THE GÉRARD MOUROU
CENTER FOR ULTRAFAST
OPTICAL SCIENCE
UNIVERSITY OF MICHIGAN

Zettawatt-Equivalent Ultrashort Pulse Laser System

ZEUS

The 3PW NSF ZEUS facility

September 15, 2021

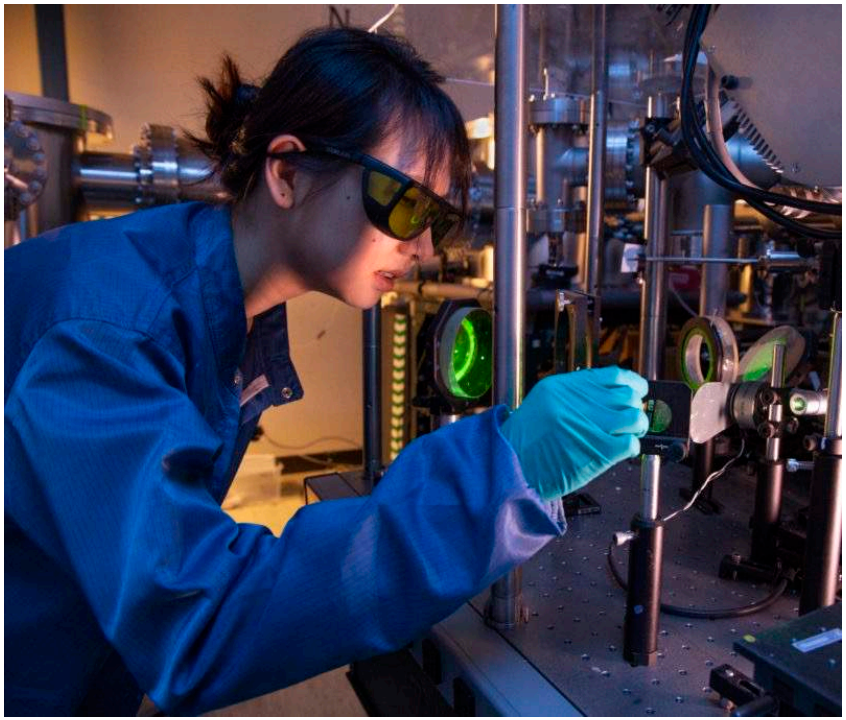
Extremely High Intensity Laser Physics Conference (ExHILP 2021)

Louise Willingale

NSF

ZEUS
Zettawatt-Equivalent Ultrashort Pulse Laser System

NSF ZEUS Facility Overview



- What is ZEUS?
- ZEUS laser system
- ZEUS target areas
- ZEUS timeline and current status
- ZEUS operating as a user facility

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ZEUS Project Team

Karl Krushelnick (PI)
Laser plasma experiment

Alec Thomas
High intensity simulation/experiment

Louise Willingale
Ion acceleration, B-fields

Igor Jovanovic
Laser driven radiation sources

Carolyn Kuranz
Lab Astrophysics

Anatoly Maksimchuk
High intensity experiment / laser development

John Nees
High power laser technology

Bixue Hou
High power laser technology

Franko Bayer
ZEUS Project Manager

Construction External Advisory Board (EAB):

- Prof. Chan Joshi (Chair / UCLA)
- Prof. Ritchie Patterson (Cornell)
- Dr. Jon Zuegel (U. Rochester)
- Dr. Csaba Toth (LBNL)
- Prof. Dr. Stefan Karsch (LMU Munich)
- Dr. Rajeev Pattathil (Central Laser Facility, UK)

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ZEUS FACILITY OVERVIEW

Zettawatt

Equivalent

Ultrashort pulse laser

System

$16M NSF funding to construct a user facility (RI-1 began October 2019)

Operations funding of $18.5M over 5 years is awarded by NSF.
Experiments for users from late 2023

2018 – new National Science Foundation program in Mid-scale research infrastructure (RI-1, RI-2)

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ZEUS FACILITY OVERVIEW

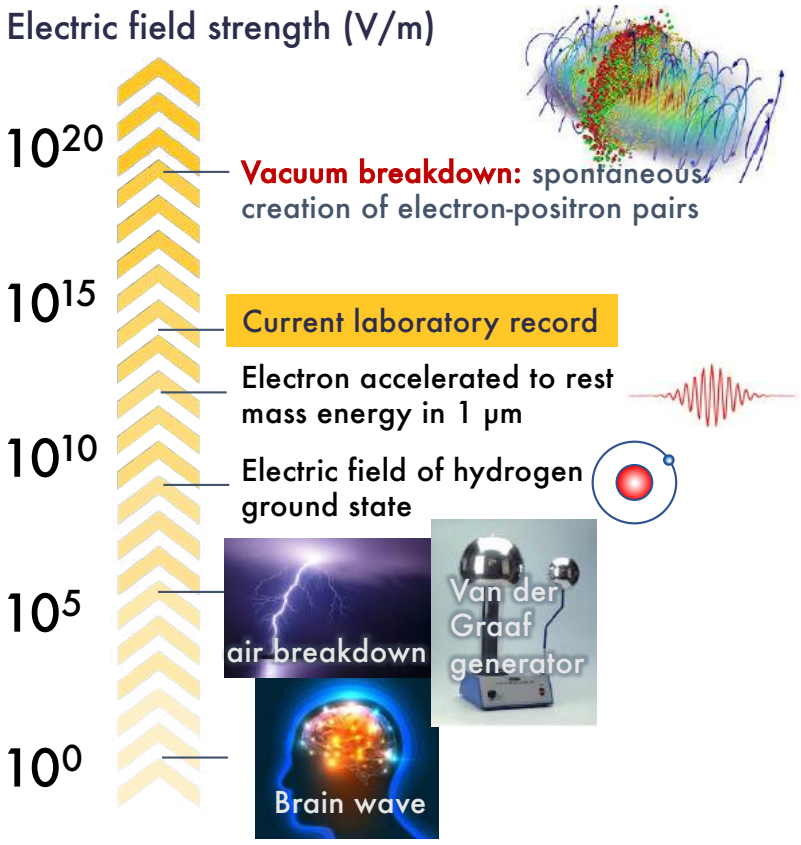
Zettawatt = 10^{21} W

Equivalent

Critical field
$E_c \sim 10^{18}$ V/m

Ultrashort pulse laser

System



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ZEUS FACILITY OVERVIEW

Zettawatt = 10^{21} W

Equivalent

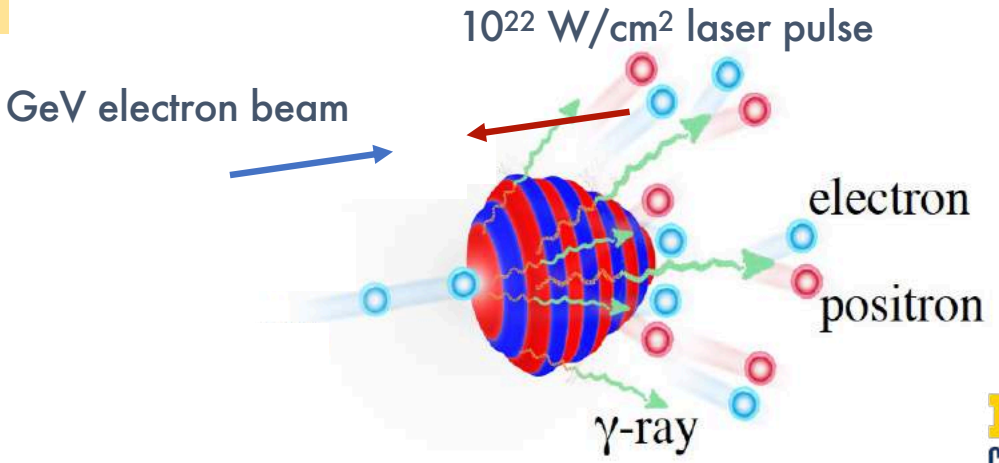
Critical field
$E_c \sim 10^{18}$ V/m

Ultrashort pulse laser

System

ZEUS power = 3 PW = 3 x 10^{15} W
(Highest power laser in the USA)

The intensity experienced by a GeV electron beam in the rest frame of reference will be equivalent to a Zettawatt power pulse!



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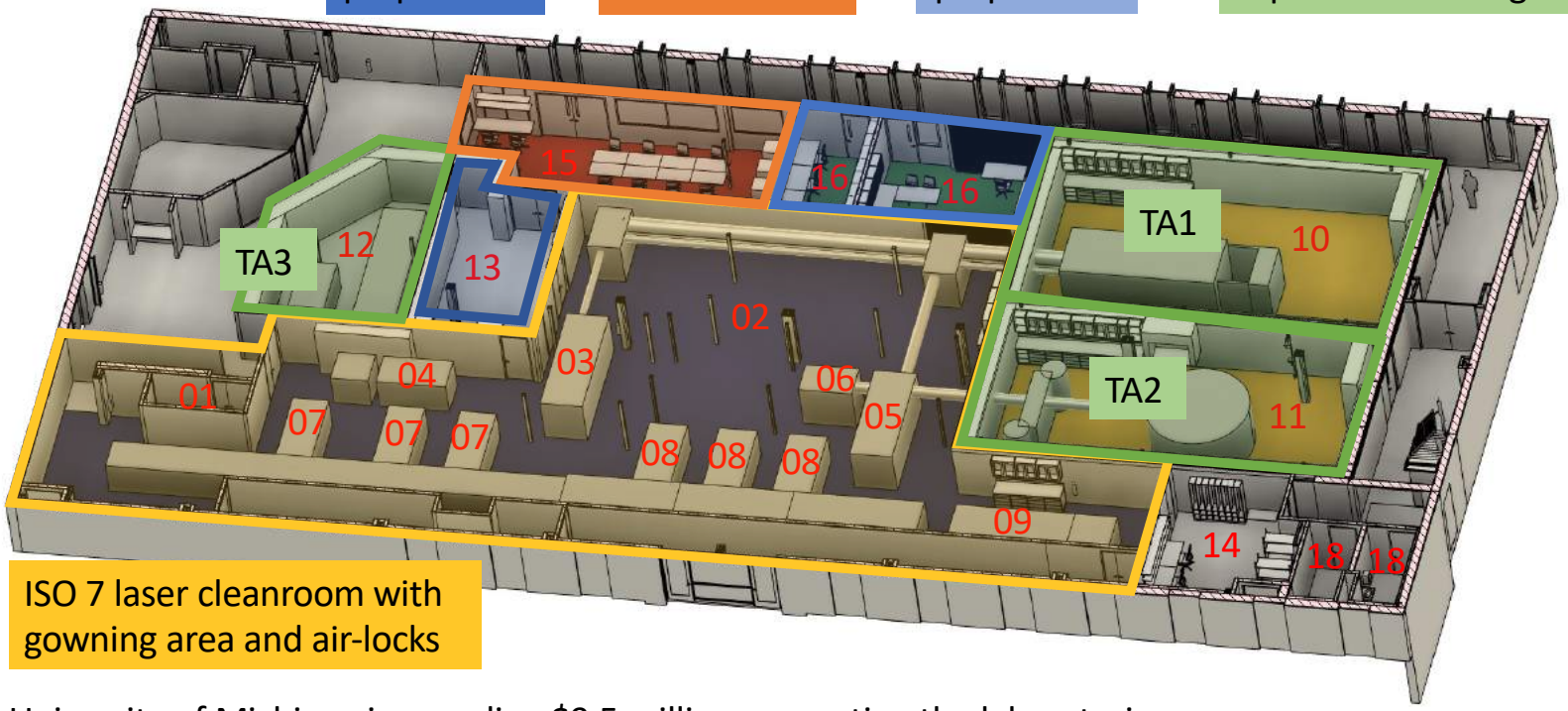
ZEUS Floor Plan

Diagnostic preparation

Experimental control room

Target preparation

Three radiation shielded experimental "target" areas



ISO 7 laser cleanroom with gowning area and air-locks

01 Suiting Vestibule
02 Laser Lab Clean room
03 500 TW compressor
04 500 TW Diagnostics
05 3PW compressor
06 3PW Diagnostics
07 Nd:YAG pump laser
08 Nd:glass pump laser
09 Nd:glass driver
10 Experim. room – Gas Target
11 Experim. room – Solid Target
12 Exp. room – Gas Target 500 TW
13 Diagnostics room 500 TW
14 Laser Control room
15 Experimental Control room
16 Target preparation room
17 Laser Utility Corridor
18 Restroom

University of Michigan is spending $9.5 million renovating the laboratories

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Other ZEUS Spaces

- Machine workshop
- Electrical workshop
- Target fabrication and characterization suite
- Offices for staff and visitors
- Meeting spaces

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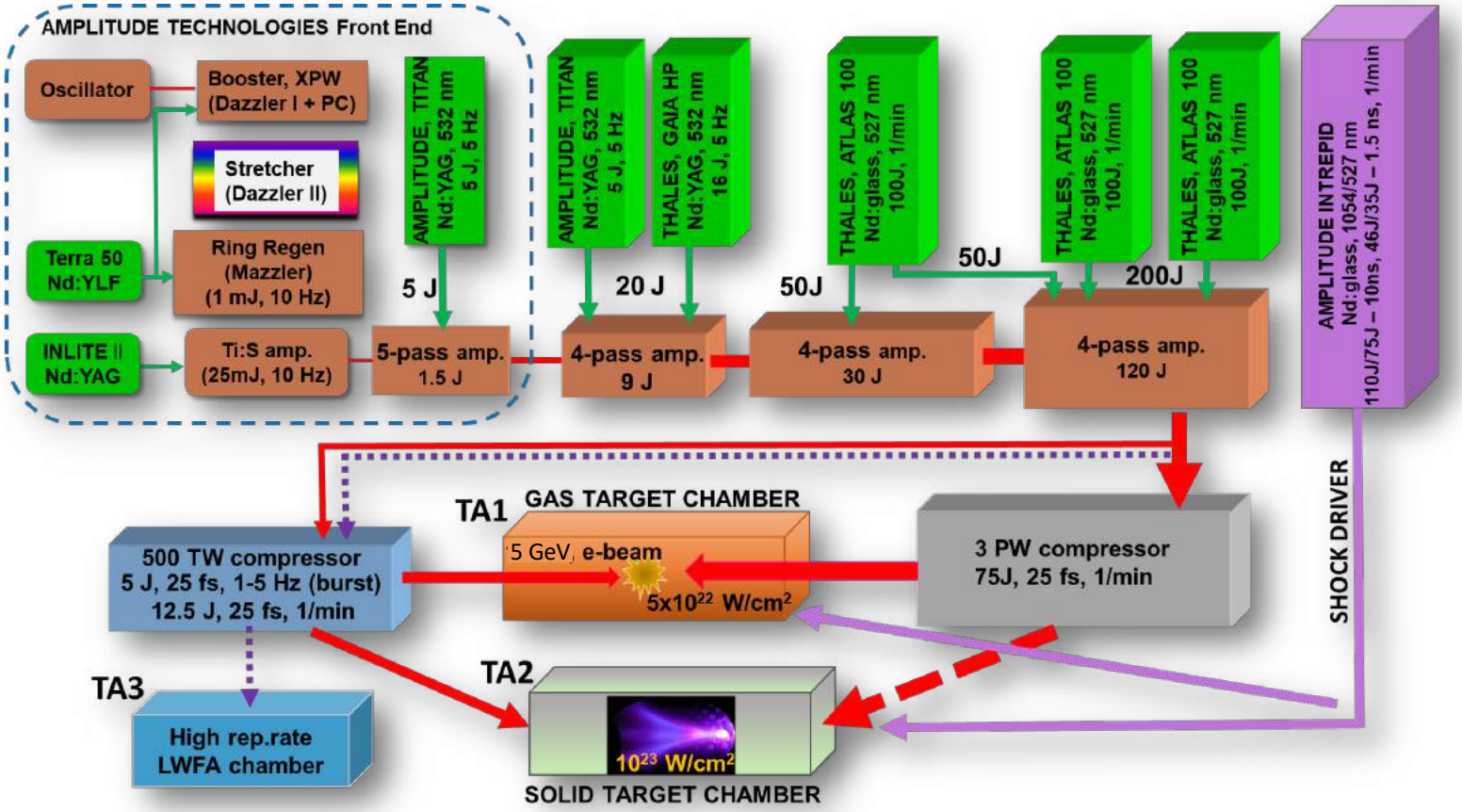
ZEUS LASER SCHEMATIC



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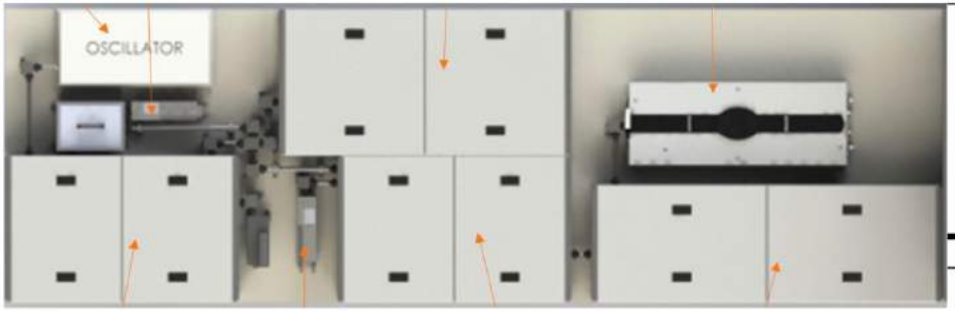
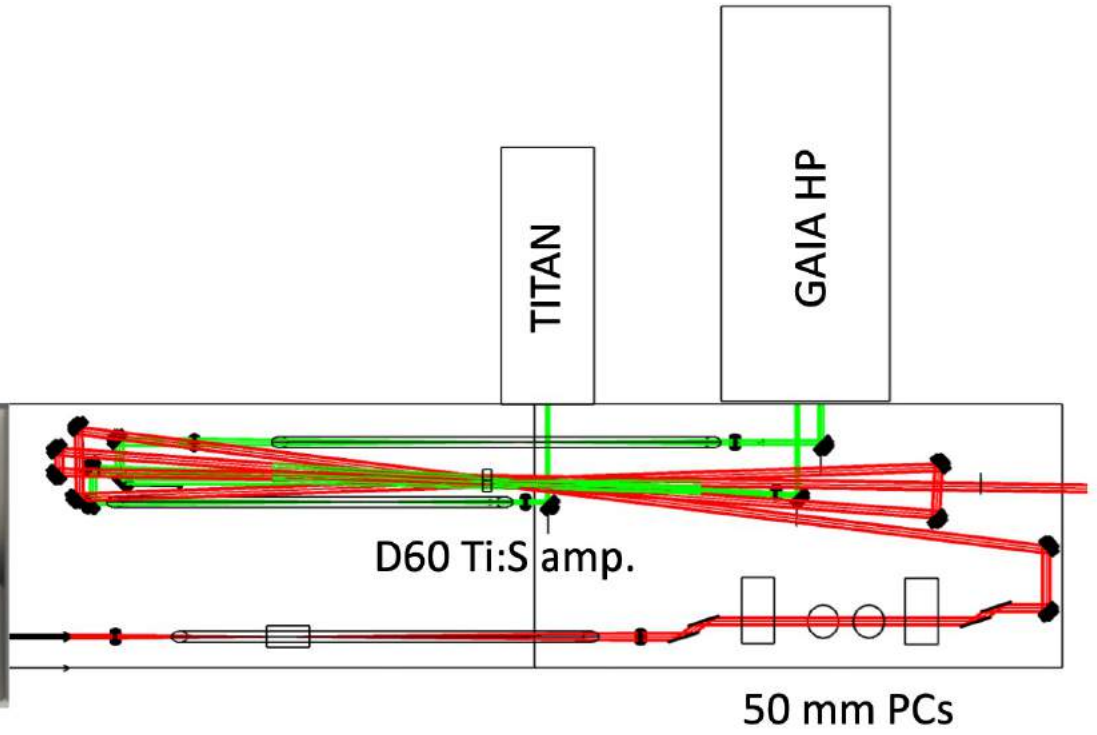
ZEUS FRONT-END AND 1ST AMPLIFIER

Amplitude Technologies front end





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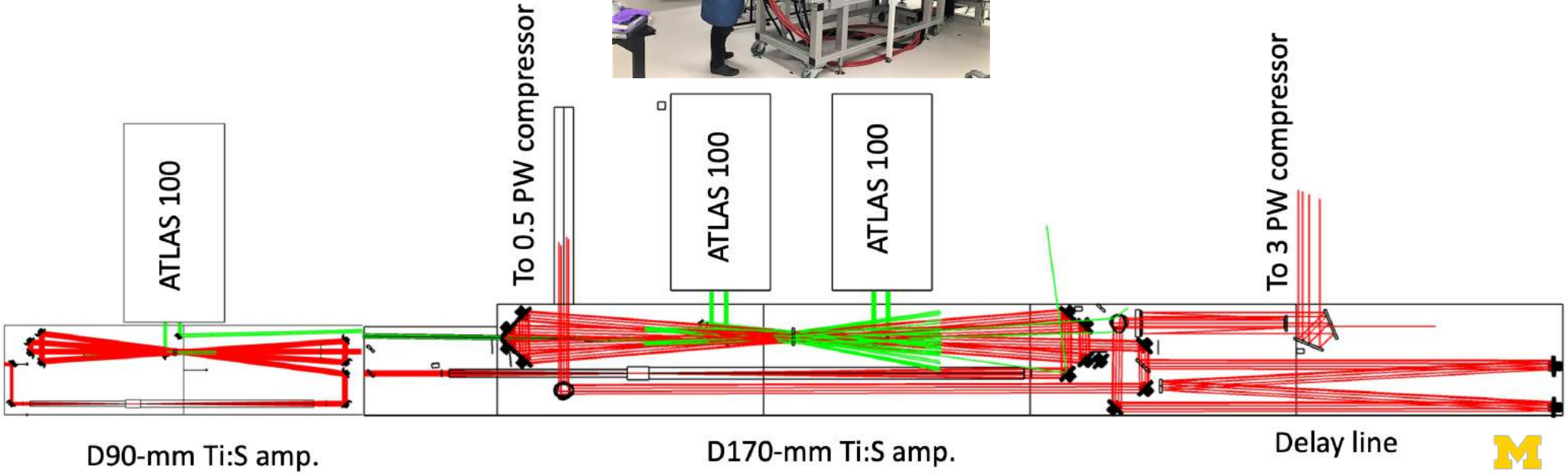
ZEUS 2ND AND 3RD AMPLIFIERS

Some of the HERCULES laser components will be reused
(Installed THALES GAIA HP and ATLAS100 lasers acquired through the NSF MRI grant)



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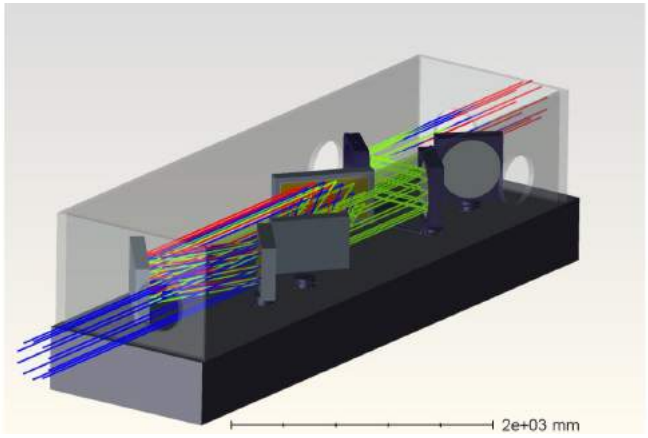
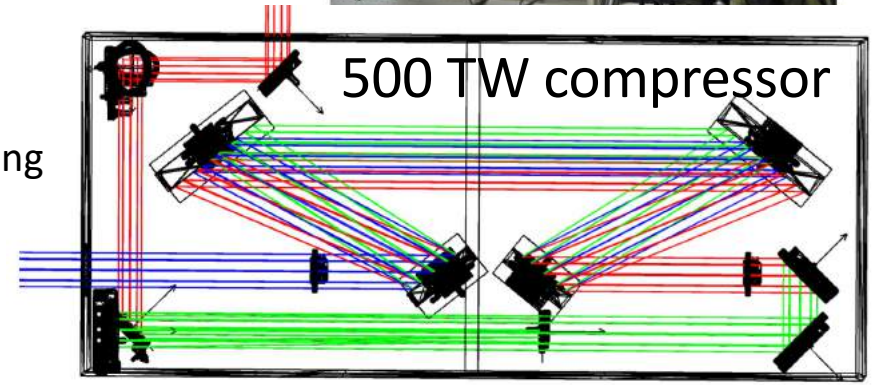
ZEUS COMPRESSORS

3 PW compressor

Existing HERCULES 500 TW compressor



ZEMAX ray tracing



500 TW compressor

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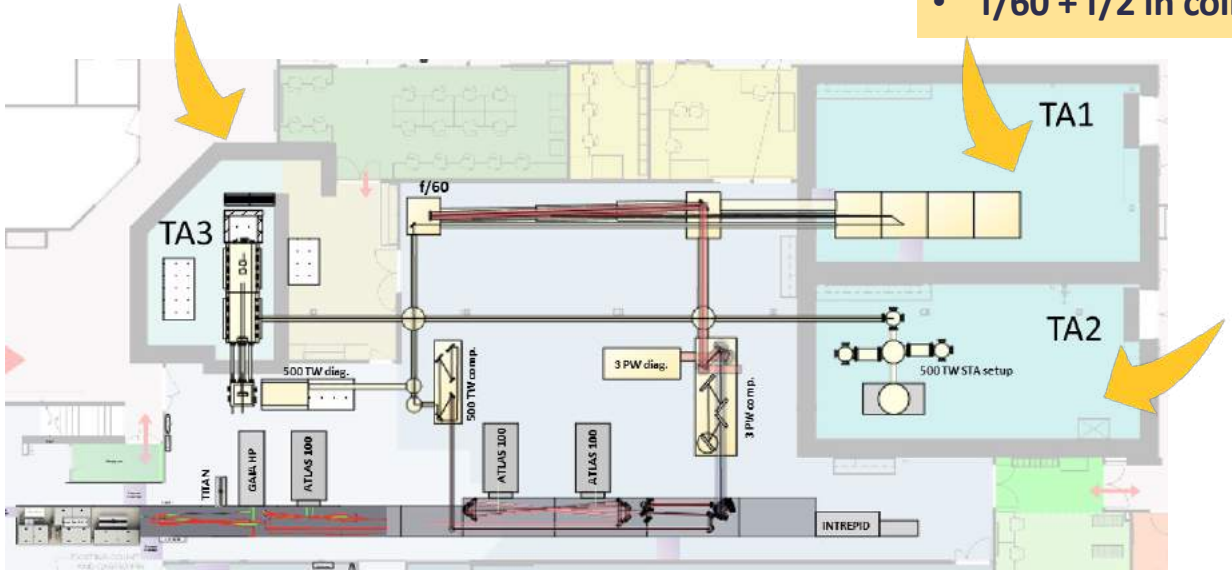
ZEUS Target Areas

Target Area 3

- <0.5 PW @ 5 Hz operation
- 1.5 ft thick concrete shielding
- f/40 and f/20 configurations

Target Area 1

- 3 PW & 2.5 + 0.5 PW configurations
- 2 ft thick concrete shielding
- Long beam pipe to accommodate up to f/60 focusing optic
- Short focusing configuration (f/2)
- **f/60 + f/2 in colliding geometry**



Target Area 2

- 0.5 PW
- (Needs funding for 3 PW upgrade and operation)
- 2 ft thick concrete shielding
- Plan to accommodate plasma mirrors and short focusing configuration

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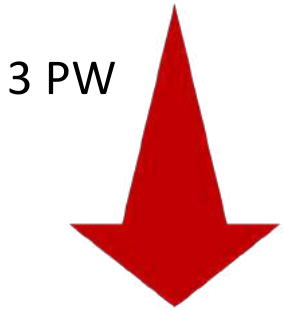
ZEUS Operational Modes

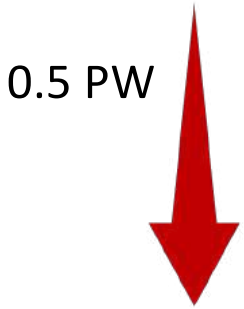
Mode 1



Target area 1

1 shot / min

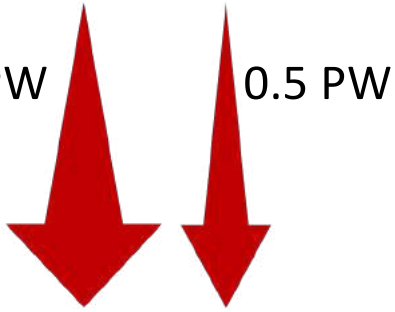
Mode 2



Target area 1/2/3

1 shot / min
or 5 Hz

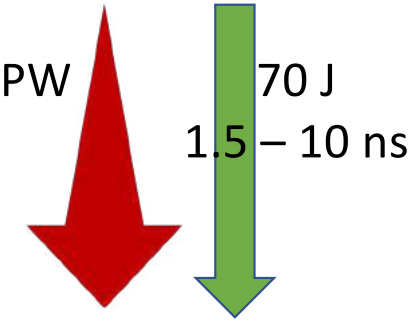
Mode 3



Target area 1

1 shot / min

Mode 4



Target area 1

1 shot / min

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ZEUS COLLIDING BEAM EXPERIMENT

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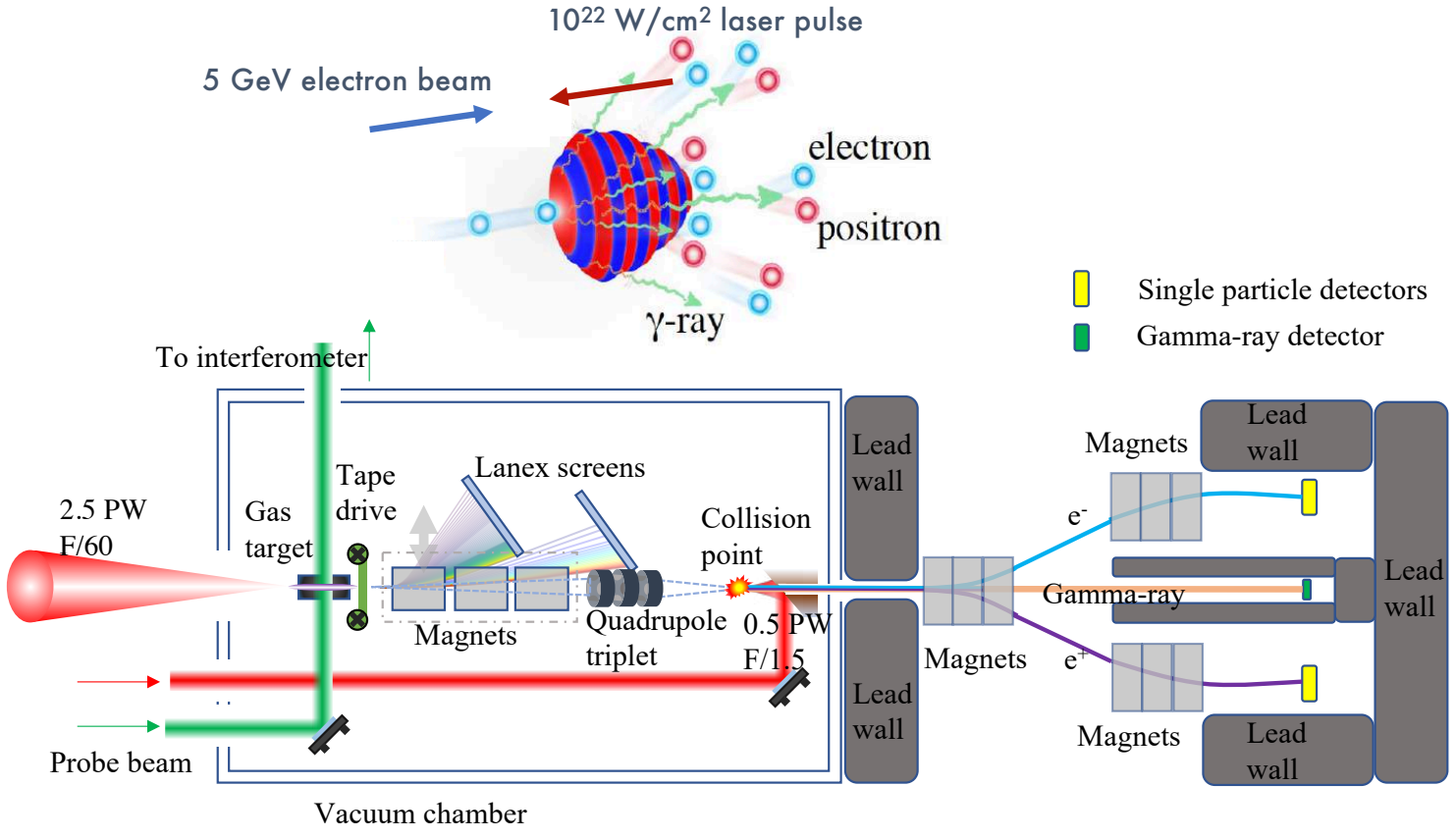

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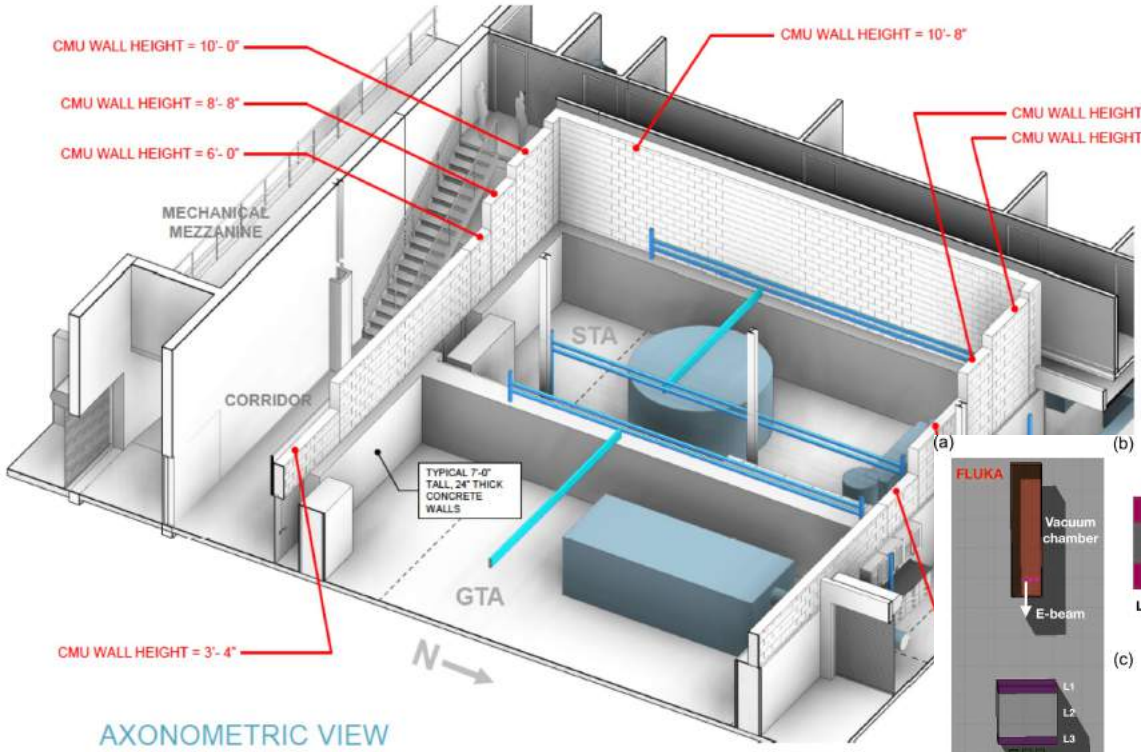
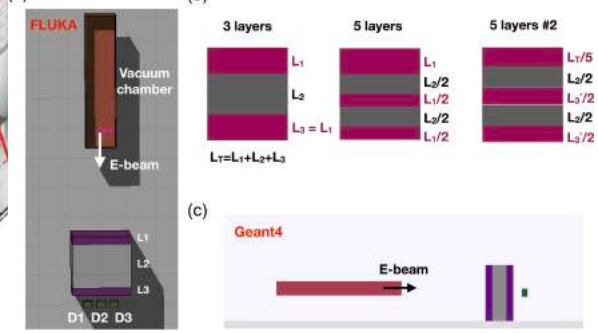
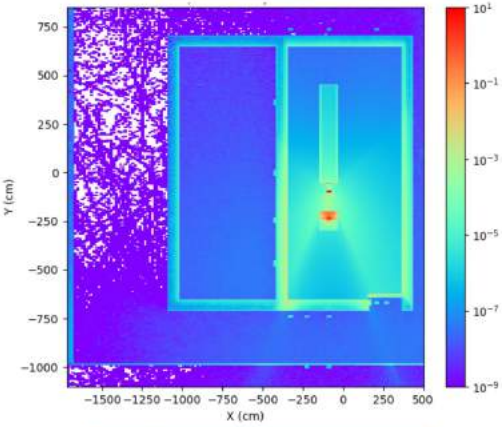
ZEUS RADIATION SHIELDING





NRC dose limit (10 CFR 20):

- <2.0 mrem/h in any unrestricted area
- <100 mrem/yr in unrestricted and controlled areas
- SLAC dose limit: 0.5 mrem/h
  4:1 safety factor



FLUKA

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T. Shi, et al., "Optimization of the Electron Beam Dump for a GeV-class Laser Electron Accelerator," Applied Radiation and Isotopes 176, 109853 (2021).

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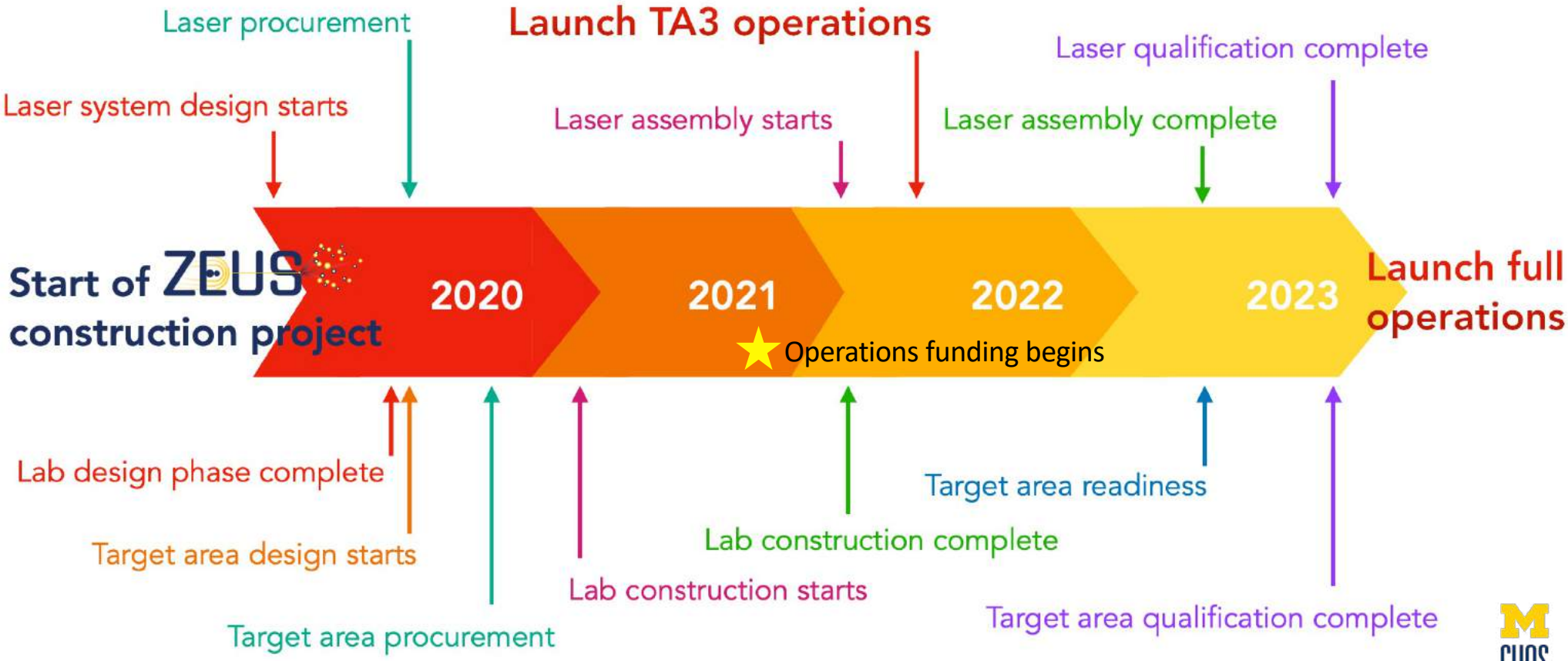
ZEUS TIMELINE



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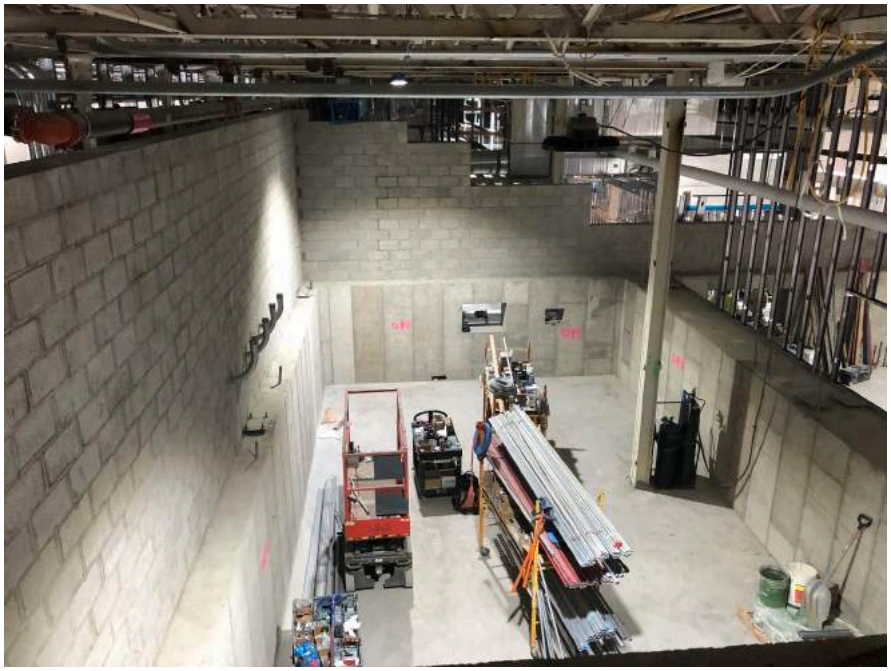
ZEUS Infrastructure Status

Michigan funded an expansion of the high field laser labs ($9.5M)

- Mar/Apr 2021: adjoining MSE/CUOS labs were moved
- Oct 2021: cleanroom construction completion
- Dec 2021: Full occupancy of the renovated areas
- May 2022: start operation in TA3 at 500 TW
- Aug 2022: start operation in TA2 at 500 TW
- Mar 2023: completion of the laser and TA1 assembly
- Apr-Jun 2023 commissioning of ZEUS system in TA1

Lab space was gutted



TA2 and TA1 shielding walls

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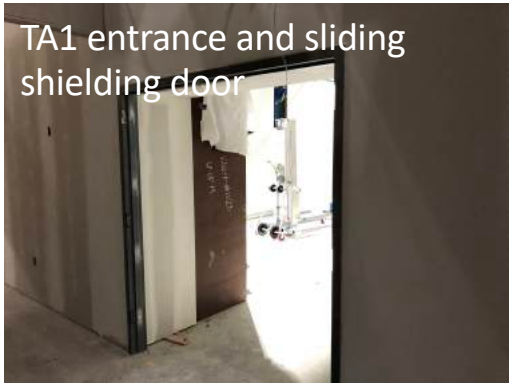
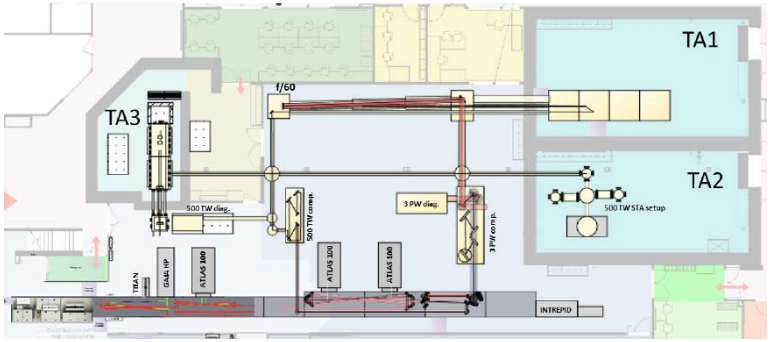
ZEUS INFRASTRUCTURE STATUS


User control room and corridor


TA1 entrance and sliding shielding door



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ZEUS User Facility

- 30 weeks a year will be offered to outside Users through a scientific merit-based proposal system
- ZEUS will support a broad range of potential experiments by offering a flexible configuration
- ZEUS will provide hands on training in high-power laser experiments to train the next generation of scientists

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ZEUS Operations Goals

- To provide users with state-of-the-art high power laser facilities for research into the basic science and applications of relativistic plasmas
- Primary community will be US academic users – but will also serve laboratory, industry and international users
- Emphasis on innovative science and flexible operation
- Emphasis on graduate student, postdoctoral training

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ZEUS Operations Model

- 30 weeks per year available for user access
- 10 weeks for maintenance
- 10 weeks for internal access

- Flexibility with number of weeks per experiment
  - Some “premade” setups allowing shorter experimental blocks and limited user preparation time
  - Longer experimental runs for more complex configurations
  - Contiguous scheduling of experiments with common set-ups
- No funding for users – only experimental access

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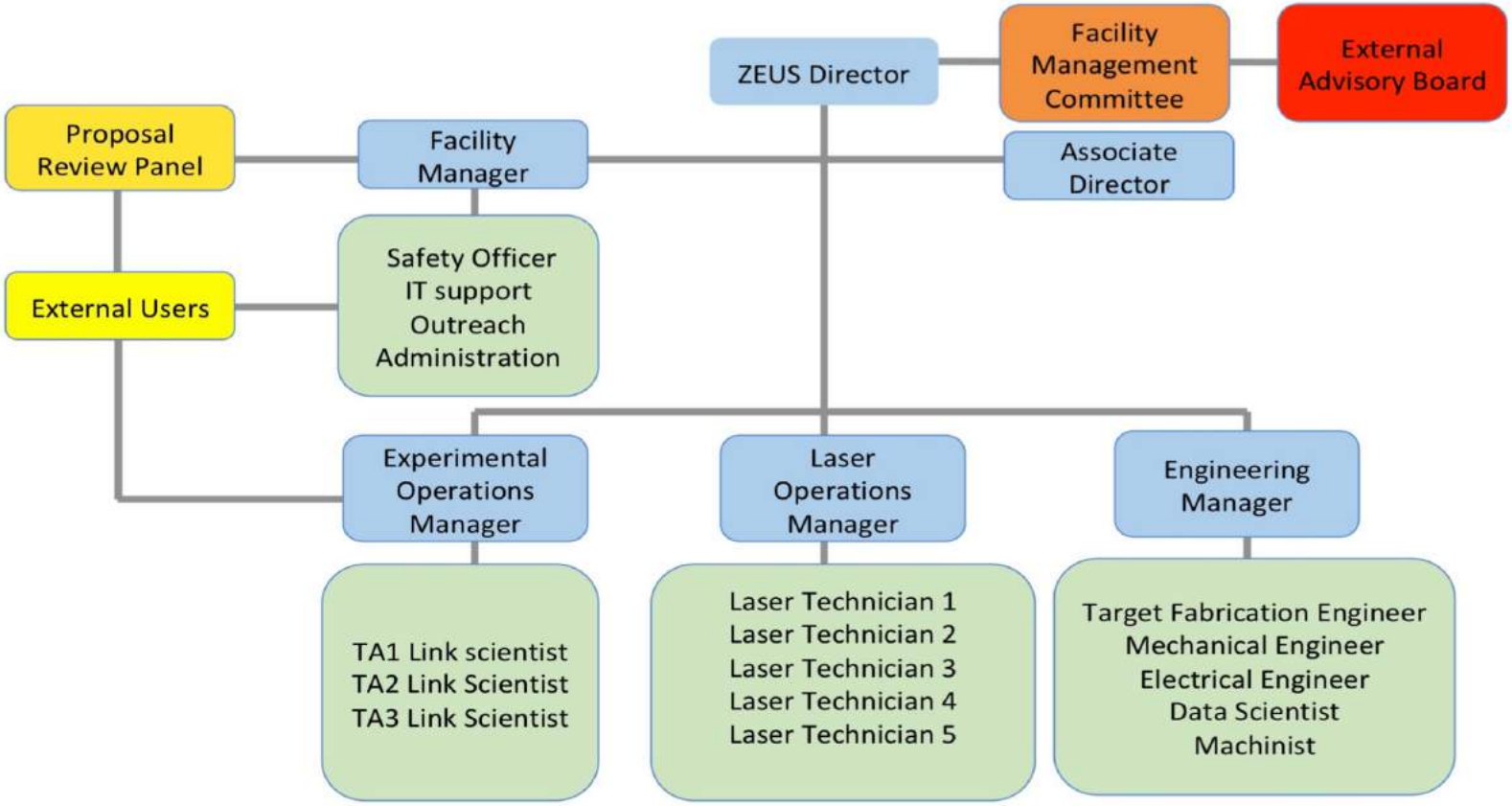
ORGANIZATIONAL STRUCTURE



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DIAGNOSTICS

CUOS diagnostics include:
Visible, x-ray and infrared CCD cameras
Optical spectrometers
XUV grazing incidence spectrometer
Electron magnetic spectrometer
Thomson parabola ion spectrometer
Visible and x-ray streak cameras
Image plate detector and reader
FROG
UV Seya-Namioka spectrometer
Scintillator / PMT for high-energy photon and neutron measurement
Activation detectors (Ge detector, scintillator coupled to PMTs)
Optical probe beams for shadowgraphy and interferometry

- Existing CUOS diagnostics are available for use.
- Information on each diagnostic will be made available on the user portal and maintained by the target area staff.
- The facility will work with external users to integrate their own diagnostics onto the system (assistance from mechanical and electrical engineering staff).

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TARGETS

Sallee Klein is our target fab engineer

200 µm x 200 µm “UM” foil

- A target fabrication engineer will be employed to prepare the targets.
- A suite of instruments for characterization will be located within the ZEUS facility.
- Basic targets will be available to users:
  - Flat foils
  - Gas jets or gas cells – variety of designs and gas types
  - Liquid jet target
- Specialist targets may be fabricated using in-house machining, or outside vendors may supply some of the parts. Cost analysis and assessment will be necessary.

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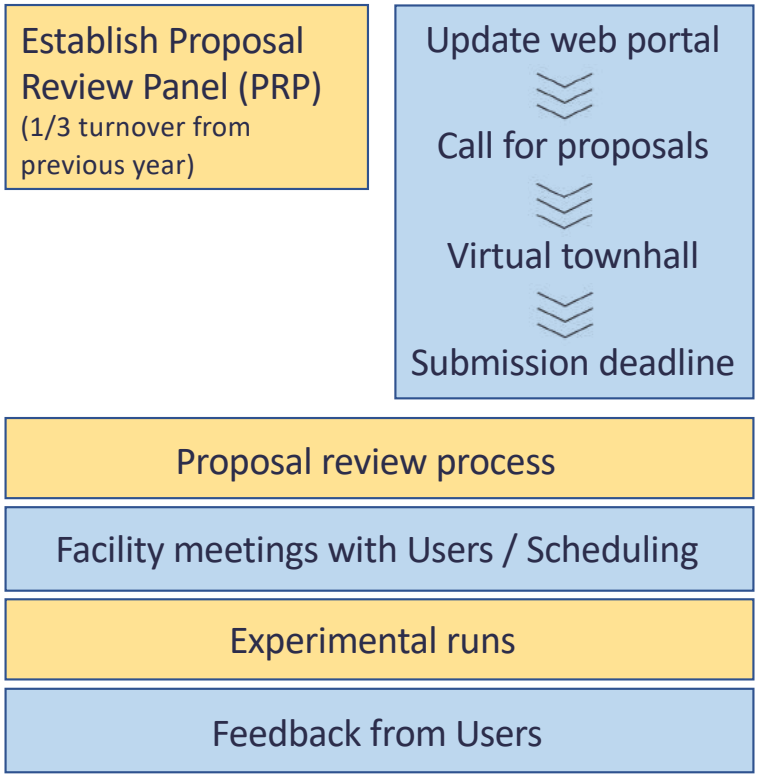
Proposal Cycle



- Annual proposal cycle
- Based on the successful processes used by other laser facilities
- Will be a transparent and independent process
- Considering using a double-blind reviewing system

The 3PW NSF ZEUS Facility

ZEUS
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- Due to begin 0.5 PW operation in mid-2022 and 3PW operation in late-2023.
- Will be a hands-on user facility with time allocated on scientific merit by an independent review panel.
- Will have flexible configuration, with a signature colliding beam geometry.

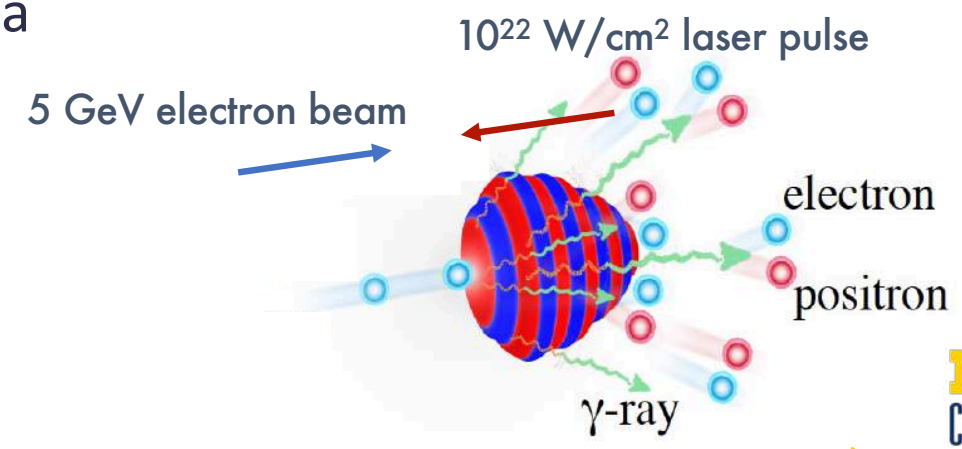
Zettawatt

Equivalent

Ultrashort pulse laser

System

Show your interest by signing up to our mailing list on the website



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