ITER-India

Vacuum system in the IN-TF and optimisation of pumping requirements

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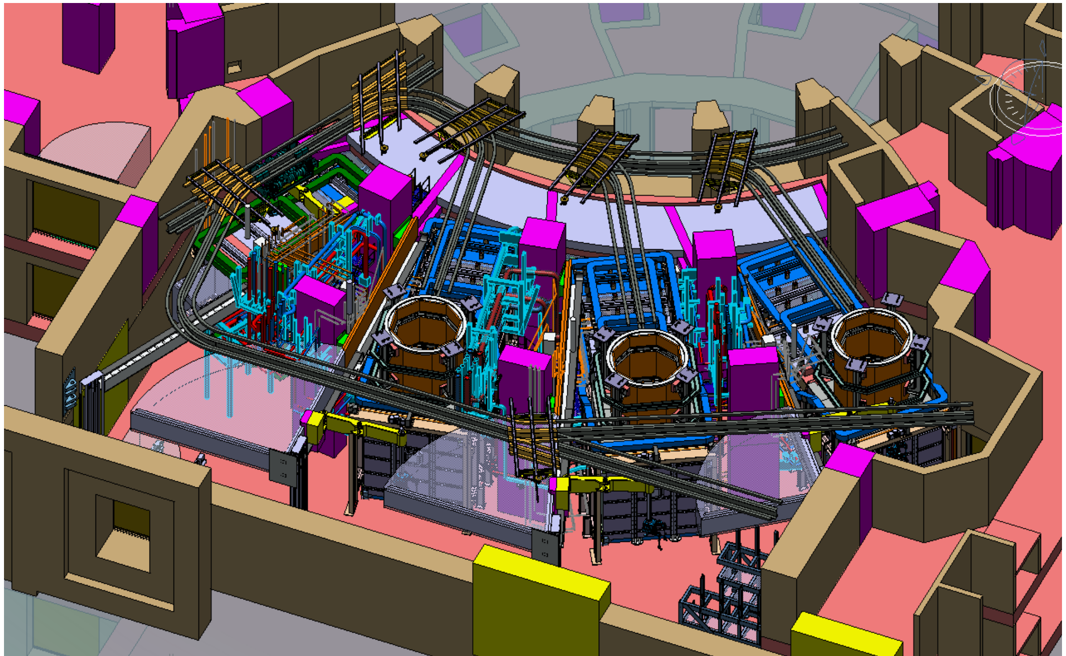
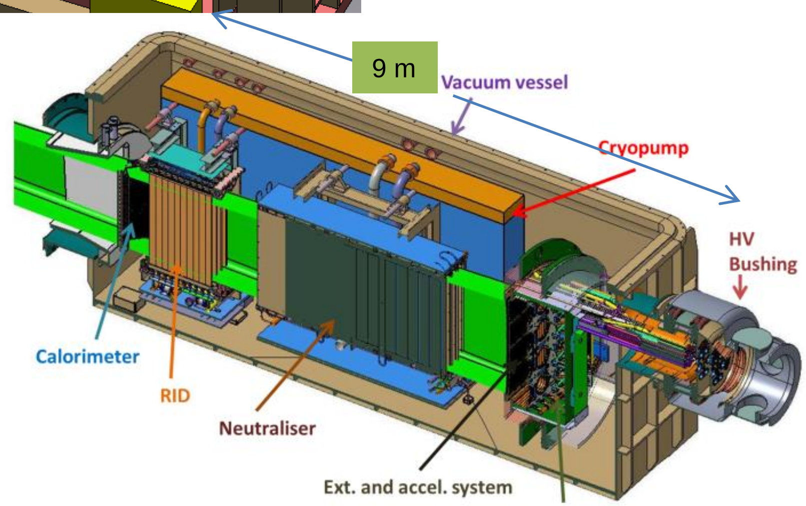
Outline

- Indian Test Facility (IN-TF) need, configuration & mandate
- Vacuum System requirements in IN-TF – External & internal
- Gas feeds, operational pressures, pressure profiles and reionisation loss
- Effective pumping area and options
- Decisions, pump configuration & cryo loads
- Summary

Need..

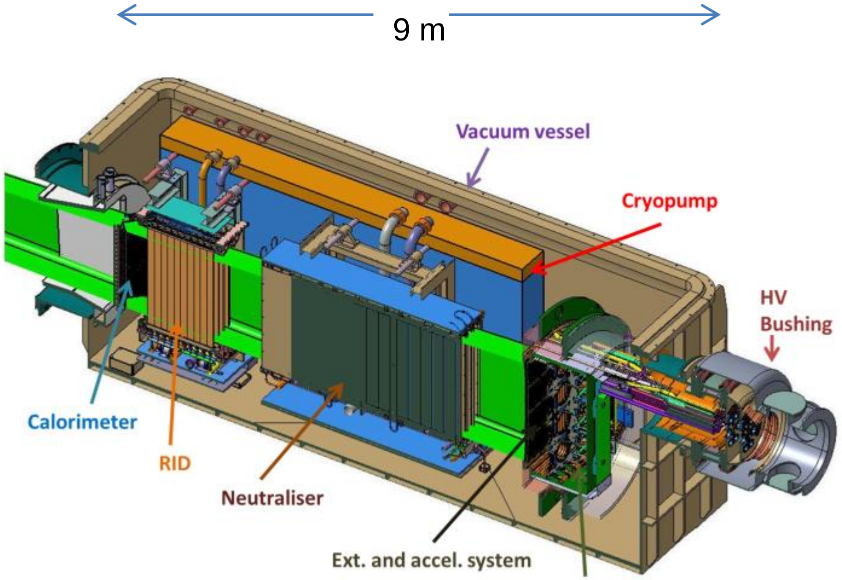



9 m
Vacuum vessel
Cryopump
HV
Bushing
Calorimeter
RID
Neutraliser
Ext. and accel. system

IN-TF need, configuration & mandate

- ITER-India (ITER-IN) procurement has Diagnostic Neutral Beam (DNB) as one of its deliverable
- DNB is an R&D intensive system - largest RF based –ve ion source in operation
  - Key issues
    - Plasma uniformity and Ion beam optics – partially addressed in the NBTF – coming up @ RFX
    - Transport (no facility available)
- ITER-IN & IPR agreed to support R&D need and approved IN-TF. ITER-IO extended support for Beam Source & PS
- IN-TF configured to replicate DNB including its transport
- Mandate therefore to operate facility as a global facility and establish deliverable beam parameters for ITER-DNB on best effort basis

INTF & DNB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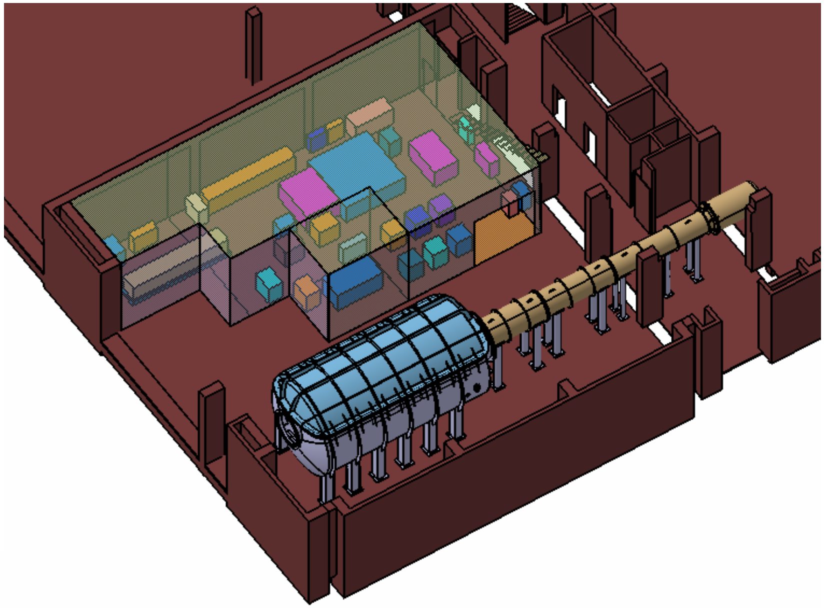
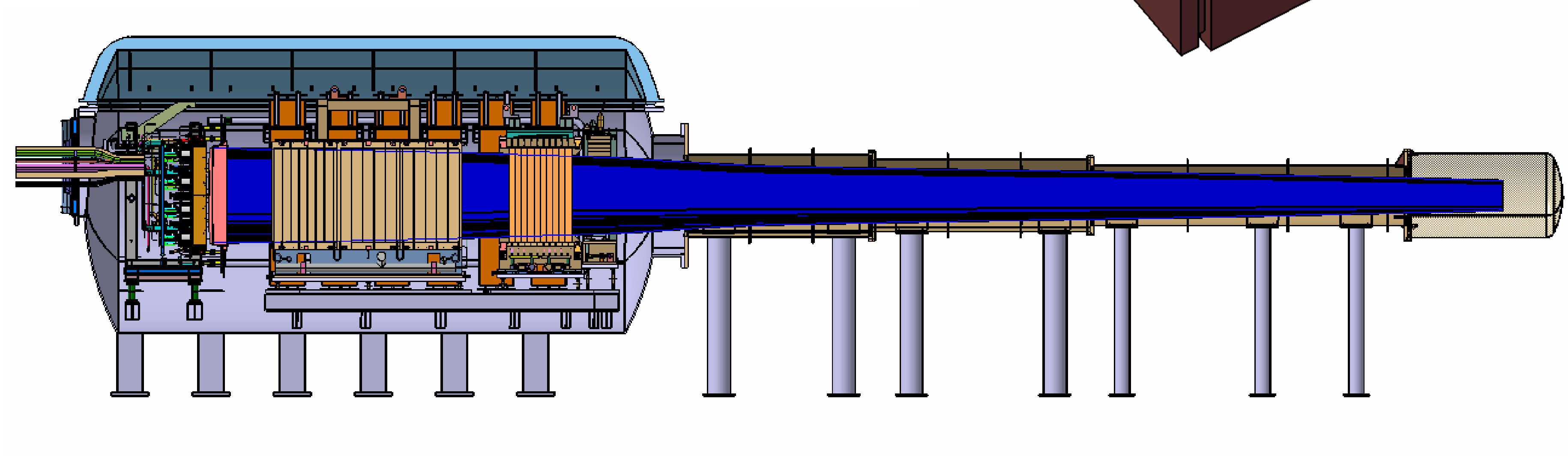
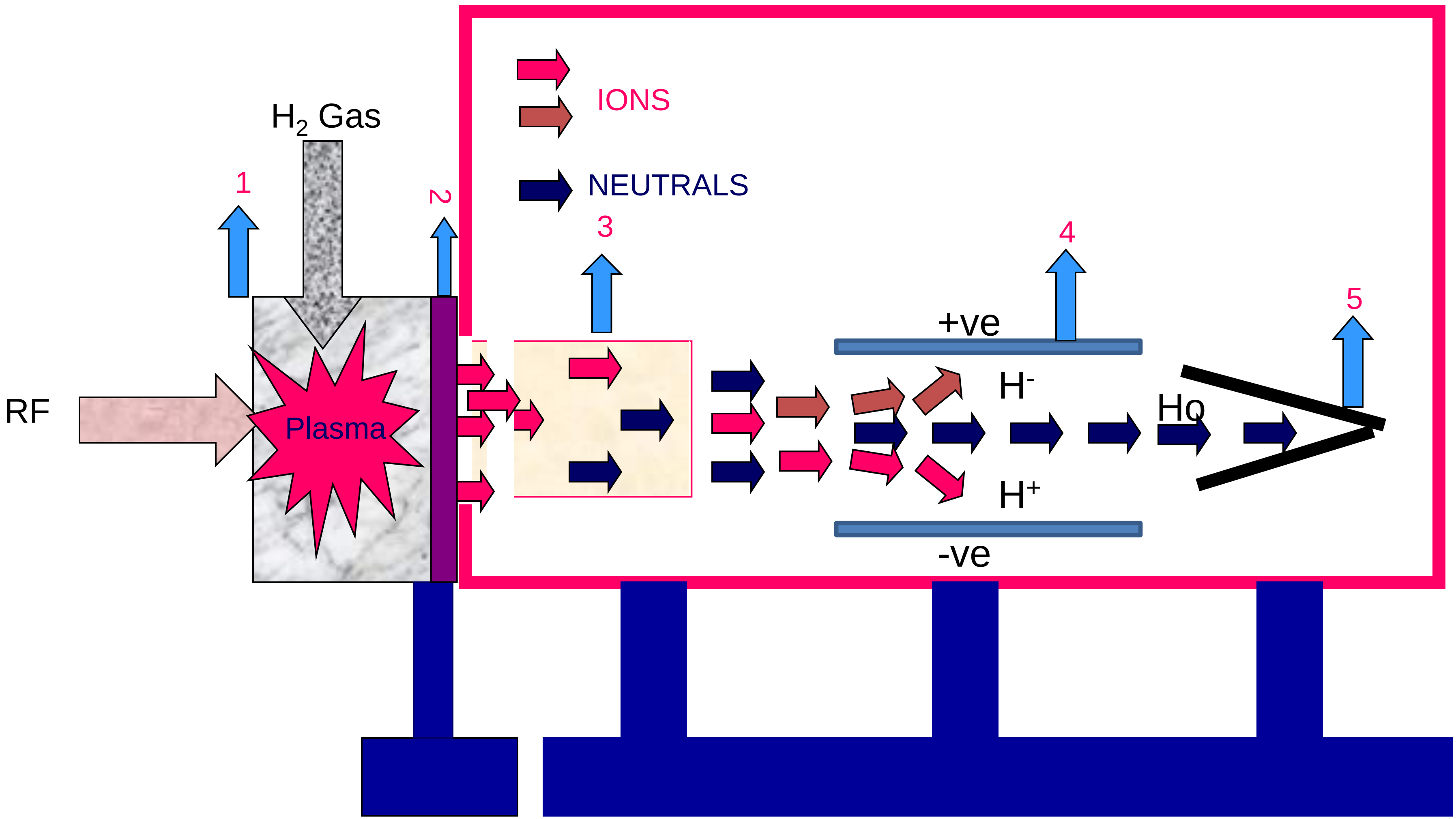




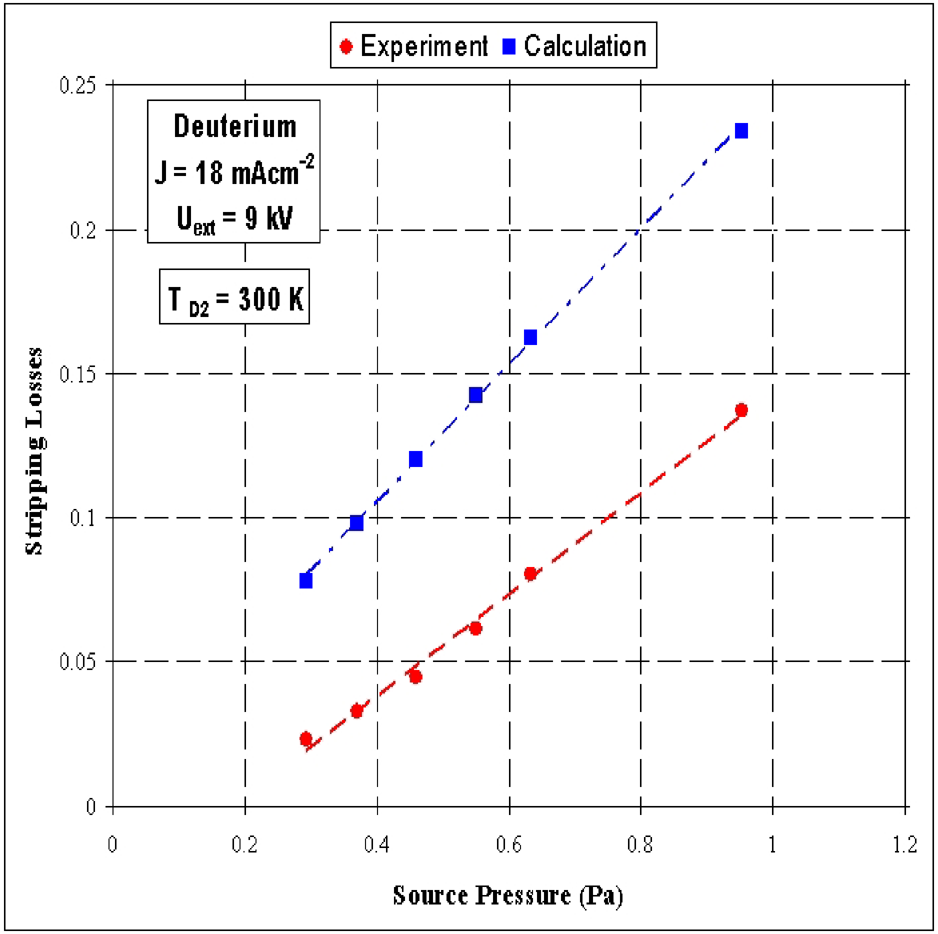
Principle of Neutral beam injector



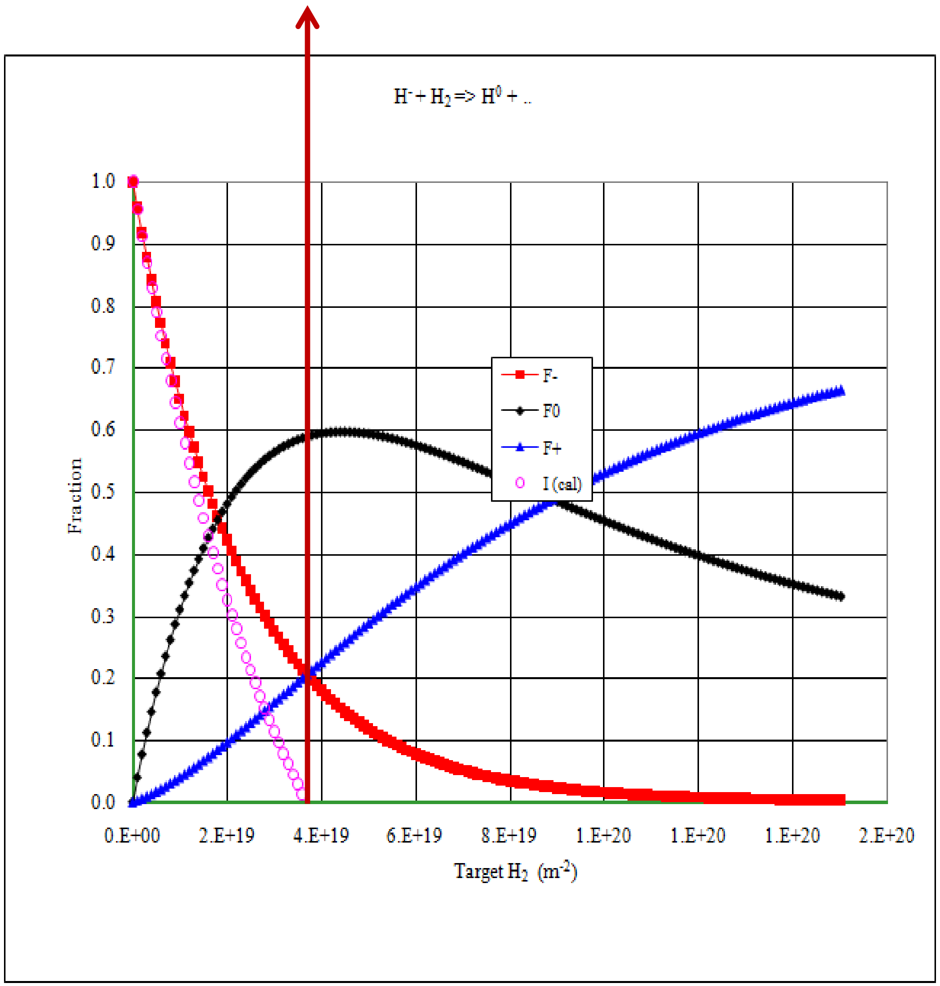
1 Ion Source **2 Extractor & Accel system** **3 Neutraliser** **4 RID** **5 Calorimeter**

Need for pressure optimization

Stripping loss in negative ion source (Courtesy – IPP – BATMAN source



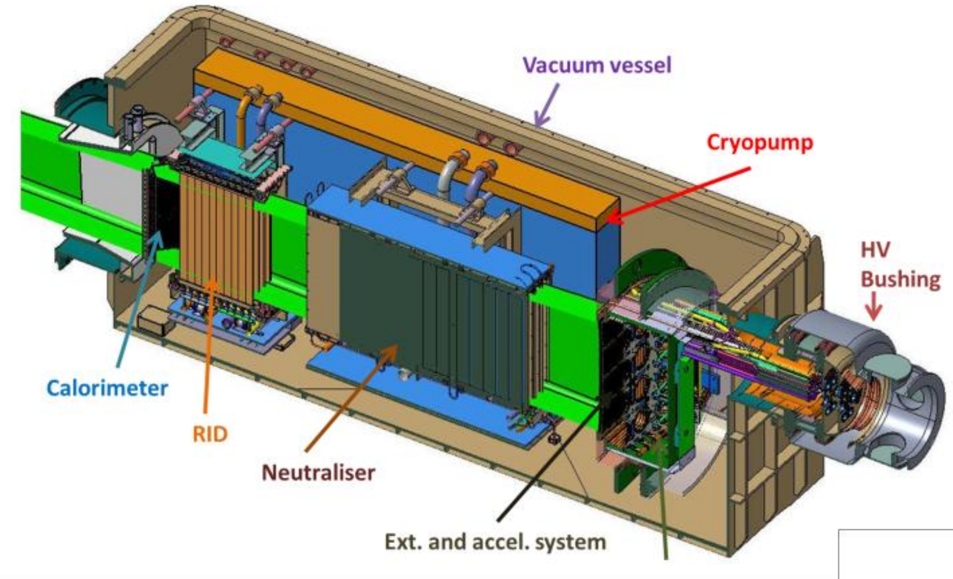
Optimum gas (target) line density in Neutralizer



Vacuum System requirements in IN-TF – External & internal

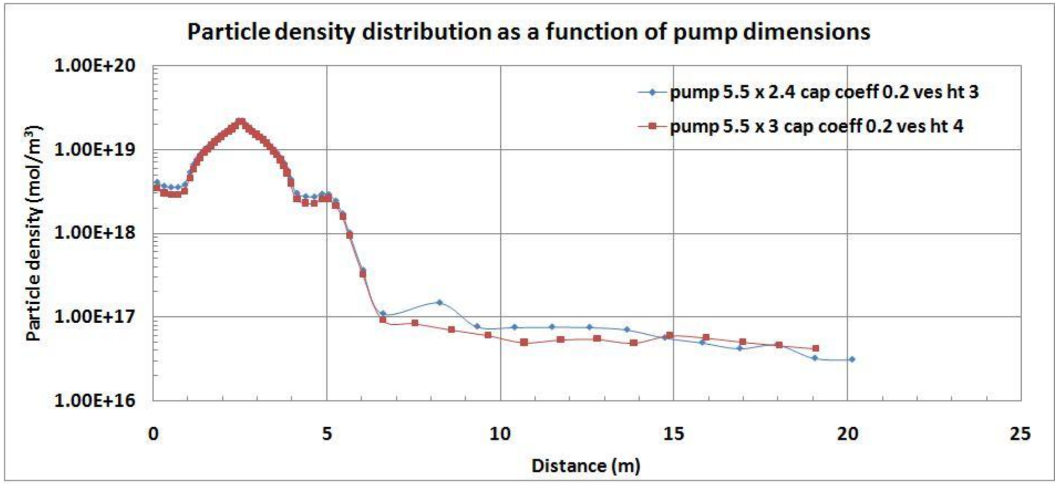
	Type of pump	Pumping speed (l/s)	Purpose
External	Rough and roots combination	Rough Roots	Base vacuum at start Support regeneration mode of cryopumps
	Turbo molecular pump	5000	Base vacuum to start cryopumping Support regeneration mode of cryopumps
Internal	Cryopumps	Desired pumping speed in ITER DNB : 3×10^6	Pumping hydrogen (7.6 Pa m^3/s from source and 7 Pa m^3/s from neutraliser)

Vacuum System requirements in IN-TF – internal*



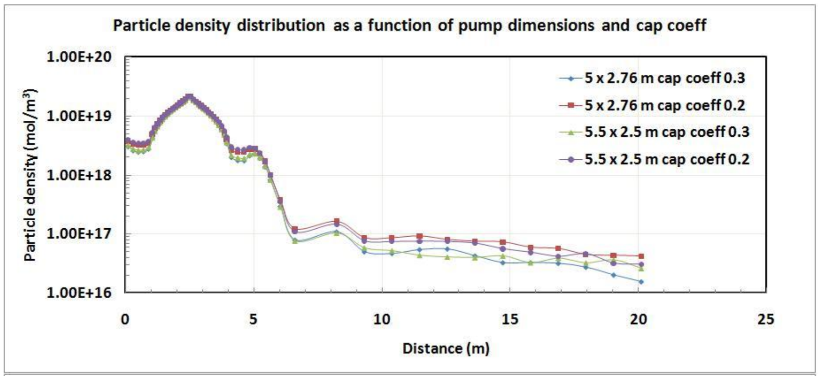
Source gas : 7.6 Pa m^3/s
Neutraliser gas : 7 Pa m^3/s

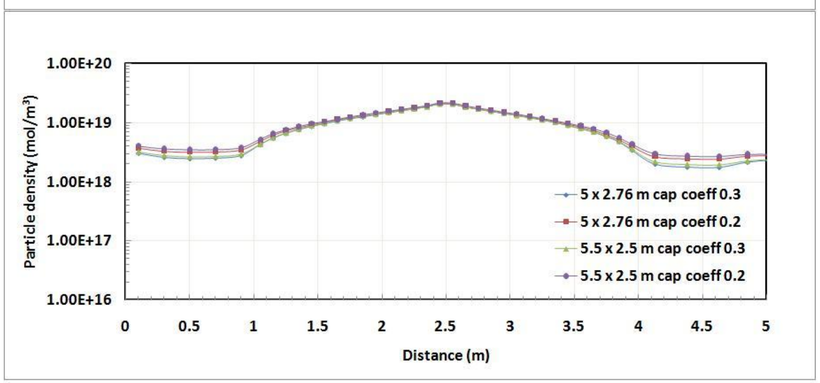
DNB uses 2 cryo sorption panels on the two sides. These pumps are developed by KIT.
For IN-TF, options are explored for alternate pump configurations



*The calculations for pressures, reionisation etc. represented here (in the ppt) have been carried out using BTR code, developed by the RF DA and made available to ITER-IN by IO

Gas feeds, operational pressures, pressure profiles and reionisation loss





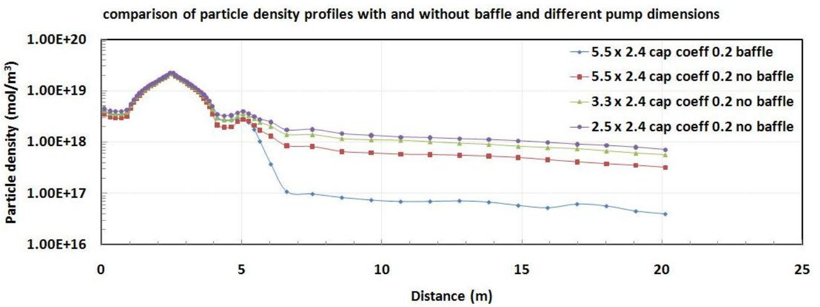
Source gas : 7.6 Pa m^3/s
Neutraliser gas : 7 Pa m^3/s

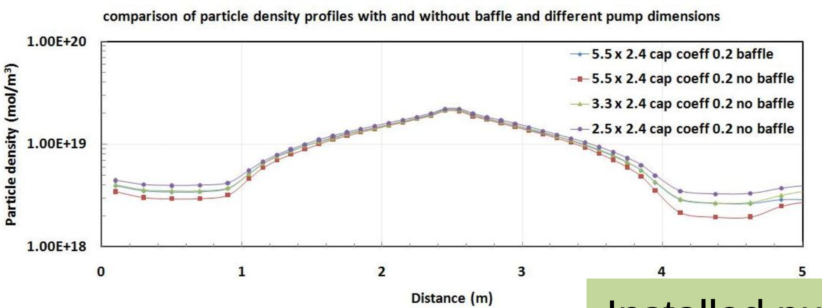
Source throughput (Pa m3/s)	Neutraliser throughput (Pa m3/s)	Pump dimension (m)	Capture coefficient	NL effective	Pressure in GG-neut region (Pa)
7.6	7	5.5 x 2.4	0.3	3.82E+19	0.011 (2.64E+18 /m^3)
7.6	7	5.5 x 2.4	0.2	4.10E+19	0.014 (3.48E+18 /m^3)
7.6	7	5 x 2.76	0.2	3.96E+19	0.013 (3.17E+18 /m^3)
7.6	7	5 x 2.76	0.3	3.74E+19	0.01 (2.46E+18 /m^3)

Operational NBI, interfacing with Tokamak, requires high investments in pumping to minimise re-ionisation. Could we live with a higher %?

Effective pumping area and options

- A well tailored pressure profile leads to low re-ionisation
- However, pumping area & cost increases if reionisation loss is to be maintained <5%
- Therefore a reassessment, based on a higher reionisation loss undertaken including w/o baffles
- Effective area assessed to be ~ 50% lower if reionisation is allowed ~20%
- Impact of reionisation assessed to be in consequential for transport studies, excepting deflection of beam due to erath's B field – mitigated by a magnetic shield





Pump dimension	Baffle	Particle density (GG-neutent)	Pressure (Pa)	Particle density (RID)	Pressure (Pa)	nL reion	Reionsation (%)
5.5 x 2.4	Yes	3.48E+18	0.014	2.41E+18	0.009	5.42E+18	5.9
5.5 x 2.4	No	2.95E+18	0.012	1.96E+18	0.008	1.23E+19	13.5
3.3 x 2.4	No	3.55E+18	0.014	2.70E+18	0.011	1.95E+19	21.5
2.5 x 2.4	No	3.97E+18	0.016	3.29E+18	0.014	2.38E+19	26.2

Installed pumping speed for IN-TF with higher reio loss is 2 x 10^6 l/s

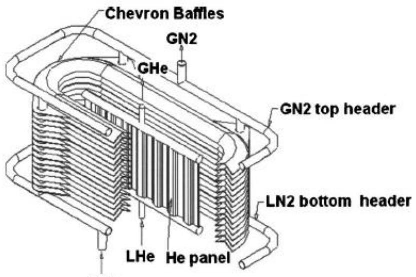
Option Evaluation – Cryo-condensation vs cryo sorption

Parameters	Pumping speeds	Regeneration frequency	Operational temperatures	Cryo genic loads	Refrigerator configuration
Cryo-condensation	~10 l/s/cm^2	Limited by 12 torr lit/lit of safety	3.8 k for H	Low on He panel due to reflective panel	Complex & expensive
Cryo sorption	similar	similar	Up to 15 K	High for He panels due to coating	Simplified.

Configuration decision & cryo loads

Present cryopump configuration in IPR SST-1 NBI

Overall pump dimensions : 3100 x 550 x 250 mm^3



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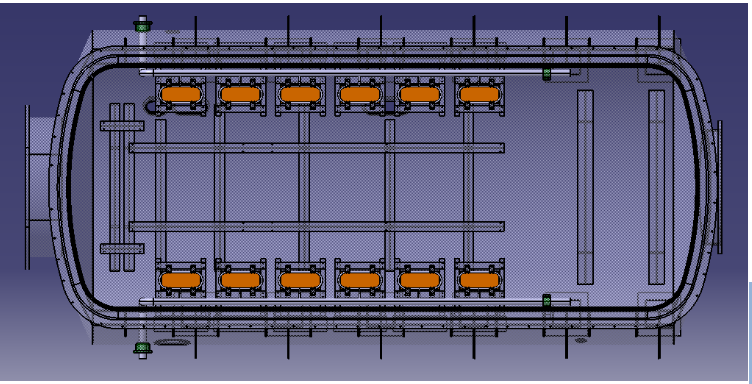

TABLE I. Parameters of the cryopump.

Parameter	Values
Baffle width (cm)	2.9
Angle (deg)	120
Interbaffle spacing (cm)	1.3
Overall dimensions of LHe panel (mm) (including ∅ 60 mm each top and bottom header)	2720 × 330
Pumping area (m^2) (surface area of elliptical channels + straight portions + headers)	1.9
Chevron area (m^2)	3.4
Bounce parameter	5
Particle transmitivity	0.23
Photon transmitivity	1.3×10^{-3}

Pumping speed for H_2 : 1.6 E 5 l/s
Capture coeff. : 0.2
Proposal: To operate the same pumps as cryosorption pumps with operational temp ~ 15 K

Cryo loads

Operation	80 K	15 K
Stand by	1) Thermal Radiation 2) Solid heat conduction	1) Thermal Radiation 2) Solid heat conduction
Pulsed	1) Thermal radiation by a) Beam Line Vessel (BLV) b) Beam Line Components (BLCs) 2) Solid heat conduction 3) Gaseous heat conduction 4) Cooling of the gas	1) Thermal Radiation 2) Solid heat conduction 3) Gaseous heat conduction 4) Cooling of the gas 5) Heat transferred by the gas accumulated to charcoal

Parameters	Components	Value
Pressure	Pressure in vessel	0.001 Pa (7.5×10^{-6} Torr)
	Pressure between neutralizer and accelerator	0.04 Pa (3.0×10^{-4} Torr)
Gas Flow	Gas flow- RID	0.5 Pa-m³/s
	Gas flow-Neutralizer	7 Pa-m³/s
	Gas flow-Beam source	7.59 Pa-m³ /s
	Total gas flow during continuous operation	14.59 Pa-m³ /s

Parameters	Components	Value
Temperature	BLC's	375 K
	BLV	310 K
	Radiation Shield (N_2 - Panel)	80 K
	Cryopanel (He-panel)	15 K
Emissivity	Charcoal coated panel	0.9
	BLC's	0.3
	BLV	0.15

Cryo loads

80 k Load (Total heat load)

Operation	Per cryopump (W)	For all 12 cryopump(W)
Stand by	645 (1290)	7748 (15496)
Pulsed	737 (1474)	8854 (17708)

e_1=0.9 (coated panel)

e_2= 0.15 (SS vessel)

A_1= 42.2 m^2 (12 cryopump surface area:-

12 front face+12 back face+4 side face)

A_2= 133 m^2(measured vessel surface area)

15 k panel load (total heat loads)

Operation	Per cryopump (W)	For all 12 cryopump(W)
Stand by (1+2)	4.8 (9.6)	57.7 (115.4)
Pulsed (1+2+3+4+5)	14.2 (28.3)	170 (340)

e_1= 0.9 (inner panel-15K)

e_2= 0.9 (charcoal coated panel-80K)

A_1= 23.5 m^2 (12 front face+12 back face+0 side face), 330x2966x2x12

A_2= 39.2 m^2(12 front face+12 back face+0 side face), 550x2966x2x12

Summary

- Internal Vacuum Pumping for IN-TF is cryosorption based
- Pumping area optimised for IN-TF purposes with higher reionisation loads in operation
- Pumping configuration – similar to SST-1 NBI cryopump & made to operate in cryosorption mode
- Cryo loads calculated and benchmarked with available design for ITER cryo pumps
- Option assessment for Cryo system for the 80 K and 15 K panels – ongoing..