Status of the pp-elastic absolute polarimeter

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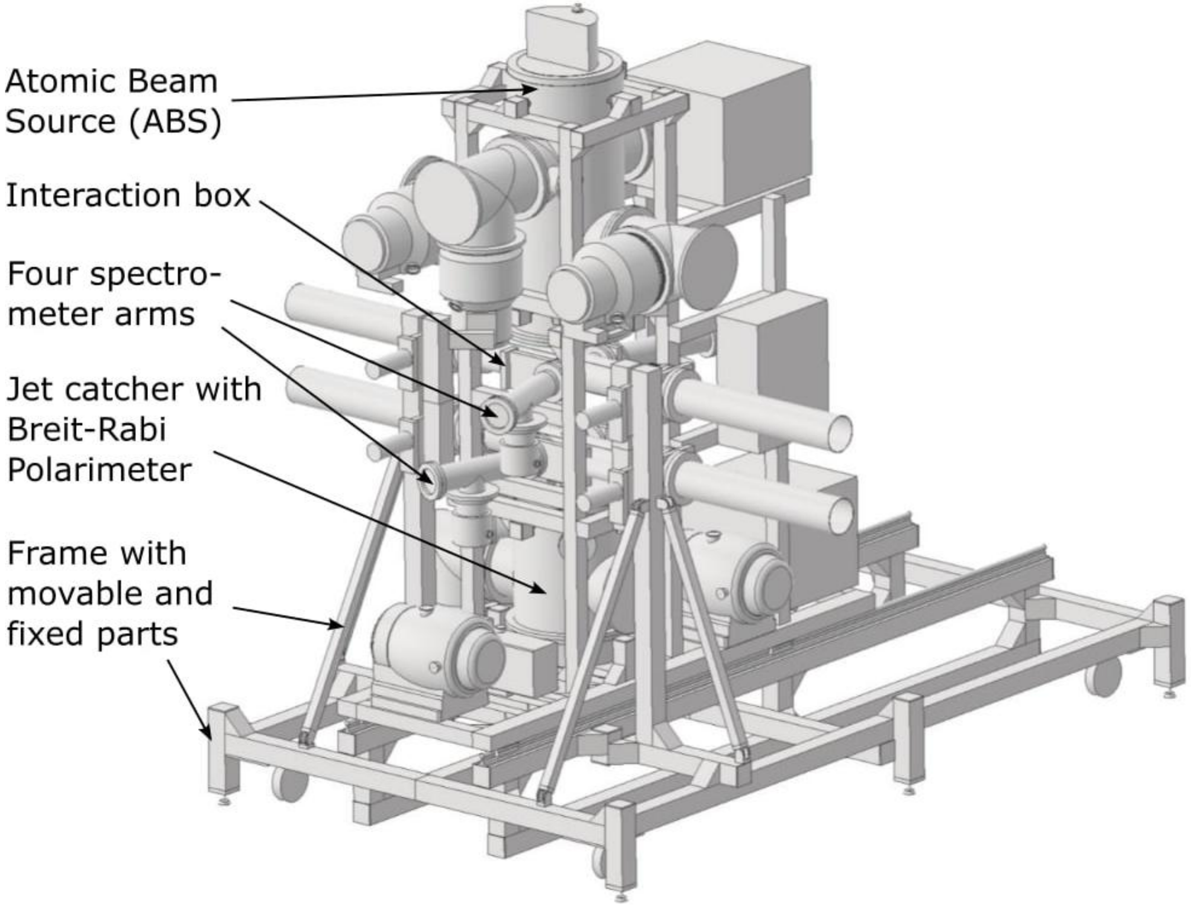
NICA Absolute Polarimeter (Apol)

To measure absolute values of proton or deuteron polarization at NICA collider rings an Absolute Polarimeter Apol with the internal polarized atomic hydrogen/deuterium jet target is being built

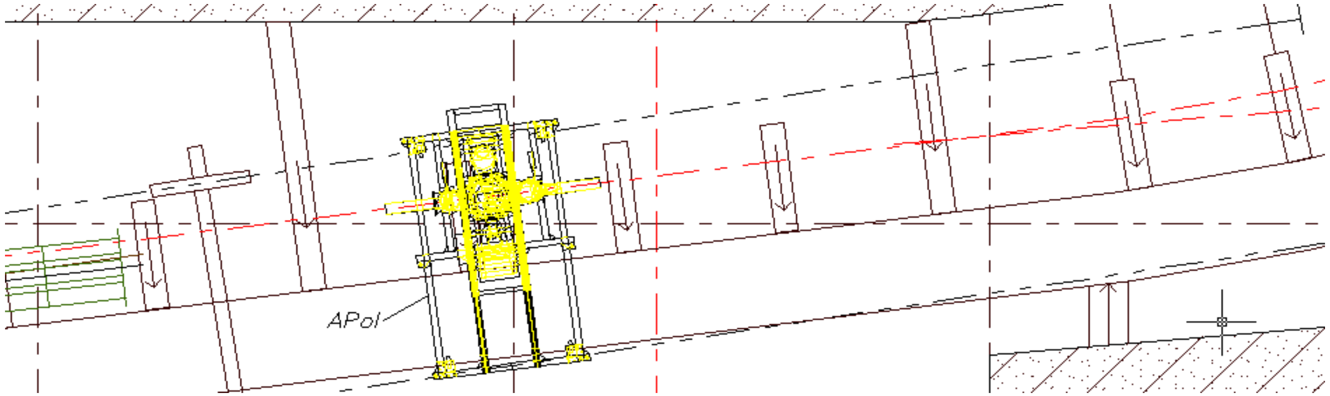


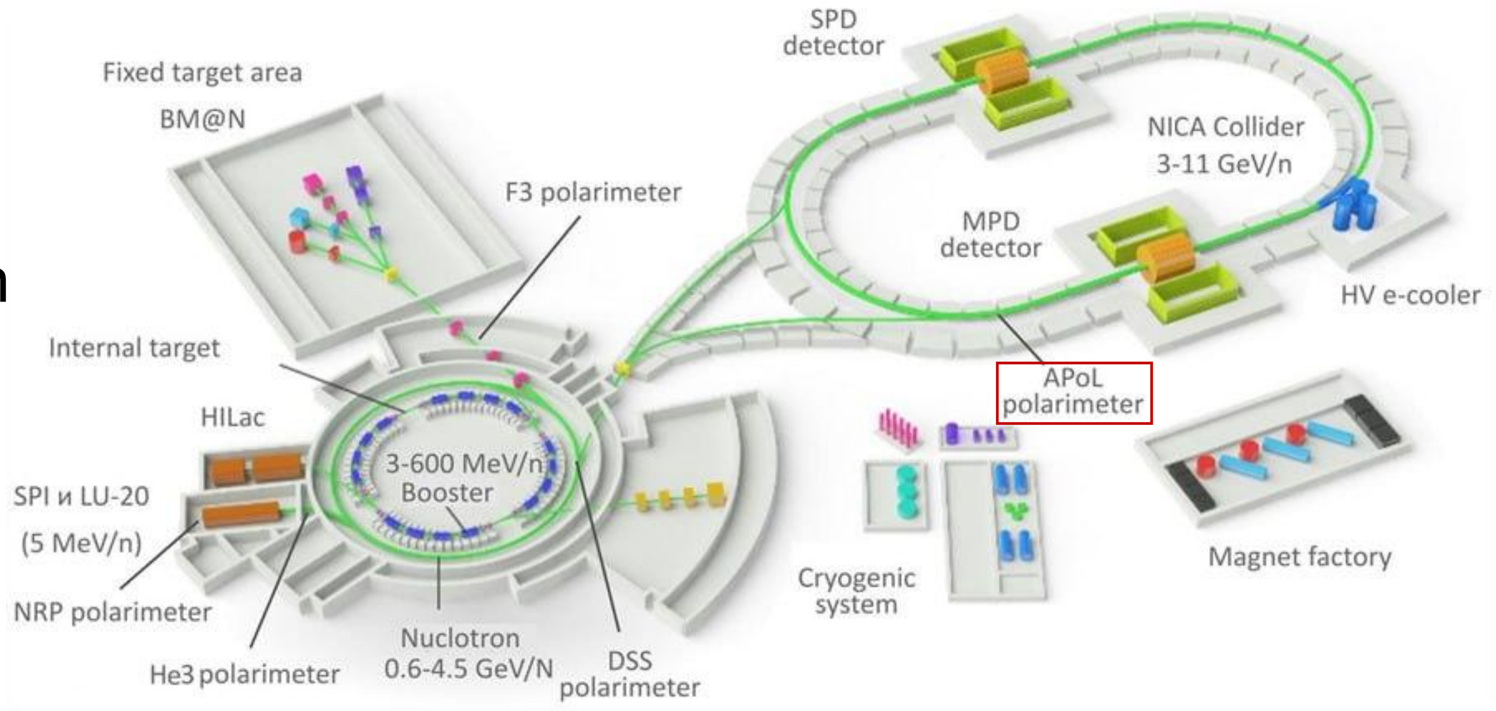
Main tasks for Apol

1. Beam polarization testing in tuning of the NICA polarization control system

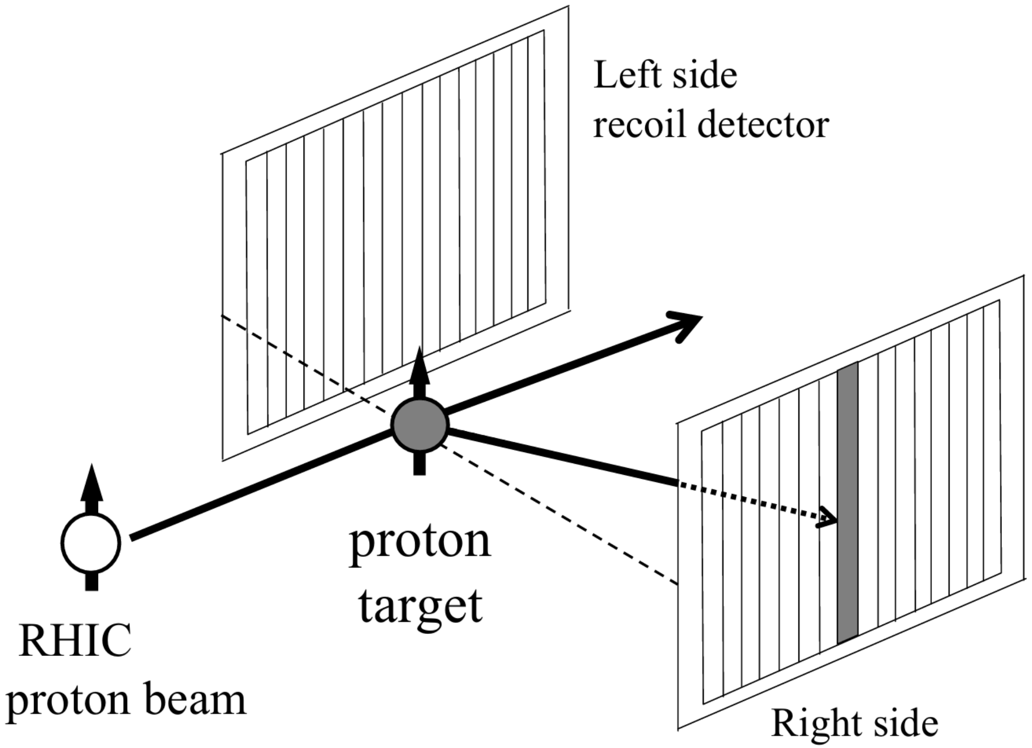
2. Determination the effect of disturbing Collider devices on beam polarization

3. Monitoring the degree of beam polarization during operation of th Collider





The operating principle: analyzing power and scattering asymmetry



https://doi.org/10.1063/1.2888110

beam energy range: **3..11 GeV**
recoil particle energy: **200 MeV**
recoil particle registration angle (in lab system): **75°**
A_N range: **20% .. 8%**

$P_{beam} = \frac{\varepsilon_{beam}}{A_N}$ - beam polarization,

$A_N = -\frac{\varepsilon_{target}}{P_{target}} = \frac{\varepsilon_{beam}}{P_{beam}}$ – analizing power of the polarimetric reaction

$$P_{beam} = -P_{target}\frac{\varepsilon_{beam}}{\varepsilon_{target}}$$

$$\varepsilon = \frac{\sqrt{N_\uparrow^L * N_\downarrow^R} - \sqrt{N_\uparrow^R * N_\downarrow^L}}{\sqrt{N_\uparrow^L * N_\downarrow^R} + \sqrt{N_\uparrow^R * N_\downarrow^L}}$$

Measurement time estimate

$$N = \Delta\sigma \cdot L \cdot \Delta\psi,$$

$$\Delta\sigma - \text{ particle scattering cross} - \text{section into the direction of registration},$$

$$\Delta\psi(= 0.016) - \text{ a relative solid angle into the direction of registration},$$

$$L - \text{ luminosity}$$

$N_A = (0.05 \cdot A_N)^{-2}$ - the number of the events needed to measure AN with the accuracy of 5%

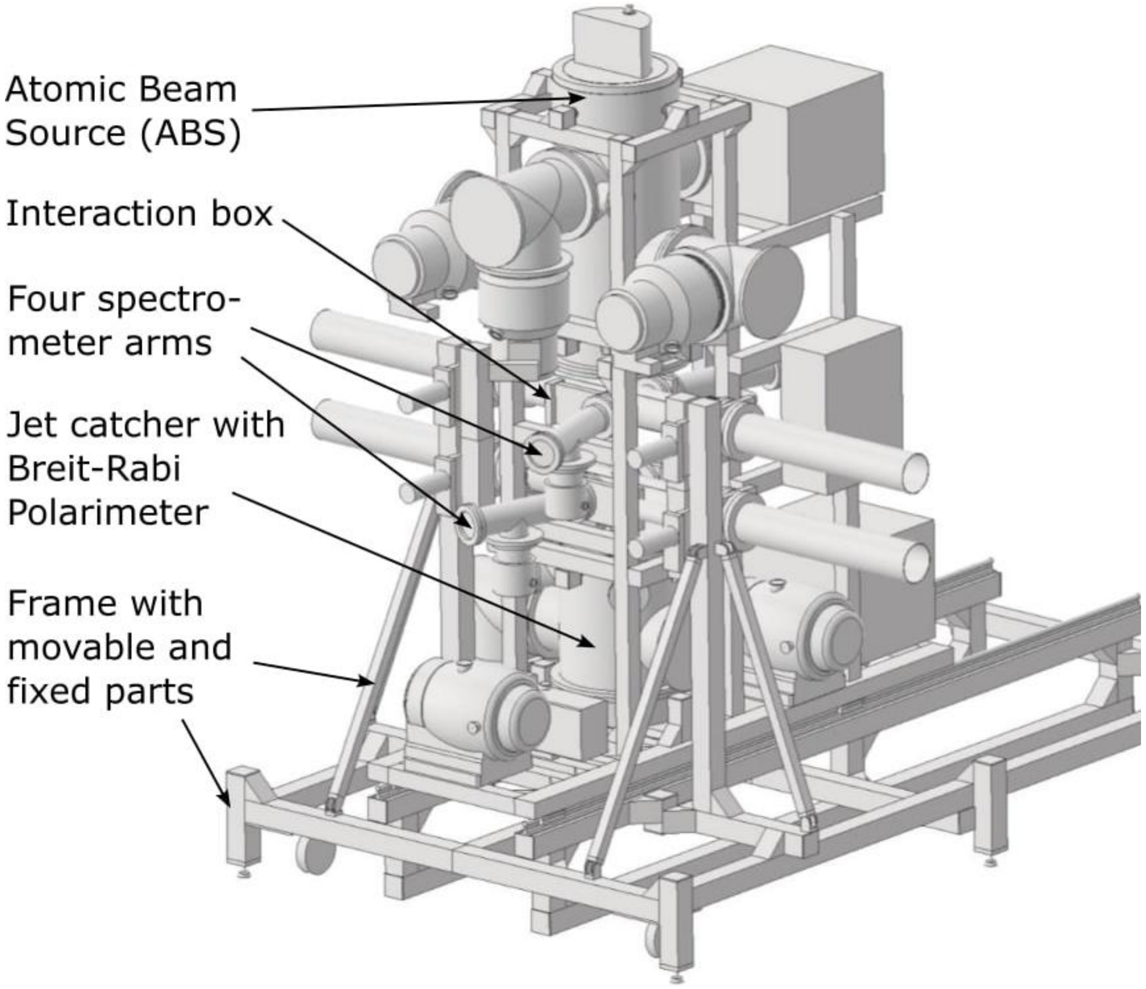
$T = \frac{N_A}{N}$ - the time needed to measure AN with the accuracy of 5%.

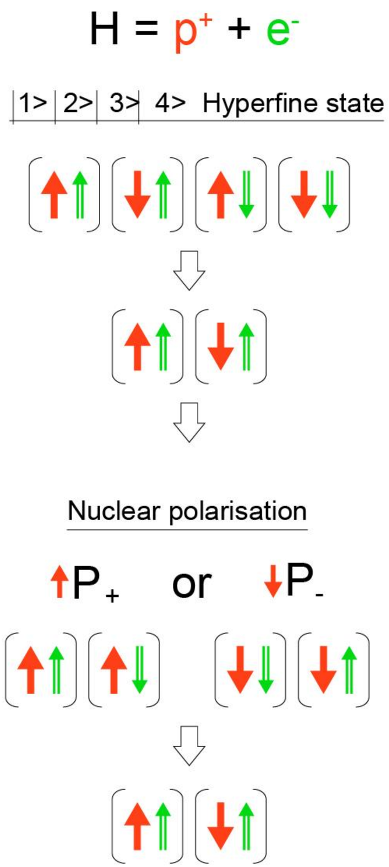
Beam, energy, GeV	Scattering cross-section, mb	Analizing power	Number of events needed for δA_N=5%	Time of measurement
3	3.08	0.195	10500	18 seconds
7	2.29	0.107	35000	73 seconds
11	1.84	0.077	67500	182 seconds

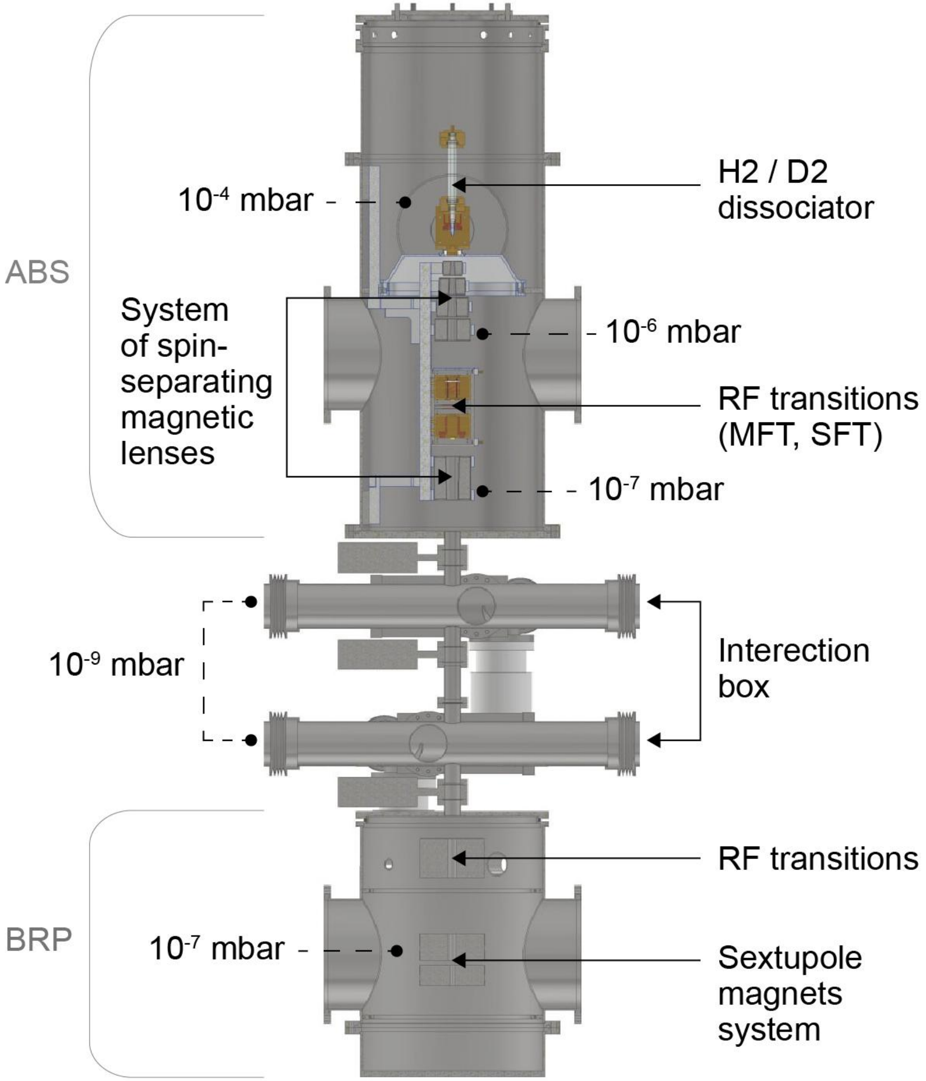
DOI: 10.1088/1742-6596/1435/1/012038

Cross-sections and analizing powers: Spinka H, Colton E, Ditzler W R, Halpern H, Imai K, Stanek R, Tamura N, Theodosiou G, Toshioka K and Underwood D 1983 NIMA 211 239-261

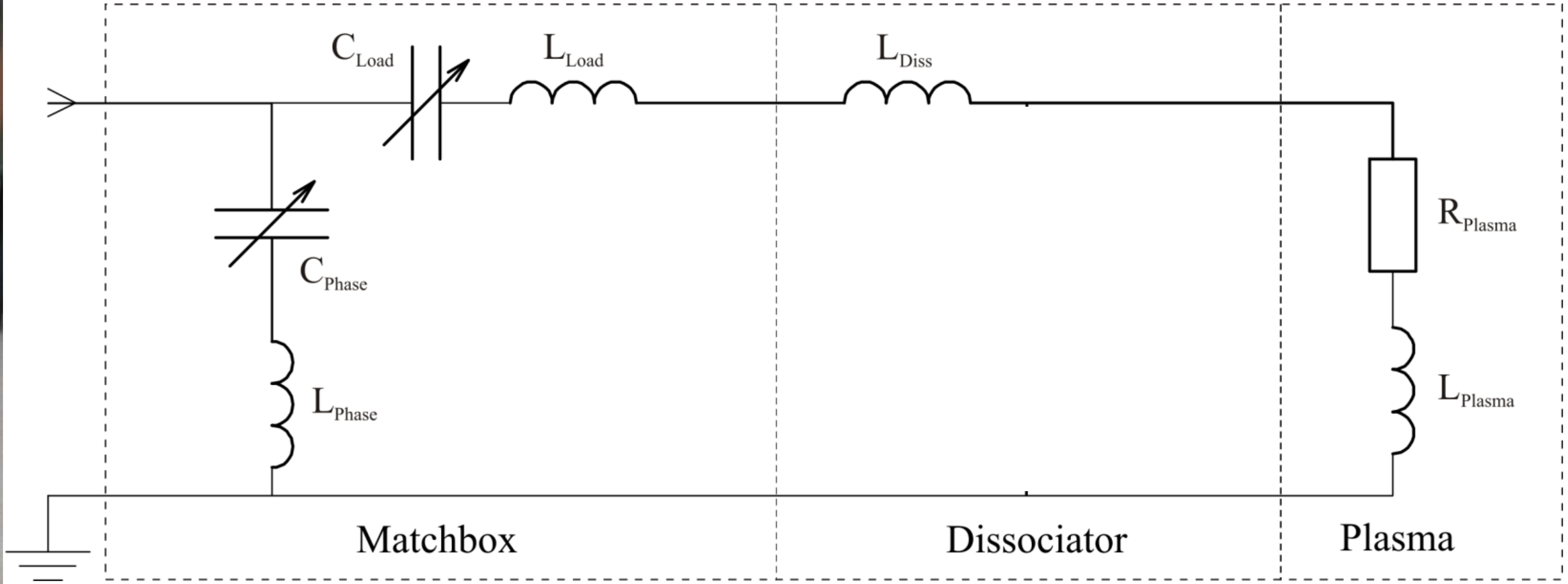
Design and operating principle of the Apol







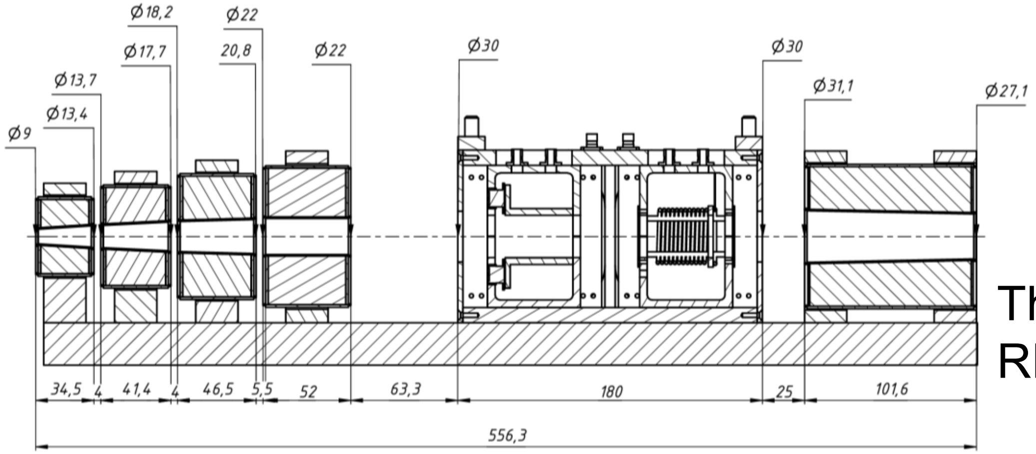
Radio – frequency dissociator



$$f = 13.56MHz$$
$$P = 280Wt$$

V.V. Fimushkin et al., "Upgrading Polarized Beam Equipment at the JINR Accelerator Facility: Future Prospects",
in: Proceedings of The 26th international symposium on spin physics (SPIN2025) Qingdao (Tsingtao), Shandong Province, China, 2025.

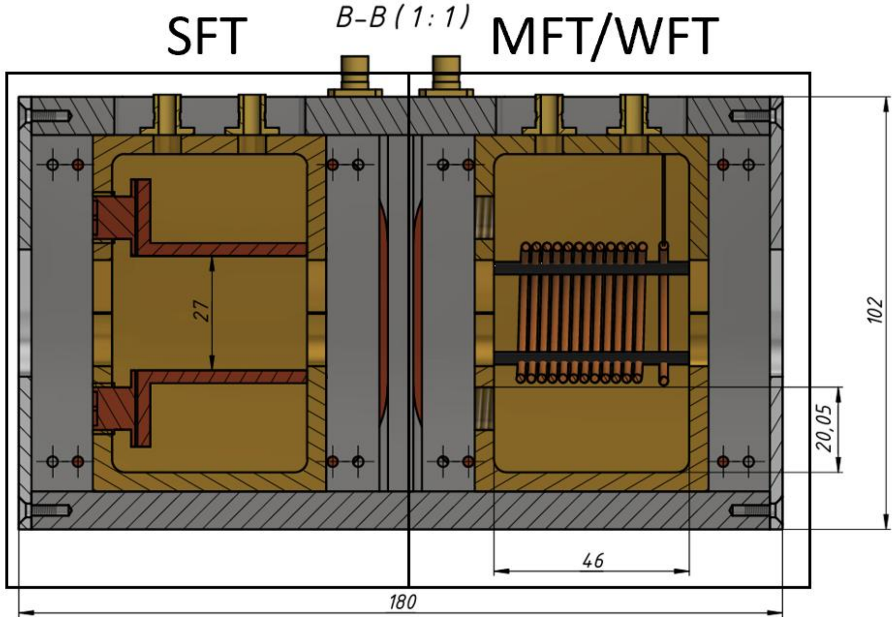
Apol multipolar magnetic system



Magnets number	Extrapolated field at average radius B_{max} ,T
1	$1,47 \pm 0,05$
2	$1,44 \pm 0,05$
3	$1,49^{+0,07}_{-0,05}$
4	$1,52^{+0,03}_{-0,01}$
5	$1,47^{+0,05}_{-0,015}$

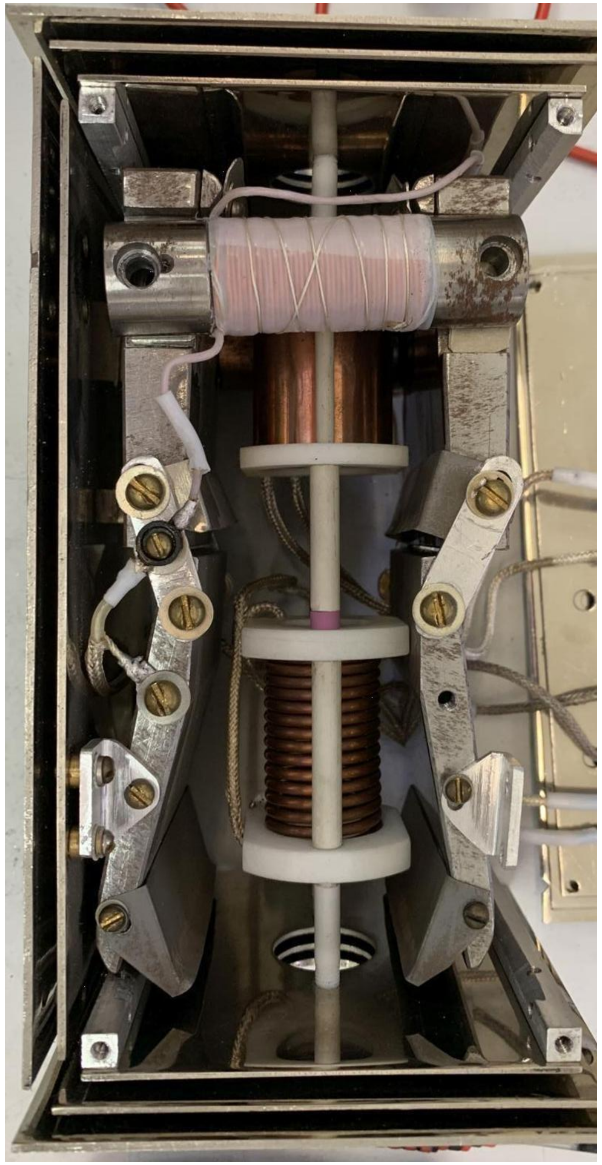
The magnetic system was based on the design of the RHIC absolute polarimeter magnetic system.

New construction Apol radio - frequency transition cells



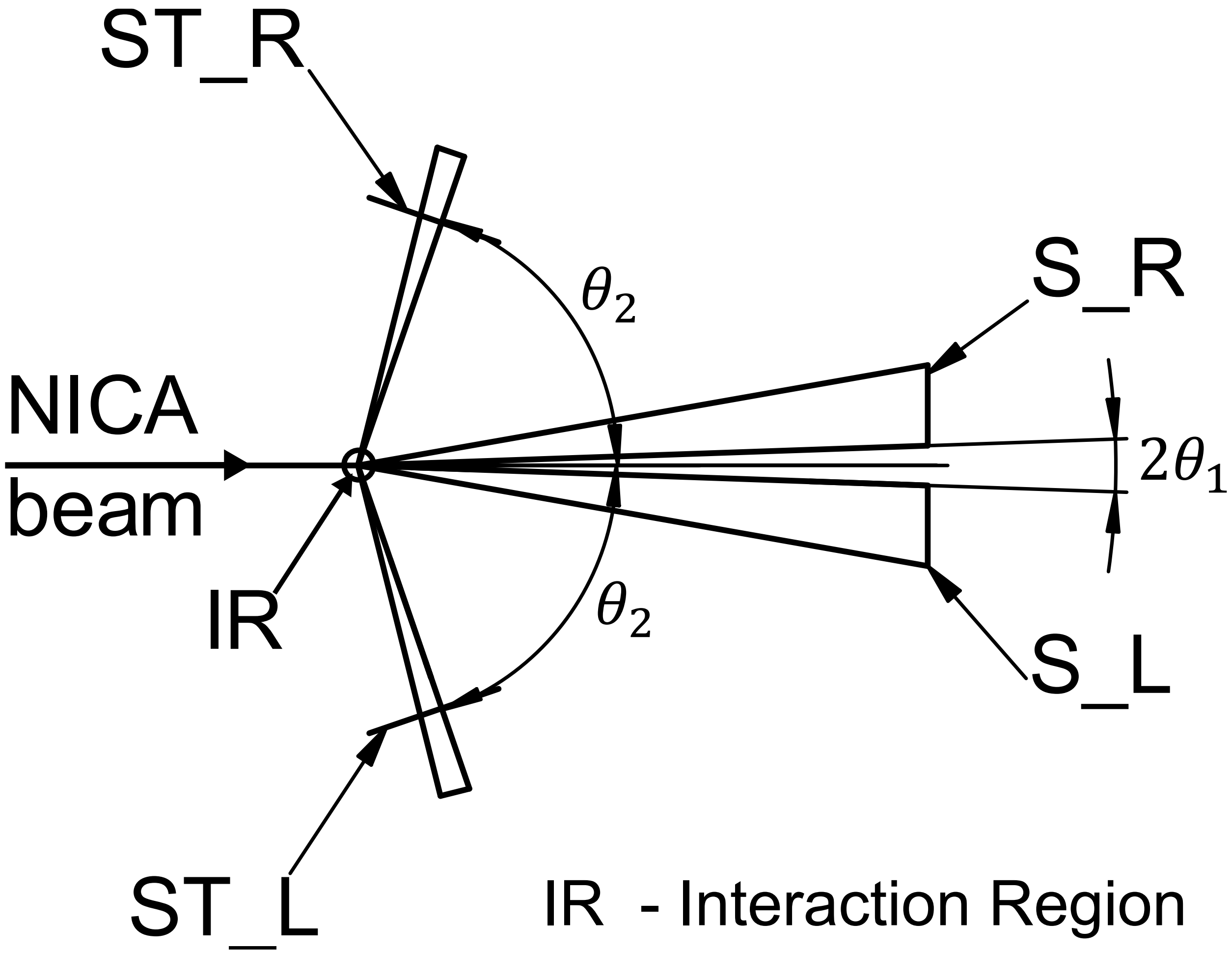
Hydrogen	Final State	Pz
MFT $\|2\rangle \rightarrow \|3\rangle$	1	+1
Deuterium	Final State	Pz
MFT $\|3\rangle \rightarrow \|4\rangle$ + SFT $\|2\rangle \rightarrow \|6\rangle$	1	+1

new construction

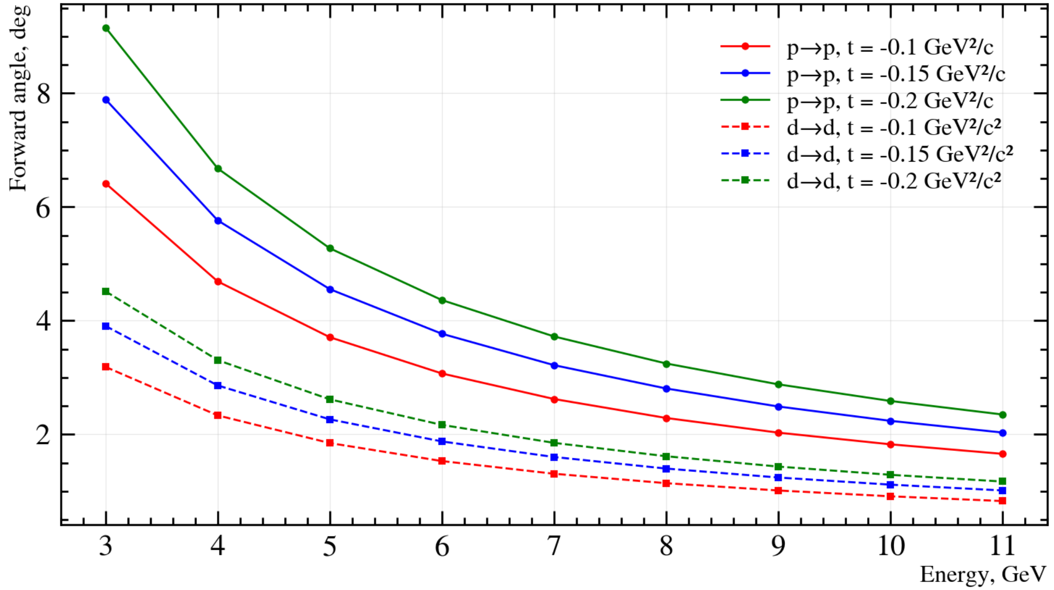


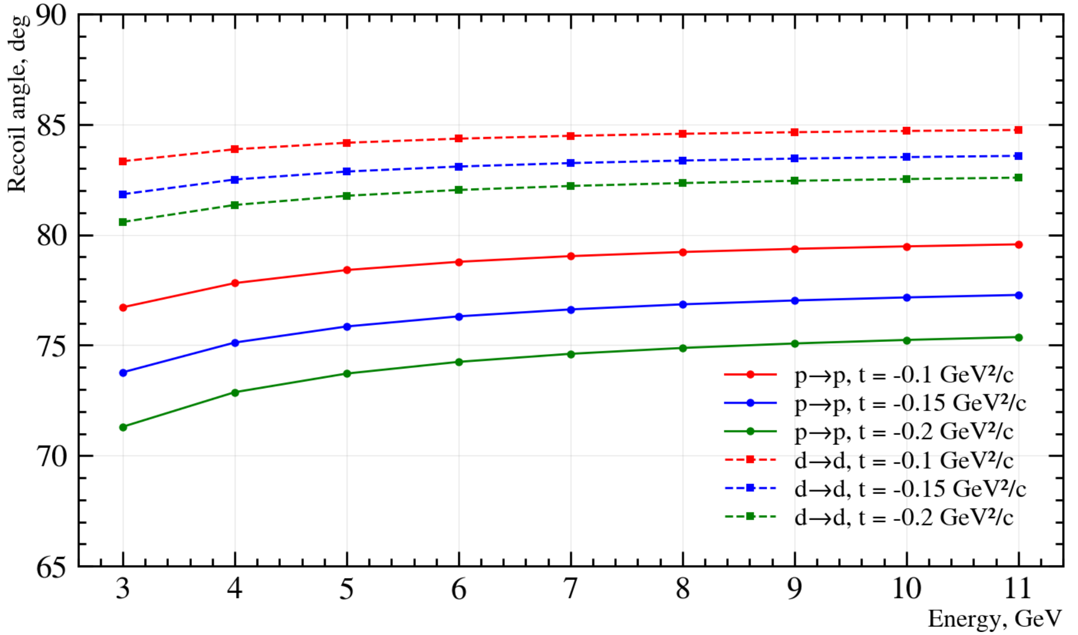
old construction

Proton/deuteron detection system

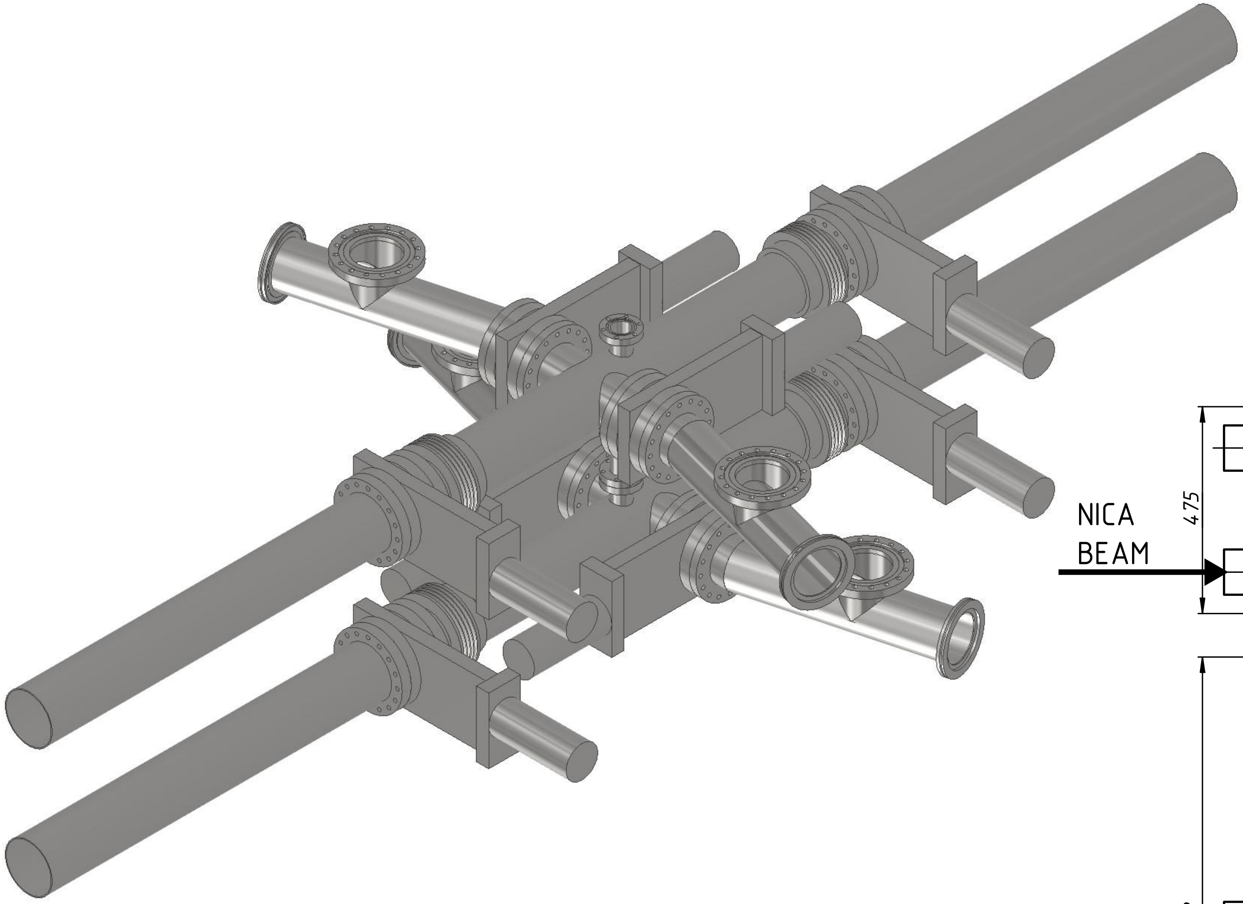


IR - Interaction Region
ST - Straw Detector
S - Scintillation Counters



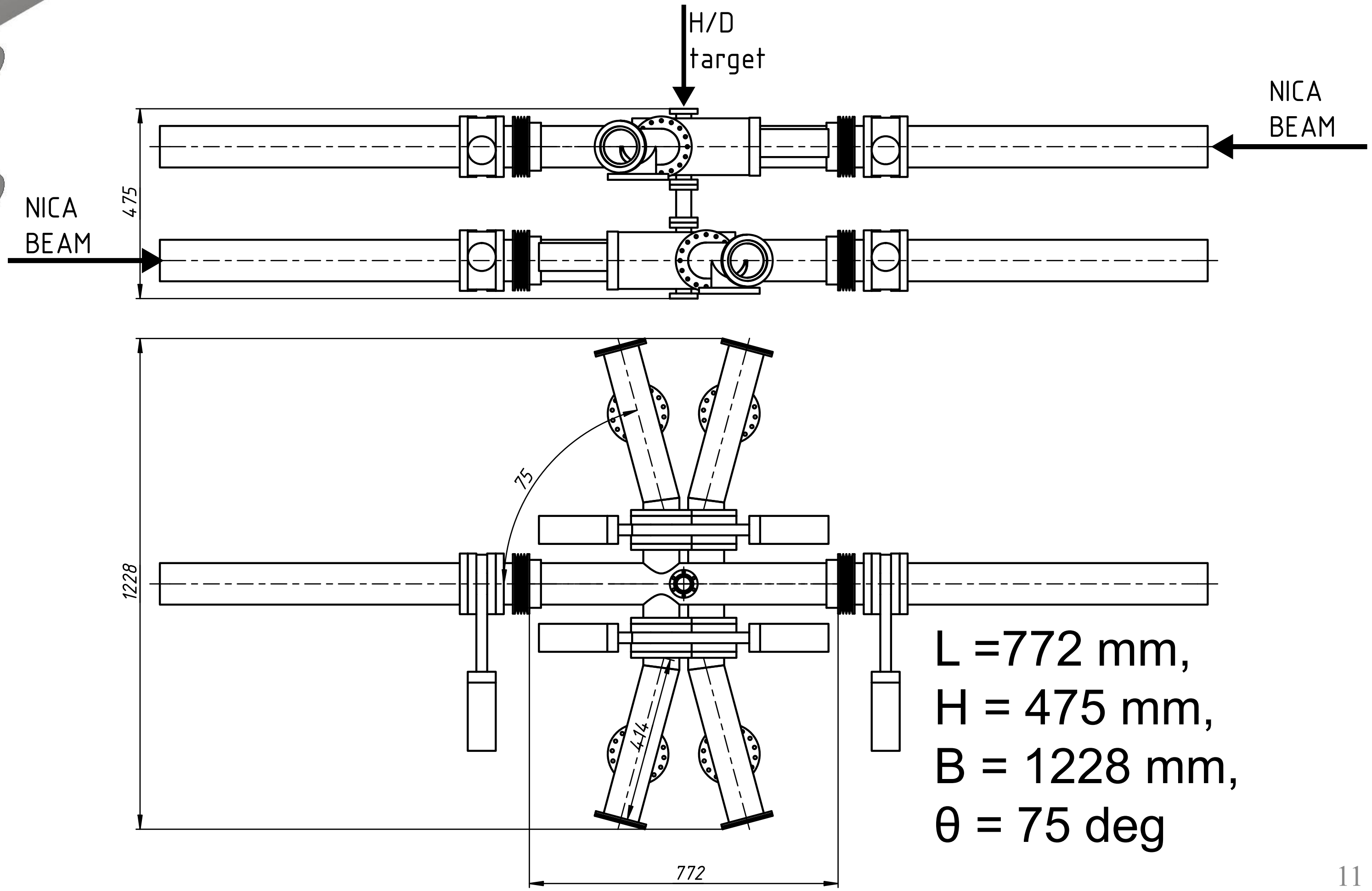


APol interaction box



APol interaction box 3D Model

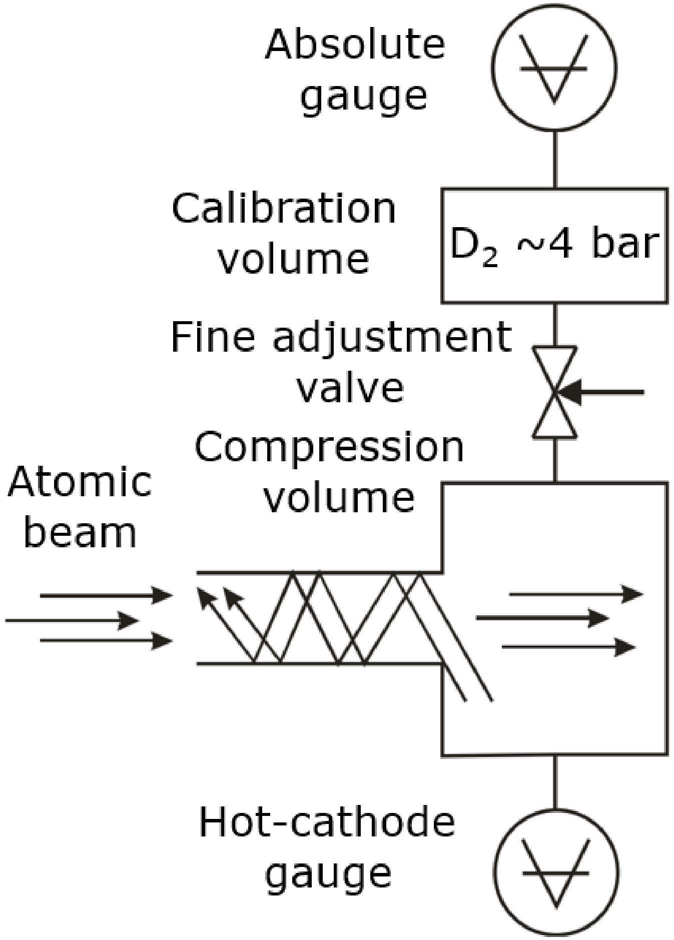
General assembly drawing of the APol interaction box

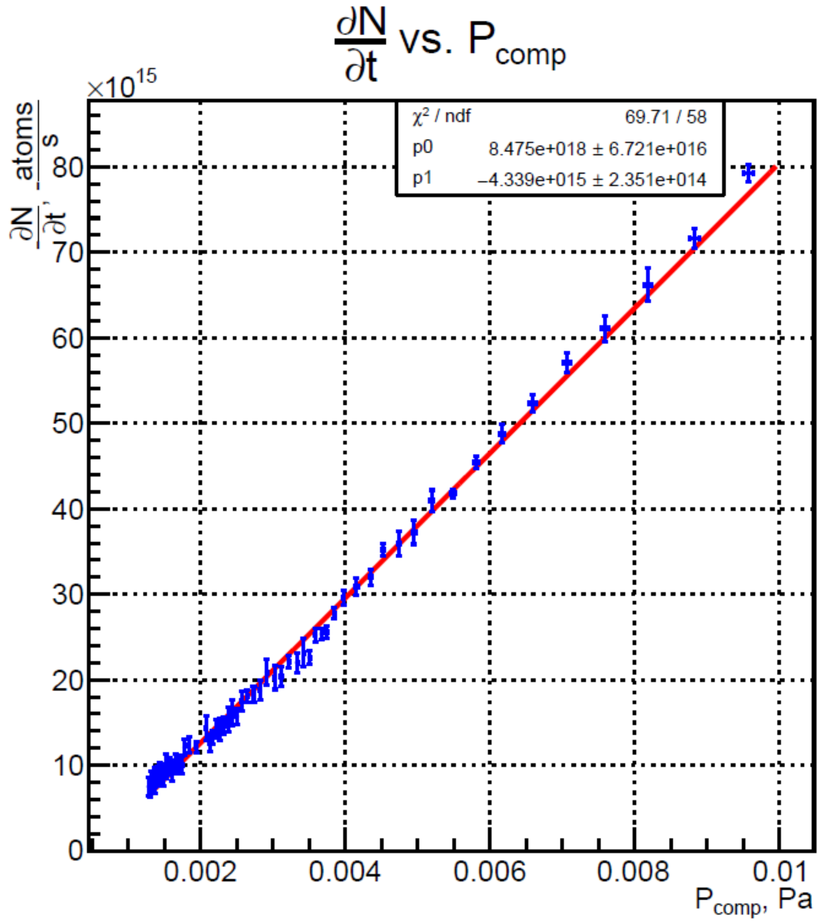


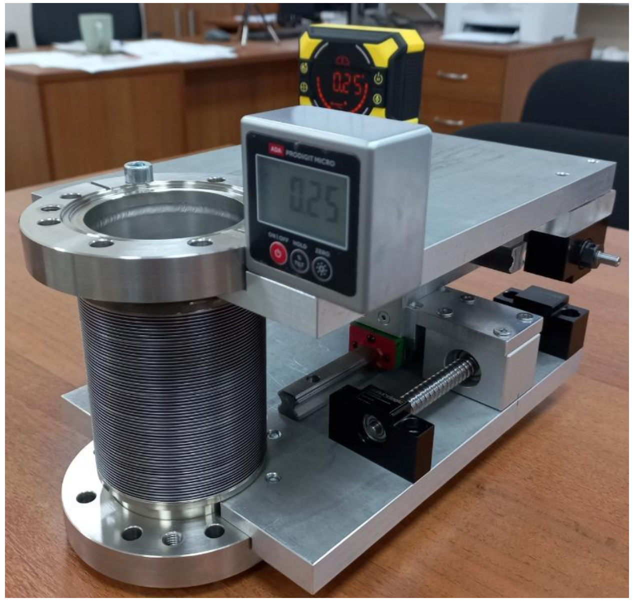
L =772 mm,
H = 475 mm,
B = 1228 mm,
θ = 75 deg

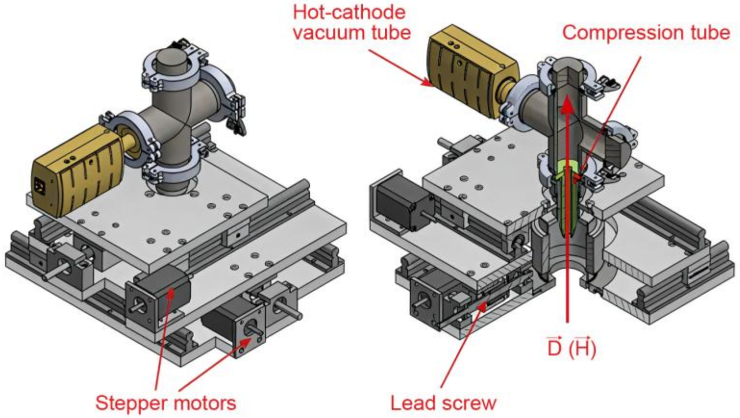
Beam profile measurement

$$\frac{\partial N_{D_2}}{\partial t} = \frac{V_{cal} \cdot \mu_{D_2}}{m_{D_2} \cdot R \cdot T_{cal}} \cdot \frac{\partial P_{cal}}{\partial t}$$

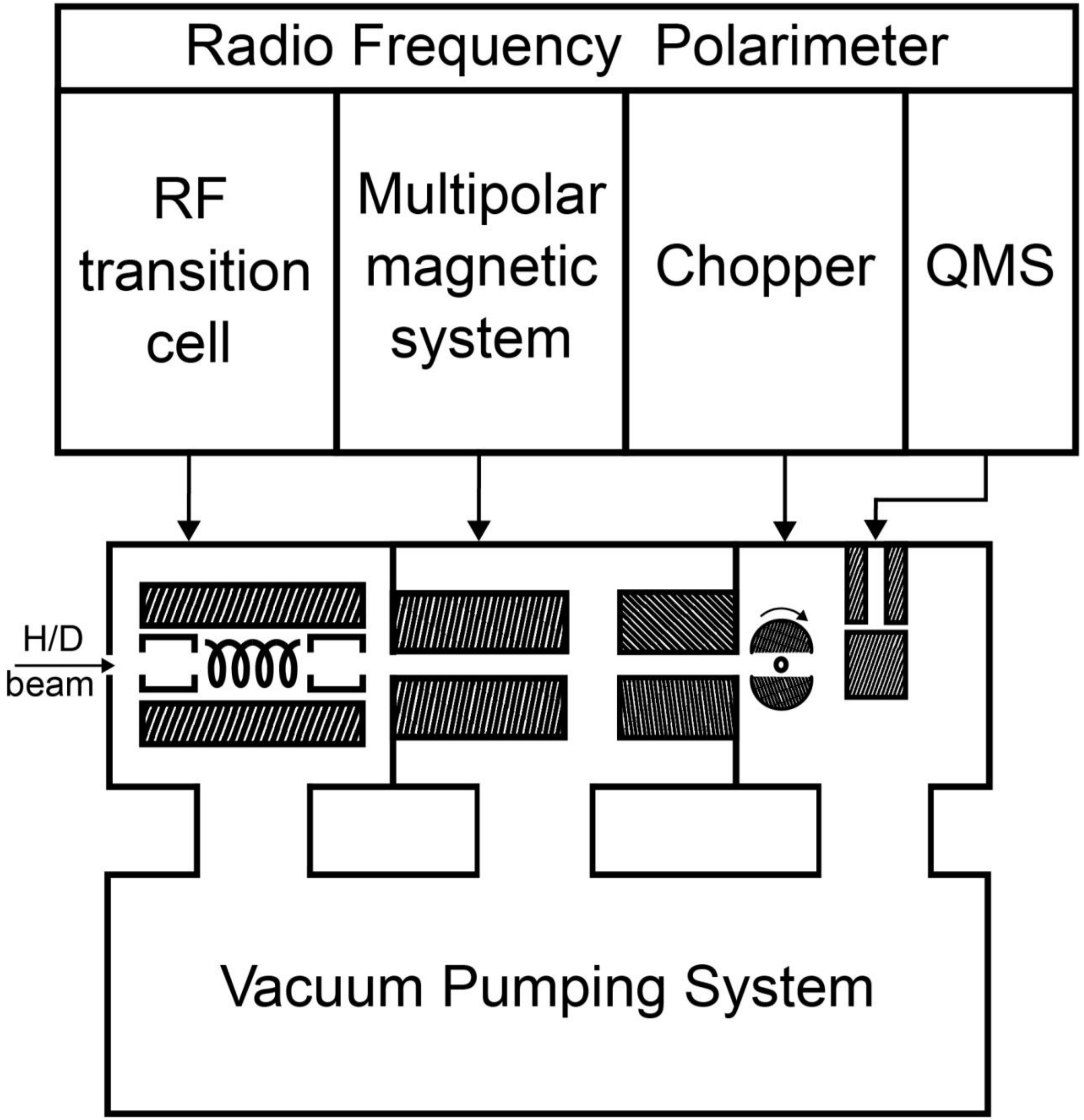








Breit-Rabi Polarimeter



The Breit-Rabi polarimeter is used for continuous monitoring of the atomic target polarization degree

Plans and Future

Near-Term Plans

Optimization of the polarized atomic beam source:

1. Nozzle temperature.
2. Gas flow rate into the dissociator.
3. Applied RF power.
4. Alignment of the dissociator nozzle.

Tuning of the Radio-Frequency (RF) transition cells.

Development and commissioning of the automated control system for the APol Polarized Atomic Beam Source (PABS).

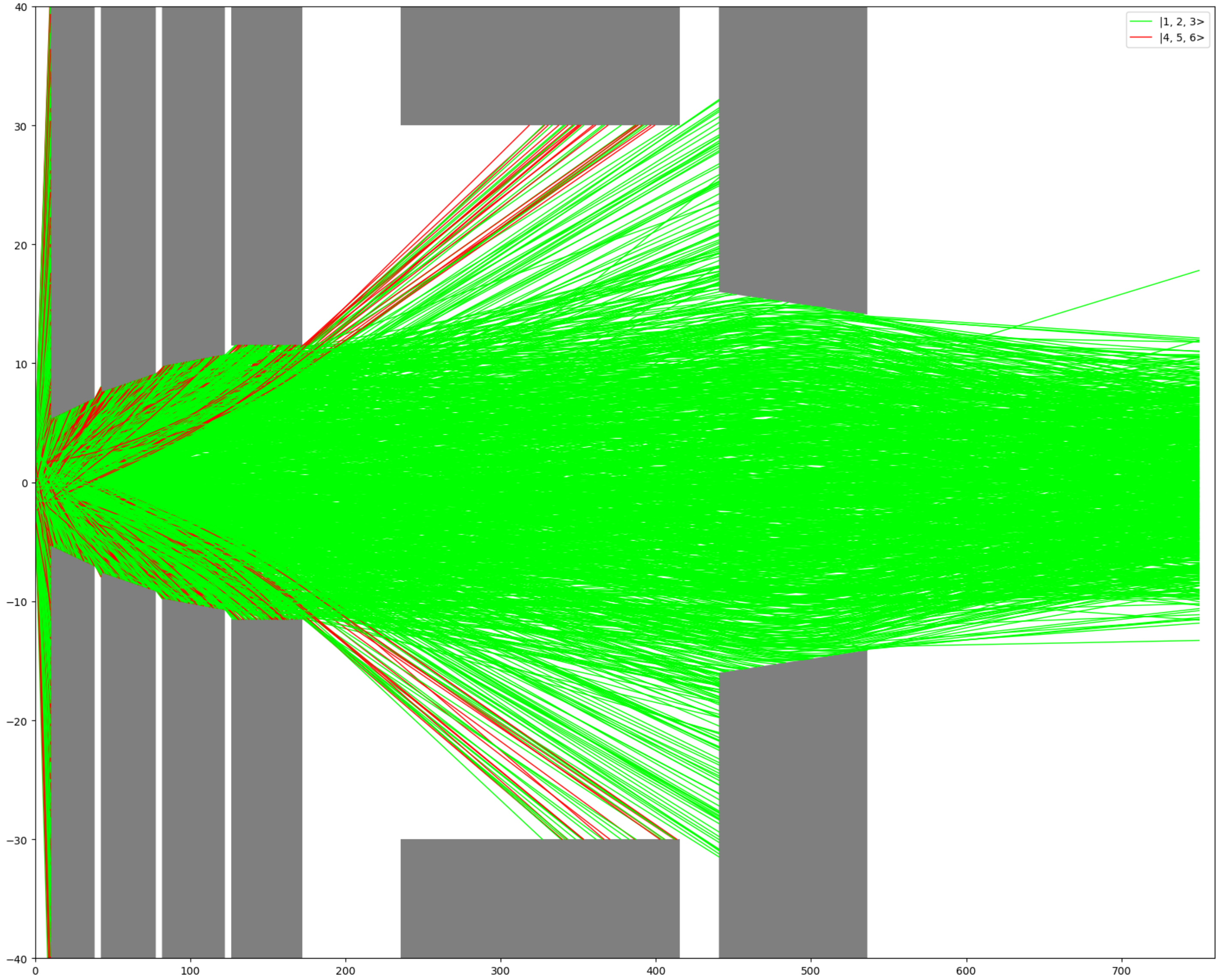
Future Outlook

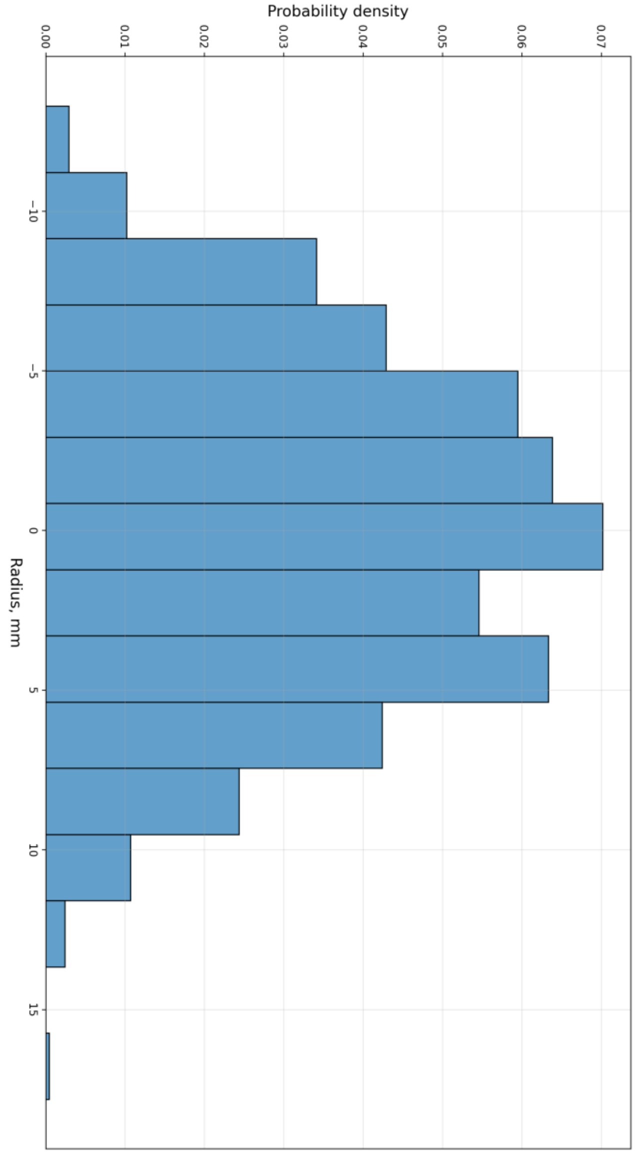
Development and setup of detector systems.

Installation of the APol setup at the NICA collider and its commissioning.

Thank you for your attention!

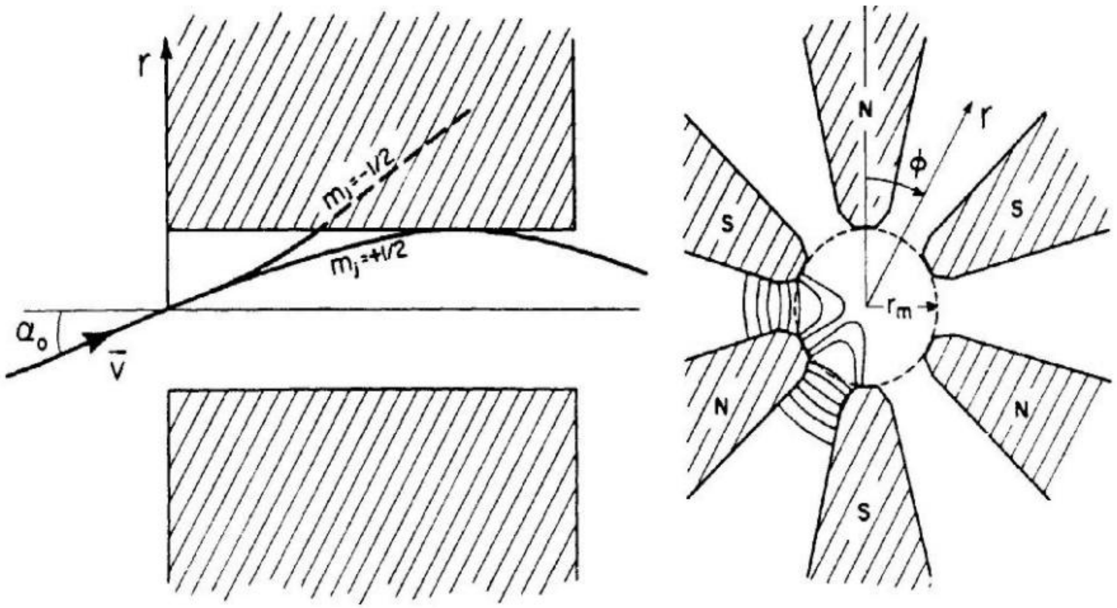
Calculation atomic beam profile





•DOI: [10.1134/S1547477125701353](https://doi.org/10.1134/S1547477125701353)

Multipolar magnetic system



A sextuple magnet used in ABS. An atom flying into a magnet with r = 0 at an angle α_0 is shown on the left; several lines of force are shown on the right

1. $$\frac{d^2\vec{r}^{\,1}}{dt^2} = \frac{1}{m} B_0 \left(\frac{N}{2} - 1\right) \frac{(\mu_e + \mu_d)}{r_0^{\frac{N}{2}-1}}\, r^{\frac{N}{2}-2}$$

2. $$\frac{d^2\vec{r}^{\,2}}{dt^2} = \frac{1}{2m}\left(\mu_d - \frac{-A_d\mu_c + \mu_c^2 B}{\sqrt{9A_d^2 - 2A_d\mu_c B + {\mu_c}^2 B^2}}\right) B_0 \left(\frac{N}{2} - 1\right) \frac{r^{\frac{N}{2}-2}}{r_0^{\frac{N}{2}-1}}$$

3. $$\frac{d^2\vec{r}^{\,3}}{dt^2} = \frac{1}{2m}\left(-\mu_d - \frac{A_d\mu_c + \mu_c^2 B}{\sqrt{9A_d^2 + 2A_d\mu_c B + {\mu_c}^2 B^2}}\right) B_0 \left(\frac{N}{2} - 1\right) \frac{r^{\frac{N}{2}-2}}{r_0^{\frac{N}{2}-1}}$$

4. $$\frac{d^2\vec{r}^{\,4}}{dt^2} = -\frac{1}{m} B_0 \left(\frac{N}{2} - 1\right) \frac{(\mu_e + \mu_d)}{r_0^{\frac{N}{2}-1}}\, r^{\frac{N}{2}-2}$$

5. $$\frac{d^2\vec{r}^{\,5}}{dt^2} = \frac{1}{2m}\left(-\mu_d + \frac{A_d\mu_c + \mu_c^2 B}{\sqrt{9A_d^2 + 2A_d\mu_c B + {\mu_c}^2 B^2}}\right) B_0 \left(\frac{N}{2} - 1\right) \frac{r^{\frac{N}{2}-2}}{r_0^{\frac{N}{2}-1}}$$

6. $$\frac{d^2\vec{r}^{\,6}}{dt^2} = \frac{1}{2m}\left(\mu_d + \frac{-A_d\mu_c + \mu_c^2 B}{\sqrt{9A_d^2 - 2A_d\mu_c B + {\mu_c}^2 B^2}}\right) B_0 \left(\frac{N}{2} - 1\right) \frac{r^{\frac{N}{2}-2}}{r_0^{\frac{N}{2}-1}}$$

DOI: 10.18720/SPBPU/3/2023/vr/vr23-336

Radio - frequency transition cells

F_{in} - F_{out} = ΔF = ±1,0 and Δm = ±1,0