Preparation of the SRC experiment

HyperNIS

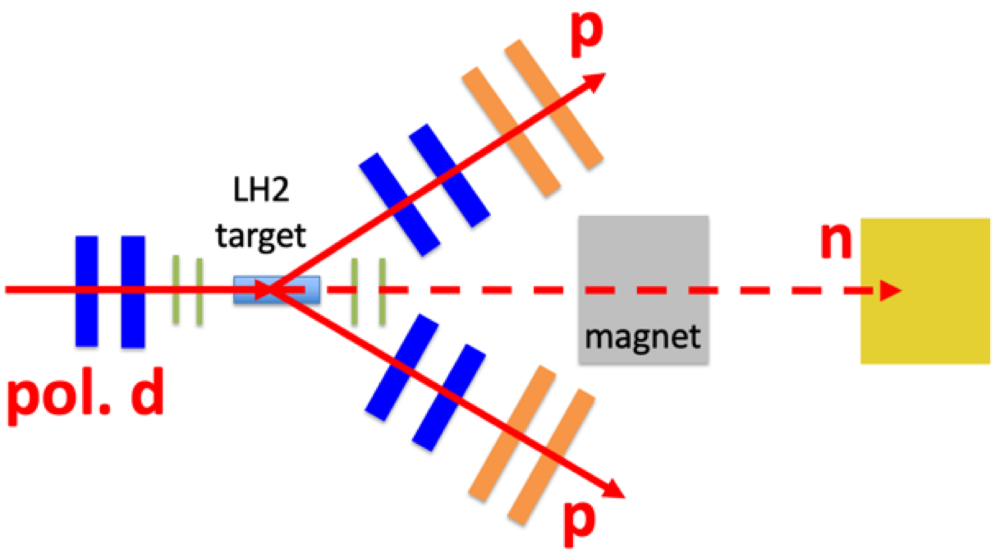
Maria Patsyuk

PAC Jan 22th 2024

Quasi-free breakup of tensor polarized deuterons in exclusive kinematics

~ 90° c.m. scattering at 6 GeV/n d energy

Ensuring large momentum transfer and interaction with a compact object

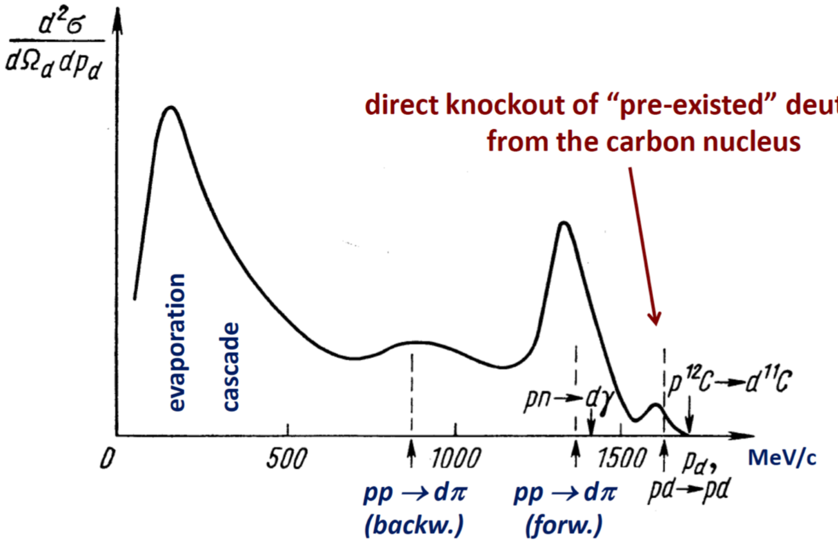


Studies of pre-existing tight configurations of nucleons

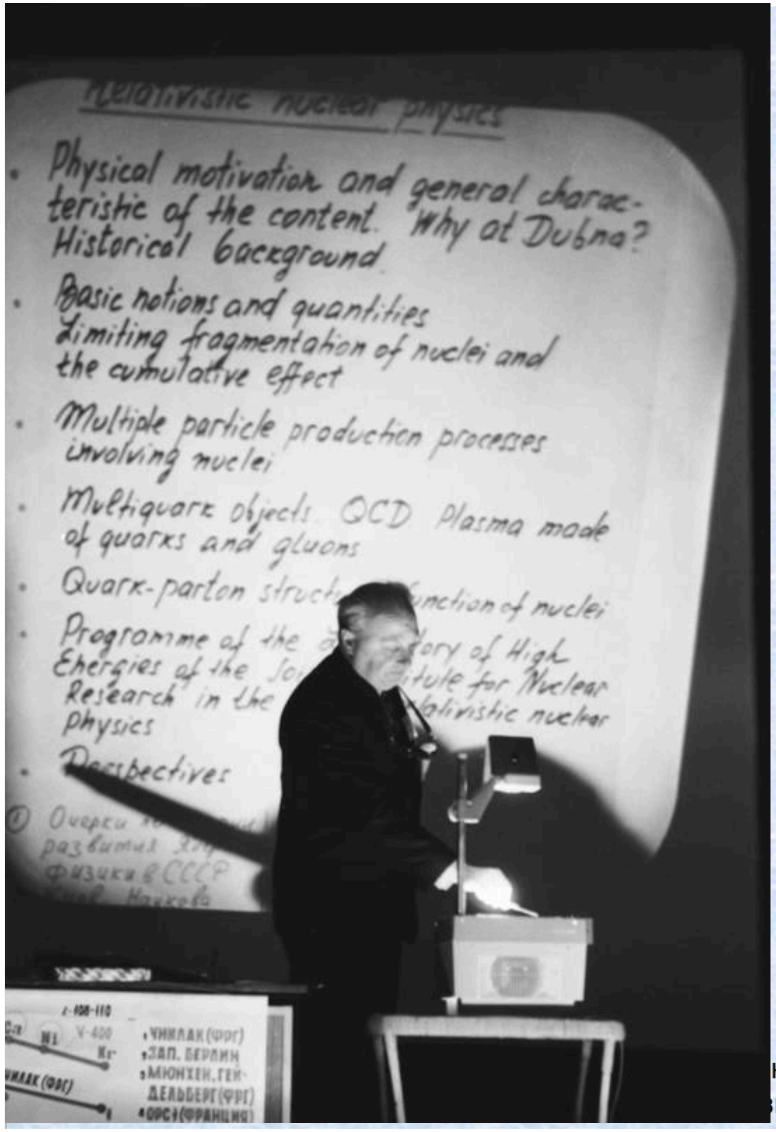
1950s – experiments with direct knockout of d, and later ^3He, ^4He

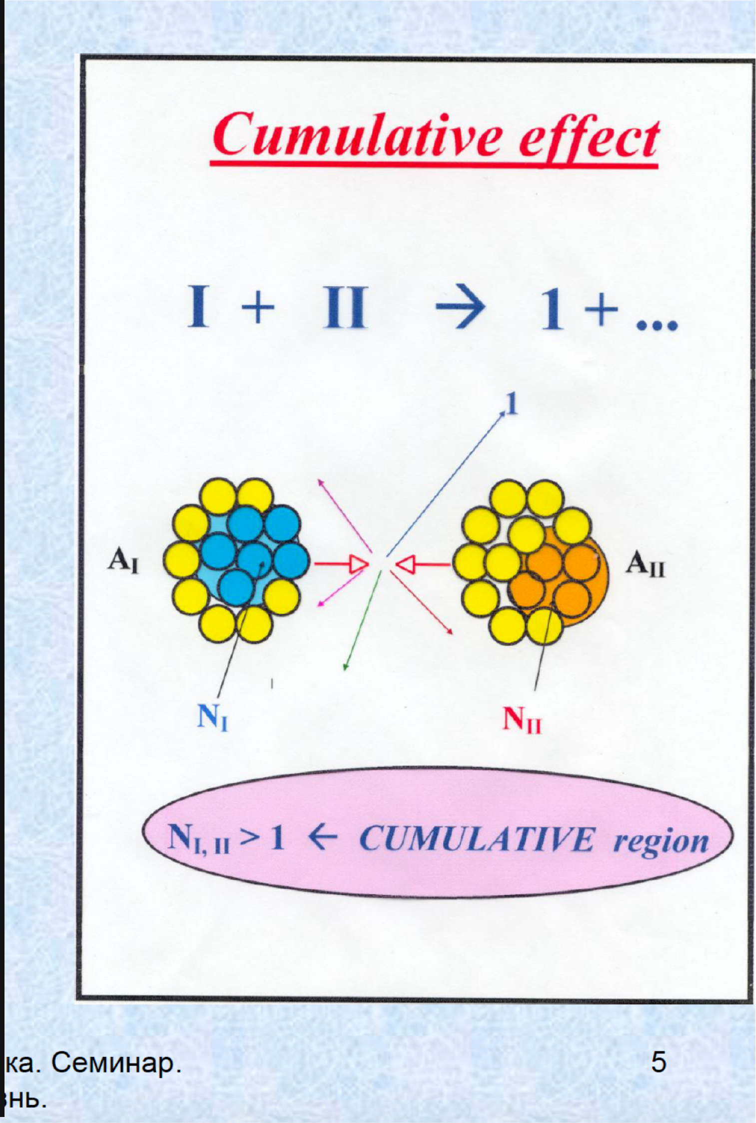
Fluctuons - tightly correlated groups of nucleons in nuclei (”quark bags”, “clusters”)

Cumulative effect



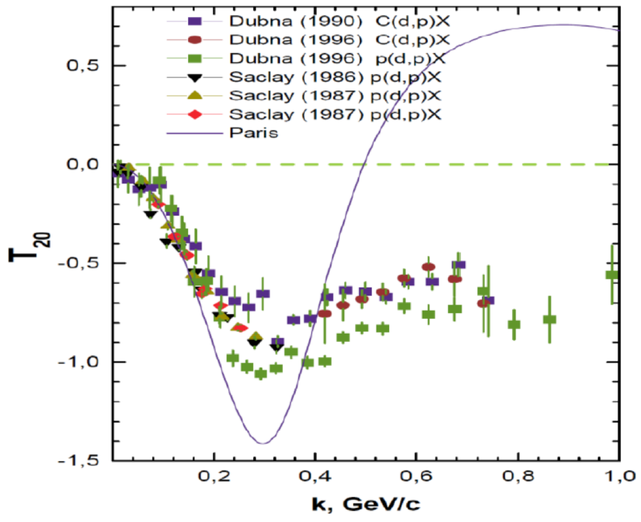
Azhgirey L.S. et al, ZhETP, 33 (*1957*), 1185

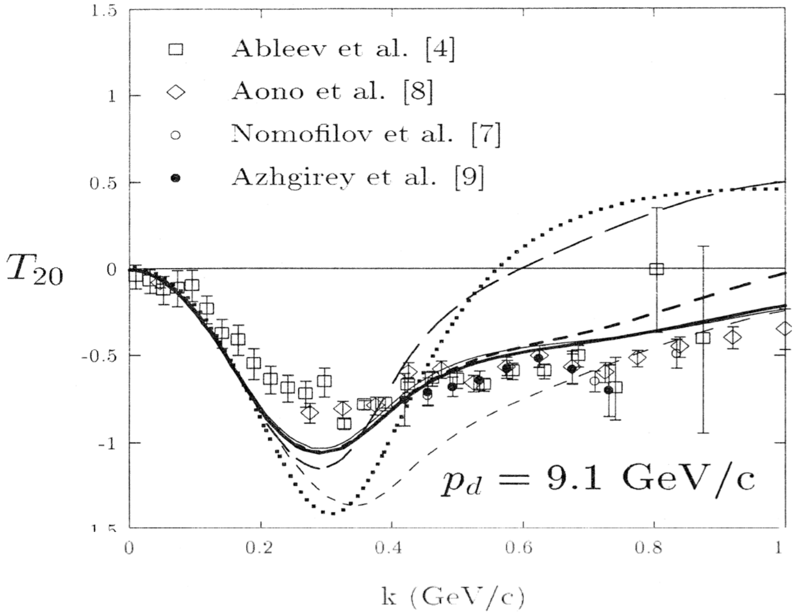




Fragmentation of polarized d measured along the beam

Backward elastic dp and inclusive d breakup at 0 degrees (d,p)X

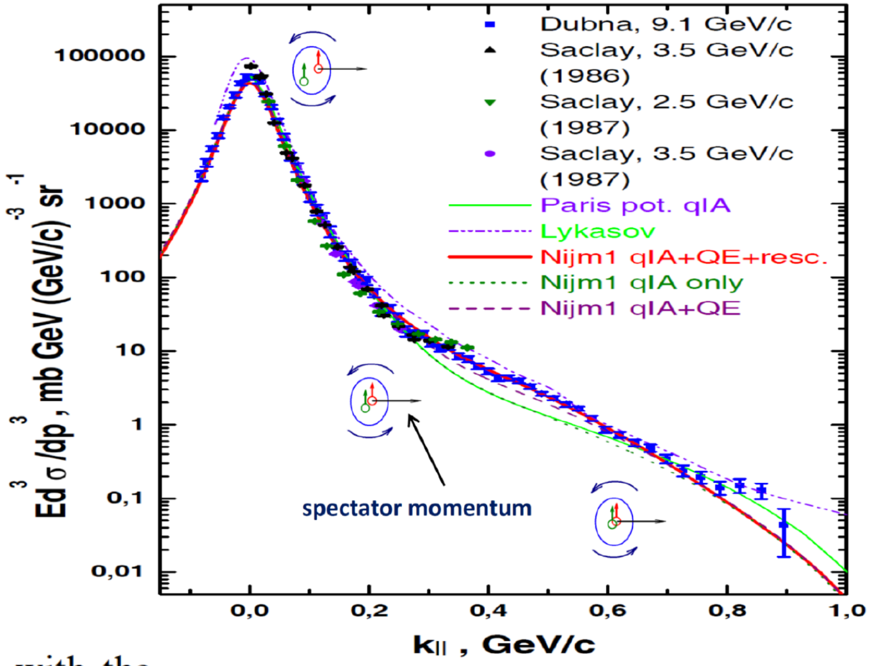




Curves show results of calculations with the Nijm-I deuteron wave function in the framework of multiple scattering: with (bold solid line) and without quark exchange (short-dashed line); and IA: with (long dashed line) and without quark exchange (dotted line).

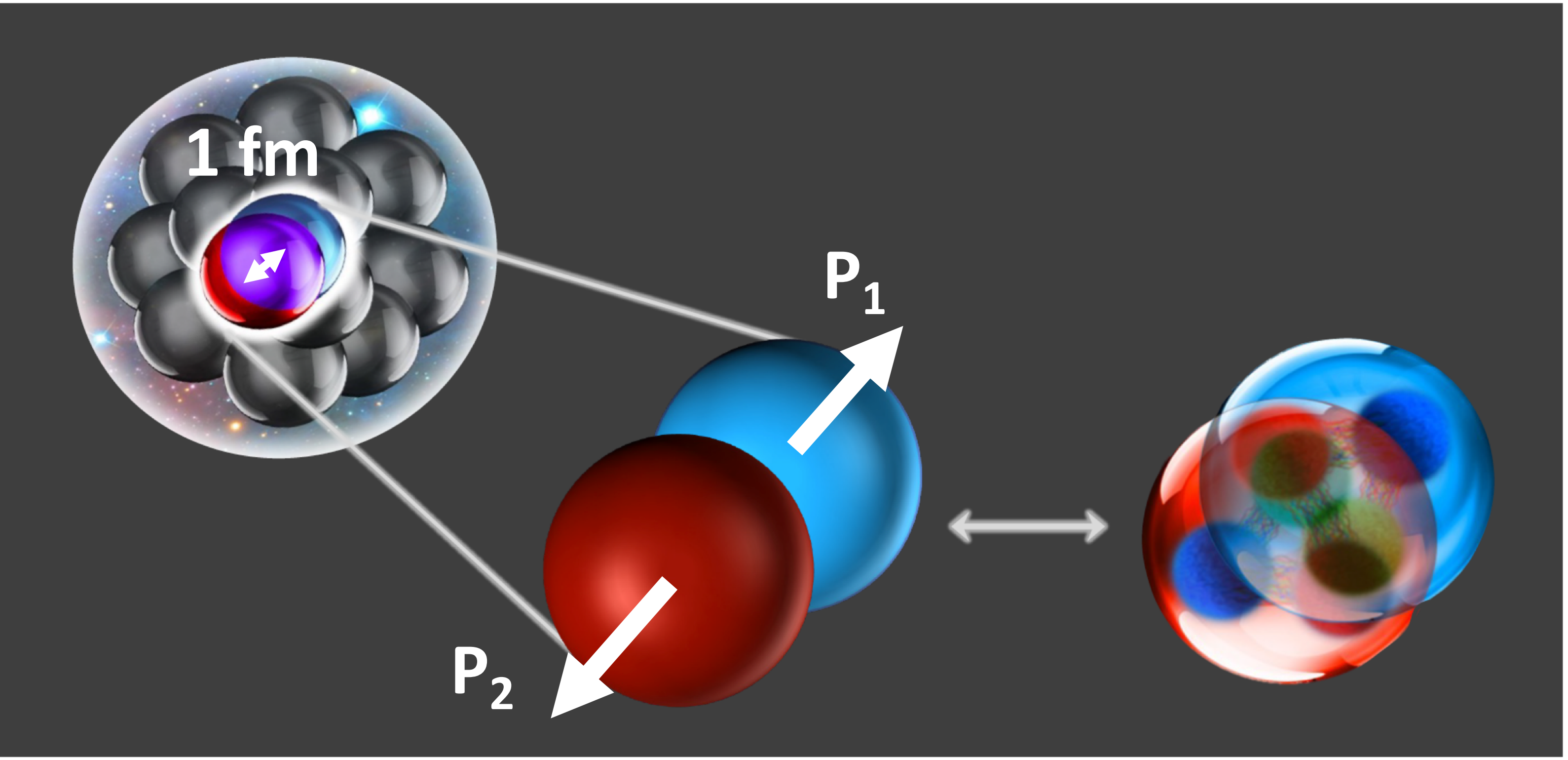
Reminder: existing data on deuteron breakup (inclusive)

p(d,p)X invariant cross section; protons are emitted at 0 degree.



Kobushkin, Phys. Lett. B 421 1998

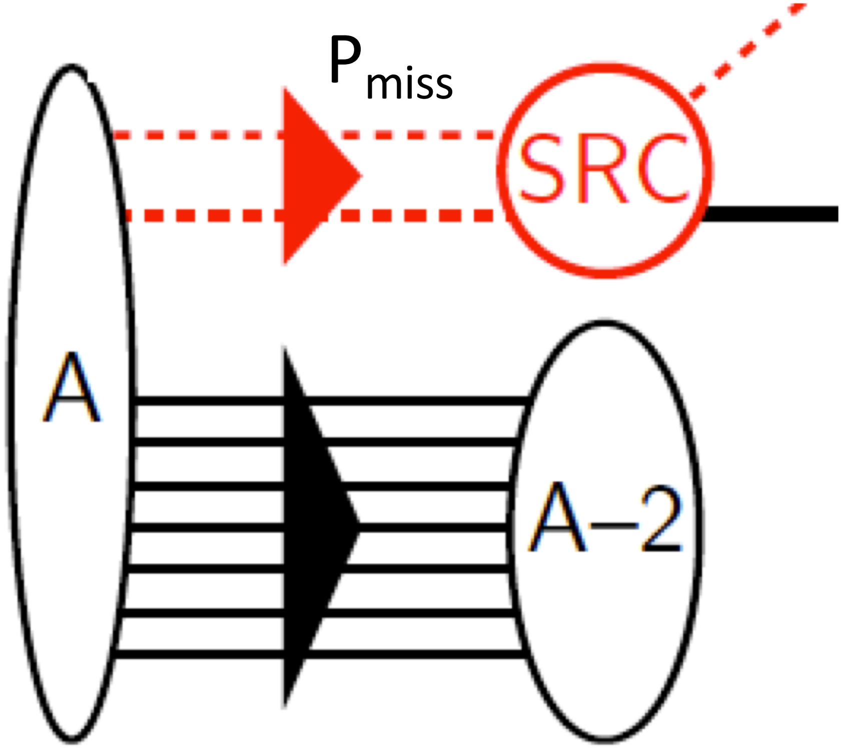
Short-Range Correlations (SRCs) – close proximity nucleon pairs



Momentum space: high relative and low c.m. momenta, compared to the Fermi momentum (p_F ~ 250 MeV/c)

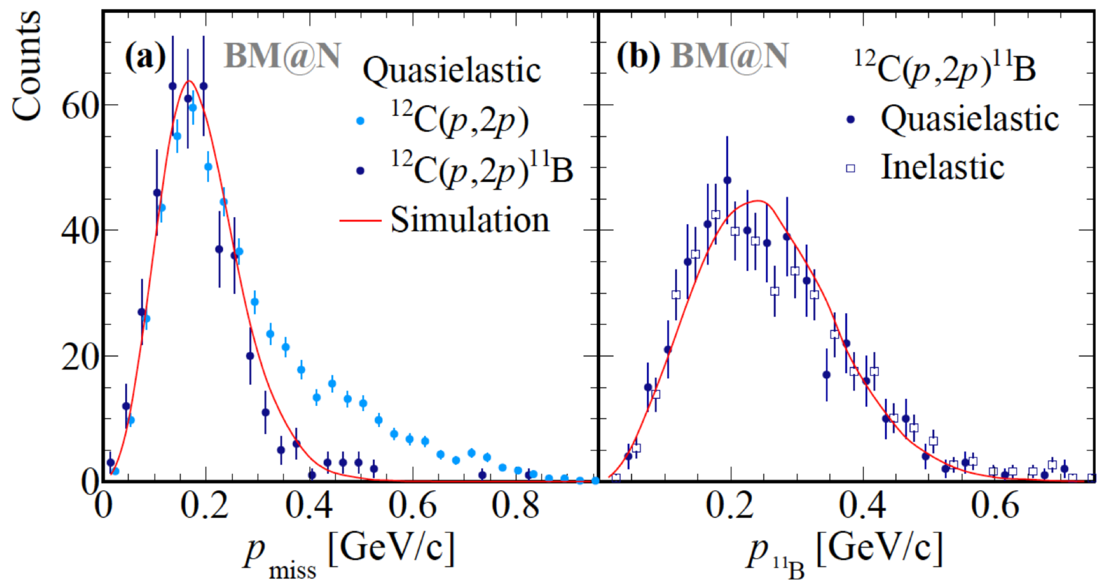
$P_1 > p_F$ $P_2 > p_F$ $P_1 \sim P_2$

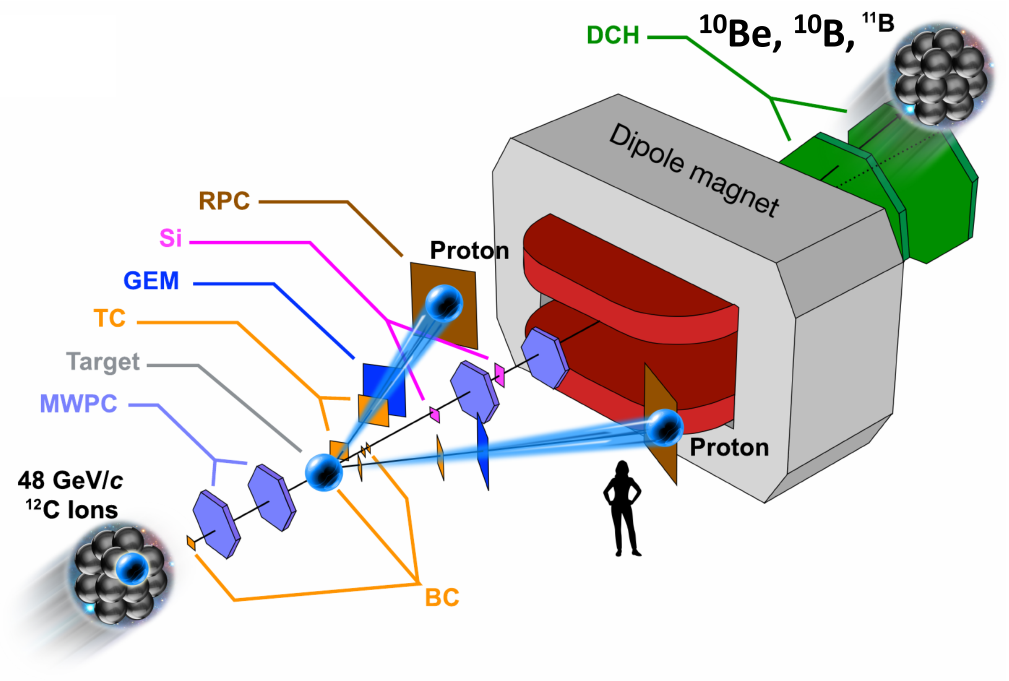
SRC motivates tensor polarized d measurements



Yu. Uzikov

SRC 2018 motivates polarization measurements



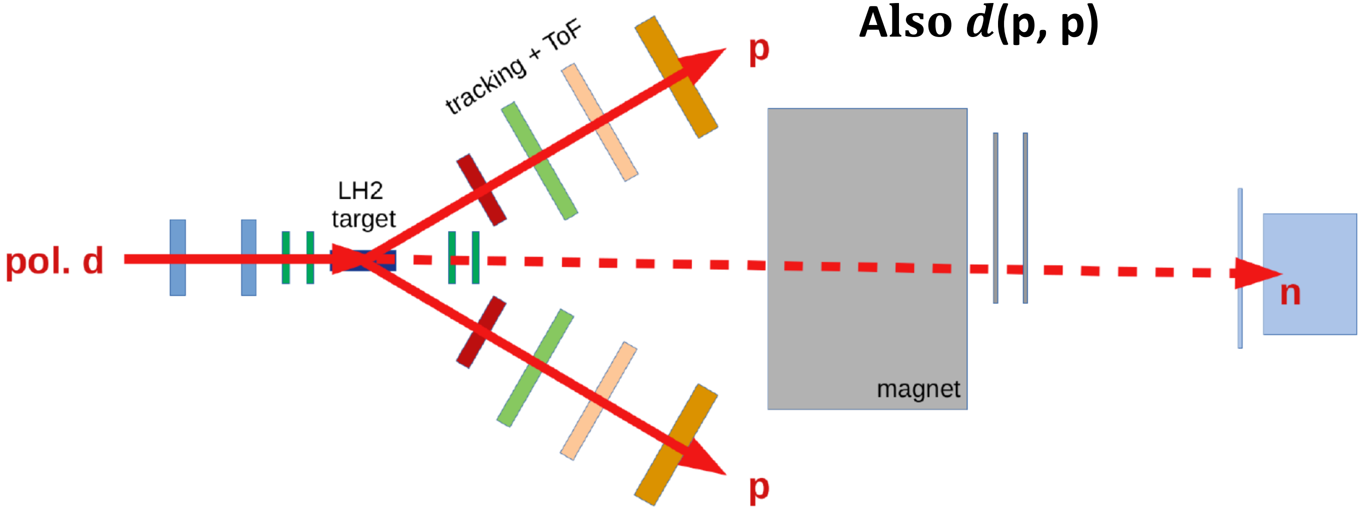


MP, J. Kahlbow et al., **Nature Physics** 17 (2021)

The quasi-free mechanism of the nucleon knockout (or impulse approximation) dominates in p+{NN}➛p+N+N

This can be checked by measuring T_{20} (q_{rel}) in p+d→p+p+n and the same kinematics

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



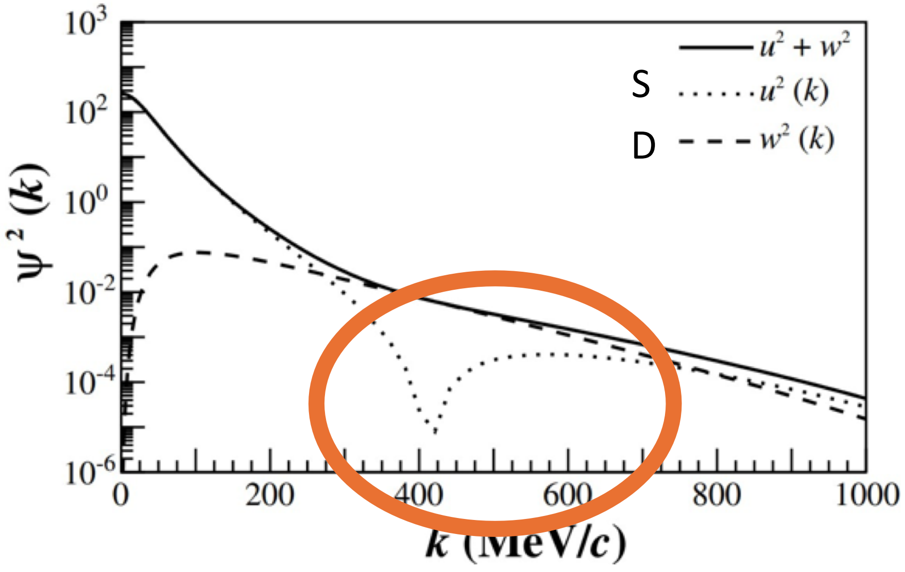
Also $\vec{d}$(p, p)

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

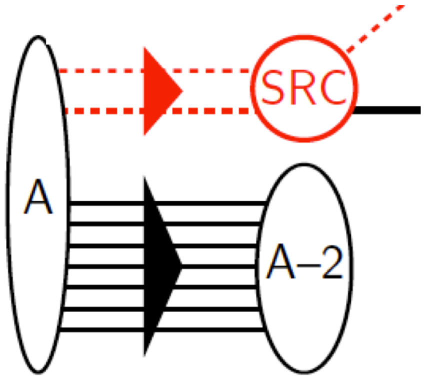
$\sigma-, \sigma+, \sigma0$ – cross sections for different tensor polarization states

- $|t|$ & $|u| > 1$ 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} – better sensitivity to admixture of small w.f. component than σ



u(k) – S-wave, w(k) – D-wave



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

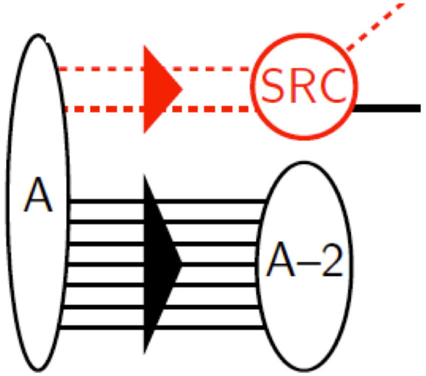
$$\sigma \sim u(k)^2 + w(k)^2$$

$\sigma-, \sigma+, \sigma 0$ – cross sections for different tensor polarization states

$$A_{zz} \sim \frac{\frac{1}{2}w^2(k) - u(k)w(k)\sqrt{2}}{u^2(k) + w^2(k)}$$

L. Frankfurt and M. Strikman, Phys.Rept. 160, 235 (1988)
V. G. Ableev, E. Strokovskii et. al, Pis'ma Zh. Exp. Teor. Fiz. 47, 11 (1988)

What can we study?



1. Relativistic description of the bound system 

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

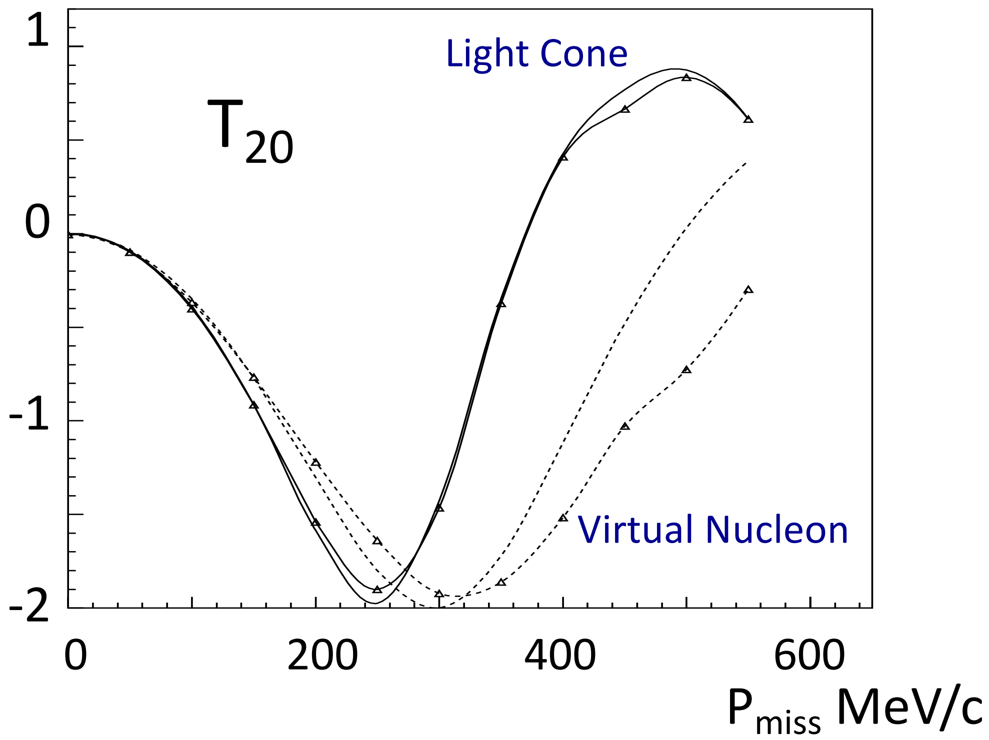
3. Final state interactions (FSI) in the high-momentum region 

4. Non-nucleonic deuteron components in polarization measurements 

Relativistic description of the bound compact system

$$T_{20} \equiv \frac{1}{3}\left(\sigma(1,1) + \sigma(1,-1) - 2\cdot\sigma(1,0)\right)$$

$$\theta_{ps} = 180^0$$



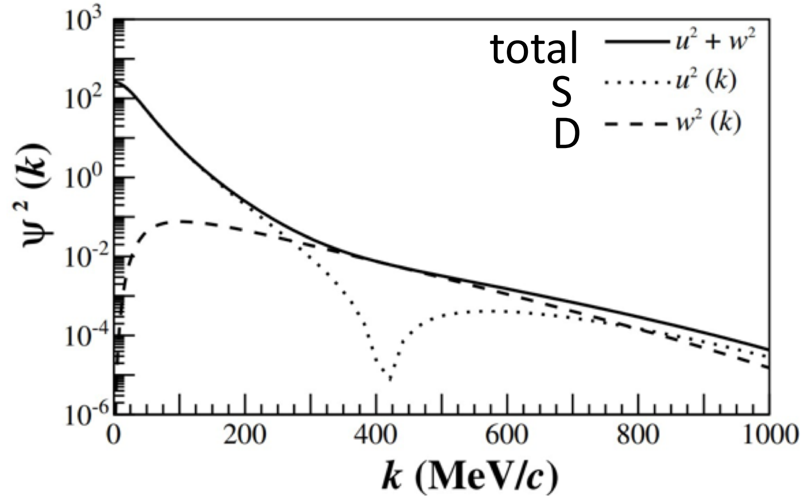
Curves with triangles Include FSI

M.Sargsian & M.Strikman, 2002

Work in Progress

Ratio between S- and D-waves of the deuteron

NN-potentials have different D-wave contribution

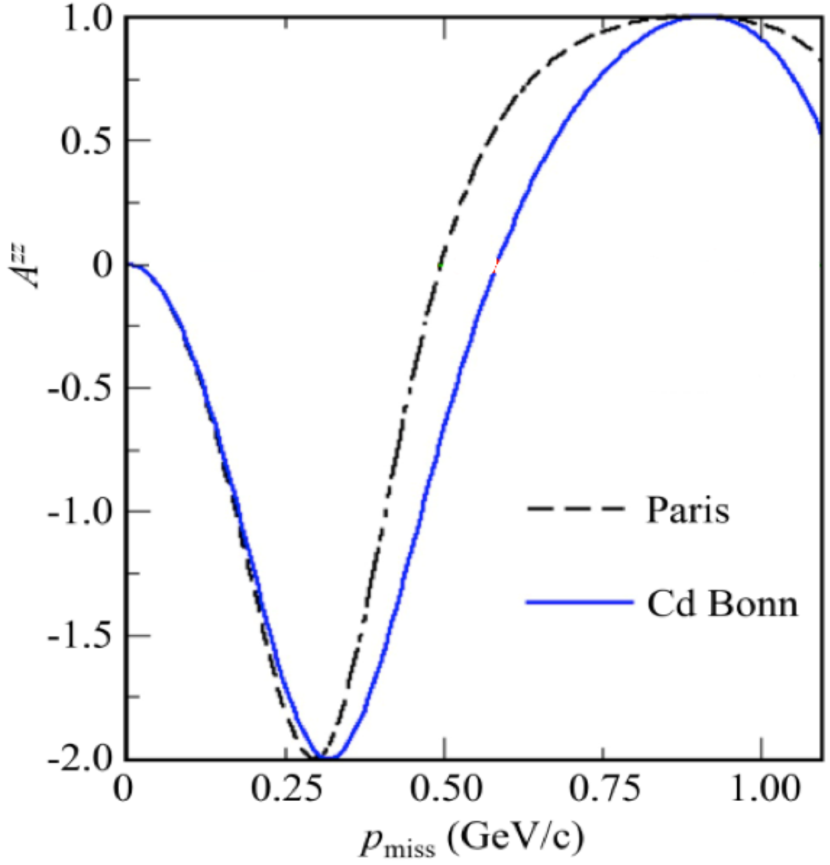


4.87% (e.g., CDBonn)

5.76% (e.g., **AV18**)

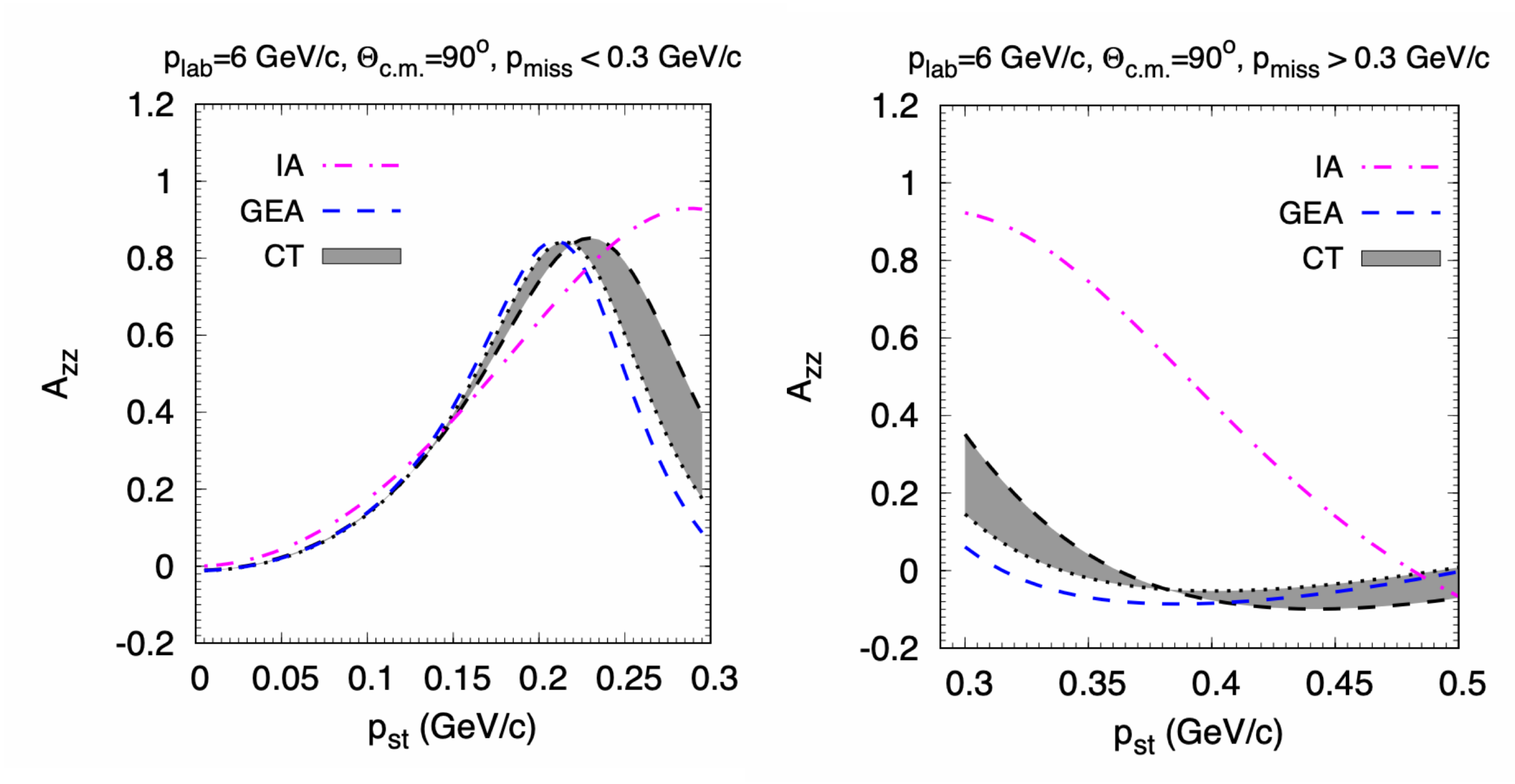
Leads to dramatic differences in relativistic description of the bound system!

Yu. Uzikov



Impact of FSI inside d

A. Larionov



IA = Impulse Approximation

GEA = Generalized Eikonal Approximation

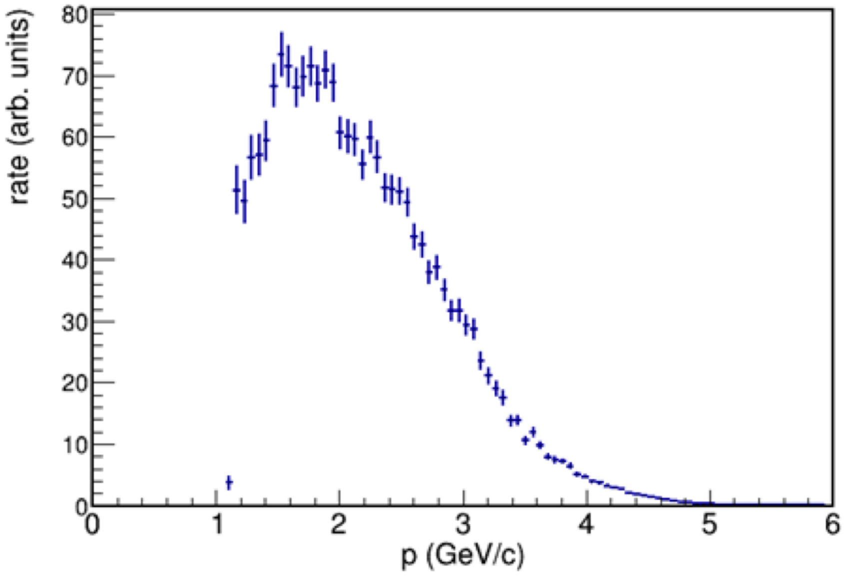
SRC event rate estimation

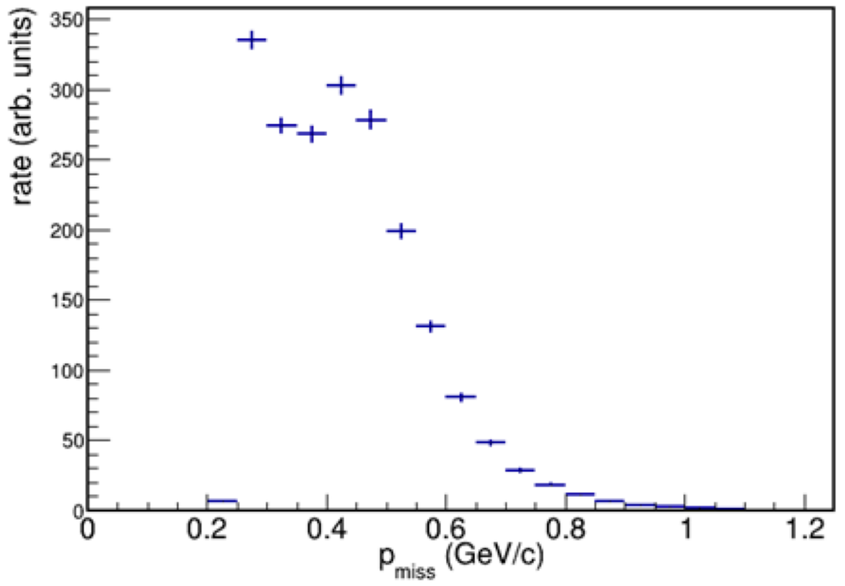
GCF-based simulation
Focus on the deuteron high-momentum tail:

- $|t|$ & $|u| > 1$ 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.

Beam intensity of 10^6 d/s

~250 k events / week with $P_{miss} > 250$ MeV/c





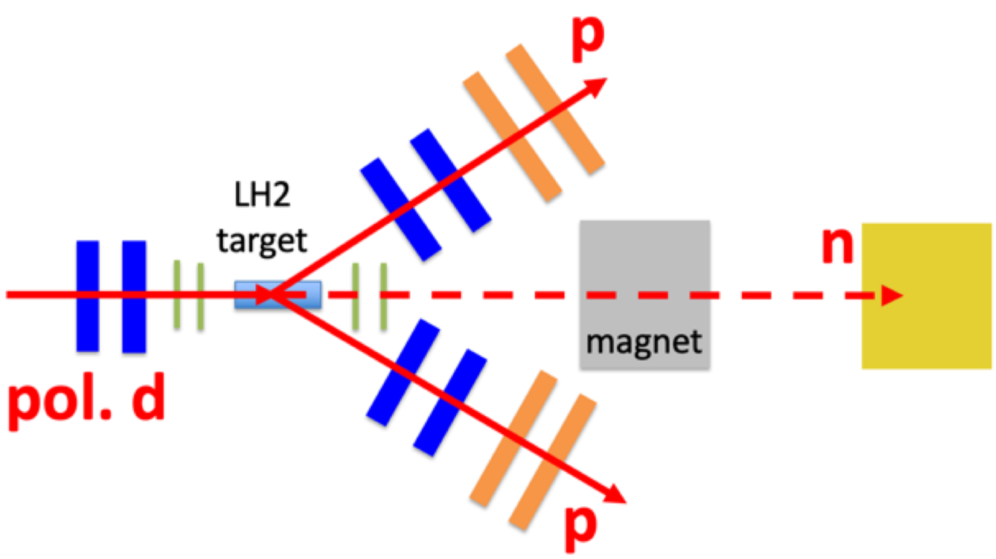
Total event rate estimation

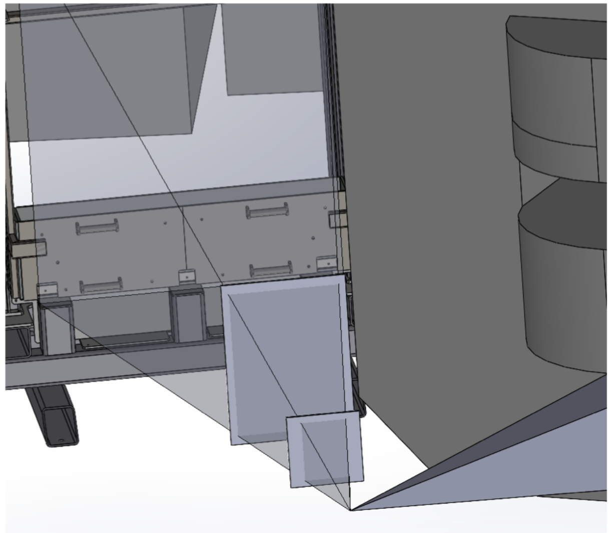
urQMD generator:

At 10^6 deuteron/s ~200 coincidence triggers/s (4/5 with pions)

Trigger rate below the DAQ limit

Experimental setup





LH2 target

Polarimeter

Neutron detector

At least 2 planes of coordinate detectors on each arm with resolution of 200 um

Position beam detectors

Time / dE beam counters

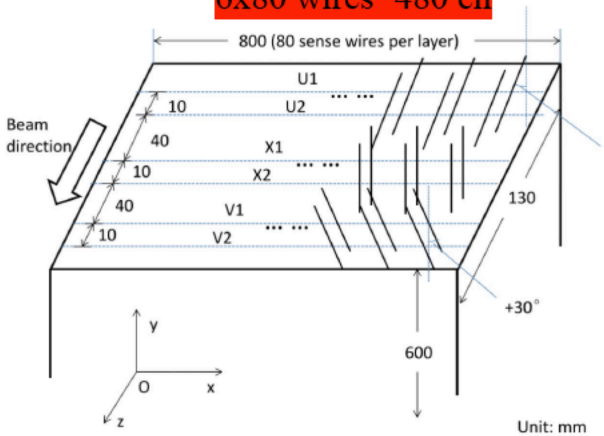
2 MWDC chambers for each arm (6 planes per chamber)

Large MWDCs at IMP-EFT

Active area	80 cm x 60 cm
Quantity	5
Position resolution （σ）	230 um
Efficiency （MIP particle）	～97%

Table 1

6x80 wires=480 ch



6 plans/det: u1u2v1v2x1x2

6 det available including electronics and experts – need detectors back
Fragile - need carefull shipment

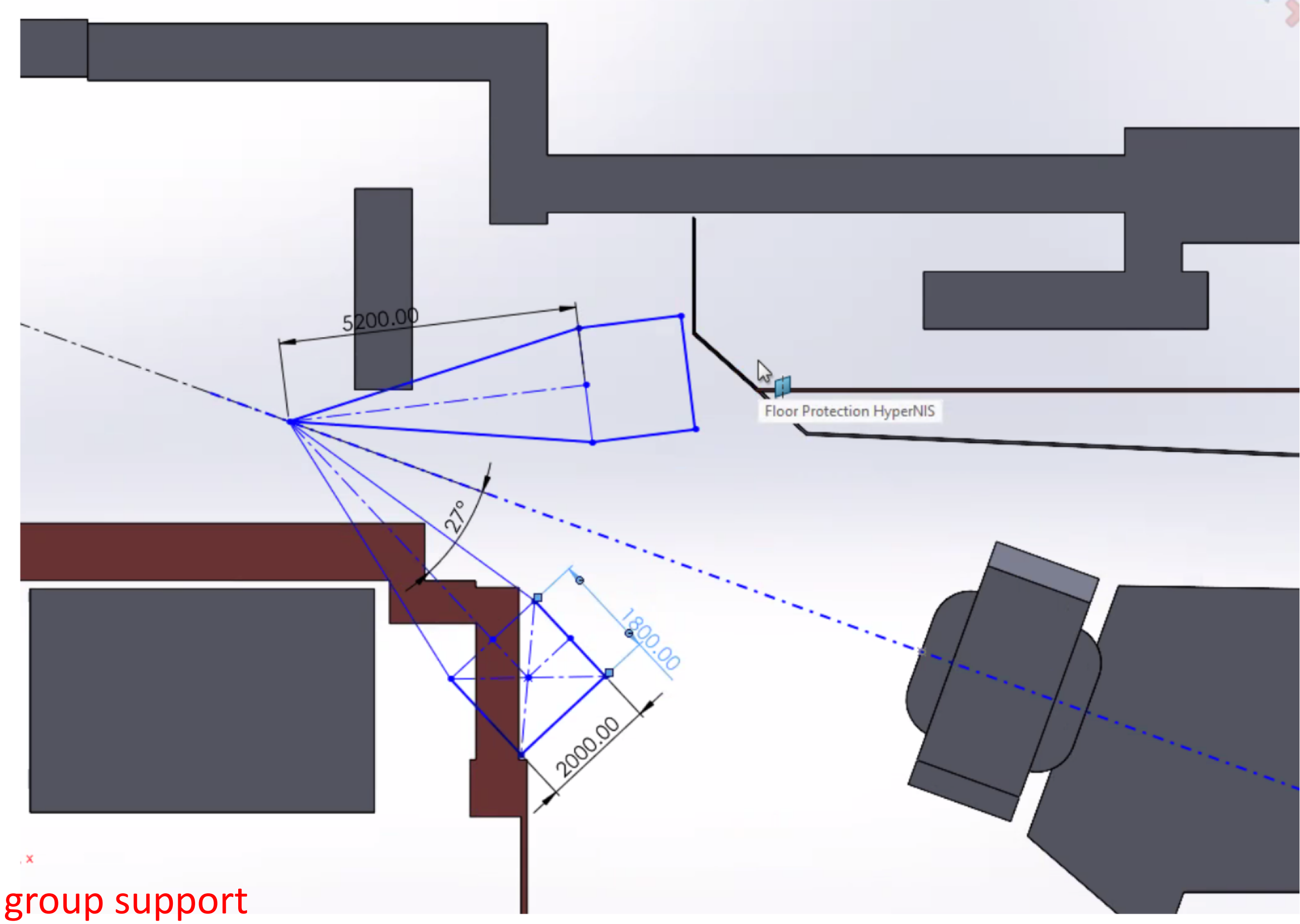
(build and ship 4 new ~100K euro)

Max singles rates 10^4 cps

Need agreement to ship MWDC back to China

Nuclear Inst. and Methods in Physics Research, A 894 (2018) 72–80

Experimental area



1. Move walls and HyperNIS container
2. A few weeks of tensor polarized deuteron beam 6 GeV/n 10^6 d/s
3. Radiation protection and approval of the area for the above
4. TOF/CAL and other detectors installation
5. 1 engineer 2 tech

TOF-CAL

1. Installation at beam height – floor enforcement
2. Power supplies and cables
3. New electronics + new connectors / signal cables

Beam time counters + trigger

1. Reconstruct /check/install/operate the 2022 counters – detector group support
2. Develop, operate trigger - Trigger group support

DAQ

1. 70 channels QTDC for the TOF array and beam counters
2. 200 Channels ADC for the CAL
3. 50 Channels QTDC for the n array
4. Integrating the MWDC output to the data stream
5. DAQ group support

Summary:

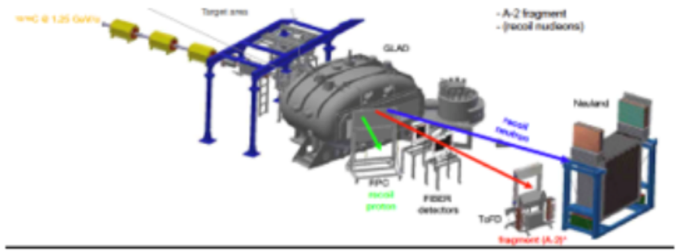
- $\vec{d}$(p, 2p)n exclusive measurement in SRC kinematics aiming at A_{ZZ} at high Pmiss
- Two-arm spectrometer with detectors and electronics partly available,

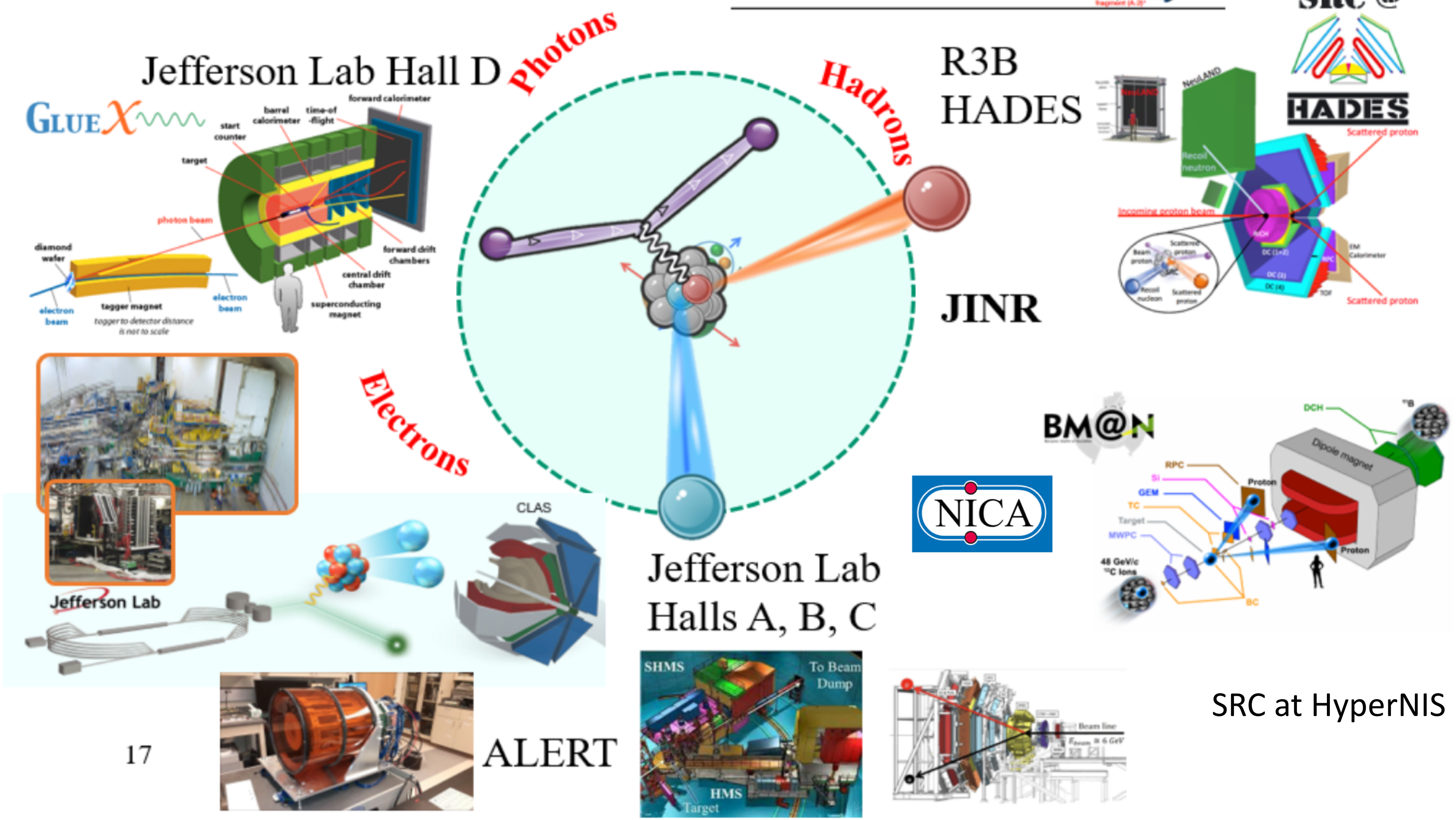
  JINR LH target + DAQ, new MWDC from China
- Can be done (assuming a contribution from JINR) in the next couple of years

  complementing the world-wide SRC effort (ALERT with polarized target at JLab)
- Theory support: Yu. Uzikov, A. Larionov (JINR)

  M. Strikman, M. Sargsian (USA)

Multimessenger SRC studies





Thank you!

SRC manpower

Category of personnel	Full name	Division	Amount of FTE
research scientists	Atovullaev T. Nepochatykh S. Patsyuk M. + HyperNIS collaborators + JINR collaborators from other groups	VBLHEP VBLHEP VBLHEP VBLHEP	1 1 1 1 1
Engineers (= students)	Atovullaeva A. Bochkova A.	VBLHEP VBLHEP	1 1
Main engineer Two technicians	Needed!!!		**3**
Total:			**7 (10)**

Cost estimate for SRC

Expenditures, resources, funding sources	Cost (thousands of US dollars)	Cost/Resources, distribution by years				
		1st y	2nd y	3rd y	4th y	5th y
International cooperation	50	10	10	10	10	10
Materials (not including DAQ*)		?	?	?	?	?
Commissioning						
R&D contracts with other research organizations						
Software purchasing	10	2	2	2	2	2
Design/construction						
- the amount of FTE,		10	10	10	10	10
- accelerator/installation,		0	0	1500	0	0

* Depending on sharing existing at JINR equipment