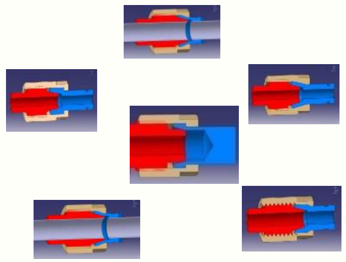
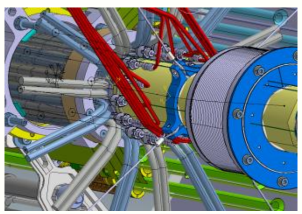
Fittings & e-breaks developments @ LAPP

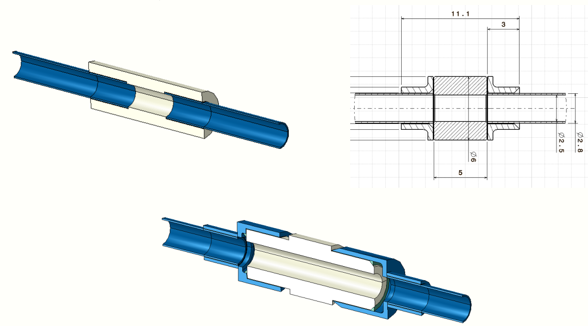


B - IBL Fittings developments

C - IBL e-break developments



A - IBL context

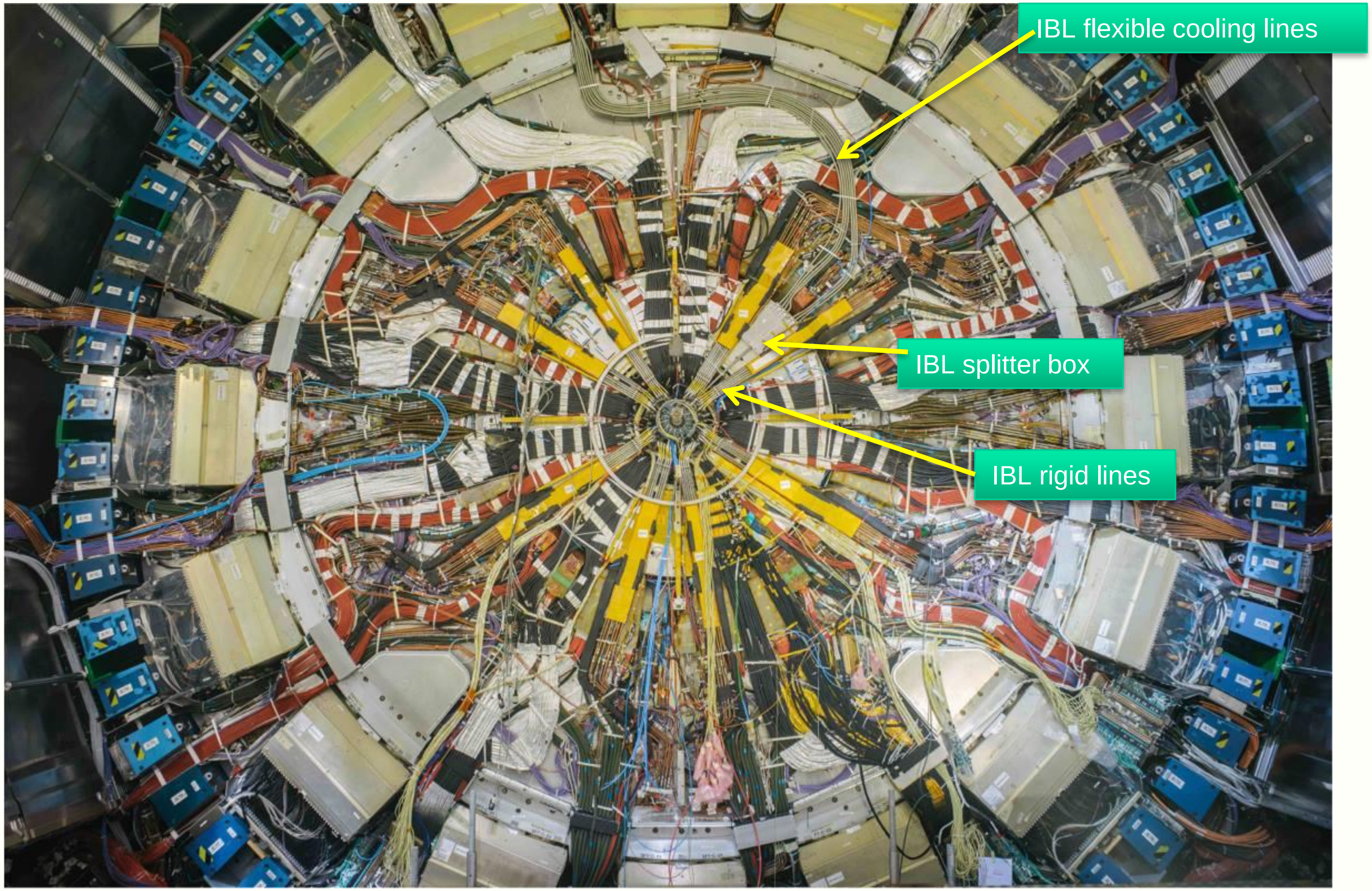


D - ITK developments

LAPP ATLAS ITK cooling team

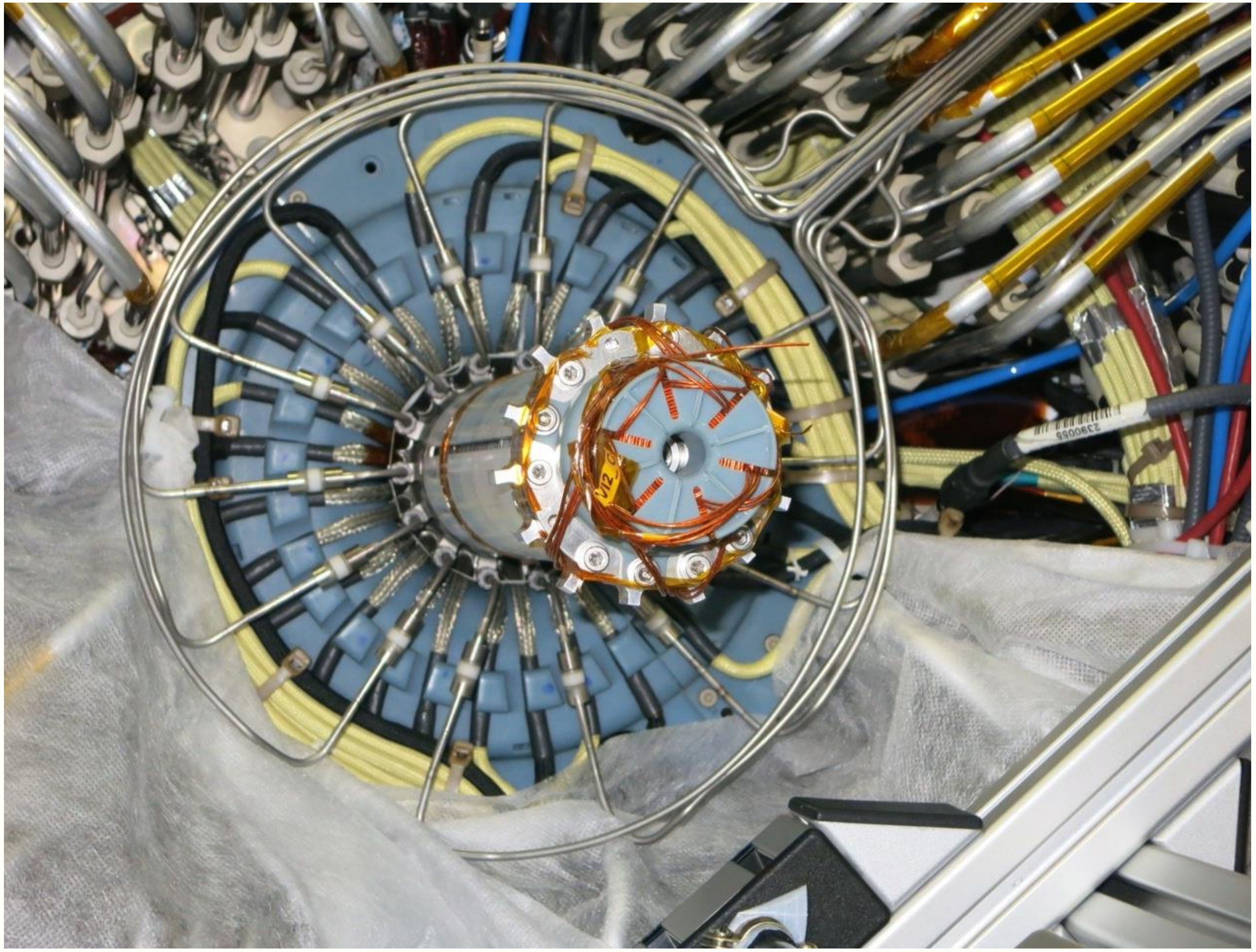
Pierre Delebecque, Stéphane Jézequel, Nicolas Massol, Olivier Prevost, Thibaut Rambure, Emmanuel Sauvan

View of the end of the tracker



IBL installed in the pit in 2014

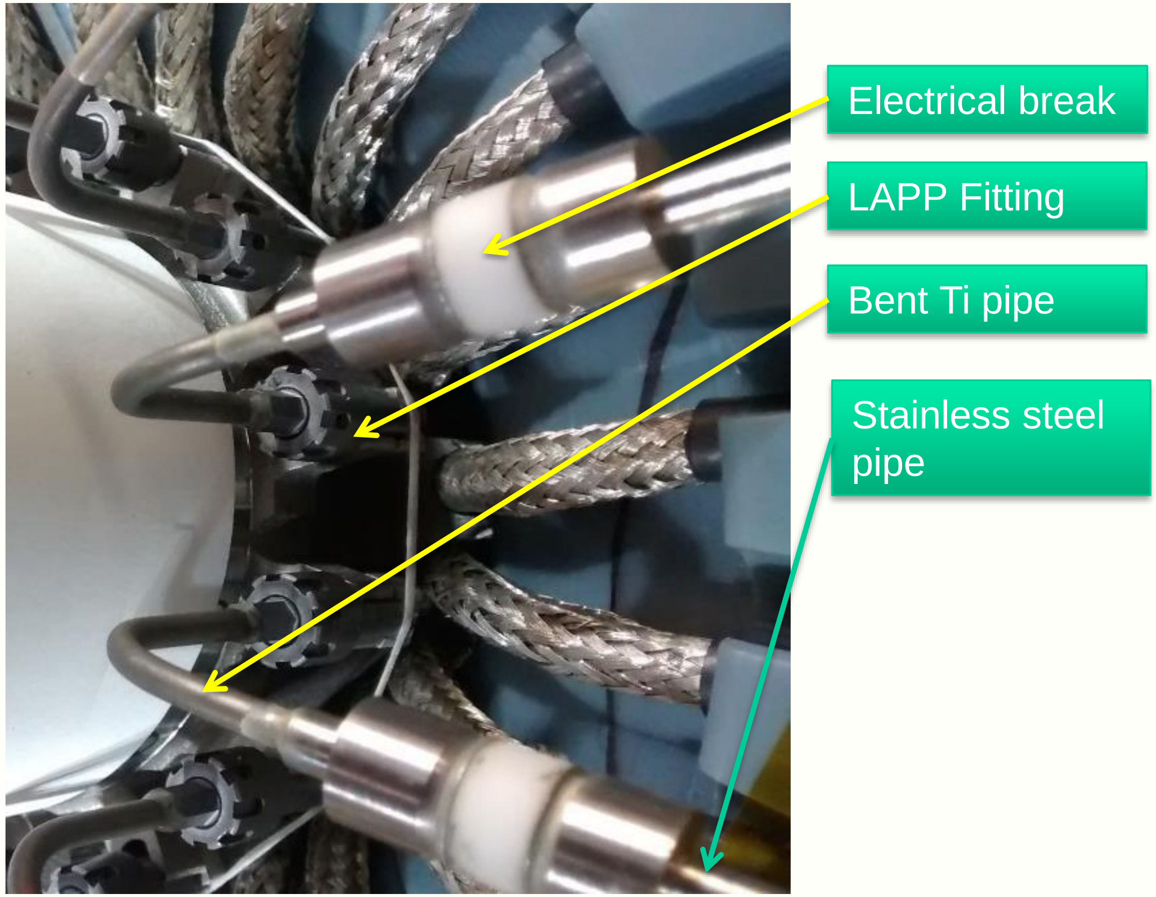
IBL context



2x14 (both sides) e-breaks and fittings installed and work very well

IBL context

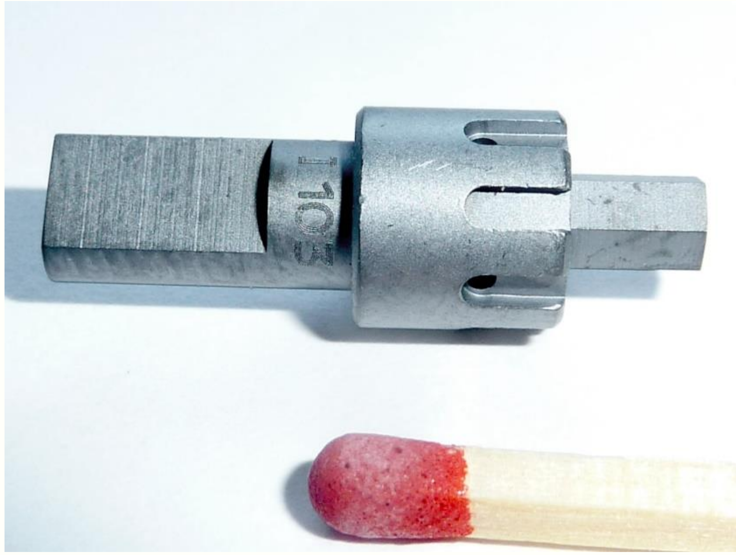
- E-breaks installed in the IBL PP1 region
- Transition between Ti and stainless steel (specific to IBL) (only Ti for ITK)
- Channel diameter is 2mm
- Elements have to withstand the pressure and temperature variations
- 10^{-8} mbar.l.s^{-1} limit leak rate

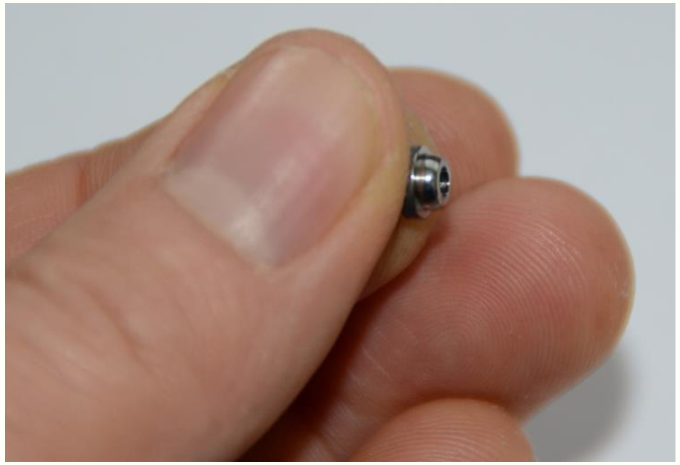


The **fittings** allow the integration in the pit and a possible dismounting of the e-break.

Fittings developments

A very small fitting

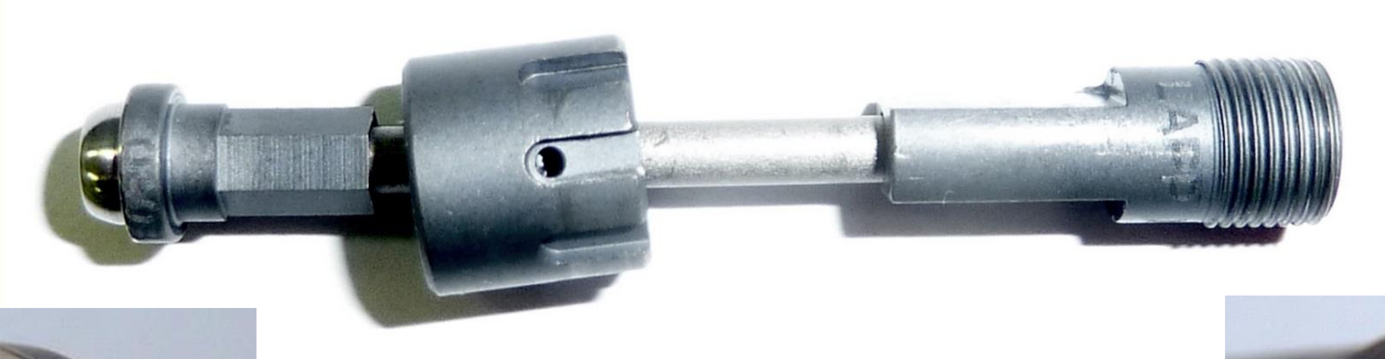


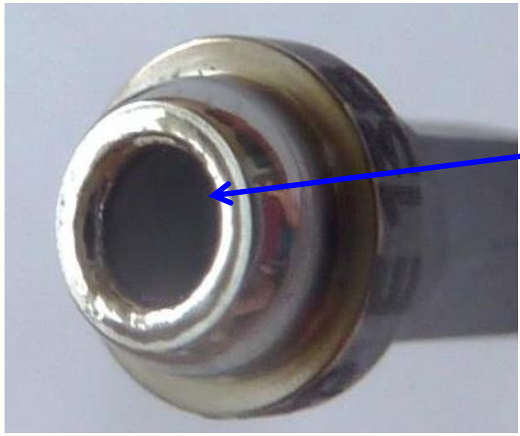


Mass=2.2g (IBL version)
Tightening torque ~2.5N.m

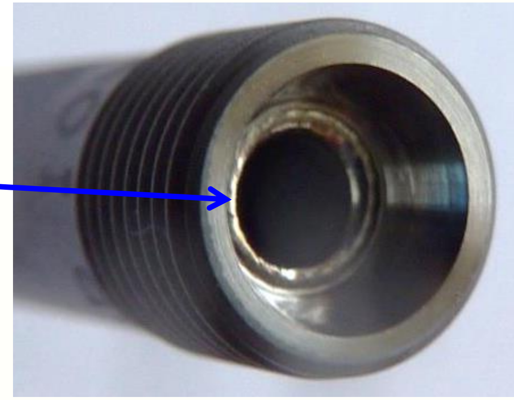
Fittings developments

Fitting welded on a titanium pipe (sample for qualification)





Electron Beam welds



- Pipes outer diameters : ϕ 1.77 mm and ϕ 2.27mm (IBL)
- Pipes wall thickness: 130 μm (IBL) 70 μm (prototyping)

Fittings developments

Why a custom fitting ?

- No industrial standard solution was complying with the IBL specifications (especially the envelope)
- Swagelok: not interested in reducing the size of their connectors
- Staübli : specific design proposed but very costly

BUT The ATLAS tracker community didn't want any custom fittings !!

Use industrial procedures for qualification

Experts (quality management and leak tightness) were asked to audit our project and give advice to define and implement the industrialisation and qualification procedures

cetim
Centre technique des industries mécaniques

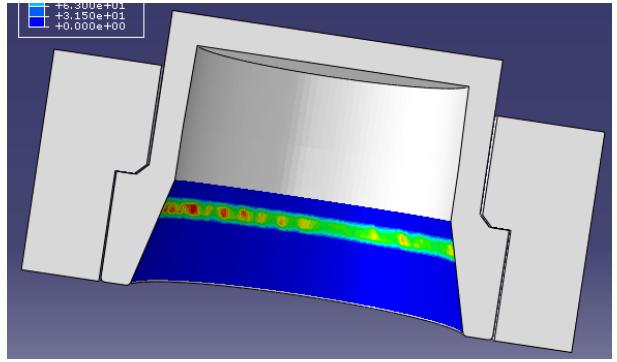
Innover en mécanique

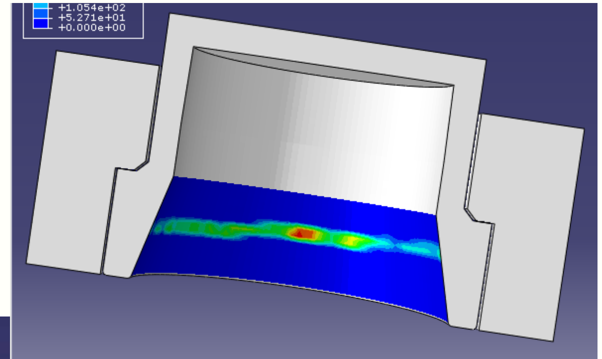
Fittings developments

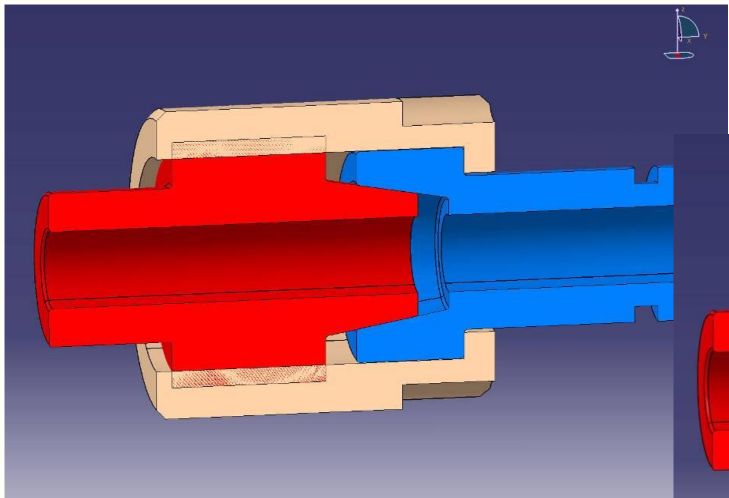
R&D phase

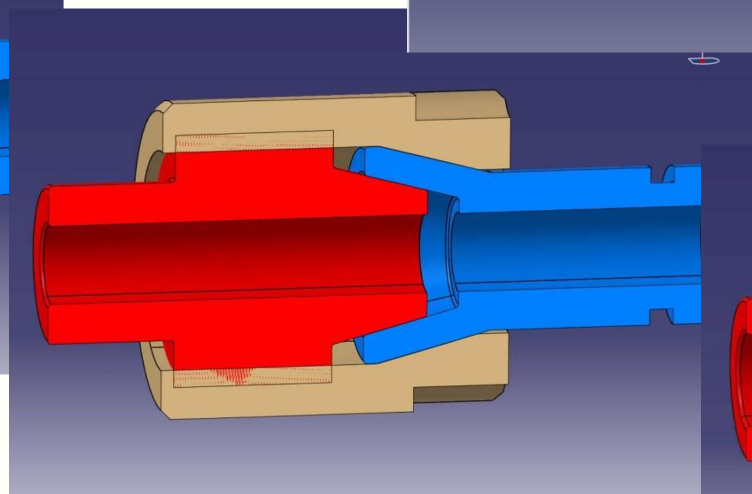
Many parameters tested before finding the good configuration

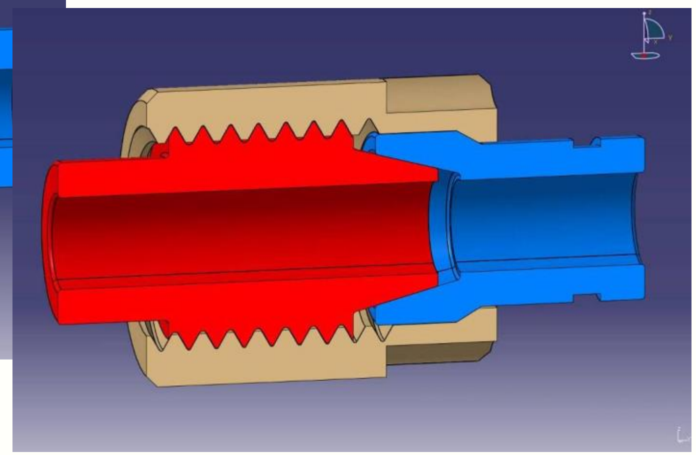
- Type of alloy
- Shape / geometry
- Surface quality
- Coating











Qualification

Validation, Qualification, Production ***(managed with CETIM industrial technical center)***

Prototypes :

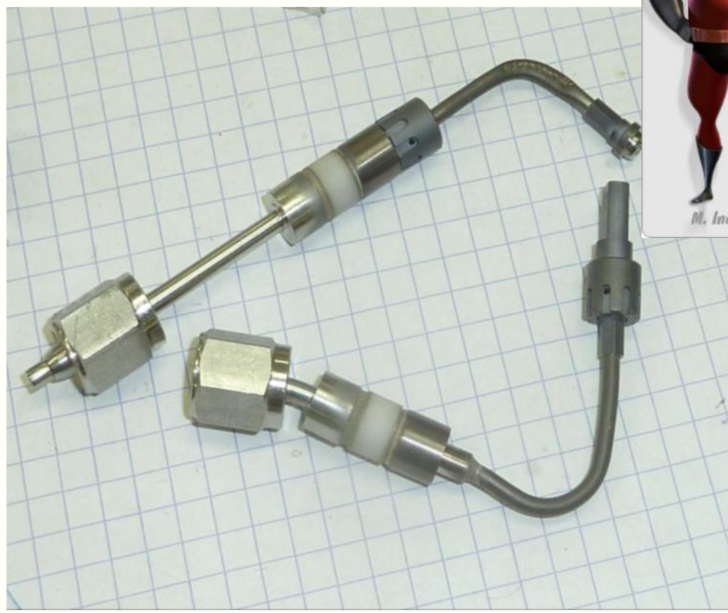
- Ceramic machining and brazing done by Microcertec (France)
- 10 + 4 prototypes produced and tested
- Validation tests on prototypes :
  - ❑ 50 CO_2 cycles (pressure from 10 to 55 bars, temp -40°C to 20°C)
  - ❑ He Leak test RT + cold
  - ❑ Ultimate hydraulic pressure test
  - ❑ 1 million 100b burst pressure test
  - ❑ Irradiation test (one sample) 250 Mrad

All the sample passed the qualification tests
Setups available at LAPP for ITK

Qualification

- About 300 fittings produced for validation/qualification and production
- 200 EB weldings
- All elements were marked and well protected
- 10 different types of tests performed

I have been pressurized to 640 Bars and I am still leak-tight!



IBL conclusion

Lessons from IBL

The fittings and the e-breaks meet the requirements and work very well

Both designs and qualification process can be reused for ITK

Questions about AL_2O_3 and titanium particles found in the CO2 filters -> Some found in the past but no more acording to the last info from the CO2 cooling team.

ITK developments - fittings

IBL OD 8mm qualified (OD pipe up to 2.5 mm) can be produced

New OD 10mm (OD pipe up to 3.5 mm) to be qualified

IBL type or more standard nut can be used depending on the space available aroung the fitting

We can provide some of them.

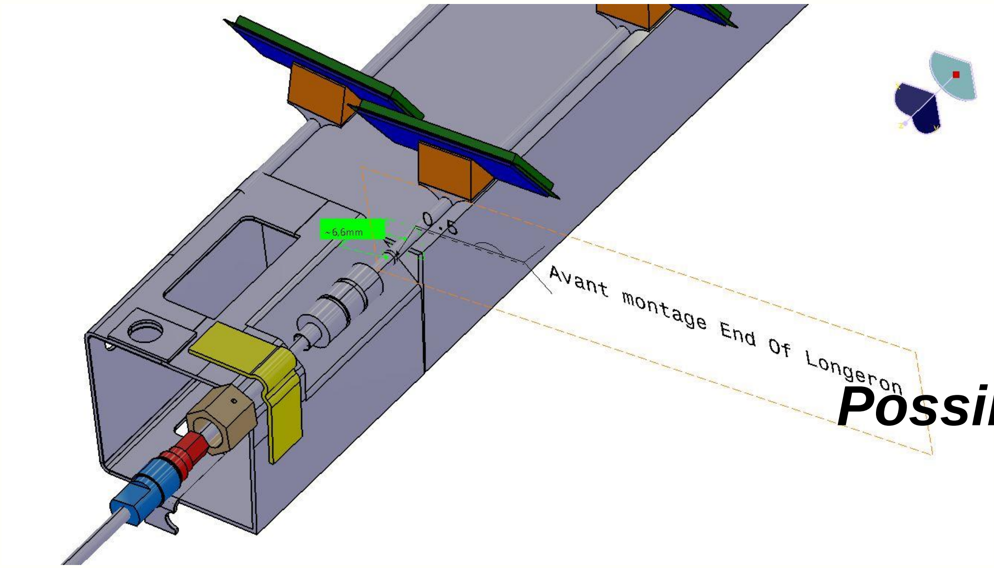
Hybrid (E-break + fitting coupled) for more compact solution to be qualified

- First developments were made for IBL but not implemented
- Thinner ceramic (600 microns)
- OD ceramic : 4 mm

Why do we need an e-break ? -> detector electronic protection

- Electromagnetic noise coming from the outside
- High current during Tig orbital welding (only for ITK)

→ **Discussion ongoing**



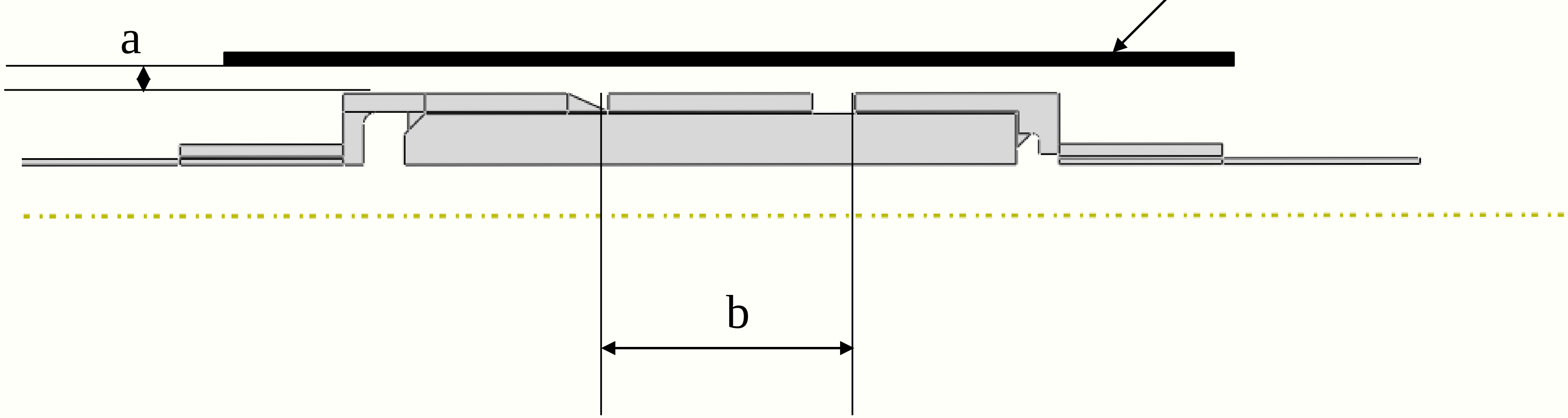
Possible e-break integration on the longeron

- Both sides are made of titanium

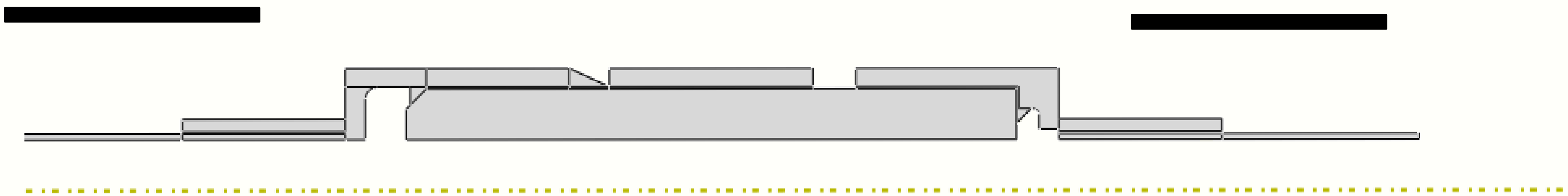
Electrical specifications

Conductive element

a and b have to be coherent

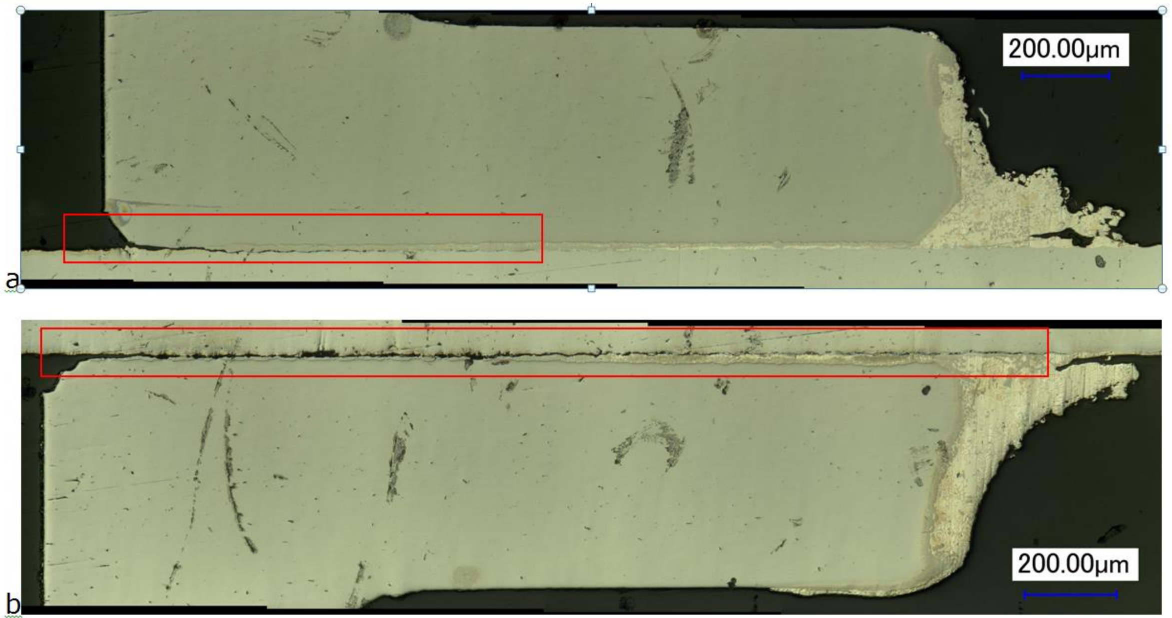


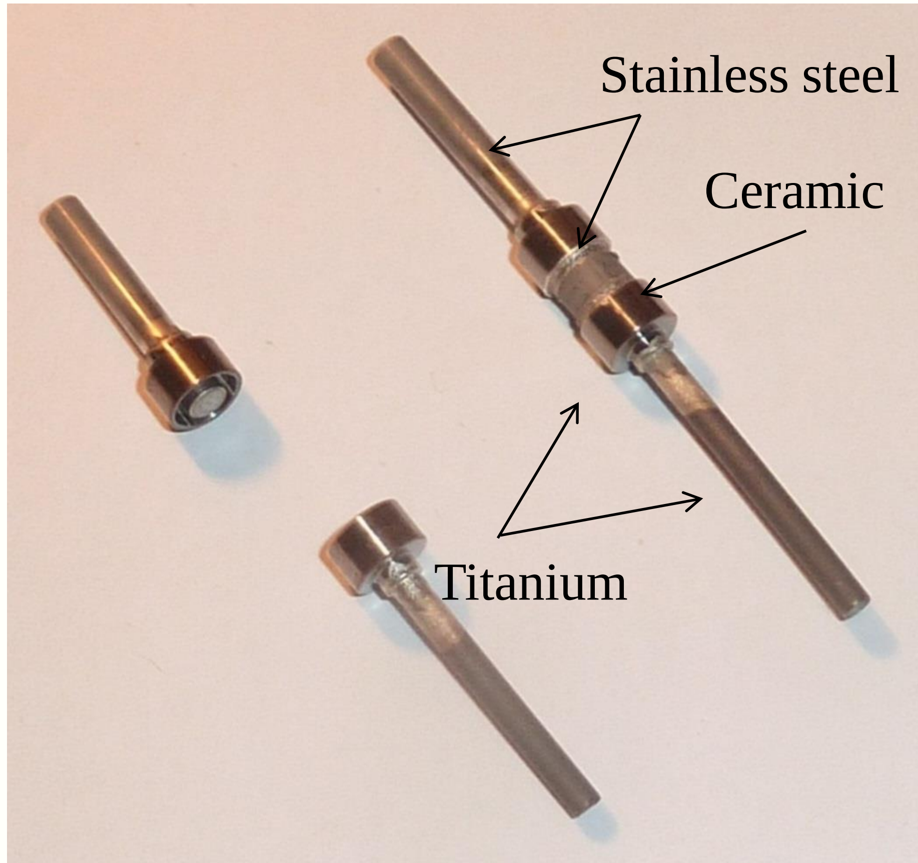
Preferred scenario



IBL - First tests made by Bodycote (active brazing)

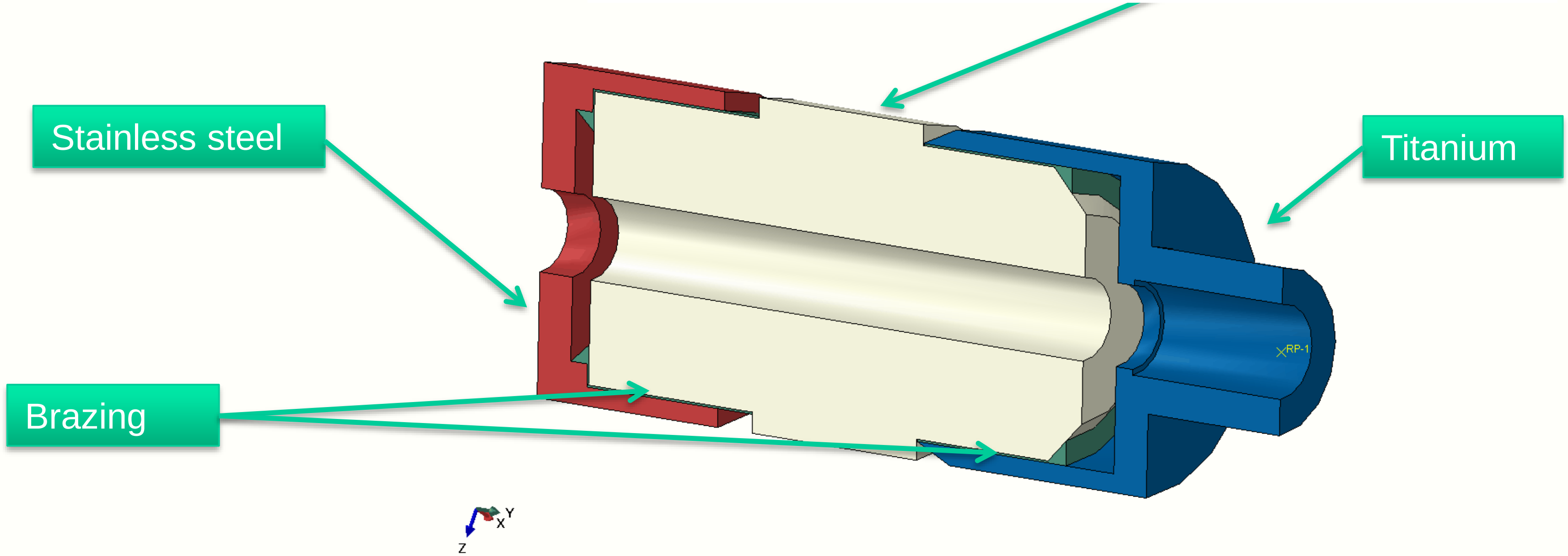
- Mixture=Cusil ABA / Silver, Copper, Titanium (could be fragilized by radiations)
- Stainless steel pipe covered with Nickel + gold
- Metalurgical analysis : cracks and some mixture missing



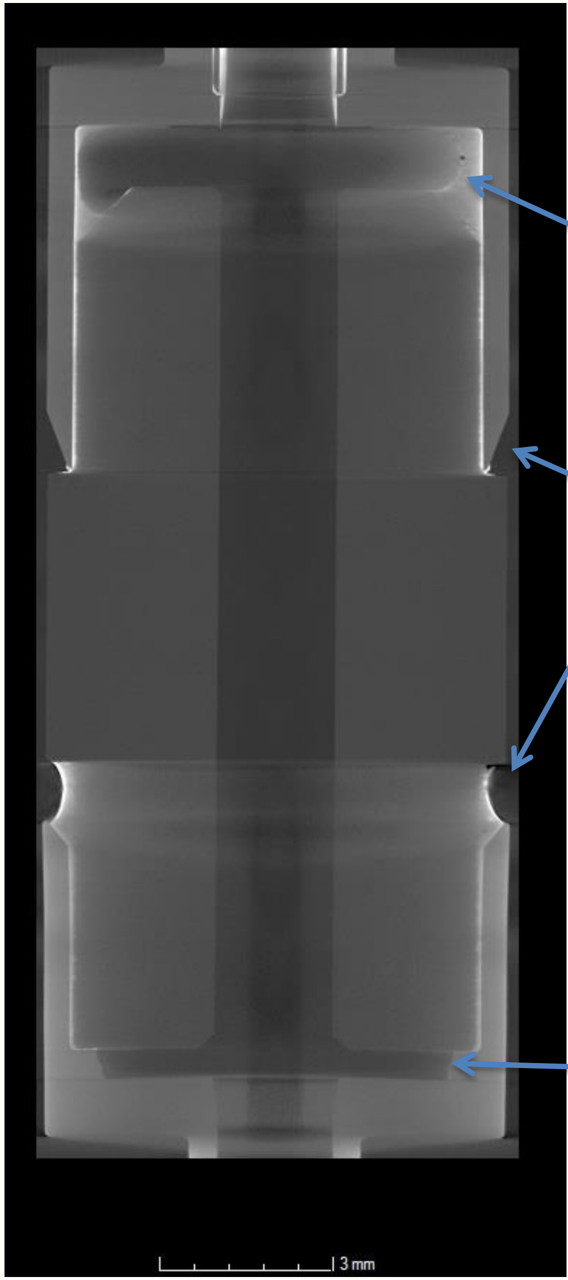


IBL E-break design (Microcertec)

IBL OD 8mm/ID 2mm qualified can be produced



First electrical tests done by John Mathewson (RAL)



Microcertec Brazing procedure

The 3 brazings are performed simultaneously in vertical position (Ti-ceramic, Ss-ceramic, Ti-Ti)

The brazing mixture is deposited here

It is expected to fill the cylindrical gap and to emerge here

Thus we can check the brazing quality of the Ti-ceramic junction by optical inspection

The stainless steel – ceramic brazing material flows down to here

We can't see visually if it filled the entire gap

Lack of brazing identified on prototypes and prod (thanks to X-rays and cut samples)

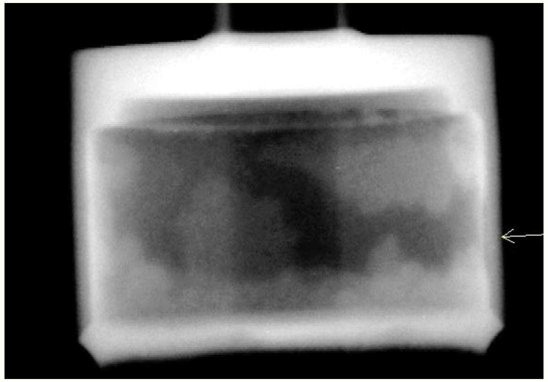
May come from metallic coating thickness variation

→ Microcertec works with a new subcontractor for brazing **(BACMI)**

Crack on the cut samples only (no crack seen with the tomography)

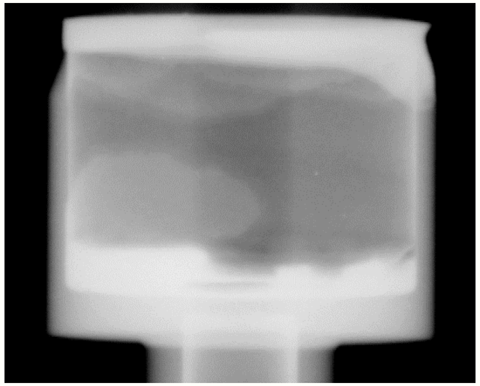
Cracks come from the cutting

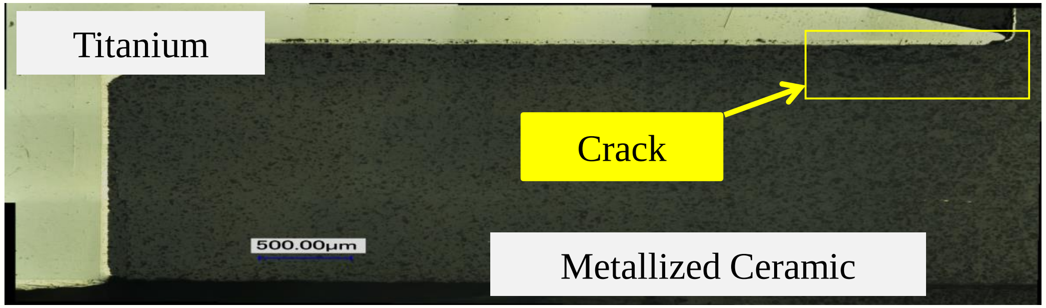
→ **Metalurgical preparation can brake the ceramic !!**

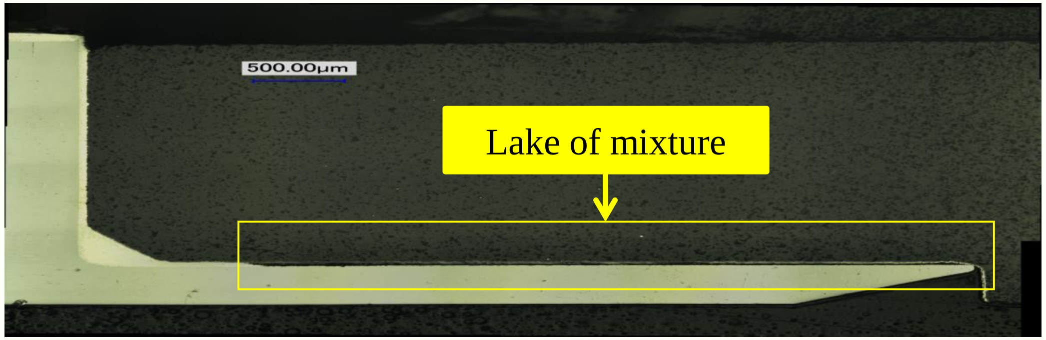


Stainless steel

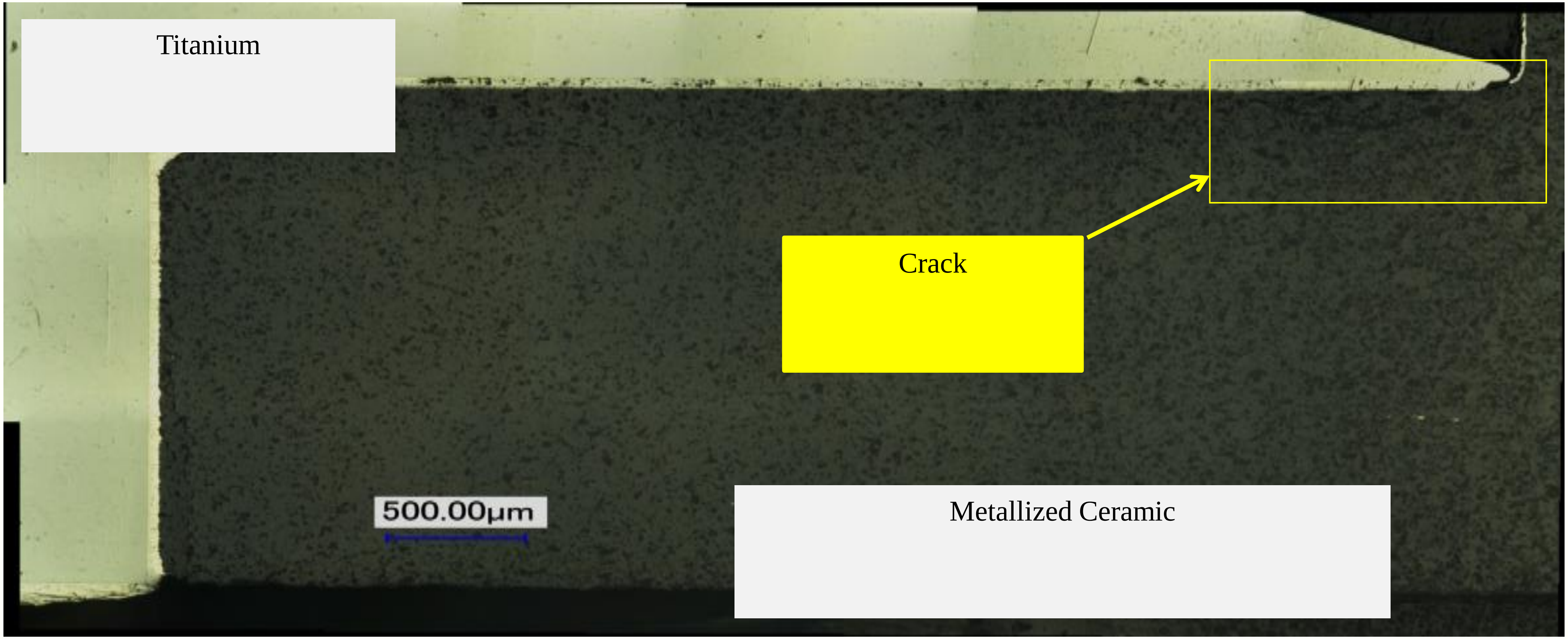
Titanium

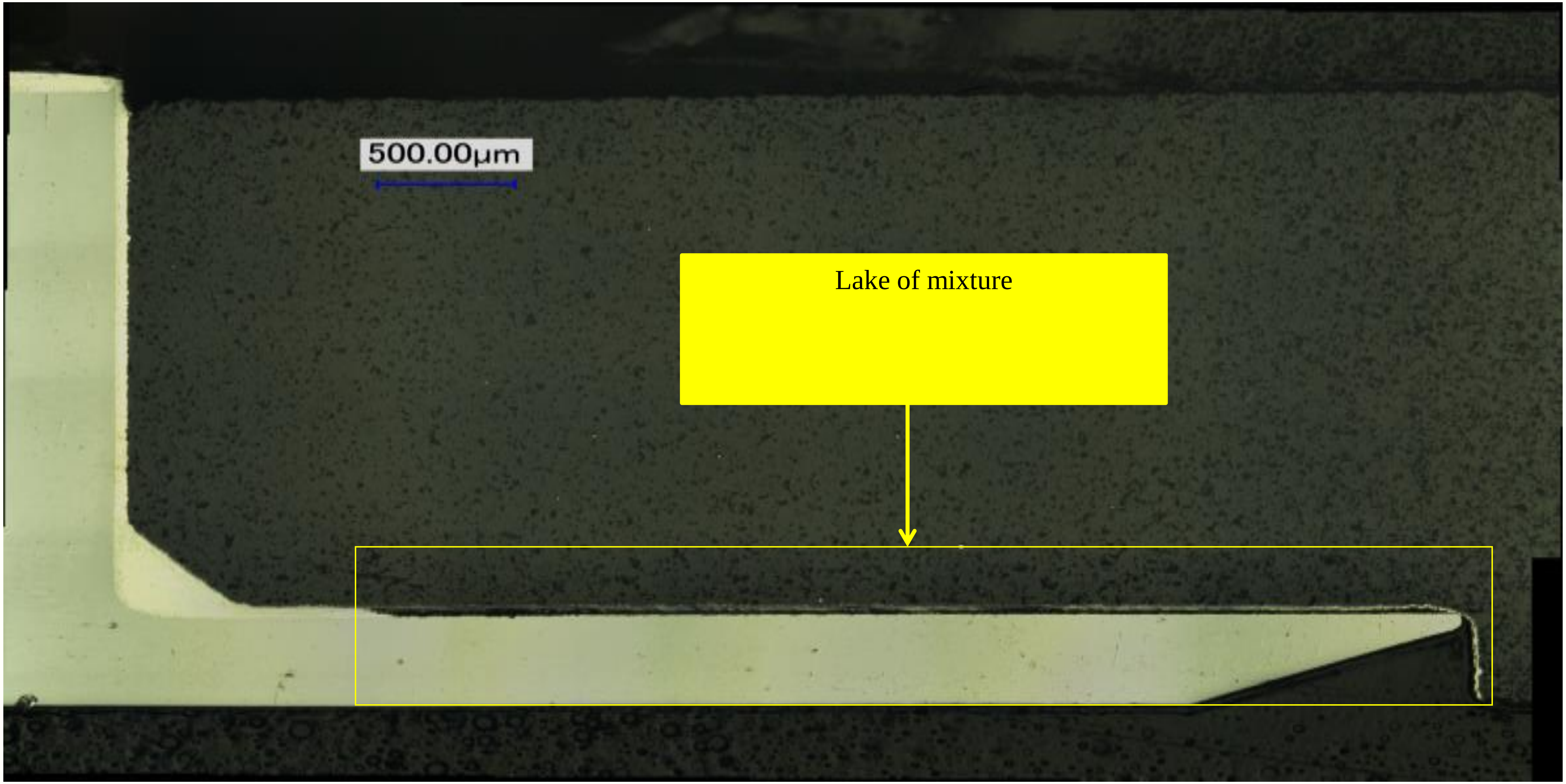






ITK developments – e-breaks



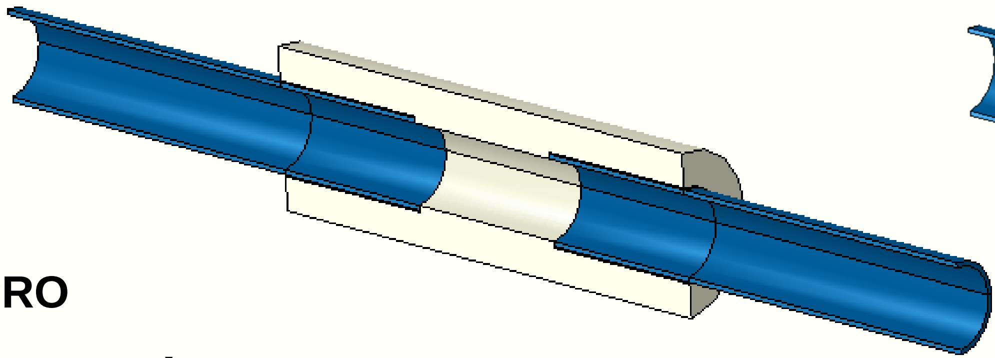

500.00µm
Lake of mixture

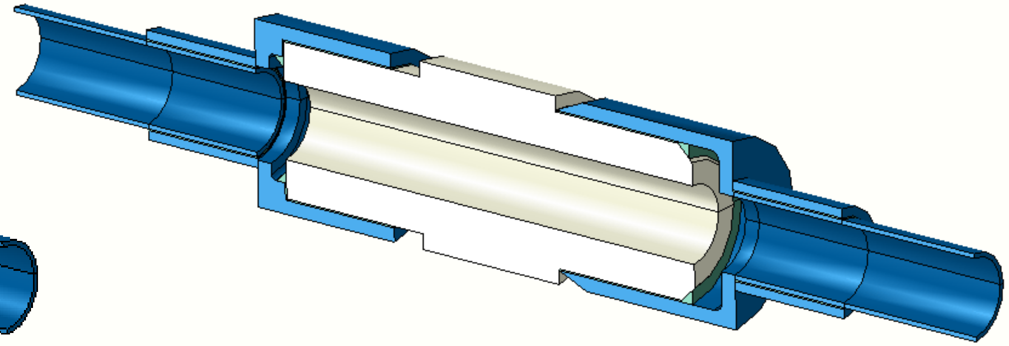
New designs

2 possible designs

New design (type 2)

IBL like (type 1)





PRO

- OD isolation
- Few pieces / brazed interfaces

CONS

- Robustness ?
- Brazing procedure ?
- Pipe not machined -> shape tolerance ?
- Metalisation thickness can't be controled

PRO

- Robustness
- Concept validated for IBL
- Still working on IBL

CONS

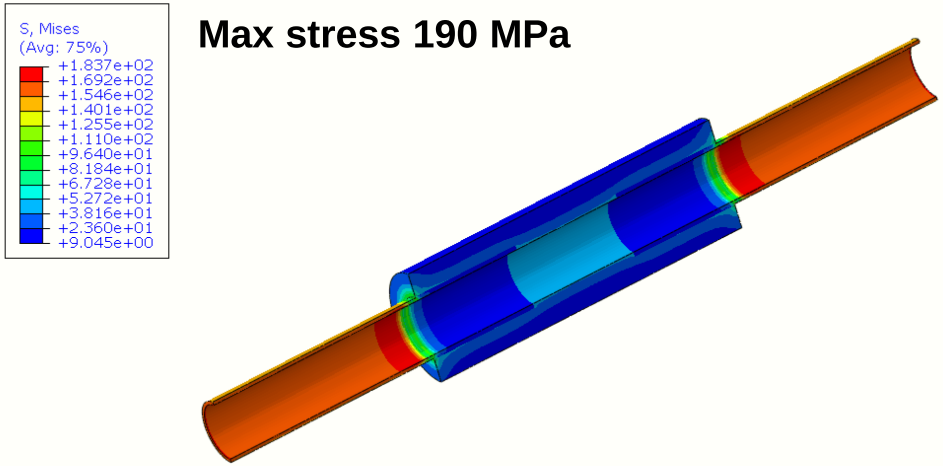
- Might need outer isolation (increase the envelop)

Type 1 / type 2 comparison

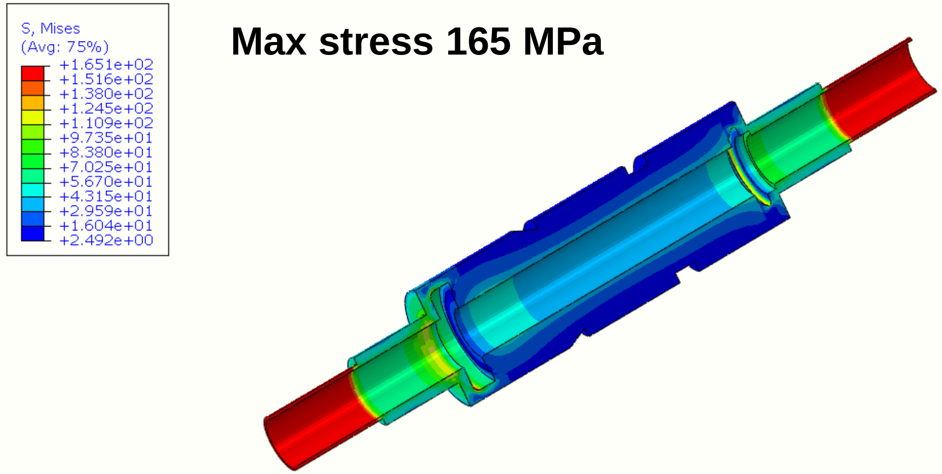
186 bars inner pressure

Von Mises criteria on complete model

Max stress 190 MPa



Max stress 165 MPa



Pressure hydraulic test made on the hybride prototype @250 bars OK

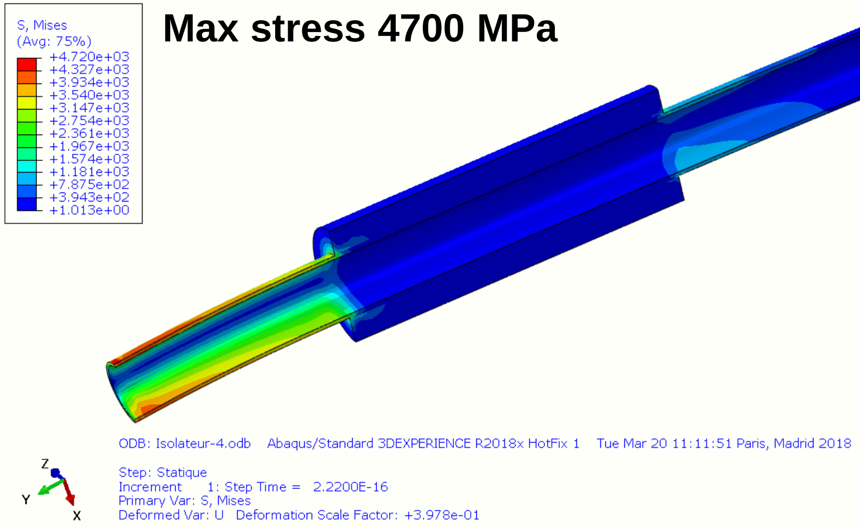
Inner pressure seems not critical

Type 1 / type 2 comparison

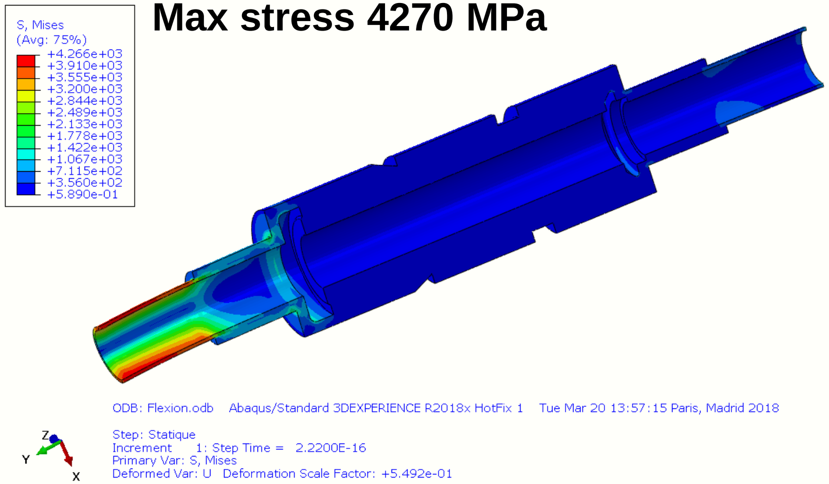
100 N flexion

Von Mises criteria on complete model

Max stress 4700 MPa



Max stress 4270 MPa



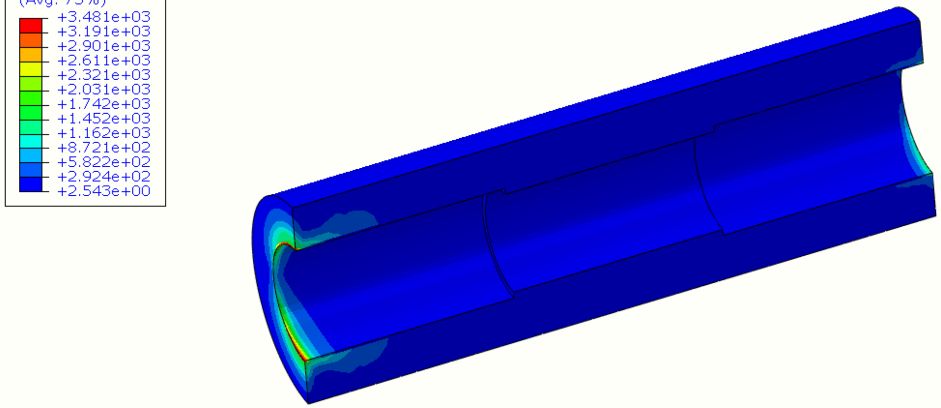
→ **The weakest part is the pipe**

Type 1 / type 2 comparison

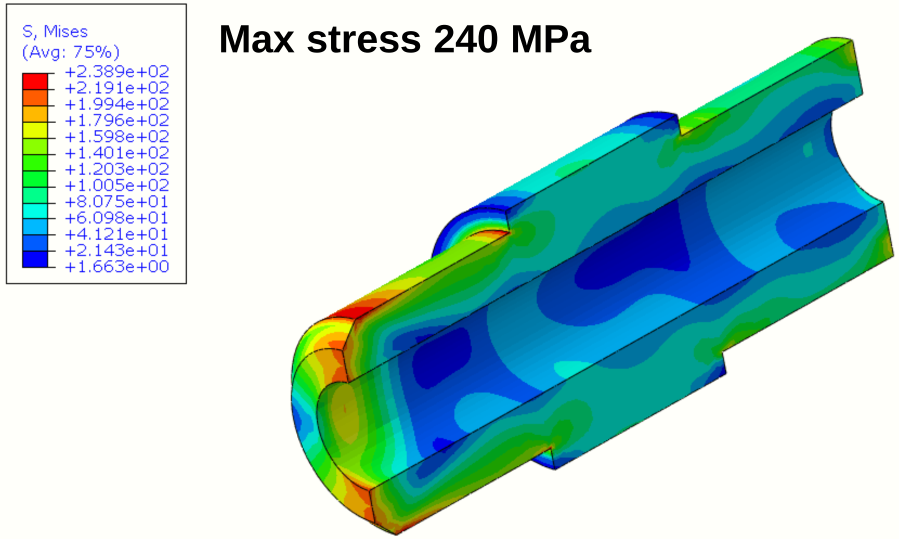
Von Mises criteria on ceramic

100 N flexion

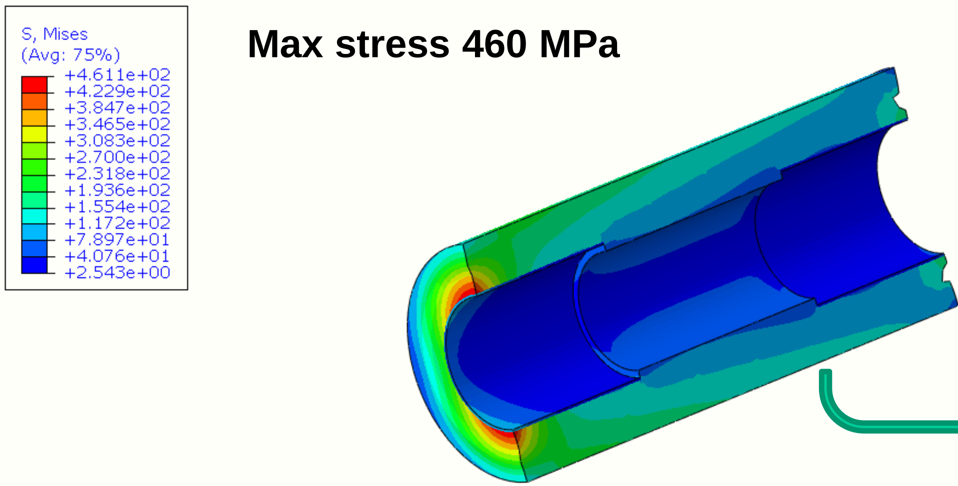
Max stress 3500 MPa



Max stress 240 MPa

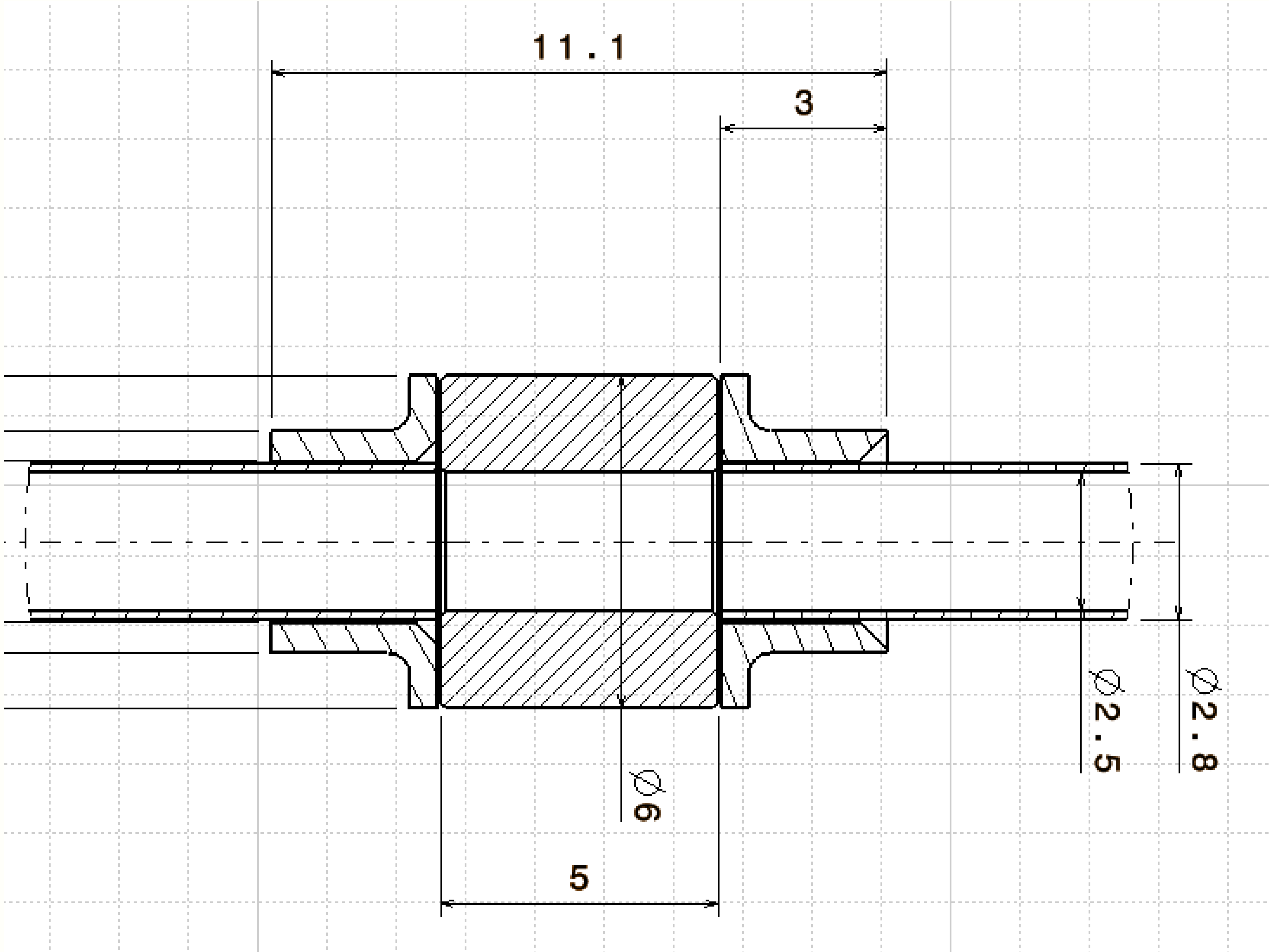


Max stress 460 MPa



For Type 2 stresses are applied on the brazing and the ceramic which limits are 1/3 titanium

Type 3 e-break



Type 1 / type 2 comparison

First conclusions

- Inner pressure load case seems not critical
- For accidental load cases the pipes should brake first but type 2 is less robust
- Accidental load cases depend on the production / integration process, same for all the detector components -> needs to be taken into account
- Tests are performed on Ceramic from IBL R&D
- Type 1 and 2 (or 3) prototype to be produced
- Releability : Microcertec/BACMI can use typical nuclear industry procedures based on strandards

Comments

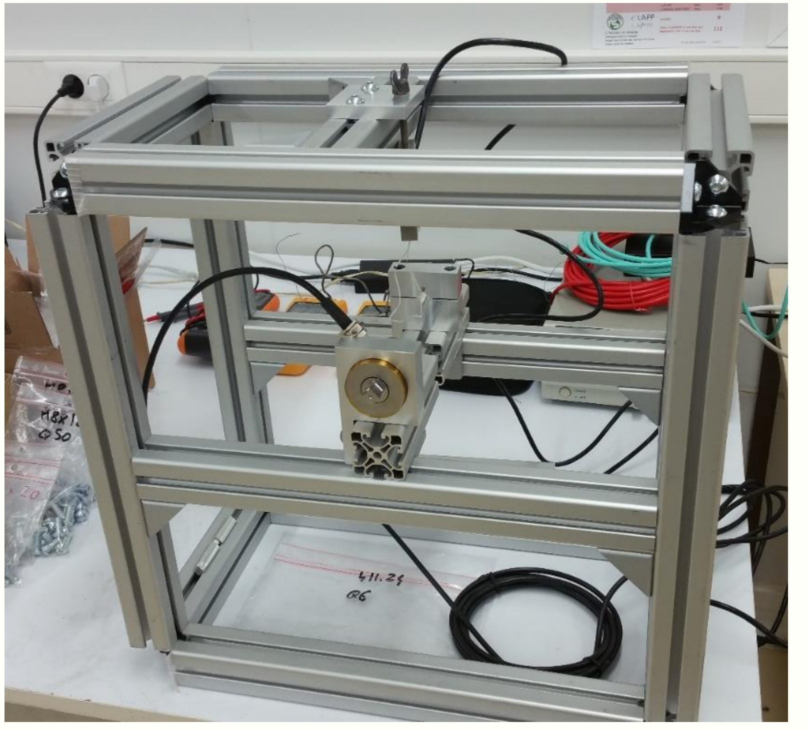
- Residual stress due to brazing can have a significant impact !

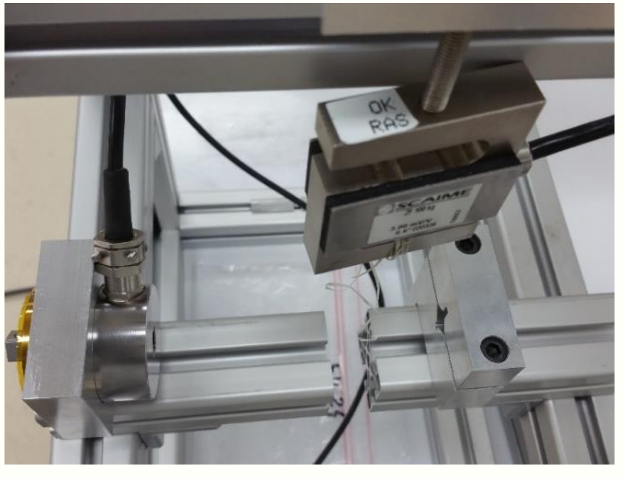
Preliminary tests on IBL CERN ceramics

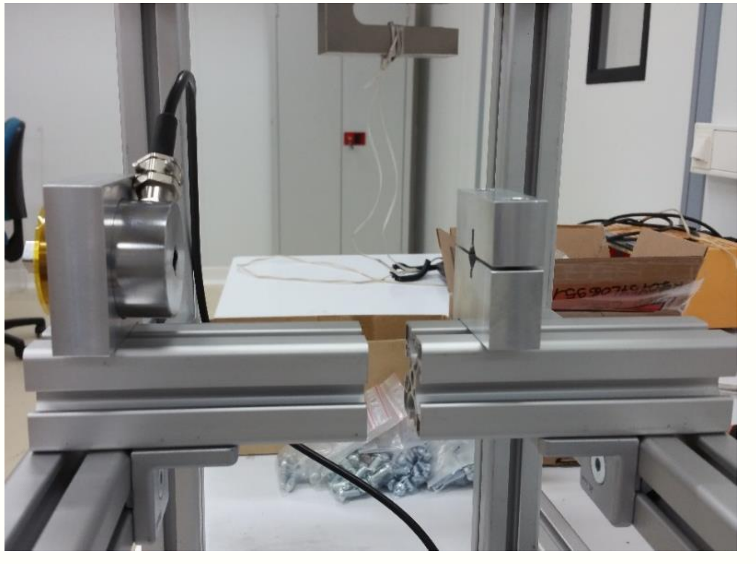
Flexion and torsion

Goal :

- Evaluate the ultimate break load depending on the ceramic wall thickness
- Needed to design the next prototypes

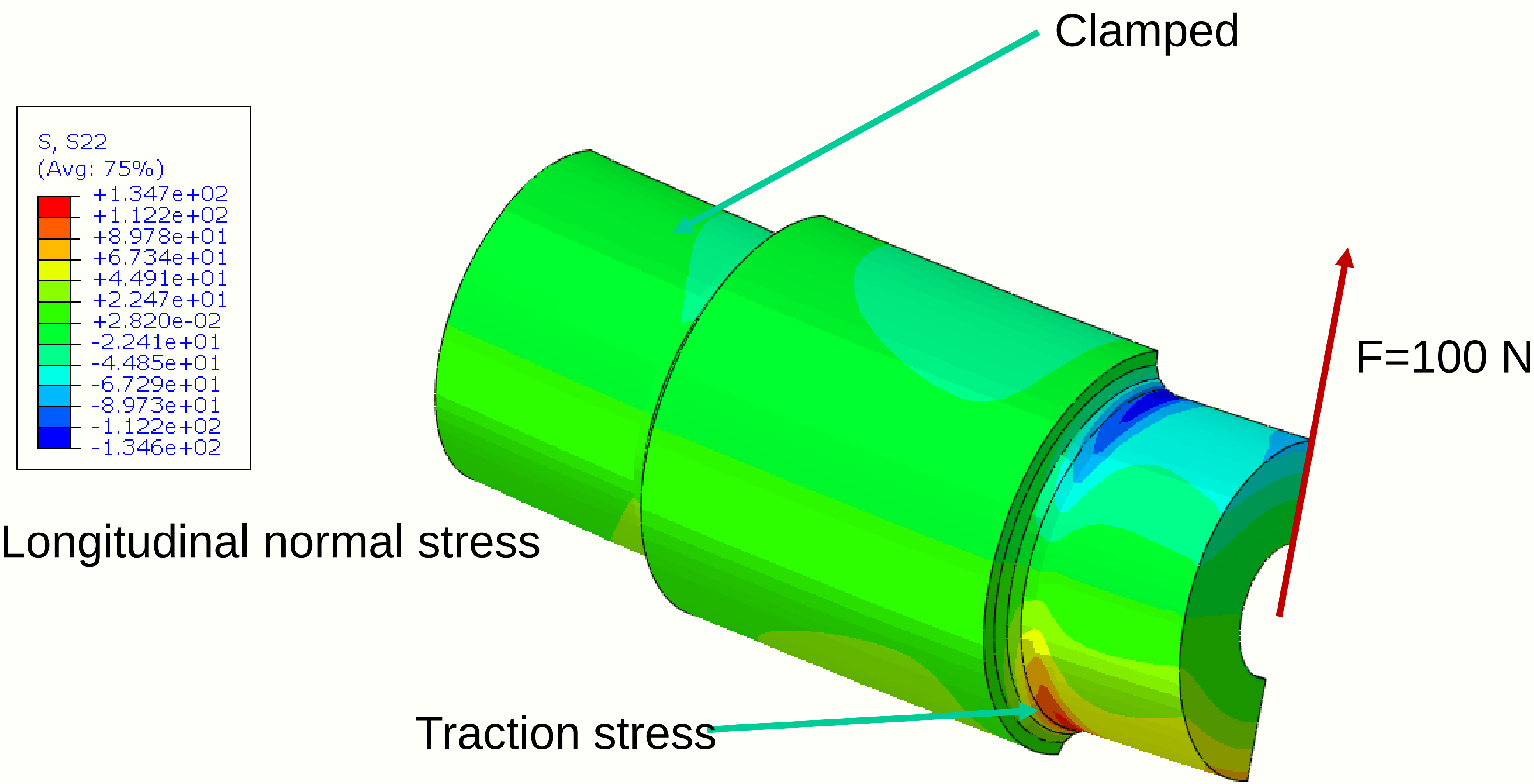






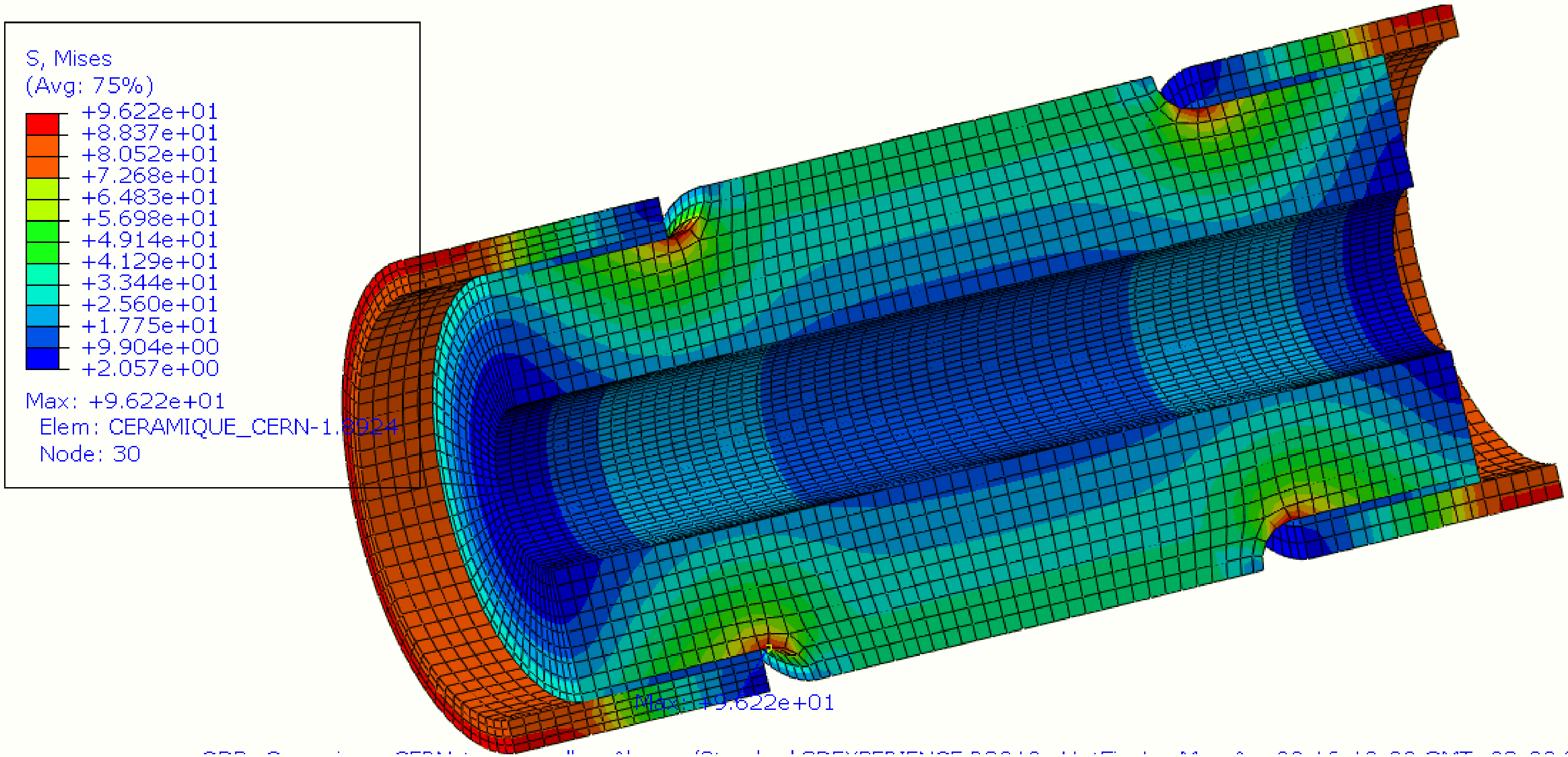
Preliminary tests on IBL CERN ceramics (ID 2 mm – wall thickness 1,5 mm)

Composite flexion : F=100 N



Preliminary tests on IBL CERN ceramics (ID 2 mm – wall thickness 1,5 mm)

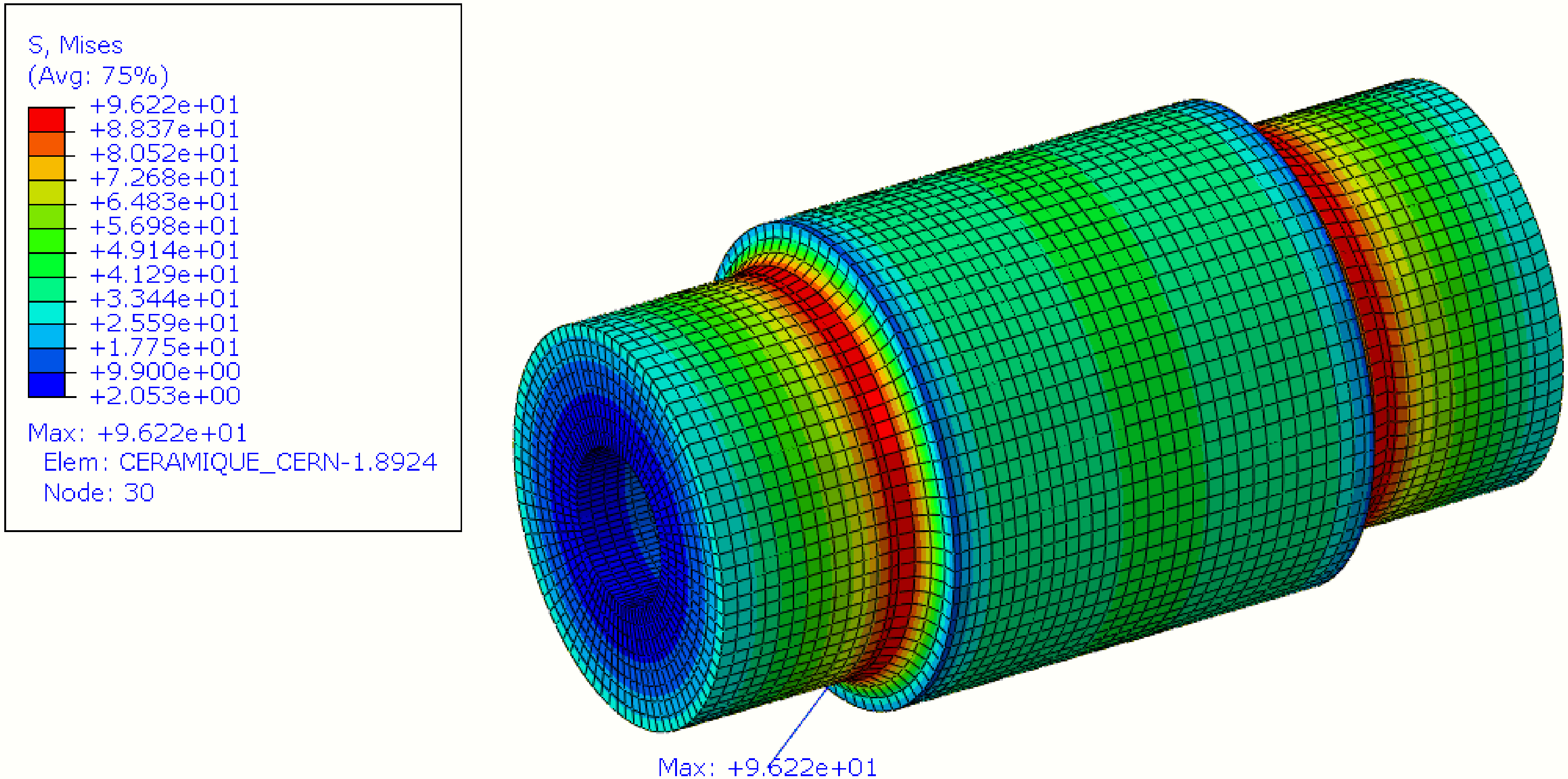
Torsion Test : T=1N.m
Complete assembly



Preliminary tests on IBL CERN ceramics (ID 2 mm – wall thickness 1,5 mm)

Torsion Test – T=1N.m

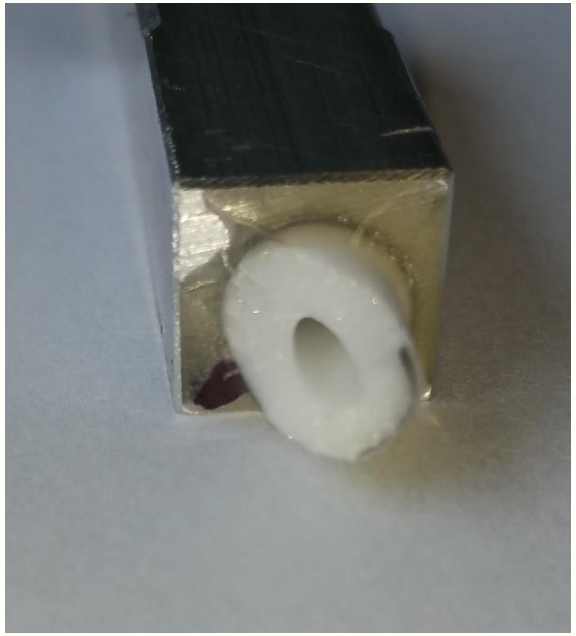
Ultimate shear stress data ??



Preliminary tests on IBL CERN ceramics (ID 2 mm – wall thickness 1,5 mm)

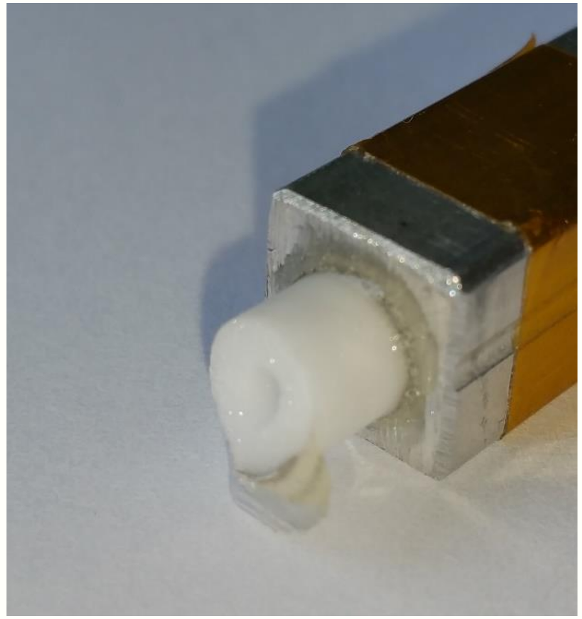
Flexion and torsion

First test results (FEA model has to be modified to fit the experimental conditions)



Torsion

Break @ 4 N.m



Flexion

Break @ 440 N (sim says 220 N)

Next steps

- Tests on remachined CERN ceramics (wall thickness 1 and 0,5 mm) – June
- 2 types prototypes to be ordered – June (delivery in October)
- Tests on new prototypes – Before end 2018

Thank you

Backup slides

IBL Specifications

- Small fitting, less than ∅8 mm :
  - Minimize material budget
  - Fit inside a limited volume
- Maximum leak rate (He) : 10^{-5} mbar.l.s-1 @ 1bar (10^{-8} mbar.l.s-1 @ 20bar retained for validation)
- Working temperature : mini -40 ° C → maxi +20 ° C
- Pressure (bar):

	Test	Max design	service ultimate at 20°C	service normal at -40°C
CO_2	150	100	70	10

- Radiation level : 1 Grad
- Pipe material : Titanium grade 2
- 20 mountings / dismountings at least

Main rules for an "industrially qualified" fitting

- A **plan** must be **defined** and **written** to make sure all aspects are considered. This plan has to be **checked** and **validated** by an **external authority**.
- **Quality control is different from quality management** : defining controls is not enough to unsure a good quality product
- **Tests devices** and **procedures must be** first themselves **qualified** to be used for tests operations. Devices must be periodically controlled to check their capabilities.
- **International standards** should be used. They can be **adapted to the specific context** but it has to be validated.
- **Parameters** (qualification and production) must be strictly **recorded and managed**. Any detail must be discussed and formalised with subcontractors. All "strategic" elements must be marked and their life must be tracked.
- The **requirement levels** must be **adapted** in order to be efficient.