RPCs and readout system for the neutrino detector of the SHiP experiment

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Abstract

SHiP (Search for Hidden Particles) is a proposed experiment to be installed at CERN, with the aim of exploring the high intensity beam frontier to investigate the so-called Hidden sector (HS).

Since the SPS proton beam interacting with the SHiP high density target is expected to produce a large neutrino flux, the experiment will also study neutrino physics with unprecedented statistics. In particular, about 10^{15} ν_τ and $\bar{\nu_\tau}$ are expected to be produced in five years (integral p.o.t. $2 \cdot 10^{20}$). A dedicated Scattering and Neutrino Detector (SND) is thus being designed. It consists of a nuclear emulsion target and a tracking fibres detector in magnetic field followed by a Muon identification system.

The Muon system is composed of iron filters interleaved with tracking planes (dimension ~2x4m^2), instrumented with Resistive Plate Chambers (RPCs), operated in avalanche mode. Each plane consists of three large gaps (~2x1.3 m^2 each) readout by two planes of perpendicular strips (pitch~1cm, length ~2m).

The RPC readout electronics is being developed in Bari. It is based on the use of front-end FPGAs connected to a concentration system, transmitting data serially at high speed via optical link to the data acquisition and control system.

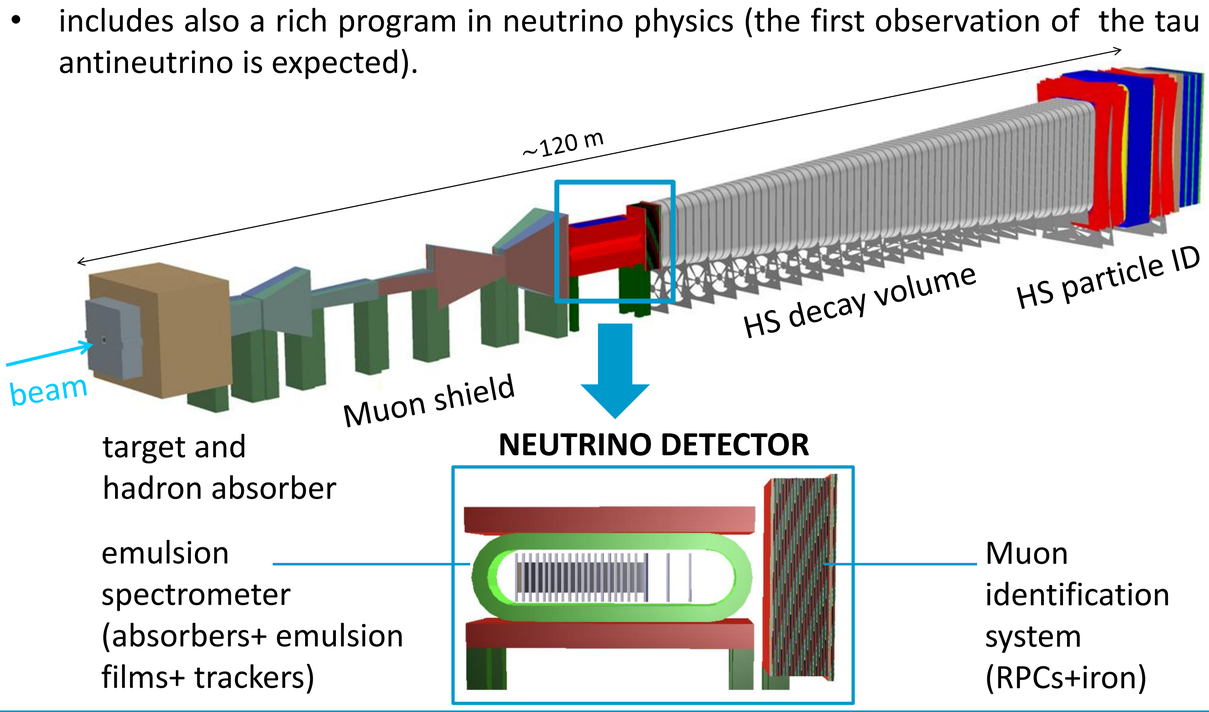
A small-scale prototype of the SHiP Muon identification system, with five RPC planes consisting of one large gap each, has been produced and exposed at CERN H4 in a test beam.

The SHiP experiment

Problems unexplained by the Standard Model (dark matter, neutrino oscillations, matter/antimatter asymmetry) could hide new physics.

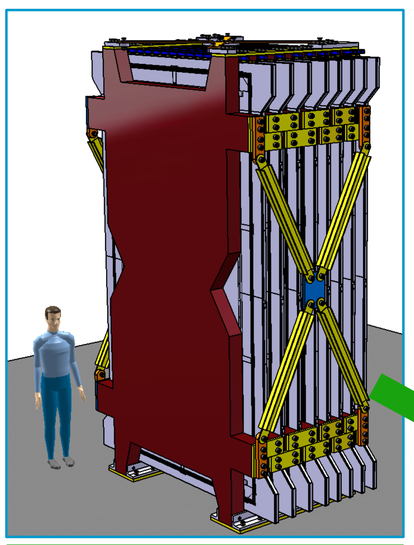
SHiP *(Technical Proposal: arXiv:1504.04956, 2015):*

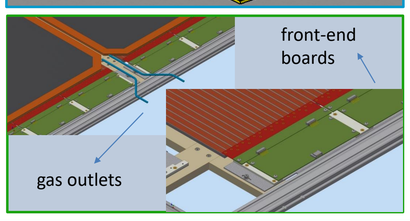
- searches for new physics in the Hidden sector (fleebly interacting particles);
- includes also a rich program in neutrino physics (the first observation of the tau antineutrino is expected).



RPCs for the Muon identification system

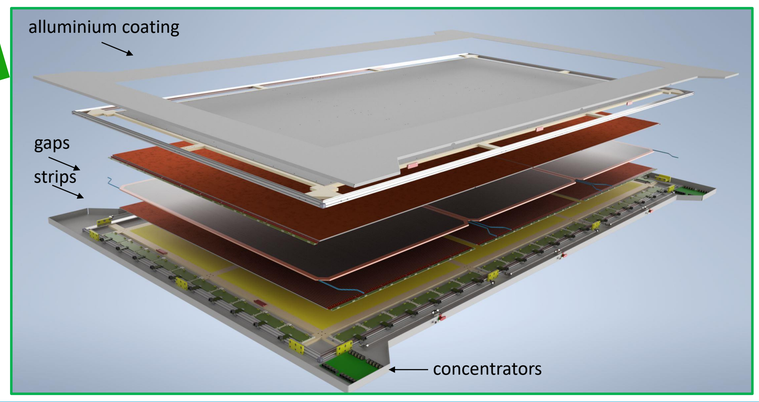
The muon system is composed of eight tracking planes interleaved with iron plates.





Features of tracking planes:

- large dimension ~2x4m^2;
- equipped with RPCs (3 gaps per plane, size ~2x1.3m^2) operated in avalanche mode;
- readout by 2 panels of perpendicular copper strips (pitch ~1cm, lenght ~2m);
- mechanical structure including all services (HV, gas distribution, front-end boards, concentrators).

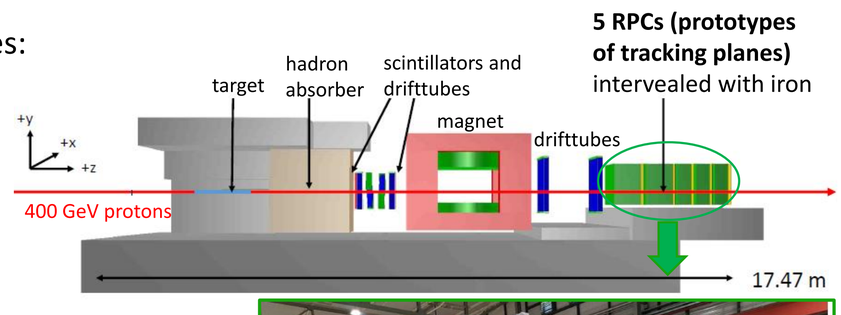


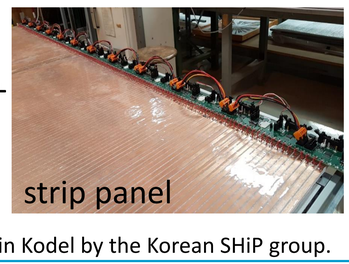
RPC prototypes

In 2018, the SHiP collaboration installed a small-scale replica of the experiment target, collecting $5 \cdot 10^{11}$ protons at 400 GeV, in the H4 beam line at the CERN SPS, in order to measure the Muon flux generated by the SHiP target.

RPC prototype (*) features:

- dimension: (195.5 x 125.0) cm^2;
- gap width = 2mm;
- 184 (x) x 116 (y) strips (pitch = 1.0625 cm);
- resistive bakelite electrode plates (thickness=2mm) covered with graphite paint;
- gas mixture: $C_2H_2F_4$(~95%)+ C_4H_{10}(~4.5%)+ SF_6(~0.5%).



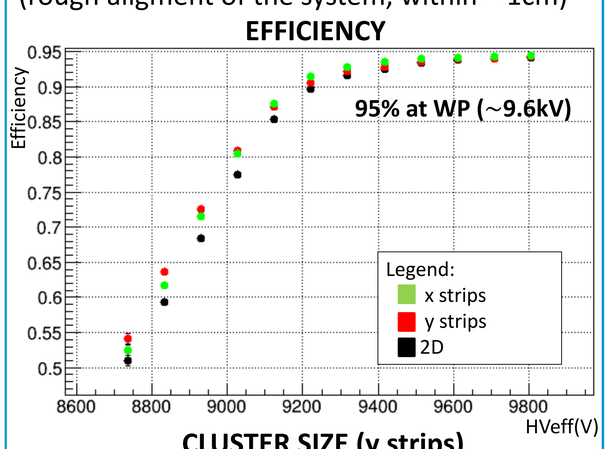


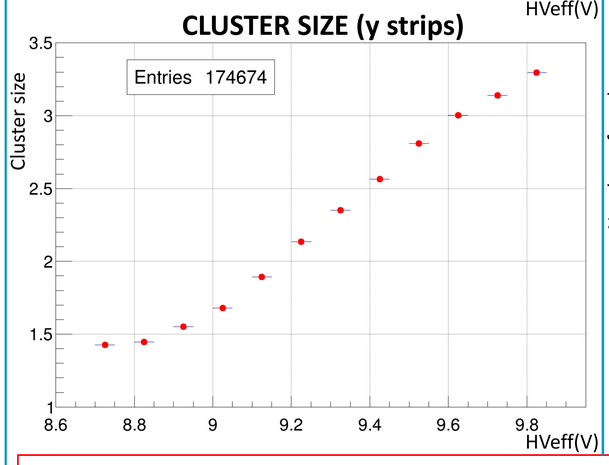
(*) gap and strips produced in Kodel by the Korean SHiP group.

Test results of RPC prototypes

TRACKING TEST OF AN RPC PROTOTYPE WITH COSMIC RAYS

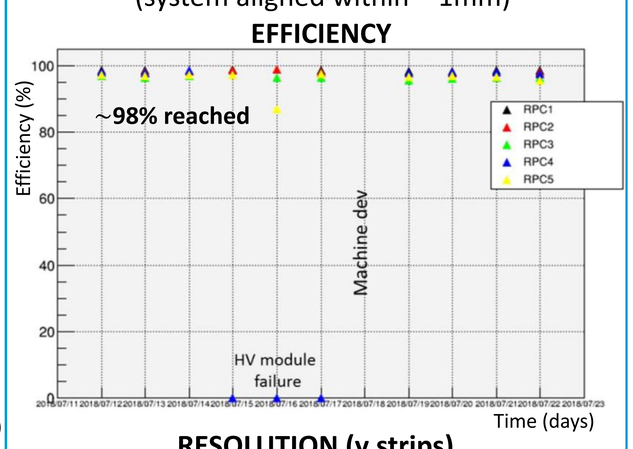
(rough aligment of the system, within ~1cm)

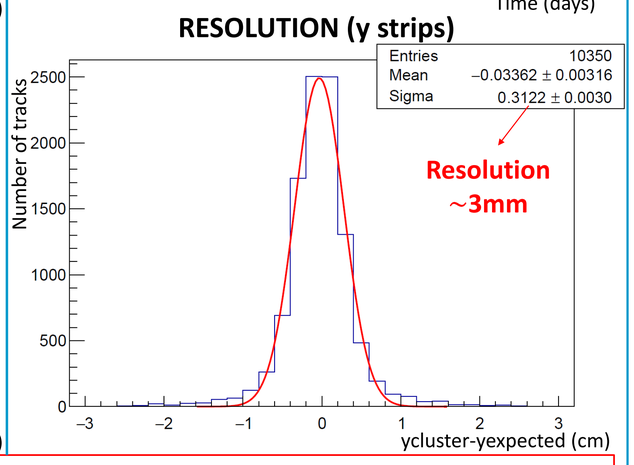




RPC PROTOTYPES PERFORMANCE DURING THE TEST BEAM

(system aligned within ~1mm)

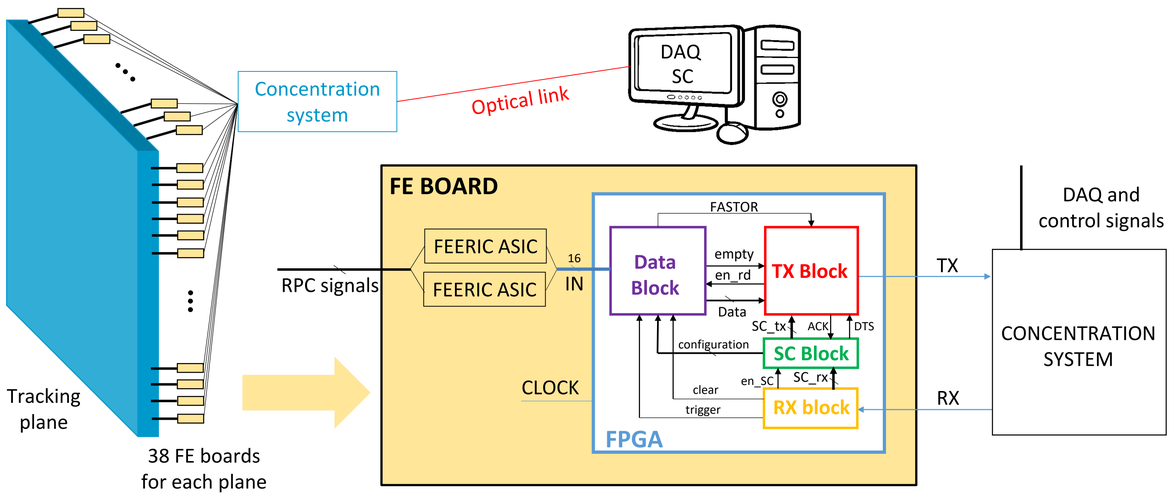




- Efficiencies of 98% reached at working point (~9.6kV).
- Resolution: about 3mm.

The RPC readout electronics for SHiP

A solution for the RPCs front-end board, transmitting data serially through optical link from the detectors to the DAQ and control system, is under development in Bari.



The FEERIC ASIC (*) is used for signal amplification and discrimination.

The front-end FPGA has been designed and simulated in Bari.

Its functionalities are:

- the acquisition of signals in triggerless mode (as required by SHiP) from strips and the association of time stamp;
- the high speed serial transmission of data from RPCs to DAQ through optical link;
- the execution of commands received by the DAQ and control system.

The possibilility to work in triggered mode (for tests) is also implemented in the FPGA.

(*) ALICE collaboration, "FEERIC: Front-End Electronics for the Resistive Plate Chambers of the ALICE Muon IDentifier", 2016.

Conclusions and outlooks

- A small-scale prototype of the SHiP Muon Identification system has been produced, tested with standard mixtures and exposed at CERN H4. A position resolution of about 3mm and efficiencies as high as 98% have been measured.
- New eco-friendly mixtures are currently under study. In order to optimize the RPCs performance with eco-gas, new gaps with reduced thickness will be produced and tested.
- A front-end FPGA for the high speed serial transmission of data from the RPCs to the DAQ system has been designed and simulated. A prototype of the front-end board hosting the designed FPGA will be realized and tested.