Status of the 5 MeV proton and deuteron He3-polarimeter (November 2025)

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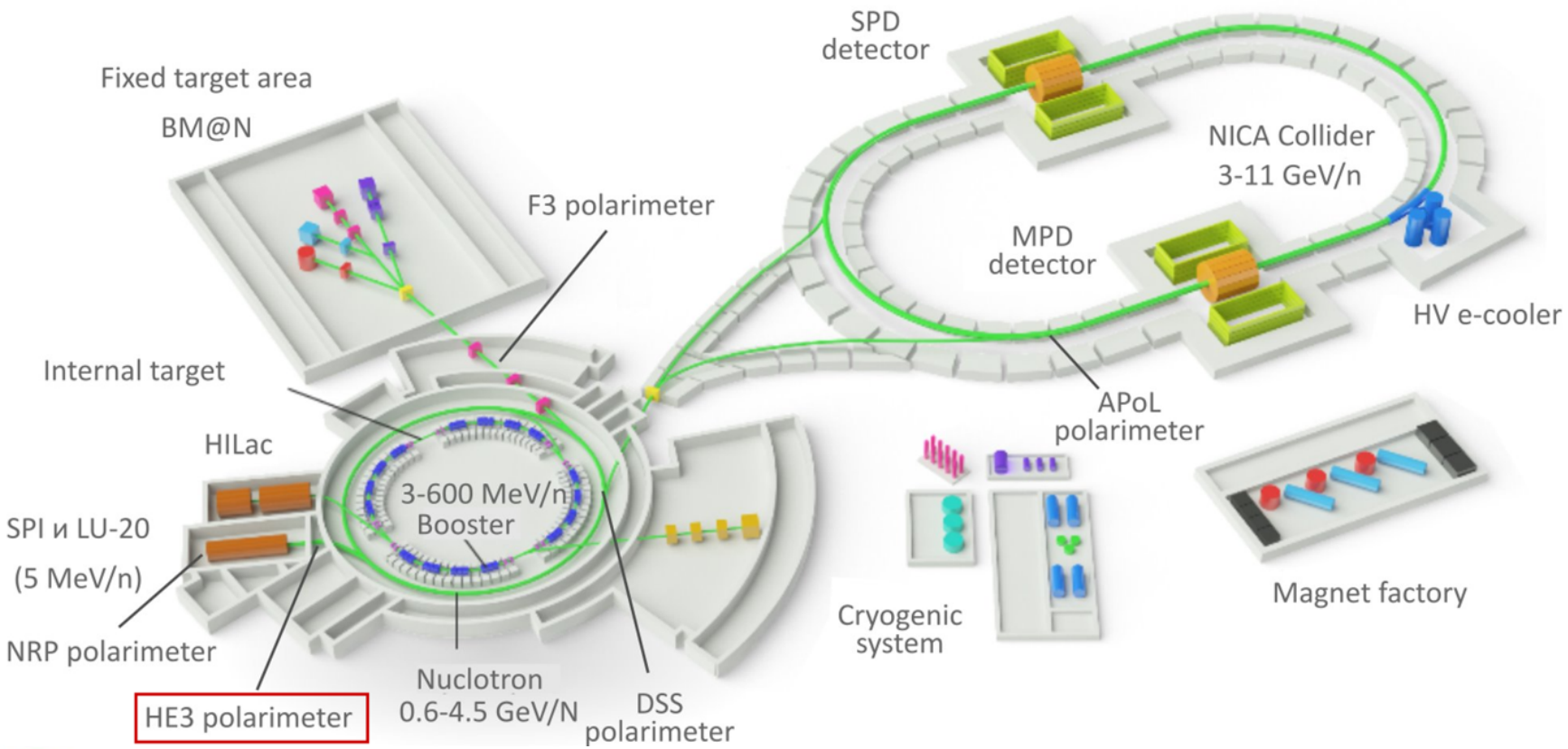
Implementation of the polarization program



Purpose and Scope

- **Objective:** Simultaneous measurement of vector and tensor polarization moments
- **Energy Range:** 4-12 MeV
- **Analyzing Reactions:**
  - ^{3}He(p,p)^{3}He - proton elastic scattering
  - ^{3}He(d,p)^{4}He - nuclear reaction for deuterons
- **Reaction Q-value:** +18.35 MeV

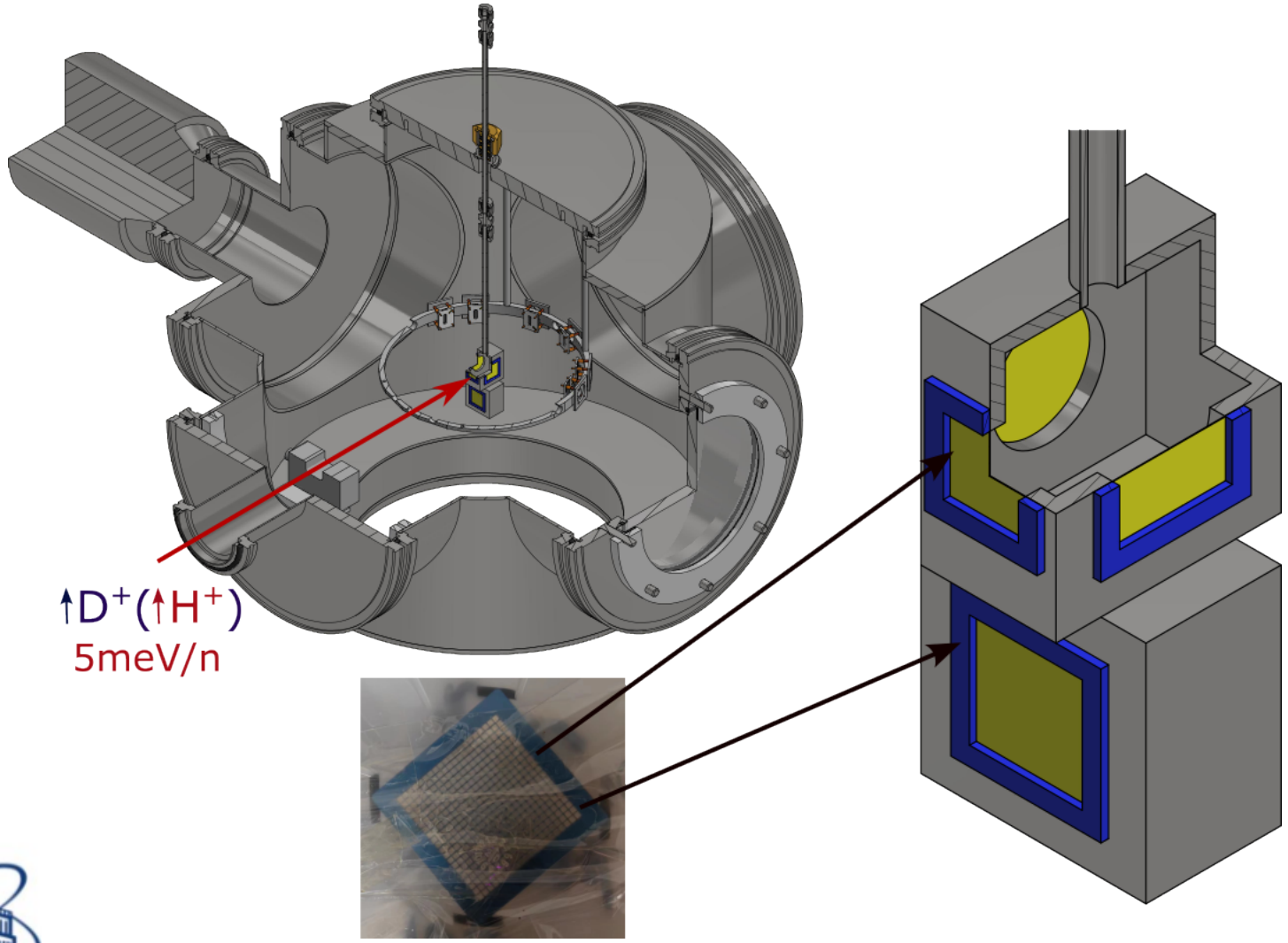
Operating Principle and Product Energies

- **Analyzing Reaction:** ^{3}He(d,p)^{4}He
- **Laboratory Detection Angle:** 27°
- **Product Energies at E_d = 10 MeV:**
  - **Protons:** $E_p \approx 26$ MeV ($\theta_{CM} = 32°$)
  - **α-particles:** $E_\alpha \approx 12$ MeV ($\theta_{CM} = 132°$)
- **Product Energies at E_d = 5 MeV:**
  - **Protons:** $E_p \approx 22$ MeV
  - **α-particles:** $E_\alpha \approx 10$ MeV

Key System Parameters

- **Target:** Gas cell with ^{3}He
  - Pressure: up to 3 atm
  - Windows: $(SiN)_n$, 100 nm
- **Detectors:**
  - **Protons (26 MeV):** Si surface-barrier detectors 300 μm with thin foil
  - **α-particles (12 MeV):** Si surface-barrier detectors 300 μm with thin foil
- **Angular Resolution:** $\pm 0.38^\circ$
- **Energy Resolution:** about 30 keV

Target



Polarization Measurement Method

- **Measured Moments:**
  - Vector: it_{11}
  - Tensor: t_{20}, t_{21}, t_{22}
- **Intensity Formulas:**

$$N_{L,R}(\theta) = K_{L,R}\sigma_0(\theta)B[1 \pm 2iT_{11}t_{11} + T_{20}t_{20} \pm 2T_{21}t_{21} + 2T_{22}t_{22}]$$

- **System of Equations:**

$$[\beta] = [T_{pol}][t], \quad [t] = [T_{pol}]^{-1}[\beta]$$

- **Energy Separation:** High product energies (12-26 MeV) ensure good signal separation

Measurement Accuracy

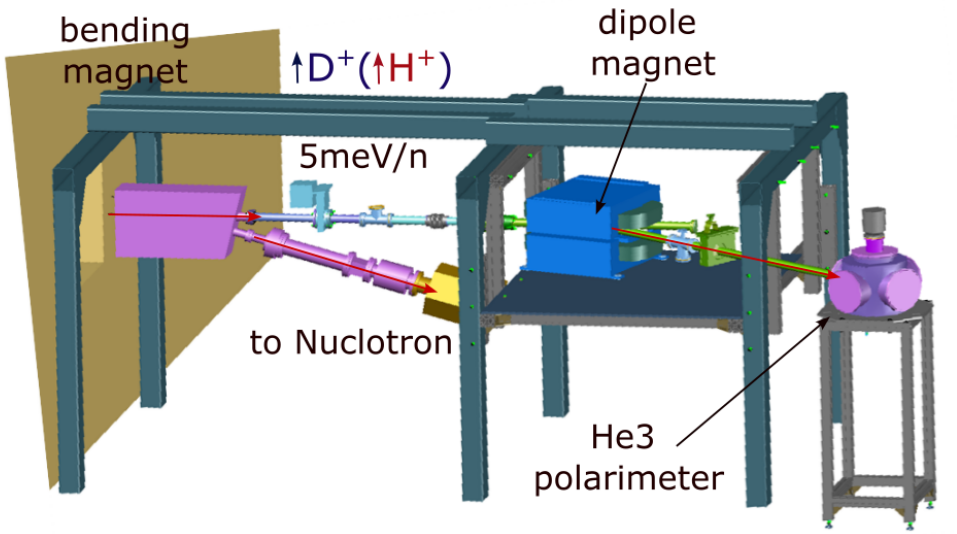
Parameter	Deuterons	Protons
5-10 MeV	2%	–
10-12 MeV	4%	–
A_{90}	–	± 0.005
Time of measurement	1 min	1 min

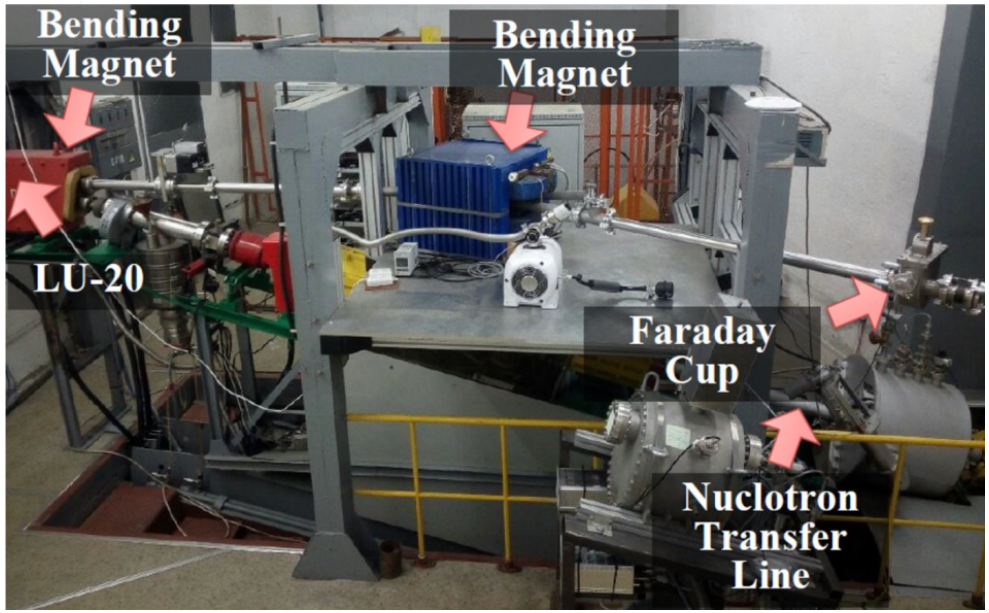
- **Detected Particle Energies:** 10-26 MeV (provides good statistics)
- **Accuracy:** 1% in 1 minutes at 20 μA beam current

Count Rate Calculation and Optimization

- **Typical Count Rate:**
  - 87.5 MHz (peak), 175 Hz (average)
- **Product Energies:**
  - Protons: 22-26 MeV
  - α-particles: 10-12 MeV
- **Problems:**
  - Dead time about 0%
  - Pulse pile-up
- **Recommendations:**
  - Reduce detector size (5×5 mm^2)
  - Increase distance to 150 mm
  - Reduce ^{3}He pressure

Installation location





Calibration

- **Absolute Calibration:**
  - T_{20}, T_{22}: reaction ^{16}O(d,α_1)^{14}N
  - iT_{11}, T_{21}: reaction ^{16}O(d,α_3)^{14}N
- **Relative Calibration:**
  - Use of Be degrading foils
  - Minimal beam depolarization
- **Calibration Reaction Energies:** 5.8, 7.4, 9.2 MeV

Advantages and Conclusions

- **Key Advantages:**
  - High analyzing power
  - **High Q-value (+18.35 MeV)** - simplifies detection
  - All high-energy products (10-26 MeV) at single lab angle (27°)
  - Simplified collimator system design
  - Reliability and ease of operation
- **Applications:**
  - Studies of spin dependence in nuclear reactions
  - Real-time beam polarization monitoring

Energy Characteristics

Table: Reaction Product Energies for ^{3}He(d,p)^{4}He

Product	$\mathbf{E_d = 5}$ **MeV**	$\mathbf{E_d = 10}$ **MeV**
Protons	≈22 MeV	≈26 MeV
α-particles	≈10 MeV	≈12 MeV
Angle (Lab)	27°	27°
Angle (CM)	32° (p) / 132° (α)	32° (p) / 132° (α)

- High product energies allow easy signal/background separation
- High energy resolution (1%) provides clear peak separation
- Large Q-value eliminates low-energy background issues

Proton Polarization Measurement

- **Reaction Used:** $^3\mathrm{He}(p,p)^3\mathrm{He}$ - Proton Elastic Scattering
- **Energy Range:** 4-10 MeV
- **Detection Method:**
  - Surface-barrier silicon detectors
  - Symmetrically positioned left/right of beam
  - Laboratory angles: 20° to 150°
- **Key Angle:** $\sim 90^\circ$ (Lab) for high analyzing power
- **Achieved Accuracy:**
  - Analyzing power A_{90}: ± 0.005 or better
  - Beam polarization ~ 0.85 with 1-2% uncertainty

Proton Measurement Parameters

- **Measured Quantities:**
  - Vector polarization via left-right asymmetries
- **Target:**
  - Same universal ^{3}He gas target
  - Pressure up to 3 atm
- **Detector Setup:**
  - Multiple detector pairs for angular distribution
  - Primary focus on $\sim 90^\circ$ for high A_{90}
- **Advantage:**
  - Uses same experimental setup as deuteron measurements
  - True universal design for p/d beams

Acknowledgments and Literature

- **Key Publications:**
  - Stephenson, Haeberli (1980) - deuteron polarimeter 5-12 MeV
  - Alley, Knutson (1993) - proton elastic scattering 4-10 MeV
  - Schmelzbach et al. (1976) - calibration measurements
  - Trainor et al. (1974) - analyzing power

FEE SPI Development for NICA

- **Purpose:** Developing Front-End Electronics (FEE) for SPI detector
- **Application:** Part of NICA setup for future experiments with NICA beams
- **Detector Type:** Silicon telescope detector
- **Key Features:**
  - Fast timing capabilities
  - Multiple channel readout
  - Compact design

Detector Configuration

- **Detector Structure:** Silicon telescope configuration
- **Anode Configuration:** 16 anode pads
- **Shaping Time:** ∼20 ns
- **Key Components:**
  - Silicon sensor array
  - Front-end electronics
  - HV power supply integration

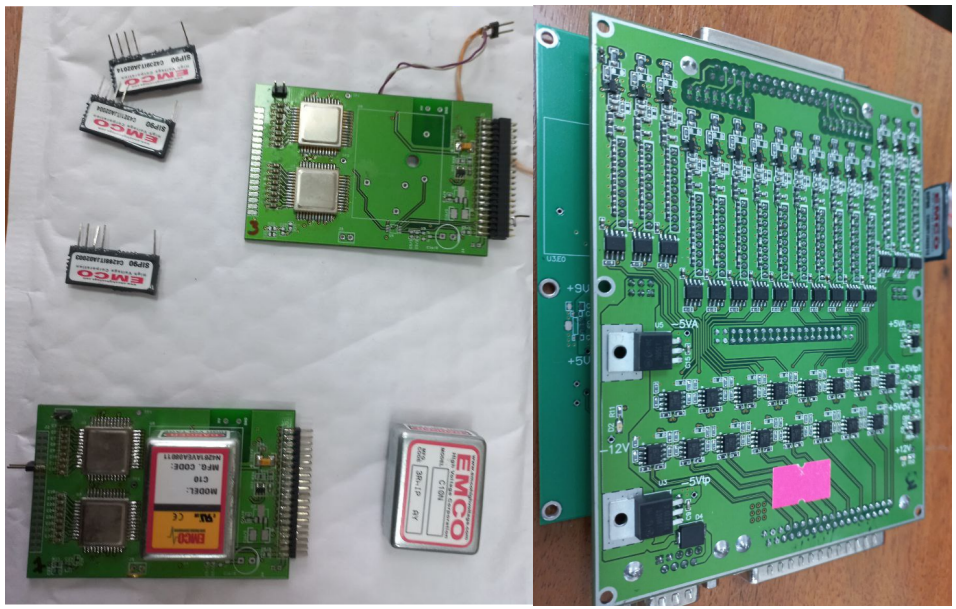


Figure: Fig. 1: Main parts of the SI detector

Front-End Electronics: Version 1

- **Based on commercial components:**
  - **Preamplifier:** AD8004
  - **Discriminator:** AD8564
- **Features:**
  - Proven commercial reliability
  - Easy prototyping
  - Standard components availability
- **Applications:**
  - Initial system testing
  - Prototype validation

Front-End Electronics: Version 2

- **Custom ASIC Design:**
  - 8 channels per chip
  - Integrated preamplifier-discriminator-LVDS converter
  - Compact solution
- **Heritage:** Similar design proposed for CBM straw tube tracker
- **Advantages:**
  - High integration level
  - Reduced component count
  - Optimized for specific application

Fast Electronics Module

- **Module:** 16-channel HAMAMATSU C-9945-14
- **Key Feature:** Integrated double counting counter
- **Power Supply:**
  - HV module from EMCO integrated on FEE PCB
  - Compact power solution
- **Benefits:**
  - High channel density
  - Built-in counting functionality
  - Integrated HV supply

Front-End Electronics: Version 3

- **Architecture:**
  - Current feedback amplifier using AD8014
  - Fast discriminators
  - Optimized for testing
- **Shaping Time:** $\sim$35 ns
- **Purpose:**
  - Prototyping and testing of Si detectors
  - System validation
  - Performance optimization
- **Features:**
  - Flexible design for various detector configurations
  - Suitable for RD phase

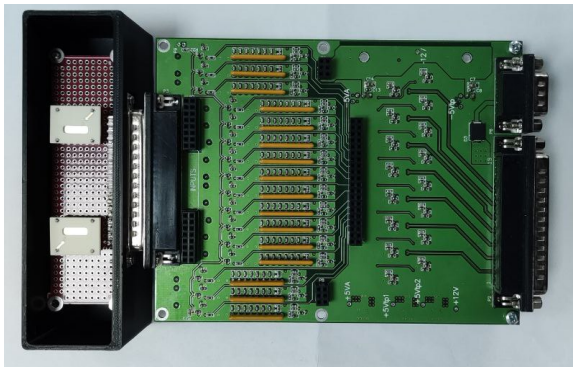


Figure: Front-End Electronics: Version 3

Performance Summary

Parameter	Version 1	Version 2	Version 3
Technology	Commercial ICs	Custom ASIC	Hybrid
Channels	16	8 per chip	Configurable
Shaping Time	∼20 ns	∼20 ns	∼35 ns
Integration	Discrete	High	Medium
Main Components	AD8004/AD8564	Custom ASIC	AD8014
Application	General	Production	R&D

Table: Comparison of FEE SPI versions

Integration with NICA

- **System Integration:**
  - Part of NICA detector complex
  - Compatible with NICA beam parameters
  - Designed for future experiment requirements
- **Expected Performance:**
  - Fast timing for particle identification
  - High channel count for spatial resolution
  - Reliable operation in beam environment
- **Development Status:**
  - Multiple versions for different applications
  - Prototyping and testing phase

Conclusions and Outlook

- **Current Status:**
  - Three FEE versions developed
  - Successful prototype testing
  - Ready for integration with NICA
- **Future Plans:**
  - Selection of optimal version for production
  - Scaling to full system requirements
  - Integration with NICA data acquisition
- **Benefits for NICA:**
  - Enhanced detection capabilities
  - Fast timing electronics
  - Custom solutions for specific needs

Thank you

for your attention

Questions?