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The GIF++ Gamma Irradiation Facility at CERN

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This document collects the user requirements and technical specifications for the construction of a new Gamma Irradiation Facility at CERN (GIF++). GIF++ is the combination of a particle test beam with a strong gamma source in the SPS experimental area.

This document shall serve as starting point for the preparation of a final GIF++ Technical Design Proposal, with input from the CERN/AB Department, CERN/PH and users. The proposal, due in March 09, will also contain reasonable cost estimates that eventually would permit the construction of the optimal set-up for the large numbers of user communities.

The final goal is to get the final approval of the GIF++ Technical Specifications by the CERN Management in spring 2009.

GIF++ is expected to be operational towards 2010.

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1 Background

At the SLHC, the experiments will have to sustain rates 10 times higher than at the LHC. For the muon detectors, studies on particle generation and absorption predict that over most of the acceptance, the rate will be dominated by background due to neutral particles, photons and neutrons with energies below 1 MeV. In the most forward regions the contribution of penetrating particles will be significant, and the rates in the inner forward stations will reach the level of several kHz/cm^2. New operating conditions or better-suited detection technologies must be studied. This demands a new series of studies on detector performance (detection efficiency, pattern recognition, resolution) and stability (radiation tolerance, aging of components), which cannot be carried out at the old GIF facility. Following the dismounting of the SPS West Area beams, simultaneous beam tests are no longer possible and the present facility is scheduled to be shutdown towards the end of 2009.

Like the GIF facility, the GIF++ will be used by all LHC experiments and the demands expressed by ATLAS, ALICE, CMS and LHCb serve as the main input for the layout of the GIF++ facility described in this report. Additionally, the CERN working group for Future Irradiation Facilities [1] has carried out an important survey whose outcome has been taken into account for the definition of the new facility.

The survey about the need of a Gamma Irradiation facility was sent to a large community of potential users. The analysis of answers shows that the users can be easily clustered in two groups with similar interests. There is a set of groups interested in the GIF to test radiation hardness of materials, small prototype detectors, electronic components and radiation monitors or dosimetry under a strong photon flux. The second set of users is focused on the characterization and understanding of the long-term behavior of large particle detectors. The latter group needs, in addition to the high rate photon background, the availability of a high energy (SPS), low rate and narrow muon beam. Especially the large area, gas-based LHC muon detectors have been extensively tested at the current GIF facility. Therefore there is evident need for the construction of a similar, improved facility to continue detector optimization studies and to cope with the demanding detector R&D for SLHC. The survey reflects the need of equipping well the facility in order to provide common services and general infrastructure to minimize administrative and setting up procedures, as well as test time. It is also important to improve user interfaces and accessibility such that more users can use them at short notice, if needed.

2 Foreseen Program of Studies of LHC and SLHC Detectors

2.1 Precision muon chambers

Studies for upgraded detectors, using Monitored Drift Tubes (MDT) and Cathode Strip Chambers (CSC) and detectors based on new technologies like Micro-Pattern Gas Detectors (MPGD) are presently already taking place. Detector prototypes need to be tested in order to understand and optimize their performance. As an example, Fig. 1 shows the results of studies at the old GIF carried out at typical LHC rates for ATLAS MDT chambers; their spatial resolution and track reconstruction efficiency degrade significantly with the particle rate [2] and therefore make them unsuitable for specific regions of the ATLAS detector. These important measurements will need to be repeated at the higher SHLC rates, see Figure 2 [3]. Stability studies will also be needed in order to validate the detectors and the components of the gas systems. MDTs and CSCs will use gas mixtures of Argon and CO_2 and aging can be caused only by impurities present in the gas or introduced by components of the detector and the gas systems. Validation studies require long run periods using the production series of detectors and components of the gas distribution system. Different gas mixtures which might be desirable for other reasons (faster drift time, saturated drift velocity and smaller sensitivity to space charge effects) will require additional studies on long-term stability.

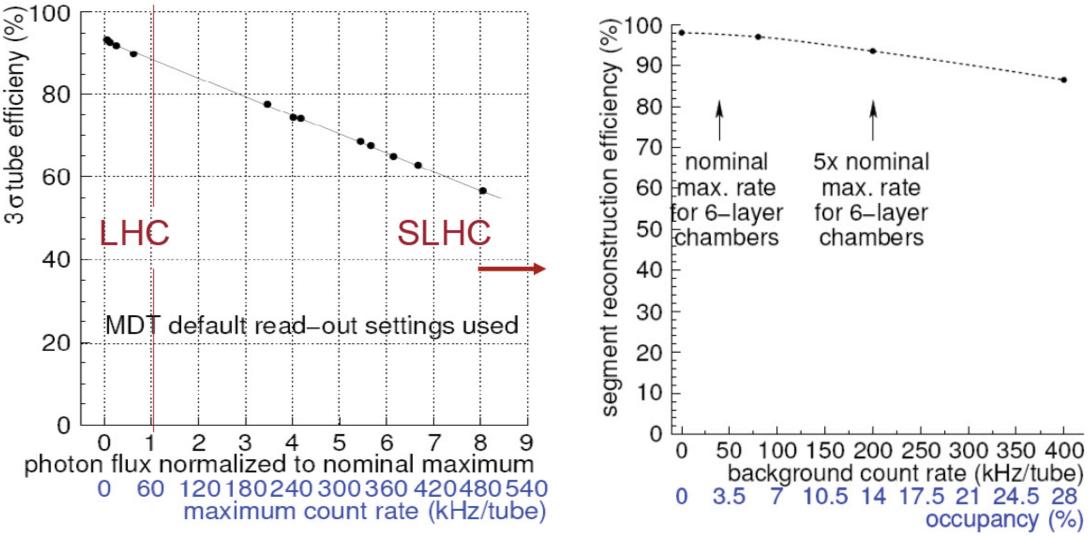

Figure 1: a) MDT resolution vs. rate, measured at GIF; b) MDT track reconstruction efficiency vs. rate, measured at GIF. Both histograms refer to LHC rates and show that chambers are well performing even when applying a safety factor of 5.

2.2 Muon Trigger chambers

The trigger chambers used in the LHC detectors are Resistive Plate Chambers (RPC) and Thin Gap Chambers (TGC). The performance and stability of the chambers in the current LHC detectors will remain the subject of extensive studies. New validation tests will be needed for SLHC, dedicated to the detector aging, with long runs performed with recirculation and purification of the gas mixture.

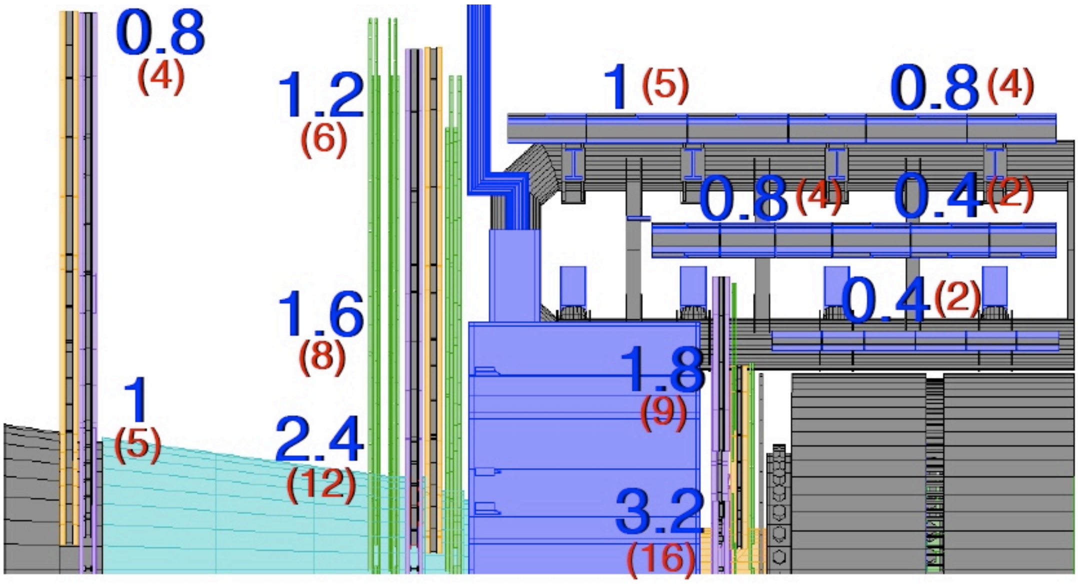

Figure 2: Detector occupancies in percent (blue values) caused by background from photons and neutrons for MDTs at various positions within ATLAS at nominal LHC luminosity. The values given in brackets include a safety factor of 5 and indicate that for backgrounds at the SLHC (factor 10 higher) a careful choice and test of the detector technology is mandatory.

In particular, the aging studies performed up to now have clearly established the need for a better understanding of the following issues:

- Gas recirculation: any improvement on the gas quality has a beneficial effect on slowing the detector aging, so further studies of the gas systems are mandatory. At the same time searches for alternative gas mixture, in particular mixtures without Freon, has to be continued.
- Environmental parameters: in tests at the GIF it has been seen that both temperature and humidity must be kept under control to preserve RPC from fast aging. This dependence has to be studied in much more detail, especially for the SLHC.

2.3 Inner tracking detectors

The GIF++ would also be used for other SLHC sub-detectors. In particular, the teams involved in the upgrade of the SLHC inner tracking systems are considering the use of 1m long silicon detectors that are on “staves” (10 cm wide) to enhance several aspects of constructions, service routing and robustness. These “staves” need to be tested with background for noise, oscillation, cross-talk and all possible readout bottlenecks that could be created in a severe high background environment.

3 The Parameters of the GIF++

The first GIF facility has proved its effectiveness over several years of operations thus most of its characteristics shall be maintained in the new facility, including source container, adjustable rates via a set of filters, lens shaped filters designed to achieve uniform flux across a plane normal to the beam axis. Other parameters should be revised specially in view of SLHC and the required upgrades matching the needs of the experiments for an upgrade are discussed in the following sections.

3.1 Beam of secondary particles simulating the signal

As for the GIF, which was hosted in the SPS West Area, a beam of secondary particles is needed to produce a track signal. Thus the main characteristics of the secondary muon beam as in the West Area (about 10^4 particles per spill traversing an area of 10 cm x 10 cm) and the option of an electron beam need to be maintained for the new facility. The beam momentum for the secondary particles needs to be of the order of 100 GeV which will allow system tests and precise tracking studies, and also the study of background (from the source) correlated with energetic muons. Thus the location of the GIF++ needs to be in an area to which SPS beams are delivered, e.g. the EHN1, the North Area.

3.2 Layout and Dimension of the Zone

Defined by the envisaged program by the experiments for the SLHC upgrade and taking into account the experience gained during the 10 years of operation of the old GIF, with a dimension of about 5 m x 5 m and a total available floor space of about 16 m^2, the dimension of the new zone has to be increased. It has to host large objects with dimensions of several square meters (detectors can be as large as 3.0 x 1.4 x 0.5 m^3 [4]) and to allow a flexible positioning at various distances to simulate the desired background rates. The minimum is 10 m (along the beam) and 7.5 m (lateral to the beam). The area shall be able to accommodate detector objects of up to 3 m total height.

A fast and easy access to the area for the large objects is mandatory. An optimum would be an access via a crane, however – as the infrastructure needed to provide a shielded and movable roof is complicated and expensive – a chicane of concrete blocks could be sufficient providing large objects can be moved through.

Another disadvantage of the old GIF was another reduction in the duty cycle which resulted from the fact that the preparations of the set-ups has always been done inside the zone which had the drawback that the source was stopped, thus long-term parasitic tests were suffering. It would therefore help to increase the duty cycle by providing the possibility of easy access to a beam area close to the GIF++ to commission with beam the devices which later will be tested in the radiation area.

To be able to study with the required accuracy the aging characteristics of muon trigger chambers, the RPCs, it is required that the zone can be temperature controlled. This can be achieved e.g. via a tent-structure within the zone.

3.3 Source for high rate particle flux to simulate accidental background

The radioactive source used in the current facility is based on ^{137}Cs, and was chosen because the spectrum of primary (662 keV) and scattered photons matches reasonably well the energy spectrum expected for background in LHC muon detectors, and because the 30 years isotope half-life makes the source rate relatively stable over the years. The intensity of the source was (in 1998) 740GBq providing up to 15 rad/h at a distance of 50 cm. In general, an outcoming uniform photon flux a factor 10 higher that the previous GIF is requested, as it corresponds to the expected step in intensity while moving to SLHC conditions. Therefore, in order to match the SLHC requirements and the increased dimension of the GIF++ zone, the intensity of the new ^{137}Cs source needs to be increased to about 10 TBq.

As for the GIF, a control of the photon rate needs to be provided. This is also one of the clear outcomes of the survey carried out among different user communities. Dose requirements vary over a large range depending on the sample type and goal of the test: detectors tests (burn-in, aging test, rate test), dosimeter, material sample and electronic components tests and validation of technologies. For instance, for detectors, it has been estimated that some regions of SLHC silicon trackers could expect a radiation dose as high as MGy/year, 20 kGy/year for calorimeters [5] and 0.1 Gy per year for the muon detectors [5], with variations in the different regions of the detectors. The required accumulated dose varies several factors. In this respect, is seems mandatory to also equip the new facility with a system of movable filters system that would permit attenuating the photon rate in several steps, to reach attenuation factors of several orders of magnitude ($\sim 10^5$).

A second irradiation beam shall be available at 90 degrees to the main (=beam) axis. This area shall be defined by a separate collimator that allows irradiation of detectors with a higher flux but over a smaller area. It shall be possible to activate or isolate the second irradiation beam using a separate shutter.

3.4 Controls and Safety

The irradiator shall be controlled from a single console located in the control room next to the area. All safety functions related to the zone shall be included into the console. This comprises search boxes, infrared detectors to signal the presence of any life forms in the zone, smoke detectors, flammable-gas detectors, emergency stops, door monitoring and check of the compressed air pressure. Radiation detectors shall continuously monitor the radiation levels inside the zone. Any detected anomaly shall force the irradiation source back into its shielded position and shall veto any possibility of further extraction. All changes of states shall be logged and alarms shall automatically being send to the responsible persons.

As for the GIF, as objects might need radiation for more than weeks, it shall be a key feature of the area to be operated remotely and even in unattended mode, as needed for very long aging tests.

3.5 Peripheral Infrastructure for GIF++

The GIF++ will be a user facility for irradiation and testing of performance and radiation hardness of particle physics detector devices. The facility is specially suited to test large area muon detectors in conditions similar to those expected in LHC and SLHC. Therefore, many detectors under test may be as large as 1x1m^2. Some users will also test materials or more specialized devices, as for example radiation monitors or dosimeters. The facility will therefore need to be equipped for irradiation of equipment, and also for being able to operate devices in a test beam or collecting cosmics data during irradiation, including reference modules/devices. Typical measurements will be related to monitoring of currents, voltages, temperatures, humidity and doses during irradiation, while the test beam/cosmics measurements will address operational parameters, resolutions, efficiencies, timing, as in any other test beam line or cosmics set-up.

The infrastructure for an optimal GIF++ layout has been divided in 3 major categories; details are presented on the table below:

- Peripheral infrastructure to condition the areas surrounding and feeding into the irradiation areas and user set-ups and auxiliary infrastructure outside the irradiation area such as preparation and storage areas to minimize set-up times, and the space needed for users to follow up the tests;
- Minimal infrastructure provided to users inside the irradiation area, and
- GIF++ common control and log systems

Fixed, peripheral Infrastructure	
Electricity	Max Power for fixed set-up and infrastructure: 2 x 25 kW Max Power available to users: 1 x 12 kW Available power in UPS (as a minimum, for the source control): 1 x 1.5 kW Arrêts d'urgence Lighting fixtures to provide 400 Lux in all areas
Fire detection system	CERN standard
Gas supply	The fenced gas supply zone shall be constructed as close as possible to the irradiation areas, to reduce the pipe network. The supplies shall have P-based switchover panels. The zone shall have two distinct areas: 1) supplies of neutral gases and 2) supply of flammable and premixed gases. The latter shall be kept between 20-25 ^{o}C Neutral gases: Ar, N_2 (high pressure, high flow for cooling purposes), CO_2 (high pressure, high flow for cooling purposes), He, Xe at > 5 bar Flammable gases: iC_4H_{10} (2 bar) and CH_4, Ar/H_2 (4 bar) Special gases: $C_2H_2F_4$, SF_6, CF_4 (4 bar)
Pipe Network	Cleaned SS with TIG welded and Swagelok/Sagana type connections Heated pipes from gas supply area to rack area for isobutane and Freon 2 common exhaust lines per area (under-pressure and purged)
Gas systems	Rack area (>20 m^2) situated as close as possible to the irradiation bunker. 2 racks with supply panels to distribute all gases (for flammable and non-flammable gases). Consumption of expensive gases such as isobutane, Xe and Freons shall be monitored per panel. Automated open-loop gas system with: 2 Mixer Racks, automated analysis rack (N_2, H_2O, O_2 measurements at ppm level in several sampling points) and small pump, Infrared analyzer (for flammable gases interlock). The design and functionality of the mixing and distribution racks shall be made in collaboration with the users. Distribution Patch panels Gas chromatograph Portable flammable gas leak detector

Gas detection Heads	Alarm system for flammable gases connected to TCR (std CERN)
Compressed air	Dry and oil-free, distributed by clean pipes with several points of use
Chilled water	Dedicated loop for the GIF area and users cooling needs The system shall deliver a signal contact ON/OFF Min. water flow: few L/min, continuous running, supply ~ 6 bar, return at ~ 3 bar
Cable & pipe trays	From individual control barracks and services area to irradiation area inside GIF++
Ethernet	10 sockets as a minimum, for fixed and portable computers, and wireless
Cables	HV (5, 15 kV) LV Signal
Final preparation area	(Minimum 4 x 4 m^2) Cohabitation of 3 to 5 groups
Storage Area	(4 x 4 m^2) and office cabinets
Crane	Max. Tons: (this depends of the skyshine radiation value)
Barracks	For users (2) For installation of electronic racks (2)
Infrastructure for test set-ups inside radiation area	
Scanning system/ Shuttle	
T-controlled environment	
H, T and P sensors	Minimal configuration: 1 H (%), 1 atm P (mbar), 4 T (^{o}C) sensors
Trigger set-up	Used when beam on and with cosmics when particle beam is off
Dose rate monitoring	
Beam extraction system from accelerator and instrumentation	Wire chambers or scintillators
Control systems and Logs	
Web based Monitoring and Logging	User(s) name & experiment(s) Particle Beam status Source exposure status Attenuation value Running time Environmental data (TCP/IP)
Hard-wired Common Control System(s)	Gas supplies and gas systems control Particle Beam data Status of Access doors and gates Video/IR monitoring of presence in the areas Source and Filters control Radiation safety monitoring Start-Stop the beam Start-Stop the source Emergency STOP

4 GIF++ Time Scale Assumptions

- Evaluation of possible scenarios and Design Proposals: June – September 08
- Preparation of a Technical Design Proposal (AB Dept): September 08 – March 09
- Design of Final Infrastructure (not related to the particle beam): September 08 – February 09
- Approval of Technical Specifications of the facility: April 09
- Procurement and construction phase: May 09 – December 09
- Infrastructure commissioning: January 10 – May 10
- Target date ‘Ready for users’: May 10
- First report of results: Dec 10

References

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[5] D.Green, LHC Detector Upgrades, Talk at the LHC Symposium, May 2003.

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