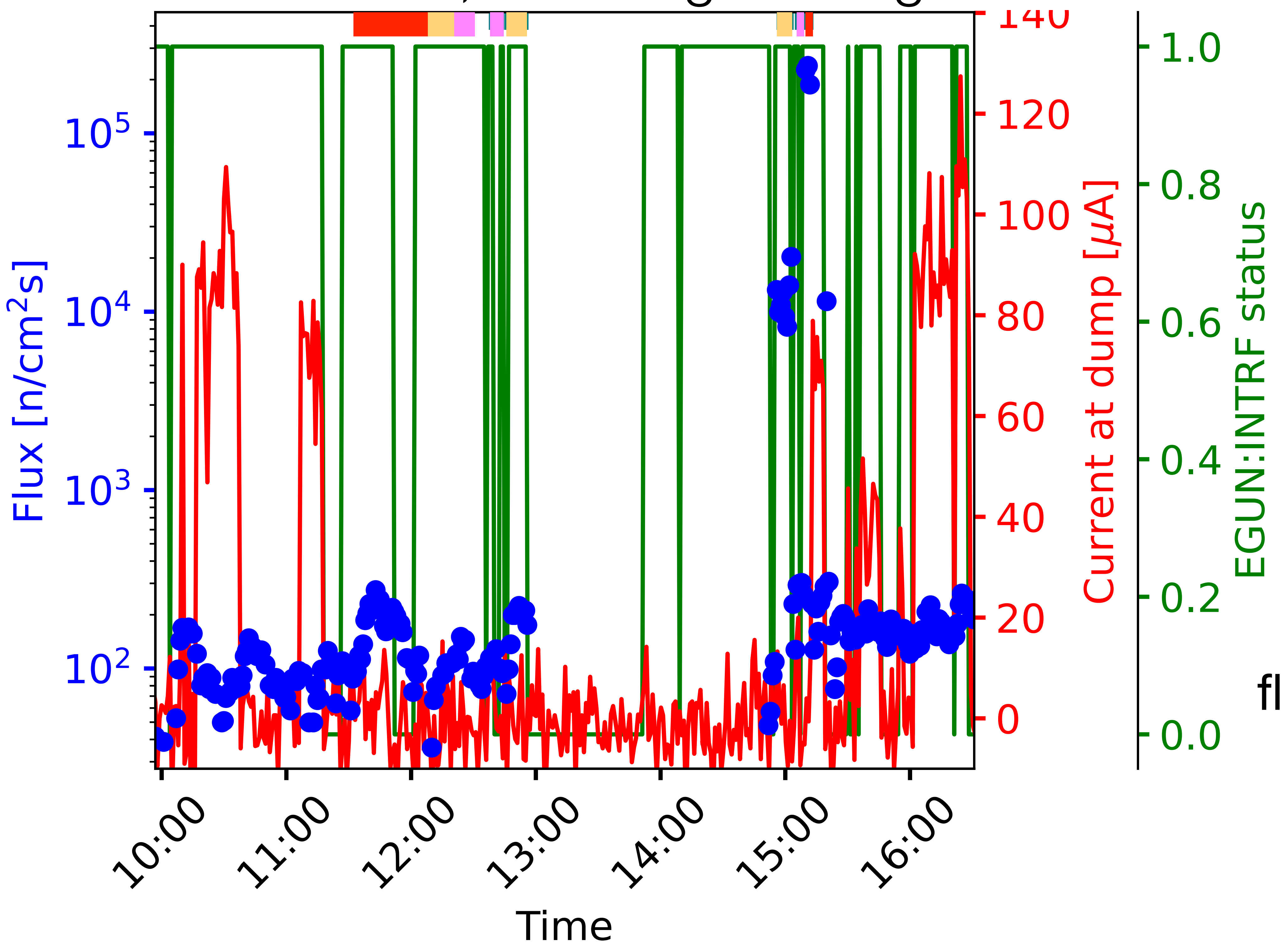
Unshielded, near targets. Aug 3



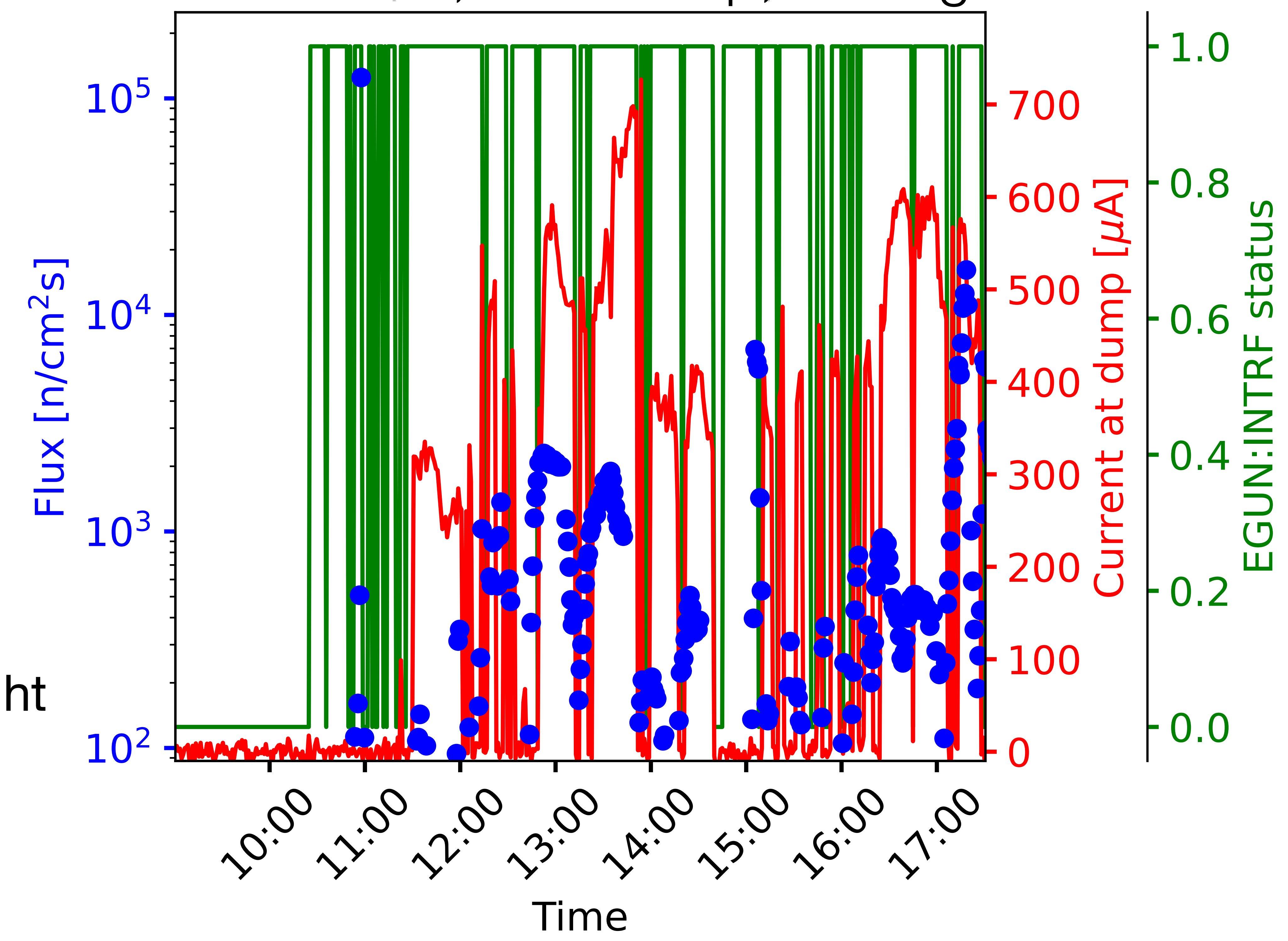
1 μm foil (What we will actually use)

10 μm foil

BeO screen

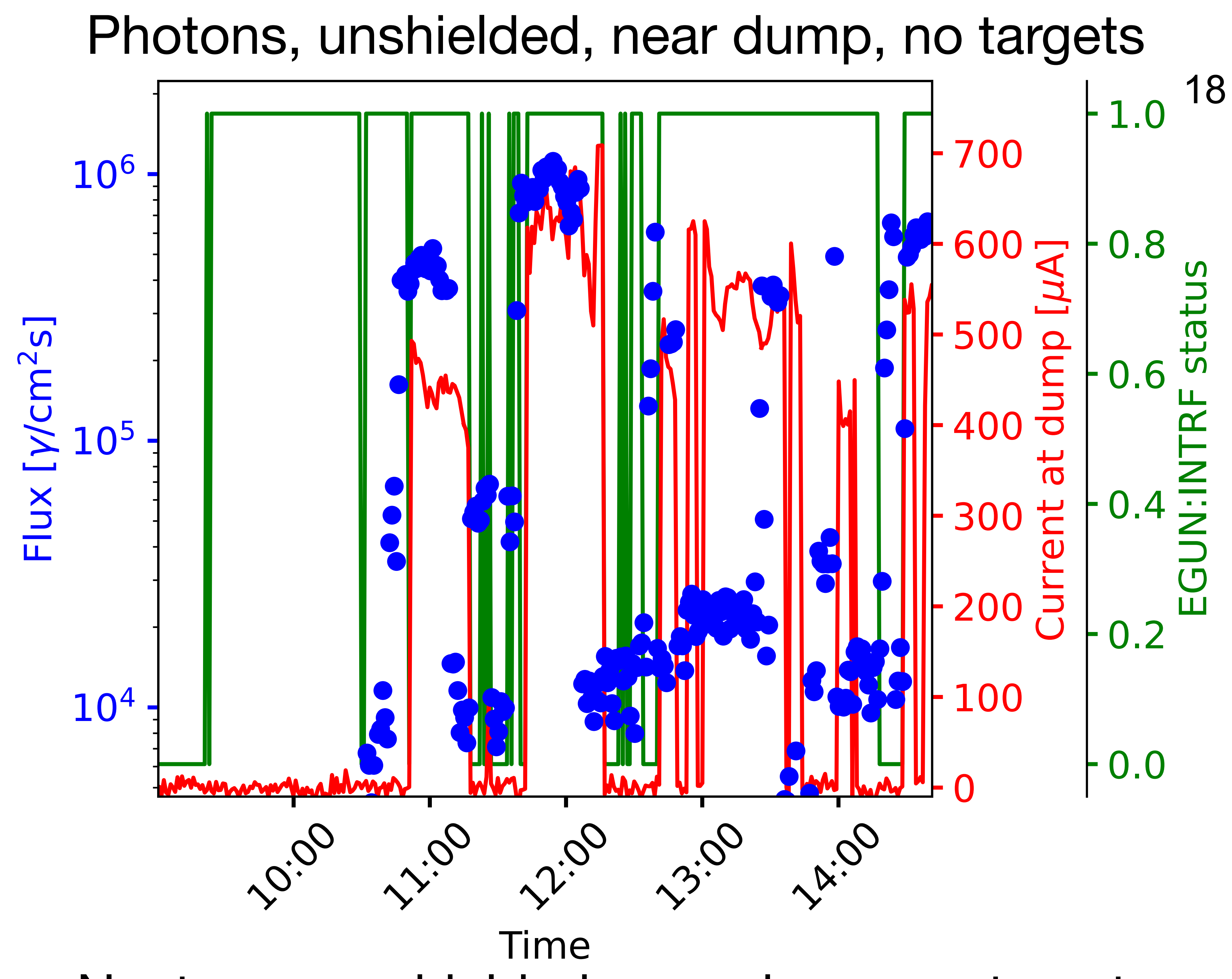
Hitting comparable fluxes in non-DarkLight running near dump already

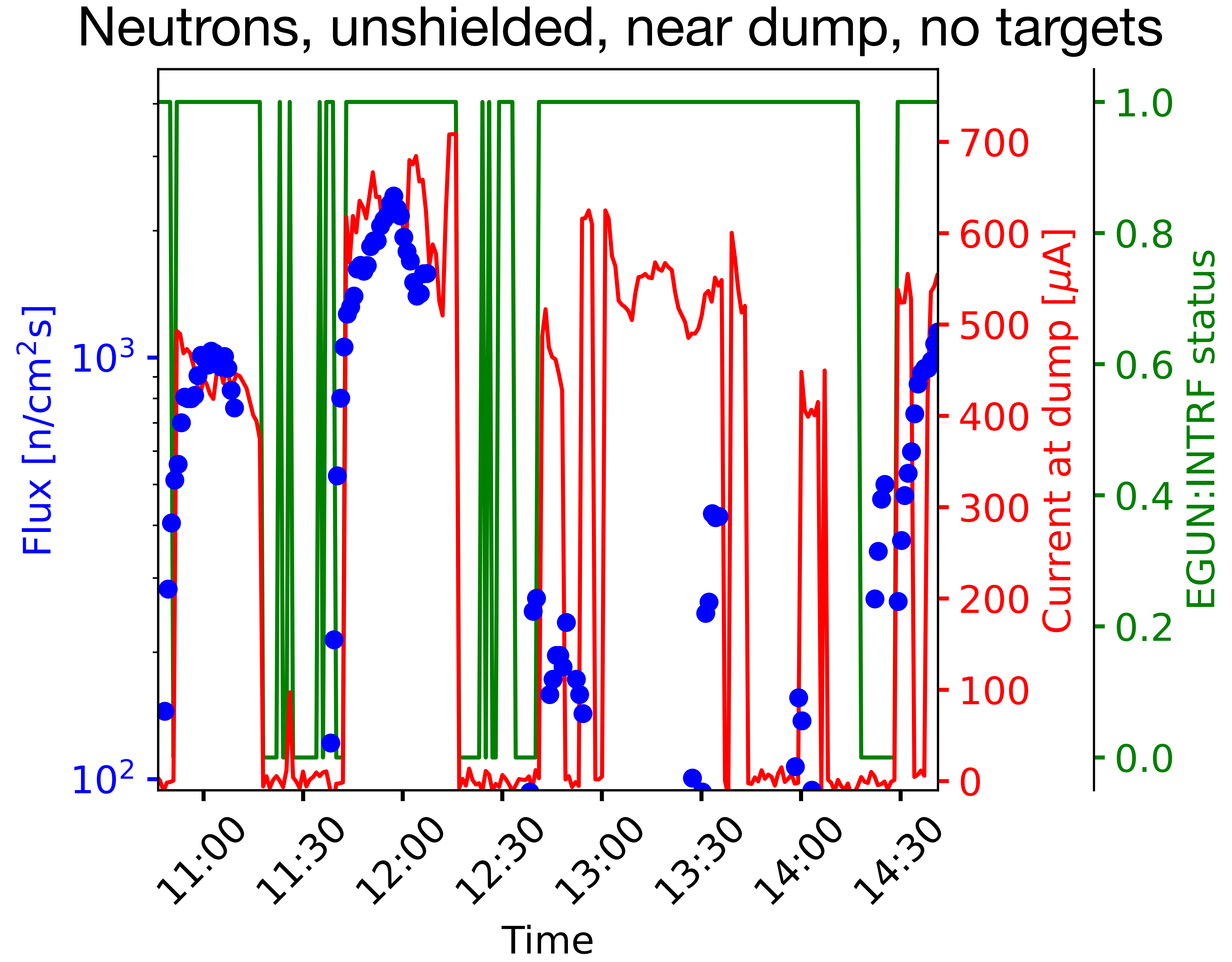
Unshielded, near dump, no targets. Oct 13



Non-DL radiation in the e-hall

- Considerable gamma ray backgrounds from e-linac itself without any DarkLight target present
  - Radiation from RF cavities significant: observed sizeable fluxes even with beam off
  - Is this something we can work to reduce? In the meantime we will likely need to account for it with shielding
- Also dealing with effects of particles scattering back from beam dump
- DarkLight team has experience with similar backgrounds from earlier tests at JLab, but big question for team is how to protect against this
- Big question for lab is is: to what extent does DarkLight actually make radiation in the e-hall worse?



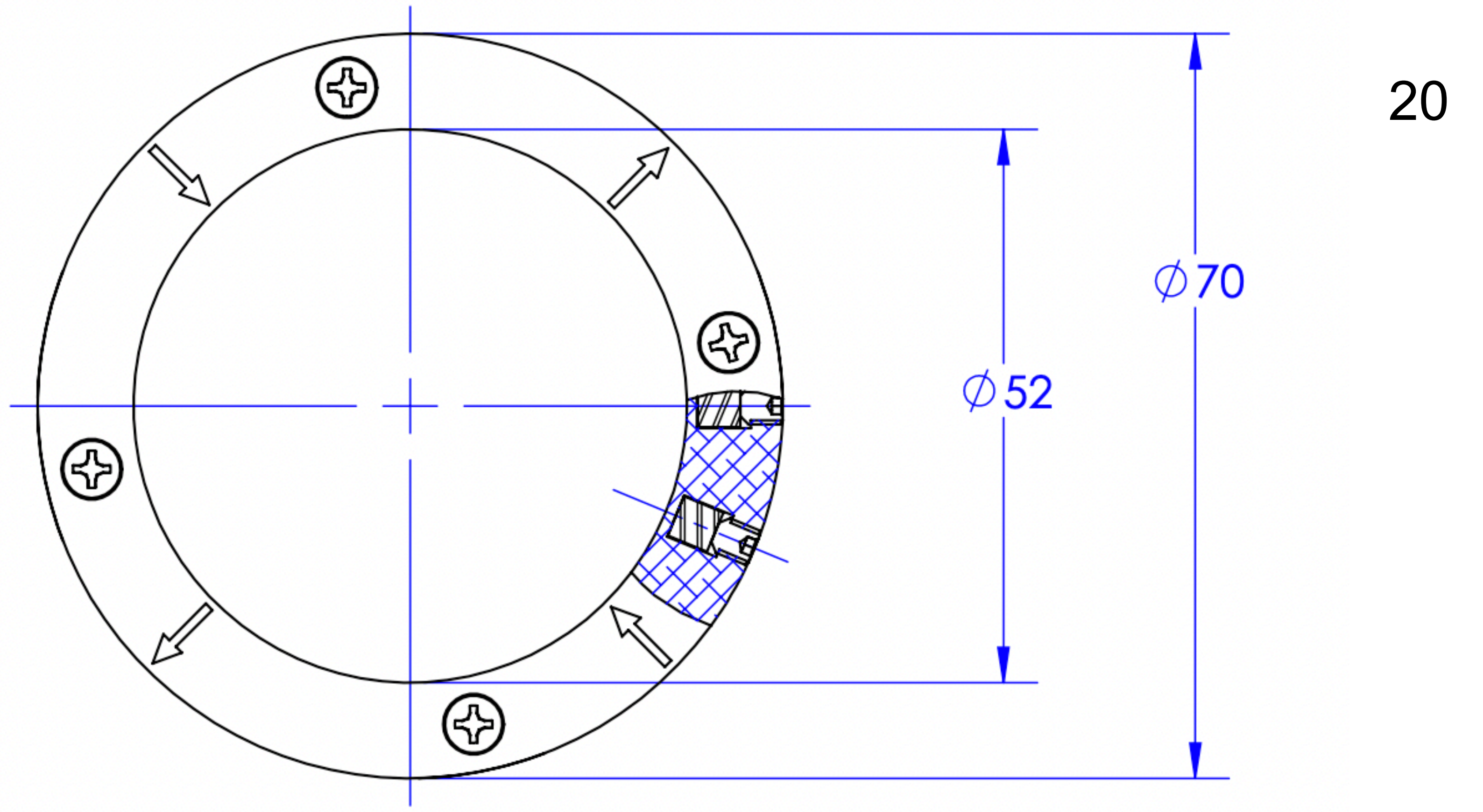


Shielding modifications

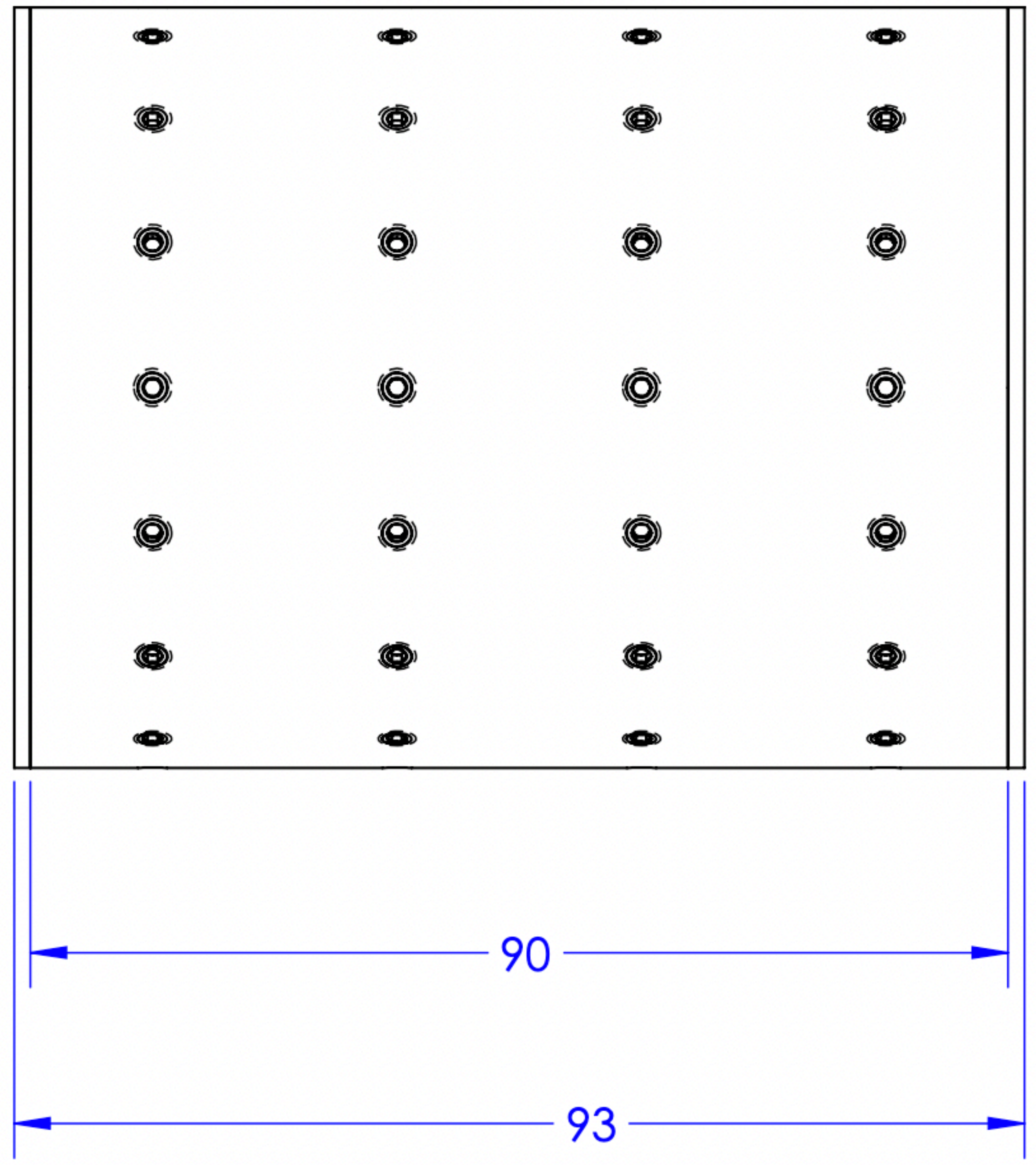
- Two shielding goals:
  - Protect sensitive electronics & detectors from radiation (target & other e-linac sources)
  - Protect e-linac and permanent magnets from additional radiation caused by target
- Read-out and trigger electronics must be ~on detector. Now working on design for shielding box - not sure yet if 1 or 2 boxes is better.
- Will need to move existing neutron shielding
  - Can we repurpose it into thinner layers surrounding experiment?
- Working towards more detailed understanding of radiation from experiment. Aveen will begin work on a FLUKA model in early November.
  - Need help from FLUKA expert - are we hiring one?
  - What are the deliverable numbers we need to produce? What is the level of detail required of the model

The permanent magnets

Units in mm



- First 3 of 5 quads will be permanent magnets to satisfy radial space constraints
- Quote obtained from SABR for three magnets: 0.3 T each, made of SmCo2:17, total outer diameter 7 cm
- A couple consequences of using permanent magnets: location and orientation must be fixed on beam pipe, and magnets must be put on before flanges
- Also can be demagnetised by high magnetic fields or lots of photon radiation
- Nearby magnetic fields e.g. stray fields from dipoles very low: no concern
- Gamma radiation: here, anticipate likely need to shield first magnet. Hope to make design with space for small lead shield around magnet.



Integration into TRIUMF ecosystem

- Want DarkLight to work as seamlessly as possible with existing TRIUMF apparatus
  - At least target ladder, possibly magnets must be added to controls
  - Shielding modifications require approval and license update
  - Vacuum needs to match e-linac specifications. All can be built to required standard and fully tested at Bates before shipping
  - Re-cleaning of components will have to be done at TRIUMF so will need to be able to disassemble everything
- Team has experience running EPICS from MUSE, Olympus, and earlier iteration of DarkLight
- What else? What affects **planning** stage and not just **installation** stage?

Conclusion and thanks

- We didn’t talk much about the science or experimental challenges today, mostly about implementation challenges and how the experiment will affect TRIUMF and the e-hall

- Want to emphasise, though, that we are really excited about this and really excited for the way so many different people and groups at TRIUMF will contribute to making this cool project possible

- Thank you for lending your time and expertise to making fundamental science at TRIUMF happen

- We really appreciate it and you!

Now, how do we move forward?

- Some interplay between experiment designs and all these other questions. E.g. if we need significant shielding around first quad and/or beam pipe (in case of worries about activation or whatever) this could affect angles of spectrometers which affects chamber construction

- Need input from accelerator people on e.g. collimator design

- Who approves drawings before we build? Anyone? How do we submit them for that?

- What are checkpoints between here and a Gate 2/3 review?

- Any points we have not foreseen that you're aware of?

TRIUMF

Thank you
Merci

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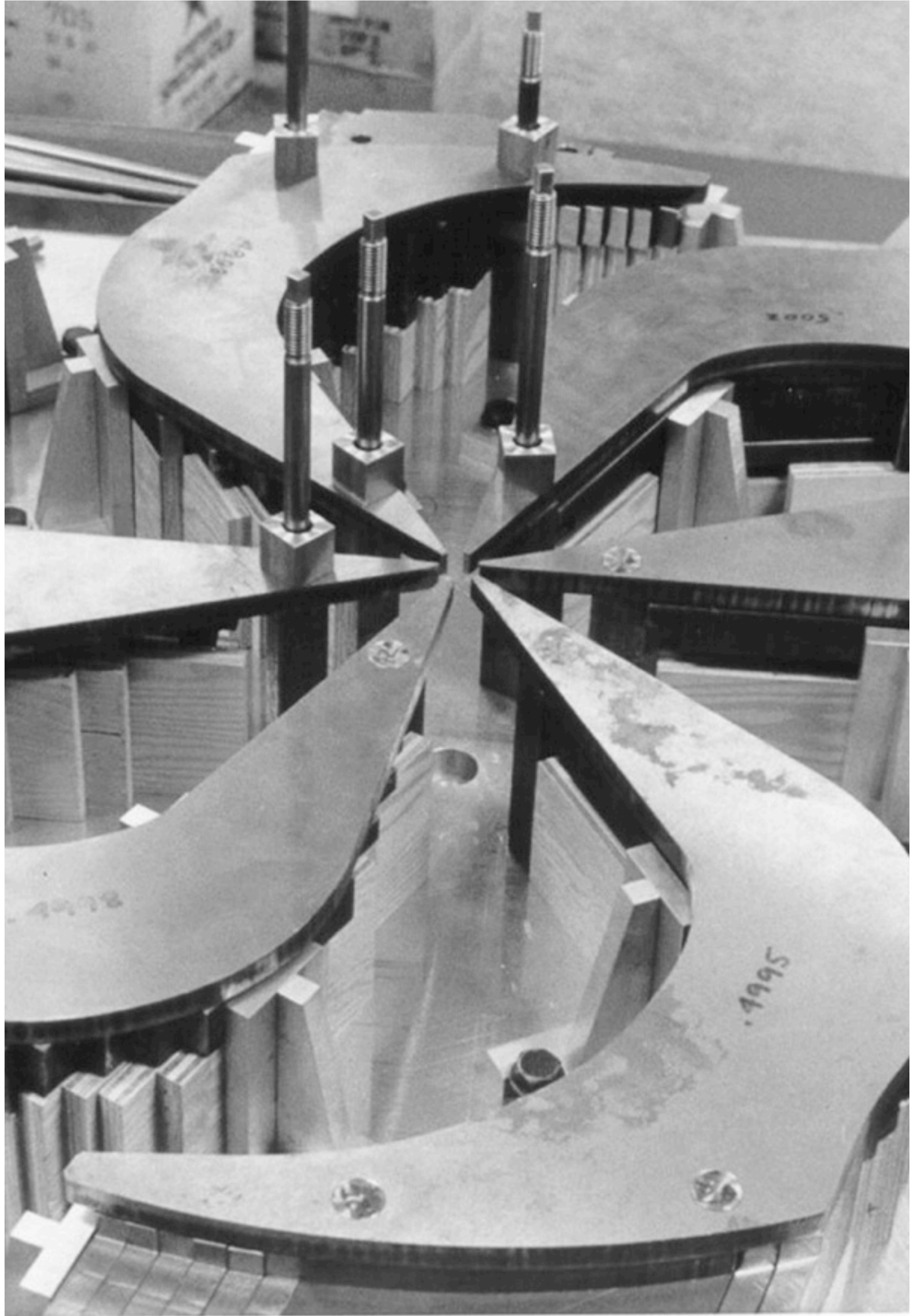

Discovery, accelerated