# ITER Pumping and Fuelling

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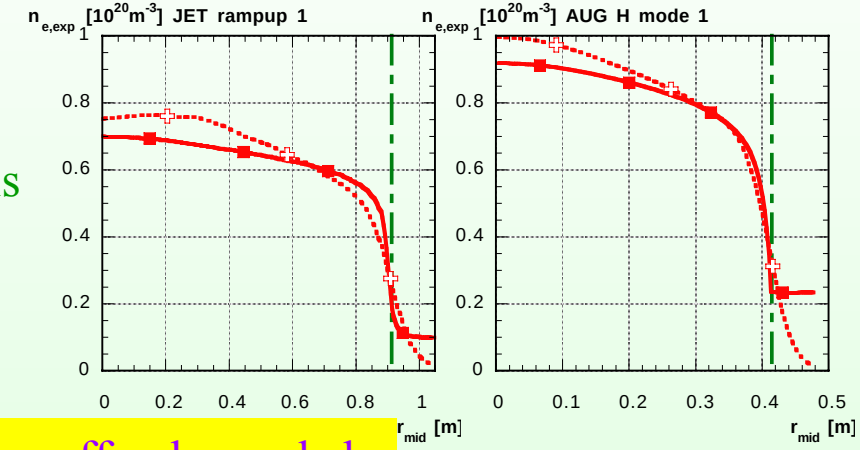
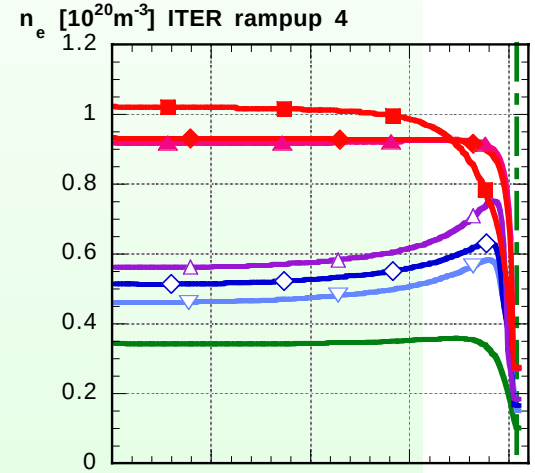
# Outline

- **Difficulty to fuel ITER with Gas Puffing alone**
  - Fuelling into pedestal region is essential -> pellets, etc.
- **Pellet Injector R&D**
  - Performed in the RF
- **PUMP R&D**
  - Performed in FZK

# The difficulty to fuel the ITER and Demo Plasma by gas puffing alon

In ASDEX-UP and JET a neutral flux across the separatrix of ~ $1x10^{22}m^3s^{-1}$ is sufficient to explain the observed density pedestals




In ITER ~$9x10^{22}m^3s^{-1}$ by gas puff only needed

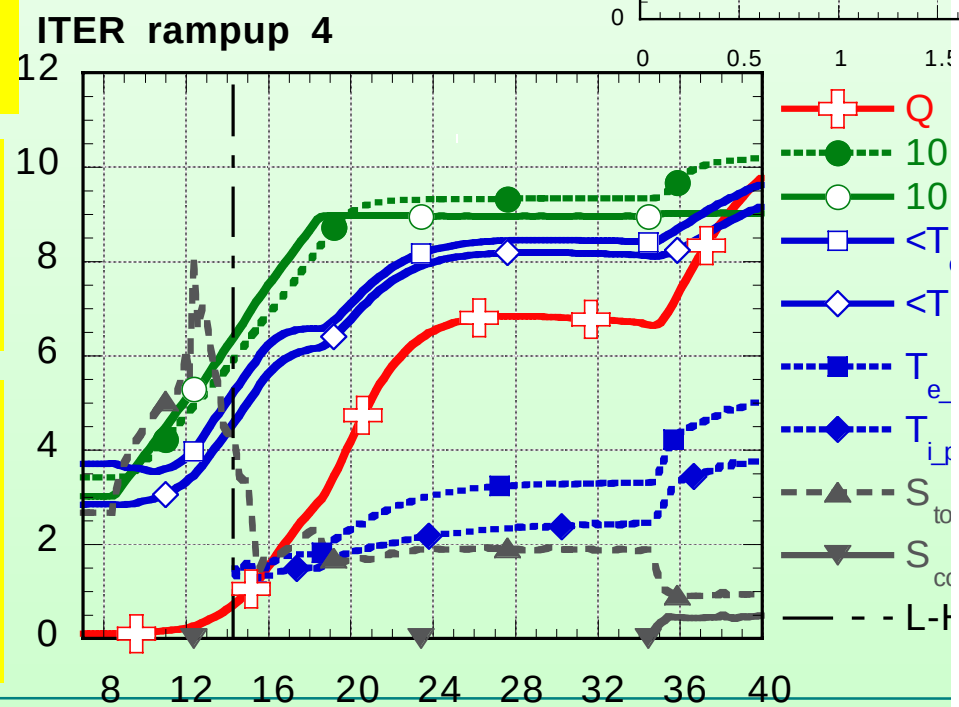
**low $T_{ped}$ results in Q = 7**

A combined edge and core fuelling of ~$3x10^{22}m^3s^{-1}$ gives better performance

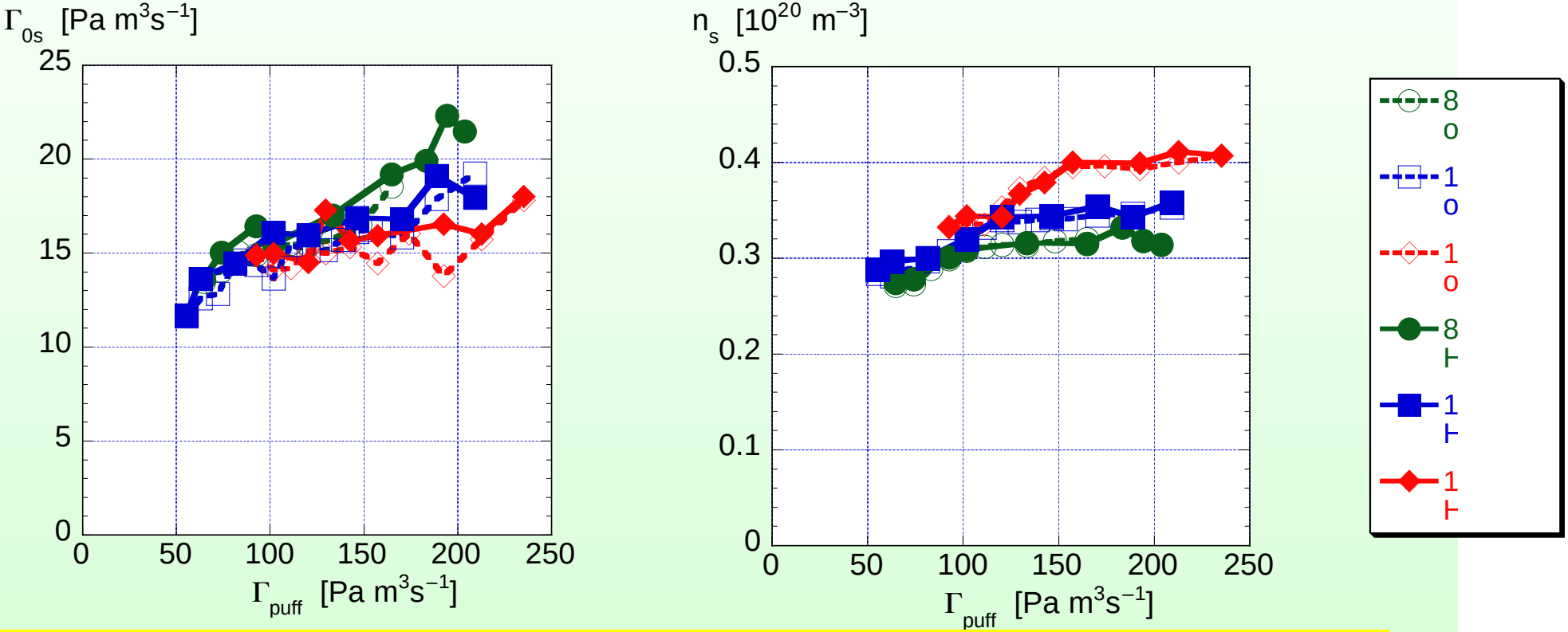
**higher $T_{ped}$ results in Q = 10**

In ITER B2-EIRENE allows only $1.8x10^{22}m^3s^{-1}$ => not possible to obtain required density => needs $8x10^{22}m^3s^{-1}$ core fuelling in addition !!

**Even higher $T_{ped}$ results in Q = 15**



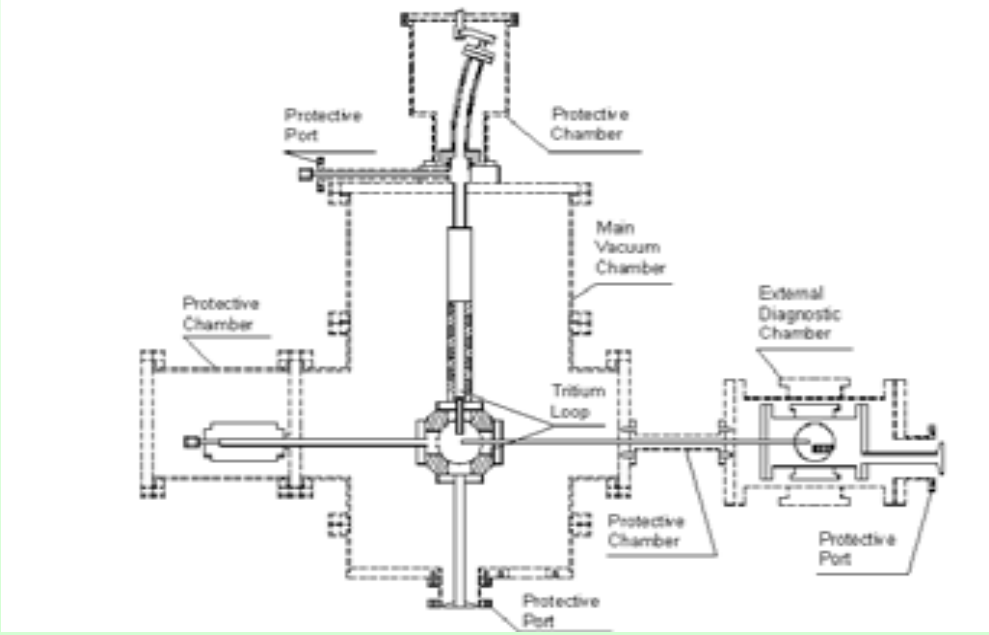
# Compatibility of SOL and core in terms of fuelling and density



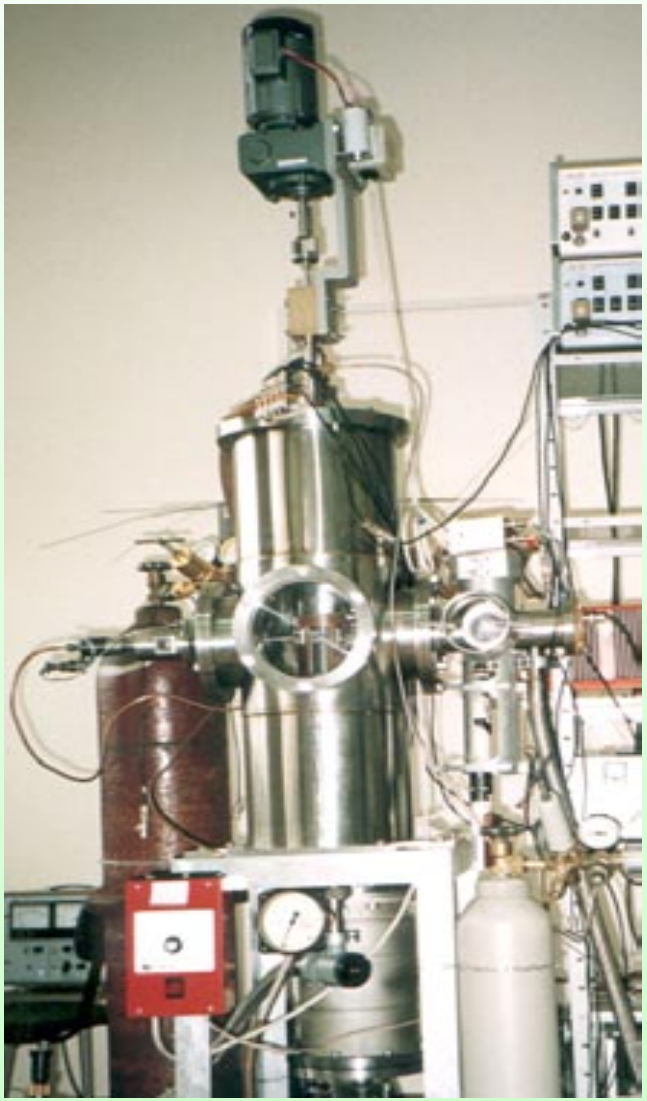

- Fuelling across the separatrix and the upstream density saturates with incresed throghput / gas puffing for a given power into the SOL => Screening effect of SOL
- Maximum core fuelling is ~ 15 Pam$^3$s$^{-1}$ (higher values only if outer divertor detaches) => but to achieve the required pedestal density ~ 70 to 80 Pam$^3$s$^{-1}$ are needed

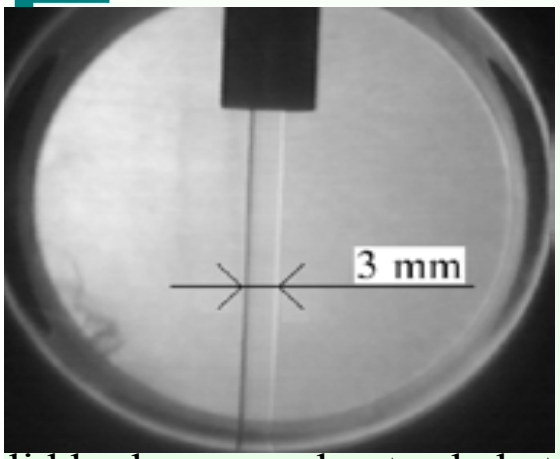
=> Core fuelling by pellets or other means essential also for AT discharges !!

# Tritium Compatible Pellet Injection System

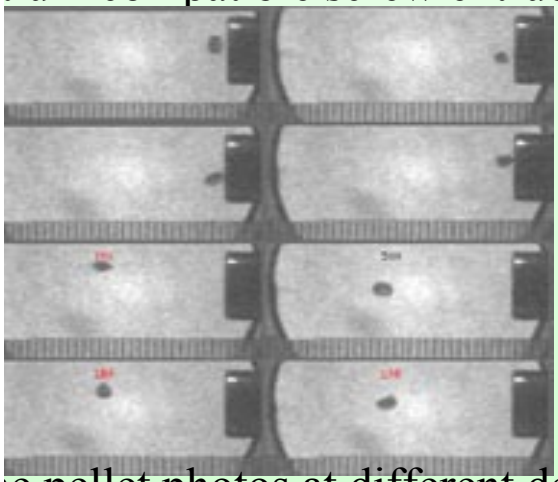



Schematic diagram of a tritium pellet injector with a screw extruder






lid hydrogen rod extruded at 11 K from
tium compatible screw extruder



e pellet photos at different delay time
the nanoflash lamp
p four photos – 0 mks, lower four
otos – 70 mks).

# TTestplan for T-pellet injection

after installation at RFNC (Sarov) the following tests are to be carried ou
Demonstration of the injector parameters with $H_2$, $D_2$ and HD.Testing of
the long-term solid $T_2$ extrusion by the screw extruder:

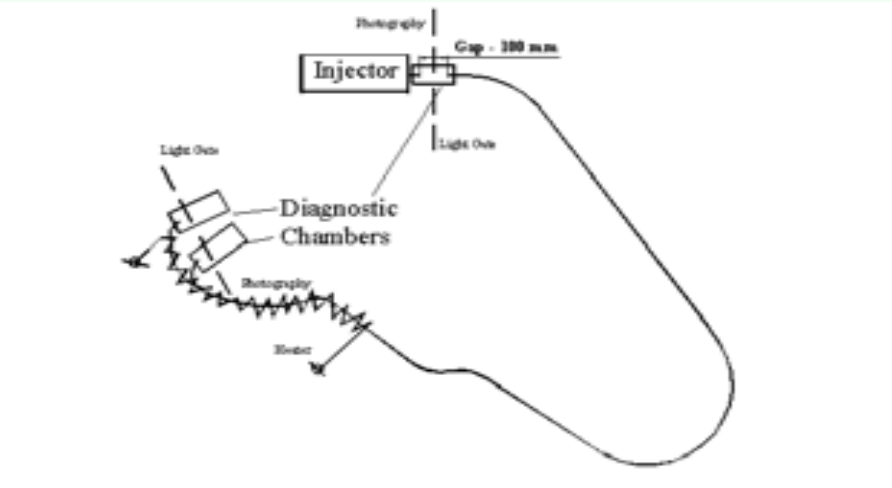
- measuring of solid $T_2$ extrusion speed;
- registration of solid $T_2$ rod view by a videocamera: estimation of tim
solid $T_2$ rod transformation from transparent to dull form;
- measurement of $T_2$ extrusion speed versus rotation speed of the sc
and extruder temperature;
- measurement of $T_2$ extrusion duration without any interruptions;
- estimation of $T_2$ strength and viscosity;
- estimation heat release by radioactive decay.

3. Testing of the $T_2$ pellet formation and acceleration:

- measurement of the maximal frequency of pellet formation with
acceleration;
- measurement of the maximal frequency of pellet injection by propel
gas;
- measurement of the pellet speed at different repetitive rates;
- demonstration of continuous pellet production and acceleration fo
long time and highest reliability;

estimation of propellant gas amount during pellet injection.

# PELLET FLIGHT TUBE MODELLING

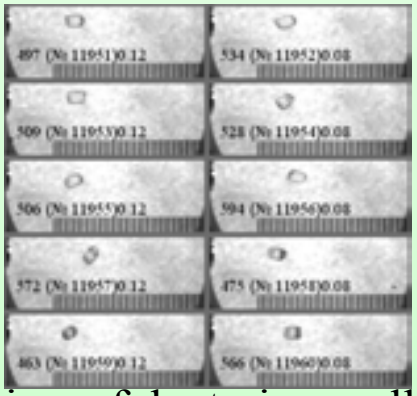



The basic experimental configuration

Overview of the guide tube installation

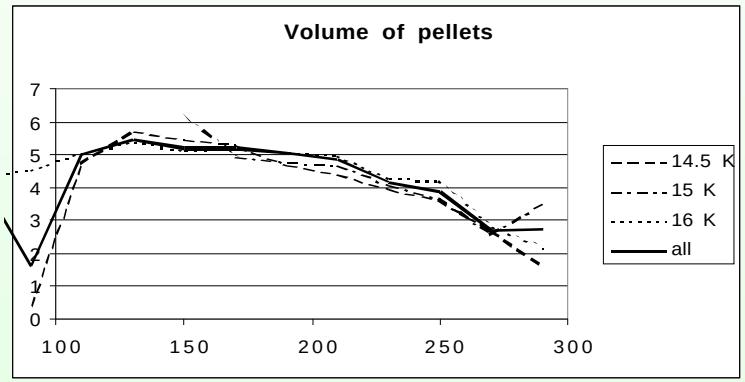
Two different configurations have been tested:

| | | | |
|---|---|---|---|
| Guide tube inner diameter | | 6 | 6 |
| Radius of curvature | | 910+70 | 70 |
| Length | | 4350 | 14312 |
| Heating | | No | Yes |
| D2 temperature | | 14-16 | 14.5-16 |
| Number of pellets | | 492 | 2319 |

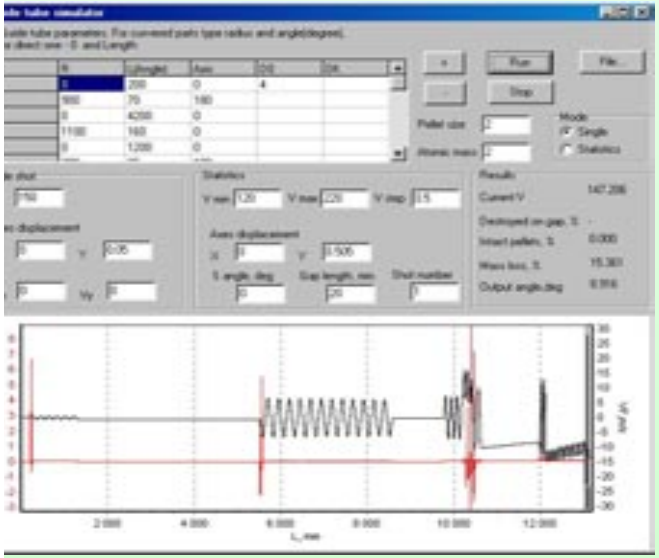


The typical view of deuterium pellets before entering into a guide tube

The influence of deuterium temperature on the pellet volume ($mm^3$)



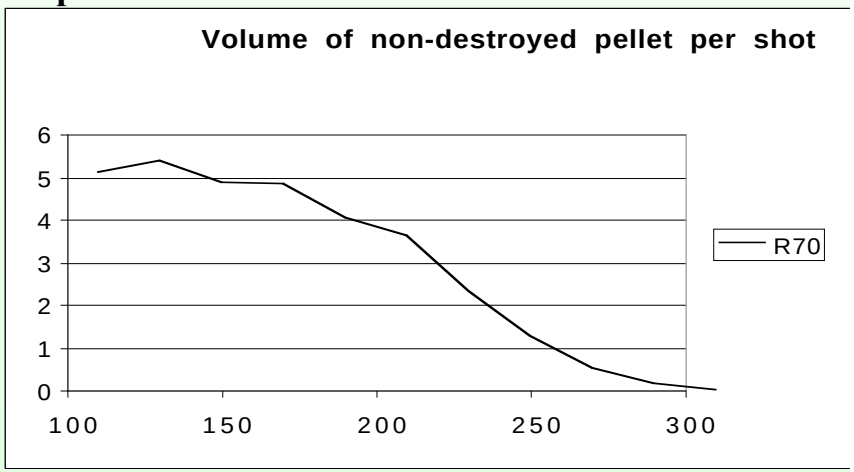

Numerical modelling



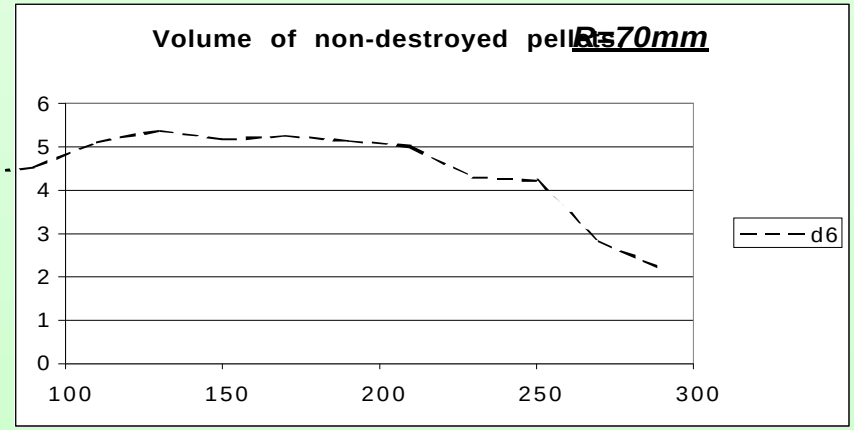
Main program window of pellet conveyance through an arbitrary curved guide tube: VR – radial velocity; VF – tangential velocity.

The average volume of non-destroyed pellets per shot versus pellet speed after conveyance through 6 cm guide tube of full-scale length with radius of curvature of 70 mm. Initial average pellet volume is 7 $mm^3$:

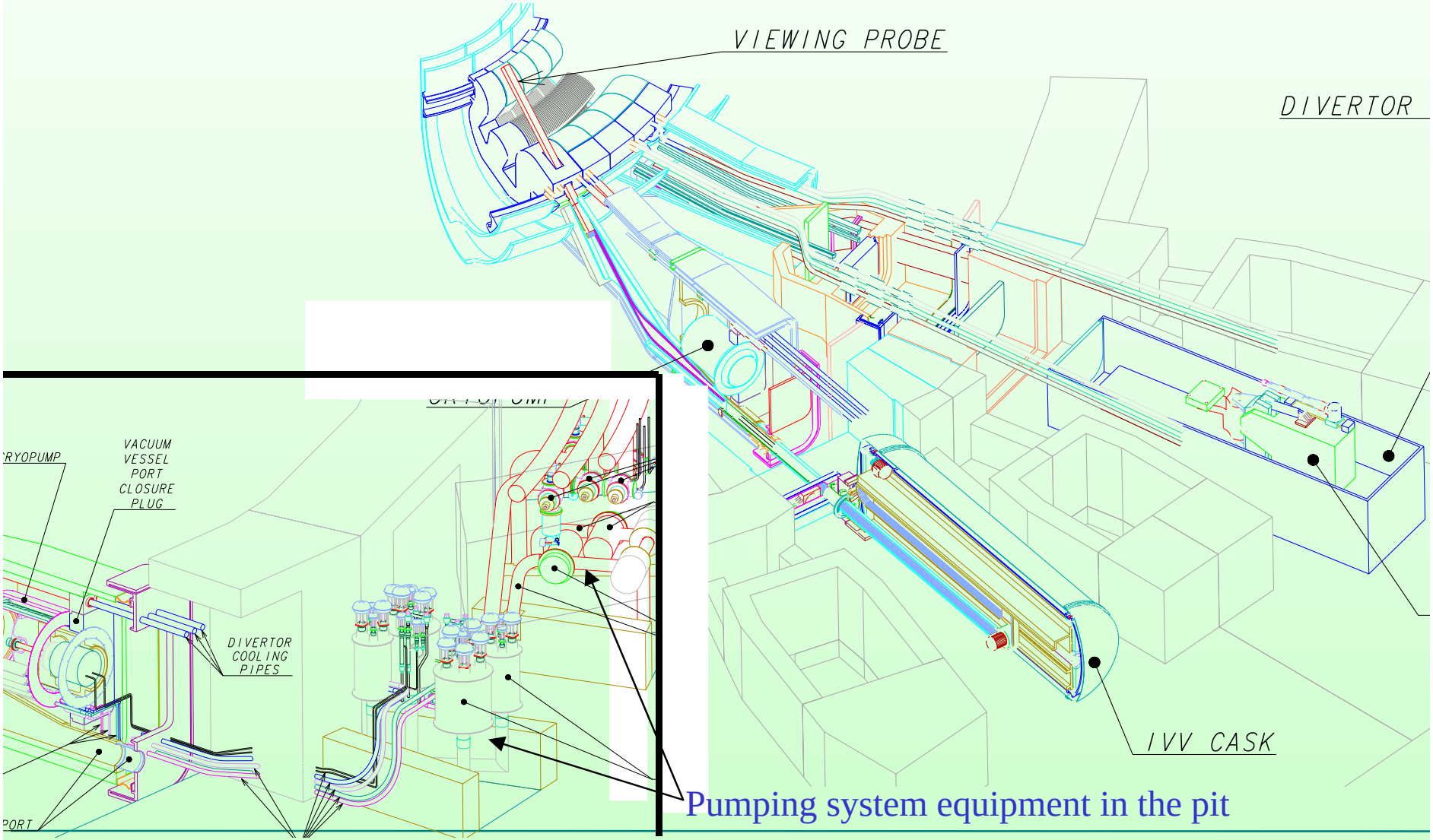
**Experiment :**




**Theory:**

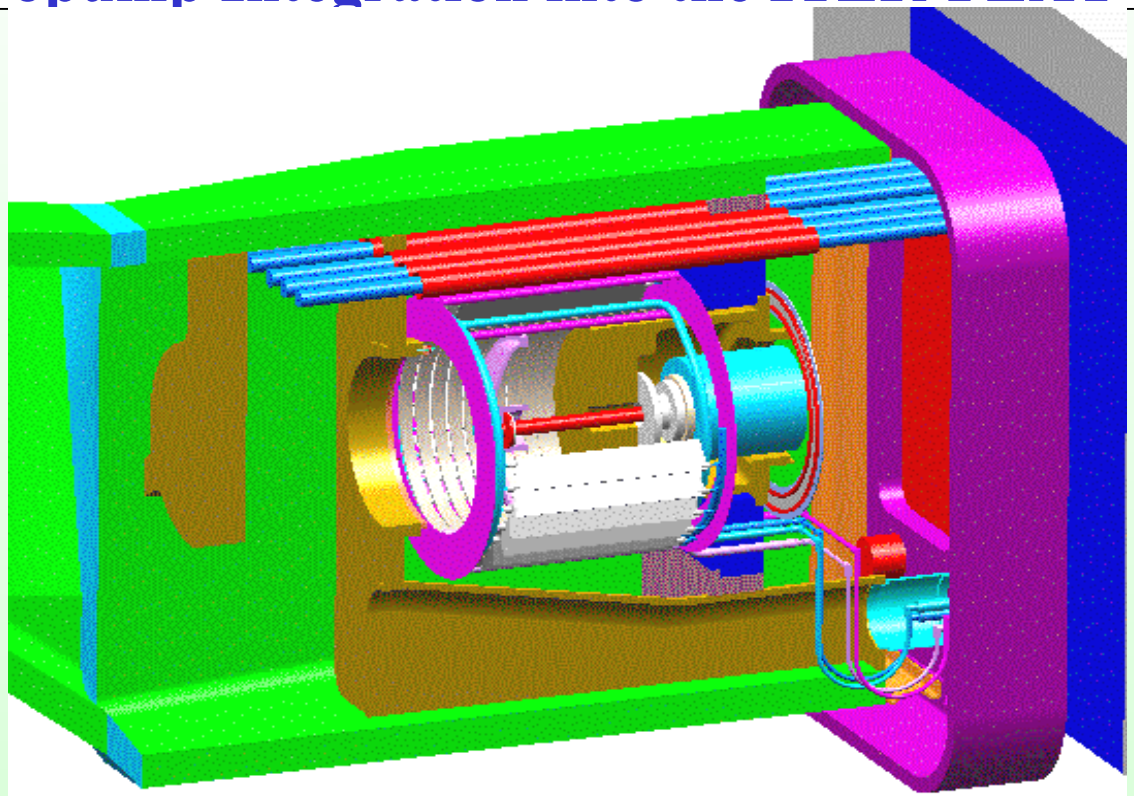


# Divertor and Auxiliary Systems Integration




Pumping system equipment in the pit

# Cryopump Integration into the ITER-FEAT Vessel



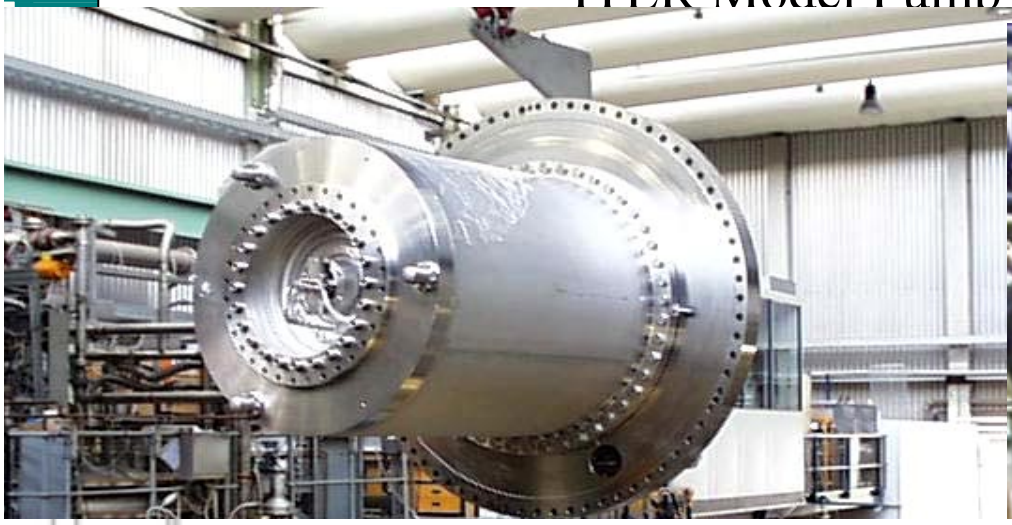
Due to space constraints the cryo pump is installed without a pump housing but with an 80 K shield

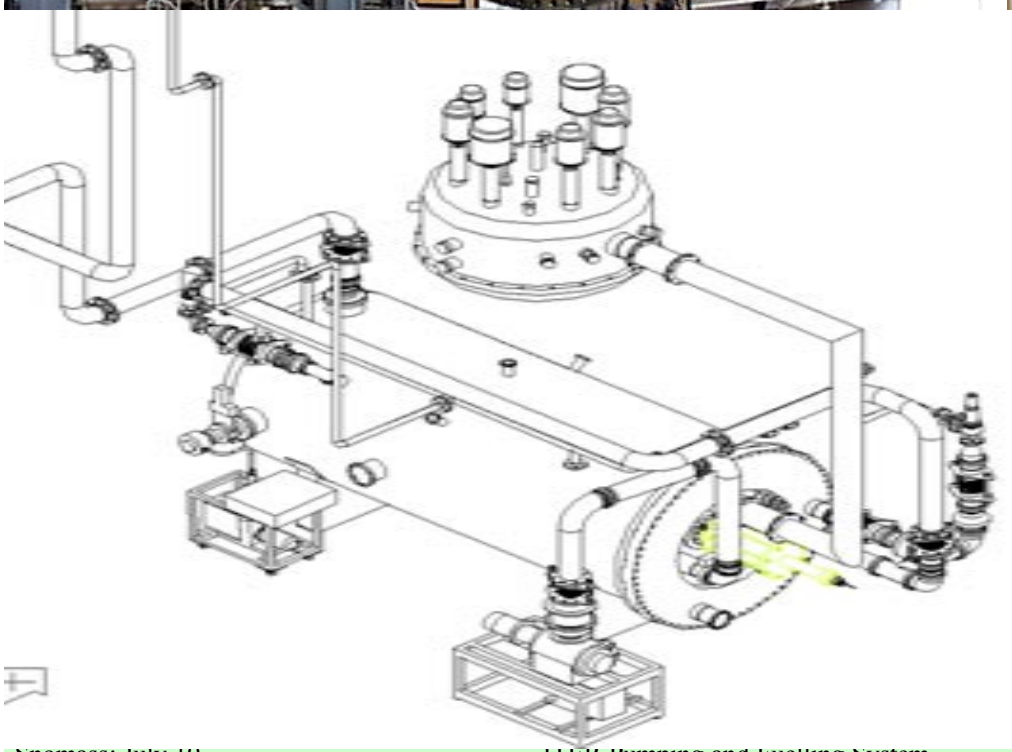
The port duct itself provides the function of a pump housing

- Larger volume and thus more margin against explosion limit
- Better neutron shielding reduces pump heat losses
- Separate pass for IVV and water cooling pipes (inside guide tubes) R&D

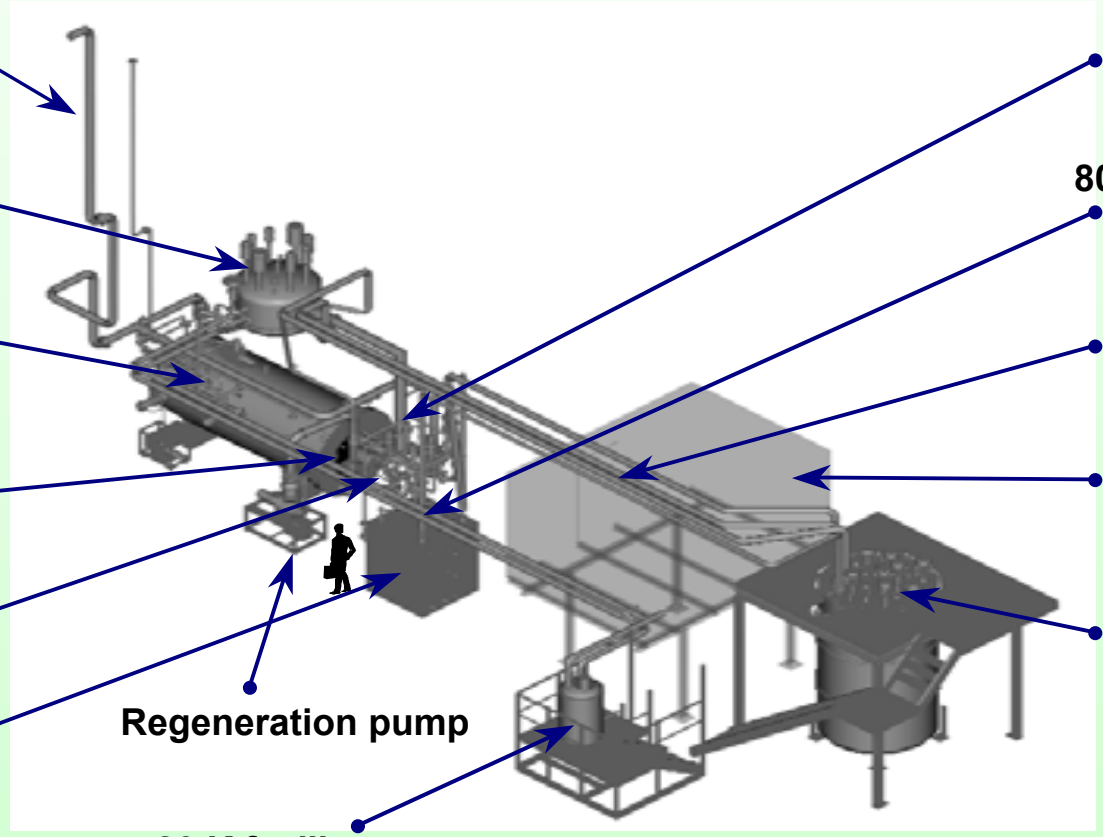
# Cryo Pump Interior (4.5 K panels) and Installation into Test Tank

# ITER Model Pump and Test Facility





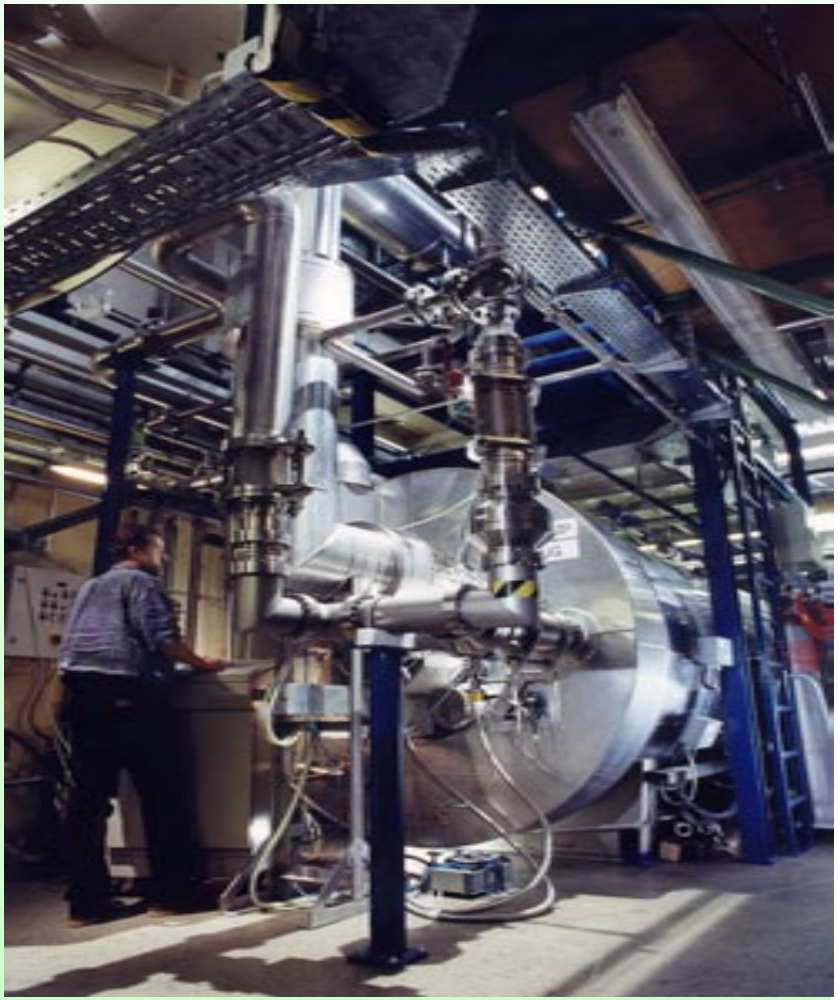
# Overview of TIMO including the new control cryostat



# TIMO facility

Bird's eye view, with the valve box, main transfer line and control cryostat

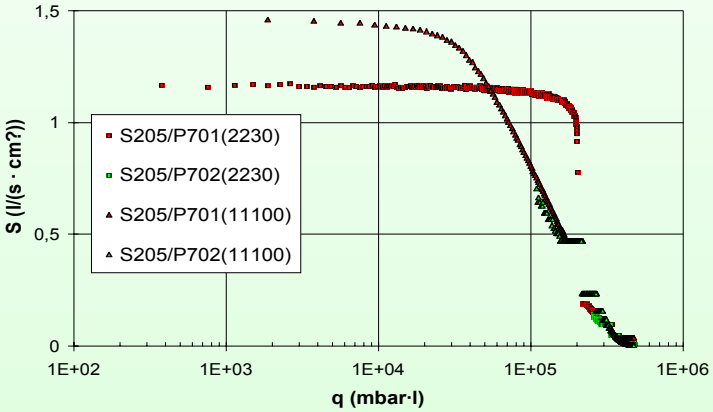
Pump Plug view of the ITER Model Pump



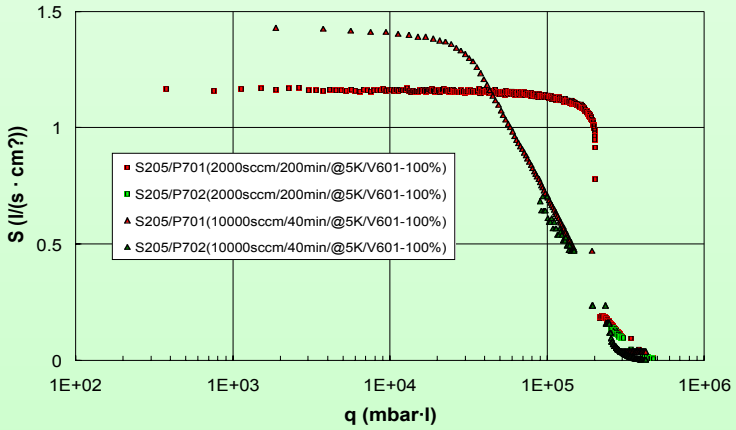
# TIMO facility

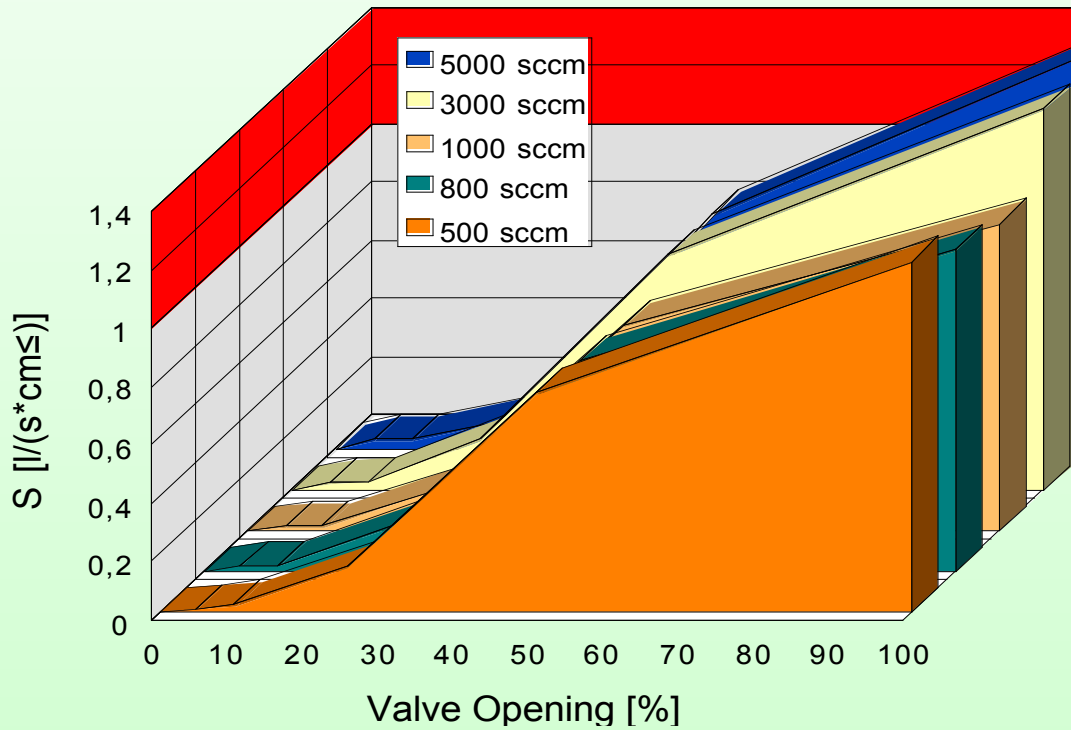
## He capacity in TIMO
**(pumping surface 4 m_)**

**Flowrates: 2230 and 11100 sccm**




**Flowrates: 2000 and 10000 sccm**




## Pumping speed data for He at different throughputs