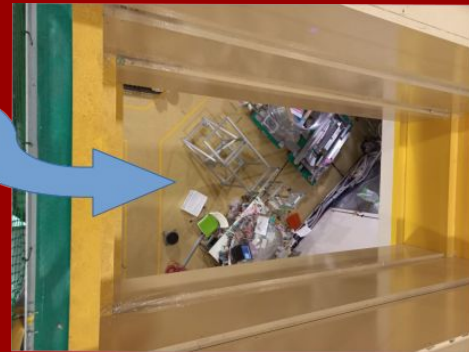


RPC chambers for CRV in the COMET Phase-I experiment

**Maxime Gouzevitch for
COMET collaboration
with explicit thanks to CMS and ATLAS RPC
colleagues for their help**

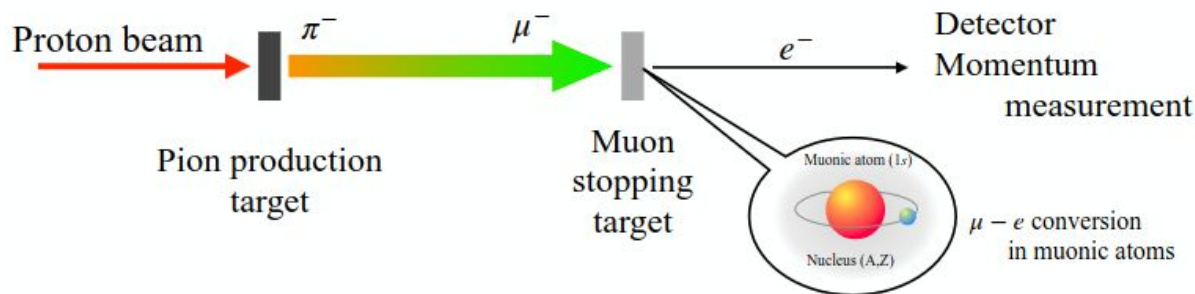


**RPC 2026
RIO DE JANEIRO**

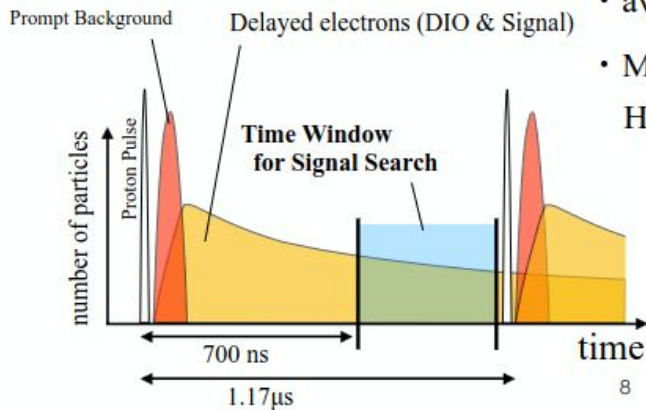
- 1) COMET experiment and CRV organisation
- 2) FRONT CRV: iRPC
- 3) Side CRV: ARGO-YBJ RPC

COMET project through phases

▶ Principle of the Experiment



▶ Utilizing a Pulsed Beam



- Delayed time window
- avoid prompt beam-related backgrounds
- Material of stopping target

Heavier nucleus ...

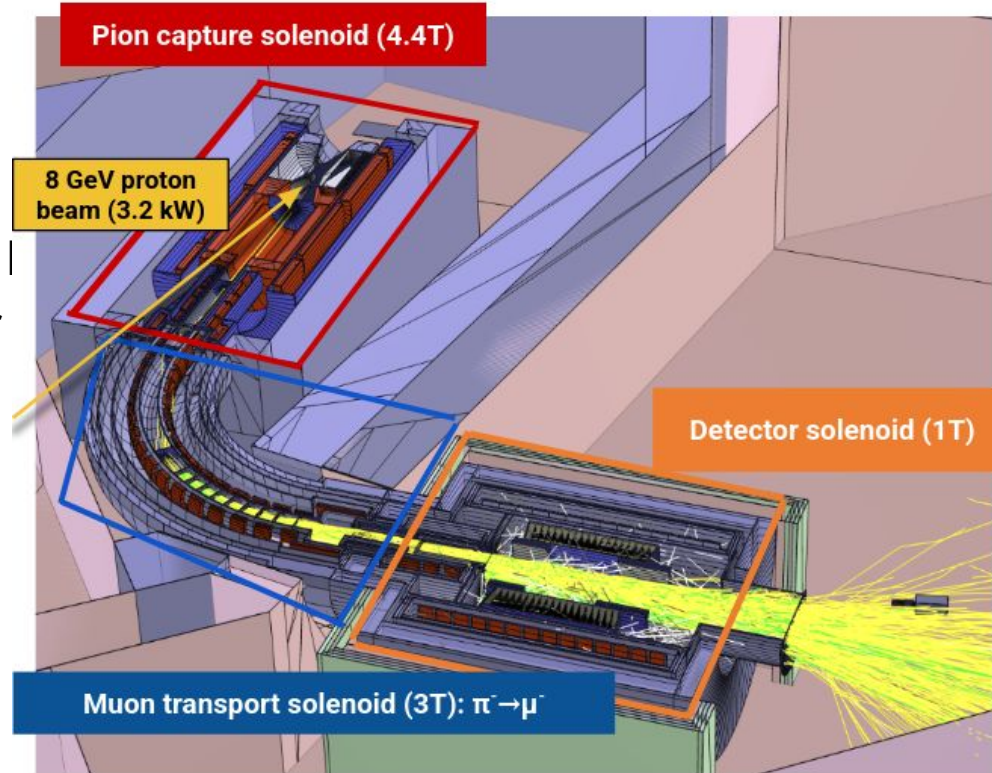
Large overlap with muon wave function
but short life time of muon

- **Aluminum** stopping target

$$\tau_{\mu} \text{ in Al} \sim 0.9 \mu\text{sec}$$

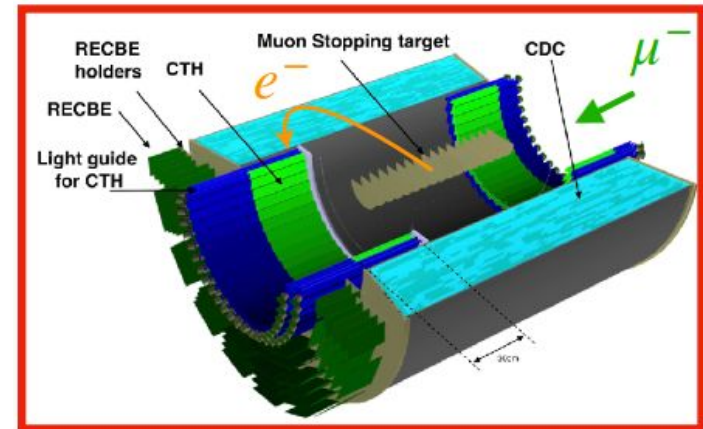
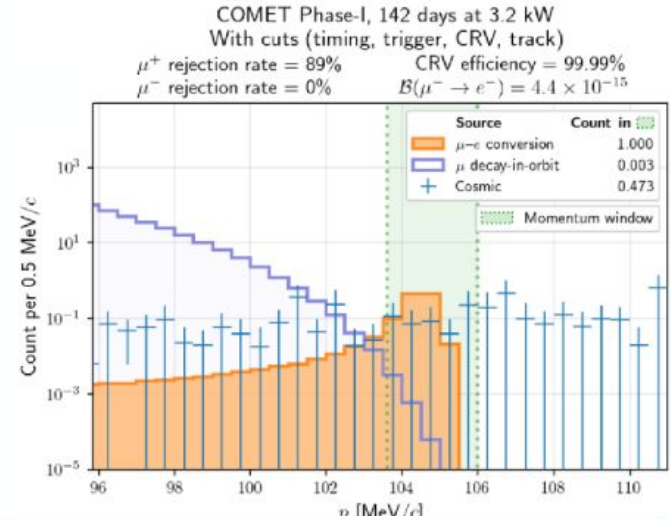
COMET Phase-I

- Build the Muon production line and muon transport inside the COMET I
- Build the Phase I COMET detector
- Measure the backgrounds
- Start with low intensity run (10% of intensity) including part of the detectors (2027).
- Extend to full intensity with an expected sensitivity of $O(10^{-15})$ to $\text{BF}(\mu \rightarrow e)$



Cosmic Rays: main background source

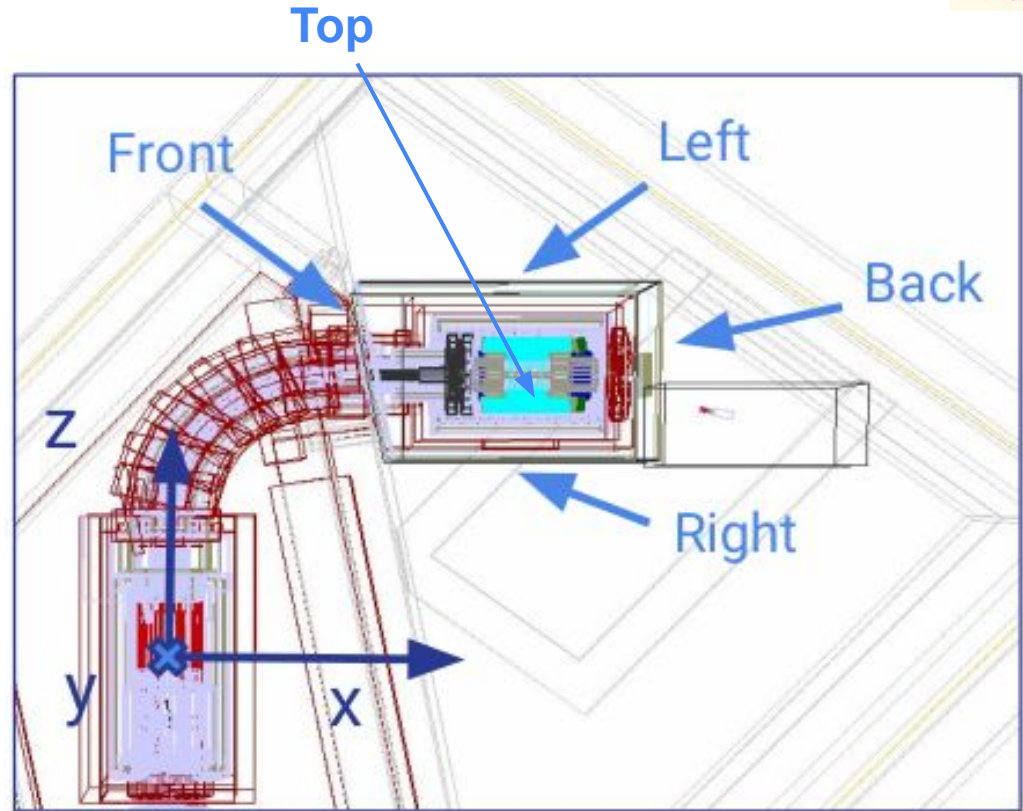
- μ^+ outside-in can behave as an e^- in-out.
- COMET is a “0 background” experiment.
Cosmic rays are numerous, but the exact configuration of the signal is hard to reproduce.
- Cosmic Ray Veto is an apparatus which is designed to behave as:
 - external muon veto - trash an event
 - muon tracker: provide a likelihood for a signal to be a muon based on space and time information.



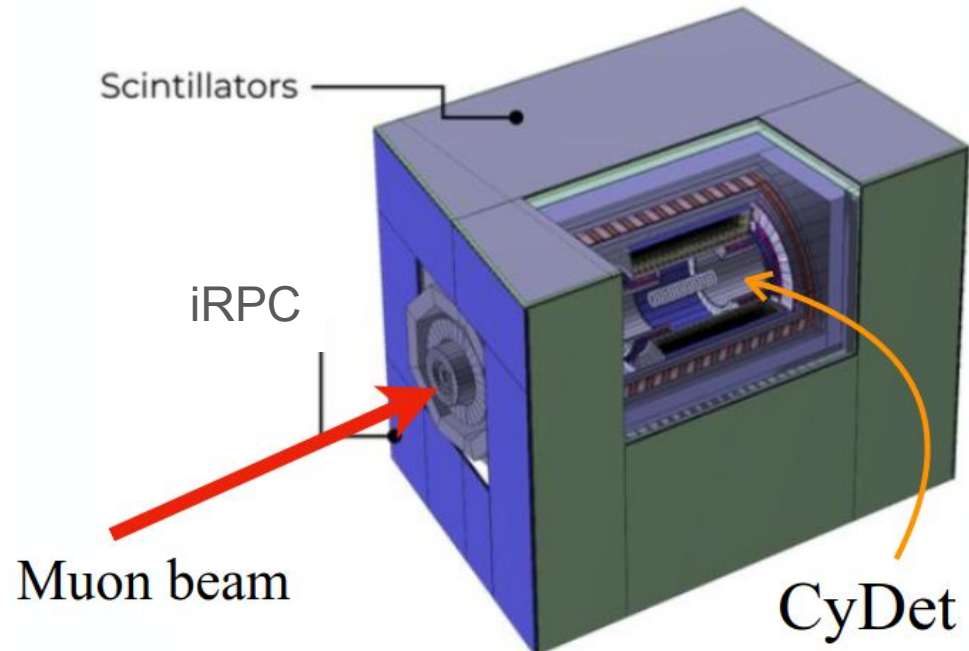
TOP: plastic scintillators

RIGHT / LEFT: moderate background $O(100 \text{ Hz/cm}^2)$
RPC from ARGO-YBJ experiment or scintillators.

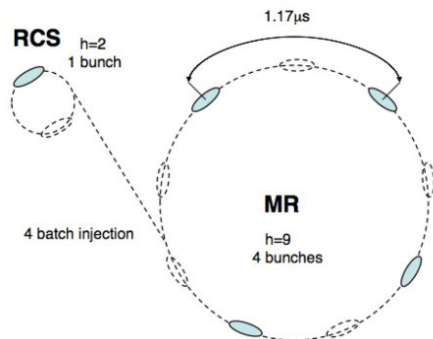
FRONT/BACK: high background (up to 3 KHz/cm^2)
iRPC like chambers.



2) FRONT CRV



Proton Beam Time Structure

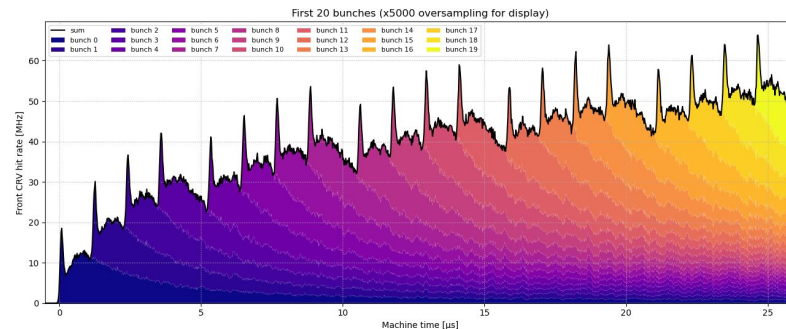
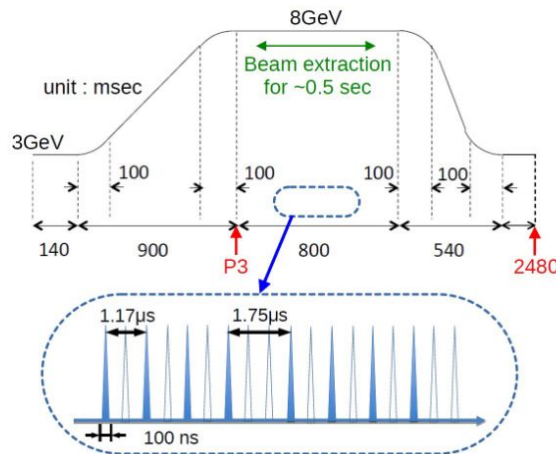


Two time scale

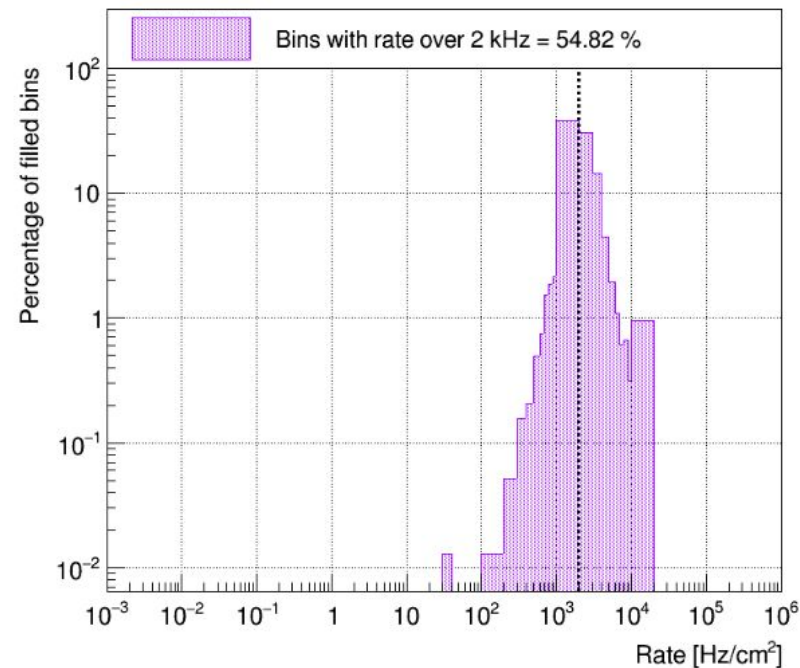
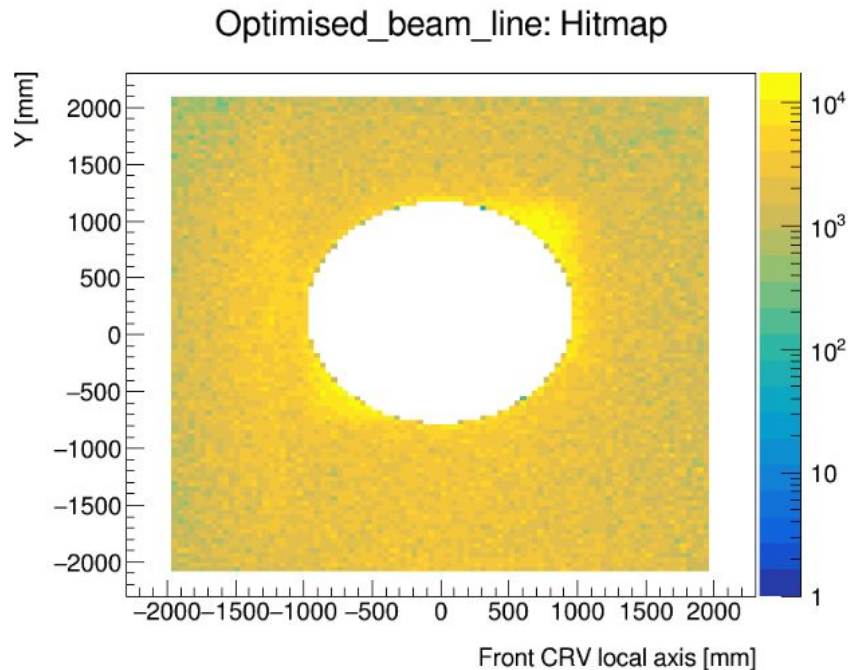
- Spill Structure
Macroscopic : 2.5 sec cycle
- Bunch Structure
Microscopic : ~1 usec

Phase-I Beam Parameters

Energy	8GeV
Power	3.2 kW
Protons/Bunch	1.6×10^7
Protons/Spill	6.2×10^{12}
Spill Cycle (Extraction)	2.48 sec
	~0.5 sec

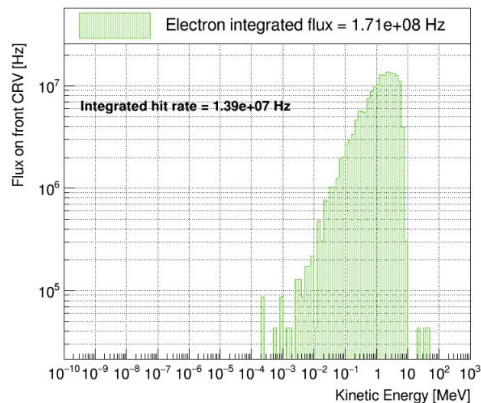
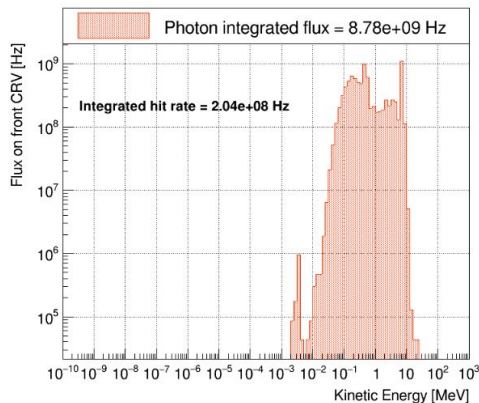
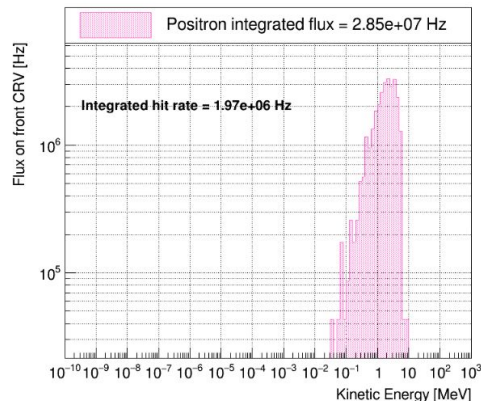
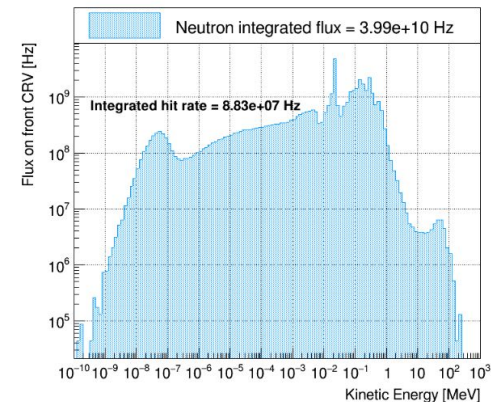


Pulsed beam with narrow signal window. But background flux over time stabilizes as a uniform flux.

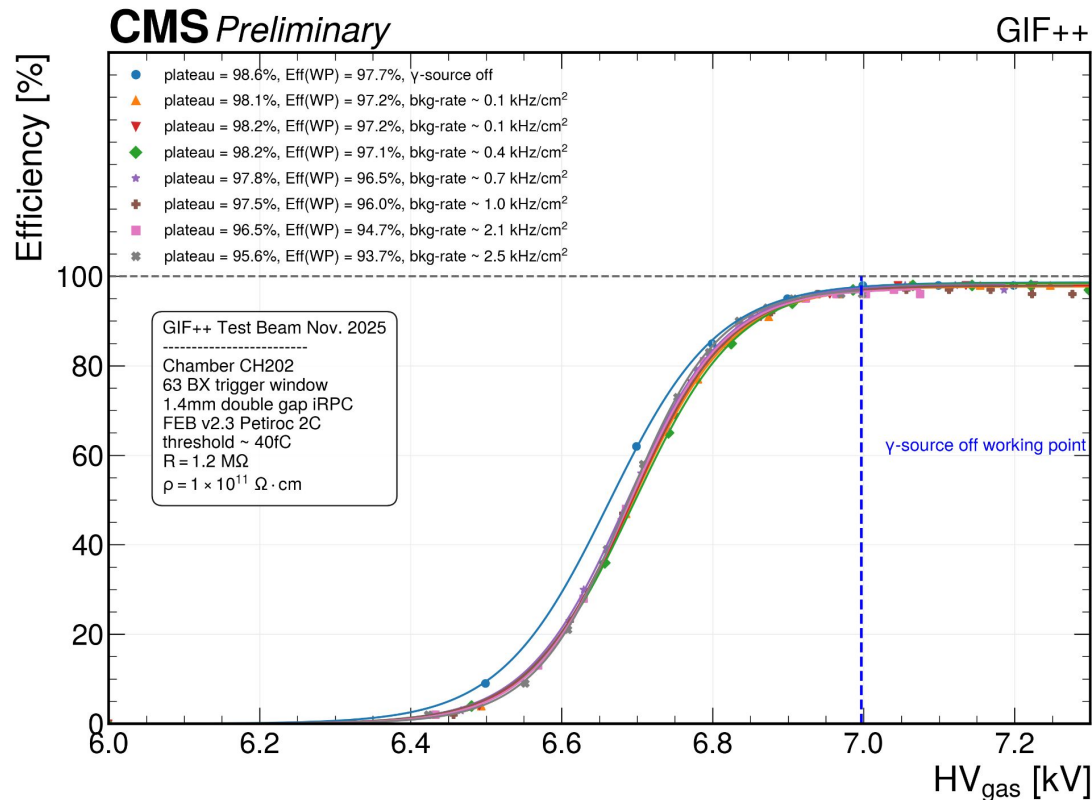


The intensity of background close to the bridge solenoid are high for iRPC. We may need to improve there the shielding or to leave this region uncovered.

Background rate in CRV front



- Background level is high due to the proximity of the pion production target.
- Sensitivity to the components taken from CMS simulations.
- Neutron background is very significant and hard to shield. Bakelite RPC is more sensitive to neutrons than glass RPC. But Bakelite RPCs were more easy to access.



Ohmic corrected S-curves of iRPC obtained in GIF++ using mTCA BEB with 63 BX (1.5 μs ~ 1 COMET spill) transmission time.

At 2.5 kHz/cm² the efficiency is 94%.

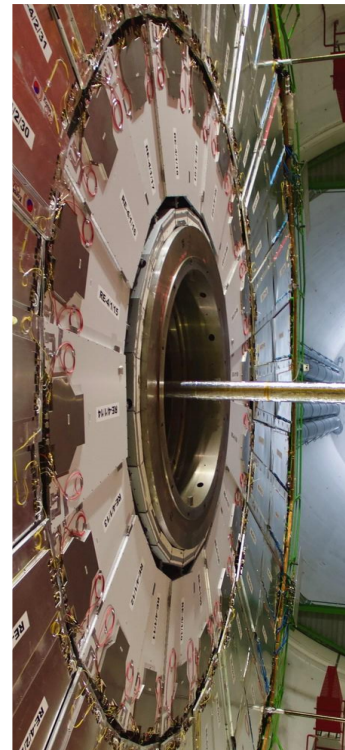
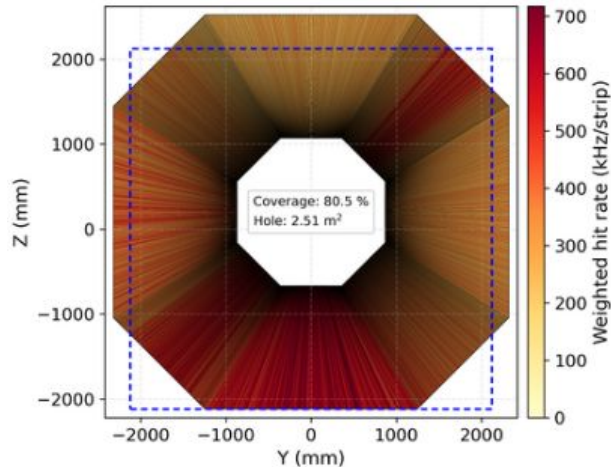
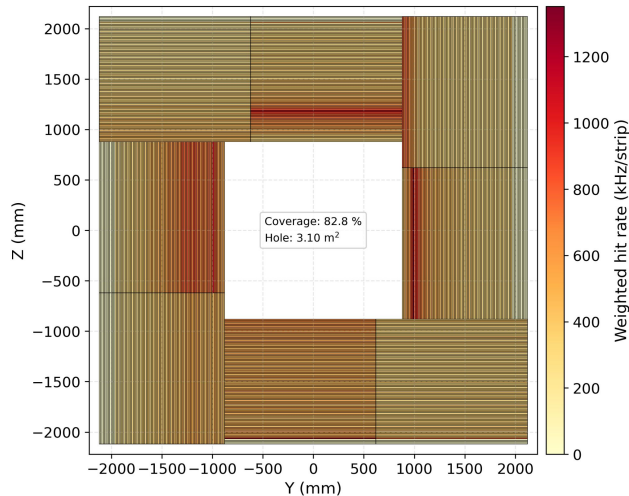
$\%$ iRPC: 99.6% efficiency

$\frac{3}{4}$ iRPC: 99% efficiency

Front CRV geometry

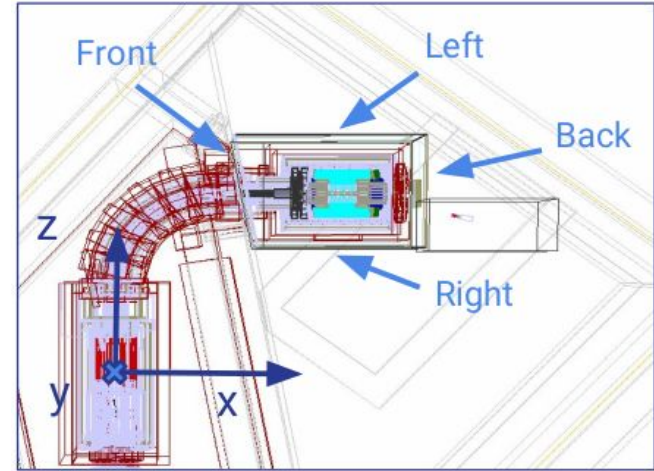
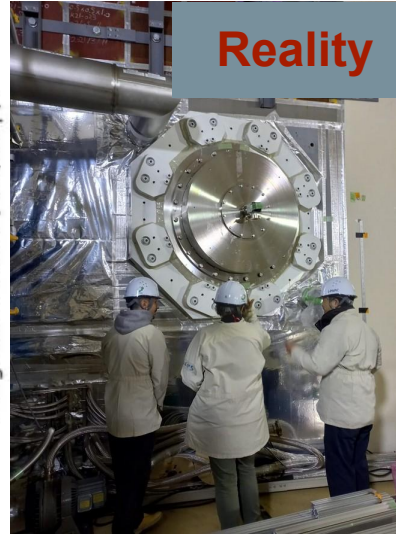
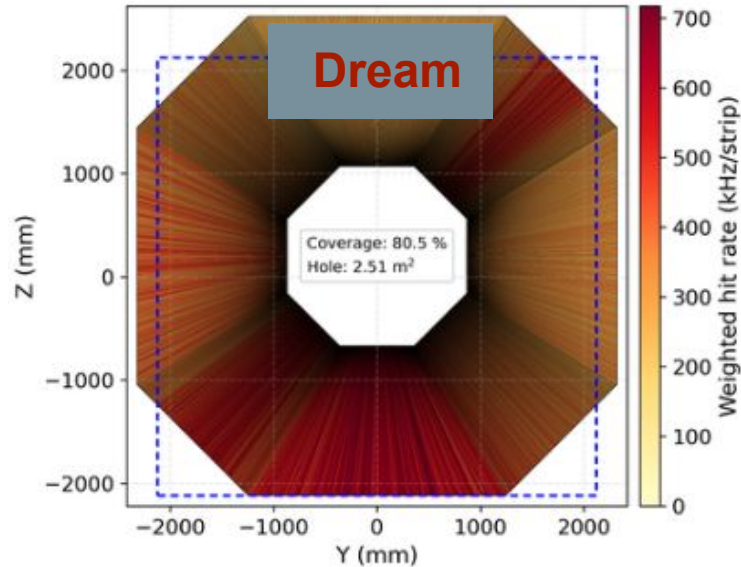
Squared option: easy geometry but uneven rate distribution across channels.
 $40 = 5 \text{ layers} * 8 \text{ detectors}$

Petal option: better rate distribution accross channels.
 $60 = 5 \text{ layers} * 12 \text{ detectors}$



The front CRV dimensions are similar to the iRPC ring:
4.5m for COMET, 6m for iRPC. 5 layers of

Front CRV geometry

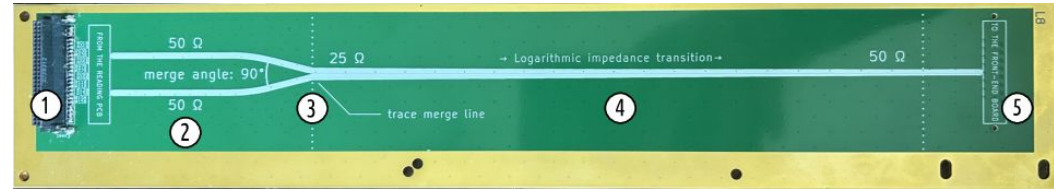
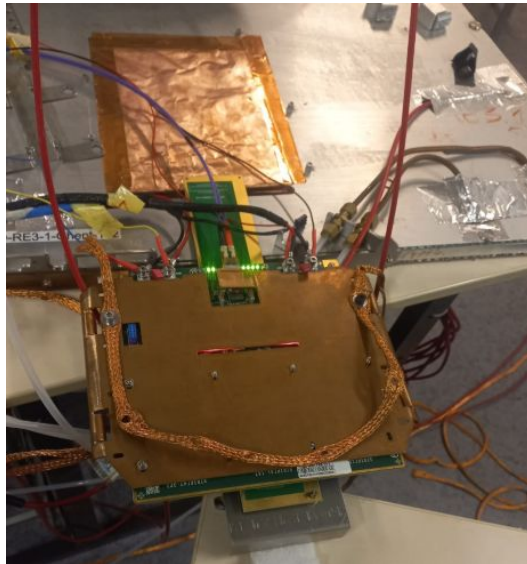
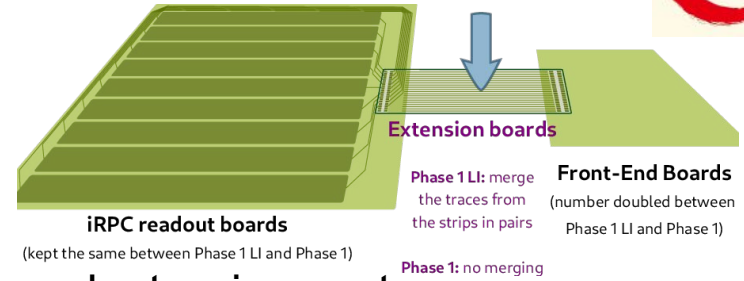


Little space and busy with pipes and structures. Engineering “head heach”.
Little “thickness” available: may need to make detectors thinner.

Front CRV geometric: extensions

A set of **extension boards** is designed to move FEB outside of iRPC foot print zone
-> reduce detector thickness.

It can also be used to merge channels and reduce electronics cost

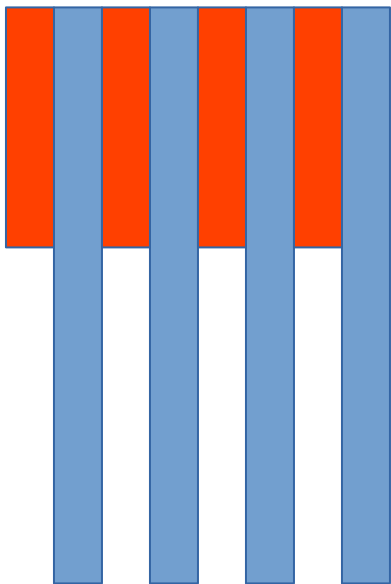


See poster for more details:

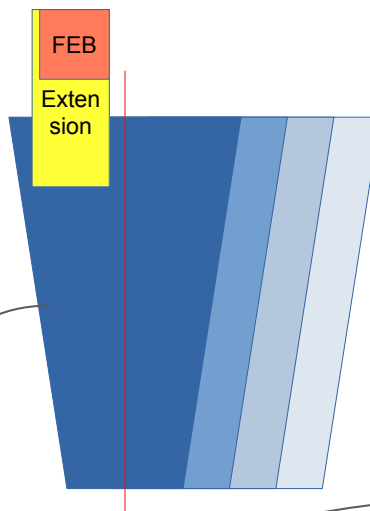
<https://indico.global/event/15349/contributions/162170/>

Extensions

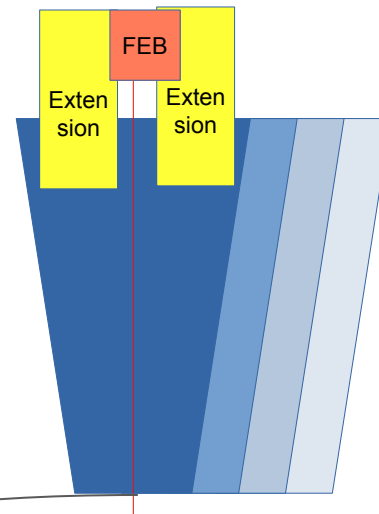
Classic iRPC stack



Extension straight



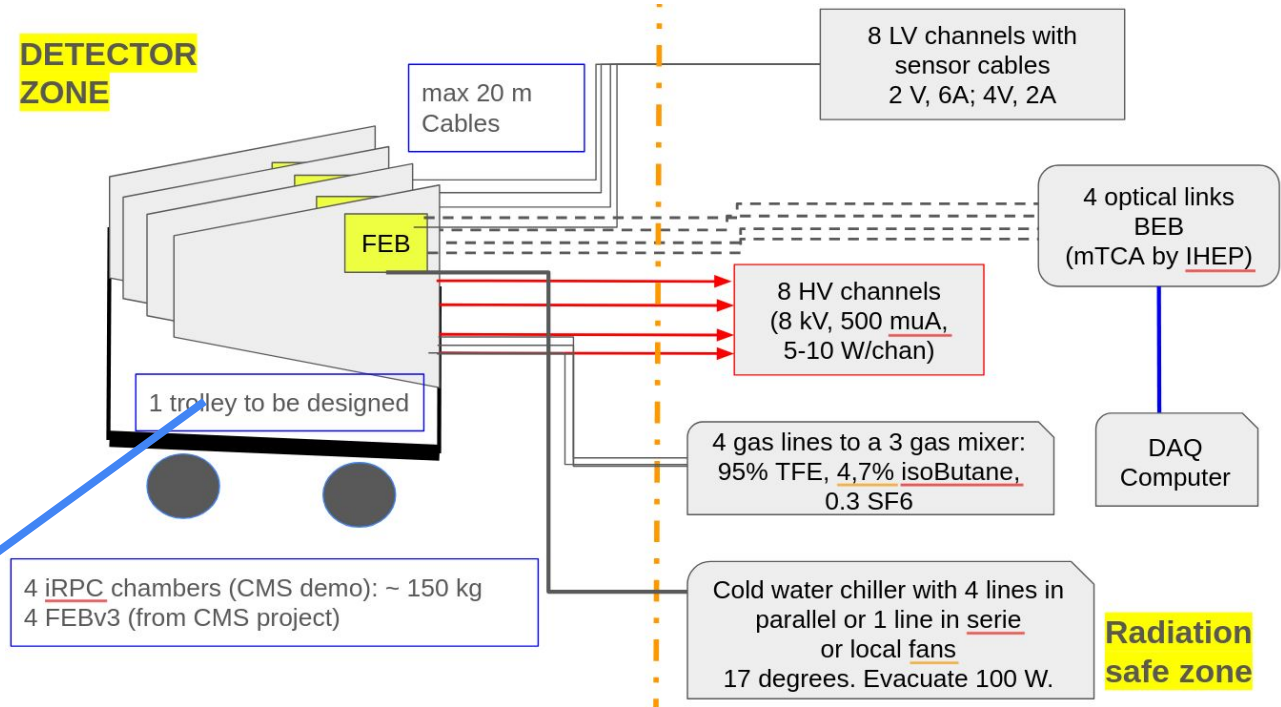
Extension merging



Low intensity phase I

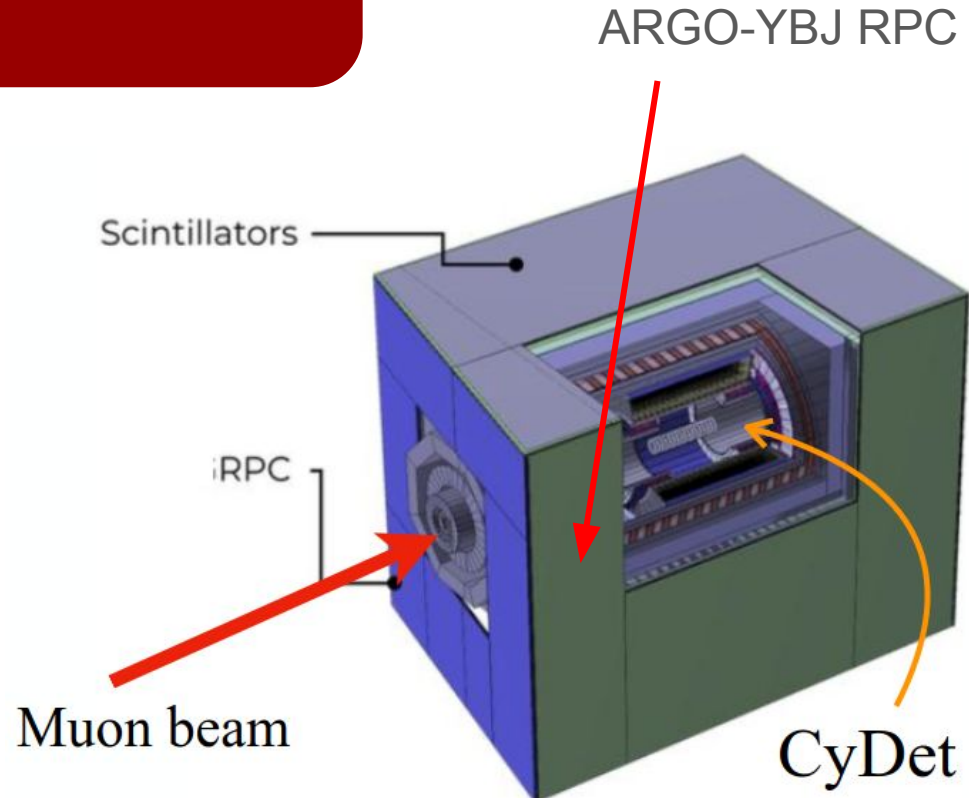


DETECTOR ZONE



Status: MOU with

2) Side CRV



What is ARGO technology

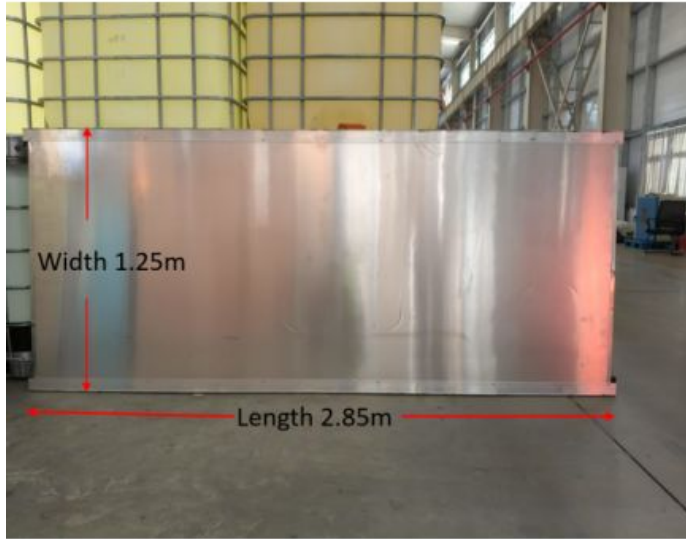


- The ARGO-RPC is form ARGO-YBJ in Tibet
- The RPCs are used as a telescope for gamma-ray astronomy
- 1836 RPCs (18360 channels) covering $\sim 6700 \text{ m}^2$

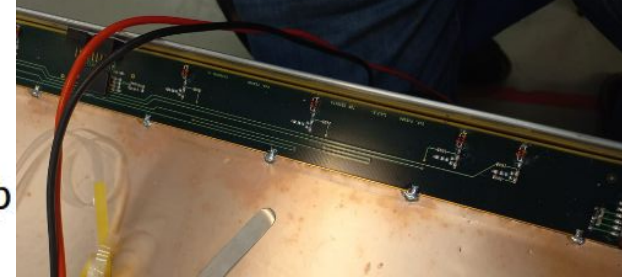
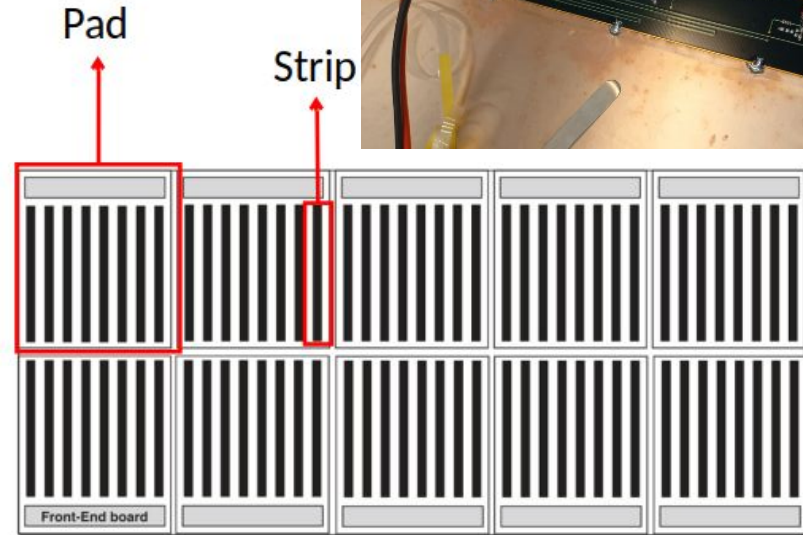


What is ARGO technology

Thickness 50 mm



Weight ~ 60 kg

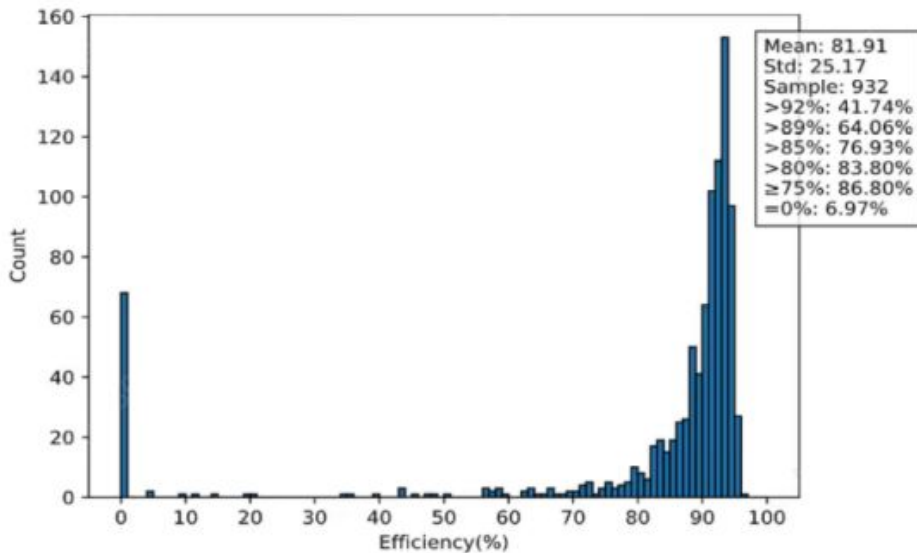
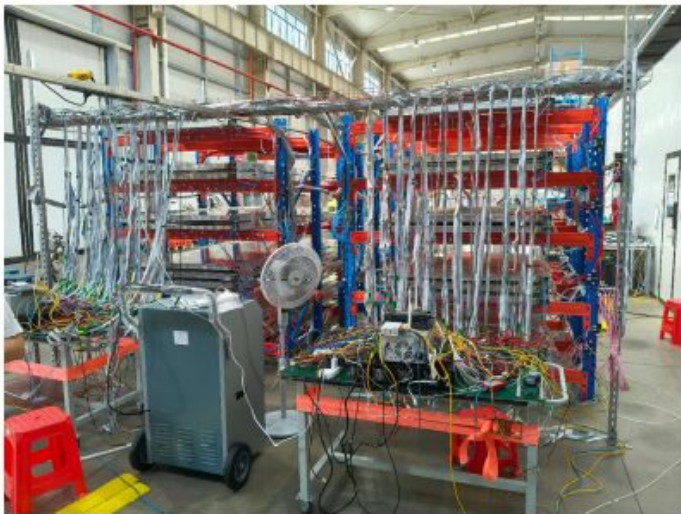


8 strips = 1 pad

10 pad = 1 RPC

Number of partitions to read is 80

What is ARGO technology



~ 1000 ARGO RPC transported to Jianmen and tested for JUNO experiment. Most of them exceed 80% efficiency and 1/2 - 90% efficiency.

~ 600 chambers still in Tibet and can be transported.

If we install stacks of 5-7 chambers we need < 200 chambers and we can reach 99.99% efficiency.

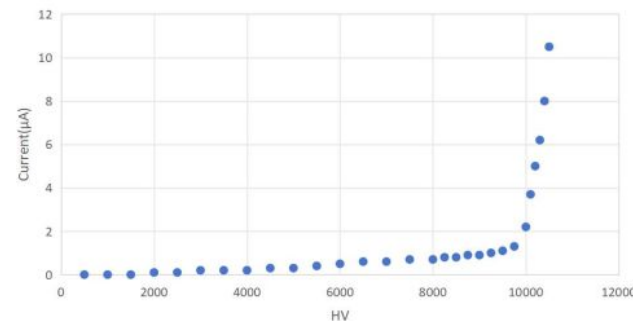
3 chambers moved to CERN for tests

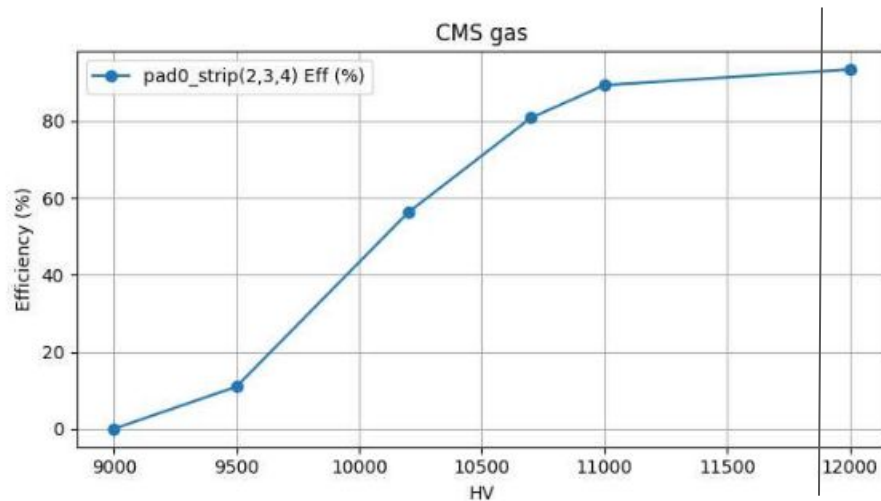
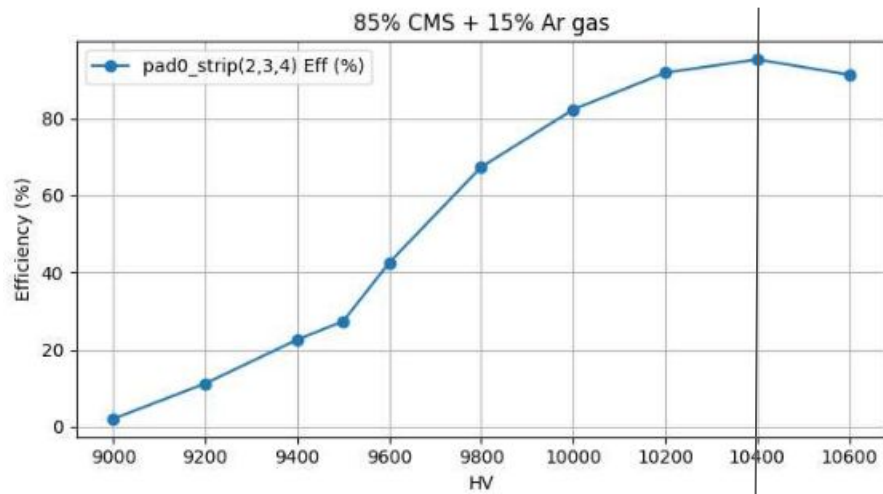
Designed for 5000m and works in Streamer mode
(**Ar/i-But/TFE = 15/10/75**)

- 1) Nov. 2025: We tested in 904 CMS RPC laboratory at CERN with Ar = 15%; CMS gas = 85%
→ Good efficiency, high currents. Saturation of the detector in GIF++ at $\sim 20 \text{ Hz/cm}^2$.
- 2) April - May 2026: with help of ATLAS colleagues we modified the FEB of ARGO (resplace few resistors) to lower the threshold and moved to CMS gas. We also moved from JUNO electronics to ATLAS Phase-0 electronics more efficient at low charge



10-28 RPC219

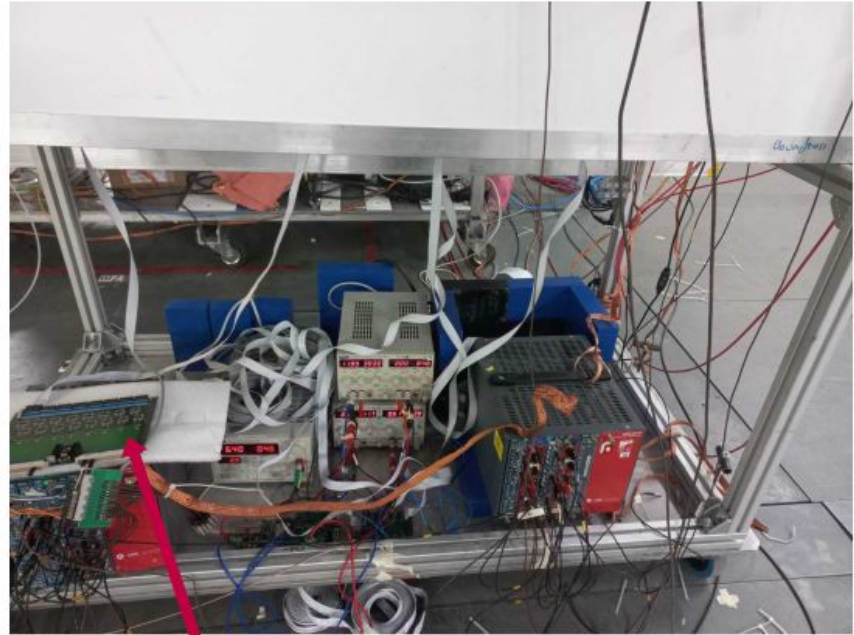




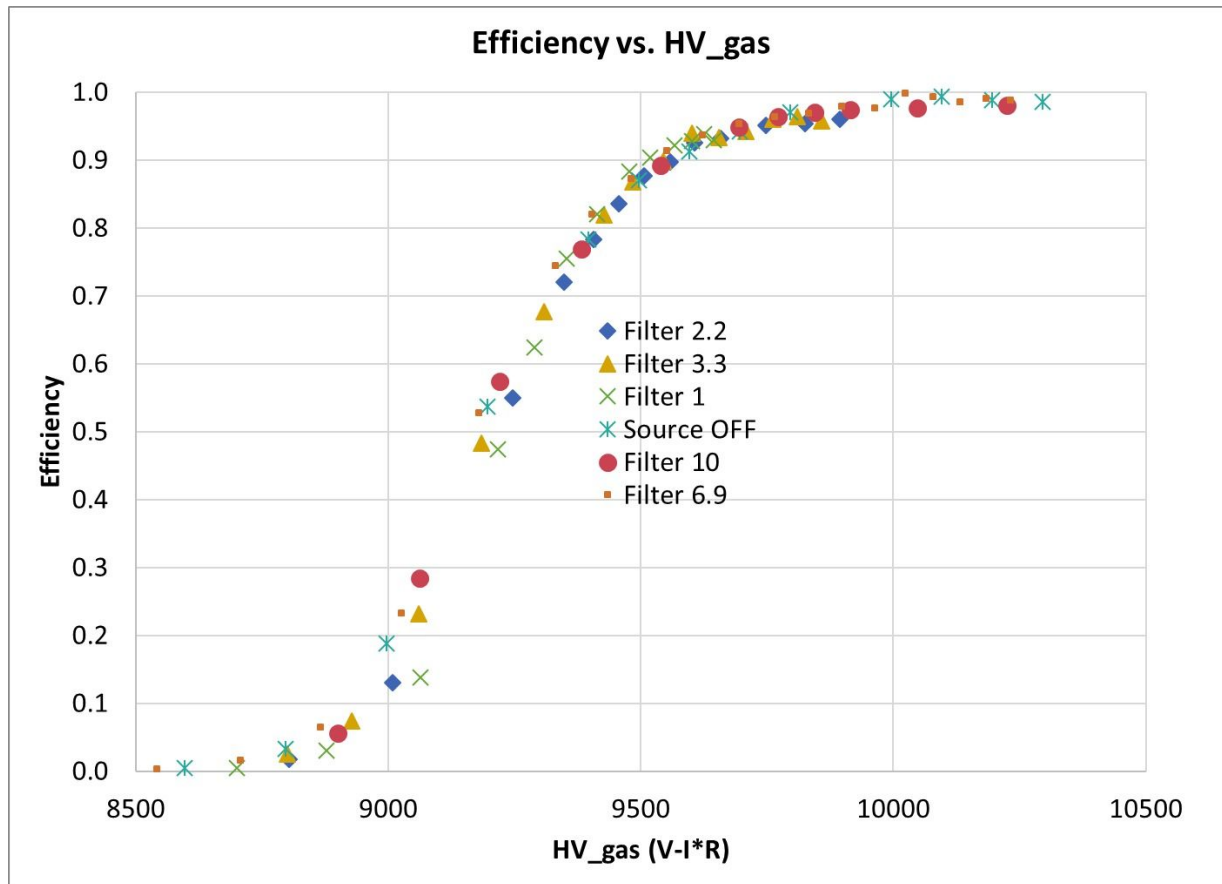
We can clearly see the “streamer configuration” of ARGO electronics with a high threshold.



Test in GIF++ is not easy: chamber size 3m x 1.2m biggest in GIF++ now



- We used by the end of test beam an ATLAS readout boards. Connected to a NIM crate and providing a logical OR of 8 Strips as a large NIM signal (100 ns).



Filter 1: 150 Hz/cm²
Efficiency above 95%

with modified FEB

The ARGO detectors
seems to meet the
COMET requirements.

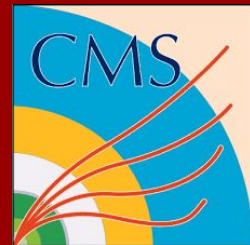
The RPC technology seems to meet the COMET PHASE-I CRV requirements:

- **iRPC in front / back**
- **ARGO on the sides**

The low intensity phase should prove the best operation configuration for iRPC and ARGO and allow to measure insitu the background rates.

The big step consist in a development of the BEB and DAQ systems for iRPC and ARGO. Followed by the full mechanical and technical design of the system.

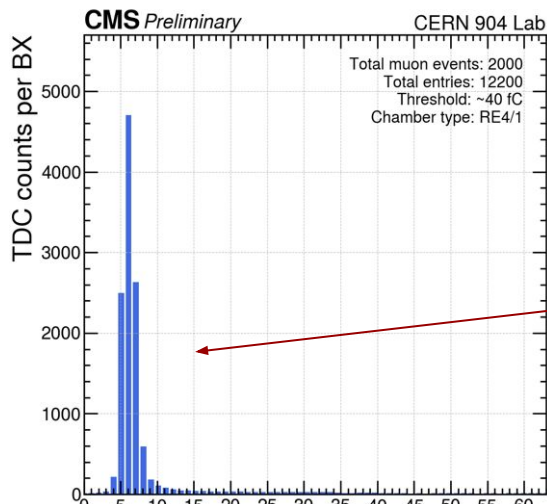
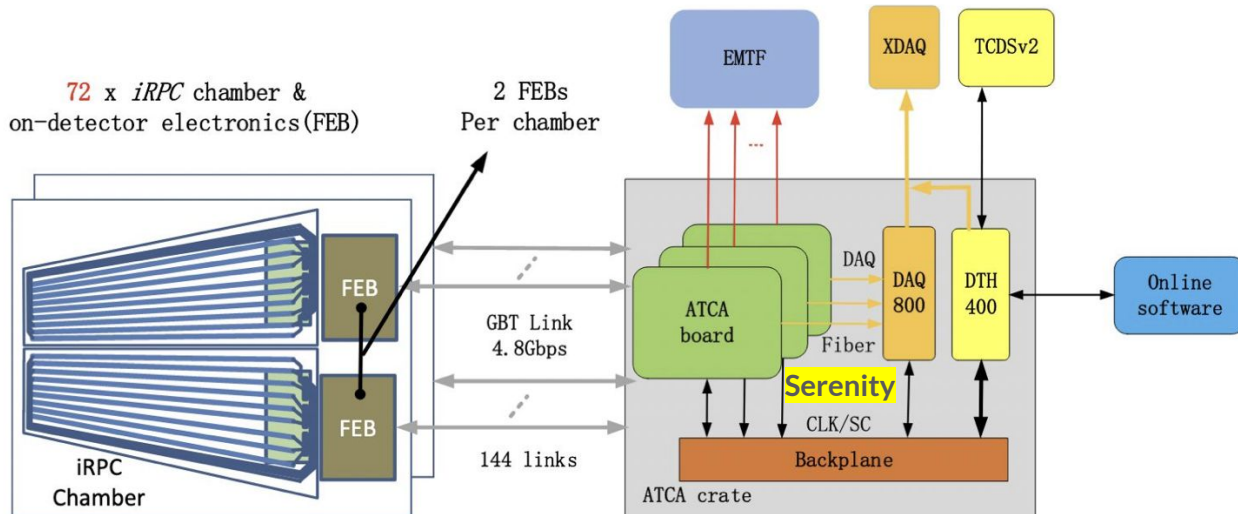
Thanks for your attention



iRPC back-end electronics

Back-end functions

- ❑ fast/slow control and monitor
- ❑ cluster finding and trigger primitive generation
- ❑ timing reference adjustment
- ❑ data acquisition



Currently we are using uTCA based BE setup

FEB TDC data recorded in few BX,
well inside the 20 BX trigger latency

Data transmission delay properly adjusted by Back-end

uTCA crate with BEB

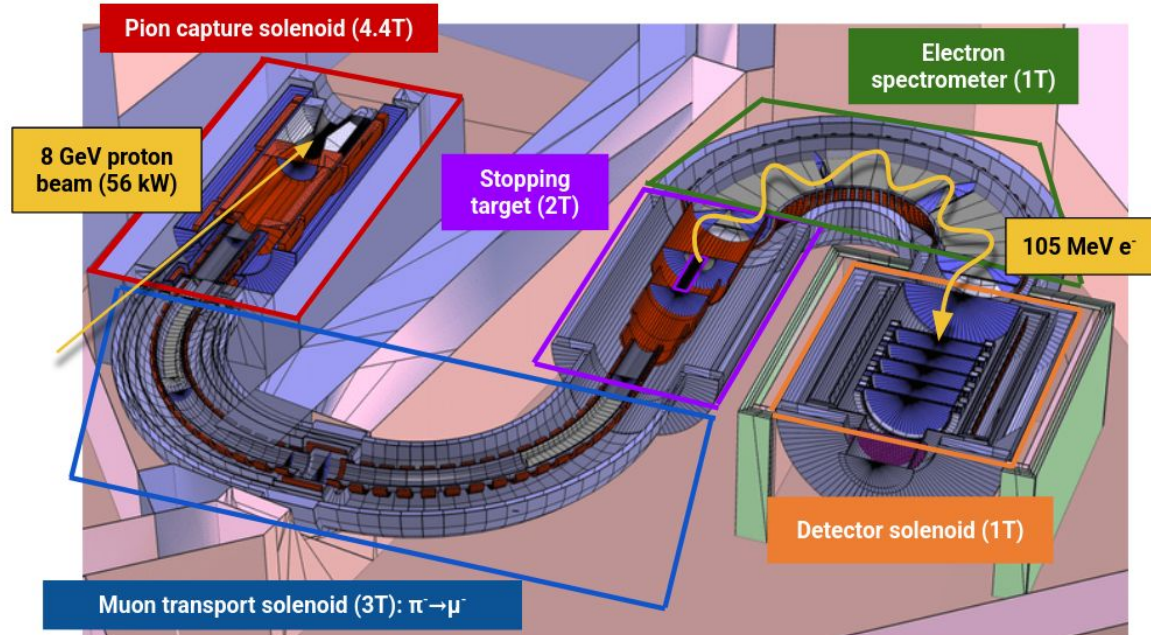


COMET Phase-I

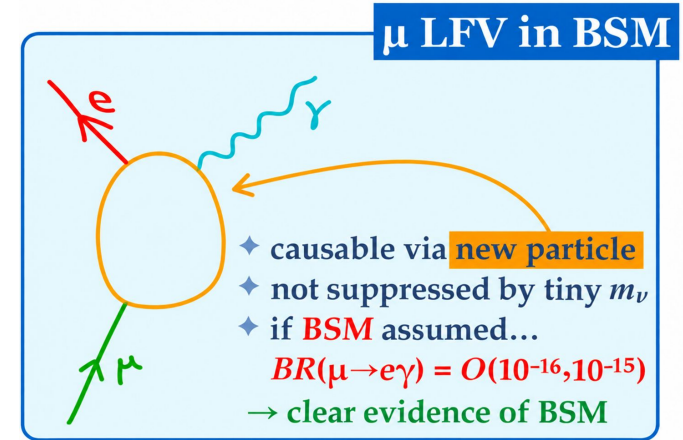
- Extend to full intensity with an expected sensitivity of $O(10^{-15})$ to $\text{BF}(\mu \rightarrow e)$

COMET Phase-II

- Complete all transport and target sensitivity of $O(10^{-17})$



- Observation of neutrino oscillations confirms the existence of neutrino mass and neutral lepton flavour violation.
- The neutrino mass terms predict charged lepton flavour violation (CLFV) at loop level.
- These processes are highly suppressed due to the tiny values of neutrino masses.
- Many beyond the SM physics models predict sizeable CLFV that may well be accessible experimentally.



One of the most interesting CLFV processes which can occur is the coherent transition of a muon to an electron in the presence of a nucleus $\mu N \rightarrow e N$.