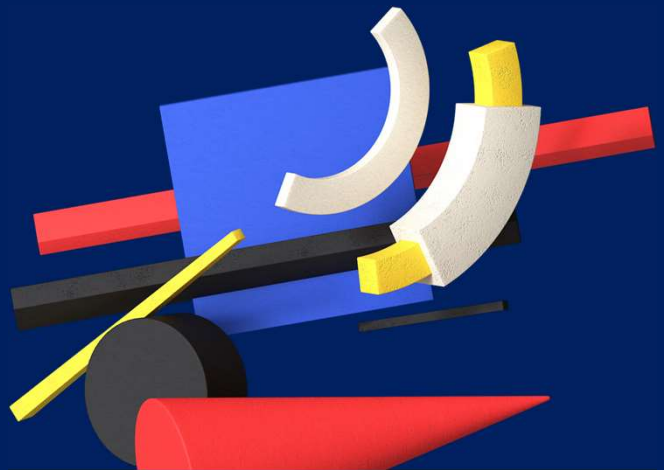
SOFTWARE-HARDWARE COMPLEX FOR MEASURING ANODE WIRE TENSION IN STRAW TUBES

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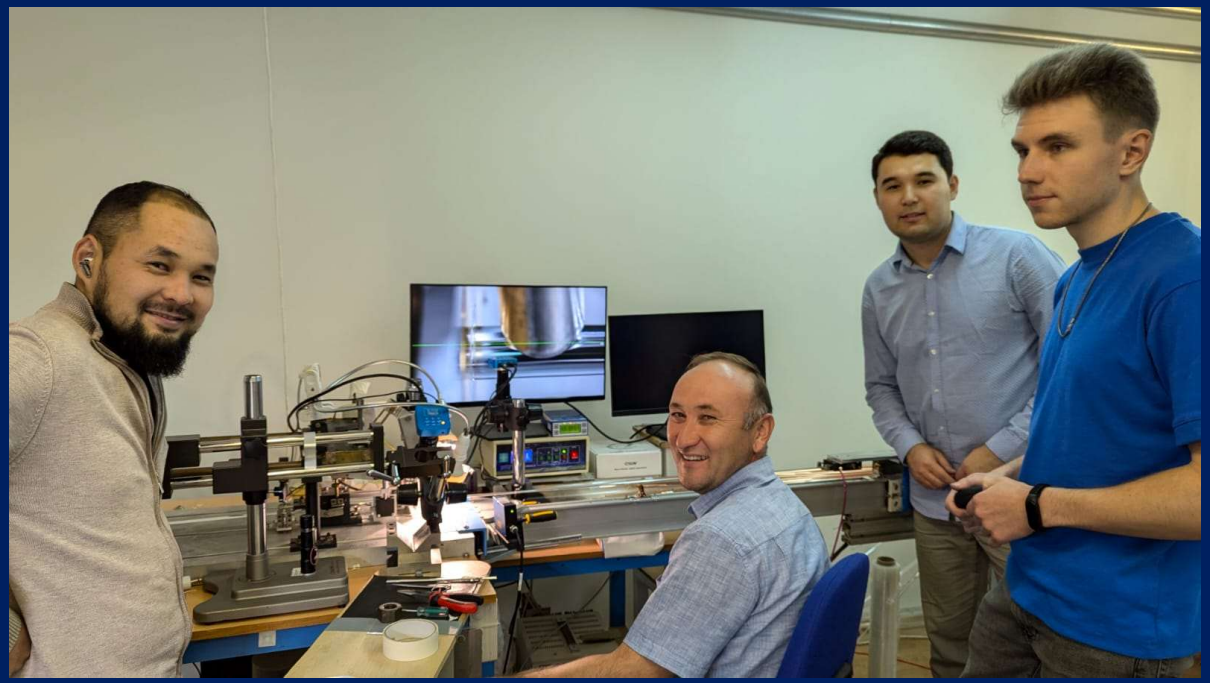
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Introduction

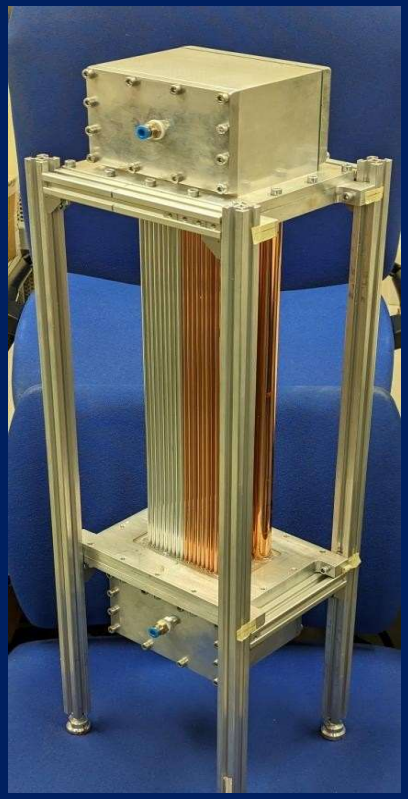
This work presents a software-hardware complex for measuring the anode wire tension in straw tubes used in the straw tracker of the SPD experiment at the NICA collider. Wire tension is critical for accurate coordinate determination, as it affects electrical stability and the wire's position correction due to electrostatic and gravitational forces.

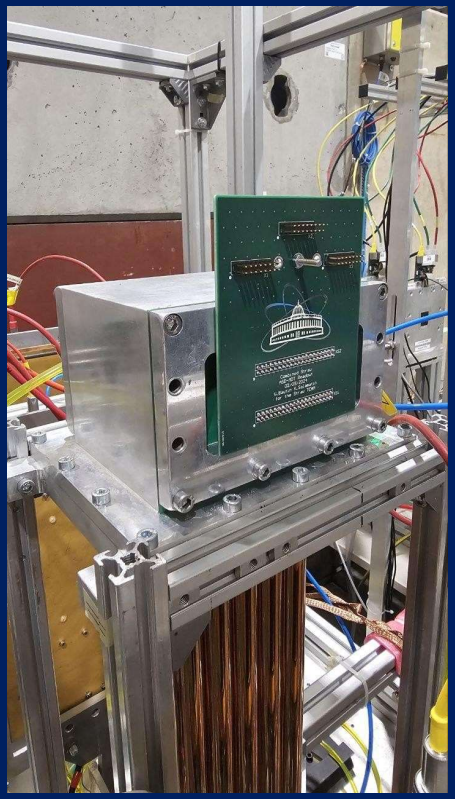


A straw tube for the SPD-NICA detector is a Mylar tube with aluminum coating, 10 mm in diameter and up to 3 meters long. A 30 μm gold-plated tungsten wire (2.7% Re) is stretched along the axis with ~100 μm accuracy.



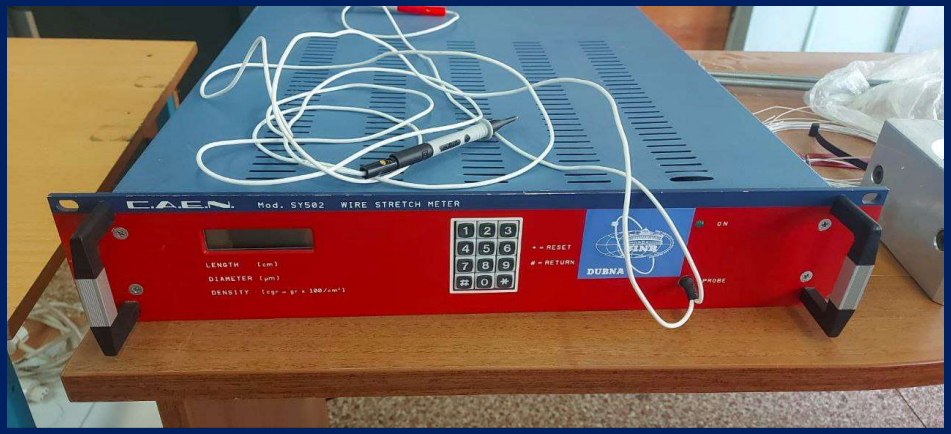






The development of wire detector technology is always linked to increasing requirements for coordinate measurement precision. Wire tension significantly impacts coordinate accuracy and is related to electrical stability and corrections due to electrostatic and gravitational forces. Thus, wire tension and its long-term stability are key quality criteria for precision wire detectors.

CAEN SY502 - Measurement Principle



Tension is measured with specialized devices like the CAEN SY502 or others. The working principle:
- The wire is excited by a current pulse.
- The tube's center is placed in a magnetic field from a permanent magnet.
- The magnetic force causes the wire to vibrate.
- The induced EMF is detected.

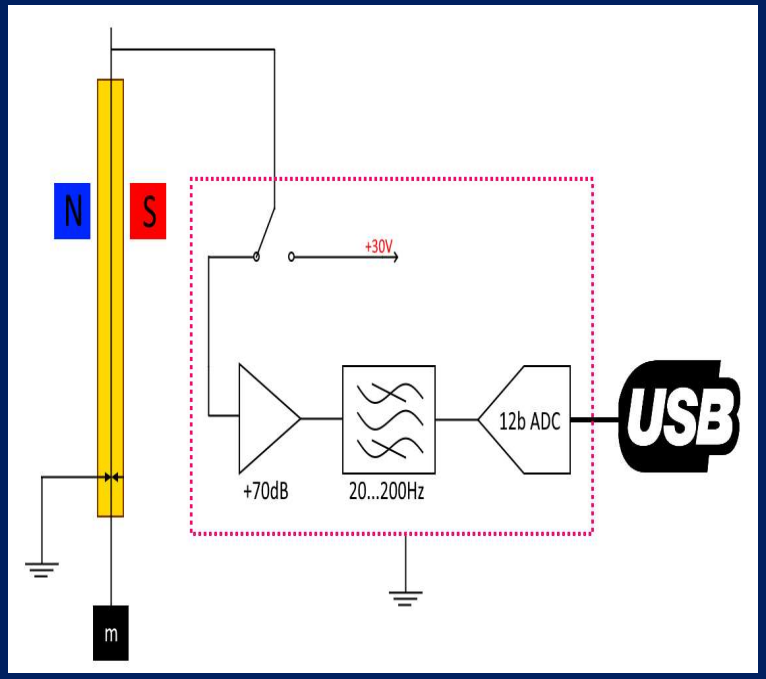
The relationship between wire tension and oscillation frequency is:
$f = (1/2L)\sqrt{(T/\tau)}$, where f – frequency, L – length, T – tension, τ – linear density.



Fig.1. Tension meter

System Architecture

To solve the problem, a software-hardware system was developed based on the STM32L4 microcontroller with a 12-bit ADC. The wire is stretched in the straw tube, with a neodymium magnet at the center. A relay switches the wire connection between the power source and amplifier input. The relay and current are controlled digitally via the microcontroller. This allows tuning the excitation pulse parameters (frequency and duration) for specific conditions.



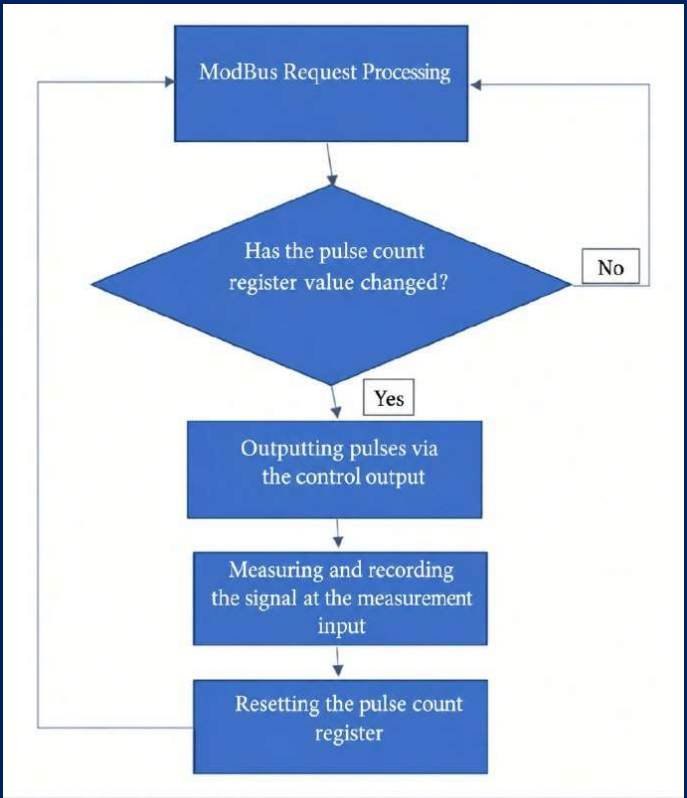
Software Description

The system software has two components:
- Embedded firmware for STM32 (C++ using Arduino and STM32 libraries)
- PC software (C++ with Qt framework)

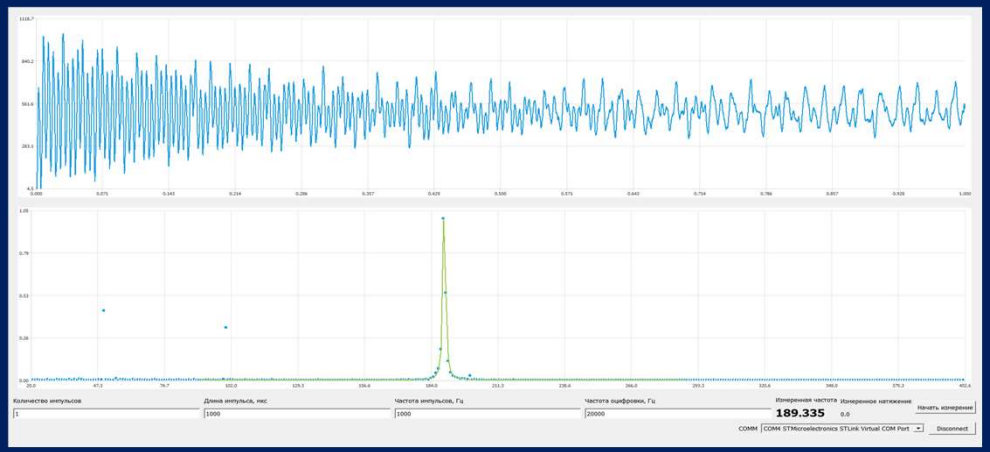
They communicate via the ModBus RTU protocol, with STM32 as a slave and the PC as master.

STM32 stores ModBus registers for:
- Number of pulses
- Pulse repetition frequency
- Pulse duration
- ADC sampling frequency

Measurement Algorithm



At start, the pulse count N is written to a register. The system generates N pulses with specified parameters. Then, the ADC enters continuous measurement mode, and its data is collected via interrupts. After measurement, the register is cleared to signal the end of the cycle. The Windows application manages settings, starts the measurements, and processes data.



A method for temperature control in drift tubes (straw trackers) of the SPD (NICA) based on wire oscillation frequency is proposed. Thermal expansion of the tube changes wire tension and its resonant frequency. An experimental setup for exciting and detecting oscillations has been developed. In the range of 15–35 °C, the dependence of the squared frequency on temperature is linear; calibration yields an accuracy of ±0.3 °C, meeting the SPD requirements. The method requires no additional sensors, using the wire itself as the sensing element, and can be implemented in the standard detector monitoring system.



Fig 2. The appearance of the experimental camera

Measurement Process & Equipment

Tension meter process:
- Device sends an electric pulse, generating a magnetic field.
- The static magnetic field excites the wire.
- Oscillations are detected by the anode and cathode.

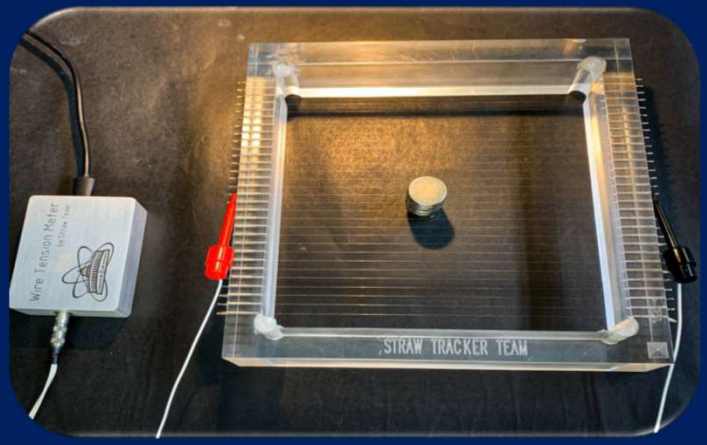


Fig.3. The process of measuring tension



Fig.4. New carbon camera tube to maintain aspect ratio.
Mock-up for testing the anode wires of the SPD straw tracker, as well as for calibrating the device and its further integration into the slow control system

Data Visualization

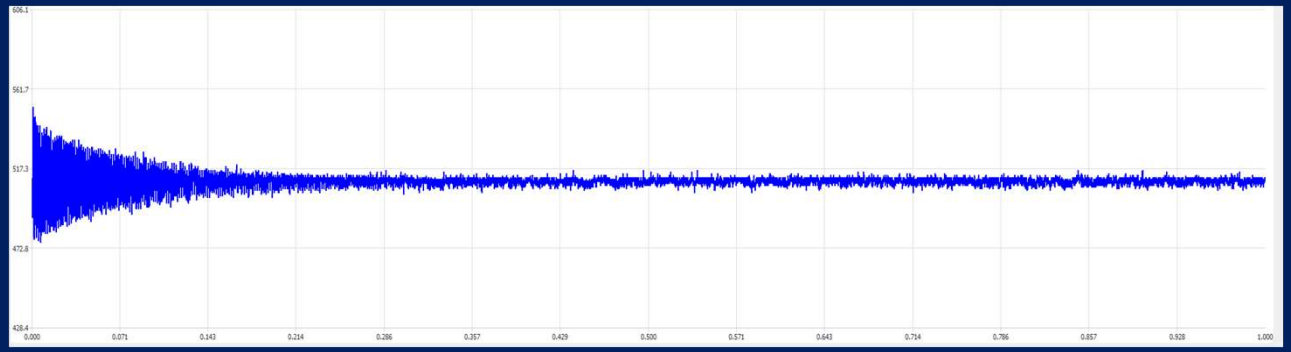


Fig.5. Pulse attenuation graph

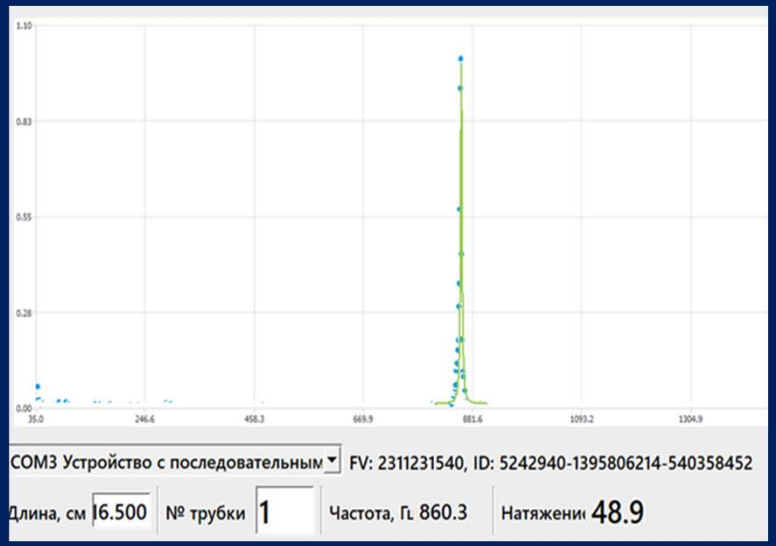


Fig.6. Graph frequency of oscillation of the wire

Damping Curve: Y – oscillation intensity, X – time/frequency

Oscillation Frequency Graph: Y – amplitude, X – frequency

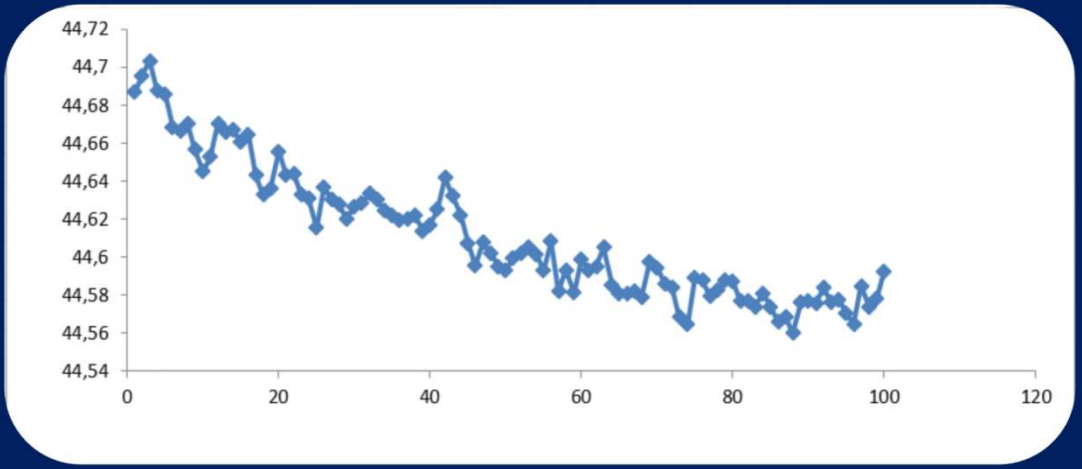
The software automatically detects and fits peaks using Gaussian approximation, which helps estimate wire tension across the entire chamber.

An electric pulse is applied by the tensioner, generating a magnetic field due to the moving electric field. This magnetic field, interacting with the static magnetic field, induces vibrations in the string wire. The resulting oscillations are measured by the anode and cathode, which detect the oscillation frequency. The first graph represents the attenuation of the oscillations over time, while the second graph shows the oscillation frequency.

Signal Processing

Название: Ayss 2

	date	straw id	tension	is good	length	freq	fit A	fit B	fit G
85	Ср сен 18 18:35:54 2024	85	44.574	true	16.500	821.165	1.076	0.007	0.000
86	Ср сен 18 18:35:58 2024	86	44.566	true	16.500	821.096	1.054	0.008	0.943
87	Ср сен 18 18:36:03 2024	87	44.569	true	16.500	821.120	1.050	0.006	0.000
88	Ср сен 18 18:36:07 2024	88	44.560	true	16.500	821.041	1.054	0.005	0.988
89	Ср сен 18 18:36:11 2024	89	44.576	true	16.500	821.191	1.069	0.010	0.958
90	Ср сен 18 18:36:15 2024	90	44.577	true	16.500	821.199	1.066	0.006	0.963
91	Ср сен 18 18:36:19 2024	91	44.576	true	16.500	821.183	1.056	0.009	0.966
92	Ср сен 18 18:36:24 2024	92	44.584	true	16.500	821.259	1.073	0.005	0.953
93	Ср сен 18 18:36:28 2024	93	44.576	true	16.500	821.190	1.044	0.007	0.941
94	Ср сен 18 18:36:32 2024	94	44.578	true	16.500	821.205	1.063	0.010	0.000
95	Ср сен 18 18:36:36 2024	95	44.570	true	16.500	821.137	1.066	0.007	0.976
96	Ср сен 18 18:36:40 2024	96	44.565	true	16.500	821.086	0.977	0.007	0.969
97	Ср сен 18 18:36:45 2024	97	44.585	true	16.500	821.270	1.047	0.009	0.950
98	Ср сен 18 18:36:49 2024	98	44.574	true	16.500	821.164	1.063	0.009	0.958
99	Ср сен 18 18:36:53 2024	99	44.579	true	16.500	821.211	1.071	0.009	0.971
100	Ср сен 18 18:36:59 2024	100	44.593	true	16.500	821.341	1.041	0.007	0.975



The user sees a signal plot, Fourier spectrum, and a computed Gaussian peak to evaluate fitting quality.

The program automatically determines the points and approximates them using a Gaussian fit. Thus, by measuring the vibrations of the wire, the tension across the entire chamber can be determined.

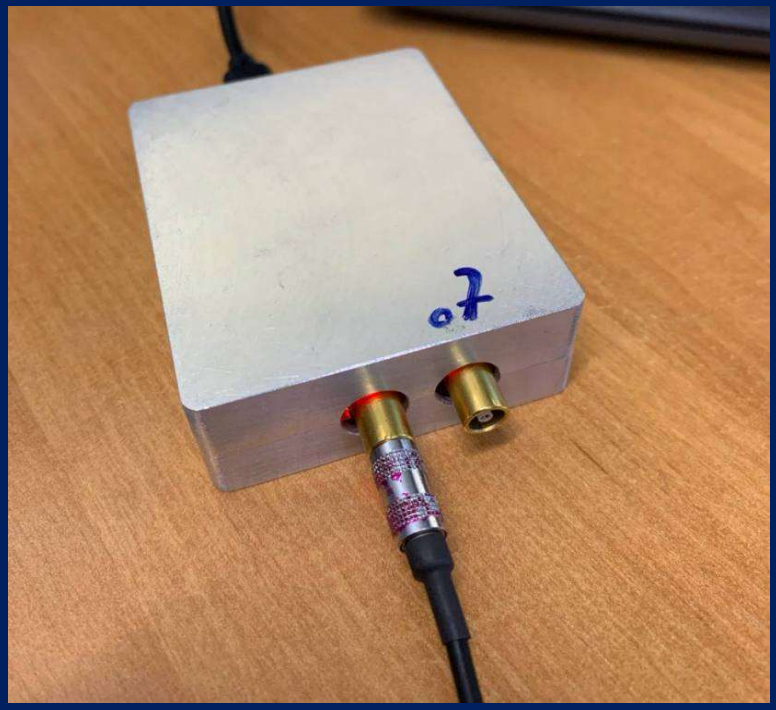
Multiple measurements are required to evaluate the errors of the tension meter.

There is a temperature dependence, constant measurements warm the wire, the tension drops because the metal expands.

Because of this, we added an improvement — it's the temperature. This is our own sensor, and it's part of the system.

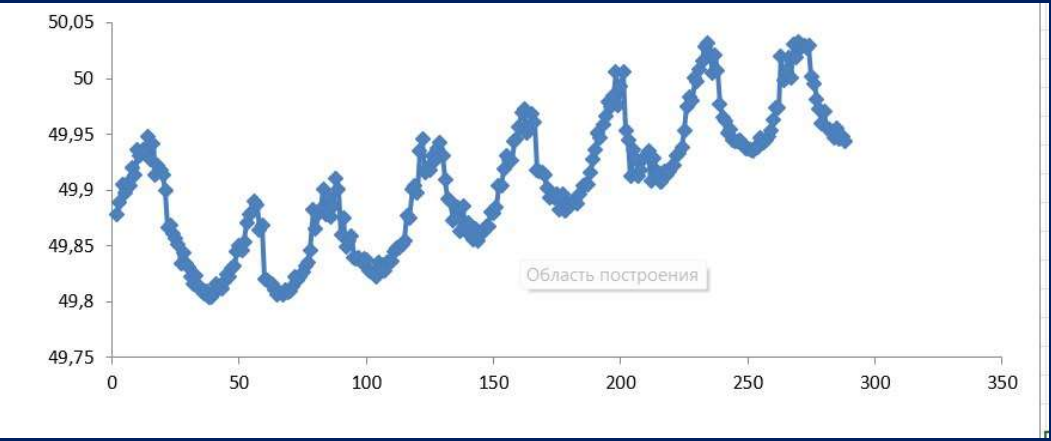
Temperature





We added the temperature measurement process. This is the first method we used: initially, we measured it using a thermohygrometer and observed how it depended on the temperature. Then we improved our tension meter device by adding our own sensor, and this became part of the system.

Environmental Influence



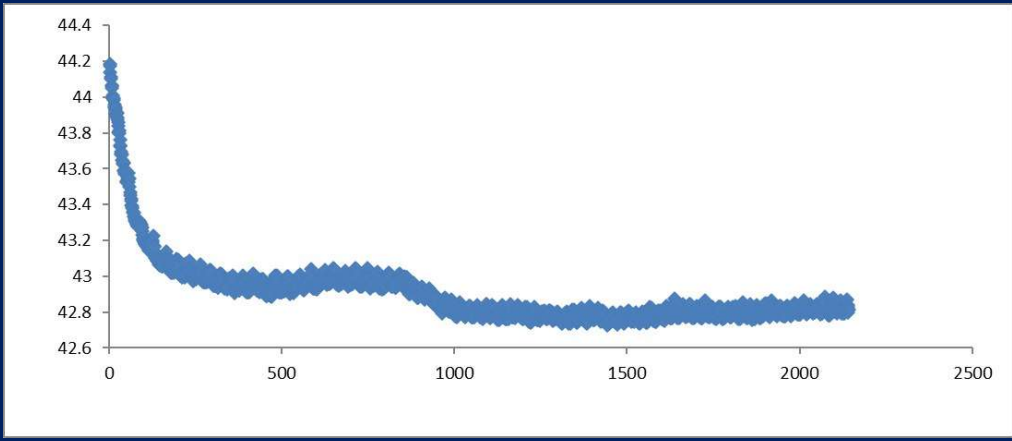


Fig.7. The result of repeated measurement of wire tension

Measurement in an air-conditioned room (20s intervals):
- Cooling is effective during air conditioner operation.

Measurement over 24 hours without air conditioning:
- Wires do not cool down between measurements.
- Tension does not fully recover; it keeps decreasing.
- Average measurement error: 30 mg.

A thermohygrometer records temperature and humidity during each test. This thermal effect needs further investigation, especially for large-scale projects where tension loss is critical.



РОССИЙСКАЯ ФЕДЕРАЦИЯ

СВИДЕТЕЛЬСТВО

о государственной регистрации программы для ЭВМ

№ 2026613256

Программа для измерения натяжения анодных нитей
Straw tension meter

Правообладатель: *Международная межправительственная организация Объединённый институт ядерных исследований (RU)*

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Hardware and Software Complex for Measuring the Tension of Anod Wires in Drift Tubes

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Abstract

This paper presents a software–hardware complex for measuring the tension of the anode wire in drift tubes used in the SPD experiment's straw tracker at the NICA collider. The tension of the anode wire is critical for ensuring the accuracy of coordinate determination,

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Conclusion

During the study, a hardware and software system was developed for measuring the anode wire tension and temperature in the straw tubes of the SPD tracker at the NICA collider. A non-contact electromagnetic measurement method was implemented, allowing for highly accurate determination of the signal wire tension. This method enables control of the detector geometry and temperature, with measurements being taken within the detector volume. The developed system was found to have significant advantages, including a user-friendly interface, ease of setup and calibration, and the speed and accuracy of tension measurements in the NICA collider's straw tubes.



Part of the STRAW TEAM
Thank you for attention !

21.10.2026