3D-Printed Connectors

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CERN | EP-DT
Detector Technologies

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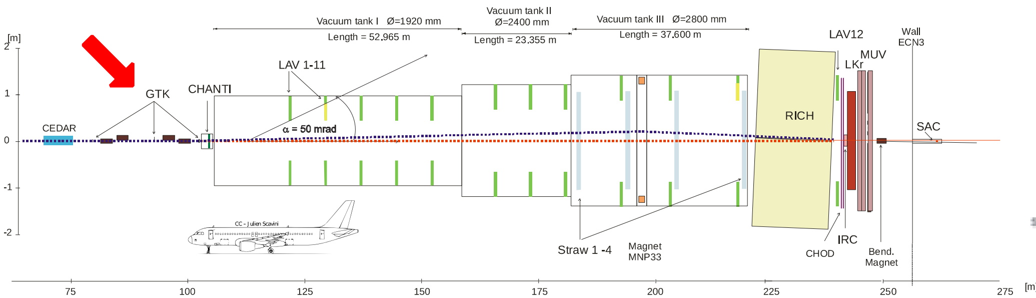
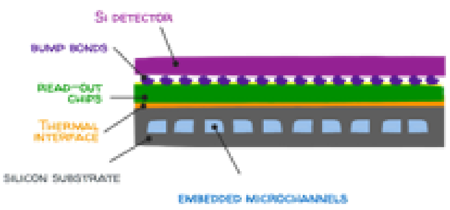
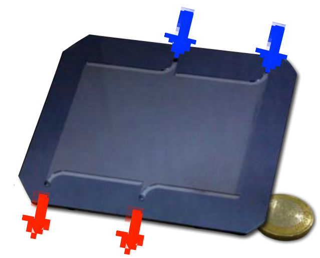
NA62 GTK Silicon Microchannel Cooling

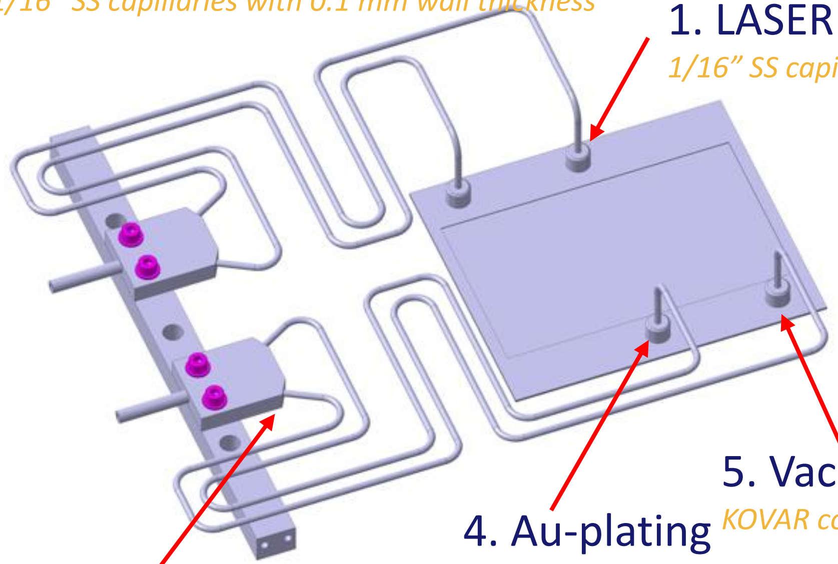






2. Bending of the capillaries

1/16" SS capillaries with 0.1 mm wall thickness



1. LASER welding

1/16" SS capillaries to KOVAR connectors

3. NICROBRAZ brazing

1/16" SS capillaries to SS manifolds

4. Au-plating

KOVAR connectors

5. Vacuum brazing

KOVAR connectors do Si

- 3 detector modules
- Liquid C_6F_{14}
- T_{op} below -10ºC
- Power dissipation 25W-48W over 6x4cm^2

A. Mapelli *et al.* 2012 JINST 7 C01111
P. Petagna *et al.*, Microelec. Journal 44 (2013) 612–618
G. Romagnoli *et al.*, Microelec. Eng. 145 (2015) 133-137

Motivations & Challenges

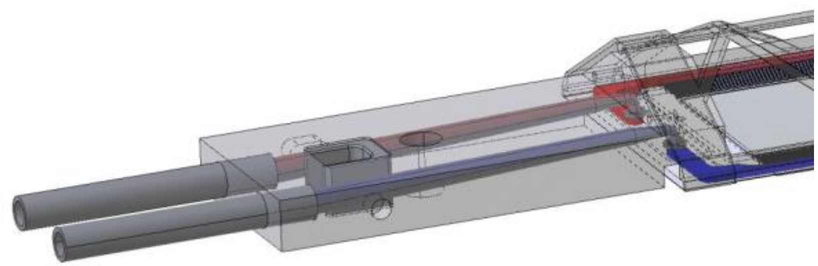
- Motivation:

  Machined metallic connectors brazed on silicon perform well.
  Are there better alternatives ?

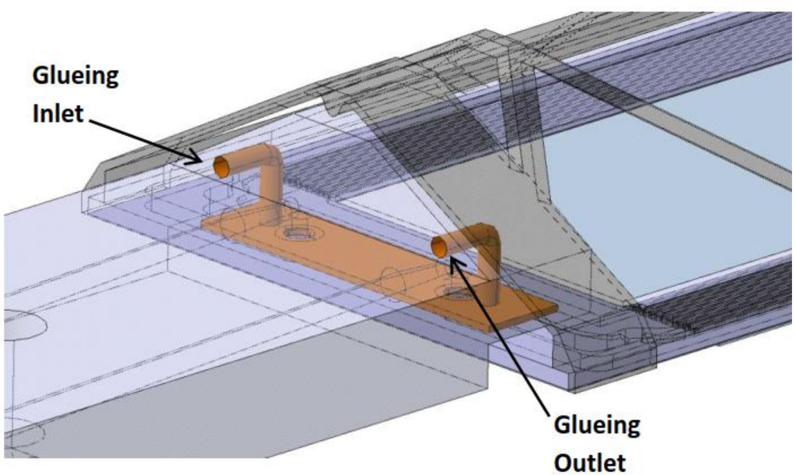
- Challenges:

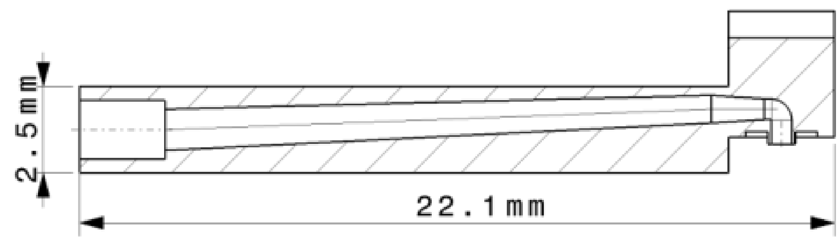
  - Bonding techniques
  - Sealing
  - Materials (Ceramics / Polymers / Metals)

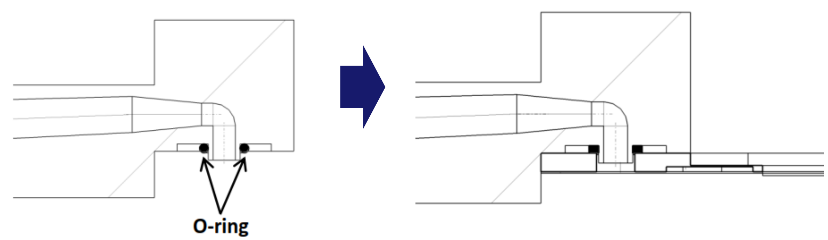
Fluidic Connector Proposed for ALICE ITS



- 3D printed connector glued to silicon frame (3D Systems printer)
- Connects Ø1.2mm tubing to Ø0.6mm inlet



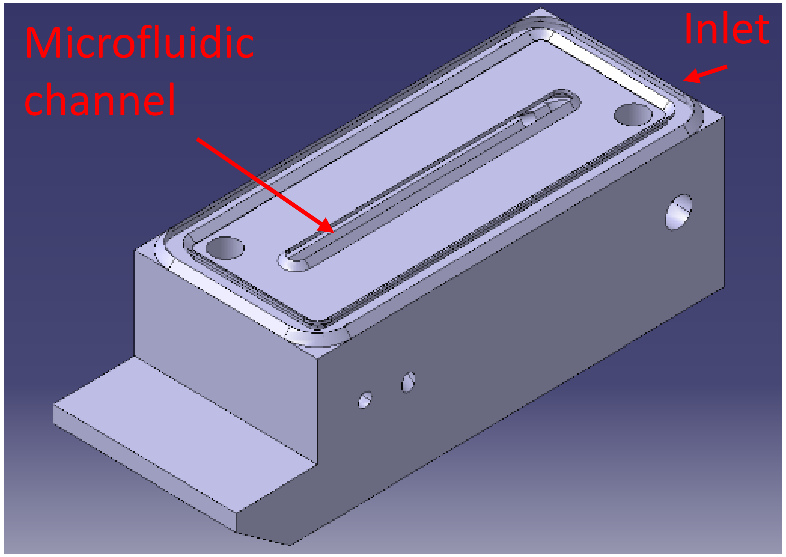




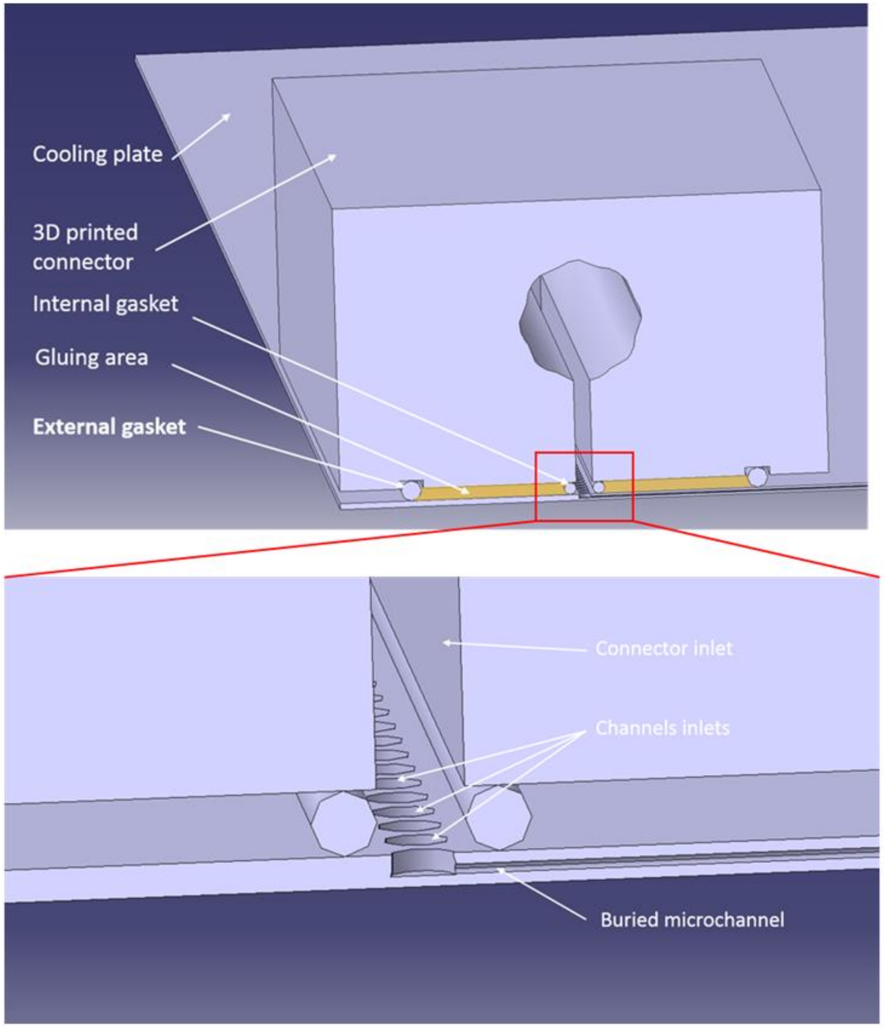
(A. Toros)

Connector Overview

- Two gasket required for tightness
- Microfluidic channel
- Inlet
- Use 1 capillary to distribute the flow over several channels

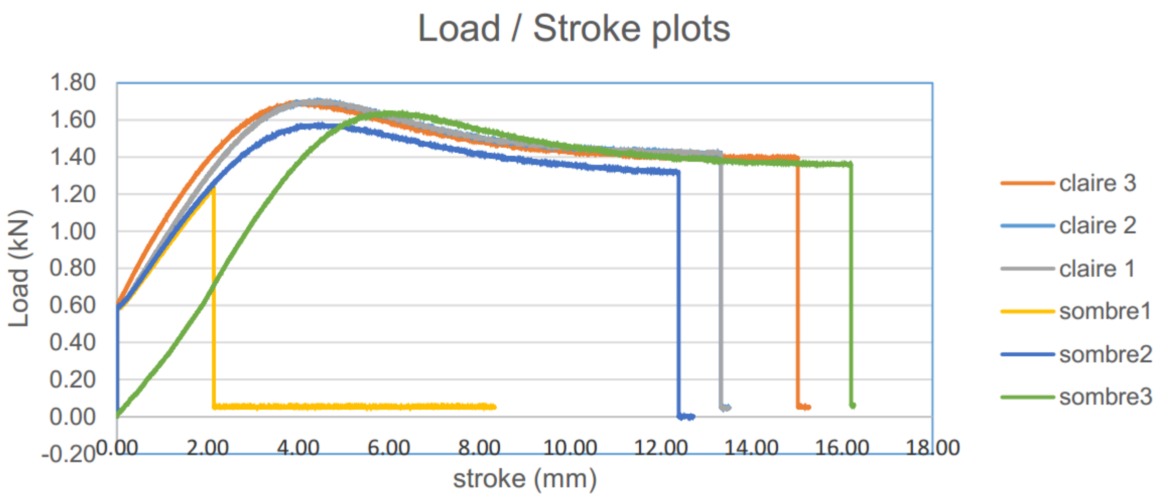


Connector overview



3D Printing Setup

- Printer: Form2 from Formlabs
- Resins: Mixture of methacrylic acid esters.
  Used in black, clear and flexible versions
- Tensile tests of resin with radiation up to 10^5 Gy
  (3.12 .10^{14} W/cm^2)

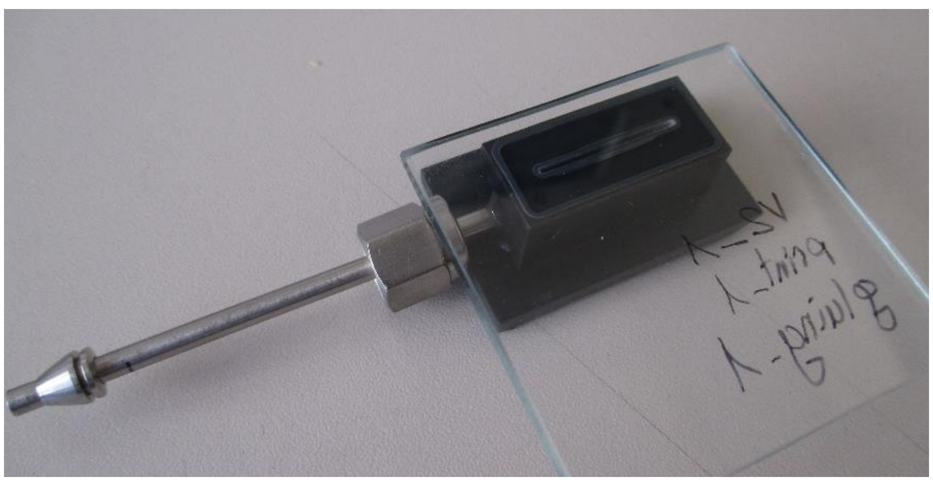


Stress vs. time plots for irradiated resin samples

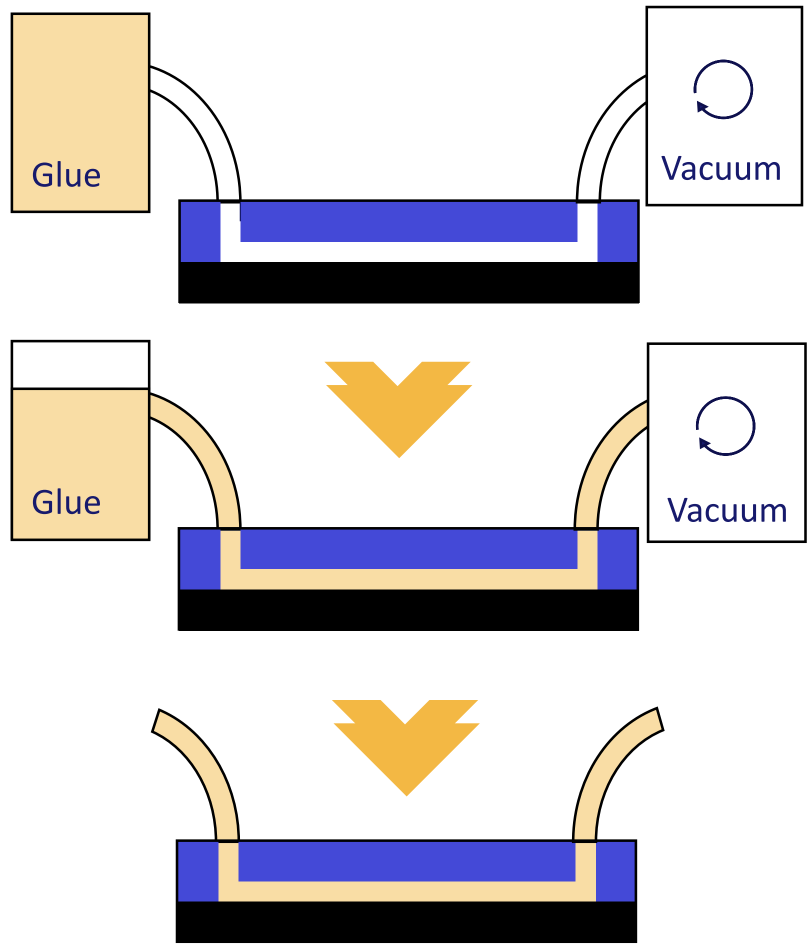
Form2 SLA printer

Gluing Procedure

1. Outgassing glue
2. Vacuum pumping glue in the connector
3. Remove the glue tank and the vacuum pump
4. Wait for the glue to dry



Glued connector viewed from under, inlet is visible on the left



Vacuum pumping glue

Test Procedure

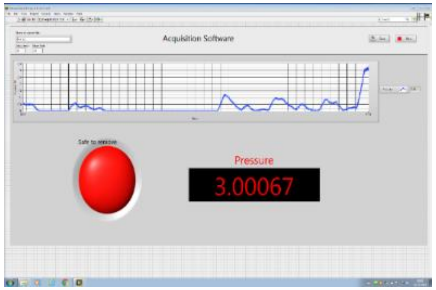
Helium leak test:

- Vacuum is made inside the glued connector, the pump records quantity of helium pumped. He leak rate is measured.
- He is sprayed around the connector and He leak rate is measured.
- The difference between the two measures gives the leak tightness of the device.

Pressure test:

- Pressure is built inside the connector with a manual pump.
- Pressure is measured by a sensor, recorded and displayed on a screen.
- Pumping until failure of the device.

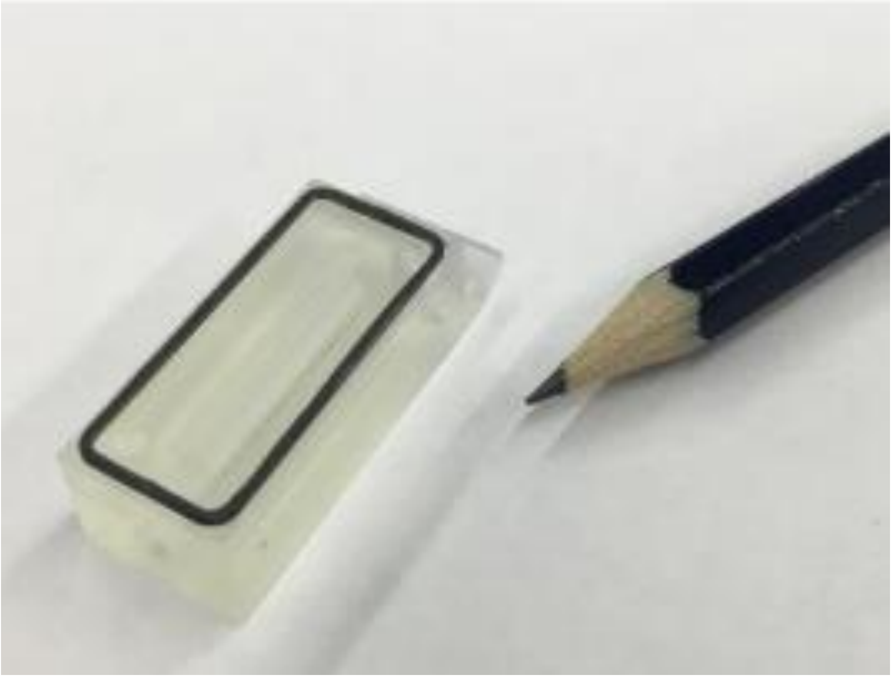
Manual pump



Pressure measured and displayed

O-rings

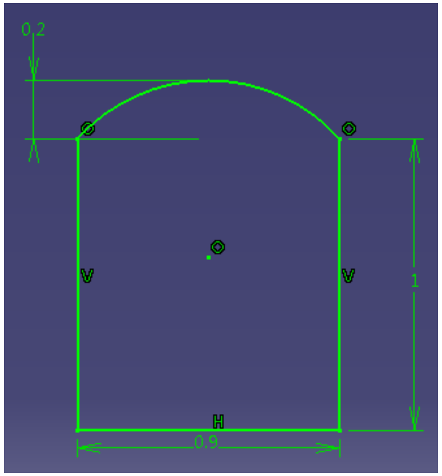
- Off-the-shelf O-rings
- Slots in the connector to maintain the O-ring in position
- Implementation complicated by small curvature radius and small diameter of O-rings



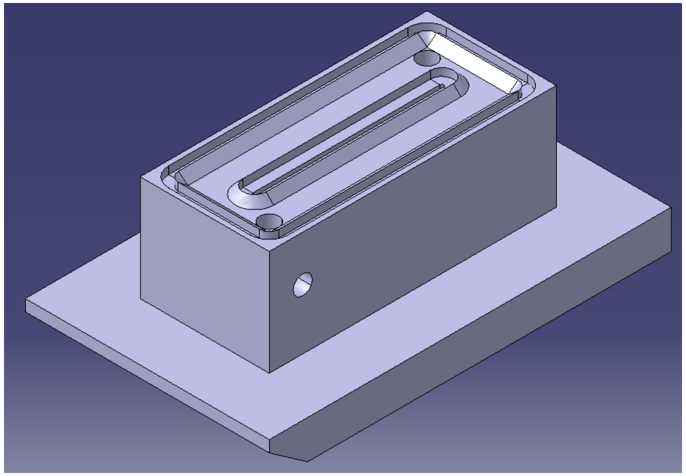
Connector with external O-ring

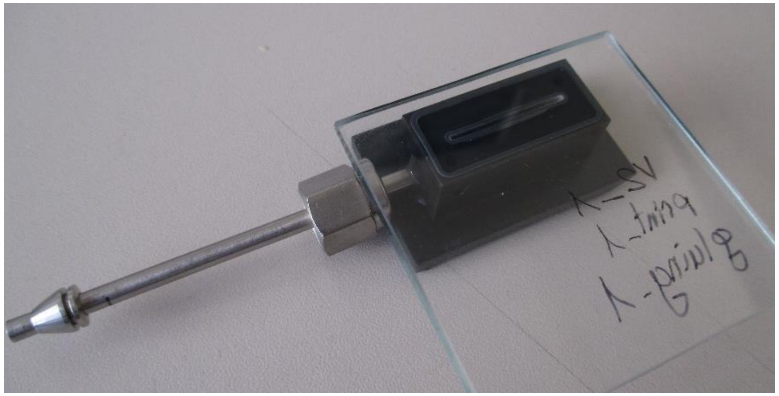
3D Printed Gasket (1/2)

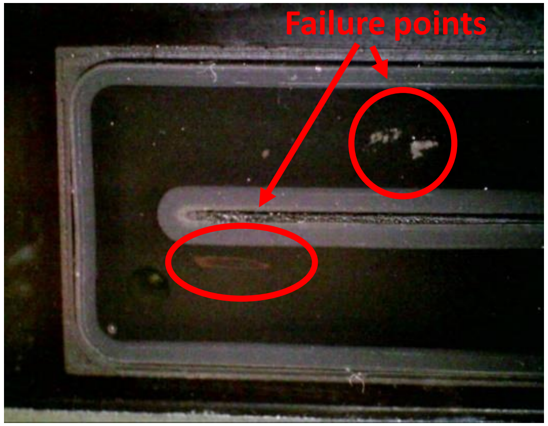
- Flexible resin
- Pressure at failure: 80 bar
- Failure location: Tube inlet
- Tightness test (He): passed
- Glue thickness: 0.8mm (deeper than usual)



Cross-section of the first 3D printed gasket


Connector used

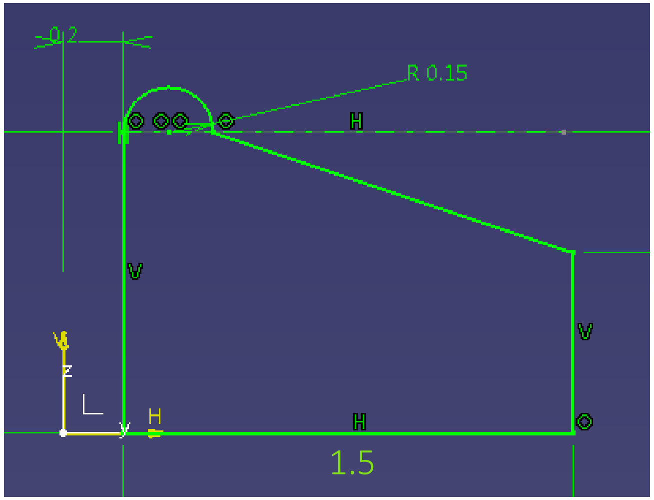

Glued connector viewed from under, inlet is visible on the left



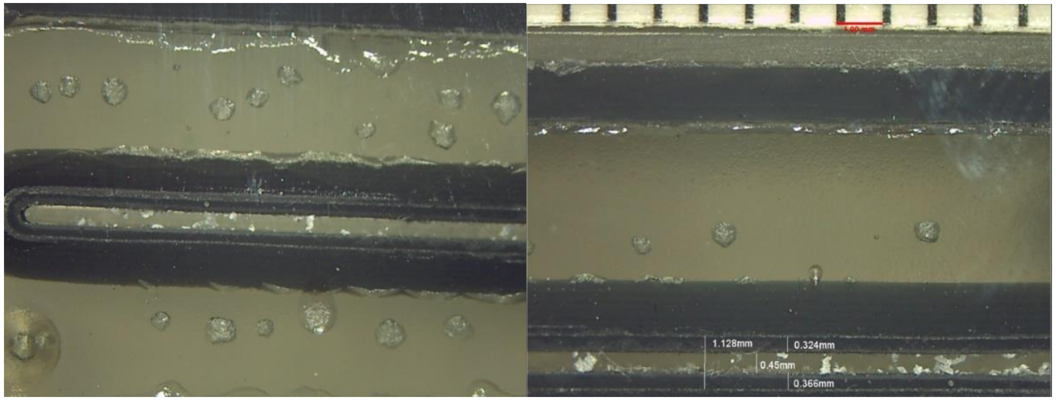
View from bottom, failure points visible

3D Printed Gasket (2/2)

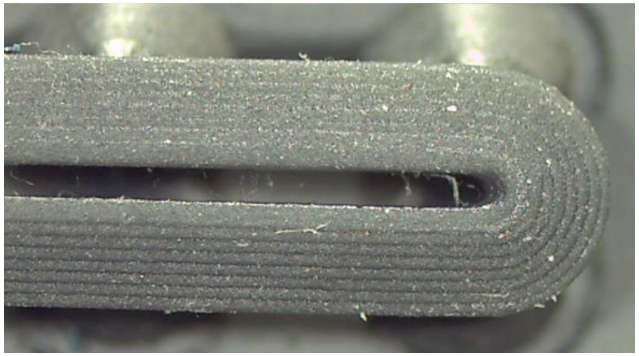
- Glued successfully
- Not tested due to delamination of gluing (due to external gasket)
- Printed layers are visible and rounded tip was flattened during the slicing



Cross-section of the second 3d printed gasket

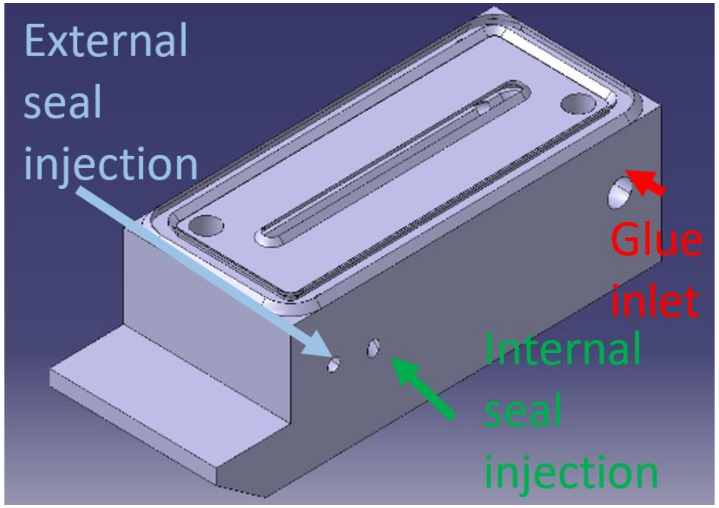


View from under after gluing, ungluing visible

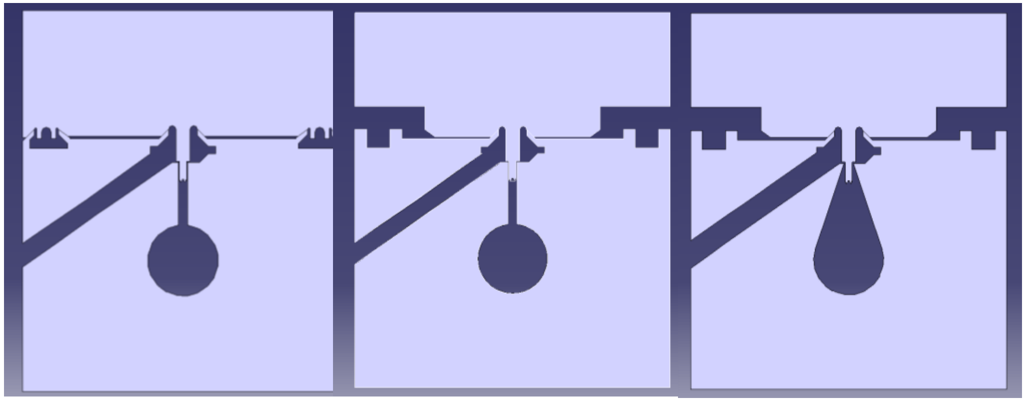

Magnified view of the gasket

Gasket Injection

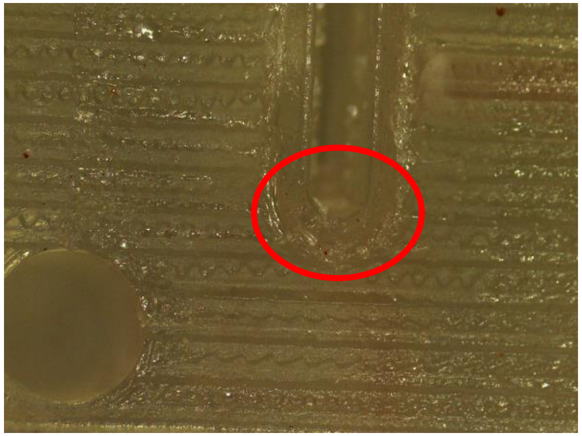
- 3D printer connector and counter-part for injection
- Leaks during injection resulting in improper shape of gasket and cooling channel filling
- 3 design test with same results



Inlet for injection in the connector



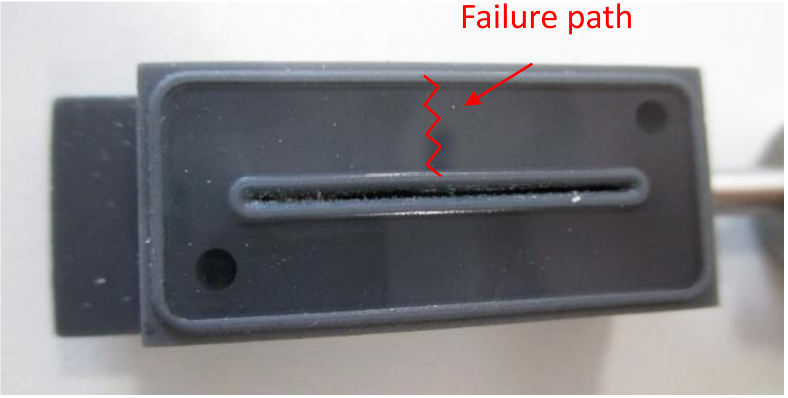
Cross-section of 3 design with counter-part mounted



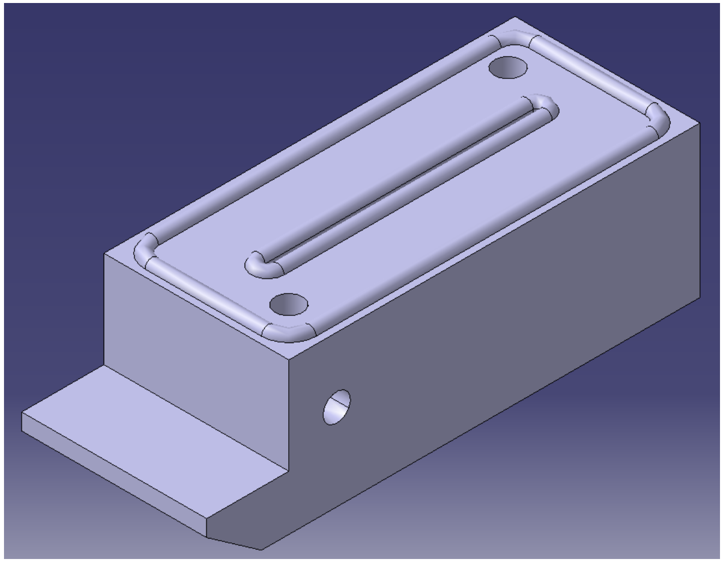
Result of the injection, extremities of the gasket not well defined

Flexible Connector

- Residues could be observed inside the channel.
- The piece was glued and the tightness was checked using the He leak test.
- No leak was detected and a pressure test was done, leading to a glass/glue interface failure at 10 bar.



Connector after pressure test



CAD model of the flexible connector

Summary

- Proof of concept of the gluing:
  - Pressure resistant
  - Helium-tight
- From the 4 tested method for sealing: 3d printed gasket and flexible connector showed that the gluing procedure works.
- Resins have potential for this application: mechanical properties after irradiation are not too much deteriorated.
- Limitations of the printers are reached: layers deforms the geometry.