Integration of Lost Alpha-Particle Diagnostic Systems on ITER

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Outlines

1. Introduction : Measurement Justification
2. Concept and System Candidates
3. ITER Integration and Prospect
4. Development of Ceramic Scintillation materials
5. Summary

Introduction : Measurement Justification 1

Lost Alpha Detectors provide measurement of the alpha particle loss rate that could bring dangerous conditions to the first wall.

The alpha particle loss rate can also give physics information about processes occurring inside the plasma.

The detectors must be mounted on the first wall or in small gaps between blanket module at the specific poloidal angle where the ripple loss is maximum. (ITER DDD, July 2001)

	Time resolution	Spatial resolution	Accuracy
Escaping alpha flux (steadystate)	100 ms	10 points (along poloidal direction)	20 %
Escaping alpha flux (transient)	10 ms		30 %

Introduction : Measurement Justification 2

Studies of energetic particle behaviours using beam ions for heating and these from DD/D^{3}He/DT reactions have provided understandings that the confinement of fast ions is governed by a number of processes,

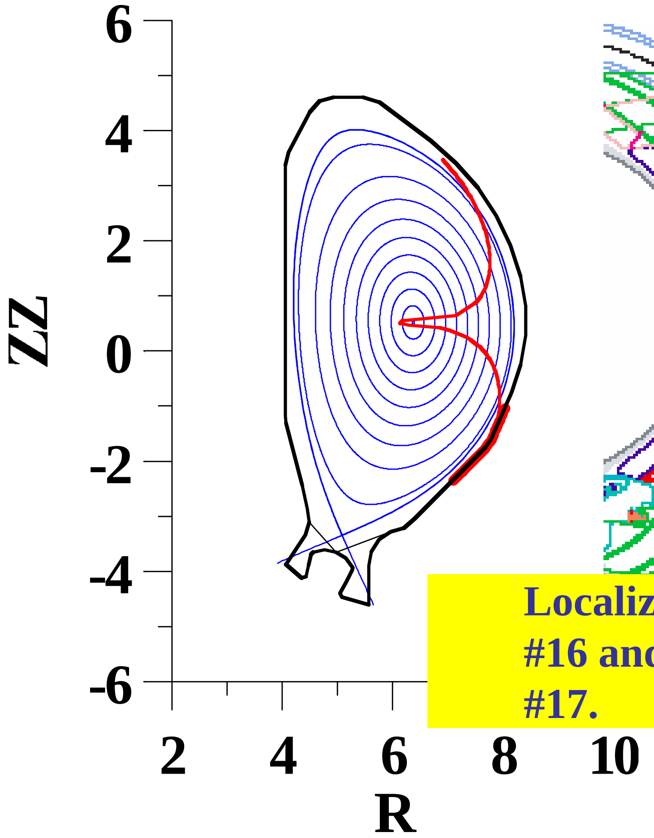
- **the magnetic structure and q-profiles**
- **the energy and pitch angle diffusion with Coulomb interaction**
- **interaction with instabilities driven by themselves**
- **the stochastic processes (stochastic ripple diffusion)**
- **and so on.**

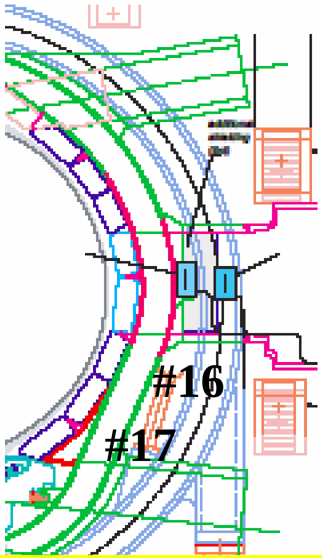
Especially some MHD events can transport alpha particles to the outer region of the plasma, and cause giant losses spiky in time and localized in space.

Studies that combine alpha particles losses and characteristics of MHD activities are needed to identify the mechanisms responsible for alpha particle transport and loss.

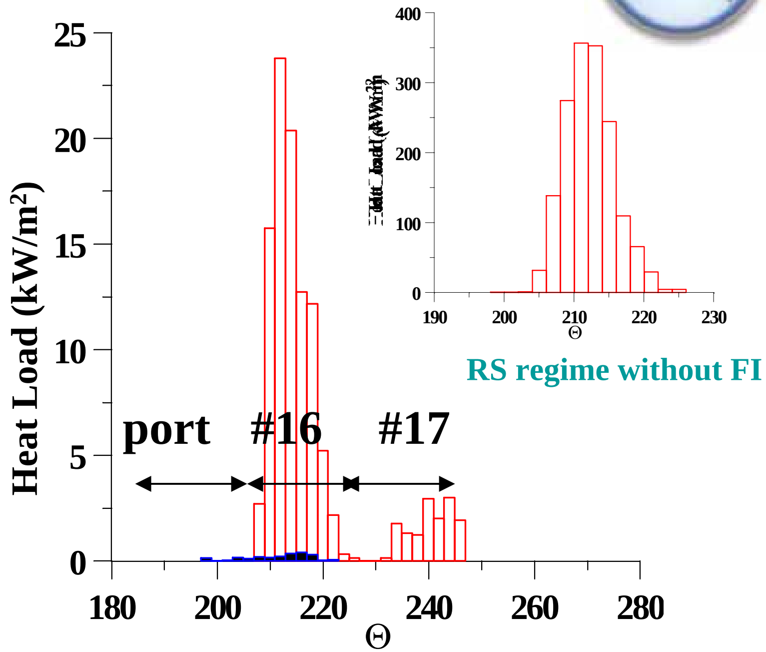
Introduction : Measurement Justification 3

Localization





Localized at lower end of BM #16 and the upper end of BM #17.



FW region marked by the thick red line undergoes alpha particle bombardment. Analysis of TF Ripple Loss of Energetic Particles (Subtask 1 by S.V. Konovalov*RRC "KurchatovInstitute", Moscow*

Poloidal distribution of the heat load. Red histogram corresponds to banana particle loss and blue one shows locally trapped α loss. The loss fraction of the former is substantial and strongly depends on tokamak operation scenarios, the birth profile and the diffusion rate, as well as the ripple structure and strength.

Concept and System Candidates 1

Candidates of Measurement Tools

Points- measurement : Energy and pitch-angle resolved

Faraday-cup detectors,

Scintillator probes,

Bolometric Imaging (Peterson et al., this meeting)

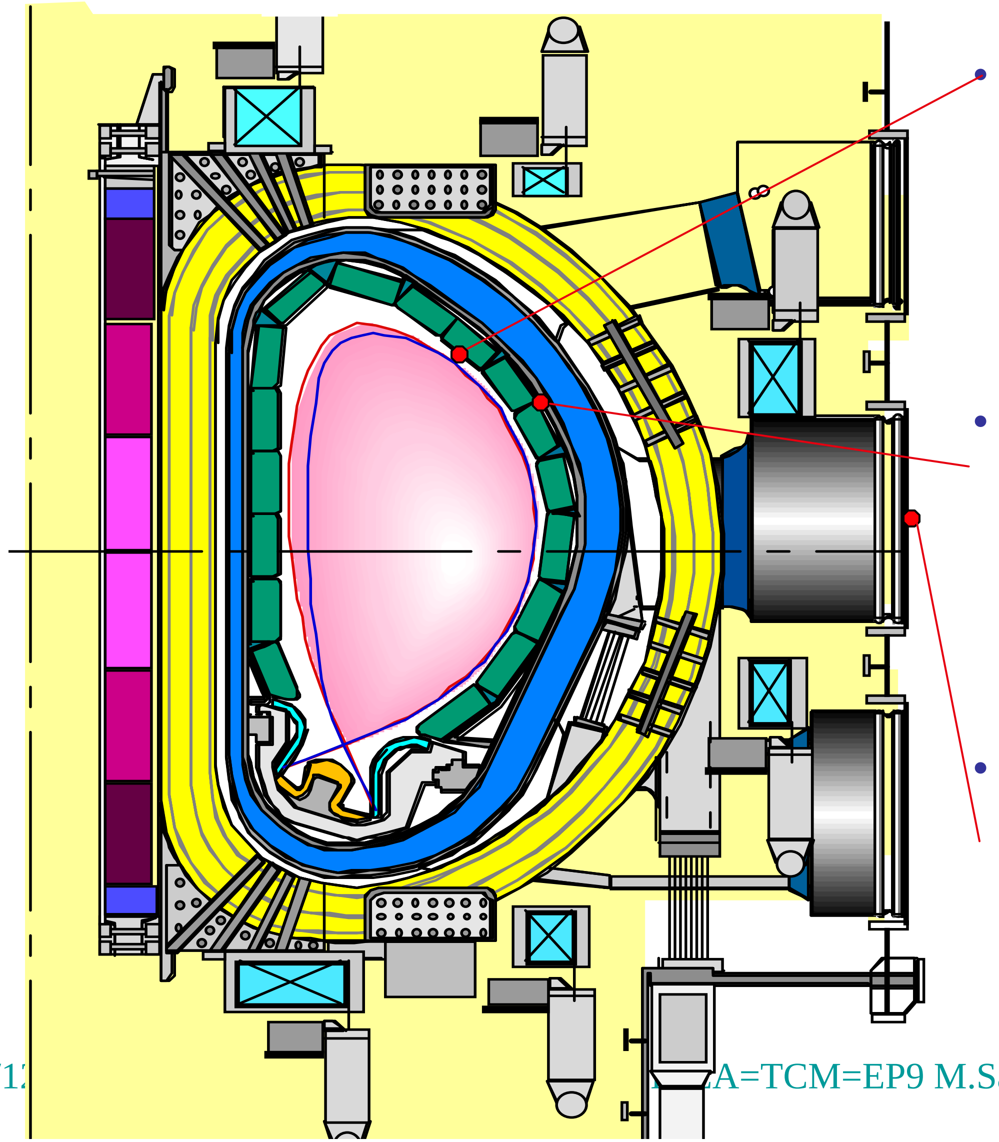
Loss imaging:

IR camera imaging,

Camera imaging of scintillators on the FW

Gamma Ray (Kipty et al., this meeting)

Radiation Field, Thermal Field Access of diagnostic system,



- **First Wall**

  Neutron Flux：3×10^{18} n/m^2 s

  γ -Flux：2×10^{3} Gr/s

  Fluence：3×10^{25} n/m^2 0.3dpa

- **Blanket GAP**：

  Neutron Flux：0.2-1×10^{17} n/m^2 s

  γ -flux：20–100 Gr/s

  fluence：0.4-2×10^{24} n/m^2

- **Port exit**

  Neutron Flux：2×10^{13} n/m^2 s

  γ -flux：~10^{-2} Gr/s

  Fluence：2×10^{20} n/m^2

Requirements to the System

Sensors

(1) **selective sensitivity to alpha particles,**

(2) **low sensitivity to other ions, neurons, electrons**

(3) **stable at high temperature (~ 700 K),**

(4) **wide dynamic range and linearity,**

(5) **mechanical endurance under conditions of high temperature and radiation exposure.**

Signal types and connections should be considered.

Faraday-cup detectors - current (micro A-mA)

Scintillator probes - 400 - 600 nm

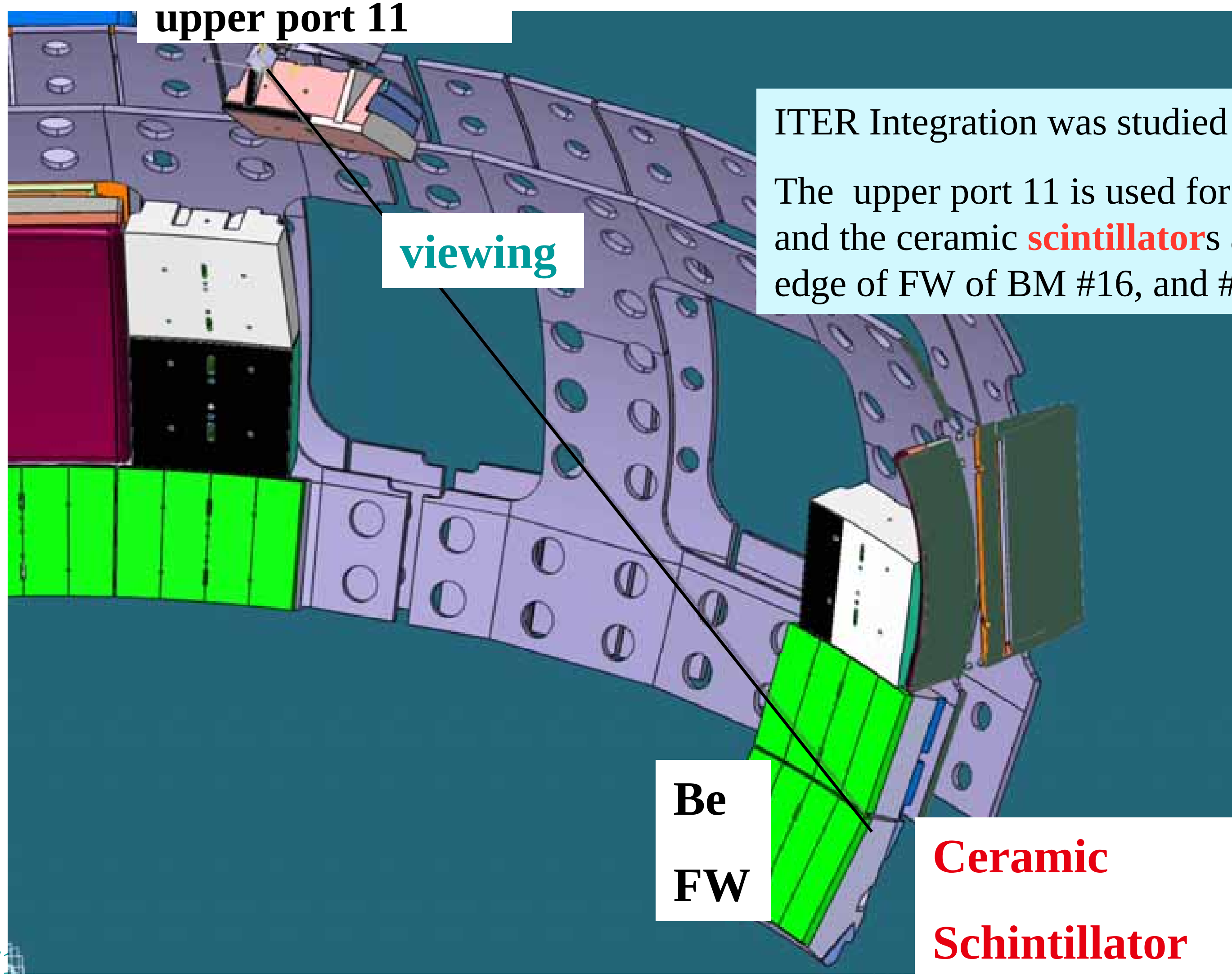
Bolometric Imaging (IR)

Loss imaging:

IR camera imaging (IR)

Camera imaging of scintillators on the FW - 400 - 600 nm

ITER Integration of Camera imaging of scintillators

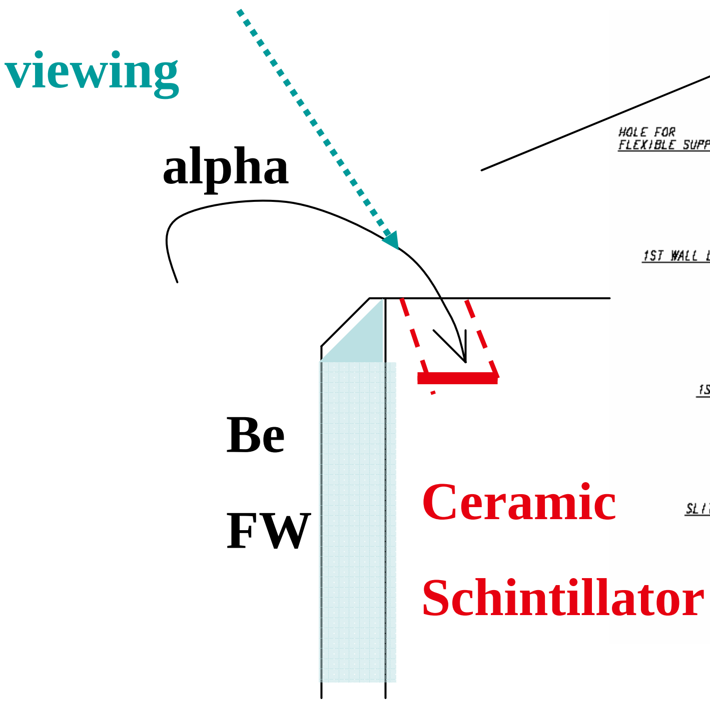


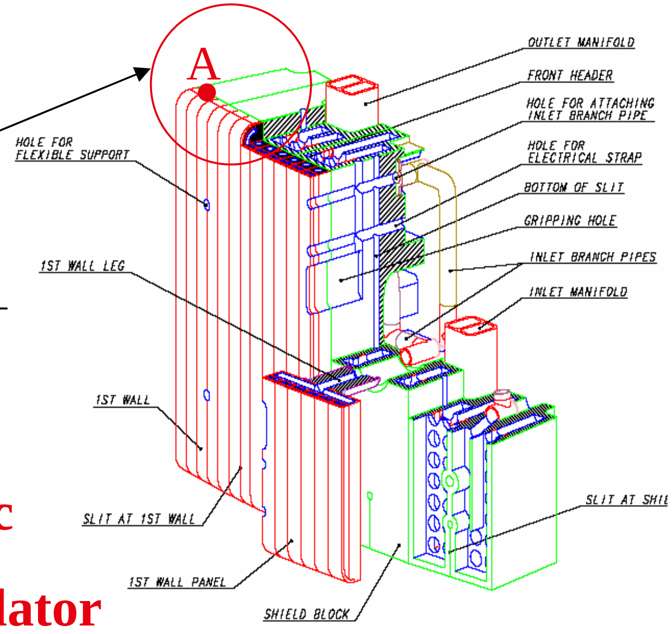
ITER Integration was studied on CAD drawings.

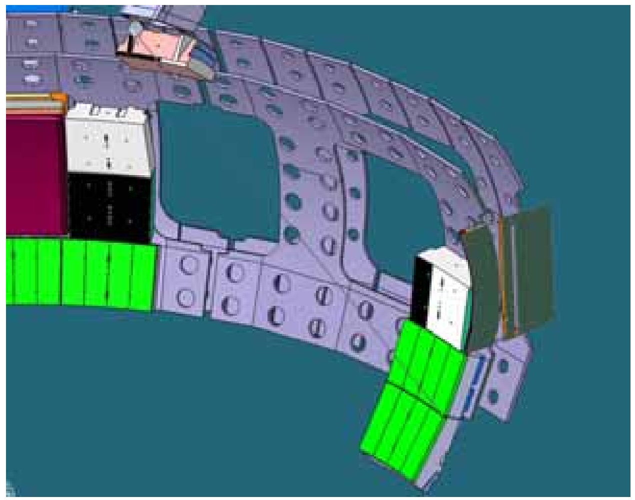
The upper port 11 is used for the viewing camera, and the ceramic scintillators are fixed behind the edge of FW of BM #16, and #17

Geometry (1)

Ceramic Schintillators are fixed in holes on the top end of FW (Cu backing) of the BM #17 , and view from the upper port camera.

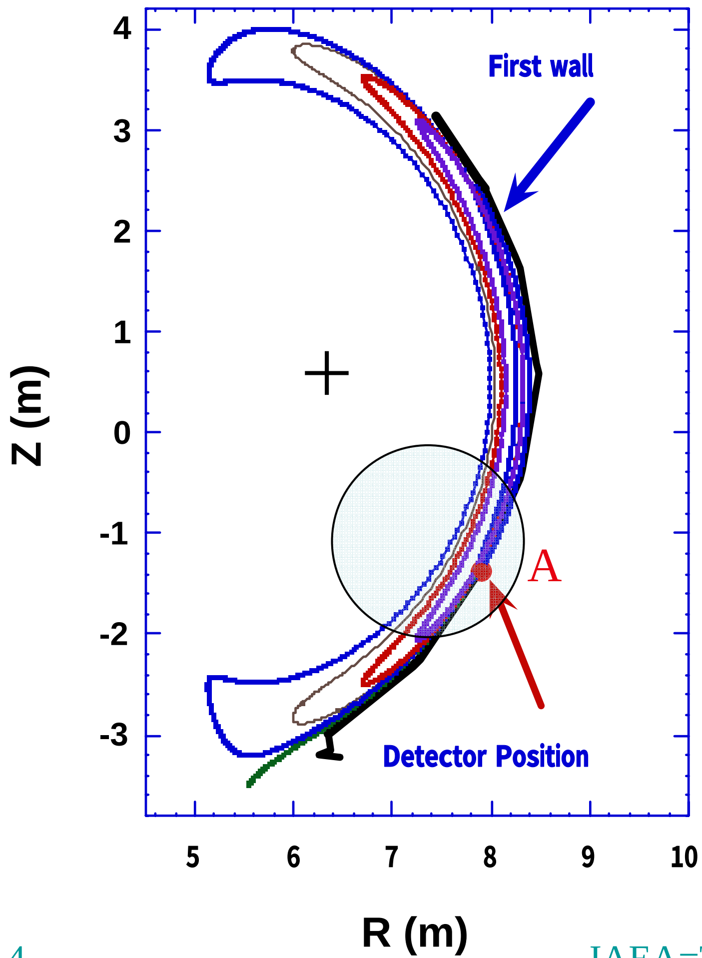






Orbit calculation for Detector position A

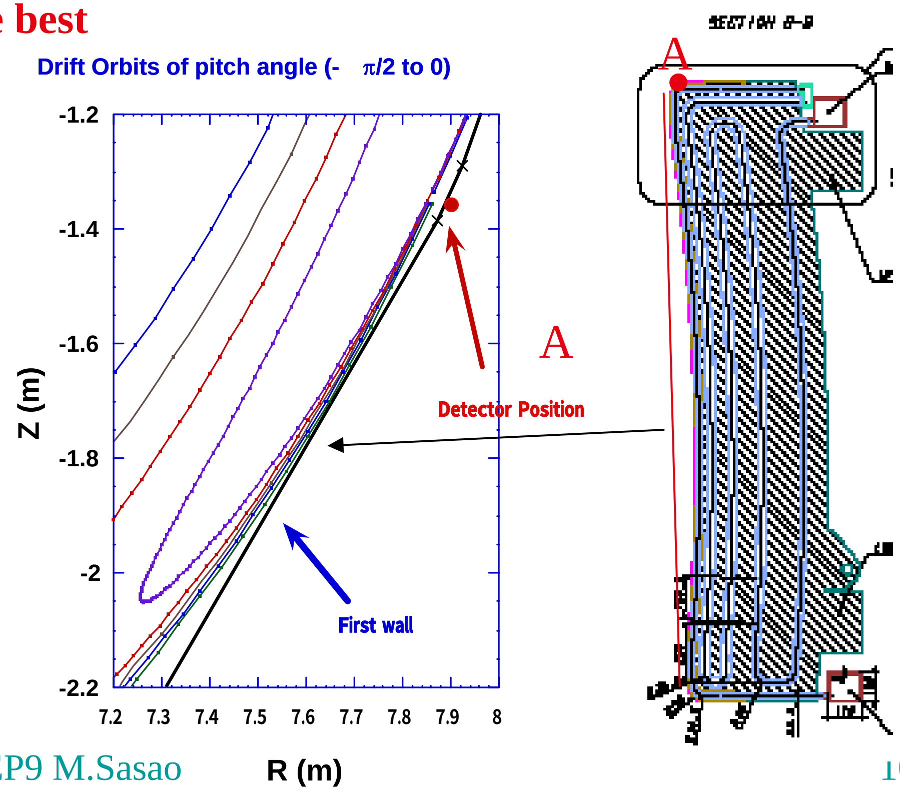
Drift Orbits of pitch angle (- π/2 to 0)



The detector position A, is not good, by two reasons.

1) **Drift orbits might not touch the wall surface ? (should be confirmed).**
2) **The poloidal angle of the lost position is not the best**

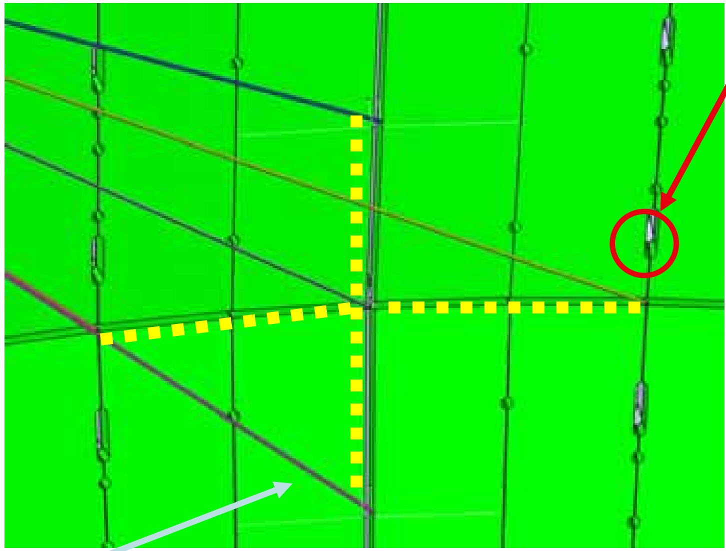
Drift Orbits of pitch angle (- π/2 to 0)

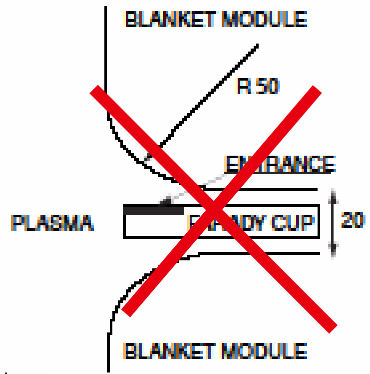


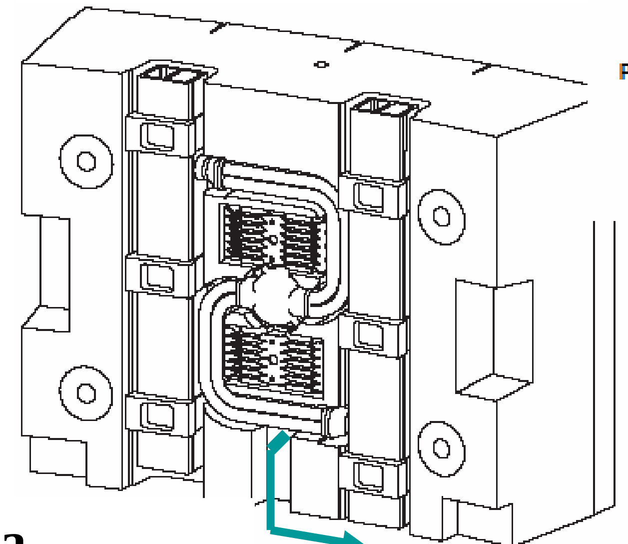
Geometry (2)

Holes for Ceramic Schintillators distributed toridally and poloidally

Extra Holes for Schintillator Probes, FC Probes and Bolometric Imaging



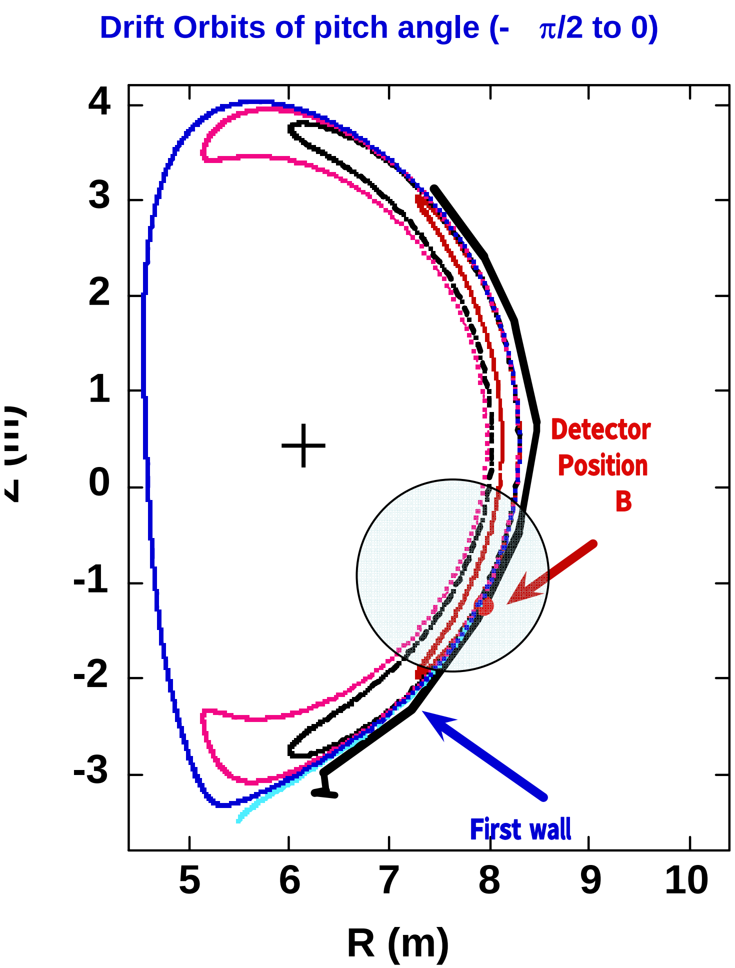




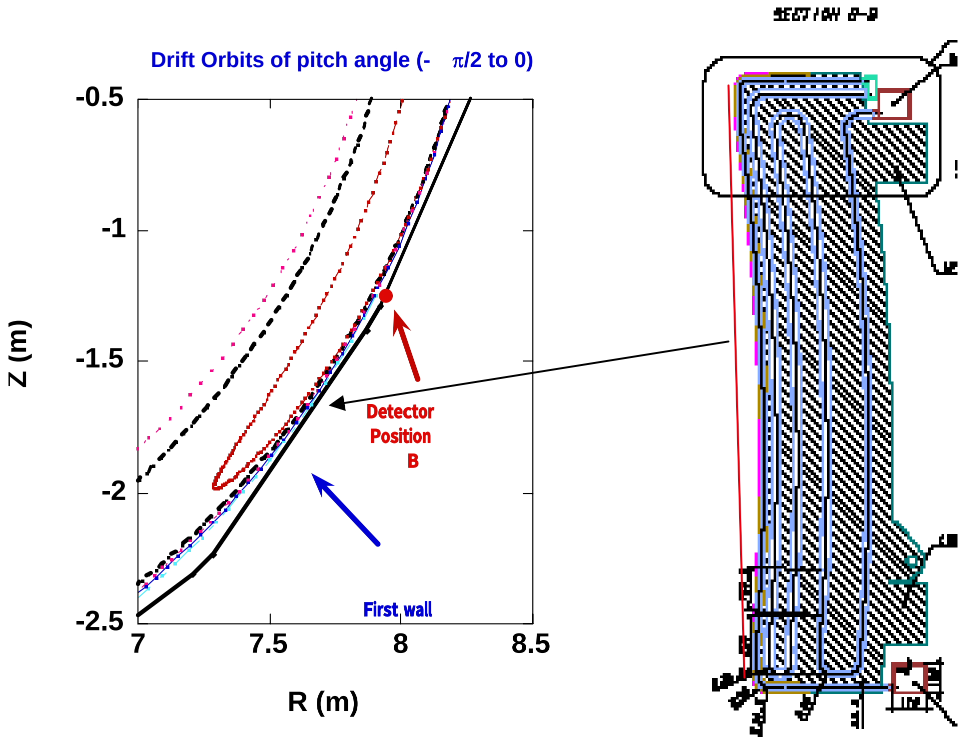
Viewing lines from the camera

Transfer lines for lights and wires

Orbit calculation for Detector position B

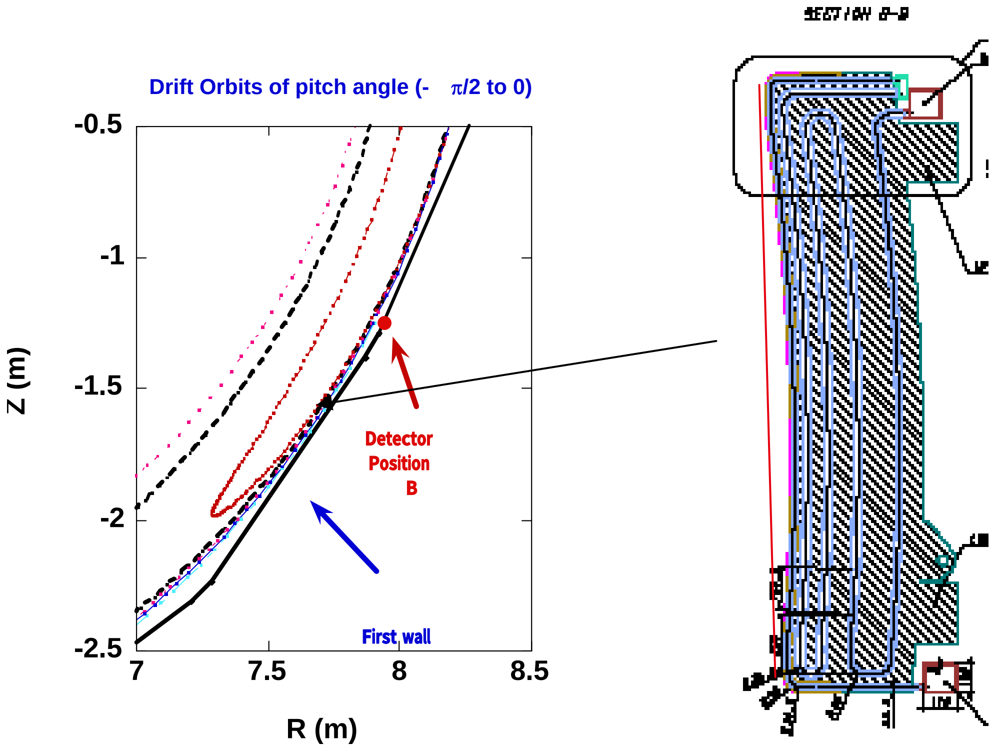


The detector position B is better.
1) **Drift orbits might not touch the wall surface.**
2) **The poloidal angle of the lost position is almost the best. Wide area of returning position is covered.**



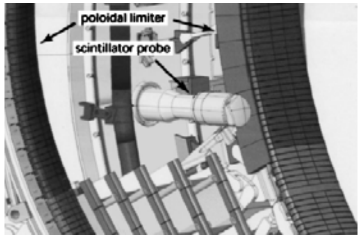
Full-gyro orbit calculation

Full-gyro orbit calculations including realistic detector designs and detailed 3D FW shapes, are needed, and now under preparation.

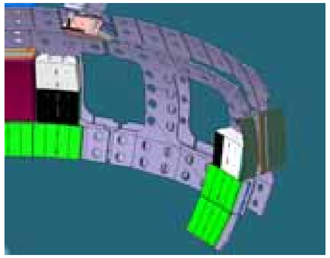


Development of Ceramic Scintillation materials

Two applications



Scintillator probes



Camera imaging of scintillators on the FW

The required properties of a scintillation plate to be used on ITER are as follows:

(1) high sensitivity to alpha particles,

(2) low sensitivity to other ions, neurons, electrons, gamma rays,

(3) stable emission at high temperature (~ 700 K),

(4) Wide dynamic range and liniearity,

(5) mechanical endurance under conditions of high temperature and radiation exposure.

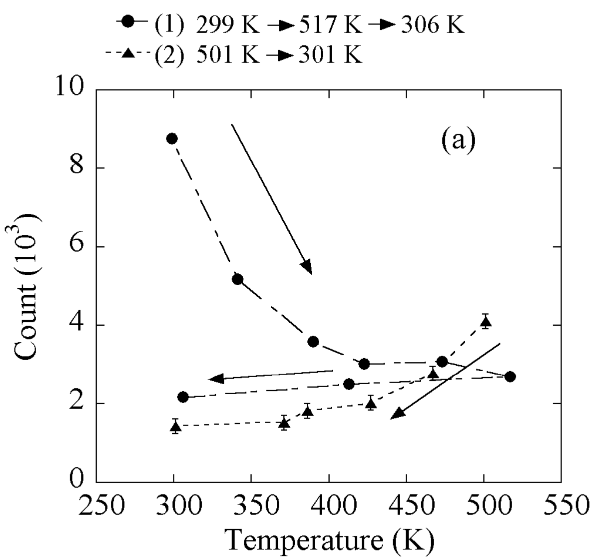
It had been known that the sensitivity of ceramic scintillator diminishes under high temperature, above 100^{o} C.

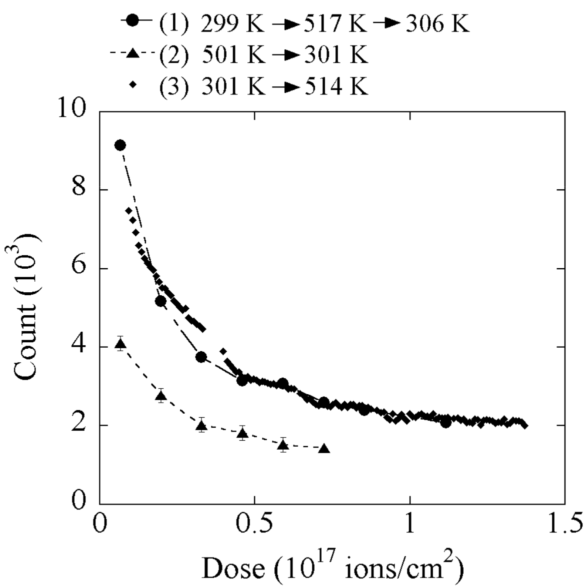
The characteristics of ceramic sheets in which scintillation materials are blended have been tested.

Development of Ceramic Scintillation materials

N. Kubo, et al., "Development of ceramic scintillators for lost alpha measurement on ITER", Proceedings of The 32nd EPS Conference on Plasma Physics (2005, Tarragona), P4.089

Changes in scintillation efficiency of $Y_3Al_5O_{12}$(Ce) of 7 keV He^+ beam bomba





(a) with temperature **(b) with dose**

The changes in scintillation efficiency were saturated at doses exceeding 10^{17} ions/cm^2 for $Y_3Al_5O_{12}$(Ce), and $Y_3Al_5O_{12}$(Cr).

Summary of the present status and future plan

Study of ITER Integration for several systems is started.

Ceramic schintillation-material-blended coatings in side holes of the FW, and viewed from the upper port camera of #11, by camera.

Probes for energy and angle-resolved measurement, Faraday-cup detectors, scintillator probes, Bolometric Imaging detectors will be installed in extra holes on the slits of FW of the BM #16.
Full-gyro orbit calculations including realistic detector designs and detailed 3D FW shapes, are needed, and now under preparation.
Signal transfer routes of least loss should be found out.

The ceramic schintillators newly developed were tested with low energy beams under high temperature shows that the efficiency does not depend on temperature, but changes by dose accumulation.
It is saturated at doses exceeding 10^{17} ions/cm^2 .
More tests and calibrations will be carried out using the 1-3 MeV alpha beam.