Status of CLAS12 Related Targets

Xiangdong Wei
Jefferson Lab

Proposed CLAS12 Experiments

- 45 Approved Proposals.
- 16 Run Groups.
- Many different targets needed.
- As new proposals still come in, this rough count is not complete.

- Liquid Target:
  H_2, D_2, ^4He.
- Gaseous Target:
  H_2, D_2, T_2, ^3He.
- High Pressure Gaseous Target:
  H_2, D_2, ^4He.
- Gas-Jet Target:
  H_2, D_2.
- Solid Target:
  C, Cu, Sn, Ta, CH_2, CD_2, Al, Pb…
- Polarized Solid Target:
  NH_3, ND_3, ^6LiH, ^7LiD, (~~HD~~).
- Polarized Gas Target:
  ^3He.

- 23+ Targets in many different shape and size, depending upon the experimental requirements.
- The great effort and excellent support from the Target Group made this possible.
- New targets are developed and built while experiments are running in Hall-B.

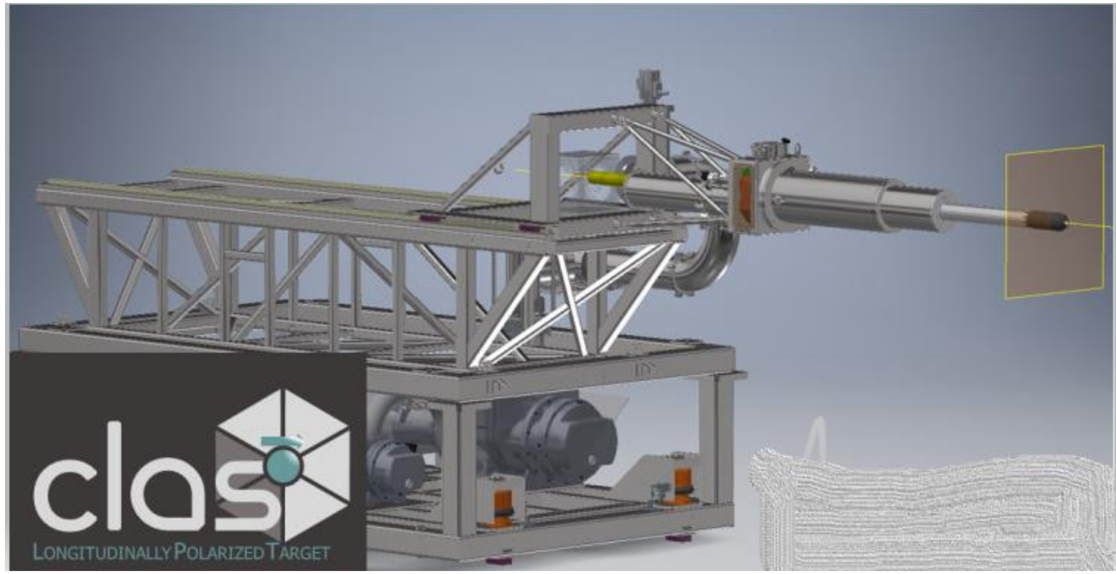
Targets used in the past with CLAS12

- CryoTarget I (Saclay Target)
  - LH_2, LD_2, nuclear.
  - Supported RG-A, RG-B RG-M.
  - Built long time ago, supporting was getting harder.

  →Need an update/upgrade

Targets used currently with CLAS12

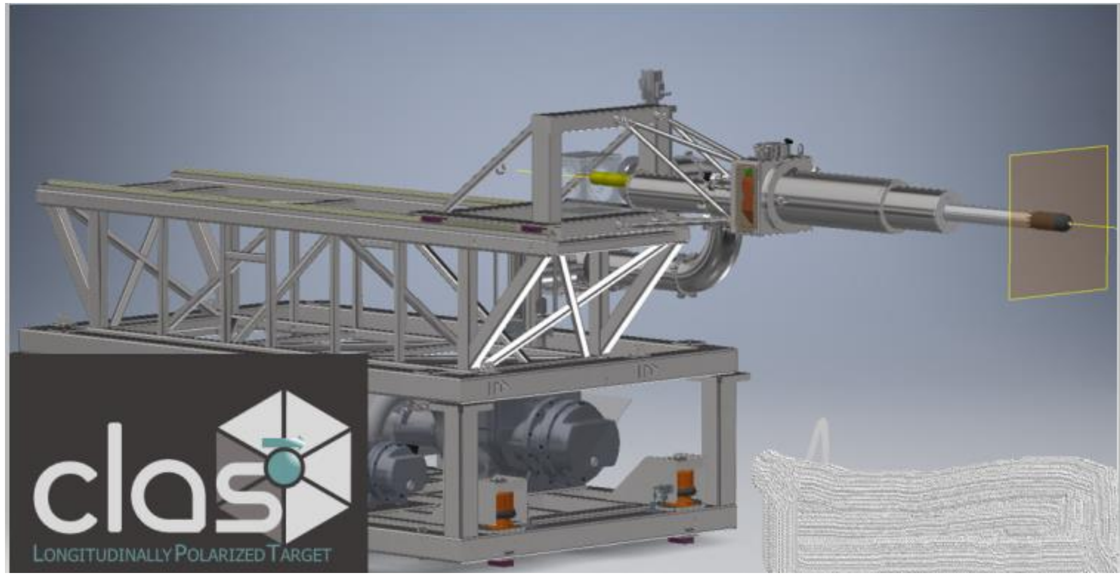
- Longitudinal Polarized Target (newly built)
  - DNP: ± Polarized NH_3, ± Polarized ND_3.
  - Unpolarized CH_2, CD_2, C, Empty Cell.
  - Supporting RG-C currently.
  - First polarized target for CLAS12 experiments.



→Hear details of target performance from James' talk (next).

→Hear the first look at RG-C data from Néomie's talk (2nd next).

Targets used in the future with CLAS12



- Longitudinal Polarized Target (Used in RG-C)
  - DNP: ± Polarized ^{6}LiH, ± Polarized ^{7}LiD.

    →New materials: Beads production, paramagnetic radical density need to be studied thoroughly in order to get highly polarized target.

    →→Irradiating target materials locally at JLab is extremely necessary for producing polarizable beads and consistent initial polarization results.

  - Supporting RG-G.

→Hear details of RG-G preparation from Sabastian's talk.

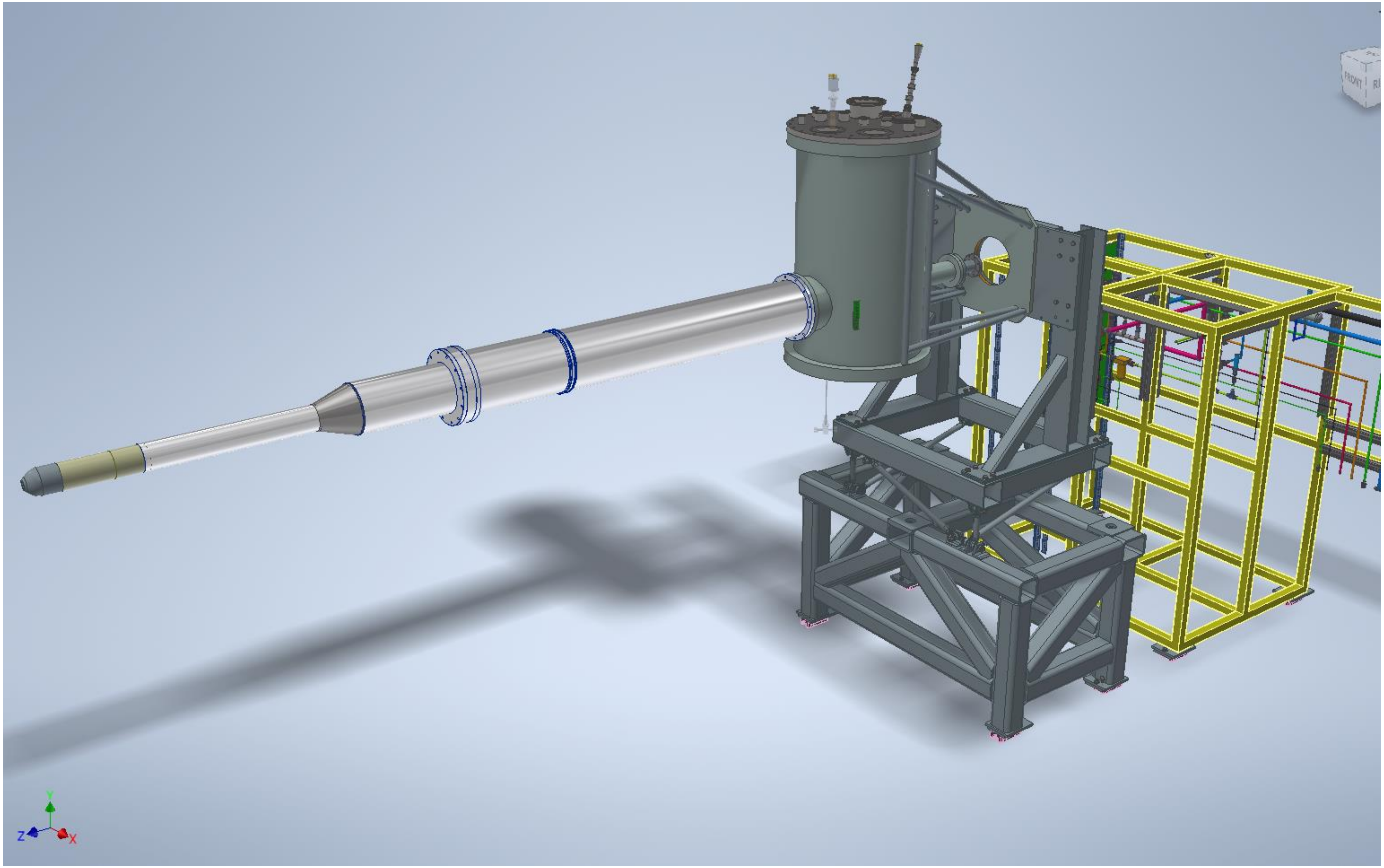
Targets used in the future with CLAS12

- CryoTarget II (Redesigned CryoTarget)
  - LH_2, LD_2, nuclear.
  - Supporting RG-D, RG-E, RG-K, RG-M...
  - Designed, currently under construction.

    →Hear details of RG-D preparation from Lamiaa's talk on Thursday.

  - The Chilean Target (Foils on a ribbon)

    →Hear details of RG-E preparation from Hayk's talk on Thursday.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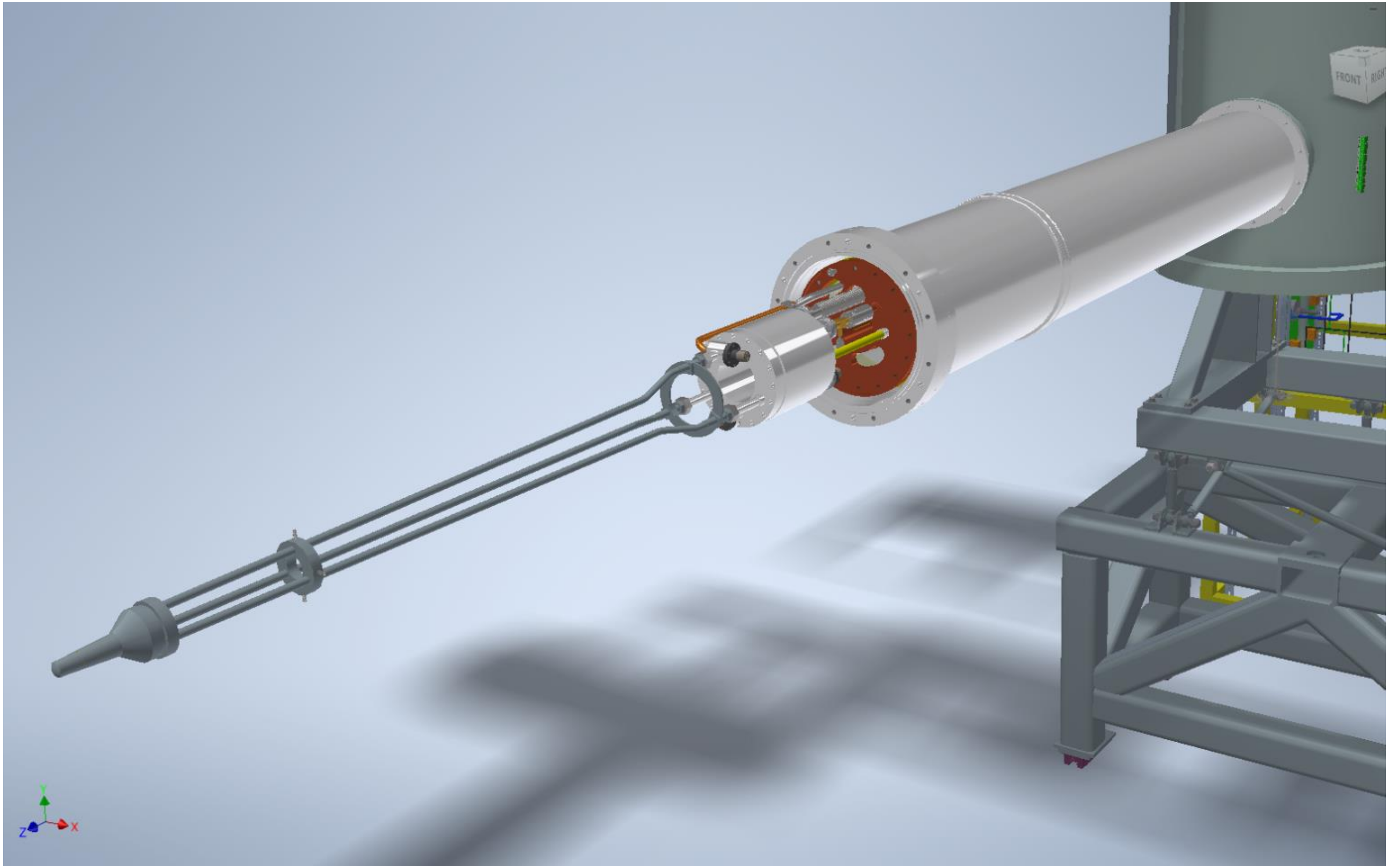
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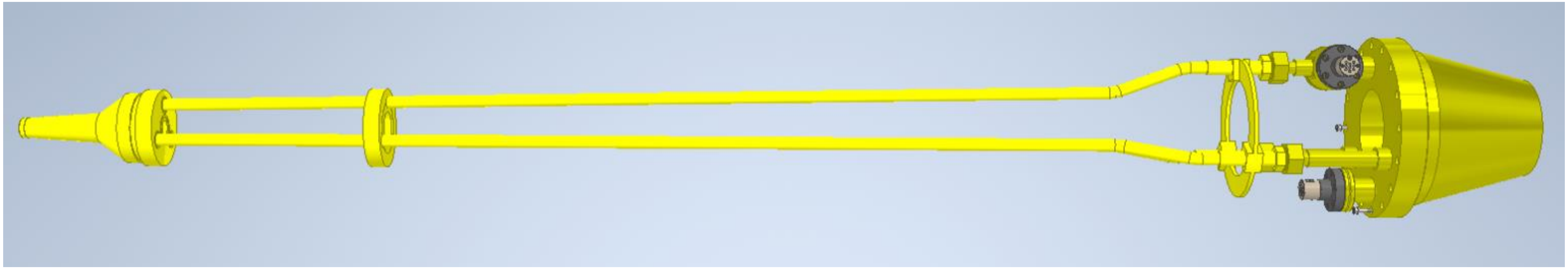
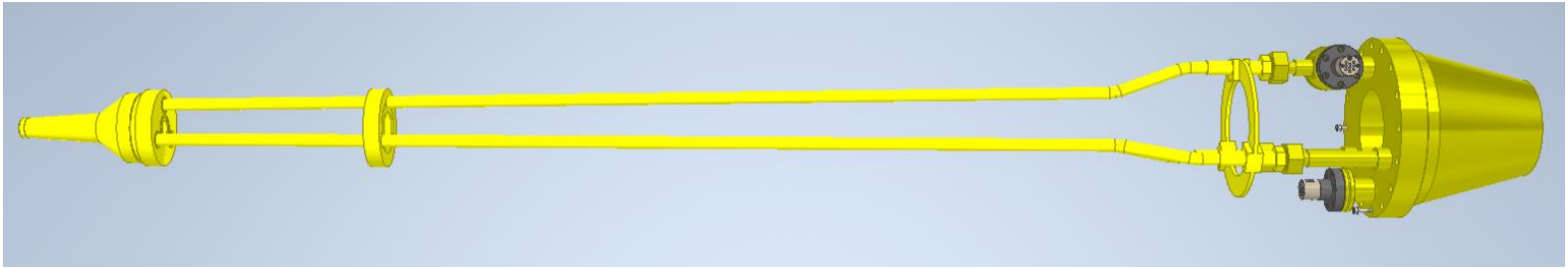
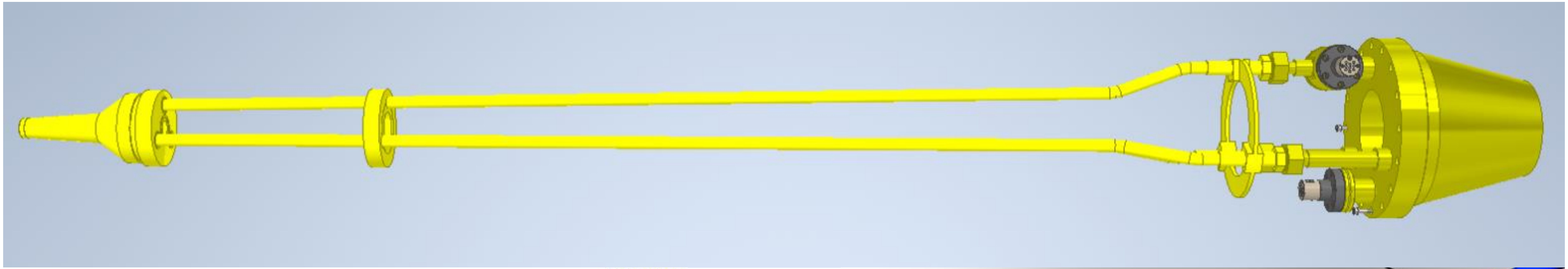
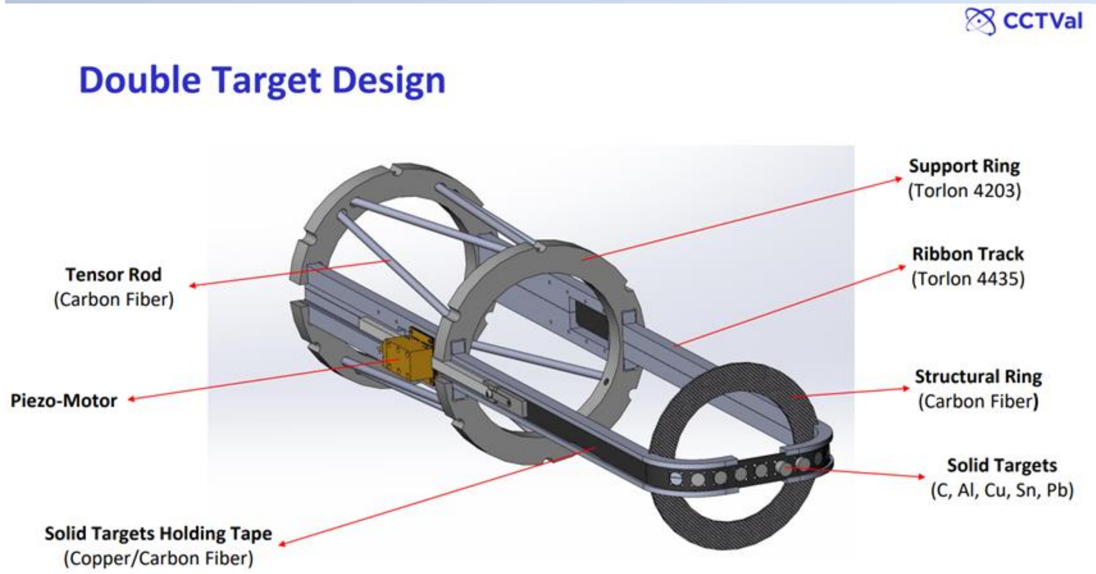


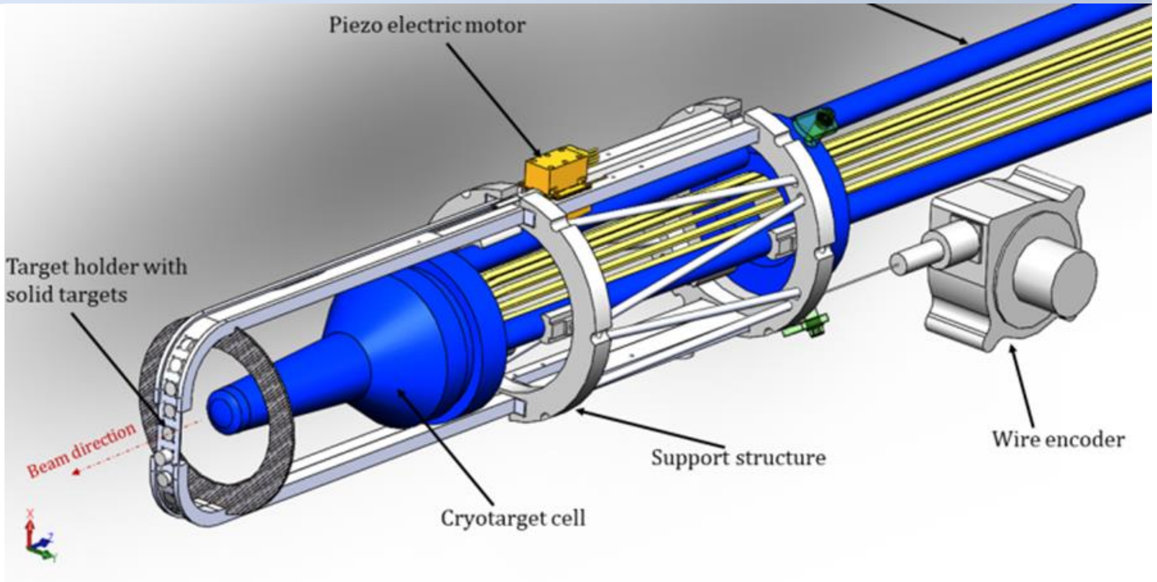
- Modular Target Condenser Design to accommodate multiple Target Configurations both current and future (J. Brock)
  - Variety of existing Cryotargets cells
  - Solid Targets
  - Chilean Target RG-E (cooled via heatshield)
  - MEOP (Proposed)
  - Tritium (Proposed)



- Controlled Heat Shield Temperature w/ Independent Cooling Circuit for heat sinking variable loads
- MFC Coolant Circuits with appropriately sized exhaust heaters to eliminate icing issues
- New EPICS and Python Control Software (J. Maxwell)
    - LAN with distributed Virtual IOC
- High Efficiency LHe Transferline for continuous filling
- Smaller LHe reservoir, 17 L reduced to 3 L
- ASME Pressure Vessel Code Compliance Construction (B. Miller)

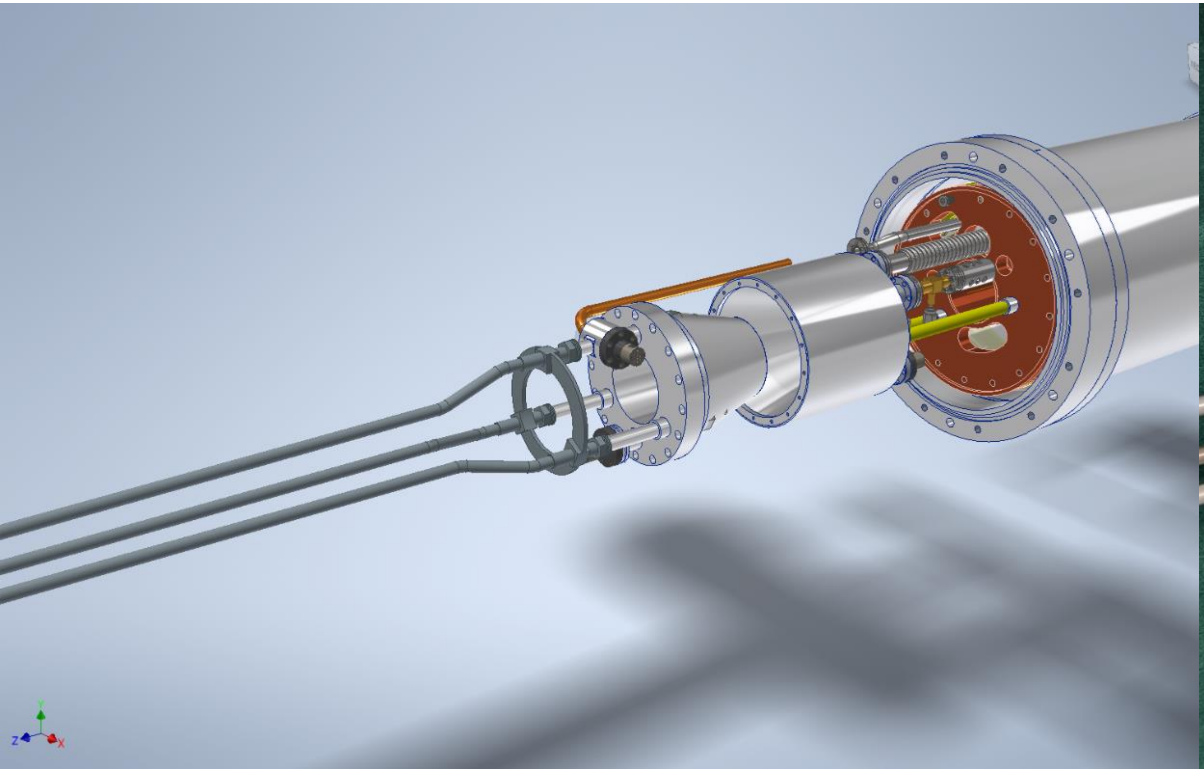






- Chilean Target (grey) will be mounted on the cryostat mounting ring.
- Targets are cooled conductively through the support structure.
- Target material change is done by moving the sample ribbon.

Parts are being fabricated



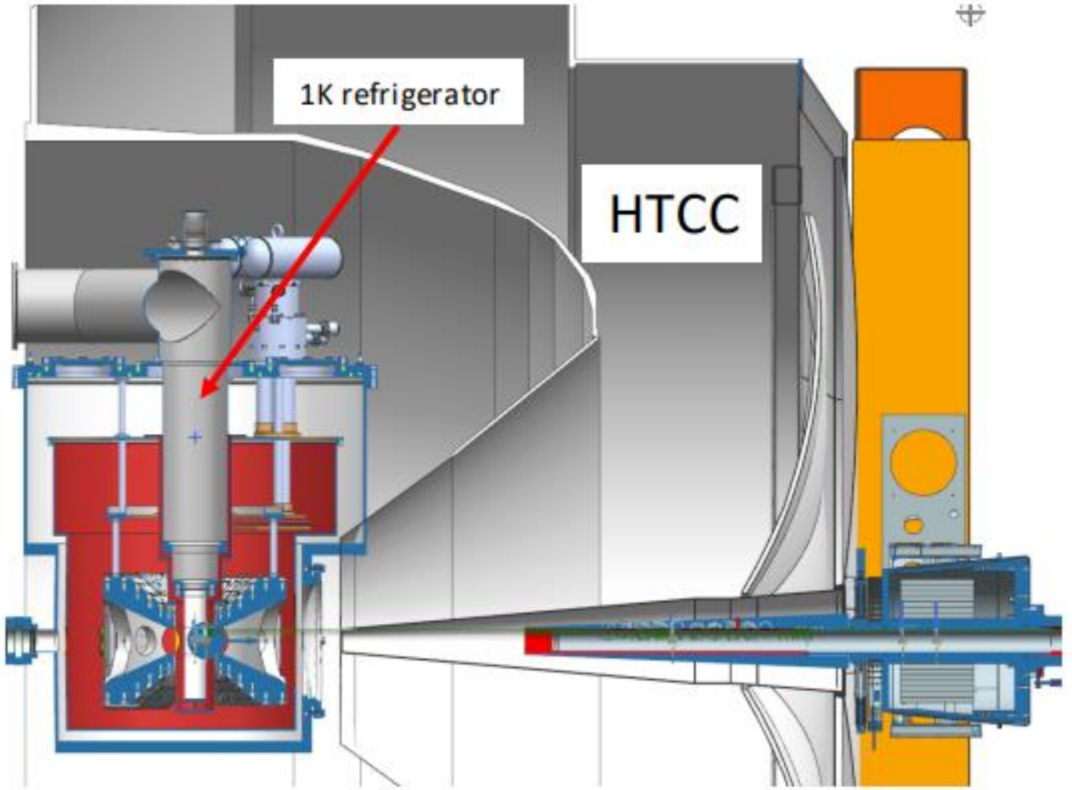
Targets used in the future with CLAS12

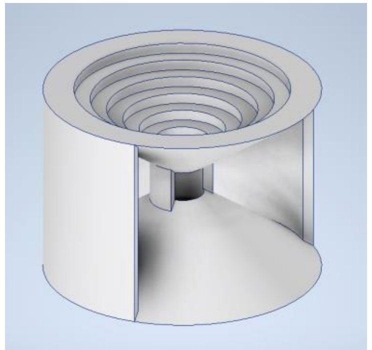
- Transversely Polarized Target

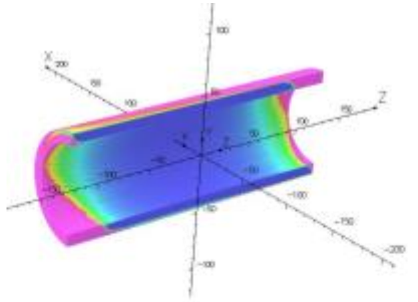
  (a shorter version of RG-C target, running vertically)

  - DNP: ±Polarized NH_3.
  - Need a new magnet with to provide transverse magnetic field.
  - Supporting RG-H.

→Hear details of RG-H preparation from Marco's talk later.

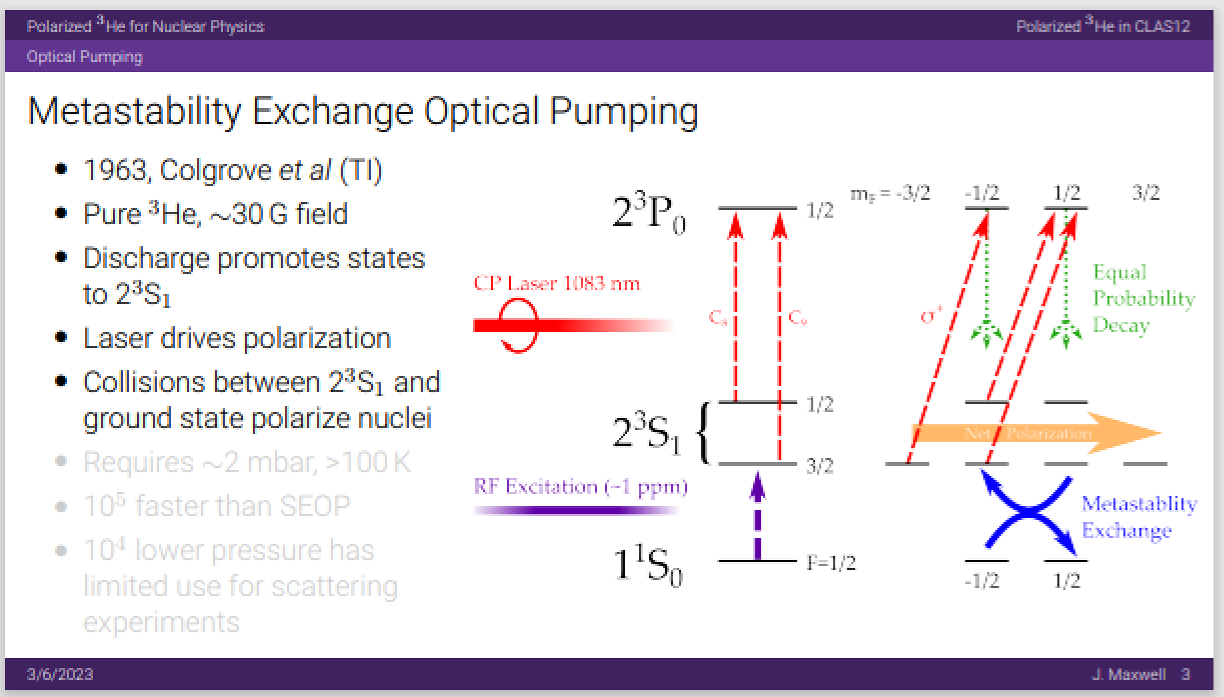


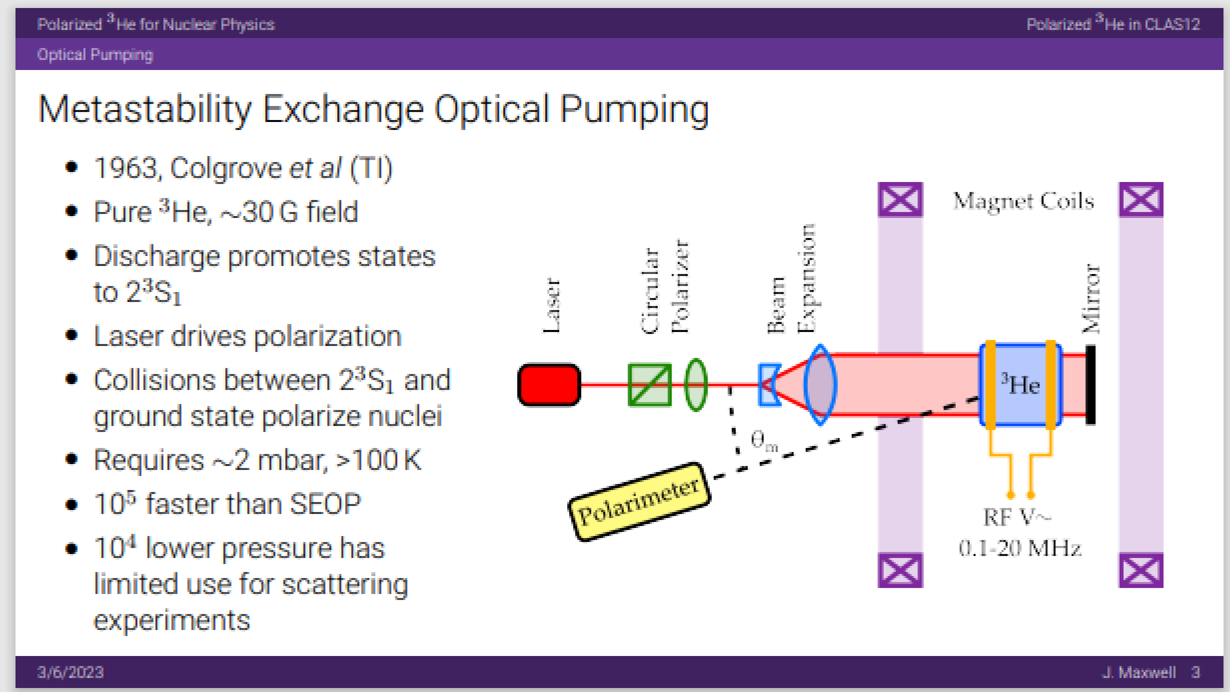




Targets used in the future with CLAS12

- Polarized ^{3}He Target
  Metastability Exchange Optical Pumping (MEOP)
  - DNP: +-Polarized NH_3.
  - Supporting RG-N
  - Maybe RG-H???





Creating a New Target for CLAS12

Double-Cell Cryo Target
- Polarize at 300 K
- Transfer to 5 K target cell
- Density increase 60×

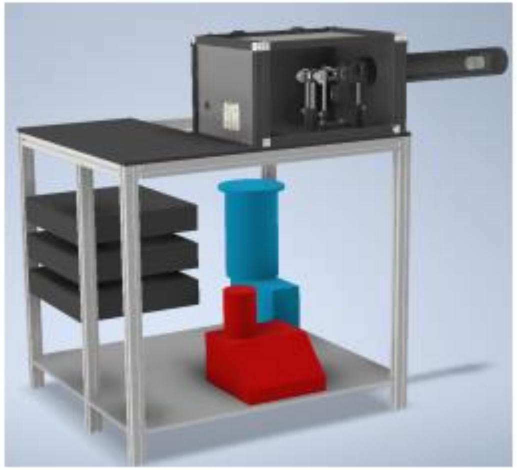
+

High Field MEOP
- High Polarization (~60%)
- High magnetic fields (5 T)
- Pressure increase 100×

- By combining established technologies: a new polarized target (Maxwell, Milner, NIM A, 2021.)
- Achieve 5.4 amg, roughly half JLab SEOP target gas density
- Polarize within 5 T solenoid: CLAS12 standard configuration

Planned Research Program

- High field MEOP test stand explore high field polarization vs. pressure and field, reproduce results of KBL
- Cryogenic tests of cells with Target Group's 4 K test stand
- Full, double-cell prototype to allow in-beam tests at JLab's injector test facility



First High Field Tests, 2022

- High Field Polarization
  - Probe laser polarimetry (Suchanek *et al.*, Euro Phys JST, 2007.)
  - Wavelength meter
  - Python DAQ software
- Limited laser power, wavelength
  - Confirmed operation of probe polarimeter
  - Mapped pump and probe laser peaks at 2, 3, 4 T
- Despite poor laser power, saw 44% polarization

Current Status

- FROST Magnet cooled in January
  - Filled with gas cylinders
  - Cold and stable since then
- High Field Tests began in February
  - Configured probe laser for higher power pump
  - Discovered flaw in new pump laser controls, requires return
- Now: 55% Polarization
  - Working on adjustments to improve polarization
  - Looking to match BNL results ~ 80%
- Starting construction of gas panel for varied pressure

Key Development Question: In-beam Performance

- How much polarization relaxation is expected at 100 mbar and 5 K in 0.5 μA beam while inside a 5 T magnetic field?
- Previously aimed to move directly to full, experiment-ready prototype
- What is the most direct approach to answering that question?

Revised Development Path

- Utilize existing cryocooler test stand for cooling
- Build minimal cryostat extension to cool cell in FROST magnet
- Simplify cell design to test depolarization. Gas exchange via diffusion.
- High polarization not main goal: understanding depolarization is.
- Have ready to take beam in early 2024.

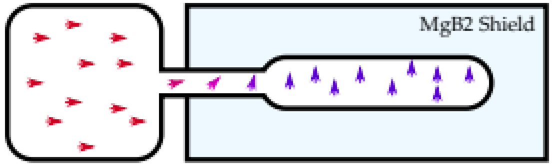
Parameter	Bates 88-02 Target Achieved	CLAS12 Target Proposed
Pumping cell pressure (mbar)	2.6	100
Pumping cell volume (cm^3)	200	120
Target cell volume (cm^3)	79	100
Target cell length (cm)	16	20
Number of atoms in pumping cell	1.2×10^{19}	3×10^{20}
Number of atoms in target cell	6×10^{19}	1.5×10^{22}
Holding field (T)	0.003	5
Polarization	40%	60%
Incident electron beam energy (GeV)	0.574	10
Cell temperature (K)	17	5
Target thickness (^{3}He/cm^2)	1.2×10^{19}	3×10^{21}
Beam current (μA)	10	2.5
Luminosity (^{3}He/cm^2/s)	7.2×10^{32}	4.5×10^{34}

Cryogenics and Heat Load

- Heat loads on 5 K target cell:
  - Beam heating (<150 mW)
  - Pumping cell at 293 K, transfer through glass and gas (<500 mW)
  - Radiative heating minimized by heat shield (<20 mW)
- Pulse-tube cryocooler for 2.5 W at 4.2 K should be sufficient (Cryomech PT425)
- JLab's Hall D cryotarget provides liquid H_2 and He_2
  - Few modifications needed to design to support a MEOP double-cell cryotarget

Transverse Polarized ^{3}He in CLAS12?

- Three high-impact Hall B experiments hoped to use transversely polarized HD-Ice Target
- Transverse with CLAS12: bulk superconductor
  - Cancel 2 T ∥ CLAS12 field
  - Create a 1.5 T ⊥ holding field
- See G. Ciullo's talk on Tuesday
- For ^{3}He: same but holding field ∼50 G
- Pumping cell in longitudinal field
- Rotate spin adiabatically in transit to target cell



Targets used in the future with CLAS12

- Tritium target.

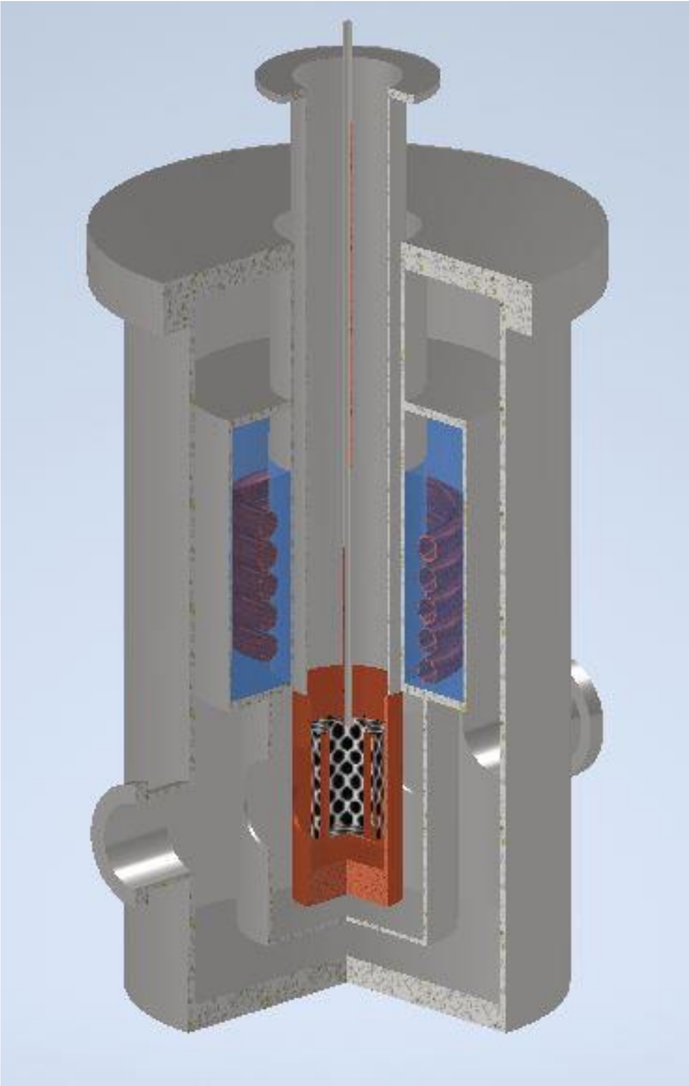
  Developed for Hall-A, will be adapted to CryoTarget II for Hall-B operation.

Irradiating Polarized Target Materials at JLab

- DNP targets require uniformly distributed paramagnetic centers in the target material for the polarizing process.
- Those paramagnetic centers are normally generated by irradiating target materials with certain dose at certain temperature, for achieving best results.
- Up to now, JLab's polarized target materials are supplied by external institution (e.g. UVA,…).
- During RG-C run, some materials were found not having enough radicals to use "as is", and require large dose in the target position with real beam time which could be used for data taking.
- For purpose of expanding material coverage and scheduling reliably, irradiating target materials onsite is absolutely necessary.

JLab Irradiation Cryostat

- A target material irradiation cryostat need to be built and be used on one of the JLab's electron machines soon.
- New proposal to DoE's Fusion Energy Sciences Office: "Spin Polarized Nuclei for Injection into DIII-D" by JLab, UVA, UC-Irvine and ORNL (Due next week), in responding to the FES' funding opportunity announcement. It is for eventually testing the polarized ^{7}LiD and ^{3}He fuels in DIII-D's tokamak plasma.
- JLab will responsible prepare irradiated ^{7}LiD pellets and later polarized pellets and system integration (during subsequent funding cycles).
- This proposal will bring in external funding and manpower to help target group to build such cryostat, develop the procedure do get the dose and temperature right, and start producing irradiated LiD beads.



A slide of Fusion Channels for proposed test, PSTP2022 in Mainz

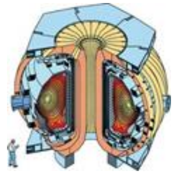
- The intended fuel:
    - $D + T \rightarrow \alpha + n$
    - and $D + {}^3He \rightarrow \alpha + p$

- Most of research Tokamaks ever built (~30 in operation today) were for studying D+D reactions.

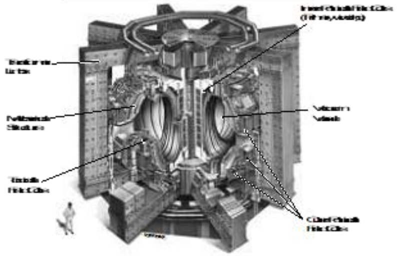
- ***I***nternational ***T***hermonuclear ***E***xperimental ***R***eactor (***ITER***) will make harvesting fusion power possible.

- The cost is ~$V_{\text{-plasma}}$ x B^2.
  $\Rightarrow$20~40 billion dollars

DIII-D (USA)
Best instrumented
$\rightarrow$most diagnostics
20m^3, 2.1T, Q<<1

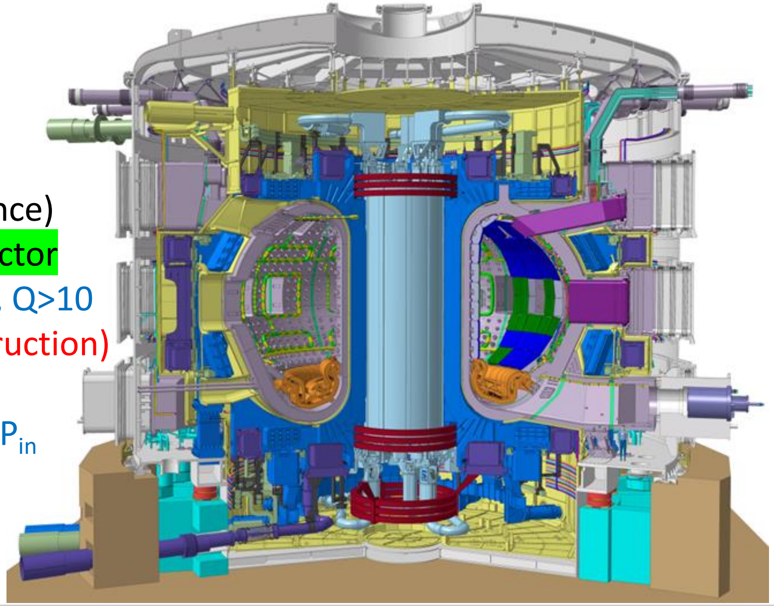


JET (UK)
Only one runs tritium
90m^3, 3.8T, Q~2/3



ITER (France)
½ GW reactor
700m^3, 5.3T, Q>10
(under construction)

$Q \equiv P_{out}/P_{in}$



Summary

- A lot of targets involved in CLAS12 experiments.
- Developing, constructing and operating them take tremendous amount of effort.
- Target group has done an excellent job.
- They need to free up some hands for developing new targets and techniques. This is going to be an issue when they have to spend all time to keep all 4-halls operational.