Cosmic-ray tracker improvements and augmented reality event-display for GIF++

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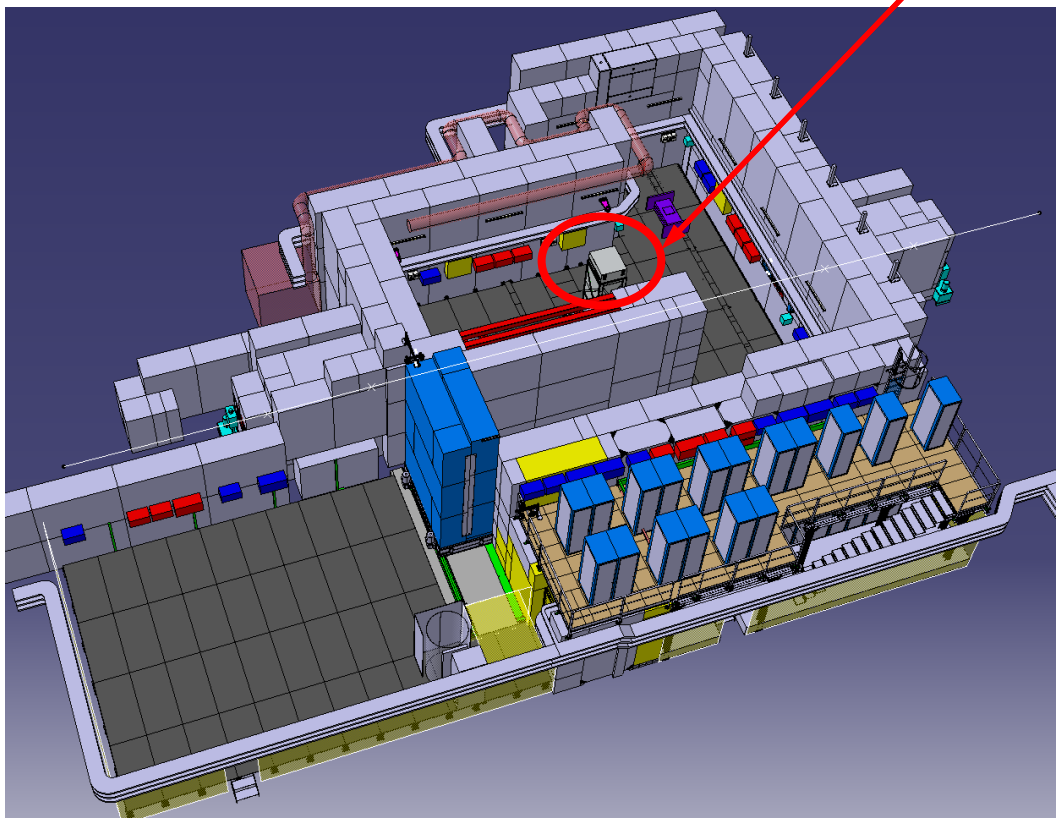
WP 15.5.4

AIDA-2020 3rd Annual Meeting - Bologna, 24 – 27 April 2017

Improvement of the GIF++ cosmic-ray tracker

Currently cosmic-ray tracker at GIF++ is covering just **one side** of the bunker (wrt the irradiation source)
Useful when the muon beam is not available
(6-8 weeks/year as main users,
plus similar time as parasitic users)



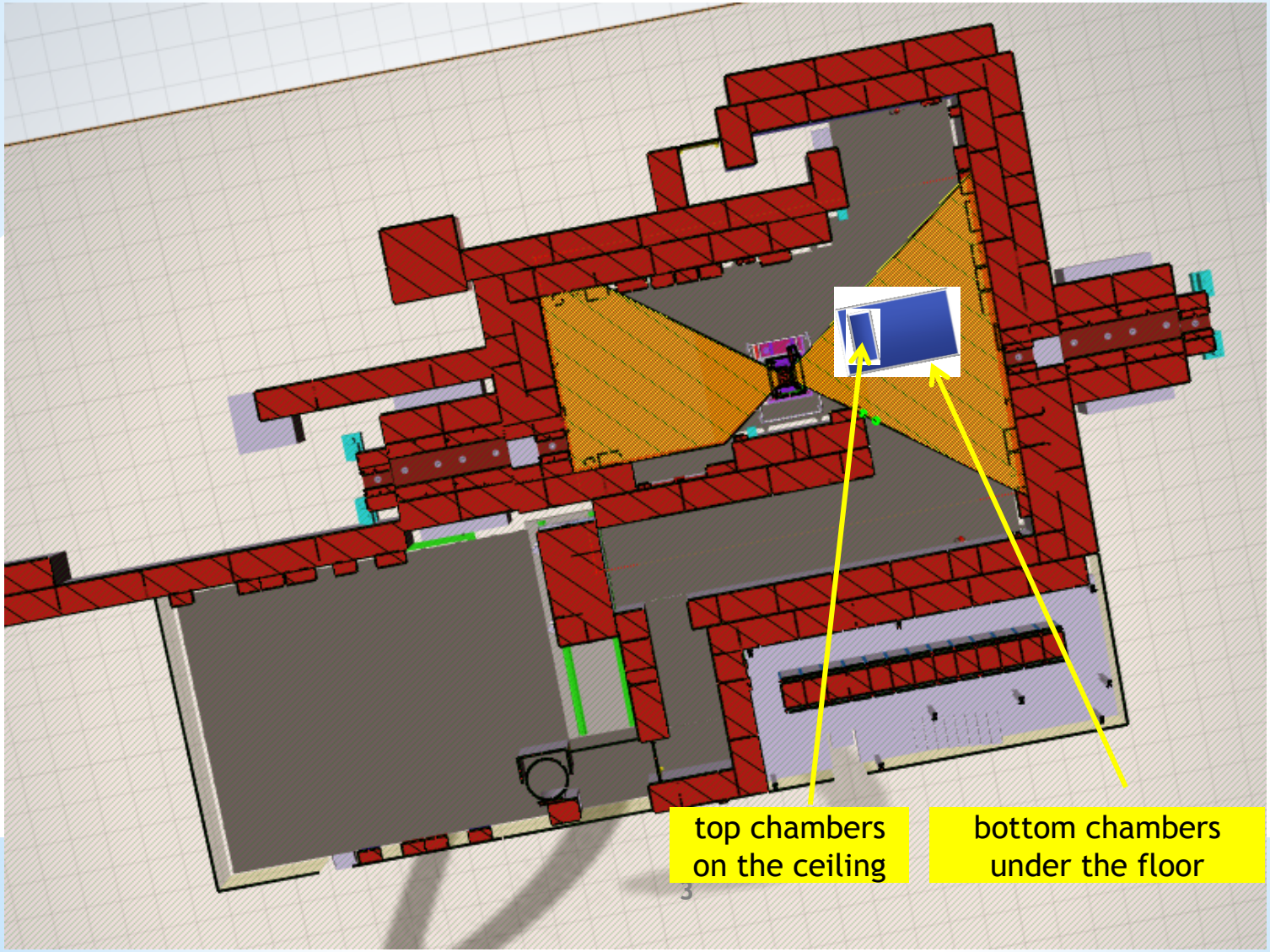
Upstream

Downstream

GIF++ bunker surface is 2 times the old-GIF, but it is already very crowded

Current cosmic tracker setup

Based on **Resistive Plate Chamber** technology



Project Motivation

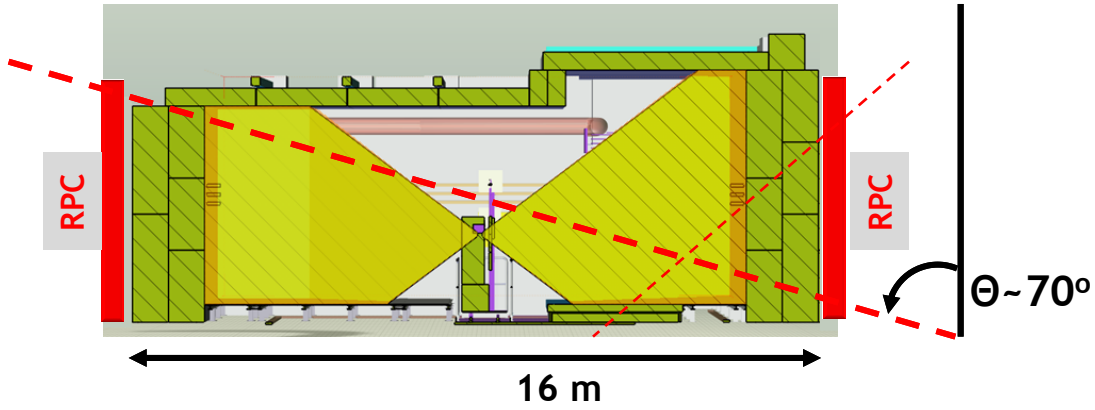
Improve the cosmic muon selection

- instrumenting a **larger area** of the facility

- selecting **higher momentum** muons

Also possible to trigger on the beam-halo, if the position of new chambers is chosen appropriately

The above requirements can be fulfilled by installing large area RPCs on the vertical walls of the facility



Using large angle cosmic muons there is no need to change orientation of the detectors wrt beam muon test

Spectrum of cosmic muons at sea level

from PDG

C. Patrignani et al. (Particle Data Group), Chinese Physics C, 40, 100001 (2016)
The Review of Particle Physics, chapter 29.3, page 8
http://www-pdg.lbl.gov/2016/reviews/rpp2016-rev-cosmic-rays.pdf

θ = 0°

θ = 75°

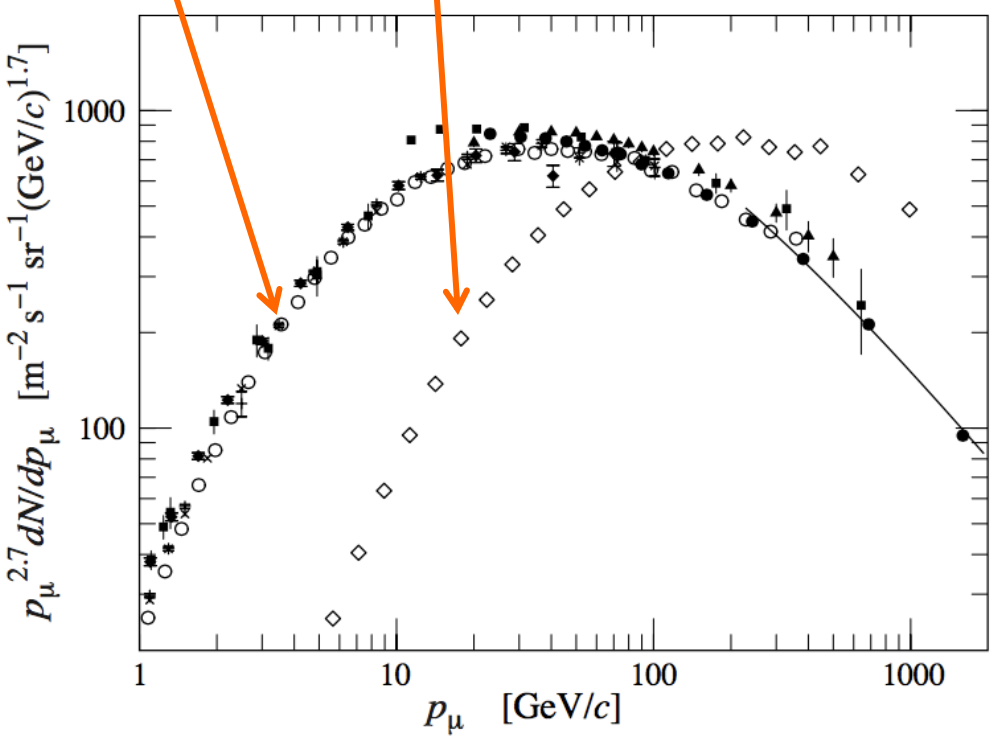


Figure 26.4: Spectrum of muons at $\theta = 0°$ (♦ [41], ■ [46], ▼ [47], ▲ [48], ×, + [43], ○ [44], and • [45] and $\theta = 75°$ ◇ [49]) . The line plots the result from Eq. (26.4) for vertical showers.

Harder spectrum at larger incidence angles

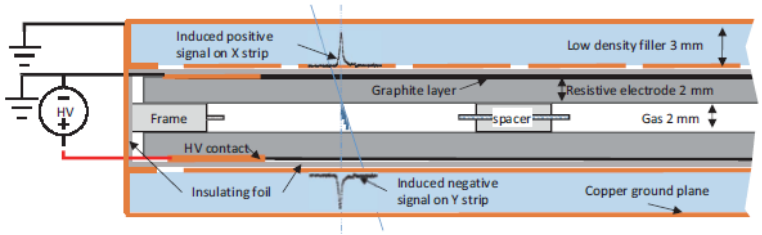
The Upgrade Project

Build **RPC chambers** to be placed on the **vertical walls of the bunker** (see pictures in next slides) with a total surface of ~12 m^2

Chambers

- 2 independent **active layers** (gaps)
- 4 **readout panels**
- 3.4 x 0.9 m^2 active area
- 1 cm **spatial resolution**

single layer



New chambers will be integrated into the already existing infrastructure :

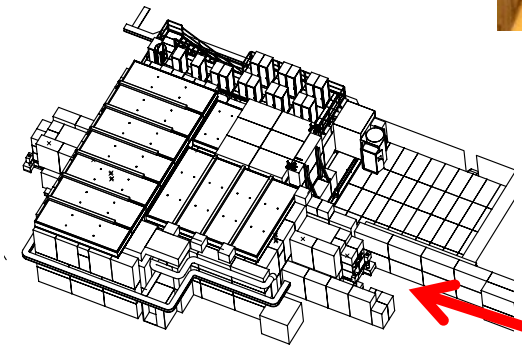
- gas system
- power supply
- DCS
- DAQ

GIF++ bunker end-walls

Downstream

Upstream

Downstream



Upstream

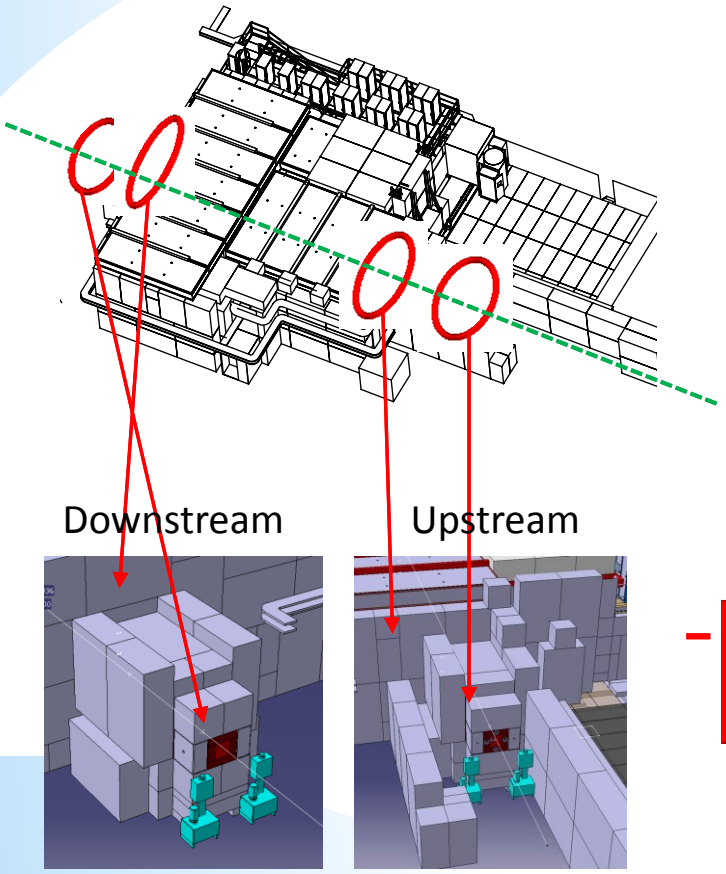
Beam

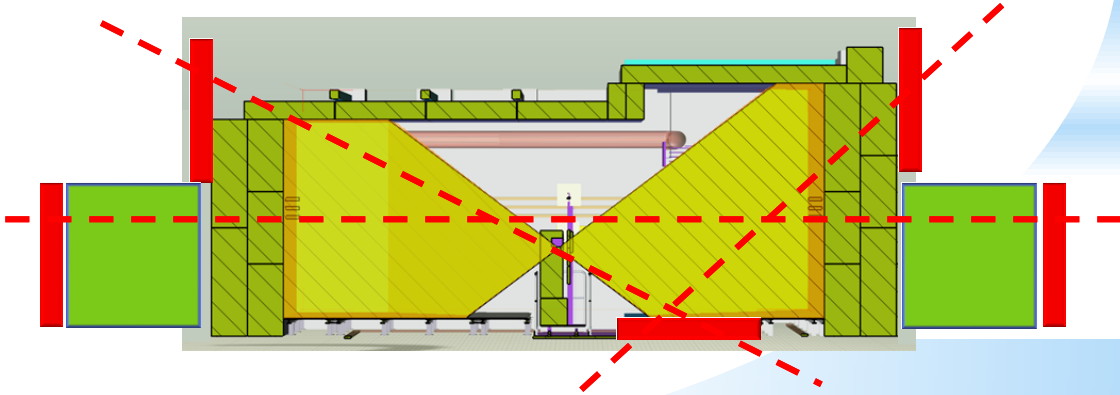
Chamber positioning

Positioning of chambers has to fit the geometrical constraints
presence of **beam dumps** on both sides

Triggering on **beam-halo** needs chambers on both sides

Coincidence with floor chambers is also possible





Chamber positioning

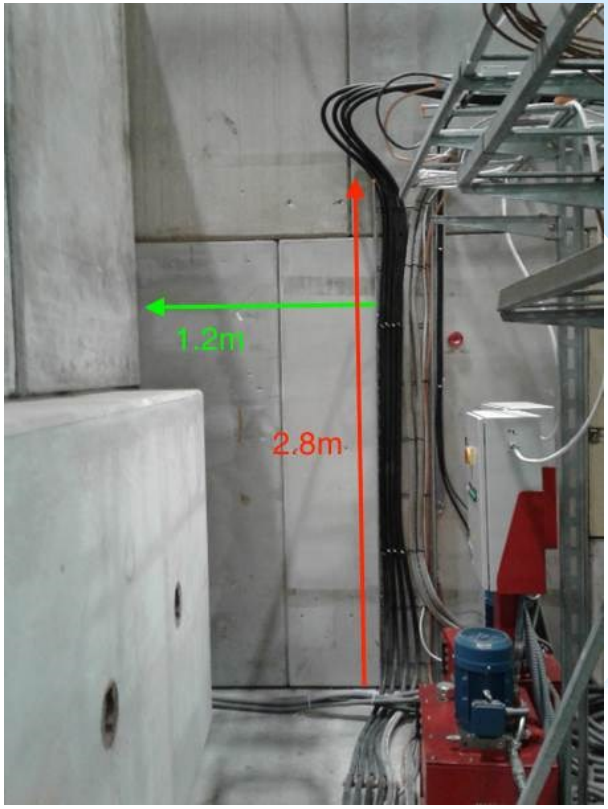
Downstream

Downstream chambers position decided after interaction with Cern Group

Chamber positioning

Downstream

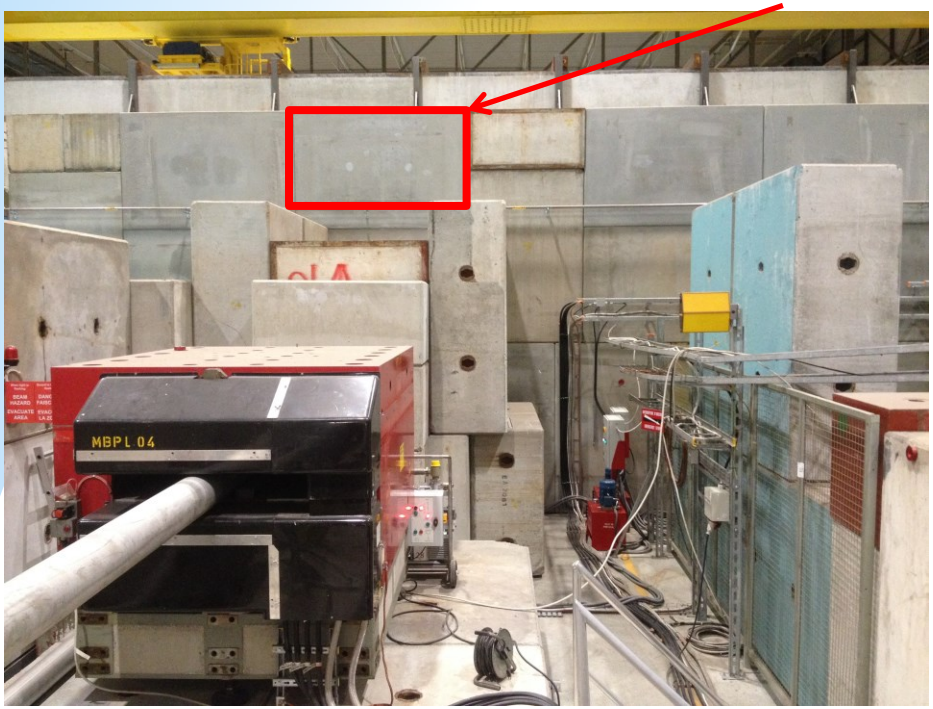
Cable
re-routing



Thanks to Martin, Giuseppe, Federico, Sylvain,……

Chamber positioning

Downstream



Upstream is on hold depending on GIF++ extension

Chamber status

Mechanics is available

Chambers are under test at BB5

Need to produce some active elements of the detectors:

- gas volumes
- readout panels

Bakelite for the gas volumes are being ordered

Timeline

Project Deadlines

Milestone:
Design of chambers
18 months

Deliverable:
Cosmic tracker installed and commissioned
44 months

2018 First Half

At material arrival, produce chambers:

- gas volumes
- readout panels
- front-end electronics

2018 Second Half

Downstream chambers can be installed
Upstream chambers waiting for news on bunker extension

Augmented reality cosmic-rays event display

AR event display framework

Combine **particle physics detector**, **real-time data acquisition** and Augmented Reality

producing a direct experience of cosmic rays for an operator inside the GIF++ bunker

GIF++ hardware infrastructure provides most of the needed support

GIF++ becoming pilot project for a new generation of tools for commissioning and maintenance of complex experimental apparatus (reduce time of interventions, enhance operator safety, …). Interfacing the system with DCS to show power status of boards or any detector element in the operator view

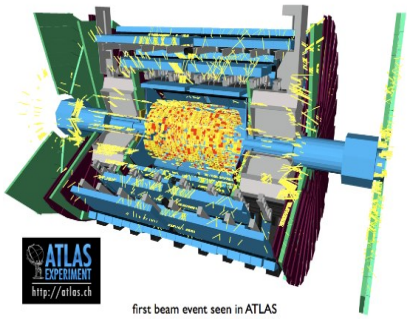
Using a **good timing detector (RPCs)** could allow to
view / stop / re-play / view in slow-motion a cosmic shower event and see its impact on a test detector

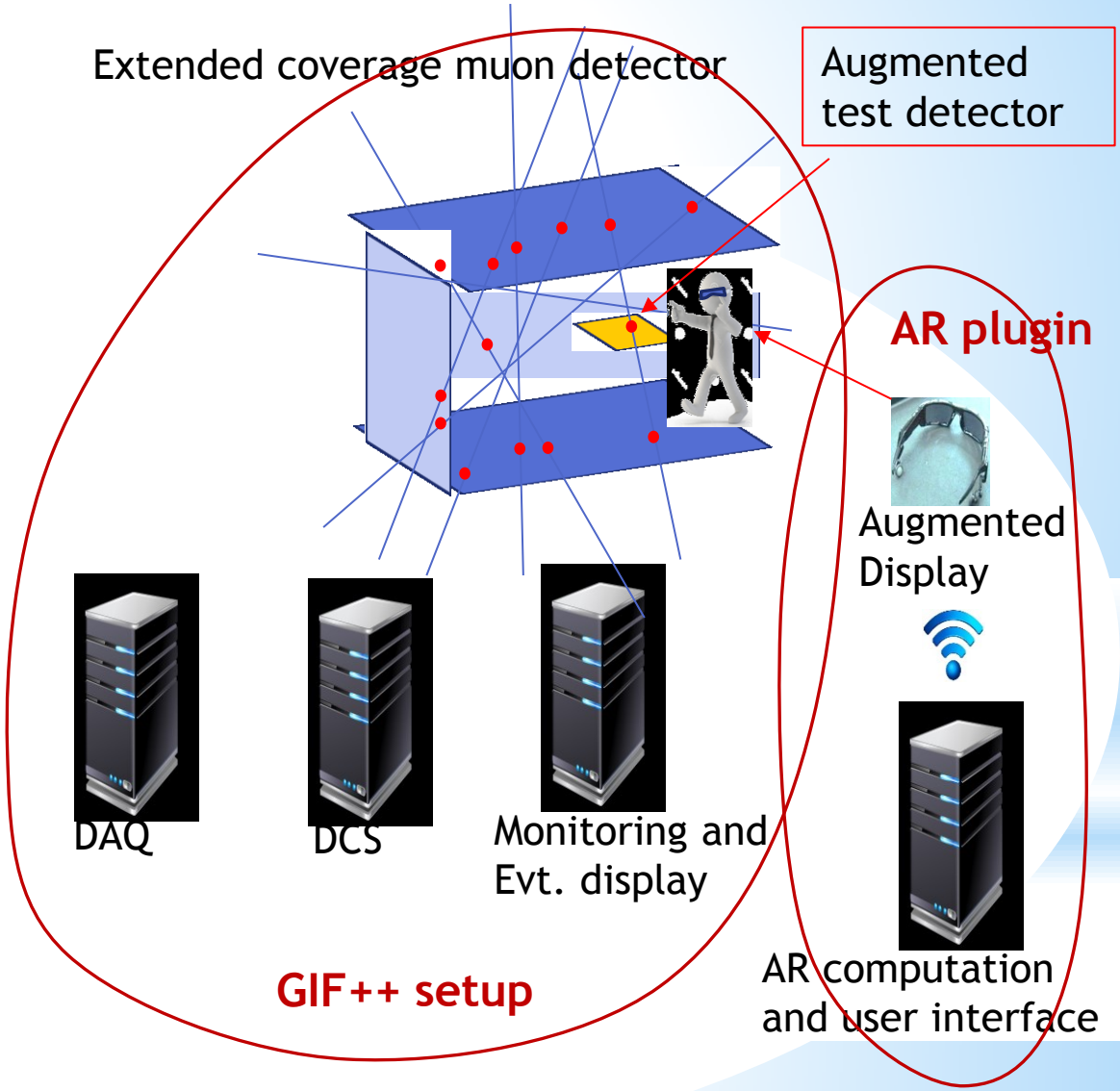
Augmented Reality Applications

- industrial control, production and safety
- cosmic-rays visualization for education and outreach (Universities, exhibitions, museum, etc.)
- visualization of any source of invisible field of radiation by replacing the type of sensors, e.g. Radio Frequency, Infrared, UV…

Relation between GIF++ and AR event display

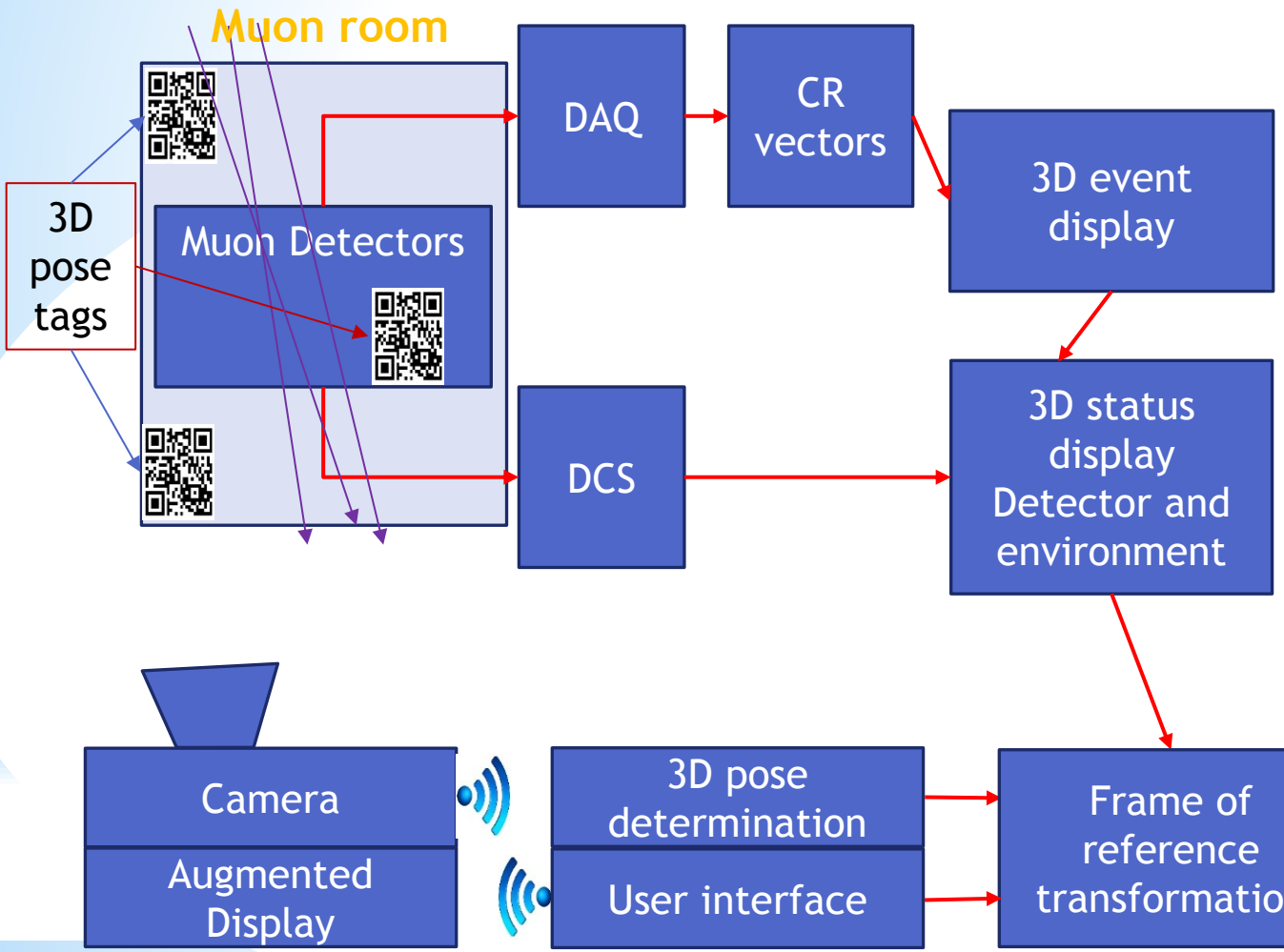
* Most of the HW is already enclosed in the GIF++, especially if the CR detector coverage will be extended and we will add the 3D event display features to the online monitoring system





* Needed:
  - **development of software for AR and user interface**
  - **AR display hardware**

Functional description of the AR display in the GIF++



Muon detectors data to construct the event display

Camera reconstruct its position through local tags

The **event display** is transformed in the reference frame of the operator

3D event is sent to the **augmented display** through the user interface

Steps for augmented reality event-display

- Data to AR demonstrator from the DAQ system (still in preparation)
- Installation of reference marker in the bunker in the coming weeks
- Start software development for the camera position calculation

Then:

- Development of user interface
- Procurement of the AR display

The Software Platform

The first step was the search for a suitable software platform to implement AR for

- **visualization** of cosmic ray tracks
- **interfacing** with Detector Control System

The software Platform : **ARToolkit** provides

set of tools implementing the base functionalities for AR application

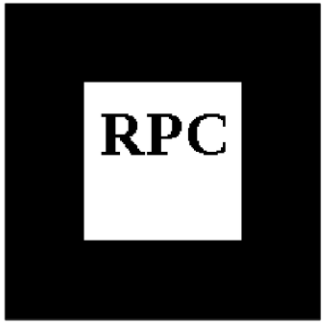
- free and open-source
- available for many platforms and OS
- supporting C++, Python, Java, Javascript
- wide community of users

Based on physical markers to be positioned and visible in the environment

Test of Software Platform

Preliminary tests were carried out at the INFN Labs of Roma Tor Vergata

ARToolkit installed on two personal computers with Linux Ubuntu 16.04 LTS 64 bit



The marker has been imported and recognized by ARToolkit
Simple geometrical figures and superimposed text drawn above instrument and detectors

Test of Software Platform

As the camera is turned toward the gas mixer control unit
the used mixture appears , with names shown on the control switches

The next steps

The next steps

- test the possibility to interface with the DCS of one of the detectors inside GIF

- develop a software module able to simulate the output form the Cosmic Trigger

- survey GIF++ area in order to define the set of markers needed

Involved institutes/people

Beneficiary of AIDA 2020 funding is **INFN**

Bologna: AIDA funding a one year post-doc position
INFN: G.L.Alberghi, D.Boscherini, C.Gessi, P.Giacomelli, A.Polini, M.Romano

Roma "Tor Vergata": AIDA funding a two-year post-doc position
INFN: R.Cardarelli, B.Liberti, L.Massa , E.Pastori
UNIVERSITY: *A.Abdallah*, G.Aielli, P.Camarri, A.DiCiaccio, L.DiStante, R.Santonico

Material : Electrodes and front end electronics (are being ordered)

Summary

- GIF++ is a unique place for detector R&D for HL-LHC:
  many users will benefit of improvements of its infrastructure
- The upgrade of the cosmic tracker will allow high-p muon trigger
  possibly allowing trigger also on muon beam halo
- The mechanics of the large area RPC chambers is available
  The active detector elements have been ordered
- The demonstrator for an augmented reality display will greatly benefit of the facility infrastructure
- While waiting for the DAQ system to be available,
  starting soon with software development for user position reconstruction