NICA Absolute Polarimeter

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To measure absolute values and signs of proton or deuteron polarization in NICA collider rings an Absolute Polarimeter APol with an internal polarized atomic hydrogen/deuterium jet target is being built.

APol 3D view

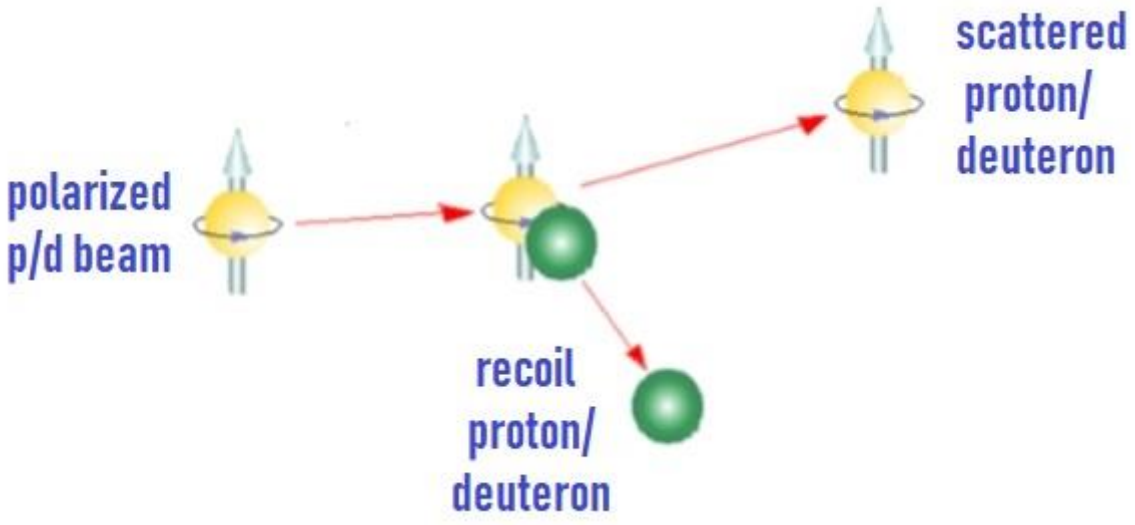
Main tasks for APol

- beam polarization testing in
  tuning of the NICA polarization control system

- determination the effect of
  disturbing Collider devices on beam polarization

- monitoring the degree of beam polarization
  during operation of the Collider

Polarimetric reaction and polarization measurement basics



beam energy range: **3..11 GeV**

recoil particle energy: **200 MeV**

recoil particle registration angle (in lab system): **75°**

A_N range: **20% .. 8%**

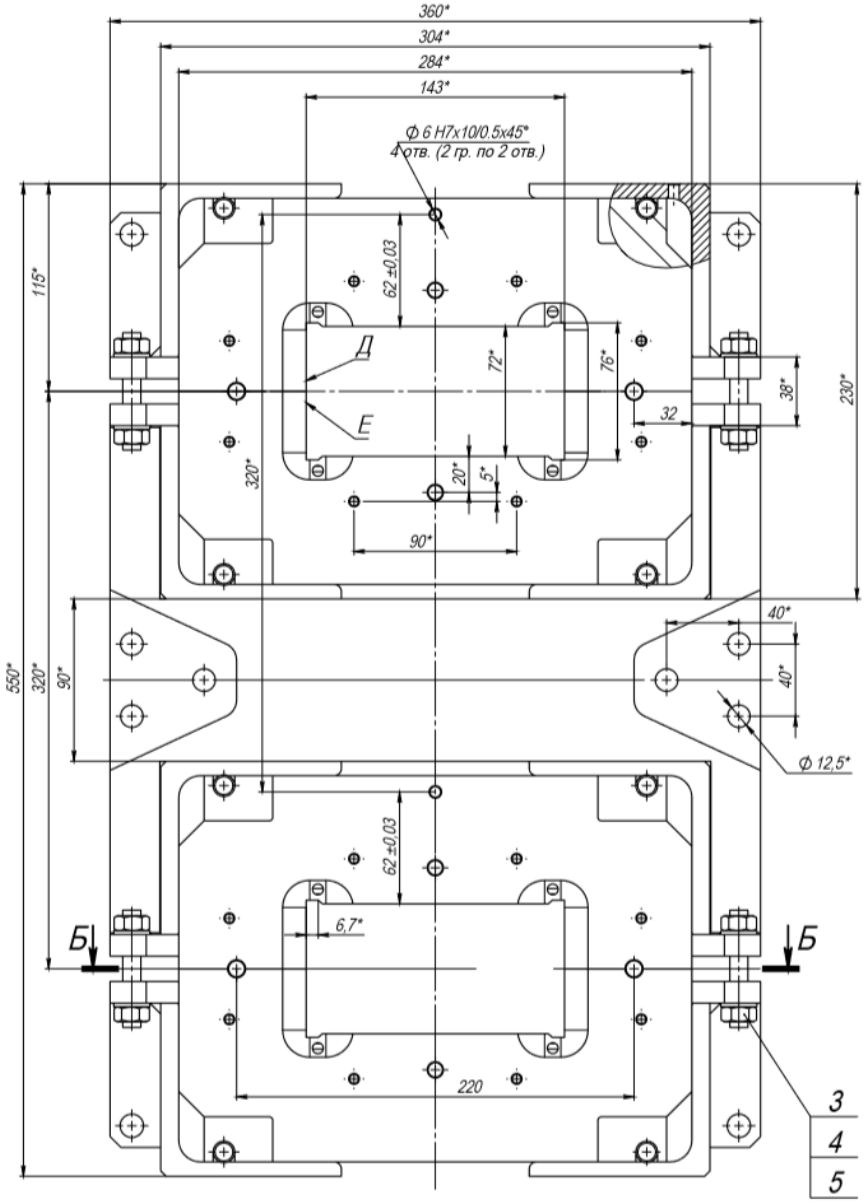
Measured beam polarization: $$P_{\text{beam}} = -\frac{\varepsilon_{\text{beam}}}{\varepsilon_{\text{jet}}} P_{\text{jet}} = -\frac{\varepsilon_{\text{beam}}}{A_N}$$

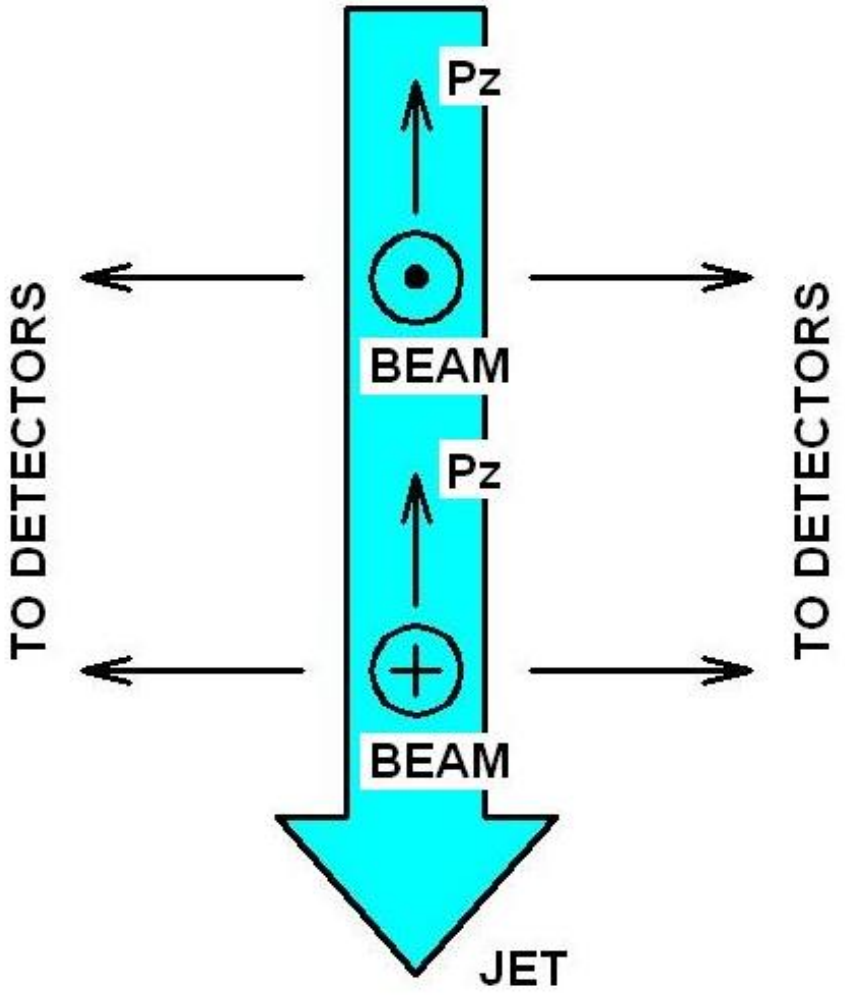
where $A_N = \varepsilon_{\text{jet}} / P_{\text{jet}}$ - analizing power of the polarimetric reaction

$\varepsilon \equiv \frac{N_{left} - N_{right}}{N_{left} + N_{right}}$ - measured assymetry

Actual geometry requirements

Section of NICA dipole magnet of collider





Mesurement time estimate

Rate of event acquisition: $N=\Delta\sigma\cdot L\cdot\Delta\psi$,
where

$\Delta\sigma$ – scattering cross-section into direction of registration,

$\Delta\psi(=0.016)$ - relative solid angle into direction of registration,

L – luminosity

In turn:

$L=N_{bunch}\cdot n_{bunch}\cdot F\cdot t_{jet}$,
where

$N_{bunch}(=10^{12})$ – number of protons/deuterons per bunch (for NICA)

$n_{bunch}(=22)$ – number of bunches (for NICA)

$F(=3\cdot10^{8}$ m*s^{-1}/503m$=6\cdot10^{5}$ s$^{-1})$ - frequency of crossing the jet
(for RHIC it is 3.8/0.5=**7.6 times smaller**)

t_{jet} $(=10^{12}$ atom/cm$^{2})$ – target thickness of the jet,

and numerically:

$L=10^{12}\cdot22\cdot6\cdot10^{5}\cdot10^{12}=1.3\cdot10^{31}$ s$^{-1}\cdot$cm$^{-2}=1.3\cdot10^{4}$ s$^{-1}\cdot$mb^{-1}

Number of events needed to measure A_N with an accuracy of 5%: $N_A=(0.05\cdot A_N)^{-2}$

Time needed to measure A_N with an accuracy of 5%: $T=N_A/N$.

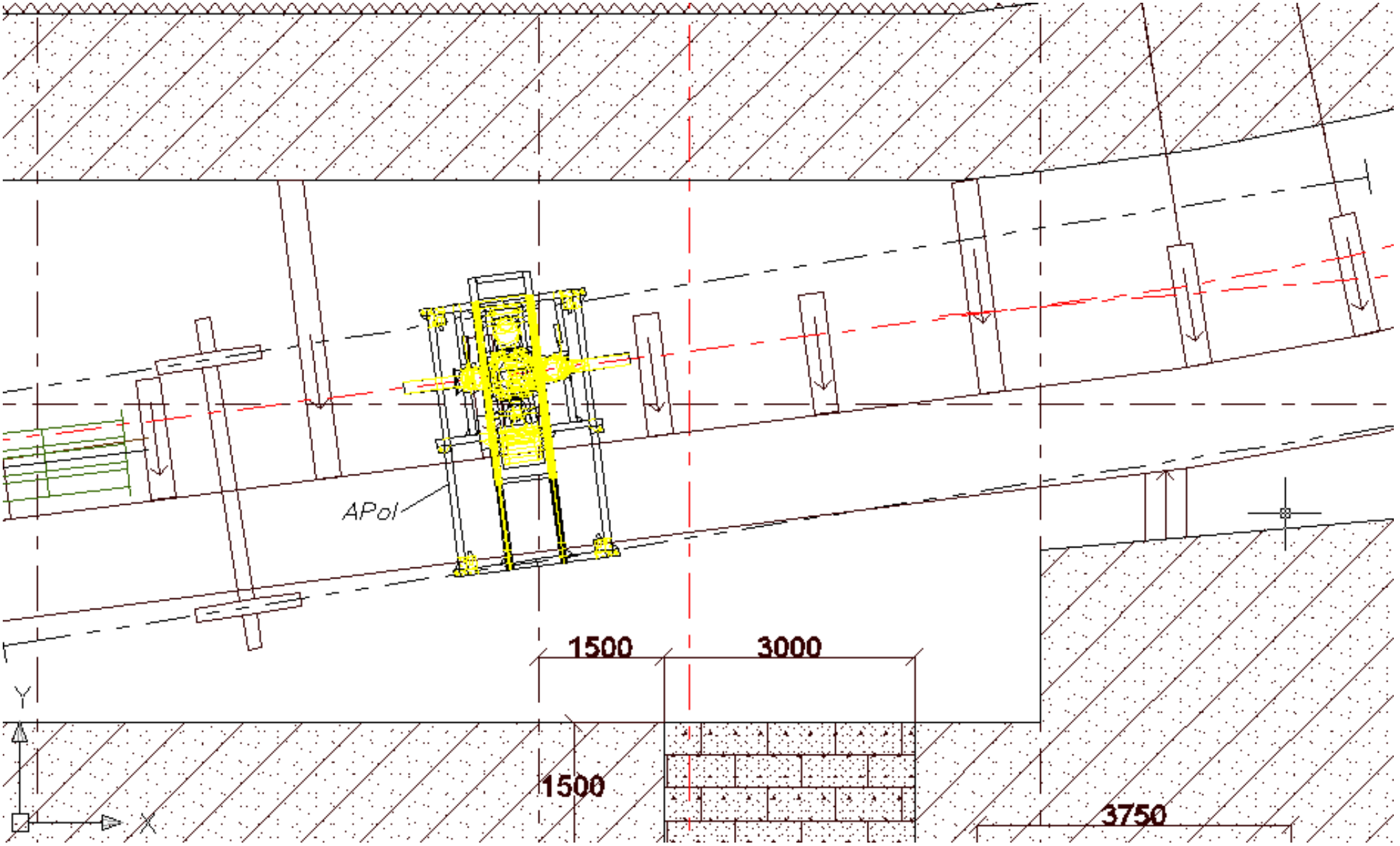
If we put numbers in the table we see:

Energy of the beam, GeV	Scattering cross-section, mb	Analizing power	Number of events needed for $\delta A_N=5\%$	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

Data for cross-sections and analizing powers are taken from NIMA **211** (1983) 239-261.

Proposed placement of the APol setup at NICA collider

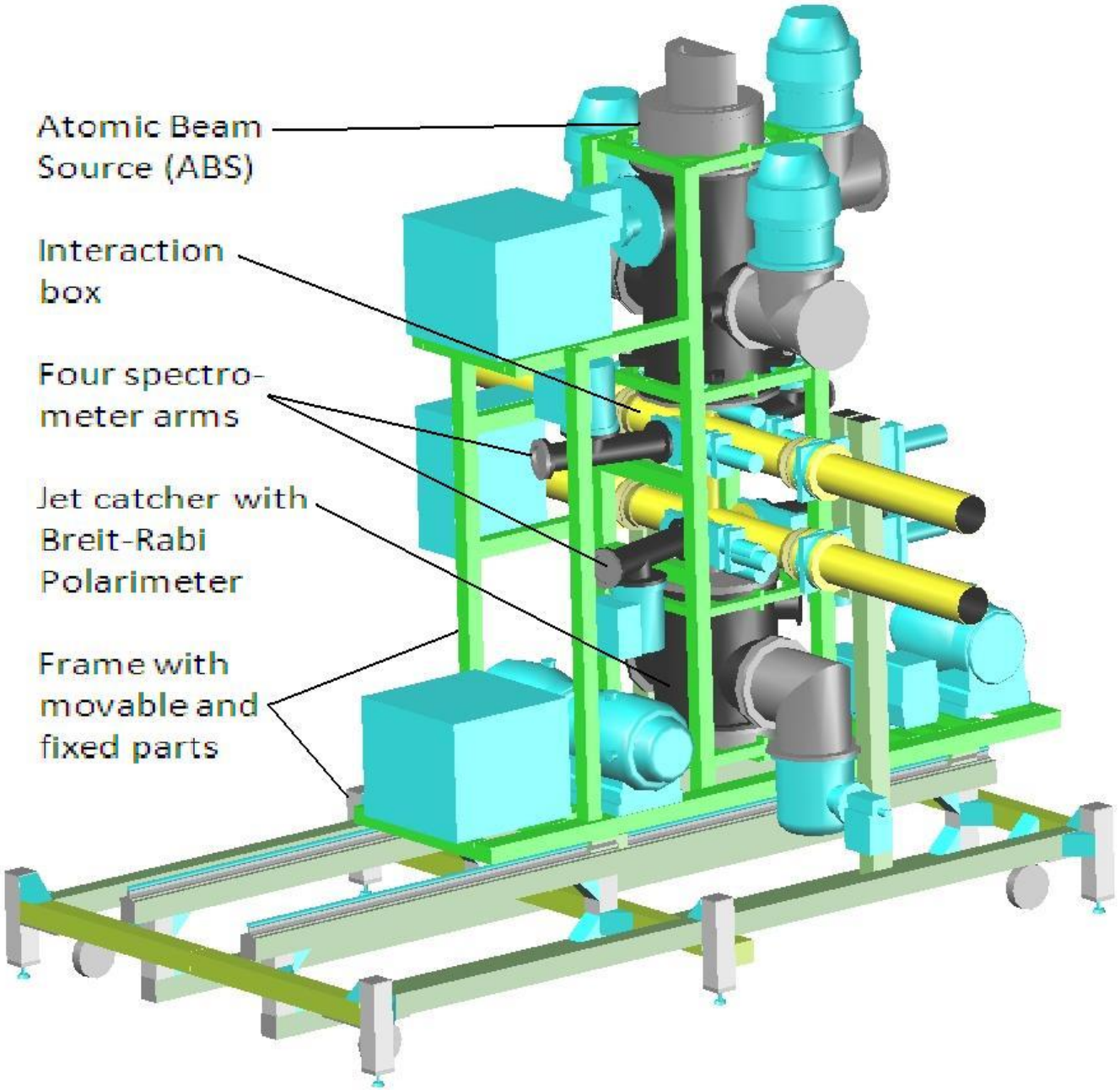
60 cm along the beam is needed for APol placement



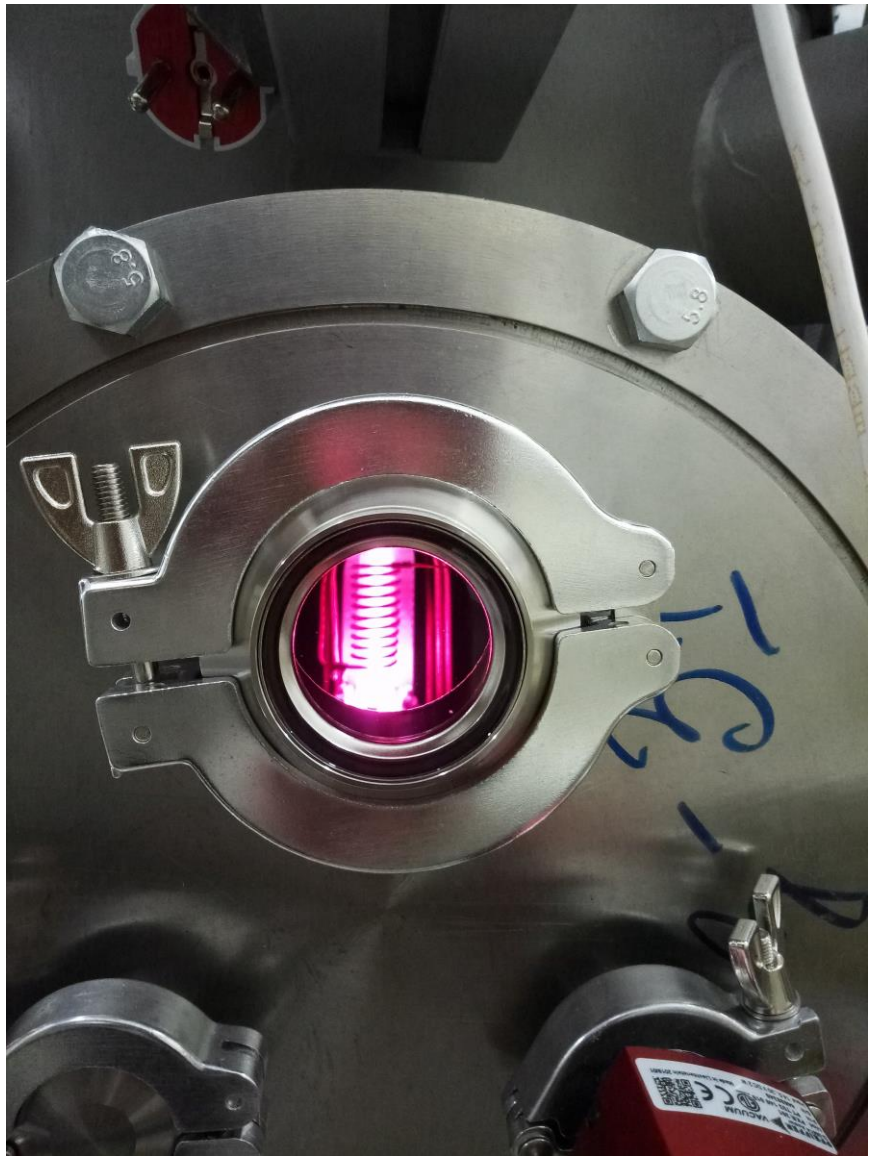
Main subunits of APol

APol cosists of:

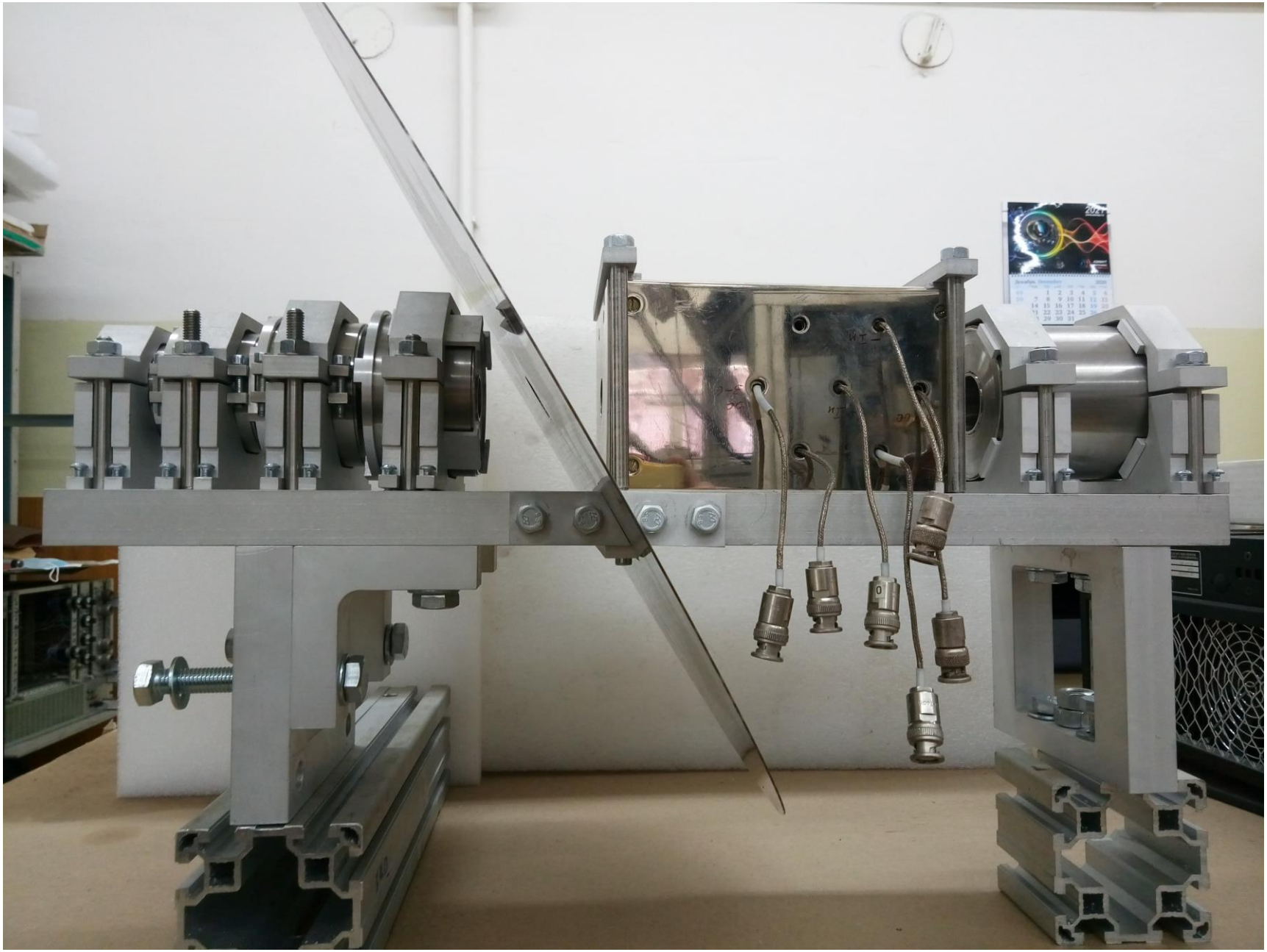
- Atomic Beam Source (ABS)
- Interaction box
- Four spectro-meter arms
- Jet catcher with Breit-Rabi Polarimeter
- Frame with movable and fixed parts



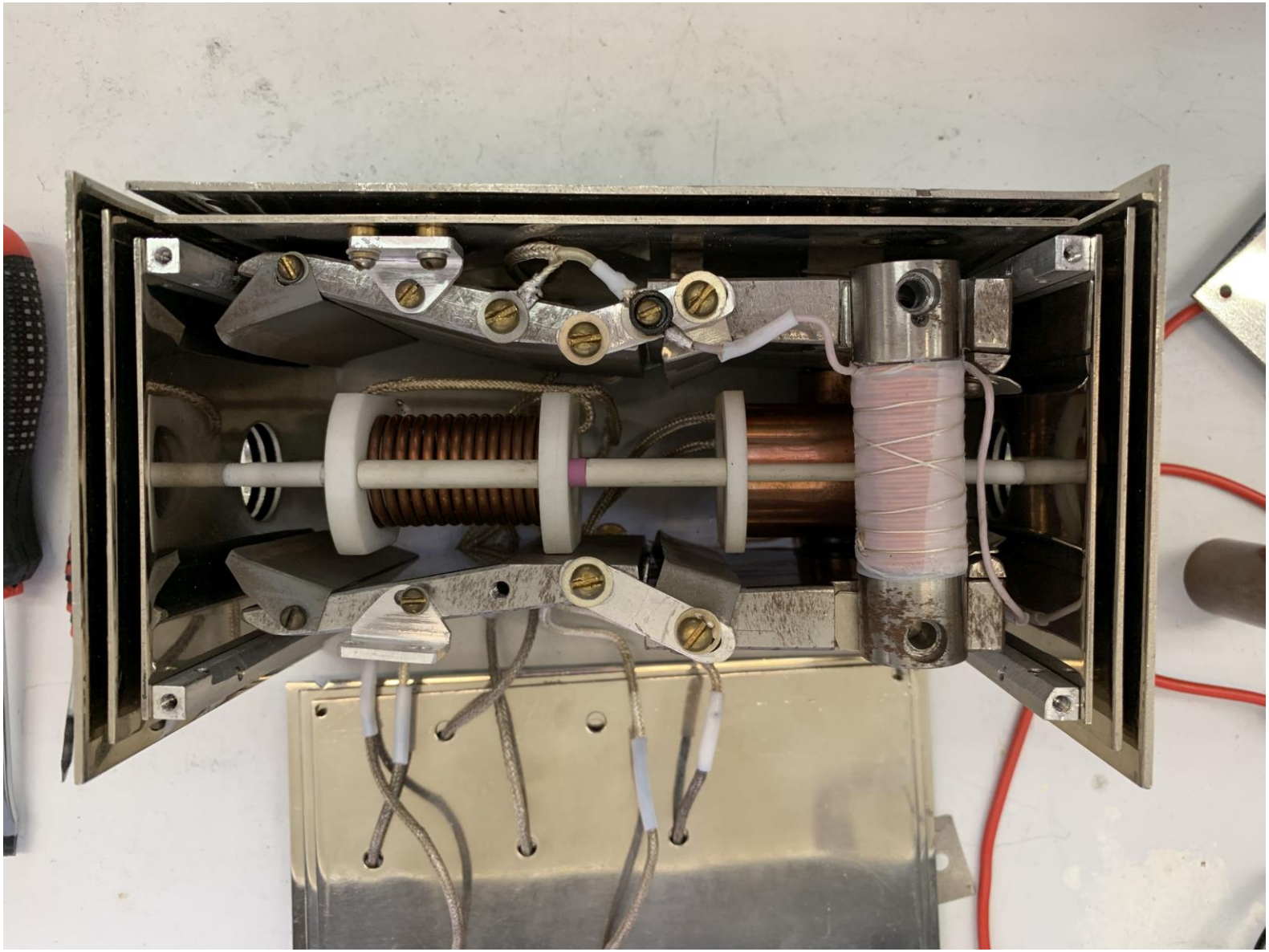
APol dissociator unit



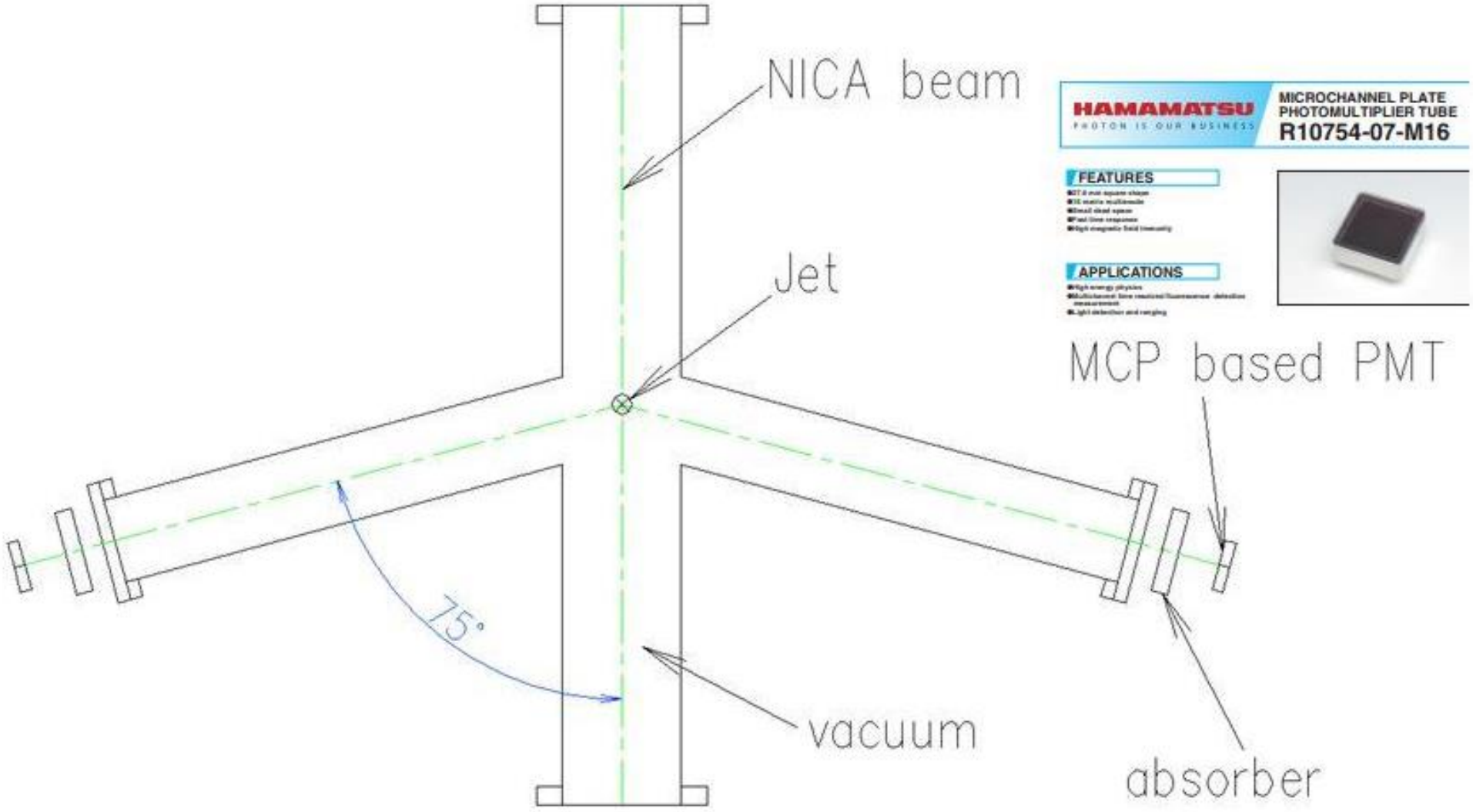
Desing of APol permanent Nd-Fe-B sextupole magnet



APol nuclear polarization cell



Preliminary scheme of APol detectors



Main operational parameters of APol:

- **steady operation mode**
- throughput of H_2/D_2

  Q = **1 torr·l/s = $3.4 \cdot 10^{19}$ molecule/s = $6.8 \cdot 10^{19}$ atom/s**
- nozzle temperature T_N=**80°K**
- speed of nozzle outflow (=speed of sound):

  for hydrogen - $c_H=(\gamma k_B T/m_H)^{0.5}$ = **1 km/s**

  for deuterium – $c_D=(\gamma k_B T/m_D)^{0.5}$ = **0.75 km/s**
- Mach number in atomic beam M=**2.9**
- most probable velocity for atomic beam velocity distribution:

  for hydrogen – **1940 m/s**

  for deuterium – **1370 m/s**
- beam temperature (=width of velocity distribution) T=**23°K**
- pole tip magnetic field of Nd-Fe-B sextupole magnets B_0=**1.7T**
- atomic beam intensity in the interaction region – **10^{17} atom/s**
- target thickness of the atomic beam in the box – **10^{12} atom/cm^2**

Vacuum conditions:

- differencial vacuum pumping system is used
- vacuum in dissociator chamber (the 1st stage): $5*10^{-4}$ mbar
- vacuum in beam forming chamber (the 2nd stage): $5*10^{-6}$ mbar
- vacuum in nuclear polarizing region chamber (the 3d stage): $1*10^{-6}$ mbar
- expected vacuum in interaction box: $1*10^{-10}$ mbar

Operational requirements:

Electric power: 10-15 kW, single phase, 220 V, 50 Hz

Cooling water: 1 m^3/h, 3 atm

Pressurized air: 6 atm

Occupied area: 6.5 m^2 (3.5m x 2m)

APol main dimensions (LxWxH): 3.5m x 2m x 3m

The polarimeter APol allows to produce
fast (few minutes) measurements of absolute values and signs of proton and deuteron accelerated beams polarization.
The measurements can be made
simultaneously on both NICA beams using a single polarized jet target.

The polarimeter APol requires
60 cm in NICA rings in “warm” gap and
normal to ring planes beams polarization axes in the interaction regions.