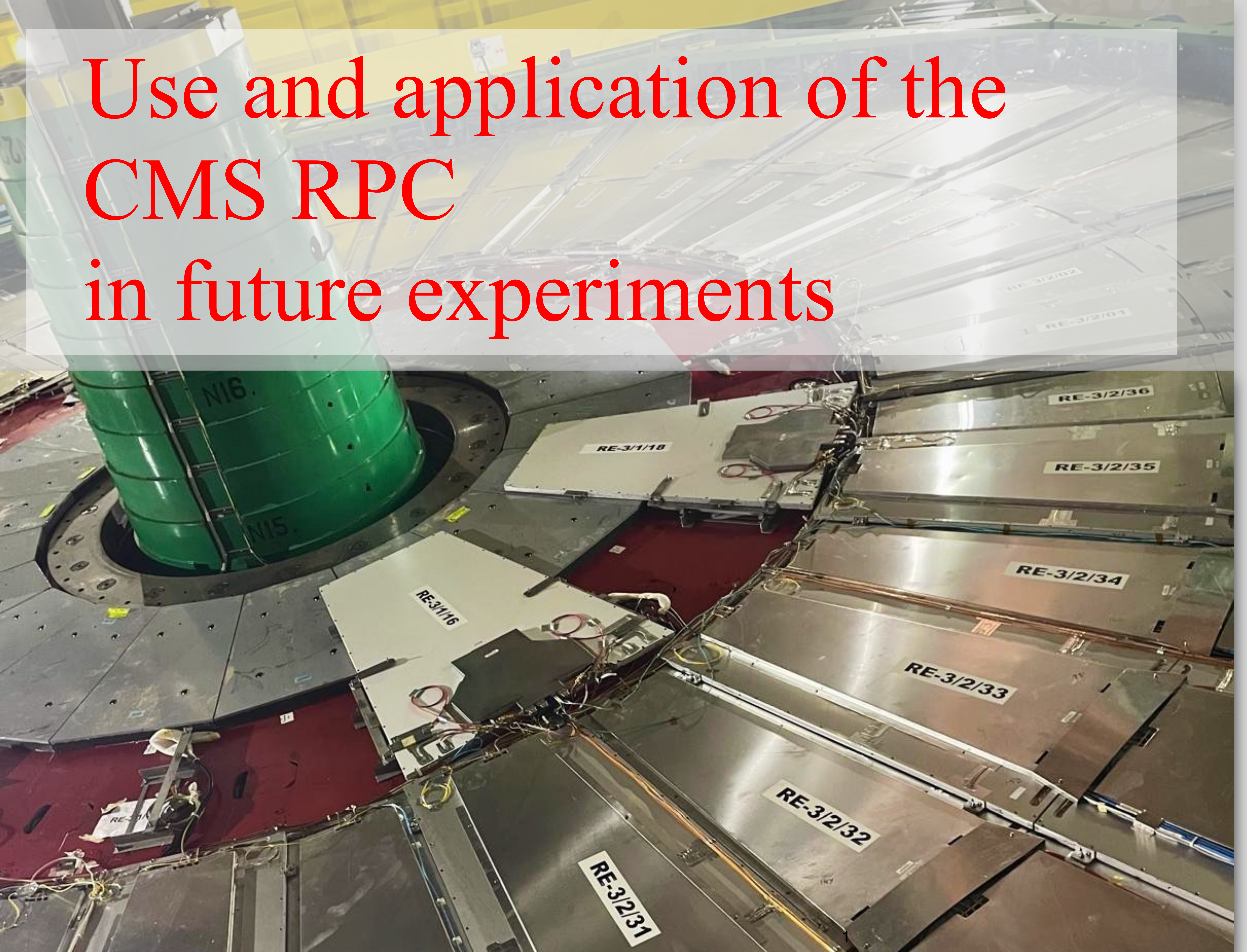
Use and application of the CMS RPC in future experiments



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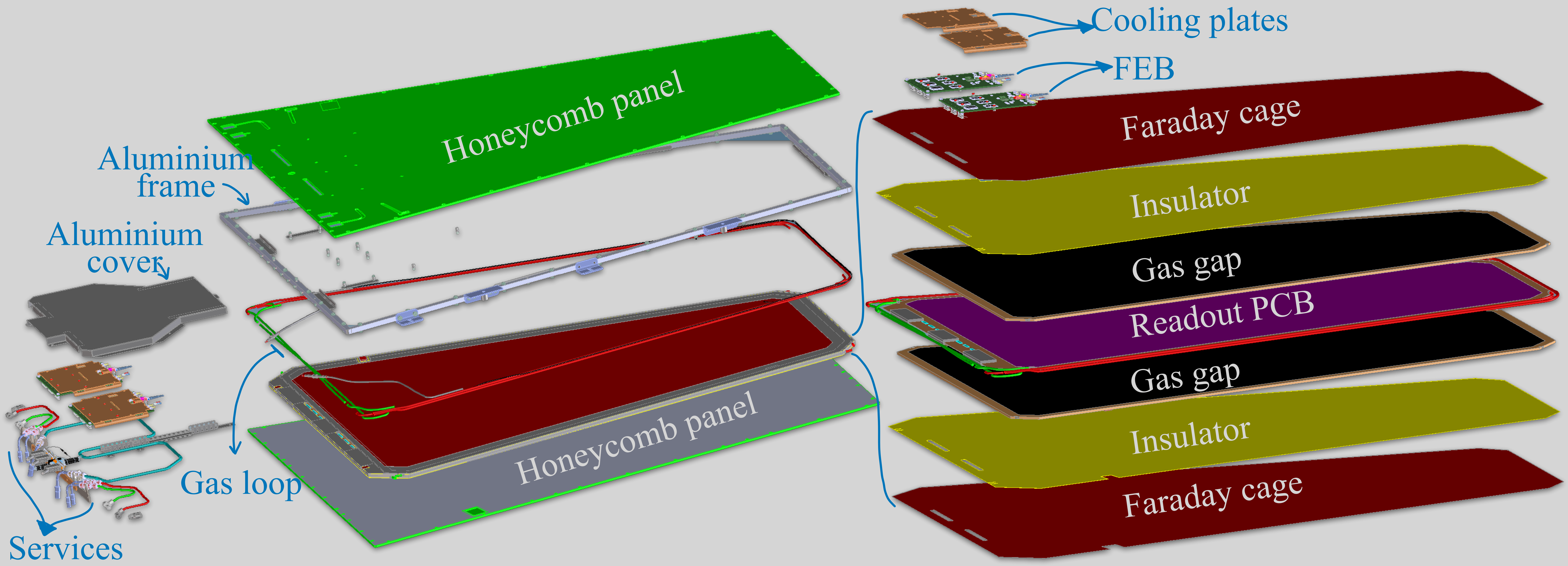
On behalf of the CMS MUON Group

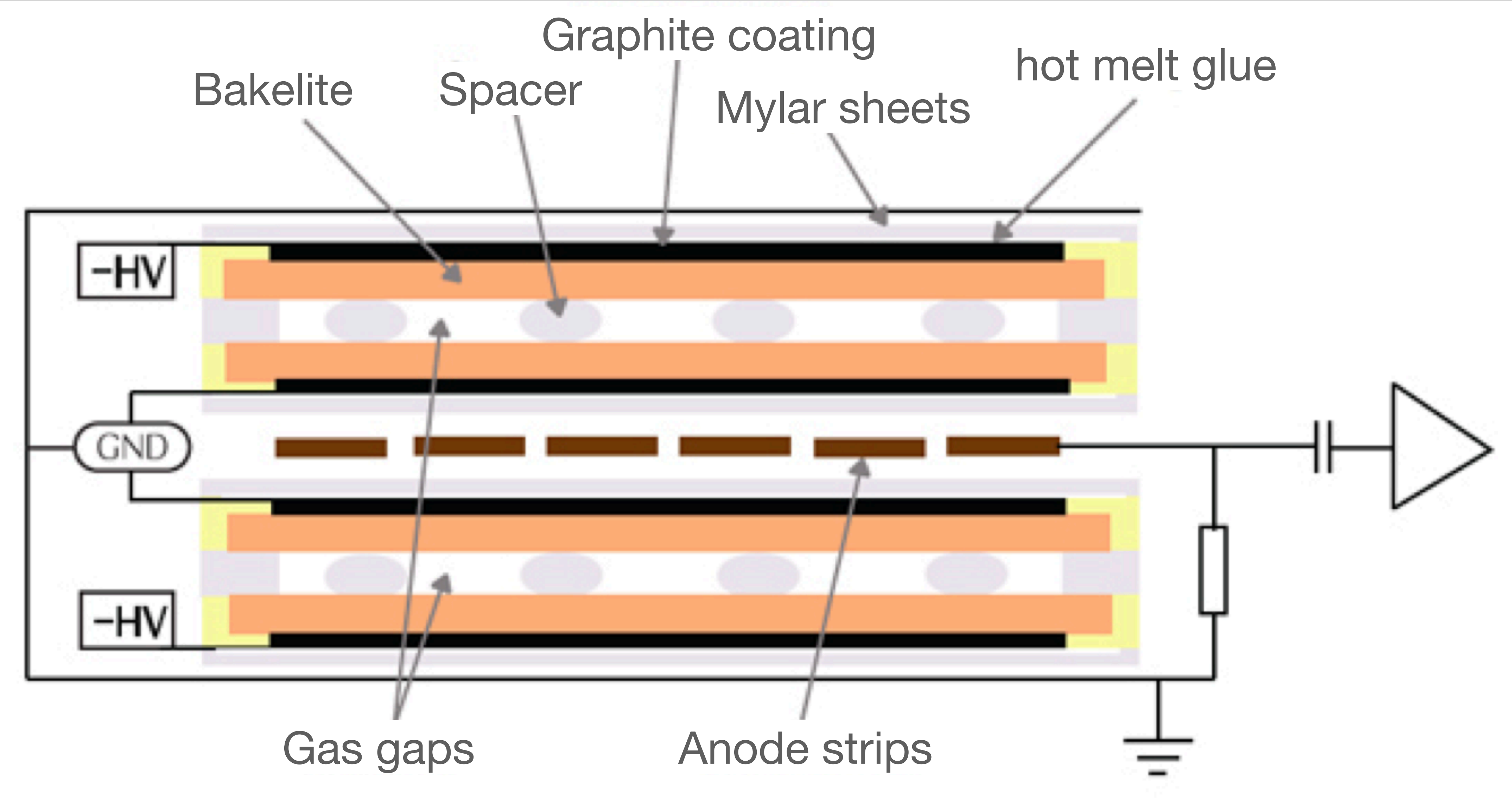
RPC 2024
Santiago de Compostela (Spain)



The iRPC as a well proven muon detector, can be an opportunity for future experiments.

The CMS iRPC

- Double-gap iRPC detectors
- Each gap made of two 1.4 mm low-resistivity (order of 10^{10} Ωcm)
- High Pressure Laminate electrodes Separated by a gas gap of the same thickness.
- Two readout panels: made of a thin (0.6 mm) Printed Circuit Board (PCB)
- Each PCB has 48 strips and equipped with a FEB.
- To identify the position along the strip, the read out of the iRPC detectors is from both sides of a strip end, low radius (LR) and high radius (HR).

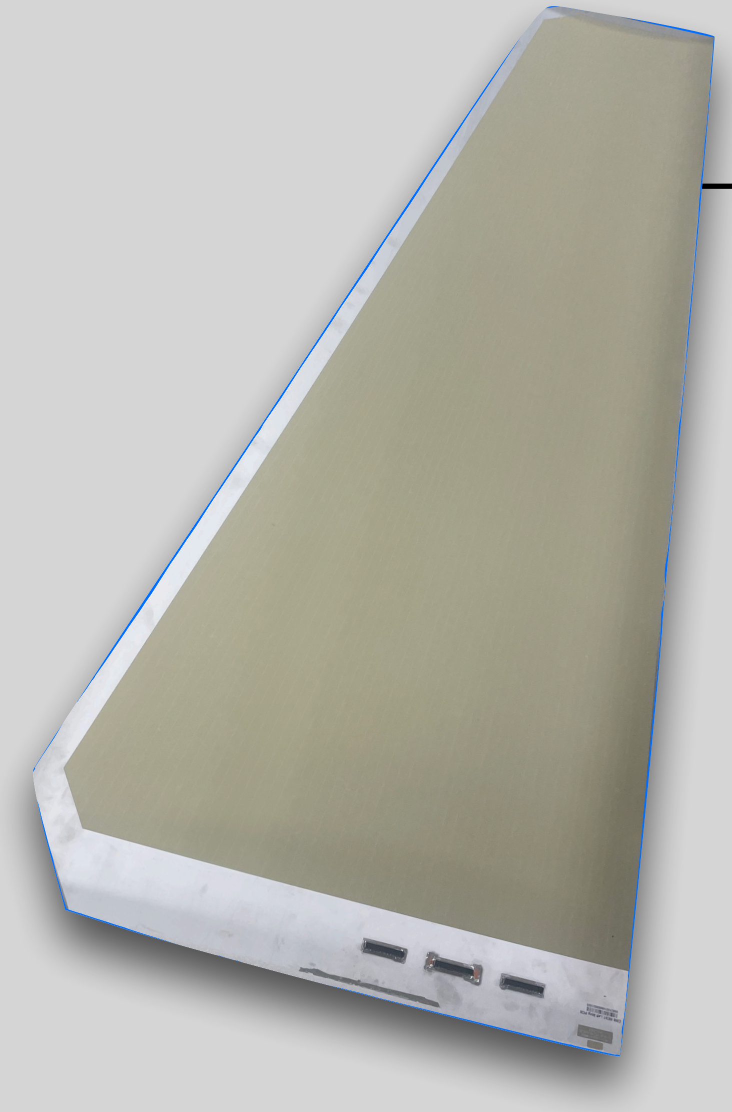


- The new layout reduces the amount of the avalanche charge produced by the passage of a charged particle through the detector.

- This improves the RPC rate capability by reducing the needed time to collect this charge.

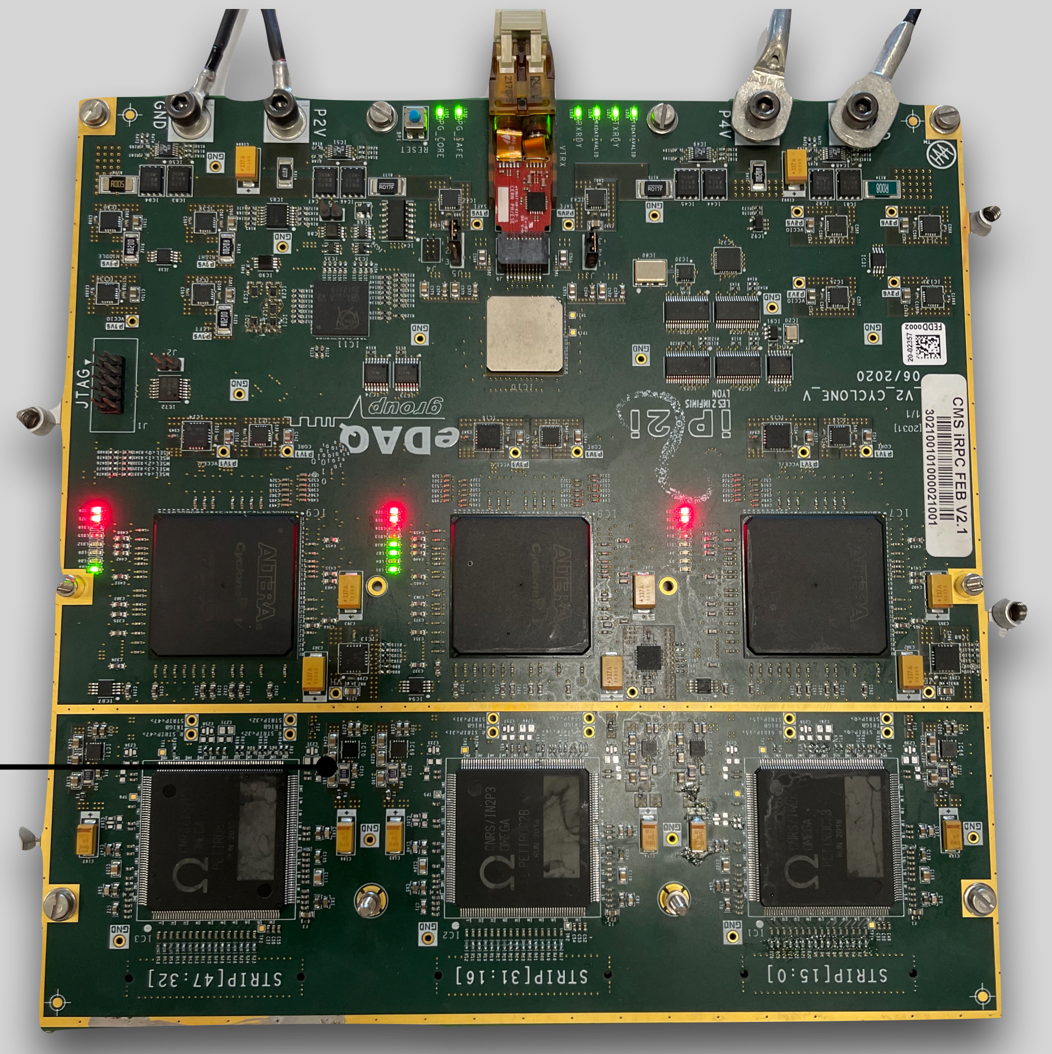
The CMS iRPC

- Bakalite :
  Long lasting, not fragile, can be very large in size, easy to handle.
  Allow use of flex piping, without a necessity of very well control of humidity.



- PCB :
  A quite large solution (60 x 170 cm^2) and resistant.
  2D readout without multi layer strip. No XY ambiguities.
  Perfect impedance matching (better than 5%).

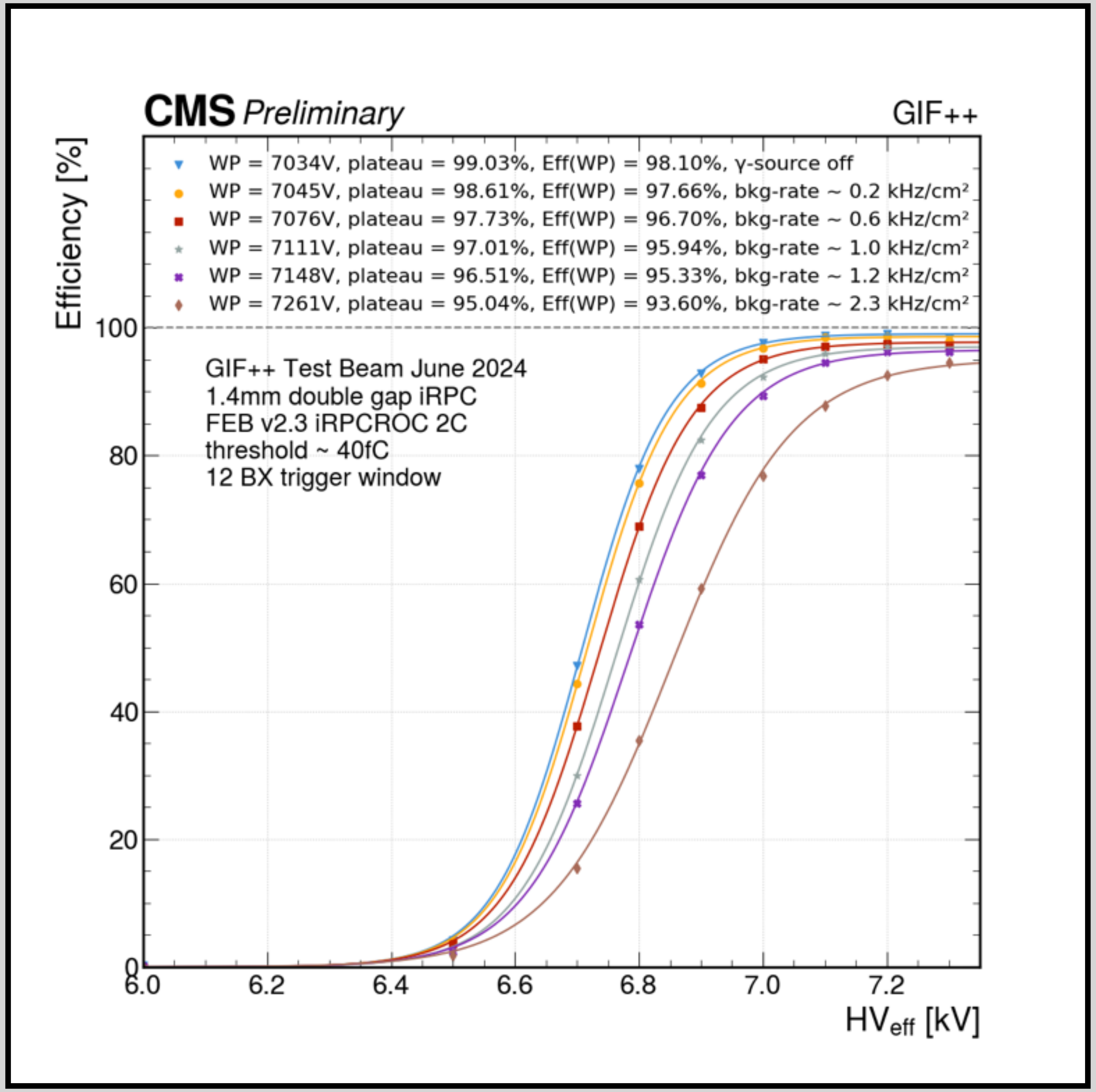
- FEB :
  FEB and PCB shape can be flexible. Easy to plug.
  Design is open to changes at component level



The iRPC is an elegant solution with low number of channels for a large chamber with 2D readout.

The CMS iRPC

	iRPC
High Pressure Laminate thickness	1.4 mm
Num. of Gas Gap	2
Gas Gap thickness	1.4 mm
Resistivity (Ωcm)	0.9 - 3 x 10^{10}
Charge threshold	< 50 fC
space resolution (eta)	1.5 cm
space resolution (phi) strip pitch driven	0.3-0.6 cm
Intrinsic time resolution	0.5 ns

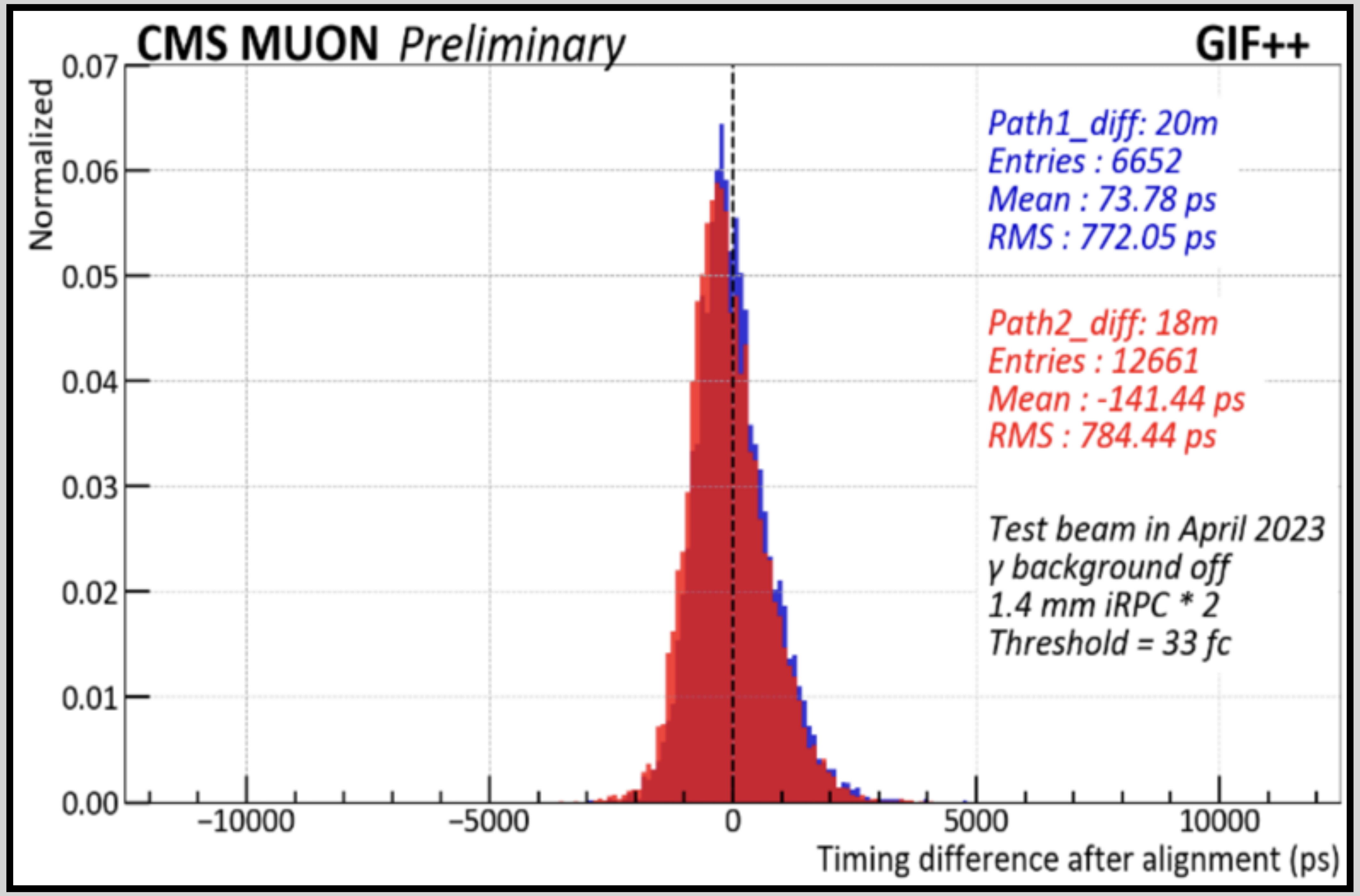


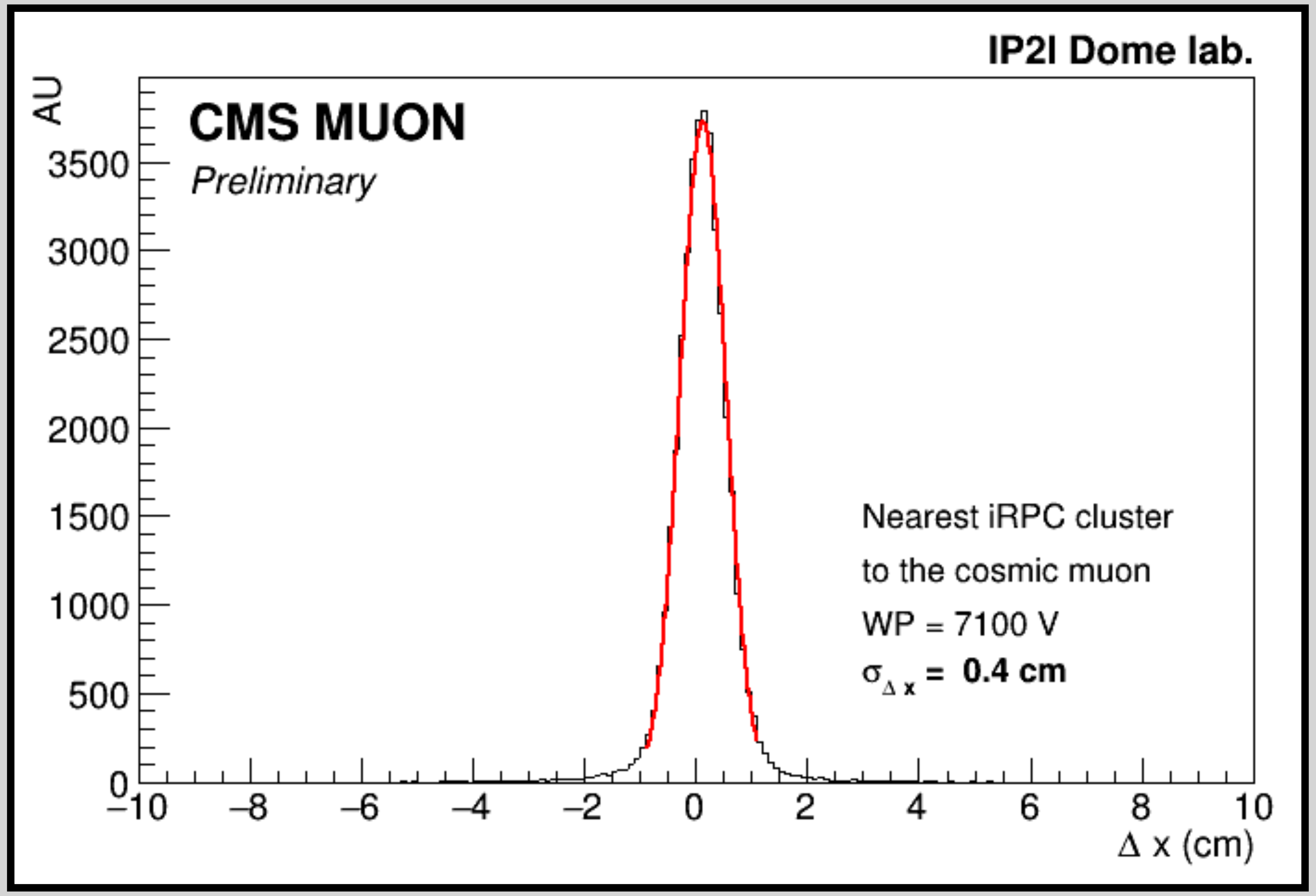
See presentation from Jules Vandenbroeck

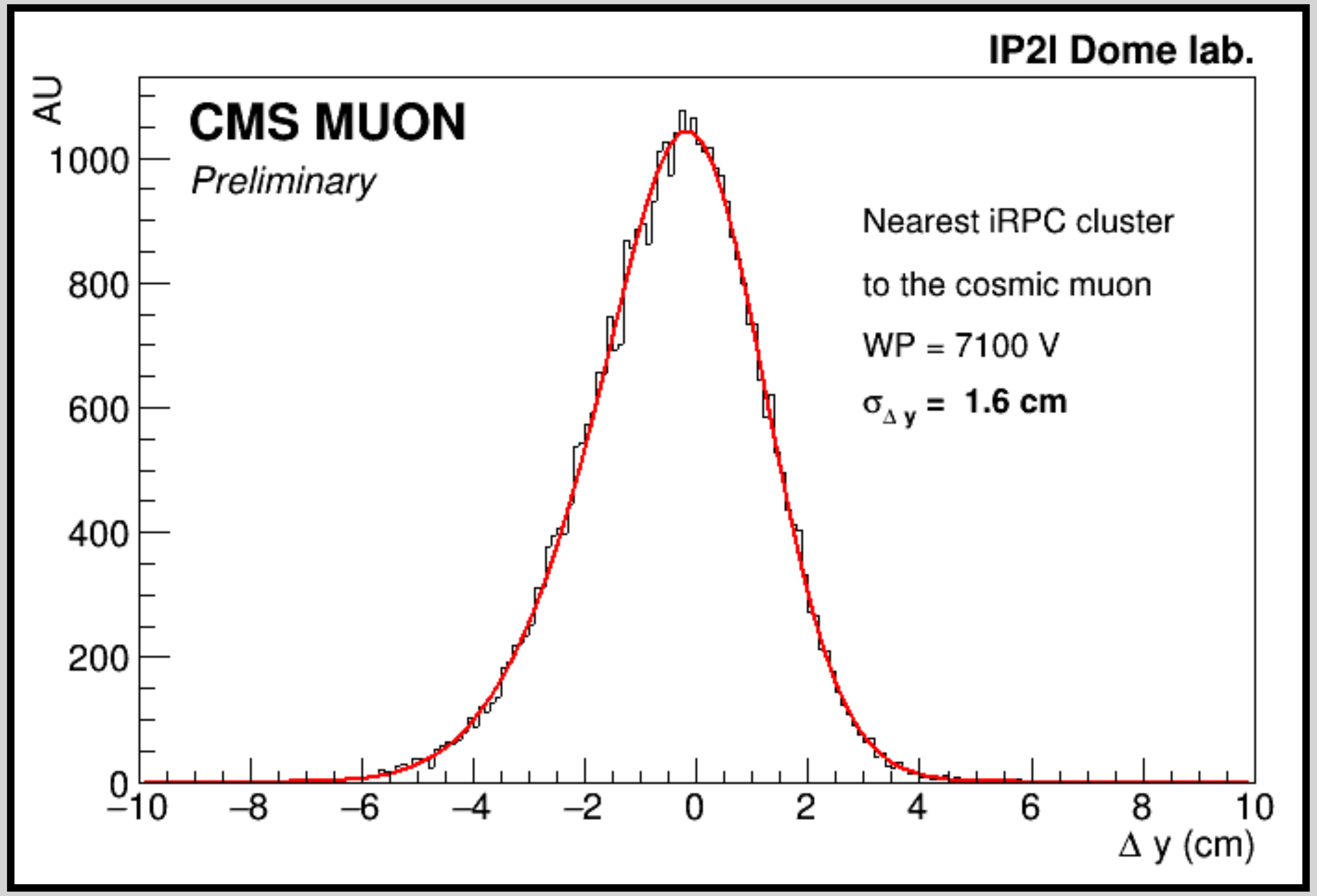
The iRPC ensures high efficiency for high background rates

The CMS iRPC

The iRPC ensures 550 ps time resolution; x, y resolution 0.4 cm, 1.6 cm





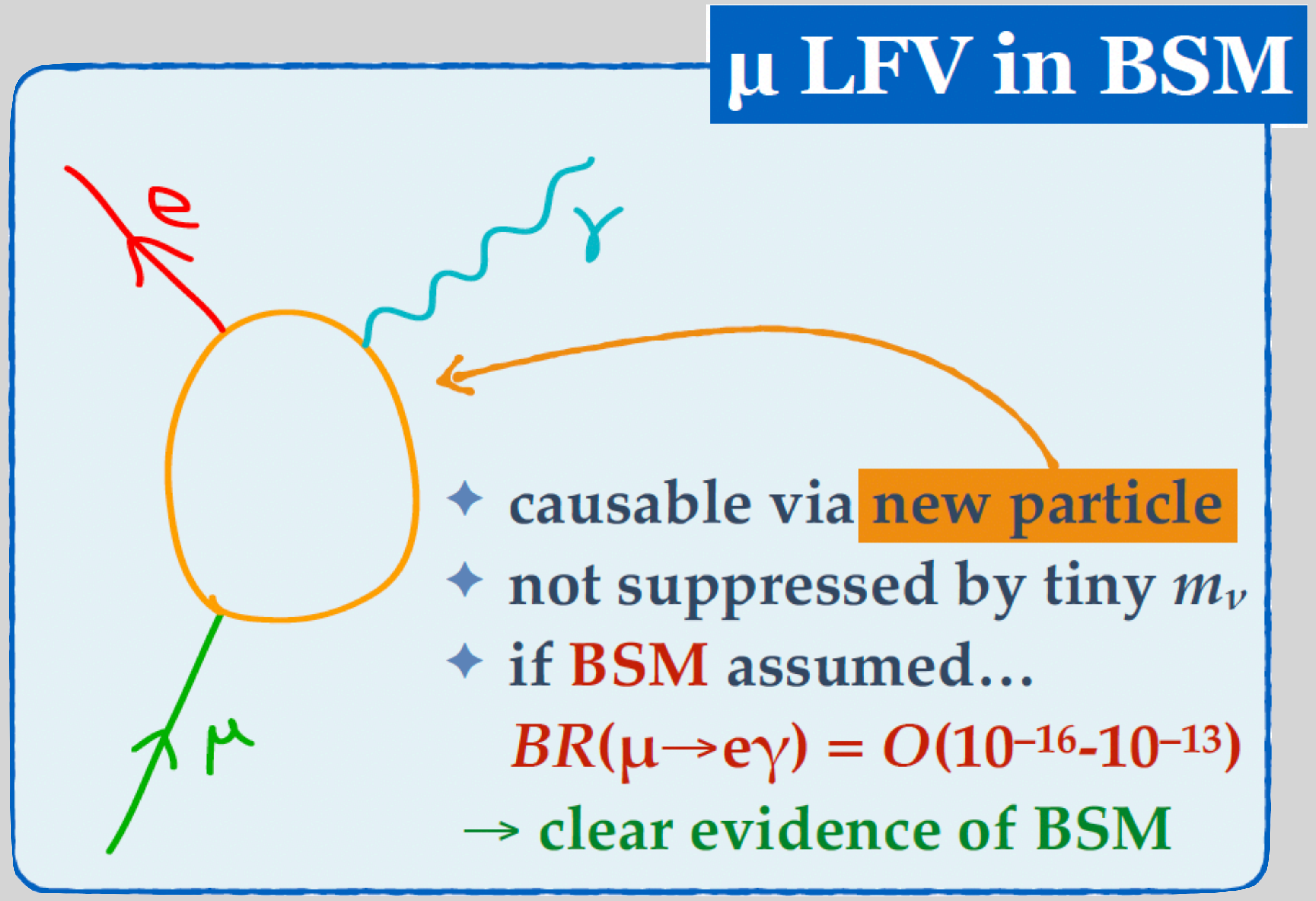


See presentation from Jules Vandenbroeck

An alternative experiment for the use of RPC chambers : The COMET Experiment

A search for muon to electron conversion at J-Parc

- 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 transition of a muon to an electron in the presence of a nucleus $\mu^- N \to e^- N$.

The image is from Hajime NISHIGUCHI Talk in ICHEP 2024

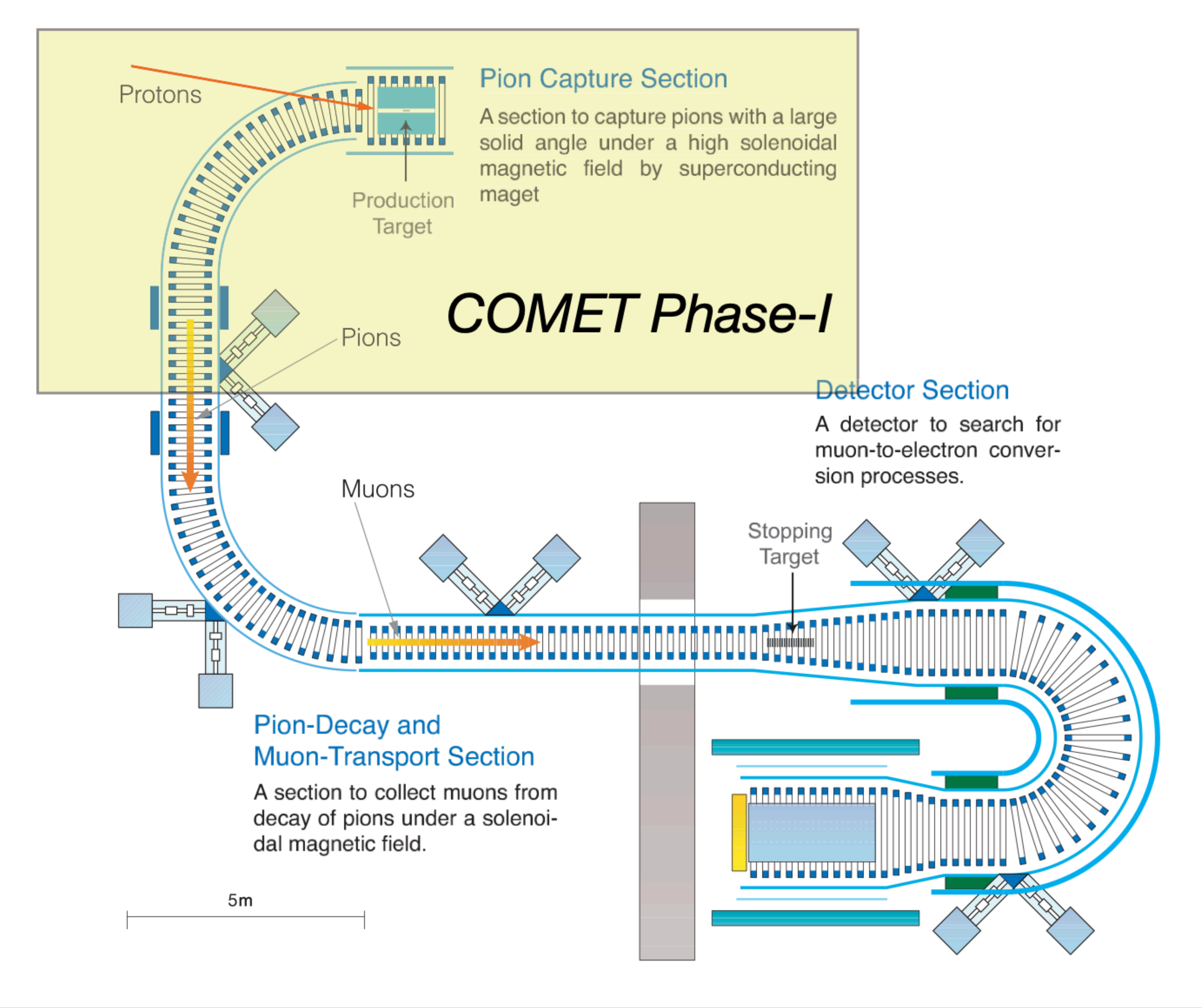
An alternative experiment for the use of RPC chambers : The COMET Experiment

COMET Phase-I

- Construct up to first 90° bend and place detector.
- Perform direct beam measurement
  - No backward σ_π data so far
  - No real background data so far
- Perform μ-e search with an intermediate sensitivity ($O(10^{-15})$)

COMET Phase-II

- Complete all transport
- Perform μ-e search with a full sensitivity ($O(10^{-17})$)



The content is from The COMET Experiment TDR

An alternative experiment for the use of RPC chambers : The COMET Experiment

Signal

- $\mu^{-}N \rightarrow e^{-}N$ is 105 MeV mono-energetic electron.

Background

- Intrinsic physics backgrounds:
  come from muons stopped in the target
- beam-related backgrounds:
  caused by both muons and other particles in the muon beam
- cosmic-rays
  produce an electron which enters the detector,
  muons which enter the detector and are misidentified as an electron.
- fake tracking events

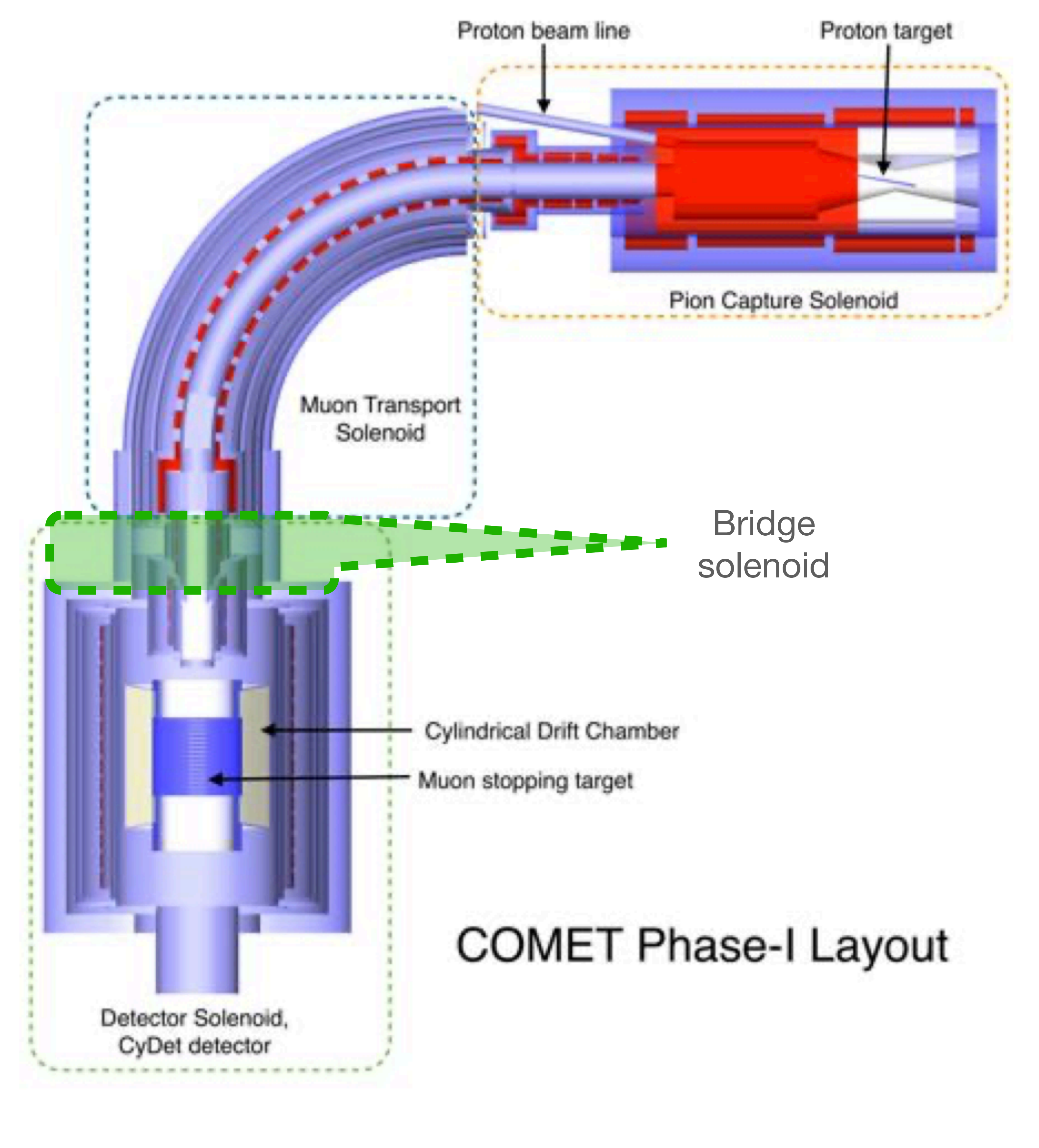
Cosmic ray backgrounds must be eliminated by shielding and detecting and vetoing the signals.

The content is from the COMET Experiment TDR

An alternative experiment for the use of RPC chambers : The COMET Experiment

Cosmic Ray Veto

- Cosmic Ray muons can decay in flight or interact with the materials around the area of the muon-stopping target and produce signal-like electrons in the detector region.
- The region around the BS that requires active shielding has a surface of 4.5 x 4.5 m².
- Simulations show a large neutron contamination hit rate of the order of kHz.
- Thin detectors,
  nanosecond time resolution,
  operated at efficiencies better than 95% is proposed.



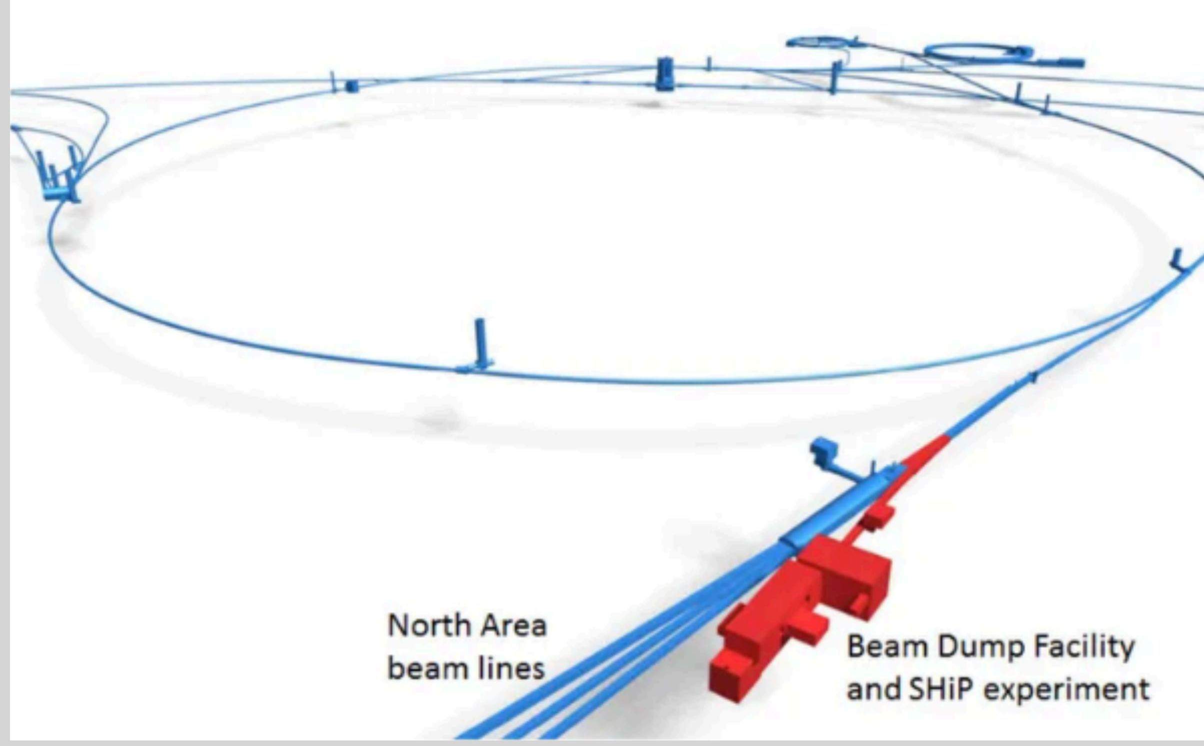
In the TDR originally a glass RPC was envisaged,

iRPC proposes a "turn key" solution.

The content is from the COMET Experiment TDR

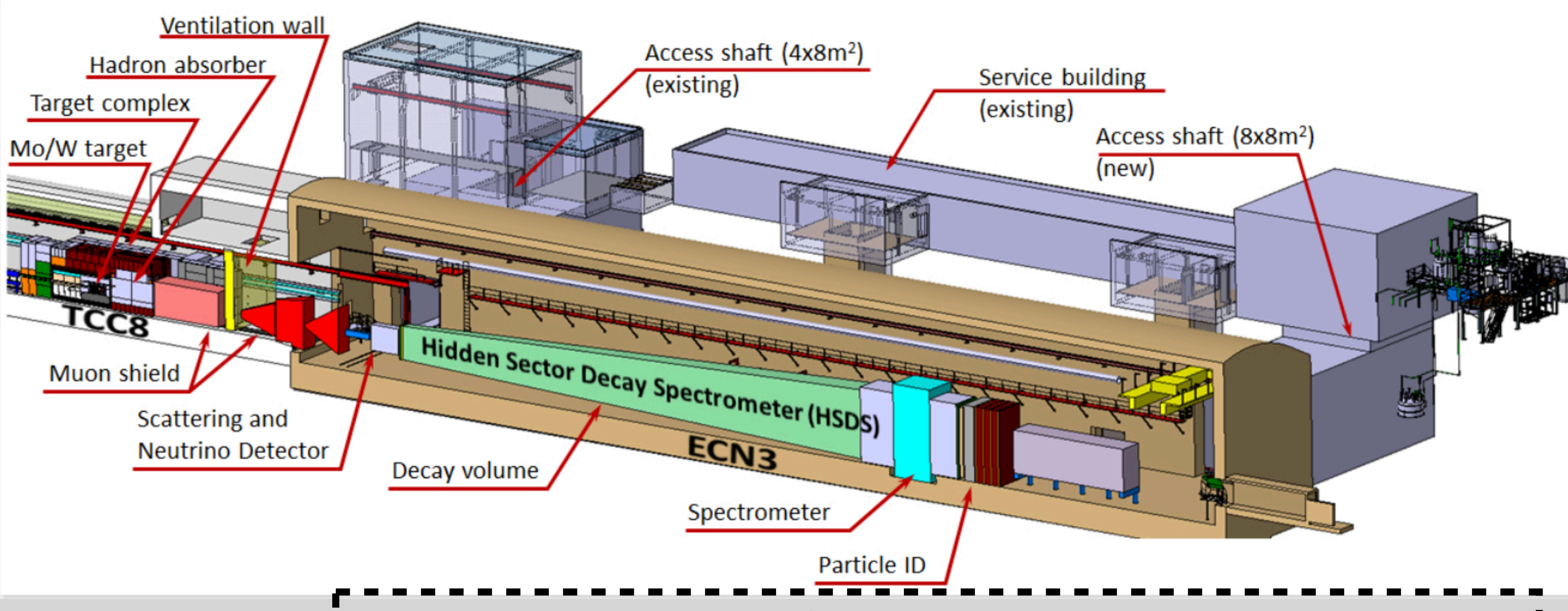
An alternative experiment for the use of RPC chambers : The SHIP Experiment

The Search for Hidden Particles:
dark photons, axions and axion-like particles, heavy neutral leptons …



- A high-intensity proton beam from the Super Proton Synchrotron (SPS) accelerator will be repeatedly sent to a target, a large metal block, producing a vast number of particles.

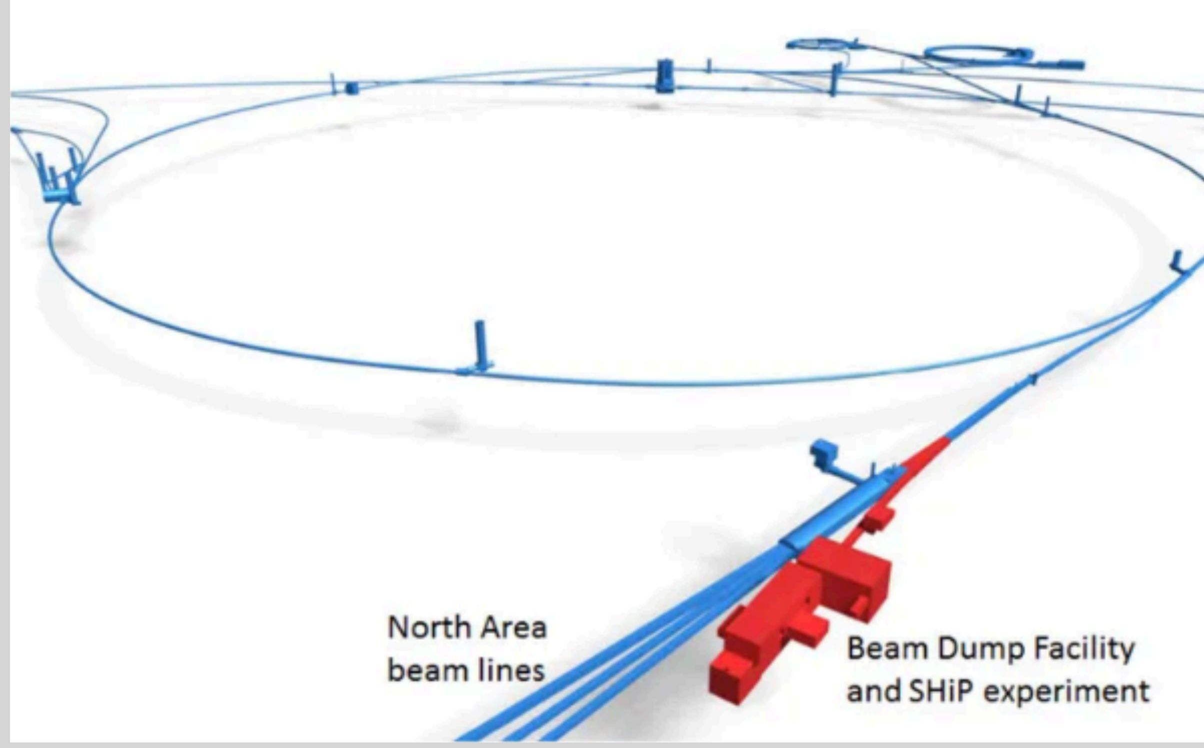
- Ship detectors will be placed several tens of metres away from the target in order to detect relatively long-lived particles and eliminate "background noise", in other words, particles such as muons that could interfere with the detection of long-lived particles.



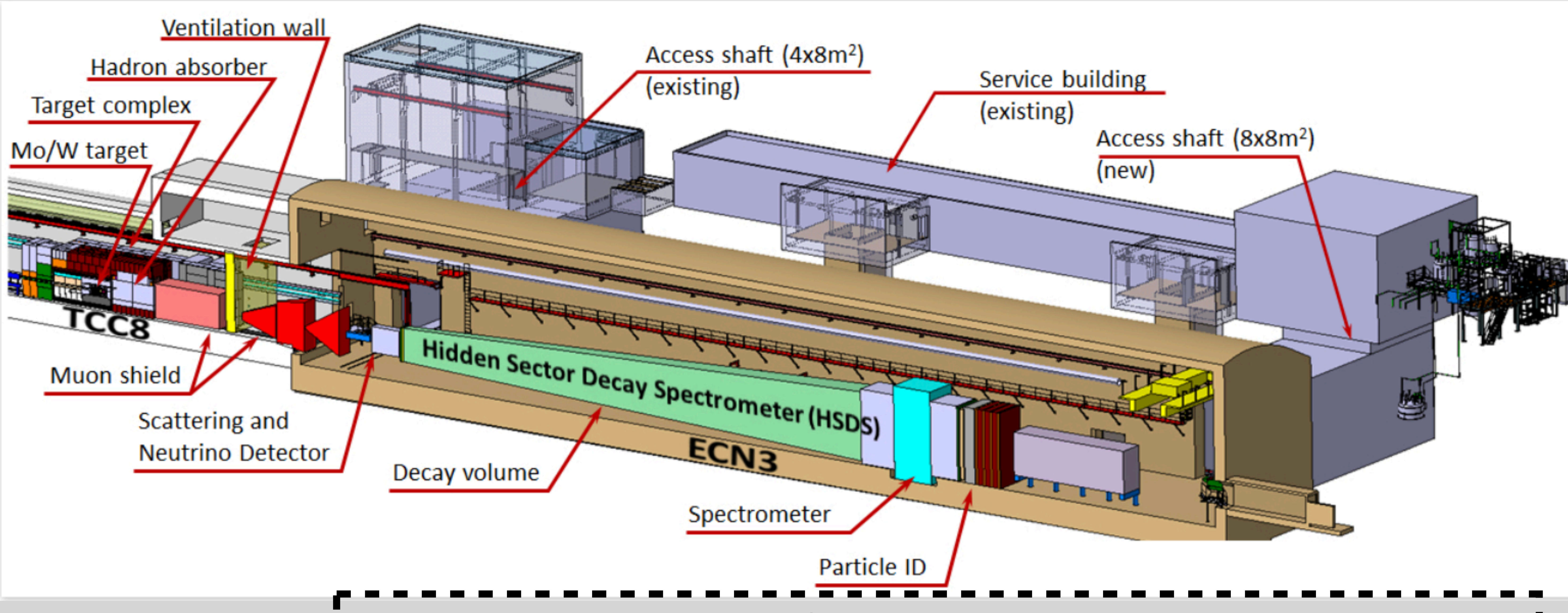
The content is from the SHIP Experiment Paper

An alternative experiment for the use of RPC chambers : The SHIP Experiment

- The layout includes two complementary detectors: the upstream Scattering and Neutrino Detector (SND) and the downstream Hidden Sector Decay Spectrometer (HSDS).



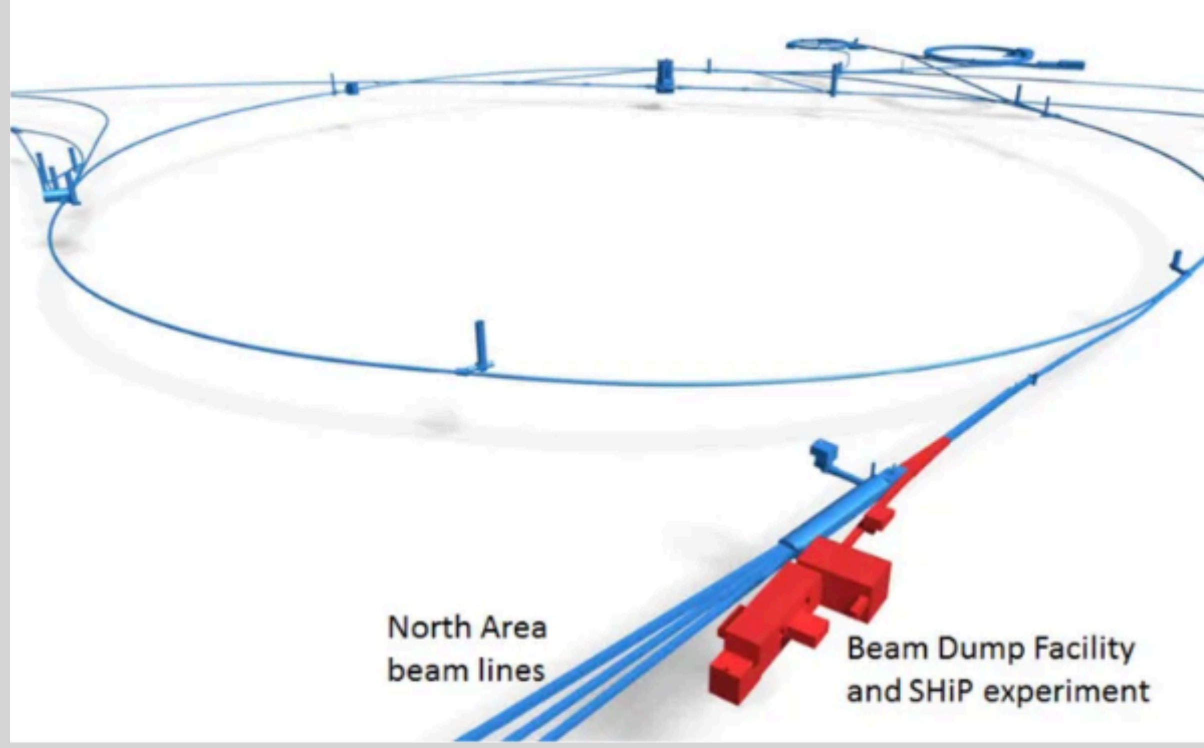
- Three additional multi-gap RPC planes act as an upstream veto for the HSDS. A time resolution of the order of 100ps required to reject the combinatorial background due to neutrino interactions and muon inelastic scattering producing tracks not correlated in time to the hidden particles.



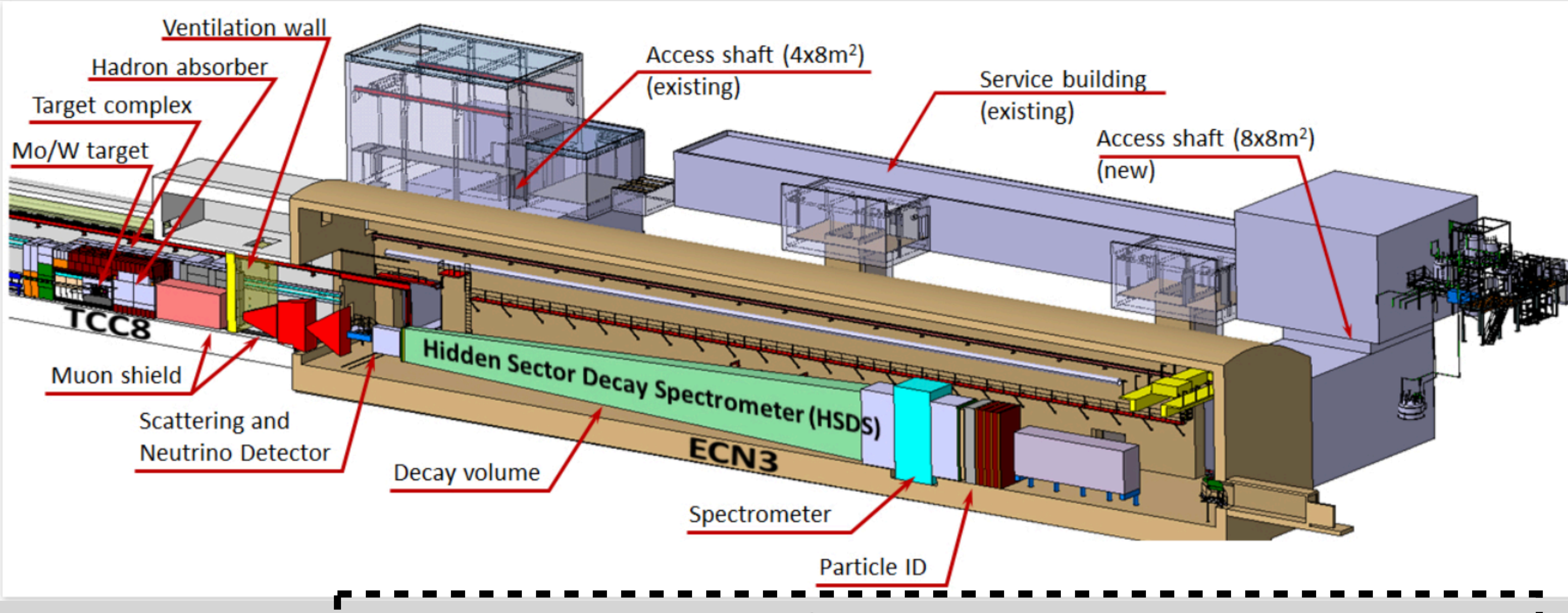
The content is from the SHIP Experiment Paper

An alternative experiment for the use of RPC chambers : The SHIP Experiment

- The SND Muon Identification System :
  detect and reconstruct the muons with high efficiency produced in neutrino interactions and in short-lived particle decays occurred in the emulsion target.



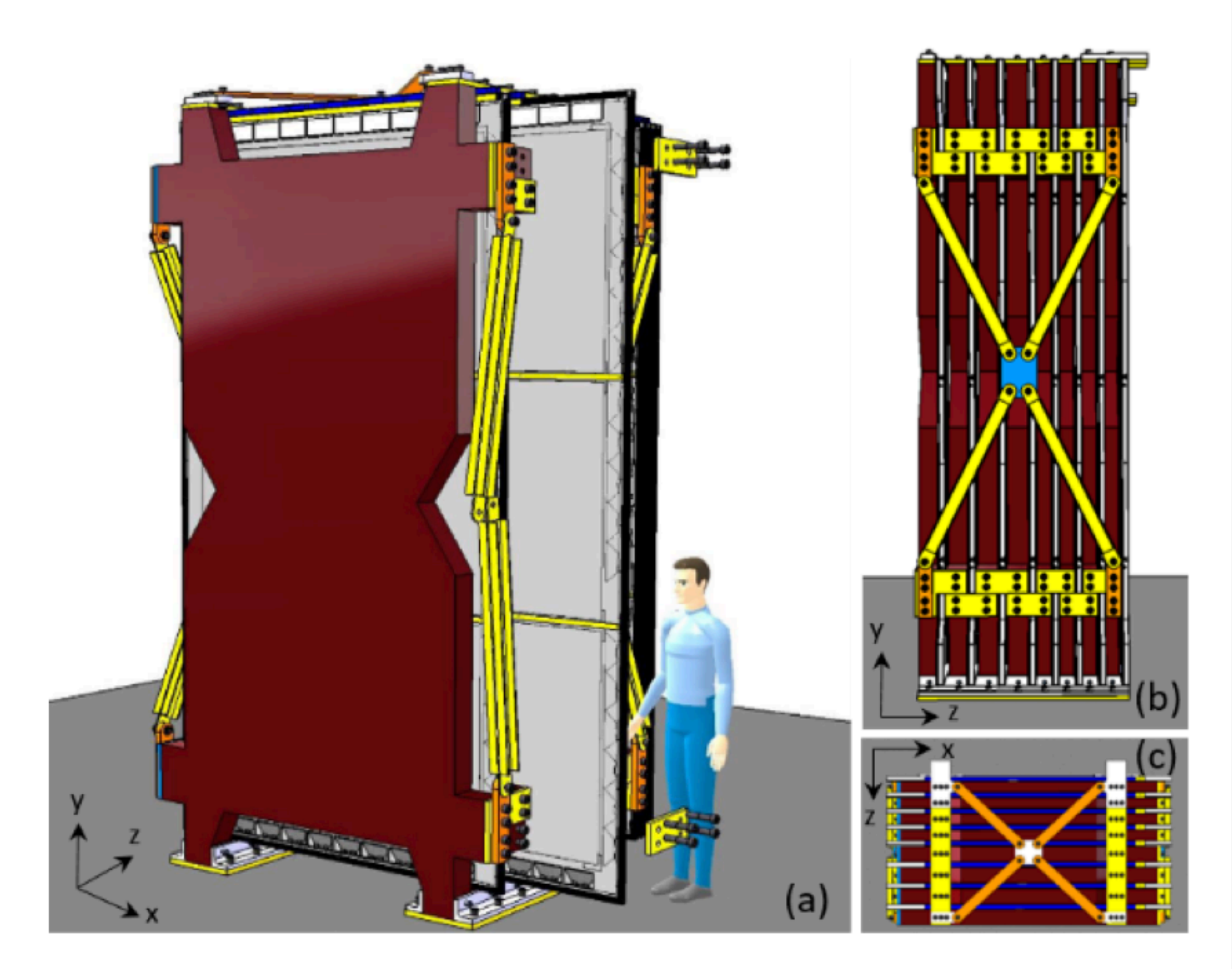
- The SND has been designed to study neutrino physics and neutrino-induced charm production with unprecedented statistics
  - a 7 m-long hybrid detector located in a magnetic field
  - followed by a Muon Identification System, based on Resistive Plate Chamber (RPC) technology



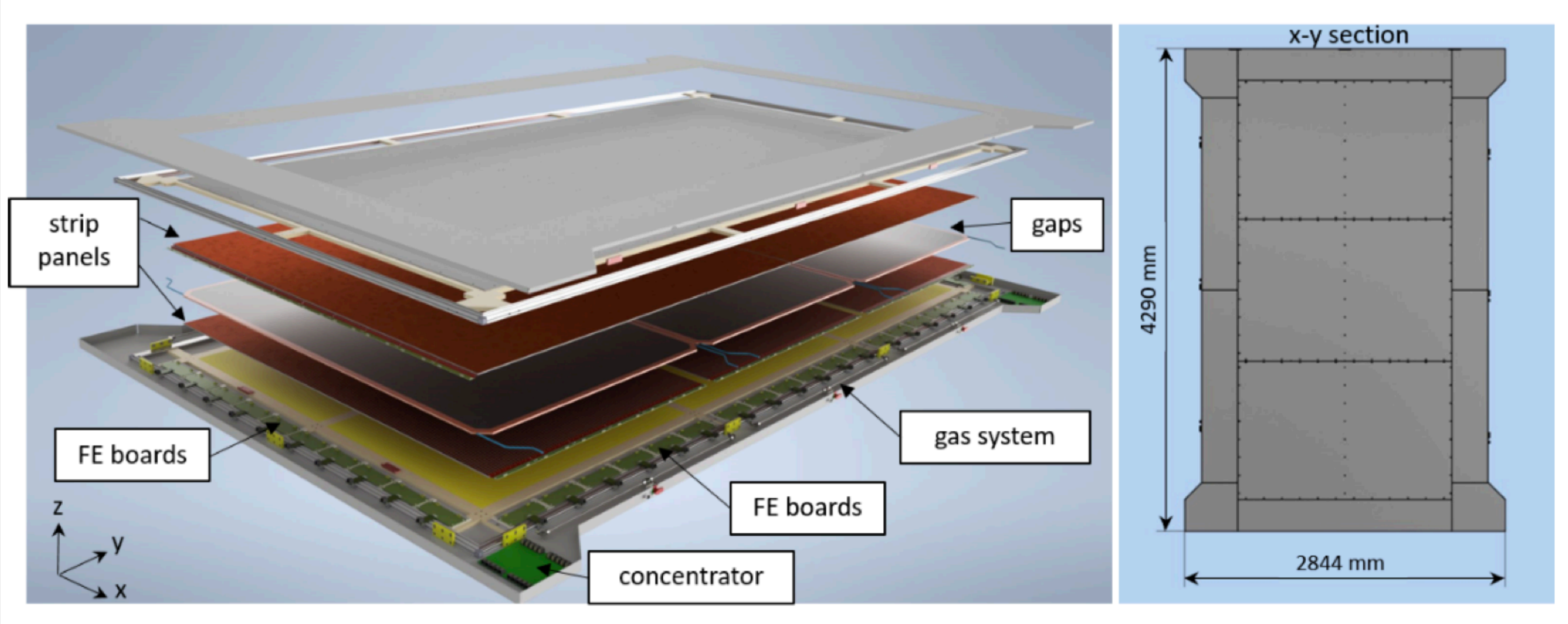
The content is from the SHIP Experiment Paper

An alternative experiment for the use of RPC chambers : The SHIP Experiment

- Maximum expected particle rate 400 Hz/cm^2
- In the design, 97% detecting efficiency has been reached with using at least three RPC planes.
- The 2D position of particles impinging on detector planes, each RPC is readout by two panels of perpendicular strips



iRPCs have somewhat garnered attention due to their ability to achieve the same performance with fewer layers and a reduced number of readout front-end boards.



The content is from the SHIP Experiment Paper

Conclusions

- The iRPC provides a very well tested gaseous muon detector.

    High efficiency at high rate

    Long lasting, not fragile, can be very large in size, easy to handle.

    2D readout without multi layer strip. No XY ambiguities

    FEB design is open to changes at component level reaching up to threshold 10 fC.

- This proven detector has attracted interest from future experiments, including COMET and The SHIP.

- Leveraging such established technology allows experiments to focus on the more complex and challenging aspects of the design.

Thank you very much