



Development of a Cosmic Muon Trigger System for CERN-GIF++

K. Maslova
on behalf of GIF++ Cosmic Trigger System Team





Outline

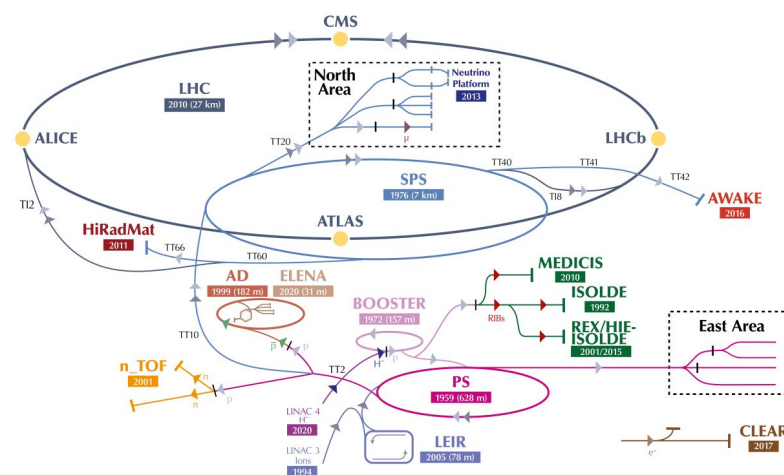
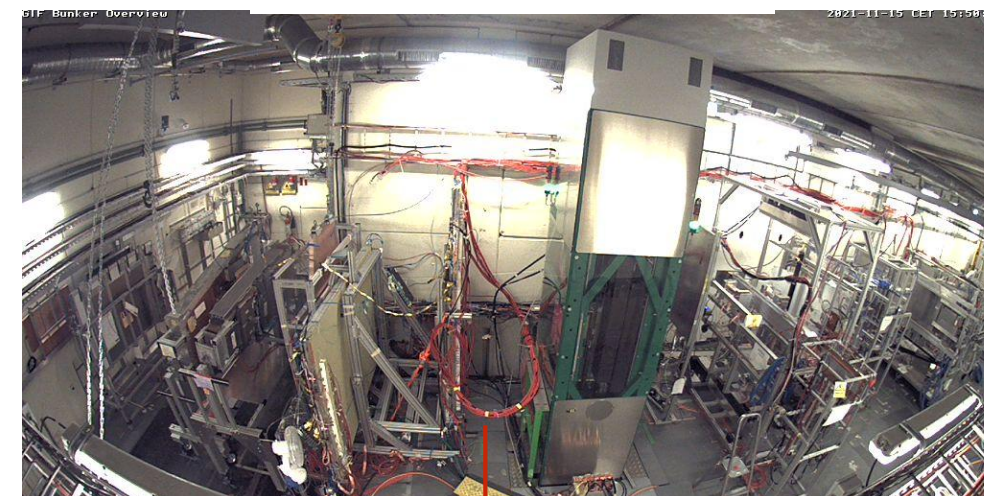
- ❑ Gamma Irradiation Facility (GIF++);
- ❑ Motivation;
- ❑ Possible design;
- ❑ Simulation results;
- ❑ Candidates;
 - ❑ Special case: CMS-RPC barrel chambers
- ❑ Conclusion

Gamma Irradiation Facility (GIF++)



- ❑ Multi User facility;
- ❑ Unique place, combining a **high energy muon** beam with a **10.5 TBq** * ^{137}Cs **gamma source**;
- ❑ Designed for testing real size detectors and in real background conditions;
- ❑ 2 irradiation zones with independent attenuation systems;
- ❑ Central Control System, wide range of available gases (+ custom gases), common DCS...

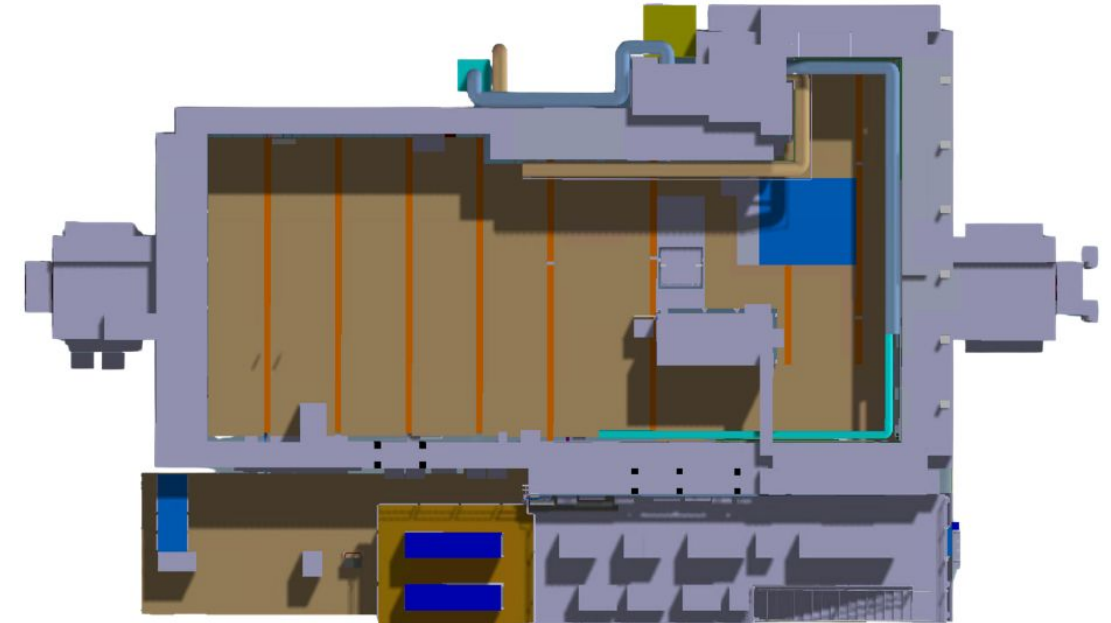
Irradiation Bunker



GIF++ R&D program

- ❑ Detector validation tests under realistic conditions: high radiation background & muon beam;
- ❑ Aging studies under HL-LHC radiation conditions;
- ❑ Search for alternative gas mixtures;
- ❑ Mass-production test of muon chambers;
- ❑ Tests of electronics;
- ❑ And more!

Irradiator
operation
throughout
the whole
year





GIF++ EP-DT Team 2026

GIF++ Physics Coordinator



Paolo

EXSO

GIF++ User Coordinator



Giuseppe

Doctoral student

GIF++ Responsible



Martin

Technician



Federico



Katherine



Enzo

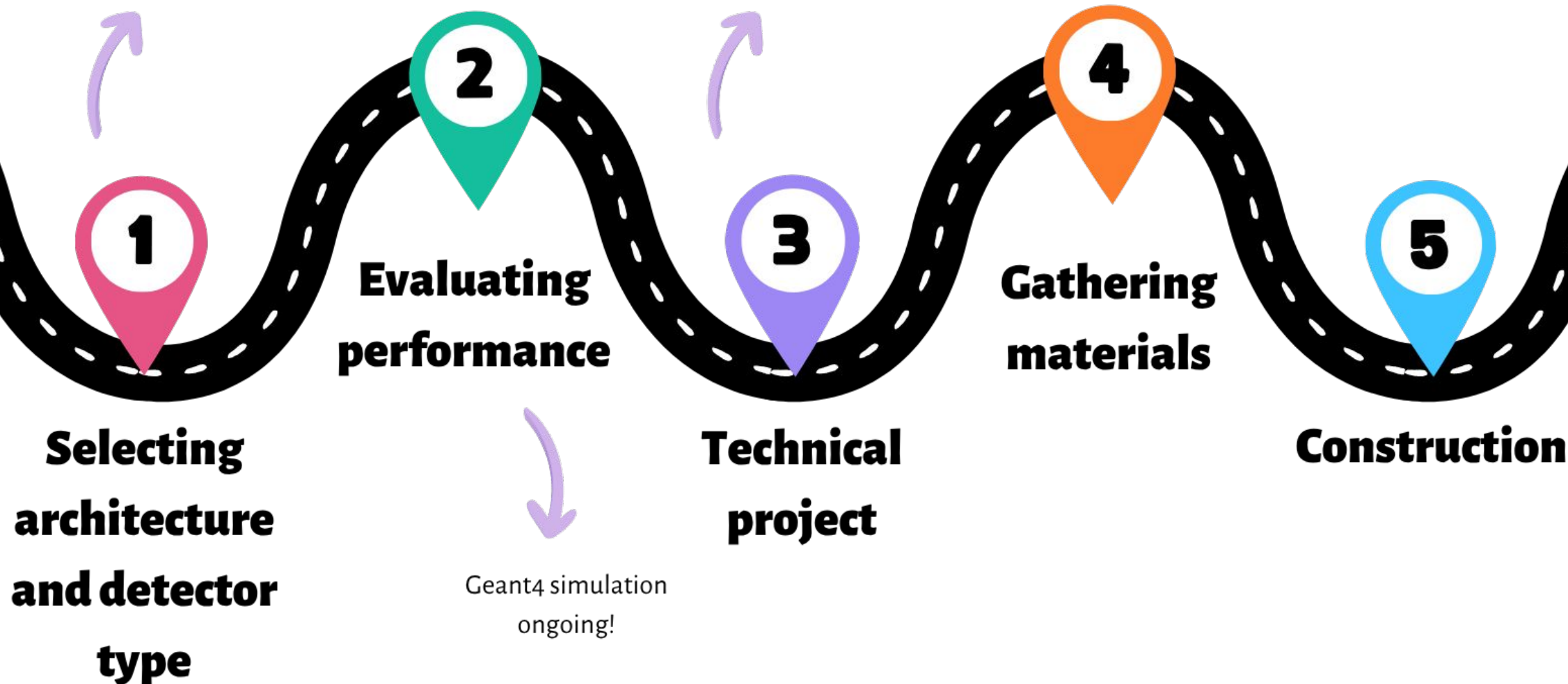


Motivation

- ❑ To **maintain the use** of GIF++ for evaluating long-term detector performance, aging and new gas mixtures studies;
- ❑ Need for a **muon source** in the absence of SPS beam, especially during LS3 (August/2026 until June/2030);
- ❑ Muon source also available outside “Test Beam” periods;
- ❑ Revive the 2019 project started by: Helio Nogima (BR), Giuseppe Pezzulo (IT) and Nikolas Zagadinis (GR) with MWPC chambers from LHCb. Stopped due to COVID and lack of person power.

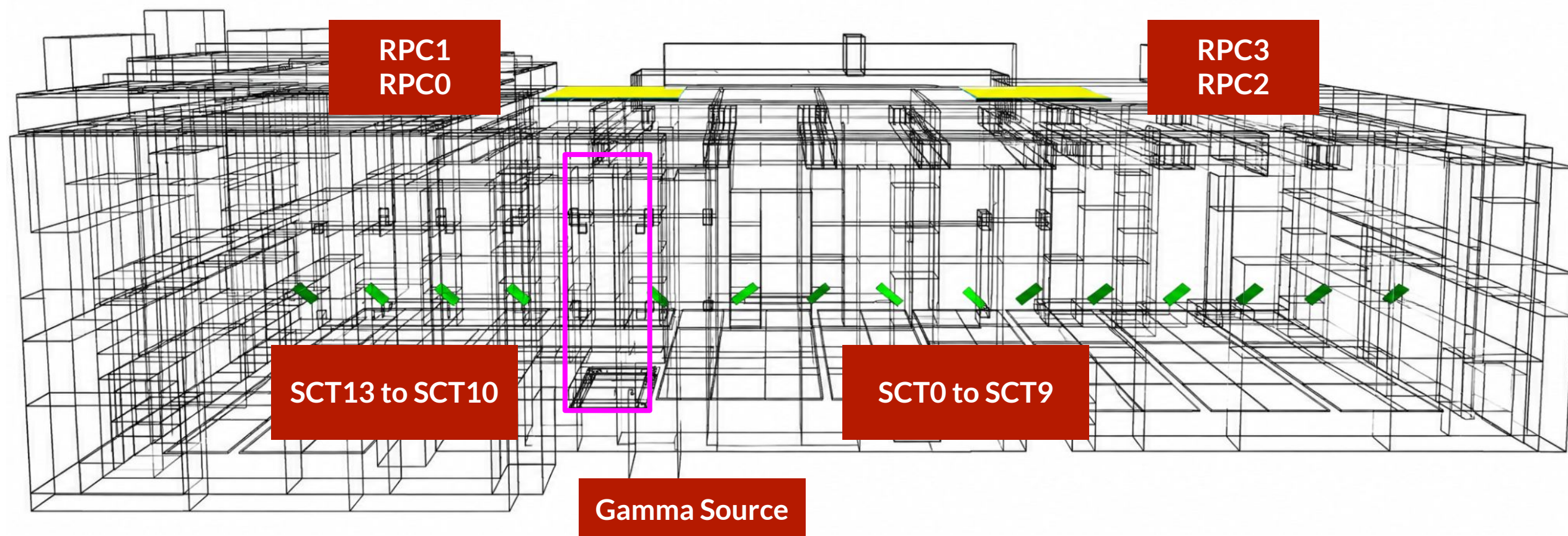
Roadmap

From the Micro workshop
on cosmics in GIF++
(June/25), we had positive
answers from CMS-RPC
and CMS-DT colleagues



Geant4 simulation - Recent design

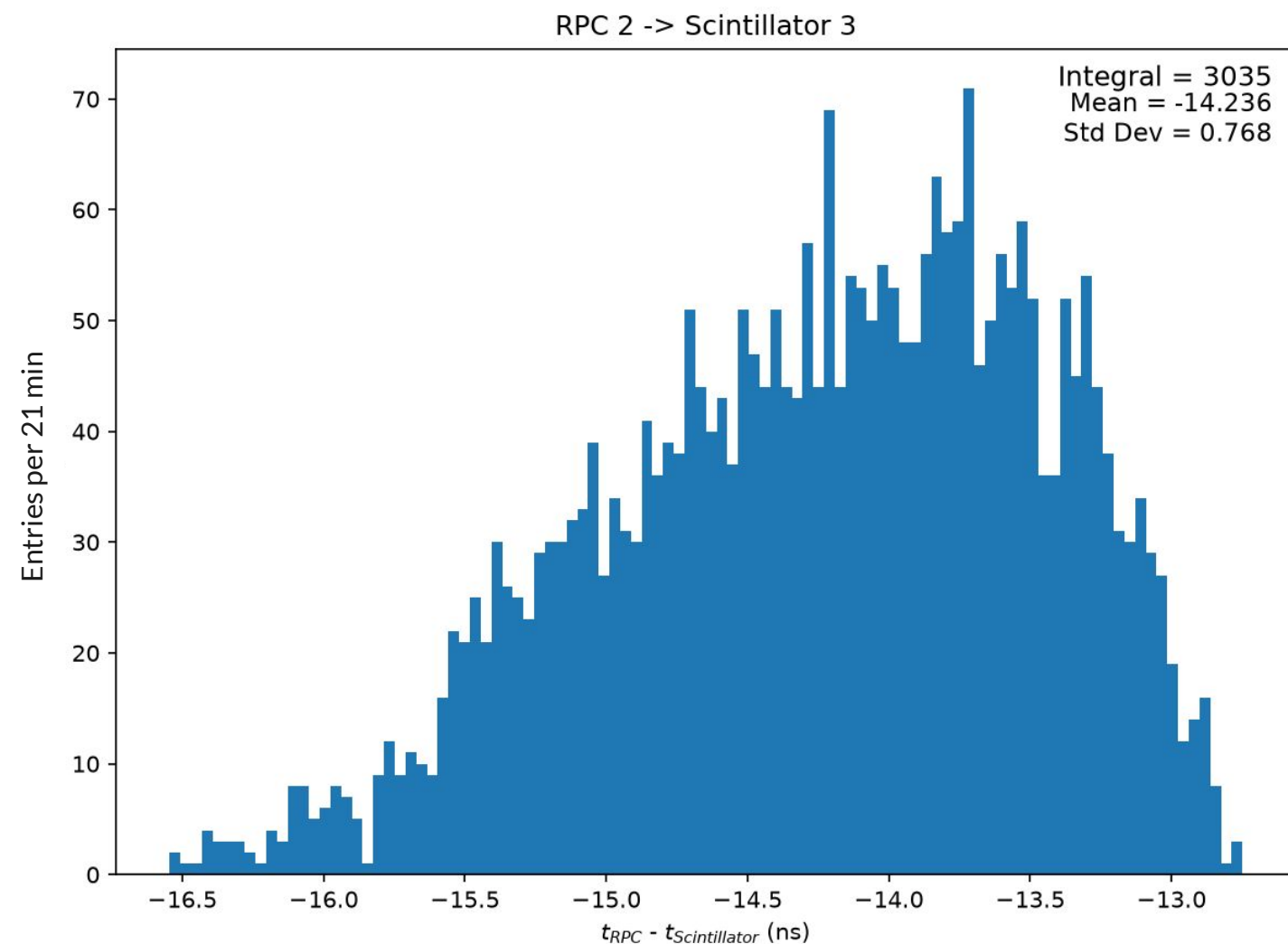
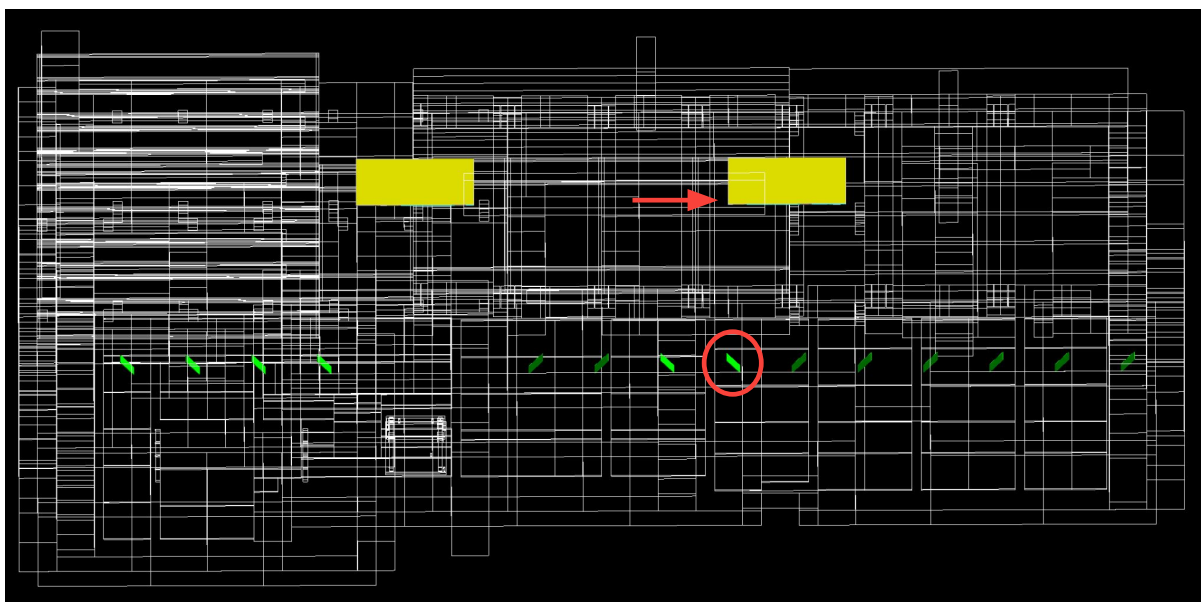
- Considers 4 RPCs: 2 pairs in 2 different positions. Areas: $2.5 \times 2.5 \text{ m}^2$;
- Considers 14 scintillators in different positions spaced by 1 m. Areas: $40 \times 40 \text{ cm}^2$;
- Considers GIF++ real dimensions and material;
- Configuration tested: scintillators in 45° and 1.5 m above the ground.



Results - one case of coincidence

In this case, as we have 3035 in approximately 21 min, it means around 140 muons/min.

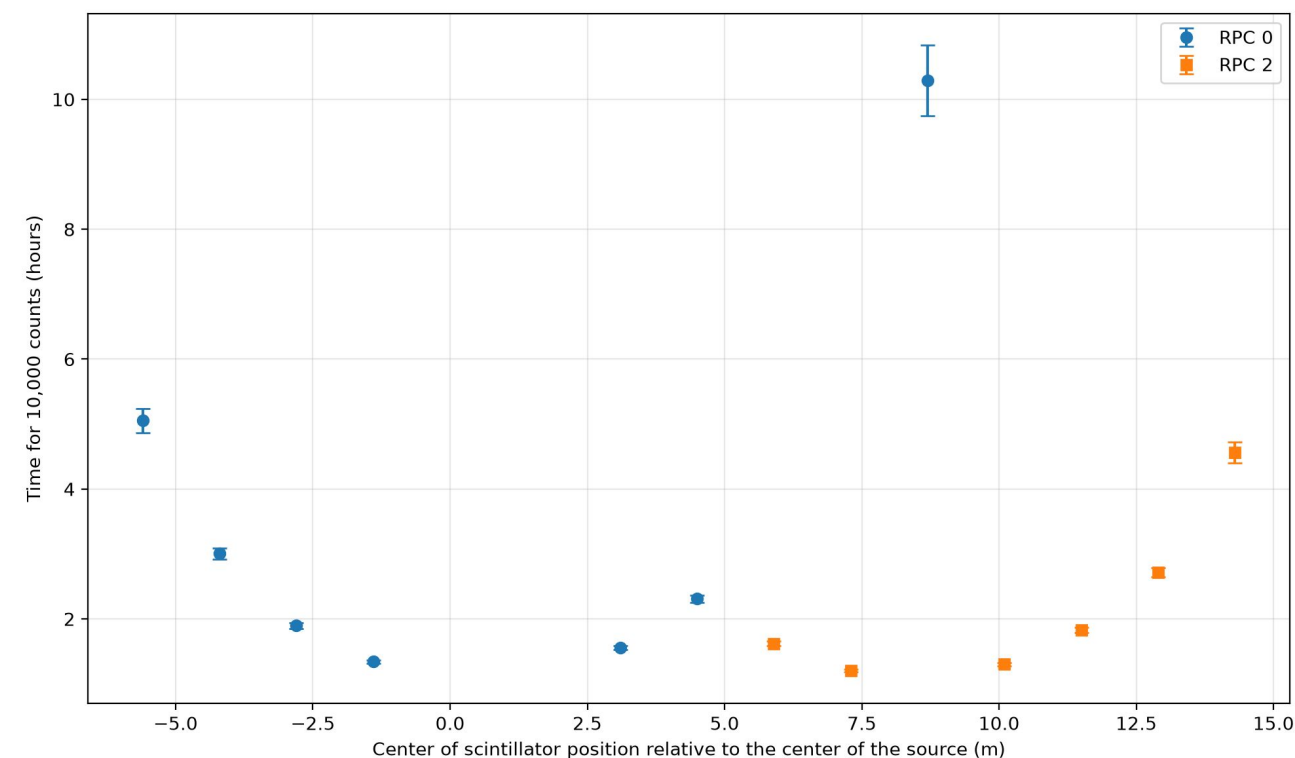
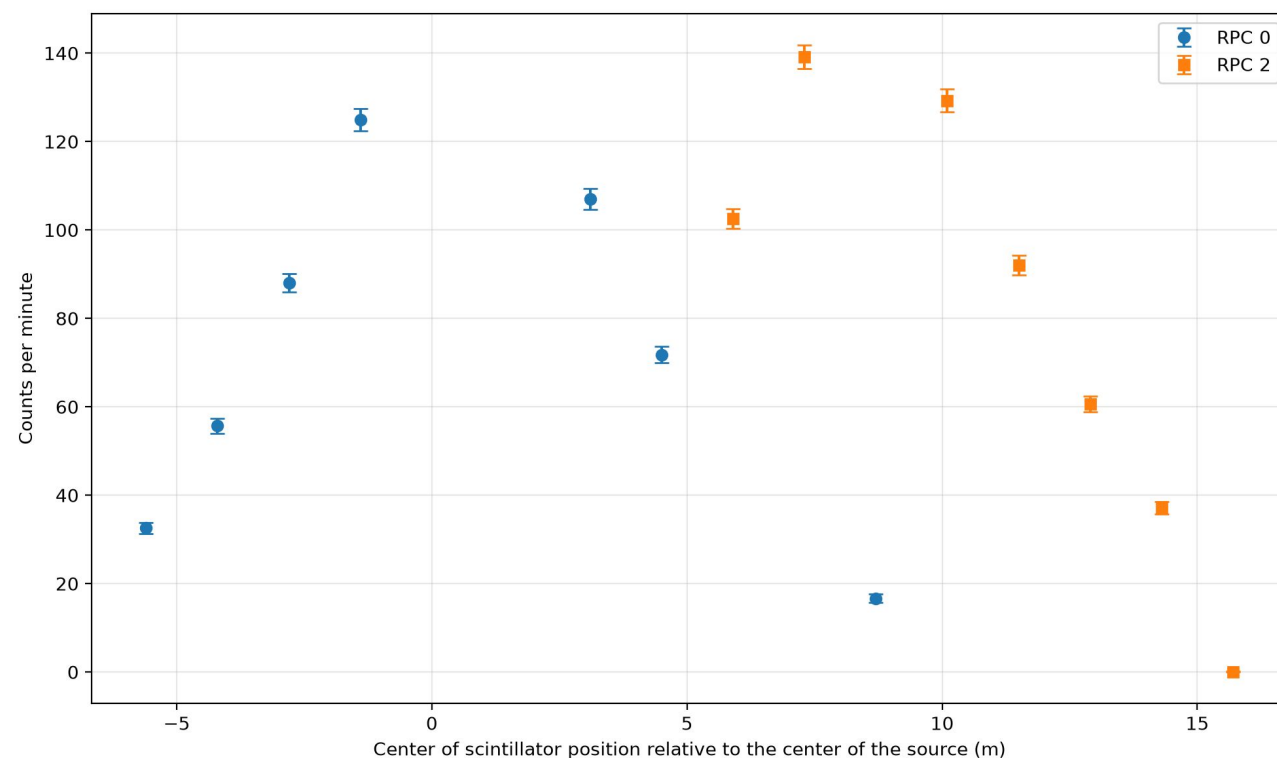
Considering an HV scan with 10 HV points and each point with 1000 triggers, it would take around 1 hour and 10 minutes.



Results - Counts/min and HV scan time needed mapping

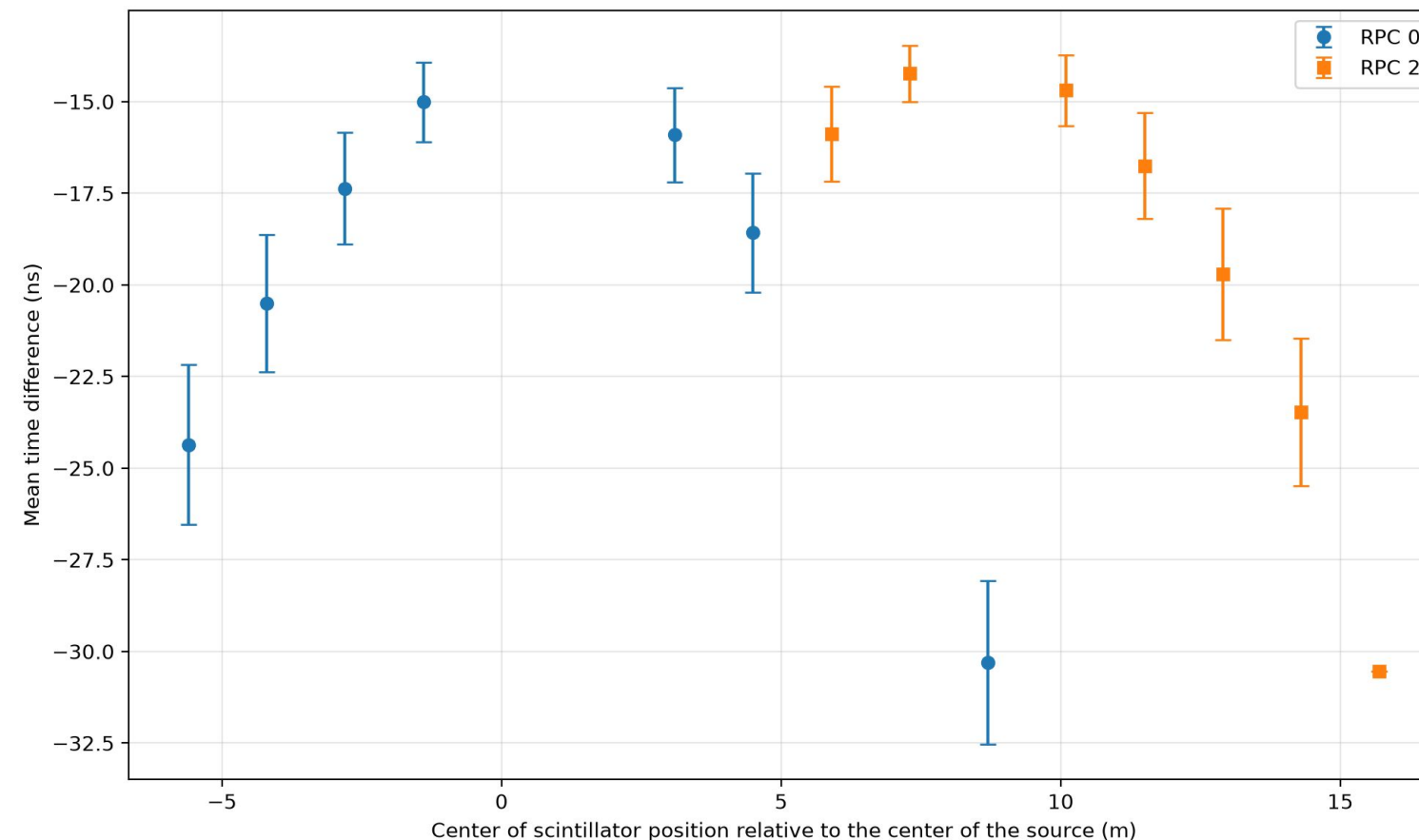
As expected, farthest the scintillator from the respective RPC, longer the HV scan time.

We considered an HV scan with 10 HV points and each point with 1000 triggers.



Results - Mean time difference of the muon coincidence

The error bar is the STD of the time distribution. This is due the ToF considering the size of the RPC. This will affect the muon time window.



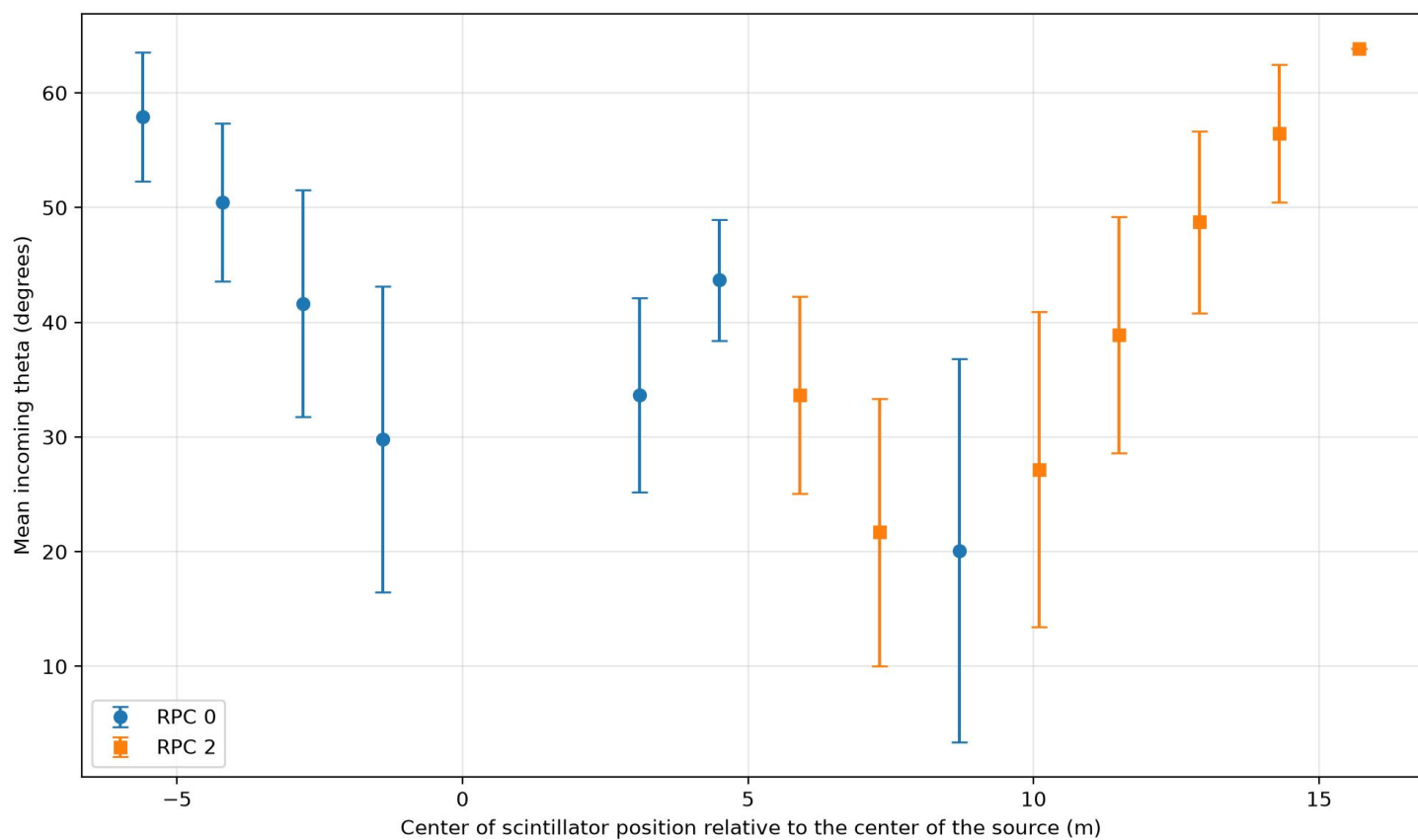


Results - Muon incident angle in the RPC

The error bar is the STD of the angle distribution.

The mean incoming angle is around 41°.

Optimize scintillator angle related to its position in the bunker.





Simulation results

Considering that:

- for the RPCs we have an area of $125,000 \text{ cm}^2$;
- for the 14 scintillators we have an area of $22,400 \text{ cm}^2$;
- the rate of the cosmic particles above 1 GeV is $1 \text{ particle/min/cm}^2$;
- using around 2.5 million events;
- we used a realistic angle and energy distribution for the muon generation (Gaisser equation).

Candidates

- ❑ MWPC (LHCb);
- ❑ MDT (ATLAS);
- ❑ CMS RPC;
- ❑ ARGO;
- ❑ CODEX (ATLAS);
- ❑ RPC (ATLAS@GIF++).

Others?

CMS RPC - Parameters & available

Parameters:

- ❑ Muon trigger detector;
- ❑ Time resolution: ≤ 3 ns;
- ❑ Operate at 9.2~9.9 kV;
- ❑ Current limit: 200 μ A
- ❑ 2 mm gap;
- ❑ STD mixture (95.2% $C_2H_2F_4$, 4.5% i- C_4H_{10} , 0.3% SF_6)

Available human resources:

- ❑ Technical coordinator: Anton Dimitrov;
- ❑ Gas coordinator: Aleksandar Aleksandrov;
- ❑ Engineer: Ivan Mihaylov
- ❑ Readout team: Mojtaba Mohammadi, Behzad Boghrati, Ece Asilar, Eduardo Coelho (...)

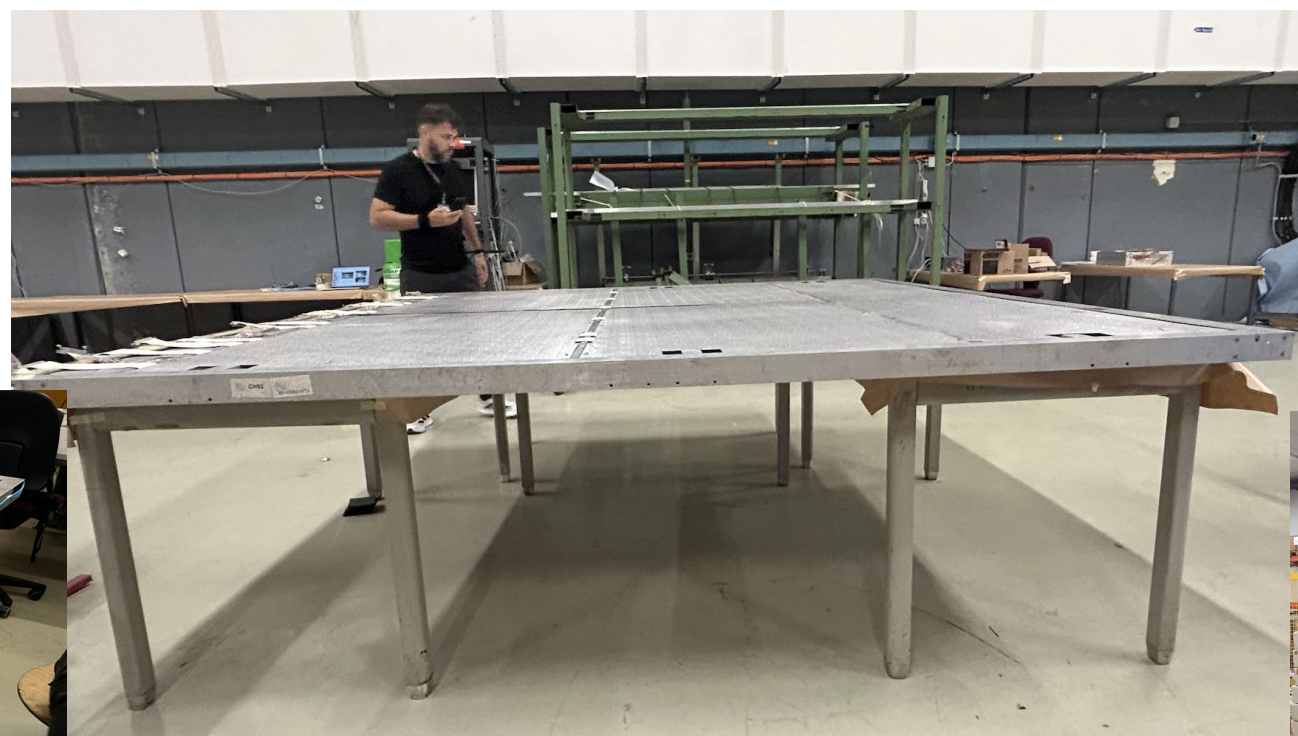
CMS RPC - What do they provided us?

- ❑ 6 chambers. Types:
 - ❑ 1 RB1: 2455 x 2080 mm²
 - ❑ 2 RB2: 2455 x 2500 mm²
 - ❑ 2 RB3: 2455 x 1500 mm²
 - ❑ 1 RB4: 2455 x 1500 mm²
- ❑ 6 spare gaps. ALL are good;
- ❑ Readout electronics for all the chambers (spares available);
- ❑ Material for HV cables;
- ❑ Space for work and test the chambers.



CMS RPC - Ongoing work

- 3 chambers leak fixed. 3 to be done after the conference;
- Readout and firmware being prepared by readout team.





CMS RPC - Next steps

- Finish the leak fixing for the 3 missing chambers in the first week of October;
- Send the chambers to CERN - Preveessin 904 lab for gas flushing;
- After 1 month of gas flushing, first week of November, power on the chambers for current tests;
- From now, it will take 3 to 6 months for the readout development. Iranian team will be at CERN to secure the right installation.



Conclusion

- Geant4 simulations demonstrate the feasibility of a large-area cosmic muon trigger system for GIF++;
- The proposed geometry, based on CMS barrel RPC chambers and plastic scintillators, provides a measurable coincidence rate and a well-defined temporal correlation between detectors;
- A coincidence window of few dozen ns is enough, accounting also with the instruments' fluctuations, allowing the trigger logic for cosmic muon selection.

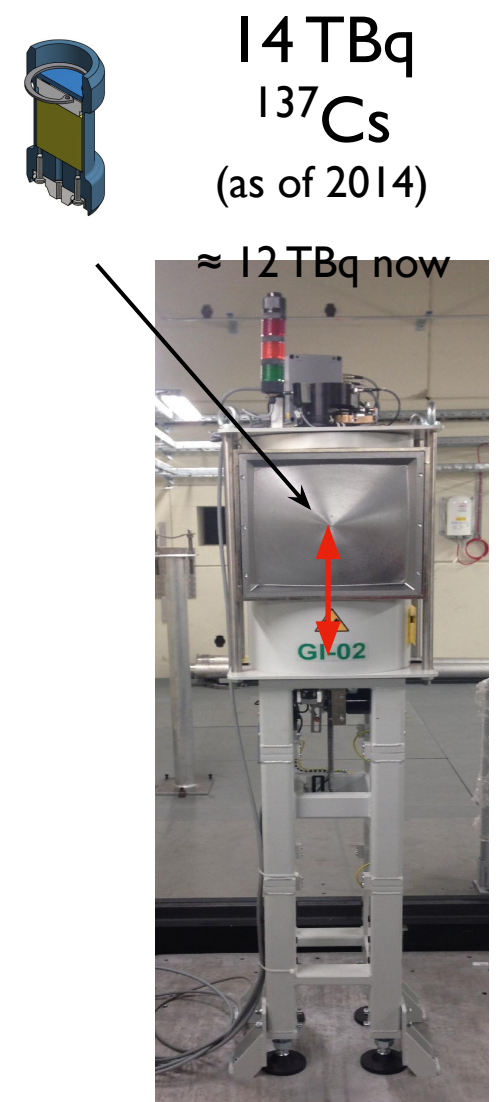
Thank you!

k.maslova@cern.ch

BACKUP SLIDES

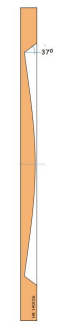
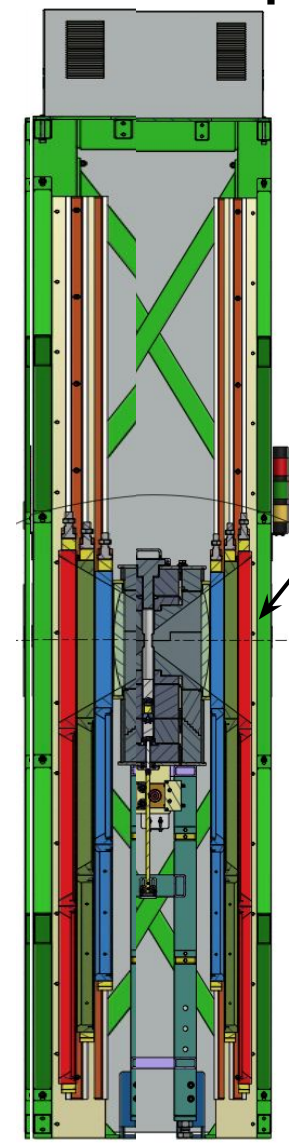
GIF++ Irradiator & Attenuation Filters

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

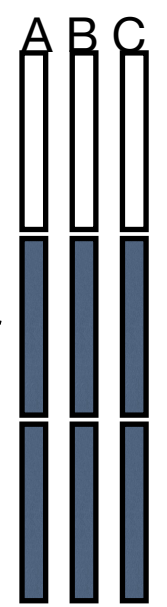


14 TBq
 ^{137}Cs
(as of 2014)

≈ 12 TBq now

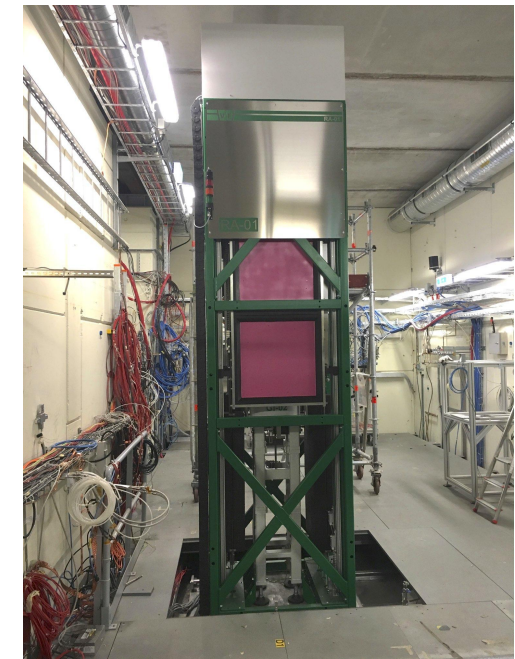


Angular correction filter provides uniform photon distribution for large area detectors



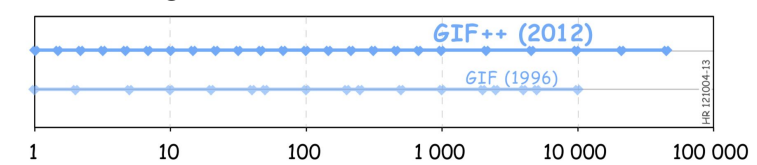
Filter System :

Absorption factor		
0	0	0
10	1.47	2.15
100	100	4.64



24 possible attenuation factors :

- 1
- 1.47
- 2.15
- 3.16
- 4.64
- 6.81
- 10



46.42
(calculated values for un-scattered gammas)

68.12

100

A B
C

Available RPC barrel chambers

- 1) RB1:
 - a) W0/RB1 OUT/9 (Chamber 47)
- 2) RB2:
 - a) W-1/RB2/3 IN/8 (Chamber 352)
 - b) W+1/RB2/2 IN/11 (Chamber 093)
- 3) RB3:
 - a) W+1/RB3/5+ (Chamber 206)
 - b) W-1/RB3/10- (Chamber 7)
- 4) RB4:
 - a) W+2/RB4/4- (Chamber 150)

CMS requirements for RPCs

Efficiency	$> 95\%$
Time resolution	$\leq 3 \text{ ns}$ (98% within 20 ns)
Average cluster size	$\leq 2 \text{ strips}$
Rate capability	$\geq 1 \text{ kHz/cm}^2$
Power consumption	$< 2\text{-}3 \text{ W/m}^2$
Operation plateau	$> 300 \text{ V}$
# Streamers	$< 10\%$

Available RPC barrel chambers

Chamber		RB1in	RB1out	RB2in	RB2out	RB2in	RB2out	RB3	RB4	RB4	RB4
RPC	Length [L]	2455									
	Width [B]	2080		2500		2500		1500	1500	2000	2500
Single gap	Length [L]	1155 1235		1155 1235		755 775 835		1155 1235	1155 1235	1155 1235	1155 1235
	Width [B]	2060		2480		2480		1480	1480	1980	2480
Total gaps	Length [L]	2435									
	Width [B]	2060		2480		2480		1480	1480	1980	2480
Strip	Length [L]	1162 B 1253 F		1162 B 1253 F		762 B 790 C 853 F		1162 B 1253 F	1162 B 1253 F	1162 B 1253 F	1162 B 1253 F
	Width [B]	2060		2480		2480		1480	1480	1980	2480
	Number of Strips	90	84	90	84	90	84	42	36	48	60
	Strip Pitch	22,7	24,3	27,3	29,3	27,3	29,3	34,8	40,6	40,8	41