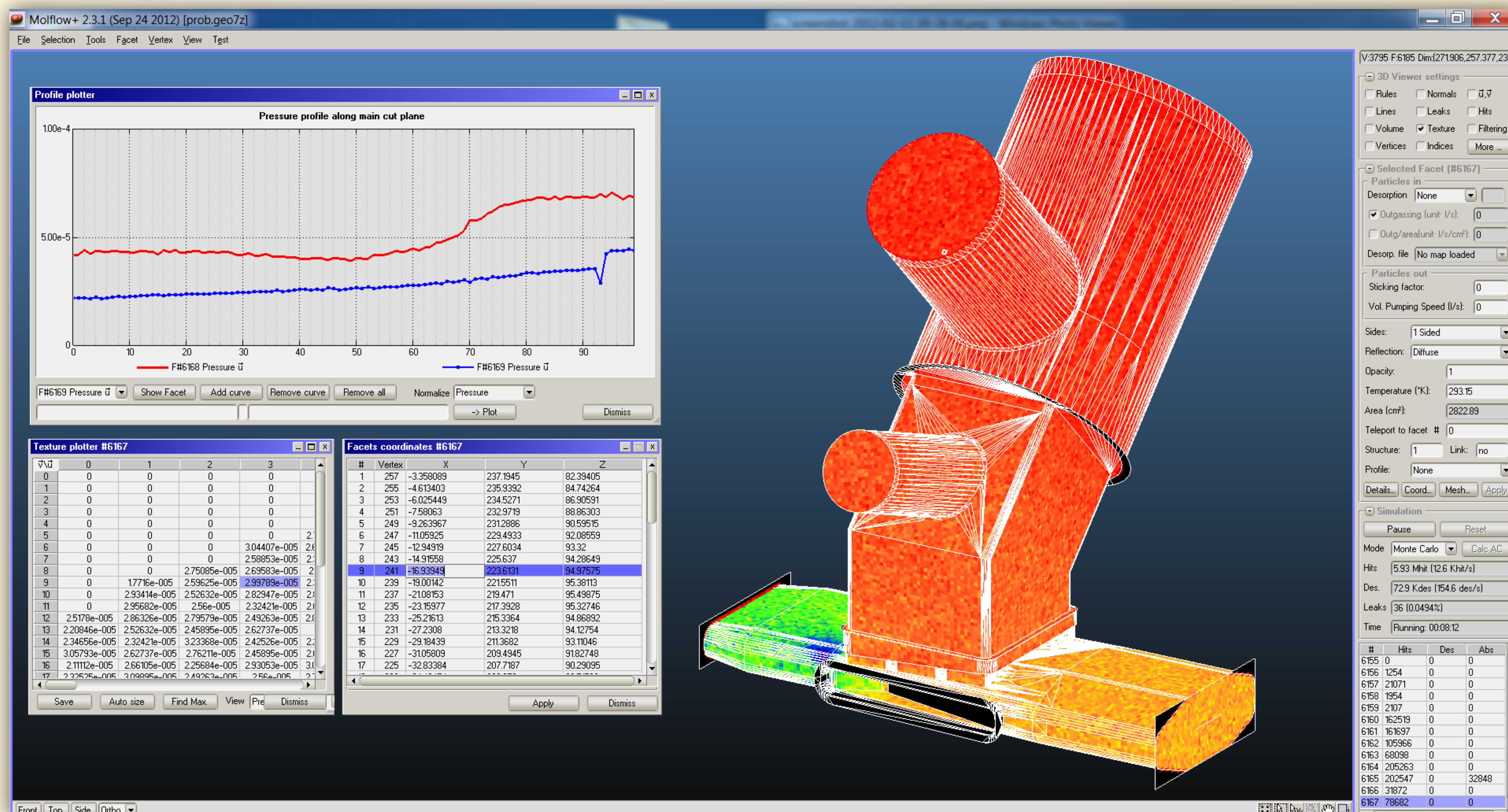
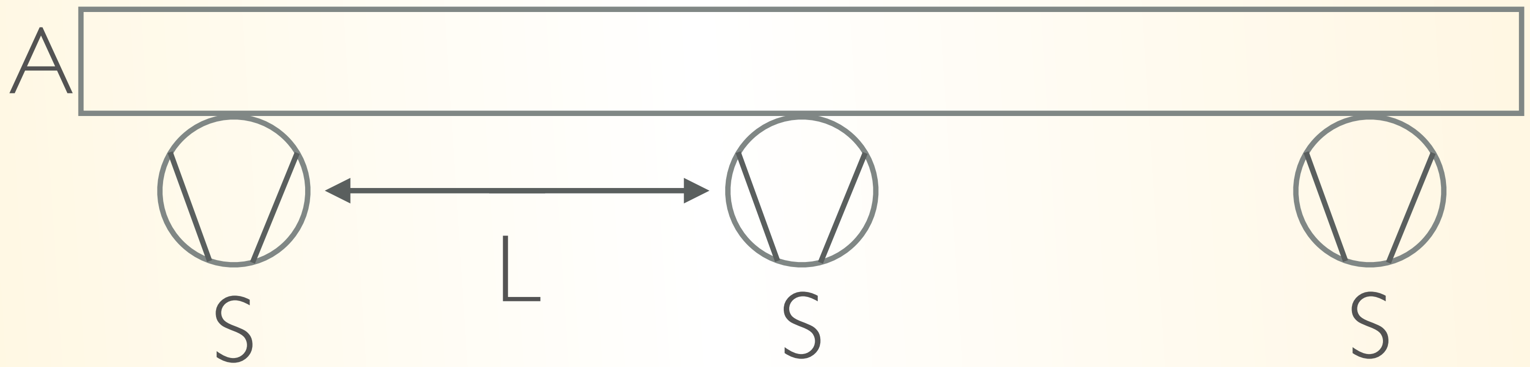
MOLFLOW SEMINAR

Monte Carlo simulation of ultra high vacuum systems

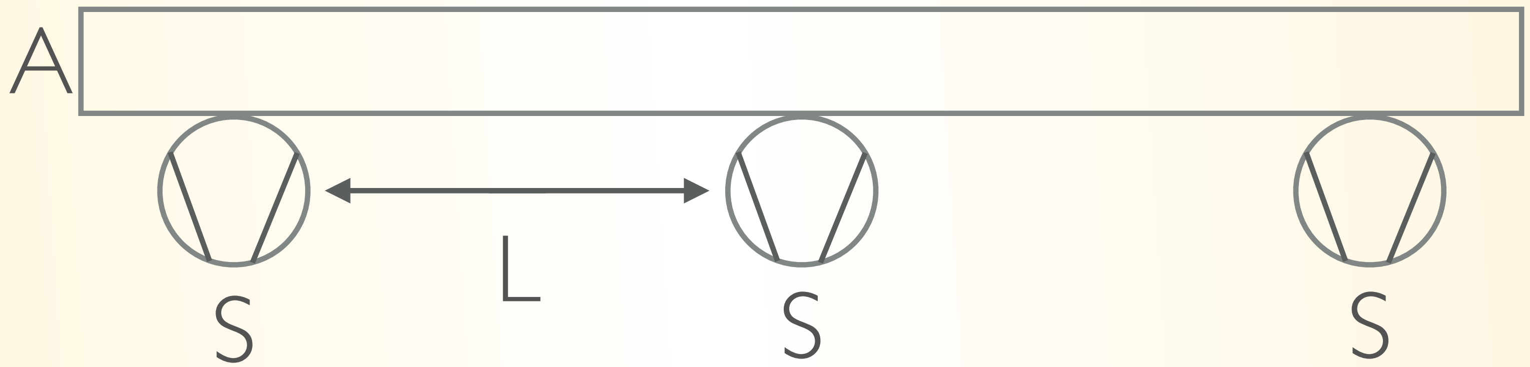


2014.11.26, KEK - Marton Ady

VACUUM CALCULATIONS: ANALYTICAL METHOD

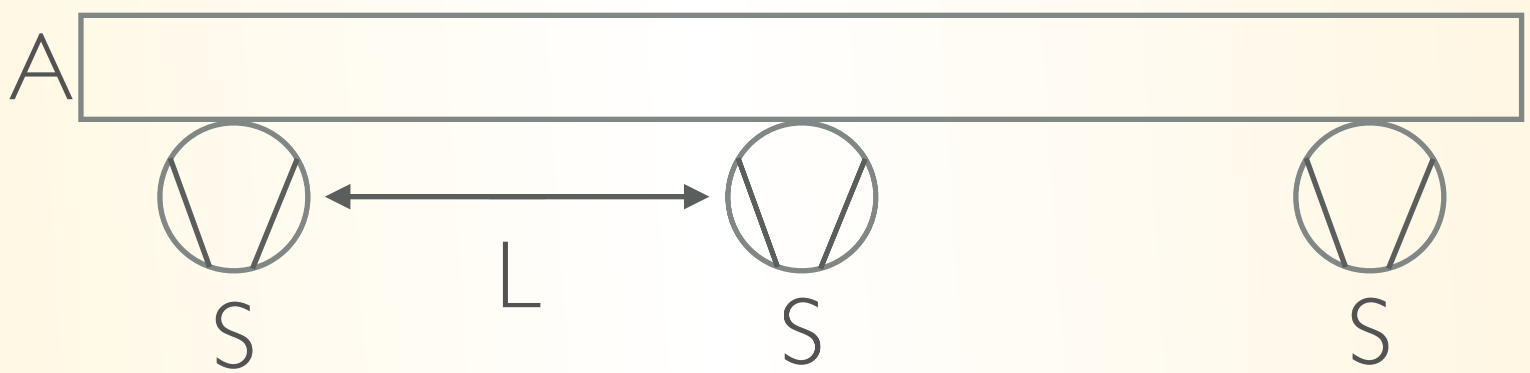


VACUUM CALCULATIONS: ANALYTICAL METHOD



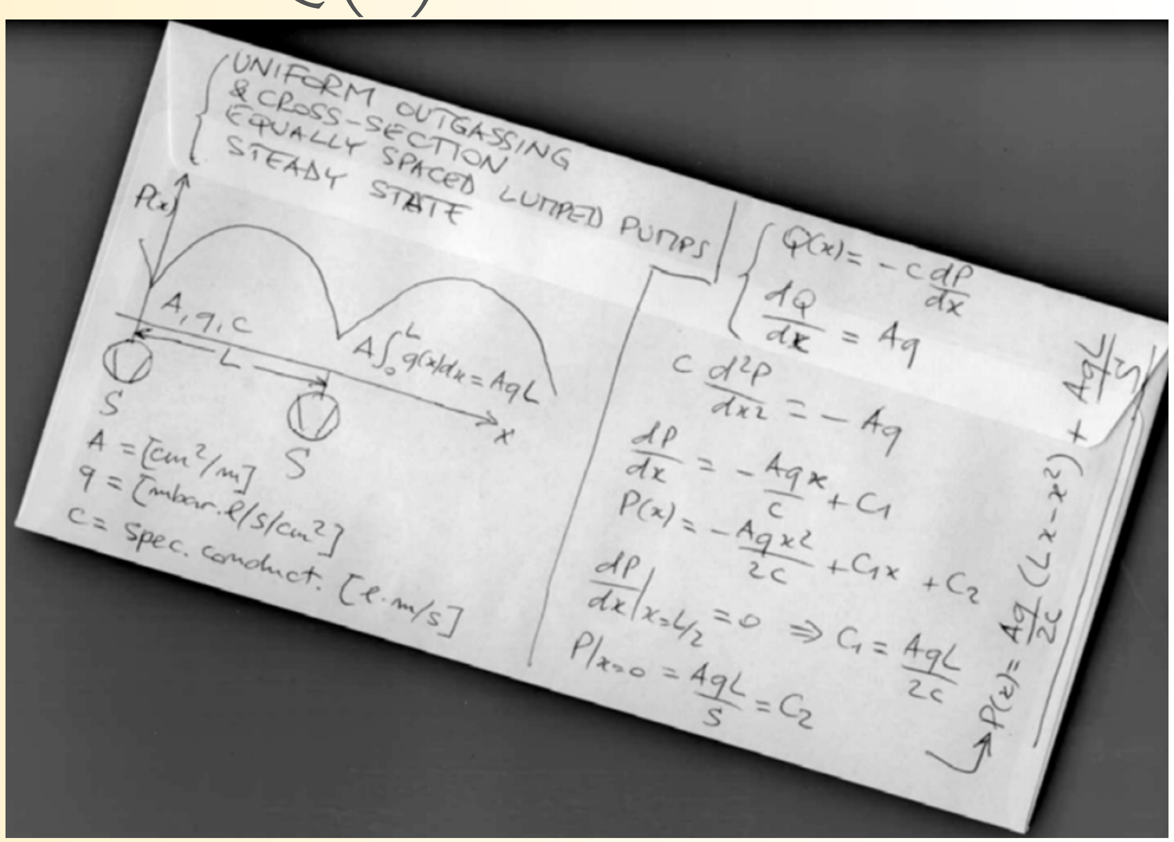
$P=Q/S$ $Q=C*(p1-p2)$

VACUUM CALCULATIONS: ANALYTICAL METHOD

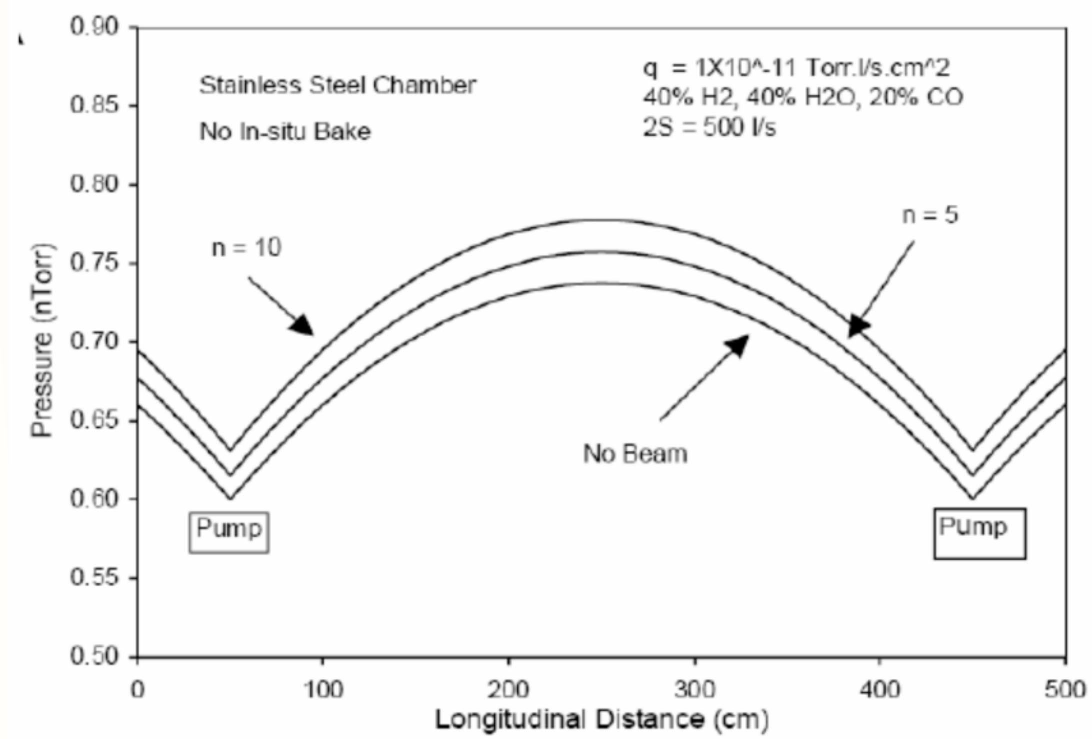


$$P=Q/S \qquad Q=C^*(p1-p2)$$

$$Q(x)=-C^*dP/dx$$



$$P(x) = Q\left(\frac{L}{S} + \frac{L^2 - x^2}{2C'}\right)$$



DIFFICULTY: CONDUCTANCE

Table 2.2 Equations for calculating the angular coefficients

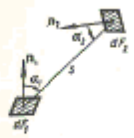
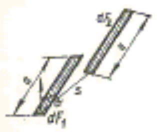
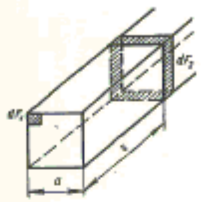
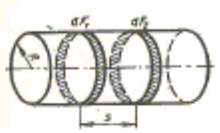
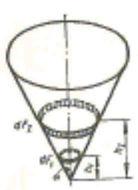
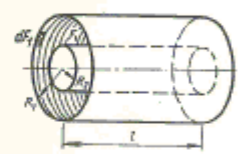
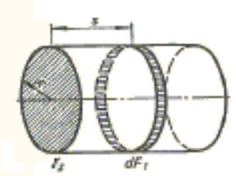
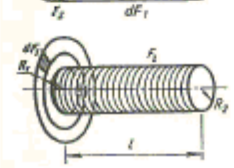
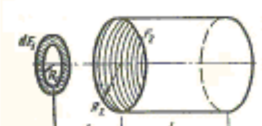
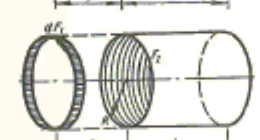
Geometric structure	*Design equation*	*References*
	I. Two infinitesimal elements	
	Two arbitrarily oriented elementary areas $d\varphi_{dF_1-dF_2}=\frac{\cos\alpha_1\cos\alpha_2}{\pi s^2}dF_2$	[47]
	Two strips of finite length and infinitesimal width with parallel generatrices $d\varphi_{dF_1-dF_2}=\frac{1}{\pi}\cos\alpha\,\mathrm{arctg}\frac{a}{s}\,dx$	[47]
	End-face element of a channel with a square cross section, located in a corner, and a channel surface element $d\varphi_{dF_1-dF_2}=\frac{as}{\pi(a^2+s^2)^{3/2}}\left[\mathrm{arctg}\frac{a}{\sqrt{a^2+s^2}}+\mathrm{arctg}\frac{a\sqrt{a^2+s^2}}{s^2+2a^2}\right]ds$	[47]
	Two annular elements on the inside surface of a right circular cylinder $d\varphi_{dF_1-dF_2}=\frac{1}{2R}\left[1-\frac{s(s^2+6R^2)}{(s^2+4R^2)^{3/2}}\right]ds$	[47]
	Two annular elements on the inside surface of a right circular cone $d\varphi_{dF_1-dF_2}=\frac{\cos^2\alpha}{2h_1\sin\alpha}\left\{1-\lvert h_1-h_2\rvert\frac{(h_1-h_2)^2+6h_1h_2\sin^2\alpha}{[(h_1-h_2)^2+4h_1h_2\sin^2\alpha]^{3/2}}\right\}dh_2$	[136]
	Two infinitesimal elements on the inside surface of a spherical cavity $d\varphi_{dF_1-dF_2}=\frac{dF_2}{4\pi R^2}$	[137]

Table 2.2 (continued)

Geometric structure	*Design equation*	*References*
	Plane element and ellipse parallel to it $\varphi_{dF_1-F_2}=\frac{ab}{\sqrt{(s^2+a^2)(s^2+b^2)}}$	[47]
	Elementary strip and infinite-length cylinder parallel to it $\varphi_{dF_1-F_2}=\frac{sR}{a^2+s^2}$	[129]
	Element on the inside surface of the outer cylinder and the inside surface of the same cylinder for a system of two coaxial cylinders $\varphi_{dF_1-F_1}=\frac{1}{2}-\frac{R_2}{4R_1}+\frac{R_2}{\pi R_1}\times\left[\frac{l}{R_2}\mathrm{arctg}\frac{\sqrt{R_1^2-R_2^2}}{R_2}-\frac{1}{2}\mathrm{arctg}\frac{l^2-4(R_1^2-R_2^2)}{4l\sqrt{R_1^2-R_2^2}}-\frac{l^2+2R_1^2}{R_2\sqrt{l^2+4R_1^2}}\times\mathrm{arctg}\frac{\sqrt{(R_1^2-R_2^2)(l^2+4R_1^2)}}{R_2 l}\right]$	[129]
	Annular element on the inside surface of a right circular cylinder and the end face of the cylinder $\varphi_{dF_1-F_2}=\frac{1}{2R}\left[\frac{s^2+2R^2}{\sqrt{s^2+4R^2}}-s\right]$	[47]
	Element of a plane ring and outside surface of a right circular cylinder $\varphi_{dF_1-F_2}=\frac{1}{\pi}\left[\frac{1}{2}\arccos\frac{R_2}{R_1}+\mathrm{arctg}\frac{R_2}{\sqrt{R_1^2-R_2^2}}-\frac{l^2+R_1^2-R_2^2}{A}\times\mathrm{arctg}\frac{A\,\mathrm{tg}\,[(1/2)\arccos(R_2/R_1)]}{l^2+R_1^2+R_2^2-2R_1R_2}\right]$, $A=\sqrt{(l^2+R_1^2+R_2^2)^2-4R_1^2R_2^2}$	[137]
	Plane annular element and inside surface of a cylinder $\varphi_{dF_1-F_2}=\frac{1}{2}\left[\frac{(l+s)^2+R_1^2-R_2^2}{\sqrt{((l+s)^2+R_1^2+R_2^2)^2-4R_1^2R_2^2}}-\frac{s^2+R_1^2-R_2^2}{\sqrt{(s^2+R_1^2+R_2^2)^2-4R_1^2R_2^2}}\right]$	[126]
	Annular cylindrical element and inside surface of a cylinder $\varphi_{dF_1-F_2}=\frac{1}{2R}\left[l+\frac{s^2+2R^2}{\sqrt{s^2+4R^2}}-\frac{(l+s)^2+2R^2}{\sqrt{(l+s)^2+4R^2}}\right]$	[126]

DIFFICULTY: CONDUCTANCE

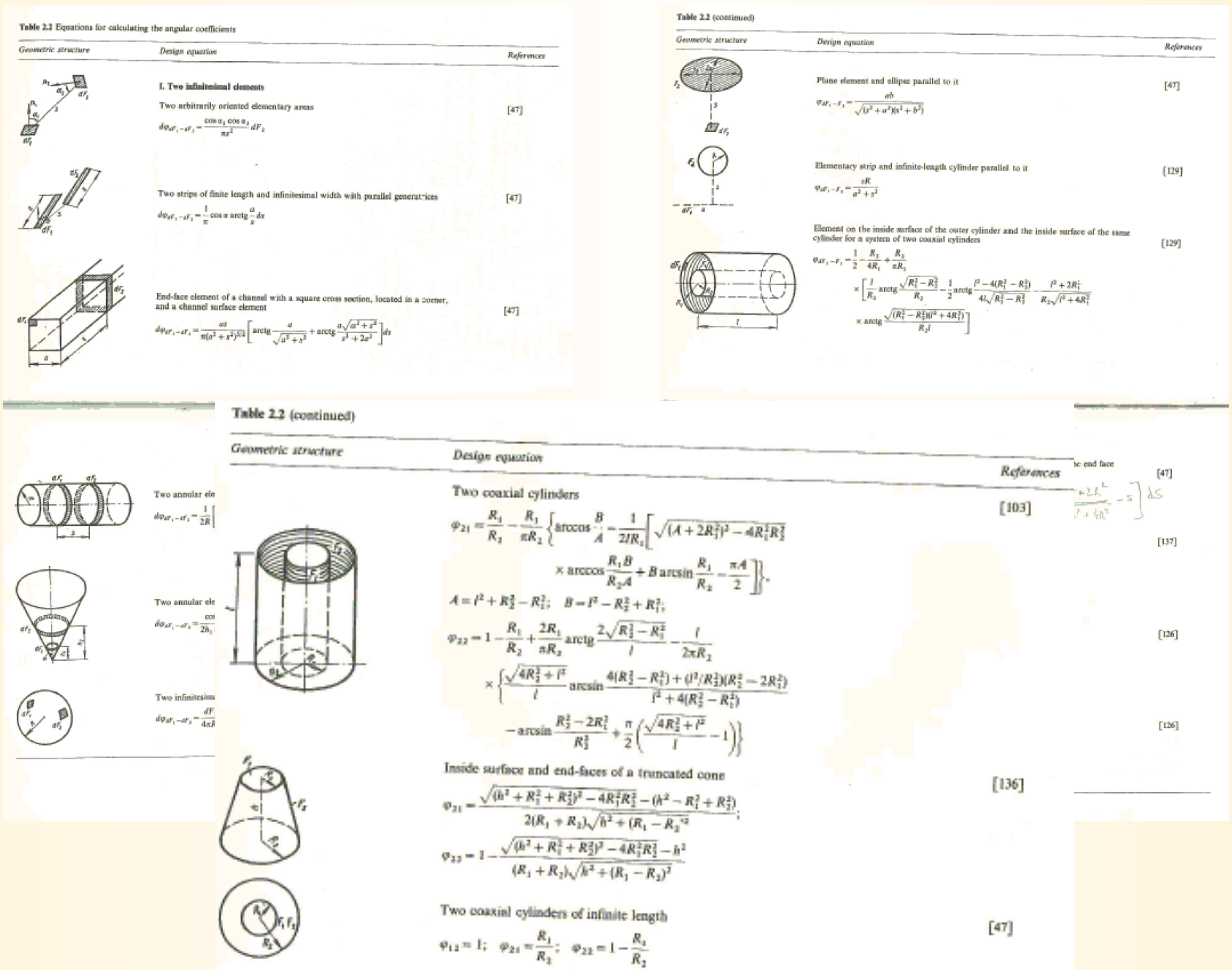


Table 2.2 Equations for calculating the angular coefficients

Geometric structure	Design equation	References
	I. Two infinitesimal elements	
	Two arbitrarily oriented elementary areas $d\varphi_{dF_1-dF_2} = \frac{\cos\alpha_1 \cos\alpha_2}{\pi s^2} dF_2$	[47]
	Two strips of finite length and infinitesimal width with parallel generatrices $d\varphi_{dF_1-dF_2} = \frac{1}{\pi}\cos\alpha \, \mathrm{arctg}\frac{a}{s} dx$	[47]
	End-face element of a channel with a square cross section, located in a corner, and a channel surface element $d\varphi_{dF_1-dF_2} = \frac{as}{\pi(a^2+s^2)^{3/2}}\left[\mathrm{arctg}\frac{a}{\sqrt{a^2+s^2}} + \mathrm{arctg}\frac{a\sqrt{a^2+s^2}}{s^2+2a^2}\right]ds$	[47]

Table 2.2 (continued)

Geometric structure	Design equation	References
	Plane element and ellipse parallel to it $\varphi_{dF_1-F_2} = \frac{ab}{\sqrt{(s^2+a^2)(s^2+b^2)}}$	[47]
	Elementary strip and infinite-length cylinder parallel to it $\varphi_{dF_1-F_2} = \frac{sR}{a^2+s^2}$	[129]
	Element on the inside surface of the outer cylinder and the inside surface of the same cylinder for a system of two coaxial cylinders $\varphi_{dF_1-F_1} = \frac{1}{2} - \frac{R_2}{4R_1} + \frac{R_2}{\pi R_1} \times \left[\frac{l}{R_2}\mathrm{arctg}\frac{\sqrt{R_1^2-R_2^2}}{R_2} - \frac{1}{2}\mathrm{arctg}\frac{l^2-4(R_1^2-R_2^2)}{4l\sqrt{R_1^2-R_2^2}} - \frac{l^2+2R_1^2}{R_1\sqrt{l^2+4R_1^2}} \times \mathrm{arctg}\frac{\sqrt{(R_1^2-R_2^2)(l^2+4R_1^2)}}{R_2 l}\right]$	[129]

Two annular ele... $d\varphi_{dF_1-dF_2} = \frac{1}{2R}$ ...

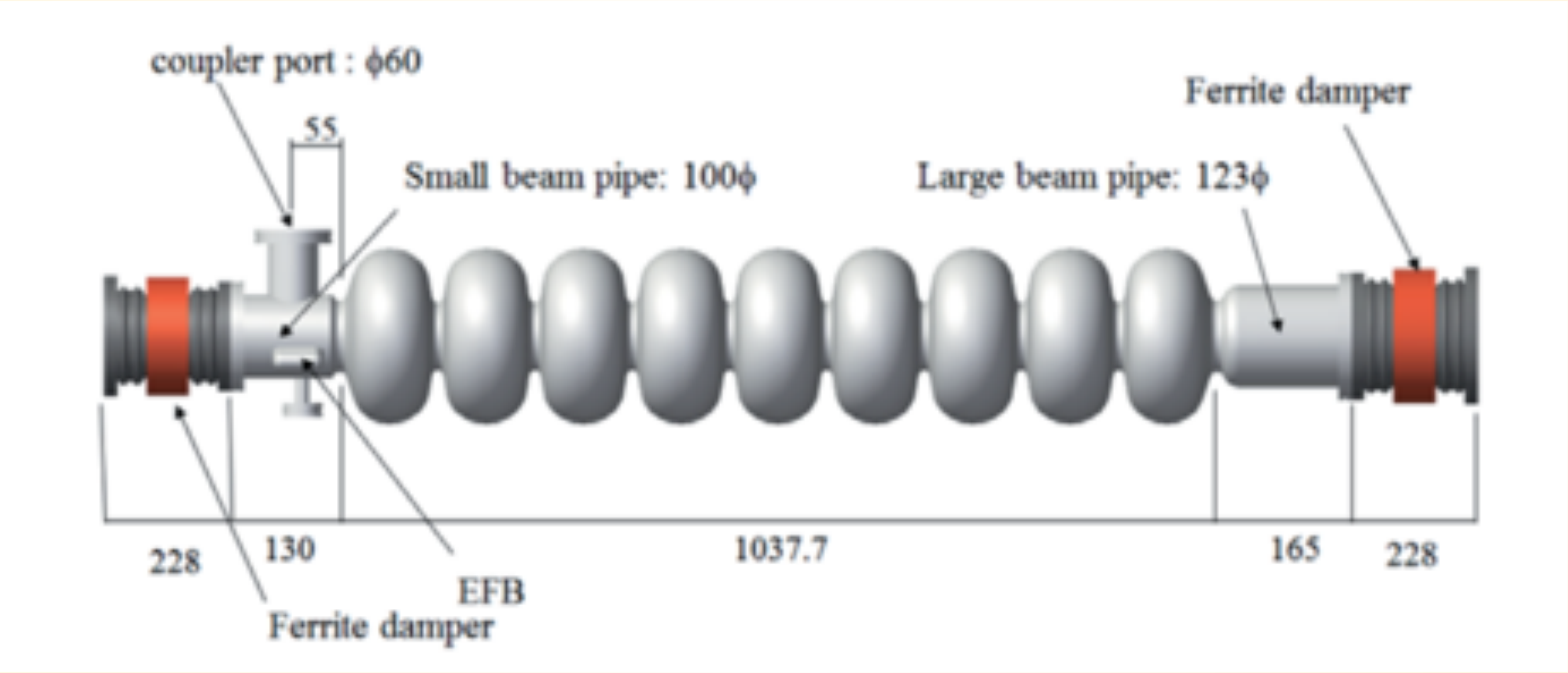
Two annular ele... $d\varphi_{dF_1-dF_2} = \frac{\cos}{2h_1}$ ...

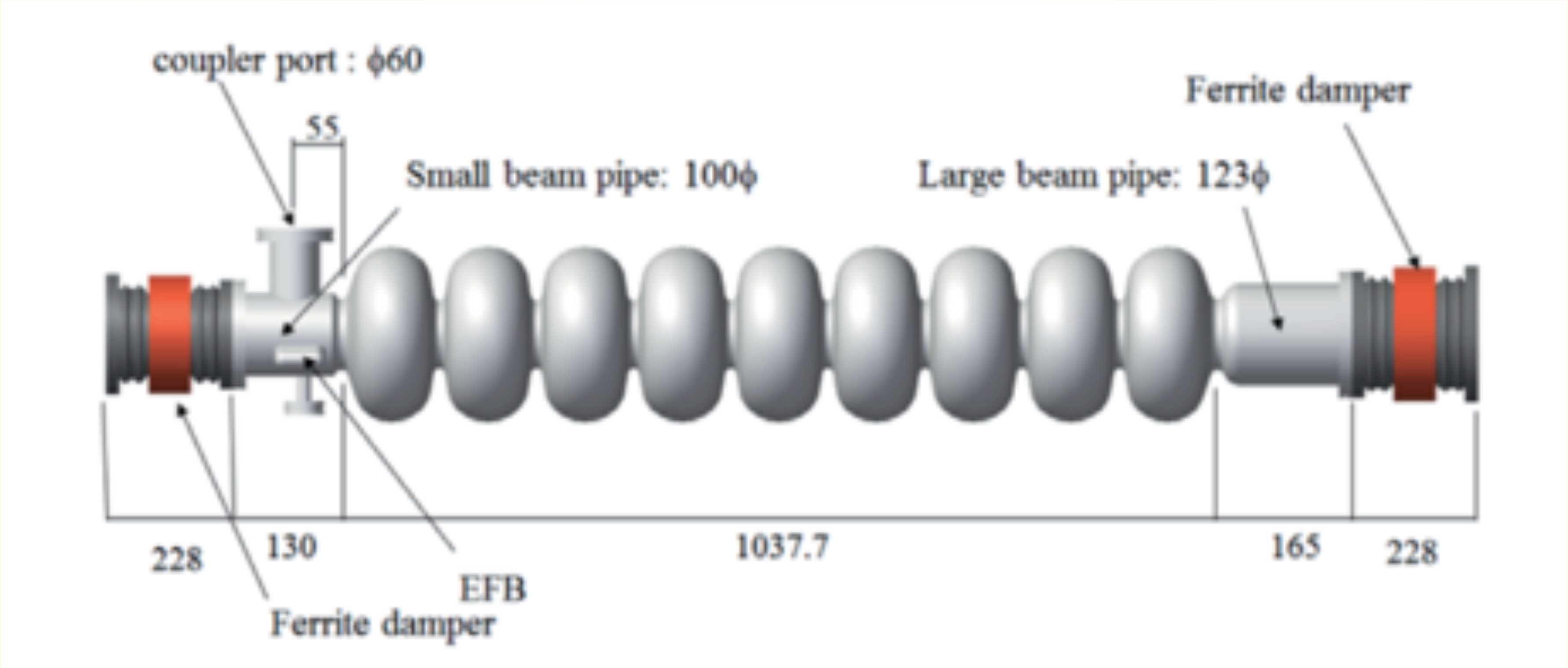
Two infinitesimal... $d\varphi_{dF_1-dF_2} = \frac{dF_2}{4\pi R}$ ...

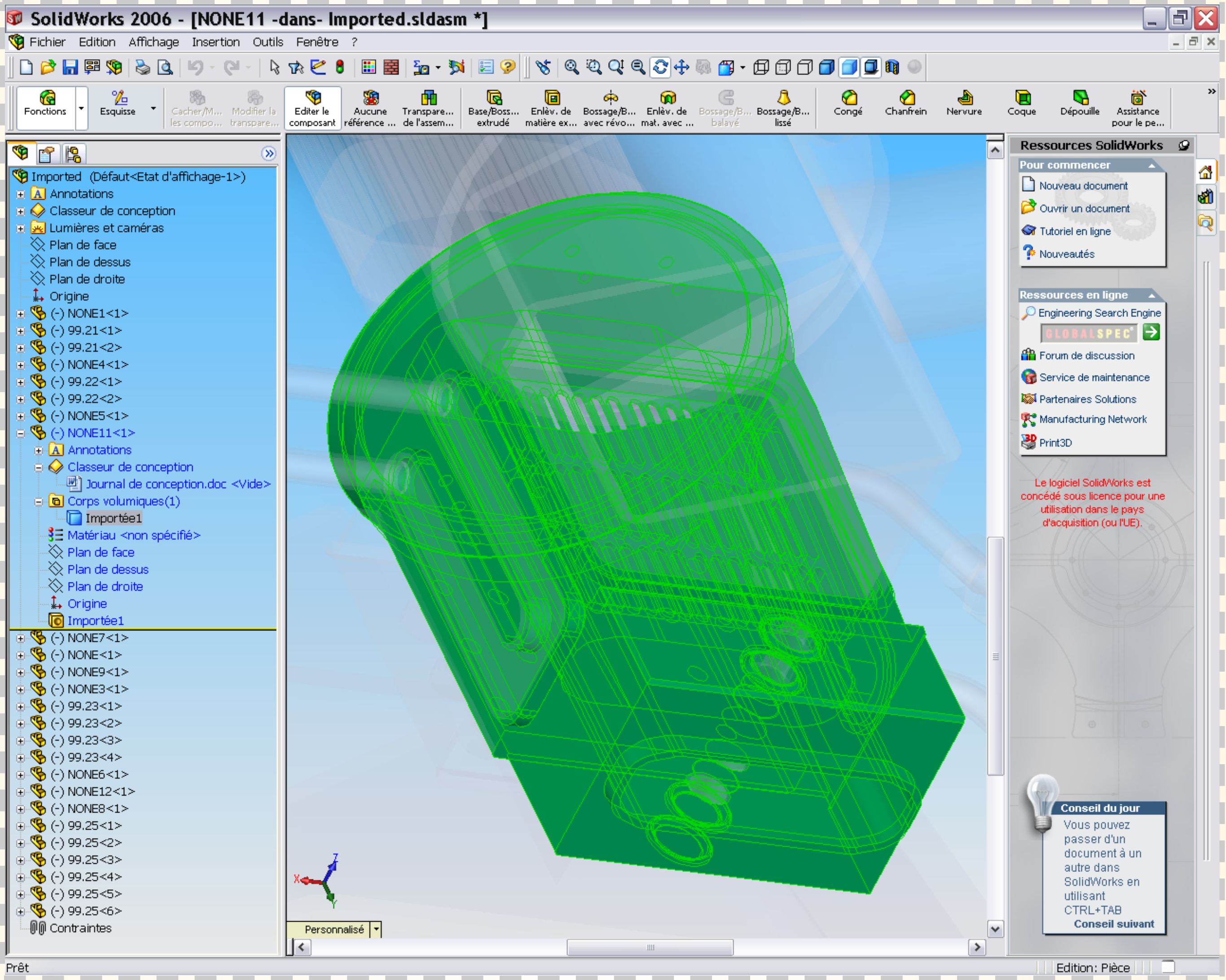
...e end face [47] [137] [126] [126]

Table 2.2 (continued)

Geometric structure	Design equation	References
	Two coaxial cylinders $\varphi_{21} = \frac{R_1}{R_2} - \frac{R_1}{\pi R_2}\left\{\arccos\frac{B}{A} - \frac{1}{2lR_1}\left[\sqrt{(A+2R_2^2)^2 - 4R_1^2R_2^2} \times \arccos\frac{R_1 B}{R_2 A} + B\arcsin\frac{R_1}{R_2} - \frac{\pi A}{2}\right]\right\}$, $A = l^2 + R_2^2 - R_1^2;\quad B = l^2 - R_2^2 + R_1^2;$ $\varphi_{22} = 1 - \frac{R_1}{R_2} + \frac{2R_1}{\pi R_2}\mathrm{arctg}\frac{2\sqrt{R_2^2-R_1^2}}{l} - \frac{l}{2\pi R_2} \times \left\{\frac{\sqrt{4R_2^2+l^2}}{l}\arcsin\frac{4(R_2^2-R_1^2)+(l^2/R_2^2)(R_2^2-2R_1^2)}{l^2+4(R_2^2-R_1^2)} - \arcsin\frac{R_2^2-2R_1^2}{R_2^2} + \frac{\pi}{2}\left(\frac{\sqrt{4R_2^2+l^2}}{l} - 1\right)\right\}$	[103]
	Inside surface and end-faces of a truncated cone $\varphi_{21} = \frac{\sqrt{(h^2+R_1^2+R_2^2)^2 - 4R_1^2R_2^2} - (h^2 - R_1^2 + R_2^2)}{2(R_1+R_2)\sqrt{h^2+(R_1-R_2)^2}}$; $\varphi_{22} = 1 - \frac{\sqrt{(h^2+R_1^2+R_2^2)^2 - 4R_1^2R_2^2} - h^2}{(R_1+R_2)\sqrt{h^2+(R_1-R_2)^2}}$	[136]
	Two coaxial cylinders of infinite length $\varphi_{12} = 1;\quad \varphi_{21} = \frac{R_1}{R_2};\quad \varphi_{22} = 1 - \frac{R_1}{R_2}$	[47]

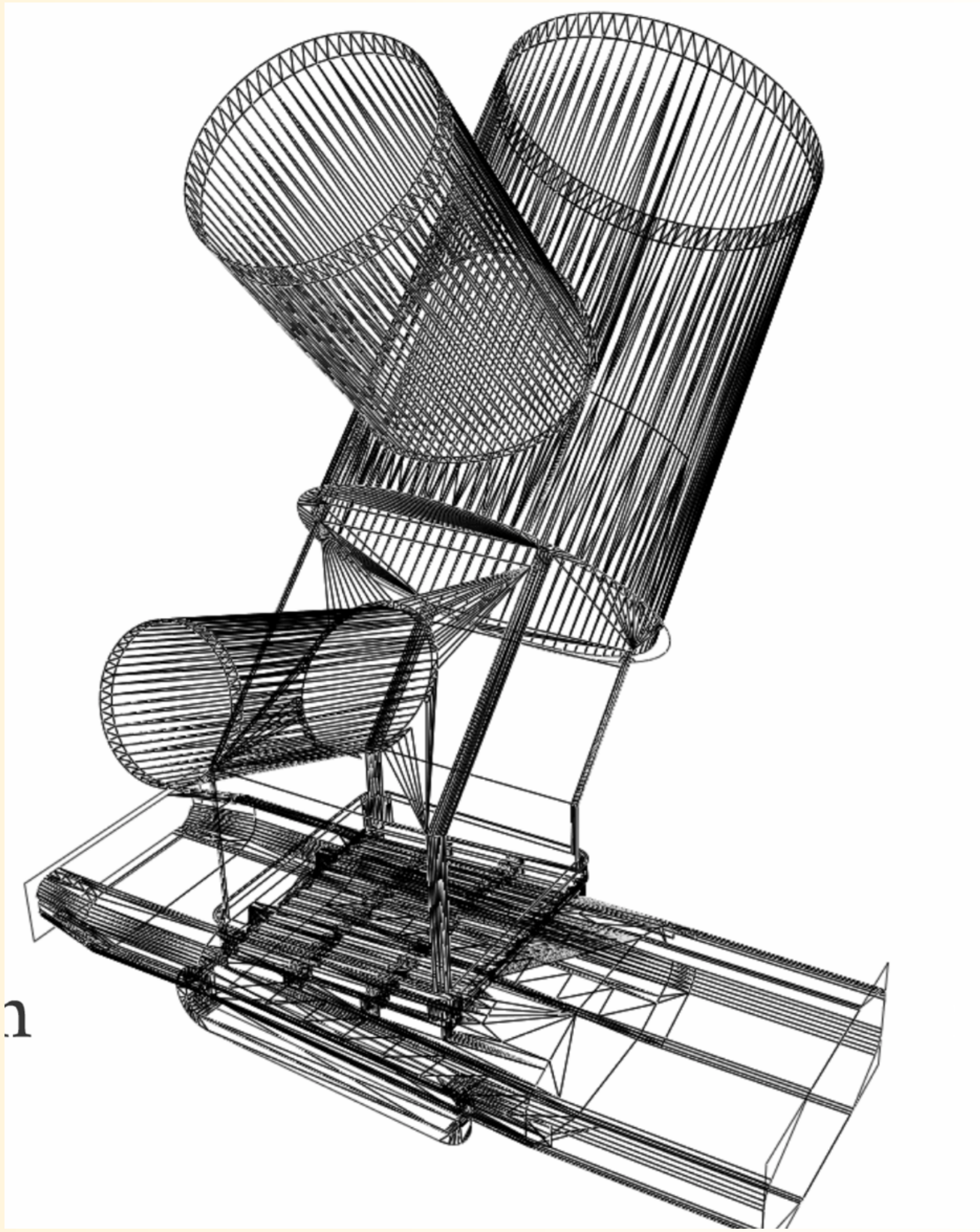

coupler port : ϕ60
55
Small beam pipe: 100ϕ
Large beam pipe: 123ϕ
Ferrite damper
228
130
1037.7
165
228
EFB
Ferrite damper


coupler port : ϕ60
55
Small beam pipe: 100ϕ
Large beam pipe: 123ϕ
Ferrite damper
228
130
1037.7
165
228
EFB
Ferrite damper


SolidWorks 2006 - [NONE11 -dans- Imported.sldasm *]
Fichier Edition Affichage Insertion Outils Fenêtre ?
Fonctions
Esquisse
Editer le composant
Congé
Chanfrein
Nervure
Coque
Dépouille
Imported (Défaut<Etat d'affichage-1>)
Annotations
Classeur de conception
Lumières et caméras
Plan de face
Plan de dessus
Plan de droite
Origine
Journal de conception.doc <Vide>
Corps volumiques(1)
Importée1
Matériau <non spécifié>
Contraintes
Ressources SolidWorks
Pour commencer
Nouveau document
Ouvrir un document
Tutoriel en ligne
Nouveautés
Ressources en ligne
Engineering Search Engine
Forum de discussion
Service de maintenance
Partenaires Solutions
Manufacturing Network
Print3D
Le logiciel SolidWorks est concédé sous licence pour une utilisation dans le pays d'acquisition (ou l'UE).
Conseil du jour
Vous pouvez passer d'un document à un autre dans SolidWorks en utilisant CTRL+TAB
Conseil suivant
Personnalisé
Prêt
Edition: Pièce

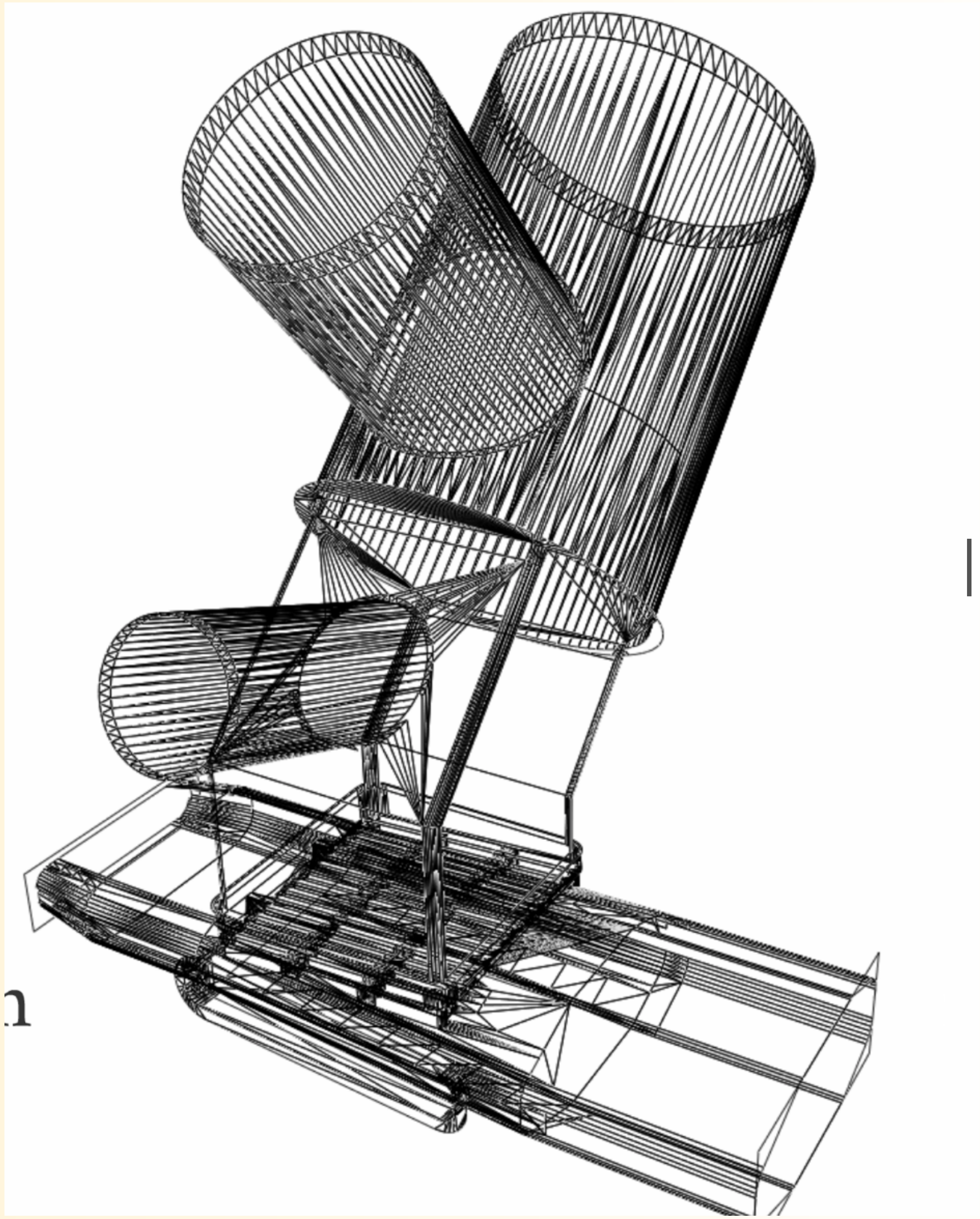
MC SIMULATIONS

Geometry: polygons



MC SIMULATIONS

Geometry: polygons



Gas input:

$pV=NkT$

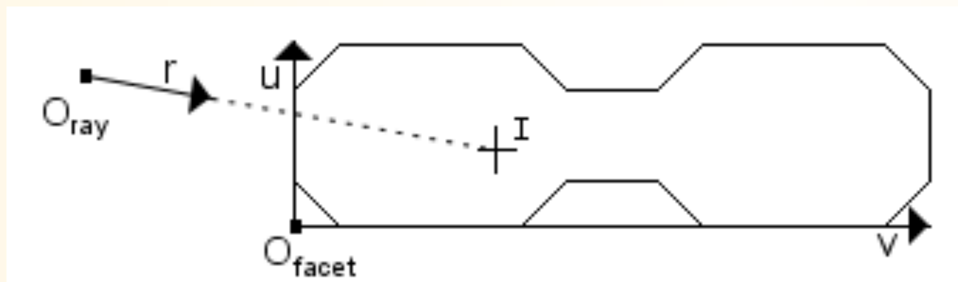
1 Pa*m^3/s = 2.4*10^{20} molecules/s

Virtual / Physical particle ratio

Ray tracing

Ray-plane intersection:

- Use Cramer's rule to find I coordinates.
- $\vec{w} = \vec{u} \wedge \vec{v}$ is **pre-calculated once** for each facet.
- Faster to solve I_u and I_v first (best elimination method than solving distance I_r first).



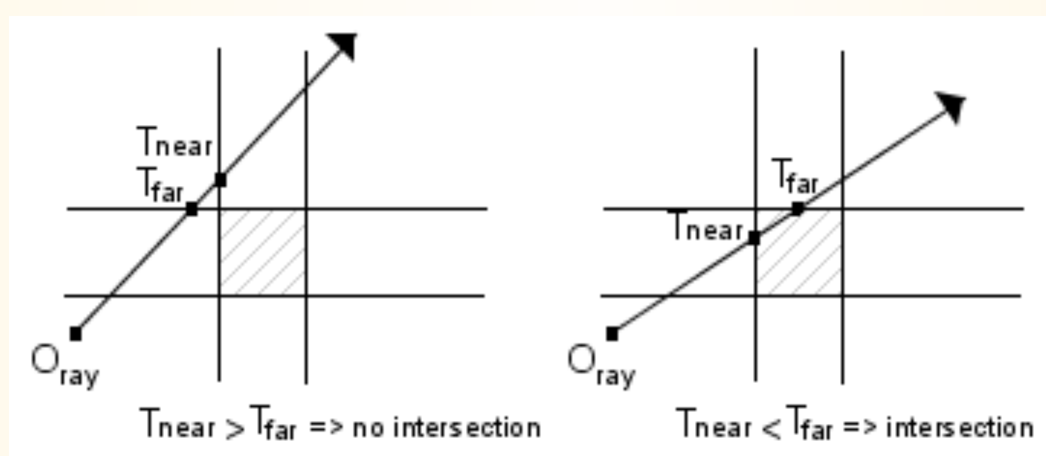
$$I_u = \frac{(\overrightarrow{O_{fr}} \wedge \vec{v}).\vec{r}}{\vec{w}.\vec{r}} \in [0,1]$$

$$I_v = \frac{(\vec{u} \wedge \overrightarrow{O_{fr}}).\vec{r}}{\vec{w}.\vec{r}} \in [0,1]$$

$$I_r = -\frac{\vec{w}.\overrightarrow{O_{fr}}}{\vec{w}.\vec{r}} > 0$$

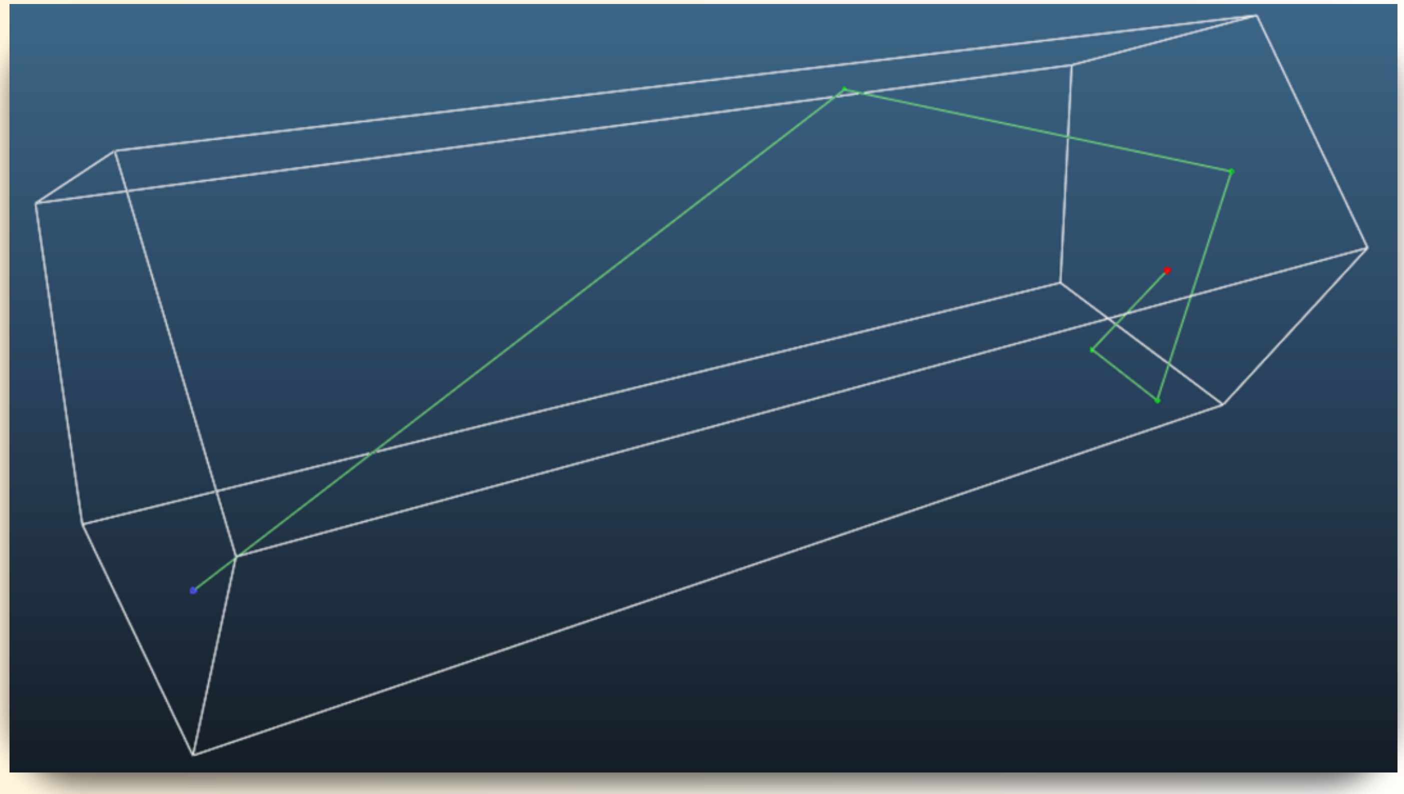
AABB Tree optimisation:

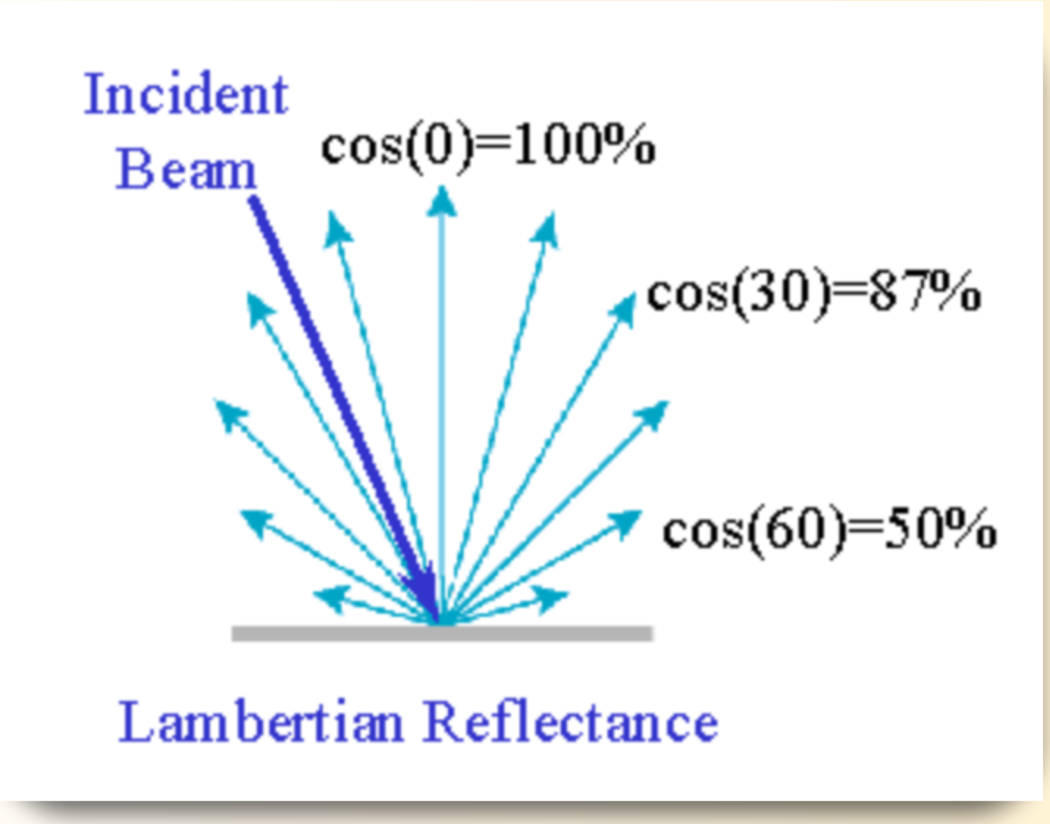
- Use of "**Axis Aligned Bounding Box**" tree structure to speed collision detection
- Box/ray intersection performed using the "**slabs method**"



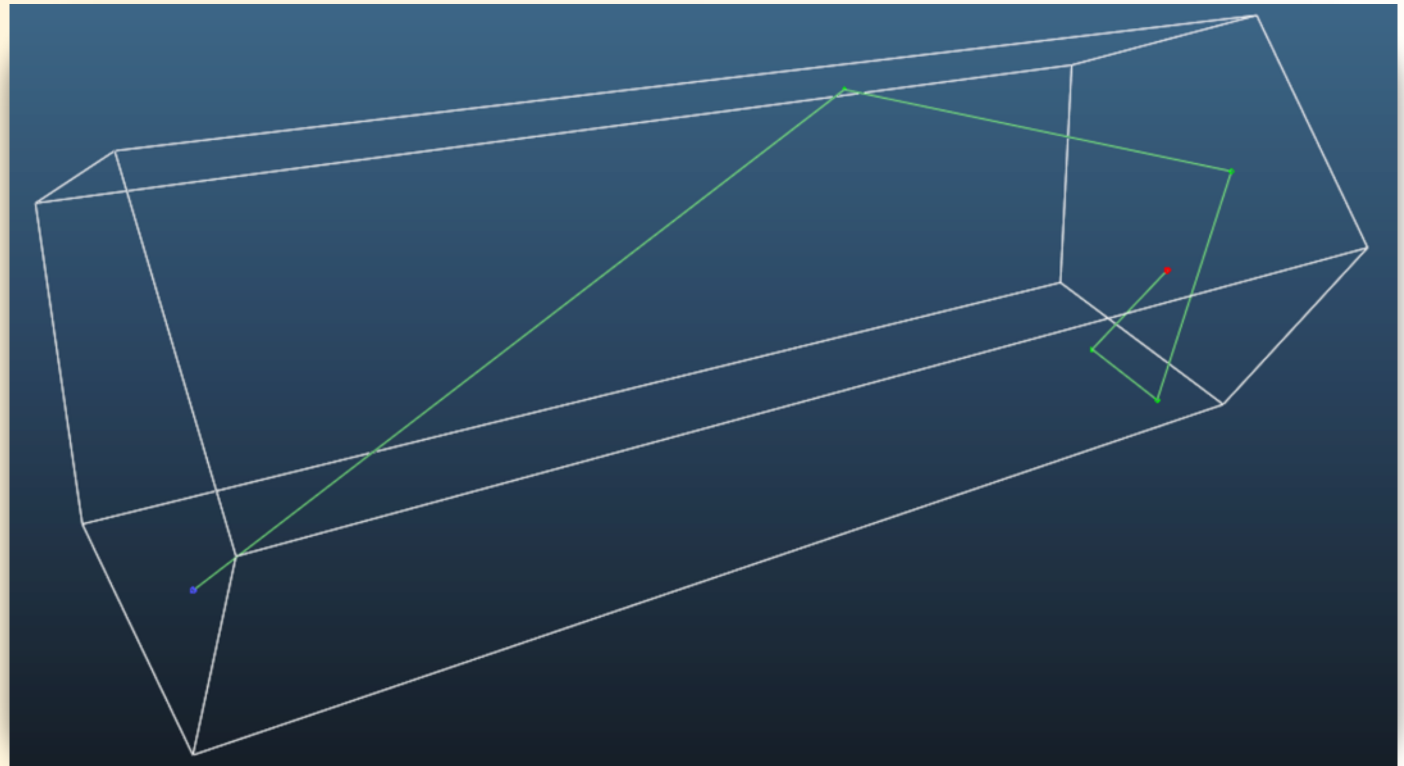
- Minimum of **8 facets per box** and maximum **tree depth of 5** (using "**best axis**" method for AABB **tree balancing**)
- Result: **more than 5 times faster** for complex geometries

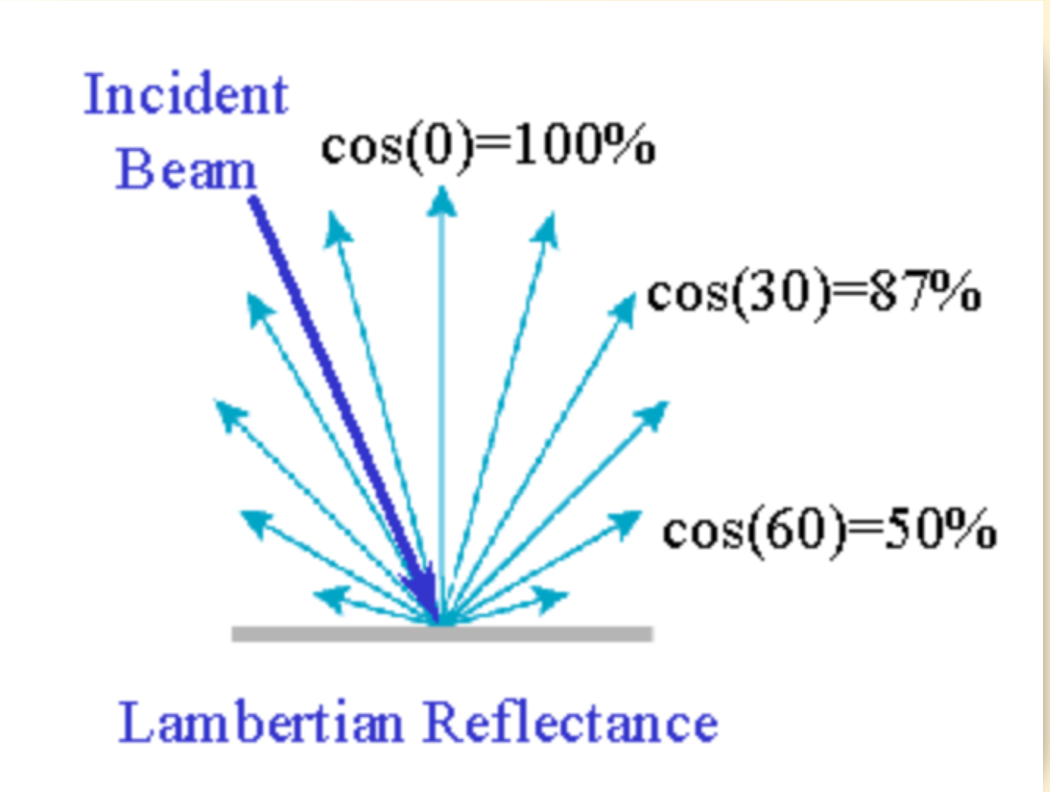
Reflection




Incident
Beam
cos(0)=100%
cos(30)=87%
cos(60)=50%
Lambertian Reflectance

Reflection

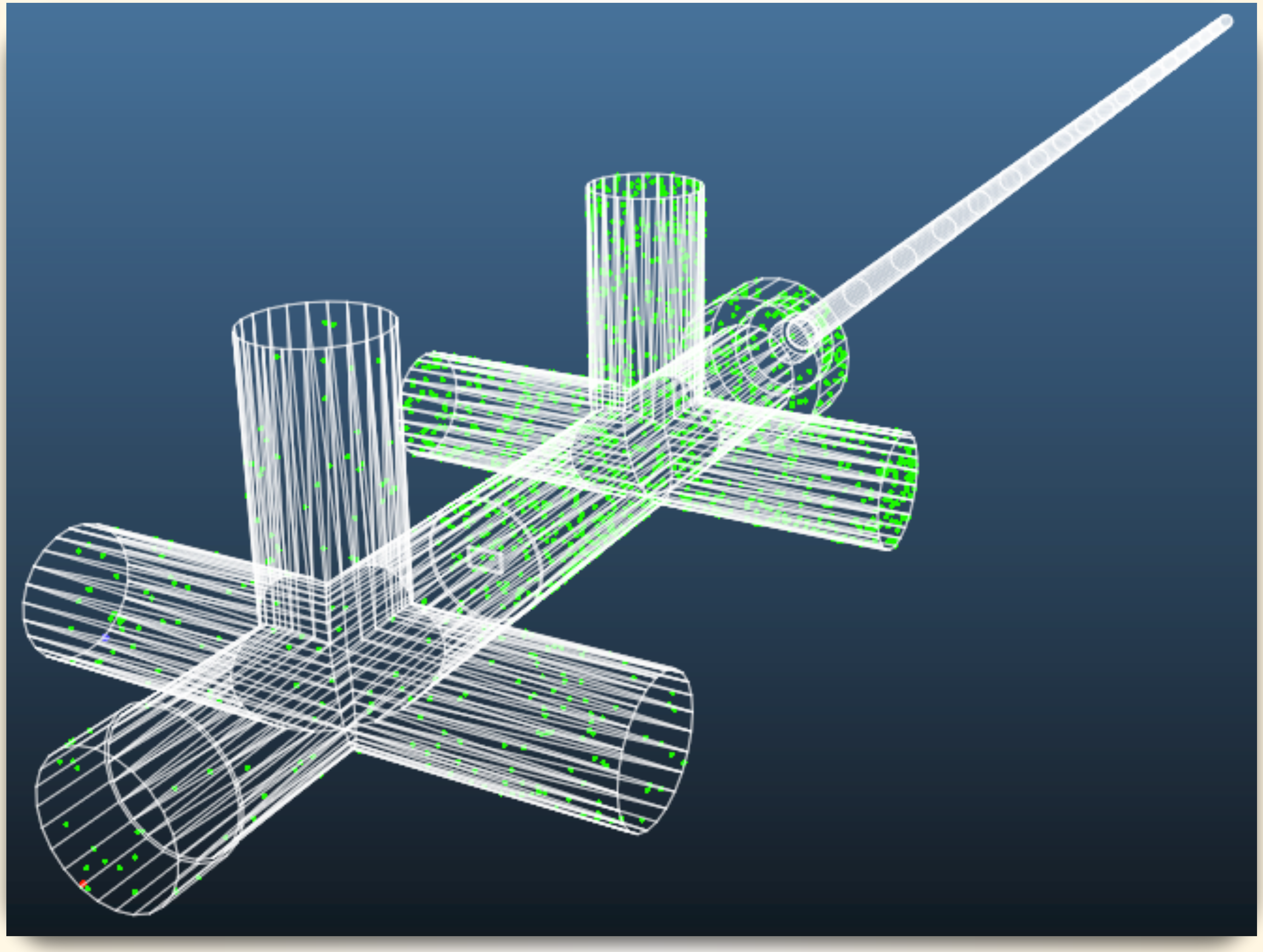




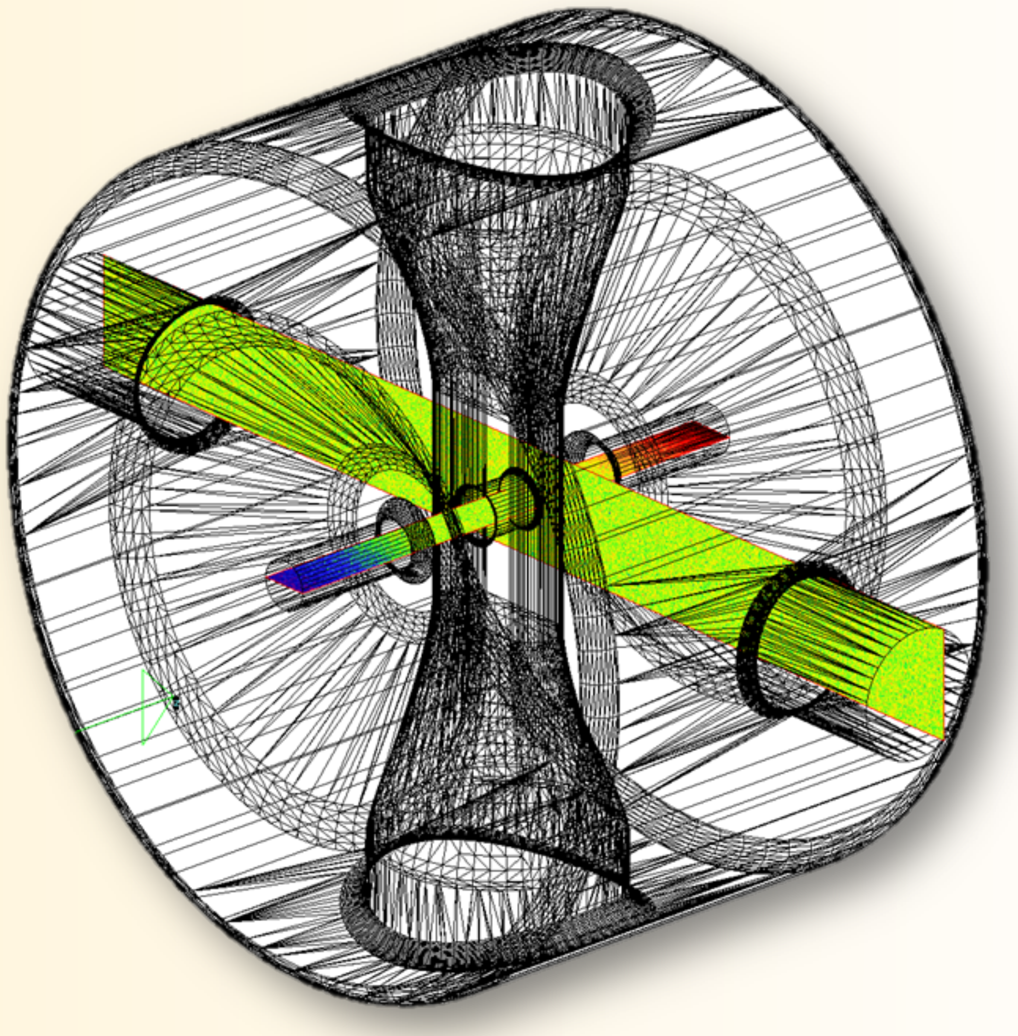
Pumping / absorption

S [m^3/s] = **sticking** [0..1] * 1/4 * A [m^2] * v_{avg} [m/s]

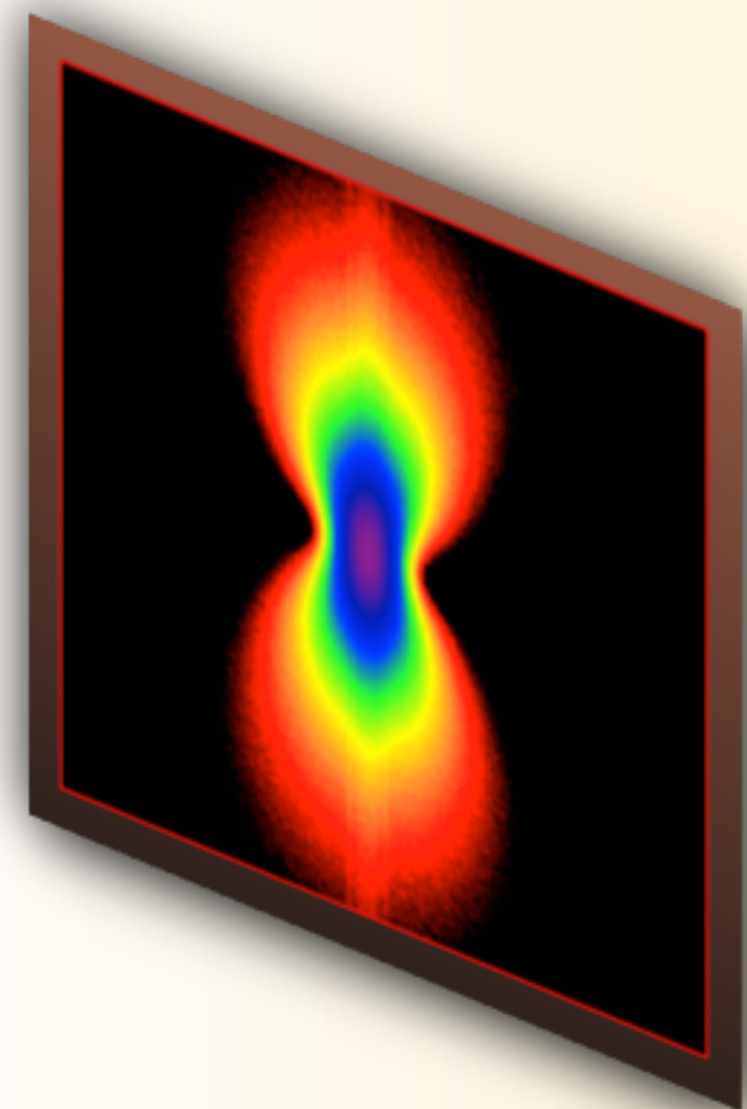
Collecting statistics



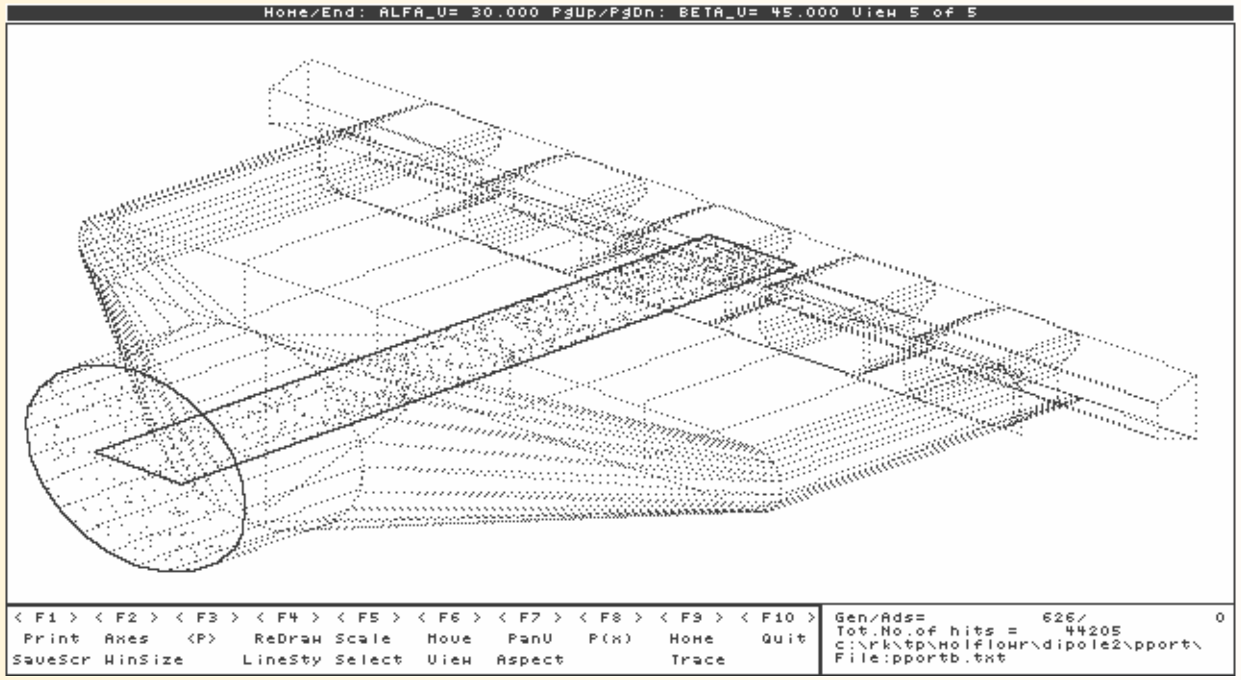
MolFlow

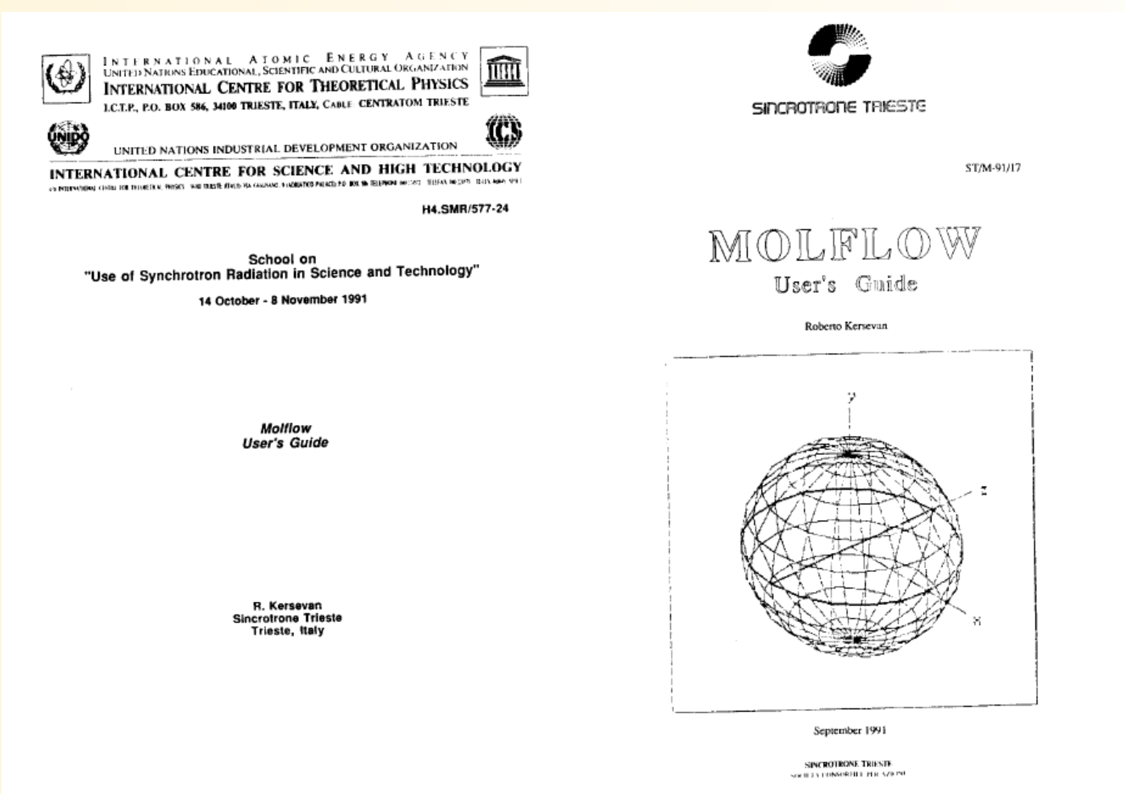


SynRad



Molflow (1990)





INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
INTERNATIONAL CENTRE FOR SCIENCE AND HIGH TECHNOLOGY

H4.SMR/577-24

School on
"Use of Synchrotron Radiation in Science and Technology"
14 October - 8 November 1991

Molflow
User's Guide

R. Kersevan
Sincrotrone Trieste
Trieste, Italy

SINCROTRONE TRIESTE

ST/M-91/17

MOLFLOW
User's Guide

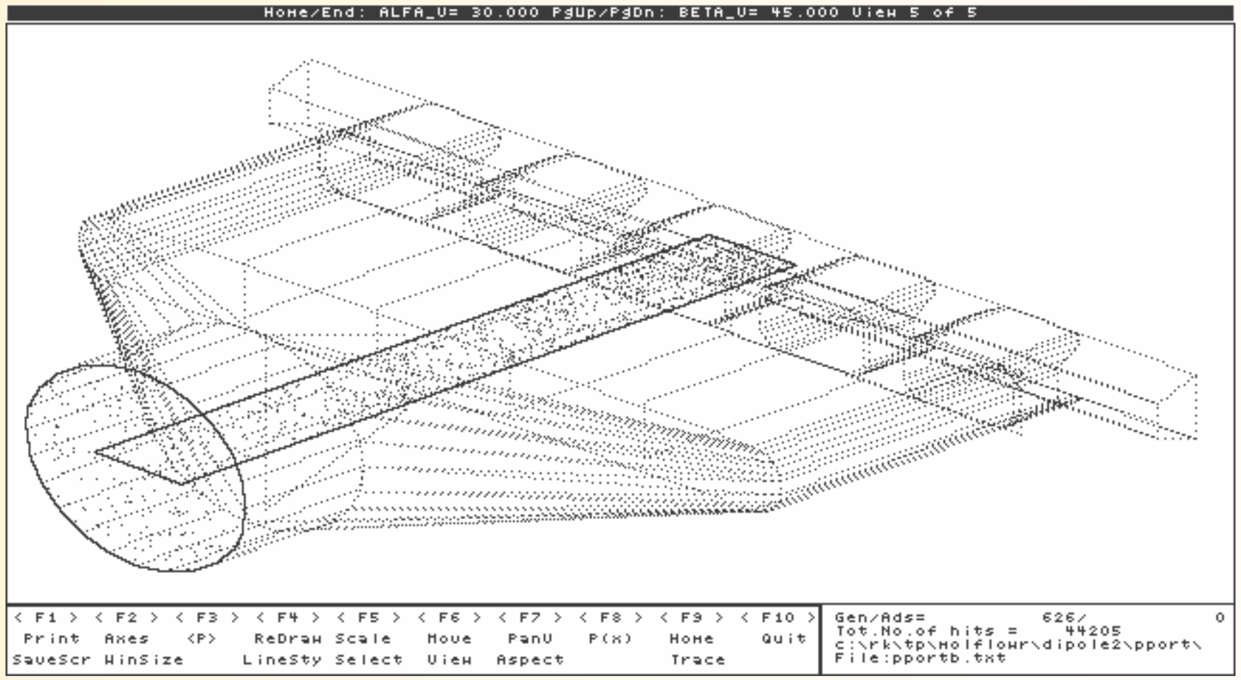
Roberto Kersevan

September 1991

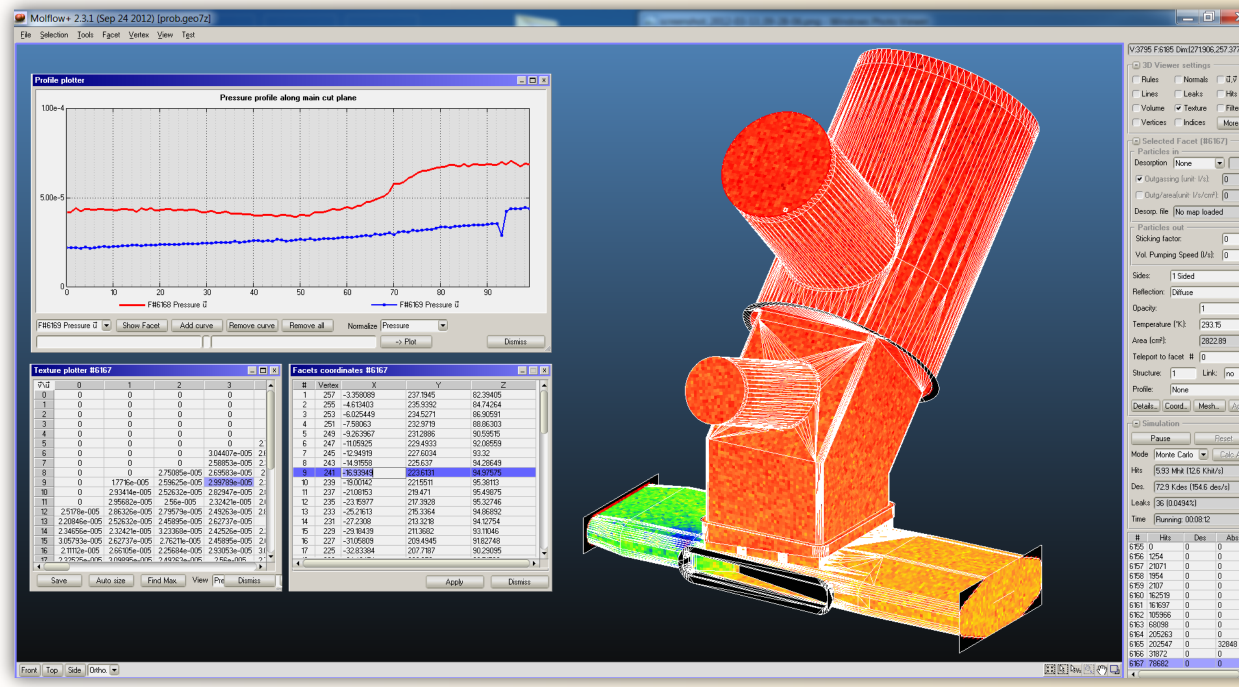
SINCROTRONE TRIESTE

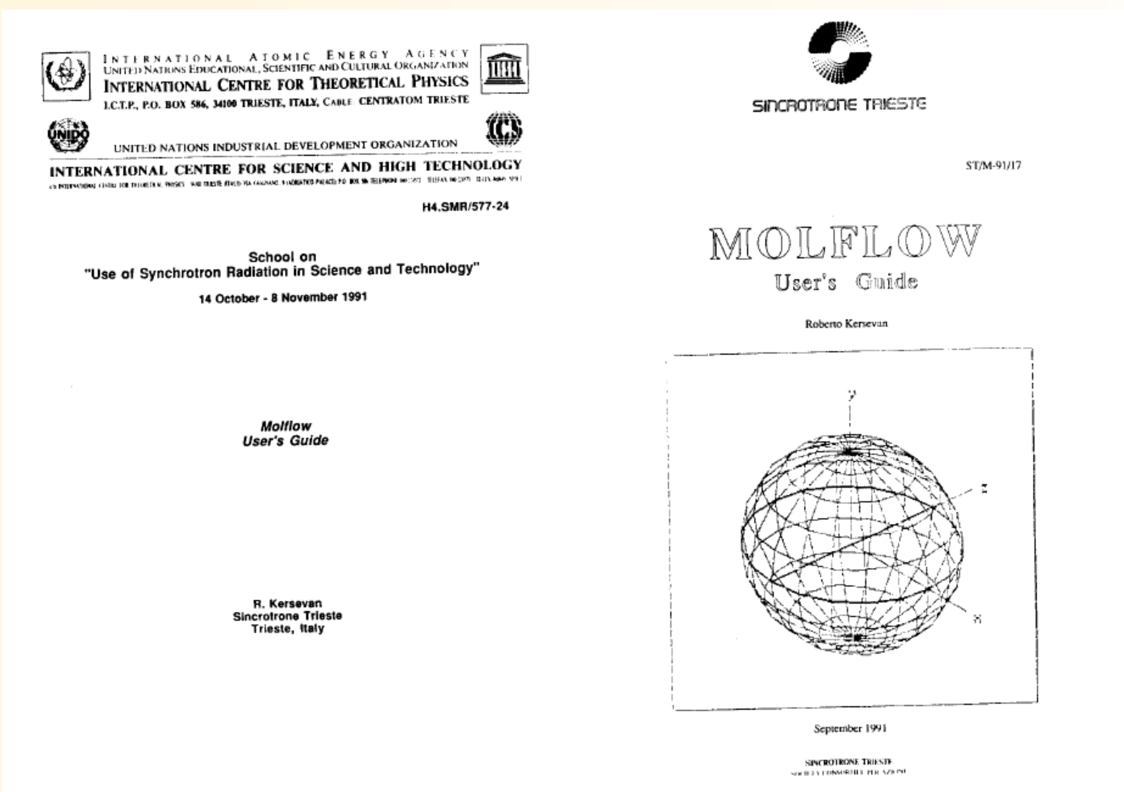
Roberto Kersevan

Molflow (1990)



Molflow+ (2008-)




INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
INTERNATIONAL CENTRE FOR SCIENCE AND HIGH TECHNOLOGY

H4.SMR/577-24

School on
"Use of Synchrotron Radiation in Science and Technology"
14 October - 8 November 1991

Molflow
User's Guide

R. Kersevan
Sincrotrone Trieste
Trieste, Italy

SINCROTRONE TRIESTE

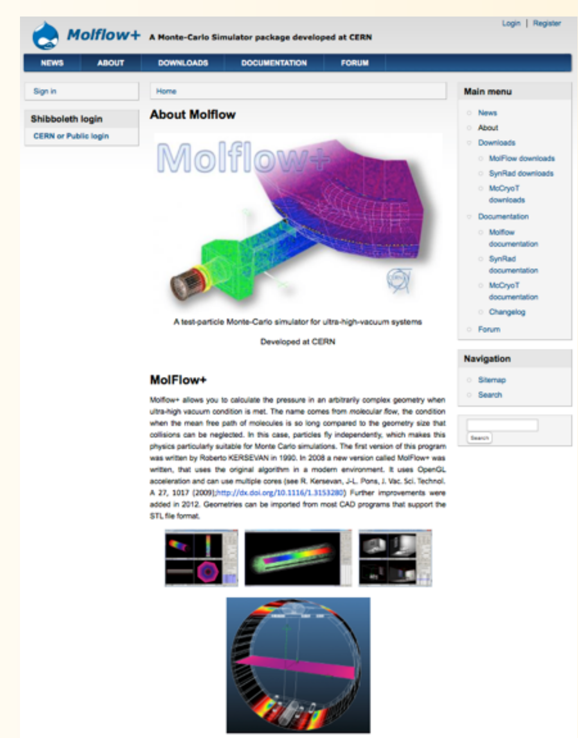
ST/M-91/17

MOLFLOW
User's Guide

Roberto Kersevan

September 1991

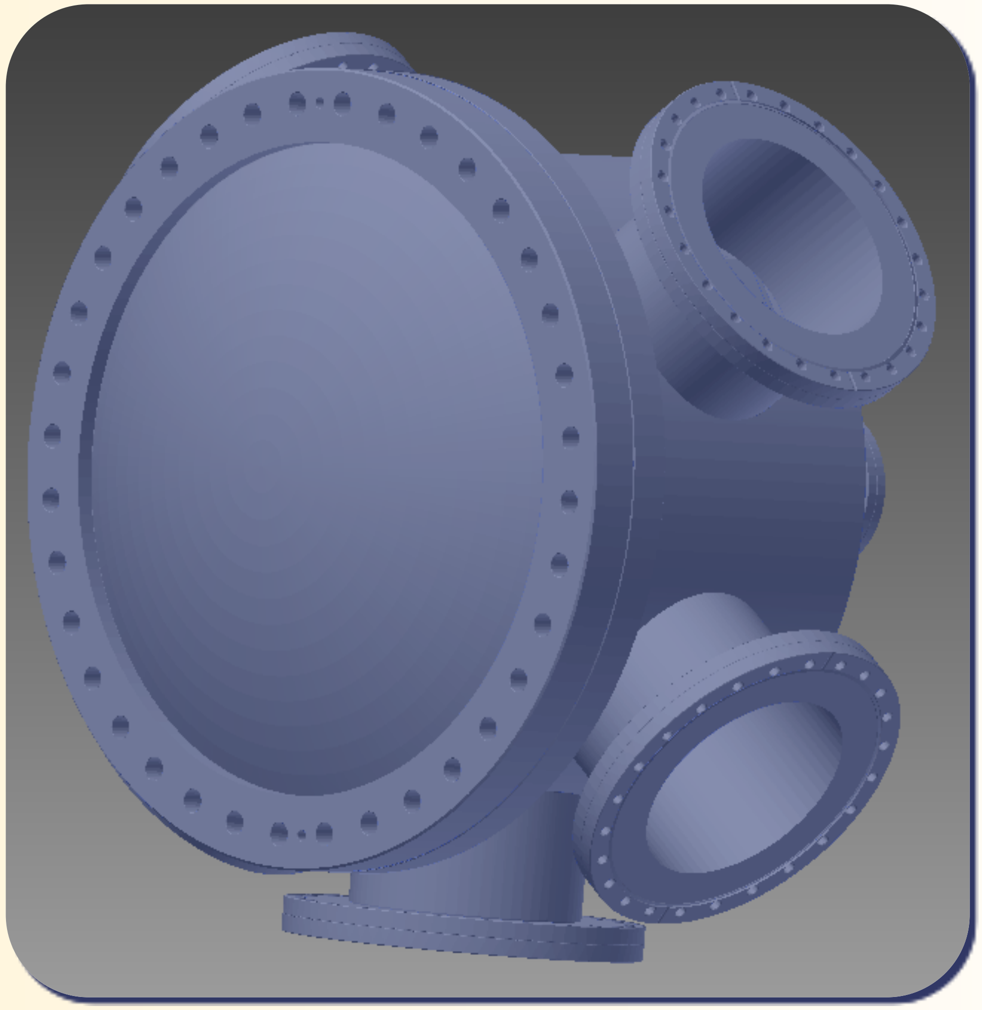
Roberto Kersevan



WORKING WITH MOLFLOW

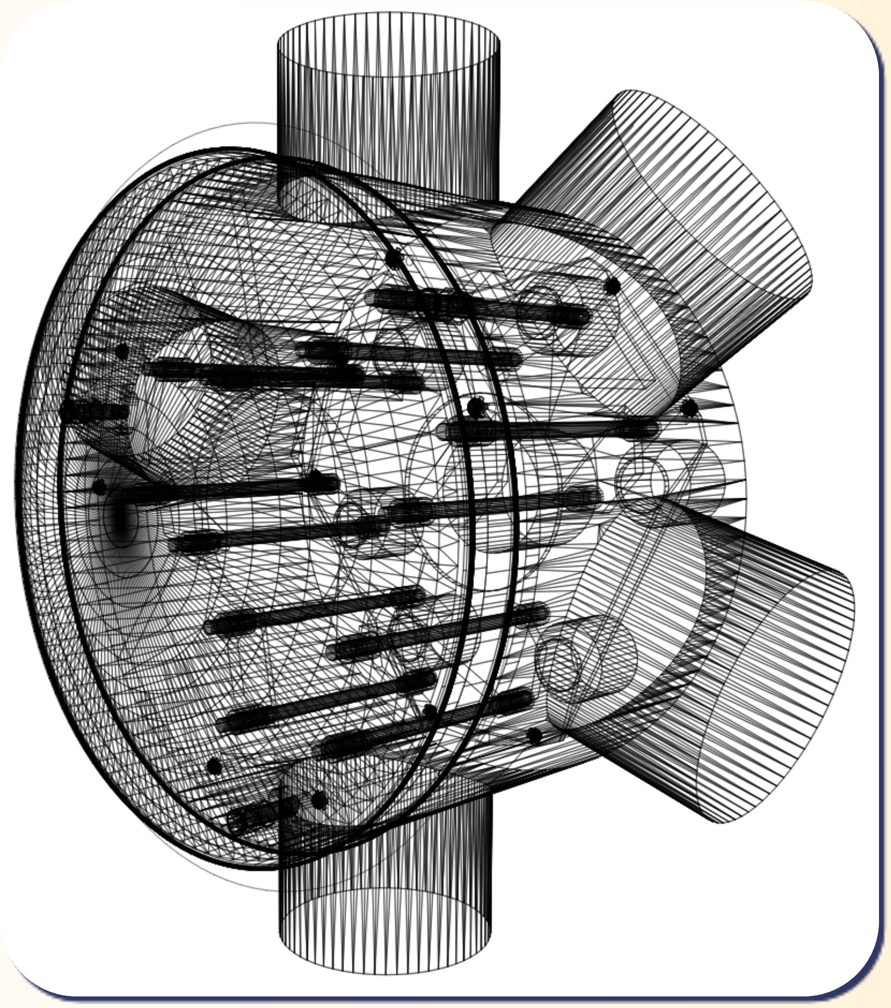
Step 1: creating geometry

CAD



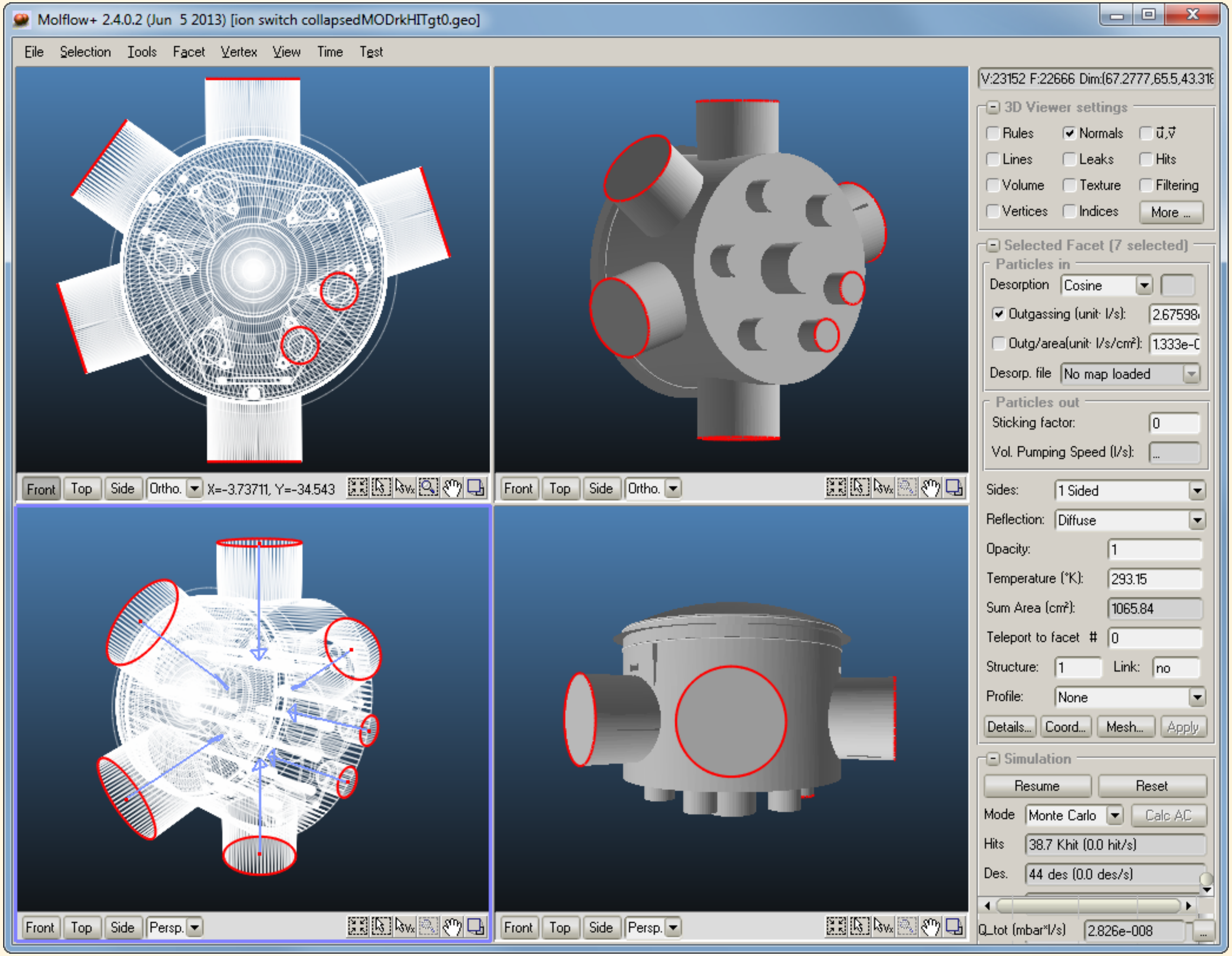
STL format

Molflow+



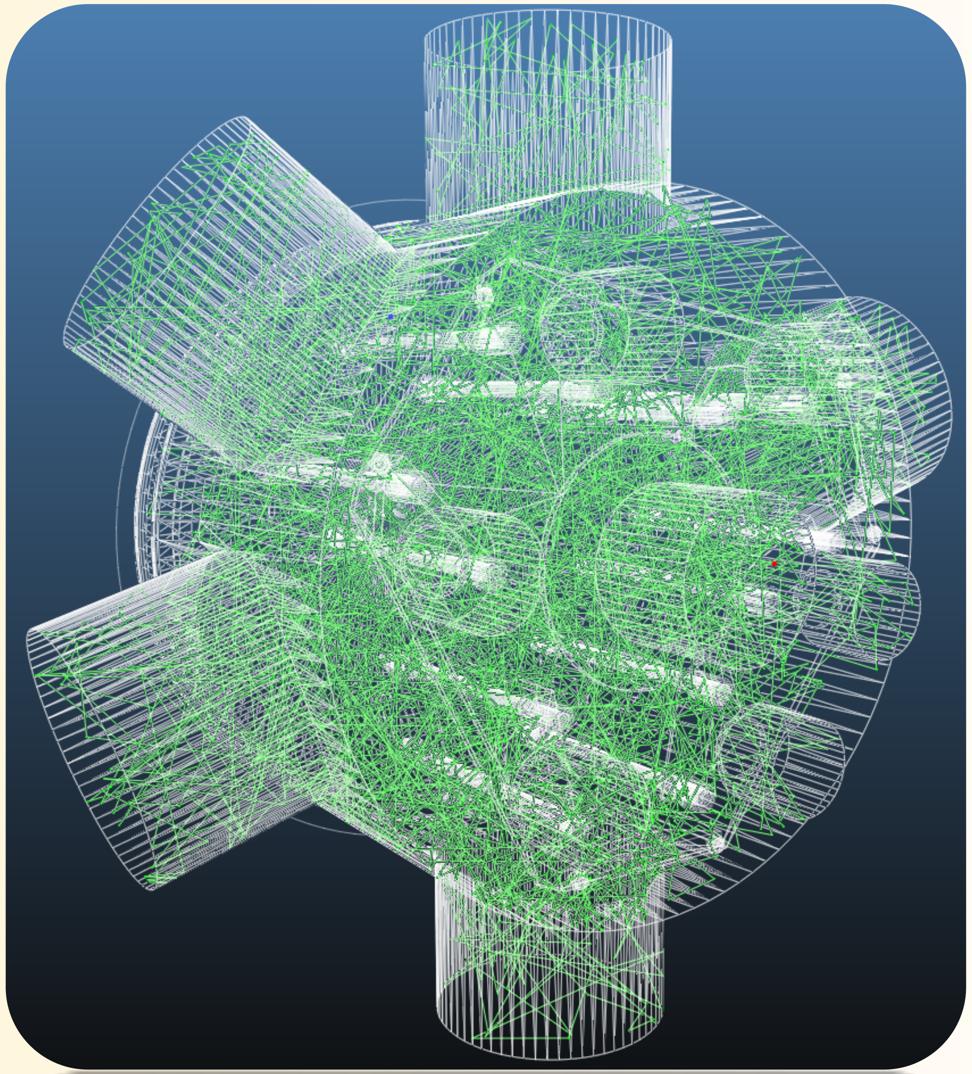
WORKING WITH MOLFLOW

Step 2: adding physics



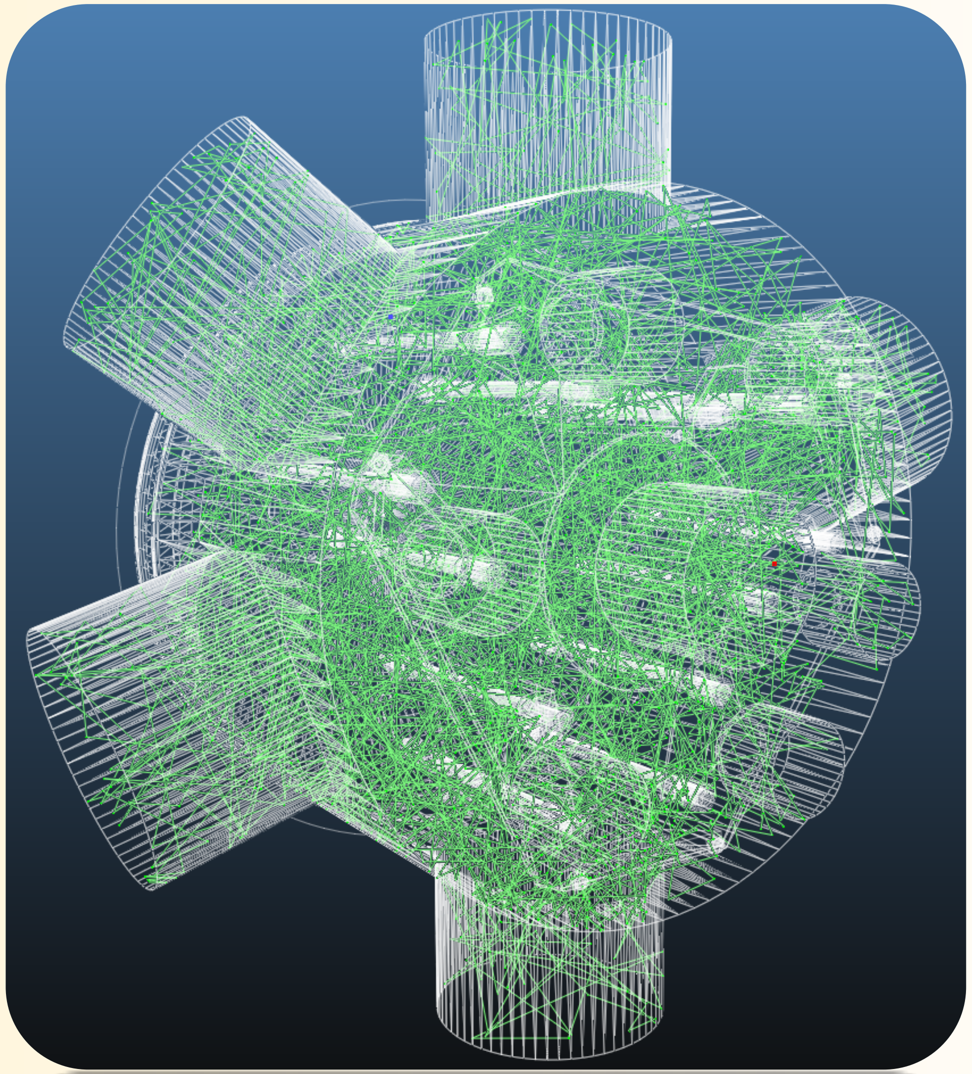
WORKING WITH MOLFLOW

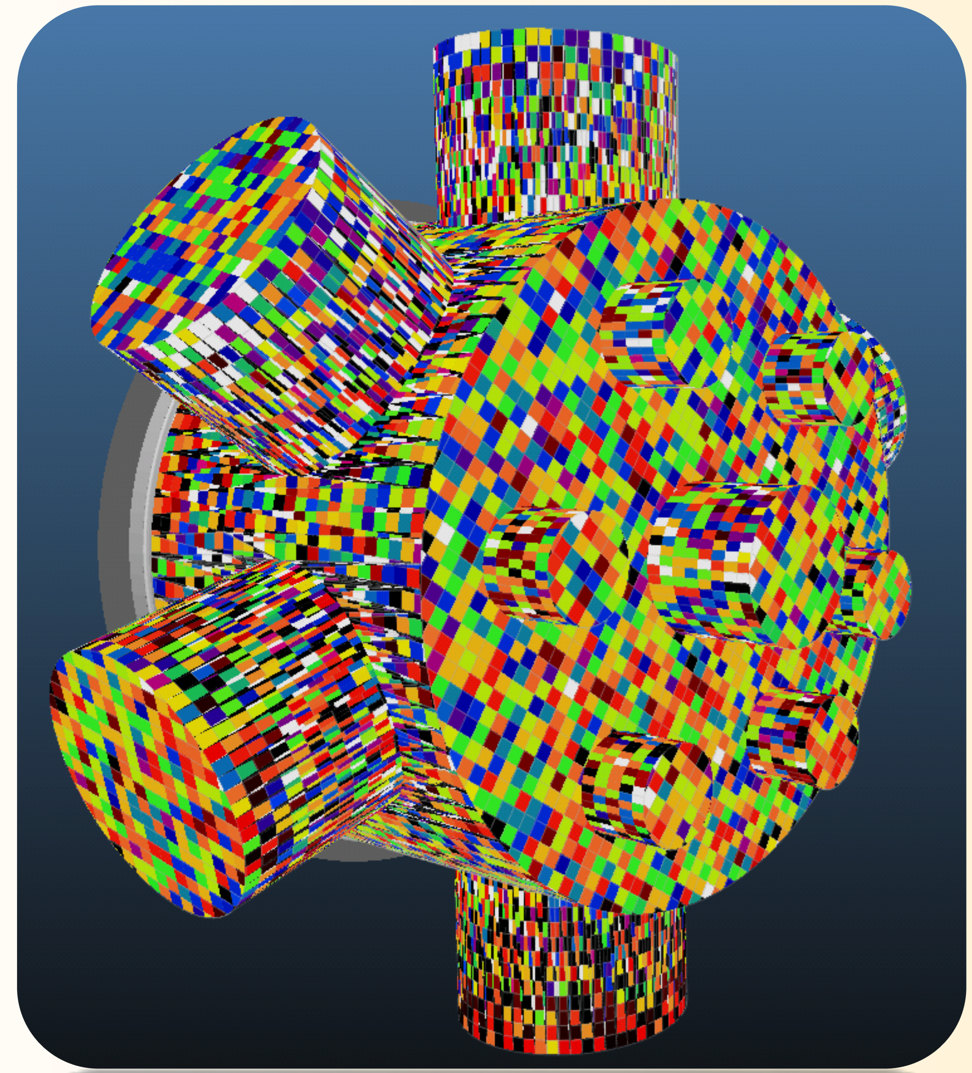
Step 3: simulation and results



WORKING WITH MOLFLOW

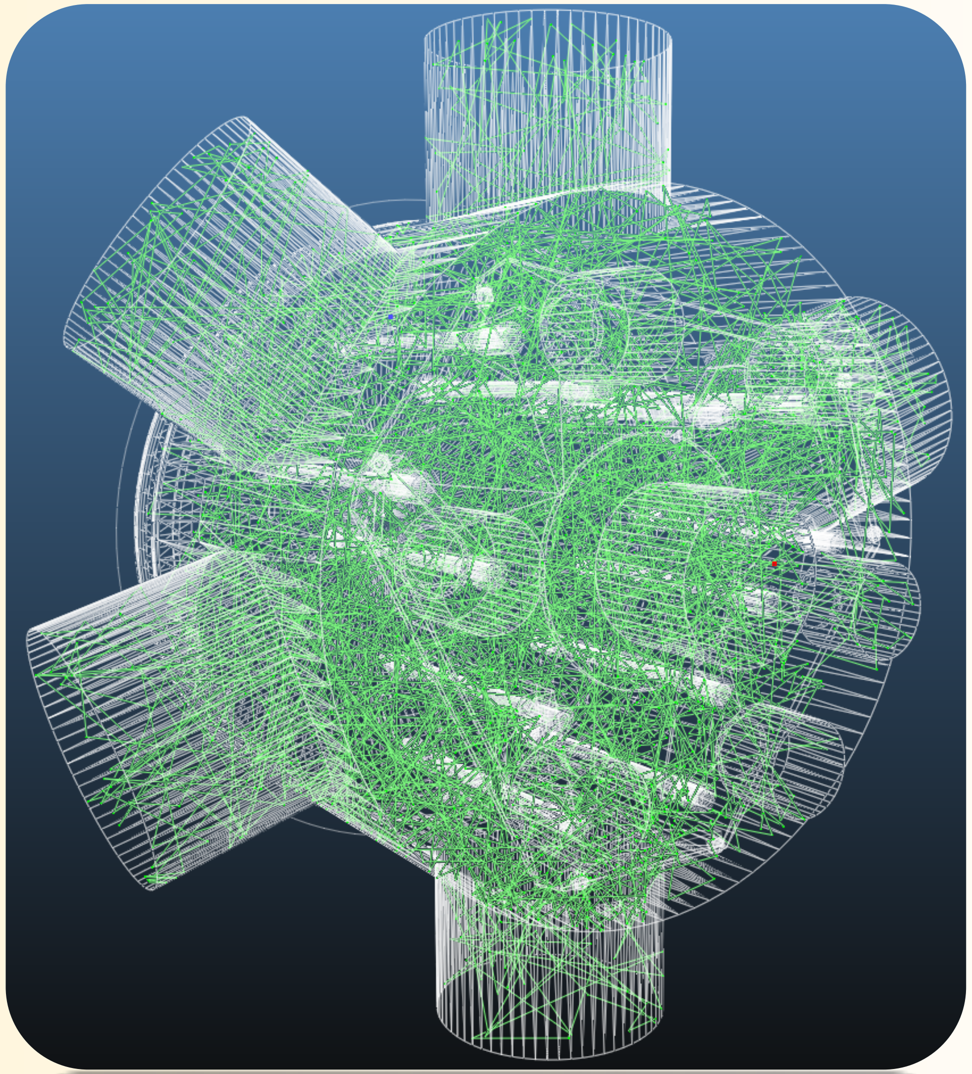
Step 3: simulation and results

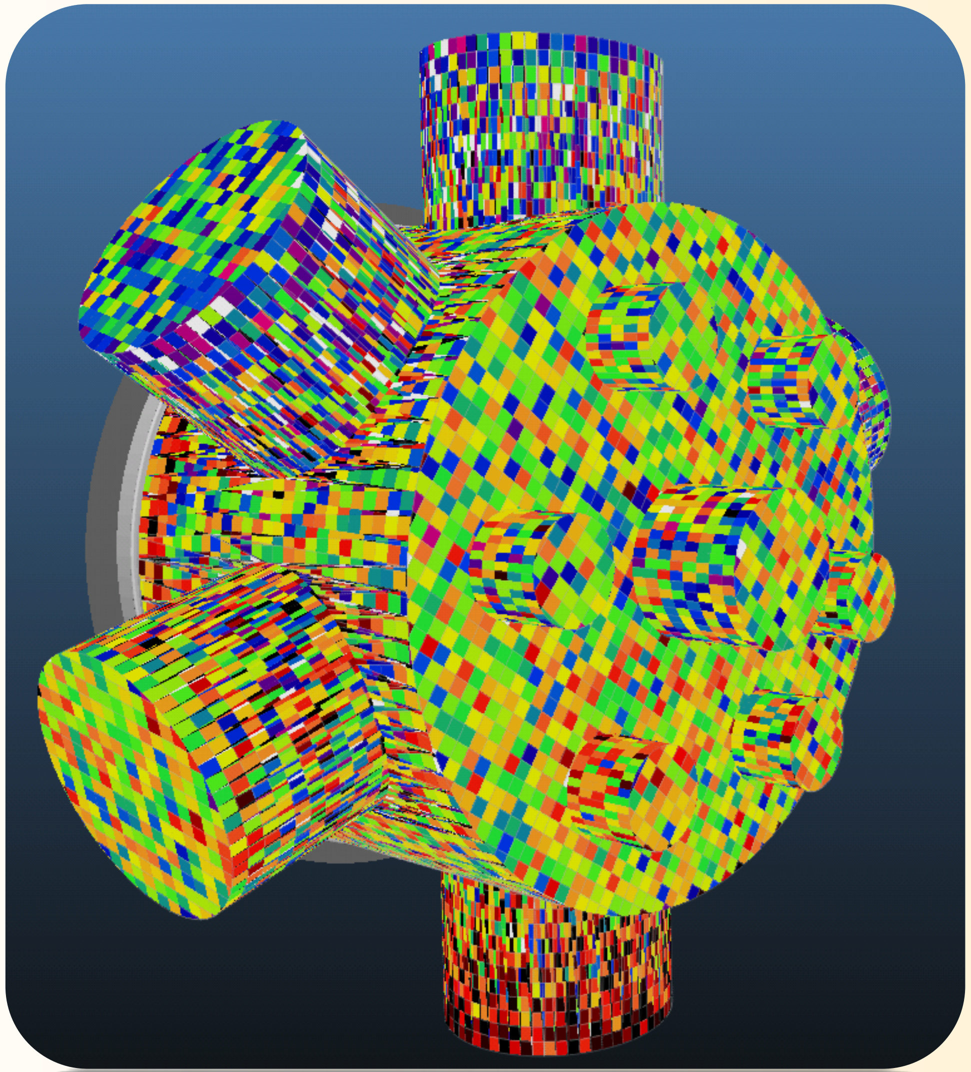




WORKING WITH MOLFLOW

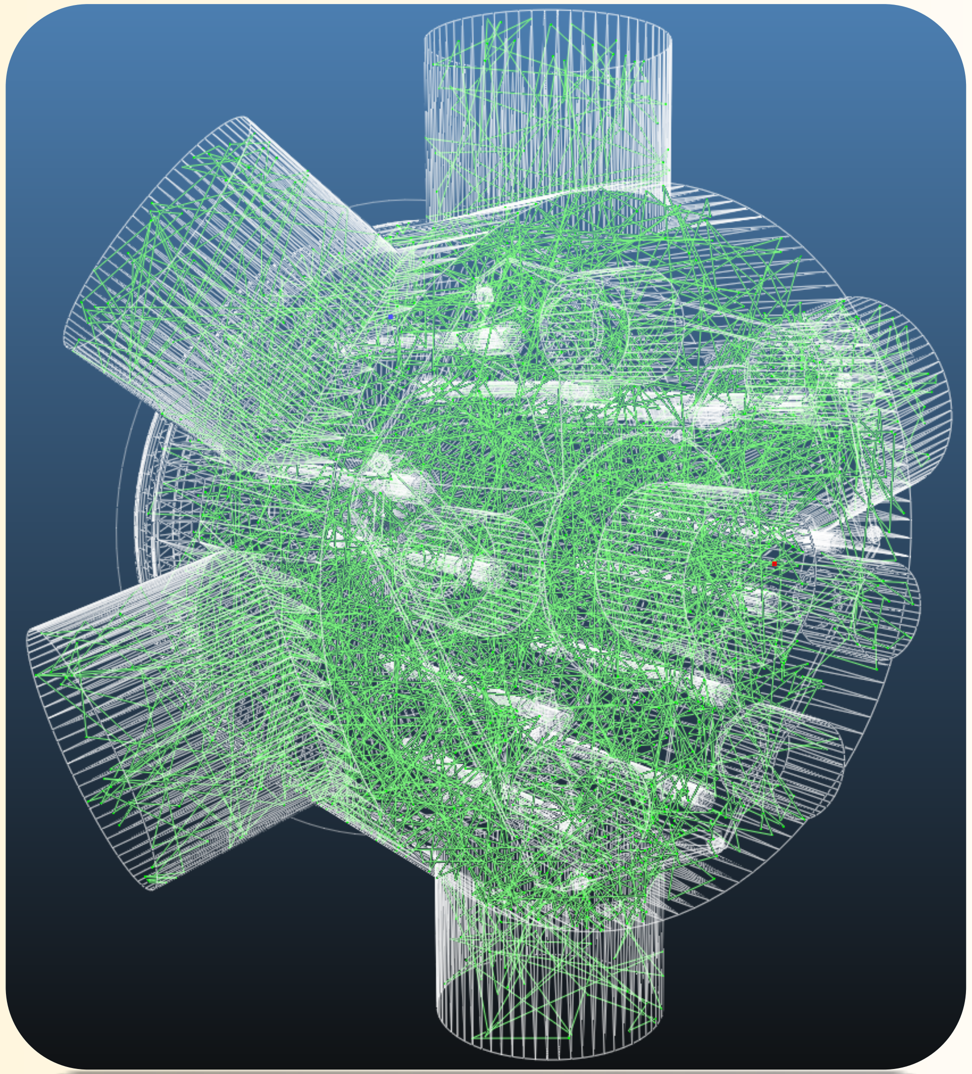
Step 3: simulation and results

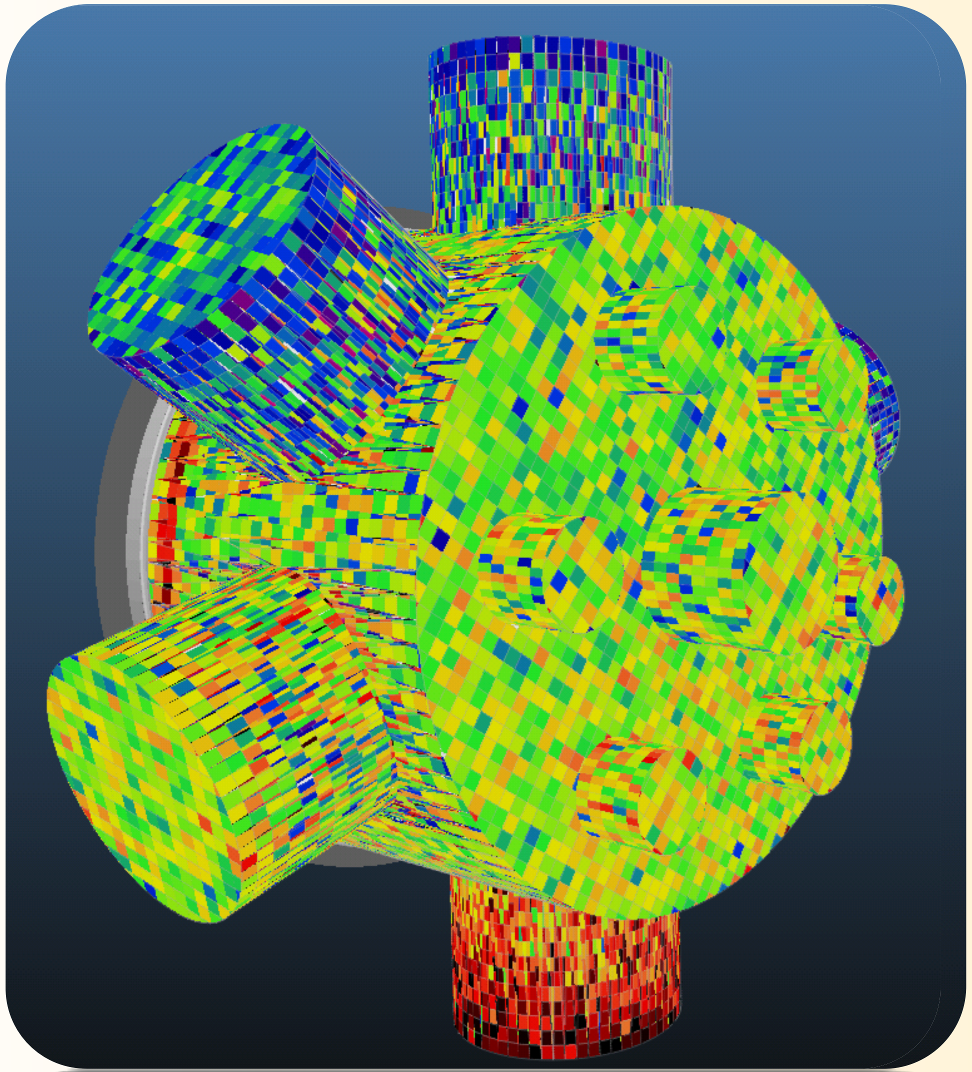




WORKING WITH MOLFLOW

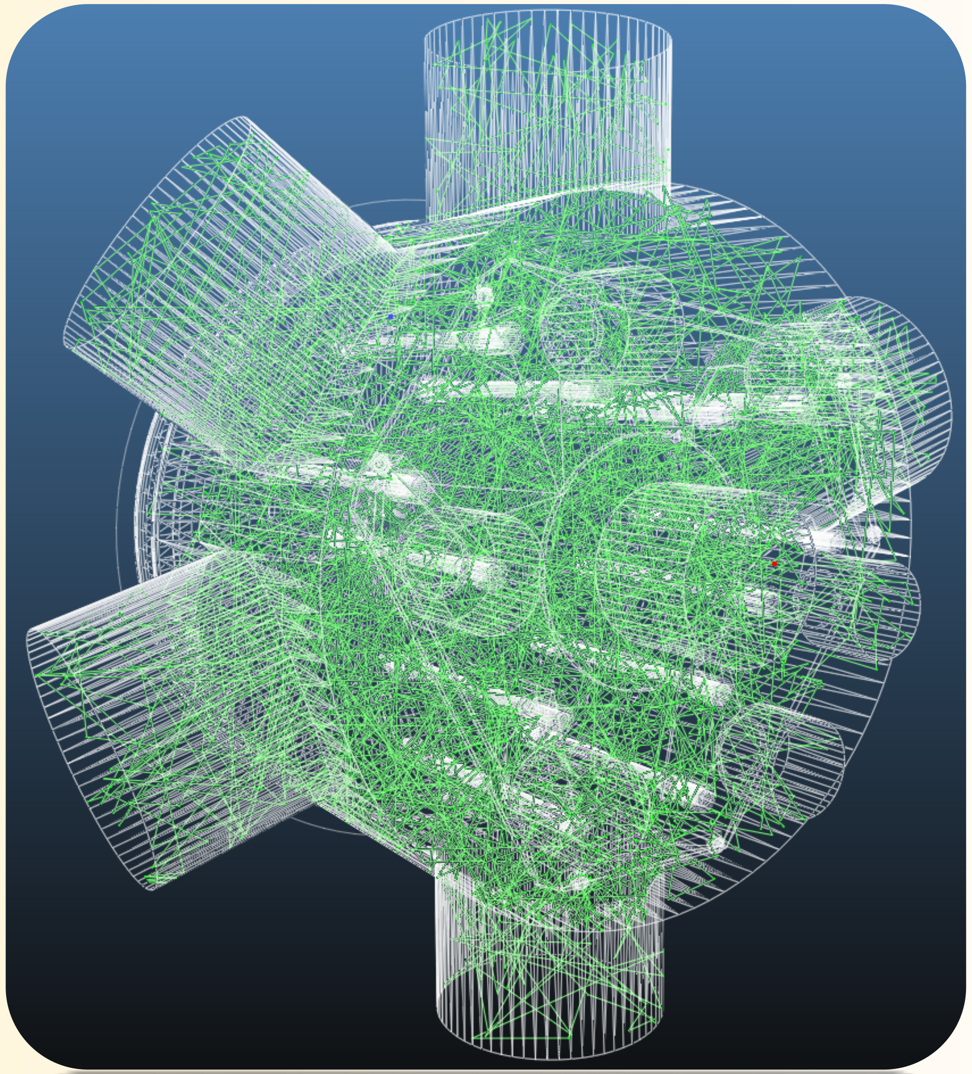
Step 3: simulation and results

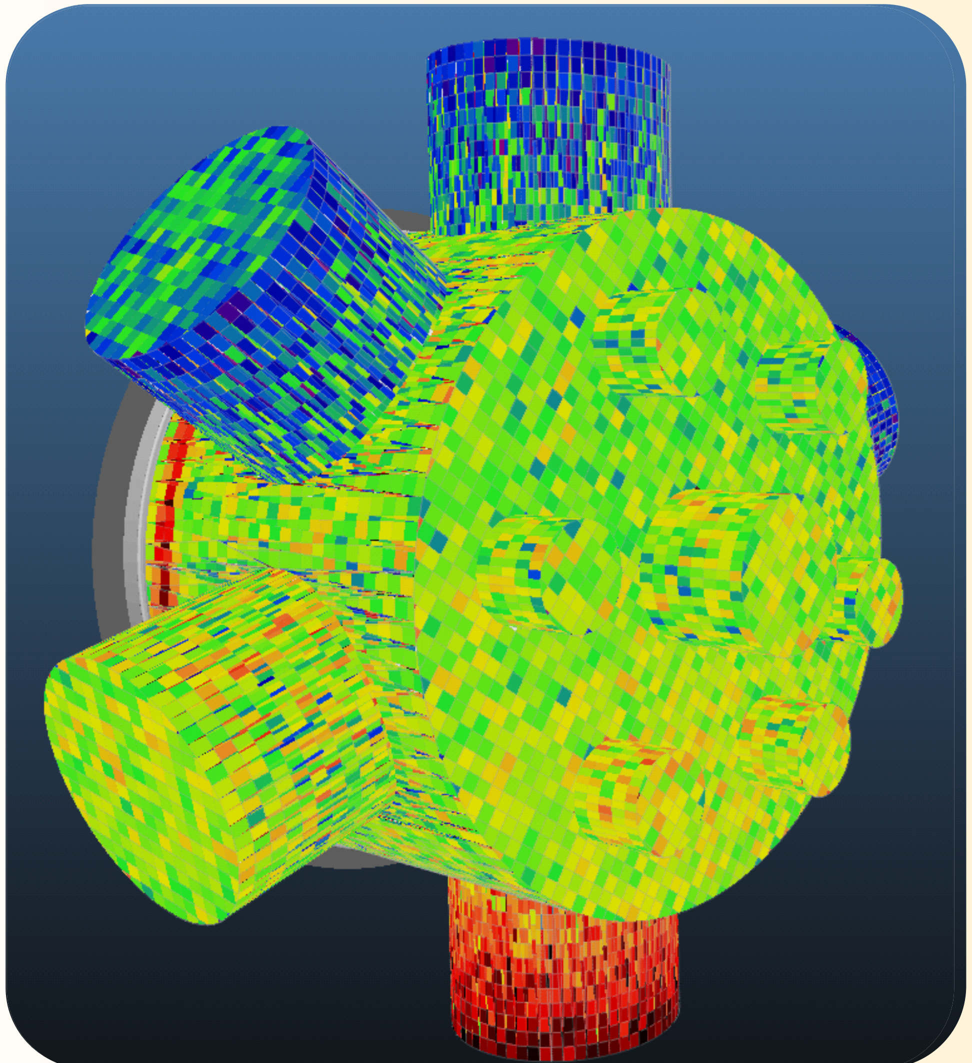




WORKING WITH MOLFLOW

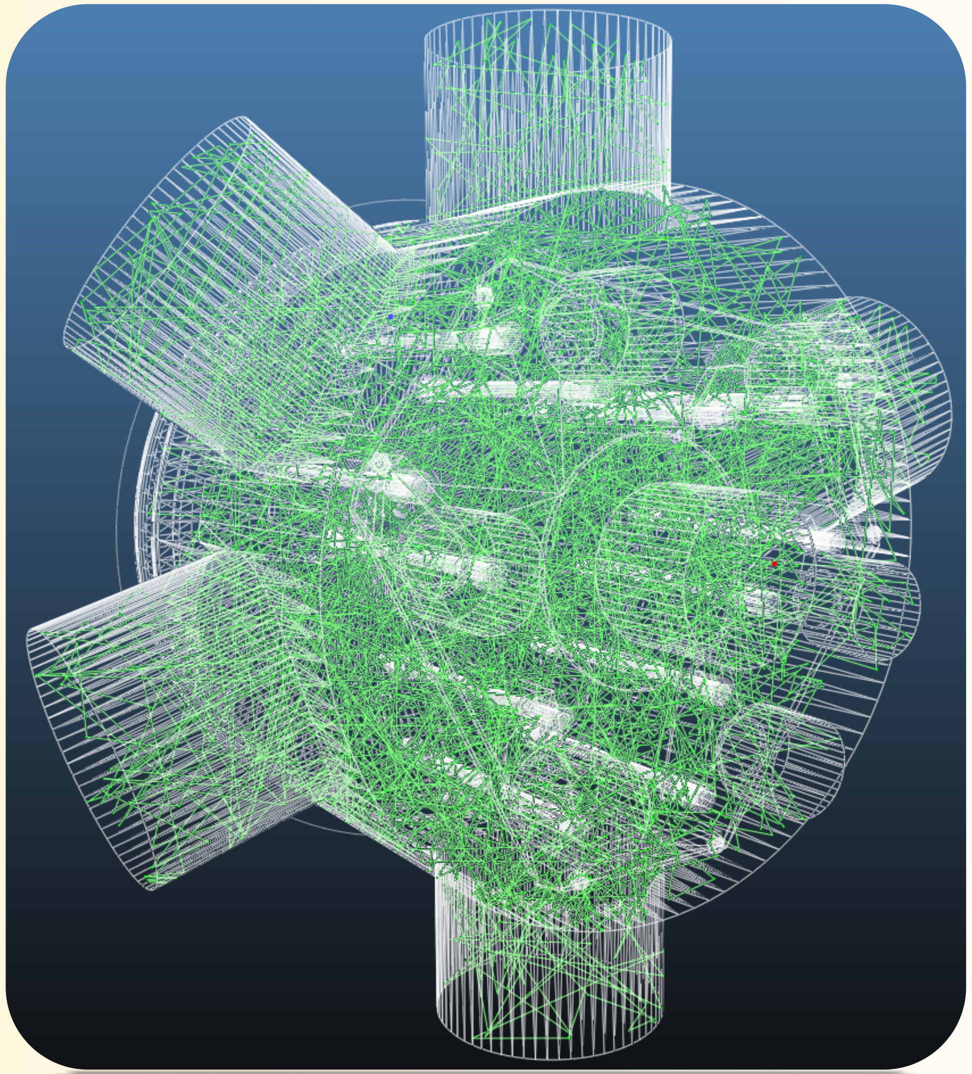
Step 3: simulation and results

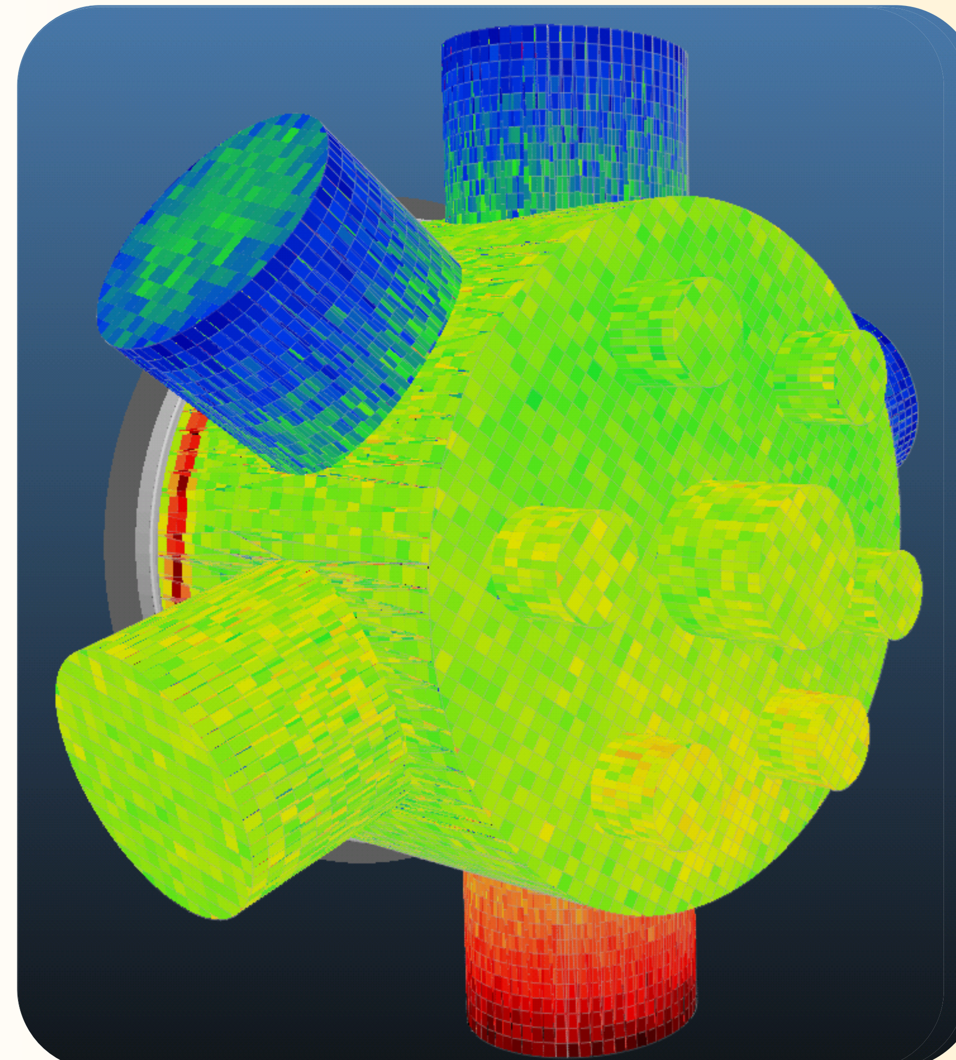




WORKING WITH MOLFLOW

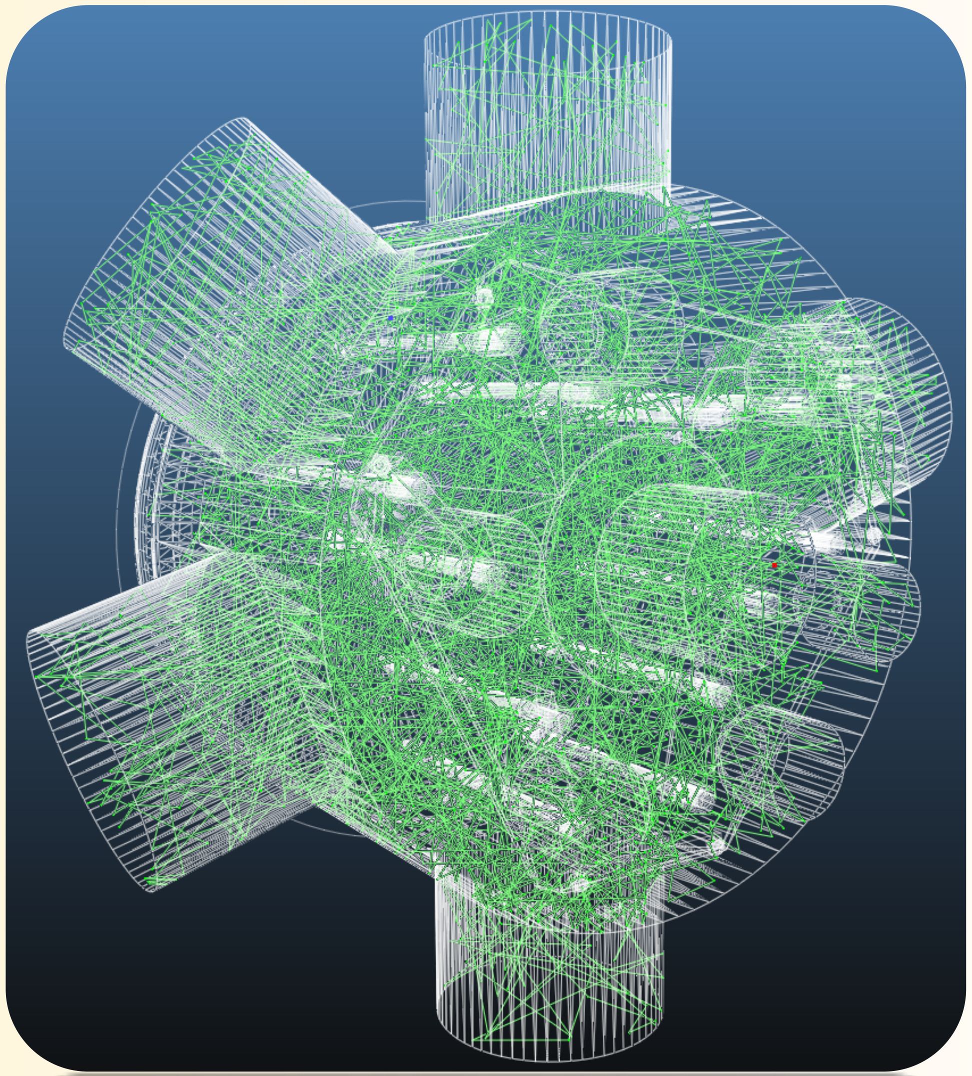
Step 3: simulation and results

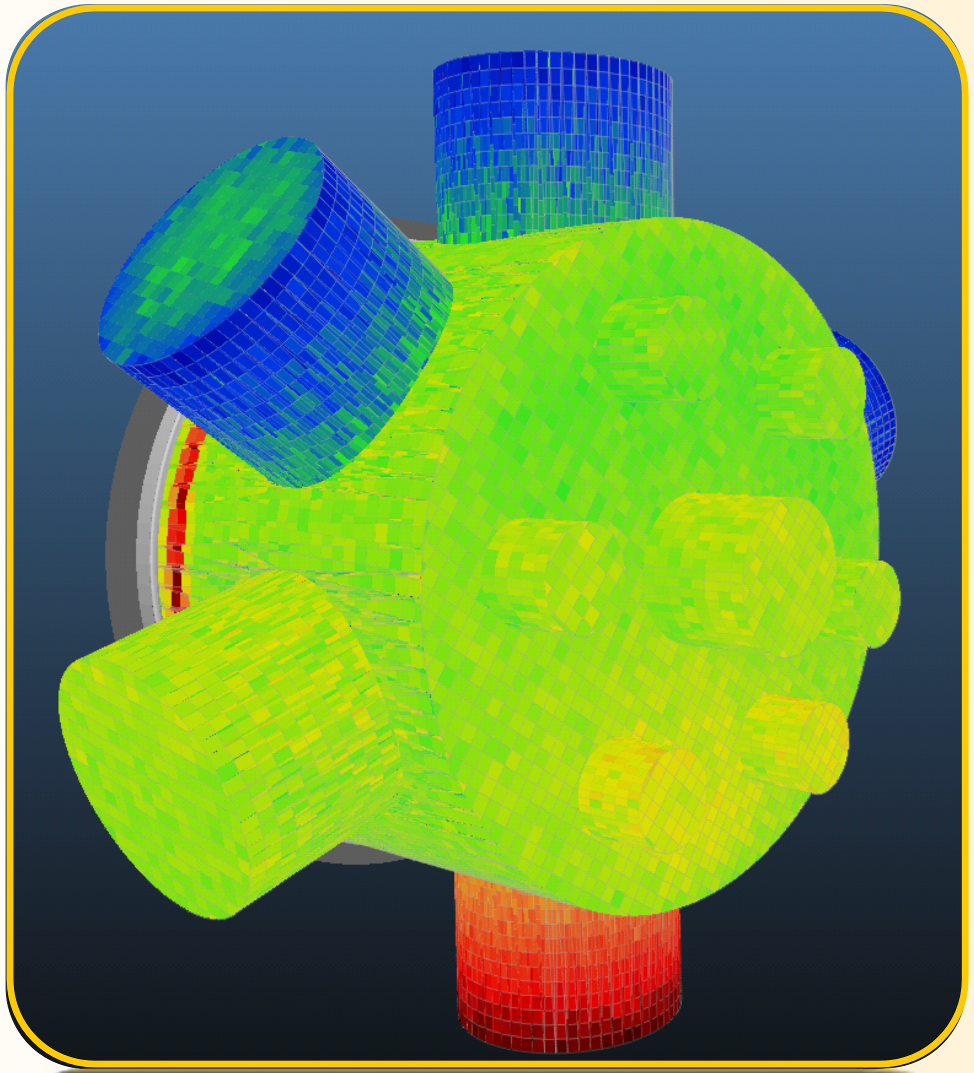




WORKING WITH MOLFLOW

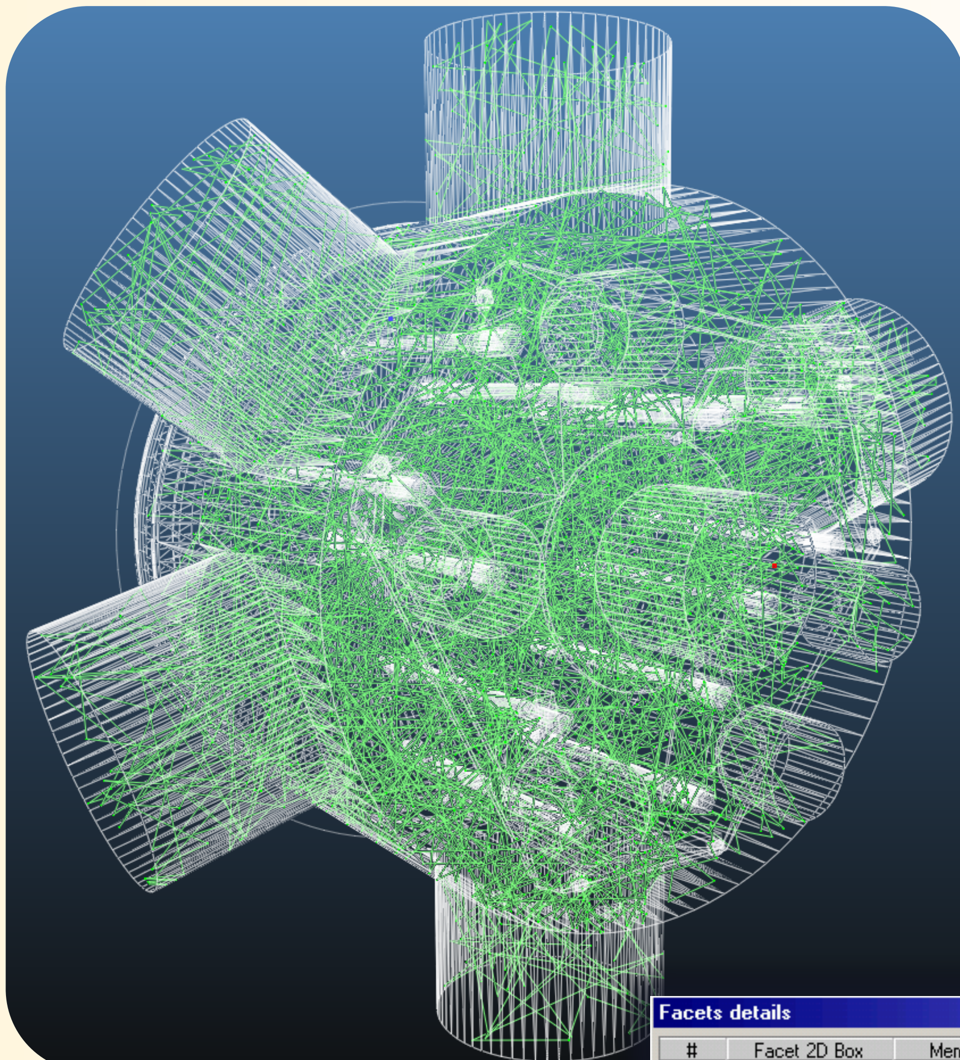
Step 3: simulation and results

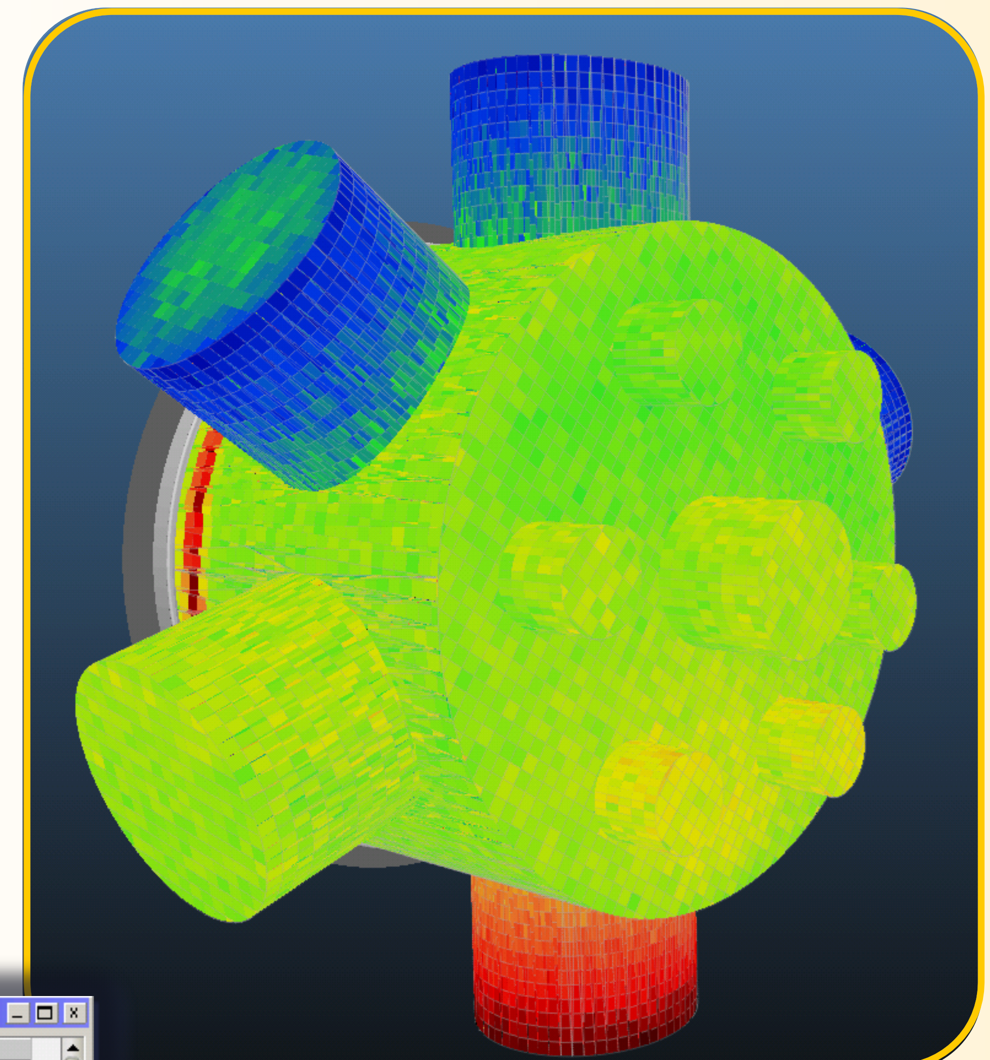


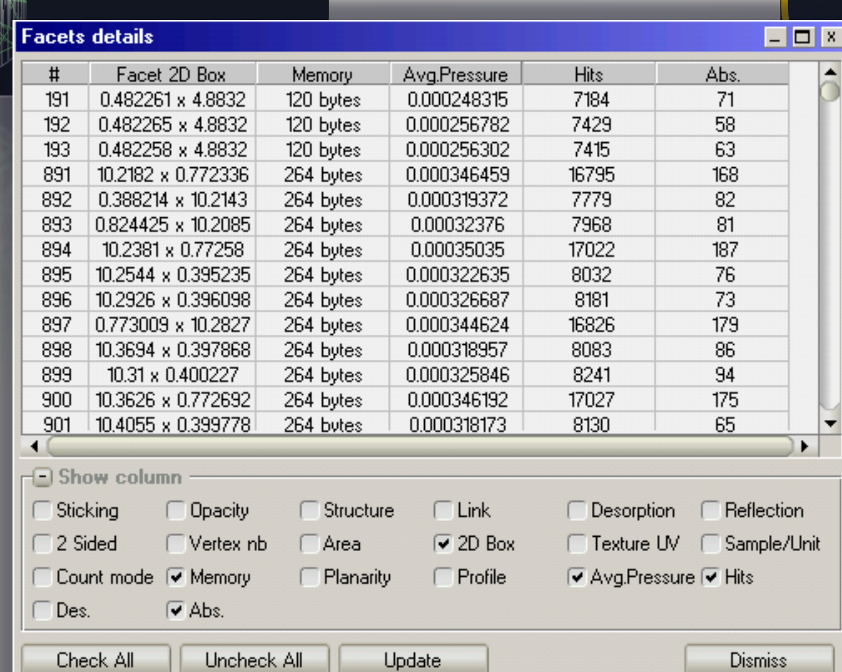


WORKING WITH MOLFLOW

Step 3: simulation and results







#	Facet 2D Box	Memory	Avg.Pressure	Hits	Abs.
191	0.482261 x 4.8832	120 bytes	0.000248315	7184	71
192	0.482265 x 4.8832	120 bytes	0.000256782	7429	58
193	0.482258 x 4.8832	120 bytes	0.000256302	7415	63
891	10.2182 x 0.772336	264 bytes	0.000346459	16795	168
892	0.388214 x 10.2143	264 bytes	0.000319372	7779	82
893	0.824425 x 10.2085	264 bytes	0.00032376	7968	81
894	10.2381 x 0.77258	264 bytes	0.00035035	17022	187
895	10.2544 x 0.395235	264 bytes	0.000322635	8032	76
896	10.2926 x 0.396098	264 bytes	0.000326687	8181	73
897	0.773009 x 10.2827	264 bytes	0.000344624	16826	179
898	10.3694 x 0.397868	264 bytes	0.000318957	8083	86
899	10.31 x 0.400227	264 bytes	0.000325846	8241	94
900	10.3626 x 0.772692	264 bytes	0.000346192	17027	175
901	10.4055 x 0.399778	264 bytes	0.000318173	8130	65