WP10: Test Beam Infrastructures for Fully Integrated Detector Tests

JM's proposal trying to incorporate comments exchanged during the mail discussion

A) This part should go (partially) to some general description of DevDet

Several of the existing puzzles in particle physics point to the TeV scale as the arena for new phenomena. The LHC proton-proton collider is at the verge of exploring this completely new energy domain in particle physics and holds the promise of fundamental new discoveries such as the origin of mass, the discovery of particles predicted by supersymmetry, new forces mediated by new gauge bosons, processes associated with the existence of new dimensions of space, and perhaps even completely unexpected phenomena. While proton-proton colliders are ideal instruments for exploring new energy domains, electron-positron colliders at the TeV scale will have the capability of extending the discovery potential through high precision measurements. These measurements will allow precise disentangling of the underlying structure of new phenomena and will provide the keys to describe new fundamental laws of nature.

Two potential future electron-positron linear colliders (LC) are presently under development within world-wide study groups: the International Linear Collider (ILC) and the Compact Linear Collider (CLIC). In Europe both projects are acknowledged as high-priority projects by the Eurpoean High Energy Physics community represented by the European Strategy Group for Particle Physics of the CERN council[1].

The ILC is based on supra-conducting accelerator technology and deviced for the energy range 0.5 - 1 TeV. It has been developed over the last about 15 years with a strong and braod involvement of European institutes in a series of workshops initiated by the European Committeee for Future Accelerators (EFCA). Collider and detector are being developed under the management of the Global Design Effort (GDE) with the goal to be ready for construction round the beginning of the next decade. Recently a Research Director has been appointed to coordinate the development of ILC detectors and their selection.

To go beyond the 1 TeV scale, a new type of machine is under development known as CLIC. Its concept is based on a challenging technology of energy transmission from a low-energy drive beam to a high-energy beam and has the potential of reaching an energy as high as 3 TeV. The CERN Council Strategy Group supports the R&D efforts to develop this technology to push forward the high energy frontier. While covering different energy domains and different machine structure, their particle detectors at linear colliders could have R&D issues to be addressed in common and more, the test beam infrastructure of detector test (EUVIF).

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[1] http://council-strategygroup.web.cern.ch/council-strategygroup/Strategy_Statement.pdf

B) This part should then become the intro to WP10 EUVIF

At high-energy colliders, because of their peculiar time structure and challenging background conditions, detectors are an integral part of the design process. Technology development and assessment for LC detectors is currently being co-funded by the EC through the EUDET Integrated Infrastructure Initiative in FP6. This successful project, now at its mid-term, defines and implements European infrastructure for research and development towards components of future LC detectors. An important aspect of EUDET, which is greatly appreciated by its partners, is the integration of partners and associates into a common scientific network, which makes common facilities available to others, facilitates the exchange of information and prepares for the future establishment of more formal collaborations.

The next logical step toward an ILC detector design is to assess system aspects of the proposed detector concepts. This means that the interplay between detector components must be studied. The principle integrating factor in linear collider event reconstruction is the concept of energy flow. In this concept, already successfully used in the LEP era, reconstructed atomic objects from different detectors are combined to what closely resembles physics objects such as leptons, photons, or jets. With the advent of imaging calorimeters, even single hadrons can be identified and measured. This opens a new dimension to physics analysis with collider detectors.

It must thus be established how single measurements from the detector components complement each other to form energy flow objects. It must be determined how the system as a whole can be integrated mechanically, how services can be distributed and how data can be collected. This requires the definition of interfaces and their implementation. It also requires to establish data conditioning and reconstruction strategies that correspond to the well studied physics requirements.

To this end, the European Vertical Integration Facility (EUVIF) proposes a unique infrastructure to integrate commensurate prototypes of LC detector components and expose them to particle beams with the required LC time structure and an appropriate energy range. It will present to users a flexible framework of infrastructure for services, data acquisition and prototype accommodation, in which complete vertical slices through future detectors can be tested. In this way, valuable data on system level performance can be established.

1.1 Concept and project objectives

The major components of the Vertical Integration Facility are schematically shown in **Error! Reference source not found.**. A special beam line delivers secondary beams to a reserved area, where particles penetrate the detector component prototypes placed into the beam line. The beam time structure is adjusted to closely resemble the time structure of intersecting beams at ILC, such that the particle rates resemble those encountered by a vertical slice through the detector.

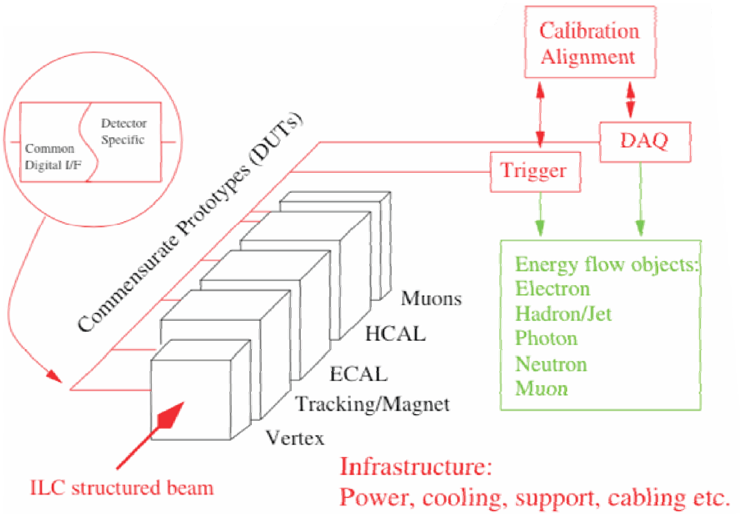

Figure 1: Schematic view of major EUVIF components

Detector component prototypes are principally those, which are being developed using the EUDET infrastructure: pixel-based vertex detectors; TPC type tracking detectors with silicon readout, supplemented with silicon strip layers; and compact structures for electromagnetic and hadronic imaging calorimeters. However, the EUVIF will allow to exchange every single components for an evaluation of alternative technologies.

Infrastructure components concern mechanical, thermal and electrical services. A major task in the preparation of these services is to define interfaces. As far as data acquisition is concerned, the definition of the architecture, definition of common interfaces as well as the interplay between trigger and data flow are major tasks.

Task 10.1: Beam line(s) set-up and generic infrastructure (e.g. expt. magnets)

Contact: Ingrid Gregor (& Emanuelle Perez)

1. General description of the task activities

At CERN a number of accelerators are currently running and prepare for the start up of LHC in 2008. One of its pre-accelerators is the Super Proton Synchrotron (SPS) which serves at the same time as accelerator for secondary beam lines which supply test beam facilities with high energetic particles. One of this test beam facility will be the dedicated test beam line for the Vertical Integration Facility.

The goal of this task is to identify and supply the beam line with the generic infrastructure necessary for the vertical integration facility. This generic infrastructure includes magnets, mechanical support structures, and gas supplies.

2. Organization participation

Participant acronym	CERN					
Estimated person-months per participant:						

3. Objectives

- Supply beam line with adequate magnets necessary for the vertical infrastructure
    - Dipole magnet for the tracking infrastructure
    - Dipole magnet for HCAL infrastructure
- Equip beam line area with gas supplies

4. Description of work

(~1/2 page, describe the work in the context of the objectives. possibly broken into sub-tasks, indicate for each sub-task the purpose of it, the participants involved in it and their role. If really indispensable, you can divide into subtasks.)

List of Deliverables for the task

(typically 1 per task per year)

Deliverables of task 1	**Person month estimate**	**Description/title**	**Nature[1]**	**Delivery month[2]**
wp.t.1				
wp.t.2				

List of Milestones for the task

Milestones	**Description/title**	**Tasks**	**Delivery**	**Means of verification**

		involved	month[2]	
wp.t.1				
wp.t.2				

[1] Nature: R=Report, P=Prototype, D=Demonstrator, O=Other
[2] Counted from the starting date

Task 10.2: Common DAQ and detector controls for integrated detector tests

Contact: Matthew Wing, Günter Eckerlin

1. General description of the task activities

For the Vertical Integration Facility a common Data Acquisition (DAQ) system has to be provided that allows easy integration of various detector components and ensure efficient data taking of the facility for varying detector setup. To allow for an easy exchange of detectors a common interface and a protocol has to be defined and prototypes for the hardware setup as well as the software components have to be provided from the common DAQ side. The different detector components should then interface to the common DAQ via these tools to ensure compatibility.

The common DAQ itself will then provide event building and if necessary event selection capability on an online computing facility (event building farm) and a network based uplink to persistent storage. The software on the event building farm should be as close as possible to the offline computing environment envisaged.

In addition detector control interfaces for detector configuration and conditions monitoring should be provided as well as the interface to calibration and alignment data for a possible online event processing in case event filter capability is needed.

2. Organization participation

Participant acronym	DESY	Brussels	UNI-GE			
Estimated person-months per participant:						

3. Objectives

- Define a common DAQ architecture including protocols, interfaces, etc
- Provide an event building facility that allows the different detectors to connect via the predefined interfaces
- Provide an detector control and monitoring infrastructure including conditions monitoring and configuration management
- Provide a prototype detector interface to the common DAQ based on ATCA/Ethernet
- Provide an online event processing with event filter capabilities based on offline software
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4. Description of work

4.1 DAQ Architecture

Define the common DAQ architecture, the protocols and interfaces to the detectors
Participating : DESY

4.2 Event Building Facility

Provide the event building facility the different detectors will interface to
Participating :

4.3 Detector Controls and Monitoring
Provide a detector control and monitoring infrastructure including conditions monitoring and configuration management.
Participating :

4.4 Detector Interface Prototype
Provide a detector interface prototype including hard and software. Likely based on ATCA and Ethernet
Participating : Brussels, DESY

4.5 Online Processing and link to Storage
Provide an online event processing and event filter test system to demonstrate the ability for online event filtering, including online calibration and alignment using offline software methodology.
Participating : DESY

List of Deliverables for the task
(typically 1 per task per year)

Deliverables of task 1	Person month estimate	Description/title	Nature[1]	Delivery month[2]
wp.t.1		DAQ Architecture description	R	18
wp.t.2		Event building facility	P	24
wp.t.3		Detector control infrastructure	P	36
wp.t.4		Interface Prototype	P	24
wp.t.5		Event filter facility	D	24

List of Milestones for the task

Milestones	Description/title	Tasks involved	Delivery month[2]	Means of verification
wp.t.1	Interface/Protocol definition	1,4	12	Write-up
wp.t.2	Event builder demonstrator	2	18	Test protocol
wp.t.3	Detector control demonstrator	3	18	Test protocol
wp.t.4	Full system test	1 - 5	36	Test protocol

[1] Nature: R=Report, P=Prototype, D=Demonstrator, O=Other
[2] Counted from the starting date

Task 10.3: Tracking infrastructure

A) Vertex

Contact: Massimo Caccia, Ingrid Gregor

1. General description of the task activities

The primary objective of the task is the design, construction, commissioning and optimisation of the infrastructure required to integrate a lightweight, high resolution, multilayer vertex detector. The vertex detector module is expected to fulfil the overall performance requirements for experiments at future linear colliders in terms of accuracy, precision, pattern recognition, robustness, data throughput, and vertexing capabilities. The infrastructure will be optimised in terms of mechanics, data acquisition and general services to comply with the different sensor technologies under development.
A baseline vertex detector module will be integrated, based on the EUDET pixel sensors. This is intended to serve as a benchmark and to allow the development of the fully integrated facility at an early stage of the project. The system evolves from EUDET in terms of geometry and engineering, matching the specifications for an experiment at future linear colliders. The six layer structure represents an active area which is larger by a factor ten in size with respect to the pixel sensor module qualified within EUDET. It will integrate about 107 pixels, providing 9000 frames/sec. The vertical integration facility will also include a target and a reference telescope upstream of the target. Interactions of the primary beam with the target will generate jet-like structures required for the full qualification of the integrated detectors.
The reference telescope provided by EUDET is an added value since it will allow the measurement of the primary particle input point on the target.

Added value:
Integration issues (creating large surface with minimal dead areas (<~10µm)

2. Organization participation

Participant acronym	DESY	INFN	MPI	UBonn	CNRS/ IN2P3	UNI-GE	IRFU
Estimated person-months per participant:	84	126	72?	72?	72	48	24

3. Objectives

- Building a global mechanical infrastructure to host multi-layer modules for vertex detectors in different technologies
- Developing the data acquisition system including hardware from EUDET JRA1 to suit the new infrastructure. This will be accomplished in close collaboration with WP 10.2 (Common DAQ).
- Producing a target system to create jet-like structures.
- Integrating the EUDET telescope upstream of the target.

4. Description of work

Within this task a small-scale full vertex detector will be provided. The interface to the overall facility will be designed in such a way that vertex detector modules in different technologies can be easily integrated and benchmarked. Possible technologies are DEPFET, ISIS, MAPS, or any other technology which is similar advanced in the R&D work for a vertex detector for a future linear collider.

4.1 Global Mechanical Structure

A global mechanical structure outside of the acceptance will allow mounting devices independent of the sensor technology. For this purpose a common mechanical interface needs to be defined. An alignment system enables an easy integration of any type of ladder adapted to this interface. Close collaboration between the developers of the different technologies is vital for this part of the work.

Partners interested to participate: DESY, IFRU, INFN (Ferrara), UBonn

4.2 Data Acquisition (Hardware and Software)

The data of this kind of detectors is typically sparsified and binary. Therefore the focus of the data acquisition system will be on data throughput and multi-event data storage and maximum event rate, compliant with a future linear collider time structured beam. This data flow could be handled by a dedicated board evolving from the EUDET telescope DAQ board. Care needs to be taken incorporating a central clock and time-stamp system (based on the proposed CALICE "Clock and Control for test-beam") to include the vertex slice in the overall vertical integration facility timing. The hardware needed to interface between the vertex slice data acquisition and the common DAQ (WP 10.2) will be developed based on the trigger logic unit (TLU) developed within EUDET. Also the necessary software will evolve from existing EUDET data acquisition software.

Partners interested to participate: INFN, UNI-GE, UBonn,

4.3 Analysis Software

Software targeted at the reconstruction and analysis of data from the high resolution, low material vertex slice will be developed evolving from the EUTelescope package. It provides functionality for calibration, alignment and offline data reduction as well as for pattern recognition and determination of the resolution of the DUT (device under test).

Partners interested to participate: INFN, DESY

4.4 Target

Jet-like particle showers necessary to fully test a vertex detector will be produced from high energy particles hitting a target. This target will be constructed of a number of thin plates in which the impinging particles showers. Simulations will help to define the optimal geometry and material. Actuators enable the target to move in and out of the beam.

Partners interested to participate: DESY?

4.5 EUDET Telescope

In order to identify the impinging particle on the target the beam particles need to be tracked with high resolution. The by then existing high-resolution pixel telescope of the EUDET project will be positioned upstream of the target to provide this information.

Partners interested to participate: All EUDET JRA1 groups

4.6 Reference System

A reference system based on existing pixel sensor will be build to serve as a benchmark and to allow the development of the fully integrated facility at an early stage of the project

The geometry of the reference system modules is defined according to the acceptance of the overall facility, namely:

1) the cross section of the electro magnetic-calorimeter module is presumed to be 54 x 54 cm^2

at a distance from the interaction point of 1.6 m the radial position to be 1.6 m away from the interaction point

2) the vertex module will be made out of five (six) layers, at radii between 1.6 and 6 cm

Based on these assumptions, the active Silicon pixel sensors at the different layers should cover an area with the following lower limits:

(1) 0.6 x 0.6 cm^2 @R1 = 1.6 cm
(2) 0.8 x 0.8 cm^2 @R2 = 2.5 cm
(3) 1.2 x 1.2 cm^2 @R3 = 3.5 cm
(4) 1.8 x 1.8 cm^2 @R4 = 5.0 cm
(5) 2.0 x 2.0 cm^2 @R5 = 6.0 cm
(6) 2.4 x 2.4 cm^2 @R6 = 7.0 cm

The baseline module will rely on the Mimosa22+ sensor, exploiting the results from the EUDET project. Whether clearly not yet optimal for an experiment at future linear colliders, this will allow to have a reference for any further development across Europe.
The Mimosa22+ will have an active pixel area of 2.0 x 1.0 mm2, which could be used in

a) one die for layers (1) & (2)
b) two dies, possibly mounted with an overlap between the sensitive areas, for layers 3, 4 & 5.
c) four dies for layer 6

For each layer a light weight mechanical structure will be designed. An effort will be made to limit the material to optimise the single point resolution.
The pixel sensors and the data acquisition board will be interconnected by a light ultra-thin flexible cable. This cable design will be based on existing experience within the consortium
Partners interested to participate: IPHC, INFN (Ferrara)?

List of Deliverables for the task
(typically 1 per task per year)

Deliverables of task 1	**Person month estimate**	**Description/title**	**Nature[1]**	**Delivery month[2]**
wp.t.1		Target system	P	
wp.t.2		Global mechanical frame	P	
wp.t.3		Interface to common DAQ	P	
wp.t.4		Reference sensor system	P	

List of Milestones for the task

Milestones	**Description/title**	**Tasks involved**	**Delivery month[2]**	**Means of verification**
wp.t.1	Target structure ready	1	27	
wp.t.2	Global mechanical frame ready	2	30	
wp.t.3	Interface to Common DAQ	3	32	
wp.t.4	Analysis software module ready	4	35	
wp.t.5	Vertex infrastructure ready	1,2,3,4	35	

[1] Nature: R=Report, P=Prototype, D=Demonstrator, O=Other
[2] Counted from the starting date

Task 10.3: Tracking infrastructure

B) Intermediate Tracker

Contact: Thomas Bergauer & Frank Hartmann

1. General description of the task activities

The infrastructure necessary to test silicon strip detectors acting as ‘intermediate tracker’ will be developed within this task. The devices can act as extension of the vertex detector to the TPC and vice versa, but similar modules can also be used as external layer around the TPC to provide precise hit information for tracking, but also as impact point for the ECAL. The system will be optimized in terms of mechanics, data acquisition and material consumption to ensure efficient resolution studies of high-precision silicon sensors. Additionally, novel techniques for connecting the silicon sensors to the readout electronics avoiding pitch adapters via a sensor-integrated routing layer will be investigated.
Silicon modules housing the sensors and readout electronics will be the central part of the setup. Its front-end electronics is based on the SiLC readout chip developed within the EUDET program. It utilizes power-cycling to cope with the proposed beam-structure for linear colliders. Because of its low duty-cycle (approx. 1%), the integrated power consumption of the readout chip is reduced by the same factor. Thus, the system will not need any active, liquid-based cooling system. If the beam structure of the vertical integration facility will not provide a beam structure with a similar profile, though, the convection cooling system developed within EUDET can be used as backup. The readout system will take advantage of the common DAQ provided by WP10.2, but adoptions will be necessary. The modules will be aligned in layers by a support structure, which has to be optimized in terms of material budget to avoid any negative influence of multiple scattering to the resolution tests of the sensors.

2. Organization participation

Participant acronym	HEPHY Vienna	IEKP Karlsruhe	ICFA Santander	CNRS-LPHNE		
Estimated person-months per participant:						

3. Objectives

- Evaluating lightweight support structures for both module carrier and overall support structure, e.g. carbon fiber, aluminum foam
- Developing prototype silicon modules with minimized material consumption for different numbers of silicon sensors (up to ladders with six sensors)
- Developing an overall support structure for modules/ladders arranged in layers
- Adapting the SiLC readout chip and developing a front-end hybrid prototype suitable for testing silicon sensors with conventional (wire-bonding) or novel (bump-bonding) connection techniques
- Integration of the front-end electronics into the central DAQ system commonly used by the other parts of the WP (both hardware and software)

4. Description of work

The goal of this task is to provide a full system to test silicon strip sensors. Each component will be designed in a way that different sensor designs can be tested. Moreover, the readout electronics should be able to be either directly connected to special sensors equipped with an integrated routing layer, omitting any pitch adapter or by wire bonding.

4.1. Module Design and Support Structure

The dimension of the electromagnetic calorimeter developed within this WP is presumably 54x54 cm2, located in a distance of 160 cm of the interaction point. Thus, the active silicon area necessary to meet the presumed acceptance of the ECAL can be estimated. The layers of the intermediate tracker will be approximately in a distance of 10 to 40 cm from the intersection point. This results in an active area of 3,5 times 3,5 cm2 at 10 cm and 14x14 cm2 at 40 cm. For an external (i.e. between the TPC and ECAL) tracking layer, though, almost the full acceptance area of the ECAL must be covered. This would require long ladders containing six silicon sensors.
The module design should be able to cope with all needs: Small area modules equipped with single sensors (at 10-20cm distance), modules equipped with two, daisy-chained sensors (at 30-40cm), but also with a ladder containing six silicon sensors in a row (at approx. 160cm). The support structure has to follow this design. Both have to be based on ultra-thin, lightweight structures constructed from e.g. carbon fiber, but also novel materials like aluminum foam will be investigated.
Partners to participate: HEPHY Vienna (Module Design), IEKP Karlsruhe (Support Structure)

4.2. Front-End Electronics and DAQ

The front-end electronics will be based around the SiLC readout chip, which is under development within the current EUDET program. When using conventional wire-bonding technique to connect the readout chip to the silicon sensor, a PCB holding the readout chip and auxiliary electronics will be developed. For tests of new connection techniques using bump bonding, the readout chip needs to be equipped with bump-bonding possibility. It will be necessary to integrate the chip into a readout chain suitable for the common DAQ system (see WP10.2). For this purpose, adaption of both, hardware and software have to be performed.
Partners to participate: LPNHE Paris (Front-End Electronics), CUNI Prague (DAQ system integration)

List of Deliverables for the task

(typically 1 per task per year)

Deliverables of task 1	**Person month estimate**	**Description/title**	**Nature**[1]	**Delivery month**[2]
wp.t.1		Module design with lightweight material	D	25
wp.t.2		Multi-layer support structure with lightweight material	P	30
wp.t.3		Development of Front-end electronics suitable to test silicon sensors using both, wire- and bump-bonding; based on the SiLC readout chip	D	30
wp.t.4		Integration of readout electronics into central DAQ system and implementation of tracker specific parts	P	30

List of Milestones for the task

Milestones	**Description/title**	**Tasks involved**	**Delivery month**[2]	**Means of verification**

wp.t.1				
wp.t.2				

[1] Nature: R=Report, P=Prototype, D=Demonstrator, O=Other
[2] Counted from the starting date

Task 10.3: Tracking infrastructure

C) Improvement of Gaseous Infrastructure

Contact : Jan Timmermans & Klaus Desch

1. General description of the task activities

TPC based tracking is pursued within international LCTPC collaboration. Particle flow approach relies on precise and robust measurement of track momenta in dense jet environment.
Infrastructure for systematic tests of various technologies (GEM vs Micromegas, Pads vs Pixels, Choice of gases) currently being built up at DESY within EUDET.

Within this Integrated Activity, the EUDET-TPC infrastructure is being made available at CERN and is being improved to become suitable for a realistic experimental test of particle flow approach. The users of the infrastructure provide various readout structures. Their further development is not part of the IA. However, the IA will provide the interfaces necessary to operate different TPC endplate modules within the TPC infrastructure.

2. Organization participation

Participant acronym	CERN	DESY	NIKHEF	Uni Bonn	CEA Saclay	Uni Freiburg
Estimated person-months per participant:	27(9)	27(9)	27(9)	27(9)	27(9)	27(9)
Participant acronym	JOGU Mainz	Brussels	Lund			
Estimated person-months per participant:	27(9)	27(9)	27(9)			

KD : Note on costs :
Total TPC EU contribution = 750 k€
Total TPC EU contribution w/o overhead = 750 k€ / 1.6 = 469 k€

assume 1 ppm = 5200€ w/o overhead.

9 institutes * 9 ppm = 72 ppm = **421 k€ personell**
This leaves ´´room´´ for 48 k€ investment cost + travels
Assume 1k€ travel / year / institute for travels to CERN : 9*3=**27 k€ travel**

21 k€ Total Investment cost

3. Objectives

KD : we have to limit the objectives to the absolute minimum, i.e. the real infrastructure part. No module and/or frontend-electronics development and investment will be possible within EUVIF.

By the end of 2009, EUDET will have created a gaseous tracking infrastructure and has offered it for access at the DESY testbeam. While 3-6 GeV electron beams as available at DESY will be valuable for initial studies of the different readout modules by the LCTPC collboration and other potential users, a thorough test of gaseous tracking within a particle flow detector will require different particle types and higher energies such as available at CERN.

Within this IA, the EUDET TPC infrastrucuture will be made available at the CERN test beam, it will be integrated with the other detector components for tests of the particle flow concept and i t will be interfaced to a common trigger, DAQ- and Slow Control System. Software and Readout-Software will be provided in order to allow users of the infrastructure to test various developments of readout modules.

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4. Description of work

The different task which have to be performed in order to make the EUDET infrastrucutre available within EUVIF are

a. Transportation of the TPC field cage and the PCMAG magnet to CERN and installation in the CERN test beam area. Coordination of construction and access. (DESY)

b. Supply of the technical support for the equipment : LiHe supply for PCMAG, Installation of electronics and HV and DAQ racks. (CERN)

c. Development of an improved Slow Control system and integration of the SC system with EUVIF (DESY, CERN)

d. Integration of Trigger and DAQ system with EUVIF, Monitoring SW (UBrussels, Lund, UBonn)

e. Integration support (Software, FPGA programming etc) for Pixel Based endplate modules (Saclay, NIKHEF, Mainz, Freiburg)

List of Deliverables for the task

(typically 1 per task per year)

Deliverables of task 1	Person month estimate	Description/title	Nature[1]	Delivery month[2]
wp.t.1		TPC and magnet installed at CERN	P	24
wp.t.2		DAQ and trigger hard- and software	P	30
wp.t.3		Full TPC infrastructure available	P	36

List of Milestones for the task

Milestones	Description/title	Tasks involved	Delivery month[2]	Means of verification
wp.t.1				

wp.t.2				

[1] Nature: R=Report, P=Prototype, D=Demonstrator, O=Other
[2] Counted from the starting date

Task 10.4: Calorimeter Prototype Infrastructure

Contact : Felix Sefkow & Christoph de la Taille & Wolfgang Lohmann

A) Electromagnetic Calorimeter

1. General description of the task activities

In order to demonstrate PFLOW performance in a realistic LC environment, a partial ultra-finely segmented electromagneic calorimeter is necessary. It will also constitute a piece (the ECAL) for the test of integration proposed here. Using the EUDET mechanical structure which is 54x150x2 cm and instrumenting only partially this structure but sufficiently to have a good test
54x54x20 cm volume will necessitate 3x3x40=360 Active Sensor Units (ASU) which is the elementary stitchable detector unit.

It can be built re-using the mechanical infrastructure developped by EUDET1 and partially equipping it with the sensors also prototyped in EUDET. This would at the same time be useful to test various components entering the PFLOW algorithms and exercising the system and technlological aspects (zero-suppression, power pulsing, mechanical assembly…) of the new « imaging calorimetry » necessary for ILC.

Using the EUDET mechanical structure which is 54x150x2 cm and instrumenting only 54x54x20 cm volume will necessitate 3x3x40=360 Active Sensor Units (ASU) which is the elementary stitchable detector unit. The ASU is a PCB with four 6-inch wafers of 9x9 cm2 and integrated readout ASICs which covers 18x18 cm2. It is assembled in slabs with Tungsten absorbers and bring all the signals to one edge which is connected to a controller board called DIF (detector Interface) which interfaces the slab to the DAQ. The proof of feasibility of such ultra-dense and segmented calorimeter will have been established by EUDET.

2. Organization participation

Participant acronym	CNRS-LLR	CNRS-LAL	OMEGA Orsay	CNRS-LPC	Uni Manchester	Prague
Estimated person-months per participant:						

3. Objectives

- Facilities for the optimization of Silicon sensors tests (LLR, LPC, Prague)
- Facilities for the test and characterization of readout systems (Omega, LPC)
- Facilities for mechanical and system integration (Manchester, LAL, LLR)

4. Description of work

The mechnical infrastructure will be studied by LLR. The sensors developed by LLR and Prague will be tested on a test bench developed by LLR and LPC. The PCB is developed by LAL, together with the VFE readout system, including the industrial aspect. The wafers are glued on PCB by Uni. Of Manchester (the unit PCB with readout system and silicon wafers glued on it is called an ASU for Active Sensors Unit.) The ASU are tested at Manchester and LLR. The unit ASU, made of 4 wafers, are connected together to make a long slab (the assembling is performed by LAL)

Sub-tasks

- Mechanics : LLR, Manchester
- Sensors : Prague, LLR
- PCB, VFE , ASU : LAL, Manchester
- Assembling : LAL

List of Deliverables for the task

Deliverables of task 1	Person month estimate	Description/title	Nature[1]	Delivery month[2]
wp.t.1		Diagnostics and test facilities	D	24
wp.t.2		Characterization of components	R	36
wp.t.3		System integration	P	45

List of Milestones for the task

Milestones	Description/title	Tasks involved	Delivery month[2]	Means of verification
wp.t.1	Test facilities available	1,2,3	24	Demonstration
wp.t.2	Components characterized	1,2,3	36	Protocols
wp.t.3	System available	4	45	Prototype

[1] Nature: R=Report, P=Prototype, D=Demonstrator, O=Other
[2] Counted from the starting date

Task 10.4: Calorimeter Prototype Infrastructure

B) Hadron Calorimeter

1. General description of the task activities

The recent progress in particle flow methods for reconstruction of high energy events, which require the measurement of individual particles in jets, and the advent of novel solid state photo-sensors (here called SiPMs) have initiated the development of highly granular scintillator calorimeters with optical readout. The technology opens revolutionary design options with photo-sensors, readout and calibration electronics embedded in the detector volume. Such an extremely compact and hermetic design as necessary for any particle physics experiment covering the full solid angle is now being developed within the EUDET integrated infrastructure initiative and will allow testing the latest generations of photo-sensors in a realistic environment.

In order to fully validate the jet energy performance, which relies on the optimal combination of different detector components, such a finely segmented calorimeter must be tested in conjunction with electromagnetic calorimeters and tracking devices in magnetic fields for momentum spectrometry, and be exposed to multi-particle events generated in a test beam, as proposed in this work package. The HCAL must here have an absorber structure made of non-magnetic material such as stainless steel, and it must be instrumented with fine granularity over the full jet volume, thus requiring about 50’000 photo-sensors and associated electronics channels. As this implies an increase by an order of magnitude with respect to previous experience, we propose to establish the facilities for realization of mass production and integration as an infrastructure network.

2. Organization participation

Participant acronym	DESY	INFN-ROMA III	IPASCR	MPI-MUC	U-BERG	U-HEID	U-WUP
Estimated person-months per participant:							

3. Objectives

(1) Facilities for the optimization of SiPM micro-structures and on-wafer sensor tests (MPI-MUC)
(2) Facilities for the characterization of packaged sensors and integrated sensor scintillator systems (U-BERG, U-HEID)
(3) Facilities for the test and characterization of readout and calibration systems (INFN-RO1, IPASCR, U-WUP)
(4) Facilities for mechanical and system integration (DESY, MPI-MUC).

4. Description of work

The work will be organized in sub-tasks according to the objectives given above.
While SiPMs have a wide field of applications form astrophysics to medical diagnostics, their design parameters need to be adapted in each case. Optimization of the micro-structures requires investigating the response to small light intensities on microscopic level. A test stand with a high precision gas laser set-up will be installed, which allows to study sensor response to

single photons in the relevant spectral region. Once the structures are optimized, large numbers of silicon wafers need to be processed. Due to inevitable spread in production parameters, the sensors need to be characterized before the wafers are cut and the sensors packaged. A probe station with semi-automatic measurement and scanning devices will be set up, and test procedures will be developed.
The full characterization of sensor parameters, as required for further integration and ultimate calibration steps must be done with packaged devices. This requires test set-ups with stabilized light sources and simultaneous read-out of many sensors. Once integrated with scintillator cells, the performance must be quantified by means of radio-active sources. The test stands and procedures will be developed for use in the network.
Light calibration systems are indispensable for detectors with optical read-out. The integrated systems need to be optimized and their electronic and optical parameters characterized. A test environment for this purpose will be established. Detector-specific interfaces for the DAQ system common to the entire test beam infrastructure will also be produced and tested.
The integration of active systems, electronics and mechanical structure requires the development of tools and testing procedures, and the mechanical construction for the integration of supplies and services. The mechanical structure will be built in a modular way, and a facility for subsequent integration and testing be installed.

List of Deliverables for the task

(typically 1 per task per year)

Deliverables of task 1	**Person month estimate**	**Description/title**	**Nature**[1]	**Delivery month**[2]
wp.t.1		Diagnostics and test facilities	D	24
wp.t.2		Characterization of components	R	36
wp.t.3		System integration	P	45

List of Milestones for the task

Milestones	**Description/title**	**Tasks involved**	**Delivery month**[2]	**Means of verification**
wp.t.1	Test facilities available	1,2,3	24	Demonstration
wp.t.2	Components characterized	1,2,3	36	Protocols
wp.t.3	System available	4	45	Prototype

[1] Nature: R=Report, P=Prototype, D=Demonstrator, O=Other
[2] Counted from the starting date

Task 10.4: Calorimeter Prototype Infrastructure

C) Forward Calorimetry

1. General description of the task

Forward calorimeters are indispensible subdetectors for any detector at the linear collider since they ensure firstly the hermeticity necessary for the complete event reconstruction to fully exploit the potential of PFA for jet energy reconstruction and secondly to maintain the sensitivity of the detector for new particle searches due to their electron detection capability .
However, there will also be unavoidable small gaps between forward and standard calorimeters either in the electromagnetic or hadronic part.
Using the integrated facility three key issues have to be understood: Firstly, do we sufficiently well describe the performance of PFA based jet energy measurement in the very forward region, and secondly, do we understand the impact of the transition region on both the jet energy measurement and on the electron detection efficiency. In addition, there is a critical quantity to be controlled specific for the forward calorimeters: the bias in the polar angle measurement of the calorimeter which is supposed to measure precisely the luminosity. The extreme precision requirement of better than 10^{-3} for the luminosity measurement
requires to correct for the small bias in the polar angle measurement introduced by the pad structure of the silicon sensors.
Answers to all these questions will be given by integrating prototypes of the forward calorimeters in the vertical integration facility and performing a full system test in a beam as proposed.
However, the forward calorimeters comprise unique challenges also with respect to compactness, the readout speed of the front-end electronics, the homogeneity and the mechnics precision.
Several steps, described below, have to be completed before we are prepared for a full system test.
Within the integrated infrastructure initiative EUDET several European laboratories joined their effort to create infrastructure focused on tests of single components of the forward calorimeters. Based on the results obtained the next step is to combine these single components to more complex aggregates and test their functionality . Finally, when a full readout chain from a sensor to the DAQ is proven to work, a sufficienctly large amount will be produced end tested to instrument the prototype calorimeters .

2. Organization participation

Participant acronym	AGH-UST Cracow	INPPAS Cracow	DESY	TAU (Tel Aviv)	West University Timisoara	Uni Dresden
Estimated person-months per participant:	48	48	48	36	20	48

3. Objectives

- a facility for sensor plane assembly and performance test.
- a flexible tungsten absorber structure for beam tests of BeamCal and LumiCal including laser positioning monitoring.
- development, production and assembly of multichannel FE electronics for beam-tests.

- development ofhigh troughput transmission lines to link the FE electronics digitizer to the common DAQ.

4. Description of work

The forward calorimeter prototypes have to be designed, constructed, tested and integrated into the common infrastructure for data acquisition, mechanics, survey and pixel tracking.
The major subtopics are listed as Objectives. The facility for sensor plane assembly will comprise the mechanical jigs to glue the sensors on a carrier structure, to electrically connect the pads to a fanout and to mount the FE ASICs.
The test of the functionality and the measurement of the characteristics of each individual readout channel will be partly automated. The task will be in the responsibility of DESY, TAU and INPPAS. The mechanical design and production of a flexible tungsten absorber structure will be done in collaboration of DESY and INPPAS Cracow. The structure will have the full depth of the calorimeter and its transversal shape will cover a sector of about 45^0 . The structure will allow to replace sensor planes in a reasonable short time. The mechanical stability will be ensured by a frame, which will be instrumented with CCD sensors to monitor the position with high accuracy using laser beams. The laser positioning monitoring will be prepared by INPPAS Cracow. The FE readout electronics for the forward calorimeters must be, to tackle the expected high occupancy, sufficiently fast to allow bunch-by-bunch readout and a to deliver a fast feedback for luminosity optimization. Based on the development done within EUDET, the fast FE ASIC design will be completed for multi-channel applications by AGH_UST Cracow. Digitization and power consumption will be optimised. The manufacturing of ASICS , serving for about 5000 readout channels, and the integration in the sensor planes for beam-tests will be shared between AGH-UST Cracow and DESY. The development of high throughput transmission lines for feeding the signals into the common DAQ will be done by University of Dresden and DESY. The West University of Timisoara will contribute to the software for the test facilities and the data transfer to the common DAQ.

List of Deliverables for the task

Deliverables of task 1	Person month estimate	Description/title	Nature[1]	Delivery month[2]
wp.t.1		Full sensor plane test facility	D	12
wp.t.2		Tungsten absorber structure	P	24
wp.t.3		FE readout electronics including data transfer lines	D	36
wp.t.4		System integration	D	44

List of Milestones for the task

Milestones	Description/title	Tasks involved	Delivery month[2]	Means of verification
wp.t.1	Test facility ready	1	12	D
wp.t.2	Tungsten absorber structure available	2	24	P
wp.t.3	Readout tested	1,3	36	R
wp.t.4	Full system test	1,2,3,4	44	R

[1] Nature: R=Report, P=Prototype, D=Demonstrator, O=Other
2 Counted from the starting date

WP.10-Task.5 – Development of Software Infrastructure for the Integrated Test Beam

Contact: Frank Gaede, Roman Poeschl

1. General description of the task activities

The aim of this task is to provide the software infrastructure that is needed for successfully operating the fully integrated detector test beam experiments and to analyze the data that is recorded in these experiments.
The tools developed in this task will be tightly integrated with and extend the existing ILC R&D software framework that has been partly developed within the EUDET project. Also the integration with the detector independent software tools that are developed in WP 2 of this proposal is of great importance.
The focus will be on tools for handling of conditions data, generic event displays and the integration of raw data files into the general ILC data format already at the DAQ level. This effort will facilitate the analysis of test beam data also for non-detector experts. The tools will be embedded into the existing grid data processing and storage infrastructure.

2. Organization participation

Participant acronym	CNRS-LAL	DESY				
Estimated person-months per participant:	96	50				

3. Objectives

- Develop a general purpose event display toolkit that can be used in the test beam DAQ system, in general detector R&D and for physics studies and data analysis
- Develop tools to store, monitor and retrieve conditions data for the integrated test beam
- Adapt and extend the existing ILC data model and persistency tools for the processing of real data already within the DAQ system

4. Description of work

In previous and ongoing test beam experiments for LC detector R&D a rather complete software framework has been developed. The framework supports all aspects of the experiments from Monte Carlo Simulation, Data Acquisition to Data Analysis. The experience from these test beam experiments, for example the ones carried out by the Calice collaboration, together with the new requirements from the fully integrated test beam experiments, show the need for extensions of the existing software framework and the development of new tools.

Of particular importance for successfully carrying out the fully integrated test beam experiments is the development of

a) a general purpose event display that can be employed in online and offline data analysis
b) a working database suite for storing conditions data in order to provide a high integrity of the data taken
c) a flexible persistency toolkit and event data model that can be used throughout the full processing chain from the DAQ to the final analysis

The packages in a) and b) will be developed in tight collaboration with the efforts in WP-2.1 that are focused on detector independent software tools.
The event display toolkit will have to be flexible enough to be adapted to new sub-detectors added to the integrated test beam or the modification of existing ones and to be used in DAQ system monitoring, in detector R&D and in the final data analysis.
A client server structure will allow for monitoring of the DAQ from remote sites.
The fully integrated test beam provides new requirements on the flexibility and usability of the conditions data system. Existing solutions will have to be extended and adapted to meet these new requirements with particular focus on user convenience. Of course providing the conditions data in an accurate and easy to use framework is indispensable for the analysis of the test beam data.
One important ingredient to the existing LC R&D software framework was the use of a common persistency tool and event data model (LCIO) throughout the processing chain. However it was not always possible to use LCIO for the actual raw data written in the DAQ system due to limitations in flexibility and performance. Introducing user defined data structures and improving the file layout with respect to I/O performance will overcome these limitations.
Usage of the same well-defined event data model and software framework in the analysis of the integrated test beam and the simulation studies for the full LC detector provides synergies for both physics communities.

List of Deliverables for the task

(typically 1 per task per year)

Deliverables of task 1	Person month estimate	Description/title	Nature[1]	Delivery month[2]
10.5.1	48	Common Event Display for online and offline	O	36
10.5.2	48	Database suite	O	48
10.5.3	48	Complete integrated framework for the fully integrated test beam data analysis ready	O	48

List of Milestones for the task

Milestones	Description/title	Tasks involved	Delivery month[2]	Means of verification
10.5.1	Event Display for online purposes running in a control room	10.5.1	24	Presentation at related meetings and workshops. Online demonstration.
10.5.2	First version of database suite	10.5.2	36	Online demonstration at related meetings.
10.5.3	first Data taking in common DAQ	10.5.3	24	first test beam data

	format (LCIO)			recorded in LCIO

[1] Nature: R=Report, P=Prototype, D=Demonstrator, O=Other
[2] Counted from the starting date

Task 10.6: Qualification of silicon sensors using standardised tests structures and procedures

Contact: Thomas Bergauer, Frank Hartmannl

1. General description of the task activities

During the mass production of silicon sensors for vertex detectors or tracking systems of future HEP experiments, an elaborate quality assurance program must be developed to ensure a high quality of the delivered sensors. Since the main sensors are produced on circular wafers, some cut-off space is available, where additional test structures (TS) can be placed. These structures allow the measurement of parameters which are not accessible on the main sensor or would require destructive measurements. The knowledge of these parameters helps monitoring the stability of the manufacturing process and compliance with the specifications. The TS are also perfectly suited for irradiation tests, avoiding the damage of the main sensors. They are optimized in a way that every single parameter is measured on a dedicated structure. To get a complete picture of the overall quality and to determine all interesting parameters, a set of test structures is necessary.
The set of test structures is characterized in dedicated test setups. Because of the very small quantities of voltage, current and capacitance, the test setups have to be very sensitive and must be optimized, e.g. in terms of shielding. Moreover, the test structures itself can be designed in a way that allows more robust measurements. This fact requires a precise adjustment of the TS layout with the test setup design in mind and vice versa. The identical behavior of TS and main sensor is assumed, however a comparison of parameters is naturally possible in the same test setup.
The main goal of the project is the possibility to offer interested groups the design of test structures to be included on their wafers. The design of tools to qualify the TS, e.g. characterization setups will also be provided to these groups.

2. Organization participation

Participant acronym	HEPHY Vienna	Uni Karlsruhe				
Estimated person-months per participant:	45	36				

3. Objectives

- Deliver the design of a set of test structures (“masks”) as so-called GDS-files which can be directly processed to silicon wafers.
- Have these set of structures processed at a wafer processing fab.
- Build and optimize a test station, where these test structures can be fully electrically characterized.
- Establish a data base where measurement results are stored for future reference and to enable comparison across different producers and production methods (FZ, MCz)

4. Description of work

First, the test structures need to be designed. This will be done using state of the art EDA (Electronic Design Automation) tools normally used for semiconductor chip design, e.g. Mentor Graphics IC station. The design is done mostly by HEPHY (Vienna) and is based on layers, which corresponds directly with the quartz masks used for wafer processing. Crucial parts of the layout

will also be simulated using field modeling software. The design will be evaluated in terms of robustness of the measurements in the test setup and will be adopted if some quantities are expected to be too low to be measured precisely.
In parallel to the design, contact to commercial semiconductor producers or non-commercial institutes equipped with a wafer processing fab will be established and details about the processing of the test structures will be discussed. This task will be performed by both, HEPHY (Vienna) and IKEP (Karlsruhe). The test structures do not cover the full wafer and can be easily arranged in the corners of wafer for other projects. Once the first version of the design is ready, the different technical details about the process relevant particularities must be discussed with the vendor and possibly the design of the structures must be slightly modified (e.g. for the so-called over- or under-etching).
For the measurement of the newly processed wafers, a light tight box must be equipped with a mechanical support which will hold the test structures. The electrical contact to the structures itself can be done by individual needles or by the help of a probe card. Needles allow more flexibility, but a probe card allows higher automatization during testing. Both options will be evaluated. The connection of the probe-card or needles to the measurement instruments will be done via a cross-point switching matrix system. The best arrangement must be evaluated to perform all measurements effectively using a low number of contacts and short cable lengths. Software based on Labview will be necessary to control the automated measurements. This task will be performed by both, HEPHY (Vienna) and IKEP (Karlsruhe) with more emphasis in Karlsruhe.
Moreover, a relational database will be designed where all these measurement results will be stored. This will be important for future mass production during detector construction to monitor the stability of the production process. Software, which automatically stores measurement results into this database, will be developed. On the other side, software programs will be designed enabling an easy access to this data. The goal is to get histograms of the data almost automatically.

List of Deliverables for the task

(typically 1 per task per year)

Deliverables of task 1	**Person month estimate**	**Description/title**	**Nature[1]**	**Delivery month[2]**
wp.t.1	20	Mask design for Test structures	P	20
wp.t.2	20	Test setup for electrical characterization	D	30
wp.t.3	5	Result Database	O	36

List of Milestones for the task

Milestones	**Description/title**	**Tasks involved**	**Delivery month[2]**	**Means of verification**
wp.t.1				
wp.t.2				

[1] Nature: R=Report, P=Prototype, D=Demonstrator, O=Other
[2] Counted from the starting date