Community Update

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Agenda

- **Introduction - Jon Zuegel, Principal Investigator**
- **Community Highlights - Co-PIs**
  - PAALS - Franklin Dollar, University of California, Irvine
  - HFP/QED - Antonino Di Piazza, University of Rochester
  - LAPP - Eva Zurek, University at Buffalo / Ed Marley, University of Rochester
  - LDNP - Ani Aprahamian, University of Notre Dame
- **Laser/Facility Update - Elizabeth Hill, Project Manager**
- **Experimental System Updates - Mike Krieger, Experimental Systems**
- **MPW Diagnostics Workshop - Steve Ivancic, Diagnostic Development**
- **Project Updates - Matthew Barczys, Lead Systems Engineer**
- **Student Highlights/Wrap-Up - Ashley Thrash, Communications Specialist**

The NSF OPAL project co-sponsored an important workshop aimed at identifying new approaches to improve laser performance

NEXT-GENERATION OPTICAL MATERIALS AND COMPONENTS FOR HIGH-POWER LASERS WORKSHOP

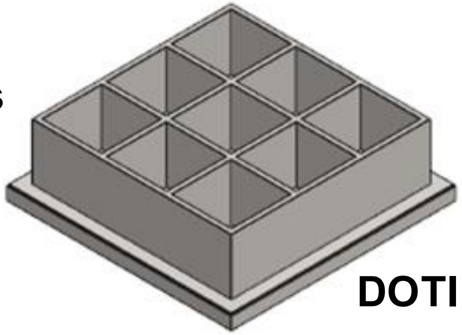
"Optical materials research may not seem like 'high-impact' science, but it proves essential to achieving high-impact results."

- **Goals:**
  - Identify scientific gaps, engage different disciplines, involve stakeholders to understand the state of the field:
    - Modeling
    - Physics-based fabrication
    - Gratings for pulse compression & beam combining
    - Diagnostics & lifetime prediction
  - Develop roadmap of interdisciplinary efforts leading to robust progress (workshop report)
  - Facilitate consensus-driven decision-making leveraging collective intelligence and wisdom
- **Identified factors limiting the field**
  - Resources available for academic research, faculty recruitment and workforce development
  - Low information flow among community
  - Limited research infrastructure due to focus on single-PI research

The project has launched a three-phase program to assess technologies for manufacturing next-generation large mirrors to reduce costs

- **Phase 1: RI-1 project prototyping**
  - Identify available technologies and companies capable of manufacturing low-cost mirrors and test as many as possible
  - Develop 150mm x 150mm ‘coupons’ that can be finished, coated, and characterized to determine the best approaches for NSF OPAL
  - Requested quotes from eight companies, placed phase-1 orders with three
  - Deliverables: coupons, scale-up plans, budgetary estimate for full-size mirrors
- **Phase 2: RI-1 project industrialization**
  - Scale best technologies from phase 1 up to mid- or full-scale
  - Reduce manufacturability risk of next-generation Off-Axis Parabolas (OAPs)
  - Manufacture, finish, and coat a 350mm x 350 mm mid-scale flat mirror and/or OAP
  - Deliverables: mid-scale mirrors, full-scale production plans, drawings, and quotes
- **Phase 3: production during a future construction project**
  - Manufacture full-size flat and/or OAP mirrors finished and coated for NSF OPAL
  - Deliverables: full-size mirrors (flat mirrors, f/8 + f/2 + f/1.7 OAPs)

Phase-1 participants



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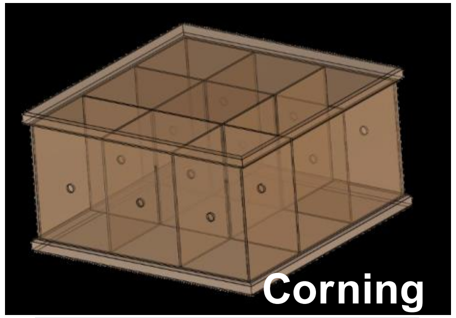
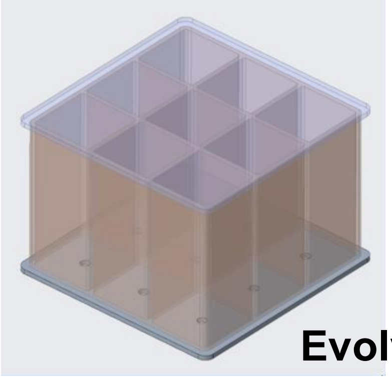




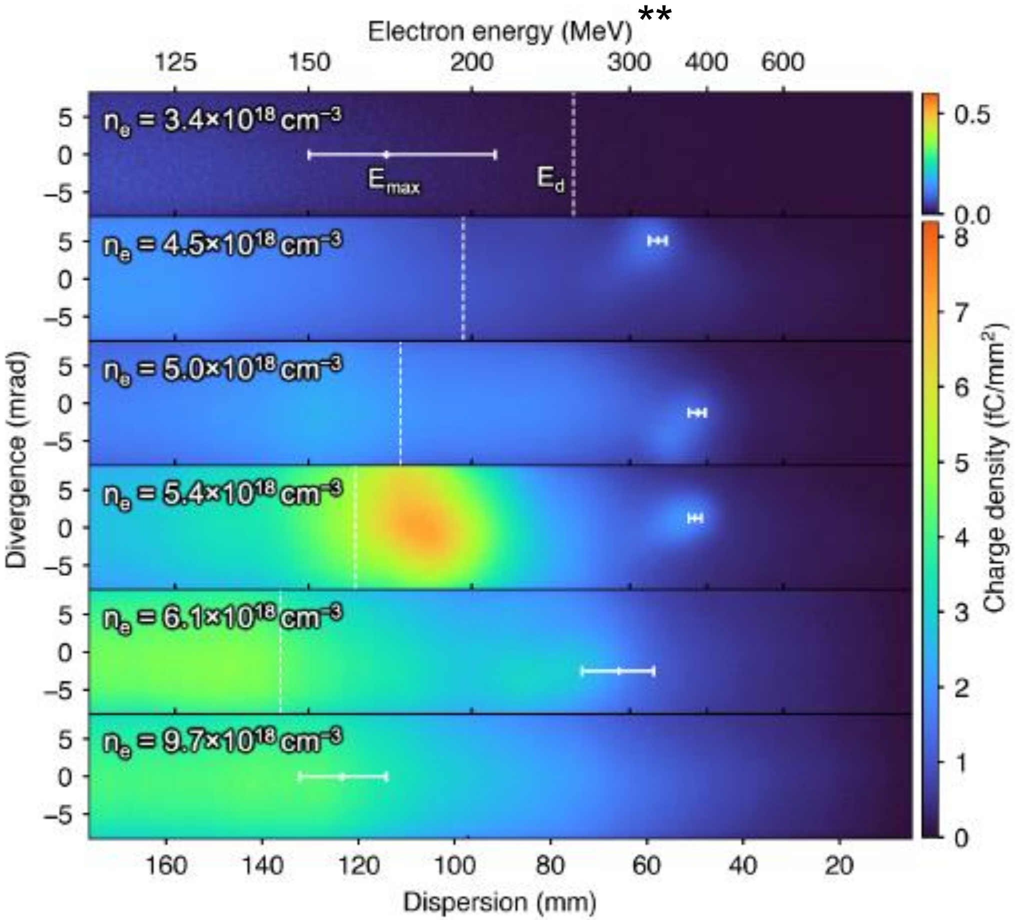
EvolvOptics

Highlights from the OPAL Community

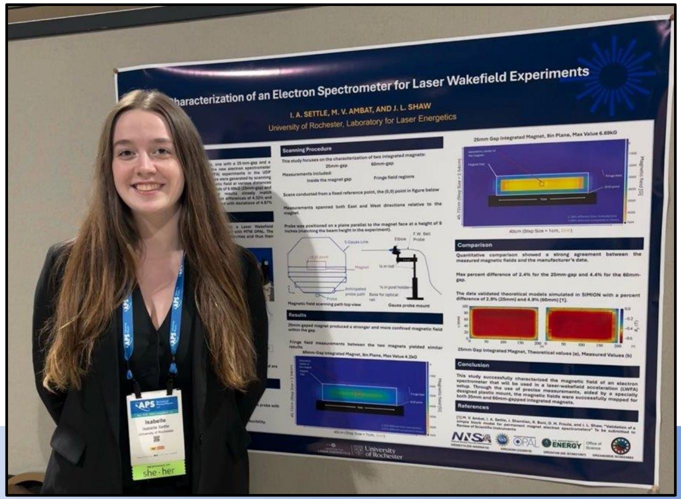
PAALS Working Group

Dephasingless LWFA* has been demonstrated for the first time**

- **Experiments led by postdoc C. Arrowsmith showed that a flying focus can be used to accelerate electrons well beyond the traditional dephasing limit, exceeding the maximum permitted energy gain by a factor of 2.**
  - This established the proof of concept for generating TeV-class electron beams using NSF OPAL
  - This demonstration completes Phase 2 on the path to the PAALS1 Flagship “Flying-Focus-Driven Laser-Plasma Accelerator for Single-Stage TeV-Class Electron Beams”
- **At least 9 new publications and 12 presentations in 2025, with strong representation by undergraduate, graduate, and postdoctoral researchers.**



Undergraduate I. Settle presenting at APS DPP



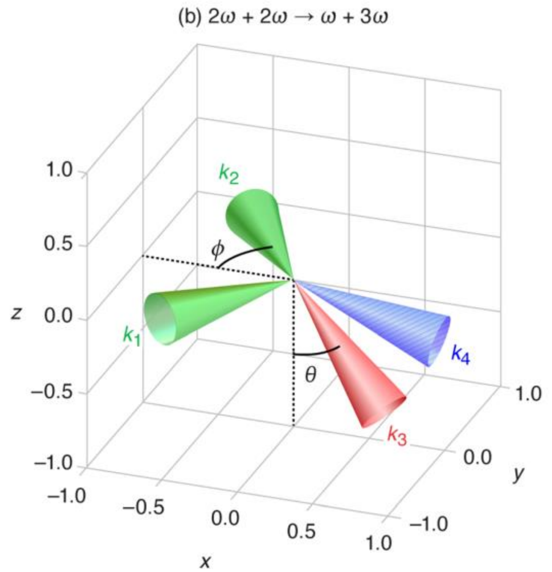
Diagnostic development for particles and light sources in Multi-Petawatt interactions

- **Multi-Petawatt Diagnostic Community Workshop to be held in Ann Arbor in May 2026**
  - Higher repetition rate diagnostics that can survive extreme environments critical for throughput
  - New diagnostics needed to measure high energy photons and electrons
- **At least 3 new publications and 4 presentations in 2025, including undergraduates presenting at the APS DPP conference**

UC Merced undergraduate S. Yeghiayan presenting work on proton diagnostics

HFP/QED Frontier Science Working Group

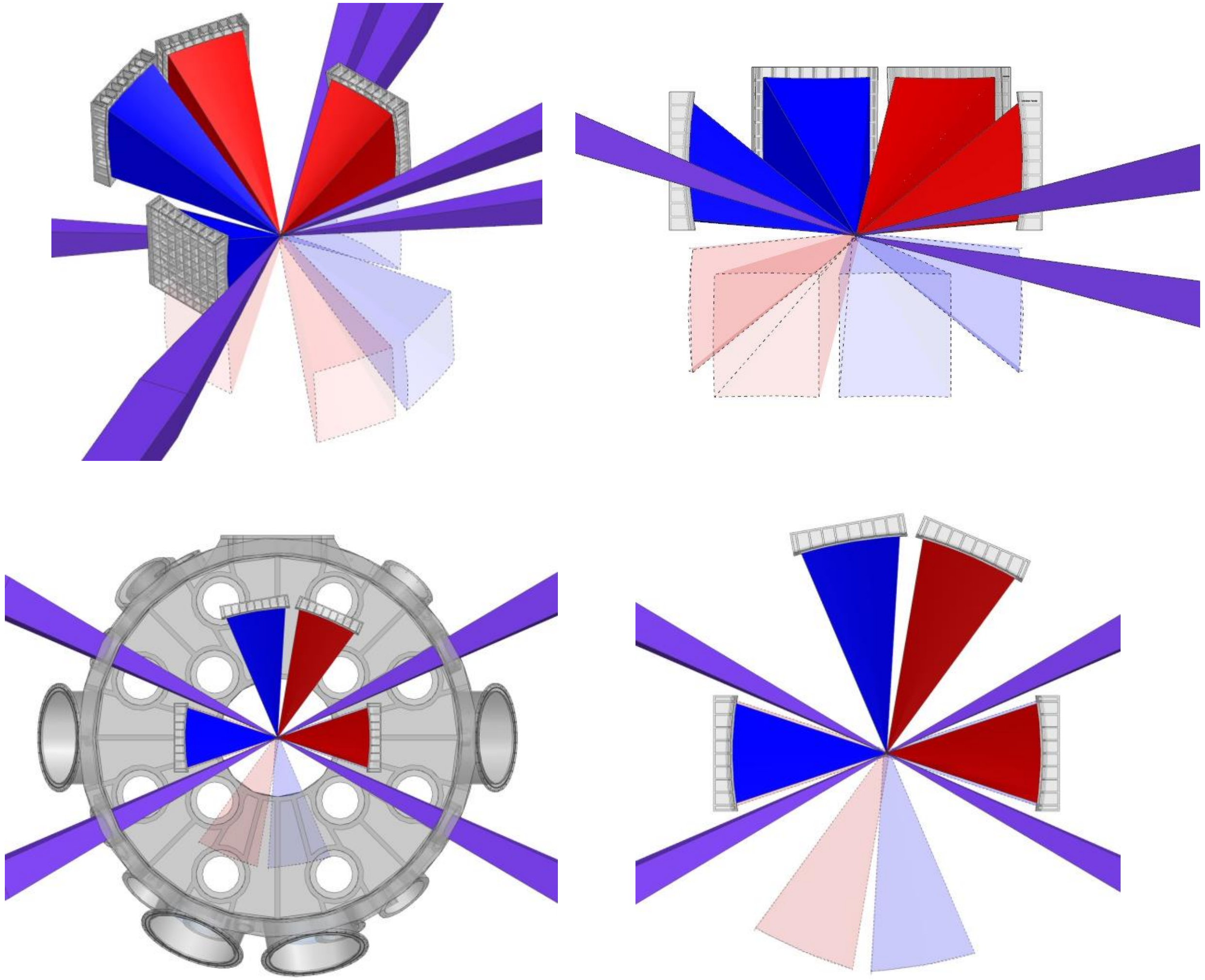
- **HFP-QED1: Fully-nonperturbative strong-field QED and the Ritus-Narozhny conjecture (future flagship expt.)**
  - **European ERC Synergy award** starting in September will focus on the possibility of testing the Ritus-Narozhny conjecture and probe fully-nonperturbative strong-field QED
  - Our teamwork continues **on the impact of high-order radiative corrections to strong-field QED processes**
- **HFP-QED2: Flagship experiment on stimulated photon-photon scattering**
  - **International team published a paper [Rinderknecht et al., Phys. Plasmas 32, 083301 (2025)]** on observing the process at NSF OPAL in the three-color setup
  - Recently updated models estimate 512 $\pm$ 113 scattered photons per shot (needs to include mispointing and/or mistiming).
  - An **ongoing collaboration with P. Norrey's group** (Oxford, L. Zhang, PhD student) aims to validate that estimate using a more detailed beams model that evolves Maxwell's equations.
  - Undergraduate student E. Dill simulations tested a method for **electrostatically sweeping laser-ionized molecules to generate regions of pure vacuum**. Encouraging results predict pure vacuum in a ~50 μm³ volume for 30 ns that were presented at the APS DPP conference last year.



- **HFP-QED3: Future flagship experiment on generating QED cascades at NSF OPAL**
  - **International team published a paper [Mironov et al., Phys. Plasmas 32, 093302 (2025)]** on generating the precursor of a QED cascade using two NSF OPAL Alpha beams
  - K. Weichman performed numerical simulations and will lead an international collaboration to investigate the feasibility of producing an actual QED cascade employing microtargets.

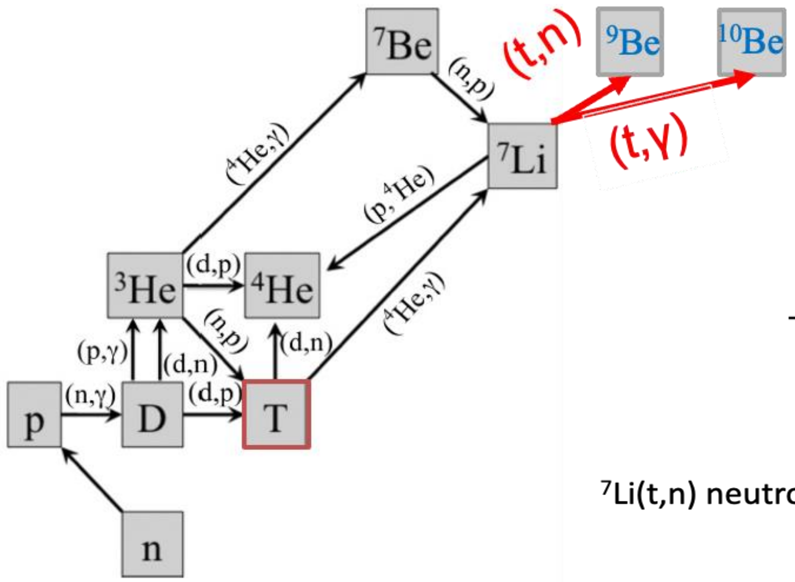
LAPP Frontier Science Working Group

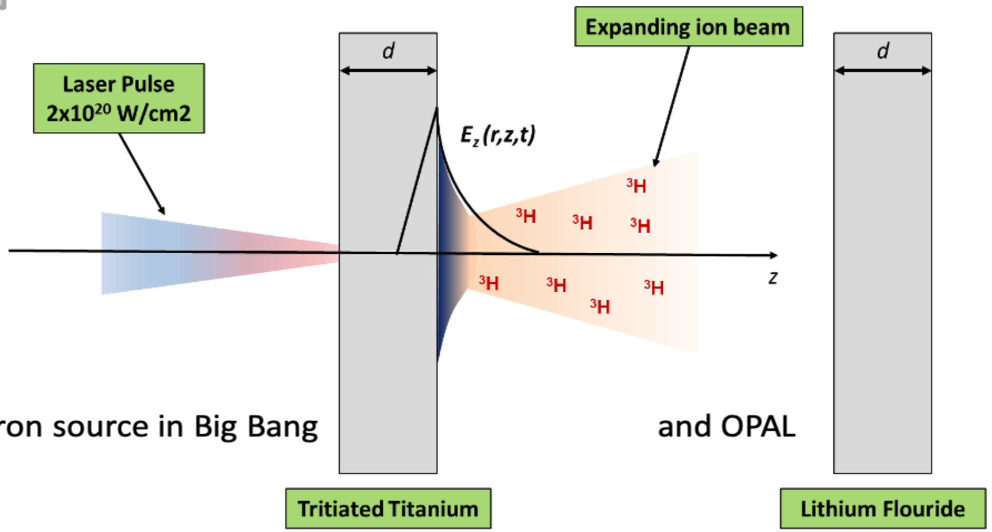
- **Worked closely with the experimental design team to develop and refine laser geometries for long-pulse and short-pulse HED interactions**
  - LAPP set the design requirements for short and long pulse interaction – we are the only flagship using both
  - The flexible geometry will allow for near co-propagating, counter-propagating, and orthogonal geometries for HED experiments
  - Pump probe experiments place restrictions on, pointing volumes, focal number, co-timing, contrast, diagnostic lines of sight etc.
- **Garnered international support and formed global collaborations for NSF OPAL**
  - Conference and workshop participation grew the OPAL community across APS, CMAP, AIRAPT & EHPRG, CDAC



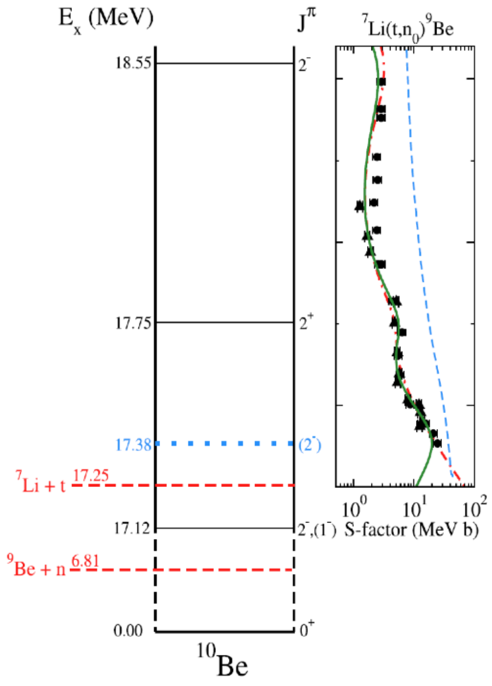
NSF OPAL as an intense tritium and neutron source for Big Bang and Supernova Studies

- **Tritium induced reactions may play an important role as strong neutron sources in explosive stellar environments with high tritium abundances such as the Big Bang and the onset of the supernova shock front. Intense tritium beams allow the study of these reactions and may also provide and intense neutron source for s- and r-process studies.**

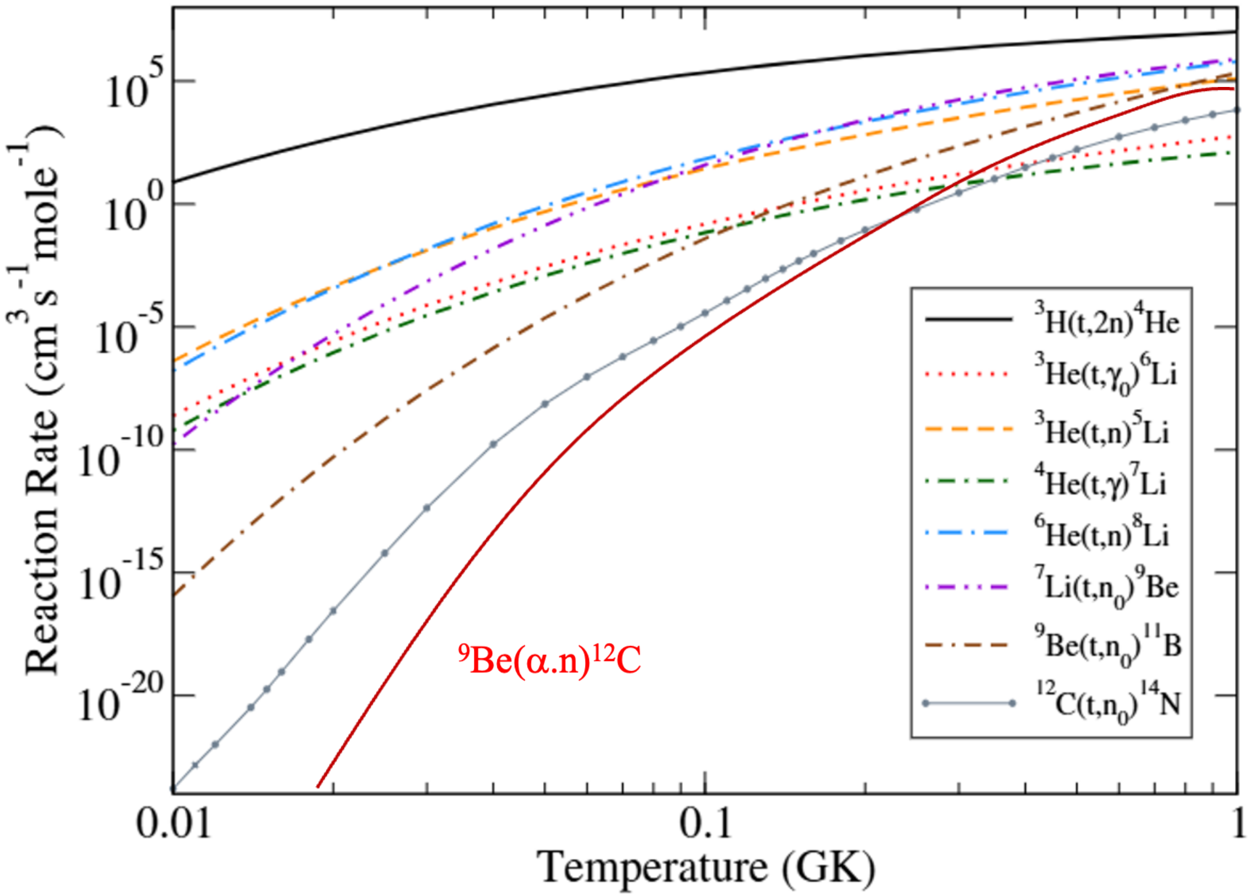




^{7}Li(t,n) neutron source in Big Bang and OPAL



Tritium Beam as Neutron Source



- **The tritium induced reactions result in neutron sources that are considerably stronger than the strongest known alpha induced neutron source (9Be(a,n)12C). The role of tritium depends on the tritium abundances generated in the first moments of the explosive event, BB or SN. It also depends on the reliability of the proposed reaction data.**
  - **Experimental verification is necessary!**

A workshop aimed at bringing together the diagnostic community for Multi-Petawatt facilities is planned for May 21-22, 2026

- **Understand and identify diagnostic technologies and detector science that will be used to address scientific frontiers for multi-petawatt facilities**
- **Identify technical gaps in bridging present diagnostic solutions to the multi-petawatt scale and leverage instrumentation solutions from complementary fields**
- **Develop and connect diagnostic scientists across the multi-petawatt physics community**
- **Working group areas to survey the state-of-the-art in**
    - Hard X-rays
    - Particle beam diagnostics
    - Ultrafast high-power optical diagnostics

Registration is open today!

Laser Systems Update

Detailed optical design is progressing for 64 distinct configurations

Main Target Chamber (MTC)

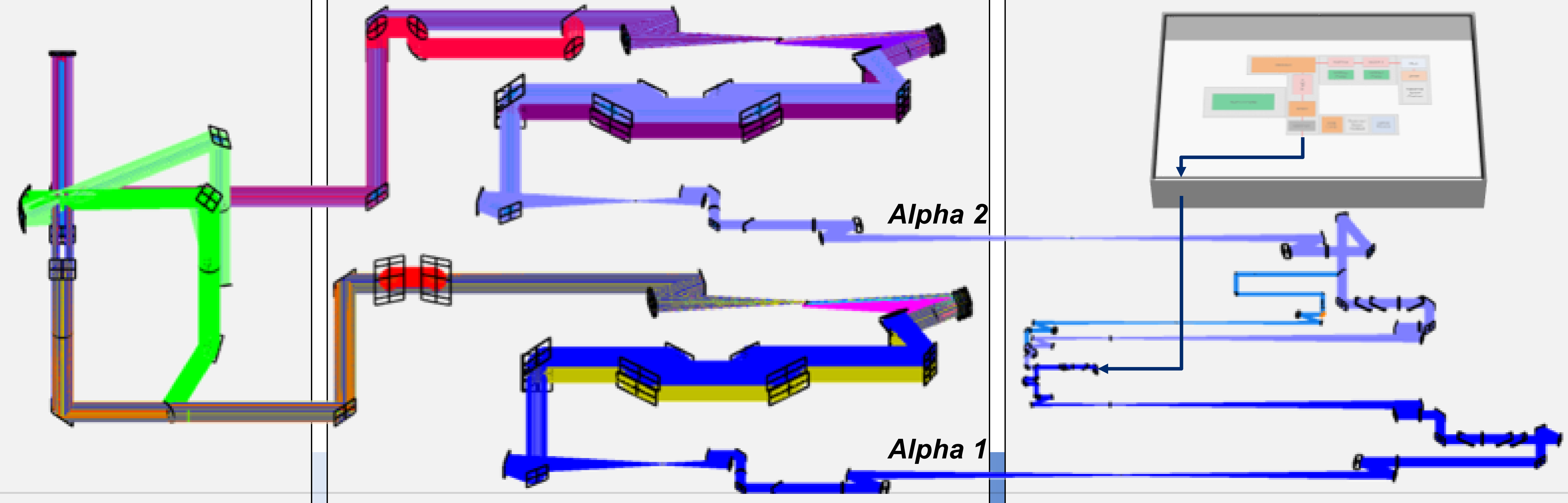
Each beam has two paths to target

Back-end and switch yard

Pulse Compressors (both)
Dual Plasma mirrors (both)
Circular polarization (Alpha 1)
Second-harmonic generation (Alpha 2)

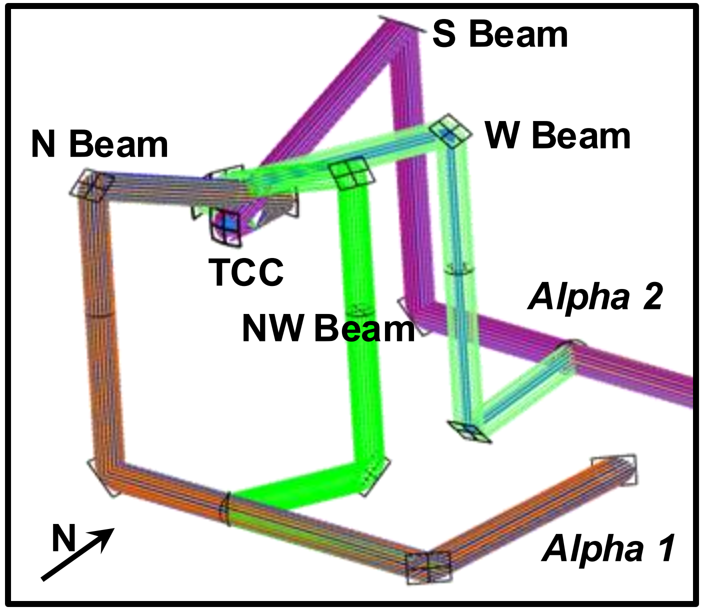
Front-end

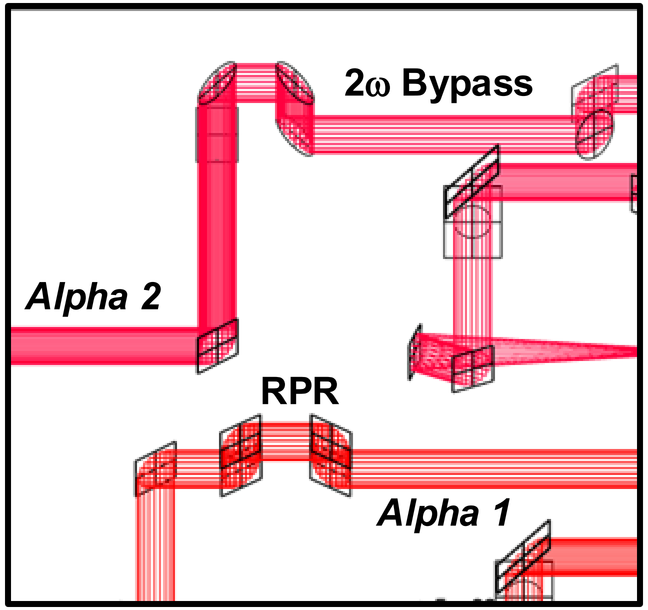
Ultrabroadband front end
NOPA-J Pump & Amp
Split & Delay Switchyard
NOPA-K Pumps & Amps (both)
(pump lasers not shown)

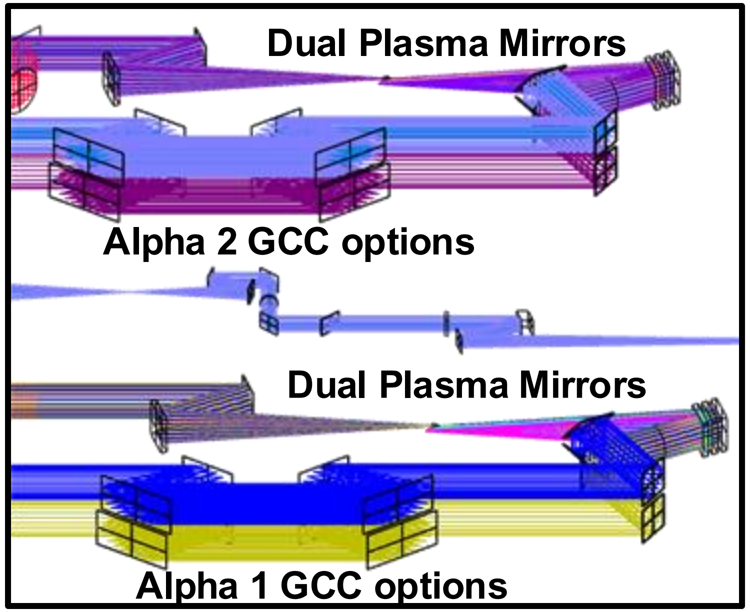


A total of 64 configurations will be provided to increase experimental flexibility

Beam	Path to MTC center	Polarization -or- SHG	Dual Plasma Mirrors
Alpha 1	N -or- NW	Linear -or- Circular	In -or- Out
Alpha 2	S -or- W	1ω -or- 2ω	In -or- Out



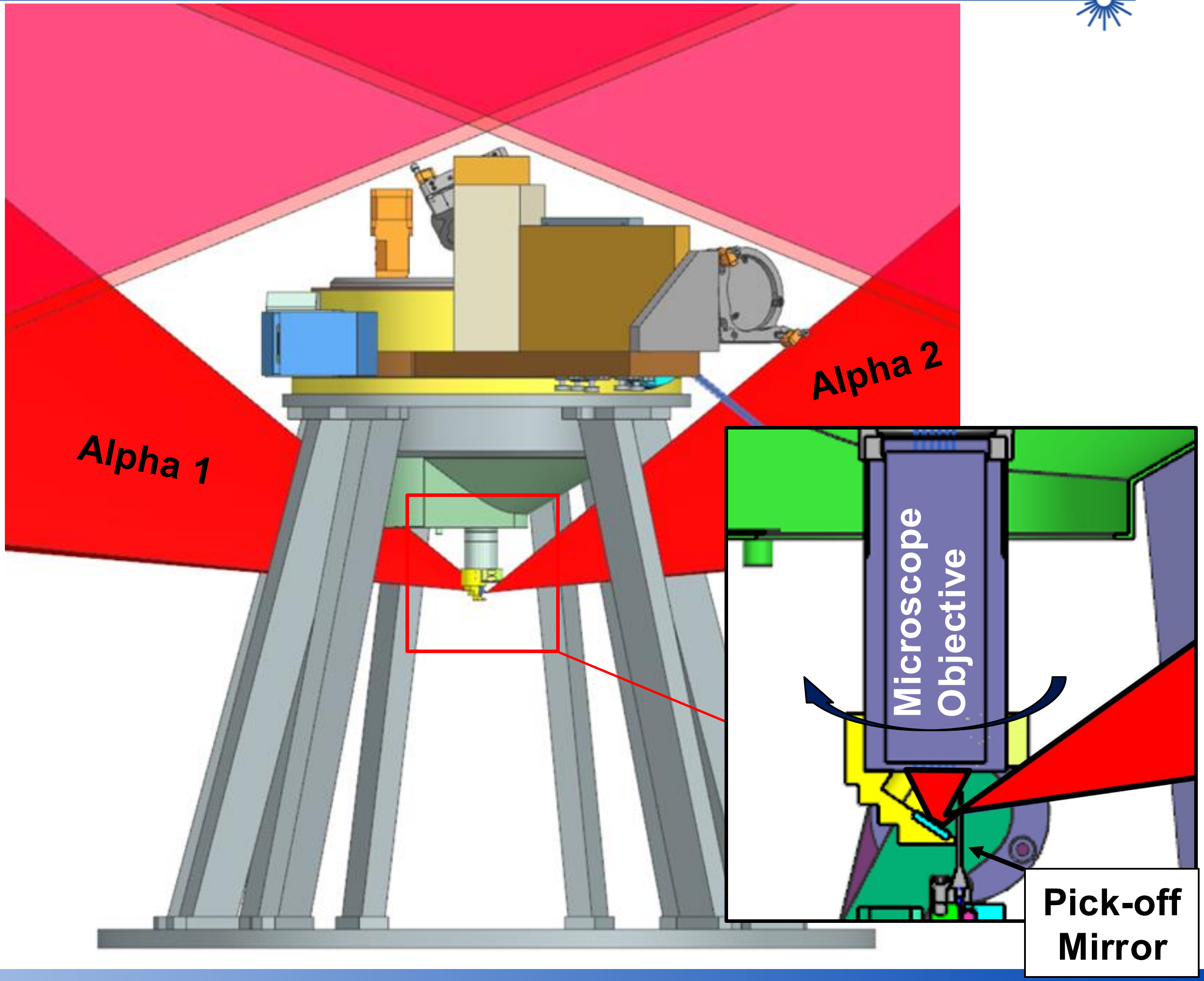




*** SHG: Second Harmonic Generation** *** RPR: Reflective Phase Retarder**

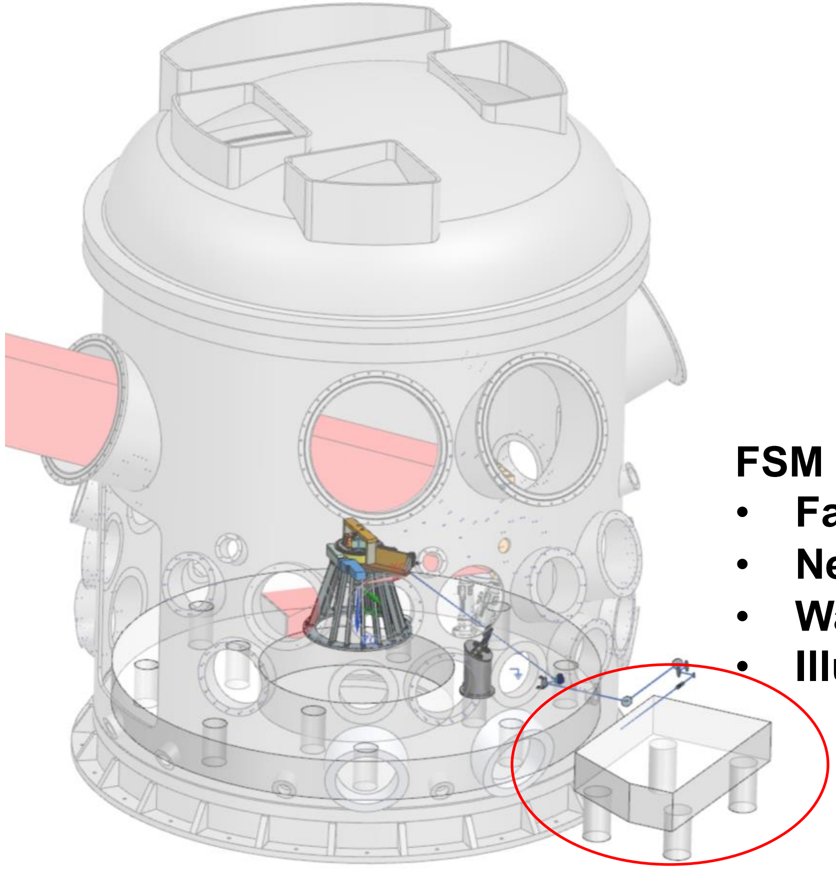
The design of the Focal Spot Microscope (FSM), a critical laser diagnostic, has made significant progress

- **Functions:**
  - Characterize & optimize focal spot before shot
  - Position target at correct focal plane
  - Must support any Alpha beam
  - Must support 5-min shot rate
- **Instruments:**
  - **Far field camera** that characterizes spot size, pointing and focal plane.
  - **Near field camera** to monitor beam profile and damage to target chamber focusing OAP
  - **Wavefront sensor** to monitor on-target wavefront, providing feedback to beamline DM
  - **Co-focused illumination source** for alignment support (CoTAC sphere, OAP optimization)
  - **Diffuse illumination source** for target imaging

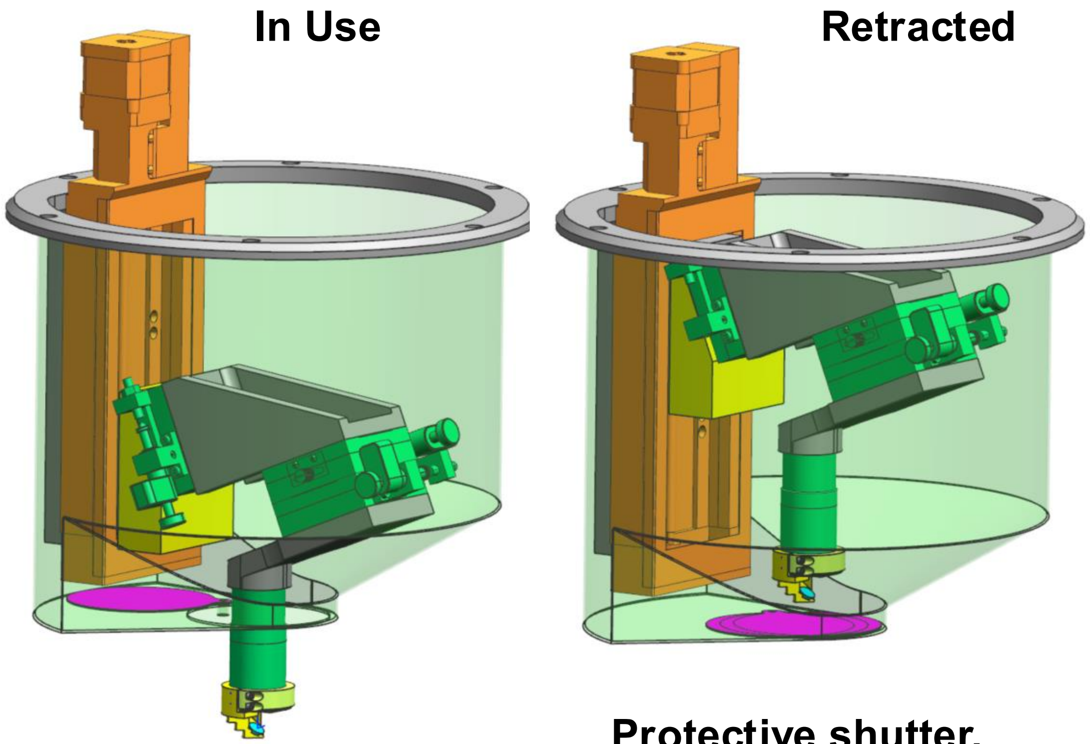


The Focal Spolt Microscope (FSM) mounted on the central pillar relays the beam to an instrument table outside the MTC

- Requires less space inside MTC, keeping beam paths and diagnostics lines-of-sight open
- Increases the distance from target interaction to sensitive electronics



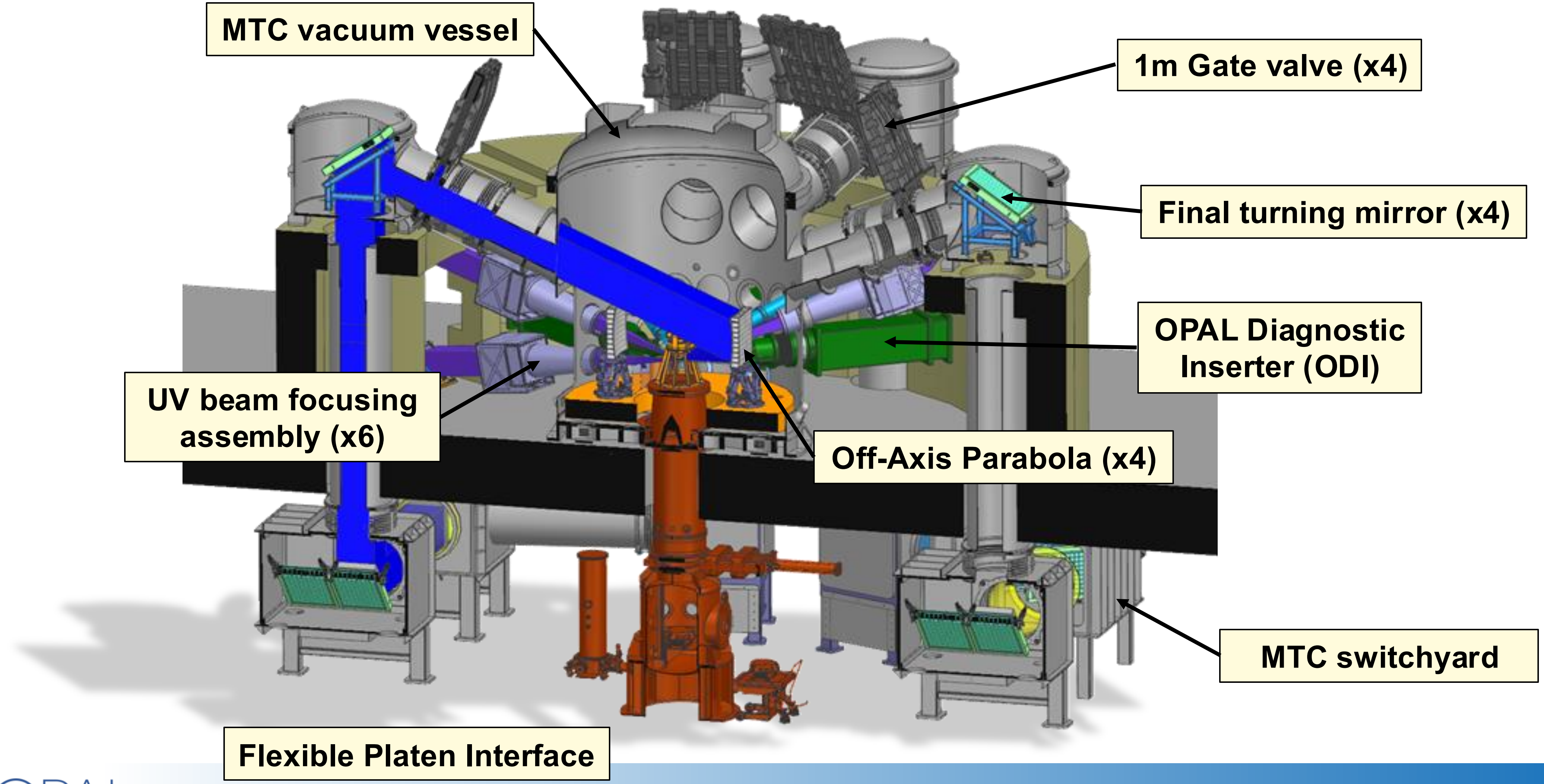
FSM table:
- Far field CCD
- Near field CCD
- Wavefront sensor
- Illumination sources



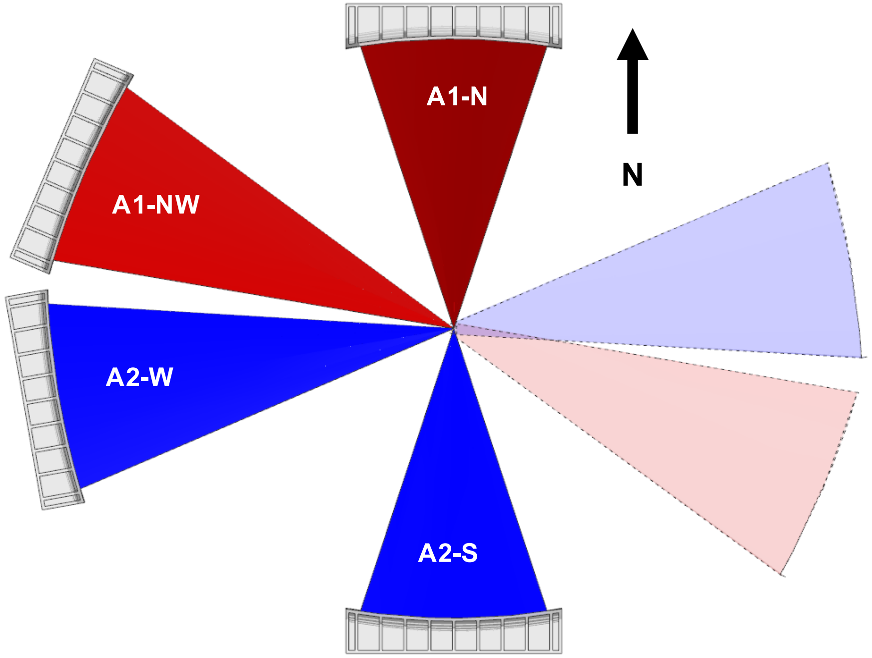
Protective shutter, closed for shots

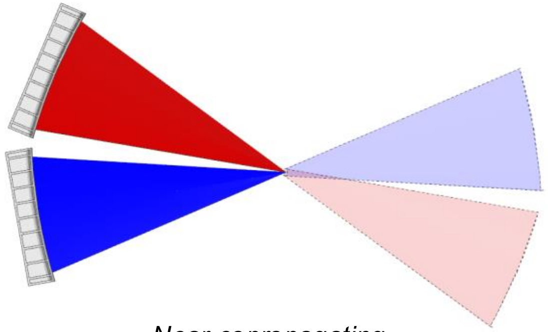
Experimental Systems Update

Main Target Chamber (MTC) overview

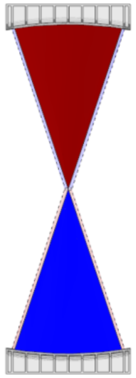


MTC Alpha beams have two delivery paths each, with differing f-numbers

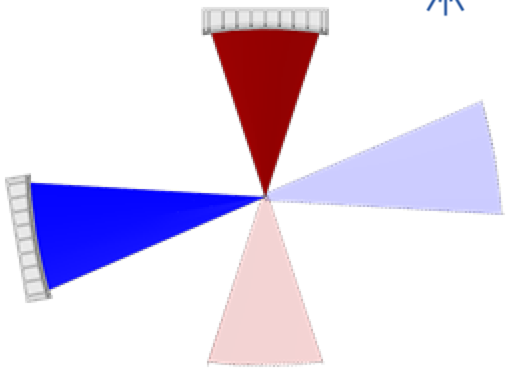




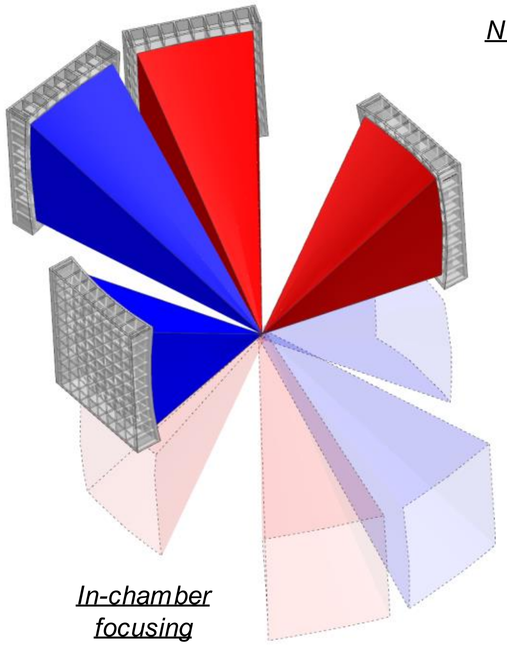
Near copropagating



Near counterpropagating



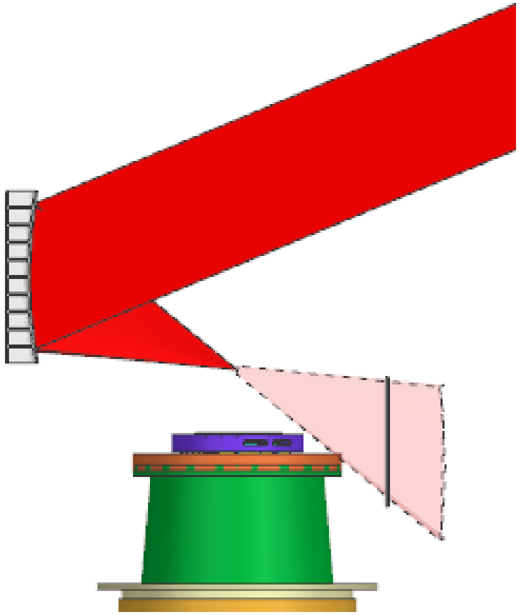
Orthogonal

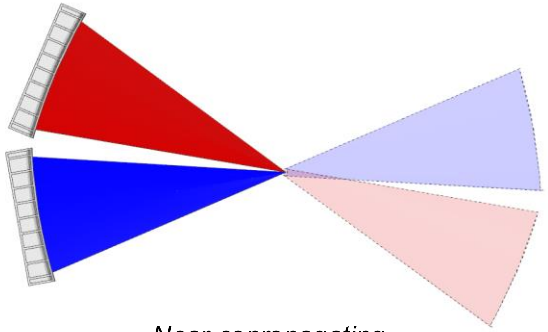


In-chamber focusing

Beam	f/#	θ(°)	φ(°)
A1-N	1.72	67.5	0
A1-NW	2.31	67.5	67
A2/B-W	2.31	67.5	99.9
A2/B-S	1.72	67.5	180

MTC Alpha beams have two delivery paths each, with differing f-numbers





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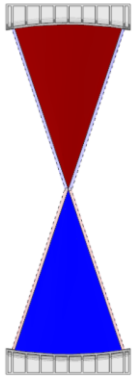

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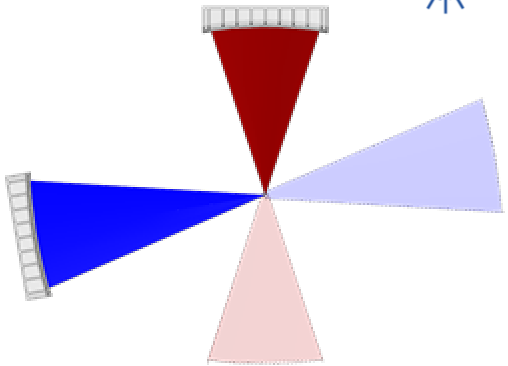

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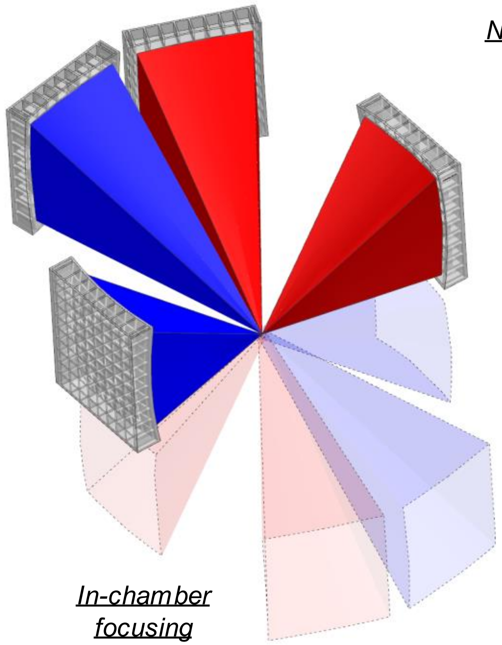

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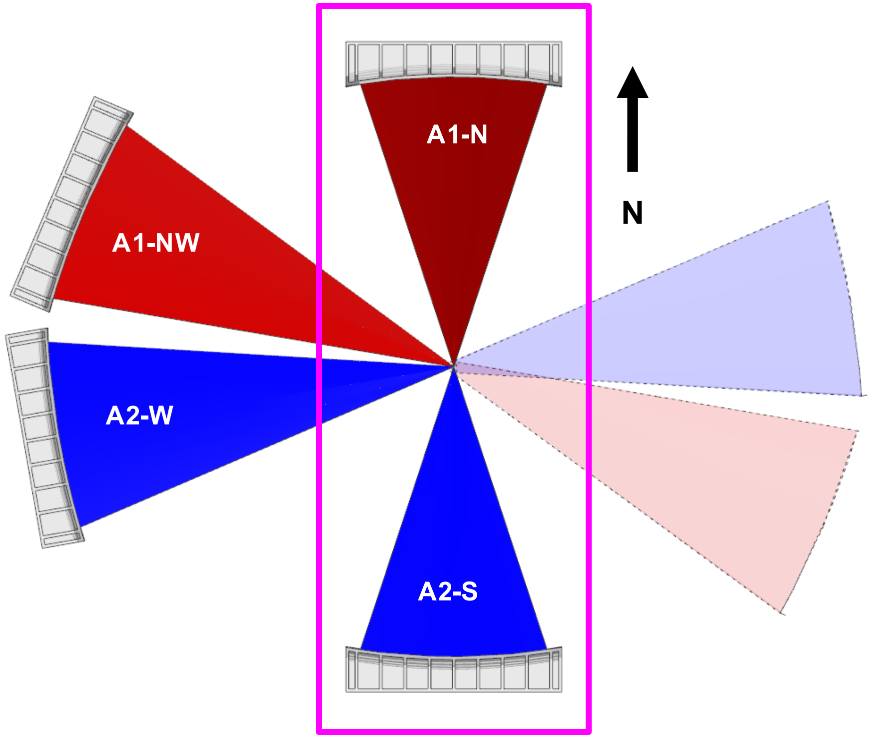
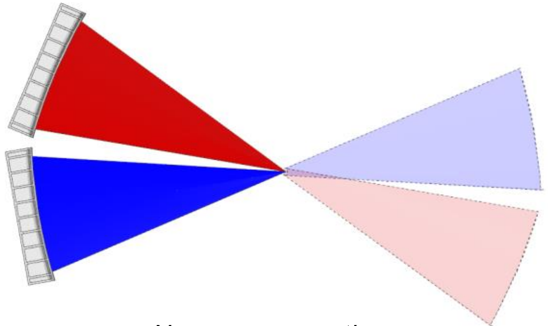
All beams are angled down ~~18°~~ 22.5°

OPAL

MTC Alpha beams have two delivery paths each, with differing f-numbers

***f/#* = 1.72**
***I* = 5 x 10^{23} W/cm^2**





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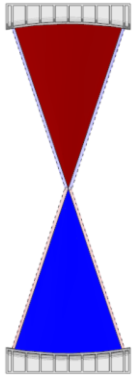
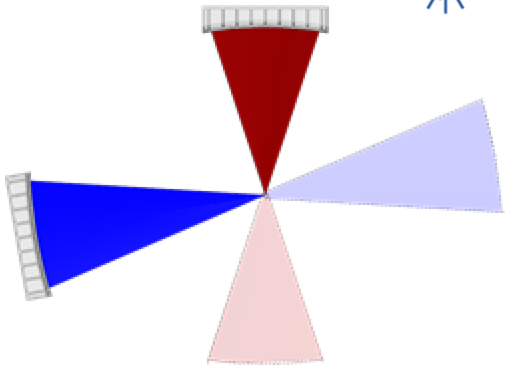


Near counterpropagating



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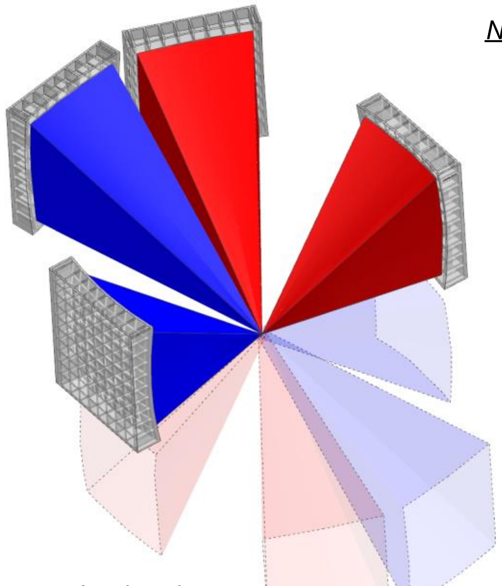

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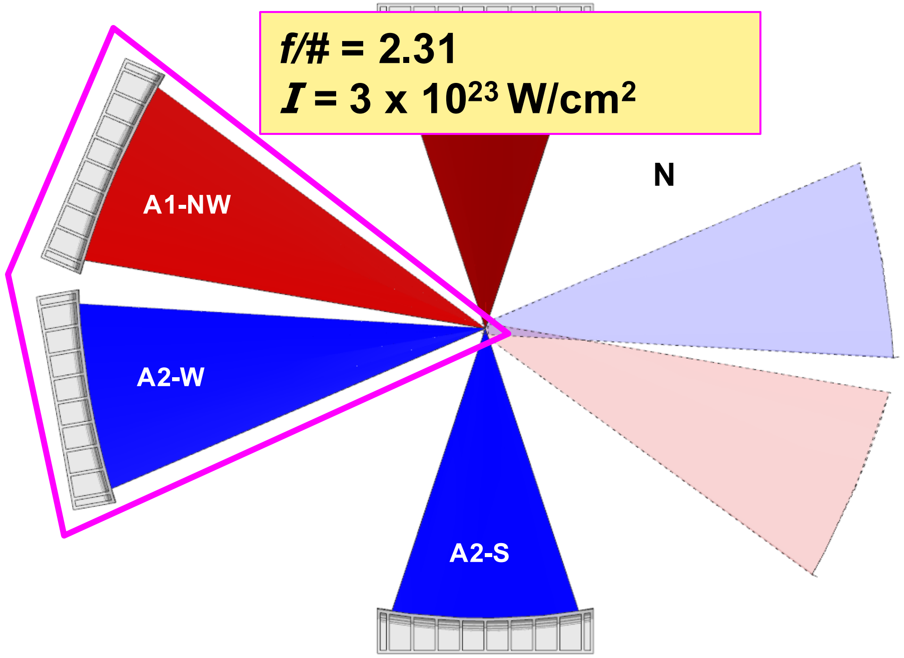

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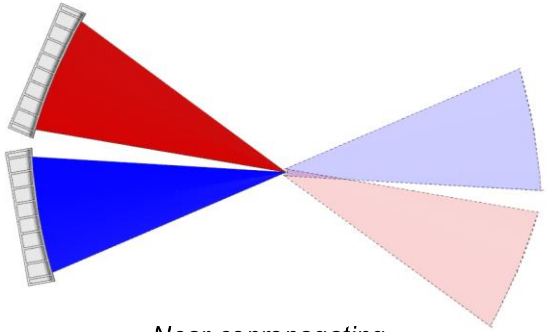

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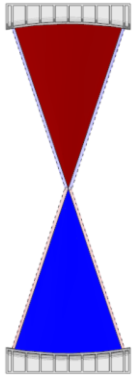

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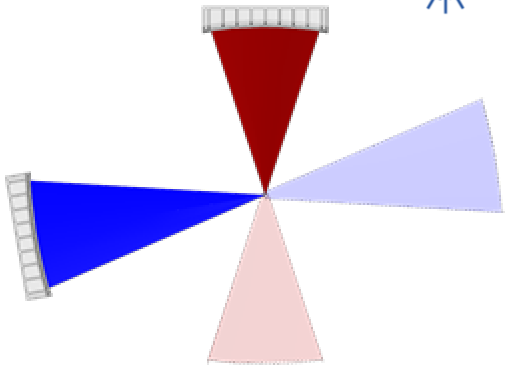

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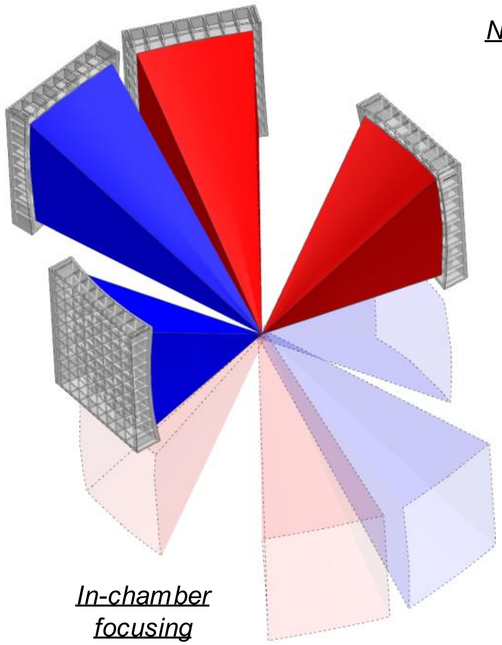

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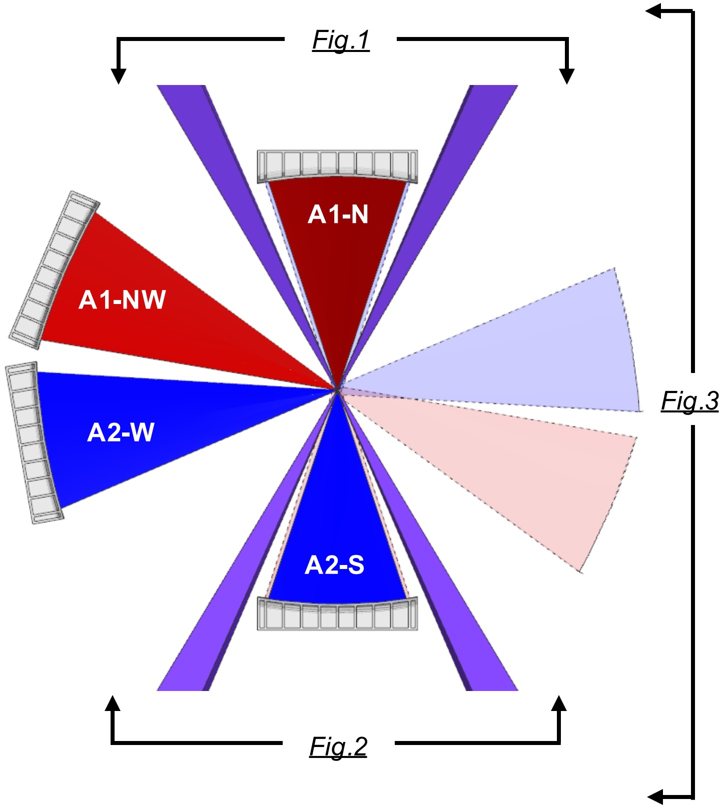
OMEGA EP Long Pulse (LP) UV beams mapping has changed based on community feedback



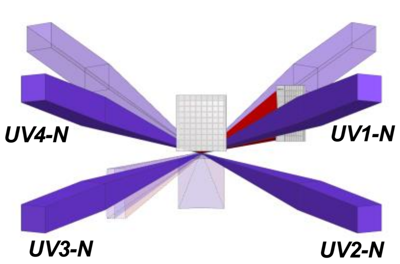


Fig.1: North UV (x4)

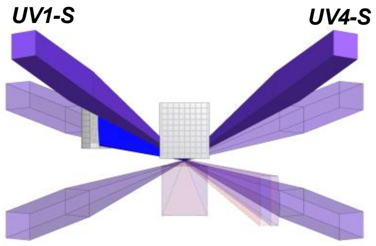


Fig.2: South UV (x2)

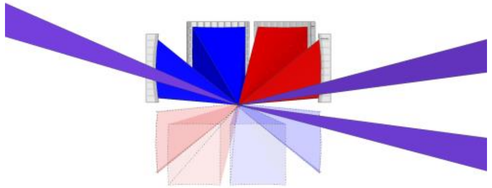
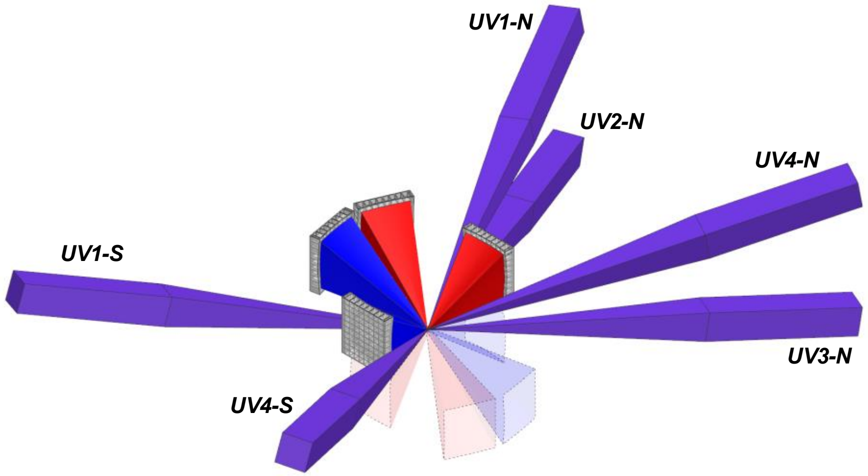
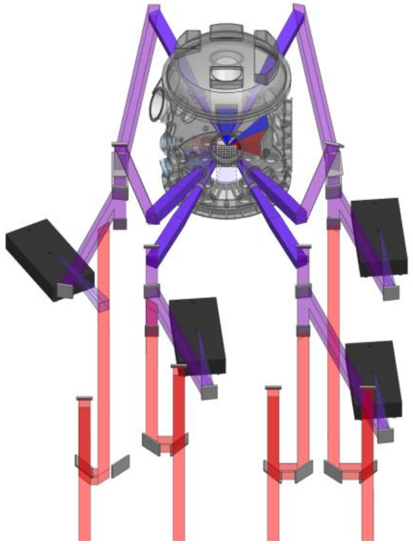


Fig.3: Looking West



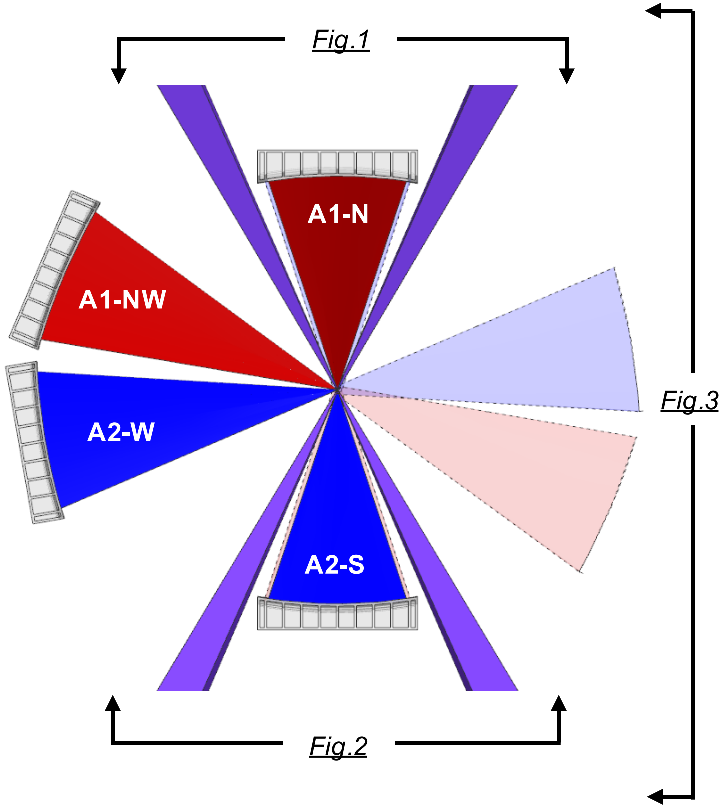
Southeast ISO



UV Beam Routing

OMEGA EP Long Pulse (LP) UV beams mapping has changed based on community feedback

- 4-UV North beams centered on equator
- 22.5° from Alpha axis in ϕ, 10° in θ



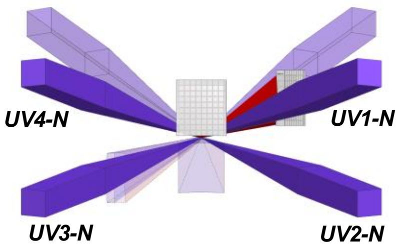


Fig.1: North UV (x4)

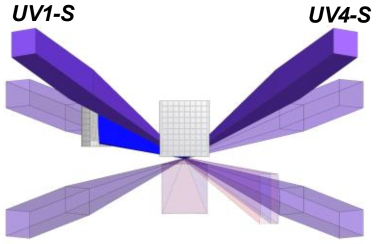


Fig.2: South UV (x2)

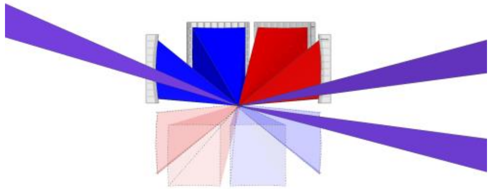
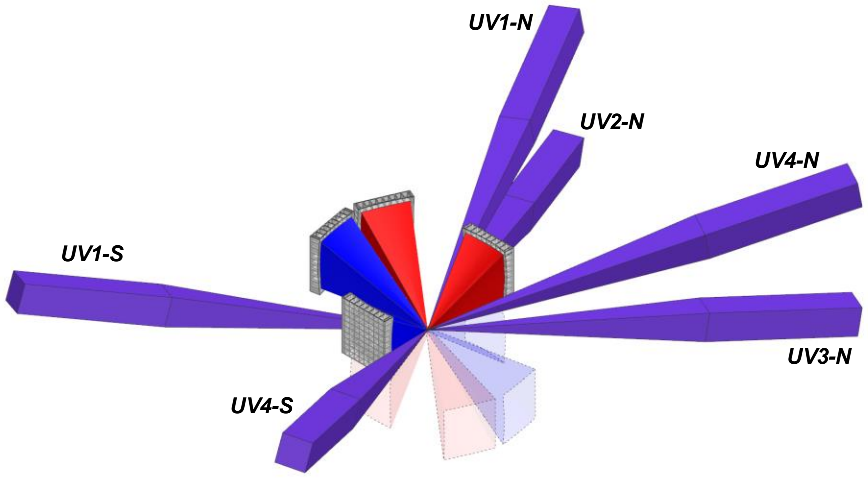
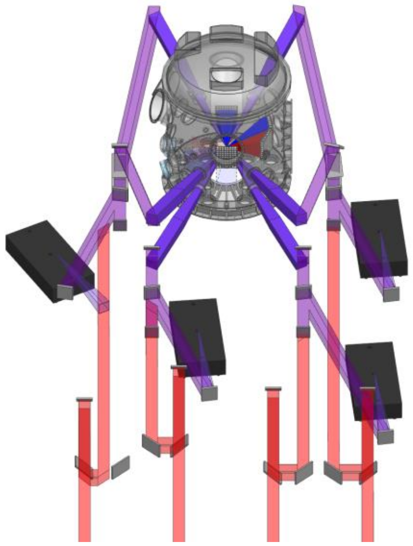


Fig.3: Looking West



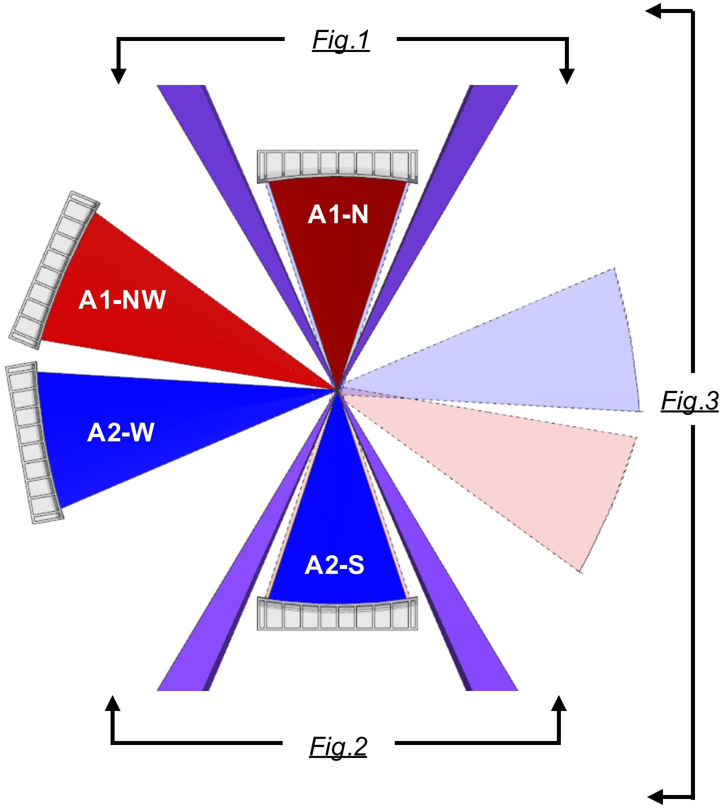
Southeast ISO

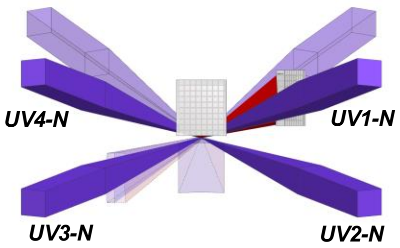


UV Beam Routing

OMEGA EP Long Pulse (LP) UV beams mapping has changed based on community feedback

- 2-UV South beams in-plane with A2-S (θ = 72°)
- 22.5° from Alpha axis





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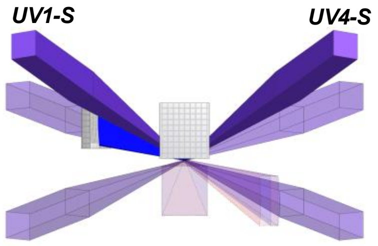


Fig.2: South UV (x2)

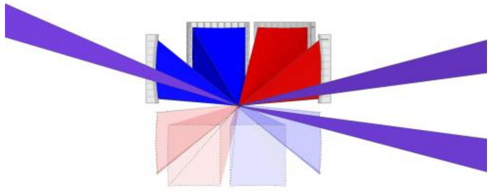
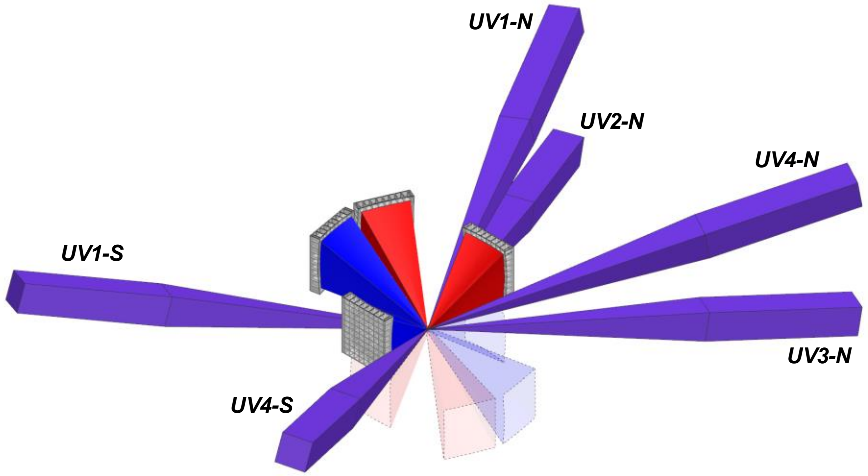


Fig.3: Looking West



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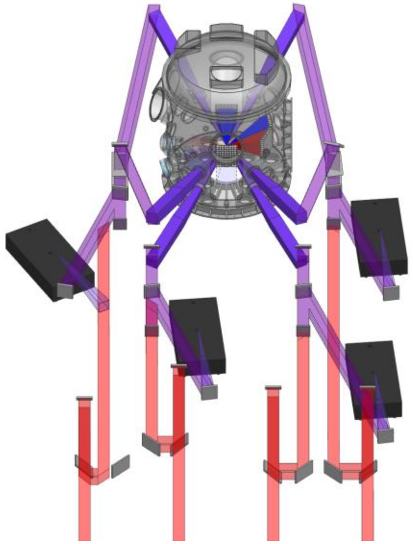
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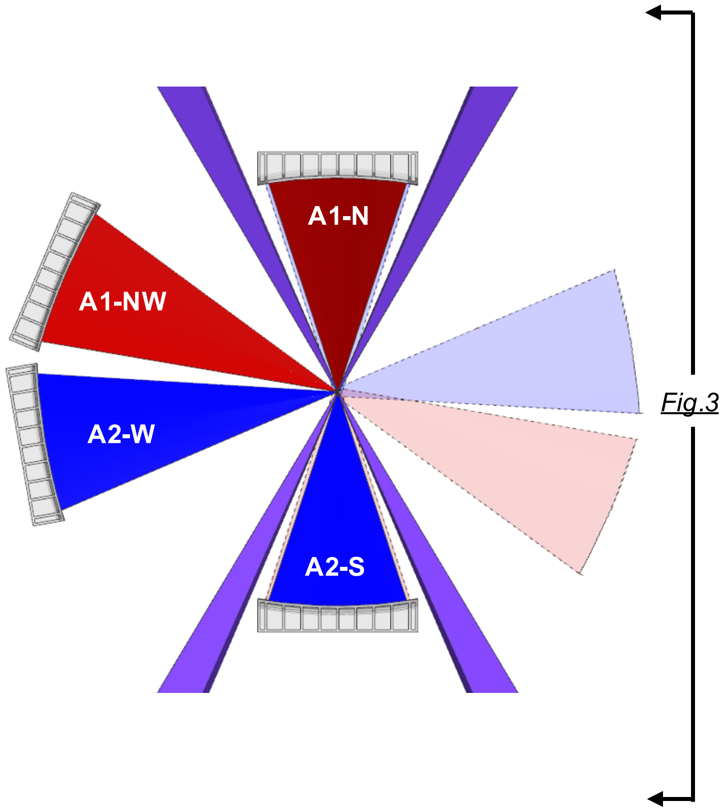


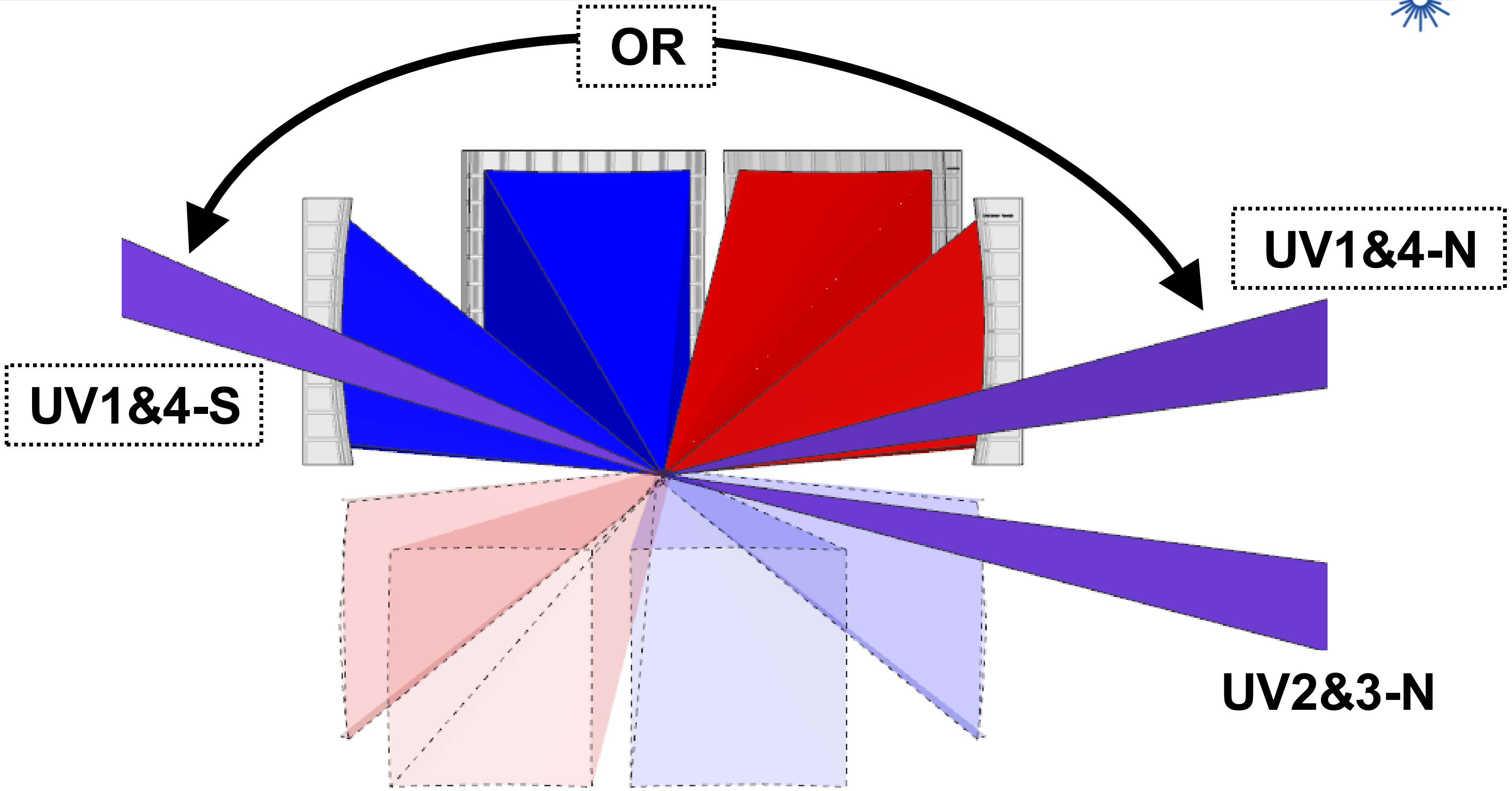
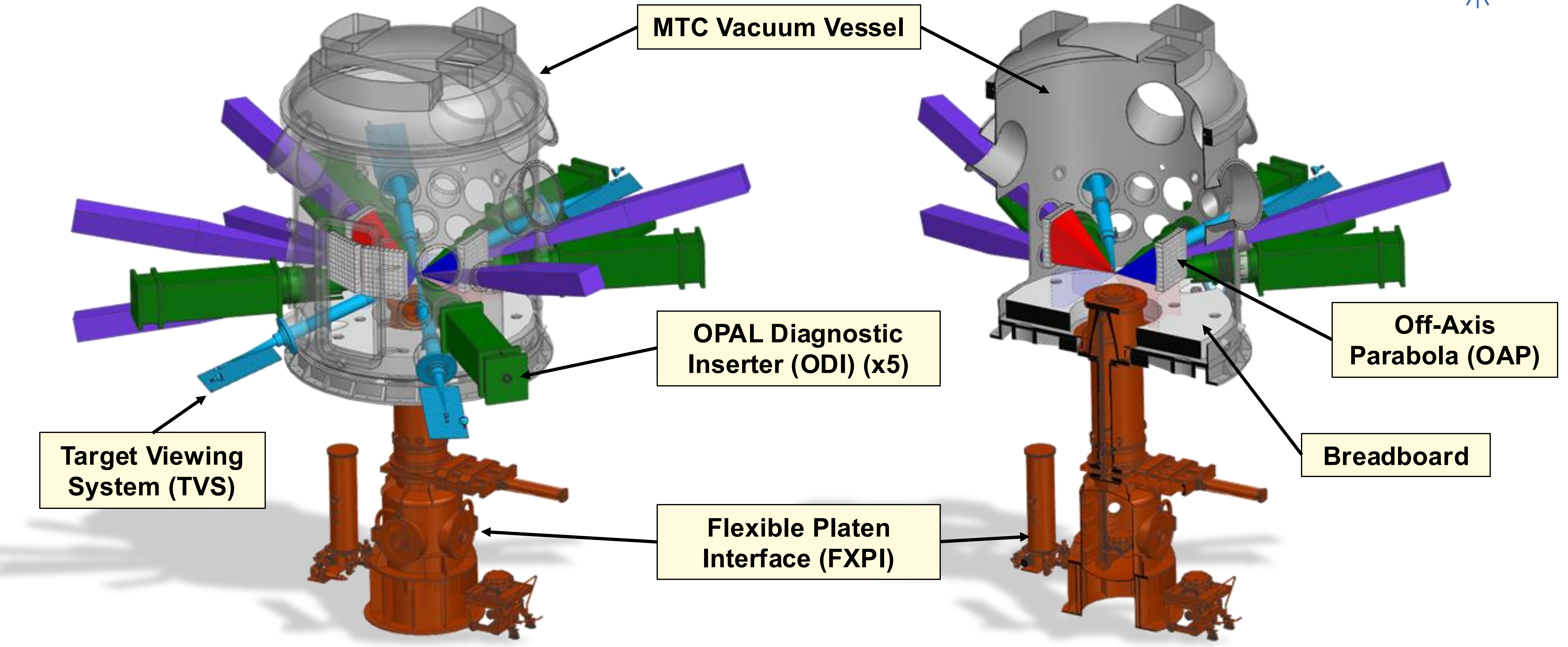
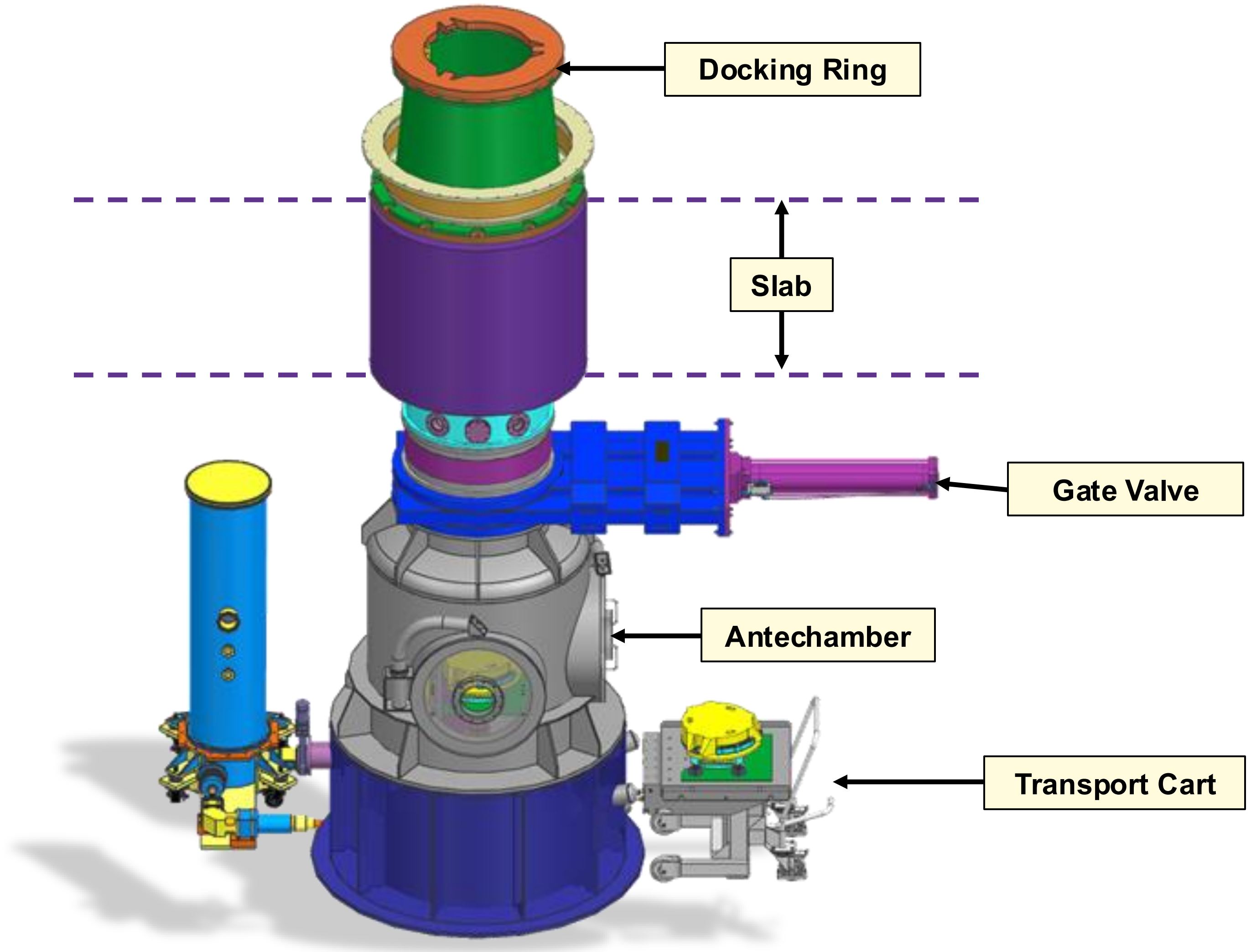


Fig.3: Looking West

Main Target Chamber (MTC) experimental systems high-level overview

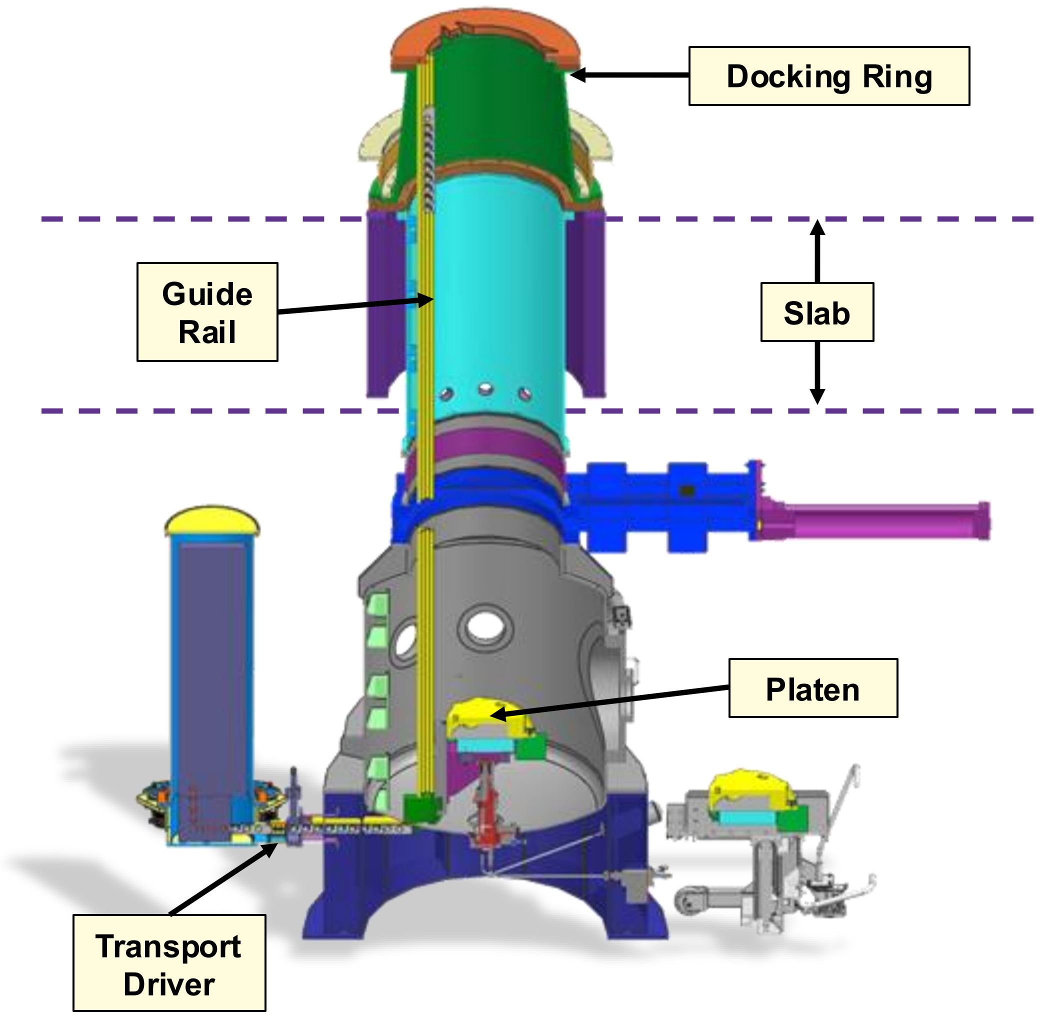


FleXible Platen Interface (FXPI) overview and capabilities



- FXPI delivers pre-configured platens to target chamber center without breaking vacuum
- Platens are pre-assembled breadboards that supply a variety of experimental systems to TCC
- Offer a flexible and capable platform to accommodate user-provided systems
- Primary use case for early operations is target system delivery

FleXible Platen Interface (FXPI) overview and capabilities



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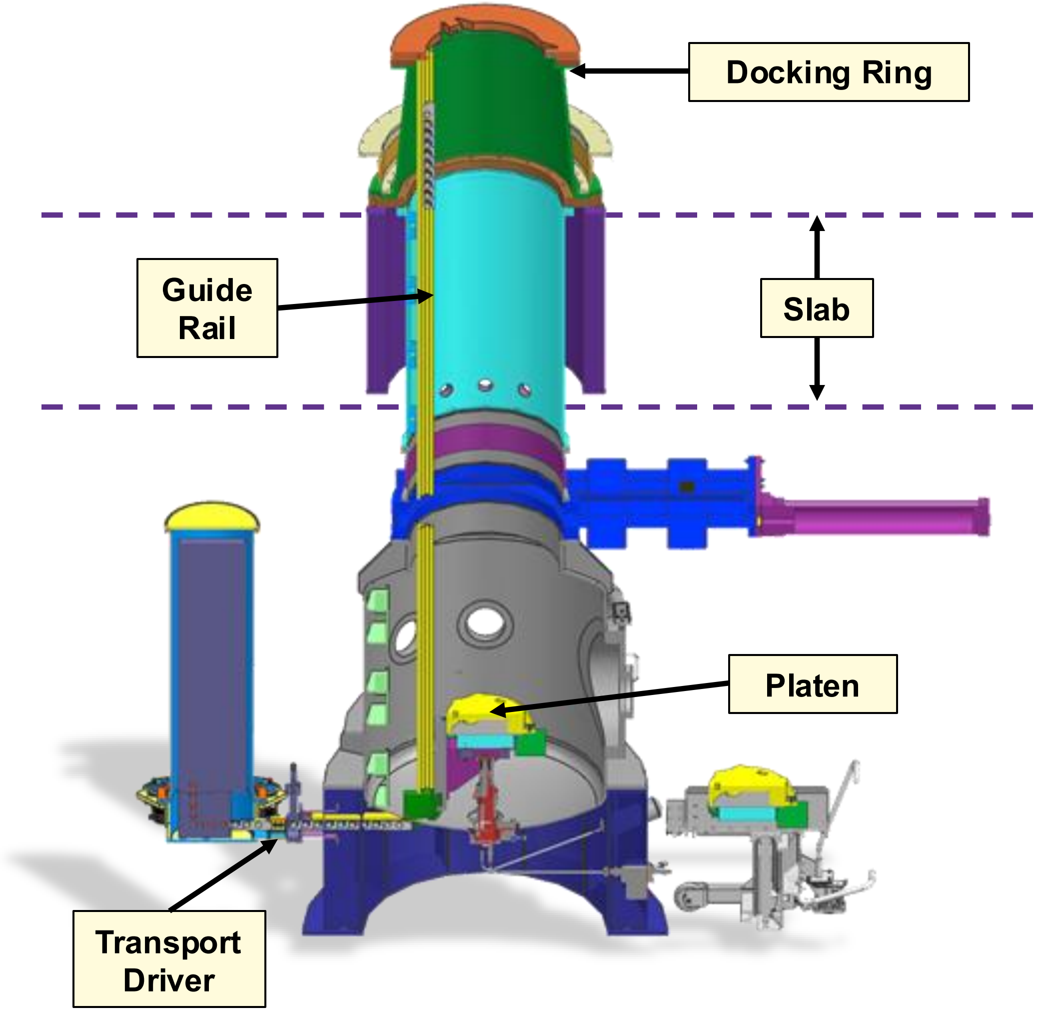
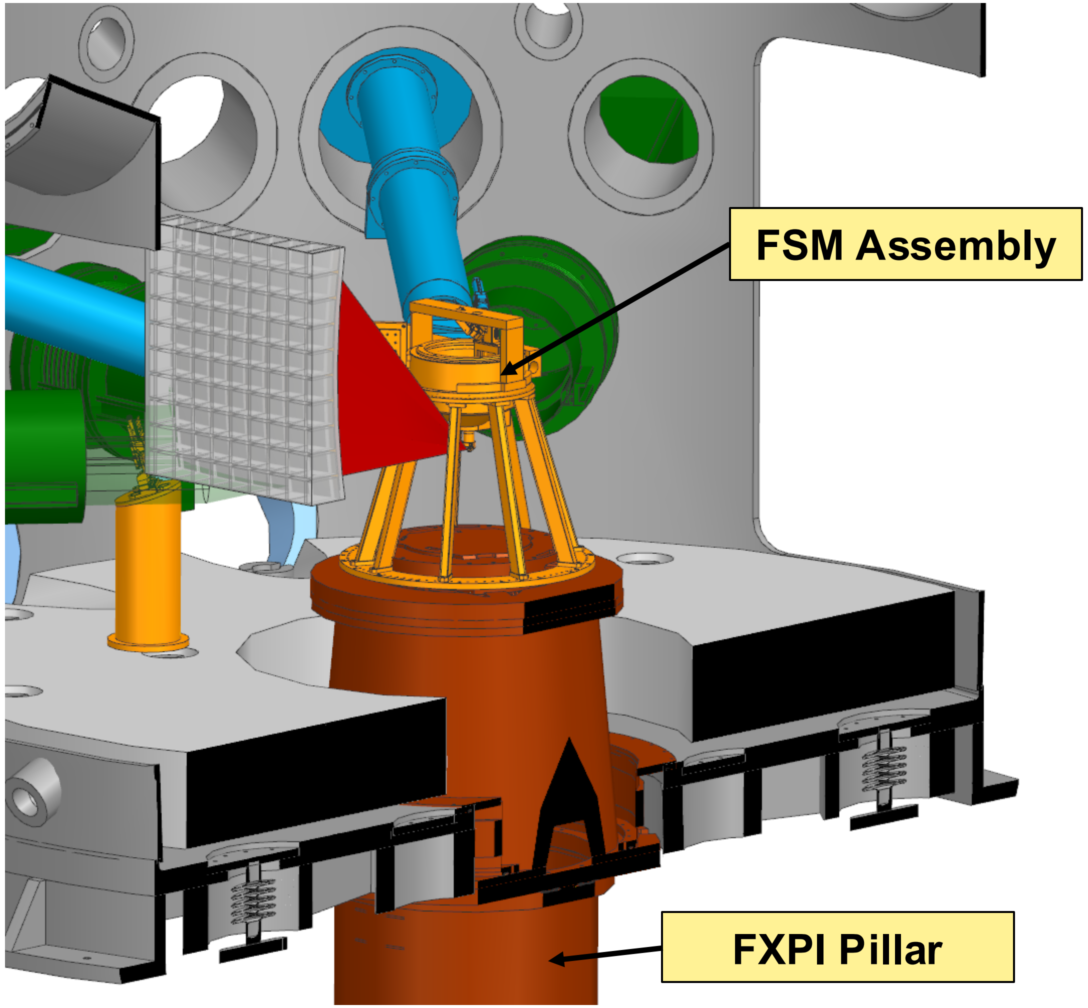
FleXible Platen Interface (FXPI) overview and capabilities



Requirement	Value
Platen size	Ø 16” **
Platen payload weight	500 lb.
Shot-to-shot stability	< 1 um RMS at TCC
Utilities	Power, control, pressurized gas*, fiber optics, ethernet
Reload / Reconfiguration time	45 min. / 60 min.

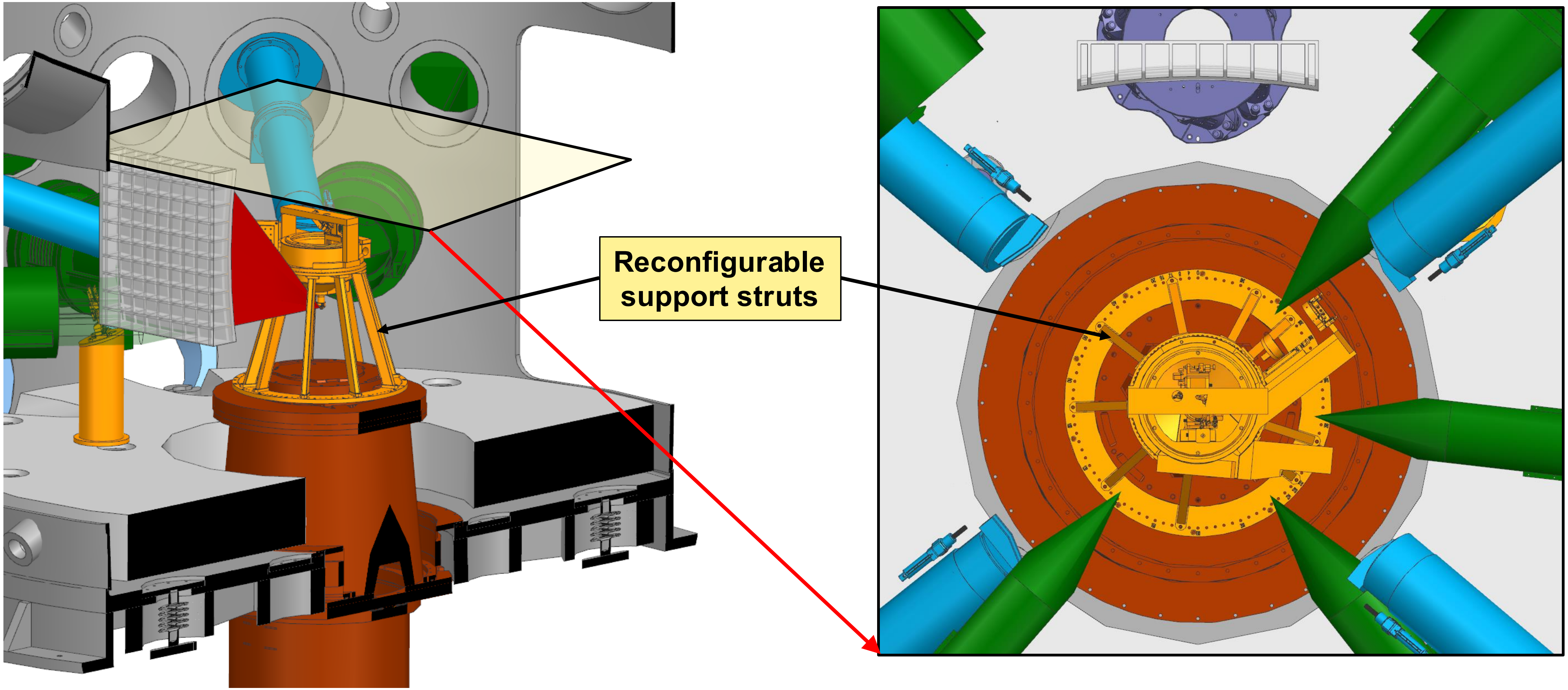
* future, does not preclude
** investigating larger dia.

MTC alignment overview – Focal Spot Microscope (FSM)

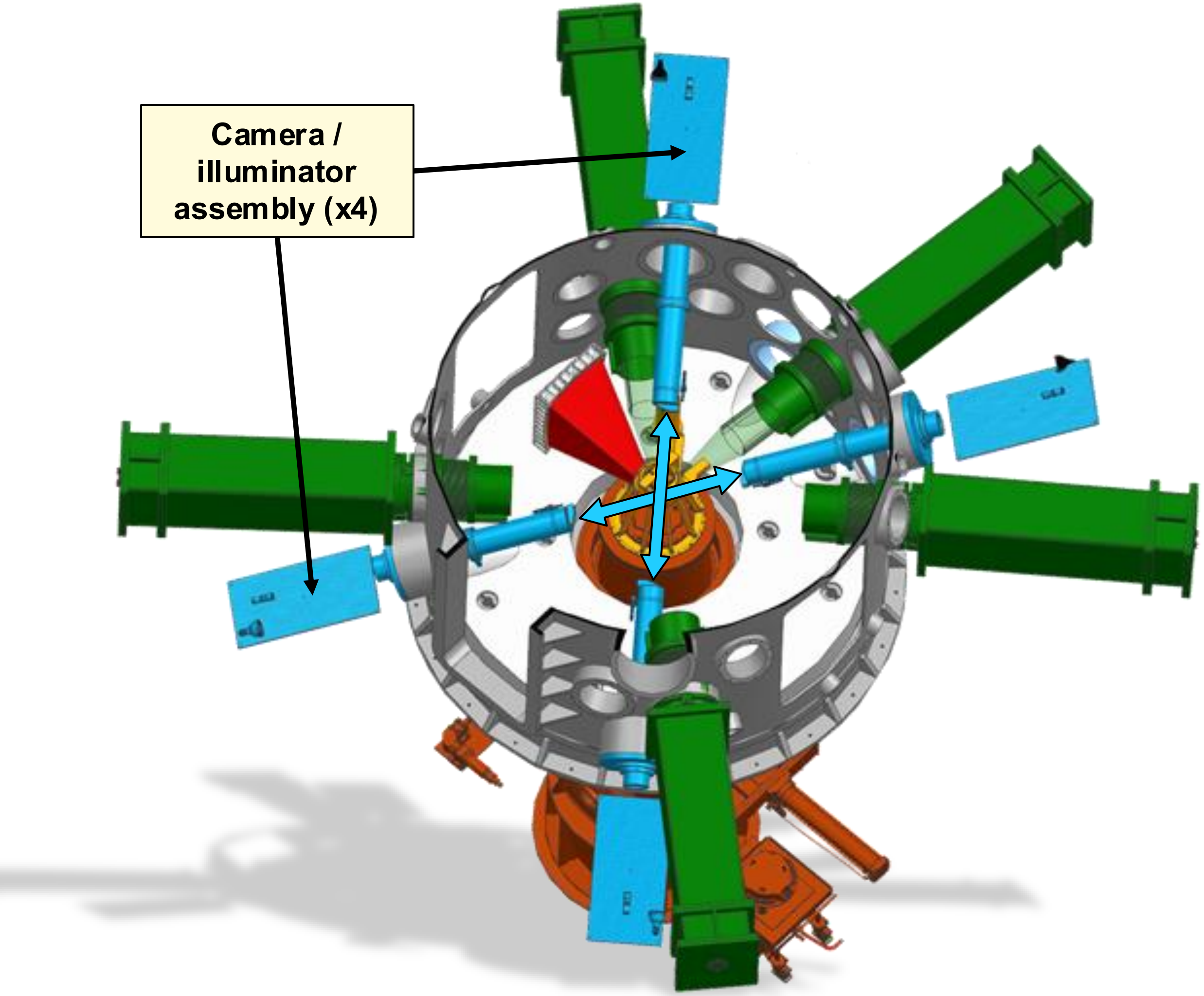


- The FSM provides a suite of diagnostic instruments to support NSF OPAL beam & target alignment near chamber center
- Compatible with all four (4) Alpha beam paths
- Inserts between shots and retracts to safe position during shots
- Configurable support struts to allow necessary lines of sight (LOS) access to interaction region

MTC alignment overview – Focal Spot Microscope (FSM)

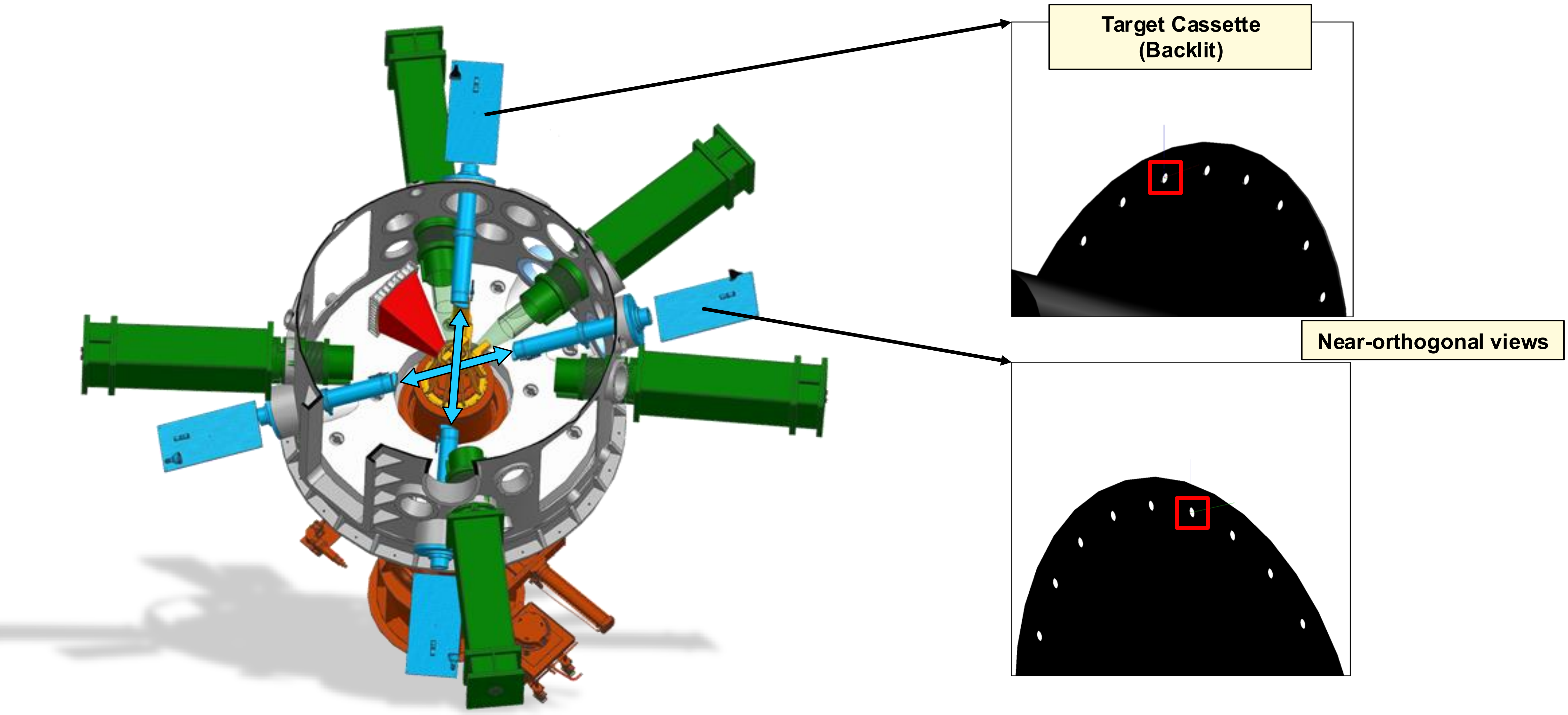


MTC alignment overview – Target Viewing System (TVS)

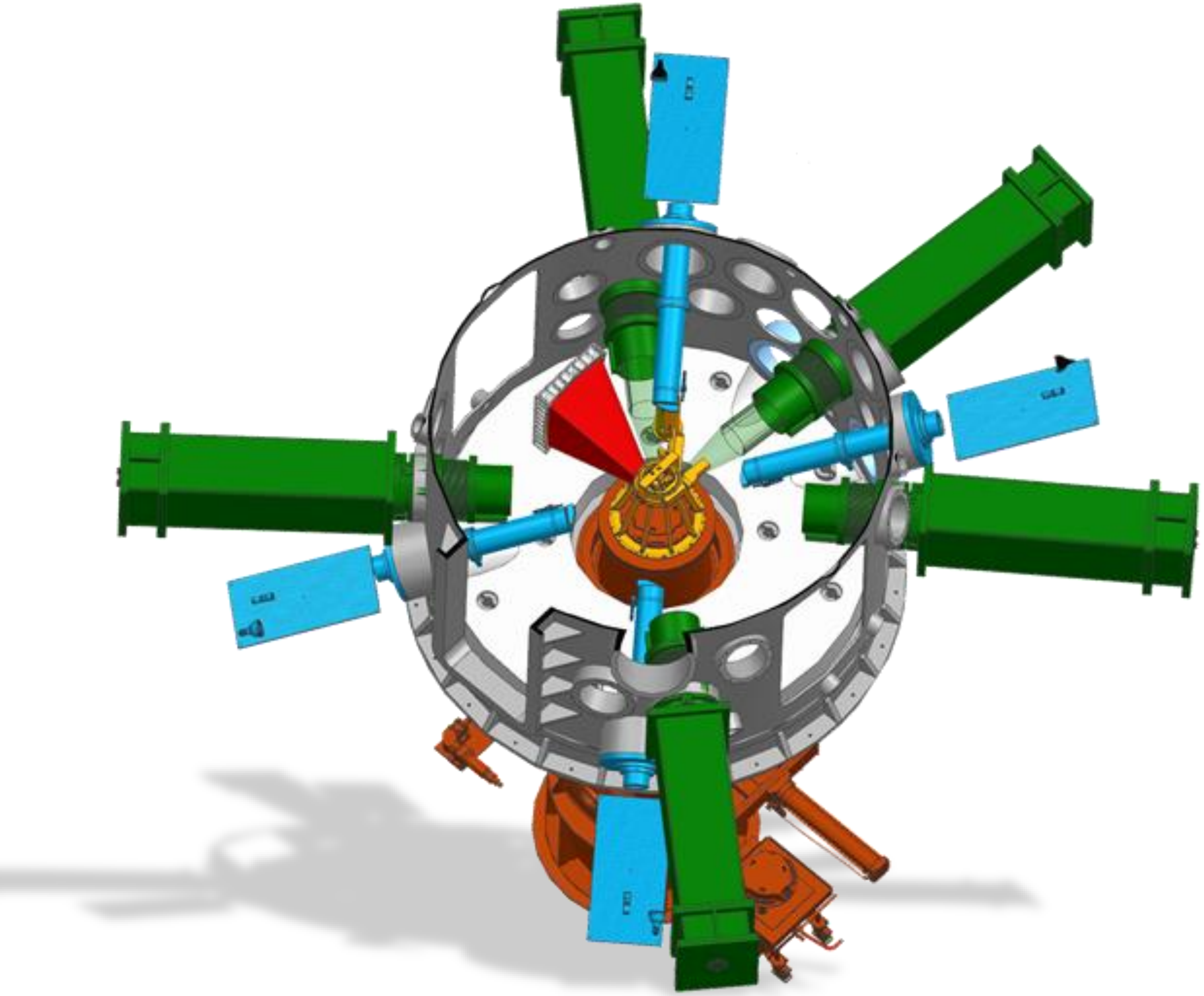


- TVS works in conjunction with FSM for near-TCC alignment of target components and beam alignment fiducials
- Provides a minimum of two near-orthogonal views such that a point of interest can be fully defined in three (3) dimensions
- FOV is greater than Alpha and UV pointing volume
- Used on every target shot
- Mechanically stable to maintain a fixed reference point that serves to define a coordinate system for the Main Target Chamber (i.e. concept of TCC)
- Telecentric system minimizes distortion over full FOV
- Backlit & front-lit

MTC alignment overview – Target Viewing System (TVS)

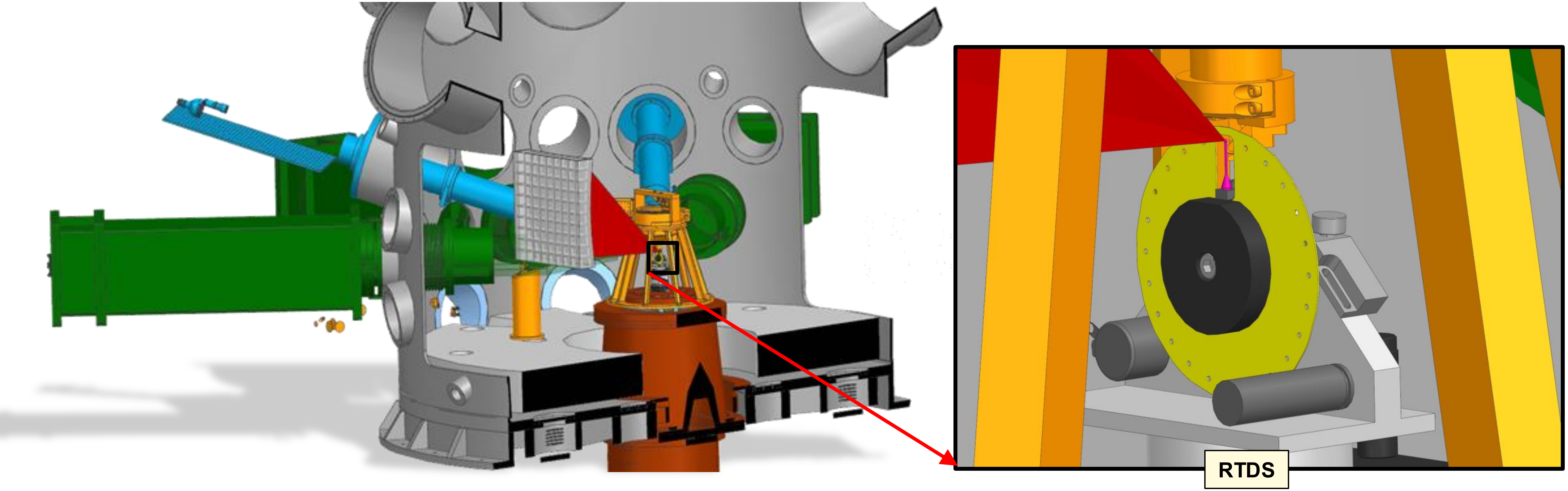


MTC alignment overview – Target Viewing System (TVS)



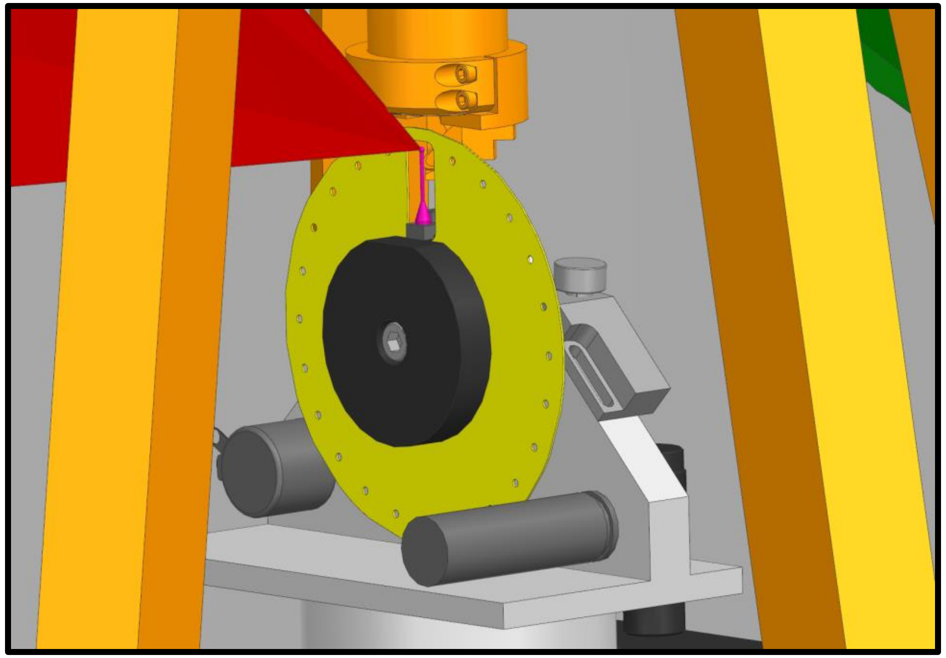
Requirement	Standard	Wide
Field-of-View (FOV)	30 mm (TCC)	60 mm (TCC)
Optical Resolution	5 μm	15 μm
Depth-of-Field (DOF)	$\pm$0.12 mm	$\pm$1.4 mm
Distortion/Telecentricity	<20 μm error	<50 μm error
Illumination Scheme	Frontlit/Backlit	Backlit

MTC alignment overview – Rapid Target Deployment System (RTDS)



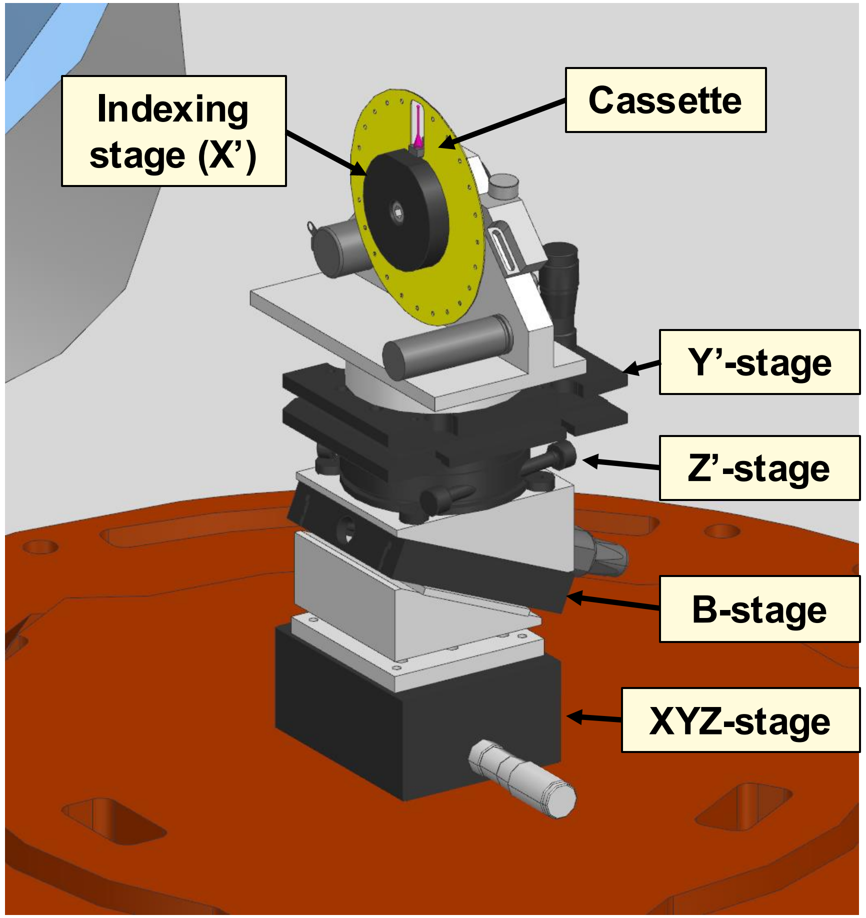
MTC alignment overview – Rapid Target Deployment System (RTDS)

- **Deploys solid, planar targets for a volley**
- **Seven (7) axes of motion**
  - *Five (5) dynamic (X, Y, Z, B*, X')*
  - *Two (2) pre-configured offline (Y',Z')*
- **Detachable target cassette holds 20 targets in individual windows**
- **Cassette orientation is set at the start of the volley allowing for target indexing within a 5 minute timeframe**
- **Contains co-timing and co-pointing alignment objects**



* B-axis = along beam (i.e. 22.5° from horizontal)

MTC alignment overview – Rapid Target Deployment System (RTDS)



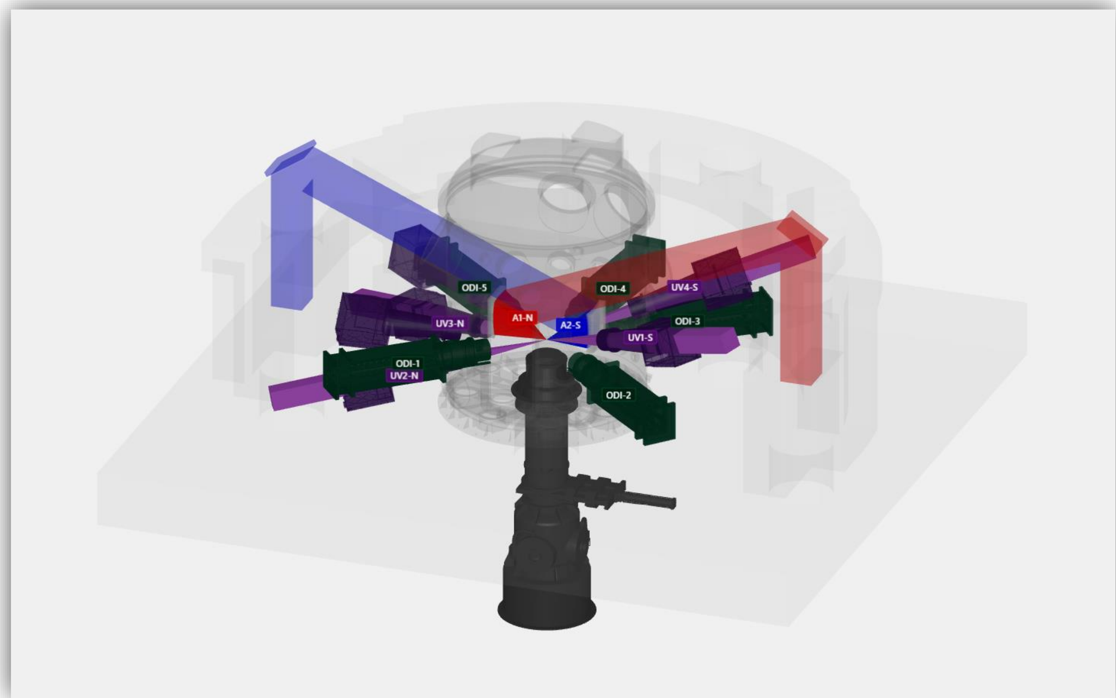
Requirement	Value
Range of motion (X, Y, Z)	25 mm
Range of motion (X’, Z’, Y’)	360°, 360°, 10° respectively
Motion precision (X, Y, Z, B)	< 1 um
Cassette size	Ø 4”
Target size	< 1 mm

Resources for future users are available on our website

- **Link to model: https://nsf-opal.rochester.edu/mtc/**

- **VISRAD layouts of current MTC design are available by request only**
  - Send email to mkri@lle.rochester.edu with request

- **Provide your Experimental Use Case (EUC) proposals using this template and submit to our Box folder**



Project Updates

The current NSF Midscale Research Infrastructure (RI-1) project is just one step in the process of completing the NSF OPAL facility

NSF RI-1 Design Award		Potential Final Design	Potential NSF Major Facility Construction	Operations & User Experiments	
FY24 - FY27		FY27 - FY29	FY29 - FY33	FY34 - FY3X	FY3X+
Conceptual Design	Preliminary Design	Final Design	Construction	Commissioning	Flagship Experiments

Feb 24, 2026:
Community Update on Zoom

May 2026:
MPW Diagnostic Workshop

Dec 2026:
RI-1 Preliminary Design Review (PDR)

Image courtesy of SWBR

NSF OPAL visibility continues to expand across media and conferences

- **EvolvOptic president, Ted Mooney, and Jon Zuegel, NSF OPAL PI, discussed the partnership that is advancing laser technology on WROC's 'WHY ROC' segment**

- **Continued strong student presence throughout NSF OPAL at various conferences**

C. Arrowsmith, presented the first demonstration on DLWFA at APS DPP

UC Merced undergraduate S. Yeghiayan presenting work on proton diagnostics

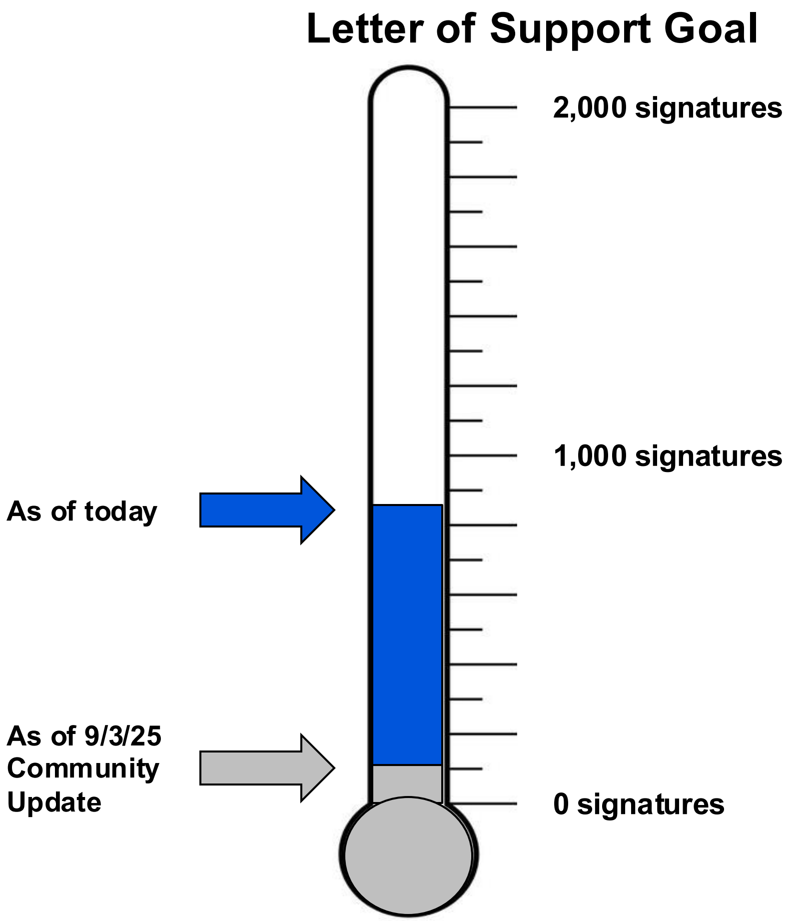
- **Video highlight on Undergraduate intern, N.V. Mararanje, showcasing a brief overview of NSF OPAL along with her contributions to the project**

- **Photonics Spectra covers MTW-OPAL and NSF OPAL team during SPIE Optifab 2025**

These events and more can be found on our LinkedIn page!

Thank you for your help in expanding NSF OPAL interest!

- **Since our last update:**
  - LinkedIn followers have increased by 175%
  - Friends of OPAL subscribers have increased by 25
- **Ways you can support NSF OPAL**
  - Signing/sharing the Letter of Support
  - Following/sharing LinkedIn page/posts
  - [Including NSF OPAL in talks/presentations]
- **We'd value your input on the following areas:**
  - Priority technical capabilities
  - User experience expectations
  - Training and workforce needs
  - Opportunities for partnerships



We will follow up with a brief survey to gather your feedback after today's session.

NSF OPAL still needs your help!

Sign an Open Letter of Support

This letter advocates for the funding of a future NSF OPAL user facility, highlighting its importance to the science community and U.S. scientific leadership. Please consider signing and forwarding to others.

https://nsf-opal.rochester.edu/letter-of-support

Visit the Website

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