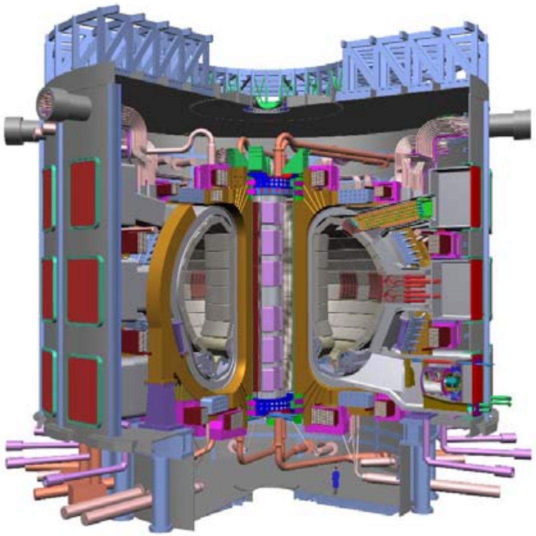

ITER

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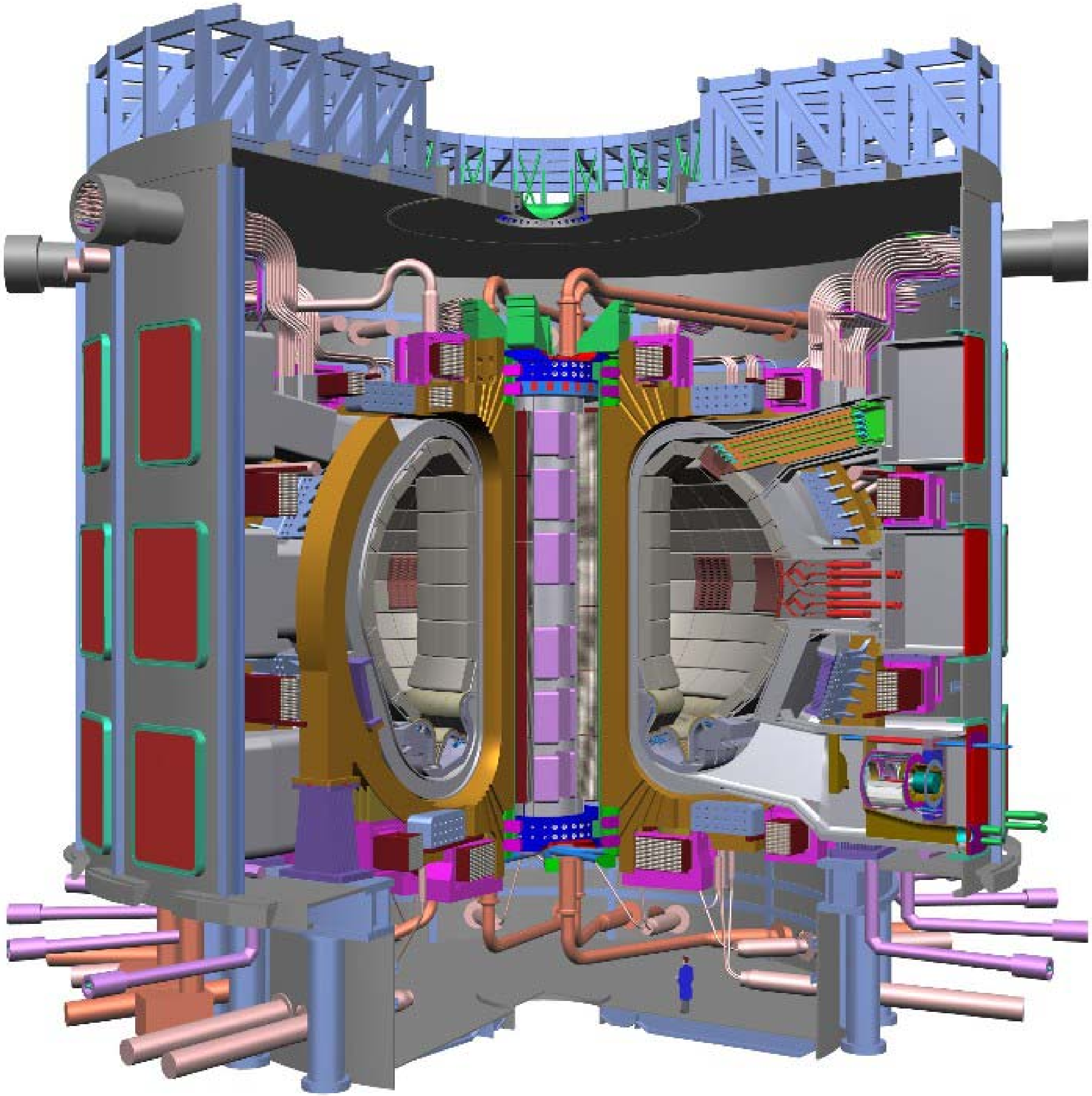
ITER Vacuum Pumping Systems

M. Wykes (michael.wykes@iter.org)

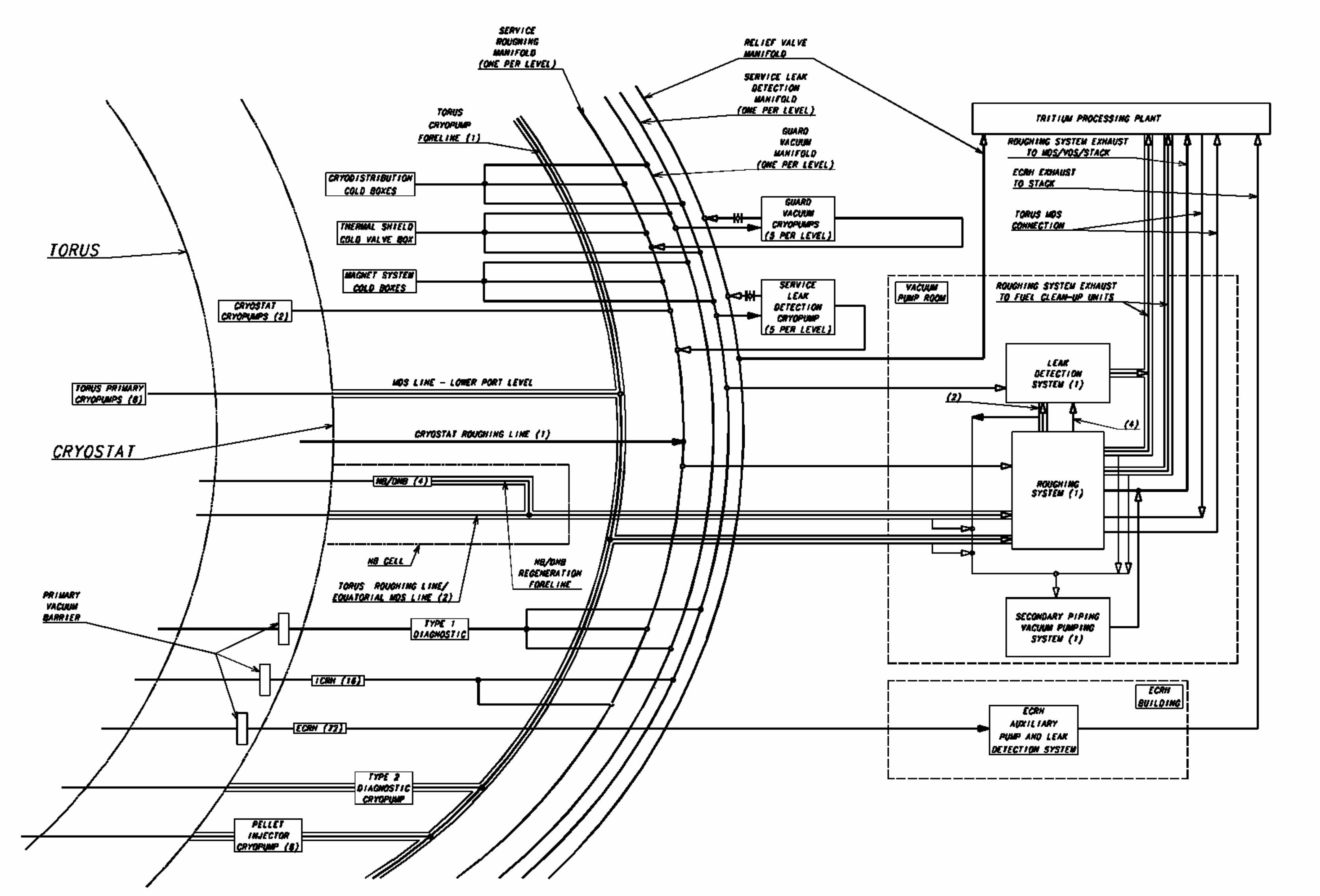
Lots of info on:	www.iter.org/bl	Please apply to John.How@iter.org for access



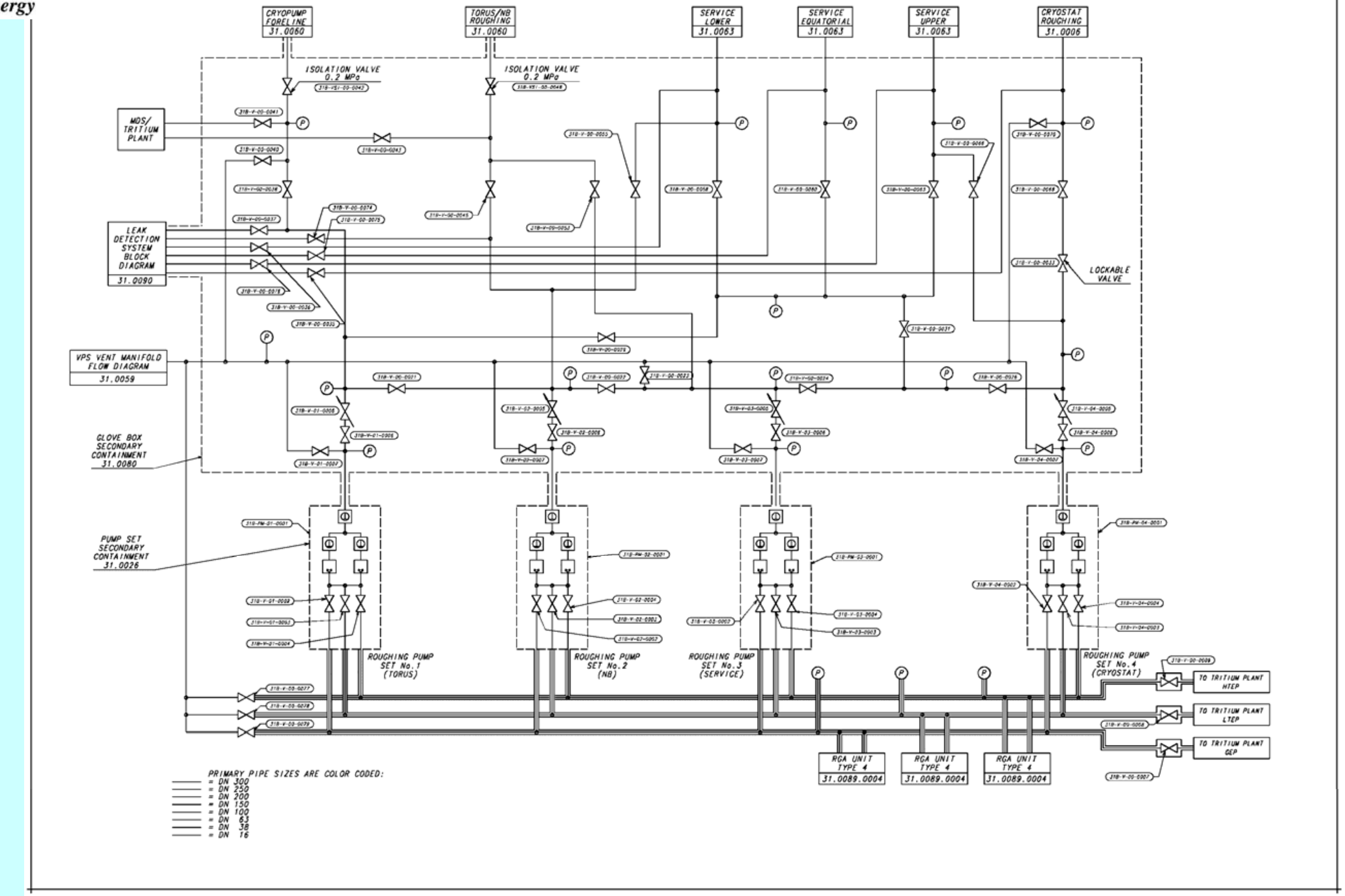
Components of the ITER Vacuum Pumping System

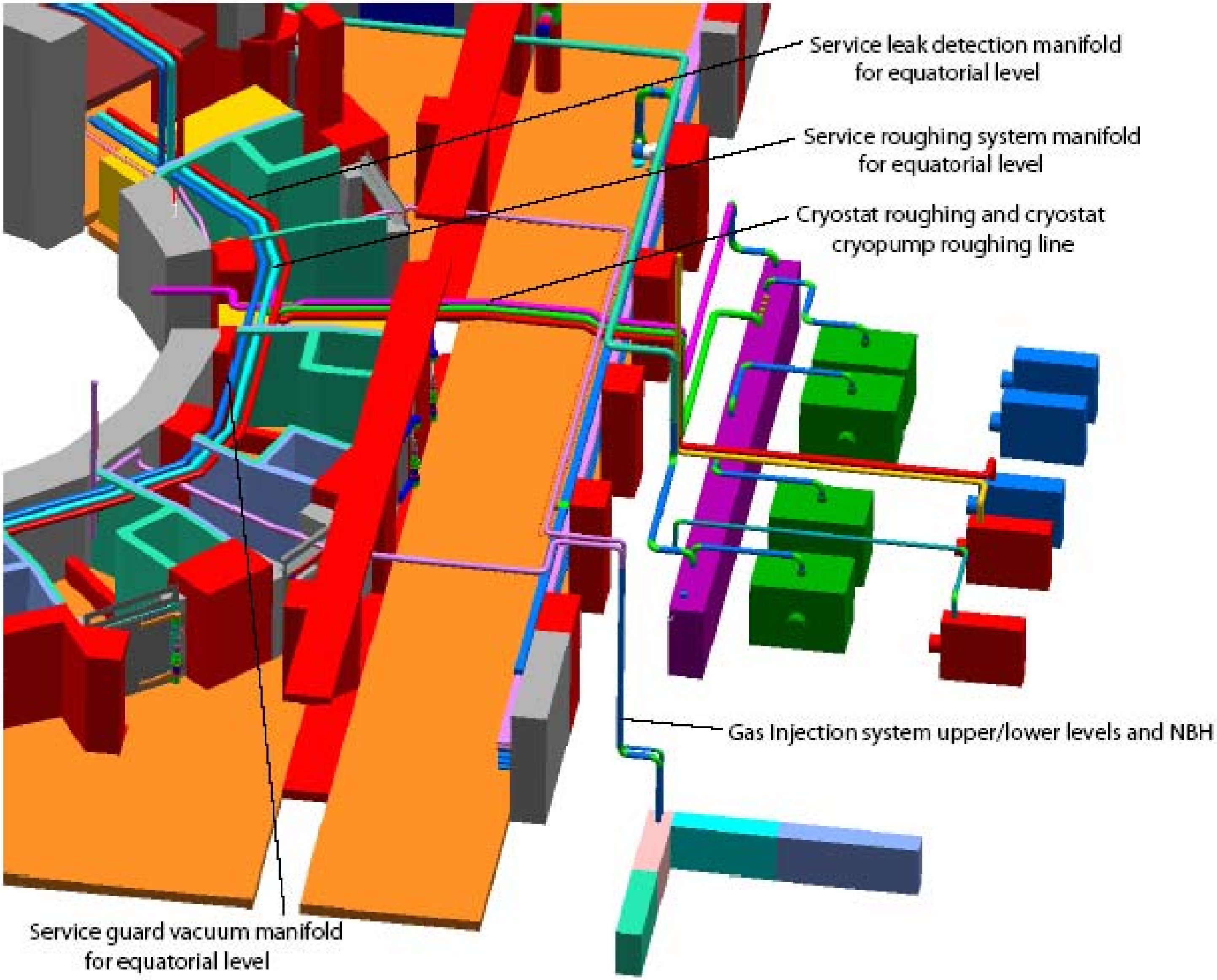
Primary torus cryopumps	handling tritium during normal DT operation
Mechanical forepumps	handling tritium during normal DT operation
Type 2 diagnostics	handling tritium during normal DT operation
Type 1 diagnostics	handling small amounts tritium during off- normal DT operation (+permeation?)
NB cryopumps	handling small amounts of tritium during dwell pumping (PFC desorption)
Service Vacuum Pumping System	handling small amounts of tritium during off-normal DT operation (leaks to primary vacuum)
Cryostat high vacuum pumps	handling small amounts of tritium during off-normal operation (i.e. T in cryostat, magnets warm)
Heating & CD (excl. NB) pumping systems	handling small amounts of tritium during off-normal DT operation

Block diagram of ITER vacuum pumping systems



Flow diagram of ITER forepumping system

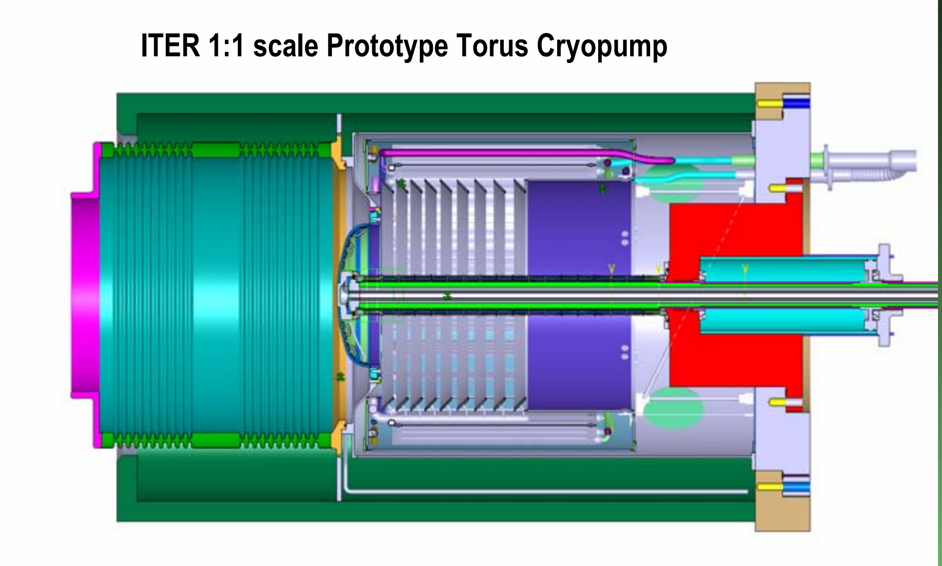




View from South East tokamak building 11-L1 Equatorial Level

11-L1-3 M.Mills 050218

ITER torus cryo-sorption pumps


ITER 1:1 scale Prototype Torus Cryopump

4 years experimental data from scale model pump (4 m^2 sorbent area) in TIMO test facility at FZK
Test results form technical basis for design of 1:1 full scale pumps

See: C. Day "Cryopumps", this School

ITER torus cryo-sorption pumps- operation modes

Pumping during bakeout: H isotopes, impurities (water, O_2 bearing gases)

GDC: H isotopes, He and impurities: 0.1-0.5 Pa, max. throughput 50 Pa.m^3/s

EC/IC discharge cleaning: H isotopes, He and impurities: 0.01-0.1 Pa, max. throughput 50 Pa.m^3/s

Transient pumpdown from crossover to base pressure after vent; air, residual gases, water etc

Transient pumpdown from crossover to base pressure after 100 K regen; H isotopes (many cycles)

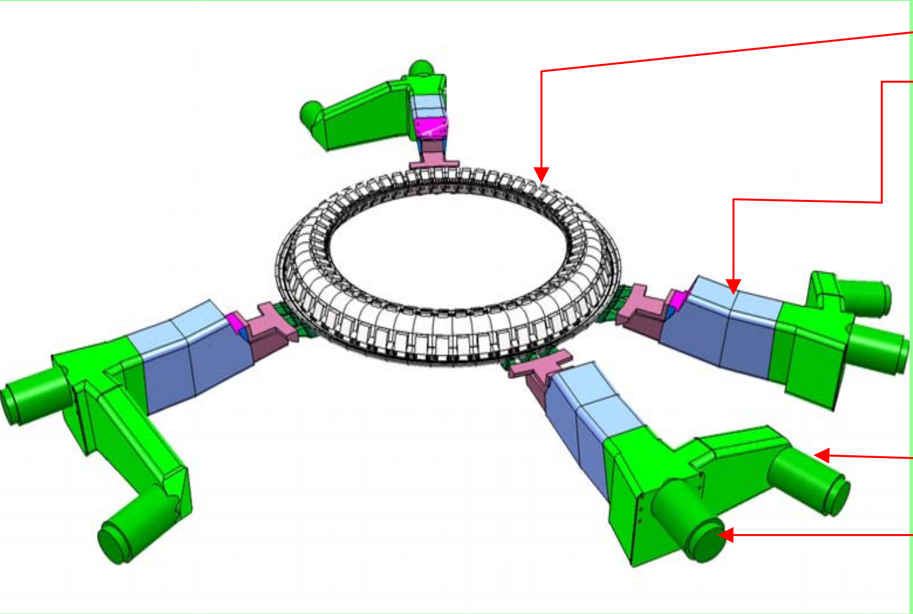
Transient pumpdown from crossover to base pressure after 300 K & 470 K regen; H isotopes and impurities (water, alkanes, QH3)

Diverted plasma exhaust: H isotopes, He, CxHy, noble+impurity gases; up to 120 Pa.m^3/s, $1<P_{PFC}<10$ Pa

Leak detection: sorbent panels at 40 K to suppress leak tracer helium pumping – all other gases pumped

More detailed info in section 4.13 of PID

ITER torus cryo-sorption pumps-& pumping ducts



54 divertor cassettes

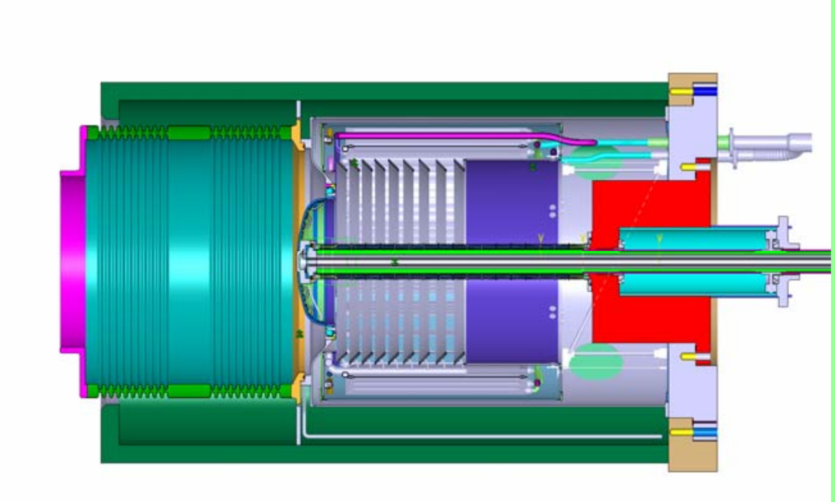
4 torus pumping ducts

Branched cryopump

Direct cryopump

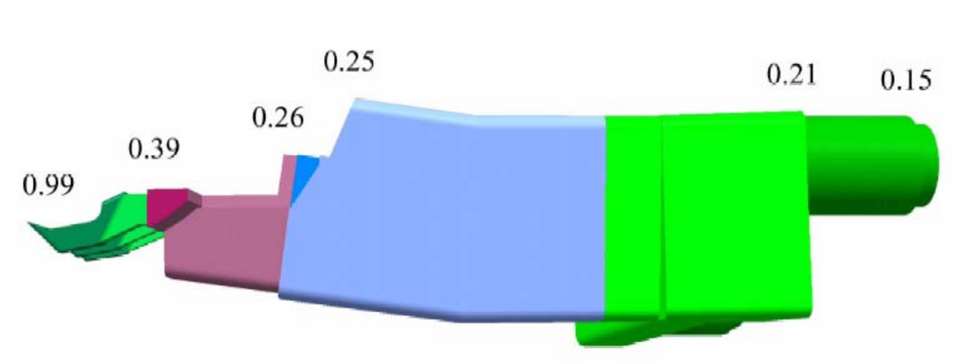
MOVAK3D (Molecular Flow) and ITERVAC (Knudsen flow) codes used as design tools. ITERVAC developed by FzK

See presentation "Cryopumps" by C. Day, this School

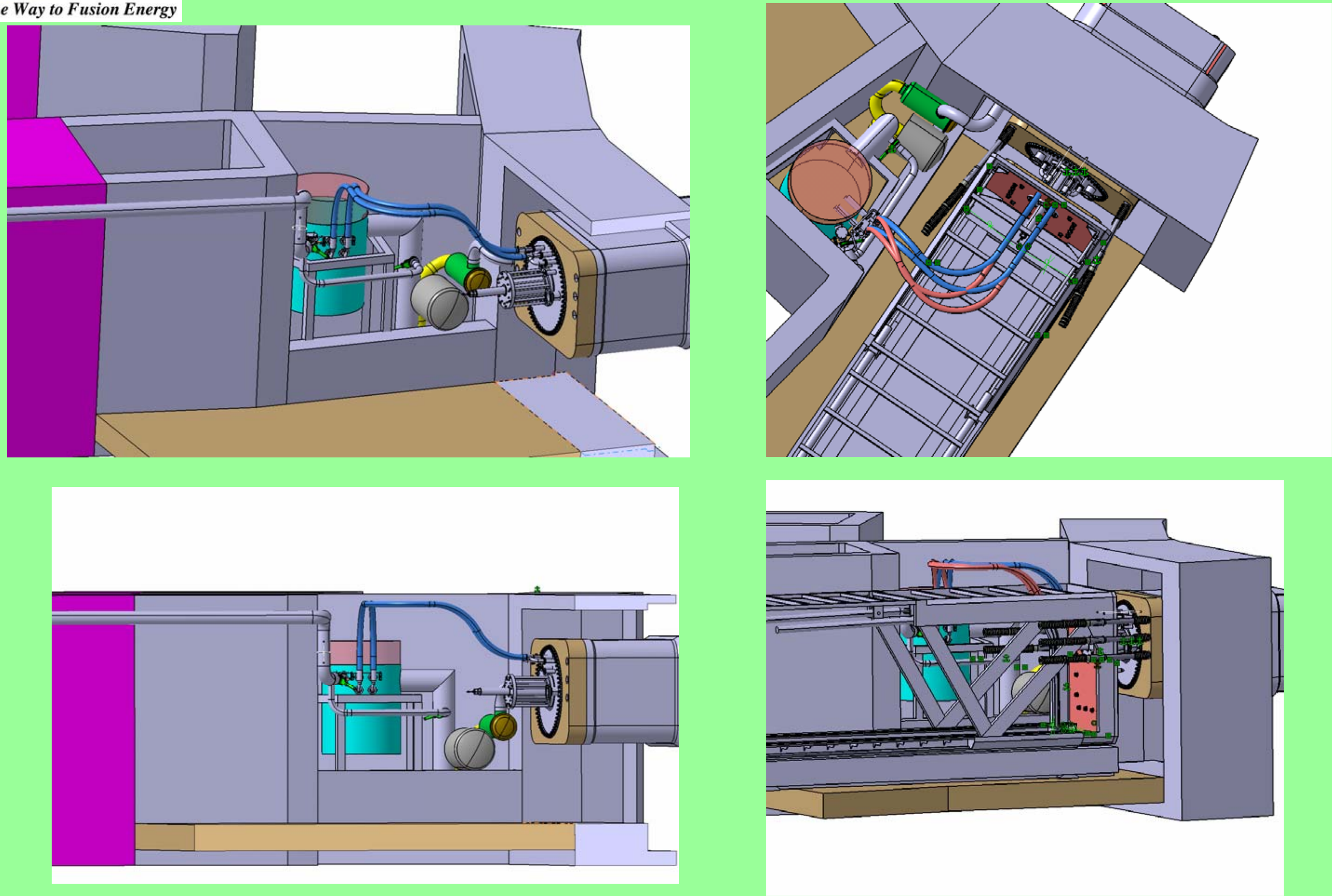


Torus cryopump

Pumping duct pressure distribution



ITER torus/cryostat cryo-sorption pump in lower port cell



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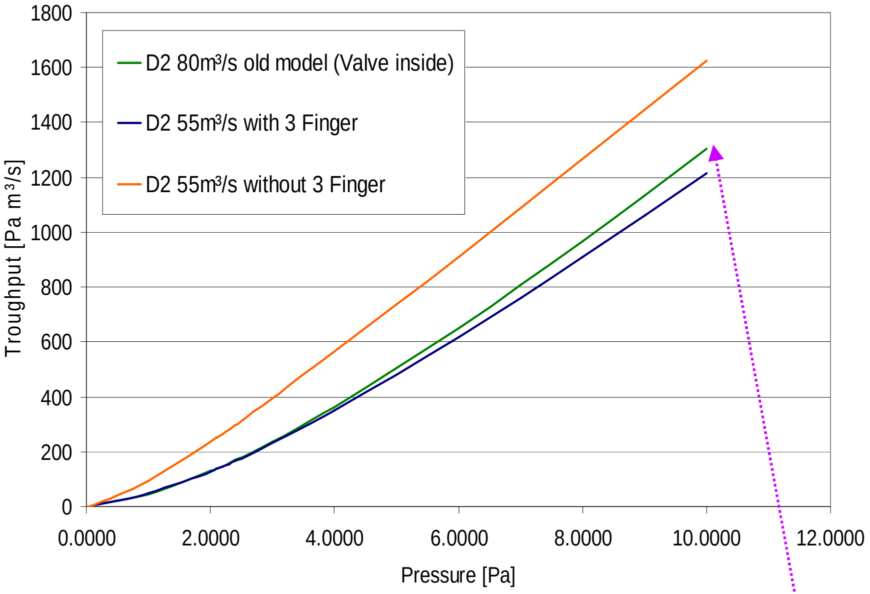
Torus Cryopump (1780 OD) has (almost) same performance as previous (1930 OD) design

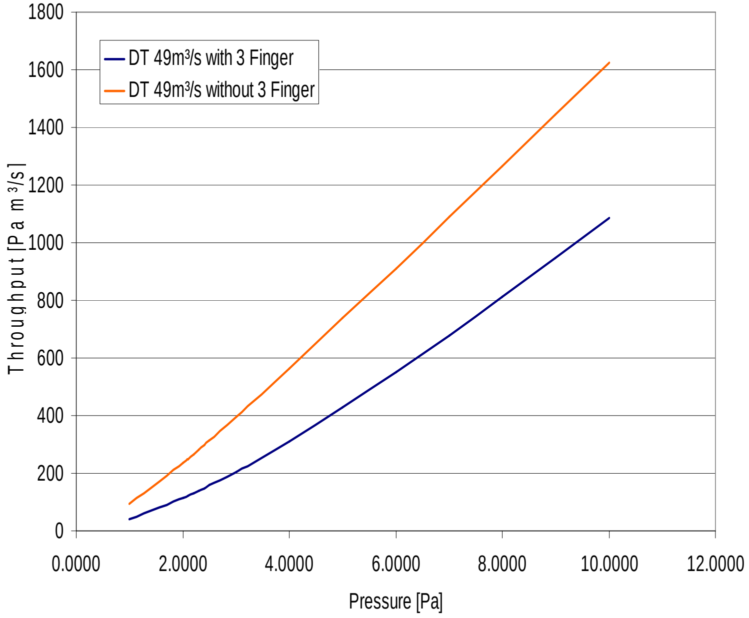
Complete pump can now be remotely removed/replaced at RH Class 2 level

Former (1930 OD design) was deficient in RH capability

For new (1780 OD) pump design, if the 3-Fingered Manifolds (3FM) are deleted (likely), the effective molecular flow pumping speed at the vessel (42 m^3/s for 4 pumps/ducts for DT) is very beneficial for both for dwell pumping and diverted plasma exhaust pumping (Knudsen flow)



Green & Blue graphs show that “80 m^3/s reference pump” and “55m^3/s DCR38 pump” have virtually same performance



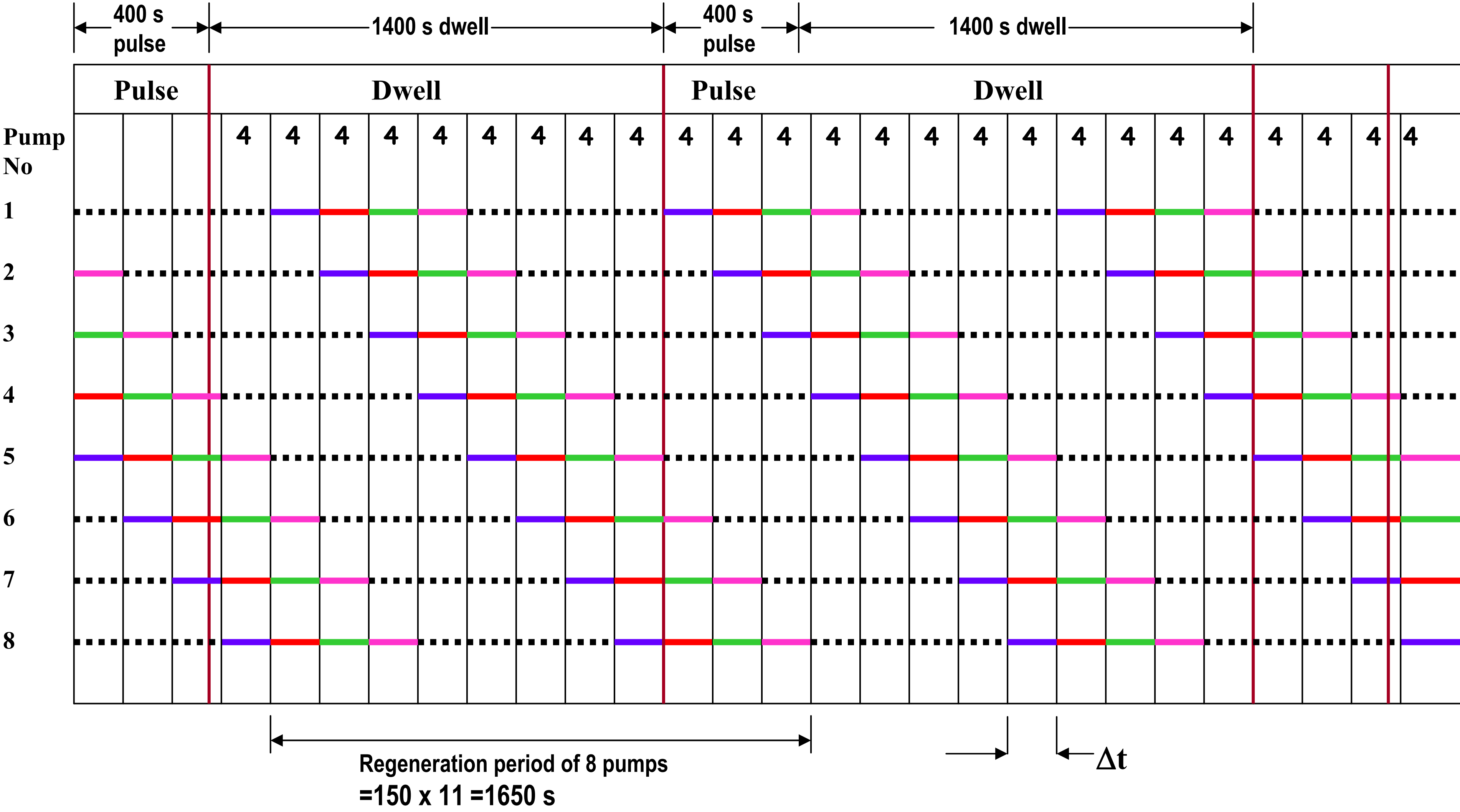
Significant increase (>60%) in throughput without 3FM

ITER torus cryopumps – T & H limits {1}

- There is an administrative limit of 120 g of T inventory in all torus cryopumps open to the torus
- *This T limit, being Administrative is somewhat arbitrary but any increase would be problematic on account of overall T plant inventory and ALARA*
- **There is a physical hydrogenic inventory limit for INDIVIDUAL torus cryopumps (inlet valve closed) such that the deflagration pressure must be < the design pressure (presently 0.2 MPa) of the vacuum vessel duct which forms the pump housing**
- For the reference torus cryopump design the free (H explosion pertinent) volume is ~ 8.5 m^3 and with a hydrogen concentration of 1.5 mole/m^3, this leads to a deflagration pressure of 2 bara. More background is given in: M. ISELI, "In-vessel hydrogen deflagration and detonation", *Fusion Eng. and Design 54 (2001),* 421 & M. Wykes, "Minimisation of the hydrogenic inventory of the ITER neutral beamline cryo-sorption pumps," 7th International Conference on Tritium Science and Technology, 13-17 September 2004, Baden-baden, Germany
- THESE LIMITS BOUND THE MAXIMUM PUMPING TIME OF AN INDIVIDUAL TORUS CRYOPUMP FOR LONG PULSE OPERATION

⟶NEXT SLIDE

8 pump+4 ducts, sequential pulsing at maximum repetition rate (400 s burn)



Regeneration period of 8 pumps
=150 x 11 =1650 s

Regeneration key ▬ Cold helium exhaust ▬ Warm-up & gas release ▬ Evacuate ▬ Cool-down

Minimum repetition time ~1400 s for 8pumps+4 ducts

Torus cryopump regeneration pattern

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ITER torus cryopumps – T & H limits {2}

☐ Reference ITER DT exhaust throughput (PID Table 4.13-3) is:

q=120 Pa.m^3/s 50:50 DT (@273 K) = 60 Pa.m^3/s T at 273 K = 0.6 NL/s of T

22.41 NL~ 1 mole ~ 6 g T; 0.6 NL T~ 6 (g) x 0.6 (NL)/22.41 (NL) ~ 0.1606 g/s — T MASS FLOW

4 pumps pumping, 4 in regeneration (see next viewgraph for pattern) — T ADMIN LIMIT

$(q/4) \times \Delta t \times \{4+3+2+1\} \leq 120$ g T

$\{0.1606/4\} \times \Delta t \times \{4+3+2+1\} \leq 120$ g T

$\Delta t \leq 298$ s [> 100 % margin]

BUT *Allowance needed for T in CxQy (on-going R&D), inadvertent over-fuelling and indeterminate factors*

Δt is the "Incremental time", important for vacuum and cryogenic functional aspects. Reference Value of Δt:
Δt=150 s

2 bar deflagration limit = 4.5 (g T/m^3) x 8.5 (m^3) = 38.3 g T — INDIVIDUAL PUMP DEFLAGRATION 2 BAR LIMIT

$\{0.1606/4\} \times \Delta t \times \{4\} \leq 38.3$ g T

$\Delta t \leq 238$ s [~ 100 % margin] BUT *Allowance needed for inadvertent over-fuelling and indeterminate factors*

Reference value of Δt= 150 is deemed to be conservative (but not overly so) and also satisfies the functional vacuum and cryogenic requirements.

150 s for regeneration evacuation stage

Smallest pipe in regeneration line is DN150 – protium flow still viscous at 10 Pa (K_n^{-1}~122)

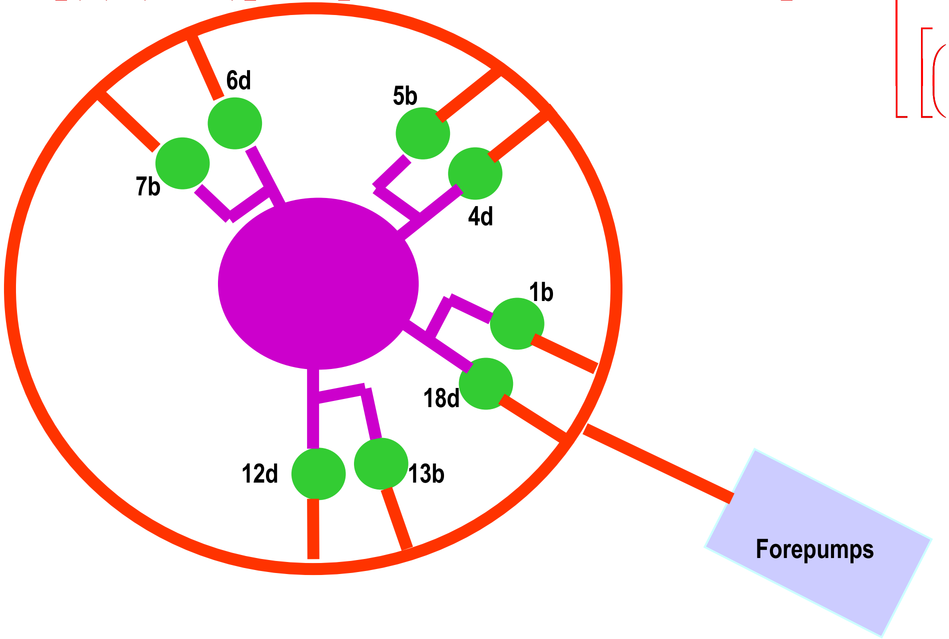
Regeneration line path is: 5 m DN150 pipe + DN 160 Isolation Valve + 150 m of DN 200 pipe from farthest cryopump to Forepump

Viscous conductance of valves not well known -assume transmission probability same for molecular & viscous flow

Use usual formula for viscous transient pump-down of vessel connected by pipe to forepump:

$$\frac{t}{V} := \left[\left(\frac{1}{E}\right)\cdot\left(\frac{1}{P}-\frac{1}{Pi}\right)\right] + \frac{1}{Sp}\cdot\left[\frac{\left[\left(\frac{Sp}{E}\right)^2+P^2\right]^{\frac{1}{2}}}{P} - \frac{\left[\left(\frac{Sp}{E}\right)^2+Pi^2\right]^{\frac{1}{2}}}{Pi}\right] + \frac{1}{Sp}\cdot\ln\left[\frac{\left[\left(\frac{Sp}{E}\right)^2+Pi^2\right]^{\frac{1}{2}}+Pi}{\left[\left(\frac{Sp}{E}\right)^2+P^2\right]^{\frac{1}{2}}+P}\right]$$

A. Roth, "Vacuum Technology", 3rd Ed., ISBN0-44-86027-4



Most adverse forepumping path = torus cryopump 7b

At reference fuelling rate (120 Pa.m^3/s 50:50 DT)

Torus cryopump pressure at t=150 s

~ 11 Pa (0.083 Torr)

Dwell pumping (between plasma pulses)

The base pressure at the end of dwell pumping has to be 0.5 mPa or less

The most constrained condition is for the 1400 s dwell period between the 400 s burn of successive plasma pulses at the maximum repetition rate (the dwell periods of 3000 s and 9000 s between 1000 s and 3000 s burn pulses are not problematic)

The main gas load during dwell pumping is outgassing of energetic deuterons and tritons implanted in the beryllium first wall during the plasma discharge preceding the dwell pumping

There is a a fairly narrow data base on outgassing rates of deuterium from beryllium and to assess the ITER dwell outgassing, measured JET gas balance data is used
("Analysis of outgassing after Joint European Torus discharges under beryllium first wall conditions", V. Philips & J. Ehrenberg, J. Vac. Sci Technol. A 11(2), Mar/Apr 1993, 437-445)

This reported outgassing rate of form $K_1 * t^n$

Where K_1 is the outgassing rate at 1 s (after outgas start) and $n=-0.73$

From a theoretical analysis, Andrew and Pick predicted a similar power law behaviour, but with $n=-2/3$

ITER dwell pumping assessment based on typical JET data (JET pulse #58837 presented NEXTSLIDE)

Dwell pump down equation and solution

$$V \bullet \frac{dP}{dt} + S \bullet P = K_1 \bullet t^n$$

Equ. 1

K_1= outgas rate 1 s after pump-down start, Pa.m^3/s
S=effective pumping speed =42 m^3/s (mass 5, torus pumps only)
V=vacuum vessel free volume = 1400 m^3
t= time into pump-down, s
P(t) = transient pressure, Pa

$$\frac{dP}{dt} + a \bullet P = \frac{K_1}{V} \bullet t^n$$

$$q_{outgas} = K_1 \bullet t^n$$

Equ. 2

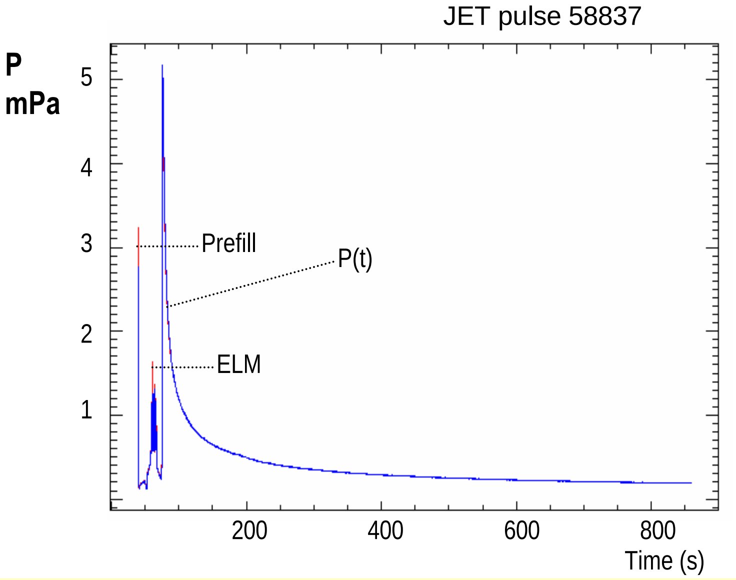
Is the time dependent hydrogenic outgassing rate from Beryllium PFC

Can be solved by Integrating Factor method to give

$$P(t_2) = \frac{K_1}{V \bullet (e^{at_2} - e^{at_1})} \bullet \int_{t_1=0}^{t_2=1400} t^n \bullet e^{at}\, dt$$

Equ. 3

Scaling of outgassing parameters from JET data



For JET pulse 58837

At peak pressure, in Equ. 1, $\frac{dP}{dt}=0$ at t= 1 s, so $P(1)=\frac{K_1}{S}$

$$K_{1JET} = \frac{S_{JET}\bullet P(1)}{t^n} = \frac{S_{JET}\bullet P(1)}{1} = 200(m^3/s)\bullet 5(mPa) = 1$$ **Pa.m³/s**

Scale to ITER on Beryllium (Be) area ratio (temperature effects discounted)

$K_{1ITER} = K_{1JET} \bullet$ **(ITER Be area)/(JET Be area)**

$=1$ (Pa.m³/s)•700 (m²)/200 (m²) = **3.5 Pa.m³/s**

Equ. 3 can be evaluated for the following parameter ranges:

K_1 = 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7 Pa.m³/s **{scaled from Be/D2 data for JET pulse 58837 on area ratio only}**

n = -2/3 [Ref 1] and n=-0.73 [Ref 2] {JET measured and Andrew& Pick theoretical}

Seff = 42 m³/s for torus cryopumps only (molecular flow mass 5)

Seff = 82 m³/s for torus cryopump + 2 Neutral Beam Cryopumps assisting torus cryopumps

SEE SLIDES 20 & 21

PARAMETRIC STUDY RESULTS ON NEXT SLIDE

Predicted terminal dwell pressure versus 1 s outgassing rate K_1 for n=-2/3 and n=-0.73 for torus cryopump+NB pumps

Terminal dwell pressure P(1400), mPa			Seff=$82 m^3/s$
	Decay index, n		Comment
K_1 $Pa.m^3/s$	n=-0.73 (measured, JET)	n=-2/3 (theoretical)	
3.5	0.217	0.344	JET K_1 scaled to ITER on area only
4	0.248	0.393	
4.5	0.28	0.442	
5	0.311	0.491	Scaled ITER K_1 with ~50% margin
5.5	0.342	0.540	
6	0.373	0.59	
6.5	0.404	0.638	
7	0.435	0.688	
7.5	0.466	0.737	
8.1	0.5		Limiting K_1 to reach 0.5 mPa with 2 NB pumps/ducts and no 3FM

Dwell pumping summary

The terminal pressure is quite sensitive to variations in n

For **n=-2/3**, terminal pressure of 0.5 mPa can only be attained up to **K_1**~ 5.1 Pa.m^3/s, ~46% above the reference (JET scaled) value of 3.5 Pa.m^3/s. For **n=-0.73**, 0.5 mPa attained at **K_1**~ 8.1 Pa.m^3/s (~130% margin on 3.5 Pa.m^3/s)

In view of the uncertainty in the **K_1** and **n** values caused by the paucity of experimental data, it is appropriate that an adequate margin is needed for the reference K_1 and n values and that a broader data base is needed

An EU PT Task is being proposed for experiments with JET once the beryllium first wall has been installed

Neutral Beam assistance for torus dwell pumping

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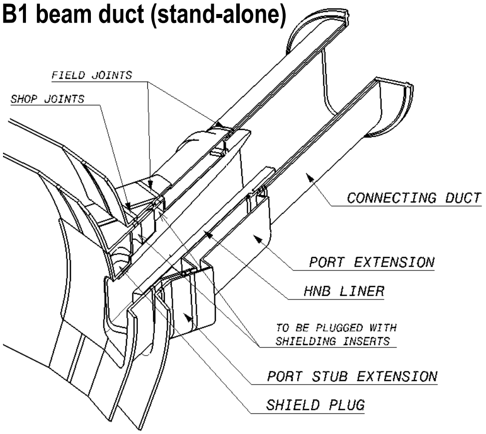
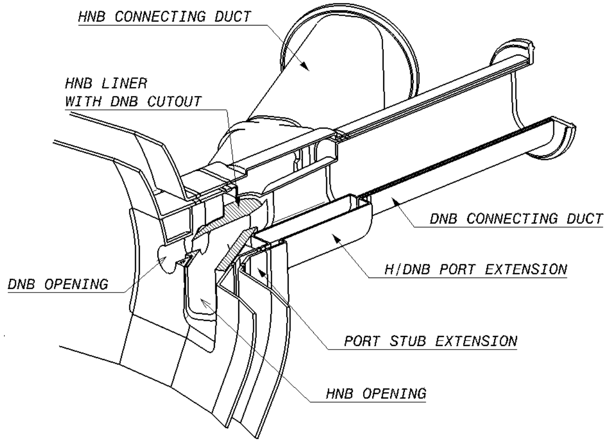
In Basic Configuration, there are 2 heating beamlines (HNB) and 1 Diagnostic beamlines (DNB)

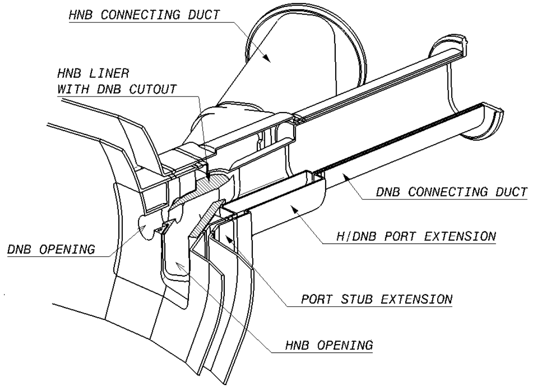
HNB1 beam duct (stand-alone)

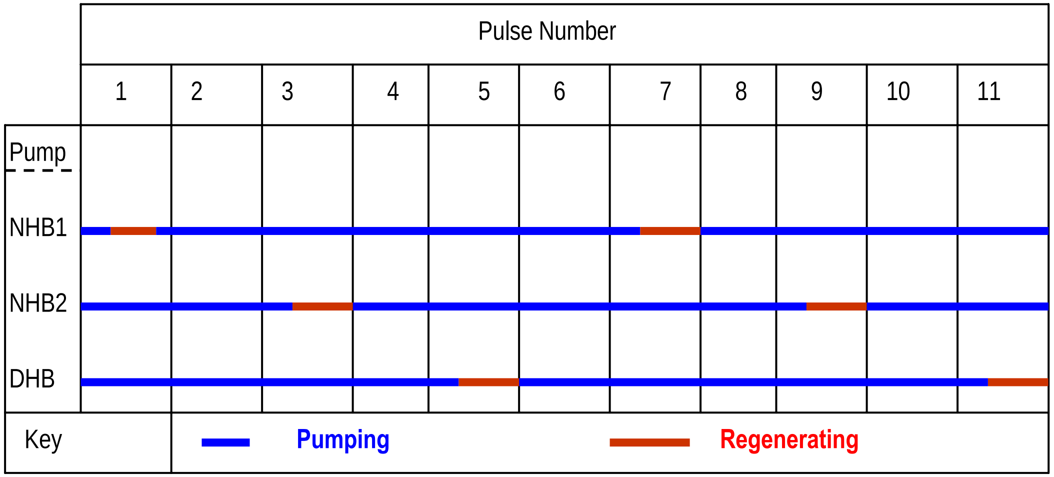


DNB1 beam duct (stand-alone)



HNB2+DNB sharing 1 duct





Always 2 out of 3 NB cryopumps available to assist torus dwell pumping during sequential pulsing at maximum repetition rate

2 NB cryopumps/ducts can add about 40 m^3/s to effective torus dwell pumping speed

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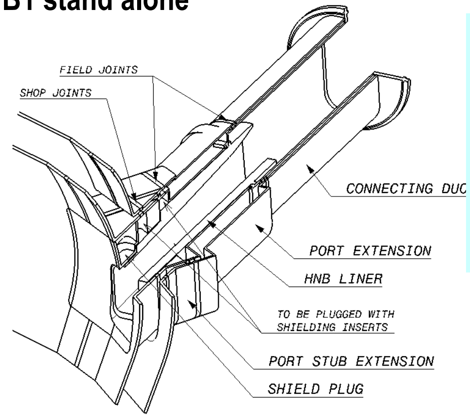
HNB1 stand alone



Molecular flow conductance (m3/s)

Rectangular pipe

C=97.1*(T/M)1/2*W2*H2*K/[(W+H)*L+2.66H*W]

Diaphragm

C=36.4*(T/M)0.5*HFS*WFS*(1- HFS*WFS / H4*W4)

C-1 =ΣCn-1

T=373 K **M=5**

H (m)	1.08	1.06	1.17	2.05
W (m)	0.552	0.552	0.552	1.112
L (m)	2.402	1.89	1.115	3.965

W=0.53
H=1.819
FS

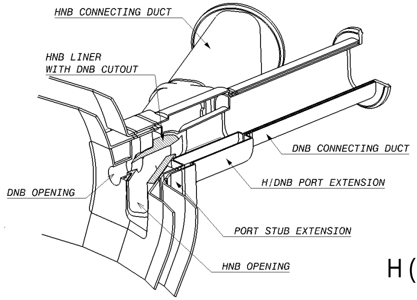
Beam duct elements as rectangular sections (approximation)

Pumping speed of HNB cryopump S_{hcp}~2,300 m^3/s (mass 5)

$$S = \frac{S_{hcp} \bullet C}{(S_{hcp} + C)} \cong C$$

S = 20.7 m^3/s

DNB1 stand alone



H (m)	1.08	0.964	1.47
W (m)	0.552	0.68	1.04
L (m)	1.5	1.65	5.307

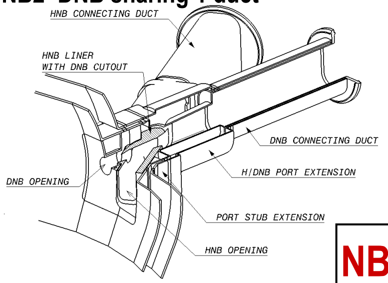
W=0.53
H=1.819
FS

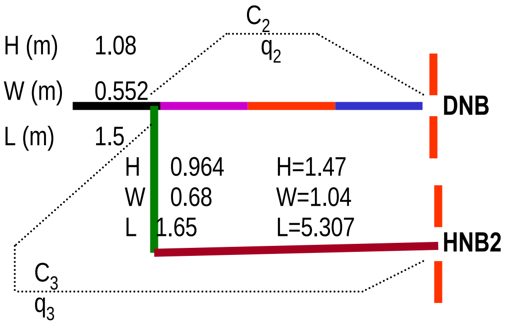
Molecular flow conductance formulae as for HNB1

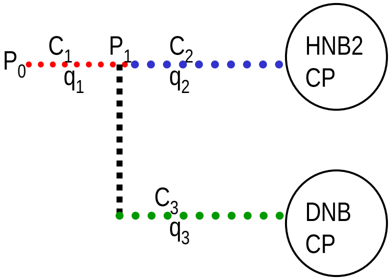
Pumping speed of DNB cryopump S_{DCP}~1,900 m3/s (mass 5)

S ≈ C ≈ 24.59 m^3/s

HNB2+DNB sharing 1 duct







C_1 =85.81 m^3/s

C_2 = 39.17 m^3/s

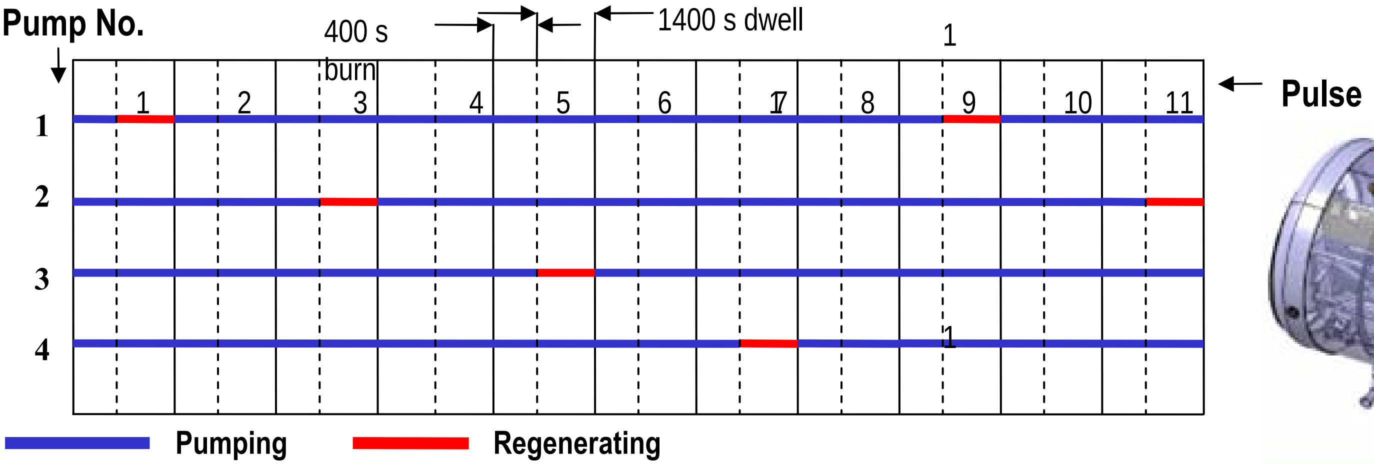
C3 = 34.47 m3/s

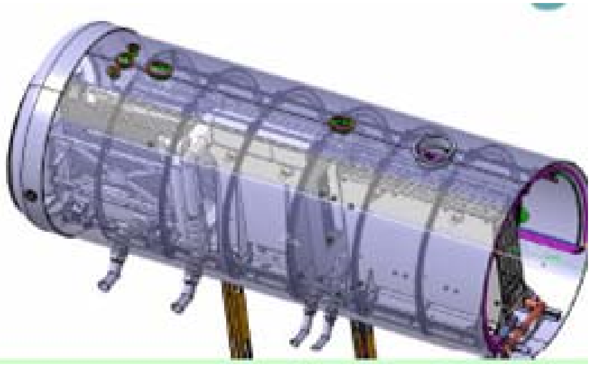
NB pumps can add ~ 40 m^3/s to torus effective dwell pumping speed

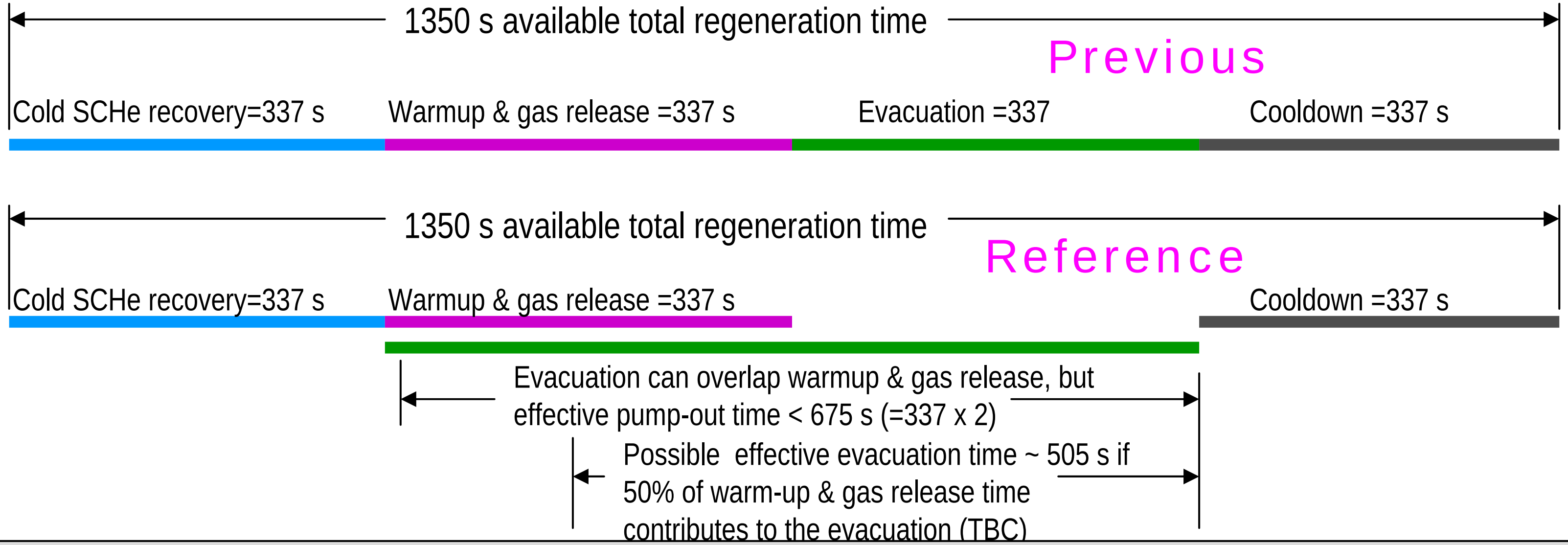
$$S = \frac{q_1}{P_0} = C_1 \bullet \frac{(C_1 + C_2)}{(C_1 + C_2 + C_3)} =$$

39.63 m^3/s

NB regeneration needs drives forepumping speed requirement







1350 s available total regeneration time

Previous

Cold SCHe recovery=337 s | Warmup & gas release =337 s | Evacuation =337 | Cooldown =337 s

1350 s available total regeneration time

Reference

Cold SCHe recovery=337 s | Warmup & gas release =337 s | Cooldown =337 s

Evacuation can overlap warmup & gas release, but effective pump-out time < 675 s (=337 x 2)

Possible effective evacuation time ~ 505 s if 50% of warm-up & gas release time contributes to the evacuation (TBC)

Total evacuation duration doubled but effective duration not – tests needed (maybe with TIMO tests of torus 1:1 cryopump). ***Working assumption~ 50% of overlap time is effective***

Terminal (crossover) pressure for sequential 400 s NB pulses with extended evacuation time (3 cryogenic stage durations 337 s)

Crossover Pressure (Pa)	Time into evacuation (s)	S_{eff} m^3/s
49.8	306.6	1.217
48.7	311.4	1.209
47.6	316.3	1.202
46.5	321.5	1.194
45.4	326.7	1.186
44.3	332	1.177
43.2	**337**	**1.169**
42.1	343.6	1.16
41	349.6	1.15
39.9	355.9	1.14
23	**505**	**0.924**

Sequential 450 s burn NB pulses at maximum repetition rate

D_2 fuelling

Sp=1.667 m^3/s

Isochronous cryogenic stage durations of 337 s

Crossover pressure reasonable if ~ half warm-up & gas release time is effective in evacuation (TBD)

With 4 isochronous regeneration stages (400 s burn) of 337 s, crossover pressure of ~43 Pa results with previous reference regeneration pattern (each pump regenerated after 8 pulses)

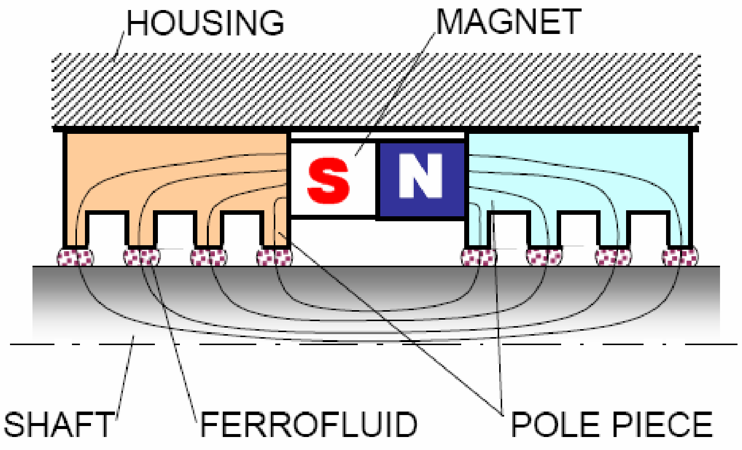
Assessment needed of warmup & gas release time, to estimate effective evacuation time (& terminal pressure)

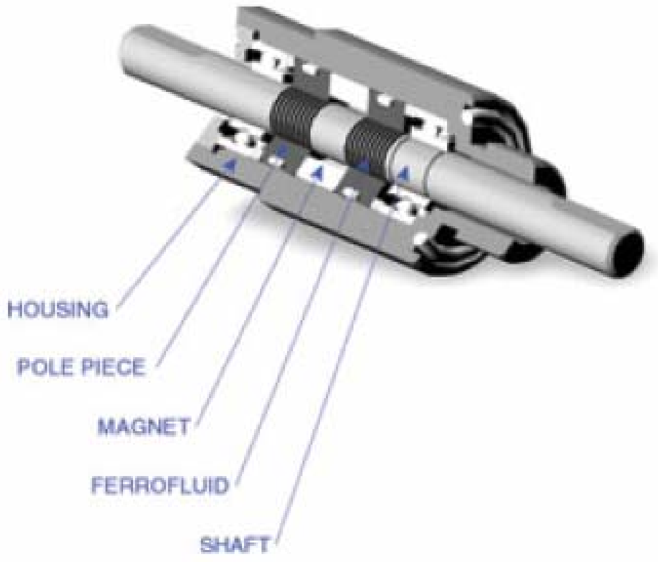
T-compatible forepumps – adaptation of “ commercial” Roots blowers to required leak tightness

Ferro-fluidic rotating shaft seal

Ferro-fluidic seals being investigated by EU PT

- Synthetic organic oil (Pv<10^{-7} Pa) loaded with magnetic nano-particles
- T has to diffuse thro liquid ring, leak rate <10^{-10}Pa.m^3/s
- Gap~ 50µm, volume ~ 1µℓ for 10cm shaft
- ΔP per ring~20 kPa (8 rings ~ 1.6 bar)
- Measured T uptake ~ 0.5 MBq/µℓ/day
- Evacuation of interspace between 2 seal halves practically reduces the leakage to zero





REFERENCES

R. Laesser, D. Murdoch, R. Penzhorn, “Use of ferro-fluidic seals in the design of tritium compatible pumps”, Fus. Sci. and Tech. 41 (2002), 621-625

A. Antipenkov, A. Mack, “The first ITER NB injector and ITER NB test facility design”, EFDA task report ref. TW3-THHN-IITF1, November 2004

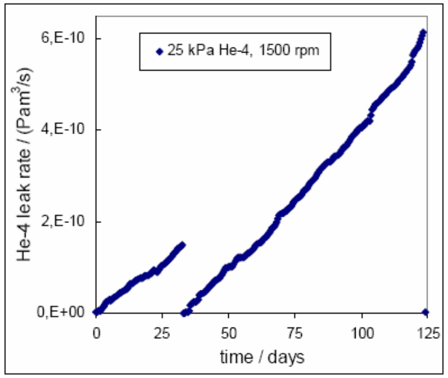
Ferro-fluidic seal tests by EUPT (FzK)

Tests with $250 m^3/h$ pump

Ferro-fluidic rotating shaft seal tests

Ferro-fluidic seals unit tested in rotating rig at FZK

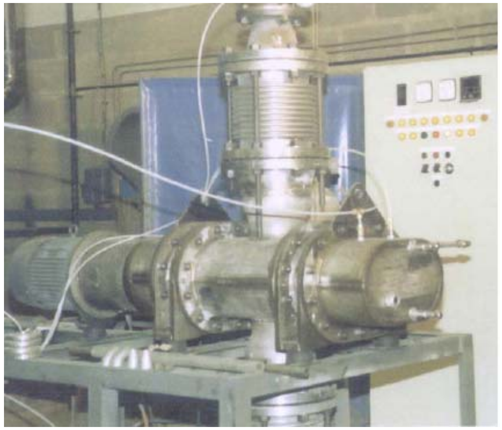
- **Helium leak tests of 125 days with seal rotating**
- **Leak rate in the range 10^{-10}Pa.m^3/s resulted**
- **Indication that perhaps leak rate increases with rpm (laminar-turbulent transition ?)**
- **On leak rate basis, meets ITER requirements**

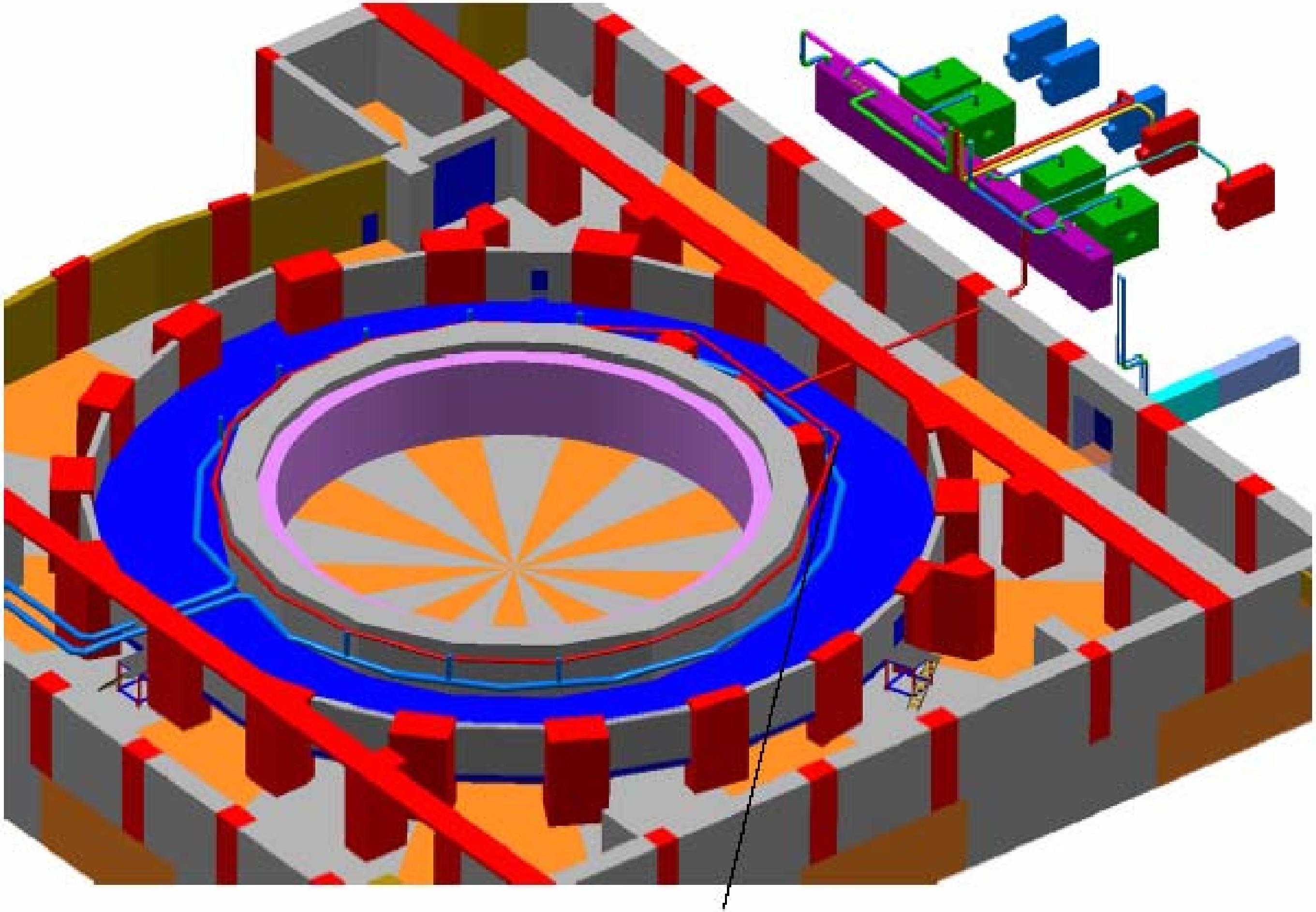


- **$250 m^3/h$ Roots pump procured from Roots Systems Ltd, fitted with ferro-fluidic seals and magnetic drive**
- **All stainless steel wetted parts with leak tight casing**
- **Test continuing at FZK**

This company has supplied 3000 m^3/h Roots pumps for a neutron spallation source of a similar quality as required for ITER

- **Ferro-fluidic seals look very promising for ITER forepumps**





Torus cryopump and direct line of sight diagnostics vacuum manifold for lower level

View from South West tokamak building 11-B2 basement

11-B2-1 M. Mills 050218

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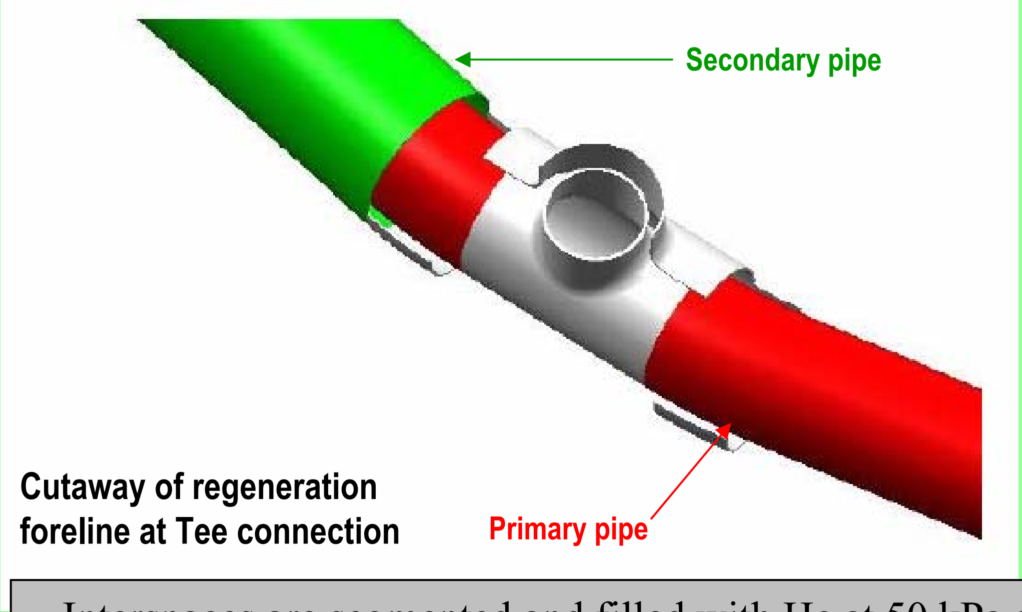
Hydrogen explosion hazard in cryopump forevacuum system



Cutaway of regeneration foreline at Tee connection

At time of design, ITER rules evolving so JET rules used:

❑ **T1 so Q1**

PRIMARY WELDS

- ❖ **Only butt welds allowed**
- ❖ **All welds must allow 100% radiography**

SECONDARY WELDS

- ➢ Fillet welds allowed
- ➢ Longitudinal welds allowed
- ➢ No radiography requirement
- ➢ Visual+ leak test only

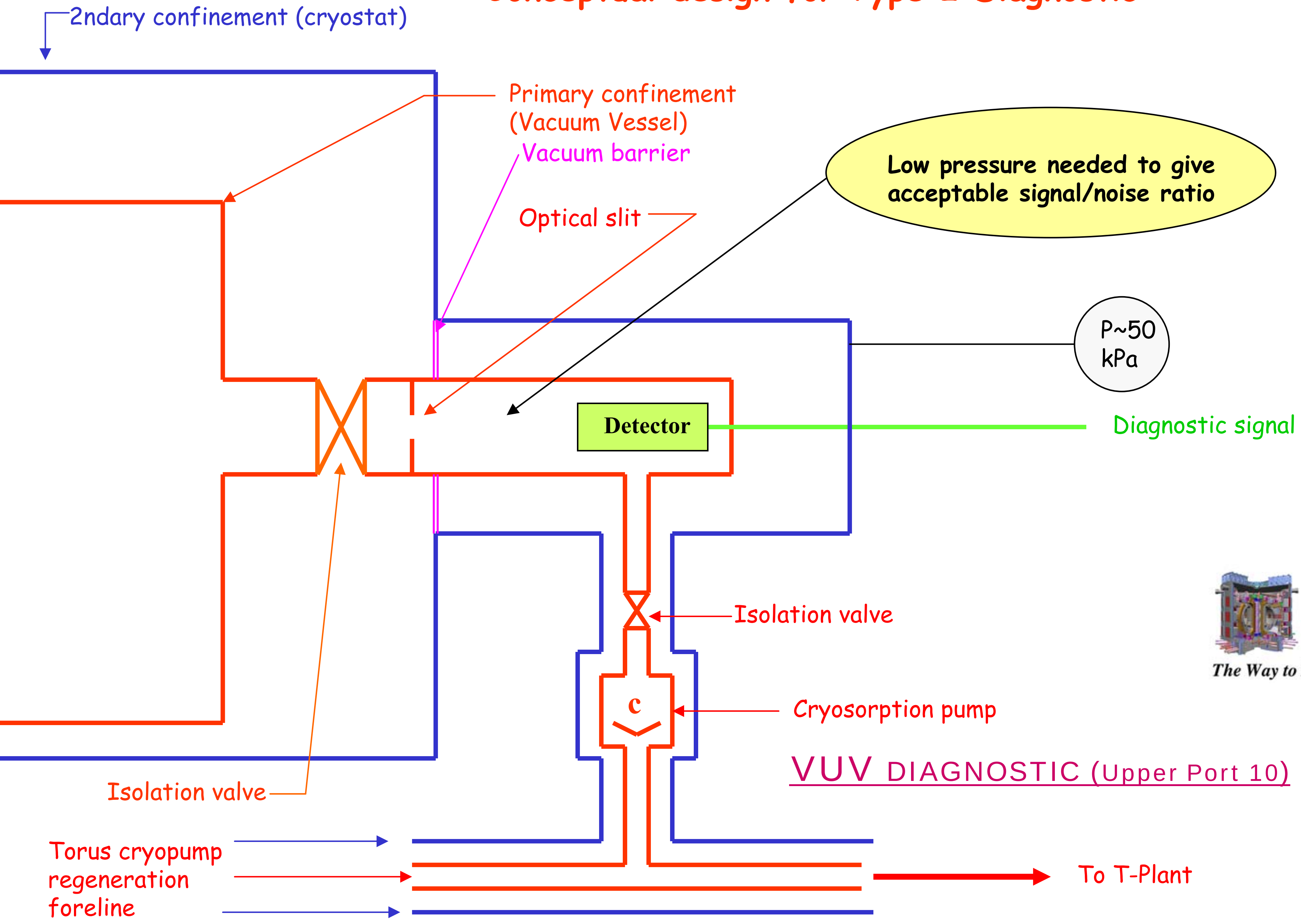
Interspaces are segmented and filled with He at 50 kPa after evacuation (pressure monitored)

- ▪ Increase in interspace pressure – leak in outer
- ▪ Decrease in interspace pressure – leak in primary (He in fuel cycle process stream)

ITER safety design guidelines recommend double confinement with inerted interspace for hydrogenic regeneration forelines between cryopumps and T-plant (under review)

In reference design, all foreline elements are doubly contained along complete path from cryopumps to forelines

Conceptual design for Type 2 Diagnostic



VUV DIAGNOSTIC (Upper Port 10)

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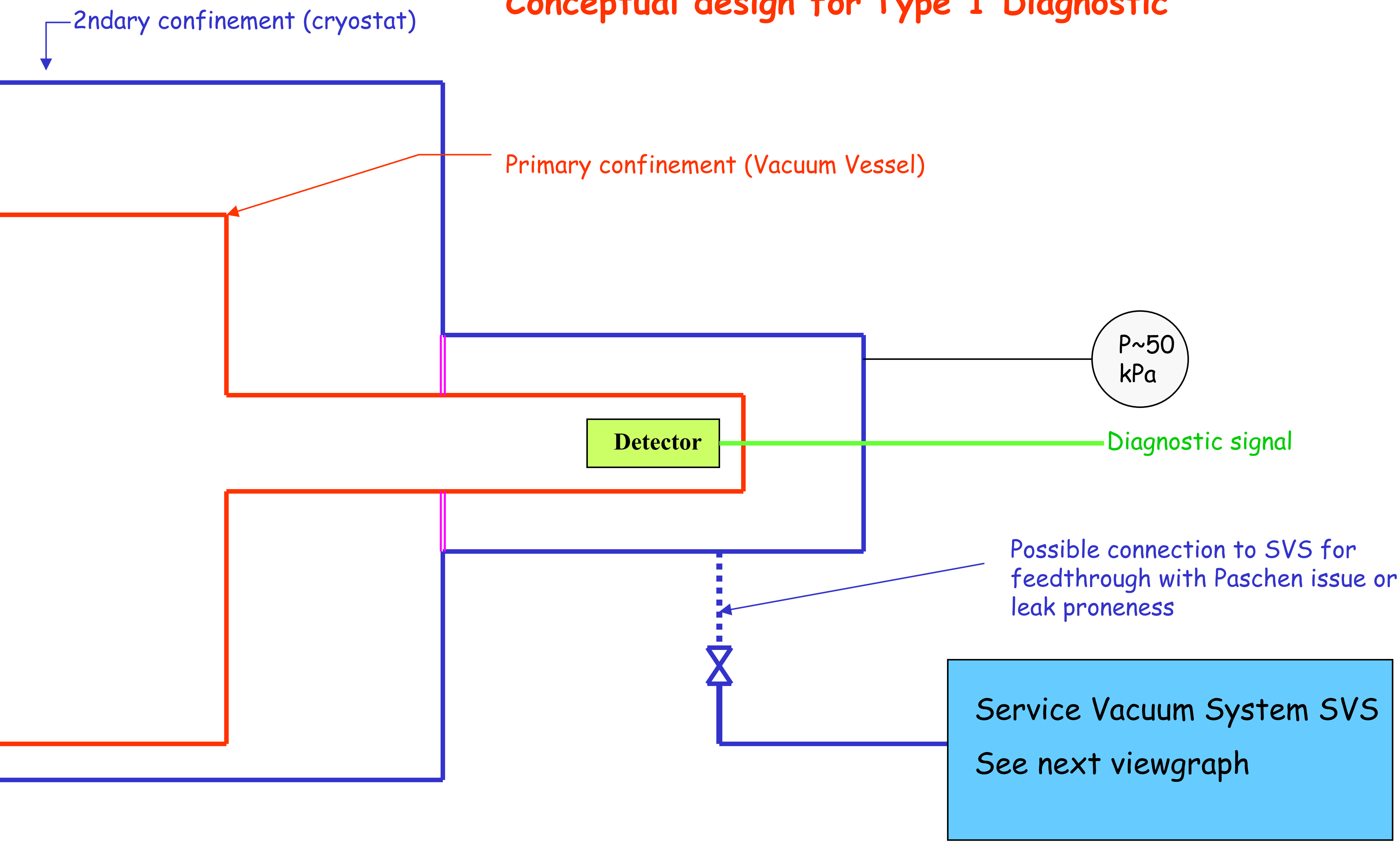
Conceptual design for Type 1 Diagnostic



2ndary confinement (cryostat)

Primary confinement (Vacuum Vessel)

P~50 kPa

Detector

Diagnostic signal

Possible connection to SVS for feedthrough with Paschen issue or leak proneness

Service Vacuum System SVS

See next viewgraph

DIAGNOSTICS (3)

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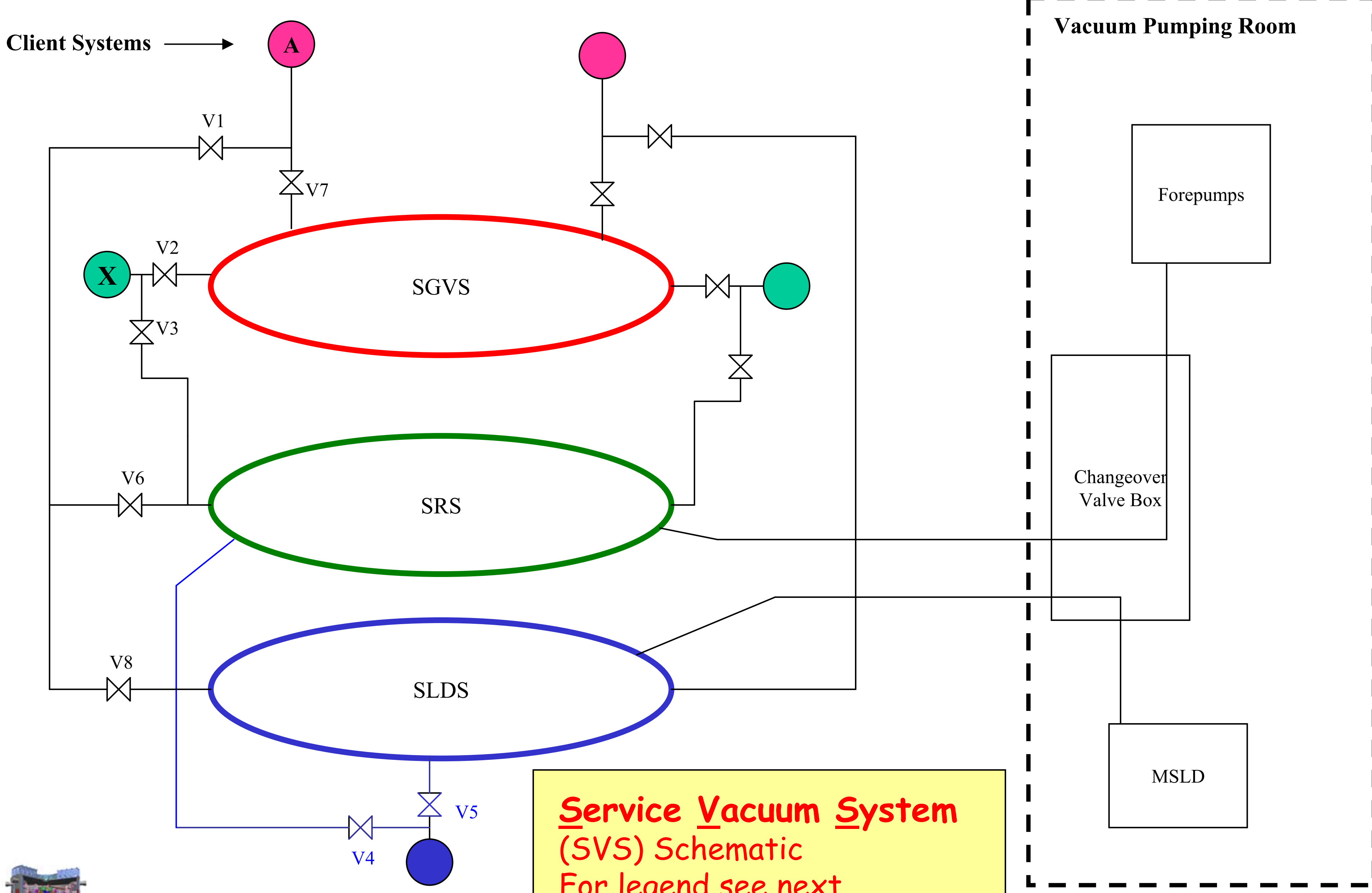

<u>**S**</u>**ervice** <u>**V**</u>**acuum** <u>**S**</u>**ystem**
(SVS) Schematic
For legend see next viewgraph

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Legend for SVS schematic

● SVS Client systems (CVB,CCB, CTB CTCB, diagnostics)

● Cryo-sorption refrigerator pumps of Service Guard Vacuum System (at least 8 {TBD})

● Cryo-condensation refrigerator pumps of Service Leak /Detection System (at least 6 {TBD})

Operational Overview

1 Rough pump down to crossover pressure of whole system:

1.1 Open all valves between Forepumps and SVS/Clients. Forepumps pumpdown all pipework, manifolds, refrigerator pumps of SVS and clients (Note clients)

1.2.Close V1, V3, V4, V7, V8 (referring to Client System A only, all other similar valves for other clients) to isolate SGVS and SLDS from forevacuum and cooldown all refrigerator pumps to evacuate SGVS and SLDS manifolds to <0.1 mPa

1.3. Sequentially open Client system isolation valves (V7 etc for other clients) one at a time to evacuate Client systems to <0.1 mPa

2. Leak detection mode

2.1 Close V7 and V4 to isolate leaking client from SRS and SGVS and open V4 and V 8 to connect client to SLDS

2.2 Using turbo pump in MSLD, evacuate branch pipe from MSLD to SLDS. Spray helium to external side of leak site and monitor response of MSLD

2.3 Isolate leaking client from SVS by closing valves V1 and V7 (client A) and vent client using Vent Gas System. Repair leak, repeat leak test per 2.1 and 2.2 above. When no leak, rough down client using SRS and re-connect to SGVS

3. Refrigerator pump regeneration (For example cryopump X in Fig , other cryopumps similar). ***One cryopump at a time***

3.1 Close valves V2 and V6, open valve V3. Warm up cryopump X and pump away released gas with Forepump set.

3.2 Close valve V3 and cool-down cryopump X. Open valve V3 when pump cold to restore crypump X to SGVS pumping

3.3 The 3 manifolds and all interconnecting pipes can be likewise isolated and connected to the SLDS for leak testing

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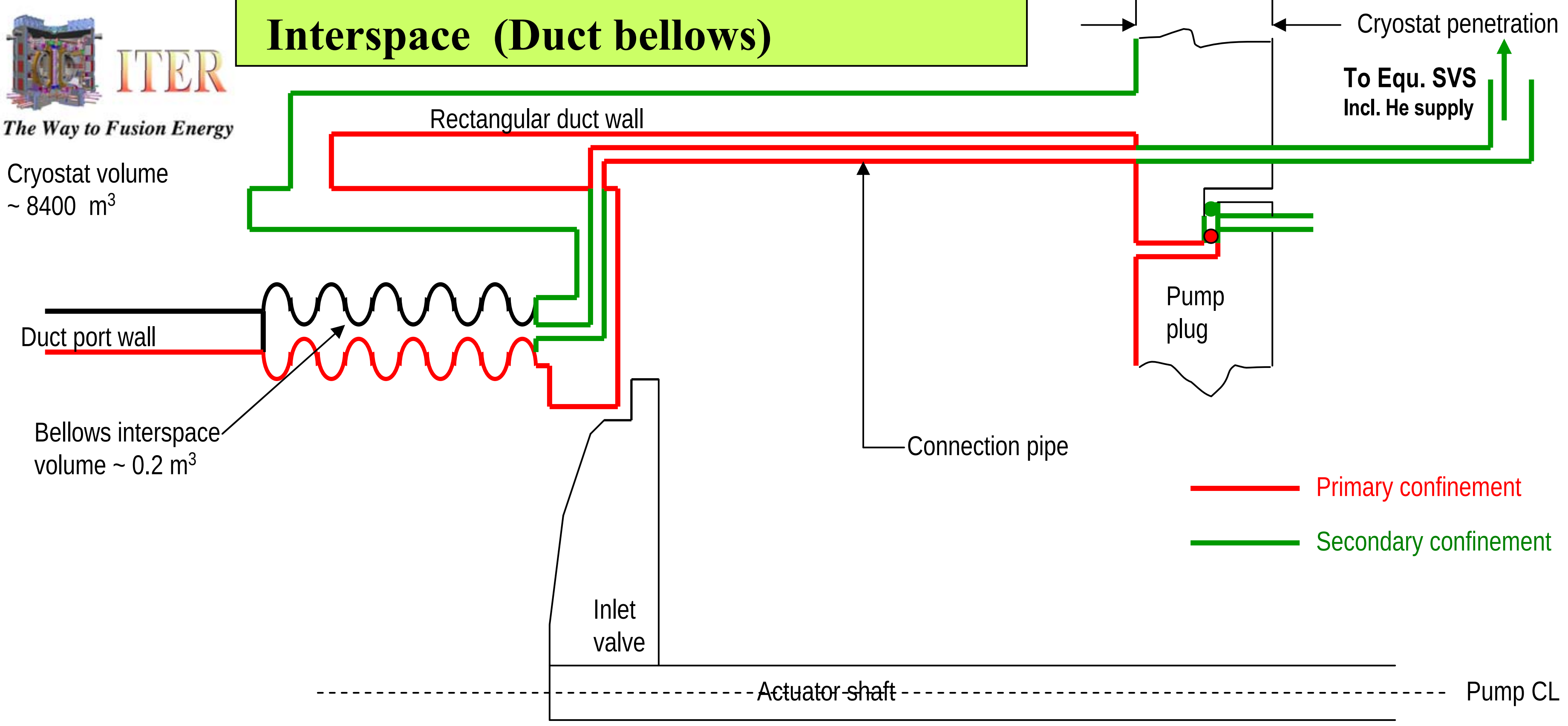
Interspace (Duct bellows)



ASSUMPTION: the duct bellows interspace has to be monitored to reveal a leak in the inner (cryostat side) or outer (torus side) bellows since the existence of a leak lowers the protection status of the magnets (particularly epoxy) against accidental tritiation.

Bellows interspace needs a connection pipe to the Port Cell side of the pump plug where pressure sensors located

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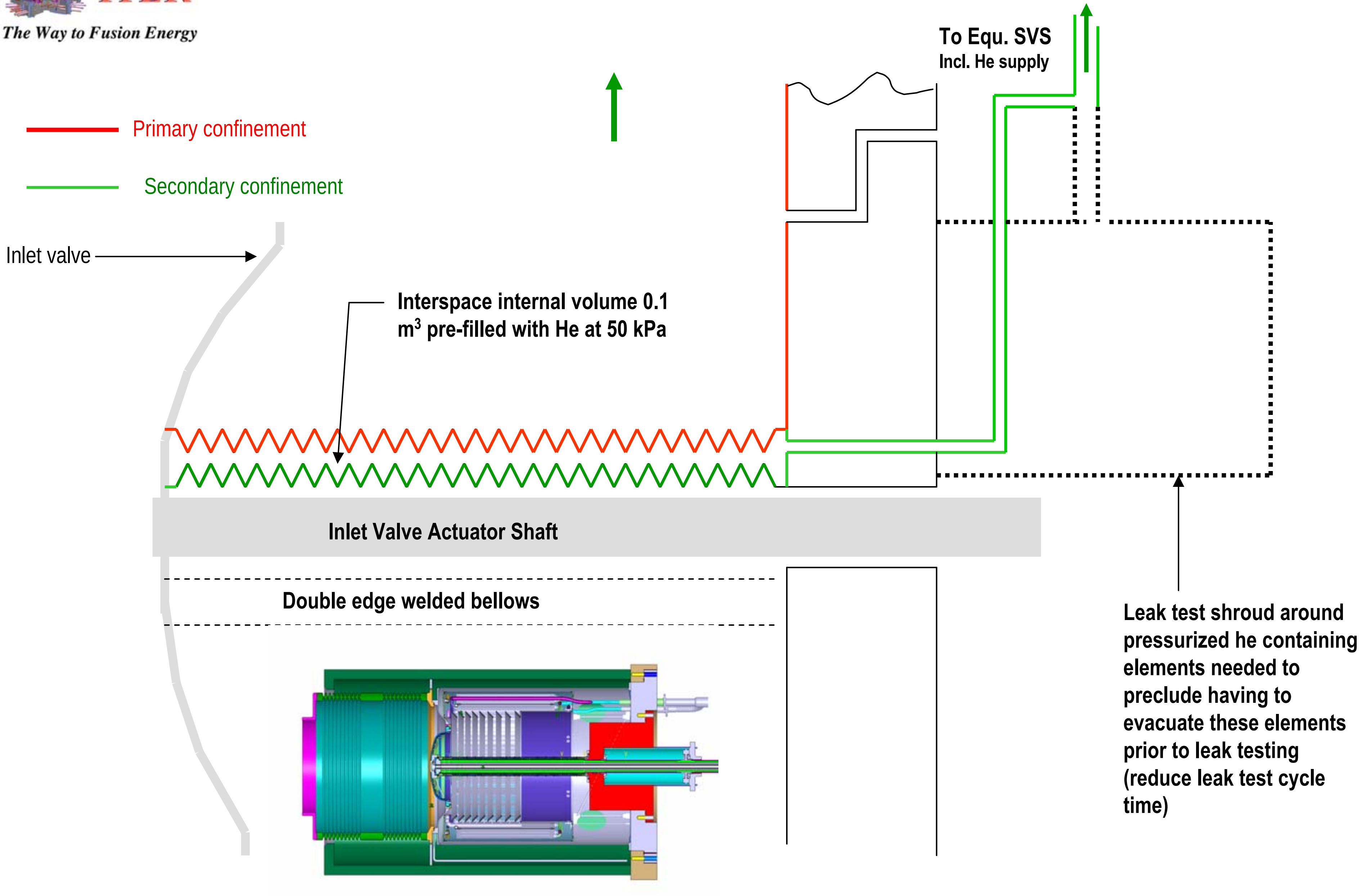
Actuator shaft bellows interspace



🟥 Primary confinement

🟩 Secondary confinement

Inlet valve

Interspace internal volume 0.1 m^3 pre-filled with He at 50 kPa

To Equ. SVS
Incl. He supply

Inlet Valve Actuator Shaft

Double edge welded bellows

Leak test shroud around pressurized he containing elements needed to preclude having to evacuate these elements prior to leak testing (reduce leak test cycle time)

Cryostat cryopump

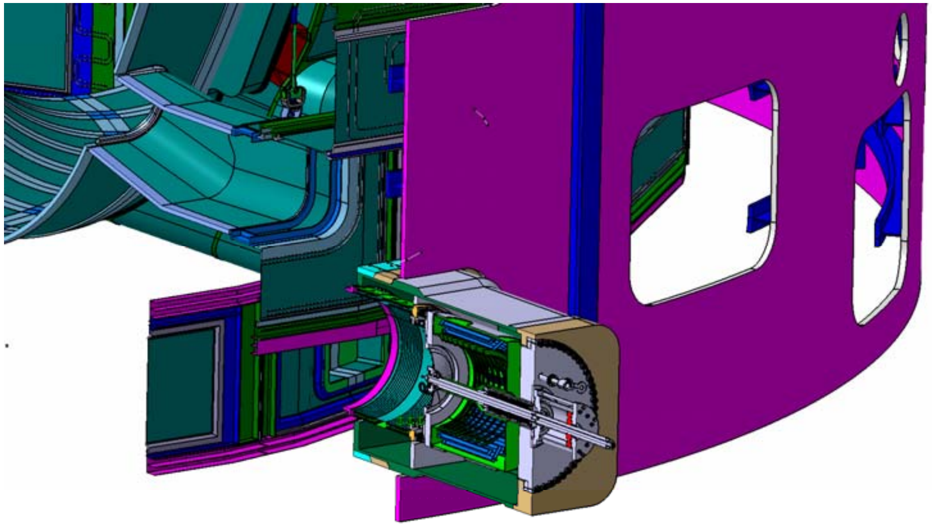
Approach to cryostat pumping is to use virtually identical cryopumps as for torus (serial procurement costs, spares, adequacy of pumping speed)

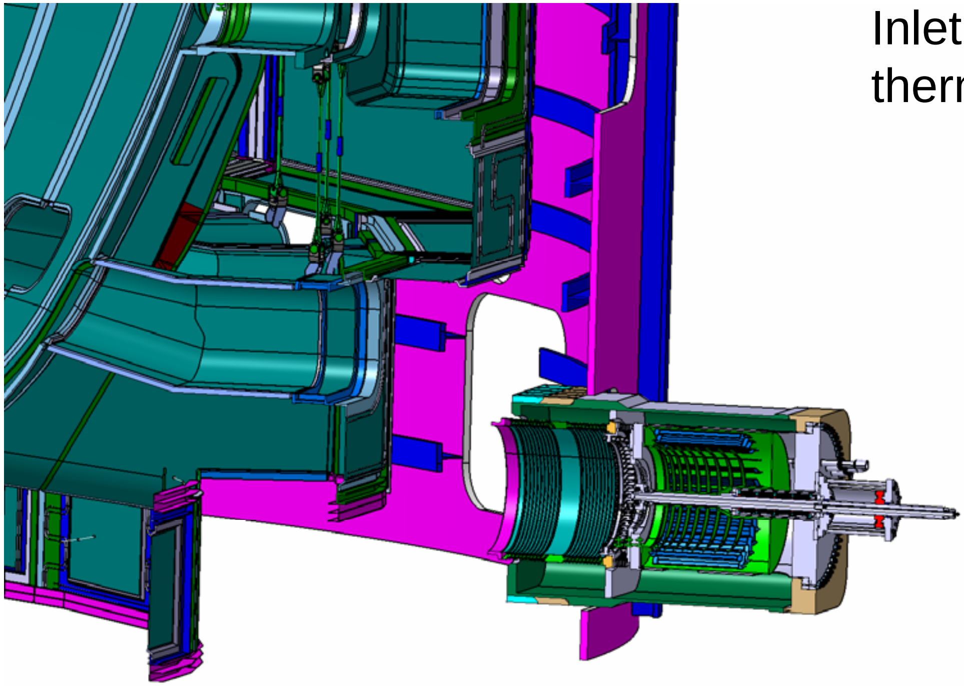
Cryostat pumps have different boundary environmental conditions to torus pumps:

- "free suction" (no long inlet ducts) from thermal shield outer zone: Location lower port cells 3 & 11
- Inlet Valve disc faces 80 K thermal shield – valve disc heated by internal 300 K helium flow rather than cooled as with torus pump
- Heat loads different (different pumped gases, lower nuclear heating)
- No T during normal operation (but during off-normal, e.g. water leak into cryostat vacuum)
- Major safety role in detecting air leaks into cryostat (O3 hazard)
- Much more "steady state" pumping during plasma operation with less frequent regeneration

Location of cryostat cryopumps (lower ports 3 & 11)

Cryostat CPs at cryostat lower port cells 3 &11





Inlet Valve disc “sees” 80 K thermal shield (CTS)

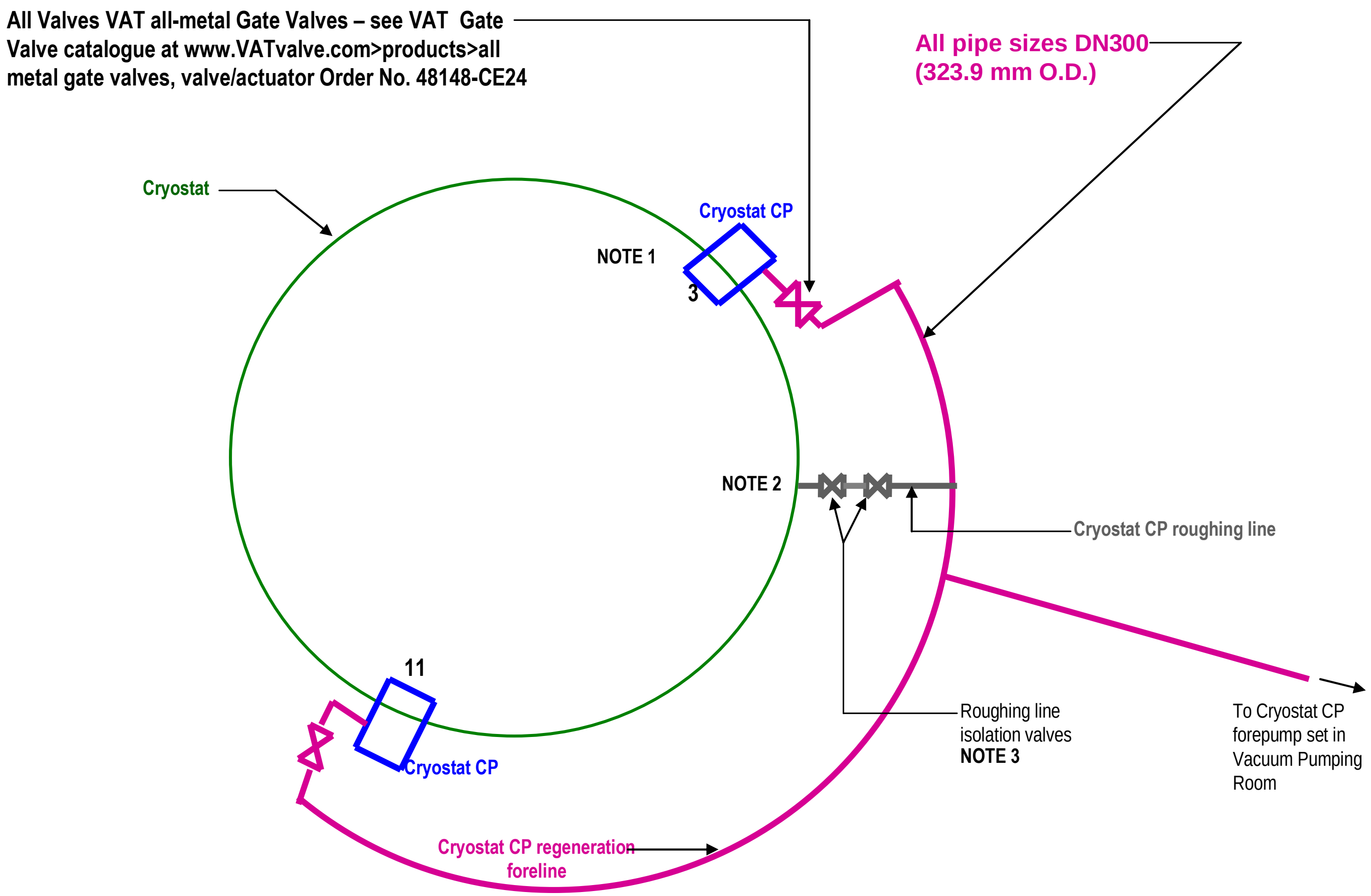
NOTE: Duct double bellows not needed for cryostat CPs.

Similarly with cryostat housing protruding into cryostat

Location and layout of cryostat roughing and regeneration forelines

Cryostat roughing and regeneration foreline, Pipe & Valve sizes, MWS, 23-01-06

Slide #1of 1


All Valves VAT all-metal Gate Valves – see VAT Gate Valve catalogue at www.VATvalve.com>products>all metal gate valves, valve/actuator Order No. 48148-CE24

All pipe sizes DN300 (323.9 mm O.D.)

Schematic lower port level showing Cryostat CP's at ports 3&11, horseshoe regeneration manifold and roughing line sharing branch to Cryostat CP forepump set in Vacuum Pumping Room

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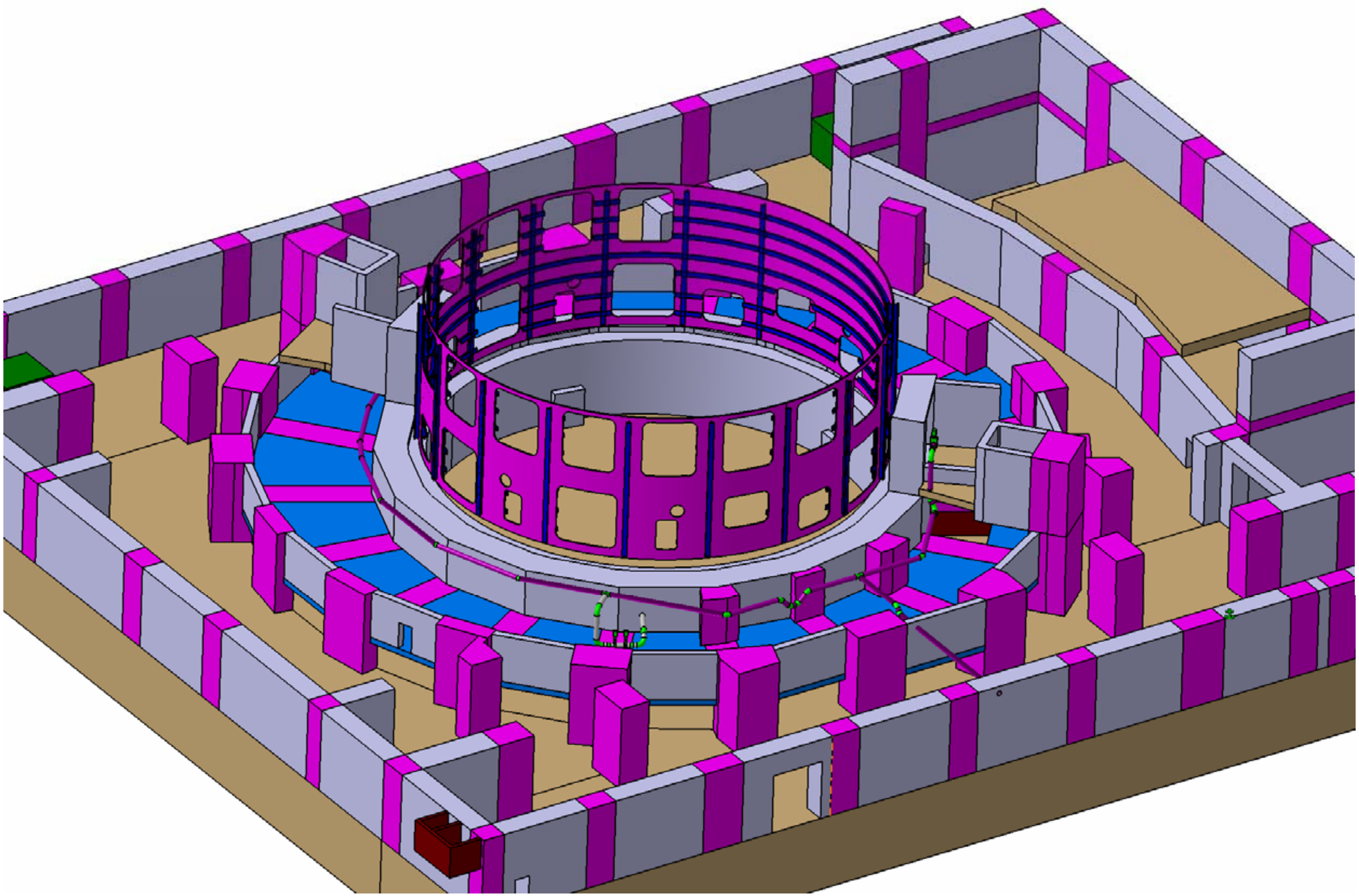
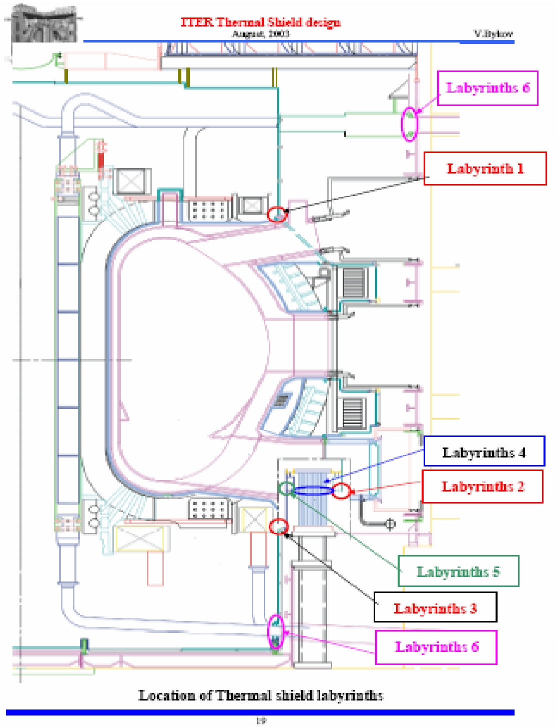
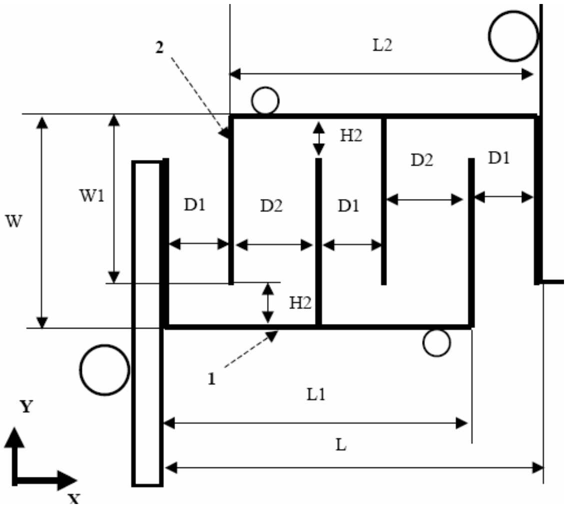
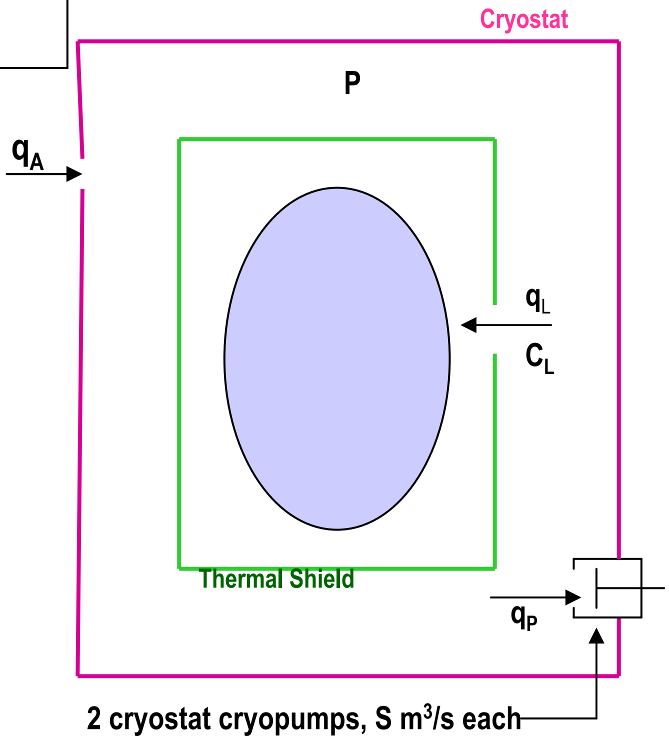
Cryostat cryopump roughing & regeneration foreline in Basement level



Cryostat cryopumps act as air leak integrator (sensitive air leak monitor against O_3 hazard)







2 cryostat cryopumps, S m^3/s each
~ 20 m^3/s each for air

Total C_L~ 20 m^3/s for air

For 1 cryostat cryopump

$q_L/q_A = q_L/(q_L + q_P) \sim C_L/(S+C_L) \sim 0.5$

$q_P/q_A = q_P/(q_L + q_P) \sim S/(S+C_L) \sim 0.5$

For 2 cryostat cryopumps

$q_L/q_A = q_L/(q_L + q_P) \sim C_L/(2.S+C_L) \sim 0.33$

$q_P/q_A = q_P/(q_L + q_P) \sim 2.S/(2.S+C_L) \sim 0.67$

Concluding remarks

- In the time available, only a fleeting overview of the many vacuum pumping systems involved in T handling has been possible
- The intention has been to give a flavour of the functional & safety issues involved.
- I will be more than happy to liaise with attendees on any aspect of ITER vacuum (that’s in the public domain). michael.wykes@iter.org

WITH MANY THANKS FOR YOUR ATTENTION

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