ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

DTT-THM-DIA-DIC/DOC-03

DTT spectroscopy equipment essential for machine operation and detachment studies: design progress status

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Midterm WPDIV-IDTT Meeting 2023

July 17 - 19, 2023, Frascati

DTT Consortium (DTT S.C.a r.l. Via E. Fermi 45 I-00044 Frascati (Roma) Italy)

DIA-DIC/DOC-03Task Distribution

Institution	Activity
ENEA (F. Bombarda, C. Cianfarani)	VUV/SX Diagnostics; design integration; DNB; LBO
RFX (L. Carraro)	VIS/Zeff/VUV/XUV Diagnostics
UniMiB (M. Cavedon)	CXRS/MSE/VIS/Zeff
PoliTo (F. Subba)	Synthetic Diagnostic of divertor D_alpha
UniTus (A. Belpane)	Thermomechanical analysis, VIS/Zeff design completion
INAF (F. Leone)	VHR Vis/VUV
RFX (M. Agostini)	THB

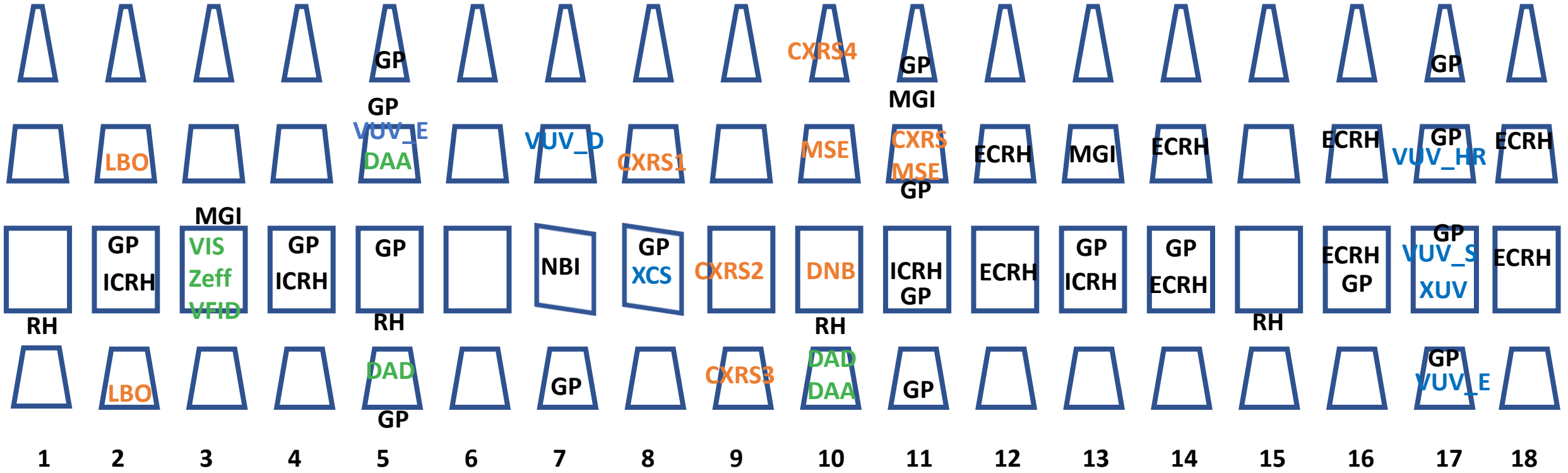
Proposal approved 14/03/2023
KoM held 07/06/2023

		PM (DTT + WPDIV)
PAX	29	25.5
Beneficiaries	4+ 1	
External Inst.	1	
PhD's	3	6.5
Systems	16	
Port positions	24	

Other resources

1) DTT (R. Romano), V. Orsetti)
2) Promech/ANN for CATIA machine design integration activities
3) LTCalcoli for stress analysis of in-vessel components
4) Research Contract with INAF (Prof. F. Leone, Dr M. Giarrusso) for VH resolution spectroscopy.

DIA-DIC-DOC-03 Diagnostic Systems



DVI	Visible & Monitors
DAA	D_alpha
DAD	D_alpha divertor
VIS	Visible Survey/Divertor
Zeff	Bremsstrahlung
VFID	Visible Filters Divertor

DXU	VUV-XUV-SX Spectrometers
VUV_E*	SPRED x Edge
VUV_D*	SPRED Imaging x Divertor
VUV_S	SPRED Survey (JET)
VUV_HR	High Resolution VUV
XUV*	SOXMOS (RFX/JET)
XCS*	Curved Crystal Spectrometer

DAS	Active Spectroscopy
DNB	Diagnostic Neutral Beam
CXRS	Charge Exchange Recomb. Sp.
MSE	Motional Stark Effect
LBO	Laser Blow Off

*In house, to be refurbished

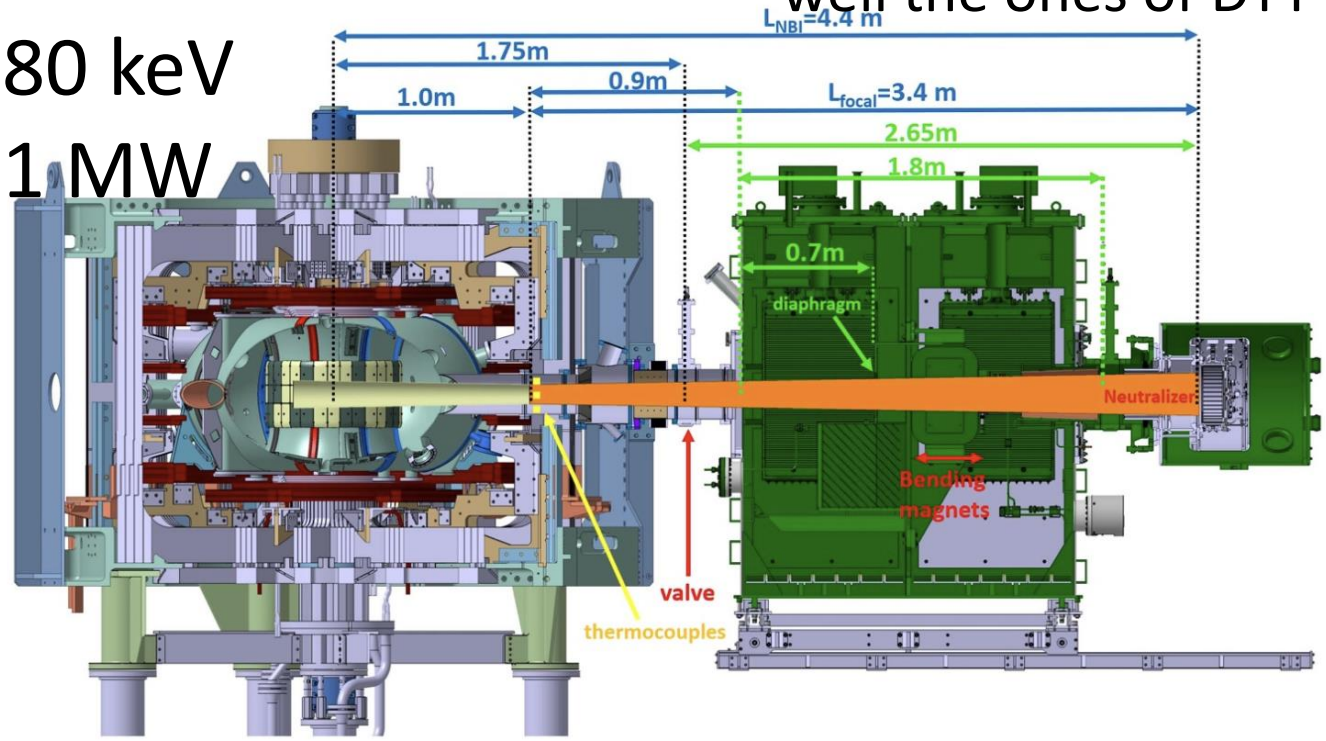
DAS Active Spectroscopy (Day2)

- DNBI ---> M. Cavedon :
  1) new evaluations of beam penetration (80 keV/8 A may not be sufficient when SOL is taken into account)
  2) Contact established with COMPASS to estimate beam losses in port duct due to neutrals and stray fields
- DNBI --> positioning in TH started (Promech)
- CXRS and MSE to be started
- LBO --> M. Cipriani : characteristics of new laser (repetitive, split beam…)

Feasibility of DNBI: the example of COMPASS (M. Cavedon)

COMPASS heating beam and plasma conditions in the SOL (ne, n0, Te) resemble very well the ones of DTT

80 keV
1 MW



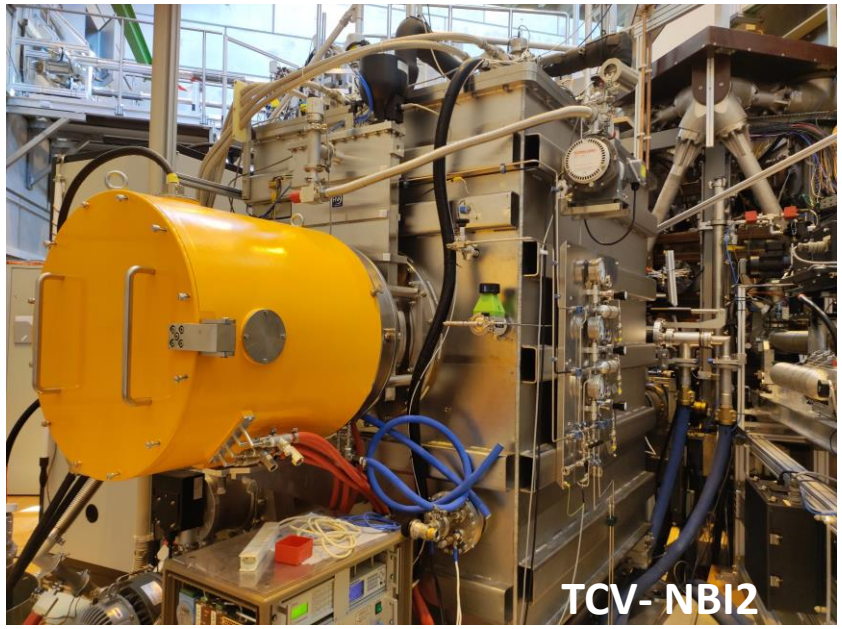
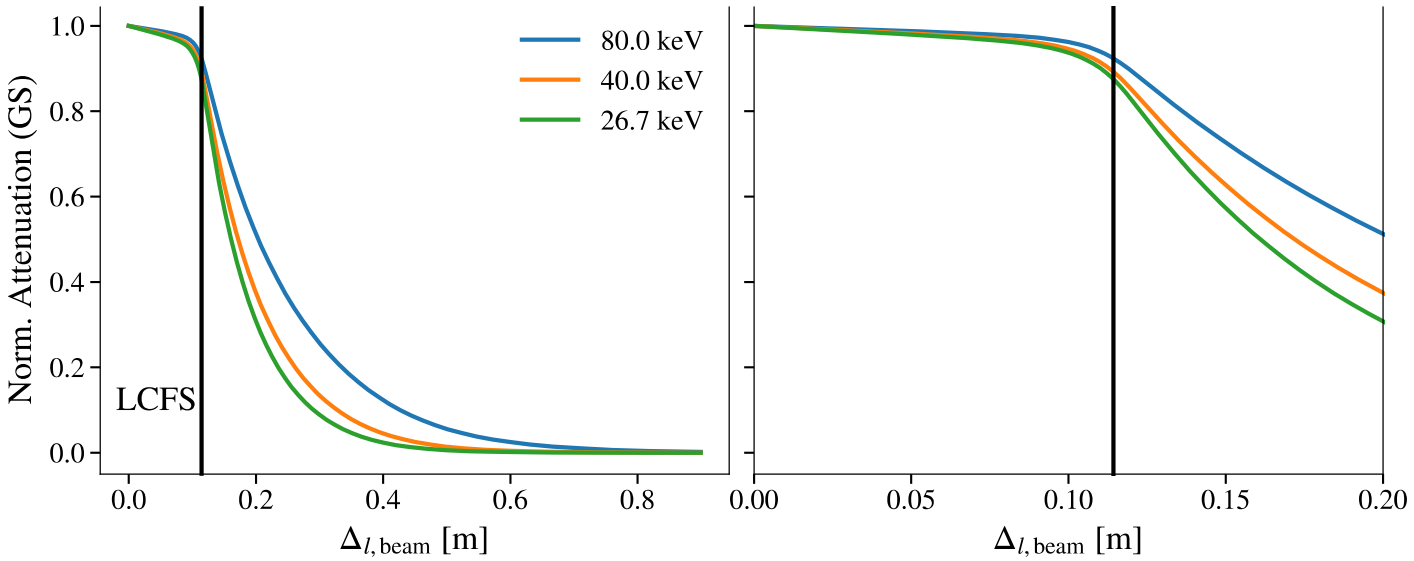


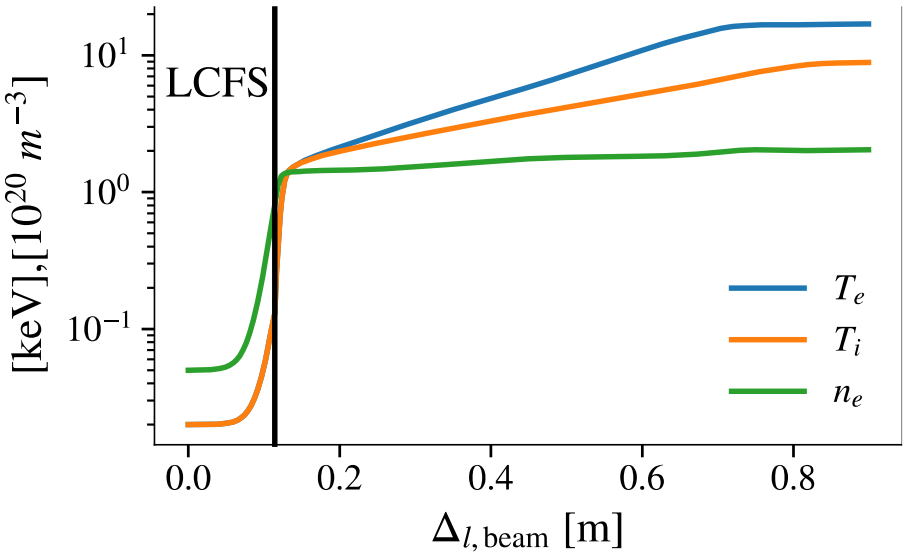
Figure 1. Side view of the NBI 0 line, next to the COMPASS tokamak vessel, based on engineering drawings. The various component mentioned in the text are shown here, along with their characteristic dimensions.

F Jaulmes et al 2022, *Plasma Phys. Control. Fusion* **64** 125001
Numerical modelling for beam duct heat loads calculations and application to the new 1 MW neutral beam injector in the COMPASS tokamak

Port 3 Sector 10: is DNBI compatible with RH?

Scenario E1 (New calculations 80 keV, 8 A)





Separatrix: T = 130 eV, n = 8.39 e19 m-3
Attenuation 80 keV: 7.603 %
Attenuation 40 keV: 10.747 %
Attenuation 26.7 keV: 12.466 %

- With preliminary assumptions for SOL conditions (very conservative!) beam penetration marginal in all scenarios except A1 (Casiraghi, 2022)
- CX cross section does not improve with energy
- Higher current ?

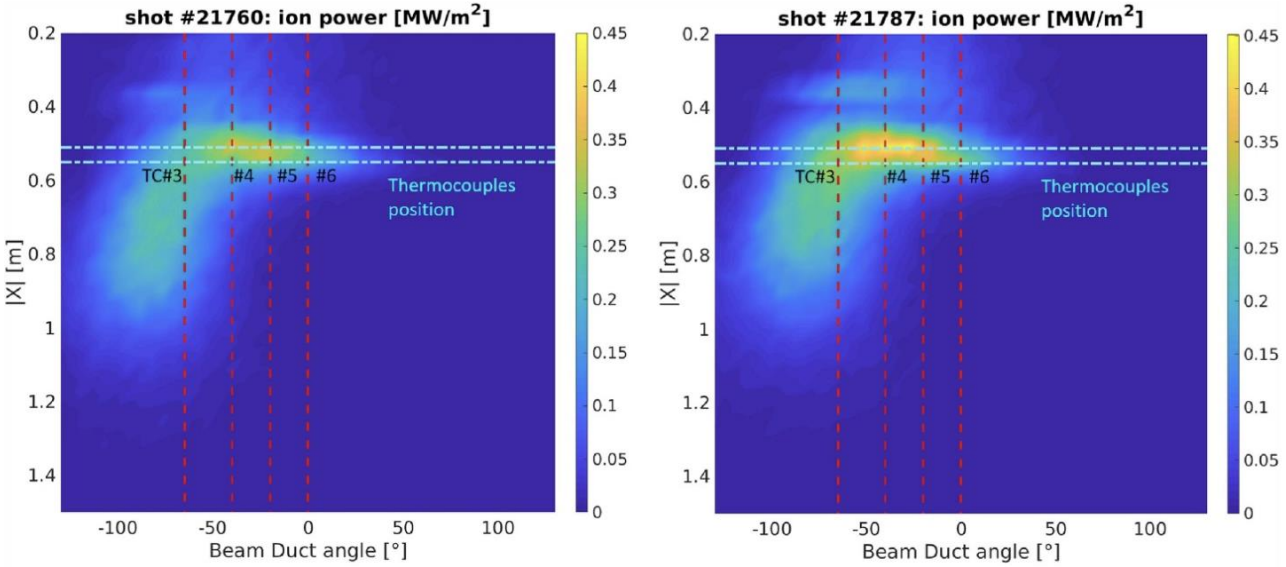
Heat loads due to the beam and residual field

Heat loads at the end of the duct

- Fast Ions in the SOL -> very localized heat load (identification of hot spots)

Power deposition along the beam duct

- Deflection of re-ionized fast neutrals -> Other possible hot spots



- Residual field at 4.5 m is still about 200 mT

⇒Very difficult to image a beam tank at such fields

- Is this a problem also for the heating beams?
- What is max R position for the beam?

Conclusions @ KoM

- On the way to find the best optimization of

Heat Loads vs CX Signal vs Position of the beam

- The other main problem which remains is the purchasability of the beam (COMPASS, TCV bought it from a russian company)

- How much interest is there from DTT on having CX and MSE diagnostics? These diagnostics remain the work horses in current tokamaks for Ti, vrot, nimp, Ip profiles but might not be the only option (polarimetry, …)

Any interest in developing local expertise with adequate R&D for new concepts?

Lasers for LBO prices and requested features (ICF group)

Energy per pulse

QS850-10Hz	47 090 €
QS850-10Hz-2W	54 330 €
QS1500-10Hz	98 340 €
QS1500-10Hz-2W	106 690 €
QS2300-10Hz	136 200 €
QS2300-10Hz-2W	145 900 €

Potential laser systems (+ 450 € shipping) @ 1064 nm

"2W" means that the system is equipped with the second harmonic generator: 532, 355, 266 nm

From KoM:

- 2W not needed, 1 J/10 Hz OK, W7X as reference installation, fixed target/movable beam, carriage to move and replace targets in/out of port (R. Neu)
- Issues with ionization in (unpumped) duct --> could severely reduce particle flux into the plasma
- Port 4 to be equipped with dedicated diagnostics tbd
- Target layer thickness to be evaluated

DXU VUV / XUV / SX

- VUV ---> refurbishing of dual SPRED for JT60-SA ongoing (C. Cianfarani):
  HC source ready for operation (PS on loan from TCV)

- VUV_DIV --> A. Belpane, A. Fassina : Design of in-vessel components:
  waiting for verification from JT60-SA imaging spectrometer

- VUV/XUV --> Acquisition of JET spectrometers (F. Bombarda, visited JET 3-5 July)

- Crystal spectrometer --> F. Bombarda : layout in TH under finalization (Promech); detector selection still pending

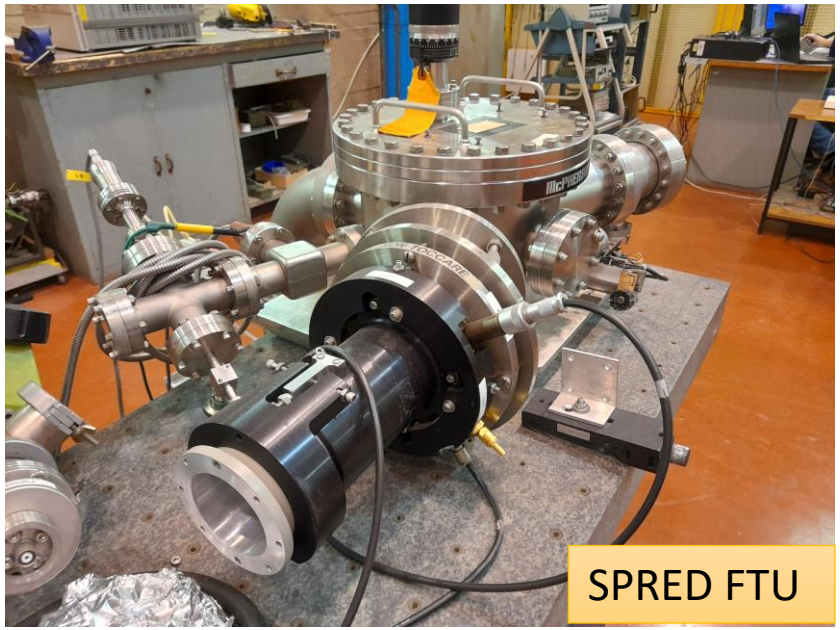
- VH Resolution VUV spectrometer --> M. Giarrusso : motivate the additional diagnostic system, to be started

JET Assets Dispersal Program

- Visit to JET 4-5 July (F. Bombarda, D. Fiorucci, A. Fassina)
- Systems already optioned for DTT (by M. Valisa):
  - KT2 VUV SPRED Survey Spectrometer (in use)
  - KT4 XUV SOXMOS (Schwob) Spectrometer (disconnected from machine since 2015)
  - KX1 Crystal Spectrometer (in use), crystals and old bending jigs already at RFX
  - KL14 & KL9A Viewing Systems --> still of interest?
- Additional requests to be submitted by September (form included) will be allocated on best interest basis.

JET SPRED and SOXMOS

Gratings (g/mm):
290
450 (10-110 nm)
2100



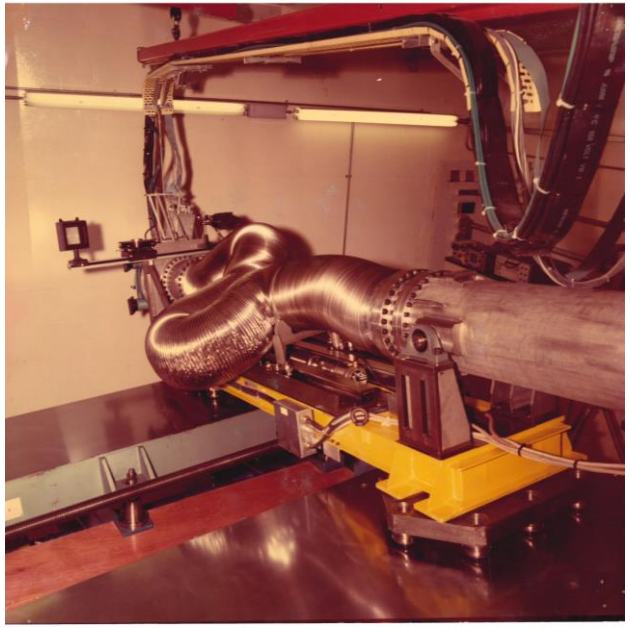
SPRED FTU

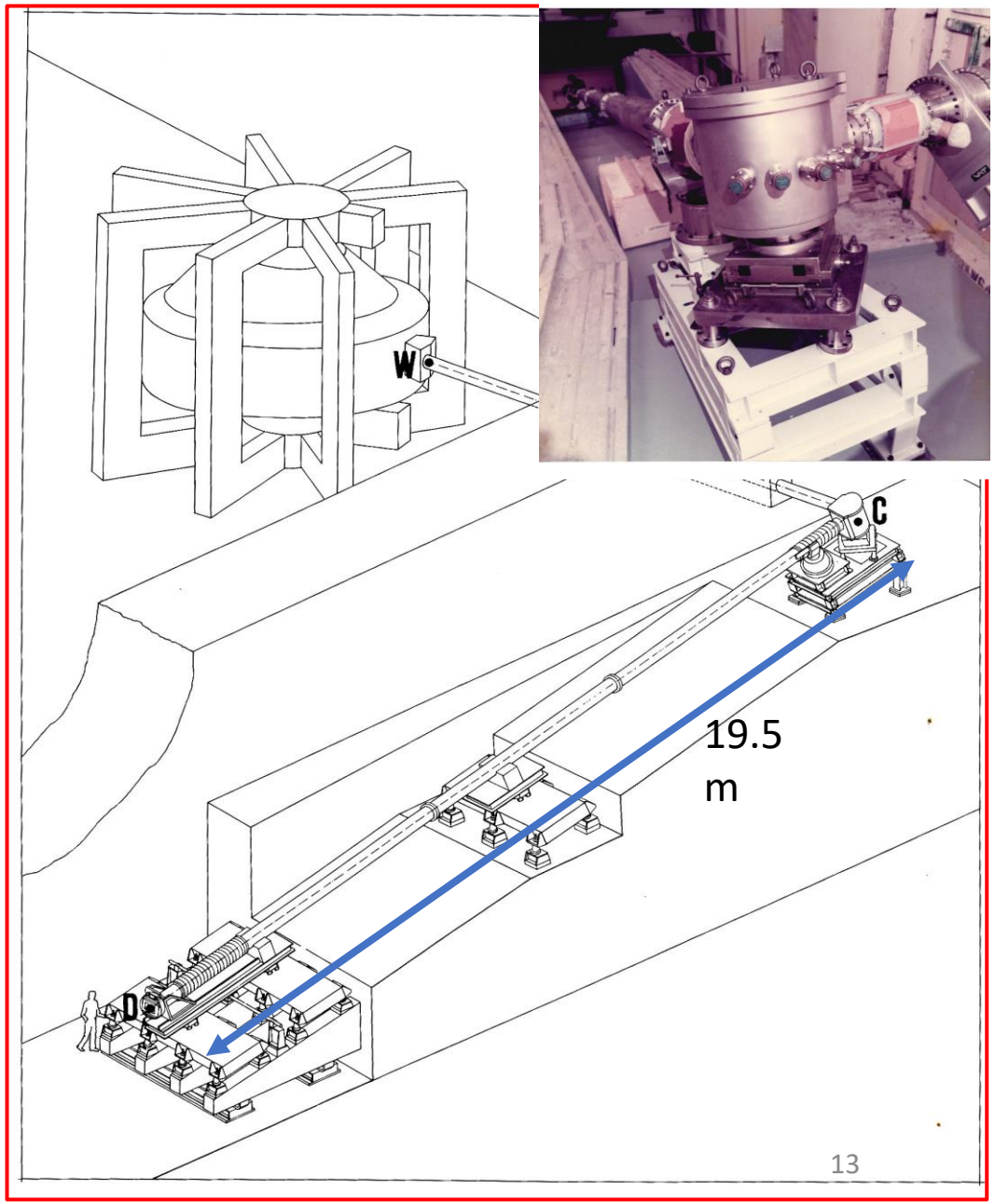
SOXMOS RFX

- Both JET instruments are in working conditions
- MCP/Phosphors + diode array detectors (old but functioning)
- May have/have traces of Be, T contamination, mild activation (no shielding ever adopted, just moved behind bio-shield) -->documentation will be provided
- Available in a couple of years
- Cost of shipping AND handling (disassembly and packaging) will be charged
- Pumps old (to be replaced)
- Glass/Ni coated deflecting mirrors to avoid direct line-of-sight was requested

JET Crystal Spectrometer (built at Frascati)

- Crystal cassette may be of interest (fully motorized)
- Output arm and bellows (unique pieces)--> could be useful
- New crystal holders and detectors already optioned by others and not of interest for DTT
- Huge hardened steel tables and sliding supports?
- No contamination /little or no activation (T compatible diagnostics from day0)

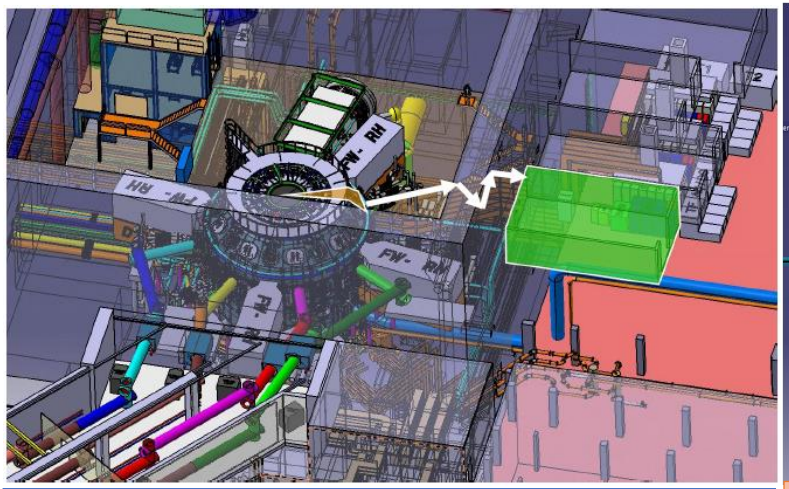




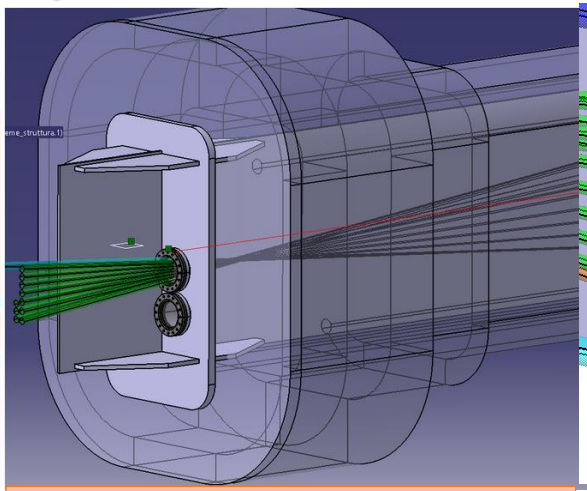
DVI Visible

- Visible/Zeff ---> L. Carraro (A. Belpane) update
- THB (Thermal Helium Beam) --> M. Agostini : To be started (Port?)
- Divertor D_alpha synthetic diagnostic --> F. Subba : so far focus more on main SOL conditions, in particular evaluation of neutrals on other diagnostics (Visible/Zeff, CXRS); update scenarios and divertor geometry
- VH resolution divertor spectroscopy --> F. Leone : motivate the additional diagnostic system, to be started (initial steps x contract)

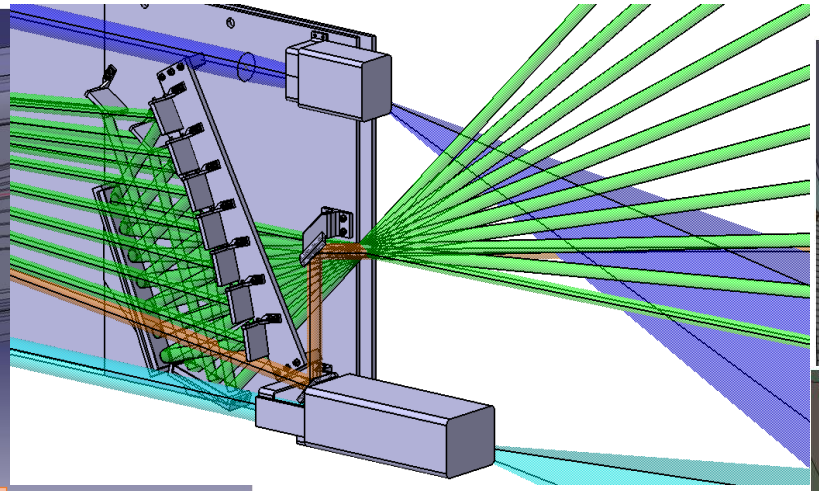
VIS: Zeff, Visible Survey, VFID



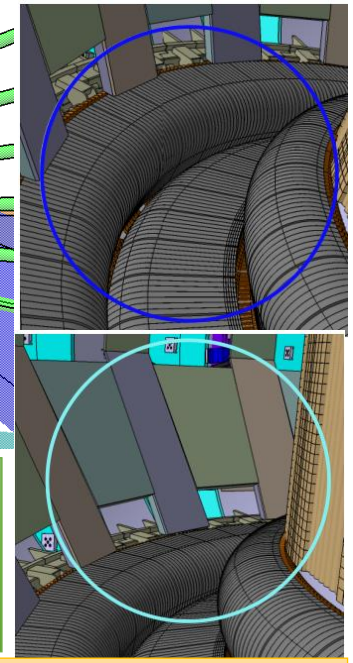
- Optical path from S3P3 to Spect. Lab traced
- 50% light loss estimated with 30 m fiber
- Dogleg design being changed?



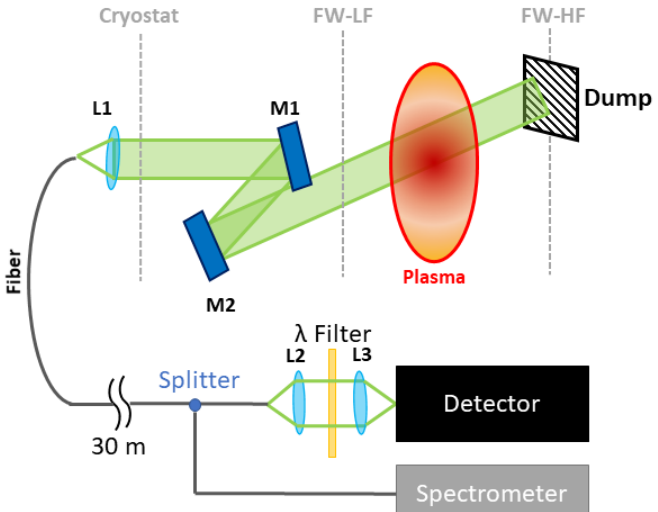
- 3 or 4 windows (CF100) on port flange
- Double sapphire glass with monitored interspace



- Port plug OK?
- Positioning of dumps on inner FW
- Shutter to be finalized



Good view of divertor, with this geometry



- Multiple systems can use the same collection optics
- Multi LoS High resolution (HR) Spectrometers and single LoS low resolution (LR) compact spectrometers (340-800 nm) : number and models tbd
- VFID can be coupled to the divertor images (additional optics in P2?)

A. Belpane et al, Proceed. 5th ECPD, Crete, April 2023; Paper to be submitted to PPCF

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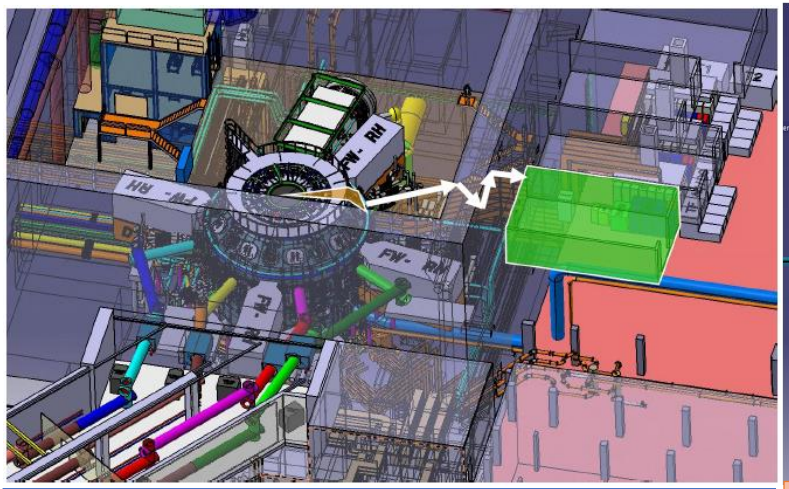

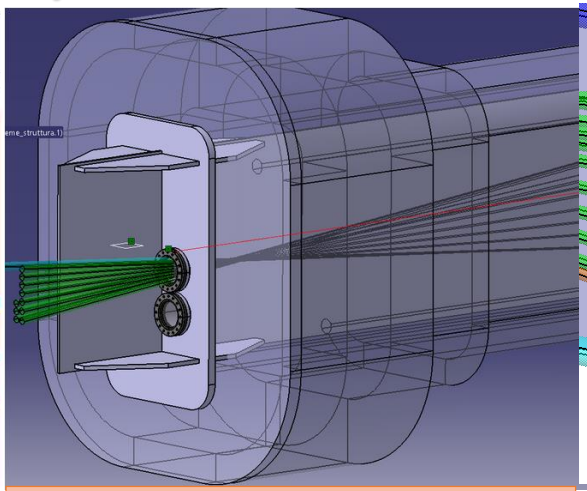

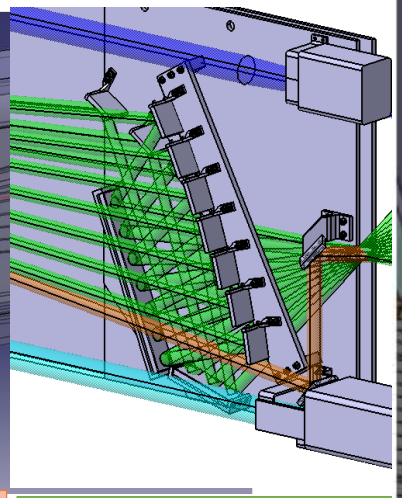

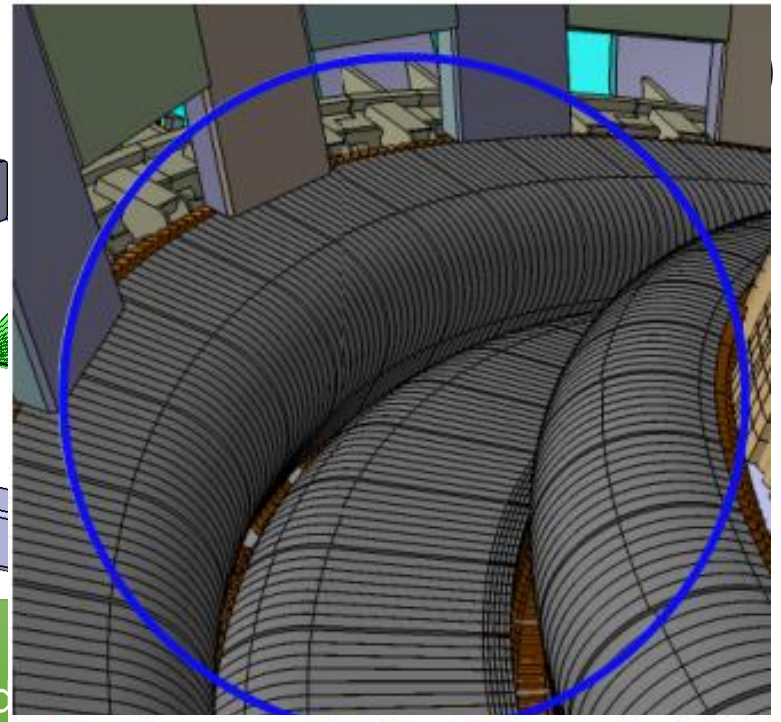

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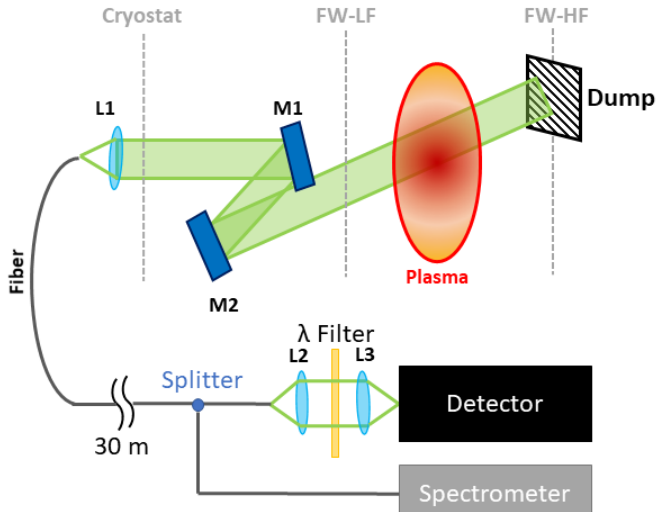

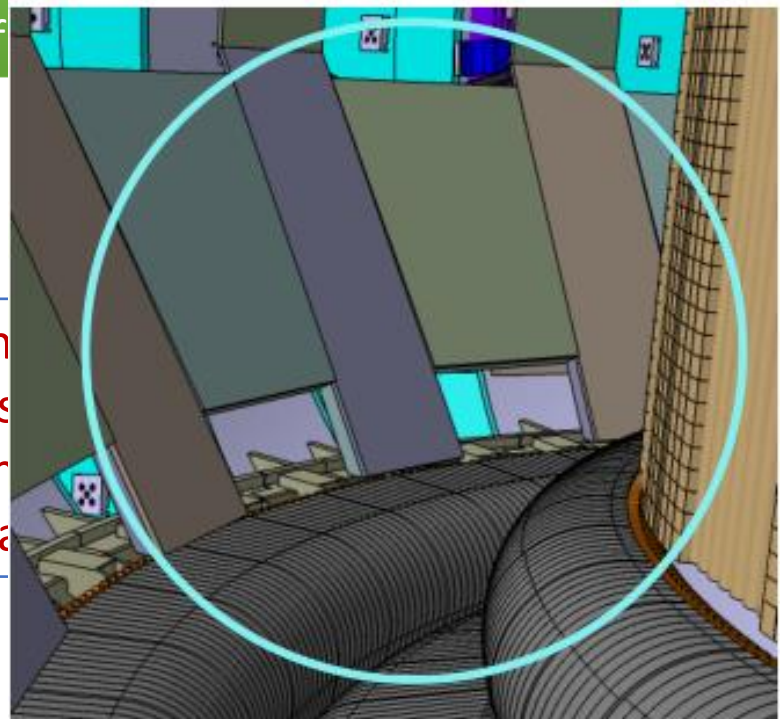

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A. Belpane et al, Proceed. 5th ECPD, Crete, April 2023;

Auxiliary Common Activities

- Complete assessment of cost diagnostics (in progress)
- Preliminary assessment of shielding structures for detectors and front-end electronics in TH (may not be necessary for a long time)
- Basic CODAS architecture for remote control
- Cable and light routing (by EoY)
- Vacuum pumping, cooling and gas requirements (by EoY)
- Integration of atomic databases (on-going)

Thank you for your attention!