

MEASUREMENTS OF THE Z^0 CROSS SECTION AND TRANSVERSE SINGLE SPIN ASYMMETRY IN 510 GEV PP COLLISIONS

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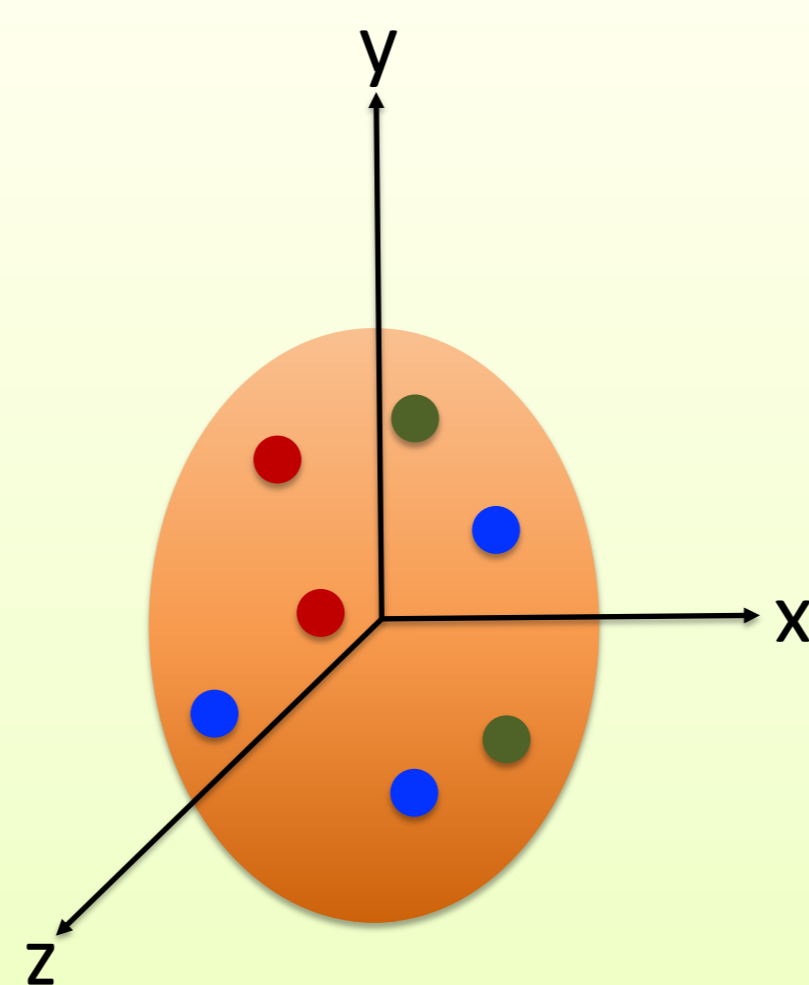
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Abstract

The differential cross section for Z^0 boson production, measured as a function of the boson's transverse momentum p_T , provides critical insights into the evolution of transverse momentum-dependent parton distribution functions (TMDs). The transverse single spin asymmetry (A_N , TSSA) of the Z^0 boson is particularly sensitive to one of the polarized TMDs, the Sivers function, which is predicted to have an opposite sign in $p+p \rightarrow W/Z+X$ processes compared to that observed in semi-inclusive deep inelastic scattering (SIDIS). In this poster, we present the first measurement of the Z^0 differential cross section as a function of p_T in $p+p$ collisions at a center-of-mass energy of 510 GeV, along with the total cross section as published by the STAR Collaboration. Additionally, we report the measurement of the Z^0 TSSA in transversely polarized $p+p$ collisions at 510 GeV.

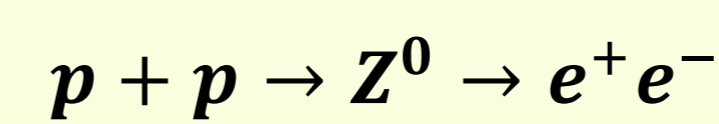
Introduction

- The internal structure of protons, described by their parton distribution functions, is an important topic in theoretical, phenomenological, and experimental studies in nuclear physics.
- Transverse momentum dependent parton distribution functions (TMDs), which encode both the parton's longitudinal momentum fraction (x) and its intrinsic transverse momentum (k_T), depict the density of partons in three dimensions.
- Experimentally, unpolarized TMDs can be extracted from Z^0 boson p_T spectrum, if the transverse momentum of the lepton pair is sufficiently small compared to Q , where Q is the mass of Z^0 . Additionally, the Sivers function, one of the polarized TMDs, can be probed through measurements of the transverse single spin asymmetry of Z^0 in polarized $p+p$ collisions.

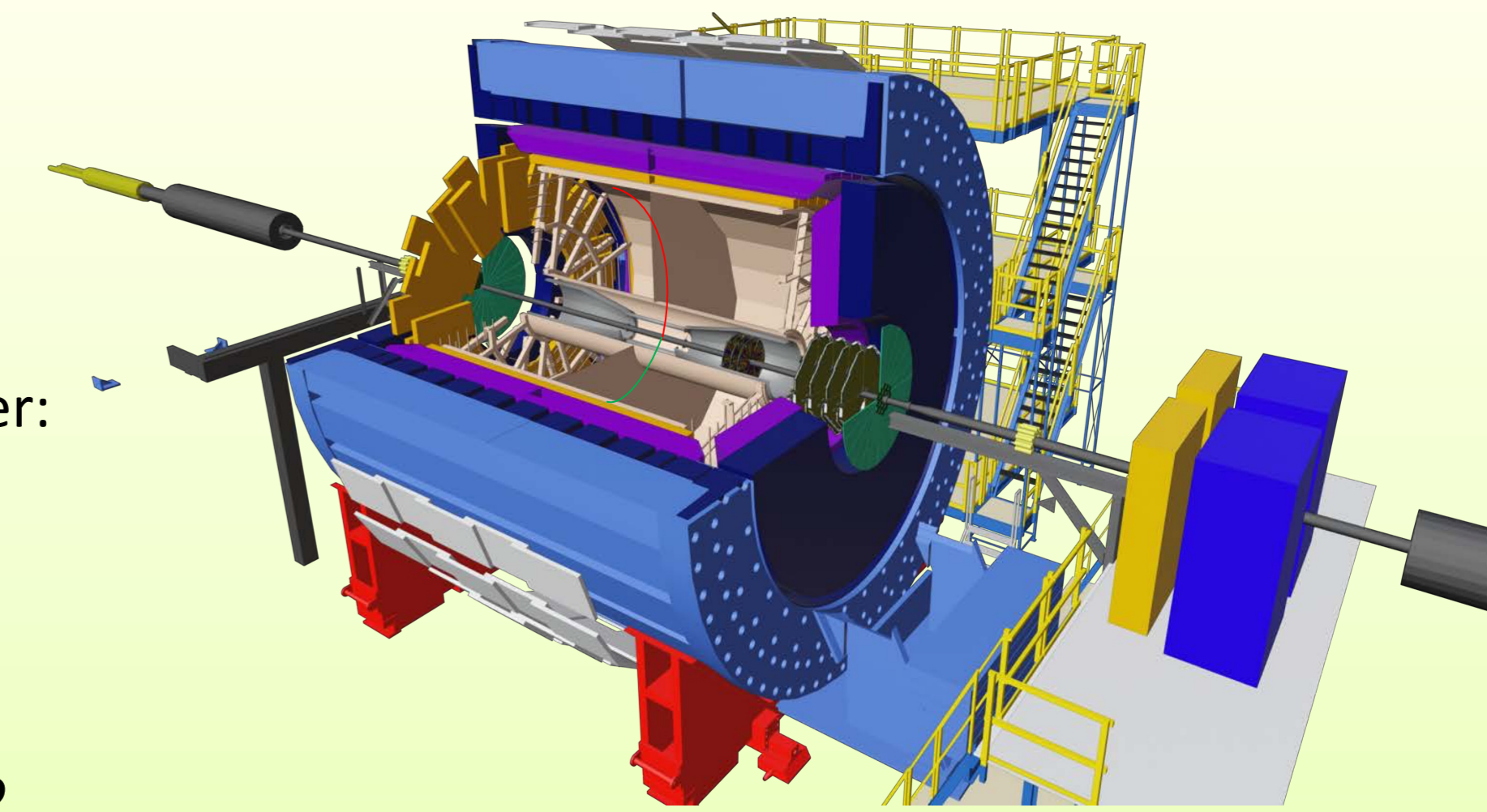


STAR detector for Z^0 reconstruction

Main subsystems used to reconstruct Z^0 at STAR:

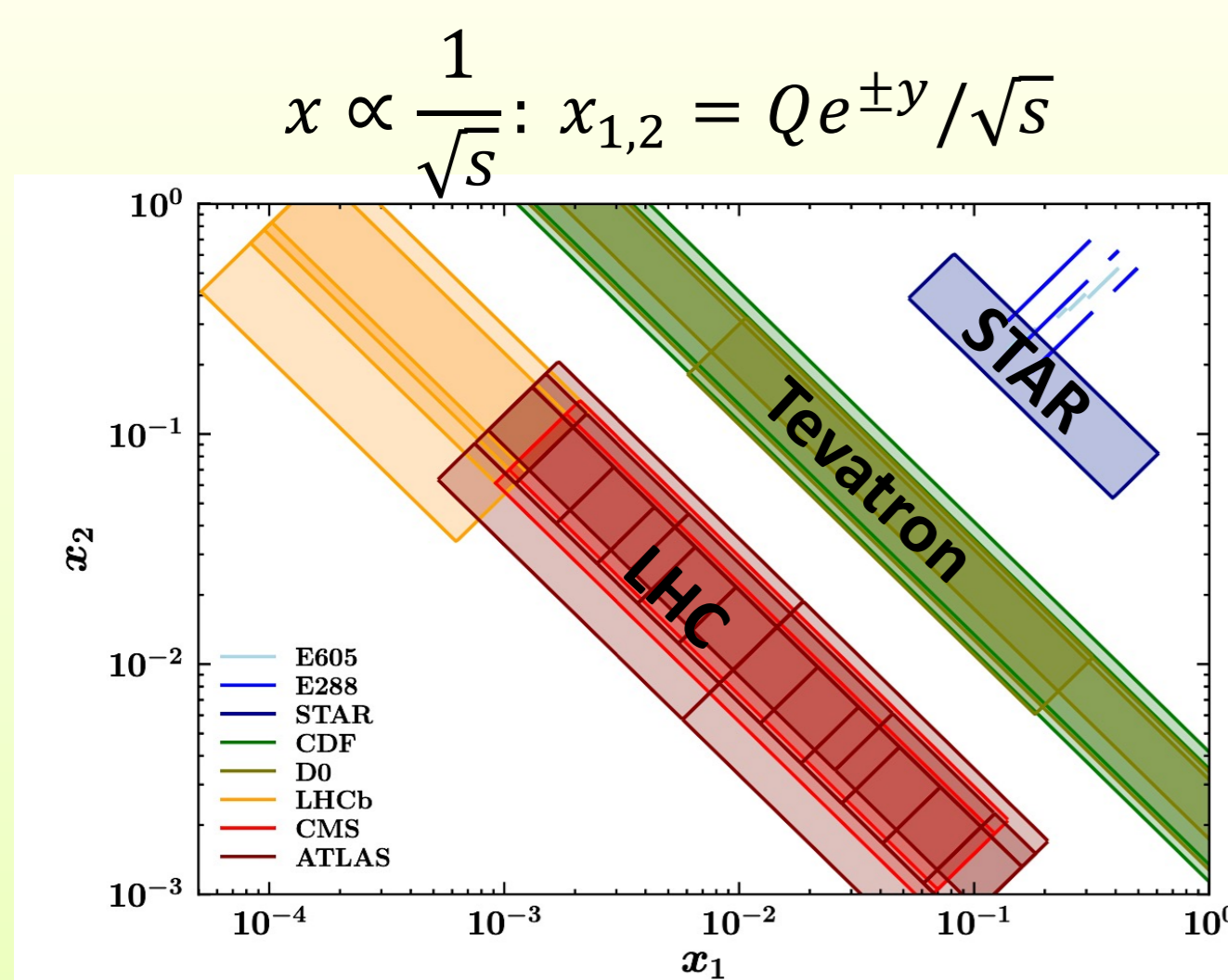


- Time Projection Chamber: $|\eta| < 1, \Delta\phi = 2\pi$, for lepton's charge, momentum
- Barrel Electromagnetic Calorimeter: $|\eta| < 1, \Delta\phi = 2\pi$, for energy measurement



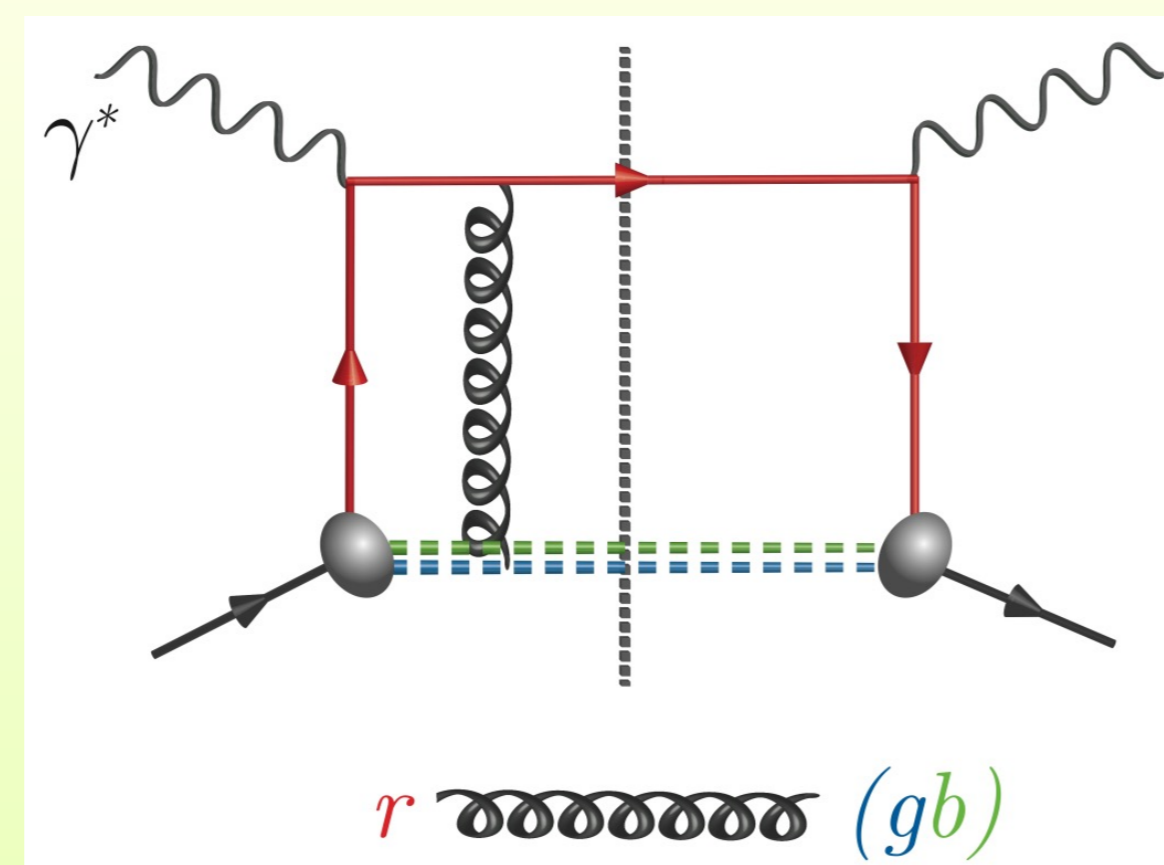
STAR detector and $Z^0 \rightarrow e^+e^-$ event display

Why Z^0 measurement at STAR

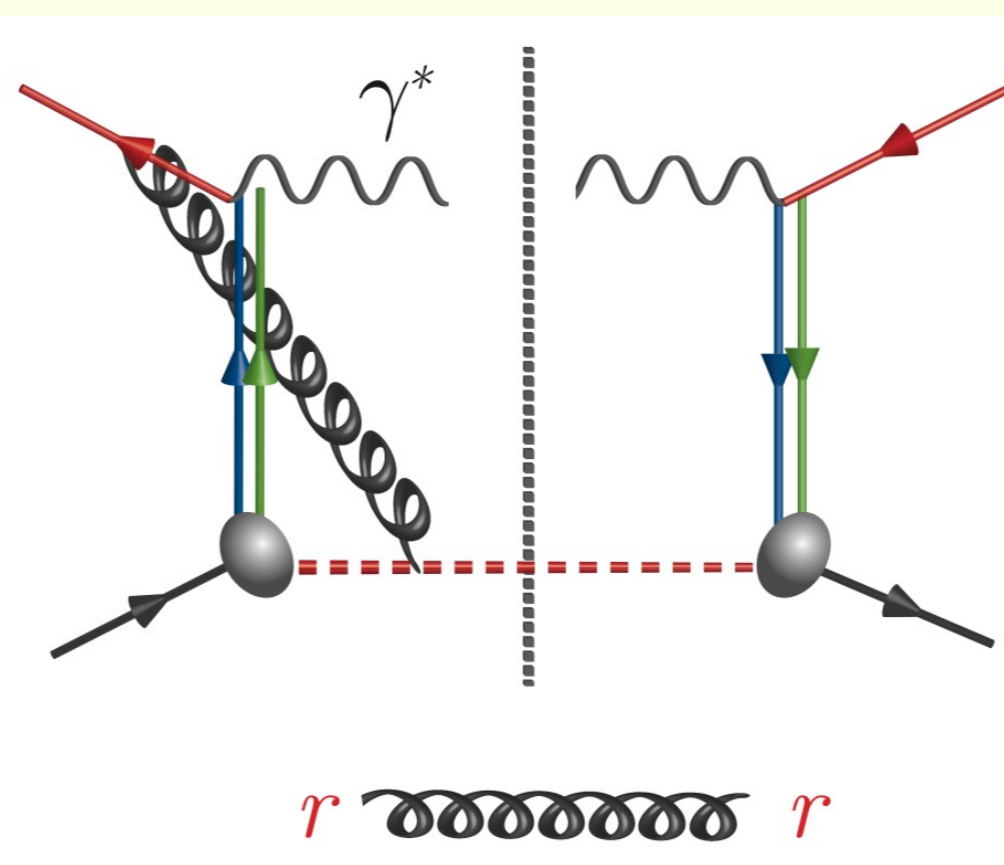


A. Bacchetta et al., JHEP 07(2020) 117

SIDIS Color attractive



DY, W, Z^0 : Color repulsive



RHIC Spin Collaboration, RHIC Spin Plan

RHIC operates at an intermediate collision energy:

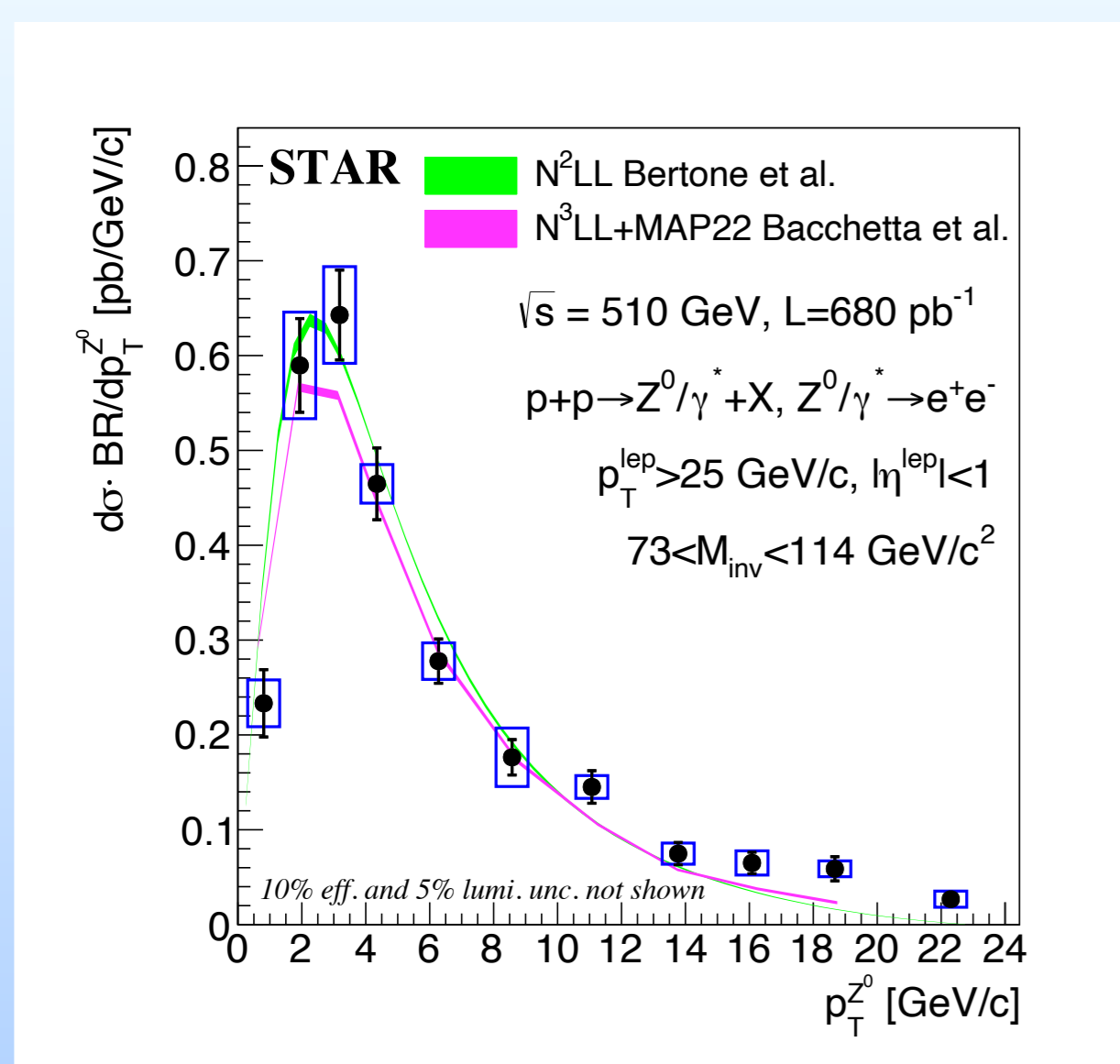
- Provides complementary data to the LHC and Tevatron experiments.

- Offers access to the large x region, enabling studies of TMD evolution as a function of x .

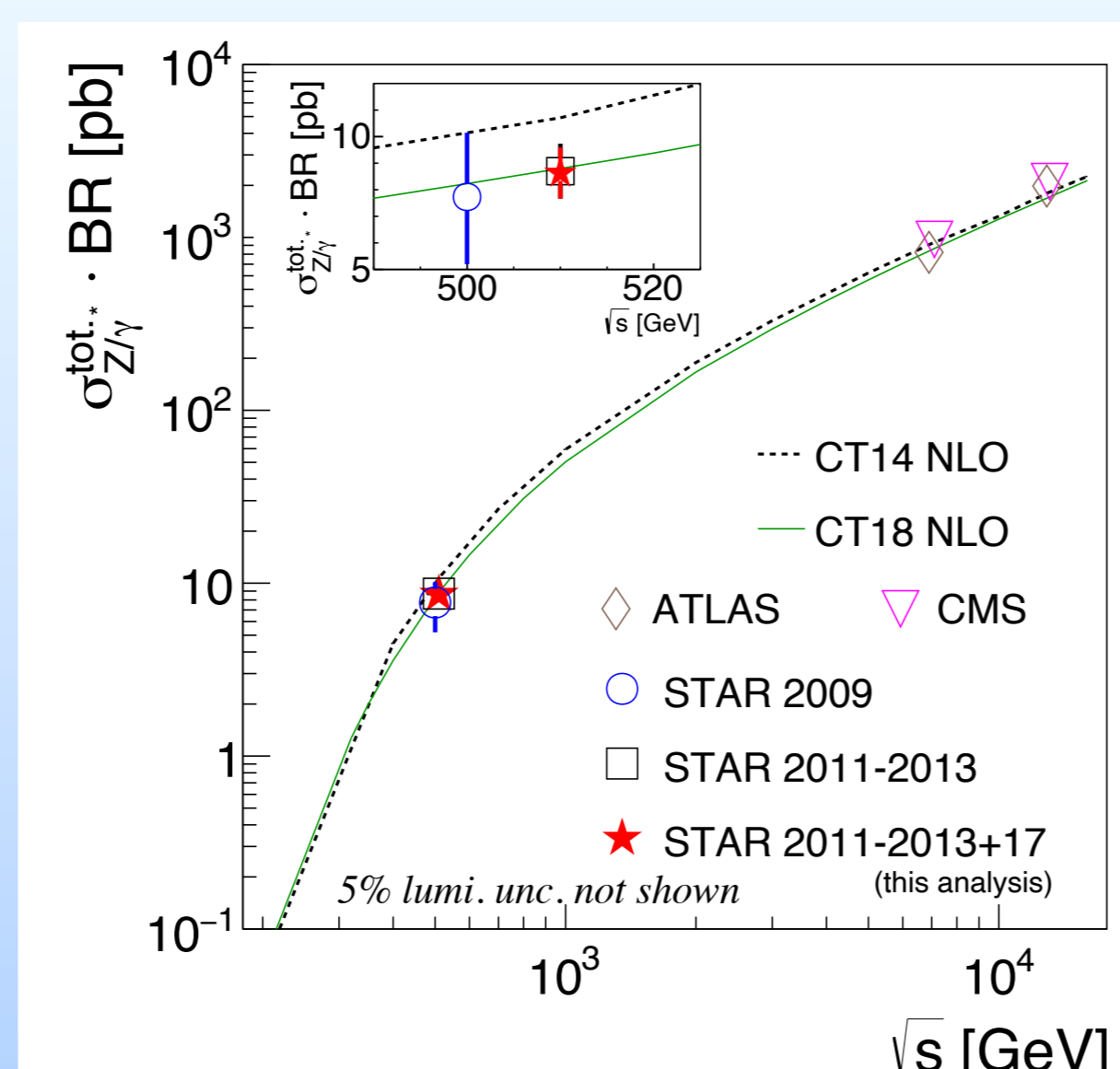
Z^0 channel at STAR complements data to SIDIS measurement from other experiments, enabling studies of TMD evolution as a function of Q^2 .

As the world's only polarized $p+p$ collider, RHIC uniquely allows Z^0 TSSA measurements at STAR, providing an opportunity to test the non-universality of the Sivers asymmetry predicted in $p+p$ collisions compared to that in SIDIS.

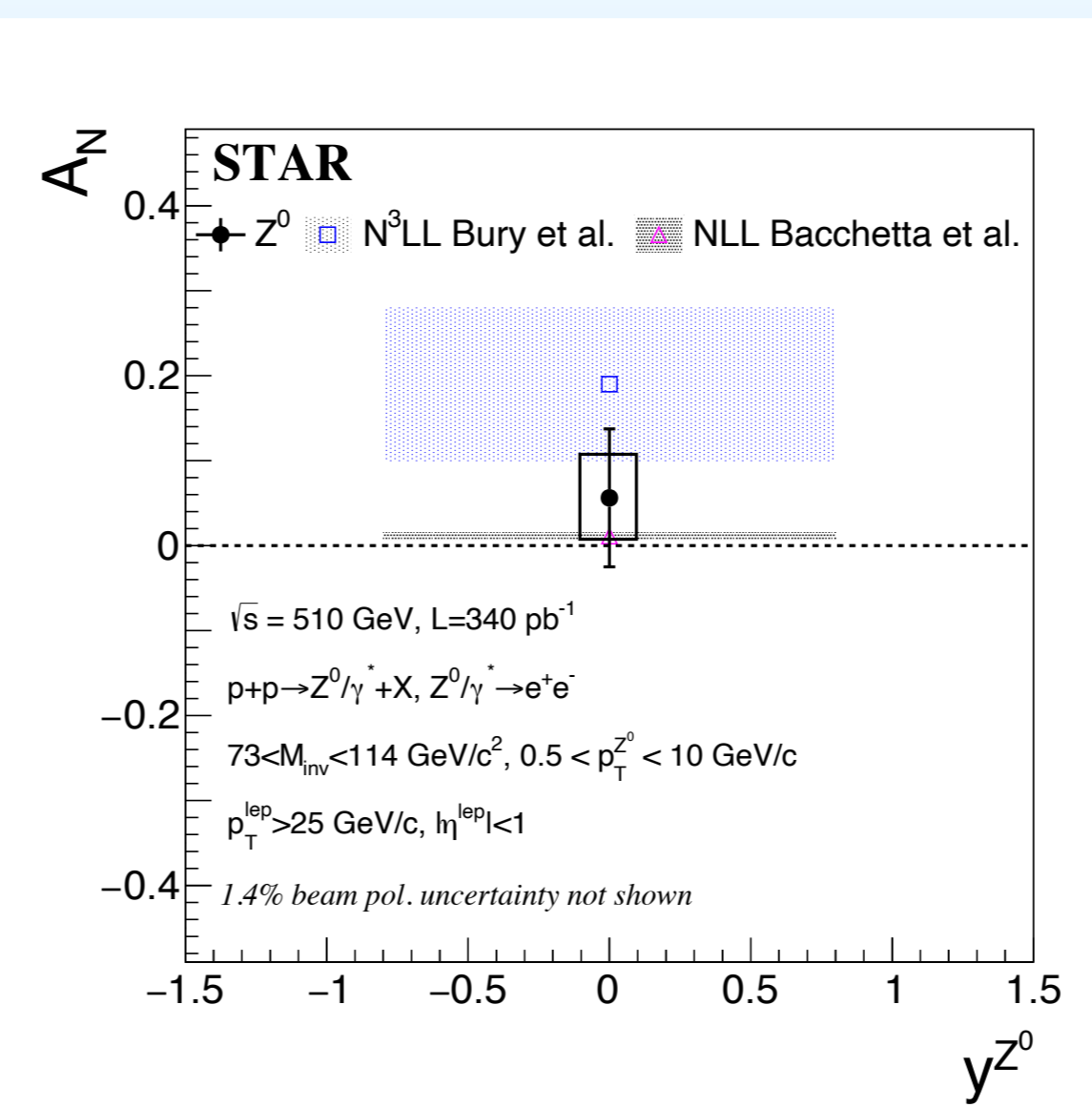
p_T spectrum of Z^0



Total cross section of Z^0



A_N of Z^0



STAR published these results in May 2024!
 STAR, Phys. Lett. B 854 (2024) 138715

- p_T spectrum: It is the first measurement of the Z^0 differential cross section as a function of its p_T in $p+p$ collisions at a center-of-mass energy of 510 GeV by the STAR experiment, using data collected from 2011-2013 and 2017.
- Total cross section: New results agree with the prior published results, with higher statistics.
- TSSA: The measured A_N is 0.056 ± 0.081 (stat) ± 0.050 (sys). Main systematic uncertainty comes from the like sign background.

Summary and outlook

- The p_T spectrum of the Z^0 measured at STAR, together with results from other experiments on DY, SIDIS, and Z^0 , provide important constraints on the x and Q^2 evolution as well as the process dependence of the unpolarized TMDs.
- The result of A_N can accommodate the sign change hypothesis that is based on the non-universality property of the Sivers function between DY/Z/W production and SIDIS, it cannot conclusively verify the prediction.
- Precision will be improved using $p+p$ data at 508 GeV that STAR collected in 2022.

Acknowledgements

We thank the STAR Collaboration, RHIC Operations Group and RCF at BNL. Special thanks go to my collaborators: Elke-Caroline Aschenauer and Salvatore Fazio.