An EP-DT Irradiation Facility beyond LS2

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

EP-DT Seminar 19.Nov 2019

M.R. Jäkel on behalf of EP-DT Irradiation Team

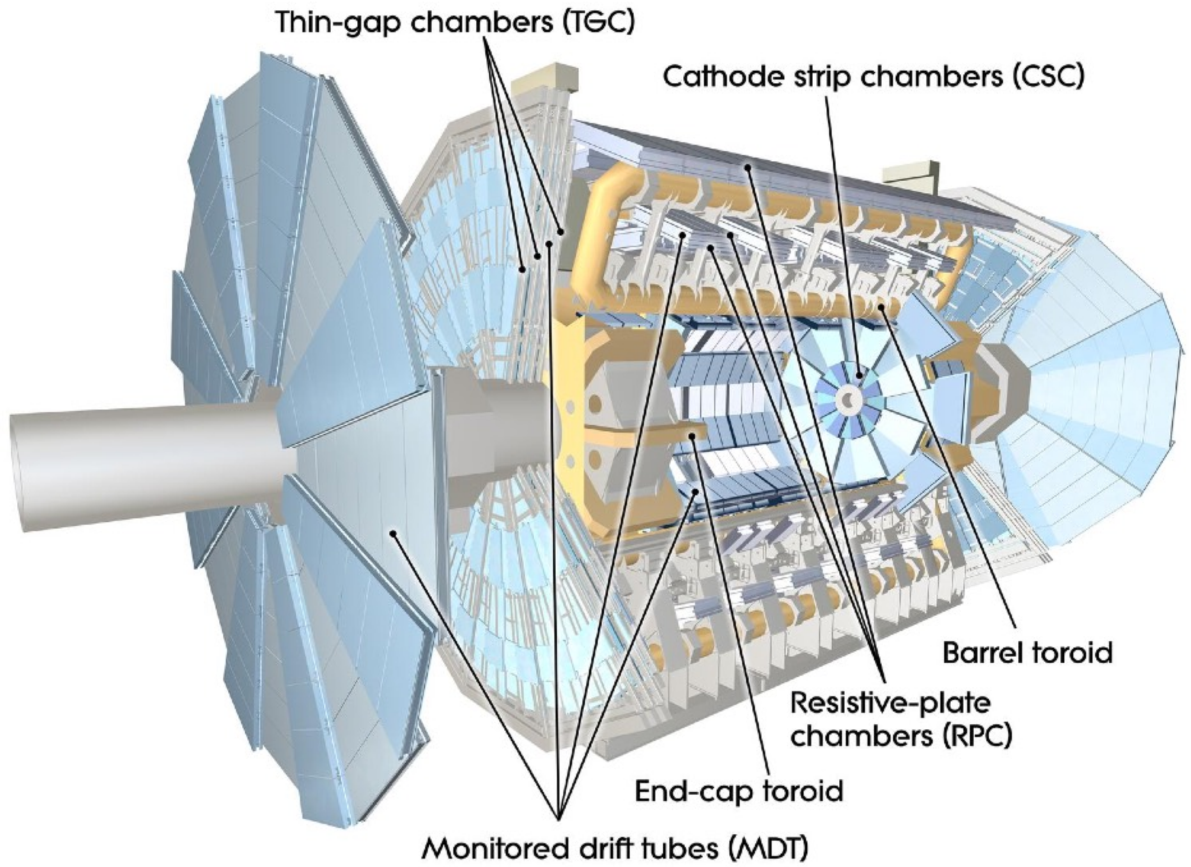
Seminar Overview

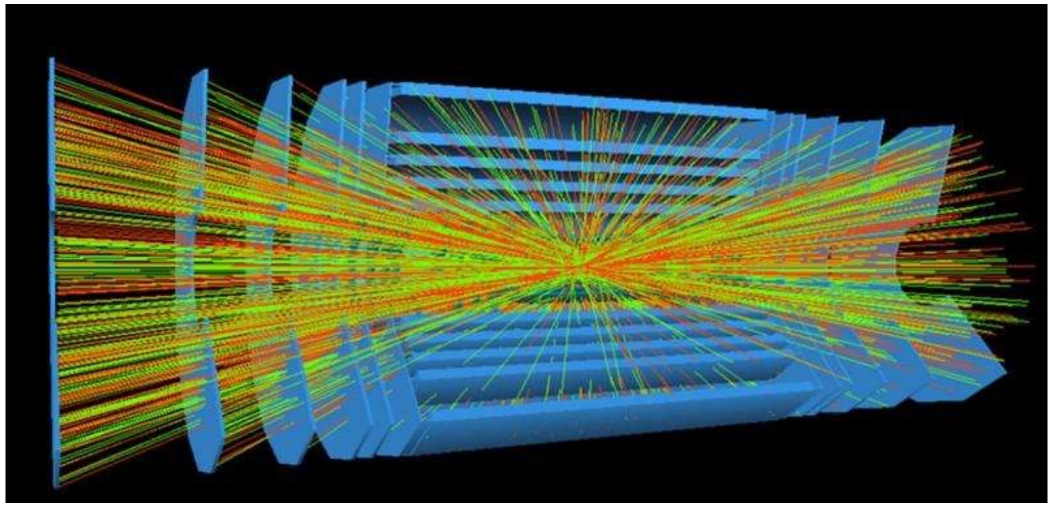
- Introduction
  - Why irradiation facilities
  - Irradiation facilities operated by EP-DT
- History
  - Original GIF @ West Area, and proposal for a new facility
  - Construction of GIF++ in EHN1
- GIF++
  - Main mode of operation
  - User Community
  - LS2 challenges
  - Recent upgrades to the facility
- Future improvements planned
- Outlook beyond LS2 (LS3?)

Irradiation Facility: what for ?

- **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

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.

HL-LHC Upgrade Requirements

❑ Radiation levels for LHC Experiments phase II upgrade (2025)

Max expected hit rates and integrated charges

Numbers refer to the hottest regions extrapolating the behavior of the present systems

	ATLAS				CMS			LHCb		ALICE		
Lumi	CSC	MDT	RPC	TGC	CSC	DT	RPC	Lumi	MWPC	Lumi Pb-Pb	RPC	
$7x10^{33}cm^{-2}s^{-1}$ 25 fb^{-1}	20	10	3	21	3	0.1	3	$4x10^{32}cm^{-2}s^{-1}$ 3 fb^{-1}	40	$4x10^{26}$ $cm^{-2}s^{-1}$ 150ub^{-1}	8	Int. charge
	770	280	13	100	170	2	14		$4x10^4$		3	Max. hit rate
$1x10^{34}cm^{-2}s^{-1}$ 100 fb^{-1}	80	40	11	84	12	0.35	12	$4x10^{32}$ $cm^{-2}s^{-1}$ 8 fb^{-1}	100	$2x10^{27}$ $cm^{-2}s^{-1}$ 1nb^{-1}	<10	Int. cha
	1100	400	18	140	250	3	20		$4x10^4$		20	Max. hi rate
$3x10^{34}cm^{-2}s^{-1}$ 350 fb^{-1}	280	140	38	280	41	1.2	42	$1x10^{33}$ $cm^{-2}s^{-1}$ 23 fb^{-1}	300	$6x10^{27}$ $cm^{-2}s^{-1}$ 10nb^{-1}	30→10	Int. cha
	3300	1200	54	430	750	9	60		$1x10^5$		125	Max. hi rate
$7x10^{34}cm^{-2}s^{-1}$ 3000 fb^{-1}	2400	1200	330	2450	350	10	360	$2x10^{33}$ $cm^{-2}s^{-1}$ 46 fb^{-1}	600			Int. cha
	7700	2800	130	1000	1700	20	140		$2x10^5$			Max. hi rate

Integrated charge in mC/cm^2 (mC/cm for MV
Max. hit rate in H

Additional tests needed on some detectors to assess their behavior during all HL-LHC → Common test facility (GIF++) strongly needed

9 P. Iengo - Muon longevity - ECFA HL-LHC 3/10/13

© P. Iengo (ECFA HL-LHC 2013)

Crosscheck with ATLAS Phase II LOI

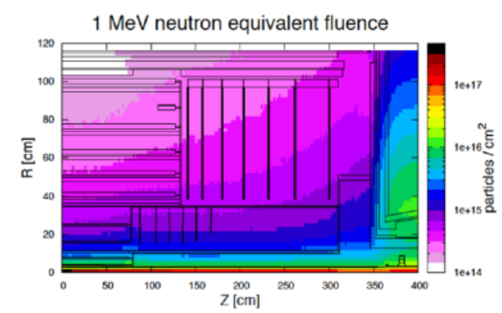


Figure 6.2: *RZ*-map of the 1 MeV neutron equivalent fluence in the Inner Tracker region, normalised to 3000 fb^{-1} of 14 TeV minimum bias events generated using PYTHIA8.

$3000\ fb^{-1}$
80mb inelastic pp crossection
2.4×10^{17} events
$dN/d\eta = N_0=5.4$ at 14 TeV
Pixel layer1 at r=3.7cm

$1MeV_{neq}$ Fluence = $2.4x10^{17}*5.4/(2*\pi*3.7^2)$ = $1.5x10^{16}$ cm^{-2}

Dose = $3.2x10^{-8}*1.5x10^{16}$ = 4.8MGy

Layer	Occupancy with 200 pile-up events (%)					
	Radius mm	Barrel (z = 0 mm)		Z mm	Endcap
Pixel: layer 0	37	0.57	Disk 0	710	0.022–0.076

The predictions for the maximum 1MeV-neq fluence and ionising dose for 3000fb^{-1} in the pixel system is $1.4 \times 10^{16} cm^{-2}$ and 7.7 MGy at the centre of the innermost barrel layer. For the

© W. Riegler (TIPP 2014)

04/06/2014 W. Riegler, CERN 23

outer (muon) detectors:

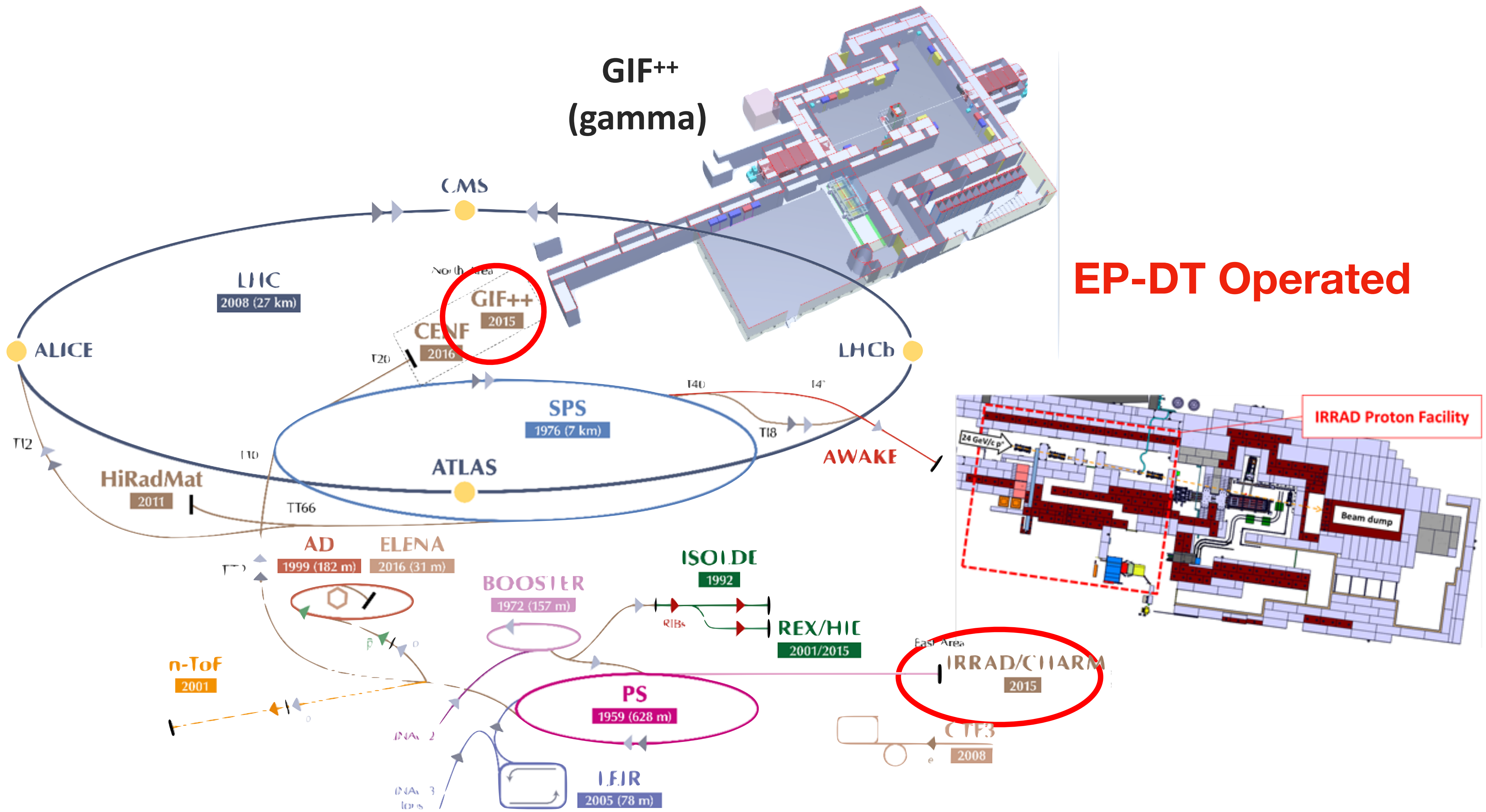
γ−BKGD ~$\mathcal{O}$(10) w.r.t. LHC

⇒ New Gamma Test Facility

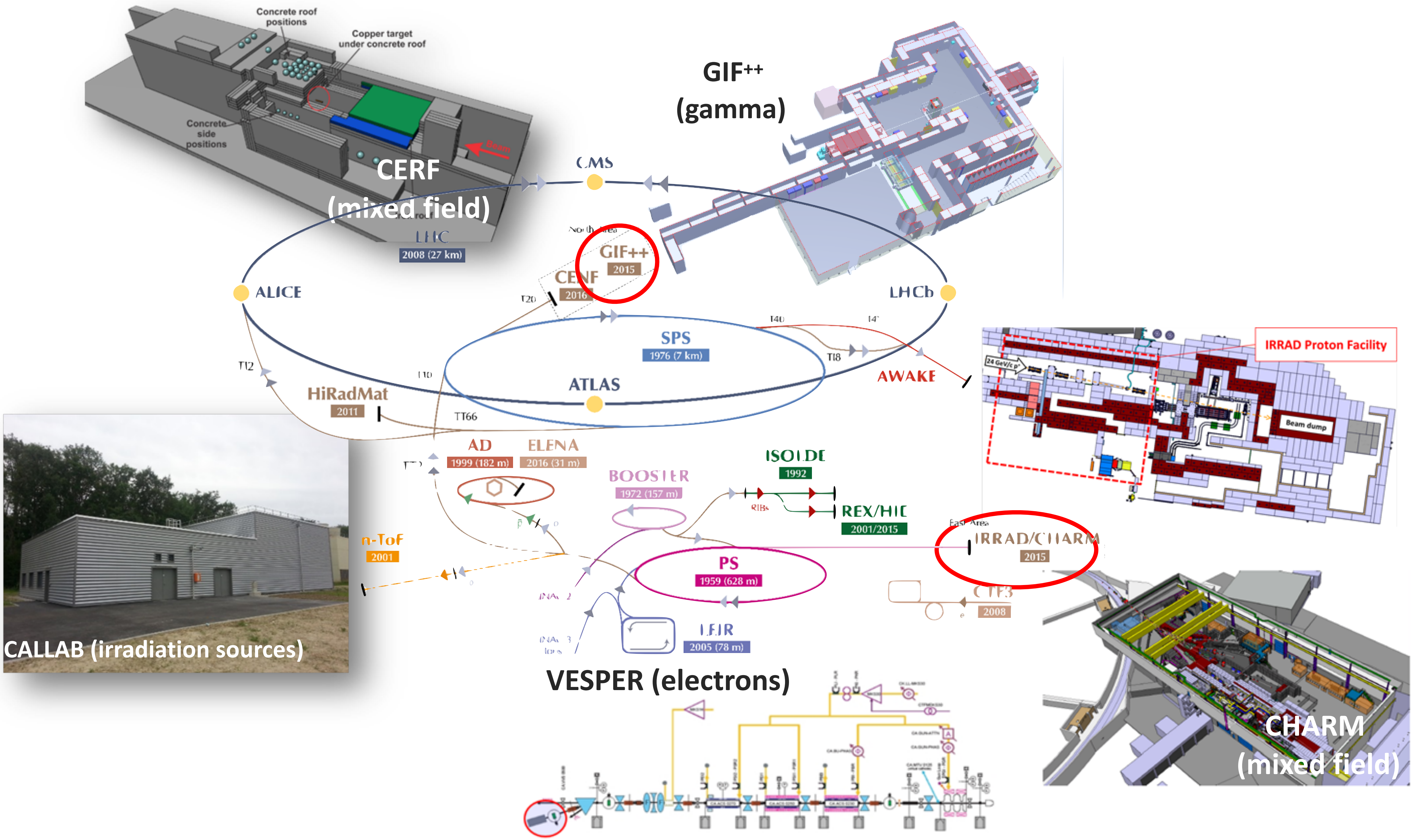
inner detectors (trackers): 10^{16} $1MeV_{neq}/cm^2$

⇒ Upgraded Proton Test Facility

CERN Irradiation Facilities



CERN Irradiation Facilities



Current EP-DT Irrad. Facilities Team

Maurice Glaser
(Honorary Member)

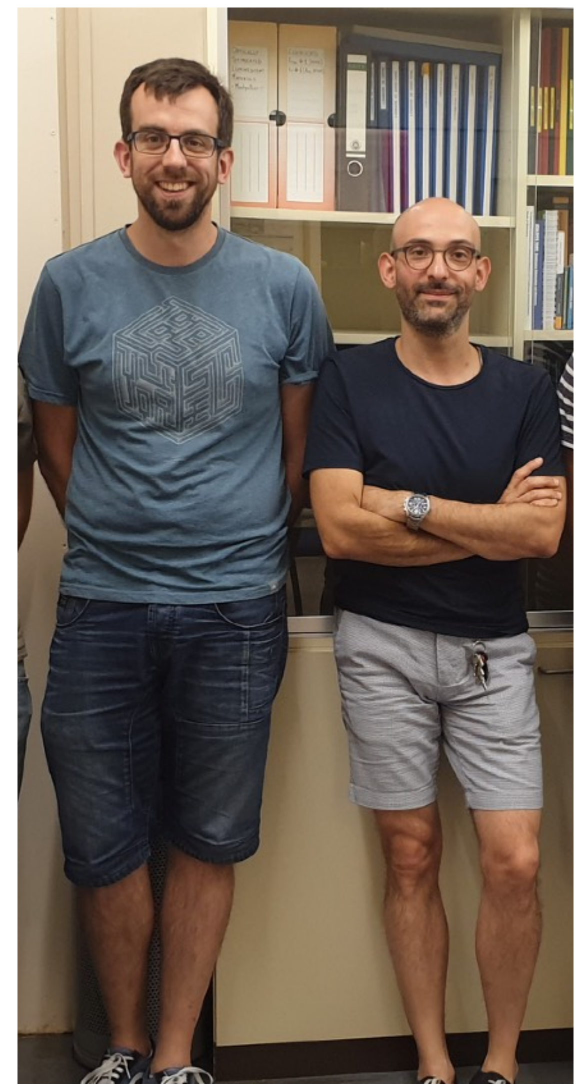
Georgi Gorine
(COAS FCC until April 2019, PhD defense spring 2020)

Martin Jaekel
(STAFF 50%)

Giuseppe Pezzullo
(STAFF)

Blerina Gkotse
(COAS-PhD, AIDA-2020)

Federico Ravotti
(STAFF)

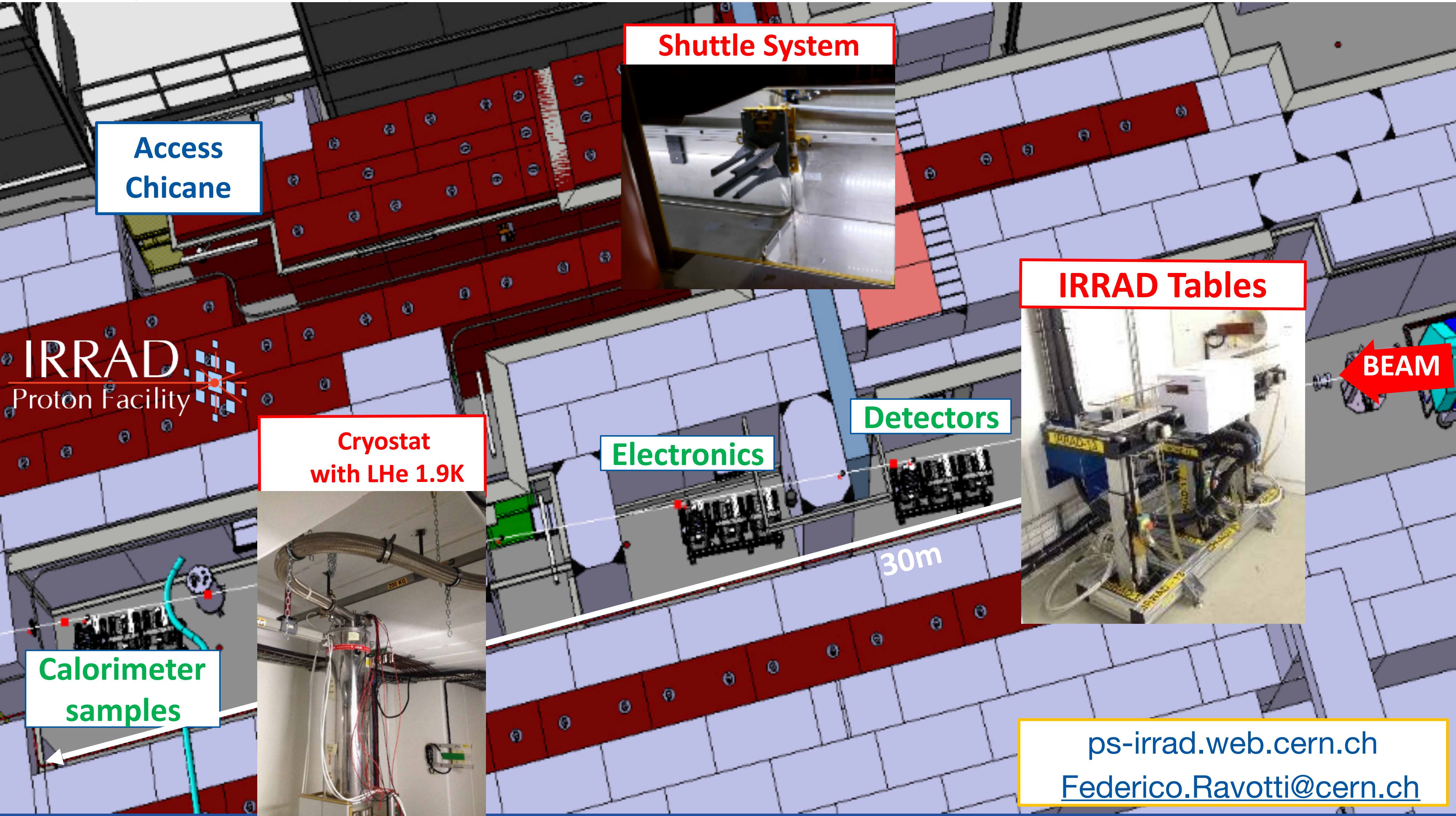


Isidre Mateu
(FELL 50%, AIDA-2020)

Viktoria Meskova
(TECH, ATTRACT)

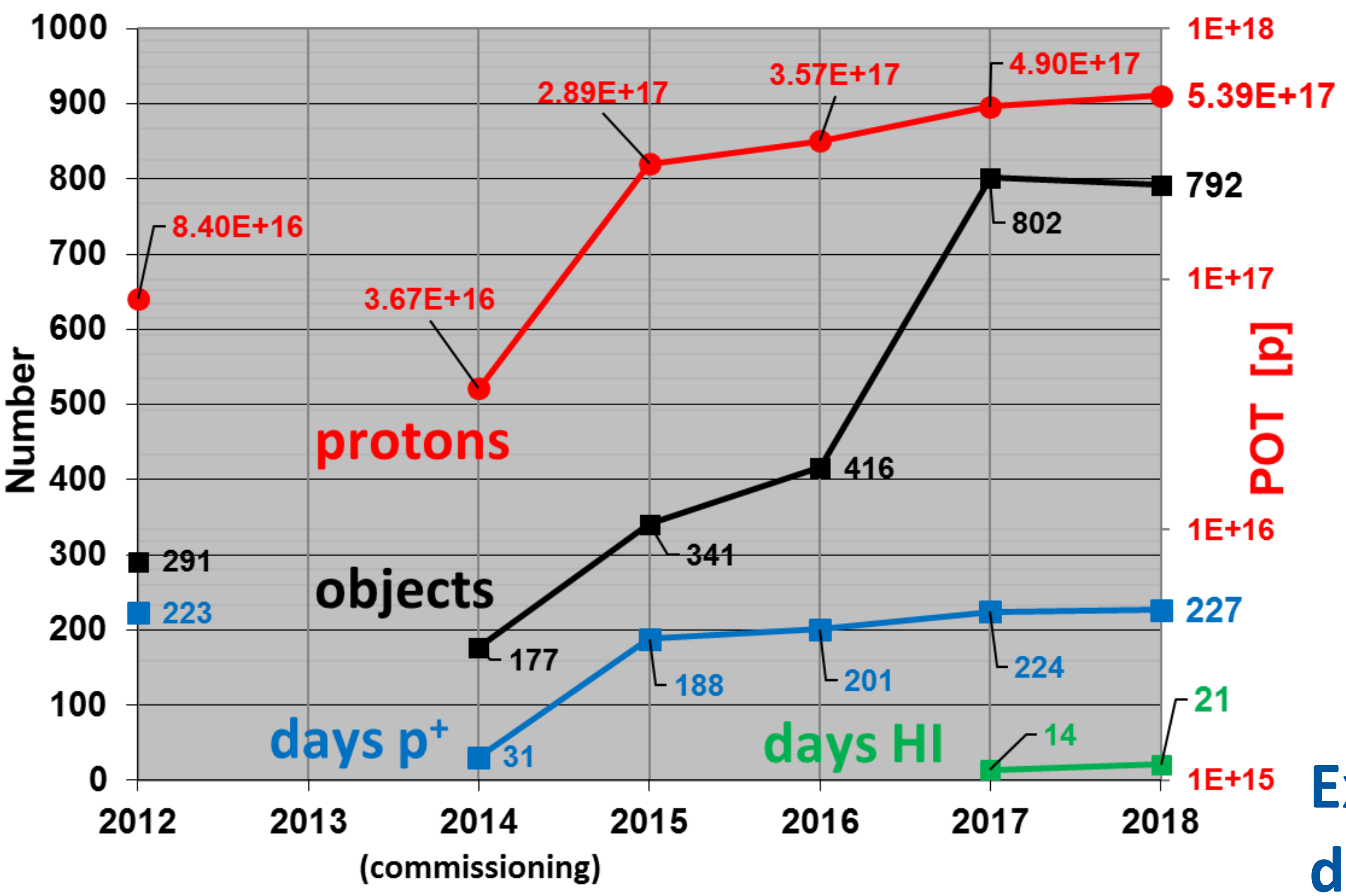
CERN Proton Irradiation Facility (IRRAD)

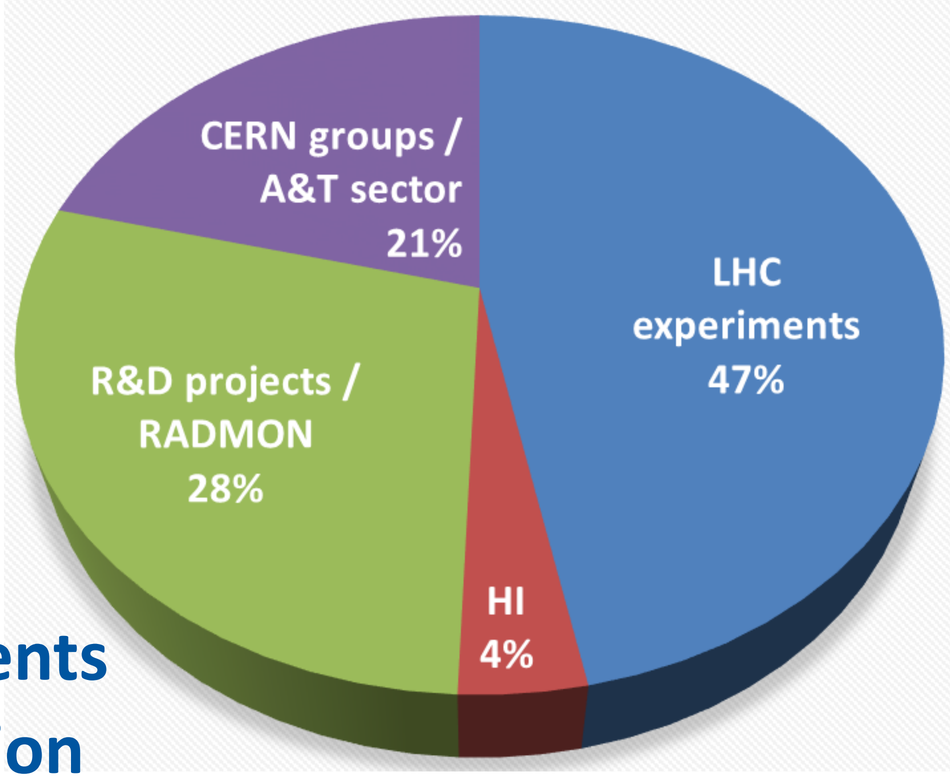
- **Testing components of the HEP experiments**
- Beam of **24 GeV/c** and size of **12×12 mm^2**
- Spills of **400 msec** every **~10sec**
- Fluence of **1×10^{16} p/cm^2 in 14 days**
- **Scanning** also in dimensions of 10×10cm^2
- **Low temperature** irradiation (-25°C)



IRRAD: Summary Run 2018

- **81 experiments completed in 2018:**
  - **92 users** registered in the IRRAD Data Manager (cern.ch/irrad-data-manager)
  - **996 objects** declared by the users
  - **792 objects** irradiated



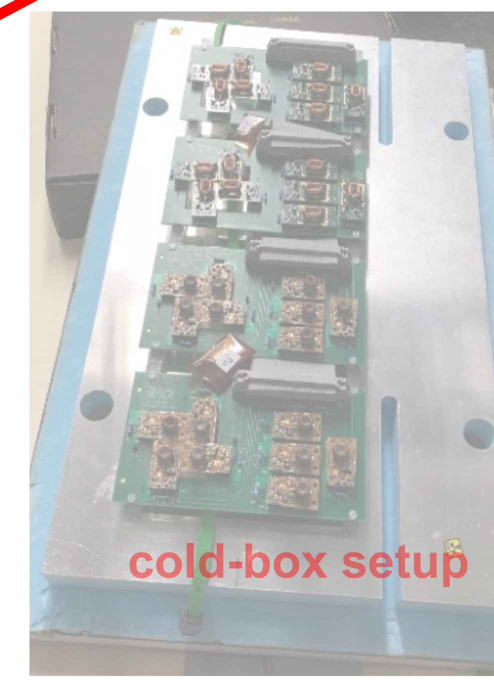


Experiments distribution

IRRAD: Summary Run 2018

Piezo actuators for Crystal Collimation, Vacuum, Cryogenics, etc. (EN,TE)

2x **FEAST2 DC/DC c**... **est** in cold-box & RT with "... arget (EP-ESE)

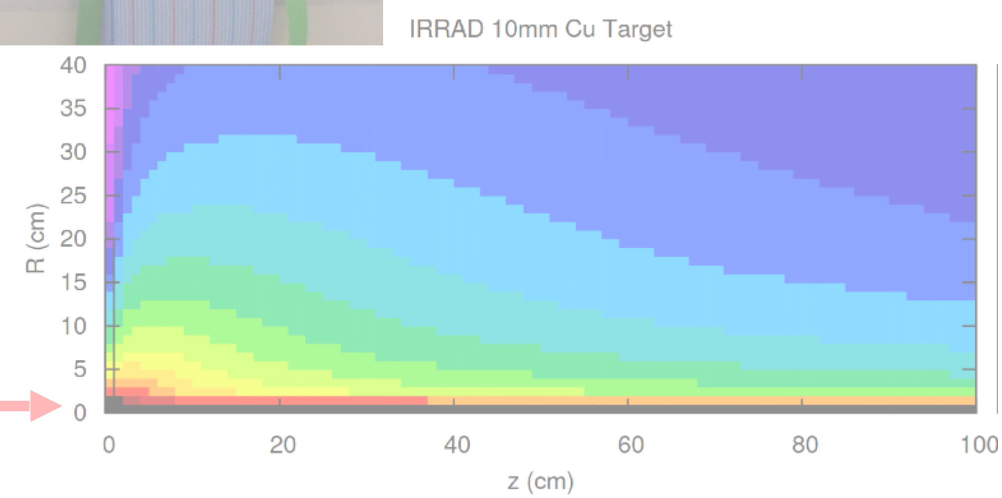


Dedicated seminar ≈ end of LS2

...Tk

CLARO ASIC for the LHCb RICH Upgrade...

1MeV eq. Φ simulation with Cu-target



Gamma Irradiation Facility < 2014

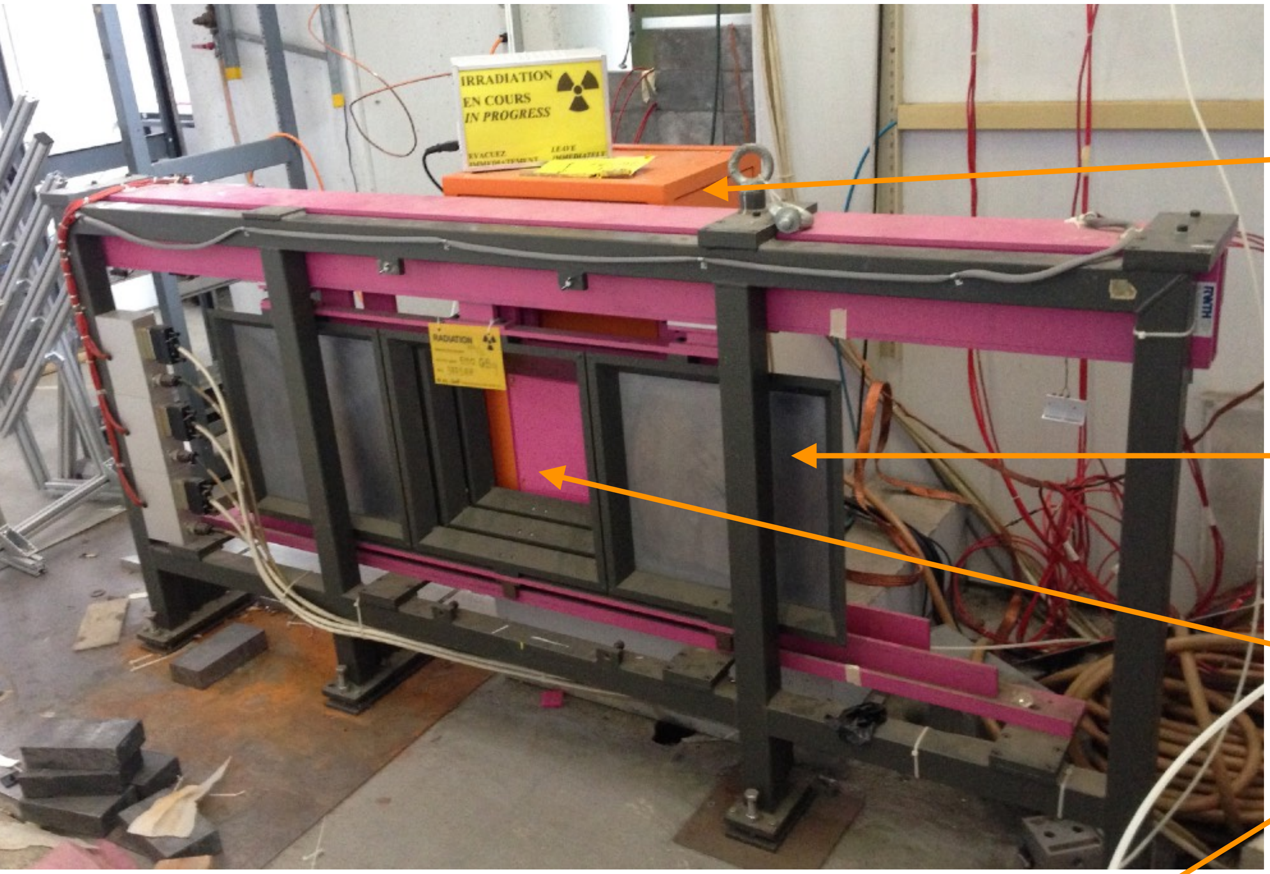
Original CERN-Gamma Irradiation Facility (GIF) has been intensively used to simultaneously expose detectors to the photons from a ^{137}Cesium source and high energy particles from the X5 beam line in SPS West Area,. From 2004 onwards, only the Cs source (≈ 0.5 TBq) was available.

Among other clients, **most LHC gas detector technologies have been validated at the GIF**:
CMS: RPC, CSC; ATLAS: MDT, RPC, TGC, CSC; ALICE : TOF, AMS, CPC, RPC; LHCb: MWPC; COMPASS detectors….

orig.GIF, Bld.190, CERN

Still fully booked all year round in 2013/2014 !

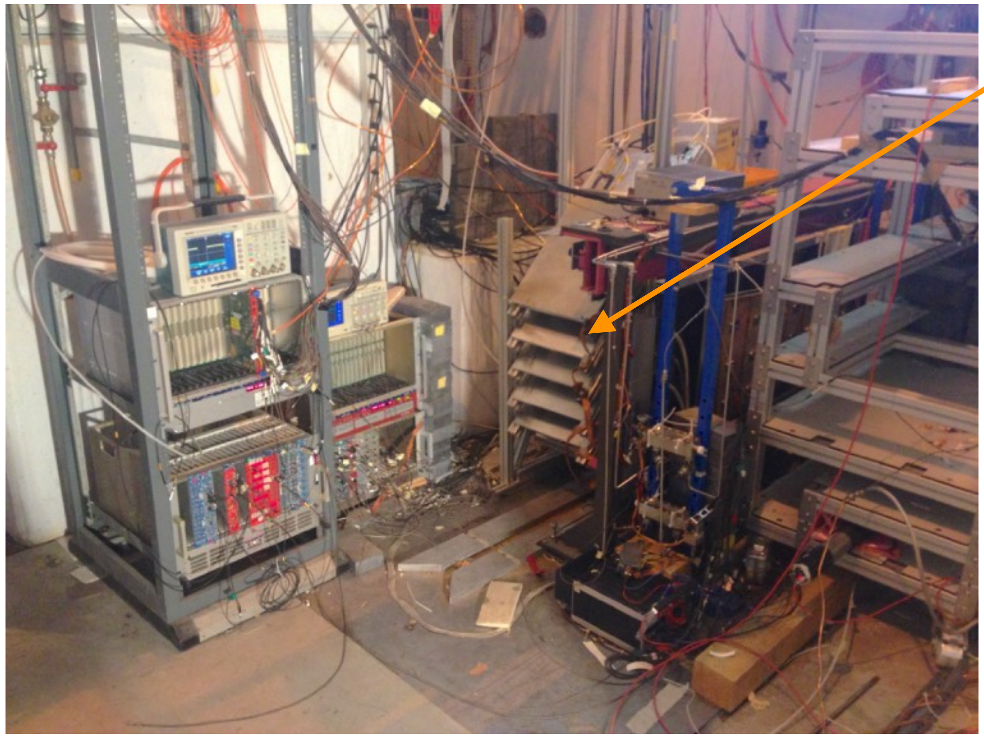
Original GIF B190

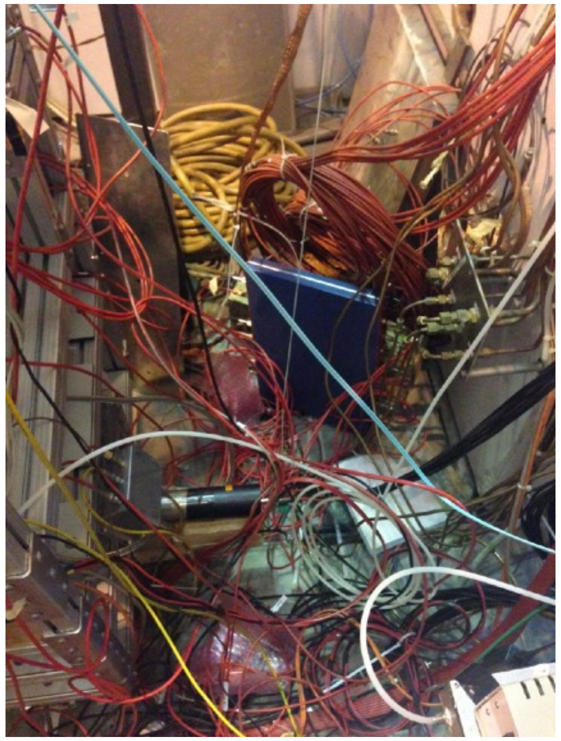


≈ 500 GBq
^{137}Cs Irradiator

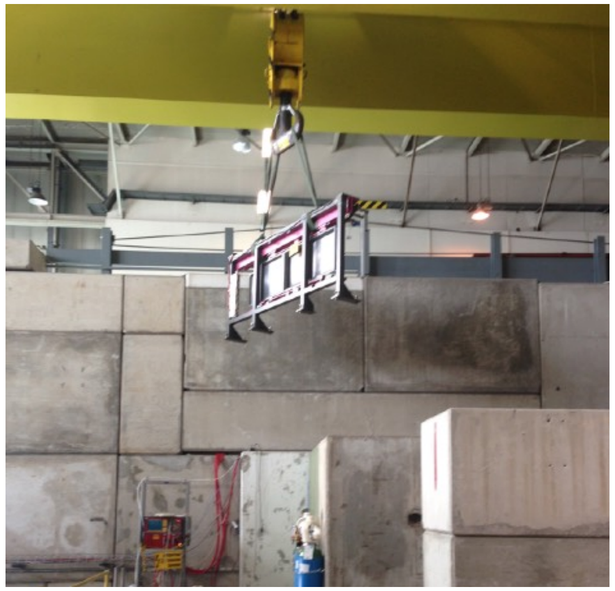
Set of Pb
absorption filters

One large field
One shutter on side





Decommissioning GIF B190 Nov. 2014


GIF++

2014 - 2018

LS1- Run 2 - LS2

Concept of a new Facility (2012-2014)

- Joint facility, operated by EP-DT (PH-DT) and EN-EA (EN-MEF)
- Unique place, combining a high energy muon beam with a 14 TBq ^{137}Cs gamma source (∝ 30 compared to orig. GIF)
- Designed for testing real size detectors, of up to several m², as well as a broad range of smaller prototype detectors and electronic / optical components.
- 100 m² irradiation bunker with 2 independent irradiation zones (≈ 30+25 m²), separated attenuation systems
- Large preparation zone to optimise the irradiation zone usage
- All year operation from Cs-Irradiator
- High energy Muon beam from H4 beam line
  7-9 weeks of dedicated beam (main user H4)
- Central Control System, recording all relevant parameters and provides interlocks, user operated DAQ and Trigger System
- Wide range of available gases (+ custom gases) in bunker & service zone

Joined Facility EN & EP

(after construction)

Engineering Department

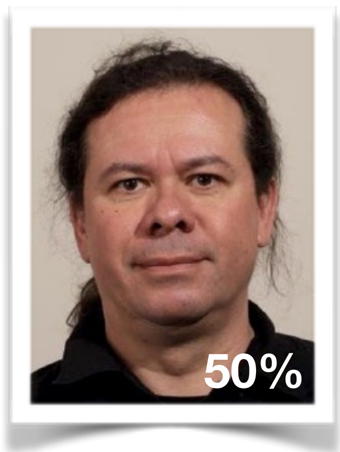
- EHN1 infrastructure
- Beam line H4
- General facility infrastructure
  - Electricity, cooling & ventilation, gas primary system…
- Access system (contact to)
- General safety EHN1 (incl. GIF)

EP-DT
Detector Technologies

- Cs Irradiator
- Local gas distribution
- User operation
  - Irradiation requests, SPS beam request, space management
  - User installations
  - User contact
- Safety (setups & users)

GIF++ EP TEAM 2016-2019

GIF Physics Coordinator



- Overall GIF coordination.
- Deputy to SPS Physics Coordinator for the GIF with authority to optimise the user schedule for all modes (beam, stand alone…), within the constrains of the SPS schedule
- Future development of the facility

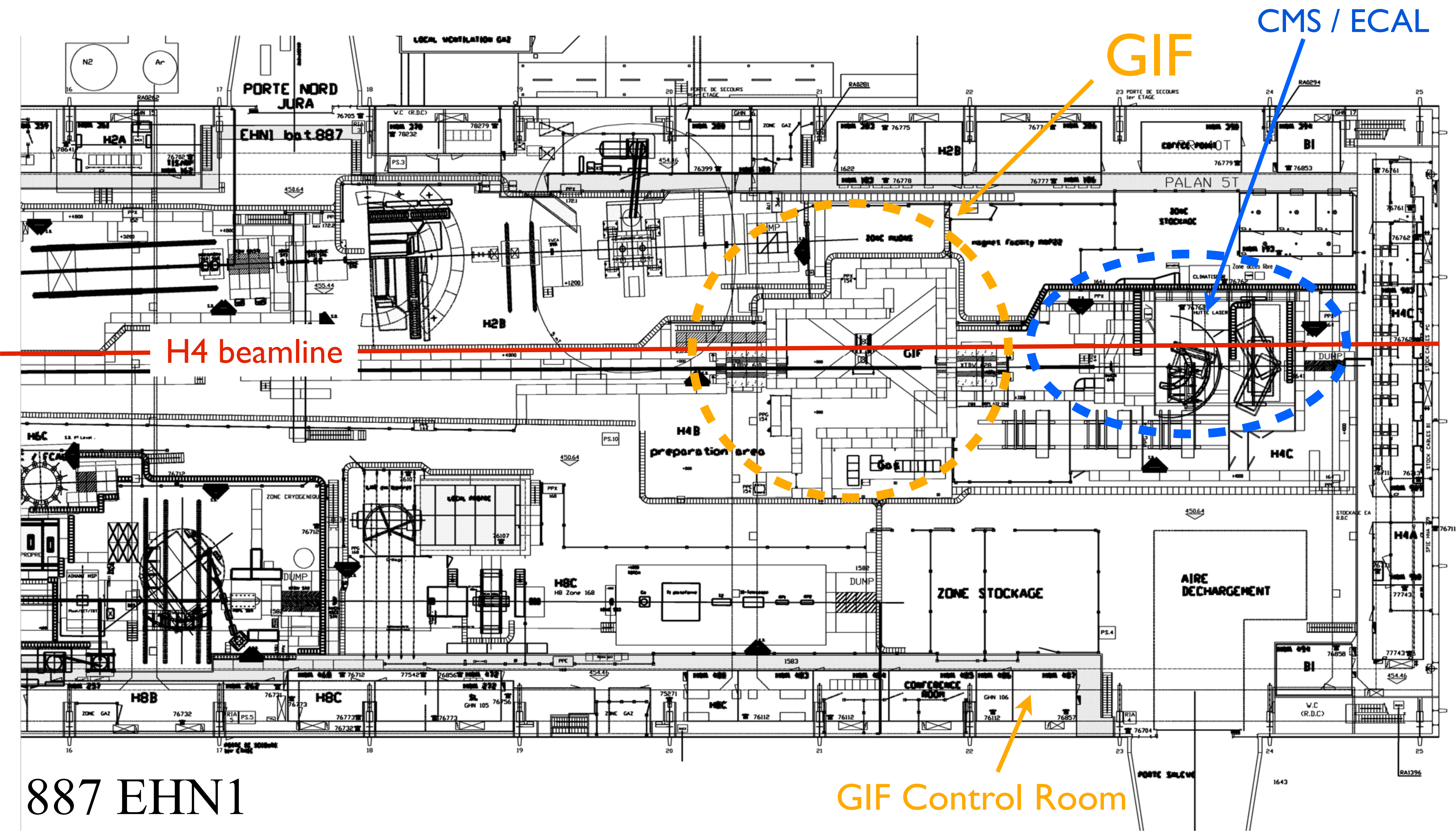
GIF User Tech.Coordinator

- Space management of the bunker & preparation zone
- Supervising user installation, installation of cables & electronics, rack space distribution, gas requests
- **Contact to EN services**
- Gas system - First level support
- Deputy EXSO

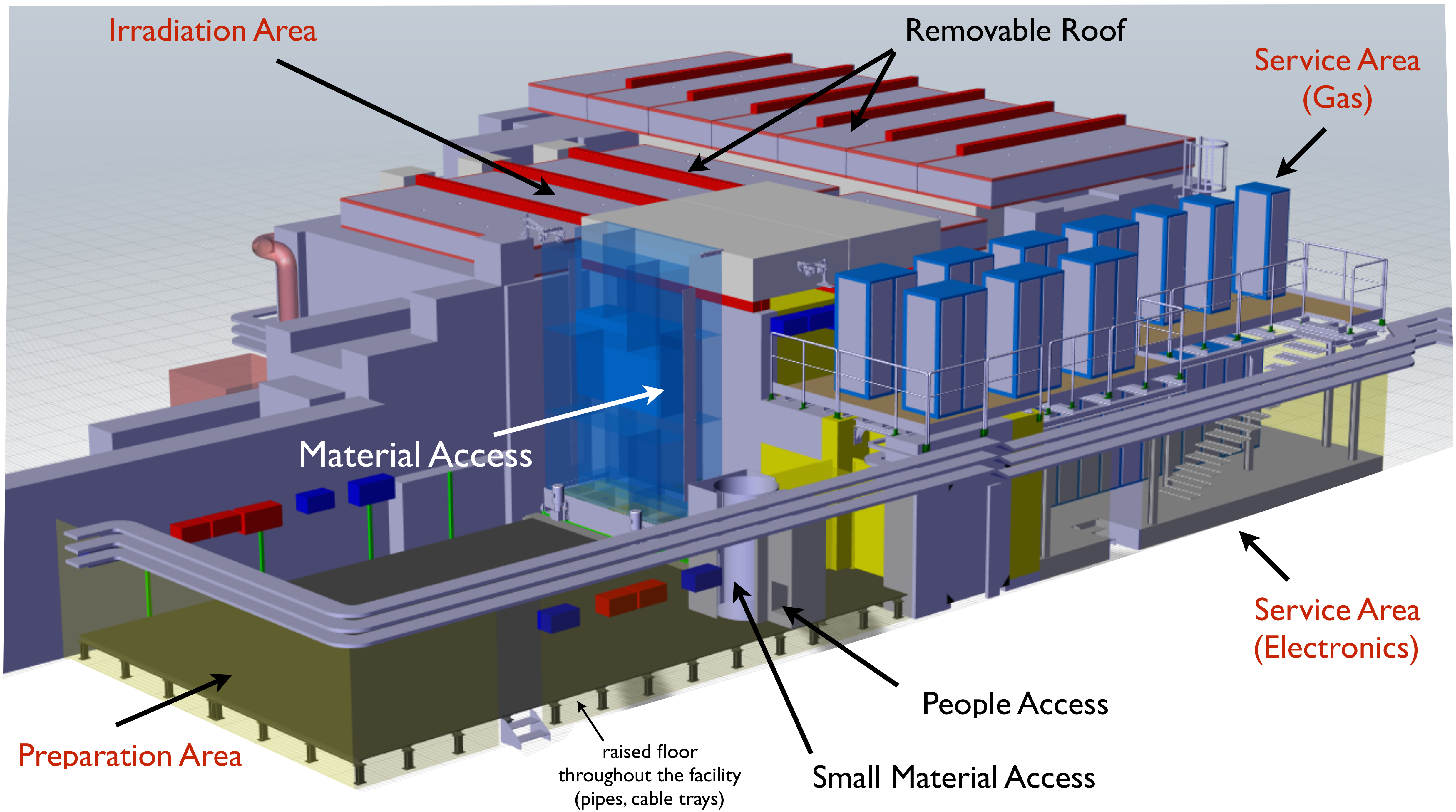
EXSO

- One **EX**perimental **S**afety **O**fficer (EXSO) for all EP irradiation facilities
- Department RSO (Radiation Safety Officer)

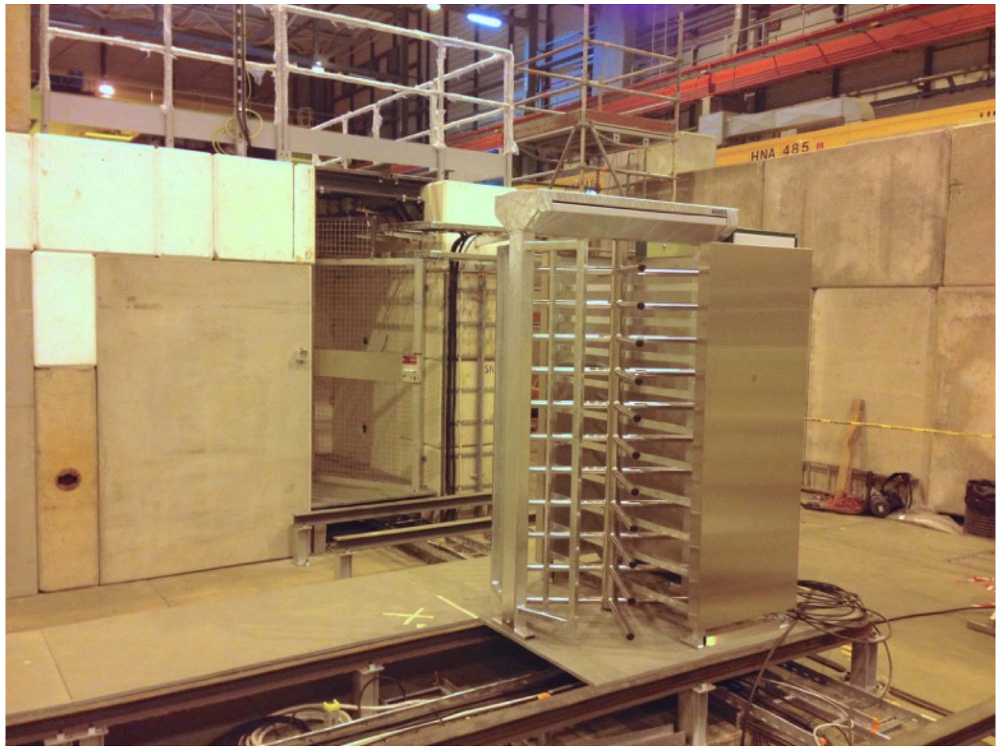
An New Home for the GIF - EHN1

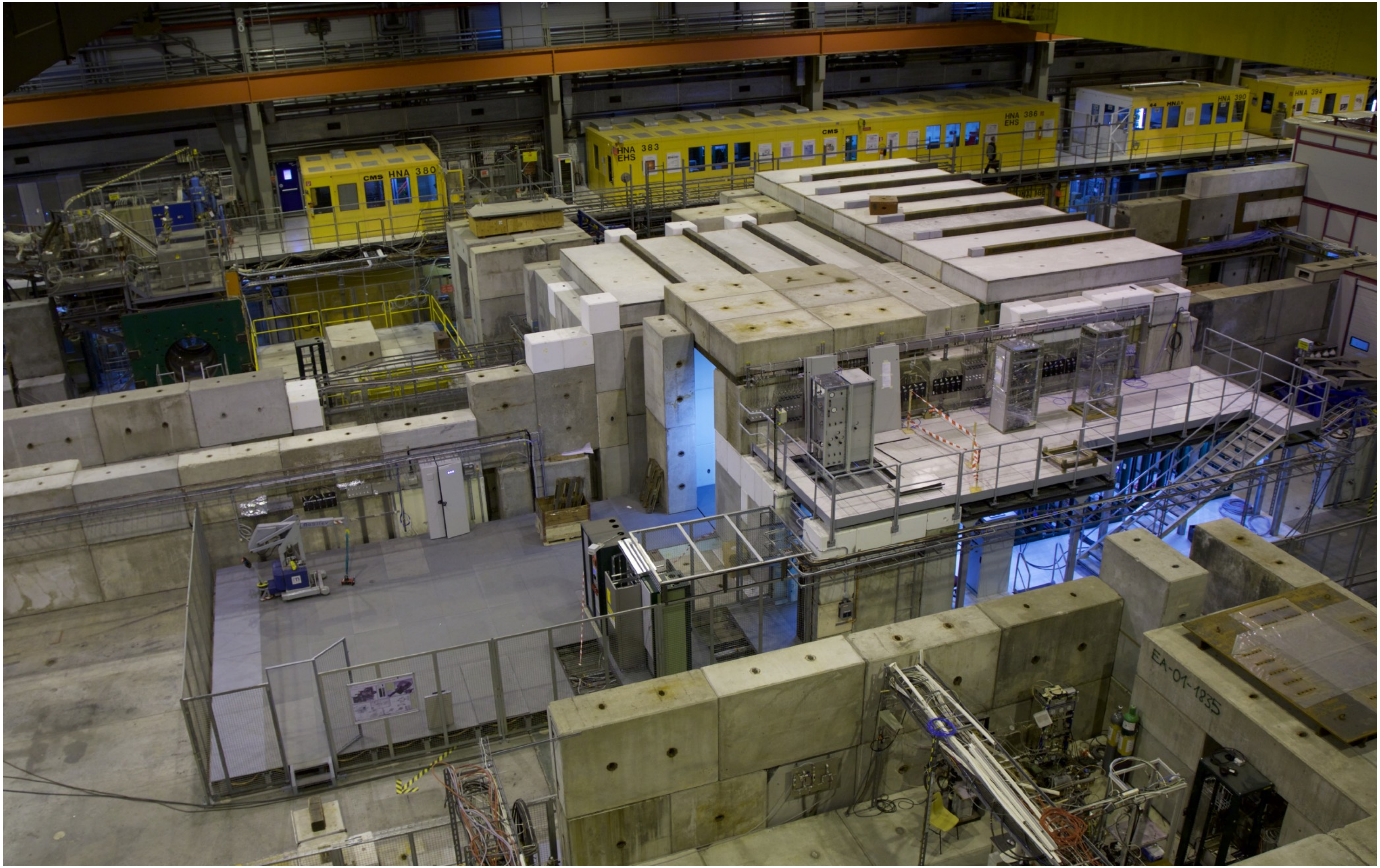


Original Facility Layout

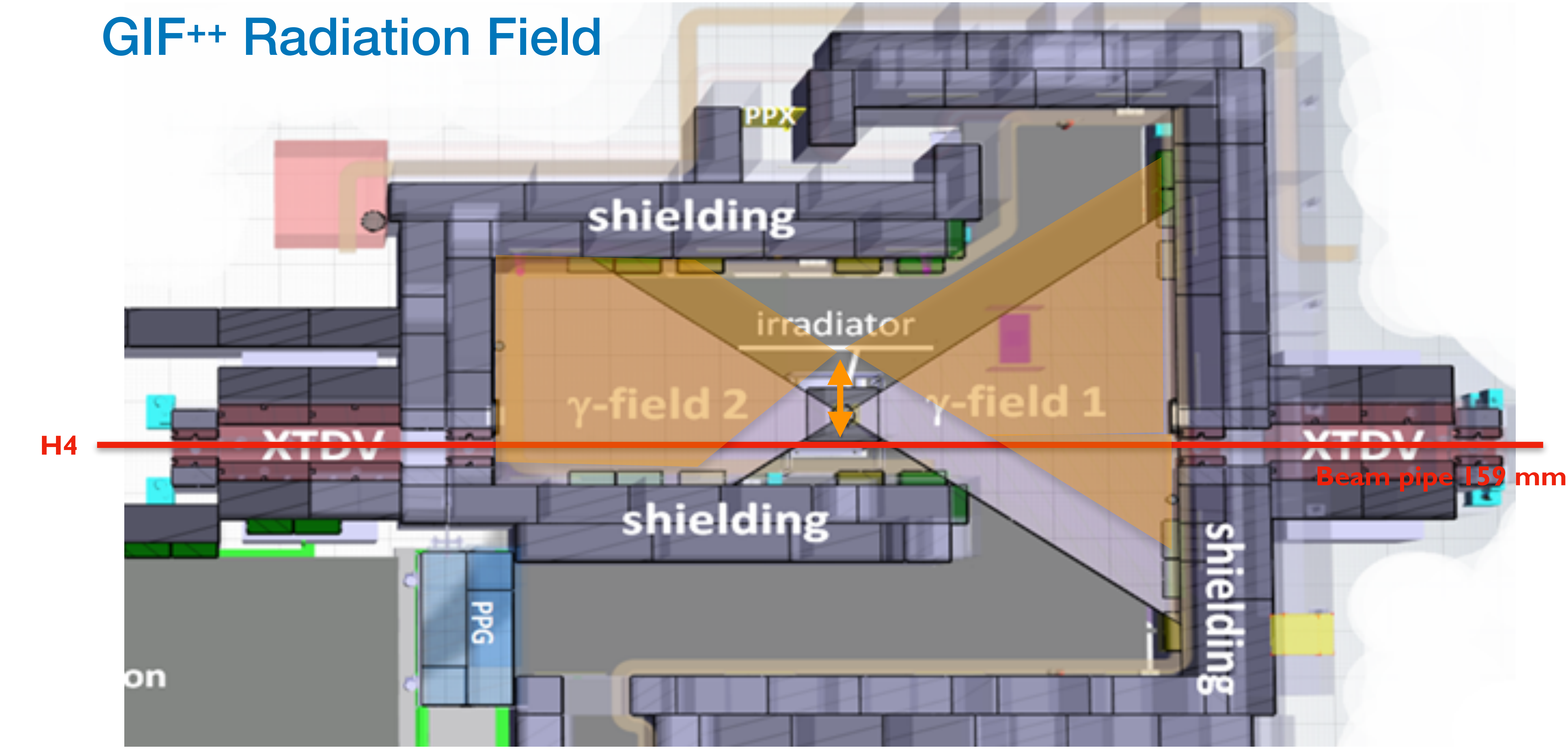


GIF++ Construction 2014



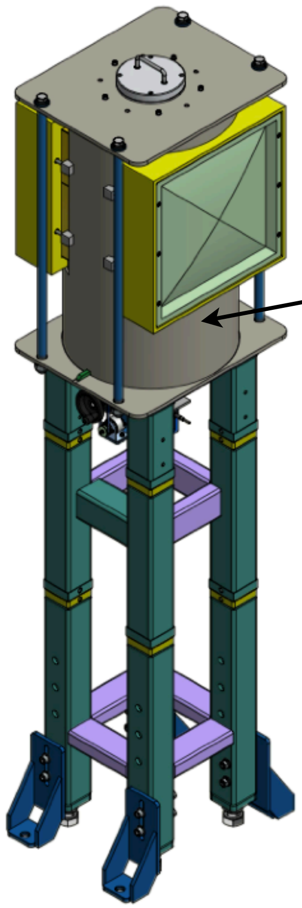

CMS HNA 380
HNA 383
EHS
CMS
HNA 386
EHS
HNA 390
HNA 394
EA-01-1835

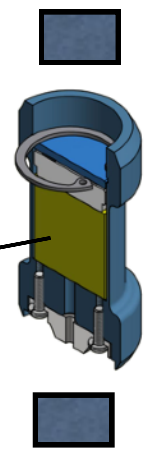
GIF++ Radiation Field



- 2 large area irradiation fields (upstream / downstream)
- Irradiator movable perpendicular to beam-line to use field optimal when beam pipe is installed to deliver electron beam to CMS-ECAL (≈ 2 weeks per year)
  - Since 2018 also need to deliver beam to Neutrino platform NP04 (several months ?)

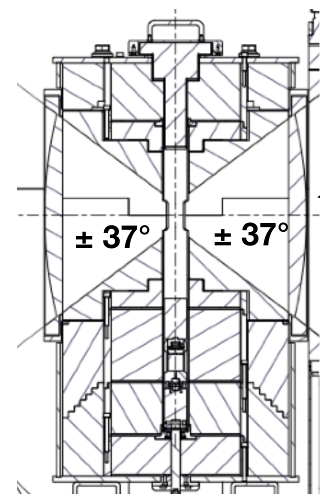
GIF++ Irradiator

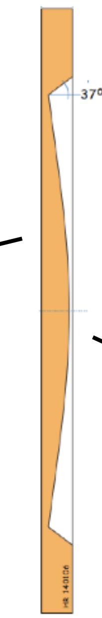




14 TBq
^{137}Cs (as of 2014)

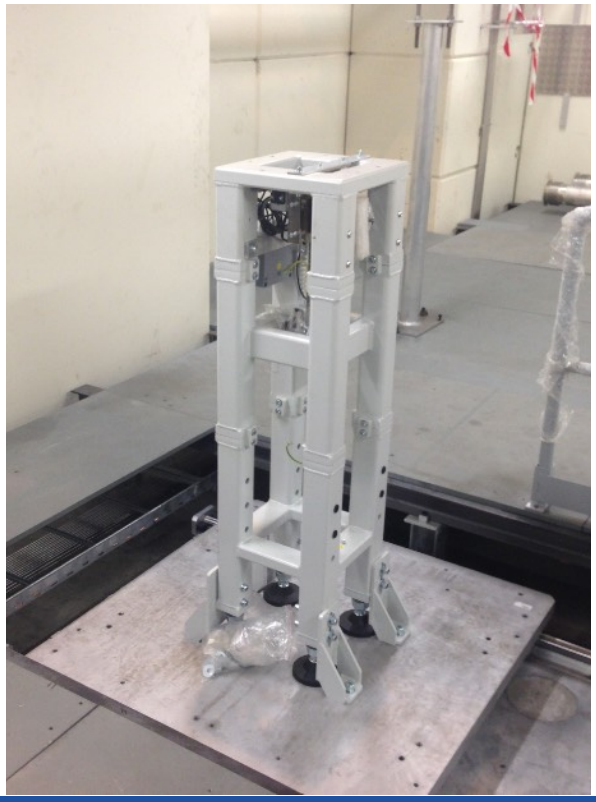
Source stacked with two cylinders of $_{74}$W





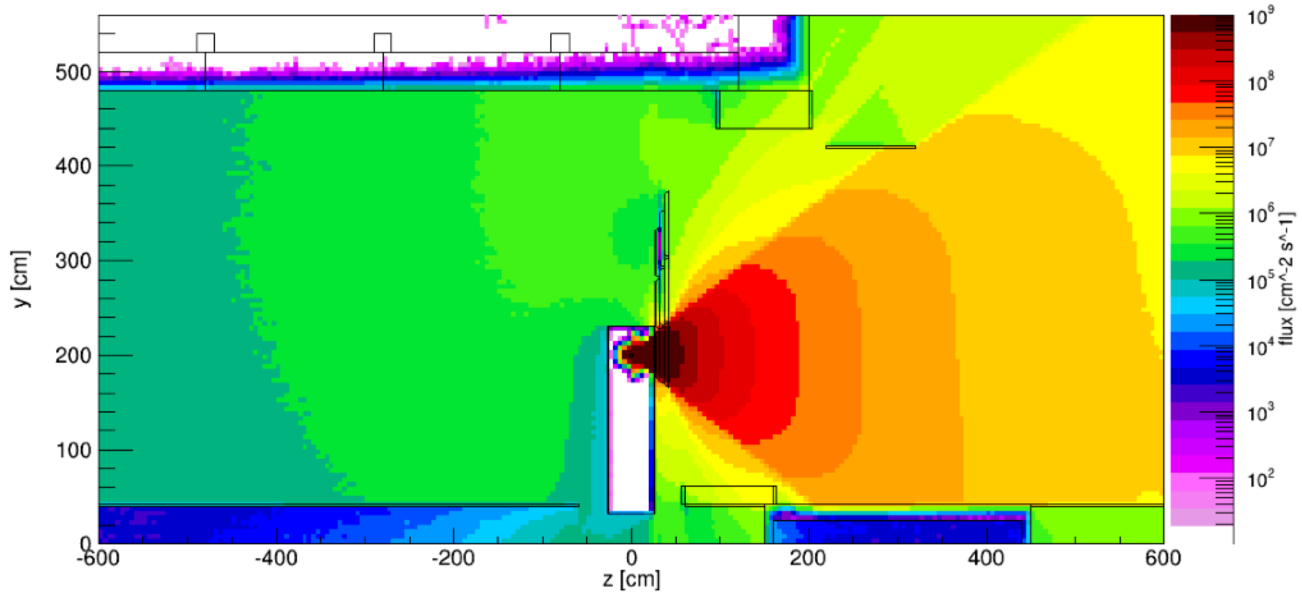
2 large irradiation fields ±37 degree (horizontal & vertical)

Angular correction filter (Fe) provides uniform photon distribution for large area planar detectors

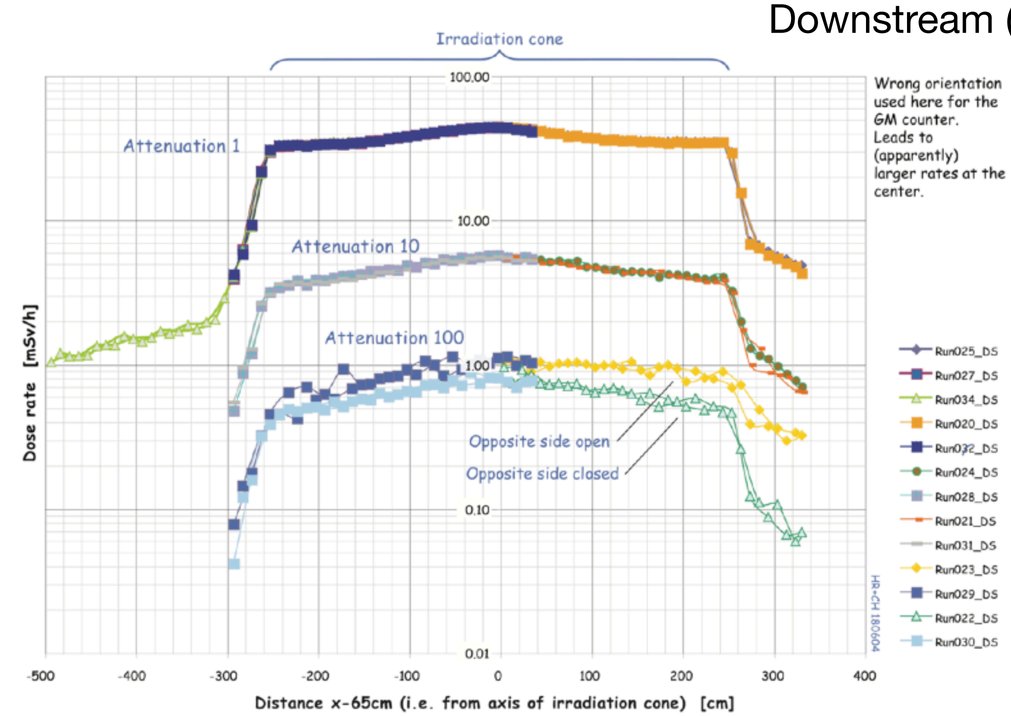


GIF++ Radiation Field

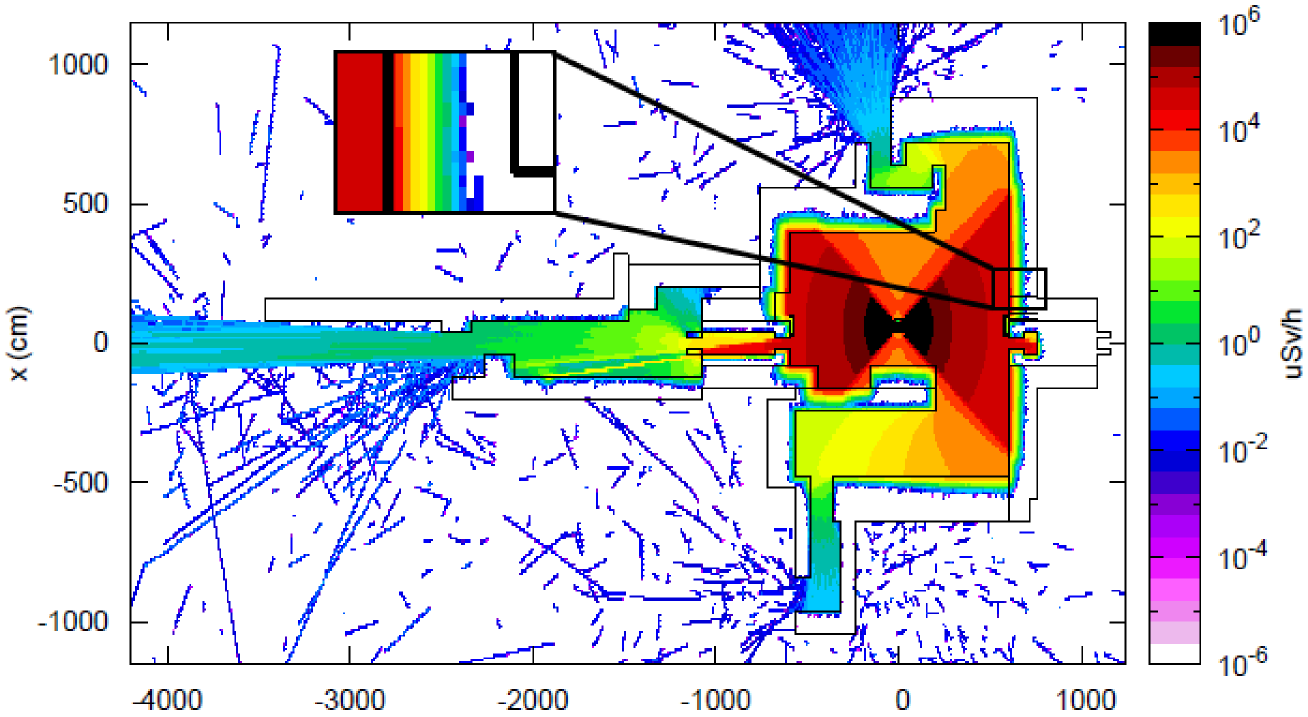
Total flux, one field, without filters



Downstream (350cm)

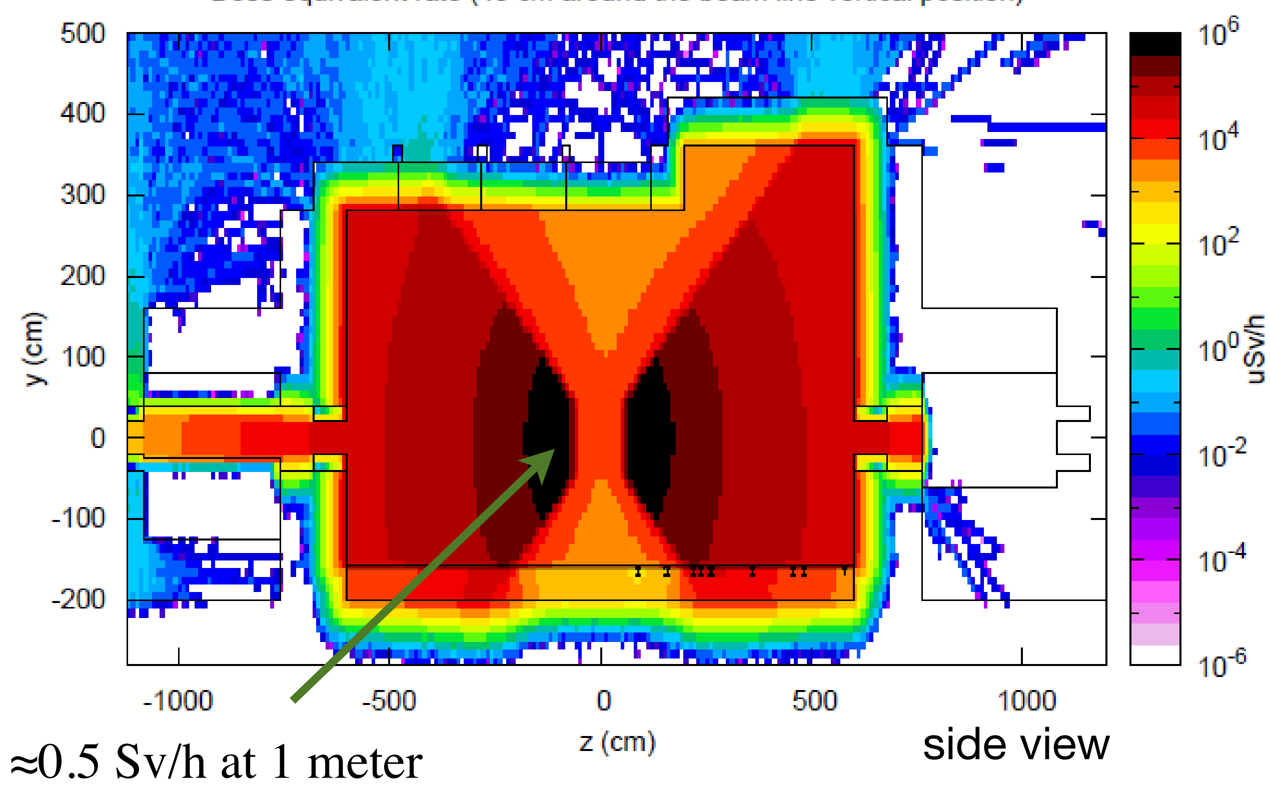


Dose equivalent rate (40 cm around the source height)



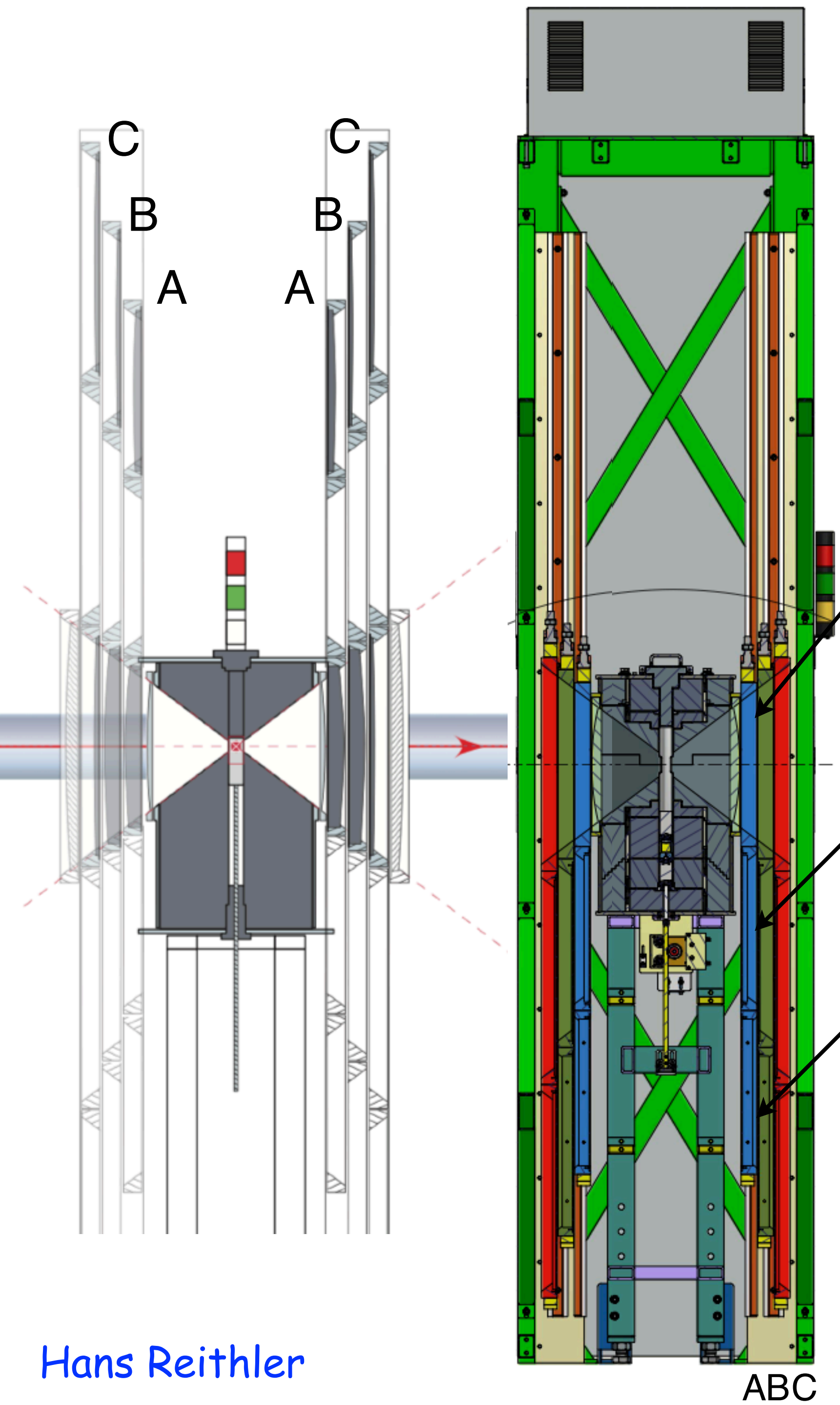
top view

Dose equivalent rate (40 cm around the beam line vertical position)



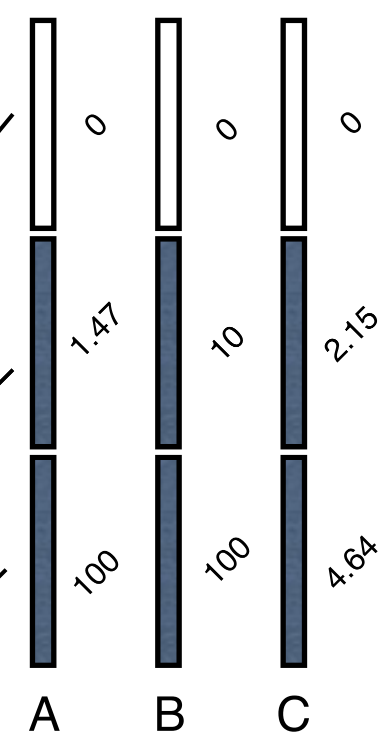
GIF++ Attenuation Filters

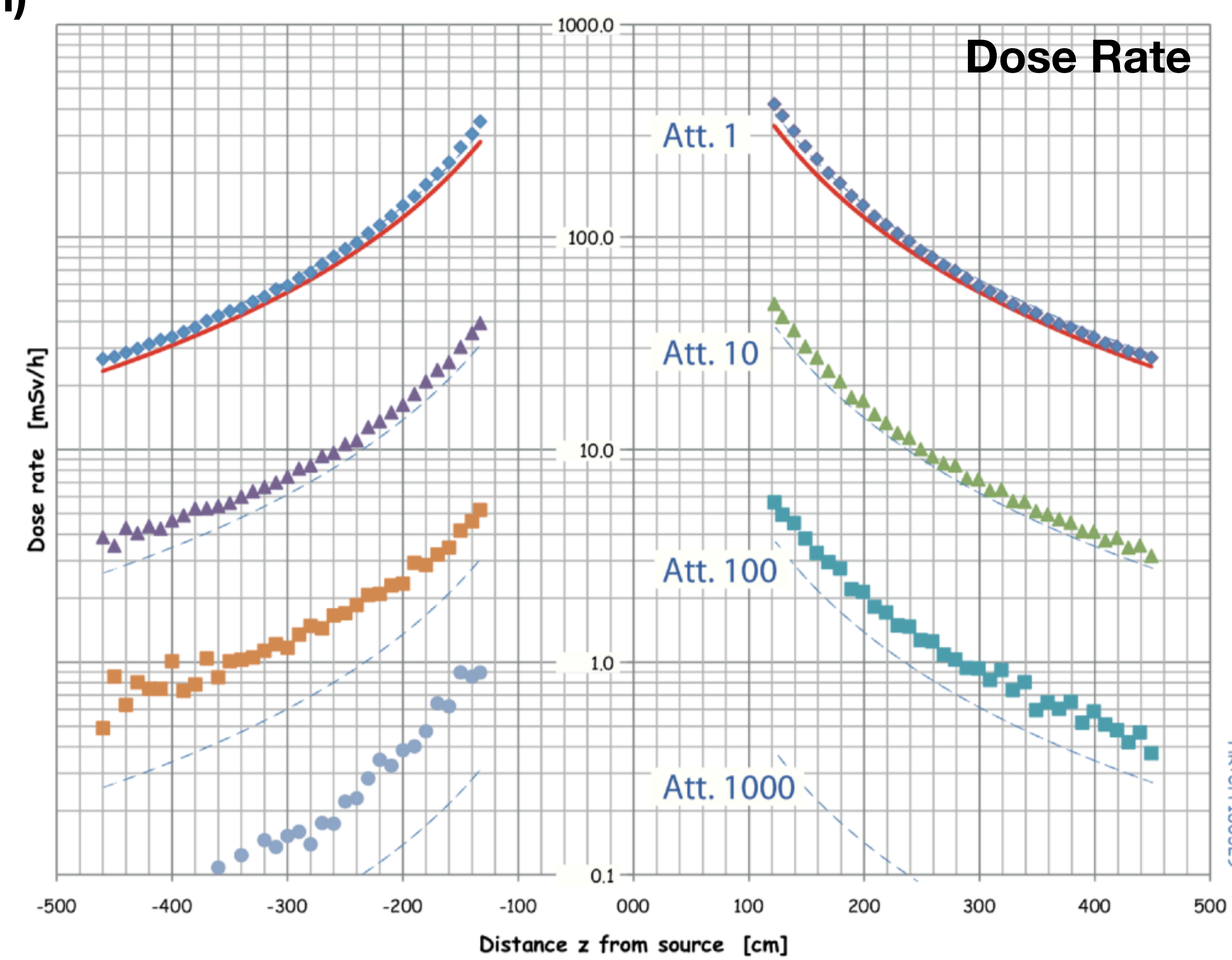
Two identical attenuation systems, each 6 absorption filters
- a total of 14 custom shaped filters (incl. ang. Correction)

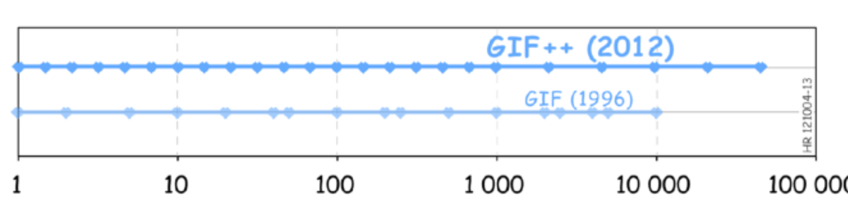


Filter System :

Absorption factor :







(calculated values for un-scattered gammas)

Hans Reithler

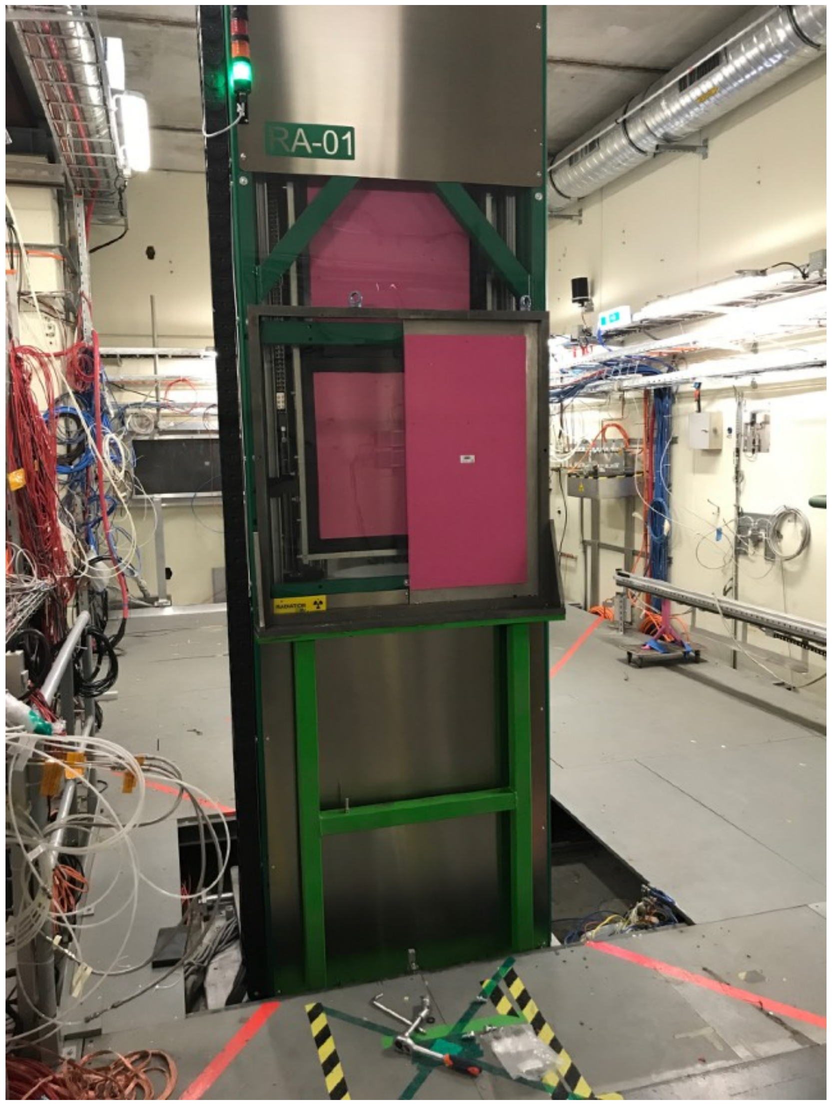
RWTH AACHEN UNIVERSITY Physics Institute III A

24 possible attenuation factors :

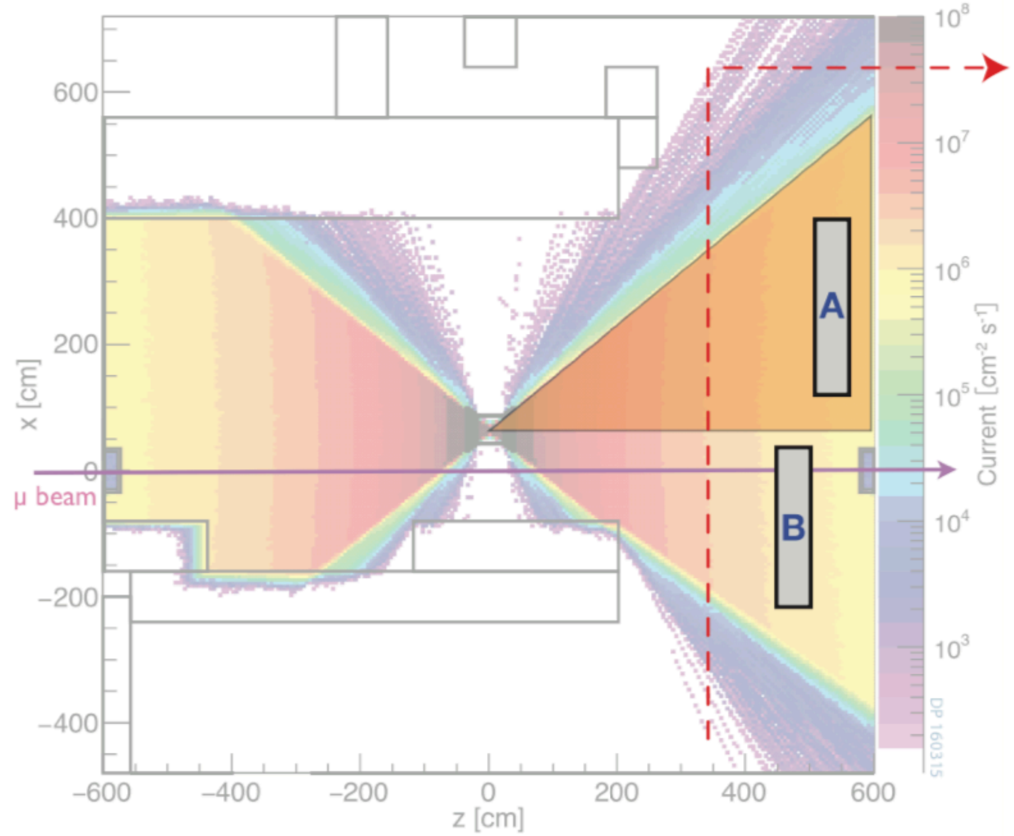
Photon current

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

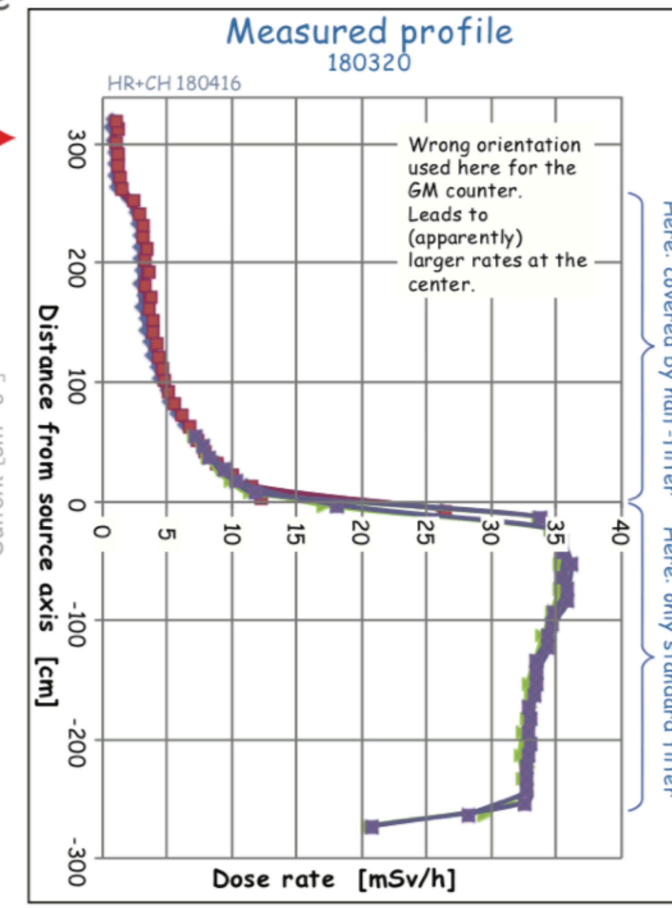
Special Case - Additional Half Filter



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

RWTH AACHEN UNIVERSITY Physics Institute III A

Irradiation Fields Run 2

GIF++ Gas System (EP-DT-FS)

The gas systems infrastructure is a key element for successful R&D programs at GIF++
The GIF++ Gas systems infrastructure is comparable to a medium size experiment.
Frequent changes related to the normal R&D activities are particularly demanding.

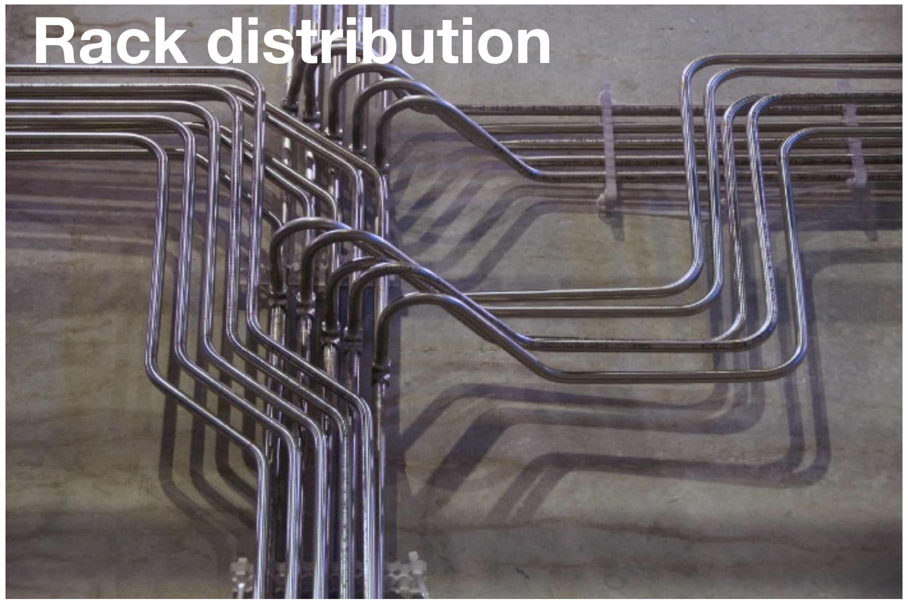
For GIF++, Gas team built and it is contacted for maintenance/operation of:

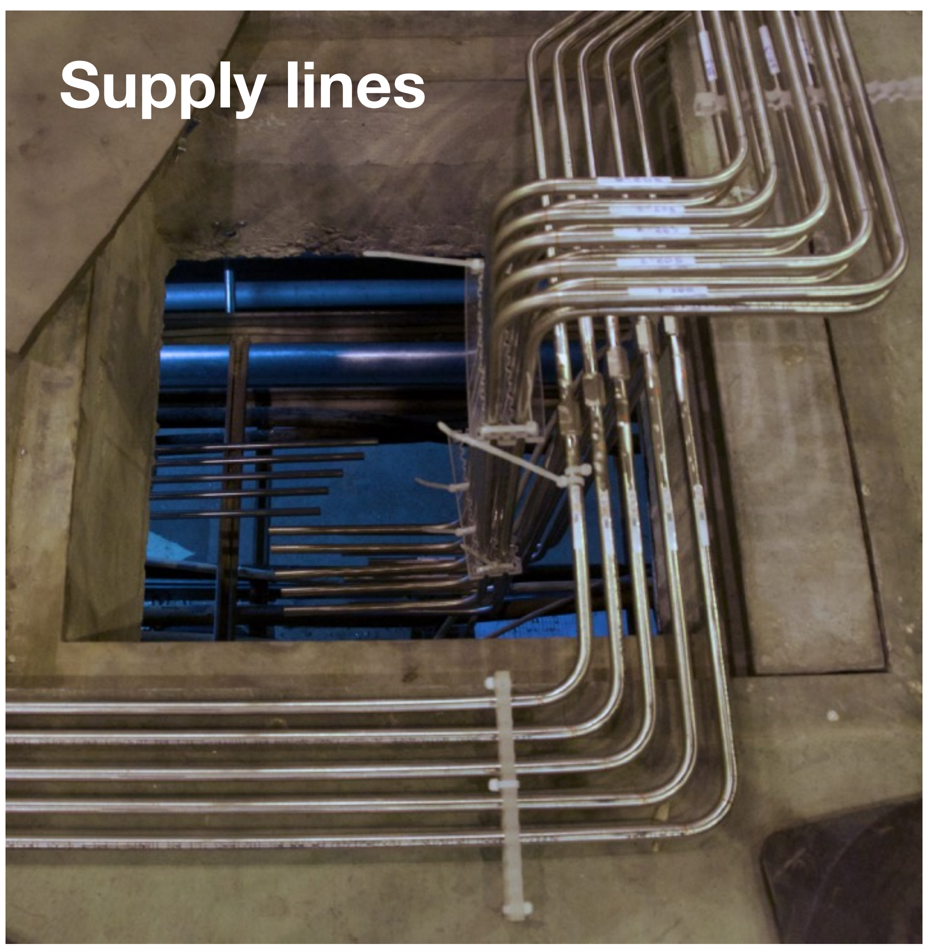
- 7 gas mixer modules
- 3 gas recirculation systems (for flow < 50 l/h)
- 1 gas recirculation system (for flow < 200 l/h still to be commissioned)
- 3 gas humidification modules
- 1 gas chromatograph
- 2 infrared analysers
- 10 O_2 and H_2O analysers
- 1 exhaust module
- 21 gas distribution panels
- regeneration of gas cleaning agents (about 10 cartridges)
- pipe work
- special gas requests (for example nC_5H_{12}, HFO, calibration bottles)
- development of interlock signals related to specific gas system conditions

In addition, EP-DT-FS Gas team developed and maintains the e-log.

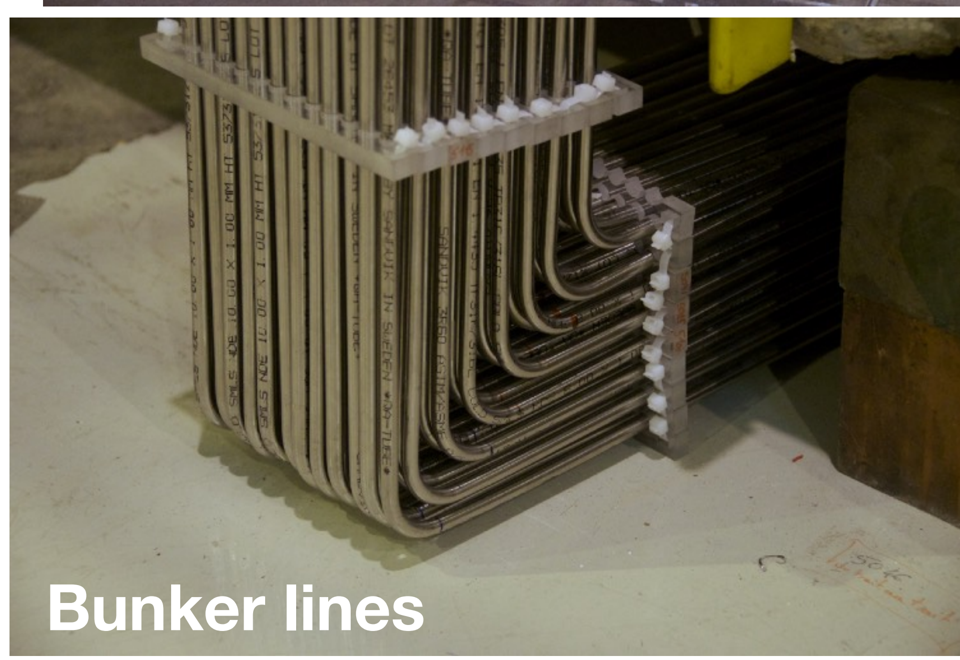
R. Guida (GIF AUM 2019)

Gas System

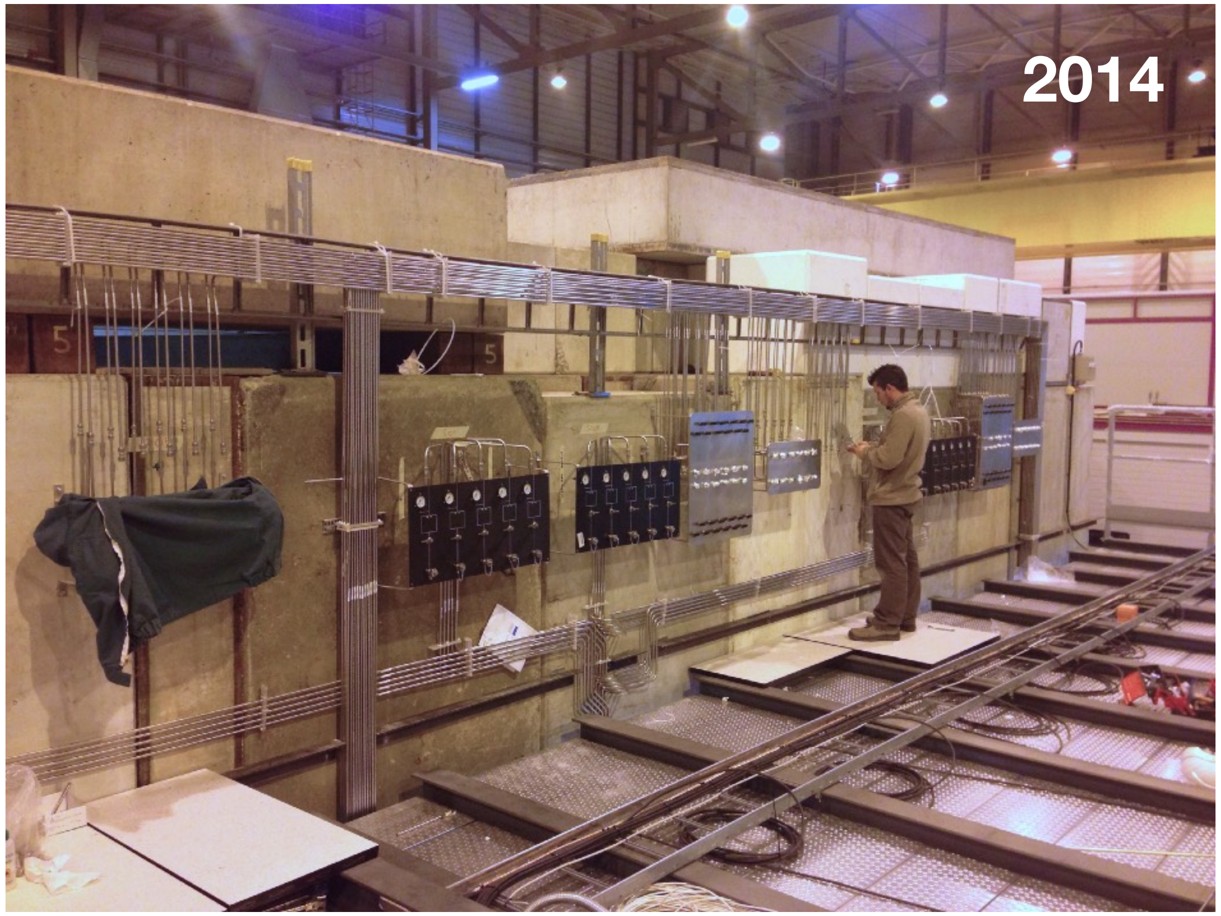

Rack distribution


Supply lines


Bunker distribution


Bunker lines


Preparation area


2014


2017

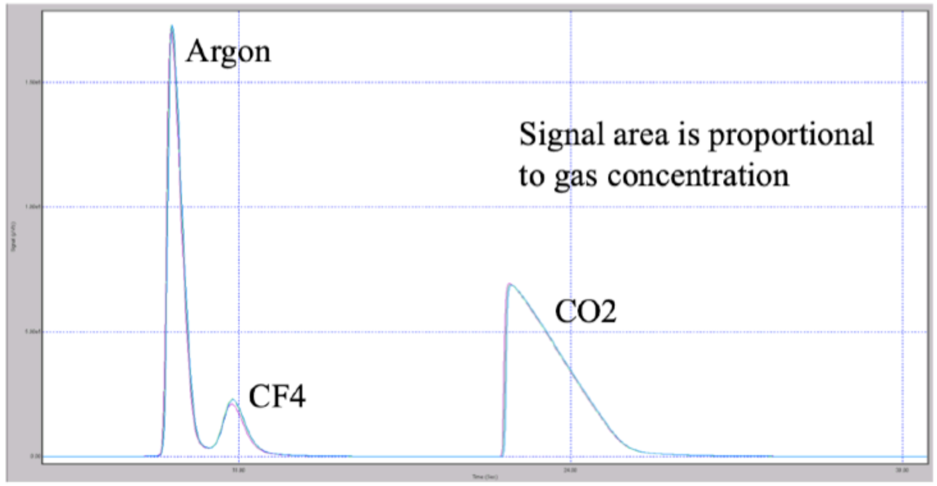

2018

Sampling manifold

PC for GC software controls

GC analyser (3 modules for large spectra gas separation)

Gas chromatogram



EP-DT-FS

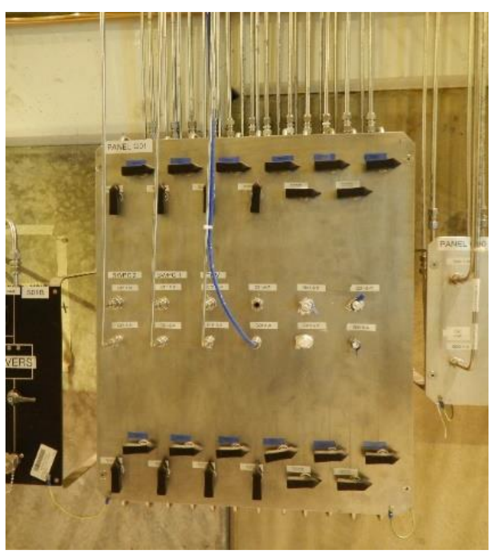
R.Guida, B. Mandelli et al

AIDA 2020

D 15.10 (M24)

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

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



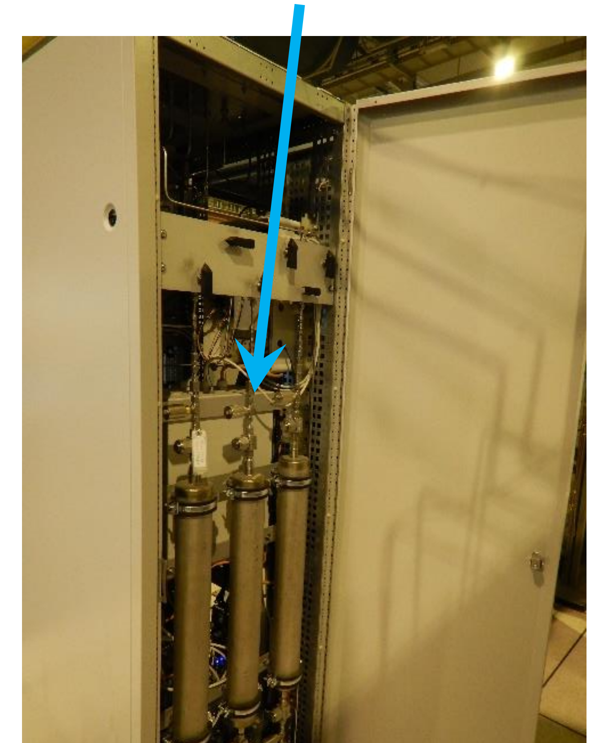
Mixture distribution

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

Additional software controlled pressure regulation for very low flow regimes

Gas mixing unit

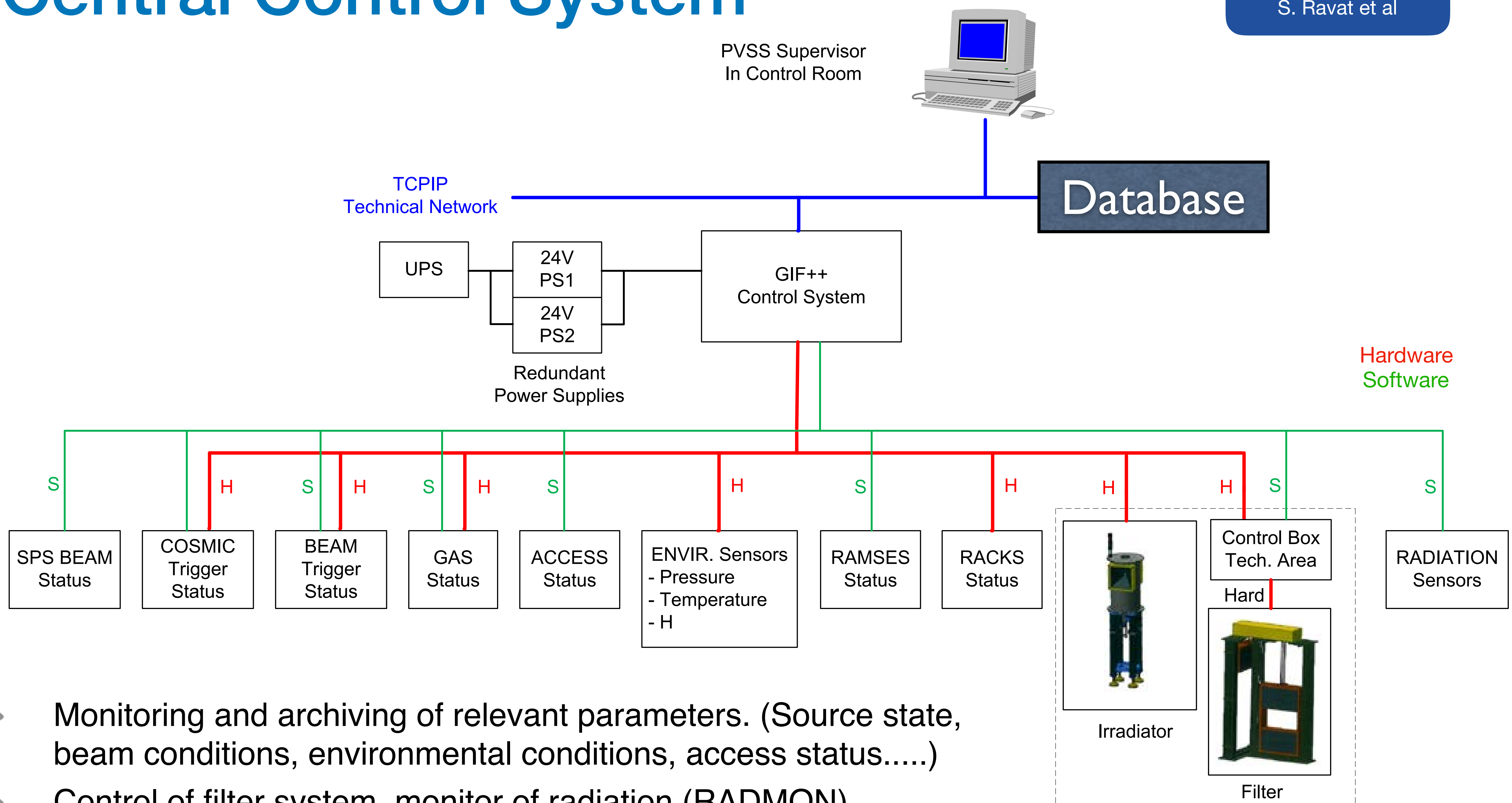
Gas purification cartridges



R. Guida (GIF AUM 2019)

Central Control System

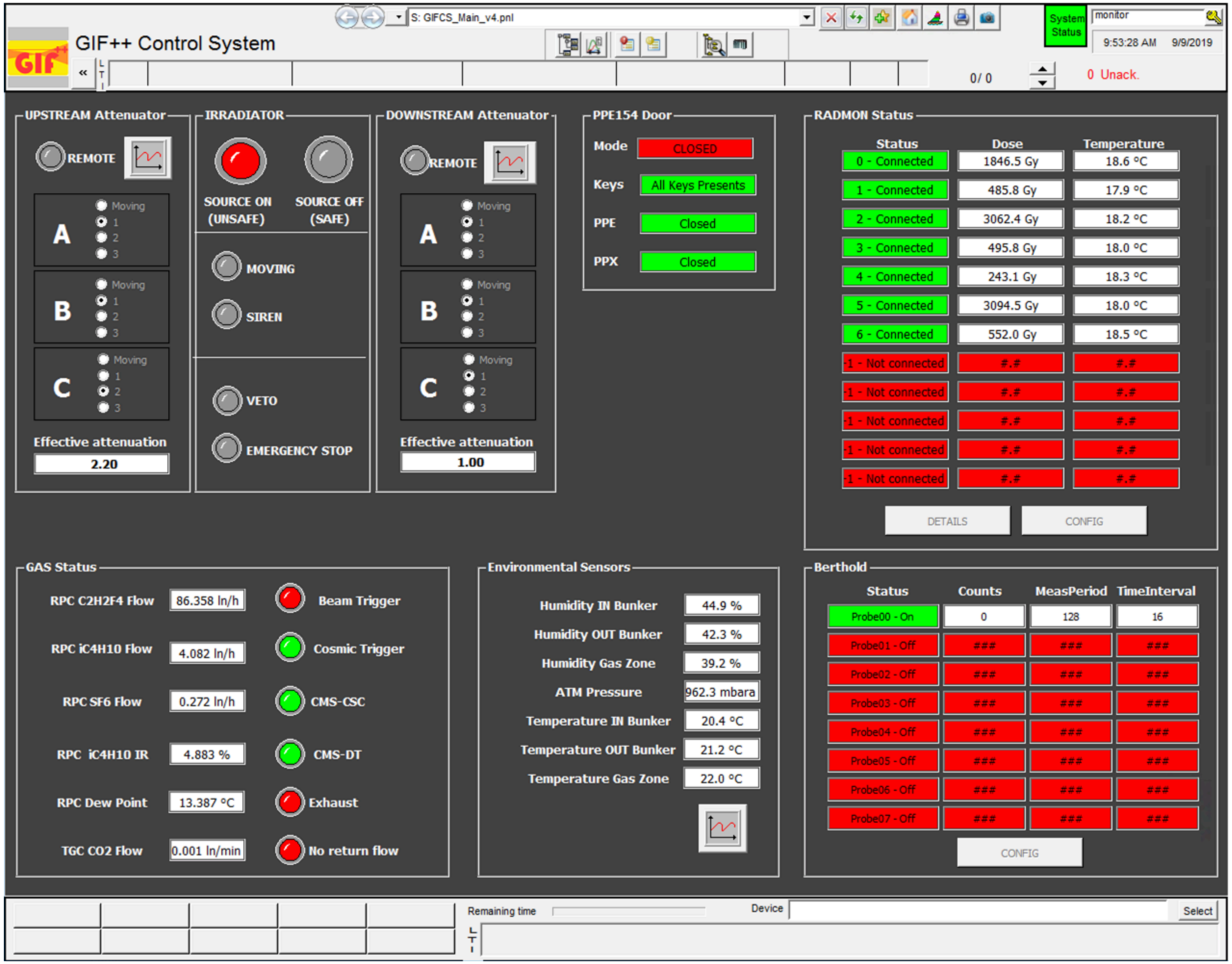
EP-DT-DI
S. Ravat et al



- Monitoring and archiving of relevant parameters. (Source state, beam conditions, environmental conditions, access status.....)
- Control of filter system, monitor of radiation (RADMON)
- Providing interlocks (e.g. on gas system faults)
- Remote monitoring, Web display....

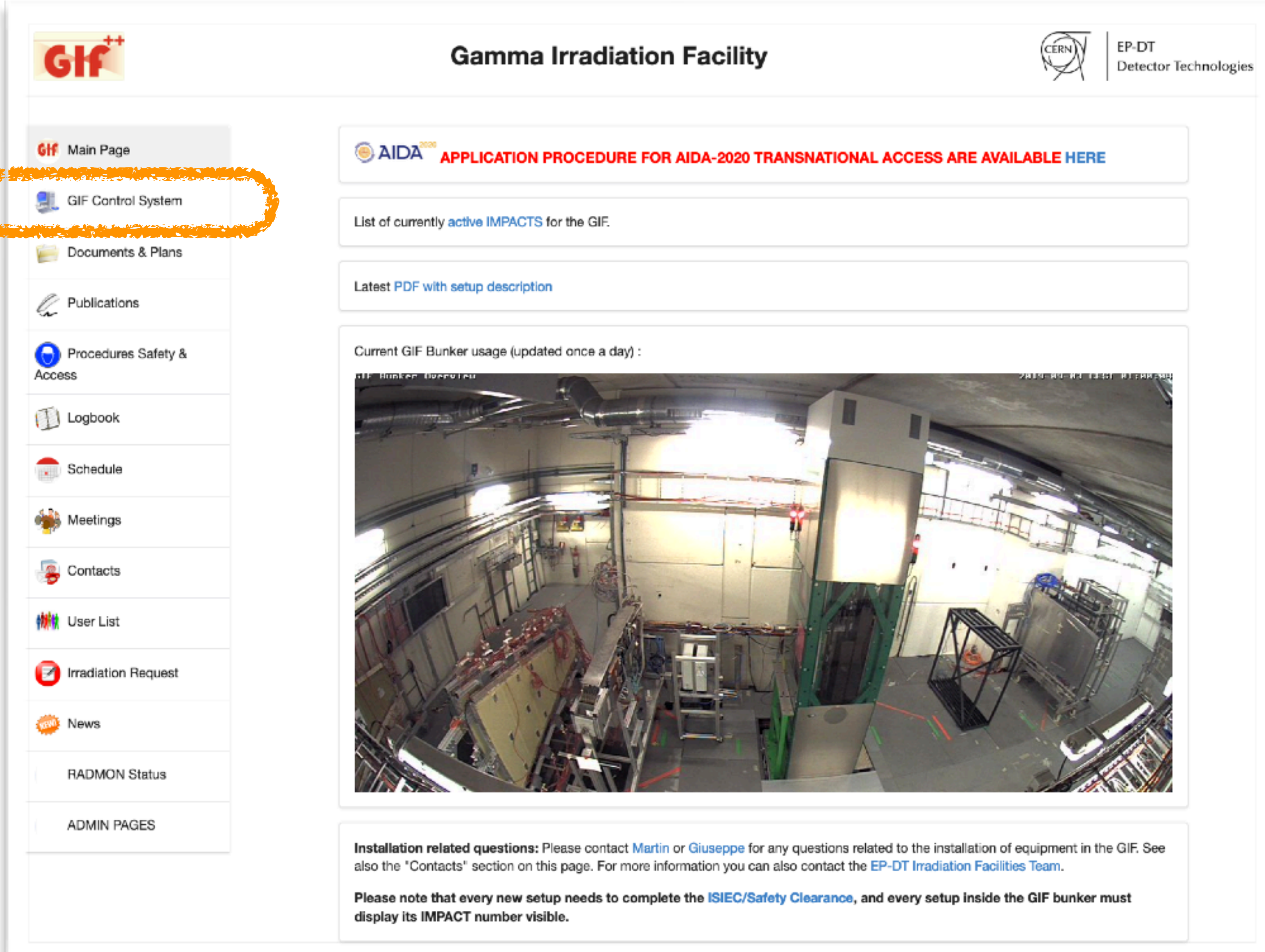
Central Control System

EP-DT-DI
S. Ravat et al



Data Retrieval Tool

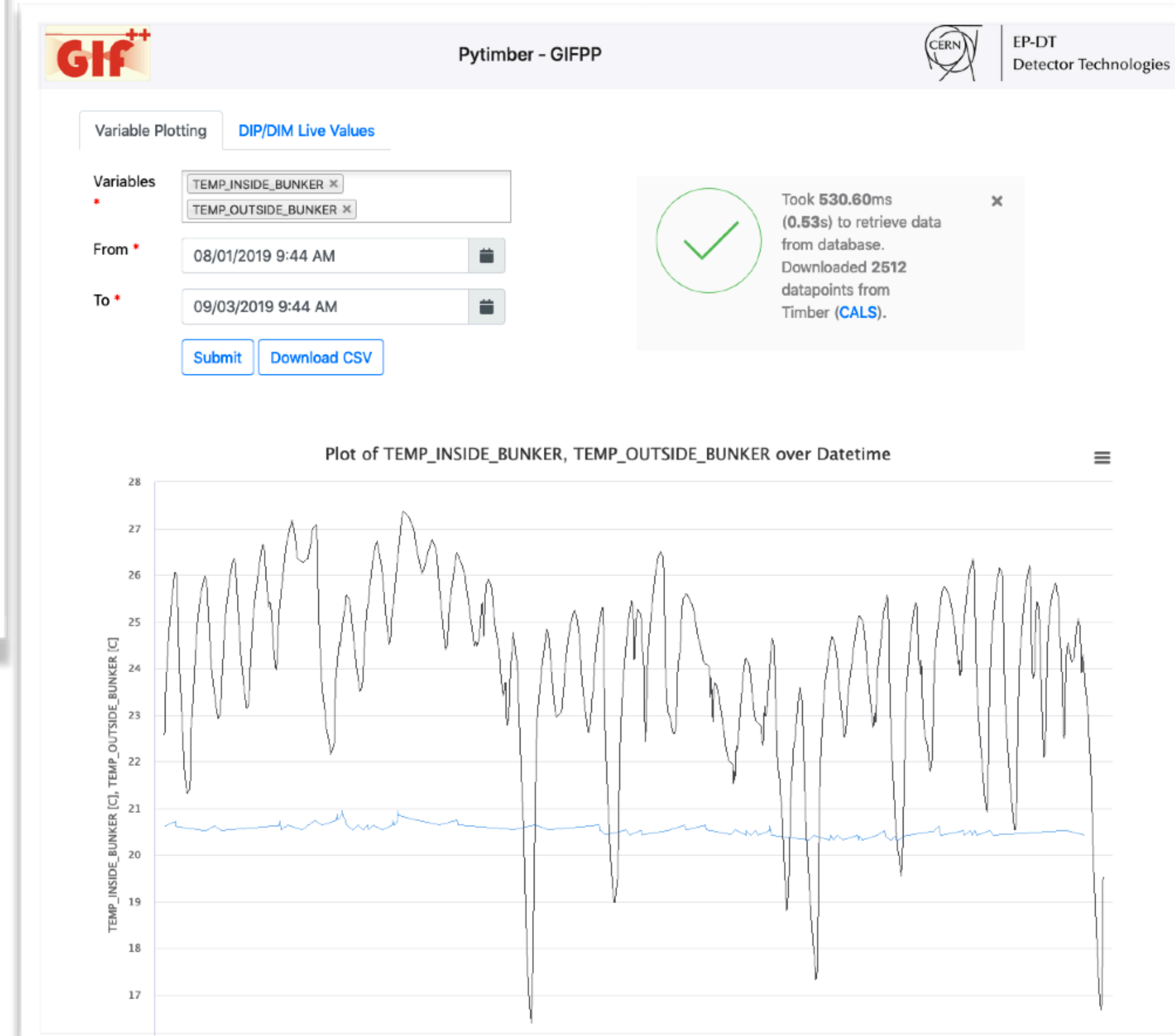
2019



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

Thanks to **Katarina Milacic**
(Summer Student)
&
EP-DT-DI

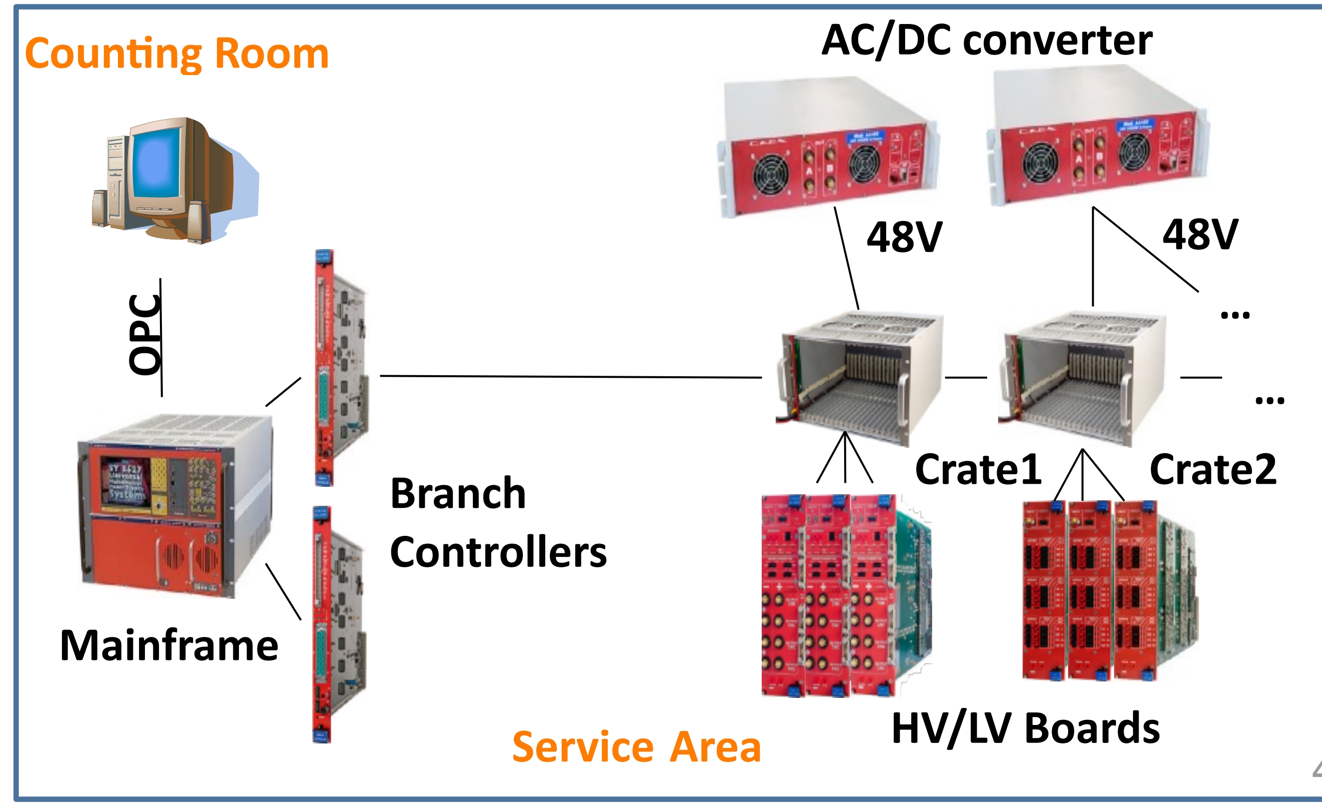
- **Improved data retrieval** (Pytimber)
- **More stable, better plotting, zooming (!)**
- **Better export to CSV with correct dates**



Restricted to members of "gif-active-users" e-group

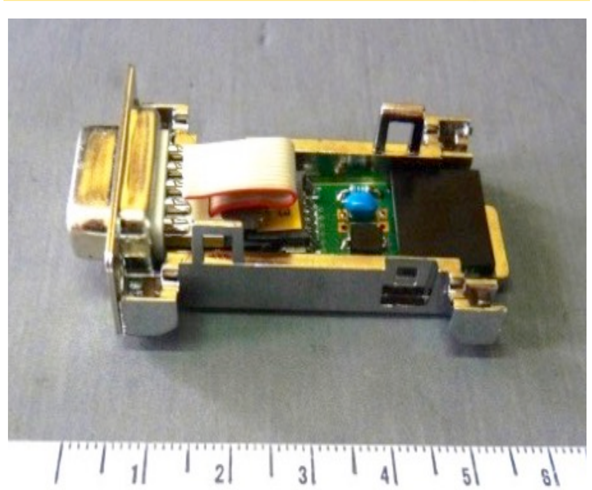
Detector Control System + Sensors

- Use PVSS/WinCC OA (as in LHC experiments)
- CAEN Easy Power System [1 mainframe, 1 Power Generator, 1-2 crates + with HV and LV boards and 1 ADC A-3801 board for monitoring (128 channels), also for ENV and gas monitoring]
- Mainframe and PC in proximity of the control room (radiation-free area) along with DAQ PCs and equipment
- EASY crates and other equipment closer to detector area



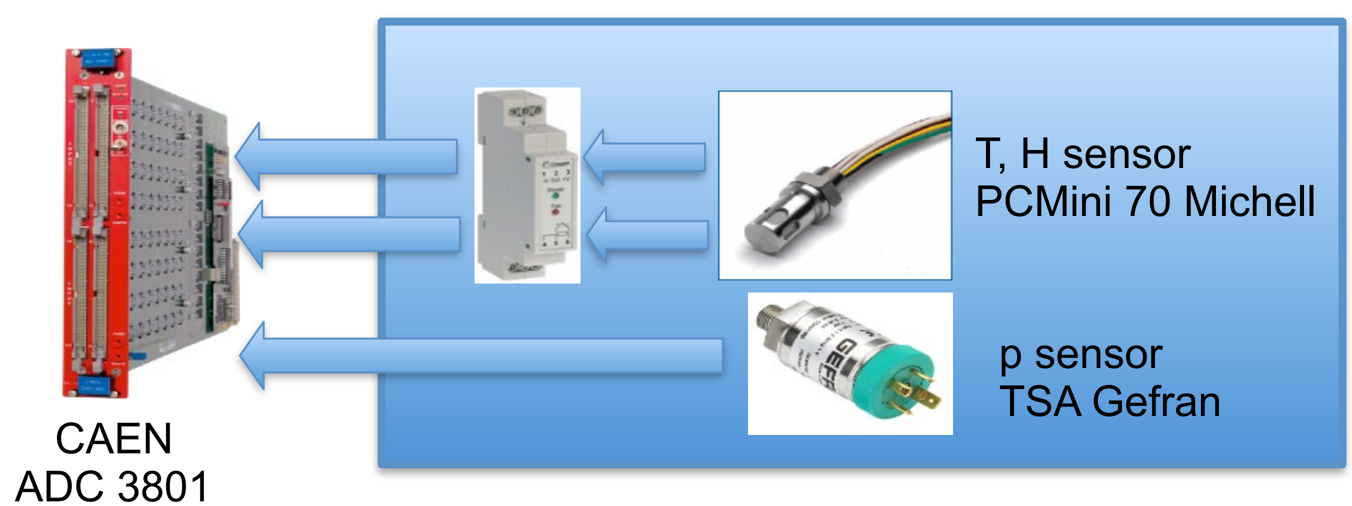
Radiation sensors

RADMON PCB BASED WITH 2 RadFETS DETECTORS
1xLAAS 1600 - till 10 Gy
1xREM 250 - till 2000 Gy

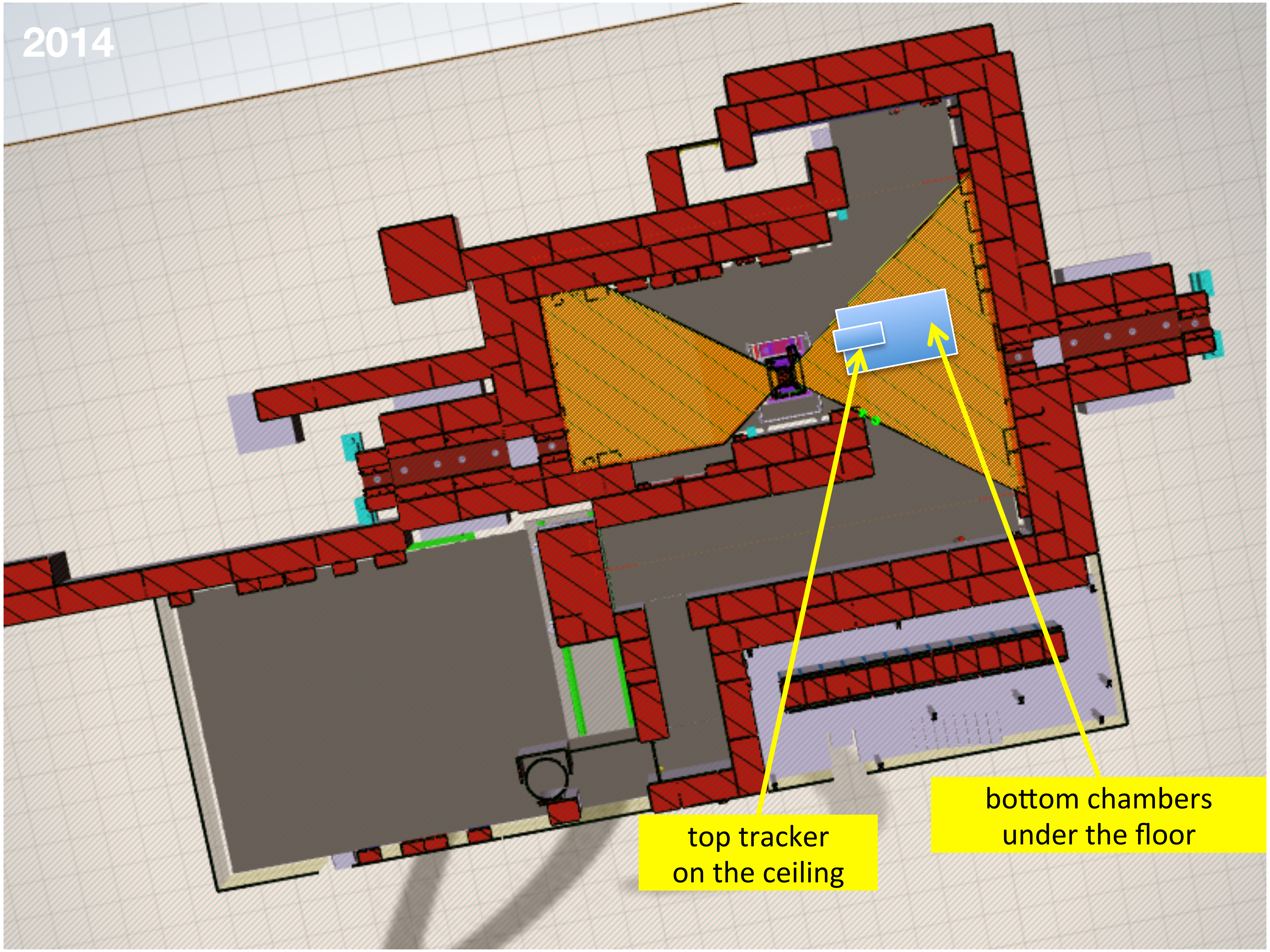


Gas and Environmental sensors

Monitoring (for both atmospheric and gases): **p, T, rH**
Baseline: 4 gas and 6 atmospheric sampling points



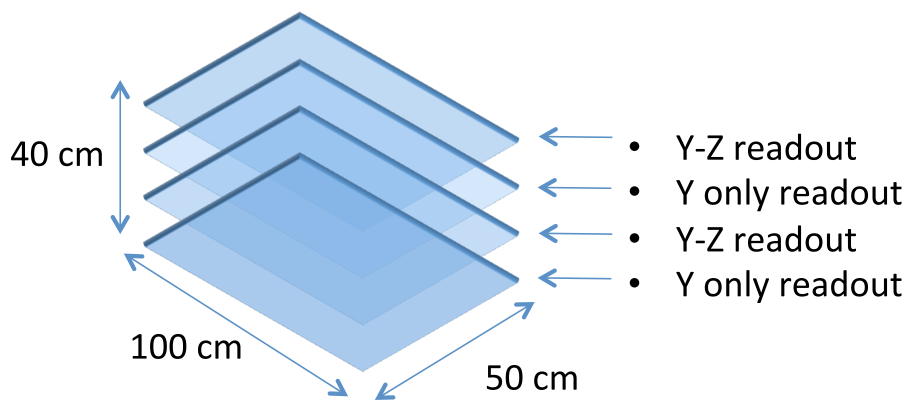
Cosmic Tracker System



Cosmic Tracker

Roof chambers

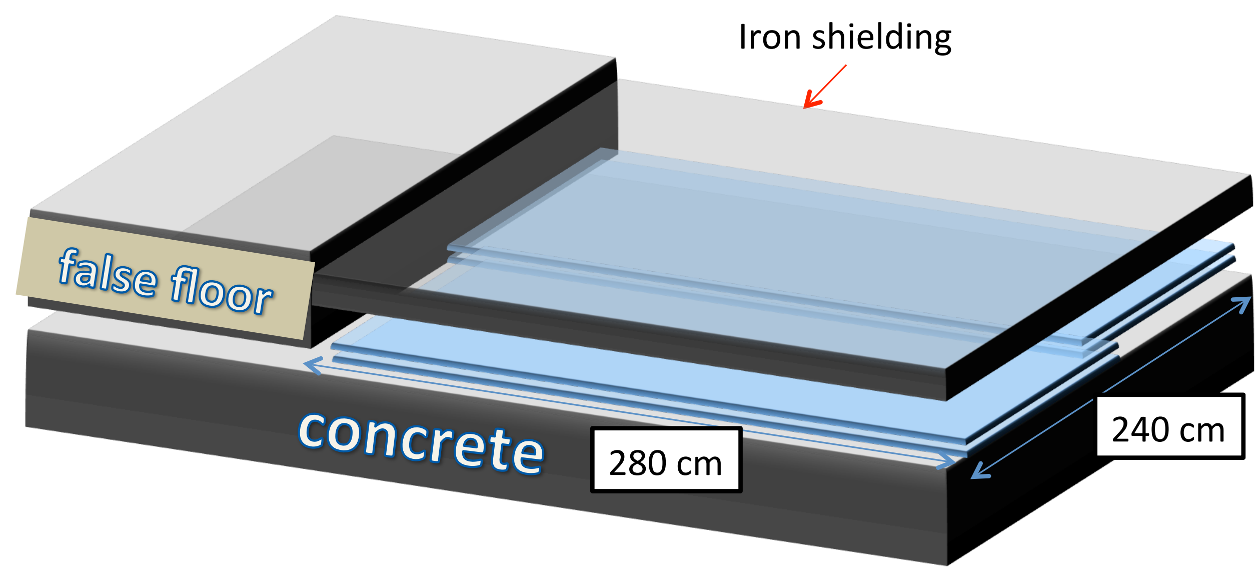
- Trigger and high time resolution
  - new RPCs with 1 mm gas gap
  - 3 - 4 independent detectors with area 1.0x0.5 m^2
  - strips 2.5 cm wide
    - 1 m long strips in all 4 RPCs
    - 0.5 m long strips in 2 out of 4 chambers



View from bottom

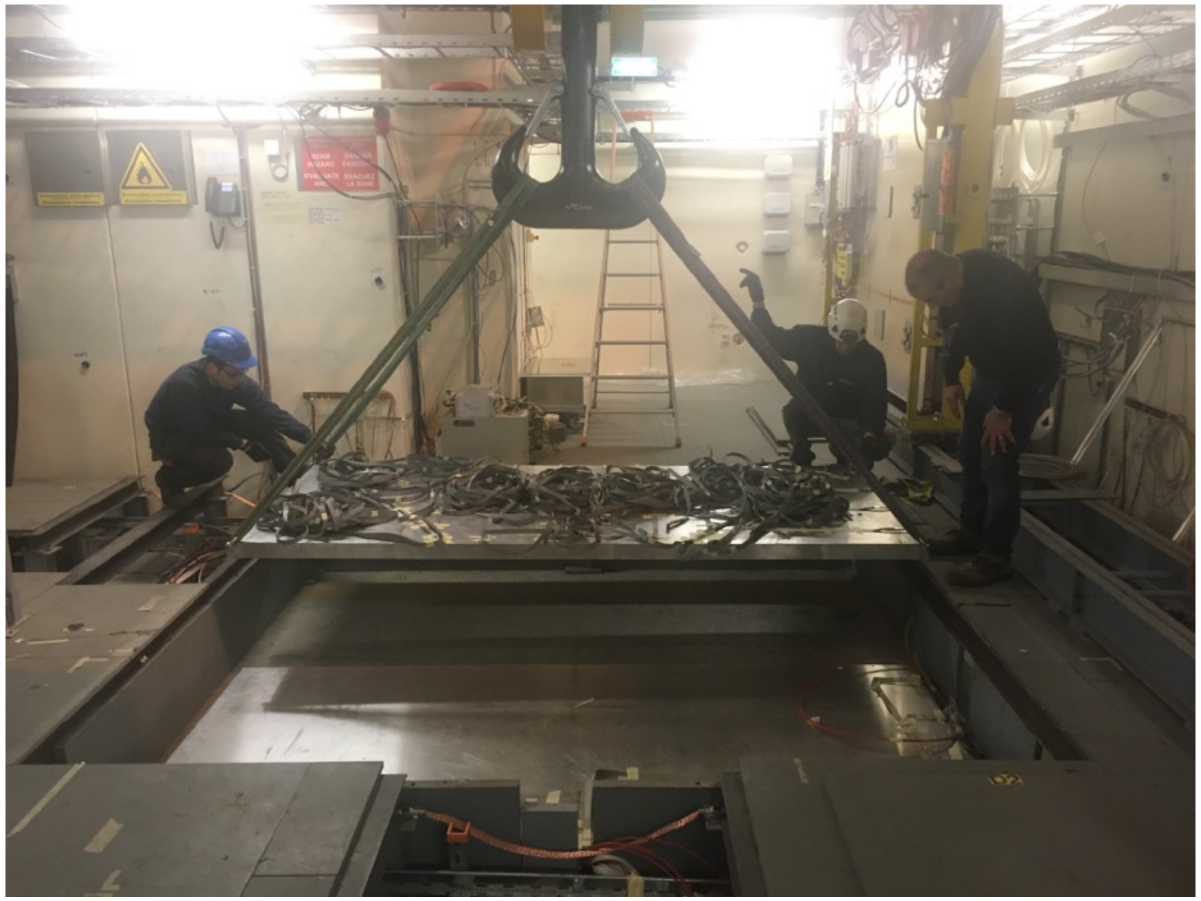
Bottom chambers

Underground detector
- ATLAS-like RPCs with 2 mm gas gap
- Double layer chambers: total size 2.8 x 2.4 m^2
- Two chambers with bi-dimensional read out with 4 cm wide strips

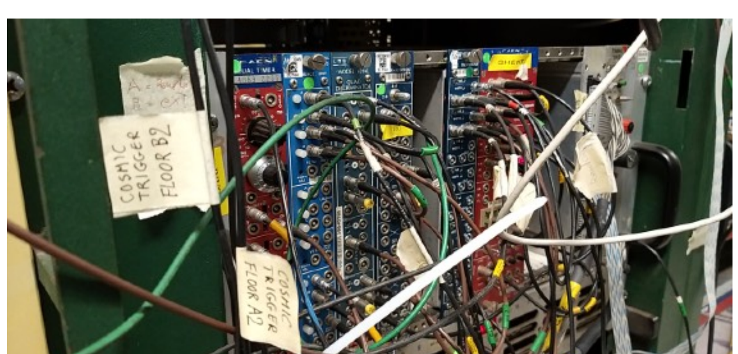


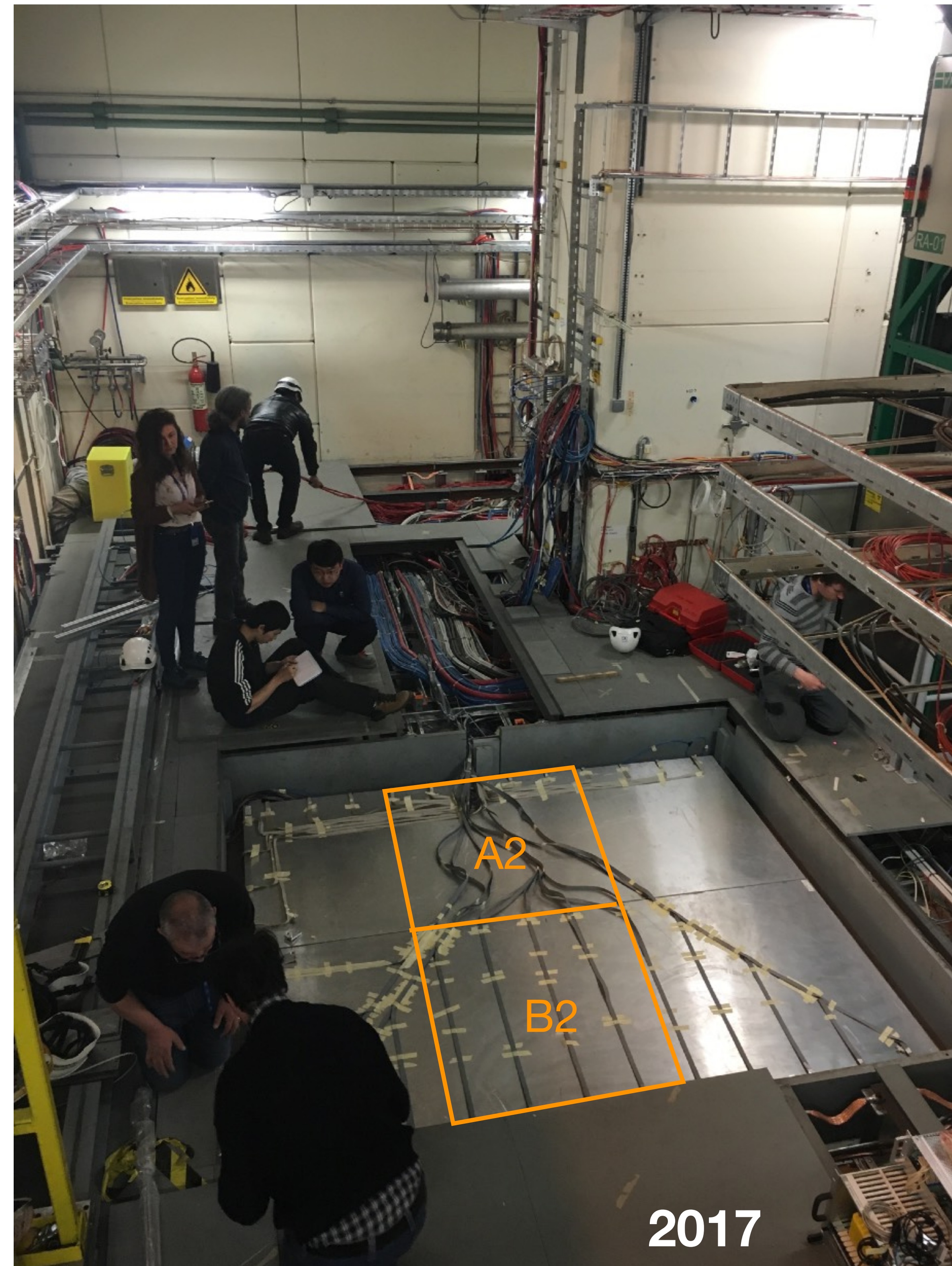
INFN Istituto Nazionale di Fisica Nucleare
AIDA

Installation of Cosmic Trigger Floor Chambers



- Installation of first floor chamber in 2015, second chamber in 2017
- NIM crate with coincidence logic between the two chamber layers
  → 2 LEMO cables
- Two trigger signals available from central part of the chambers, need additional crates with NIM modules to provide trigger from entire chambers



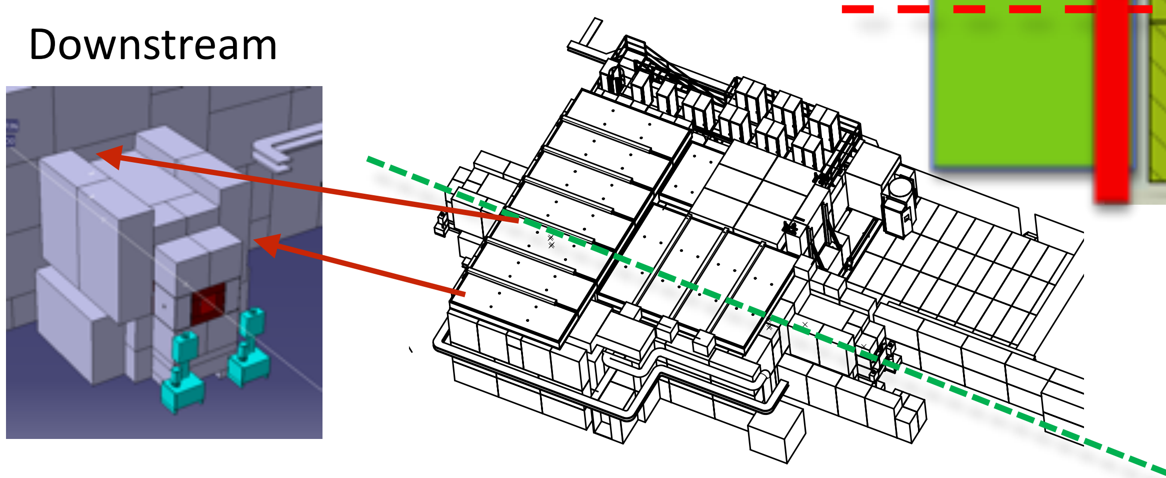


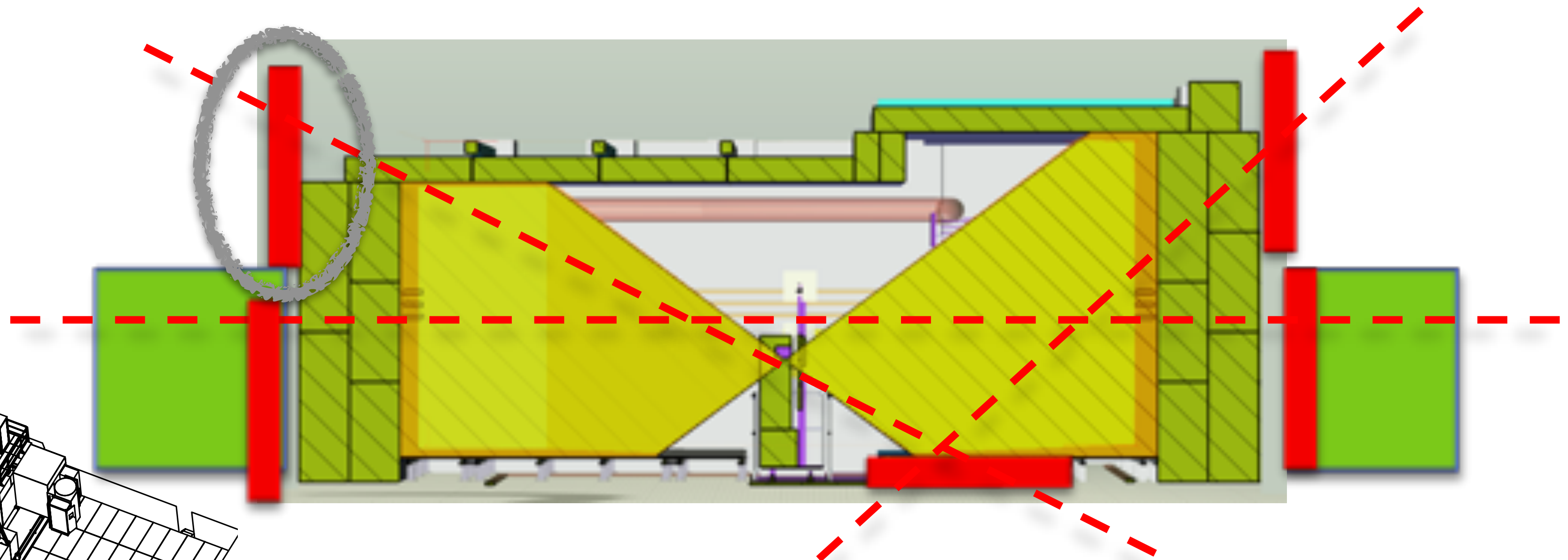
Installation of Cosmic Tracker Roof Chambers

- Roof chamber support designed during 2018 (incl. steel shielding)
- Installation of supply during 2019 Bunker Extension
- Raising of 2 roof tiles by 40 cm to provide additional shielding
- Installation of 3 chambers finished, readout to be completed in late 2019 / early 2020

Extended Cosmic Trigger

AIDA 2020
deliverable D15.11



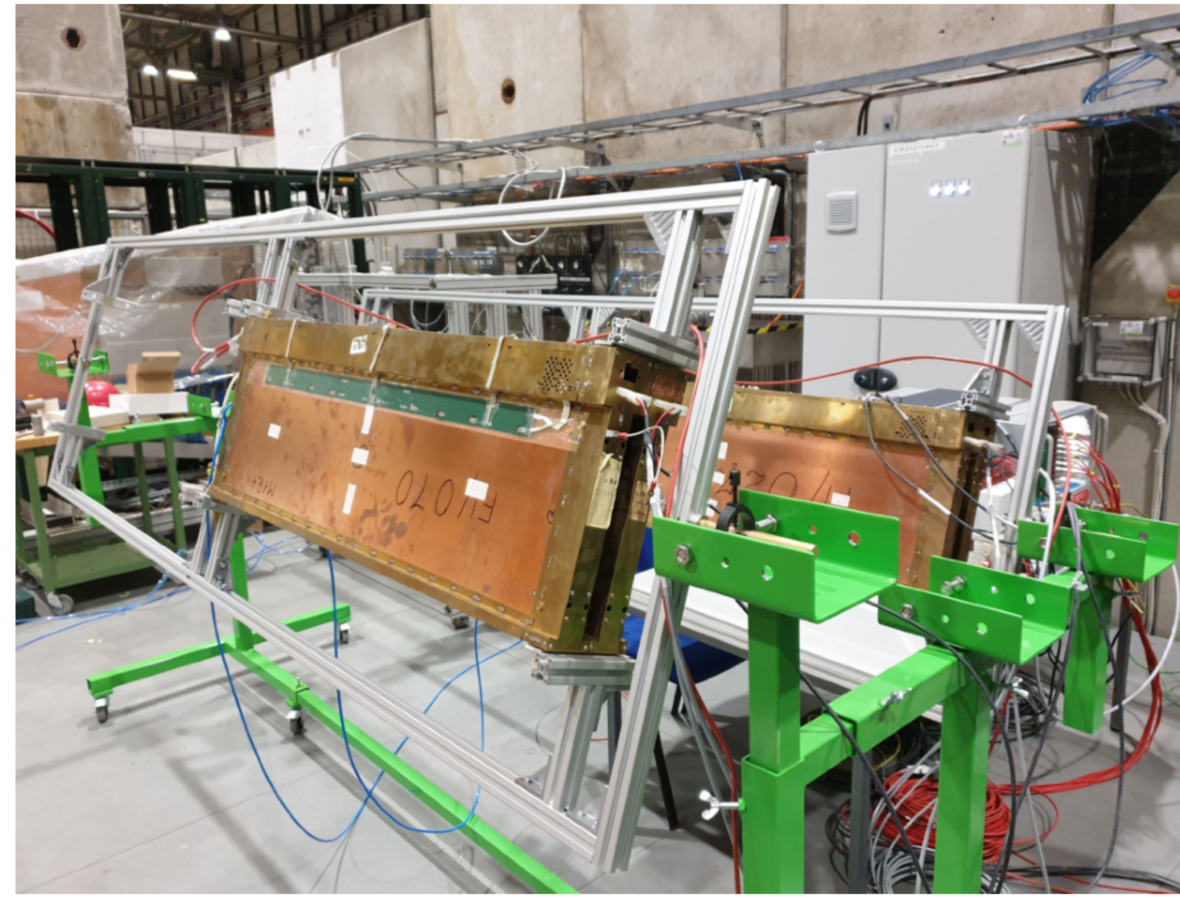


- **Additional 2 trigger chambers to be installed outside GIF bunker for triggering on beam halo**
  Position of downstream chamber fixed, upstream chamber can be defined now
- **2 additional chambers planned for cosmic trigger**
  Position of downstream chamber fixed, original proposed position of upstream chamber to be redefined.
- **Material on site, completion expected during 2020**

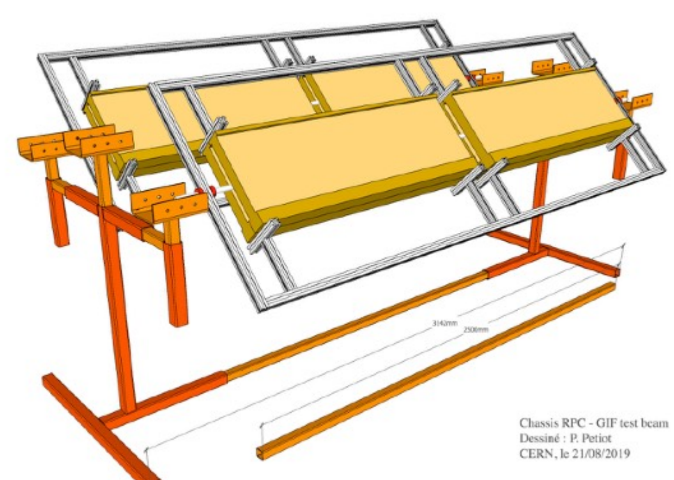
LHCb MWPC based Cosmic Trigger

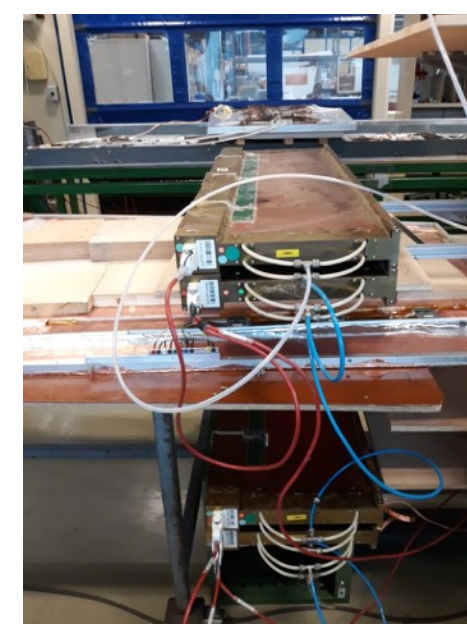
2019

- 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 ≈ 10^5
- 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

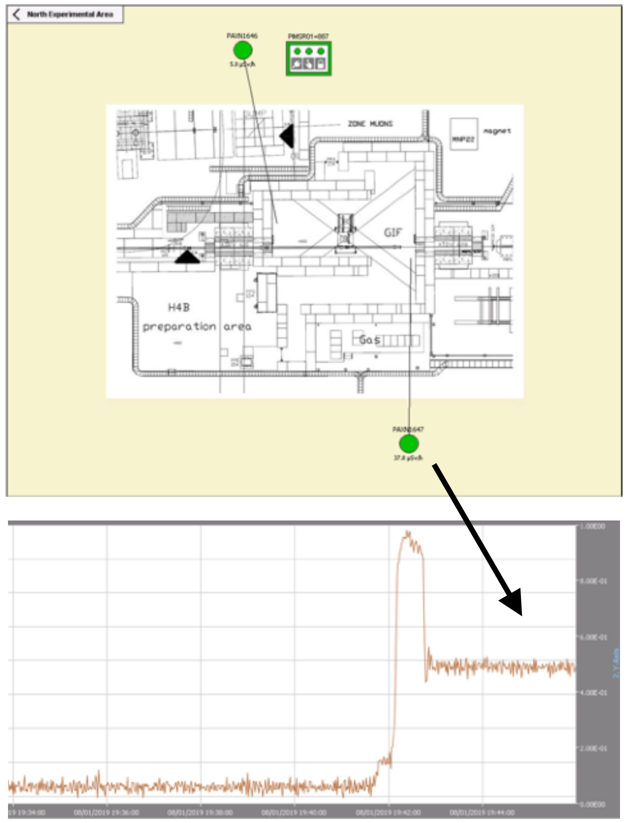




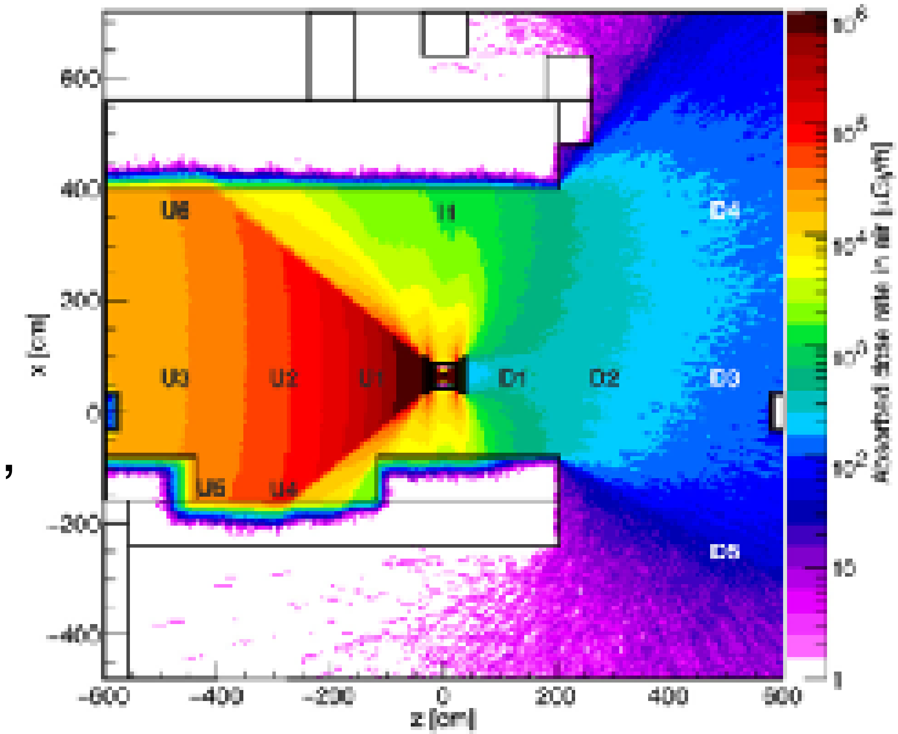
More info about the LHCb MWPC: see W.Riegler note http://cds.cern.ch/record/681186?ln=en;

Radiation Monitoring

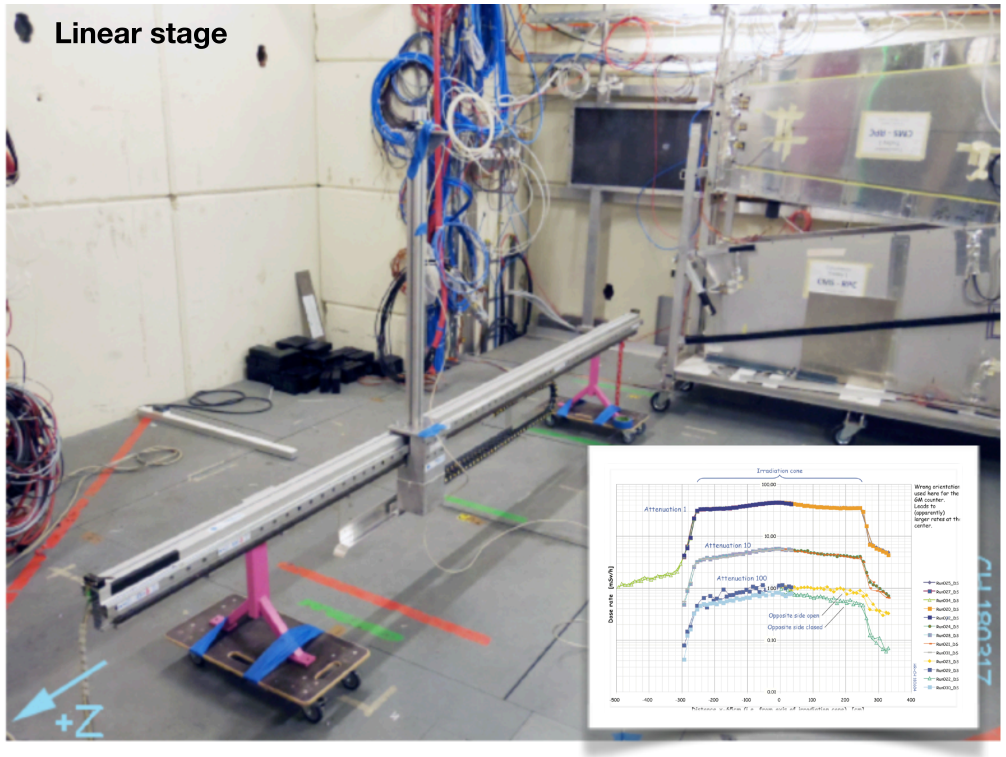
The Radiation Field in the New Gamma Irradiation Facility (GIF++) at CERN
D. Pfeiffer, G. Gorine, H. Reithler, B. Biskup, A. Day, A. Fabich, J. Germa, R. Guida, M. Jaekel, F. Ravotti,
Nuclear Inst. and Methods in Physics Research, A 866 (2017) 91-103

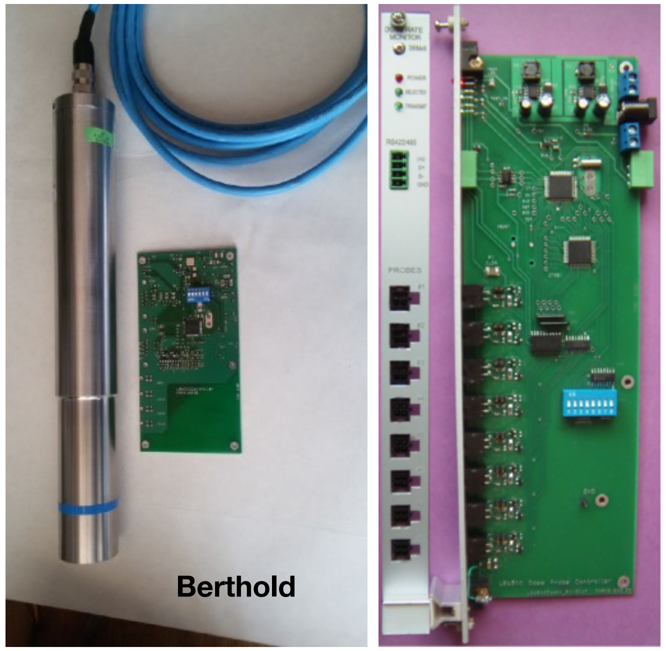


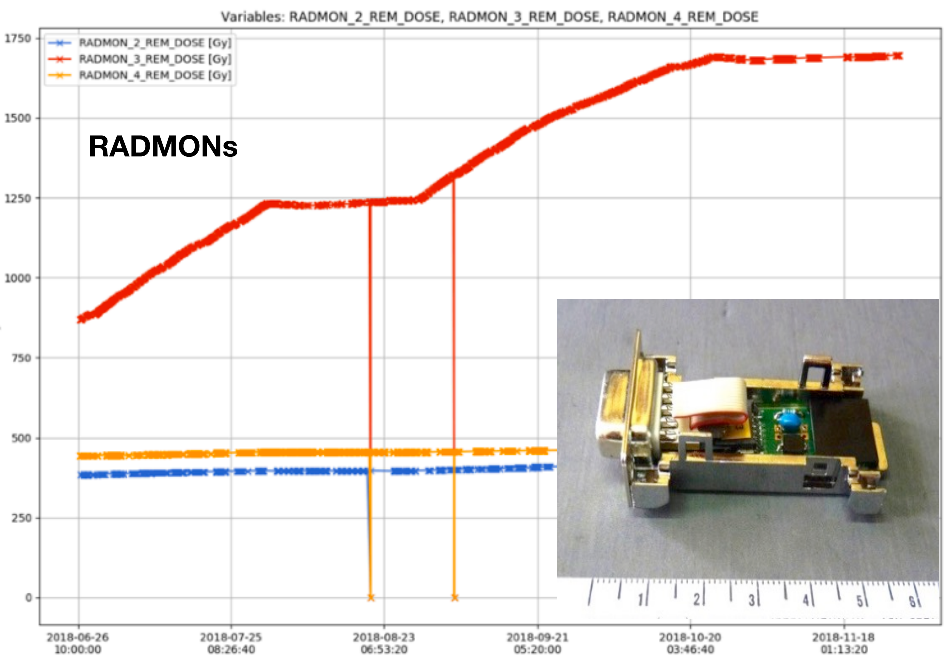
- 12 x RADMON sensors, that can be distributed throughout the facility
- 2 independent REMUS detectors, accessible via DIP & TIMBER
- 2 Berthold counter GM LB6500 (P.Iaydjiev et al) + AUTOMESS AD6 dosemeter with external probe
- 3.2m translation stage, remote controlled, that can be equipped with dosemeter / counter



(b) D closed/U open.







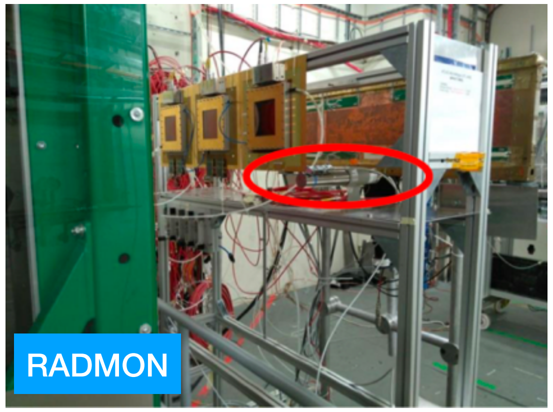
GIF User Operation

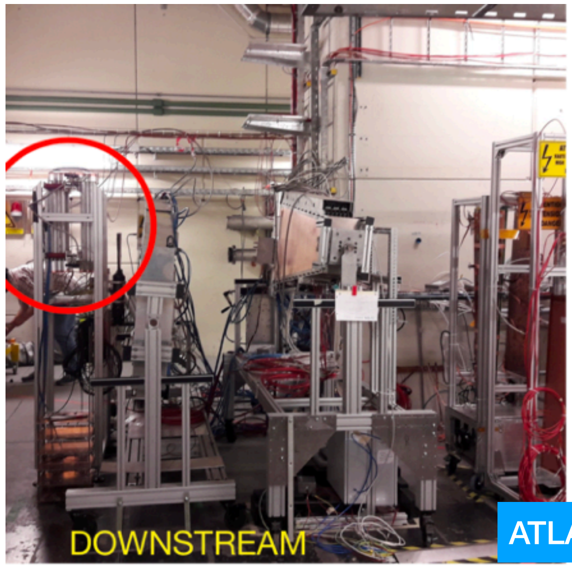
GIF++ Main R&D

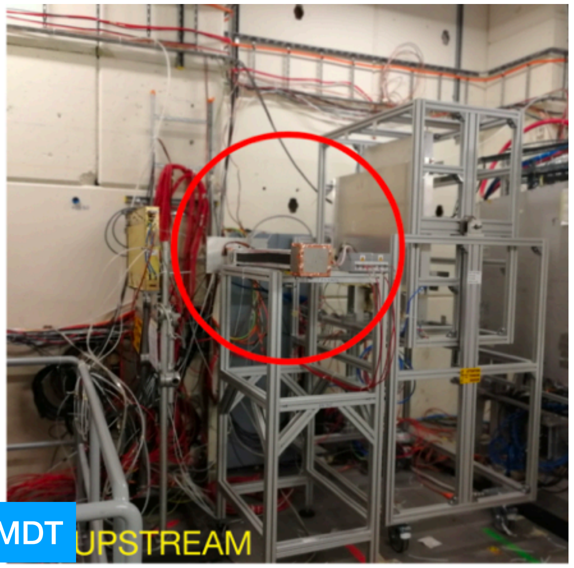
- Ageing tests under radiation
- Detector validation tests in presence of high radiation background + muon beam

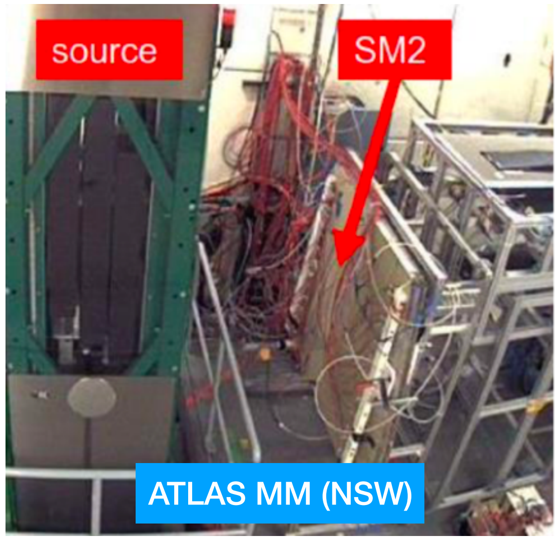
Annual User Meeting :

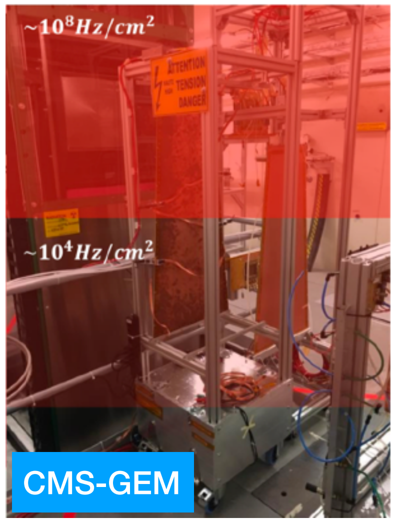
https://indico.cern.ch/e/GIF-AUM-2018 / GIF-AUM-2019

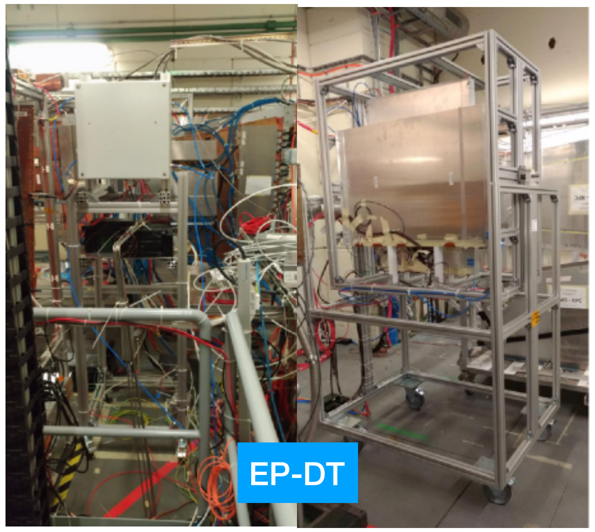


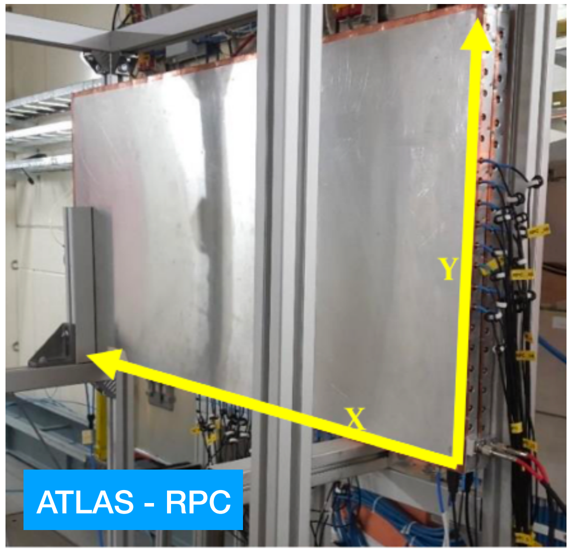


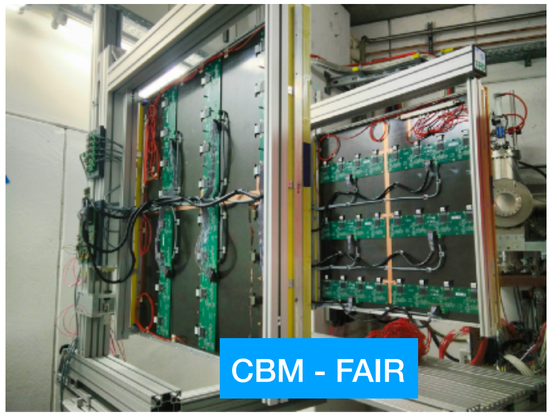










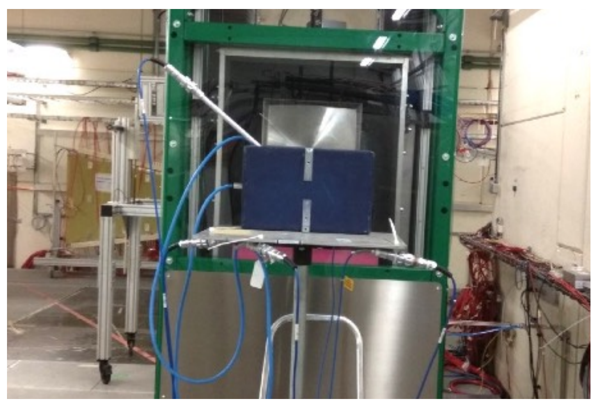


Facility designed / optimised for Muon gas detectors for the LHC experiments upgrade projects, but also hosts a large variety of other users (e.g. BLMs for beam instrumentation)

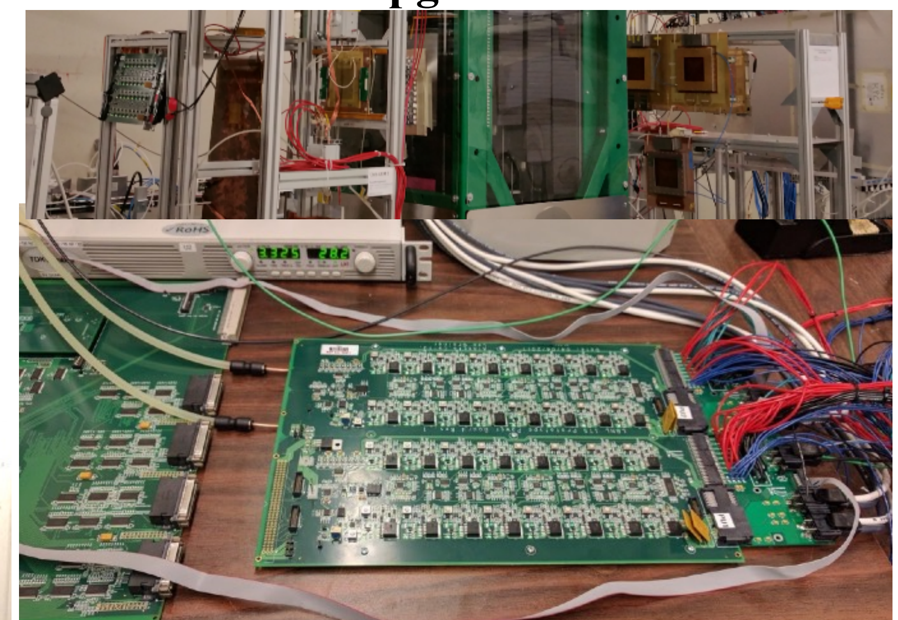
Wide Range of Smaller Test Campaigns

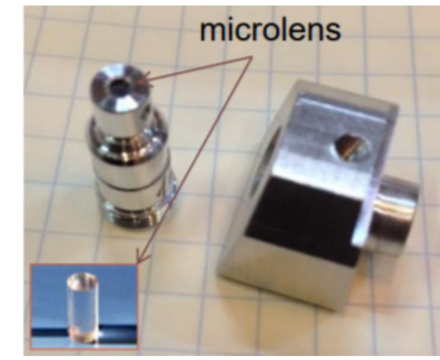
EN-CV - tightness of cooled cables manifolds

Filter box -collaboration btw ESA and CERN

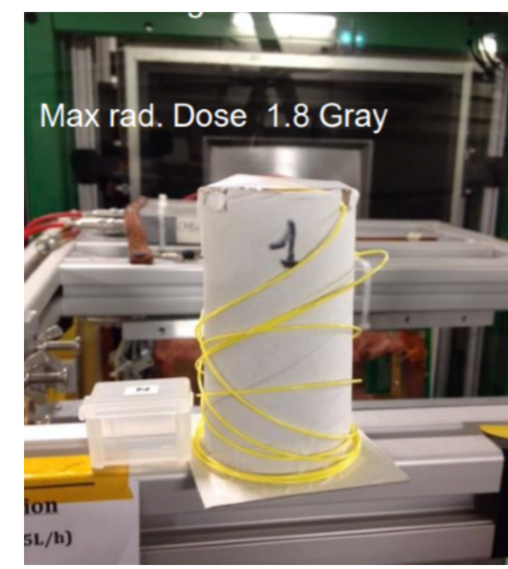


ALICE ITS Upgrade Power Board

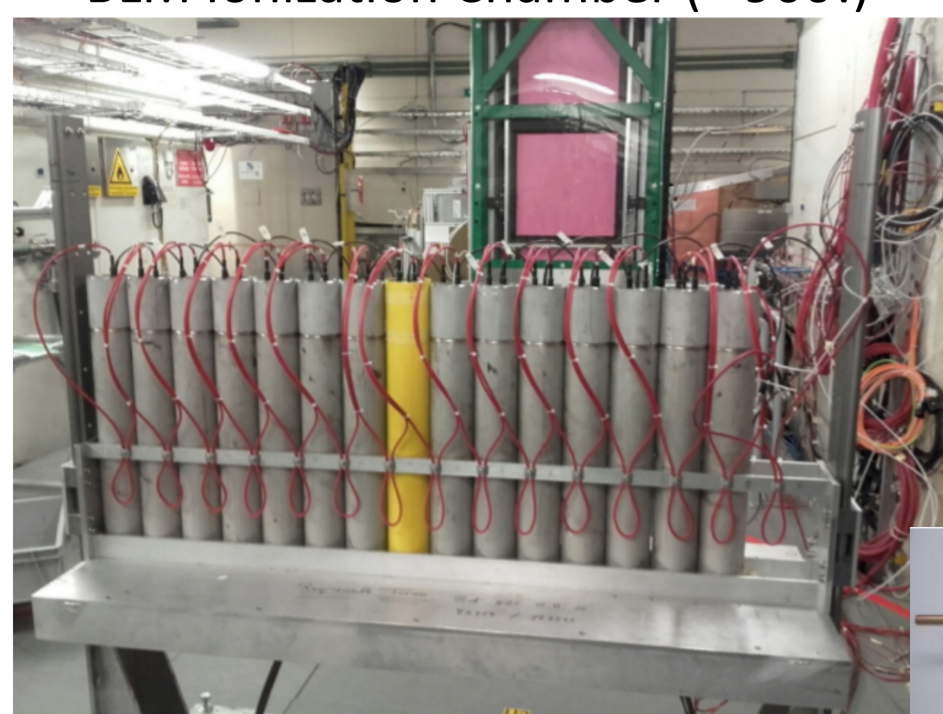




µlens and optical fibres for the TOP PID detector of Belle II experiment



BLM Ionization Chamber (≈ 900!)

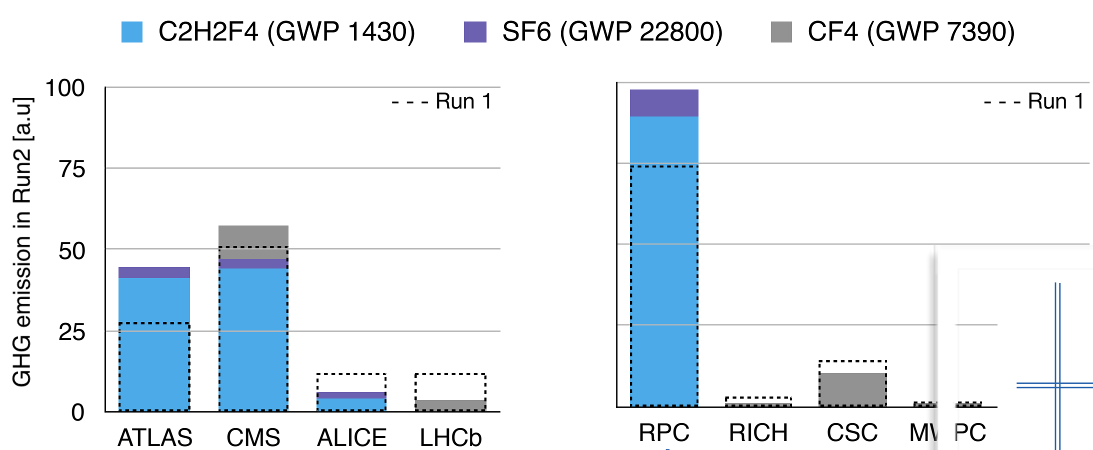


Plastic scintillator rods with Gafchromic™ films - CMS UMD collaboration

Eco Friendly Gas Mixtures

B. Mandelli, DT Group Meeting Jun 2019

Where does the GHG emission come from?



Very large Detector volumes

Small Detector volumes

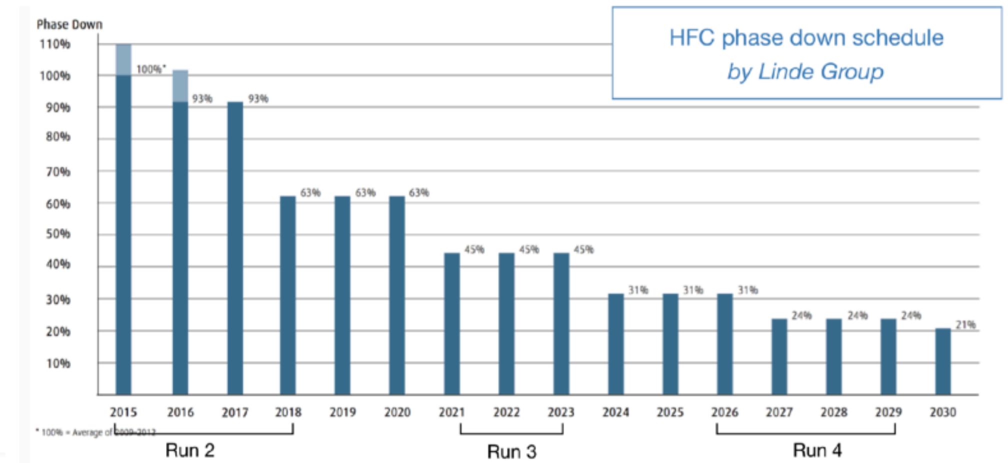
Leaks in detectors *(ATLAS and CMS)*

Gas Recuperation systems *(CMS - LHCb)*

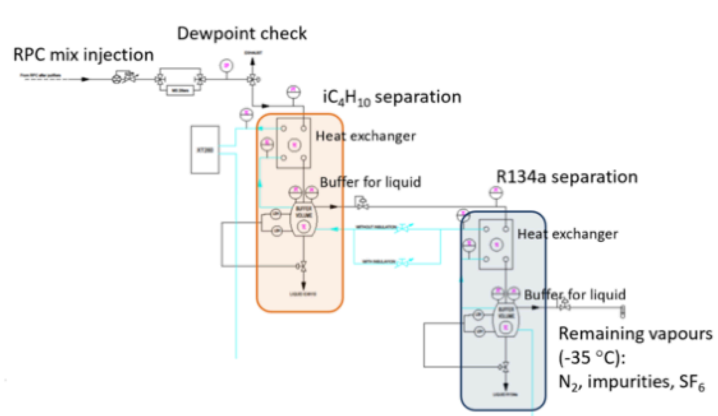
Gas Reci... *(LH...*

"A day of operation at CERN is a day of a cruise ship [operating]." Bo...

Beatrice Mandelli 2



New system for the recuperation of $C_2H_2F_4$ (and SF_6)



Experimental set-ups for eco-gas studies

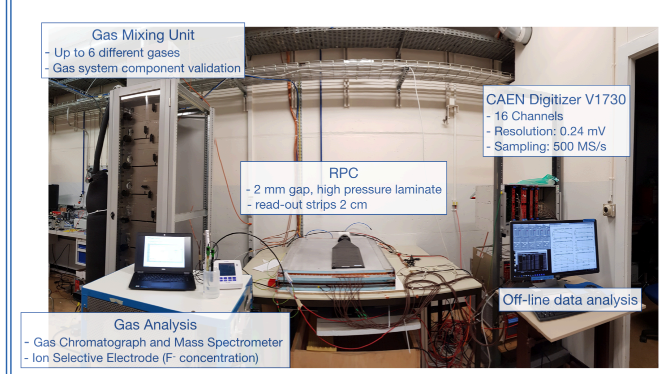
The goal is to find an eco-friendly gas mixture that is compatible with the current ATLAS and CMS RPC systems (i.e. no change in HV cables, FEB electronics, gas system, etc.)

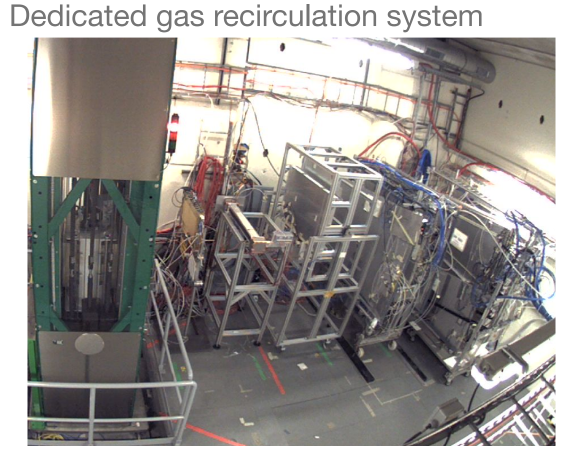
Laboratory set-up

- Search for new eco-friendly gas mixtures
  - Up to 6 components in gas mixture
  - Characterisation of new eco-gases
- Validation of gas system components

GIF++ set-up

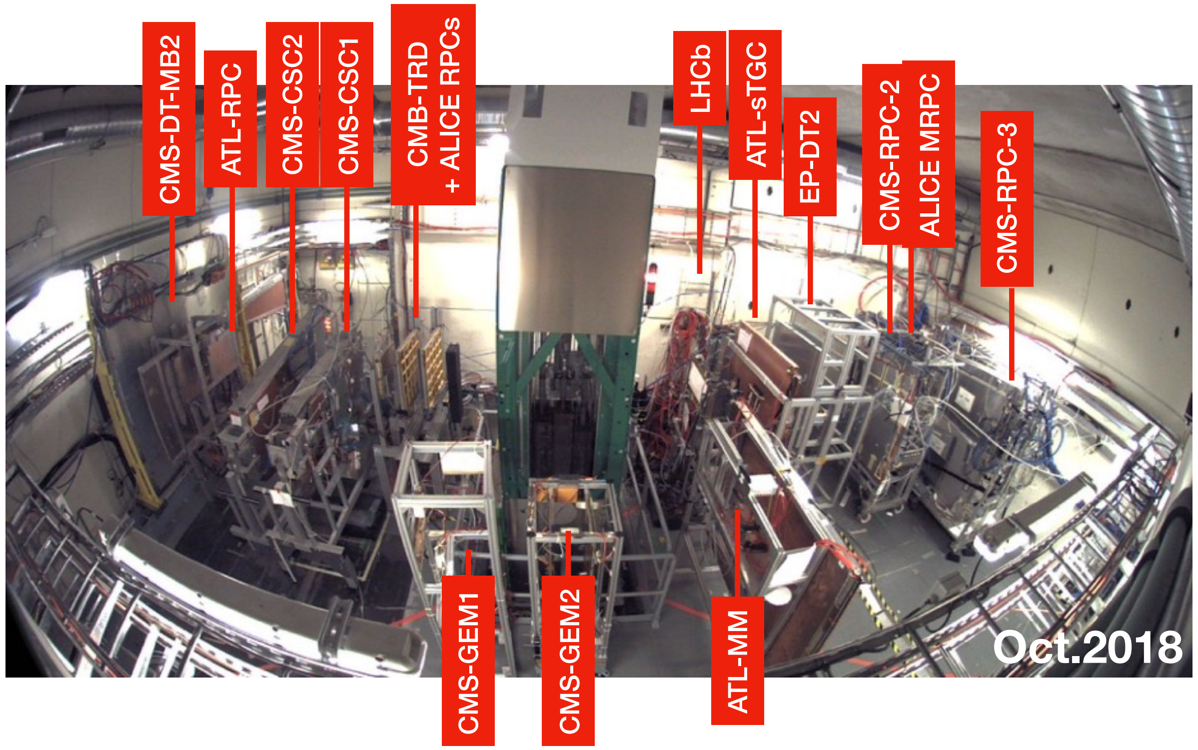
- Validation of selected eco-friendly gas mixture in LHC and HL-LHC environment
  - Rate capability, time resolution, etc.
  - Gas mixture radiation tolerance
- Validation of gas system with new eco-friendly gases
  - Dedicated gas recirculation system





Beatrice Mandelli 7 12 Jun 2019

2018 Muon Beam Overview



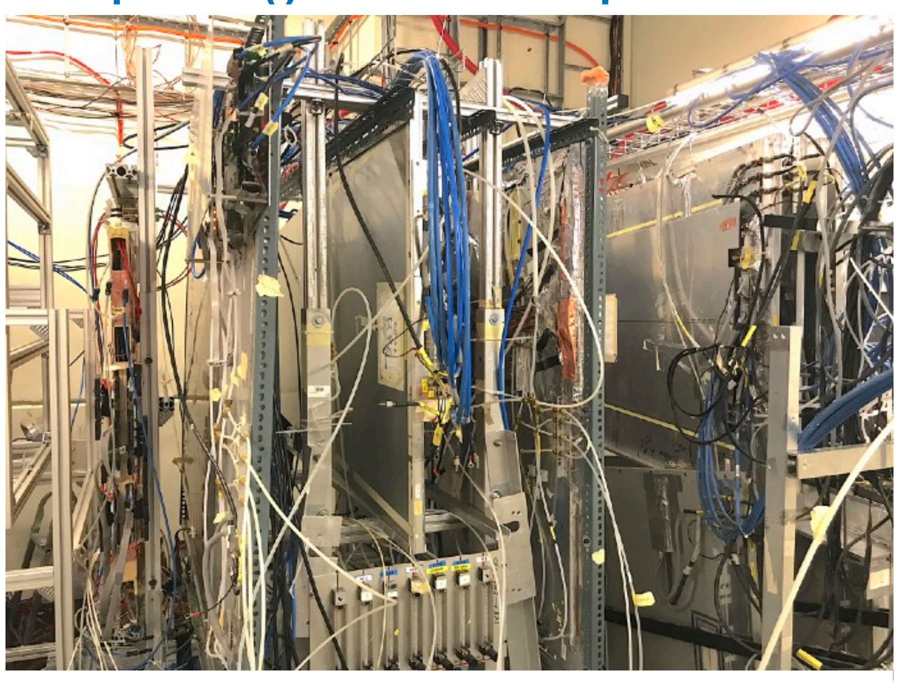
Very successful run in 2018 with **9 - 11 different setups simultaneous in the muon beam** during 7 weeks of shared beam time with RD51.

Extensive gamma-irradiation program throughout 2018 with **22 large setups competing for irradiation**.

Challenging optimisation between high- and low-field irradiation.

Nr #	IMPACT		position (meters from the source)		setup size (beam dir x width x height)	#weeks (total)	Apr 25-01	May 02-08	Aug 01-07	Aug 08-14	Aug 15-21	Aug 22-29	Oct 24-30
1	117032	ATL-sMDT	0.5	Upstream	0.8 x 1.2 x ? m	3	-	-	X	X	X		-
5	115206	ATL-sTGC	1.5	Upstream	0.5-1 x 1.5 x 1.5 m	3					X	X	X
3	106299	ATL-MM & MM-LM2M0	1.5	Upstream	1m x 1.4m x 1.8m	1	X						-
18	112713	EP-DT 2	3.5	Upstream	1 x 1 x 2 m	6	X	X	X	O	X	X	X
14	112859	CMS-RPC1	4	Upstream	1.1 x 2.36 x2.2 m	6	-	X	X	X	X	X	X
15	112858	CMS-RPC2	1.8	Upstream	0.8 x 0.8 x 2.2 m	2	X	X					
16	112857	CMS-RPC3	2.8	Upstream	0.8 x 1.8 x 2.2 m	7	X	X	X	X	X	X	X
		ALICE MRPC	2.8	Upstream	(CMS-RPC3 hosted)	1							X
20	112288	LHCb-M2R2	1.5	Upstream	0.6m x 1m x 1.8m	7	X	X	X	X	X	X	X
2	112197	ATL-Phase-II system test	3	Downstream	0.4 m x 0.6 m x 1.8 m	5	X	X	X	X	X		-
6	114660	ATL-RPC	4-4.5	Downstream	0.80 x 0.8 x 1.80 m	5		X	X	X	X		X
7	107041	CMS-CSC1	2.4	Downstream	0.85 x 2.22x1.8 m	7	X	X	X	X	X	X	X
8	107044	CMS-CSC2	3.3	Downstream	0.85 x 2.8 x 1.8 m	7	X	X	X	X	X	X	X
12	104078	CMS-DT-MB2	5	Downstream	0.5 x 2.5 x 3 m	2	X						X
17	106277	EP-DT 1	2	Downstream	0.5 x 0.8 x 1.8 m	4			X	X	X	X	
19	102679	CBM-TRD MWPC	1.5	Downstream	?	1							X
						Total :	9	9	10	10	11	8	11

Up to 11 (!) detector set-ups in beam….



… often with multiple chambers per setup

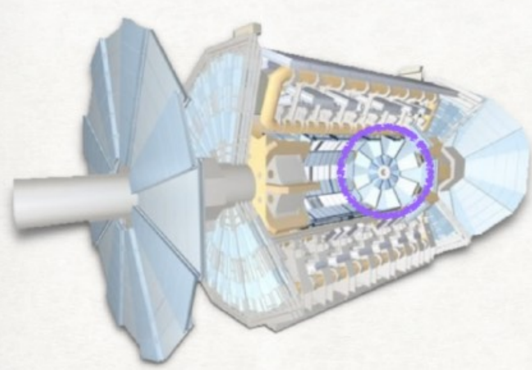
LS2 Operation

- **Irradiator fully operational throughout LS2**
  - Except ≈ 1 week of Irradiator maintenance each year
  - Several short stops due to EHN1 infrastructure maintenance & consolidation
- **Most long term irradiation test are continuing**
  - Continuous conflict between High γ-irradiation campaigns (max.collective dose) vs. low radiation ageing tests
    - For realistic results, this dose collection cannot be accelerated beyond a certain ratio. E.g. CMS-DT requested ≈ 4 month with 1/15 field
  - Bunker space was occupied to a large extend
- **Addition challenge**
  - Several mass production test campaigns to be fit in parallel to long term irradiation (ATLAS NSW Micromegas & sTGC, ATLAS RPC)
  - Multiple access needed per week (to swap chambers) in addition to frequent absorption filter change and source ON/OFF intervals.

Example of a (planned) Mass Production Test @ GIF

THE ATLAS NEW SMALL WHEEL

Upgrade of the innermost end-cap region of the Muon Spectrometer



Upgrade required to operate the Muon Spectrometer at higher rates

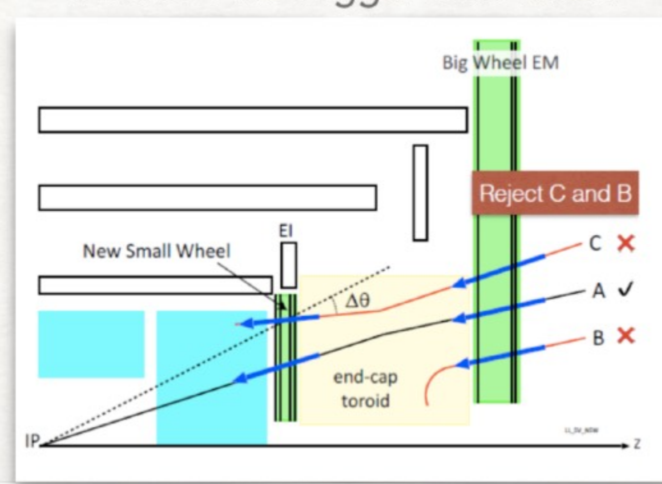
Run III (starting 2021): 2 x design Luminosity

HL-LHC (starting 2026): 5-7 x design Luminosity

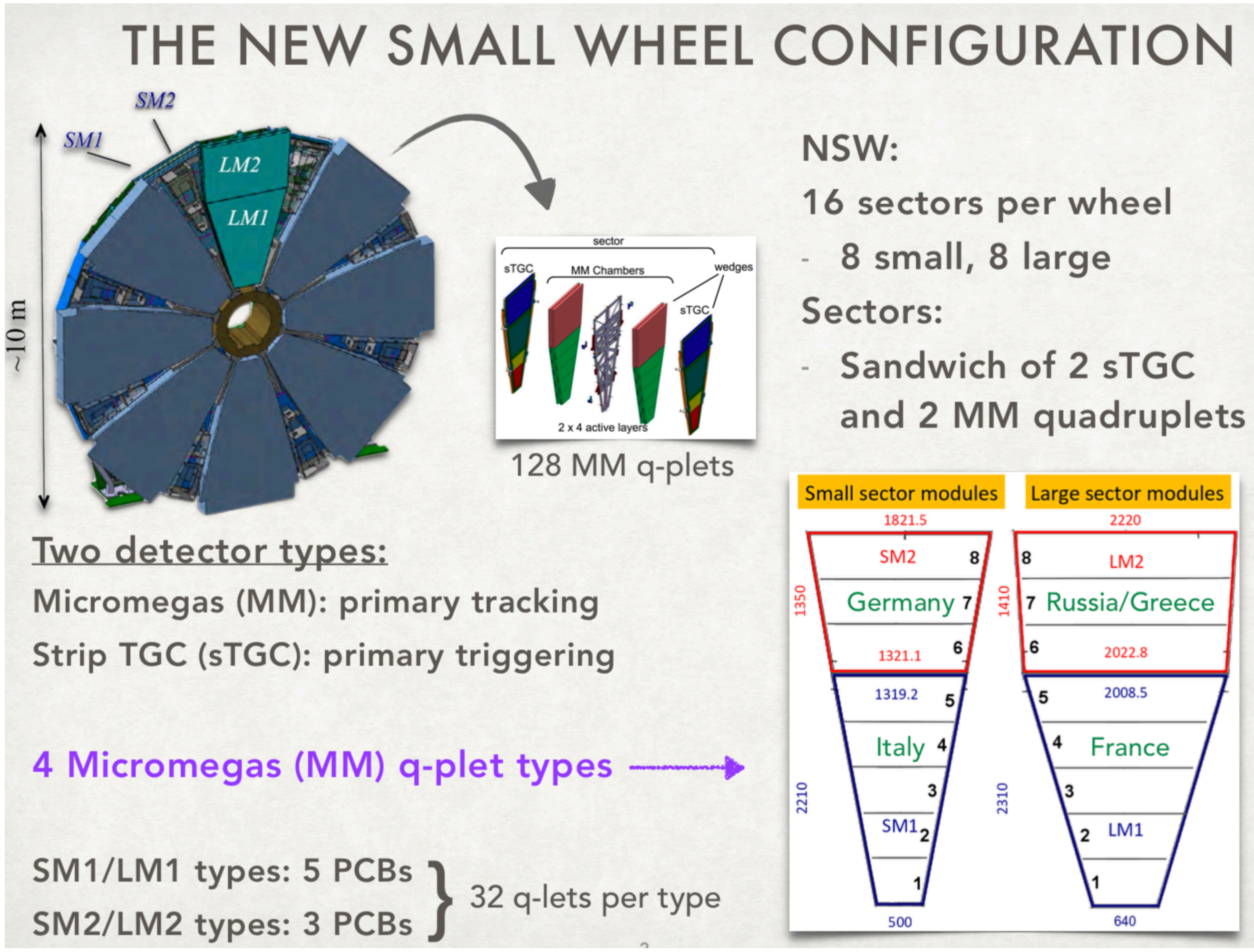
Motivations:

- Tracking:
  MDT/CSC performance will drop significantly at HL-LHC rates (expected: up to 15 kHz/cm^2)
  → Install detectors which can withstand the rates
- Triggering:
  Current L1 Muon trigger relies mostly on Big Wheel: High fake rates on end-cap regions
  → Extend trigger coverage up of $|\eta|$=2.7
  → More robust trigger to reduce the fake rates

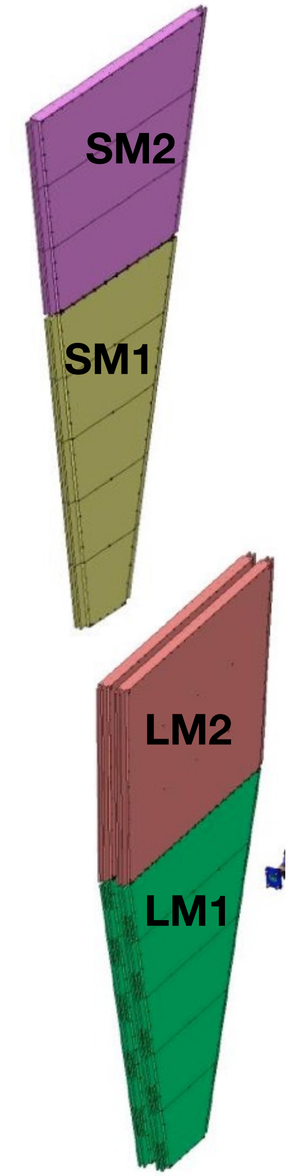
Above 90% trigger fake rates!



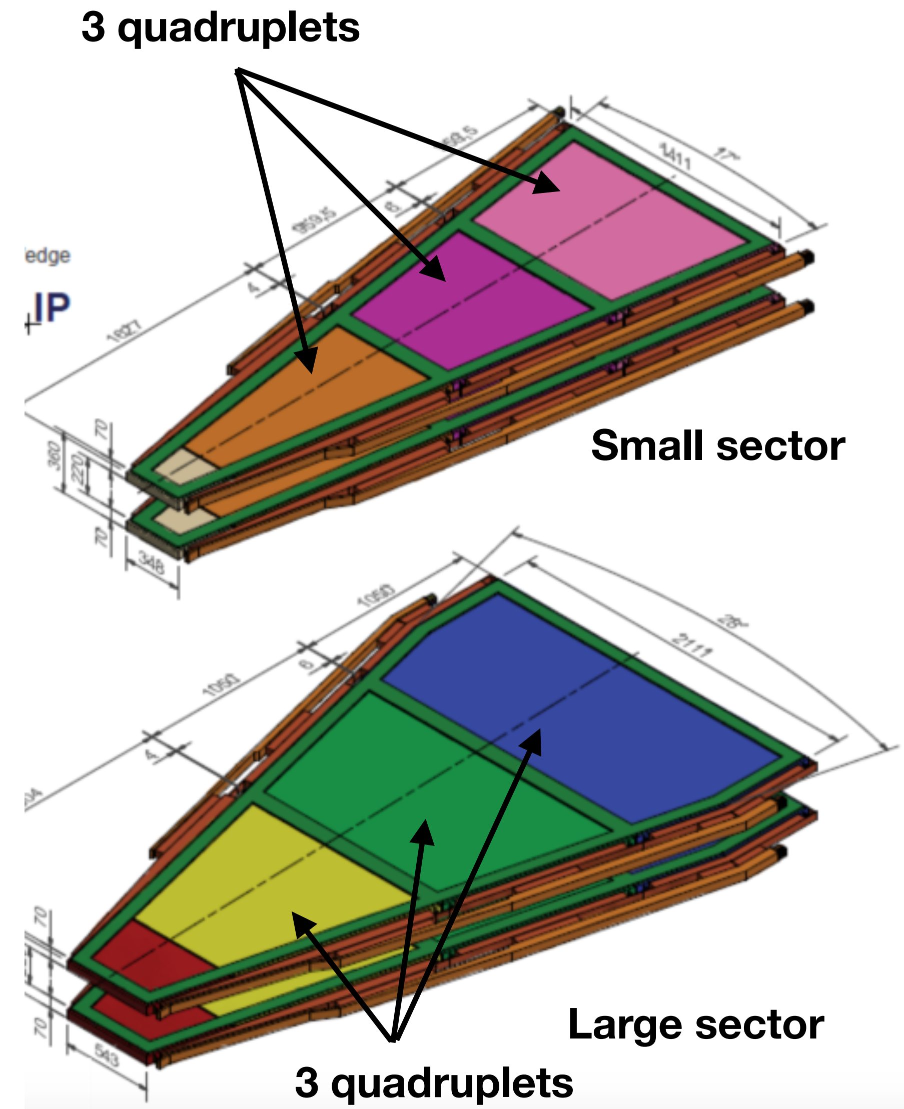
Lorenzo Pezzotti, Ivan Gnesi, George Glonti, Alan Peyaud - GIF AUM 2019



Micromegas

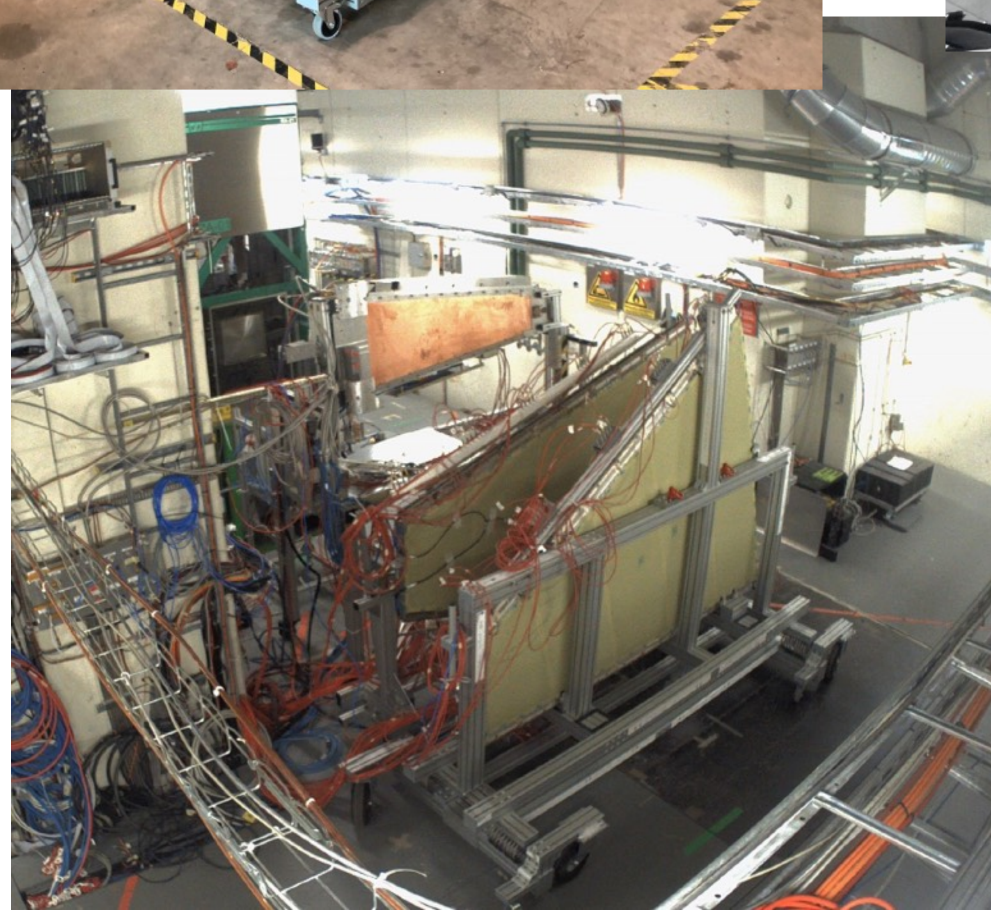


sTGC



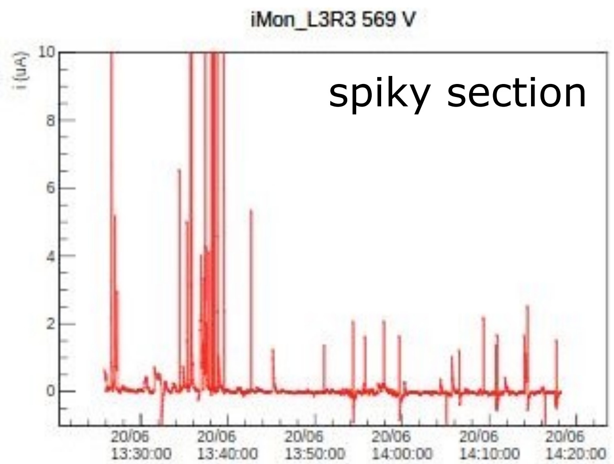
- A wide array of different chambers to be tested
- Different setups (moveable trollies) for different type of chambers
- Micromegas and sTGC chambers arrive independently at GIF++
- Need to be tested independently - spread over both irradiation fields
- In addition - long term irradiation studies on selected chamber (MM SM1-M3)

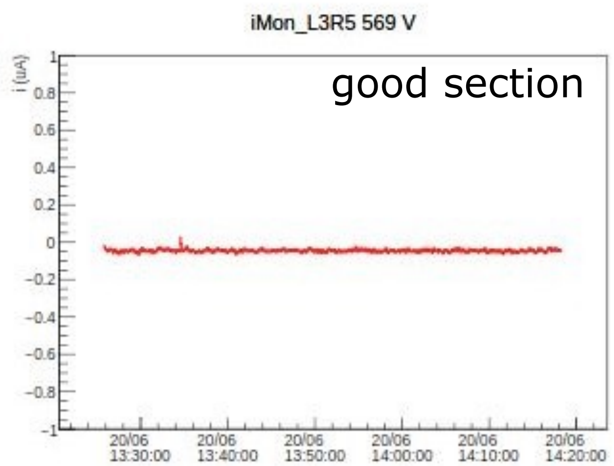
Micromegas



sTGC

Typical test procedures



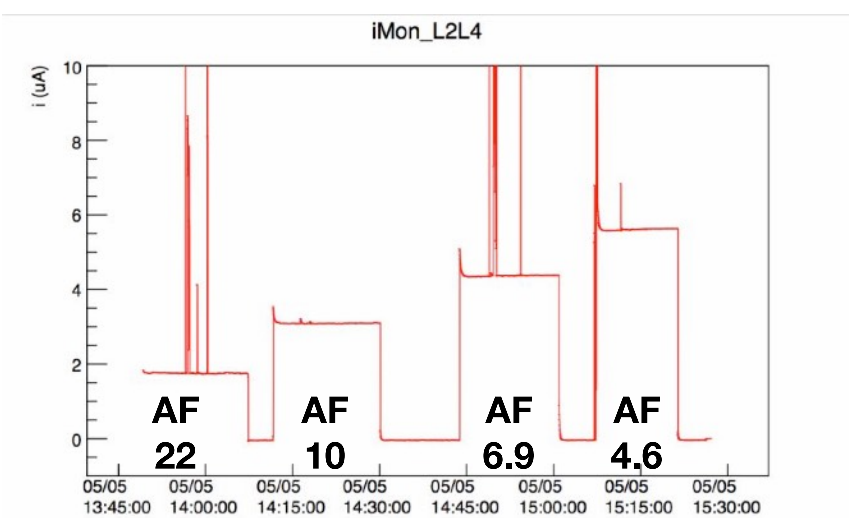


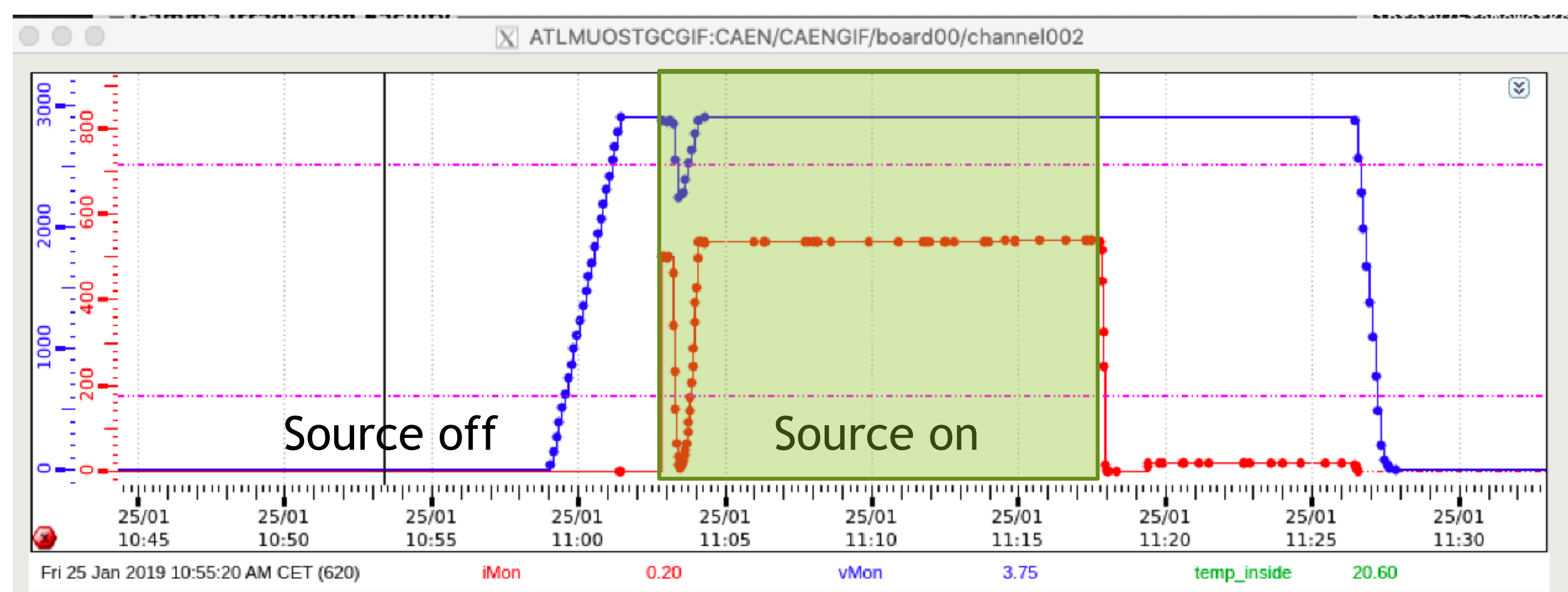
Micromegas

- flushing Ar/CO2 (> 10 volumes) before testing
- rising HV up to nominal 570V
- data taking over 2h
- data processing
- summary report

sTGCs

- Install the chamber in the bunker
- Flushing for 24h with pentane/CO2
- Put source off
- Ramp up HV (2800 V)
- Check that we don’t have current
- Switch on the source for ½ hour
- Switch off the source for few minutes
- Should have no current
- End of the test





Example of an unforeseen Mass Production Test @ GIF

Following slides are based on (if not otherwise stated) :

A Large Ion Collider Experiment

ALICE

MASS TESTING OF ALICE TPC ROC AT GIF++

Robert Münzer for ALICE TPC collaboration
IKF Frankfurt / CERN

Annual GIF User Meeting 2019
10 Sept. 2019

https://indico.cern.ch/e/GIF-AUM-2019

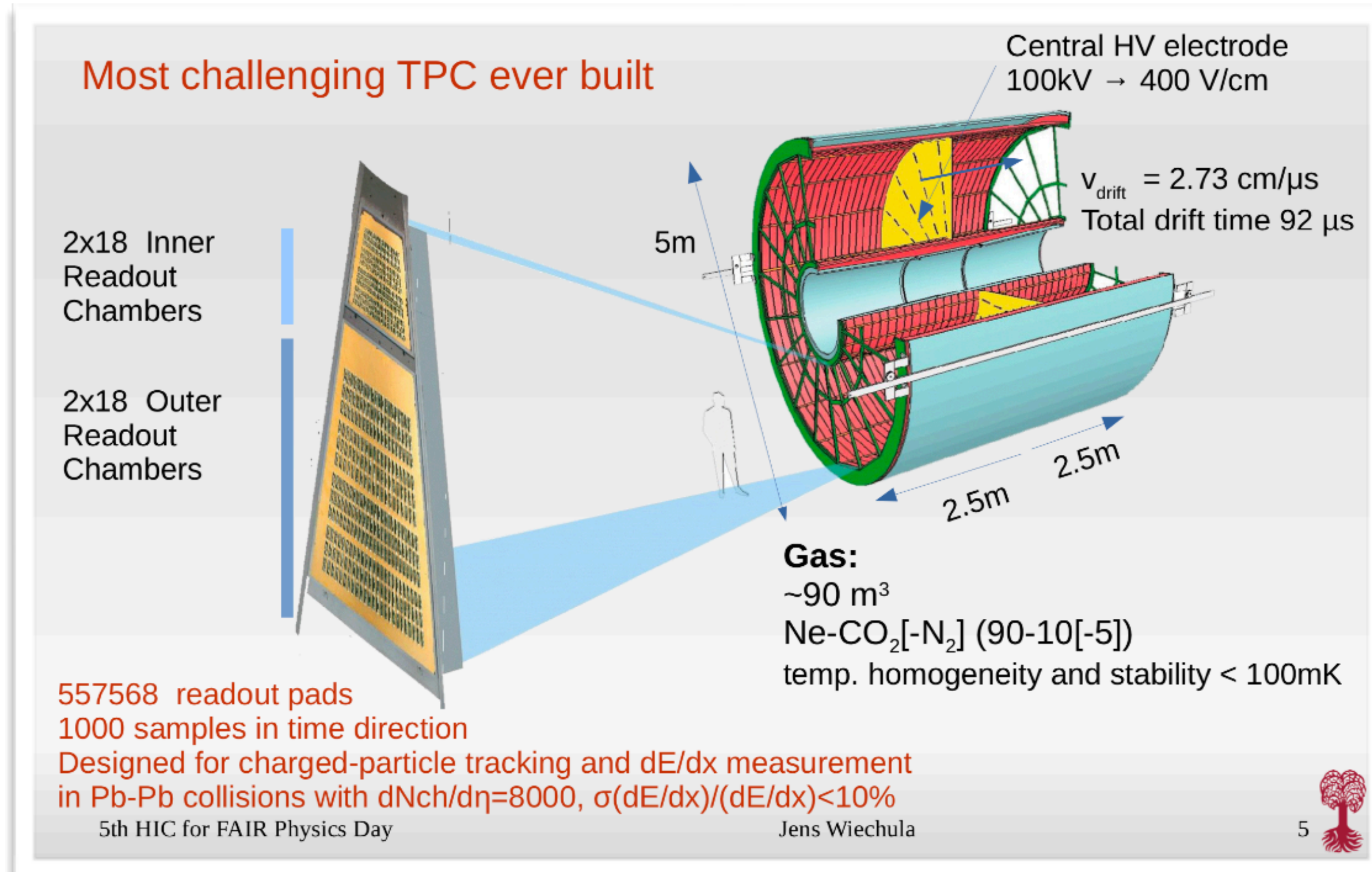
ALICE TPC Upgrade

Goal: operate ALICE at high rate, record all MB events

- ✓ 50 kHz in Pb-Pb (~10 nb^{-1} in RUN 3 and RUN 4)
- ✓ no dedicated trigger, reduce data size, preserve PID
- ✓ Average event spacing: ~20 μs
- ✓ Event pileup: 5 on average
- ✓ Triggered operation not efficient

Continuous readout with GEMs

- ✓ Stable operation under LHC conditions
- ✓ new electronics / HV system / novel calibration / online reconstruction schemes



GEM production at CERN

- Production rate: 40-60 GEMs/month

GEM QA

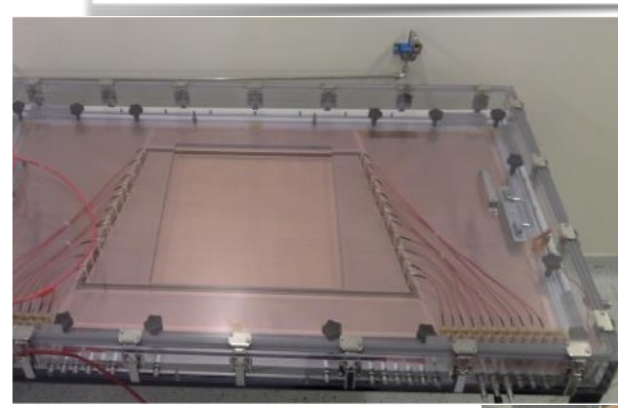
- After every production step / shipping: HV test at identical conditions at all institutes, Dedicated long-term stability test

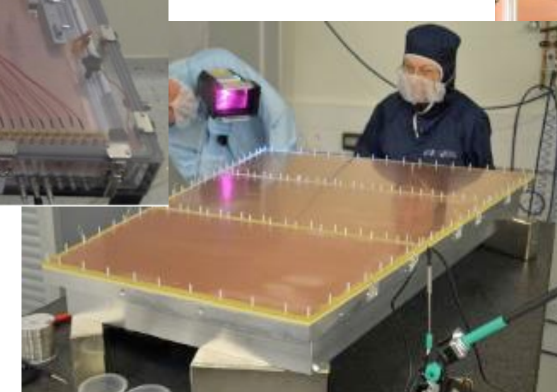
GEM framing / ROC assembly and testing

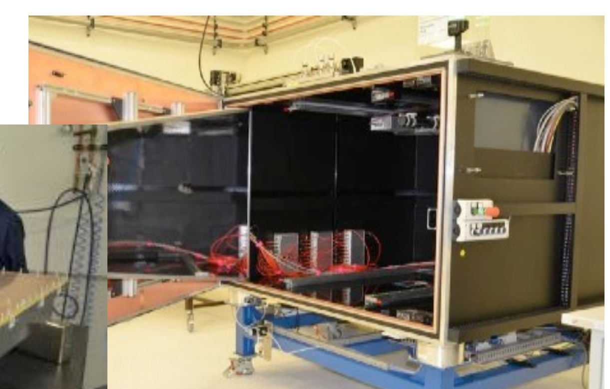
- 2-3 IROCs/month, 4 OROCs per month
- Each chamber is packed in its own gas box

Final stress test and storage at CERN

- Full irradiation with hadrons or X-rays

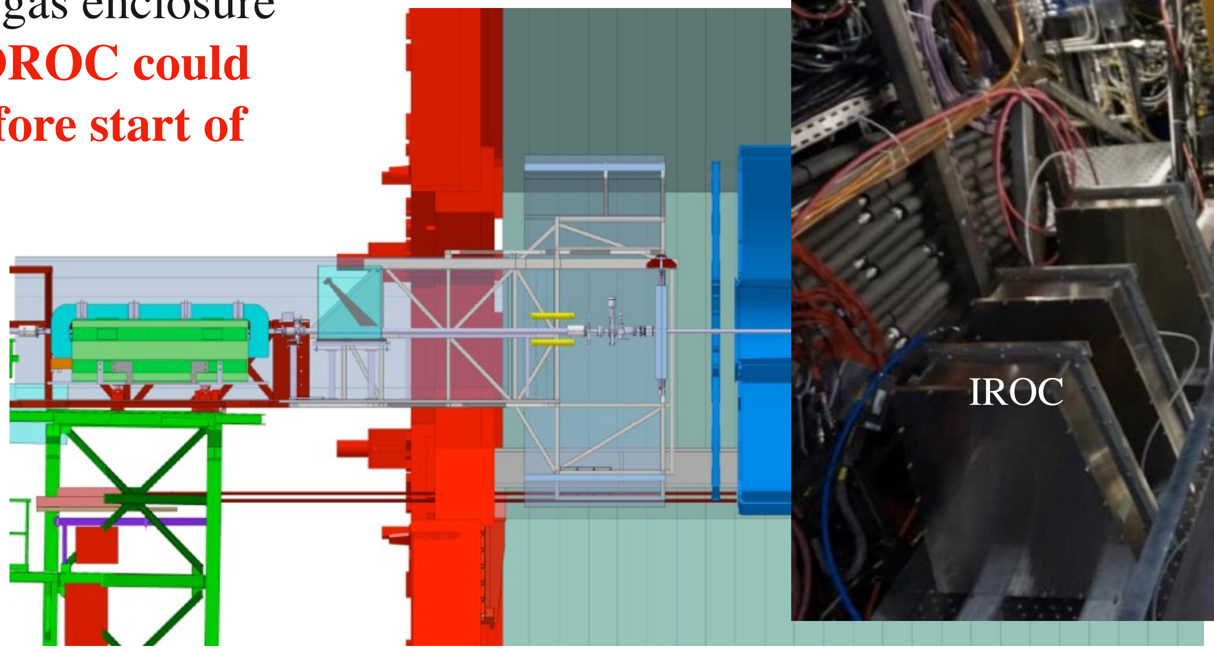


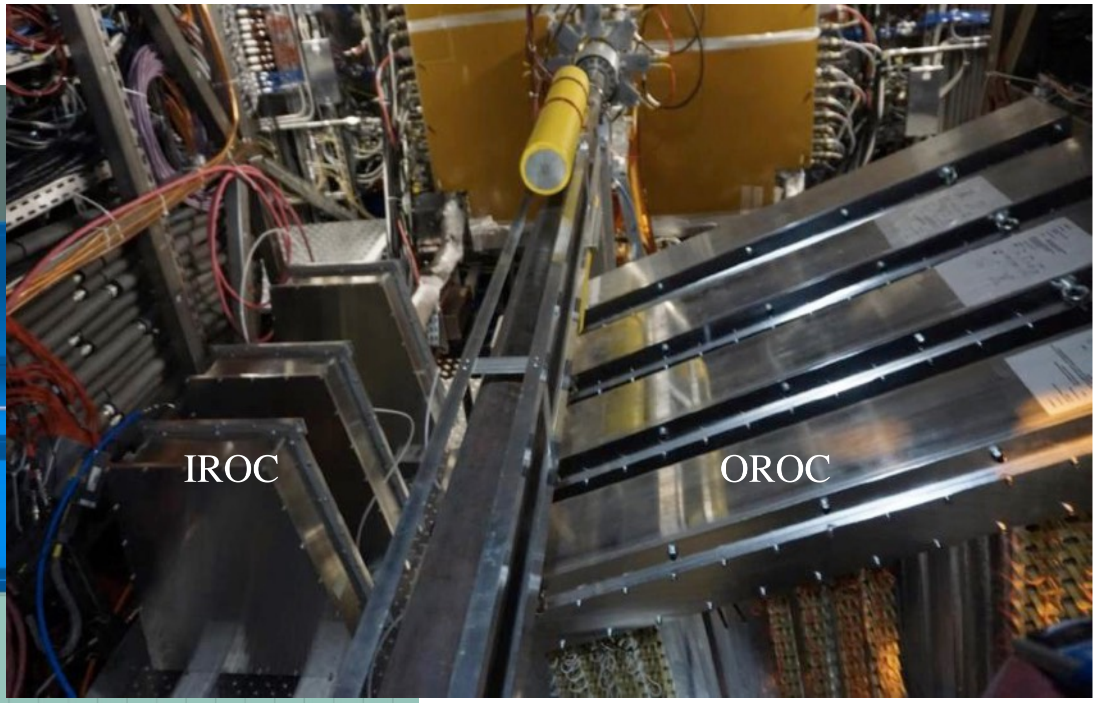




ROC TESTS IN THE ALICE CAVERN AT THE LHC

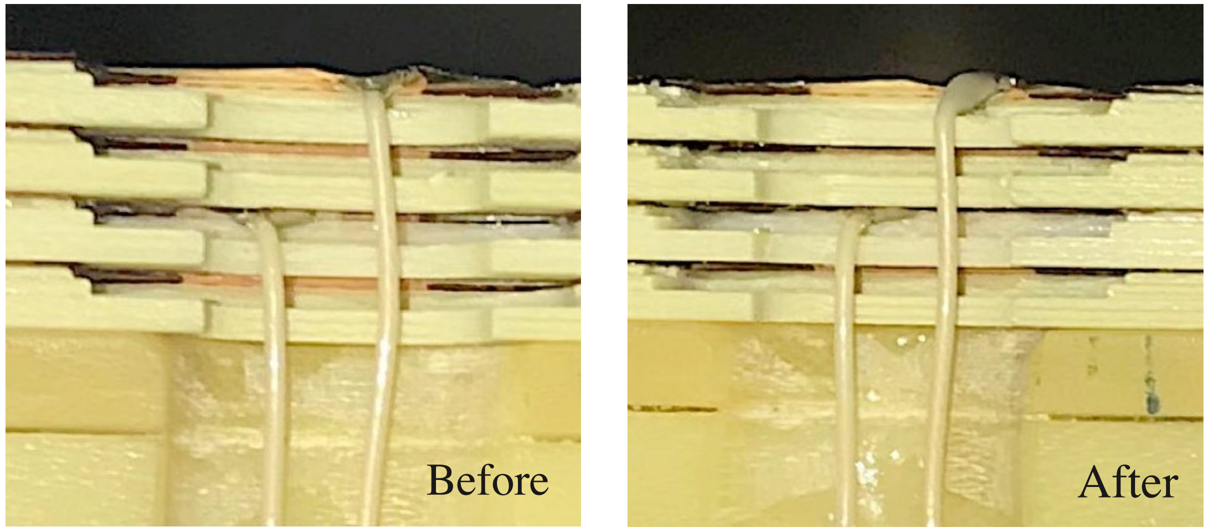
Test area close to LHC beam pipe, where doses up to 10 times of Run 3 are reached
ROC can be tested in their own gas enclosure
Only 28/45 IROC and 13/40 OROC could be tested in ALICE cavern before start of LS2





SPOTES ISSUE DURING IRRADIATION

Cavern allows to irradiate ROC with >10x higher particle load on GEM stack
Imperfections around solder points can be reliably identified
Problem solved by applying small amount of epoxy in critical spot

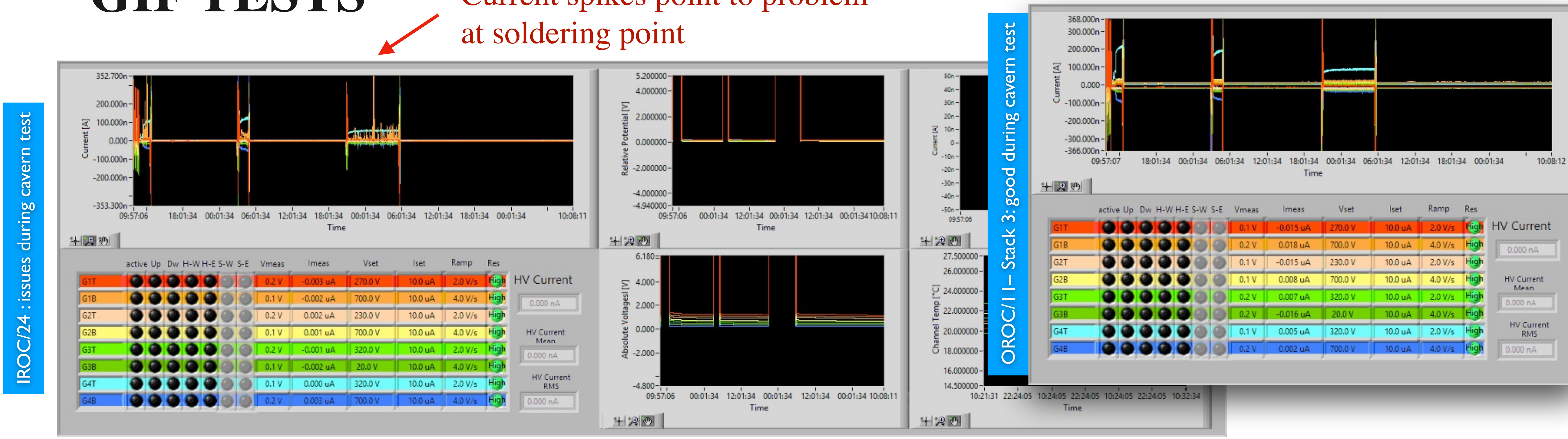


Not spotted during x-ray tests

10% of assembled stacks affected

GIF TESTS

Current spikes point to problem at soldering point

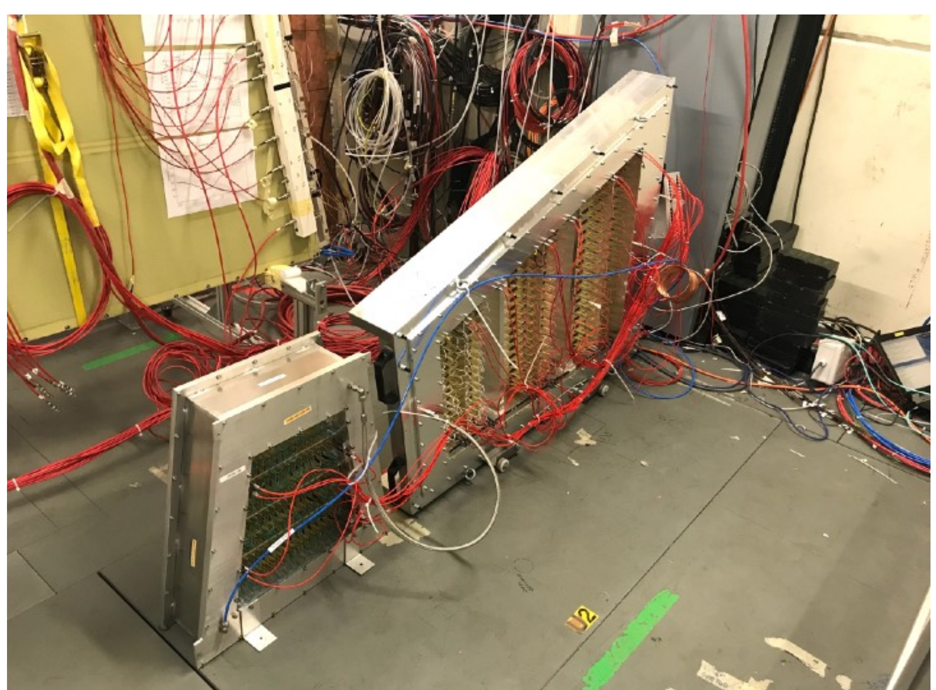


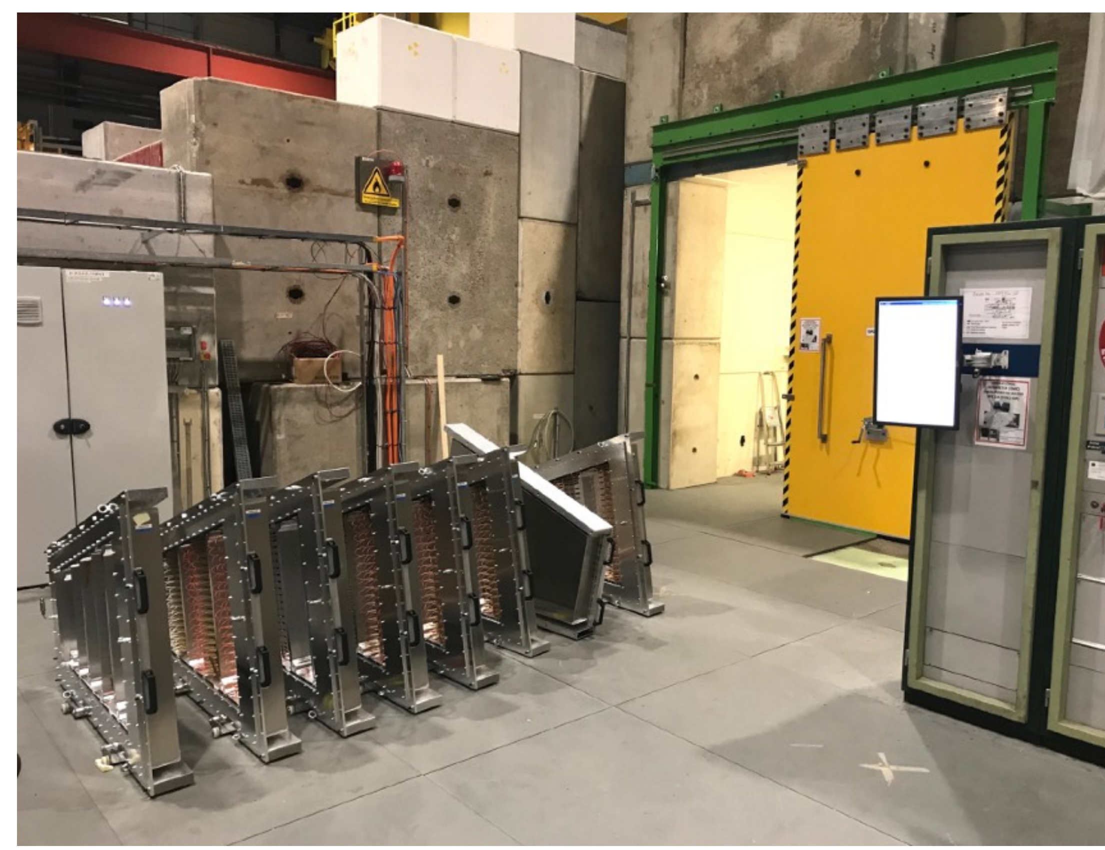
Before starting mass testing we did reference measurement: 4 stacks were put into GIF (2 good / 2 bad), Full intensity

⇒ GIF++ irradiation allows to spot issue

→ Started mass testing (up to 8 OROC per week)

Goal: Test all remaining chambers (17 IROC / 27 OROC)





Where are the tested / repaired ROC now ?

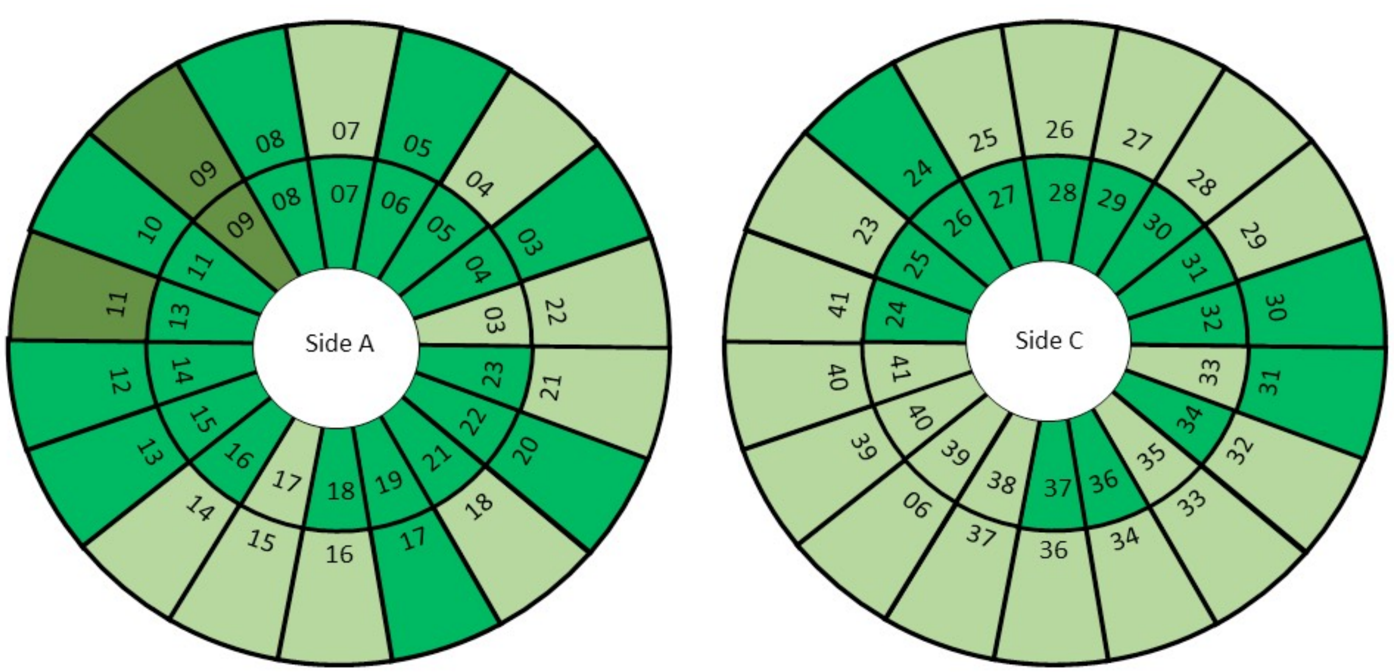
Procedure:

- ~4 month of testing at GIF
- Gas flushing: ~1d
- 0.5-1h irradiation at full intensity
- Swap chambers afterwards

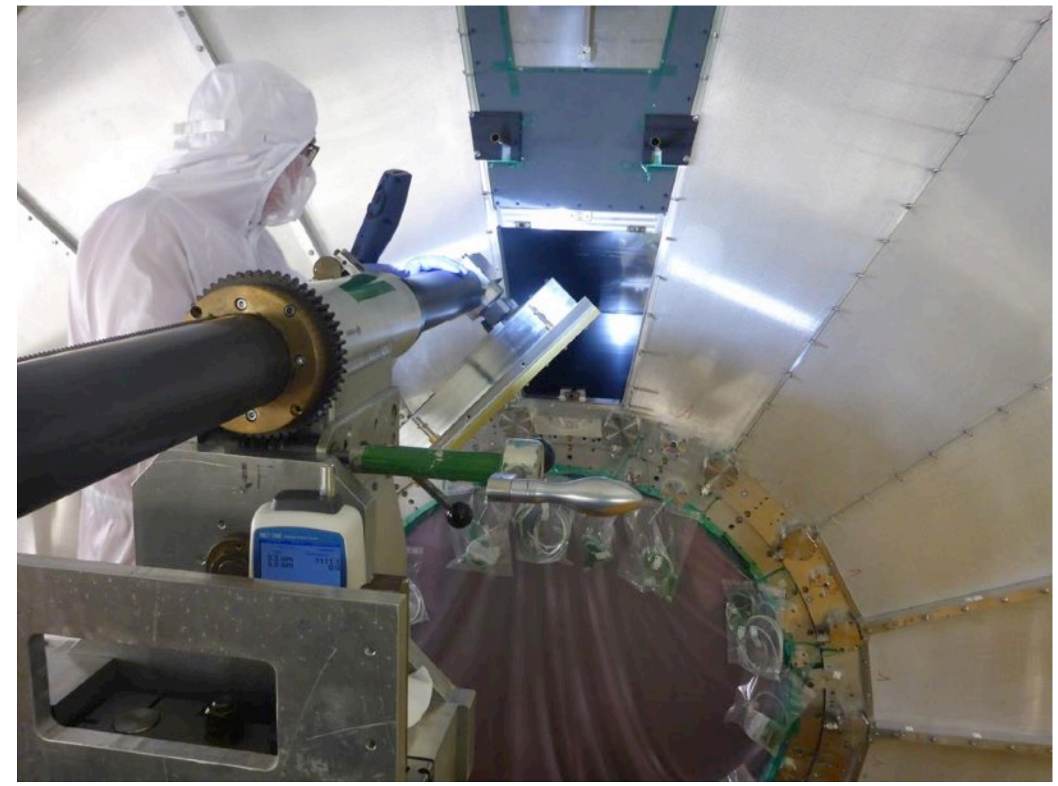
All chamber validated at GIF++

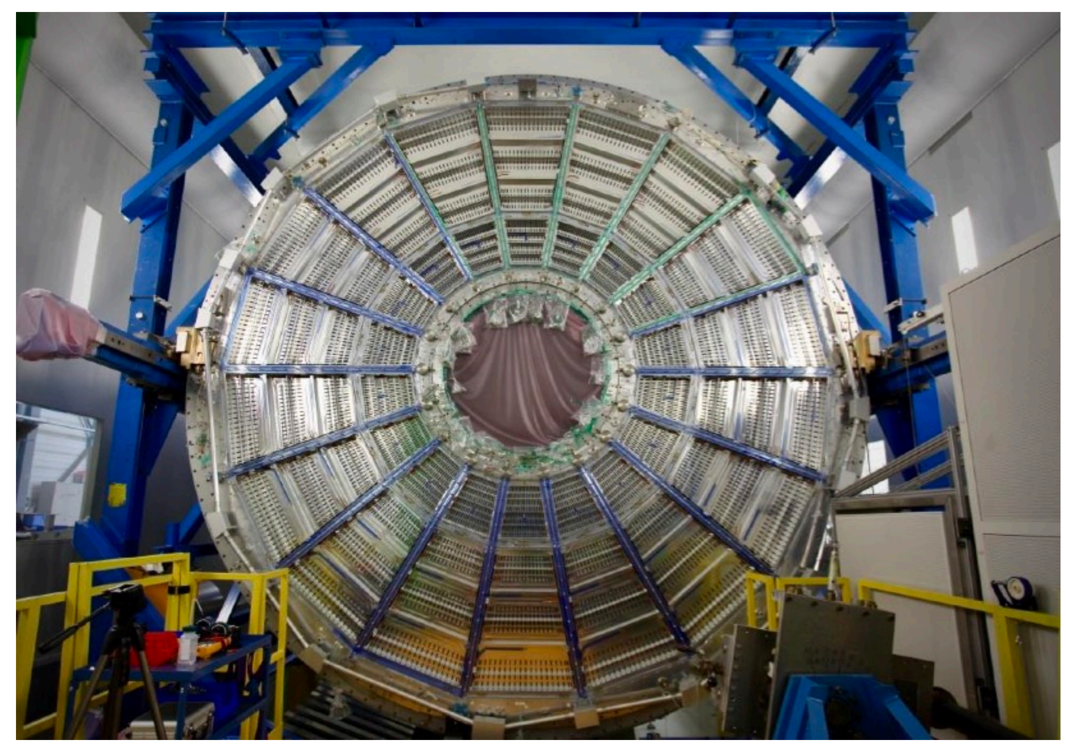
- 67% OROC
- 37% IROC

~10% shows issues (repaired and retested)



Test OK with beam
Test OK at GIF
Test OK at GIF/with beam





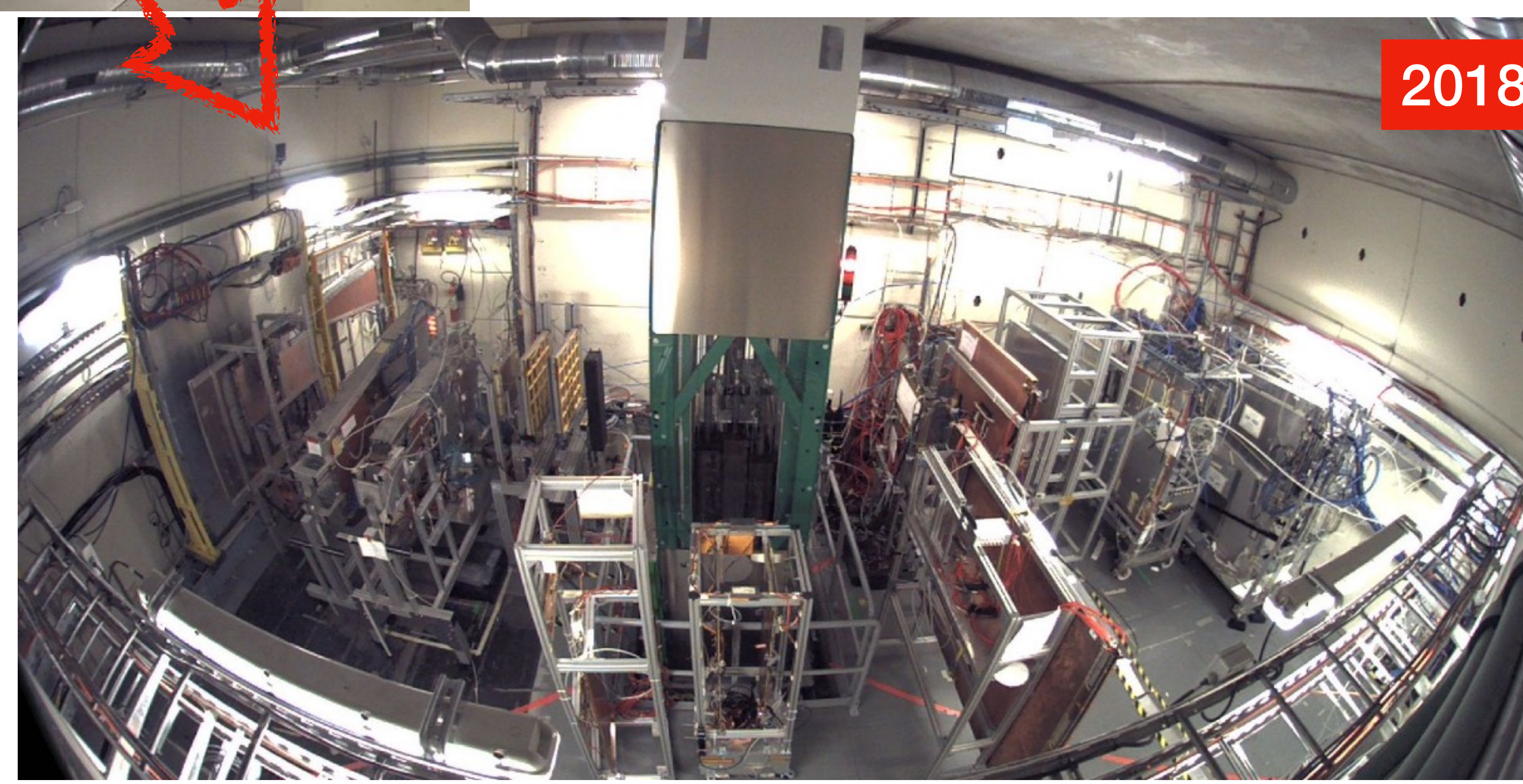
Successful installed in ALICE TPC !

Bunker Extension July 2019

- **GIF^{++} was huge improvement over previous facility**
- **Two irradiation field with independent absorption filters**
- **> 2 times the available irradiation space ≈ 100m^2 bunker zone with 2 x ≈ 25 m^2 irradiation zone**

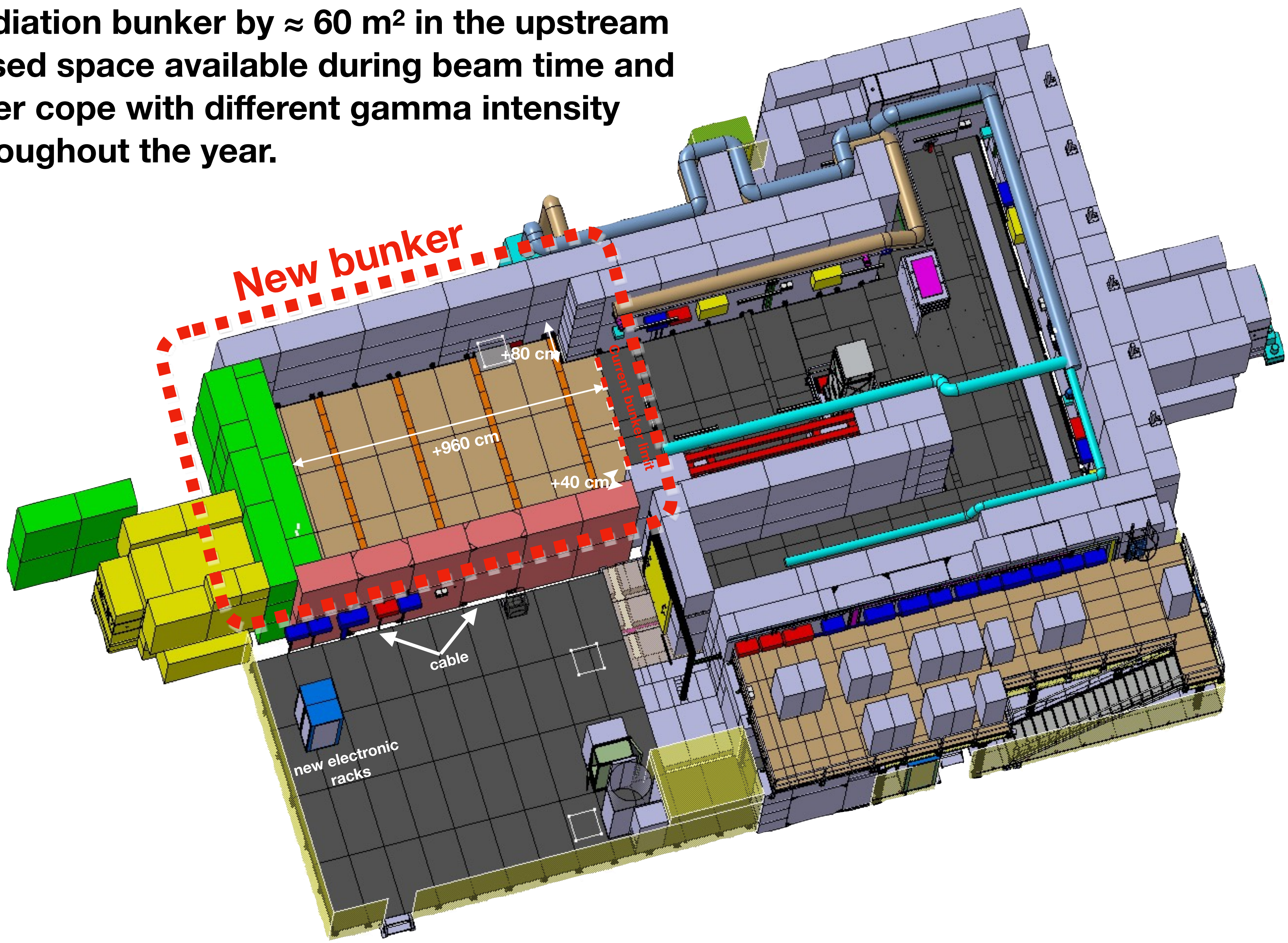
Growing demand over last years !

- **Need for more space along the beam line to ensure proper access to detectors**
- **Need for a dedicated low-irradiation zone, further away from the Cs source**



Extended Irradiation Bunker

Extension of irradiation bunker by ≈ 60 m² in the upstream direction. Increased space available during beam time and allows us to better cope with different gamma intensity requirements throughout the year.



- **ECR https://edms.cern.ch/document/1905810/**

GIF Extensions - Constrains and Challenges

- **Irradiator fully operational throughout LS2**

- **Strong demand for irradiation**
- **Important mass production tests to be finished (e.g. ALICE TPC)**
- **Critical productions tests ongoing or planned (e.g. ATLAS NSW)**
- **Long term irradiation to be finished…**

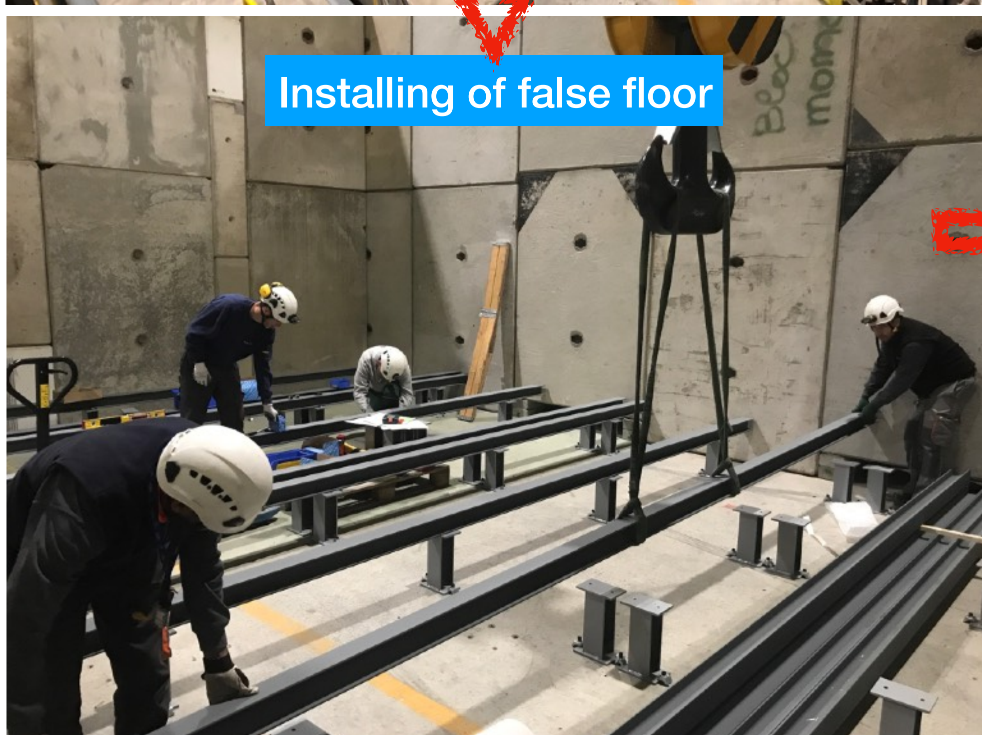
- **Careful timing and precise planning needed**

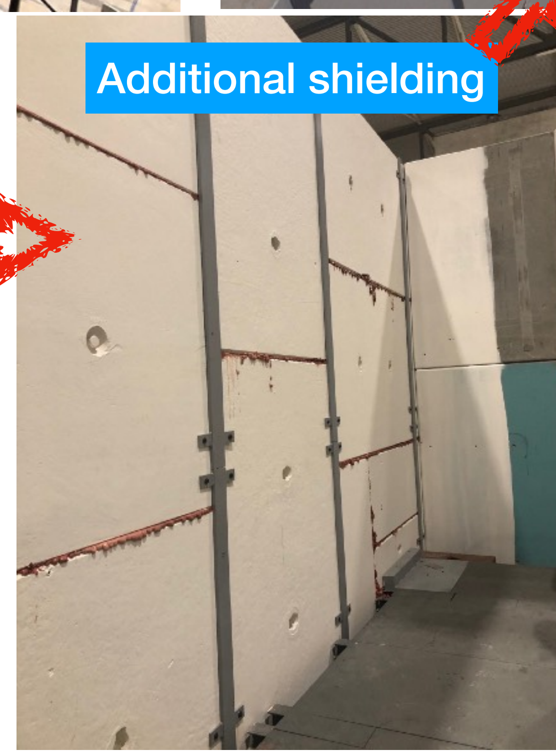
- **Minimal disruption of test campaigns**
- **Synchronised with the critical deliverables from users**
- **Shutdown of only 3 weeks envisaged during July**
  - **Including annual irradiator maintenance (1 week)**

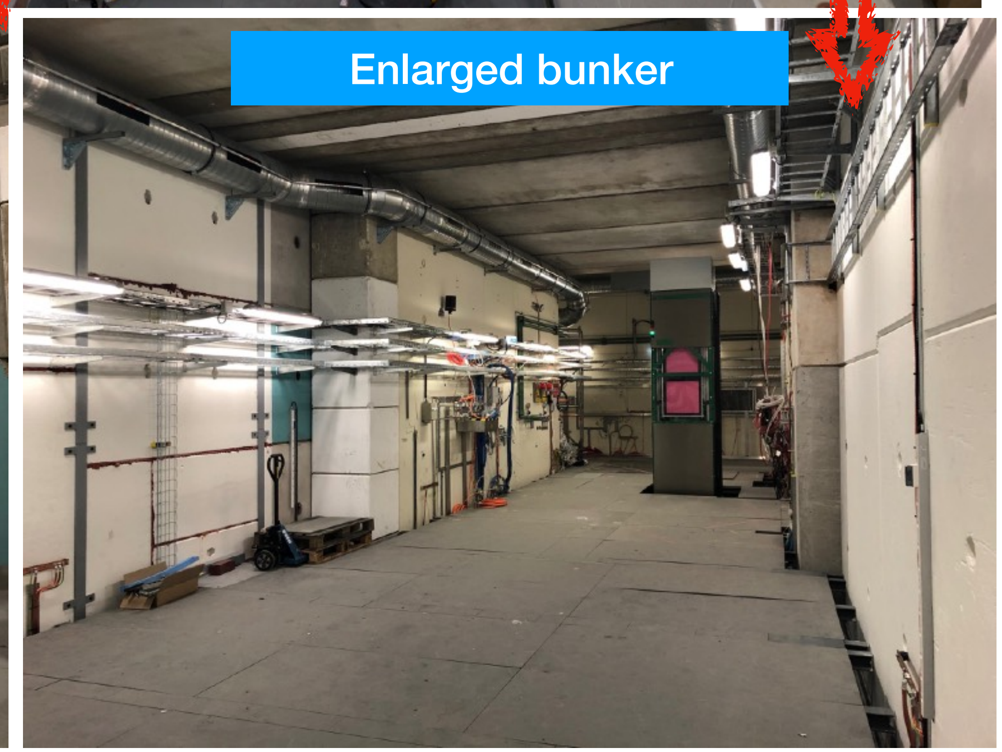
Preparation

- Freeing area in PPE 144 & PPE 172
  - Re-routing external cables, remove cable trays
- Modify fixation of electrical switchboards, gas panels…

Bunker Extension







Extension of Alcove

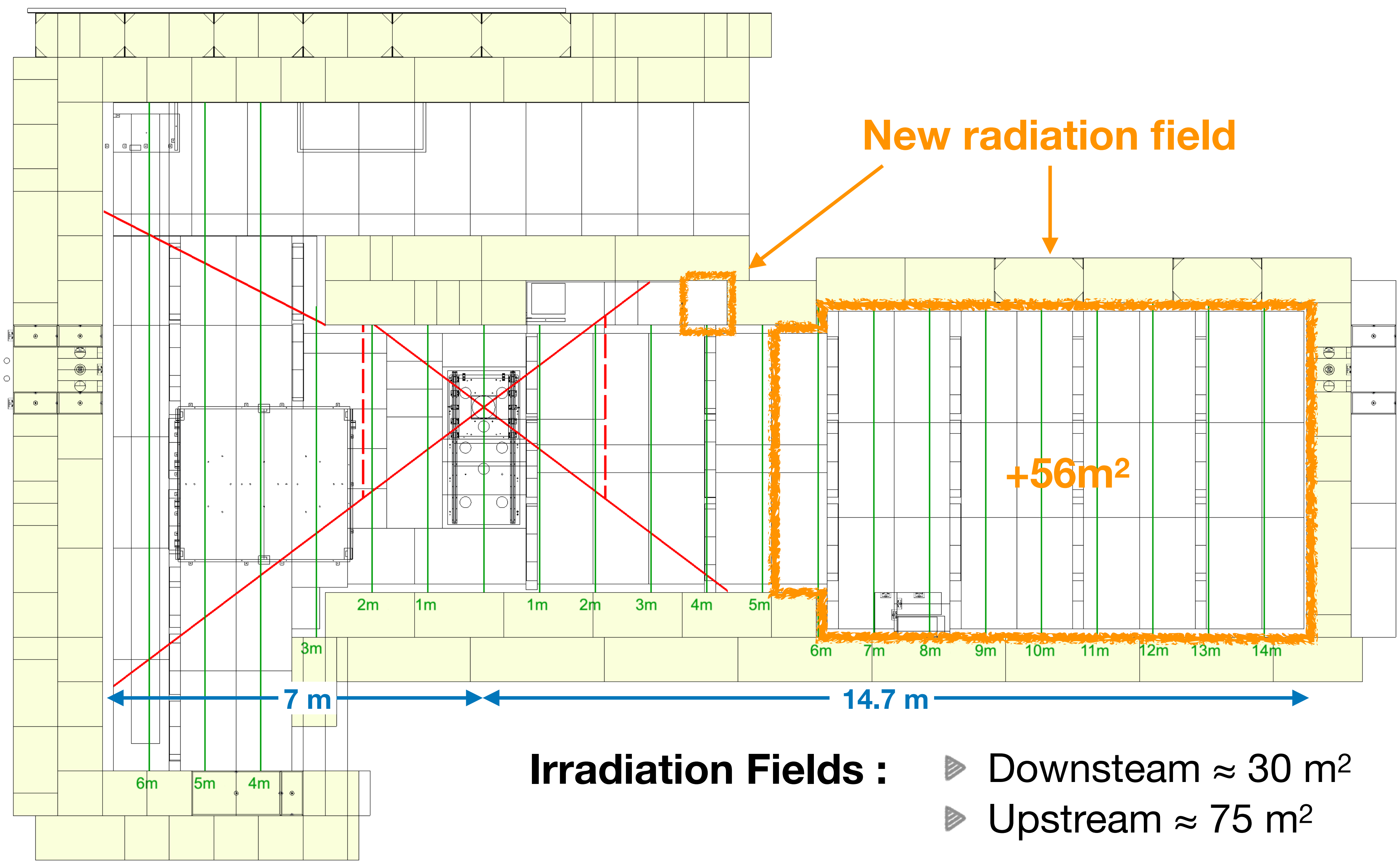
- **Enlarge** (preserve) **valuable space close to irradiator for big chambers**
- **Needed removal of large part of the roof**
- **Weakened shielding compensated by additional blocks outside**

Source Displacement

Movie

- Better distribution of setups between fields
- Easier access for large setups
- Free space of cosmic trigger
- Moved by 1m (preserving low irradiation field)
- Custom made transport support
- Only possible with the help of EN-HE, HSE, RP…. and VF

New Bunker Layout



Irradiation Fields :

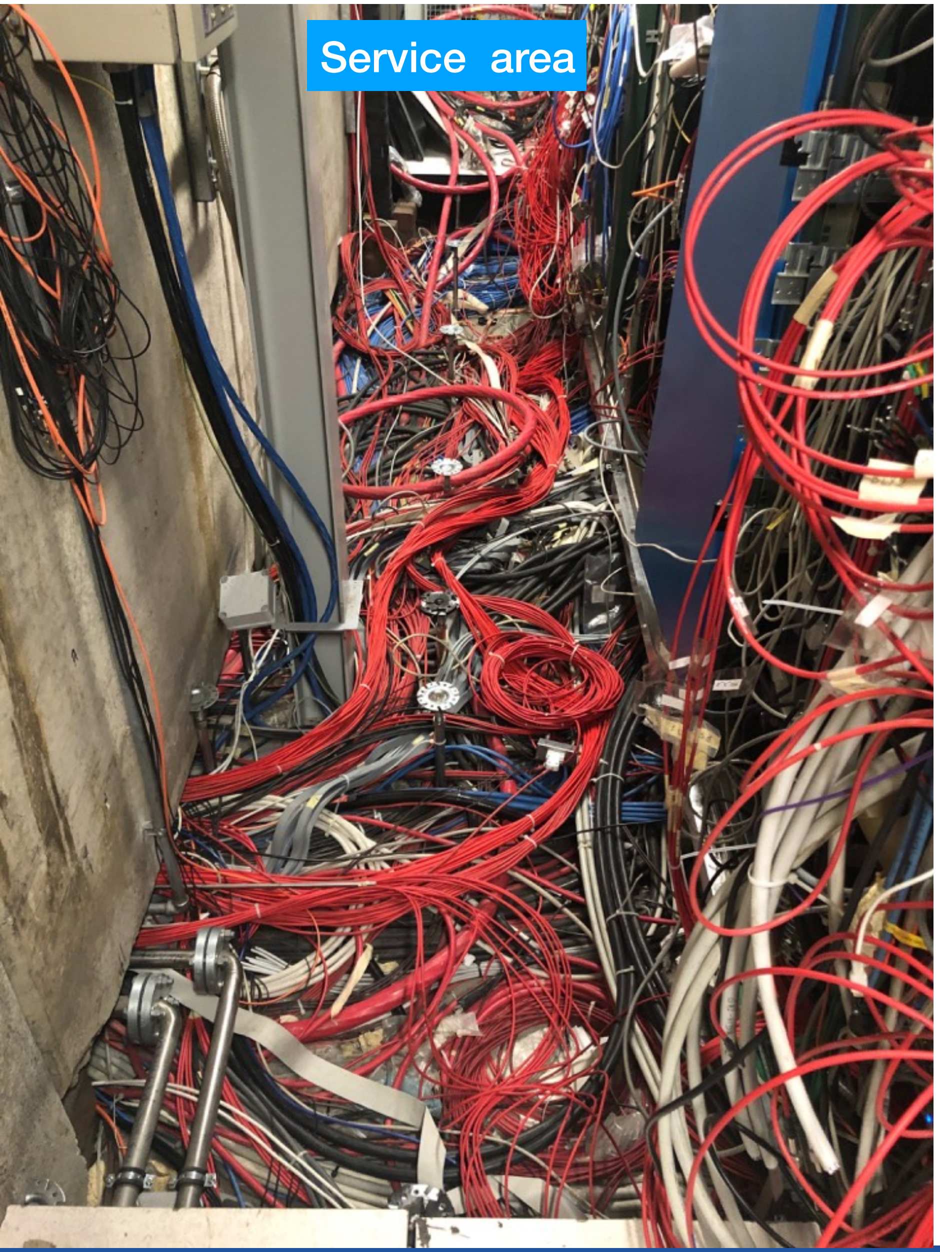
- Downsteam ≈ 30 m²
- Upstream ≈ 75 m²

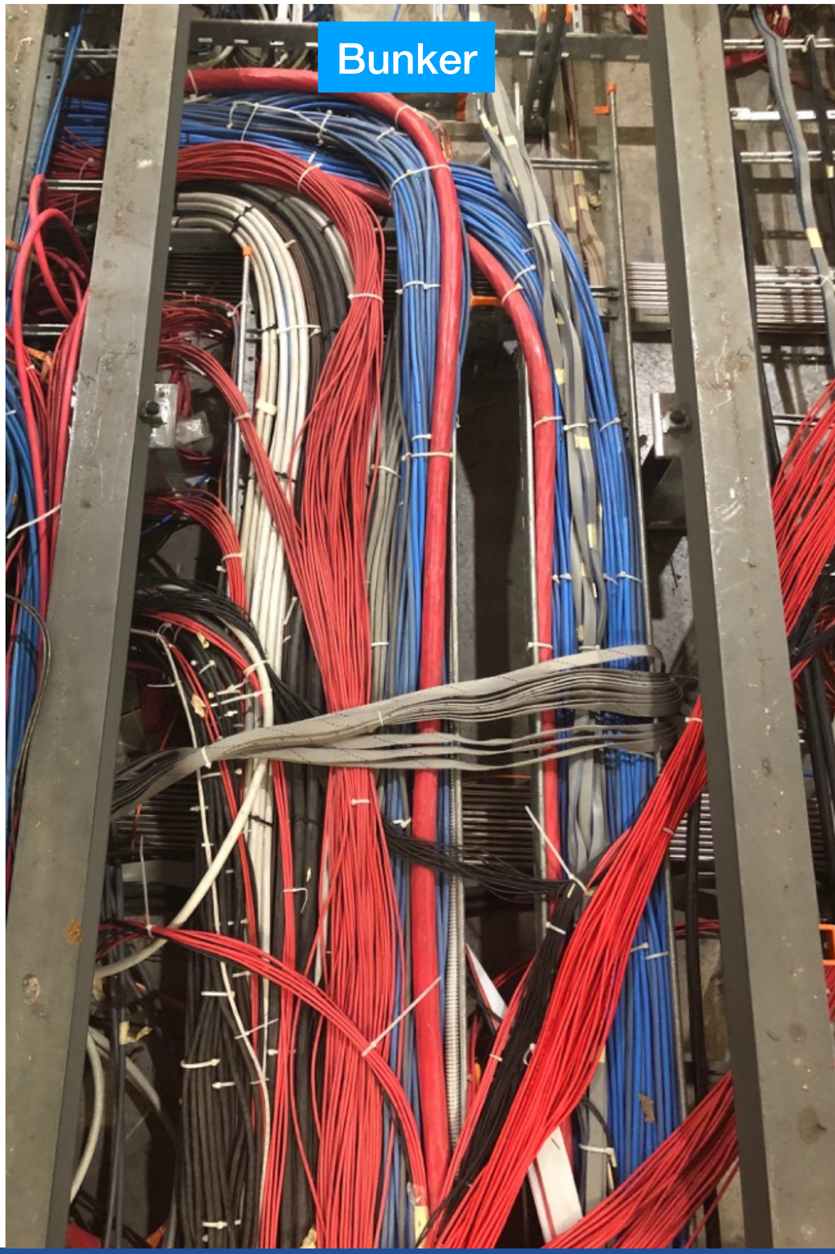
Irradiator Displacement :

- 98 cm towards upstream
- ≈ + 1.5 cm in additional height

De-Cabling & Re-Cabling

- Chance to remove (= cut) unused cables from previous setups
- Re-routing cables for new locations
- Freeing valuable space in cable galleries
- Installing additional cables





GIF++ New Bunker July 2019

ATLAS ALICE LHCb CMS

EN-EA EN-CV BE-ICE

EP-DT EP-DSO

HSE-RP BE-DSO

HSE-OHS EN-HE …..

THANKS !

- **Finished on schedule !**
  - 3 week stop of Irradiator
    - including 1week maintenance test.
- **Finished within budget**

Conclusion - Bunker Extension

- **Bunker extension finished in time**
- **Significant improvement (!) that allows us to space the set-ups as needed** (dimensions, filter needs…)
- **Easy access zones available for ongoing mass production tests, allowing quick exchange of chambers to be tested**

- **Problem remaining:** **non-uniform shadowing of set-ups** (by other chambers, supports…)
  - We try to better use the radiation field by lifting chambers and minimising shadowing
  - Some constrains due to accessibility requirements for chambers, and stability of setups

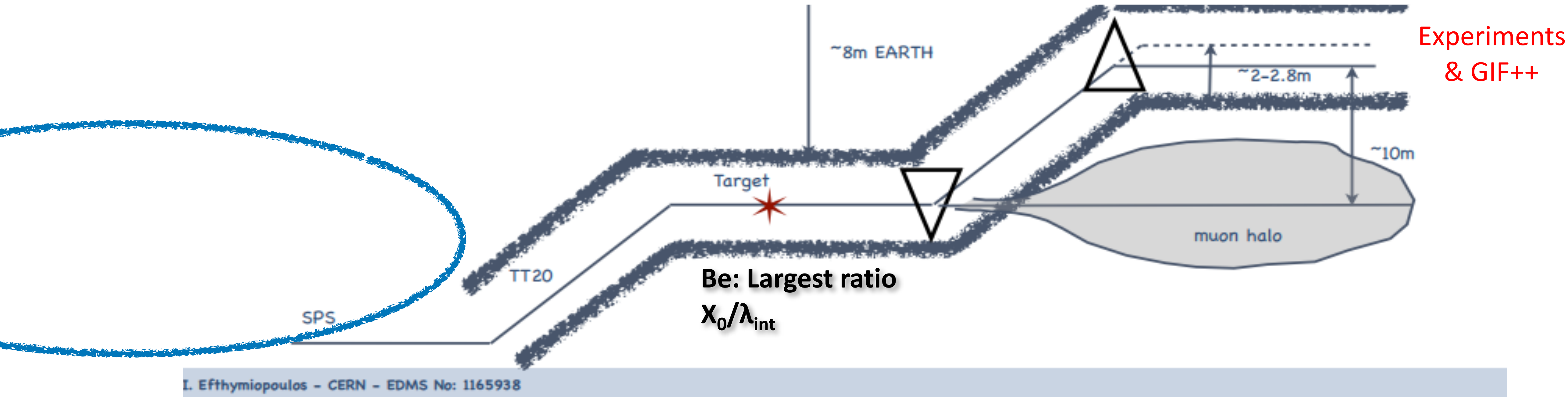
The Way Forward…

Can we improve the Muon Beam ?

- More intense Muon beam ?
- Better focused ?
- Adjustable ?

⇒ Let's ask EN-EA !

The North Area Beam Lines – Design Principle

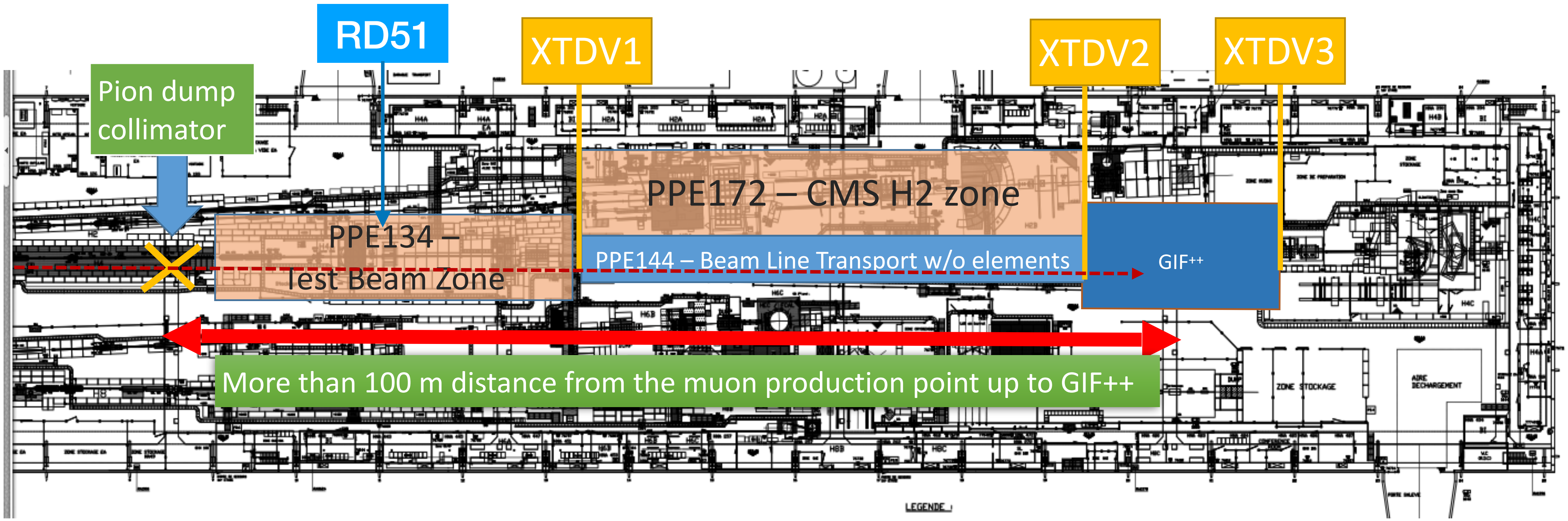


"Wobbling" of the beam *before* and *after* the target allows for flexibility on the particles selected and transported to the experimental areas – strong correlation between the momenta/angles/rates between H2 / H4 – also small tuning in H4 is always necessary after each 'Wobbling change' (every week normally)

Based on slides from N. Charitonidis

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

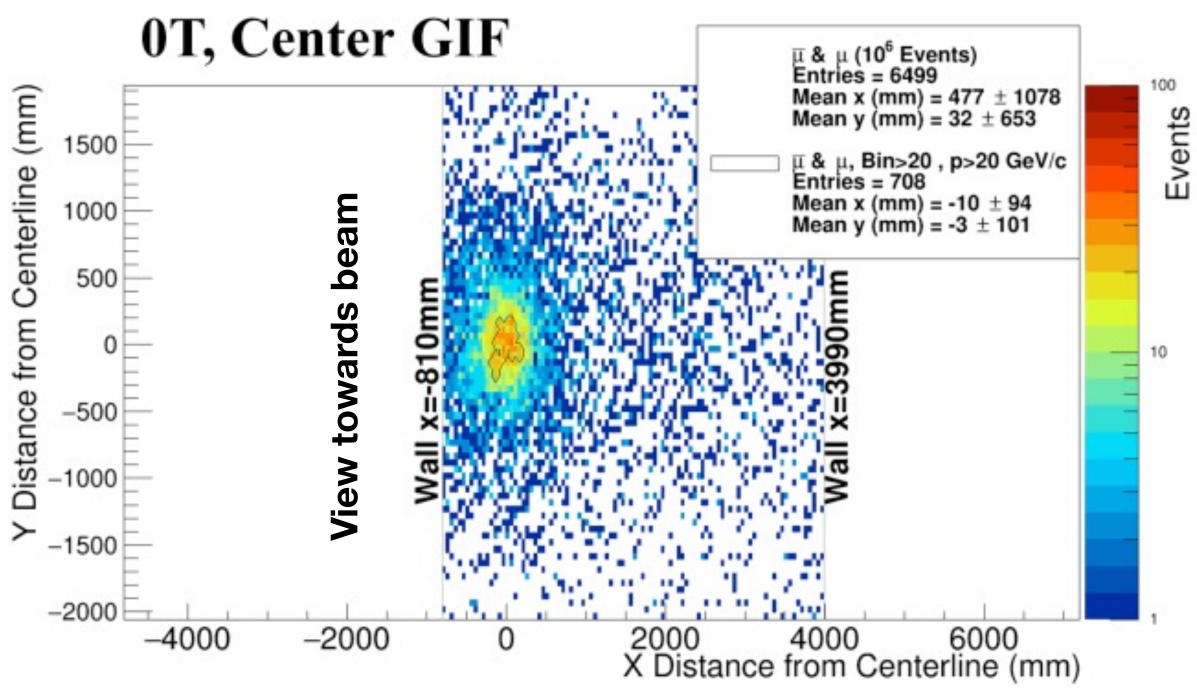


- The "dumping" collimator is ≈ 1.1 m of iron the jaws of which also have a little opening that cannot be closed fully ("collimator ≠ dump")
  Some pion contamination inevitable → GIF^{++} used to keep closed XTDV2 and often XTDV1.
  XTDV1,2 = 3.2 m of iron (efficient dump)…however:
  - Behind XTDV1 : A radiation monitor placed for a good reason – XTDV is not meant to be a "dump" but to PROTECT people behind it
  - GIF^{++} ≈ 80 m after XTDV1, and multiple scattering causes a good fraction of the muons to be lost before.

Based on slides from N. Charitonidis

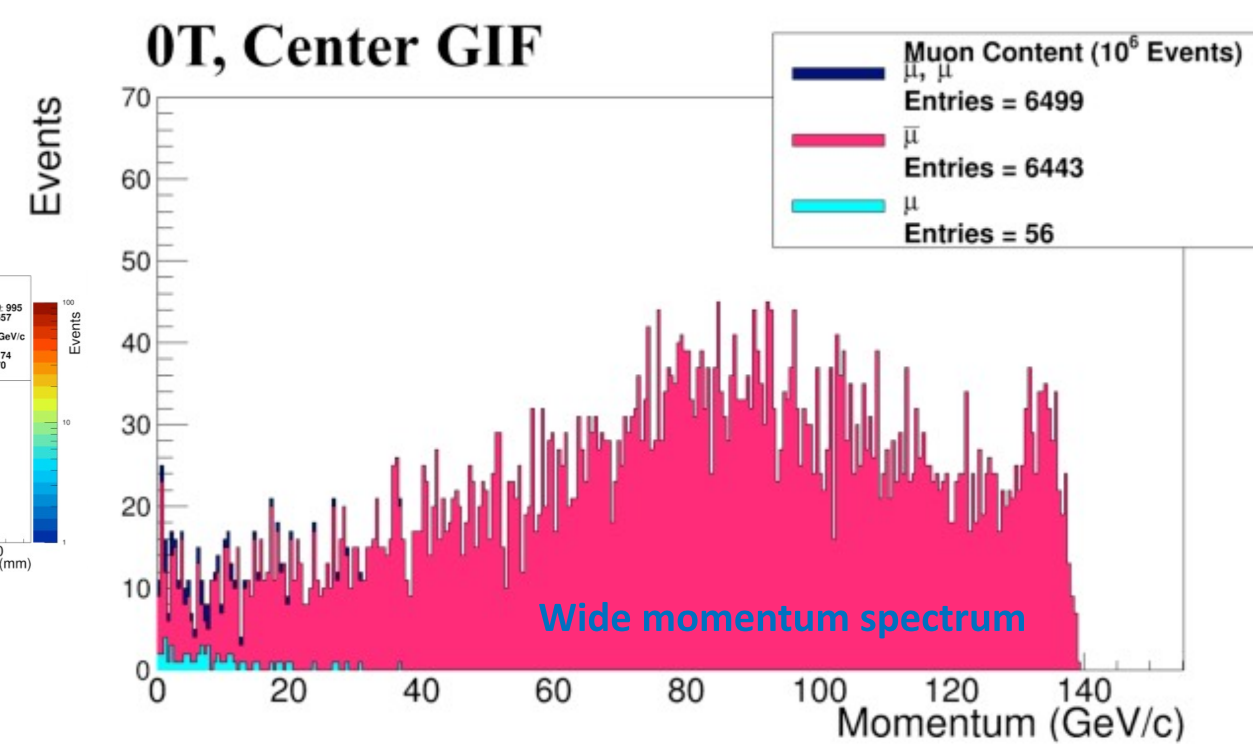
Simulations of muons @ GIF++ (1)

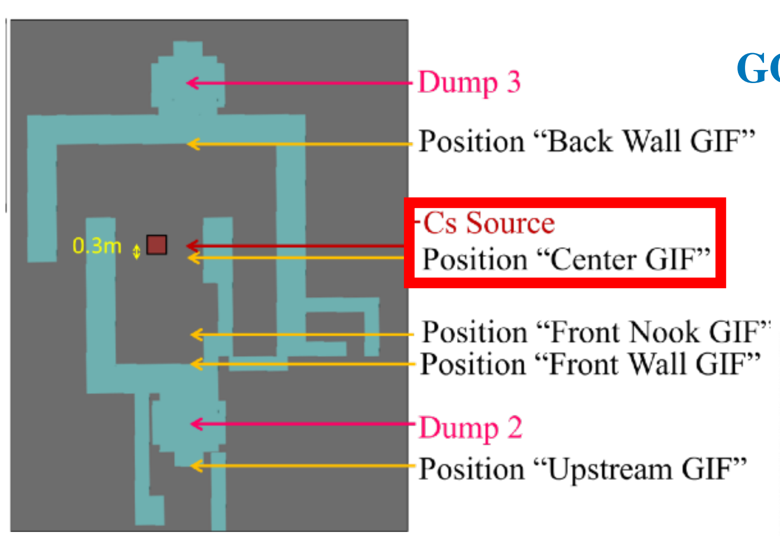
- Extensive Monte-Carlo simulations with detailed geometry model done by summer student R. Margraf (Univ. Lenigh). Report available here.

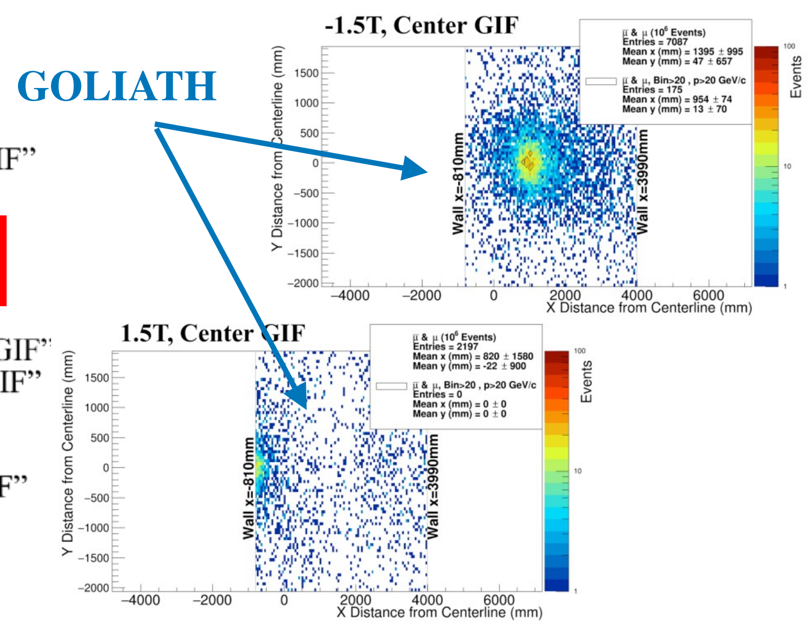


10^6, 150 GeV/c mixed beam impinging on the collimator

Note the spatial and natural momentum spread.







Based on slides from N. Charitonidis

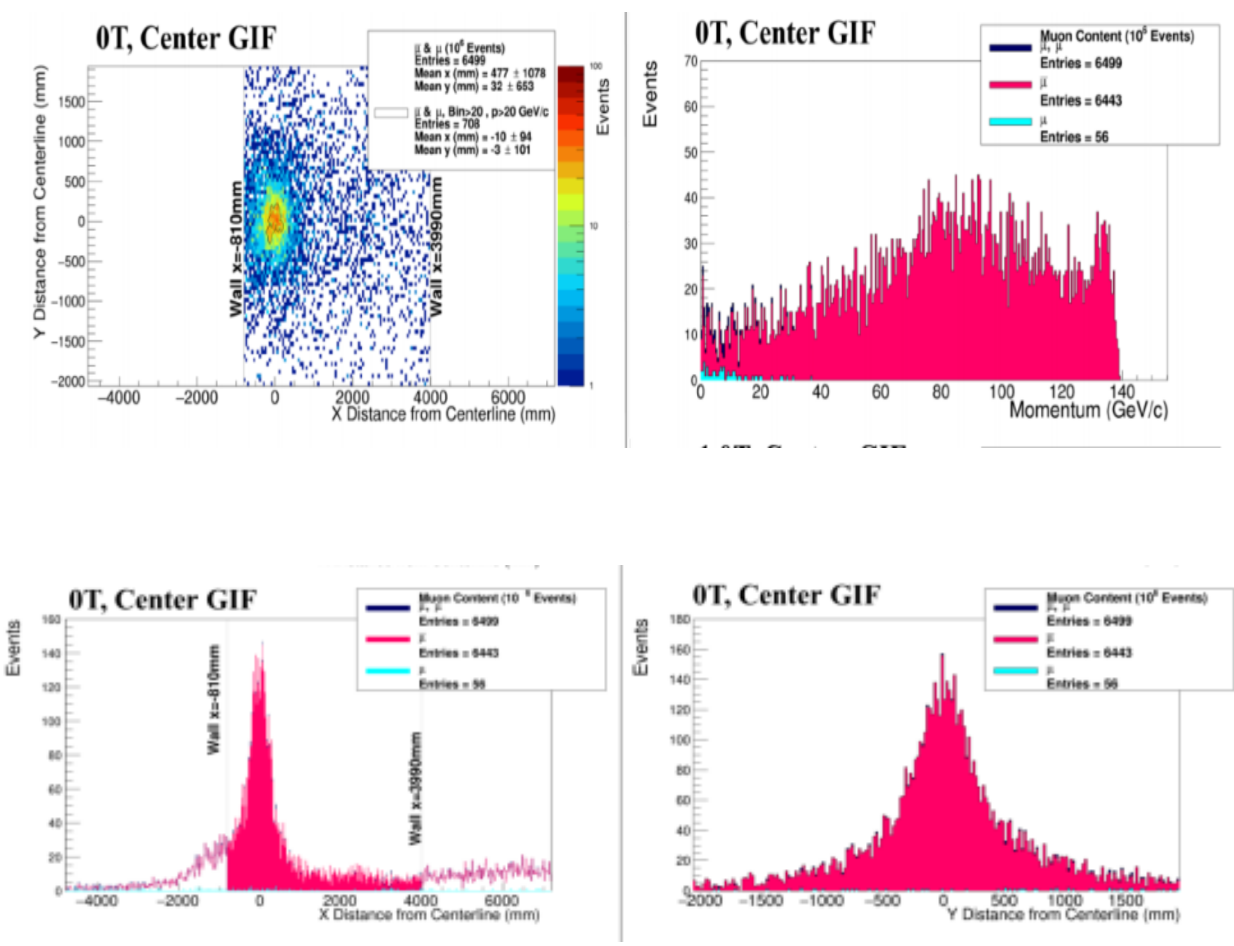
A new proposal for a pion dump before GIF++

- Two new beam dumps in front of GIF++, which can be **manually** moved out of the beam for hadrons / electrons @ PPE164
- Flexibility on the amount of iron that can be in front of the beam (2 or 1 blocks).
- XTDV in front of GIF++ always flexible (interlocked with PPE144)
- HSE/RP tentatively agrees to the new beam dump with a slight re-enforcement of the shielding.
- Still some details to be clarified (side shielding?)…..
- Costs : Minimal / free

Based on slides from N. Charitonidis

Monte-Carlo (preliminary) comparison

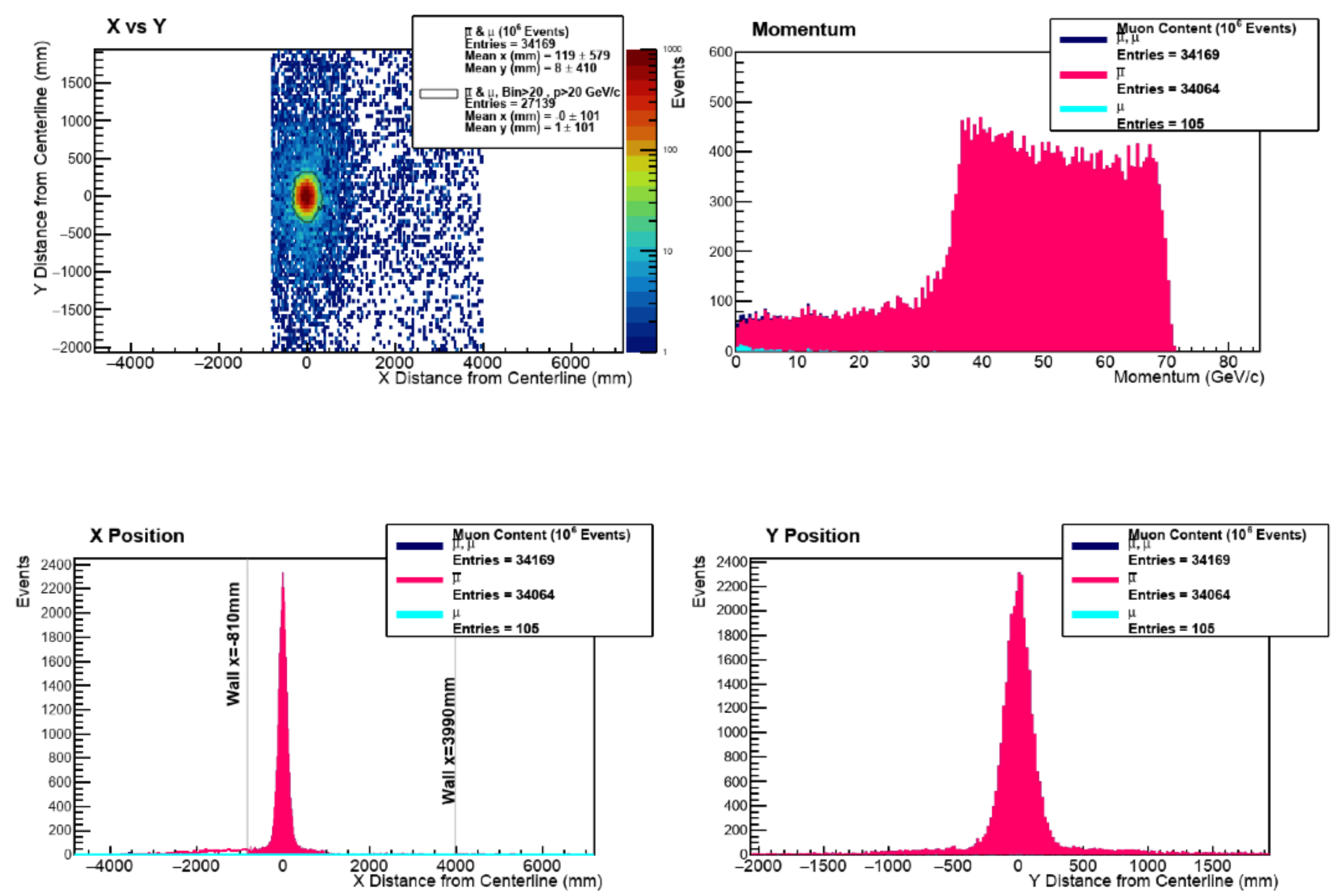
Current configuration (150 GeV)



6.5k muons per 10^6

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

New configuration (80 GeV)



35 k muons per 10^6

Better defined momentum and more 'focused' beam

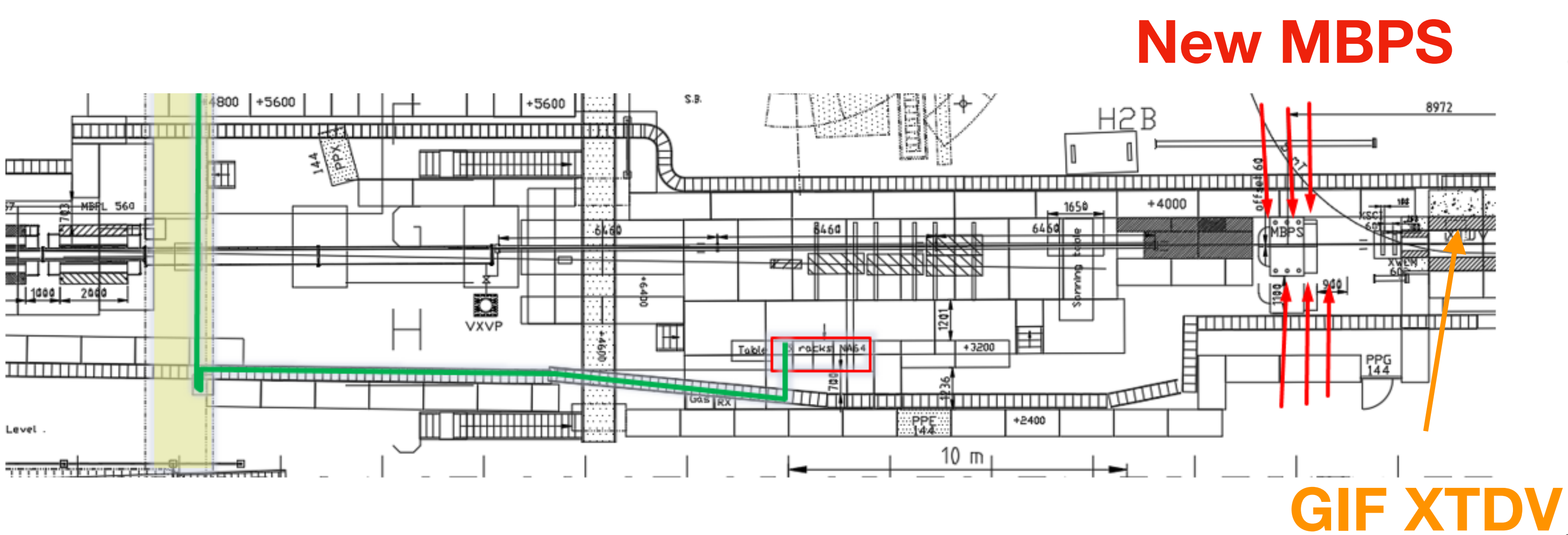
Concerns from RP about accessing the bunker during muon beam are currently investigated.

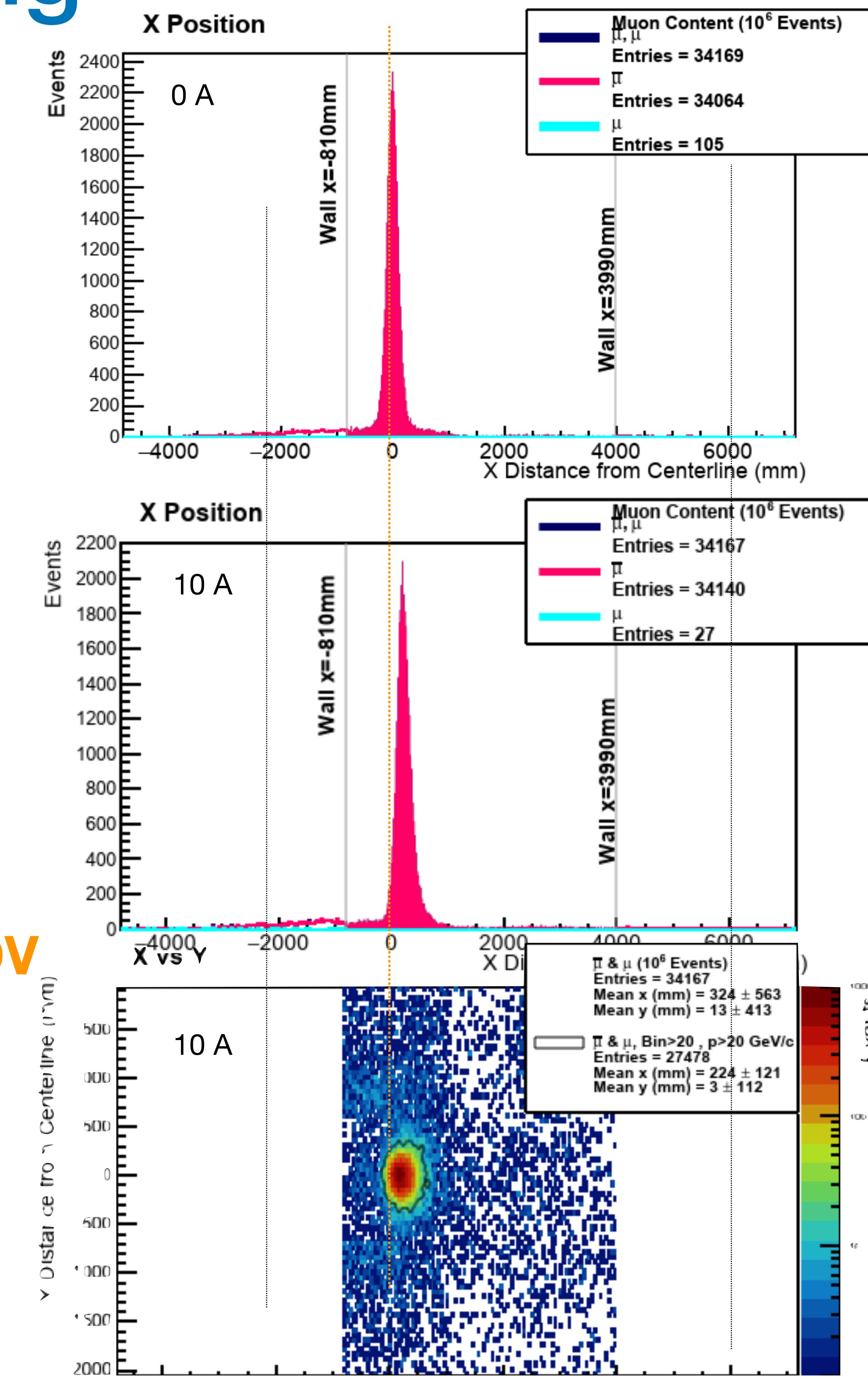
Based on slides from N. Charitonidis

And what about beam steering

Nikos quickly investigated this possibility.

- Yes, it is possible to place a dipole that will be moved (by hand) inside/outside the beam line, filled with iron (for stronger field) just in front of our XTDV
- 10 A would give ≤ 30 cm horizontal steering at the position of the irradiator

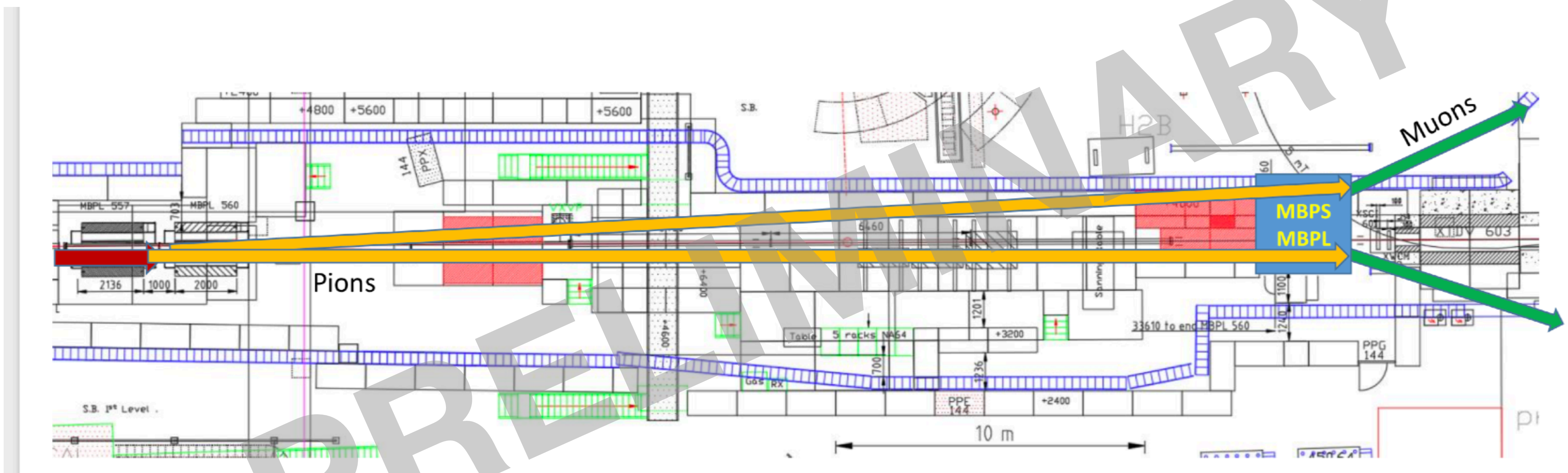




- Magnet will be free, 12 kCHF for cabling / power supply

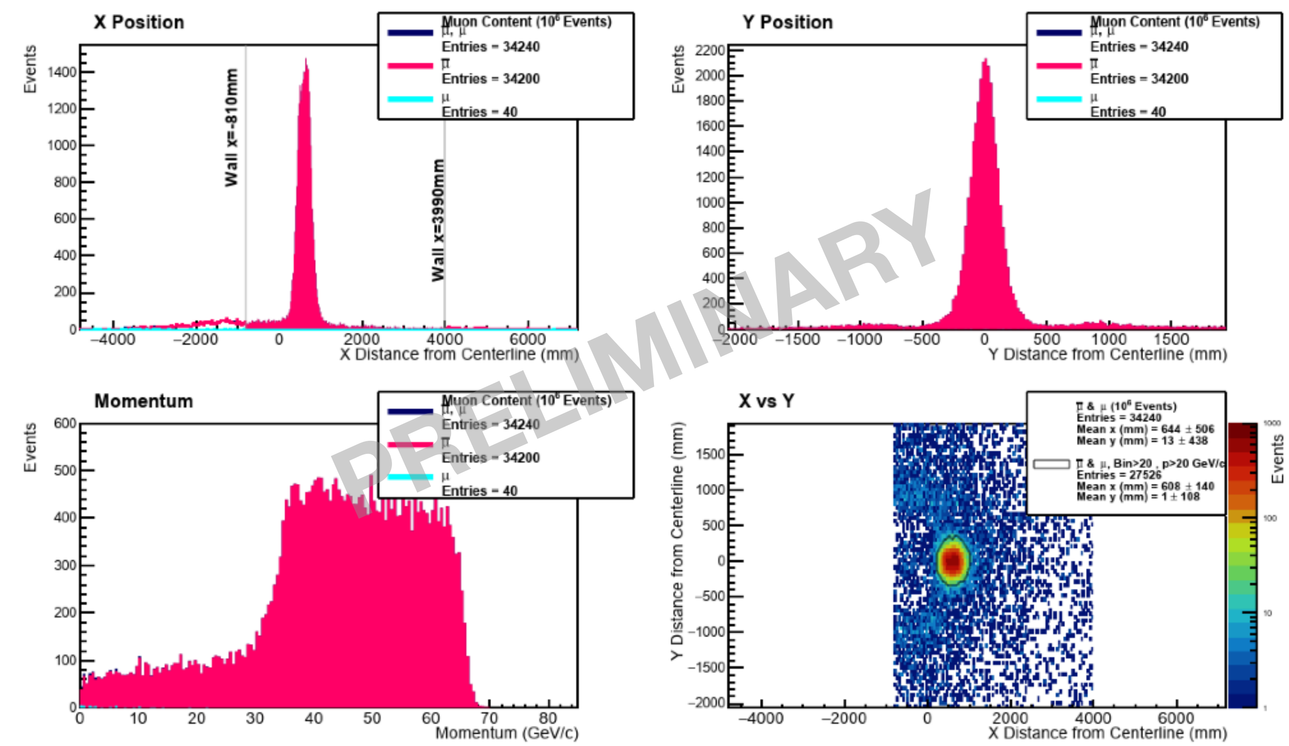
Based on slides from N. Charitonidis

Beam steering (2)



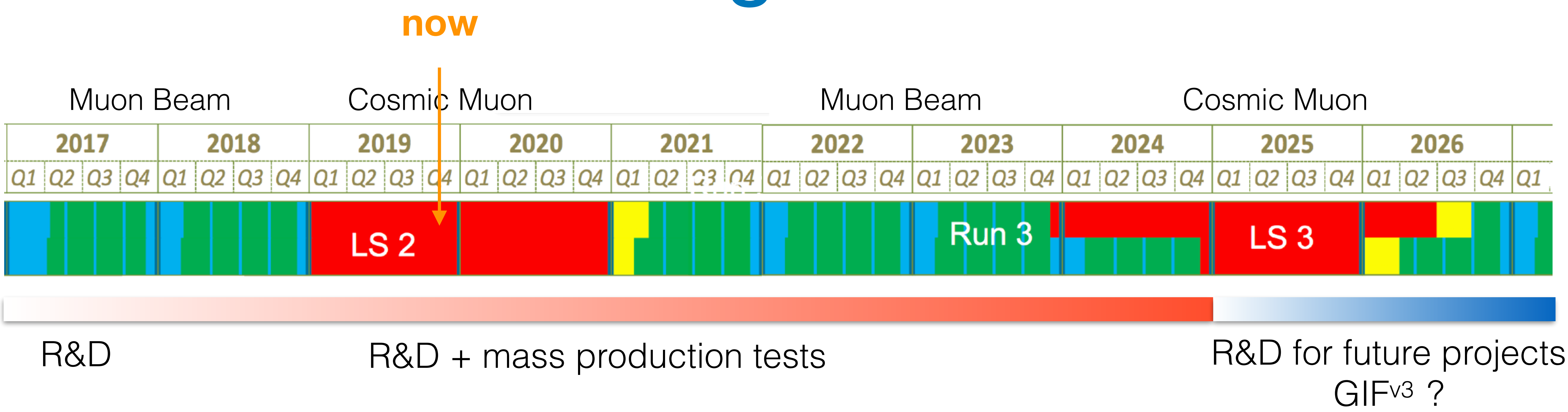
- We currently also investigate if magnets before PPE144 could be used to pre-steer the beam slightly, increasing the deflection to ≈50-70 cm.

- Further investigation and simulation needed !
- Requests needs to come from users



And beyond LS3 ?

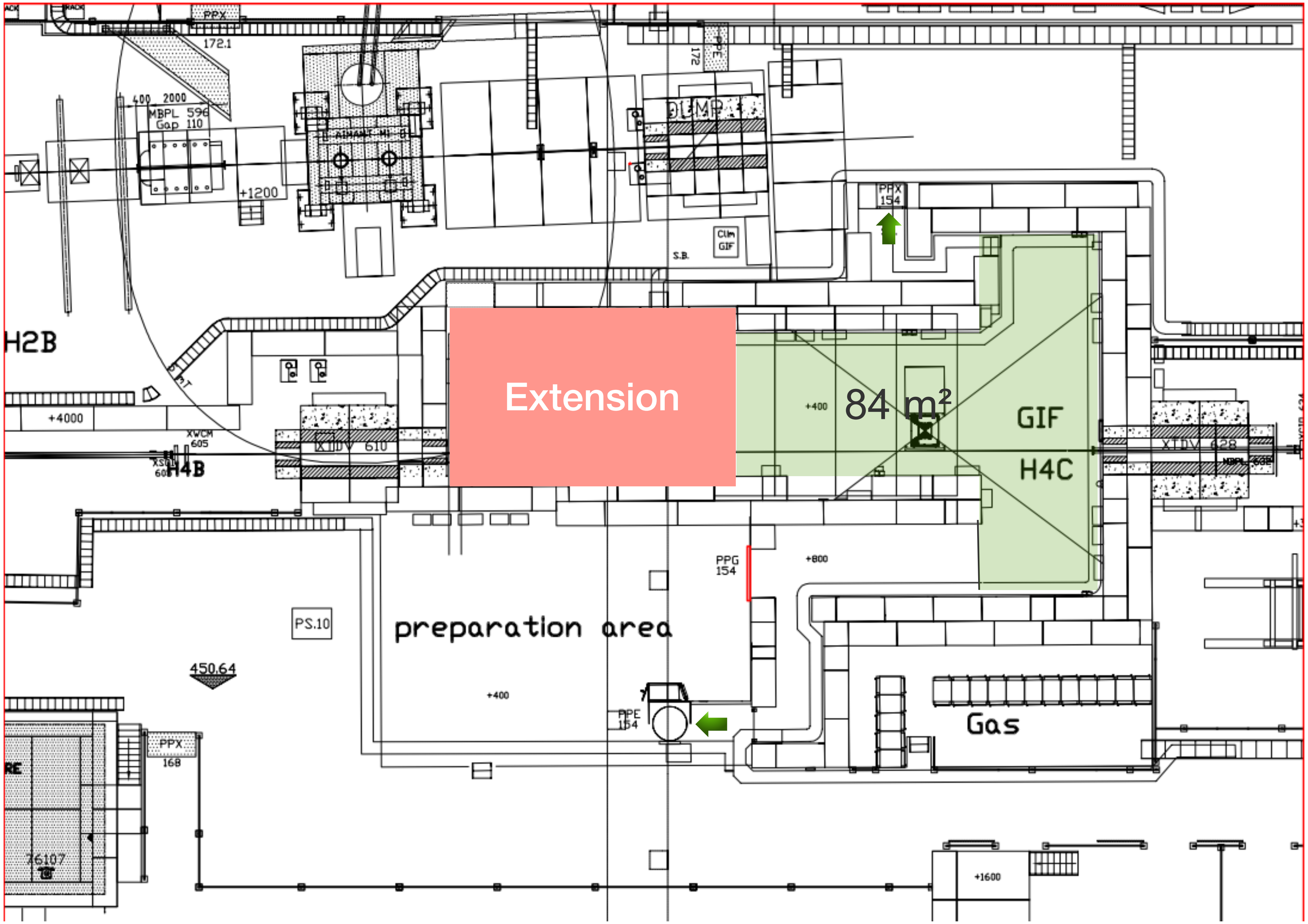
The Big Picture…



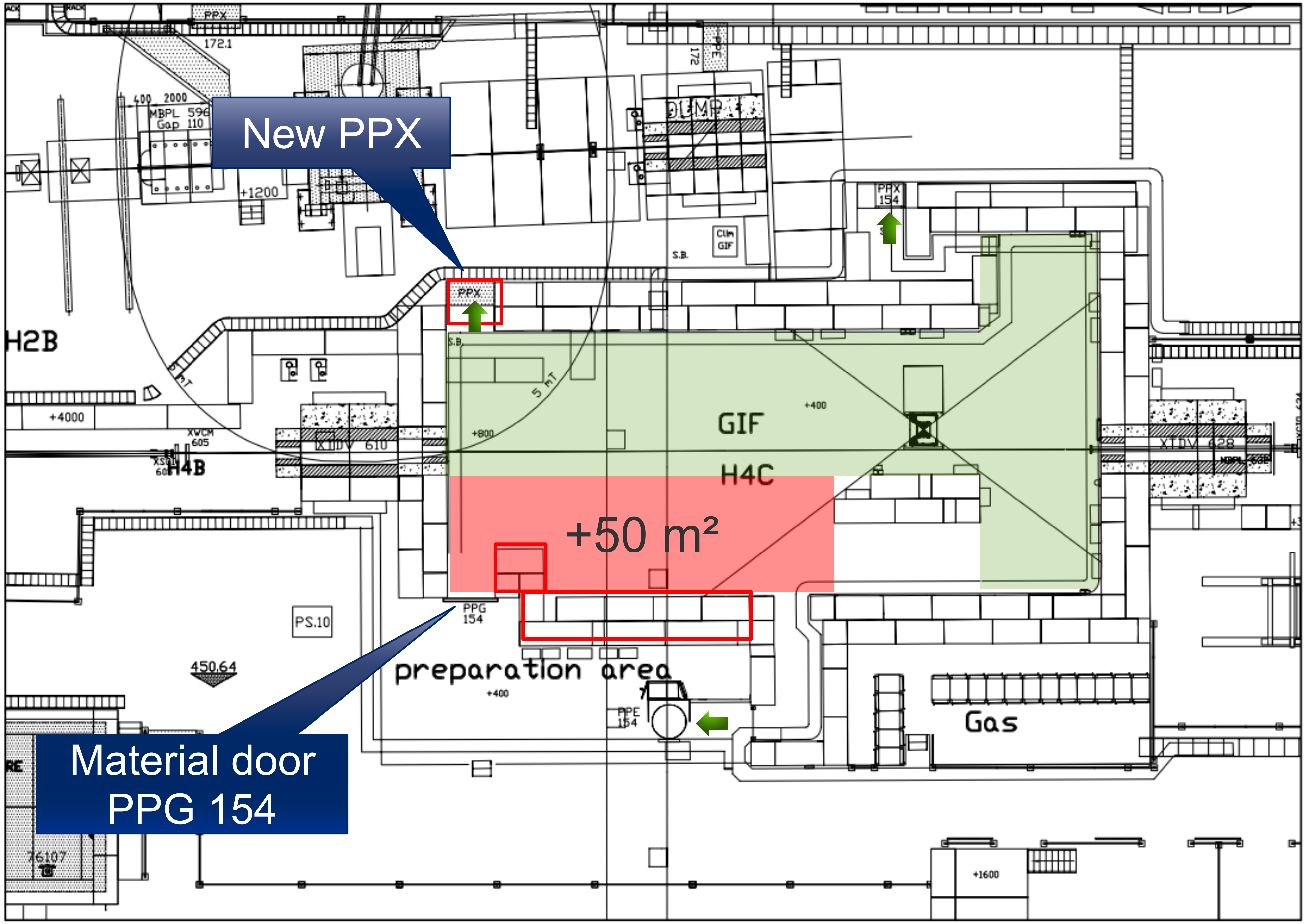
- Currently the lifetime of the facility is stated as 10 years (2014-**2024**)
  (after this, the Cs Source (≈ 11TBq) needs to be re-certified or exchanged)

- Possible upgrades - and the resulting downtime of the facility - need to be compatible with R&D requirements
- Cs source replacement should be straight forward as long as new source stays < 100 TBq (bunker shielding, handling of source, legal obstacles). Actual source strength defined by R&D needs and bunker size
- Budget needs to be allocated for upgrades

Phase 1 Extension - July 2019



Phase 2 Extension - LS3 ?



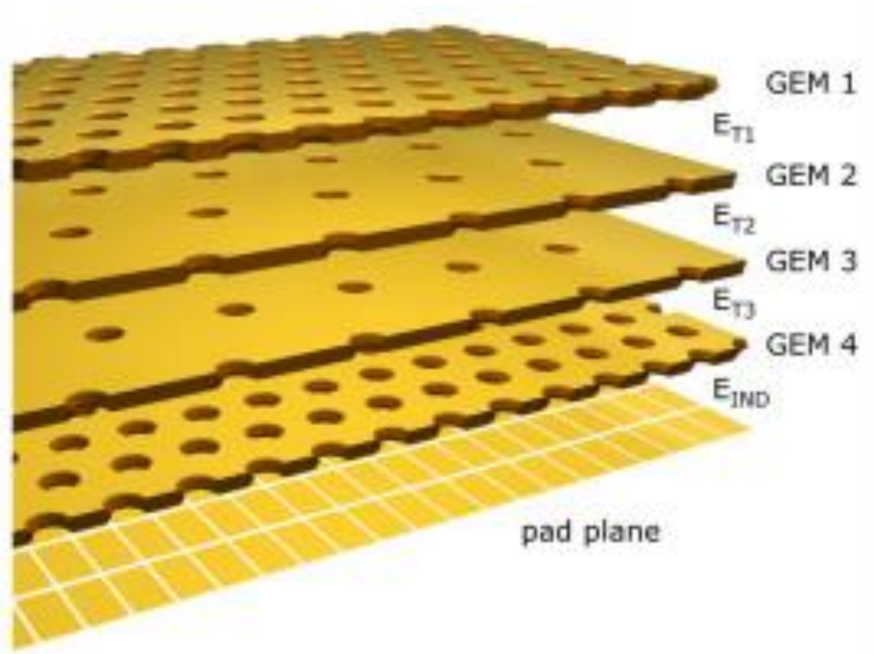
Irradiator Upgrade ?

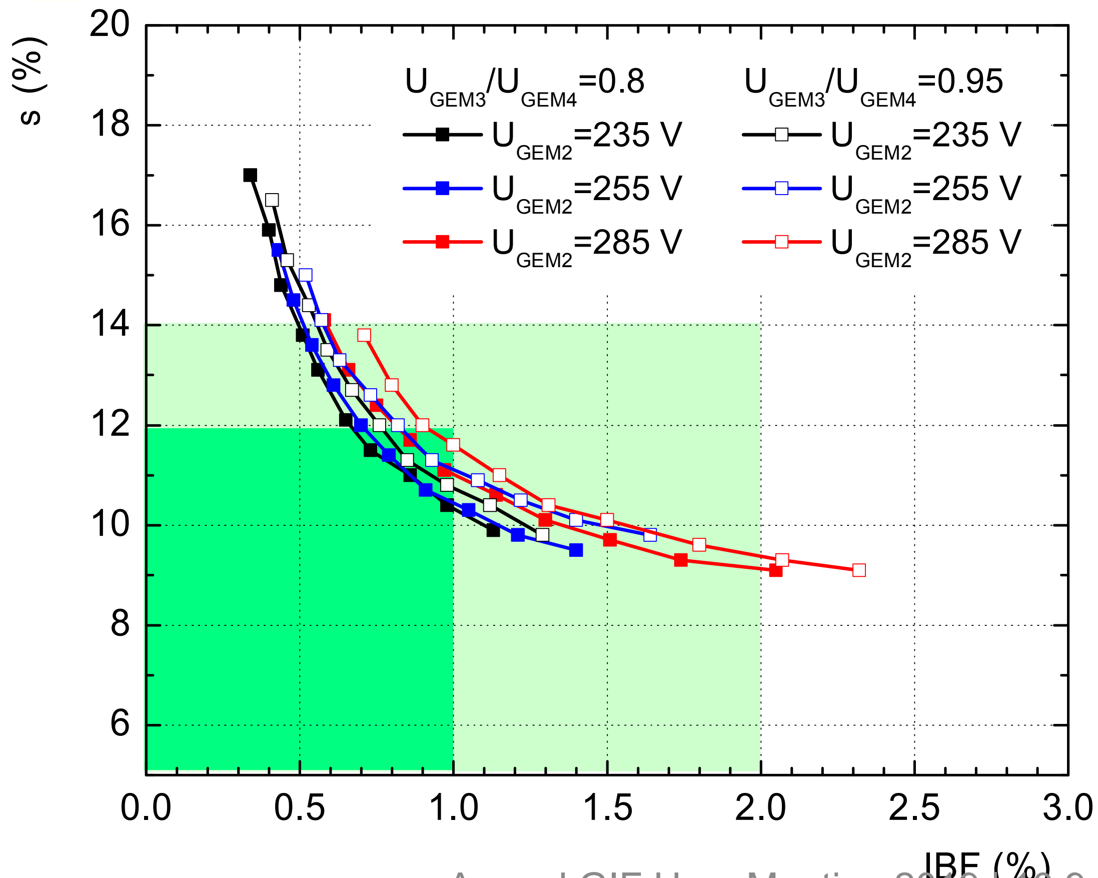
- Standard VF Irradiator design was significantly modified to have 2 large opening (74° H&V), instead of the usual small area shutter.
- Replacement of Cs capsule with higher intensity one is possible. Costs will mainly depend on required TBq.
- Similar Irradiator exist with multiple source carousel, allowing up to 5 (+1 empty) capsules to be loaded. Mixture of different intensity and gamma sources (Cs, Co,..) could be realised
  - Changing of Irradiator dimensions would most likely need a redesign of the complete attenuation system, as all filters have been calculated and custom made for existing geometry. Costs significant.

Thank you
for your attention

Backup Slides

ALICE TPC UPGRADE FOR RUN 3

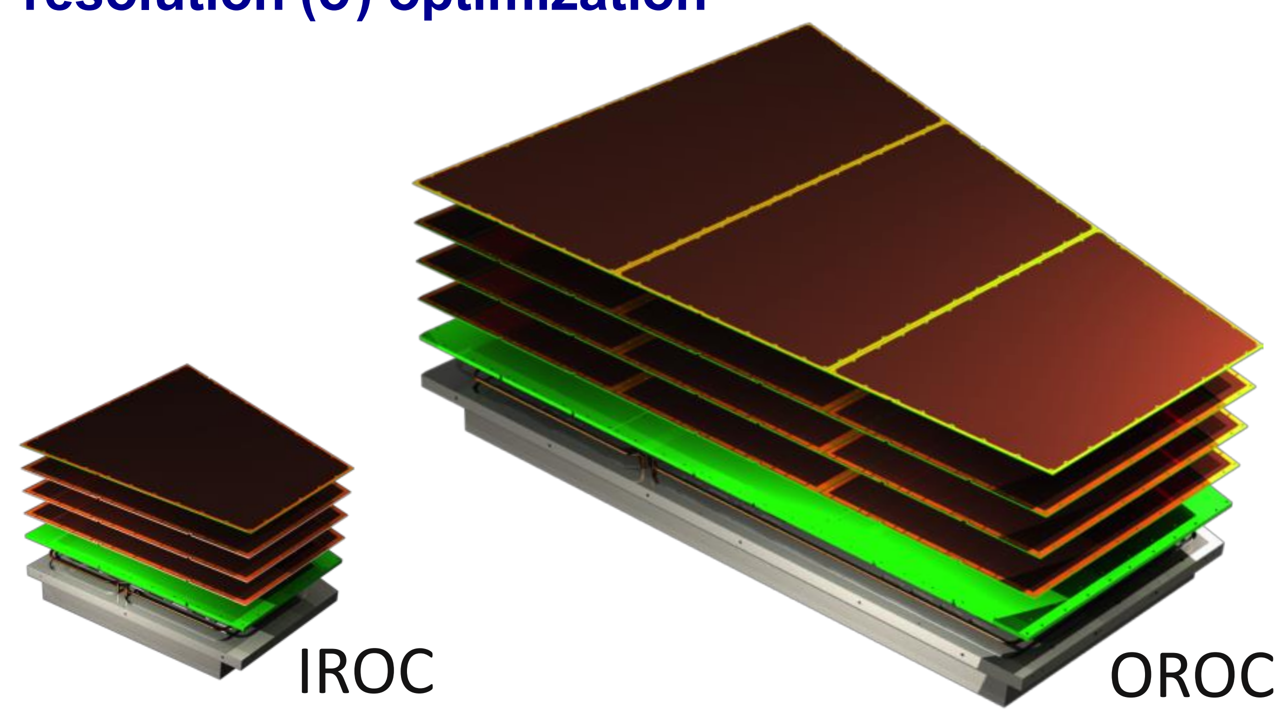




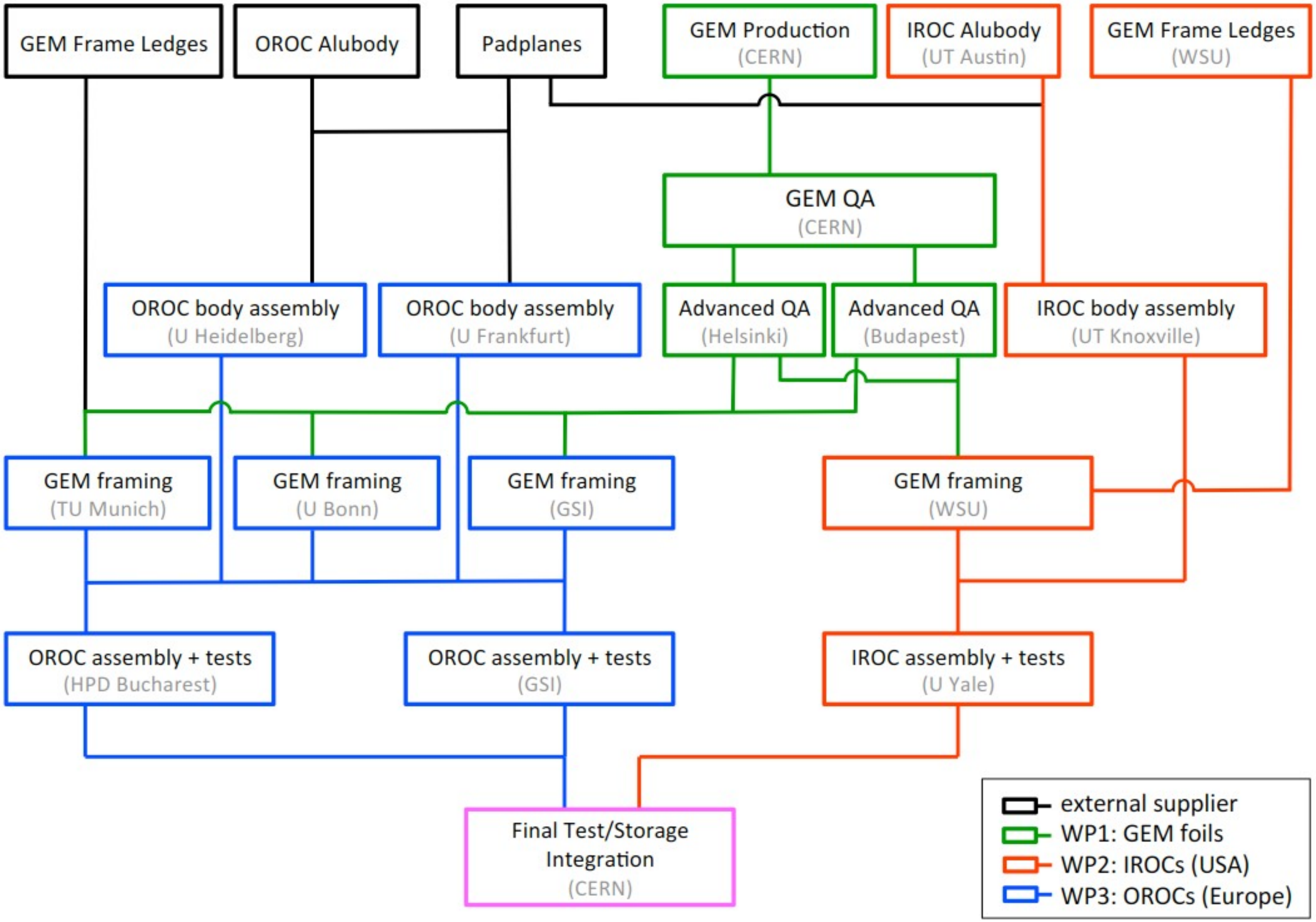
Solution:

- **Quadruple GEM stacks with different hole pitch and rotation of whole pattern**
- **Optimized field configuration and gain profile**
- **Robust against discharges**

Compromise between IBF and energy resolution (σ) optimization



ALICE TPC ROC PRODUCTION



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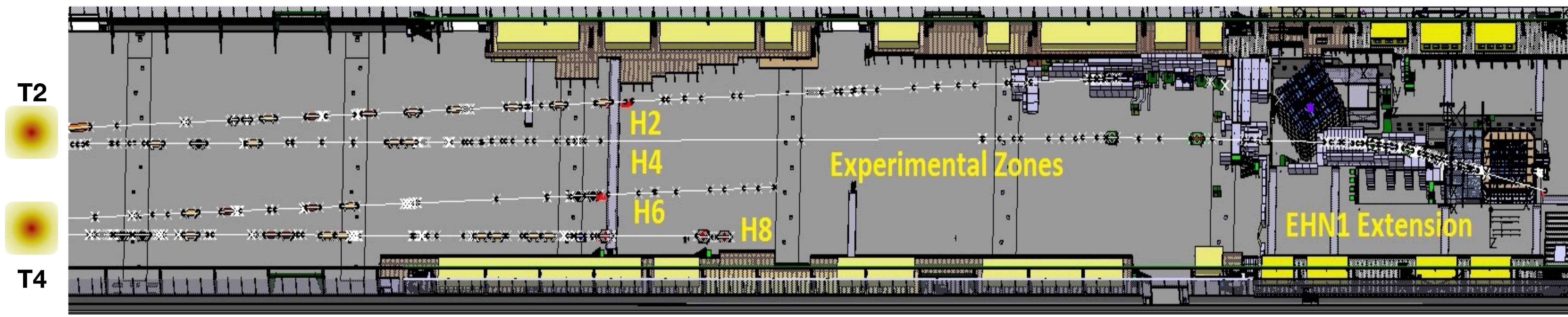
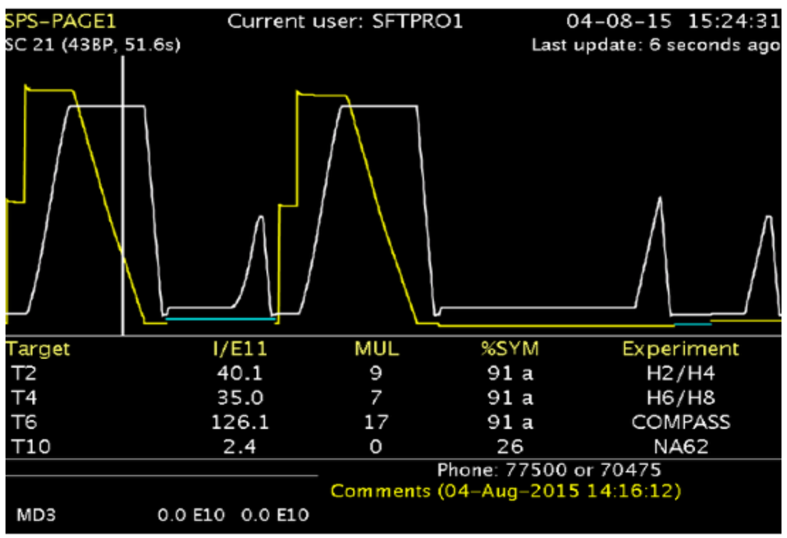
The Experimental Hall North 1 – EHN1





Hosts permanent fixed target experiments and quasi permanent test beams of large LHC experiments, as well as many non-permanent test beams for detector R&D

⇒ A dynamic building that adapts to the user needs

SPS : protons/ions @ 400 GeV/c

Maximum momenta available to the users in the SPS Test Beam Facilities :

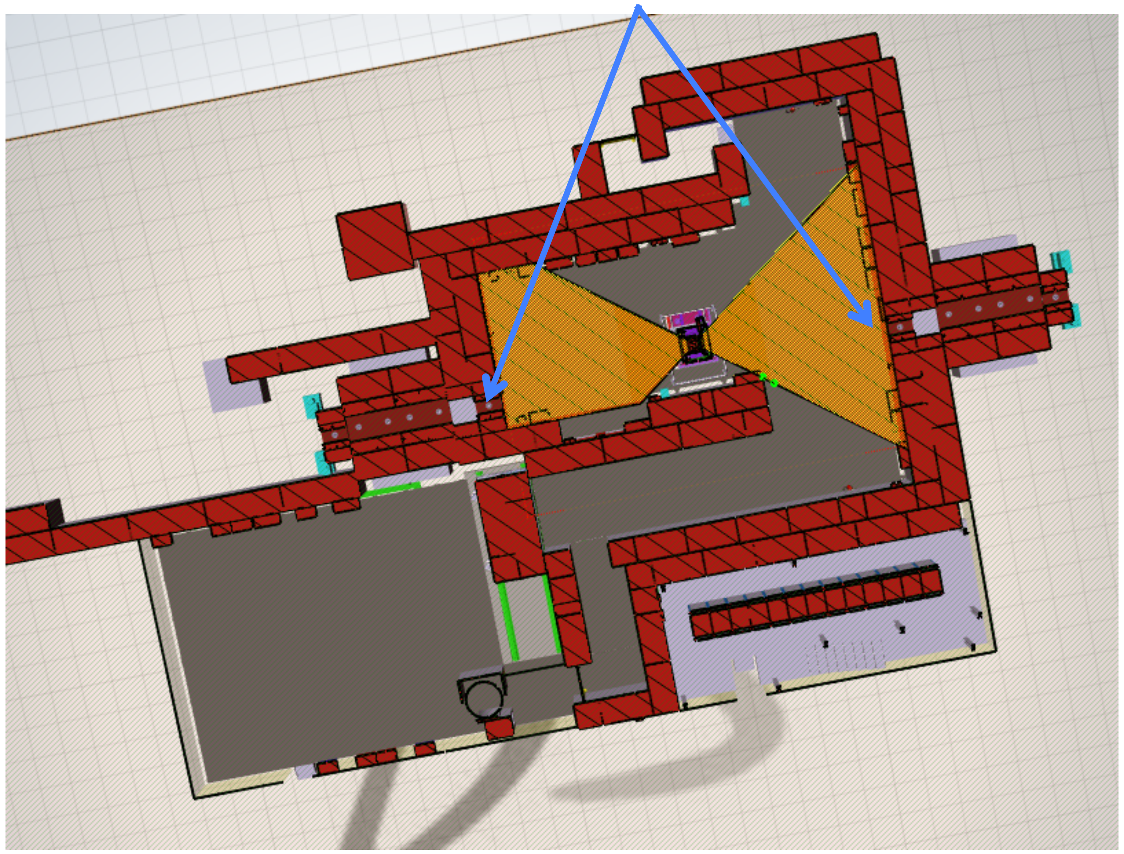
North Area → ≤400 GeV/c (primary beam) or ≤ 380 GeV/c (secondary beam)

Mixed hadrons or pure electrons

- Spill duration approx. **5 seconds**
- Usually : 2 cycles / SPS supercycle for NA
- Spill length / repetition frequency dependent on the physics program of all the facilities served by SPS and LHC → Variability to be expected.

Beam Tracker

beam-position detectors



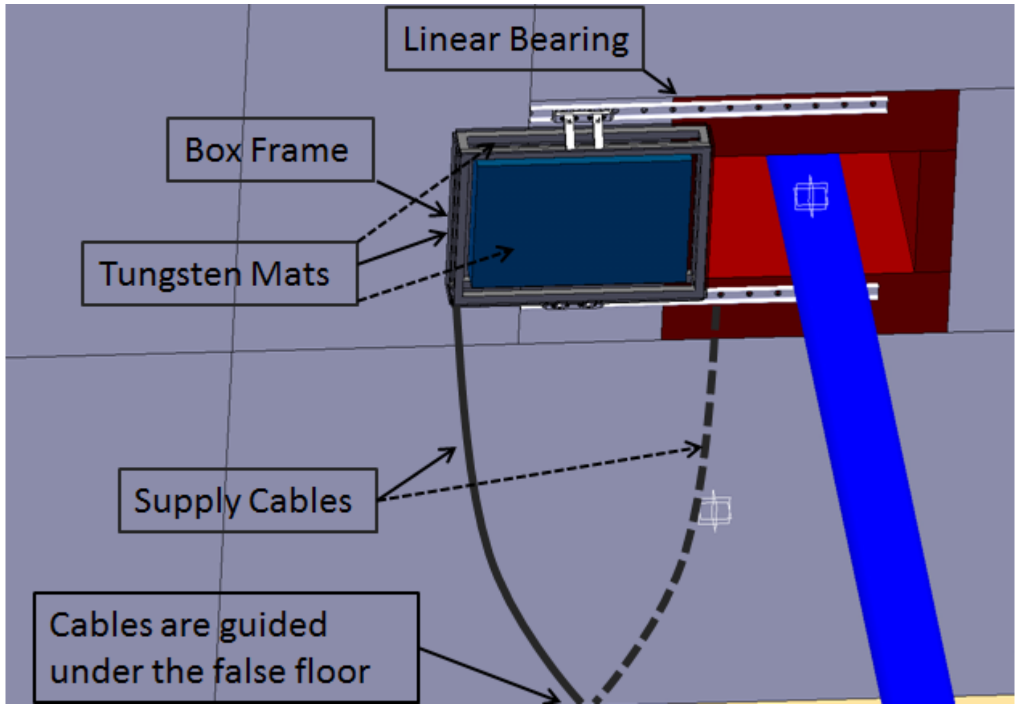
Detectors
- Two Thin-Gap-Chamber 4-plets (60x40cm²) with strips, wires and pads in each gap
- Spatial resolution measured on test beam ~80µm

Electronics (original plan)
- 4 layers (instead of 8) will be equipped with temporary front-end and readout electronics during 2014
- final electronics for the 8 layers will be implemented in 2015

However… "some" delay on the electronics has account

Currently used :

Beam Trigger (2 pairs of scintillators)



DAQ system

Requirements

- Create a trigger from beam tracker (TGC) and/or cosmic tracker (RPC)
- Distribute the trigger to different Detectors Under Test (currently up to 5 DUTs)
- Synchronise the events from the TGC/RPC with the DUTs for tracking/efficiency purpose

Implementation

- Based on a **Trigger Logic Unit** module provided by EUDET community and intensively used in test beams (DESY, CERN, FERMILAB, …)
- Unit provides **trigger signal** and **trigger number** to all detector DAQs
- Requires busy signal from detectors DAQs
- This module synchronises the different DAQ systems