# Transverse Momentum Dependent Nucleon Structure From Pions Impinged on a Transversely Polarized Proton Target

Robert Heitz

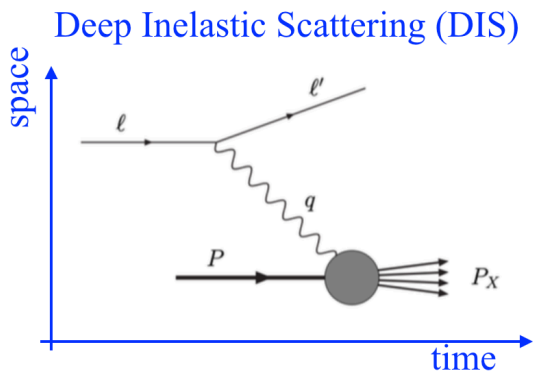
University of Illinois

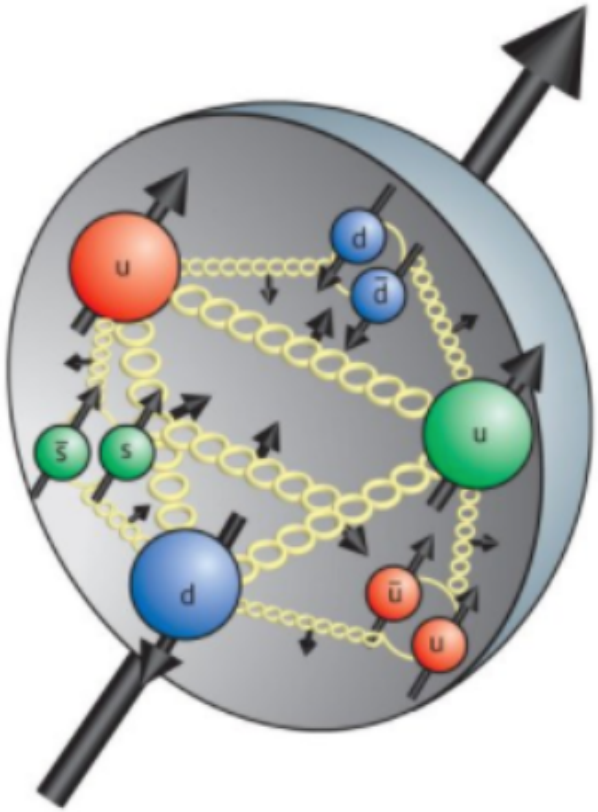
April 30, 2019

# Outline

# Proton Structure

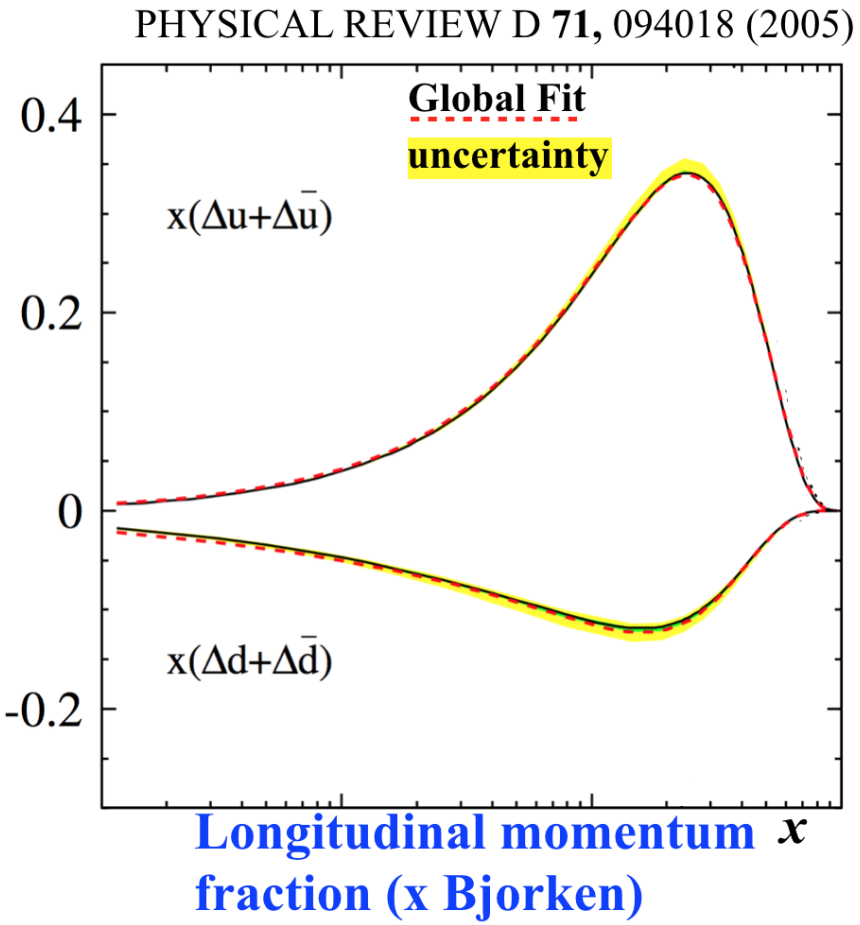
$\sigma$




- Protons are made up of:
  - up/up/down valence quarks (describe proton quantum numbers)
  - sea quarks and gluons

# Longitudinal Proton Spin Structure




Proton helicity distribution

$\Delta q = q^+ - q^-$

aligned quarks - anti-aligned quarks

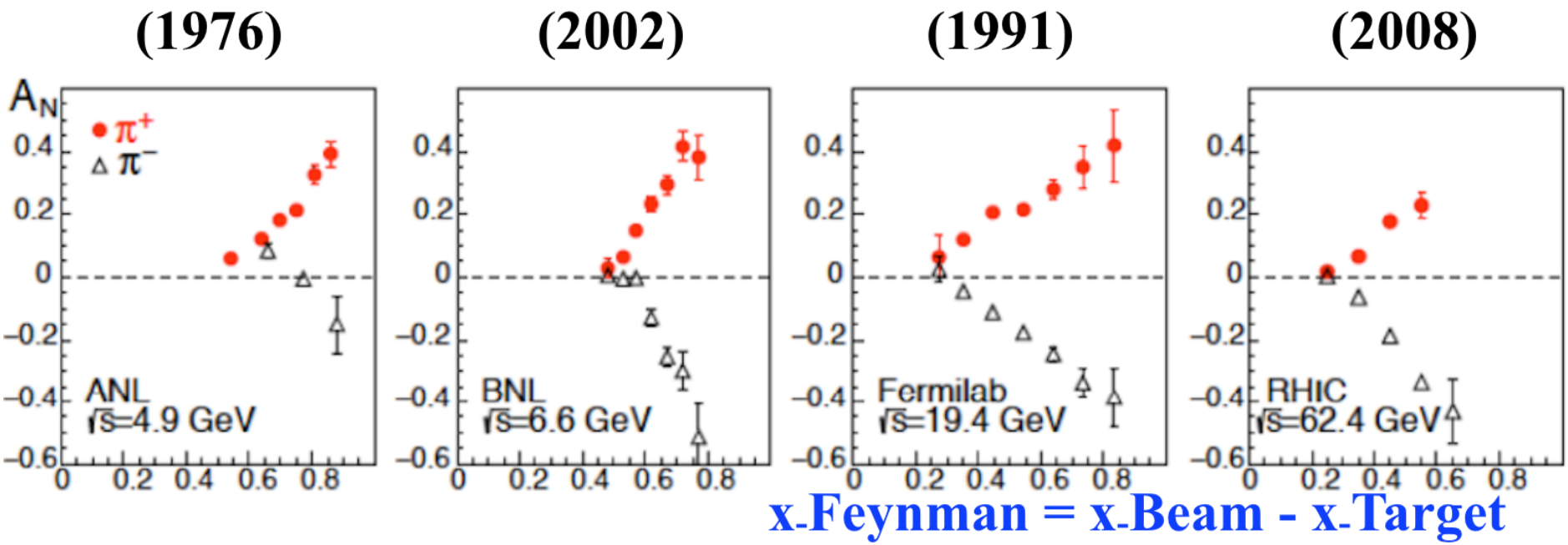
- Helicity distributions determined from $l^\uparrow + p^\uparrow \rightarrow l' + \pi + X$
- Integration gives the spin contribution from each quark flavor

# Transverse Proton Spin Structure

- In a quark collinear approximation the quark transverse momentum should be small

  $\Rightarrow$ Analyzing power, $A_N = \frac{1}{P}\frac{\sigma^{\pi}_{Left} - \sigma^{\pi}_{Right}}{\sigma^{\pi}_{Left} + \sigma^{\pi}_{Right}} \sim 10^{-4}$

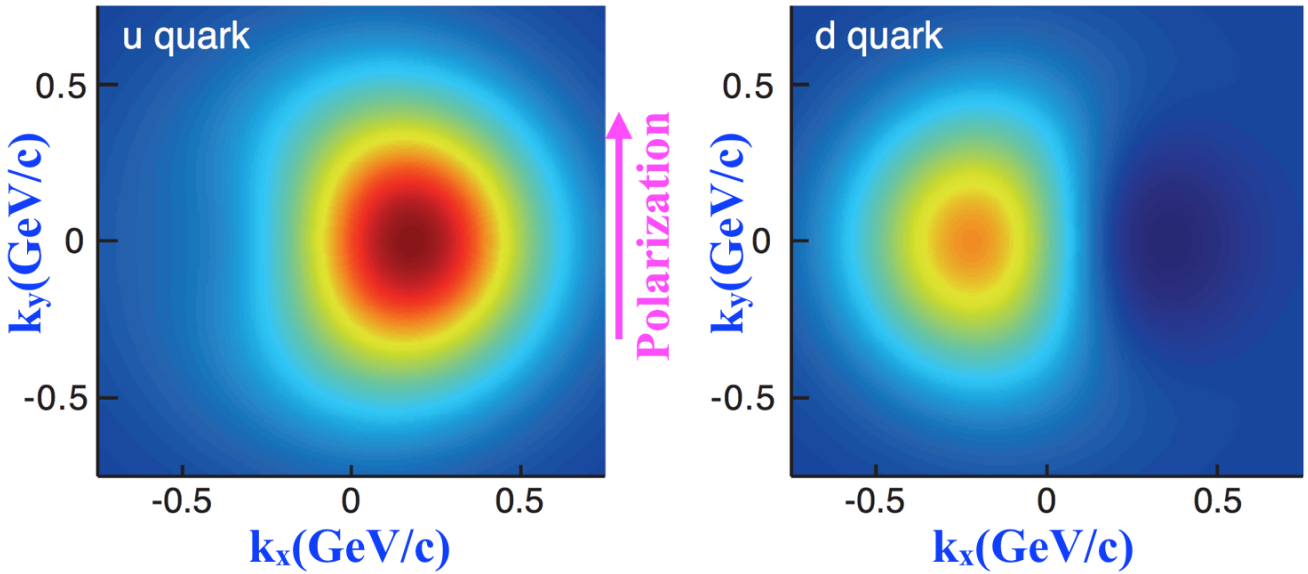
- E704 ($p^{\uparrow} + p \rightarrow \pi + X$) found much greater asymmetries




- $A_N$ is found large independent of the center of momentum energy

# Sivers Effect

- One possible way to explain large single spin asymmetries
- Gives a correlation between proton transverse spin and transverse momentum of a parton



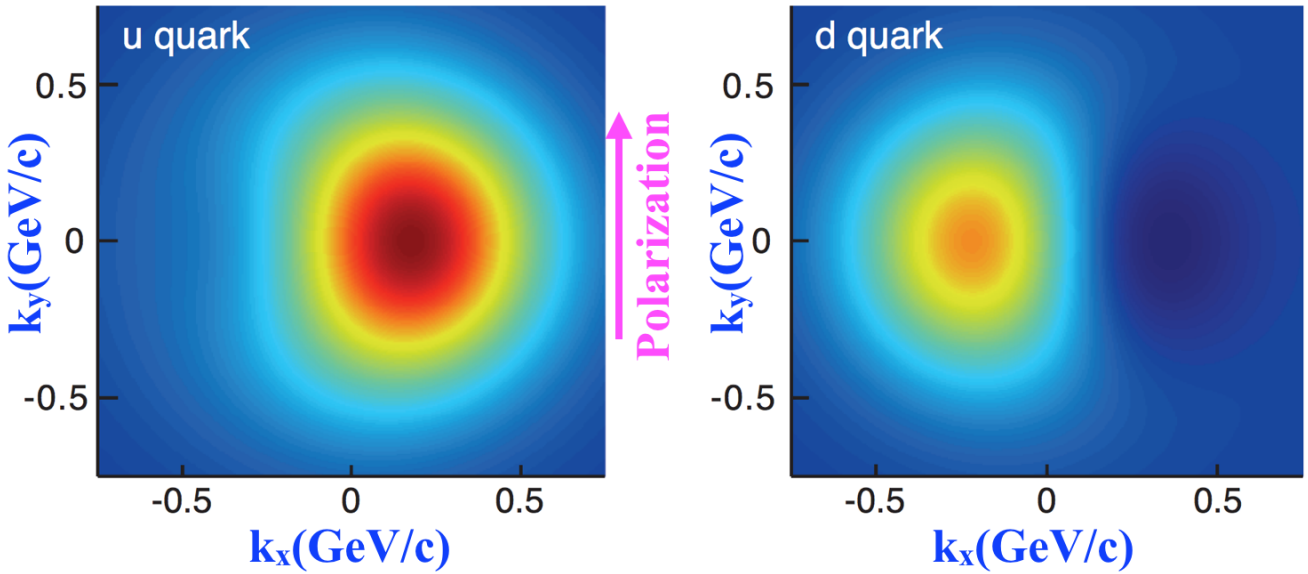

Lattice calculations of the quark transverse momentum in a polarized proton.

- Surprising result from theory: Sivers function is non-universal
- Expected to flip signs between

$$l + p^{\uparrow} \to l' + \pi + X \text{ and } h + p^{\uparrow} \to l + \bar{l} + X$$

# Sivers Effect

- One possible way to explain large single spin asymmetries
- Gives a correlation between proton transverse spin and transverse momentum of a parton




Lattice calculations of the quark transverse momentum in a polarized proton.

- Surprising result from theory: Sivers function is non-universal
- Expected to flip signs between

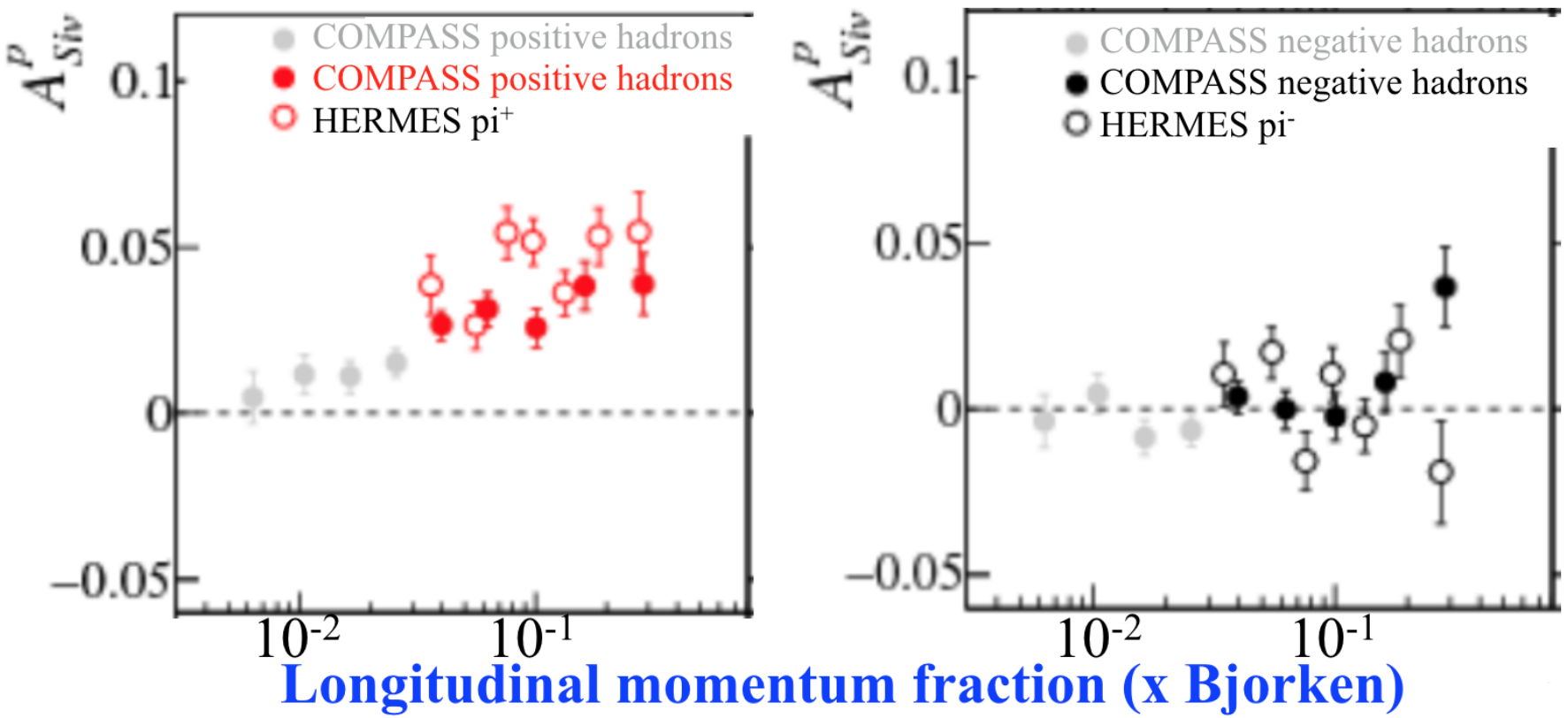
$$l + p^{\uparrow} \to l' + \pi + X \text{ and } h + p^{\uparrow} \to l + \bar{l} + X$$

**NSAC milestone for 2015**

# Sivers Measurement

- COMPASS and HERMES measured a non-zero Sivers amplitude from semi-inclusive deep inelastic scattering (SIDIS)

$$l + p^{\uparrow} \rightarrow l' + h + X$$




Sivers Amplitude related to the Sivers function