WP15 Report
Upgrade of beam and irradiation test infrastructure

Federico Ravotti (CERN) & Marcel Stanitzki (DESY)

AIDA-2020 3rd Annual Meeting
Bologna, 26/04/2018
• **Task 15.1**: Scientific coordination (CERN, DESY)

• **Task 15.2**: Improvements of test beam infrastructure for high precision tracking (CERN, DESY)

• **Task 15.3**: Improvements of the DESY test beam infrastructure (DESY)

• **Task 15.4**: Improvements of the test beam infrastructure at LNF (INFN)

• **Task 15.5**: Improvements of the infrastructure for irradiation tests (CERN, INFN, VU, INRNE, JSI, USFD*)

*associated partner linked to CERN*
WP15 Satellite Meeting @ 6th BTTB Workshop (16/1/2018)
  - https://indico.cern.ch/event/683891

- 2nd event after Barcelona in 2017
  - https://indico.cern.ch/event/591285/

- WP15 has a large overlap of activities and participants with BTTB
  - in particular within Tasks 15.2, 15.3 and 15.4
  - irradiation facilities upgrade activities (Task 15.5) are driven by user requirements ...

- Chasing people for slides, milestone & deliverable reports and publications
WP15 Status @ M36

- Milestones due in M36
  - MS85 *Installation and commissioning of instantaneous dose rate monitoring system*
    - Already online
  - MS86 *Test of the different software modules as event display, camera position tracking and user interface*
    - Already online

- Deliverables due in M36
  - D15.2 *Silicon strip reference tracker at DESY*
    - Extension of scope -> M45
  - D15.8 Cold irradiations at Birmingham
    - Already online

- Publications: 49 Records in CDS
  - 17 are Milestone & Deliverable Reports
AIDA-2020 Extension: Proposal from WP15 (D15.4 & D15.5)

- **D15.4 New Frascati beamline:** now M44, postpone to M50
  - the delay of the Frascati beam line upgrade results from a re-allocation of resources in the machine division of the laboratory, which was dictated by external constraints and recommended by an independent advisory body.
  - the presently estimated date for completion leave little safety margin and almost no time to support initial usage within the project duration, while an extension would allow for optimizing the facility for the maximum benefit of users.

- **D15.5 Frascati photon tagging system:** now M42, postpone to M52
  - the photon tagging facility requires the new beam line to be operational and would be commissioned right after the beamlines have gone operational.
• Other activities within WP15 (achieved or being achieved) could be further followed-up or extended for the benefit of our users community:
  • Beam telescope support (D15.1)
  • User support at test-beam area (D15.2 & D15.3)
  • Test-beam areas online database (D15.6)
  • Exploit the demonstrator of augmented reality at GIF++ (D15.11)
  • …

• AIDA-2020 and WP15 in particular provided the “glue” to bring together activities and people from many EU laboratories/institutes in realizing tasks which would not have been necessarily funded otherwise
  • Strong argument to continue the project for another year!
• Parallel Session Summary
  • Heard updates on all our activities
  • Reports on all Milestones and Deliverables
  • Interesting discussions on
    • Interplay with WP5
    • Plans for our main facilities
  • Plans for the AIDA2020 Extension
• Lots of great slides
  • Check it out
WP15 Structure

WP15.2

J. Dreyling-Eschweiler
DESY

WP15.3

M. Stanitzki
DESY

WP15.4

P. Valente
Frascati

WP15.5

F. Ravotti et al.
CERN, INFN, VU, INRNE, JSI, USFD

DESY-II
Test Beam Facility

CERN PS & SPS Test Beam Areas

DESY II Test Beam Facility

BTF @ LNF

IRRAD

GIF++

JSI Triga Reactor

U.o.B. Cyclotron Facility
A common tool used by many different users from various experiments

Today & User interfaces
A workhorse for various (HEP) test beams: 7 copies at 5 different test beam facilities (CERN PS/SPS, DESY, SLAC, ELSA)

• 3 pillars of EUDET-type telescope package: from data to results

**EUDET-type hardware**

- Defined Interfaces
  - DUT integration e.g. in μm-precise stages
  - TLU communication

  **Starting point:** [beam-telescopes.github.io](http://beam-telescopes.github.io)

**EUDAQ DAQ software**

- Defined Interfaces
  - Producer for DUT-DAQ communication
  - Converter for data proc.

  **Starting point:** [eudaq.github.io](http://eudaq.github.io)

**EUTelescope Track Reconstruction SW**

- Interfaces
  - To EUDAQ 1 events
  - DUT implementation

  **Starting point:** [eutelescope.github.io](http://eutelescope.github.io)
Deliverables achieved
AIDA2020 inputs
- FTE: 10% (05/15-06/16) and 40% (07/16-today)
- For AZALEA: 80k
- For 10x Mimosa spares: 30k

AIDA2020 results
- AZALEA was installed at PS T10, CERN, in September 2016
- Milestone (MS32) and Delivery (D15.1) already achieved in 2016/7
- Starting point of documentation: telescopes.desy.de
- Usage of AIDA supported telescopes
In 2017/18: Reviews of the last decade and future needs

• Dedicated workshop “Future opportunities for Test Beams at DESY”
  Hamburg, 5-6 October 2017, https://indico.desy.de/indico/event/17998/

• During the POF review appearance in MT and MU contributions

• Asking the community in the “Beam Telescope 2025” Forum at
  BTTB6

Main results and outlooks:

• “EUDET-type beam telescopes are a common tool (hardware, DAQ, reconstruction software) used by many different users from various experiments”

• Continuous development (hardware and software) and support are needed

• Specific needs and started collaborative efforts:
  1) Better time resolution
  2) Test beam database

Breaking News: BTTB7 at CERN in the week 14-18 January 2019
WP15.3.1: External silicon tracker for 1T magnet in the DESY test beam

- Design requirements: large activate area with spatial resolution <10 µm, limited space for large user case.
- 6 layers of SiD strip sensor with 2 KPiX readout chips bump-bonded chosen to fulfil the requirements; hold by mechanical support (cassettes) with movable rails.

SiD Sensor:

- **Nov 2016**: 25 sensors ordered at Hamamatsu;
- **July 2017**: Sensor arrived;
- **Sep 2017**: All sensor quality verified; send to IZM
- **Feb 2018**: Start final assembly -> glue & wire-bond Kapton flex cable.
• Module assembly status:
  • 3 modules assembled but none up to spec
    → many tests to qualify the components & assembly process.
    → confident on every single component functioning
    → suspect assembly process - e.g. glue or gluing tool

• DAQ hardware and software ready:
  • DAQ well studied from an identical setup (KPiX on an Ecal sensor): including beam tests in May & Oct 2017.
  • Transfer knowledge to ongoing Module tests.

• EUDAQ2 integration: close collaboration w/ WP5
  • Ready: run control, data collector, data conversion.

• Other components:
  • mechanical support: cassette ready, sensor frame and rails in production;
  • Power supply system ready at DESY.
• Sensors delivered on time, and other hardware/software on time, thus **MS59 on time in M30**.

• **Sensor assembly is more problematic than expected**
  • first module tests started from Feb 2018, partially work ➔ slow down assembly process ➔ tests to inspect assembly process and components.
  • Will take more time than expected

• **Extension of scope request**
  • Lesson learn from BTB6 and latest DESY Test Beam User workshop:
    • better deliver telescope in a complete package: **hardware**, TLU, DAQ and a **reconstruction suite** like EUTElescope for the EUDET-type pixel telescopes.
  • **Move to M45 with extended scope**
    • 1 or 2 test beam weeks needed in fall 2018 at DESY;
    • Additional software development and time to perform a 1\textsuperscript{st} full telescope analysis;
    • Extra point: integrating the recently delivered (15/12/2017) AIDA2020-type TLU.
WP15.3.2: Environmental slow control system

- A central monitoring system maintained by DESY
- Commercial Rack-based data logger with data stored in MySQL DB, integrated to EUDAQ2
- 1st user operations by interns, finished by 01/2018
- MS33 on time in M18; D15.3 on time in M30
- Status & plan:
  - Ready for internal/external users;
  - As part of foreseen upgrade/maintain: deploy DQM4HEP for monitor once it is integrated to EUDAQ2.
• MS70 – photon tagging components: achieved
  • Hardware, firmware and software fully tested, also with (electron) beam
  • Final commissioning and D15.5: Photon tagging will be operational after the new beam-lines installation
• MS34 – new beam line components: delayed, but:
  • Full funding now available
  • Infrastructural work well advanced: old line dismantled, building modifications and hall preparation on-going
  • New magnets design completed and production started
  • New power supplies in production
  • Vacuum, supports, services advancing in parallel
The BTF upgrade is a complex project and a huge effort
  - Schedule and delays influenced by:
    - Funding timing
    - Administrative overhead
    - Interference of infrastructural work with accelerator complex operations

The main uncertainty comes from the construction of the new magnets
  - All projects started and almost all productions on-going

Civil engineering on track

Upgrade of cooling, power, services also proceeding

Updated schedule for new beam-lines
  - BTF-1 expected restart: June 2018
  - BTF-2 installation and commissioning: first months of 2019
  - Move D15.4 (New Frascati beam line) to M50
  - Enables use of BTF by AIDA2020 users

Photon tagging ready, need to be installed on new line
  - Move D15.5 (Photon tagging) to M52
WP15 Structure

WP15.2
J. Dreyling-Eschweiler
DESY

WP15.3
M. Stanitzki
DESY

WP15.4
P. Valente
Frascati

WP15.5
F. Ravotti et al.
CERN, INFN, VU, INRNE, JSI, USFD

DESY-II Test Beam Facility
CERN PS & SPS Test Beam Areas
DESY II Test Beam Facility
BTF @ LNF
IRRAD
GIF++
JSI Triga Reactor
U.o.B. Cyclotron Facility
Task 15.5: Improvements of the infrastructure for irradiation tests

- D15.6 – CERN Proton Facility Upgrade
  - contactless fluence monitor (VU)
  - IRRAD samples & users management sw. / storage area equipment (CERN)
  - CERN online database on irradiation facilities of interest for HEP (CERN)

- D15.7 – RadHard instrumentation for CERN Proton Facility (CERN)

- D15.8 – Cold Irradiations at Birmingham Facility (USFD)

- D15.9 – Large objects transport system for neutron irradiations (JSI)

- D15.10 – Upgrade of GIF++ Facility gas system (CERN)

- D15.11 – GIF++ Facility Upgrade
  - instantaneous dose-rate monitor (INRNE)
  - improved cosmic-rays tracker & demonstrator of augmented reality (INFN)

**all Milestones achieved!**
Task 15.5: Contactless Fluence Monitor (VU)

- Investigation of **Si** and **GaN** sensors for large fluence irradiation monitoring
- Combining results from various measurement techniques: TDTL, DLTS, PPIS, PIL, etc.

<table>
<thead>
<tr>
<th>Type of irradiation</th>
<th>Electrons</th>
<th>Protons</th>
<th>Pions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>6.6 MeV</td>
<td>24 GeV/c</td>
<td>300 MeV/c</td>
</tr>
<tr>
<td>Fluence range</td>
<td>10^{16}-5 \times 10^{16} e/cm^2</td>
<td>10^{12}-10^{16} p/cm^2</td>
<td>10^{11}-3 \times 10^{15} \pi^+/cm^2</td>
</tr>
<tr>
<td>Si material</td>
<td>CZ n-Si</td>
<td>CZ p-Si</td>
<td>CZ n-Si</td>
</tr>
<tr>
<td>Dopant concentration</td>
<td>10^{15} cm^{-3}</td>
<td>3 \times 10^{15} cm^{-3}</td>
<td>10^{12} cm^{-3}</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of irradiation</th>
<th>Protons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>8 MeV</td>
</tr>
<tr>
<td>Fluence range</td>
<td>10^{12}-10^{16} p/cm^2</td>
</tr>
<tr>
<td>Si material</td>
<td>p-Si</td>
</tr>
<tr>
<td>Dopant concentration</td>
<td>10^{15} cm^{-3}</td>
</tr>
</tbody>
</table>

**mc-Si**

- **inexpensive material for mass production**

**SI-GaN** (MOCVD) hadron-irradiated

- **Semi-Insulating GaN** is a promising material for particle/imaging detectors
  - lack of detailed studies of radiation-induced defects
  - The **AT-GaN** showed insignificant changes after neutron irradiation
  - **GaN LED sensors** can be used for detection of hadron irradiation

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**24 GeV/c proton irradiated by fluences**
- 783 H+: 1.05\times 10^{16} cm^{-2}
- 784 H+: 5.63\times 10^{15} cm^{-2}
- 786 H+: 1.80\times 10^{15} cm^{-2}
- 787 H+: 1.15\times 10^{14} cm^{-2}

**Photon Energy (eV)**
- hv_~\sim 3.81 eV (cw HeCd)
- I_~\sim 3 W/cm^2 photon counting reg.

**PL Intensity (a.u.)**
- 0 to 100

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D15.6 (M24)
Task 15.5:

- Testing components of the HEP experiments
- Beam of 24 GeV/c and size of 12×12 mm²
- Spills of 400 msec every ~10 sec

- Fluence of 1×10¹⁶ p/cm² in 14 days
- Scanning also in dimensions of 10×10 cm²
- Low temperature irradiation (-25°C)
Task 15.5: IRRAD Data Manager

- **Registration** of samples, users, experiments, dosimeters, etc.
  - edit, clone, delete, print, etc.
- **Printing** traceability labels
- **Different views** for admin and users
- **Interaction lengths estimation** based on the elements/compounds of the samples
- **Continuously improved**
  - users feedback
  - ML and automatic UI generation (Blerina’s PhD)

**Example of sample layer details**

**Usage Statistics since April 11th 2018**

- Registered experiments: 25
- Users: 28
- User projects: 15
- Registered samples: 361
- Irradiated samples: 73
Welcome to the Irradiation Facilities Database. This website hosts information about facilities for radiation testing at CERN, in EU, and worldwide.

This website is of public access and its content has been compiled from a variety of sources. Data accuracy and completeness rely on the information submitted by the facility coordinators.

March 2017: Database entries are being validated by the facility coordinators.
Task 15.5: CERN Proton Facility Irradiation Facilities Database

Statistics

- 209 irradiation facilities
- 377 visits in 2018

Follow-up

- Interest from the test-beam users community for equivalent web application on worldwide test-beam areas (forum discussions @ BTTB6)

- CERN team can adapt the SW infrastructure (http://cern.ch/test-beam-facilities), but it is necessary to:
  - define the relevant information
  - input the first dataset
  - appoint a responsible person (knowledgeable for data validation, follow-up, reminders)

Visitor countries for 2018

26 April 2018

F. Ravotti (CERN) & M. Stanitzki (DESY) - AIDA-2020 3rd Annual Meeting
Task 15.5: RadHard instrumentation for IRRAD

- Need to replace **cardboard sample holders** above $10^{16} \text{ p/cm}^2$
  - activation
  - material deterioration
  - radioactive waste

- Material tested in **IRRAD** and **JSI**:
  - Cardboard, Nylon, Carbon fibre, PEEK, ULTEM1000

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**Proton Irradiation (ongoing)**

- Study the **sensitivity** and **time response** for optimizing BPM instr. w.r.t. the beam conditions
- BPM and mini-BPMs detectors replaced in 2018
- New BPM detectors: **production by the end of LS2** to address **radiation damage** issues and need of **new patterns** adapted to IRRAD beam optics
Task 15.5: Cold Irradiations at Birmingham Facility – LN\textsubscript{2} Cooling

- New design LN\textsubscript{2} box: construction completed by Sheffield April 2018
- Improved Z-support (new pillar) for better movement control
- Cooling stable to operational irradiation temperatures at Birmingham (measured)
- Scanning system and software testing at Sheffield Robotics (2\textsuperscript{nd} LN\textsubscript{2} cooling unit)
- Ready for installation at Birmingham during next operational shut down in 2018
Task 15.5: Transport System for Large Objects at TRIGA Reactor (JSI)

M. Mikuz

1st Irradiations

- ATLAS - silicon wafers (DESY)
  - thermo-mechanical studies (2e15 n/cm²)

- Atlas Tile calorimeter upgrade
  - shaper/digitizer card (8e12 n/cm²)

More Kids on the Block

- CMS calorimeter upgrade – Si sensors
  - hexagonal sensor coming from an 6” wafer with the dimensions of 12.6 x 13.6 cm (and a thickness of 320µm)
  - 18 sensors, 2 pieces each of 3 types and 3 fluences (2*3*3)
  - up to 1e15 n/cm²

- ATLAS full sensor QA
  - square sensors out of 6” wafers
  - up to 2e15 n/cm²

- ~12cm x 20cm samples
- 10^{15} n/cm² (1 MeV Si eq.) < 1h
Task 15.5:

Main R&D:

- Ageing tests under radiation
- Detector validation tests in presence of high radiation background + muon beam

Joint facility, operated by EN-EA and EP-DT

Unique place, combining a high energy muon beam ($\pm 100$ GeV/C, $10^4$ muons per spill) with a 14 TBq $^{137}$Cs gamma source (2014)

Designed for testing real size detectors, of up to several m$^2$, as well as a broad range of smaller prototype detectors and electronic / optical components.

100 m$^2$ irradiation bunker with 2 independent irradiation zones, separated attenuation systems

All year round operation from Cs-Irradiator

Central Control System, wide range of available gases (+ custom gases) in bunker & service zone

Irradiation Bunker

Control Room

Preparation Area

Service Area (electronics, gas)
Material Access Door (MAD) installed, allowing fast installation/removal of setups (access no longer requires a transport request to remove concrete blocks)

3.2m translation stage installed (thanks to H.Reithler, Univ.Aachen). First full field mapping completed with Automess AD-6 with external probe 15/H. Results to be distributed soon, including measurements with half-filter. System available for further measurements on request.

One shielded rack installed in upstream alcove, outside of main irradiation cone. Dose rate in this rack significantly influenced by scattered gammas. At an attenuation factor of 6.9, we reach ≈ 0.1 mSv/h inside rack.
Task 15.5: GIF++ a possible way forward ...

- Currently investigation ongoing if irradiation zone can be extended upstream (+40 m²),
  - Compatible with new PPE-144 zone proposal
  - More space for placing set-ups in muon beam, already during Run 3
  - Lower radiation zone, due to increased distance (up to ≈ 15 m from source). Reduced need of attenuation.
  - More space for mass production tests

ECR approved, IEFC approval & budget pending

- Part of broader long term plan to cope with future requirements for a gas detector test facility (sideways extension, source upgrade etc.)
  - Will depend on the future needs for R&D, currently under discussion
  - Cs-Source certified until LS3 (14→11 TBq). Needs to be re-certified or exchanged during LS3.
The gas systems infrastructure is a key element of the successful R&D programs performed at GIF++

- Mixing units, gas recirculation systems and gas analysis modules are used for detector R&D studies

Commissioning of the new second generation gas recirculation system will probably start in autumn (when new resources will be finally available)

Partial funding of the gas system equipment and two CERN technical students

M.R. Jaekel
R. Guida
Task 15.5: GIF++ Facility Upgrade (Instantaneous Dose-rate monitor)

- The first version of the 2–channel counter board designed at INRNE, Sofia tested at GIF++ in June 2016;
- Final design (8-channel) board designed and tested in November 2017 (supported by AIDA-2020 TA);
- Integration of the Berthold data in GIF++ DCS is ongoing.

Comparison RADMON vs. Berthold Probes, 2017

<table>
<thead>
<tr>
<th></th>
<th>Total dose Gy</th>
<th>Irradiation time hours</th>
<th>Dose per hour (RADMON) mGy/h</th>
<th>Probe counts cps</th>
<th>Probe cps (dead time correction)</th>
<th>Dose per hour (probe) mGy/h</th>
<th>Maximum cps per probe for the correct dose estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADMON2 + probe2</td>
<td>15.9</td>
<td>96</td>
<td>166</td>
<td>18500</td>
<td>25342</td>
<td>178</td>
<td>45500</td>
</tr>
</tbody>
</table>

Final board installed at GIF++, 2017
Mechanics of new chambers is available

Need to produce some of the active elements of the detectors:
  - gas volumes
  - readout panels available
  - Front-end electronics to be tested

Chambers test stand at CERN-BB5 area;

Discussions with EP-DT and EN-EA groups at CERN to define chambers installation details & schedule.
Milestone MS86 in M36:
Test of the different software modules as event display, camera position tracking and user interface

Present status of the infrastructure software:

GIF++ Cosmic rays tracker DAQ and event reconstruction
* Software in development as a C program on a Linux machine, reading VME timing pattern readout modules
* Event reconstruction is a module of the DAQ generating the track vectors. The simulated tracks generator is ready
* Tracks are available on an UDP port

GIF++ DCS
* Software developed as a WinCC software on a Windows machine, connected to a CAEN mainframe and receiving gas system data form the gas DCS.
* DCS module publishing DCS data for the ARtDeCo (Augmented Reality to DCS) module is in development. It will associate virtual instruments tags and monitoring data

Software Platform for Augmented Reality:
* ARToolKit chosen as software platform
* The software has been tested in the INFN Labs of Roma Tor Vergata
* The software is able to recognize black&white markers and to show superimposed text above instruments and detectors
* Next steps: test the communication between DCS and ARToolKit; survey GIF++ area in order to define the set of markers needed

Funding:
* 20 kEUR used to finance a 1-year Post Doc contract with INFN - Rome Tor Vergata
WP15 Milestones Summary

WP 15.2

DESY-II & CERN Test Beam Facility

WP15.3

DESY-II Test Beam Facility

WP15.4

BTF

WP15.5

CERN IRRAD

MS32

BTF components installed

MS33

MS34 (M18) ↓ (M42)

MS59

MS70

MS16

MS35

MS17

MS37

MS36

MS85

MS86

U.o.B Cyclot. Facility

CERN GIF++

JSI Triga
WP15 Deliverables Summary

- **WP15.2**
  - DESY-II & CERN Test Beam Facility

- **WP15.3**
  - DESY-II Test Beam Facility

- **WP15.4**
  - BTF

- **WP15.5**
  - CERN IRRAD
  - JSI Triga
  - CERN GIF++
  - U.o.B Cyclotr. Facility

**Deliverables**

- D15.1 (M36) (M45)
- D15.2 (M30) (M42) (M45)
- D15.3 (M50)
- D15.4 (M30) (M50)
- D15.5 (M42) (M52)
- D15.6 (M44)
- D15.7 (M44)
- D15.8 (M48)

**Scope Extension**

**New BTF beamline**
• WP15 is delivering improvements to Test Beam and Irradiation Facilities
  • Improve capabilities and user experience

• AIDA2020 is providing the “glue” to make activities happen, that may not have happened otherwise
  • Every task leader gave a clear overview of the impact of AIDA-2020 in his activity in terms of material and or manpower support (see parallel session talks)

• WP15 has several activities that would benefit from an AIDA2020 extension
  • Will allow to have real user operation at Frascati (D15.4)
  • Few other activities where we could build on things we already achieved in AIDA2020
  • AIDA2020 is crucial forum for “us facility people” to meet and exchange ideas

• Thanks to the team from Bologna for hosting us at this fantastic place