eRHIC as a Nucleon Tomograph

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DNP Fall Meeting
Newport Beach CA
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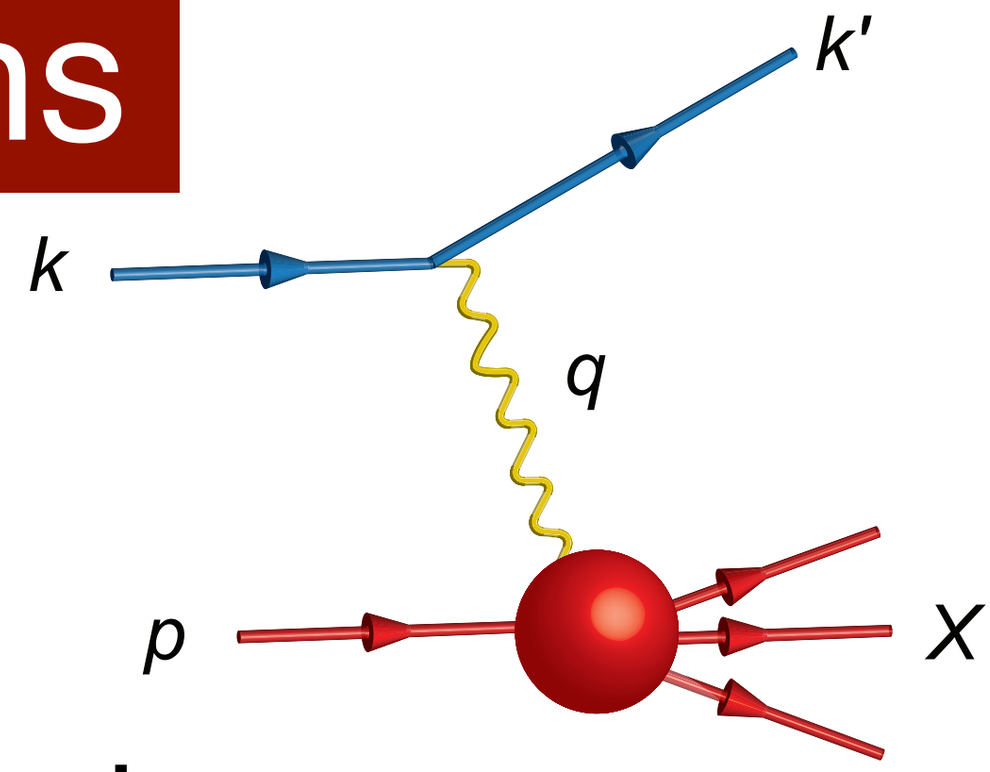
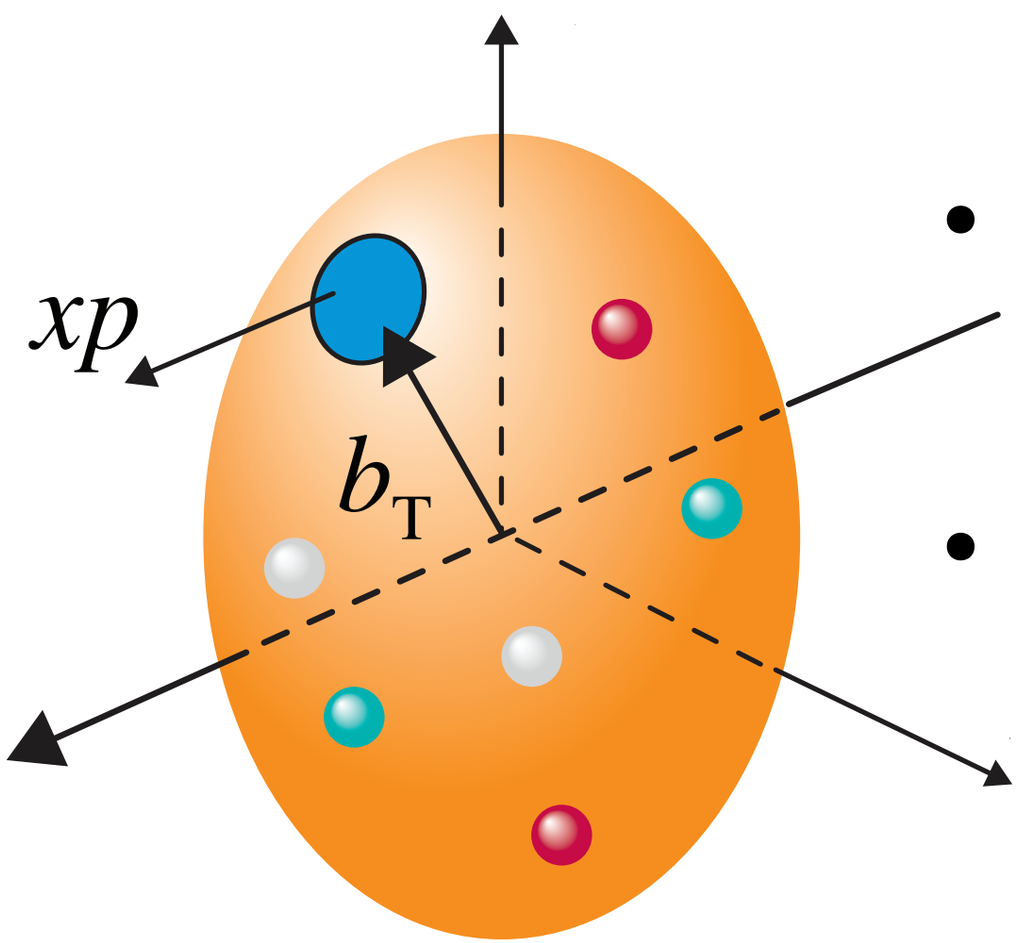
eRHIC is planned as a state-of-the-art Electron-Ion Collider, to be located a Brookhaven National Lab as a major expansion to the existing RHIC complex by the addition of a high-intensity electron beam. The well-understood nature of the electron probe and the extreme luminosity of the eRHIC machine, one thousand times greater than that of HERA, will provide an exquisitely precise characterisation of nucleonic matter and its interactions. By studying both exclusive and semi-inclusive interactions, eRHIC will probe the distribution and motion of partons within the nucleon. With high polarisation of the electron and proton beams, the spin-dependence of these distributions will also be studied. eRHIC will therefore access a new frontier in our understanding of nucleon structure: detailed tomographic imaging of matter, analogous to the MRI and CT scans used in medicine, but at a scale of less than one femtometre. This "nucleon femtoscope" will provide us with the definitive view, at the smallest of scales, of the material that composes the visible universe

e-nucleon collisions

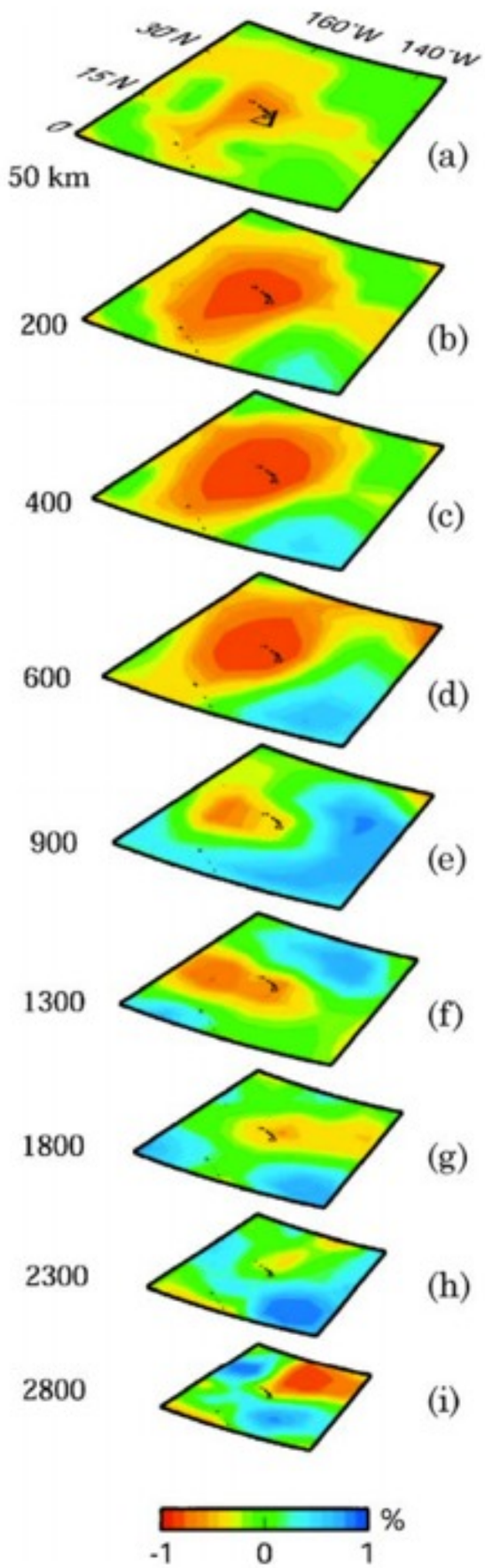


- Scatter electron off nucleon
- Interact with quark, not nucleon
  - resolve partonic structure
- **Perfect tool to study nucleon structure**



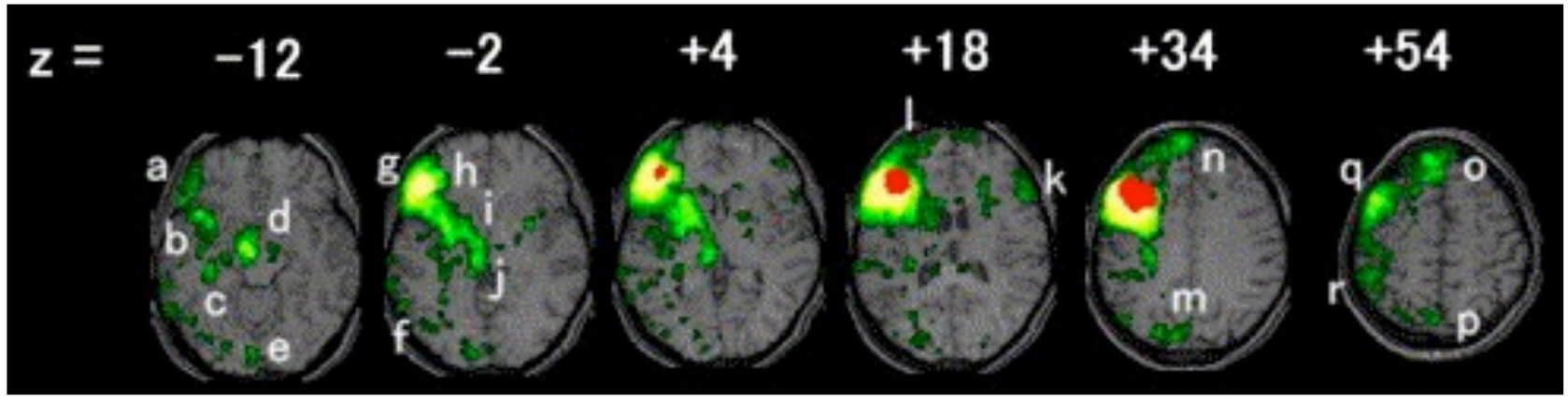
- Longitudinal momentum structure (x):
  - already known: PDFs
- Transverse structure?
  - **Tomography**: 2D "slices through x"

Tomography



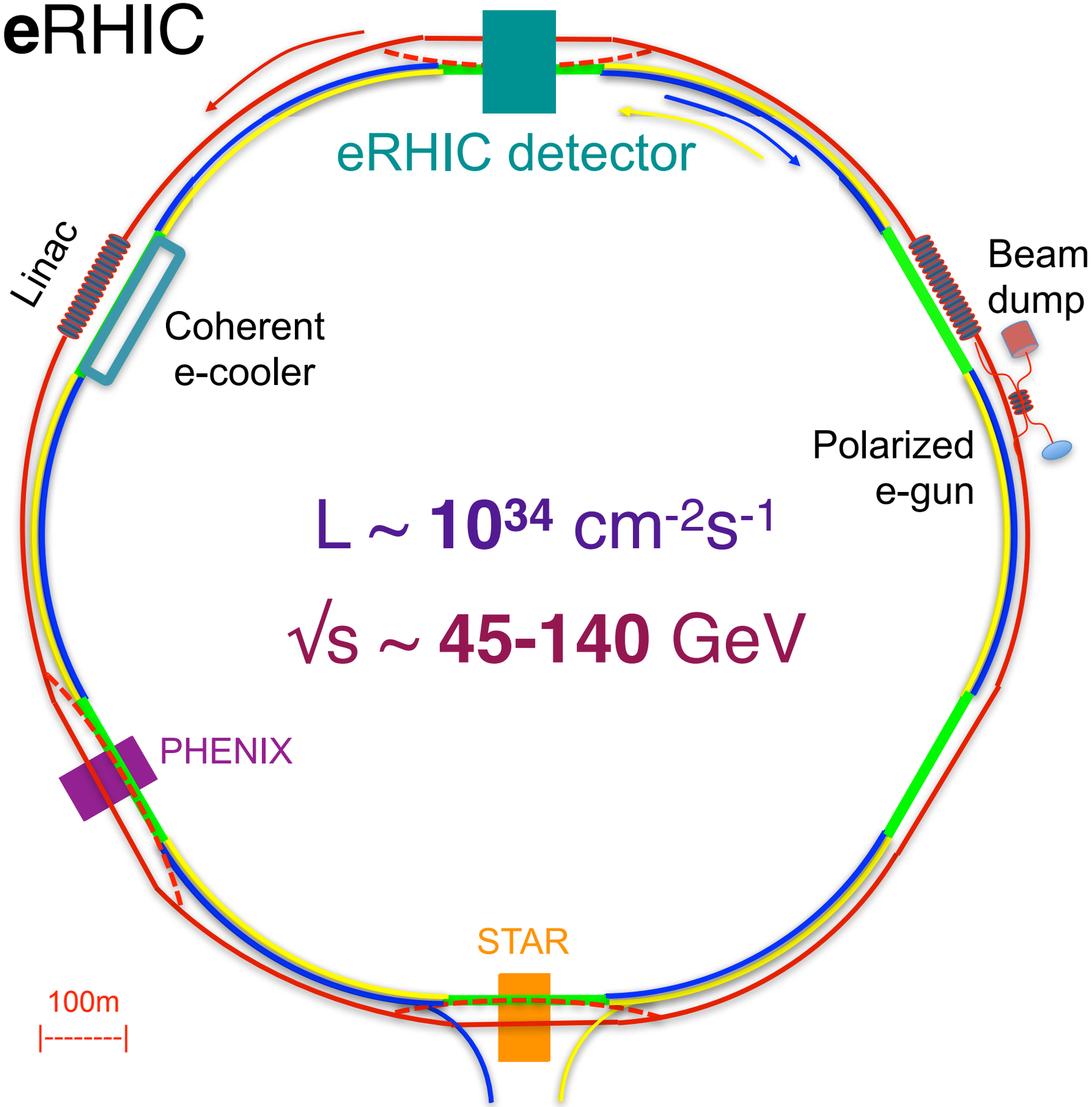
J. Lei, D. Zhao, Earth and Planetary Science Letters **241**, 438–453 (2006).

E. Takahashi, K. Ohki, D-S. Kim, NeuroImage **34**, 827-838 (2007).



- **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?

What is eRHIC?

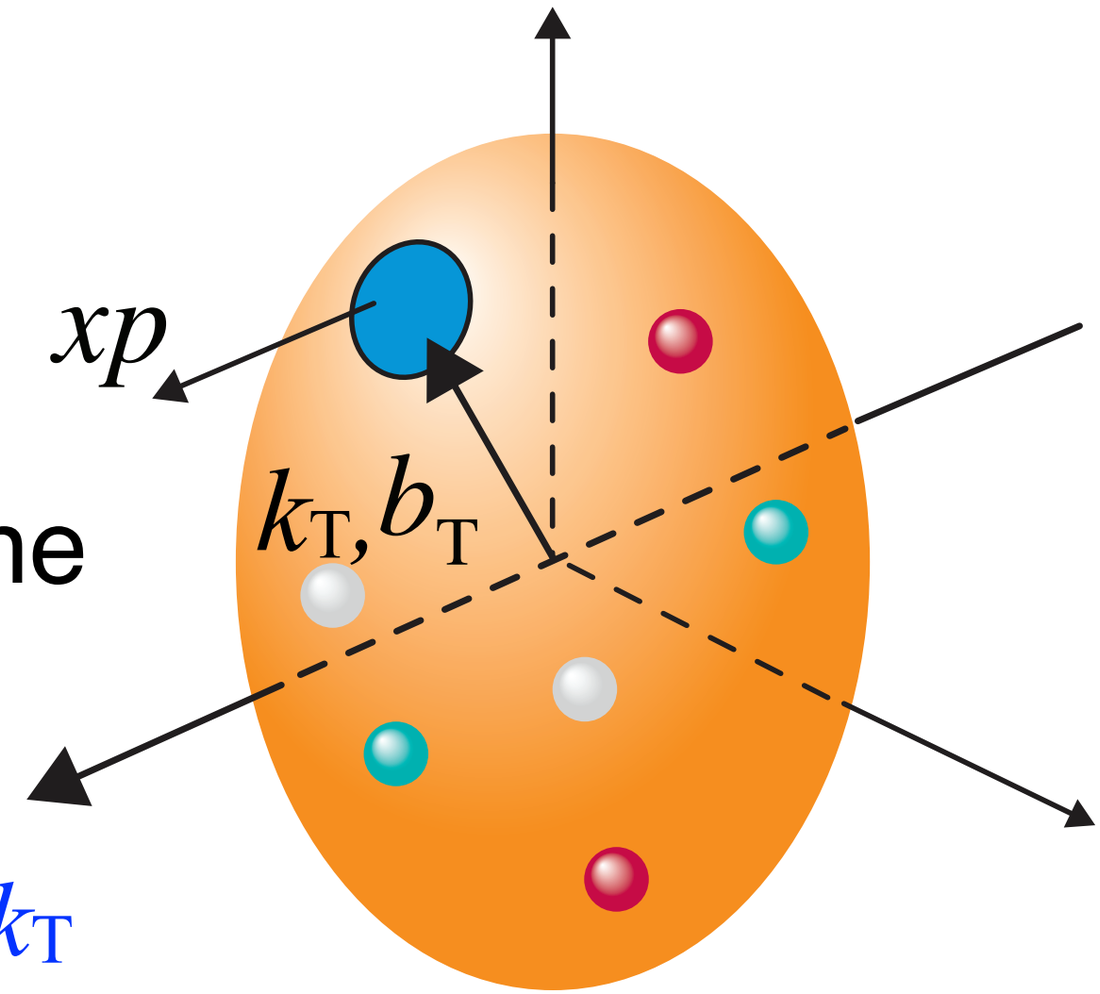


RHIC +
high **intensity**,
high **energy**
electron beam

p and e
polarised

Hadron beams
A=1 to A=238

Nucleon Tomography



- 2D image in transverse plane
- Two types, two tools:

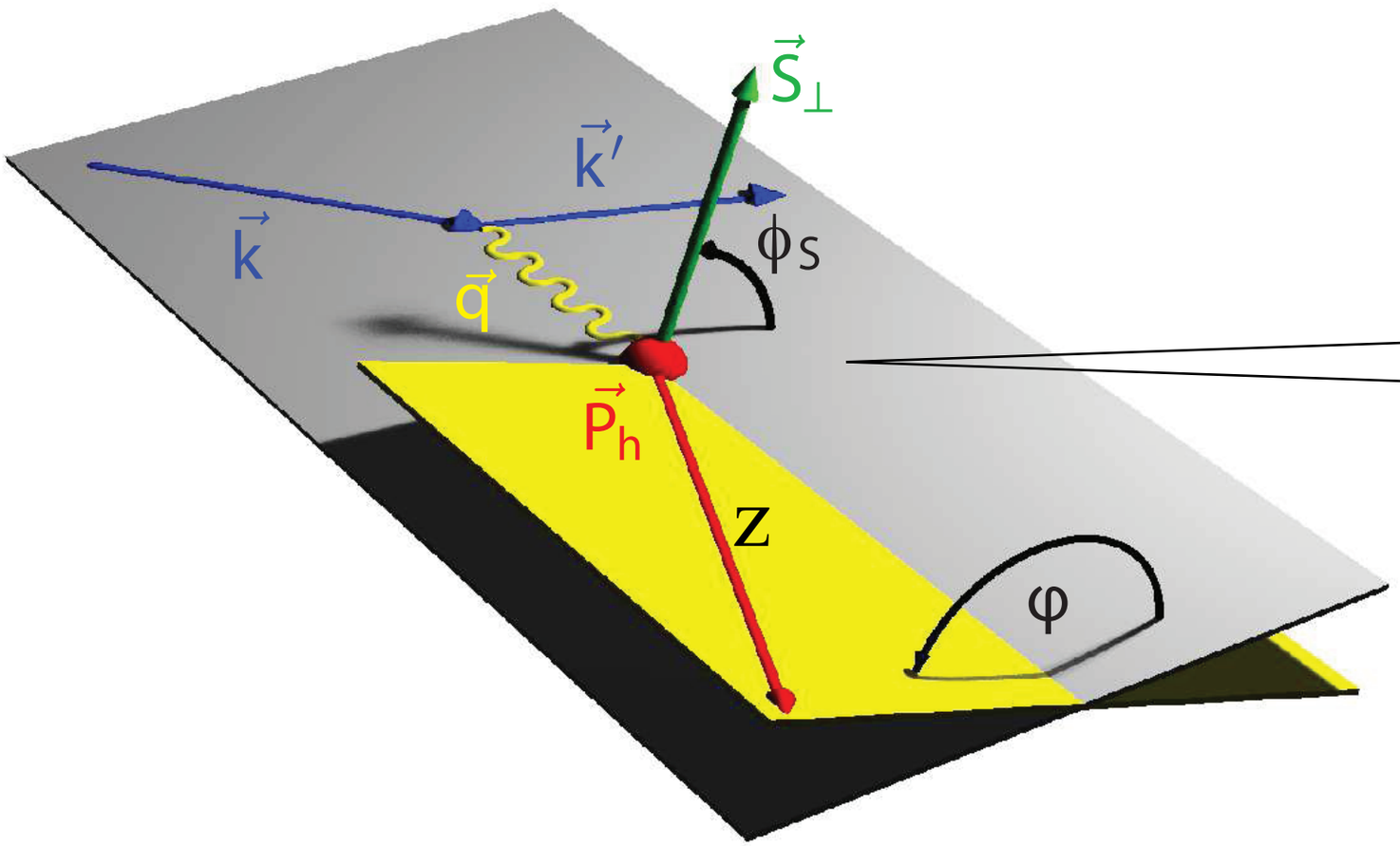
1. Transverse **momentum**, k_{T}

   Semi-inclusive production

2. Transverse **position**, b_{T}

   Exclusive production

SIDIS



Semi-**I**nclusive
Deeply **I**nelastic
Scattering

Measure the electron + a single hadron

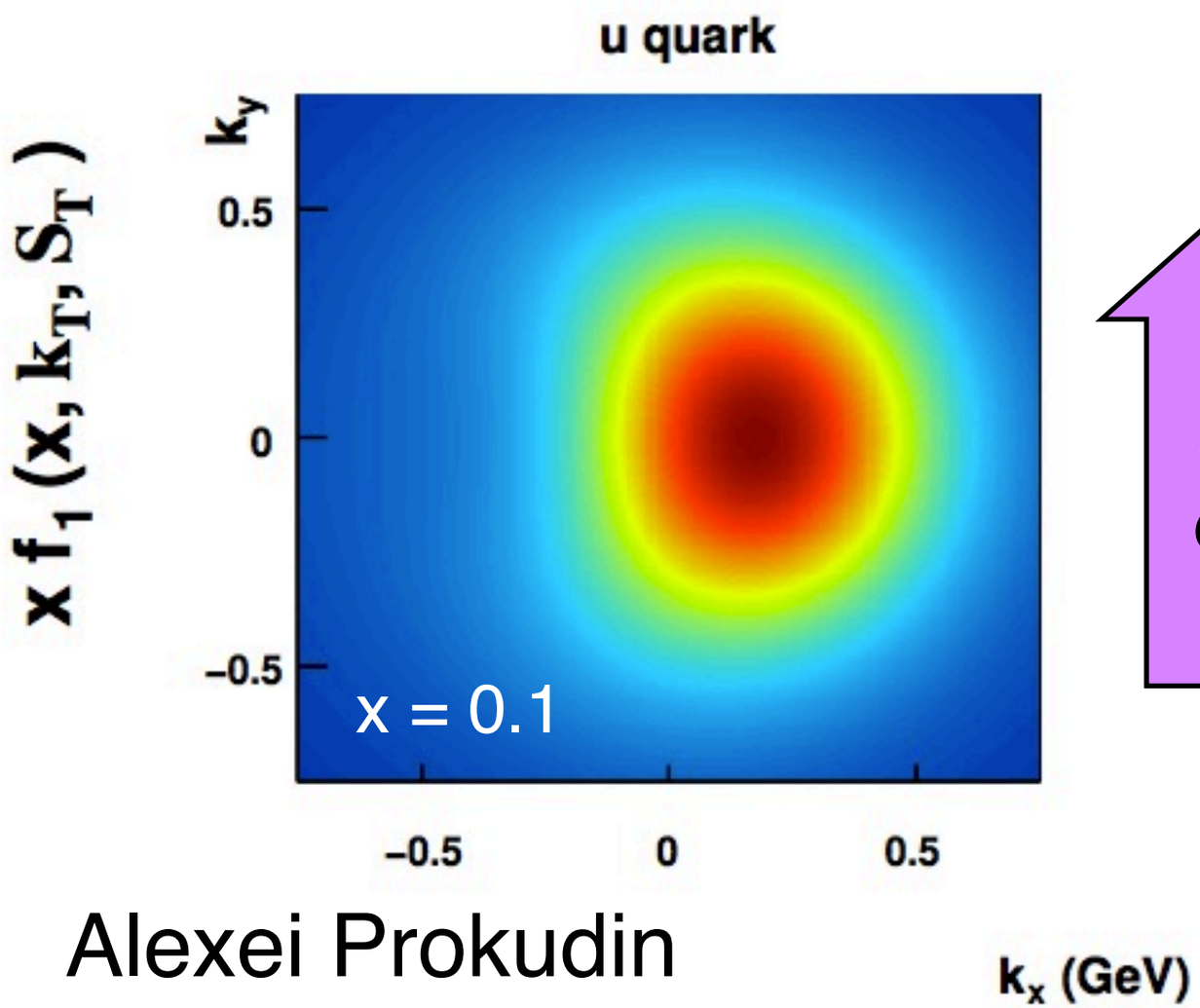
⇓

characterised via (z, p_T)

DIS x, Q^2 + semi-inclusive z, p_T (+ spin ϕ) ⇒ Multi-dimensional

SIDIS

- Gives additional hadron information
  - extract "*transverse-momentum-dependent distributions*": **TMD**s



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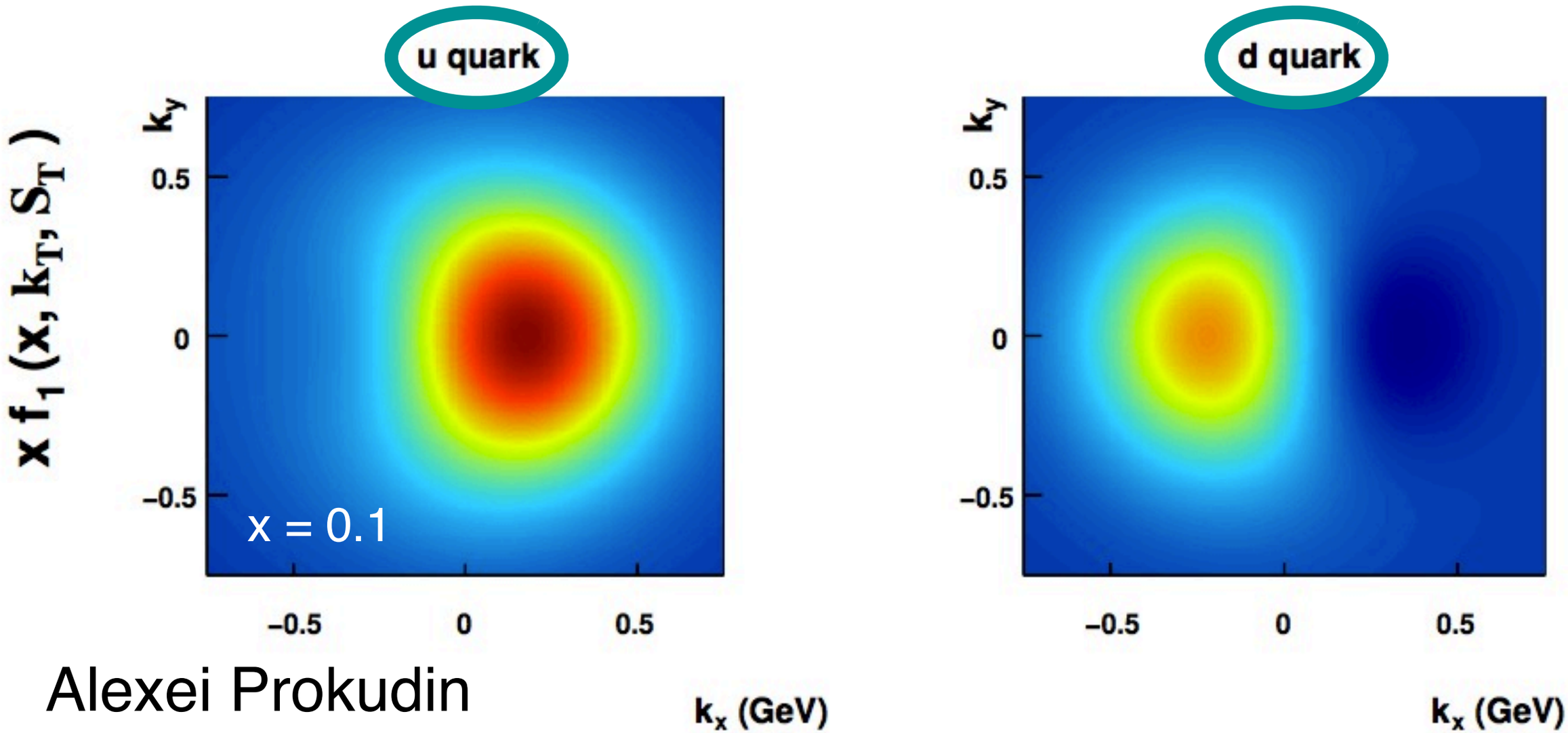
Spin

1) Spin-dependence: see deformation of parton distribution

SIDIS

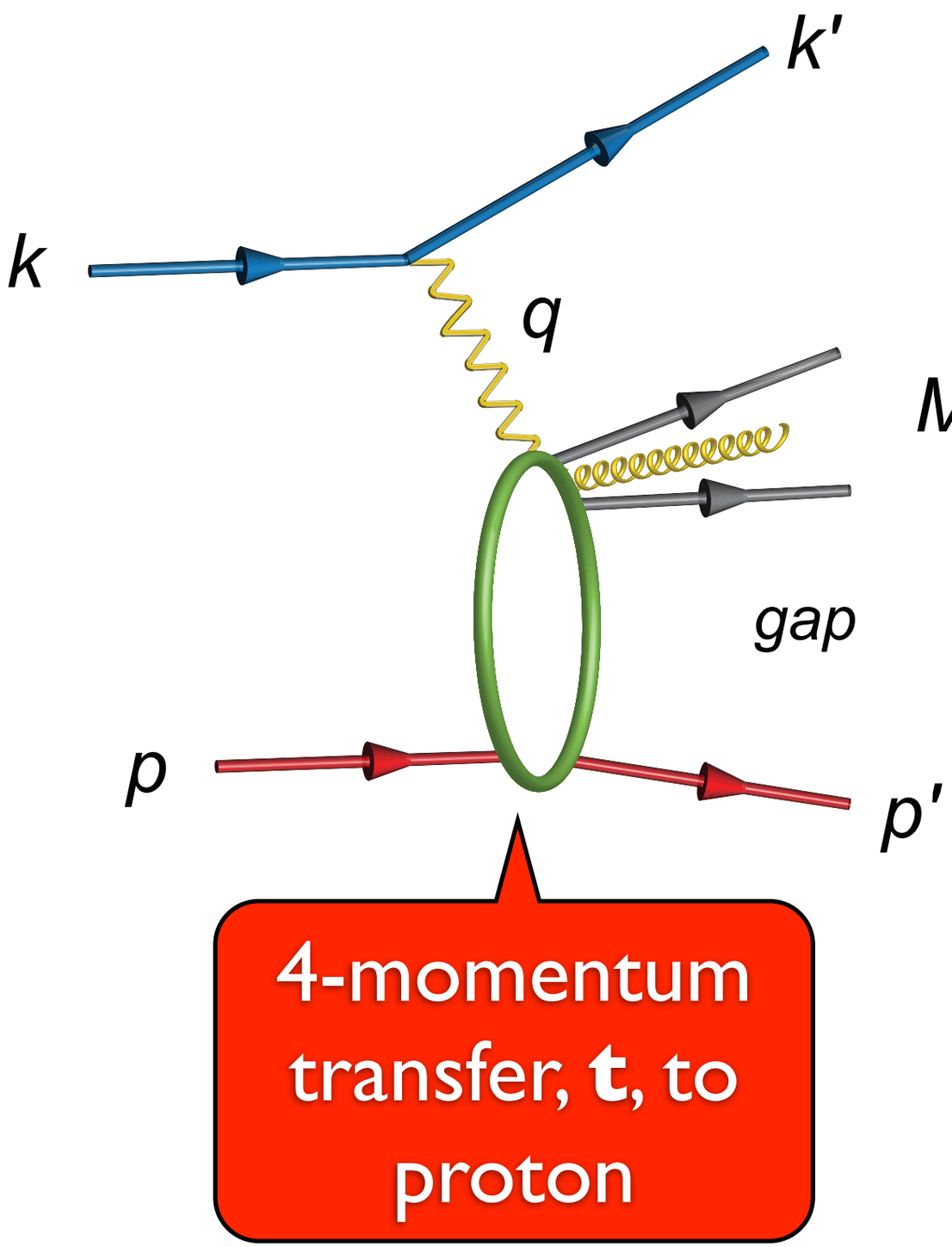
- Gives additional hadron information
  - extract "*transverse-momentum-dependent distributions*": **TMD**s



Alexei Prokudin

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

Exclusive production



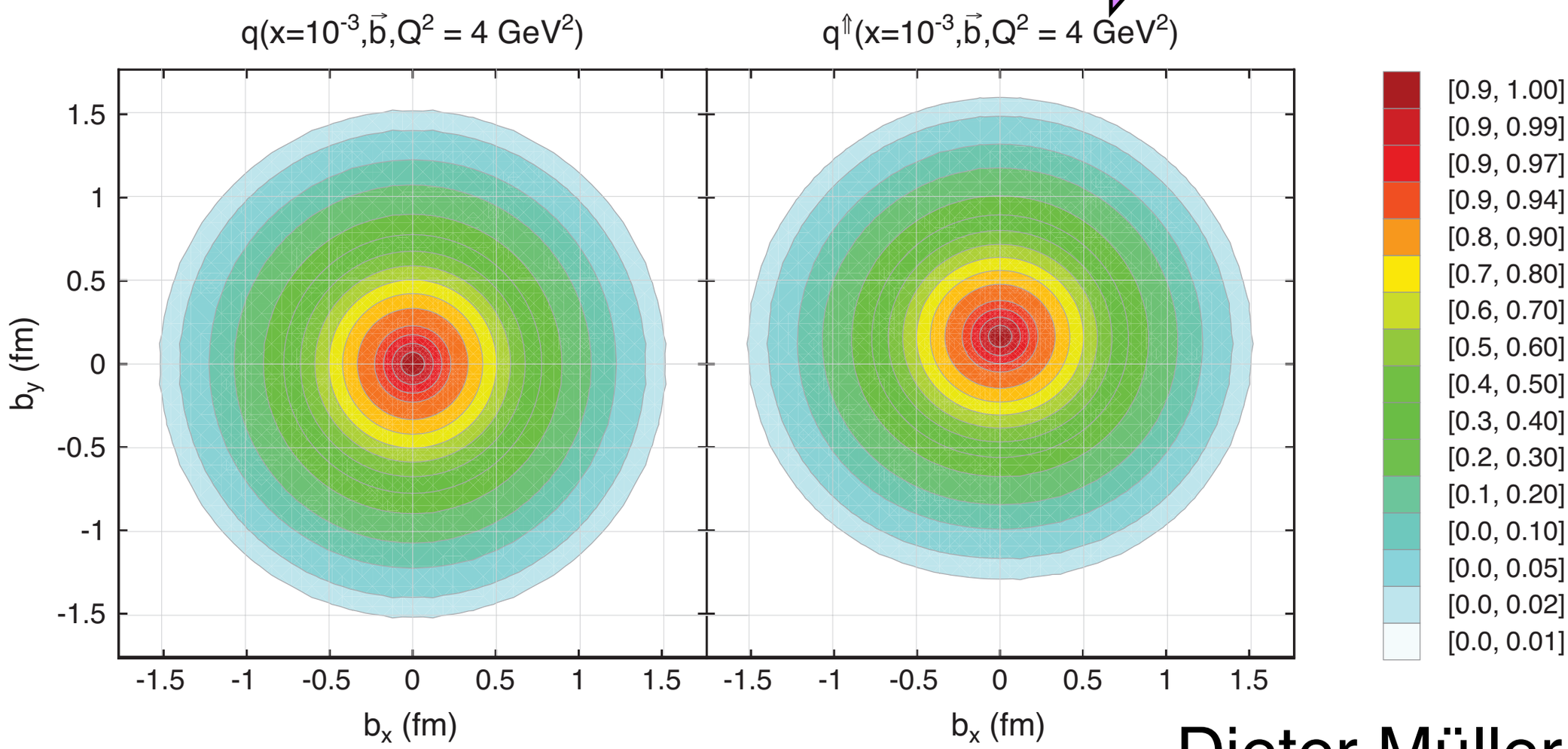
Exclusive reaction: M_X is a single boson: γ, J/ψ, ϕ...

- Provide access to "*generalised parton distributions*", **GPD**s

Exclusive production

- Fourier transform of $d\sigma/dt$:
  - b dependence
  - 2D spatial picture

Spin → Investigate effect of spin



Dieter Müller

Overview

- TBA

Backup

- Detailed slides here for which there isn’t room in the main talk.
- ...