The CERN Gamma and Proton Irradiation Facilities during and beyond Long Shutdown 2

on behalf of the GIF++ and IRRAD Facilities Teams (EN and EP CERN department)
Outline

- Team and Facilities in the CERN EP department
- GIF++ Facility at EHN1
  - Users and performance
  - Cs irradiator, Radiation field, User infrastructure
  - Bunker extension 2019, LS2 Operation and beyond
- IRRAD Facility at EA
  - Users and performance
  - Experiments Data Management, Beam Instrumentation R&D
  - Technical Area extension 2020, User infrastructure after LS2
- Run 3 operation
- Conclusion
Current EP-DT Irradiation Facilities Team

Martin
- GIF++ Physics Coordinator (deputy to SPS Physics Coordinator for the GIF)
- Future development of the GIF++ facility

Federico
- EP-DT Facilities Team Responsible, IRRAD Facility Coordinator
- Irradiation Facilities EXSO

Giuseppe
- Manager GIF++ & IRRAD: users supervisor, contact to EN services
- GIF++ Gas system first level support, deputy EXSO

Isidre, FELL
- AIDA-2020 EU-project Dosimetry (RADMON), Beam Instrumentation studies for IRRAD

Blerina, COAS / PhD
- AIDA-2020 EU-project Facilities Computing Infrastructure & R&D, Data Management

Viktoria, TECH
- ATTRACT EU-project Development Beam Profile Monitor devices with microfabrication
CERN Irradiation Facilities

CERN Irradiation Facilities

CALLAB (irradiation sources)

VESPER (electrons)

GIF++ (gamma + muons)

IRRAD (protons)

CHARM (mixed field)

EP-DT Operated Irradiation Facilities

See Blerina’s Presentation!
GIF++ @ EHN1

Irradiation Bunker

- Joint facility, operated by EP-DT and EN-EA
- Unique place, combining a high energy muon beam with a 14 TBq $^{137}$Cs gamma source
- 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.
- 160 m$^2$ irradiation bunker with 2 independent irradiation zones (30 m$^2$ & 75 m$^2$), separated attenuation systems
- All year operation from Cs-Irradiator
- Muon beam (H4) for 7-9 weeks per year
- Central Control System, recording all relevant parameters and provides interlocks
- Wide range of available gases (+ custom gases) in bunker & service zone
- > 20 different large setups scheduled during end of Run 2

*as of 2014
Bunker area contains:
- Gas panels
- Electricity outlets
- Network sockets
- Environmental monitoring
- Gas/smoke detection
- Radiation monitoring
- Air conditioning

Irradiation Fields:
- Downstream ≈ 30 m²
- Upstream ≈ 75 m²

2 x Irradiation Area

Removable Roof

Material Access

People Access

Small Material Access

Service Area (Gas)

Service Area (Electronics)

Raised floor throughout the facility (pipes, cable trays)

H4
GIF++ Main R&D

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

Annual User Meeting:
https://indico.cern.ch/e/GIF-AUM-2018 / GIF-AUM-2019

Facility designed / optimised for Muon gas detectors for the LHC experiments upgrade projects, but also hosts a large variety of other users
Wide Range of Smaller Test Campaigns

EN-CV - tightness of cooled cables manifolds

Filter box - collaboration btw ESA and CERN

ALICE ITS Upgrade Power Board

BLM Ionization Chamber (≈ 900!)

Plastic scintillator rods with Gafchromic™ films - CMS UMD collaboration

μlens and optical fibres for the TOP PID detector of Belle II experiment
**GIF++ Irradiator & Attenuation Filters**

One $^{137}$Cs source, two identical attenuation systems, each consisting of one angular correction filter (Fe) and 6 absorption filters - a total of 14 custom shaped filters

**14 TBq $^{137}$Cs** (as of 2014)

Angular correction filter provides uniform photon distribution for large area detectors

**Filter System:**

<table>
<thead>
<tr>
<th>Absorption factor</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>1.47</td>
<td>2.15</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>4.64</td>
<td></td>
</tr>
</tbody>
</table>

**24 possible attenuation factors:**

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>21.54</td>
<td>464.2</td>
</tr>
<tr>
<td>1.47</td>
<td>31.62</td>
<td>681.3</td>
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<td>2.15</td>
<td>46.42</td>
<td>1000</td>
</tr>
<tr>
<td>3.16</td>
<td>68.12</td>
<td>2154</td>
</tr>
<tr>
<td>4.64</td>
<td>100</td>
<td>4642</td>
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<tr>
<td>6.81</td>
<td>146.8</td>
<td>10000</td>
</tr>
<tr>
<td>10</td>
<td>215.4</td>
<td>21544</td>
</tr>
<tr>
<td>14.68</td>
<td>316.2</td>
<td>46415</td>
</tr>
</tbody>
</table>

(calculated values for un-scattered gammas)
The Radiation Field in the New Gamma Irradiation Facility (GIF++) at CERN
Nuclear Inst. and Methods in Physics Research, A 866 (2017) 91-103

GIF++ Radiation Field & Monitoring

Total flux, one field, without filters

 brasilei 2020

Approximately 0.5 Gy/h @ 1m

12 x RADMON “movable” sensors
2 REMUS detectors, on DIP & TIMBER
2 Berthold counter GM LB6500
Automess AD6 with external probe
3.2m translation stage for field mapping

Optional Half Filter

Berthold
**GIF++ Available Infrastructure**

**Central Control System (PVSS)**

- GIF++ Control System
- PVSS Supervisor
- In Control Room
- PVSS Project (CCC)
- Central Database
- UPS
- 24V PS1
- 24V PS2
- Redundant Power Supplies
- TCP/IP Technical Network

**DAQ System**

- Event builder
- Event builder
- Event builder
- Event builder
- Event builder
- Event builder
- Event builder
- Event builder

**Beam Trigger**

- (2 pairs of scintillators)

**Monitoring**

(for both atmospheric and gases): p, T, rH

Baseline: 4 gas and 6 atmospheric sampling points

**DCS System**

- OPC
- Mainframe
- Branch Controllers
- AC/DC converter
- 48V
- 48V
- Crate1
- Crate2
- HV/LV Boards
- Service Area

**Gas and Environmental sensors**

- T, H sensor
- PCMini 70 Michell
- p sensor
- TSA Gefran

- CAEN ADC 3801
Central Gas System

The gas system infrastructure is a key element of the successful R&D programs performed at the GIF++

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

Wide range of available gases available
Possibility to use pre-mixed bottles (local gas point)

Gas Area

- Local gas point
- Gas distribution

- Gas recirculation module
  - Sampling manifold
  - PC for GC software controls
  - GC analyser (3 modules for large spectra gas separation)
  - Gas chromatogram

- Mixture distribution
- Monitoring of pressure, O2/H2O, temperature, atmospheric pressure
- Additional software controlled pressure regulation for very low flow regimes
- Gas mixing unit

Gas chromatographic analysis: allows monitoring gas mixture composition and presence of impurities on return from detectors under test
Bunker Extension 2019

- Displaced by 1m (preserving low irradiation field)
- Better distribution of setups among fields
- Easier access for large setups
- Freeing space of cosmic trigger ground chamber

+60m² !
GIF++ Improvements 2019

- New electronic racks (prep. area)
  Short cable path to extended bunker area
- New primary gas distribution panels
  Increased flow rate for commonly used gases
- New gas distribution panels in extension
  (to be finished during 2020)
- Additional electric outlets in bunker
- Improved web page and data retrieval tool (PyTimber)
- Completion of cosmic trigger with 3 (of 4) roof chambers
- Extension of cosmic trigger with external chambers
LS2 Operation

- **Irradiator fully operational throughout LS2**
  - 1 week of Irradiator maintenance each year, + stopped during CERN Christmas closure
  - Possibly several short stops (days) due to EHN1 infrastructure maintenance & consolidation

- **Main challenge in 2020**: several mass production test campaigns continuing in parallel (ATLAS NSW)
- frequent access to change chambers, filter scans, source on/off cycles
- **Most long term irradiation test continue**
  - Improved space eased the conflict between high \( \gamma \)-irradiation campaigns (max.collective dose) vs. low radiation ageing tests
  - Shadowing effect on setups further away from source. Some mitigation possible by placing setups at different height. (\( \rightarrow \) to consider during frame design !)
LHCb MWPC based Cosmic Trigger

- During the LS2, several m² of muon chambers (including read out electronic and cabling) became available from LHCb due to an upgrade.
- This would open the possibility to install a second fixed permanent cosmic trigger (e.g. upstream).
- Ongoing discussion about possible installation & maintenance (main problem= manpower during LS2).
- Demonstrator built that can be installed around existing set-ups.

- Two gaps in one chamber.
- Gas gap: 5 mm
- Wire: Gold-plated Tungsten, 30 μm dia.
- Wire spacing: 2 mm
- Wire length: 210 mm
- Wire mechanical tension: 60 gf
- Gas mixture: Ar/CO₂/CF₄ (40:55:5)
- Gas gain: G ≈ 10⁵
- Charge/mip: ≈ 0.8 pC @ HV ≈ 2.7 kV
- Field on wires: 262 kV/cm, on cathodes 6.2 kV/cm
- Gain uniformity: ≤ 30%
- Gap efficiency: ≥ 95% in 20 ns window (σt ≈ 3.9 ns)
- Rate/channel: max 2 MHz in M1, < 0.6 MHz M2-M5
- Max. operating voltage: 3 kV
- LV 3.5V, 1.5 A per chamber. Build-in chamber LV-regulator, tolerance +-100mV
- Typical HV 2700V
- Signal output - LVDS. Readout from anode wires groups.
- Active area is 968 x 200 mm (granularity 40x200mm) x 24

More info about the LHCb MWPC: see W. Riegler note [http://cds.cern.ch/record/681186?ln=en](http://cds.cern.ch/record/681186?ln=en);

Trigger chambers placed and aligned at 45° to optimize the incident rate of cosmic rays and the irradiation seen by the detector to study the performances.
Muon Beams @ GIF++ up to LS2

- Muons are created by the pion decays
  - Selecting 150 GeV/c secondary momentum → Pion content very satisfactory
  - Lower momenta more pion enriched

Current configuration (150 GeV)

>100 m distance from the muon production point up to GIF++

6.5k muons per $10^6$

Current configuration can still be used (e.g. when running in parallel with RD51)

Based on slides from N. Charitonidis (EN-EA)
A new proposal for a pion dump before GIF++

- Two new beam dumps in front of GIF++, which can be manually moved out of the beam for hadrons / electrons @ PPE164
- XTDV in front of GIF++ always flexible (interlocked with PPE144)
- Some radio protection issues need to be clarified (e.g. beam dump shielding, and max. Muon intensity)
- Possibility of beam horizontal steering under investigation

New configuration (80 GeV)

Based on slides from N. Charitonidis

Concerns from RP about accessing the bunker during muon beam are currently investigated.
IRRAD @ East Area
IRRAD Facility Layout

- A reference facility for proton irradiation experiments (see previous BTTBs)
- Testing components of the HEP experiments with proton beam of 24 GeV/c
- Not operational during LS2, infrastructure extension project in 2020
**Beam Parameters**

- \( p^+ \) are delivered in “spills” of \( \sim 5 \times 10^{11} \ p \)
- Typical figures *(high intensity)*: 3 spills per CPS(*)
  - \( \sim 1 \times 10^{16} \ p \ \text{cm}^{-2} \ \text{5 days}^{-1} \ (12 \times 12 \ \text{mm}^2 \ \text{FWHM}) \)
- Design figures *(maximum)*: 6 spills per CPS
  - \( \sim 1 \times 10^{17} \ p \ \text{cm}^{-2} \ 4 \ \text{days}^{-1} \ (5 \times 5 \ \text{mm}^2 \ \text{FWHM}) \)
- Standard size: \( 12 \times 12 \ \text{mm}^2 \ \text{(FWHM)} \)
- Spot size from \( 5 \times 5 \) to \( 20 \times 20 \ \text{mm}^2 \)
- Possibility to run with Heavy Ion beams (Xe, Pb)

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**IRRAD Performance**

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**Examples of irradiated samples in 2018**

- **Piezo Actuators** for Crystal Collimation, Vacuum, Cryogenics, etc.
- **RD53A modules** for ATLAS ITk
- **CLARO ASIC** for the LHCb RICH Upgrade

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(*) CPS = PS Super cycle

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**IRRAD often operated with non-standard beam conditions** (e.g., various intensities and/or shapes) or with other type of particles such as Heavy Ions!
IRRAD Data Manager

To be extended for GIF++ and other facilities in AIDAnova proposal.

Registration -> Planning -> Follow-up -> Dosimetry Results -> Traceability -> History
Beam Instrumentation Upgrade

- Today’s BPMs are produced with standard PCB manufacturing techniques, and show:
  - **big degradation** due to glue bubbling/burning ➢ **Need to change** **INSULATING MATERIAL**
  - (relatively) low “transparency” to the beam
  - very radioactive and long cool-down required ➢ **Need to reduce** **METAL THICKNESS**

- New devices manufactured with microfabrication techniques
  - study/understand **effect of metal layers stacking**

Testing @ CERN VESPER facility (200 MeV electrons)

- Various metal thicknesses (1-100 nm)
- Various substrate material and thickness

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Mini-BPM (old)

Micro-BPM (new)

CMI EPFL Center of MicroNanoTechnology

Technical Area Extension

Based on integration model from D. Brethoux (EN-EA)
User Infrastructure after LS2

TH100 Temperature and Humidity Test Chamber, from LIB Industries

Internal dimensions: 400x500x500 mm³ / 100 litres
Temp. range: -70 to 150 °C
Rel. humidity range: 20-98%

LabVIEW: VI function blocks & full controller VI

Suss PM8 Probe Station (4 manipulators, thermo-chuck 5-125 °C and a vibration isolated table in EM isolated dark box) + Keithley 4200A SPA

Run 3 Operation

- **GIF++ Irradiation request**:
  - All irradiation request are handled via [IMPACT.cern.ch](https://IMPACT.cern.ch), GIF Facility
  - All setups need to fill in an “Initial Safety Information on Experiments at CERN (ISIEC)“ on arrival and pass the safety inspection
  - All requests for muon beam are collected by the **GIF++ Physical Coordinator**
  - Weekly users operation meeting (Thursday 9h15)

- **SPS North Area Physics : 2021 Q2**
  - Call for beam time request in Sep./Oct. 2020 (!)

**IRRAD Irradiation request**:

- Call for irradiation experiments sent to dedicated e-group: [irrad-ps-users@cern.ch](mailto:irrad-ps-users@cern.ch)
- Complex experiments to be discussed in advance: [ps.یرداد@cern.ch](mailto:ps.یرداد@cern.ch)

**PS EA Irradiations : 2021 Q2/Q3**

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M.R. Jäkel

BTTB8 28.01.2020, Tbilisi
Conclusion

**GIF++:**
- GIF++ irradiator [OPERATIONAL](#) throughout LS2
- Several major improvements (e.g. bunker extension) in 2019
- Major improvements for muon beam envisaged for 2020
- Number of users keeps increasing, stig demand for a muon / gamma facility
- Preparations for Run 3 have started

**IRRAD:**
- IRRAD [NOT OPERATIONAL](#) throughout LS2
- Looking for alternatives? see: [www.cern.ch/irradiation-facilities](#)
- R&D on Data Management and Beam Instrumentation continues
- Major improvements / upgrades planned in 2020
- New equipment for post-irradiation tests after the LS2
The prototype efficiency more than 98% (on single bi-gap) up to 27 fC threshold

Voltage 2650 V

Muon efficiency detectors measured in October 2018 with a muon beam at GIF++ vs gamma background counting rate per readout channel (35x25mm)

The detectors have a very high rate capability going up to 10 MHz/cm²