Status of the new Source of Polarized Ions for the JINR accelerator complex

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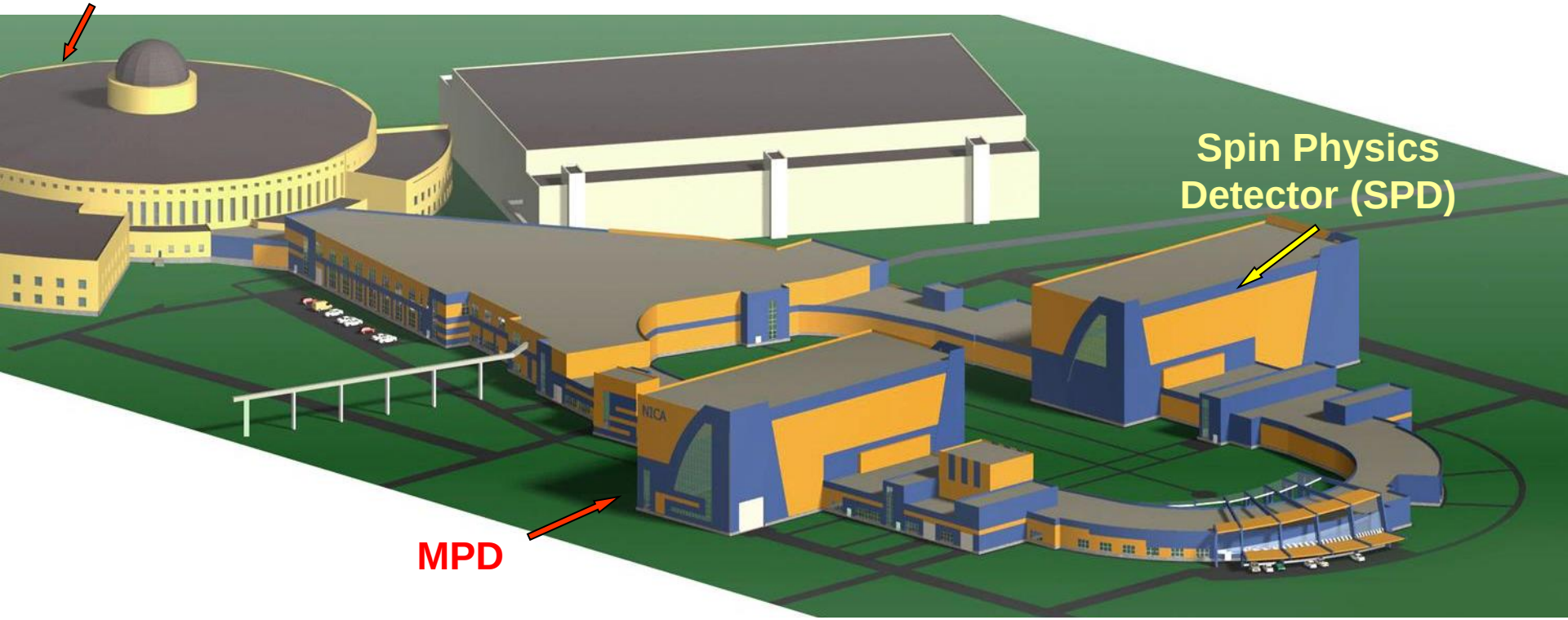
General view of the NICA facility

The new flagship JINR project in high energy nuclear physics, **NICA** (**N**uclotron-based **I**on **C**ollider f**A**cility), aimed at the study of phase transitions in strongly interacting nuclear matter at the highest possible baryon density, was put forward in 2006



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} $cm^{-2} \cdot s^{-1}$

- 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:

$$H^{o}\uparrow + D^{+} \Rightarrow \mathbf{H^{+}}\uparrow + D^{o}$$
$$D^{o}\uparrow + H^{+} \Rightarrow \mathbf{D^{+}}\uparrow + H^{o} \qquad \sigma \sim 5 \cdot 10^{-15}\ cm^{2}$$

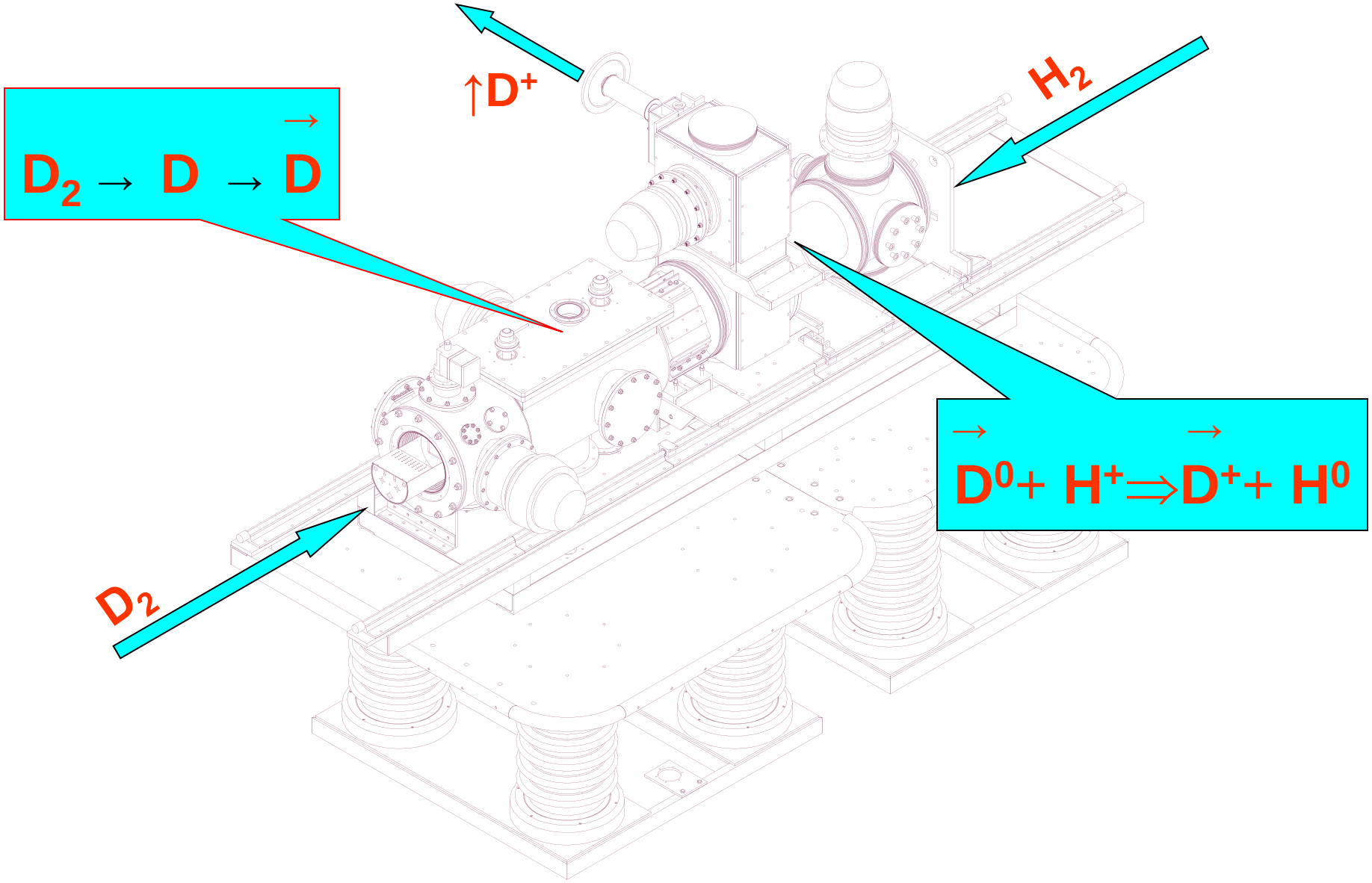
- The design output current of the **SPI** is up to **10 mA** for **$\uparrow D^{+}$ ($\uparrow H^{+}$)**
- The **D^{+}** polarization will be up to 90% of the maximal vector **(± 1)** & tensor **(+1,-2)** polarization
- The **SPI** is based in substantial part on the equipment from IUCF(Bloomington,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

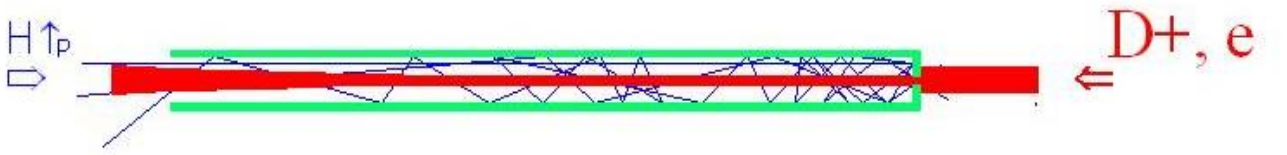
- increase intensity of the polarized D^+ beam
- reduce emittance of the polarized beam
- considerably reduce H_2^+ ion current which is difficult to be separated from polarized D^+ due to similar mass of the ions

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)

$$H^{o}\uparrow + D^{+} \rightarrow H^{+}\uparrow + D^{o}$$



11 mA of $H^{+}\uparrow$ 80 % polarization has been obtained from the INR source

ABS development

Atomic Beam Source (ABS) of the SPI has been producted 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/cm^3 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

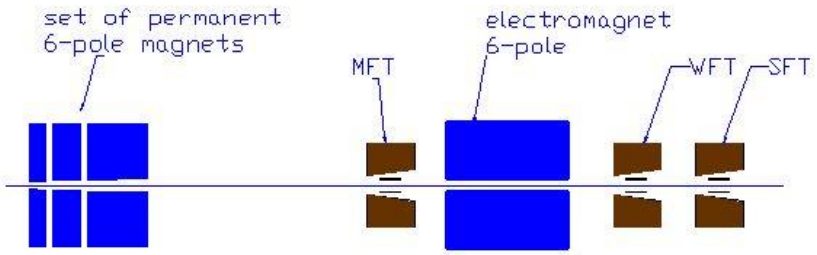
  $I_D = 8 \cdot 10^{16}$ at/s $I_H = 5 \cdot 10^{16}$ at/s

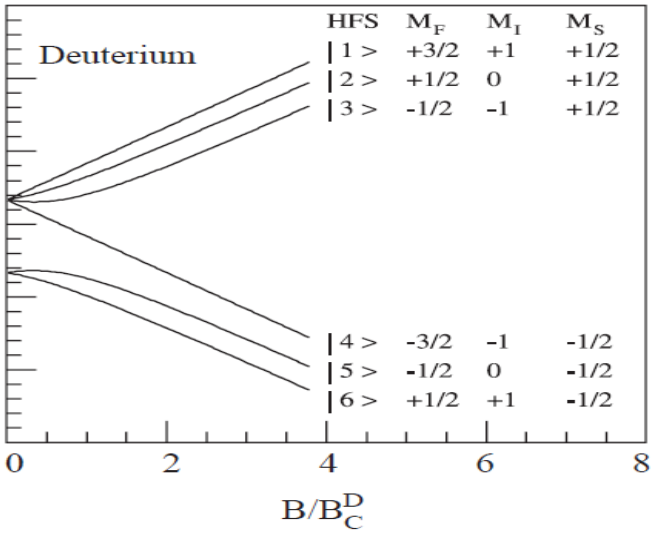
- Nozzle temperature was scanned over a range of 16…80 K

  The optimum nozzle temperature is about 27 K

  The optimum feed rate is about 0.045 mbar · l / pulse

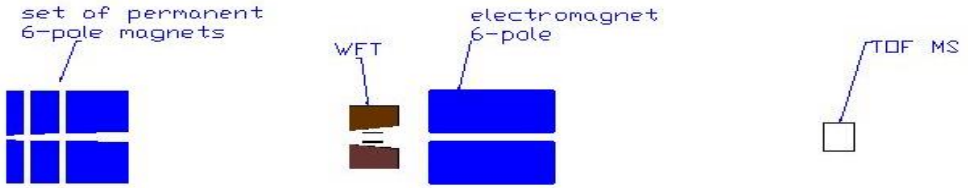
RFT scheme and deuteron polarization



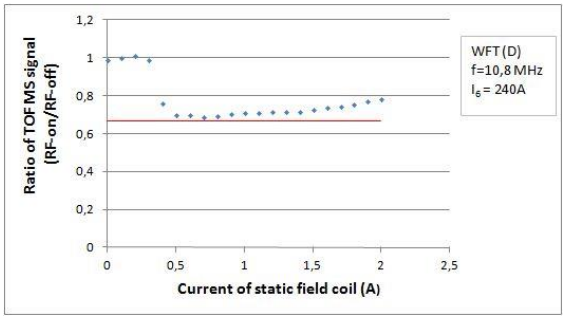


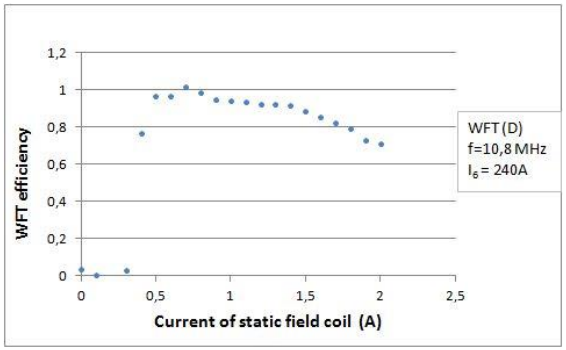
HFT between 6poles	HFT after 6poles	Final D hfs	P_Z	P_{ZZ}
MFT $3 \rightarrow 4$	WFT $1 \rightarrow 4$, $2 \rightarrow 3$	3,4	-1	+1
MFT $3 \rightarrow 4$	SFT $2 \rightarrow 6$	1,6	+1	+1
MFT $1 \rightarrow 4$	SFT $3 \rightarrow 5$	2,5	0	-2
MFT $1 \rightarrow 4$	SFT $2 \rightarrow 6$	3,6	0	+1

Tests of the WFT



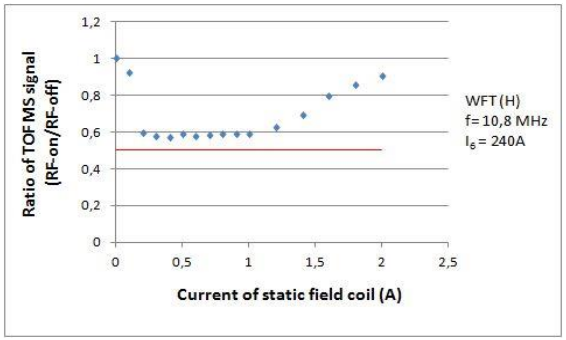
Deuterium atoms

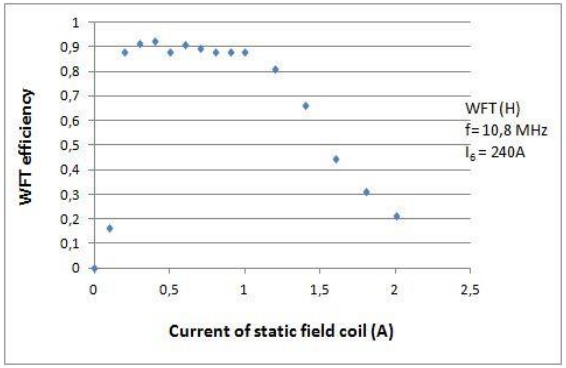




D atoms WFT efficiency – 0.95

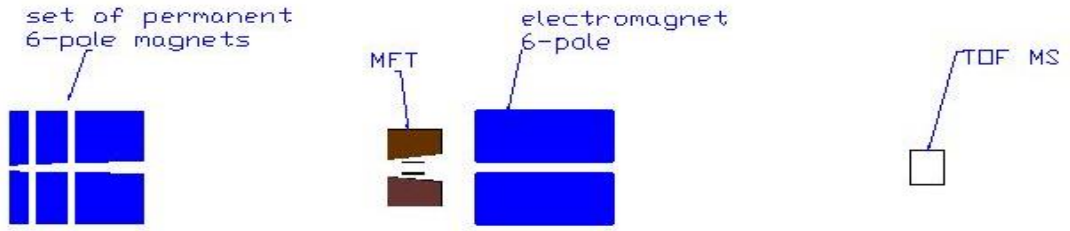
Hydrogen atoms



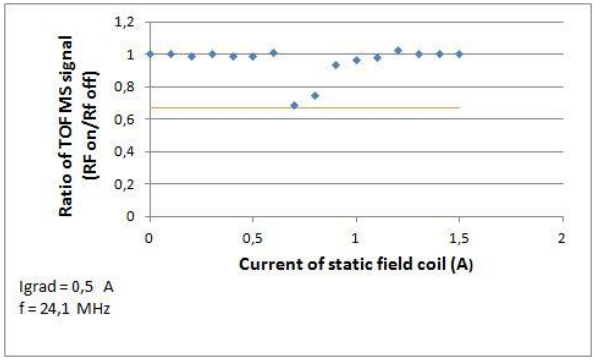


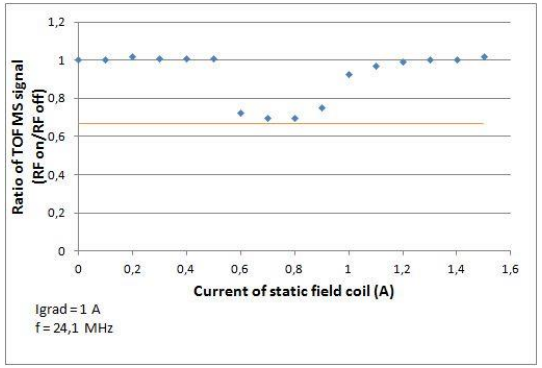
H atoms WFT efficiency – 0.90

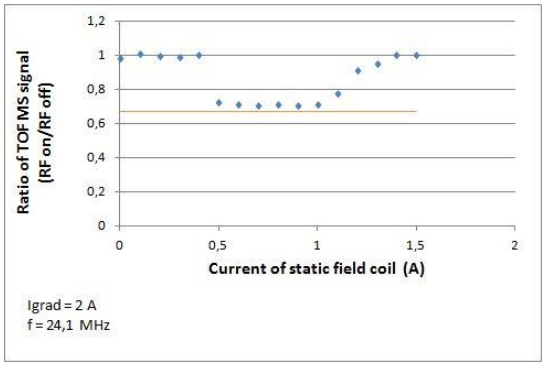
Tests of the MFT



Deuterium atoms







3 → 4 mode

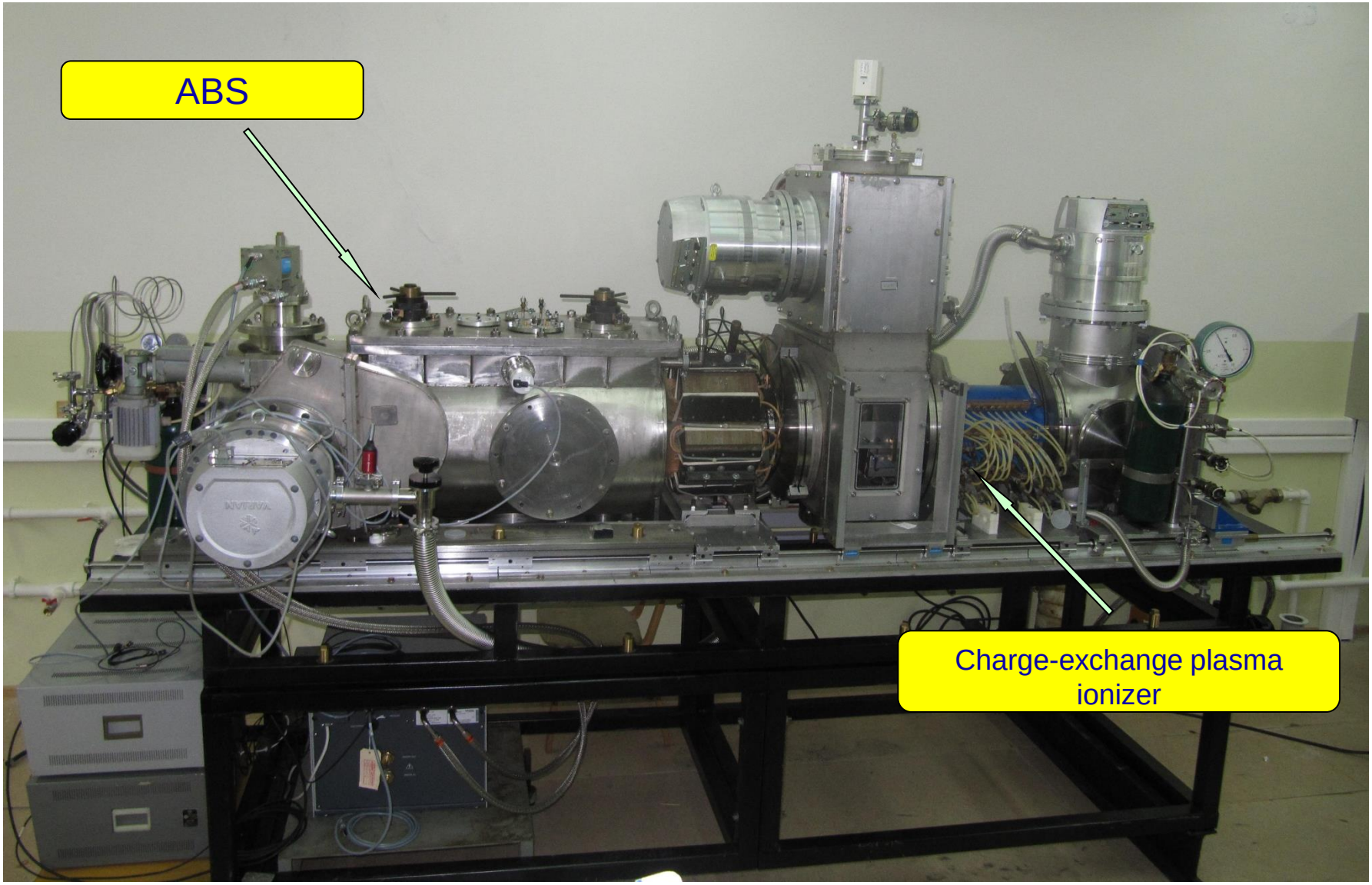
1→ 4 mode

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

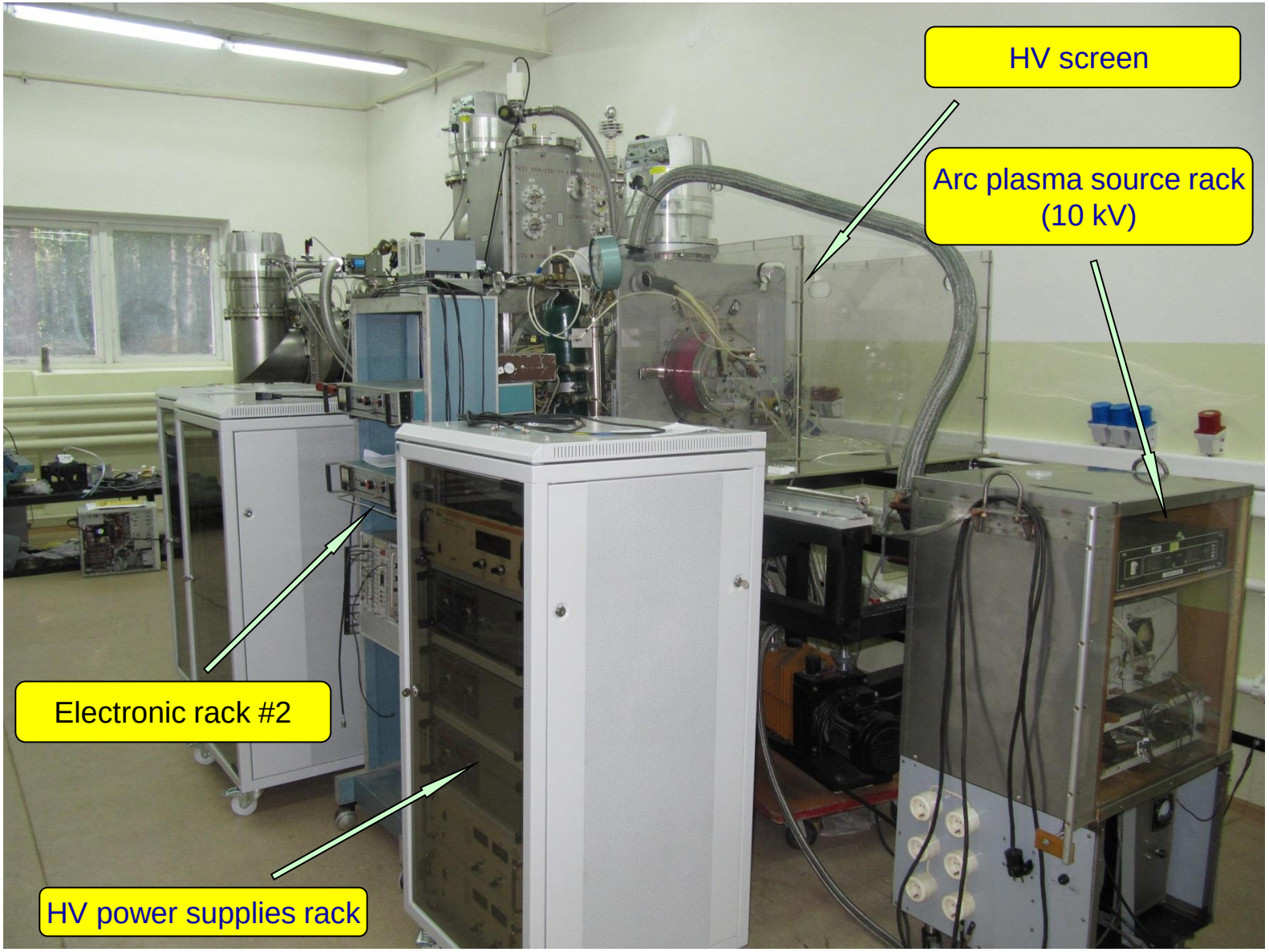
General view of **SPI** (September 2012)



SPI view from the dissociator chamber

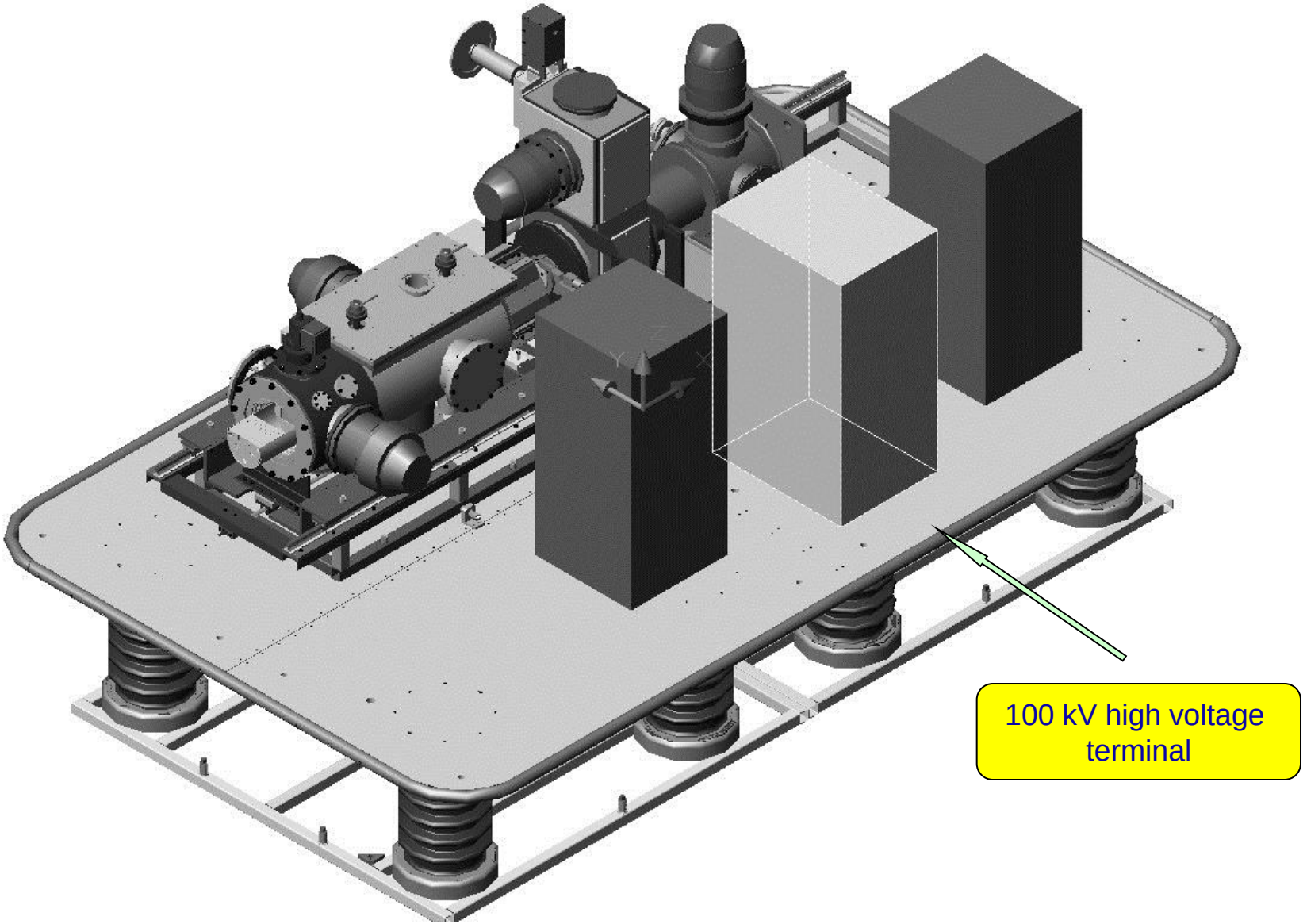
General view of **SPI** (June 2013)

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



General view of **SPI** (October 2014)

SPI layout at the linac HV - terminal



Tests bench program of the SPI in 2014

- operating with deuterium plasma arc source, running with the charge exchange ionizer

to date, the first phase of work was completed at the energy of the accelerated ions up to 10 keV

- start-up and testing of SPI mode of polarized protons obtaining

at present this work is in progress

- 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

- development of control system components for primary analysis & data acquisition and for fiber optic system of data transmission is in progress now

JINR & INR of PAS Contract for 2014-2015 year

- Development and prototyping of the atomic beam mass spectrometer to adjust the RF-units of the SPI and power supplies pulsed plasma generator to operate the charge-ionizer for a polarized ion source of hydrogen and deuterium at energies up to 25 keV

- Accelerating voltage up to 25 kV will significantly increase the polarized beam current at the output of the SPI

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 2014-2015
- SPI assembling and commission run at the linac is planned by the end of 2015

Thank you