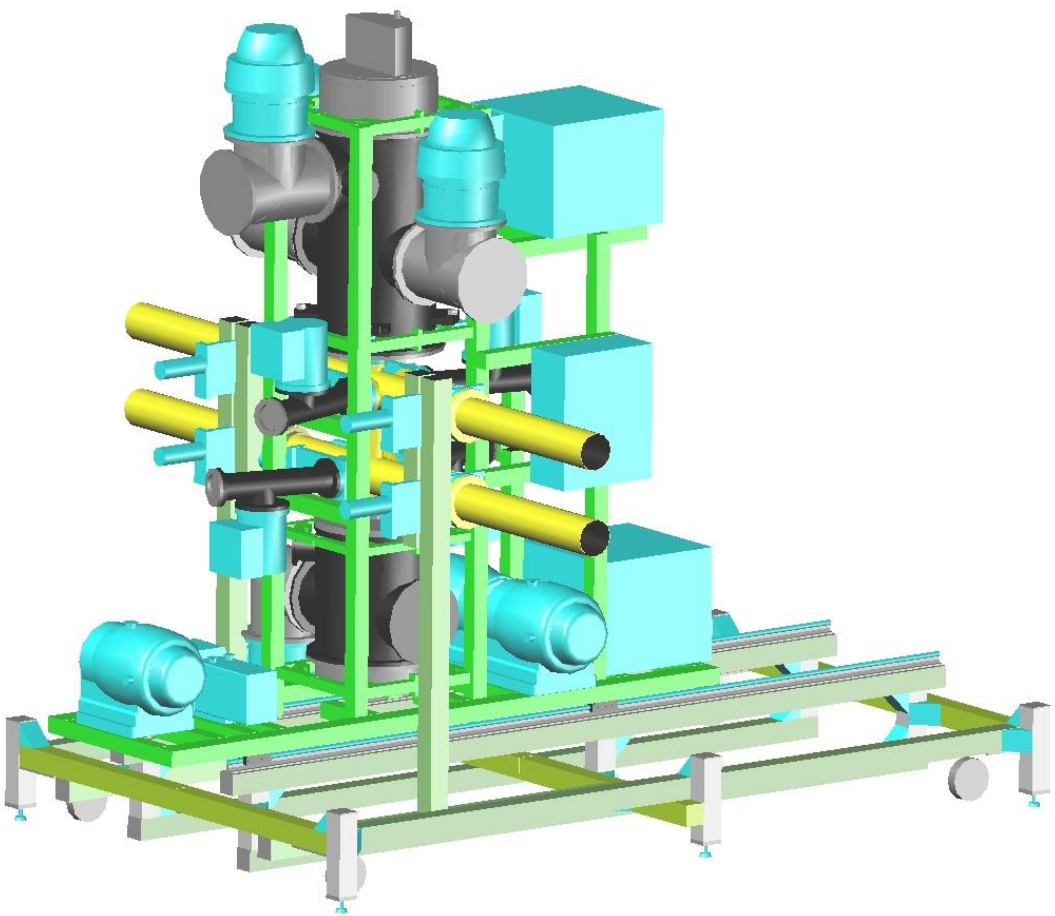
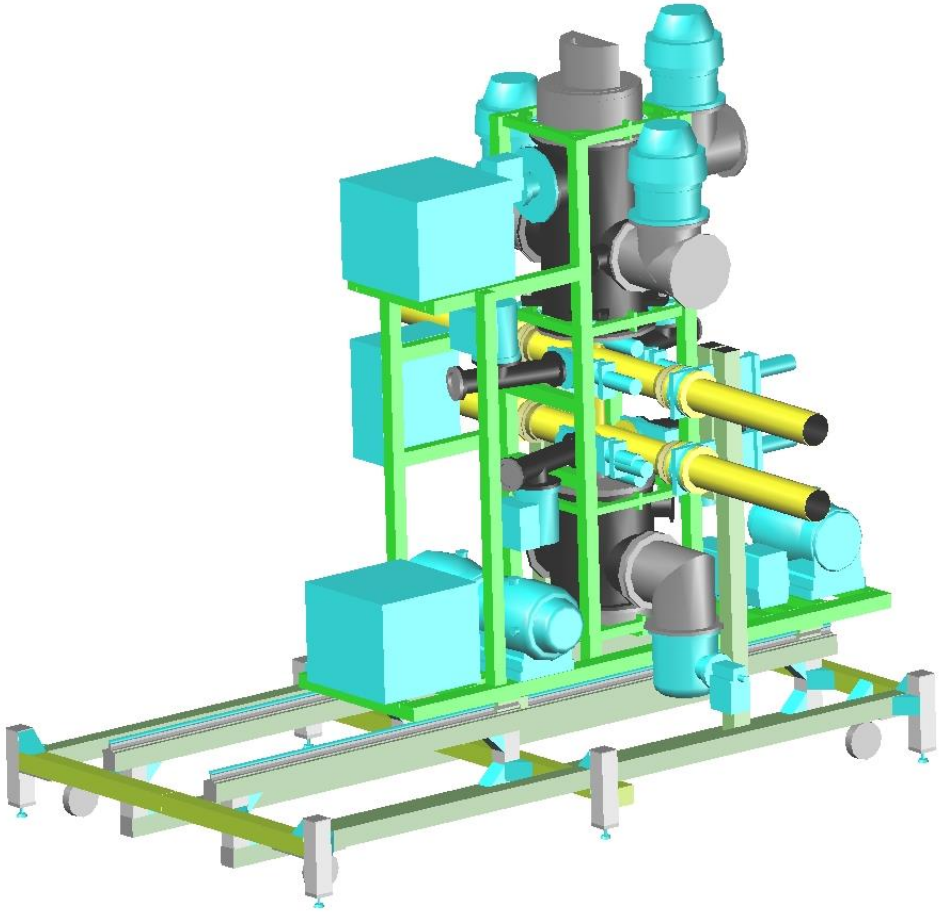
NICA Absolute Polarimeter

V.V. Fimushkin, M.V. Kulikov, R.A. Kuzyakin, Yu.V. Prokofichev,
A.M. Shumkov (JINR, Dubna)

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 views





Main tasks for APol

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

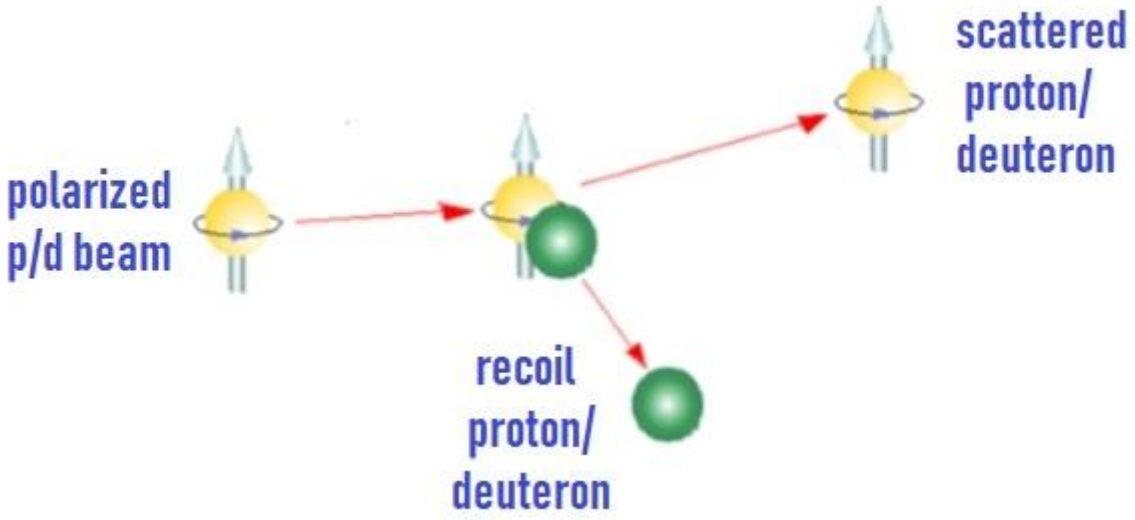
- determination the effect of
  disturbing Collider devices on beam polarization

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

The set-up development is carried out within the JINR theme 02-0-1065-2007/2019

"Development of the JINR Basic Facility for Generation of Intense Heavy Ion and Polarized Nuclear Beams Aimed at Searching for the Mixed Phase of Nuclear Matter and Investigation of the Polarization Phenomena at the Collision Energies up to $\sqrt{S_{NN}}$ = 11 GeV".

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%**

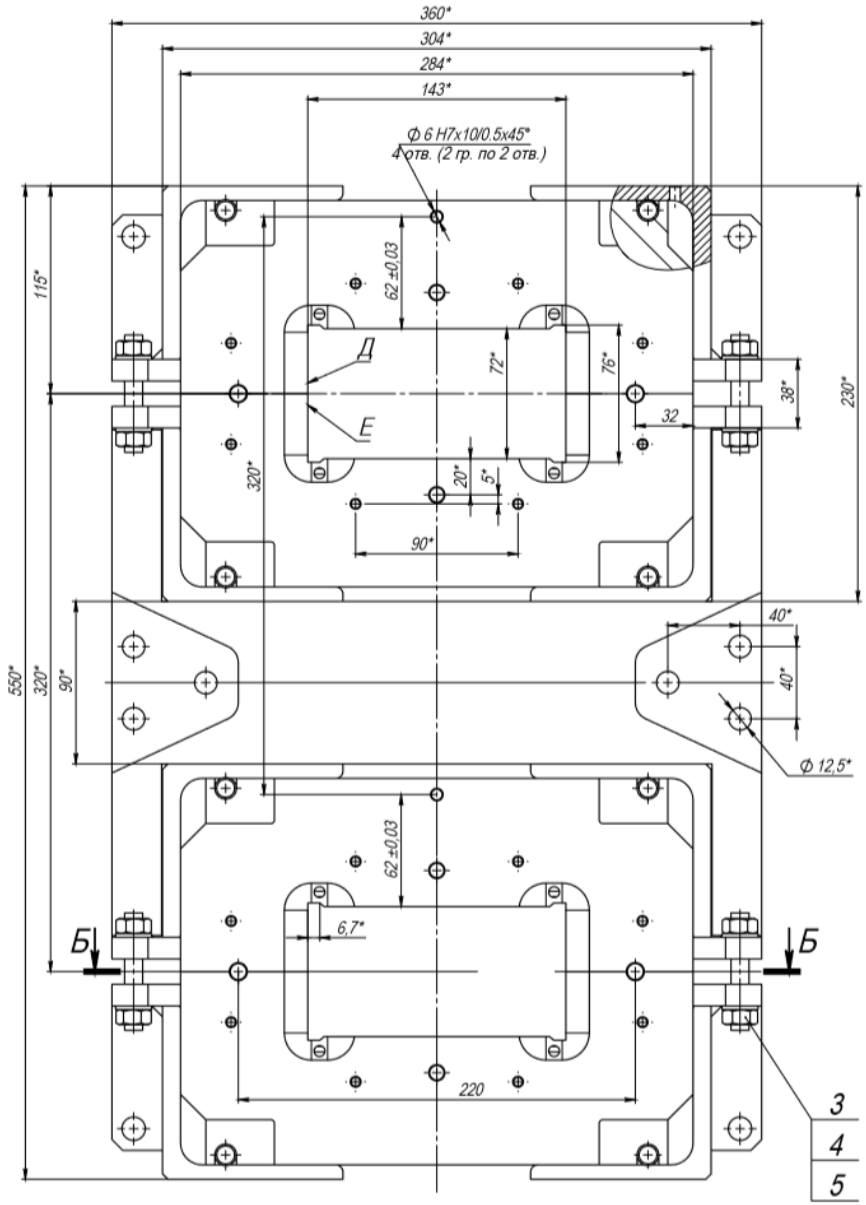
Measured beam polarization: $$P_{\text{beam}} = -\frac{\varepsilon_{\text{beam}}}{\varepsilon_{\text{jet}}} P_{\text{jet}} = -\frac{\varepsilon_{\text{beam}}}{A_N}$$

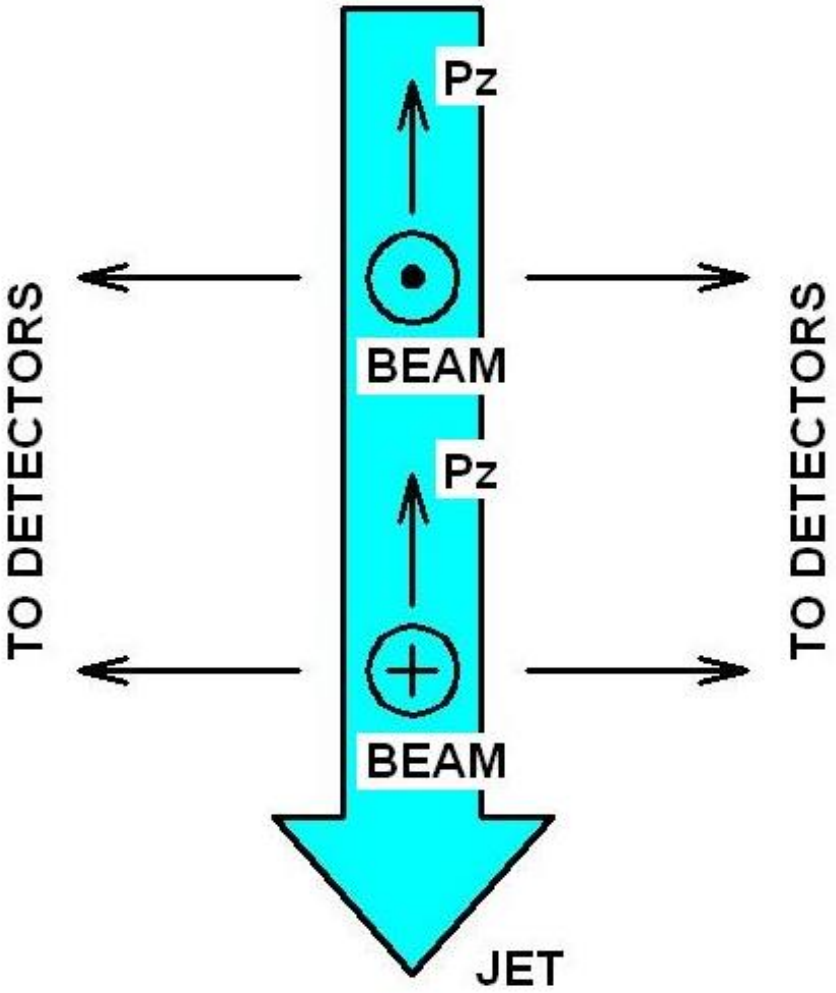
where $A_N = \varepsilon_{\text{jet}} / P_{\text{jet}}$ - analizing power of the polarimetric reaction

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

Actual geometry requirements

Section of NICA dipole magnet





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%: $T=N_A/N.$

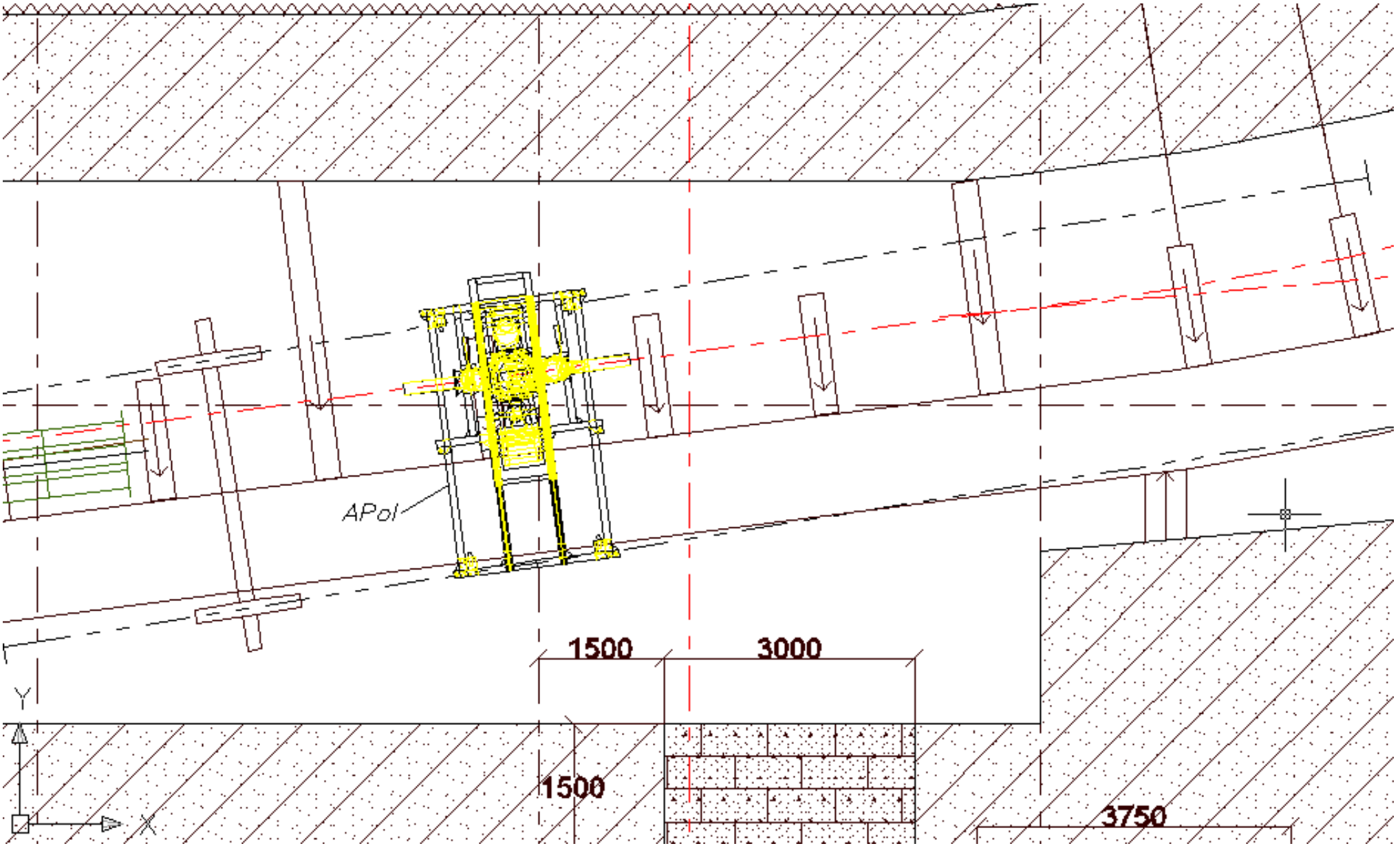
If we put numbers in the table we see:

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.

Placement of APol at NICA collider

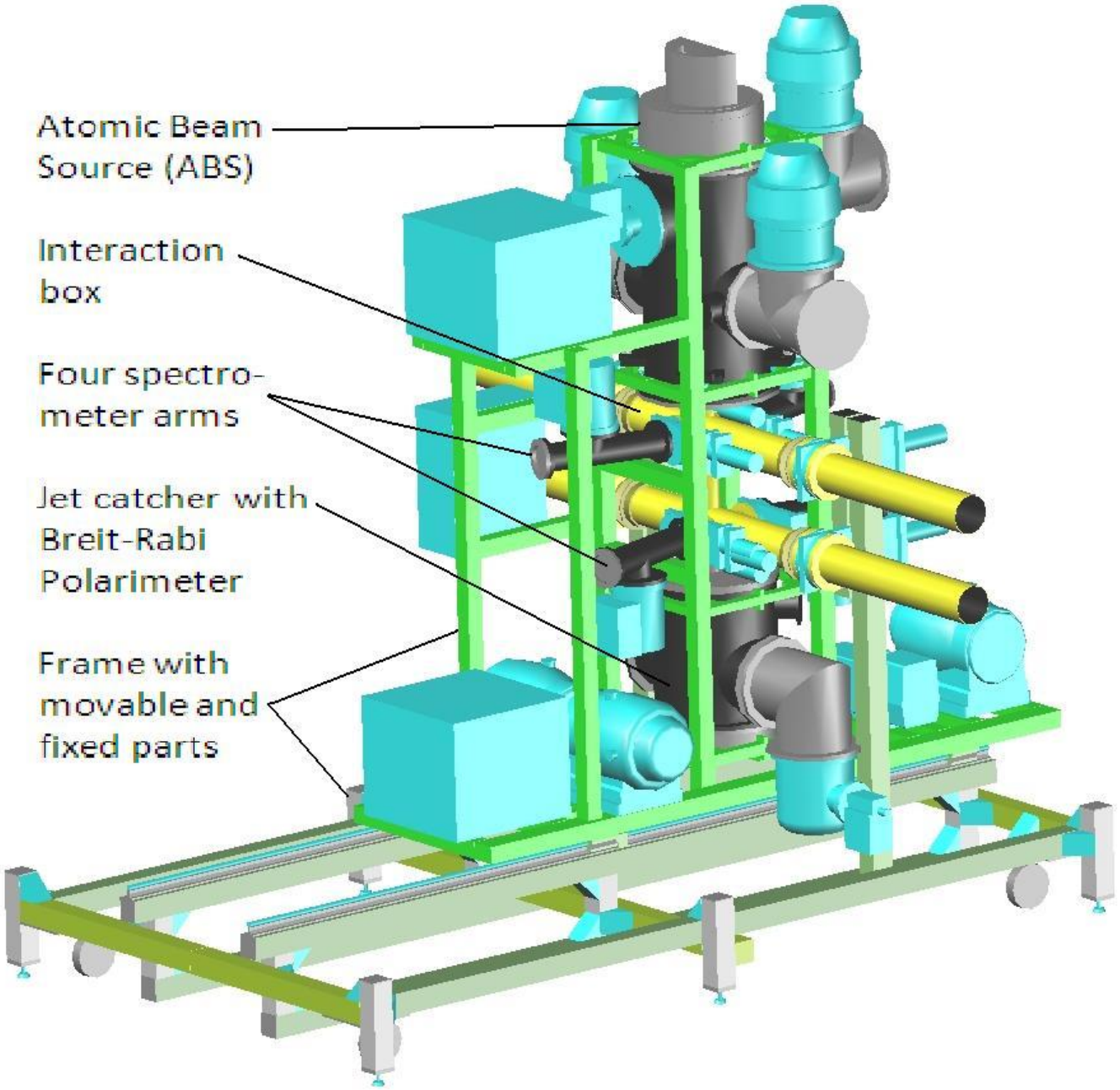
60 cm along the beam is needed for APol placement



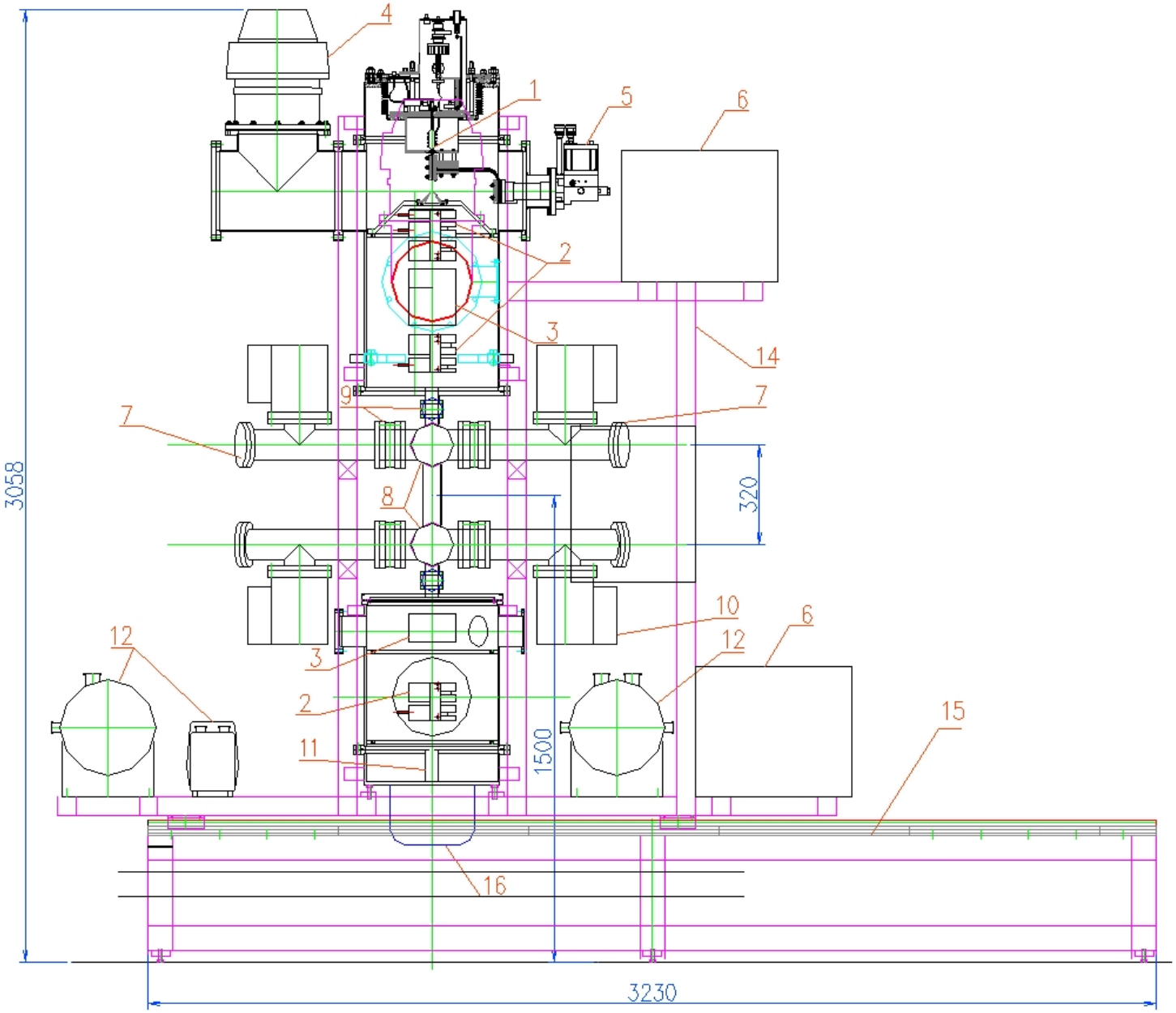
Main subunits of APol

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



Design and main dimensions of APol



Parts of APol:

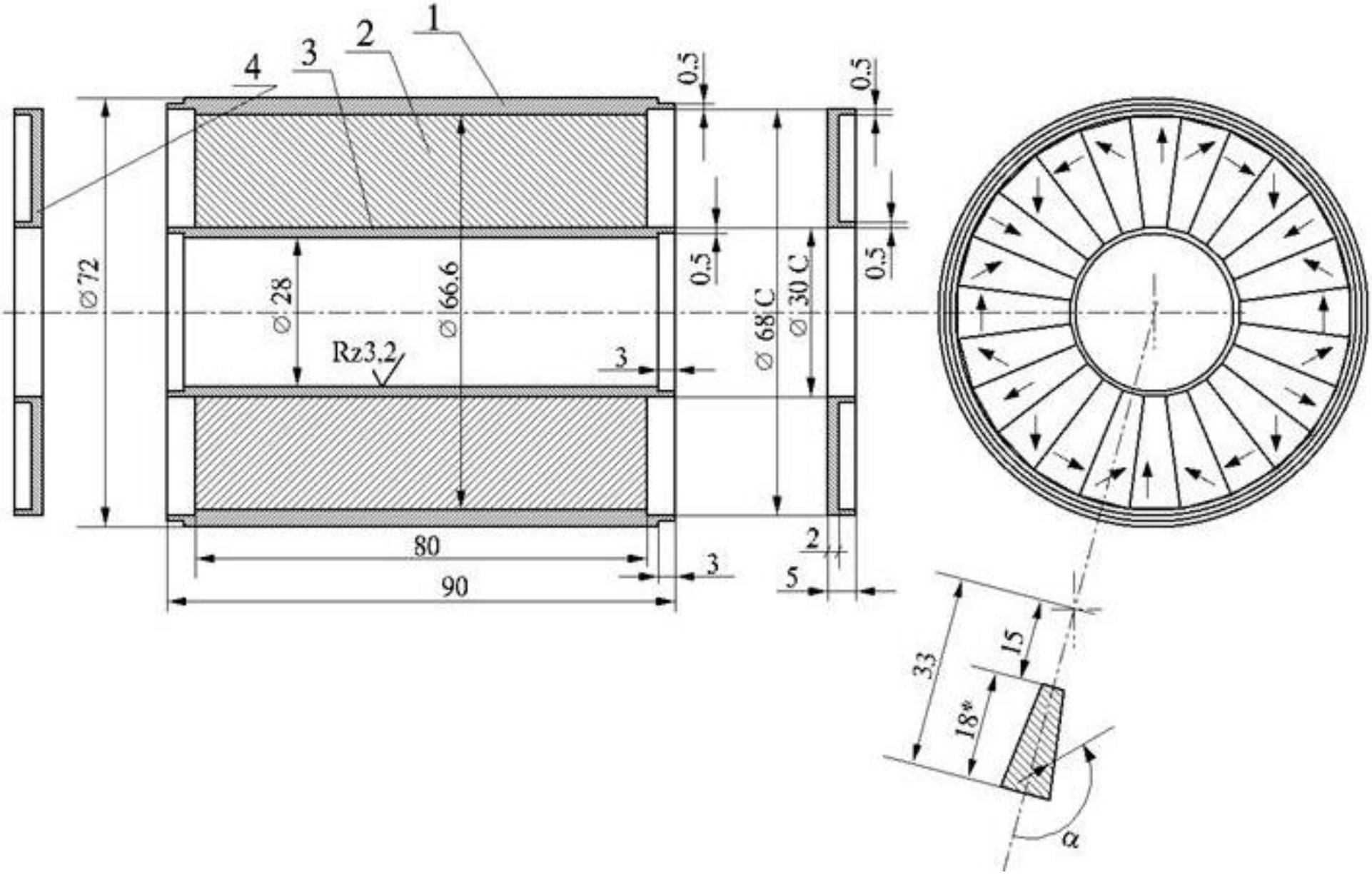
1. Dissociator
2. Sextupole magnets
3. Nuclear polarization cells
4. Turbomolecular pumps 1850 l/s
5. Cryocooler (78K)
6. Cryocooler compressor
7. Detector arm
8. Interaction box
9. UHV valves
10. Turbomolecular pumps 450 l/s
11. Mass-spectrometer
12. Forepumps
14. Movable frame
15. Fixed frame
16. Cryopump 3200 l/s

Caclulated target thickness

10^{12} atoms/cm^2

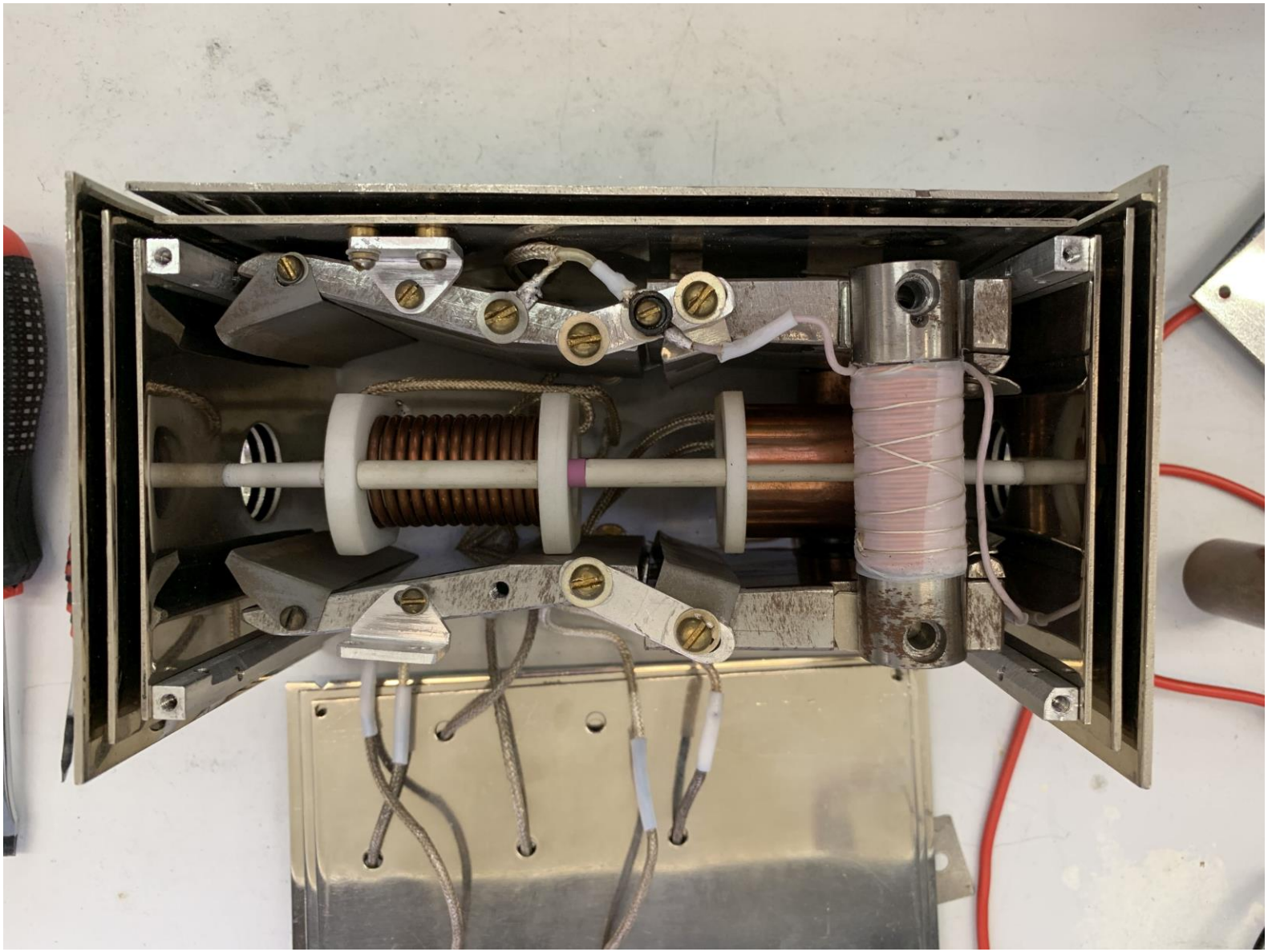
APol dissociator unit

Desing of APol permanent Nd-Fe-B sextupole magnet (example)

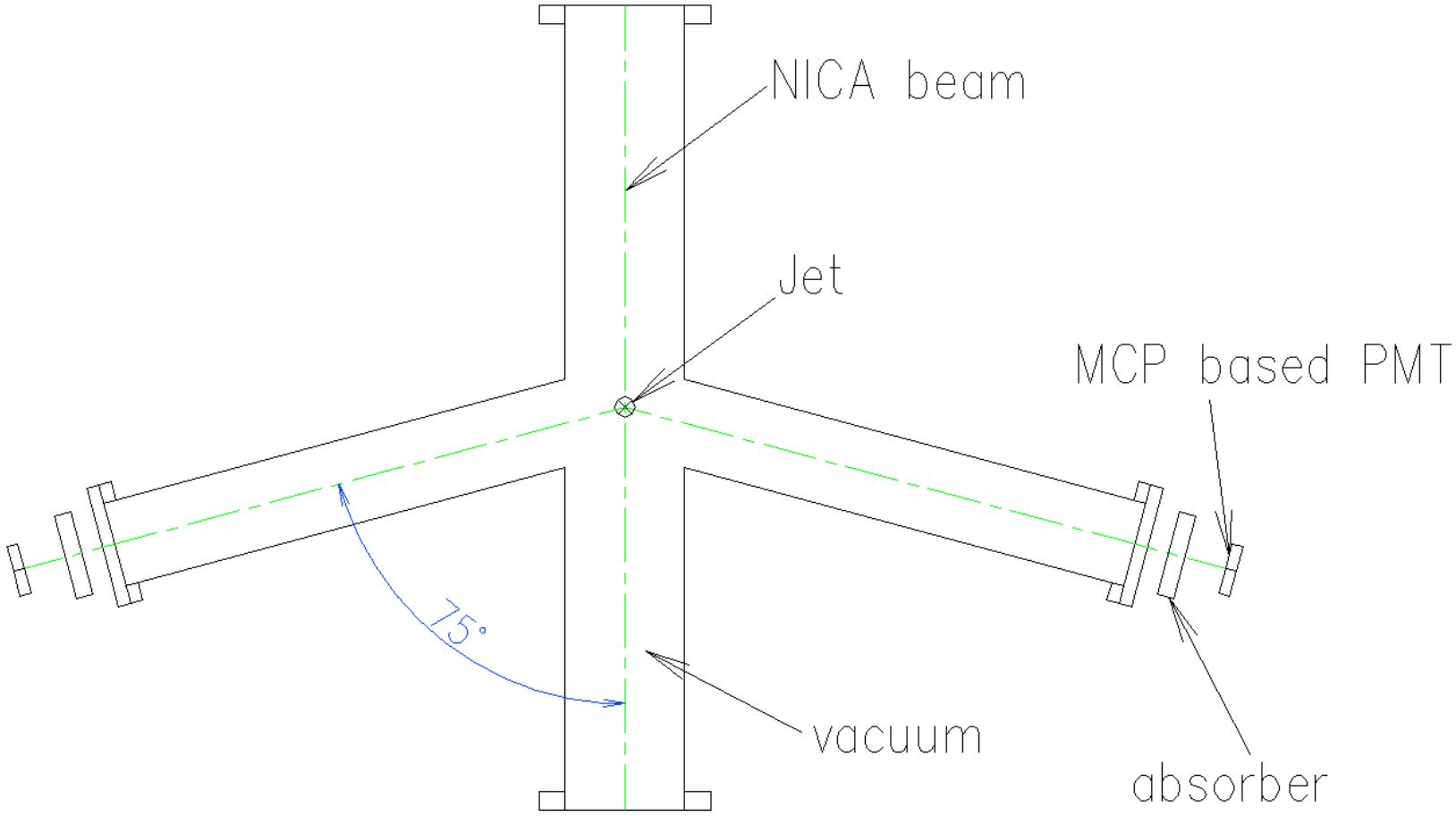


Arrows show a direction of magnetization

APol nuclear polarization cell



Preliminary scheme of APol detectors



APol frame with vacuum chambers of ABS and Breit-Rabi polarimeter.

Some 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**
- target thickness of the atomic beam in the box – **10^{12} atom/cm^2**

Needful equipment:

- vacuum chamber of the Atomic Beam Source – (ready)
- vacuum chamber of the Breit-Rabi polarimeter – (ready)
- cryogenerator Cryodyne 350CP and cryocompressor Brooks 8200 – (in stock)
- cryopump Cryo-Torr 250F (3200 l/s) (or analogue)– 1 unit
- turbomolecular pumps Pfeiffer HiPace 2300 (1850 l/s) (or analogue) – 3 units
- turbomolecular pumps Agilent TwisTorr 304 FS (220 l/s) (or analogue) – 4 units
- forevacuum dry scroll pumps Edwards XDS35i (or analogue) – 3 units
- forevacuum pump Alcatel Pascal 2021SD (or analogue) – 1 unit
- UHV valves (VAT or analogue), Dn 40 – 3 units
- vacuum gauges – 7 units
- vacuum components
- RF transition cells for nuclear polarization of hydrogen/deuterium atoms
- assembly of NdFeB permanent sextupole magnets – 5 units
- mass-spectrometer for hydrogen/deuterium

- RF voltage generator and high voltage modulator for dissociator generator
- RF amplifier 500MHz, 20W – 1 unit
- RF amplifier 250MHz, 25W – 1 unit
- remote control system
- mounting racks and enclosures for electrophysical equipment

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

Conclusion

The polarimeter APol allows to make

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.