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Proposal to the CERN SPSC

A GIF++ Gamma Irradiation Facility at the SPS H4 Beam Line

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On behalf of the GIF and GIF++ User Communities[3]

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3 ALICE experiment, ATLAS experiment, CMS experiment, LHCb experiment, COMPASS experiment, NA62 experiment, LHC Beam loss monitors, CERN PH-DT, CERN PH-ESE, CERN DG-SCI, CERN DG-SCR, CERN EN-STI, CERN TE-CRG, CERN TE-MSC, CERN BE-BI, RD-50 and RD-51 Collaborations.

Contents

1. Introduction

In this document we propose to install a gamma-irradiation facility, combined with a high-energy particle beam, in the EHN1 H4 beam line at the SPS. The operation of particle detectors at the LHC and its future upgrades for sLHC will be characterized by large sustained hit rates. Therefore, the detailed knowledge of the performance of detectors under high particle fluxes and a precise understanding of possible ageing of detector materials under permanent particle bombardment are crucial for an optimized design and efficient operation mode. For this purpose, the GIF facility was created in the SPS west area in the mid 90ies [1]. It combined irradiations by a high-rate ^{137}Cs source, providing a large area flux of photons with energy of 662 KeV, together with the availability of high-energy SPS charged particle beams. The GIF facility has been used extensively for many years, with scheduled source irradiations during some 50 weeks per year. Despite the disappearance of the west area beam lines in 2004, the GIF facility is still heavily used to date. However, there is a need for a stronger source and for regaining the possibility to carry out simultaneous detector performance tests with a high-energy beam.

The Working Group on Future Irradiation Facilities at CERN [2] was created in December 2007 on the request of several CERN department heads. Given CERN's obvious need for irradiation infrastructures in the future it was felt necessary to get a broad view of the requirements as well as a CERN-wide coherent approach towards the investments to be made. As part of its mandate, the Working Group has conducted a broad web-based enquiry on user needs for irradiation facilities at CERN. Among other future irradiation facilities [3], the enquiry included questions about gamma irradiations with and without beam. As a result of the input from the users, implementation plans have been prepared for a future GIF facility, called GIF++, at the H4 beam line in EHN1. The starting point for the design of the GIF++ is the experience from the GIF and the collection of updated user requirements, followed by design studies involving several CERN departments and the agreement, by all users, of the technical specifications for the construction of the optimal facility. The requirements have been collected via questionnaires sent to users communities in particle physics and in-depth discussions with the LHC upgrade program teams.

In this document, the results of the user enquiry are presented in section 2. The parameters of the future GIF++ facility are described in section 3, followed by the implementation plan in section 4. Details on the operation of the facility are described in section 5, while the beam time request for the coming years is expressed in section 6.

2. Survey on the demand for a Gamma Irradiation Facility and feedback from the questionnaire

The CERN Working Group for Future Irradiation Facilities has carried out a survey on the demand and requirements for future irradiation facilities at CERN. The survey was sent to a large community of potential users. A web-based questionnaire was prepared for each type of facility addressing questions regarding the required radiation field, the facility infrastructure, the irradiation experiments to be performed, the annual required beam time and the time scale for the projects that would be performed in the facilities.

For gamma irradiation, two options were presented: i) exposure of objects to the radiation field of a high intensity gamma source, and ii) a large-area gamma irradiation facility combined with a particle test beam of low intensity. The total number of answers obtained to date is 29 and 8 respectively. For the latter, some single answers group the demands of several LHC detector communities with similar requirements; thus they represent a very large and spread community while statistically it appears negligible. Fig. 1 shows the questionnaires filled, for the two options, according to membership in collaborations or groups performing generic R&D for LHC and sLHC. As mentioned, it does not represent quantitatively the complete GIF and GIF++ communities.

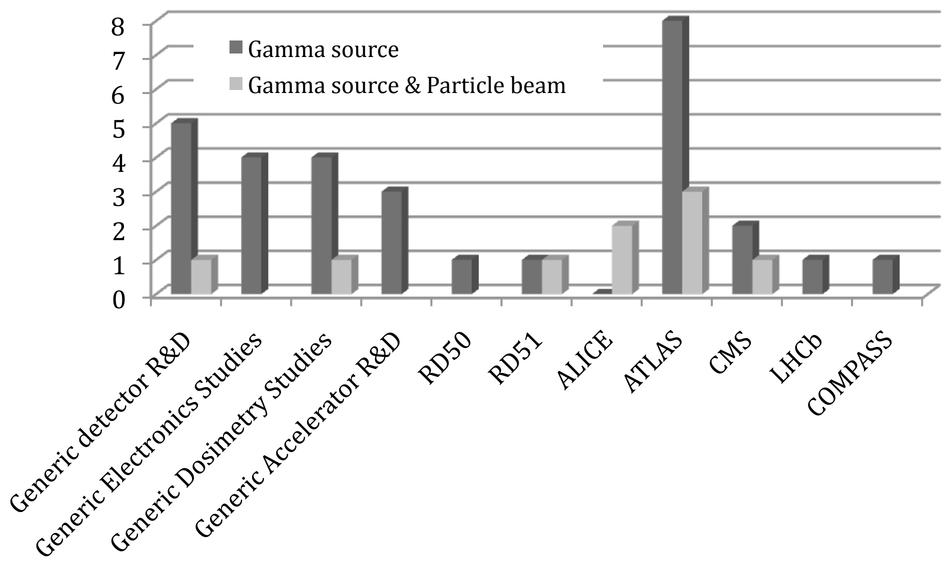

Fig. 1. Number of questionnaires filled for the gamma irradiation (only source -in dark grey- and source plus beam -in light grey-) clustered according to membership in collaborations or groups doing generic research for LHC and sLHC. The total takes into account double counting for members of several collaborations.

A detailed analysis of all answers shows that the users can be easily clustered in two groups of similar interests. There is a large set of groups interested in testing radiation hardness properties of small prototype detectors and detector materials, electronic components (ASICs, cables, optoelectronics, power supplies, fibers, etc.) and radiation monitors or dosimetry under a strong photon flux (Fig. 2). The second set of users is focused on the characterization and understanding of the long-term behavior of large particle detectors, in particular chambers for the LHC and sLHC muon systems, under high-background irradiation rates. The latter group needs a large area, high rate photon background combined with a high energy (SPS), low rate and narrow muon beam. The new facility is planned to be able to serve simultaneously the needs of these two communities.

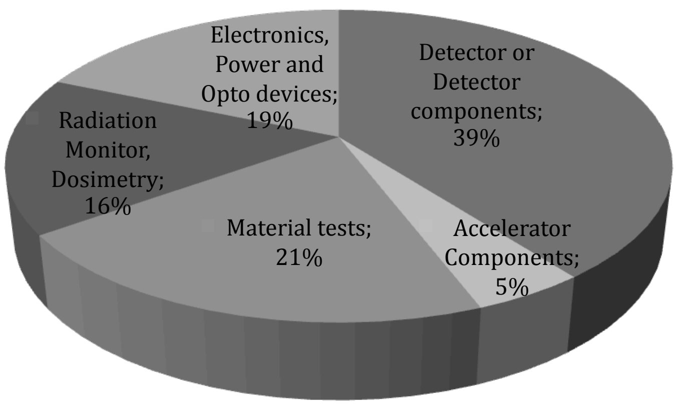

Fig. 2 Type of equipment or material to be irradiated in a gamma facility (no particle beam).

The survey also 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 the facility can serve more users, even at short notice. Fig. 3 shows the user's estimate of the number of weeks per year needed for their gamma irradiation tests. The figure does not include the primary use of the SPS H4 beam line simultaneously to the gamma source. Some muon detectors groups have expressed the wish of installing their large area detectors permanently in the area and this would represent the largest load in the zone.

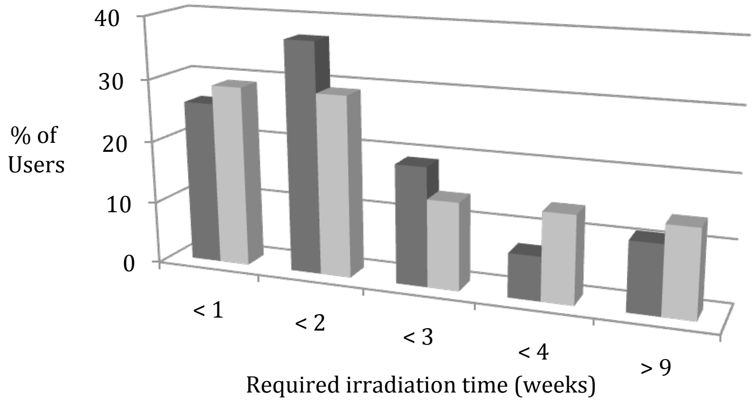

Fig 3. Data form the users questionnaire. Required annual gamma irradiation time in weeks at the facility, for users using exclusively the source (dark columns) and users using also the beam line (lighter columns). For the latter, the allocation of time for using simultaneously the SPS H4 beam line is not included.

Gamma dose requirements vary over a large range depending on the sample type and goal of the test: detectors tests (burn-in, aging test, rate capability test, etc.), dosimeter, material sample and electronic components tests and validation of technologies. For sLHC detectors, silicon trackers will be exposed to a radiation dose as high as MGy/year, 20 kGy/year for calorimeters and 0.1 Gy per year for the muon detectors [4]. Thus, even for the same type of equipment, required accumulated dose and dose rate can vary several orders of magnitude. In this respect, is seems mandatory to equip the gamma source with a filter system that would permit attenuating the photon rate in several steps, to reach attenuation factors of several orders of magnitude (~10^4-10^5).

3. GIF++ specifications

Users of the first GIF facility have recognized its effectiveness over more than a decade of operation, thus many 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 new dose requirements for sLHC. The irradiation field characteristics and infrastructure presented here have been set after a detailed analysis of the questionnaire mentioned in the previous section, and specially, taking into account the outcome of several discussions held with individual users to better understand the requests issued in the questionnaires, the size and importance of the corresponding user communities, and the relevance for CERN and future experiments at CERN. Safety aspects have also imposed limitations to the choices presented.

3.1. Irradiation field

The selected gamma source is ^{137}Cs, ~7-10 TBq. A source of this intensity will provide up to 2 Gy/h at a distance of 50 cm. The ~10 times higher outcoming uniform photon flux than in the previous GIF corresponds to the expected step in intensity while moving to sLHC conditions. ^{137}Cs is chosen because the spectrum of primary (662 keV) and scattered photons matches reasonably well the energy spectrum expected for background in LHC muon detectors (~1 MeV). The 30 years isotope half-life makes the rate from the ^{137}Cs source relatively stable over the years, as compared to a ^{60}Cobalt source, which was preferred by some users due to its higher energy (1.17 MeV and 1.33 MeV photons).

The beam will deliver a maximum muon flux of about 10^4 particles per spill traversing an area of 10x10 cm^2. The beam momentum needs to be of the order of 100 GeV to allow system tests and precise tracking studies, and also to study the background (from the source) correlated with energetic muons.

An EHN1 location in the SPS H4 beam line was recognized as the most appropriate implementation of GIF++.

3.2. Layout and dimension of the GIF++ bunker

Front gamma irradiation field: area dedicated for very large area detectors, where several detectors set-ups can be irradiated at the same time. Some muon detectors that will be tested at the GIF++ can be as large as 4 m high and 3 m wide.

Rear gamma field: A second irradiation beam will be available at 180 degrees to the main, large area photon field. This area will be defined by a separate collimator that allows irradiation of small detectors and components with a higher flux but over a smaller area. It will be possible to activate or isolate the second irradiation gamma beam using a separate shutter.

3.3. Radiation control and safety

The irradiator will be controlled from a single console located in the control room next to the area. All safety functions related to the zone will be included into the console. This comprises search boxes, infrared detectors to signal the presence of any life forms in the zone, smoke detectors, explosive flammable-gas detectors, emergency stops, door monitoring and any other safety system required specifically for the operation of the radioactive source. Radiation rate monitors will be installed inside and outside the irradiation volume to monitor the correct operation of the source controls, as well as the SPS beam operation. Any detected anomaly will force the irradiation source back into its shielded position and will veto any possibility of further extraction. All changes of states will be logged and alarms will automatically being sent to the responsible persons.

As objects might need radiation for long periods of time, it will be a key feature of the area to be monitored remotely and even in unattended mode, as needed for very long detector aging tests (~ several months). More than 70% of the answers to the GIF++ questionnaire show that users will need to access the object under test for manipulation or to carry out measurements in the course of the experiment.

3.4. Peripheral infrastructure

The GIF++ is a facility specially suited to test large area muon detectors in conditions similar to those expected at the LHC and sLHC. 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, as well as performance under severe background conditions.

The infrastructure for an optimal GIF++ layout has been divided in 3 major categories:

- Peripheral infrastructure to condition the areas surrounding the bunker (preparation and storage areas, gas systems) and feeding into the irradiation bunker;
- Minimal infrastructure provided to users inside the irradiation bunker, including the beam related equipment, and
- GIF++ common control and log systems.

Some detailed specifications for the needed infrastructure are presented in the table below:

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 is constructed as close as possible to the irradiation areas to reduce the pipe network. The supplies will have P-based switchover panels. The zone will have two distinct areas: i) supplies of neutral gases (Ar, N2, CO2, He, Xe) and ii) supply of flammable, premixed and special gases (iC4H10 and CH4, Ar/H2, C2H2F4, SF6, CF4). The latter will be kept between 20-25 ^{o}C.
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	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 will be monitored per panel. Automated open-loop gas system with: 2 Mixer Racks, automated analysis rack with several sampling points, Infrared analyzer (for flammable gases interlock). The design and functionality of the mixing and distribution racks will be made in collaboration with the users. Distribution Patch panels. Portable flammable gas leak detector.
Gas detection Heads	Alarm system for flammable gases connected to the CERN CCC (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 will 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	Area outside the bunker equipped with services for setting-up and testing detectors before entering the bunker. Minimum area requiered: 4 x 4 m^2. Cohabitation of 3 to 5 groups.
Storage Area	(4 x 4 m2) and office cabinets.
Crane	Available on request for moving detectors and opening the large door.
Barracks	2 barracks for the users and 2 for installation of electronic racks.
Infrastructure for test set-ups inside radiation area	
Scanning system/ Shuttle	Scanning system to scan equipment across the beam.
T-controlled environment	Area at 20 ^{o}C, 30-50% relative humidity and corresponding monitoring sensors with remote readout.
Trigger set-up	Used when beam on and with cosmics when particle beam is off.
Dose rate monitoring	Movable radiation sensors, remote reading.

Beam extraction system from accelerator and beam instrumentation	Standard wire chambers or scintillators in the beam line.
Control systems and Logs	
Web based Monitoring and Logging	User(s) name & experiment(s). Particle Beam status. Source exposure status, attenuation value and rate. 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 and source. Emergency STOP.

4. Implementation plan

4.1. The H4 beam line

The H4 line in the EHN1 (CERN Building 887) area of the SPS provides a high-energy, high-resolution secondary proton beam. Alternatively it can be used to transport primary protons, electrons from γ- conversion, polarized protons for Λ decay, enriched low-intensity beam of antiprotons, or K+. The main parameters are a beam momentum of Pmax= 330 (450) GeV/c with a precision of $\Delta p/p = \pm 1.4$ % and an acceptance=1.5 μSr; the beam height from the floor level is 2060 mm.

The beam time will be shared with other quasi-permanent installations, such as the CMS calorimeter test area, and test set-ups such as the RD-51 beam test, NA63 test stand, etc. Fig. 4 shows the floor plan of part of the hall, and indicates the location of the GIF++ bunker and surrounding areas.

Even when the GIF++ will not be the primary user of the H4 beam, the ^{137}Cs source can be continuously used for gamma irradiation tests. Technical solutions are presently under consideration in order to permit safe access to the CMS area during gamma irradiation in GIF++. The only constraint is that whenever the CMS calorimeter test area downstream the GIF++ area uses the beam, a vacuum pipe inside GIF++ needs to be installed, thus chambers need to get out of the beam axis.

4.2. The GIF++ bunker

Fig. 5 shows the proposed GIF++ bunker layout. The layout has yet to be optimized to maximize the attenuation of radiation through the access chicanes. The bunker area has a floor area of about 170 m^2, with a total height of about 4.8 m. It can host simultaneously very large objects with dimensions of several square meters and allows flexible positioning at various distances from the gamma source to simulate the desired background rates.

Due to the high dose rate of the future irradiator, the GIF++ area requires a vented concrete ceiling to guarantee the safety of personnel in adjacent areas and accidental evacuation of gas by natural convection.

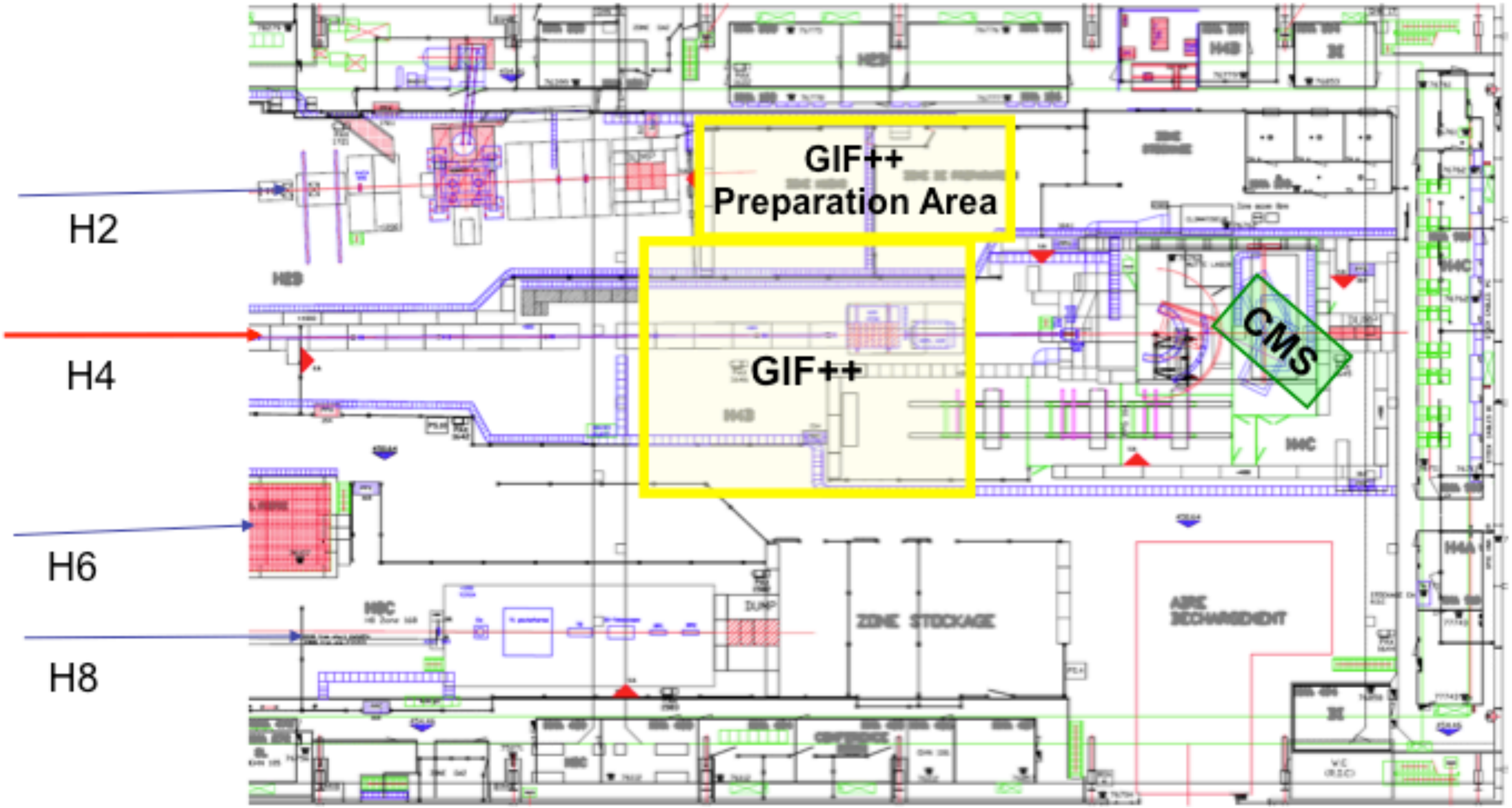

Fig. 4 Floor plan of part of the H4 beam line in the EHN1 (CERN Building 887). GIF++ is located at the end of the beam line, downstream the CMS ECAL beam test area. About 100m upstream the GIF++ bunker, the following test areas are currently in operation: Compass-Calo, CALET, INSURAD, CMS-ECAL, CMS-BCM, NA63, RD51, LHCf, SiTRD.

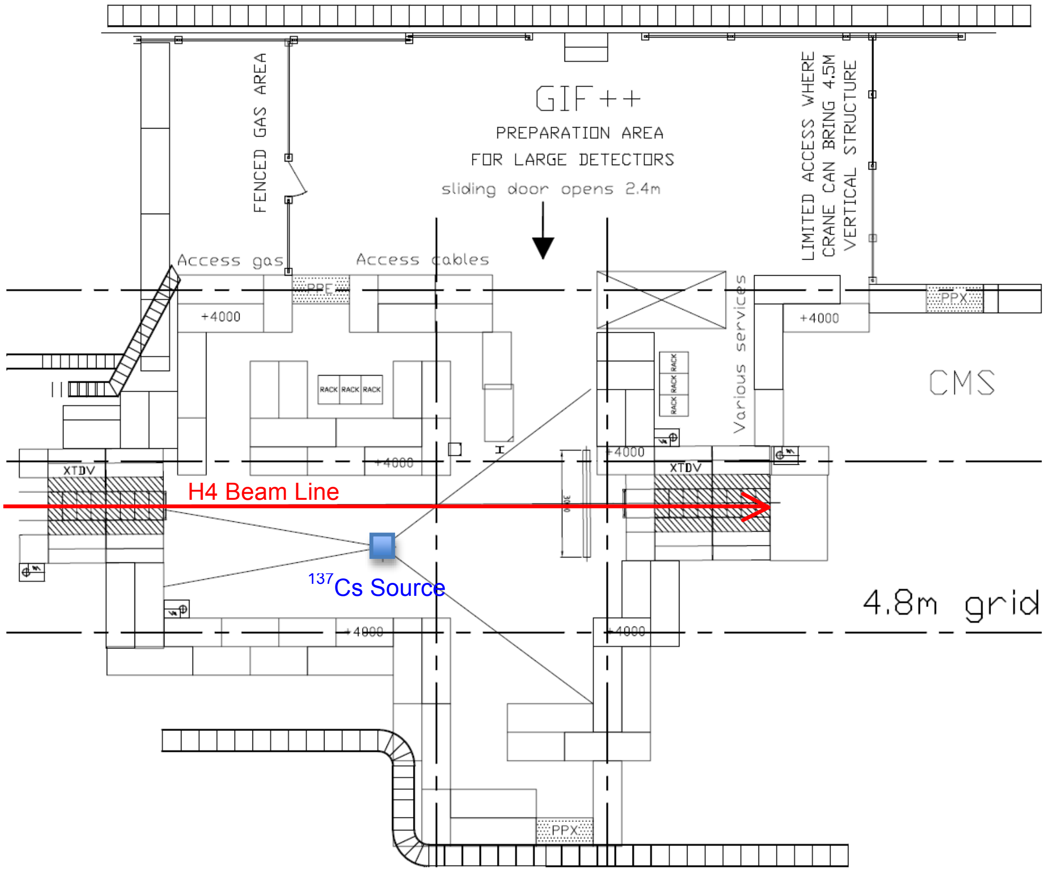

Fig.5: Layout of the GIF++ bunker and its surrounding preparation area.

While the particle beam passes the GIF++ area at about 2 m height from the floor level, the gamma source is placed at 1.50 m height and at 1 m aside of the beam line in order to optimize the irradiation area both to the front and rear fields (Fig. 6).

The new GIF++ provides a preparation area of about 3.5 m x 10 m very close to the bunker and with easy access to the bunker. This area permits commissioning the devices that later will be tested in the radiation area, thus it dissociates the time period used for the preparation of set-ups from the irradiation periods. In addition, an area dedicated to gas rack equipment is available in the closest vicinity and accessible at all times. It will be equipped with gas distribution and some dedicated gas analysis equipment.

Heavy detectors and equipment to be carried between the truck unloading platform, the dedicated preparation zone next to the control room and any of the short-term common storage areas may be handled by the crane inside the EHN1 area. Installation of detectors and equipment inside the bunker shall be done using individual wheeled supports or motorized traction systems. The covered irradiation room and surrounding facilities use the floor and underground services existing in the hall.

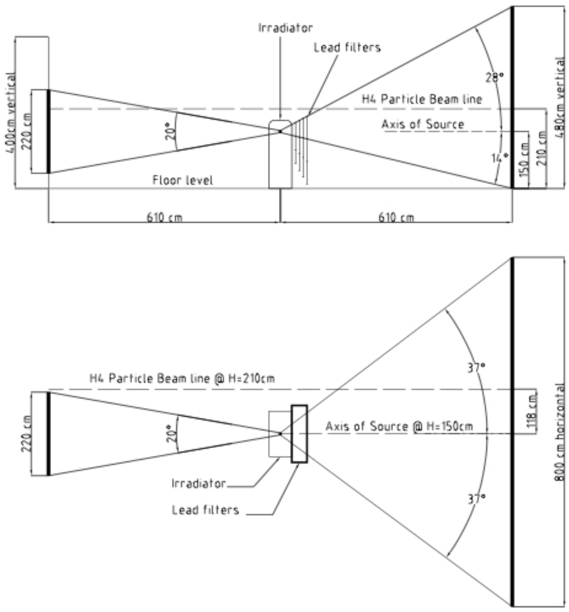

Fig. 6 Lateral and top views of the gamma irradiator and H4 beam line.

5. Operation of the GIF++ facility

The operation of the future GIF++ will closely follow the model of the current GIF facility. The responsibility will essentially be shared between the GIF++ users and a number of CERN services, in agreement with their general mandate. The EN-MEF group will take responsibility for the maintenance of the GIF++ beam line and corresponding equipment. The EN-MEF group will provide assistance to the users for the installation and integration of their equipment under test, as well as for optimizing the required beam conditions. The EN-MEF group will also maintain the fixed gas supply installations. The PH-DT group will provide assistance and liaise with the users on a day-to-day basis. The group will share with the users the responsibility for the maintenance of the gas mixing and purification plants and for maintaining the control system of the facility. The PH-DT group will follow up on the annual maintenance of the ^{137}Cs source by a competent external firm. A representative of the PH-DT group will fulfill the role of TSO of the facility. The DG-SCR group will take responsibility for monitoring of all ionizing radiation in the area in view of safety regulations. The DG-SCR group will also provide radiological risk assessments for the GIF++ facility in view of its different test conditions. Last but not least, the users take responsibility for their specific detectors and peripheral equipment such as user-specific gas equipment, cables, power supplies, readout electronics, DAQ, etc. The users also take responsibility for all data taking shifts.

6. Estimate of requested beam time for the first years of GIF++ operation

The current planning foresees a completion of the GIF++ installation by mid-2010. A running-in time, alternatively with and without beam, of approximately 8 weeks will be required to commission the facility in all aspects, such as controls, safety, beam optimization and mapping of the gamma irradiation fields. This running-in period shall include 2 weeks with secondary SPS beam of modest intensity.

Following the results of the user requirements questionnaire, the GIF++ data taking with beam will mostly be based on muon beams at energies above 100 GeV, complemented occasionally with charged pions, protons and electrons. Intensities of a few hundreds of muons per spill will be required. An estimated total annual particle beam time, as a main H4 user, of 6 to 8 weeks spread over three ~2-week periods will be required. This estimate takes already into account that users will occasionally use the H4 beam in parasitic mode with non-GIF++ primary use. Concerning the gamma-source, the estimated total annual exposure will amount to some 48 weeks, in analogy to the current GIF usage. This estimate includes scheduling with parasitic running. The above beam time requests cover the first 5-year period of GIF++ running, and will most likely extend beyond in view of the LHC running and preparations for sLHC.

As for the past GIF facility with SPS west-area beam, we propose that the annual allocation of particle beam time and its sharing between the GIF++ users is managed by the SPS coordinator. In analogy with the current beam-less GIF facility, we propose that the SPS coordinator will also manage the allocation and sharing of exposure time at the gamma source. The simultaneous use of GIF++ by multiple users will be organized such that one 'Main User' is assigned by the SPS Coordinator and, as far as the 'Main User' needs permit, further parasitic users make use of the zone.

7. Conclusions

The current document describes a proposal to implement a new gamma irradiation facility, combined with a high-energy particle beam in the SPS H4 beam line in hall EHN1. This new GIF++ facility is motivated by strong needs from the LHC and sLHC detector and accelerator communities for the tests of LHC components and systems. The new facility follows up on the very successful GIF facility in the SPS west area, which lost its access to a particle beam in 2004 and which currently suffers from a lack of sufficient source intensity. The GIF++ facility presented in this proposal takes into account the requirements from the users and has been discussed extensively with them. It is subject to some further optimizations in the layout, in particular in view of more extensive radiation impact studies. We ask the SPSC committee to endorse the scientific case for the new GIF++ facility and ask it to support the implementation of the facility in the H4 location. We also ask the SPSC to confirm that H4 beam time will be available for GIF++ at the level of 6-8 weeks per year after mid 2010, when the facility will be completed.

8. Acknowledgements

We would like to thank all those who have contributed or provided input to this proposal, specifically:

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