sPHENIX TPC monitoring system

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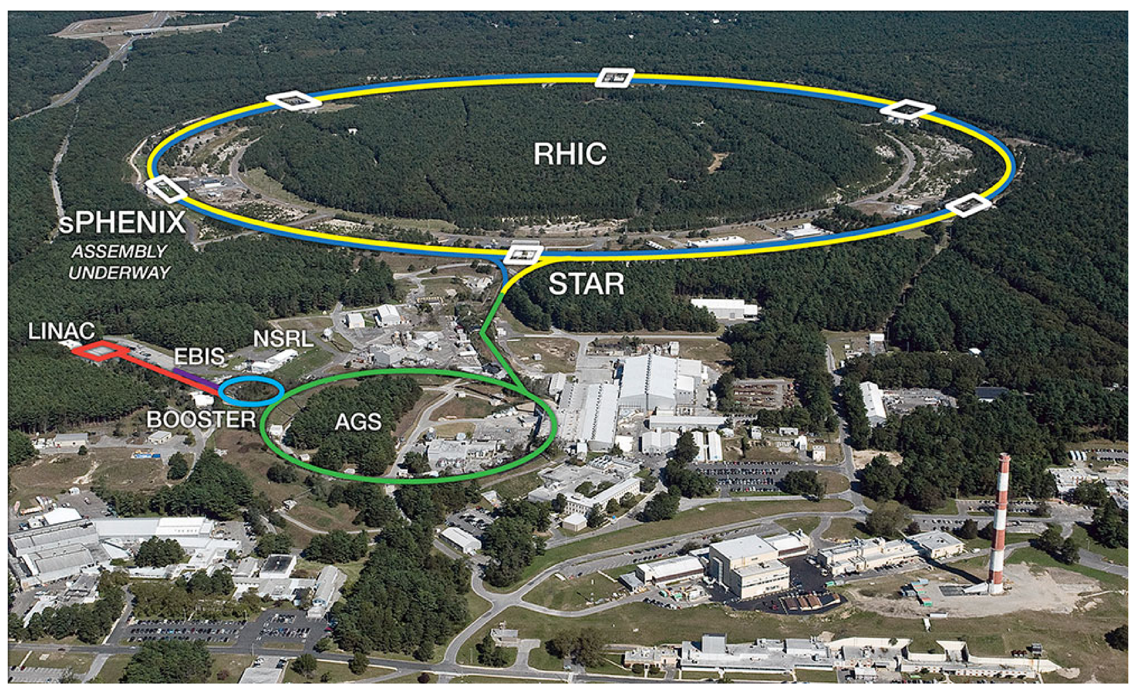
1. Introduction

sPHENIX is a new detector experiment at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL). The Time Projection Chamber (TPC) is the central tracking detector of the experiment. The working gas of the TPC is Ar/CF_4 60 : 40. Amplification of the electron is carried out using a stack of four Gas Electron Multipliers (GEMs) (quad-GEM), inspired by ALICE. The high voltage stability of the GEM foils is important. Discharges need to be detected to preserve their health. A spark detection system has been developed to automatically detect and record the sparks and operate the high voltage power supplies accordingly.

2. sPHENIX

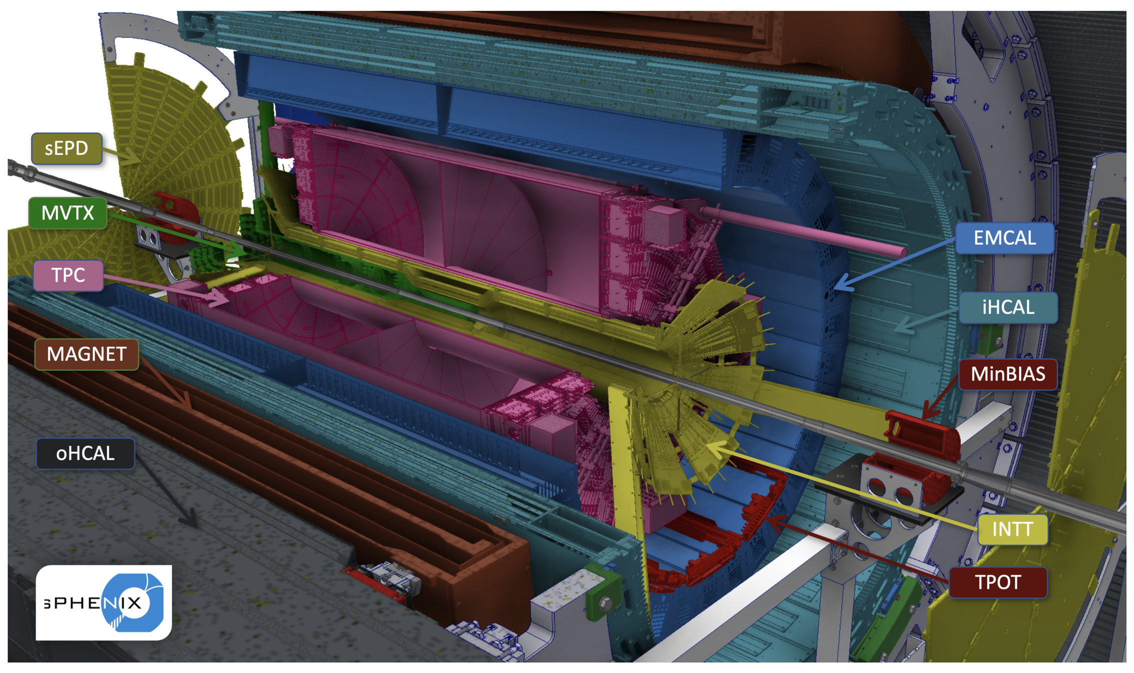
sPHENIX is located at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL). It will study properties of Quark Gluon Plasma by various probes:

- Upsilon spectroscopy
- Jet quenching

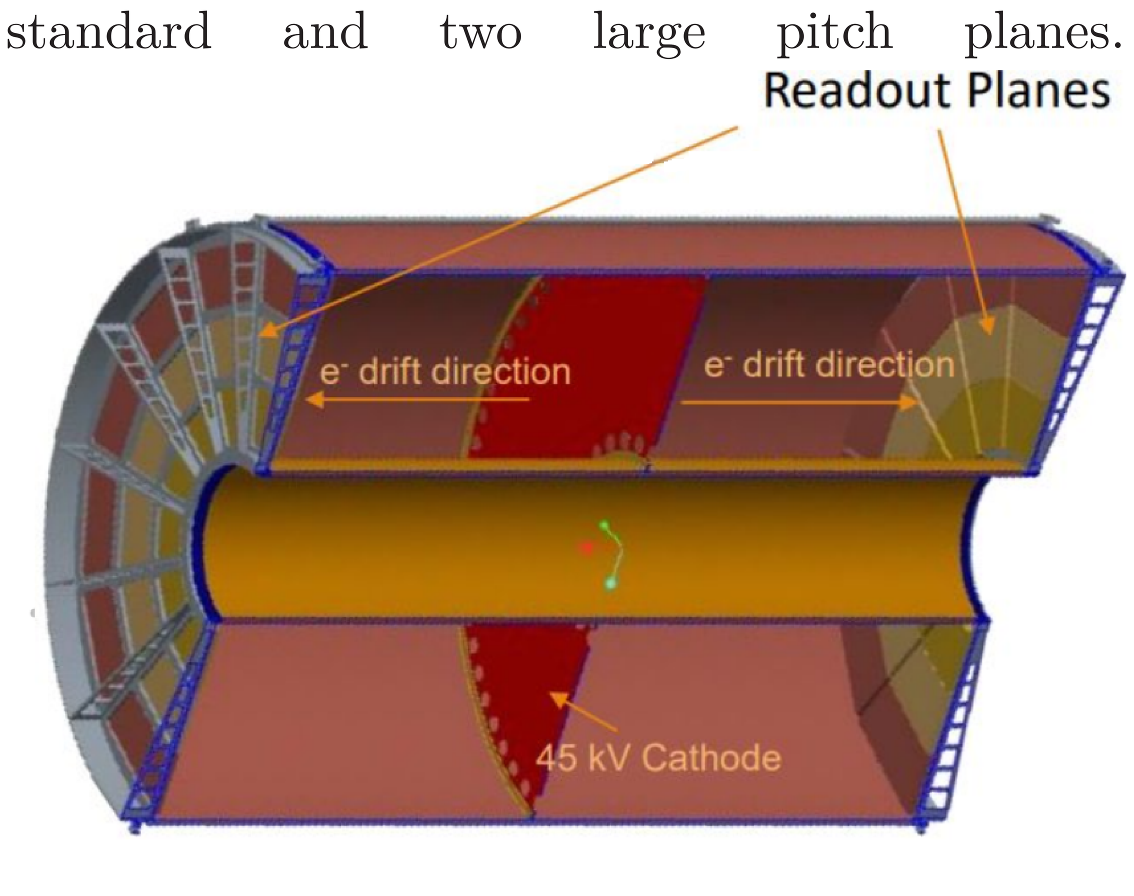


The commission of the detector began in May 2023. Strength of the magnetic field is 1.4 T. One of its subdetectors is the Time Projection Chamber (TPC).

- 20 cm < R < 78 cm, 2.11 m long
- $|\eta| = 1.1$
- Drift Field: E = 400 V/cm
- Gas mixture: Ar/CF_4 60:40 (originally planned to be Ne/CF_4 50:50)
- Field provided by flexible circuit cards
- Prioritizes momentum resolution
- Targeted spatial resolution: <150 μm



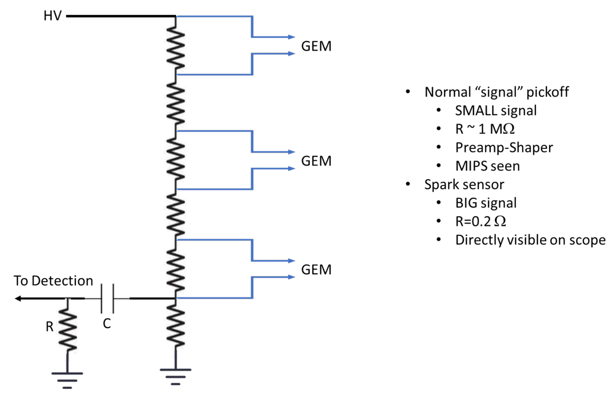
Gas Electron Multiplier (GEM) foils are quad-stacked, 36 modules are placed per side. Each stack contains two standard and two large pitch planes.



3. System Characterization

2.1. Voltage divider

- The voltage divider is used to supply operational voltages for GEMs. Voltages are designed to provide an effective gain of 2000 and ion back-flow of 0.3%
- When powering GEMs with a resistor chain only one high voltage (HV) channel powers a whole module.
- If small resistor values are used in the chain, in the case of a spark, a large amount of current (compared to the nominal) will be driven through the system. A large amount of energy will be dissipated.
- Large resistor values limit the energy of sparks, but it is harder to detect sparks through the power supply current.
- A capacitor connected to the bottom of the bottom GEM is used as a pick-off capacitor for triggering and event counting.

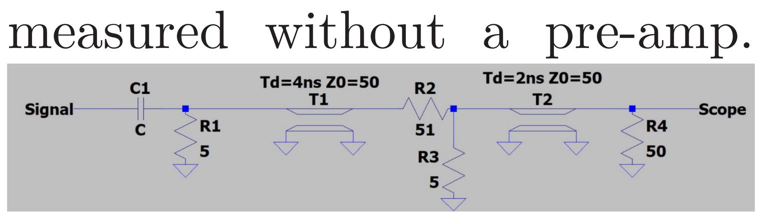


2.2. Spark Characterization Set Up

- Pre-Production GEMs were used: they differ from production by tail length.
- Each side of a GEM connects to an SHV cable which leads to an independently controlled HV module: this differs from the real GEM stacks.
- The anode plane was grounded by shorting cards.
- A gas line was run from a gas mixing unit.
- Initially, an Am^{241} source was mounted in the chamber.
- Voltage had to be raised above operating to produce sparks at a rate of a few Hz.
- The alpha signals were noise to spark signals.
- Later the source was removed, instead sparks were created by raising the delta V across one GEM while keeping transfer gaps the same: we could independently study sparks initiated in each GEM.
- This allowed for control of which GEM produced sparks.

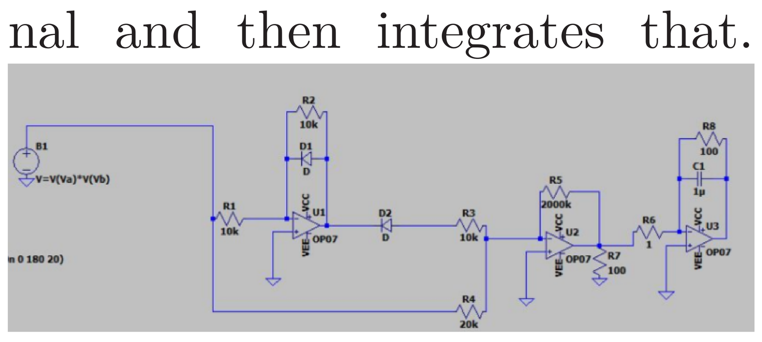
4. Digitizing spark signals

A 1 MegaOhm resistor to ground is a common choice when using a pickoff capacitor. A finite resistance to ground is necessary to protect electronics, a large one allows for larger signals. In our case it turns out that spark signals are much larger than expected. Therefore, instead a 5 Ohm resitor was used, as well as an additional attenuator. This signal was measured without a pre-amp.

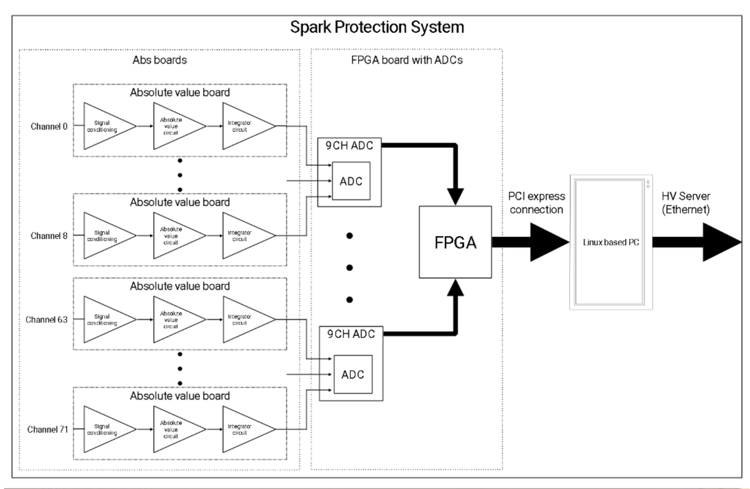


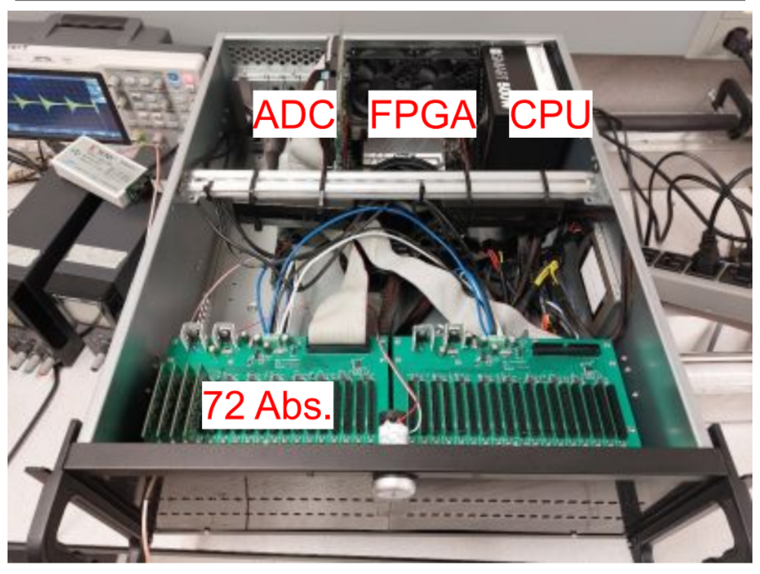
Main requirement of the spark signal digitizer system was being able to continuously monitor 72 channels simultaneously with fast and reliable signal detection. The original signal is bipolar and has high frequency, requires high-speed and expensive ADCs. The idea is to convert this signal to a unipolar, pulse-like signal that can be digitized with a slower ADC.

For this, we designed an absolute value-integrator board. It takes the absolute value of the input signal and then integrates that.



The outputs of the absolute value boards are connected to a digitizer board. This board has eight 9-channel ADCs connected to an FPGA. The board is connected to a PC using PCI-Express communication. This PC is able to communicate with the high voltage power supplies and intervene in their operation using a TCP/IP connection in case of a spark is detected.





The resulting ADC count distribution contains admixture of high ionization physics signals and sparks. There is no clear distinction between them. Lower ADC value is safer but causes more trips. The goal is finding an ADC value with tolerable trip rate and see if there is damage. We chose 200 ADC, in this case, trip rate is in the order of 1 trip per day without damaging events.