LhARA Project

General Facility Infrastructure and Integration (WP6)

LhARA Review
Accelerators and Technology
27th October 2022

Neil Bliss UKRI-STFC Technology Department

Content

- Stage 1 and Stage 2 vision
- General radiation protection considerations
- Power consumption and operation (skill required, maintenance and operation costs, reliability considerations, too early?)
- Milestones and Timeline for the design
- Required resources (material and personnel)
- Available resources (material and resources)
- Project scientific, technical, schedule, and financial risks attendant and the degree to which they are addressed in proposed activity – partly covered in WP1 presentation. Intention is to cover WP6 risks.
- Other risks and proposed mitigations

Additional slides for information

1. Radiation Shielding Study Detail
2. Overall Schedule for Facility Construction
3. Engineering & Technology Scope of Work Plan (STFC-Daresbury Laboratory) during CDR stage of the project

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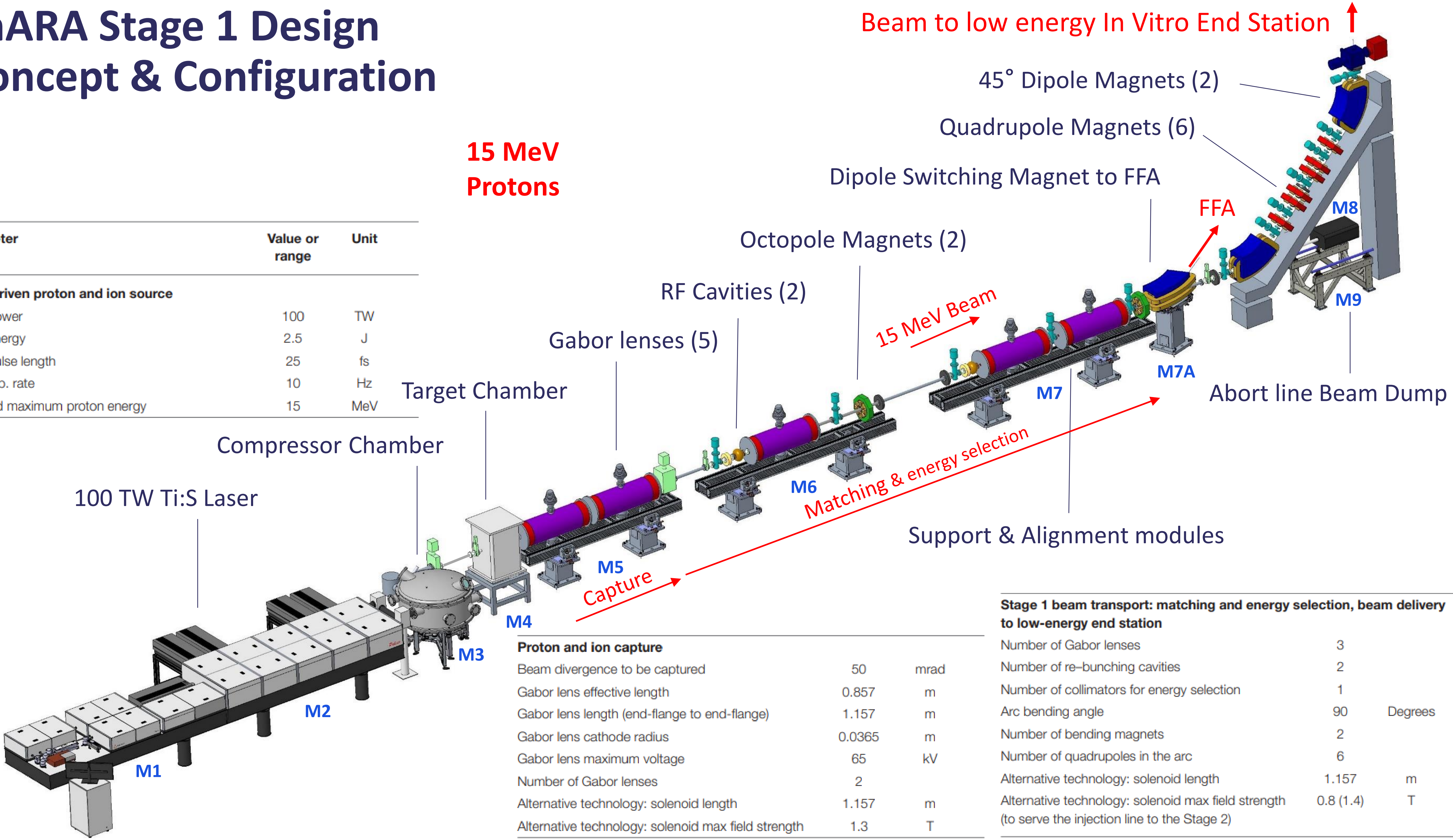
LhARA Stage 1 Design Concept & Configuration

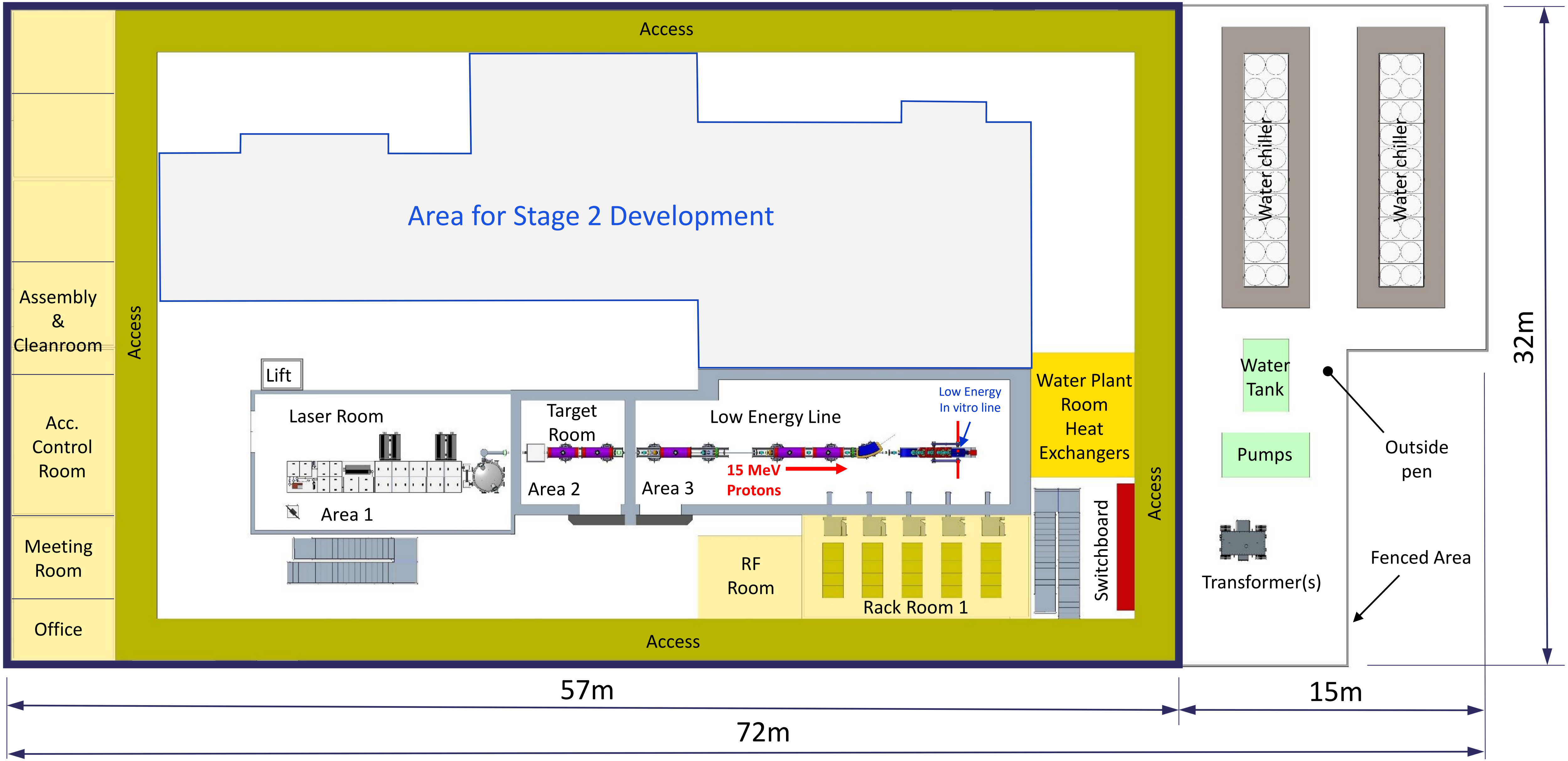


Parameter	Value or range	Unit
Laser driven proton and ion source		
Laser power	100	TW
Laser energy	2.5	J
Laser pulse length	25	fs
Laser rep. rate	10	Hz
Required maximum proton energy	15	MeV

Proton and ion capture		
Beam divergence to be captured	50	mrad
Gabor lens effective length	0.857	m
Gabor lens length (end-flange to end-flange)	1.157	m
Gabor lens cathode radius	0.0365	m
Gabor lens maximum voltage	65	kV
Number of Gabor lenses	2	
Alternative technology: solenoid length	1.157	m
Alternative technology: solenoid max field strength	1.3	T

Stage 1 beam transport: matching and energy selection, beam delivery to low-energy end station		
Number of Gabor lenses	3	
Number of re–bunching cavities	2	
Number of collimators for energy selection	1	
Arc bending angle	90	Degrees
Number of bending magnets	2	
Number of quadrupoles in the arc	6	
Alternative technology: solenoid length	1.157	m
Alternative technology: solenoid max field strength (to serve the injection line to the Stage 2)	0.8 (1.4)	T

Plan View Layout of Facility – Stage 1



Stage 1 Facility Vision

- We foresee a staged infrastructure with a lower-energy (shallower depth, in-vitro) initial capability, followed by a higher-energy (larger depth) provision.

- Stage 1 technology is the TW laser, target, beam capture, matching & energy selection, inclined beamline, low energy in vitro end station, research area, building and infrastructure.

- To build the full building size ~57m long x ~32m wide x ~14m high on a UKRI-STFC National Laboratory site to take advantage of available experience, multidiscipline technical expertise, approved radiation site authorisation and electrical power capability.

- The full facility footprint excluding any new roads is ~72m long x ~32m wide that includes external infrastructure in a fenced off area ~15m x 32m slide 6); Transformer(s), water chillers, water tank and pumping. Heat exchangers and additional pumping are proposed to be located inside the building.

- A new facility purpose build for the LhARA requirements as it is not foreseen that there is an existing building available.

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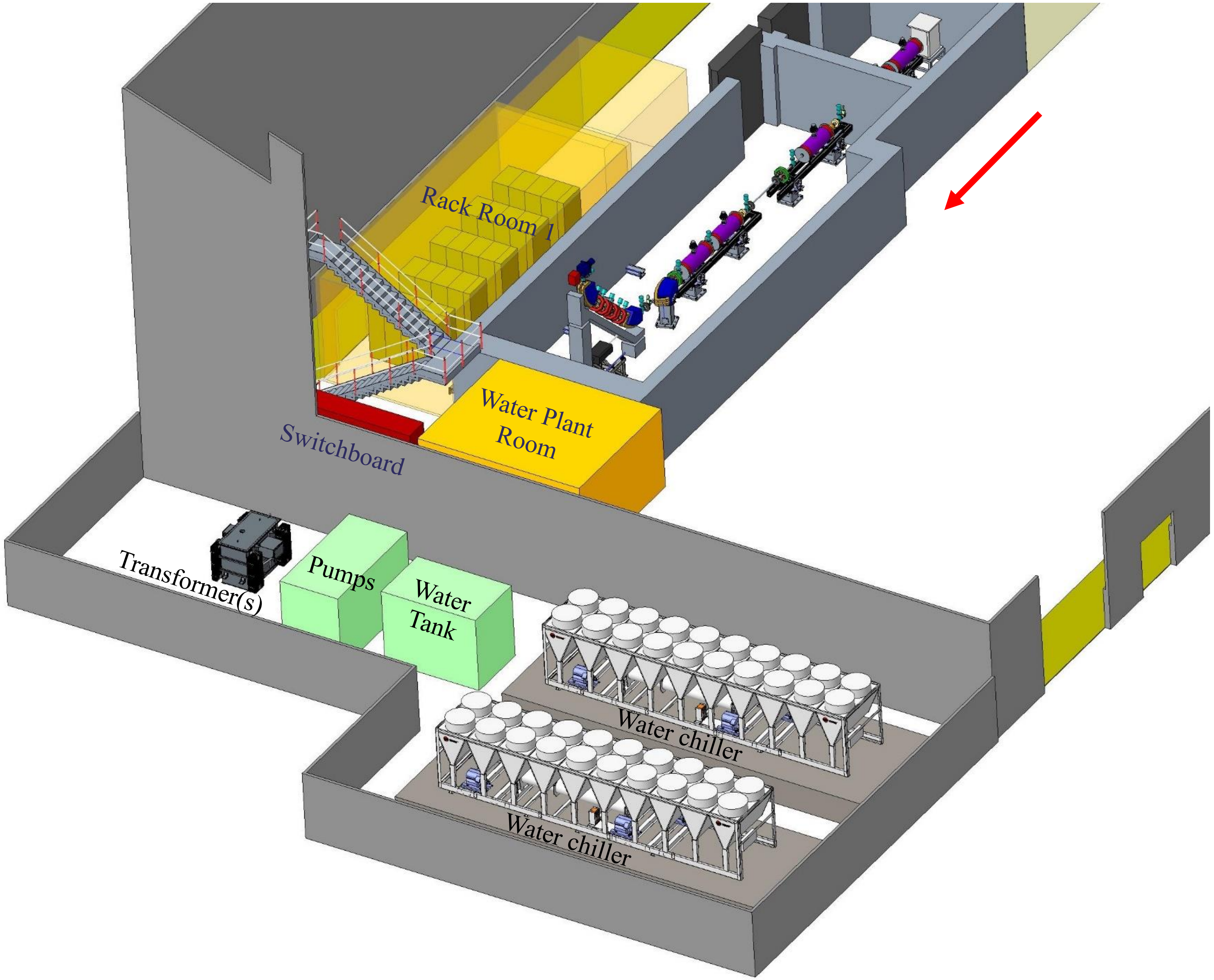
Water Chillers, Pumping and Transformer pen



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Stage 1 Facility Vision continued

- Rooms to the left of the accelerator complex include; Accelerator control room, meeting room, assembly/ local clean room, capacity for in vivo control room and prep. room for stage 2 exploitation.

- Construction sequence of stage 1 is foreseen to start with the laser room, followed by the target room, followed by the low energy line room. The laser room constructed by thermal wall insulated panels. The target and low energy line rooms constructed from radiation shielding blocks (walls) and roof beams (roof) constructed from dense concrete or potentially a concrete box/dense aggregate fill sandwich or steel box/dense aggregate fill. More on that later.

- Construction sequence to enable installation and commissioning of the low energy line while the target room is operating by including radiation stops in the beamline. Similarly, radiation stops included at the aperture to the FFA room and the high energy line room to enable installation and commissioning of downstream rooms when upstream rooms are operating. Permit to work system and operational procedures to ensure safe working.

- Stage 1 construction includes
  - the main electrical switchboard located close to the transformer(s).

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Stage 1 Facility Vision continued

- A power supply, control & instrument rack room for ~ 20 racks is included outside of the radiation shielding close to the equipment to reduce the cable lengths that enter the low energy line room via shielded labyrinths. The room will have a local HVAC system to control temperature and cleanliness for the magnet power supplies and control instrumentation.
- A room for RF is shown if required but RF power sources and location in or outside the radiation shielding is not specified.
- A lift and 2 sets of stairs are foreseen from ground level to 1st floor level on top of the radiation shielding roof beams.
- An overhead crane is proposed for the installation and decommissioning of the shielding.

- Slide 9 shows the stage 1 accelerator concept at ground level by a cutaway view of the shielding and also the **Research Area** next to the **In Vitro End Station** located above the radiation shielding structure.

- A local **Control Station** is foreseen next to the **In Vitro End Station** for control and quick access.

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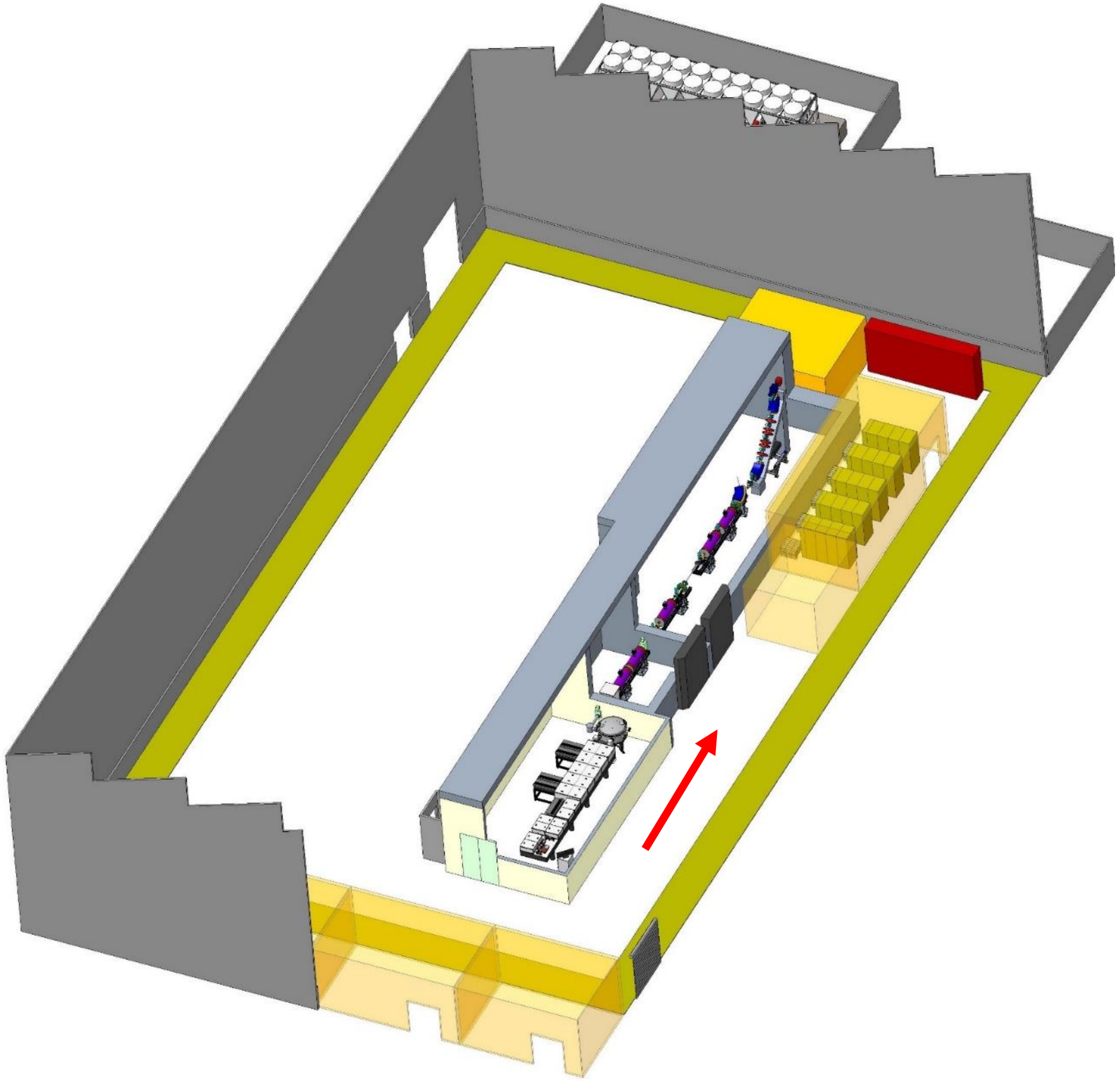
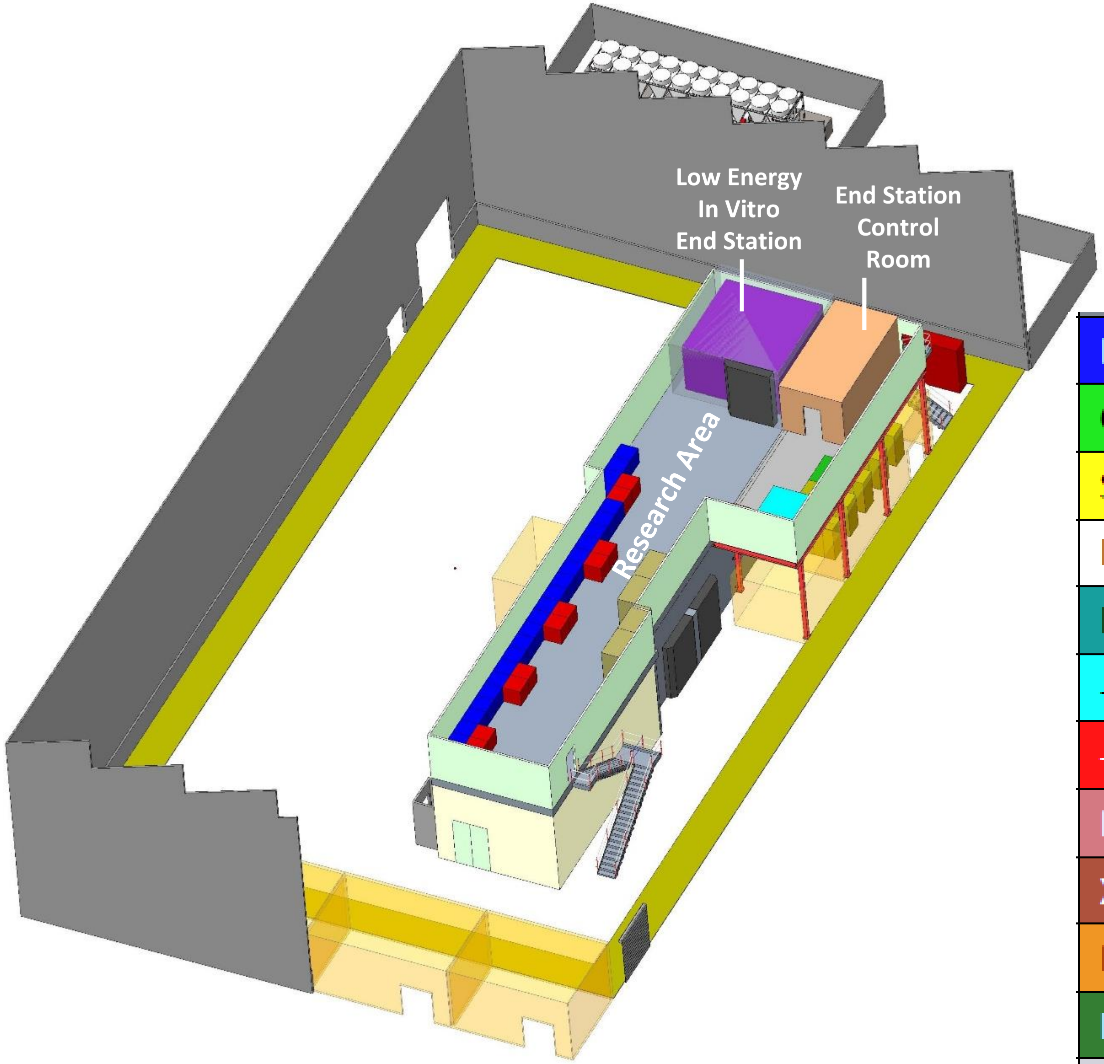
Stage 1 Building Concept



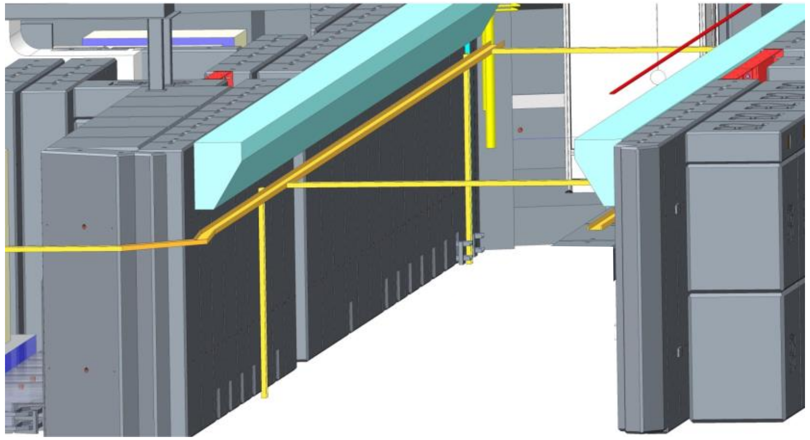
Ground Floor with shielding cutaway



Research Area Floor

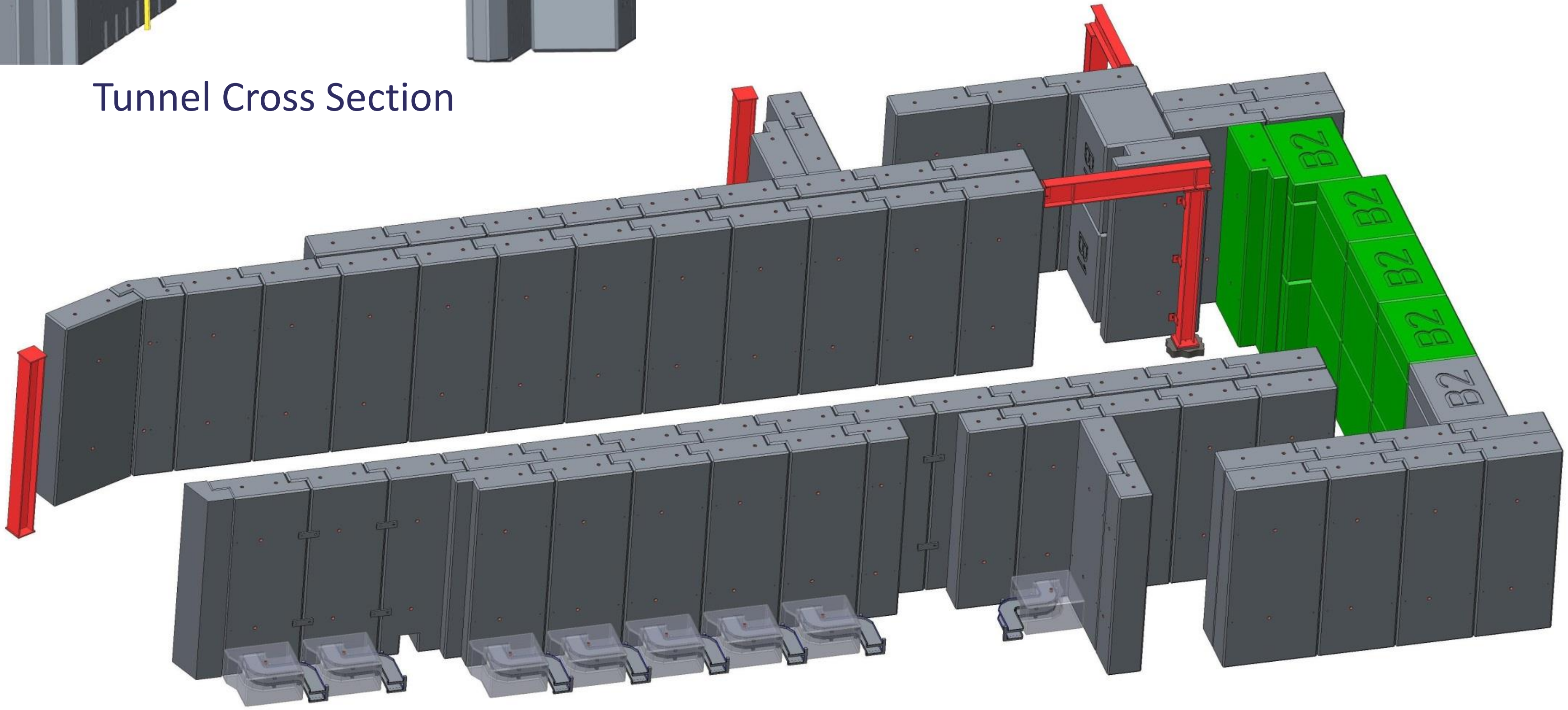
- Benching
- Class II cabinet (4)
- Sink/MilliQ (2)
- Handwash
- Ice
- -80ºC Freezer (2)
- -20ºC Freezer (4)
- Fridge (4)
- X-ray irradiator
- Robotics
- Hypoxia chamber
- Storage

Radiation Shielding Construction - Example

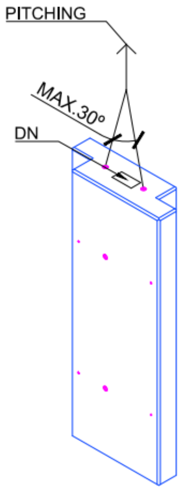


Tunnel Cross Section

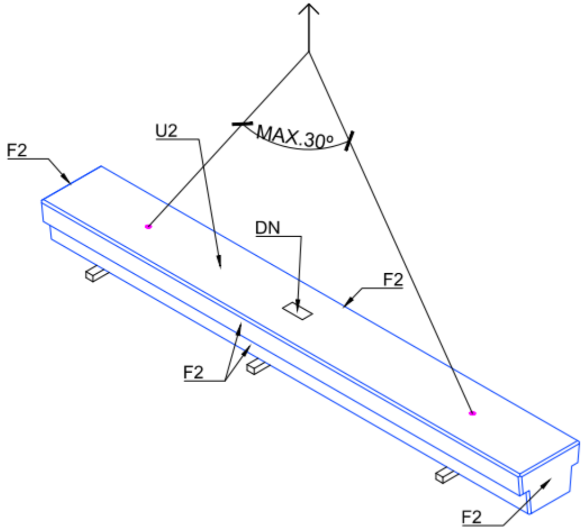
Sliding
shield door
photograph



Electrical cable labyrinths

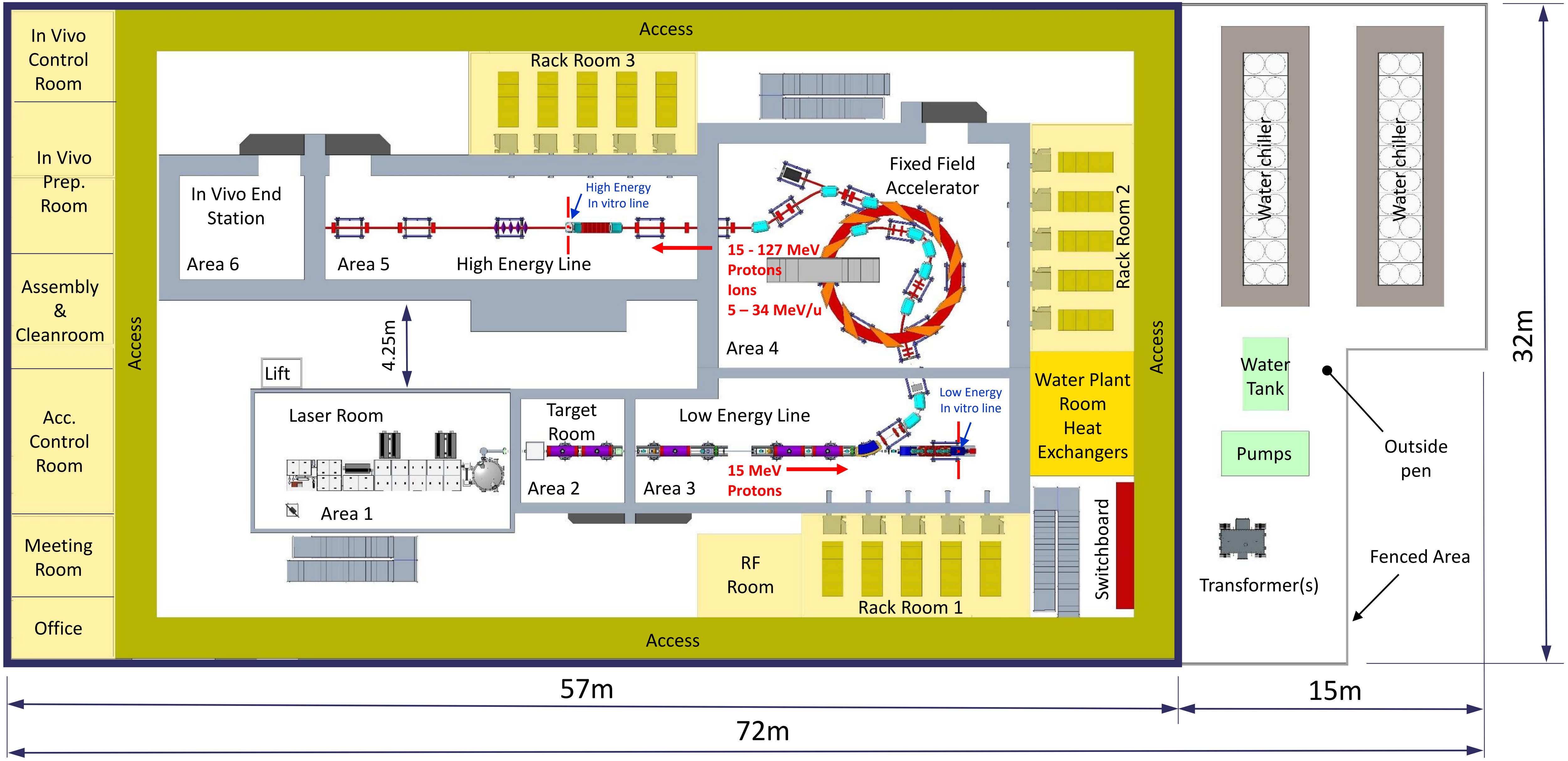


Walls blocks



Roof beams

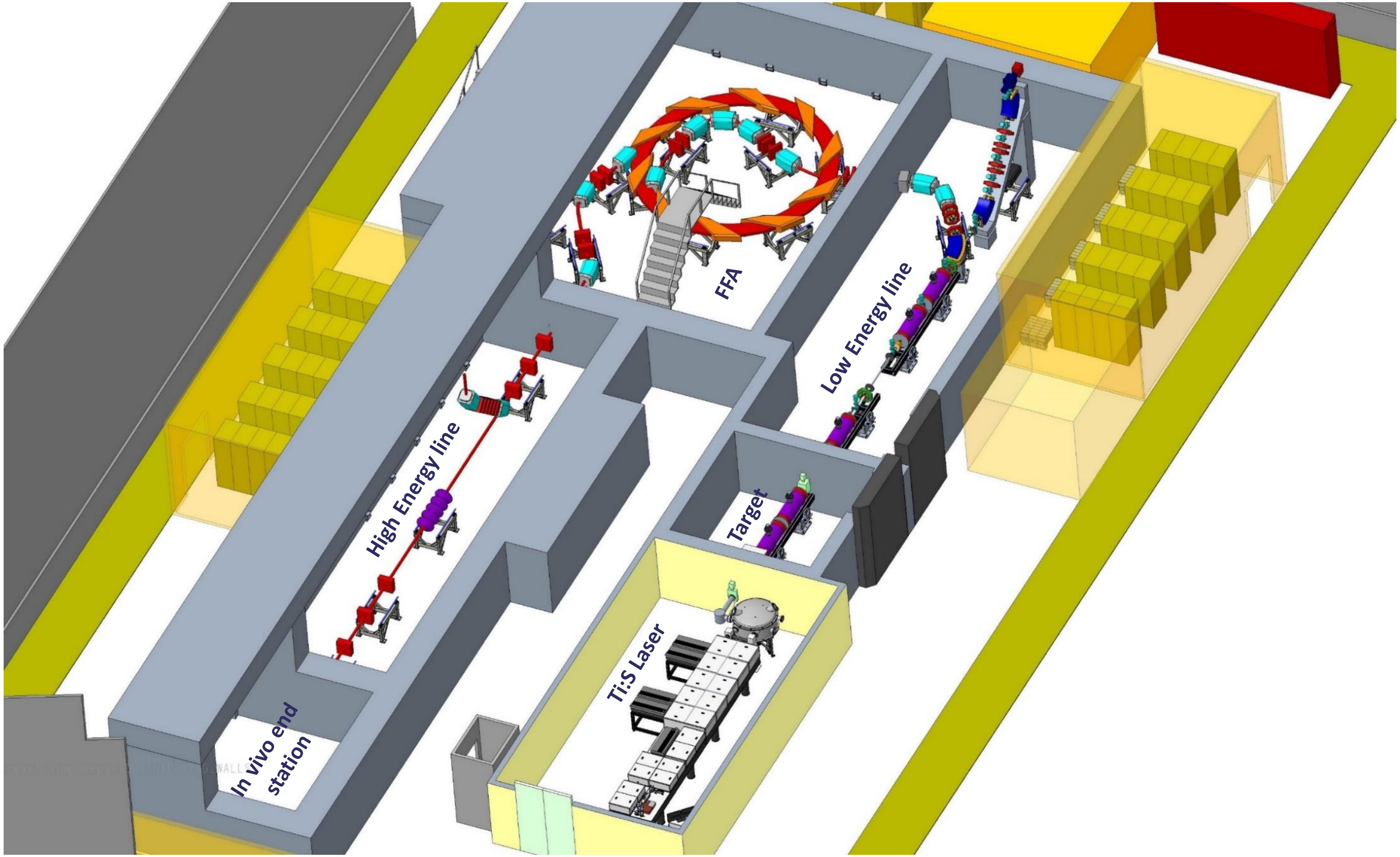
Stage 2 Facility Vision



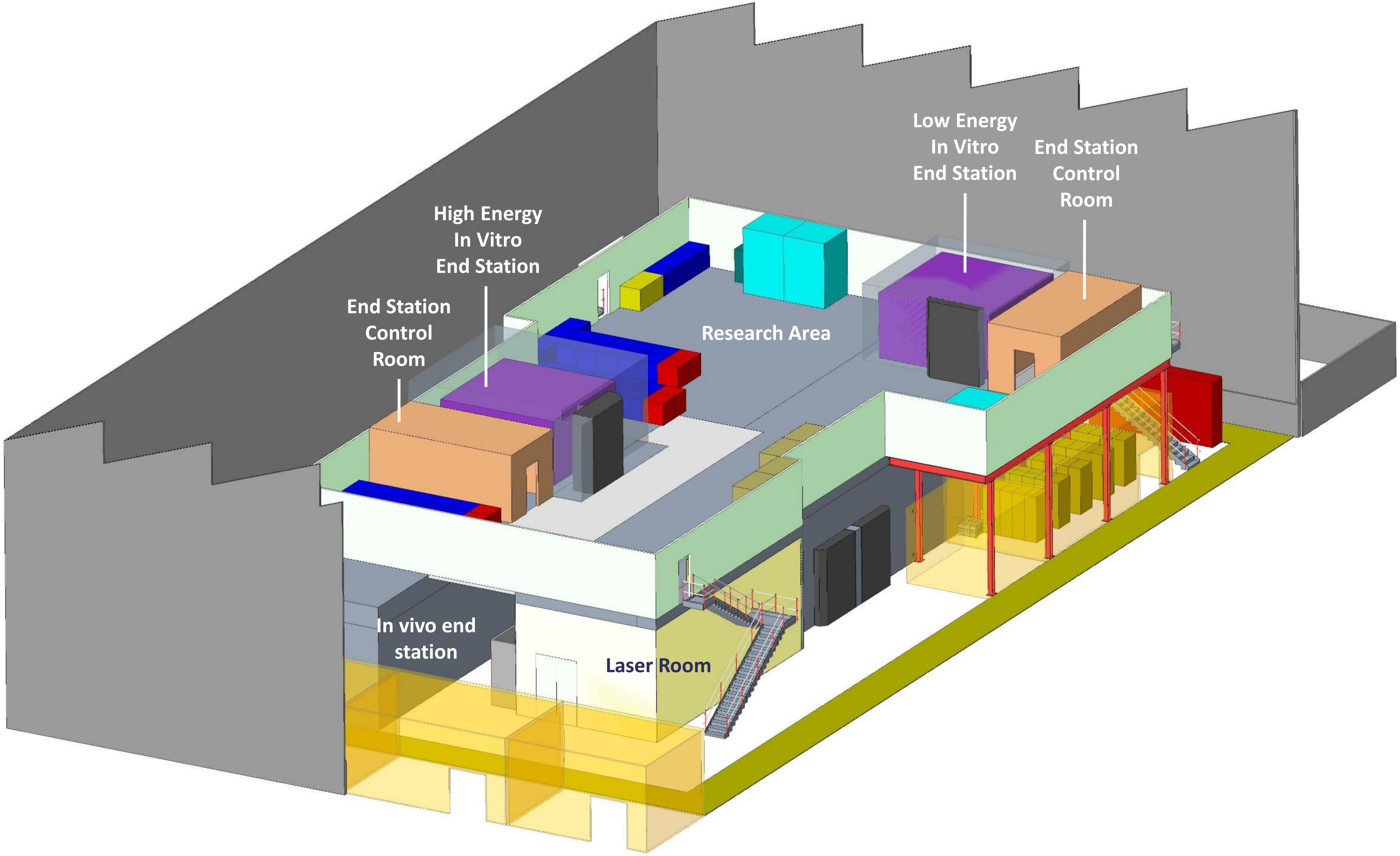
Stage 2 Facility Vision

- Stage 2 of the facility is the implementation of the Fixed Field Accelerator (FFA), high energy line, high energy in vitro end station, in vivo end station, extension to the Research Areas on the ground & 1st floor and extension of the technical services that include 2 extra rack rooms.
- Slide 11 shows the ground floor layout.
- Slide 13 shows the ground floor 3D CAD model.
- Slide 14 shows the 1st floor Research Area extension.
- Slide 15 shows the cross-section through the building
- Slide 16 shows the schematic layout of the facility equipment that can be seen more clearly in document 1272-pa1-pm-sch-0001-v1.0-LhARA schematic which is available in large format PowerPoint and pdf formats.

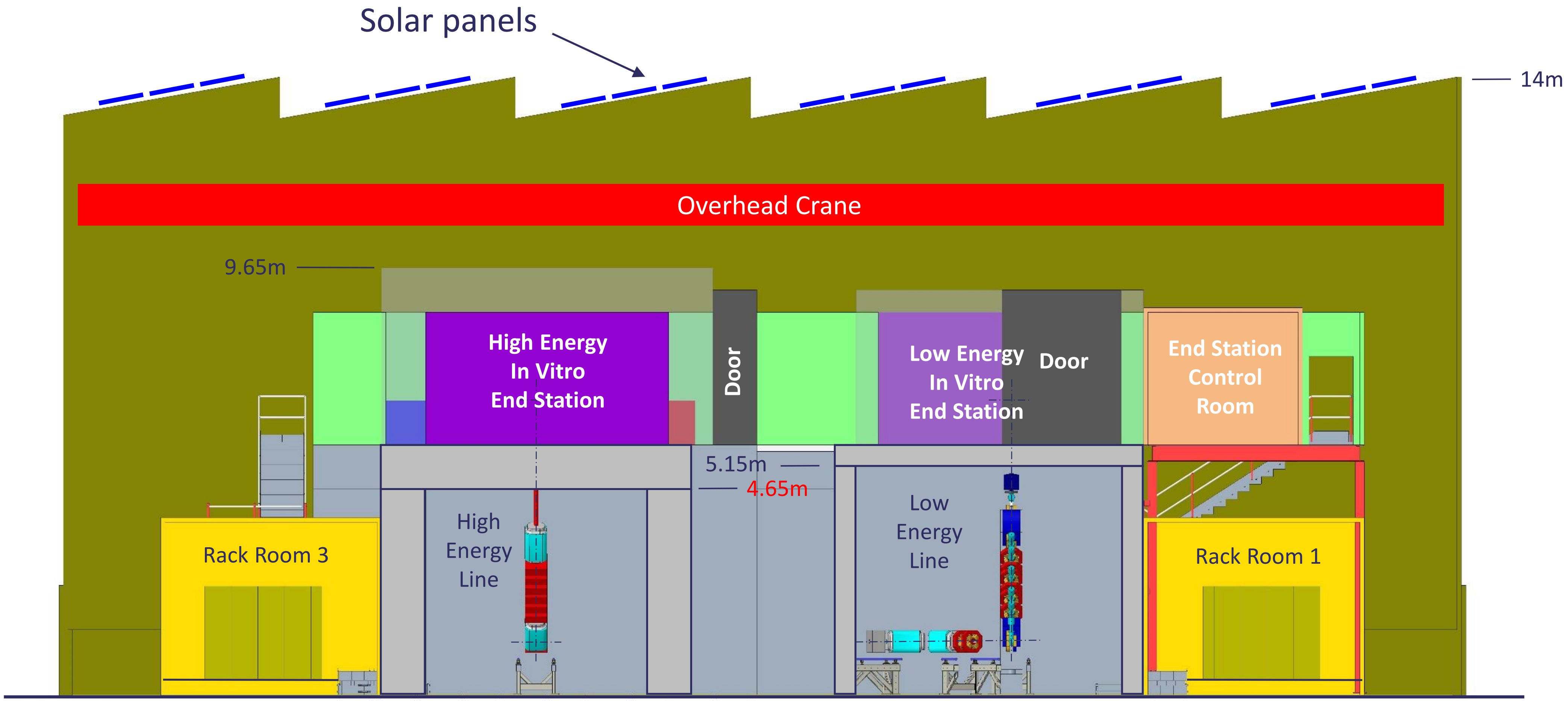
Building Concept Design with cutaway to ground floorshow equipment



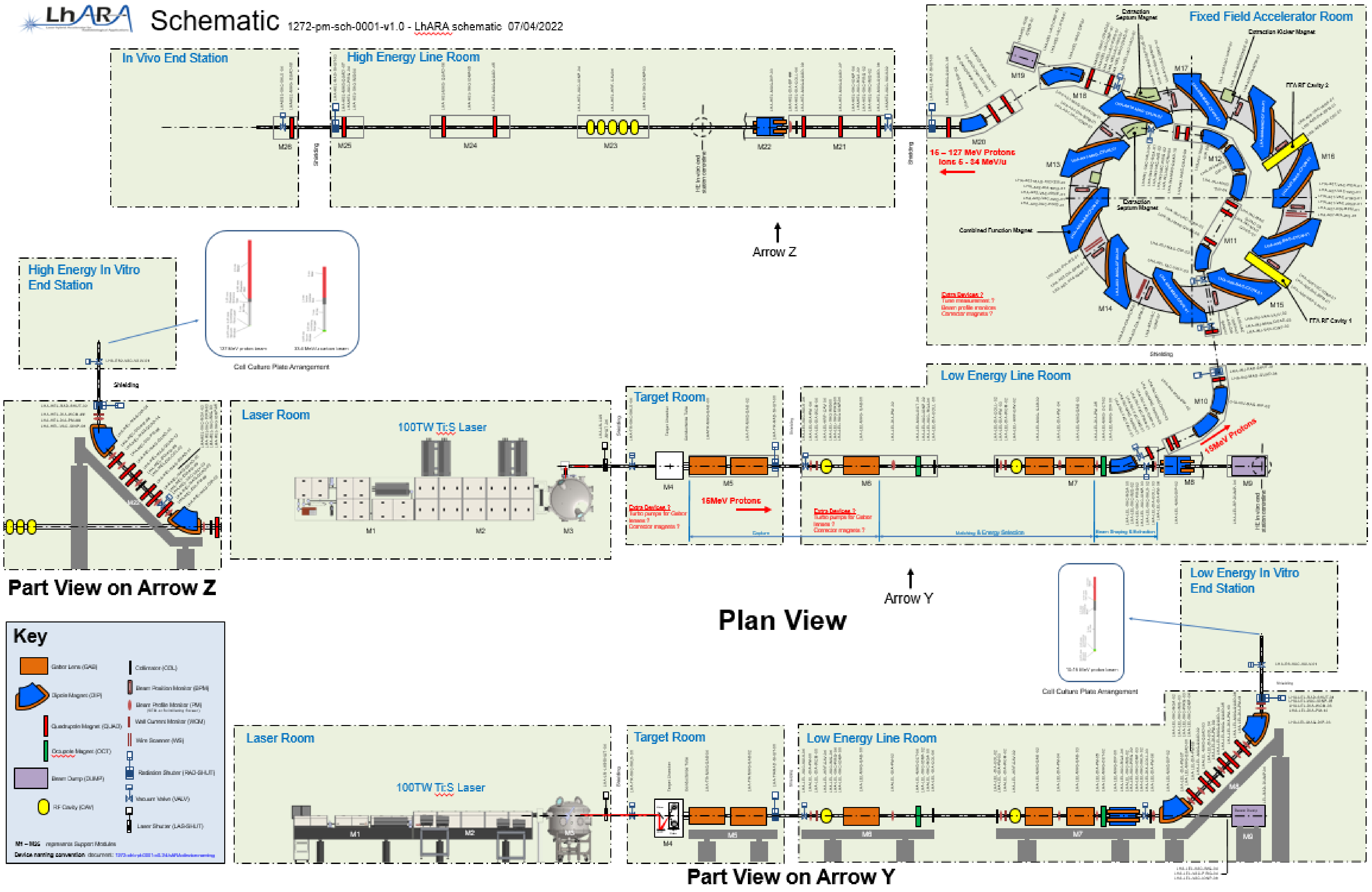
Building Concept Design showing the Research Area on the 1st floor



Cross section through building



Document: 1272-pa1-pm-sch-0001-v1.0-LhARA schematic https://stfc365.sharepoint.com/sites/ITRF



Schematic notes

- Used to identify all the required devices that informs the cost model
- Defines current baseline configuration
- Enables quick and easy way to discuss and agree design before extensive CAD modelling
- Large format size (A0) for clarity of detail
- Adopts a device naming convention to avoid confusion by eliminating multiple names
- Device name will be the name in the control system
- Document: 1272-pa1-ctrl-rpt-0001-v0.3-LhARA-device-naming
- Schematic shows the vacuum valves and hence the vacuum regions
- M1 – M26 numbering represents support modules that helps plan the off line assembly and testing informs the cost model

Radiation Shielding Study by TUV SUD (formerly Nuclear Technologies)

- The plan is to spend £50k in the CDR phase on a Radiation Shielding Study by a specialist company TUV SUD – containing the following 4 sub reports:
  - A high-level shielding design basis report that creates a point of reference for all shielding & radiation protection calculations
  - Radiological Classification of Areas
  - Preliminary Bulk Shielding Requirements
  - Concrete Sustainability Appraisal

More detail available in slides 22 – 26

Idea to consider composite shielding blocks

- Concrete / dense aggregate sandwich or
- Steel / dense aggregate sandwich

CALA radiation shielding solution, Munich.
Cast in situ solution

Forster Sandwich Construction - Forster Bau Ingolstadt (forster-bau.de)

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Resources (for engineering & civil aspects of WP6 by STFC-DL)

			Year 1	Year 2	Year 3	Year 4	Year 5
CDR & Technical Design Studies Only			**FY 22-23**	**FY 23-24**	**FY 24-25**	**FY 25-26**	**FY 26-27**
Integration staff estimate (SY)		**Total**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
	STFC activity lead, Group, Department.		**Stage 1 & 2 CDR**		**Stage 1 TDR**	**Stage 2 Technical Design**	
WP management	N Bliss, PGM, Technology.	1.20	0.20	0.25	0.25	0.25	0.25
Mechanical engineering design specification	T Jones, P&ME (DL), Technology.	4.70	0.50	0.80	1.00	1.20	1.20
Electrical engineering design specification	S Griffiths, EE, Technology.	3.70	0.05	0.55	0.90	1.10	1.10
Controls specification	G Cox, CS&SI, Technology.	2.00	0.05	0.25	0.35	0.65	0.70
Technical services specification	A Goulden, BP&F, ASTeC.	1.90	0.00	0.40	0.50	0.50	0.50
Vacuum specification	A Vick, VS, ASTeC.	1.30	0.00	0.20	0.50	0.30	0.30
Radiation protection specfication	A Goulden, BP&F, ASTeC.	0.40	0.025	0.075	0.10	0.10	0.10
STFC Technical Staff Total		**15.20**	**0.83**	**2.53**	**3.60**	**4.10**	**4.15**
Non staff		**£k**	**£k**	**£k**	**£k**	**£k**	**£k**
Radiation Protection Study (specialist company)		**100**		50	50		

Risk Management (WP6)

Number	Name	Description	Likelihood	Impact	Score	Mitigation	Mitigated Likelihood	Mitigated Impact	Mitigated score
1	Fixed Field Accelerator (FFA) Performance.	FFA does not deliver parameters in performance specification.	3	5	15	Continue R&D on the critical item that is the FFA spiral magnet. Construct a prototype before production of 10 magnets.	1	5	5
2	Gabor lens performance	Gabor lens does not deliver parameters in performance specification.	4	5	20	Continue a R&D plan that involves the construction of a prototype Gabor lens and have a back up plan available that uses solenoid magnets in the place of Gabor lens.	2	5	10
3	MA Cavity construction	Delay or technical difficulties in construction of Magnet Alloy (MA) cavity	5	4	20	Establish close collaboration with CERN, J-PARC & KURNS institutes, where similar systems have been constructed and are in operation. Component parts manufactured by industry.	5	1	5
4	Injection and extraction magnets	Insufficient availablility of injection and extraction magnets suppliers.	3	4	12	Design and construct of injection and extraction magnets by STFC national laboratorie expertise. Component parts manufactured by industry.	3	2	6
5	Facility infrastructure	Facility infrastructure is not fit for purpose.	4	4	16	Include facility infrastructure design during the Conceputal Design Report (CDR) stage to provide a fit for purpose design that will inform the project cost and schedule.	1	4	4
6	Radiation protection	Radiation bulk shielding thickness, labyrinths and services penetrations are inadequate to meet specification.	4	5	20	Conduct radiation protection assessment during the CDR phase of the project to satisfy safety leglislation and identify construction method to inform cost and schedule.	1	5	5

End

Radiation Shielding Study Detail

next 4 slides

Radiation Shielding Study by TUV SUD (Nuclear Technologies, Birchwood) - Detail

Shielding Design Basis Report

- A high-level shielding design basis report that creates a point of reference for all shielding & radiation protection calculations, with content agreed by pertinent stakeholder prior to publishing. This would include:
  - Source terms and how they would be modelled for shielding calculations
  - Legal and operating dose constraints, ALARP principle
  - Outline of shielding approach and how shielding design will demonstrate dose constraints can be achieved
  - Compositions and densities to be assumed for shielding materials
  - Any other universal assumptions that will apply for shielding and other radiation protection calculations for the facility

Radiation Shielding Study by TUV SUD (Nuclear Technologies, Birchwood) – Detail continued

Radiological Classification of Areas

- Work alongside the STFC RPA to develop a dose rate design criterion scheme to ensure annual dose criteria can be achieved.
- Apply layout and/or advise with RPA input how layout might be optimised/improved from a radiation protection perspective.
- The added value this provides is that it helps demonstrate implementation of ALARP at concept design phase and can potentially reduce some shielding requirements via intelligent layout.

Radiation Shielding Study by TUV SUD (Nuclear Technologies, Birchwood) – Detail continued

Preliminary Bulk Shielding Requirements

- Consider each active area and source term for the facility to develop bulk shielding requirements for a baseline material (e.g. regular concrete) for normal operations and fault scenarios.
- Consider available space & footprint in each area. Where there is scope to decrease the shielding requirement by improving beam dump composition, demonstrate how this can be achieved.
- Conduct analysis for a sandwich concrete/aggregate construction and optimise for concrete vs. aggregate thickness.
- Conduct analysis for alternative (e.g. heavy or low carbon concrete as required).
- Confidence in results obtained where required via independent methods and/or rationalising against comparable scenarios in other STFC projects.
- The preliminary bulk shielding report will be produced summarising assumptions, methods and tabulated results of the analysis.
- This assessment provides scope for some shielding optimisation between beam stop & bulk shielding and with compound bulk shielding layers. This can help inform the cost model, reduce facility footprint and/or alongside the sustainability appraisal, help reduce the carbon footprint for the shielding.

Radiation Shielding Study by TUV SUD (Nuclear Technologies, Birchwood) – Detail continued

Concrete Sustainability Appraisal

- Conduct environmental assessment for concrete associated with shielding, with embodied carbon as key assessment indicator.
- Consider two representative materials of those outlined in the bulk shielding assessment / shielding design basis.
- Analysis will provide an estimation of embodied carbon in concrete broken down by concrete constituents. This will help provide guidance at the concept design stage about the most significant contributors to embodied carbon for the considered concrete types.
- Benefit would be the potential to increase scope to more materials and/or consider impact of upcycling etc.

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Overall Schedule for Facility Construction

next 4 slides

LhARA Project Schedules & Milestones

3 documents:

1. 1272-pa1-pm-ppl-0005-v1.0 - ITRF CDR milestones and deliverables 2022-10-18 (Already covered in PM WP1 talk)
2. 1272-pa1-pm-ppl-0004-v0.7 - ITRF CDR schedule 2022-09-20 (Already covered in PM WP1 talk)
3. 1272-pa1-pm-ppl-0001-v2.0 - ITRF schedule 2022-07-20

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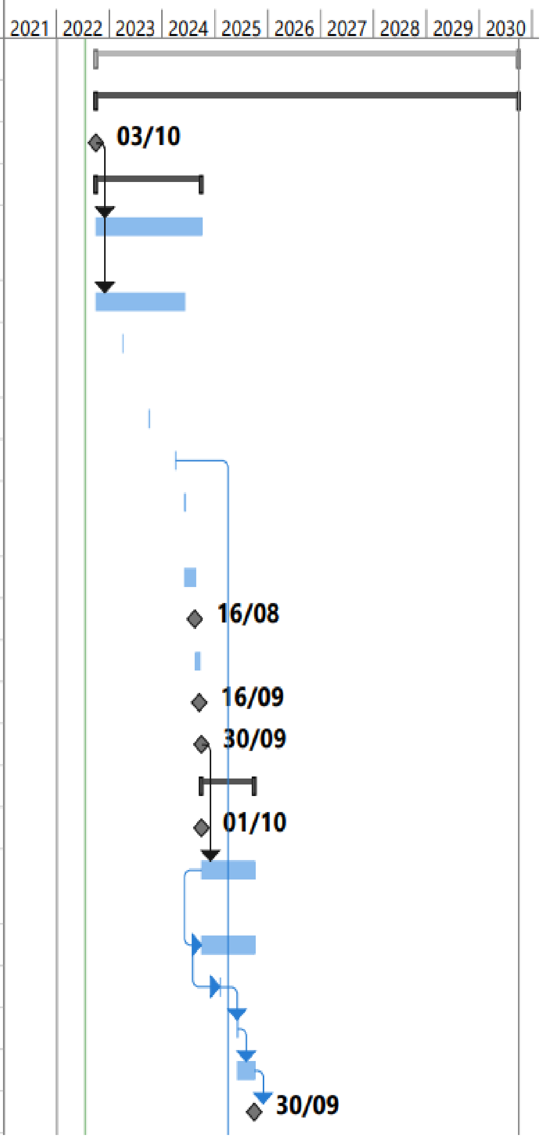
Full Project Schedule

1272-pa1-pm-ppl-0001-v2.0 - ITRF schedule 2022-07-20

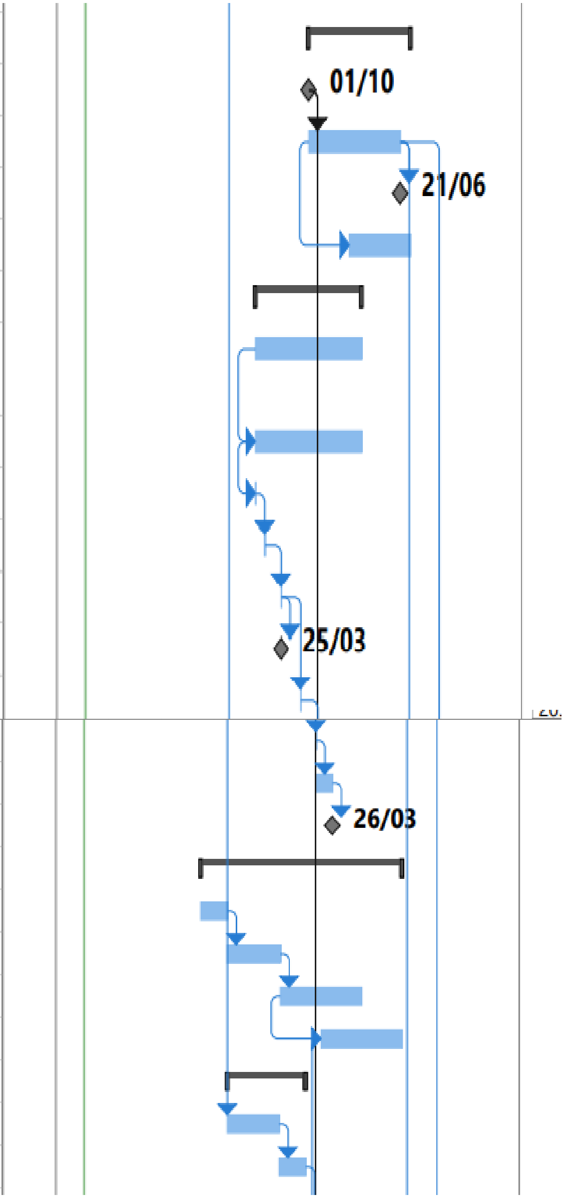
ID	Ta Mc	WBS	Task Name	Duration	Start	Finish	Predecessors
0		0	**ITRF schedule**	**2087 days**	**Mon 03/10/22**	**Tue 01/10/30**	
1		1	**ITRF**	**2087 days**	**Mon 03/10/22**	**Tue 01/10/30**	
2		1.1	**Project Start**	**0 days**	**Mon 03/10/22**	**Mon 03/10/22**	
3		1.2	**Conceptual Design Report (CDR) - 2 years**	**521 days**	**Mon 03/10/22**	**Mon 30/09/24**	
4		1.2.1	Project Management Plan; scope, specifications, risk, finance, stakeholders, deliverables	521 days	Mon 03/10/22	Mon 30/09/24	2
5		1.2.2	Technical studies	437 days	Mon 03/10/22	Tue 04/06/24	2
6		1.2.3	Preliminary Conceptual Design Review (6 months) - refine scope, specifications, define parameters and schematic diagram of facility equipment.	2 days	Wed 05/04/23	Thu 06/04/23	
7		1.2.4	Interim Conceptual Design Review 1 (12 months) - specify baseline design	2 days	Wed 04/10/23	Thu 05/10/23	
8		1.2.5	Interim Conceptual Design Review 2 (18 months) - refine specification & design	1 day	Wed 03/04/24	Wed 03/04/24	
9		1.2.6	Final Conceptual Design Review (20 months) - final specification & design ready for CDR write up	1 day	Wed 05/06/24	Wed 05/06/24	
10		1.2.7	Start CDR writing	52 days	Thu 06/06/24	Fri 16/08/24	
11		1.2.8	Chapter authors complete CDR writing	0 days	Fri 16/08/24	Fri 16/08/24	
12		1.2.9	Proof reading and final adjustments to CDR	21 days	Mon 19/08/24	Mon 16/09/24	
13		1.2.10	CDR Publication	0 days	Mon 16/09/24	Mon 16/09/24	
14		1.2.11	**CDR phase complete**	**0 days**	**Mon 30/09/24**	**Mon 30/09/24**	
15		1.3	**Stage 1 Technical Design Report (TDR) - 1 year**	**261 days**	**Tue 01/10/24**	**Tue 30/09/25**	
16		1.3.1	****- Technical Design Funded (3 years activity) - ****	**0 days**	**Tue 01/10/24**	**Tue 01/10/24**	
17		1.3.2	Project Management Plan; Scope, Specifications, Risk, Finance, Stakeholders, Deliverables	261 days	Tue 01/10/24	Tue 30/09/25	14
18		1.3.3	Technical studies, engineering design, procurement management	261 days	Tue 01/10/24	Tue 30/09/25	17SS
19		1.3.4	Design Review 1 (4 month)	1 day	Wed 05/02/25	Wed 05/02/25	18SS
20		1.3.5	Design Review 2 (8 month)	1 day	Wed 04/06/25	Wed 04/06/25	19
21		1.3.6	Write stage 1 TDR	84 days	Thu 05/06/25	Tue 30/09/25	20
22		1.3.7	**Stage 1 TDR Complete**	**0 days**	**Tue 30/09/25**	**Tue 30/09/25**	**21**



Full Project Schedule

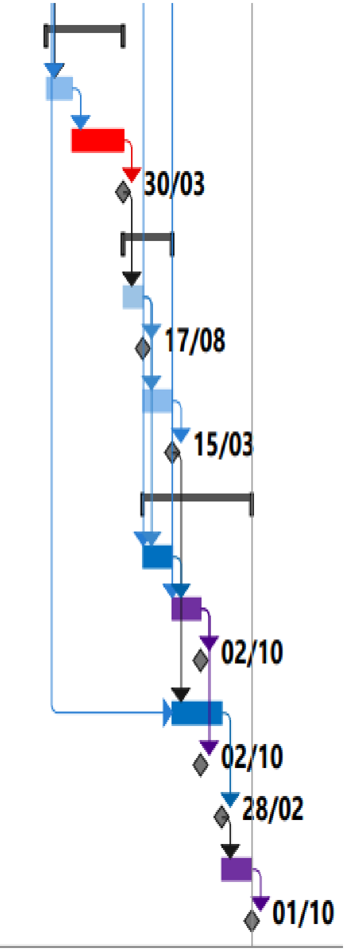
1272-pa1-pm-ppl-0001-v2.0 - ITRF schedule 2022-07-20

23	**1.4**	**Stage 1 Procurement & testing**	**500 days**	**Thu 01/10/26**	**Wed 30/08/28**	
24	**1.4.1**	**** - Construction Project Funded - ****	**0 days**	**Thu 01/10/26**	**Thu 01/10/26**	
25	1.4.2	Stage 1 Equipment Procurement	450 days	Thu 01/10/26	Wed 21/06/28	24
26	**1.4.3**	**Front end available for installation**	**0 days**	**Wed 21/06/28**	**Wed 21/06/28**	**25**
27	1.4.4	Stage 1 Offline Assemby & Testing	300 days	Thu 08/07/27	Wed 30/08/28	25SS+200 days
28	**1.5**	**Stage 2 Technical Design - 2 years**	**522 days**	**Wed 01/10/25**	**Thu 30/09/27**	
29	1.5.1	Project Management Plan; Scope, Specifications, Risk, Finance, Stakeholders, Deliverables	522 days	Wed 01/10/25	Thu 30/09/27	
30	1.5.2	Technical studies, engineering design, procurement management	522 days	Wed 01/10/25	Thu 30/09/27	29SS
31	1.5.3	Design Review 1 (4 months) part of TDR	1 day	Wed 01/10/25	Wed 01/10/25	30SS
32	1.5.4	Design Review 2 (8 months) part of TDR	1 day	Wed 03/12/25	Wed 03/12/25	31
33	1.5.5	Design Review 3 (12 months) part of TDR	1 day	Wed 25/03/26	Wed 25/03/26	32
34	**1.5.6**	**Stage 2 TDR phase complete**	**0 days**	**Wed 25/03/26**	**Wed 25/03/26**	**33**
35	1.5.7	Design Review 4 (16 months) part of construction project	1 day	Wed 05/08/26	Wed 05/08/26	33
36	1.5.8	Design Review 5 (20 months) part of construction project	1 day	Wed 02/12/26	Wed 02/12/26	35
37	1.5.9	Finalise technical design	82 days	Thu 03/12/26	Fri 26/03/27	36
38	**1.5.10**	**Stage 2 Construction design complete**	**0 days**	**Fri 26/03/27**	**Fri 26/03/27**	**37**
39	**1.6**	**STAGE 2 Procurement & Testing**	**991 days**	**Tue 01/10/24**	**Tue 18/07/28**	
40	1.6.1	Tender & award contract for prototypes	131 days	Tue 01/10/24	Tue 01/04/25	
41	1.6.2	Prototypes construction & test	260 days	Wed 02/04/25	Tue 31/03/26	40
42	1.6.3	Stage 2 Equipment Procurement	400 days	Wed 01/04/26	Tue 12/10/27	41
43	1.6.4	Stage 2 Offline Assemby & Testing	400 days	Wed 06/01/27	Tue 18/07/28	42SS+200 days
44	**1.7**	**Building Specifiation & Architect Design**	**386 days**	**Tue 01/04/25**	**Tue 22/09/26**	
45	1.7.1	Specification & Layout (part of TDR)	255 days	Tue 01/04/25	Mon 23/03/26	8
46	1.7.2	Architect design (part of TDR)	131 days	Tue 24/03/26	Tue 22/09/26	45



Full Project Schedule 1272-pa1-pm-ppl-0001-v2.0 - ITRF schedule 2022-07-20

47	1.8	**Building Construction**	**391 days**	**Thu 01/10/26**	**Thu 30/03/28**	
48	1.8.1	Tendering & awarding buiding contract	130 days	Thu 01/10/26	Wed 31/03/27	46,24
49	1.8.2	Construction building	261 days	Thu 01/04/27	Thu 30/03/28	48
50	1.8.3	Building handover complete	0 days	Thu 30/03/28	Thu 30/03/28	49
51	1.9	**Radiation Shielding & Technical Services**	**250 days**	**Fri 31/03/28**	**Thu 15/03/29**	
52	1.9.1	Stage 1 Installation of shielding, technical services and PS system	100 days	Fri 31/03/28	Thu 17/08/28	50
53	1.9.2	Building ready for equipment installation of Stage 1	0 days	Thu 17/08/28	Thu 17/08/28	52
54	1.9.3	Stage 2 Installation of shielding and technical services	150 days	Fri 18/08/28	Thu 15/03/29	52
55	1.9.4	Building ready for equipment installation of Stage 2	0 days	Thu 15/03/29	Thu 15/03/29	54
56	1.10	**Equipment Installation in Building & Commissioning with Beams**	**553 days**	**Fri 18/08/28**	**Tue 01/10/30**	
57	1.10.1	Stage 1 Equipment installation & testing in building	150 days	Fri 18/08/28	Thu 15/03/29	52,25
58	1.10.2	Stage 1 Commissioning with Beams	143 days	Fri 16/03/29	Tue 02/10/29	57,25
59	1.10.3	Start Research with Stage 1 - Low energy	0 days	Tue 02/10/29	Tue 02/10/29	58
60	1.10.4	Stage 2 Equipment Installation, PS system and Testing in building	250 days	Fri 16/03/29	Thu 28/02/30	55,43SS
61	1.10.5	Stage 1 Commissioning with Beams complete	0 days	Tue 02/10/29	Tue 02/10/29	58
62	1.10.6	Construction Project complete, ready to start Stage 2 Commissioning with Beams	0 days	Thu 28/02/30	Thu 28/02/30	60
63	1.10.7	Stage 2 commissioning with beams	153 days	Fri 01/03/30	Tue 01/10/30	62
64	1.10.8	Start Research with Stage 2 - Full energy	0 days	Tue 01/10/30	Tue 01/10/30	63



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Engineering & Technology Scope of Work Plan (STFC-Daresbury Laboratory) during CDR stage of the project

next 7 slides

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Engineering & Technology Scope of Work (CDR)

Mechanical, Alignment and Integration

- The building design and internal infrastructure concept to take account of the staged construction of the project as described in the pre-CDR.
- Schematic layout, 2D CAD layouts and 3D CAD model of the facility that also considers the optimum arrangement for auxiliary rooms and technical services.
- General space management and optimisation to determine building size and requirements.
- Access and ingress
- Radiation shielding solutions
- Integration and interface management of systems of the various work packages and disciplines
- Equipment support and adjustment conceptual design
- Survey and alignment methodology of equipment within the facility
- Procurement, assembly, test and installation methodology

Engineering & Technology Scope of Work (CDR)

Vacuum

- General design objectives and design principles
- Assessment of the vacuum specification for the various vacuum regions of the laser-accelerator complex.
- Vacuum flow diagram
- Vacuum pumping
- Pressure measurement
- Cleanliness
- Particulate Control
- Valves
- Bakeout
- Vacuum control system

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Engineering & Technology Scope of Work (CDR)

Control System

- Control System Architecture
- Network Infrastructure
- EPICS Environment
- Equipment Interfaces
- Controls Hardware
- User Interface Software
- Control Room
- Signal Distribution
- Naming Convention
- Timing and Synchronisation System
- Interlocks & Protection Systems
- Feedback Systems

Engineering & Technology Scope of Work (CDR)

Electrical Engineering

- Estimated power consumption for services and accelerator equipment
- Electrical distribution scheme, integrity and diversity
- Cable management, quantity, segregation and route optimisation
- Safety and functional Earthing schemes
- Assess technical challenges of specialist electrical equipment, pulse power supplies
- Quantity, size and limitations of accelerator equipment, power supply, control & Instrument
- Layout, size and location of infrastructure, rack rooms, RF systems
- Impact of energy efficiency against performance on services and accelerator equipment
- Reliability, Maintainability and replace ability of accelerator electrical equipment

Engineering & Technology Scope of Work (CDR)

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Engineering & Technology Scope of Work (CDR)

Cooling Systems, HVAC & General Services

- Cooling load – Estimated load for environmental stability and accelerator equipment.
- Cooling system – Number of circuits and types (coolant properties), estimate of coolant flow rates, pump and primary pipe sizes based on cooling load.
- Heating, Ventilation and Air Conditioning (HVAC) – Environmental stability requirements and proposed solution(s)
- Room services requirements table
- General building services; artificial lighting, telecommunications and data, security systems, building management system, lightning protection, public address system, information display systems, lifts, cranes.
- Environmental sustainability – consideration of alternative primary cooling equipment, alternative sustainable concrete types and other energy efficiency and sustainability options.

Engineering & Technology Scope of Work (CDR)

Safety Systems

- Radiation Shielding (IRR17) estimated thicknesses, material selection and construction methods.
- Personnel safety system compliance with IRR17 and Accelerator Code of Practice in accordance with IEC61508. Adopting current best practise for accelerator access control and key exchange systems, that will shielded areas to be searched prior to operation of the laser and accelerator system.
- Local Exhaust Ventilation requirements – Extract / Exhaust systems (COSHH 2002)
- HAZoP Process outline for systems integration
- Emergency lighting, Fire alarm and Fire suppression systems