



**FUSION  
FOR  
ENERGY**

# **Radiological and Environmental Monitoring System**

## **Market Survey - System Description**

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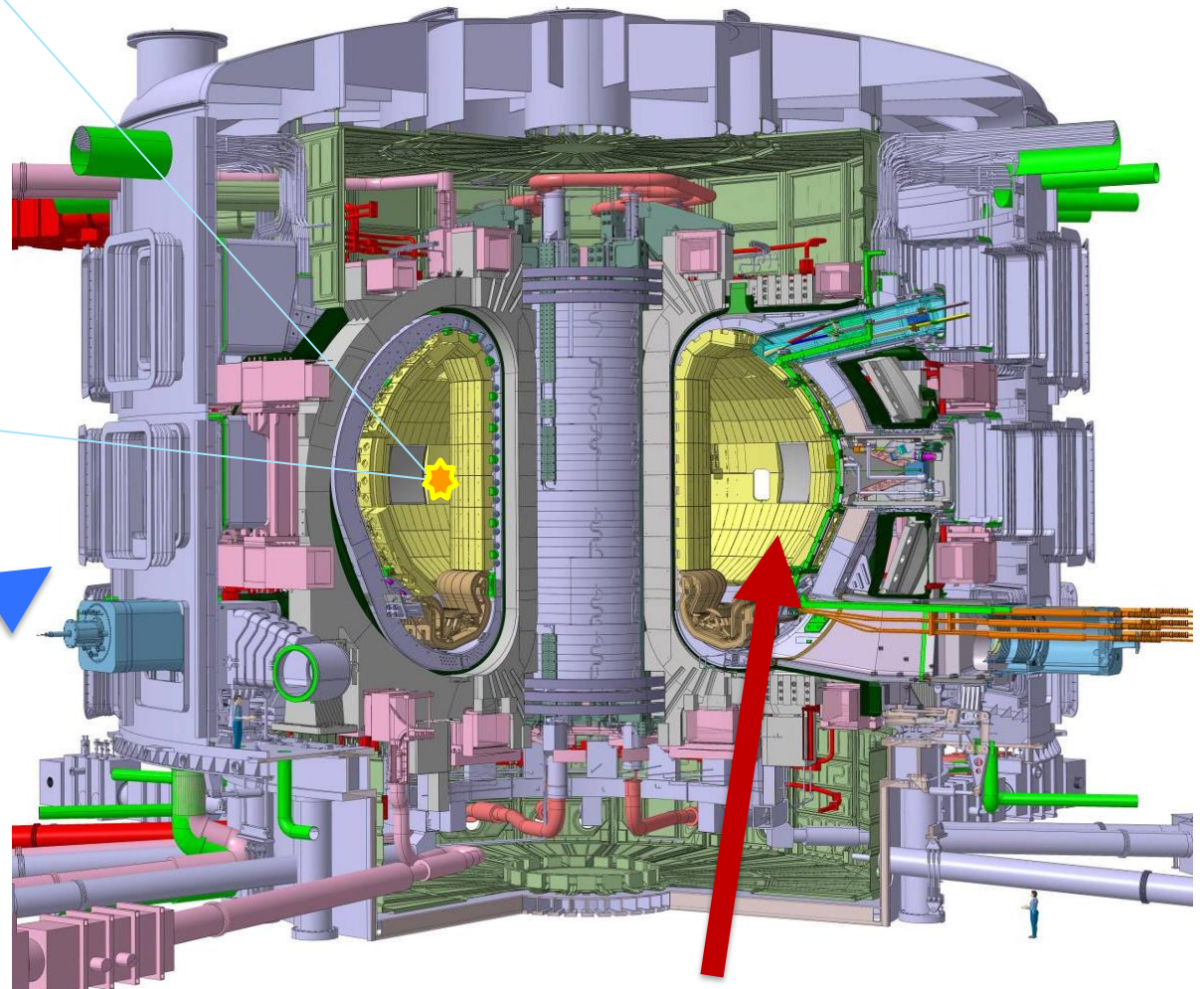
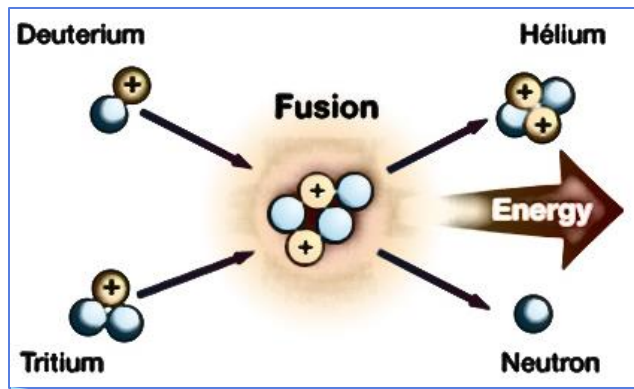


Aim of the presentation is to inform potentially interested suppliers on:

- Function of the ITER Radiological and Environmental Monitoring System (REMS)
- Scope of the whole F4E procurement package\*;
- F4E procurement strategy with the planned Supply contracts for:
  - Tokamak Complex for Nuclear Operation;
  - Hot Cell Complex for Nuclear Operation;

*\* Any proprietary instrument shown in this presentation has to be considered only as a proposal coming from the Preliminary Design and not as a final choice. The Manufacturer and/or supplier of each type of equipment may change and will be fixed at the time of contract award.*

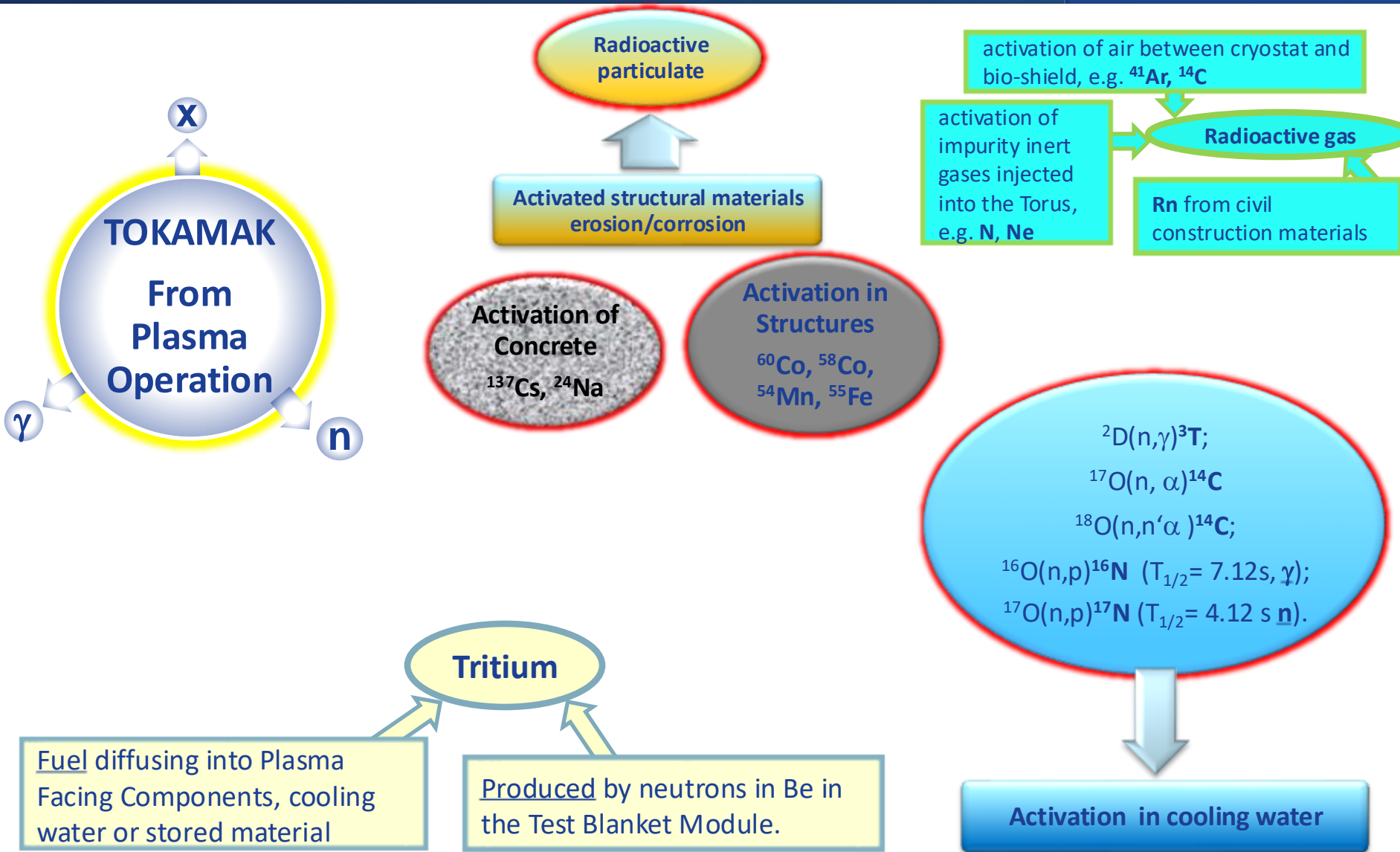
# REMS Overview: The TOKAMAK



Cryostat

Toroidal Vacuum vessel

# REMS Overview: Radiological Hazards



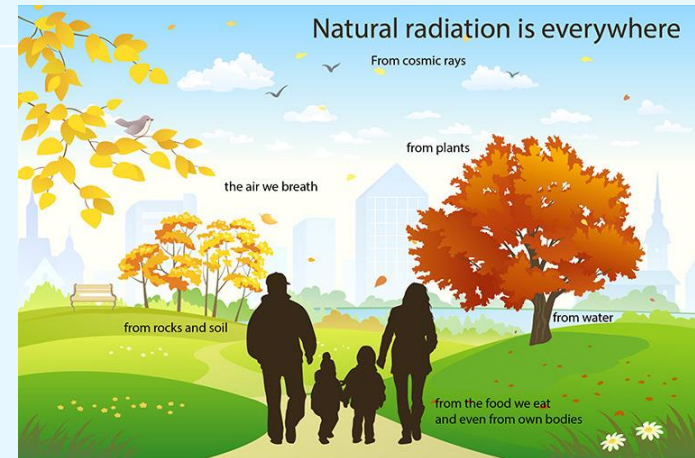


The Radiological and Environmental Monitoring System provides:

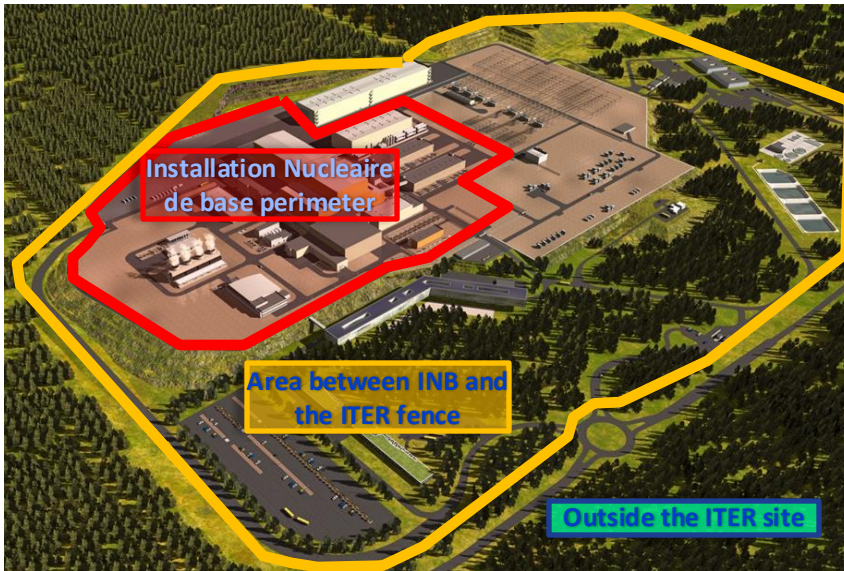
## Health and Radiological monitoring of Workers



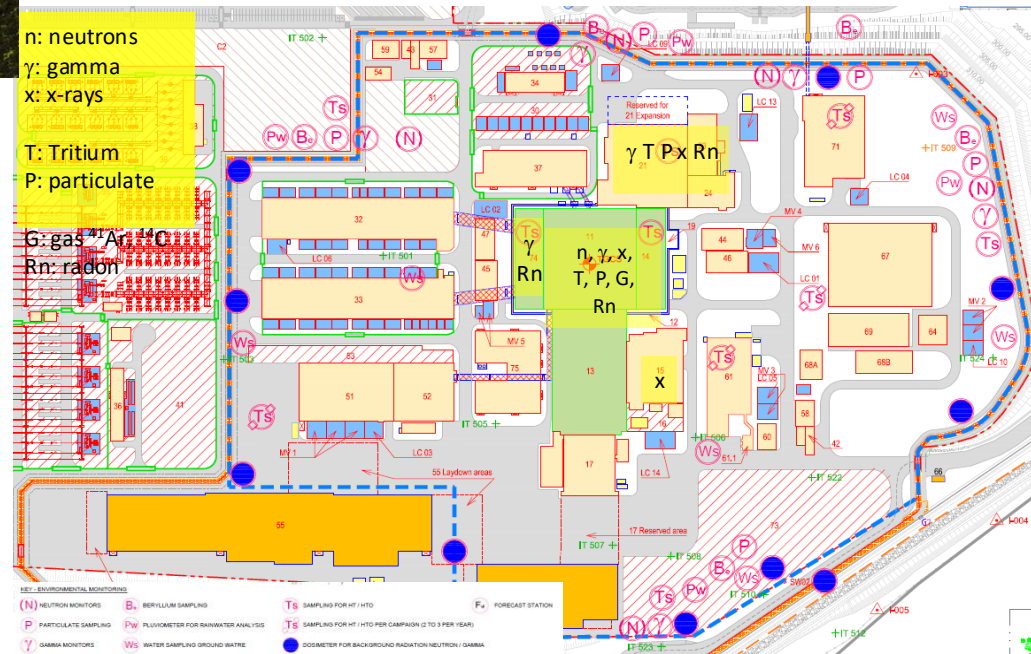
## Area and environmental monitoring for Public



by **assisting ITER IO** in the protection from ionizing radiation and Be during the whole life of ITER from construction to operation and decommissioning.

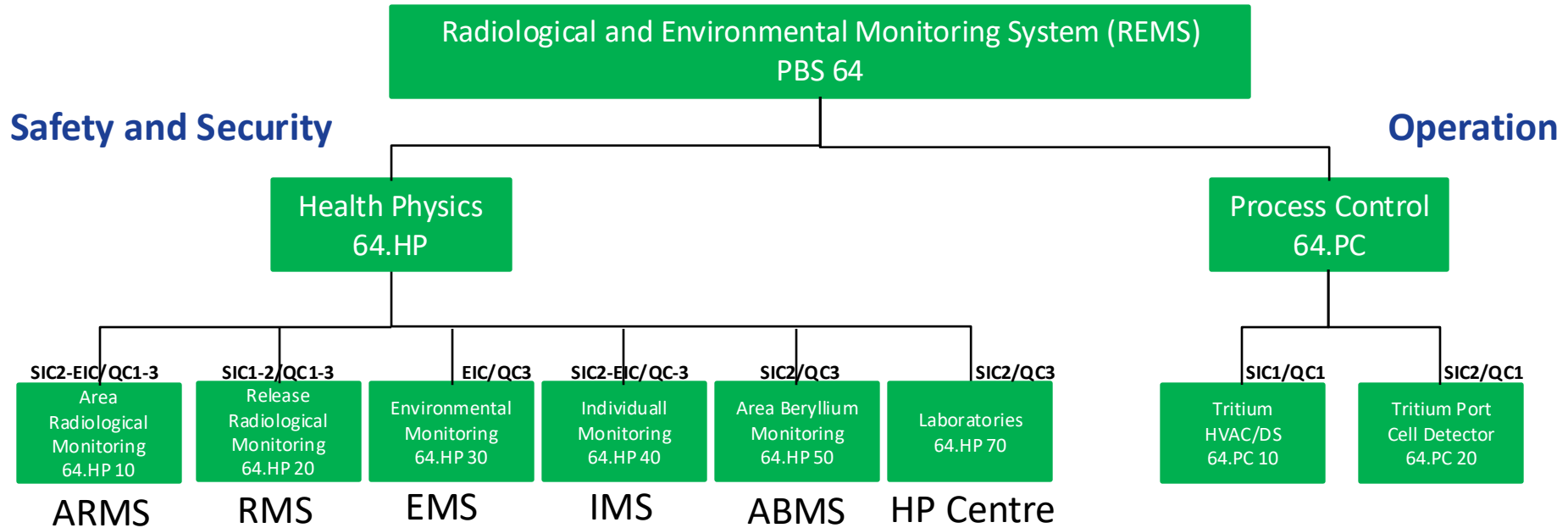


Radiological and environmental monitoring is performed with both portable and fixed equipment



Public, environment and worker protection require monitoring for the radiological hazards both in- and off-site

# Overview of REMS: Sub-systems



## 1. Area Monitoring to confirm Compliance with reference Radiological Zoning Limits.

white	unregulated zone (< 80 $\mu\text{Sv}$ in one month)
Blue	supervised zone (< 7.5 $\mu\text{Sv}$ in one hour)
Green	controlled zone - not specially regulated (< 10 $\mu\text{Sv/h}$ )
Yellow	controlled zone - specially regulated (< 100 $\mu\text{Sv/h}$ )
Orange	controlled zone - specially regulated (< 100 $\text{mSv/h}$ )
Red	controlled zone - human access forbidden ( $\geq 100 \text{ mSv/h}$ )

## 3. Area Monitoring of Workplace Hazards and efficiency of confinement-Worker protection.



## 2. Area Sampling to confirm compliance with reference limits of Be concentration in air.

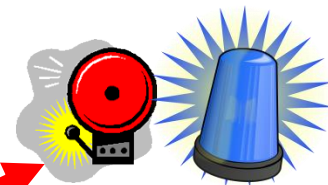
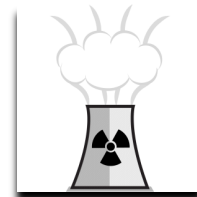
Beryllium zone	Air concentr. ( $\mu\text{g}/\text{m}^3$ )	Access and control conditions
Beryllium non-controlled zone	< 0.01	<ul style="list-style-type: none"> <li>no plausible risk of presence of Be,</li> <li>no access limitation.</li> </ul>
Beryllium controlled zone	$0.01 < [\text{Be}] < 0.2$	<ul style="list-style-type: none"> <li>no dispersion risk for Be aerosols, vapour and dusts,</li> <li>possible presence of Be, in concentrations above the detection limits of monitoring equipment,</li> <li>access limited to Be-qualified personnel,</li> <li>stay times and possible safeguards adapted to the risk of exposure, depending on the operations to be performed.</li> </ul>
Beryllium zone with respiratory protection	> 0.2	<ul style="list-style-type: none"> <li>presence of contamination and/or potential to exceed the limits for Be controlled zone.</li> <li>Access limited to especially qualified Be-staff.</li> <li>Confined and ventilated zone requiring use of respiratory protection gear.</li> </ul>





# Area Radiological Monitoring Sub-system (ARMS)

Stationary, mobile and portable radiation/contamination monitors and samplers inside the ITER facility rooms



Local rad. Warning in rad. contr. areas



Local warning on malfunctioning.



Inform HP-C & Operator in CSS (M/B-up) and CODAC

Detect accident/incident



Check rad. levels within ITER rad. zoning limits

white
Blue
Green
Yellow
Orange
Red

- unregulated zone (< 80  $\mu$ Sv in one month)
- supervised zone (< 7.5  $\mu$ Sv in one hour)
- controlled zone - not specially regulated (< 10  $\mu$ Sv/h)
- controlled zone - specially regulated (< 100  $\mu$ Sv/h)
- controlled zone - specially regulated (< 100 mSv/h)
- controlled zone - human access forbidden ( $\geq$  100 mSv/h)



Monitor radiation hazard during operation and decommissioning and efficiency of confinement



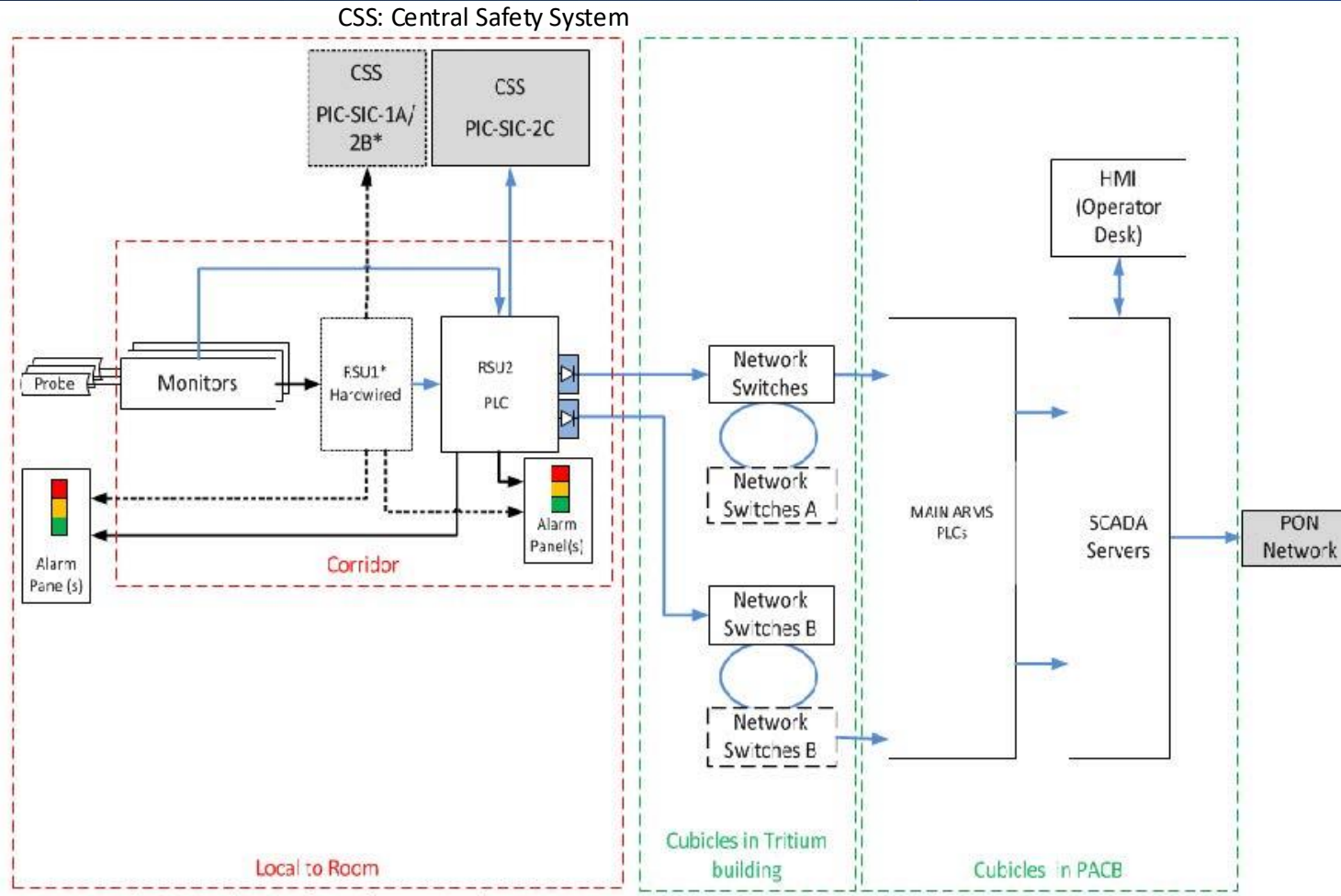
Inform CSS to allow/block access



Data to CODAC for archiving

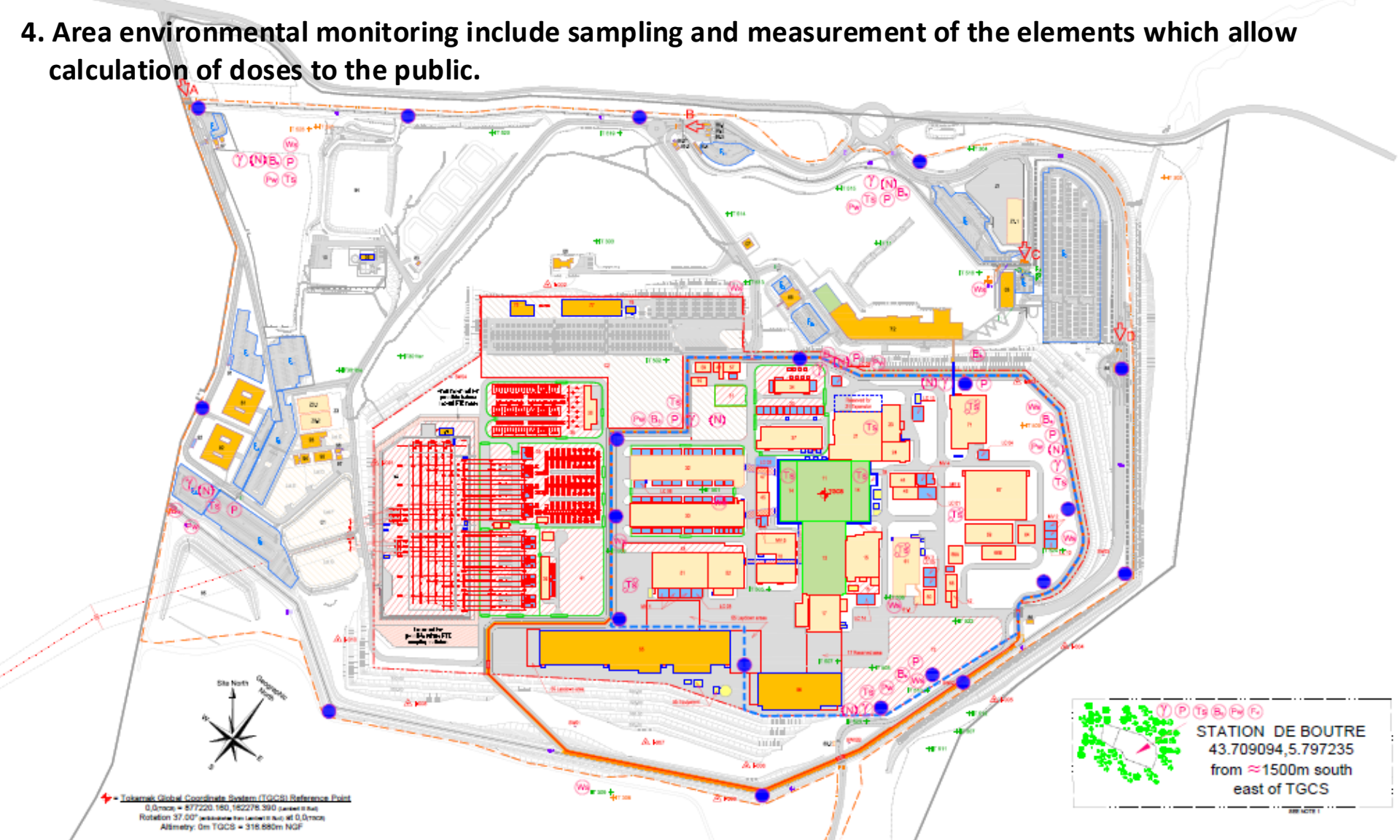
# ARMS: Architecture

- In the architecture the local alarms presented to the workers are processed locally to the room.
- This is done in the Radiological Synthesis Units (RSU), typically located in the corridors or airlocks (lower radiological and magnetic exposure).



\*PIC-SIC-1A/2B interface where required.  
 PIC-SIC-1A/2B will have a second independent channel (not shown) with independent monitor and logic  
 Grey boxes refer to out of REMS scope systems

4. Area environmental monitoring include sampling and measurement of the elements which allow calculation of doses to the public.



STATION DE BOUTRE  
 43.709094, 5.797235  
 from ≈1500m south  
 east of TGCS

↑ Tokamak Global Coordinate System (TGCS) Reference Point  
 0,0 mtrs = 877220,150, 182278,390 (rounded to 0.1m)  
 Rotation: 37,50° anticlockwise from Cartesian X axis, all 0,0 mtrs  
 Altitude: 0m TGCS = 316,680m NGF

KEY - ENVIRONMENTAL MONITORING

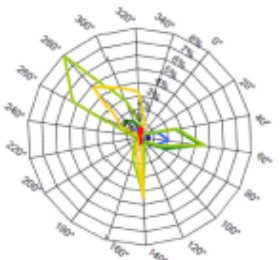
- (N) NEUTRON MONITORS
- (P) PARTICULATE SAMPLING
- (Y) GAMMA MONITORS
- (Be) BERYLLIUM SAMPLING
- (PW) PLUVIOMETER FOR RAINWATER ANALYSIS
- (Ws) WATER SAMPLING GROUND WATRE
- (Ts) SAMPLING FOR HT / HTO
- (Ts) SAMPLING FOR HT / HTO PER CAMPAIGN (2 TO 3 PER YEAR)
- (Fst) FORECAST STATION
- (Blue Circle) DOSIMETER FOR BACKGROUND RADIATION NEUTRON / GAMMA

KEY - BUILDINGS AND AREAS

- (Yellow Box) COMPLETED BUILDINGS
- (Grey Box) ROADS

KEY - BOUNDARIES AND DETAILS

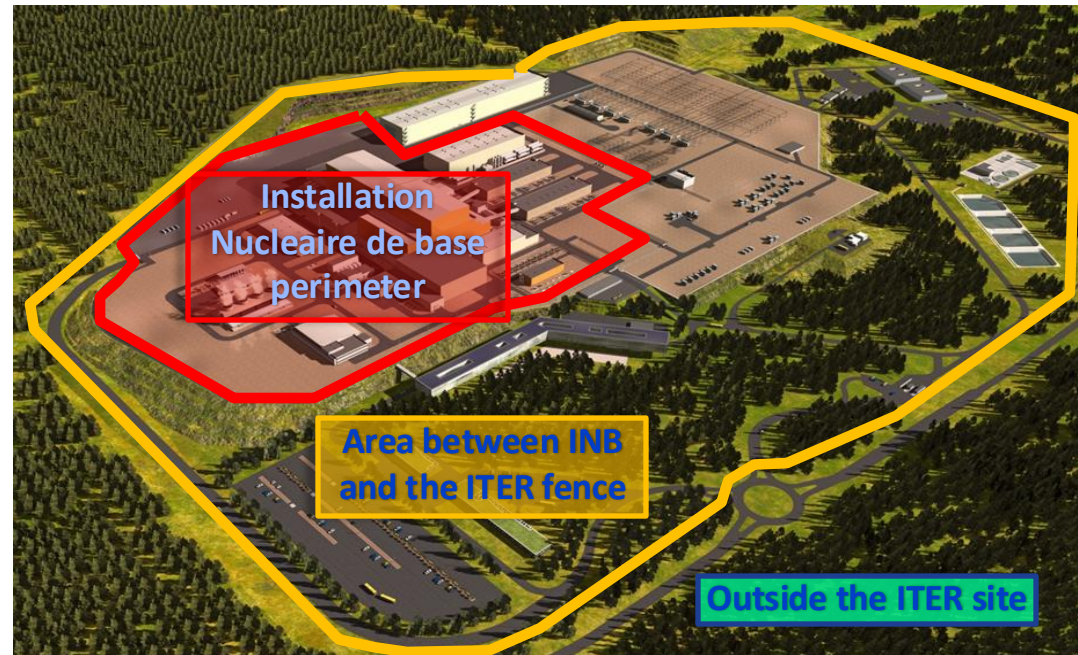
- (Blue Dashed Line) VIRTUAL INB PERIMETER
- (Red Dashed Line) IO PLATFORM BOUNDARY
- (Red X) ITER SITE ENTRANCE POINTS





Inside the INB perimeter and between INB perimeter and ITER fence;

- a)  $\gamma$  background
- b) Neutrons
- c) Tritium (HT, HTO)
- d) Radioactive particulate
- e) Beryllium
- f) Groundwater and Rainwater
  - $^{14}\text{C}$ , HT/HTO,
  - $\beta$ ,  $\gamma$  emitting particulate
  - Chemicals, Toxic



Outside the ITER site.

1.  $\gamma$  background
2.  $\alpha$ ,  $\beta$ ,  $\gamma$  emitting particulate, Be
3.  $^{14}\text{C}$  gas, HT/HTO
4. Rainwater
5. Meteorology (wind speed/direction, temperature, humidity and pressure).



# REMS Overview: Main Functions Release Monitoring System Gaseous

5. Monitoring of the release pathways of liquid and airborne radioactive substances and the quantity discharges determined to demonstrate compliance with the authorised effluent discharge levels and to determinate the impact of the release of radioactive substances on the environment in the vicinity of the plant (French Order).

### SIC DUCT

Diameter of 1.20 m

Qv = 44 820 m<sup>3</sup>/h

### NON SIC DUCT

Diameter of 4.00m

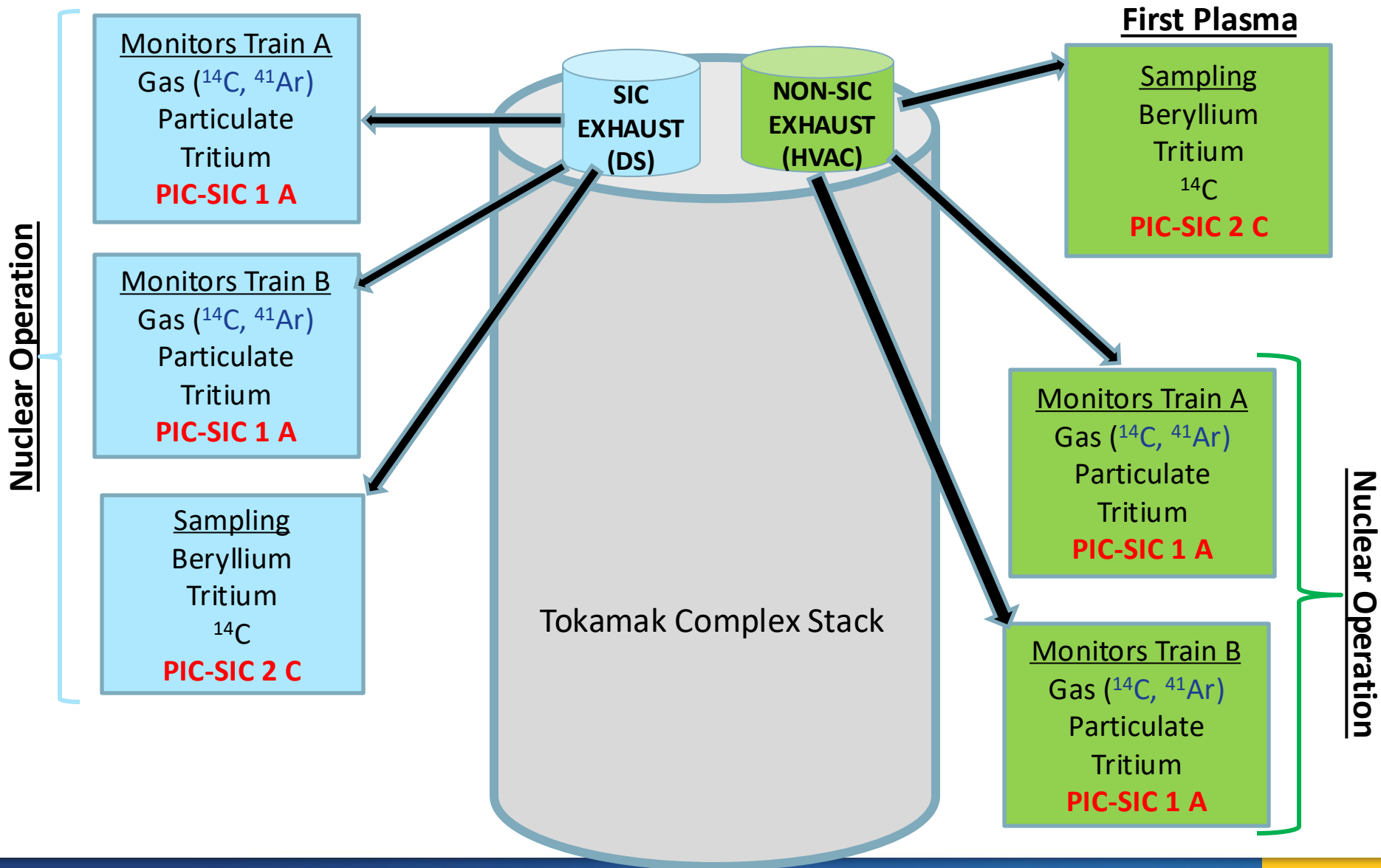
Qv = 547 421 m<sup>3</sup>/h



**PIC-SIC1 or 2**

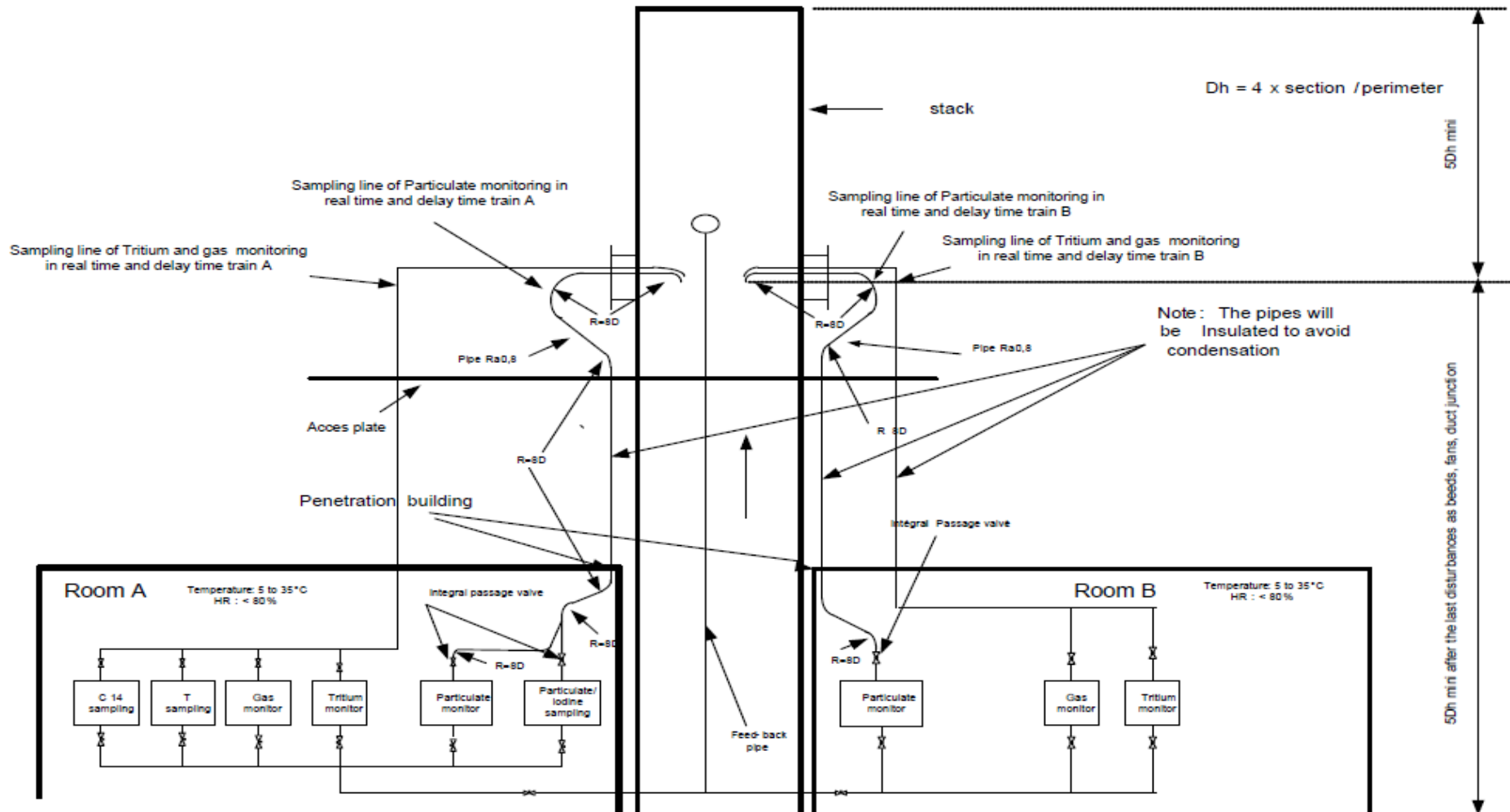
- $\beta$  &  $\gamma$  emitters (Tritium, <sup>14</sup>C, <sup>41</sup>Ar, radioactive dust)

# REMS-RMS for TKC: Simplified Description



# RMS: Location of equipment

- In order to fulfil the environment/public protection function, main considered aspects:
  - Location: protection of the PIC-SIC1 equipment ensuring accessibility for maintenance/repair;
  - Piping: length, bending, surface roughness, junctions/welding;
  - Space availability for the PLCs (PIC-SIC cubicles), penetrations.



# RMS: I&C Architecture



SIEMENS S7-400FH  
PIC-SIC-2



Sampling

Tritium  
<sup>14</sup>C

**PIC-SIC 2 C**

Quantitative  
information  
network

Quantitative  
information  
network

Digital A&W  
Hard-wired

Monitors Train A

Gas  
Particulate  
Tritium

**PIC-SIC 1 A**



HIMA PLANAR 4  
PIC-SIC-1



Monitors Train B

Gas  
Particulate  
Tritium

**PIC-SIC 1 A**



# RMS Equipment: Monitors and Samplers

Equipment Type	Parameter values	Safety class	Quality Class	Seismic Class
Be Particulate samplers	Trapping efficiency > 99%	SIC-1	Q1	SC1(F)
HT/HTO discrimination samplers	Trapping efficiency > 95 % HT and HTO	SIC-1	Q1	SC1(S)
Carbon 14 samplers	Trapping efficiency > 85 % CO and CO <sub>2</sub>	SIC-2	Q1	SC1(S)
sampling lines with insulation valves	aerosols constraints ( Ra 0.8 μm)	SIC-2	Q1	SC1(F)
Flow rate measurement	Nominal flow: 45000 m <sup>3</sup> /h	SIC-1	Q1	SC1(F)
Tritium monitors type IC	5x10 <sup>3</sup> Bq/m <sup>3</sup> up to 10 <sup>10</sup> Bq/m <sup>3</sup>	SIC-1	Q1	SC1(F)
Tritium monitors type PC	5x10 <sup>3</sup> Bq/m <sup>3</sup> up to 10 <sup>10</sup> Bq/m <sup>3</sup>	SIC-1	Q1	SC1(F)
Particulate samplers and monitors	0.1 Bq/m <sup>3</sup> up to 10 <sup>5</sup> Bq/m <sup>3</sup>	SIC-1	Q1	SC1(F)
Gas monitors ( Ar-41 and C-14)	100 Bq/m <sup>3</sup> up to 10 <sup>8</sup> Bq/m <sup>3</sup>	SIC-1	Q1	SC1(F)
HT/HTO discrimination samplers (bubblers)	Trapping efficiency (NF M 60 822-1)	SIC-1	Q1	SC1(S)
Carbon 14 samplers (bubblers)	Trapping efficiency (NF M 60 822-1)	SIC-2	Q1	SC1(S)

# REMS Overview: Main Functions

6. Monitor and record the contamination of personnel & tools inside controlled areas and at INB entrance/exit.



7. Data to HP-Centre, CSS and CODAC for :



Recording and Archiving  
(HP-centre, CODAC)



Informing on the site radiological status



Allowing/Blocking Access  
(HP-centre, CSS)

## 1) Personnel dosimetry:

- a) **Internal**: to monitor and record internal contamination (inhaled, ingested and absorbed radiological isotopes (i.e. dust of ACP, Tritium and beryllium):
- a) In-vivo measurements (whole body counting based on x-ray and  $\gamma$ , emission);
  - b) Radiotoxicological analysis (excreta monitoring)
- a) **external** to monitor and record  $\alpha$ ,  $\gamma$ ,  $\beta$  and n radiation exposure:
- a) passive such as:
    - Optical Stimulated Luminescence (OSL),
    - Thermo-Luminescence Dosimetry (TLD),
    - Radio Photo Luminescence (RPL)
  - b) active such as Electronic Personal Dosimeters.

- 2) Contamination checking:
- a) Personnel and small items: to avoid spreading of contamination inside the controlled areas, contamination checking is installed at interface of potentially contaminated areas;
  - b) Floors: routine inspection programme for floor contamination inside and outside controlled areas;
  - c) Movement of other materials inside controlled areas: contamination will be checked by portable devices and smear tests will be performed;
  - d) Movements of radioactive material outside ITER site: check of all packages containing nuclear material. Contamination will be checked by portable devices and smear tests will be performed. Fixed monitors located at the INB fence entrance and exit will monitor workers and vehicles.



## Portables

- X, beta gamma dose and dose rate,
- Neutron dose and dose rate,
- Alpha, beta gamma surface contamination,
- Tritium in air concentration,

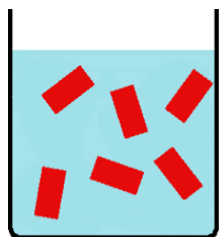


## Support to the HP operations

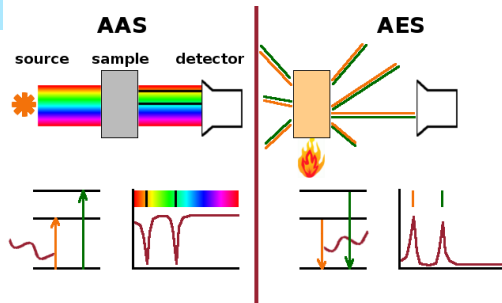
### Beryllium laboratory

(40,000-60,000 samples/y)

#### Be sample preparation

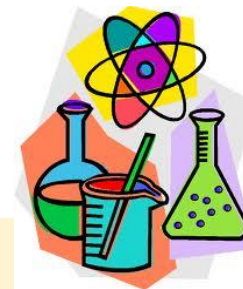


#### Be analysis



### HP Offices

### HP laboratory



#### Capability:

*Gaseous/liquid/particulate releases;*

*Airborne/surface contamination;*

*Background radiation*

Radioactive sample preparation

$\beta$ ,  $\gamma$  counting laboratory

Tritium analysis laboratory

# TKC REMS: Instrumentation Scope

Stationary radiation monitoring inside the rooms of ITER facility

ARMS

- 88  $\gamma$ -dose rate monitors
- 14 n-dose rate monitors
- 3 C-14 air samplers
- 9 Part. air monitors
- 14 Part. Air samplers
- 11 Rad. Gas monitors
- 128 signaling units
- 46 RSU (Siemens S7)
- 130 Conn. Points for mobile equip.
- 34 Electrical Distribution Boxes
- 280 sampling & outlet lines (20 m each)
- 9 Control cubicles
- 1 Plant control system
- 4 Workstation

Stationary Be monitoring inside the rooms of ITER facility

ABMS

- 10 Be air samplers portables

Process Control

Stationary monitoring of:

- Tritium HVAC/DS
- Tritium Port Cell Detector

- 46 Logic modules 2/3
- 388 sampling & outlet lines (20 m each)
- 47 Radiological Synthesis unit (SIEMENS S7)
- 16 Electrical Distribution Boxes
- 4 REMS cubicles

RMS

Stationary monitoring of:

- Gaseous effluents at releases (radiological and Be)
- Liquid effluents prior to discharge (rad.)

- 4 Rad. particulate monitor and samplers
- 4 Gas monitors
- 2 Gas monitors
- 2 Sampling lines with isolation valves (35 m each)
- 2 Radiological Synthesis unit (HIMA PLANAR R4)
- 2 Electrical sub distribution boxes
- 1 C-14 sampler (bubbler)
- 1 Beryllium sampler
- 2 Radiological Synthesis unit (SIEMENS S7)
- 2  $\gamma$ -detectors viewing liquid waste transfers to CEA

- Tritium monitors (see following slide)

- Personnel dosimetry;
- Bioassay system;
- Contamination checking;
- Portable and mobile monitors

IMS

- **1500 + 50** Worker dosim. integr. ( $\beta/\gamma/x$ ) + (n)
- **750** Worker Electr. dosim. ( $\beta/\gamma/x$ )
- **2** Electr. dosim. reader
- **1** Plant control system
- **200** Zoning dosim. integr. ( $\gamma/n$ )
- **2** Whole body counter
- **15** Hand & Foot monitors
- **2** Whole body personnel contamination monitors ( $\beta/\gamma$ )
- **2**  $\gamma$ -portal monitors (personnel control)
- **2** Tool contamination monitors
- **1** Vehicle monit. INB entrance/exit ( $\beta/\gamma$ )
- **30** Mobile  $\gamma$ -dose rate monitors
- **4** Mobile radioactive gas monitors
- **25** Mobile  $\beta/\gamma$ - particulate continuous air monitors
- **5** Mobile C-14 air samplers (bubbler type)
- **25** Mobile Rad. particulate
- **18 + 5** Portable dose rate monitors ( $\beta/\gamma/x$ ) + (n)
- **6** Portable radio-nuclide identification instruments
- **10** Portable contamination survey monitors ( $\beta/\gamma$ )
- **2** Portable contamination floor monitors ( $\beta/\gamma$ )

Radiological and chemical monitoring **outside ITER Buildings:**

- INB perimeter;
- INB-fence area
- Outside ITER

EMS

- **22** dosimeter integrators ( $\beta/\gamma$ )
- **20** dosimeter integrators (n)
- **8** Dose rate monitors ( $\beta/\gamma$ )
- **8** Dose rate monitors (n)
- **8** Particulate samplers
- **3** Be samplers
- **8** Rainwater-pluviometers
- **10** Groundwater- sample taking equipment
- **10** Industrial water- sample taking equipment
- **2** Offsite monitoring station
  - Gamma dose rate monitor (**1**)
  - C-14 sampler (**1**)
  - Radioactive particulate (**1**)
  - Pluviometer (**1**)
  - Rainwater droplet size (**1**)
  - Weather station (**1**)
- **5** NOx gas analysis instruments
- **1** EMS cubicles
- **1** EMS Plant Control System
- **1** Working station (PC)
- **2** Laboratory equipped vehicles.

- *Tritium monitors*  
(see following slide)



Health physics laboratories and  
offices

Laboratories

- **4** Surface wipe (smear) counters for  $\beta/\gamma$  emitters (automated or manual)
- **4** counters low-level counter (automated sample counting for air samples, dried liquids on planchet etc.) for  $\beta/\gamma$  emitters
- **4** Liquid scintillation counter (for all the bubbler sampler analyses)
- **2** Liquid scintillation counter (low-level) (for special sample analyses)
- **4** Gamma-ray spectrometer (lab-based) (germanium detectors)
- **2** Portable, electrically-cooled germanium spectrometer
- **10** Portable liquid scintillation counters (for field use to assess contamination)
- **3** Total gamma detector
- **2** Shielded cabinet for storage or radioactive sources
- **3** Liquid sample collection bottles
- **1** Gamma irradiator for onsite instrument calibrations
- **3** ICP-MS
- **11** Fume hood
- **1** Cabinets for chemical products
- **1** Cabinets for samples storage
- **12** Bench/cupboards
- **1** Set of equipment for sample preparation ( calcination furnace, drying chamber, centrifuge, cutting mills, oxydizer, sieving machine, balances, freeze drying device, distillation system)
- **1** REMS cubicles
- **2** Electrical sub distribution boxes

## ARMS

**52** T in air monitors: Ionization Chamber  
Detection range:  $3 \cdot 10^4$  Bq/m<sup>3</sup> –  $10^{10}$  Bq/m<sup>3</sup>

**30** T in air samplers:  
Bubblers, >95% HT/HTO

## RMS

**2** T monitors  
Ionization Chamber  
Detection range:  $3 \cdot 10^3$  Bq/m<sup>3</sup> –  $10^{10}$  Bq/m<sup>3</sup>

**2** T monitors  
Proportional Counter  
Detection range:  $3 \cdot 10^3$  Bq/m<sup>3</sup> –  $10^{10}$  Bq/m<sup>3</sup>

**2** T sampler (bubbler)  
Bubblers, >95% HT/HTO

## EMS

**14** T samplers : Bubblers, >95% HT/HTO

## Process Control

**138** Tritium HVAC/DS Detectors: Ionization Chamber  
Detection limit:  $10^8$  Bq/m<sup>3</sup>  
Detection range:  $3 \cdot 10^6$  Bq/m<sup>3</sup> –  $3 \cdot 10^{11}$  Bq/m<sup>3</sup>

**10** Tritium Port Cell Detectors: Ionization Chamber  
Detection range:  $3 \cdot 10^4$  Bq/m<sup>3</sup> -  $10^{10}$  Bq/m<sup>3</sup>

## IMS

**2** T exhalation monitor: Detection limit  $< 10^5$  Bq/m<sup>3</sup>

**50** Mobile T in air monitors: Ionization Chamber  
Detection range:  $3 \cdot 10^4$  Bq/m<sup>3</sup> -  $10^{10}$  Bq/m<sup>3</sup>

**22** Portable T in air samplers  
Bubblers, >95% HT/HTO  
Cryogenic 100% efficiency

**25** Portable T in air monitors: Ionization Chamber  
Detection range:  $3 \cdot 10^4$  Bq/m<sup>3</sup> -  $10^{10}$  Bq/m<sup>3</sup>

## Seismic

- Not available
- Tritium monitors
  - Tritium samplers

Available

- gas monitoring
- particulate sampling

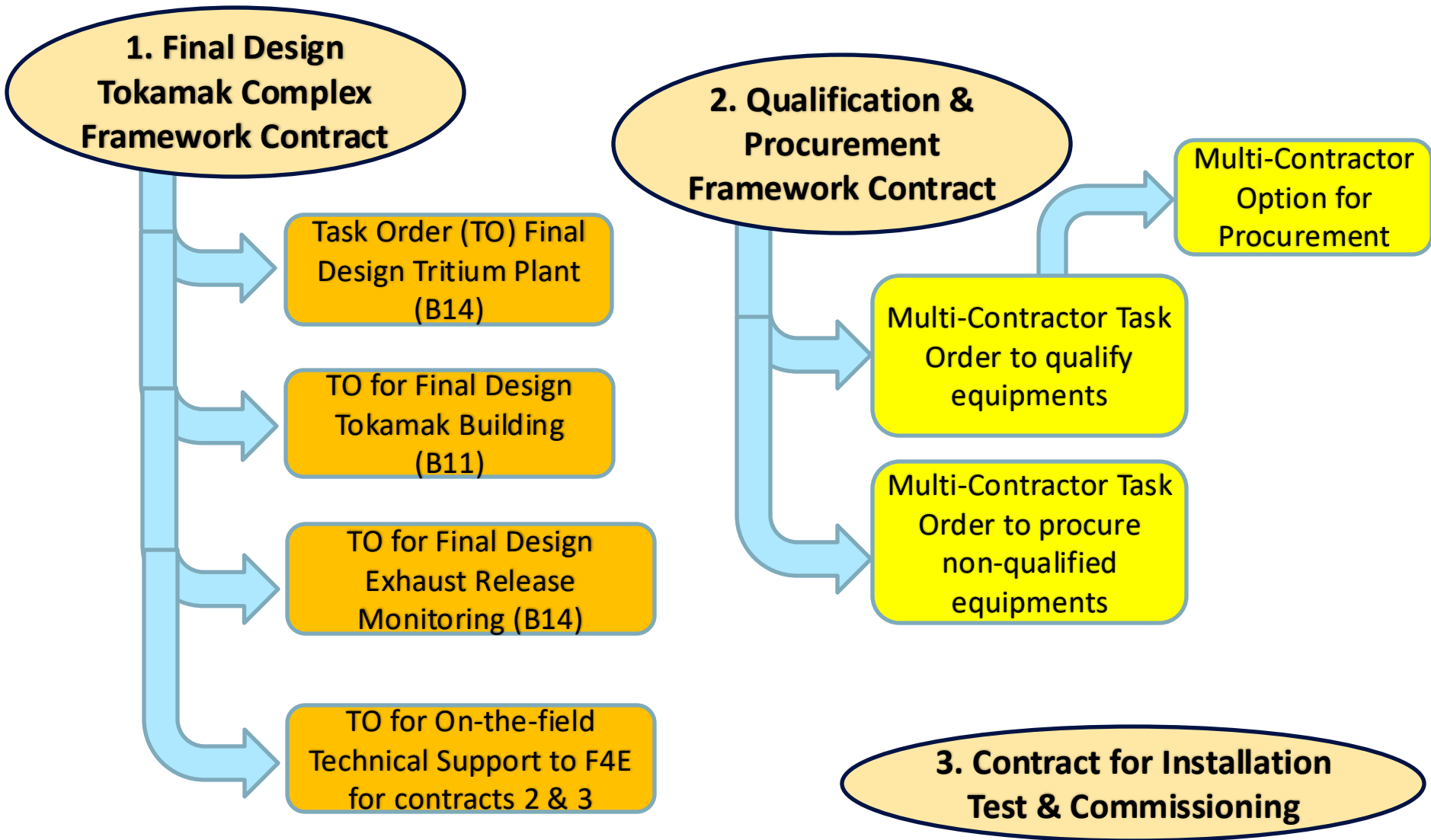
## Radiation Hardness

qualification issue mostly  
solved by carefully  
location of instrument

## Static Magnetic Field

- Not available > 15 mT
- Tritium monitors
  - Tritium samplers
  - Gas monitors

- In some cases, qualification issue solved by carefully location of instrument taking into account high magnetic load areas and with the possibility of adding magnetic shielding.
- In other cases, customization may be needed with impact on cost/schedule.







22	23	24	25	26	27
			★	<u>REMS PA Amendment#2 TP Procurement/Installation/Test &amp; Commissioning (03/2025)</u>	
◆ <u>OMF-1116 :Task Order (TO) #01 TKM REMS VE (09/2022)</u>					
Execution VE TKC. Outcome: 1) Interface maturity; 2) Qualification Technical Specifications; 3) Optimization of Prel. Des. (06/2023)					
Competitive CfT phase for FwC					
◆ <u>FWc-XXXX: TO support of TKC REMS Qualification/Procurement/Installation/Test &amp; Commissioning (06/2024)</u>					
TO for F4E support (09/2030)					
◆ <u>FWc-XXXX :Task Order (TO) #01 TP FD (06/2024)</u>					
Execution FD TP (06/2027)					
◆ FDR for TP (10/2025)					
◆ Closure FDR for TP (05/2027)					
◆ <u>FWc-XXXX :Task Order (TO) #02 TKM FD (03/2025)</u>					
Execution FD TKM (06/2027)					
◆ FDR for TKM REMS (07/2026)					
◆ Closure FDR for TKM (05/2027)					
◆ <u>FWc-XXXX :Task Order (TO) #03 RMS FD (06/2025)</u>					
Execution FD RMS (06/2027)					
◆ FDR for TKM RMS (10/2026)					
◆ Closure FDR for RMS (05/2027)					

25

26

27

28

29

30

FWc-XXXX: Final Design and support of TKM REMS Qualification /Procurement/Installation/Test & Commissioning (09/2023)

TO for F4E support (09/2030)

◆ REMS PA Amendment#2 TP Procurement/Installation/Test & Commissioning (03/2025)

Competitive CfT phase

◆ Multiple FWc (re-opening competition )TKM+TP+RMS Qualification, Procurement/Installation/Test & Commissioning (03/2026)

◆ TOs (with competition) with all manufacturers for TKM+TP+RMS QUALIF. + (PROCUR. + delivery ) (option) (3/2026)

Contractors A/B/C  
type X, Y, Z

Firm task 1: TOs Qualification in parallel (03/2027)

◆ Optional Task 2: procurement (12/2026)

Contractor A/B/C: cheapest price on successfully qualified type X,Y items

◆ TOs (without competition) for TKM+TP+RMS NOT-QUALIFIED Procurement + packing shipping (03/2026)

Contractor A: cheapest price by item quoted at FWc-XXXX financial proposal (award stage)

Contractor B: cheapest price by item quoted at FWc-XXXX financial proposal (award stage)

◆ Delivery of TKM+TP+RMS (03/2029)

New CfT or release of optional tasks under TOs for installation/commissioning of TKM REMS (02/2029)

TKM+TP+RMS installation & commissioning (12/2029)