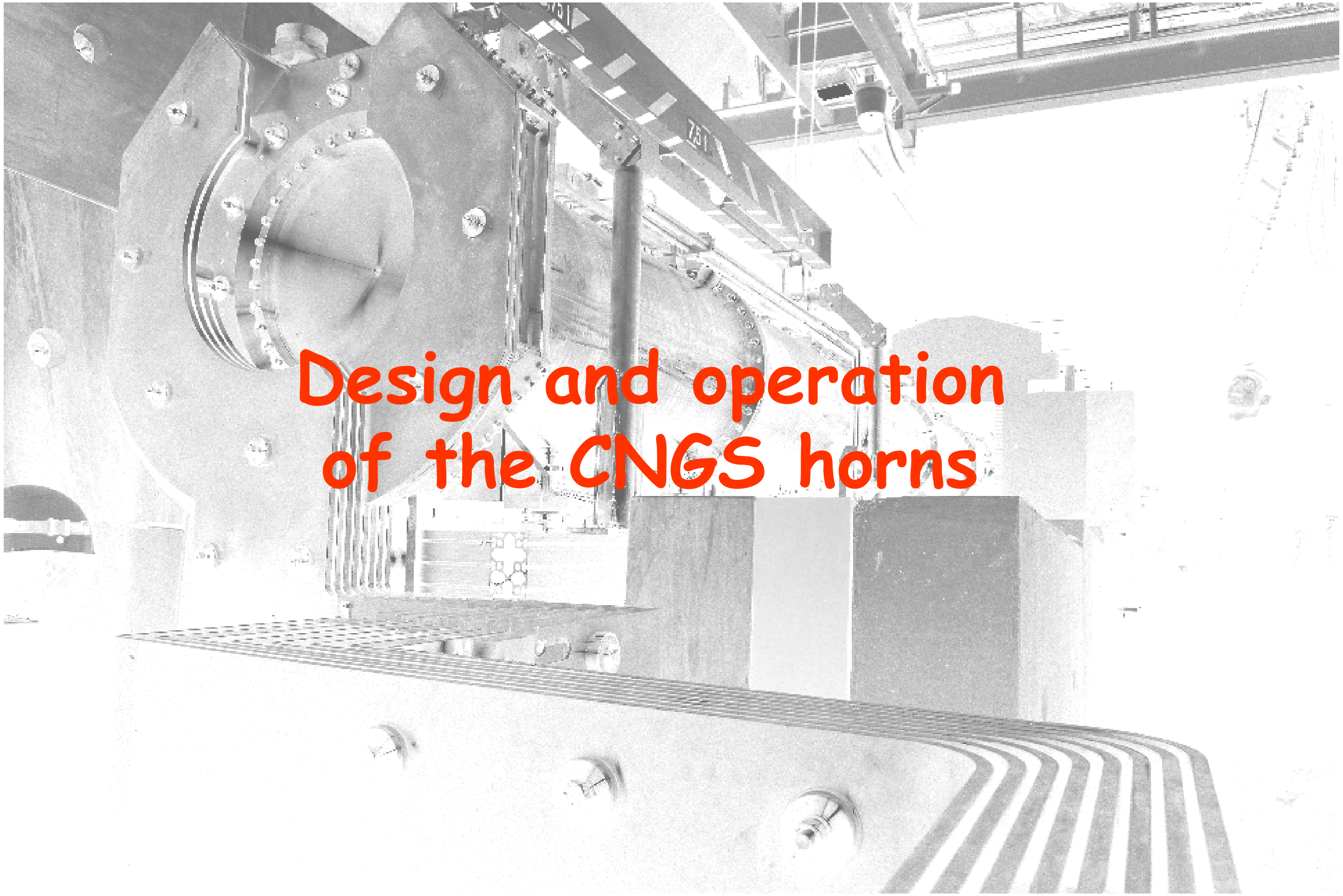
Design and operation of the CNGS horns



Design and operation of the CNGS horns

- **Outline**
  - **I) Design**
    - WANF -> CNGS / Most important changes and improvements
  - **II) Operation**
    - First steps, preliminary conclusions
  - **III) Annex**
    - Test cell – Compare surface coatings under high radiation

I) Design

- **Design of horns for CNGS extrapolated from WANF experience**

- **WANF operation:**
  - 1994 -> 1998
  - 2 pulses of 10 ms spaced by 2.7 s each 14.4 s (SPS cycle)
  - 1.2E+13 protons/spill (6ms)

- **WANF horn systems:**

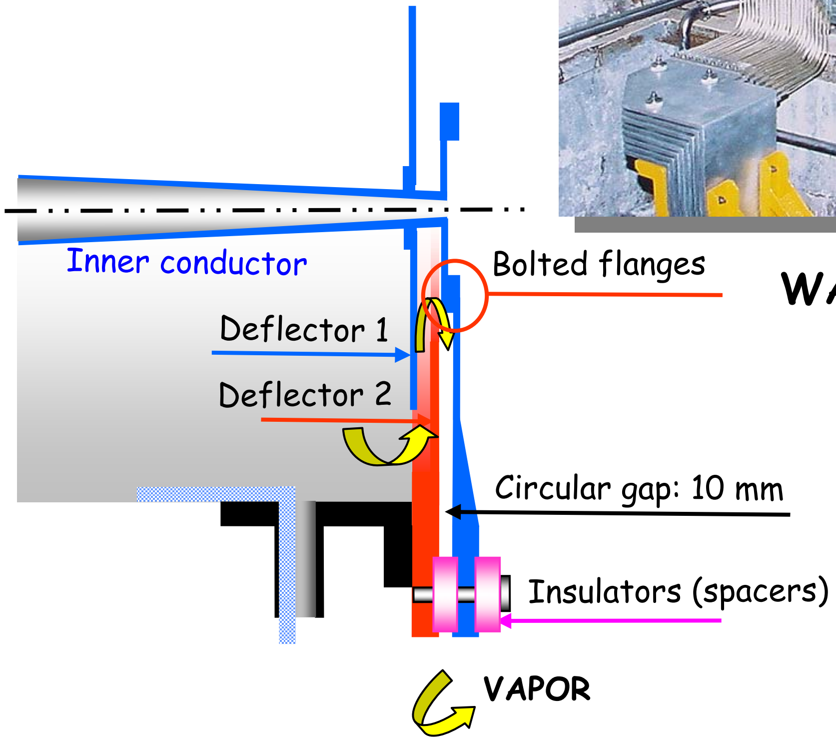
	WANF	CNGS
– H/R length	6.9 m (electrical connections included)	
– Horn diam.	420 mm	700 mm
– Reflector diam.	800 mm	1100 mm
– Striplines	6.00 m	16 m
– Ratio of the pulse transformers	: 32	H 16, R32
– Calculations for	10*7 pulses	2x10*7 pulses
- Distance horns/power supplies:	250 m	1 km

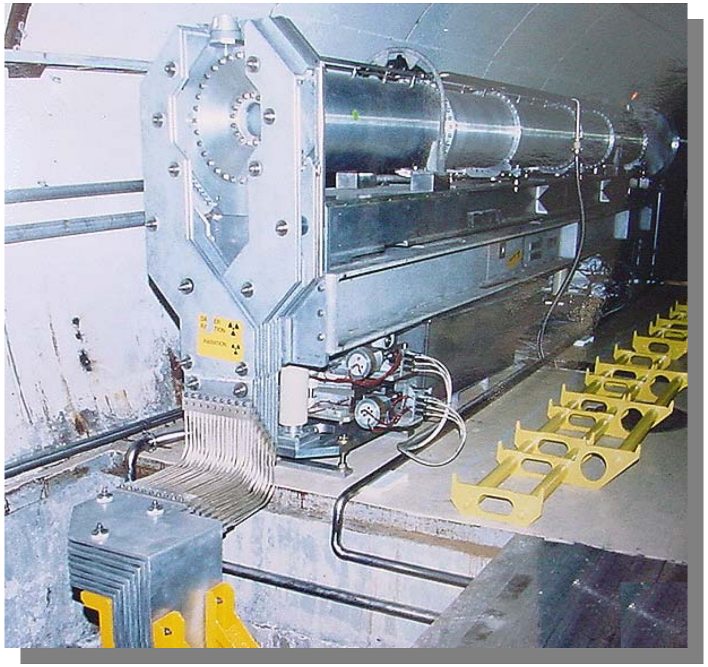
  - **No service gallery**

CNGS

I) Design

Family resemblance !





WANF HORN

CNGS HORN

I) Design

- Main evolutions on horns from WANF #10 years CNGS

WANF	CNGS
"Open" construction	Water vapor tightness
Time consuming, manual operation to disconnect the horn from the strip-lines	Fast coupling system (developed by LAL/Orsay)
Main water flexible hose connected by hand	Automatic water coupler, coaxial to the drain
2 high pressure feed lines for cooling	1 low pressure feed line + 1 spare
Inner conductor in 4 pieces with flanges bolted together, centered by "Arclex" discs	Monolithic inner conductor without bolts and centered by cables (spiders)
Complex set of support frames with remote controlled bases	Decoupled frames made with rigid standard profiles – No remote controlled bases requested

I) Design

1) Glass ring insulator
(new development from a LAL initial study)

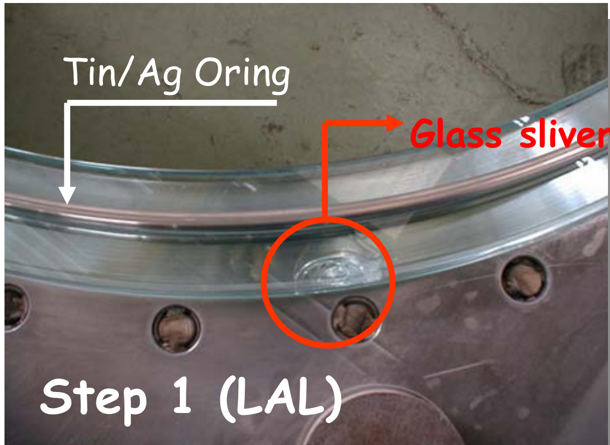
Preliminary conclusions of the failure

-Dimensional ratio not correct

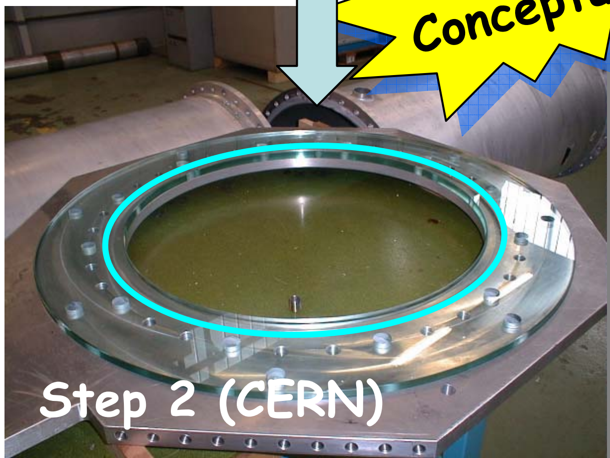
-Flatness of the surfaces

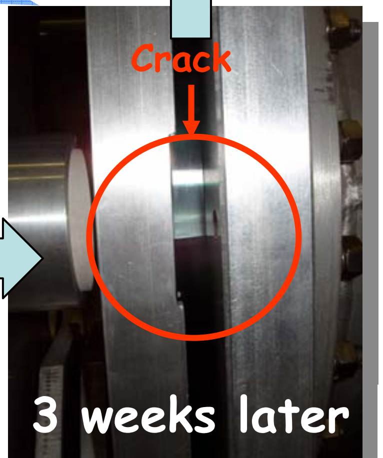
-Drilled holes = breaking points

-No separate functions for the clamping bolts



Problem = Conceptual





CERN technical mini-review

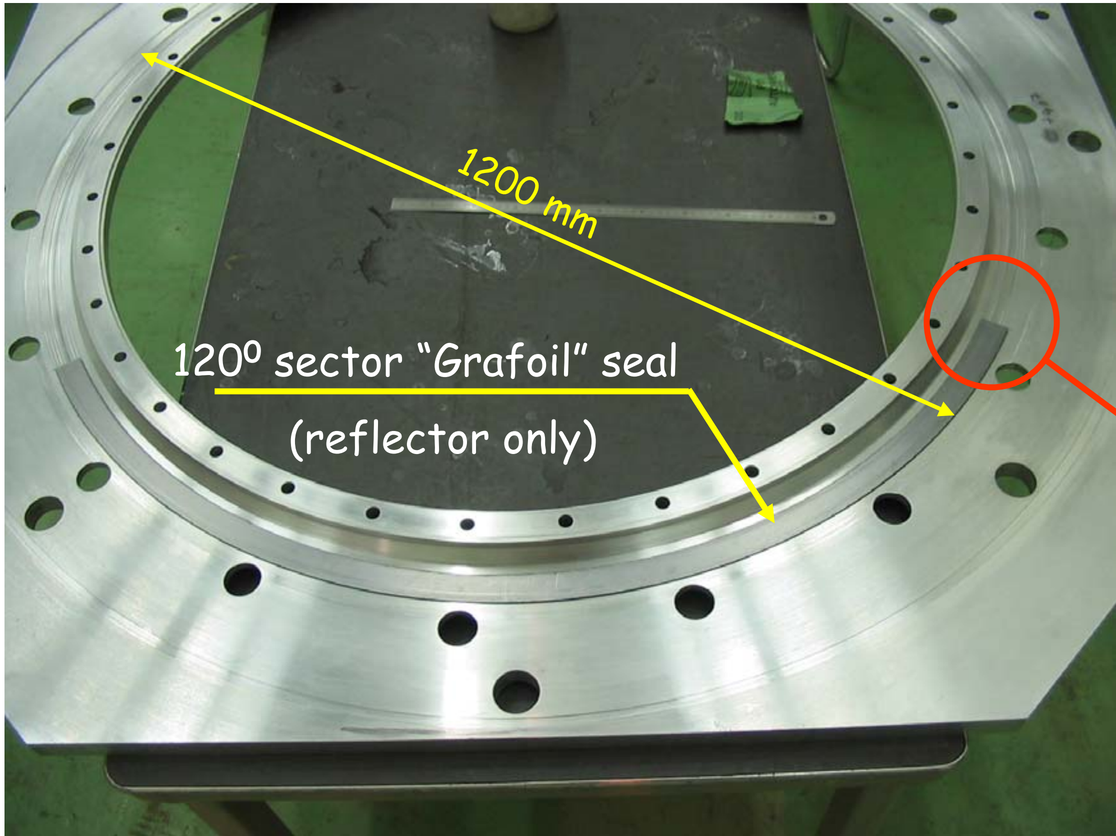
Report on Observations of the CNGS Horns at CERN

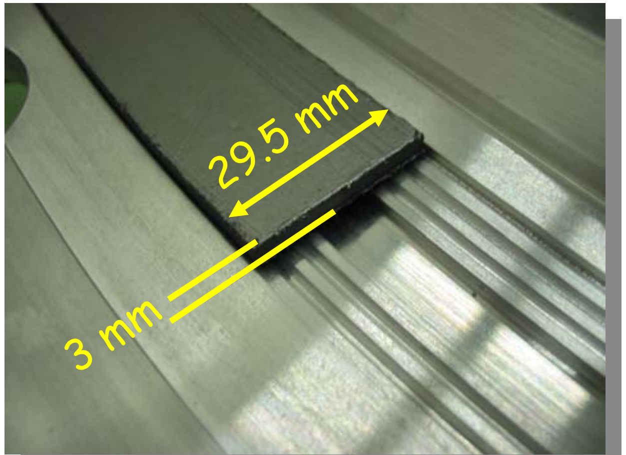
By Larry Bartoszek, P.E., 8/28/05
Updated 9/2/05
BARTOSZEK ENGINEERING

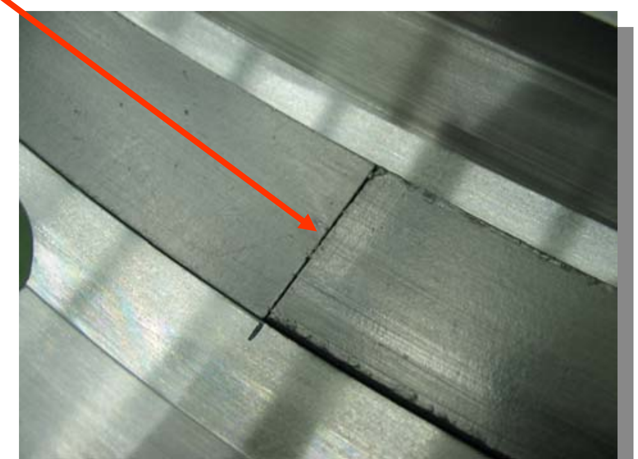
My visit to FNAL

I) Design

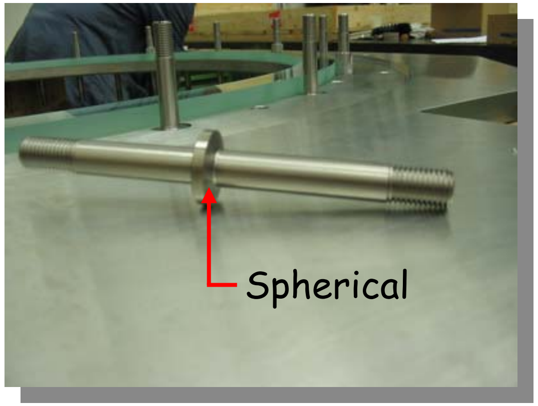
2) Glass ring installation (reflector)



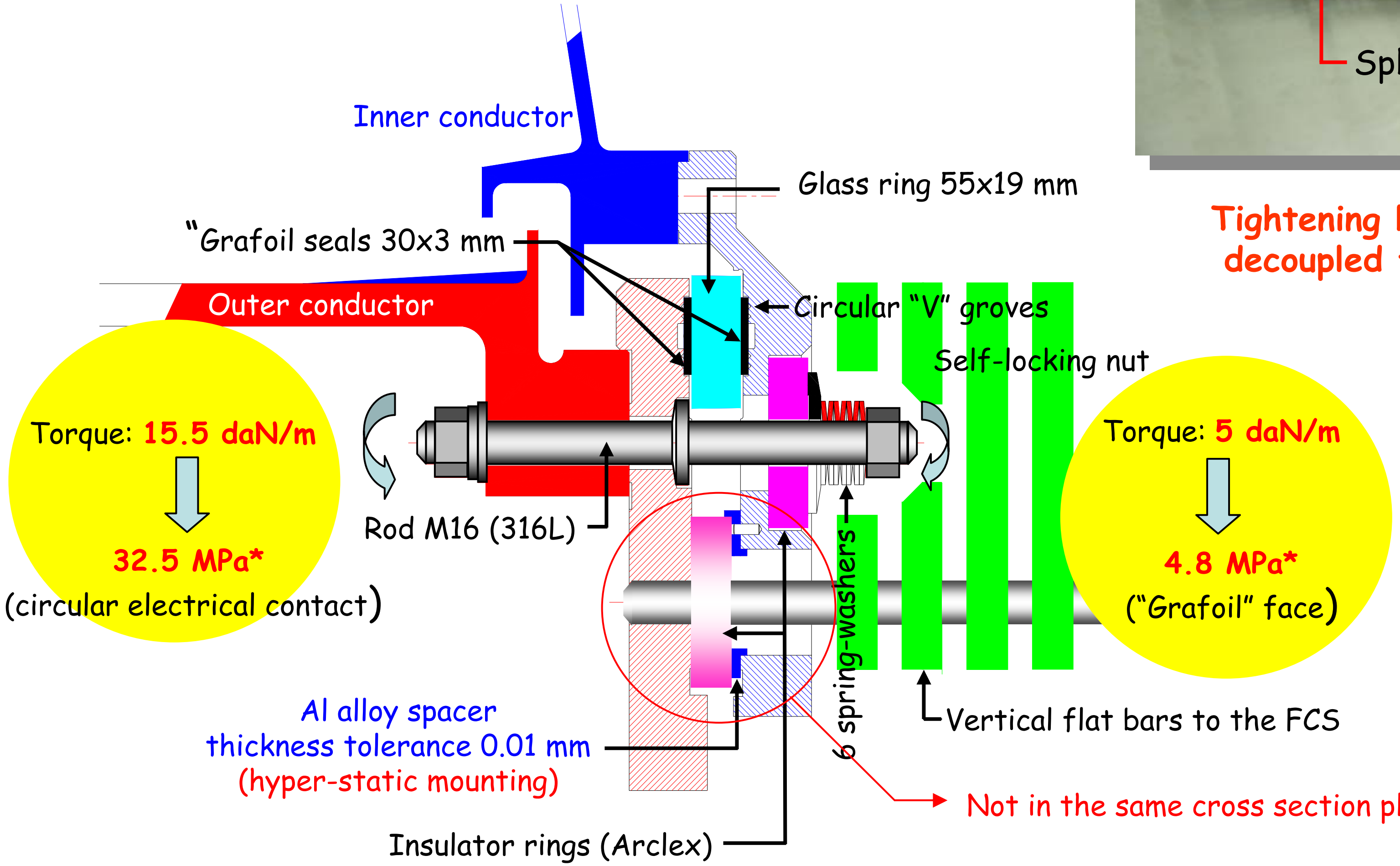




I) Design



Tightening bolts with decoupled functions

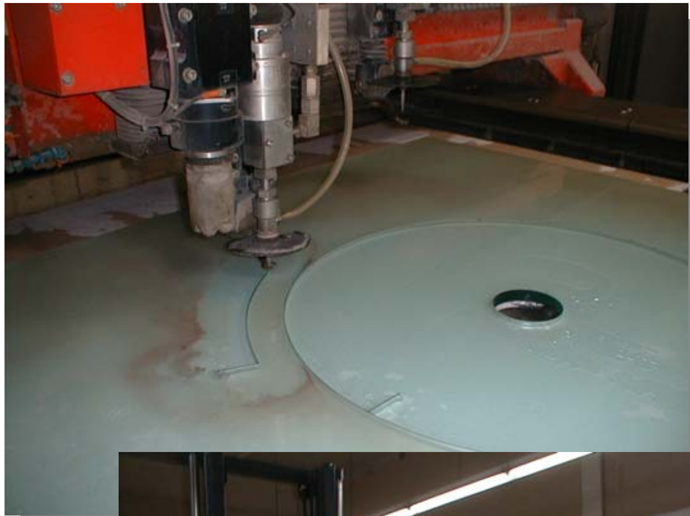


*Computation based on FD E25030 standard

I) Design

Machining of the glass ring insulator

10 times cheaper than conventional method



Glass cutting by "Hydrojet" process
(firm: Wyss)

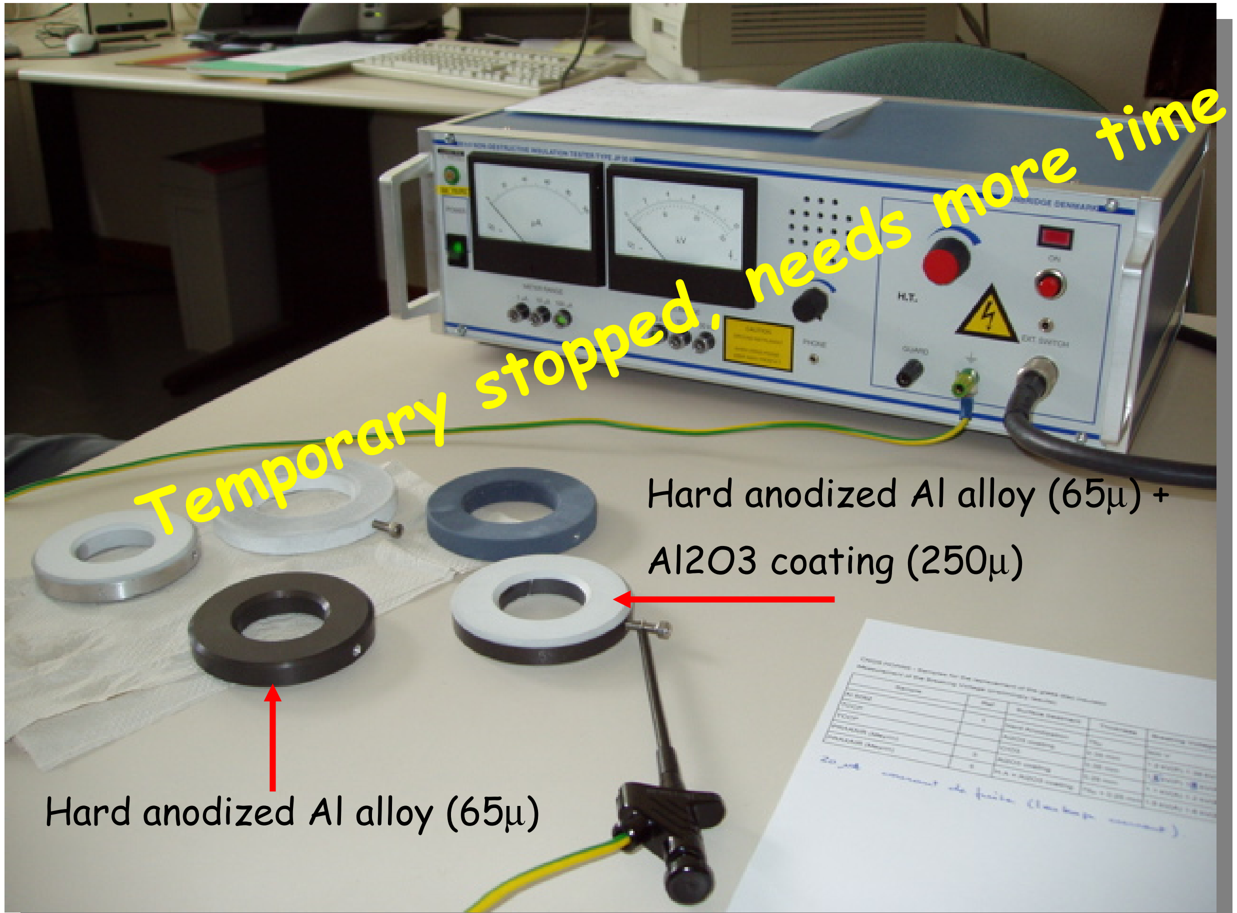
I) Design

Water-tightness, glass insulator
(electrical connection side)

Alternative proposal for the replacement of the glass insulator

Al2O3 coating by "Schoopage" process

Temporary stopped, needs more time for tests



Hard anodized Al alloy (65µ) +
Al2O3 coating (250µ)

Hard anodized Al alloy (65µ)

Breaking voltage in
wet area: 1.5 kV

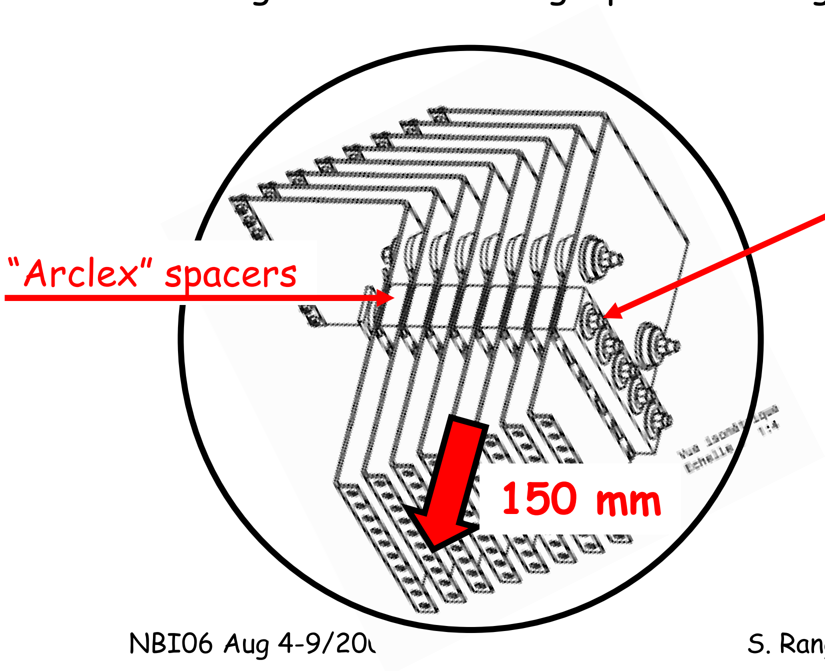
No previous experience in high radiation areas

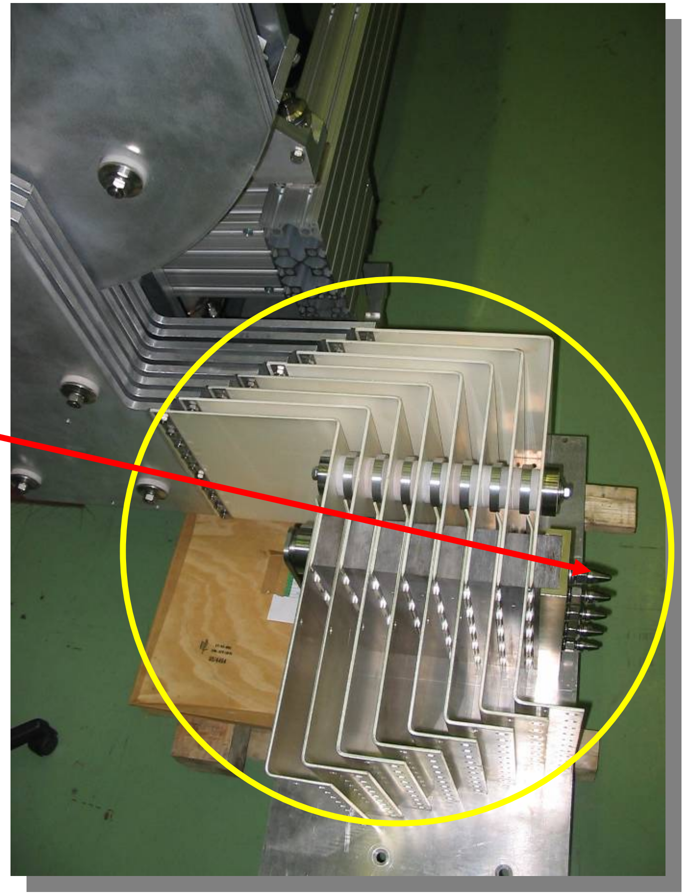
I) Design

Electrical connection to the strip-line (Fast Coupling System – FCS)

- **Development LAL/Orsay**

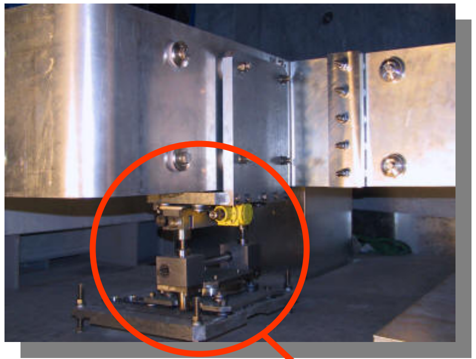
- Copper square plates 5 mm thick, silver plated 15µ
- 5 nuts M16 reachable from the passageway
- Misalignment default accepted: +/- 2 mm
- Need 150 mm movement of the strip-line end part
- Self-locking nuts 316L with graphite coating (seizing)





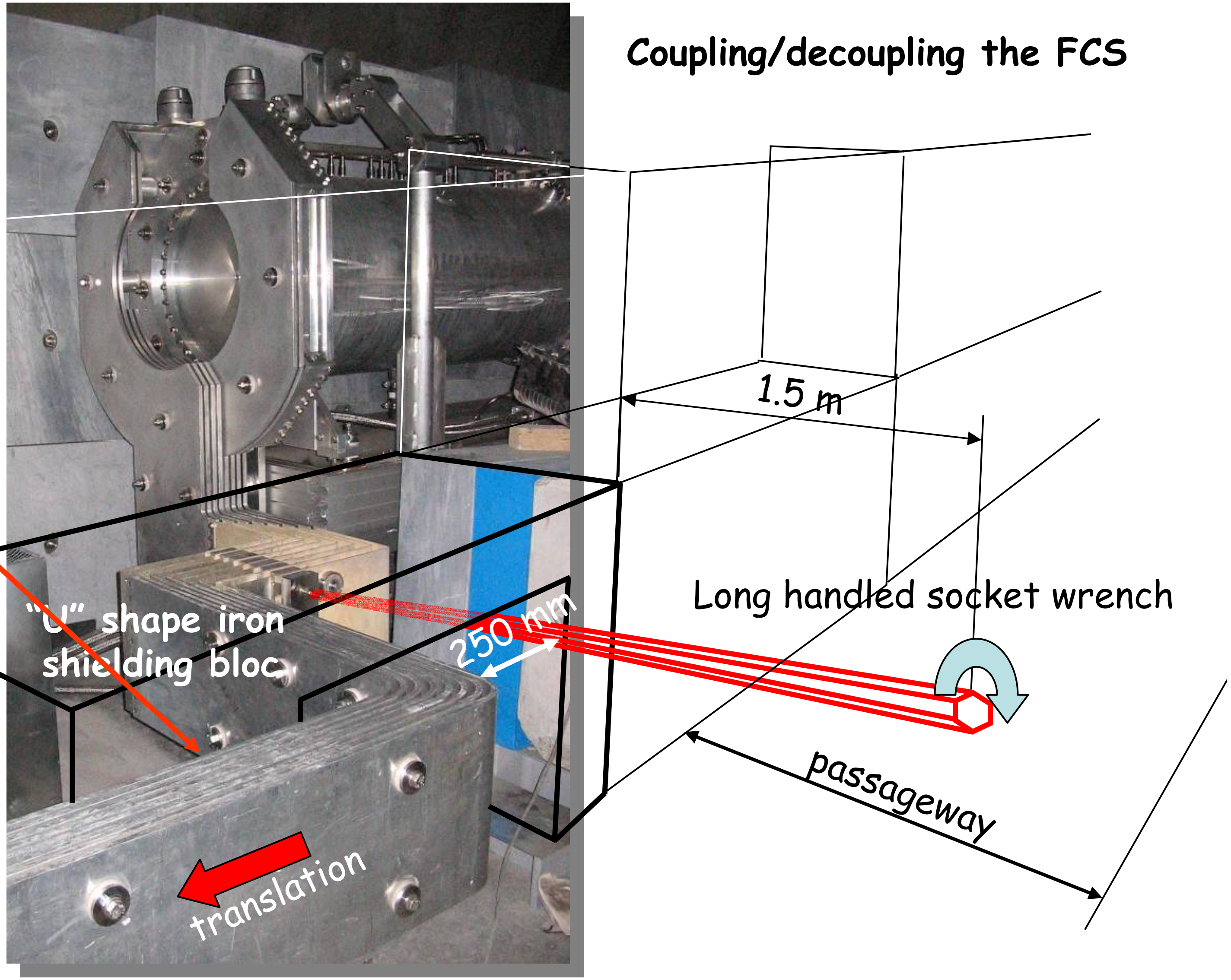
I) Design

Coupling/decoupling the FCS



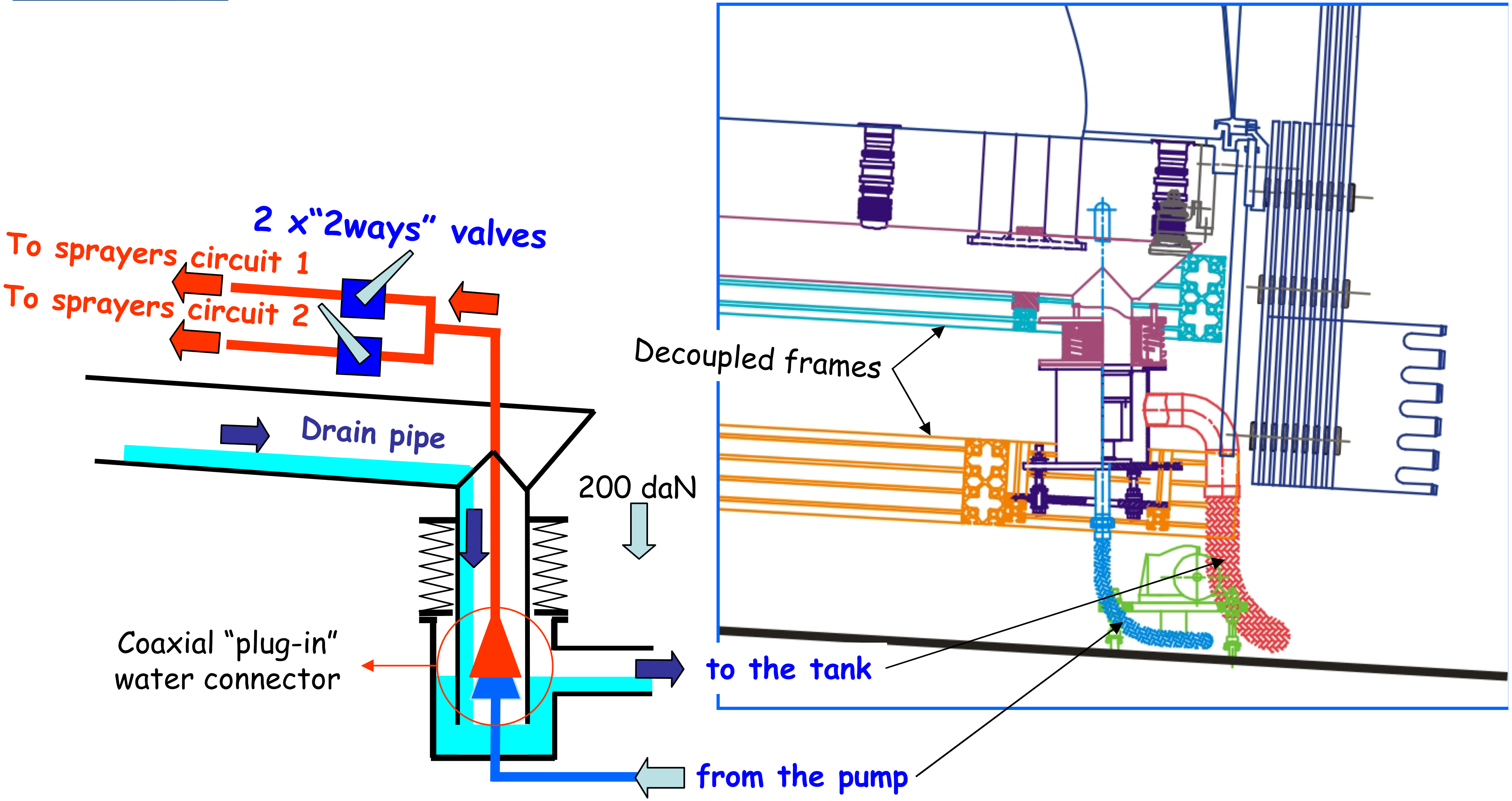
"Slave" base

"Master" base
(in the trench)



I) Design

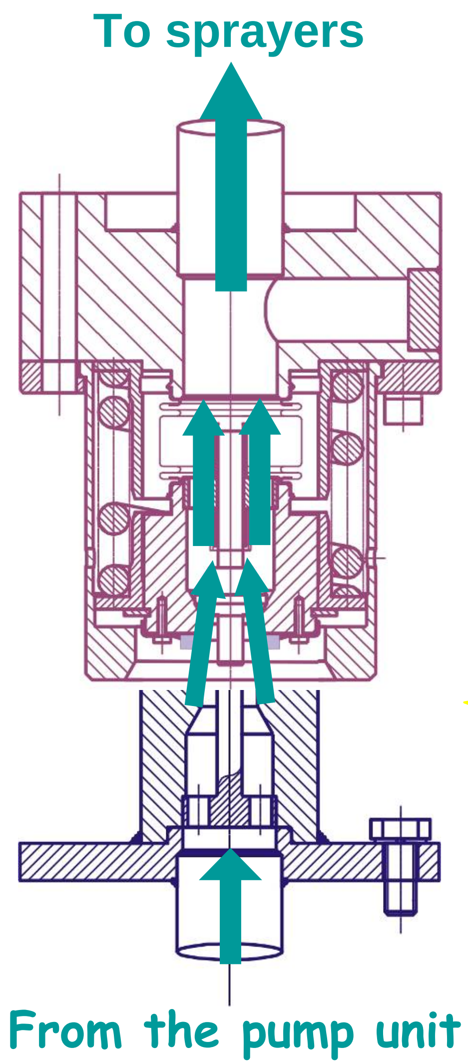
Coaxial "plug-in" water connector



Scheme

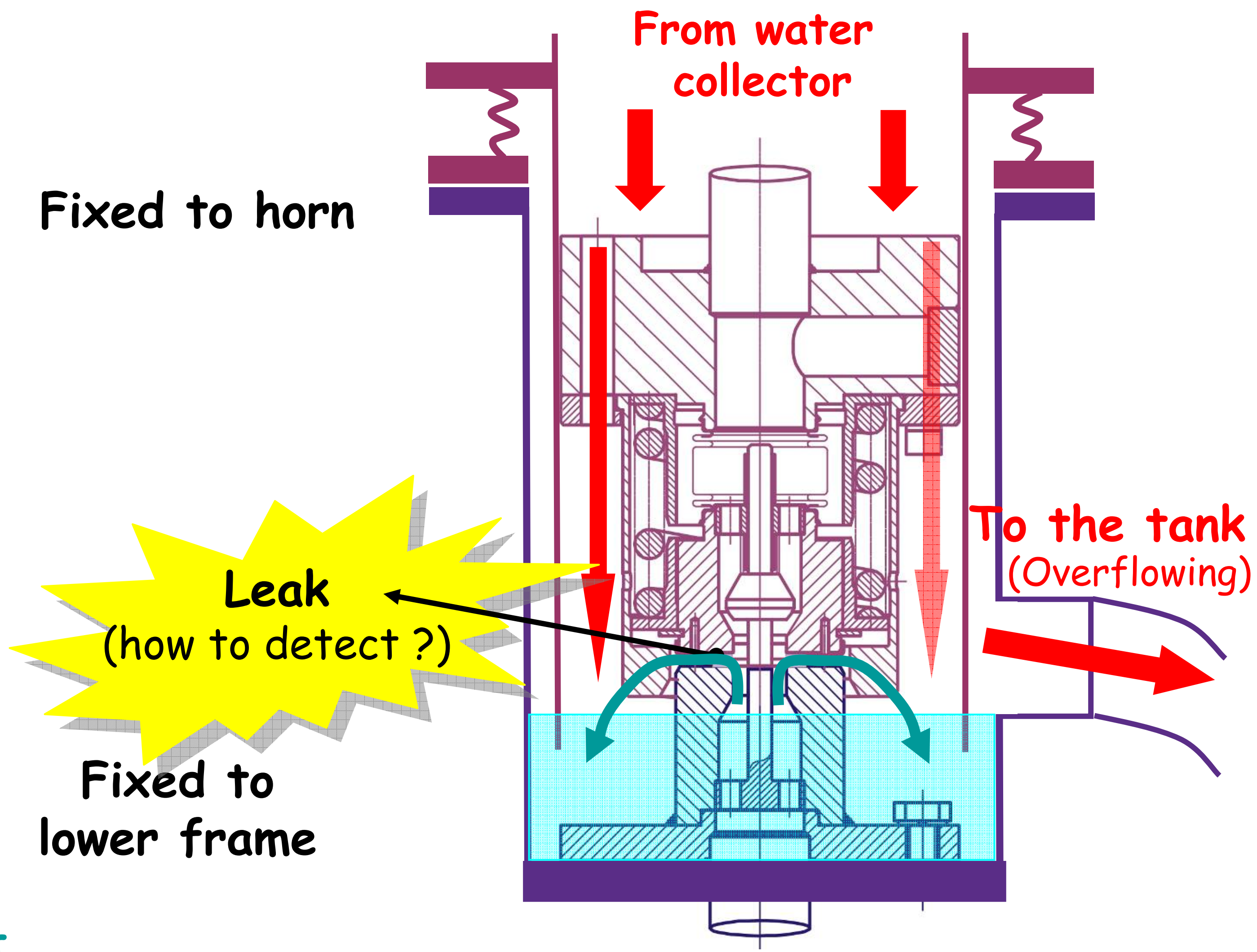
Design of the CNGS horns

Coaxial “plug-in” water connector



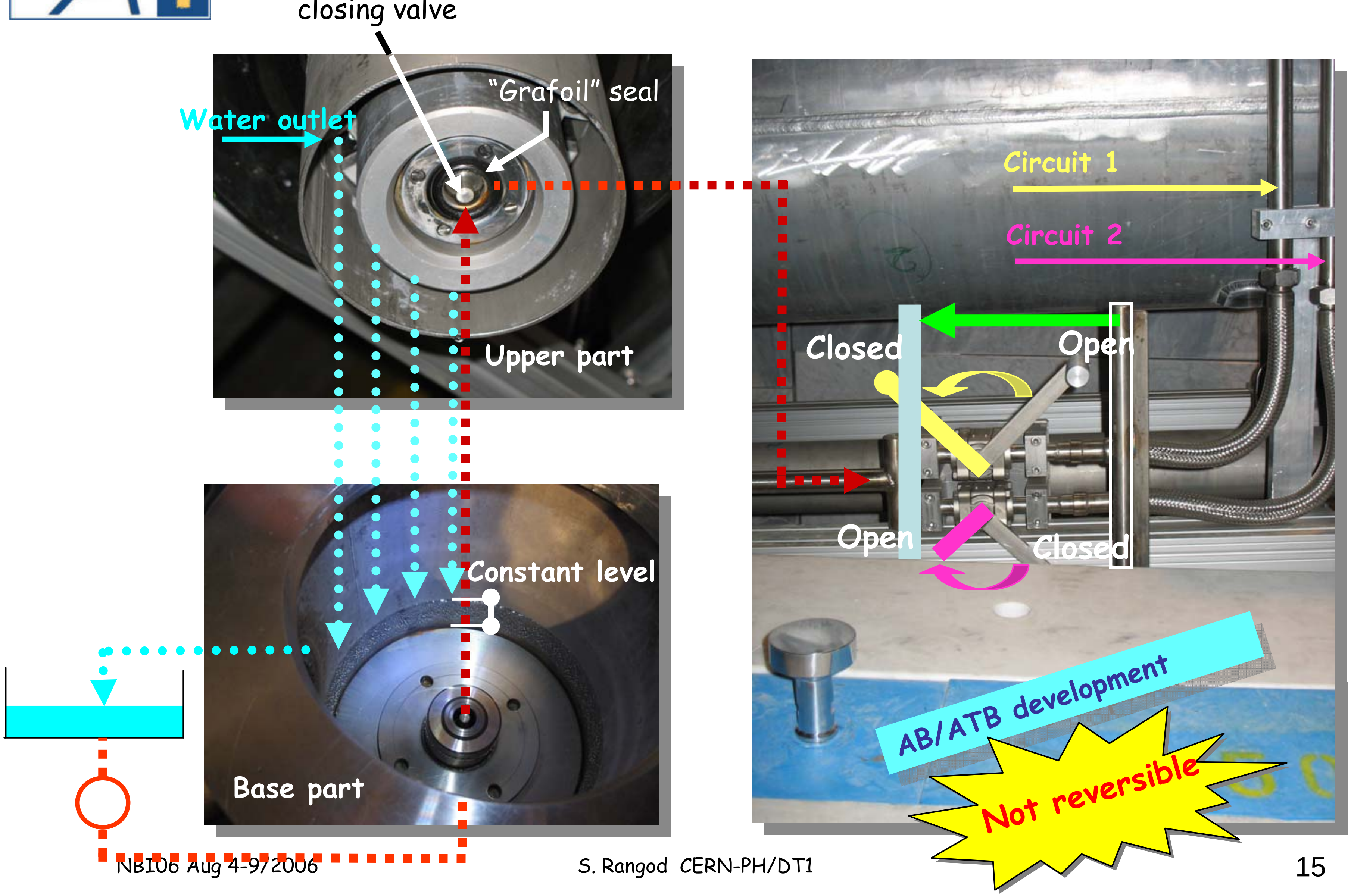
Fixed to horn

Fixed to lower frame



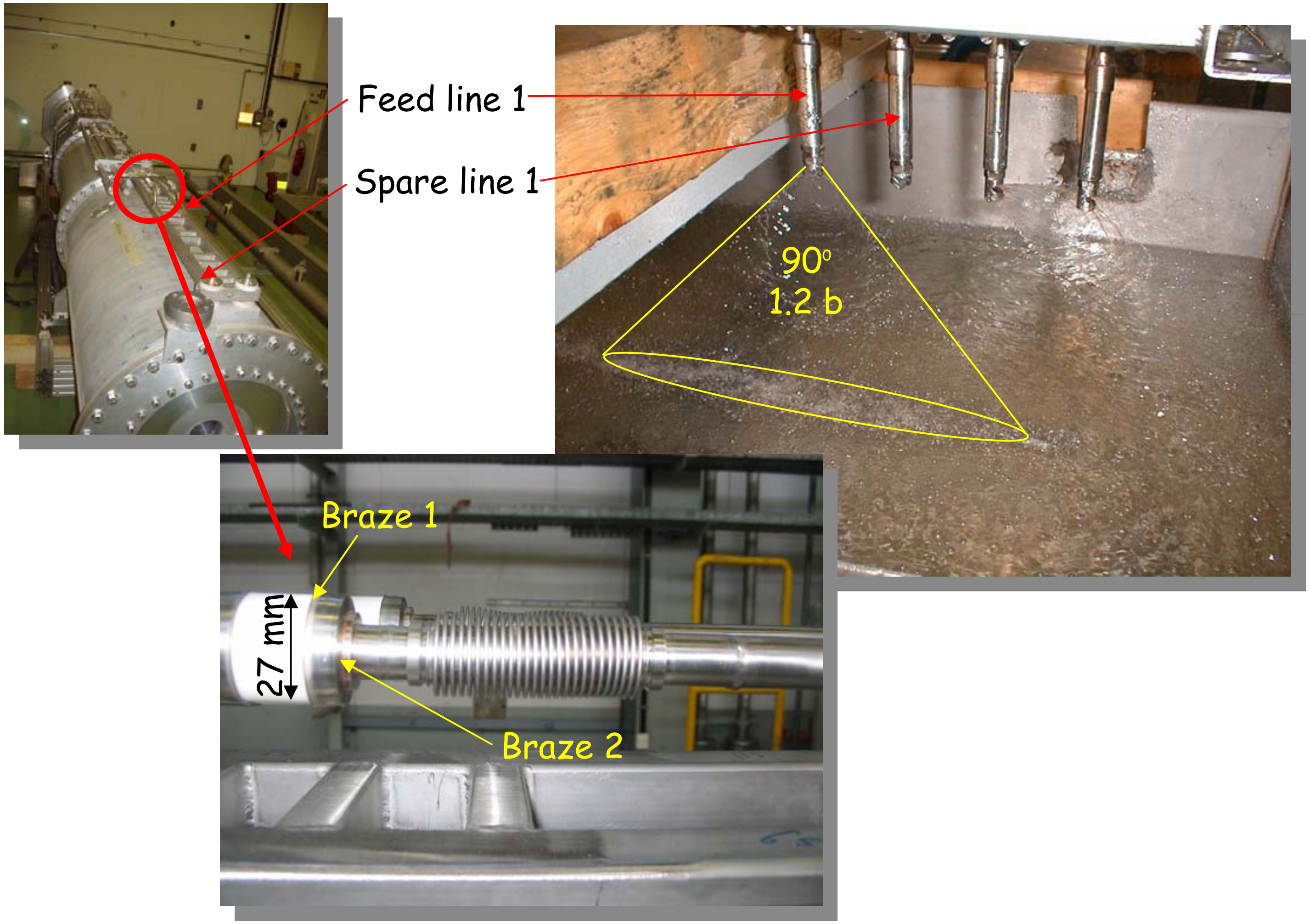
I) Design

Coaxial "plug-in" & selection of the cooling circuit



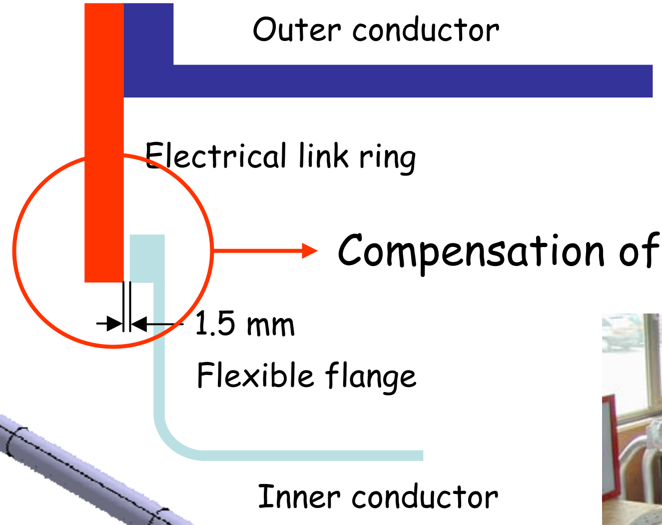
I) Design

- Cooling feed lines – insulators & sprayers

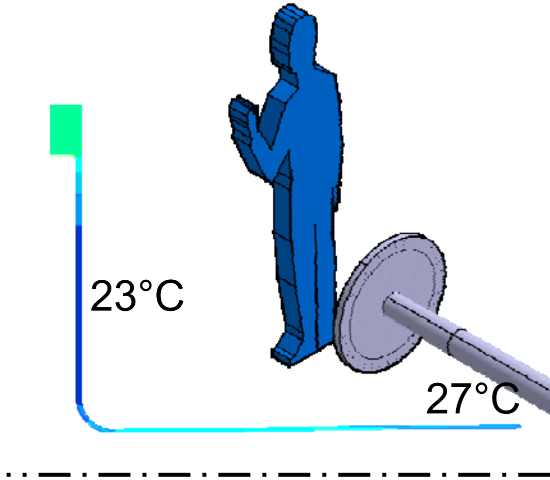


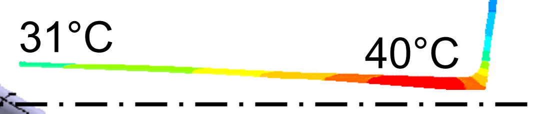
I) Design

Inner conductor parameters



Compensation of the thermal expansion offset





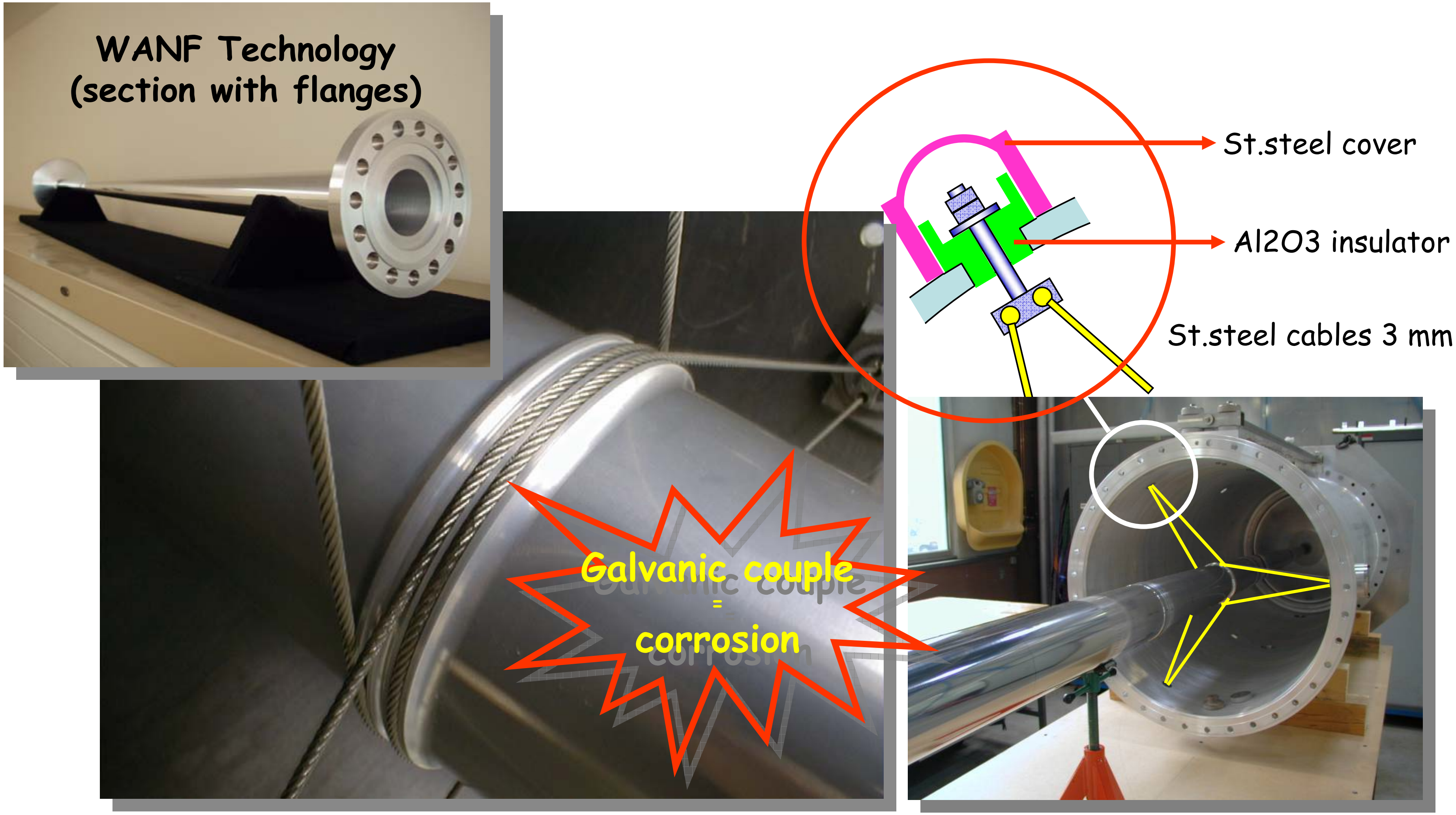
- length : 6.65 m
- thickness. : 1.8 mm
- diameter : from 30.8 to 136 mm
- 9 conic parts and 2 end flanges
- 6082 Al alloy
- EBW

Δt 10°C on 95% of the total length

Thermal computation: LAL (water 20 °C)

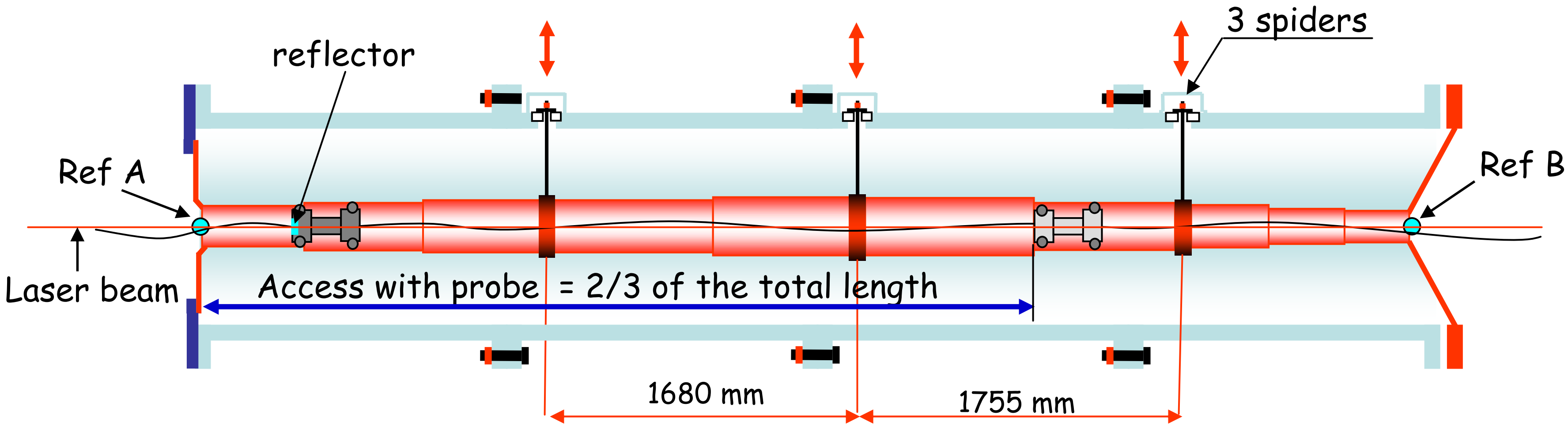
I) Design

Inner conductor – Detail of the spiders



I) Design

Inner conductor – alignment/straightness



Probe for alignment
LAL development

II) Operation

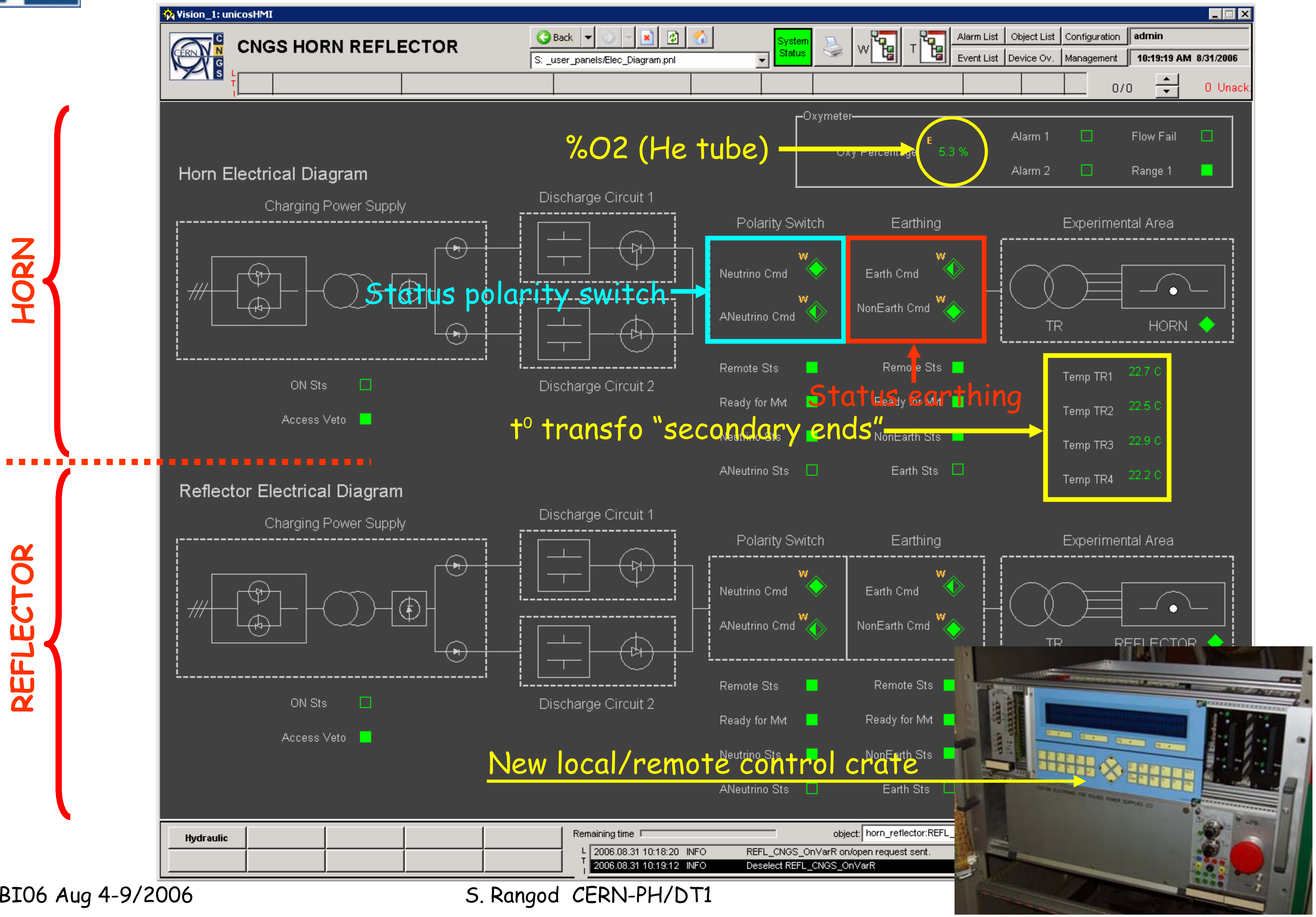
Parameters – Simulation and measured

Updated 15 April 2003	Unit	HORN SYSTEM	REFL. SYSTEM
Duty cycle		2 pulses 50 ms apart all 6 s	
Peak current in horn	kA	150	180
Transformer ratio		16	32
Primary current peak	kA	9.375	5646
Total capacitance for two switching sections	µF	45.4 x 90 x 2 = 8172 8160	45.4 x 90 x 2 = 8172 8160
Pulse duration	ms	7.5 6.5	10 9.8
Charging voltage	V	7700 6300	6300 5800
Total stored energy	kJ	2 x 119 = 238 162	2 x 80 = 160 138
Max. voltage on element	V	280	150
Mean power dissipated in element by current only (2 pulses)	kw	16	10.5
Mean power dissipated in element (inner + outer conductor) for 7.2 x 10**13 pot per 6s cycle	kw	10	6
Total power dissipated in element (2 pulses)	kw	26	16.5
Waterflow for δθout- δθin = 5°C	l/min	75 50	48 50

New capacitors 340x12x2

II) Operation

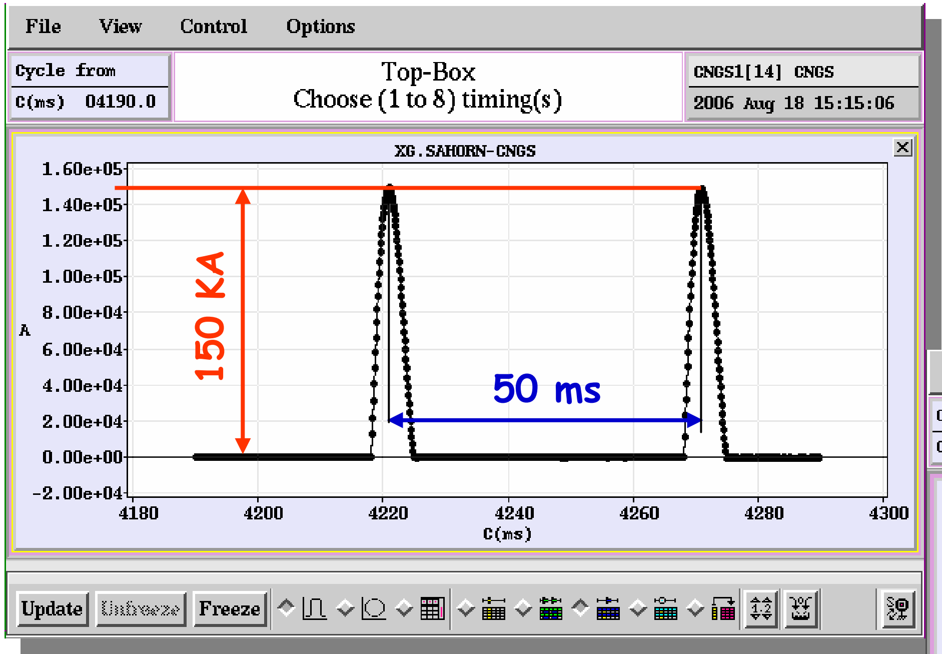
Control screen for the status of the power circuits



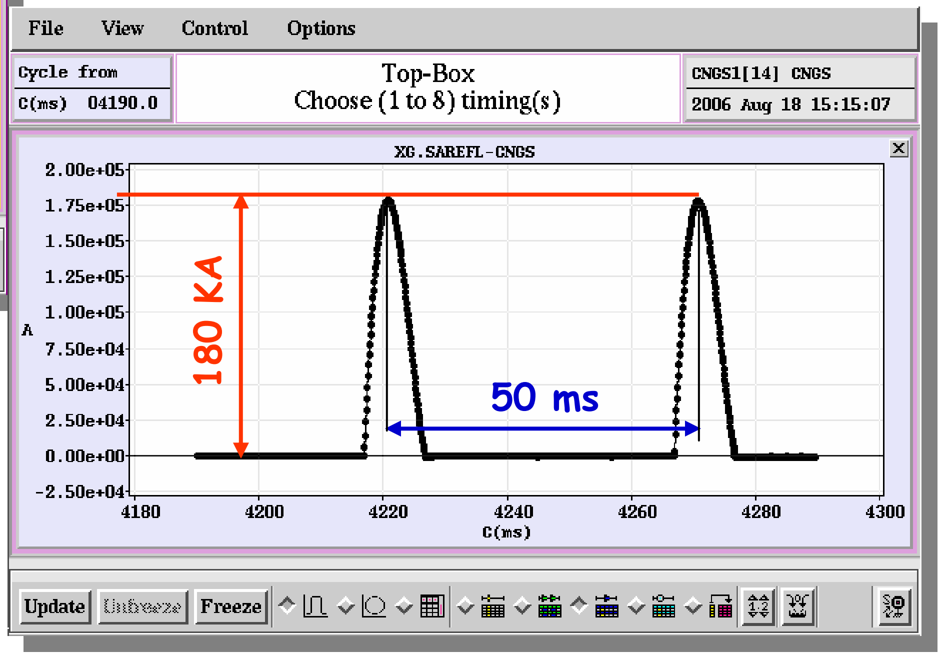
II) Operation

H/R pulses (nominal current)

REFLECTOR

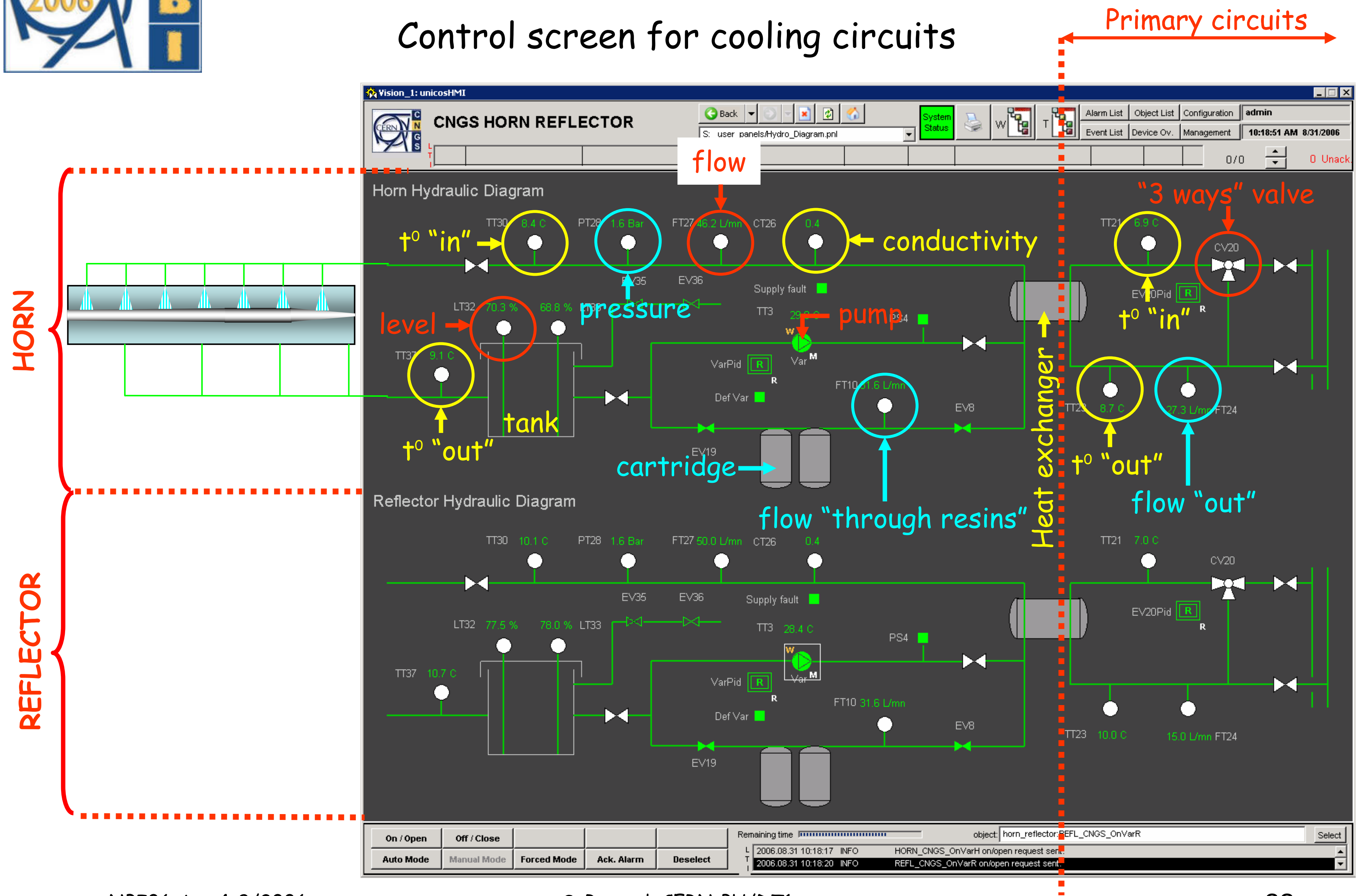


HORN

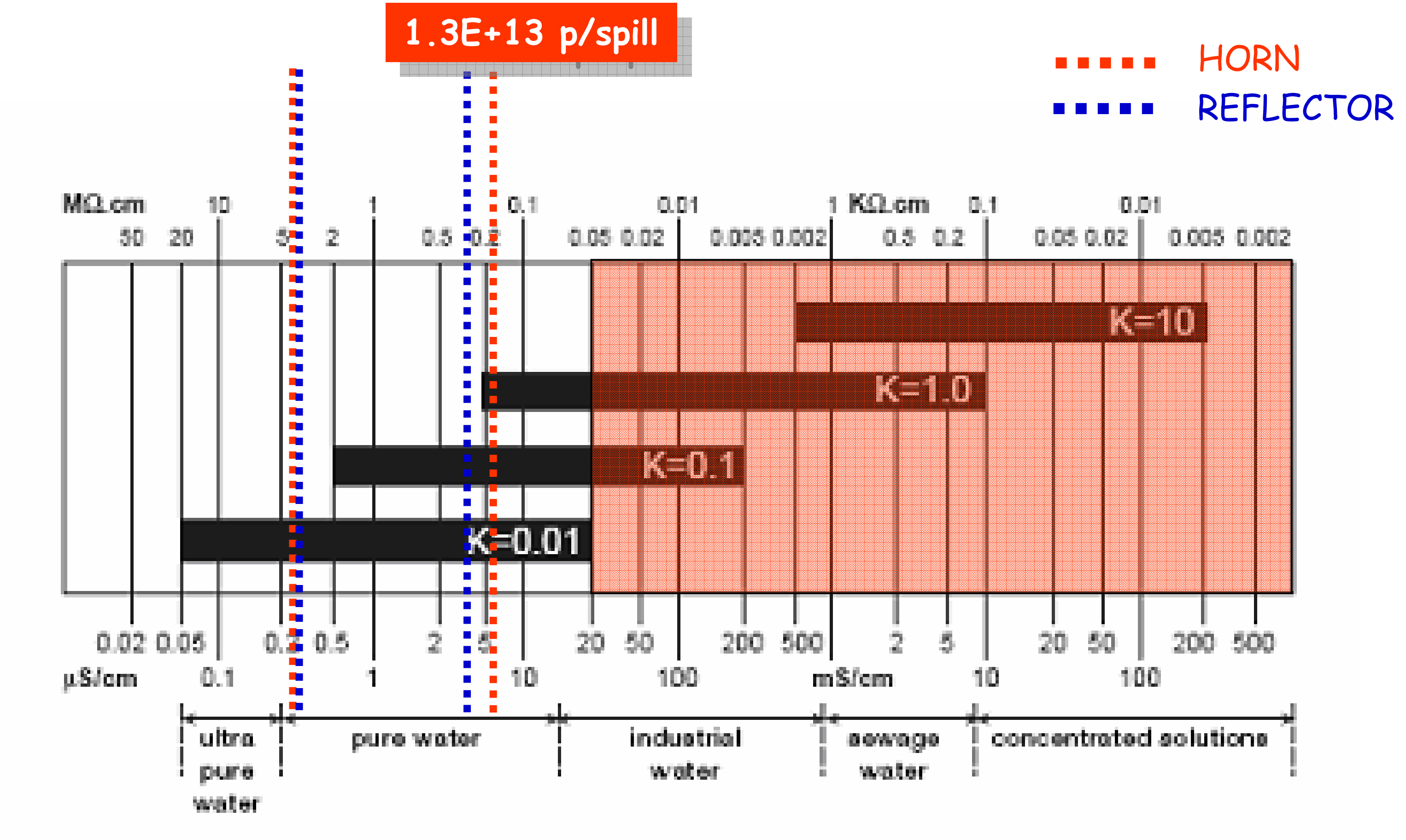


II) Operation

Control screen for cooling circuits

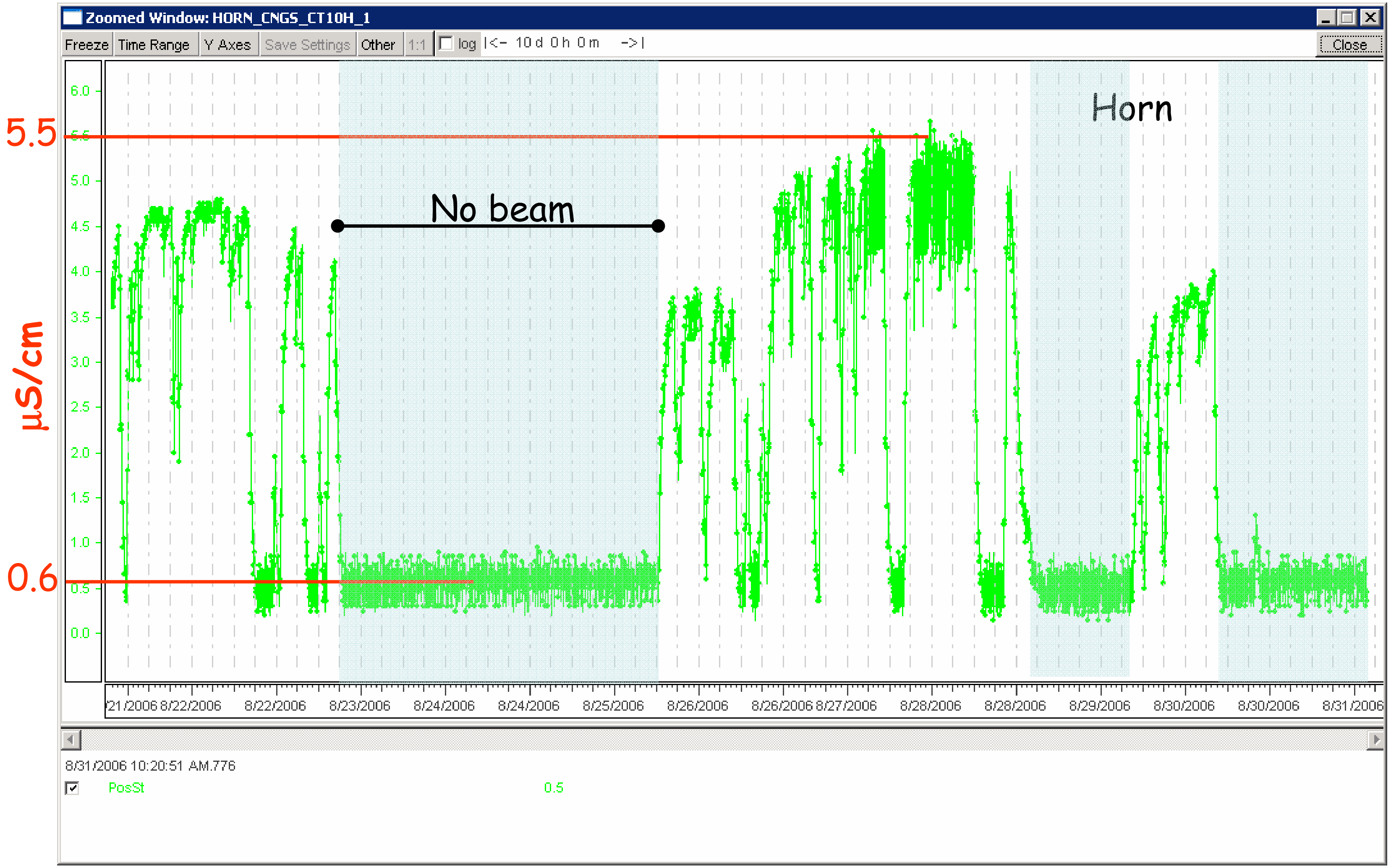


Cooling - Conductivity factor of the water



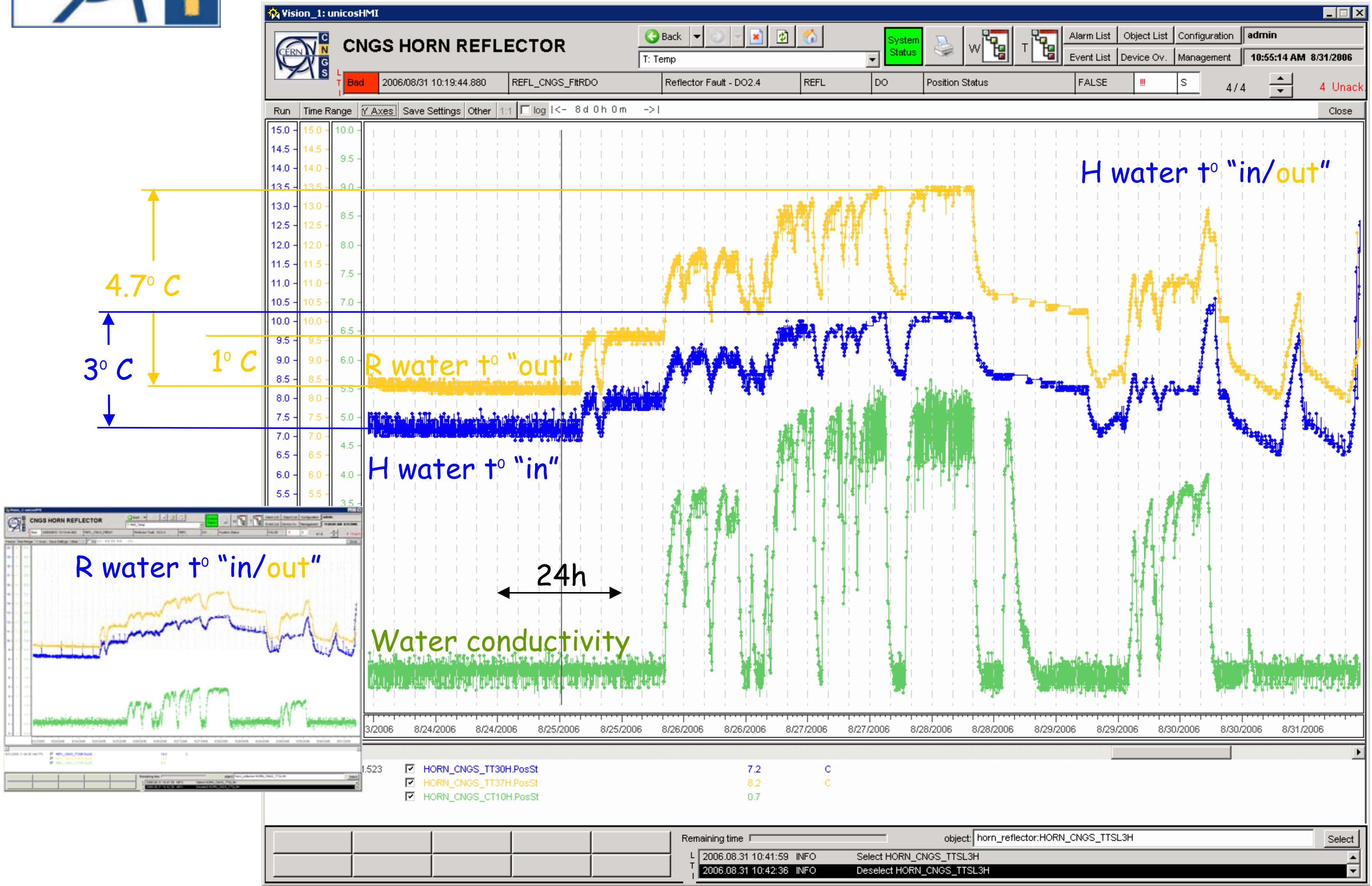
II) Operation

Water conductivity (trend/10 days)



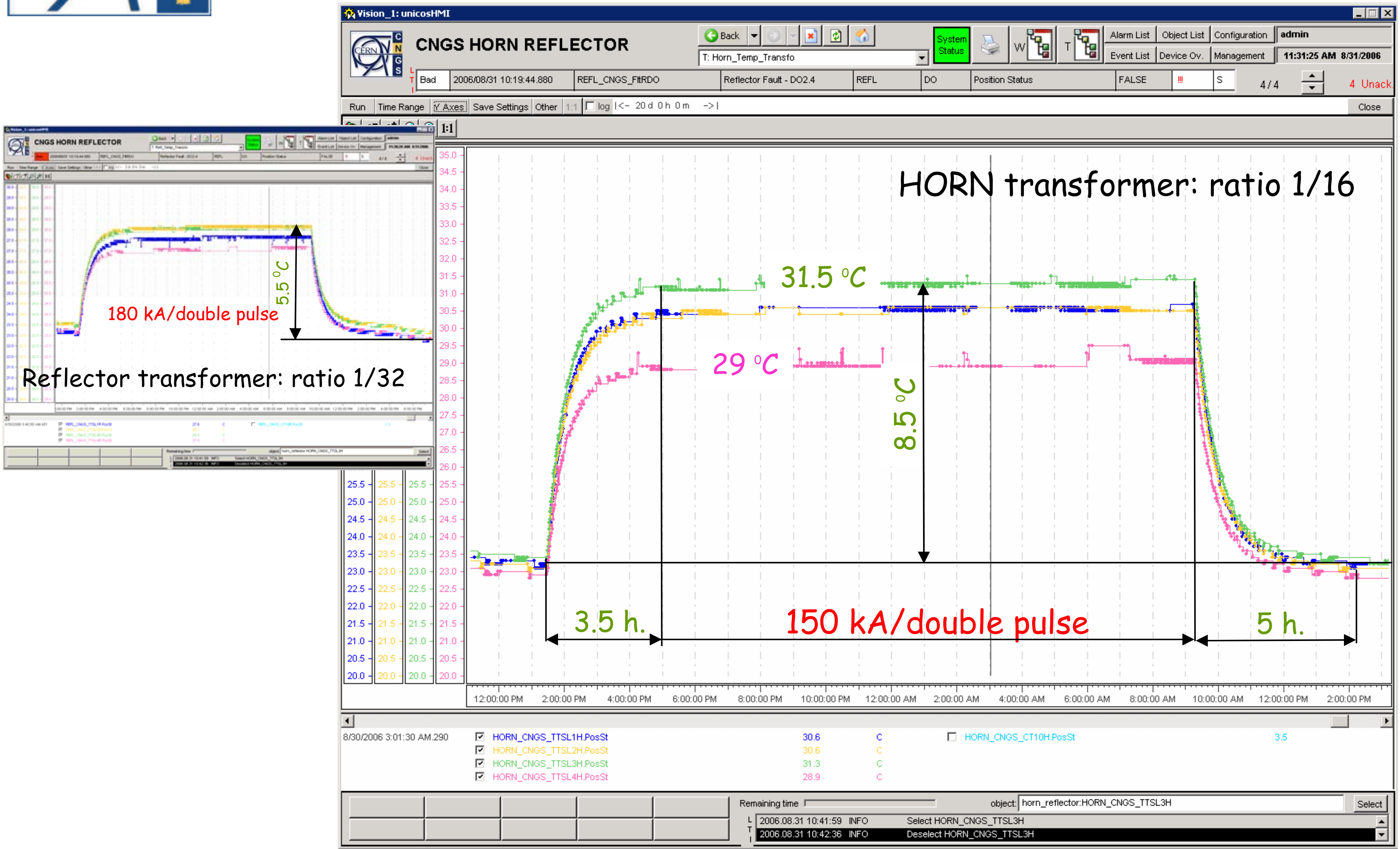
II) Operation

H/R cooling – temp. water "in/out" (trend/8 days)



II) Operation – Pulse transformers

Temp. of the 4 secondary coil ends (trend/1 day)



Preliminary conclusions

- **About 400.000 double pulses done at nominal currents (commissioning + run)**

- Very good reliability of the power supplies and controls
- Water cooling units well dimensioned; good efficiency of the low pressure sprayers
- No problem observed on the pulse transformers recuperated from WANF

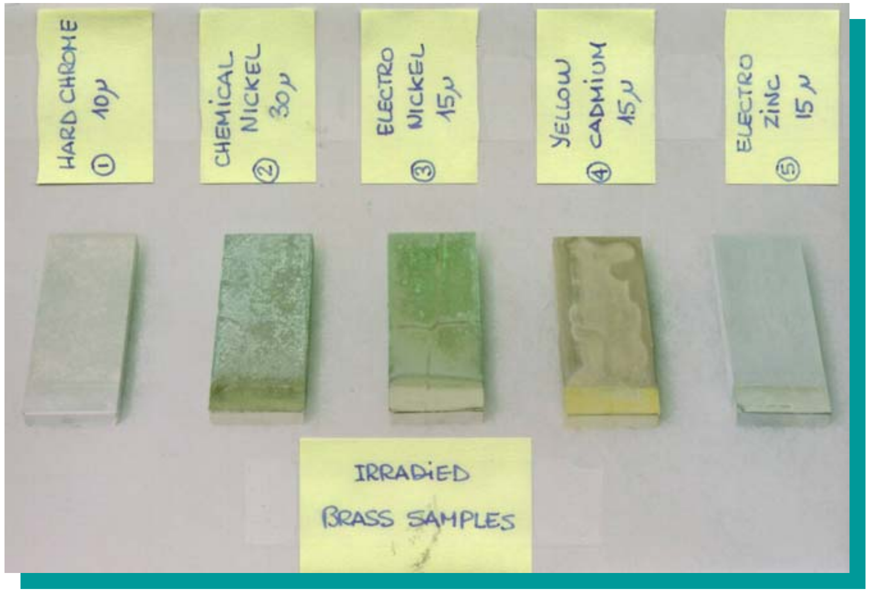
Long term…
- Effect of the corrosion due to the galvanic couple (S.Steel/Al alloy)
- No previous experience with:
  - Large glass insulator rings
  - “Grafoil” material in high radiation areas
  - Fast Coupling System

III) Annex

- **Cell test (drawer)**
  - **GOAL: to compare the efficiency of several protective coatings in high radiation areas.**
  - WHERE: under the horn, 4.7 m downstream the target focal plane.
  - HOW: Visually only
  - WHEN: 1 time each year at the end of the yearly shut-down (proposal)

III) Annex

- **History (WANF)**
  - Few different samples protected with several types of coatings installed in hurry before the beam starts in 1995
  - Placed on the top of the horn shielding, immediately downstream the target T9
  - Duration 3 years corresponding to 20 months with beam



III) Annex

- **Design & Installation of the drawer**

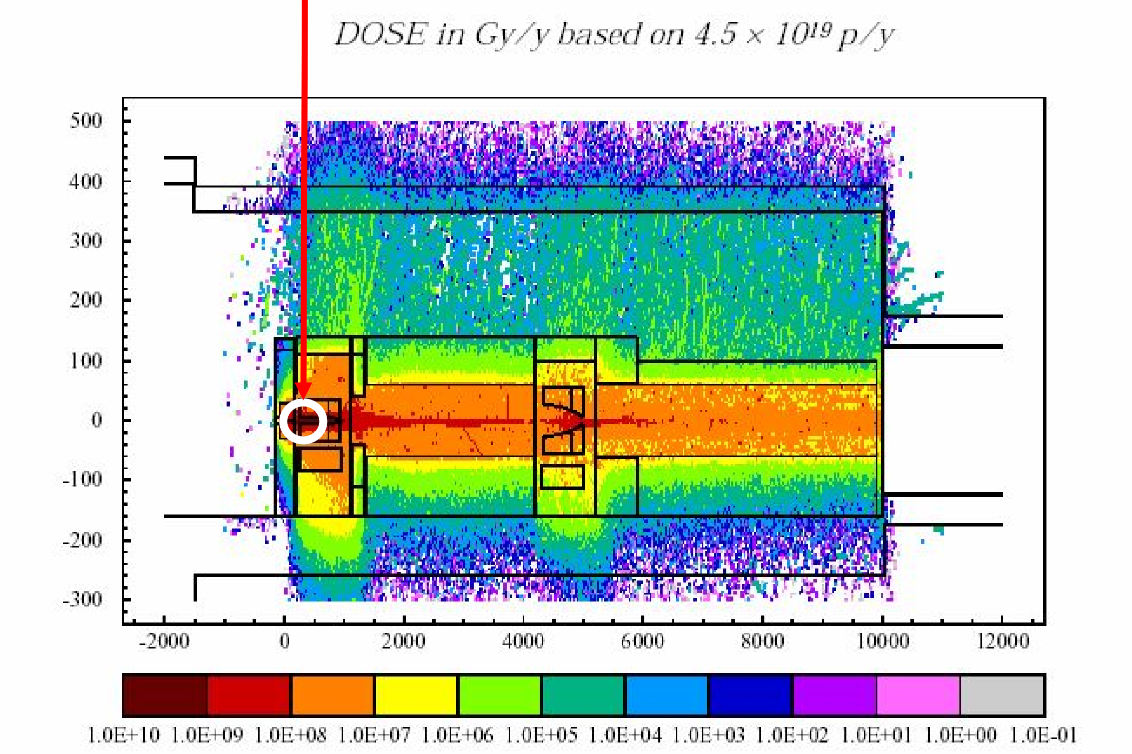
- Fully built with light Al alloy
- 40 samples, dimensions (mm): 35 x 70, thickness: 3
- Frame for samples centered on the vertical axis of the beam
- Distance to the target focal plane: 4.70 m
- Total movement of the drawer: about 1680 mm
- Slides out or pushed back in few seconds
- Each sample is engraved to avoid errors

- ***A second identical set is placed in TSG4 (same atmosphere, but no radiation) for comparison***

- ***A dosimeter will be installed on the drawer***

III) Annex

Dose/y and types of coatings



Surface treatment	Thickness of treatment (µm)	Aluminum 6082	Copper Purity 9.9%	Steel OS 235 GR	Bronze	Graphite 98%	Bio resin
Without treatment		X	X	X	X	X	X
Chromium conversion coating Alodine 1200		X					
Chromium conversion coating Alodine 1500		X					
Chromium conversion coating Alodine 160		X					
Anodising	20	X					
Hard anodising	40	X					
Black hard anodising	40	X					
Silver plating	12		X				
Silver plating + passivating	12		X				
Cadmium plating	7-10			X			
	20			X			
Chromium plating	20			X			
Epoxy resin 2 components coating				X			
Gold plating	1-2		X				
	10		X				
	30		X				
Anodising emaital titanox	10	X					
Tin plating	10		X				
Graphit coating					X		
Electroless nickel plating	15	X	X	X	X		
Sulphamate nickel plating	10	X	X	X			
	30	X	X	X			
Black oxidation				X			
Red polyamide		X					
Black polyamide		X					
Zinc plating, blue passivating	15			X			
Zinc plating, green passivating	15			X			
Xylan 1010				X			

III) Annex

Test cell – Samples and support frame