**CERN** CH-1211 Geneva 23 Switzerland



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EDMS Document No.

Date: 2015-03-25

## Work Package Description

## **FUTURE CIRCULAR COLLIDER**

## **RF R&D ACTIVITIES**

#### Abstract

Superconducting radiofrequency (SRF) accelerating structure is a key technology for future colliders at the energy frontier, for which the wall-plug efficiency will be one of the biggest challenge.

This document describes the FCC SRF Work Package. The objective of this WP is to identify the ultimate limits, the showstoppers and define the R&D topics that need to be addressed in order to optimize the SRF technology for large superconducting RF system. This document compiles the sub-WP items with definition of scope, deliverables and milestones. CERN resource impact has been evaluated in order to provide feedback to potential international partners.

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## History of Changes

Rev. No.	Date	Pages	Description of Changes
0.0	2015-03-24	All	Initial submission
0.1	2015-04-27	All	Rama's comments& corrections added
0.2	2015-05-05	10	Eric's WP description added
0.3	2015-05-20	All	Reshuffled after discussion with Erk and Karl
0.4	2015-06-05	1-2	CERN-STFC-LNL Collaboration Agreement WP1
0.5	2015-09-18		CAVITY FABRICATION -HIGH VELOCITY FORMING OF SUPERCONDUCTING RF STRUCTURES transferred from STP WP

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# 1 COLLABORATION AGREEMENT "KE2722/BE/FCC" (P. CHIGGIATO)

#### 1.1 FRAMEWORK FOR SCIENTIFIC COLLABORATION IN SUPERCONDUCTING RF CAVITIES TECHNOLOGY

CAVITILS	LCHNOL	701	-		-	
Participant	CERN	STFC	LNL			
Person						
months						
Туре	All types					
Objectives						
1) Establish a fra	amework	for scientific	c collaborati	on in Super	conducting	RF cavities
technology with	the aim to	o combine e	expertise, to	achieve sci	entific goals	s and to
develop commor	ı specializ	ed knowled	ge			
2) Investigate in	novative	cavity fabrio	cation techn	iques and e	valuate the	ultimate
performance of 8	300 MHz 5	5 cell cavitie	es			
<b>Description of</b>	Work					
The FCC RF syste	em will be	e made up o	of a large nu	imber of acc	celerating ca	avities.
Cavity design, fa	brication	and perform	nance are k	ey R&D topi	ics.	
The contribution	s to the c	ollaboration	are defined	as follow:		
Task 1 (CERN):	1					
a) RF design	of the 5-	cell 800 MH	z cavities.			
b) The supply	y of the H	ligh Purity	OFHC Coppe	er material i	required for	the cavity
forming in	the size	required by	INFN.			
c) Developm	ent of the	e full infrast	ructure for	the niobium	n sputter-co	ating of 5-
cell 800 M	Hz coppe	r cavities:				
a) The de	sian, mar	nufacturing	and operati	ion of a sur	face proces	sina bench
for the ch	emical ar	nd/or electr	opolishina d	of 5-cell 80	0 MHz copr	er cavities
prior to co	ating	,	openering (		• · · · · = ••pp	
h) The de	scian ma	nufacturing	and onera	tion of a co	nating henc	h for such
cavities	based on	current th	and opera	the art fo	r magnetro	n niobium
cavities, i	f alliptica		le state of	the art io	i magnetio	
		I Cavilles.				teet beach
c) The de	sign, mai	nuracturing	and operat	ion of a cry	ogenic RF	test bench
for such c	avities.					
To these r	urnoses (	CERN will er	xecute all re	levant studi	ies materia	1
procureme	nt and a	nalvses nro	totyning an	d tests as s	een fit for tl	ne
DUrDOSE		, 000, pro				
Pa. 90001						
Task 2 (INFN):						
a) The fabric	ation of f	our coomles		5-cell conne	r cavities	

- a) The fabrication of four seamless 800 MHz 5-cell copper cavities
- b) The development of surface processing and coating techniques on seamless 6 GHz cavities, in view of a possible application to 800 MHz cavities, including: the role of the microstructure of niobium at the interface between copper and niobium, the effect of the high deposition temperatures on SRF properties of niobium, the study of improved

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XX

deposition magnetron sources for the niobium deposition, and the study of thermal boundary resistance between copper and liquid helium. c) INFN will also investigate the possible application of either spinning, backextrusion or alternative seamless fabrication techniques for the production of a single-cell 400 MHz cavity. For these initial investigations the technical drawings of the LHC 400 MHz cavity will be provided by CERN. In collaboration with CERN an optimisation of the cavity design (HOM coupler, FPC, etc.) will be considered. These investigations should be summarised in a feasibility report including first estimates of tooling cost and providing the basis for prototyping activities d) For the achievement of these goals, INFN will be free to subcontract part of the work to Consorzio Futuro in Ricerca (CFR). CFR has been traditionally collaborating for years with INFN, through the support and coordination of students, scientific fellows, young researchers and foreign experts, that have contributed to the performance of R&D on superconducting cavities, in the framework of a Master Programme called "Surface Treatments for Industrial Applications" promoted by INFN and the University of Padua.RF design of the 5-cell 800 MHz cavities. Task 3 (STFC): a) Microscopic and surface characterization of samples produced by the other parties, representing either routine or innovative surface preparation processes or coating. b) Development of in-house 3D Nb/Cu coating capabilities. Deliverables Month **D1:** - 6 GHz cavities: delivery of 15 units completed M12 - 800 MHz cavities: toolings for 800 MHz production ready **D2:** - 6 GHz vacities: delivery of units 16 to 28 completed M24 - 800 MHz cavities: first 800 MHz cavity module ready - 400 MHz feasibility study: intermediate report on study status D3: - 6 GHz vacities: delivery of units 29 to 32 completed M48 - 800 MHz cavities: all 4 800 MHz cavity modules ready - Feasibility study for 400 MHz production available **CERN Resources (Manpower) [Person. Months (PM)** STAFF FELL/PJAS PhD **CERN Resources (Material) [kCHF]** Total budget (details in KE2722/BE/FCCAnnex 2): XX Year 1 XX XX

- Year 2
- Year 3

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Year 4	
to INFN (450 000 EUR)	
To STFC (104000 GBP)	

XX 470 000

## 150 000

## 2 CAVITY DESIGN (R. CALAGA)

2.1 CAVITY DESIGN	
Participant	
Person	
months	
Туре	
Objectives	
Define a viable cavity design for the FCC-ee and FCC-hh RF system to covrequirements for both the highest accelerating gradient and very high beacurrents with the same machine. A possible design and layout of a 2 <sup>nd</sup> ha cavity system to provide landau damping or bunch profile manipulation. <b>Description of Work</b> Detailed study on the RF scenarios, optimum gradient and staging, RF free choice, cavity shape and aperture optimization, number of cells and cavit ryomodule layout, and cryogenic loads. Study of variable Qext fundament couplers would seem to be desirable for energy efficiency <b>Task 1:</b> Evaluate and detail the requirements for the possible scenarios <b>Task 2:</b> Study cavity design and HOM damping and power extraction cont <b>Task 3:</b> Study FPC concepts and options (fixed vs variable couplers)	ver the am rmonic equency ies/c tal power
Deliverables	Month
D1: Concepts and parameters	M12
<b>D2:</b> Cavity and layout design	M24
D3: Document results	M48
CERN Resources (Manpower) [Person. Months (PM)]	
STAFF	9
A. Butterworth	1
R. Calaga	2
	26
FELL/PJAS	36
PELL/PJAS PhD CERN Resources (Material) [k(HE]	36 0
PhD CERN Resources (Material) [kCHF] Total budget:	36 0
PhD CERN Resources (Material) [kCHF] Total budget: Travels	36 0 20 10
FELL/PJAS         PhD         CERN Resources (Material) [kCHF]         Total budget:         Travels         Material budget for PHD student	36 0 20 10 10
FELL/PJAS         PhD         CERN Resources (Material) [kCHF]         Total budget:         Travels         Material budget for PHD student         Arbitration decision	36 0 20 10 10

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Z.Z CAVIIY IMPE	DANCE	AND HOM	2						
Participalit									
months									
Obiectives									
Impedance estima and hadron schem	tes fror es.	n RF caviti	es and s	stabili	ty limit	ts for	the d	ifferer	nt lepton
Description of W	ork								
might dictate to a impedance estimat HOM charaterizatio warm transitions a stability limits with <b>Task 1</b> : Define the impedances	large extension and on and on adeque e impected impecod impected impecod impected impected impeco	xtent the F the difference power calc essary. The ate HOM d lance budg	RF syste nt cavity ulations confor amping get for b	em des y layous inclui mity c shoul	ign. Thuts and ding ta of the R d be vo	neref d stag pers RF str erfier nd ar	ore, co ging o and o ucture d. nd nar	ompre f the F other c es with	ehensive RF system cold to hin the
Task 2: Evaluate I damping Task 3: Evalaute 1	longitud the effe	linal and t	ransvers e HOM i	se imp power	edanco losses	e spe	ectra f	or cav	ities with
Task 2: Evaluate I damping Task 3: Evalaute 1	longitud the effe	linal and t	ransvers e HOM	se imp power	edanco losses	e spe	ectra f	or cav	ities with
Task 2: Evaluate I damping Task 3: Evalaute 1 Deliverables D1: Concepts and	longitud the effe	dinal and the sects of larg	ransvers e HOM	se imp power	oedanco losses	e spe	ectra f	or cav	ities with Month M12
Task 2: Evaluate I damping Task 3: Evalaute t Deliverables D1: Concepts and D2: Impedance bu	longitud the effe parame	dinal and the sects of larg	ransvers e HOM   criteria	se imp power	losses	e spe	ectra f	or cav	Month M12 M24
Task 2: Evaluate I damping Task 3: Evalaute 1 Deliverables D1: Concepts and D2: Impedance bu D3: Document res	longitud the effe parame idget an	dinal and the sects of larg	ransvers e HOM   criteria	se imp power a for v	oedanco losses arious	e spe	ectra f	or cav	Month M12 M24 M48
Task 2: Evaluate I damping Task 3: Evalaute 1 Deliverables D1: Concepts and D2: Impedance bu D3: Document res CERN Resources	longitud the effe parame idget ai ults (Manp	dinal and the sects of larg sectors and stability sower) [P	ransvers e HOM p criteria erson.	se imp power a for v <b>Mont</b>	oedanco losses arious hs (PM	e spe	ectra f	or cav	Month M12 M24 M48
Task 2: Evaluate I damping Task 3: Evalaute f Deliverables D1: Concepts and D2: Impedance bu D3: Document res CERN Resources STAFF	longitud the effe parame idget ar ults (Manp	dinal and the sects of larg	ransvers e HOM   r criteria erson.	se imp power a for v Mont	oedanco losses arious hs (PM	e spe scen	ectra f	or cav	Month M12 M24 M48
Task 2: Evaluate I damping Task 3: Evalaute f Deliverables D1: Concepts and D2: Impedance bu D3: Document res CERN Resources	longitud the effe parame idget ai ults (Manp	dinal and the sects of larg	ransvers e HOM p criteria erson.	se imp power <u>a for v</u>	oedanco losses arious hs (PM	e spe	ectra f	or cav	Month M12 M24 M48 9 1
<b>Task 2</b> : Evaluate I         damping <b>Task 3</b> : Evalaute I <b>Deliverables D1:</b> Concepts and <b>D2:</b> Impedance bu <b>D3:</b> Document res <b>CERN Resources</b> STAFF	longitud the effe parame idget ai ults (Manp	dinal and the sects of larg	ransvers e HOM   r criteria erson.	se imp power <u>a for v</u>	oedanco losses arious hs (PM	e spe	ectra f	or cav	Month         M12         M24         M48         9         1         2
Task 2: Evaluate I damping Task 3: Evalaute f Deliverables D1: Concepts and D2: Impedance bu D3: Document res CERN Resources STAFF	longitud the effe parame idget ar ults (Manp	dinal and the sects of larg	ransvers e HOM   <u>r criteria</u> erson.	se imp power <u>a for v</u>	oedanco losses arious hs (PM	e spe	arios	or cav	Month         M12         M24         M48         9         1         2         36
<b>Task 2</b> : Evaluate I         damping <b>Task 3</b> : Evalaute I <b>Deliverables D1:</b> Concepts and <b>D2:</b> Impedance bu <b>D3:</b> Document res <b>CERN Resources</b> STAFF	longitud the effe parame udget an ults (Manp	dinal and the set of larg	ransvers e HOM p criteria erson.	se imp power a for v Mont	oedanco losses arious hs (PM	e spe	arios	or cav	Month         M12         M24         M48         9         1         2         36         0
Task 2: Evaluate I damping Task 3: Evalaute f Deliverables D1: Concepts and D2: Impedance bu D3: Document res CERN Resources PhD CERN Resources	longitud the effe parame idget ar ults (Manp	dinal and the sects of larg	ransvers e HOM   criteria erson.	se imp power a for v Mont	oedanco losses arious hs (PM	e spe	arios	or cav	Month         M12         M24         M48         9         1         2         36         0
Task 2: Evaluate I damping Task 3: Evalaute f Deliverables D1: Concepts and D2: Impedance bu D3: Document res CERN Resources STAFF =ELL/PJAS PhD CERN Resources Fotal budget:	longitud the effe parame udget an ults (Manp	dinal and the sects of larg	ransvers e HOM   criteria erson.	se imp power a for v Mont	oedanco losses arious hs (PM	e spe	arios	or cav	Month         M12         M24         M48         9         1         2         36         0         20
Task 2: Evaluate I         damping         Task 3: Evalaute I         Deliverables         D1: Concepts and         D2: Impedance bu         D3: Document res         CERN Resources         STAFF         EELL/PJAS         PhD         CERN Resources         Fotal budget:	longitud the effe parame idget an ults (Manp	dinal and the sects of larg	ransvers e HOM p criteria erson.	se imp power	oedanco losses arious hs (PN	e spe	arios	or cav	ities with Month M12 M24 M48 9 1 2 36 0 0 20 10
Task 2: Evaluate I damping Task 3: Evalaute f Deliverables D1: Concepts and D2: Impedance bu D3: Document res CERN Resources STAFF =ELL/PJAS PhD CERN Resources Fotal budget:	longitud the effe parame idget ar ults (Manp	dinal and the sects of larg	ransvers e HOM p criteria erson.	se imp power a for v Mont	oedanco losses arious hs (PM	e spe	arios	or cav	Month         M12         M24         M48         9         1         2         36         0         20         10         10

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# 3 CAVITY MATERIAL AND PERFORMANCE (WALTER VENTURINI DELSOLARO)

3.1 SUPERCONDUCTING MATERIAL DEVELOPMENTS										
ParticipantCERNUNIGEHZBTUWTRIUMF?JLAB?										
Person	Person									
months										
Туре										
Objectives										

Investigation of classical and novel materials for their RF performance limits at moderate to high fields, at frequencies in the 400–800 MHz range. Study of BCS and extrinsic sources of RF loss (surface preparation prior to RF test, thermal treatments, flux expulsion, thermal currents).

The method followed will be to systematically characterize the material parameters influencing the surface resistance (microstructure, chemistry, I,  $\lambda$ ,  $\xi$ , Hc1, etc), and relate them to the RF performance and to the production and test parameters.

A key objective is to mitigate the Q-slope in SC thin films up to 10-15 MV/m. The final goal is coating FCC cavities with competitive performance/cost as compared to the bulk Nb technology.

#### **Description of Work**

**SC thin films**: the Nb-Cu technology is the Laboratory hallmark for SRF cavities. After the era of LEP2 and LHC based on magnetron sputtering, it has been revived for the HIE-ISOLDE post accelerator, where a bias sputtering method was used. The community is presently focusing on energetic condensation methods, of which HIPIMS is favorite at CERN. The initial baseline material choice for FCC is Nb-Cu.

Beyond Nb-Cu, alternative materials (A15, multilayers) are promising in the timeframe of FCC and will therefore be actively researched.

**Bulk-Nb**: the workhorse of SRF worldwide is a mature technology, with some novel developments coming on the stage recently (Ti and N doping).

The measurement techniques, analysis methods and underlying SRF physics are largely common to SRF thin films.

In the framework of SRF for FCC the scope for bulk Nb is limited to establish state of the art infrastructures and performances, providing a standard to enable comparisons with novel materials.

The WP is structured into the following tasks:

Task 1: Cu surface preparation prior to coating Task 2: DC and AC sample characterization Task 3: RF measurements and diagnostic tools Task 4: Nb-Cu coatings

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<b>Task 5:</b> Alternative materials: A15 coatings <b>Task 6:</b> Preparation and test of bulk Nb surfaces	
Deliverables	Month
D1a: Document on Cu surface preparation protocols	M22
D1b: Tumbling system (tbc)	?
<b>D2a:</b> Document on I, $\lambda$ , $\xi$ , Tc, Hc1, and microstructure measurements	M22
<b>D2b</b> : Inductive Tc/RRR measurement bench at CERN with cryocooler	M26
<b>D2c:</b> Nb-Cu sample studies: DC/AC vs coating parameters correlations	M32
D3a: Document on RF surface impedance measurements	M22
<b>D3b:</b> Digital multi frequency LLRF system for high Q measurements	M26
<b>D3c:</b> Variable coupler system for vertical cryostat tests	M26
D3d: Test bench for monocell 800 MHz FCC type cavity	M32
D3e: Temperature mapping system for FCC cavites	
D3f: Magnetic field mapping system for FCC cavites	M32
D4a Nb-Cu and bulk Nb sample studies: DC/AC vs RF correlations	M32
<b>D4b:</b> Commissioning of refurbished 1.3 GHz coating bench (DC magnetron cavity test)	M24
<b>D4c:</b> Measurement of first bias-HIPIMS 1.3 GHz cavity	M26
<b>D4d:</b> Optimized biased HIPIMS for 1.3 GHz cavites (finalized protocol with coating parameters and procedures, supported by RF tests)	M30
<b>D4e</b> : Installation and commissioning of coating bench for ECC cavities	M34
<b>D4f:</b> Coating of a single cell FCC Nb-Cu cavity (800 MHz)	M47
<b>D4g:</b> Measurement of a single cell FCC Nb-Cu cavity (800 MHz)	M48
<b>D4h</b> : Measurement of a prototype FCC cavity (400 MHz)	M48
<b>D5a:</b> Sputtering A15 onto copper samples with good superconducting dc properties	M20
<b>D5b:</b> Sputtering of A15 on copper substrate for Quadrupole Resonator	M26
<b>D5c:</b> Coating of FCC single cell cavity with A15	M38
D5d: Coating FCC cavity with A15	M48
D6a: test of monocell 1.3 GHz bulk Nb (reference cavity)	M24
D6b: test of monocell FCC cavity bulk Nb (reference cavity)	M30
CERN Resources (Manpower) [Person. Months (PM)]	
STAFF	70
	0
	0
FELL/PJAS	108
PhD	36
CERN Resources (Material) [kCHF]	
Total budget estimate:	600
	0
	0

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#### Arbitration decision

## **4 CAVITY FABRICATION (KARL SCHIRM)**

_						1
4.1 HIGH VELC	CITY FOR	MING OF SU	IPERCONE	DUCTING	GRF STRUC	TURES
Participant	CERN	Bmax (FR)				
Person	56					
months						
Туре	All types					
1 Thorough under	arctanding o	f the electro	hydroulic f	orming pr		to connor and
niobium aeome	etries for Sur	erconducting	RF structure	es.	ocess applied	a to copper and
2. Characterisatio	n and model	isation of copp	er and niot	pium for fa	ist forming.	
3. Production of a	niobium fun	ctional structu	re.			
Description of l	Moule					
Cupercenducting		tructuras ara	traditiona	lly fabrics	atad from ch	aat matal
formed using a w	vide range a	and combinet	ion of tech	ny idunica	ninning do	en drawing
necking and hydr	coformina	The metals in	volved are	niques. s pure nio	bium as we	ll as Oxvoen
free OFE copper	typically us	ed for prelimi	inary trials	Geomet	ries used fo	r SRF cavities
can be axisymme	etric (e.g. l	HC, ILC, SPL	.) or non-a	ixisymme	tric (e.g. HL	-LHC crab
cavities). Electro	n-beam wel	ding is typica	ally used to	o join forr	med structu	res to obtain
the final geometr	γ.					
The possible forn	ning technic	ques can be c	compared a	along diff	erent charad	cteristics of
merit: complexity	y of set-up,	equipment a	nd dies, p	recision c	of formed ge	ometry,
regularity of form	ied thicknes	ss, metallurg	y, reprodu	CIDINLY OF	results, cos	SL.
Hiah-velocity for	ming is a po	otentially alte	rnative pr	ocess. It	involves a h	igh-strain rate
deformation, thro	ough a proc	ess lasting a	few millise	econds, th	nat allows re	eaching higher
formability (large	er plastic de	formation, sr	naller spri	ngback).	Applications	s to copper and
niobium have on	ly recently l	peen started	using elec	tro-hydra	ulic forming	(EHF).
Advantages are e	expected in	metallurgy, g	geometrica	al precisio	n, reproduc	ibility,
suitability for eco	nomic, larg	e series prod	luction.			
The project prop	ocal aime tr	study and a	nnly this t	ochnology	, initially for	- the
application to HI	-I HC crab c	avities comb	ppiy uns u vining the	competer	y IIIILIAIIY IOI	Une N of EN/MME
(the Engineering	Departmen	t / Mechanic	al and Mat	erials End	ineering Gr	oup) and
BE/RF (the Beam	is Departme	ent/Radio-Fre	auencv Gi	roup) with	the indust	rial partner
Bmax (in Toulous	se, France).	EHF could al	llow the de	esign of th	ne crab cavi	ty – as well as
developing Futur	e Circular C	ollider (FCC)	-type SRF	structure	s - to be op	timised using
fewer parts and v	welds positi	oned in lower	field area	IS.		_
EN-MME, will use	its internal	l resources in	:			
- Engineering	and mechai	nical design	the FUE -		ing on the st	(norion co soined
- inumerical r	t FEM motho	de and bydroo		Cocess rely	ning on the e>	cperience gained
- Materials, n	netallurgy. S	EM/FIB analys	is		a Autouyn.	

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- Mechanical testing including high-strain rate characterization of the materials (possibly exploiting the agreement between CERN and Politecnico di Torino which is leader in this field).
- CMM metrology
- Machining and sheet metal forming
- Electron beam welding to assemble the final structure

EN-MME would work closely in collaboration with BE-RF physicists and engineers.

Bmax would also perform advanced simulation and modelling work, and contribute their specific know-how in electro-hydraulic forming.

The result of the study is expected to be a thorough understanding of the process and the identification and influence of its parameters on copper and niobium, as well as a complete HL-LHC crab cavity prototype (in copper and/or niobium). In particular, the development of microstructure and of physical (e.g. Residual Resistivity Ratio, RRR) and mechanical properties induced by the regime of strain rates associated to the EHF process will be investigated as a function of the process parameters in the whole temperature range relevant for the application.

It should allow to introduce high velocity forming as a qualified, referenced alternative for the forming of accelerating structures throughout laboratories world-wide.

**Task 1:** learning period, first simple EHF tests on copper and simple geometries Milestone 1: Identification of key project issues and required contributions. Deliverable 1: Report on the state of sheet metal forming for SRF applications, potential of EHF, state-of-the-art, detailed project plan for numerical simulation, forming, testing.

#### Task 2: project programme

Milestone 2: production of simulations and formed components Deliverable 2: Report covering EHF tests, comparisons with numerical simulations, testing and qualification of produced structures in copper and niobium.

**Task 3:** application of know-how to structural components Milestone 3: production of a functional, complex geometry SRF component in niobium Deliverable 3: Final structural component, summary report of findings.

Deliverables	Month
D1. First simple EHF tests	M6
D2. Project programme	M24
D3. Application of know-how to structural components	M6
CERN Resources (Manpower) [Person.Months (PM)]	
STAFF 5	20
PM/year	
FELL/PJAS (starting mid-2015)	36
PhD	0
CERN Resources (Material) [kCHF]	
Total budget estimate for test bench, PCBs, components and FSU	275
Year1	50
Year2	50

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Year3						100
Arbitration dec	ision					/ 5
Transferred form	n STP to F	RF as part of	f the "SPL" a	activities. Res	olutely tak	es up a
technological cha	allenge fo	r the produ	ction of larg	e series of ca	vities. Fello	w -> Nov `15
5 CRYOMOL	JULE CI	ALLENG	ES (KARI	. SCHIRM)		
5.1 CRYOMOD	ULE DES	IGN	1			
Participant						
Person						
months						
Туре						
<b>UDJECTIVES</b>	omodulo	avout (Nursh	or of coulting	cold to war	trancitions	
- Cavity/Cryo	budget est	imate (static	(dynamic)	, cold-lo-warm	i transitions	)
- Helium ves	sel and in	terfaces, tuni	ng system. n	nagnetic/therm	nal shielding	
- Vacuum ve	ssel desig	n, structural	support, alig	nment		
Description of	Work					
Deliverables						Month
D1:						M12
D2:						M24
D3: Document r	esults		waara Marat			M48
CERN Resource	es (manp	ower) [Pe	rson. Mont	ns (PM)]		0
STAFF						0
						0
						0
FELL/PJAS						0
PhD						0
<b>CERN Resource</b>	es (Mate	rial) [kCHF	-			
Total budget est	imate:	2 Bit	-			0
-						0
						0
Arbitration dec	ision					

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5.2 FUNDAM	IENTAL PO	WER COUP	LERS			
Person						
months						
Type Objectives						
objectives						
Define a desig highest accele machine. How to build a Do we have to	in for the FC rating gradi a variable co b have two o	CC-ee RF system ient and ver oupler cover different fixe	stem to cover by high bean bing the Qex and couplers	er the requi n currents w t range ? ?	rements for vith the sam	both the e
<b>Description</b>	of Work					
Detailed study How to build a Do we have to Task 1: Study	y on the RF a variable FF o have two o y FPC conce	FPC: PC covering different fixe pts and opti	the Qext ra ed couplers ions, fixed v	nge ? ? s variable c	ouplers	
Deliverables						Month
D1: RF Simula	ations					M24
D2: 3D model						M48
CERN Resou	rces (Manr	ower) [Pe	rson. Mont	hs (PM)]		
STAFF						12
E. Mont	esinos					6
A. Bouc	cherie					6
FELL (1 x TTE	)					30
PhD	/					0
CERN Resou	rces (Mate	rial) [kCHF	]			
Total budget a	octimator					60
Travels	estimate.					10
Mockup	S					50
Arbitration d	lecision					

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5.3 TUNING	SYSTEM A	ND AUXILI	IARIES		<u>г г</u>	
Participant						
months						
Туре						
Objectives						
	C 147 1					
Description of	of Work					
Deliverables						Month
D1: Concepts	and parame	eters				M12
D2: Compone	nts and desi	ign				M24
D3: Documen	t results					M48
CERN Resou	rces (Manp	ower) [Pe	erson. Mont	ths (PM)]		0
STAFF						1
						2
FELL/PJAS						36
PhD						0
CERN Resou	rces (Matei	rial) [kCHF	=]			20
lotal budget e	estimate:					10
						10
Arbitration d	ecision					20

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6 LLRF SY	'STEM (W	I. HOFLE	)			
6.1 FAST CA	VITY FEED	BACKS FO	R COUPLE	D BUNCH	MODES. CA	VITY TRIP
HANDLI	NG – IMPEI	DANCE MI	TIGATION	1		
Participant						
Person months						
Туре						
Objectives						
-	C 14/ - 1					
Description of	of Work		for 7 polo	upping to		plad
Strong RF fee	driven by th	e necessary	ror z pole i ntal cavity i	running to a	suppress cou	pied
buildi modes	unven by ti			Inpedance		
Deliverables						Month
D1: Concepts	and parame	eters				M12
D2: Compone	nts and des	ign				M24
D3: Documen	t results					M48
<b>CERN Resou</b>	rces (Manp	ower) [Pe	rson. Mont	ths (PM)]		
STAFF						0
						0
						0
						-
FELL/PJAS						0
CEDN Desour	rcos (Mato		=1			0
Total budget e	stimate:		- 1			20
lotal baaget t	Sumate:					10
						10
Arbitration d	ecision					1

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7.1       POWER DISTRIBUTION SYSTEM FOR FCC-EE         Participant
Participant       Person         months
Person       Image: Construct of the state
months       Image: Mark Straight of the straight of the straight of the straight of the results of WP 1.1.         Objectives       - Conceptual design of the RF power distribution for FCC-ee         Description of Work
Type       Objectives         - Conceptual design of the RF power distribution for FCC-ee         Description of Work         The possible RF power distribution scenarios shall be elaborate and detailed in the light of the results of WP 1.1.         In particular a review of the existing technology shall be presented:         - Solid state amplifiers         - IOT's         - Klystrons
Objectives         - Conceptual design of the RF power distribution for FCC-ee         Description of Work         The possible RF power distribution scenarios shall be elaborate and detailed in the ight of the results of WP 1.1.         In particular a review of the existing technology shall be presented:         - Solid state amplifiers         - IOT's         - Klystrons
<ul> <li>Conceptual design of the RF power distribution for FCC-ee</li> <li>Description of Work</li> <li>The possible RF power distribution scenarios shall be elaborate and detailed in the ight of the results of WP 1.1.</li> <li>In particular a review of the existing technology shall be presented:         <ul> <li>Solid state amplifiers</li> <li>IOT's</li> <li>Klystrons</li> </ul> </li> </ul>
Description of Work The possible RF power distribution scenarios shall be elaborate and detailed in the ight of the results of WP 1.1. In particular a review of the existing technology shall be presented: <ul> <li>Solid state amplifiers</li> <li>IOT's</li> <li>Klystrons</li> </ul> Task 1: Evaluate and detail the possible scenarios (including estimation/comparison of cost & efficiency)
<ul> <li>The possible RF power distribution scenarios shall be elaborate and detailed in the ight of the results of WP 1.1.</li> <li>In particular a review of the existing technology shall be presented: <ul> <li>Solid state amplifiers</li> <li>IOT's</li> <li>Klystrons</li> </ul> </li> </ul>
In particular a review of the existing technology shall be presented: <ul> <li>Solid state amplifiers</li> <li>IOT's</li> <li>Klystrons</li> </ul> <li>Fask 1: Evaluate and detail the possible scenarios (including estimation/comparison of cost &amp; efficiency)</li>
<ul> <li>Solid state amplifiers</li> <li>IOT's</li> <li>Klystrons</li> </ul> Fask 1: Evaluate and detail the possible scenarios (including estimation/comparison of cost & efficiency)
<ul> <li>IOT's</li> <li>Klystrons</li> </ul> Fask 1: Evaluate and detail the possible scenarios (including estimation/comparison of cost & efficiency)
- Klystrons Fask 1: Evaluate and detail the possible scenarios (including estimation/comparison of cost & efficiency)
Task 1: Evaluate and detail the possible scenarios (including
Task 1: Evaluate and detail the possible scenarios (including
estimation/comparison of cost & efficiency)
Task 2: Simulate, design and built a movable 1/4 WG transformer (prototype)
Deliverables Month
<b>D1:</b> Concepts and parameters <b>M12</b>
D2: Components and design M24
D3: Document results M48
CERN Resources (Manpower) [Person. Months (PM)]
STAFF 3
ELL/PJAS 36
ELL/PJAS 36 PhD 0
ELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       0
ELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       50         Total budget estimate:       50
ELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       50         Fotal budget estimate:       50         O       0
ELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       50         Total budget estimate:       50         O       0         O       0
ELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       50         Total budget estimate:       50         0       0         Arbitration decision       0
FELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       0         Total budget estimate:       50         0       0         Arbitration decision       0         Second priority. To be reassessed when RF system is defined.       0
FELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       50         Total budget estimate:       50         0       0         Arbitration decision       0         Second priority. To be reassessed when RF system is defined.       50
FELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       50         Total budget estimate:       50         0       0         Arbitration decision       0         Second priority. To be reassessed when RF system is defined.       50
FELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       0         Total budget estimate:       50         0       0         Arbitration decision       0         Second priority. To be reassessed when RF system is defined.
FELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       50         Total budget estimate:       50         0       0         Arbitration decision       0         Second priority. To be reassessed when RF system is defined.       50
FELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       50         Total budget estimate:       50         0       0         Arbitration decision       0         Second priority. To be reassessed when RF system is defined.       50
FELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       0         Total budget estimate:       50         0       0         Arbitration decision       0         Second priority. To be reassessed when RF system is defined.       50
FELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       0         Total budget estimate:       50         0       0         Arbitration decision       0         Second priority. To be reassessed when RF system is defined.       50
FELL/PJAS       36         PhD       0         CERN Resources (Material) [kCHF]       0         Total budget estimate:       50         0       0         Arbitration decision       0         Second priority. To be reassessed when RF system is defined.       50

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.2 HIGH ∧	/OLTAGE C	HALLENGE	S FOR THE	HIGH PO	WER RF S	/STEM
articipant						
erson						
onths						
/ре						
bjectives						
odernize agi	ng technolo	gy and deve	elop robust a	and reliable	e HV equipr	nent for the
PRF system	(e.g. klystro	on modulato	rs, fast prot	ection syst	em)	
escription of	of Work					
lark angaing	for LUC +			or stopp		
vork ongoing	tor LHC - t	o de reasses	ssed at a lat	er stage		
eliverables						Month
1:						M12
2:						M24
3:						M48
ERN Resou	rces (Man	ower) [Pe	rson. Mont	:hs (PM)]		
TAFF						
ELL/PJAS						0
hD						0
ERN Resou	rces (Mate	rial) [kCHF	]			
otal budget e	estimate:					0
						0
						0
roitration d	lecision			tion		
ddressed in	the fram	work of the	ELHC opera	ation		

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7.3 DEVEL	OPMENT O	VERY HIC	GH EFFICIE	NCY KLYS	TRONS	
Participant						
Person						
months						
Туре						
Objectives						
Development efficiency	of klystrons	with ultima	itely high -	90% RF po	wer producti	on
<b>Description</b>	of Work					
Using new bui	nching theoi	ry 90% (at	least in sim	ulation) loo	ks possible f	or
FCC/CLIC/ESS	5 klystrons					
Low voltages	achievable					
No new techno	ology, simpl	y a design l	breakthroug	Jh		
Ductoty up o o o		lidetice ver	ive d			
Prototypes an	a further va	lidation req	uirea			
Deliverables						Month
D1: Concents	and narame	eters				M12
D2: Compone	onts and des	ian				M24
D3: Documen	it results	igii				M48
CERN Resou	rces (Mann	ower) [Pe	rson. Mon	ths (PM)]		
STAFF						0
						0
						0
FELL/PJAS						0
PhD						0
CERN Resou	rces (Mate	rial) [kCHF	-]			
Total budget e	estimate:					0
						0
Aubituation d	locicion					0
Arbitration d	ecision	work of the	CLIC proj	oct		
Addressed II	i the framy		e CLIC proj	ect		

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/					
7.4 SOLID STATE	AMPLIFIERS				
Participant					
Person					
months					
Туре					
Objectives					
High power solid stat	te amplifiers tec	chnology – st	art of the a	rt, advances	&
perspectives					
<b>Description of Wor</b>	k				
Deliverables					Month
D1:					M12
D2:					M24
D3:					M48
<b>CERN Resources (I</b>	Manpower) [Po	erson. Mont	:hs (PM)]		
STAFF					0
					0
					0
FELL/PJAS					0
PhD					0
<b>CERN Resources (I</b>	4aterial) [kCH	F]			
Total budget estimat	e				0
					0
					0
Arbitration decisio	n	-			
Second priority. To	be reassesse	d			

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7.5 INDUCTIVE OUTPUT TUBE (IOT)         Person         nonths         Pype         Dbjectives         IOTs designed for various applications         Series production has been < 100 kW         ESS requires 1.2 MW plus overhead         Future machines require:         More power another factor of 10?         Better efficiency         Better reliability         Smaller footprint, etc         Deliverables         D1: Concepts and parameters         M12         D2: Components and design	7.5 INDUCTIVE OUTPUT TUBE (IOT)         Participant         Person         months         Type         Objectives         Objectives         IOTs designed for various applications         Series production has been < 100 kW         ESS requires 1.2 MW plus overhead         Future machines require:         More power another factor of 10?         Better efficiency         Better reliability         Smaller footprint, etc         Deliverables         Month         D1: Concents and parameters	.5 INDUCTIVE OUTPUT TUBE (IOT)		
Participant       Image: Constraint of the second sec	Participant		7.5 INDUCTIVE OUTPUT TUBE (IOT)	
Person       Image: Constraint of the second s	Person       Image: Constraint of the second s	articipant	Participant	
nonths       Image: Construction of the second	months       Image: Market Strength Strengt Strengt Strength Strength Strengt Strength Strength St		Person	
ype       Iors       Month         Dbjectives       IOTs designed for various applications       Series production has been < 100 kW	Type       Image: Constraint of the second sec	Person	months	
Dbjectives         IOTs designed for various applications         Series production has been < 100 kW	Objectives         IOTs designed for various applications         Series production has been < 100 kW	Person nonths	Гуре	
IOTs designed for various applications         Series production has been < 100 kW	IOTs designed for various applications Series production has been < 100 kW ESS requires 1.2 MW plus overhead Future machines require: More power another factor of 10? Better efficiency Better reliability Smaller footprint, etc Description of Work Deliverables Month M12	verson nonths ype	Objectives	
Series production has been < 100 kW	Series production has been < 100 kW ESS requires 1.2 MW plus overhead Future machines require: More power another factor of 10? Better efficiency Better reliability Smaller footprint, etc Description of Work Month Deliverables Month M12	Person nonths ype Dbjectives	IOTs designed for various applications	
ESS requires 1.2 MW plus overhead Future machines require: More power another factor of 10? Better efficiency Better reliability Smaller footprint, etc Description of Work Deliverables Month D1: Concepts and parameters M12 D2: Components and design M24	ESS requires 1.2 MW plus overhead Future machines require: More power another factor of 10? Better efficiency Better reliability Smaller footprint, etc  Description of Work  Deliverables Month 1: Concepts and parameters M12	Person nonths ype D <b>jectives</b> IOTs designed for various applications	Series production has been $< 100 \text{ kW}$	
Future machines require:         More power another factor of 10?         Better efficiency         Better reliability         Smaller footprint, etc         Description of Work         Deliverables       Month         D1: Concepts and parameters       M12         D2: Components and design       M24	Future machines require:         More power another factor of 10?         Better efficiency         Better reliability         Smaller footprint, etc         Description of Work         Deliverables         Month         1: Concepts and parameters	Person     Image: Constraint of the second sec	ESS requires 1.2 MW plus overhead	
Future machines require:         More power another factor of 10?         Better efficiency         Better reliability         Smaller footprint, etc         Description of Work         Deliverables         D1: Concepts and parameters         M12         D2: Components and design	Future machines require:         More power another factor of 10?         Better efficiency         Better reliability         Smaller footprint, etc         Description of Work         Deliverables         D1: Concepts and parameters	Person     Image: Constraint of the second sec		
More power another factor of 10?         Better efficiency         Better reliability         Smaller footprint, etc         Description of Work         Deliverables         D1: Concepts and parameters         M12         D2: Components and design         M24	More power another factor of 10? Better efficiency Better reliability Smaller footprint, etc Description of Work  Deliverables Month P1: Concepts and parameters M12	Person     Image: Construction of the second s	Future machines require:	
Better reliability Smaller footprint, etc Description of Work Deliverables Month D1: Concepts and parameters M12 D2: Components and design M24	Description of Work Deliverables Month D1: Concepts and parameters M12	Person     Image: Construction on the second s	More power another factor of 10?	
Smaller footprint, etc	Description of Work       Deliverables     Month       D1: Concepts and parameters     M12	Person nonths ype Dbjectives IOTs designed for various applications Series production has been < 100 kW ESS requires 1.2 MW plus overhead Future machines require: More power another factor of 10? Better officiency	Better reliability	
Description of Work Deliverables Deliverables D1: Concepts and parameters D2: Components and design M24 M48	Description of Work Deliverables Month D1: Concepts and parameters M12	Person       Image: Construct of the second se	Smaller footprint, etc.	
Description of Work Deliverables Deliverables D1: Concepts and parameters D2: Components and design M24 M48	Description of Work Deliverables Month D1: Concepts and parameters M12	Person       Image: Construct of the second se		
Description of Work Deliverables D1: Concepts and parameters D2: Components and design M24 M48	Description of Work Deliverables Month D1: Concepts and parameters M12	Person       Image: Construct of the second se		
DeliverablesMonthD1: Concepts and parametersM12D2: Components and designM24D3: Desument resultsM48	Deliverables Month	Person       Instruction         Nonths       Image: state stat	Description of Work	
DeliverablesMonthD1: Concepts and parametersM12D2: Components and designM24D3: Desument resultsM48	Deliverables Month	Person       Image: Constraint of the second state of the second s		
D1: Concepts and parameters     M12       D2: Components and design     M24       D3: Desument results     M48	01: Concepts and parameters M12	Person       Image: Constraint of the second s	Deliverables	Month
M24     M24	The concepts and parameters MIZ	Person       Image: Constraint of the second s	D1: Concepts and parameters	M12
N/O	<b>D2:</b> Components and design <b>M24</b>	Person       Image: Constraint of the second s	<b>D2:</b> Components and design	M24
<b>M48</b>	D3: Document results M48	Person       Image: Constraint of the second s	Document results	M48
CERN Resources (Manpower) [Person. Months (PM)]		Person       Image: Constraint of the second s	CERN Resources (Manpower) [Person. Months (PM)]	
O O	CERN Resources (Manpower) [Person. Months (PM)]	Person       Image: Constraint of the second s	STAFF	0
0	CERN Resources (Manpower) [Person. Months (PM)]     0	Person       Image: Constraint of the second s		0
0	CERN Resources (Manpower) [Person. Months (PM)]     0       STAFF     0	Person       Months         ype       Image: Second S		0
	CERN Resources (Manpower) [Person. Months (PM)]       STAFF       0       0	Version       Months         ype       IOTs designed for various applications         Series production has been < 100 kW		•
ELL/PJAS U	CERN Resources (Manpower) [Person. Months (PM)]       STAFF       0       0       0	Person       Image: Constraint of the second s	-ELL/PJAS	0
	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O         FELL/PJAS         O         O         O	Person       Nonths         Nype       Initial Init		0
CERN Resources (Material) [KCHF]	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O	Person       Initial and and a stress of the s		0
	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O	Person       Initial and a strengthy a strengthy and a strengthy a strengthy and a strengthy and a strengthy a strengthy and a strengthy a strengthy and a strenging thy a strengthy and a strenging the strengthy and	iotal budget estimate:	0
0	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O	Person       Image: Constraint of the second s		0
0	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O         O         O         O         ELL/PJAS         O         PhD         CERN Resources (Material) [kCHF]         O	Person       Image: Constraint of the second s		()
0 0	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O         FELL/PJAS         O         PhD         CERN Resources (Material) [kCHF]         Total budget estimate:         O	Person       Image: Constraint of the second s	hitration decision	
0 0 Arbitration decision	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         PhD         O         O         PhD         O         D         O         PhD         O         D         O <td>Person       Months         ype       IO         Dbjectives       IOTs designed for various applications         Series production has been &lt; 100 kW</td> ESS requires 1.2 MW plus overhead         Future machines require:         More power another factor of 10?         Better efficiency         Better reliability         Smaller footprint, etc         Description of Work         Disconcepts and parameters       M12         Disconcepts and parameters       M12         Disconcepts (Manpower) [Person. Months (PM)]       TAFF         O       0         ELL/PJAS       0         hD       0         ERN Resources (Material) [kCHF]       0         otal budget estimate:       0         O       0         O       0         O       0	Person       Months         ype       IO         Dbjectives       IOTs designed for various applications         Series production has been < 100 kW	Arbitration decision	tion with ESS
0         0 <td< td=""><td>CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O</td><td>Person       Image: Second Secon</td><td>Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora</td><td>tion with ESS.</td></td<>	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O	Person       Image: Second Secon	Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora	tion with ESS.
0 O Arbitration decision Addressed in the framwork of the SPL/ESS study. Collaboration with ESS.	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         CERN Resources (Material) [kCHF]         Total budget estimate:         O <td>Person       Interview       Interview</td> <td>Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora</td> <td>ition with ESS.</td>	Person       Interview	Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora	ition with ESS.
0 O Arbitration decision Addressed in the framwork of the SPL/ESS study. Collaboration with ESS.	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O         CERN Resources (Material) [kCHF]         Total budget estimate:         O <td>Person       Image: Constraint of the set of the</td> <td>Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora</td> <td>ition with ESS.</td>	Person       Image: Constraint of the set of the	Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora	ition with ESS.
0 O Arbitration decision Addressed in the framwork of the SPL/ESS study. Collaboration with ESS.	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O	Terson       Image: Construct of the second se	Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora	ition with ESS.
0 O Arbitration decision Addressed in the framwork of the SPL/ESS study. Collaboration with ESS.	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O	Terson       Image: Constraint of the second s	Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora	ition with ESS.
0 O Arbitration decision Addressed in the framwork of the SPL/ESS study. Collaboration with ESS.	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O	Terson       Image: Constraint of the set of the	Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora	tion with ESS.
0 0 Arbitration decision Addressed in the framwork of the SPL/ESS study. Collaboration with ESS.	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         O         0	Image: State of the state of the second state of the se	Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora	ition with ESS.
0 O Arbitration decision Addressed in the framwork of the SPL/ESS study. Collaboration with ESS.	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         0	Image: Solution of the second seco	Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora	ition with ESS.
0 0 Arbitration decision Addressed in the framwork of the SPL/ESS study. Collaboration with ESS.	CERN Resources (Manpower) [Person. Months (PM)]         STAFF         0	Image: series of the series	Arbitration decision Addressed in the framwork of the SPL/ESS study. Collabora	ition with ESS.
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## ANNEX A: MANDATE OF FCC SRF WP

The mandate of the FCC Radio Frequency (SRF) Work Package has been defined as follow:

- Study the RF technologies including conceptual aspects required for the FCC accelerator and identify the possible design and performance limitations for the accelerator.
- Identify challenges, opportunities for technological breakthroughs and set the R&D program.
  - Understand impacts of technologies
  - Prioritize R&D topics
  - Define scope, schedule, cost guidelines
  - Reporting on Specific Technologies R&D Programs
- Set up collaborations to address standard FCC issues and R&D opportunities
- The R&D activities will then be followed in the frame of the Accelerator R&D Work Package which is sub-divided in three Sub-Work Packages:
  - High field Magnet Program
  - Superconducting RF Program
  - Special Technology Program (all except Magnet and RF)

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## ANNEX B: SRF WBS STRUCTURE (DRAFT)

To ease understanding the organisation of the different items, the WBS struture has been rearraged accordingly:

Energy driven

Power driven

Beam driven

Reliability driven

Radiation driven

Accelerator driven

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## **ANNEX C: RESPONSIBLE PERSONS**

The following Table aims at easing contacts with CERN Sub-Tasks Coordinators WP # Description Contact Person COLLABORATION AGREEMENT P. CHIGGIATO (CERN) "KE2722/BE/FCC" CAVITY DESIGN R. CALAGA (CERN) CAVITY MATERIAL AND WALTER VENTURINI PERFORMANCE DELSOLARO (CERN) KARL SCHIRM (CERN) CAVITY FABRICATION **CRYOMODULE CHALLENGES** KARL SCHIRM (CERN) LLRF SYSTEM W. HOFLE (CERN) POWER SYSTEM TBD

### ANNEX D: CERN RESOURCES (PERSONNEL & MATERIAL)

**ANNEX E: ARBITRATION: FELL, DOCTS & MATERIAL**