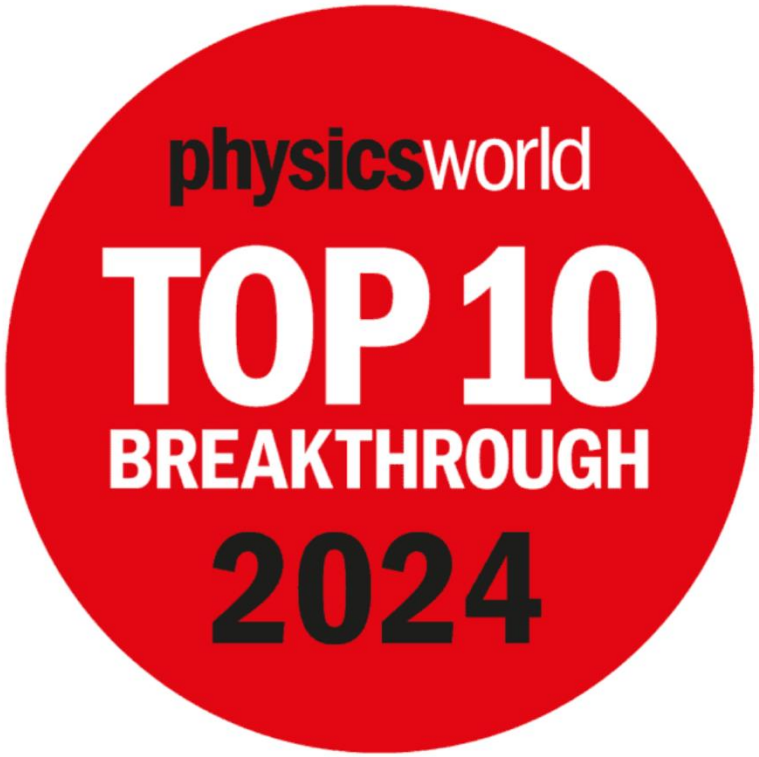
Status of the SRC program

HyperNIS+SRC project

Maria Patsyuk (JINR)

61th JINR PAC, Jan 2025



Two distinct descriptions of nuclei unified for the first time

To Andrew Denniston at the Massachusetts Institute of Technology in the US, Tomáš Ježo at Germany's University of Münster and an international team for being the first to unify two distinct descriptions of atomic nuclei. They have combined the particle physics perspective – where nuclei comprise quarks and gluons – with the traditional nuclear physics view that treats nuclei as collections of interacting nucleons (protons and neutrons). The team has provided fresh insights into short-range correlated nucleon pairs – which are fleeting interactions where two nucleons come exceptionally close and engage in strong interactions for mere femtoseconds. The model was tested and refined using experimental data from scattering experiments involving 19 different nuclei with very different masses (from helium-3 to lead-208). The work represents a major step forward in our understanding of nuclear structure and strong interactions.

"This work builds on a lot of results published by the group these past years"

Prof. Or Hen
Associate Director for Research and Development,
Laboratory for Nuclear Science, MIT

Modification of Quark-Gluon Distributions in Nuclei by Correlated Nucleon Pairs

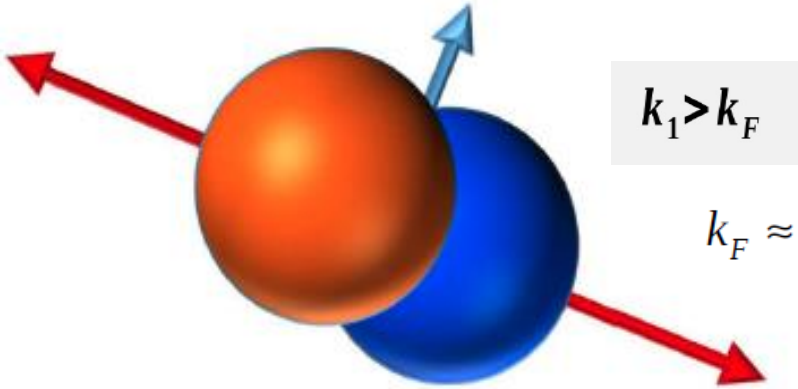
https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.133.152502

Short-Range Correlations (SRCs) – close-proximity nucleon pairs

Short-range, short-lived,
highly correlated nucleon pairs

High momentum of correlated nucleons,
low pair momentum

$r \sim R$



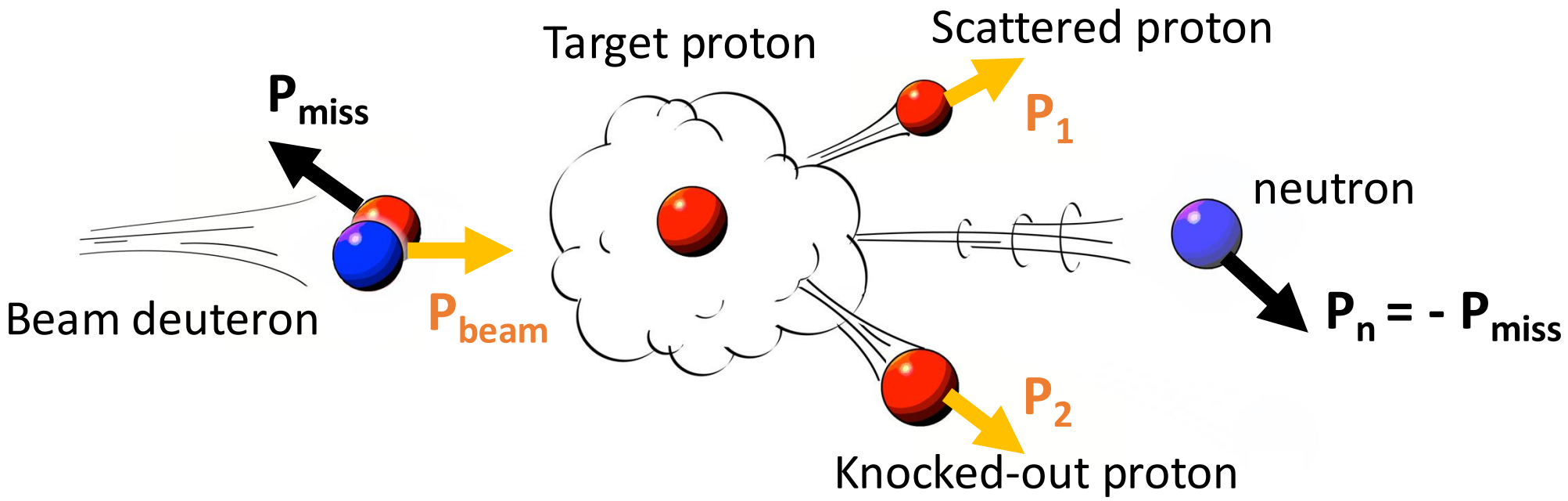
$k_1 > k_F \quad k_2 > k_F \quad k_1 \simeq k_2$

$k_F \approx 250$ MeV/c

Position-space

Momentum-space

Quasi-free d**(p,2p)** scattering

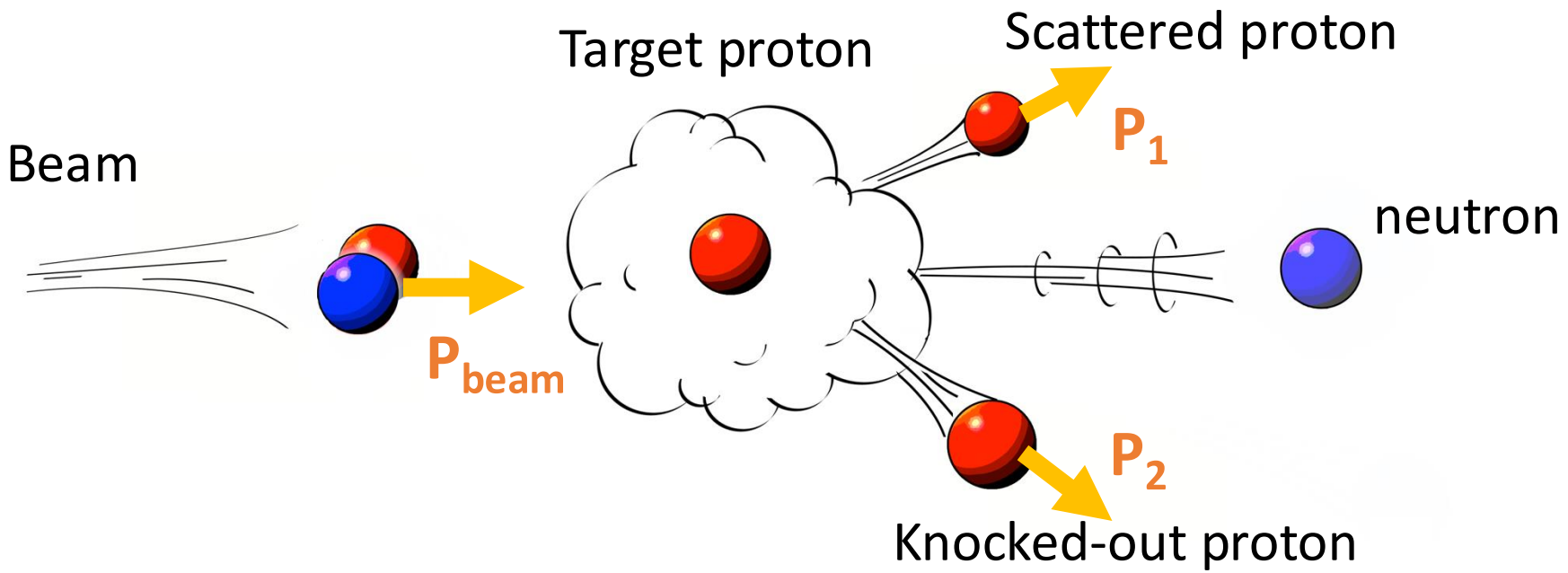


Reconstruct initial nucleon momentum $\mathbf{P}_{miss}$ from scattered particles

$\mathbf{P}_{miss} = P_1 + P_2 - P_{beam}$

~ 90° c.m. scattering

A_{ZZ} for hard quasi-free breakup of d: $\vec{d}$(p, 2p)n

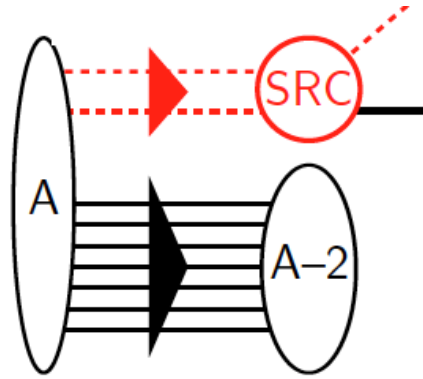


- $|t|$ & $|u| > 1$ GeV^2
- $60^0 < \theta_{cm}$
- Two-arm acceptance: $20^0 < \theta_{lab} < 45^0$; $-20^0 < |\varphi_{lab}| < 20^0$
- $p_{miss} > 0.25$ GeV/c.

$$A_{zz} = \frac{(\sigma_- + \sigma_+ - 2\sigma_0)}{\sigma_{unpol}}$$

σ_- , σ_+ , σ_0 – cross sections for different tensor polarization states

Study of two nucleons at a short distance at large momentum transfer:



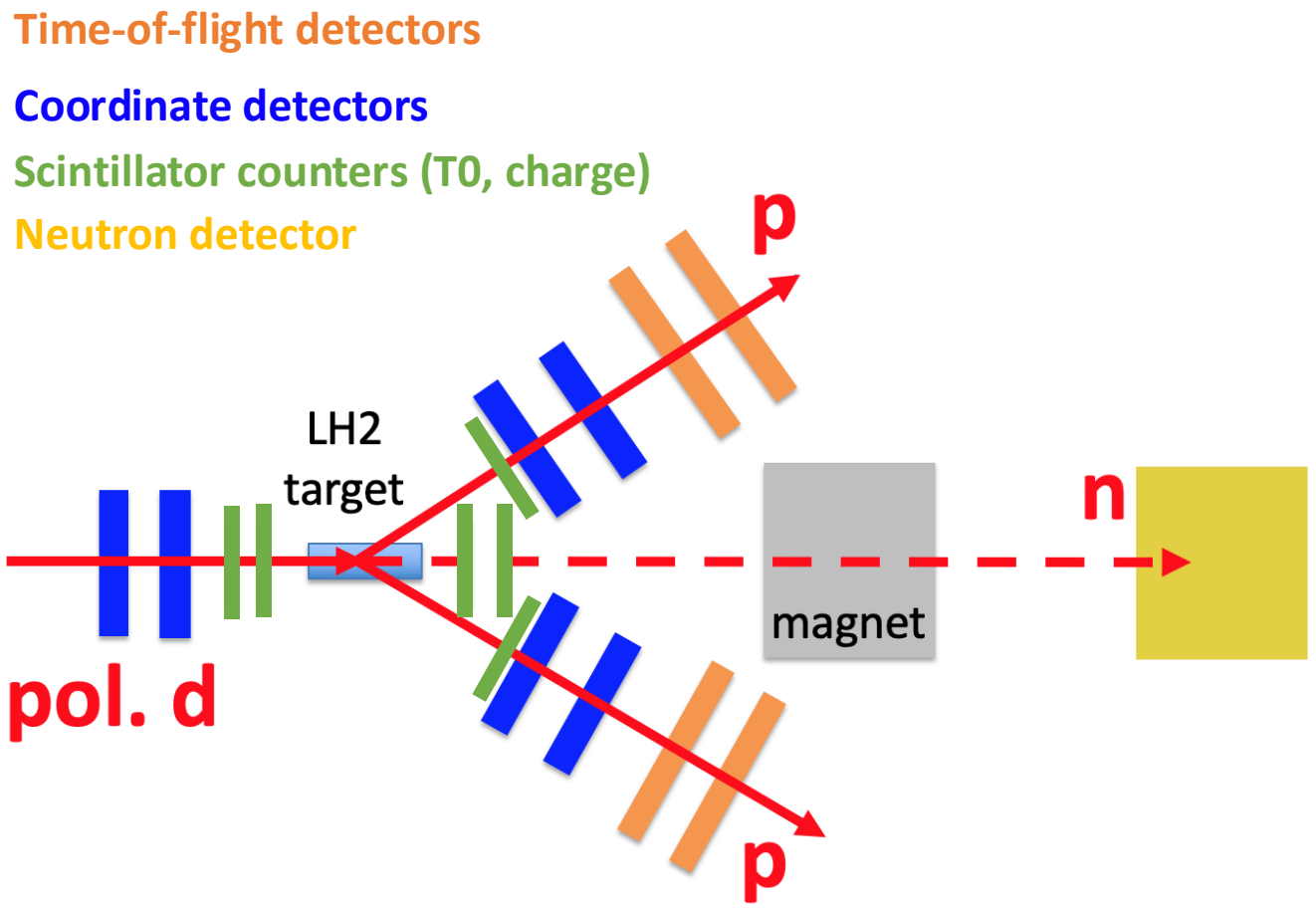
1. Relativistic description of the bound system

2. Ratio between S- and D-waves of the deuteron

3. Final state interactions in the high-momentum region

4. Non-nucleonic deuteron components in polarization measurements

Hard quasi-free breakup of the deuteron: $\vec{d}$(p, 2p)n



Two-arm spectrometer (TAS) like in 2022

A polarimeter separately or incorporated into the setup

Expected trigger rate < 5kHz based on single arm trigger

Polarimetry

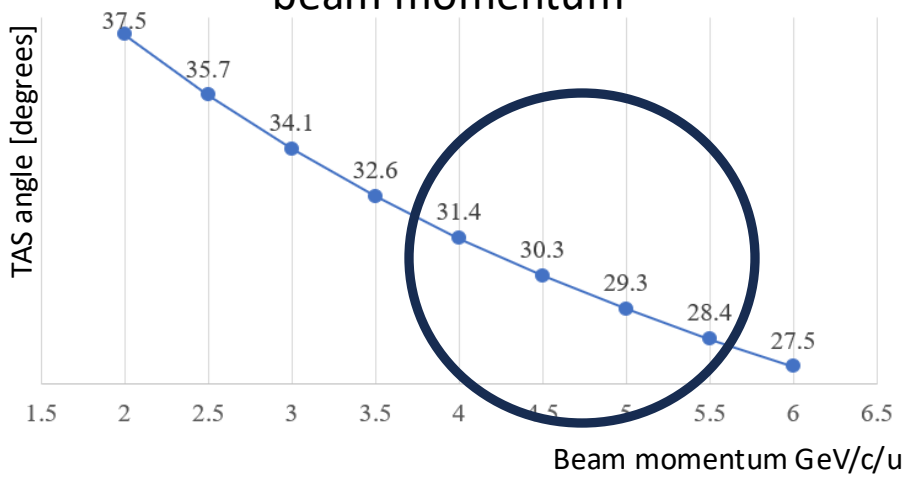
An international PostDoc was going to tackle this task,

but he refused the position in Nov. 2024

We need a PostDoc!

Beam properties

The angle of TAS as a function of the beam momentum



Momentum: for the maximum d momentum of 6 GeV/c/nucleon the spill is only 2 s and period 10 s. If we decrease energy by 30% (6 -> 4 GeV/c), then the spill can be >=5 s.

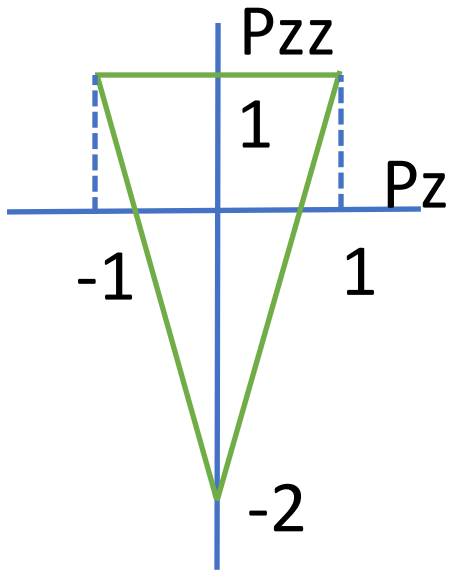
Intensity: up to 10^{8} ions/s, but we will use ~ 10^{6} ions/s

Focusing/Beam spot size 4 cm (x) 2 cm (y) at the target

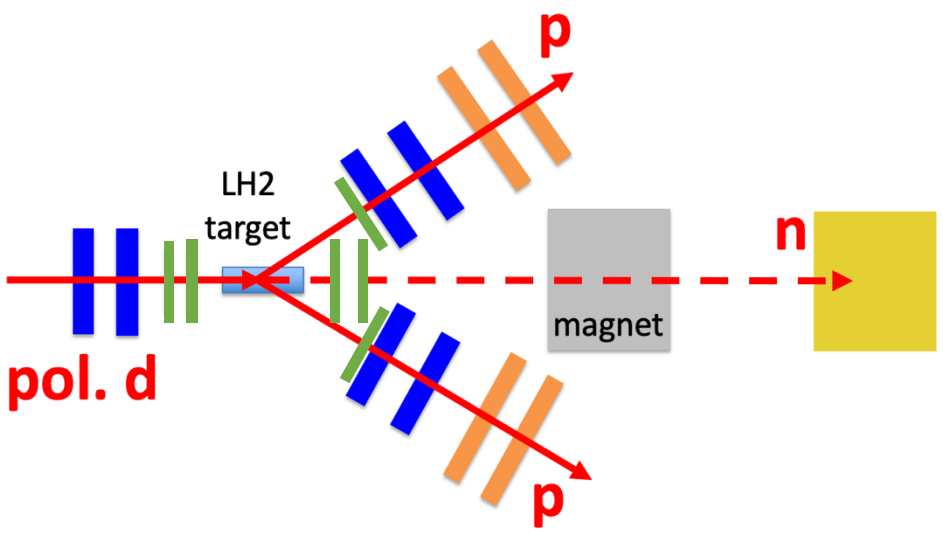
Maximum beam momentum available at HyperNIS – currently 3.6 GeV/c/u

Vacuumized beam line – do we need it?

Polarization state (Pz, Pzz) = (0, -2)



Detectors availability



Time-of-flight detectors (Arm TOF) Scintillator BC counters (T0, charge)	available
Coordinate detectors	Not yet available
Neutron detector	Interest from HGND group (prototype tested in 2022 at BM@N)

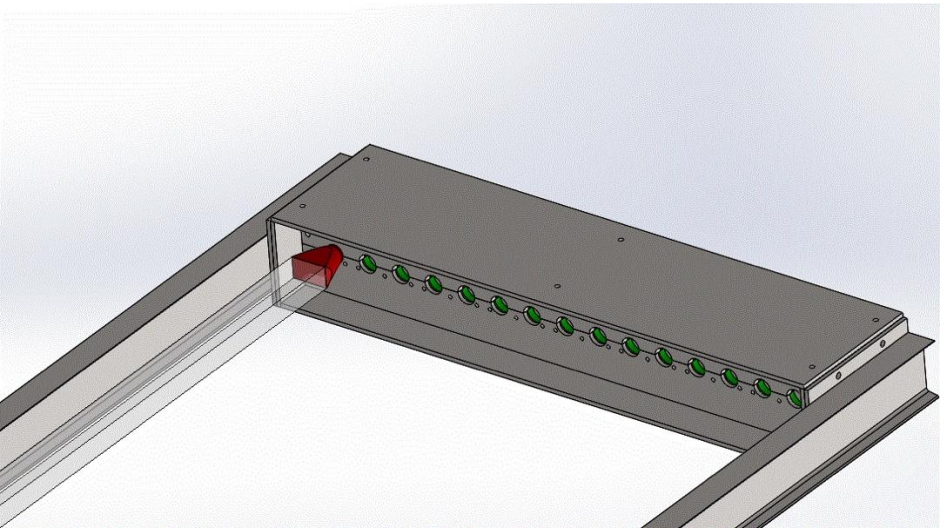
It would be beneficial to work with the coordinate detectors available at LHEP

Investigating possibilities to get the coordinate detectors from the Chinese groups

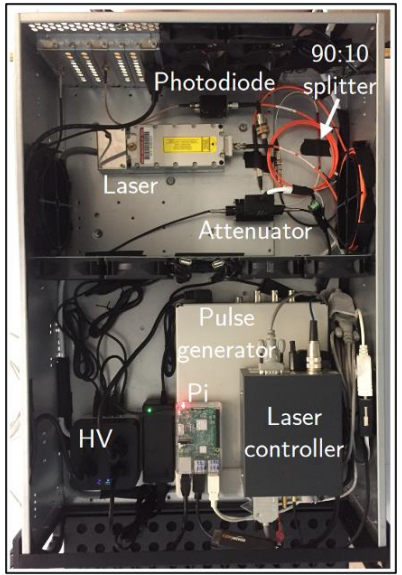
Arm TOF

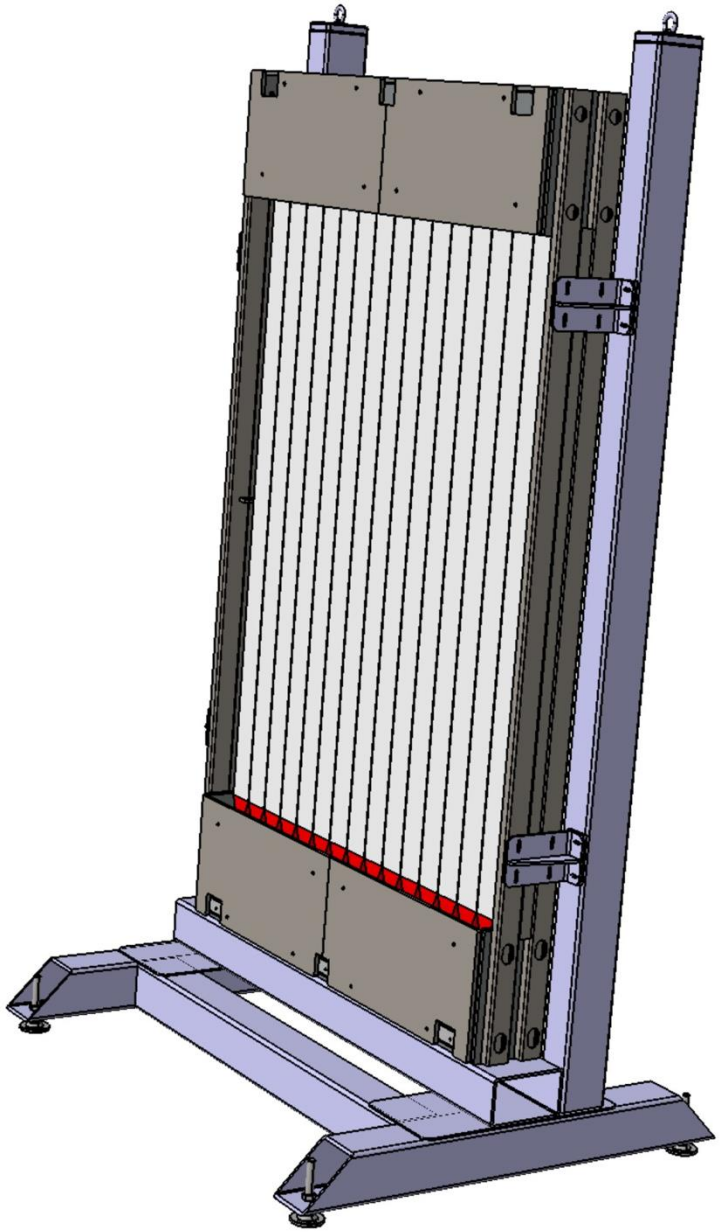
- active area 200cm (Y) x 150cm (X)

- timing scintillator array:
  - 200cm x 10cm x 6cm BC-408, PMT R13435
  - ToF resolution <= 80ps
  - 15 bars
  - 30 (+5 spare) channels per arm
  - HV is at BM@N, new HV cost is $50k
  - A new frame is needed (and new floors)



Laser calibration system available

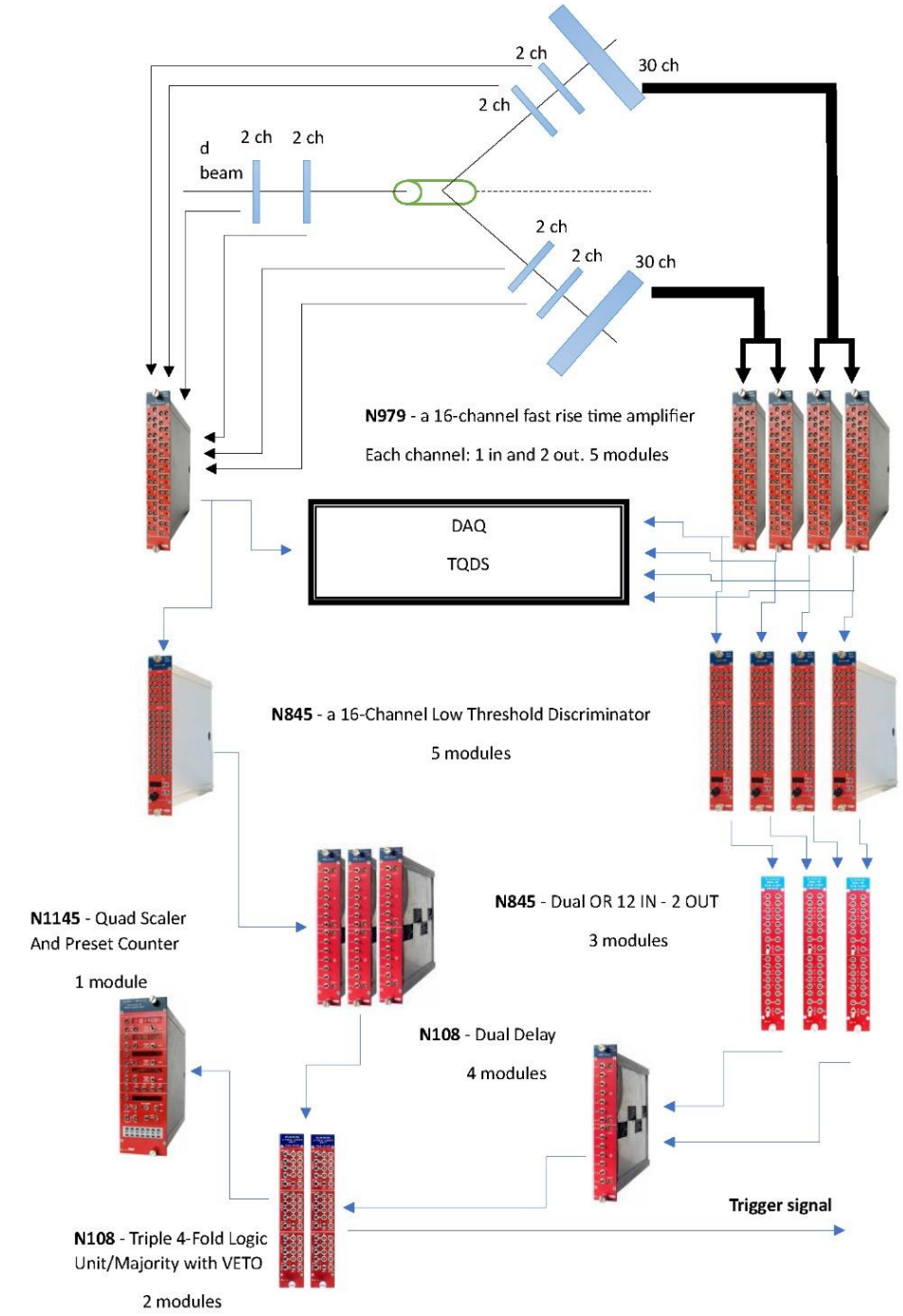




Trigger based on LRS/CAEN modules

DAQ group info:
Trigger can be made based on only TQDC modules

Need an electronics expert or a student to work on this task



Year	Plan
2024	PAC approval, 2022 data analysis, engineering work at cite, buy electronics
2025	Tracking detectors, engineering work at cite, construction of the experimental setup, run with deuteron beam (if NICA schedule allows)
2026	Data analysis, run with deuteron beam

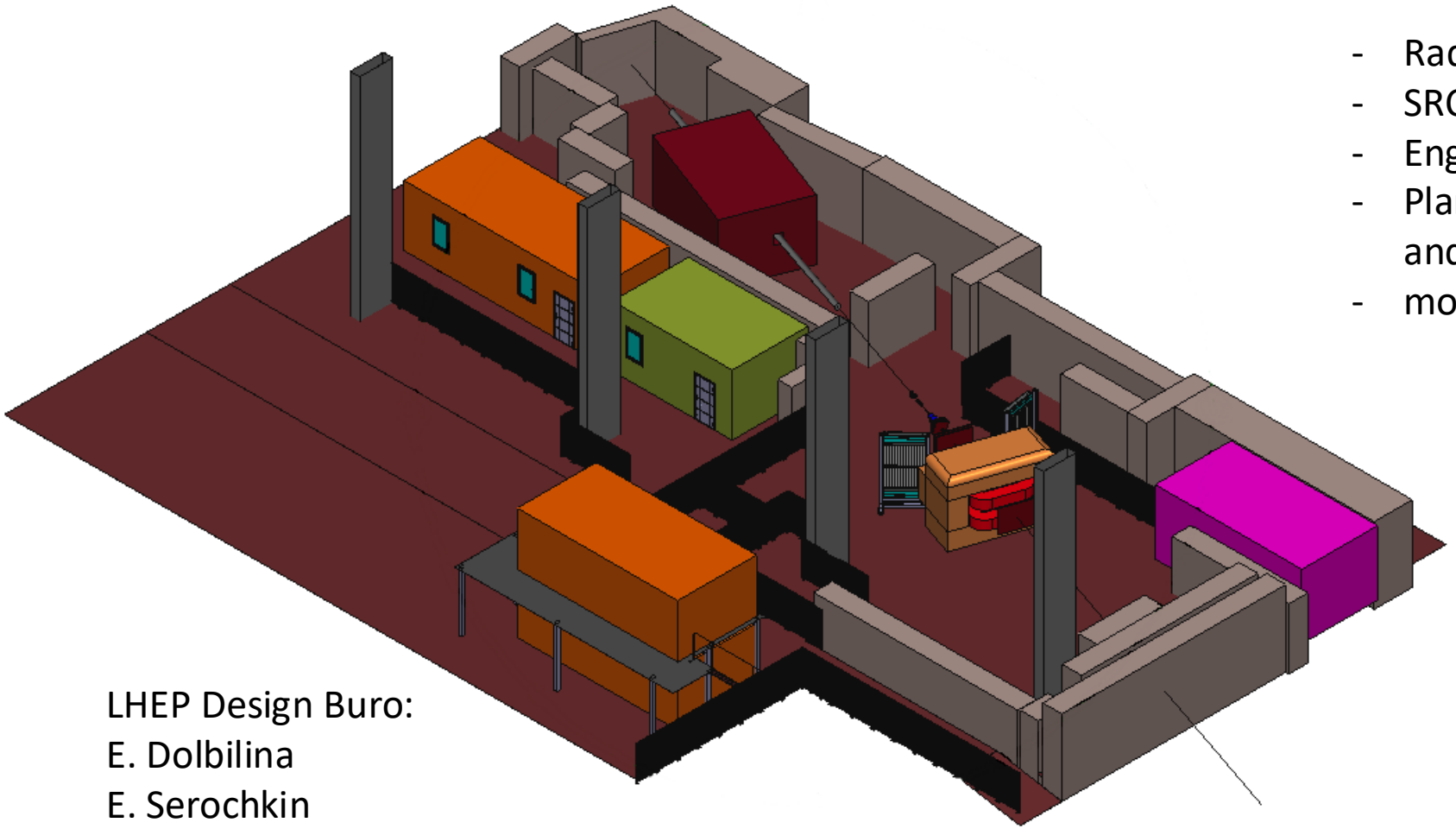
Phase II

2027	Improve magnetic field, add coordinate detectors downstream the magnet, run with C beam
2028	Data analysis, run with C beam

Status of the preparation:

- Simulation of the detector setup – ongoing
- 3d model of the experimental area
- Radiation hardness estimation – ongoing
- Preparation of the area – started
- Need 4 position-sensitive detectors for the arms: the best option – CSC detectors available (can be build) at VBLHEP
- Manpower: need an engineer and a PostDoc
- Need a dedicated budget for SRC

3D model of the HyperNIS experimental area



LHEP Design Buro:
E. Dolbilina
E. Serochkin

The 3D model is used for

- Radiation simulation (Fluka)
- SRC experimental setup arrangement
- Engineering work at cite
- Planning of interchange between SRC and HyperNIS measurements
- more

Radiation hardness requirements

	№	Ion	Momentum [GeV/c/u]	Intensity [ions/s]	Target
SRC	1	deuterons	6	10^7	LH
	2	^{12}C (future exp.)	2 - 4	10^7	LH
	3	^{12}C	2 - 4	10^{5*}	Pb 3 mm
HyperNIS	4	deuterons	3.5	10^5	^{12}C
	5	^{6}Li	3.5	10^5	^{12}C
	6	^{7}Li	3.5	10^5	^{12}C
	7	^{12}C	3.5	10^5	^{12}C
	8	^{12}C	3.5	10^5	Steel 4 mm

Beam spot size 4 cm (X) x 2 cm (Y) , Spill length 4-5 s

The maximal dose will be estimated for case 1

*Intensity for the Lead target should be within the rad. Requirements for the LH + 10^7

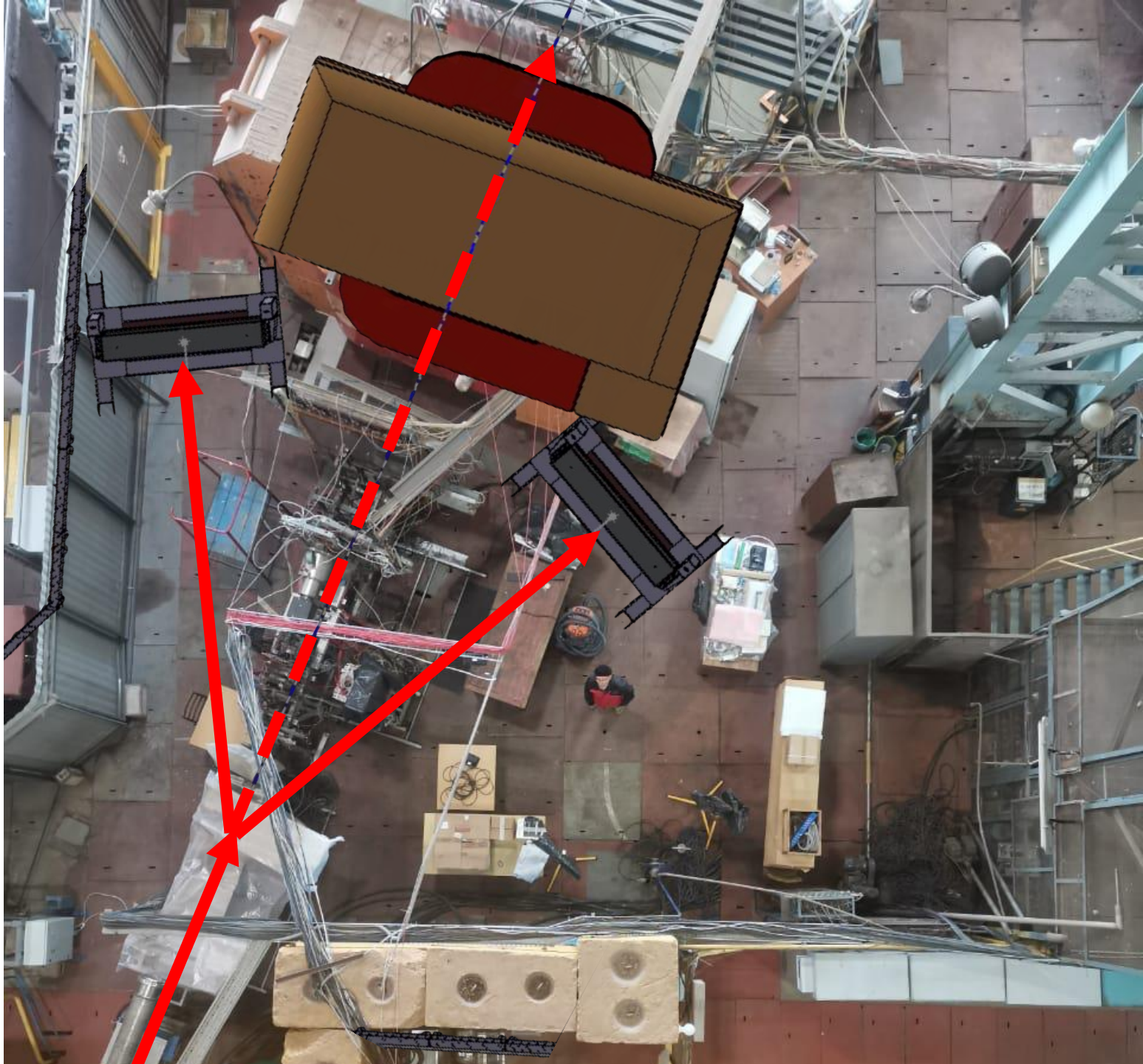
Radiation environment assessment

Simulation of the radiation environment is essential for the commissioning of the experimental setup

The maximal radiation load corresponds to dp collisions at 6 GeV/c/u and 10^7 ions/s intensity

Currently the formal task specification approval is in progress at Rad. Safety Dept. JINR → final simulations → report → improvement of the radiation protection

The HypeNIS experimental area



Preparation to take the beam: done, started, to do

- Restore powering of the magnet elements along the beam line
- Two magnetic lenses at HyperNIS - organize the cabling
- The vacuum chamber in 2SP-40-VP1 magnet in the beam line needs to be exchanged to allow beam delivery to the HyperNIS area
- Check the maximum beam momentum that can be delivered to the HyperNIS area
- Beam lock – fixed by the HyperNIS group
- Connect the SP-40 magnet to the power and water and test it
- Put water pipes and power cables in cable channels
- Safety system of two doors to the area and alarm/info
- Vacuum beam pipe – the pumps have been ordered, the old pipe is there

LH2 target

- The BM@N target from 2022 is fully suitable, however…
- The target group can make a new twin target for SRC assuming there is funding
- The cost of the new target (same as at BM@N) is ~**$150k**

DAQ system

- Arm TOF + BC = 80 TQDC channels = 5 TQDC modules
- **1 module** of synchronization
- **1 module** of run control
- Crate
- Readout for the coordinate detectors

- 2 TQDC and a Run Control were ordered
- The HyperNIS group has a suitable crate

Manpower

HyperNIS group

Аверьянов А.В.,
Аксиненко В.Д.,
Аникина М.Х.,
Герценбергер С.В.,
Дементьев Д.В.,
Короткова А.М.,
Охрименко О.В.,
Пляшкевич С.Н.,
Парфенова Н.Г.,
Фещенко А.А.,
Хворостухин А.С.,
Шереметьев А.Д.
Саламатин А.В.,

SRC group

Patsyuk Maria
Atovullaeva Asya

Chinese groups:
Prof. Hongna Liu
(Beijing Normal Uni),
Prof. Zhihong Ye
(Tsinghua Uni) and a
student

Tel-Aviv University:
Prof. Eli Piasetzky
and a student

Timur Atovullaev
Madalena Miloi
Students:
Bochkova A.
Cherepanov S.
Garkin A.

Julian Kahlbow
Alexey Larionov (BLT)

Target group
DAQ group

Preparation of the new experiment

Data analysis of 2022

Need:
- engineer
- PostDoc
- electronics technician/student

PAC 2024 approved the HyperNIS + SRC project without a dedicated budget for SRC

item	Cost, k$
Target	150
Arm coordinate detectors	135 (Chin.) / ? (JINR)
DAQ + HV	70
Cables, Connectors/adapters	20
Frames and support	10
Setup service	25 / year
Trips and meetings	35 / year
Total	420 first year

Summary:

- $\vec{d}$(p, 2p)n exclusive measurement in SRC kinematics aiming at A_{ZZ} at high P_{miss}
- Two-arm spectrometer, JINR LH target + DAQ, need coordinate detectors
- Can be done in the next couple of years complementing the world-wide SRC effort
- We need: JINR support on the equipment and manpower.

Thank you for the attention!

- Recommendation. The PAC supports the proposed experiment with hypernuclei at the Nuclotron, the plans to expand the setup for the SRC study, and recommends approval of this project until the end of 2029 with ranking A.