# Special Technical Meeting on the 11T Dipole QH-Trace to Wire Jointing

## Test campaign, samples, and jointing procedures

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*GE - Contract S197/TE

CERN – Virtual room https://indico.cern.ch/event/978144/ – 2020.11.27

# Outlook

- Introduction
- Motivation - Test plan
- Jointing concepts – Inventory of samples
- Preparation of the samples / procedures
- Concluding remarks

# Introduction

| Magnet ID | Impregnated QHs | External QHs | QH Failure - NCR |
|---|---|---|---|
| LMBHB001 – P0 – Proto | X | | None |
| LMBHP001 – P1 – Hybrid | X | | None |
| LMBH**B**002 – S1 | X | | None |
| LMBH**A**001 – S2 | X | | None |
| LMBH**A**002 – S3 | | X | **1 circuit in C14** |
| LMBH**B**003 – S4 | | X | **1 circuit in C17** |
| LMBH**A**003 – S5 | | X | Not tested at cold |
| LMBH**B**004 – S6 | | X | Not yet fabricated |
| LMBH**A**004 – S7 | | X | Not yet fabricated |

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# Motivations

- Following the QH failures observed in the magnets S3, and S4, it was decided to put on hold the assembly of the last coils, C26 to C35, and to **conduct a test campaign aiming at characterizing the quality of the soldered joints**
  - Those used in the magnets S3, S4, and S5 (with almost the same concept, based on the use of a pin connector, as for the prototype magnet P1, the hybrid assembly H1, and the first two series magnets S1, and S2)

    **AND**
  - Alternative jointing concepts / procedures
- **Determine the root cause** of the non conformity
- Based on the results, implement **a solution that will guarantee robustness, endurance, reliability**

# Characterization – Test plan

- For the different jointing procedures under consideration
- **Electrical tests:**
  - **Endurance**: carry out a sufficient number of discharge tests at RT (up to 50), on representative samples, see list in Slide 7
  - **Robustness**: determine the effective margin of each jointing concept, w.r.t. the actual test conditions applied during the magnet construction (increase progressively the energy deposit, up to destruction of the sample)
- **Other quality control**:
  - Carry out **NDT** (computed tomography) and **metallographic examination** under a microscope in order to verify the quality of the soldered joints, looking for pores, cavities, and cracks, but also checking material diffusion at the interface between:
    1. The QH-trace and the solder material
    2. The solder material and the wire (w and w/o connector)

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| Sample Reference | Jointing concept | Tinning | Cleaning | Pickling | By | Nb | Picture |
|---|---|---|---|---|---|---|---|
| 1. ES-AE (S3, S4, and S5) | Pin connector | X | X | X | GE-S197/TE | 2 x 4 |  |
| 2. ES-SE | Pin connector | | X | X | GE-S197/TE | 4 |  |
| 3. ENS-AE | Pin connector | X | | | GE-S197/TE | 1 |  |
| 4. ENS-AE-DP | Pin connector | X | | X (partial) | GE-S197/TE | 3 |  |
| 5. ENS-SE | Pin connector | | | | GE-S197/TE | 2 |  |
| 6. ENS-SE-DP | Pin connector | | | X (partial) | GE-S197/TE | 4 |  |
| 7. EGB-AE | Pin connector | X | X | X | GE-S197/GE | 3 |  |
| 8. EF-AE | No connector<br>Wire on QH-trace | X | X | X | GE-S197/TE | 6 |  |
| 9. FCGB-SE | Flat connector | | X | X | CERN | 4 |  |
| 10. FCGB-SE - Omega | Flat connector + Omega | | X | X | CERN | 4 |  |
| **Total Nb of samples** | | | | | | **39** | |

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# Material utilized to fabricate the samples

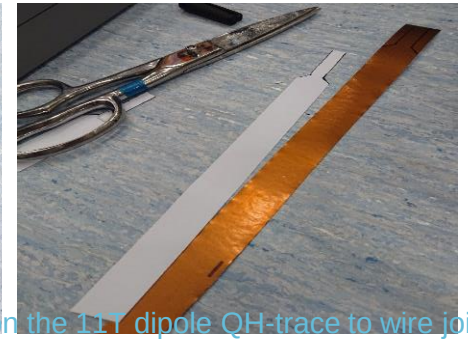
**Saddle external layer**
**HCMBH_C046-BP000018**


**Green cable**
**HH1819**

**Harting Connector**
**RM 16M23K**

*Courtesy GE – M. Andreini et al.*

**Remaining pieces of PCB after cuttings**

# Preparation of samples, 1

- A template (chablon) is used to draw the contour of the sample on the QH strip
- The sample is cut from the QH strip with chisels

*Courtesy GE – M. Andreini et al.*

- A heat gun (temperature set to 650°C) is utilized to strip off the trace in the soldering area
- For this, the end of the sample is heated for 60 seconds at a distance of 50 mm

# Preparation of samples, 2

- When the end of the QH strip is hot enough, polyimide separates easily, a blade is inserted between the copper layer and polyimide film in order to peel it off

*Courtesy GE – M. Andreini et al.*

- The excess of glue is then removed by means of a fiberglass pencil and fine sandpaper. Finally, alcohol is used to remove any residue

# Soldering equipment, consumables, and parameters

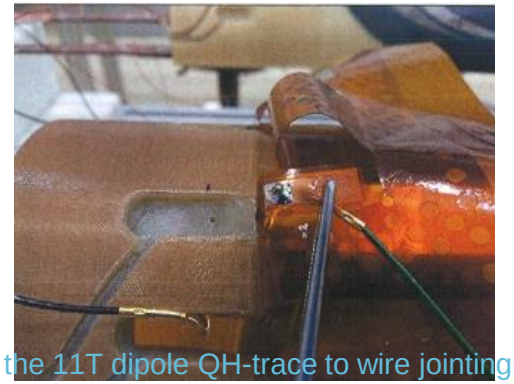

*Courtesy GE – M. Andreini et al.*

- Soldering with a Weller power unit 80 W, 230 V
- The samples were tinned, and soldered, with the temperature potentiometer set to 350°C


Surgical clamp to hold the QH-trace and wire / connector

Flux MOB39


Solder $Sn_{60}Pb_{40}$

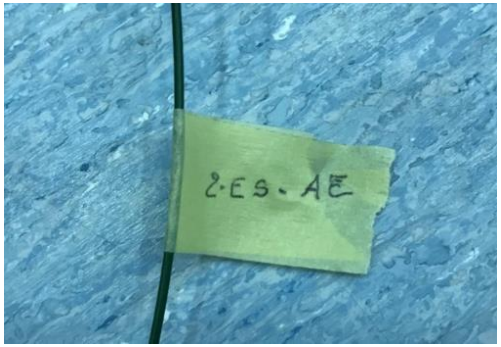



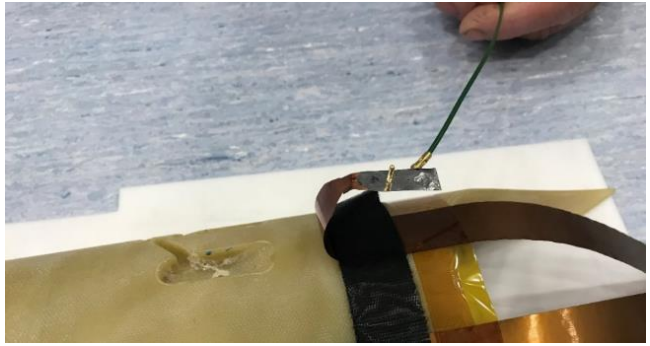
# What's been done till then
# Magnets S3, S4, S5

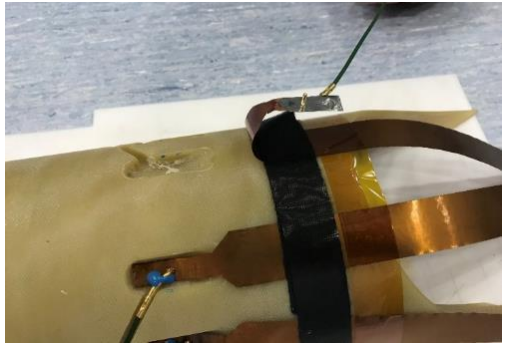
# Identification of samples – soldering position

*Courtesy GE – M. Andreini et al.*

Each sample has a label with an ID that also indicates the position where the sample was soldered on the saddle



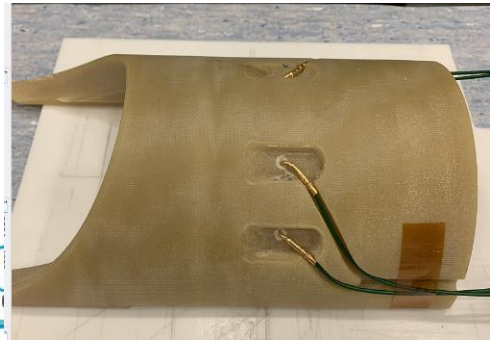



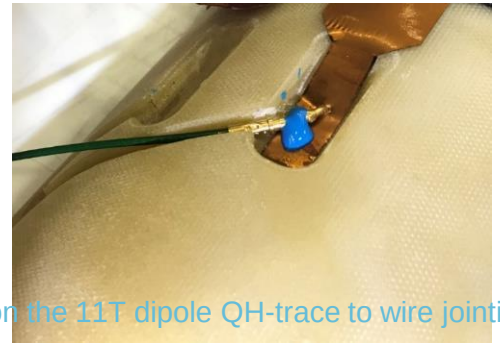


The saddle has holes to house the tip of the pin connector

The sample is put in place and a hole of Ø 1.6 mm is drilled for the connector to pass through the sample,

The connector is hold in position by a drop of Eccobond





# Preparation of samples with tinning of the QH-trace Series AE

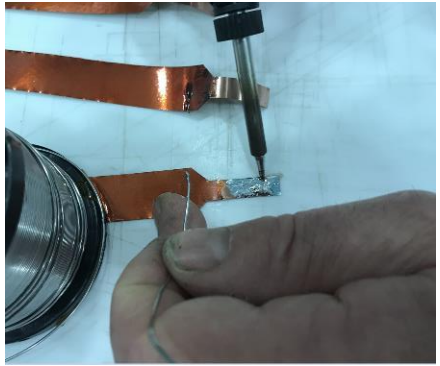
*Courtesy GE – M. Andreini et al.*

- Prior to tinning, the samples are pickled with MOB39, and the Weller power potentiometer is set to 350°C

- The tinning is carried out on the sample flat (not on the saddle)
- At that stage, the QH-trace is not yet drilled for the positioning of the connector

| Echantillons Standards ***avec Etamage*** |
|---|
| Avec nettoyage |
| Avec decapage |
| 1-ES-AE |
| 2-ES-AE |
| 3-ES-AE |
| + 1 en supplément 7-ES-AE |
| 4-ES-AE |
| 5-ES-AE |
| 6-ES-AE |
| + 1 en supplément 8-ES-AE |





# 1. Samples with tinning, cleaning and pickling

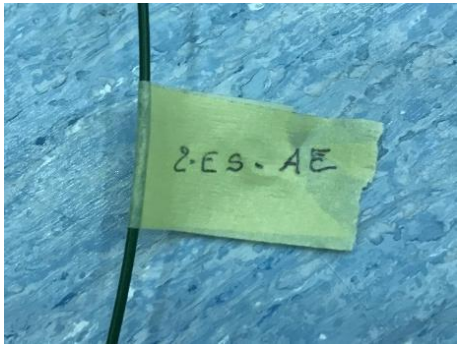
*Courtesy GE – M. Andreini et al.*

## Series ES-AE

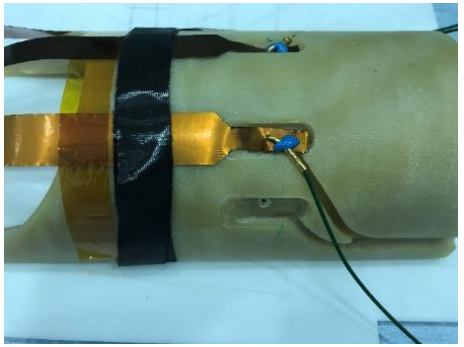
### List of samples

| Echantillons Standards ***avec Etamage*** |
|---|
| Avec nettoyage |
| Avec decapage |
| 1-ES-AE |
| 2-ES-AE |
| 3-ES-AE |
| + 1 en supplément 7-ES-AE |
| 4-ES-AE |
| 5-ES-AE |
| 6-ES-AE |
| + 1 en supplément 8-ES-AE |

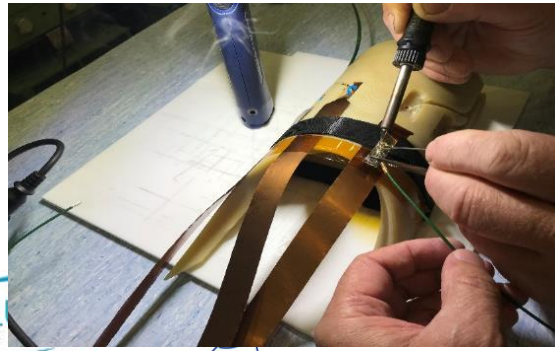
### Identification

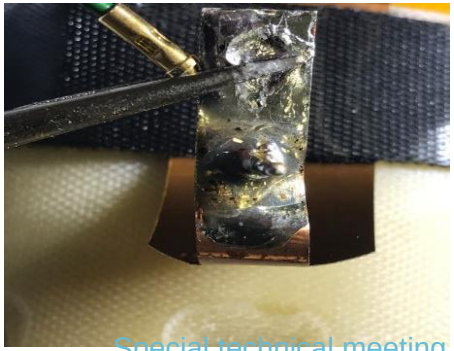


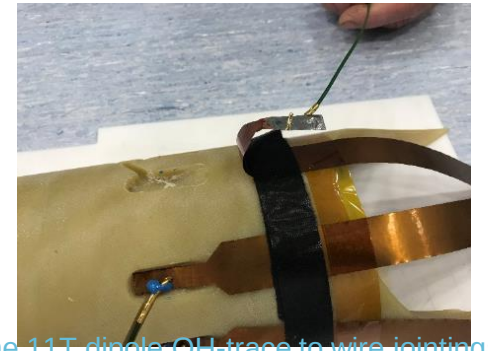

### Position recording



### Samples soldering





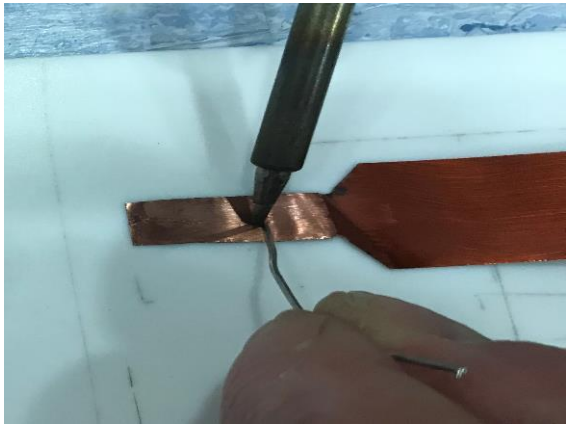


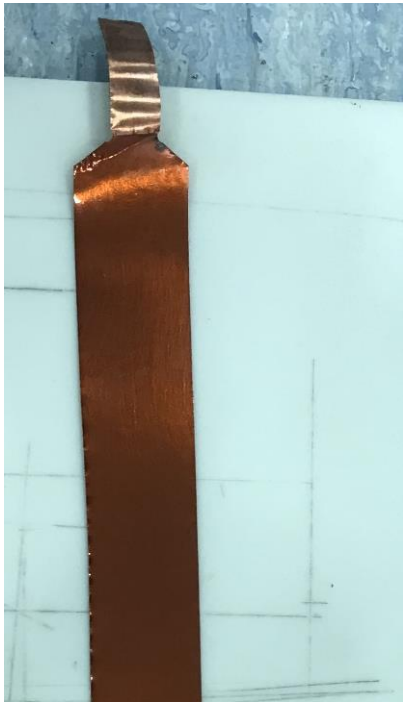
# Degraded conditions
# Defects created

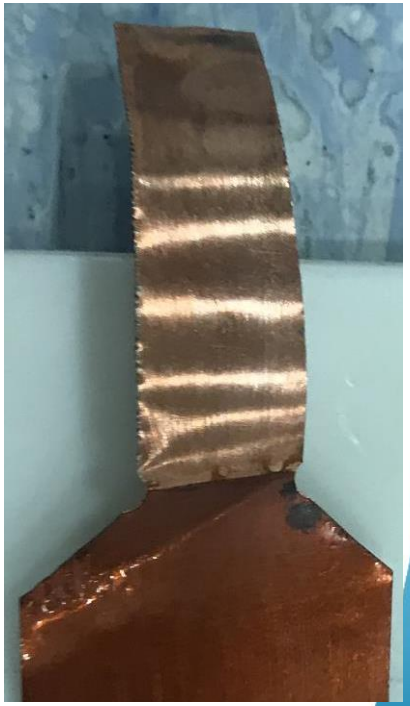
# Samples w/o cleaning Series ENS

*Courtesy GE – M. Andreini et al.*

- The soldering area was touched with fingers, and stored in open air in order to trigger oxidation
- The **samples, oxidized, were then used without cleaning**





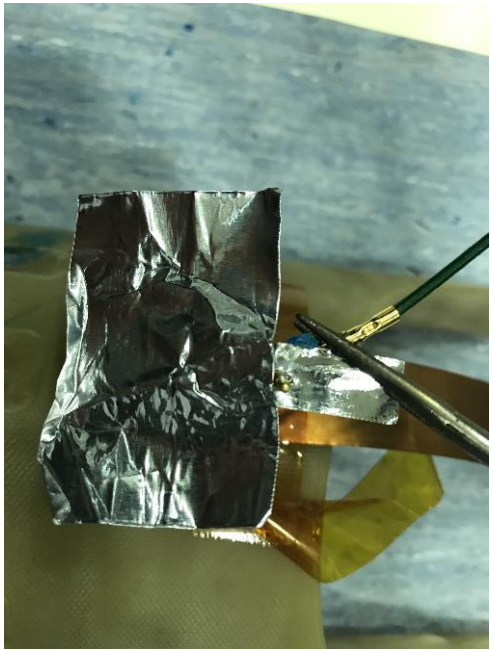


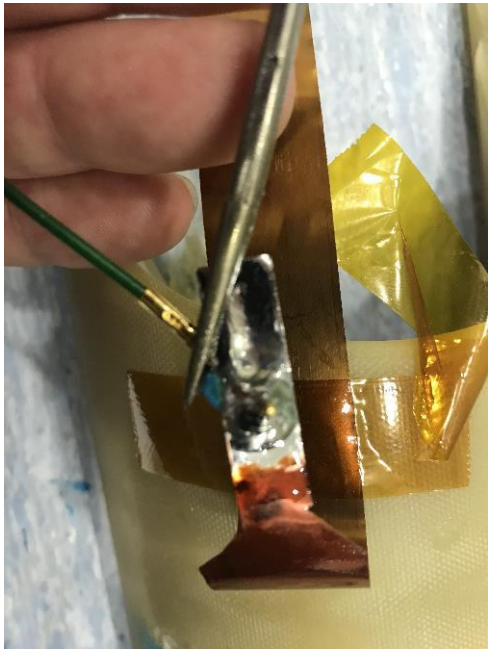
# 4. Samples with tinning and partial pickling, w/o cleaning
# Series ENS-AE-DP

*Courtesy GE – M. Andreini et al.*

| Echantillons Standards avec Etamage<br>sans nettoyage<br>Avec décapage partiel |
|---|
| 1-ENS-AE-DP |
| 2-ENS-AE-DP |
| 3-ENS-AE-DP |

- **Partial pickling** was done
- Part of the soldering area was protected by means of adhesive tape in order to reduce the part of it fluxed with MOB39



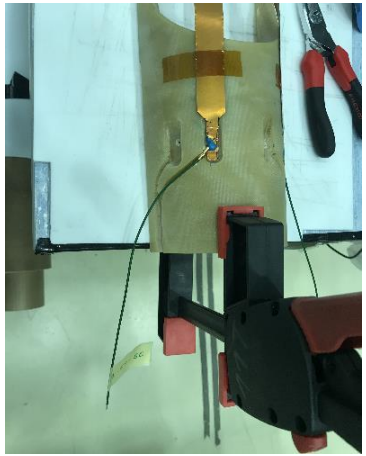


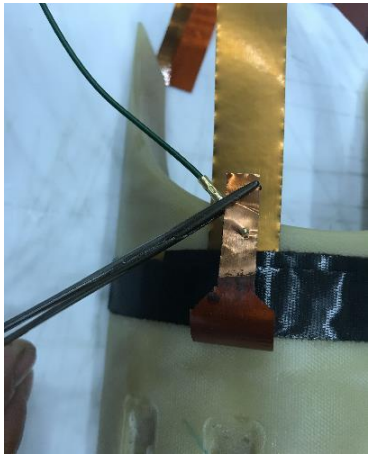
# 5. Samples w/o cleaning, w/o pickling and w/o tinning Series ENS-SE

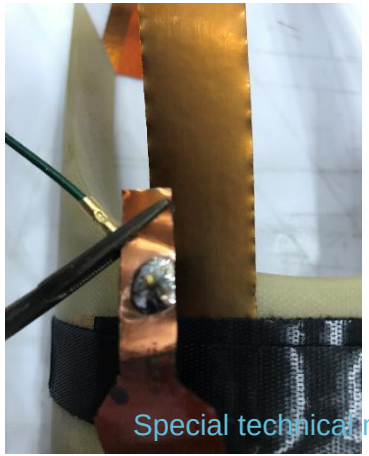
*Courtesy GE – M. Andreini et al.*

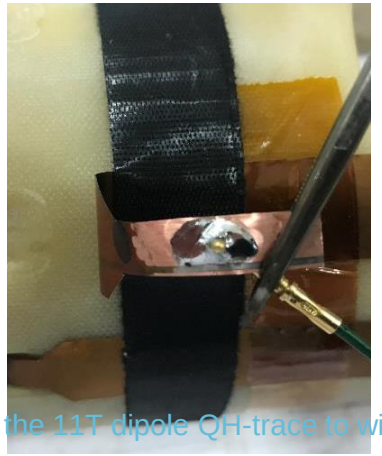
| Echantillons Standards **Sans Etamage**<br>sans nettoyage<br>sans décapage |
|---|
| 1-ENS-SE |
| 2-ENS-SE |

- There were only two samples of this type because it was **almost impossible to solder in these conditions**, **without cleaning, pickling, and tinning**, despite all efforts put on trying, including playing with heating





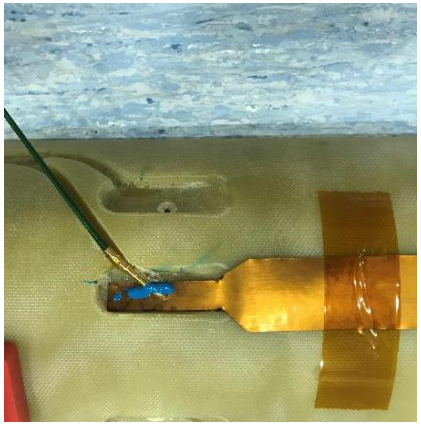


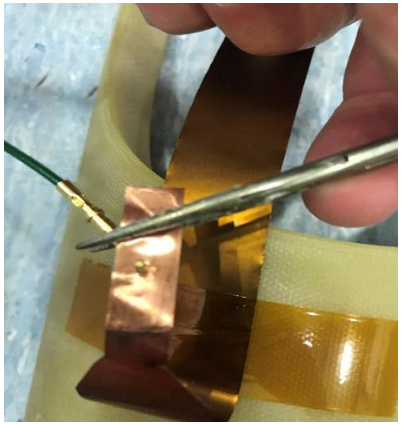


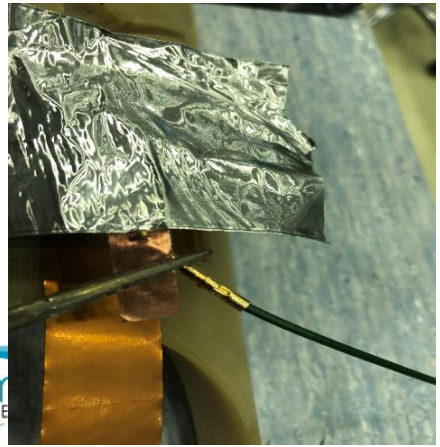
# 6. Samples w/o cleaning, partial pickling, and w/o tinning Series ENS-SE-DP

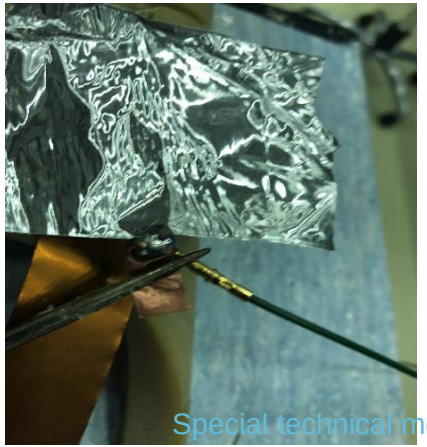
*Courtesy GE – M. Andreini et al.*

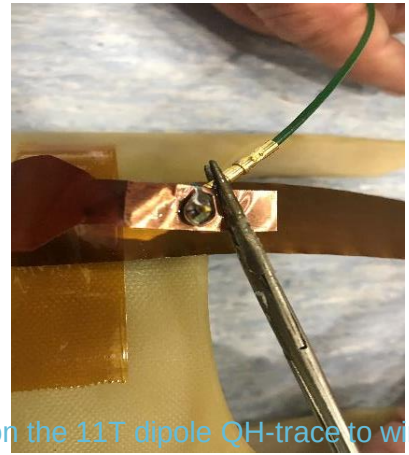
| Echantillons Standards Sans Etamage<br>sans nettoyage<br>Avec décapage partiel |
|---|
| 3-ENS-SE-DP |
| 4-ENS-SE-DP |
| 5-ENS-SE-DP |
| 6-ENS-SE-DP |









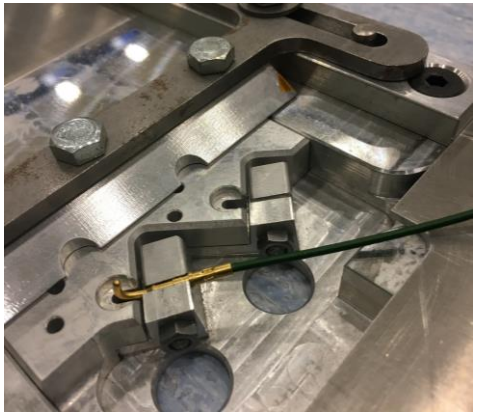


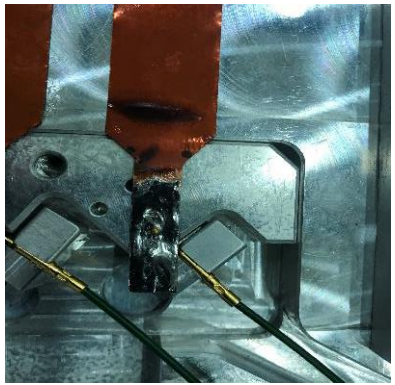
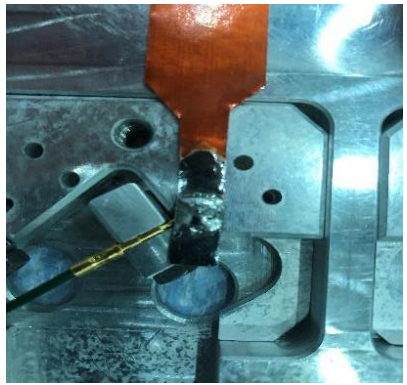
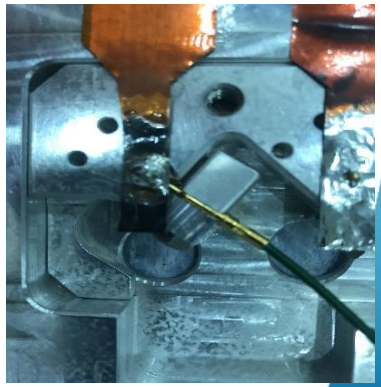

TIME FOR
SOMETHING
NEW

# 7. Samples made with soldering jig (pin connector) Series EGB-AE

*Courtesy GE – M. Andreini et al.*

| Echantillons réalisé avec outillage/ Gabarit de brasage<br>**Avec Etamage**<br>Avec nettoyage<br>Avec decapage |
|---|
| 1-EGB-AE |
| 2-EGB-AE |
| 3-EGB-AE |

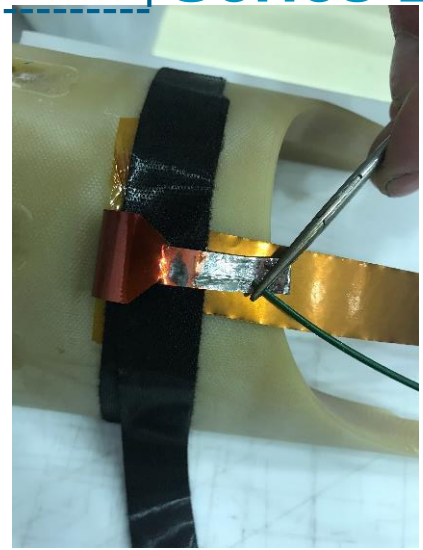
- The pin connectors are positioned in the jig, then the sample is put in place in the assembly
- **On the jig, the pin connector is soldered on a flat surface**
- This process facilitates a lot the soldering of the connector to the QH-trace

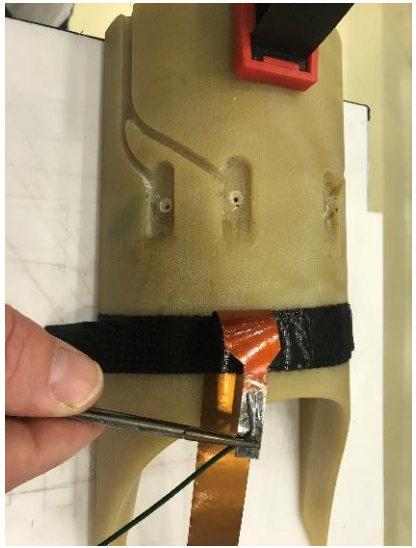
# 8. Samples wire soldered on QH-trace, with tinning

*Courtesy GE – M. Andreini et al.*

## Series EF-AE

| Echantillons brasage du fils sur piste<br>***avec Etamage***<br>Avec nettoyage<br>Avec decapage |
|---|
| 1-EF-AE |
| 2-EF-AE |
| 3-EF-AE |
| 4-EF-AE |
| 5-EF-AE |
| 6-EF-AE |



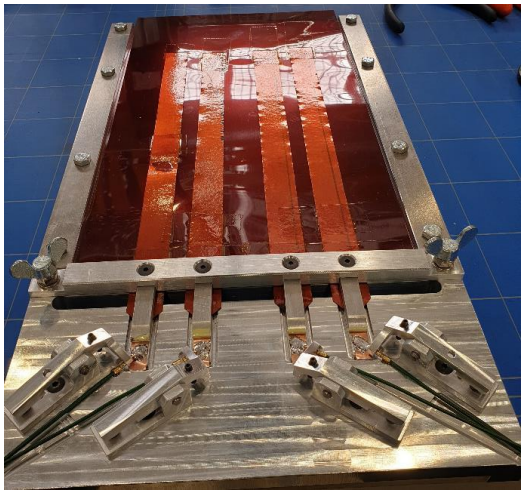


The samples were made **with cleaning, pickling, and tinning**

# 9. Sample with flat connector on soldering jig Series FCGB-SE

*Courtesy L. Favier – R. Principe*

- Functional requirements:
  - Soldering in flat position
  - Accurate positioning of the connector w.r.t. the QH-trace during soldering



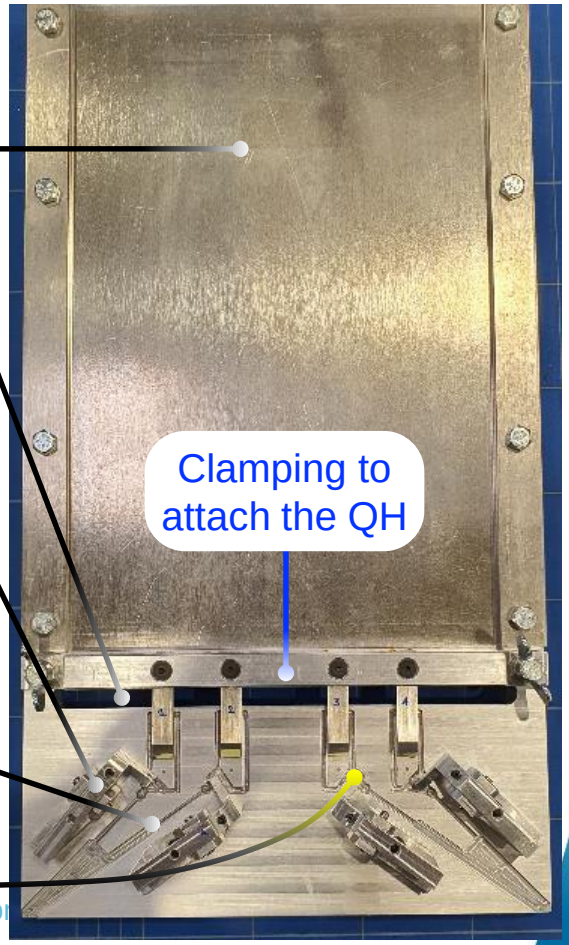
Base plate for the positioning of the QH body

Slot for clearance of the cut part of the QH

Spring-loaded fingers to hold the connector in place

Slot for routing of the wires, -55° and -45°

Soldering area



# Four options were tried for the flat connector

*Courtesy L. Favier – R. Principe*

## Option1

Connector used “as delivered” with wire crimped

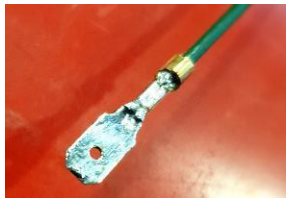
## Option 2

Connector used “as delivered” with pre-tinning $Sn_{60}Pb_{40}$ of the flat part

## Option 3

Modified connector:

- Removal of the side lugs
- Pre-tinning $Sn_{60}Pb_{40}$ of the flat part
- Manual adjustment of the crimping in order to fit better the soldering jig
- Reinforcement of the crimped part by soldering $Sn_{60}Pb_{40}$
- Grinding off material excess after crimping (for better fitting @ assembly)



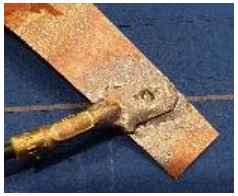
## Final version

Option 3, w/o pre-tinning $Sn_{60}Pb_{40}$ of the flat part

# Soldering trials on QH samples

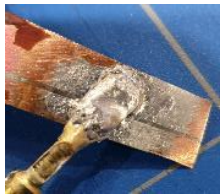
**Option1**:

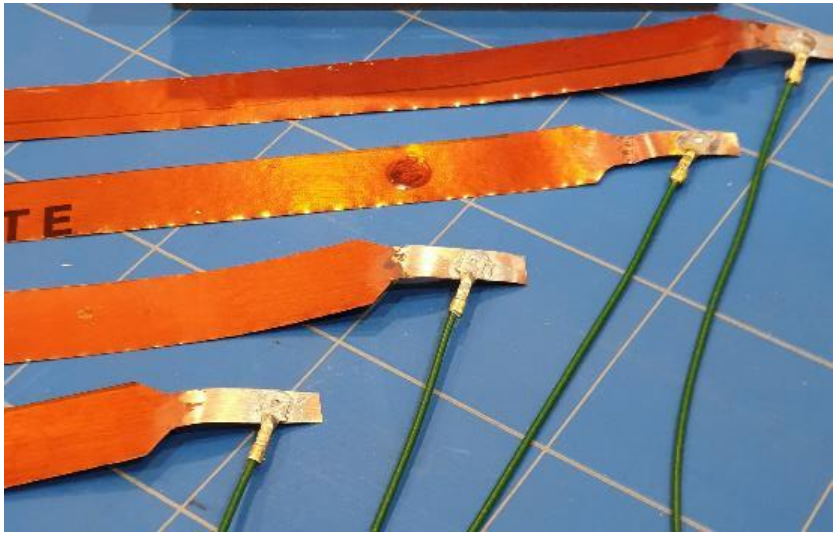
- Pickling MOB39
- Solder $Sn_{60}Pb_{40}$
- Solder wire Ø 1mm



**Option2**:

- Pickling MOB39
- Flat part tinned with $Sn_{60}Pb_{40}$
- Solder $Sn_{60}Pb_{40}$
- Solder wire Ø 1mm



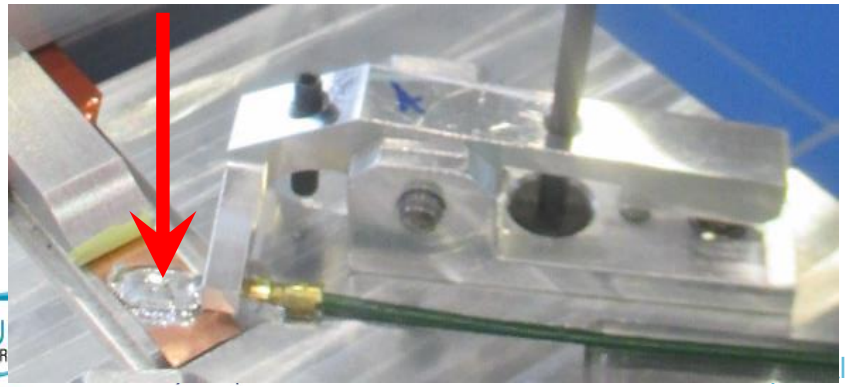


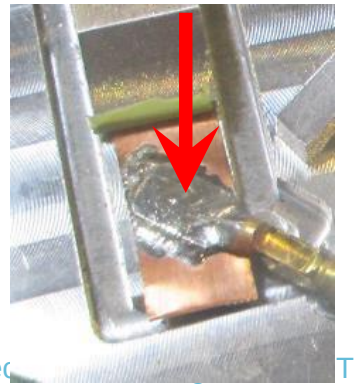
# Soldering trials on QH samples

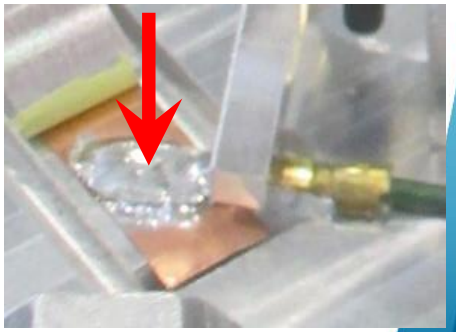
- Utilization of MOB39 is difficult on the QH-traces because:
  - Cleaning with Scotch-Brite is not convenient because of the small size of the QH-trace, the production of dust, and debris
  - It implies careful cleaning with ethanol, as there is dust and debris everywhere
  - It is difficult to apply a uniform layer of MOB39 only on the soldering area
  - MOB39, when liquid, is spreading around, and this is hardly kept under control, implying a difficult execution of the work
  - The final cleaning, including of the tooling, is long and tedious
- Thus the idea of using a solder wire, which contains the pickling agent, with the following advantages
  - Faster, and cleaner execution of the work
  - Final cleaning easier, and less risky for the QH
  - Better visibility of the interface between QH-trace and connector
  - Better look and quality of the soldered joint

# Final soldering conditions, on a soldering jig

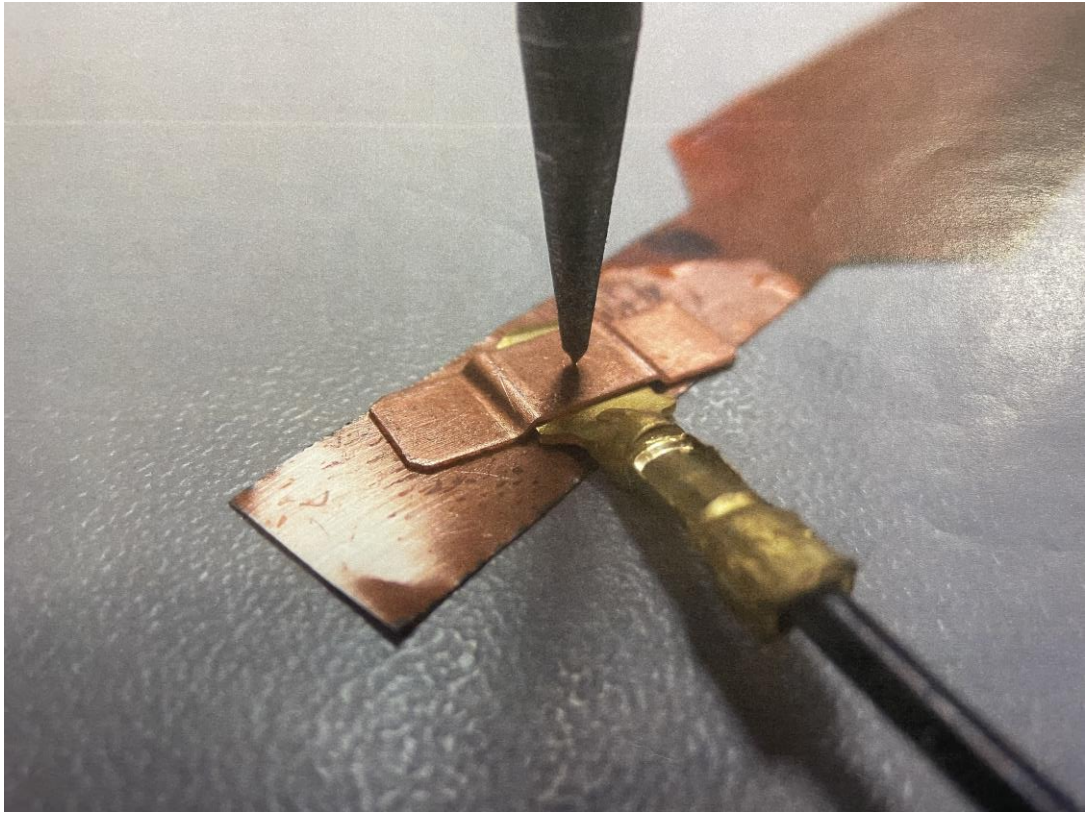
- Cleaning with ethanol of the flat connectors, and QH-traces (soldering area)
- Soldering with wire $Sn_{60}Pb_{40}$, Ø 1mm
- As to the contact conditions between the QH-trace and the connector, in addition to the action by the spring-loaded finger, the welder applies pressure on the connector with a stainless steel rod (this gives better results)
- As a quality check, the welder verifies the presence and geometry of the fillets around the connector, and the good coverage of the flat part of the connector







# 10. Sample with flat connector and Omega FCGB-SE



# Outlook

- Introduction
- Motivation - Test plan
- Jointing concepts – Inventory of samples
- Preparation of the samples / procedures
- Concluding remarks

# Conclusions

- The test plan to characterize the jointing concept used in the magnets S3 to S5, and the new concepts under consideration, was described
- A list of the different samples was presented
- Four alternative concepts/procedures have been tried (characterization in the next two talks)
- The soldering procedures were described for the different concepts
- Two soldering jigs were designed and fabricated in order to improve and facilitate the execution of the work, and to maximize the probability of success (quality-wise), thus increasing the robustness of the process
  - One for pin connectors
  - One for flat connectors / wire direct on QH-trace

***Thank you for your attention!***
***Questions?***