Pion Collection

What we have learned from CNGS Horn realisation at LAL.

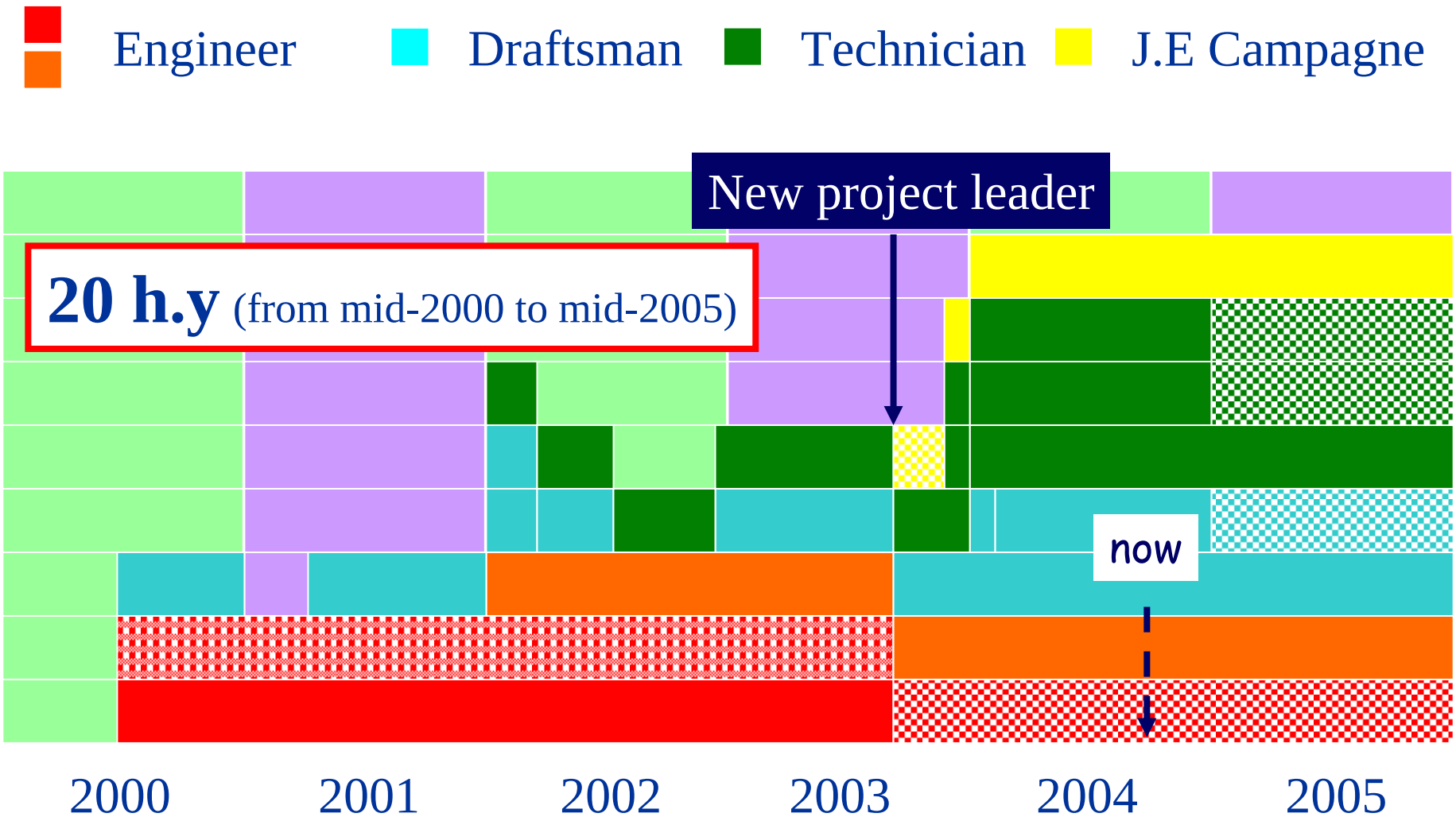
Project Leader: J.E C
Responsible Engineer : J.L Borne
+ 1,5 Engineers
+ 2 Draftsmen
+ 3Technicians

Present LAL FTE team

Introduction/Management

- The Horn/Reflector and their equipments (FCS, Strip-lines, cooling) was "in kind" contributions of the IN2P3 institute (delegate to LAL).
- From 2000 to end of 2003: two engineers at LAL (a senior and a young) were in charge of the conception with a know-how transfer from CERN expertise (namely S. Rangod & J.M Maugain).
- End of 2003 :
  - The senior engineer has left the laboratory for personal conveniences; while the young engineer was on sick-leave;
  - The LAL director asked me to lead the team. I was in charge of the OPERA-LAL team and we had finished with success the design and production of the front-end chip of the Target Tracker.

Human resources



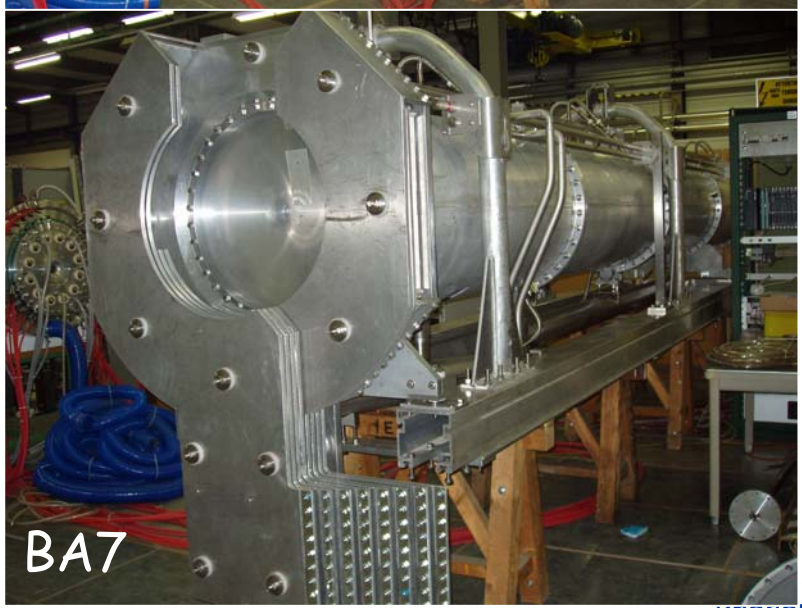
Lesson 1: lack of resources…

The human resources were largely insufficient. That is to say, it should have been at least 2 times more.

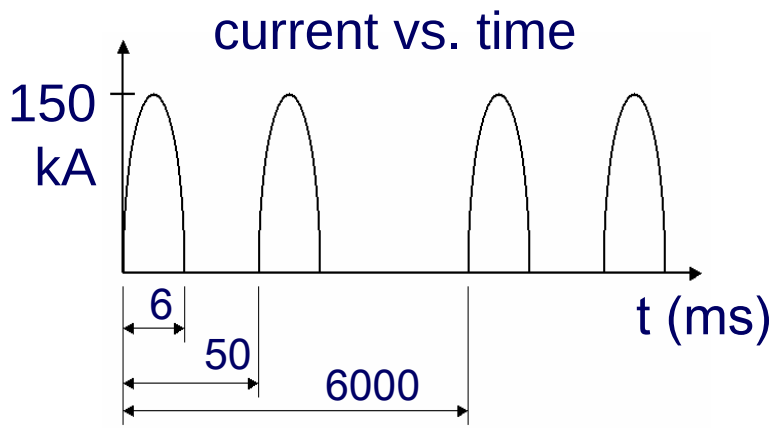
1 Project Leader relationship with CERN
1 Engineer supervisor (senior)
1 Team for computation (1 engineer + 1 assistant): thermal and mechanical stresses
1 Team for the Inner Cond and O. Cond. (1 engineer + 1 draftman + physicists): link with the physicists
1 Team for the Electrical part (3 engineers + 3 draftmen) : Stripline, Fast Coupling, Horn connexion (surface)
1 Team for the Water Cooling (3 engineers + 3 draftmen): Horn In and Out, Fast water coupling, Radioactive Water deionisation
1 Team for the Horn support and positioning (1 engineer + 1 draftman)
1 Team for general drawing (2 draftmen)
1 Team for the control and tests
1 Team for mounting: 5 technicians (1 experienced)

~ 10 engineers, 10 draftmen, 5 technicians 2÷3 years

First Horn at CERN 7th April 04

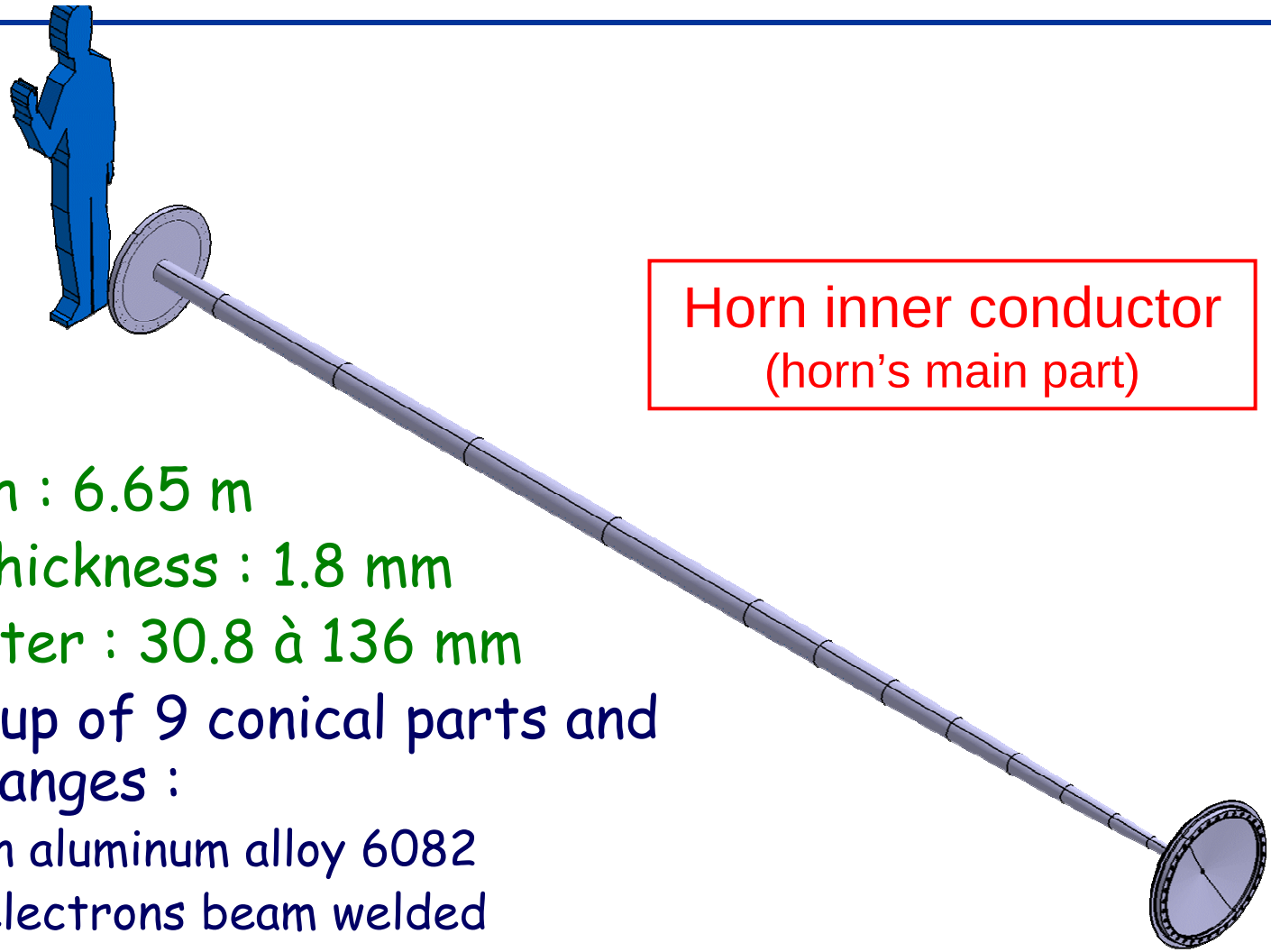


The 1st Horn had successfully passed a 65,000 double nominal pulses test early may 04. The water cooling of the Inner and Outer Conductor has also been controlled Ok.



(2 10^7 double-pulses in 5 years)

Horn I.C Design & Studies



Horn inner conductor
(horn's main part)

Length : 6.65 m

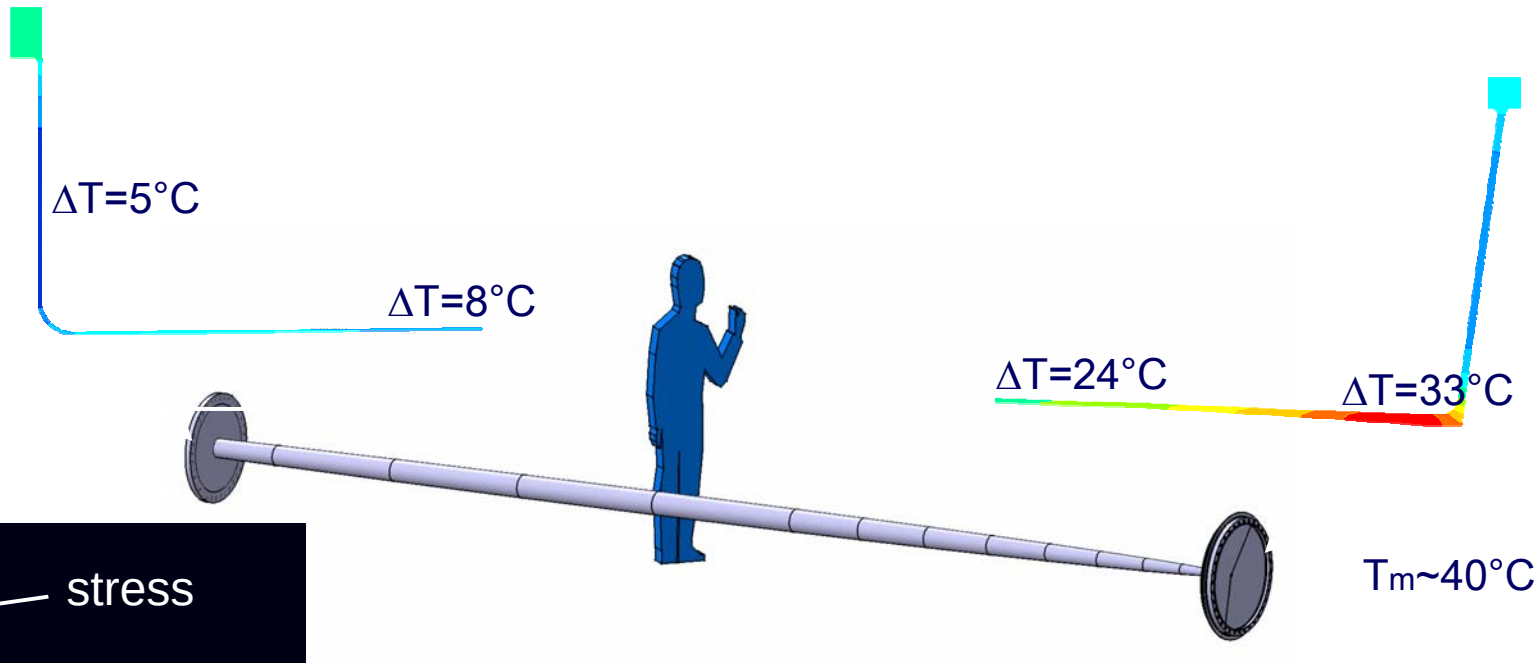
Min. thickness : 1.8 mm

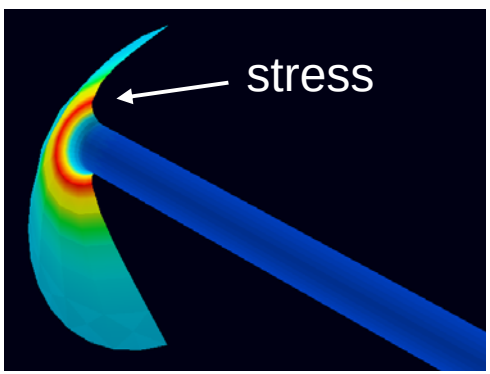
Diameter : 30.8 à 136 mm

Made up of 9 conical parts and 2 flanges :

1. in aluminum alloy 6082
2. electrons beam welded

Thermal study





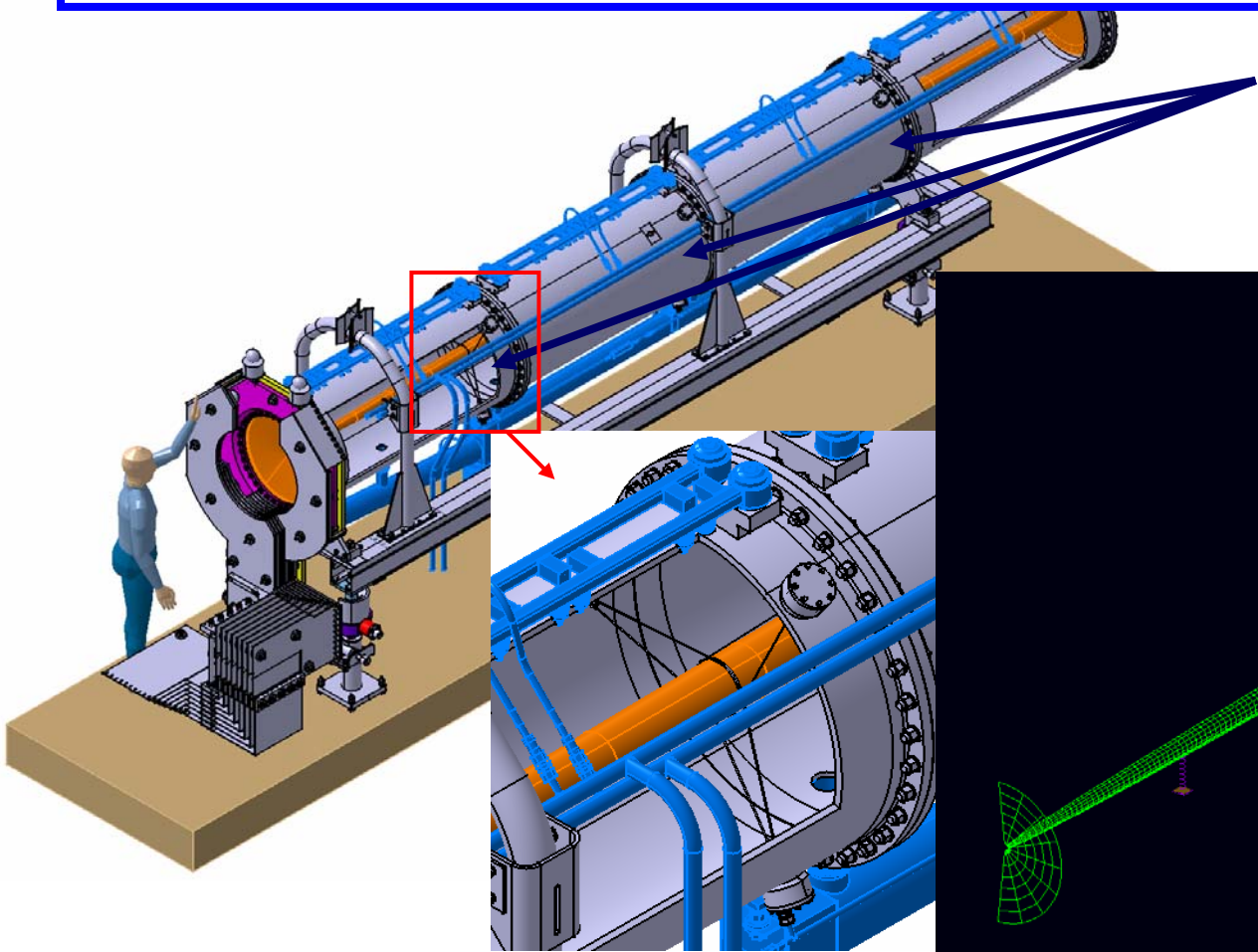
1.5 mm 'dynamic' thermal expansion enable by thin flange

$-0.75 < \Delta L_{dyn} < 0.75$ mm
(thanks to a 1.2 mm enforced displ. [ΔL_m=1.2 mm])

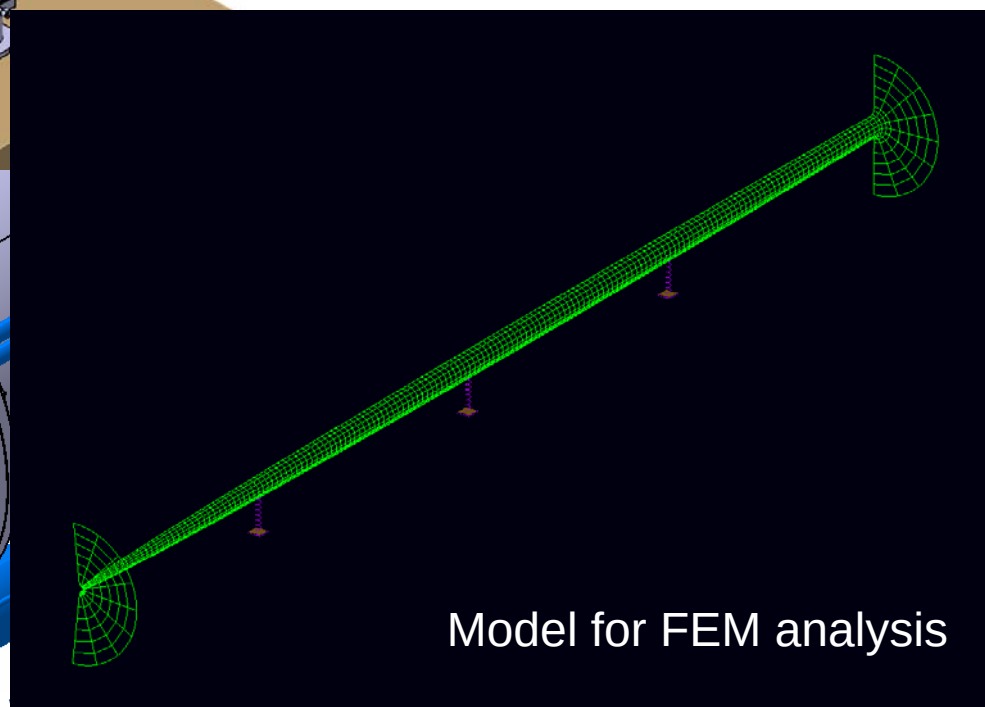
Cyclical thermal stress
$-10 < \sigma < 10$MPa

Static study

There is a minimum of matter (improvement w.r.t "WANF" horn)



3 sets of cables reduce inner conductor deformation (bending)



Model for FEM analysis

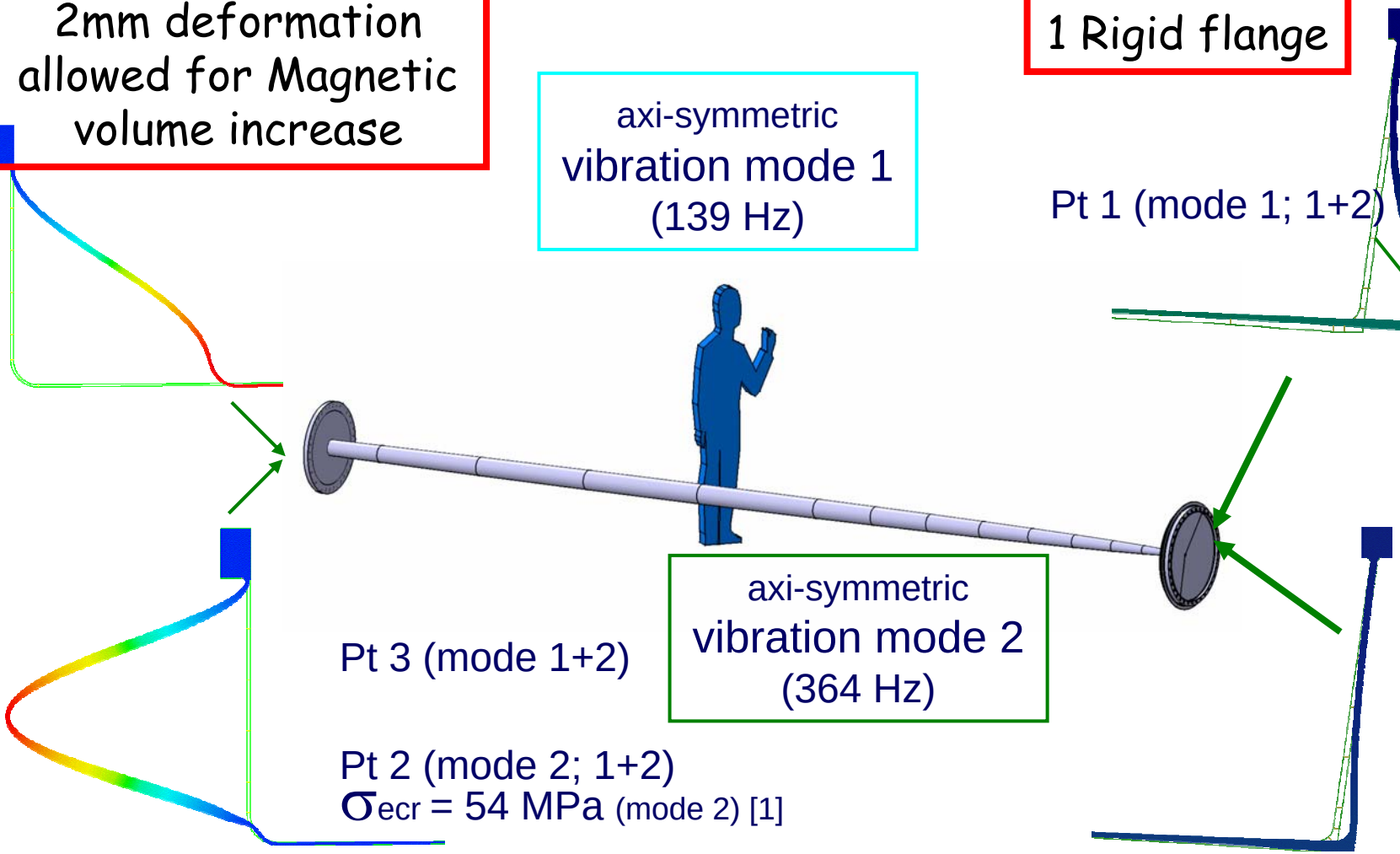
Dynamic study: fatigue strength

2mm deformation allowed for Magnetic volume increase

1 Rigid flange

axi-symmetric
vibration mode 1
(139 Hz)

Pt 1 (mode 1; 1+2)



Pt 3 (mode 1+2)

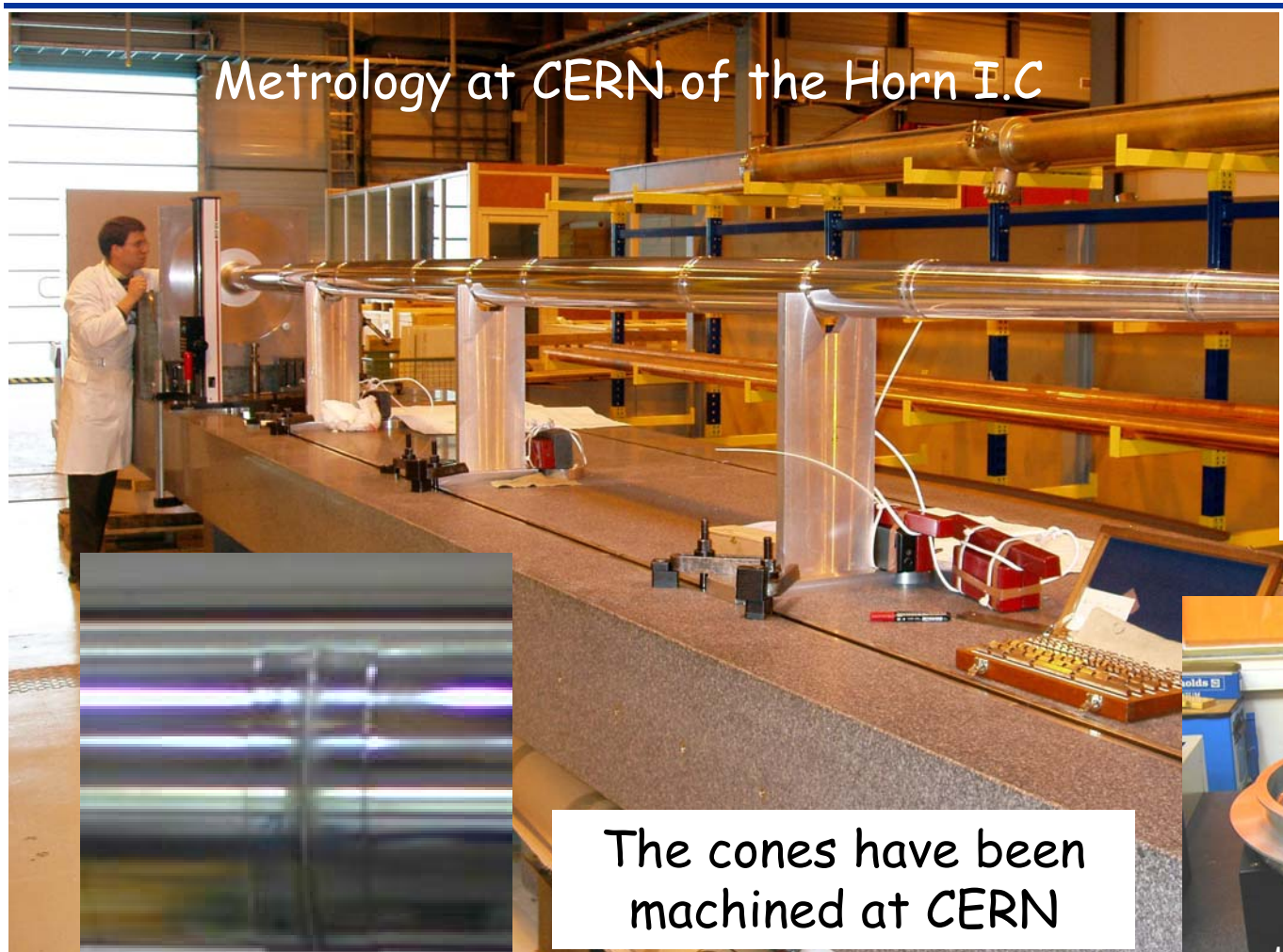
axi-symmetric
vibration mode 2
(364 Hz)

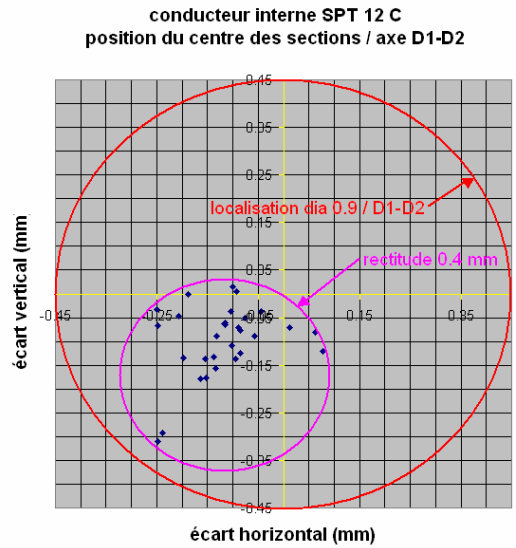
Pt 2 (mode 2; 1+2)
σ_{ecr} = 54 MPa (mode 2) [1]

[1] : From Marek Kozien's Ansys study (Cern / Cracow university)

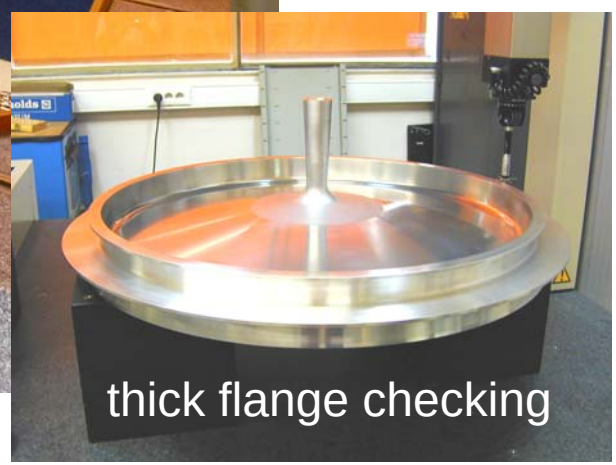
mode 1, mode 2, mode 4

Horn I.C realisation





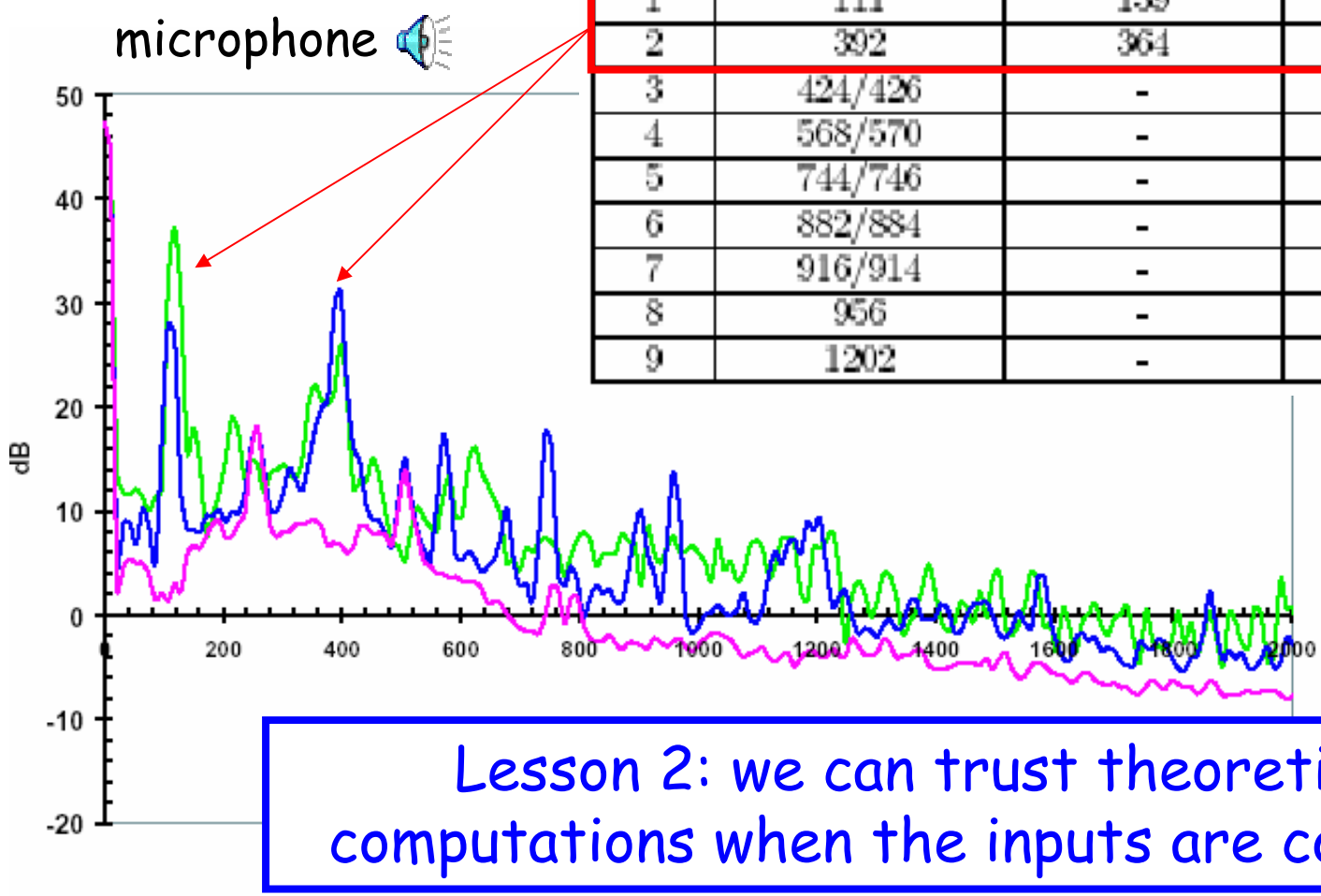
The cones have been machined at CERN



EB welding

Measurements with the real Horn

Mode	Meas. Ref. (Hz)	Calc. Ref. (Hz)	Meas. Microp. (Hz)
1	111	139	107.66
2	392	364	398.36
3	424/426	-	-
4	568/570	-	570.63
5	744/746	-	742.9
6	882/884	-	904.39
7	916/914	-	-
8	956	-	958.22
9	1202	-	1200.00



Lesson 2: we can trust theoretical computations when the inputs are correct…

S.Gilardoni thesis

Lesson 2: Material allowed/forbidden

Ok NO

Aluminium
Brass
Copper
Stainless Steel but limit the use (radioactive waste)
Nickel (only to coat the Inner Cond. à la NuMI)
Iron: except with epoxy painting for small pieces
Glass: it will turn to black colour but does not loss its property
ARCLEX composite in dry sector (eg. electrical connexion spacing)
Ceramic insulator: Ok
Plastic: NO
Grease: NO

It is a nightmare: verify everything and the cost increase in general…

eg. ball bearing

Realisation problems…

We had to face major problems :

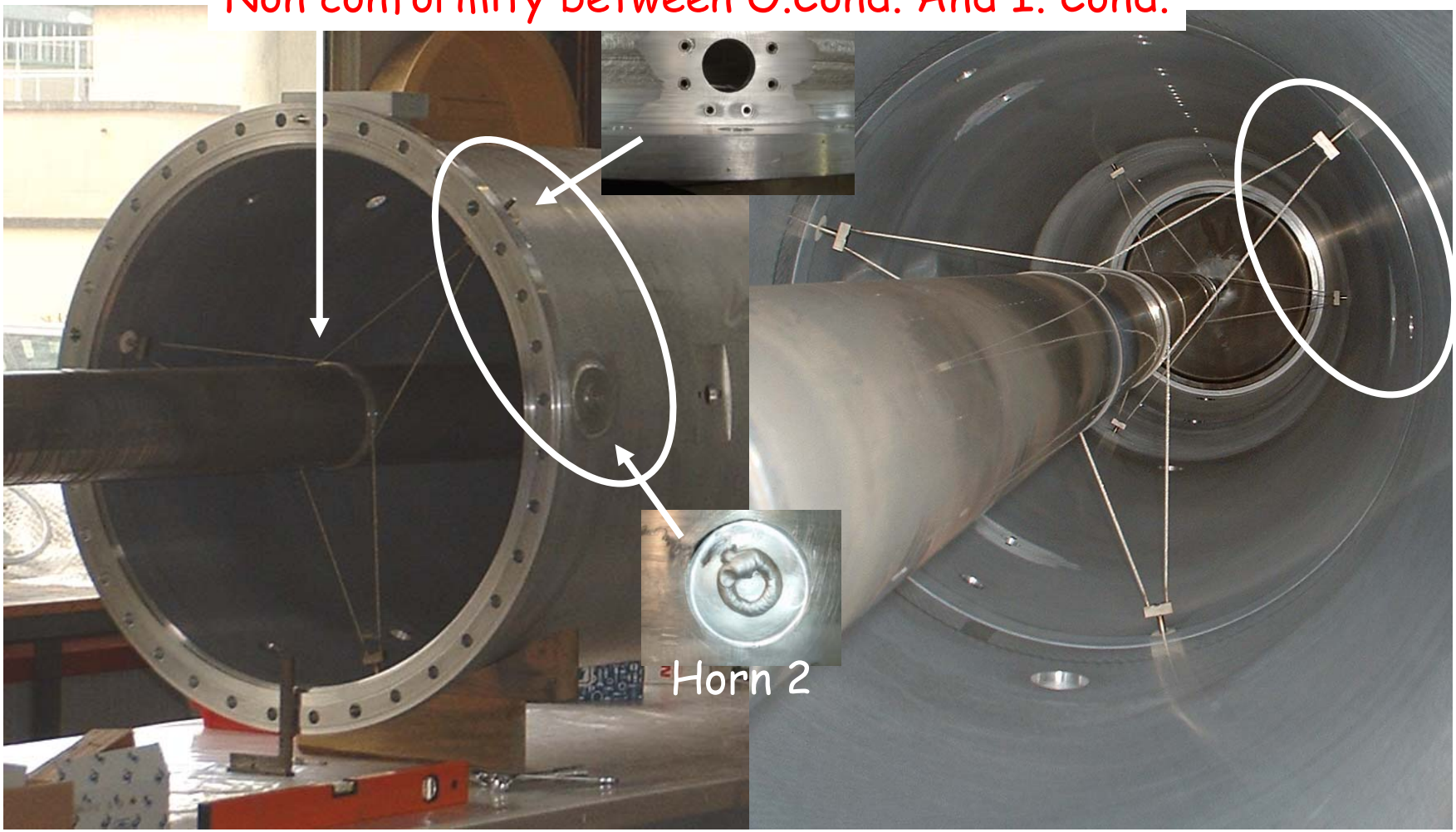
a) Non conformity of the cabling system which able to align the Horn Inner Conductor — Cured by LAL

b) Very bad quality of the electrical surface machined by SIMIC company — 3 FT LAL technicians during 2 months

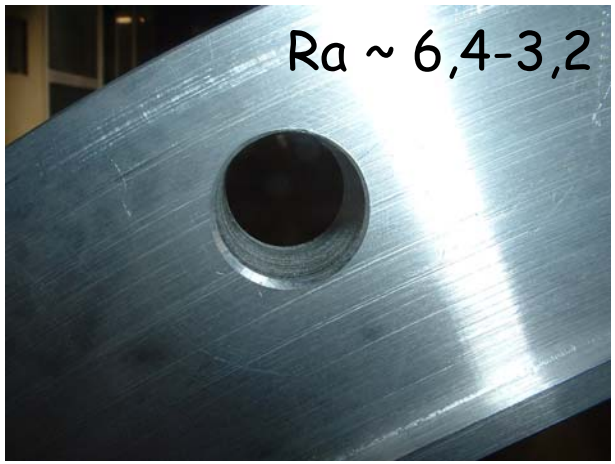
c) Welding quality questionable for some pieces — Checked with LAL expertise

Horn cabling system

Non conformity between O.Cond. And I. Cond.



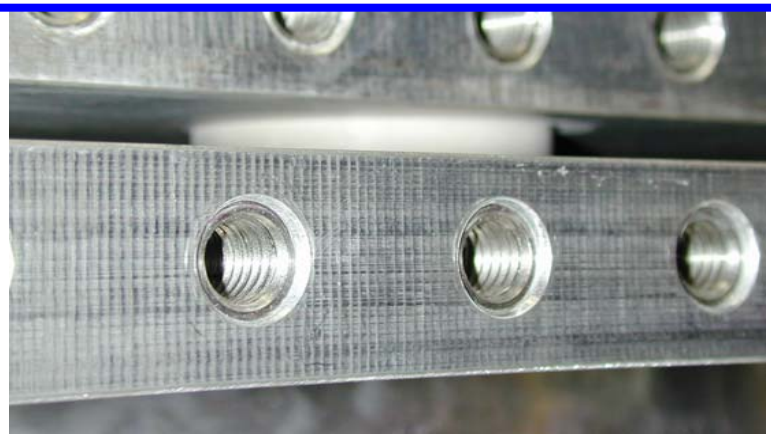
Electrical surfaces (I)

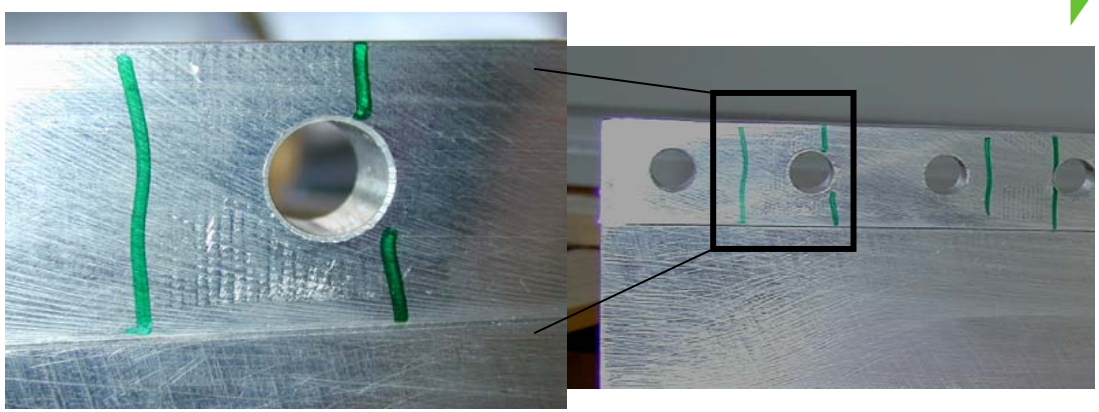


Hand polishing at LAL during 2 months by 3 FT technicians

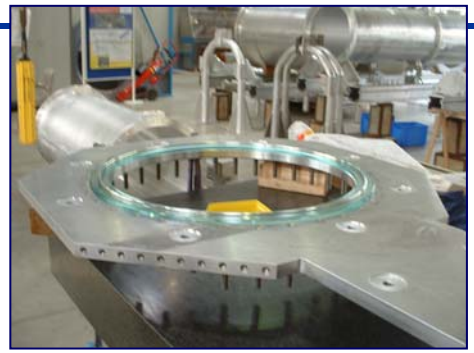
Electrical surfaces (II)

Lesson 3: electrical surfaces are crucial (150÷180)kA

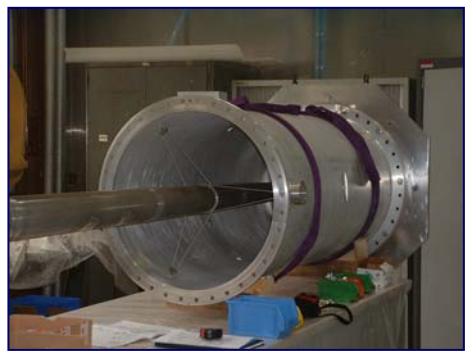




Mounting phases



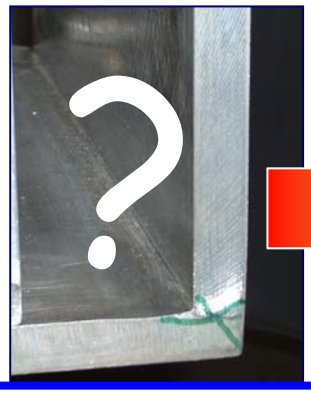



Adjusted at final phase

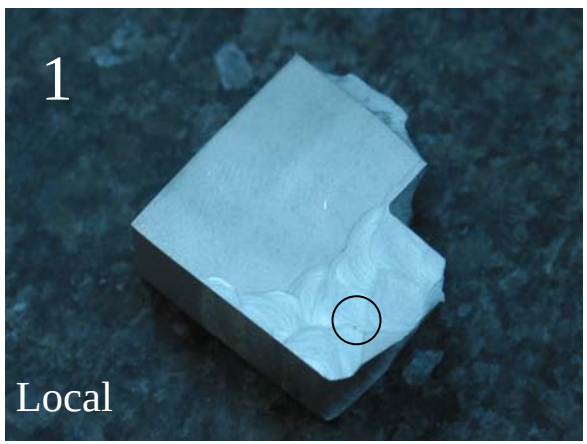

Insertion of External Conductors around the Inner Conductor. Close the magnetic volume and put on the frame…

Welding x-check

LAL Document : TSB/200312-1



Lesson 4: the welding is crucial for the electrical current



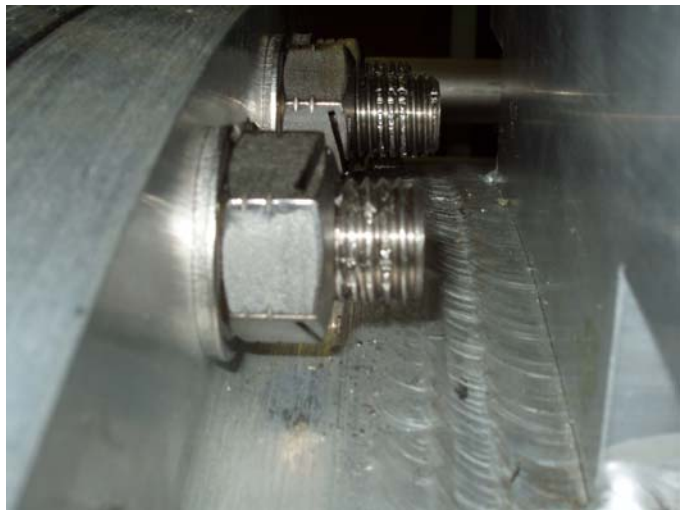
Cut a small piece for investigation (SEM)

Let the welding cordon visible, it does not matter and prove that the welding is well done…

Lesson 5: "innovation does not mean always improvement…"

The "new" connexion system is elegant but rely on the machining precision (cumulative errors) and restrict a lot the flexibility necessary for the stripline connexion which was a guide line for the "old" system…

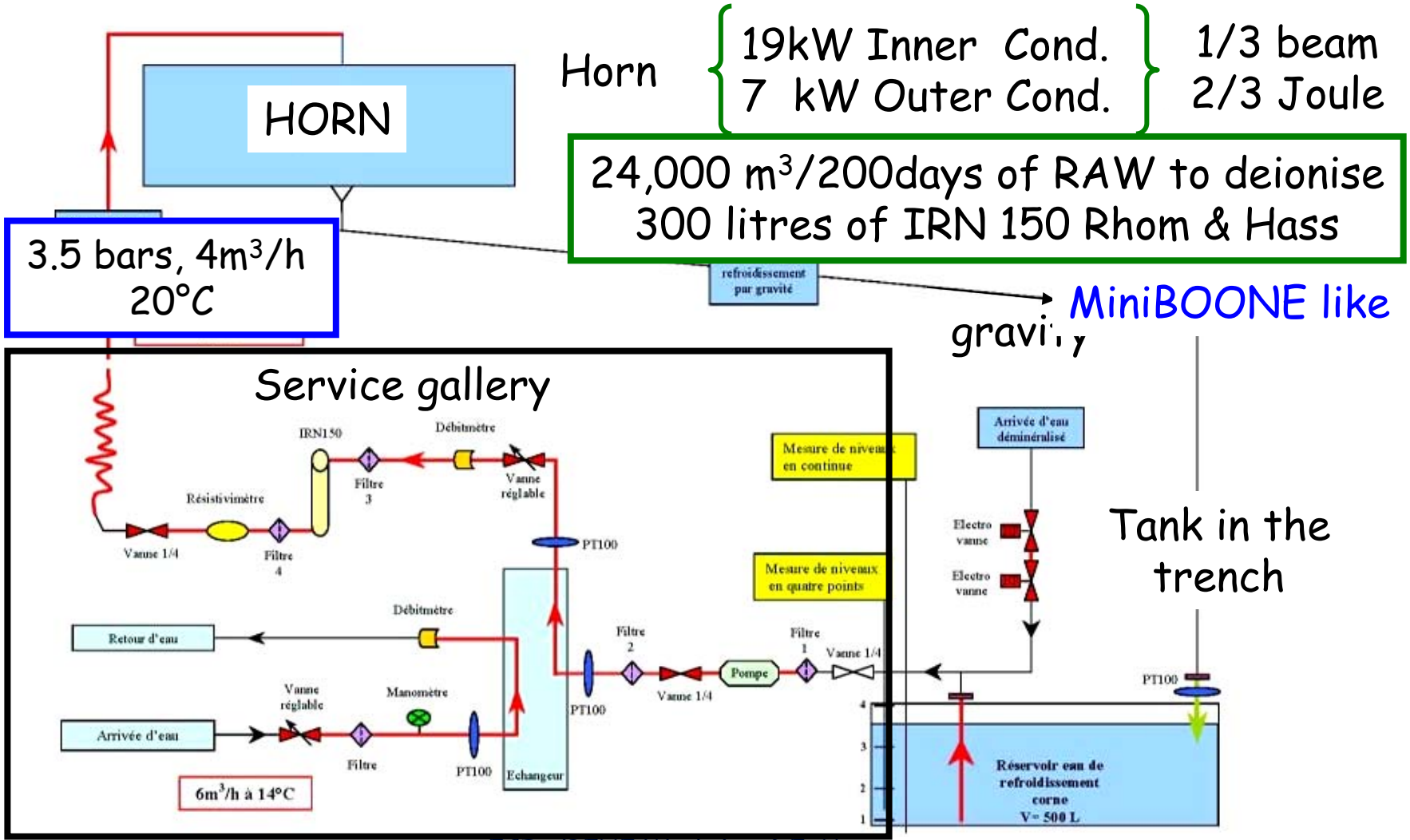
Nuts & Bolts



- Bolt quality: A4
- Use smaller bolts to use properly the BINX nuts
- Use Grower washer spilt

Lesson 6: check the quality of the nuts & bolts and the torque this is crucial !

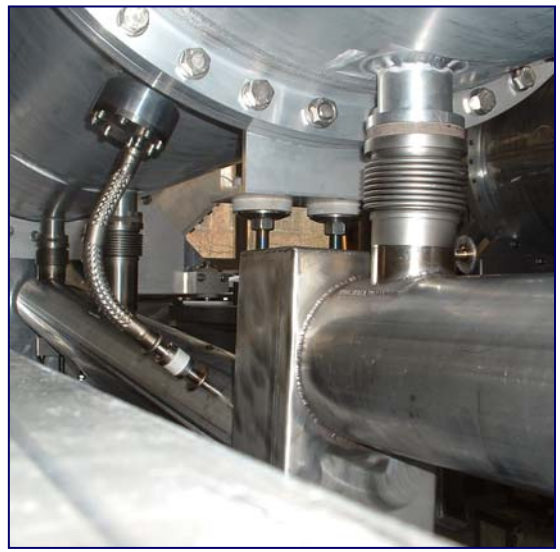
Cooling System: principle



Cooling System : mounting phases

IC + OC + flanges cooling

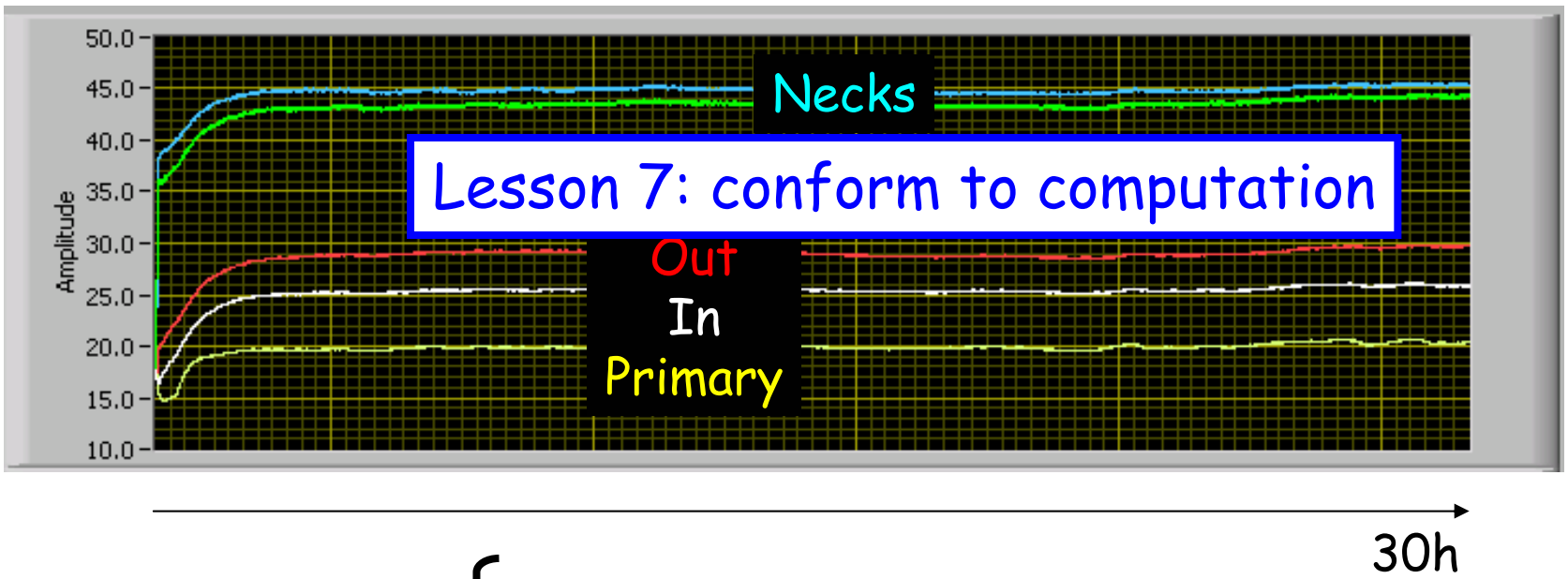
Decoupling mechanical vibrations of OC and Water System



Welding of the water cooling system to avoid leak.

Cooling System : measurement at CERN BA7 with Horn 1 and minimal cooling

Test at BA7 with CERN cooling installation (may 04/Horn 1)



In: reference

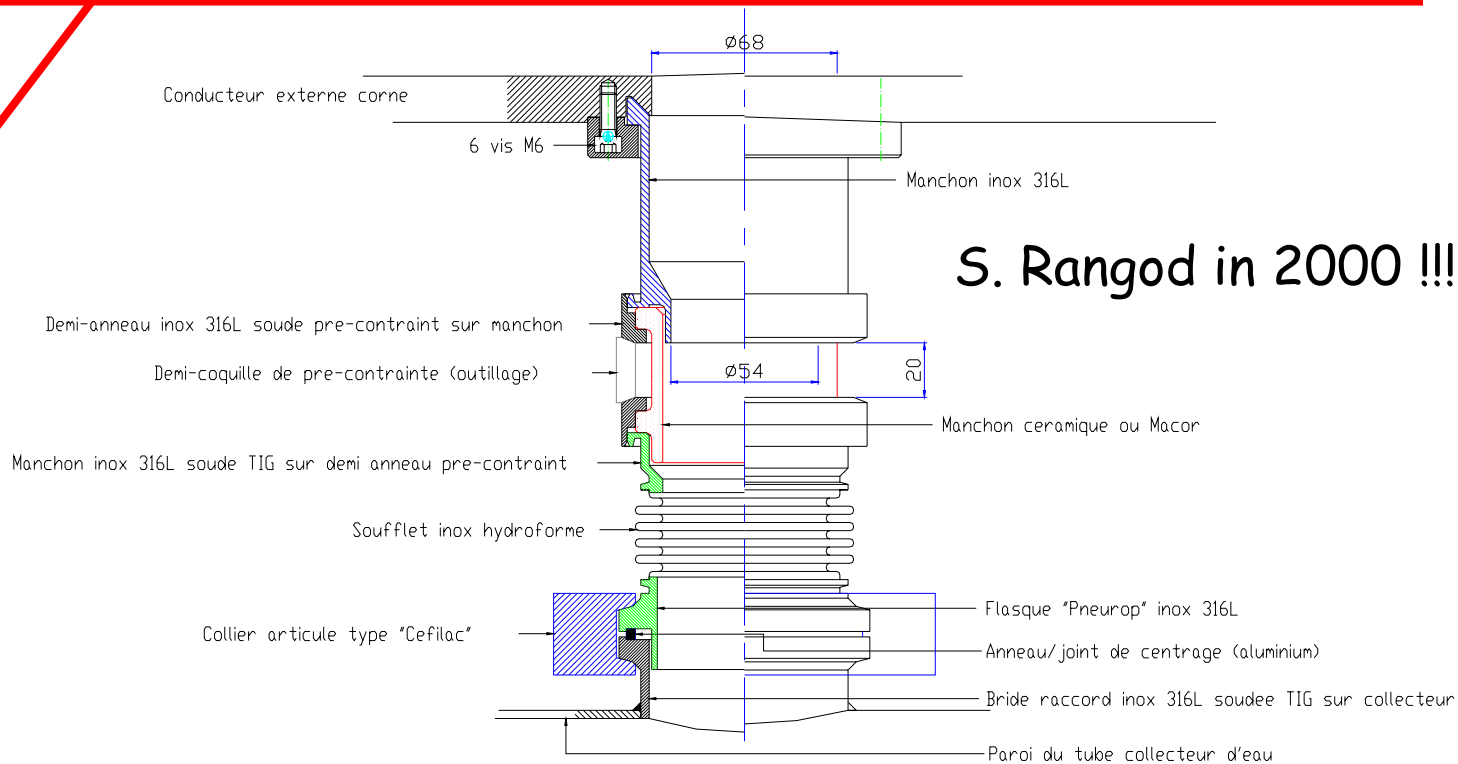
- Neck temperature : +(13 ÷ 15) °C
- Out temperature (~ Outer Cond.): +(4 ÷ 5) °C

Expected 1/3 more with Beam ON
But primary water foreseen at ~ 14°C

Water Collection problem

Collection of radioactive cooling water

The ARCLEX (mica + glass) composite is not safe enough
And all the collection should be rebuild.



S. Rangod in 2000 !!!

Lesson 8: follow recommendations given by experienced people…

Horn : controls at LAL

Lesson 9: a reception by CERN should have been done at LAL.

Horn ready for tests:

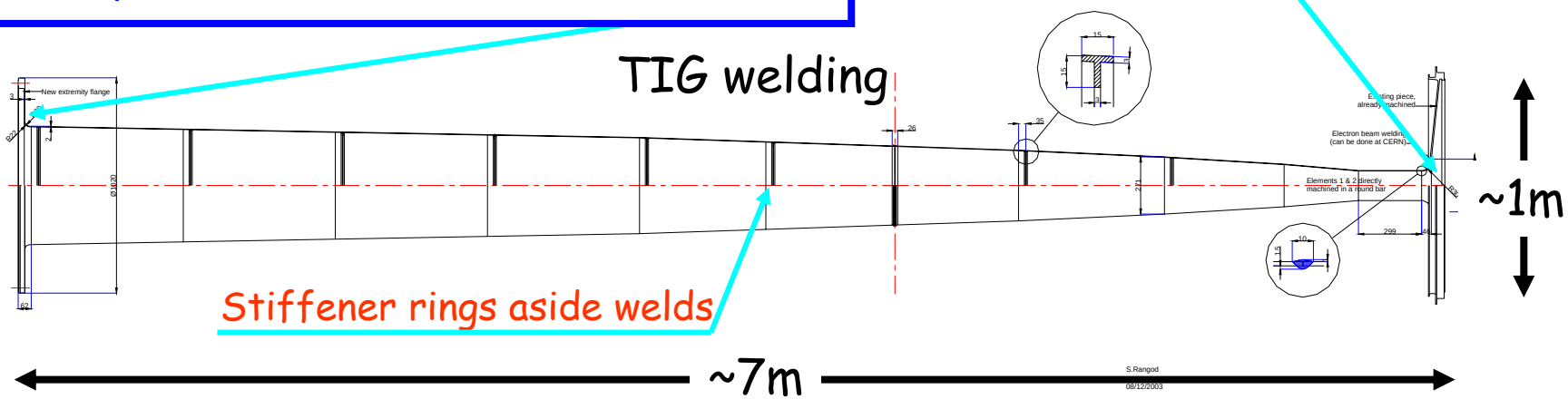
- water test for leakage search;
- electrical decoupling test:
  - 2kV frame-Ext. Cond.
  - 1kV sprinklers - Ext. Cond.

R.I.C : problems pointed out by CERN

25th Nov. 03, S. Rangod send a red light to LAL concerning the machining of the flanges (at least) that does not allow good and robust welding.

Lesson 10: the welding is crucial for life time of the object but also for the electrical current

Radial welds in the most stressed area, not accepted



CERN proposal for the design of the reflector inner conductor

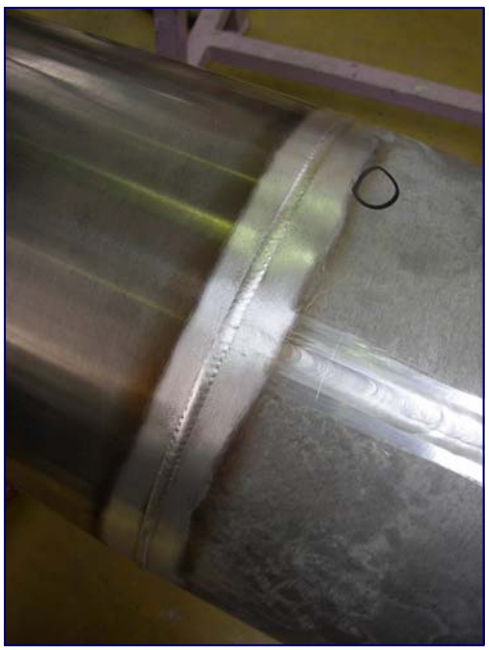
S. Rangod

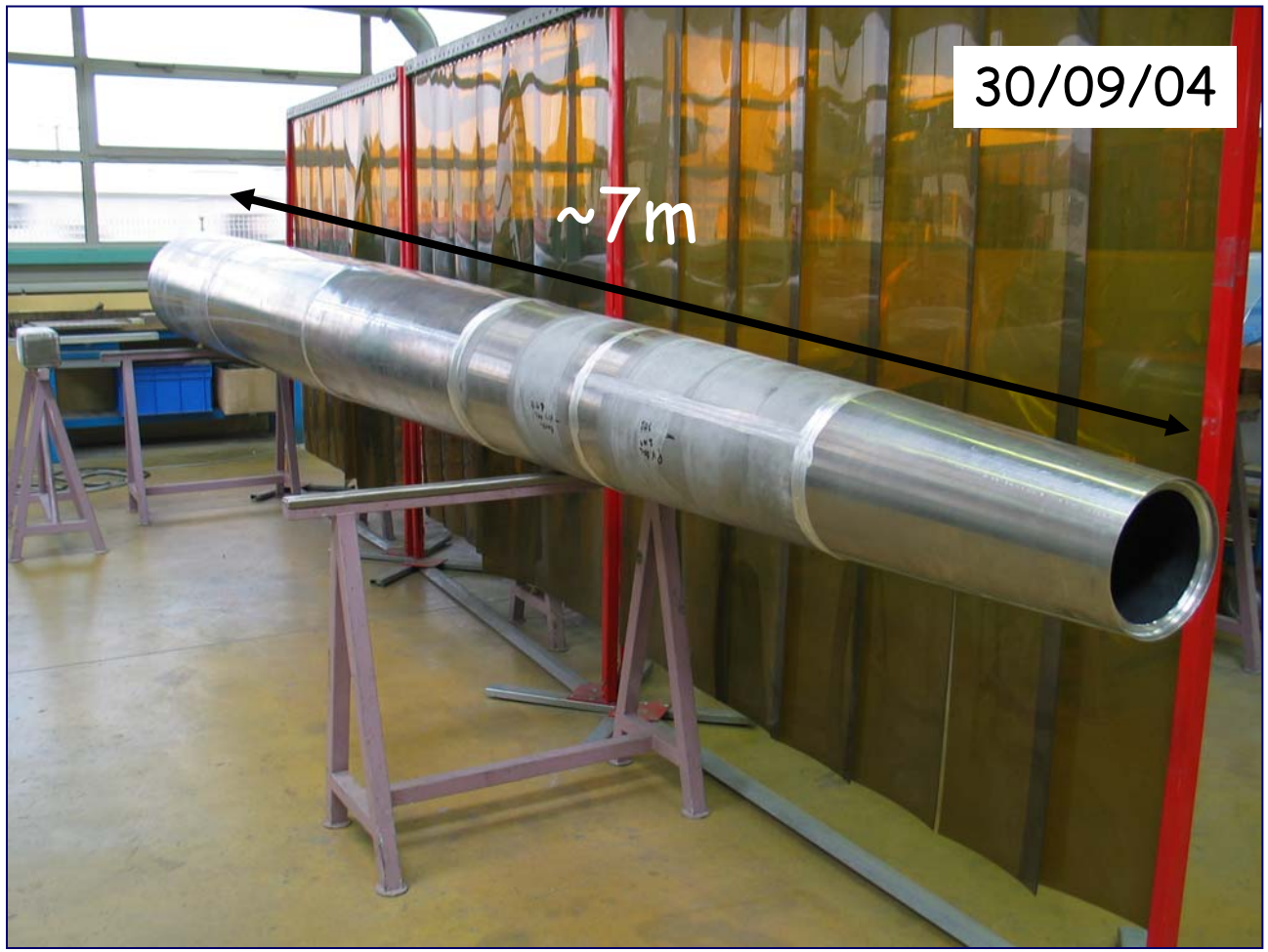
R.I.C : new fabrication

2mm Al thick plates rolled and welded

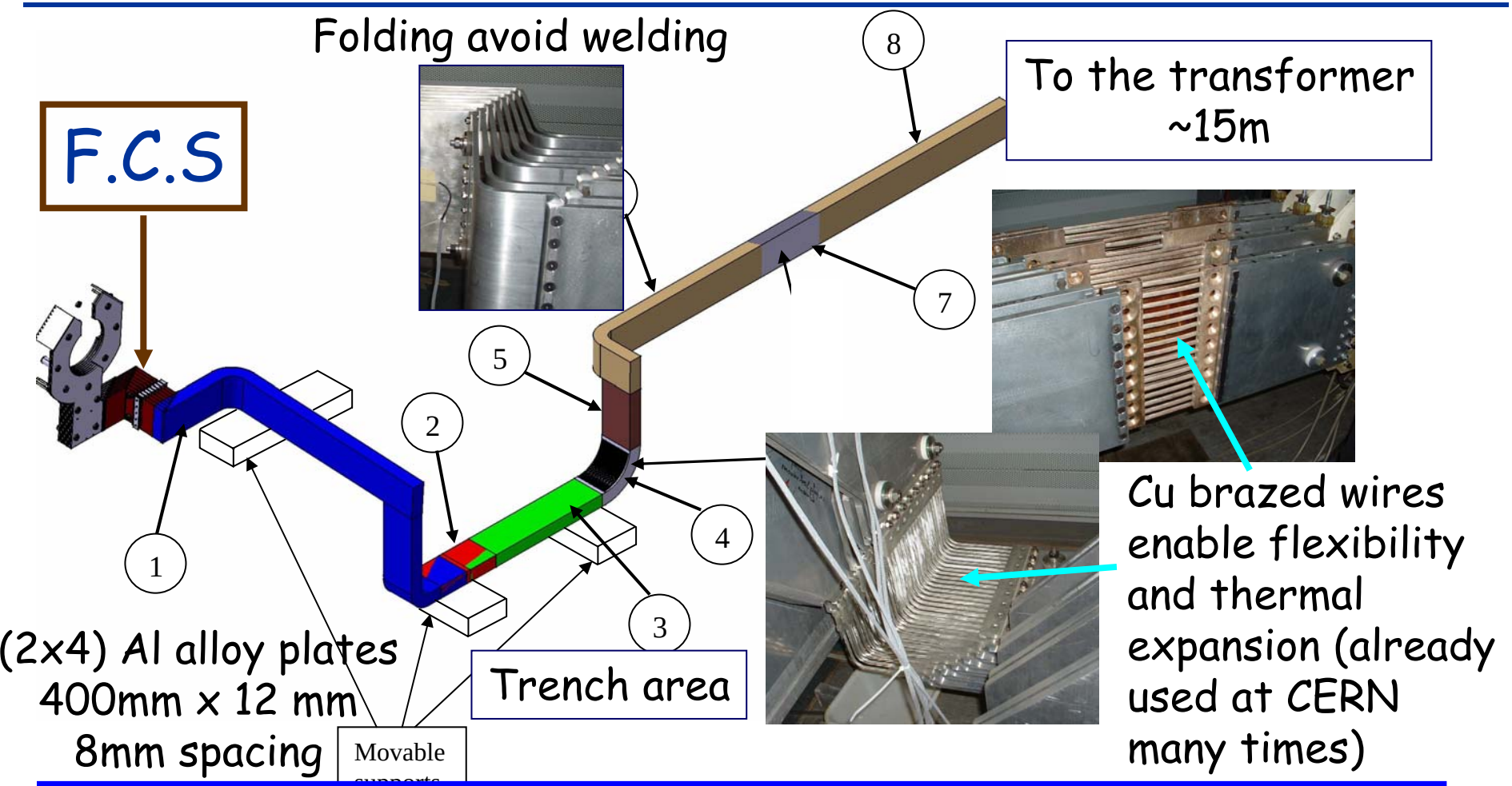
R.I.C : continued

Orbital
&
Longitudinal
TIG welding





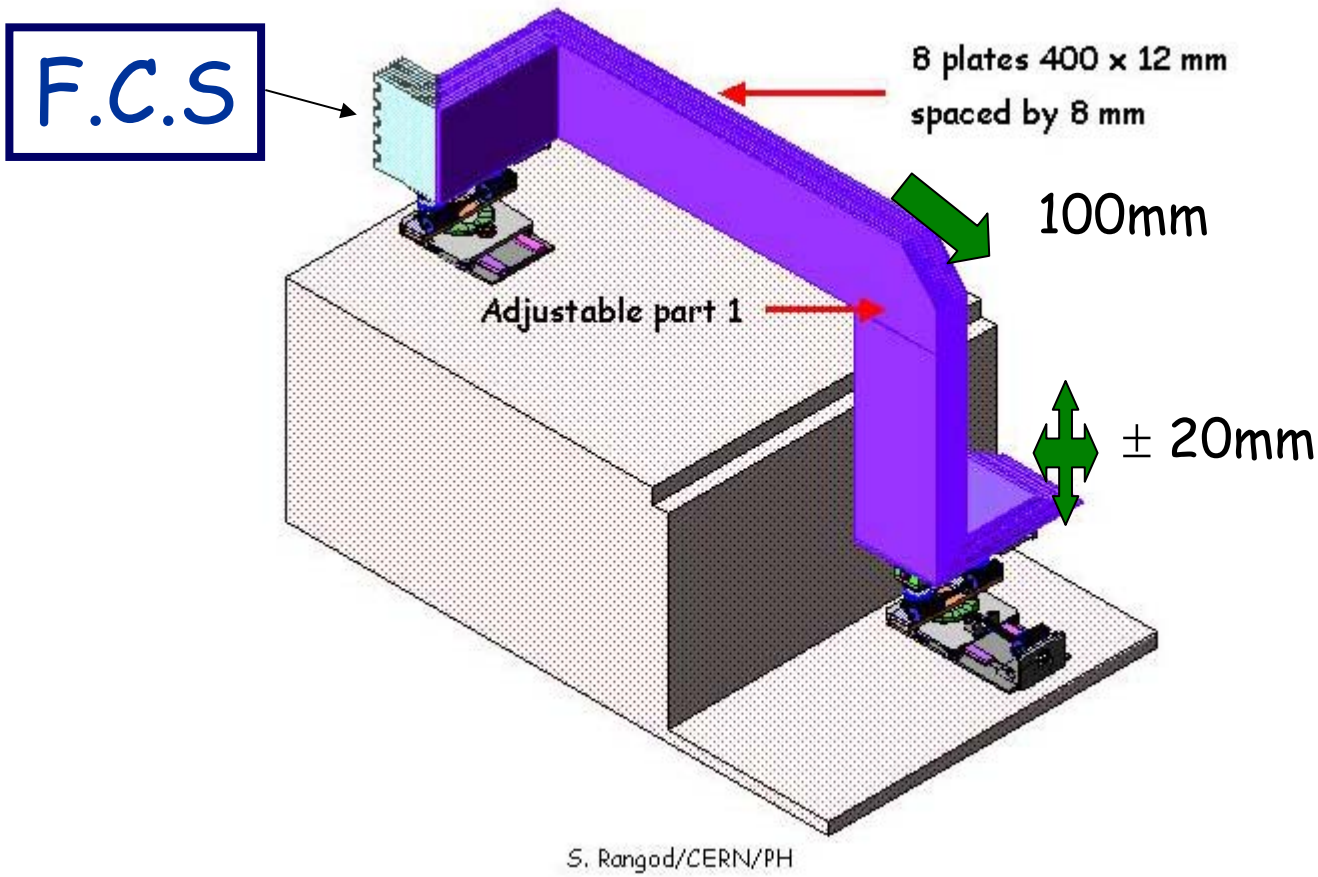
Strip-lines : simple drawing and some realisations at CERN "mécano"



Lesson 11: this is a complicated object which requires a lot of attention (flexibility for the mounting…)

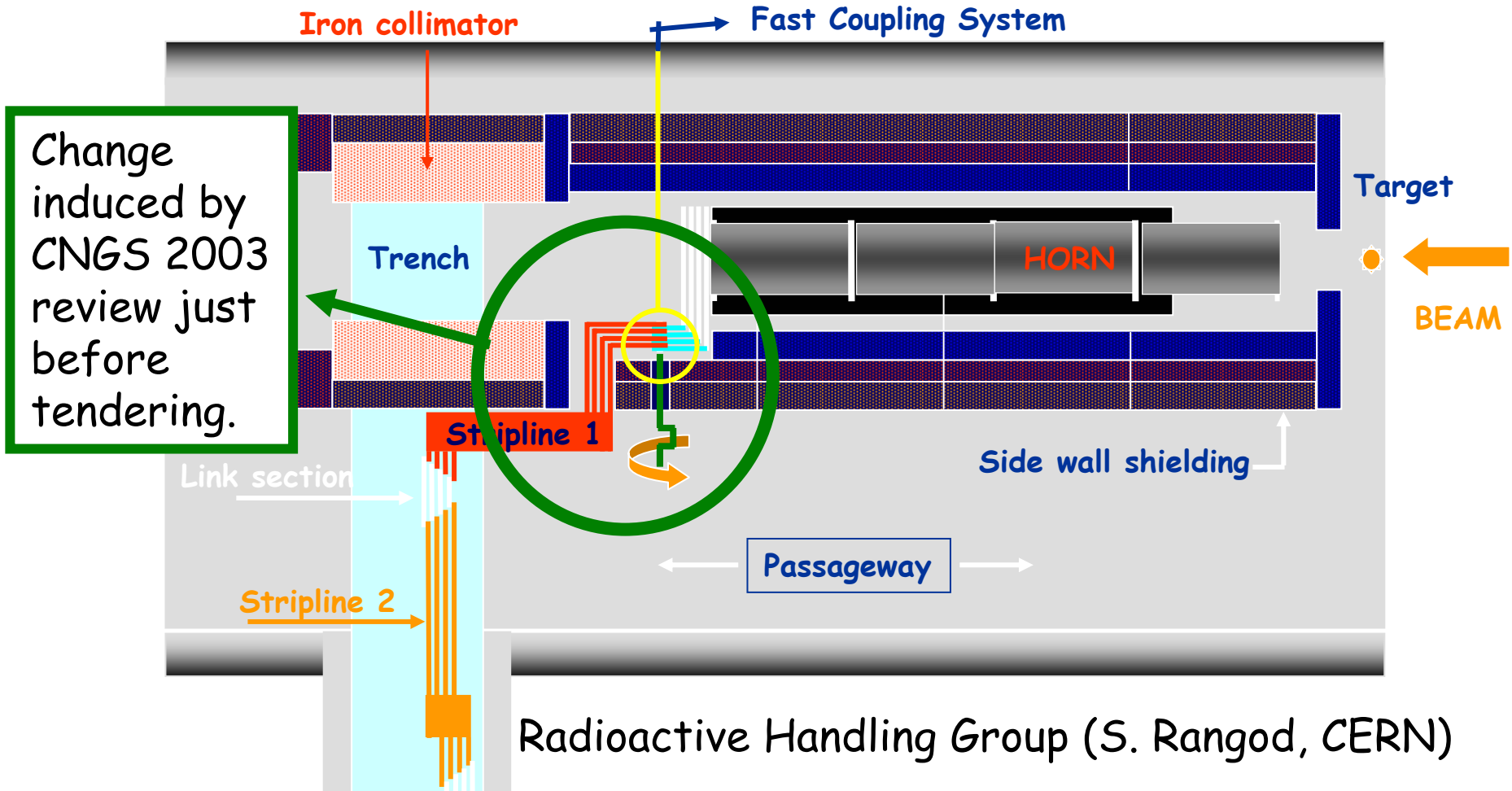
Strip-lines: movable part to plug the FCS (conception by CERN)

Movable part to plug and unplug the F.C.S



S. Rangod

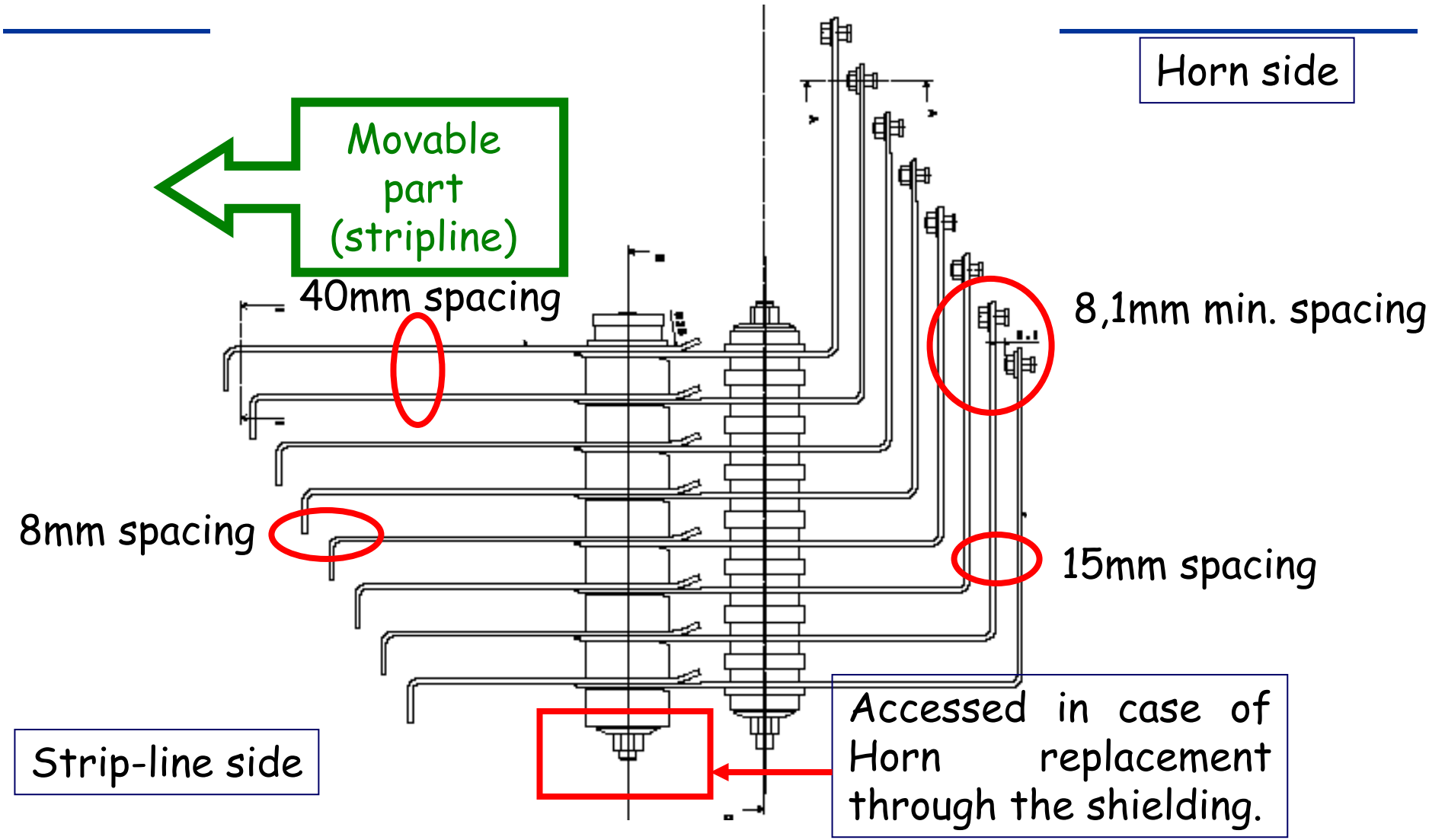
Fast Coupling System



Radioactive Handling Group (S. Rangod, CERN)

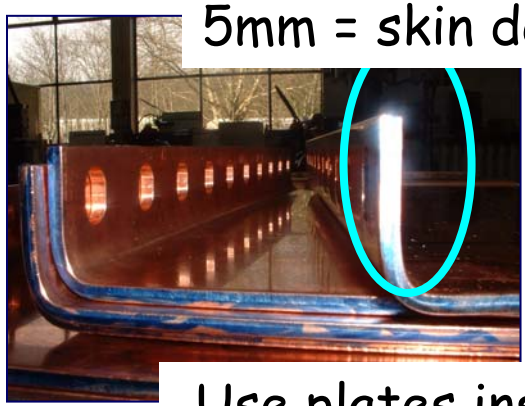
Lesson 12: this is a complicated object too and CERN had not ready-made solution from past experience. Link with Maintenance Local Staff.

F.C.S : conception of modified version



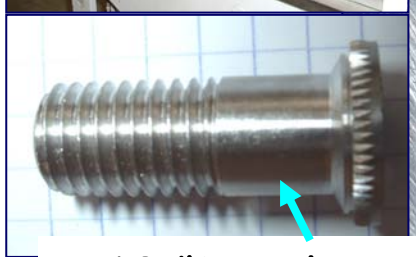
F.C.S : 1st realisation at LAL

at LAL



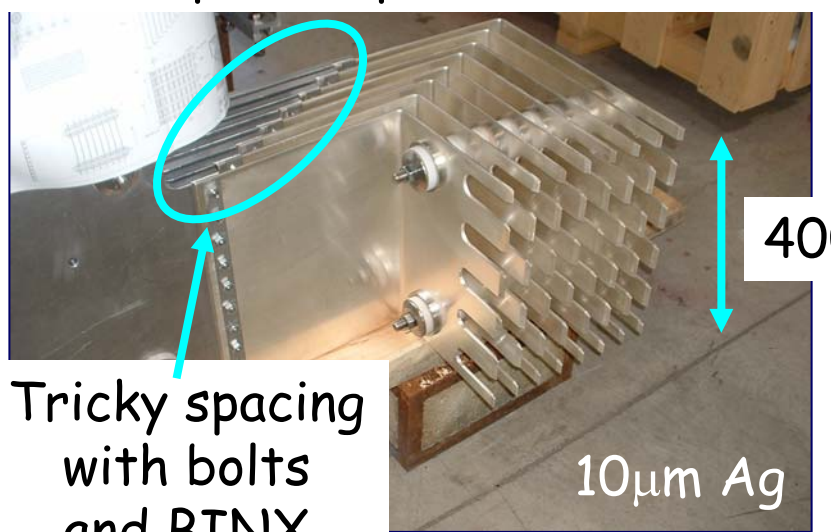
5mm = skin depth

Use plates instead of cables from CERN past experiences.



M10 "La Clusienne" bolts very efficient

Feb.-Mar. 04



Tricky spacing with bolts and BINX nuts

400mm

10µm Ag

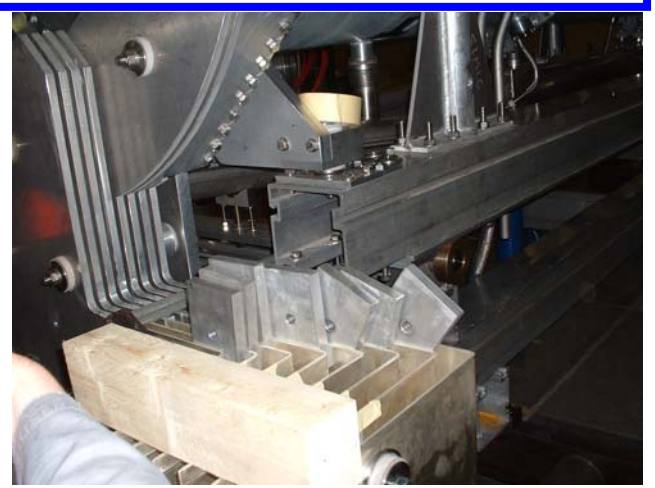
F.C.S : mounting at CERN BA7

Strip-line part: errors due to lack of prototype (lack of time too, stressed by the schedule)

- gravity !!!
- ARCLEX bars not coupled to Copper plates
- Spacing between ARCLEX and Copper plate too tight for the plug in.

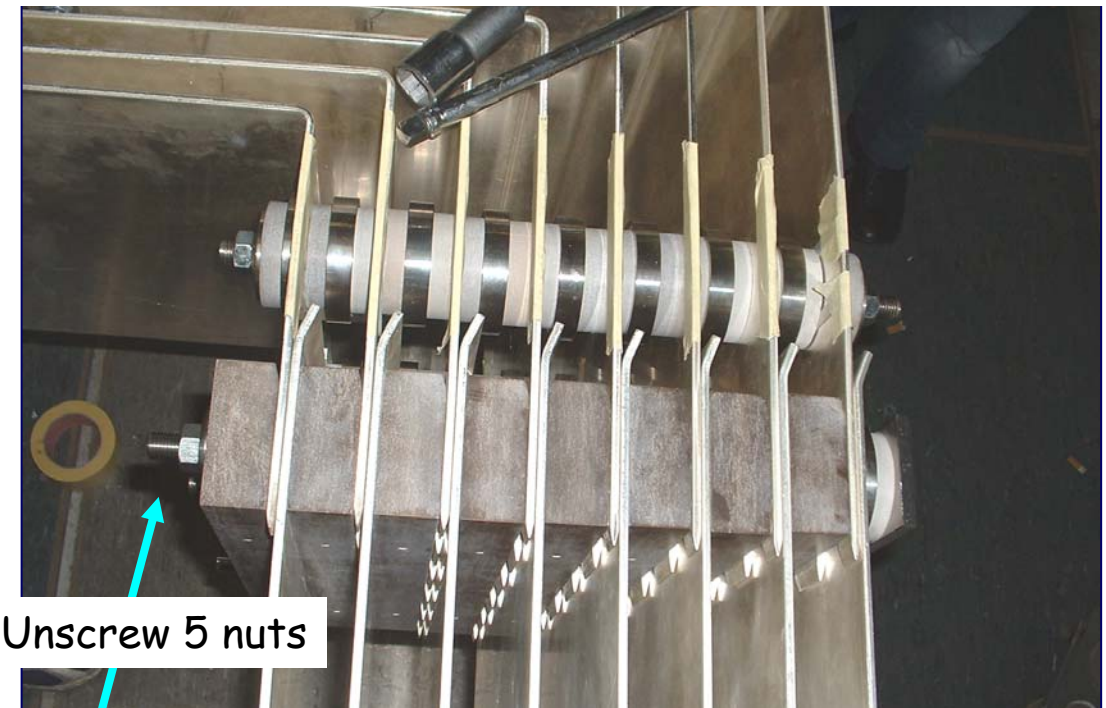
Lesson 13: Drawing is absolutely not sufficient for this job

Horn part: geometry not mastered



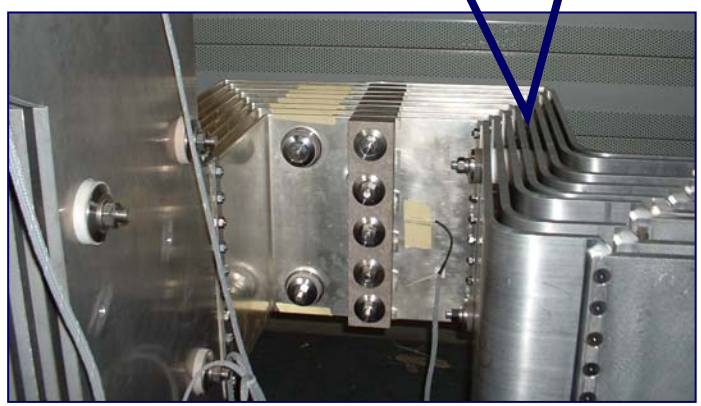
F.C.S : mounting at CERN BA7

With some difficulties, we have managed to work out and proceed to the Horn tests. And the connexion was validated (no heating).



In operations the unplug/plug of the FCS should be done in few minutes.

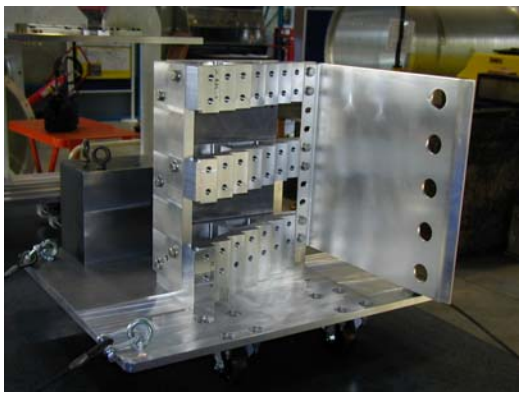
CERN "mécano" strip-line in BA7

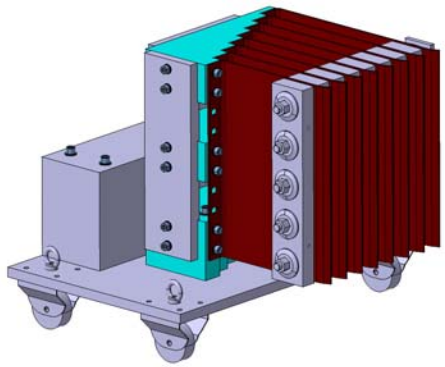


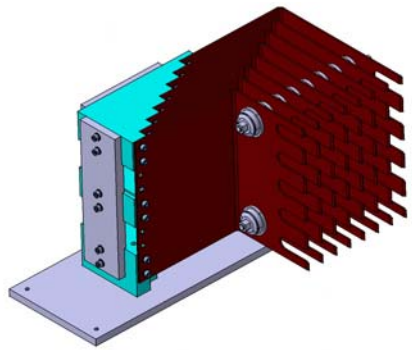
Folding can be precise enough

F.C.S : new prototype at LAL

We are now engaged in a full scale prototype test bench at LAL







Strip-line "simulation"

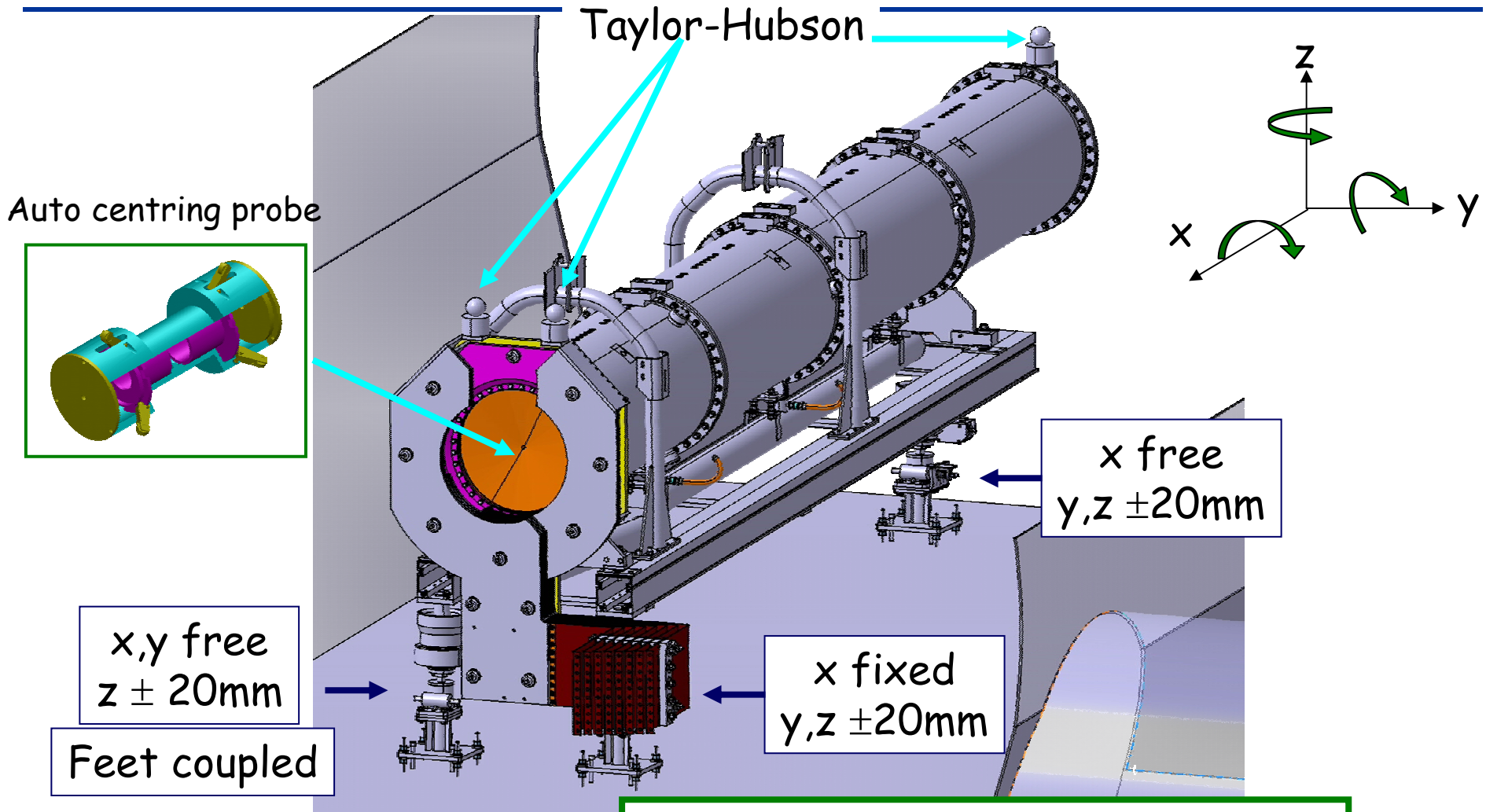
Test the ARCLEX bar fixing, the spacing operation as well as the F.C.S plug in.

Horn "simulation"

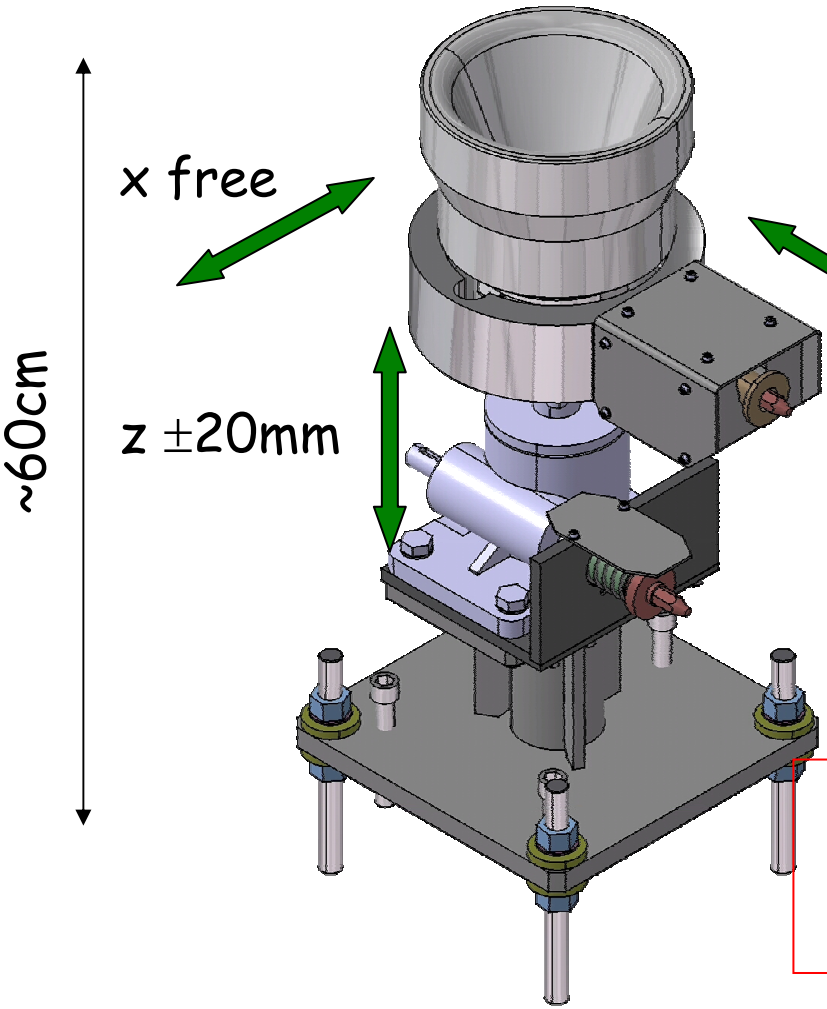
This should answer to: How to design a mounting tool and a mounting scenario to guaranty the geometry ?

In progress since October 04

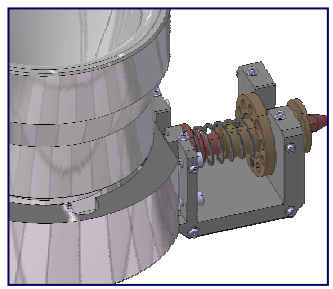
Geometrical positioning



Adjustable feet: 1st Prototype



Detail on the indexation mechanism



22th June 04

Due to an interaction with the water cooling system automatic plug in, there will be a drastic redesign by CERN.

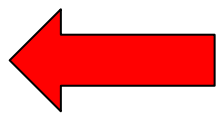
From CNGS 2004 review

Some costing

kCHF/k€

item	CERN original estimate (MoU in 2000)	LAL & CERN estimate (20 July 2004)
2 Horns + 1 Reflector	600 **/ 390**	920 / **600**
2 Cooling systems	100 / **65**	181 / **118**
3 Support Systems		
(originally motorized)	220 / **143**	62 / **40**
2 sets of striplines	170 / **111**	268 / **174**
		(incl. fast coupling)
		(incl. 20 kEuro tests)
Total	**1090 / 709**	1431 / **932**

May still increase…



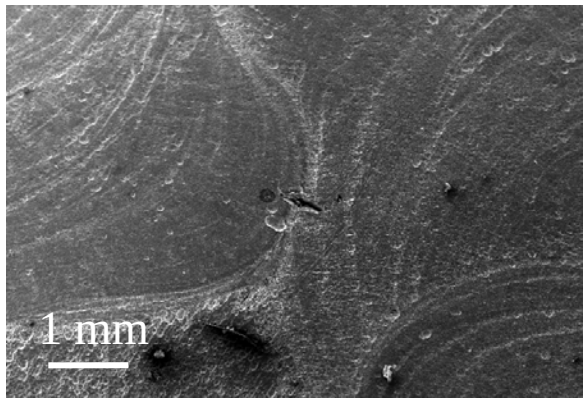
+30%

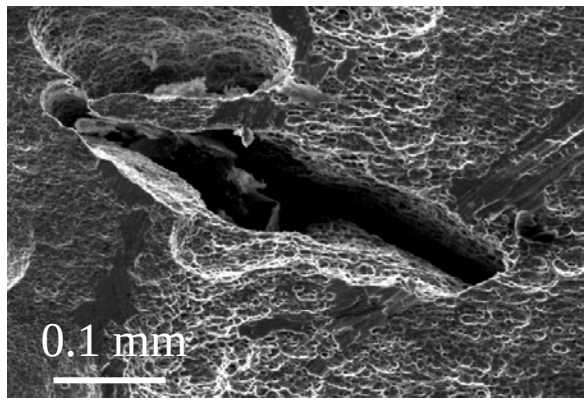
It may turn out that it would have been wrong by a factor 2…

END

Welding x-check

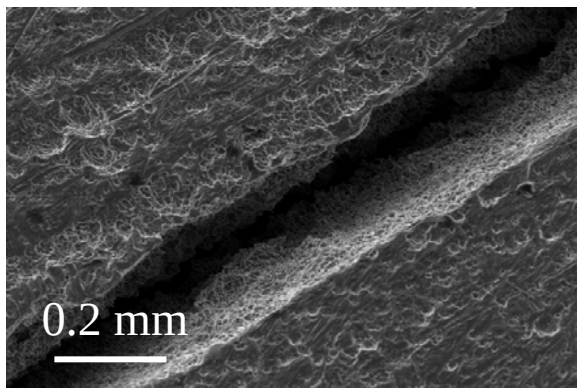
Electronic microscope investigation at LAL

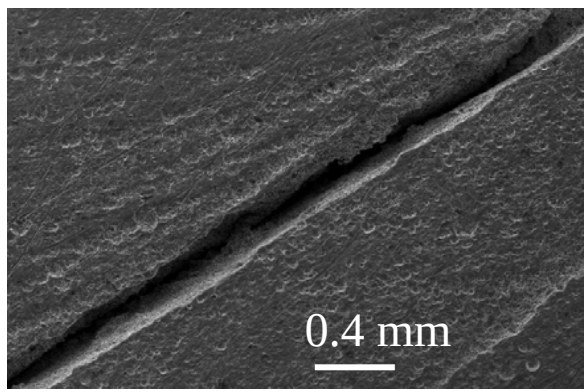




Internal welding structure is Ok

Investigation with electronic microscope





Crack clearly visible starting from the surface. (only in this sample)

New Protocol CERN-IN2P3-LAL

LAL Responsibility:

1) Horn & Reflector Supports
2) Fast Coupling System
3) Reflector Inner Conductor
4) Reflector and Horn-2 assembly/modifications
5) Horn & Reflector + FCS + Supports drawings

IN2P3 contribution fixed to 650k€ material + 20 men.y

CERN Responsibility:

1) Striplines
2) Water cooling systems
3) Horn-1 modifications and the specifications for Horn-2 & Reflectors

Estimate at ~ 300k€ + manpower

Control & Reception at LAL by CERN & LAL

Laser tracker measurements