ILC Cryo-module studies

- Bellows and stability issues in interconnections
- St.steel/Ti transitions by explosion bonding: first results

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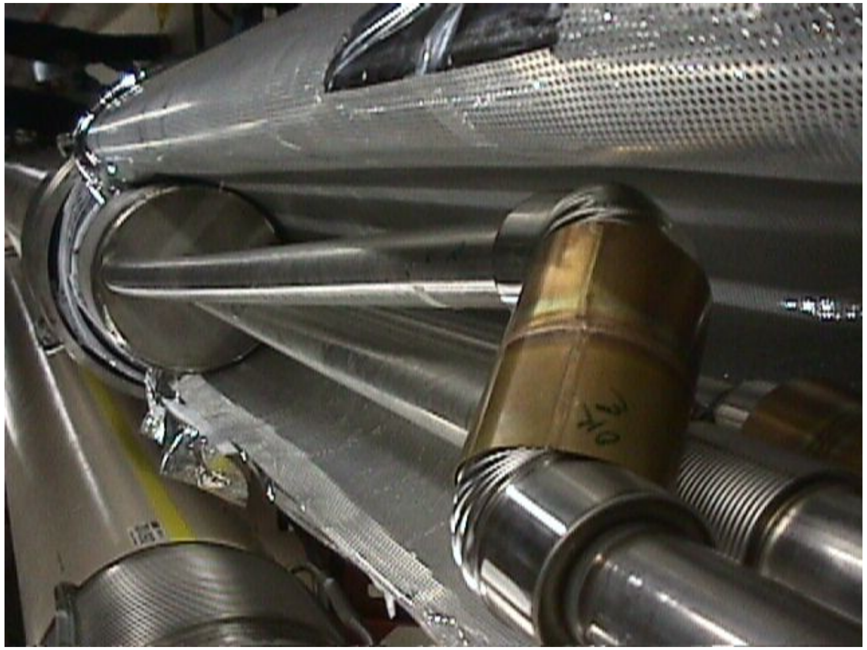
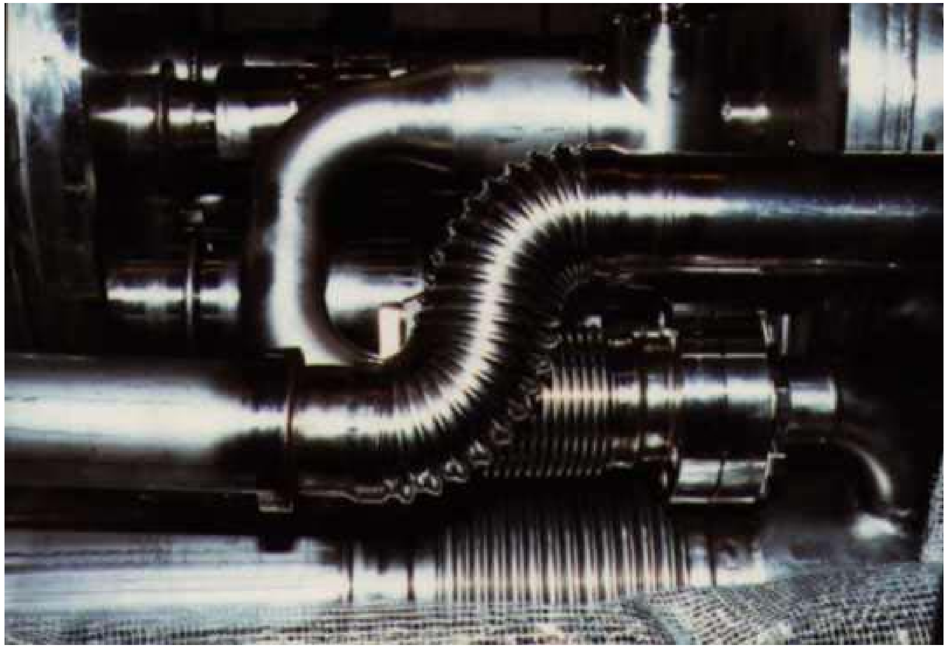
CERN, TS/MME G.Arnau, A.Gerardin, S.Sgobba,

Global instability…too often forgotten

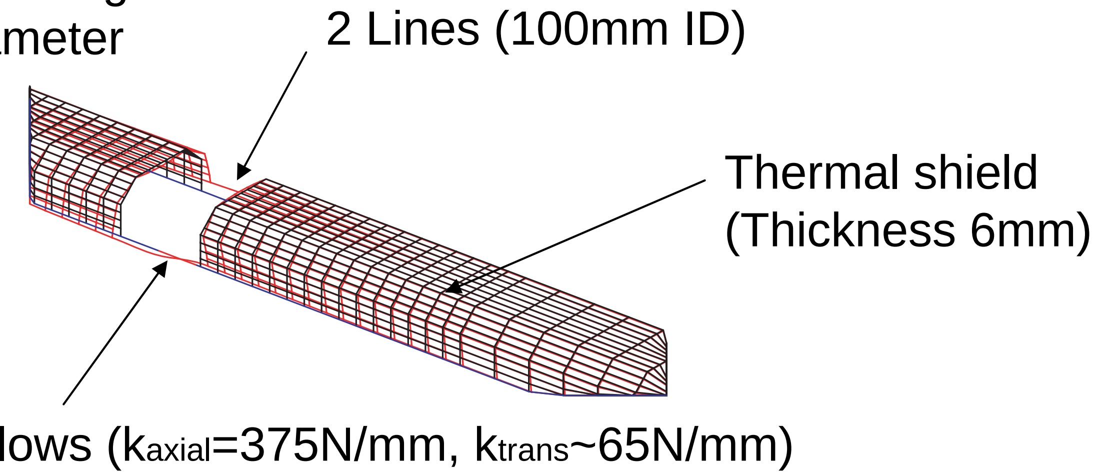




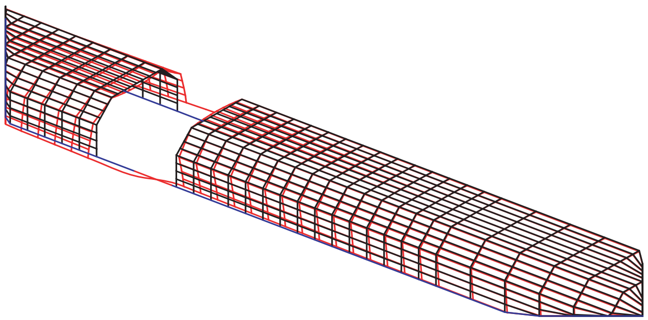
→ ***Correct guiding of the bellows extremities is a must.***

Thermal shield stability

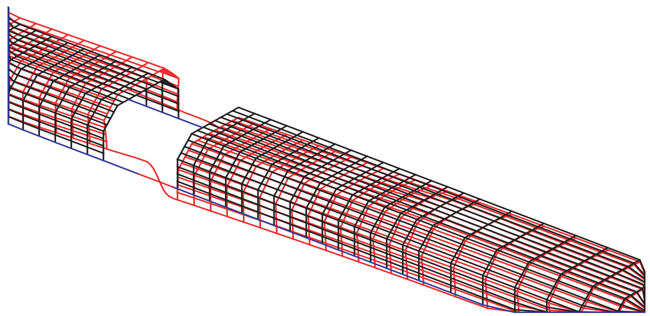
- ref. geometry TTFIII drawings
- increased cryo line diameter



Instability of the thermal shield can occur under internal pressure.



Critical pressure ~ 25bars

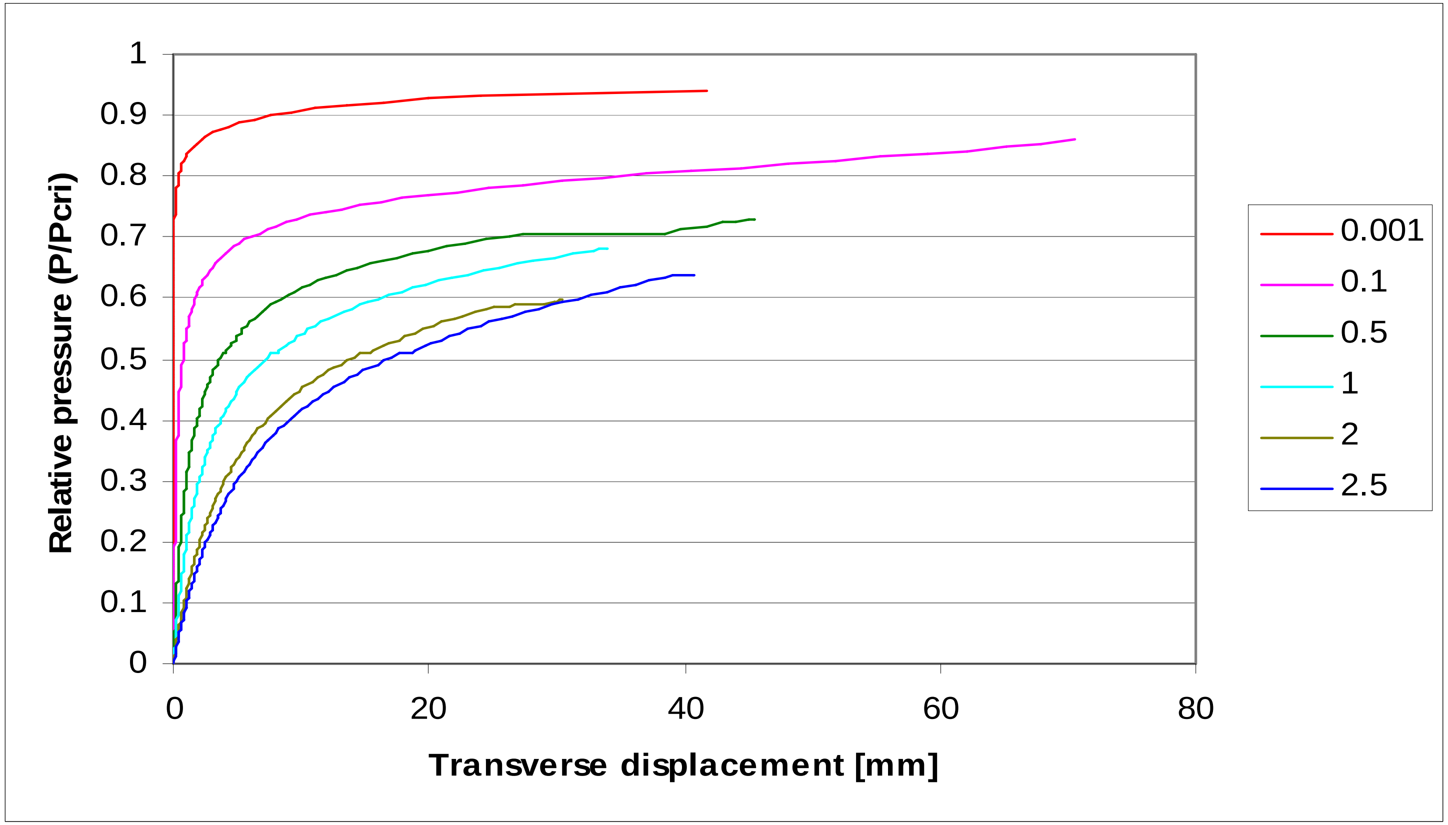


P mode ~ 40 bars

→ Stability of the thermal shield has to be checked carefully (boundary conditions, stiffnesses, …)

Thermal shield stability: sensitivity to initial imperfection

Initial imperfection can lead to **large transverse displacements** at relatively low pressure:
• plastic deformation of bellows
• large transversal forces → cavity/quads alignment?
• interference with other equipment

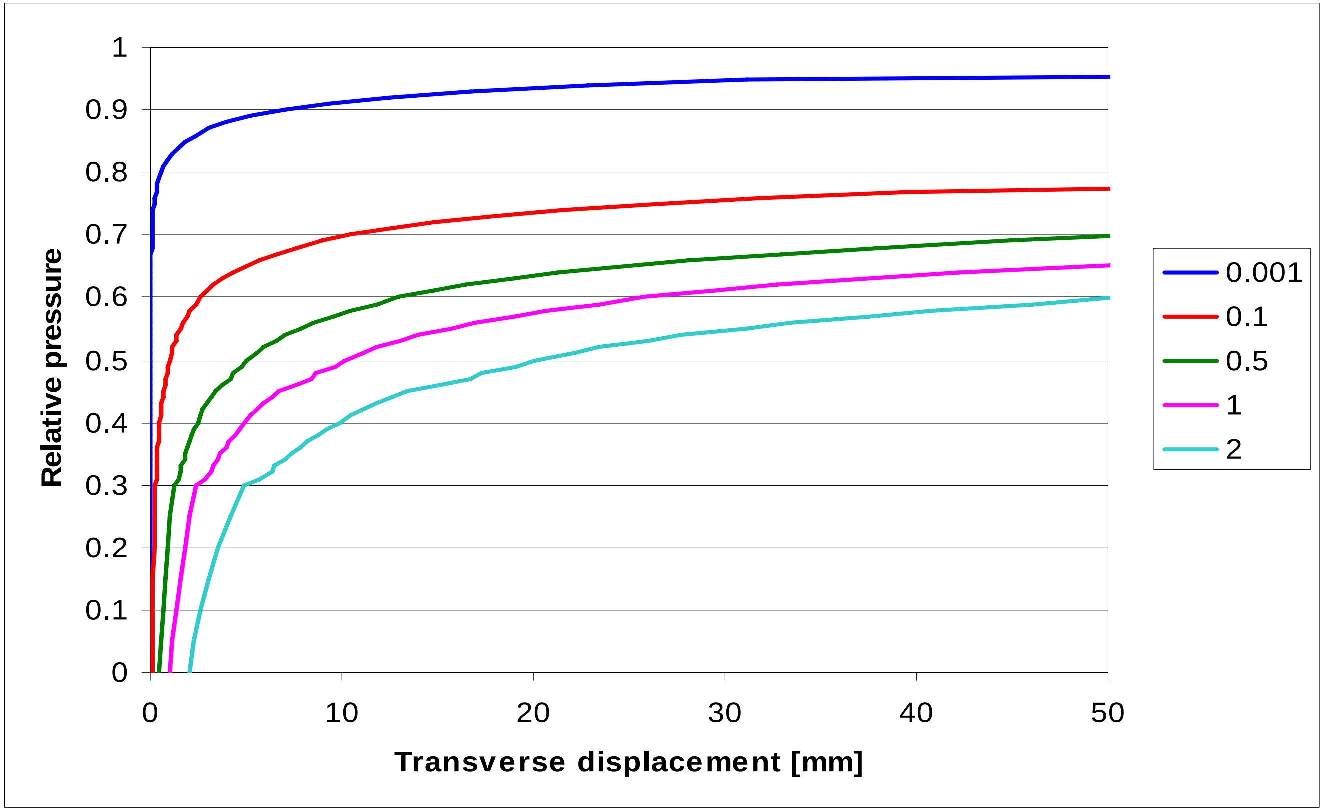


Pumping line stability: sensitivity to initial imperfection

Hypothesis:

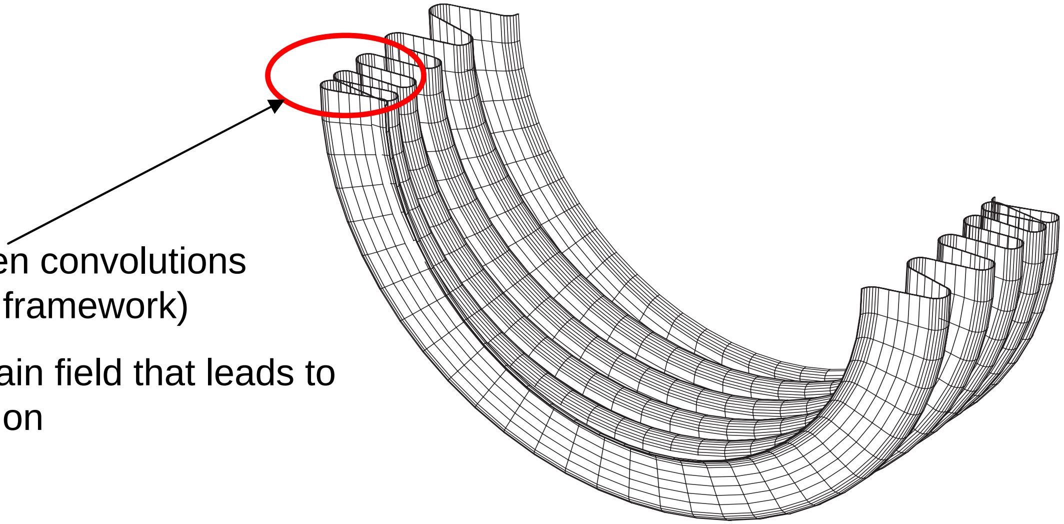
- Tube diameter: 300mm, tube thickness: 2 mm (instead of 3mm)!
- Bellows axial stiffness ~150N/mm

(Critical pressure: 13.3 bars (need to be recalculated for a tube thickness of 3mm))



Intercavity bellows

Preliminary study has been done for short version (5 convolutions):
• Under axial stroke (4mm), high cycle fatigue should occur (10^6 cycles),
• Introduction of a lateral offset of 4mm leads to probably low cycle fatigue regime and local contact between convolutions,



Contact between convolutions (outside EJMA framework)

High plastic strain field that leads to damage evolution

Some preliminary conclusions

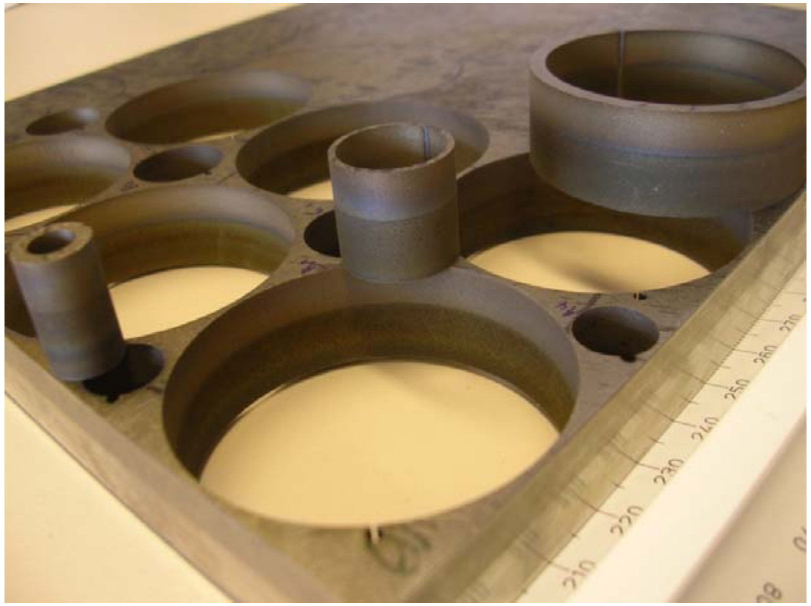
- Global stability could be an issue
- More detailed study of thermal shield and puping line bellows can be done
- Model of the intercavity bellows has been done. Fatigue life can be estimated.

→ CERN’s expertise on bellows calculation is available for further work.

Ti-316LN transitions by explosion bonding

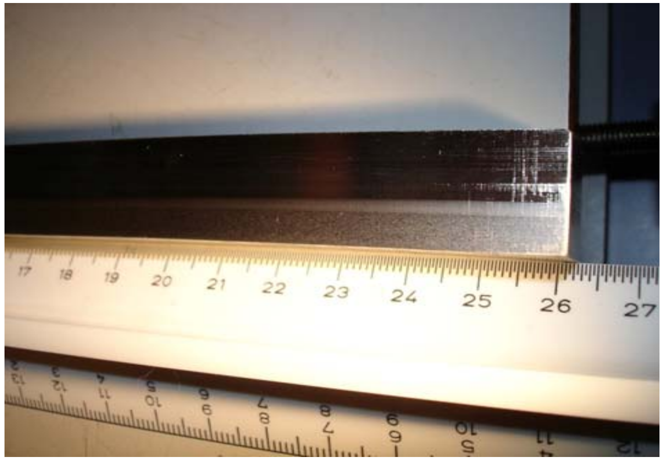
- Prototype plate made for CERN by Powder Metallurgy Institute (PMI), in Minsk, Bielorussia.
- Metallurgical characterization of samples.
- Pipe samples cut by electro-erosion:
  - 6 samples 42.8/48.2 (size of ILC connection pipe between He vessel and bi-phase pipe)
  - 4 samples 15.2/17.2
  - 3 samples 6/10

  Dimensions for which CERN has orbital welding machines (4 samples 15.2/17.2 and 3 samples 6/10)



Metallurgical characterisation of Ti-316LN transition produced by explosion bonding

▪Metallography



▪Mechanical testing

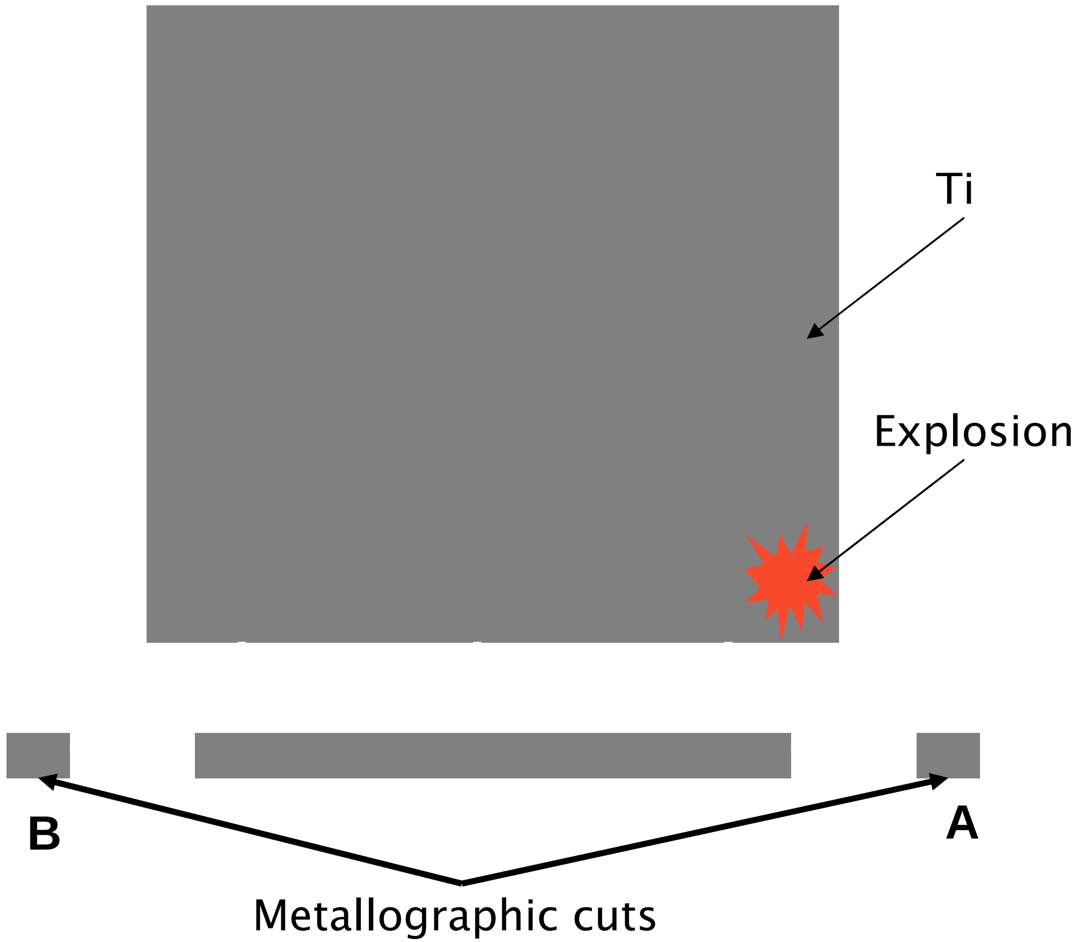
▪Gonzalo Arnau Izquierdo Materials engineer TS/MME/MM

▪Alexandre Gerardin: Materials technician TS/MME/MM

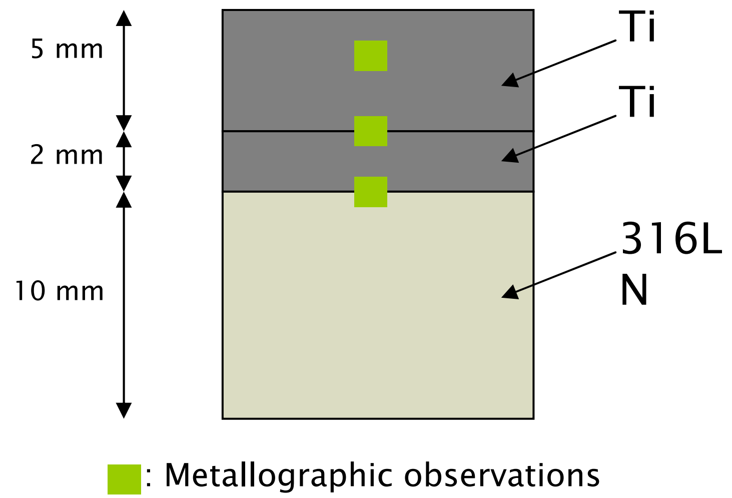
▪Stefano Sgobba: Materials engineer TS/MME/MM

Metallography

- Ti : Grade 2
- Stainless steel : 316 LN



- Thickness detail:



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Metallography (sample A)

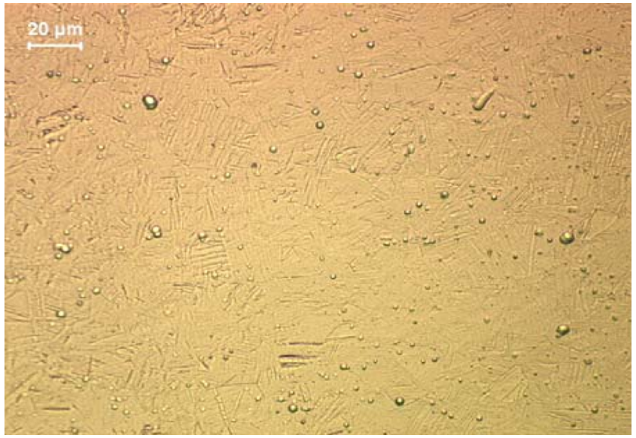
- Interfaces :

Interface Ti/316 LN

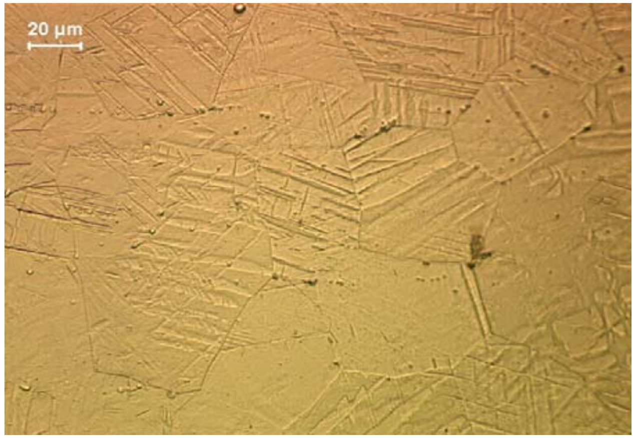
Interface Ti/Ti

- ‘Wave’ amplitude about 50 µm for Ti-Ti bonding

- Microstructures :



Microstructure Ti t=2 mm



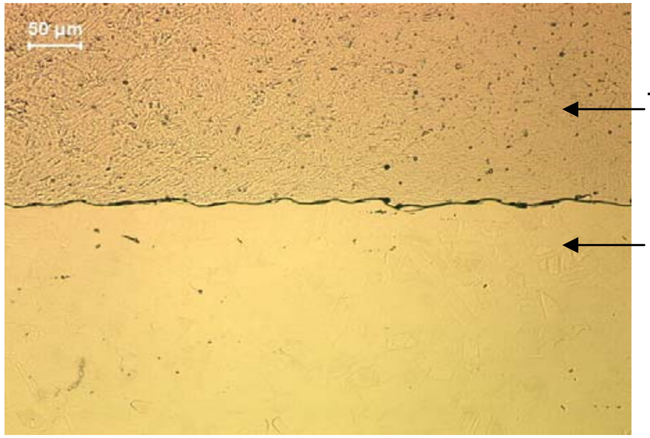
Microstructure Ti t=5 mm

- Greater grain size for 5 mm thick Ti.

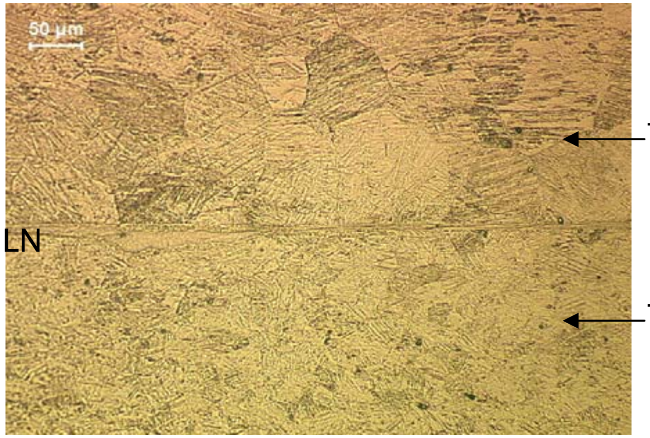
Results from B. Bellanger ESIA and TS/MME/MM
EDMS 774145

Metallography (sample B)

- Interfaces :



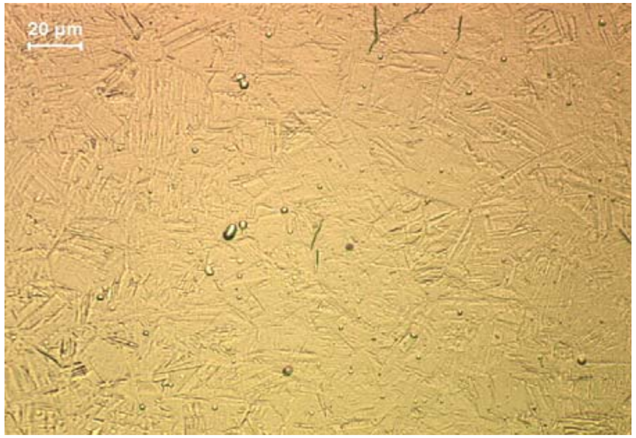
Interface Ti/316 LN



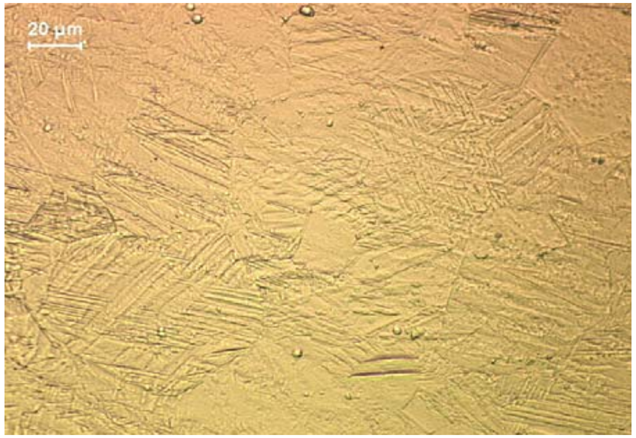
Interface Ti/Ti

- 'Wave' amplitude nearly unexisting

- Microstructures :



Microstructure Ti t=2 mm



Microstructure Ti t=5 mm

- Greater grain size for 5 mm thick Ti.

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▪*Metallography*

▪Conclusions:

▪Bonding Ti/316 LN :

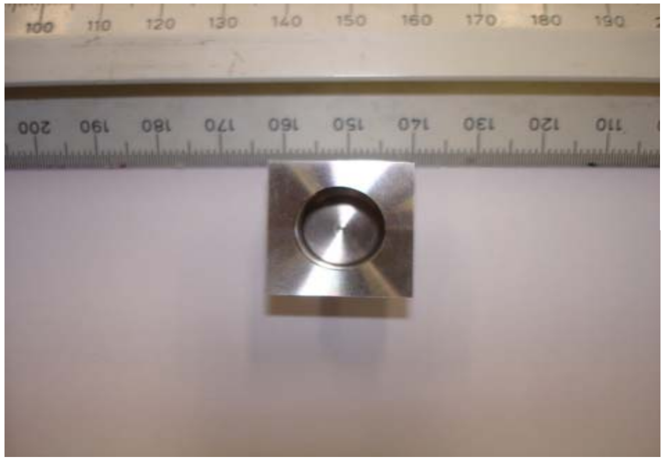
- No cracks detected
- Low ‘wave’ amplitude similar away and close to explosion location

▪Bonding Ti/Ti :

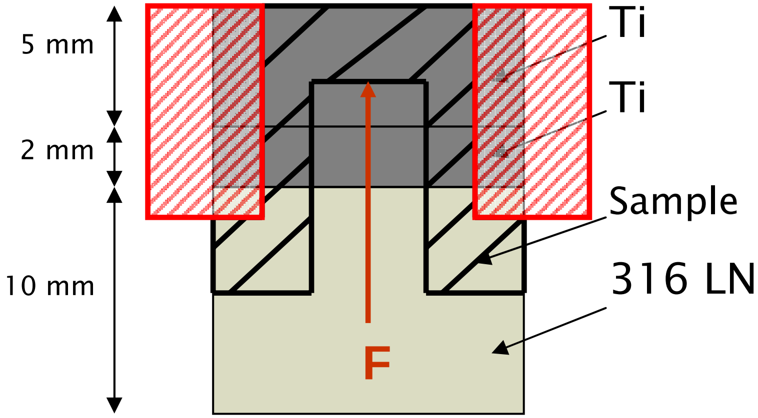
▪Close to explosion location ‘wave’ amplitude is nearly 50 µm

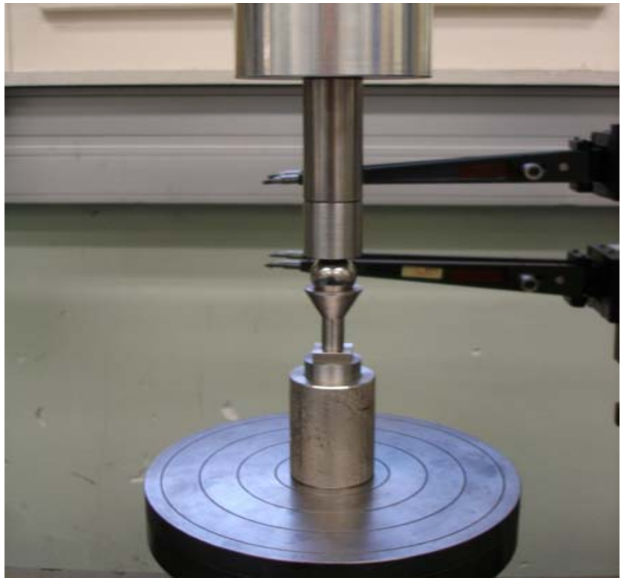
▪*Mechanical testing*

▪Tensile testing



Samples



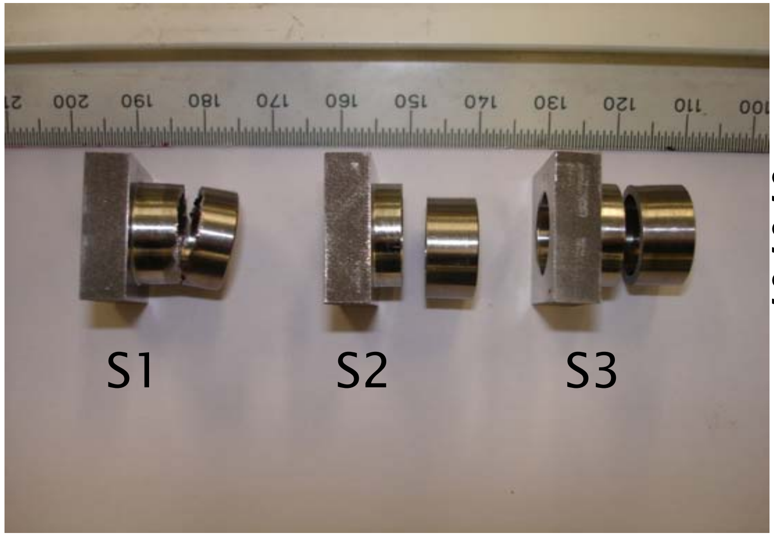


Assembly setup, design G. Arnau, developed for CLIC bimetals, testing, evaluation and summary: A. Gerardin

Mechanical testing

- Tensile testing
  - Results:

Samples	Maximum force (kN)	Rm (MPa)	Displacement (mm)
S1	46.8	735.6	0.81
S2	48.2	757.7	0.79
S3	50.5	793.8	1.00
Average	*48.5*	*762.4*	*0.87*

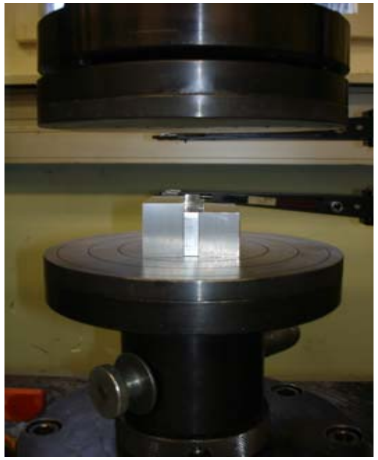


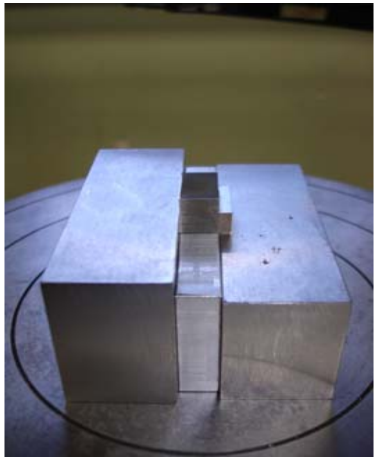
S1: Rupture interface Ti–Ti
S2: Rupture interface Ti– 316 LN
S3: Rupture interface Ti– 316 LN

▪*Mechanical testing*

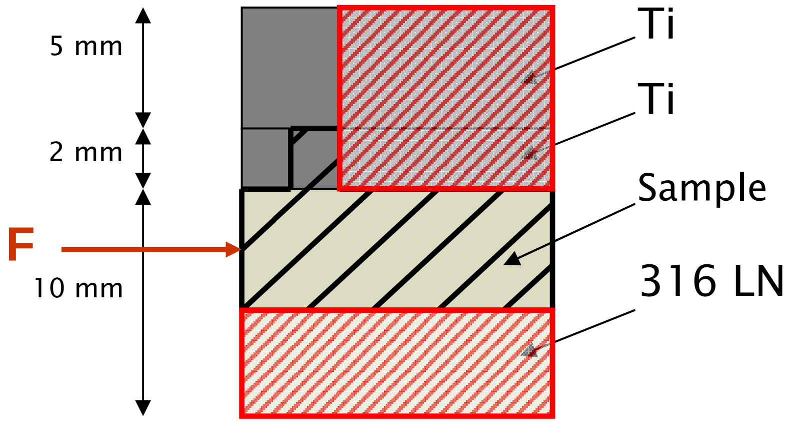
▪Shear testing on Ti/st.steel interface

Samples





Assembly set-up



G. Arnau / A. Gerardin/ S. Sgobba TS/MME/MM

Mechanical testing

- Shear testing
  - Results:

Samples	Maximum force (kN)	τ (MPa)	Displacement (mm)
T9–H3–W6	32.8	≥ 359.6	1.29
T9–H2–W4	21.6	≥ 360	0.97
T9–H1–W2	10.4	≥ 347.2	0.94

Distortion of the tooling before breakdown

G. Arnau / A. Gerardin/ S. Sgobba TS/MME/MM

Mechanical testing

- Conclusions:
  - Tensile :
    - Average Rm = 762 MPa
    - Breakdown on both Ti-Ti and Ti-316 LN interfaces
    - Displacement at breakdown could be measured between 0.8 and 1 mm
  - Shear :
    - Maximum τ measured ≥ 360 MPa , improved tooling will allow more accurate measurements

First conclusions and next steps

- Metallography:
  - no cracks
  - clean and uniform interface (limited explosion effect)
- Mechanical tests:
  - Reproducible results → uniform interface

Further work:

- Ti and st.steel welding qualification on pipe samples
- Leak-tightness qualification of pipe samples:
  - at RT
  - at RT after LN thermal shocking
  - at LN2 T
  - In LHeII
- Metallography after LN2 thermally shocking
- Cost saving study of these transitions for ILC.

→ More conclusive results around mid 2007.

Thank you for your attention