# 20 MeV electrons and bremsstrahlung at Turkish Accelerator and Radiation Laboratory

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**Turkish Accelerator and Radiation Laboratory**

**09.10.2025, NP2025, Darmstadt**

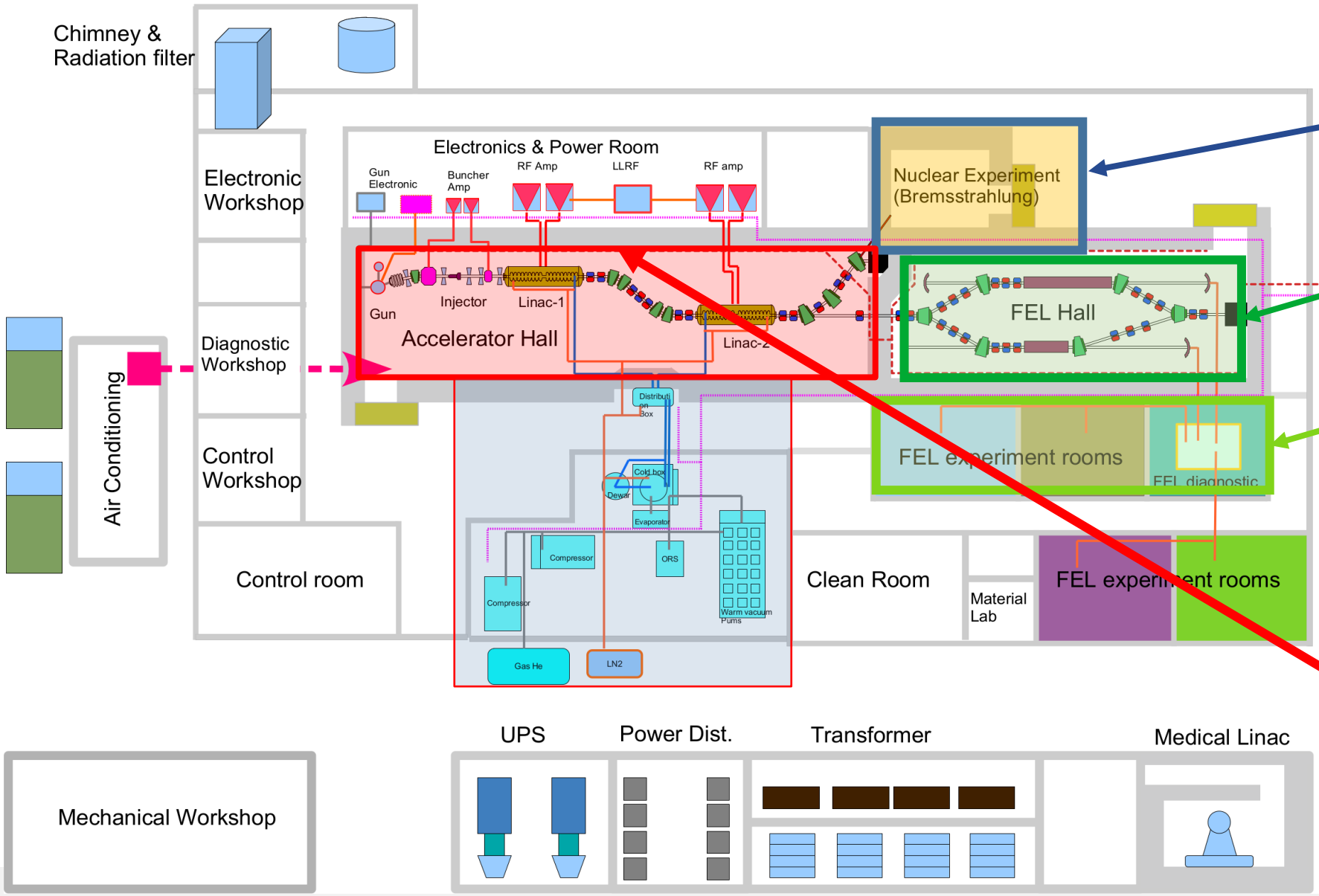
TARLA

# Turkish Accelerator & Radiation Laboratory (TARLA)


- Located at the outskirts of Ankara (Turkey) about 15 km south of the city center
- Founded as a part of Ankara University, but granted independent status as a National Laboratory as of 2021
- Main goal is to construct an superconducting electron linac to use for nuclear and radiation physics as well as to generate a Free Electron Laser(FEL)
- TARLA is intended as a user facility welcoming researchers from all over the world
- one half of LINAC has been completed giving 20 MeV(18.6 MeV exactly)
- The other half is set to be completed in early of 2027, the Gamma experimental station in summer/fall 2027, FEL in 2028 and the first FEL experimental stations to be put in use in 2029
- The first beam time applications for nuclear and radiation physics are planed for spring 2026

# TARLA view

# TARLA Electron Linear Accelerator




**Nuclear Experimental Station**

**FEL**

**FEL Experimental stations**

## TARLA Linac

$E_{beam}$ = 0-40 MeV

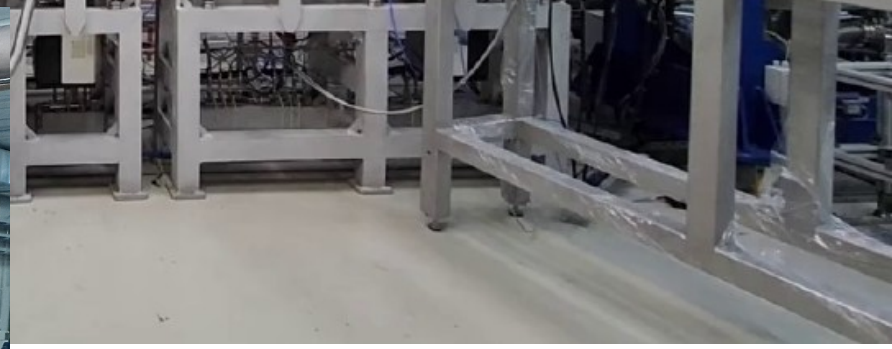
Max $I_e$ = 1.5 mA

Micropulse duration = 0.5-6 ps

Micropulse repetition = 26 MHz/$2^n$

$E_{bremssrahlung}$ = 0-30 MeV

# Beamline (15/06/2025)

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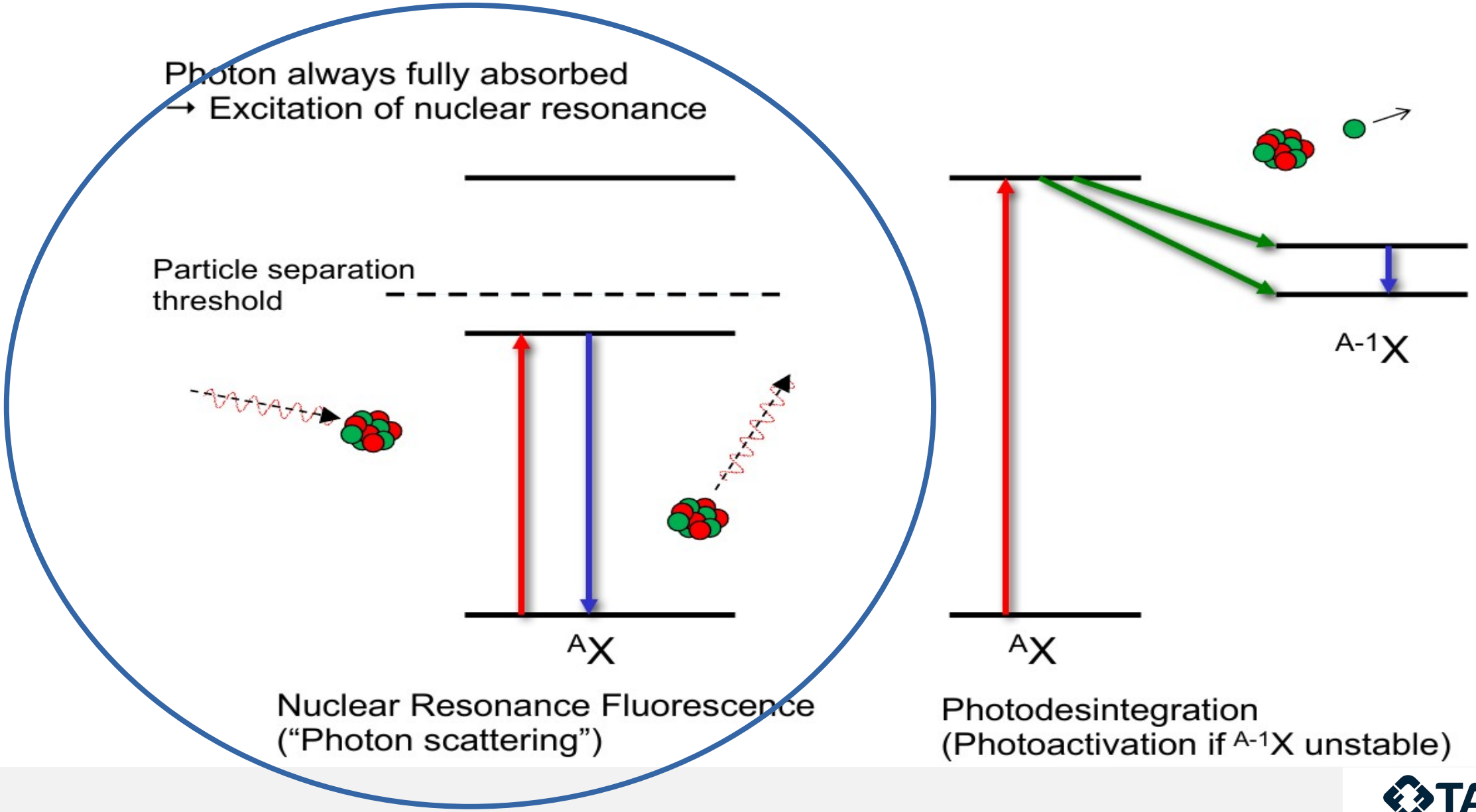
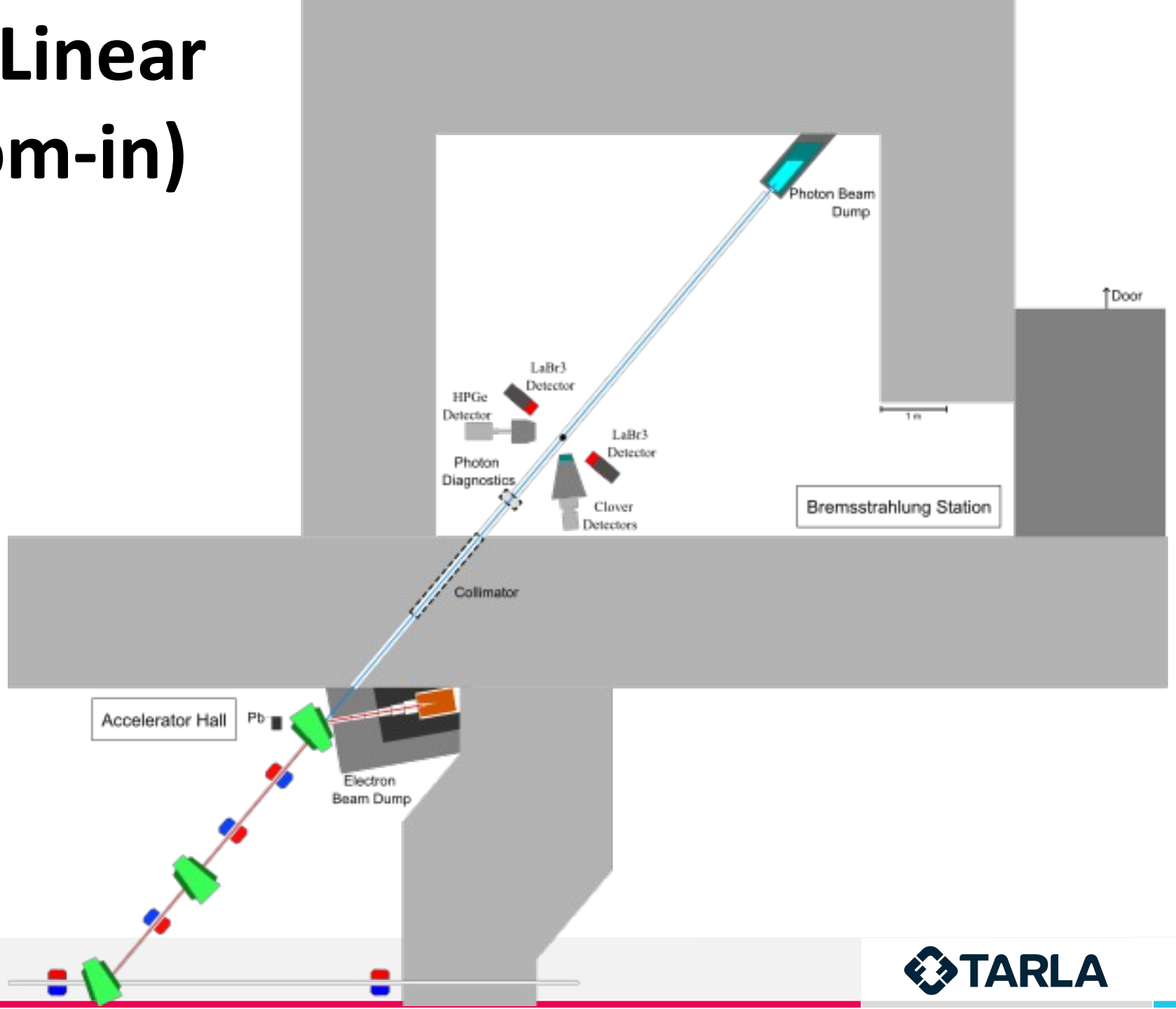
# Photonuclear Reactions



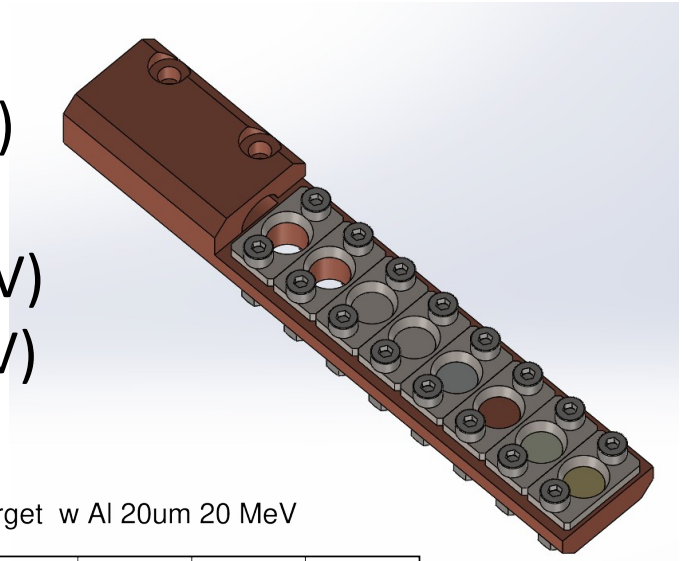
# TARLA Electron Linear Accelerator(Zoom-in)

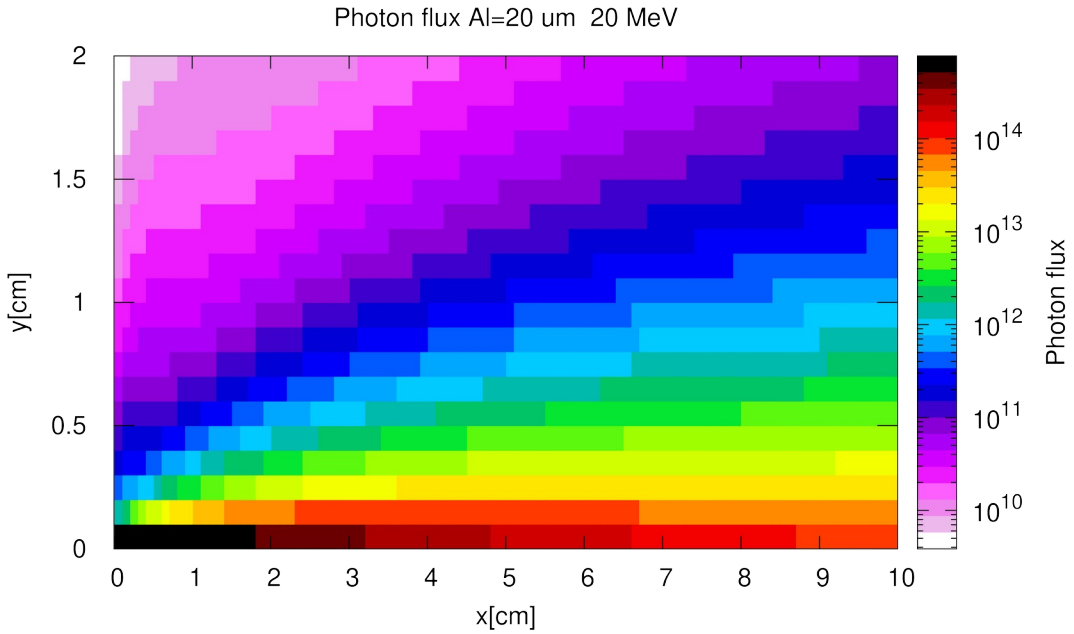


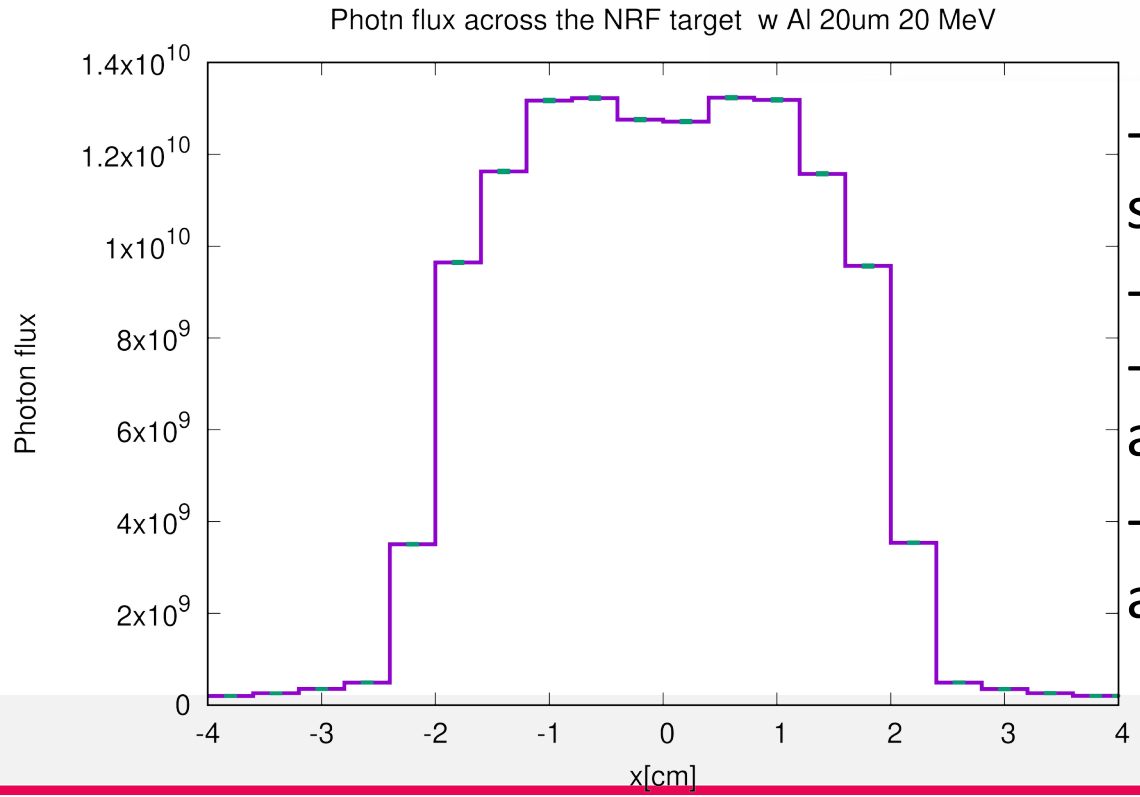
# Conversion (Bremsstrahlung) Targets

Four/Five targets:

- 1 µm of Au ($S_n$ ~8 MeV)
- 1 µm of W ($S_n$ ~7 MeV)
- 6 µm of Cu ($S_n$ ~10 MeV)
- **20 µm of Al** ($S_n$ ~13 MeV)
- *40 µm of Al*






- Photon flux at the NRF target is more than sufficient at ~$10^{10}$ Photons/(cm$^2$ s)
- spot size of R=1.5 cm and a shadow of 0.75 cm
- HPGe detectors have to be placed in the backward angles
- $LaBr_3$(Ce) detectors can be placed in the forward angles

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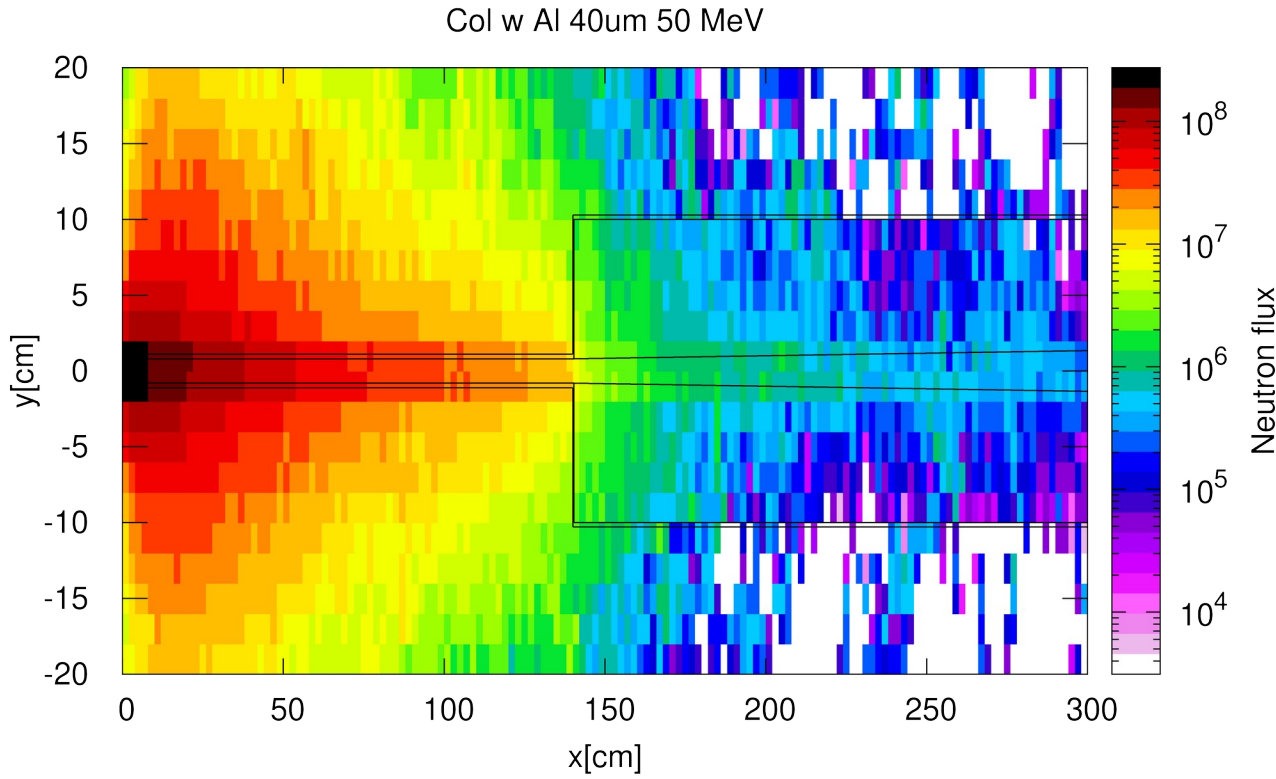
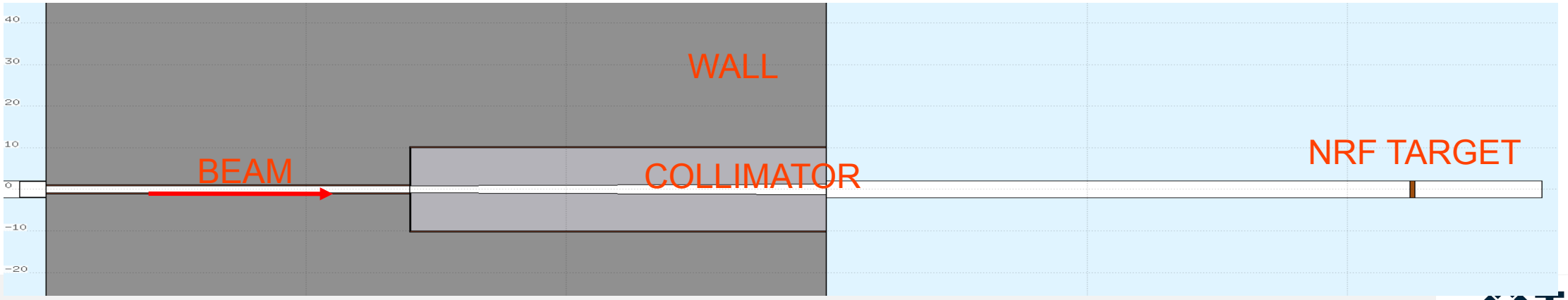
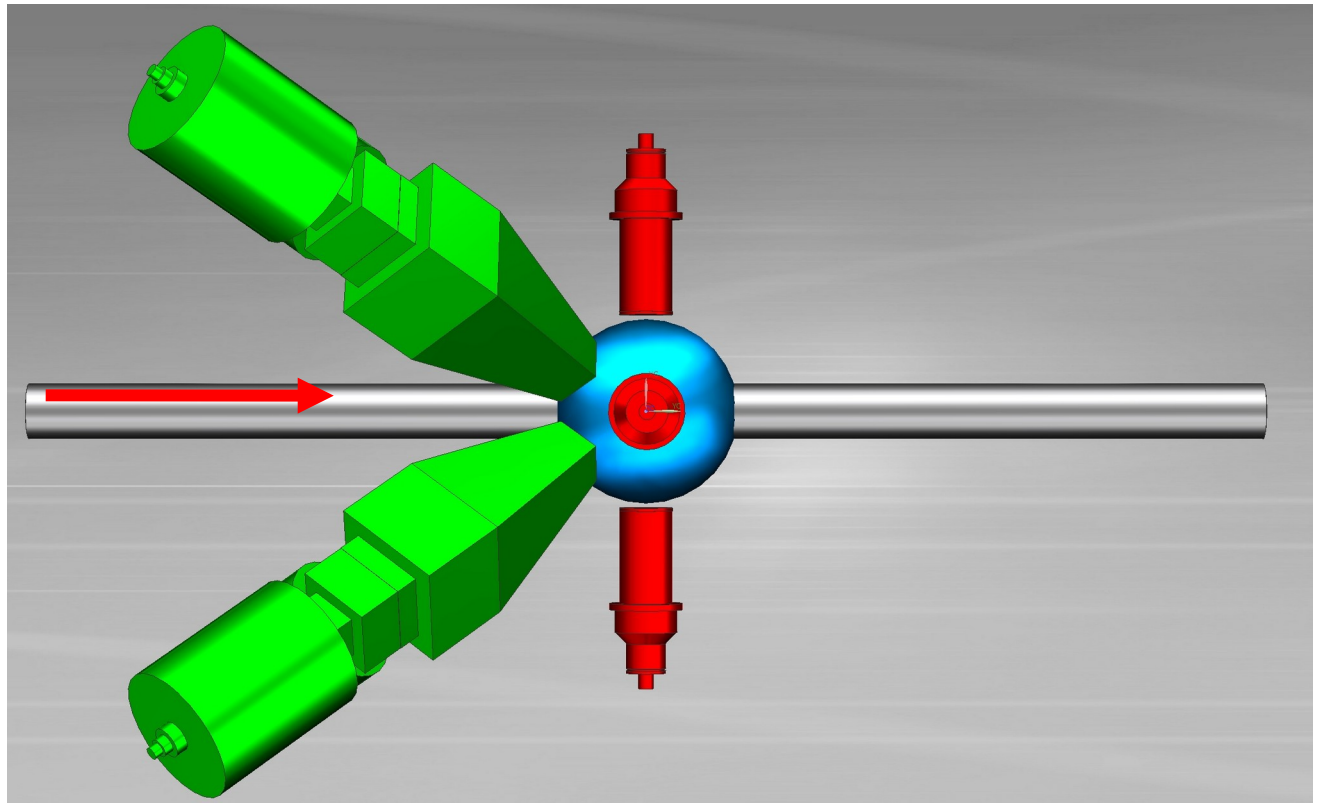
# Collimator and Neutrons

- Overall length of the beam pipe in the wall is 3 m
- At start the Al opening is 16.2 mm and at the end it is 27 mm giving an opening angle of 6.75 mrad
- At NRF target(2.25 from the collimator) the full spot size would be R=2.25 cm(R=1.5 cm flat and 0.75 cm shadow)



# Detector setup at TARLA



- HPGe would be 45° relative to the beam and 90° to each other
- LaBr3 would 90° relative to the beam and 90° to each other

Proposed setup would consist of:

- 2 Clover HPGe (with BGO)
- 2 Single crystal HPGe (with BGO)
- 4 Large Volume $LaBr_3$

Status:

- Clover and Single crystal HPGe are non-site and operational
- FAT and SAT tests have been completed successfully
- $LaBr_3$ will be purchased next year

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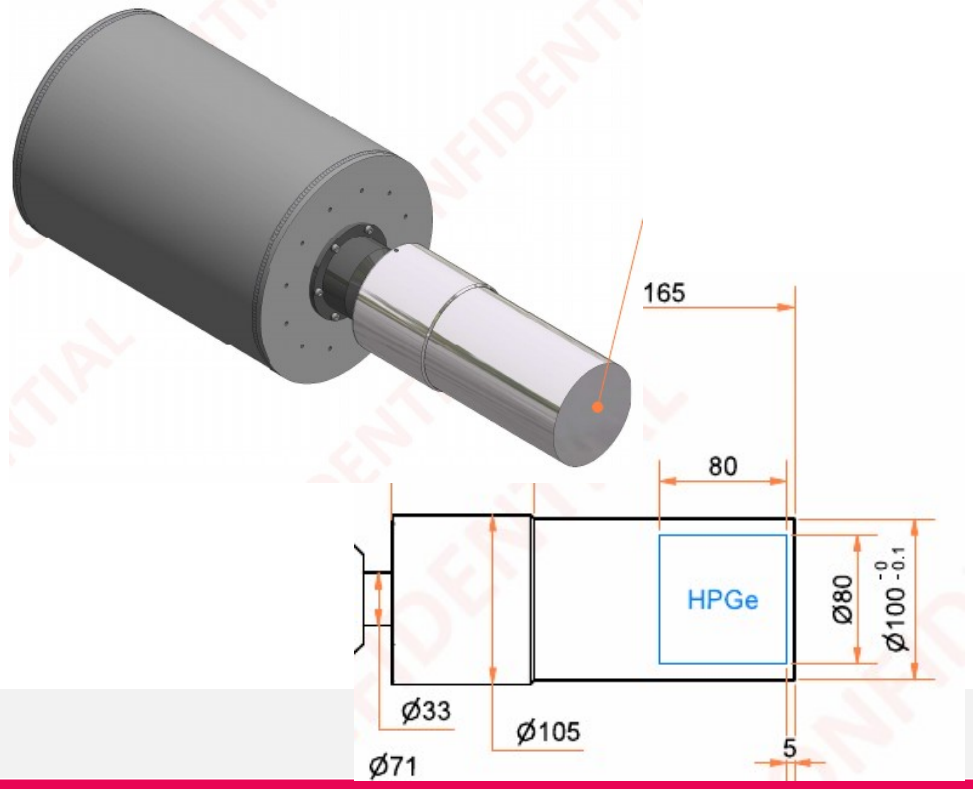
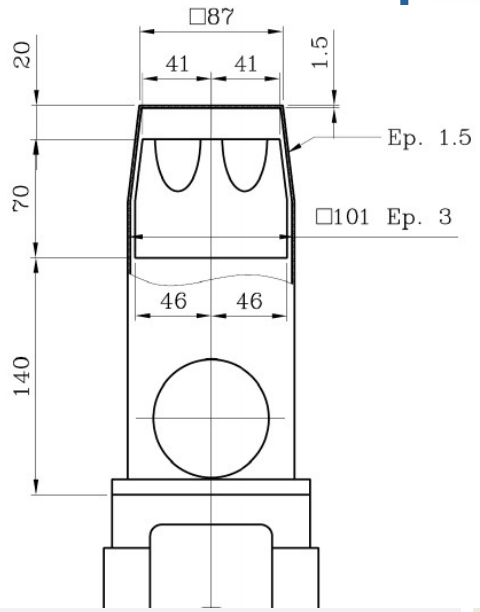
# About HPGe detectors

2 Single HPGe crystal 80x80:
- relative efficiency ≥ 100%
- The energy resolution <2.5 keV at 1.33 MeV and <1.4 keV at 122 keV.




- 2 Clover detectors: 4x50x70 (~3 kg)
- mean relative efficiency of each crystal is >20%, whereas the total relative efficiency in “add-back” mode is > 130%
- The energy resolution of the four shaped crystals is typically <2.1 keV at 1.33 MeV and <1.05 keV at 122 keV. In add-back mode, the energy resolution is still excellent: 2.3 keV at 1.33 MeV.
- Used in EUROGAM, EUROBALL(since 1992), CLARA, AFRODITE, INGABALL.



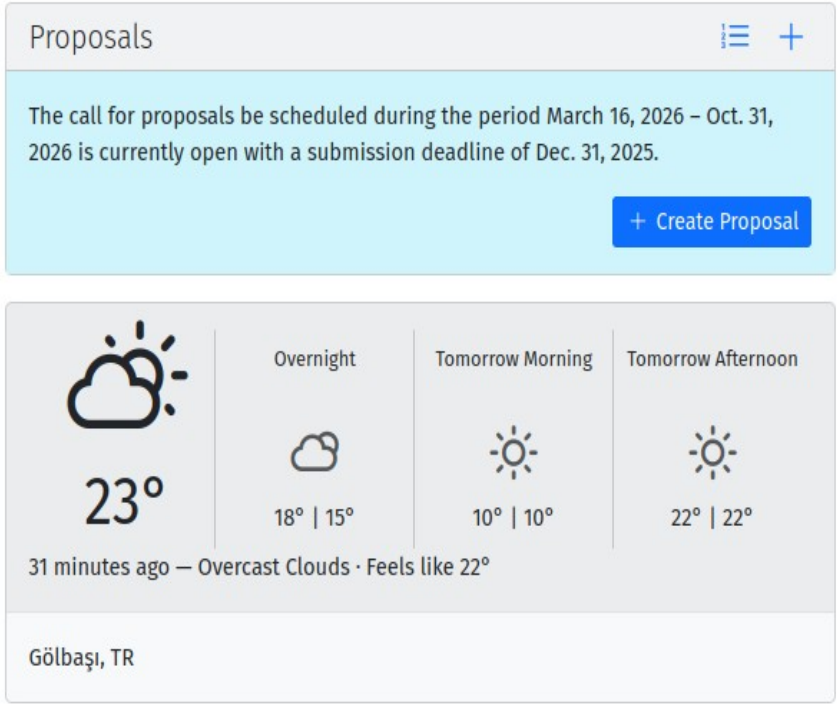


EUROBALL type Clover detector 4x50x70

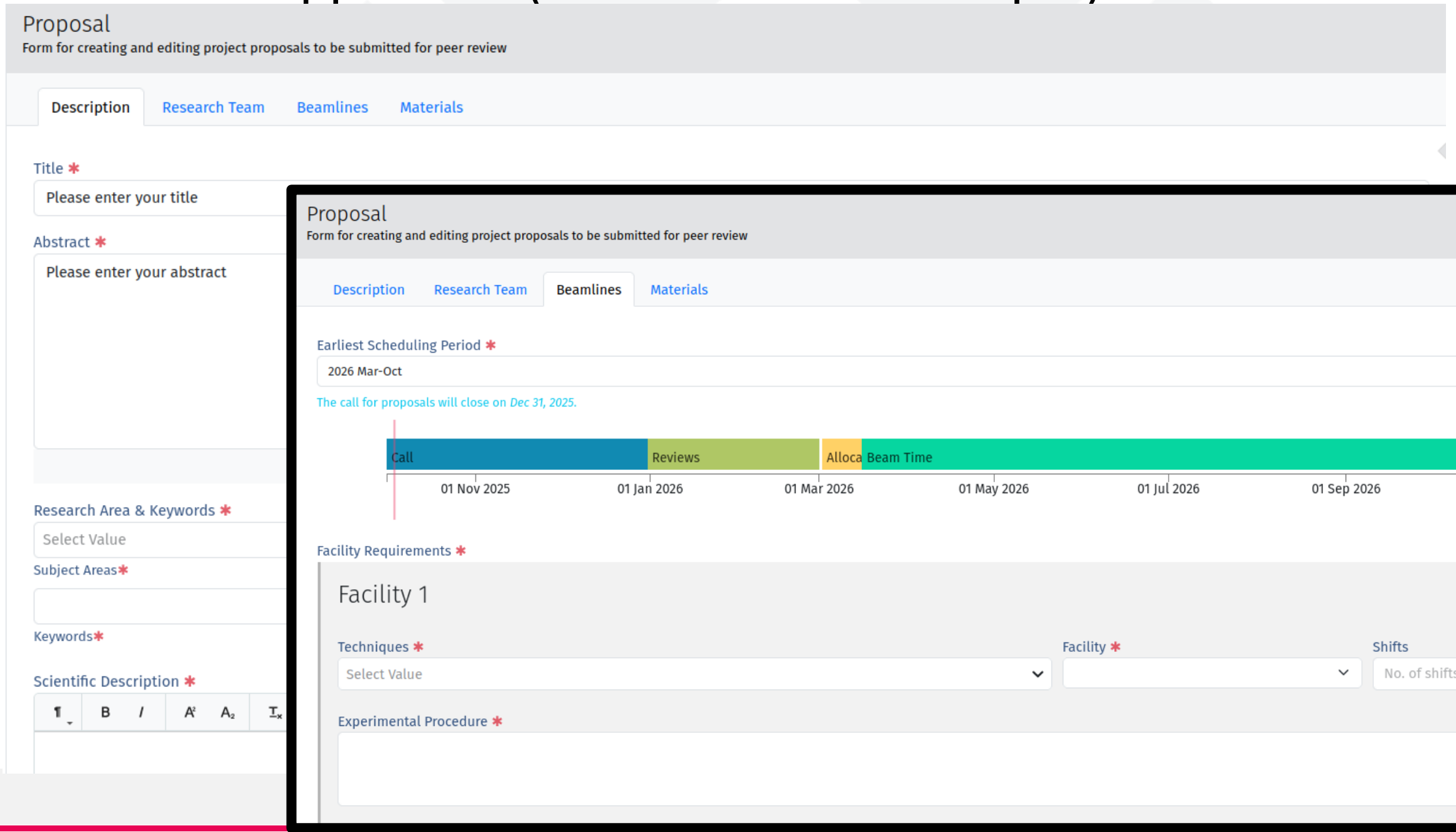
# Beamtime application

- Beamtime application website is being created
- Operational next week https://en.tarla-fel.org/apply-for-bematime and https://en.tarla-fel.org/tarla-user-portal-guide/
- we want to open it early and keep it open longer(6 months) ~ spring 2026

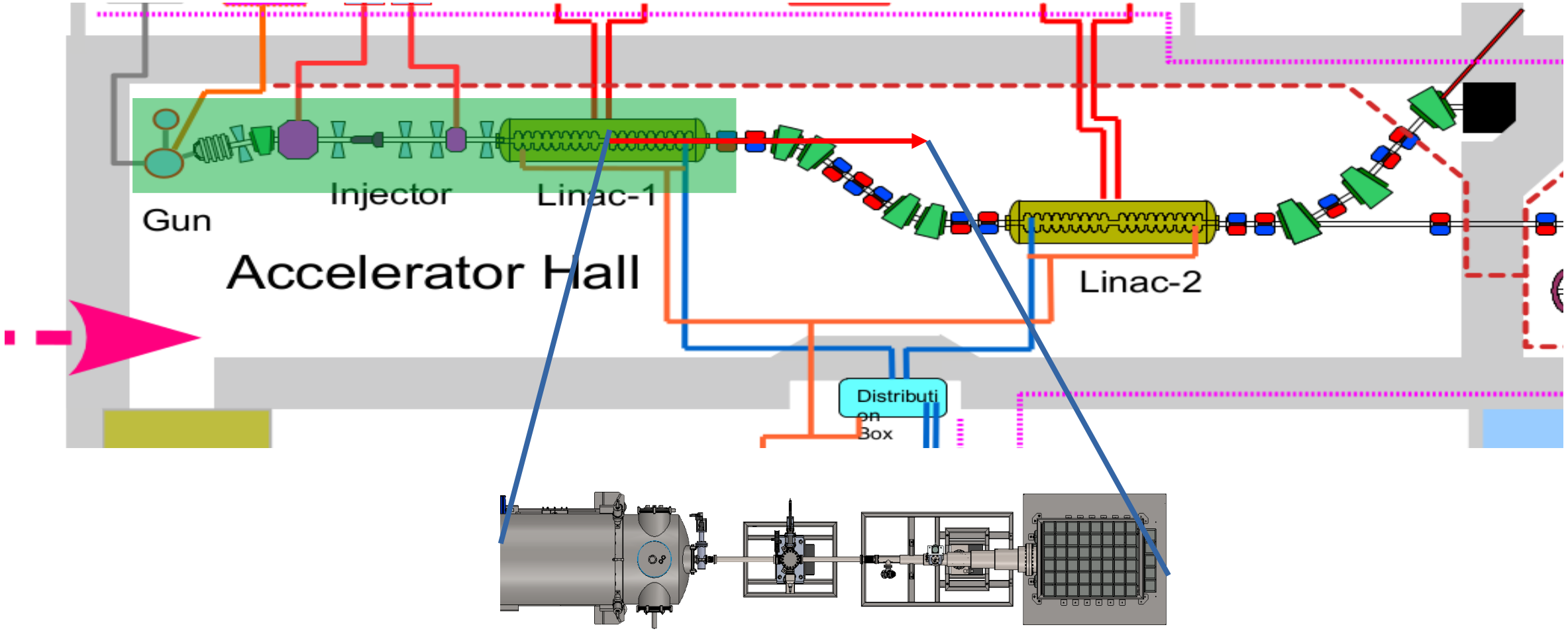




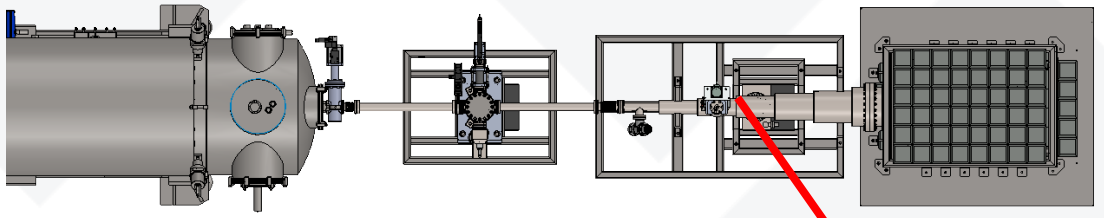
# Beamtime application(table tot laser example)



# TARLA Current physics experimental stations

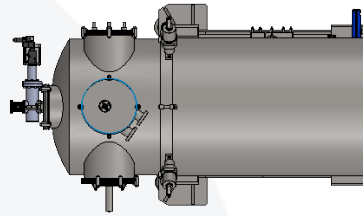


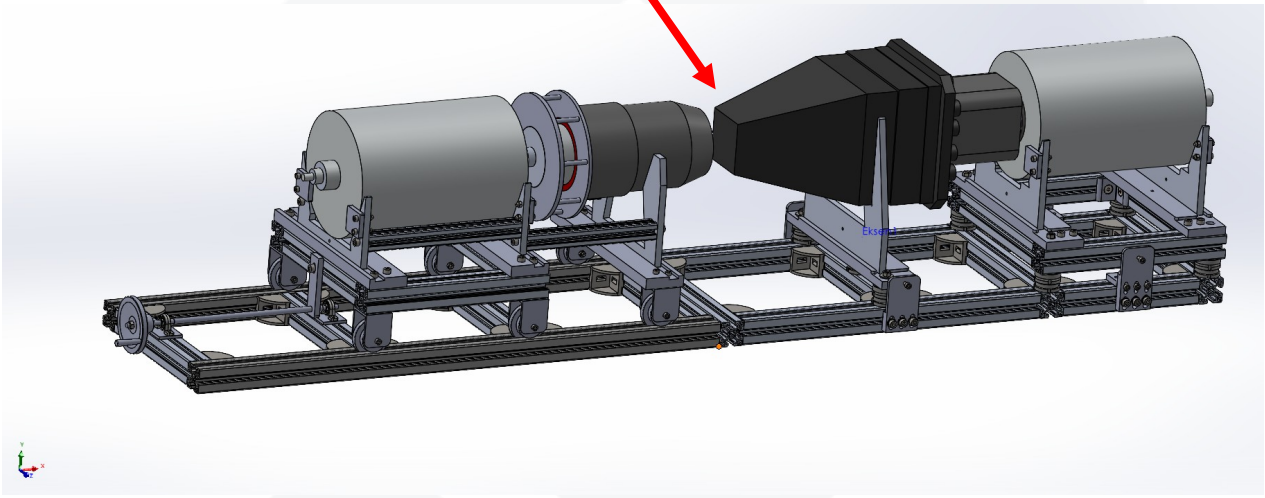
# Fast transfer 20 MeV experimental station



- This is an "offline" setup up to 20 MeV
- Sample transfer time down to 5 s, slower option available
- Current/dose rate is somewhat limited(~2 uA/~100 kGy/h) but sufficient
- Suitable for all activation and radiation physics experiments.
- Sample size is limited ~1.5 g or ~1.5 mL (D=10 mm, L=20 mm)

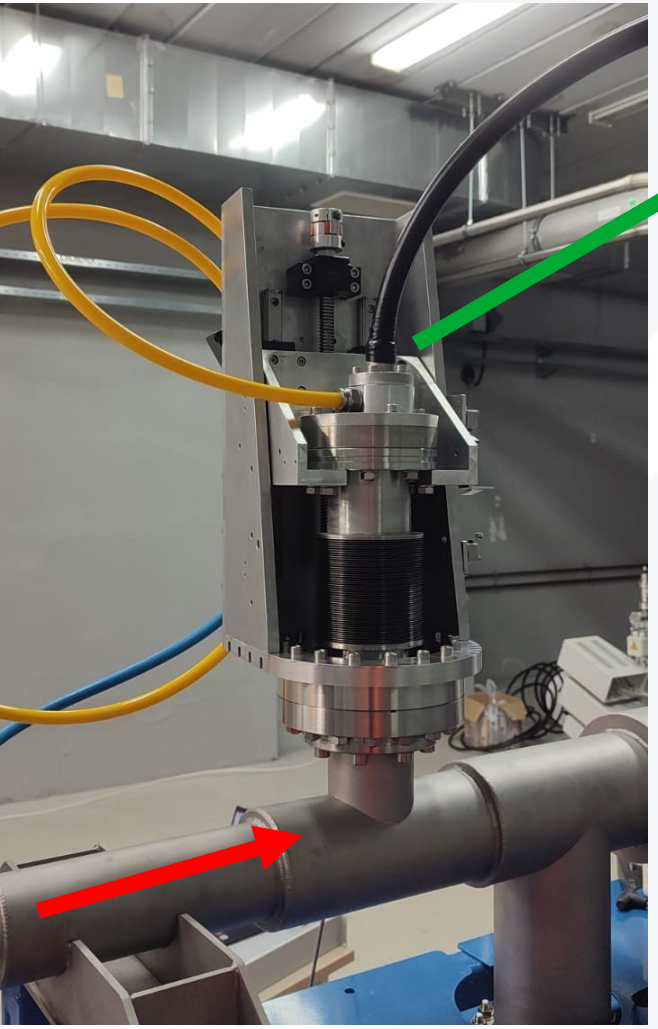
Fast sample transfer system (Rabbit)

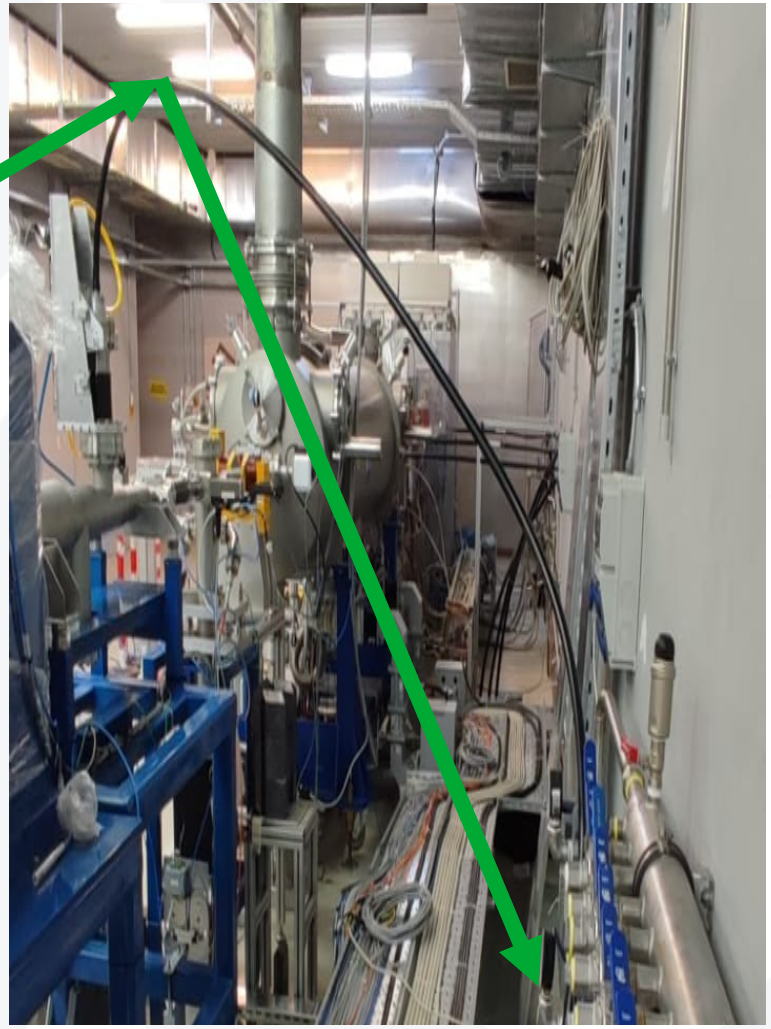


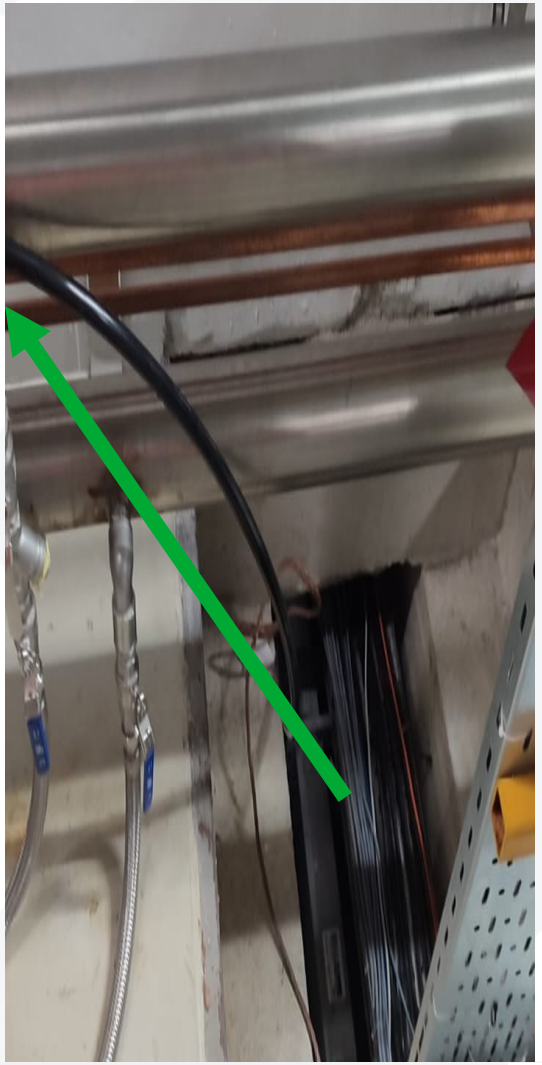


# Fast sample transfer system(07/10/2028)

**50 % complete and 2-2.5 s transfer time**







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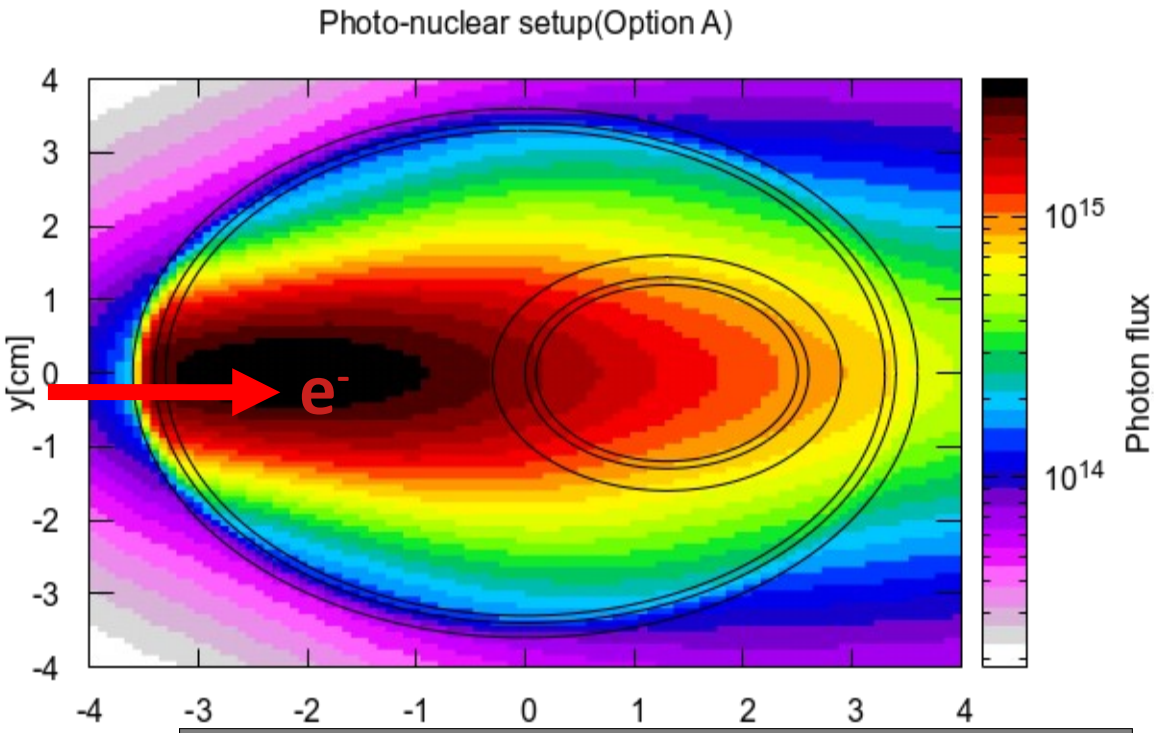
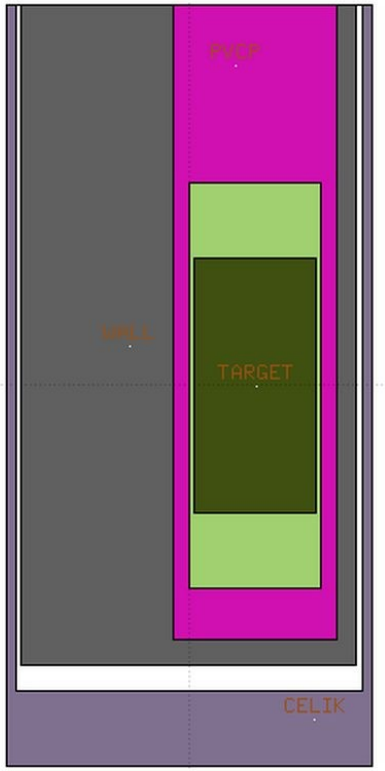
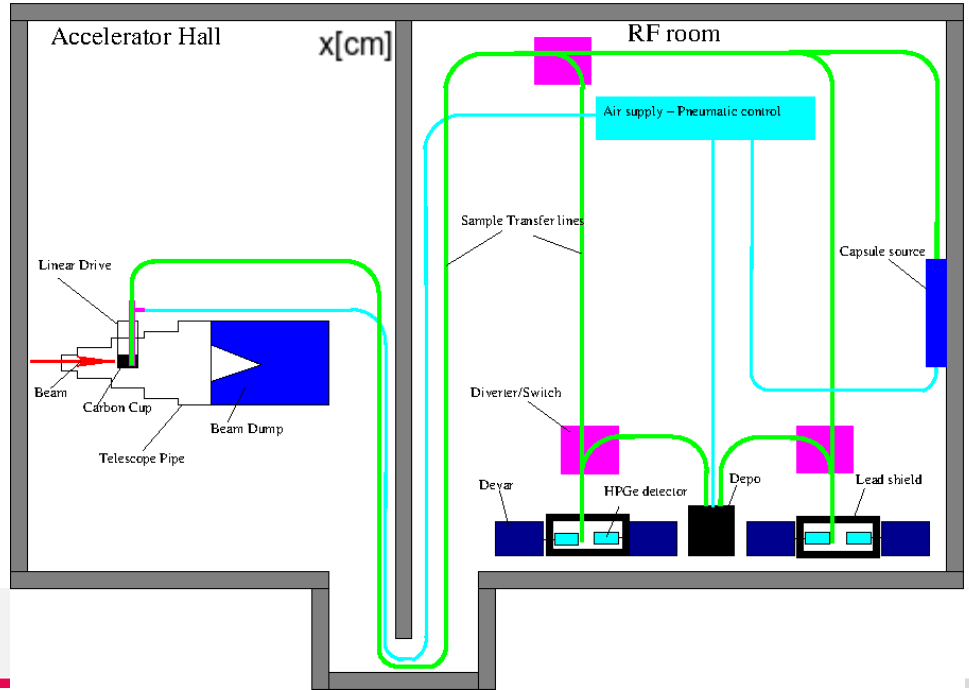
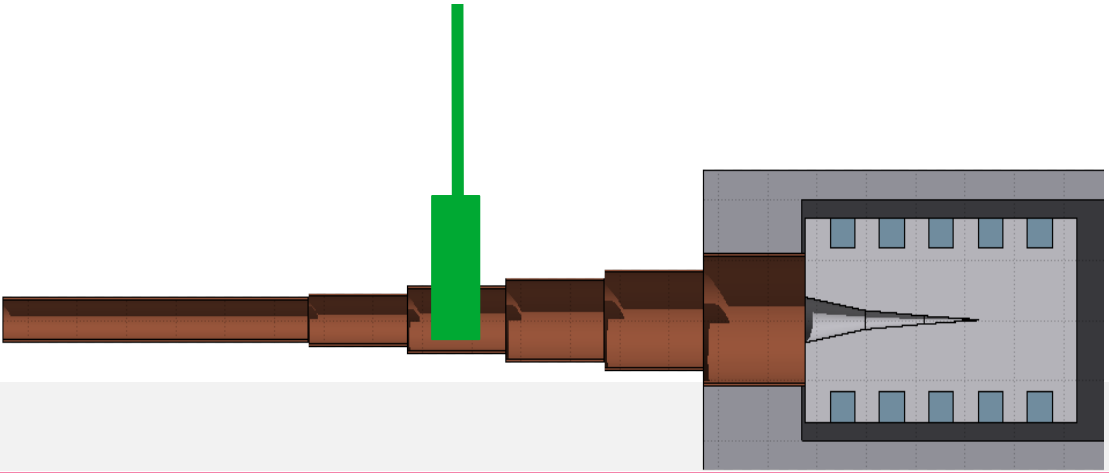
# Experiments at 20 MeV

- Sample placement system for off-line photo-nuclear reactions
- Carbon cup used as bremsstrahlung source
- Plastics for pipe and sample holder/transfer
- Activation experiments
- PAA and other applied studies
- Radiation physics
- <u>off-line setup</u>

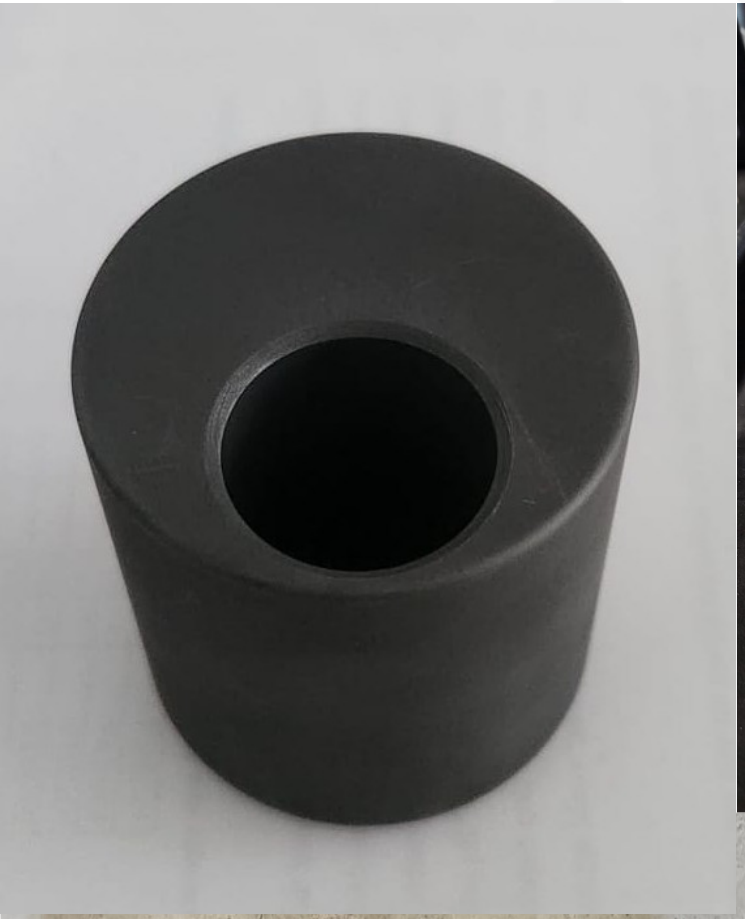


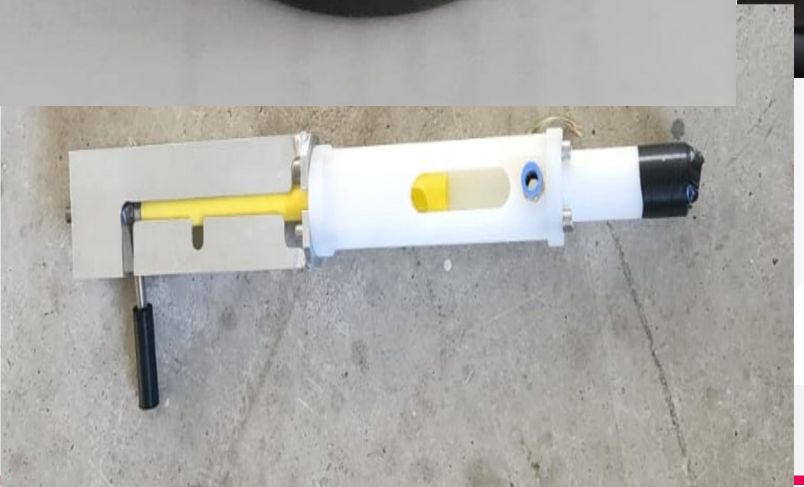



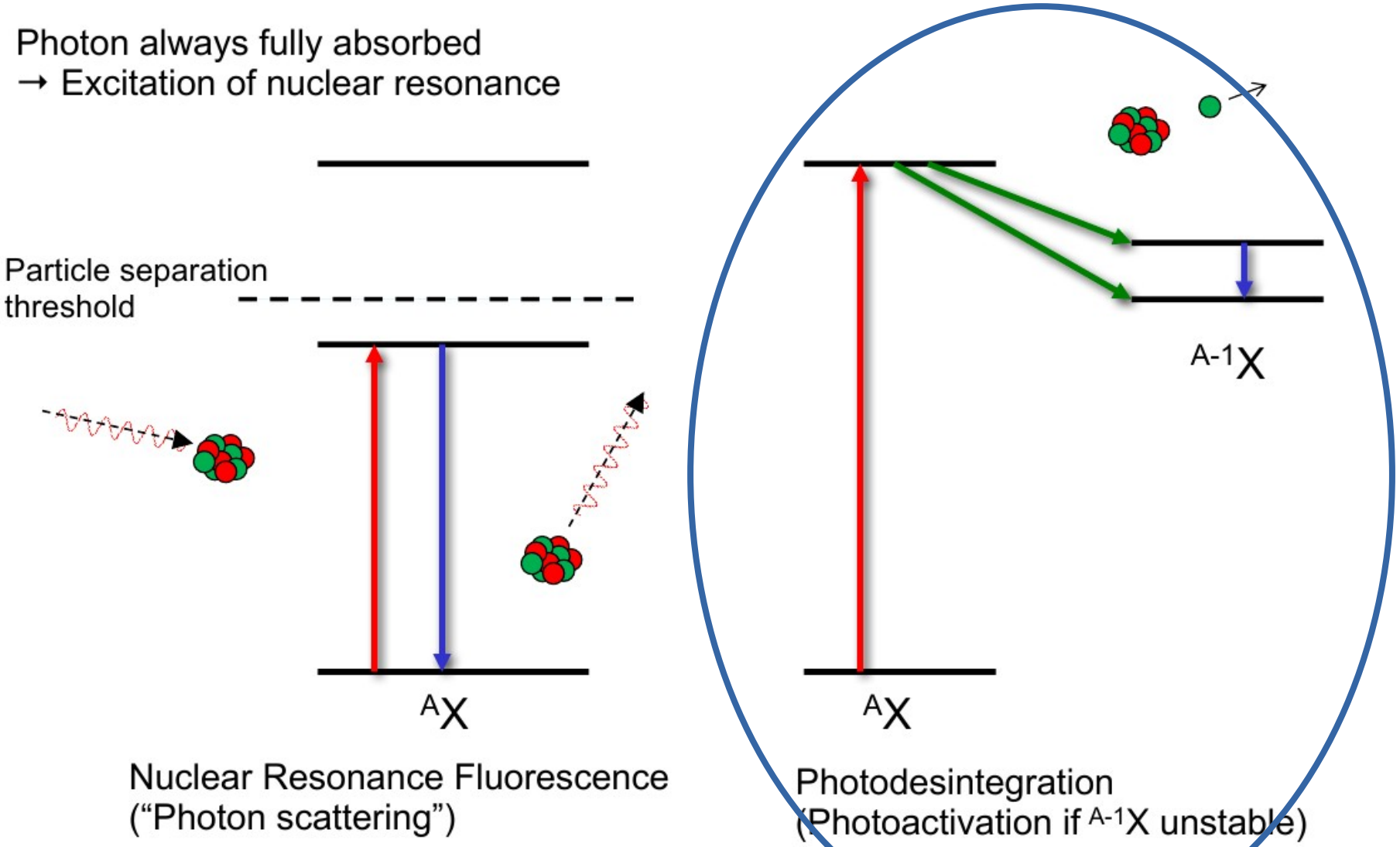



# Fast sample transfer system (Details)





# Photonuclear Reactions




**Research:**

- Nuclear Resonance Florescence (γ,γ')
- **Photo-neutron reactions (γ,n)**
- **Other separation reactions (Astrophysics) (γ,p); (γ,α)**
- Photofission

**Applications:**

- Gamma Imaging
- Material science
- Medical Radio isotopes
- Detector research

# Outlook:TARLA future – 5 year plan (up to 2030)

- Reaching the maximum energy of the accelerator (38.3 MeV) in 2026
- Once the Gamma experimental station is operational in 2027 we start with the NRF
- 2028, Experiments above the neutron threshold (nuclear structure of the giant dipole resonances (GDR) from studies of gamma and neutron decays, photodisintegration cross-sections, etc.)
- Resolution of the large literature discrepancies of the partial (γ,xn) cross-sections with improved measurements
- More detectors, especially neutron detectors
- 2029, Photofission (γ,f), even more detectors, charged particle detectors
- On the FEL side in 2028 we expect to have first light and in 2029 to commissioning and start using the experimental stations

# Summary

- TARLA linac is shaping up nicely
- First section giving 20 MeV is ready
- Fast transfer station is assembled and the next month activation and radiation experiments should start (discussion under way to make this station permanent)
- Full 40 MeV LINAC(second RF exit) is planed to be completed by the mid of 2027
- the first experiments with photon beam (bremsstrahlung) in summer/fall 2027
- *the first experiments with photon beam (FEL) in 2029*
- the first NRF experiments with a New Gamma spectroscopy setup
- 2028-2029, Beyond NRF we have plans for GDR and Photofission studies in next 5 years

# Thank you for your attention!

**TARLA TEAM:**

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And if you wish to propose activation experiments at TARLA or learn details about the detector setup feel free to contact me at hdapo@tarla-fel.org

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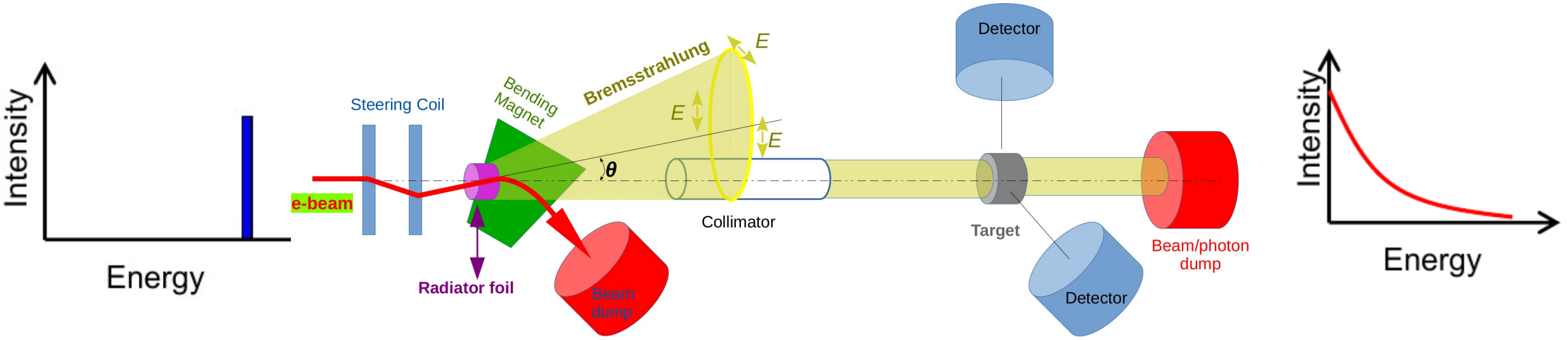
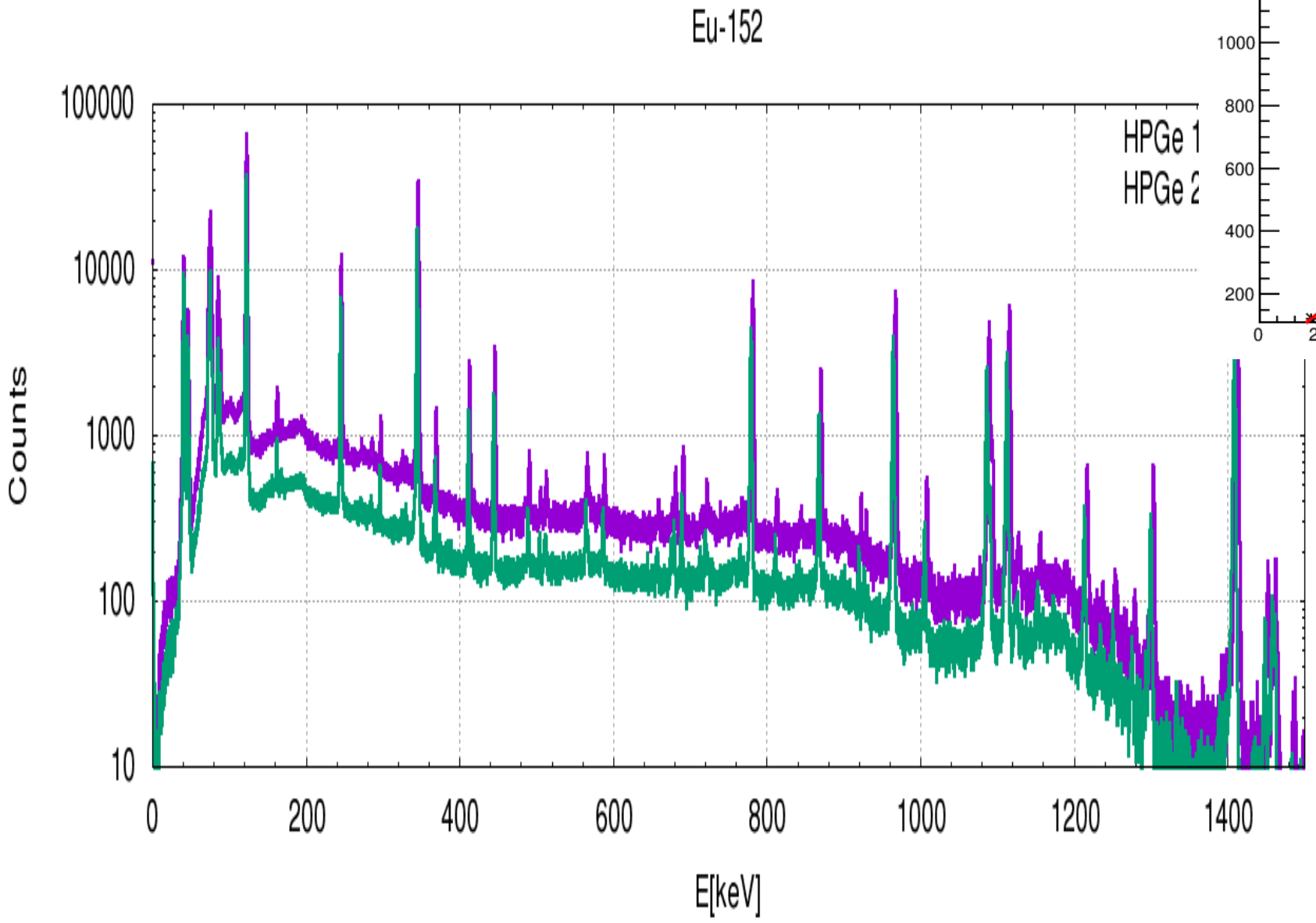
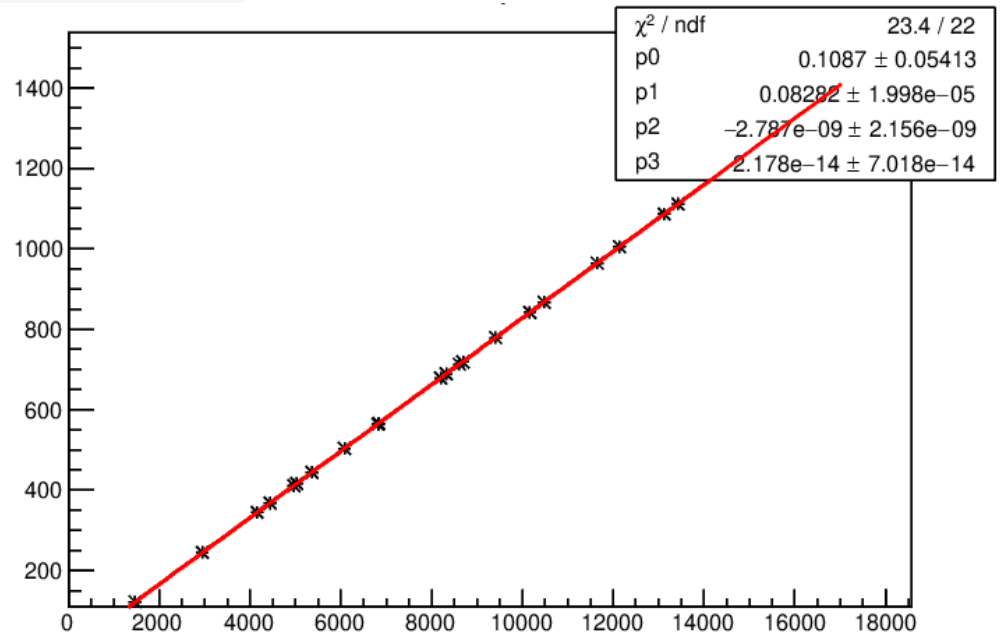
# TARLA
# Nuclear Physics experimental station




- From monochromatic electron spectrum one produces a continuous “white” photon spectrum
- High photon intensities possible

# Detector characterization

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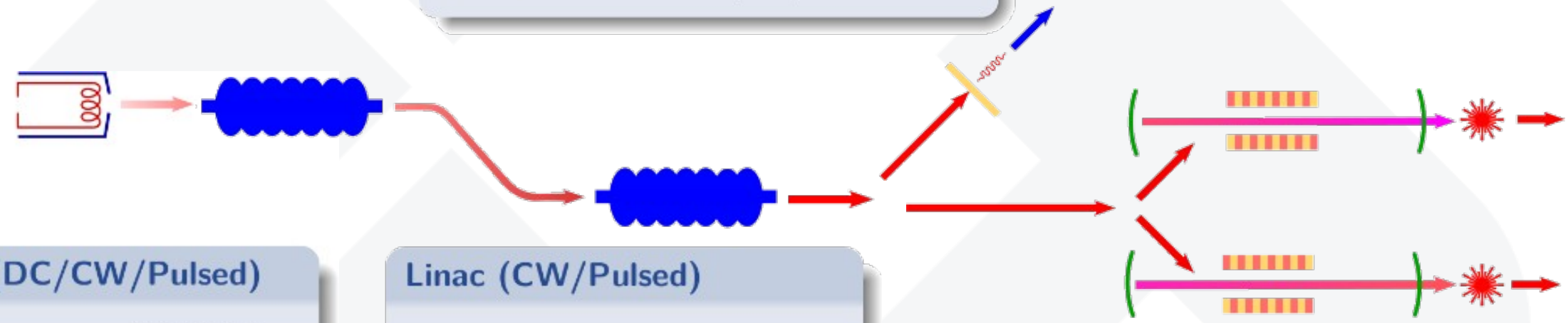
# TARLA Beams

## Polarized $\gamma$-Source (CW/Pulsed)

| | |
|---|---|
| Photon Energy | 0-30 MeV |
| Photon flux | $> 10^{10}\ cm^{-2} s^{-1} MeV^{-1}$ |
| Detectors | HPGe, LaBr, BaF |



## Injector (DC/CW/Pulsed)

| | |
|---|---|
| Energy | 100-250 keV |
| Max. Bunch Chrg | 125 pC |
| Max. Current | 2 mA |
| Bunch length | 500 ps /DC |
| Bunch repetition | 1kHz-26MHz/DC |
| Pulse repetition | 100 Hz /CW |
| Pulse duration | 40 $\mu$s/CW |
| Emittance | <10 mm.mrad |

## Linac (CW/Pulsed)

| | |
|---|---|
| Energy | 5-40 MeV |
| Max. Bunch Charge | 125 pc |
| Max. Current | 1.5 mA |
| Bunch length | 0.5-6 ps |
| Bunch repetition | 1 kHz-26 MHz |
| Pulse repetition | 100 Hz/CW |
| Pulse duration | 40 $\mu$s /CW |
| Emittance | <12 mm.mrad |

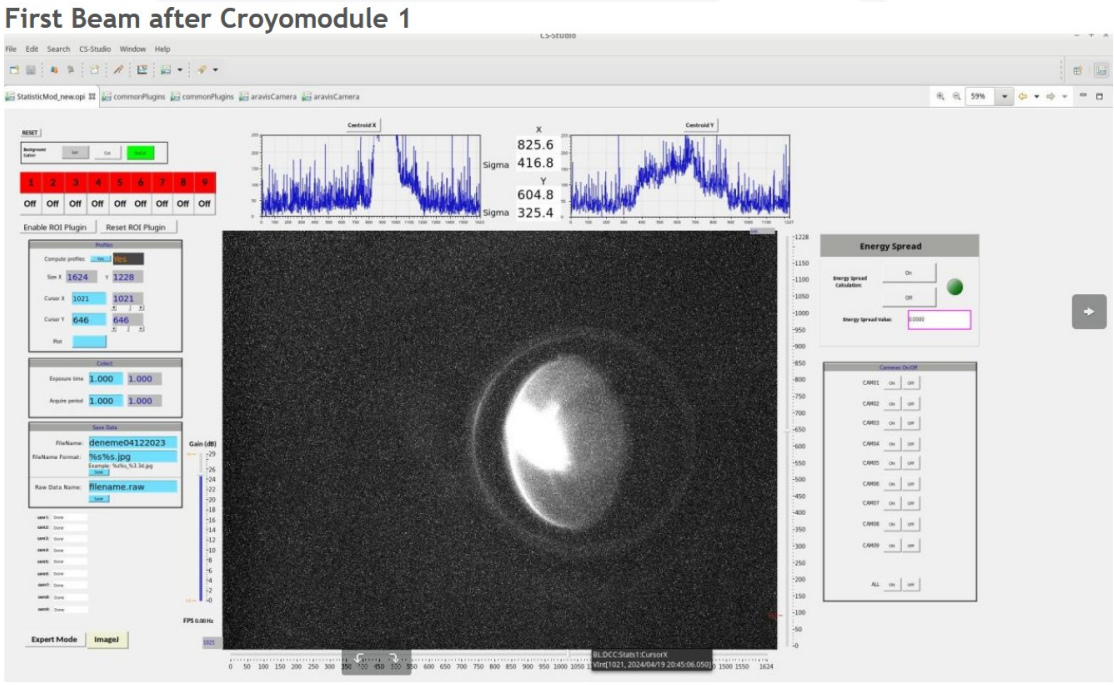
## Free Electron Laser (CW/Pulsed)

| | |
|---|---|
| Photon energy | 4-300 meV |
| Wavelength | 5-350 $\mu$m |
| Pulse Length | 0.5-10 ps |
| Polarization | Linear |
| Repetition Rate | 13 MHz - 1kHz |
| Pulse repetition | 100 Hz/CW |
| Pulse duration | 100 $\mu$s/CW |
| Max Pulse energy | 2 $\mu$J |
| Max Peak Power | 2 MW |
| Max Average Power | 100 W |

Linacs driving two secondary beam station

# First acceleration through Linac1

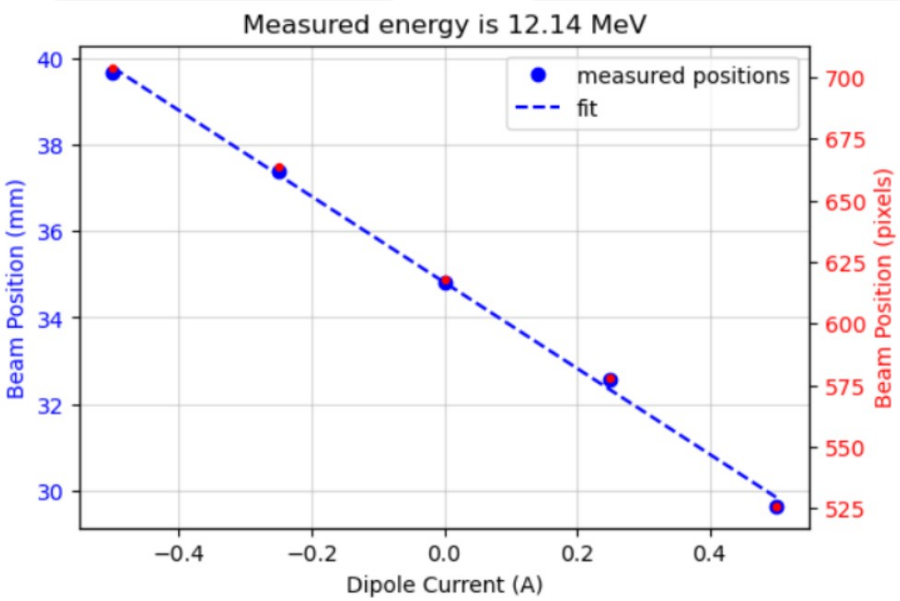
First beam on the beam profile monitor after Linac1




## 19 April 2024

**Beam acceleration through superconducting cavities. First time at TARLA and in Türkiye.**

**Energy measurement:** vary steering magnet field, check beam deflection and calculate energy.



# How it works

# Photo-nuclear reactions on short lived nuclei

| Target | Reaction | Product | Decay |
|---|---|---|---|
| $^{24}Mg$ | $^{24}Mg+\gamma->^{23}Mg+n$ | $^{23}Mg$ | $^{23}Na$ |
| $^{32}S$ | $^{32}S+\gamma->^{31}S+n$ | $^{31}S$ | $^{31}P$ |
| $^{28}Si$ | $^{28}Si+\gamma->^{27}Si+n$ | $^{27}Si$ | $^{27}Al$ |

| Nucleus | Half-life(s) | Gamma Enerji (keV) |
|---|---|---|
| $^{23}Mg$ | 11.3046 | 440.5<br>2390.6<br>1950.6 |
| $^{31}S$ | 2.5535 | 1266.1<br>3134.1<br>3505.9 |
| $^{27}Si$ | 4.15 | 2212.01<br>2982.00<br>1014.52<br>1720.3 |