WP11 – Detector prototype testing in testbeams

This work-package describes the test-beam infrastructures that need to developed for R&D and prototyping of the key detector technologies planned to be used in SLHC experiments, Neutrino experiments and for Super B detector construction in Europe. The typical detector elements that will be developed and tested are silicon detector system or new gas detector system for tracking and muon systems, and also calorimeter systems. The measurements in these facilities cover efficiencies, noise, time, position and energy resolutions – basically all the critical performance parameters for new detector systems. The measurements are carried out with beam conditions as close as possible to those the detectors will see in their final implementation.
The beamlines at CERN have been used 1998-2006 to test detector parts for LHC. These beamlines therefore have a significant part of the basic infrastructures needed to provide beams also for SLHC prototypes, but major infrastructural improvements and adaptations are needed to support, install and operate these detectors in the beamline and perform the measurements needed. An additional concern is access to low energy beams for neutrino detector testing, where additional infrastructure development is needed, both to provide such a beam and for particle ID in this low energy beam. Testing equipment for novel gas detectors (Micro Pattern Gas Detector (MPGD) systems), with applications at SLHC, for Neutrino detectors, or for Linear Collider detector systems, is also foreseen. The SuperB detector development will use mainly the Frascati National Laboratory testbeam, where similar new developments are needed, including beam monitoring and beam energy calibrations systems for low energy beams. The basic infrastructures in the DESY beamline are sufficient and no changes are planned as part of this work-package.
It is considered that the operation of the beamlines and the particle beams themselves, are largely covered by the missions of these laboratories (CERN, DESY, NLF). The infrastructures discussed here are therefore the additional equipment needed to improve these beamlines to they required standards for future experiments, and to install, operate and make efficient and meaningful measurements of R&D and prototype detector elements in these beamlines. This includes preparatory work and measurements carried out on the samples in connected laboratories. In many cases such tests are carried out using detectors irradiated (see WPs 8-9) to the doses expected in their future user environment to increase the realism of the tests.
With these infrastructures in place most the detector R&D foreseen for the major projects above over the coming 4 years can be evaluated and tested in common high quality beamline infrastructures. Some of the supporting infrastructure equipment are moveable such that they can be moved from one beamline to another as needed.
The testbeam infra-structures developments are divided into three subgroups:

1. Basic infrastructures as beamline equipment changes, magnets for testing in magnetic fields, cryogenics equipment, particle ID systems (task 1),
2. Specific support equipment for detector operation as data acquisition systems and readout, reference telescopes and mechanical support of devices under tests, control and monitoring systems, trigger chambers and timing equipment that allow the timing between asynchronous beam-particles and reference clocks (task 2),
3. And finally more general support facilities that allow also pre and post measurements in surrounding lab areas to take place, the primary example are equipment for cooling and thermal performance evaluation (task 3).

Work package number	WP11		**Start date or starting event:**				M1	
Work Package title	Detector prototype testing in testbeams							
Activity type	RTD							
Participant number								

Participant short name	CERN	CU Prague	CTU	FOM	Uni Bonn	Uni Freiburg	Uni Goettingen	UNIGE-DPNC
Person-months per participant	66	18	10	15	15	12	12	60
Participant number								
Participant short name	UH	INFN	RWTH Aachen	ICFA	CNRS	IFIC	UNIGLA	UniSofia
Person-months per participant	16	91	24	12	40	16	24	30
Participant number								
Participant short name	INPPAS	KFKI-RMKI	CEA	NTUA	NRCPS			
Person-months per participant	26	18	14	10	10			

Objectives:

Task1: Improvements of beamlines.

- Adapt beamlines for SLHC, Neutrino and Super B detector testing – with layout, beam-energies and intensities optimized to cover the requirements from these large users.
- Improve access to and particle ID for low energy beam at the CERN SPS and install basic neutrino detector testing infrastructures in such a beamline.
- Build and install beam monitor and beam calibration system at the LNF testbeam, and setup of a Tagged Photon Beam.

Task 2: Detector test infrastructures in beamlines

- Development of DAQ and readout systems for detector testing.
- Development of reference telescope systems and mechanical support tables for detector testing, allowing to position, scan and rotate the DUTs (Devices Under Test).
- Develop detector control systems and monitoring in beamlines.
- Improve triggering and timing systems in beamlines.

Task 3: Test equipment for thermal characterization

- Build cooling systems and equipment for thermal characterization of detector modules, to be used in lab and during testbeam operation.

Description of work:

<u>Task 1. Improvements of beamlines.</u>

Subtask 1: Beam line setups at CERN. The following new/improved infrastructures are needed in these beamlines:

- Optimization and improvement of the beamlines layout and equipment to support parallel use for SLHC detector tests, neutrino detector testing and for gas detector testing.
- Implements low energy beamline for neutrino detector testing in particular, including particle ID for this beamline.
- Install cryogenics for LAr based detectors, magnet and muon detectors, and tank for water Cherenkov tests for long baseline neutrino detector testing. The muon detector implementation foreseen is with Micromega systems and the readout support in general for such systems is planned under task 2.

The leading groups: CERN, UNIGE-DPNC representing several Swiss groups, CRNS, CEA, NTUA, NRCPS, KFKI-RNKI.

Subtask 2: Improvement of testbeam line setup at LNF.

- Install beam monitor and profiler to continuously monitor the beam quality, position and width. The implementation can be done with GEM chambers.
- Improve the beam energy calibration to improve the energy resolution and correct for non-linearity and hysteresis of the momentum selection magnets. This requires a small precise calorimeter and field probes in these magnets.
- Develop a reliable tagged photon beam with low background at low energies.

The leading groups are from INFN.

Task 2. Detector test infrastructures in beamlines.

To read out and control the detector elements being developed during testbeam operation a significant amount of surrounding support equipment is needed. This equipment is generally build up and maintained in a specific beamline, suitable for the bulk of the tests for a specific component, but the equipment can in most cases be moved to other beamlines if special tests are needed - for example with a different beam (different energy range, intensity or timing structure).
Specific support equipment for operation the detector in the beamlines are data acquisition systems (DAQ) and detector readout systems, reference telescopes and mechanical support tables, detector control systems (DCS) and computers for detector monitoring and offline checks. Additionally, cooling systems are needed as discussed in task 3. These tasks include commissioning and initial operation of the infrastructures, and the tasks are strongly correlated to provide overall infrastructural support to the beamlines.

Subtask 1: Develop DAQ and readout for stand-alone tests: We will develop DAQ systems for the SLHC systems compatible with the SLHC readout parameters and the new front end electronics in the SLHC detector systems, including monitoring functions. This includes readout of beam telescopes such that full rate tests are possible in some cases. DAQ and specific readout systems will also be developed for neutrino detector testing, for 3D vertex and general MSGD systems, and for the LNF testbeam lines. The lead groups are: CERN, CU Prague, INFN, INPPAS, UniSofia, UNIGE-DPNC, IFIC, ICFA, UNIGLA, Uni Freiburg, Uni Bonn, Uni Goettingen, CNRS, CEA, NTUA and NRCPS.

Subtask 2: Beam telescopes for the beamtests. Improve beam telescopes to be used for SLHC testing and make compatible with high rate readout, and build a low material straw tube telescope for the LNF facility. Mechanical support tables for the Detectors Under Tests (DUT), allowing to position, scan and rote the DUTs. The lead groups will be FOM, Uni Bonn, Uni Freiburg, INFN and HU.

Subtask 3: Detector Control Systems (DCS). The DCS systems are crucial to set up voltages and detector parameters, for monitoring of key parameters and for safe operation of the detectors being tested. Monitoring hardware and software need to be developed for operation of the detectors, These systems must be compatible with the final protocols and environment of the detectors. The lead groups are CERN, UNIGE-DPNC, CU Prague, CTU, INFN, CRNS, CEA, NTUA and NRCPS.

Subtask 4: Trigger and timing modules for the beamlines. This equipments is needed that allow the timing between asynchronous beam-particles and the readout systems clock to better than a nanosecond and to trigger on particles in the beam for readout. TOF measurements will be needed for particle identification in the low energy beamlines. The lead groups are KFKI-RMKI, CERN and INFN.

Task 3. Test equipment for thermal characterisation.

The thermal performance of detectors is one of the most critical parameters in modern detector system. With increased granularity, stringent speed requirements, high packaging density, and irradiation damage, advanced low mass cooling systems are critical for the detector system, and thermal performance is among the most crucial parameters that need to be tested and verified for new detector systems. This task covers the cooling infrastructures needed to test detector systems in the lab and to carry out detailed measurements there, and also in the testbeams where the system need to be cooled during operation and the effect of different temperatures studied. Such measurements are particularly important for the detectors that have been irradiated to their final doses (see WP8 and 9) before being put into the testbeam. These devices cannot be operated, and in some cases even stored, without sophisticated cooling and control systems.

The goal of the work in this task is therefore to develop cooling plants and test (beam) box(es) which can be operated at low temperatures of -40C or even lower, for detailed testing of SLHC ID systems. It is also foreseen to develop a thermo-hydraulic testbench for the thermal and fluid dynamical characterization of tracker modules and subsystems for SuperB. Lead group are RWTH Aachen, CERN, FOM, CTU and INFN.

Deliverables of tasks	**Person month estimate**	**Description/title**	**Nature**[1]	**Delivery month**[2]
11.1.1		Layout and implementation of improved beamlines for SLHC, Neutrino detector testing at the CERN-SPS, including low energy capabilities	O	M26
11.1.2		Improved beamline for SuperB detector testing at LNF including monitoring, calibration and tagged photon beam	O	M30
11.1.3		Basic infrastructure for neutrino detector testing (toroid, cryogenics, water cherenkov tank)	O	M30
11.2.1		Development of DAQ and readout systems for the detector testing in these beamlines	R	M26
11.2.3		Development of DCS and monitoring systems	R	M36
11.2.4		Development of reference telescope systems	R	M30
11.2.5		Development of triggering and timing systems in beamlines	R	M30
11.3.1		Thermal testbenches and environmental chambers for detector testing	O	M26
11.3.2		Cooling system(s) development	O	M42

Mile-stone	**task**	**Description/title**	**Nature**[1]	**Delivery month**[2]	**Comment**
1	11.1	Layout proposal for CERN SPS beamlines	R	M15	
2	11.1	Specifications for LNF-Frascati beam changes	R	M12	
3	11.1	Detailed plan for neutrino testing infrastructure	R	M15	
4	11.2	Detailed implementation plan for DAQ, DCS and readout in the CERN SPS and LNB testbeam	R	M12	
5	11.2	Design specifications for telescope and mechanical supports	R	M15	
6	11.2	Detailed specification for timing and triggering system in beamlines	R	M15	
7	11.7	Specifications for cooling and thermal testbenches at CERN and INFN-Pisa	R	M12	

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