Radiation safety at the PRIMA facility: a review of shielding solutions and personnel dose assessment

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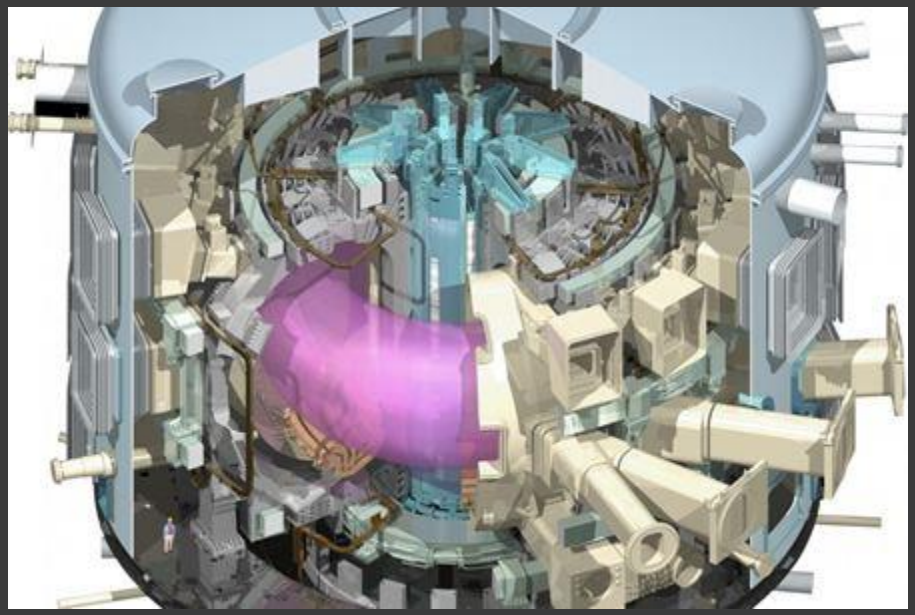
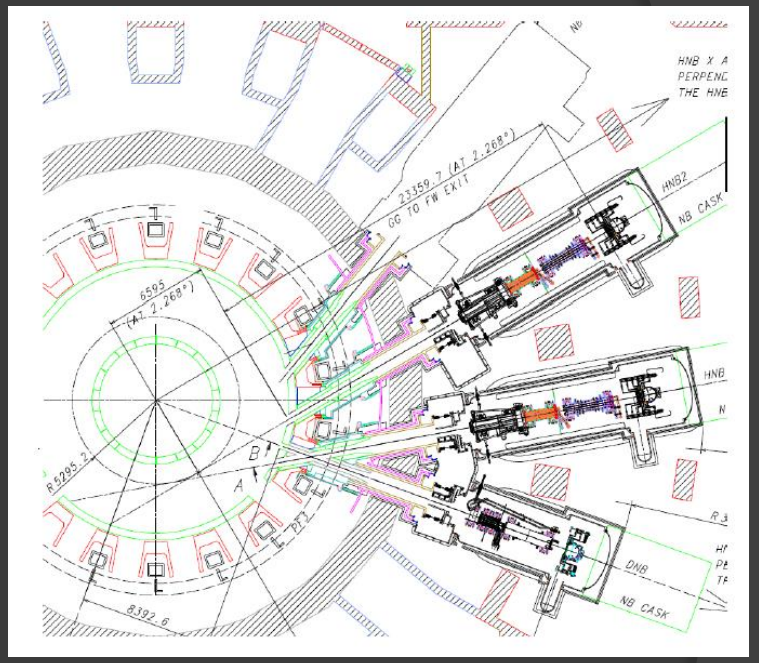
Outlines

- ITER Neutral Beam System
- PRIMA Project in Padua
- RP solutions and design
- Workers safety
- Population safety
- Conclusion

ITER neutral system

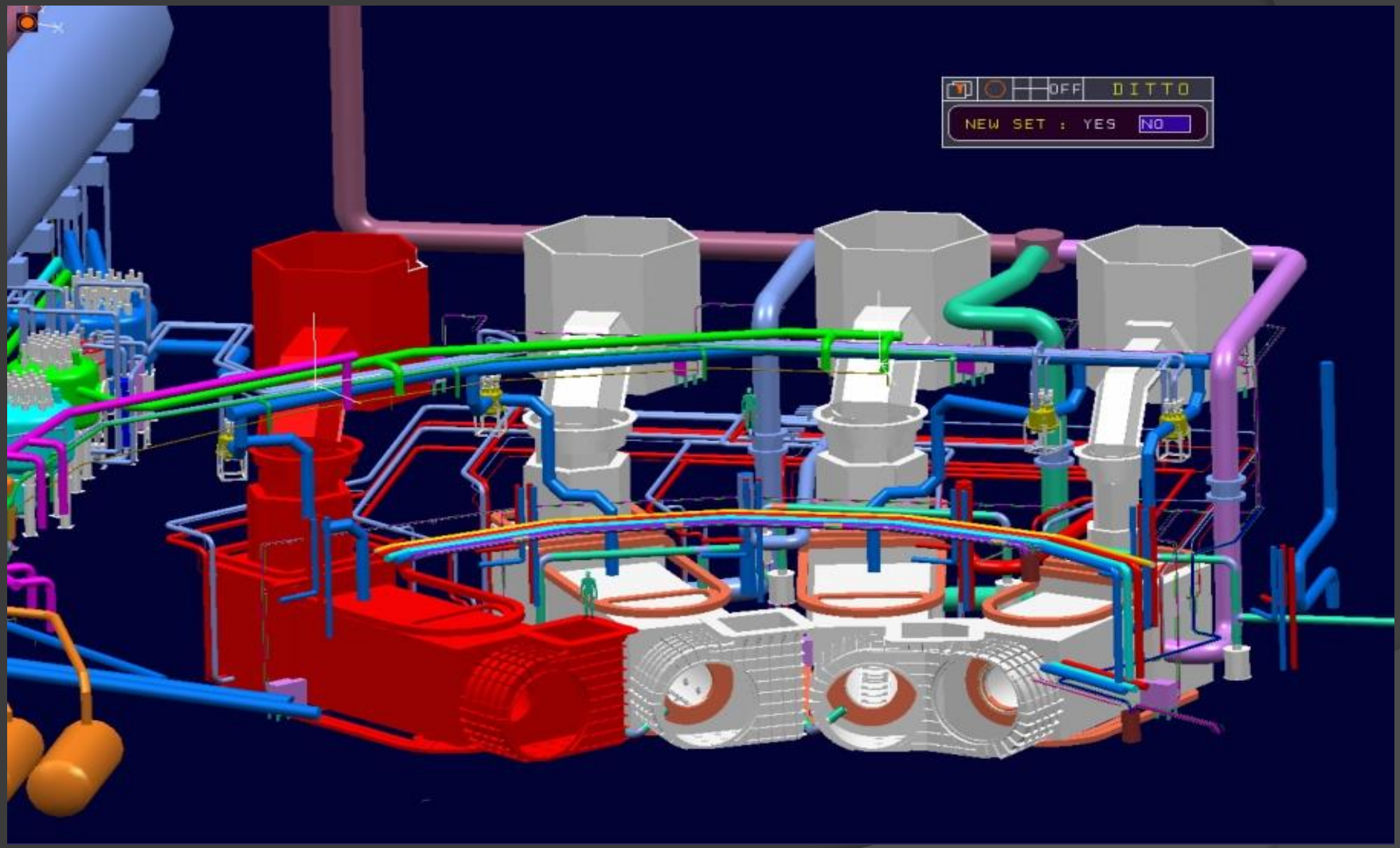
PRIMA is the testing facility for the ITER NBIs (Neutral Beam Injectors).



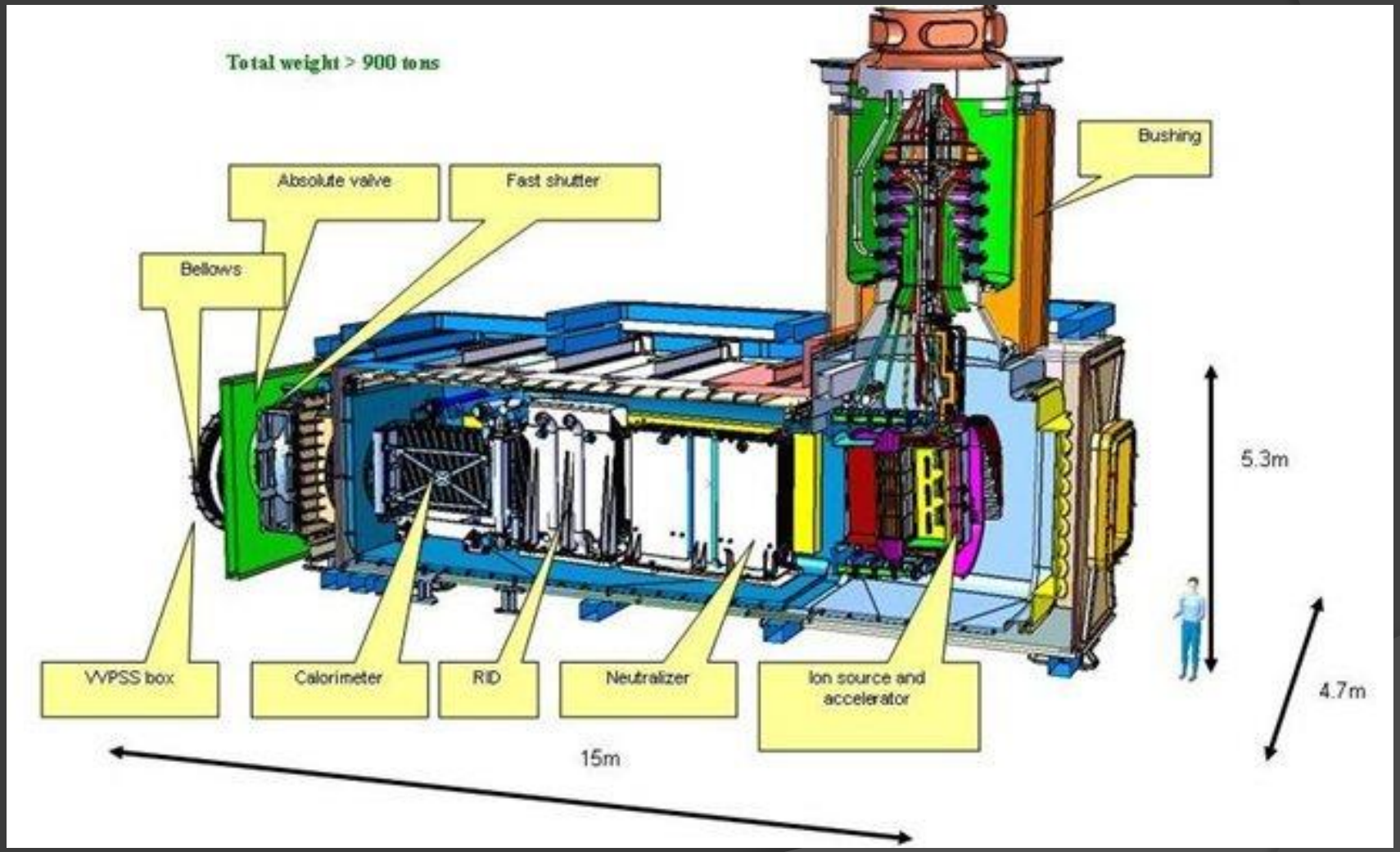


The NBI system delivers a high-energy beam of neutral atoms (typically a hydrogen isotope such as deuterium) into the core of the tokamak plasma. These energetic atoms transfer their energy to the plasma, raising the overall temperature

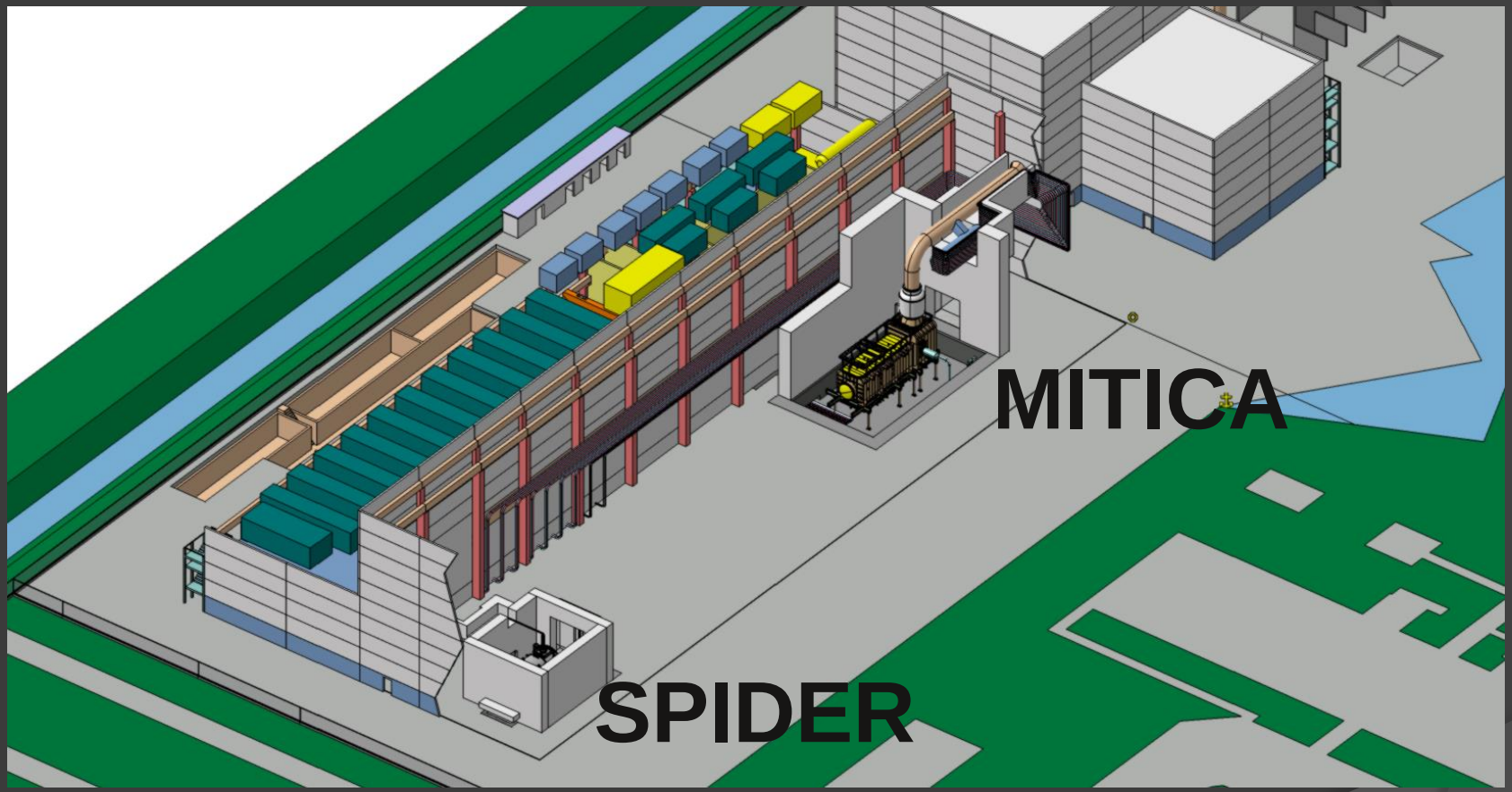
ITER Neutral Beam Injector layout



ITER Neutral Beam Injector



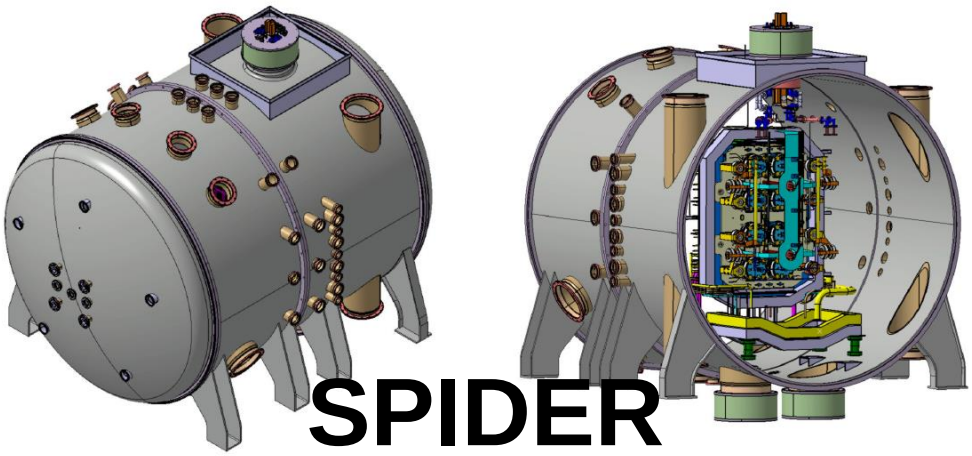
PRIMA project



- Megavolt ITER Injector Concept Advanced - the whole system
- 1 MeV, 40 A

- Source for Production of Ion of Deuterium Extracted from RF Plasma - ion source only
- 100 keV, 40 A

Proton and deuteron reactions



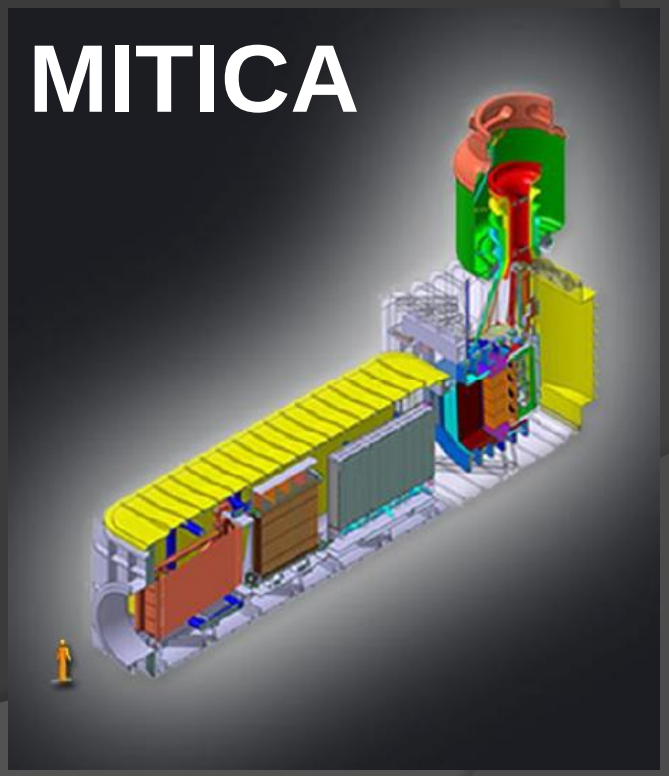
In the case of the deuterons the following (d,d) reactions may occur:

$^{2}H + {}^{2}H \Rightarrow {}^{3}He + n$

$^{2}H + {}^{2}H \Rightarrow {}^{3}H + {}^{1}H$

And then:

$^{2}H + {}^{3}H \Rightarrow {}^{4}He + n$



Protons and deuterons with a maximum energy of 1 MeV are completely stopped in the dumps.

Their mean free path in such material is about 0.1 mm and the dump walls are at least 2 mm thick.

Actually in SPIDER the maximum energy will be about 100 keV

Sources at MITICA and SPIDER

- neutrons and photons production due to D-D and D-T interactions in the dump
- airborne tritium in working premises
- activation from neutrons produced during irradiation phase
- activated corrosion products (ACP) in the coolant and on the inner surface of the cooling pipes and of the other cooling system components

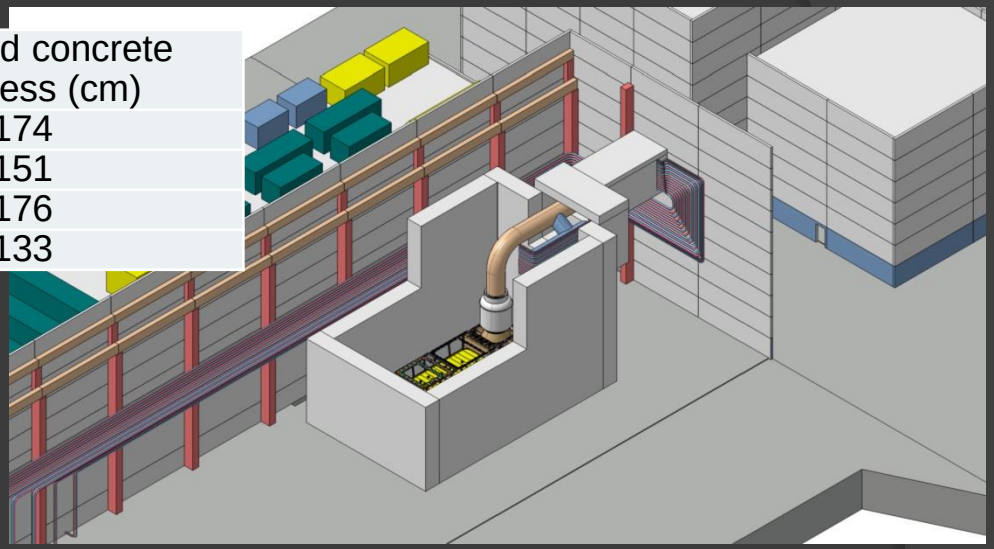
Italian dose limits and design constraints

Categories (zoning)	Individual Effective Dose Limits (mSv/ year)	Annual Constraints (mSv/ year)	Hourly Constraints (μSv/ h)
Population (free zone)	1	0.5	0.25
Cat. B Radiation Workers (supervised zone)	6	3	1.5
Cat. A Radiation Workers (controlled zone)	20	10	5

- The constraints adopted for the PRIMA design were stated multiplying the limits by a safety factor of 0.5.
- The hourly constraints are obtained by considering 2000 hours of working time during each year.

MITICA Shielding Walls

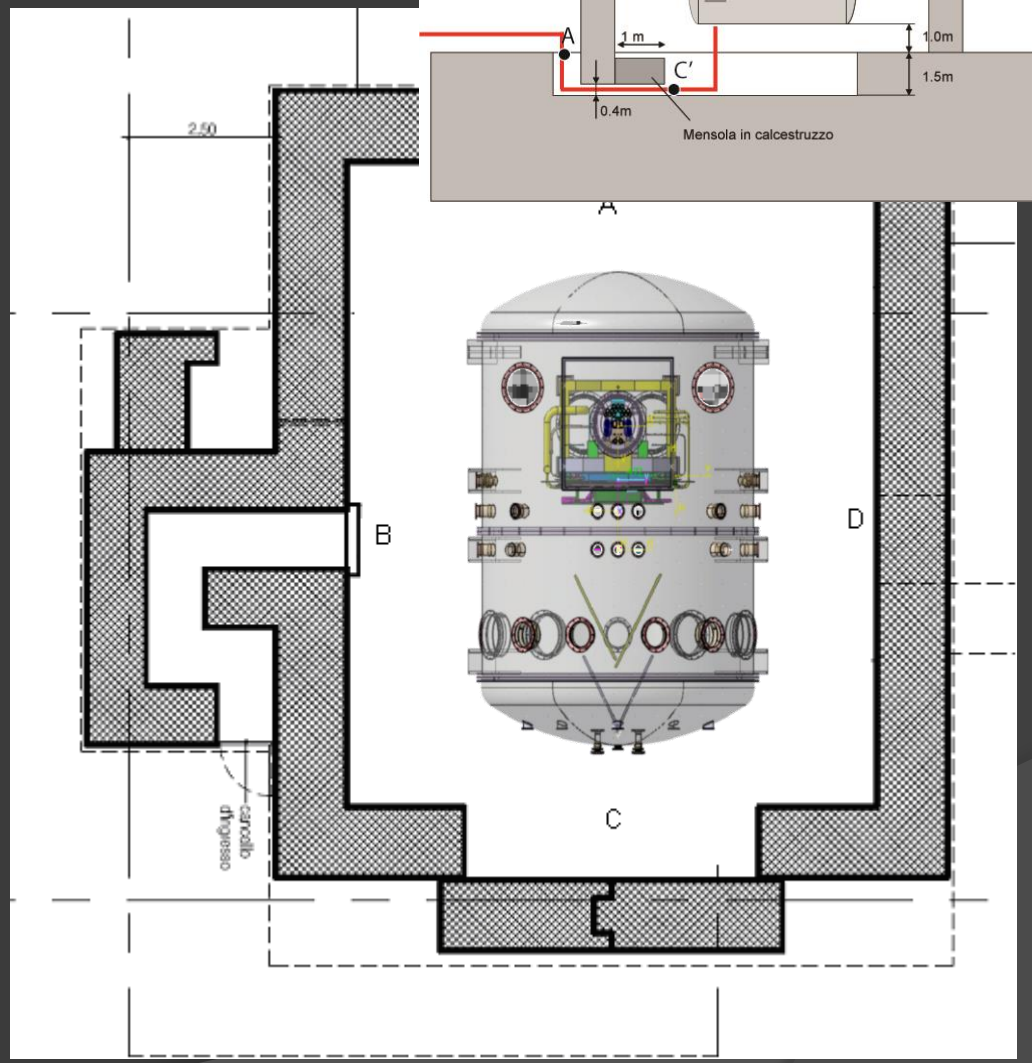
	Attenuation coefficients	Standard concrete thickness (cm)
BL VESSEL	1,09E+06	174
BS VESSEL	1,71E+05	151
NB front end	1,22E+06	176
NB rear end	4,12E+04	133



- 180 cm from the floor and for an eight of 3 m from the MITICA symmetry axis in the front end and BL vessel areas,
- 155 cm from the floor and for an eight of 3 m (as above),
- 135 cm from the floor and for an eight of 3 m from the MITICA symmetry axis in the rear end area,
- the upper part of the MITICA wall, over 3 m from the MITICA symmetry axis, could have a thickness reduced by 30% of the lower one
- 95 cm of standard concrete for the roof, reduced by a 20% in the area of the BSV

SPIDER shielding walls

- 120 cm from the floor and for an eight of 3 m from the SPIDER symmetry axis in the front end and BLV areas,
- 95 cm from the floor and for an eight of 3 m from the SPIDER symmetry axis in the BSV area,
- 80 cm from the floor and for an eight of 3 m from the SPIDER symmetry axis in the rear end area,
- the upper part of the SPIDER walls, over 3 m from the SPIDER symmetry axis, could have a thickness 30% less of the lower one
- 90 cm is needed for the ceiling



Anticipated worker groups

- Administration
- Engineering & Technical Support
- Facility Services
- Maintenance (mechanics, electricians, welders, etc.)
- Operations
- Safety Group
- Scientific Support

MITICA: Workers annual dose

Group	Neutron-Photon dose (mSv)	Activation dose (mSv)	Tritium dose (mSv)	ACP dose (mSv)	Total annual dose (mSv)
Administration	0.00	0.00	0.00	0.00	0.00
& Tech. Support	0.5	0.00	0.00	0.00	0.50
Facility Services	0.5	0.00	0.00	0.00	0.50
Maintenance	0.5	0.55	0.00	0.18	1.23
Operations	0.5	0.00	0.00	<0.001	<0.501
Safety Group	0.5	0.00	0.00	<0.001	<0.501
Scientific Support	0.5	0.00	0.00	0.00	0.50

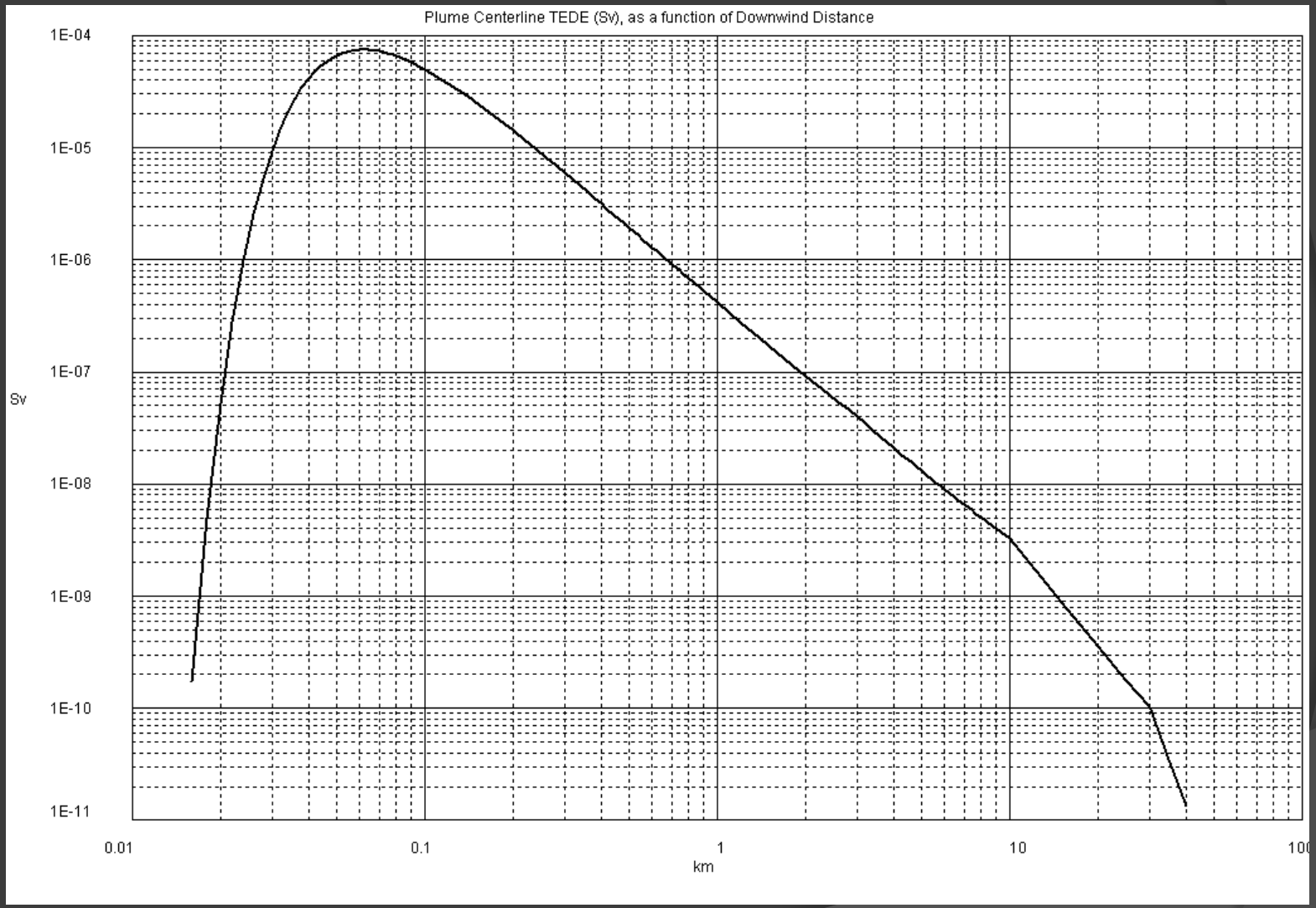
SPIDER: Workers annual dose

Group	Neutron-Photon dose (mSv)	Activation dose (mSv)	Tritium dose (mSv)	ACP dose (mSv)	Total annual dose (mSv)
Administration	0.00	0.00	0.00	0.00	0.00
& Tech. Support	0.5	0.00	0.00	0.00	0.50
Facility Services	0.5	0.00	0.00	0.00	0.50
Maintenance	0.5	0.2	0.00	0.001	0.701
Operations	0.5	0.00	0.00	<0.001	<0.501
Safety Group	0.5	0.00	0.00	<0.001	<0.501
Scientific Support	0.5	0.00	0.00	0.00	0.50

Annual doses due to tritium intake

Exposure way	Distance from the source	Reference Group	Dose
Inhalation + Submersion (HOT-SPOT)	40 m	Workers	0.23 µSv/yr
	100 m	Population	0.16 µSv/yr
	1000 m	Population	15 nSv/yr
Inhalation + Submersion (GENII-LIN)	< 100 m	Workers	N.A.
	100 m	Population	0.15 µSv/yr
	1000 m	Population	0.5 nSv/yr
Total dose (RESRAD)	Constant for d > 50 m	Population	1.65 µSv/yr
Total dose (GENII-LIN)	50 m	Population	0.55 µSv/yr
	1000 m	Population	1.1 nSv/yr

Dose to population after general fire



Dose for maintenance of cooling loops

Critical Item	Total Dose (μSv/yr)			
	MITICA		SPIDER	
	t = 6 hr	t = 24 hr	t = 6 hr	t = 24 hr
Main Pump	11300	83.9	59.1	0.6
Heat Exchanger	7400	51.8	38.1	0.3
Large Valve	4500	35.4	23.4	0.2
TOTAL	23.2E3	171.1	120.6	1.1

Conclusions

- The analysis described in the current work indicates that the radiation safety system for PRIMA facility is appropriate in maintaining the individual doses for workers and population well below the Italian (and internationally stated) regulatory limits.
- The analysis has shown that, from the radiological point of view, PRIMA is safe both for the workers and the population.
- The final safety report for SPIDER has been submitted to the Italian regulatory authorities for the licensing process to be completed.
- The analysis for MITICA is completed and the final report is in the publishing phase

THANK YOU