17th March 2004

JRA2 in the CARE proposal

Title: Charge production with Photo-injectors

Acronym: PHIN **Coordinator: A. Ghigo (INFN-LNF)**

Deputy: L. Rinolfi (CERN)

Participating Laboratories and Institutes:

Institute	Acronym	Country	Coordinator	PHIN Scientific Contact	Associated to
CCLRC Rutheford Appletone Lab. (20)	CCLRC-RAL	UK	P. Norton	G. Hirst	
CERN Geneva (17)	CERN	CH	G. Guignard	G. Suberlucq	
CNRS-IN2P3 Orsay (3)	CNRS-Orsay	F	T. Garvey	G. Bienvenu	CNRS
CNRS Lab. Optique Appl. Palaiseau (3)	CNRS-LOA	F	T. Garvey	V. Malka	CNRS
ForschungsZentrum ELBE (9)	FZR-ELBE	D	J. Teichert	J. Teichert	
INFN-Lab. Nazionali di Frascati (10)	INFN-LNF	I	S. Guiducci	A. Ghigo	INFN
INFN- Milan (10)	INFN-MI	I	C. Pagani	I. Boscolo	INFN
Twente University- Enschede (12)	TEU	NL	J.W.J. Verschuur	J.W.J. Verschuur	

Main Objectives: Perform Research and Development on charge-production by interaction of laser pulse with material within RF field and improve or extend the existing infrastructures in order to fulfil the objectives. Coordinate the efforts done at various Institutes on photo-injectors.

Cost:

Total Cost	Requested Cost
3.851 M€(FC) + 2.150 M€(AC) Total = 6.001 M€	**3.542 M€**

JOINT RESEARCH ACTIVITY ON PHOTOINJECTORS (JRA3 – PHIN)

The JRA on photoinjector is mainly devoted to improve the characteristics of the electron sources for the future e^+e^- colliders. In particular the PHIN JRA is addressed to:

- Development of the high charge e^- beam (drive beam) for the RF power source of the two-beam linear collider CLIC (CERN).
- Realisation of high brightness e^- beam for CLIC main beam studies and for tests of linear collider sub-systems.
- Realisation of the first photoinjector that uses a photocathode, laser driven, in a superconducting RF gun for application in ELBE (Rossendorf) and possible use in TESLA Test Facility (Desy).
- Study of the TESLA electron source.
- Realisation of new electron source for NEPAL (Orsay) test stand.
- Realisation of the new injector for TEU-FEL (Twente). Realization of new photo cathodes and methods to improve the stability and durability of the cathodes under various modes of operation, including laser duration and power.

Benefits are also expected in picosecond and femtosecond chemistry, cancer therapy, medical imaging, light sources and free-electron lasers. Concerning the latter, side benefits exchange of information and common workshops are planned with the complementary JRA dealing with the studies of the generation of transversely strongly-cooled e^- beams specifically needed for synchrotron radiation sources.

The technique of charge-production studied in this JRA covers the interaction of lasers with photoemissive materials within an RF field. The goal is to produce an electron source with brightness unachievable with conventional thermoionic gun. In fact two features contribute to improve simultaneously the charge, the current and the emittance of the beam: the first is due to the fact that the electron current density production is more efficient in the photoemission process respect to the thermoionic one. The second is that the voltage on cathode, necessary to reduce the space charge and the electron shielding effects, is much higher in an RF gun (100MV/m) respect the DC one (10 MV/m).
The peak current from photoinjector is at least one order of magnitude higher than a thermoionic injector and the emittance is one order of magnitude lower.

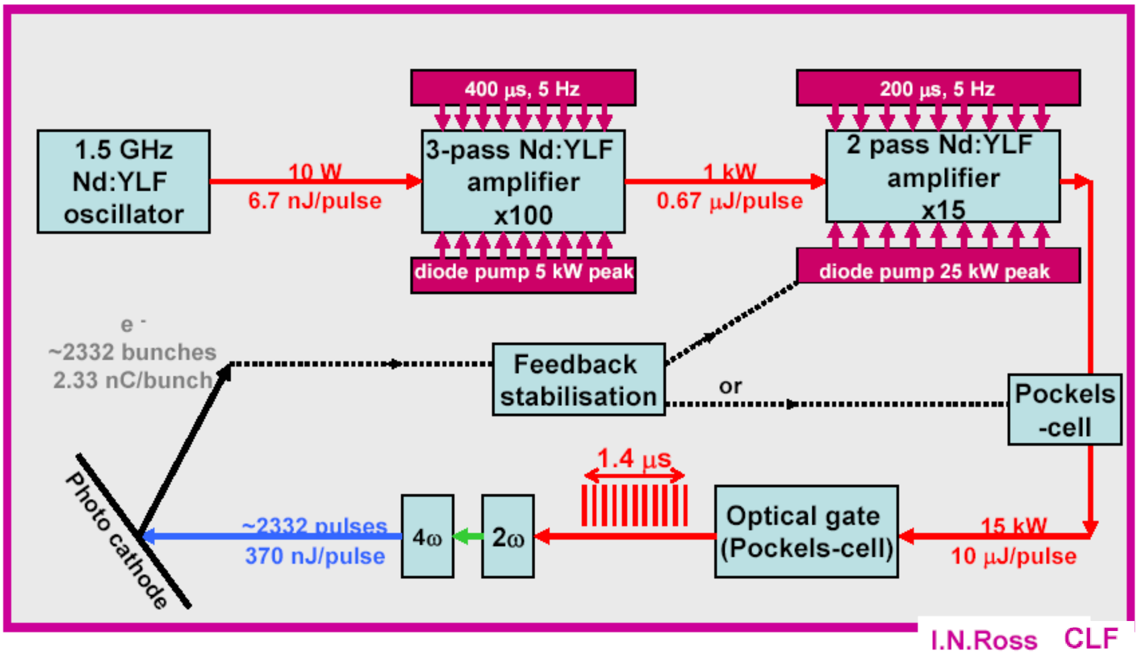
As said before, one of the main PHIN JRA topics concerns the CTF3 drive: the requests on the CLIC test facility drive beam (CTF3) photoinjector are very challenging, as shown in the following table, for the long train of pulses, the high charge per bunch, the pulse to pulse charge stability, photocathode lifetime and the temporal structure.

CTF3 Drive Beam Parameters

	Unit	CTF3
Pulse train duration	μs	1.548
Pulse train charge	nC	5434
Average current in the pulse train	A	3.51
Number of bunches in the sub-pulse	-	212
Odd/even sub pulse width (FWHM)	ns	140.735
Number of bunches in the pulse train	-	2310
Bunch charge	nC	2.33
Bunch width (FWHH)	ps	10
Distance between bunches	ns	0.667
Charge stability (rms)	%	$\leq$ 0.25
Repetition rate	Hz	1 - 50
Minimum QE at λ_{laser}	%	3
Minimum lifetime at QE_{min}	h	40

A layout of the laser proposed for CTF3 is shown in the figure below

CTF3 Laser system



An alternative photoinjector is also explored: an energetic and bright electron beam is generated from the interaction of a high intensity laser with a gas jet. The electric field generated in the plasma of the order of 1TV/m, boosts the electron of plasma, from 0 to 200 MeV in less than 1mm. The very good quality of the electron beam (normalized emittance < 2πmm-mrad) and the transverse initial size of the beam can be very small, of the order of few hundred microns. Regarding this subject, PHIN JRA aims at the production of mono-energetic electron beam of few hundred MeV (ΔE/E<0.1, Normalized emittance<0.1 πmm-mrad), mono-energetic electron beam with variable energy from 1 to 50 MeV.

The development of a superconducting photoinjector is also proposed in the PHIN JRA: the superconducting cavity of the RF gun is a TESLA type half cell closed by shallow cone with a centered hole in which the cathode is situated. Special insulation and RF filters are inserted to decouple the cathode zone from the rest of the cavity. The goal is to produce very high quality beam with charge per pulse and temporal structure optimized for ELBE superconducting accelerator and for TESLA test facility.

1. SCIENTIFIC AND TECHNOLOGICAL EXCELLENCE

1.1 Objectives and originality of the joint research project

1.1.1 **Main Goal:** Perform R&D on charge-production by lasers and improve or extend the existing infrastructures in order to fulfil the objectives. The aim is to produce long trains of high charge electron pulses with an unprecedented stability in terms of pulse-to-pulse charge, and transverse and longitudinal structure. A new generation of photoinjector with super-conducting RF gun is foreseen. A test of a very promising alternative electron source is also expected. The completion of these three subjects will put the participating laboratories at the forefront of electron production.

In order to fulfil the program, the coordination of the efforts produced by the various Institutes on this topic is mandatory.

Global objectives:

- Create a synergy of efforts for various photoinjector applications.
- Identify and deal with common problems.
- Perform R&D on electron production, improve existing infrastructures and carry out validation tests of developed models.

Specific Objectives:

- Study and model the beam dynamics in the RF gun.
- Develop normal and SC RF-guns for medium-high charges.
- Optimize the RF guns in order to satisfy thermal constraints and vacuum requirements of photo-cathode.
- Optimize the combined system laser-photo-cathode for various applications, seeking for a trade-of between cathode lifetime, laser power and wavelength.
- Study and develop optical and laser installations for the generation of the various space and time beam-distributions related to the various PI applications.
- Investigate means of generating complex timing, and of shaping laser pulses.
- Develop necessary instrumentation.
- Make the necessary developments to improve existing installations in order to satisfy the objectives.

1.1.2 The objectives are addressed by bringing together the expertise which the various European Institutes developed in one of the three main areas of interest for the photo-production of electrons, which are:

- Charge production and photo-cathodes.
- Lasers, including high-power, short-pulse and low-power, long-pulse lasers.
- RF guns, beam-dynamics studies, flat-beam optics.

An important aspect of the project is to make existing infrastructures available to all participants in order to perform tests and R&D experiments. Conversely, the R&D activities made in common may result in extensions and improvements of these existing infrastructures for the benefits of all partners.

Bringing the efforts of each laboratory together is one of the most beneficial aspects, since industry doesn’t provide complete sub-systems of photo-injectors, which, therefore, need to be specifically developed for each application.

The outcome of this R&D program is also of general interest for the industry working on related domains like the lasers.

1.2 Execution-plan of the joint research activity

The JRA-PHIN is subdivided into four work packages, which correspond to the main areas of interest indicated above. The content of each work-package is detailed below.

a. **Plan for Work-package 1 – Management & Communication**
The following tasks are treated:
- Oversee and coordinate the work of the entire JRA. (INFN-LNF, CERN, CCLRC-RAL, FZR, CNRS-Orsay).
- Organize the Steering Committee meeting (INFN-LNF, CERN).
- Ensure proper reviewing and reporting as well as dissemination of the knowledge within the JRA and the CARE project (INFN-LNF, CERN).
- Creation of tools, databases and web site are foreseen (INFN-LNF, CERN, CCLRC-RAL, FZR, CNRS-Orsay).

b. **Execution plan for Work-package 2 – Charge Production**

The objective of the charge production work package is the development of semiconductor photo-cathodes with improved properties, especially lifetime and quantum efficiency:
- Construction, preparation and extension of test equipments (FZR, CNRS, TEU).
- Improvement of fabrication technology, basic knowledge and study of new materials (CERN, FZR).
- Tests at different labs and comparative studies, time measurement diagnostics (CERN, FZR, TEU).
- Study of an alternative way for photoelectron production (CNRS-LOA), using a high-intensity laser with a gas jet. Acceleration by laser wake field of electrons up to several 100 MeV. Production of mono-energetic electrons.

Deliverables:
- Reports on photo-cathode production and improved preparation equipments.
- Photo-cathode preparation chamber with ultra high vacuum technology.
- Reports on test results, with optimised properties according to the needs of the photo-injectors of the project partners, improved diagnostics.
- Reports on tests with mono-energetic electrons up to 50 MeV, to benchmark the model with improved diagnostics.
- Reports on tests with the generation of high energy (200 MeV) mono-energetic electron beams with low emittance for injector application.

c. **Execution plan for Work-package 3 - Lasers**.

The work-package is divided into two tasks:
First Task
Design and develop laser system to meet the requirements of the CTF3 photo-injector (program already undertaken in CTF2). The laser system will consist of:
- High power mode-locked oscillator.
- One or more high power amplifiers.
- Frequency conversion stage to generate the required UV wavelength for the photo-cathode.

Development activities:

- Increase the power of existing oscillators (CCLRC-RAL, CNRS-LOA).
- Optimise the design of the amplifiers for required power output at minimum cost and complexity (CCLRC-RAL, CERN, CNRS-LOA).
- Efficiently convert the laser output wavelength to UV using new harmonic generator crystals (CCLRC-RAL, CERN, CNRS-LOA).
- Establish ultra-high stability including the use of charge and pointing stability feedbacks (CCLRC-RAL, CERN, INFN-LNF).

Second Task

Investigate and test systems for complicated, ultra-fast, optical waveforms according to user specifications, as those for the new generation of FEL, with benefits for linac photo-injectors.

Use expertise of CNRS-LOA and access to their Ti:Sa laser for test.

Test and study of Ti:Sa laser pulse jitter, laser diagnostics and stability on photocathode.

The waveform systems considered are:

- Liquid Crystal Modulator-Computer Programmable (LCM-CP) system.
- Collinear acousto-optic programmable dispersive filter (AOPDF-DAZZLER).

Development activities:

- Computer codes for the algorithm driving the shaping system (INFN-Mi, CNRS-LOA).
- Tests of both the LCM-CP and the AOPDF-DAZZLER (INFN-Mi, INFN-LNF, CNRS-LOA).
- Ensure sub-picosecond synchronisation to the RF (INFN-Mi).

Deliverables:

Laser-System meeting CTF3 requirements:

- High power oscillator.
- Specific amplifiers.
- Specific frequency conversion stages.
- Test of feedback systems.

Pulse shaper:

- Model, waveform synthesis.
- Assessment of various temporal-profile pulses.
- Photo-cathode test results on timing, jitter and stability.

d. **Execution plan for Work-package 4 – RF guns and beam dynamics**.

The aim of this WP is the development of RF guns for high charge and high average current or very short pulses. Improve the associated test stands. Spin-off for high power light-sources is expected. The work-package is divided into three tasks.

First Task

- Design and technical evaluation of photo-injectors for high charge, high average current, or short pulses (CNRS-Orsay, CERN).
- Numerical simulation and engineering optimisation for a Super-conducting RF photo-gun; cavity, coupler, RF focusing (FZR).
- Design optimisation and construction of new SC RF gun prototype (FZR).

Second Task

- Study and construction of two RF guns at 3 GHz for the injectors of the existing test facilities CTF3 (CERN) and NEPAL (CNRS-Orsay).
- Installation and commissioning of long pulse train of high charge and short bunches at CERN (CERN, INFN-LNF).
- Improvement of test stand NEPAL in order to achieve the gun tests mentioned above (CNRS-Orsay).

Third Task

For the alternative photo-cathode device proposed by CNRS-LOA, development (beam dynamics) and acquisition of:

- 0-50 MeV compact electron spectrometer (CNRS-LOA, CERN)
- 0-1 GeV electron spectrometer (CNRS-LOA, CERN)

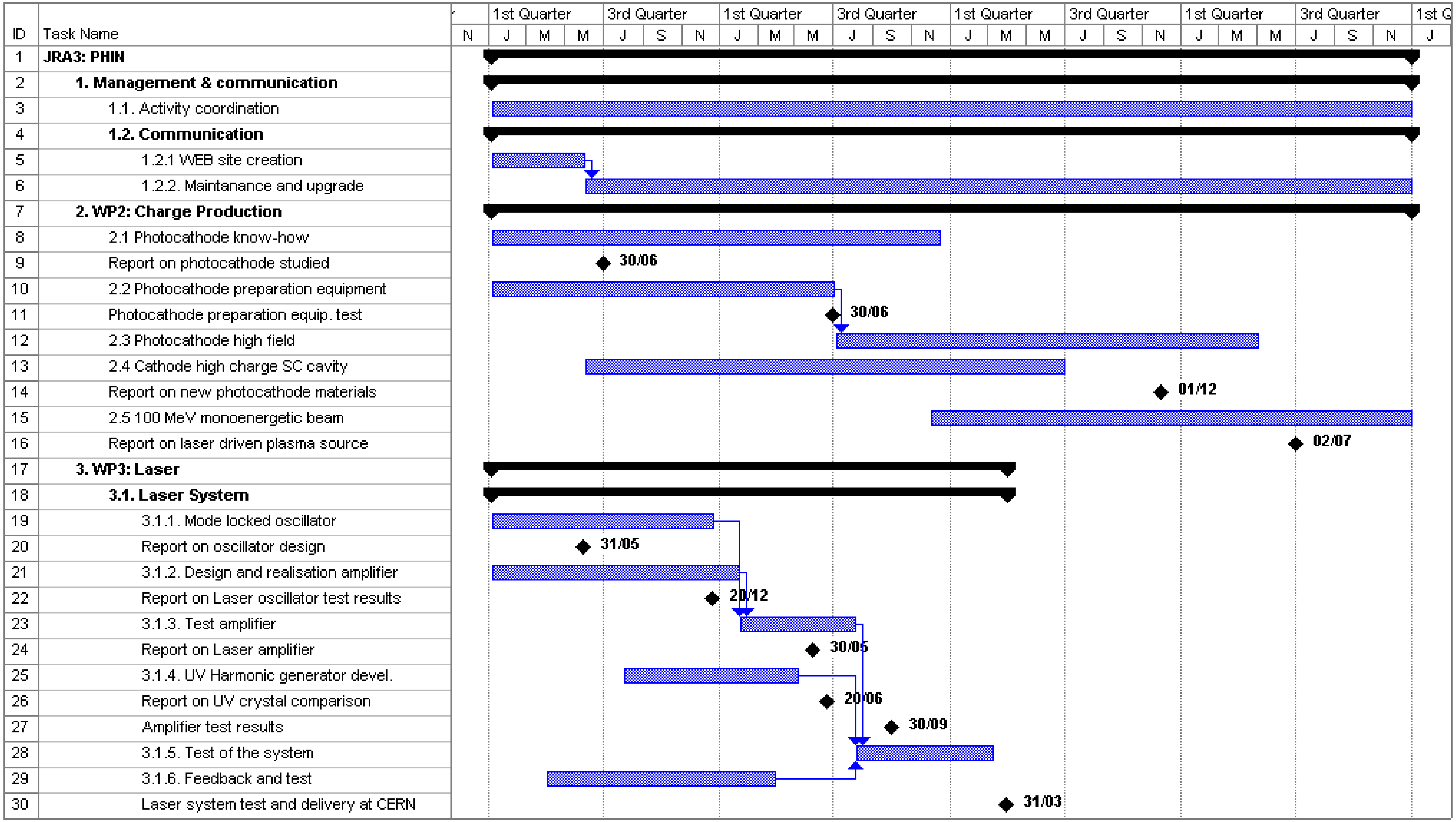
Deliverables:

- Design evaluation of high-charge photo-injector.
- Engineering of SC photo-gun.
- Prototype of SC gun.
- RF gun for CTF3 and NEPAL high-charge short bunches.
- Prototype of RF gun with CLIC characteristics for test.
- Spectrometers at different energy range for mono-energetic e^- beam diagnostics.
- Improvements of test facilities CTF3 and NEPAL.

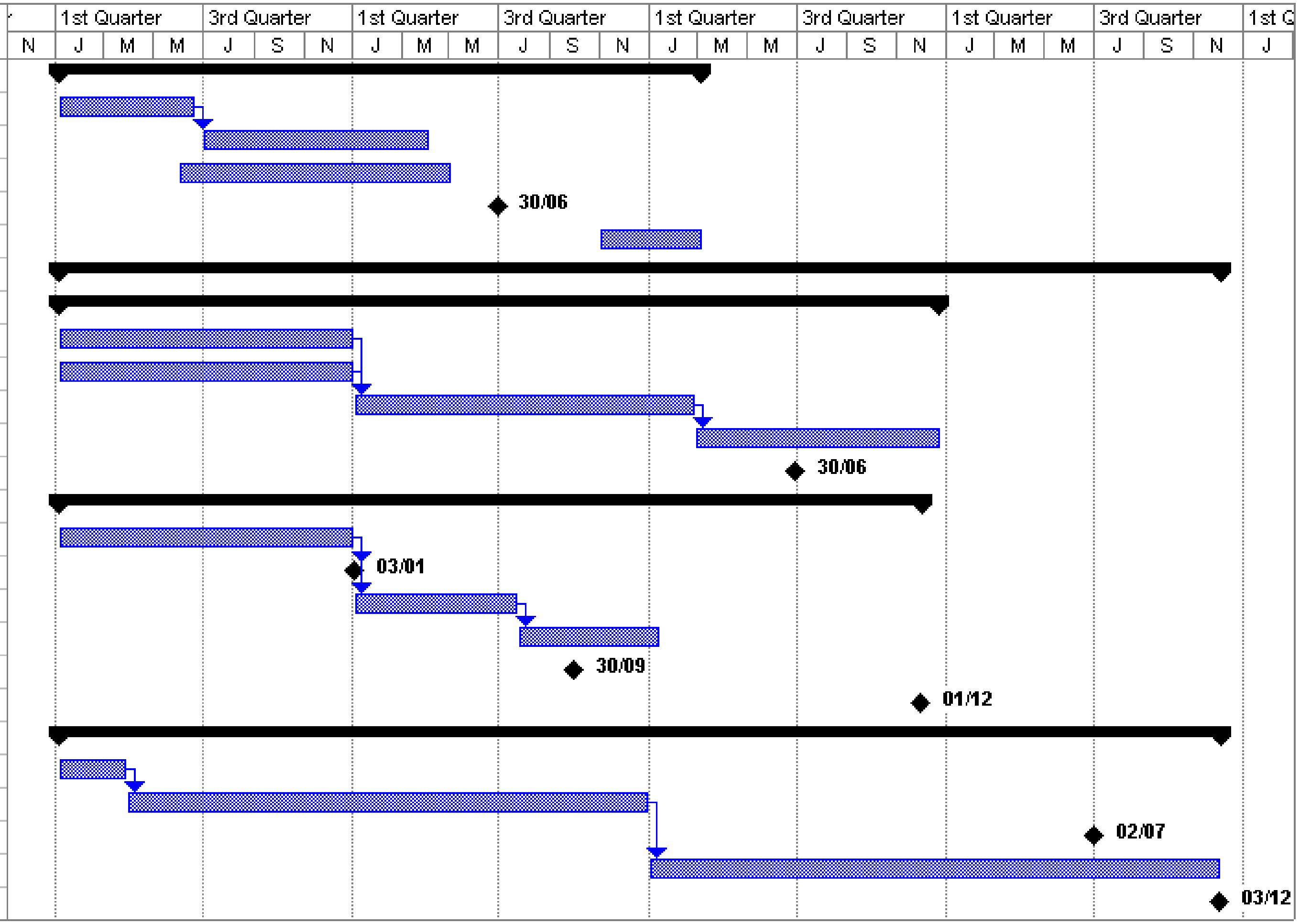
1.2.1 Multi-annual implementation plan

The Gantt chart (Fig. 1.2.1) shows the general planning by trimester over the period 2004-2007 for each Work Package.

Fig. 1.2.1: PHIN-JRA Multi-annual implementation plan



ID	Task Name
31	**3.2. Pulse shaping system**
32	3.2.1. Simulation and design
33	3.2.2. Phase mask acquisition and test
34	3.2.3. Dazzler acquisition and test
35	Report on pulse shaper comparison
36	3.2.4. Timing jitter stability test
37	**4. WP4: GUN**
38	**4.1. SC RF gun**
39	4.1.1. Technology development
40	4.1.2. RF gun simulation optimisation
41	4.1.3. SC RF Gun realisation
42	4.1.4. SC RF gun test
43	I Report on photocathode test in SC cavity
44	**4.2. 3 GHz RF gun**
45	4.2.1. 3 GHz RF gun design
46	Report on 3 GHz RF gun design
47	4.2.2. 3 GHz RF gun construction
48	4.2.3. 3 GHz RF gun test
49	3 GHz RF gun test results
50	Report on 3 GHz RF gun at CERN
51	**4.3. Spectrometer for e- beam**
52	4.3.1. 1-50 MeV Spectrometer design
53	4.3.2. 1-50 MeV Spectrometer construction
54	Report on low energy spectrometer
55	4.3.3. 0-1 GeV Spectrometer
56	Report on high energy spectrometer



The Milestones of the project with the task number are listed in Table 1.2.1

Table 1.2.1: PHIN-JRA Milestones

Milestone Number	Date	Tasks or sub-tasks to be completed by milestone date	Task number
1	30/06/2004	Report on photocathode studies	2.1
	30/05/2004	Report on laser oscillator design	3.1.1
2	01/12/2004	Report on 3 GHz RF gun design	4.2.1
	20/12/2004	Laser oscillator test results	3.1.1
3	30/05/2005	Report on laser amplifier	3.1.2
	20/06/2005	Report on UV conversion crystal comparison	3.1.4
4	30/06/2005	Photocathode preparation equipment test	2.2
		Report on pulse shaper comparison	3.2
5	30/09/2005	Amplifier test results	3.1.3
		3 GHz RF gun test result and delivery to CERN	4.2.3
6	30/01/2006	3 GHz RF gun test results at CNRS-Orsay	4.2.3
7	31/03/2006	Laser system test results and delivery at CERN	3.1.5
8	30/06/2006	Report on photocathode test in SC cavity	2.4
9	01/12/2006	Report on 3 GHz RF gun commissioning at CERN	4.2.3
		Report on new photocathode materials tests	2.1
		Report on 3 GHz RF gun at CNRS-Orsay	4.2.3
10	30/06/2007	Report on low energy spectrometer performances	4.3.2
		Report on laser driven plasma source	2.5
11	01/12/2007	SC RF gun test results	4.1.4
		Report on high energy spectrometer	4.3.3

1.2.2 Detailed implementation for the first 18 months

The detailed implementation plans for the first 18 months of each Work Package are shown in the following Gantt charts (Fig. 1.2.2).

Fig. 1.2.2a: First 18 months implementation plan of WP2: CP

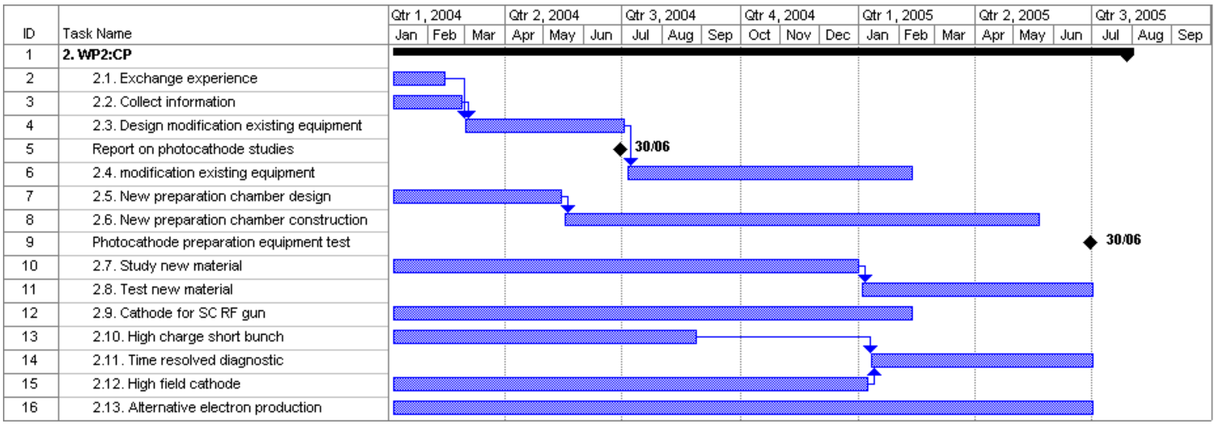


Fig. 1.2.2b: First 18 months implementation plan OF WP3: LAS

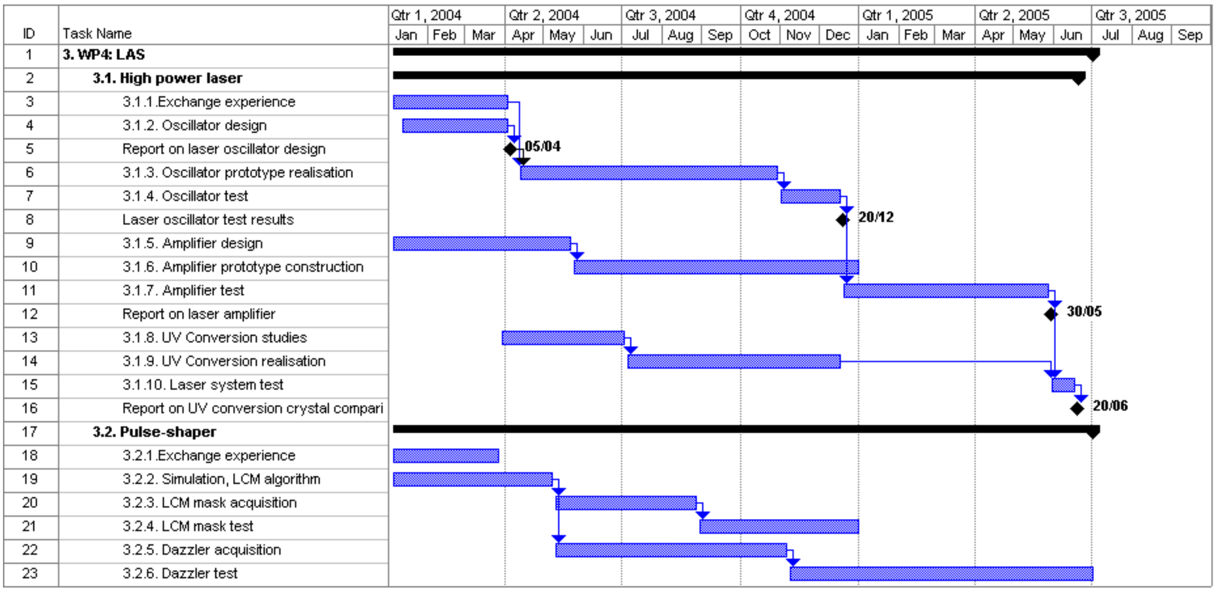
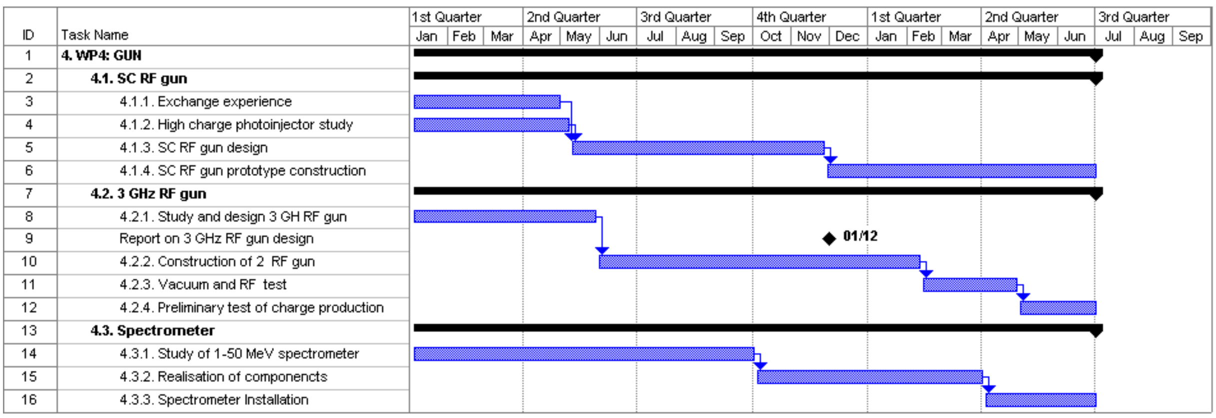


Fig. 1.2.2c: First 18 months implementation plan OF WP4: GUN



2. QUALITY OF THE MANAGEMENT

2.1 Management and competence of the participants

Table 2.1.1 lists the work-packages and their coordinators.

Table2.1.1: List of work-packages and related coordinators

PHIN coordinator	A. Ghigo (INFN-LNF)
Deputy	L. Rinolfi (CERN)

Work Package	Full name	Short name	Coordinator	Laboratory
WP1	Management and Communication	M&C	A. Ghigo	INFN-LNF
WP2	Charge Production	CP	J. Teichert	FRZ-ELBE
WP3	Lasers	LAS	G. Hirst	CCLRC-RAL
WP4	RF Guns and Beam Dynamics	GUN	G. Bienvenu	CNRS-Orsay

The Steering Committee of the JRA is made up of: a Coordinator, a Deputy Coordinator and three work-package Coordinators: one for WP2-CP, one for WP3-LAS and one for WP4-GUN. The Steering Committee attends regular 2-day meetings three times per year and videoconferences in between.

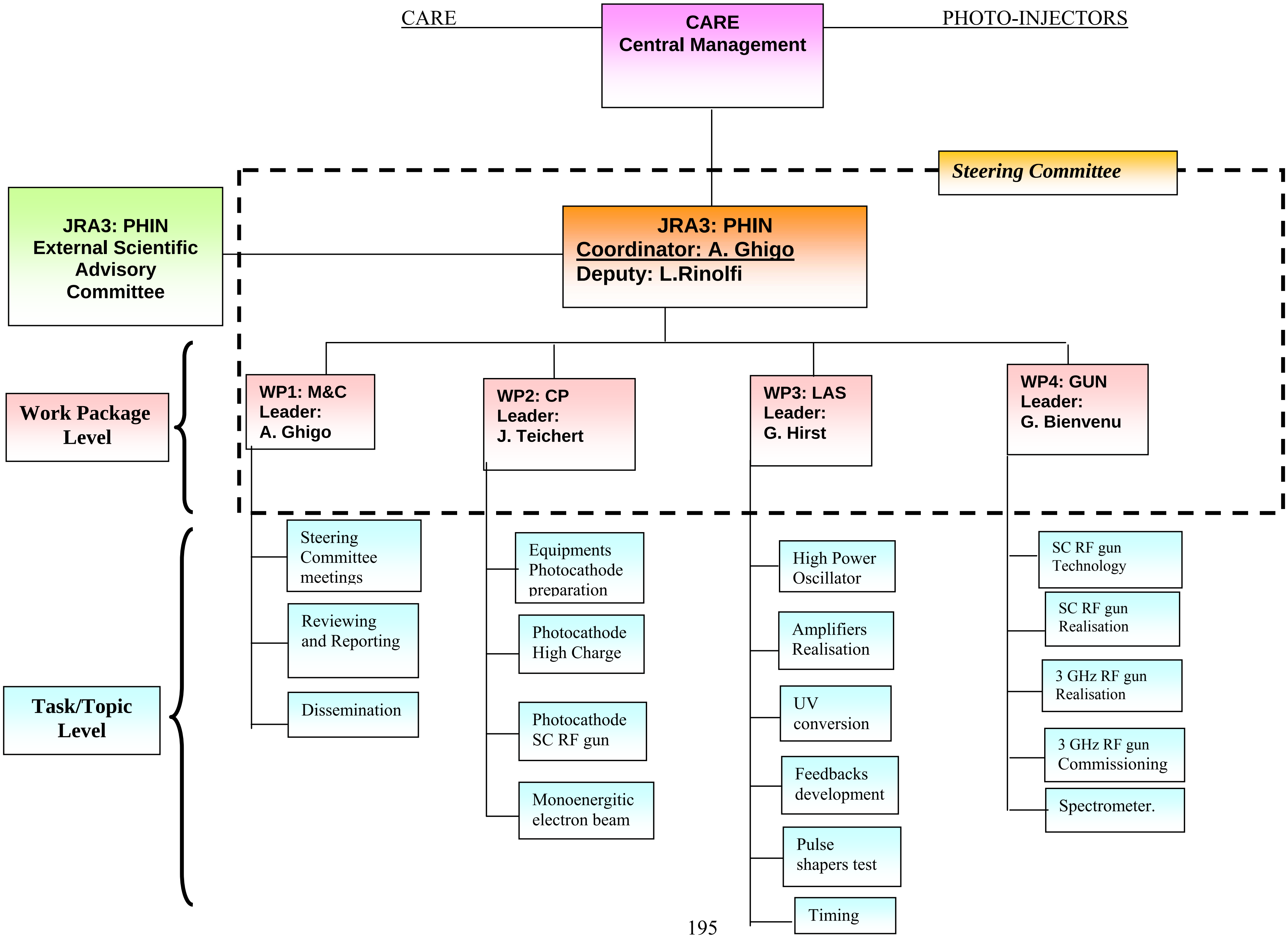
An External Scientific Review Committee, made up of 3 experts to be selected in the field, is foreseen in order to provide scientific evaluation of the results, milestones and achievements. Regular 2-day meetings with the members of the Review Committee will take place at least once a year.

Eight laboratories are collaborating to this JRA. They are all involved in one or more of the four activities covered by the work-packages on photo-injectors. They have developed important expertise in these subjects and they are ready to share this know-how with other participants. All the contractors have existing infrastructures, which can be used for the R&D on the JRA topics and brought to the disposal of the other institutes. Collaborations already exist, gathering some of the participants, which are now used to work in common.

Periodic meetings will be held for the development of the lasers, photo-cathodes and RF-guns, at a sufficient rate, so that designs can be developed, which satisfy all the participants. Dedicated meetings for each work-package will also take place, which may involve all the participants of the JRA, or only part of them. Information will be provided, on a dedicated web site, to all participants and to people working in the same areas.

The field of applications of the sources based on interaction of lasers with photo-material within an RF field is extended to:

- High-energy physics for high-charge e^- beams, low-emittance beams for beam tests and future LC main beams,
- picosecond and femtosecond chemistry,
- Cancer therapy and medical imaging,
- Light sources,
- Longitudinally polarized electrons using circularly polarized laser for production.


CARE
PHOTO-INJECTORS
CARE
Central Management
Steering Committee
JRA3: PHIN
External Scientific
Advisory
Committee
JRA3: PHIN
Coordinator: A. Ghigo
Deputy: L.Rinolfi
Work Package
Level
WP1: M&C
Leader:
A. Ghigo
WP2: CP
Leader:
J. Teichert
WP3: LAS
Leader:
G. Hirst
WP4: GUN
Leader:
G. Bienvenu
Task/Topic
Level
Steering
Committee
meetings
Reviewing
and Reporting
Dissemination
Equipments
Photocathode
preparation
Photocathode
High Charge
Photocathode
SC RF gun
Monoenergitic
electron beam
High Power
Oscillator
Amplifiers
Realisation
UV
conversion
Feedbacks
development
Pulse
shapers test
Timing
SC RF gun
Technology
SC RF gun
Realisation
3 GHz RF gun
Realisation
3 GHz RF gun
Commissioning
Spectrometer.

2.1.2 Role and expertise of participants

Table 2.1.2a illustrates the participation of the different institutes in the Work Packages.

Table 2.1.2a: participants for each work package

Institute	WP1: M&C	WP2: CP	WP3: LAS	WP4: GUN
CCLRC-RAL	X		X	
CERN	X	X	X	X
CNRS-Orsay	X	X	X	X
CNRS-LOA		X	X	X
FZR-ELBE	X	X		X
INFN-LNF	X		X	X
INFN-Mi			X	
TEU		X	X	

Table 2.1.2b shows the role of the participants and their research effort in the different work packages of the PHIN JRA in terms of professional person-months. The estimated total person-power needed to carry out the Activity is close to 90 years FTE.

Table 2.1.2b: Participants roles in each work package

Institute	WP/Topic	Roles	Person-months
CCRLC-RAL	WP1: M&C	WP3-LAS Coordinator	3
	WP3: LAS	Design, construction and test of complete laser system	27
CERN	WP1: M&C	JRA-PHIN Coordinator deputy	3
	WP2: CP	Photo-cathode development	64
	WP3: LAS	High power laser system for CTF3 commissioning	32
	WP4: GUN	CTF3 gun construction	50
CNRS-Orsay	WP1: M&C	WP3-GUN Coordinator	3
	WP2: CP	Photocathodes study	32
	WP3: LAS	Laser commissioning	51
	WP4: GUN	Gun prototype construction. Test stand diagnostics	207
CNRS-LOA	WP2: CP	Alternative photo electron production	60
	WP3: LAS	Pulse shaping test in existing laser system	0
	WP4: GUN	Measurement line for test with mono-energetic beams	78
FZR-ELBE	WP1: M&C	WP2-CP Coordinator	3
	WP2: CP	Preparation equipment, cathode development	84
	WP4: GUN	Study and construction of the SC prototype gun.	87
INFN-LNF	WP1: M&C	JRA-PHIN Coordinator	6
	WP3: LAS	Laser-RF Synchronisation. Feedback	48
	WP4: GUN	Beam Dynamics studies	72
INFN-MI	WP3: LAS	Waveform for laser ultra-short pulses	96
TEU	WP2: CP	Photocathode development	46
	WP3: LAS	Laser test for high current	10

In Table 2.1.2c, the expertise and the existing infrastructures of the participating institutes are briefly summarized.

Table 2.1.3: Participants expertise and relevant infrastructure

Institute	Specific Expertise	Infrastructure
CCRLC-RAL	Central laser facility in the forefront of the field, most important laser center in the world, specialized in very high power laser systems.	
CERN	Accelerator Design and technology. Construction and operation of photoinjector. Photocathode technology. CTF3 test facility for drive-beam recombination scheme	CTF3
CNRS-Orsay	Design and construction of electron injectors for CERN and DESY, photo RF gun, test stand with photo-injector (NEPAL).	NEPAL
CNRS-LOA	Laser development and production of charged particles by means of a laser plasma. Acceleration in the laser wake field. Ti:Sa power-lasers.	
FZR-ELBE	Development and operation of an RF photoinjector with superconducting cavity, ELBE electron linear accelerator and SRF gun test-stand.	ELBE
INFN-LNF	Accelerator design and technology. Normal conducting linac. Test beam facility. High brightness photo-injectors R&D.	
INFN-Mi	Manipulation of the laser output pulses, study of ultrafast optical waveforms.	
TEU	Photocathode preparation chamber. High power laser systems. Free Electron Laser and accelerator physics	TEU-FEL

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CNRS-LOA/ENSTA

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2.2 Justification of financing requested

2.2.1 PHIN-JRA budget

Among the eight participants of the PHIN-JRA, four are using the Additional Cost model (AC) and four the Full Cost model (FC). The total expected budget is 6.001 M€, the requested EU funding is 3.542 M€. More than one third of the requested budget will be dedicated to temporary post-doc contracts: this will contribute to the improvement of skill and expertise of young physicists in a strategic domain for accelerators.

Table 2.2.1a summarizes the budget requested from the European Union for each participating Institute, while Table 2.2.1b shows the additional internal cost of the project for participants using the AC cost model.

Table 2.2.1a: Budget requested from the European Union (k€).

Institute	Cost Model	WP1: M&C		WP2: CP		WP3: LAS		WP4: GUN		**Total**	
		Exp. Cost	Req. Cost	Exp. Cost	Req. Cost	Exp. Cost	Req. Cost	Exp. Cost	Req. Cost	Exp. Cost	Req. Cost
CCRLC-RAL	FC	**15**	**10**	**0**	**0**	**363**	**105**	**0**	**0**	**378**	**115**
CERN	AC	**20**	**20**	**50**	**45**	**970**	**948**	**200**	**165**	**1240**	**1178**
CNRS-Orsay	FC	40	15	330	210	427	225	1318	305	2115	755
CNRS-LOA	FC	0	0	10	10	5	5	995	425	1010	440
CNRS SubTotal	FC	**40**	**15**	**340**	**220**	**432**	**230**	**2068**	**730**	**3125**	**1195**
FZR-ELBE	AC	**15**	**15**	**265**	**245**	**0**	**0**	**130**	**120**	**410**	**380**
INFN-LNF	AC	35	35	0	0	60	60	180	180	275	275
INFN-MI	AC	0	0	0	0	225	225	0	0	225	225
INFN SubTotal	AC	**35**	**35**	**0**	**0**	**285**	**285**	**180**	**180**	**500**	**500**
TEU	FC	**0**	**0**	**348**	**174**	**0**	**0**	**0**	**0**	**348**	**174**
Total		125	95	1003	684	2050	1568	2578	1195	6001	**3542**

Table 2.2.1b Internal costs not accounted for in above table for participants using the AC cost model (k€).

Institute	**Cost Contribution**
CERN	1300 (*)
FZR	735
INFN-LNF	525
INFN-Mi	350
Total	**2910**

(*) This corresponds to 1980 kCHF.

The cost breakdown for each Institute and each Work Package is shown in Table 2.2.1c.

Table 2.2.1c: PHIN-JRA costs per participant (k€).

Laboratory	**CCLRC-RAL**	**CERN**	**CNRS-ORSAY**	**CNRS-LOA**	**FZR-ELBE**	**INFN-LNF**	**INFN-Mi**	**TEU**
Cost model	FC	AC	FC	FC	AC	AC	AC	FC
Durable equipment	0	0	250	0	0	0	0	0
Consumables & prototypes	0	1135	410	325	190	85	65	50
Temporary Staff	246	75	200	100	200	150	150	119
Permanent Staff	117	/	1230	570	/	/	/	174
Travels	15	30	25	15	20	40	10	5
Total	**378**	**1240**	**2115**	**1010**	**410**	**275**	**225**	**348**
Requested contribution	**115**	**1178**	**755**	**440**	**380**	**275**	**225**	**174**

The profile of requested EU funding over four years of the PHIN-JRA duration is shown in Table 2.2.1d.

Table 2.2.1d Profile of Requested EU Funding over JRA Duration (k€).

Institute	2004	2005	2006	2007	Total
CCRLC-RAL	**55**	**50**	**10**	**0**	**115**
CERN	**650**	**280**	**190**	**58**	**1178**
CNRS-LAL	350	280	80	45	755
CNRS-LOA	100	130	130	80	440
CNRS SubTotal	**450**	**410**	**210**	**125**	**1195**
FZR-ELBE	**120**	**140**	**100**	**20**	**380**
INFN-LNF	90	90	80	15	275
INFN-MI	80	70	60	15	225
INFN SubTotal	**170**	**160**	**140**	**30**	**500**
TEU	**100**	**50**	**20**	**4**	**174**
Total	1545	1090	670	237	**3542**

2.2.2 The largest part of the requested EU funding is for consumables and prototype completely dedicated to this project.

3. EUROPEAN ADDED VALUE

3.1 Interest for European research infrastructures and their users

The R&D activities on photoinjector proposed in this JRA are devoted to improve the performances of the new generation of electron injectors for future accelerators. The project results are mainly addressed to the high-energy linear colliders community. Nevertheless, all European infrastructures that are involved in the accelerator physics and related uses should be extremely interested in the exploitation of the JRA results.

The existing infrastructures that immediately benefit of the JRA on photoinjector are:
CTF3 (CLIC test facility) is an intermediate step to demonstrate the technical feasibility of the key concepts of the new power source for CLIC. CTF3 will be used to test the CLIC critical components and in particular will provide the 30 GHz RF power needed to test the main beam accelerating structure. The photoinjector will be an important upgrade of this facility allowing:

- Flexibility in manipulating the time structure of the electron beam.
- Smaller transverse and longitudinal emittances, resulting in more efficient beam transport and bunch length manipulation.
- No low energy tails.
- Dramatic reduction of radiation losses.

NEPAL is a multipurpose RF test stand. The new photoinjector will be a major improvement in order to test new beam dynamics models, instrumentation and diagnostics.

ELBE is a super-conducting RF test stand. The SC RF Gun developed in the JRA allows to use such SC RF gun in the TESLA project and in the FEL community due to:

- Small transverse and longitudinal emittances.
- High charge electron pulse.

TEU FEL is a Free Electron Laser emitting in the far-infrared range. The new photocathode material developed in the JRA could permit to increase significantly the brightness of this source and improve stability and operation time of photo cathodes.

3.2 Exploitation of results

The aim of the PHIN activities is to study, design and realize a new series of photo-injectors for the applications described before. The first prototype of the entire system made up of laser, photo-cathode and RF gun will be immediately applicable, as direct exploitation, in the CLIC Test Facility (CTF3). The second prototype will be used for improving the performance of the NEPAL test stand and the superconducting RF gun will improve the ELBE test stand with large benefits for all the infrastructure users.

The results of the PHIN-JRA will be freely available to the entire scientific community.
The major benefits for other communities come from the studies on the more challenging characteristics of the different components of the photoinjector system (*i.e.*, very stable high power laser, high efficiency and long lifetime photocathode, etc.). The potential users are in the following research fields:

- light sources and free-electron lasers,

- medical imaging,
- picosecond and femtosecond chemistry,
- cancer therapy,
- high brightness e^- beams.

3.3 Risk assessment

In the JRA on photoinjector, different technologies are developed in parallel by several laboratories. Because of the system complexity and the expected performance improvements with respect to the existing technologies, a risk evaluation is needed, even if each institute expertise and role in the collaboration minimize the risk of project failure. In the following table, the list of research topics are presented together with the estimated risk and the possible corrective action. The estimated risk level for the items is 1 or 2.

Table 3.3a: Definition of risk level

Risk Level	Meaning
RL1	Low Risk: minor error might happen, could be easily corrected since no technical challenge is involved. Scope of the project is unchanged. Minor impact on schedule (<3 months) or cost (<5%) might be necessary.
RL2	Medium Risk: A small downgrading of the final objectives might be required. Alternatively a small delay (<1 year) and cost increase might be necessary (<20%) to maintain the initial objectives.
RL3	High Risk: Significant downgrading of the objectives might be required. Alternatively more R&D, more time (>1 year) and more money (>20%) would be required.

Table 3.3b: PHIN activities risk levels

Activity	Task	risk level	corrective action
WP2:CP	Photocathode high charge	1	Add more time for development
	Photocathode for SC cavities	2	Revert to more standard technique
	50 MeV monoenergetic beam	2	Add more time and investment for development
	100 MeV monoenergetic beam	2	Add more time and investment for development
WP3:LAS	Amplifier	2	Add more time and investment for development
	UV harmonic generators	1	Lower the requested performance
WP4:GUN	3 GHz gun delivery and test	1	Add more time for commissioning