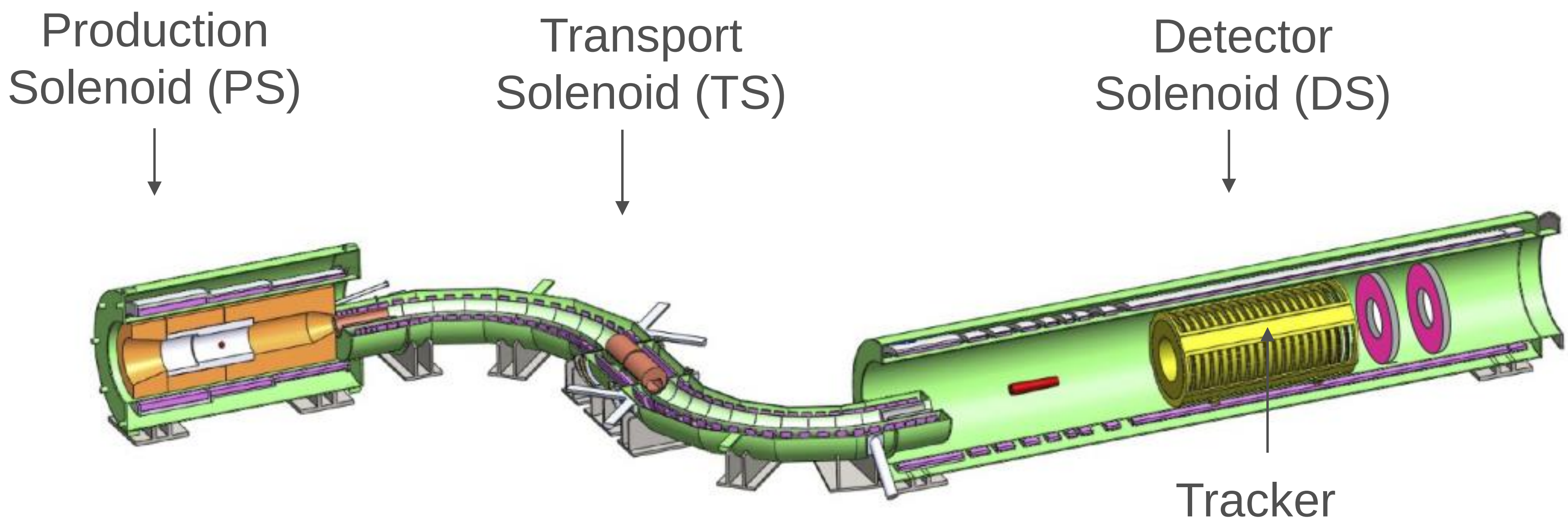


Mu2e DS Tracker – Support systems layout analysis

Student: Gabriele Taddei
Supervisor: Giuseppe Gallo

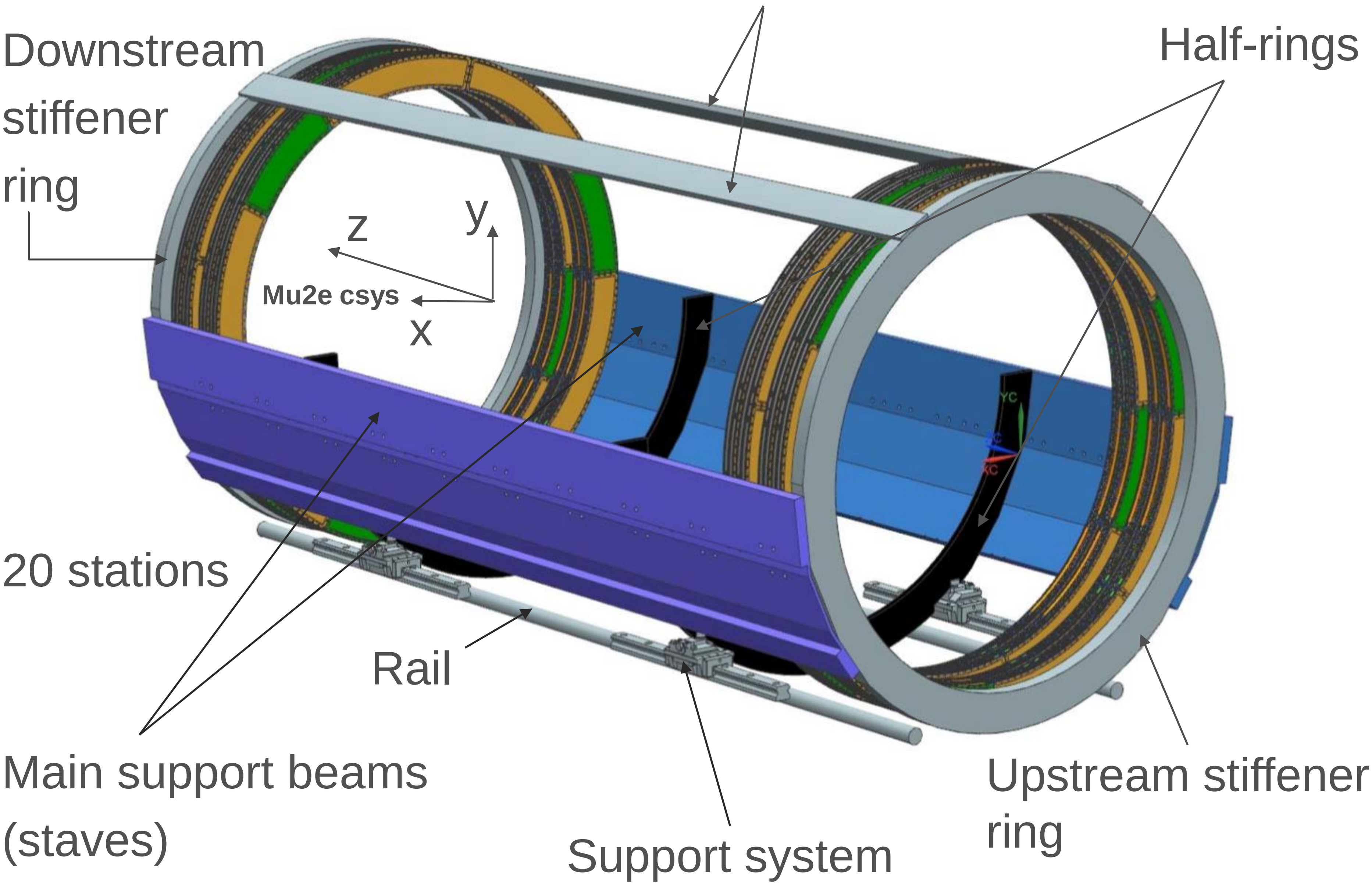
Final Review, Summer Student 2016

09/21/2016

Overview

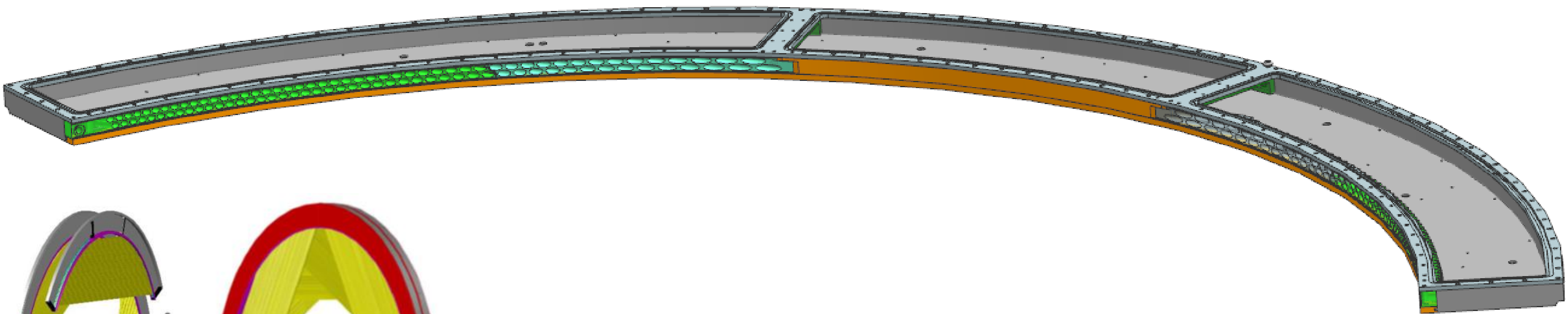
- Tracker existing design
- Task # 1: Conceptual design of electrical and gas system
- Task # 2: Analytical evaluation of mounting planes uncertainty
- Task # 3: Planes pressure contact analysis

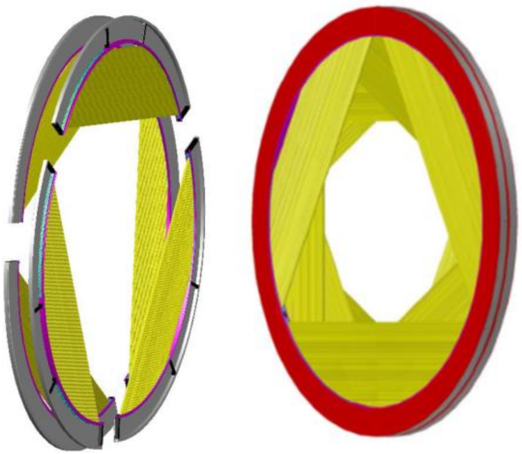
Tracker Frame



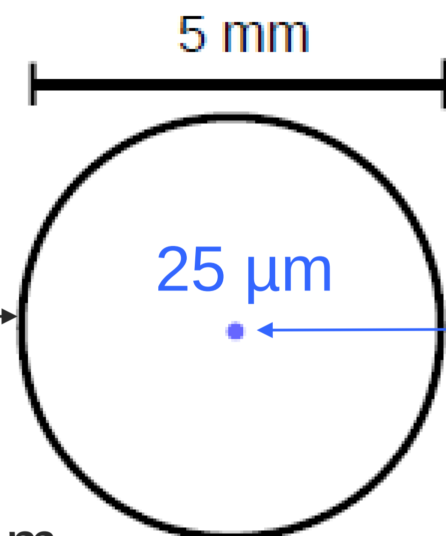
Mechanical construction

1 panel contains 96 straws





Gas: Ar-CO_2 (80:20)



straw

sense wire

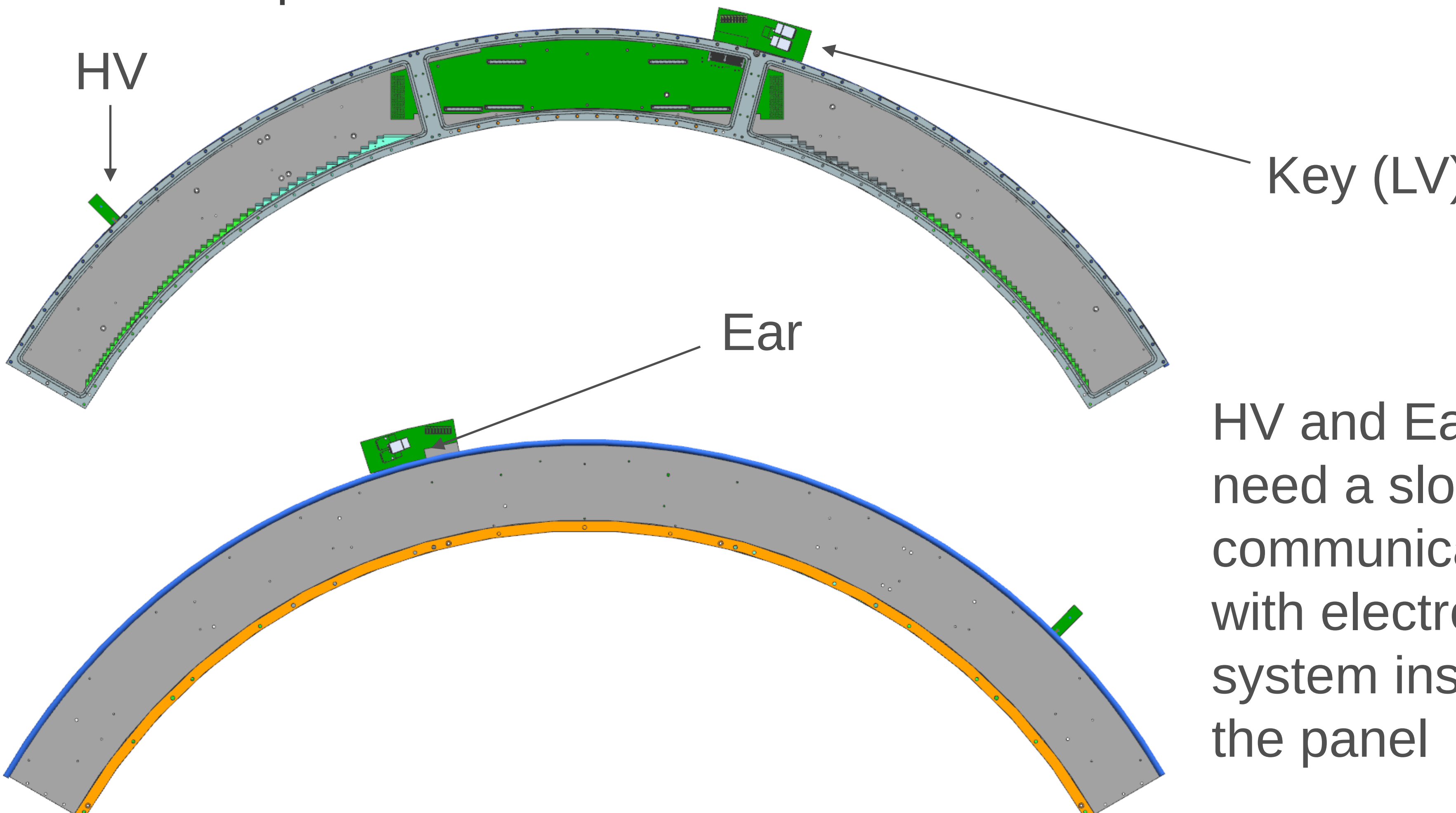
Mylar wall

Wall thickness = 15 µm

Gold plated tungsten

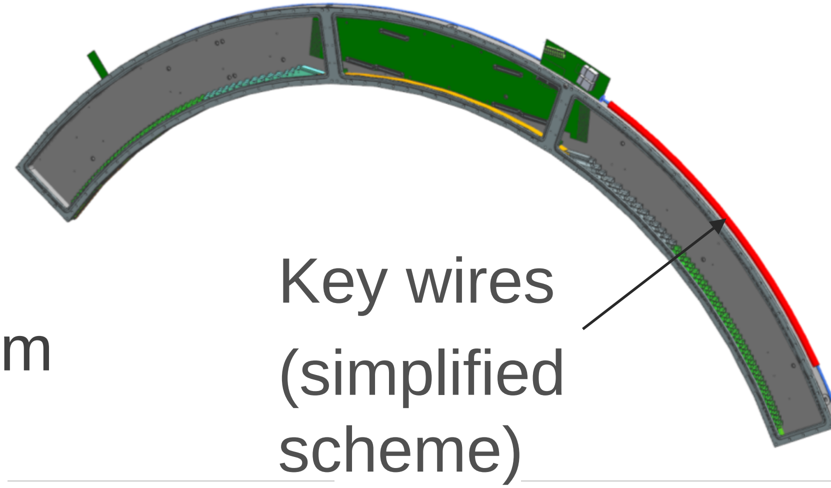
T1: Conceptual design of electrical and gas system

As the mechanical design is in advanced status, conceptual design and interfaces with electrical and gas systems need to be developed



HV and Ear need a slot to communicate with electronic system inside the panel

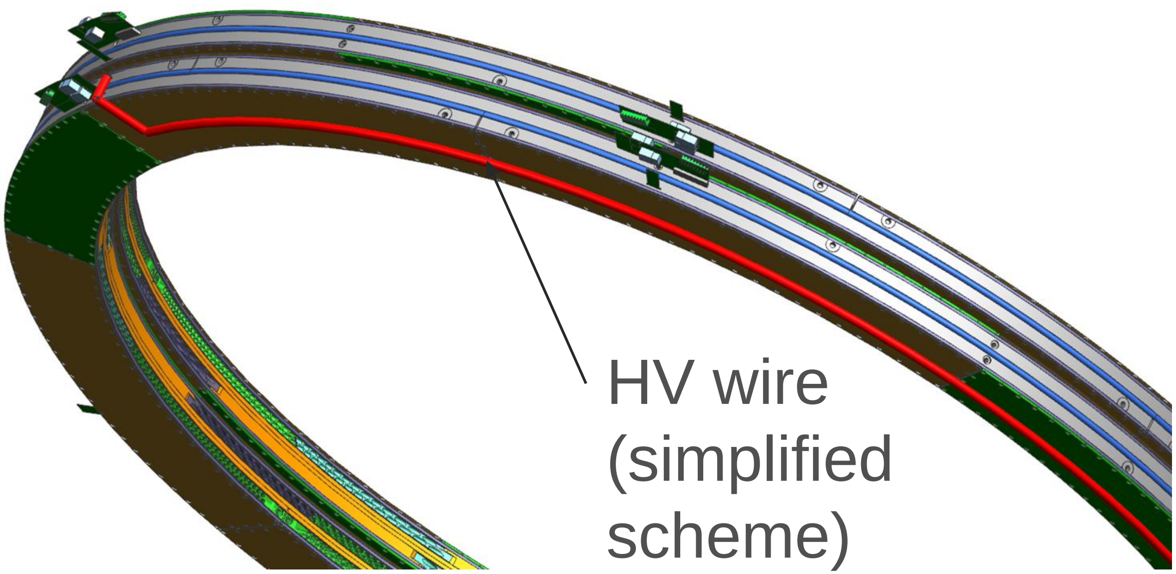
Panel cables layout



To work, Key needs:

32 20Ga square wires (s = 0.812 mm each)

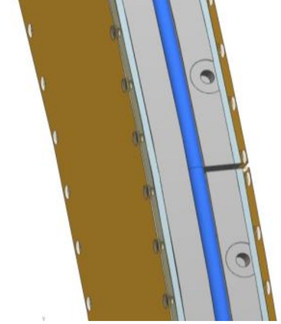
6 fiber wires ($Ø_{jacket}$ = 2 mm each)



HV cable follows radial and axial direction

Fermilab

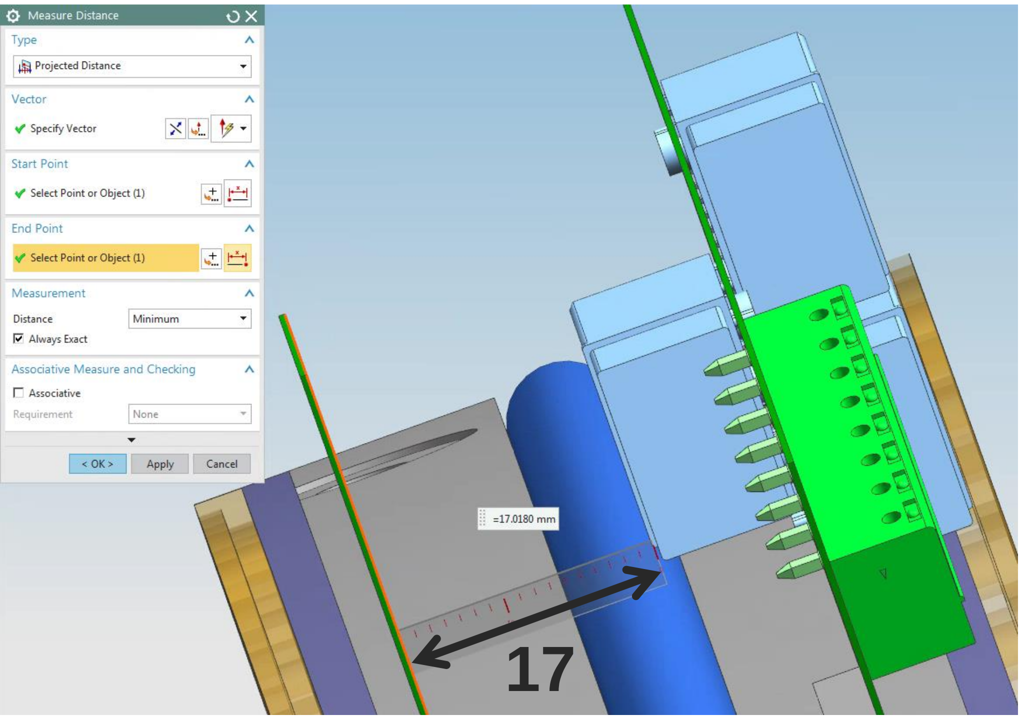
Panel cables layout – space constraints

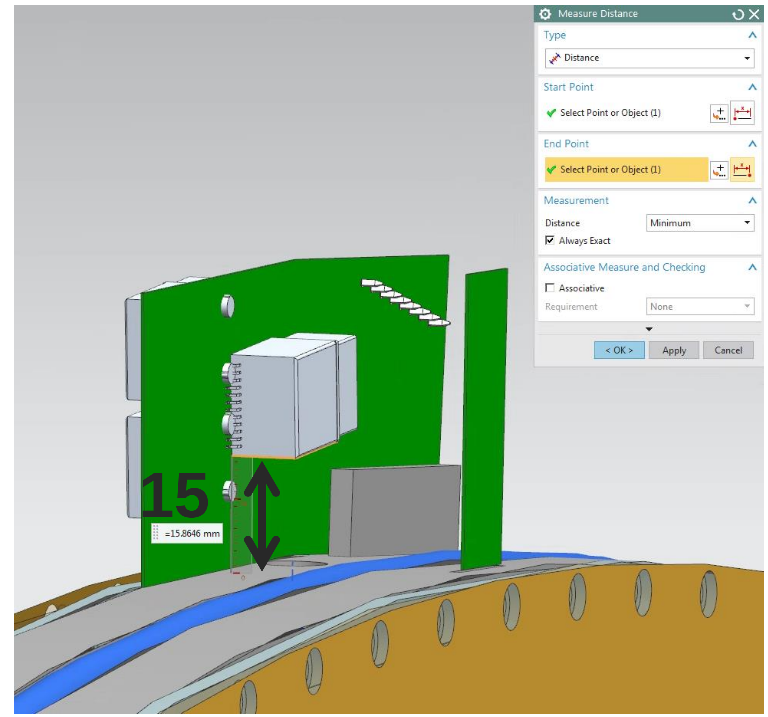


Along Z-axis:

Plane thickness = 47 mm

Laser tracking spheres encumbrance = 14 mm



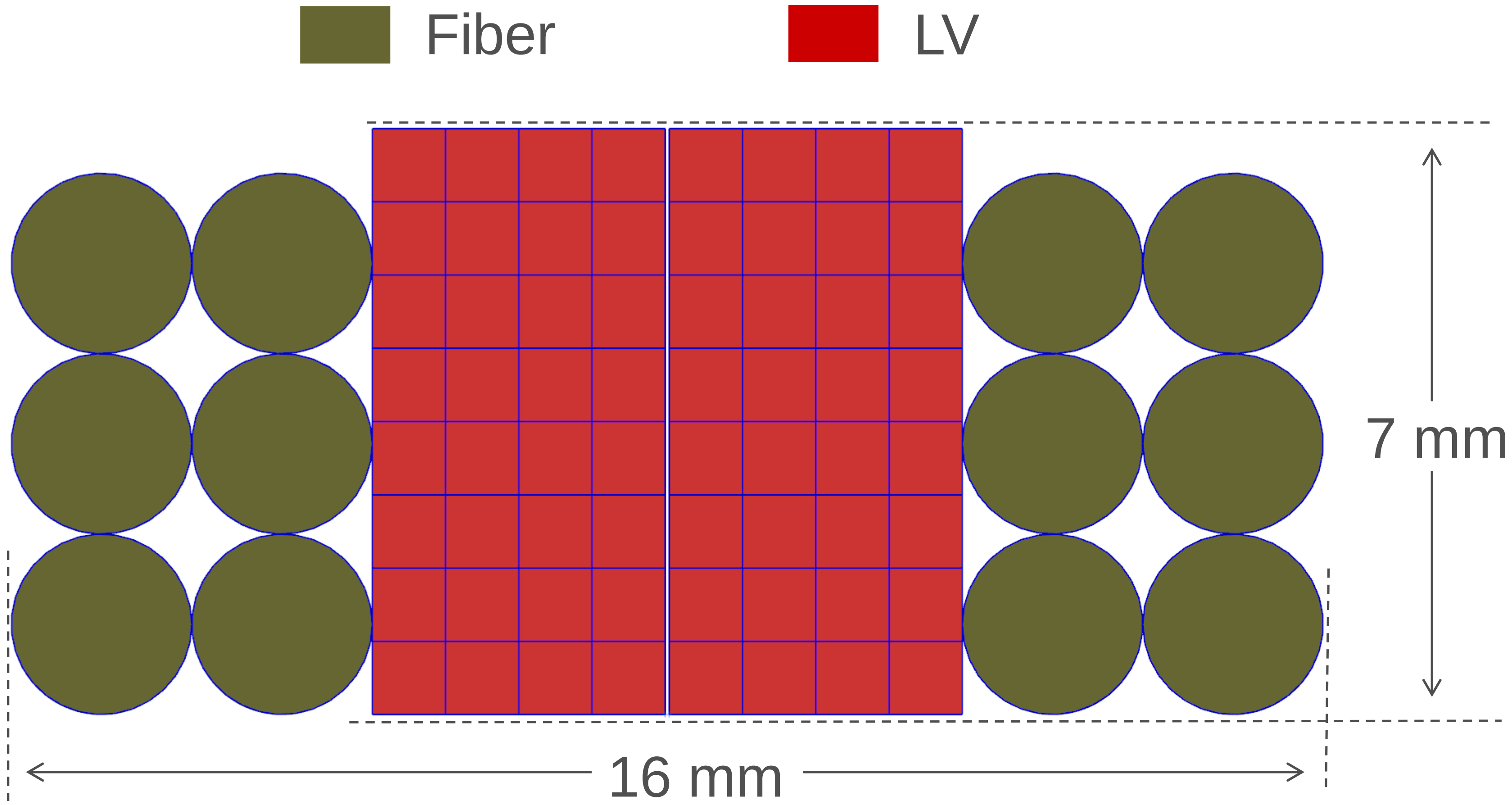


Key - HV minimum distance = 17 mm

Fiber connector minimum distance (from panel lateral surface) = 15 mm

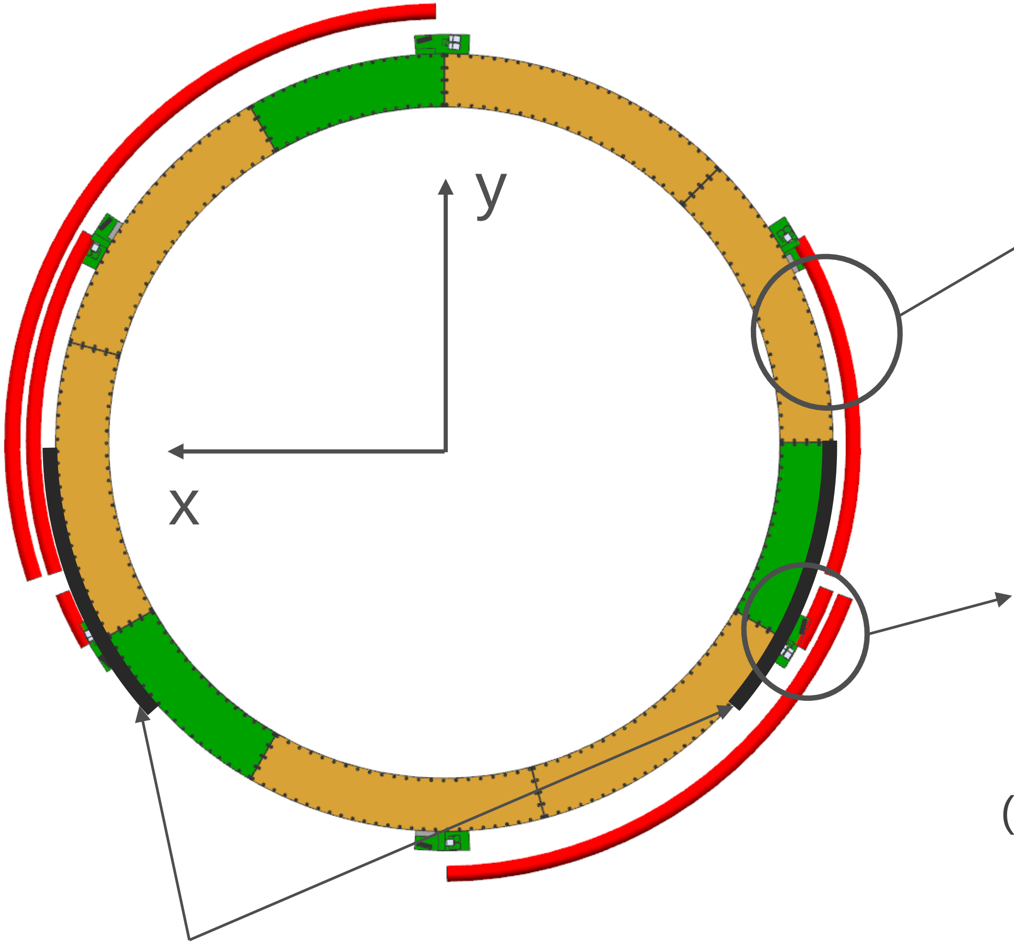
Panel cables layout – attempt

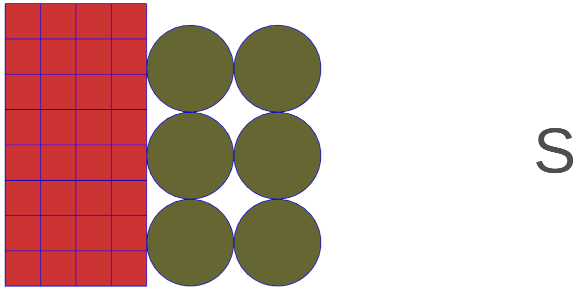
Considering the condition of maximum encumbrance, i.e. two bundles belonging to different Key-HV groups, an optimal solution is (section view):

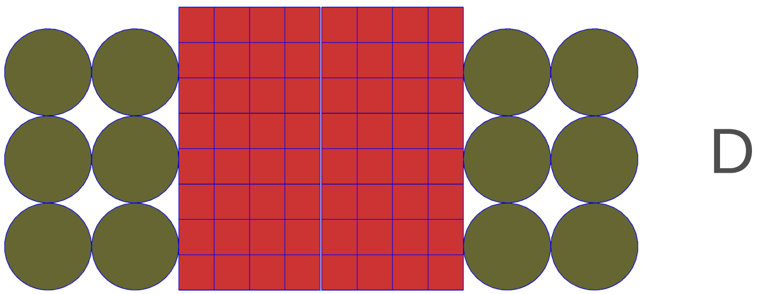


Panel cables layout – attempt

View of plane design (cables in red are not in the true radial position, they are in contact with panel):



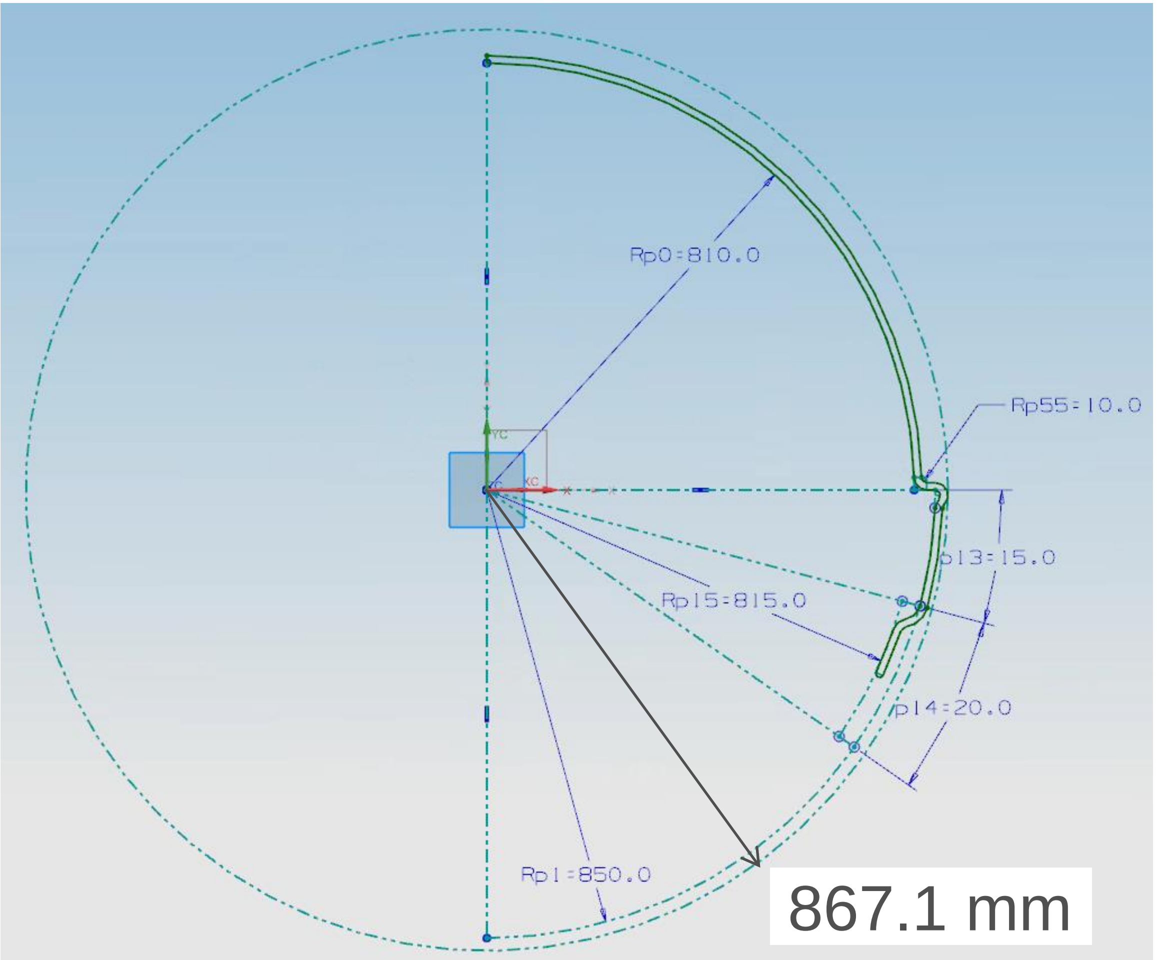


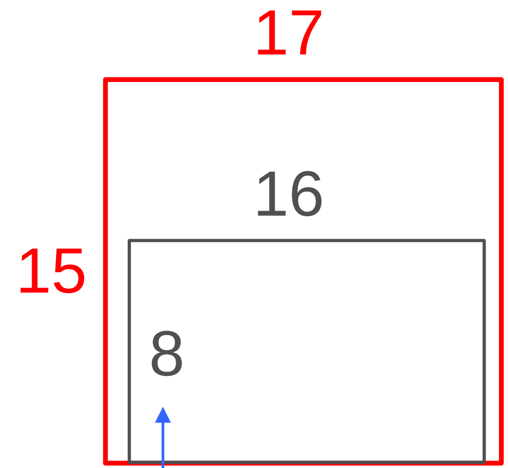


(Condition of maximum encumbrance)

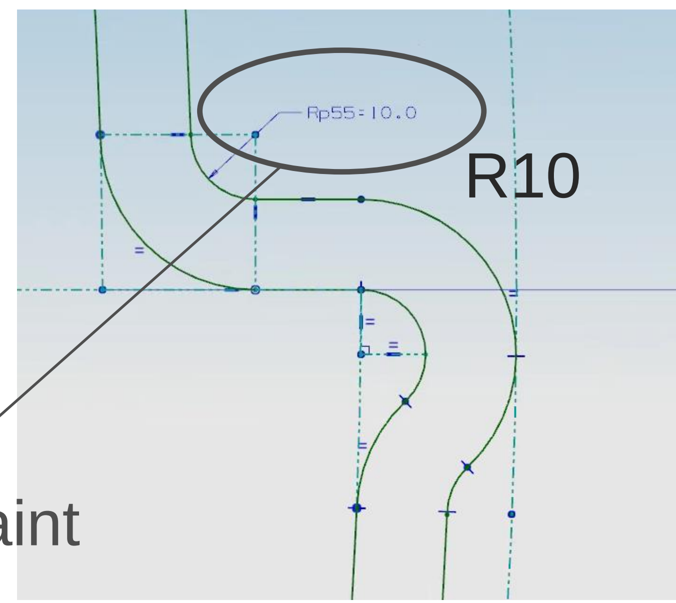
S = single bundle D = double bundle

Panel cables layout – attempt



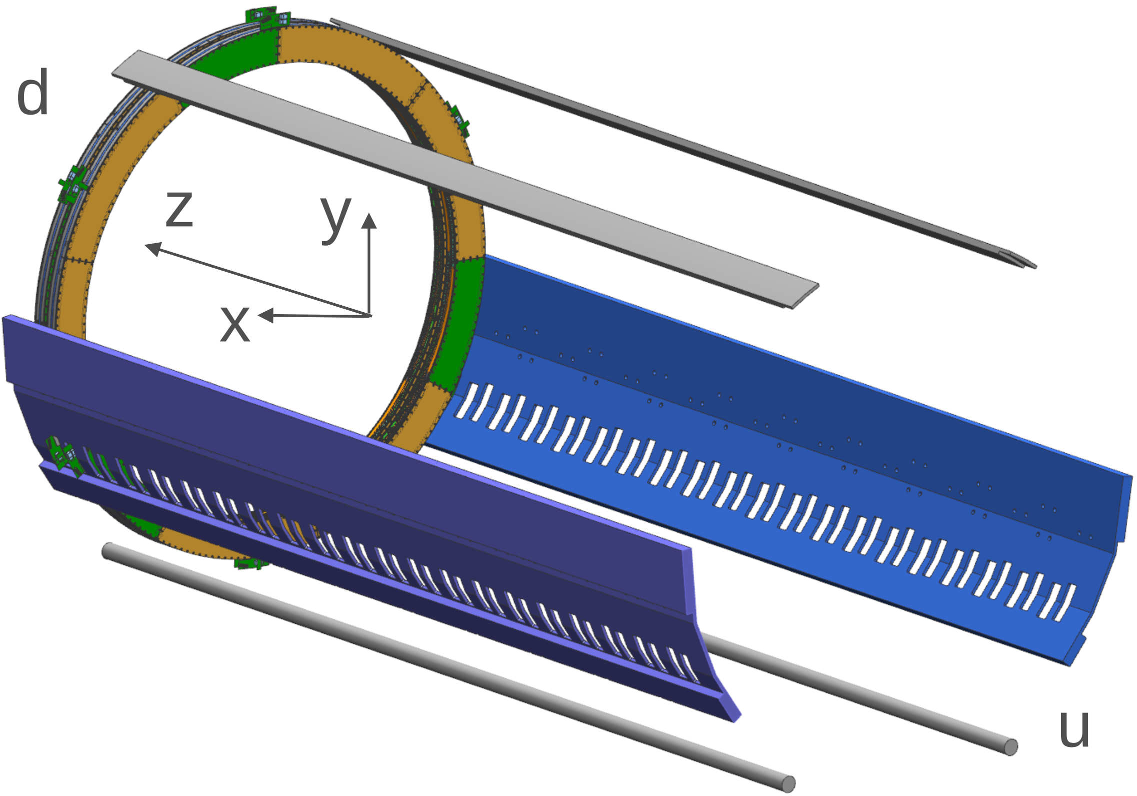


1 mm in addition due to cooling pipe

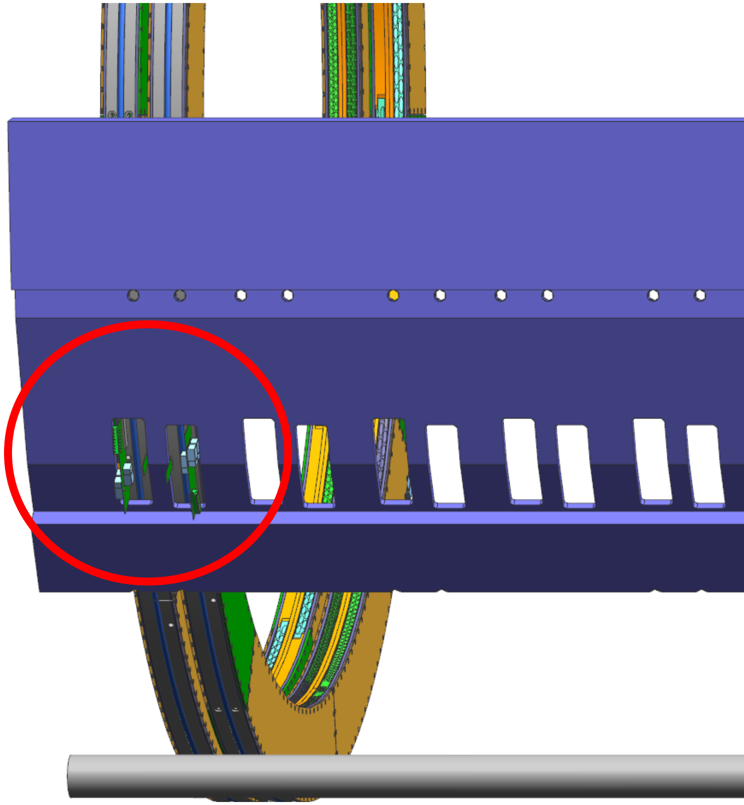


Technological constraint

Axial groove cables layout



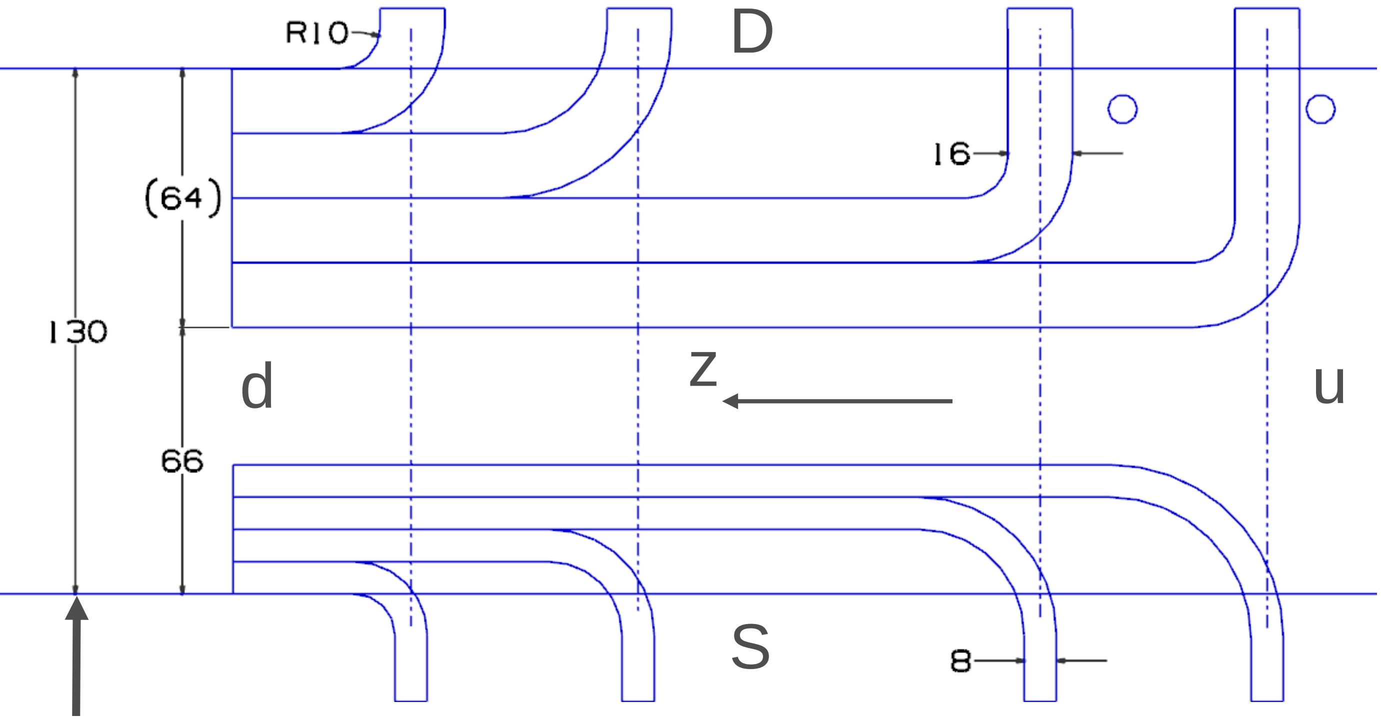
d = downstream u = upstream



Slots on axial groove (temporary design in pictures) have to be created to make room for Key and HV cards

Axial groove cables layout – attempt

For # 2 stations, a possible layout is (α plane):



Axial groove slot

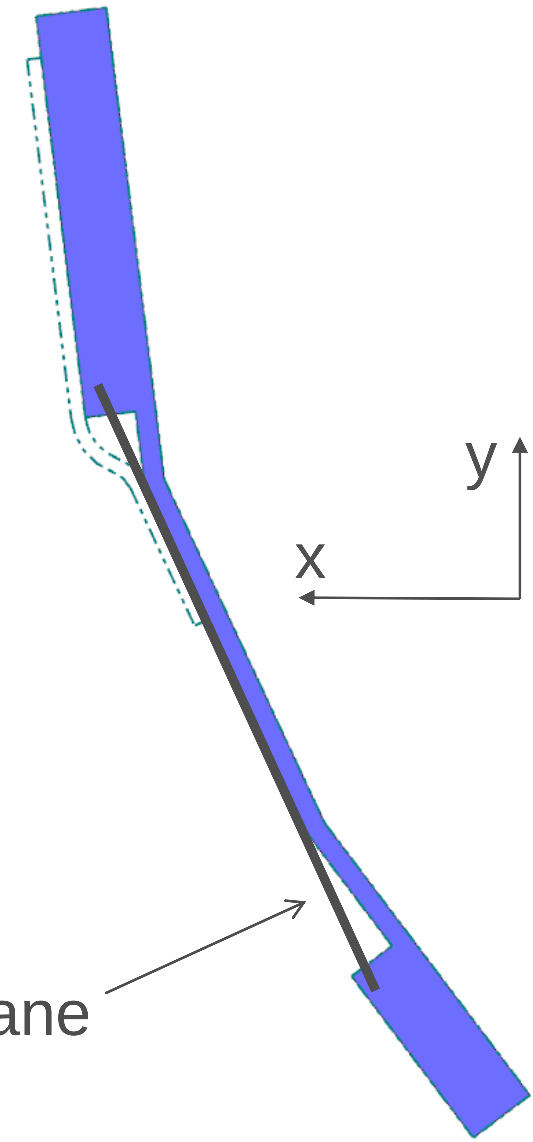
S = single bundle

D = double bundle

d = downstream

u = upstream

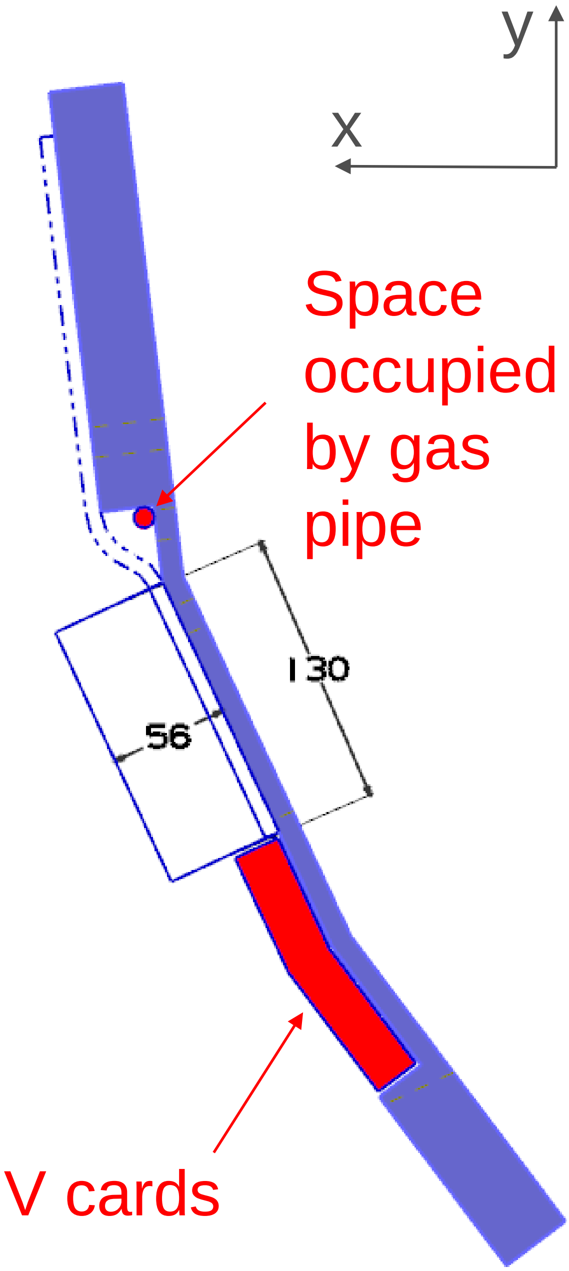
α plane



Axial groove cables layout – attempt

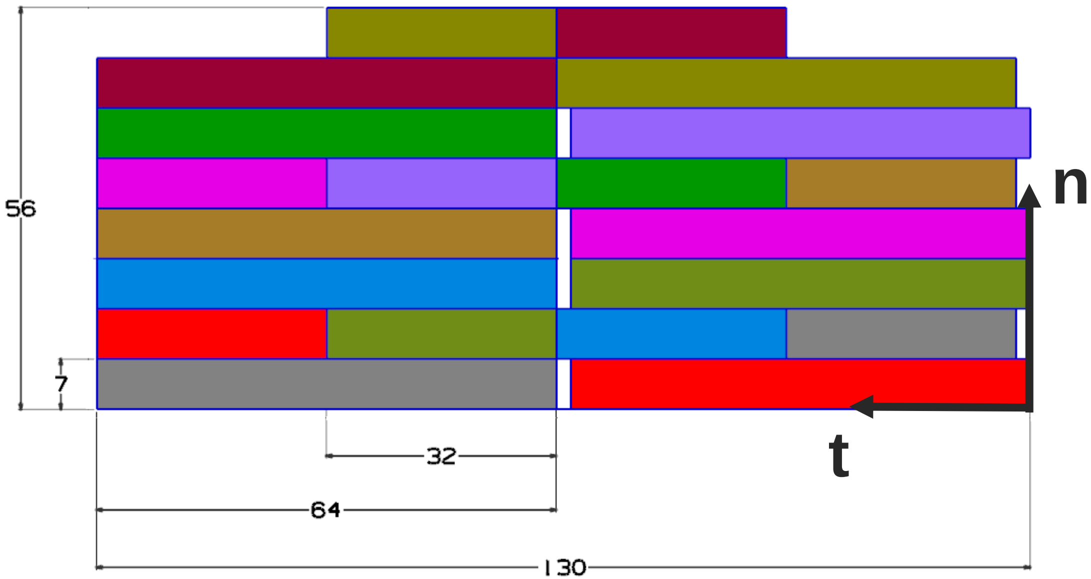
For # 20 stations, maximum radial extension of cables is 56 mm at **downstream** side of the tracker

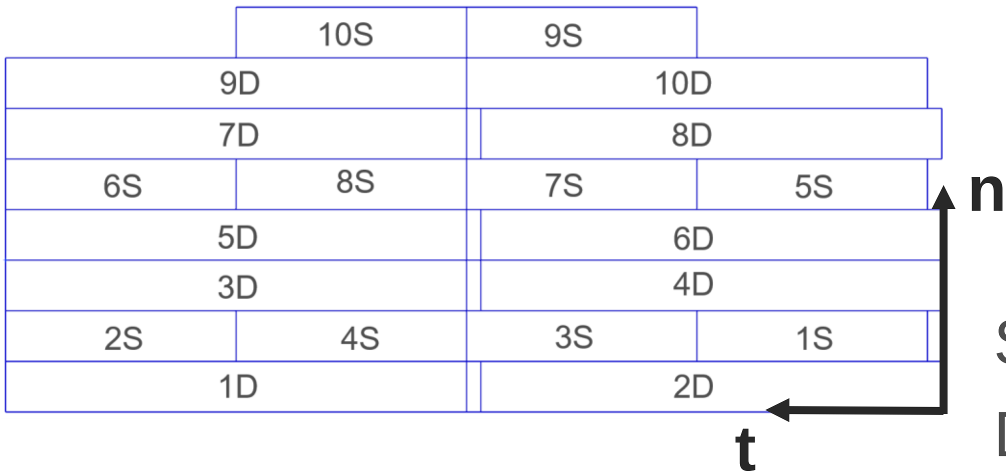
According to the proposal design, maximum radial encumbrance is 888 mm

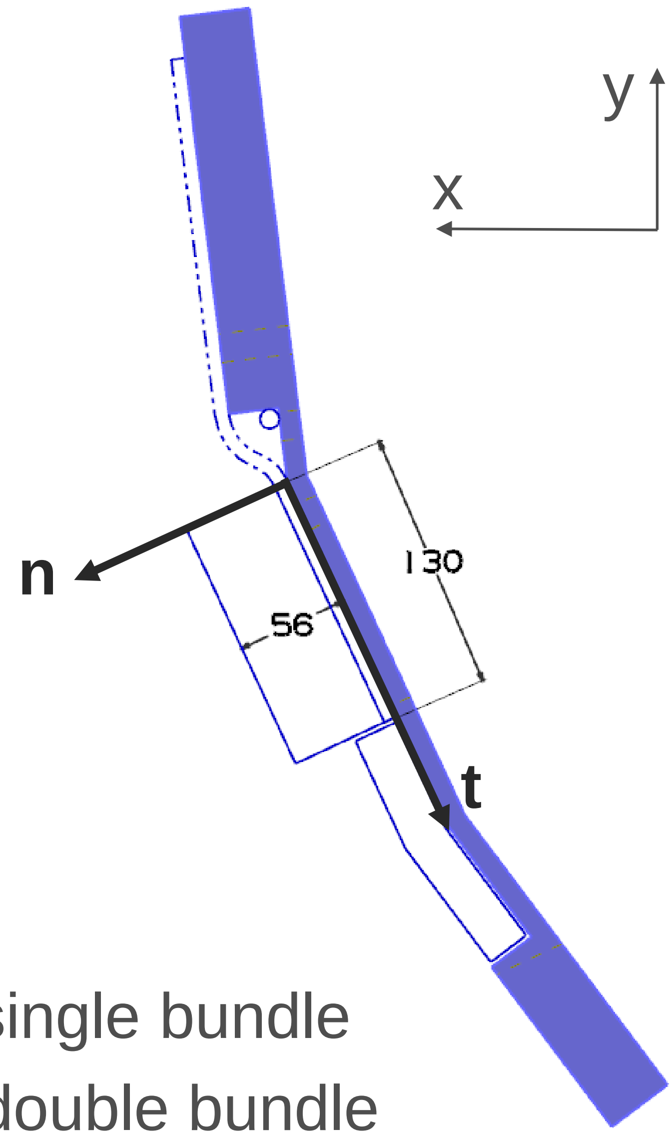


Axial groove cables layout – attempt

Each color represents # 2 stations (x' - y' section view):





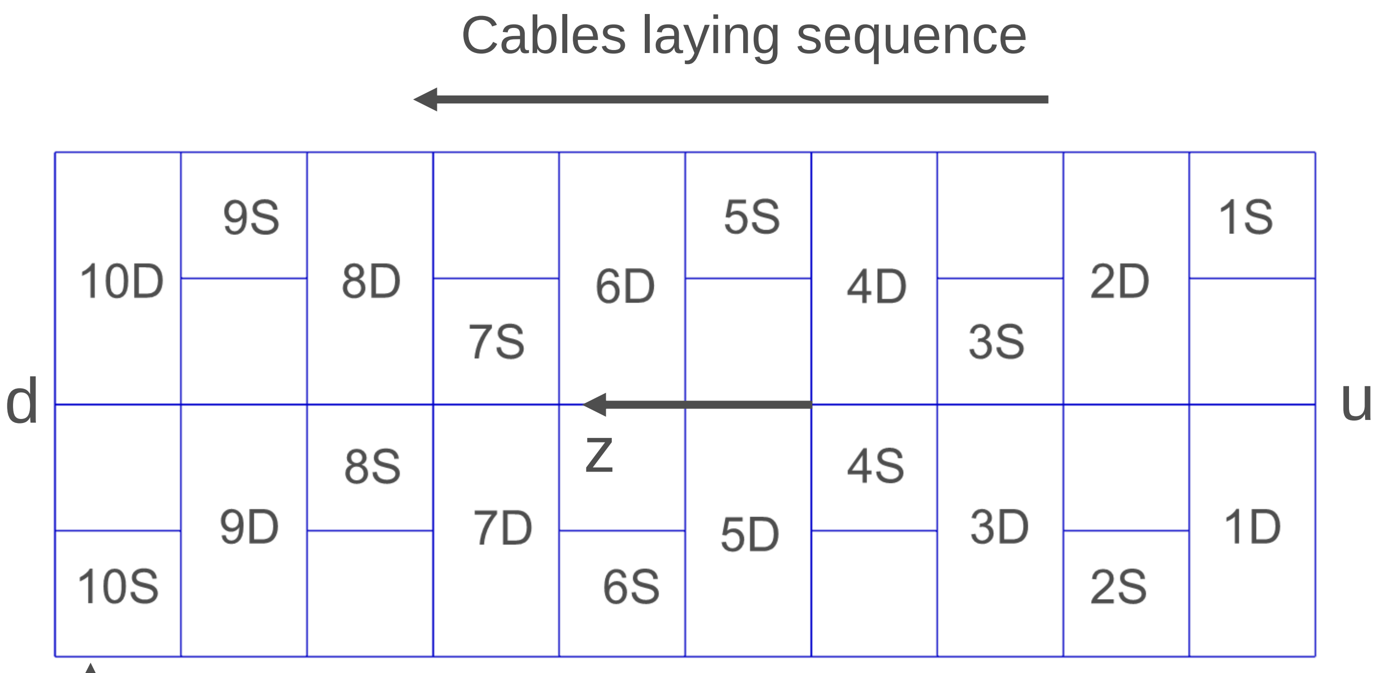


S = single bundle

D = double bundle

Axial groove cables layout – attempt

Overlapping simplified scheme (α plane):



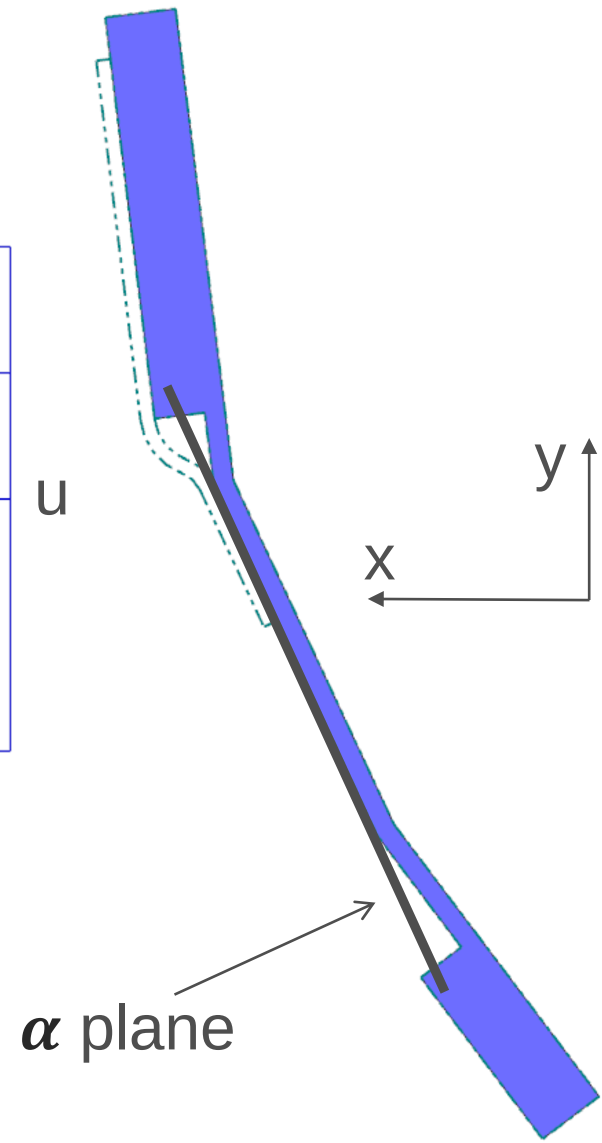
Axial groove slot

S = single bundle

D = double bundle

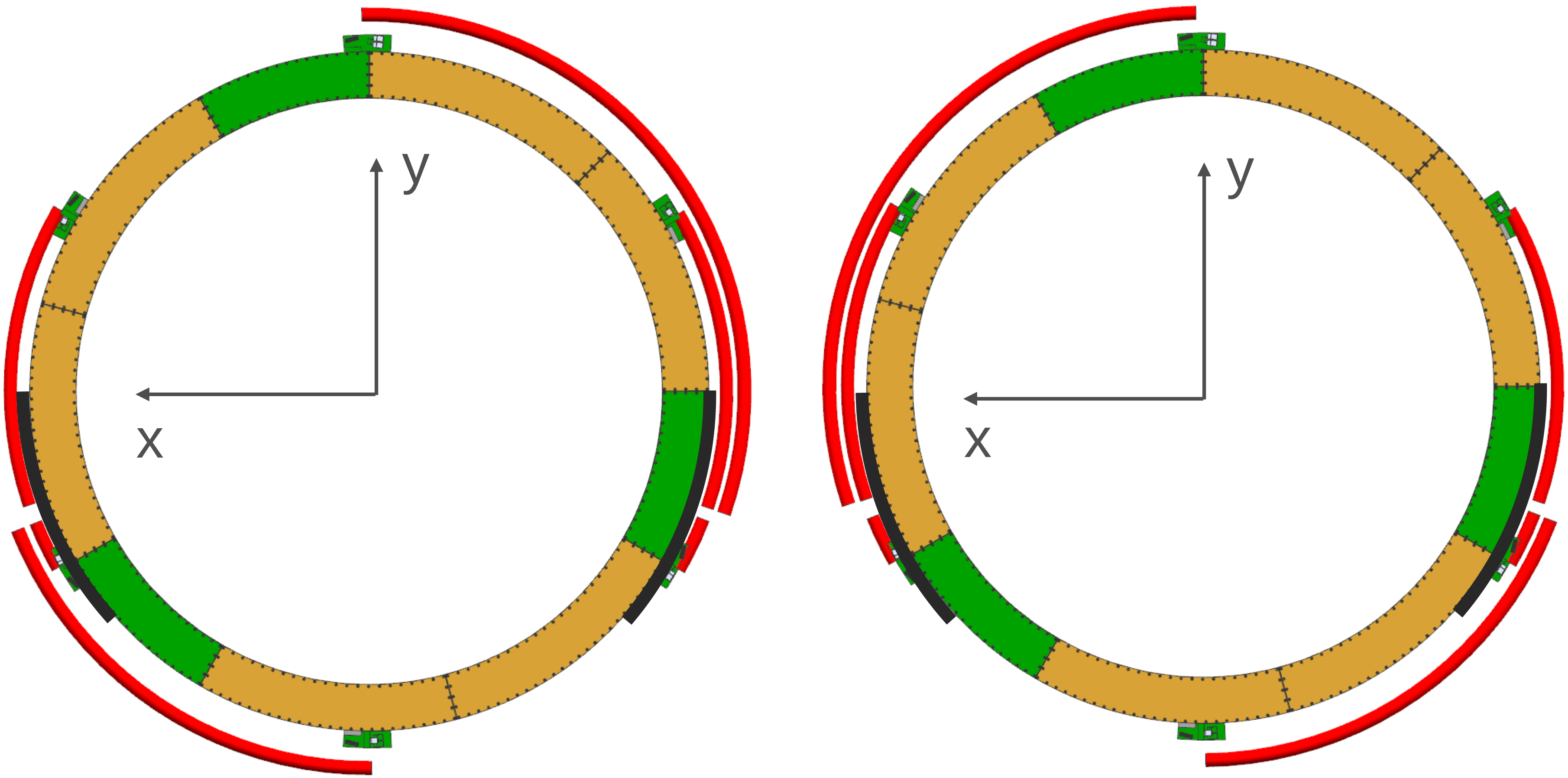
d = downstream

u = upstream



Axial groove cables layout – attempt

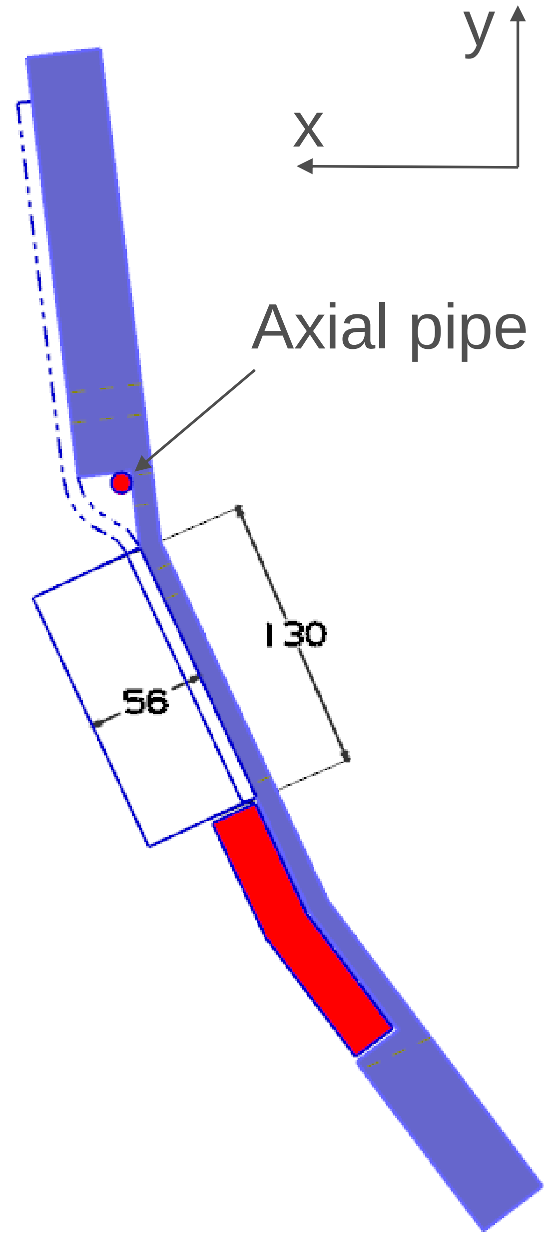
N.B. To make the layout above possible, every 2 stations cables have to follow this sequence (cables in red are not in the true radial position, they are in contact with panel):



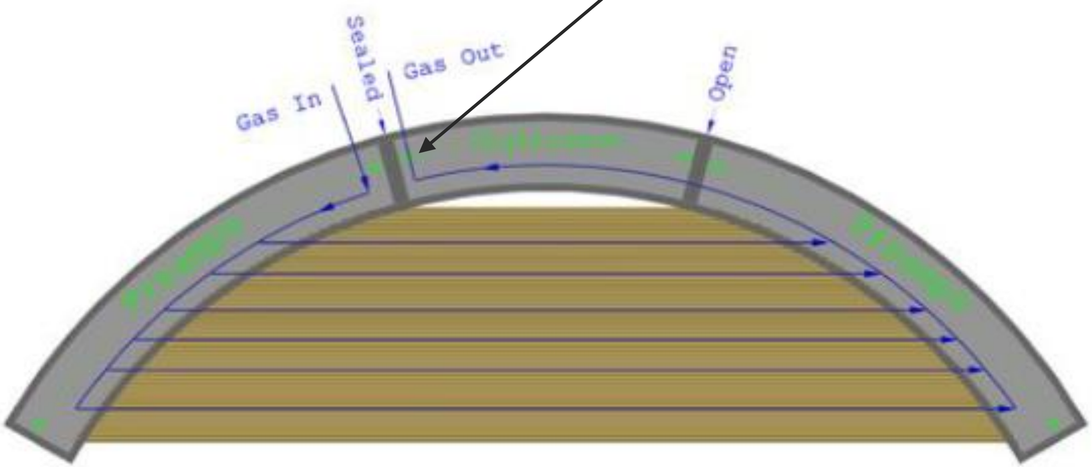
Gas pipeline layout

We assume we have:

- # 1 main inlet axial pipe (as shown);
- # 1 main outlet axial pipe;
- Layout surrounding the plane (radial and circumferential pipes) is still work in progress

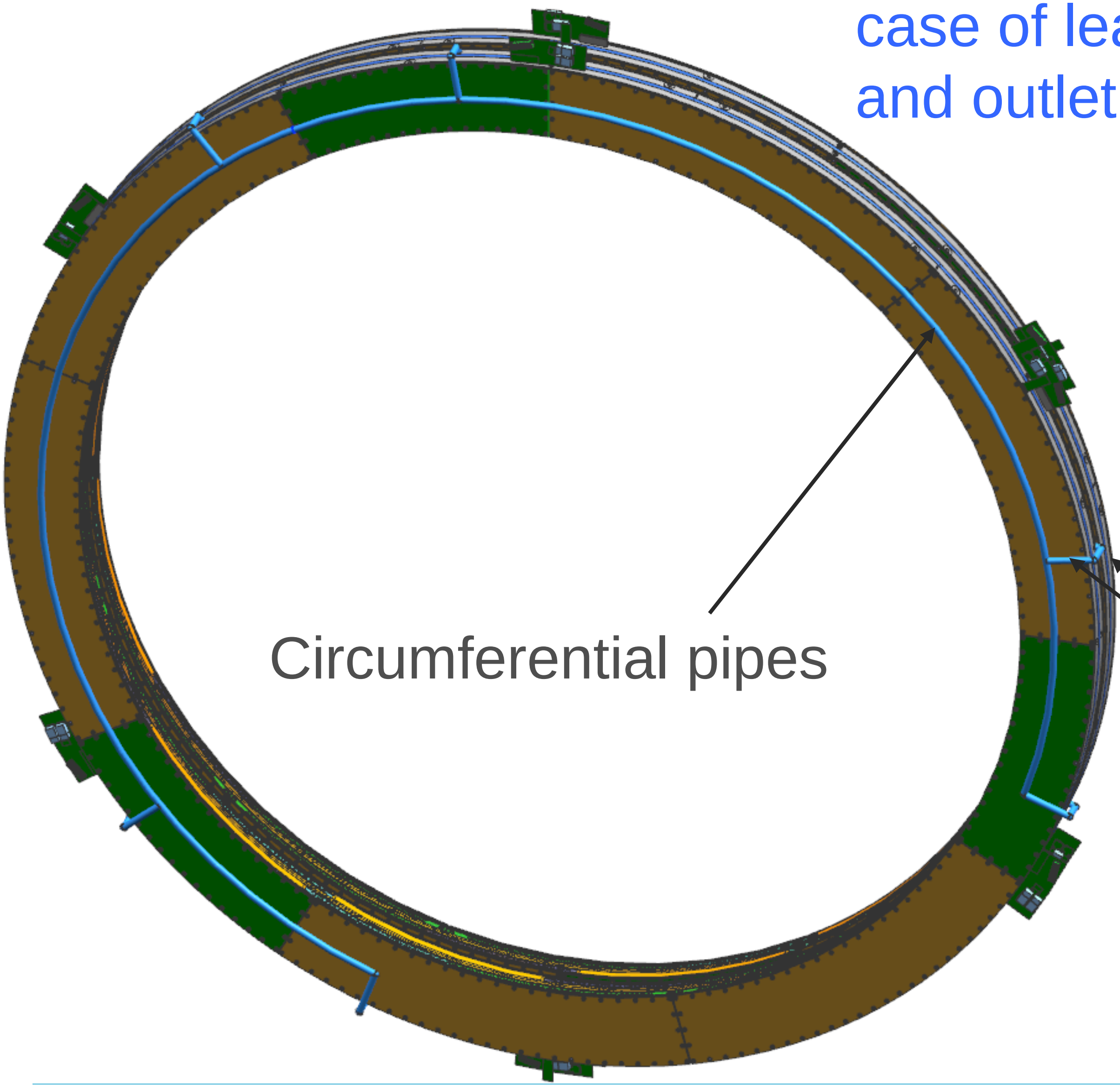


Radial pipes (installed inside the panel manifold)

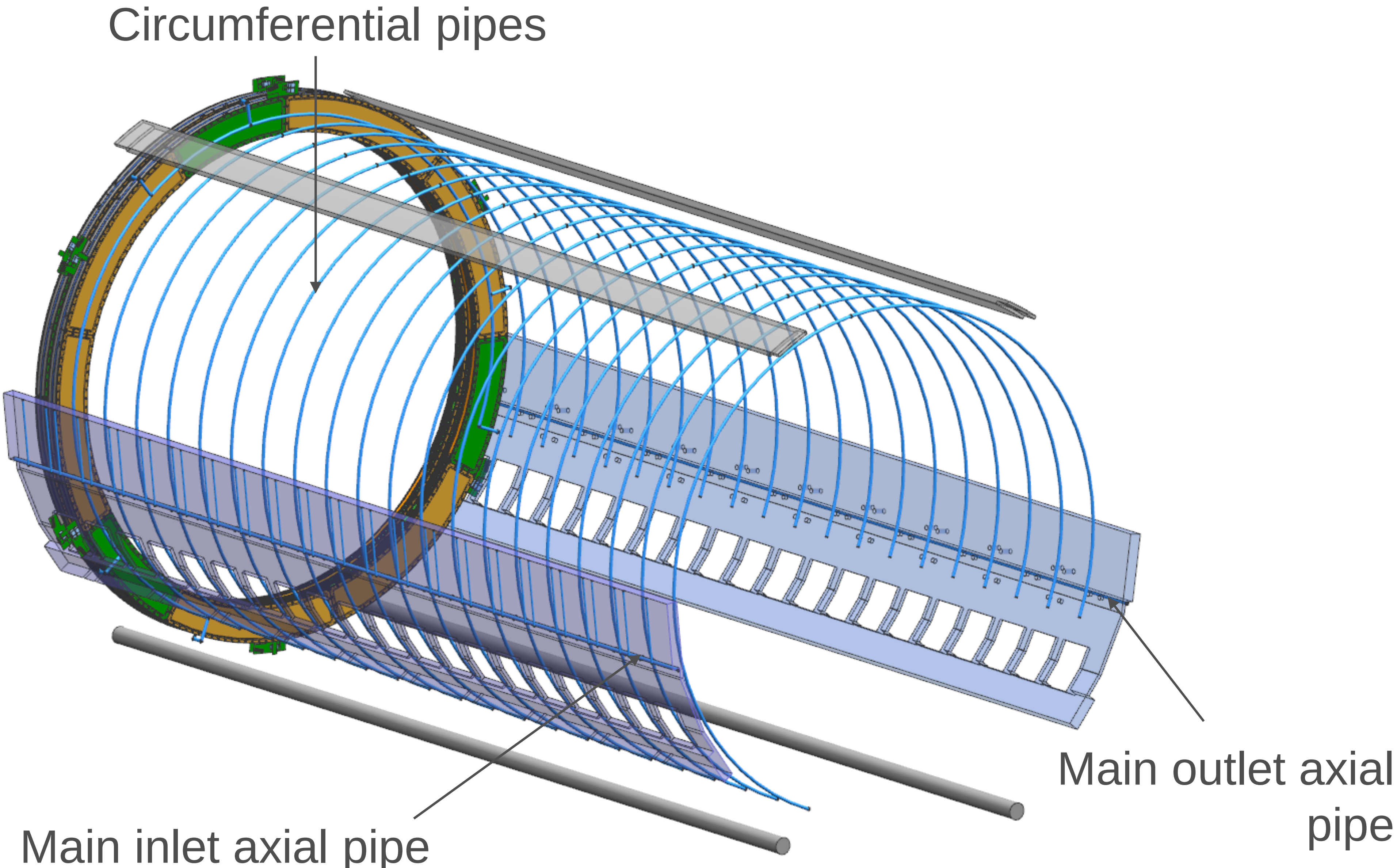


Gas pipeline layout

Requirements and specifications: each panel needs to be isolated in case of leakage (independent inlet and outlet gas lines)



Gas pipeline layout – attempt

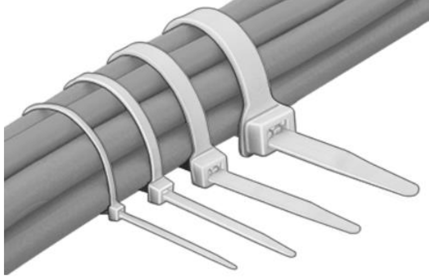


Cables fixing

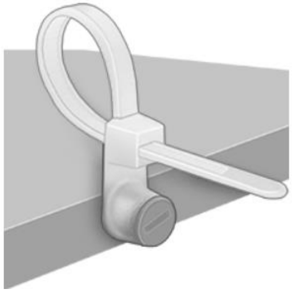
a) Vacuum compatible Cable Tie

b) Vacuum glue

1) Zip Tie

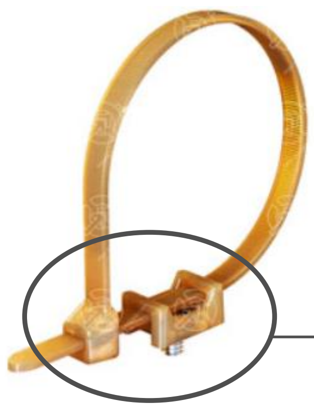


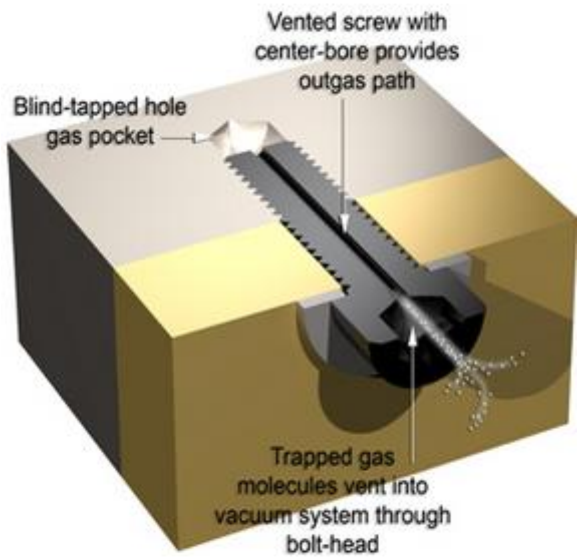
2) Mountable Cable Tie



- PEEK (Polyether ether ketone) Cable (up to 10^{-10} Torr)
- Stainless steel Cable (up to 10^{-11} Torr)

Radial direction

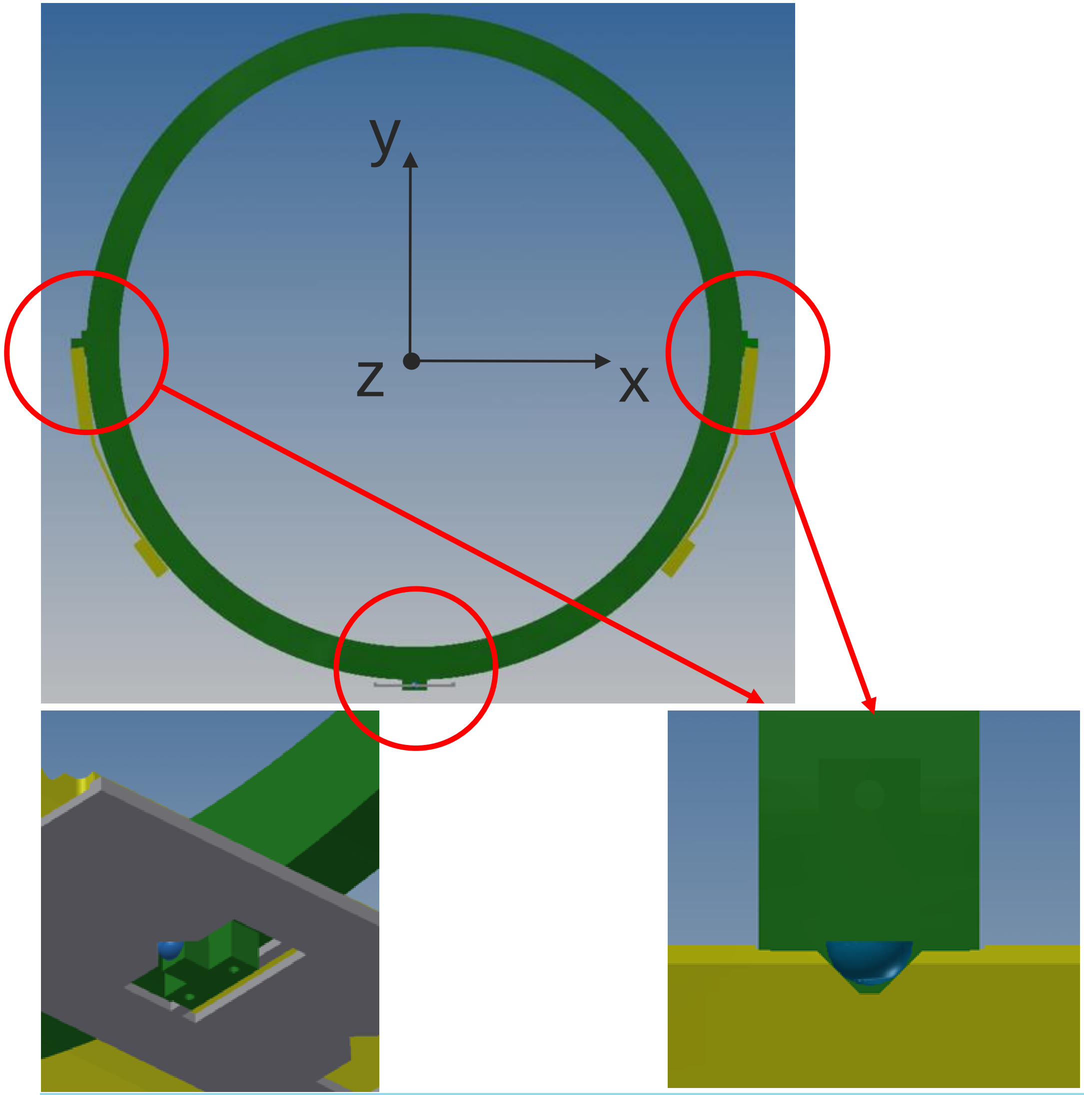


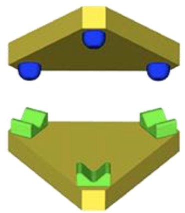


Vented screw

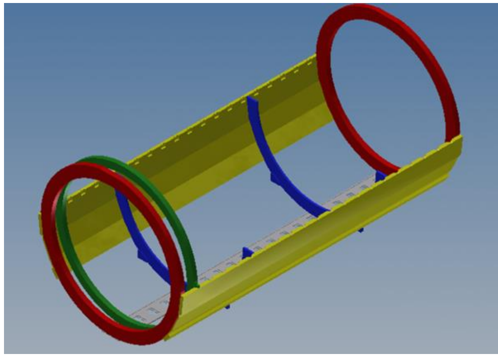
Kinematic mount (by courtesy of ANL)

Kinematic mount is realized through 3 grooves: 0°, 180°, 270°



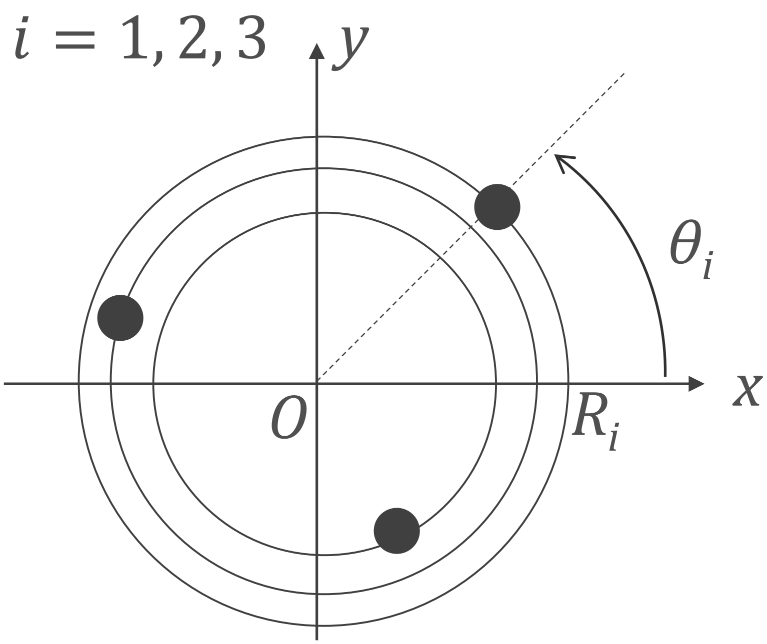


Through 3 points of contact, 6 degrees of freedom are removed, the constraint is **isostatic** (no stress due to heat or assembly errors)

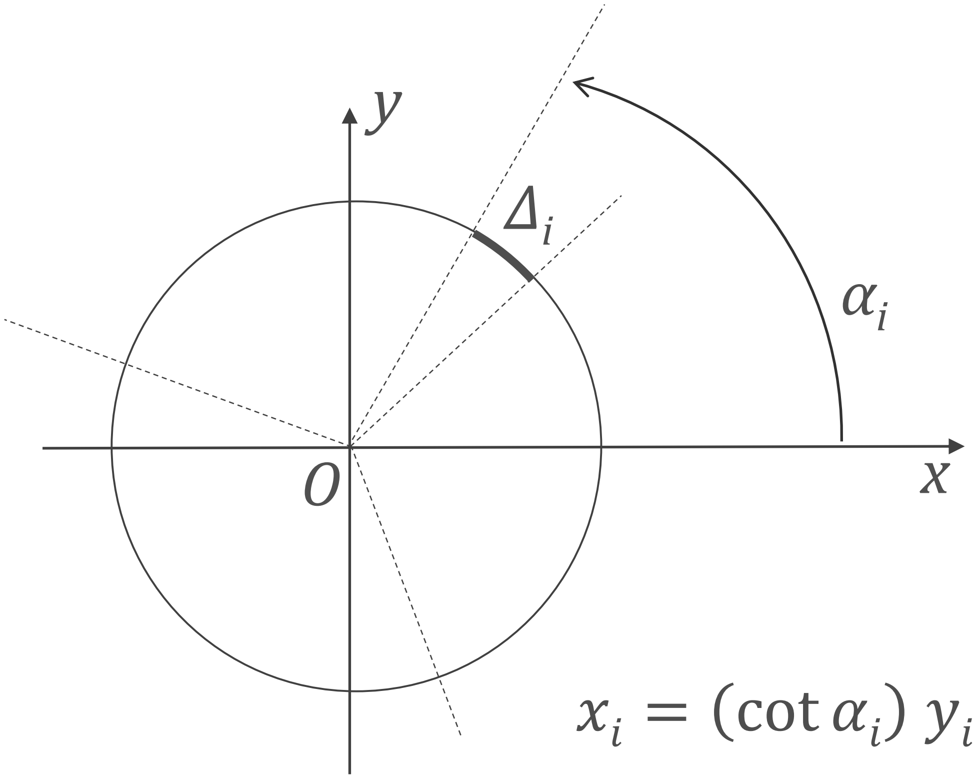


T2: Analytical evaluation of mounting planes uncertainty

When aligning balls and grooves, errors affect position of both of them; we assume that only grooves direction is affected by errors. The aim is to find the configuration that minimizes misalignment.



$$(x_i, y_i) = R_i(\cos\theta_i, \sin\theta_i)$$



$$x_i = (\cot\alpha_i)\, y_i$$

T2: Analytical evaluation of mounting planes uncertainty

$$\begin{pmatrix} \overline{x}_i \\ \overline{y}_i \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} x_i + x_0 \\ y_i + y_0 \end{pmatrix} \approx \begin{pmatrix} 1 & -\theta \\ \theta & 1 \end{pmatrix} \begin{pmatrix} x_i + x_0 \\ y_i + y_0 \end{pmatrix} =$$

$$= \begin{pmatrix} x_i + x_0 - \theta y_i \\ y_i + y_0 + \theta x_i \end{pmatrix} \qquad (1)$$

$x_0, y_0, \theta R \ \leq 0.1\, mm$

$$\overline{x}_i = (\cot\alpha_i)\, \overline{y}_i \qquad (2)$$

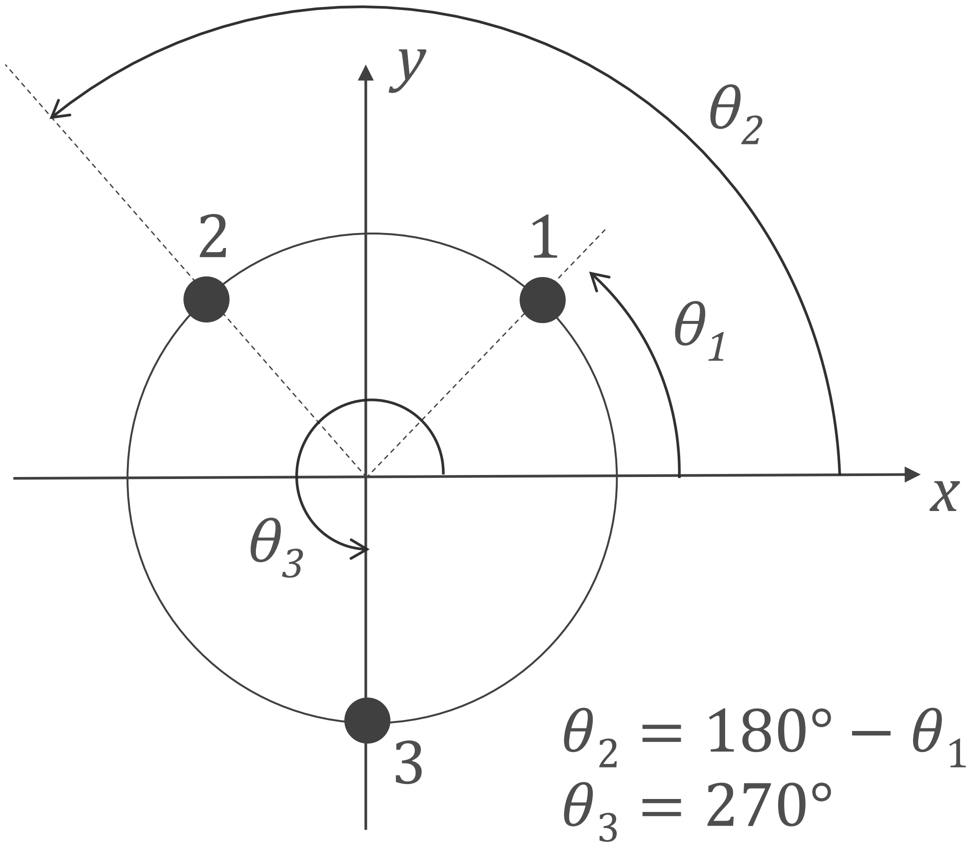
$$\alpha_i = \theta_i + \frac{\Delta_i}{R_i} \qquad (3)$$

$$\boxed{-x_0 \ \sin\theta_i + y_0 \cos\theta_i + \theta R = \Delta_i}$$

$$\begin{pmatrix} -\sin\theta_1 & \cos\theta_1 & 1 \\ -\sin\theta_2 & \cos\theta_2 & 1 \\ -\sin\theta_3 & \cos\theta_3 & 1 \end{pmatrix} \begin{pmatrix} x_0 \\ y_0 \\ \theta R \end{pmatrix} = \begin{pmatrix} \Delta_1 \\ \Delta_2 \\ \Delta_3 \end{pmatrix}$$

3 variables to consider $(\theta_1, \theta_2, \theta_3)$

T2: Analytical evaluation of mounting planes uncertainty



$$\theta_2 = 180° - \theta_1$$
$$\theta_3 = 270°$$

Assuming that:

- 1 ball is on the lower half and 2 balls are on the upper (more stability)
- a symmetrical configuration is preferable (centroid on vertical axis, if balls 1 and 2 are identical)

there is only 1 variable left, θ_1

$$0° \leq \theta_1 < 90°$$

$$\begin{pmatrix} -\sin\theta_1 & \cos\theta_1 & 1 \\ -\sin\theta_1 & -\cos\theta_1 & 1 \\ 1 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_0 \\ y_0 \\ \theta R \end{pmatrix} = \begin{pmatrix} \Delta_1 \\ \Delta_2 \\ \Delta_3 \end{pmatrix}$$

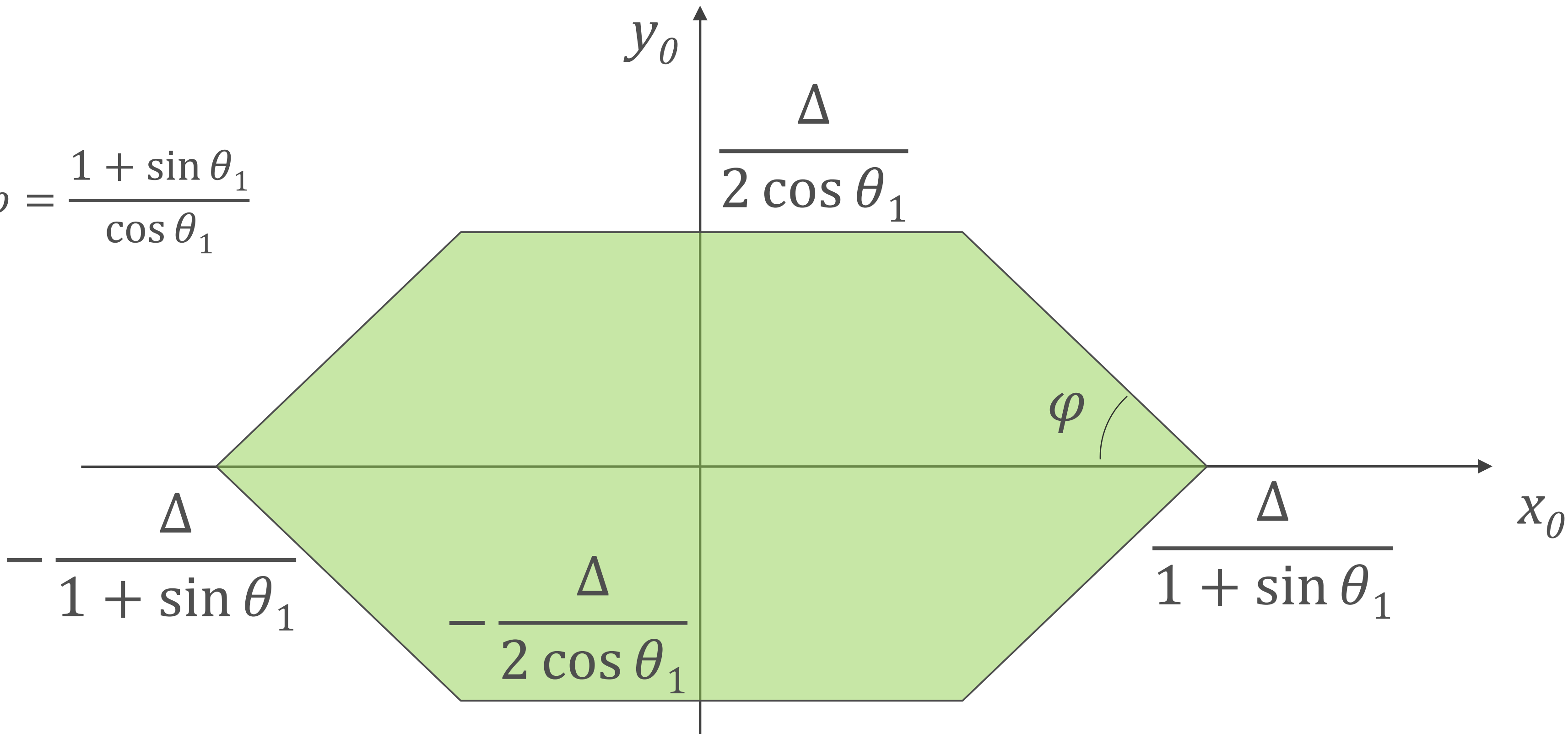
$$-\frac{\Delta}{2} \leq \Delta_i \leq \frac{\Delta}{2}$$

T2: Analytical evaluation of mounting planes uncertainty

$$
\begin{cases}
-\Delta \leq (-\sin\theta_1 - 1)x_0 + \cos\theta_1 \, y_0 \leq \Delta \\
-\Delta \leq (-\sin\theta_1 - 1)x_0 - \cos\theta_1 \, y_0 \leq \Delta \\
-\Delta \leq 2\cos\theta_1 \, y_0 \leq \Delta
\end{cases}
$$

$$A = A(\theta_1)$$

$$\tan\varphi = \frac{1+\sin\theta_1}{\cos\theta_1}$$



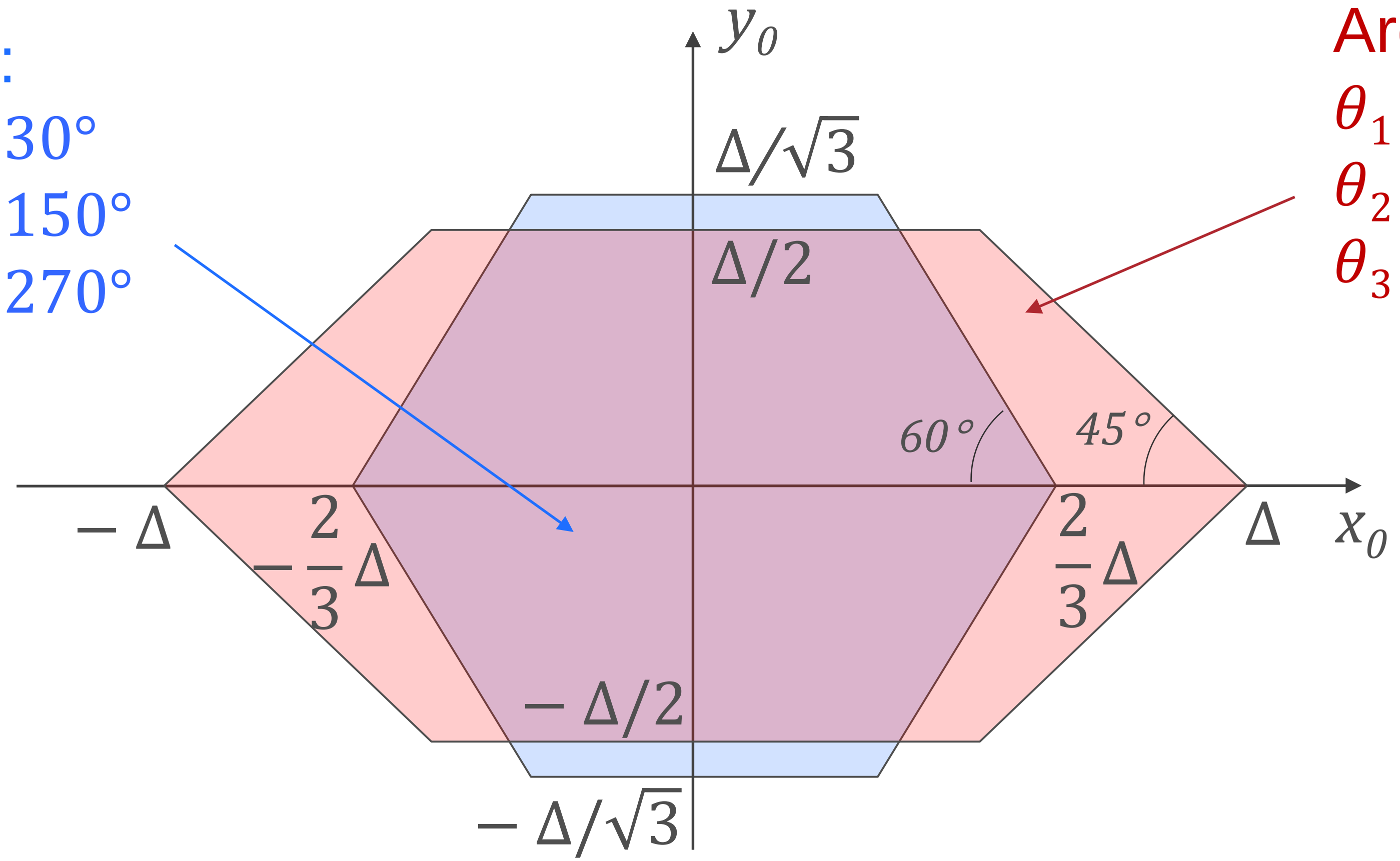
T2: Analytical evaluation of mounting planes uncertainty

$$A = \frac{3}{2} \cdot \frac{\Delta^2}{(1 + \sin\theta_1)\cos\theta_1}$$

$\theta_1 = 30°$ Ideal configuration

Ideal:
$\theta_1 = 30°$
$\theta_2 = 150°$
$\theta_3 = 270°$

Argonne:
$\theta_1 = 0°$
$\theta_2 = 180°$
$\theta_3 = 270°$



T3: Planes pressure contact analysis

Argonne proposed a **sphere - cylindrical groove** as support point (HertzWin software):

R_s = 9.525 mm

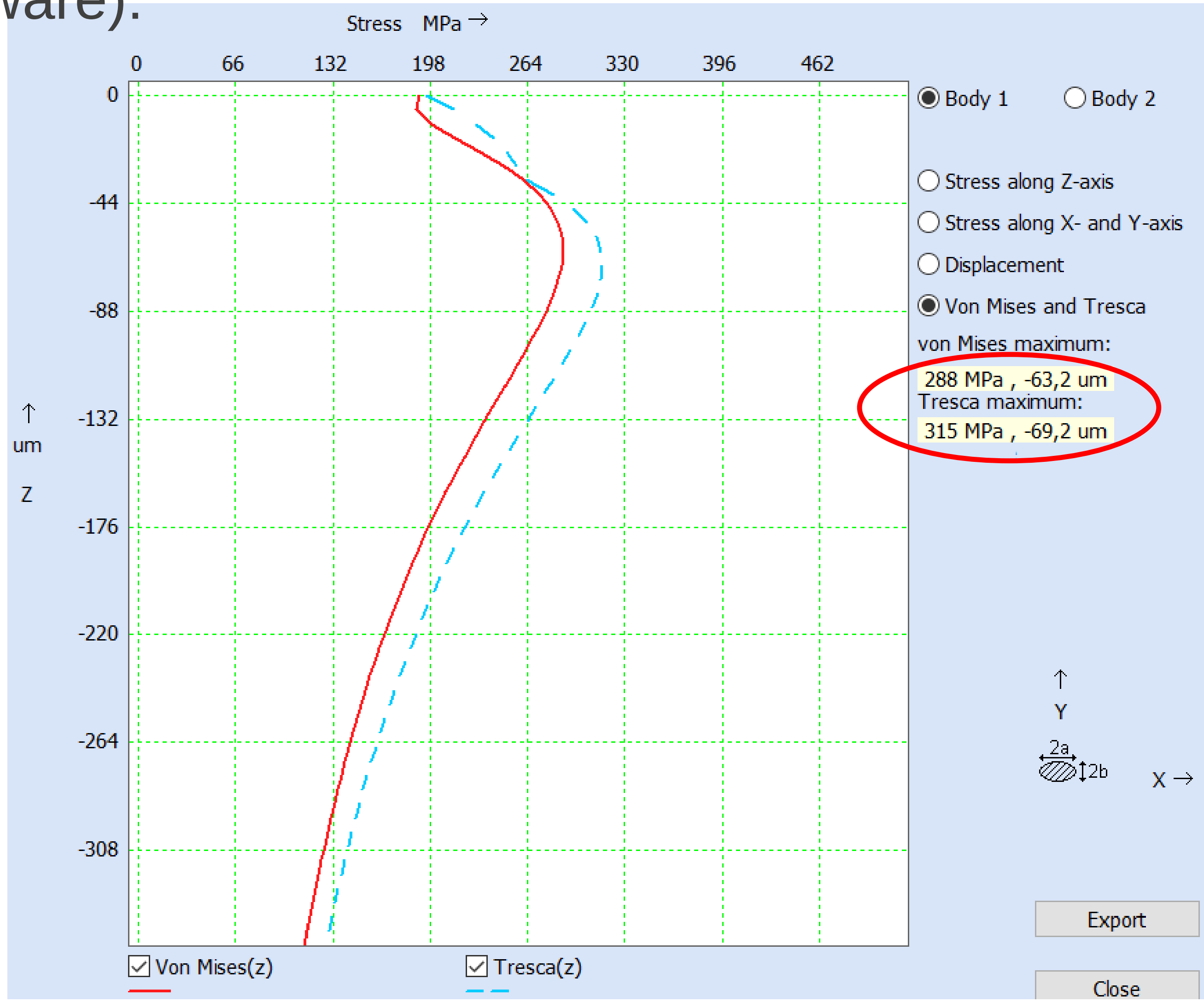
R_{cg} = 9.600 mm

(both stainless steel)

σ_{eqVM} = 288 MPa

σ_y = 290 MPa

SF = 1.01 ✗



T3: Planes pressure contact analysis

Different materials are chosen:

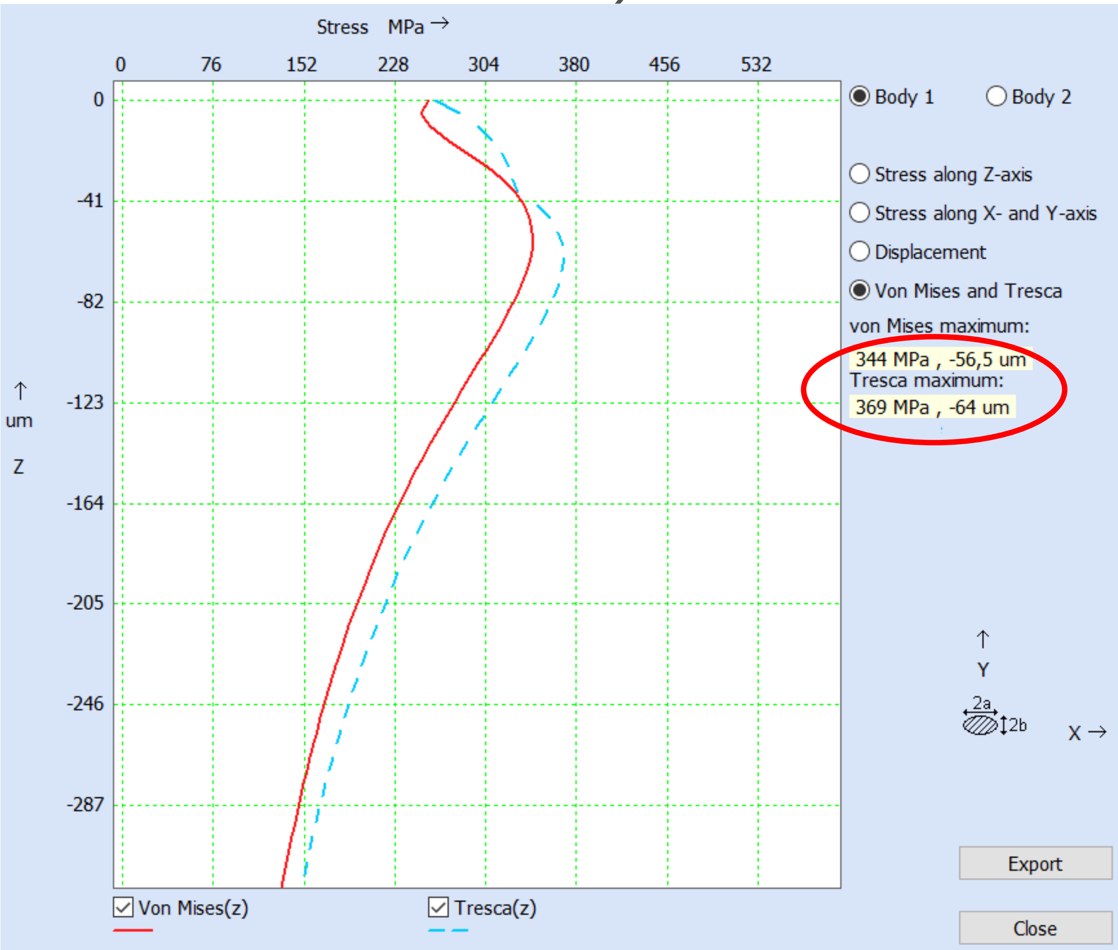
R_s = 9.525 mm (silicon-nitride ceramic ball)

R_{cg} = 9.600 mm (stainless steel, coated with WC)

σ_{eqVM} = 344 MPa

σ_y = 1000 MPa

SF = 2.91



Pressure contact sensitivity analysis

We may change dimensions:

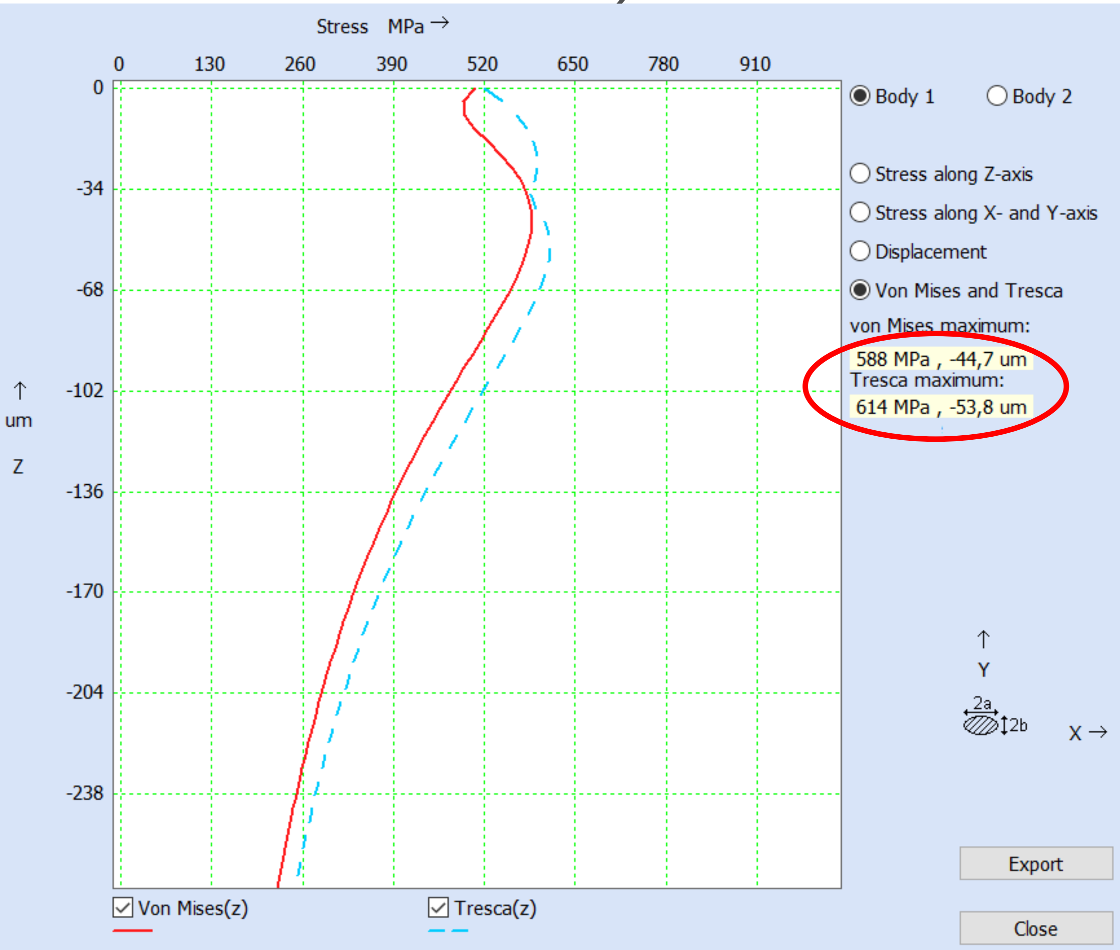
R_s = 4.850 mm (silicon-nitride ceramic ball)

R_{cg} = 4.900 mm (stainless steel, coated with WC)

σ_{eqVM} = 595 MPa

σ_y = 1000 MPa

SF = 1.68



Next steps

- Complete the design of electrical and gas system (with all details) and provide final layout drawings
- Refine Argonne proposal design of plane support points along with fabrication drawings

Thank you for your attention!