SEVENTH FRAMEWORK PROGRAMME

THE PEOPLE PROGRAMME

Grant agreement for: **Initial Training Networks**

Annex I – "Description of Work

Proposal acronym: MC-PAD

Proposal full title: Marie Curie Training Network on Particle Detectors

Grant agreement no.: 214560-2

Date of approval of Annex I by Commission: xx yyy 2008

PART A:

A.1 List of beneficiaries and project summary

A.1.1 List of Beneficiaries

Beneficiary no.	Beneficiary name	Beneficiary short name	Country	Date enter project	Date exit project
1 (co-ordinator)	European Organization for Nuclear Research (CH)	CERN	Switzerland	m 1	m n
2	Stiftung Deutsches Elektronen-Synchrotron (DE)	DESY	Germany	m 1	m n
3	Gesellschaft für Schwer-ionenforschung mbH (DE)	GSI	Germany	m 1	m n
4	Jožef Stefan Institute (SI)	JSI	Slovenia	m 1	m n
5	AGH University of Science and Technology (PL)	AGH	Poland	m 1	m n
6	Laboratori Nazionali di Frascati - Istituto Nazionale di Fisica Nucleare (IT)	LNF	Italy	m 1	m n
7	Stichting voor Fundamenteel Onderzoek der Materie (NL)	NIKHEF	Netherlands	m 1	m n
8	Paul Scherrer Institut (CH)	PSI	Switzerland	m 1	m n
9	University of Hamburg (DE)	UHH	Germany	m 1	m n

Associated partner no.	Associated partner name	Associated partner short name	Country	Date enter project	Date exit project
1	Evatronix SA (PL)	Evatronix	Poland	m 1	m n
2	Polish Academy of Sciences (Polska Akademia Nauk) PAN (PL)	IFJ		m 1	m n
3	Micron Semiconductor Ltd. (UK)	Micron	United Kingdom	m 1	m n
4	National Institute of Materials Physics (NIMP), Bucharest	NIMP	Romania	m 1	m n
5	Photonis SAS Holding	Photonis	France	m 1	m n

A.1.2 Project Summary

Keywords: Physical sciences, Experimental Physics, Electronics engineering, Radiation Detectors

Abstract

The challenging questions of particle physics, like the origin of mass, the existence of new forms and states of matter, can only be addressed in technically complex and expensive large-scale research facilities. Well coordinated international effort is required to design, build and operate world class infrastructure comprising accelerators of highest energy and/or intensity and detector systems of unprecedented performance. Frequently the quality of the results and hence the progress of science is limited by the quality of the detectors and by the level of understanding of their characteristics and performance. Future detectors need to cap current state-of-the art performance in terms of position and energy resolution, number and density of read-out channels, dynamic range and noise, speed, radiation tolerance, robustness and reliability. We propose an Initial Training Network on Particle Detectors which spans 4 years. A multi-site network has been formed which comprises nine academic participants, three associated industrial partners and one associated academic partner from eight European countries. It will provide extraordinary training opportunities to young researchers (physicists and engineers) in the field of radiation detectors. The proposed Training Network will play an essential role to form a new generation of excellent detector scientist which is required to conceive, design, build and exploit the next generation of experiments which may come into operation in the years 2012-2020. Internationally renowned supervisors will provide scientific and technical training at the highest level. The trainees will be integrated in existing collaborative structures and profit from a unique spectrum of expertise and facilities available in the network. Complementary training, involving particularly our industrial partners, e.g. in communication skills, project and financial management, is an integral part of the programme.

PART B:

B.1 Description of the joint Research Training Programme

B.1.1 Project Overview

A multi-site network has been formed which will provide excellent training opportunities to young researchers in the field of radiation detectors for the next generation of particle physics experiments and other applications. We are targeting mainly physicists and (electronics) engineers. The network with the acronym MC-PAD (**M**arie **C**urie – **PA**rticle **D**etectors) comprises nine academic participants, three industrial partners and an associated academic partner.

The proposed ITN will make substantial contributions to an internationally-coordinated effort in developing new and optimising existing particle detector technologies to make them suitable, well understood and reliable solutions. The training network covers major detector categories present in modern particle physics experiments. Moreover, the network is not limited to the development of basic sensors only, but includes the design, construction and integration of fully functional detector systems. This means that important aspects like front-end electronics design, mechanical integration, system architecture and signal processing are part of the overall approach.

The proposed research will be organized as a number of common projects carried out in small teams, involving typically two to five network partners. Some of the projects are related, e.g. by addressing the same problem from a different angle, others are largely independent. The projects focus mainly on the development of novel particle detector devices and fully functional prototype detector systems for particle physics experiments at SLHC, ILC, CLIC, FAIR, DAFNE or Super-B-Factories. Generally, the projects aim to establish novel detector concepts, extend and optimize the performance of existing devices or adapt and integrate devices in larger systems.

The projects are grouped into the following categories:

- radiation tolerant silicon detectors,
- gaseous detectors,
- calorimetry,
- photon detection and particle identification,
- monolithic detectors and front-end electronics,
- simulation tools.

B.1.2 Concept and Project Objective(s)

This training network is formed by major European institutions in the field of radiation detectors in which European science has a leading role worldwide. The network will contribute to reinforce this role through challenging common projects. The results of the proposed projects will find their applications in the next generation of particle physics experiments like at the SLHC, the Super-B factory, ILC and FAIR, as well as in astro-particle physics, medicine, photon science and a number of other scientific and industrial applications.

The main scientific achievement of this training network will be an overall and clearly visible gain in the performance of particle detectors for SLHC, ILC and other future particle physics experiments. The R&D conducted in the network is expected to lead to the following main results:

- Silicon tracking devices: Availability of specifically engineered materials and optimized detector layouts which withstand the unprecedented radiation loads expected in SLHC or FAIR.
- Novel tracking detectors: Understanding the intrinsic limitations. New performance records for novel particle detectors like MAPs, 3D semiconductor detectors, GEMs or Micromegas;
- Photon detectors: Development for fast single photon detection devices, able to cover large areas and/or operate in high magnetic fields.
- Construction and complete characterization of fully functional prototypes of particle detector subsystems for considered applications in HEP experiments (calorimetry, particle ID).

B.1.3 Overall Approaches and Methodology

Detector development projects in particle physics normally follow a sequence of well-identified phases.

- First the measurement problem needs to be identified and a (detector) concept needs to be developed. 'Practical' aspects, like technical feasibility and cost-effectiveness, may not be a main focus at this stage, but deserve some consideration even at this early phase.
- Lectures, talks, literature/database studies and discussions with colleagues allow developing a clear understanding of the state-of-art in the field.
- Simplified analytical calculations, from back of the envelope type to using mathematics software or home-grown programs, are made to obtain a rough estimate of the expected performance and possible limitation of the envisaged new concept.
- The concept is tested and refined by Monte-Carlo calculations and other appropriate tools (e.g. Finite Element models), which should provide a realistic performance evaluation.
- If the chosen concept still appears promising, a (small scale) prototype device is designed and built.
- An appropriate test bench is designed and set up in the laboratory.
- The new device is tested and its performance compared with state-of-the-art devices.
- Tests with particle beams allow characterizing the device under realistic conditions.
- Questions like robustness, aging, lifetime tests, behaviour after strong irradiations and other environmental effects, must be considered.
- Aspects related to (industrial) mass production, quality control and assembly are studied.
- The developed device can finally be integrated in a larger detector system.

For devices like solid state sensors, microelectronics, gas detectors, vacuum based photodetectors, very powerful tools and refined methods have been developed over the years, to allow an in-depth characterization. The network has access to the full spectrum of equipment and infrastructure to perform this work. This also holds for the range of simulation and analysis software tools.

Trainees will often be integrated in ongoing projects and therefore they will be exposed to the full sequence of a detector development. The trainee will then concentrate on a certain aspect or sub-project, for which the above sequence is still a very valid guide. The progress of the projects is documented in various ways. Presentations at different levels (team, group, department, collaboration), usually publicly accessible on the internet, document the evolution of the project and allow for direct feedback by colleagues. Written documentation, i.e. short technical notes or more comprehensive design reports are appropriate to mark the completion of some of the phases.

Modern large particle experiments at the LHC or the ILC comprise hundreds of square meters of active detector surface. More and more detector concepts rely on industrial technologies originally developed for micro electronics (photolithography, micro-structuring) and optics, which can only be performed in a competitive and cost effective way by specialized high tech companies. Collaboration with industrial partners already in the design and prototype phase is an absolute must to guarantee the perfect match of requirements and final deliveries. The industrial and academic partners provide complementary input to the project and often dispose of complementary equipment for testing and quality control. Direct collaboration with the industrial partners, by working with their development and production teams, will be a unique experience for the trainees, contribute to an efficient idea and technology transfer from academia to industry and generally boost the advancement of the projects.

B.2 Implementation

B.2.1 Planning of work packages, milestones and deliverables

The typical projects drawn up for the researchers will last 3 years. We expect the researchers to spend about two thirds of their time at the main partner of the project. The other third will be spent at one or several other partners involved in the project in order to profit from special infrastructure, exchange with other trainees and colleagues and to contribute to a general transfer of knowledge and technologies between the partners. Project-specific plans and lists of milestones and deliverables have been drawn up for each of the 12 projects.

Table: List and schedule of milestones

Milestone no.	Milestone name	WP no's	Lead beneficiary	Delivery Date	Comment
P1-M1	Test set-ups (at CERN an GSI) operational	1	CERN	m10	Set-up
P1-M2	Full size detector modules tested	1	CERN	m30	Prototype
P2-M1	Definition of specifications	2	UHH	m6	Report
P2-M2	Layout of sensor prototypes	2	UHH	m21	Report
P2-M3	Source set-up available	2	PSI	m12	Report
P2-M4	Bump boding of single sided sensors	2	PSI	m15	Report
P3-M1	Radiation damage for epitaxial sensor materials;	3	UHH	m18	Measurement

P3-M2	Performance of epitaxial prototype detectors	3	UHH	m30	Measurement
P3-M3	Simulation of charge transport in radiation damaged crystals	3	UHH	m30	Software
P3-M4	Simulation tools for 3D detectors	3	UHH	m12	Software
P3-M5	Characterization of irradiated 3D detectors	3	UHH	m30	Measurement
P4-M1	Small prototype single mask GEM available	4	CERN	m3	Prototype
P4-M2	C-GEM prototype available	4	LNF	m12	Prototype
P4-M3	Full scale prototype single mask GEM available	4	CERN	m15	Prototype
P5-M1	ILC-TPC prototype available	5	DESY	m09	Prototype
P5-M2	Discharge protection technology established	5	DESY	m12	Prototype
P5-M3	PANDA prototype available	5	DESY	m20	Prototype
P6-M1	Design calorimeter structure on the basis of Monte Carlo studies	6	DESY	m12	Report
P6-M2	Very thin sensor planes for each of the calorimeters	6	DESY	m24	Prototype
P7-M1	Optical module with X-HPD tube	7	CERN	m12	Prototype
P7-M2	Scint. fibre tracker prototype with G-APD readout	7	CERN	m18	Prototype
P7-M3	Prototype PET based camera	7	CERN	m22	Prototype
P8-M1	Compact PET module with SiPM readout available	8	JSI	m12	Prototype
P8-M2	RICH counter with B-field sensitive sensors available	8	JSI	m24	Prototype
P9-M1	MPW submission of pixel analog circuit in 130nm	9	NIKHEF	m12	Layout
P10-M1	MAPS SOI functionality	10	AGH	m18	Prototype
P10-M2	'MAPS SOI radiation hardness test'	10	AGH	m24	Report
P11-M1	Single channel discrete diamond detector front-	11	GSI	m08	Prototype

	end available				
P11-M2	Calorimeter front-end ASIC available	11	GSI	m18	Prototype
P11-M3	Calorimeter multi-channel readout	11	GSI	m30	Prototype
P12-M1	First version of generic MC code available	12	LNF	m9	Software
P12-M2	MC code tested against available data	12	LNF	m24	Report
P12-M2	Parameters for an optimized calorimeter structure	12	LNF	m30	Specifications

Table: Tentative schedule of project reviews

Review no.	Tentative timing	Planned venue	Comments

Table: Work package list

Work package no.	Work Package Title	Type of activity	Lead beneficiary	Person months	Start month	End month
WP 1	Radiation Tolerant Mini-strip Tracking Detectors	RTD	CERN	72		
WP 2	Hybrid Pixel Detectors	RTD	PSI	72		
WP 3	Radiation Hard Crystals / 3D Detectors	RTD	UHH	72		
WP 4	Micro Pattern Gas Detectors	RTD	CERN	60		
WP 5	TPC with MPGD Readout	RTD	DESY	108		
WP 6	Very Forward Calorimetry	RTD	DESY	72		
WP 7	Advanced Photodetectors	RTD	CERN	24		
WP 8	Photodetectors for High-B Fields	RTD	JSI	36		
WP 9	Front-end Electronics for Hybrid Pixel Detectors	RTD	NIKHEF	60		
WP 10	Monolithic Detectors	RTD	AGH	36		
WP 11	Front-end Electronics	RTD	GSI	60		
WP 12	Optimization of Monte Carlo Tools and Comparison with Benchmark Data	RTD	LNF	60		

WP 13	Network coordination	MGT	CERN		1	48

Table: List of Deliverables

Del. no.	Deliverable name	WP no.	Lead beneficiary	Estimated indicative person-months	Nature	Dissemi-nation level	Delivery Date
P1-D1	Set-ups at CERN and GSI commissioned	1	CERN		R	PU	m10
P1-D2	Recommendations on materials and designs	1	CERN		R	PU	m36
P2-D1	Simulation of sensor response	2	UHH		R	PU	m18
P2-D2	Characterization of prototype sensors	2	UHH		R	PU	m36
P2-D3	Characterisation of irradiated CMS standard sensors	2	PSI		R	PU	m12
P2-D4	Characterisation of irradiated single sided sensors	2	PSI		R	PU	m36
P3-D1	Simulation of signal shape for detectors of general geometry	3	UHH		O	PU	m16
P3-D2	Running scenario for epi sensors for SLHC	3	UHH		R	PU	m24
P3-D3	Performance of epi detectors at high luminosities	3	UHH		R	PU	m36
P3-D4	Optimised reconstruction algorithms	3	UHH		O	PU	m30
P3-D5	Performance of 3D detectors at high luminosities	3	UHH		R	PU	m36
P4-D1	Characterization of single GEM mask small prototype	4	CERN		R	PU	m09
P4-D2	Analysis of C-GEM beam test	4	LNF		R	PU	m18
P4-D3	Technology assessment report C-GEM	4	LNF		R	PU	m21
P4-D4	Technology assessment report single mask GEM	4	CERN		R	PU	m33

P5-D1	Evaluation of effectiveness of discharge technologies	5	DESY		R	PU	m18
P5-D2	Analysis of ILC-TPC testbeam campaign	5	DESY		R	PU	m24
P5-D3	Beam tests of PANDA prototype analyzed	5	DESY		R	PU	m32
P6-D1	design of the sensor planes	6	DESY		R	PU	m12
P6-D2	Function test of sensor planes in the laboratory	6	DESY		R	PU	m24
P6-D3	Beam test results from multi-pad sensor planes	6	DESY		R	PU	m30
P7-D1	Test results of X-HPD lab tests	7	CERN		R	PU	m18
P7-D2	Test results of fibre tracker and calorimeter	7	CERN		R	PU	m21
P7-D3	Characterization of PET based camera	7	CERN		R	PU	m24
P8-D1	First laboratory test results	8	JSI		R	PU	m16
P8-D2	Test results of RICH prototypes	8	JSI		R	PU	m30
P9-D1	Translation of the analogue part of the pixel circuit from 0.25 to 0.13 um	9	NIKHEF		R	PU	m12
P9-D2	Simulation and evaluation of different readout architectures	9	NIKHEF		R	PU	m24
P10-D1	Characterization of MAPS SOI prototypes	10	AGH		R	PU	m24
P10-D2	MAPS SOI technology assessment	10	AGH		R	PU	m36
P11-D1	Multi-channel high speed front end electronics	11	GSI		O	PU	m24
P11-D2	Assessment of calorimeter front-end ASIC	11	GSI		R	PU	m24
P11-D3	Test beam results of a multi-channel diamond detector system	11	GSI		R	PU	m34
P11-D4	Characterization of calorimeter multi-channel readout	11	GSI		R	PU	m36
P12-D1	First version of generic code with simple controls	12	LNF		R	PU	m9

P12-D2	Comparison of new MC with available data	12	LNF		R	PU	m24
P12-D3	Proposal for an optimized detector	12	LNF		R	PU	m30

Table: Work Package descriptions. Common research projects of the MC-PAD network.

Work package number	**WP 1**				**Start date or starting event:**						
Work package title	**Radiation Tolerant Mini-strip Tracking Detectors**										
Activity type	**RTD**										
Participant id	**CERN**	**GSI**	**JSI**	**UHH**	**Micron**						
Person-month per beneficiary:	36	36	0	0	0						

Objectives

Develop silicon detector modules for Particle tracking in a high rate and high occupancy environment.

Description of work

For the ATLAS- and CMS-upgrades for the SLHC, the high luminosity upgrade of the LHC, as well as for several FAIR experiments, radiation tolerance paired with high rate capability and high occupancy is the biggest challenge. Both issues will be jointly addressed in this project. The CERN based ESR will study radiation damage as well as signal deterioration in close contact with P3, the GSI based ESR will focus upon system aspects, system integration and robust detector operation at highest radiation doses and occupancies. This includes the detailed investigation of the deterioration of the signal shape. The considerable difference in radiation fields of the SLHC as compared to FAIR as well as differences in the timing scheme and signal intensities make this project particularly challenging and interesting.

Deliverables

P1-D1	Set-ups at CERN and GSI commissioned	m10
P1-D2	Recommendations on materials and designs	m36

Work package number	**WP 2**			**Start date or starting event:**							
Work package title	**Hybrid Pixel Detectors**										
Activity type	**RTD**										
Participant id	**DESY**	**PSI**	**UHH**	**Micron**							
Person-month per beneficiary:	0	36	36	0							

Objectives

Develop hybrid pixel detectors for tracking at the innermost regions of the LHC and SLHC and photon research at X-FEL.

Description of work

The performance of the presently installed pixel detectors closest to the LHC beam will degrade considerably after a few years due to radiation damage. Also the newly developed X-ray sources, in particular the European X-FEL, pose unprecedented requirements in terms of radiation hardness and instantaneous photon densities. Based on existing and future (see project P3) measurements of the macroscopic radiation damage, this project aims at an optimized design of the pixel sensor. The corresponding read-out electronics, which is an integral part of a pixel detector system, is addressed in project P9.

The project focuses on cost effective hybrid pixel detectors using "standard" components. A key part will be the careful modeling of the sensor response as a function of the radiation fluence and annealing scenario. The work will use commercial solid state device simulation tools as well as specifically developed programs to simulate signal shapes. Lab measurements on prototype detectors and test experiments in photon and particle beams (e.g. at DESY and CERN) will allow to study and improve the performance under realistic conditions.

Deliverables

P2-D1	Simulation of signal response	m18
P2-D2	Characterization of prototype sensors	m36
P2-D3	Characterisation of irradiated CMS standard sensors	m12
P2-D4	Characterisation of irradiated single sided sensors	m36

Work package number	**WP 3**			**Start date or starting event:**							
Work package title	**Radiation Hard Crystals / 3D Detectors**										
Activity type	**RTD**										
Participant id	**CERN**	**JSI**	**UHH**								
Person-month per beneficiary:	0	36	36								

Objectives

New materials and read-out geometries for ultra radiation hard sensors.

Description of work

Epitaxially-grown silicon sensors (in particular using p-type crystals) with thicknesses up to 150 µm will be fabricated and investigated. Based on past measurements they are expected to be radiation hard in terms of increase of effective doping concentration. Using solid-state measurement techniques, the microscopic and macroscopic damage will be studied as function of type of radiation, radiation dose and annealing scenario. Measurements with small pixel/strip prototype sensors connected to LHC/SLHC speed electronics will start in the second year with the aim to determine charge collection efficiency, detection efficiency, and position resolution as well as to optimize reconstruction algorithms.

Within the framework of the CERN-RD50 collaboration the performance of 3D detectors will be investigated. A prototype of the double column type detectors (3D-dct) will be processed by mid 2008 (IRST, CNM, Glasgow University) followed by further iterations. The initial focus will be the measurements of the signal formation in different columns. Simulation tools will be developed to interpret the measurements and to improve the design. Studies of charge collection efficiency and position resolution will follow for various sets of operation parameters (e.g. radiation dose, annealing and temperature). Special emphasis will be devoted to the development of algorithms for position reconstruction. Finally a running scenario for the SLHC will be proposed.

P3-D1	Simulation of signal shape for detectors of general geometry	m16
P3-D2	Running scenario for epi sensors for SLHC	m24
P3-D3	Performance of epi detectors at high luminosities	m36
P3-D4	Optimised reconstruction algorithms	m30
P3-D5	Performance of 3D detectors at high luminosities	m36

<table>
<tr><td>Work package number</td><td colspan="2">WP 4</td><td colspan="4">Start date or starting event:</td><td colspan="6"></td></tr>
<tr><td>Work package title</td><td colspan="12">Micro Pattern Gas Detectors</td></tr>
<tr><td>Activity type</td><td colspan="12">RTD</td></tr>
<tr><td>Participant id</td><td>CERN</td><td>GSI</td><td>LNF</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Person-month per beneficiary:</td><td>36</td><td>0</td><td>24 (ER)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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Objectives

High precision and ultra-low mass tracking detectors based on the GEM technology.

Description of work

The CERN group is currently optimizing the single mask GEM technology which allows building large area detectors. The R&D program consists of the construction and evaluation of small size detector prototypes and the performance comparison with detectors of alternative technologies. Based on the results of these studies a full size prototype detector will be designed, constructed and studied in a test beam. Electronics cross talk issues will be addressed in readout structure design by detailed detector and signal simulations and the radiation tolerance and material budget will be investigated.

The LNF group is working on an ultra-light, cylindrical and dead-zone free triple-GEM detector (C-GEM) made of five concentric layers. A small size prototype has already been built successfully. The proposed detector is optimized for applications where large size combined with low mass is essential. The project is technologically innovative and represents a significant step forward with respect to the existing vertex tracking technology.

Deliverables

P4-D1	Characterization of single GEM mask small prototype	m09
P4-D2	Analysis of C-GEM beam test	m18
P4-D3	Technology assessment report C-GEM	m21
P4-D4	Technology assessment report single mask GEM	m33

Work package number	**WP 5**			**Start date or starting event:**							
Work package title	**TPC with MPGD Readout**										
Activity type	**RTD**										
Participant id	**CERN**	**DESY**	**GSI**	**NIKHEF**	**UHH**						
Person-month per beneficiary:	0	36	36	36	0						

Objectives

Large volume tracking for ILC and PANDA at FAIR using MPGD and pixel readout.

Description of work

The Time Projection Chamber (TPC) is the detector of choice for large volume tracking with minimal material with highest information density. It is used in the ALICE experiment at the LHC and will be a key technology for the next generation of experiments e.g. at FAIR (PANDA) and at the International Linear Collider. In order to cope with the enormous particle densities and data rates, the TPCs will need to be equipped with micro-patterned amplification, gating and readout structures.

All 3 ESRs will work on technological feasibility and prototype studies which will be realized in the frame of existing large experimental collaborations. For PANDA, a GEM-TPC will be tested in the running experiment FOPI. DESY and NIKHEF are pursuing the development of a large high precision TPC as the main tracker for a detector at ILC. A large prototype is being constructed in the framework of the EC-funded EUDET project, which will serve as a detailed test of large MPGD detectors and demonstrate their capabilities for large scale applications. The ESR at NIKHEF will participate in a particularly innovative development, namely the creation of an amplification grid directly on the readout chip by advanced wafer post-processing techniques.

Deliverables

P5-D1	Evaluation of effectiveness of discharge technologies	m18
P5-D2	Analysis of ILC-TPC testbeam campaign	m24
P5-D3	Beam tests of PANDA prototype analyzed	m32

Work package number	**WP 6**			**Start date or starting event:**								
Work package title	**Very Forward Calorimetry**											
Activity type	**RTD**											
Participant id	**DESY**	**UHH**	**AGH**	**LNF**	**IFJ**							
Person-month per beneficiary:	36	0	36	0	0							

Objectives Development of very forward calorimeter for the ILC.

Description of work

One of the functions of the ILC forward calorimeters is to measure the luminosity delivered by the machine with an accuracy of better than 10^{-3} resulting in mechanical precision requirements on the micrometer level. The calorimeters are exposed to e^+e^- pairs from beamstrahlung, a new phenomenon at the ILC. They have to be equipped with radiation hard sensors and fast and low power FE electronics to allow feedback for beam tuning. Both calorimeters must be compact and finely segmented to reach the required performance.

There is already a close collaboration between AGH Cracow, IFJ Cracow and DESY within the ILC-FCAL and EUDET projects. In this framework, the ESRs will work on the following topics: Monte Carlo studies to optimise the shape and granularity of the calorimeter, sensor development for both calorimeters (Silicon, GaAs and CVD diamond), sensor performance studies in the laboratory and test beam, development of ultra-thin sensor planes for both calorimeters, integration of sensor planes and FE ASICS, preparation of a fully equipped prototype module for performance studies in the EUDET test beam.

AGH Cracow will focus the activities on the development of the FE ASICS (see P11) and DESY on the sensor development and sensor plane tests. Monte Carlo simulations and integration of sensor planes and FE ASICs will be done in a common effort.

Deliverables

P6-D1	Design of the sensor planes	m12
P6-D2	Function test of sensor planes in the laboratory	m24
P6-D3	Beam test results from multi-pad sensor planes	m30

Work package number	**WP 7**			**Start date or starting event:**							
Work package title	**Advanced Photodetectors**										
Activity type	**RTD**										
Participant id	**CERN**	**LNF**	**Photonis**	**PSI**							
Person-month per beneficiary:	24 (ER)	0	0	0							

Objectives

Development and application of novel photodetectors.

Description of work

The development of novel photodetectors like Hybrid Photodetectors (HPD) and Geiger-mode Avalanche Photodiodes (G-APD), pursued during the past years in close collaboration with industry, led to exciting perspectives for applications ranging from particle physics (e.g. calorimetry, particle identification, tracking using scintillating fibres) to astro-particle physics and medical imaging. The ongoing development program covers concept, design, construction and performance evaluation of various photodetectors. Most of the work is done in close collaboration with the industrial partner Photonis. The project comprises 3 lines of activities: (1) Integration of an X-HPD in a pressure sphere and measure performance under water. (2) Design, construction and test of a scintillating fibre tracker module for ATLAS with G-APD readout. Test of a prototype of a highly granular lead-scintillating fibre or tile-wavelength shifter calorimeter readout with G-APDs at the Frascati Test Beam facility. (3) In collaboration with PSI: Test of a positron emission tomography (PET) camera based on long axially oriented crystals with wavelength shifter strip readout with G-APDs.

Deliverables

P7-D1	Test results of X-HPD lab tests	m18
P7-D2	Test results of fibre tracker and calorimeter	m21
P7-D3	Characterization of PET based camera	m24

Work package number	**WP 8**			**Start date or starting event:**							
Work package title	**Photodetectors for High-B Fields**										
Activity type	**RTD**										
Participant id	**DESY**	**CERN**	**JSI**	**Photonis**	**UHH**						
Person-month per beneficiary:	0	0	36	0	0						

Objectives

Development of photodetectors compatible with high magnetic fields and their application for particle identification and medical imaging.

Description of work

Photodetectors for particle identification in particle physics experiments but also in scintillation detectors for multimodal medical imaging often have to operate in magnetic fields exceeding 1 T. In addition they are required to efficiently detect single photons. While the traditionally used phomultiplier tubes (PMTs) do not work in high magnetic fields, standard semiconductor light sensors (photodiodes, avalanche photo-diodes (APDs)) are not sensitive to single photons. Novel sensors, e.g. multianode micro-channel plates (MCP), silicon photomultipliers (SiPM) and Geiger mode APDs, are currently being evaluated. The aim of this project is to develop and test novel position sensitive single photon detectors for operation in high magnetic fields, and use them in prototype devices.

Prototype photon detectors will be tested in collaboration with CERN, Photonis and other network partners. Pulsed light sources will allow scans of the spatial uniformity of response, sensitivity and time resolution. The photon detectors will be installed in two prototype detector set-ups, a proximity focusing ring imaging Cherenkov counter, and a PET apparatus.

Deliverables

P8-D1	First laboratory test results	m12
P8-D2	Test results of RICH prototypes	m24

Work package number	**WP 9**		**Start date or starting event:**								
Work package title	**Front-end Electronics for Hybrid Pixel Detectors**										
Activity type	**RTD**										
Participant id	**NIKHEF**	**PSI**									
Person-month per beneficiary:	36	24(ER)									

Objectives

New readout architectures for the front-end electronics for the upgrades of the ATLAS and CMS pixel detectors.

Description of work

The present LHC pixel detectors are based on n-on-n silicon pixel sensors with a readout using 0.25 micron CMOS technology. The radiation hardness of both sensor and electronics has been the subject of many tests and is well understood. The inner layer of the pixel system is estimated to last approximately 3 years at high LHC luminosity requiring a replacement of the inner layer of the pixel detector. A simple copy of the system is not sensible as the present chips suffer from the limitations of the 0.25 micron technology which was the state of the art at the time of construction. During the project we aim at the development of a full scale pixel chip based on 0.13 micron CMOS technology. This technology offers the opportunity to implement new features like an increased high rate capability, which is especially important for the innermost pixel layer. In addition a reduction of the readout pitch can be envisaged.

Deliverables

P9-D1	Translation of the analogue part of the pixel circuit from 0.25 to 0.13 um	m12
P9-D2	Simulation and evaluation of different readout architectures	m24

Work package number	**WP 10**		**Start date or starting event:**								
Work package title	**Monolithic Detectors**										
Activity type	**RTD**										
Participant id	**AGH**	**IFJ**	**JSI**	**UHH**	**DESY**						
Person-month per beneficiary:	36	0	0	0	0						

Objectives

Monolithic active pixel sensors and detectors based on silicon-on-insulator technologies.

Description of work

Detectors for a future high luminosity B-factory and for the proposed International Linear Collider require precision vertex reconstruction in a high track density and radiation dose environment. Compared with current silicon strip and hybrid pixel detectors, a significant reduction in overall material thickness is needed to achieve the desired vertex resolution. Considerable progress in the development of thin CMOS-based Monolithic Active Pixel Sensors (MAPS) in recent years makes them a viable technology option. The most serious concerns are their radiation hardness and their readout speed. These will be addressed in several prototypes, some already existing and others still to be designed.

The work is embedded in detector development teams (including super-BELLE and ILC) and will cover MAPS design, readout electronics, detector irradiations, detector testing and vertex detector layout studies.

Deliverables

P10-D1	Characterization of MAPS SOI prototypes	m24
P10-D2	MAPS SOI technology assessment	m36

Work package number	**WP 11**			**Start date or starting event:**							
Work package title	**Front-end Electronics**										
Activity type	**RTD**										
Participant id	**AGH**	**DESY**	**EVATRONIX**	**GSI**							
Person-month per beneficiary:	36	0	0	24(ER)							

Objectives

Very low noise electronics for ILC-calorimeters and ultra fast microwave circuits for diamond detectors.

Description of work

CVD-diamond sensors, polycrystalline as well as single crystal, are promising candidates for the high in-beam intensities projected for FAIR and for TOF (time-of-flight) applications in experiments at FAIR. In the absence of appropriate electronics from other applications, ultra fast microwave analogue pre-amplifier and discriminator circuits have to be developed.

Likewise, the more than 100 000 channels of the front-end electronics for the silicon luminosity detector LumiCal of the forward calorimeter (FCAL) for the ILC pose a number of major challenges, like dynamic range, speed, noise, particle occupancy, linearity, signal amplitude, resolution and power consumption. Prototypes of discrete electronic components as well as integrated front-end and ADC conversion ASICs will be designed, produced and tested. A prototype digital readout system will be developed for LumiCal. The devices will be tested extensively on the respective detectors. The digital components will be developed and built in close collaboration with the company Evatronix. The EST and ER will closely work together with the respective detector experts on one side and the analogue circuit designers on the other.

Deliverables

WP11-D1	Multi-channel high speed front end electronics	m24
WP11-D2	Assessment of calorimeter front-end ASIC	m24
WP11-D3	Test beam results of a multi-channel diamond detector system	m34
WP11-D4	Characterization of calorimeter multi-channel readout	m36

Work package number	**WP 12**		**Start date or starting event:**									
Work package title	**Optimization of Monte Carlo Tools and Comparison with Benchmark Data**											
Activity type	**RTD**											
Participant id	**CERN**	**LNF**										
Person-month per beneficiary:	36	24(ER)										

Objectives

Improved description of the neutron response in calorimeters and gas detectors.

Description of work

P12. Optimization of Monte Carlo Tools and Comparison with Benchmark Data

CERN, LNF ; ESR : 3 yrs, ER : 2 yrs (contact person : S. Miscetti, LNF)

The detailed simulation of lead/scintillating fibre (Scifi) calorimeters of different structures using Monte Carlo tools (Fluka, Geant4) is relevant to evaluate their energy response and sensitivity to neutrons. The effect of background neutrons on the energy deposition measured in gas chambers is expected to be a significant limitation for gas detectors in many experiments. To model these accurately the physics models in Geant4 for neutrons will be validated. Also they will be coupled with simulation of resulting gammas and the ionization in Geant4 and transport of lower energy electrons/gammas in the Garfield tool, to create an integrated tool for assessing the effects of neutrons in gas detectors.

The project comprises three main activities:

The comparison of detailed simulation with already existing and new test beam data, in order to understand the increased efficiency and to study the dependence of the efficiency on neutron energy and on calorimeter thickness.

The optimization of the efficiency with respect to calorimeter structure, lead/Scifi ratio, overall thickness, signal readout and type of fibre, using Monte Carlo techniques and the working-out a proposal for an optimized detector.

The validation physics models for neutron interactions relevant to gas chamber ionisation, improvement if needed and creation of application coupled with Garfield for studying the effect of neutrons on gas detectors.

Deliverables

WP12-D1	First version of generic code with simple controls	m9
WP12-D2	Comparison of new MC with available data WP 12	m24
WP12-D3	Proposal for an optimized detector	m30

Work package number	**WP 13**	**Start date or starting event:**								
Work package title	Network coordination									
Activity type	**MGT**									
Participant id	**CERN**									
Person-month per beneficiary:	48									

Objectives

Effective of use of network resources, optimal training for researchers, maximum impact.

Description of work

The work package comprises the management and administration of the MC-PAD network in agreement with the Commission's rules, contractual obligations and the agreed network procedures. This includes reporting (scientific and financial) to the Commission, supervision of all network activities, ensuring the application of standards and procedures across the whole network, organization of common network training events, organization of management meetings.

Deliverables

Reports

Minutes

B.2.2 Management structures and procedures

The network will be managed by a Supervisory Board (SB) and an Executive Board (EB) according to the diagram below.

The main tasks of the Supervisory Board are to support the Executive Board with advice, to monitor its activities and to follow up the general operations and progress of the network. The Supervisory Board comprises a representative of each of the network partners, including associated and industrial partners and will meet twice a year. The Board elects its chairperson that is not a member of the Executive Board. The Board should monitor all actions taken by the Executive Board to ensure that the network's goals are effectively fulfilled. It appoints two external advisors for an independent peer-review of the quality of the training programme.

The Executive Board is in charge of the overall management of the network's research and training programme. The EB is chaired by the Co-ordinator of the MC-PAD network. The other members of the EB are appointed by the Supervisory Board for a period of one year (renewable): the deputy network co-ordinator, a co-ordinator for the training program, a co-ordinator for selection matters, and deputies for the latter two.

One of the EB's tasks of particular importance is organisation and follow-up of recruitment. It assures that the selected candidates are matched with a project and assigned to a supervisor and that a career development plan including a personal training schedule is established. The organisation of network wide training events and workshops will be initiated by the EB. Two external experts will provide feedback and advice on the quality and organisation of the training activities.

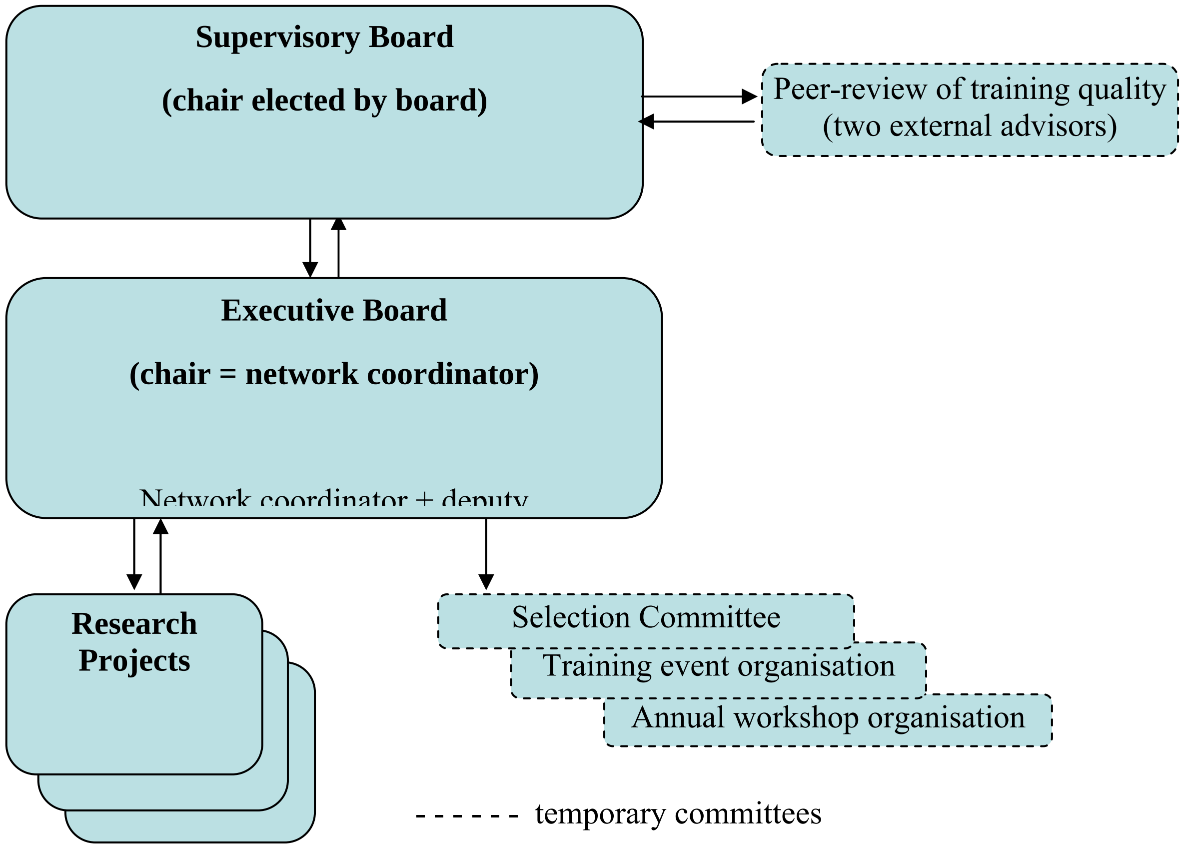

Diagram: Management of the MC-PAD network.

The EB will follow up the research carried out in the projects of the network. For each project, contact persons have been identified who manage and follow up the progress of the projects and also monitor the development of the researchers assigned to the project.

Frequent contact and exchange of results between the partners within a project is mandatory and is organised by the partners of that project. Structural problems, disputes or changes to the research plans must be reported to the EB. If required, the EB will intervene to try and solve disputes amicably.

The Executive Board will have monthly meetings using modern telecommunication means. The Executive Board has the freedom to appoint committee members for a finite duration in time, to organize selection, implement training and prepare the annual workshops.

An administrative employee will be financed on a part-time basis from the network's management budget. He/she will support the activities and the organisation of the network, in particular the financial follow-up and reporting, and provide administrative help to the recruited researchers.

- *Rules for decision-making*

The Executive decisions for the implementation of the research training programme will be taken by the Executive Board. Any changes in the research and/or training programme will have to be approved by the Supervisory Board. Where such changes may have impact on the contractual obligations of the ITN, they will be submitted to the EC Project Officer in charge of the ITN for approval.

Scientific and administrative co-ordination of the research projects (WP 1-12)

The scientific and administrative co-ordination of the individual research projects WP 1-12 are carried out by the participating institutes. The project contact persons will inform the Executive Board about progress, delays or unforeseen problems of technical or other natures. Whenever possible, the EB will propose and monitor corrective measures.

Financial management

The network co-ordinator has the overall responsibility for the financial management of the ITN. The financial management will be handled by each participating institution. Financial controlling and management will the responsibility of the local finance departments, which will create budget codes and all necessary monitoring tools as well as other formal financial arrangements. Expenditure for each researcher is monitored closely according to expenditure type in order to ensure compliance with the relevant ceilings and rules of the Commission. Additionally, local finance departments report to the network co-ordinator of the ITN for an overall control of the funds as well as potential active redirection of funds. The network participants are in charge of an appropriate auditing of their financial matters.

B.2.3 Planning of conference and Visiting Scientists contribution

We will organize a number of meetings and training events as summarized in the table below. The *kick-off meeting* will take place very soon after the start of the project. Its main purpose is to bring together the participants of the network, to form the management structure and discuss details of the research and training programme and its implementation.

We plan to organize *network training events* and *open training events* which involve the researchers from several or all research projects. Whenever possible, the training will put emphasis on the common aspects in detector development. Many of the training events aim at subjects that lie outside the normal particle physics training programs. Topics of these training events are, for example, radiation damage, ageing of detectors and microelectronics. The topics are chosen such that researchers from several projects should profit from the training during their daily research activities. It is stressed that the training events are open to all members of the networks.

The *annual meetings* bring together all people involved in the network, i.e. the recruited researchers, their supervisors and the members of the Executive and Supervisory Boards. The meetings have a two-fold function. (1) The projects present scientific progress reports to promote sharing of ideas and dissemination of results. Talks and posters will be presented by the ESRs and ERs in the projects. Written reports of these yearly workshops will result in a collection of proceedings which provides an overview of the scientific progress of the research carried out at the network institutes and projects. (2) Meetings of the Supervisory and Executive Boards will permit a review of the overall progress of the network and a discussion of possible adaptations of strategy and implementation to cope with experienced difficulties or shortcomings. These meetings will start the preparation of the annual reports which will be completed in the following weeks.

The *closing meeting* towards the end of the project is an excellent occasion for the young researchers to discuss and disseminate their scientific results. It will also serve as a forum to critically review and compare the overall scientific progress with the goals, and to judge the achievements and impact of the network in the fields training and dissemination.

Table: Tentative schedule of network meetings and training events

	Milestones	**Dates (months after start)**	**Deliverables**
1.	Kick-off meeting	m1-m2	Protocol
2.	Network training events	m9, m18, m30	Training certificates
3.	Open training events	m12, m24, m36	Training certificates
4.	Annual meetings	m12, m24, m36	Proceedings, annual reports
5.	Closing meeting	m48	Report, recommendations

Visiting Scientists

We consider the recruitment of visiting scientists (VS) an excellent way of efficient knowledge transfer into the network projects and a means to significantly enhance the training capacity and quality. We intend to recruit senior scientists with an international reputation for a total duration of 18 months.

Visiting scientists, generally senior researchers with an international reputation in the field of radiation detectors, will be invited to work for periods of typically 1-2 months with one of the network participants. The VS will be chosen for their specific expertise, know-how and skills. They will work with the local team on their project, in direct contact with the ESRs and ERs. The trainees will profit from their particular expertise and experience. These visits will contribute to a mutual transfer of knowledge between the network and outside institutions.

Visiting scientists will also be invited to give special lectures and seminars, preferably at the network's training events.

Large infrastructures are available on the various sites and at the sites of the industrial partners. The use of these highly-specialised experimental set-ups is quite often in the hands of very few experts. Visiting scientists can transfer essential knowledge among the different institutes. Also the evaluation of certain development processes at other institutes can reveal new roads to success. For young researchers it is attractive to get training from well known experts on the use of specialised apparatuses.

B.3 Impact

B.3.1 Research Indicators of Progress

B3.1.1 Research activities

As stipulated by the ITN requirements, the training objectives will be clearly defined in the Career Development Plan. Progress will be monitored regularly to ensure coherence and identify deviation from the plan (be it under-achievement of targets or identification of additional objectives). Great importance is given to regular and frequent contact between the researcher and his/her supervisor. Close personalized professional contact is considered the principal steering mechanism for meeting scientific as well as the training objectives projected in the researcher's Career Development Plan. Regular meetings and an annual international plenary of researchers and supervisors will also be organized. EC Project Officers will be invited. Researchers will all make short presentations and/or provide posters on their work, reporting on the state of their project or the achievement of a milestone. This event will allow all participating personnel to put their own contributions and achievements into perspective, improve networking and identify potential synergies in their work.

B3.1.2 Training activities

The ITN's Executive Board is directly responsible for the organisation and co-ordination of the training program. A Supervisory Board consisting of one member from each participating institution and, in particular, representatives of our industrial partners, will monitor the quality of the programme.

The trainee's progress and expected output will be monitored and supported in the following way:

- In the first 6 weeks, a Career Development Plan comprising scientific and training objectives and milestones is defined in an induction interview with the supervisor, and is recorded in a report which is signed by the supervisor and the trainee.
- Continuous supervision of the trainee by his/her supervisor.
- Regular status discussions between trainee and supervisor.
- Gatherings of Marie Curie trainees will be organized, including short presentations and/or poster sessions.
- The work of the trainee will be documented both by internal reports and presentations, as well as contributions to publications and presentations at international conferences or workshops.

To peer-review the quality and organisation of the network's training activities, two external advisors will be appointed. These will be internationally renowned researchers in our field with long-standing experience in scientific education.

For all training courses, feedback questionnaires filled by the trained researchers will help to optimize the content of the programme and contribute to assuring highest quality.

B3.1.3 Management and impact

B.3.1 Dissemination and Impact

By the very nature of the large international scientific collaborations in high energy physics, all researchers will be immersed in a pool of *networking* possibilities. Whether it is via inter-team meetings or via collaboration meetings and international conferences, the researchers will have excellent networking opportunities both in academic areas of activity and with the industrial partners involved on the ITN.

Dissemination of research results in the particle physics world is most commonly done using journal publications, presentations at conferences (with subsequent publication in proceedings) or seminars of which a great number are given at the network's institutions. This gives the researchers ample opportunity to hone their skills in writing or making presentations.

A *network web site* will be created and maintained. It will serve for the internal communication and information exchange between the network partners. It will also be used for outreach purposes, advertisements of vacancies, announcement of network events as well as relevant conferences and workshops. Research results, in the form of notes, talks etc. will be published on this web site (in so far as industrial / confidentiality clauses allow).

B.4 Ethical Issues

(not applicable)

B.5 Gender aspects

Gender balance or, in more general terms, equal opportunities moved into the focus of the human resource policy of many large organizations. In the MC-PAD project, the network participants are committed to a fair treatment in recruitment and career development regardless of sex, ethnic origin, physical handicap, sexual orientation or religion, nationality, etc. Equally important are respect and dignity in the workplace, a reasonable balance between work and home-life and an appropriate support for working parents. Improving the gender balance is still an issue in our field of research, namely high energy physics, although the representation of women varies considerably from country to country.

Comment: Although in several places it is mentioned that ESRs are normally expected to obtain PhDs, this aspect should have received more attention in the cases where ESR activity is mostly carried out in one of the labs. ESR recruitment by the network and PhD enrolment at a university do not appear to be seamless.

All the Labs participating in the MC-PAD network are experienced in supervising PhD students and guiding them through the phases of their research and training until the final submission of their thesis. In order to be able to so so, the labs have by now well-established programmes for doctoral students. In the following we give two exaples.

DESY in Hamburg collaborates with several universities, predominantly with the University of Hamburg. Candidates for thesis research have to satisfy the universities' terms of admission for doctoral theses. In the MC-PAD network this will be taken care of in the recruitment procedure. Several non German students received their PhDs from Hamburg University in the past.

As for the ESRs which will mostly work at NIKHEF, they will enrol in the Research School of Subatomic Physics for PhD students, which is formed by several Dutch Universities and Institutes. Already now a substantial part of the PhD students that participate in this school are non Dutch students. Apart from the research that is carried out in the different labs or groups, the students follow joint schools and lectures and have the opportunity to share their experience with colleagues.

Comment: The means for establishing long-term collaborations or lasting structured training programmes between the partner's organizations should be better specified.

Modern particle physics experiments rely on a strong collaborative effort of all involved partners. One goal of the MC-PAD ITN is to strengthen and improve these collaborations in order to meet the challenges of a future generation of particle detectors. A key aspect is the involvement and the training of young scientists, which will work on their projects in international teams and at different partner sites. Naturally, this experience and the established contacts will extend beyond the end of the MC-PAD ITN and the projects currently proposed. Through these contacts and the knowledge of the infrastructure and the experts in the field, long-lasting and future collaborations are facilitated.

A number of training events will be organised in the framework of the MC-PAD ITN, both internal to the network and open to participant from outside. Through the response to the calls for the training events and through direct feedback from the trainees we will be able to judge the potential interest in a continuation of these training programmes.

As the projects the researchers will work on will extend beyond the end of the MC-PAD ITN and future research topics will require similar infrastructure and skills, both the collaborations and the training programme will last.

PART C:

(to be filled in later)

PART D:

(to be filled in later)