The New Sorgentina Fusion Source Project

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Workshop «Radiazione per l'Innovazione» - RAIN 2015
Istituto Nazionale di Fisica Nucleare INFN
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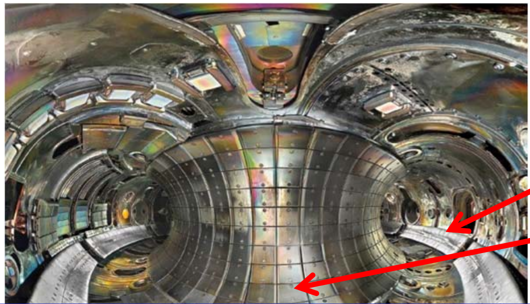
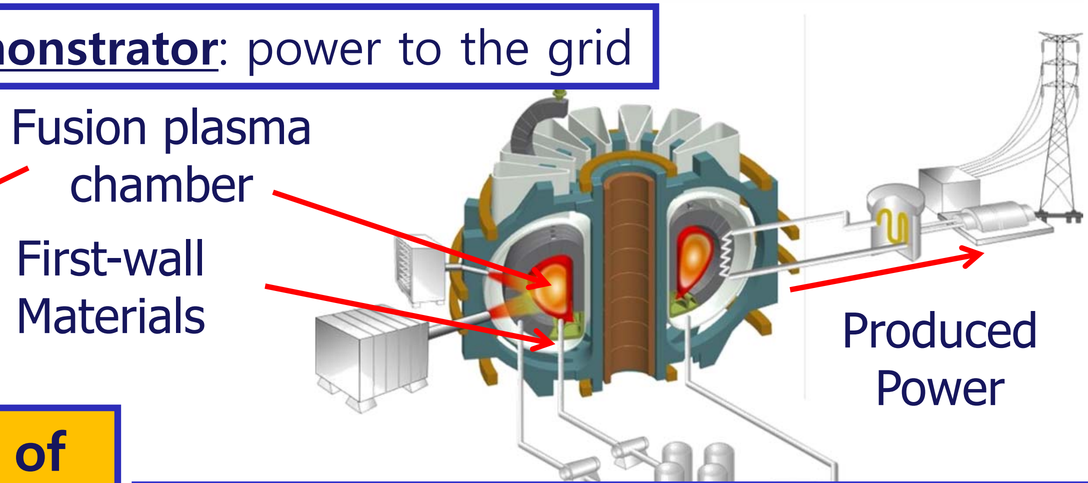
Sorgentina Neutron Source for Fusion R&D, Science and Materials Technology

- Neutron Source supporting Fusion Technology
- Sorgentina: Main Conceptual Design
- Facility key component (1/2): Ion Source and Accelerator
- Facility key component (2/2): Target
- Sorgentina Performances and Applications

Neutron Source supporting Fusion Technology

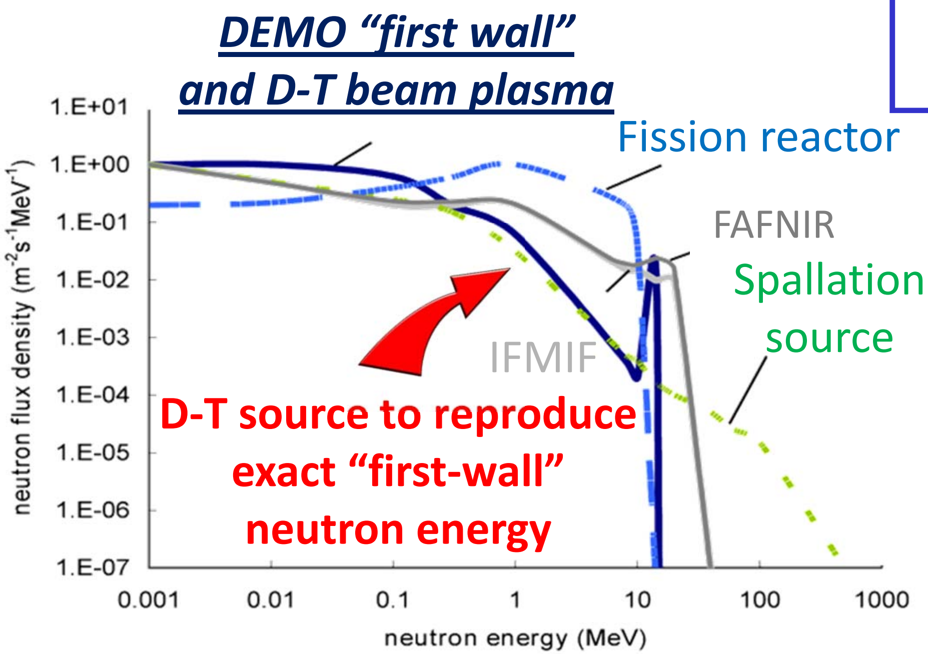
DEMO First Fusion Reactor Demonstrator: power to the grid





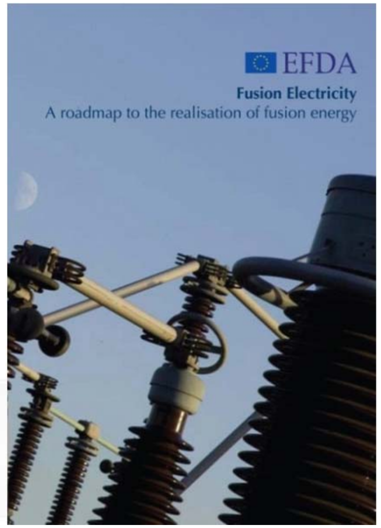
R&D Mission: Development of Neutron Resistant Materials

Design neutron source to reproduce material damage in DEMO caused by neutron flux



14 MeV Irradiation to achieve targets:

20 dpa on steel
10 dpa on copper
dpa on tungsten



New Sorgentina Fusion Source Design

"Sorgentina" Neutron Source Designed by ENEA

Design Strategy
Implementing proven technology from industry for critical components

→ Particle Accelerator
→ Rotating Target

→ Few R&D not for feasibility but just optimization
→ Reduced construction time, licensing and costs

Deuterium-Tritium High-energy Nuclides Collide and undergo Fusion

Neutrons produced
D + T → ^{4}He + n (14 MeV)

Sorgentina Design Concept

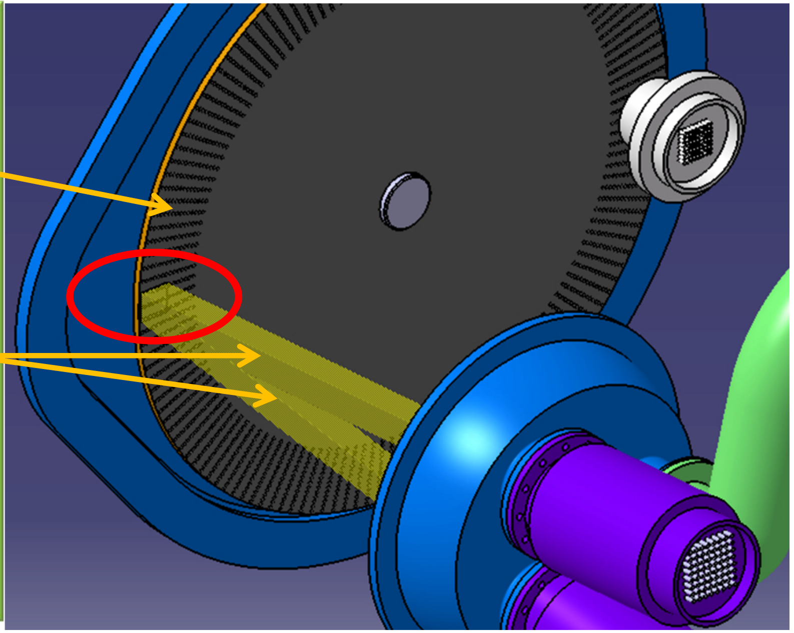
Rotating Target
(Deuterium-Tritium enriched layer)

+

Deuterium - Tritium Ion Beam

↓

Fast Neutron Flux for Material Testing



Sorgentina Conceptual Design

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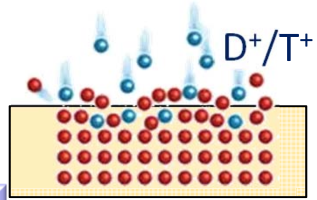
Rotating Target D-T Source: Proven Design

Up-scaling previous facility layout

Aiming at high availability factor



D-T diffusion release

On-line reloading by D-T ion implantation

D-T concentration in target layer

Optimized Beam energy / current

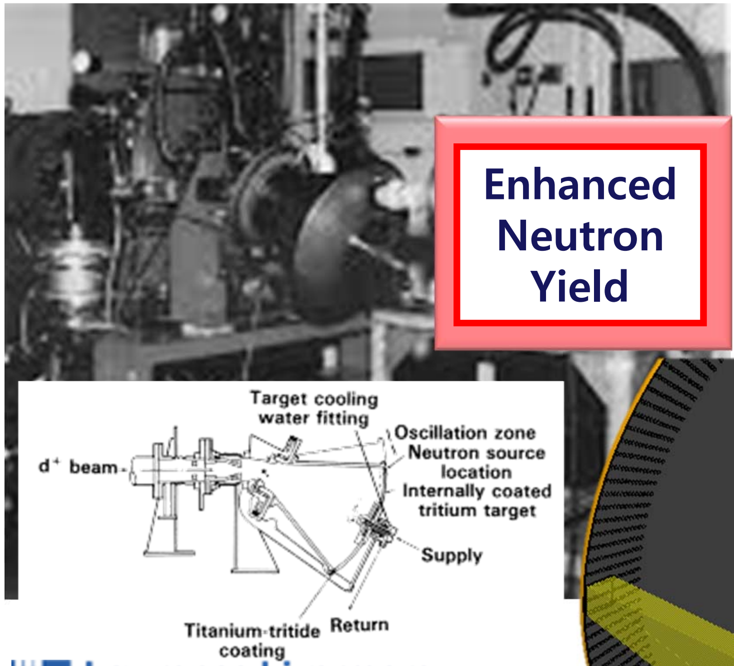
D-T enriched hydride layer thickness

On-line layer deposition by PVD (sputtering)

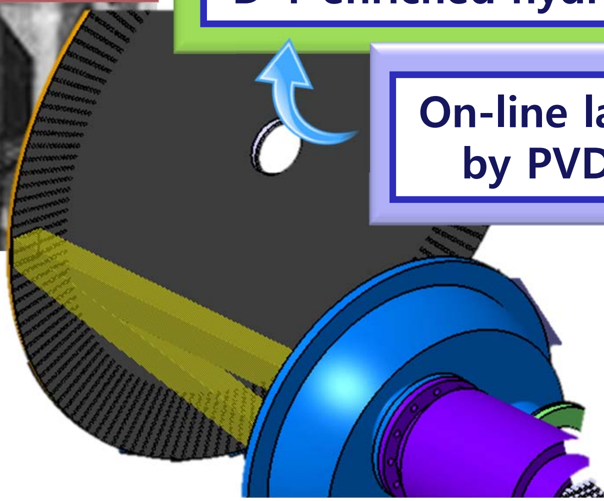
Enhanced Neutron Yield

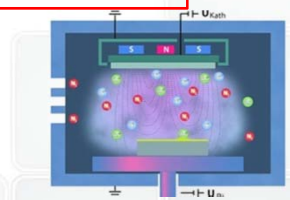
Beam Thermal Power

D-T ion sputtering



Lawrence Livermore National Laboratory





Early '80s: RTNS I-II…

… 2015: New Sorgentina

Part 1) Ion Source & Accelerator

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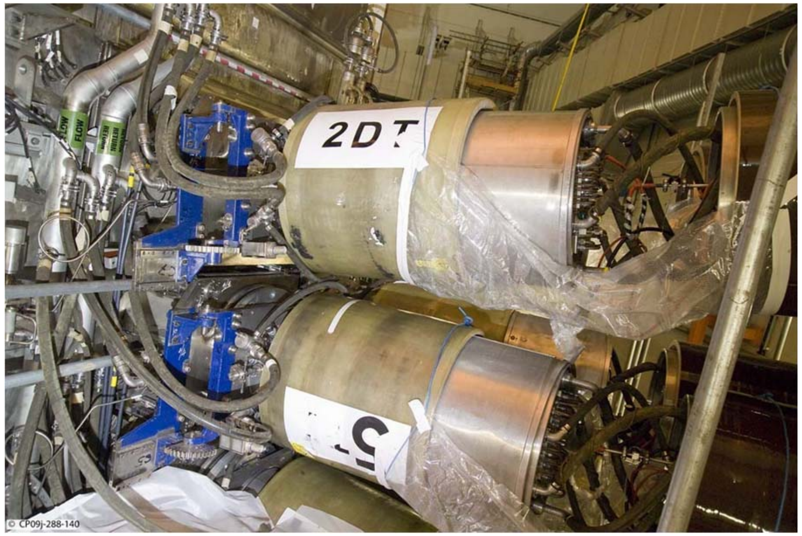
Requirements

- Optimized Current
- Optimized Voltage (HVPS)
- High yield in monoatomic ions



Ion Source and Accelerator utilizing Neutral Injector Systems technology at JET tokamak

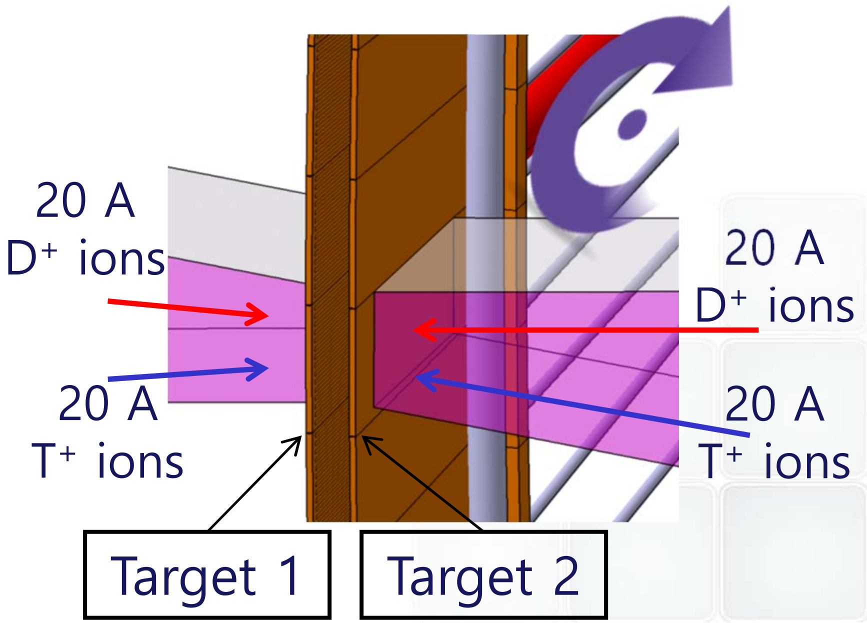
Radio-Frequency Ion Source	Ion species composition **$D^+:D_2^+:D_3^+$ ~95:2:3**

Pulse duration up to 1 hour (PINI systems)

Beam cross-section: **20cm x 10cm**

Ion Current: 20 A (D^+) + 20 D (T^+) = 4**0 A**

Accelerator beam energy: **200 keV**

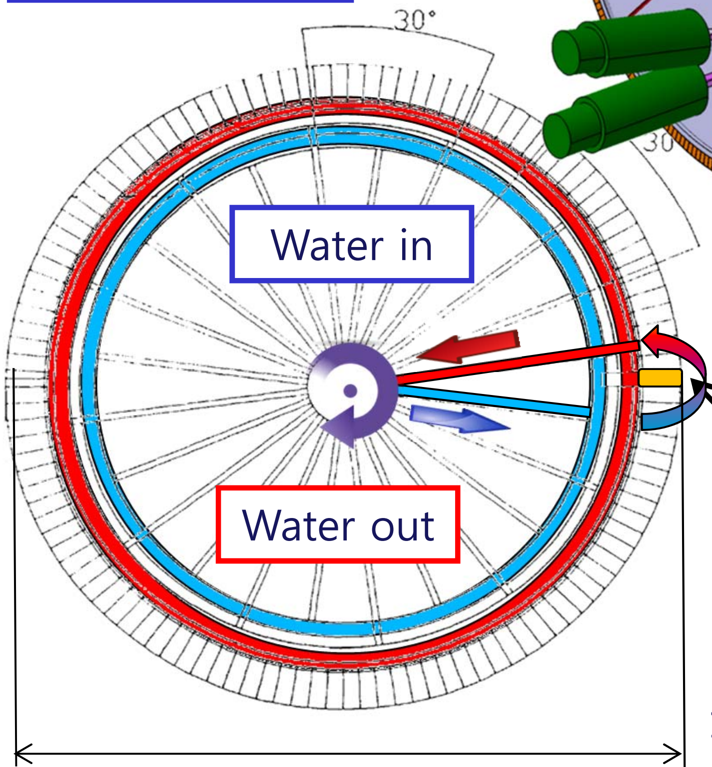


EFDA JET

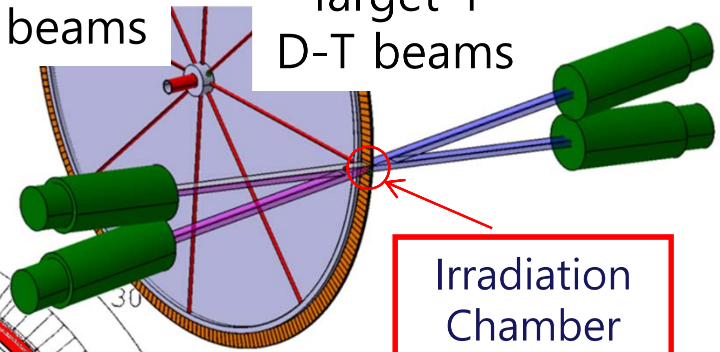
Part 2) Rotating target system

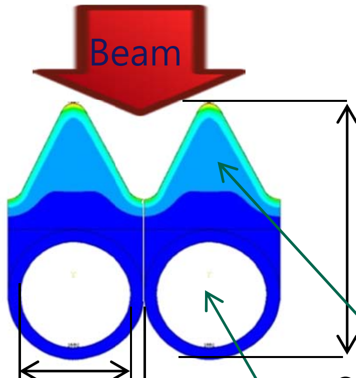
Rotating target technology is employed to enhance cooling

8 MW Target CuCrZr



Diameter ~ 4450 mm





- Centrifugal stress on pipes: 60 MPa (180 MPa limit)
- Fatigue stress: 160 MPa maximum (200 MPa for 10^9 cycles)

Power Ion Beams

1000 rpm
2 m radius

120 plates cover outer crown

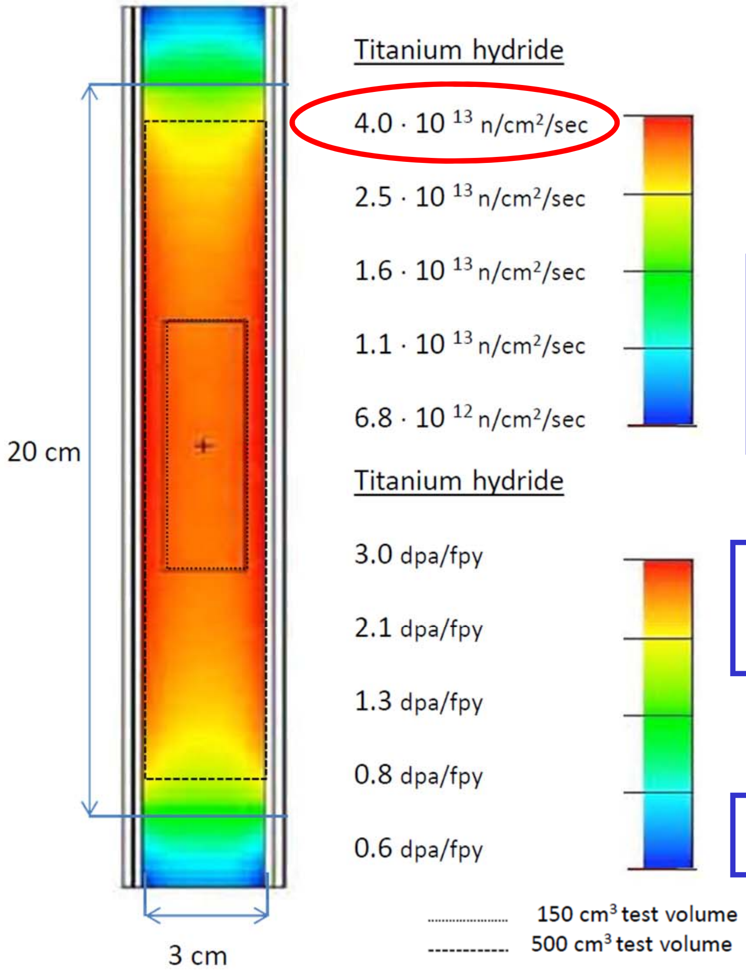
Heat flux	400 MW/m^2
Plate height	250 mm
Tube diameter	2 mm
Rotation period	60 ms (1000 rpm)
Beam-plate interaction time	0.48 ms
Heat transfer coefficient	40 kW/m^2/°C
Fluid average velocity	9 m/sec
Fluid inlet pressure	300 bar
Fluid inlet temperature	30 °C
Inlet-outlet temperature difference	20°C

Irradiation Performances

Main Experimental Irradiation Aims

1) Main tests for fusion materials irradiation

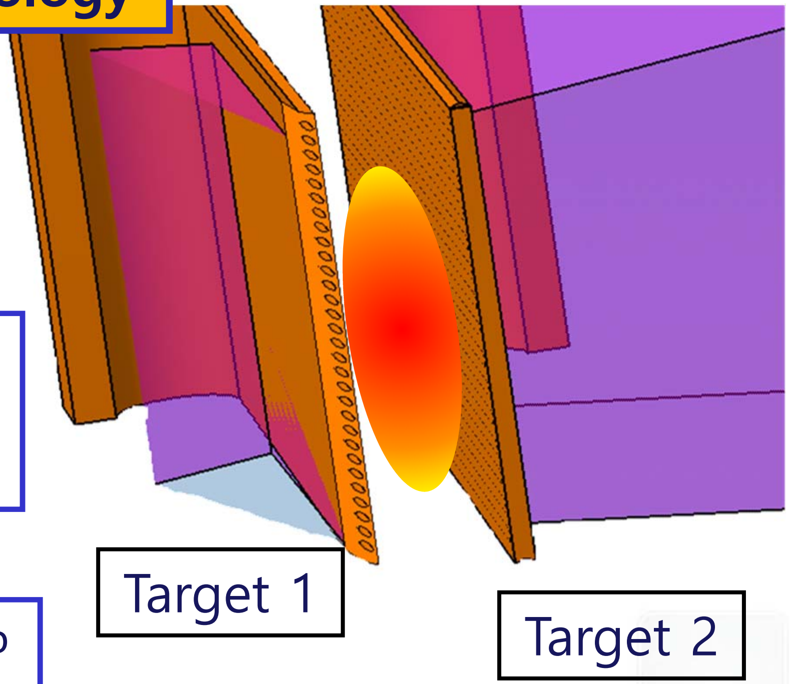
2) General fast neutron applications technology



Total Emission Intensity ~ 4 10^{15} n/sec

Irradiation up to 2 dpa/fpy peak

> 2 dpa in 250 cm^3



Irradiation Performances

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<u>Main Experimental Irradiation Aims</u>

1) Main tests for fusion materials irradiation

2) General fast neutron applications technology

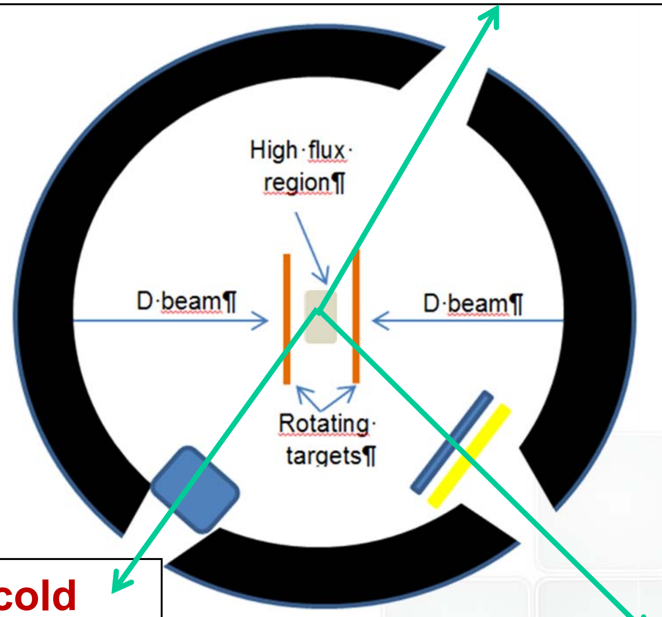
<u>Fusion Technology Applications</u>

- Steel/tungsten/copper irradiation
- Transmutation studies on:
  - ✓ ceramic insulators
  - ✓ optical fibers
  - ✓ window materials
- Low activation materials selection
- Cross section data library validation
- Tokamak neutron diagnostic devices
- Tritium production components

<u>Fast-thermal Neutron Applications</u>

- Irradiation of electronic chips
- Neutron imaging
- Prompt gamma activation analysis
- Component test for large sources

14 MeV neutron irradiation station
detector/diagnostics tests
Electronics (aerospace, avionics)
Industry, pharmaceutics, biology



Thermal/cold neutron beam
neutron imaging
neutron scattering

Super-cold neutrons
Cryo-moderators
fundamental physics

Thanks for your attention

Any questions?

D-T on-line recharge & Titanium on-line reload

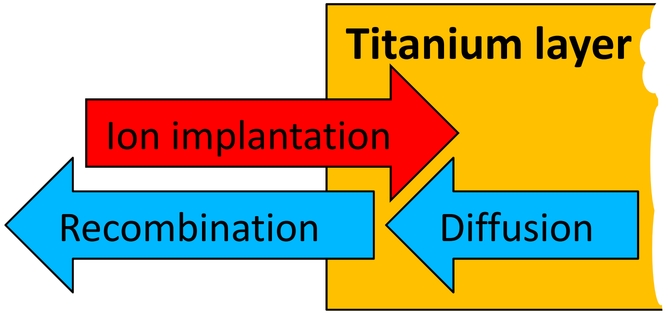
D-T fuel target recharge Requested reliable for entire Titanium temperature range

Hydrogen solubility is higher in β-phase

150°C 200°C 300°C 500°C

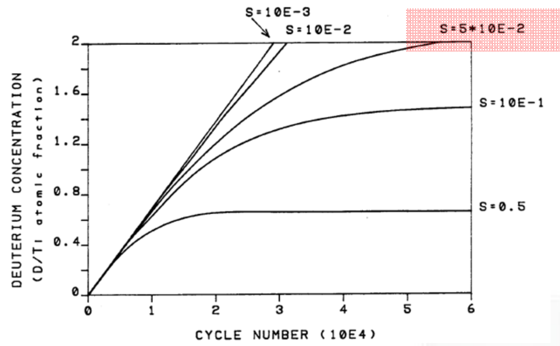
stable $Ti(TD)_2$ | $Ti(TD)_2$ dissociates

Ti α-phase | Ti β-phase



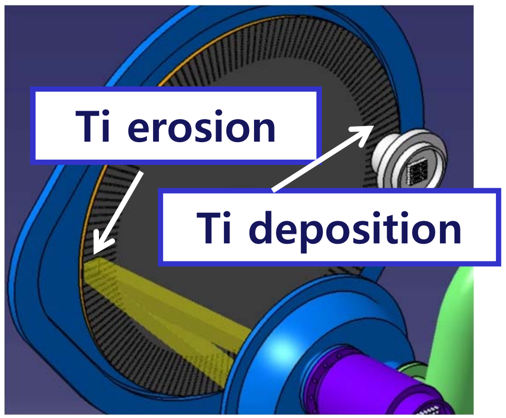
TRIM code simulations pointed out:

- D-T outgassing by recombination
- D-T outgassing decreases for low surface sticking factor



Recharge process feasible

Titanium hydride on-line depostion high erosion rate



Process requirements:

- Deposition speed: 1 Angstrom/sec
- Operating pressure: 2-3 mtorr
- Operational time: 8000 hours
- Ambient gas: D-T 50%-50%
- Surface speed: 350 m/s

Preliminary analysis:
- Evaporation
- Ion sputtering