



中国科学院
CHINESE ACADEMY OF SCIENCES



中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences

Spin Physics at HIAF

Boxing Gou
on behalf of the HIAF spin team

Qingdao • September 22-26, 2025

26th International Symposium on Spin Physics (SPIN2025)



➤ Efforts towards polarized beams/targets for HIAF

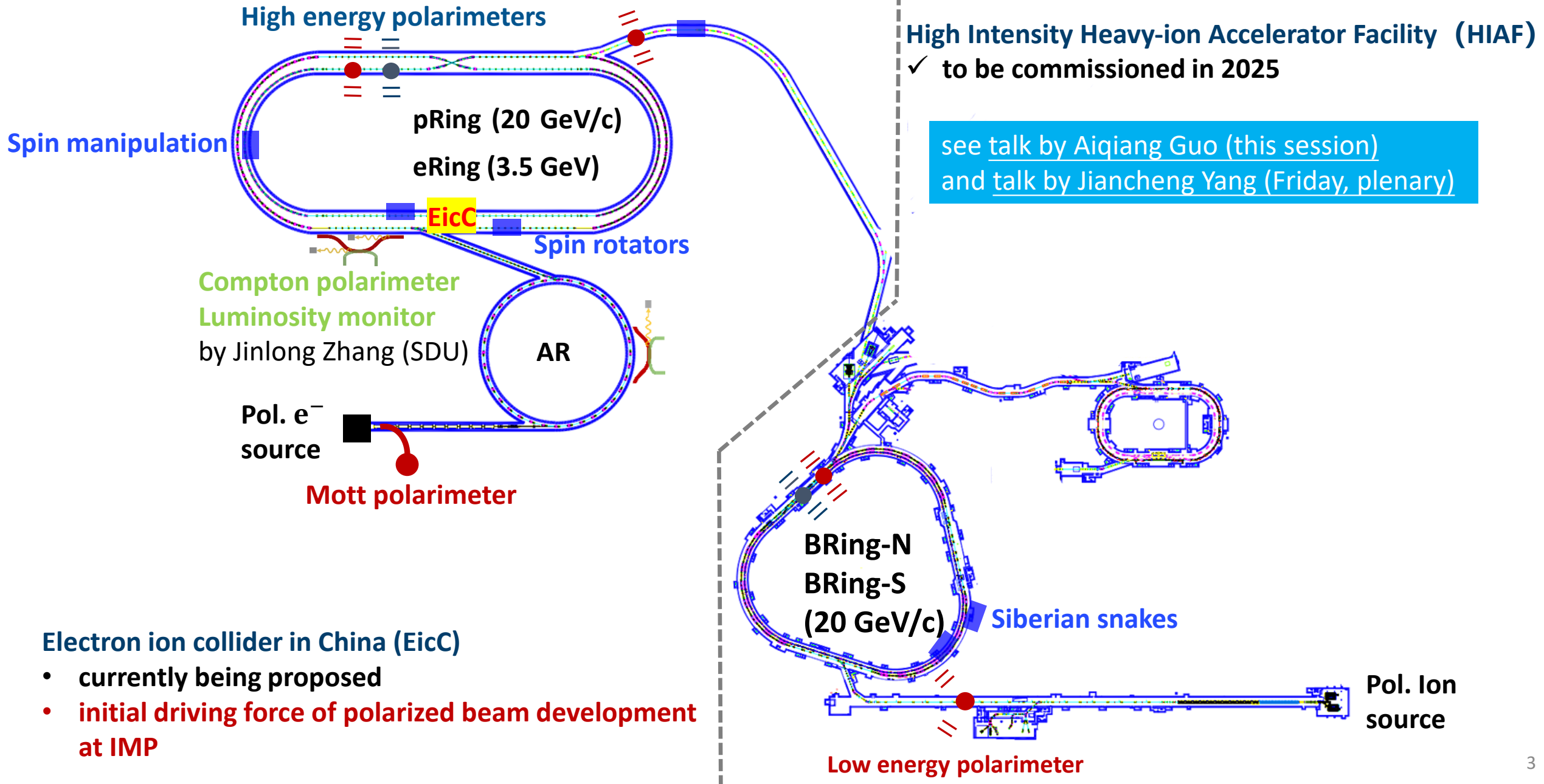
- Polarized ion sources
- Acceleration of polarized beams
- Beam polarimetry and polarized targets

➤ Spin physics at HIAF in the near future

- Atomic, nuclear and hadron physics
- New boson search
- Test of time-reversal symmetry
- **Spin-rotating polarized target**

Final-state polarization measurements not covered

[see talk by Yutie Liang \(Tuesday\)](#)



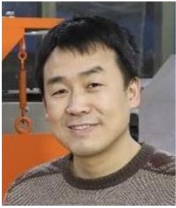
Electron ion collider in China (EicC)

- currently being proposed
- initial driving force of polarized beam development at IMP

- Efforts towards polarized beams/targets for HIAF
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Efforts towards polarized beams/targets at HIAF

- A team for **polarized ion source**, **polarized beam acceleration** and **polarized target**
- International collaborations



team leader



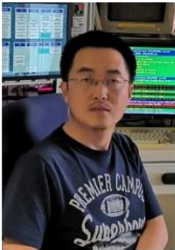
pol. ^3He



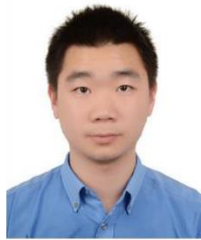
engineering
vacuum



pol. H/D source



polarimeter
pol. H target



pol. ion source
pol. H target



magnet



beam diagnostic



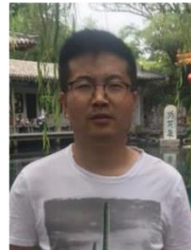
polarimeter
pol. H target



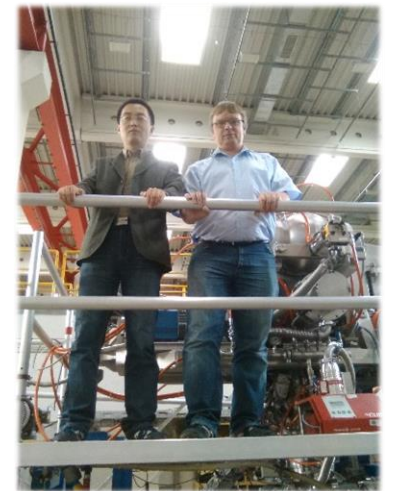
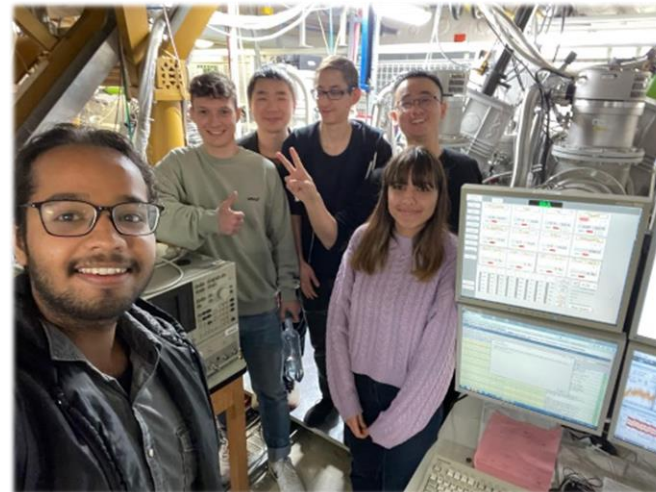
pol. beam acc.
spin manipulation



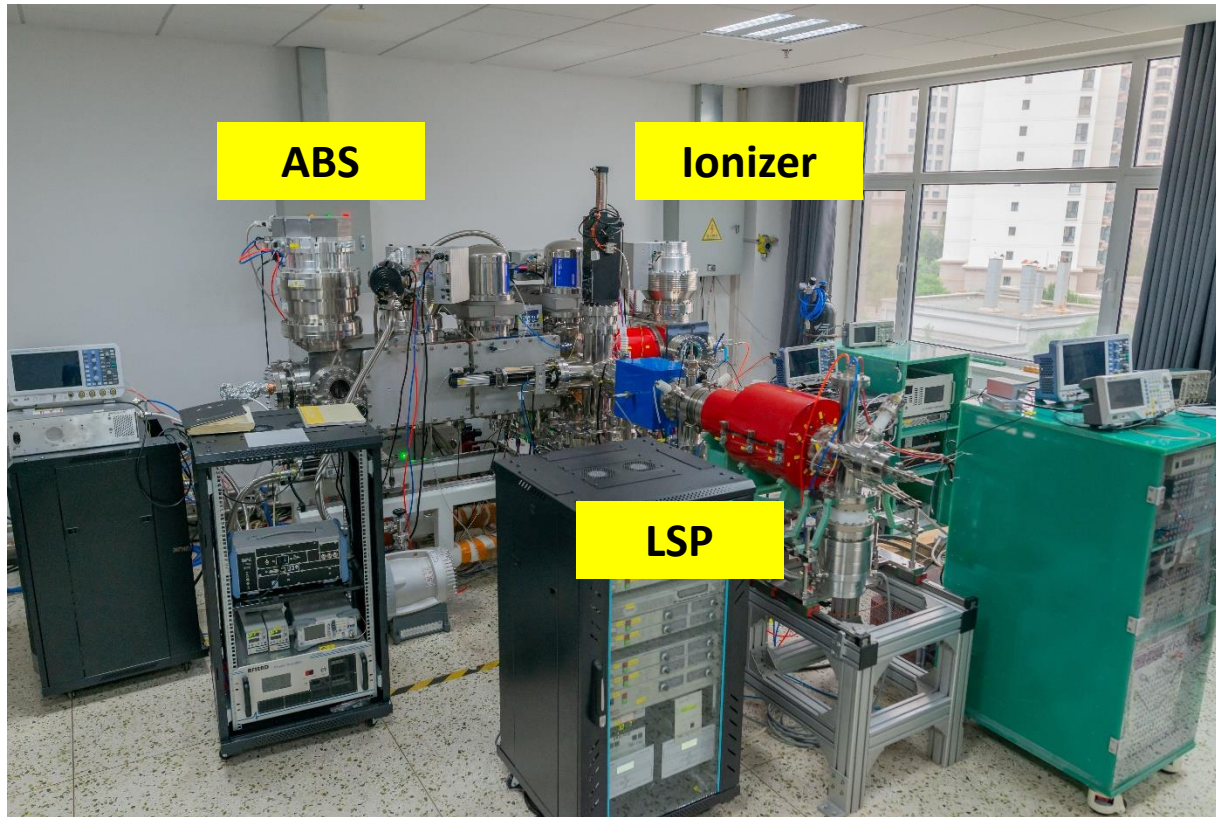
ionizer
Lamb-Shift
polarimeter



control system



Efforts towards polarized beams/targets at HIAF



A polarized H^+/D^+ source already built at IMP

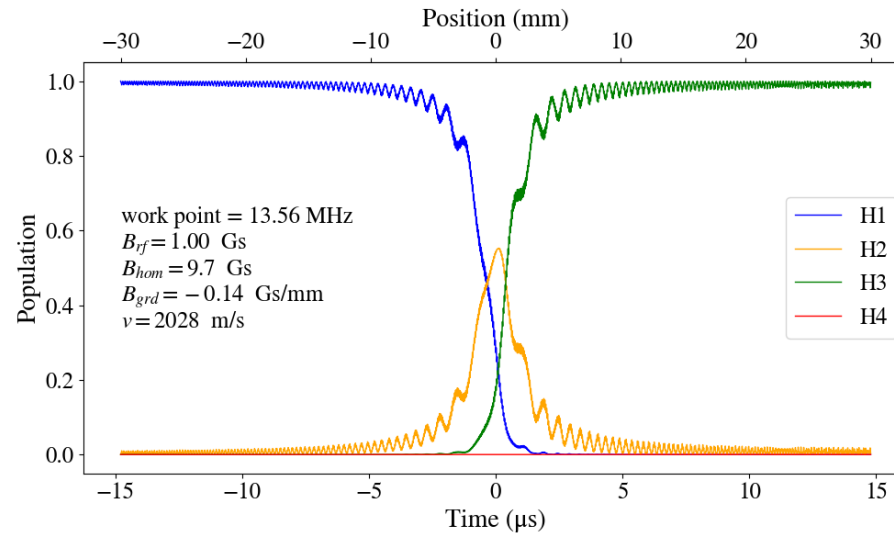
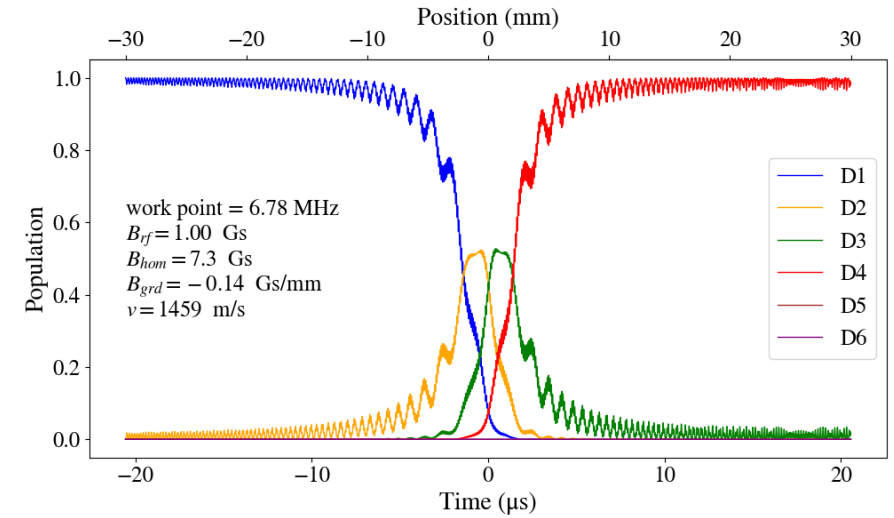
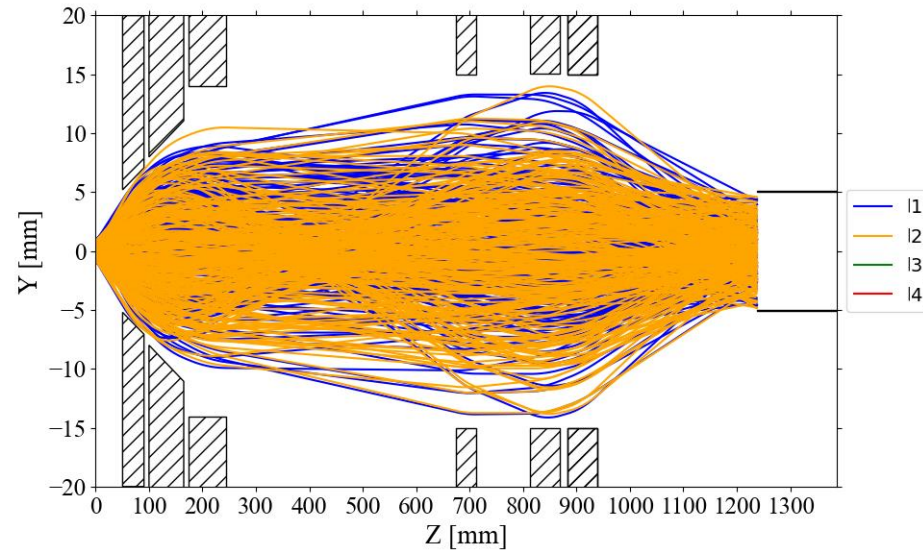
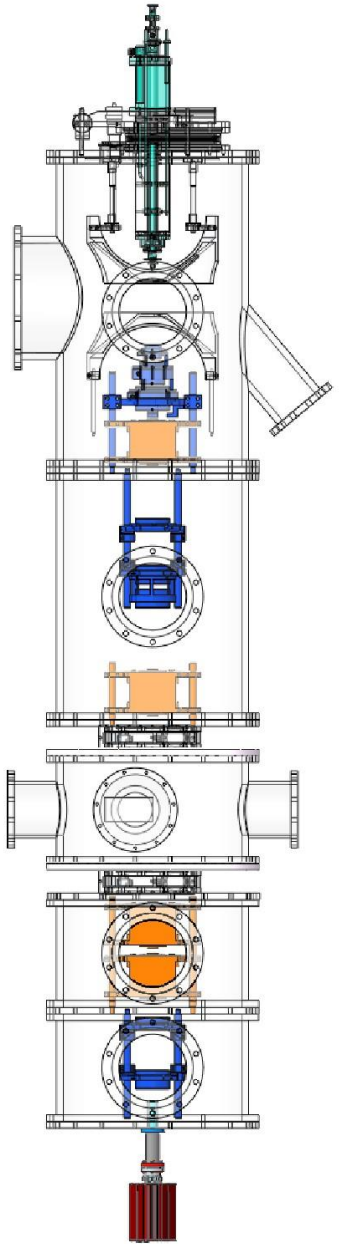
- **Intensity: > 1 mA**
- **Polarization: $> 80\%$**
- **Repetition frequency: 2-5 Hz**
- **Pulse width: > 100 us**

see [talk by Yaojie Zhai](#) (Tuesday)
and [talk by Sheng Zhang](#)

Polarized beam acceleration at HIAF investigated by Minxiang Li et al.

- constant field solenoid Siberian snake: [NIMA 1031, 166405 \(2022\)](#)
- tensor-polarized deuteron beam: [Phys. Rev. Accel. Beams 28, 094002](#)

PIT design in progress



PIT design in progress

- ✓ Preliminary mechanical design
- ✓ Atomic tracking in sextuple magnet
- ✓ Zeeman transition in RF units

see talk by Xiaorong Lv (Tuesday)

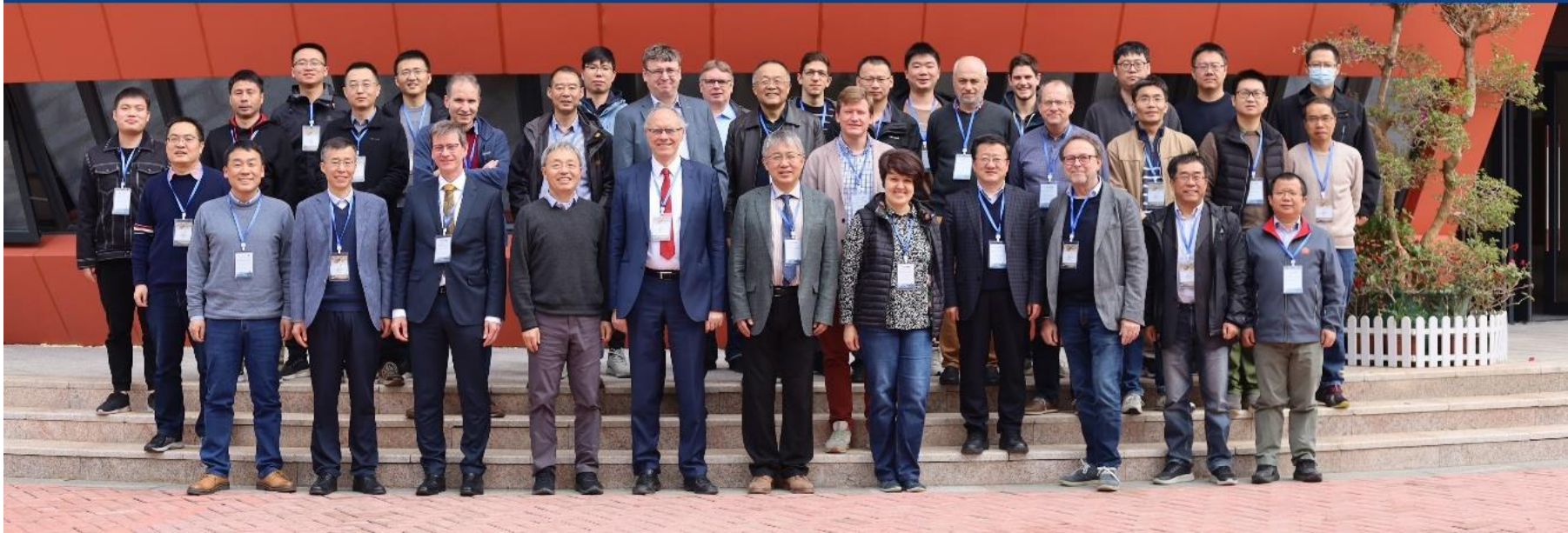
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 - Test of time-reversal symmetry
 - Spin-rotating polarized target

Spin physics at HIAF

- A kick-off workshop last year (PBT2024)
- Productive discussions about spin physics at HIAF
- Welcome all of you to PBT2026 next year!

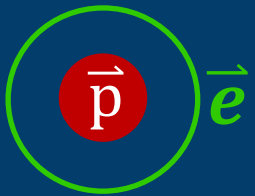


The 1st Workshop on Polarized Beam and Target - Physics and Applications (PBT2024)



Spin physics at HIAF

- Nice spin physics at HIAF with polarized target and (un)polarized beams
- Polarized gas target will be used as both **proton target** and **electron target**



- Ideas and collaborations are more than welcome!

① pol. e target

$$Z^{Q+} + \vec{e} \rightarrow Z^{(Q-1)+} + \hbar\omega$$

$$p\vec{e} \rightarrow pe$$

unpol. beams (A, p)

pol. electron capture (atomic physics)
proton EM radii, new boson search

② pol. p target

$$A\vec{p} \rightarrow Ap$$

unpol. heavy ion beams (C, Ca, Au, ...)

→ many body structure
nuclear physics

③ heavy target

$$\vec{d}A \rightarrow Anp$$

pol. d beams

EOS

nuclear physics

④ pol. p target

$$p\vec{p} \rightarrow pp$$

$$\vec{p}\vec{p} \rightarrow pp$$

pol. p beams

A_N
 A_{NN} } → NN spin dynamics
glueball in t channel
hadron physics

⑤ pol. d target

$$\vec{p}\vec{d} \rightarrow pd$$

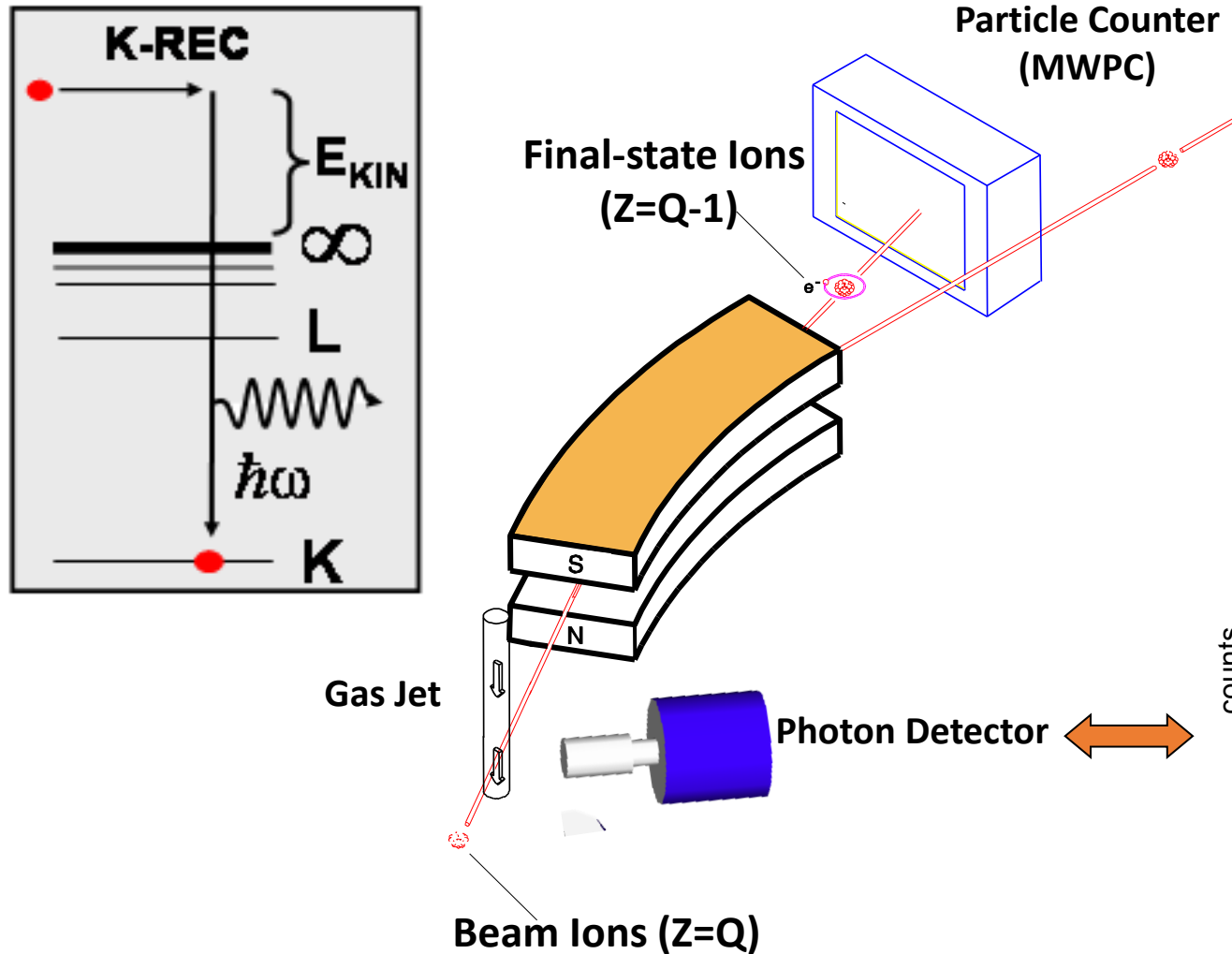
pol. p beams

test of time reversal symmetry

Polarized e^- capture

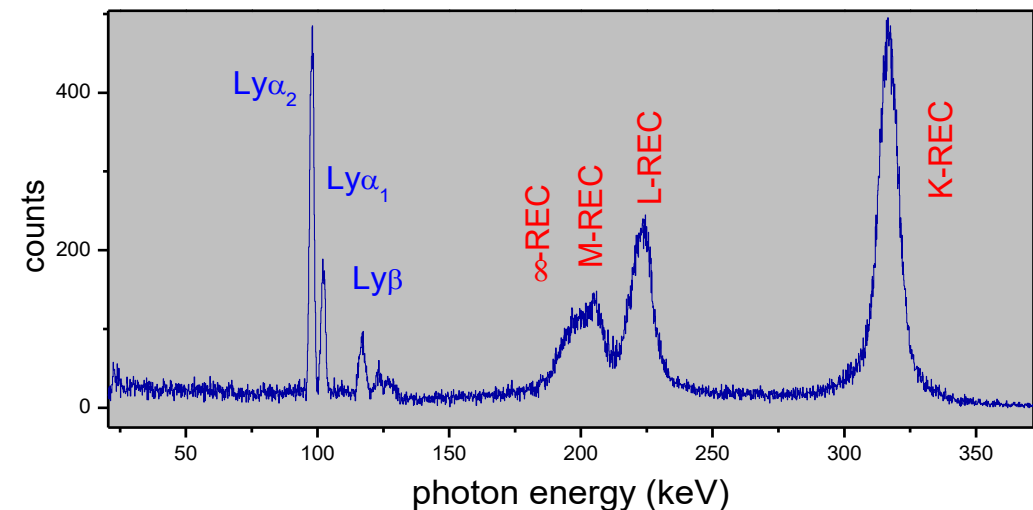
REC with pol. e target

➤ Radiative electron capture (REC): $Z^{Q+} + e^- \rightarrow Z^{(Q-1)+} + \hbar\omega + \dots$



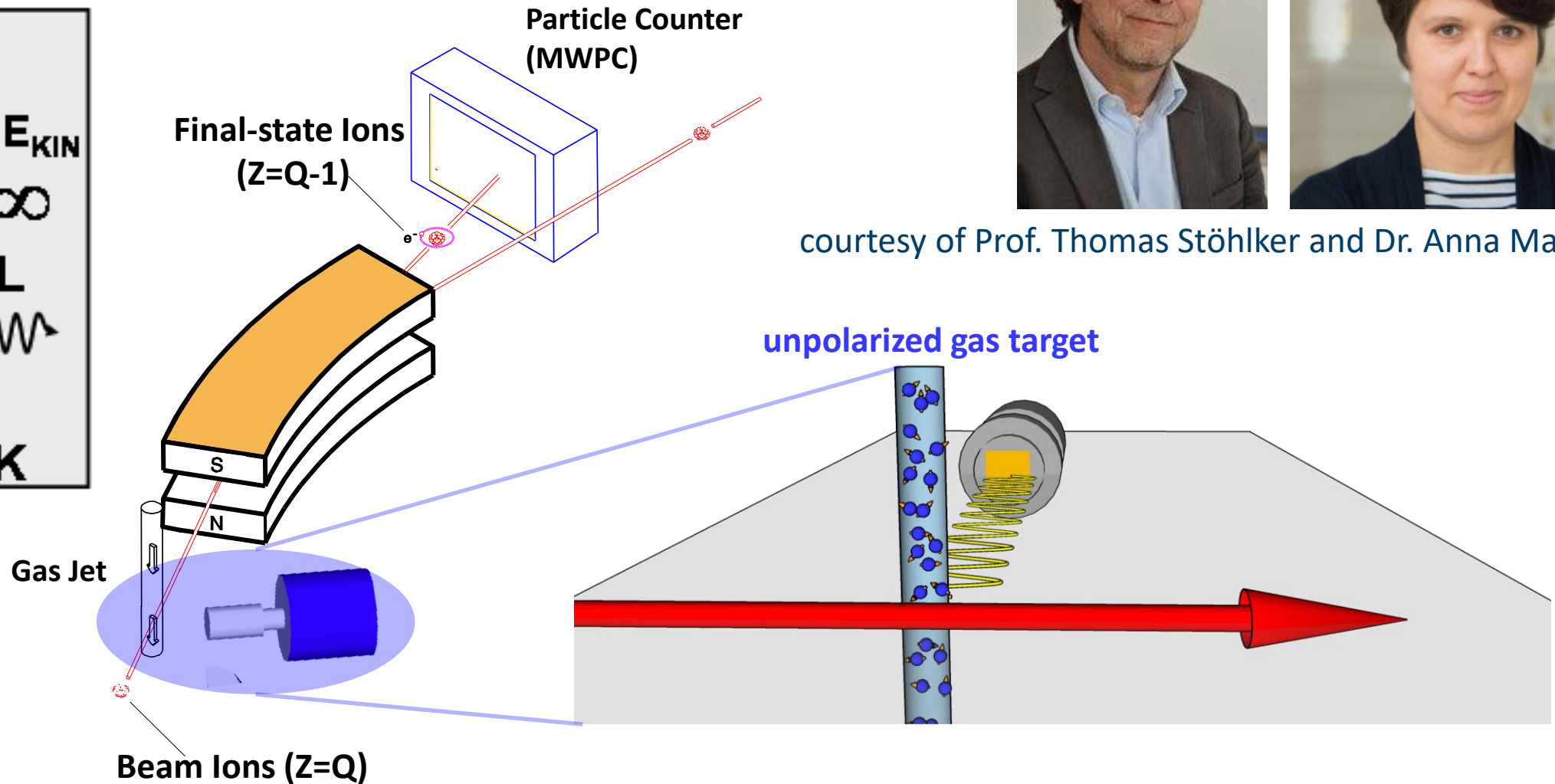
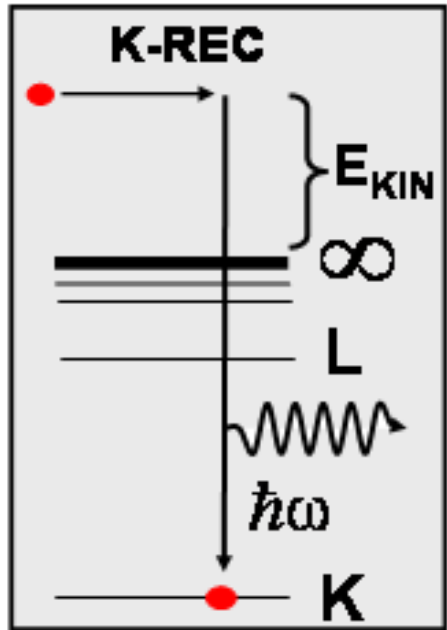
courtesy of Prof. Thomas Stöhlker and Dr. Anna Mayorova

$U^{92+} + N_2$ @ 295 MeV/u



REC with pol. e target

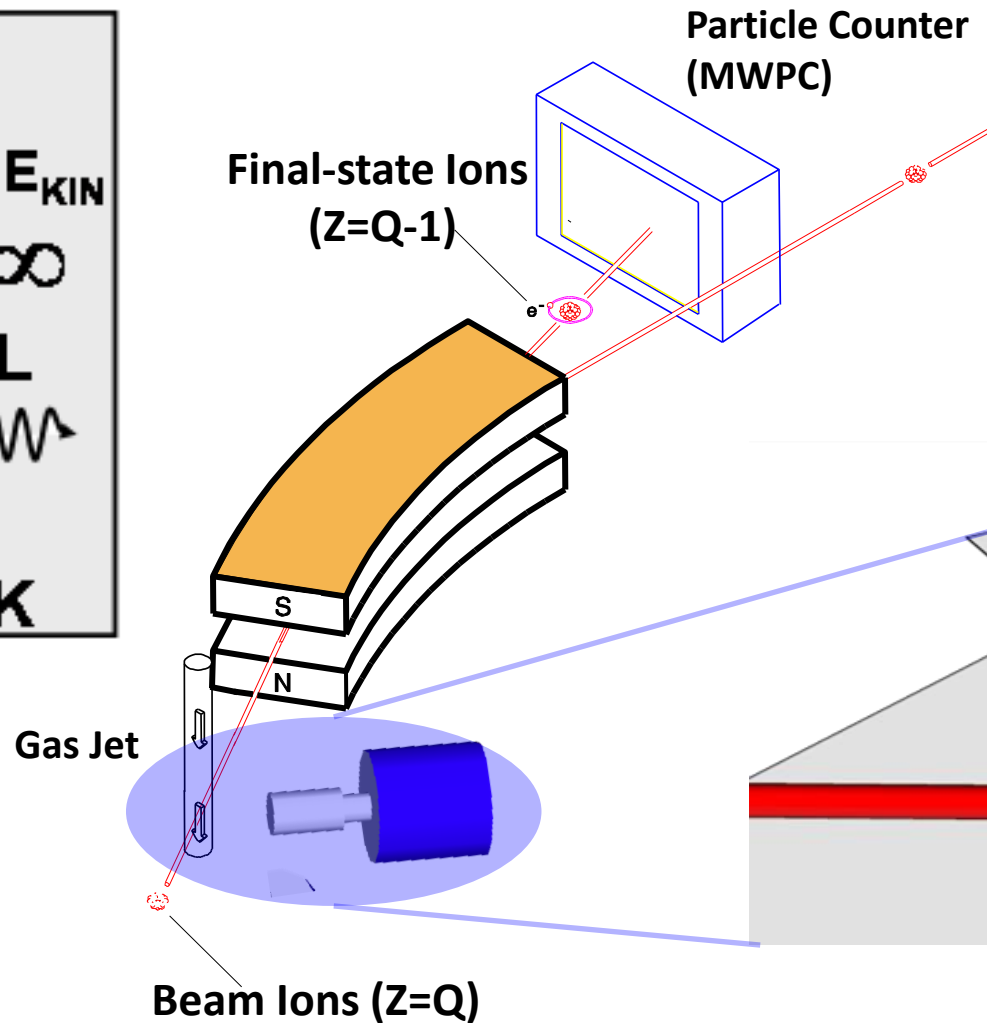
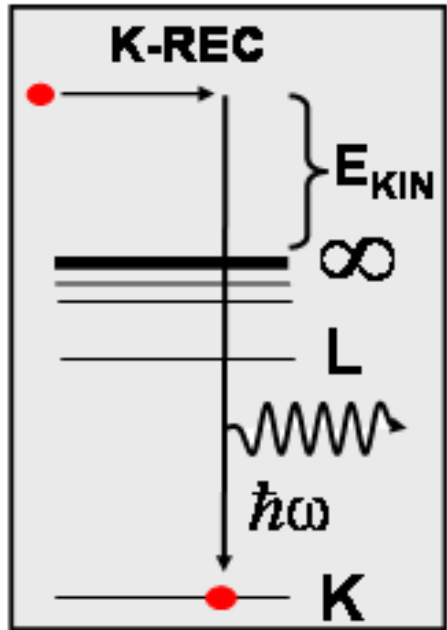
- Radiative electron capture (REC): $Z^{Q+} + e^- \rightarrow Z^{(Q-1)+} + \hbar\omega + \dots$
- Sensitive to ion and electron spin states



courtesy of Prof. Thomas Stöhlker and Dr. Anna Mayorova

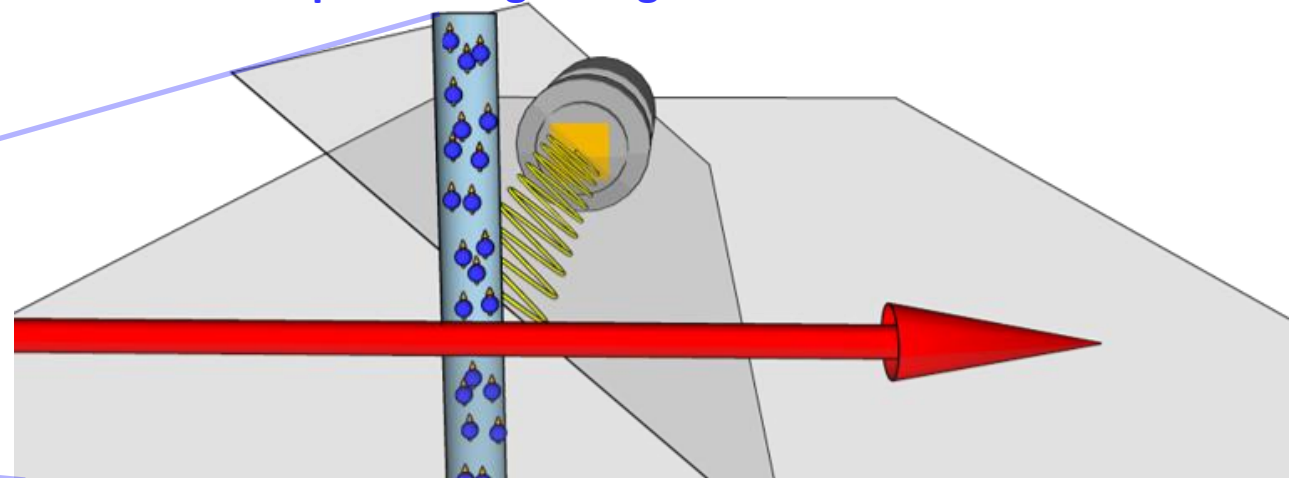
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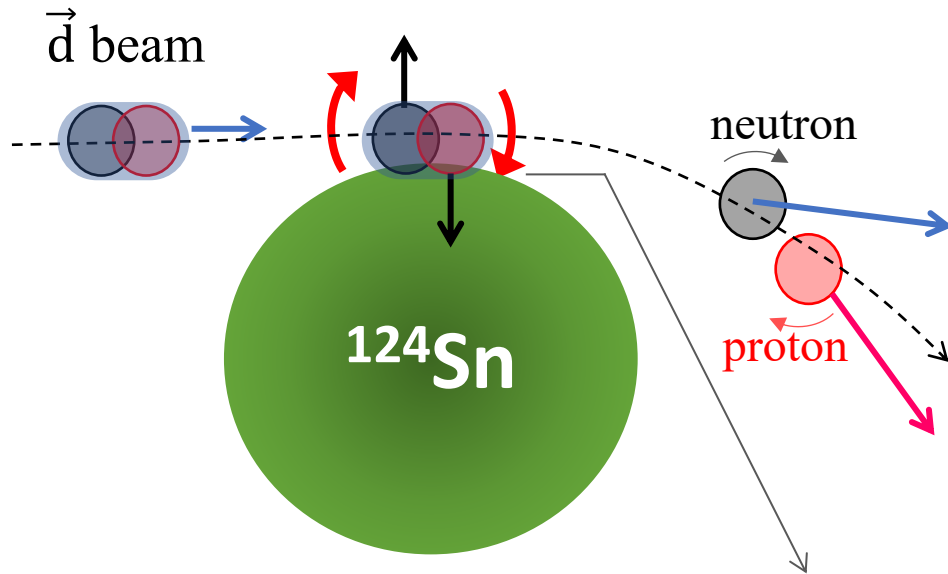
courtesy of Prof. Thomas Stöhlker and Dr. Anna Mayorova

polarized gas target



EoS and isovector force

EoS study with pol. d beam



Due to the difference of nuclear forces neutron and proton experiences, **extra rotation** occurs !

Isovector force

- $F_v \propto \delta^2 \frac{dE_{\text{sym}}}{d\rho} \frac{d\rho}{dr} \left(\delta = \frac{\rho_n - \rho_p}{\rho} \right)$
- Attractive to p , repulsive to n
- Comparable with Coulomb force

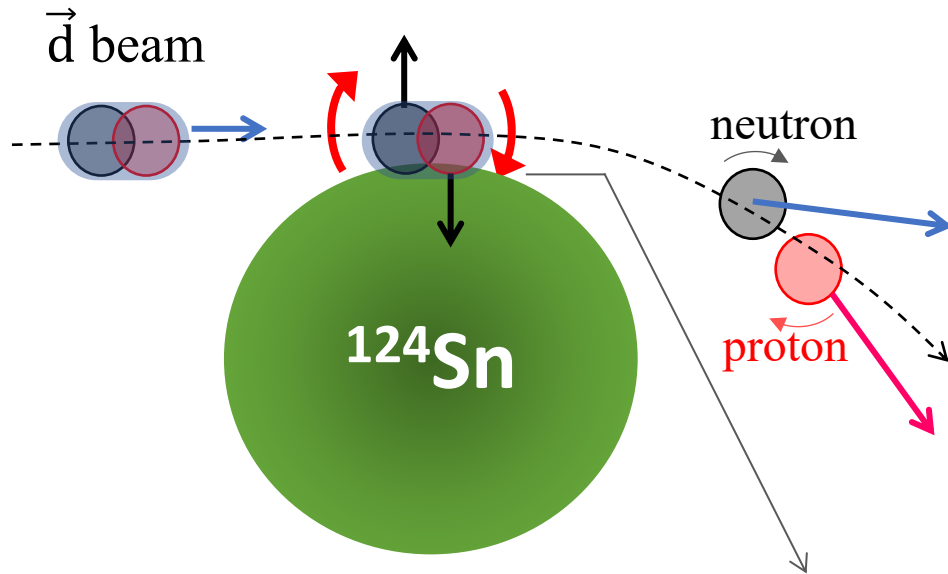


courtesy of Prof. Zhigang Xiao

PRL 115, 212501 (2015); **PRC 101**, 024603 (2020)

- Coulomb force: leads to *Coulomb polarization* (Oppenheimer et al., 1935)
- Isovector force: leads to *isovector reorientation* (**IVR**)

EoS study with pol. d beam



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Such measurements can be extended with polarized deuteron target and (radioactive) heavy ion beams

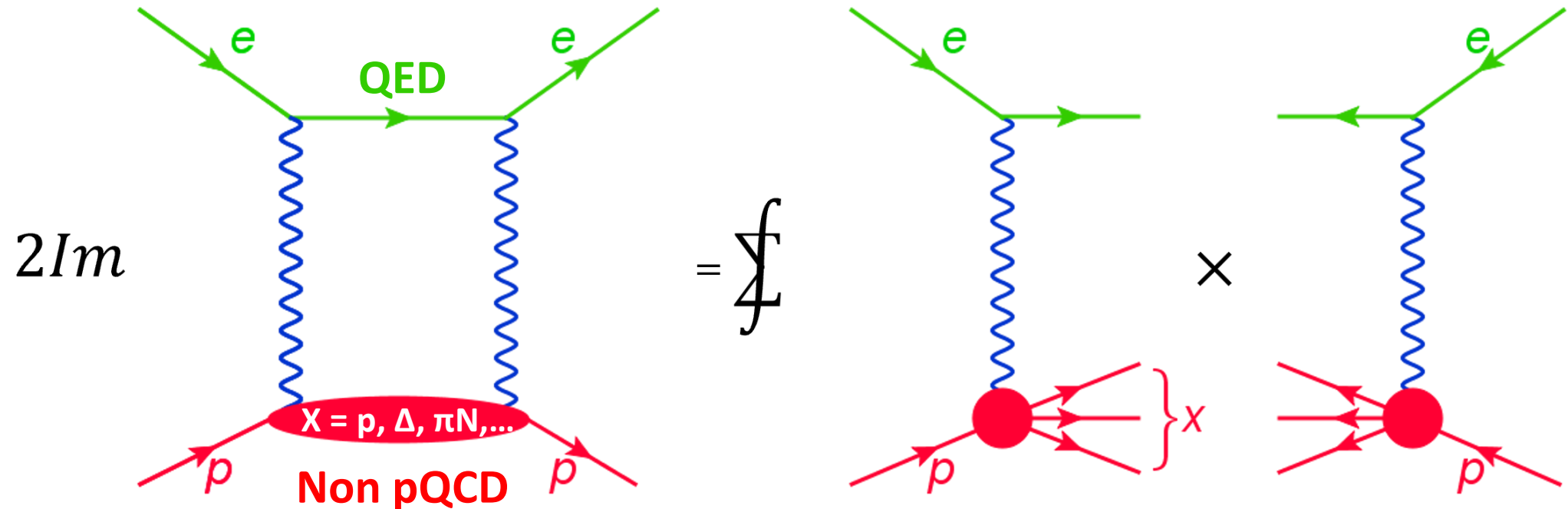
New boson search

T-odd effects with transverse spin asymmetry

- transverse single spin asymmetry ($A_{\perp}$) is a T-odd observable
- arises from two-photon exchange in electron elastic scattering

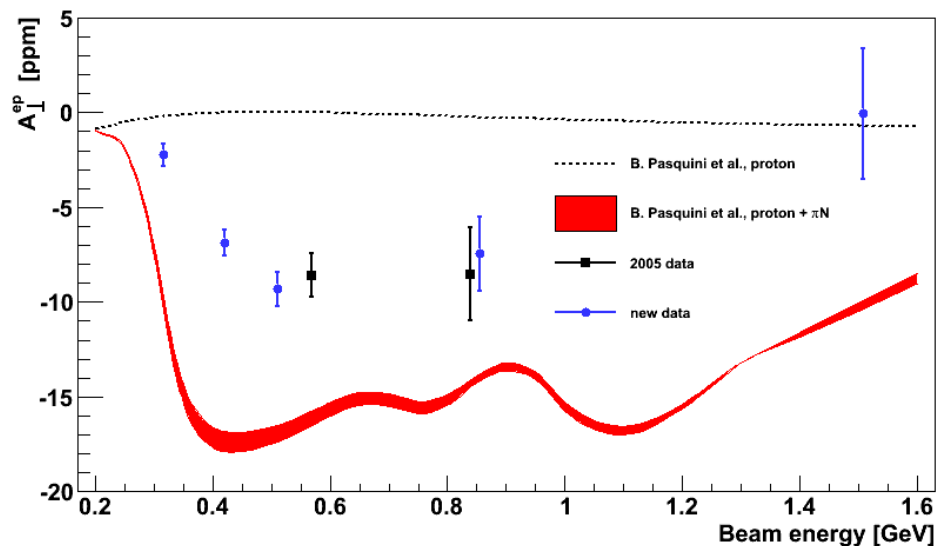
$$A_{\perp} \propto \frac{\text{Im}(\mathcal{M}_{\gamma}^* \mathcal{M}_{2\gamma})}{|\mathcal{M}_{\gamma}|^2}$$

Nucl. Phys. B 35 (1971) 365.



Exp. data vs calculation ($A_{\perp}^{\bar{e}p}$)

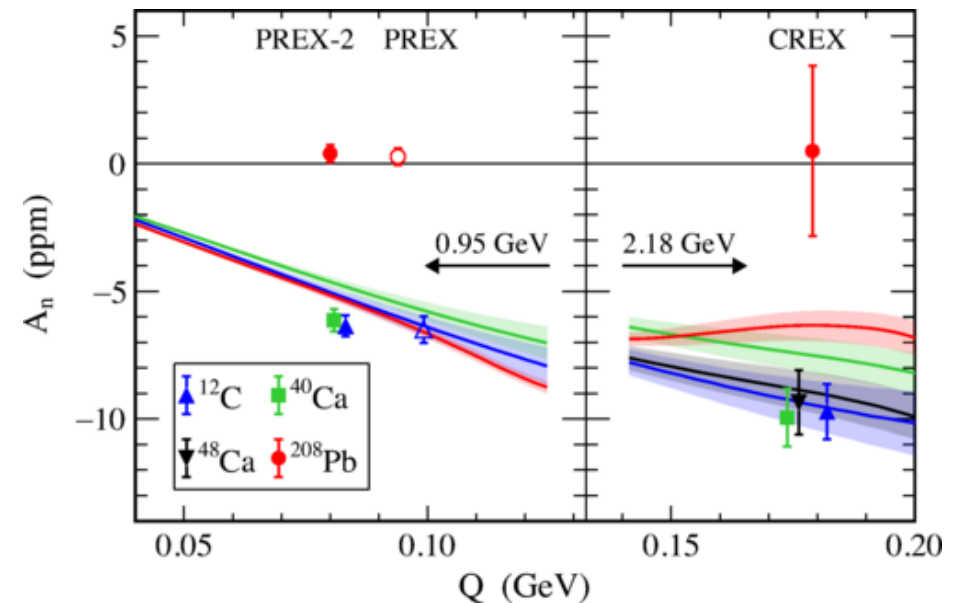
- surprising discrepancies between theory and exp. data
- observed at different laboratories
- not only in $\bar{e}p$, but also in $\bar{e}A$



A4 @ MAMI

Phy. Rev. Lett. 124, 122003 (2020)

Phy. Rev. Lett. 94, 082001 (2005)

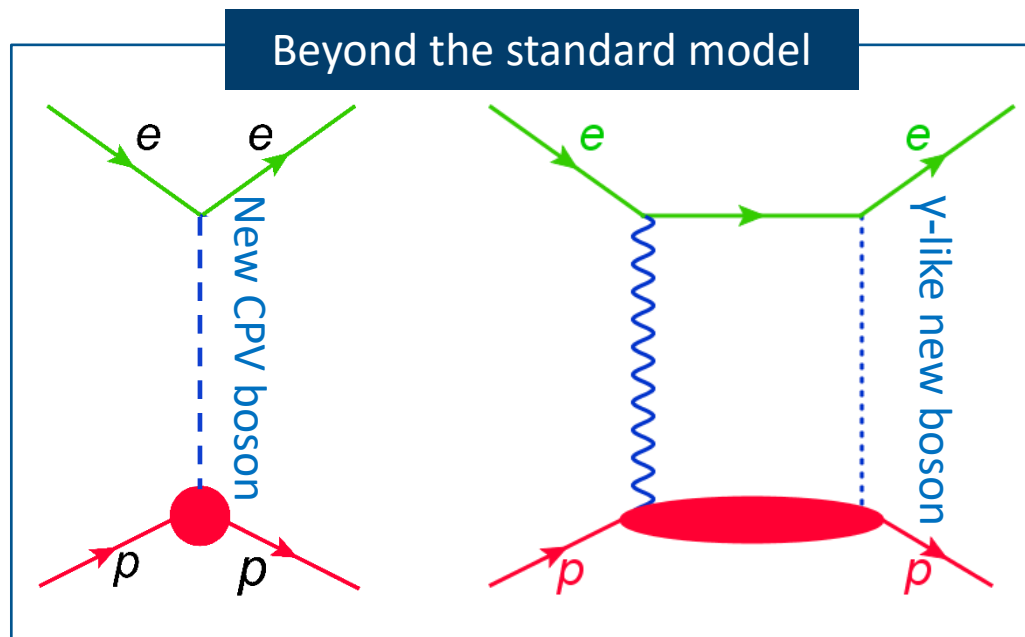
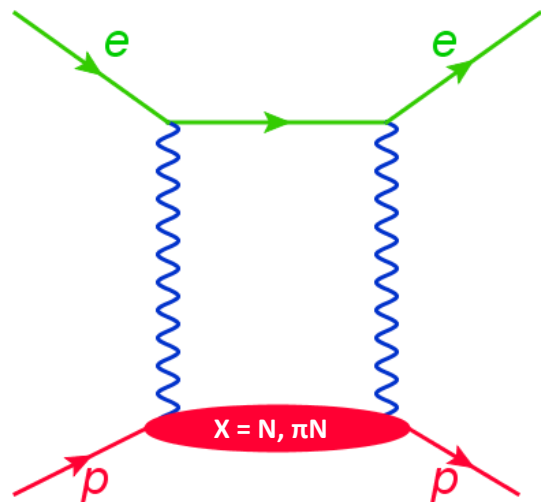


PREX, PREXII, CREX @ JLab

Phy. Rev. Lett. 109, 192501(2012)

Phy. Rev. Lett. 128, 142501(2022)

How to understand the surprise

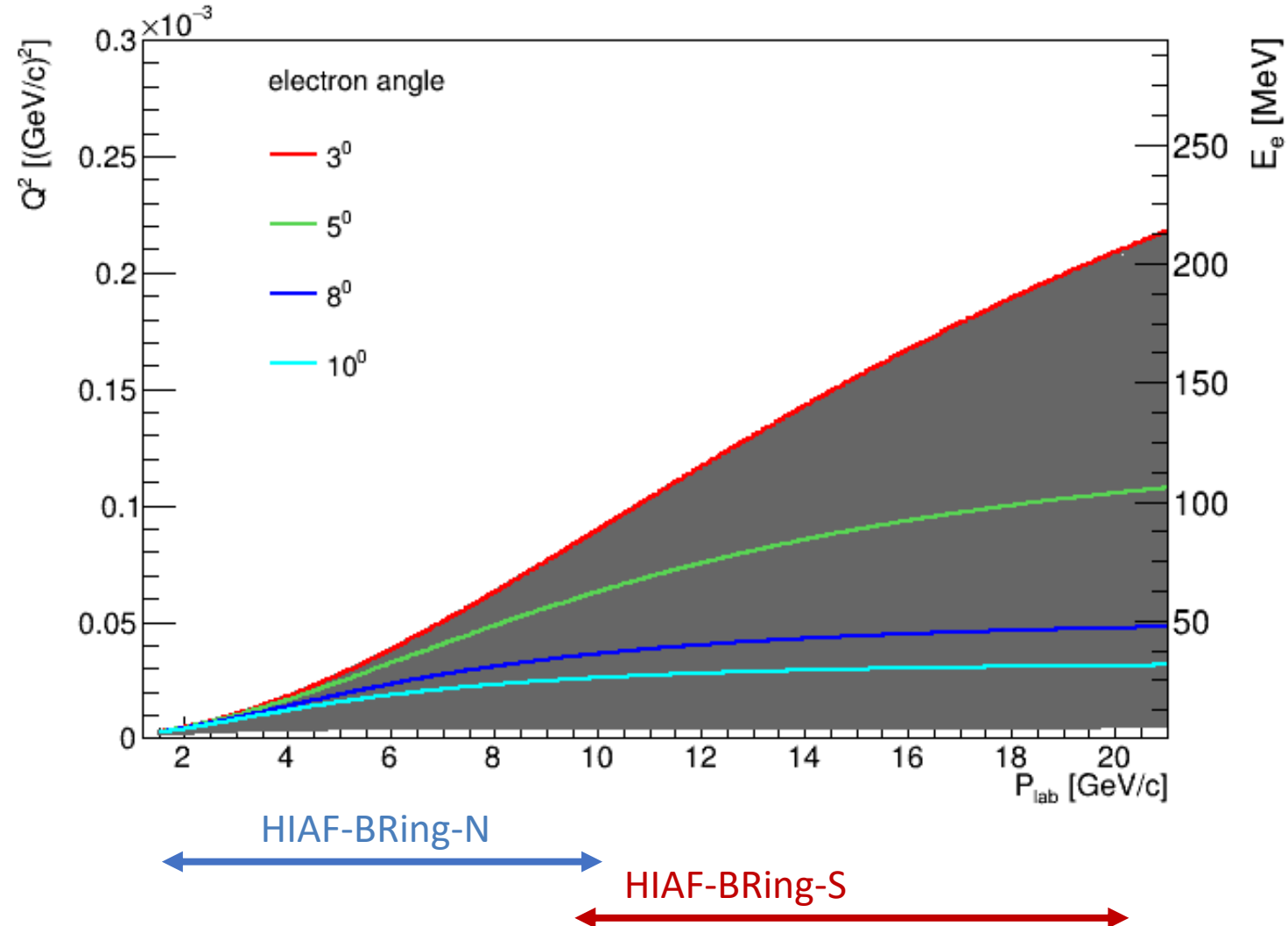


- More intermediate state?
 - MAID database and CLAS data need improvement?
 - **New unknown boson?**
- Hard to test new-physics hypothesis in $\vec{e}p \rightarrow ep$
- Possible intermediates: $X = N, \pi N \dots \rightarrow$ **Non-pQCD uncertainty**
 - Lorentz effect with transverse $\vec{e}$ beam $\rightarrow A_{\perp} \propto \frac{m_e}{E} \sim 10^{-6}$ **(tiny signal)**

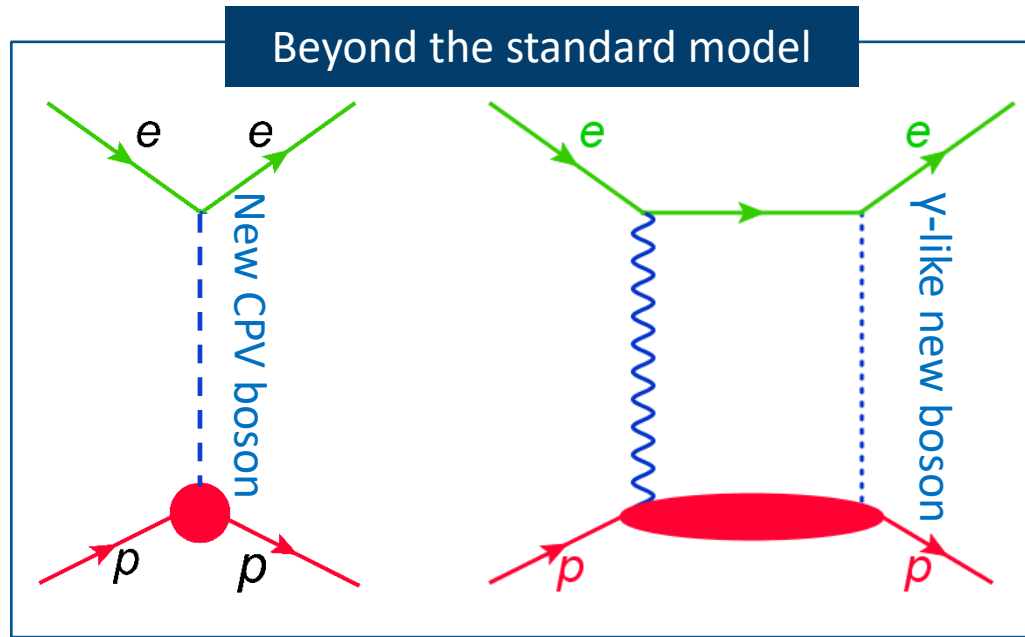
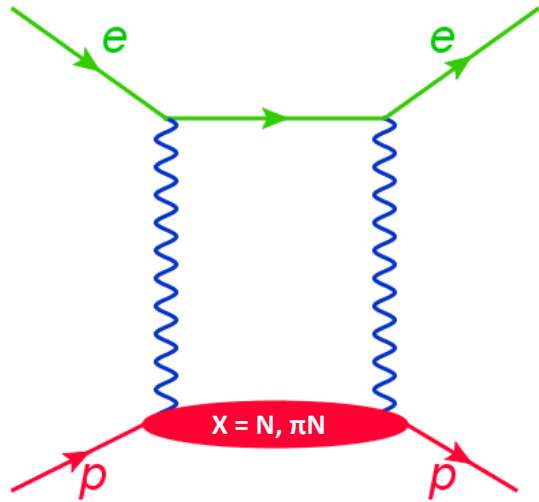
New idea: $p\bar{e} \rightarrow pe$?

With **proton beam** and **electron target**, ultra low $Q_2 (< 1 \times 10^{-5})$ accessed in pe scattering

Reminder: Q_2 in ep scattering ($10^{-2} \sim 10^{-1}$)



Transverse spin asymmetry: $p\bar{e}$ vs $\bar{e}p$



- **New unknown boson?**

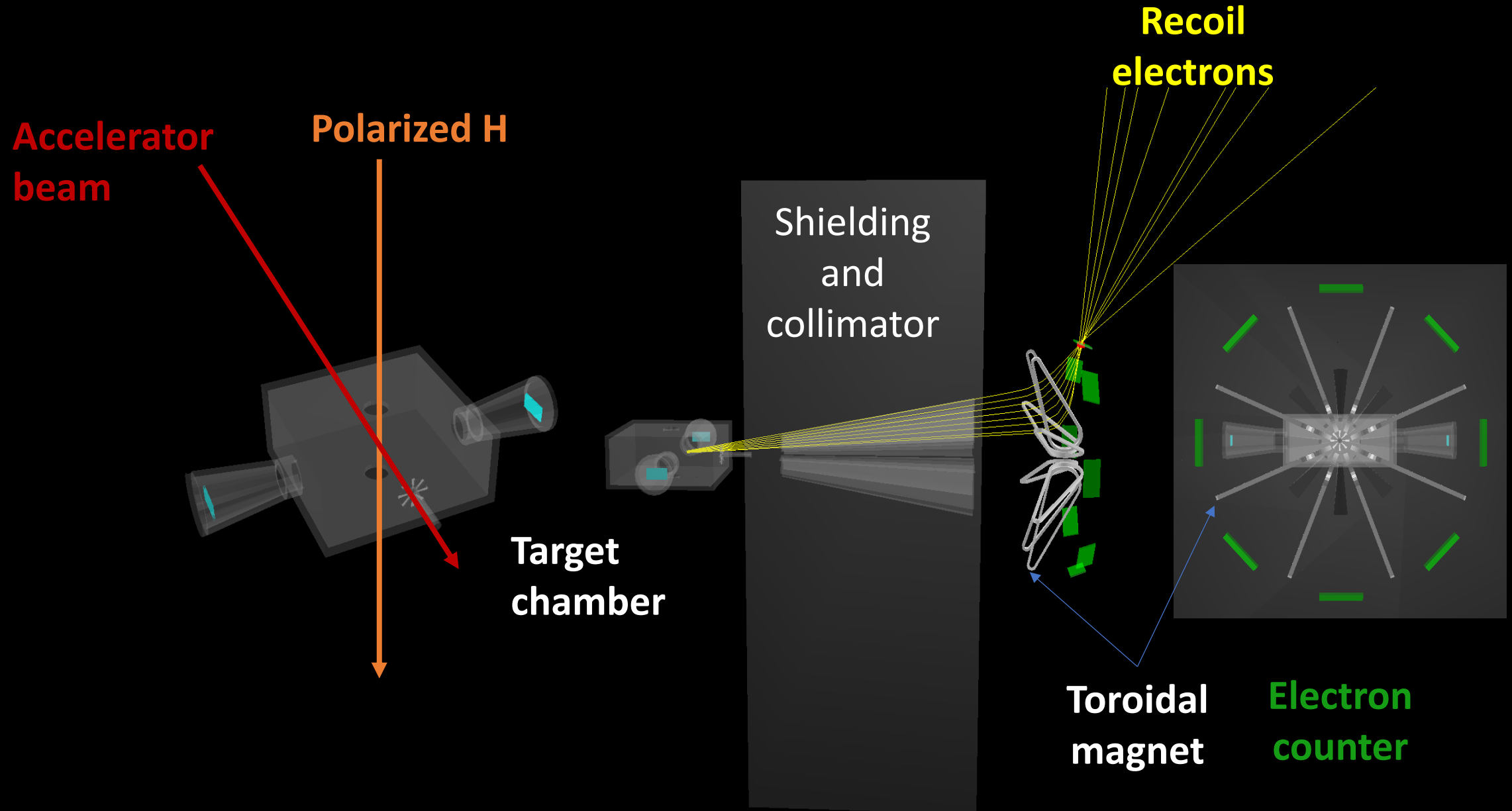
- In $\bar{e}p \rightarrow ep$

- possible intermediates: $X = N, \pi N \dots \rightarrow$ **Non-pQCD uncertainty**
- Lorentz effect with transverse $\bar{e}$ beam $\rightarrow A_{\perp} \propto \frac{m_e}{E} \sim 10^{-6}$ **(tiny signal)**

- In $p\bar{e} \rightarrow pe$ (very-low Q_2)

- $X = N \rightarrow A_{\perp}$ calculated with **G_E and G_M (no theoretical uncertainty)**
- No Lorentz effect $\rightarrow A_{\perp}$ **increases by 3 orders**

Detection system

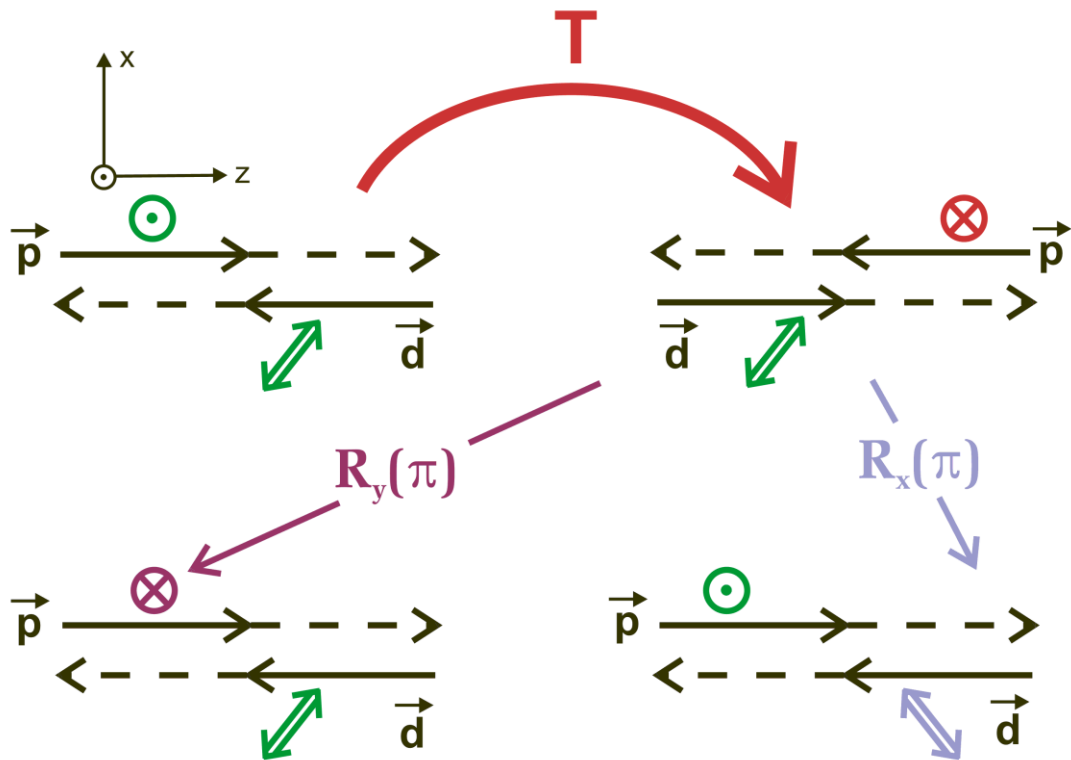


Test of time-reversal symmetry

Test of time-reversal symmetry

Parity conserving (unlike EDM)

Time-reversal violating



plot from the TRIC website

Aim: test of time reversal symmetry

Reaction: pd elastic scattering

- Proton: vector polarized
- Deuteron: tensor polarized
- Forward scattering: zero degree

Observable: total cross section asymmetry $A_{y,xz}$

Proposed since early 1990s

<https://tric-experiment.hiskp.uni-bonn.de/>

<https://www.fz-juelich.de/en/ikp/ikp-2/research/previous-list/tric>

[P. Lenisa et al. EPJ Tech. Instr. \(2019\) 6](#)

[N. Nikolaev, F. Rathman, A. Silenko, Yu. Uzikov., PLB 811 \(2020\) 135983](#)

Test of time-reversal symmetry

New approach to search for parity-even and parity-odd time-reversal violation beyond the Standard Model in a storage ring

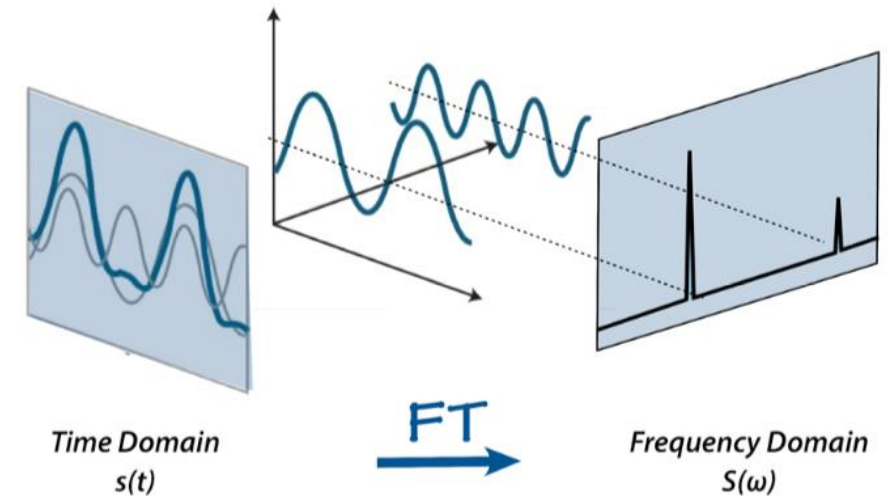
N.N. Nikolaev, F. Rathmann , A.J. Silenko, Yu.N. Uzikov

Phys. Lett. B 811, 135983 (2020)

[see talk by Yuriy Uzikov \(Tuesday\)](#)

Main idea

- Conceived in the JEDI collaboration
- **Beam polarization rotates** with an RF solenoid
- Experimental asymmetry oscillates
- False asymmetry easily separated via **Fourier analysis**



Test of time-reversal symmetry

New approach to search for parity-even and parity-odd time-reversal violation beyond the Standard Model in a storage ring

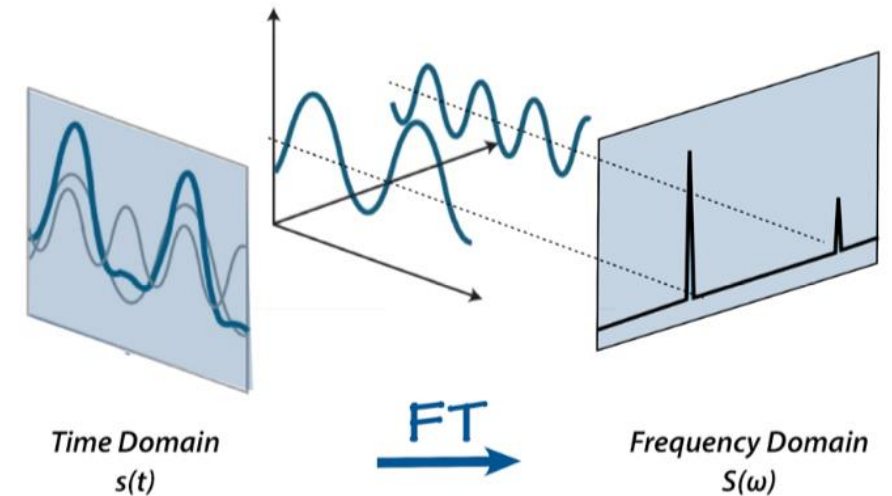
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Spin-rotating polarized target?

Spin-rotating target

Spin-rotating polarized target

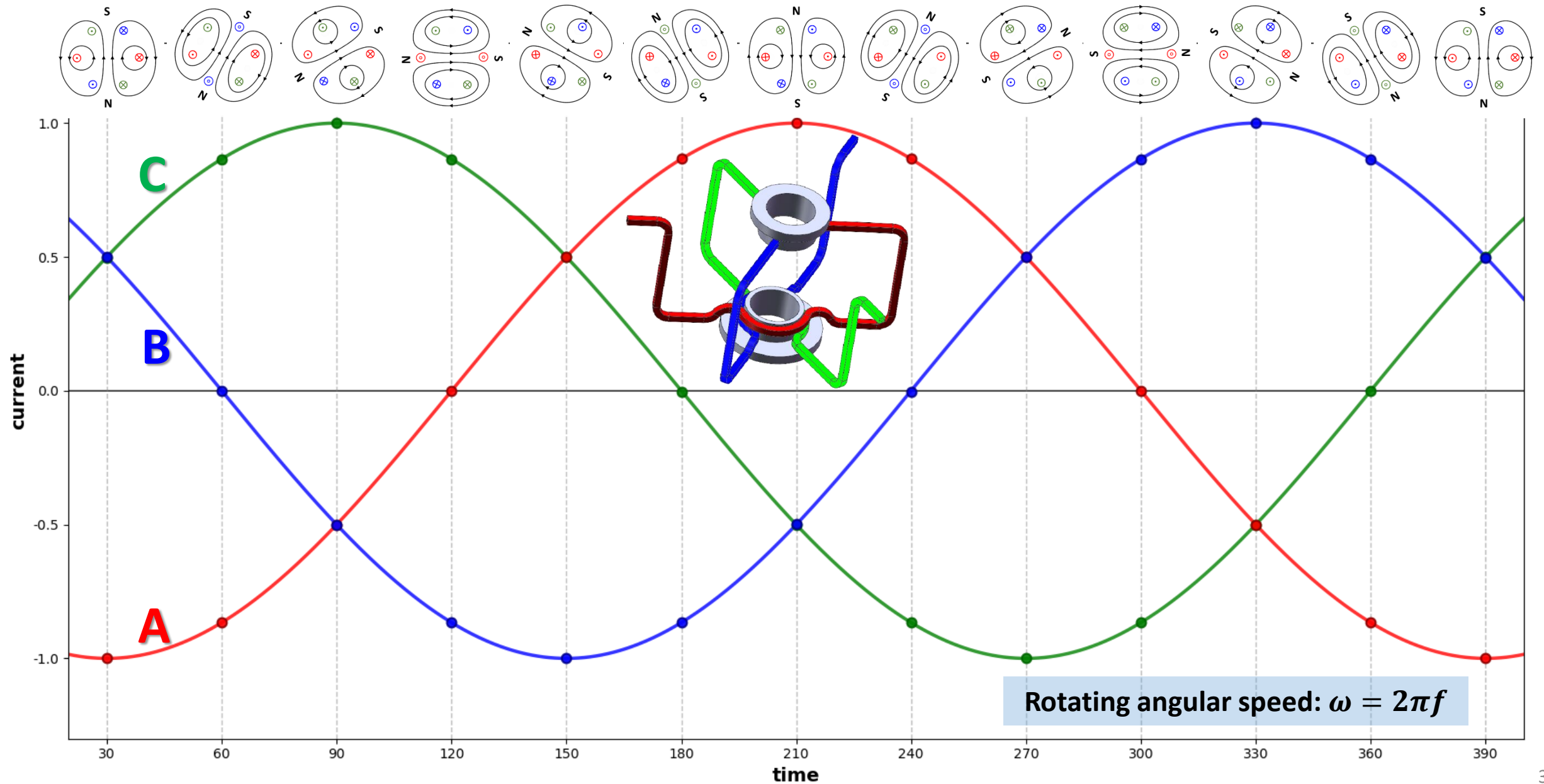
- Atoms polarized in pol. H/D gas target
- Electron spin aligned with the holding field at interaction point
- Proton/deuteron spin attached to electron spin (HF not too strong)
- Up to now, only static holding fields are used: transverse, longitudinal or superposed
- **How to make a rotating field?**
 - Triple coils driven by 3-phase rf current (proposed in this talk)
 - Static dipole $\vec{B}$ superposed by perpendicular RF $\vec{B}$
 - proposed for NICA
 - private communication with N.N. Nikolaev

Spin-rotating polarized target

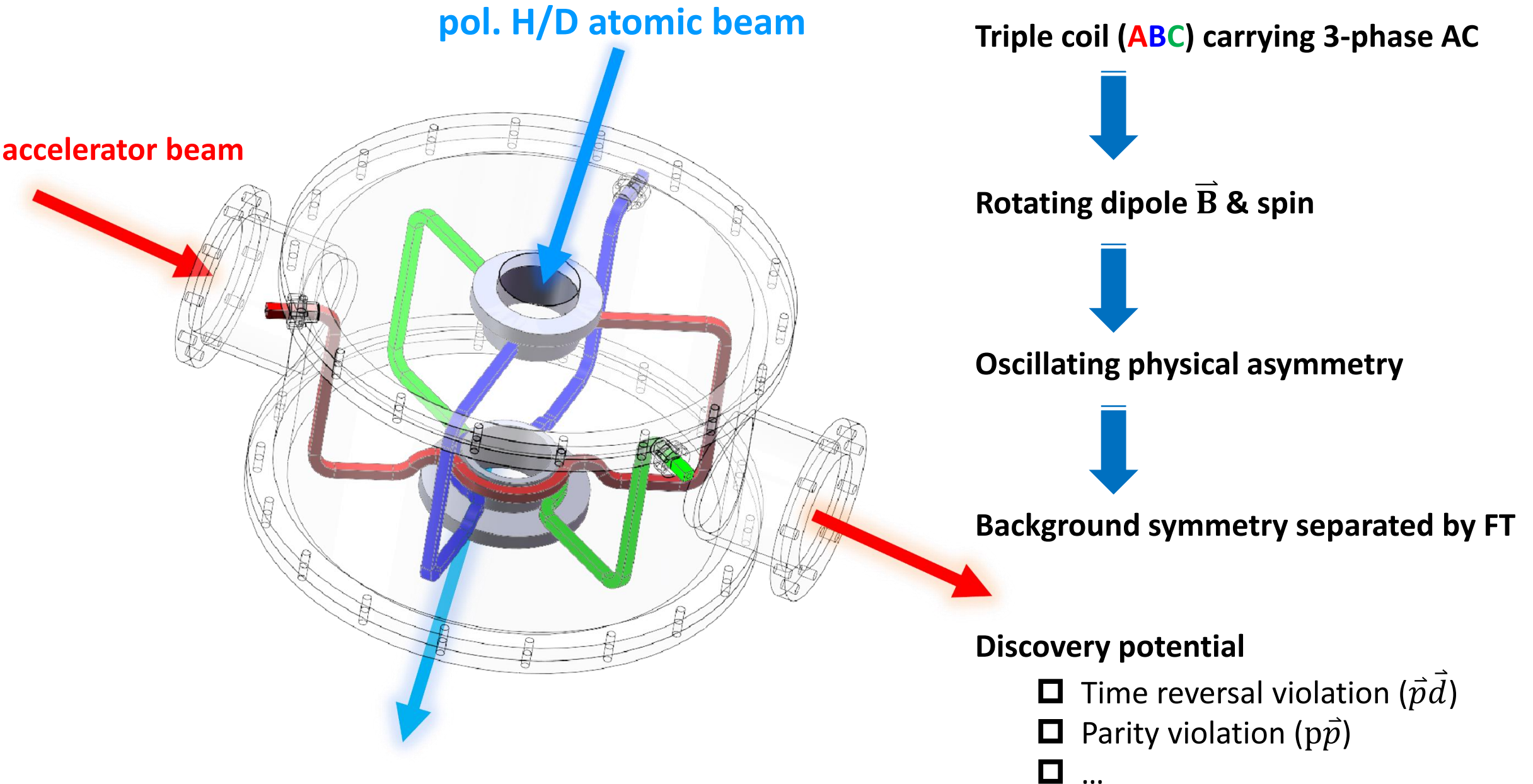
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It was really joyful that Prof. Nikolaev who was trying to contact HIAF-SPIN team, was introduced to me just a few days after I was inspired by their fantastic paper, when we surprisingly found out that we had similar ideas!!!

Rotating magnetic field



Spin-rotating polarized target



Summary

- Tools for spin physics at HIAF being developed
- Physics with polarized beam/target at HIAF
 - Atomic, nuclear and hadron physics
 - New physics search with $p\vec{e}$
 - Test of time-reversal invariance with $\vec{p}\vec{d}$
 - Spin-rotating polarized target

Thank you!

Welcome to PBT2026 (March 5-8 2026, Huizhou) !!!

