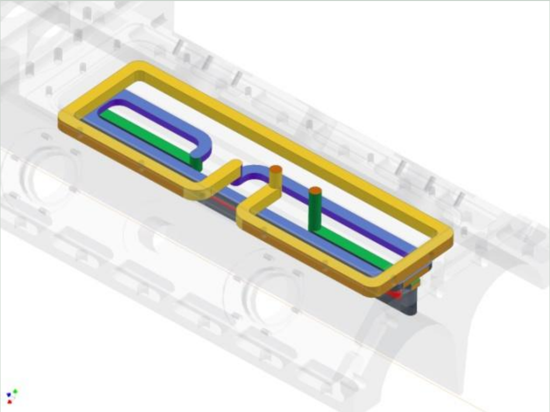
RFQ Mechanical Design

by **Juergen Pozimski**
on behalf of
Peter Savage

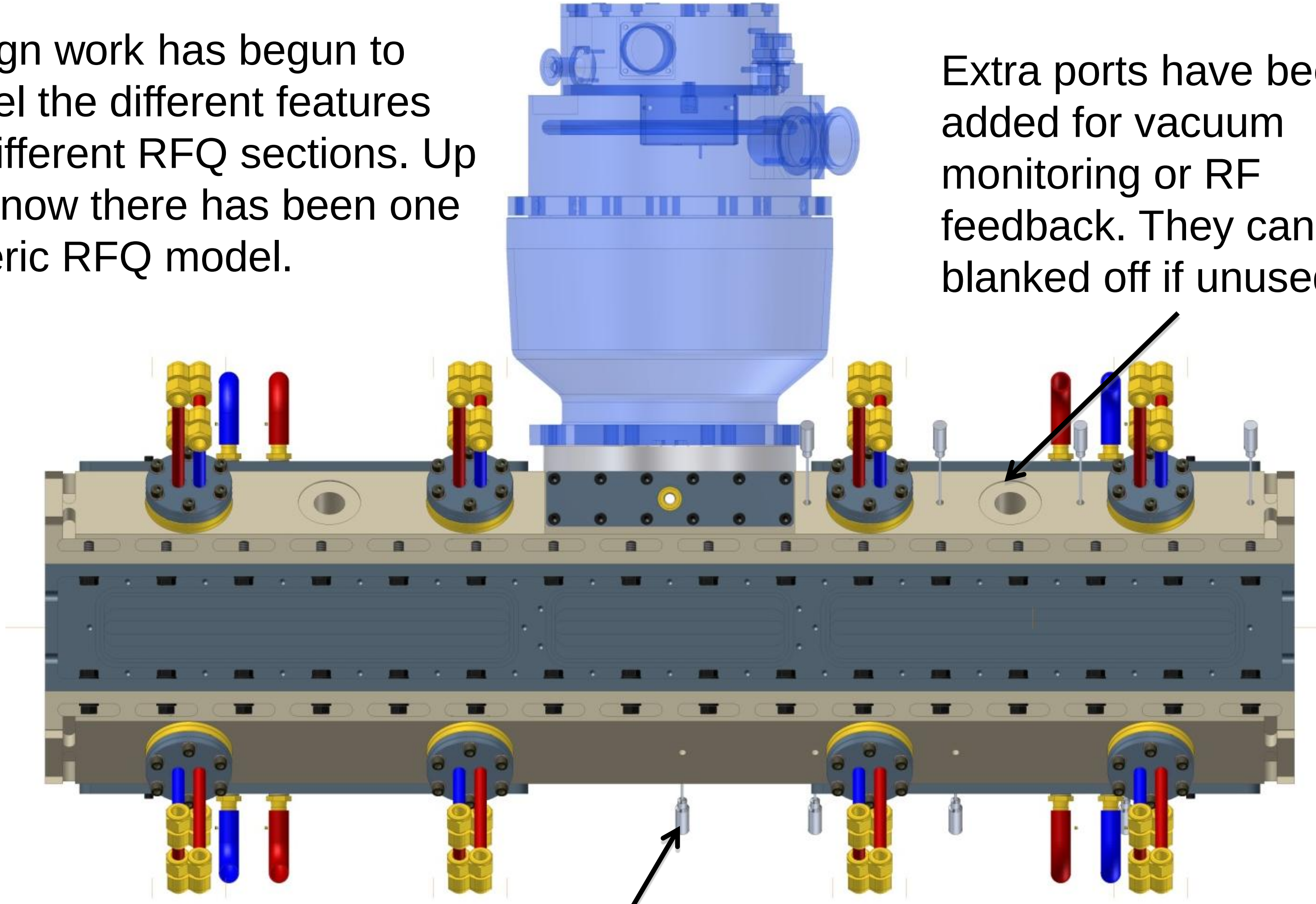


UKNF Plenary Meeting
29th – 30th November 2010

Latest RFQ design

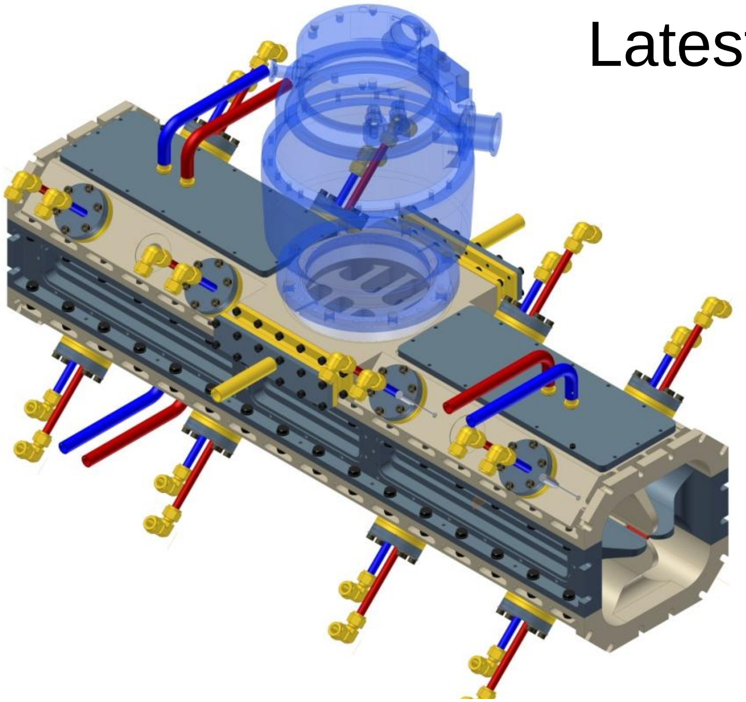
Design work has begun to model the different features for different RFQ sections. Up until now there has been one generic RFQ model.

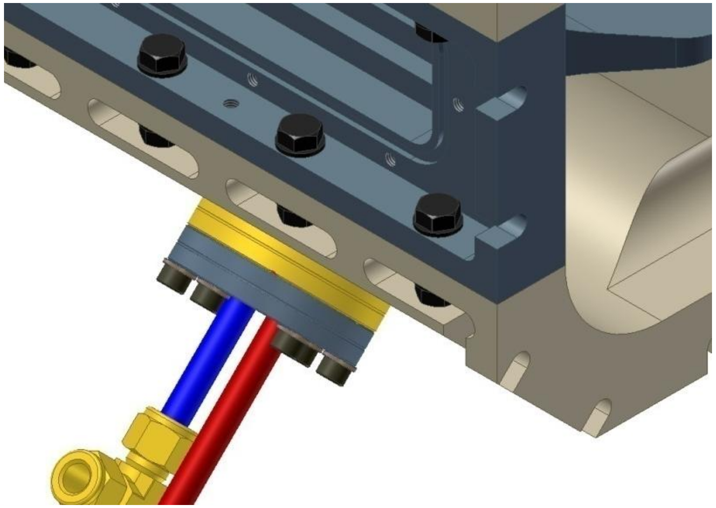
Extra ports have been added for vacuum monitoring or RF feedback. They can be blanked off if unused.



Thermocouples along the length of the RFQ

Latest RFQ design





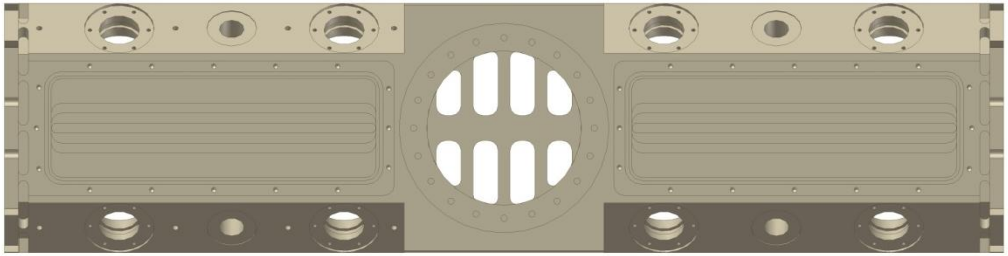
The vane to vane clamping design has been improved. The previous design used studding that crossed from major vane to major vane. This obstructed access to the cooling channels in the minor vanes and created unwanted (crushing) loads across the minor vane cooling pockets.

In addition the new design would allow for removal of one vane section without unclamping the entire assembly.

Furthermore, this new design has a smaller transverse profile, reducing material costs.

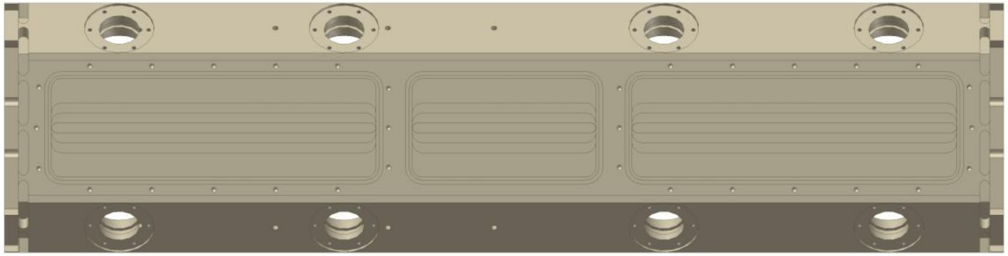
Vane comparison

Major vane - top



Minor vane – left or right

Major vane - bottom



We are now at the stage of design for manufacture.

The vanes are being simplified and unified as much as possible. This will reduce machining time and hence cost and will reduce the likelihood of machining errors.

Vane comparison

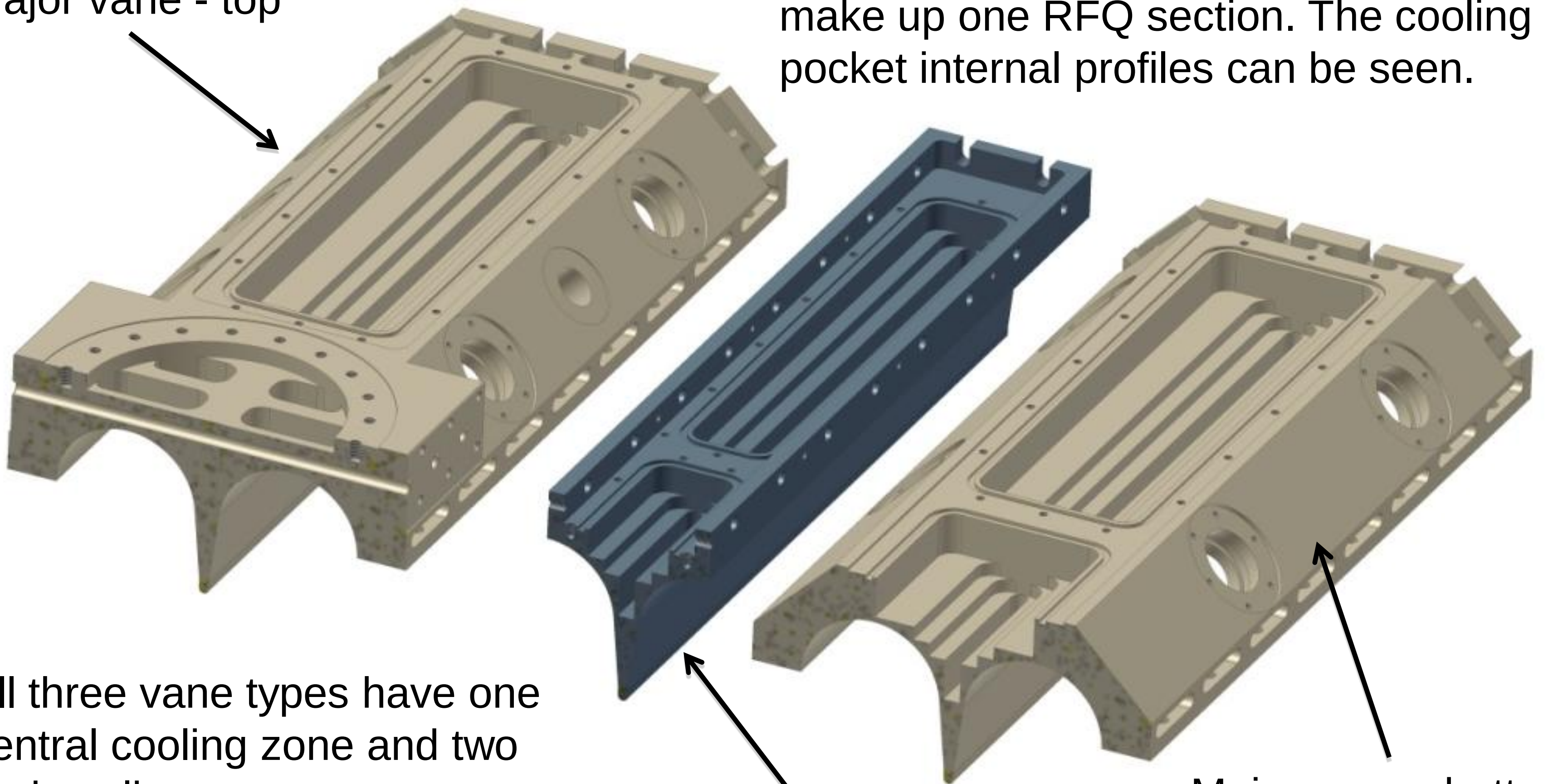
RFQ Section	Vanes	Vacuum Port	Tuner Ports	Cooling Pockets Ends	Cooling Pockets Middle	Squirt Nozzle	Matching Section *	Sealing Groove **	Specific Length	Specific vane modulations
1	Major Top	Yes	Yes	Yes	No	Yes *	Yes *	No	1	Ver_1
	Major Bottom	No	Yes	Yes	Yes	Yes *	Yes *	Yes	1	Ver_1
	Minor Left	No	No	Yes	Yes	Yes *	Yes *	Yes **	1	Hor_1
	Minor Right	No	No	Yes	Yes	Yes *	Yes *	Yes **	1	Hor_1
2	Major Top	Yes	Yes	Yes	No	No	No	No	2	Ver_2
	Major Bottom	No	Yes	Yes	Yes	No	No	Yes	2	Ver_2
	Minor Left	No	No	Yes	Yes	No	No	Yes **	2	Hor_1
	Minor Right	No	No	Yes	Yes	No	No	Yes **	2	Hor_1
3	Major Top	Yes	Yes	Yes	No	No	No	No	3	Ver_3
	Major Bottom	No	Yes	Yes	Yes	No	No	Yes	3	Ver_3
	Minor Left	No	No	Yes	Yes	No	No	Yes **	3	Hor_3
	Minor Right	No	No	Yes	Yes	No	No	Yes **	3	Hor_3
4	Major Top	Yes	Yes	Yes	No	Yes ?	No	No	4	Ver_4
	Major Bottom	No	Yes	Yes	Yes	Yes ?	No	Yes	4	Ver_4
	Minor Left	No	No	Yes	Yes	Yes ?	No		4	Hor_4
	Minor Right	No	No	Yes	Yes	Yes ?	No		4	Hor_4

* at extreme ends only (entry and exit)

** on upward facing interfaces only

Cooling pocket design

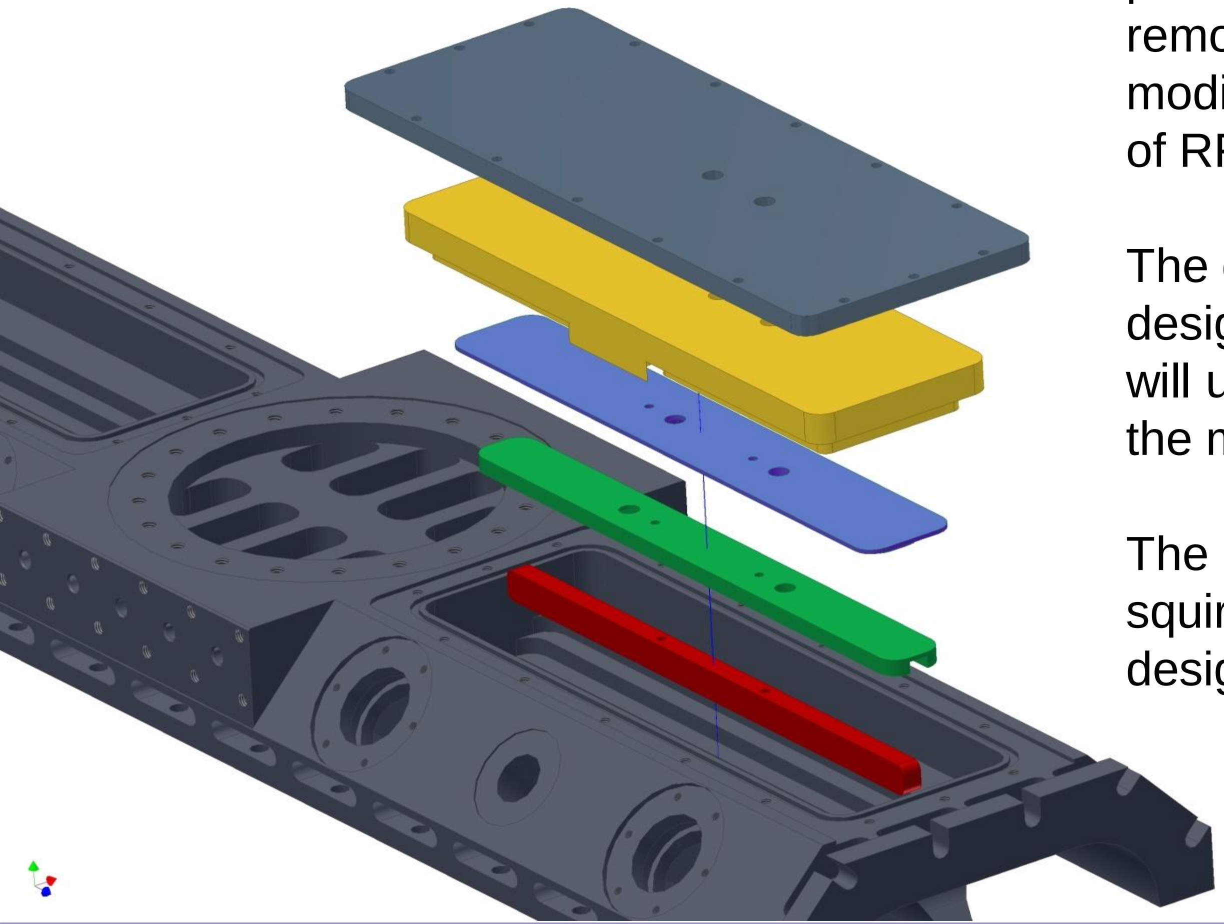
A sliced view at the transverse mid plane for the three vane section types that together make up one RFQ section. The cooling pocket internal profiles can be seen.



All three vane types have one central cooling zone and two end cooling zones.

The baffle design

The open cooling pocket is filled with a baffle to direct the flow of cooling water.



For ease of manufacture the baffle is assembled from layers of shaped plates. These plates can be removed for cleaning and / or modification to change the pattern of RFQ cooling if required.

The goal is to use the same baffle design throughout. The minor vanes will use the same lower layers as the major vanes.

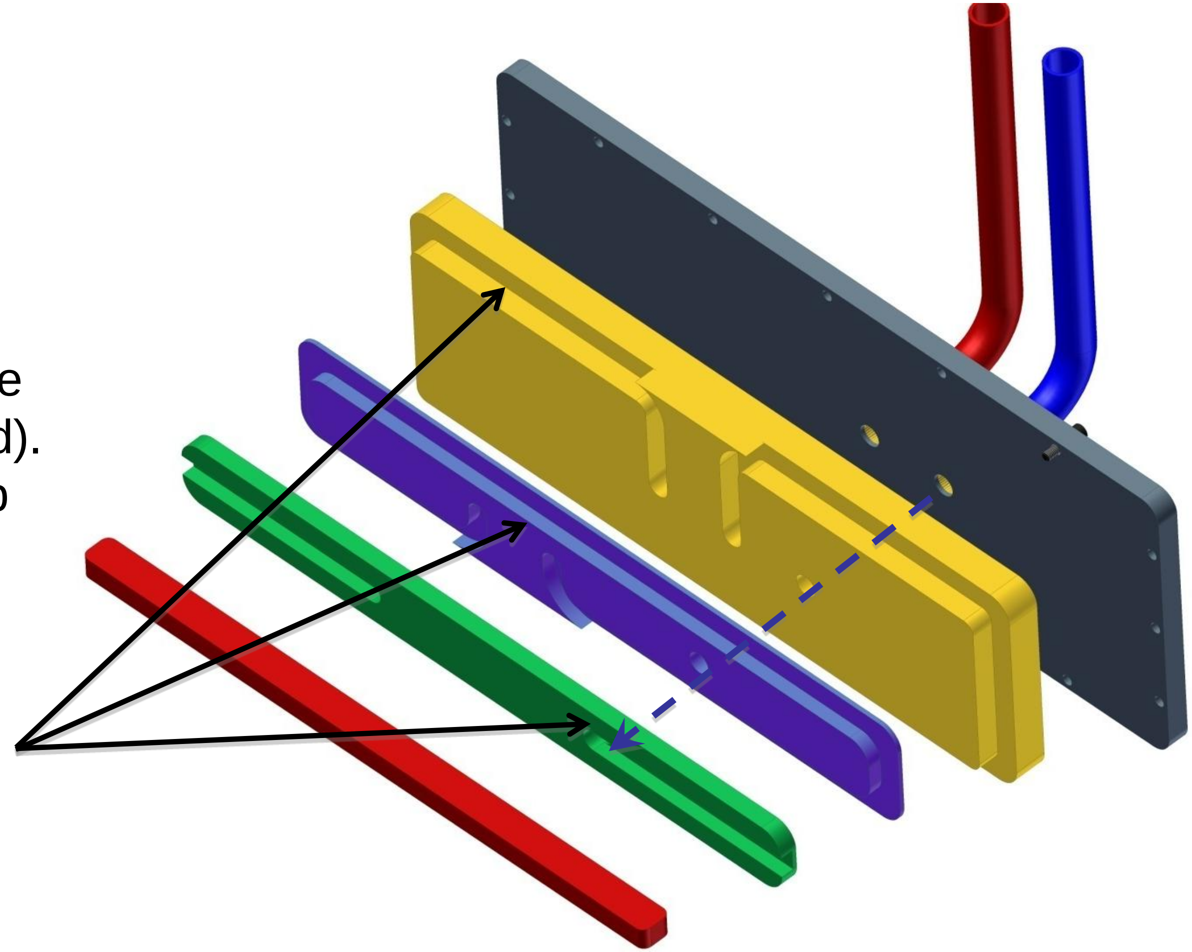
The next task is to incorporate the squirt nozzle design into the baffle design for the RFQ entry region.

The baffle design

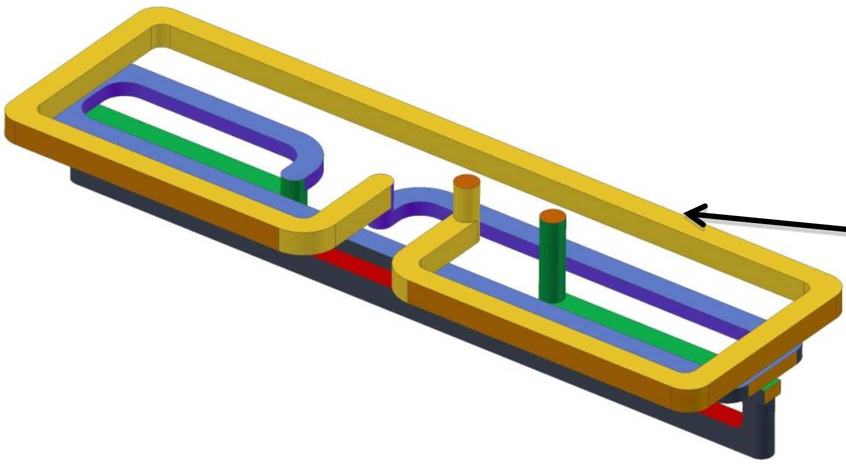
An exploded view showing the layered assembly that forms the baffle.

Water is directed straight through the assembly to the hottest region first (arrowed). This is close to the vane tip in the region of the RFQ entrance.

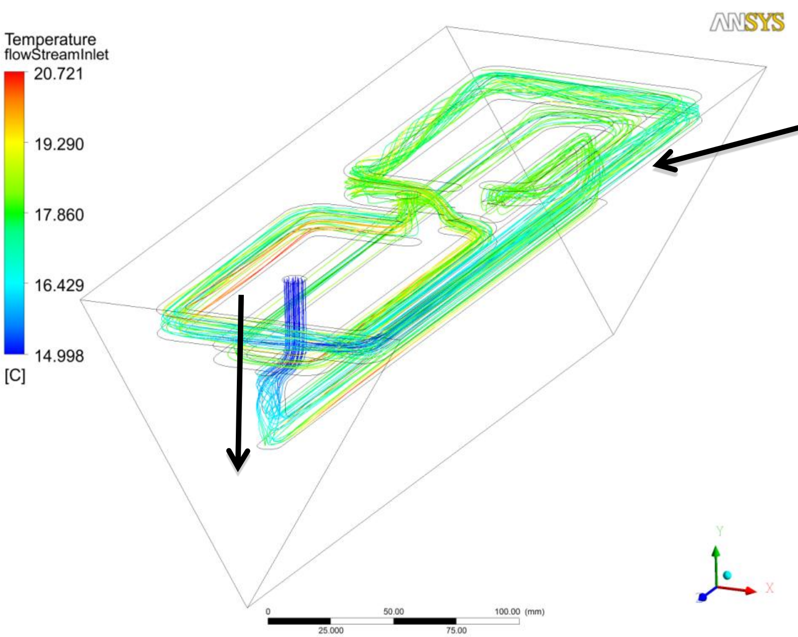
Water flows along these milled out channels.



Cooling water path

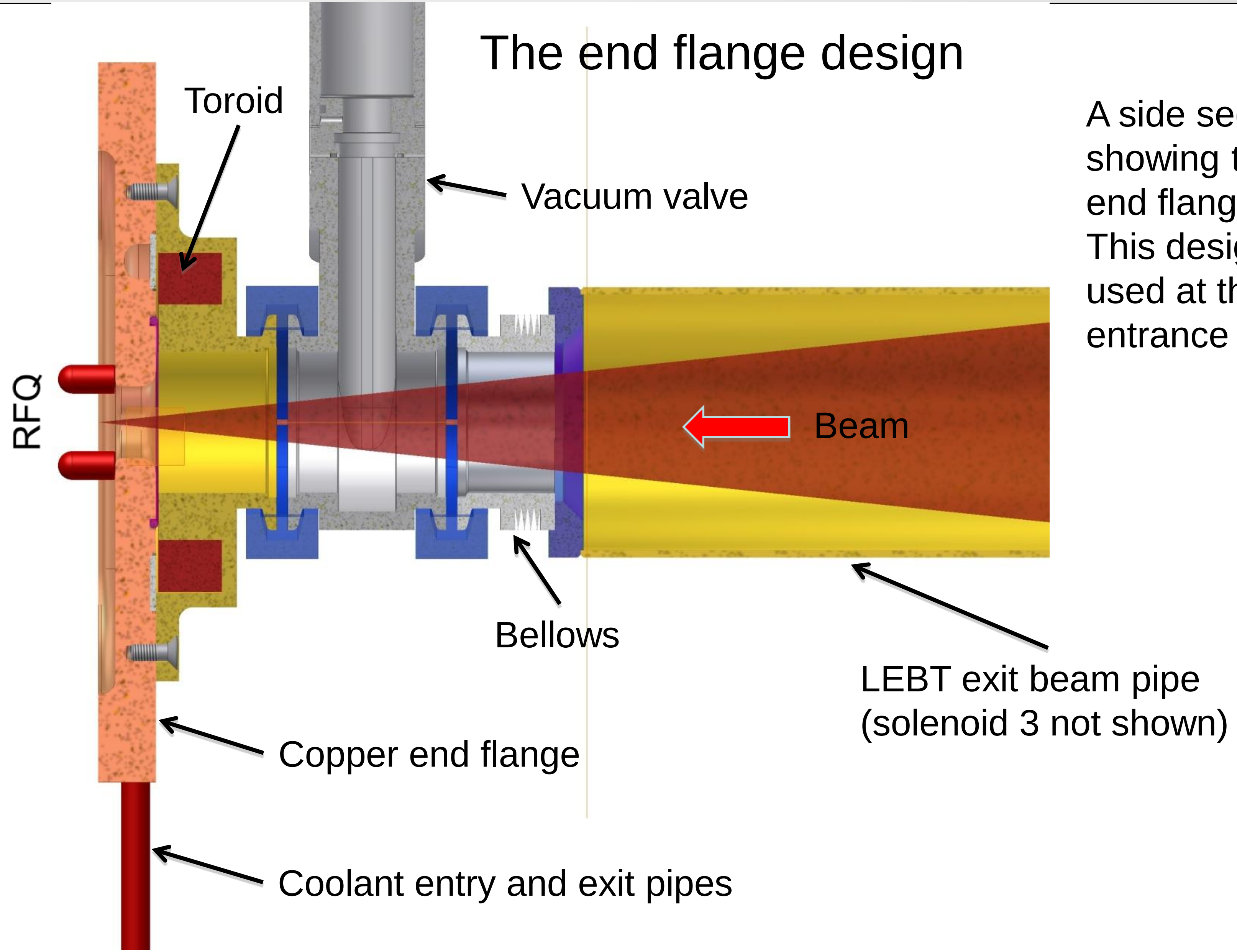


By performing a subtraction of the baffle and RFQ vane from an abritrary solid volume we can see the flow channel for the cooling water.



Scott's has performed an initial CFD analysis to identify whether this concept is worth pursuing. Initial results using a simplified vane geometry show that the design will work. A further study needs to be done to balance the cooling performance with the engineering complexities.

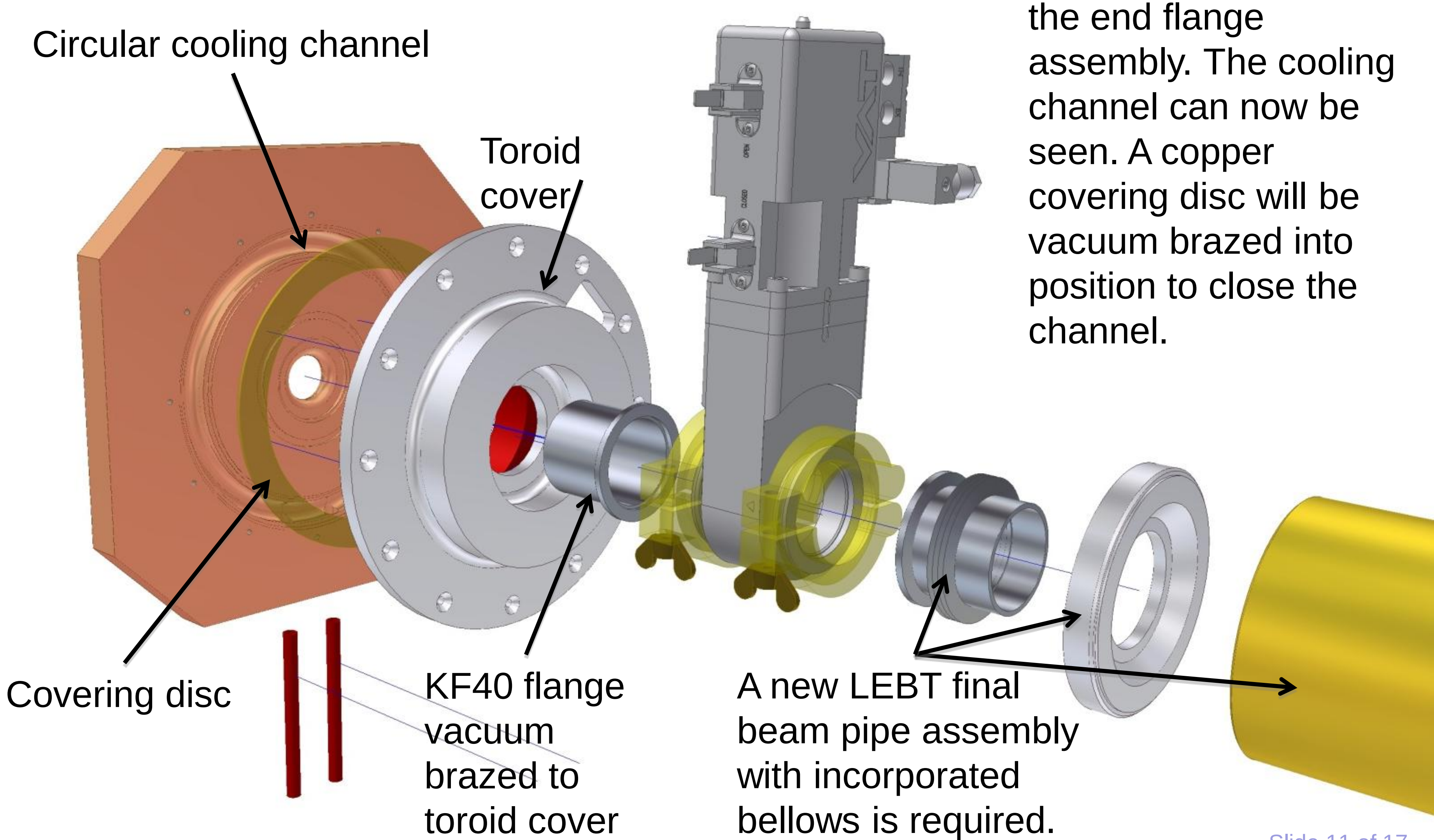
The end flange design



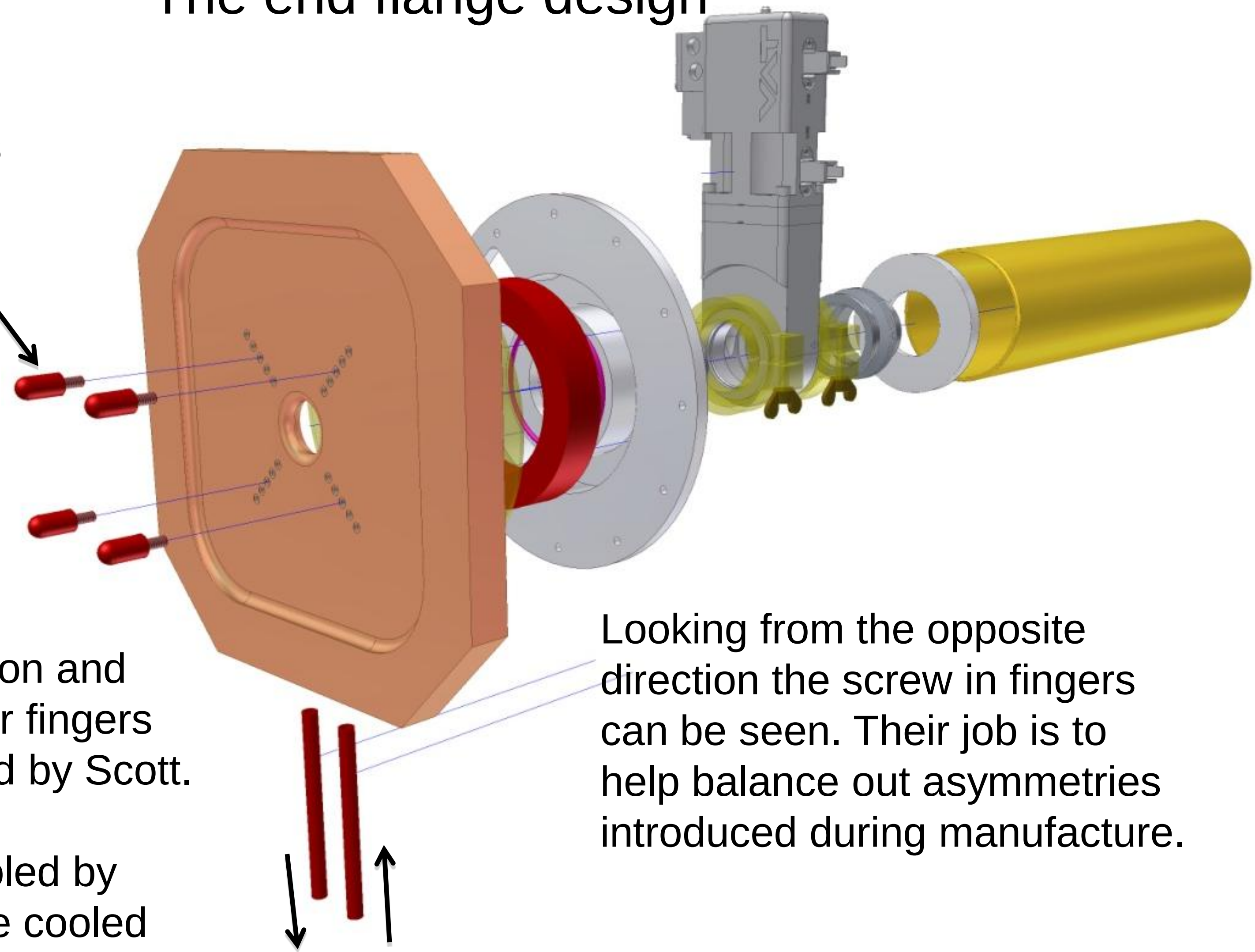
A side section view showing the RFQ end flange region. This design will be used at the RFQ entrance and exit.

The end flange design

An exploded view of the end flange assembly. The cooling channel can now be seen. A copper covering disc will be vacuum brazed into position to close the channel.



The end flange design



Copper Pi mode stabilising fingers

The optimum position and length of the copper fingers has been calculated by Scott.

The fingers are cooled by conduction from the cooled copper end flange.

Water in / out

Looking from the opposite direction the screw in fingers can be seen. Their job is to help balance out asymmetries introduced during manufacture.

Material for the RFQ manufacture

Supplier:

A potential material supplier for the bulk C103 (C10100 *U.S. spec*) copper has been found.

Cost:

The total cost for enough copper to build the entire 4m long RFQ is approximately £40k.

Extruded profile:

To cut down on material waste and reduce machining time the option of having the material supplied as extruded profile is being investigated. Early indications are that despite the additional cost of tooling the material cost is approximately 50% that of bulk copper.

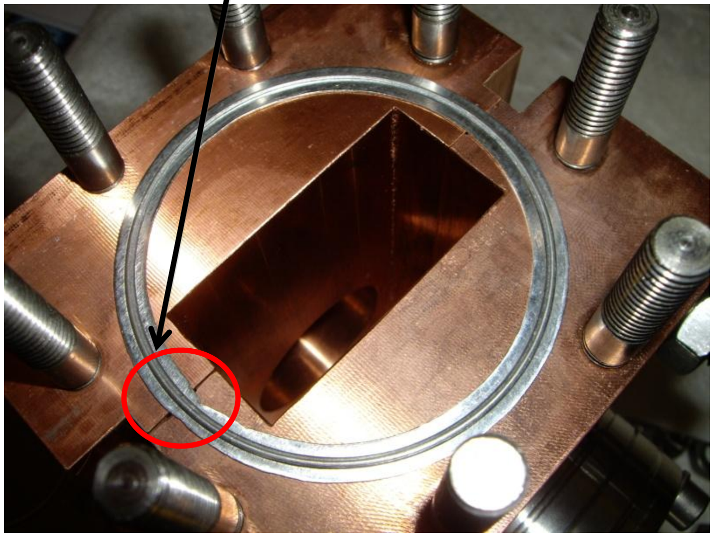
Specification:

CERN specify a maximum grain size of 90 microns for vacuum applications. We aim to follow this specification. Talks with Tecvac Ltd are underway to establish whether they can heat treat the material to the CERN specification.

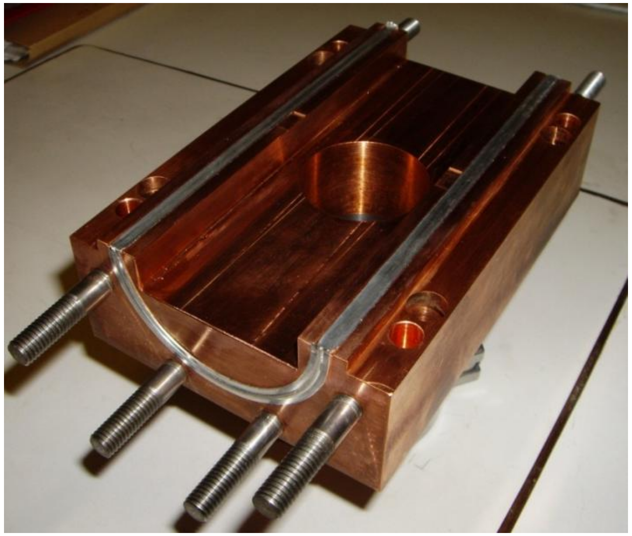
Indium wire vacuum test

The latest Indium wire vacuum test was not successful. It reached a pressure of 10^{-5} mbar. A spray with acetone indicated a leak.

Upon inspection once disassembled the grooves appeared to be well filled. The reason for the leak is not (visually) obvious. Can only suspect the longitudinal to transverse seal interface as Indium is regularly used in one plane to seal for vacuum.....



End view of Indium test assembly



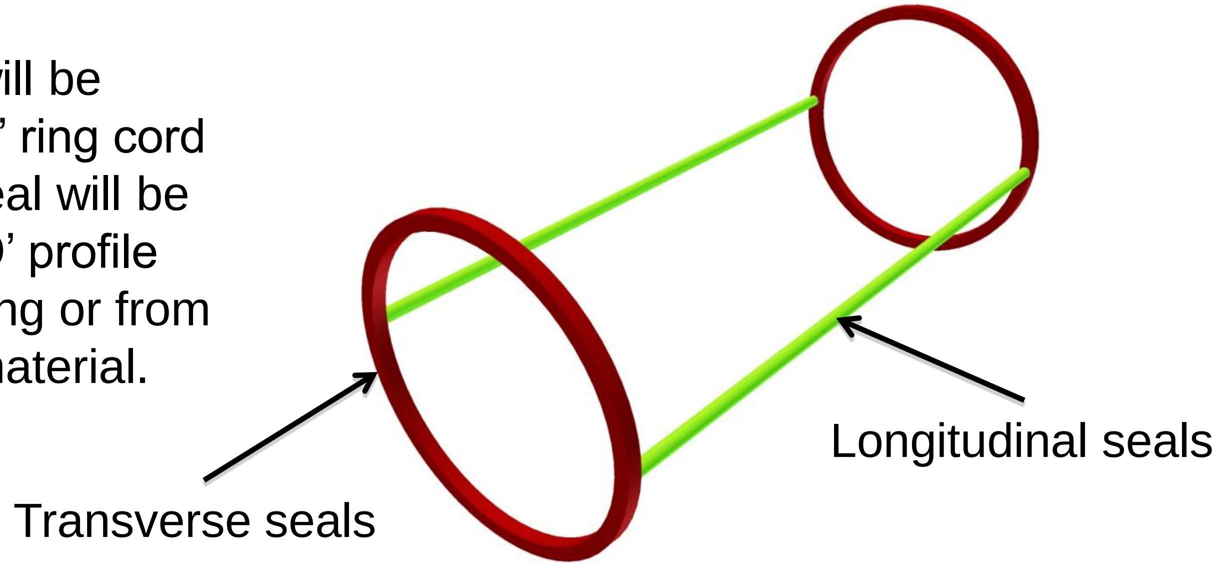
Lower half of Indium test assembly

The next vacuum sealing test

TWI have quoted for performing tests of: laser beam welding; vacuum brazing and electron beam welding. Each *test* would cost approximately £23K.

An earlier investigation into using a 3D ‘O’ ring was discontinued due to being unable to find a manufacturer. It has therefore been proposed to test a bonded 3D ‘O’ ring that will be assembled in-house. The first test will use either Butyl or Viton rubber (for low outgassing) bonded with a cyanoacrylate adhesive.

The longitudinal seal will be formed from regular ‘O’ ring cord while the transverse seal will be formed from either a ‘D’ profile ring, a square profile ring or from a ring cut from sheet material.



Next steps...

1. Identify the best vane to vane vacuum sealing method.

2. Produce a manufacturable squirt nozzle design and build that into the existing baffle design.

3. Perform next iteration of cooling analysis with more realistic geometries.

4. Perform analysis of vane to vane clamping load produced by current bolt pitch if the 3D ‘O’ ring design is pursued.

5. Find a company capable of heat treating the copper to required specification.

6. Decide how to proceed to manufacture. The preferred course from an engineering perspective is to manufacture the first 1m length only. This will allow lessons learned during manufacture and assembly to be fed into the design of the remaining three sections. The Physics perspective favours manufacture of the first two 1m RFQ sections so that particle acceleration and not just focusing can be demonstrated.

7. Start planning the layout of Engineering drawings.

8. Talk to Daresbury ETC again regarding manufacture when next level of design detail is known.

Thank you.