BGC “v3” design & integration

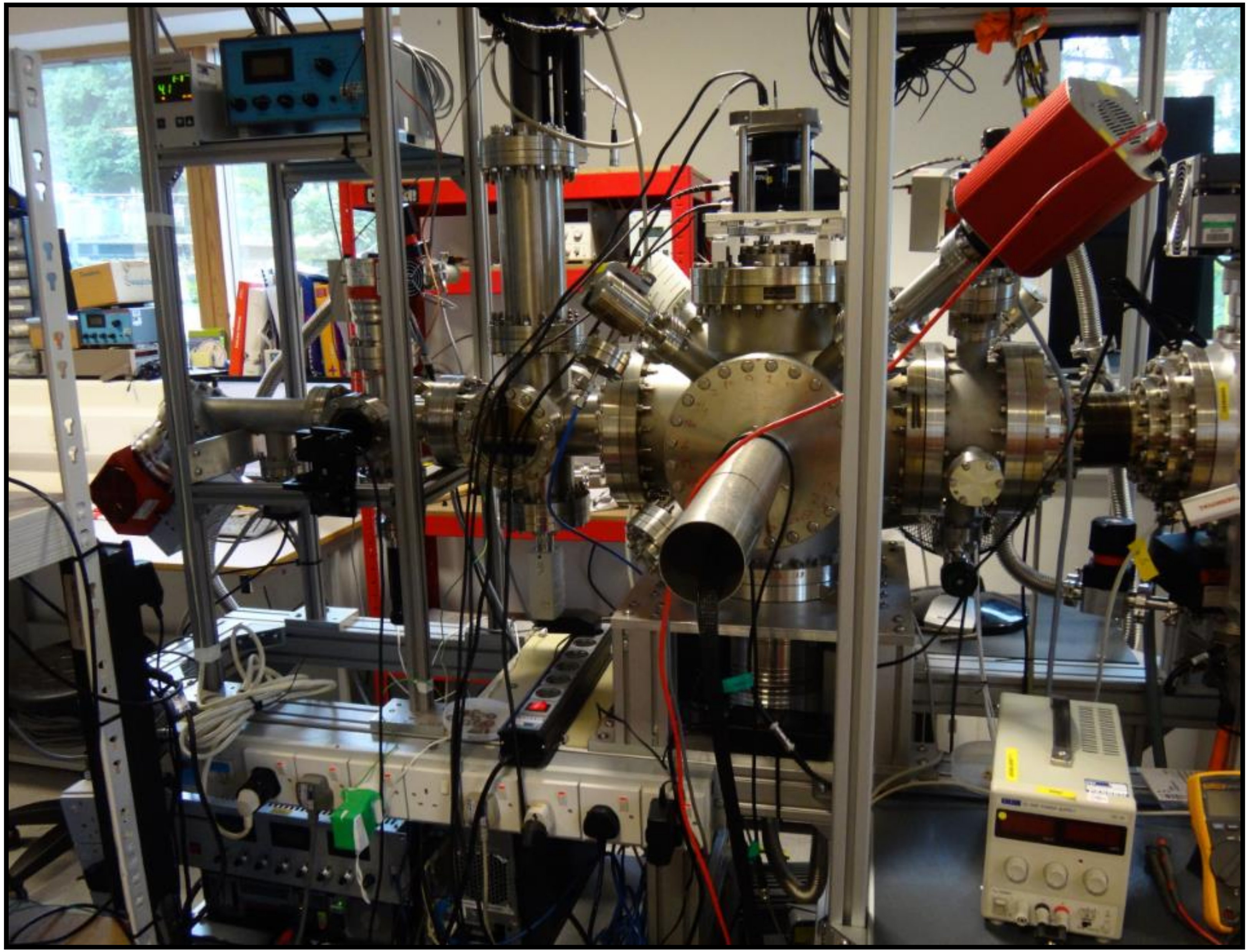
CERN TE-VSC

Marton Ady / Giuseppe Bregliozzi / Eric Page

BGC review meeting, CERN, 27.11.2018

Context

“v1” setup (past)



Context

- “v2” instrument currently assembled in Cockroft institute

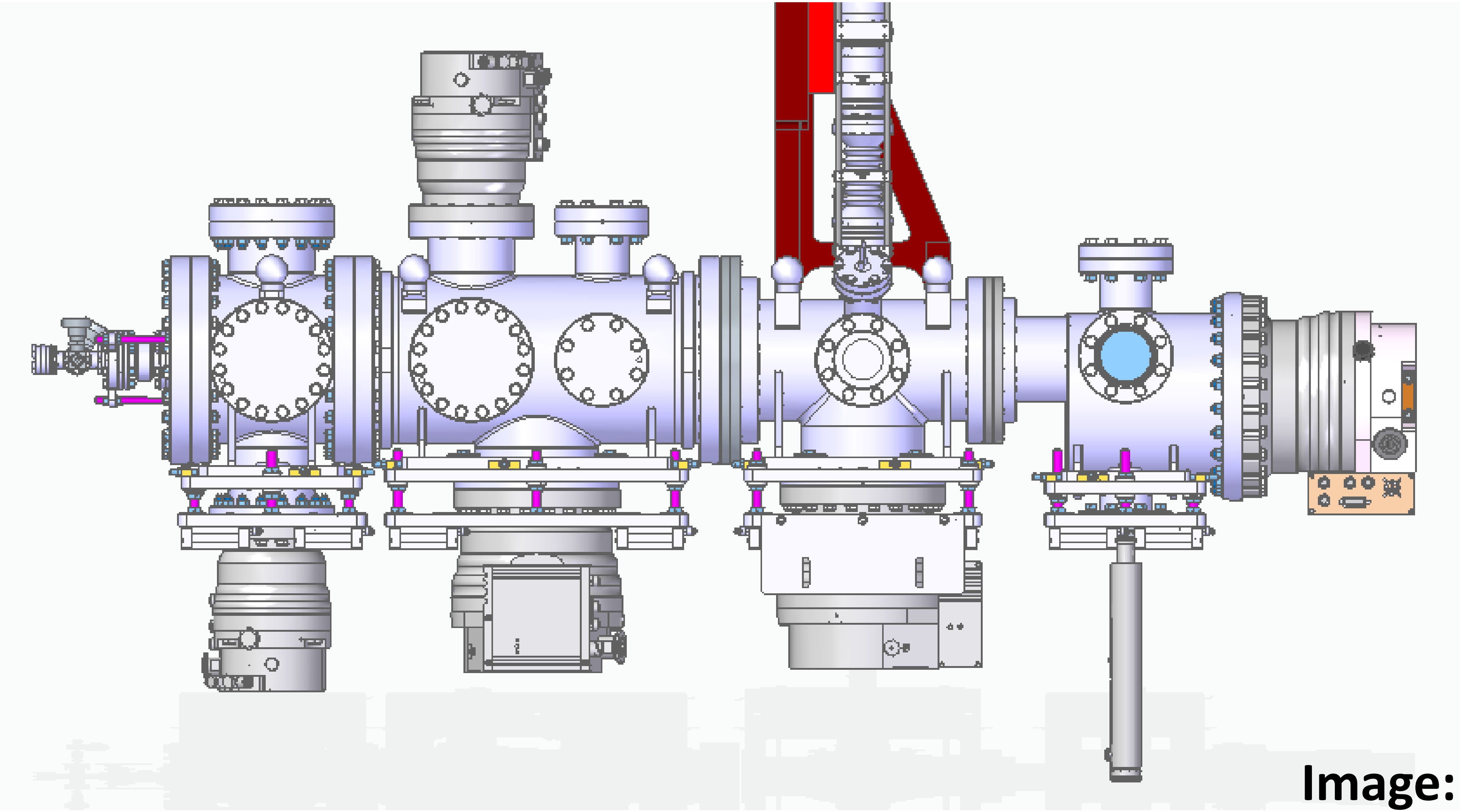
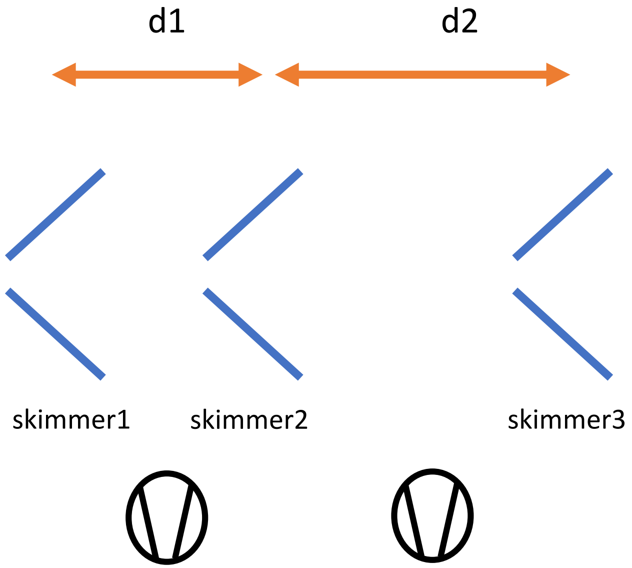


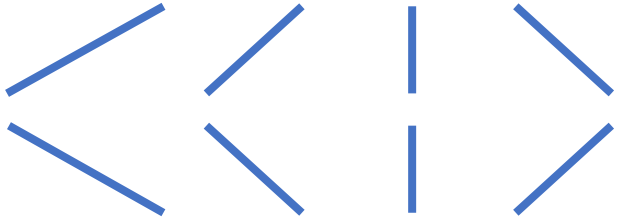
Image: Hao Zhang

From last review meeting

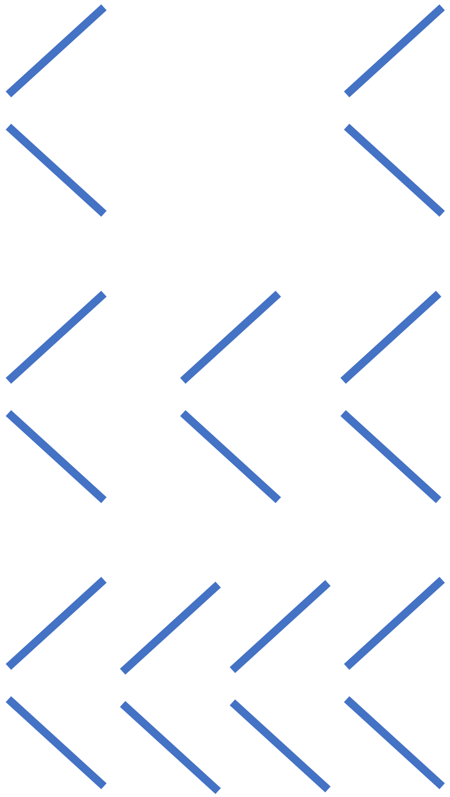
Free parameters, low pressure part



Distance between skimmers

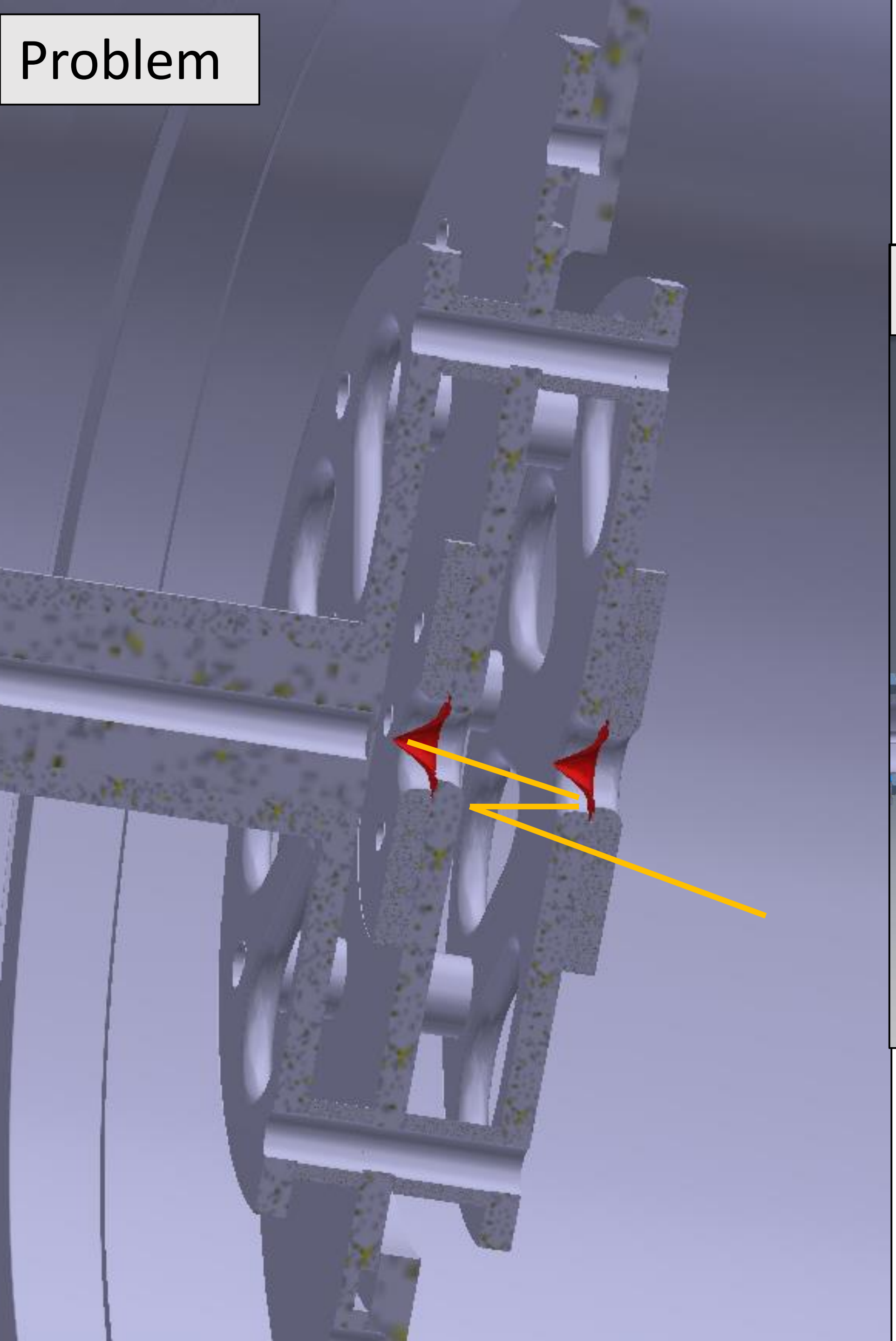


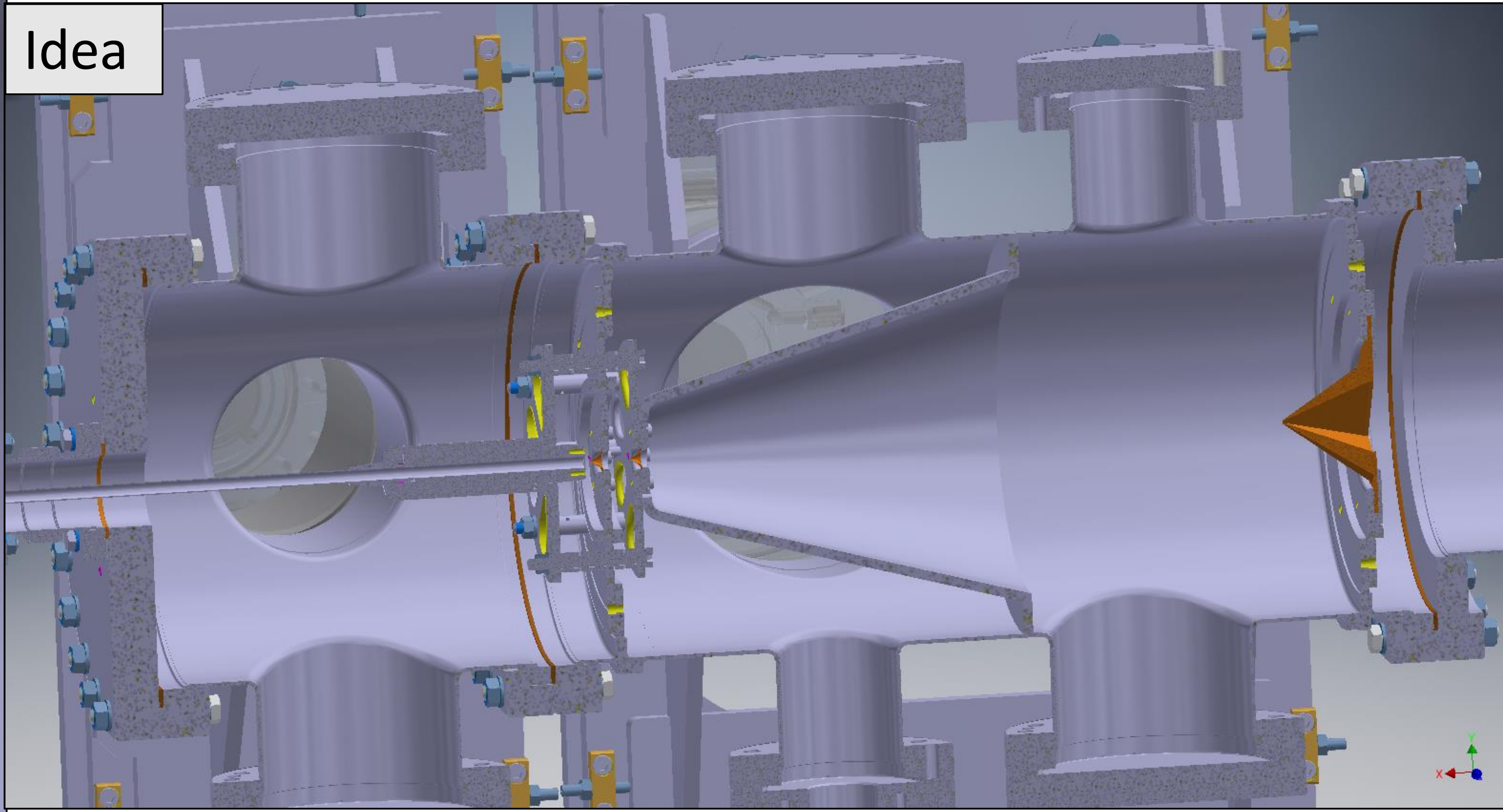
Skimmer shape



Number of skimmers

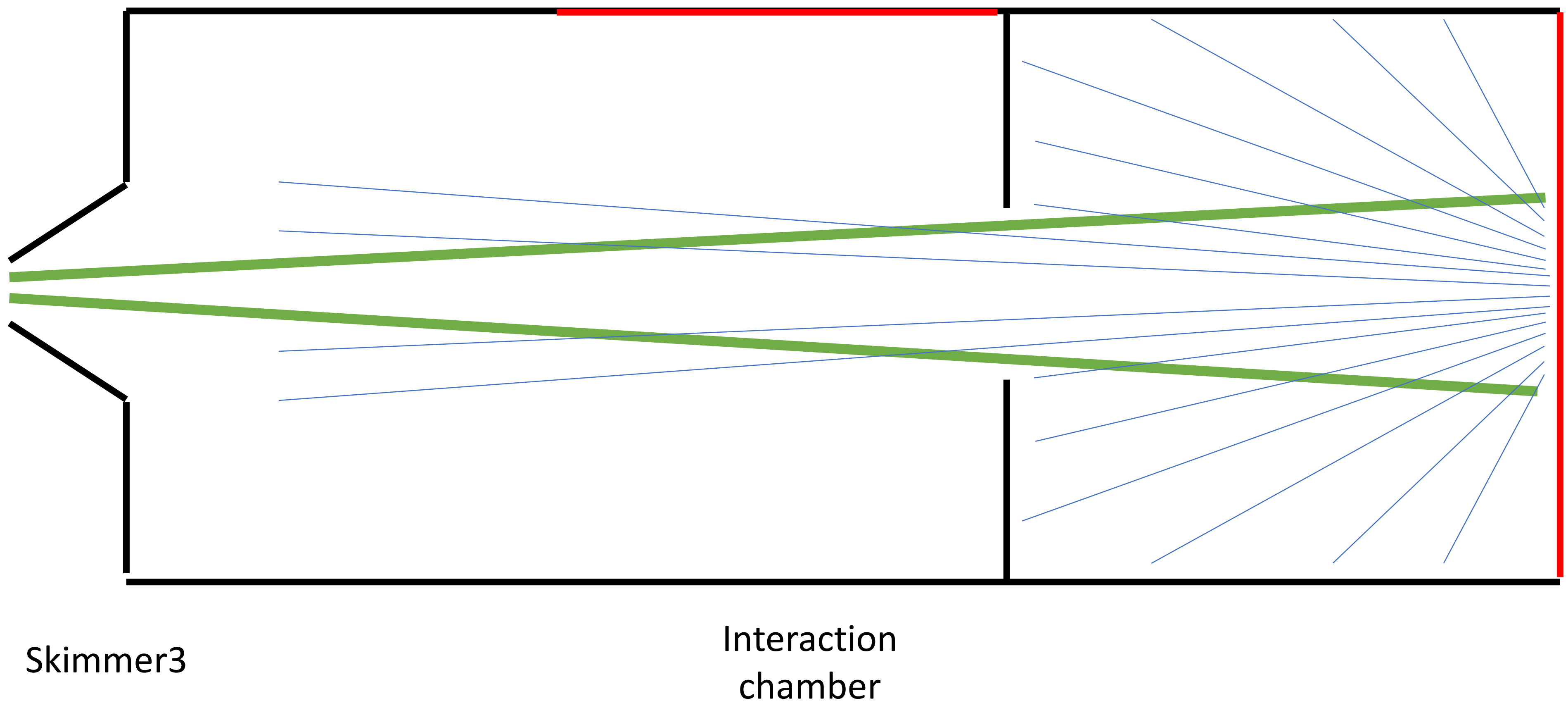
From last review meeting



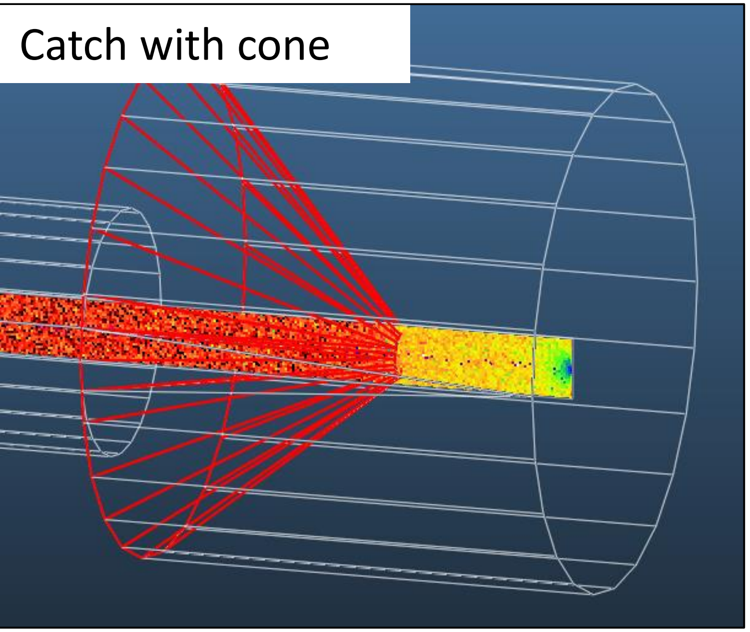


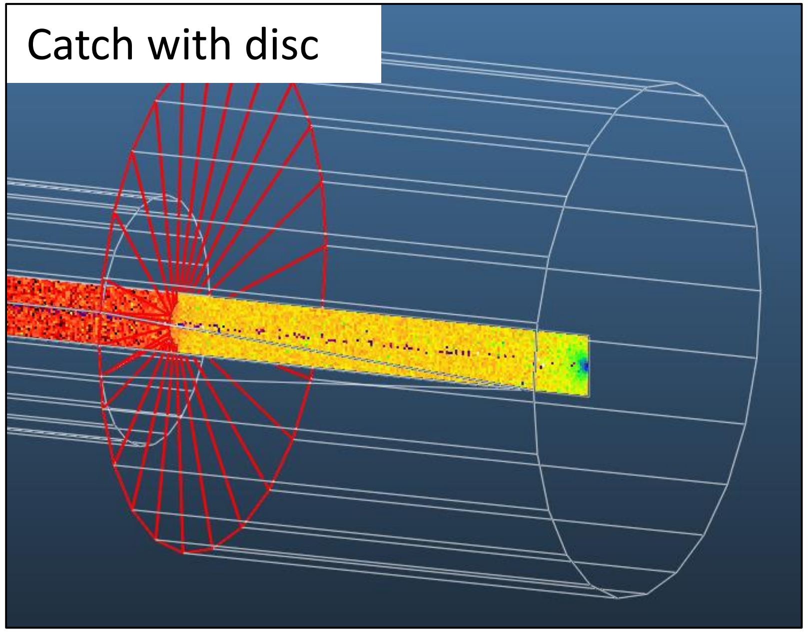
From last review meeting

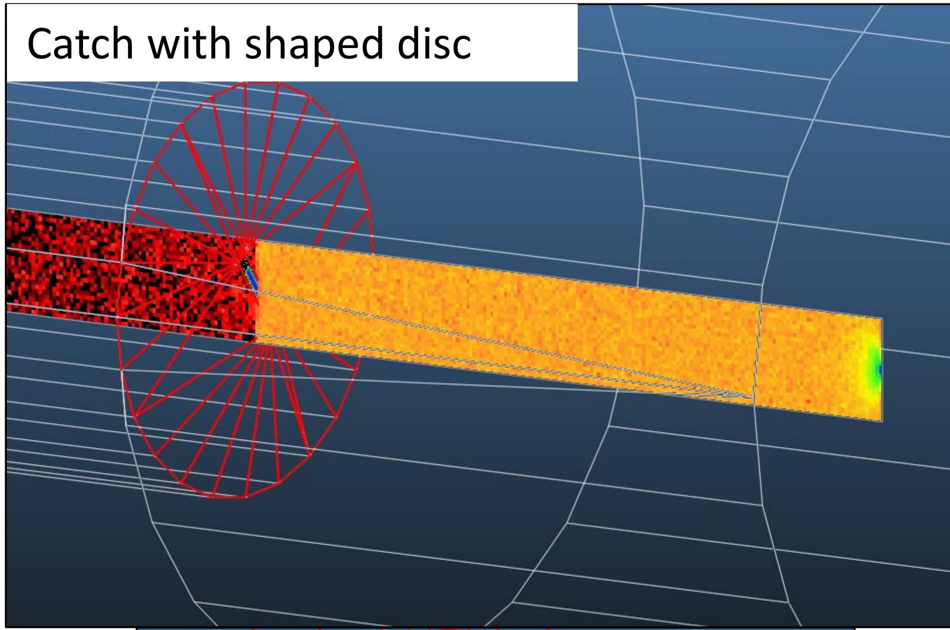
Backscattering reducer

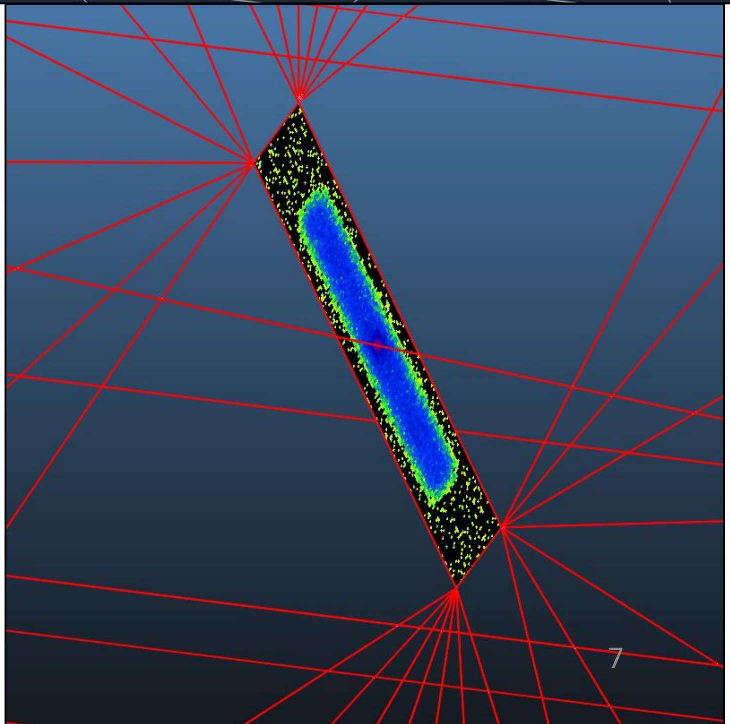


From last review meeting



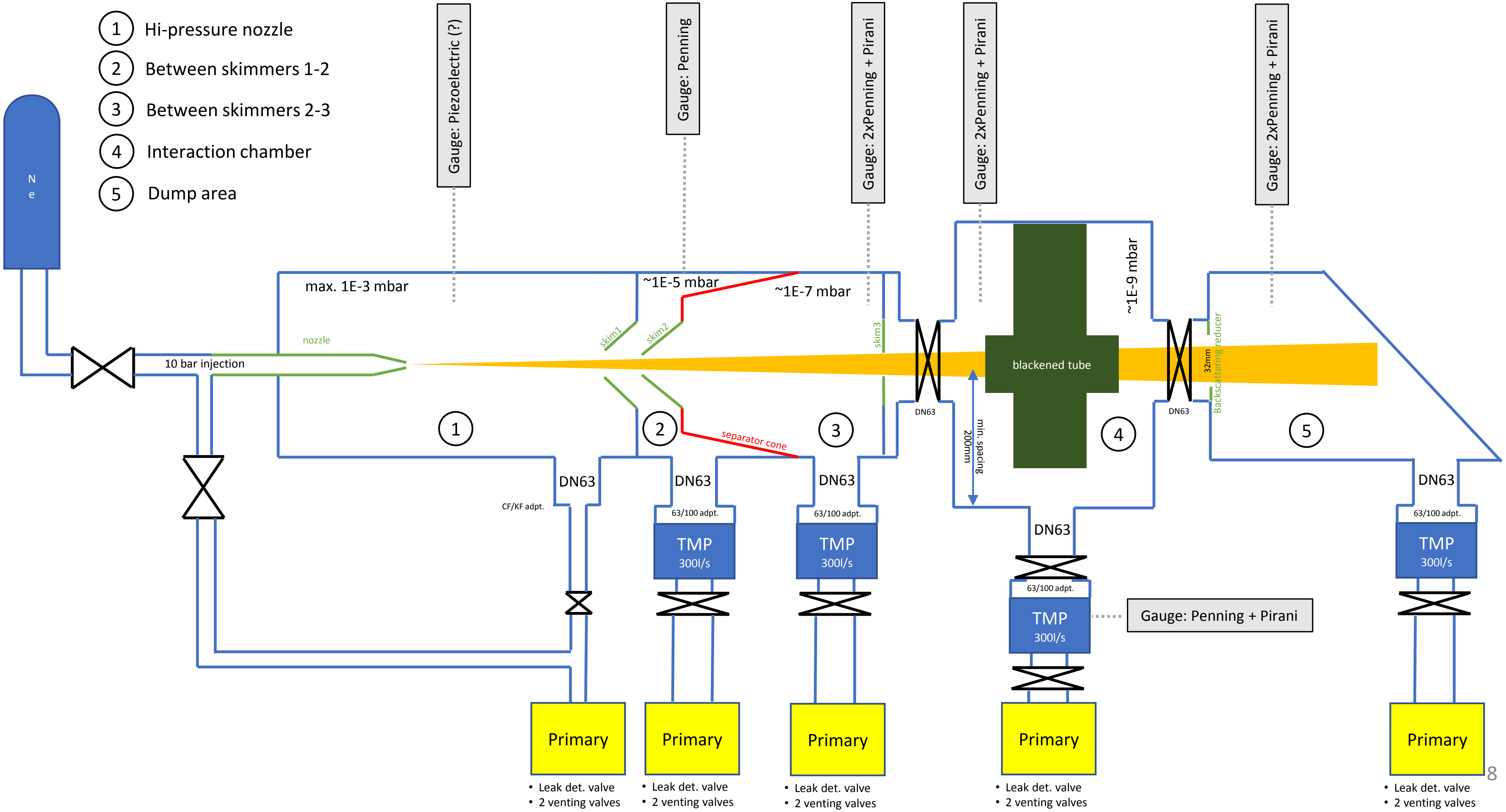






Context

- “v3” instrument needs to be more compact (goes in the LHC)

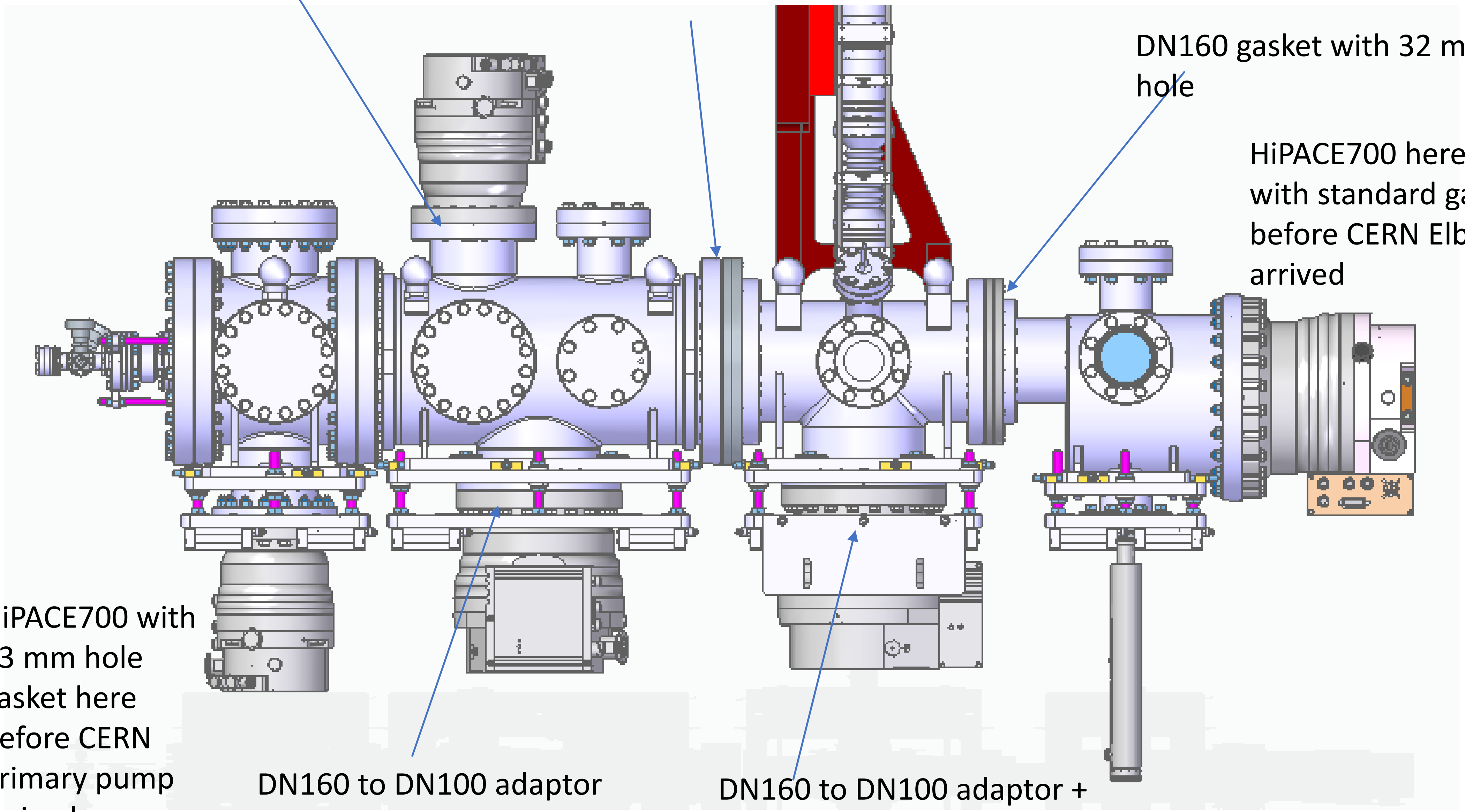


DN100 gasket with 63 hole

I don’t think DN160 gasket with 63 mm hole needed since there is 3 skimmer upstream

DN160 gasket with 32 mm hole

HiPACE700 here with standard gasket before CERN Elbow arrived



HiPACE700 with 63 mm hole gasket here before CERN Primary pump arrived

DN160 to DN100 adaptor + DN100 gasket with 63 hole + Hipace300

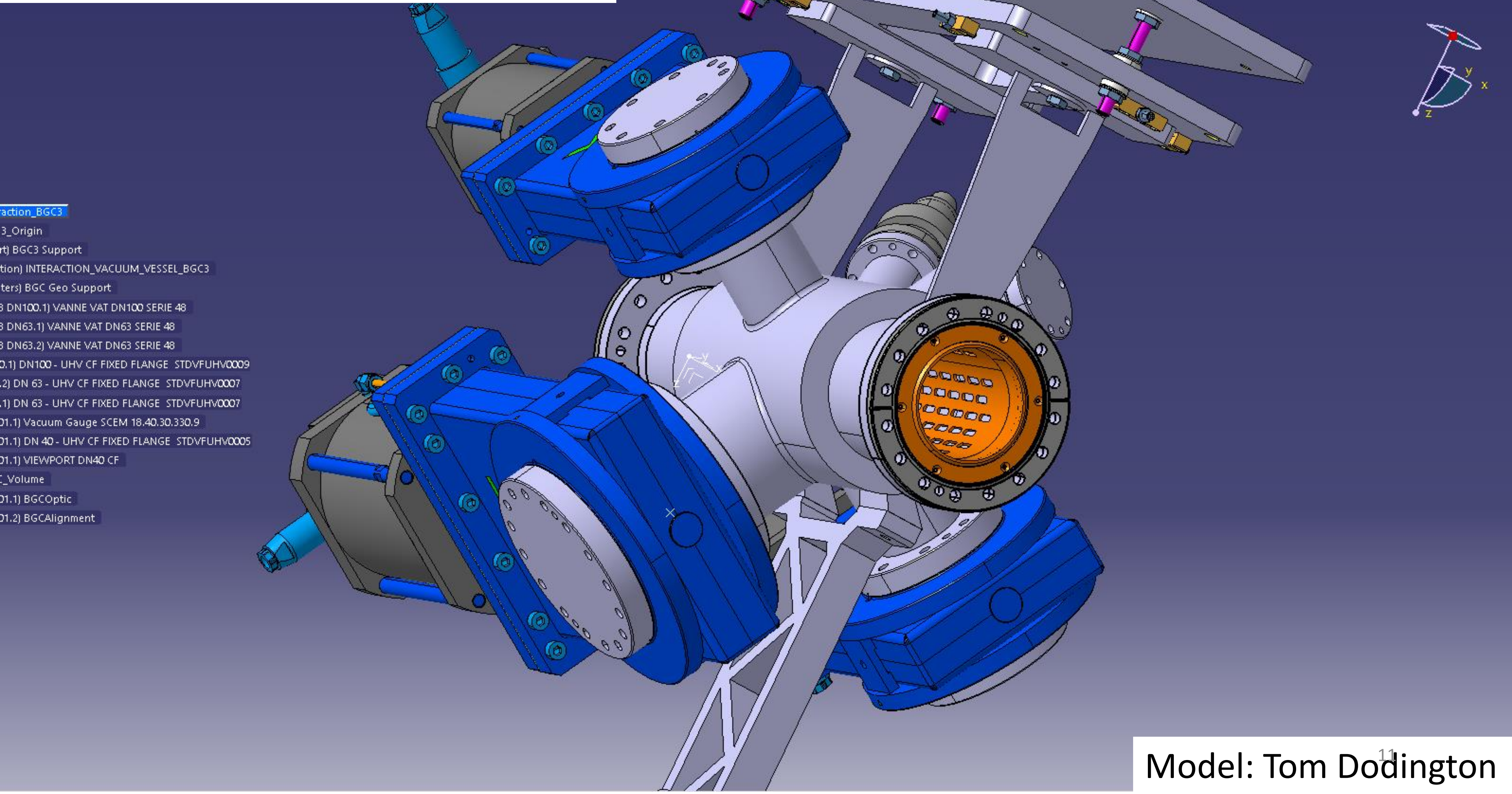
DN160 to DN100 adaptor + DN100 gasket with 63 hole + Hipace300

Slide: Hao Zhang

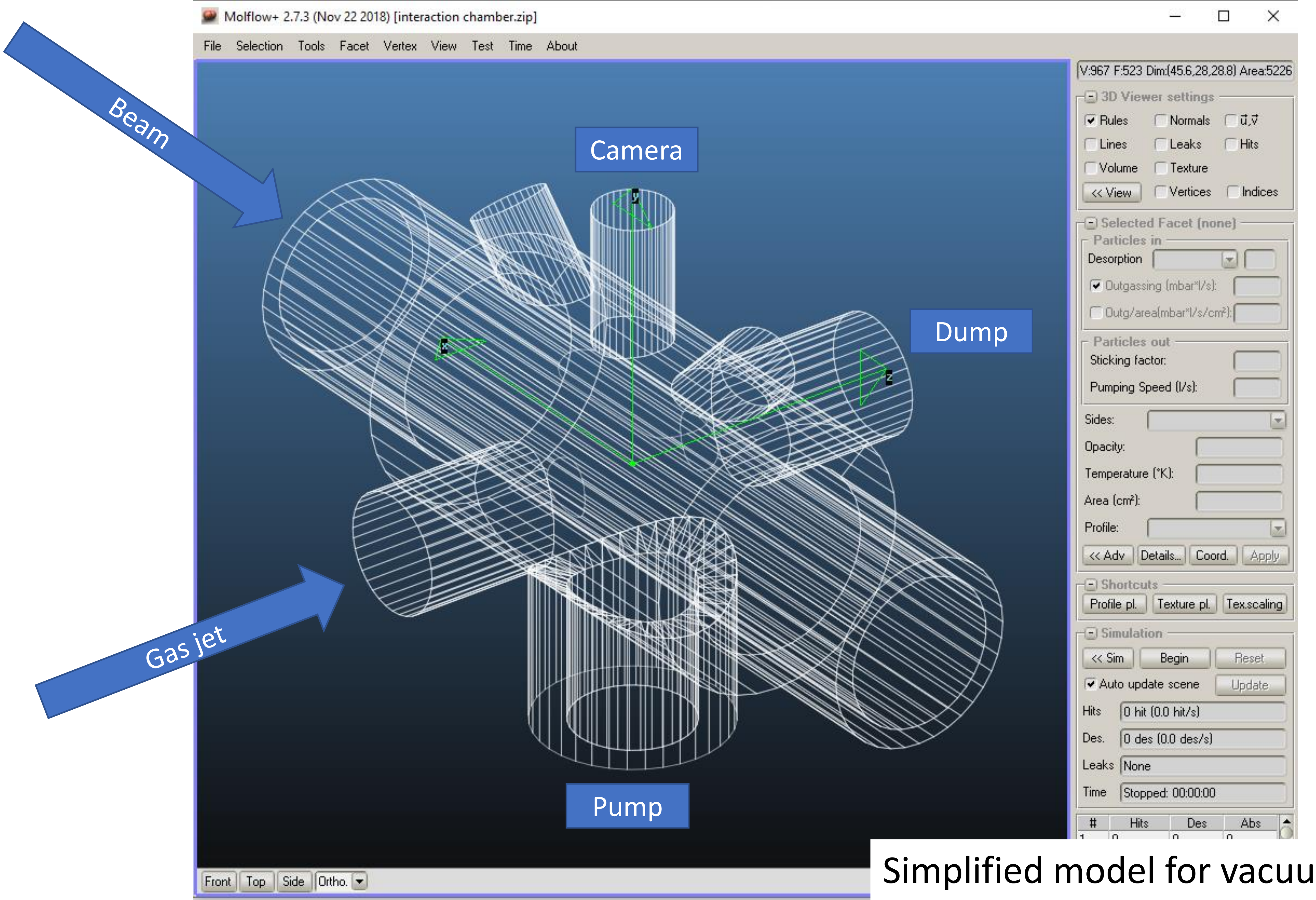
Simulation goals

- Look for a suitable “v3” design
- Understand pressure sensitivity to…
  - Changing gas jet size
  - Changing distances
  - Changing pump sizes
  - Using smaller valves
  - Adding “backscattering reducer”
  - Changing dump area
    - 90 deg. elbow
    - Pump offset
    - Pump tilting

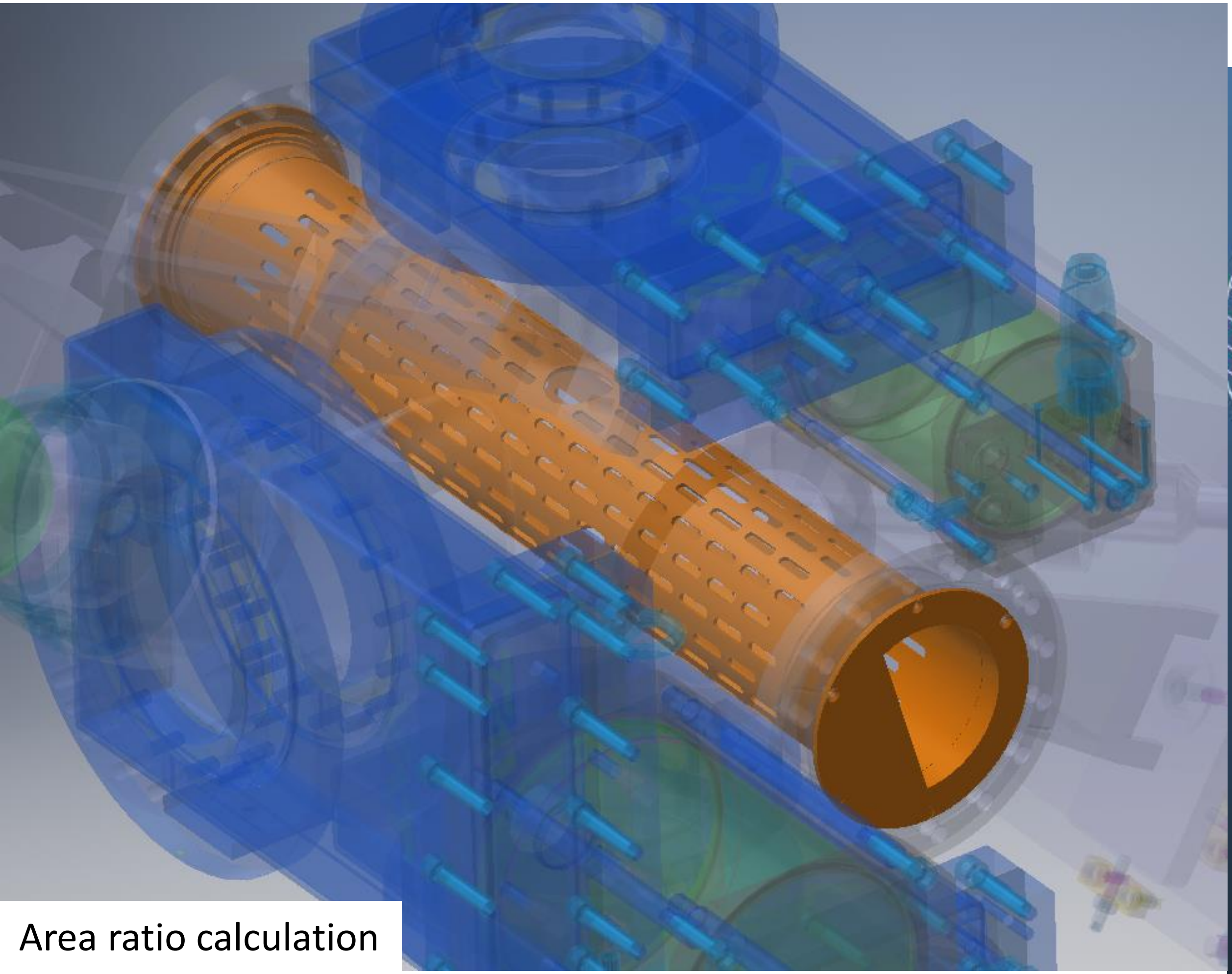
One fix point: the interaction chamber



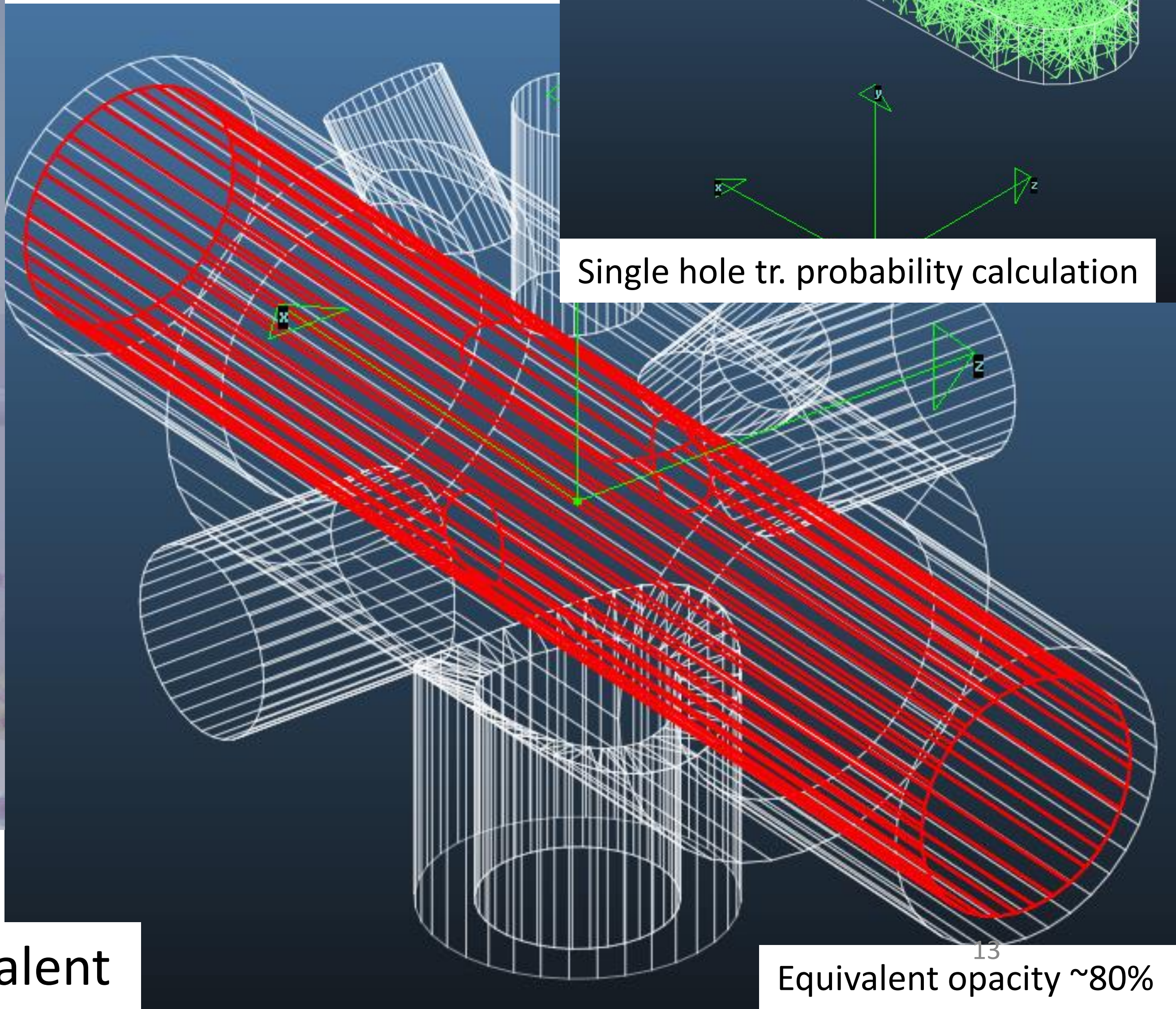
Model: Tom Dodington



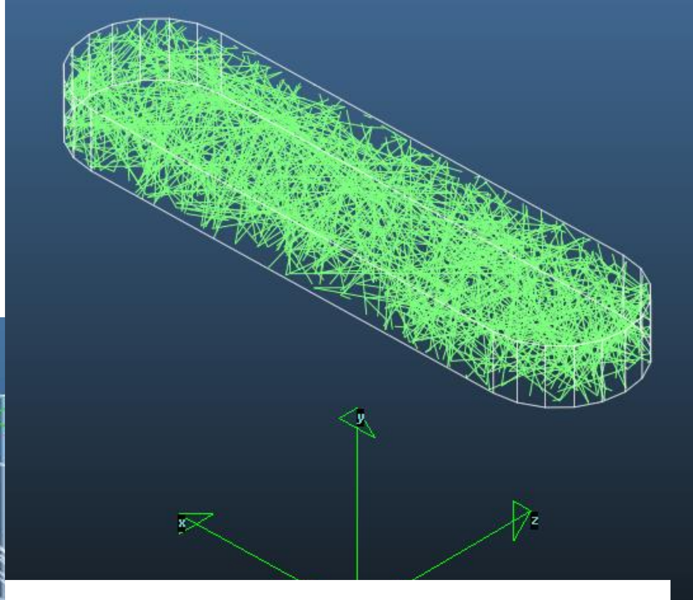
Simplified model for vacuum simulation



Area ratio calculation



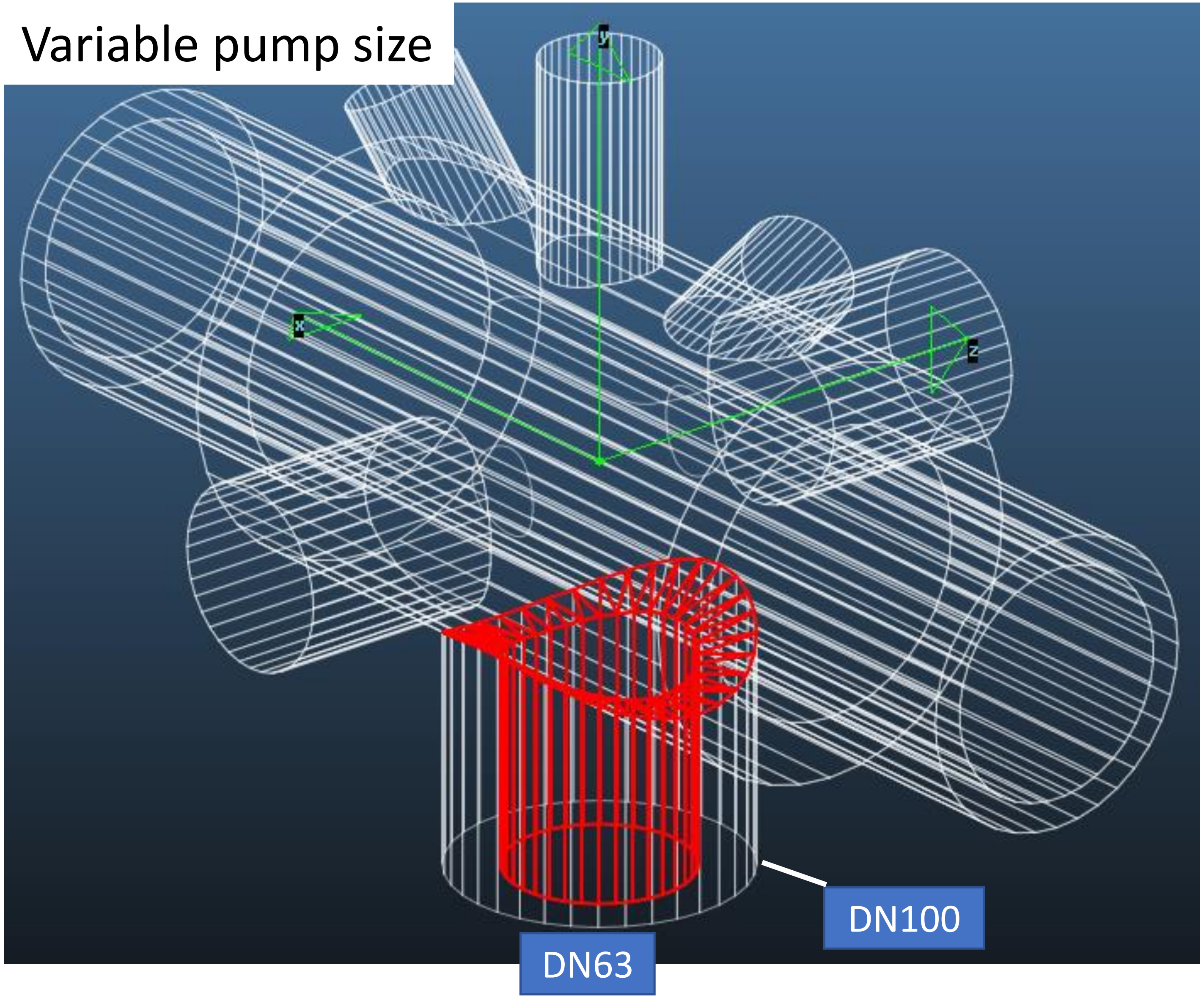
Equivalent opacity ~80%



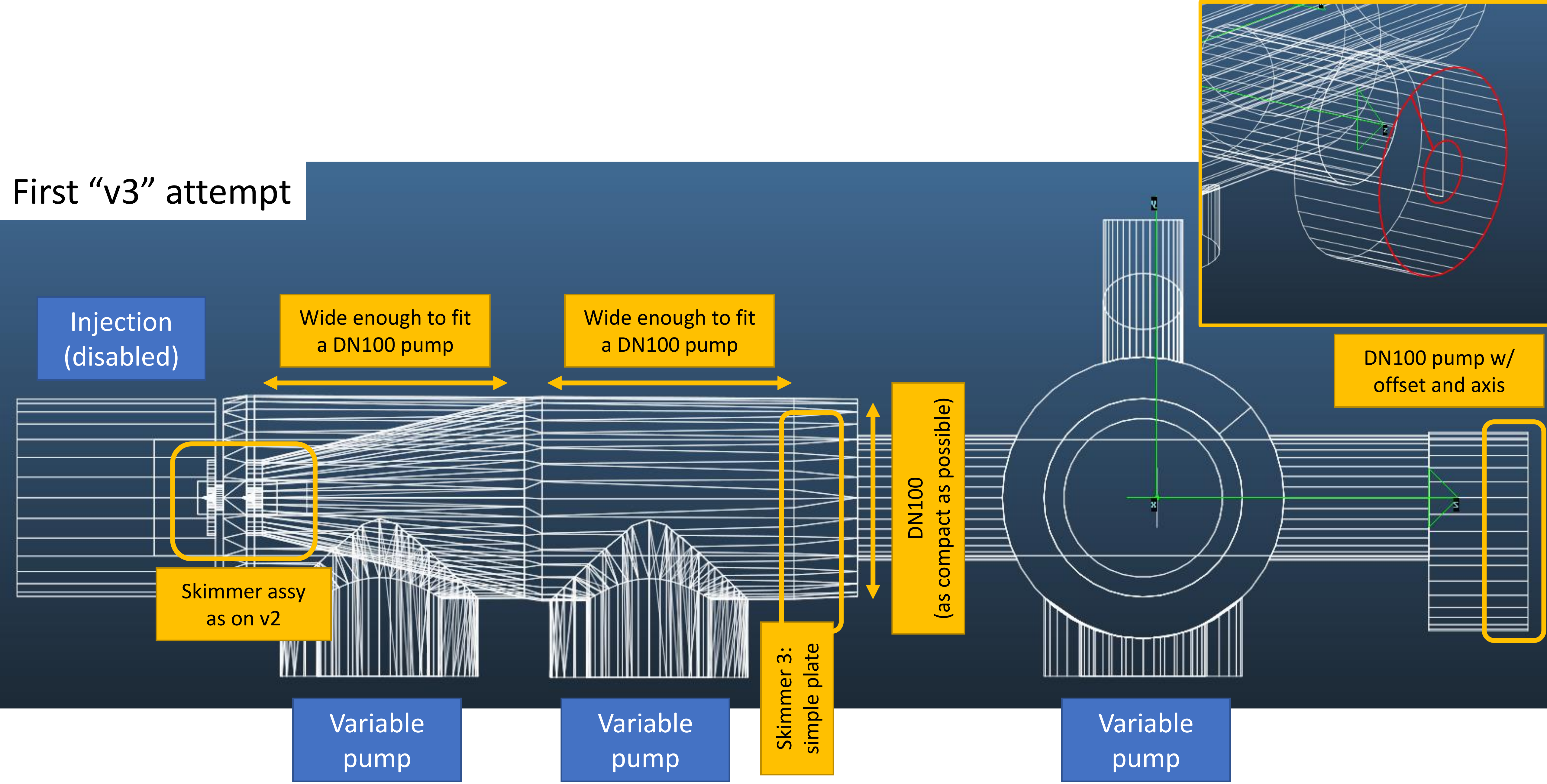
Single hole tr. probability calculation

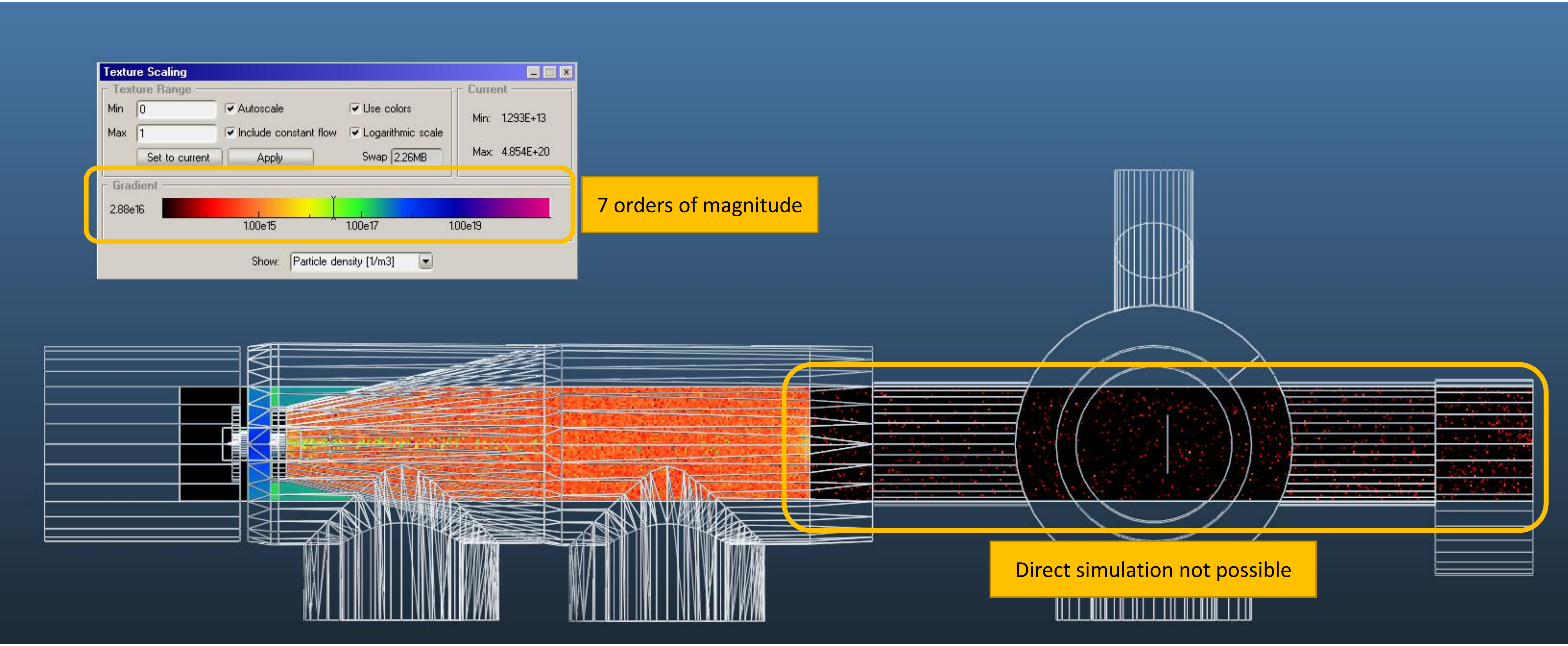
Replacing impedance insert with vacuum equivalent

Variable pump size

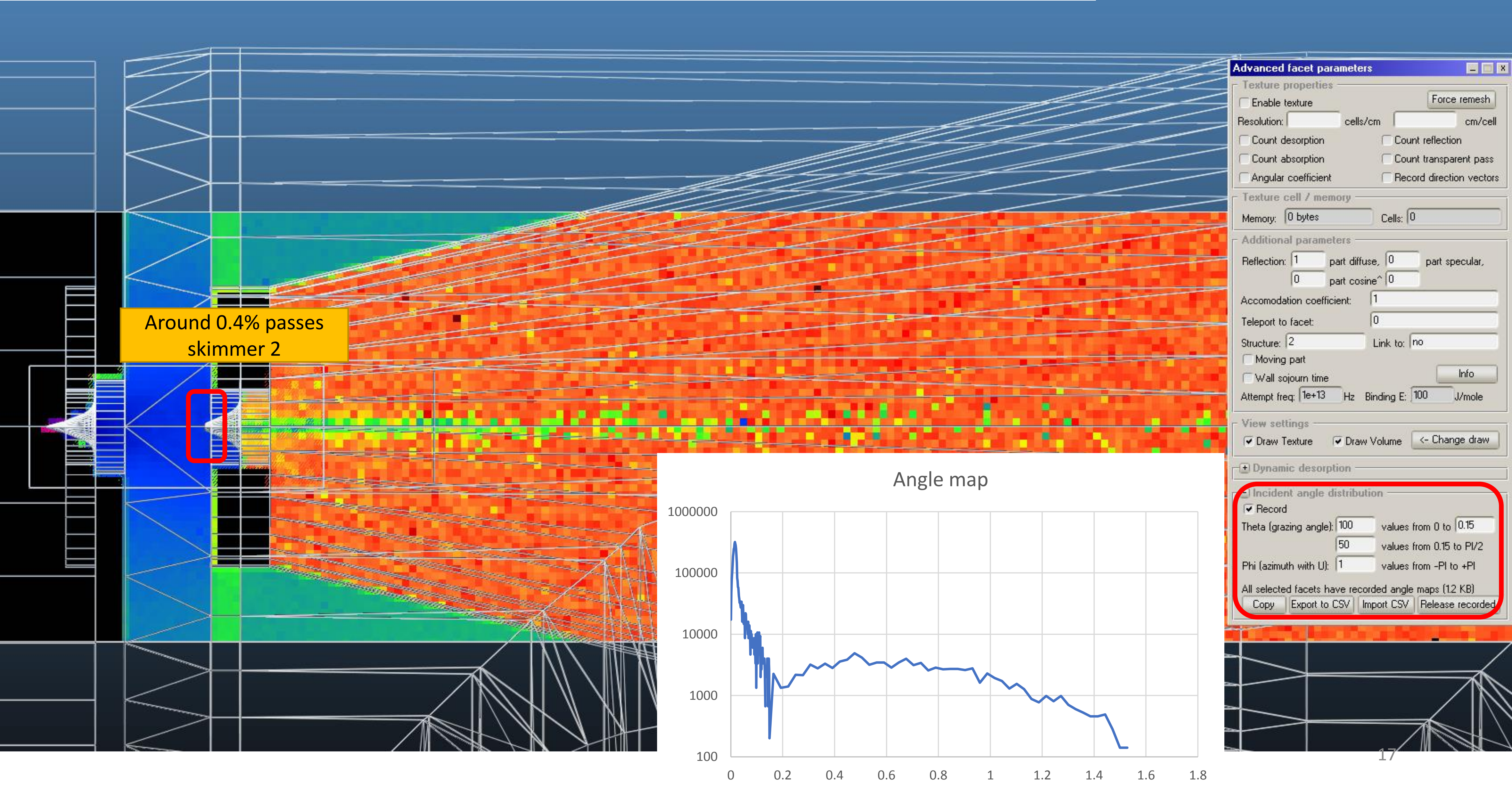


First “v3” attempt

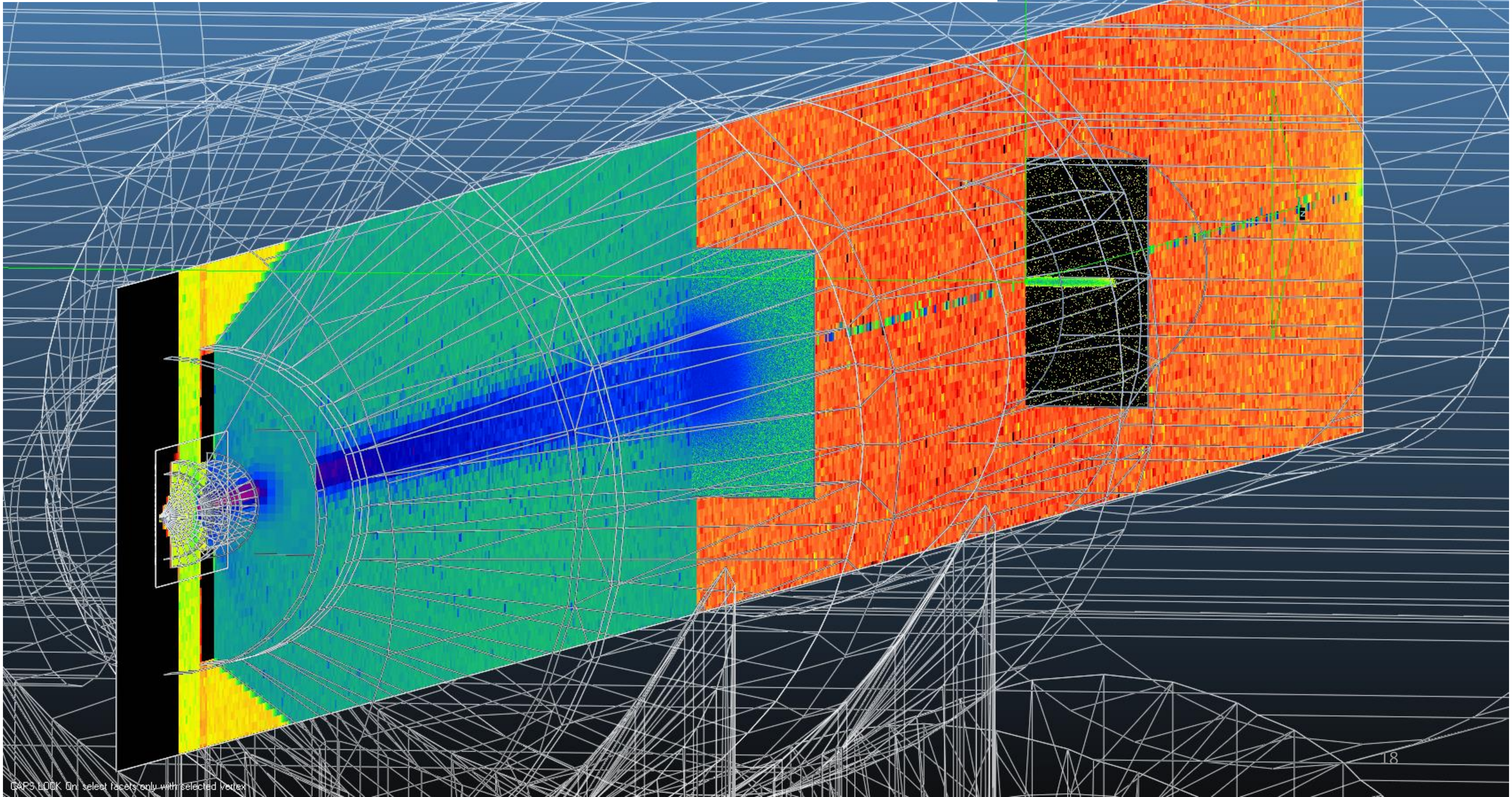


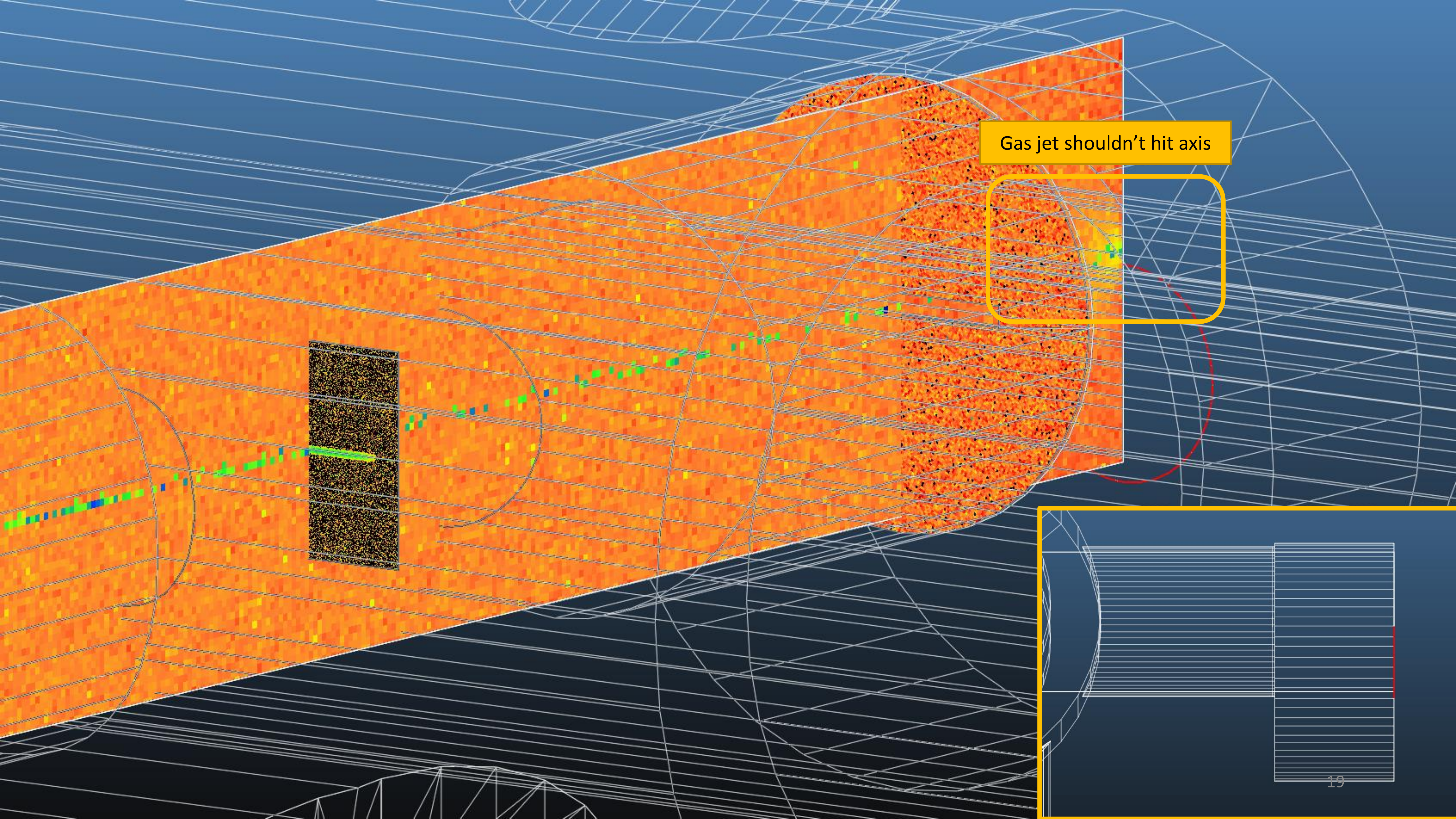

Texture Scaling
Texture Range
Min 0
Max 1
Autoscale
Include constant flow
Use colors
Logarithmic scale
Set to current
Apply
Swap 2.26MB
Current
Min: 1.293E+13
Max: 4.854E+20
Gradient
2.88e16
1.00e15
1.00e17
1.00e19
Show: Particle density [1/m3]
7 orders of magnitude
Direct simulation not possible

Iterative simulation 1st step: record angular distribution on skimmer 2



Iterative simulation 2nd step: use recorded distro for outgassing



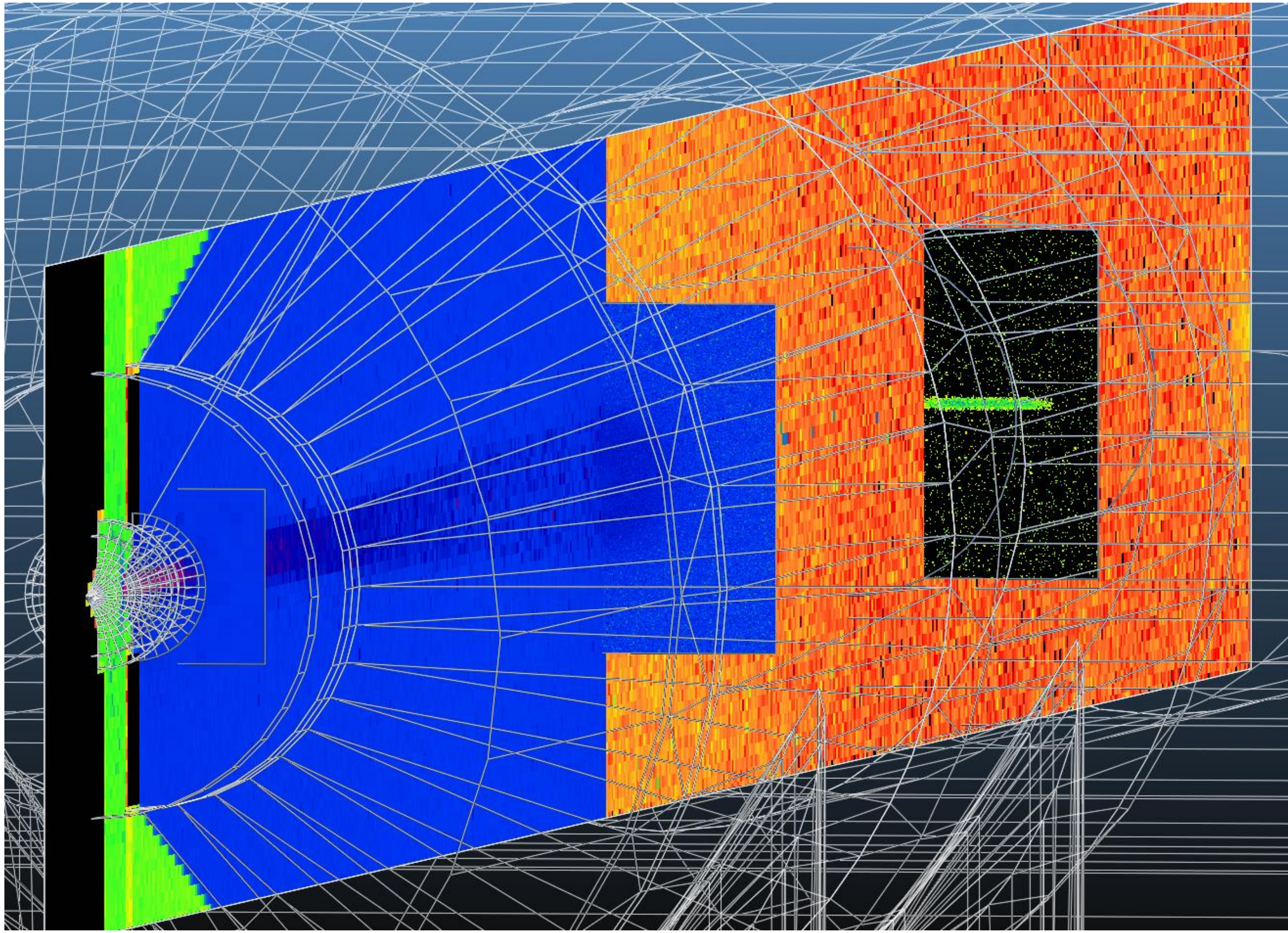

Gas jet shouldn’t hit axis

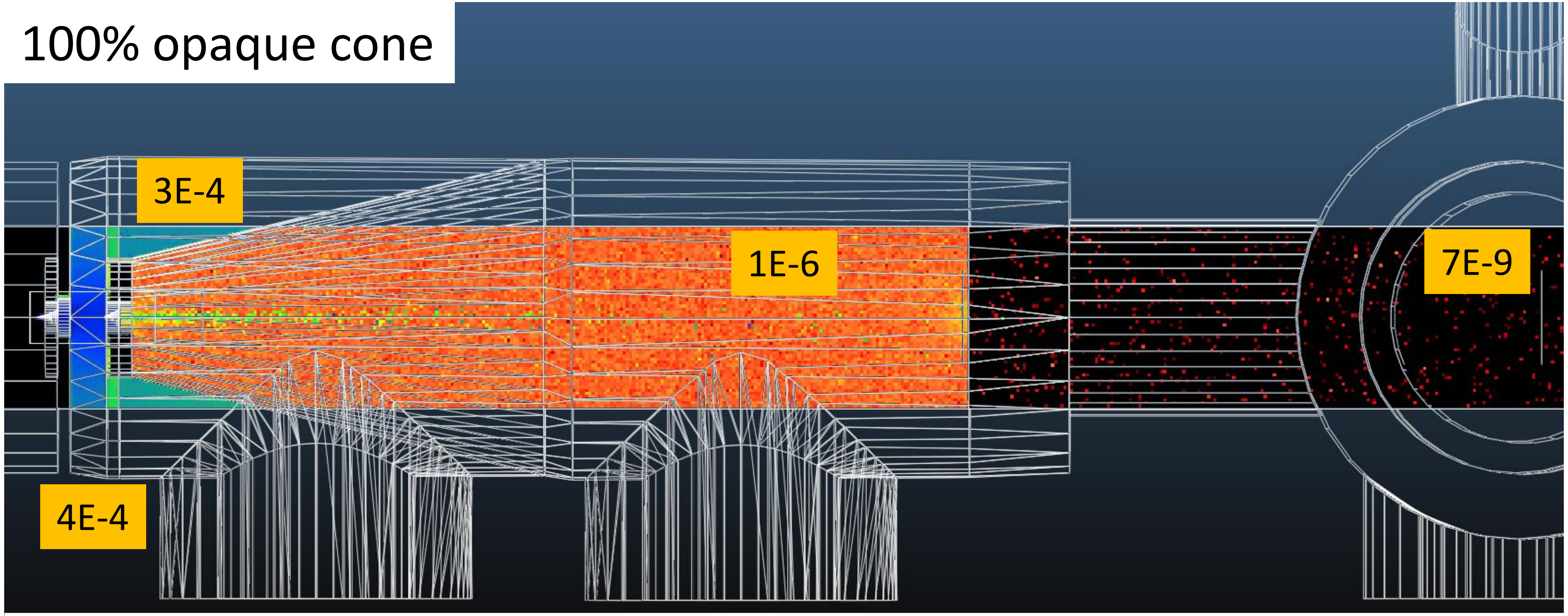
300l/s pump, 4x0.4mm skim3						
	SKim1-2	Skim2-cone	cone-skim3	IP	Dump	
100% opaque cone	8.7E-04	6.7E-04	3.3E-07	2.3E-09	4.7E-09	
			3.7E-07	2.5E-09	5.1E-09	
99.9% opaque cone	8.7E-04	6.3E-04	8.0E-06	8.7E-09	6.7E-09	<- seems probable, chosen as reference
99% opaque cone	7.7E-04	5.3E-04	6.0E-05	3.3E-08	1.3E-08	
99.9% op cone, increased skim2, pumps DN100 and 300l/s	2.6E-04	1.9E-04	2.9E-06	9.6E-09	5.8E-09	
			2.9E-06	7.6E-09	7.2E-09	
99.9% op cone, increased skim2, first two pumps DN63 w/ 170l/s	3.8E-04	3.2E-04	9.4E-06	2.0E-08	1.0E-08	
			9.6E-06	2.1E-08	1.2E-08	
99.9% op cone, increased skim2, first two pumps DN63 w/ 80l/s	6.0E-04	5.2E-04	2.8E-05	5.0E-08	2.6E-08	
			2.8E-05	5.4E-08	2.4E-08	
99.9% op cone, increased skim2, first two pumps DN63 w/ 170l/s + IP 170l/s	3.8E-04	3.0E-04	9.2E-06	3.0E-08	1.3E-08	
99.9% op cone, increased skim2, first two pumps DN63 w/ 80l/s + IP 80l/s	3.9E-04	3.2E-04	9.4E-06	3.4E-08	1.5E-08	
99.9% op cone, increased skim2, first two pumps DN63 w/ 80l/s + IP 80l/s, no imped.insert	3.9E-04	3.2E-04	9.3E-06	3.8E-08	2.0E-08	
op cone, increased skim2, pumps DN100 and 300l/s	2.6E-04	1.8E-04	4.8E-07	2.8E-09	5.7E-09	
			4.8E-07	3.5E-09	5.6E-09	
			4.8E-07	3.2E-09	5.4E-09	no imped. insert
			4.8E-07	1.6E-09	7.2E-09	backscattering reducer
op cone, increased skim2, first two pumps DN63 w/ 170l/s	4.0E-04	3.3E-04	1.0E-06	4.0E-09	4.4E-09	
			1.0E-06	4.7E-09	6.2E-09	
op cone, increased skim2, first two pumps DN63 w/ 80l/s	6.2E-04	5.6E-04	2.3E-06	7.2E-09	3.6E-09	
			2.2E-06	6.5E-09	6.5E-09	
op cone, increased skim2, first two pumps DN63 w/ 170l/s + IP 170l/s	4.0E-04	3.3E-04	1.1E-06	7.0E-09	6.4E-09	
			1.0E-06	6.5E-09	6.9E-09	
			1.0E-06	6.2E-09	6.7E-09	no imped. Insert
			1.0E-06	5.3E-09	7.2E-09	backscattering reducer
	4.0E-04	3.3E-04	1.1E-06	4.8E-09	5.6E-39	dn40 valves
			1.0E-06	6.0E-09	7.0E-09	dn40 valves
op cone, increased skim2, first two pumps DN63 w/ 80l/s + IP 80l/s	6.2E-04	5.6E-04	9.6E-07	1.0E-08	7.2E-09	
			1.0E-06	8.8E-09	7.8E-09	

Gas jet -> 20mm: skimmer 2 and 3 need to be increased

Gas jet **radius**

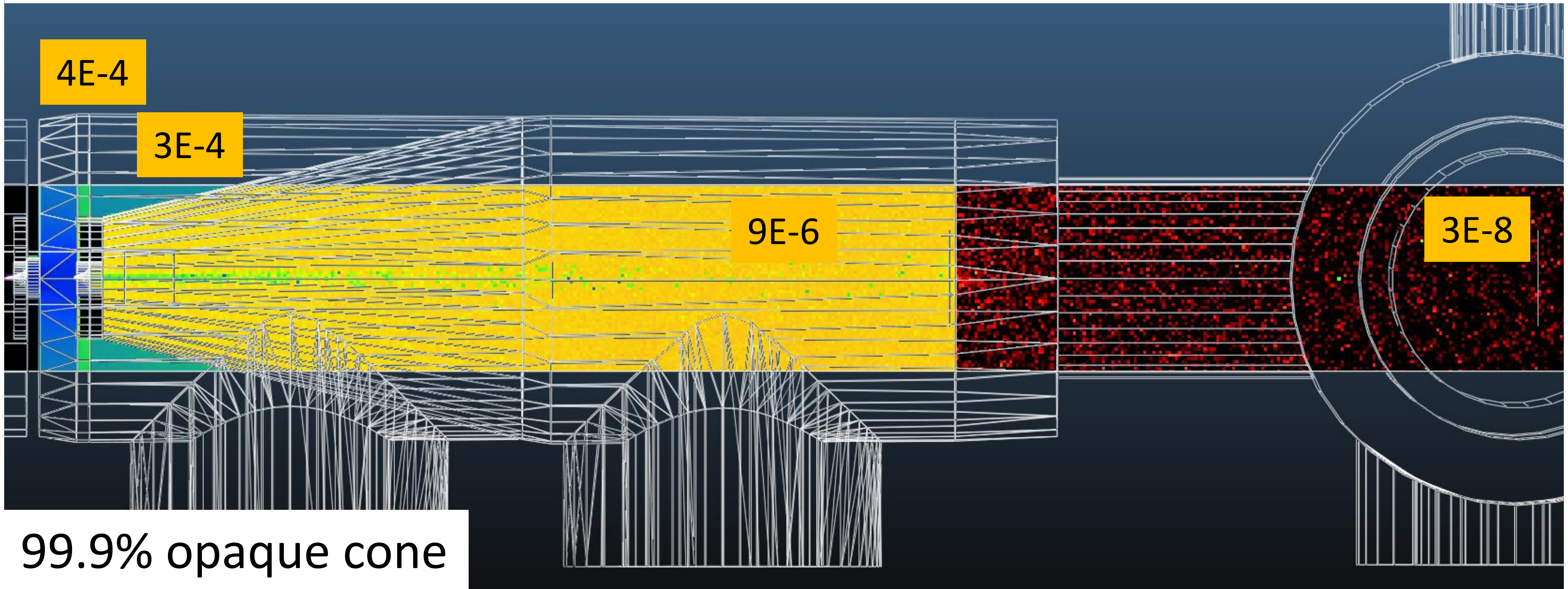
Skimmer1	Skimmer2	Skimmer3	IP	Dump entrance
0.00	0.2	3.99	6.43	8.26
		2.00	3.23	4.15
0.00	0.45	6.64	10.72	13.77
		6.60	10.65	13.68
		0.20	0.32	0.41





6E-9

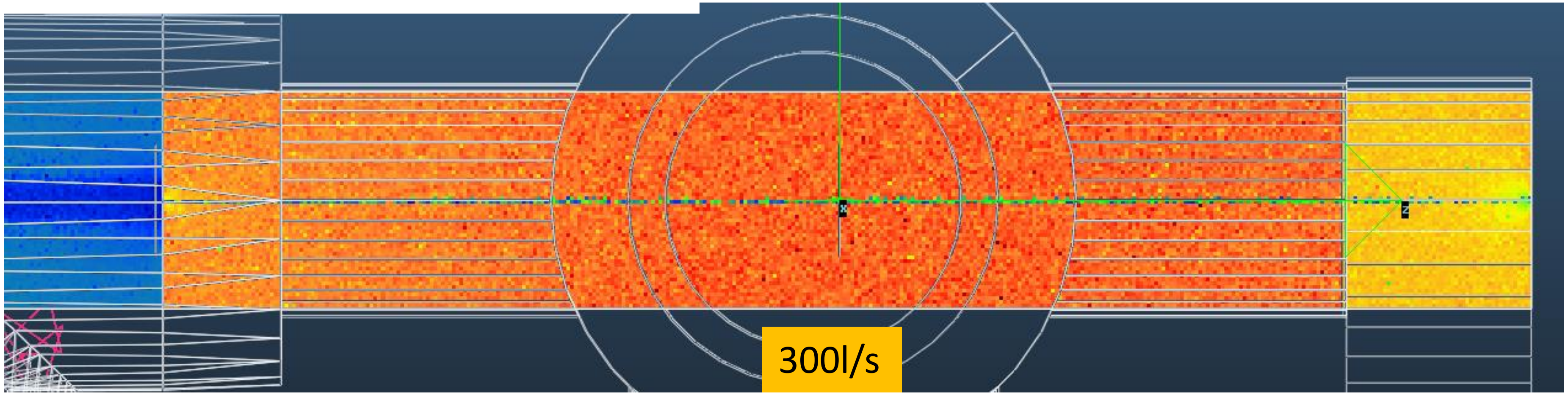
DUMP



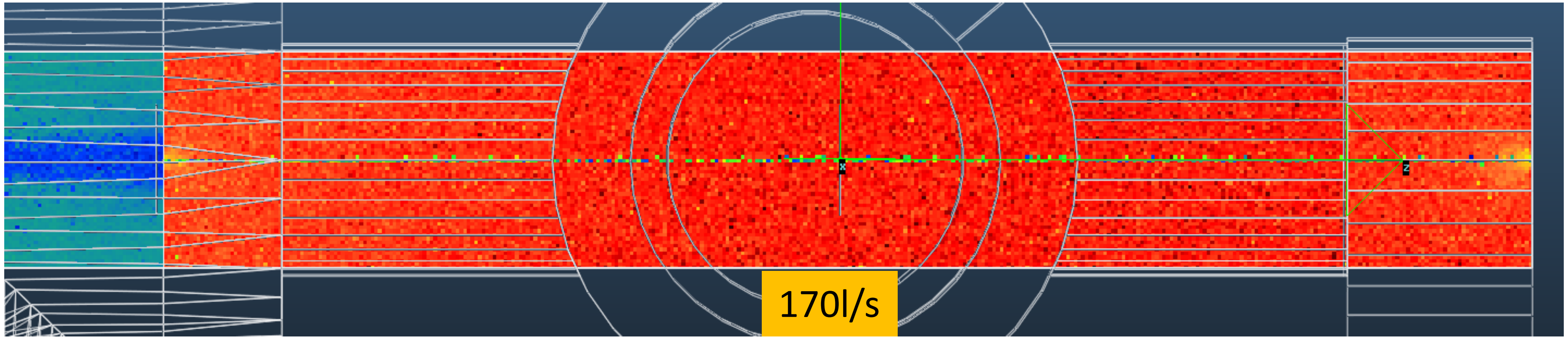
1E-8

DUMP

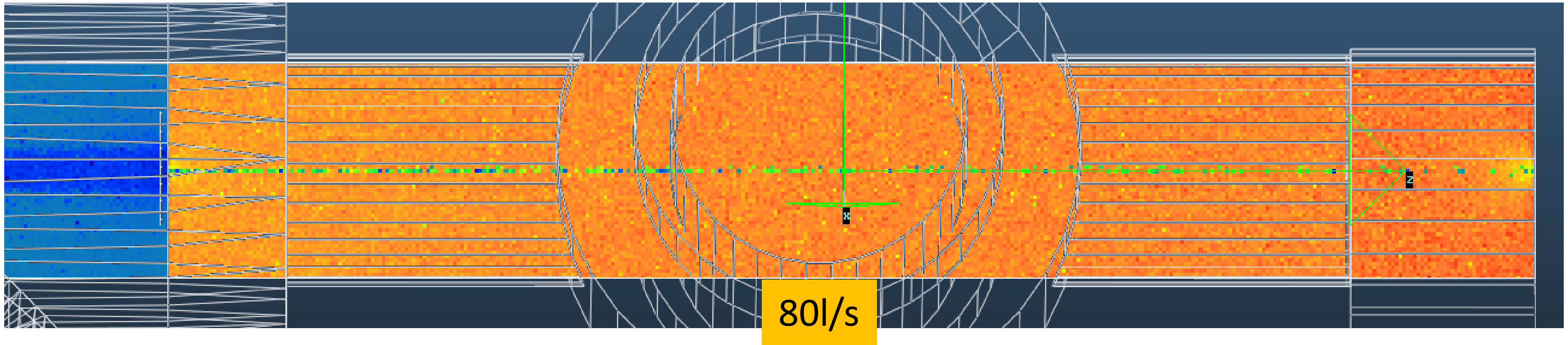
Role of backscattering reducer



Strong interaction chamber pump:
beneficial
(less gas load from dump area)



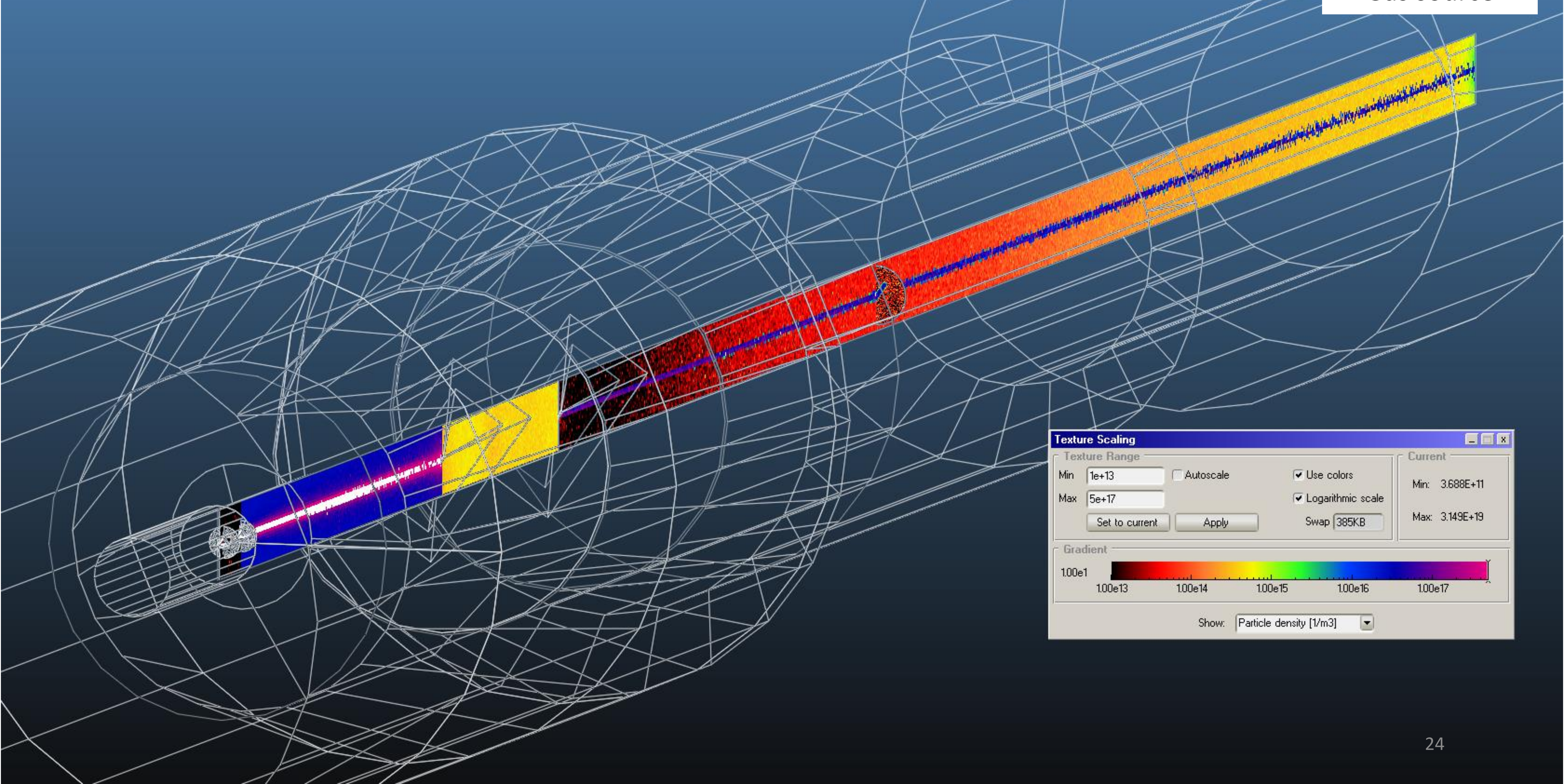
Reduced interaction chamber pump:
slightly beneficial



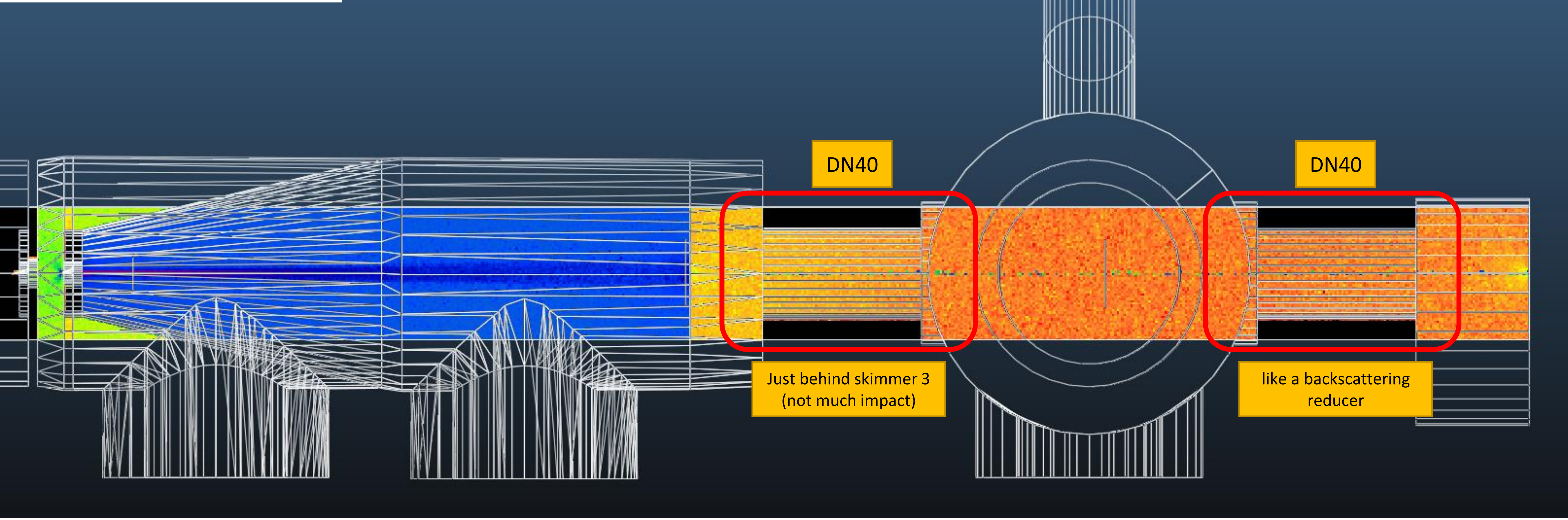
Weak interaction chamber pump:
slightly adverse
(less pumping from dump area)

Looking back to my slides from Darmstadt

Simplified geometry, strong pumping everywhere



Reducing valves?



- Current Engineering Change Request: DN63 ports
- Using DN40 valves on the interaction chamber acts as a weak backscattering reducer
- Very slight increase of pressure in dump area, and reduction in interaction chamber
- Variations near statistical error, for simplicity: “no vacuum impact”

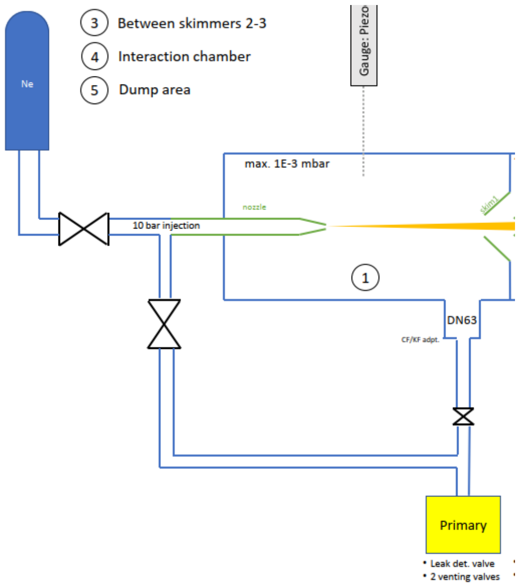
Cone: 100% opaque, Skimmer 2: 900um, Skimmer 3: 13.2/0.4mm

Case	Between skimmers 1-2	Between skimmers 2-3	Interaction chamber
1	**250 l/s**	**250 l/s**	**250 l/s**
	2E-4 mbar	5E-7 mbar	3E-9 mbar
2	**170 l/s**	**170 l/s**	**250 l/s**
	3E-4 mbar	1E-6 mbar	4E-9 mbar
3	**80 l/s**	**80 l/s**	**250 l/s**
	6E-4 mbar	2E-6 mbar	7E-9 mbar
4 / 5 / 6 / 7	**170 l/s**	**170 l/s**	**170 l/s**
	default / no impedance insertion / backscattering reducer / DN40 valves		
	3E-4 / 3E-4 / 3E-4 / 3E-4 mbar	1E-6 / 1E-6 / 1E-6 / 1E-6 mbar	7E-9 / 6E-9 / 5E-9 / 6E-9 mbar
8	**80 l/s**	**80 l/s**	**80 l/s**
	6E-4 mbar	2E-6 mbar	1E-8 mbar

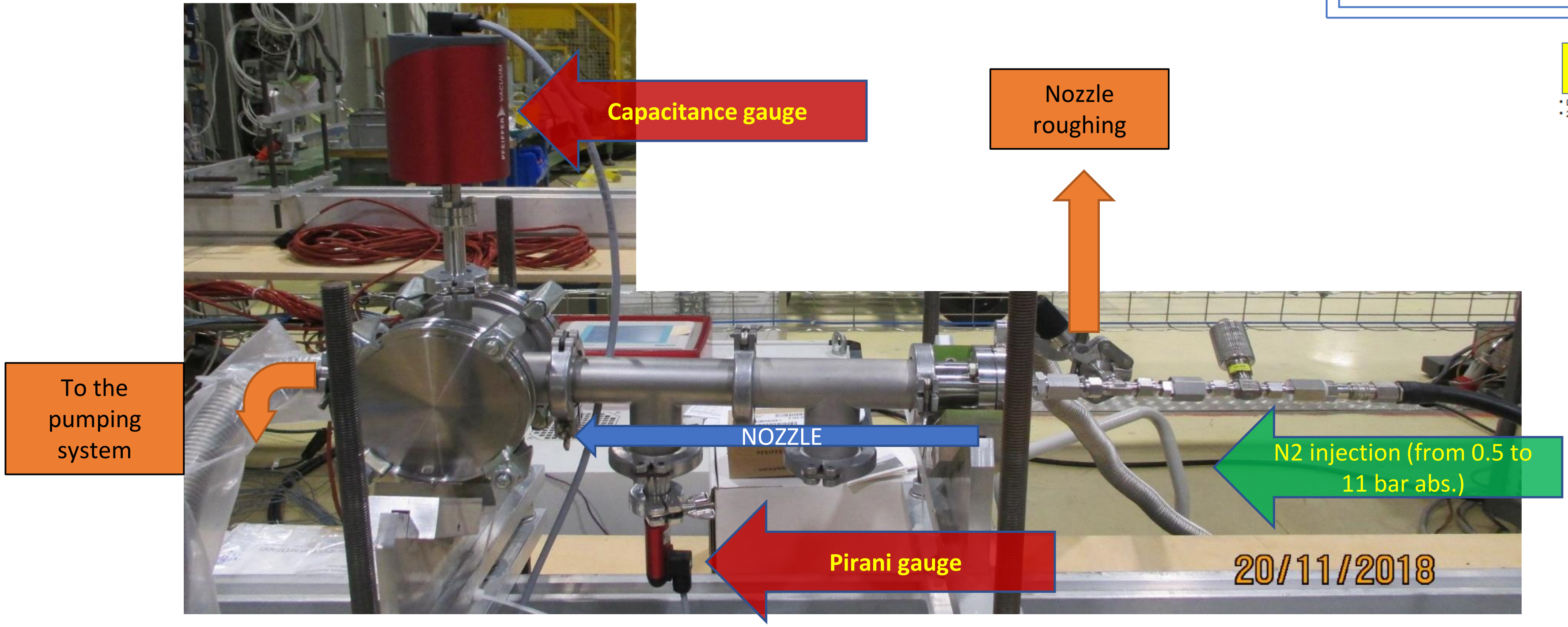
Conclusions (simulations)

- Many free parameters when designing “v3” instrument
- Parameter change: mostly localized / predictable impact
- Strongly suggesting leak-tight cone separation
- DN63 pumping ports (with DN100 pumps) acceptable
- Backscattering reducer still effective, but no dramatic improvement
- Vacuum-wise OK to use DN40 valves on interaction chamber
- Sensitive compromise between gas jet density and IP background pressure to be found
- Nozzle chamber pumping still an issue
- Dump area optimization: to do
- LHC Neon impact / risk assesment: to do
- Operation interlock logic: to do

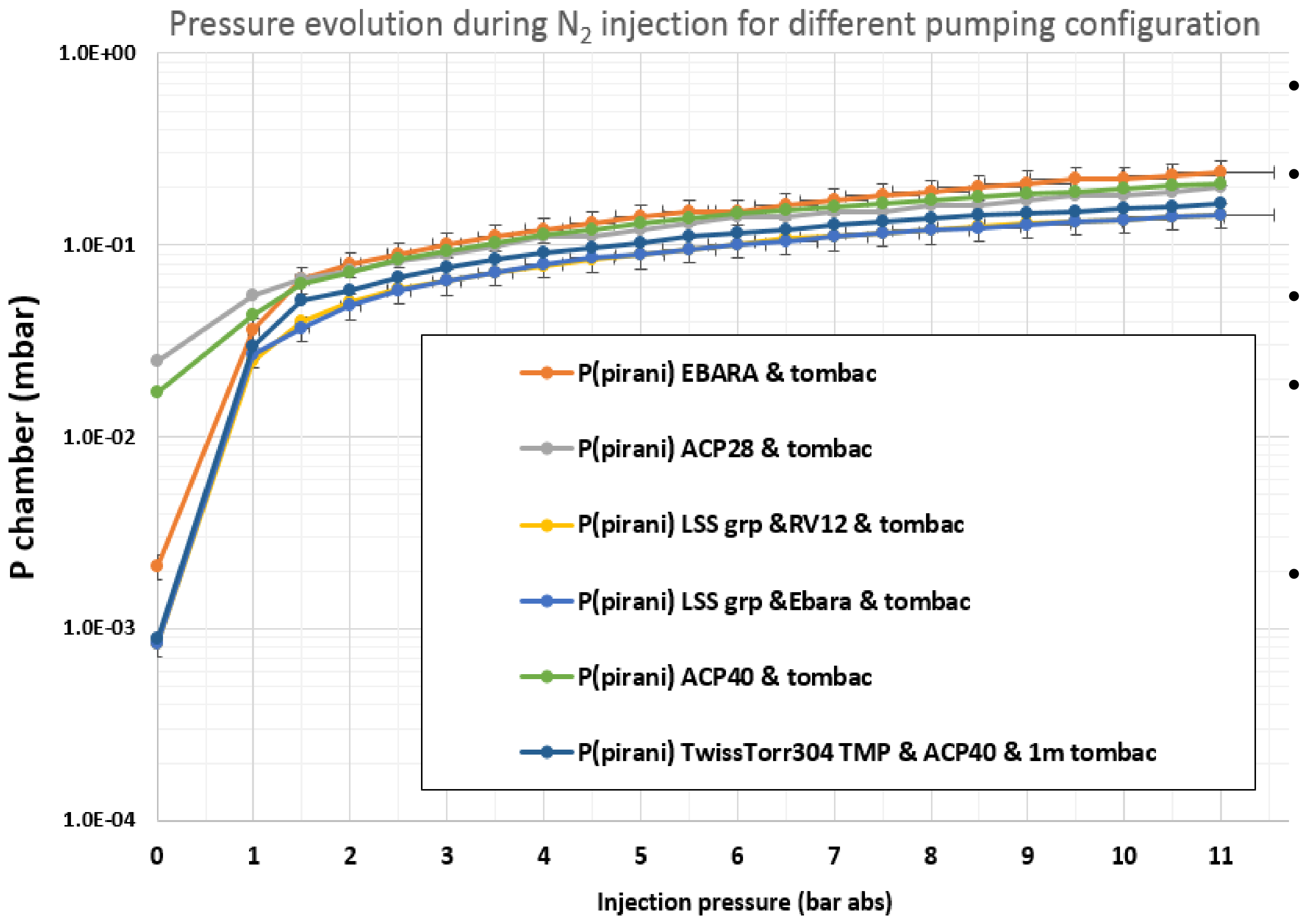
Dry pumps test for first vacuum chambers



- Nozzle is 30 µm diameter over 300 µm length
- Setup configuration:



Dry pumps test for first vacuum chambers



- Laminar flow through the nozzle.
- Measured with a leak detector (atm pressure side of nozzle) Q_{He} 2.5E-2 mbarl/s
- Calculated using gas viscosity for QN_2 1.5E-2 mbarl/s
- For every primary dry pump test, the measured pressure with an inlet pressure of 5 bar is between 10^{-1} and 1.5×10^{-1}mbar range.
- For a turbo molecular pumping group with any primary pumps (including rotary vane pump), the pressure remains in the same range.

These primary pumps do not managed to absorb the gas flow coming from the nozzle.
To be tests and confirm the impact of pressure low 10-1 mbar on the gas jet
We could think to plan some test in Cockcroft institute beginning of next year.

Beam Gas Curtain (BGC) Vacuum Controls Requirements

- **Cabling request (RQF0966942):**
  - Includes more than 33 cables
  - Still has to be modified according to last-minute changes (3x additional VPG missing)
  - OSVC signature awaiting…
- **UA43:**
  - Full Rack Re-arrangement and dedicated manpower for equipment installation, including inter-rack cabling, valve-interlock hardware configuration and Profibus network integration
  - 7x gauge controllers, 3x Valve controllers, 3x specific Valve-Interlock Crates and 5x dedicated Vacuum Pumping Group controllers
- **LHC Tunnel:**
  - 5x local crates and 3x Mini-Racks Installation for Vacuum Pumping Groups
  - Require EN-EL's intervention for electrical distribution (not informed yet, awaiting ECR…)
- **PLC/SCADA development:**
  - 3x Non-Standard Vacuum Pumping Groups requiring new specific PLC & SCADA development
  - Full database integration (Vac-DB)
  - New dedicated Control types, Synoptic integration (incl. Face-Plate) and Widget development required

Missing resources: Not in the LS2 baseline

Beam Gas Curtain (BGC) Vacuum Requirements

- **Final assembly & Commissioning of the system:**
  - The system shall be carefully tested in the lab to mimic all possible operation scenarios;
  - Calibration curves for different gases shall be carried out;
  - A detailed operation procedure shall be validated on the system and handled to VSC-ICM to be then integrated in the SCADA application;
  - Safety margin and a detailed risk analysis shall be defined and agreed.

- **LHC Tunnel -> Excepted installation during YETS 2021-2022(?):**
  - Full Support to the assembly in the tunnel;
  - Validation & commissioning of the vacuum system;
  - Commissioning of system.

Missing resources: Not in the LS2 baseline

Outlook: LHC Beam Vacuum simulation

- Fully detailed analysis of pressure profile on the LHC vacuum sector for different gases: need to finalize the BGC system to know the pressure ‘escaping’ from the interaction chamber.
- Impact of this gas on possible beam lifetime (nuclear cross section) and determine the quantity of gas condensed on the beam screen surface of the neighbourhood cryogenic stand alone magnets: planning of the thermal regeneration.

Outlook: BGC Jet Simulations

- Finalize “demonstrator instrument” design including pumps, which will be first installed in the LHC
- Model neighboring region (extract apertures from LHC layout DB)
- Model gas propagation from the instrument to the surroundings
- Draw conclusions on operation (Ne accumulation on beamscreen, etc.)

Conclusions

- Detailed simulation of the BGC is ongoing to optimize the design, pumping schemes, and aperture of the different chambers;
- TE-VSC needs to guarantee a proper gas density on the jet while keeping as low as possible the pressure in the LHC beam vacuum;
- The optimization of the BGC is crucial to have a system that would allow possible intervention during operation and maintenance during longer intervention of time;
- The first ‘chambers’ is still under study: Difficult to reach the required performance with ‘standard’ vacuum system.
- A detailed cost (hardware & resources) schedule review is missing for TE-VSC to proper guarantee the completion of the project