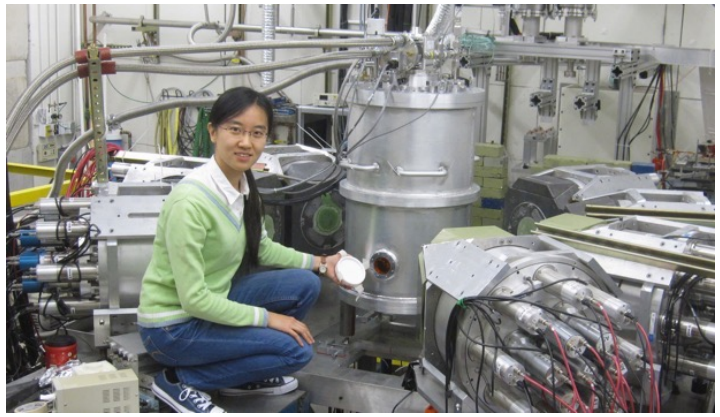
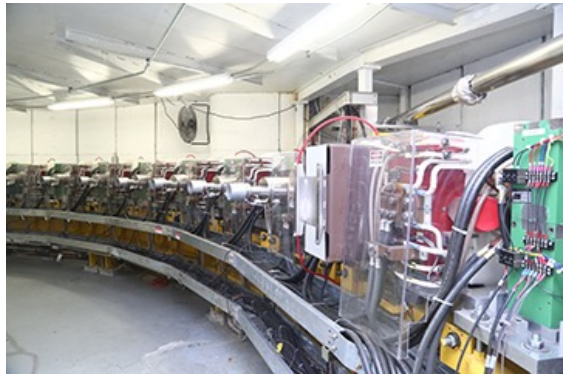
TUNL Accelerator Facilities: Capabilities and Upgrades

TUNL



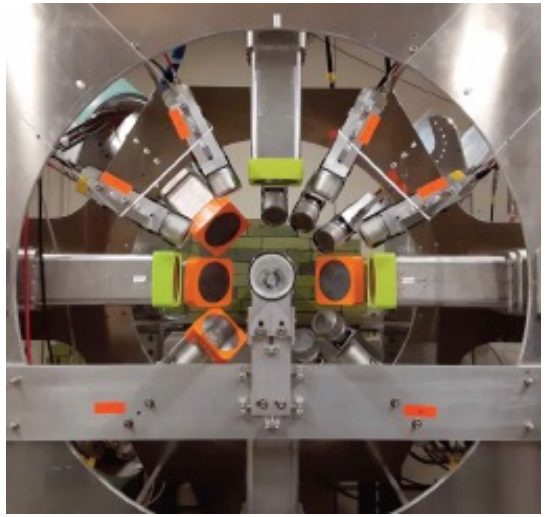
Accelerator Facilities

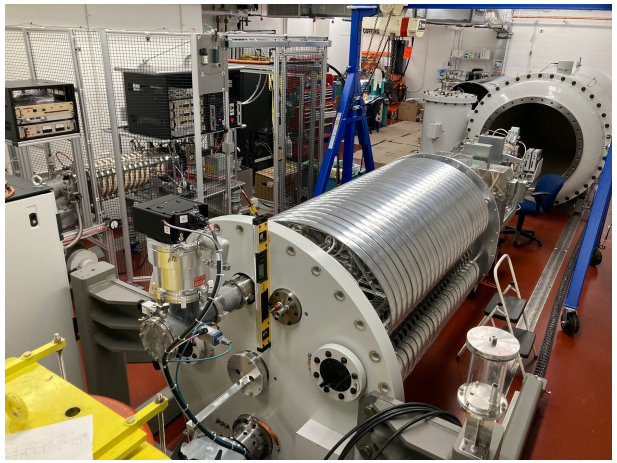
- High Intensity Gamma-ray Source (HIGS)
- Laboratory for Experimental Nuclear Astrophysics (LENA)
- Tandem Accelerator Laboratory

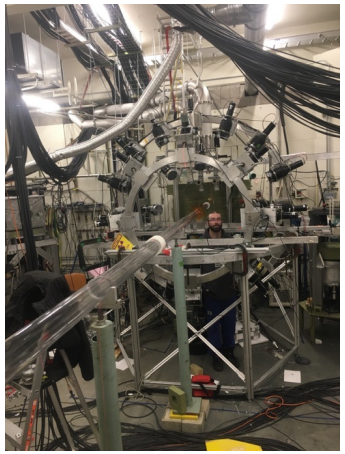


Research Program Components:

- Nuclear Structure and Fission
- Nuclear Astrophysics
- Low-Energy QCD
  - Nucleon Structure
  - Few-Nucleon Systems







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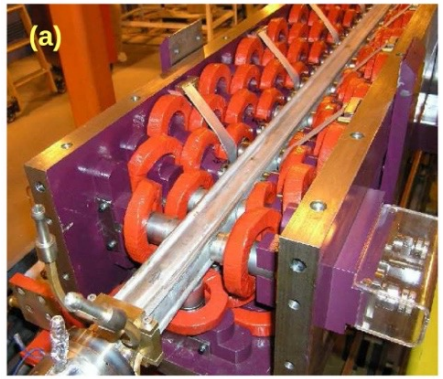
TUNL

Features that enable basic and applied research

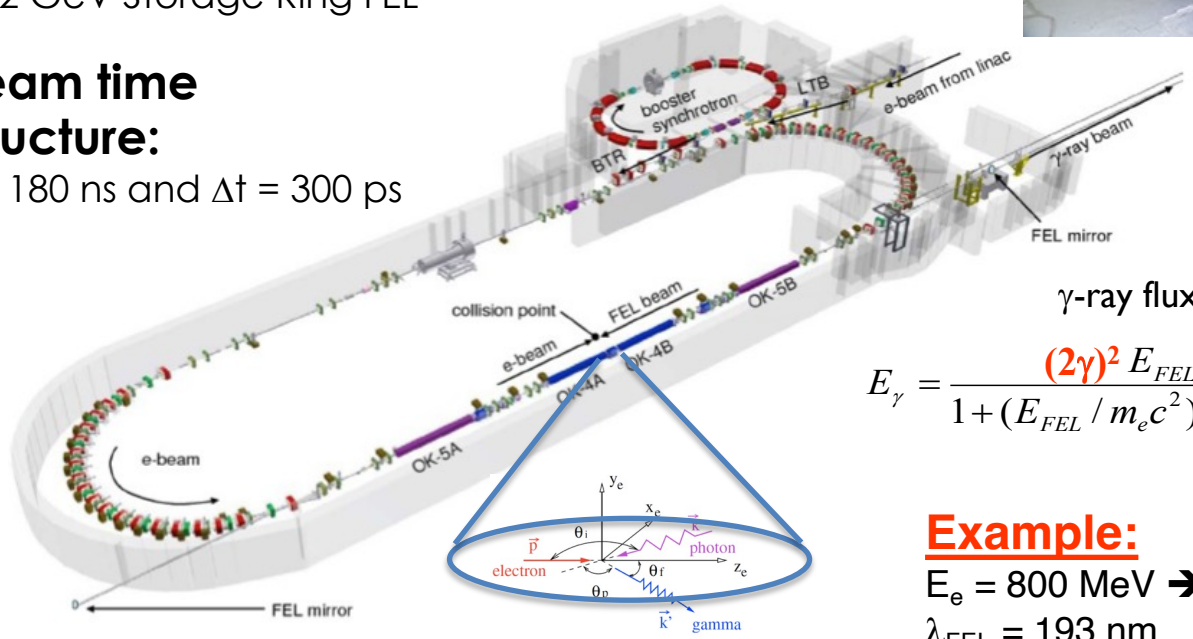
- Wide beam energy range: 1 to 120 MeV
- Selectable beam energy spread (by collimation)
- High beam intensity on target (>10^7 γ/s @ ΔE/E = 5%)
- >95% beam polarization (linear and circular)



1.2 GeV Storage Ring FEL

Beam time structure:

T = 180 ns and Δt = 300 ps



γ-ray flux → $I_e * P_{oc}$

$$E_\gamma = \frac{(2\gamma)^2 E_{FEL}}{1+(E_{FEL}/m_e c^2)(1+\cos(\theta))}$$

Example:

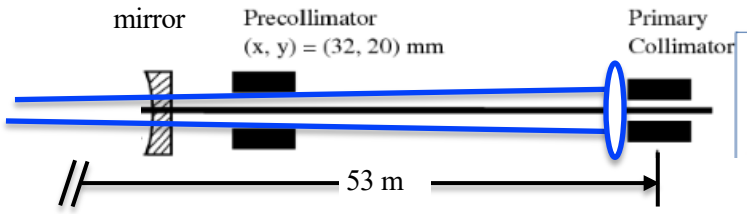
E_e = 800 MeV → γ = 1566

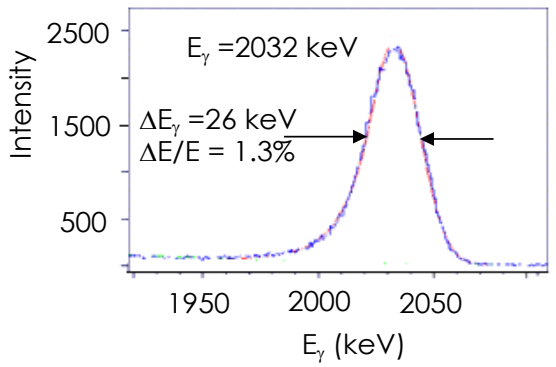
λ_{FEL} = 193 nm

E_{FEL} = 6.43 eV

E_γ = 63.1 MeV

Energy resolution by collimation





Overview of Research at HIγS

HIγS operates about 1500 hours/year for nuclear physics research

PAC reviews

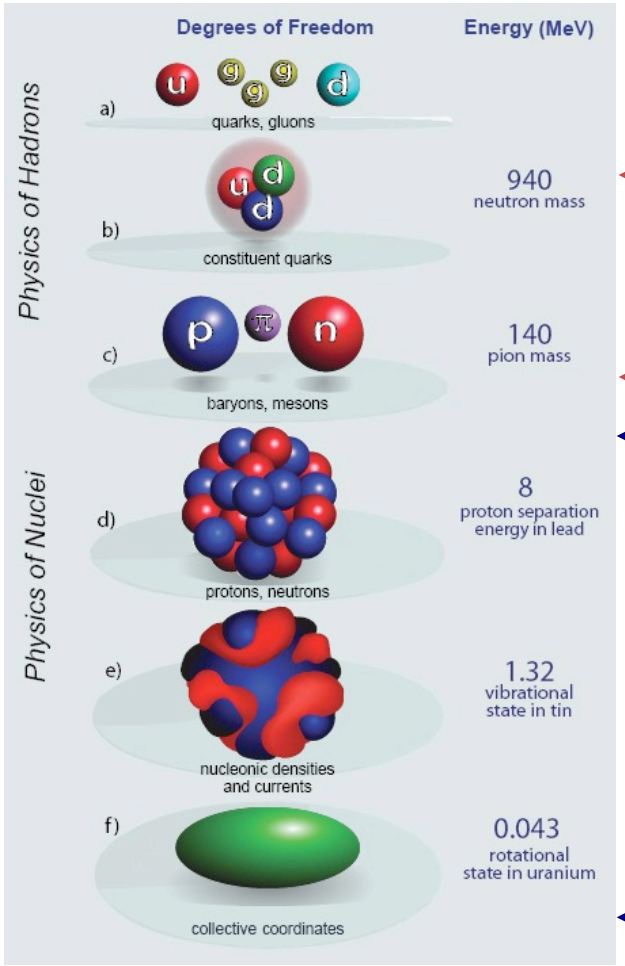


Figure from 2007 USA Nuclear Science LRP

Low-Energy QCD:

19 institutions: 13 USA + 6 international

Compton Scattering

nucleon electric and magnetic polarizabilities
nucleon spin polarizabilities

35 institutions: 14 USA + 21 international

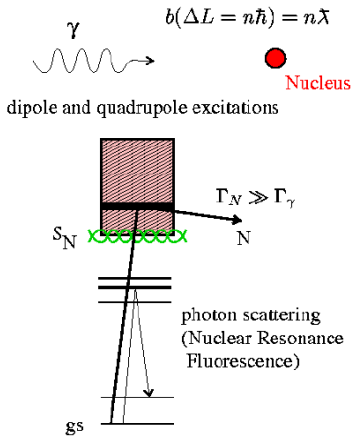
Few-nucleon Systems

photodisintegration of ^{2}H, ^{3}He and ^{3}H (cross sections, target-beam helicity dependent cross sections, polarization transfer)

Many-body Strongly Interacting Systems:

Nuclear Structure and Nuclear Astrophysics

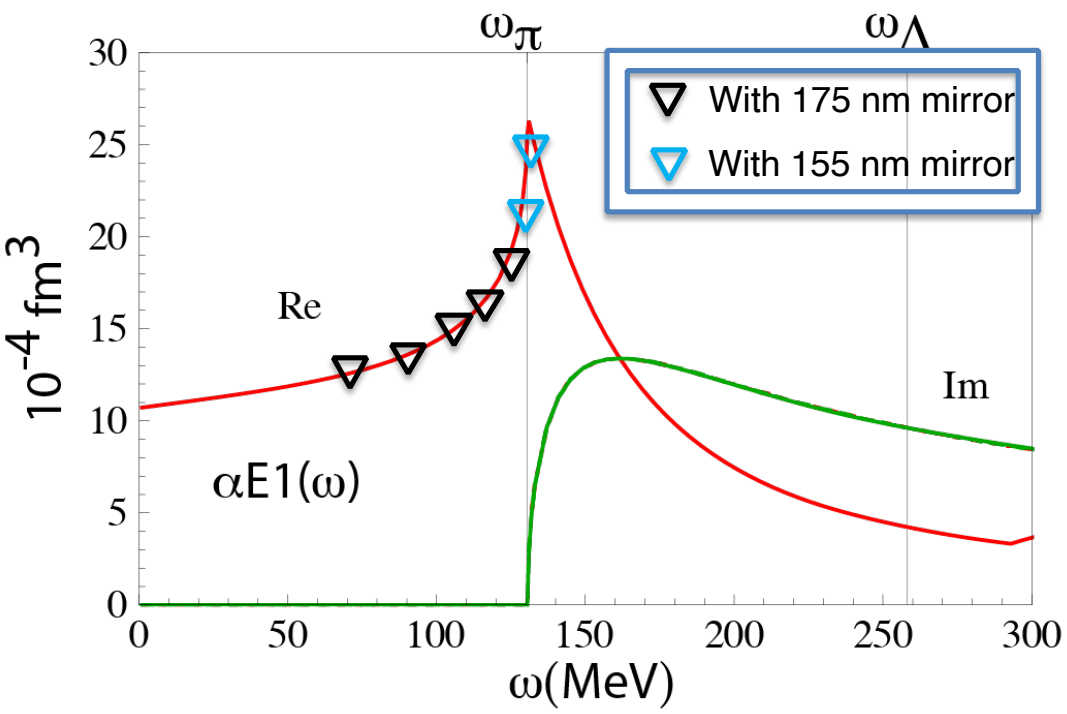
NRF, (γ,γ')
(γ,n), (γ,p), (γ,α) and (γ, fission) reactions

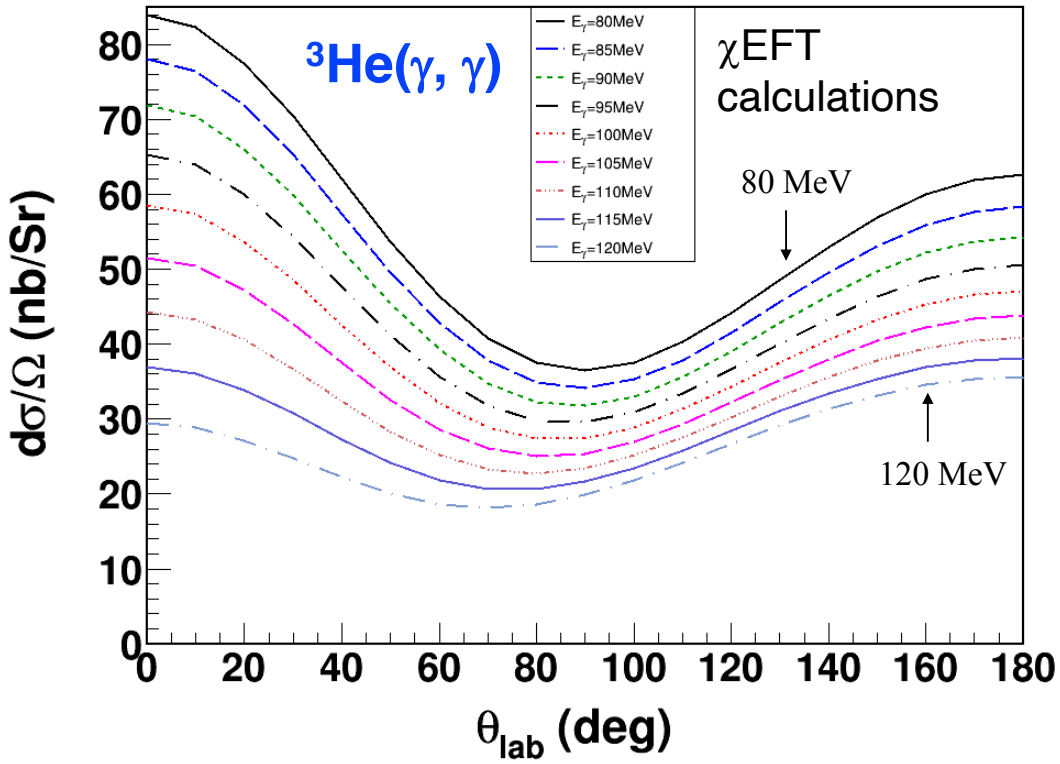


Applied Research:

- Nuclear Security
- Medical Isotope R&D
- γ-ray Detector R&D

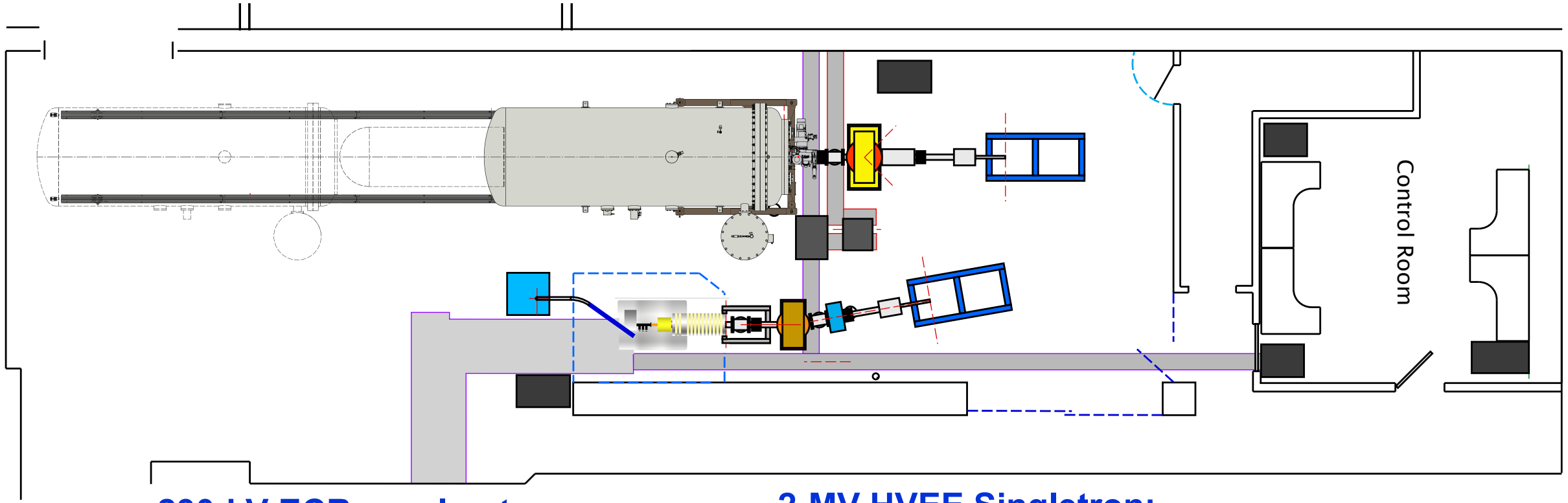
HIGS: R&D of FEL optical cavity mirrors for Compton Scattering





- **Major focus on measurements of neutron EM polarizabilities**
  - Compton scattering from liquid H,D,^{3}He, and ^{4}He targets at E_γ = 65 - 120 MeV
  - E_γ = 100 - 120 MeV made possible through development of 175-nm cavity mirrors by collaboration of TUNL-Laser Zentrum Hannover (LZH)
  - **E_γ = 130 - 150 MeV with 155-nm mirrors, R&D underway with TUNL-LZH collaboration**
  - **Requesting an additional 1500 hours operation/year for carrying out the Compton-scattering program**
  - **Upgrade of the electron injector system at HIGS for reliable stable operation**

Laboratory for Experimental Nuclear Astrophysics: *LENA II Upgrade*



230-kV ECR accelerator:

~ 20 mA DC H^+

Slow pulsing (10% duty cycle)

Replaces:

200-kV ECR accelerator:

~ 4 mA DC H^+

2-MV HVEE Singletron:

DC beam current at 250 kV: 0.5 mA (H), 0.4 mA (He)

DC beam current at 1 - 2 MV: 2 mA (H and He)

Pulse frequency: 0.125, 0.25, 0.5, 1, 2, 4 MHz

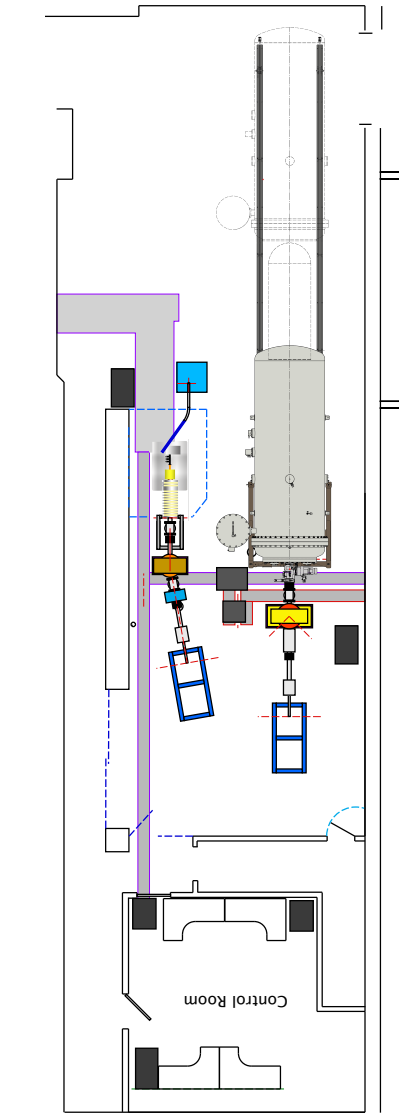
Pulse width: 2 – 20 ns

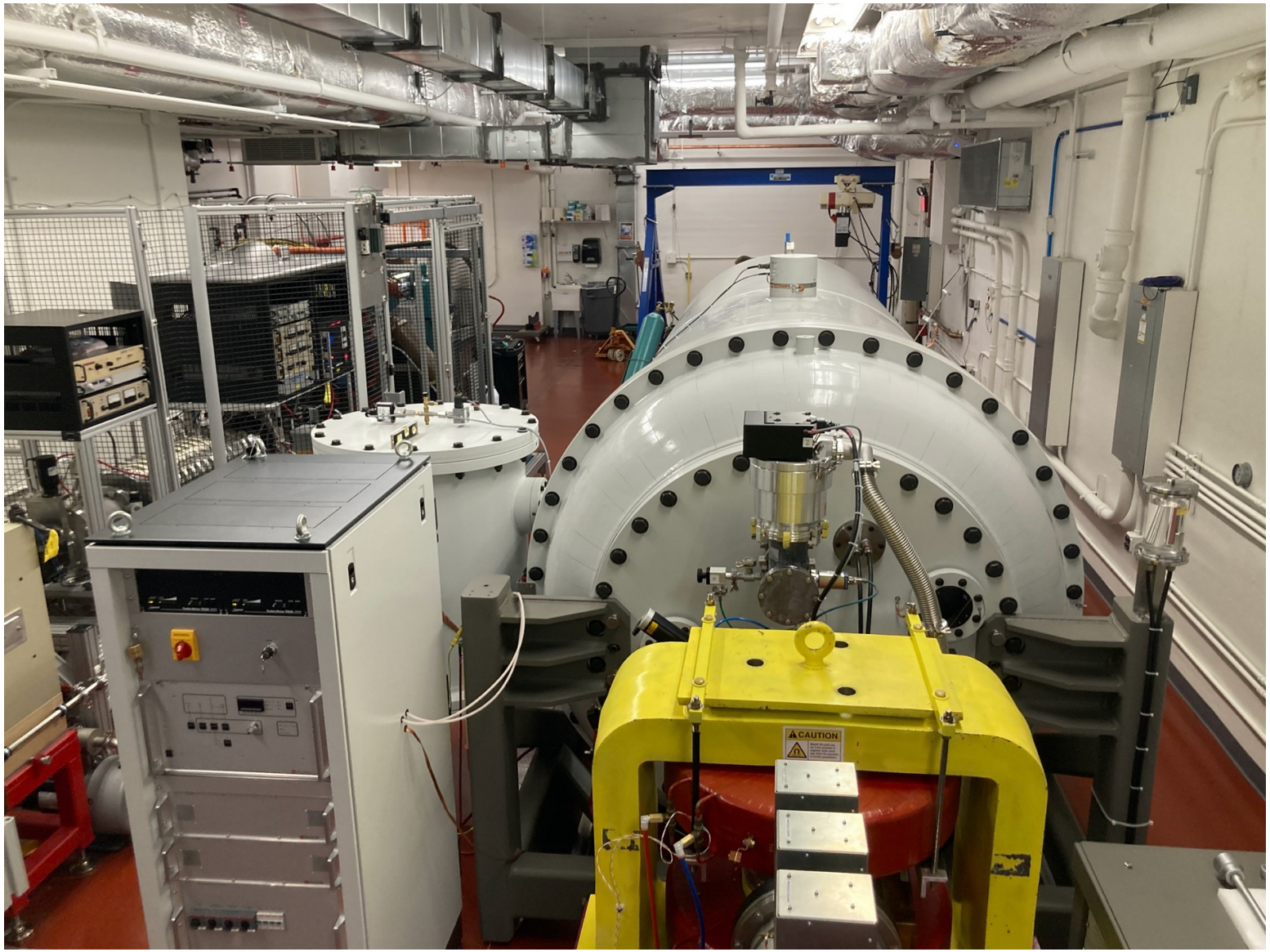
Replaces:

1-MV JN van de Graaff

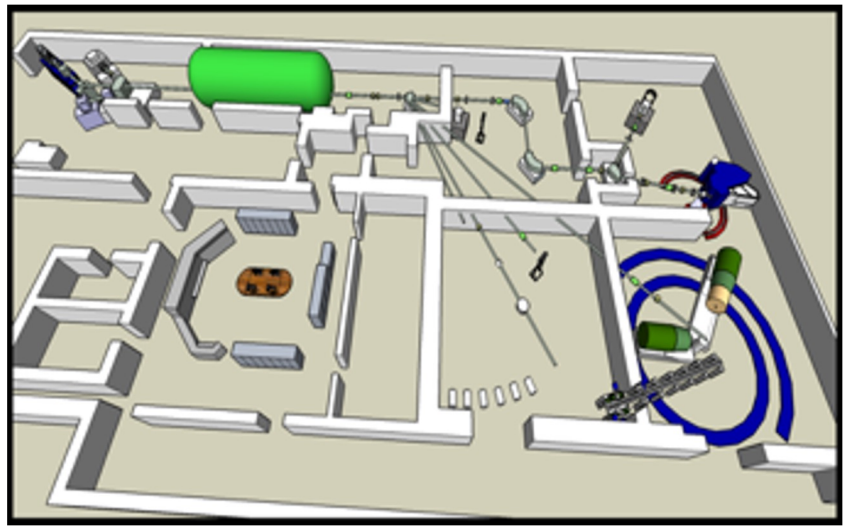
~ 0.1 mA DC H^+

Looking from the momentum analysis magnet toward the Singletron





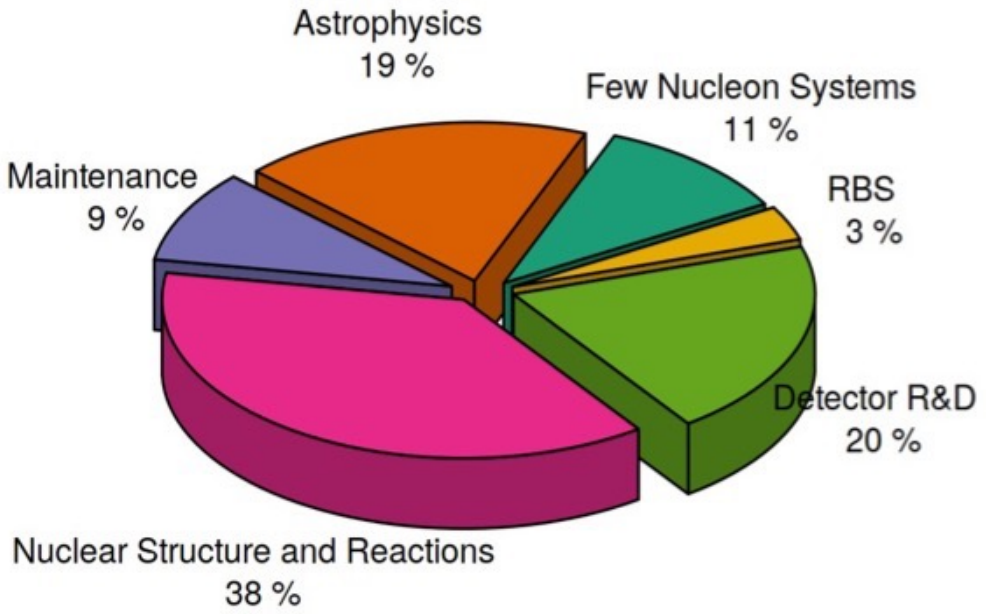
Low Energy Injector Upgrade for the Tandem Accelerator Laboratory



Light-ion beams: p, d, ^{3}He, ^{4}He
Secondary beams: n

Period: July 2017 – March 2020
Days scheduled = 698 (71% scheduled)

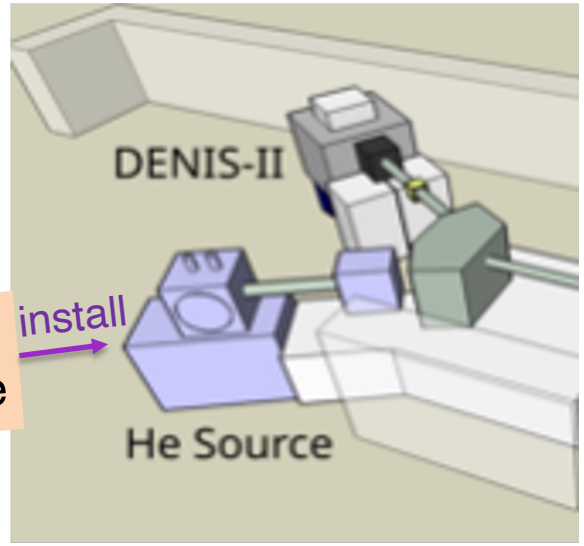
Total hours run = 8,873



Upgrade aging ion sources:

- Ion sources are over 50 years old
- Performance (beam current capability and stability) inadequate for supporting the research program in the lab
- Reliability becoming low

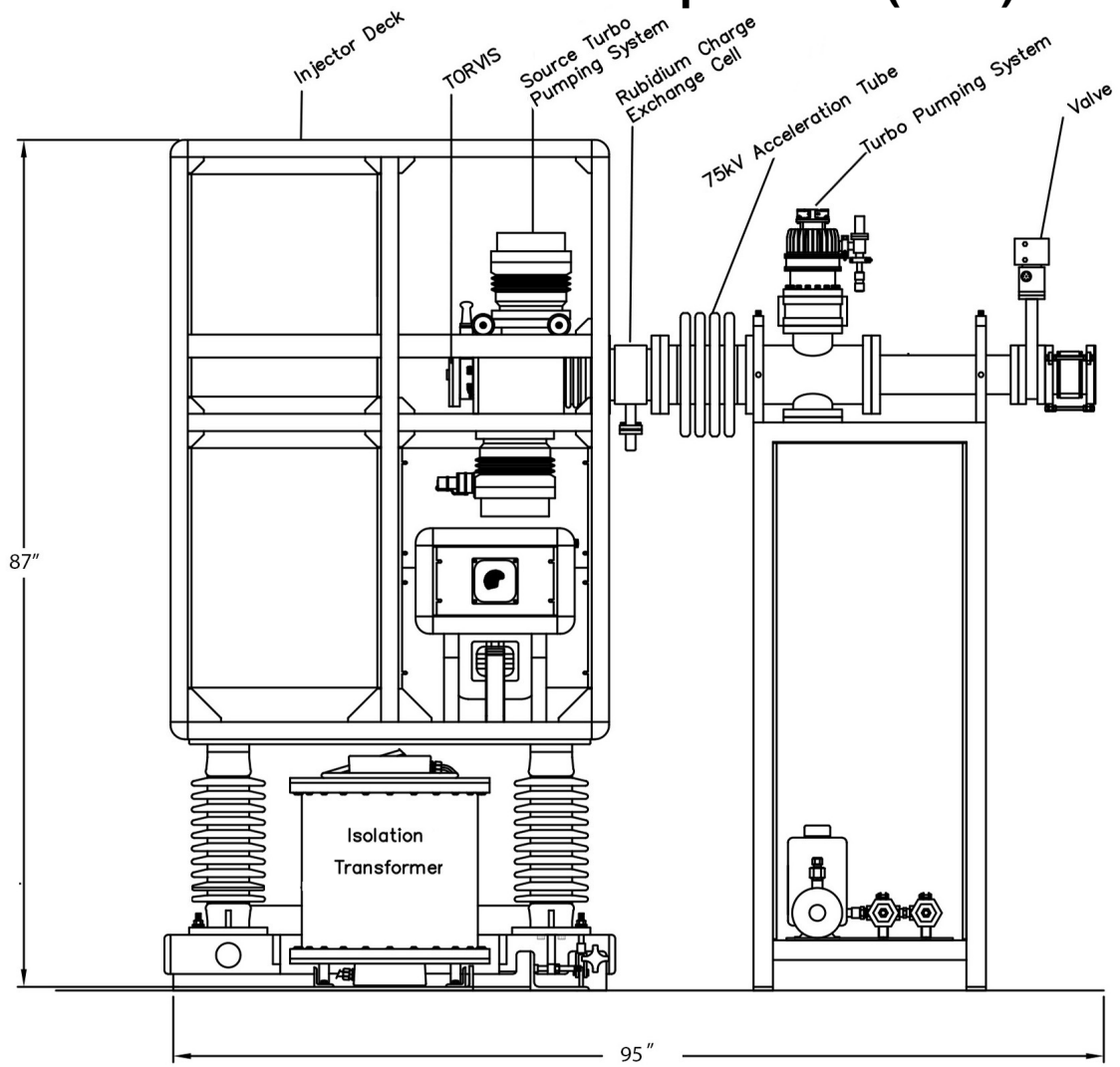
Low Energy Injector Upgrade: Strategy



SNICS II ion source → install

replace with

TORVIS (H/He) by
National Electrostatics Corporation (NEC)



Performance Specifications

- TORVIS H/He ion source
  - 75 kV source deck *Narrower beam pulses*
  - 100 μA H^-
  - 20 μA He^- } *x 5 current sources*
- SNICS-II ion source *New ion beam capabilities*
  - Heavy ion beams
  - 90-degree magnet for ion implantation

Summary and Outlook

HIGS

- New FEL optical cavity mirror capability for λ = 175 nm (E_γ = 100 – 120 MeV)
- R&D underway for FEL optical cavity mirror capability for λ = 155 nm (E_γ = 120 – 150 MeV)
- **Increase in HIGS operation by about 1500 hours/year for optimum pursuit of nucleon structure measurements**
- **Upgrade of the electron injector system at HIGS for reliable stable operation**

LENA

- Upgrade is in the final stage
- Systems commissioning will start during the first half of 2023
- **Upgrade for large angular coverage with HPGe detectors for optimum use of beam capabilities**

Tandem

- Low-energy injector upgrade underway:
  - TORVIS ordered
  - TORVIS installation during fall 2023
  - SNIC-II installation by 1st quarter 2024

Key:
Black – recently achieved or in final stage of being implemented
Blue – underway or imminent (funded)
Red – proposed investments