Cristian **Pira**

iSAS TA2
Energy savings from the cryogenics
High-Temp SRF

23 January 2023

Scientific Context

- The final goal is energy saving from the cryogenics **developing a high performance SRF cavity operating at 4.2 K.** *Very challenging.*

- State of the art is Nb_3Sn on Nb → **limitations:**
  - *Nb is expensive;*
  - *low thermal conductivity may affect max gradient;*
  - *no facilities ready in Europe (All R&D programs are in USA).*

- The **Nb_3Sn on Cu** technology is the **most promising alternative** and is **currently develop in iFAST** H2020 project. (by CEA, HZB, INFN, STFC, RTU, IEE, UniSiegen)

- Nb_3Sn on Cu has the advantage that it can also be **attractive for industrial partners**
  → conduction-cooled, turn-key SRF for smaller accelerators.

- The **world's first prototype Nb_3Sn cavity on Cu** is planned to be built in **iFAST** (expected $Q_0 > 10^9$ @ 4K)
- Independent on this topic is also conducted at CERN in the framework of FCC R&D

- **Further optimizations to the process are expected to be needed to implement the cavities in a cryomodule.**

Scope

- **Save energy moving SC cavity operation from 2K to 4K**
- **Optimization of the results obtained in iFAST (and ARIES) for «High T» SC thin-film cavities on Cu**

- It will go to study and **develop fundamental properties for cryomodules that have not been explored in iFAST:**
  - **RF cavity tunability** (studying stability/resiliance against mechanical deformation and thermal stress)
  - **Flux trapping** (studying flux trapping and thermal current induction aiming at reducing the Surface Resistance)

- The **R&D** will be conducted **on small samples, QPR and 1.3 GHz cavities.**
  - *Coatings will be done at INFN, STFC (Nb_3Sn via PVD) and CEA (ALD coatings)*
  - *Tunability will be studied with mechanical strength measurements on small samples at CEA, tuning system for 1.3 GHz cavity to be implemented at HZB.*
  - *Flux trapping will be studied on samples and choke at STFC, on planar samples, QPR and 1.3 GHz cavities at HZB, 1.3 GHz cav. at CEA.*

- **Main coating will be Nb_3Sn,** but results obtained in iFAST with other materials will be take into account.

- **Final deliverable will be one tunable 1.3 GHz cavity operating at 4.2 K fully characterized in terms of flux trapping**

Team

Mechanical test on coupons + characterizations, ALD coatings on coupons and cavities + 1.3 GHz cavities RF test

Mechanical test on cavities, Magnetometry on coupons, QPR RF test +MG, 1.3 GHz cavities RF test + MG

Nb_3Sn coatings on coupons and QPR and 1.3 GHz cavities, morphological characterization, polishing

Nb_3Sn coatings on coupons and QPR and 1.3 GHz cavities, morphological characterization, choke cavities and penetrations characterizations + MG

Tasks nominal scenario (900 k€)

- **T2.1 Coordination (Pira, INFN)**

- **T2.2 Working Cavity @4.2 K (Valizadeh, STFC)**
  - Flux trapping and RF Tunability of iFAST cavity as reference (M2.2.) 34 - HZB
  - Optimized cavity (D2.2) 46 – INFN

- **T2.3 RF Tunability (Kugeler, HZB)**
  - Design and manufacturing of Tuner for Vertical Q VS F Test @4.2K (D2.3.) 24 - HZB
  - Mechanical characterization on planar samples (M2.3.) 30- CEA

- **T2.4 Flux trapping (Malyshev, STFC)**
  - Modification of choke cavity test system for flux trapping measurement (M2.4) 12 STFC
  - Comparative study of flux dynamics on Nb3Sn on Cu samples with different coating conditions (D2.4) 30 HZB

- **T2.5 Adaptive Layer (Proslier, CEA)**
  - Developing high T adaptive layer on Cu (M2.5) 18 CEA
  - Comparative study of Nb3Sn on Cu sample with and without adaptive layer on planar samples and QPR (D2.5) 38 STFC

WP Timeline

Task	Deliverable Milestone	Year 1	Year 2	Year 3	Year 4
		1 2 3 4 5 6 7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22 23 24	25 26 27 28 29 30 31 32 33 34 35 36	37 38 39 40 41 42 43 44 45 46 47 48
2.1 Coordination		Periodic Meetings (in person/online)			
2.2 Working Cavity @4.2K	M2.2	Flux trapping and RF Tunability of iFAST cavity as reference (M34) - HZB			
	D2.2	Optimized cavity (46) – INFN			
2.3 RF Tunability	D2.3	Design and manufacturing of Tuner for Vertical Q VS F Test @4.2K (24) - HZB			
	M2.3	Mechanical characterization on planar samples (30) - CEA			
2.4 Flux Trapping	M2.4	Modification of choke cavity test system for Flux Trapping meas. (12) STFC			
	D2.4	Comparative study of flux dynamics on Nb3Sn on Cu samples with different coating conditions (30) HZB			
2.5 Adaptive Layer	M2.5	Developing hight T adaptive layer on Cu (18) CEA			
	D2.5	Comparative study of Nb3Sn on Cu sample with and without adaptive layer on planar samples and QPR (38) STFC			

Tasks minimum scenario (555 k€)

less FTE, less samples, less tests → HIGH RISK!

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Tasks ambitious scenario (1100 k€)

New cavity substrates
On nominal scenario iFAST
Cu substrates would be re-used

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  - Optimized cavity (D2.2) 46 – INFN
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  - Design and manufacturing of Tuner for Vertical (Q VS F Test @4.2K) (D2.3.) 24 - HZB
  - Mechanical characterization on planar samples (M2.3.) 30- CEA
  - **Exploration of one other Superconductor**
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  - Modification of choke cavity test system for flux trapping measurement (M2.4) 12 STFC
  - Comparative study of flux dynamics on Nb3Sn on Cu samples with different coating conditions (D2.4) 30 HZB
  - **Exploration of one other Superconductor**
- **T2.5 Adaptive Layer (Proslier, CEA)**
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Detailed Budget Scenarios

NOMINAL SCENARIO BUDGET

Beneficiary short name	Person-months	Monthly personnel cost	Personnel costs	Travel	Equipment and consumables	Other direct costs	Sub-contracting	Material direct costs	Total direct costs	EC requested funding (without overheads)
CEA	24,0	7.620,00	182.880,00	2.000,00	140.000,00		10.000,00	152.000,00	334.880,00	150.000,00
HZB	36,0	7.600,00	273.600,00	10.000,00	230.000,00			240.000,00	513.600,00	250.000,00
INFN	72,0	5.000,00	360.000,00	10.000,00	150.000,00			160.000,00	520.000,00	250.000,00
STFC	56,0	7.500,00	420.000,00	10.000,00	100.000,00			110.000,00	530.000,00	250.000,00
Total	**188,0**		**1.236.480,00**	**32.000,00**	**620.000,00**	**0,00**	**10.000,00**	**662.000,00**	**1.898.480,00**	**900.000,00**

MINIMUM SCENARIO BUDGET

Beneficiary short name	Person-months	Monthly personnel cost	Personnel costs	Travel	Equipment and consumables	Other direct costs	Sub-contracting	Material direct costs	Total direct costs	EC requested funding (without overheads)
CEA	12,0	7.620,00	91.440,00	2.000,00	68.000,00		5.000,00	75.000,00	166.440,00	75.000,00
HZB	24,0	7.600,00	182.400,00	10.000,00	100.000,00			110.000,00	292.400,00	160.000,00
INFN	52,0	5.000,00	260.000,00	10.000,00	80.000,00			90.000,00	350.000,00	160.000,00
STFC	50,0	6.500,00	325.000,00	10.000,00	80.000,00			90.000,00	415.000,00	160.000,00
Total	**138,0**		**858.840,00**	**32.000,00**	**328.000,00**	**0,00**	**5.000,00**	**365.000,00**	**1.223.840,00**	**555.000,00**

AMBITIOUS SCENARIO BUDGET

Beneficiary short name	Person-months	Monthly personnel cost	Personnel costs	Travel	Equipment and consumables	Other direct costs	Sub-contracting	Material direct costs	Total direct costs	EC requested funding (without overheads)
CEA	48,0	7.620,00	365.760,00	5.000,00	180.000,00		15.000,00	200.000,00	565.760,00	200.000,00
HZB	36,0	7.600,00	273.600,00	20.000,00	230.000,00			250.000,00	523.600,00	300.000,00
INFN	80,0	5.000,00	400.000,00	20.000,00	180.000,00			200.000,00	600.000,00	300.000,00
STFC	86,0	6.500,00	559.000,00	20.000,00	100.000,00			120.000,00	679.000,00	300.000,00
Total	**250,0**		**1.598.360,00**	**65.000,00**	**690.000,00**	**0,00**	**15.000,00**	**770.000,00**	**2.368.360,00**	**1.100.000,00**

EU – in kind contribution
(nominal scenario)

- RF tests, Helium, chemicals
- FTE, deposition system, mechanical traction system

- PhD or Postdoc 3 years, tuning mechanism
- LHe, VTS testing, QPR testing

- Post Doc 4 years, chemicals
- FTE, coating consumables

- Post Doc 4 years, samples, Hall probes and controllers, consumables for Choke cavity facility
- FTE, coating consumables, facility operation consumables (electricity, cooking water, cryolab operation

EU – in kind contribution
(minimum scenario)

- Helium and consumables
- FTE, mechanical traction system

- 1/2 PhD, tuning mechanism
- 1/2 PhD, test infrastructure and operation

- Post Doc 3 years
- FTE, chemicals, coating consumables

- PhD 3.5 years or postDoc 3 years, samples, Hall probes and controllers, consumables for Choke cavity facility
- FTE, coating consumables, facility operation consumables (electricity, cooking water, cryolab operation

EU – in kind contribution *(Ambitious scenario)*

CEA
- RF tests, chemicals, Helium
- FTE, deposition system, mechanical traction system

HZB Helmholtz Zentrum Berlin
- Post Doc 4 years , Helium, QPR tests, VTS tests, tuner mechanism
- Cost difference

INFN LNL
- Post Doc 4 years, chemicals, cavities
- FTE, chemicals, coating consumables

UKRI
- Post Doc 3 years + PhD 3.5 Y, samples, Hall probes and controllers, consumables for Choke cavity facility
- FTE, coating consumables, facility operation consumables (electricity, cooking water, cryolab operation