



Experience on superconducting cavities series production

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INFN Milano - LASA

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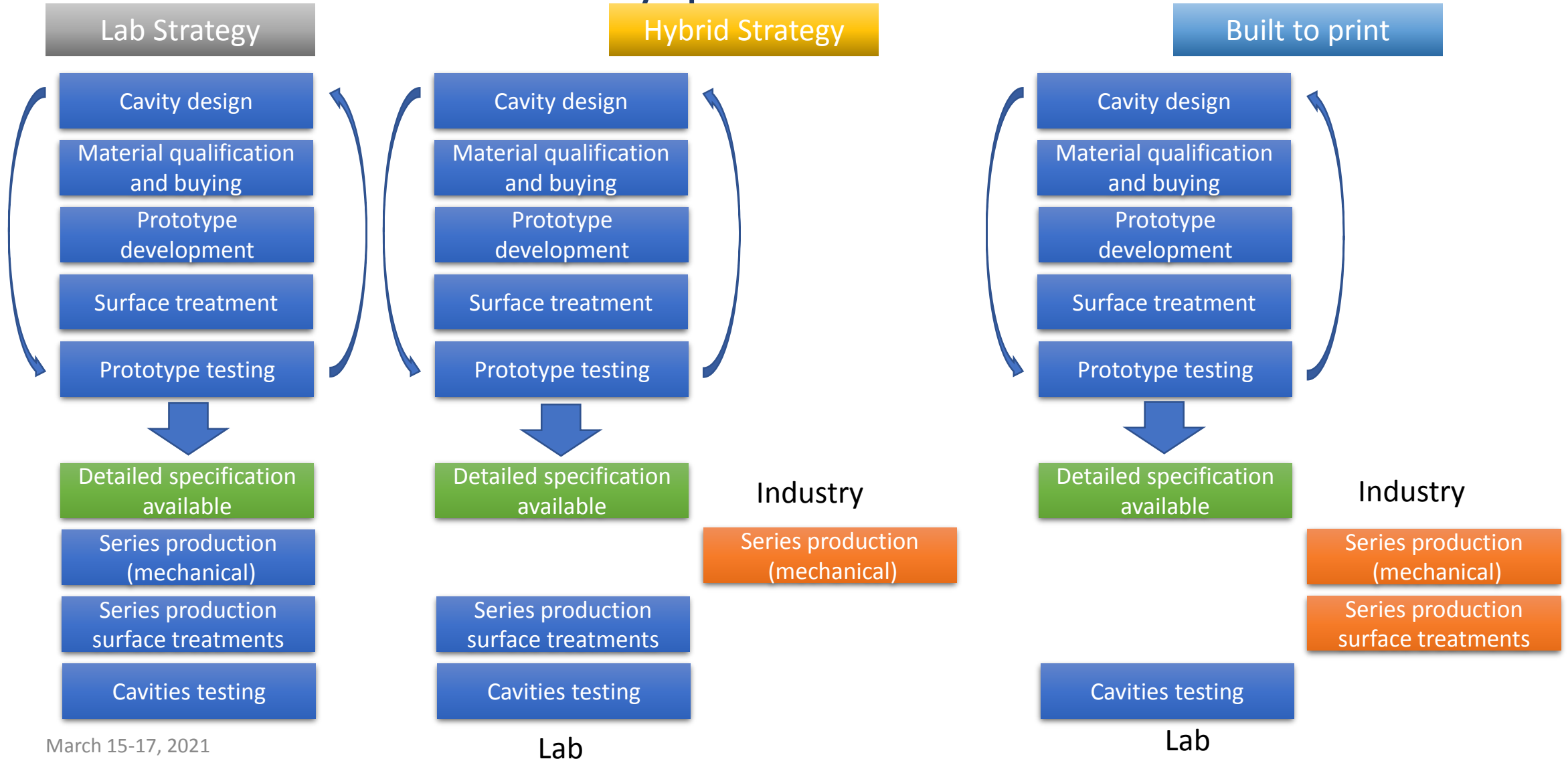
Outline

- Intro
- Series production:
 - From lab to industry
 - Reason for industrialization
- Example for
 - 1.3 GHz cavities (E-XFEL)
 - 3.9 GHz cavities (E-XFEL)
 - 704.42 MHz cavities (ESS)

Introduction

- INFN LASA has a long experience on **cavity design, fabrication and qualification** of SC cavities.
- We shared with DESY the production of the **800 cavities** for European-XFEL cavity production with European companies.
- Afterwards, we have been in charge of the design, production and test of the **20 cavities for the 3.9 GHz** module for European-XFEL.
- We are now involved in the ESS project as responsible for the Italian In-Kind contribution to the Medium Beta Section of the Superconducting Linac with **36 cavities**.
- We are also starting our activities towards the production of the **36 Low Beta cavities** for the PIP-II accelerator of the LBNS at FNAL.

From lab to industry production



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Reason for industrialization



Large projects require **large number** of cavities and **massive number of high quality Nb sheets** and components.



Laboratories resources couldn't be able to manage large number of cavities with enough quality, man-power, optimized cost, scheduling respect, etc



High production rate: **order of some cavities/week**



Series production: needs process optimization, not always part of the lab knowhow

Large scale cavities production critical aspects

- **Cavity design** and its related feasibility must be verified/optimized for **series production**
 - **Cavity design** must foresee for possible **repairing actions** on the cavity (i.e., tank removal for a new bulk surface treatment).
- **Debugged and solid recipe is a must:**
 - no R&D feasible during industrial production -> **Risk for delays**
- Usually **long production cycle:**
 - from EBW to final steps (E-XFEL): **about 3 months**
- **Large number** of cavities components **involved in the production cycle** i.e., in different production phases
- **Long time delay for any feedback** from cavity testing to the production system:
 - **Risk for several defective cavities** and a **long and expensive recovery process**
 - **To reduce the risk, intermediate diagnostic tools must be set up** (as optical inspections, RGA, UPW resistivity, etc.)
 - **Preventive maintenance** on plants to mitigate possible faults is a **must**
 - **Prepare retreatment strategy**
- Pressure Equipment Directive (**PED**) **has impact** on the production cycle in term of planning and scheduling

Extremely high-quality control of the production is a must!



European-XFEL 1.3 GHz Cavities

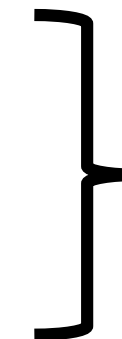
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From Lab to the Industry for E-XFEL cavities

- **Material** and vendor qualification for Nb
- **Cavity design qualification**
- **Surface treatment** qualification
- Cavity producer **qualification**: mechanical fabrication
- Procurement of Nb and semi- finished parts
- **Definition** of the “external” QA/QC for the company
- **PED issue analysis** (E-XFEL is cat. IV, modul B + F)
- **Technology Transfer to the companies for series cavities production**
- **Set up of infrastructures**
- **Qualification** of the transferred technology: DCV e RCV
- Set up of the **external QA/QC** system at the industry
- **Series cavities** production: continuous monitoring of key parameters



Preparatory phase
Laboratory level



Series production
Industry level

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European-XFEL 3.9 GHz Cavities

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E-XFEL series production overview for 3.9GHz

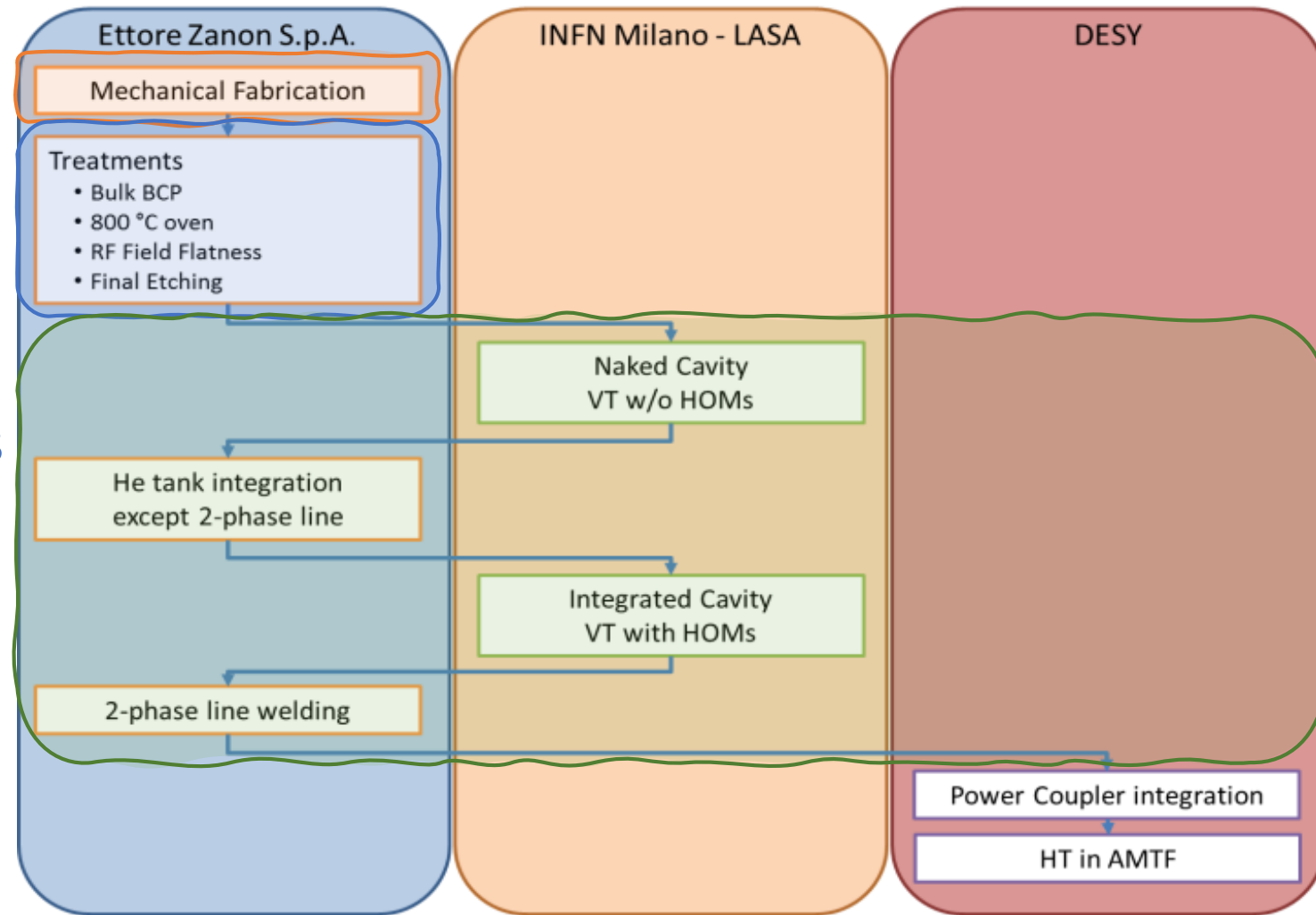
- 10+10 Cavities:
 - 8+2 spare (1st batch); 8+2 spare (2nd batch);
- INFN-DESY:
 - DESY: Eddy Current Scanning of Niobium Sheets
 - INFN:
 - supervision of the cavity production and QC at the company
 - At LASA: final steps (accessories assembly, 4h HPR, slow pumping and RGA), cold VT
- Industry
 - only one qualified company to benefit from 1.3 GHz infrastructure
 - Recipe: only BCP
 - PED: cat. IV, module G



European-XFEL 3.9GHz cavity QA/QC

QA/QC base on three Acceptance Levels

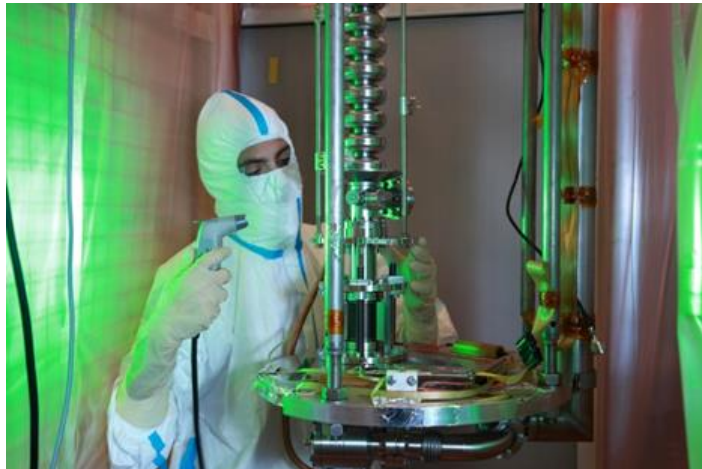
- **Al1:** from raw material to cavity mechanical production
- **Al2:** main cavity treatments up to final treatments
- **Al3:** cold VT qualification, He-tank integration and delivery to DESY for string assembly





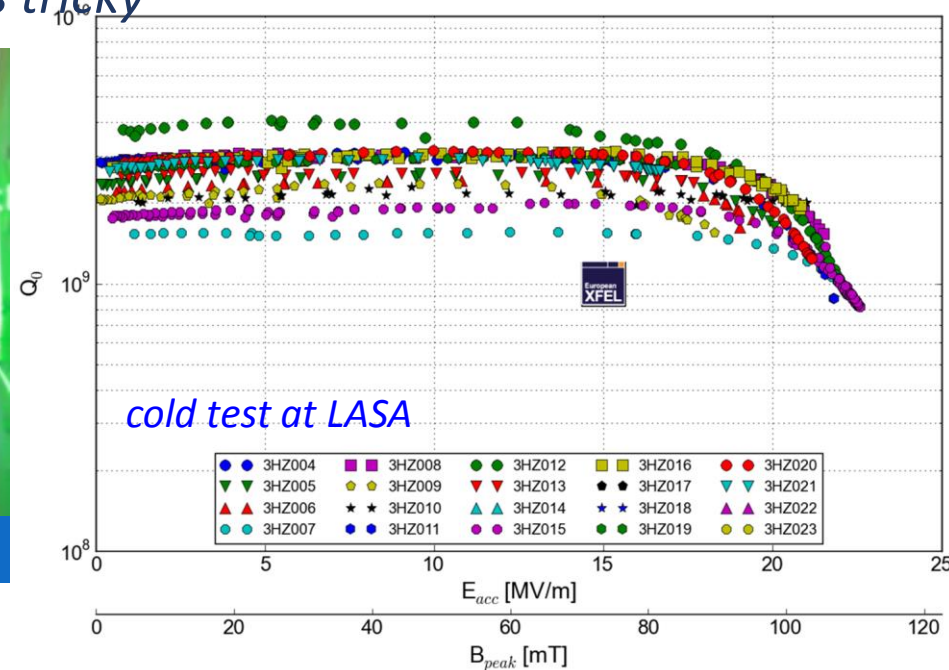
E-XFEL 3.9 GHz series production: results

- All 20 cavities overcome the requests!
- Improvement of the QC (based on the 1.3 GHz experience)
 - *Inner visual inspection after bulk BCP and annealing (check of the surface quality)*
- 3 prototypes lessons learnt
 - *Adaptation of the 1.3 GHz infrastructures for BCP treatment to the smaller dimensions of the 3.9 GHz cavities was tricky*

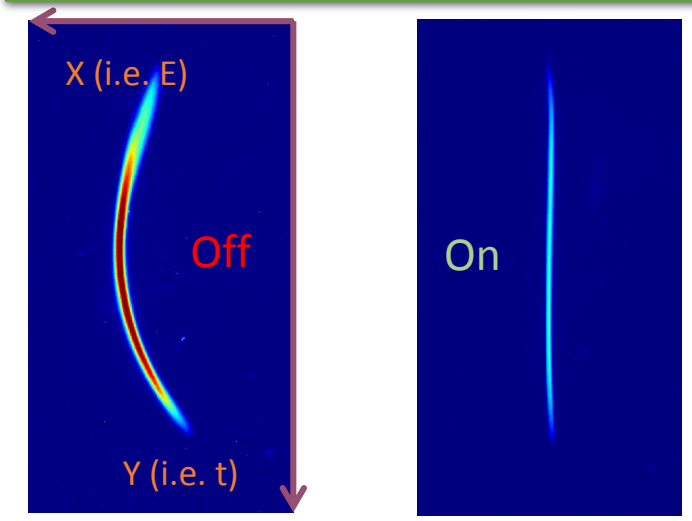


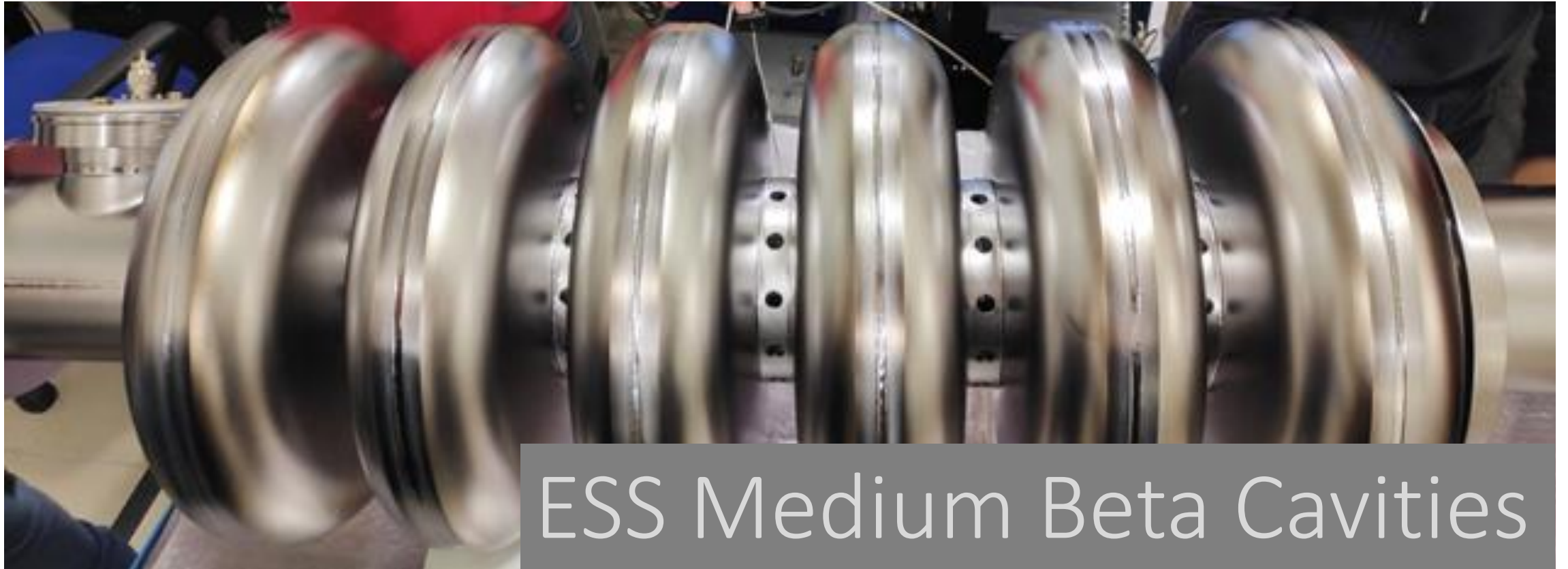
Preparation for VT at LASA clean room

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RF Curvature Linearization by AH1

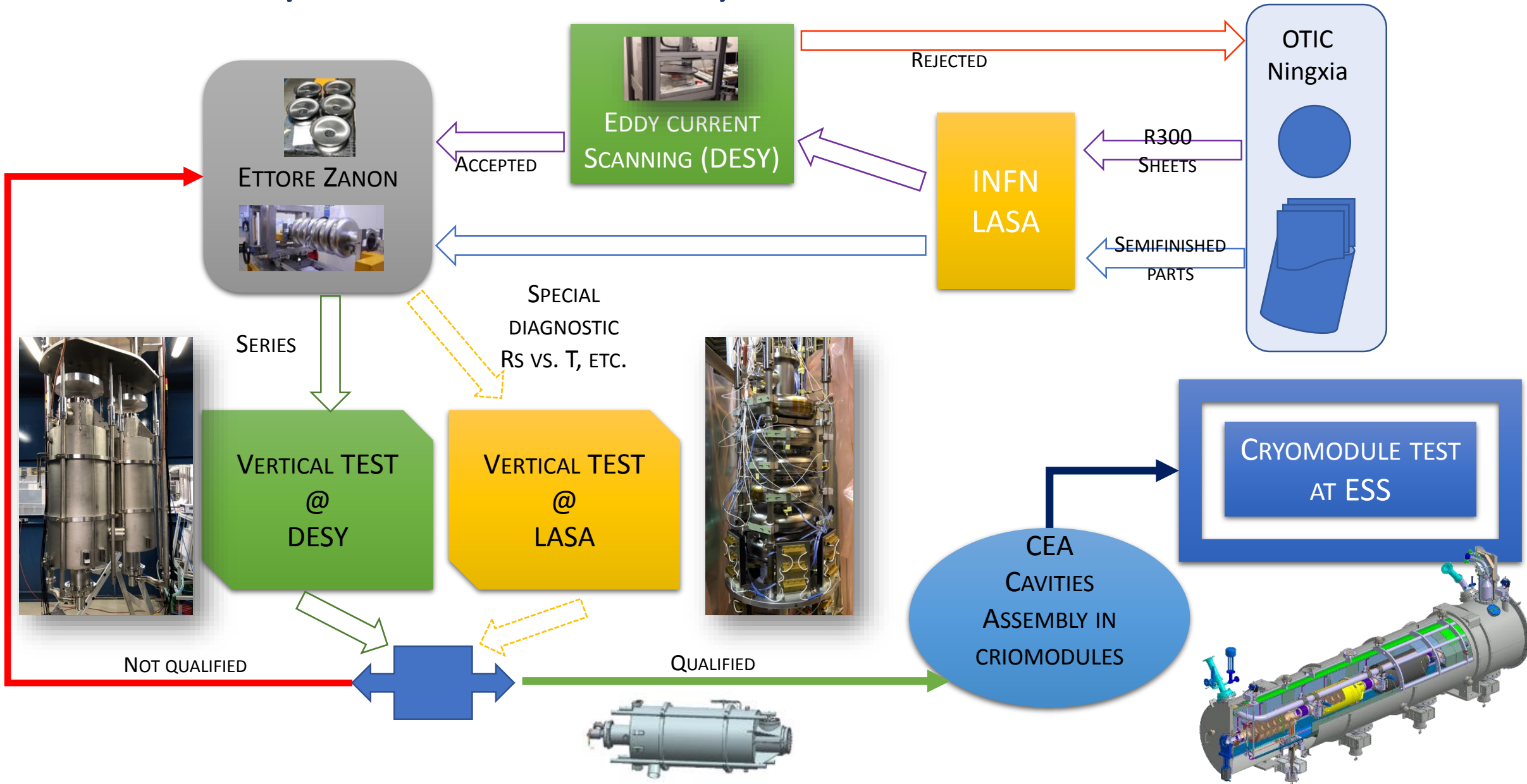




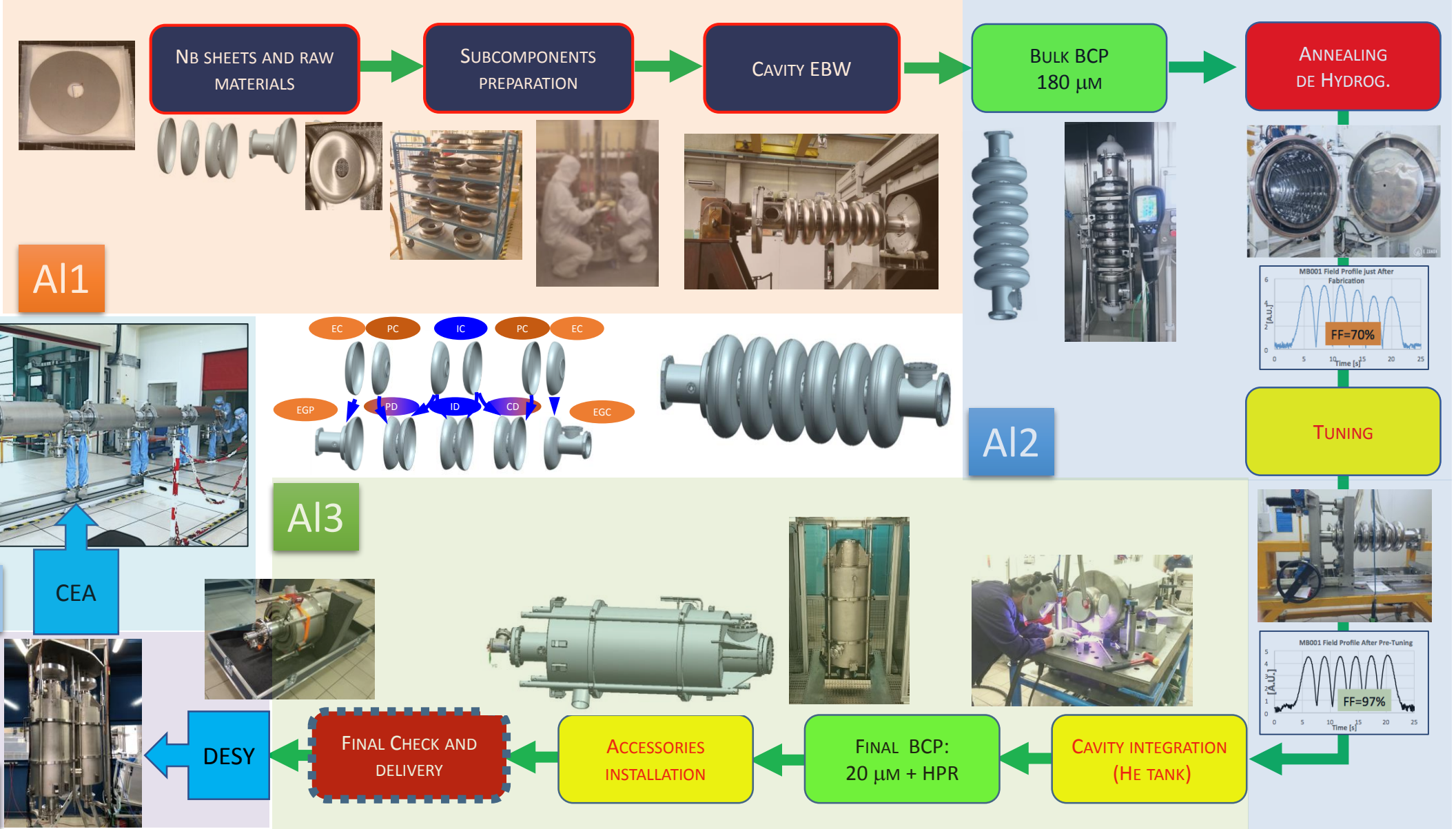
In-Kind Contribution

- LASA is responsible for Italy of this contribution to ESS
- 36 Medium Beta cavities, fully treated and prepared for VT at vendor, ready for installation in cryomodule
 - R&D on prototypes necessary for setup treatment at vendor and QA/QC control
 - PED art. 4.3 included from beginning
- Five entities (INFN, DESY, CEA, ESS and cavity vendor) involved in the process
- Well defined interfaces are key point for success of collaboration
- QA/QC is mandatory to supervise the whole process

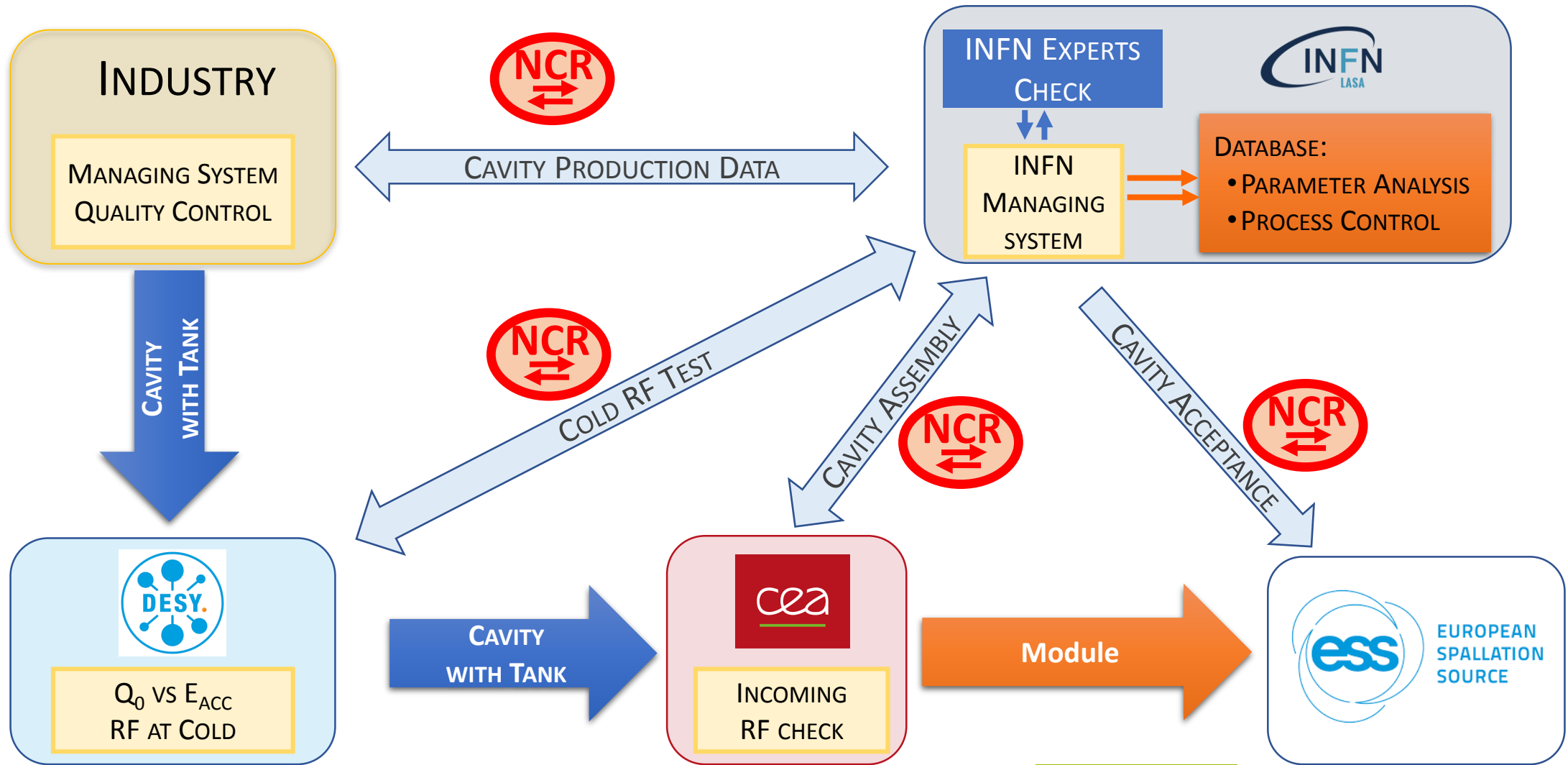
MB Cavity Production Cycle



MB Cavity 5-Acceptance Levels



QA/QC and document flow



Document and data management developed in the framework of **brightness** collaboration

Fabrication QA/QC and document flow

- \approx 200 documents per cavity
- Total of \approx 8000 documents to be:
 - Exchanged among EZ, INFN, ESS and CEA
 - Managed and stored with INFN ALFRESCO DMS
 - Analyzed for statistics, deviations, guidance and feedback for production

6. Inspection Sheet - Cavity in helium tank

Dimensional control

	37	38	39	40	41	42	43	44
Max value	8.002	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Min value	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Measured Value								
Result								

Inspection: 2/3/2017 13.34 Operator name: ESS MB Dressed Cavity Mxxx

Description: Date: Name: 3282.0.000.000 Serial-No. N° di serie

Inspection sheet Y_F15

Final RF Spectrum before delivery (in vacuum)

Frequency [MHz]	149.8	299.6	449.4	599.2	749.0	898.8
Q value	691.901	684.148	697.148	700.080	702.207	702.878
Frequency @ 22 °C [MHz] (scale)	697.890	694.140	697.140	700.052	702.189	702.870

ESS MB Dressed Cavity Mxxx

1. Inspection Sheet - Cavity in helium tank

Coordinate system

ESS MB Dressed Cavity Mxxx

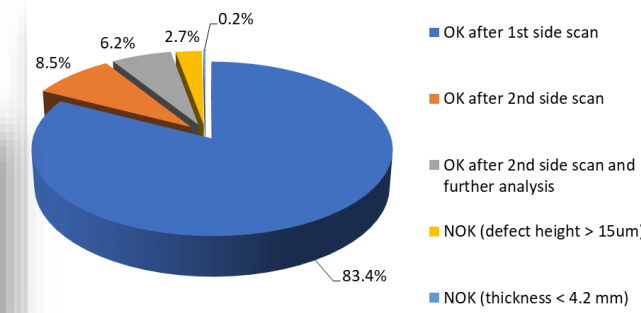
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MB Results

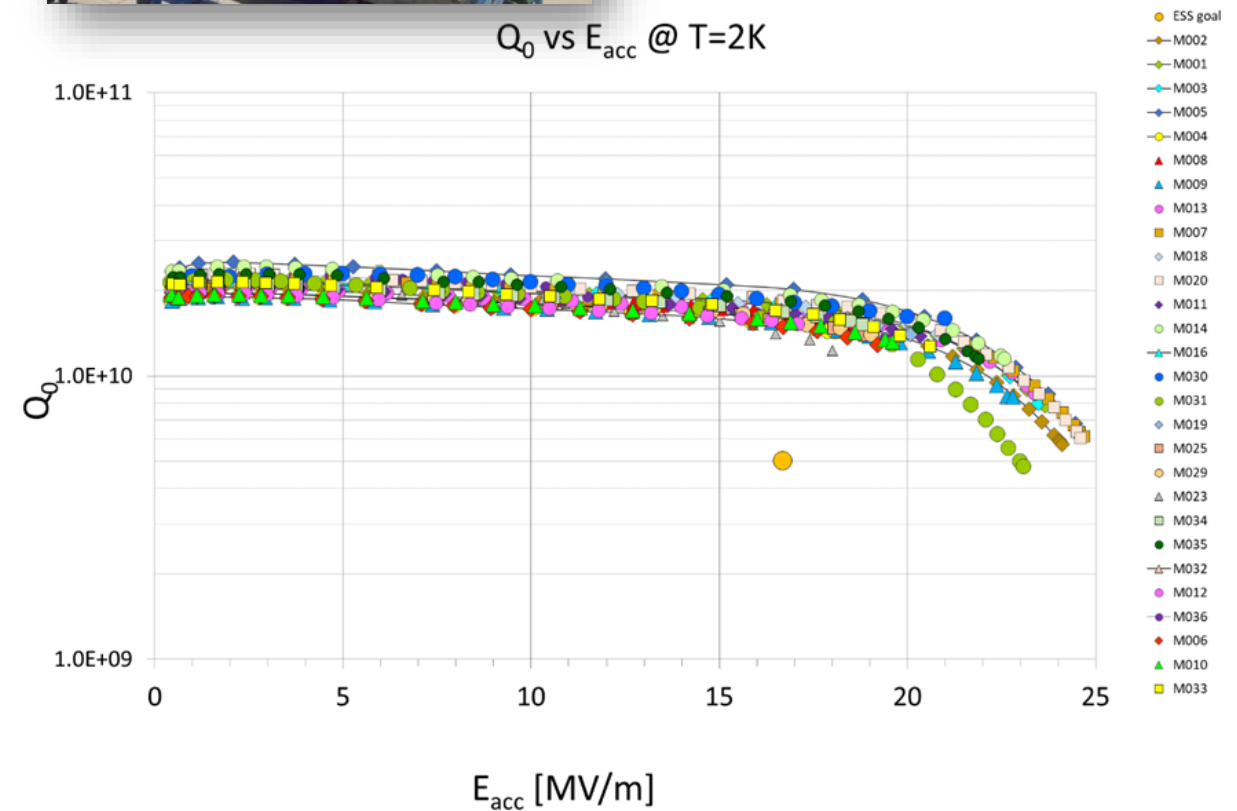


- Production is on going
- Prototypes used:
 - To setup production
 - To prepare test infrastructure at LASA and DESY
 - To debug module assembly
 - To finalize QA/QC
- Lessons learnt:
 - Niobium inspection on vendor site to limit possible delays
 - Very good planning needed for tight schedule projects
 - Cross-check between different sites (incoming-outgoing documents)

ECS @ DESY



Q_0 vs E_{acc} @ T=2K



Thanks for your attention!