



Status of the **S**ource of **P**olarized **I**ons project for the **JINR** accelerator complex (September 2013)

**V.V. Fimushkin, A.D. Kovalenko, L.V. Kutuzova,
Yu.V. Prokofichev**

• *Joint Institute for Nuclear Research, Dubna*

A.S. Belov, V.N. Zubets, A.V. Turbabin

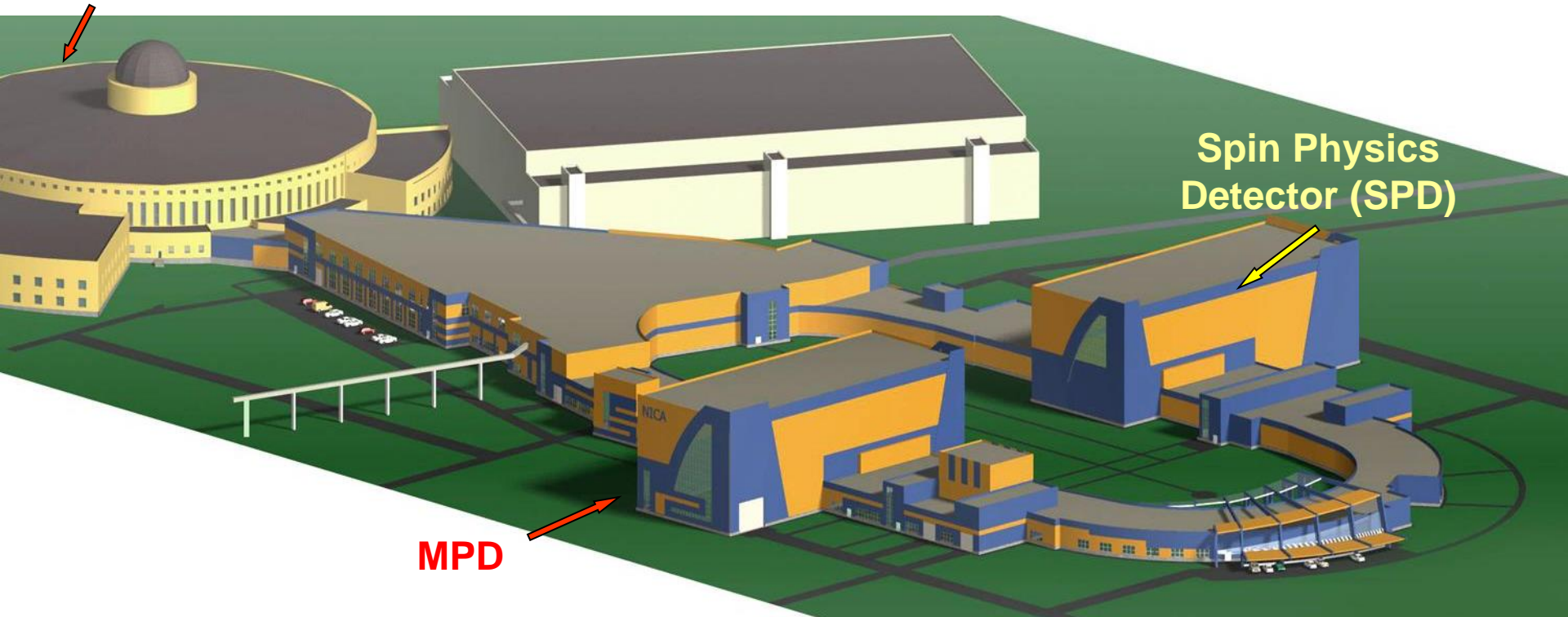
• *Institute for Nuclear Research of Russian Academy of Sciences,
Moscow*

General view of the NICA facility

The new flagship JINR project in high energy nuclear physics, **NICA**

(**Nuclotron-based Ion Collider fAcility**), aimed at the study of phase transitions in strongly interacting nuclear matter at the highest possible baryon density, was put forward in 2006

SPI & linac



MPD

**Spin Physics
Detector (SPD)**

The **NICA** program consists of several subprojects

Physics with **polarized light ion beams** is considered as an important part of the **NICA** collider program also

The expected luminosity of polarized beams is planned at the level of $10^{32} \text{ cm}^{-2} \cdot \text{s}^{-1}$

- Development of the polarization program at **NUCLOTRON/NICA** facility supposes the substantial increasing of pulsed intensity of source of the polarized light nuclei
- **The new project:** **S**ource of **P**olarized **I**ons project (**SPI-project**) assumes the design and production of **the universal high-intensity source of polarized deuterons & protons**
- As the first step the increase of intensity of the accelerated polarized D^+ beam is supposed
- The important fact is depolarization resonances are absent in the total energy range of the **NUCLOTRON-M** but only for the **deuteron beam**

The main purpose of the **SPI-project** is to increase the intensity of the accelerated polarized beams at the JINR Accelerator Complex up to **10^{10} d/pulse**

The **SPI-project** assumes the development of the source using charge-exchange ionizer

Nearly resonant charge-exchange reactions for production of polarized protons & deuterons are:



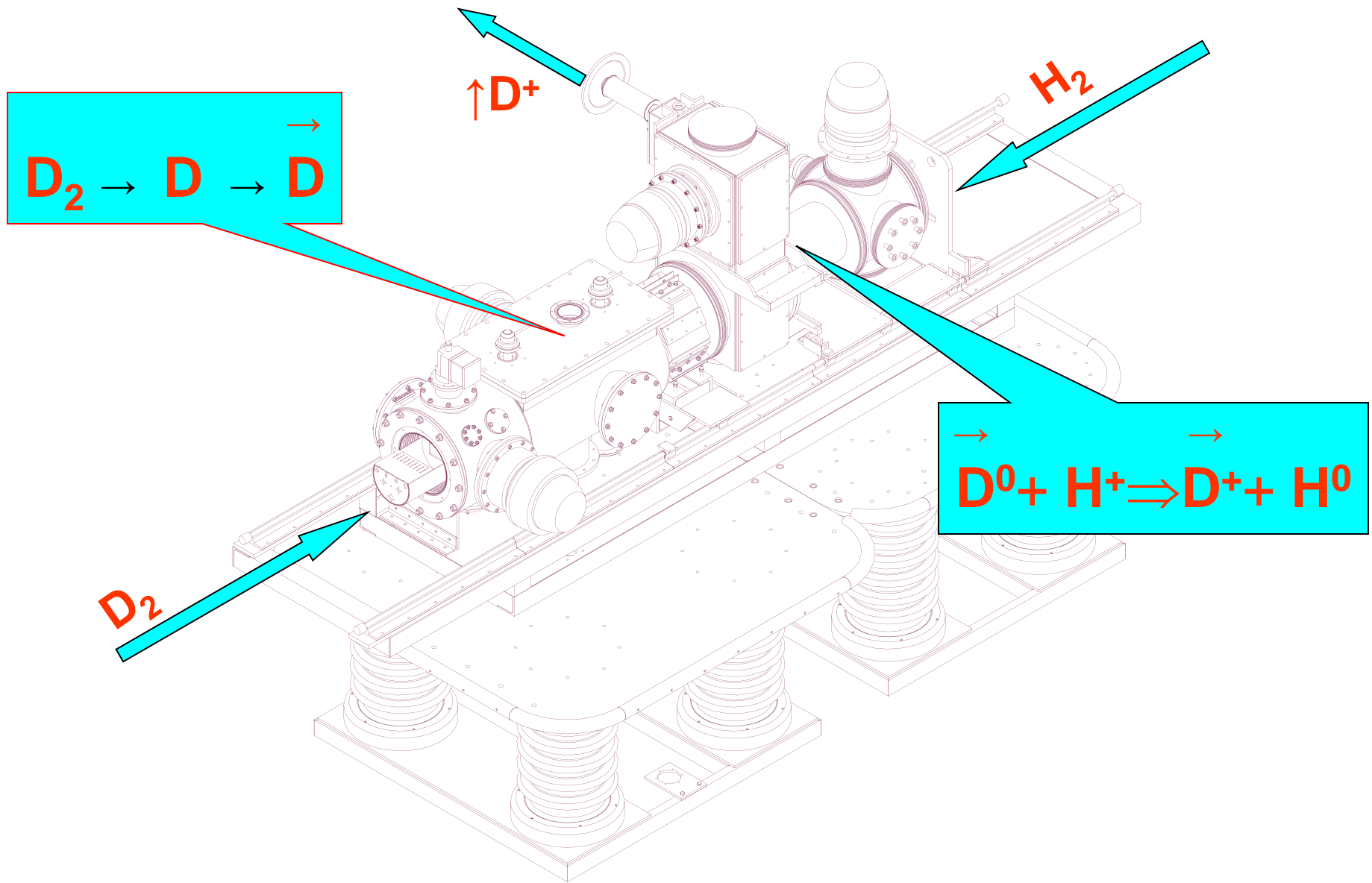
- The design output current of the **SPI** is up to **10 mA** for $\uparrow\text{D}^+$ ($\uparrow\text{H}^+$)
- The **D⁺** polarization will be up to 90% of the maximal vector (± 1) & tensor (**+1,-2**) polarization
- The **SPI** is based in substantial part on the equipment from IUCF(Bloomington, USA)

***The project is realized in close cooperation with INR of RAS
(Moscow, Russia)***

The SPI-project includes the following stages:

- development of the high-intensity **Source of Polarized Ions**
- complete tests of the **SPI**
- modification of the linac pre-accelerator platform & power station
- remote control system (**console of linac**) of the **SPI** under the high voltage
- **SPI & Linac** runs with polarized beam and polarization measurements at the linac output

NEW SOURCE OF POLARIZED IONS (DEUTERONS)



The **NUCLOTRON** feature is that the injection is possible only for **positive ions**

Therefore it is expedient to use the **source of positive polarized deuterium ions**

Note: The highest intensity of the beam is reached for positive polarized ion sources with charge-exchange plasma ionizer and the storage cell

- **SPI-source** assumes to use the storage of polarized deuterium atoms and production of **positive polarized deuterons** by resonance charge-exchange in the hydrogen plasma

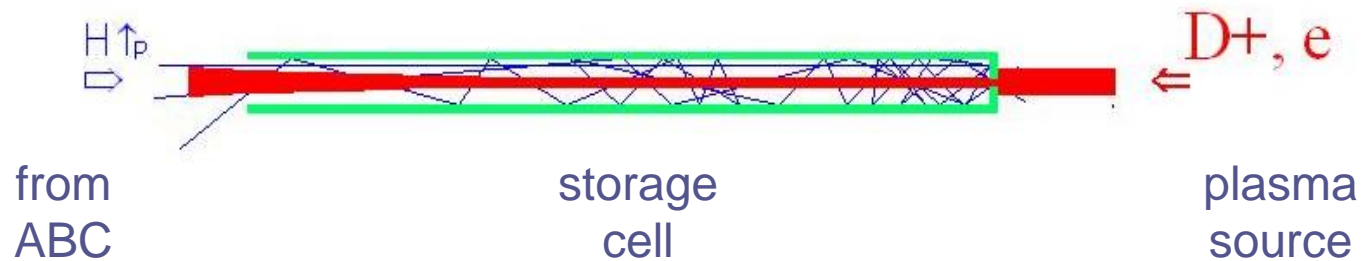
The ionizer with storage of polarized atoms for the SPI allows

- increase intensity of the polarized D^+ beam
- reduce emittance of the polarized beam
- considerably reduce H_2^+ ion current which is difficult to be separated from polarized D^+ due to similar mass of the ions

INR RAS polarized ion source

- atomic beam-type source with resonant charge-exchange plasma ionizer and with a storage cell in the charge-exchange region

(Belov et. al. INR RAS, 1986, 1999)



11 mA of H⁺↑ 80 % polarization has been obtained from the INR source

ABS development

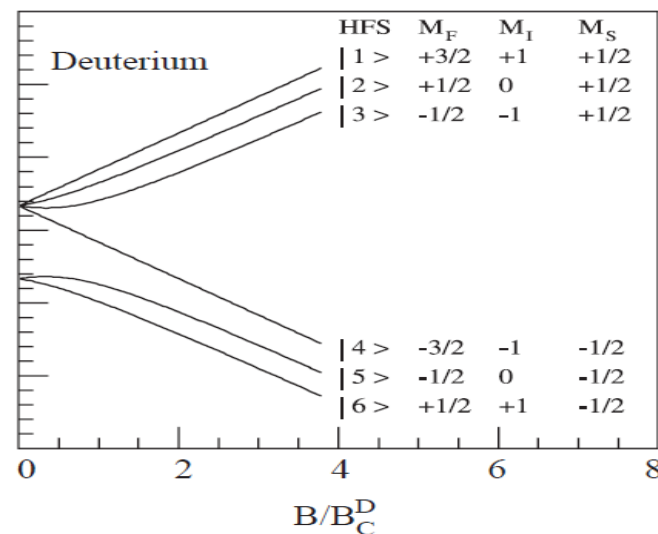
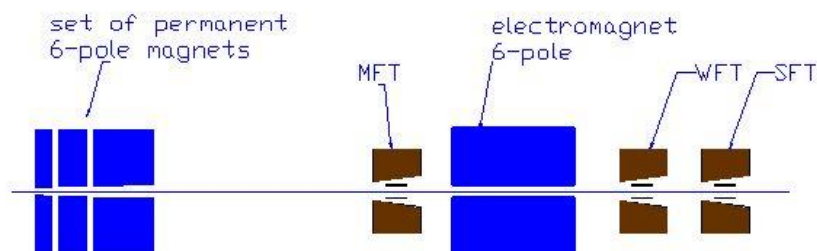
Atomic Beam Source (ABS) of the SPI has been produced and tested at
INR RAS

- ✓ The pulse density of atomic D beam at the distance of 150 cm from the cooling nozzle outlet is $2.5 \cdot 10^{+10}$ at/cm³ at the most probable velocity of $1.5 \cdot 10^{+5}$ cm/s
- ✓ Functional tests of WFT&MFT of the RF cells of the nuclear polarization of deuterium (hydrogen) atoms were performed

ABS tests results

- Atomic D & H beam intensities were measured
The averaged beam intensities are
 $I_D = 8 \cdot 10^{16} \text{ at/s}$ $I_H = 5 \cdot 10^{16} \text{ at/s}$
- Nozzle temperature was scanned over a range of 16...80 K
The optimum nozzle temperature is about 27 K
The optimum feed rate is about 0.045 mbar · l / pulse

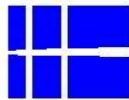
RFT scheme and deuteron polarization



HFT between 6poles	HFT after 6poles	Final D hfs	P_Z	P_{ZZ}
MFT $3 \rightarrow 4$	WFT $1 \rightarrow 4, 2 \rightarrow 3$	3,4	-1	+1
MFT $3 \rightarrow 4$	SFT $2 \rightarrow 6$	1,6	+1	+1
MFT $1 \rightarrow 4$	SFT $3 \rightarrow 5$	2,5	0	-2
MFT $1 \rightarrow 4$	SFT $2 \rightarrow 6$	3,6	0	+1

Tests of the WFT

set of permanent
6-pole magnets



WFT



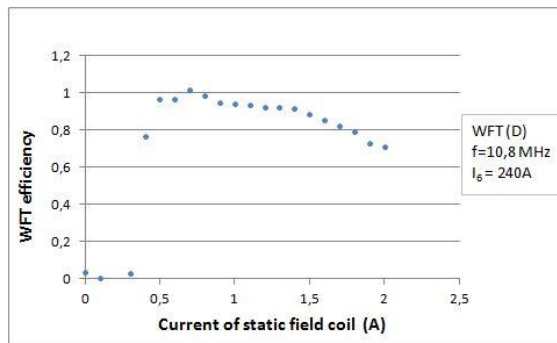
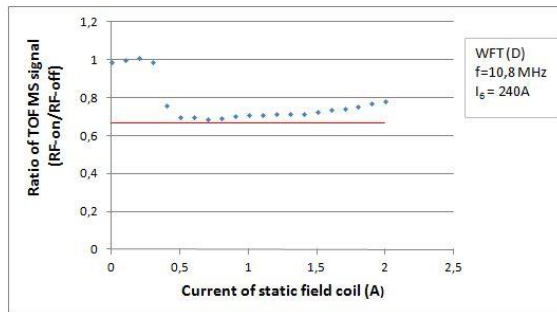
electromagnet
6-pole



TOF MS

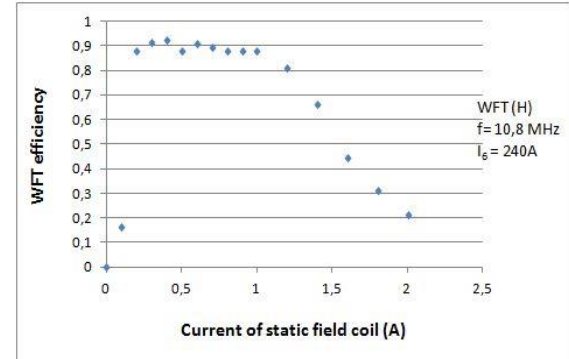
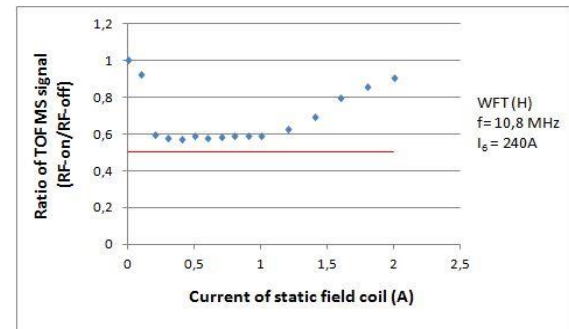


Deuterium atoms



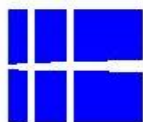
D atoms WFT efficiency – 0.95

Hydrogen atoms



H atoms WFT efficiency – 0.90

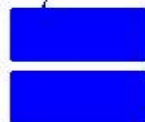
set of permanent
6-pole magnets



MFT



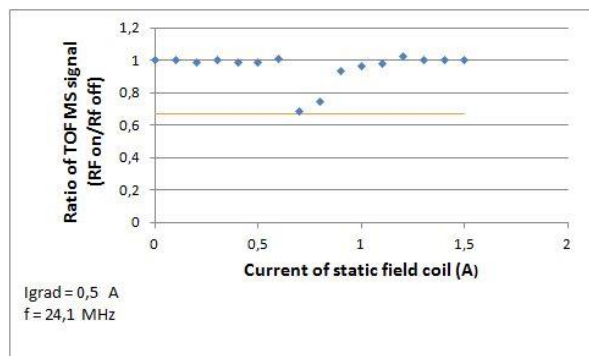
electromagnet
6-pole



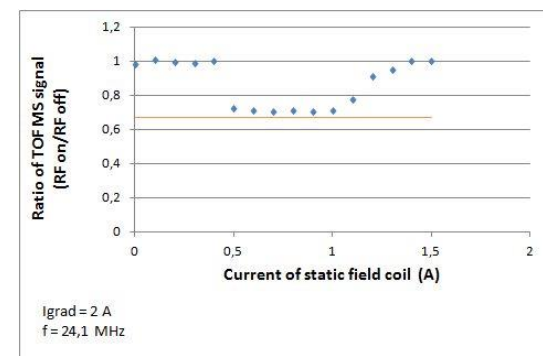
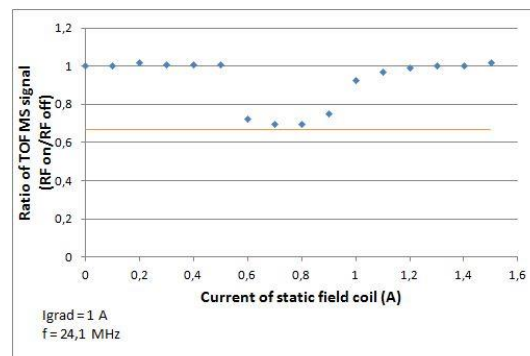
TOF MS



Deuterium atoms



3 → 4 mode



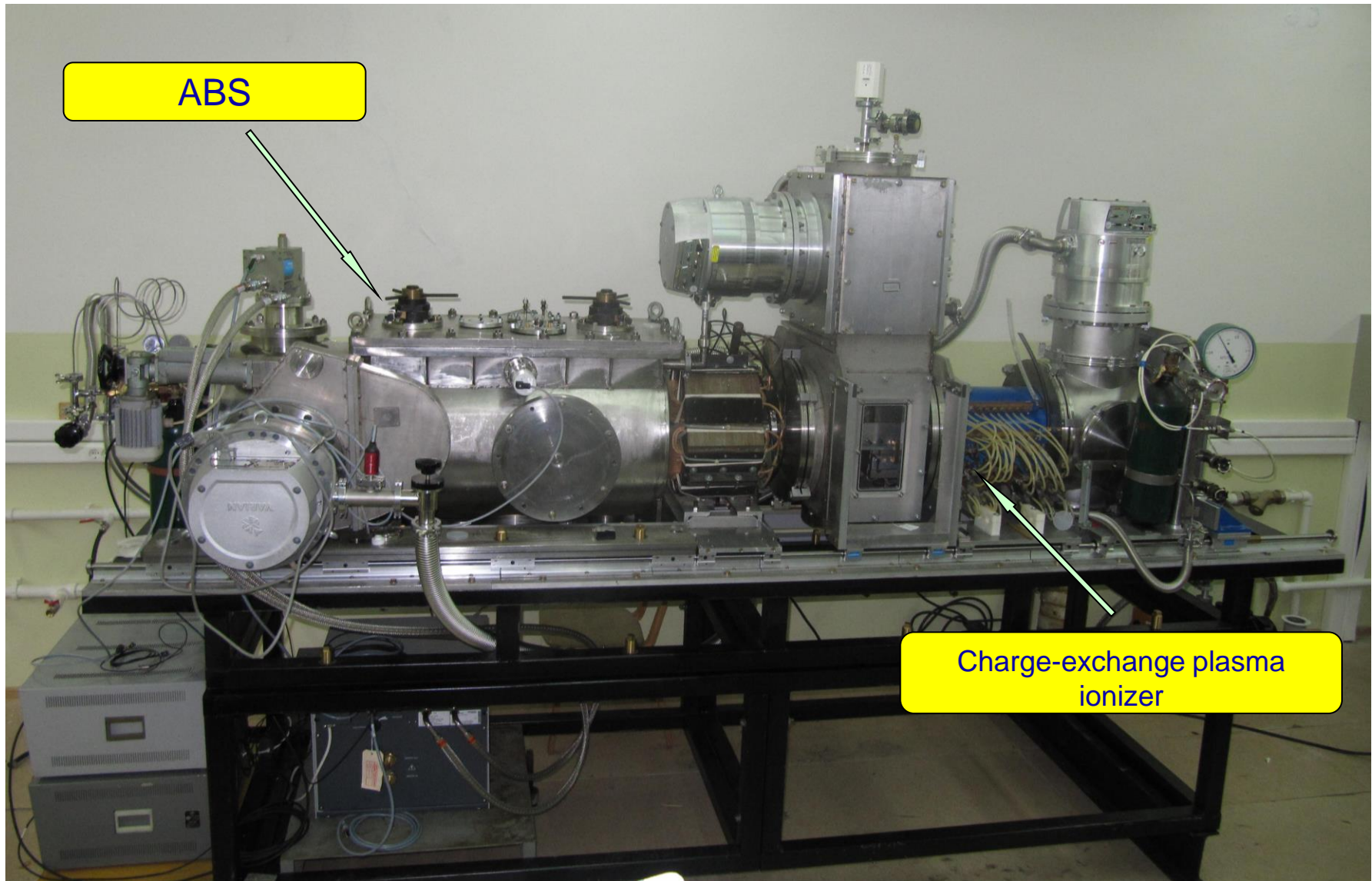
1 → 4 mode

The work which is carried out at JINR includes

- assembly and tests of the charge-exchange plasma ionizer, including the storage cell in the ionization volume
- optimization of the ion-optical system up to 25 keV and transport of the high-current deuteron beam
- long-term tests of the SPI with the storage cell in the ionizer
- polarimetry of the accelerated beam at the output of linac

It is necessary to develop control system components for primary analysis & data acquisition and for fiber optic system of data transmission

General view of **SPI** (September 2012)



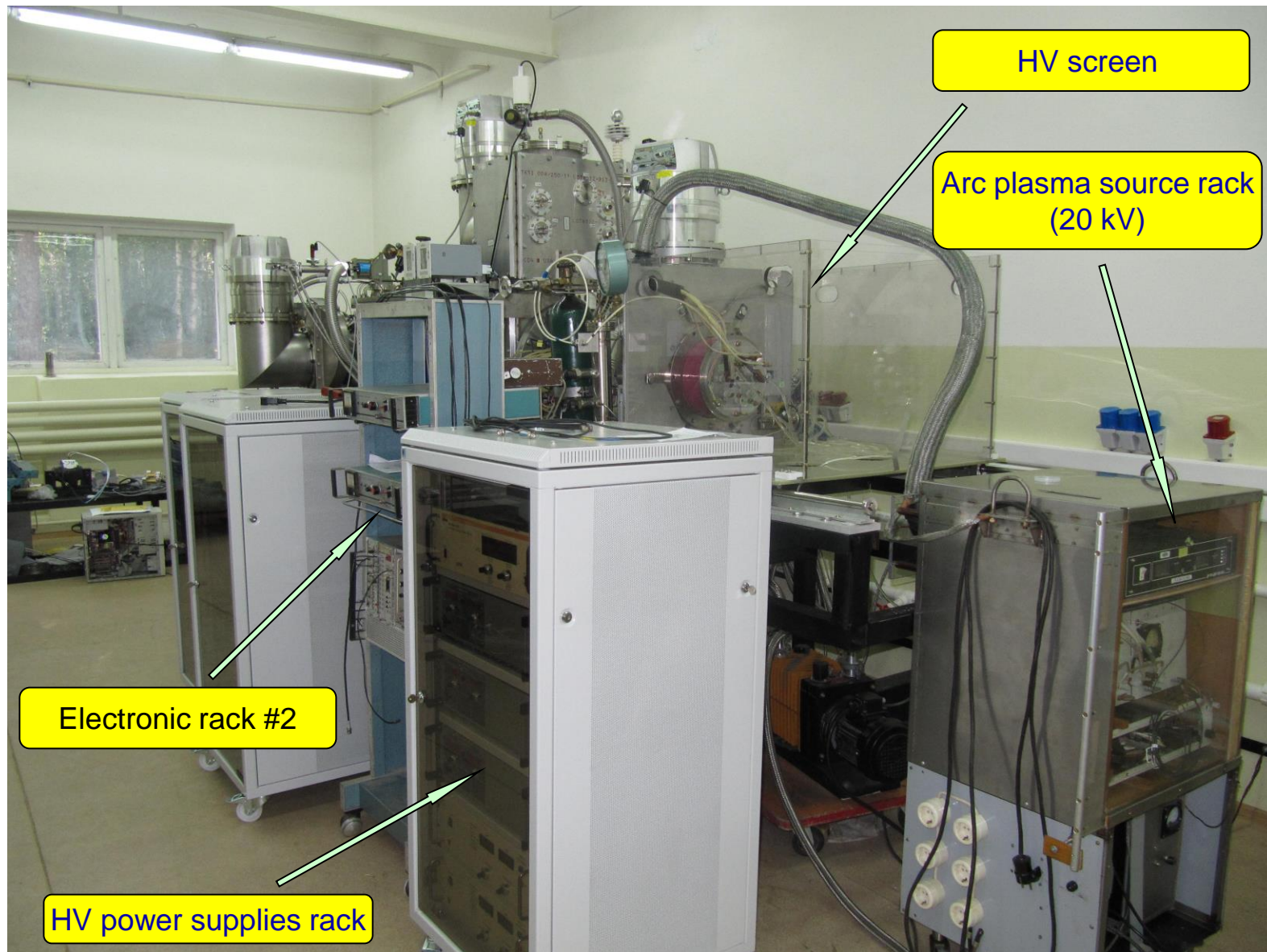
SPI view from the dissociator chamber



General view of **SPI** (June 2013)



General view of **SPI** (June 2013)



Tests bench program of the SPI in 2013

- operating with deuterium plasma arc source, running with the charge exchange ionizer
- start-up and testing of SPI mode of polarized protons obtaining
- operating with hydrogen plasma arc source, running with the charge exchange ionizer including the storage cell in the ionization volume
- start-up and testing of SPI mode of polarized deuterons obtaining

Summary

- Active development of the SPI at JINR began in mid-2011
- In August 2012, the ABS was transported from the INR of RAS (Moscow) and assembled at JINR
- All-inclusive SPI-testing will be carried out at JINR in 2013



Thank you