WPSA Enhancements: FILD status and plans

21-07-2025

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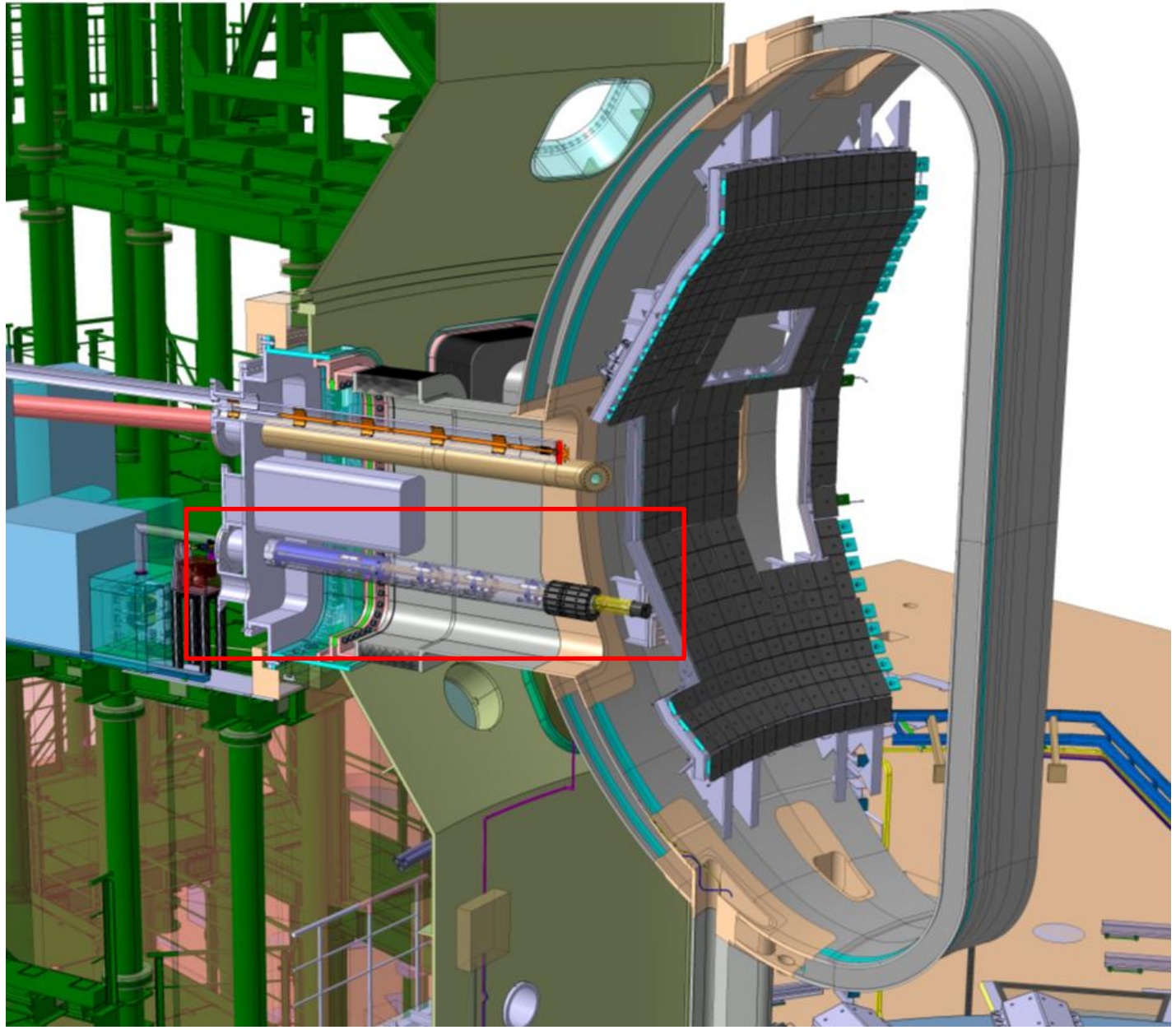
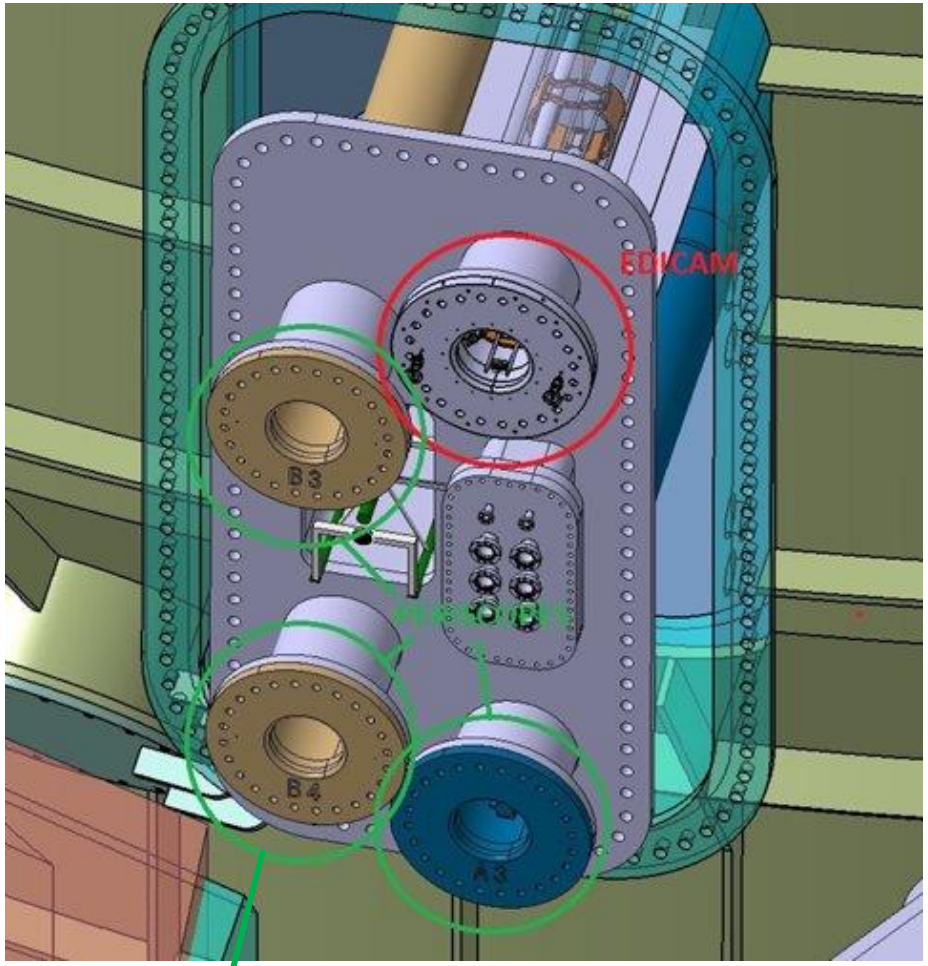
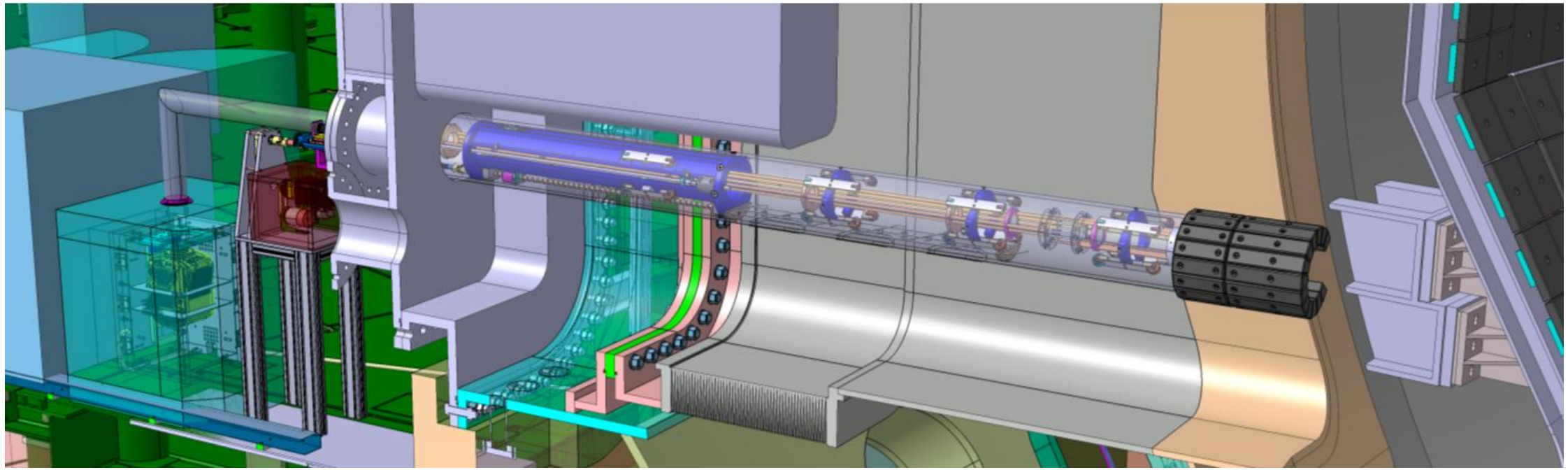
FILD Re-Located At Equatorial Port In Sector 18





Flange B4 (confirmed after QST´s periscopes coverage study)

FILD Displaces 0.7 m Stroke Moving Between Parking And Measuring Positions



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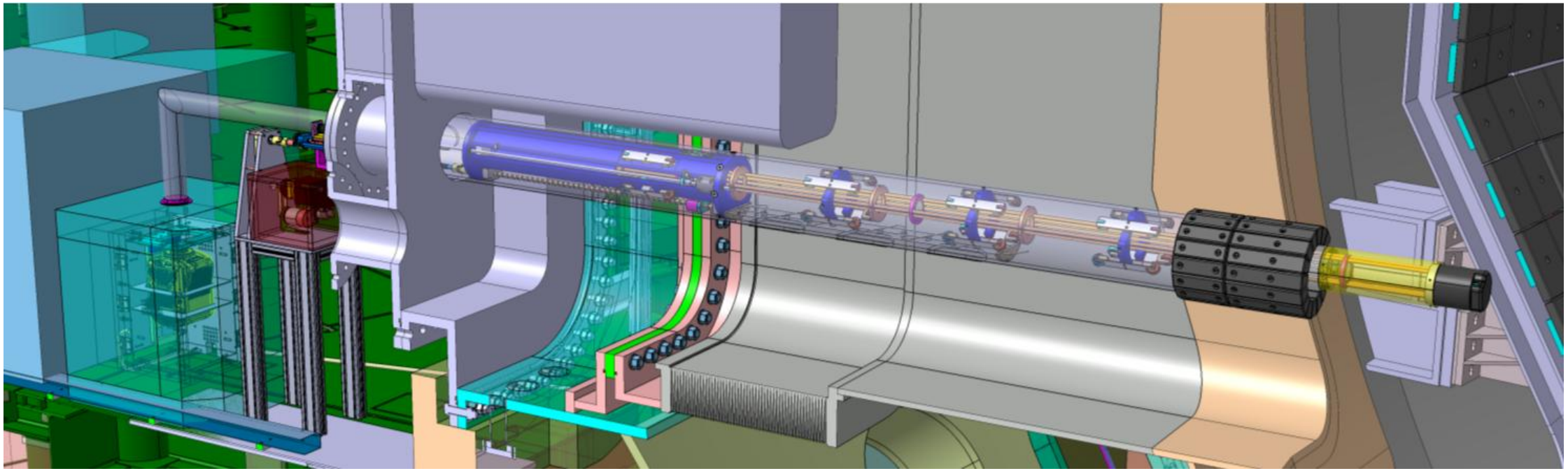
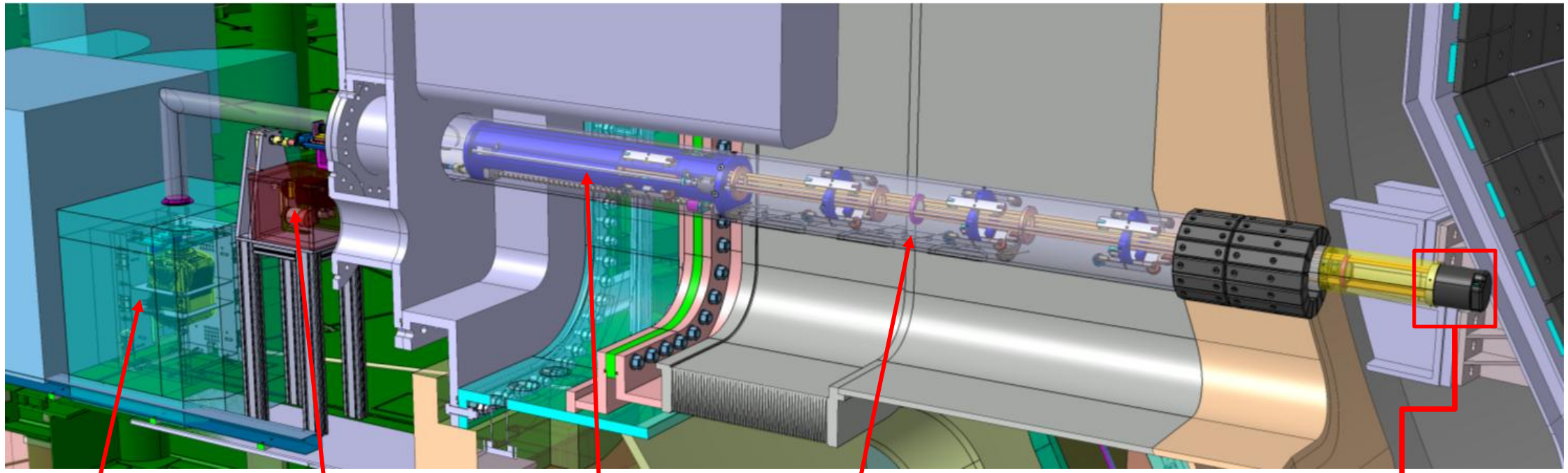


FILD Head Collects Fast Ions Escaping From Plasma



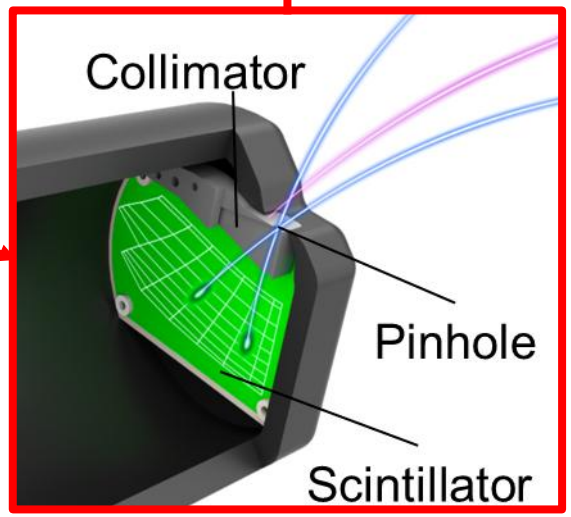
Light acquisition system

Motion drive unit

Motion guide system

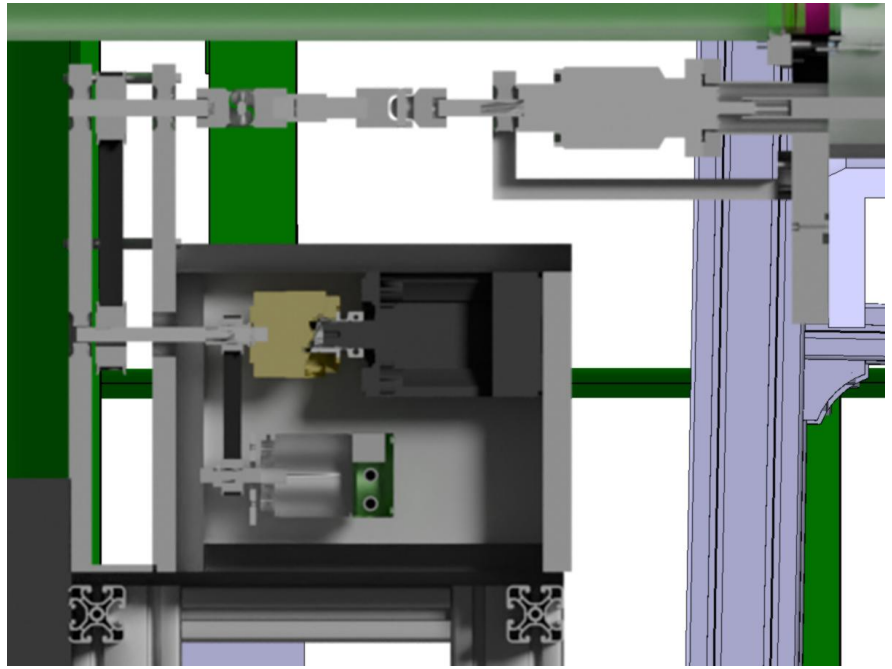
Port plug

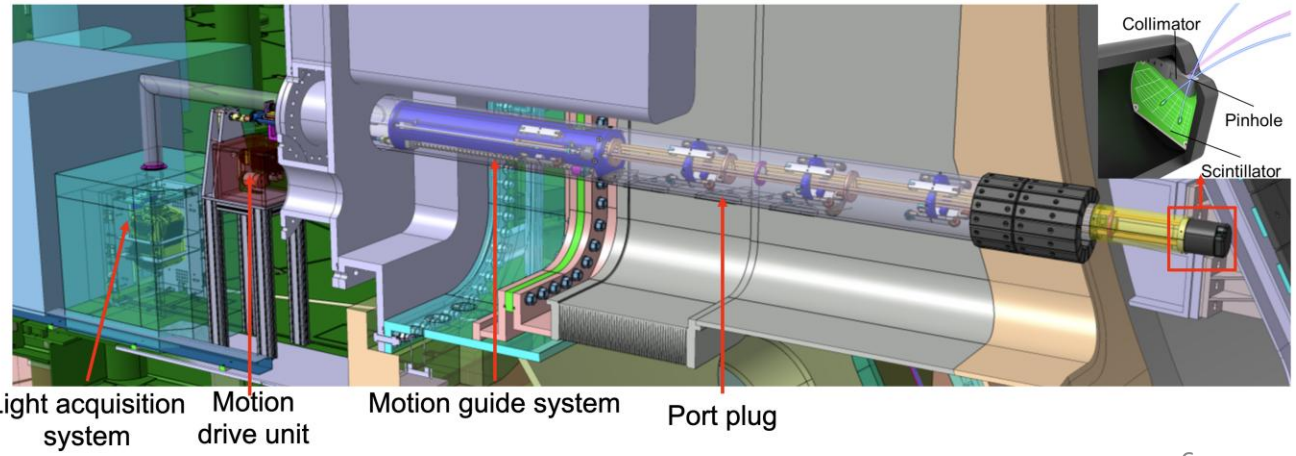
Probe head (measuring)



FILD Design Adapted to Sector 18 as Recommended

- Key mechanical components procurement under preparation
  - Port plug, supporting structure, motion drive unit and test chamber discussed w/ 3 companies
  - While waiting on quotation, technical specification for Public Call being prepared (to be launch after summer)





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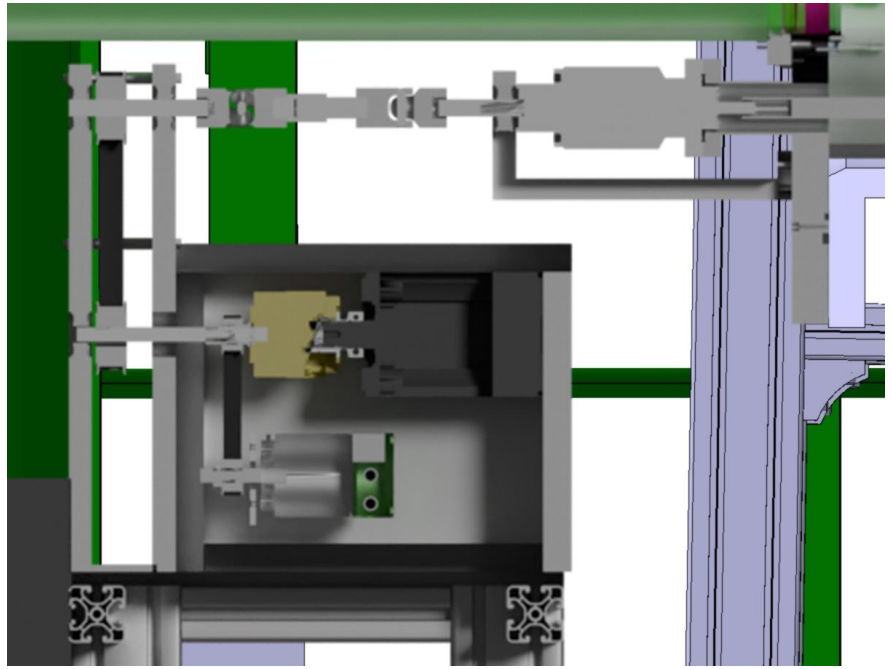

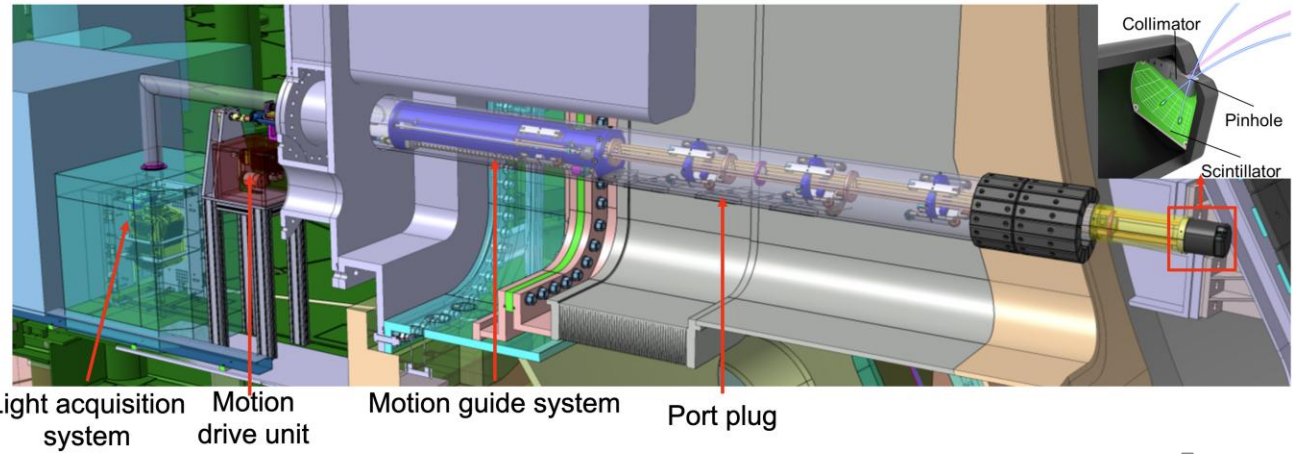

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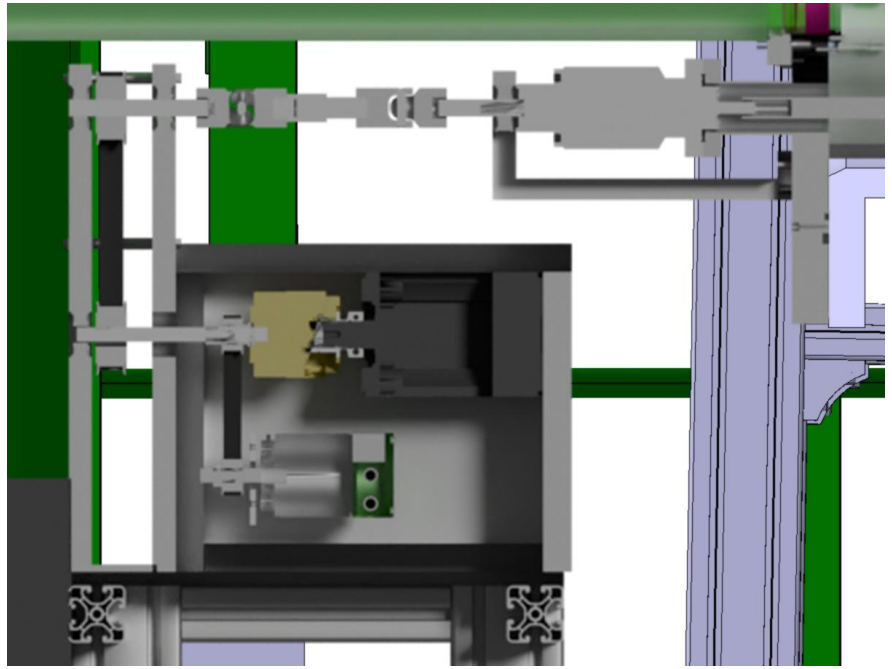
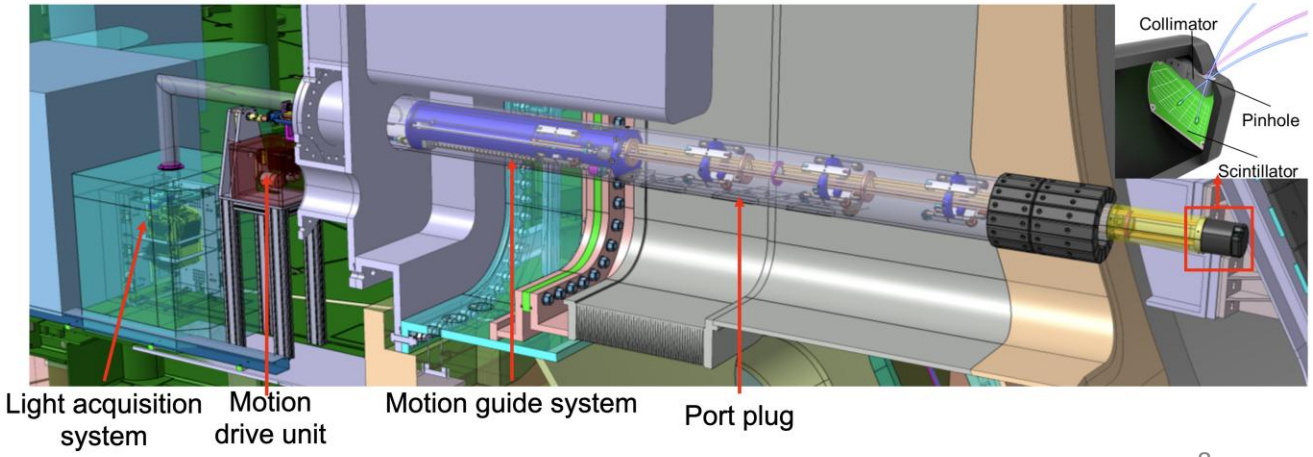
- CAD Configuration Model updated (v5, 07/2025)
  - Electronics cabinet relocated to PIG room after last TCM (to be discussed with QST)
  - Neutronics assessment to be launched, planning ongoing with F4E BCN: model preparation for MCNP can start





Updated Configuration Model (v5, 07/2025) Available for Reference

IN-VESSEL MODIFICATIONS

- Shutter removal based on thermal simulaitons
- Simplification of head graphite tiles
- Dimensioning of rollers
- Heat sink detailed model
- Cables management tray detailed model

EX-VESSEL MODIFICATIONS

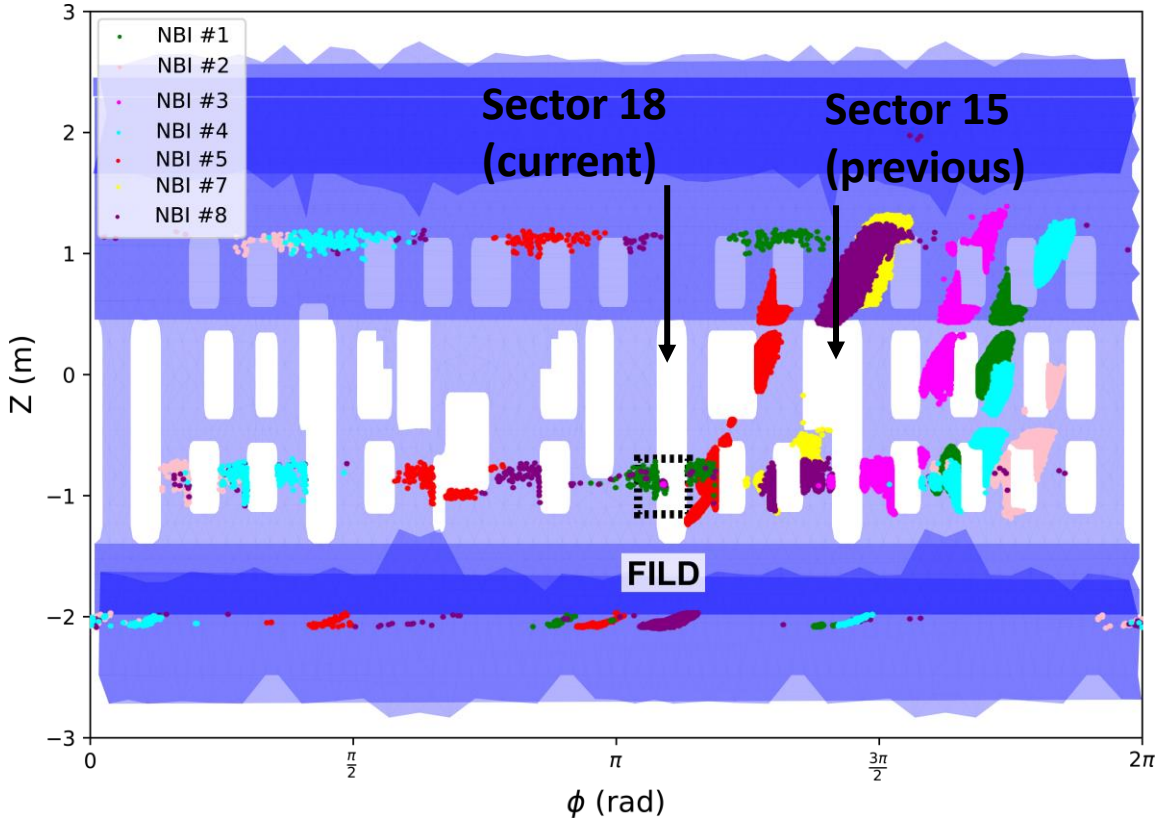
- Reallocation of camera shielding box
- Shielding box neutronic and iron dimensioning
- Driving unit design, including motor, encoder, belts, cardan joints and feedthrough
- Optical path preliminary design
- Location of electronics cabinet in the basement (to be discussed/agreed with QST/F4E)

Updated design at port 18

V5.0 FILD INTEGRATED GLOBAL_measuring_position.stp
https://users.jt60sa.org/?uid=29P38L

FILD Synthetic Modelling In Preparation of Commissioning

- ASCOT simulations to prepare for FILD exploitation
  - ➢ Meeting held with Experiment Team to coordinate modelling activities
  - ➢ Geometry consistency confirmed between FILD, wall and NBI injection using IDM configuration models
  - ➢ Effect of TF ripple, and EFCC being included in simulations



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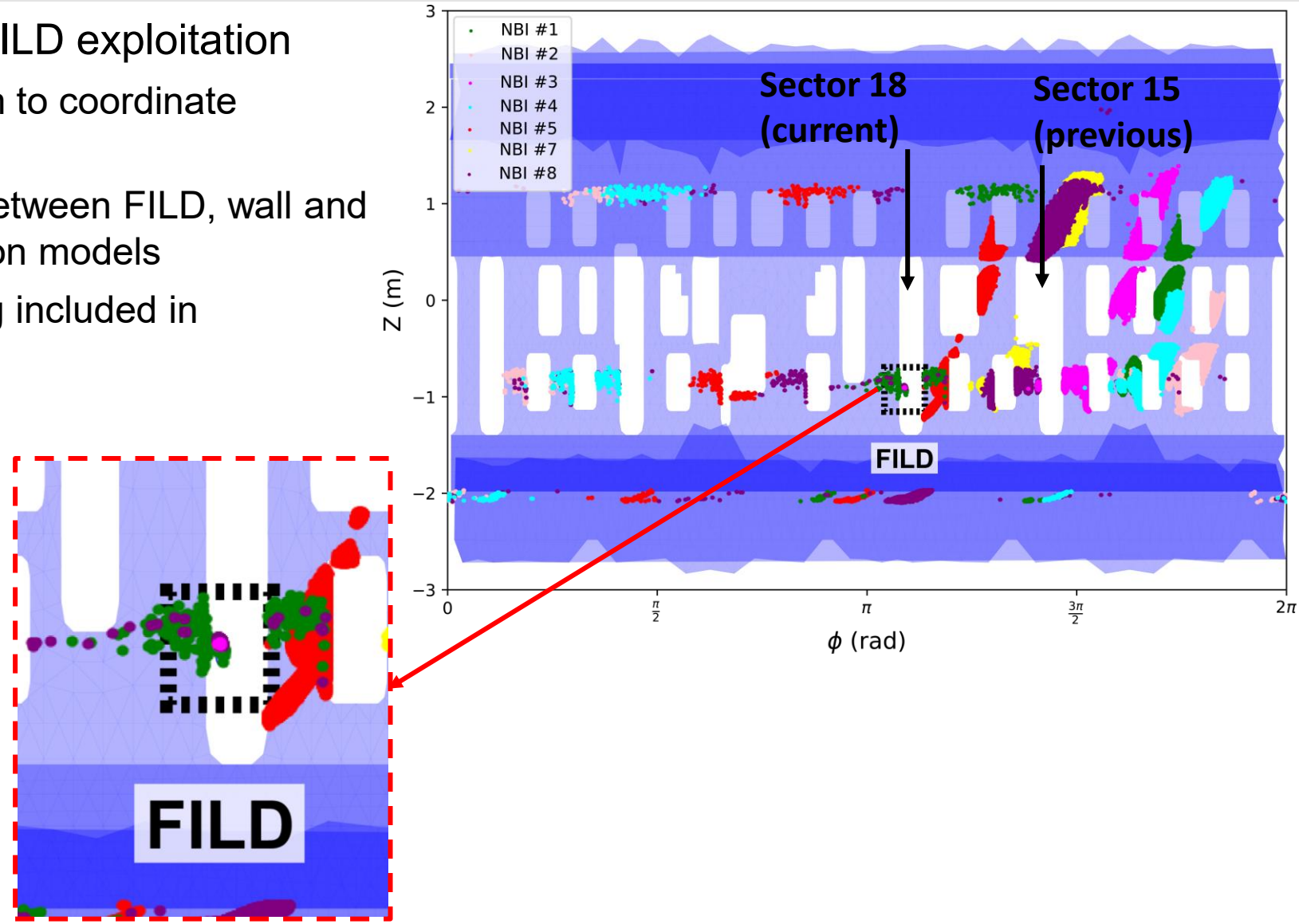
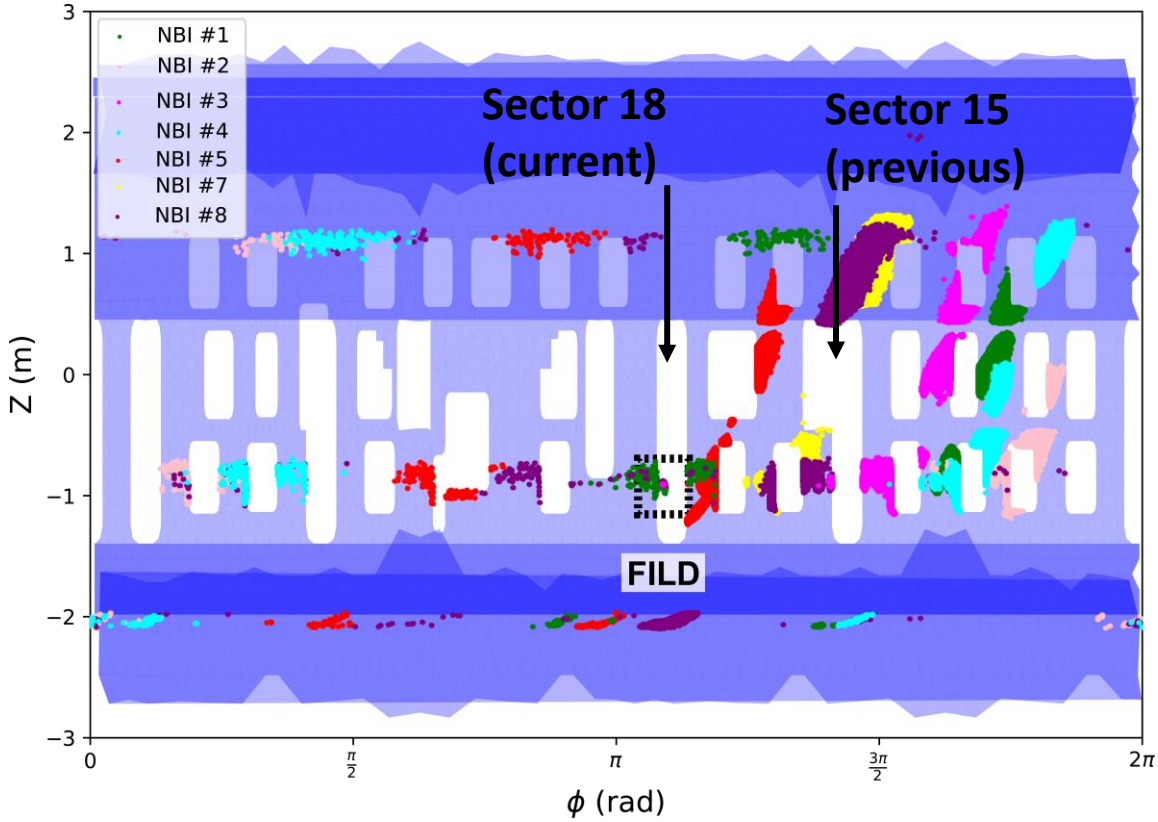
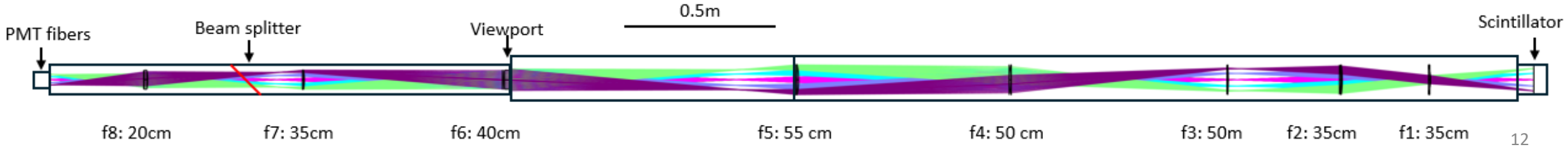


FILD Synthetic Modelling In Preparation of Commissioning

- ASCOT simulations to prepare for FILD exploitation
  - Meeting held with Experiment Team to coordinate modelling activities
  - Geometry consistency confirmed between FILD, wall and NBI injection using IDM configuration models
  - Effect of TF ripple, and EFCC being included in simulations
- Optical design concluded
  - ZEMAX analysis performed to optimize optical transmission
  - Combination of ZEMAX and FILDSIM allows for high fidelity synthetic camera frames
  - BBAR lenses selected, compatible w/ UHV and radiation tolerance





Summary and Future Plans

- Mechanical design completed and procurement under preparation
- Light Acquisition System preliminary design completed and procurement under preparation (independent from mechanics procurement)
- CAD Configuration Model updated:
  - Ready for preparation for MCNP Neutronics simulations
  - Ready for discussions with QST/F4E (e.g. electronics cabinet location in PIG room)

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<u>FUTURE PLANS</u>

- Launch public calls for mechanics and electronics procurements after summer
- CAD model to be defeatured for MCNP implementation
- Agreement on vacuum test chamber needed (dedicated for FILD or larger for testing multiple systems)

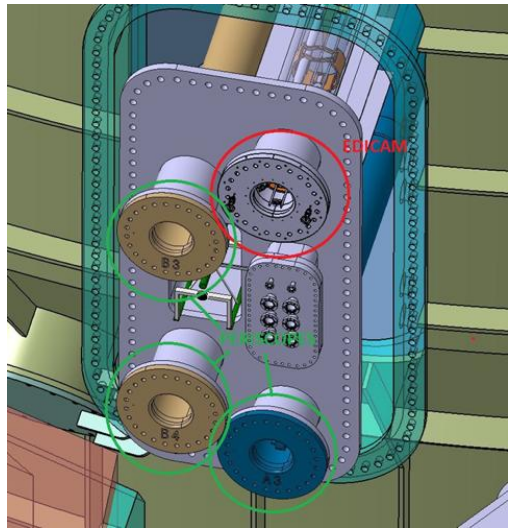
BACKUP

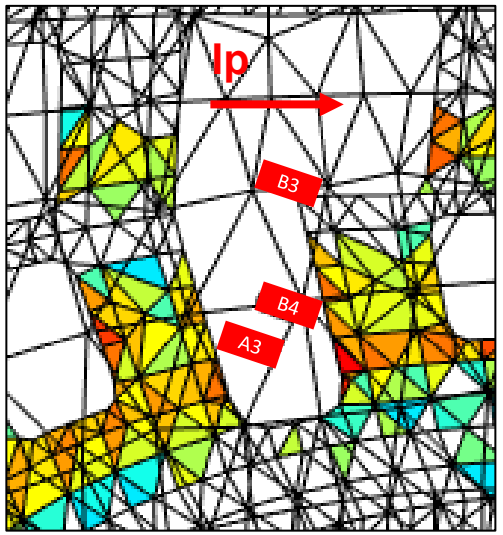
Outline

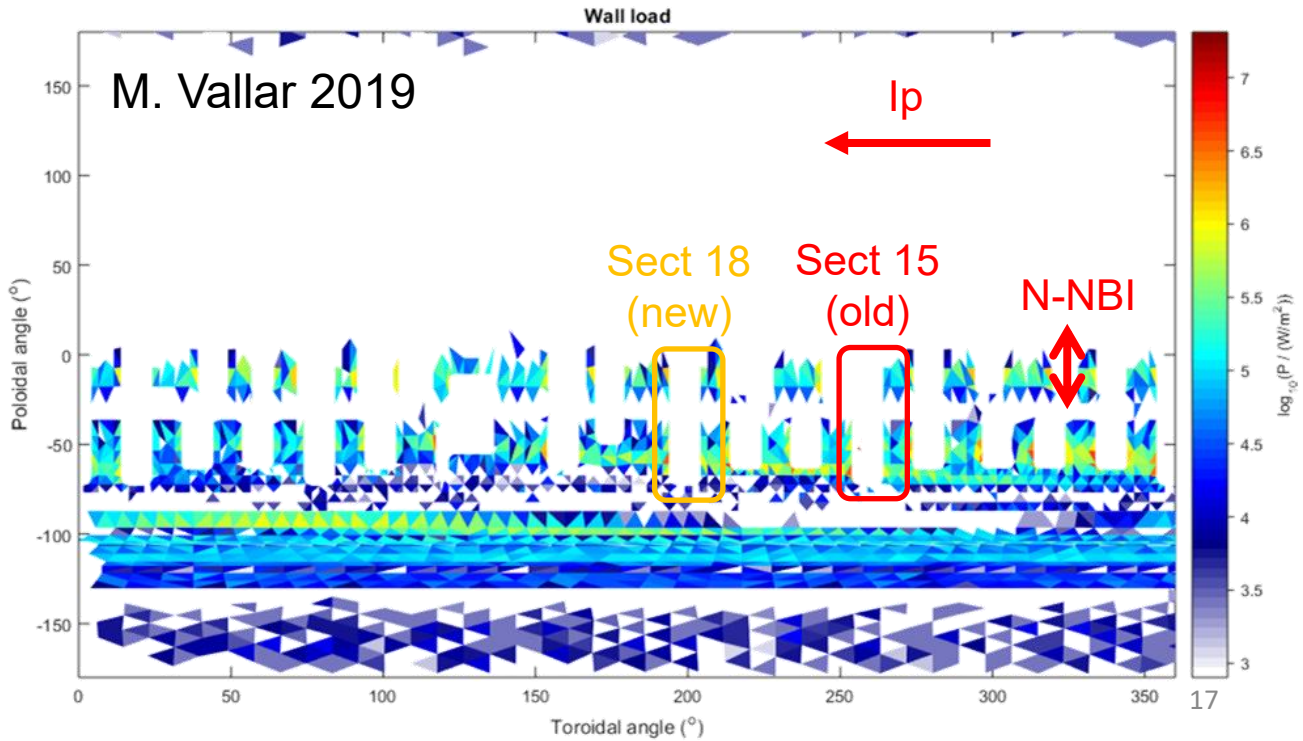
- **Updates since last DRM**
  - ➢**Relocation of diagnostic to sector 18**
  - ➢In vessel components are ready for manufacturing
  - ➢Ex-vessel components preliminary design
- Manufacturing drawing of port plug
- Questions regarding electronics cabinet and network

At TCM, Nakano-San Informed IR Camera Remains During ME2 and FILD is Relocated to Sector 18

- Previous location was sector 15, port B4
- On Sector 18, available ports are B4, B3 and A3
- On Preferred option is B4:
  - Lower port plugs receive larger flux due to grad B drifts
  - Left port plugs receive larger flux due to current direction
  - Collimator optimized for B4 poloidal location
- ASCOT is being re-runed under WPSA CM with toroidal coordinate corrected wrt previous simulations
- Clarifying port availability is important to optimize computational and human resources







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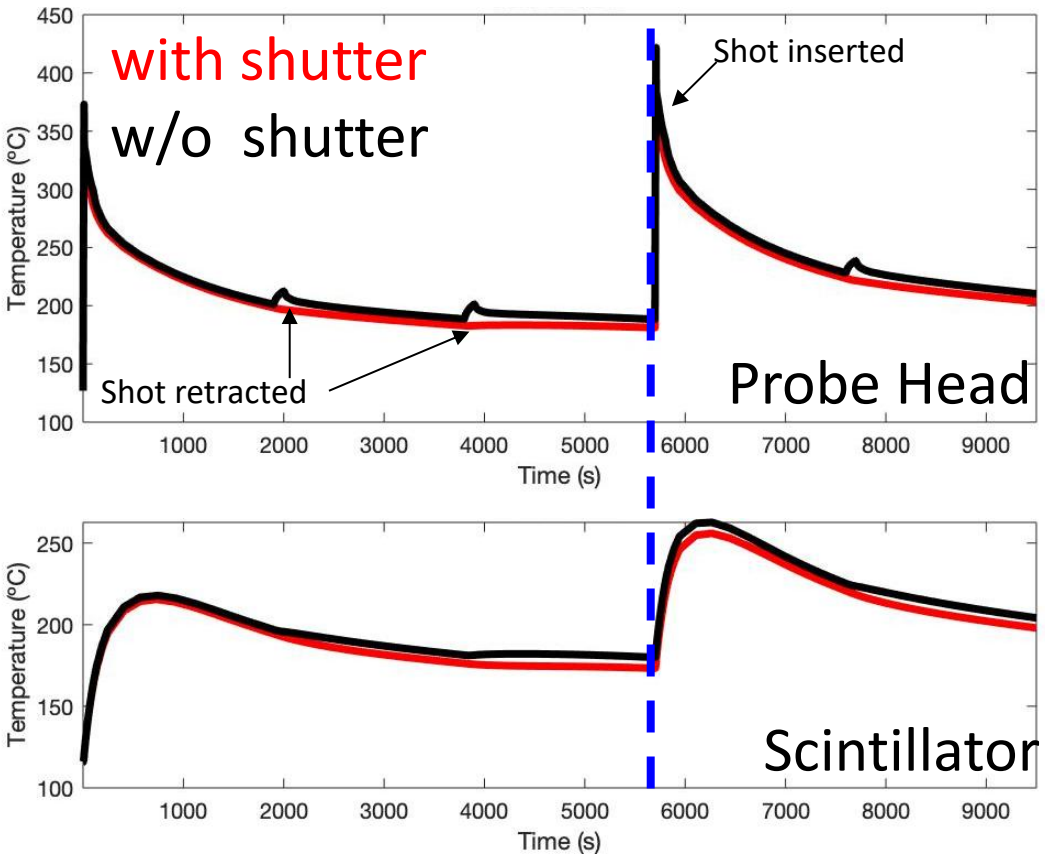
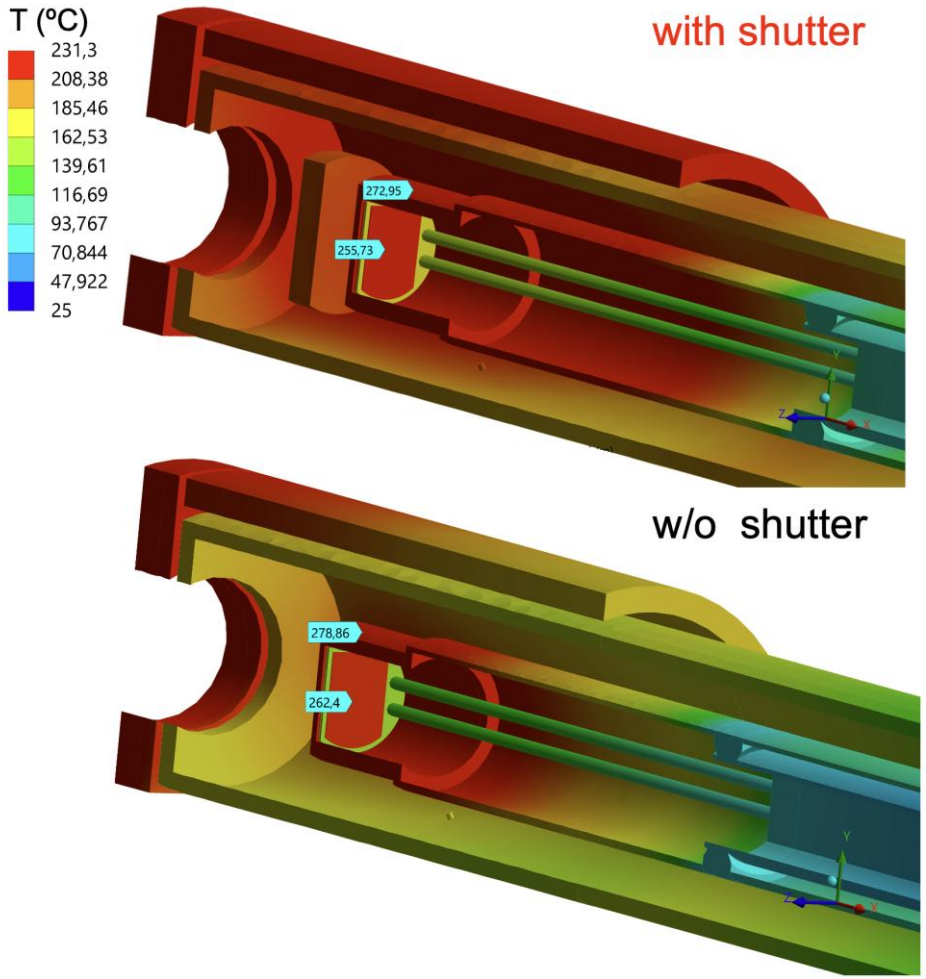
In Vessel Detailed Design is Concluded

Shutter has been removed it has negligible influence on resulting head and scintillator temperatures

- Temperature rise during insertion dominates over irradiation at retracted position
- Avoiding shutter reduces operational risks

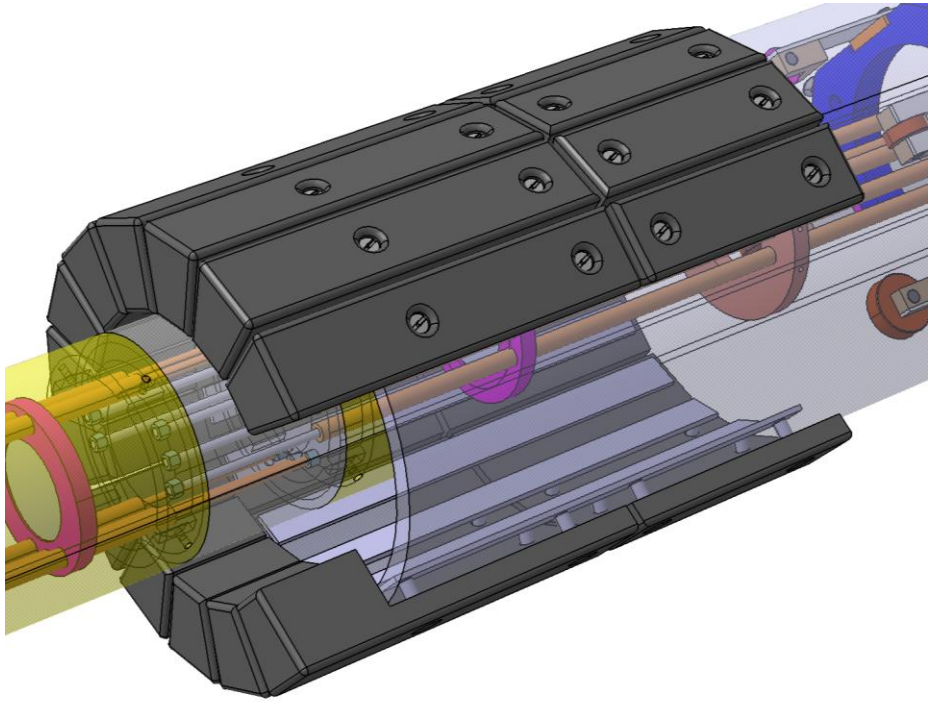


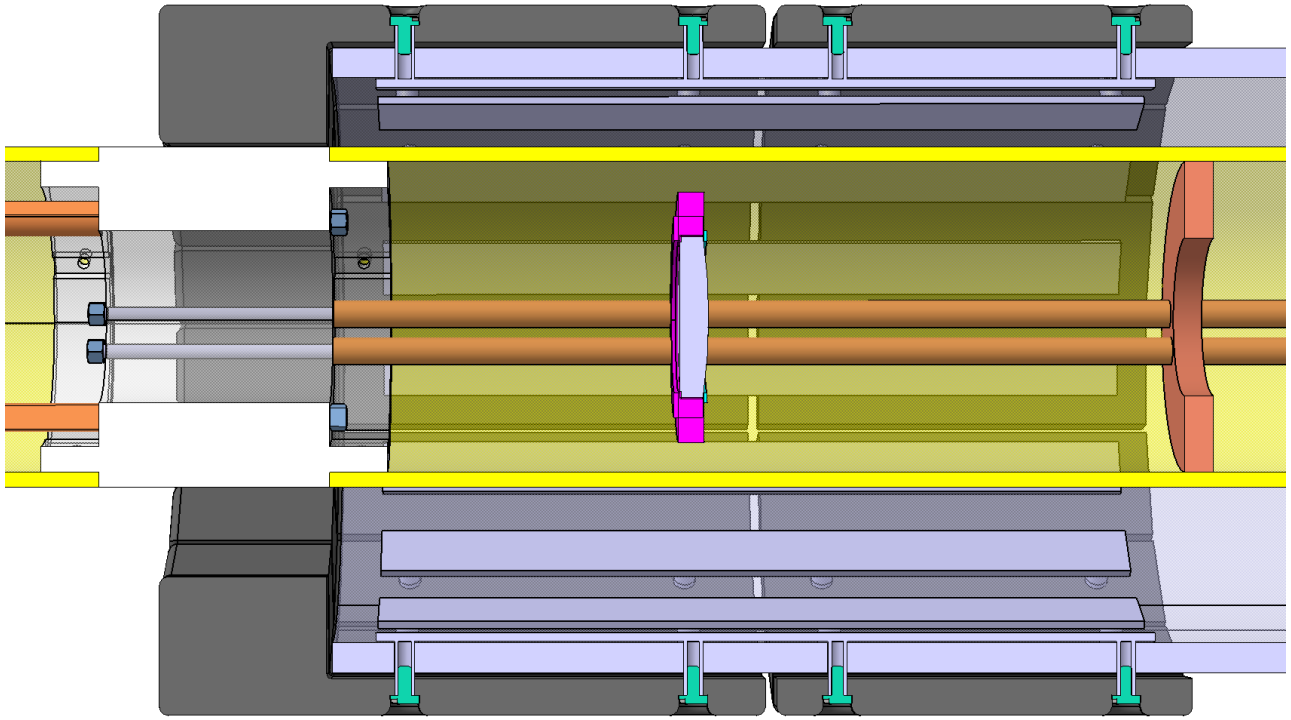


In Vessel Detailed Design is Concluded

Clamping of graphite tiles to the port plug is designed in detail, following design for W-7X FILD

- Provides safely clamping and easy installation
- Tails are behind limiter and do not intersect any field line

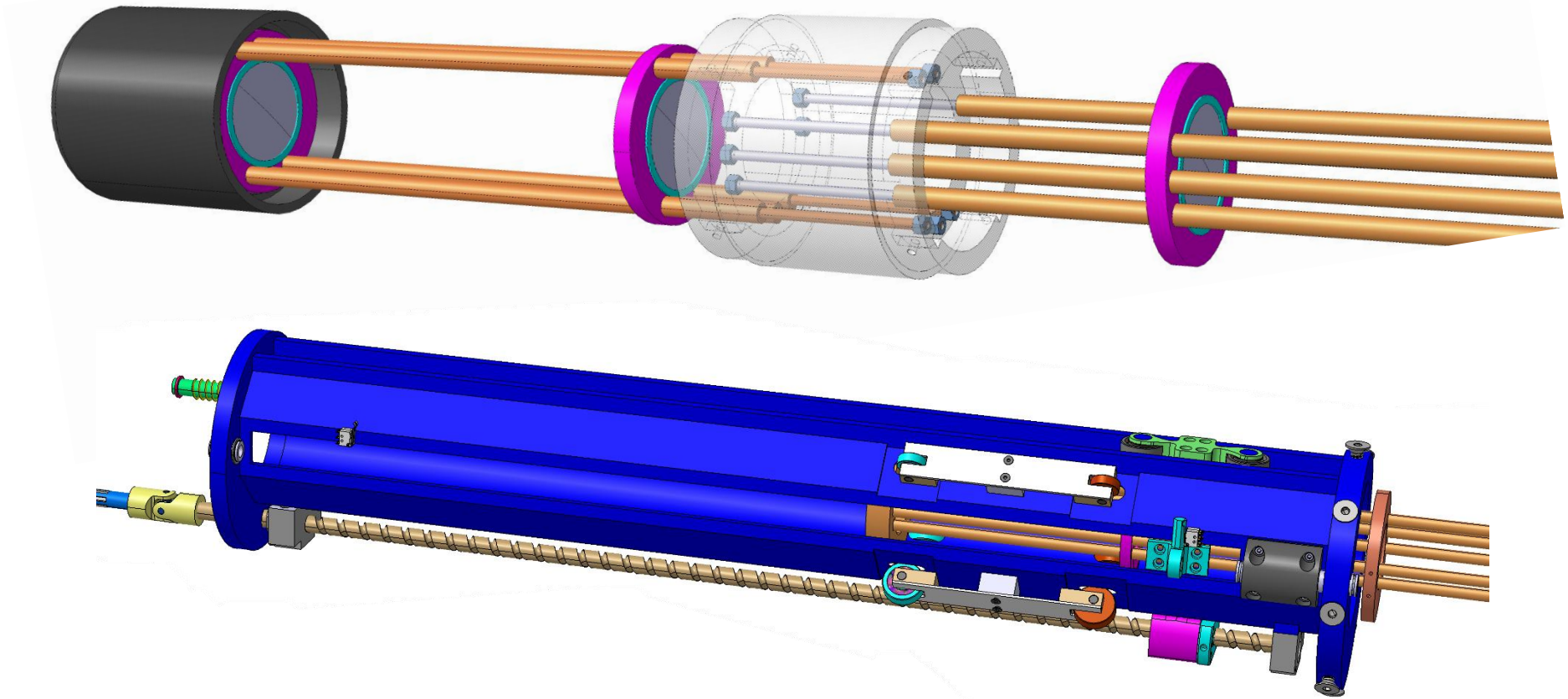




In Vessel Detailed Design is Concluded

Assembly sequence is designed in detailed, finding no issue on assembly

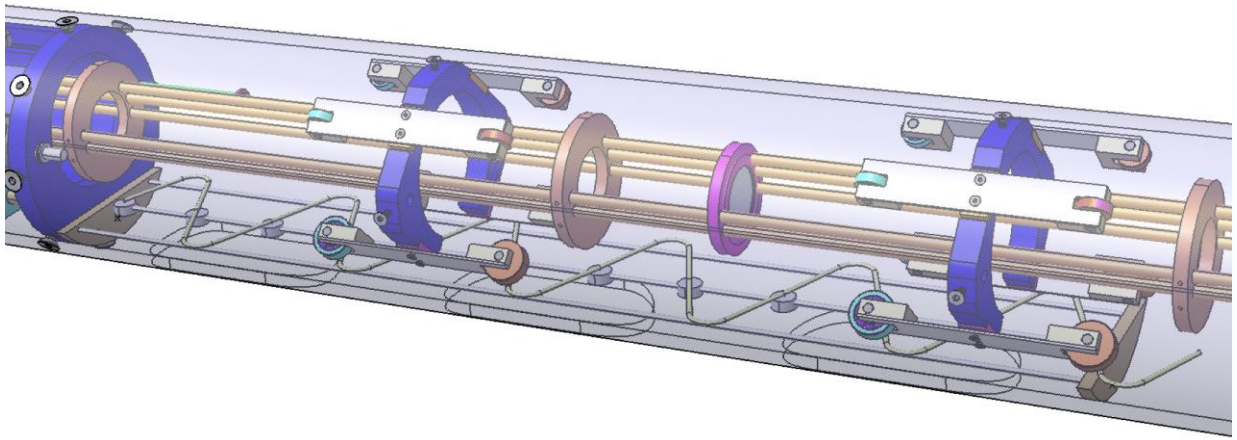
- Assembly of components will be tested at laboratories at University of Seville prior acceptance tests

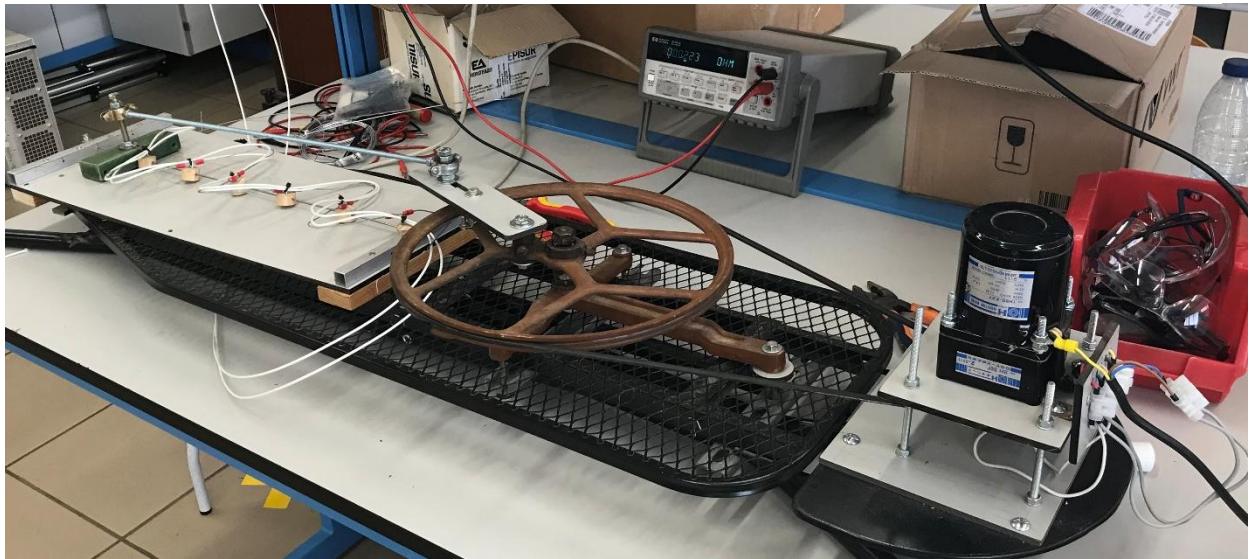


In Vessel Detailed Design is Concluded

Cable management inside the reciprocating system is designed in detail

- Space reservation and cables guides have been implemented on the in-vessel design
- Copper S cable distribution has been already tested in the University facilities
- High precision multimeter demonstrates a low drop on resistivity (<1%) after 10^4 cycles on preliminary tests

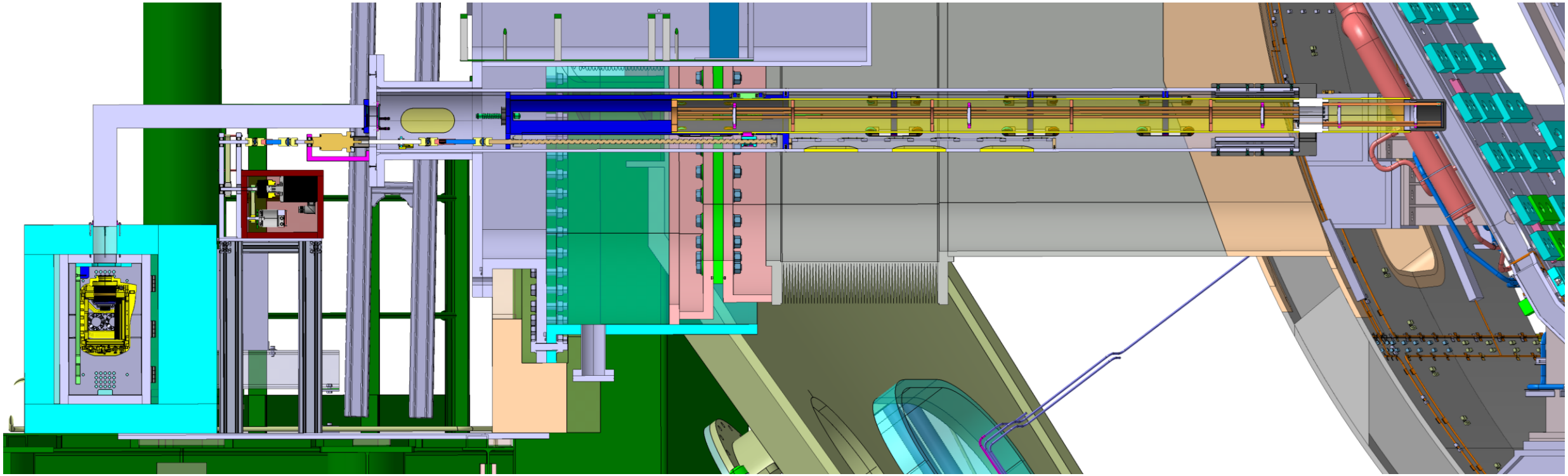




In-Vessel Detailed Design is Concluded

In vessel components are ready for manufacturing

- *In-vessel design is independent of ex-vessel design: driving unit and DAQs*
- Once port is confirmed, we propose start manufacturing already port plug, reciprocating system and probe head
- This is important to start the acceptance tests ASAP
- Detailed calibration and validation of out vessel unit relies on HUV performance of in-vessel design



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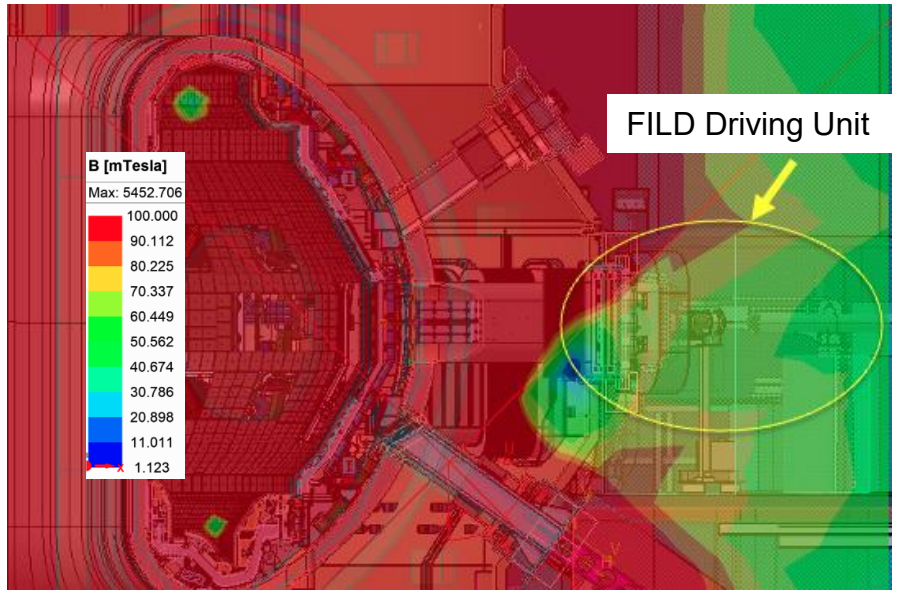
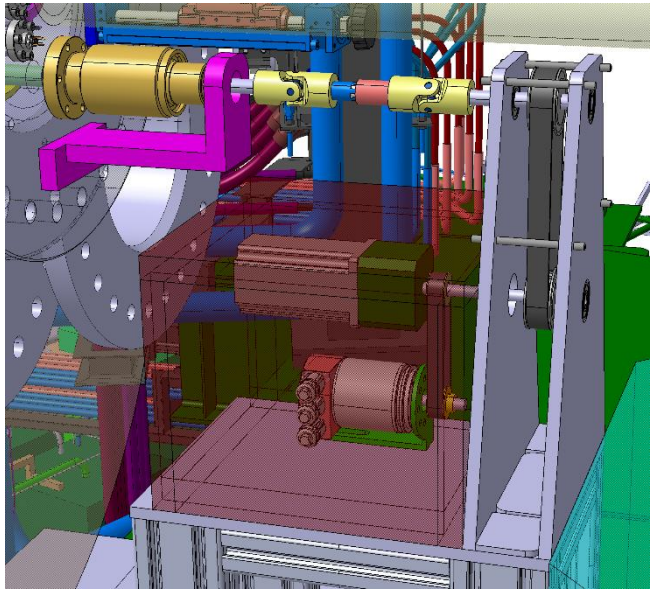
Driving Unit Consists of Servo Motor, Tested in AUG

- Driving unit used on AUG FILD and X-Point Manipulator: AKM5 Kollmorgen
  P. de Marné et al. Fus Eng and Design 123, 754 (2017)
  - ➢ Extensively tested moving during discharges: 90 mT, 2c m of soft iron shielding
  - ➢ Tested steady above 1 T without shielding. Movement tests under 1 T planned for October

- Plenty of back up solutions to be tested at the lab, e.g.:
  - ➢ Edge Thomson Scattering that withstand 100 mT without shielding
  - ➢ MAST-U FILD, McLennan 23HT18C230. Slow, but good precision. 0.5 cm SS shielding <300 mT
  - ➢ At ITER FILD the shielded cabinet includes 15 mm of soft iron to reduce magnetic field below 5 mT

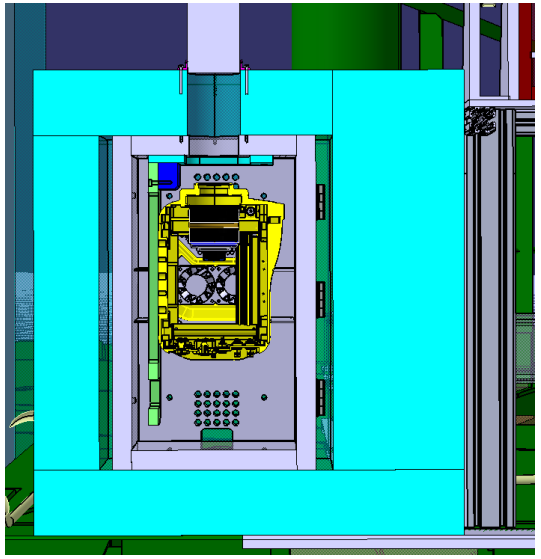
- Safely drives rotary feedthrough using a double cardan joint, that accommodates eventual misalignments

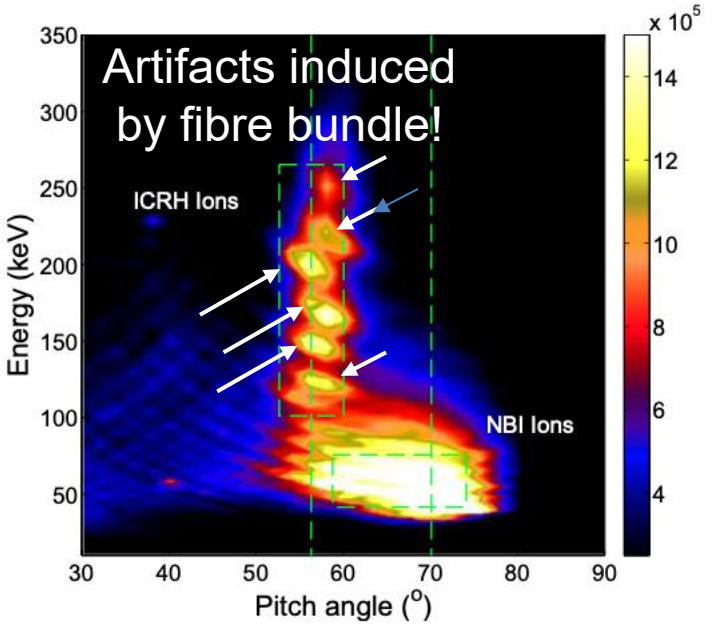




Camera Shielded Cabinet For Neutrons and Magnetic Field

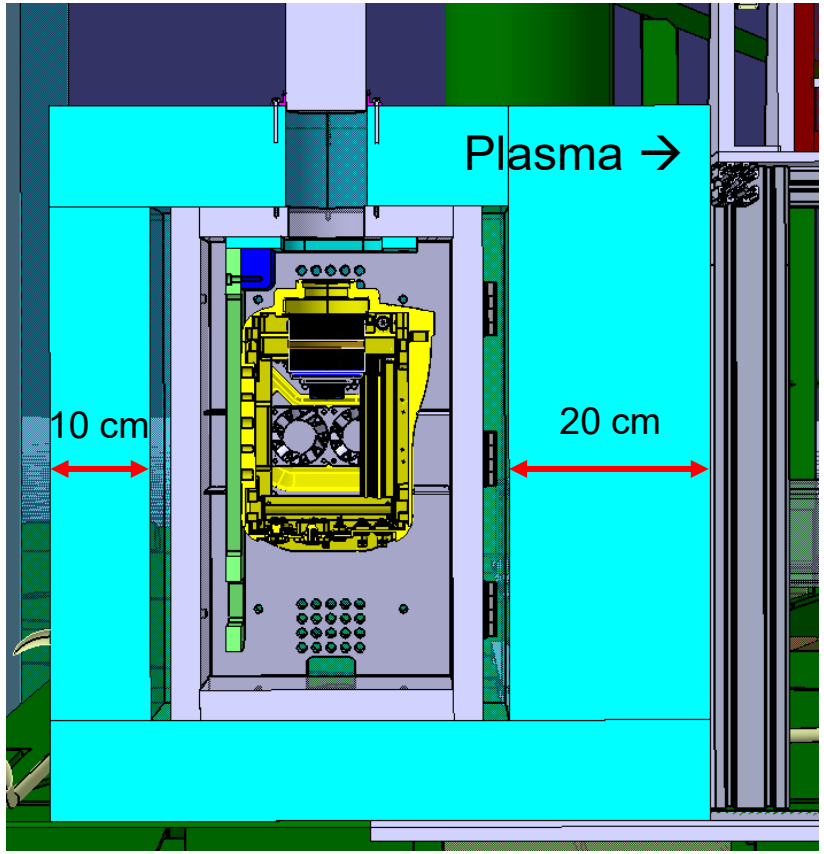
- 15 mm soft iron layer, tested under similar fields in AUG and the same camera model
- 20 cm poly protection as Tangential Phase Contrast Imaging
- Mirror for dogleg acts as beam splitter to 4x4 fibers that transfer light to PMTs
- Camera located right next to viewport allows for direct visualization of scintillator plate and lower maintenance
- Experience with fiber bundles in AUG and JET, stressed the importance of direct view:
  - Fiber bundles reduce the velocity-space resolution
  - Induce artifacts
  - Difficult applying tomography techniques

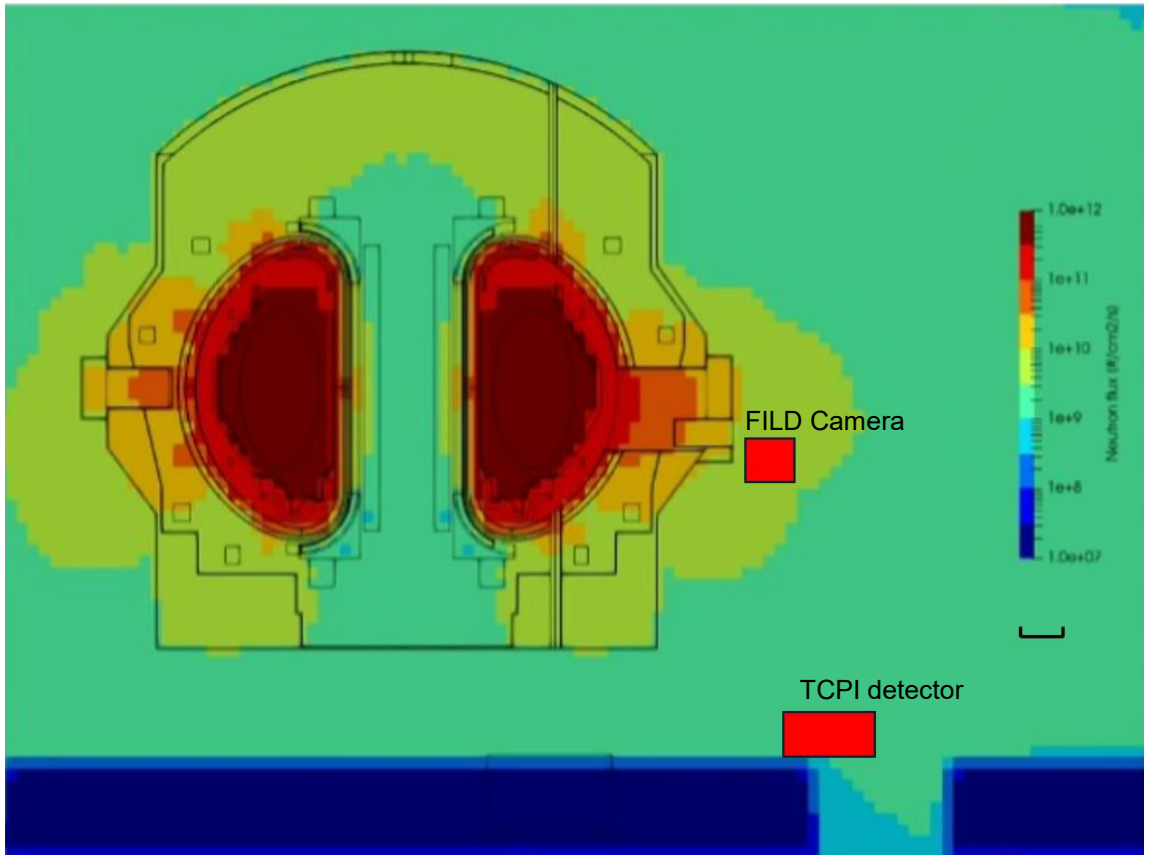




Camera Shielding Box Preliminary Designed, Based on TPCI

- TPCI preliminary uses 15 cm of borated polyetilene and 1 cm lead under a flux of 10^9 n/cm^2/s and gammas $5 \cdot 10^8$ p/cm^2/s
- Extra space allocated for additional shielding if required





(TPCI Preliminary Neutronics Assessment)
Courtesy of F4E

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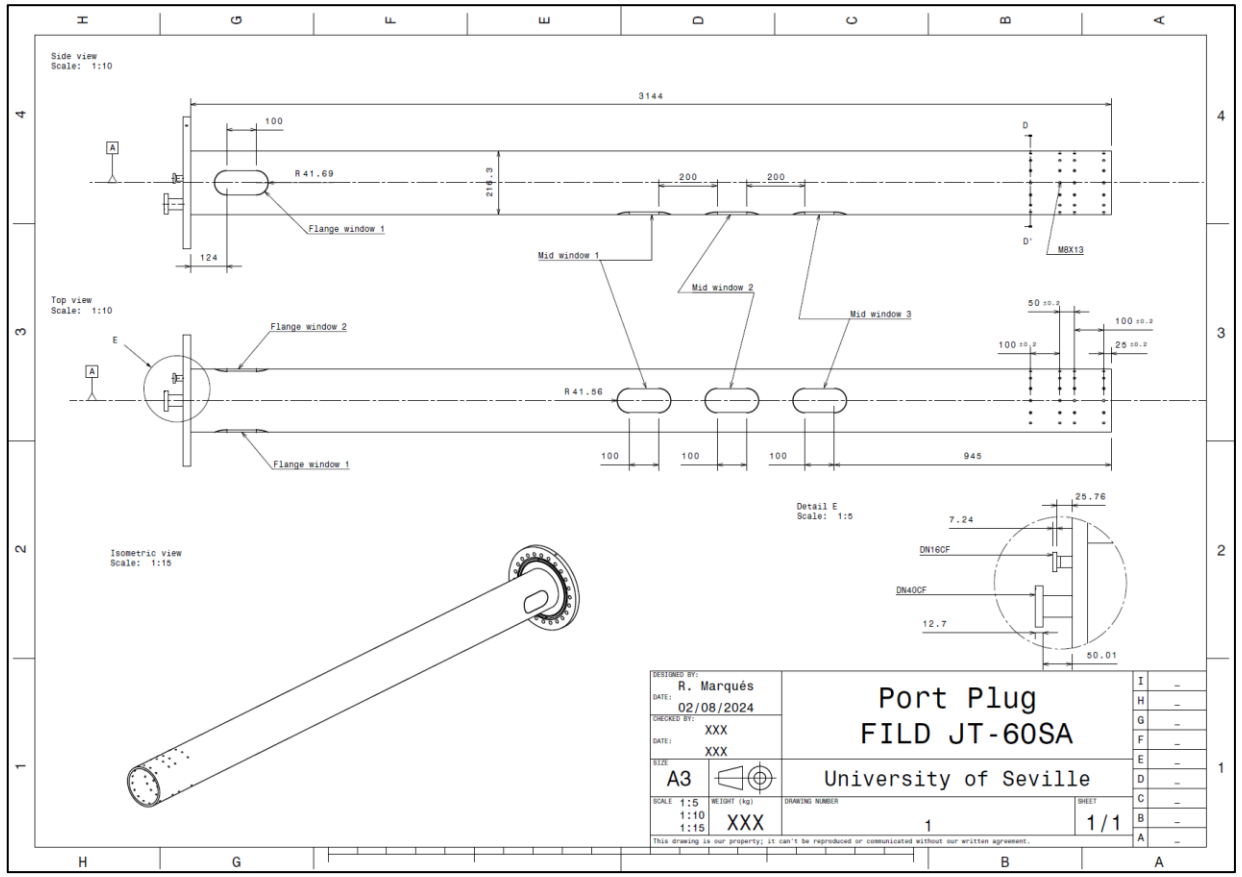
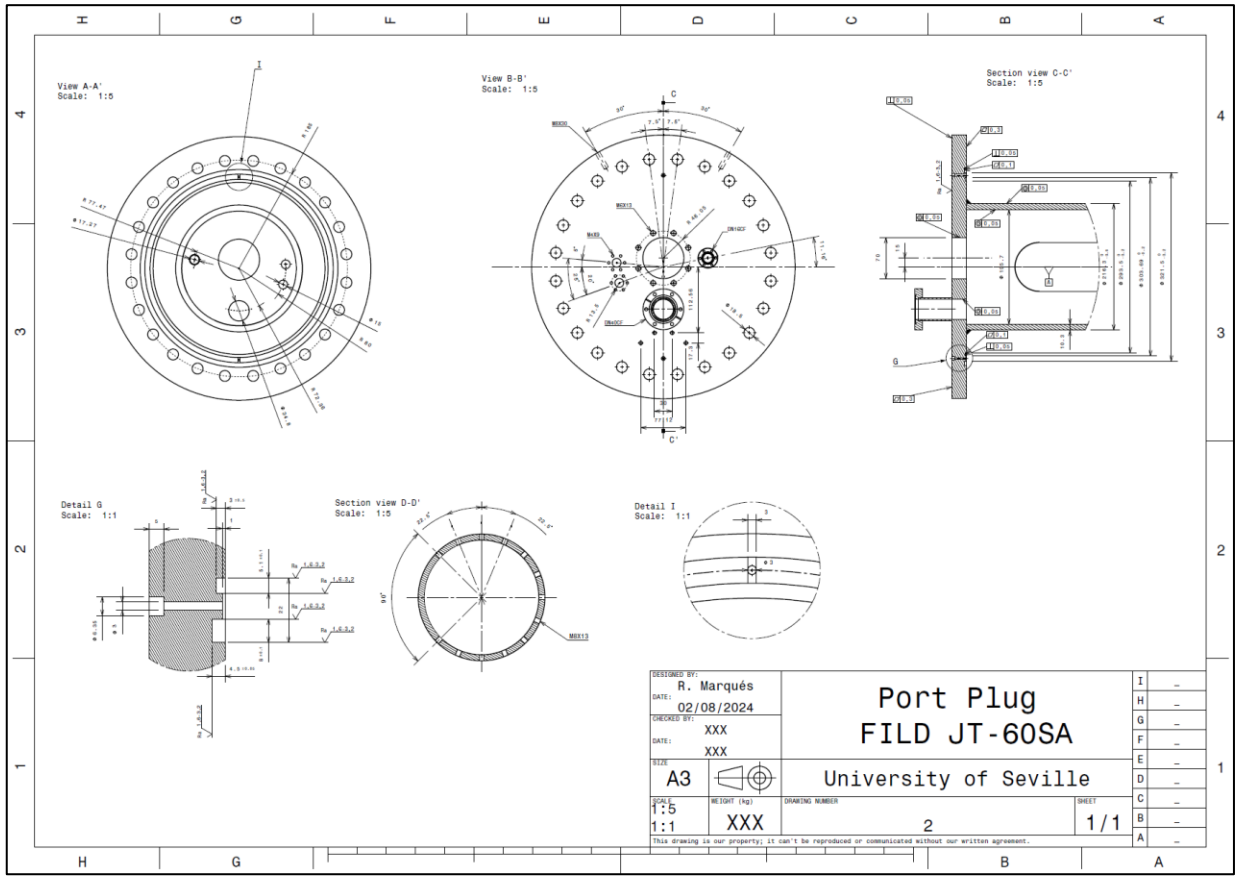
Manufacturing Drawings of Port Plug Are Prepared To Be Reviewed By QST

Port Plug manufacturing drawings.

- Tolerances and roughness/welding dimensions were compared and checked with manufacturing drawings from EDICAM, which is located right on top of FILD diagnostic
- Double HUV sealing has been considered in the flange (vacuum barrier)
- HUV welding considered on the nipple connections of the flange





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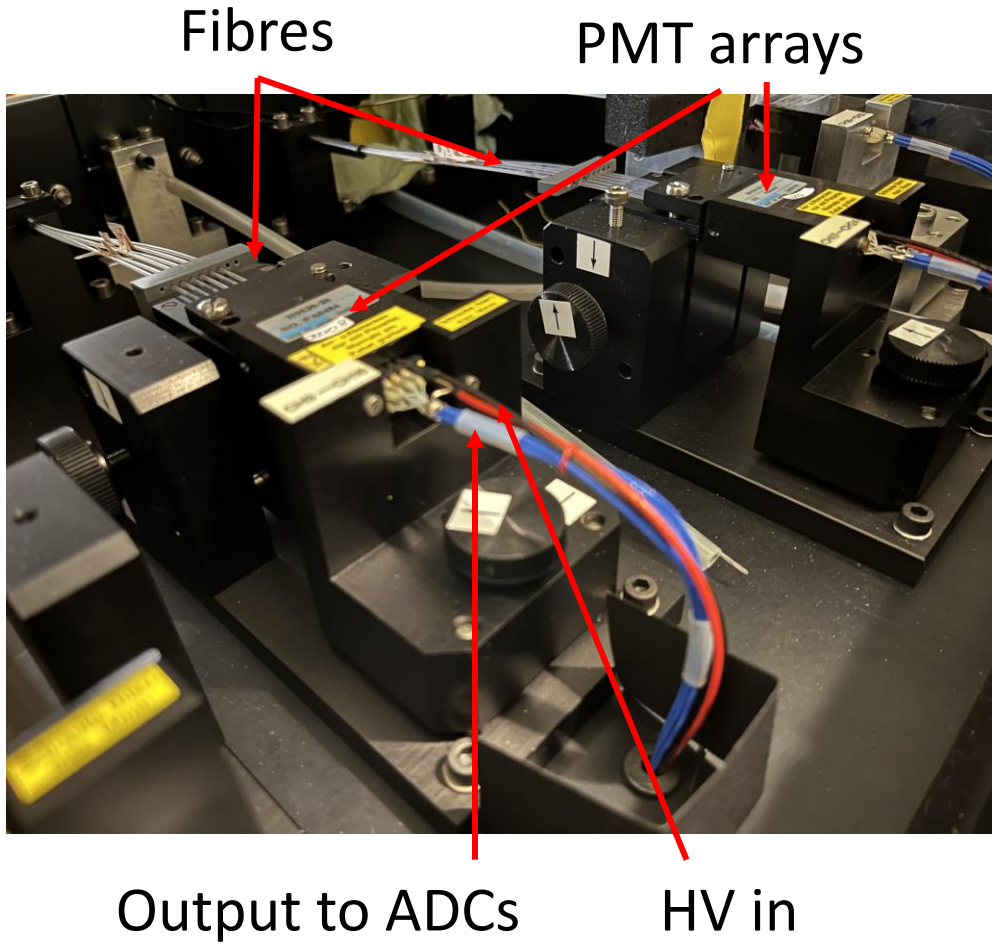
PMT Implementation Similar to FILD2 at AUG

- Fibres similar to Laser Components HCP-M0800T
  - Low loss (@850nm </=8dB/km), NA=0.37
  - Bending radius > 10 cm
  - 1 mm diameter (silica 0.8mm + 0.2mm insulating)
  - 2 mm clearance around fibre for rectangular arrangement
- Fibres connected to two Hamamatsu H9530 arrays
  - Linear array of 8 channels
  - Preamps embedded
  - Voltage from each channel recorded by digitizers at the basement
- 1kV PS shared by both PMT arrays
  - Low ripple and noise required < 2mVp-p
  - E.g. FAST ComTec NHQ 202M
- NIM crate contains both PS and ADCs



Auxiliary DAQs for Thermocouples, Timing and Triggering

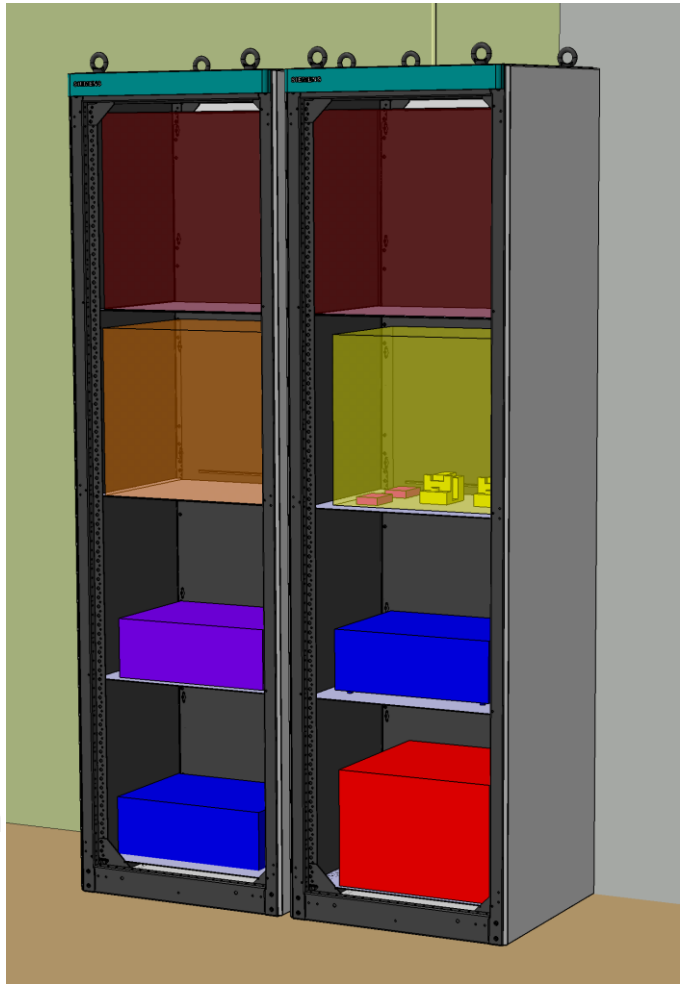
- 12-slots fan cooled crate (e.g. NIM8304) hosts multiple DAQs:
  - 2 slots for PMT ADCs
  - 1 slot for thermocouple instrumentation
  - 1 slot for 1kV PS

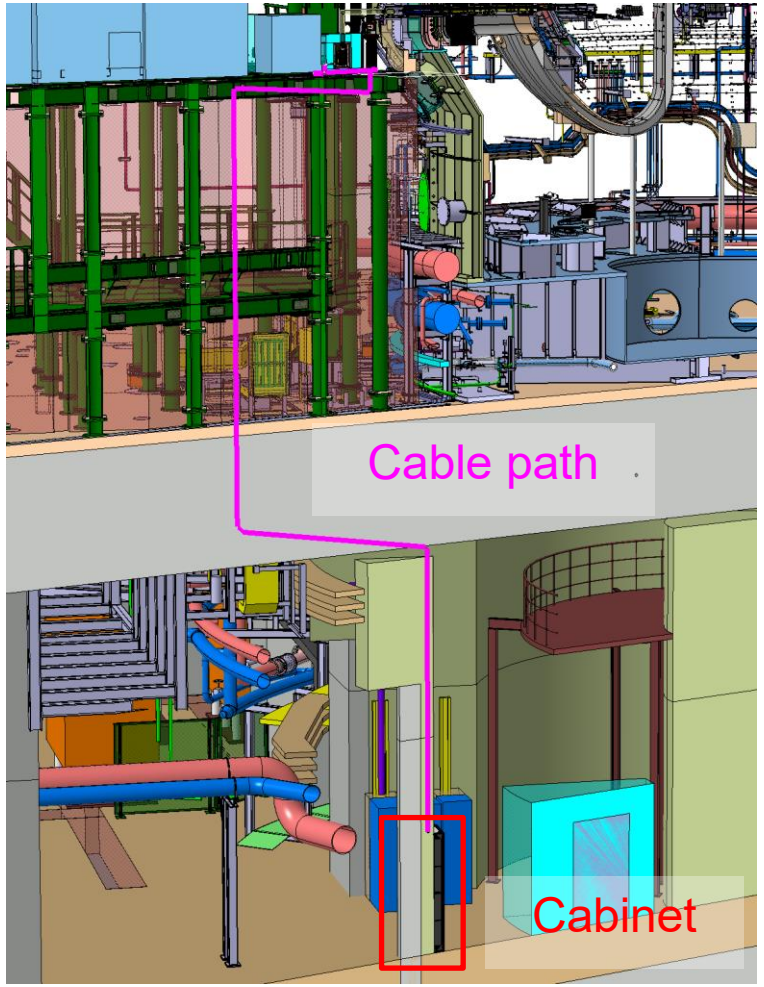
- Other components depend on preselection of specific DAQs components, but space is pre-emptively allocated for:
  - 2 NIM card for 5V clock and triggering modules
  - Space for copper to fibre converters
  - Space for camera external PS

- Both PMTs themselves and auxiliary electronics located in a cabinet in the basement

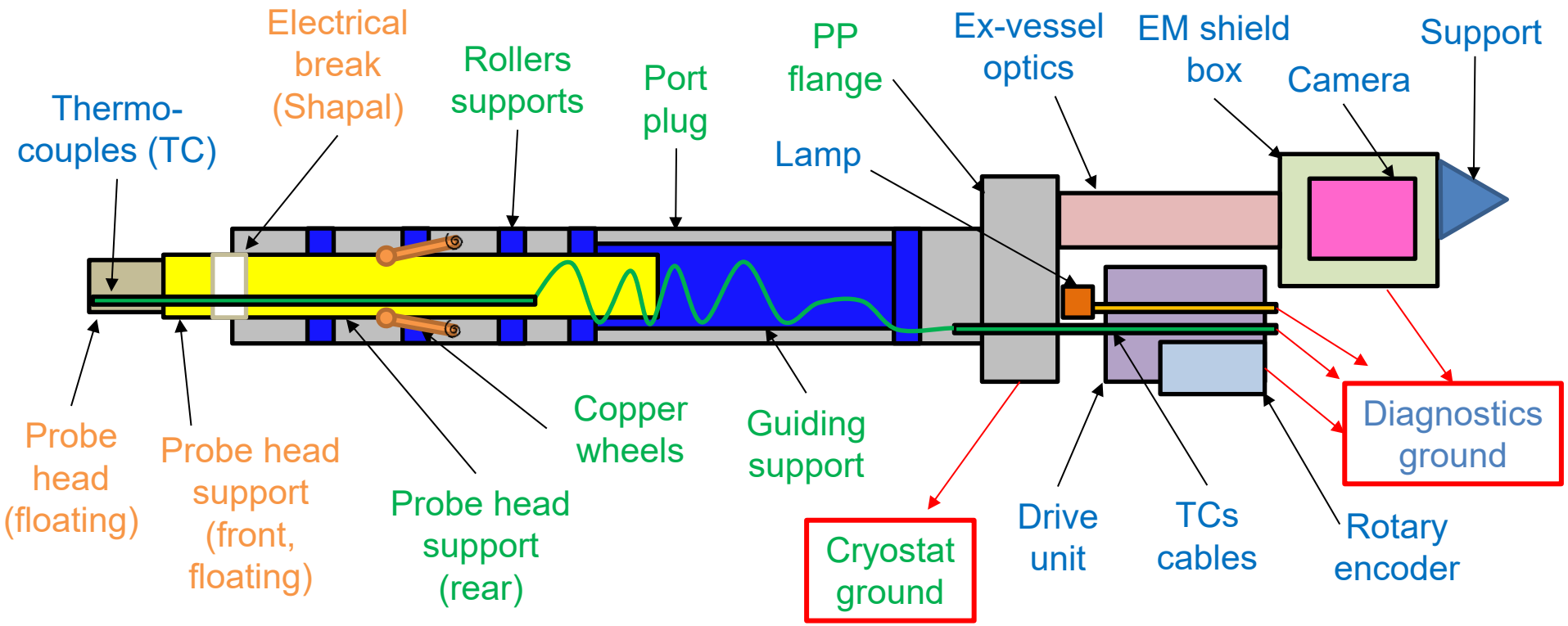
Electronics Cabinets Located in the Basement

- Distance to port plug should be minimized as much as possible to shorten fibber length
  - At the proposed location: L = 24 m
- Electrical connections diagrams updated
- Cabinets holds:
  - NIM crate
  - PMTs
  - Camera media converter
  - Auxiliar electronics of driver unit
  - PLC to control servomotor
  - PCs for camera acquisition
  - PCs for PMT acquisition
- Can you confirm availability of location?
- Does QST requires any specific version of Linux / Windows?
- Can QST specify the remote connection protocol with PCs in the basement?
- Can QST specify whether any triggering / clock can be distributed to the cabinets?
- Is there an IR camera system that covers the location of the FILD probe head?





FILD Grounding Scheme



- Port plug, guiding support, probe head support (rear), optics (in-vessel) are electrically interconnected and grounded to cryostat ground
- Electrical components (rotary encoder, drive unit, camera, calibration lamp, thermocouples), ex-vessel optics and EM shielding box connected to diagnostics ground and isolated from all other components
- Special case: Probe head and probe head support (front) electrically floating while measuring, connected to cryostat ground in parking position using copper wheels

FILD Grounding Scheme