Troubleshooting the Ionization Profile Monitor (IPM) for CSNS 1.6 GeV RCS

M. A. Rehman[1], R. J. Yang[1], Z. Xu[1], P. Forck[2], W. Huang[1], X. J. Nie[1], S. Wang[1], X. Li[1], J. Sun[3]

[1]IHEP/CSNS, [2]GSI, [3]PSI

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Abstract

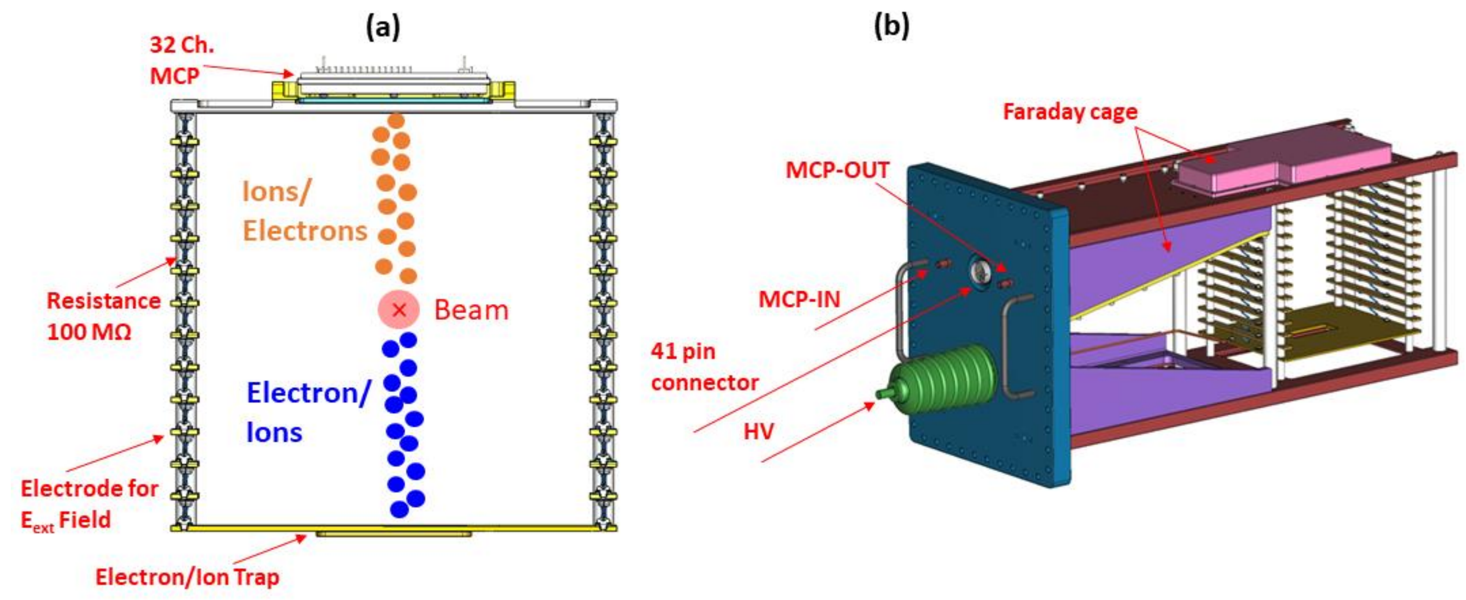
Non-invasive and turn-by-turn beam transverse profile monitoring is essential for the tunning and operating CSNS 1.6 GeV Rapid Cyclic Synchrotron (RCS). A residual gas Ionization Profile Monitor (IPM) was designed and installed in RCS for horizontal beam profile measurement. However, several challenges related to Electromagnetic Interference (EMI), vacuum, and MCP operation in the IPM were identified. The EMI is induced by the beam itself and further accelerator components. An improved Faraday cage was implemented to counteract the EMI issues. In order to achieve the desired MCP gain, a suitable pull-down resistor was incorporated into the MCP power supply circuit. After these improvements, the IPM was commissioned successfully.

Introduction

- **The China Spallation Neutron Source (CSNS) is one of the major scientific facilities in China, constructed to deliver intense pulsed neutron beams for diverse scientific research and industrial applications**
- **The CSNS accelerator complex comprises an injector LINAC that accelerates the H⁻ beam to 80 MeV**
- **H⁻ beam undergoes electron stripping through a foil, leaving behind a proton beam that is then injected into a Rapid Cyclic Synchrotron (RCS) to further increase its energy to 1.6 GeV**
- **The accelerated proton beam collides with a solid tungsten target to produce neutrons**

- **The non-invasive and turn-by-turn monitoring of the beam transverse profile plays a critical role in the tuning and operation of the CSNS 1.6 GeV RCS.**
- **For this purpose, a prototype Ionization Profile Monitor (IPM) system has been developed to monitor the horizontal beam profile.**

Parameters	Values	Units
Injection Energy	80	MeV
Ring Circumference	227.92	m
Extraction Energy	1.6	GeV
Repetition Rate	25	Hz
Number of Bunches	2	
f_{rev}	1.02 – 2.44	MHz
Beam Intensity	2.5×10^{13}	ppb



Troubleshooting the IPM

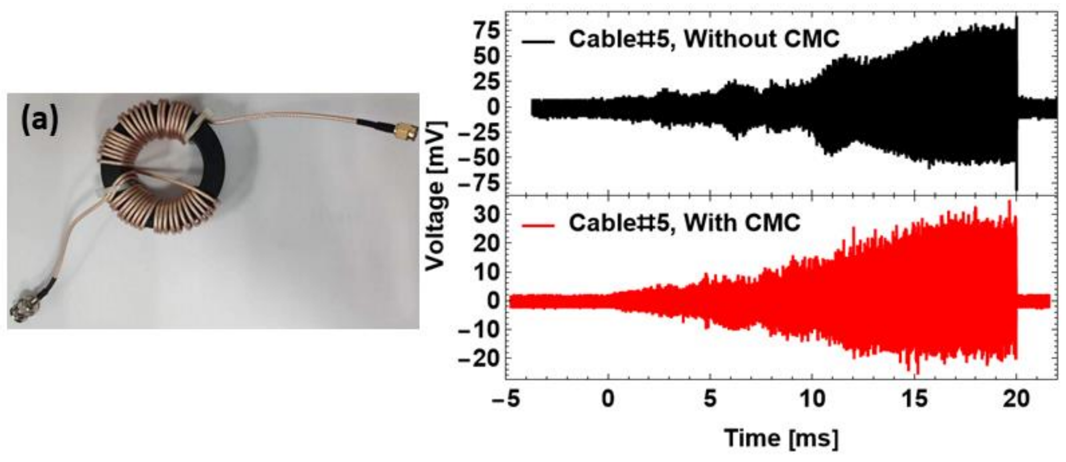
In the initial stage of the IPM commissioning, several challenges were encountered

1. Electro-Magnetic Interference (EMI)

1.1 Common Mode Noise

Common mode noise occurs when unwanted electrical signals or interference from various accelerator components, such as AC Magnets, RF Cavities, and ground loops induce interference on the IPM readout cables

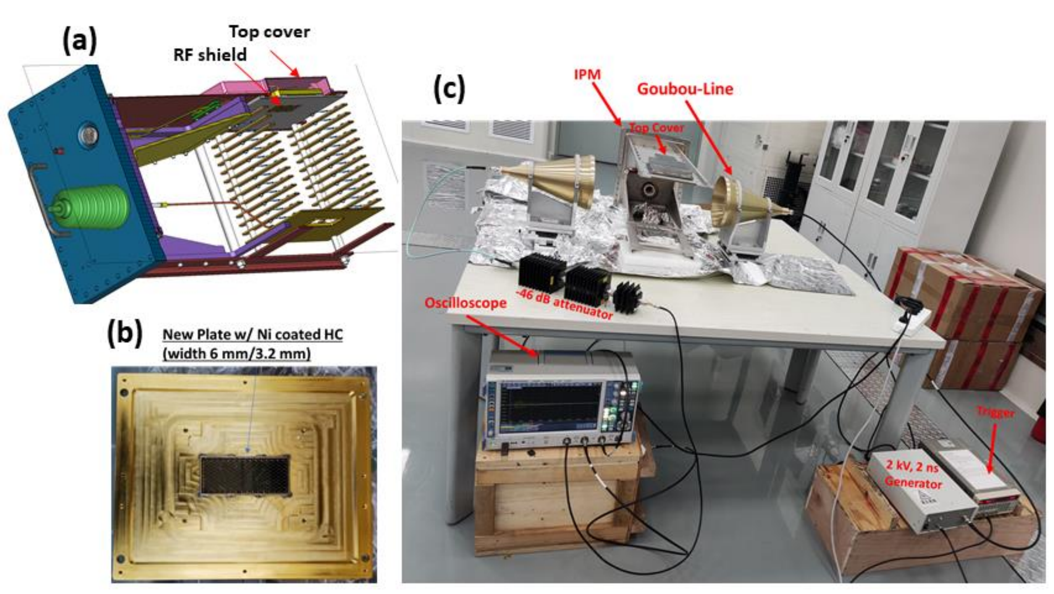
The photo shows the CMC suppressing common noise on the IPM readout cables



The implementation of the CMC effectively suppressed the common mode noise

1.2 Beam-Induced Noise

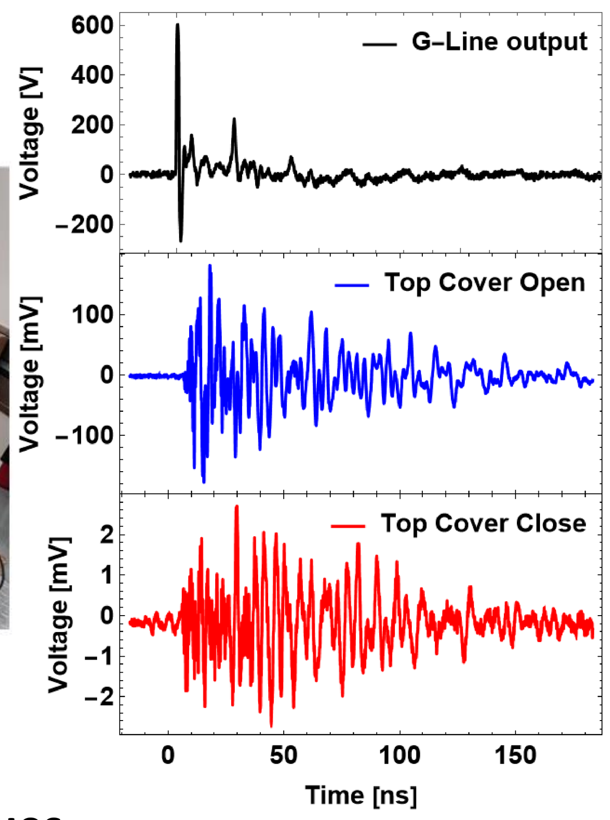
The electromagnetic field of the proton beam induces image current on the isolated Copper anodes of MCP



(a) The IPM model shows the location of the RF shield. (b) The RF shield. (c) The EMI test stand of IPM.

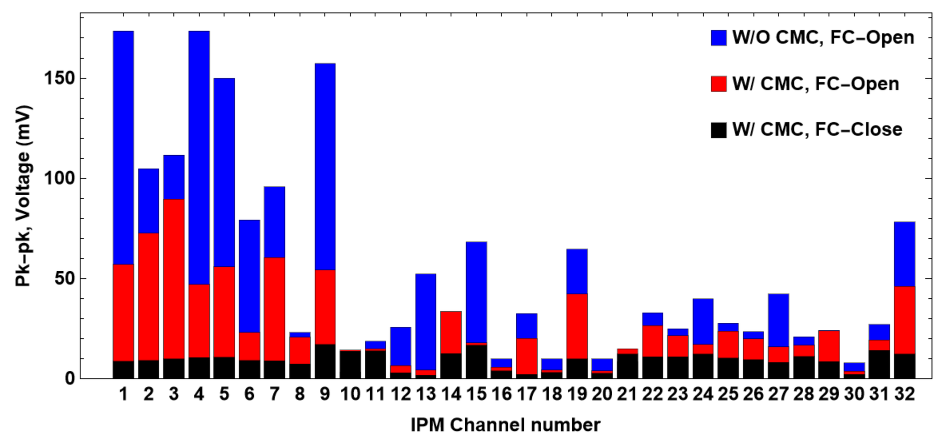
In order to verify the electromagnetic compatibility of the RF shield and FC. Tests were conducted using the Goubau Line

Lab test achieved **SE=-42 dB**



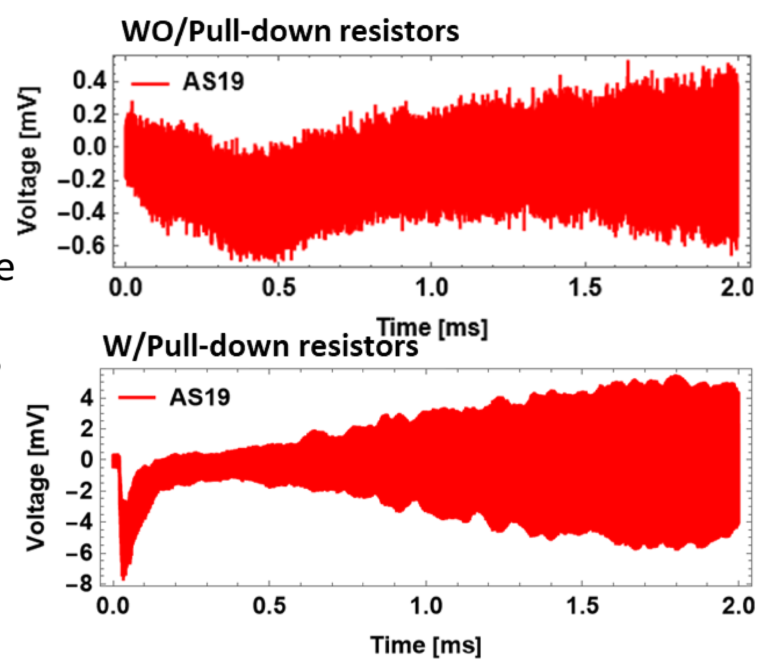
The improved IPM has been installed on the beamline. The bar chart displays the beam test. Despite the improvements, we only achieved about **-20 dB of SE**.

One potential reason for this could be the displacement of FC parts and Indium filling during installation.



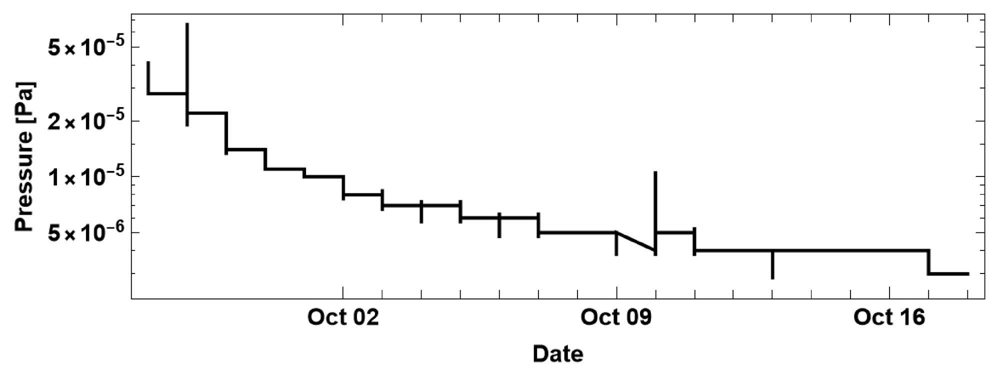
2. MCP Operation

- Two independent power supplies were utilized to provide high voltage to the MCP IN and OUT terminals.
- In order to prevent the coupling betwee power supplies a **1 MΩ pull-down resistor** was incorporated into the MCP OUT power supply circuit.
- The inclusion of the pull-down resistor enabled the desired MCP gain to be attained.



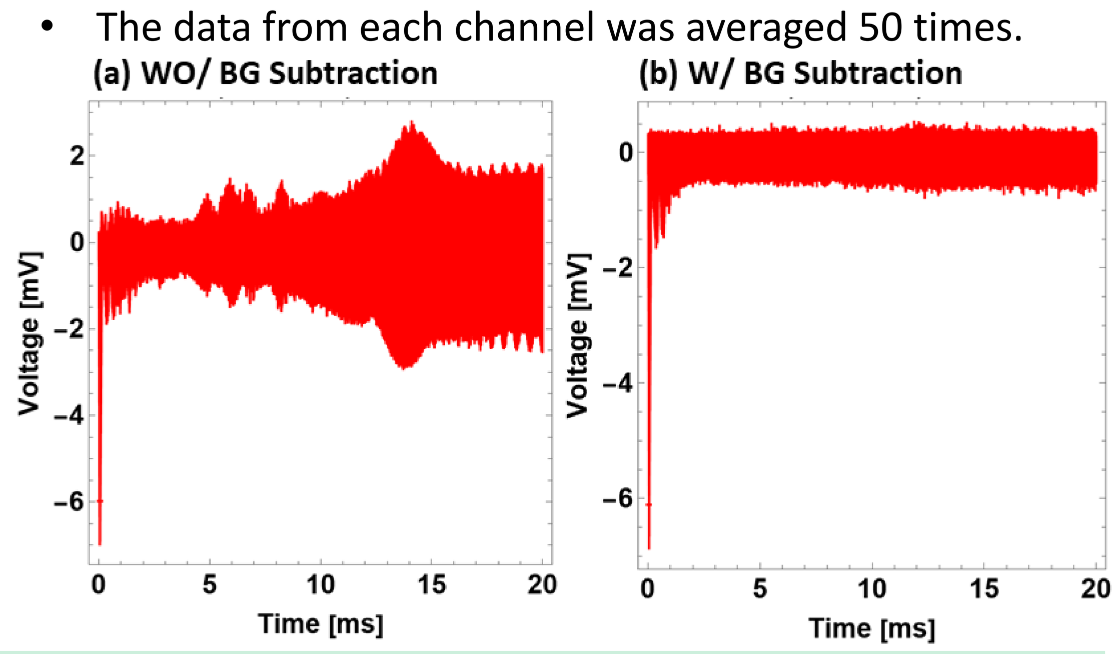
3. Vacuum Issues

- The FC only has a vacuum vent through the RF shield opening. The MCP, which is also located in the FC, requires a vacuum pressure of 10^{-4} Pa to operate.
- It took nearly a month to reach the pressure of 10^{-6} Pa.
- To achieve a faster vacuum recovery, additional vacuum vents are necessary.



4. Analysis Techniques

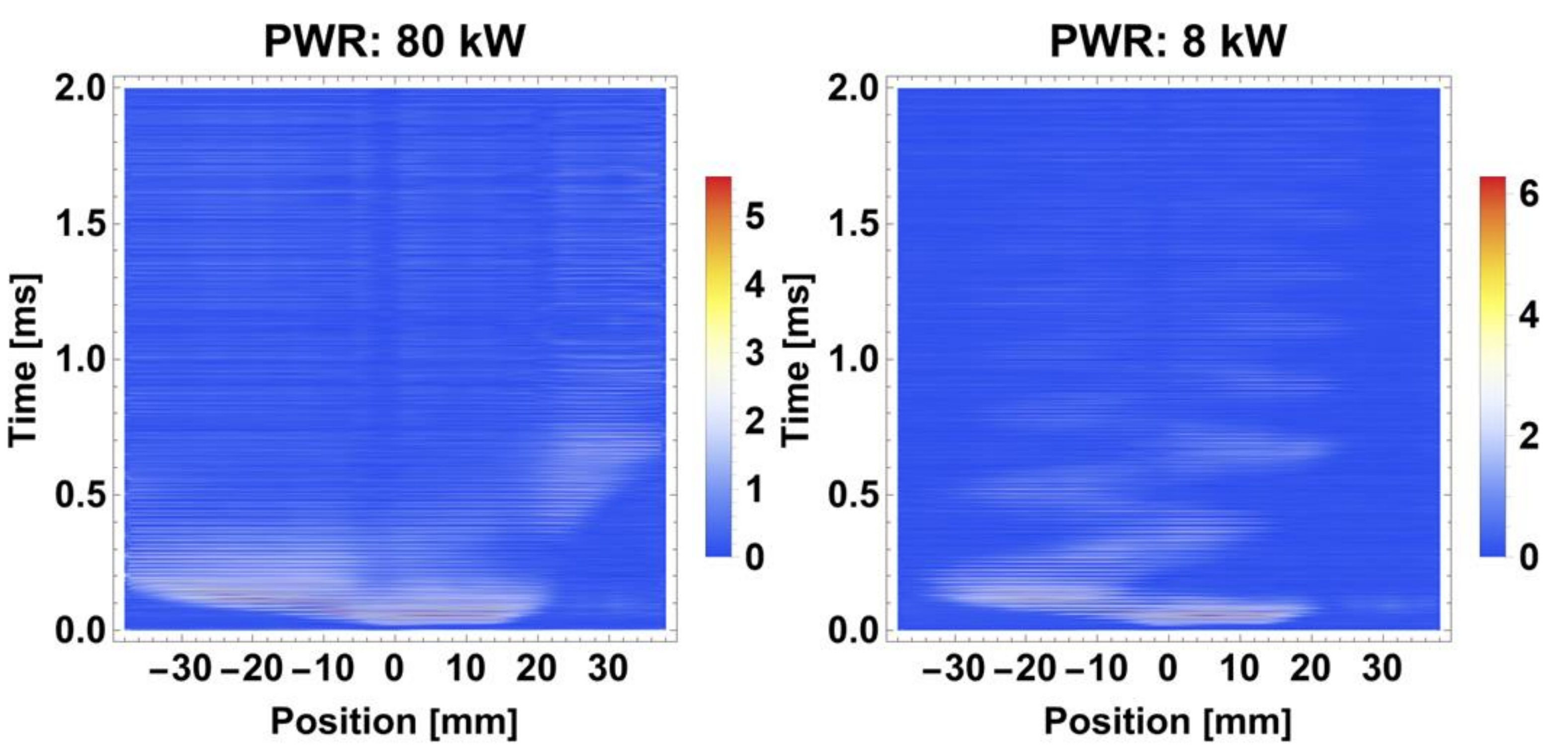
- The beam-induced noise has been significantly reduced by -20 dB. However, and noise is still noticeable.
- The image current can be excluded with background subtraction.
- The data from each channel was averaged 50 times.



Beam Profile Measurement

The bunch-by-bunch horizontal beam profile of the RCS beam was successfully observed from the IPM

- The beam profile was measured from IPM at several different beam powers
- The beam profile can be observed only up to 200 µs due to MCP saturation
- MCP saturation confirmed with the beam power of 0.8 kW
- To observe the beam profile for the entire 20 msec acceleration cycle, the MCP saturation issue needs to be solved. The gated IPM is currently under consideration to solve this issue.



Summary

- The IPM prototype was designed for the RCS, and during beam commissioning, Following challenges were faced and solved
  - EMI→RF-shield, Faraday cage
  - MCP power supply coupling→ Pull down Resistor
  - Vacuum→ Longer pumping duration
  - Analysis→ Background subtraction
- We observed the bunch-by-bunch beam profile at several different beam power
- MCP saturation was identified
- The IPM prototype for the CSNS RCS was successful, leading to the successful observation of a bunch-by-bunch beam signal

References

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