10th Beam Telescope and Test Beam Workshop

20-25.06.2022, Lecce

http://www.cern.ch/gif-irrad

Martin R. Jaekel, Federico Ravotti
Giuseppe Pezzullo, Blerina Gkotse
EP-DT-DD

The CERN Gamma Irradiation Facility GIF++ during Run 3 and beyond

Beams Department

EP-DT
Detector Technologies

Outline

- Team and facilities in the CERN EP department
- EP Radiation Facilities
  - The need for Radiation Facilities
  - GIF++ and it's infrastructure
  - GIF++ during 2021
- Major improvements during the last years
  - Bunker extension, pre-dump installation, control room extension
- Upcoming challenges to tackle
- Conclusion

EP-DT-DD
Irradiation Facilities

Current EP-DT GIF++ Team

- GIF++ Physics Coordinator
  (Deputy to SPS Physics Coordinator for the GIF++)
- Overall facility responsibility
- Future development of the GIF++ facility

- Tasks leader AIDAinnova & RADNEXT EU-projects
- Facilities Computing (Controls, DAQ, Data Management) M&O / R&D

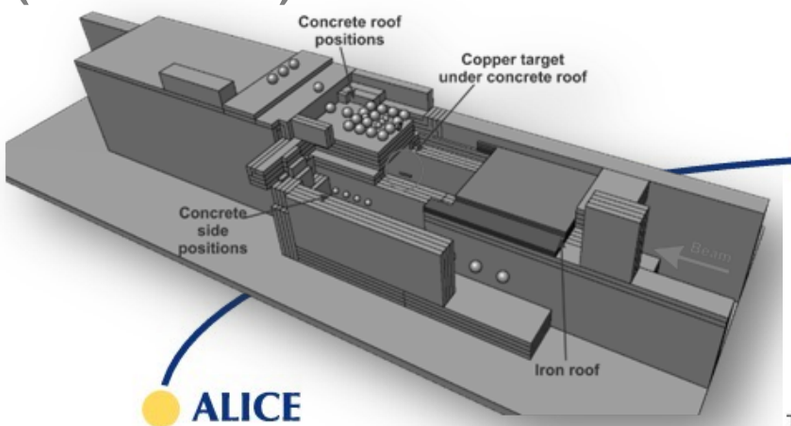
- EP-DT Facilities Team Responsible, IRRAD Facility Coordinator
- Irradiation Facilities EXSO

- GIF++ & IRRAD: users supervisor, contact to EN services
- General user support
- Gas system first level support,
- Deputy EXSO

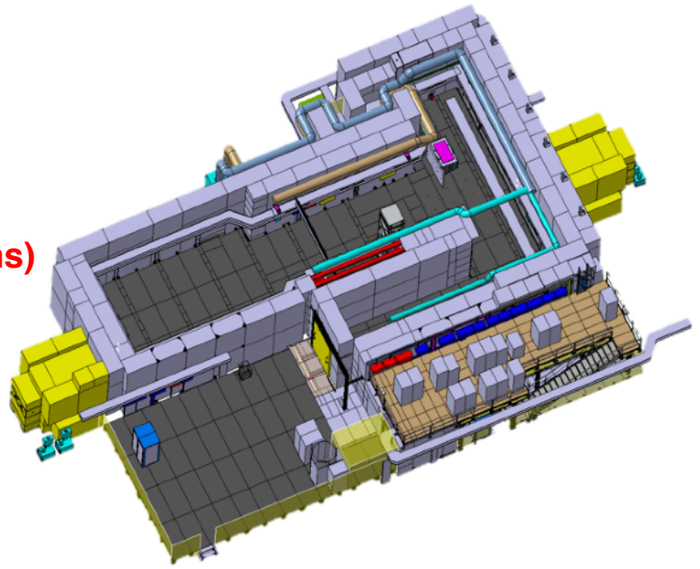
CERN Irradiation Facilities

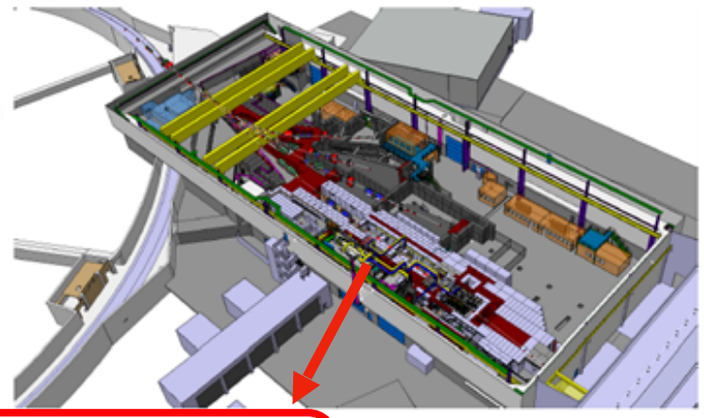
EP-DT operated Irradiation Facilities

CERF (mixed field)



GIF++ (gamma & muons)



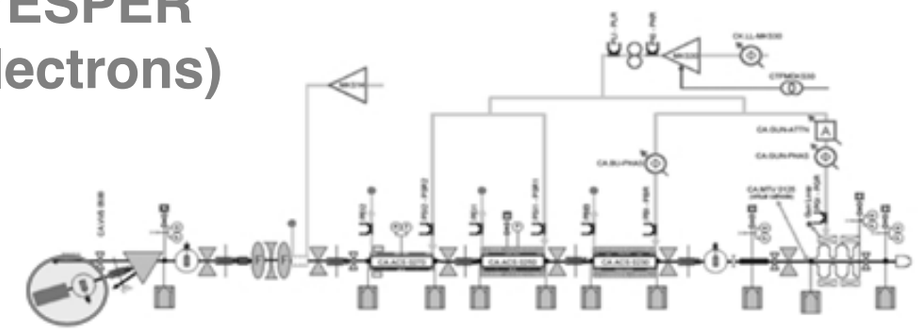


IRRAD (protons)

CHARM (mixed field)

CALLAB (irradiation sources)

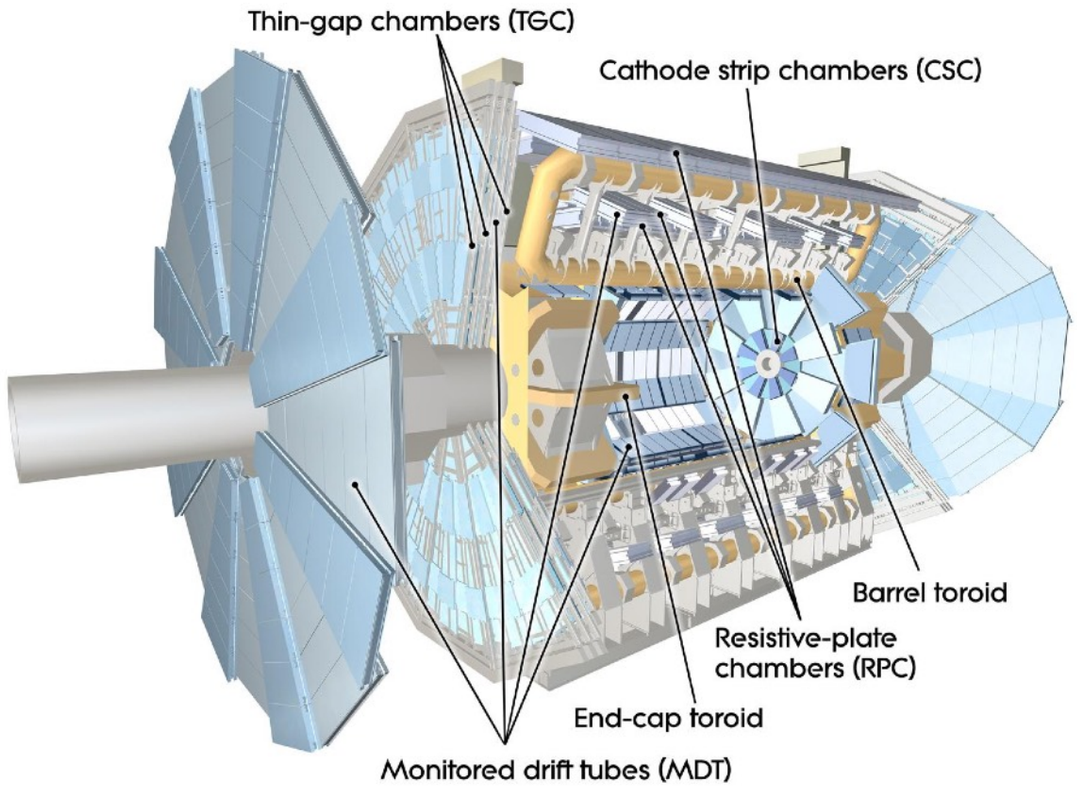
VESPER (electrons)

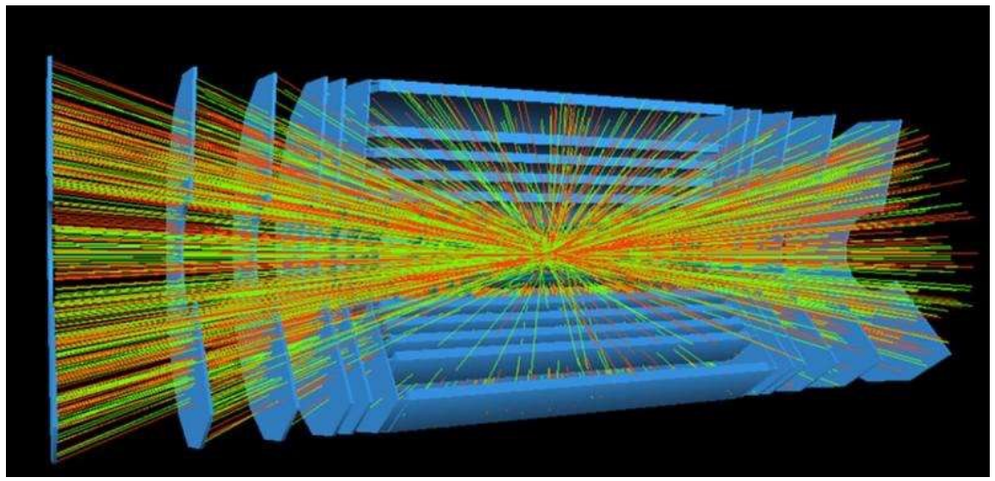


Irradiation Facility: Why ?

- **Radiation damage studies on:**
  - **materials** used around accelerators/experiments
    - structural material, glues, pipes, insulations, thermal materials, …
  - **electronic components**
    - transistors, memories, COTS, ASIC, …
  - **semiconductor** and **calorimetry** devices
    - silicon diodes, detector structures, scintillating crystals …
    - **equipment sitting in the inner/middle layers of HEP experiments**
- **Test and development of prototypes / final assemblies / electronics equipment before installation:**
  - performance **degradation after long exposure**/ageing (TID, NIEL, …)
  - functional **degradation of electronics** (SEU, latch-up, …)
- **Test and calibration of components:**
  - **dosimeters**, radiation monitoring / measurement devices
  - detector performance in presence of high background

One use case :
Muon Chambers for the (HL)-LHC Experiments





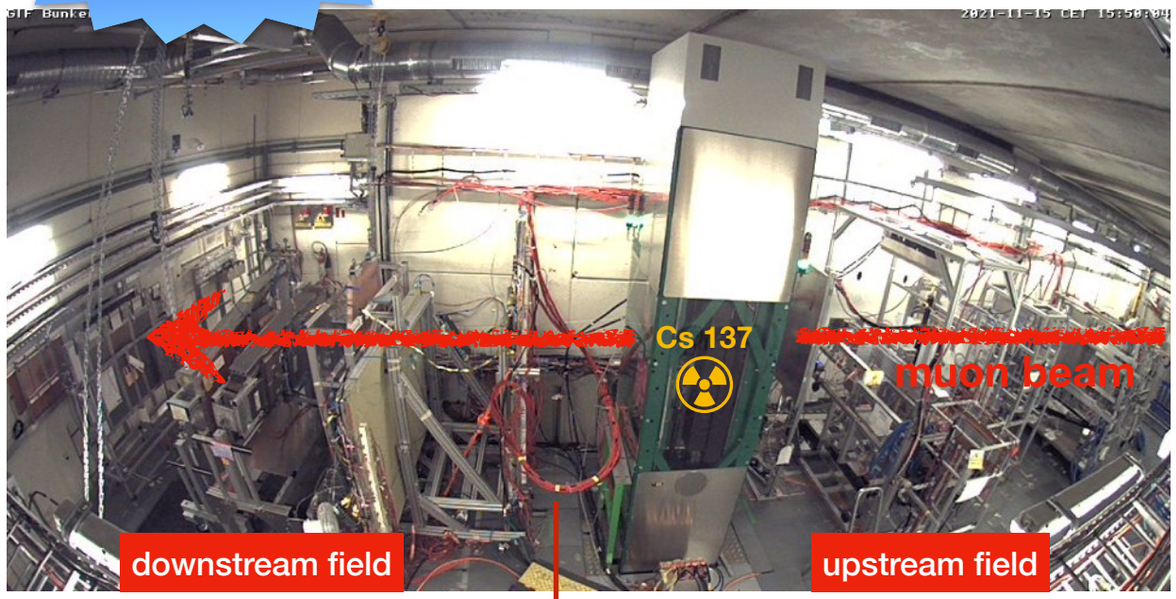
- **Depending on their final position in an LHC experiment, different muon chambers will experience very different working conditions**
  - Need to withstand the expected radiation accumulated for the lifetime of the chamber
    (+ safety factor)
  - Need to operate reliable in identifying muon tracks within large background radiation caused by collisions and activation of nearby material

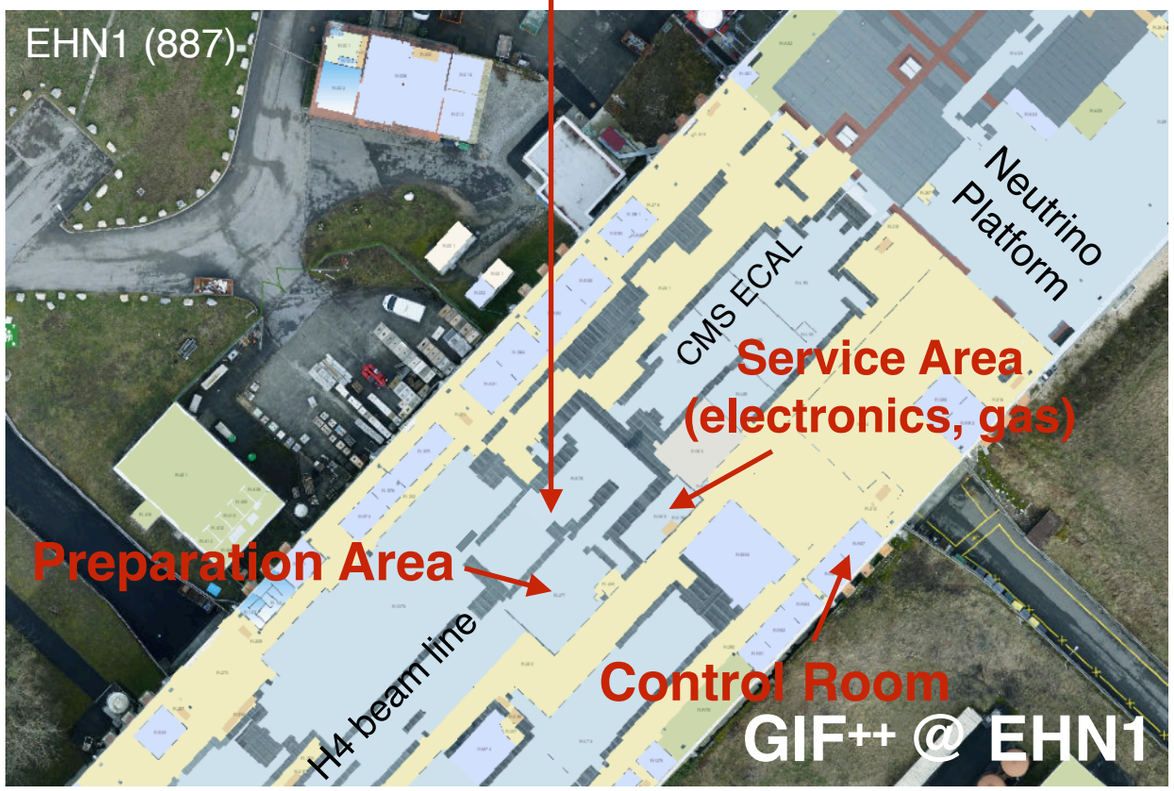
- **A test facility need to address both points**
  - Long term irradiation (often several years) with highest possible field allowed for ageing studies of materials and electronics
  - Adjustable irradiation field that can be tuned to the expected working conditions for each chamber, in combination with Muon tracks from test beam or cosmic.

GIF++ @ EHN1

Irradiator operation throughout the whole year

Irradiation Bunker





https://gif-irrad.web.cern.ch/

- Joint facility (EP & BE) operated by EP-DT-DD
- Unique place, combining a high energy muon beam with a 14 TBq* ^{137}Cs gamma source
- Designed for testing real size muon gas detectors, of up to several m², as well as a broad range of smaller prototype detectors and electronic / optical components
- 160 m² irradiation bunker with 2 independent irradiation zones (30 m² & 75 m²), separated attenuation systems
- All year operation from Cs-Irradiator
- Muon beam (H4) for 7-9 weeks per year (on average)
- Central Control System, recording all relevant parameters and provides interlocks
- Wide range of available gases (+ custom gases) in irradiation bunker & preparation zone
- around 15-20 different large setups scheduled during the year (up to 14 participating in muon beam time in parallel)

*) as of 2014

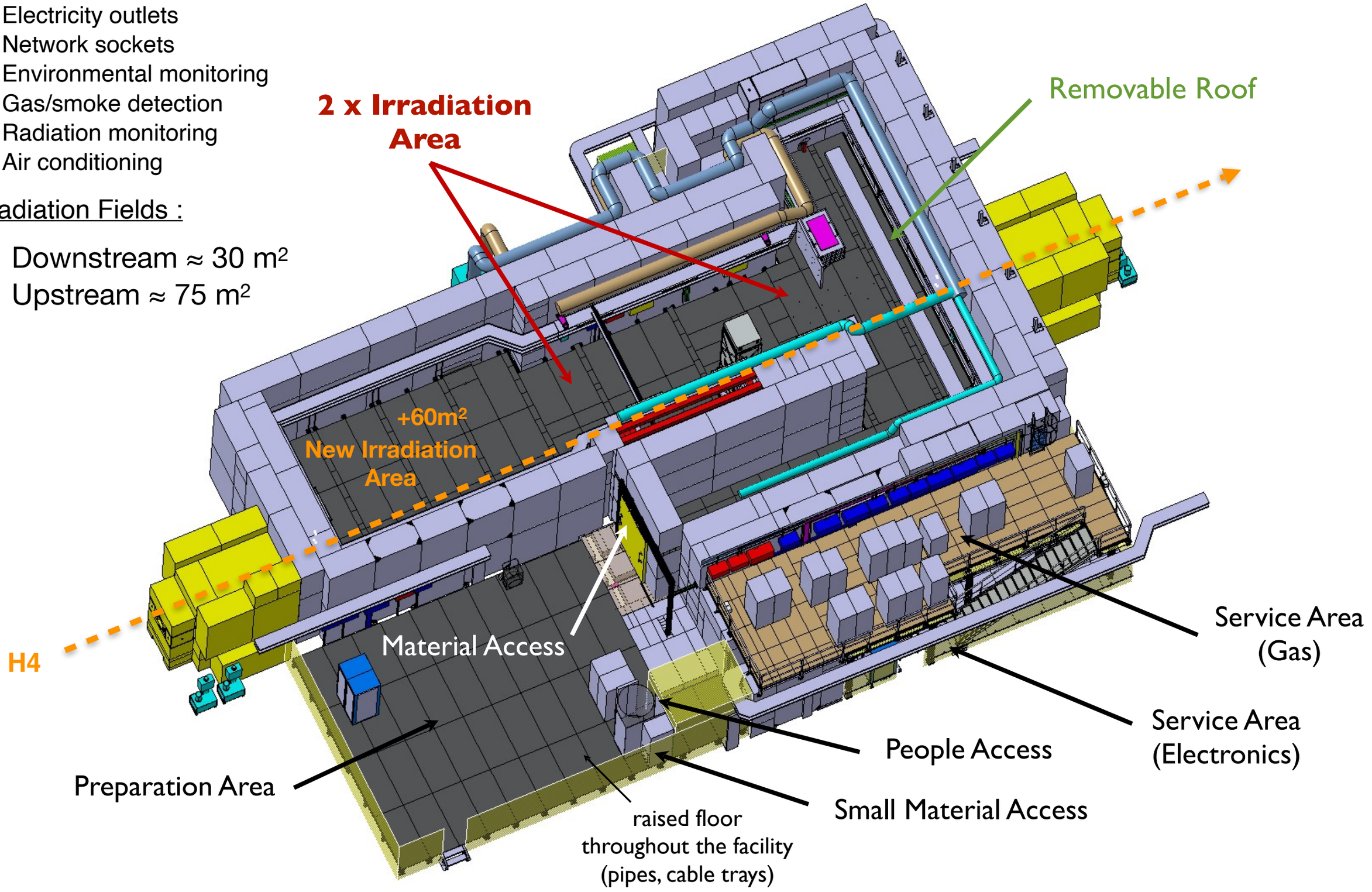
GIF++ Facility Layout

Bunker area contains :

- Gas panels
- Electricity outlets
- Network sockets
- Environmental monitoring
- Gas/smoke detection
- Radiation monitoring
- Air conditioning

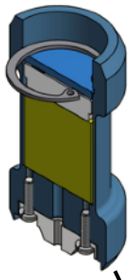
Irradiation Fields :

- Downstream ≈ 30 m²
- Upstream ≈ 75 m²

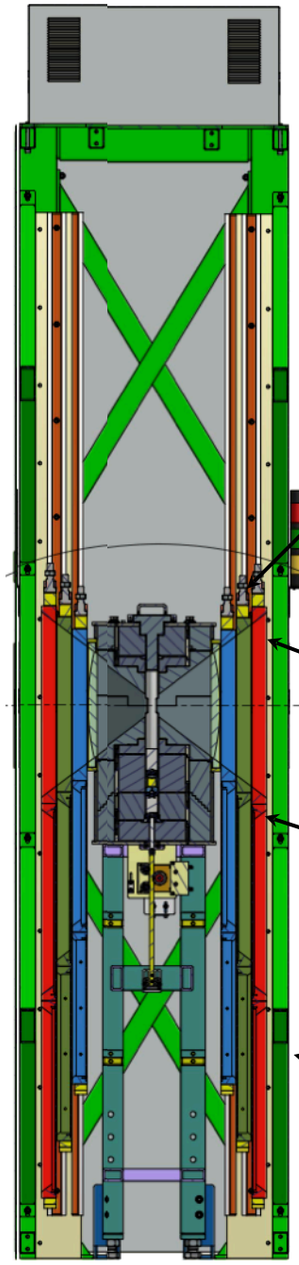


GIF++ Irradiator & Attenuation Filters

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)



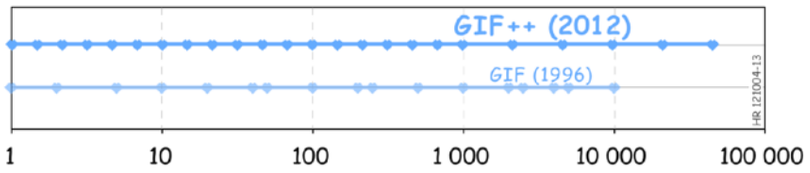
Angular correction filter provides uniform photon distribution for large area detectors

Filter System :

Absorption factor		
0	0	0
10	1.47	2.15
100	100	4.64

24 possible attenuation factors :

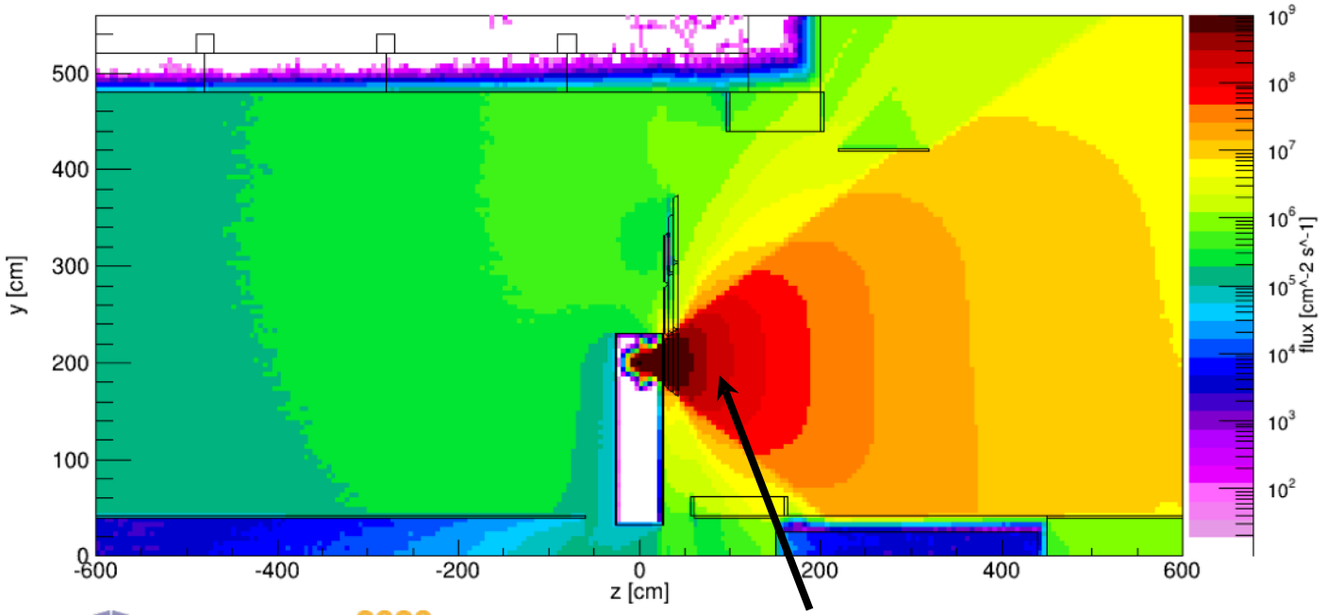
1	21.54	464.2
1.47	31.62	681.3
2.15	46.42	1000
3.16	68.12	2154
4.64	100	4642
6.81	146.8	10000
10	215.4	21544
14.68	316.2	46415



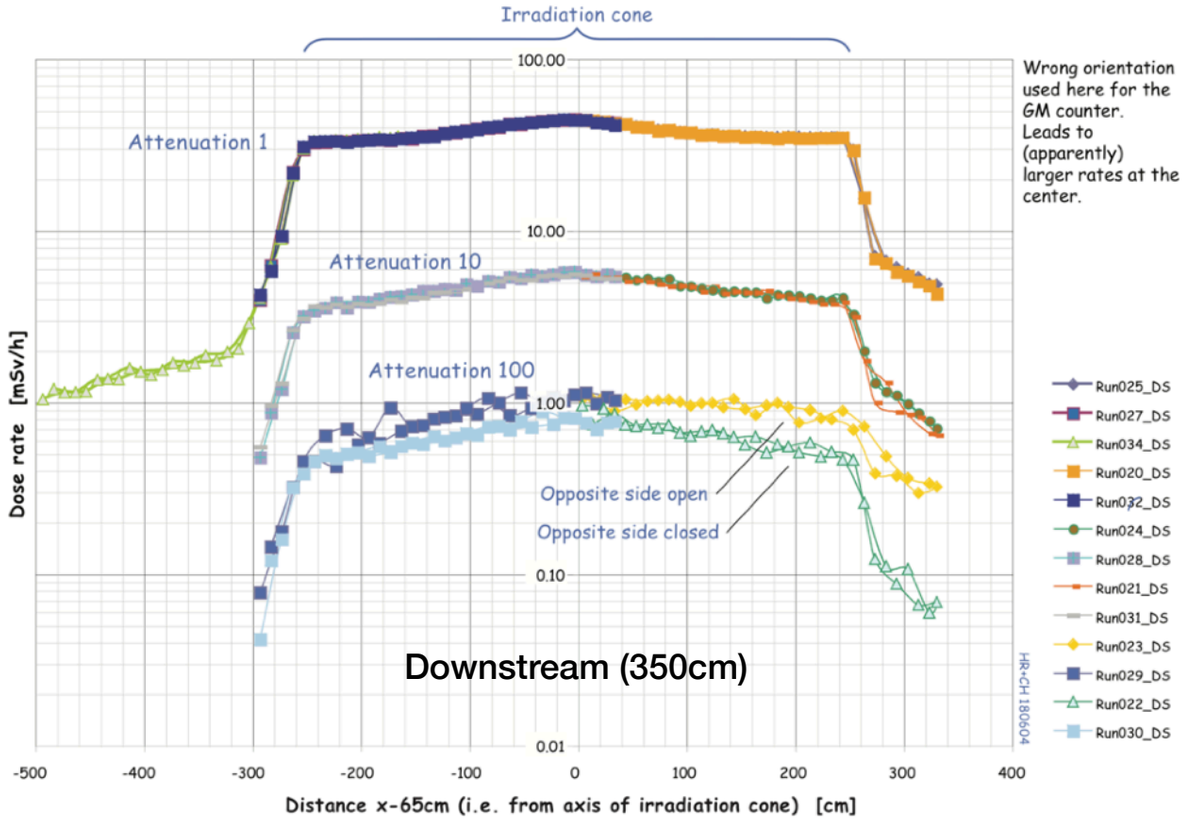
(calculated values for un-scattered gammas)

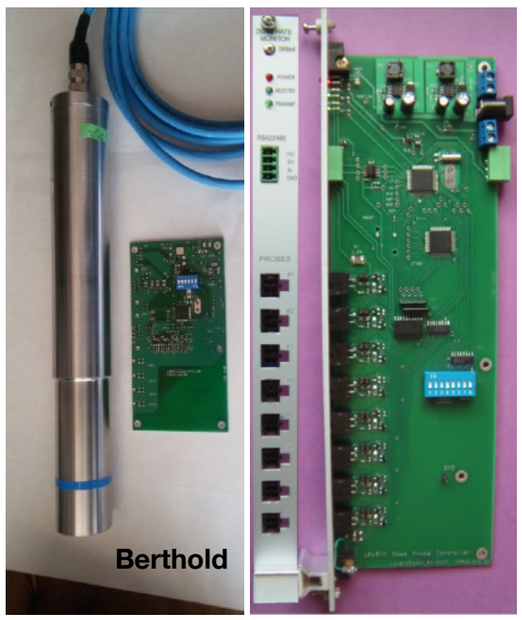
GIF++ Radiation Field & Monitoring

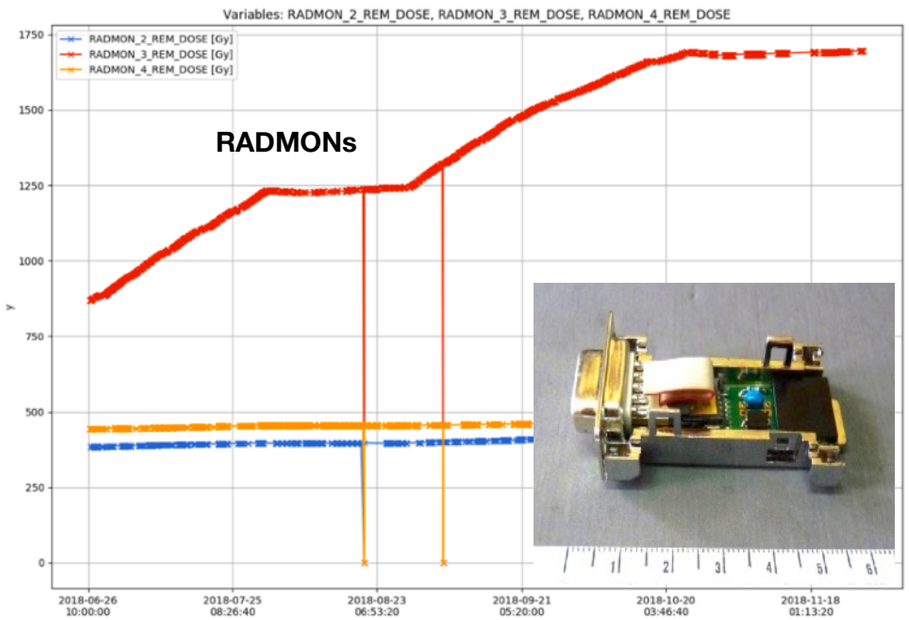
Total flux, one field, without filters



≈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

Central Gas System

EP-DT-FS
R.Guida, B. Mandelli et al

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)

AIDA 2020 **Partial funding of the gas system equipment and two CERN technical students**

Mixture distribution

Monitoring of pressure, O2/H2O, temperature, atmospheric pressure

Additional software controlled pressure regulation for very low flow regimes

Gas mixing unit

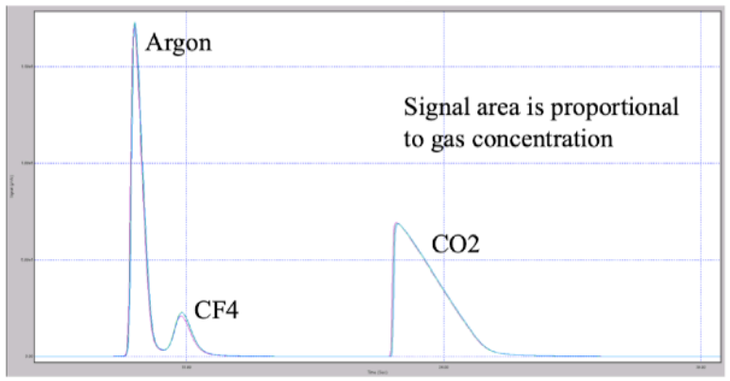
Gas recirculation module

Sampling manifold

PC for GC software controls

GC analyser (3 modules for large spectra gas separation)

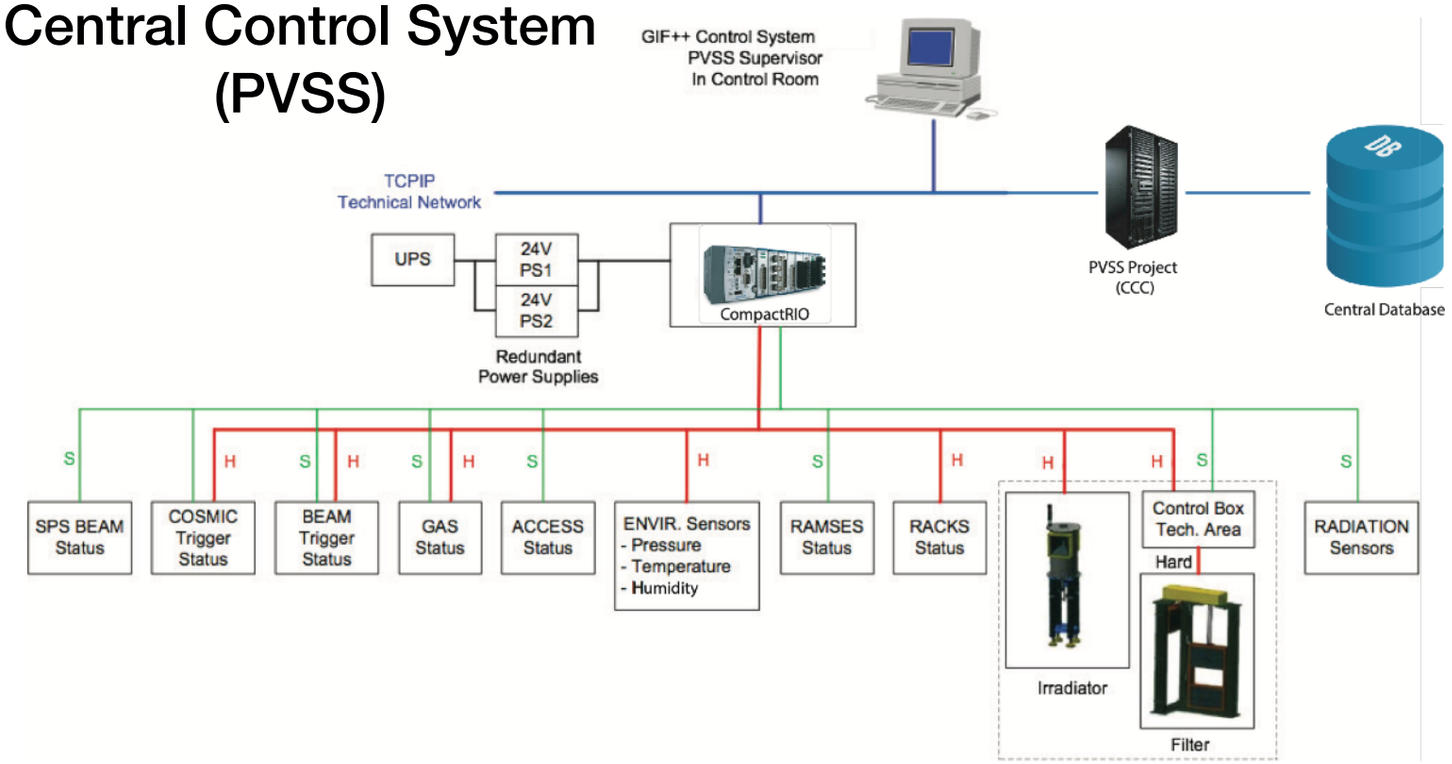
Gas chromatogram



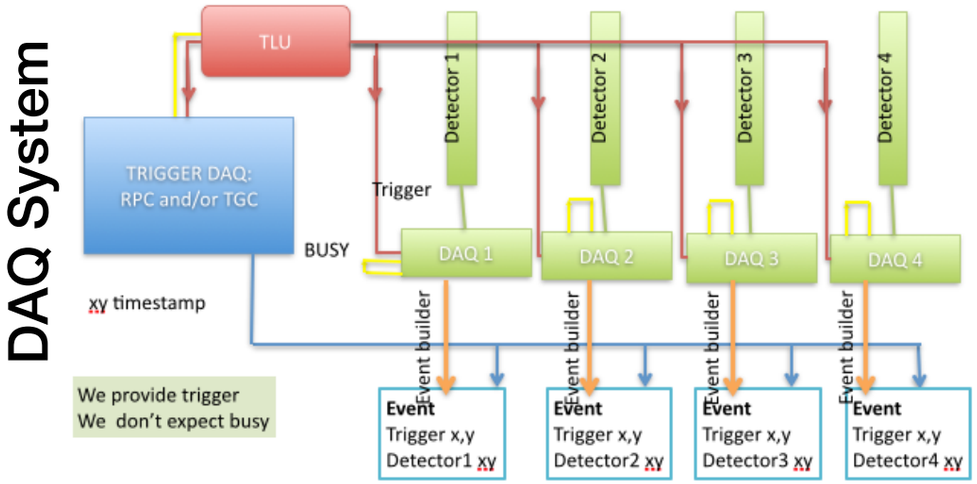
Gas chromatographic analysis : allows monitoring gas mixture composition and presence of impurities on return from detectors under test

GIF++ Available Infrastructure

Central Control System (PVSS)

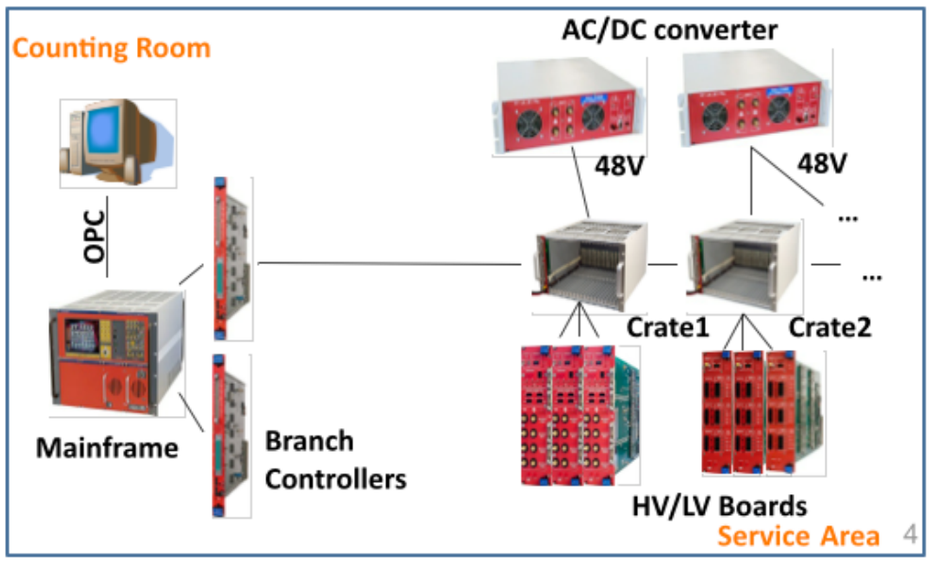


DAQ System



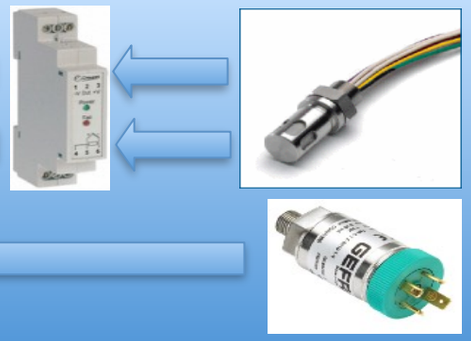
Beam Trigger
(2 pairs of scintillators)

DCS System



Gas and Environmental sensors

CAEN
ADC 3801

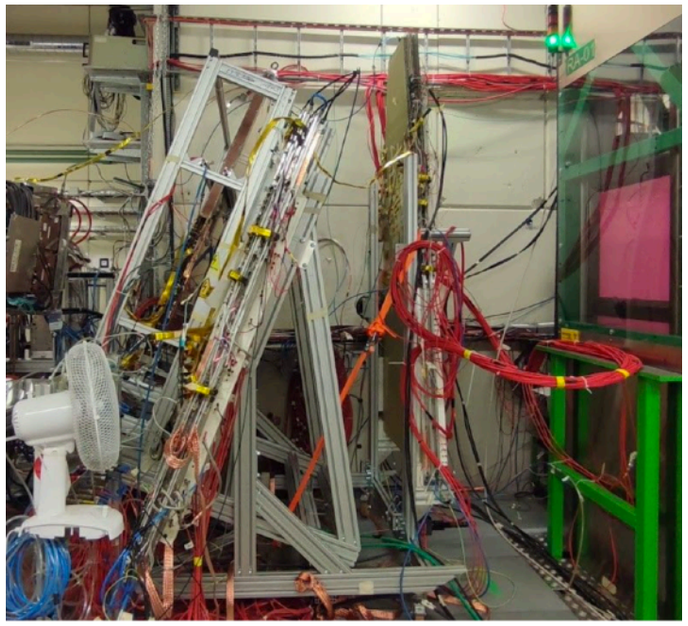


T, H sensor
PCMini 70 Michell

p sensor
TSA Gefran

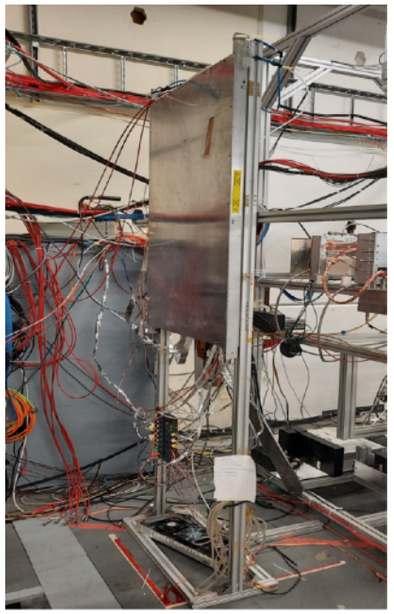
Very successful beam time 2021

14 setups participating in parallel, including ATLAS RPC, CMS CSC, ATLAS NSW MM & sTGC, ProTov, ATLAS sMDT, CMS RPC, ECOgas, EP-DT, CMS iRPC, CMS DT, RE21/CBM

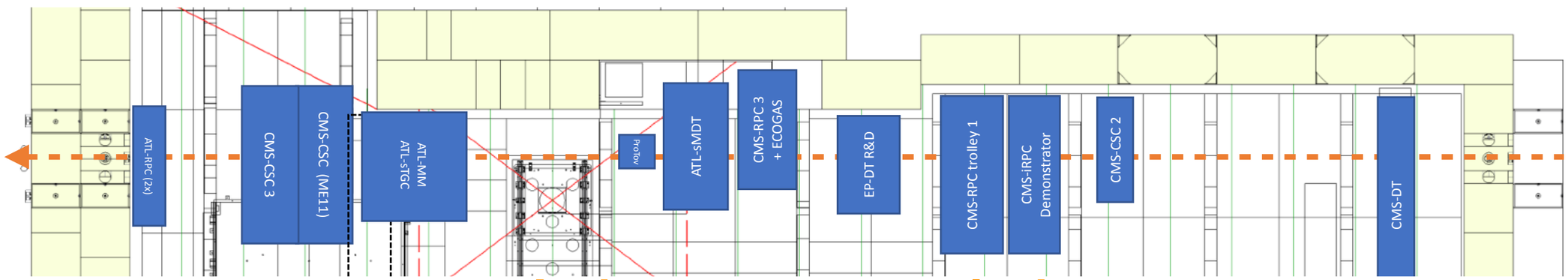


First combined data taking of ATLAS NSW MM and sTGC with final electronics und realistic background radiation

Performance measurement for ATLAS RPC BIS78 chamber inc. readout system, in presence of HL-LHC radiation background



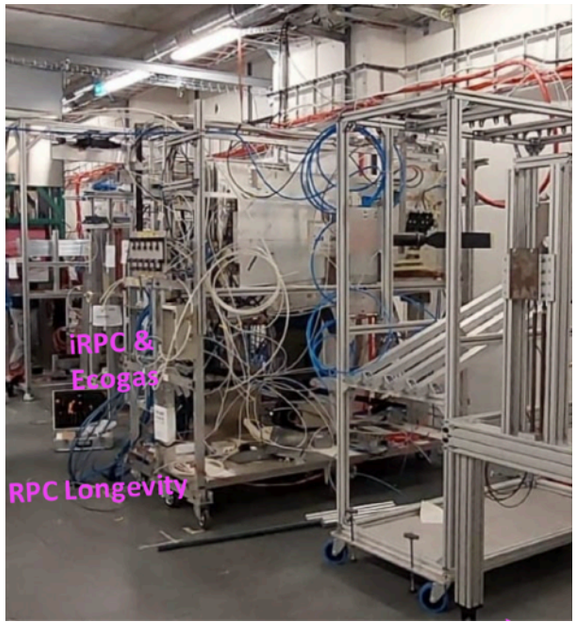
CBM@Fair - checking performance of GEM & RPC chambers under harsh CBM radiation background



And many more results !

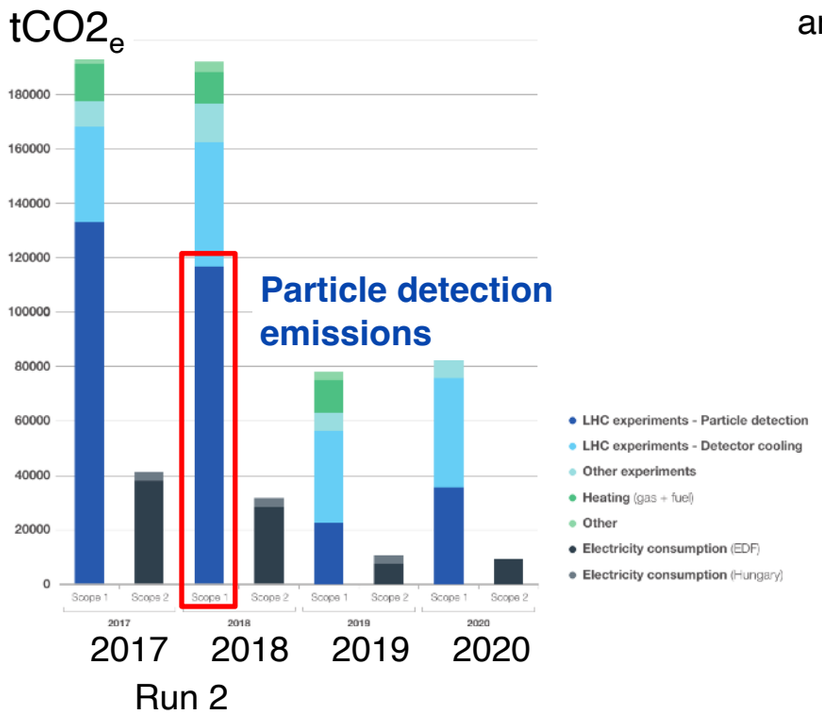
Please see the Annual User Meeting for details https://indico.cern.ch/e/GIF-AUM-2021

ECOgas



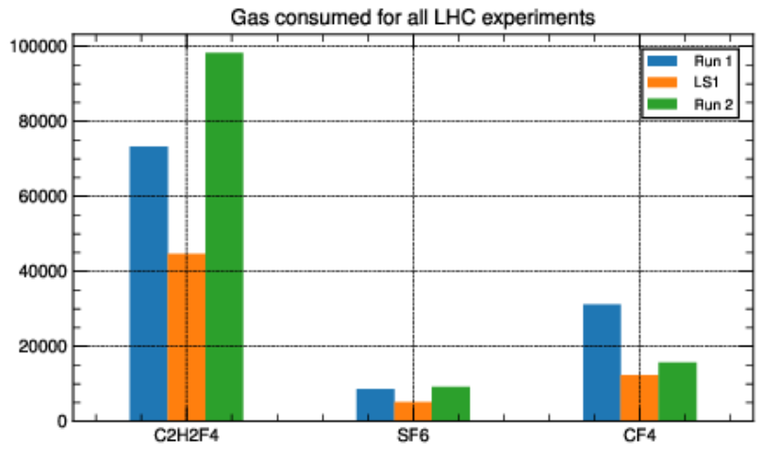
ECOgas - search for environmentally friendly gas mixture with lower Global Warming Potential (GWP) than standard RPC mixture

https://hse.cern/environment-report-2019-2020



CERN emissions during 1 year of Run 2 ~ **220 000 tCO2e**
Half of them from particle detectors → mostly due to leaks and operation

- **C2H2F4/R-134a** biggest contributor → leaks from RPC detector during operation
- **CF4** → due to operation of CSC and RICH systems
- **SF6** → Related to RPCs as R-134a



- Test of alternative gas mixtures with reduced GWP
- Gas recirculation, better flow and pressure regulations
- Monitoring, detection of abnormalities
- Offline analysis, deeper understanding of dynamics
- Some potential candidate mixtures - not a trivial search !

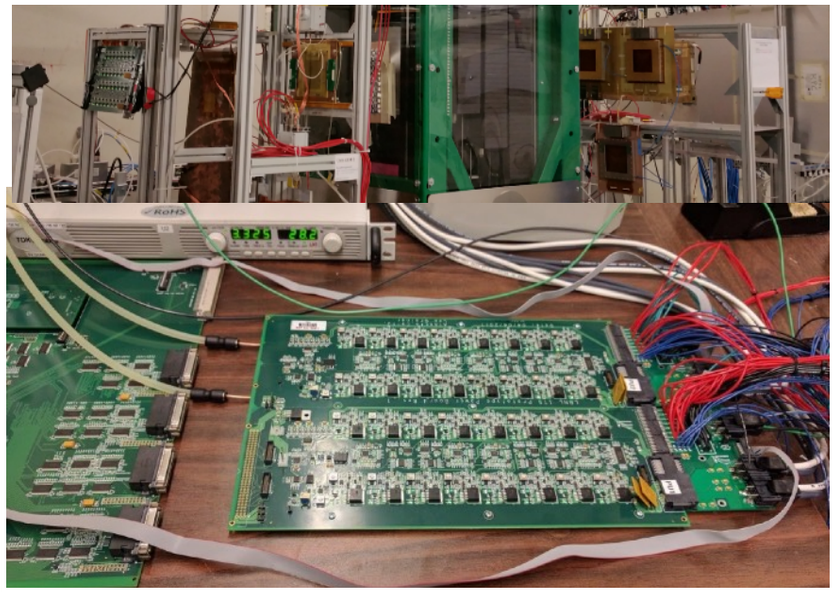
Studies to reduce greenhouse gas emissions from detectors at the LHC / Gianluca Rigoletti (EP-DT-FS)
EP-DT Seminar : https://indico.cern.ch/event/1155238/

Wide Range of Smaller Test Campaigns during last Years

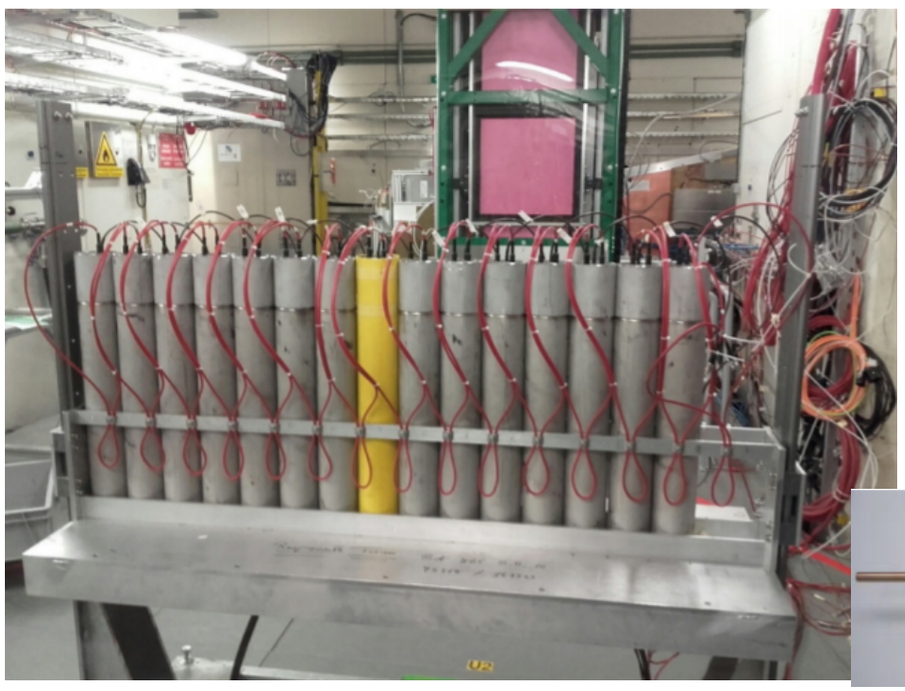
EN-CV : tightness of cooled cables manifolds

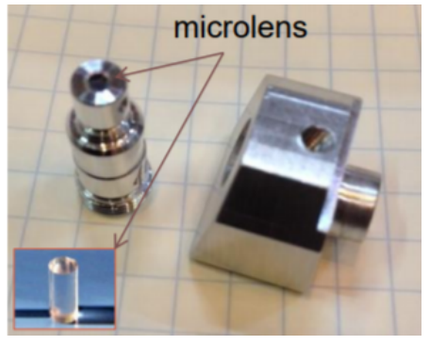
Filter box - collaboration btw ESA and CERN

ALICE ITS Upgrade Power Board



BLM Ionization Chamber





***μ*lens and optical fibres for the TOP PID detector of Belle II experiment**

Plastic scintillator rods with Gafchromic™ films - CMS UMD collaboration

GIF++
Recent Improvements

GIF++ Improvements over the last Years

Bunker Extension along Beam Line (2019)

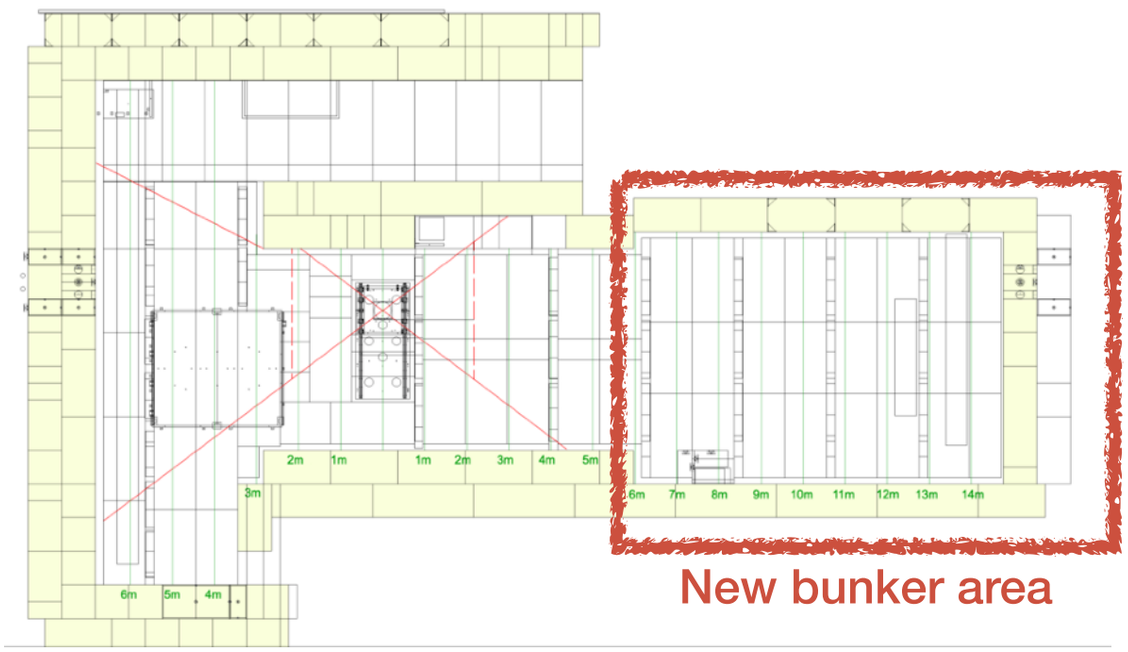

Bunker extension


Enlarged bunker

- Increased the irradiation area by 60 m²
- Better distribution of setups between fields
- Easier access for large setups
- Significant increase of space along beam path
- Dedicated low irradiation field area upstream

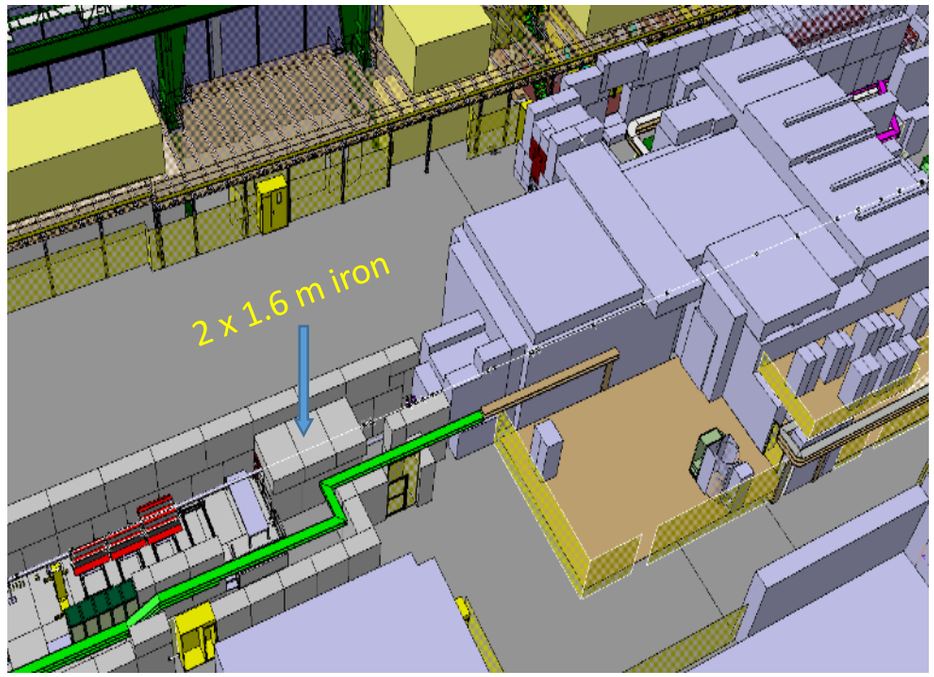
  (reduced the need to use attenuation filters)
- Significant increase of space along beam path (+10m)

  (allows more setups to participate in dedicated muon beam runs)



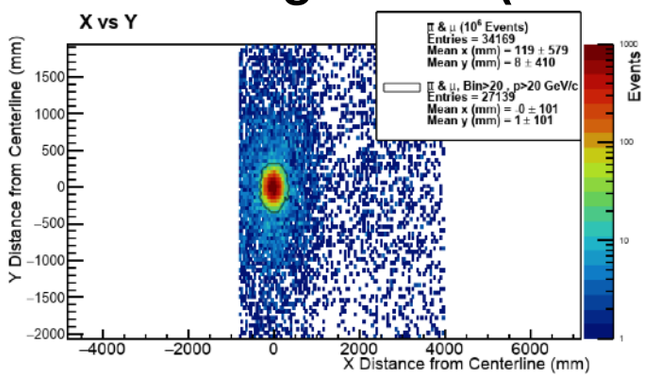
GIF++ Improvements over the last Years

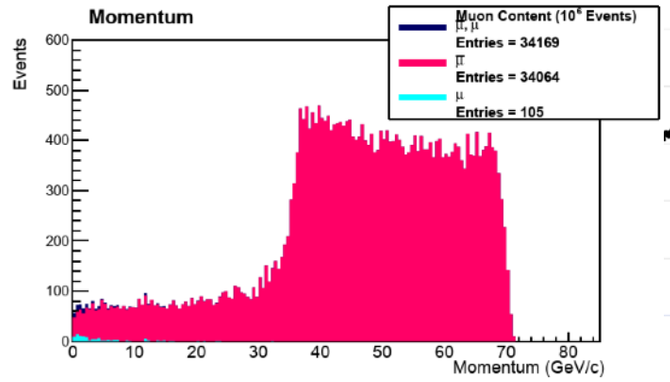
Installation & Commissioning of the GIF++ Pre-Dump (2021)

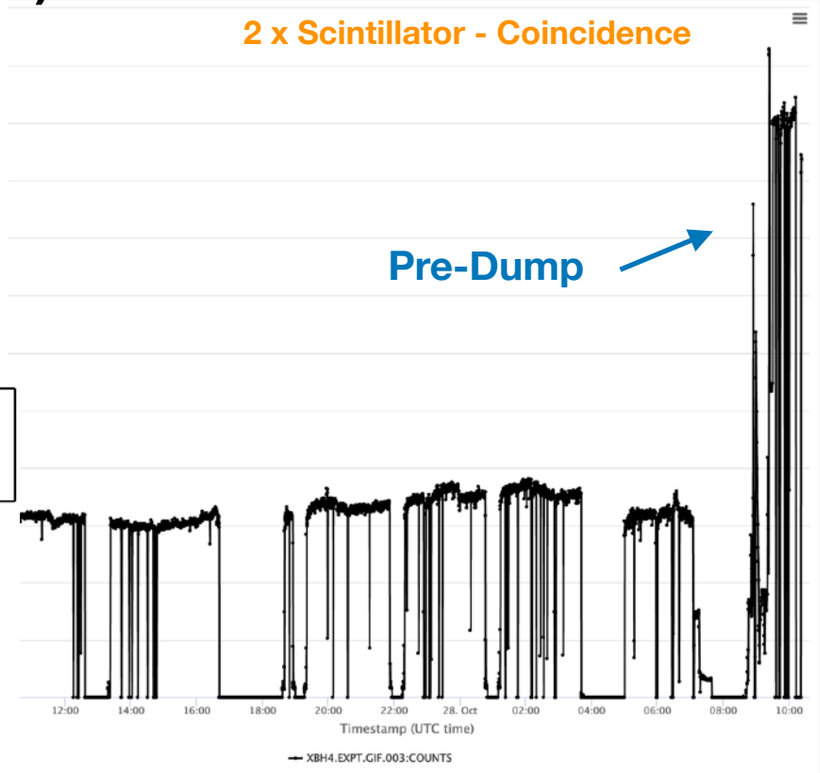


- Two new beam dumps in front of GIF++, which can be **manually** moved out of the beam for hadrons / electrons @ PPE164
- Better focused beam, as muon are produced directly in front of the irradiation bunker (previously ≈ 100 m upstream)
- Higher intensity in some configurations, especially when running in parallel with upstream setups
- Possibility to run in parasitic mode with upstream pion run, while maintaining a clean muon beam due to the extra shielding

New configuration (80 GeV)







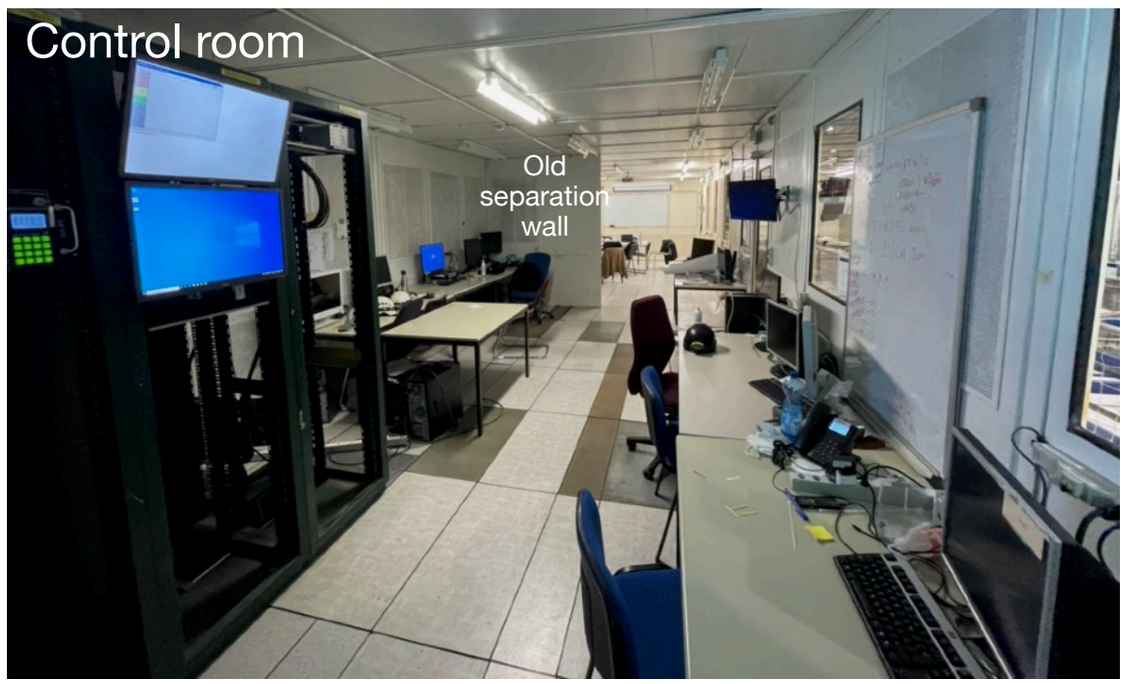
GIF++ Improvements over the last Years

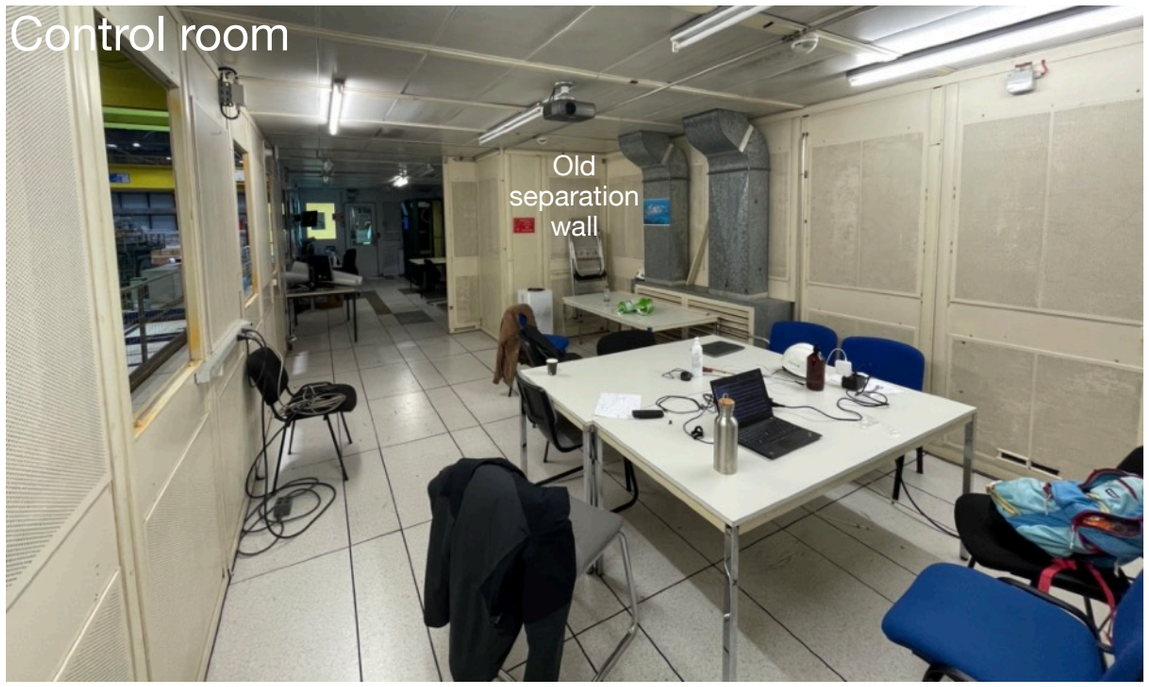
Extension of the GIF++ Control Room (2022)

Restrictions of CoVid-19 pandemic in control room occupancy were "challenging".
Satellite control rooms needed to be used.

But even outside of a pandemic, the GIF++ control room could no longer host the increased user base (following the 2019 bunker extension) during beam time with ≥ 14 setups x 1-2 people.

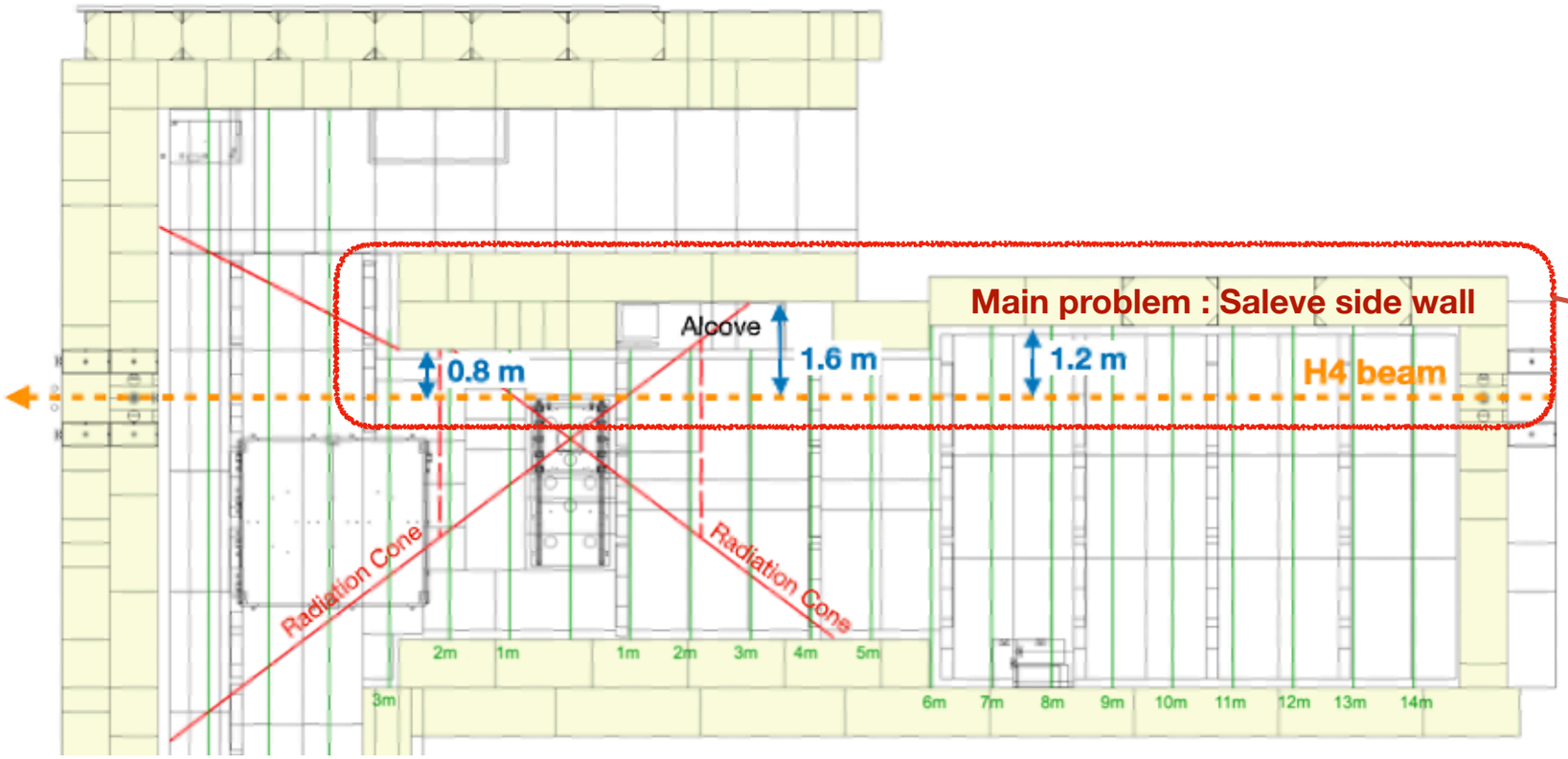
We needed to find a solution ! With the help of BE-EA we could add a sparsely used meeting room by removing the separation wall. Significant increase the footprint of the GIF++ control room, allowing again the operation from a single control room.



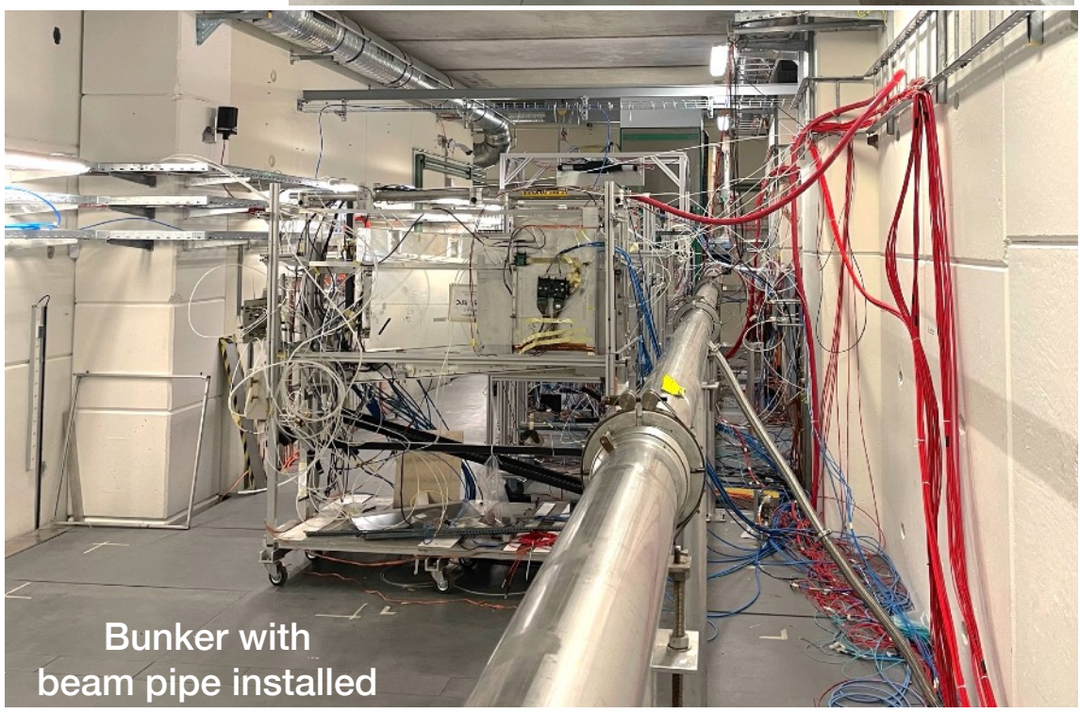


Upcoming Challenges

Upcoming Challenges



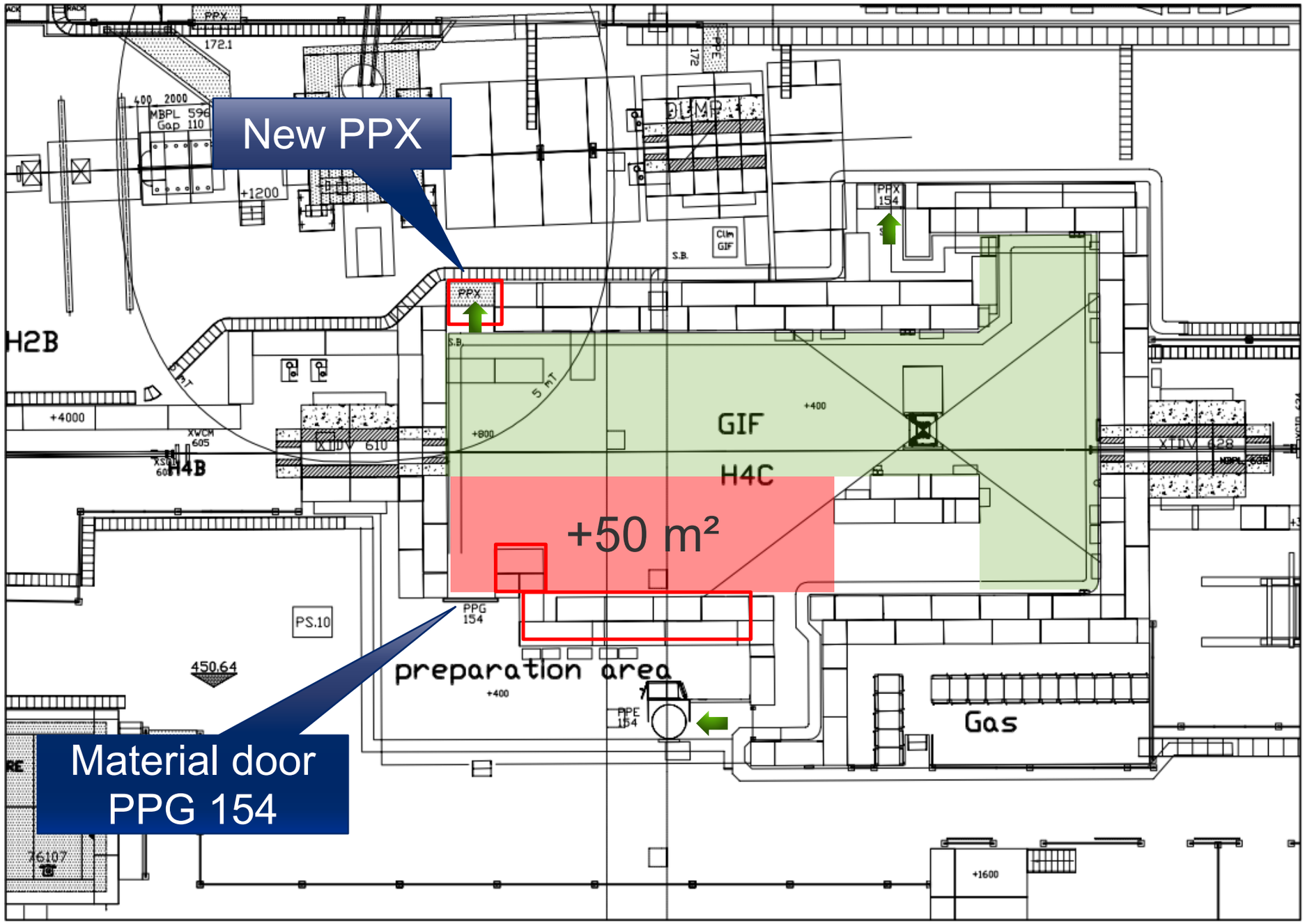
- The increased number of setups along the beam path leads to significant - and **very uneven** - **shadowing** for some experiments
- Not possible to spread the setups more evenly, especially during beam time when they all need to be aligned along beam path
- Not possible to place all parts of **big chambers** inside the beam path due to proximity of Saleve side wall to beam path



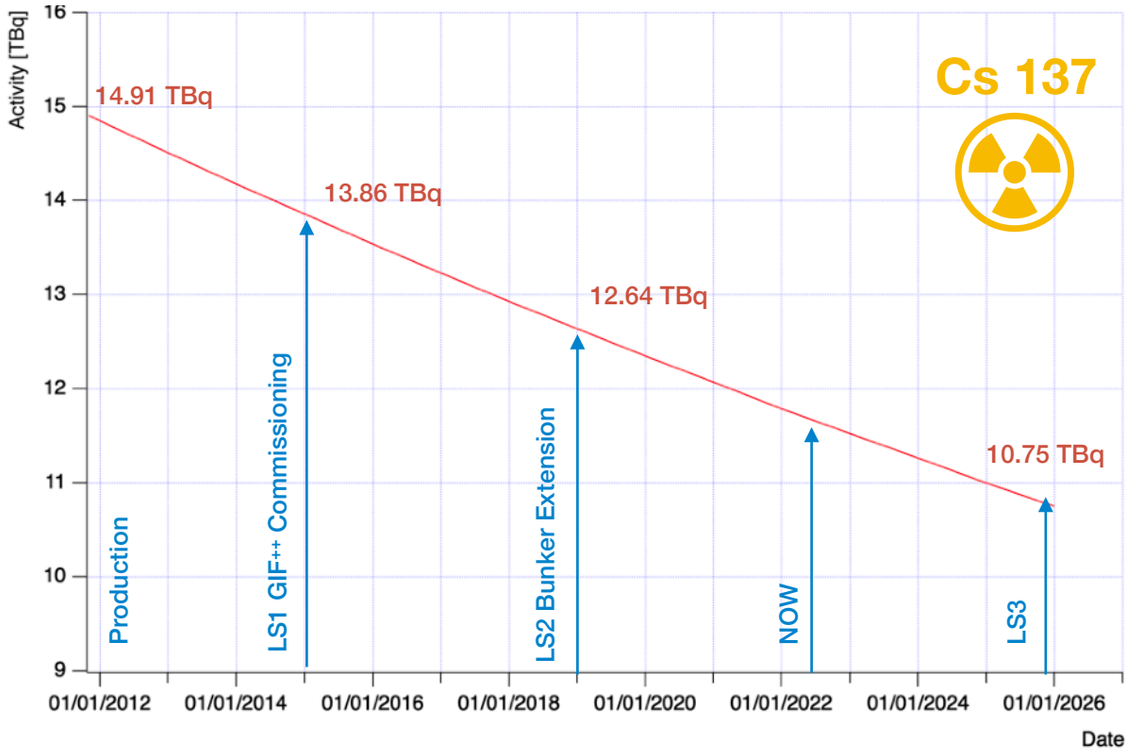
Aiming for LS3

Phase 2 Extension - Proposal

Conversion form Preparation Area to Irradiation Area



Upcoming Challenges



With a half life of ≈ 30 y, the effects of the radioactive decay are starting to show !

From 14 TBq during commissioning, we are now < 12 TBq, and < 11 TBq for the next LS

Already now, several setups compete for the space closest to the Irradiator (=highest gamma field)

- Difficult to plan the replacement of the current Cs source
  - Very few producer of high intensity sources, with biggest manufacturer currently not available
- Current dimensions of Irradiator capsule can limit the reachable activity
  - Housing and bunker designed for ≤ 100 TB, but capsule dimensions could limit us to ≈ 20 TBq
- On site loading of new source appears to be technical possible
  - Permit for this operation uncertain.
- A new Irradiator with increased dimension could be envisaged.
  Opens the possibility to add multiple sources in one Irradiator via loading carousel
  - Significant higher costs. Might need a redesign of the attenuator system.

Irradiation Requests

- For irradiation request using muon beam, we follow the SPS schedule (each ≈ November for the next year)
  - Irradiation requests should be sent to the **GIF-Physics Coordinator**
  - We have some flexibility inside the bunker beam path, but especially during the second half of the year we then to be very full

- For gamma irradiation only, you can contact us throughout the year.
  - Scheduling (e.g. filter settings, floor plan…) is normally down during the weekly meetings
  - Access is handled by IMPACT

- If arriving, please allow some time for the “administrative” part
  - Safety courses needed
  - Safety equipment (helmet, shoes,…)
  - Dosimeter (personally & operational)

Conclusion

GIF++ is a unique facility, not easy to replace

**Essential for new detector development,
including the search for eco friendly gas mixtures**

Essential for urgent large scale testing of chambers (e.g. ALICE TPC)
(shipping of large chambers is very problematic)
**and important ageing test when using new gas mixtures
(e.g. ATLAS NSW)**

Very successful first beam year in Run 3, despite all challenges

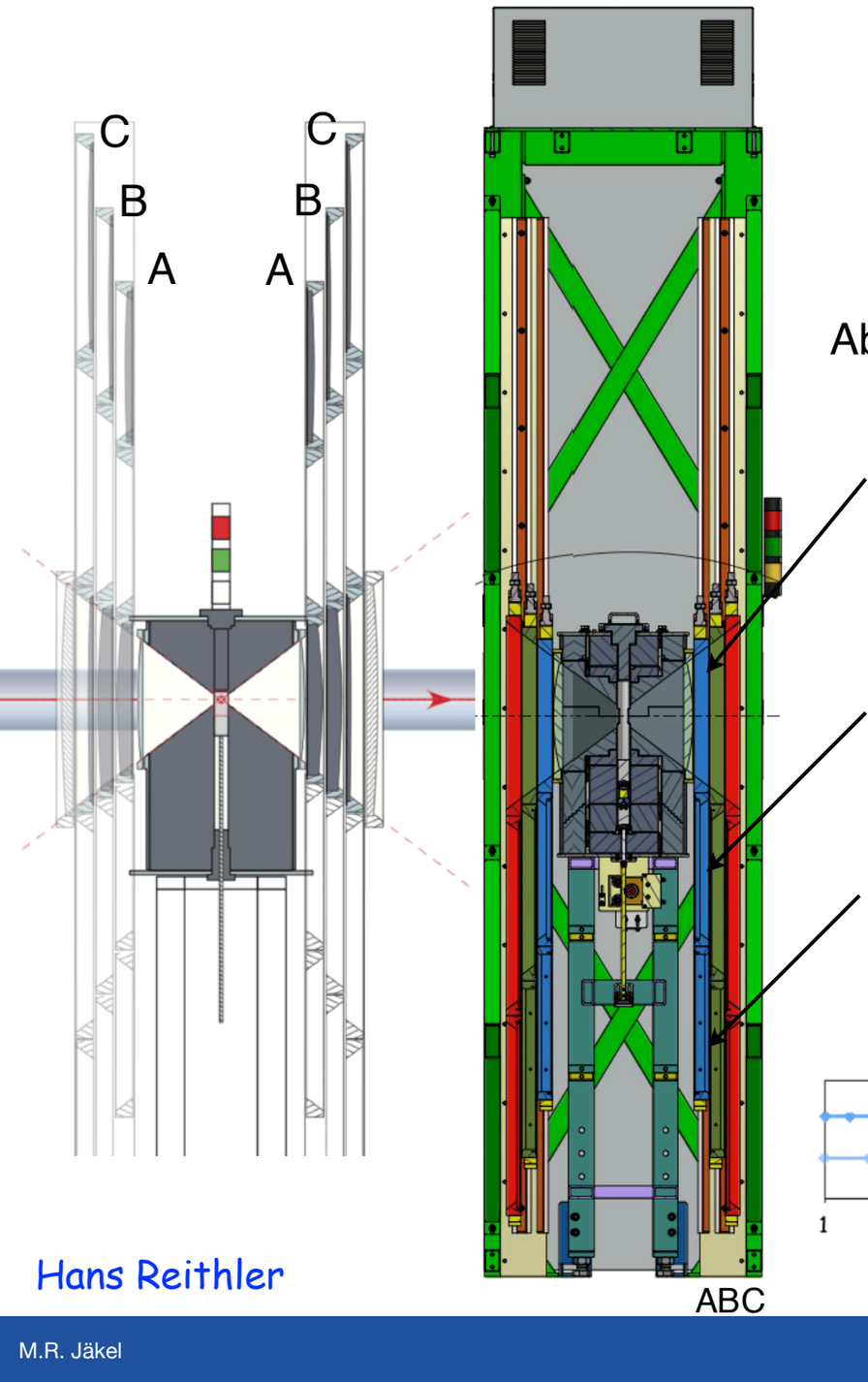
Originally designed for the development and commissioning of the HL-LHC muon chambers, the proposal to operate the GIF++ beyond LS3 (2026) is under finalisation

**Strong support from the community needed
for proposal (and its costs) to be approved**

Backup Slides

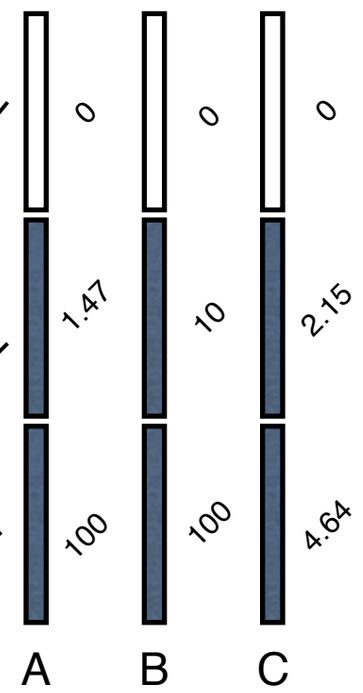
GIF++ Attenuation Filters

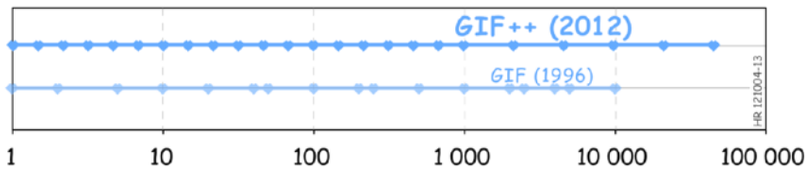
Two identical attenuation systems, each 6 absorption filters
- a total of 14 custom shaped filters (incl. ang. Correction)



Filter System :

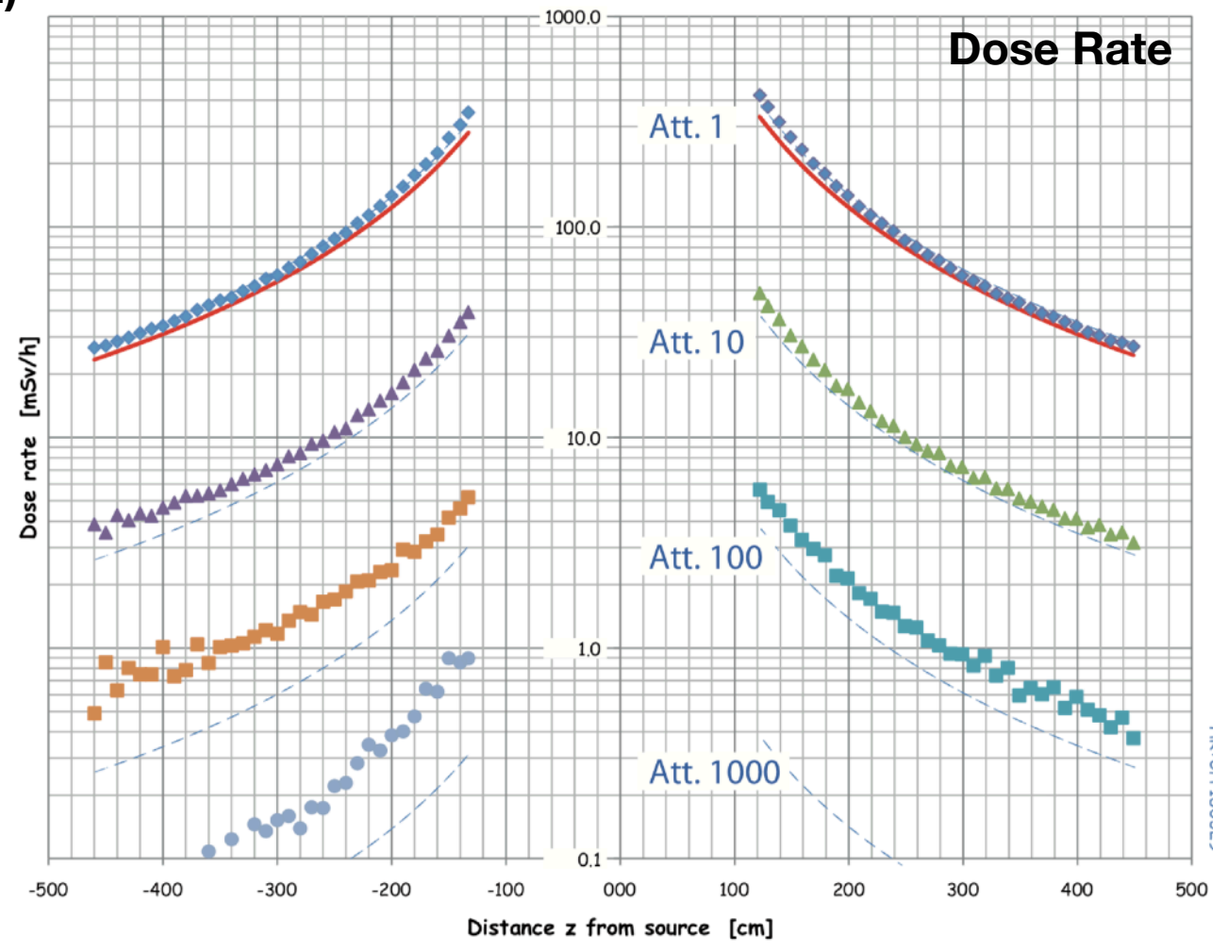
Absorption factor :





(calculated values for un-scattered gammas)

Attenuation 1/10/100/1000; 46k at opposite side



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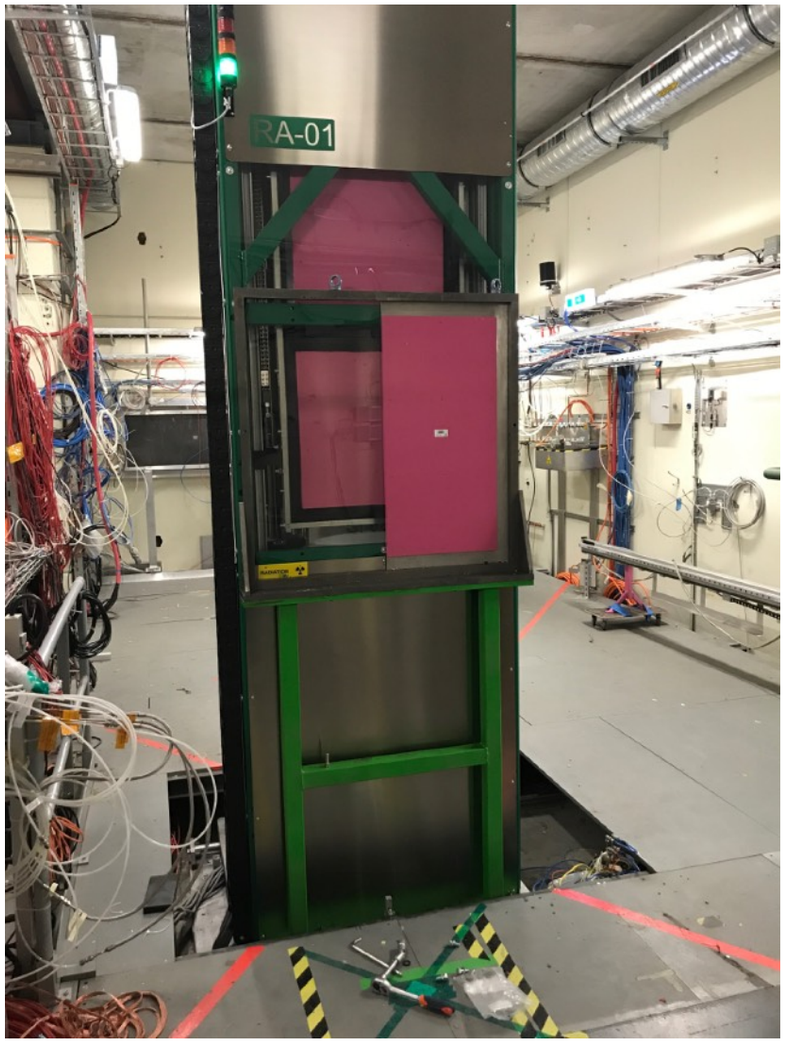
24 possible attenuation factors :

Photon current

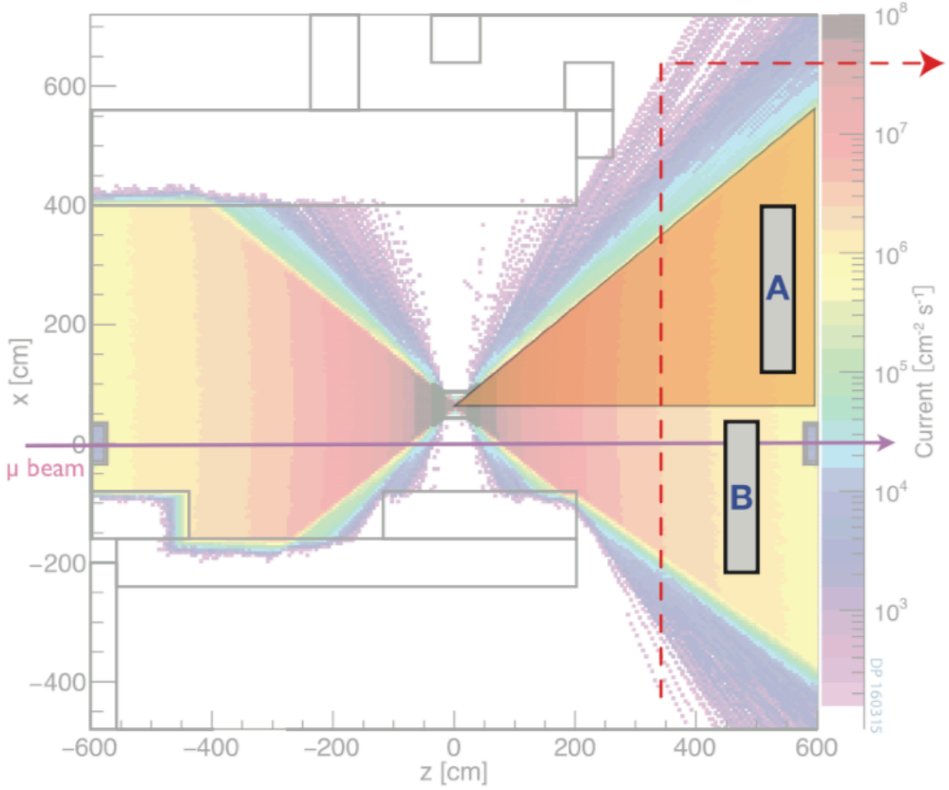
1	10	100	1000
1.47	14.68	146.8	2154
2.15	21.54	215.4	4642
3.16	31.62	316.2	10000
4.64	46.42	464.2	21544
6.81	68.12	681.3	46415

Hans Reithler

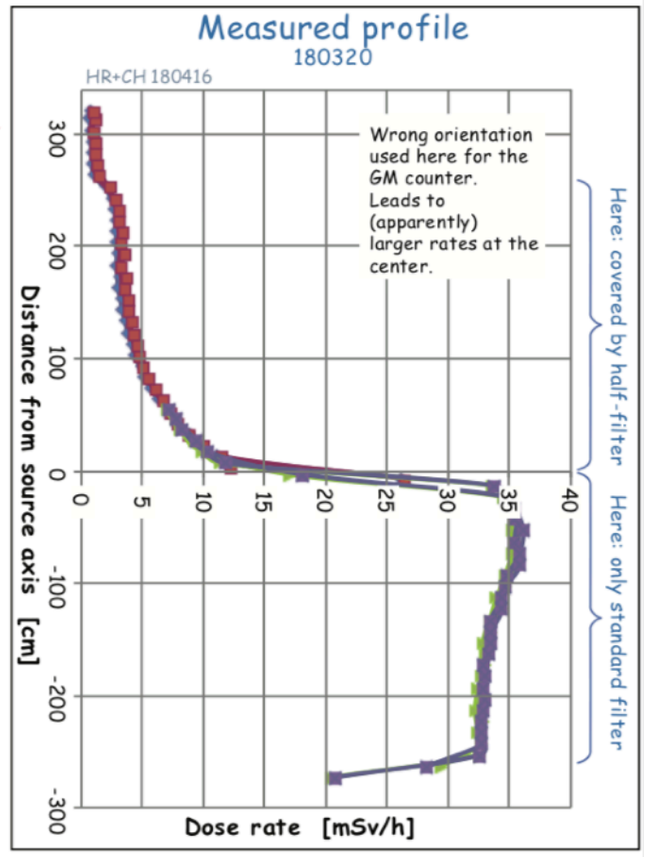
Special Case - Additional Half Filter



A filter covering PART of the solid angle can provide a smaller intensity for detector "A" without reducing the intensity for detector "B".



Note linear dose rate scale, on this figure.



To permit simultaneous operation with somewhat different attenuation, at the same downstream side, a HALF-FILTER with nominal att. 15 was proposed / constructed. Currently not in use.

Hans Reithler

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