Tomography

- Imaging in 2D slices
- Tomographic techniques in many fields: medicine, oceanography, seizmology...
- Want to do the same for nucleons
  - How to “image” on scales of $10^{-15}$ fm?


Nucleon Tomography

• 2D image in transverse plane

• Two types, two tools:
  1. Transverse momentum, $k_T$
     Semi-inclusive measurements
  2. Transverse position, $b_T$
     Exclusive measurements
1) Transverse momentum
SIDIS

**Semi-Inclusive Deeply Inelastic Scattering**

Measure the electron + a single hadron

characterised via $(z, p_T)$

\[ \text{DIS } x, Q^2 + \text{semi-inclusive } z, p_T + \text{spin } \phi \rightarrow \text{Multi-dimensional} \]
SIDIS

- Gives additional hadron information
  - extract “transverse-momentum-dependent distributions”: TMDs

1) Spin-dependence:
   see deformation of parton distribution
   e.g. Sivers function

Alexei Prokudin
• Gives additional hadron information
  ▶ extract “transverse-momentum-dependent distributions”: TMDs

2) Identify hadrons: decompose **flavour** dependence
Kinematics

Current data for Sivers asymmetry:
- COMPASS: $h^\pm$: $P_{hT} < 1.6$ GeV, $z > 0.1$
- HERMES: $\pi^0, K^\pm$: $P_{hT} < 1$ GeV, $0.2 < z < 0.7$
- JLab Hall-A: $\pi^\pm$: $P_{hT} < 0.45$ GeV, $0.4 < z < 0.6$

Planned:
- JLab 12

Variable $E \rightarrow$ wide span in $x, Q^2$

Explore the sea
Luminosity \(10^{34} \text{ cm}^{-2}\text{s}^{-1}\): 100s times HERA

- Measurements with \(\pi, K\) very precise
  - mostly **systematics**-dominated

- Rare signals accessible
  - e.g. **gluon** Sivers
    - \(g \rightarrow c + c\bar{c}\)
    - use D meson pairs

- Nowhere but an EIC

![Graph showing single spin asymmetry](image)

- Model calculations with different pair \(k_T\)

\[\gamma N^{\uparrow} \rightarrow D\bar{D} + X\]

\(\sqrt{s} = 140\ \text{GeV}\)

Uncertainties for 100 fb\(^{-1}\)
2) Transverse position
**Exclusive production**

Exclusive reaction: produces a **single** boson: $\gamma$, J/$\psi$, $\phi$...

Provides access to "generalised parton distributions", GPDs
- **Fourier transform of $d\sigma/dt$:**
  - $b$ dependence
  - 2D **spatial** picture

Dieter Müller
J/psi production

Tiny statistical errors in < 1 year running

Fine binning in \((x, Q^2, t)\)

\[ \gamma^* + p \rightarrow J/\psi + p \]

\[ \int L dt = 10 \text{ fb}^{-1} \]

20 GeV on 250 GeV

\[ 0.0016 < x_V < 0.0025 \]

15.8 GeV\(^2\) < \(Q^2 + M^2_{J/\psi}\) < 25.1 GeV\(^2\)
J/ψ production

Distribution of gluons

\[ e + p \rightarrow e + p + J/\psi \]

\[ 15.8 < Q^2 + M_{J/\psi}^2 < 25.1 \text{ GeV}^2 \]
• **Nucleon imaging**: a major EIC goal
  ▶ tomographic view matter on scales $\sim 10^{-15}$m
• eRHIC provides the necessary
  ▶ luminosity
  ▶ energy **variability**
• Proposed to begin operations $\sim 2022$. 
What is eRHIC?

RHIC + high intensity, high energy electron beam

p and e polarised

Hadron beams A=1 to A=238

L \sim 10^{34} \text{ cm}^{-2}\text{s}^{-1}
\sqrt{s} \sim 45-140 \text{ GeV}