14th conference of young scientists and specialists (“Alushta-2025”)
8 – 15 June 2025

Optimization of the detector configuration for the new SRC experiment with a polarized deuteron beam

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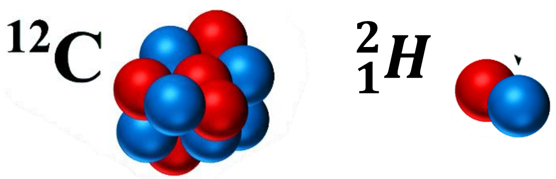
Patsyuk M., Atovullaev T.

Dubna 2025

Experimental Strategy for Probing SRCs

1. Compact deuteron = SRC



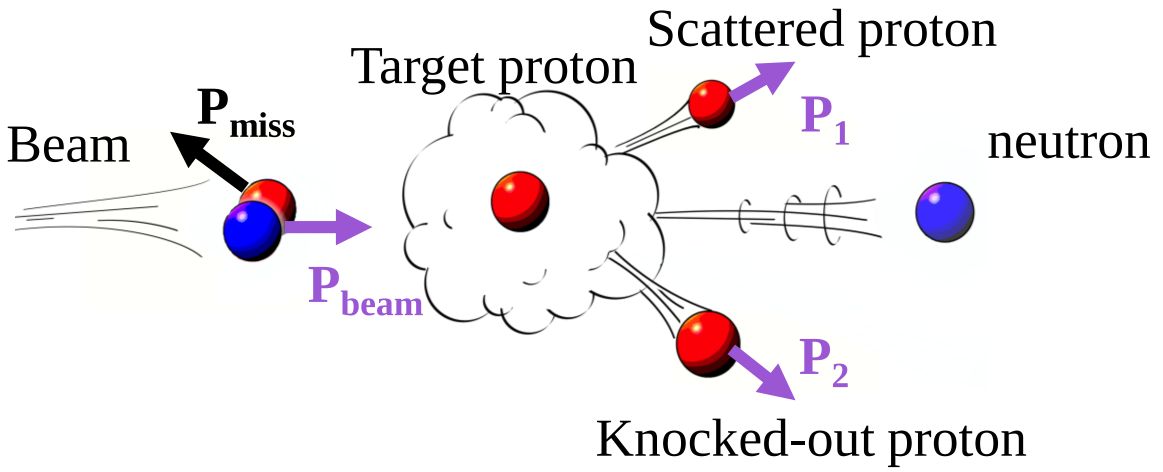
2. Tensor asymmetry[1, 2]

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

allows to study:

- relativistic description of the bound system;
- final state interactions in the high-momentum region;
- non-nucleonic deuteron components in polarization measurements.

3. Quasi-free (p,2p) scattering



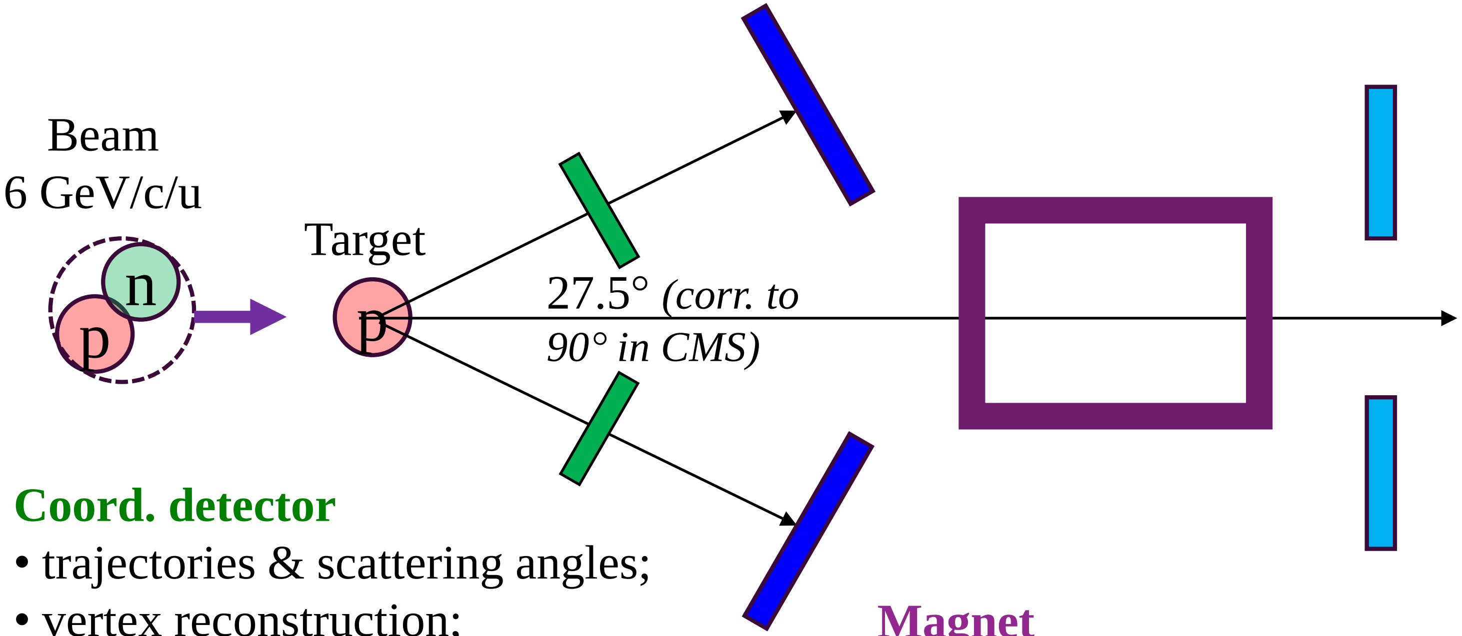
Experimental requirements

1. $\mathbf{P_{miss} = P_1 + P_2 - P_{beam}}$ → reconstruct neutron momentum (SRC signature).
2. **|t|, |u| > 1 GeV²** → hard, short-distance collision;
3. $\boldsymbol{\theta_{cm} > 60°}$ → wide scatter (high Q²).
4. $\boldsymbol{20° < \theta_{lab} < 45°; |\varphi_{lab}| < 20°}$.

[1] *L. Frankfurt and M. Strikman, Phys.Rept. 160, 235 (1988),* [2] *V. G. Ableev, E. Strokovsky et. al, Pis'ma Zh. Exp. Teor. Fiz. 47, 11 (1988)*

Experimental setup

Need to build a new experimental setup in the new place



Coord. detector
- trajectories & scattering angles;
- vertex reconstruction;
- momentum measurements.

ToF detector
- proton identification;
- time-of-flight measurements.

Magnet
Deflect the unreacted beam

Neut. Det
- detect the recoil neutrons.
- SRC event identification.

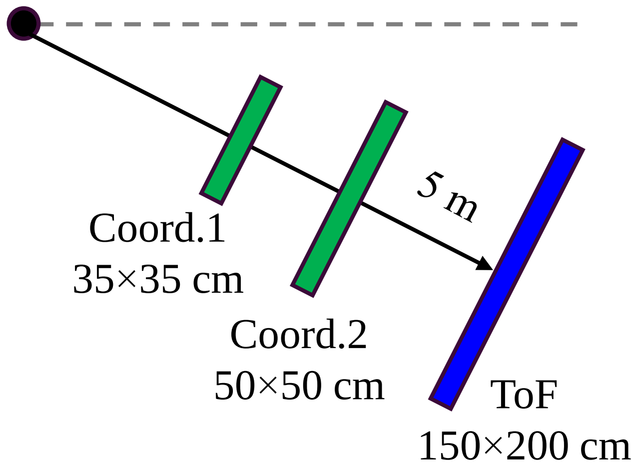
Software and research methods

Generator: Generalized Contact Formalism
Simulations: Geant4
Reconstructions: CERN ROOT

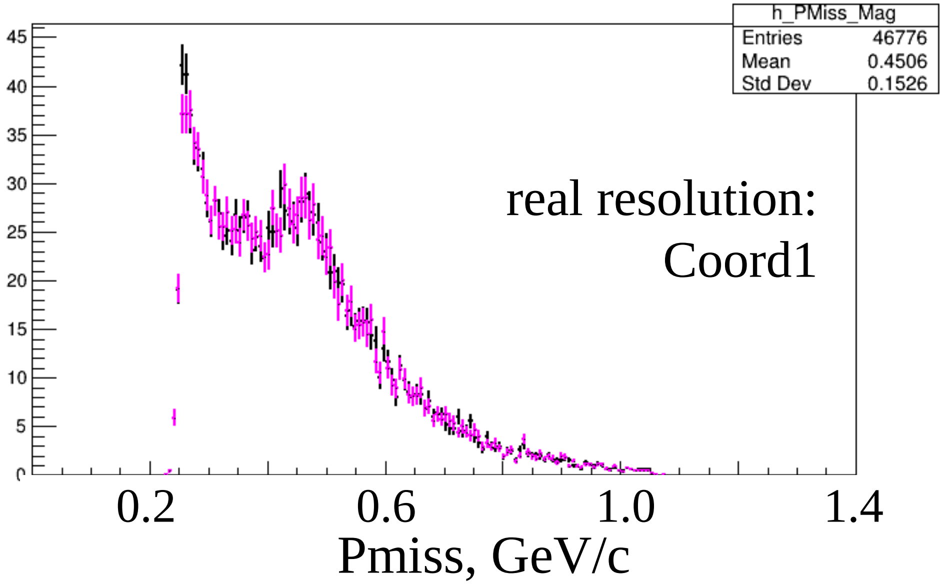
What we vary:

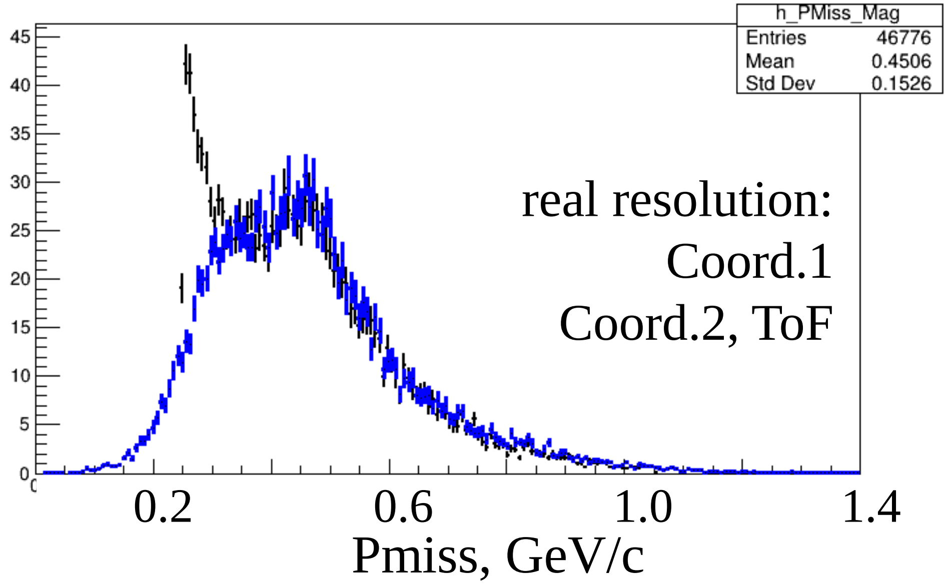
1. Optimize the arm detector configuration and achieve the best Pmiss resolution
2. Consider neutron detector and find its optimal location in order to measure the neutron momentum
3. Optimize the arm angle and length to measure the SRCs

Arm detectors' resolution



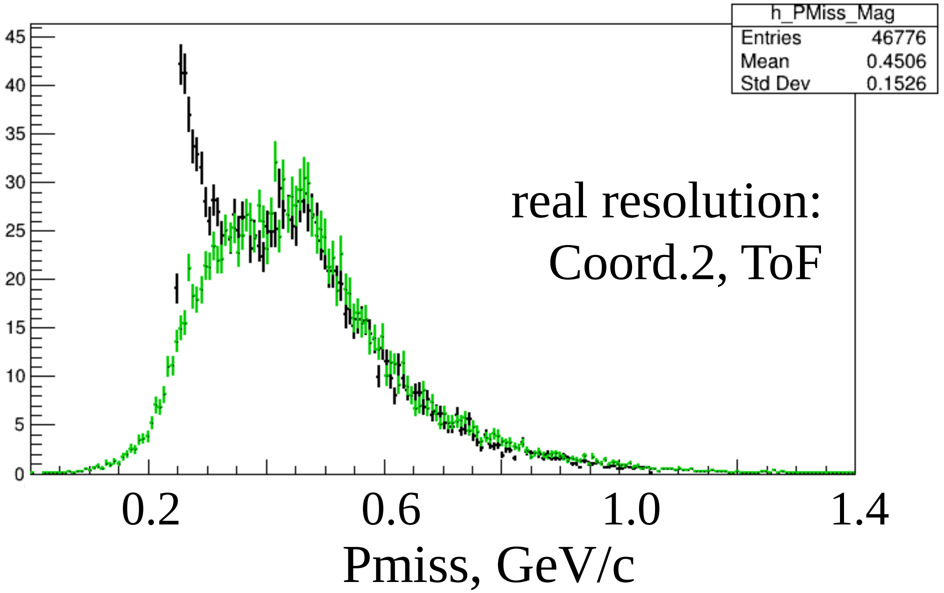
MWDC_res = 230 µm,
Tof_res = 90 psec

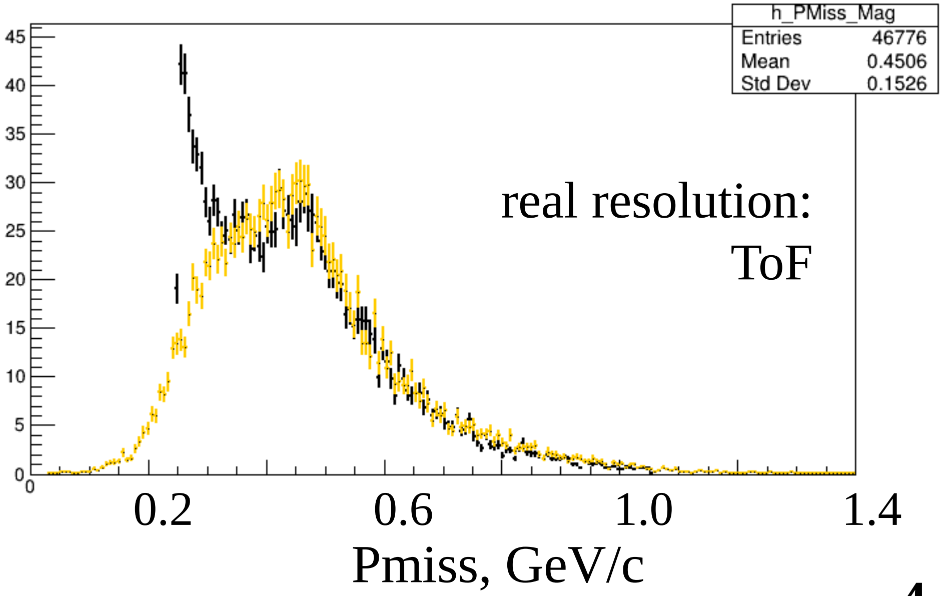




Coordinate Detector : pmiss reconstruction is insensitive to the coordinate detector resolution (up to 1mm)

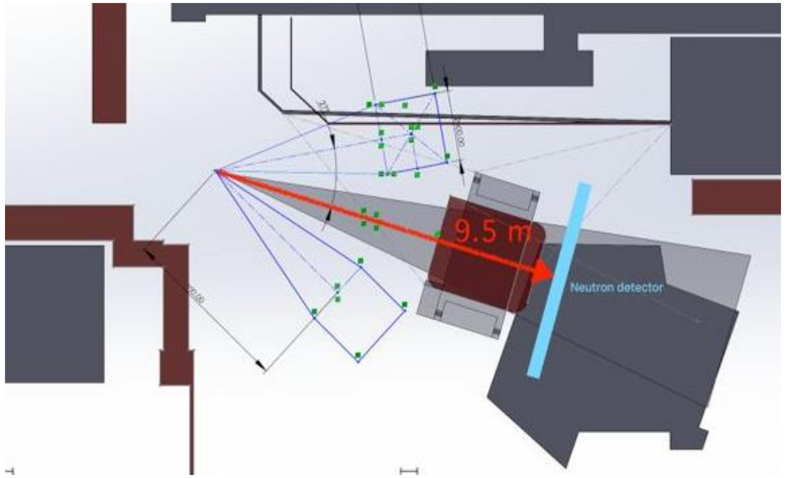
ToF resolution suppresses low momentum pmiss reconstruction.

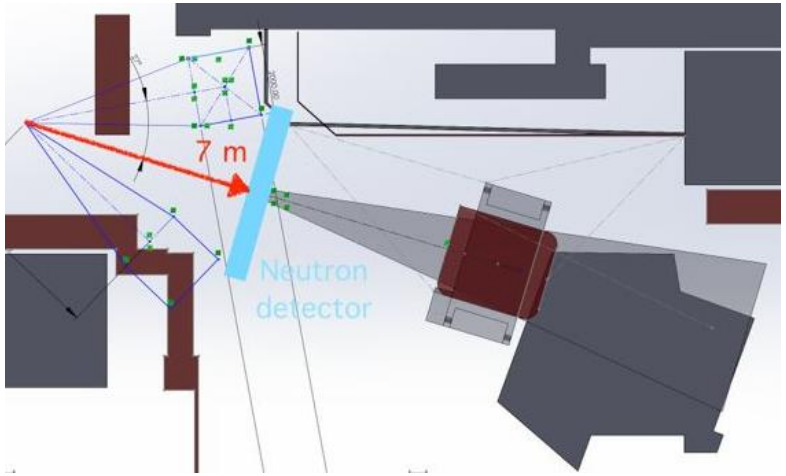


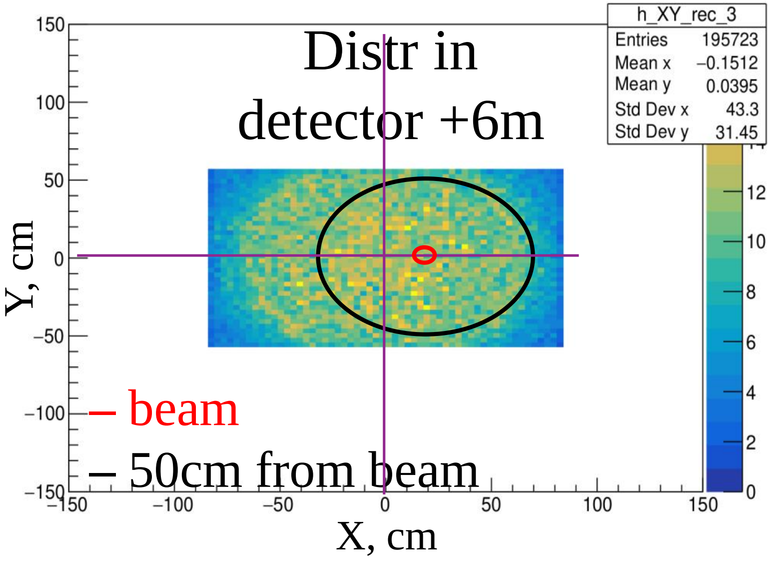


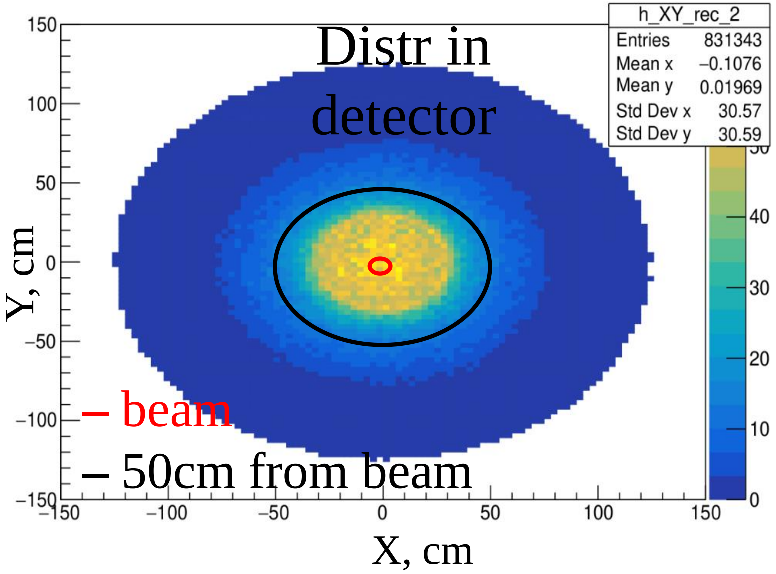
Neutron detector position options

GEOM_1	GEOM_2









•Geom_1:

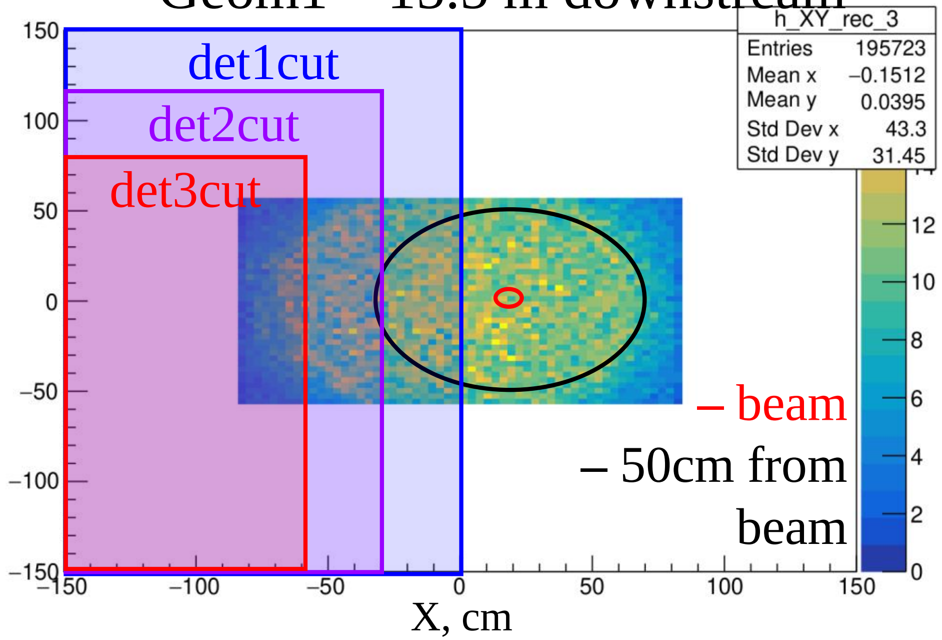
- ✓ the beam is deflected by the magnet.
- ✓ closer to the center of the beam.
- ✓ allows to measure more neutrons

•Geom_2:

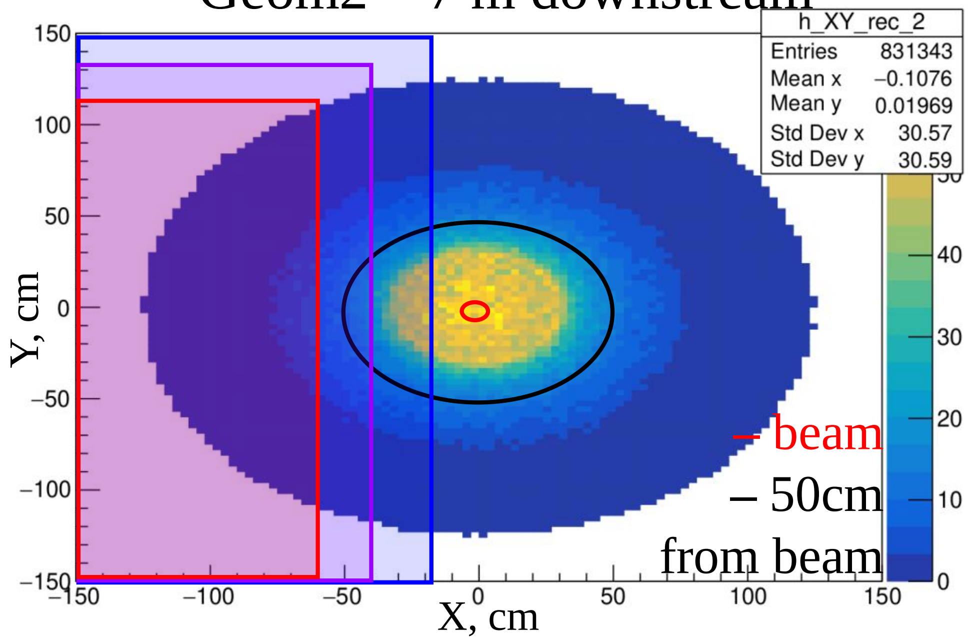
- ✓ the beam isn't deflected by the magnet.
- ✓ Farther from the center of the beam.
- ✓ less neutrons are detected

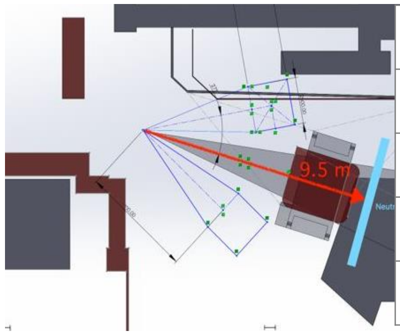
Geom1 vs Geom2

Geom1 – 15.5 m downstream

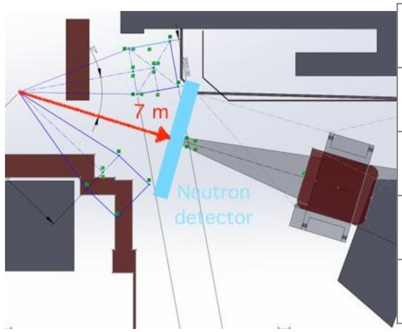


Geom2 – 7 m downstream



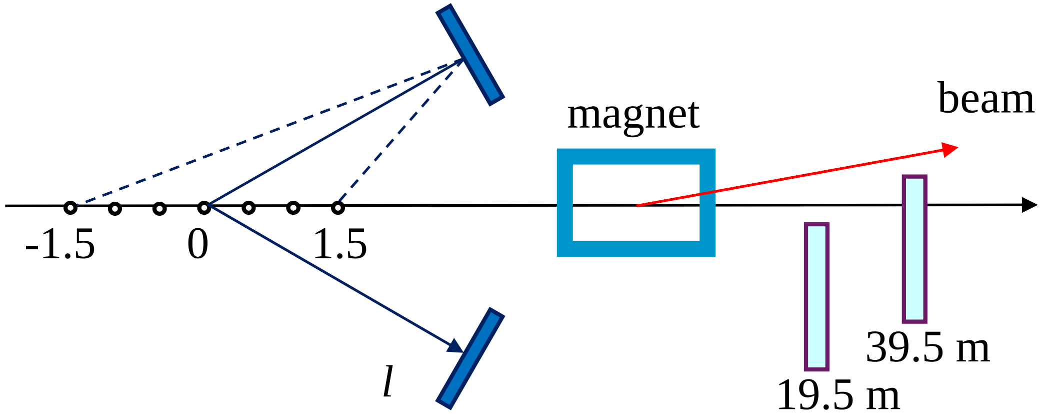


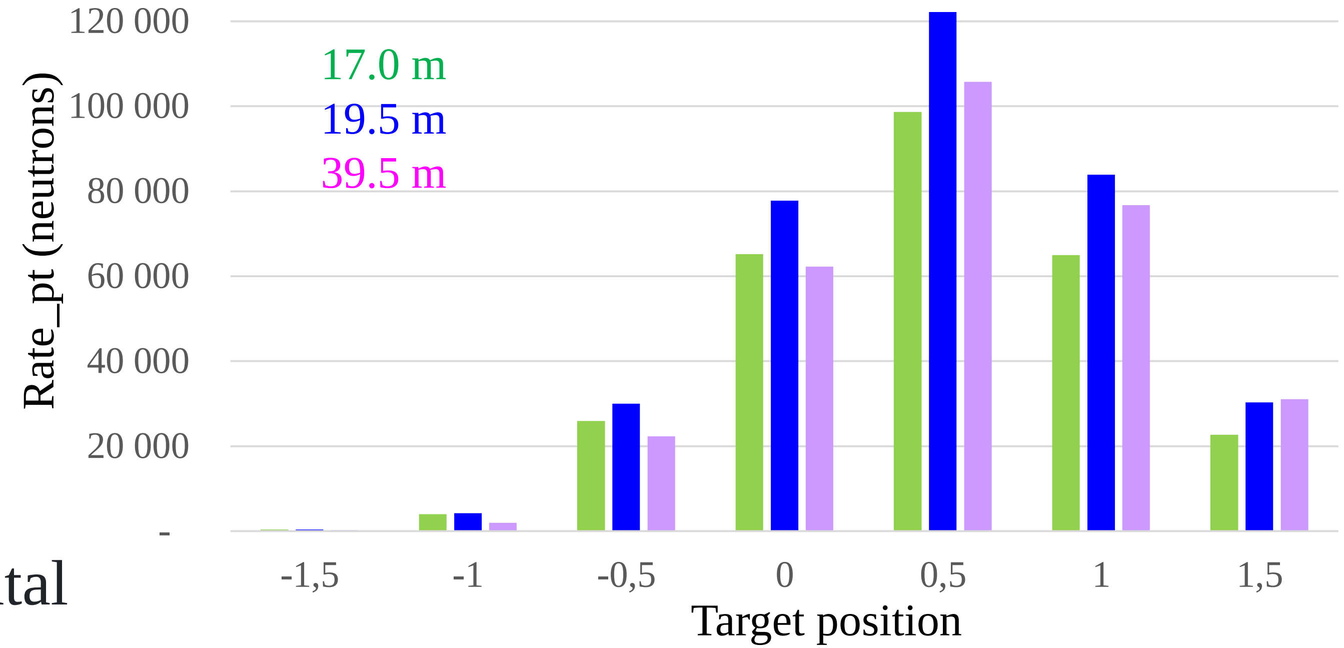
cut	[cm]	total rate	%
wo cut	–	461 109	100,00%
Det1cut	X < 0	231 718	50,25%
Det2cut	X < -30	150 388	32,61%
Det3cut	X < -60	85 400,8	18,52%



cut	[cm]	total rate	%
wo cut	–	461 109	100,00%
Det1cut	X < -20	117 023	25,38%
Det2cut	X < -40	45 064	9,77%
Det3cut	X < -60	12 406,3	2,69%

Target position





•**Target Movement:** Limited experimental zone, target moved back/forth to adjust arm length.

•**Neutron Rate:** Neutron rate maximized with 0.5m downstream target shift.

•**Max Neutron Rate :** observed at 19m distance.

	17 m	19.5 m	39.5 m
pos	Rate_pt	Rate_pt	Rate_pt
-1.5	376	399	189
-1	3 963	4 193	1 972
-0.5	25 897	29 993	22 314
0	65 155	77 749	62 248
0.5	**98 637**	**122 163**	**105 711**
1	64 956	83 883	76 715
1.5	22 649	30 316	31 051

Summary

1. Two-arm spectrometer (two coordinate planes and TOF detector):
   - Calculating the Pmiss resolution for the given coordinate (~100-500 um) and TOF (90 ps) resolutions, the largest smearing is from TOF resolution
   - Defined the optimal target position (arm angle and length) maximizing the number of SRC events

2. Optimized the position of the neutron detector for neutron momentum measurement

Future steps:

- Continue simulation work with beam momentum 4 GeV/c/u;
- Consider coordinate detectors (spatial resolution 100, 500, 1000 μm) and assess resolution of Pmiss reconstruction;
- Optimization of generator's settings.

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Thank you for your attention!

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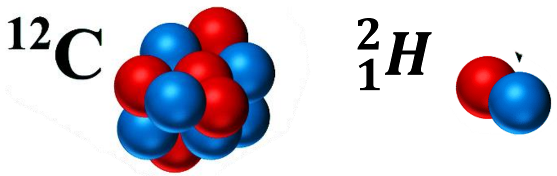
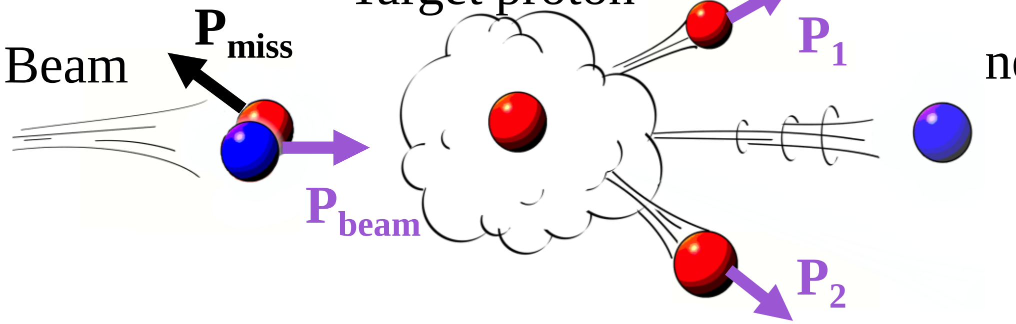


2. Tensor asymmetry[1, 2]

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

3. Quasi-free (p,2p) scattering



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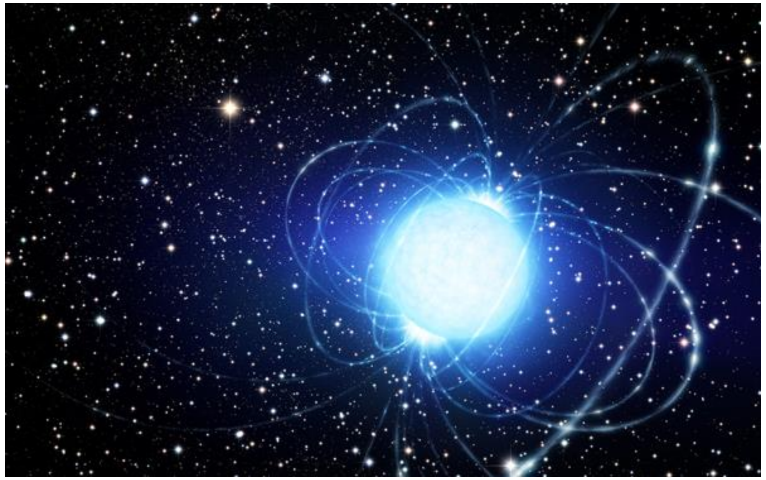
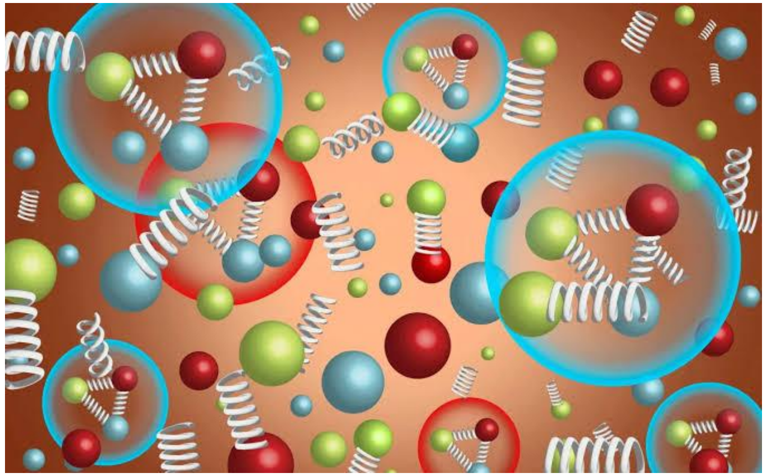
Short-range correlations with a polarized beam





•**Fundamental Understanding**: Deepen understanding of the strong force, which is one of the four fundamental forces of nature.

•**Nuclear Structure**: Provide essential information for constructing more accurate and predictive models of nuclei, nuclear matter, and neutron stars.

•**Quark-Gluon Structure**: Contribute to understanding how the properties of nucleons (like their spin) evolve as you probe smaller and smaller distances, where the underlying quark and gluon structure becomes important.