STRING ASSEMBLY & LESSONS LEARNED

BE-RF-SRF/PM/BR, EN-MME/EDM/FS, EN-ACE/SU, TE-VSC/SCC/BVO

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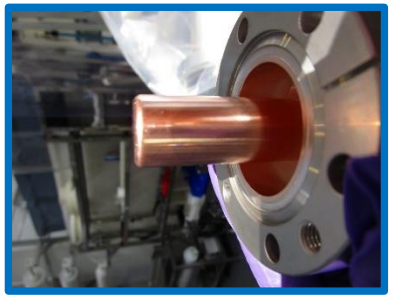
Outline

- Objective and challenge
- Assembly workflow
- Cleanroom facilities and equipment
- Components preparation procedures
- String assembly
  - FPCs Test box assembly
  - Double tubes preparation
  - FPCs preparation
  - HOMSs and pick-up preparation and assembly
  - FPCs assembly
  - Warm transitions assembly
  - String alignment
  - String connection
  - Validation tests
- Conclusions and Acknowledgements

Objective



Clean assembly of DQW Crab cavities and their components

Minimized particle and external Contamination

Preserve cavity performances for the machine

The Challenge

New technology

Complicated design

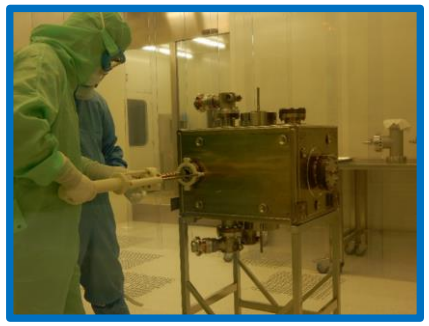
Very tight schedule to keep a chance to install the cryomodule in SPS in January **2018**

Constraints

- Delivery time of parts
- No time for blank assembly
- Preparation and assembly during the vacation period: Ressources availability
- No extra time from the schedule

Assembly Workflow

HOMSs and pick-up antennas mounting



FPCs mounting

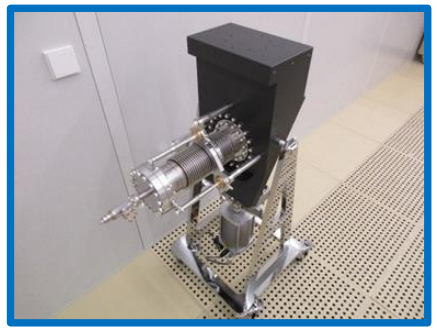
Cavity reception

2 months
Form Mid of June
To mid of August

Connection and test validation

Survey

Warm transitions assembly



Cleanroom Facilities and equipment

Cleanroom facilities

ISO5 for preparation

ISO5 clean booth for sub-assembly and pieces conditioning

2x ISO4 for assembly

Panel inside cleanroom

Panel outside cleanroom

Patch panel
-2 pumping ports
-4 gas inlet (N2, He, spare)
-4 RF N type connectors (RF measurement)
-Electrical power outlet
-VGA and HDMI ports (for the VNA)
-RJ 45 port

Cleanroom equipment

Standard clothes for cleanroom
ISO5 and ISO4

Particle counter Lighthouse
6 channels measurement
From 0.3 to 10 um

Gun Gas
3x ion gun with 0.01 um filter

Hoover inside the cleanroom

Vacuum equipment

Pumping unit

-Slow pumping unit (50 mbar l/s), membrane pump, turbo pump

-Outside of the cleanroom

RGA

-Thermo scientific

Leak detection

-Oerlikon detector

-Connected to the pumping unit

Venting

-All metal Micro valve VAT Series 59

-Adjustable gas flow 1.10^{-10} to 100 mbar l/s

-N_2 gas (bottle N2 : 99.9999% by vol)

-0.2 µm filters (Millipore and Swagelok)

String assembly tooling

Constraints

- Weight (cavity fully equipped≈ 200 Kg)
- Space (width, height)
- Clean environment compatible
- Time delivery of pieces for preparation and assembly

Warm transition trolley (week 28)

Valve and cavity Lifter

- Not well adapted
- We had to find the way to transfer all components on the trolley

Cavity trolley (week 30)

Load test did not show deformation
Alignment system for valve has to be improved

Components preparation procedures

Constraint: All parts can't be proceeded at the same place

Components preparation

- Degreasing (Detergent NGL cleaning technology)
- Rinsing with demineralized water and alcohol
- Blow with filtered N_2 gas
- Conditioning in cleanroom ISO5
    - Wipes (100% polyester)+alcohol (70% Isopropanol)
    - Double plastic bag packed with N_2

Cleaning procedure in ISO5 before IS04 entering

- Vacuum components
- flanges holes clean with Q-tips
- Wipes (polyester 100%)
- Blow with filtered N_2 gas
- Particle counting
- Let part rest in ISO4 before assembly

Cavity preparation before cleanroom entering

- External part of the cavity is not degreased and not rinsed
- Cleaning outside of the cleanroom
    - Acetone alcohol with cleanroom wipes
    - Blow with filtered N_2 gas

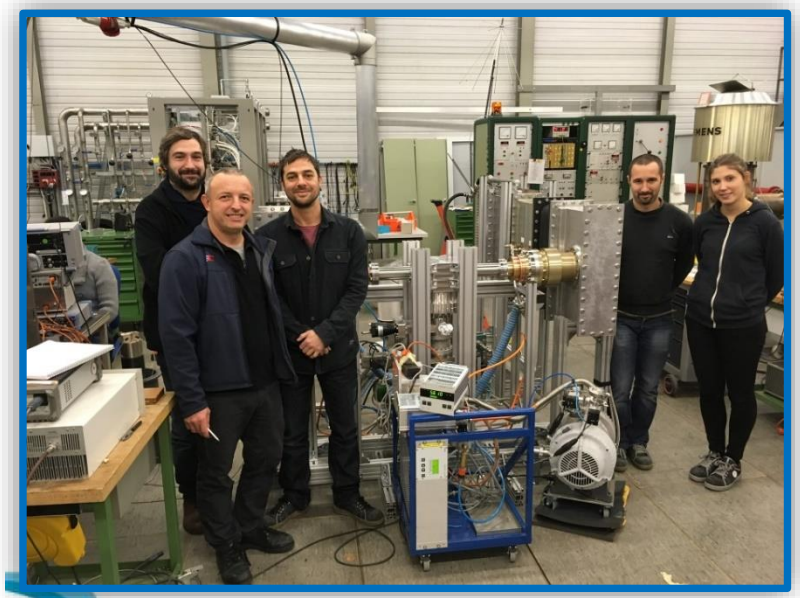
Cleanliness control

Particle counting for sensitive components
Acceptance level: ISO4

String assembly

FPCs test box assembly

Test box assembly (Dec 2016)
-Baked out
-Leak tight (Leak rate: 10^{-10}mbar l/s)
-Ready for RF conditioning



After 5 months of conditioning BE/RF/PM (E.Montesinos talk)
The First two DQW FPC have been processed up to
30 kW CW (limited by test box)
75 kW full reflection all phases (limited by RF tube amplifier)

Double tubes preparation

Cu layer Coating

- Sputtering process (end of June 2017)

→ **peel off**

- Galvanic surface treatment (mid of July 2017)

Au layer of 2 µm as buffer layer

Cu layer of 10 µm

Passivation (Sulfo-chromic bath)

3 double tubes delivered for cleanroom preparation 13th of July 2017

Adhesion test

- **Ultra sonic bath**

Detergent NGL cleaning Technology (20g/l) at 50°C

10W/l during 10min

- **Thermal shock**

3 cycles

1 min in N_2 liquid + 5 min at room T°

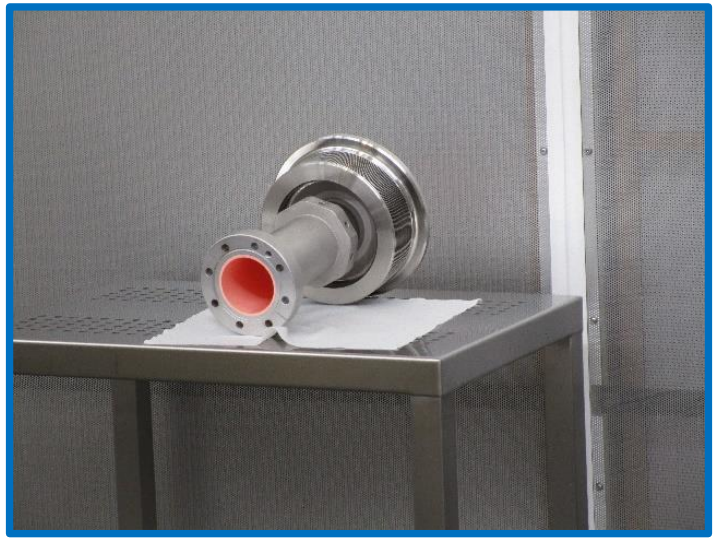
Double tubes preparation

Rinsing Process

Ultra pure water rinsing
P = 7 bars
TOC ≈ 20 ppb
ρ_{inlet} = 18 MΩ.cm
ρ_{outlet} = 17.5 MΩ.cm
Under filtered N_2 gas atmosphere

Alcohol
Ethanol 99.9%
P= 5 bars

Drying under laminar ISO5 flow

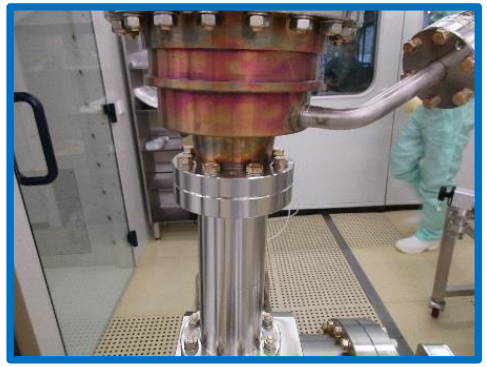


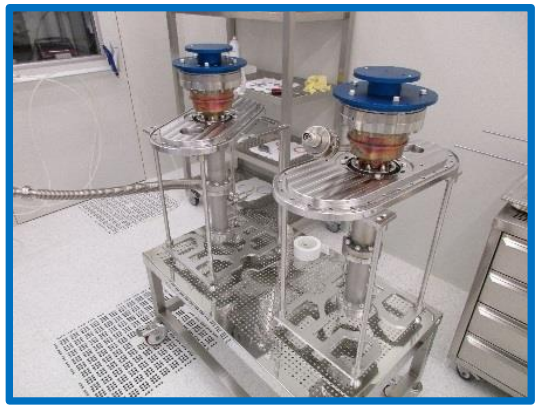
Stored under filtered N_2 gas
And double plastic bag packed

3 double tubes delivered for cleanroom assembly 14/07/2017

FPCs preparation: Double tubes connection

Components cleaning before assembly



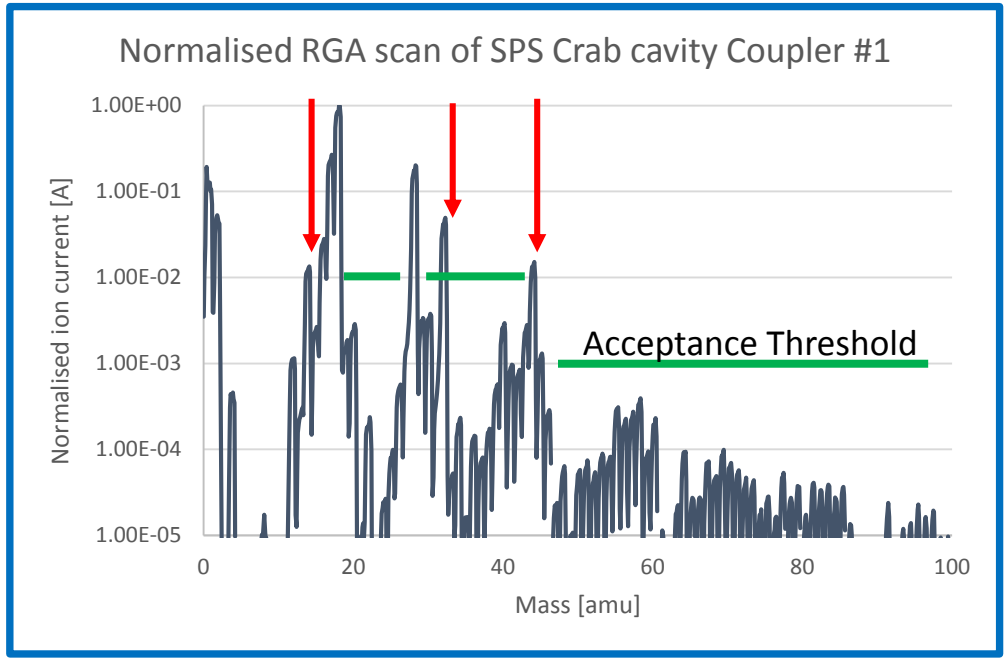


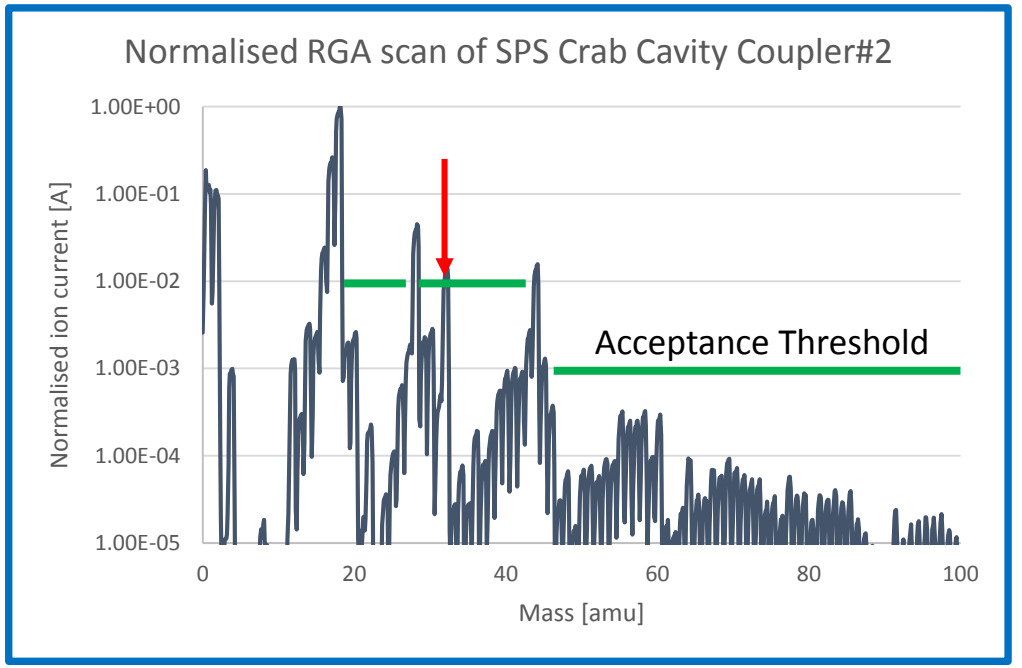
FPCs preparation: Validation test

Leak tight

Leak rate: 6e10^{-10} mbar l/s

Ready for cavity mounting week 30





Air leak on Coupler 1, leak detection showed the leak was on the DN16CF flange of the vacuum chamber

Peak 32 is a characteristic of W filament RGA

No contamination

HOMSs and Pick-up preparation

Rinsing Process

Ultra pure water rinsing
P = 7 bars
TOC ≈ 20 ppb
ρ_{inlet} = 18 MΩ.cm
ρ_{outlet} = 17.5 MΩ.cm
Under filtered N_2 gas atmosphere
Drying by heating and pumping

Storage under vacuum

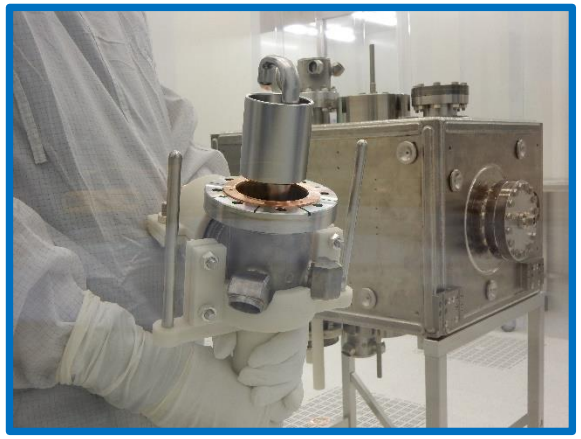
Leak detection validation

Ready for mounting on Crab cavities
1st set available for Crab 1 week 19
2nd set available for Crab 2 week 25

HOMSs and Pick-up assembly week 20

Cleaning

HOMS mounting withourN_2 gas flushing



Pick up mounting without N_2 gas flushing

Leak tight
1.1e-9 mbar l/s

HOMSs feedthrough changing week 28-29

Issue

Leak on the feedthrough ceramics during the RF cold test of the partially dressed Crab 1 (cf A. Castilla talk)
Little time to find and make new feedthrough

Solution

RF feedthrough (7/16) used for LHC
PMB Alcen
Manufacture of new antennas
Limited power to 200W max

Thermal shocked
Leak tight

Actions

Replacement of the feedthrough on Crab 1
Preparation and mounting of the new feedthrough on Crab2

Both Crab cavities were leak tight and ready for the FPCs mounting week 29

FPCs assembly on Crab cavities week 30-31

Mounting done without N_2 gas flushing

Very sensitive handling

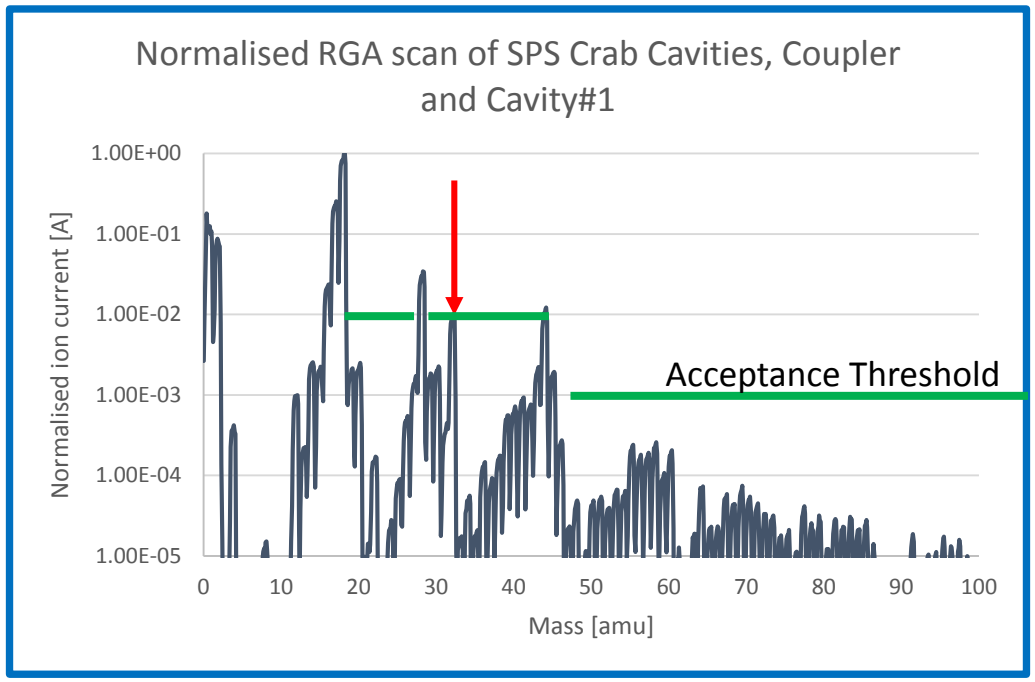
Risk to touch the cavity with the FPC antenna

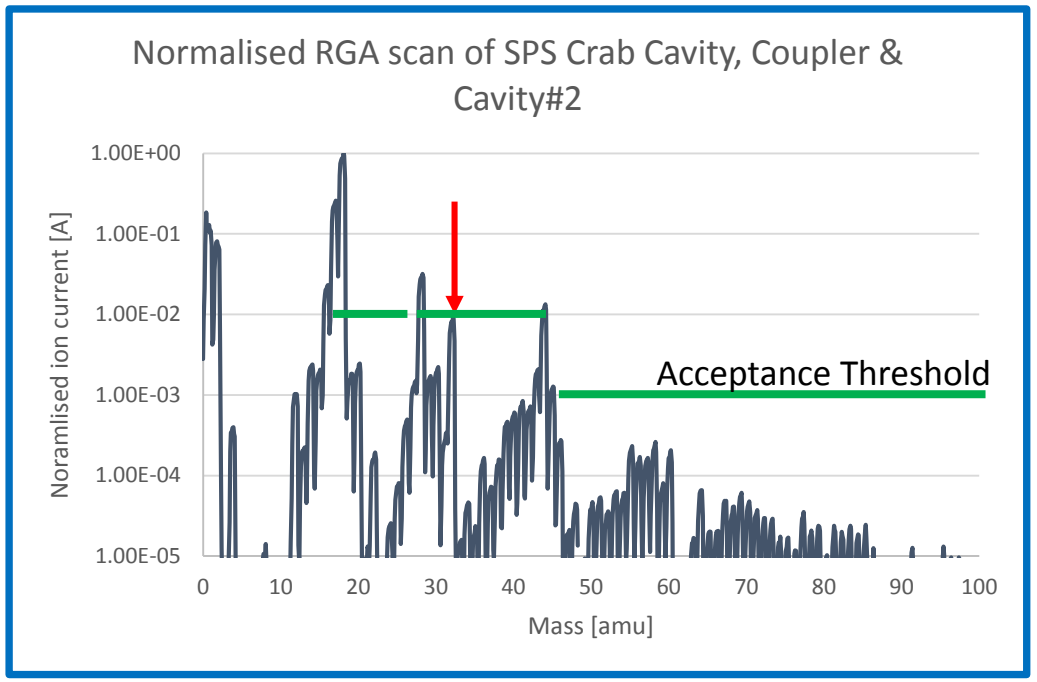
Metallic particles production

Crab Cavities fully equipped validation test

Leak tight

Leak rate : $6e^{-10}$ mbar l/s





Peak 32 is a characteristic of W filament RGA

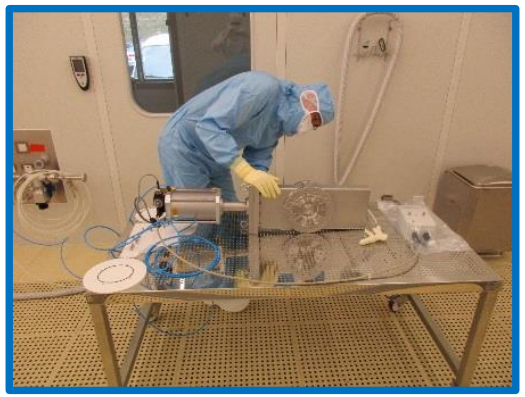
No contamination

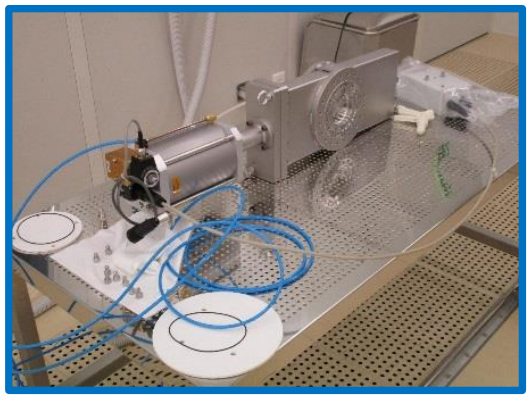
Both cavities fully assembled and validated week 31

Warm transition preparation and assembly

RF All metal valves and bellows preparation

Cleaning Process





Issue

After cleaning particle number is in the ISO4 threshold

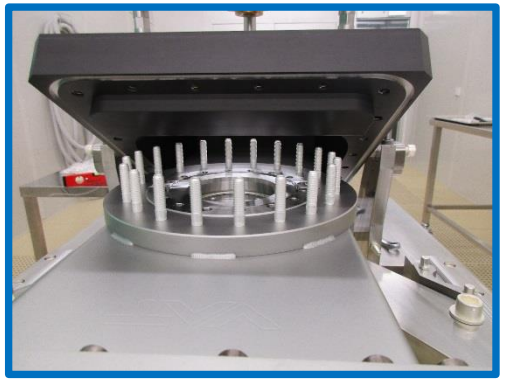
After opening and closing cycles ⟹ particle production

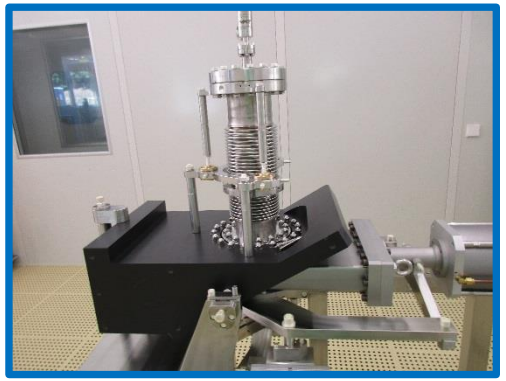
We can't assure the cleanliness after using the valve

We decided to continue

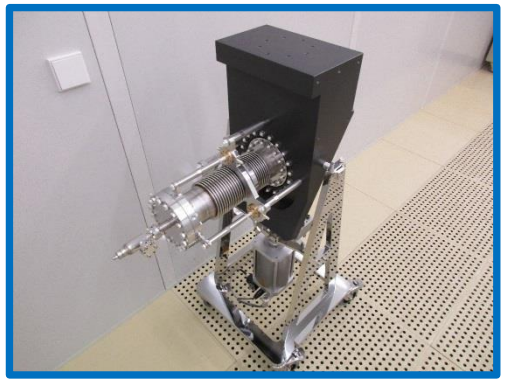
Warm transitions and inter cavity bellow preparation
Week 31-32

Vertical assembly

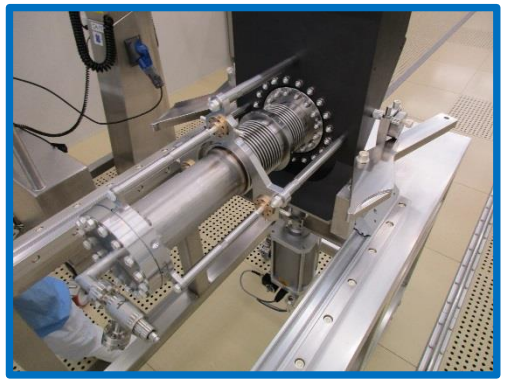




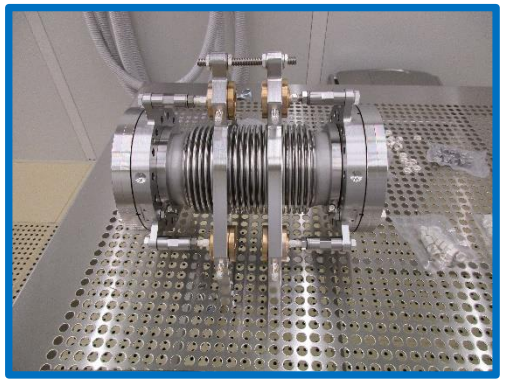
Down Stream warm transition



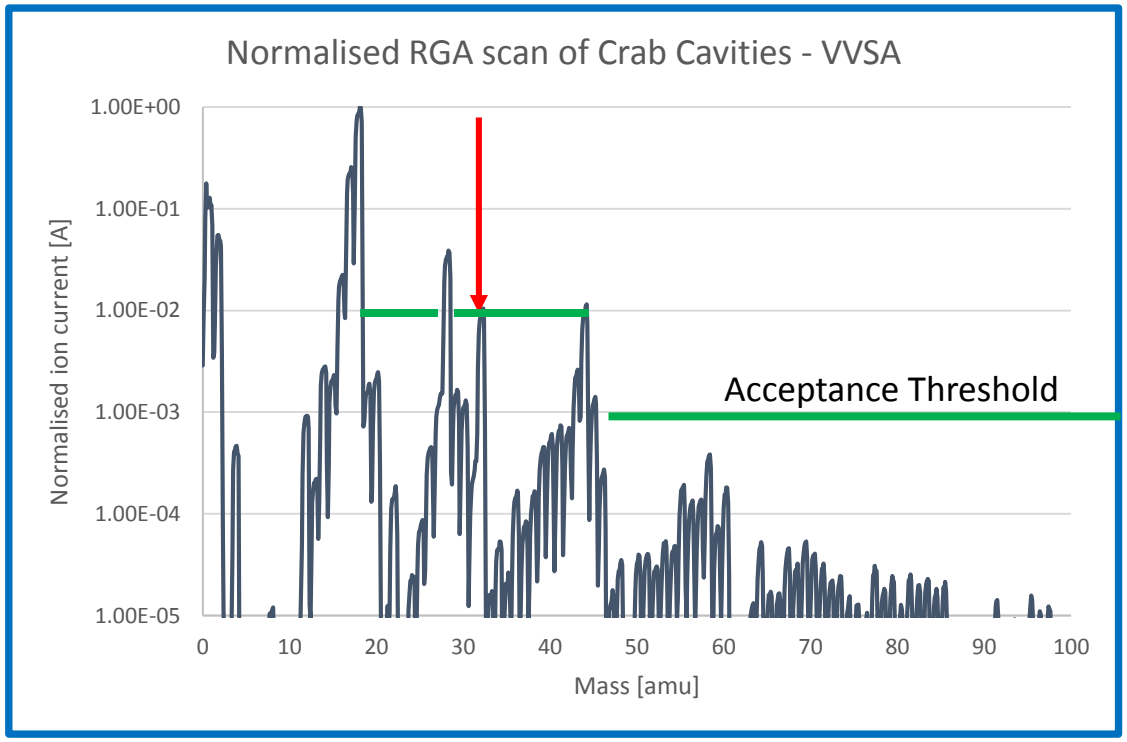
Up Stream warm transition

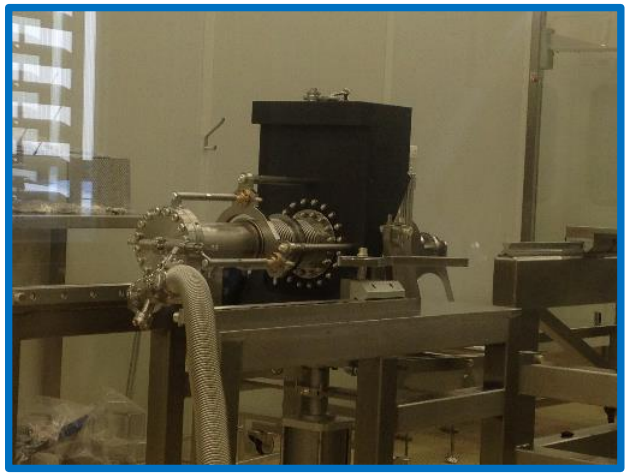


Inter cavity bellow



Warm transitions validation test





Peak 32 is a characteristic of W filament RGA

No contamination, leak tight

Warm transitions validated week 32

Installation of cavities and warm transitions on the trolley week 33

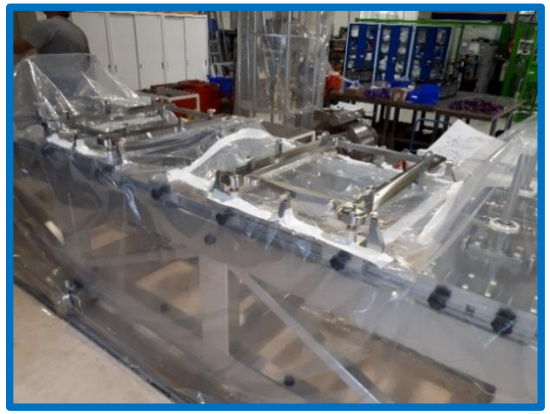
Issue

Cavity Lifter not well adapted : impossibility to put the cavities on the trolley

Solution (no choice)

Cavities and trolley protected with plastic bag

Do the installation outside the cleanroom by using the crane



Cleaning

Ready for alignment week 33

String cavity alignment week 32-33

Goal: Alignment of components for the string connection
Alignment of the string for cryostating

Equipment

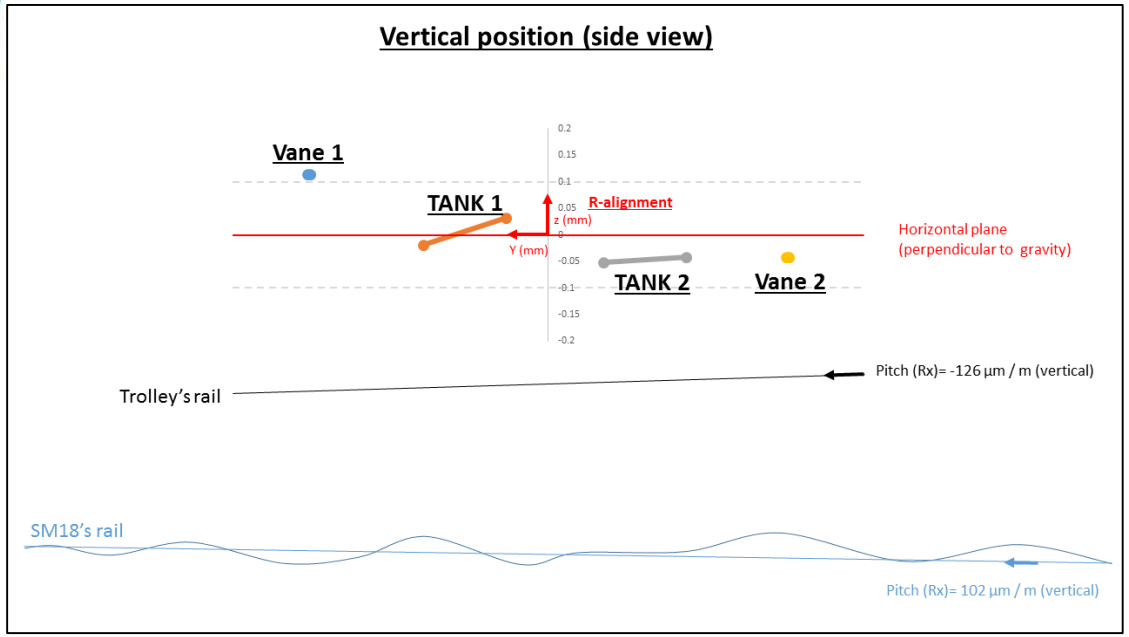
- Aluminum tripod
- LASER tracker AT401 of Leica
- 1 x reflector CCR 0.5 inches
- 1 x reflectors CCR 1.5 inches

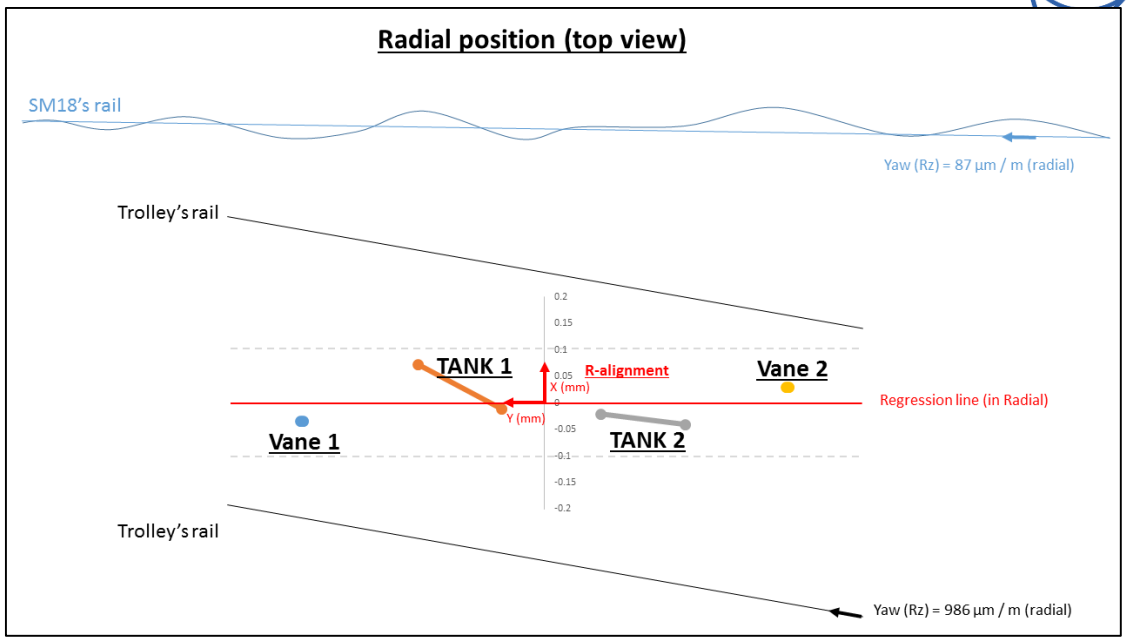
Survey done inside the cleanroom

Survey campaign
Alignment reference chosen: cleanroom's rail
Pb: Non-parallelism between SM18's rail and trolley's rails
Due to lack of time we continued with the SM18's rail

The string had to be realigned outside the cleanroom after connection for cryostating

String cavity alignment before connection





3D-rotation compared to the nominal angle

	Rx (pitch)	Ry (roll)	Rz (yaw)
Vane 1	-29.99996° [-30°] -0.523598 µrad [-0.523599 µrad]	-236 µrad [0 µrad]	-2 µrad [0 µrad]
TANK 1	-79 µrad [0 µrad]	102 µrad [0 µrad]	-131 µrad [0 µrad]
TANK 2	-18 µrad [0 µrad]	155 µrad [0 µrad]	-30 µrad [0 µrad]
Vane 2	30.014287° [-30°] 0.523848 µrad [-0.523599 µrad]	-689 µrad [0 µrad]	172 µrad [0 µrad]

Vertical Z axis

All components aligned at 115 µm

Radial X axis

Components aligned with a regression line of the 4 components at 70 µm

Rotation

2 tanks: differences below 200 µrad

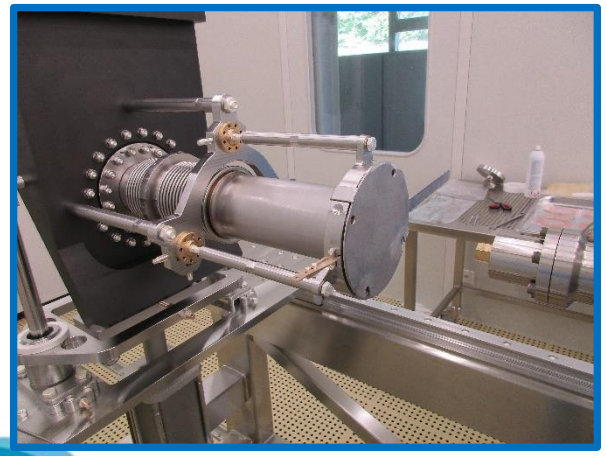
2 valves : A maximum of 700 µrad in Ry

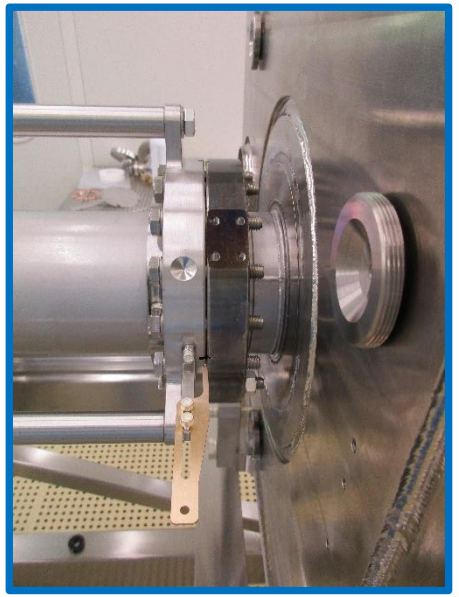
Not perfect but acceptable for the components connection

Components Connection in ISO4 cleanroom

Cleaning before ISO4 entering

Connection done without N_2 gas flushing





String cavity alignment after connection

Before pumping

The displacement of all the components follows the theoretically displacement (trolley's rails trajectory)

Vertical Z axis

All components aligned at **130 µm**

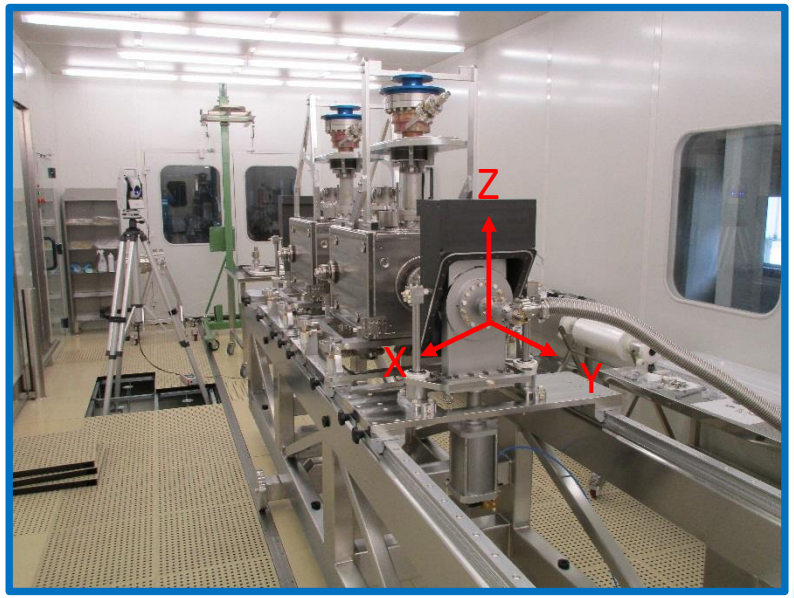
Radial X axis

Components aligned with a regression line of the 4 components at **230 µm**

Rotation

2 tanks: no difference

2 valves : Some rotation higher than **1 mrad on Rx**



Under vacuum

Both valves : vacuum impact the pitch rotation Rx

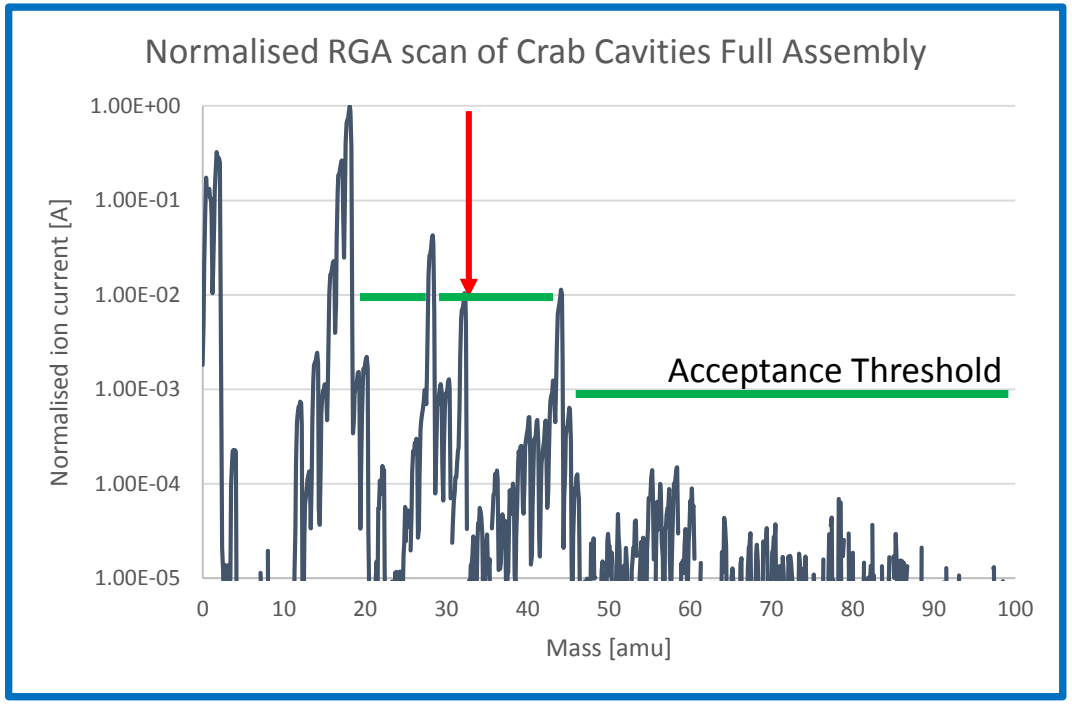
Both Tank : no impact

Outside the cleanroom

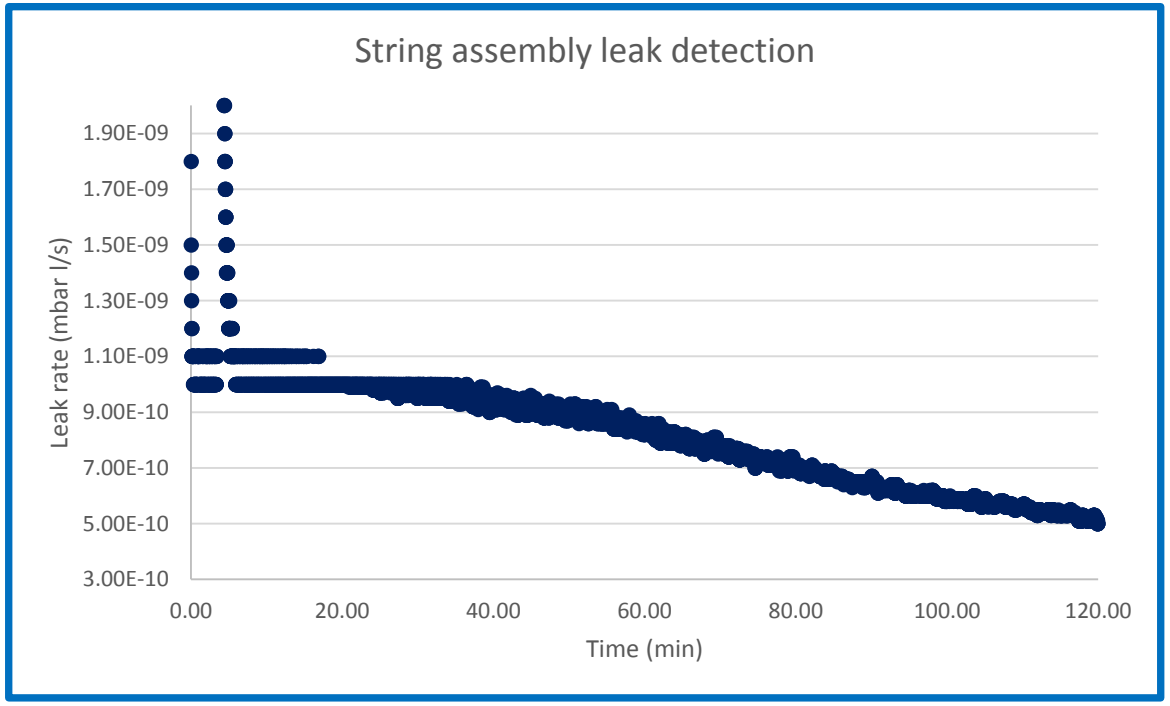
A new alignment should be done to be below 100 µm

The 2 valves Rx rotation should be corrected

Leak detection and RGA validation tests



Peak 32 is a characteristic of W filament RGA
No contamination



Leak tight
Leak rate: 5e-10 mbar l/s

Cavity string validated and ready for cryostating week 33

Conclusions

- Objective fulfilled
- Only 2 weeks late on the planned schedule
- String assembly leak tight without contamination : have to be confirm during the cold test
- The cleanliness of the assembly have to be confirmed by the RF test
- Main issues solves (HOMSs feedthrough, Lifter and tooling)
- Gain knowledge and experience, training people for the next assembly
- Things to improve for future Crab string assembly
  - Handling tooling
  - Gate valve cleaning procedure
  - Alignment Procedure

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