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China Spallation Neutron Source

LOW INTENSITY BEAM CURRENT MEASUREMENT OF THE ASSOCIATED PROTON BEAM LINE AT CSNS*

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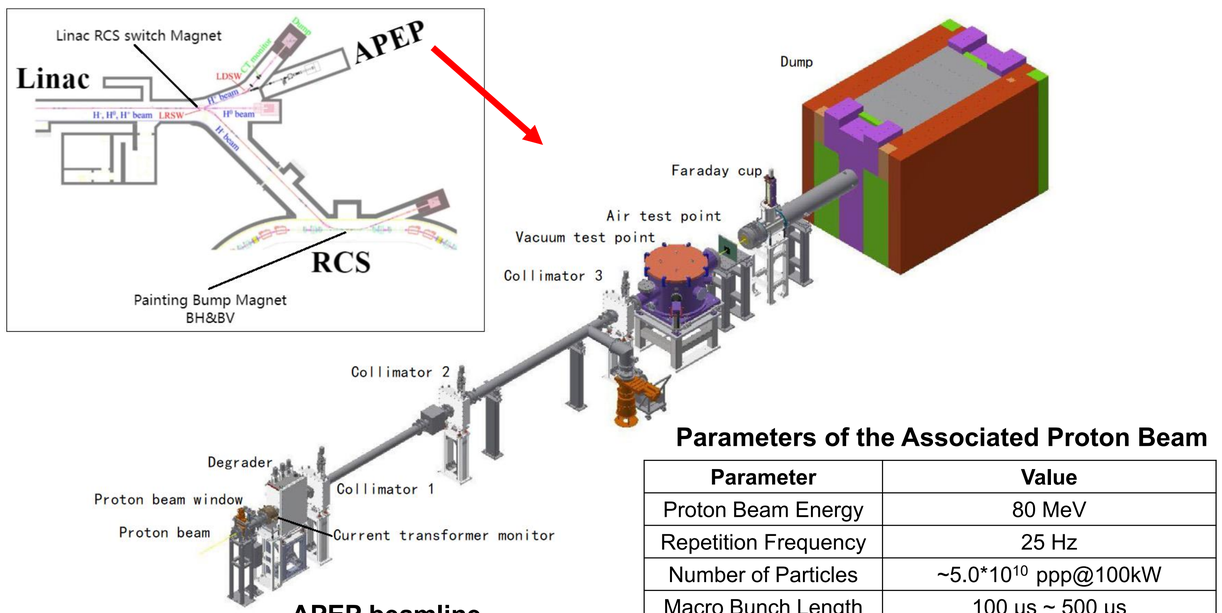
I. Introduction

The Associated Proton beam Experiment Platform (APEP) beamline is the first proton irradiation facility to use naturally-stripped protons which come from H- beams interacting with the residual gas in the linac beampipe at CSNS. The stripped beam current, which is in the order of 0.1% of the original H- beam and approximately 10 mi-croamperes, should be measured precisely to provide the proton number for irradiation experiments.



APEP beamline

Parameters of the Associated Proton Beam

Parameter	Value
Proton Beam Energy	80 MeV
Repetition Frequency	25 Hz
Number of Particles	~5.0*10^{10} ppp@100kW
Macro Bunch Length	100 μs ~ 500 μs
Proton Beam Intensity	20 μA@400 μs,100 kW

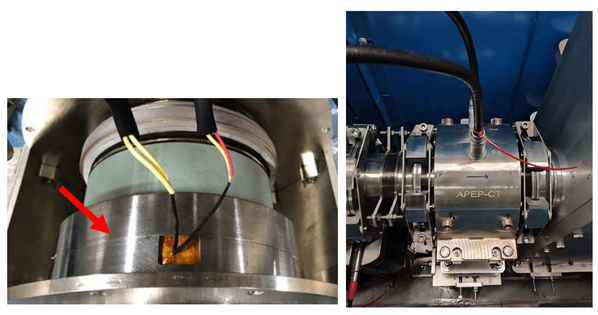
II. Design

Sense:

- **Soft magnetic core:**
  Fe-based nanocrystalline alloy ($\mu_r \approx 100000$@10 Hz)
  f_{fill}: filling factor of core (tape thickness: 20μm)
- **Calculation of the equivalent inductance:**
  Do=160mm; Di=130mm; h=25mm
  Secondary coil: 50 turns for the signal
  Additional coil: 1 turn for the online calibration.
- **a double-layered DT4 magnetic shield to reduce environmental stray magnetic field impact.**

Calculation of Different Magnetic Shields

Layer Material	b mm	a mm	p	μ_r	S
DT4	162.0	160.0	1.0252	6000	37.8
DT4	158.0	156.0	1.0258	6000	38.7
Permalloy	162.0	158.0	1.0513	106	1220



magnetic shield

Sense

Electronic:

- A trans-impedance circuit to get a smaller load impedance.
- A low-noise operational amplifier with a low input bias current Ib.
- A technique of baseline dynamic feedback for the baseline drifting.
- Effective low-pass filtering will improve the signal-to-noise ratio.

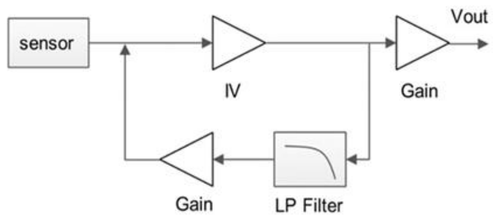


Diagram of CT electronics

III. Shielding and Grounding

A comparative experiment was made among the noise measurements of four-core cables (two-core twisted pair with braided outer shield) and triaxial cables under different ground-ing methods with the same sensor and electronics.

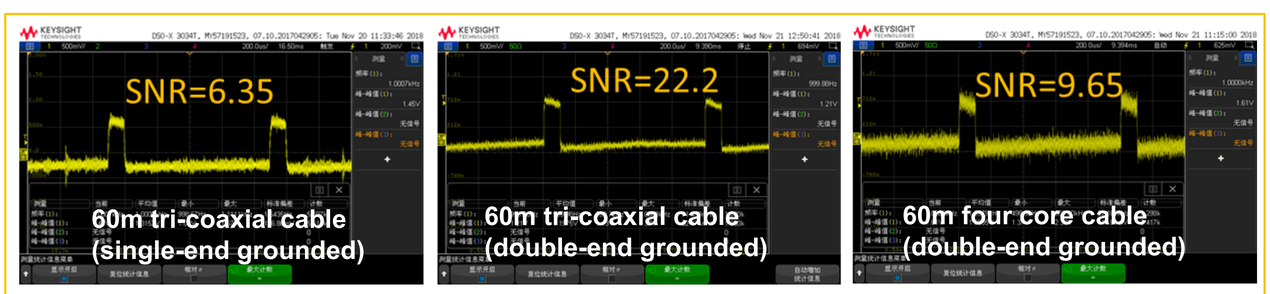


Diagram of the Grounding and cable selection experiments

After the multi-point grounding test, it was found that outermost layer of triaxial cable was grounded to the vacuum pipeline at the sensor end, and the electronic end was grounded to cabinet ground to achieve the best effect.

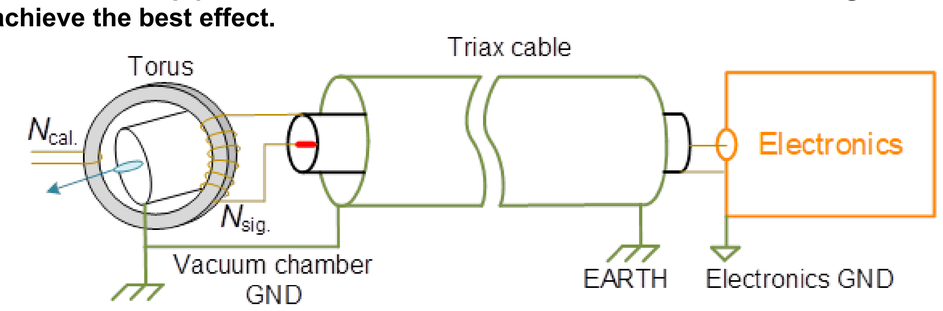
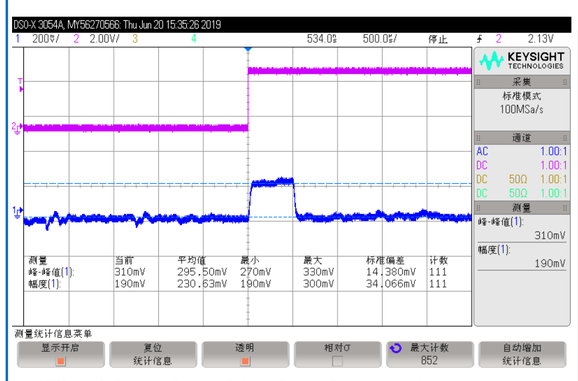


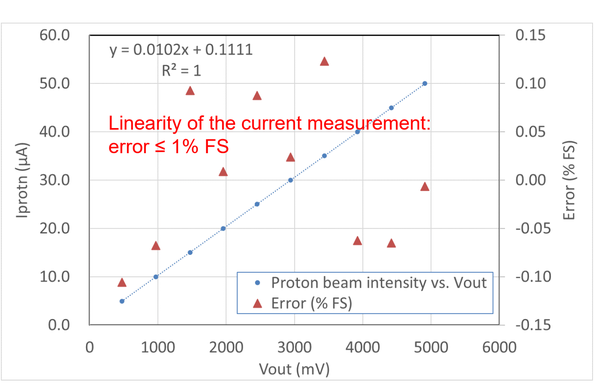
Diagram of the triax cable grounding to minimize noises.

IV. Calibration

- Precise DC/AC current source: KEITHLEY 6221
  - 25Hz pulsed square wave
  - Pulse Width: 500 μs
  - Current Range: 2~10 μA
- Current goes through the calibration coil of the APEP-CT sensor.



The blue signal is the electronics output with 1 uA calibrated input current.

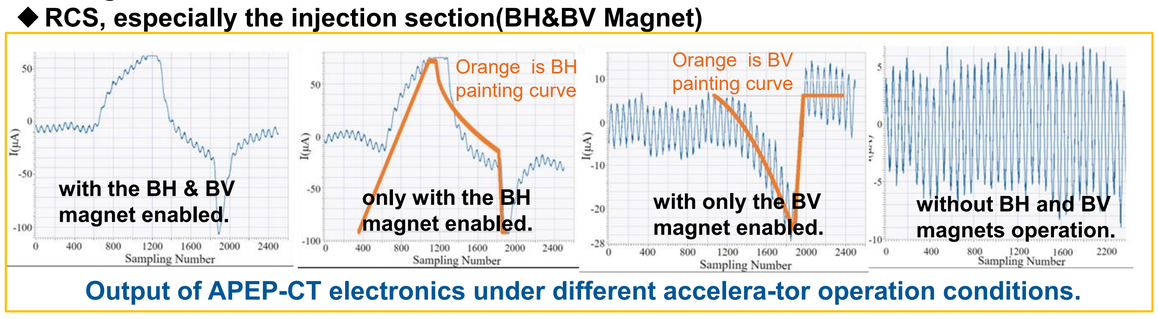


CT Electronics Calibration Data

V. Interference Investigation

When the accelerator is running, it is found that the measurement system outputs a large interference signal.
A thorough examination of the CT interference sources.

- **Along the APEP beamline**
- **RCS, especially the injection section(BH&BV Magnet)**

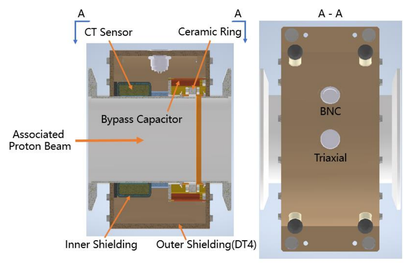


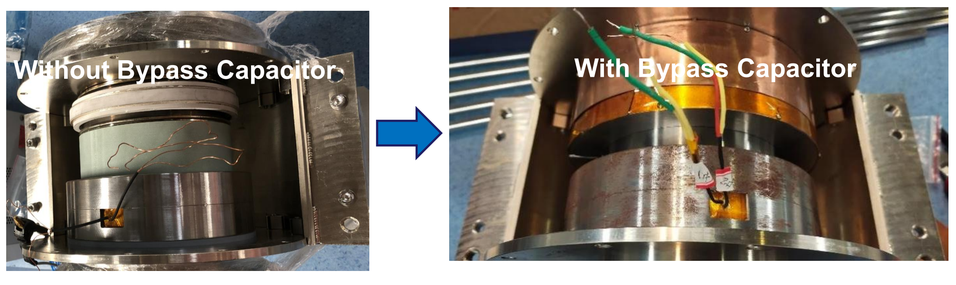
Output of APEP-CT electronics under different accelera-tor operation conditions.

The main contribution of interference is from BH, followed by BV, which has a high similarity to the current curve of the power supply during the beam injection in the phase space painting mode.

VI. Troubleshooting

- **Bypass capacitor installed**
- **Interference signal subtracted in DAQ system**
  - DAQ is triggered by the Timing system
  - Collect the Interference signal once without a beam and save it as the background interference signal.
  - Subsequently, for each subsequent signal collection with a beam, the interference signal is subtracted in order to restore the beam signal.

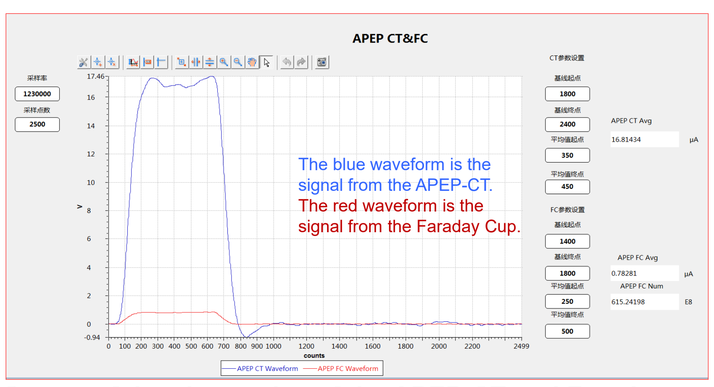




A bypass capacitor over the ceramic gap was built in the APEP-CT sensor.

VII. CONCLUSIONS

Improved by the above methods, we successfully measured the associated pro-ton beam in low intensity. the amplitude of the pulsed associated proton beam intensity is clearly measured as 16.8 μA. The APEP-CT system achieves a signal-to-noise ratio improvement and meets the design specification for microampere-level current intensity measurement.



Output of the electronics of the APEP-CT and Faraday cup

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★ National Mega-Science Project

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