The AIDA-2020 Advanced European Infrastructures for Detectors at Accelerators project has received funding from the European Union’s Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

This work is part of AIDA-2020 Work Package 15: Upgrade of beam and irradiation test infrastructure.

The electronic version of this AIDA-2020 Publication is available via the AIDA-2020 web site or on the CERN Document Server at the following URL: http://aida2020.web.cern.ch/search?p=AIDA-2020-D15.10

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DELIVERABLE REPORT

GIF++ GAS SYSTEM

DELIVERABLE: D15.10

Document identifier: AIDA-2020-D15.10
Due date of deliverable: End of Month 24 (April 2017)
Report release date: 31/05/2017
Work package: WP15: Upgrade of beam and irradiation test infrastructures
Lead beneficiary: CERN
Document status: Final

Abstract:

Within the “CERN irradiation facility upgrade” task, this deliverable includes the upgrade of the gas systems infrastructure for the new CERN Gamma Irradiation Facility (GIF++).
AIDA-2020 Consortium, 2017
For more information on AIDA-2020, its partners and contributors please see www.cern.ch/AIDA2020

The Advanced European Infrastructures for Detectors at Accelerators (AIDA-2020) project has received funding from the European Union’s Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168. AIDA-2020 began in May 2015 and will run for 4 years.

Delivery Slip

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Executive summary

This deliverable report summarises the upgrade activities related to the gas systems infrastructure for the new CERN Gamma Irradiation Facility (GIF++). It includes details about the achieved results (D15.10).

The gas systems infrastructure is a key element for the many successful R&D programs performed at GIF++. New mixing units and gas recirculation modules have been developed and build for GIF++. Further development allowed to build and test systems for detectors requiring high gas filtering capacity. Additional distribution panels have been added and a second infrared analyser installed. Gas analysis and especially gas chromatography are now available to all GIF++ users.

1. INTRODUCTION

The Gamma Irradiation Facility (GIF++) [1][2] is a unique place where high energy charged particle beams (mainly muons) are combined with gammas from a 14 TBq $^{137}$Cs source which simulates the background radiation expected at the LHC experiments. The GIF++ started operation in April 2015 (Figure 1).

The high-luminosity LHC (HL-LHC) upgrade is setting new challenges for particle detector technologies. The increase in luminosity will produce a higher particle background with respect to present conditions. The GIF++ were built to allow to study performance and stability of detectors at LHC and in view of the future HL-LHC upgrades.

![Figure 1: View from outside of the new GIF++ facility. The irradiation bunker as well as the preparation area and the electronic and service areas are visible. The total length of the facility is about 30 meters.](image)

GIF++ is a joint facility between the CERN Engineering (EN) and the Experimental Physics (EP) Departments in the framework of the AIDA and AIDA-2020 programme. EN provided the general infrastructure for housing irradiator, detectors and the beam line elements. EP contributed the Caesium irradiator and the infrastructure for the operation of gaseous detectors (i.e. gas systems). The EP department is also the main contact with the users’ community, defines the requirements and provides daily coordination of the activities.
The GIF++ irradiation bunker has a total surface of 100 m² divided in two regions, upstream and downstream of the irradiator along the beam line direction. The large surface available allows to test simultaneously several real size LHC-detectors (up to several square meters) as well as small prototype detectors. More than 20 setups are under test in the new facility. They include seven different gaseous detector technologies: Drift Tubes, Gas Electron Multiplier, Cathode Strip Chambers, MicroMegas, Resistive Plate Chambers, glass based Resistive Plate Chambers and Thin Gap Chambers. Alongside the bunker a two-floor area has been prepared and it is hosting the gas systems and electronic services. Each floor contains about 20 racks. A large preparation zone (about 80 m²) is available for preliminary tests before moving the detectors into the irradiation bunker. The irradiation bunker and preparation zone are equipped with gas lines, electricity and network.

Thanks to the AIDA-2020 project, the GIF++ has been equipped with a powerful and flexible gas system infrastructure. New gas mixing units and gas recirculation systems have been built and achieve a performance beyond the expectations specified in Deliverable D15.10. Additional gas distribution panels have been installed and gas analysis modules have been developed with a sensitivity beyond the specs in Deliverable D15.10. The results achieved will be described in detail in the following chapters.

2. GAS MIXING UNITS

The beam and cosmic triggers are based on TGC and RPC gaseous detector respectively. Figure 2 shows the gas systems built to prepare and distribute the gas mixture. Figure 3 shows the piping and instrumentation (P&I) diagram of the systems.

RPC detectors make use of three components humidified gas mixture containing R134a, iC₄H₁₀ and SF₆. TGC uses a two components mixture containing nC₅H₁₂ and CO₂.

Since both RPC and TGC detectors make use of flammable gases, two standard racks have been used to divide the ATEX part from the non-ATEX part. An additional and dedicated control rack is hosting the power supply and the controls for the two mixers. The software controls allow to tune the gas flow and the mixtures composition. All parameters were made available to the users using a CERN standard exchange protocol.
3. GAS DISTRIBUTION PANELS

At present 21 distribution panels are connecting the GIF++ gas service area to the irradiation bunker and the detector preparation area. They allow to distribute the gas mixture prepared for detector under test and infrastructure (like the beam and cosmic triggers). Each panel contains six supplies (OD 8 mm) and six return (OD 8 mm) lines. Two different types of gas distribution panels are available in the gas service area: the first type (Figure 4) connects the service area to the irradiation bunker only, while the second type (Figure 5) allows to distribute the gas mixture to the service area, the irradiation bunker and the preparation zone. Figure 6 shows the corresponding gas panels installed in the irradiation bunker.

Within AIDA-2020, additional gas supply panels have been added to allow independent operation of different detector setups and to perform gas chromatographic analysis of the gas mixture in different points of the gas circuit (in particular before and after the detectors under test).

Figure 3: P&I diagram of the RPC and TGC gas mixing units.

Figure 4: Gas mixture distribution panel allowing to connect the gas service zone to the irradiation bunker.
Figure 5: Gas mixture distribution panel allowing to connect the gas service zone to the detector preparation area and to the irradiation bunker.

Figure 6: Gas mixture distribution panels installed in the irradiation bunker.

4. GAS RECIRCULATION UNITS

At the CERN-LHC, 90% of the experiments use gas mixture recirculation systems. It is therefore mandatory to perform R&D and validation tests for new detectors using gas recirculation systems creating the conditions in which the detectors will be operated once installed in the experiments.

In a gas recirculation system, the gas mixture is collected at the output of the detectors and it is reused after being purified. Depending on the detector construction and performance, the fraction of recirculated mixture can go up to 100%. Gas recirculation systems are used for two main reasons: they allow to drastically reduce both operational costs and greenhouse gas emissions.

As a result of a R&D program on gas systems, a new portable gas recirculation unit has been developed [3]. The new unit is much cheaper than the previous version and, most importantly, it is much more reliable and easier to operate. Five new gas recirculation systems have been produced for detector R&D at GIF or in preparation for tests at GIF with the contribution of ADIA-2020. Development and construction of these units is part of an additional achievement with respect to D15.10.
Figure 7 shows the P&I diagram of the new recirculation unit where the main functional blocks are highlighted. Figure 8 shows a picture of the gas recirculation unit.

A further development has been conducted to produce a new version of gas recirculation unit for a detector requiring a large absorption capacity for impurities in the gas mixture. This version (Figure 9) includes an automated gas purification module with cartridges of larger capacity.

**Figure 7:** P&I diagram of the new gas mixture recirculation unit. The main functional blocks are highlighted in the figure.

**Figure 8:** Front and rear view of the gas recirculation unit. In the front view the function of each panel is described, while in the rear view the gas purification unit is visible.
5. GAS MIXTURE ANALYSIS

The performance of all gaseous particle detectors is very sensitive to the gas mixture. A correct and stable composition is a basic requirement for good and safe long term operation of gaseous detectors. In this context, the monitoring of the gas mixture becomes of fundamental relevance [4].

5.1. INFRARED ANALYSERS

Infrared analysers are used to check the mixture flammability level. A second device has been added for the new gas systems for the RPC detectors test programme. The unit is performing continuous online analysis.

Figure 9: View of the third generation of gas recirculation unit developed especially for detectors requiring high filtering capacity at the level of the gas purification unit.

Figure 10: Infrared analysers used to monitor the gas mixture flammability and to produce interlock signals in case the flammability threshold is crossed.
5.2. GAS CHROMATOGRAPHY

Gas chromatography analysis allows to separate gas mixture components and to spot the presence of impurities created during the detector operation under intense background radiation. The GIF++ gas systems infrastructure has been equipped with a gas chromatograph containing three separate modules. Each module is in fact a stand-alone gas chromatograph with specific gas separation characteristics. The gas chromatographic analysis of the gas mixture allows to detect and quantify gas mixture components present in concentration as low as few ppmV.

Figure 11 shows a picture of the gas chromatograph with the sampling manifold. An example of gas analysis performed where the main mixture components are separated and quantified is also visible.

![Gas Chromatography Station]

Figure 11: Gas chromatographic station (on the left) with an example of gas chromatogram (on the right) where the mixture components are separated, identified and quantified.

5.3. O₂/H₂O ANALYSIS MODULE

Even if the O₂/H₂O concentrations might appear as a very basic parameter, they are one of the most important indicators for good operation conditions of gaseous detectors. In fact, not only it is useful to continuously monitor the O₂/H₂O levels during normal operation, but in addition any abnormal value can point to a more serious problem in the gas supply quality or in the detector construction or the detector operation.

The GIF++ has been equipped with a standard LHC O₂/H₂O gas analysis module (Figure 12). The module is equipped with a system of electro-valves allowing to select between more than 20 different gas streams.
6. EXHAUST PRESSURE REGULATION

The exhaust pressure regulation system (Figure 13) creates slight under-pressure (about 1 mbar) in the exhaust line to guarantee that gases are exhausted through the exhaust line out of the building. This is particularly important at GIF++ since the gas service area is located at higher height with respect to the detector position and many detectors use gases heavier than air.

7. CONCLUSIONS

The CERN-GIF++ irradiation facility is a unique place for detector R&D and the gas systems infrastructure is a key element for almost all R&D programs performed at GIF++. 

Figure 12: View of the O₂/H₂O gas analysis module installed at the GIF++ facility.

Figure 13: Exhaust pressure regulation system for the GIF++ facility.
All deliverables listed in D15.10 have been successfully achieved. As foreseen, the new mixing units are operational and additional gas distribution panels have been included at the supply and in the gas systems. New gas recirculation modules have been developed and built for GIF++. Further developments allowed to design gas recirculation systems for detectors requiring high gas filtering capacity. Gas analysis and gas chromatography are now available to all GIF++ users. Two infrared analysers have been installed for detectors using flammable gas components. An automated O₂/H₂O analysis module has been built.

Design, components and construction procedures described in this document followed the experience and development of the gas systems for the LHC experiments.

8. REFERENCES


ANNEX: GLOSSARY

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<tr>
<td>ATEX</td>
<td>The ATEX directive consists of two EU directives describing what equipment and work environment is allowed in an environment with an explosive atmosphere. ATEX derives its name from the French title of the 94/9/EC directive: Appareils destinés à être utilisés en ATmosphères EXplosibles.</td>
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<tr>
<td>GIF++</td>
<td>New CERN Gamma Irradiation Facility</td>
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<td>CERN</td>
<td>European Organization for Nuclear Research</td>
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<tr>
<td>LHC</td>
<td>Large Hadron Collider</td>
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<td>OD</td>
<td>Outer diameter</td>
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<tr>
<td>P&amp;I</td>
<td>Process and Instrumentation</td>
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<td>ppmV</td>
<td>part per million in volume</td>
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<td>R&amp;D</td>
<td>Research and Development</td>
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<td>RPC</td>
<td>Resistive Plate Chamber detector</td>
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<td>TGC</td>
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