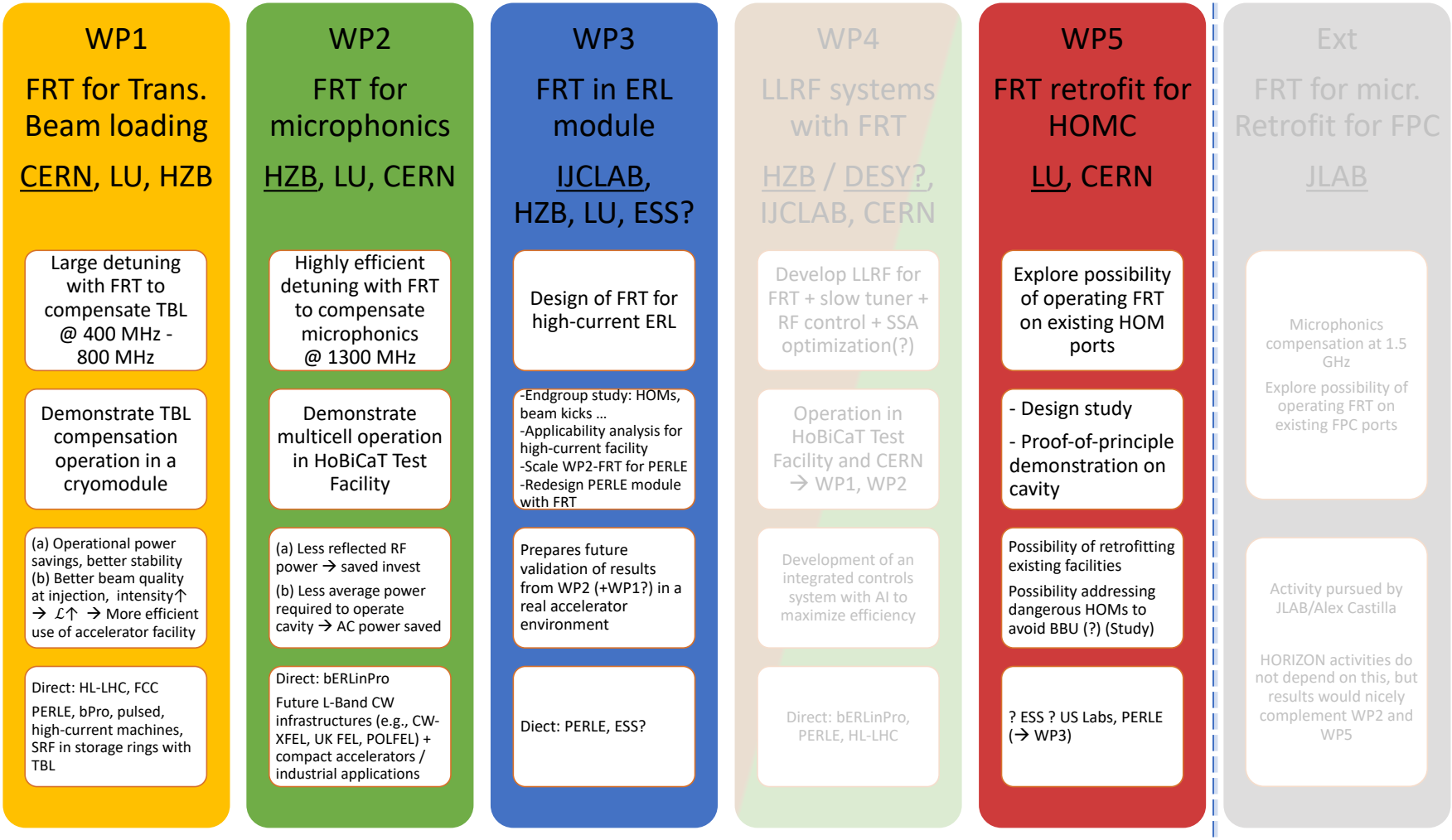
TA#1 FRT

J. Knobloch with lots of help from A. Macpherson and N. Shipman


WP1
FRT for Trans. Beam loading
CERN, LU, HZB
Large detuning with FRT to compensate TBL @ 400 MHz - 800 MHz
Demonstrate TBL compensation operation in a cryomodule
(a) Operational power savings, better stability
(b) Better beam quality at injection, intensity↑ → ℒ↑ → More efficient use of accelerator facility
Direct: HL-LHC, FCC
PERLE, bPro, pulsed, high-current machines, SRF in storage rings with TBL
WP2
FRT for microphonics
HZB, LU, CERN
Highly efficient detuning with FRT to compensate microphonics @ 1300 MHz
Demonstrate multicell operation in HoBiCaT Test Facility
(a) Less reflected RF power → saved invest
(b) Less average power required to operate cavity → AC power saved
Direct: bERLinPro
Future L-Band CW infrastructures (e.g., CW-XFEL, UK FEL, POLFEL) + compact accelerators / industrial applications
WP3
FRT in ERL module
IJCLAB, HZB, LU, ESS?
Design of FRT for high-current ERL
-Endgroup study: HOMs, beam kicks …
-Applicability analysis for high-current facility
-Scale WP2-FRT for PERLE
-Redesign PERLE module with FRT
Prepares future validation of results from WP2 (+WP1?) in a real accelerator environment
Diect: PERLE, ESS?
WP4
LLRF systems with FRT
HZB / DESY?, IJCLAB, CERN
Develop LLRF for FRT + slow tuner + RF control + SSA optimization(?)
Operation in HoBiCaT Test Facility and CERN → WP1, WP2
Development of an integrated controls system with AI to maximize efficiency
Direct: bERLinPro, PERLE, HL-LHC
WP5
FRT retrofit for HOMC
LU, CERN
Explore possibility of operating FRT on existing HOM ports
- Design study
- Proof-of-principle demonstration on cavity
Possibility of retrofitting existing facilities
Possibility addressing dangerous HOMs to avoid BBU (?) (Study)
? ESS ? US Labs, PERLE (→ WP3)
Ext
FRT for micr. Retrofit for FPC
JLAB
Microphonics compensation at 1.5 GHz
Explore possibility of operating FRT on existing FPC ports
Activity pursued by JLAB/Alex Castilla
HORIZON activities do not depend on this, but results would nicely complement WP2 and WP5

Summary over all activities

Totals	Entries	Horizon Costs	FTEy (Horizon)	Invest (Horizon)	FTEy (matching)	Invest (matching)	Scaled
Minimal	16	721 k€	4,625	258 k€	3,375	124 k€	638 k€
Nominal	32	1249 k€	8	449 k€	6,25	299 k€	1275 k€
Ambitious	42	1674 k€	10,75	599 k€	8,25	319 k€	1674 k€
Current assumption for FTE cost is:			100 k€/FTEy				
What about Travel/Collaboration funds? How much?							

Partners:
CERN, Lancaster University, IJCLAB, HZB

Summary of the WPs

	FRTs for Transient detuning		Rational	Benefit	Entries	Horizon Costs	FTEy (Horizon)	Invest (Horizon)	FTEy (matching)	Invest (matching)
WP1	Minimal	Implement and test FRT in 400 MHz test cryomodule	FRT design is already in development, cryomodule exisits	Validation for HL-LHC	3	**170 k€**	1	70 k€	1	30 k€
	Nominal	Minimal + Design study for TD of 800 MHz multi-cell	Design work only requires FTE, lays basis for PERLE/WP3	Ready for proof-of-concept for PERLE/WP3, FCC-ee	8	**328 k€**	2	128 k€	2	72 k€
	Ambitious	Nominal + Fabrication & RF test of tuner performance	Testing would provide more solid basis for PERLE/WP3	Proof-of-concept for PERLE/WP3, FCC-ee	12	**518 k€**	3	218 k€	3	82 k€
	FRTs for Microphonics detuning		Rational	Benefit	Entries	Horizon Costs	FTEy (Horizon)	Invest (Horizon)	FTEy (matching)	Invest (matching)
WP2	Minimal	Design/ Fabricate/RF test of FRT for single-cell cavity at 1300 MHz	Single cells exist, material properties and FoM can be abalized	FoM proof-of-concept for 1.3 GHz operation	9	**413 k€**	2,25	188 k€	1,625	94 k€
	Nominal	Minimal + Design/ Fabricate/RF test of FRT for multi-cell cavity at 1300 MHz	Multi-cell cavity exists, full demonstration of microphonics compensation under realistic conditions lays solid foundation for CW XFEL, bERLinPro …	FoM proof-of-concept for CW XFEL, bERLinPro + all 1.3 GHz CW machines	17	**721 k€**	4	321 k€	3,25	227 k€
	Ambitious	Nominal + Design integration into bPro LINAC module	Implement lessons learned to ready LINAC module design for production with FRT	bERLinPro ready for LINAC production	18	**746 k€**	4,25	321 k€	3,75	227 k€
	FRTs for ERL CM		Rational	Benefit	Entries	Horizon Costs	FTEy (Horizon)	Invest (Horizon)	FTEy (matching)	Invest (matching)
WP3	Minimal	End-group design study; mechanics + BBU	FTE only, Study to determine feasibility of WP1 FRT (nominal) for use in high-current ERL	PERLE, ESS, mid-frequency high-current CW machines	2	**63 k€**	0,625			
	Nominal	Minimal + FRT design study (RF + Mechanics) for ERL				**€**	1			
	Ambitious	Nominal + design study to adapt PERLE CM	v2 Module design ready for PERLE --> link to TA#3	FRT module design for PERLE "ready" for production	6	**200 k€**	2			
	Adapting FRTs		Rational	Benefit	Entries	Horizon Costs	FTEy (Horizon)	Invest (Horizon)	FTEy (matching)	Invest (matching)
WP5	Minimal	RF Design study for combined FRT + HOMS at 400 - 1300 MHz	FTE only, Study of feasibility for HOM port use of FRT	Show-stoppers reviewed for CW Accelerators with HOM ports	2	**75 k€**	0,75		0,75	
	Nominal	Minimal + Mechanical design and integration	FTE only, Design ready for production	PERLE, ESS retrofit design ready	3	**100 k€**	1		1	
	Ambitious	Nominal + Fabrication & RF test of tuner performance	Invest required	Proof-of-concept for HOM retrofit PERLE, ESS	6	**210 k€**	1,5	60 k€	1,5	10 k€

Feedback still needed for WP3

	FRTs for Transient detuning		Rational	Benefit	Entries	Horizon Costs	FTEy (Horizon)	Invest (Horizon)	FTEy (ma
WP1	Minimal	Implement and test FRT in 400 MHz test cryomodule	FRT design is already in development, cryomodule exisits	Validation for HL-LHC	3	**170 k€**	1	70 k€	1
	Nominal	Minimal + Design study for TD of 800 MHz multi-cell	Design work only requires FTE, lays basis for PERLE/WP3	Ready for proof-of-concept for PERLE/WP3, FCC-ee	8	**328 k€**	2	128 k€	2
	Ambitious	Nominal + Fabrication & RF test of tuner performance	Testing would provide more solid basis for PERLE/WP3	Proof-of-concept for PERLE/WP3, FCC-ee	12	**518 k€**	3	218 k€	3
	FRTs for Microphonics detuning		Rational	Benefit	Entries	Horizon Costs	FTEy (Horizon)	Invest (Horizon)	FTEy (ma
WP2	Minimal	Design/ Fabricate/RF test of FRT for single-cell cavity at 1300 MHz	Single cells exist, material properties and FoM can be abalized	FoM proof-of-concept for 1.3 GHz operation	9	**413 k€**	2,25	188 k€	1,62
	Nominal	Minimal + Design/ Fabricate/RF test of FRT for multi-cell cavity at 1300 MHz	Multi-cell cavity exists, full demonstration of microphonics compensation under realistic conditions lays solid foundation for CW XFEL, bERLinPro …	FoM proof-of-concept for CW XFEL, bERLinPro + all 1.3 GHz CW machines	17	**721 k€**	4	321 k€	3,2
	Ambitious	Nominal + Design integration into bPro LINAC module	Implement lessons learned to ready LINAC module design for production with FRT	bERLinPro ready for LINAC production	18	**746 k€**	4,25	321 k€	3,7
	FRTs for ERL CM		Rational	Benefit	Entries	Horizon Costs	FTEy (Horizon)	Invest (Horizon)	FTEy (ma
WP3	Minimal	End-group design study; mechanics + BBU	FTE only, Study to determine feasibility of WP1 FRT (nominal) for use in high-current ERL	PERLE, ESS, mid-frequency high-current CW machines	2	**63 k€**	0,625		
	Nominal	Minimal + FRT design study (RF + Mechanics) for ERL	Implement WP1 (nominal) results @800 MHz to design FRT for PERLE	FRT design developed PERLE, ESS upgrade	4	**100 k€**	1		
	Ambitious	Nominal + design study to adapt PERLE CM	v2 Module design ready for PERLE --> link to TA#3	FRT module design for PERLE "ready" for production	6	**200 k€**	2		
	Adapting FRTs		Rational	Benefit	Entries	Horizon Costs	FTEy (Horizon)	Invest (Horizon)	FTEy (ma
WP5	Minimal	RF Design study for combined FRT + HOMS at 400 - 1300 MHz	FTE only, Study of feasibility for HOM port use of FRT	Show-stoppers reviewed for CW Accelerators with HOM ports	2	**75 k€**	0,75		0,7
	Nominal	Minimal + Mechanical design and integration	FTE only, Design ready for production	PERLE, ESS retrofit design ready	3	**100 k€**	1		1
	Ambitious	Nominal + Fabrication & RF test of tuner performance	Invest required	Proof-of-concept for HOM retrofit PERLE, ESS	6	**210 k€**	1,5	60 k€	1,5

Breakdown within WP1

	WP1: FRT for TBL					Horizon		Matching			
	Task		Min	Nom	Amb	Personnel	Invest	Personnel	Invest	Milestone	Comment
Year 1	1-1.1	Adapt exisitng/design and build new 400MHz FRT for integration into LHC ¼ cryomodule.	1	1	1	0,25	50 k€	0,25		FRT adapted for cryomod	Matching Manpower: CERN?
	1-1.2	Integrate FRT equipped cavity into LHC cryomodule	1	1	1	0,375	20 k€	0,375		Cryomodule equipped with FRT cavity	Matching Manpower: CERN?
		Minimal	2			0,625	70 k€	0,625			
		Nominal	2			0,625	70 k€	0,625			
		Ambitious	2			0,625	70 k€	0,625			
Year 2	1-2.1	High power tests of FRT equipped cavity in LHC ¼ cryomodule	1	1	1	0,375		0,375	30 k€	FRT cryomodule tested	Matching Manpower: CERN?
	1-2.1	Rf and mechanical design and construction of new FE characterization setup for 600 MHz - 800 MHz		1	1	0,125	28 k€	0,125	12 k€	FE characterization setup ready	Matching Manpower: CERN?
	1-2.3	FE Characterisation @ 600MHz -800MHz		1	1	0,125		0,125		FE material characterized	Matching Manpower: CERN?
	1-2.4	RF design of FRT for multicell FCC TD application		1	1	0,25		0,25		FRT design completed	Matching Manpower: CERN?
		Minimal	1			0,375		0,375	30 k€		
		Nominal	4			0,875	28 k€	0,875	42 k€		
		Ambitious	4			0,875	28 k€	0,875	42 k€		
Year 3	1-3.1	Mechanical Design and Manufacture of FRT for multicell FCC TD application		1	1	0,25	30 k€	0,25	10 k€	FRT produced	
	1-3.2	Vertical Cold test of FRT and bare multicell cavity (SEL mode)		1	1	0,25		0,25	20 k€	VTA cold test with FRT performed	
	1-3.4	Equip multicell cavity with FRT, jacket and slow tuner			1	0,25	50 k€	0,25			
		Minimal									
		Nominal	2			0,5	30 k€	0,5	30 k€		
		Ambitious	3			0,75	80 k€	0,75	30 k€		
Year 4	1-4.1	Adapt HoBiCaT to accommodate multicell cavity			1	0,25	20 k€	0,25		Cryomodule equipped with FRT cavity	Microphonics generation installed in WP2
	1-4.2	Test multicell jacketed with FRT and slow tuner (GD mode) in HoBiCaT			1	0,25	20 k€	0,25	10 k€	FRT cryomodule tested	at HZB
	1-4.3	Design integration of FRT equipped cavity into existing LHC cryomodule			1	0,25		0,25			
		Minimal									
		Nominal									
		Ambitious	3			0,75	40 k€	0,75	10 k€		

Breakdown within WP2

WP2: FRT for microphonics					Horizon		Matching			
Task		Min	Nom	Amb	Personnel	Invest	Personnel	Invest	Milestone	Comment
2-1.1	RF & mechanical design and construction of new FE characterization setup for 1.3GHz	1	1	1	0,25	28 k€	0,25	12 k€	FE characterization setup ready	Partially as visitor at CERN for knowledge transfer via WP1
2-1.2	FE Characterisation @ 1.3GHz	1	1	1	0,25				FE material characterized	
2-1.3	RF design and mechanical design of FRT for 1.3GHz single-cell cavity microphonics compensation	1	1	1	0,5	30 k€	0,25	10 k€	FRT design completed	
2-1.4	Procure equipment to run FRT tests at HZB (chiller, HV, ...)	1	1	1		25 k€		12 k€		
	Minimal	4			1	83 k€	0,5	34 k€		
	Nominal	4			1	83 k€	0,5	34 k€		
	Ambitious	4			1	83 k€	0,5	34 k€		
2-2.1	Mechanical Design and Manufacture of FRT	1	1	1		30 k€	0,25	10 k€	FRT#1 produced	
2-2.2	Vertical cold test of FRT single-cell cavity	1	1	1	0,25	15 k€	0,125	15 k€	Cold test of single-cell complete	Test at HZB or CERN
2-2.3	Jacket single cell cavity	1	1	1		15 k€	0,125		Single-cell jacketed	
2-2.4	Design modification 1.3 GHz multicell TESLA cavity for FRT		1	1	0,25		0,25		Multicell design adapted	
2-2.5	Design FRT for 1.3 GHz multicell cavity		1	1	0,5		0,25		Design multicell adaptaion	
	Minimal	3			0,25	60 k€	0,5	25 k€		
	Nominal	5			1	60 k€	1	25 k€		
	Ambitious	5			1	60 k€	1	25 k€		
2-3.1	HoBiCaT test single-cell cavity with FRT (SEL mode)	1	1	1	0,5	15 k€	0,125	15 k€	Single-cell tested in HoBiCaT	
2-3.2	Modify existing multicell TESLA cavity to accommodate FRT		1	1		30 k€	0,5	100 k€	Multicell ready to accomodate FRT	Use existing 9-cell and adapt beam tube
2-3.3	Fabricate FRT for multicell cavity		1	1	0,125	30 k€	0,125	10 k€	FRT for multicell produced	at CERN?
2-3.4	Vertical cold test of FRT + multicell cavity (SEL mode)		1	1	0,25	33 k€	0,125	13 k€	Vertical test FRT with multicell	Large VTS@HZB or at CERN
2-3.5	Prepare FRT/multicell integration into HoBiCaT		1	1	0,125	10 k€	0,125		HoBiCaT ready for multicell and FRT	
	Minimal	1			0,5	15 k€	0,125	15 k€		
	Nominal	5			1	118 k€	1	138 k€		
	Ambitious	5			1	118 k€	1	138 k€		
2-4.1	LLRF + FRT tests in HoBiCaT	1			0,5	30 k€	0,5	20 k€		
2-4.2	Perform HoBiCaT Test of FRT with multicell (GD mode)		1	1	0,5	30 k€	0,25			
2-4.3	LLRF + FRT + Slow Tuner (+ Piezo?) tests in HoBiCaT		1	1	0,25	30 k€	0,25	30 k€		
2-4.4	Concept study of FRT in bERLinPro LINAC module		1	1	0,25		0,25			
2-4.5	Integrate FRT design into bERLinPro LINAC module			1	0,25		0,5			
	Minimal	1			0,5	30 k€	0,5	20 k€		
	Nominal	3			1	60 k€	0,75	30 k€		
	Ambitious	4			1,25	60 k€	1,25	30 k€		

Breakdown within WP3

Task	WP3: FRT integration into PERLE cryomodule	Min	Nom	Amb	Horizon Personnel	Horizon Invest	Matching Personnel	Matching Invest	Milestone	Comment
3-1.1	Full RF Design of FRT for microphonics compensation @800MHz		1	1	0,25					RF Design ready for 800 MHz FRT
3-1.2	Mechanical Design of FRT for microphonics compensation @800MHz		1	1	0,125					Mechanical design ready for 800 MHz FRT production
	Minimal									
	Nominal	2			0,375					
	Ambitious	2			0,375					
3-2.1	Redesign of Endgroup with FRT port	1	1	1	0,25					
3-2.1	Study of effect of FRT on HoMs, BBU, coupler kick with view to high-current, multi-turn operation	1	1	1	0,375					
3-2.3										
3-2.4										
3-2.5										
	Minimal	2			0,625					
	Nominal	2			0,625					
	Ambitious	2			0,625					
3-3.1	Design study to adapt PERLE cryomodule for FRT			1	0,5				Concept for FRT integration into PERLE module ready for design	
	Minimal									
	Nominal									
	Ambitious	1			0,5					
3-3.1	Integration study to adapt PERLE cryomodule for FRT			1	0,5				Redesign of PERLE module for FRT ready	
	Minimal									
	Nominal									
	Ambitious	1			0,5					

Breakdown within WP5

Task	WP5: FRT retrofit for HOM ports	Min	Nom	Amb	Horizon Personnel	Horizon Invest	Matching Personnel	Matching Invest	Milestone	Comment
5-1.1	Analyze concept of FRT on HOM port	1	1	1	0,375		0,375		Feas. Report: cavity type , f, Micr vs TD, FRT-HoM concept, HoM mitigation e.g. damping vs. detuning	Matching: LU, Decision point on frequency/cavity type
	Minimal	1			0,375		0,375			
	Nominal	1			0,375		0,375			
	Ambitious	1			0,375		0,375			
5-2.1	RF Design of FRT-HoM device for a cavity with existing HOM port	1	1	1	0,375		0,375		RF design to meets criteria identified in previous milestone.	Matching Manpower covered by Lancasetr
5-2.2	Mechanical Design of FRT-HoM device		1	1	0,25		0,25		Full mechanical design and tech drawings.	Matching Manpower covered by Lancasetr
5-2.3	Development of LLRF, measurement and controls for test			1	0,125		0,125		LLRF, measurement and controls developed and tested.	Matching Manpower to be sourced
	Minimal	1			0,375		0,375			
	Nominal	2			0,625		0,625			
	Ambitious	3			0,75		0,75			
5-3.1	Fabrication of FRT-HoM device.			1	0,125	30 k€	0,125	10 k€	FRT-HoM device built	Matching Manpower to be sourced
5-3.2	Testing of FRT-HoM device in vertical cryostat or HobiCat			1	0,25	30 k€	0,25		FRT-HoM device tested	Matching Manpower to be sourced
	Minimal									
	Nominal									
	Ambitious	2			0,375	60 k€	0,375	10 k€		
	Minimal									
	Nominal									
	Ambitious									