Photodisintegration of Deuteron in Low-energy region: HIγS Frozen Spin Target (HIFROST)

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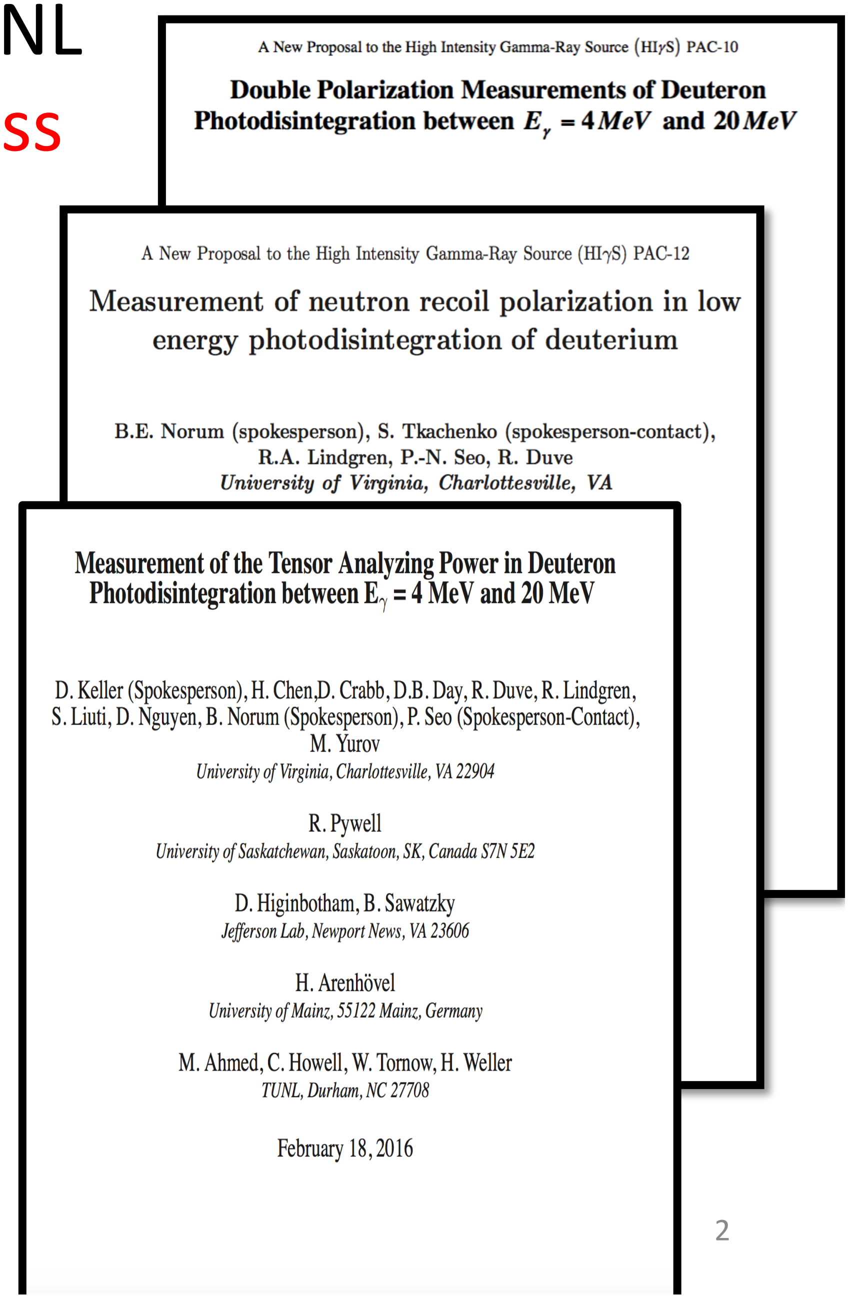
Spin Physics Conference, 9/27/16

Deuteron Photodisintegration Program in Low Energy at HIγS/TUNL –currently active progress

- GDH sum rule using $\vec{d}(\vec{\gamma},n)p$ between E_γ=4 MeV and 20 MeV
- Measurement of $P_{y'}$ in $d(\vec{\gamma},\vec{n})p$
- Measurement of the tensor analyzing power in deuteron photodisintegration between E_γ=4 MeV and 20 MeV


A New Proposal to the High Intensity Gamma-Ray Source (HIγS) PAC-10

Double Polarization Measurements of Deuteron Photodisintegration between $E_\gamma = 4\,MeV$ and $20\,MeV$

A New Proposal to the High Intensity Gamma-Ray Source (HIγS) PAC-12

Measurement of neutron recoil polarization in low energy photodisintegration of deuterium

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Measurement of the Tensor Analyzing Power in Deuteron Photodisintegration between E_γ = 4 MeV and 20 MeV

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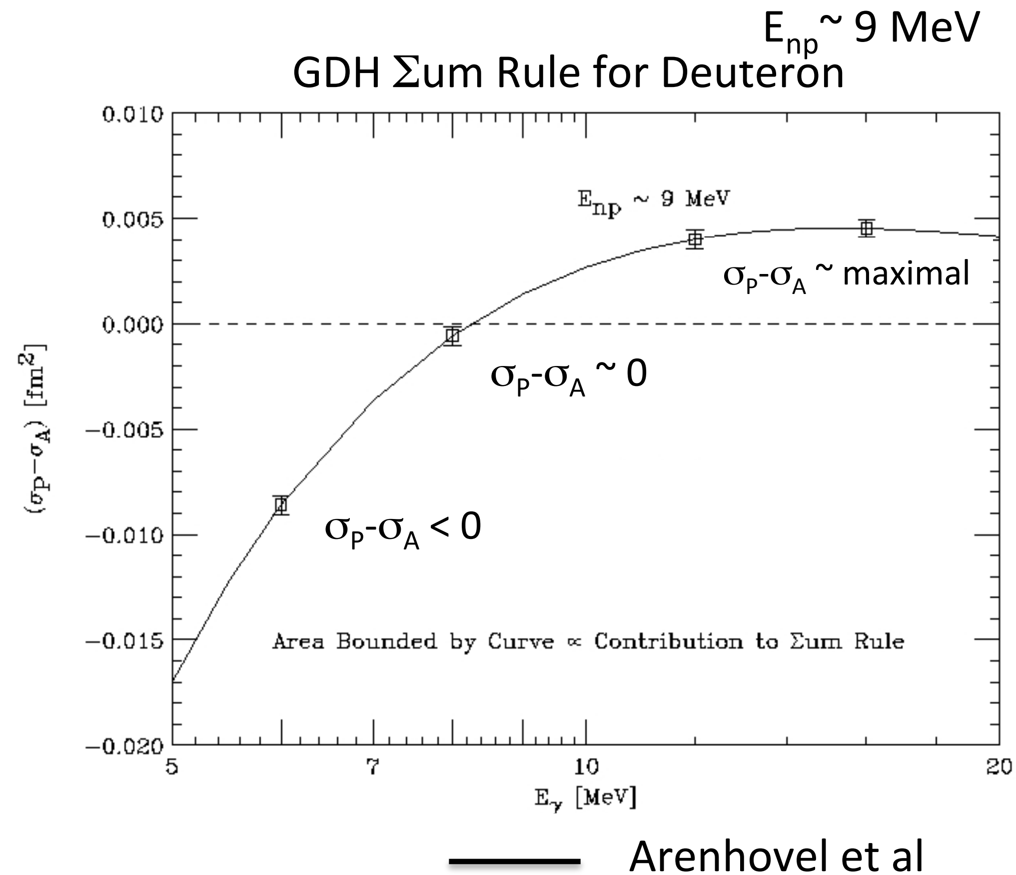
Gerasimov-Drell-Hearn Sum Rule

$$\int_{\omega_2}^{\infty} \frac{\sigma_P^{tgt} - \sigma_A^{tgt}}{\omega} d\omega = -4S_{tgt}\pi^2\alpha\left(\frac{\kappa_{tgt}}{m_{tgt}}\right)^2$$

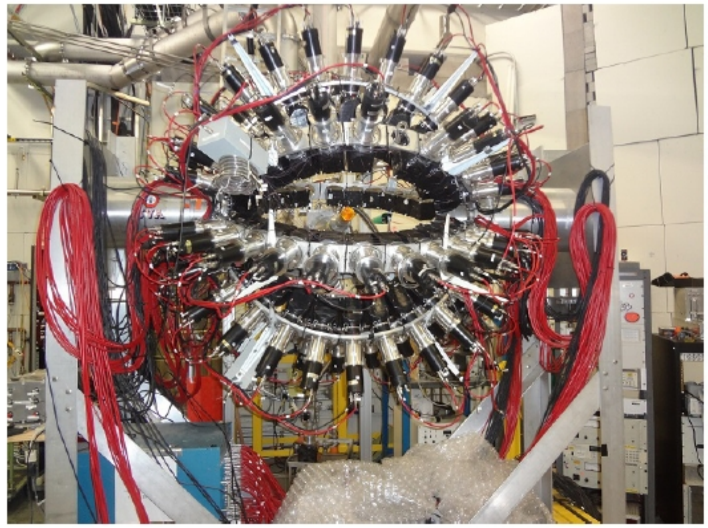
Target	κ	$\int GDH$
p	1.79	$204.0\,\mu b$
n	-1.91	$232.0\,\mu b$
d	-0.14	$0.6\,\mu b$

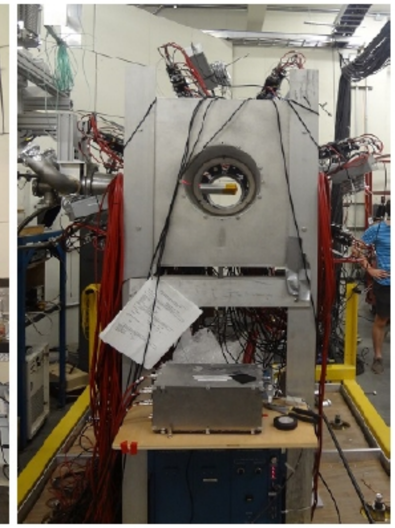


$$\int_{\omega_2}^{\infty} \frac{\sigma_P^{d} - \sigma_A^{d}}{\omega} d\omega = \int_{\omega_2}^{\omega_\pi} \frac{\sigma_P^{d} - \sigma_A^{d}}{\omega} d\omega + \int_{\omega_\pi}^{\omega_{\max}} \frac{\sigma_P^{d} - \sigma_A^{d}}{\omega} d\omega + \int_{\omega_{\max}}^{\infty} \frac{\sigma_P^{d} - \sigma_A^{d}}{\omega} d\omega = 0.6$$

Gerasimov-Drell-Hearn Sum Rule

The measurements:





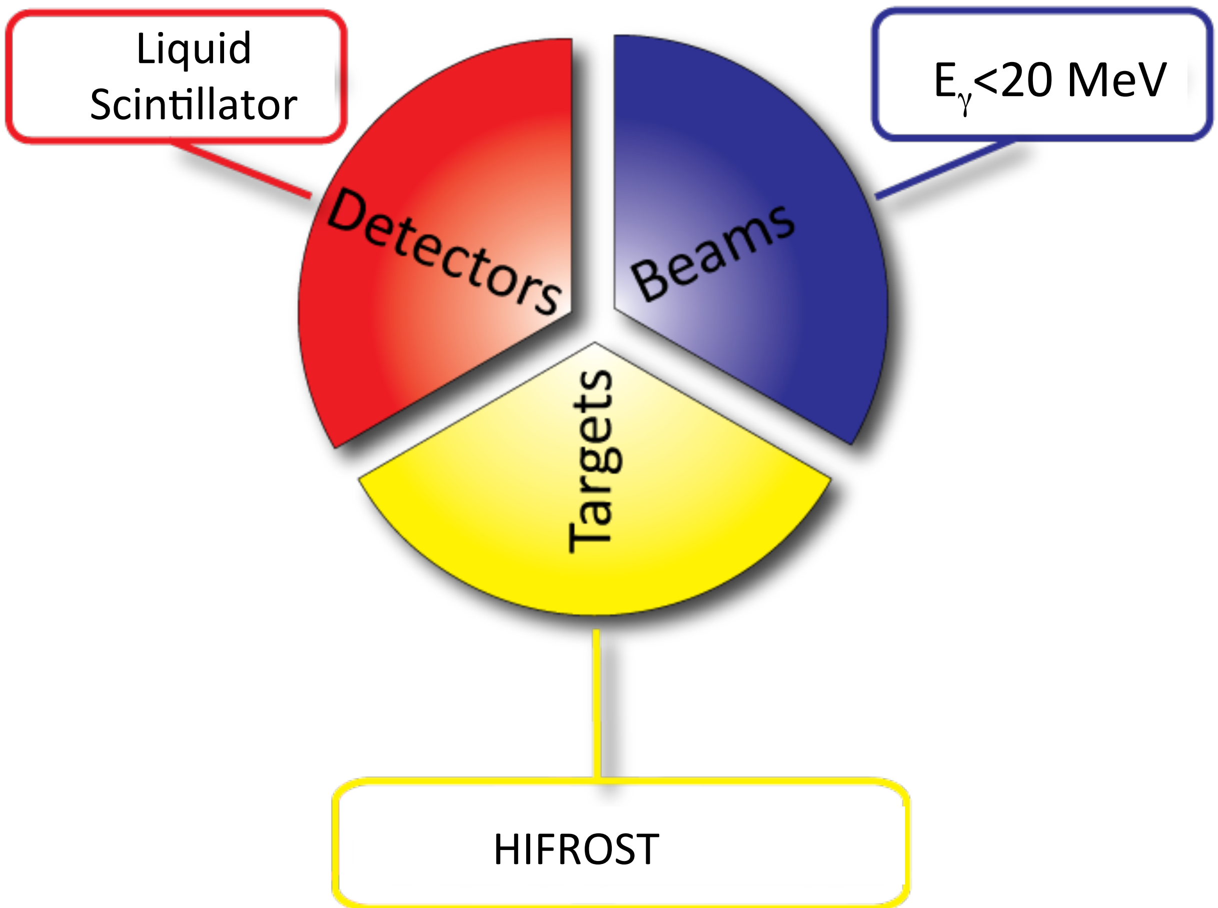
$$\frac{d\sigma}{d\Omega}=\frac{d\sigma_0}{d\Omega}\left[1-P_1^d P_c^\gamma T_{10}^c(\theta)+P_2^d T_{20}^c(\theta)\right]$$

Circular photon polarization
Longitudinal target polarization

$$\frac{d\sigma}{d\Omega}=\frac{d\sigma_0}{d\Omega}\left[1+P_l^\gamma \Sigma^l(\theta)\cos 2\varphi+P_2^d T_{20}(\theta)+P_l^\gamma\left\{\cancel{P_1^d T_{10}^l(\theta)\sin 2\varphi}+P_2^d T_{20}^l(\theta)\cos 2\varphi\right\}\right]$$

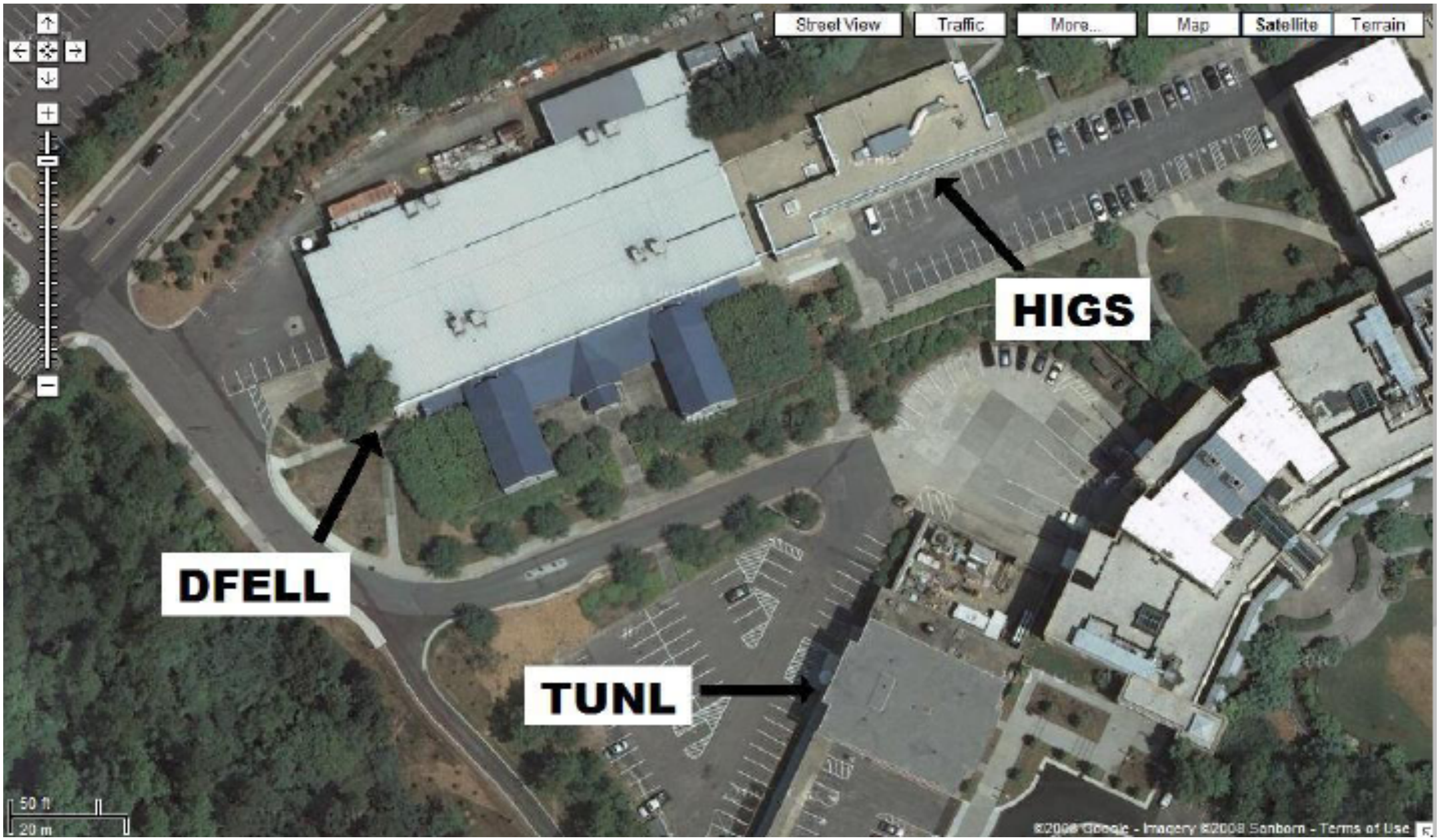
Linear photon polarization
Longitudinal target polarization

Experiments



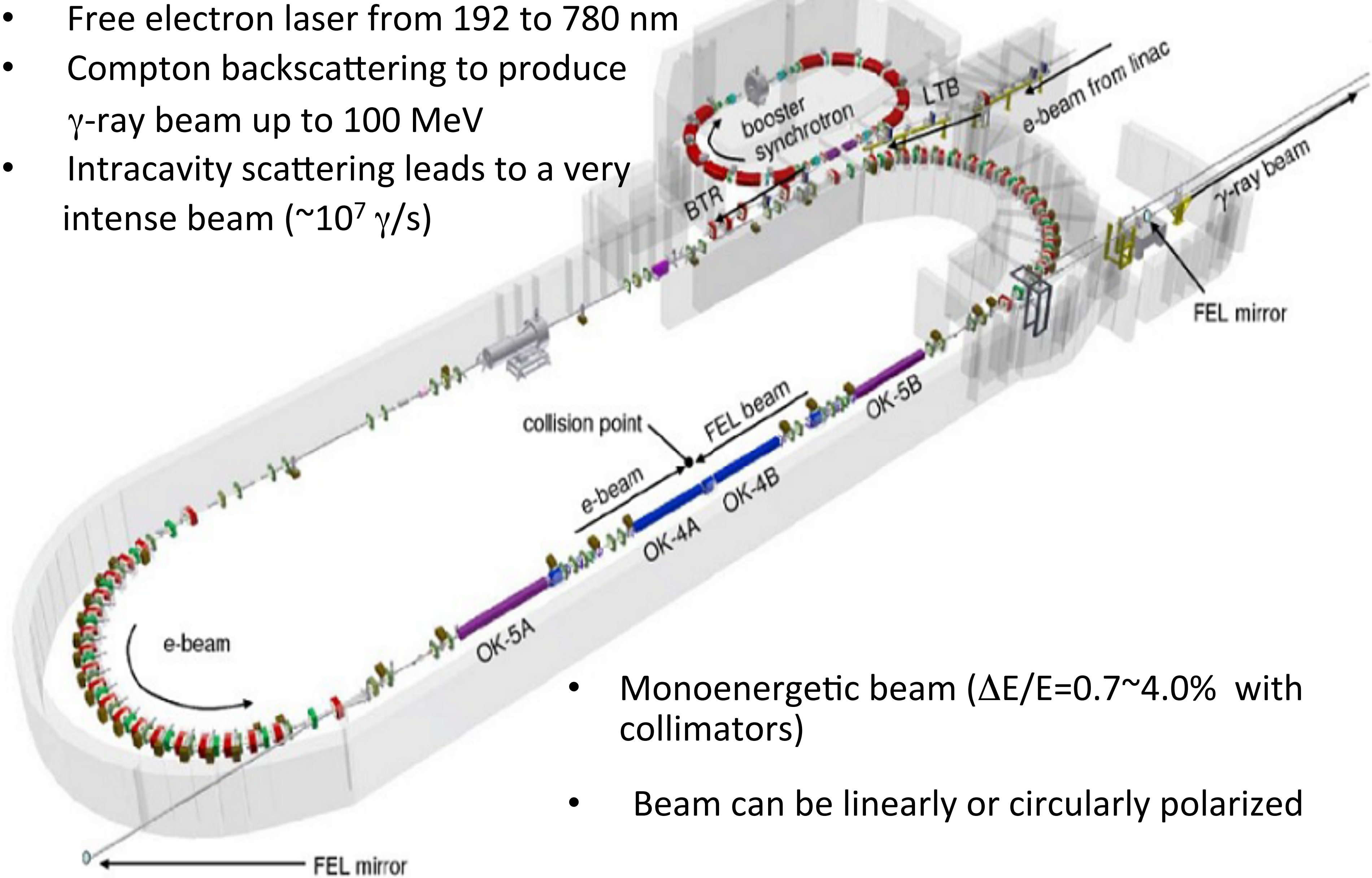
High Intensive Gamma Source (HIγS)

in Duke Free-Electron Laser Laboratory (DFELL)



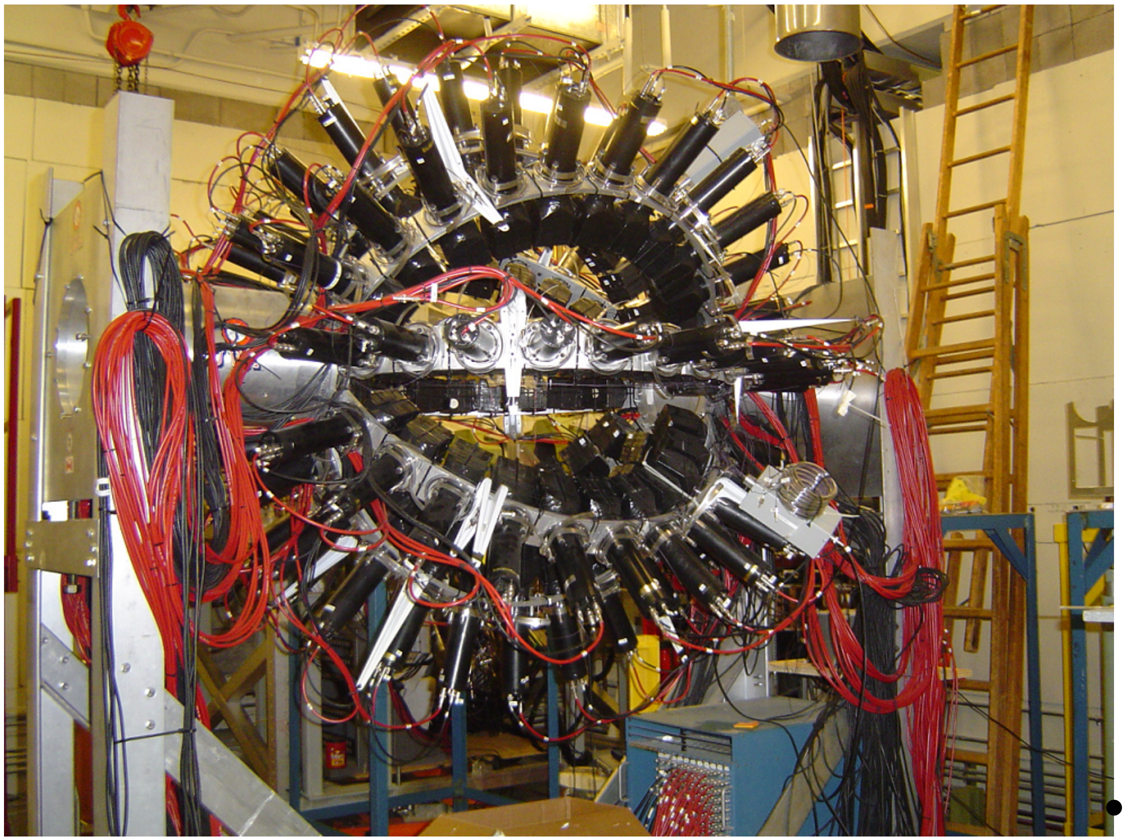
High Intensive γamma Source (HIγS)

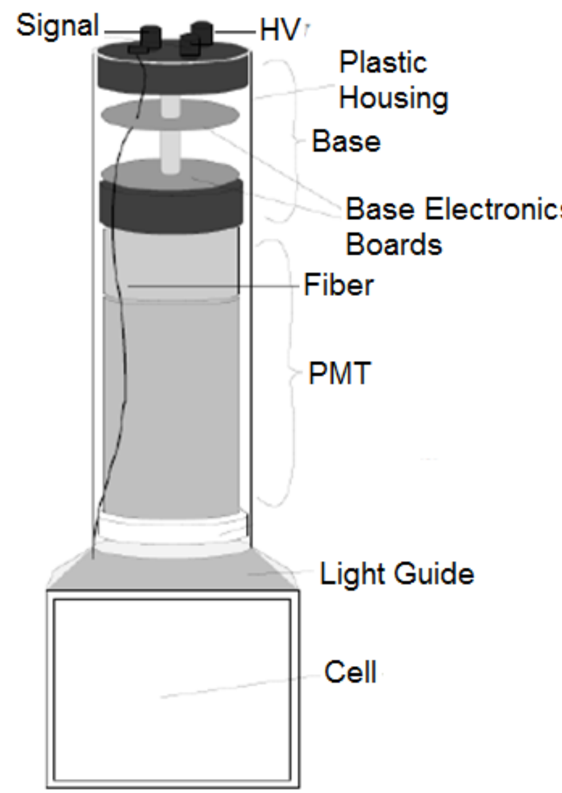
- Free electron laser from 192 to 780 nm
- Compton backscattering to produce γ-ray beam up to 100 MeV
- Intracavity scattering leads to a very intense beam (~10^7 γ/s)



- Monoenergetic beam (ΔE/E=0.7~4.0% with collimators)
- Beam can be linearly or circularly polarized

Blowfish detector cell

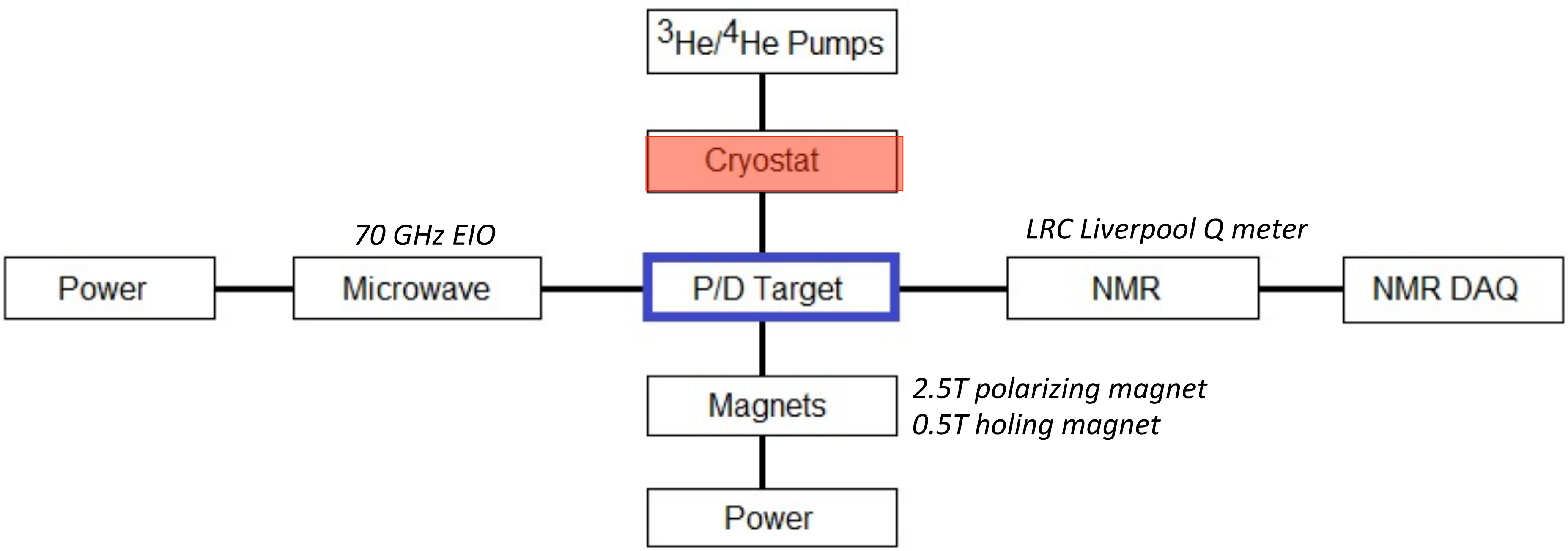




- 88 BC-505 liquid scintillator
- 8-evenly spaced arms in ϕ
- 11-evenly spaced in θ
- cover ¼ of 4π

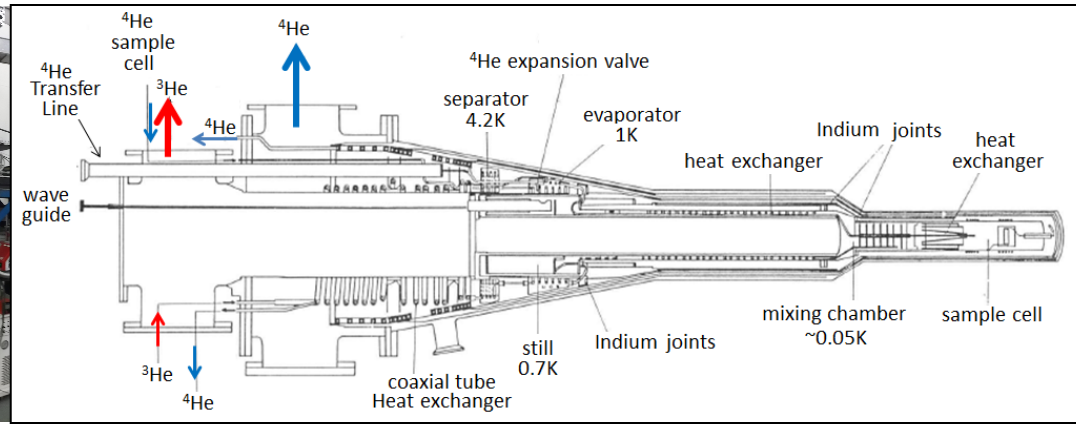
HIγS FROzen Spin Target (HIFROST)

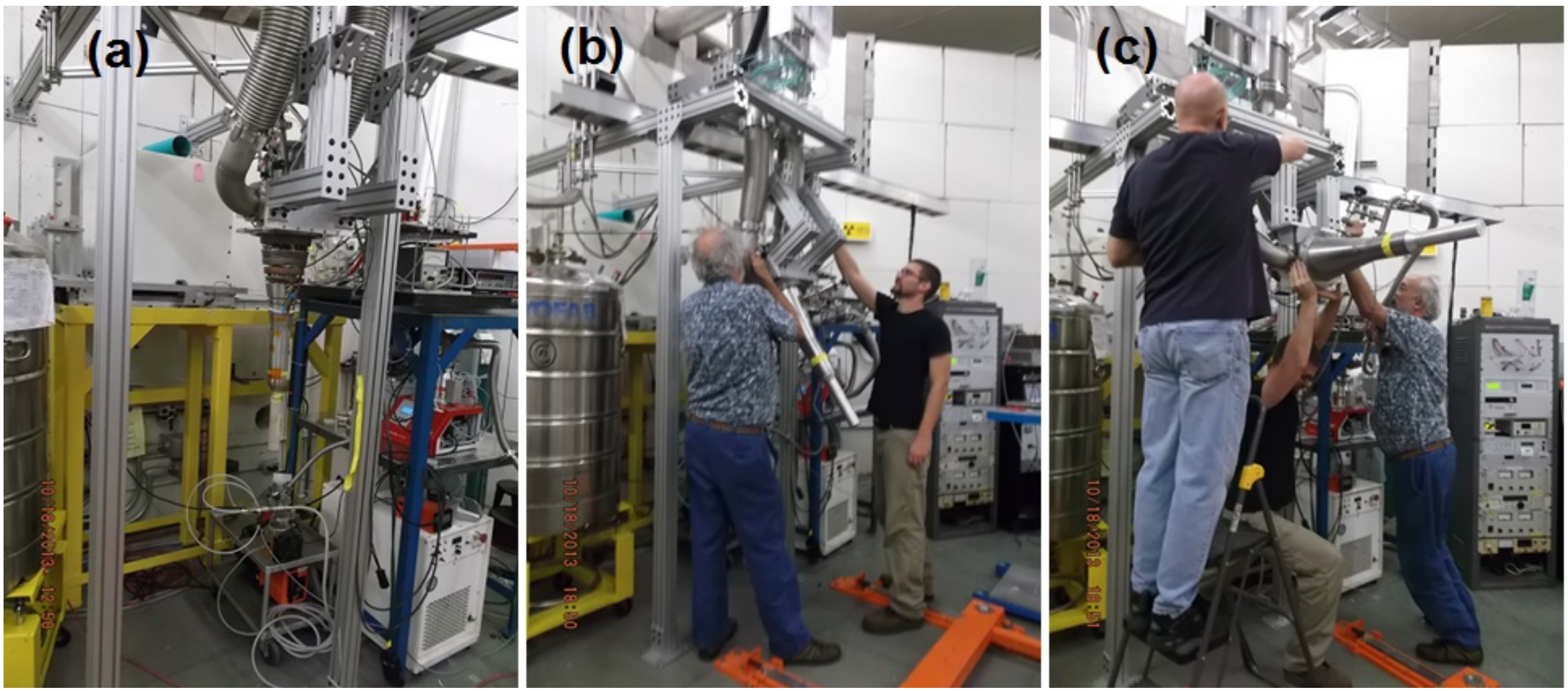
- Originally designed by T. Niinikoski in 1970's
- Used at CERN and GKSS in Germany in early 2000's
- Moved to in 2011 and modified by UVa (270mK)
- Moved to Duke in 2013 (190mK)
- Moved back to UVa in 2015 (150mK)



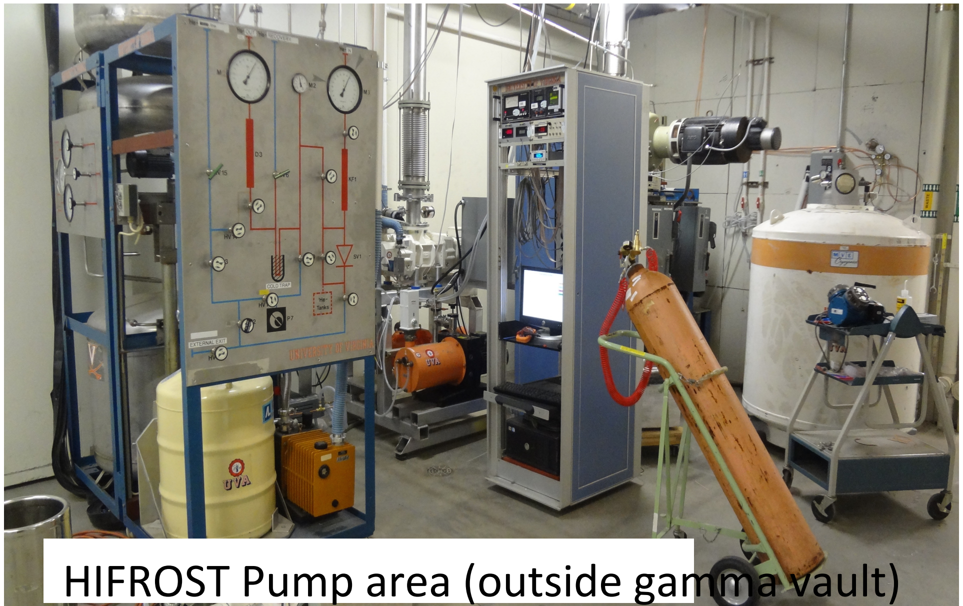
HIγS FROzen Spin Target (HIFROST) at Duke/TUNL

target cryostat

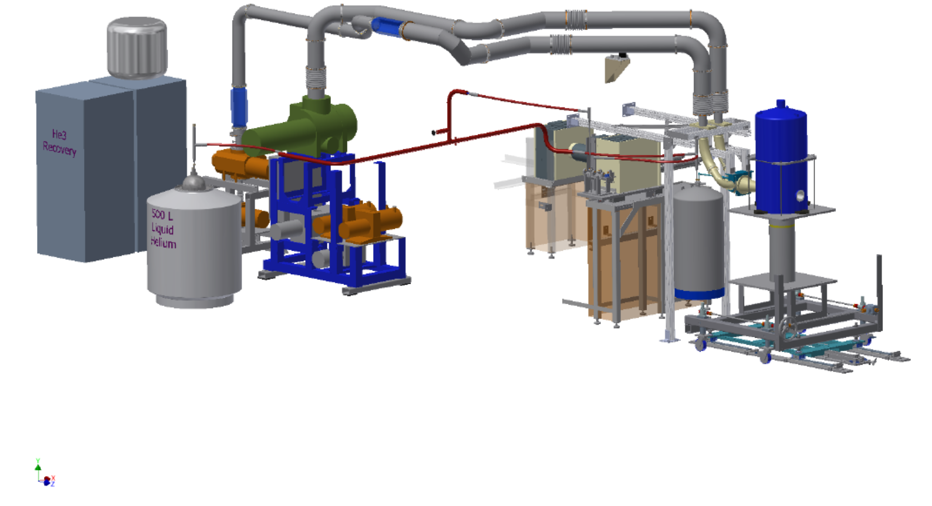




HIγS FROzen Spin Target (HIFROST) at Duke/TUNL

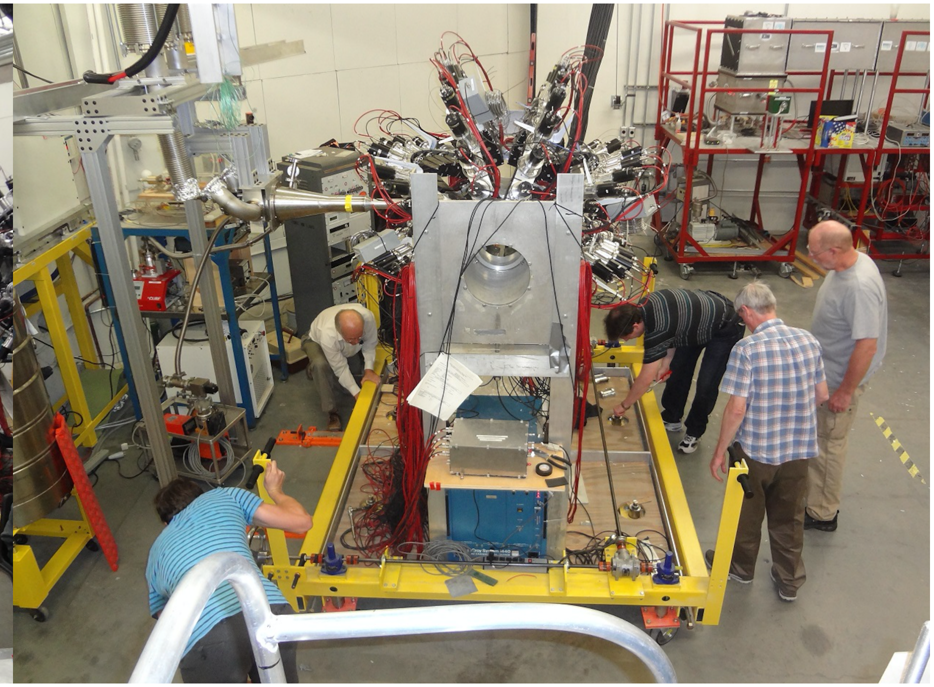


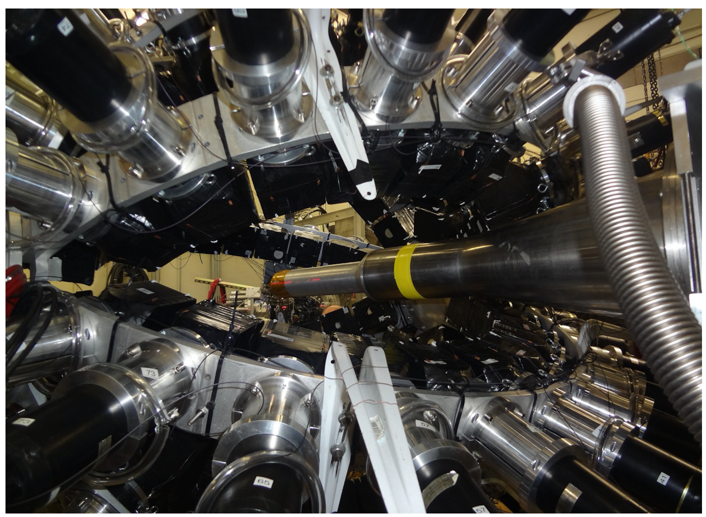
HIFROST Pump area (outside gamma vault)



HIFROST fridge area (inside gamma vault)

HIγS FROzen Spin Target (HIFROST) at Duke/TUNL





HIγS FROzen Spin Target (HIFROST) at Duke/TUNL

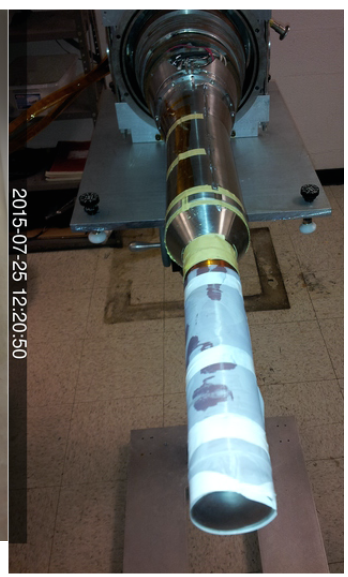
- Jan 2014: a holding coil was damaged

  ->need a new IVC and capillary for LHe, rewinding a holding coil, testing/mapping

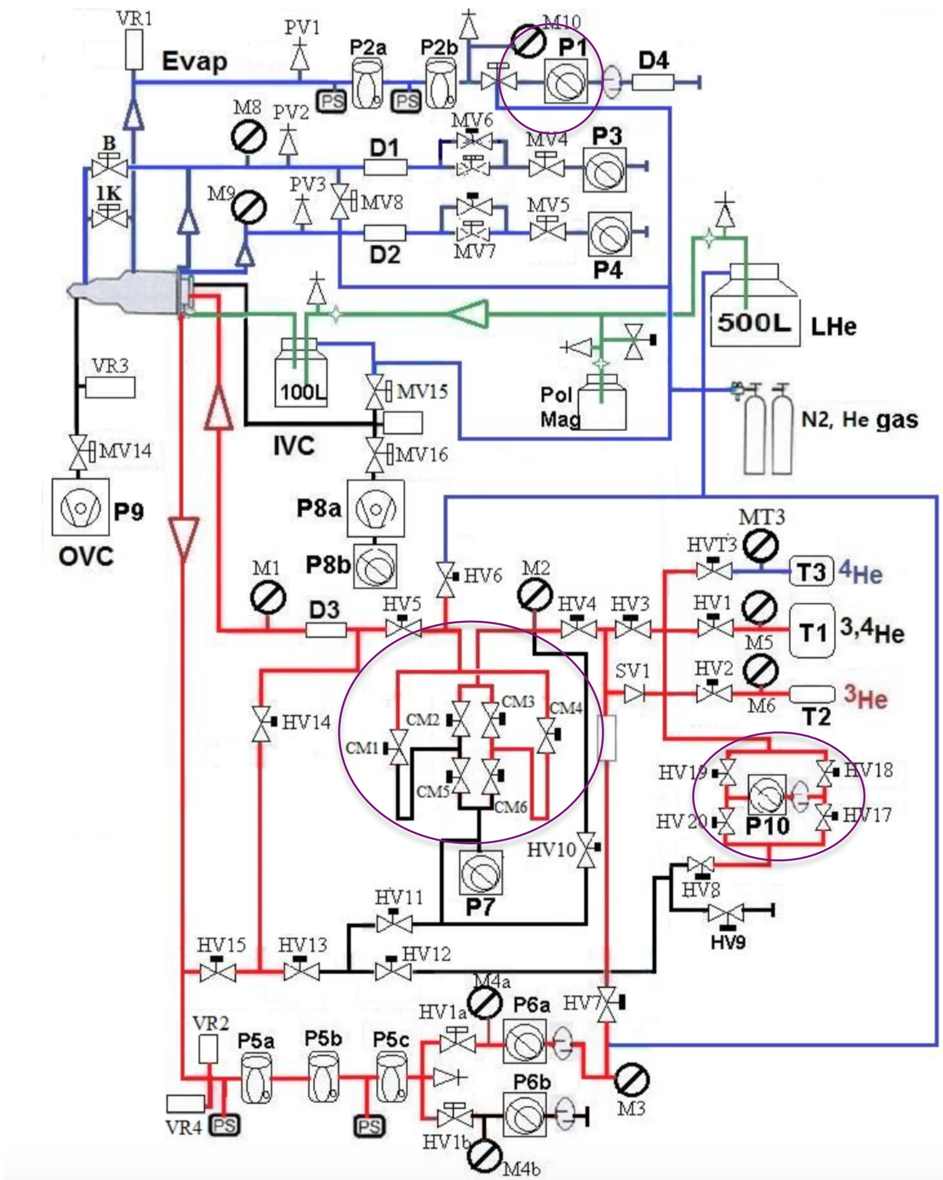
- Feb 2014: OVC damaged during fridge assembly

  -> fixed by JLab

- Jul 2014: designed and built 3He recovery manifold
- Jul 2014: mechanical pump (evap) failures

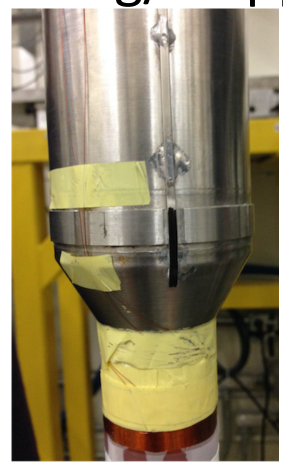
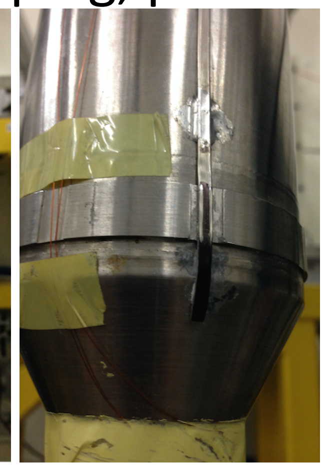


HIγS FROzen Spin Target (HIFROST) at Duke/TUNL



HIγS FROzen Spin Target (HIFROST) at Duke/UVa

- Oct 2014: dilution reached 190mK
- Jan 2015: the new LHe caplillary on IVC on was crushed during assembly
  ->need a new IVC and winding a coil, testing/mapping, power training
- Mar/April 2015: only dilution to 150mK,
  found external head loading,
  -> moved fridge back to UVa

- Jun 2015 – resolved 4K heat leak problem
- Nov 2015 – finish rebuilding and testing/mapping a holding coil
- Dec 2015 – cooled the holding coil to superconducting temperatures
- Jun 2016 – trained the coil to 24.5A though holding coil with fridge
- Jul 2016 – installed dual cold trap in gas flow system at Duke
- Aug 2016 – completed replacing a mechanical pump for 1K pot at Duke

Frozen Spin Polarized Target Commissioning Results Summary

- ✓ All vacuum systems operational
- ✓ Cryogenic liquid transfer established
- ✓ 1 K evaporative precooler online
- ✓ Holding magnet ramped to 0.5 T
- ✓ NMR installed and tested
- ✓ DNP microwave generator tested
- ✓ d-butanol material irradiated and polarized
- ✓ Polarizing magnet ramped to 2.5 T
- ✓ GDH, P_{zz} and FSP experiments approved
- ❏ Dilution below 100 mK (frozen spin target)

Gerasimov-Drell-Hearn Sum Rule target: HIFROST

Current Status:

- Two cooldowns at HIGS in spring
  - Revealed issues with heat leaks, magnet shorts and pumping speeds

Microwave system:

- Appeared that COBER PS not putting out enough power. Subsequently determined that power meter malfunctioning power meter

NMR System:

- All components ready
- Tuning required

Polarizing Magnet:

- Fringe field range measured
- 5 G limit for pacemakers established

Gerasimov-Drell-Hearn Sum Rule

(Other experimental preparations)

Detectors:

- All damaged Blowfish cells repaired
- Characterize response with monoenergetic neutrons
- Realign and check Blowfish array
- Develop procedures for moving/rotating Blowfish

Data Acquisition:

- Ready
- Used in July with subset of detectors
- Two parallel/redundant channels
  - FADC based
  - "traditional" two-gate system

Analysis:

- Follow procedures of previous Blowfish experiments
- GEANT-4 simulation packages ready
  - target new
  - Blowfish rotated

Future Work

Target returned to Duke in autumn 2016

Dilution optimization attempts below 150 mK

Target material loaded into refrigerator

Data run (~100 hours beamtime allotted)

Analysis, writeup and publication of results

AIM TO FINISH FIRST RUN BY JUNE 2017