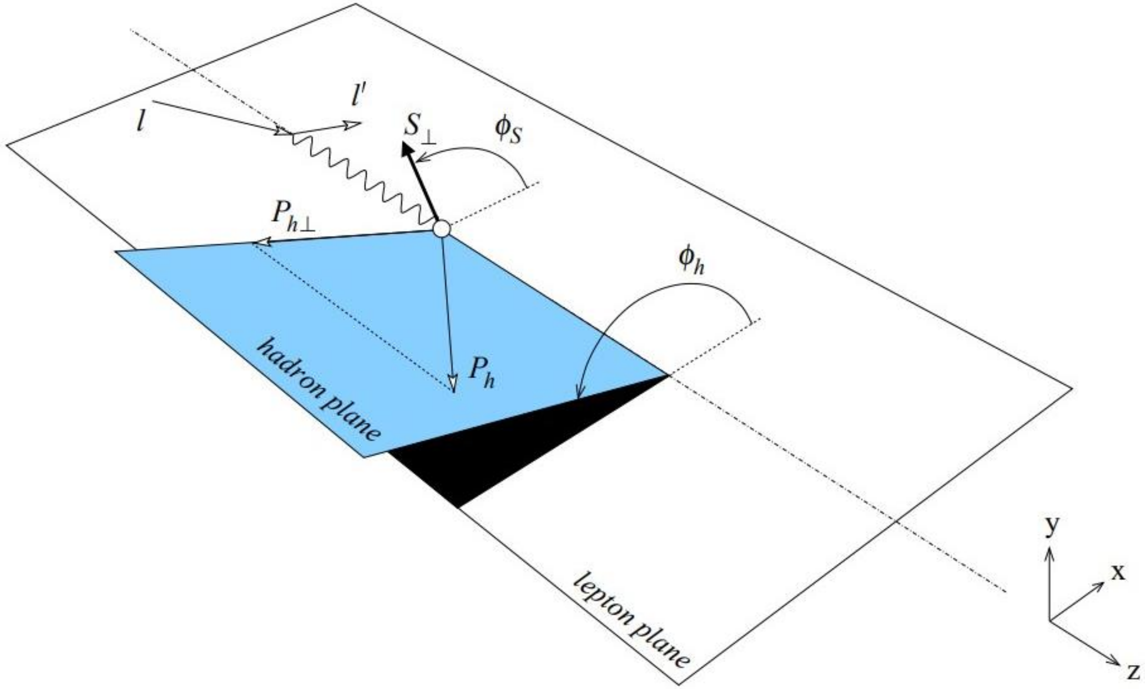
NPS Collaboration Meeting

SIDIS plan



Bacchetta et al. JHEP 0702 (2007) 093

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PHY2012430 and PHY2309976

THE CATHOLIC UNIVERSITY OF AMERICA

Jefferson Lab

Aside on Kinematics

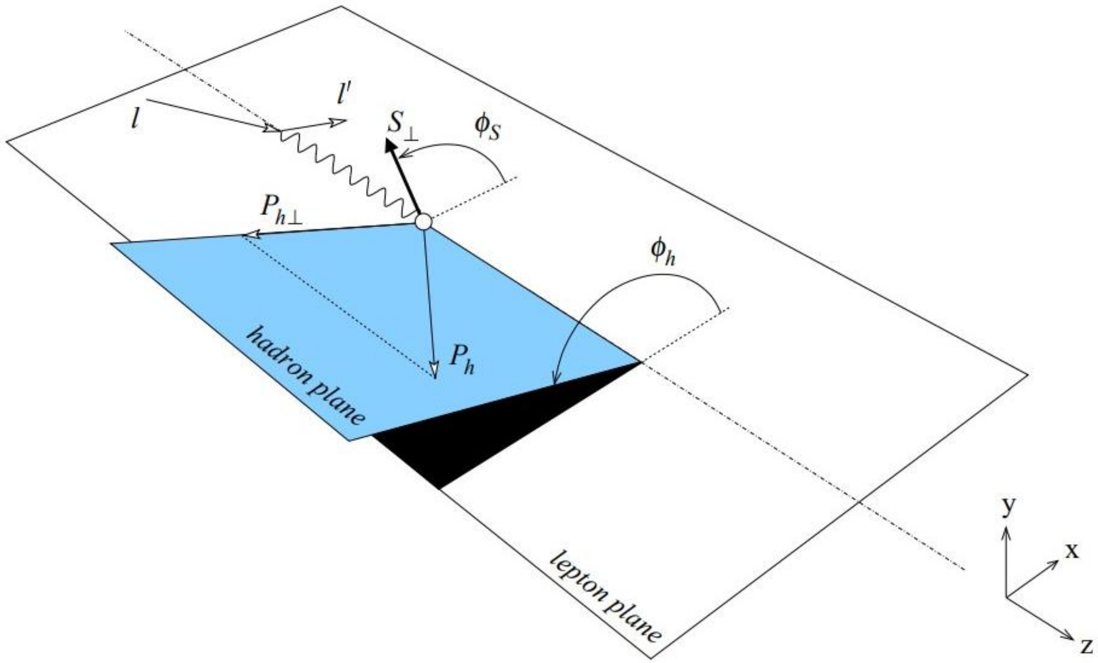
Jefferson Lab

Key Variables

- x: Bjorken scaling variable (momentum fraction of the struck quark)
- Q^2: Squared momentum transfer from the electron
- z: Fraction of virtual photon energy transferred to the π^0
- P_T: Transverse momentum of the detected hadron relative to virtual photon
- ϕ: Azimuthal angle of the hadron
- M_x^2: Missing mass squared
- And more ...

It is useful and constructive to define these variables yourself by hand (both data and monte carlo)

Understand the physics behind the variables, not the variable names – different nomenclature! P_h $P_{h\perp}$



Bacchetta et al. JHEP 0702 (2007) 093

Talk at 2023 Hall C Winter Meeting
https://indico.jlab.org/event/758/contributions/13804/attachments/10619/16051/pi0_sidis_2024_f.pdf

SIDIS Formalism

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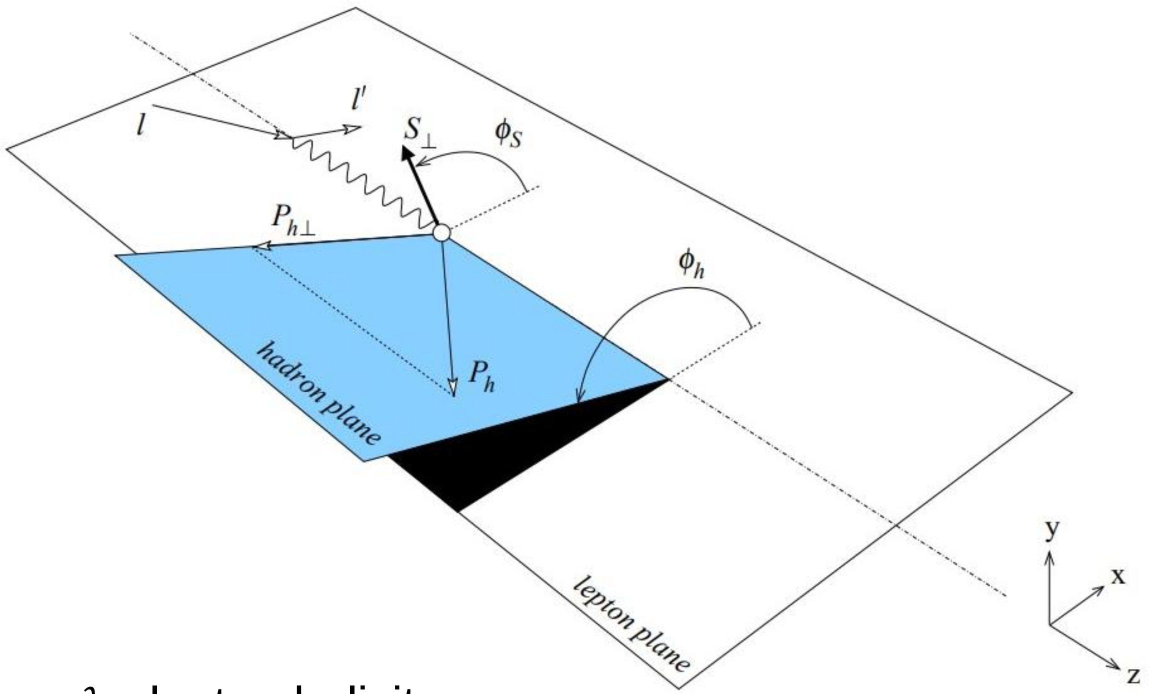
- General expression for SIDIS, 8 leading twist structure functions, 18 structure functions to twist-3
  - Bacchetta et al. JHEP 0702 (2007) 93
- Keeping only unpolarized and beam polarized SIDIS structure functions up to twist-3
  - Subscripts indicate unpolarized and longitudinally polarized beam and target, respectively.

$$\frac{d\sigma}{dx\,dy\,d\psi dz\,d\phi_h dP_\perp^2} = \frac{\alpha^2}{xyQ^2}\frac{y^2}{2(1-\epsilon)}\left(1+\frac{\gamma^2}{2x}\right)\Big\{F_{UU,T}+\epsilon F_{UU,L} + \sqrt{2\epsilon(1+\epsilon)}\cos\phi_h F_{UU}^{\cos\phi_h} + \epsilon\cos(2\phi_h)\,F_{UU}^{\cos 2\phi_h} + \lambda_e\sqrt{2\epsilon(1-\epsilon)}\sin\phi_h F_{LU}^{\sin\phi_h}\Big\}$$



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λ_e: lepton helicity

$$\gamma = \frac{2Mx}{Q}$$

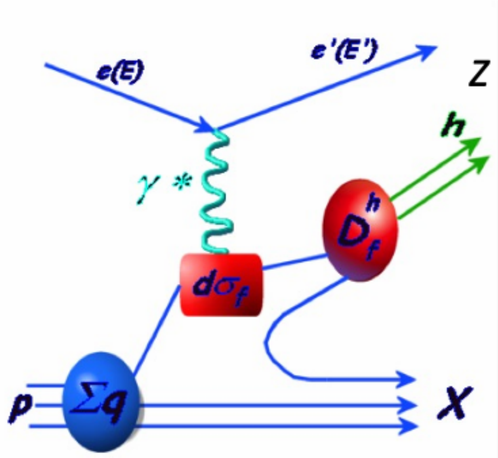
$$\epsilon = \frac{1}{1+2\frac{|q^2|^2}{Q^2}\tan^2\left(\frac{\theta_e}{2}\right)}$$

Flavor Decomposition of SIDIS

$$\frac{1}{\sigma_{(e,e')}}\frac{d\sigma}{dz}(ep \to hX) = \frac{\sum_q e_q^2 f_q(x) D_q^h(z)}{\sum_q e_q^2(x) f_q(x)}$$

$f_q(x)$: *parton distribution function*

$D_q^h(z)$: fragmentation function



$M_x^2 = W'^2 \sim M^2 + Q^2\,(1/x - 1)(1 - z)$

- Leading-Order (LO) QCD
- after integration over $p_{h\perp}$ and ϕ_h
- NLO: gluon radiation mixes x and z dependences
- Target-Mass corrections at large z
- ln(1-z) corrections at large z

With p_T and k_T dependences, some kind of convolution is necessary to obtain final $P_{h\perp}$

Towards Cross Sections

- $\dfrac{\frac{d^6\sigma}{d\Omega_e\, dE_e\, dx\, dP_T^2\, d\phi}}{\frac{d\sigma}{d\Omega_e\, dE_e}} =$

$$\frac{\frac{\alpha^2}{xyQ^2}\frac{y^2}{2(1-\epsilon)}\left(1+\frac{\gamma^2}{2x}\right)\left\{F_{UU,T}+\epsilon F_{UU,L}+\sqrt{2\epsilon(1+\epsilon)}\cos\phi_h F_{UU}^{\cos\phi_h}+\epsilon\cos(2\phi_h)\,F_{UU}^{\cos 2\phi_h}+\lambda_e\sqrt{2\epsilon(1-\epsilon)}\sin\phi_h F_{LU}^{\sin\phi_h}\right\}}{\frac{d\sigma}{d\Omega_e\, dE_e}}$$

Is this notation consistent?

Is the ratio even valid?!?

- Semi-Inclusive Structure Functions: This ratio is related to the semi-inclusive structure functions, which describe the distribution of hadrons produced in the fragmentation of the struck quark. These functions are essential for understanding the hadronization process and validating the factorization framework.
- Experimental considerations: Efficiencies, backgrounds, radiative corrections, consistency between experiments / kinematic settings, etc.

Towards cross sections – Complete!

Thank you

Questions?

Towards Cross Sections – Data Analysis

Jefferson Lab

- Detector Calibrations
  - Reference Times / Timing Windows
  - HMS Hodoscope – Avnish Singh
  - HMS Drift Chambers - Yaopeng Zhang & Avnish Singh
  - HMS PID – Mitch Kerver & Paul Anderson
    - Cherenkov, Calorimeter
- Detector Efficiencies
  - Drift Chamber – Yaopeng Zhang & Avnish Singh
  - HMS Calo / Hodo / Trigger - Other experiments
- Other Studies / Efficiencies
  - Boiling Correction – Richard Trotta
  - Luminosity / fADC deadtime / etc. – Richard Trotta
  - Target density fill-factor correction – Mark / Julie
  - BCM / BPM / Optics – Christine Ploen / Josh Crafts
  - Trigger thresholds

- Event Selection
  - Electron PID
  - Coincidence Time
  - Missing mass cut
  - Pion reconstruction - Wassim
  - Accidental Coincidences -Wassim

The HMS detectors are quite well calibrated and understood. Don't fixate on the passes. Focus on making and documenting your analysis scripts to re-run the analysis again

- You inevitably will re-run scripts
- Even if just to make plots for your thesis

Towards Cross Sections – Data Analysis

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  - -Wassim

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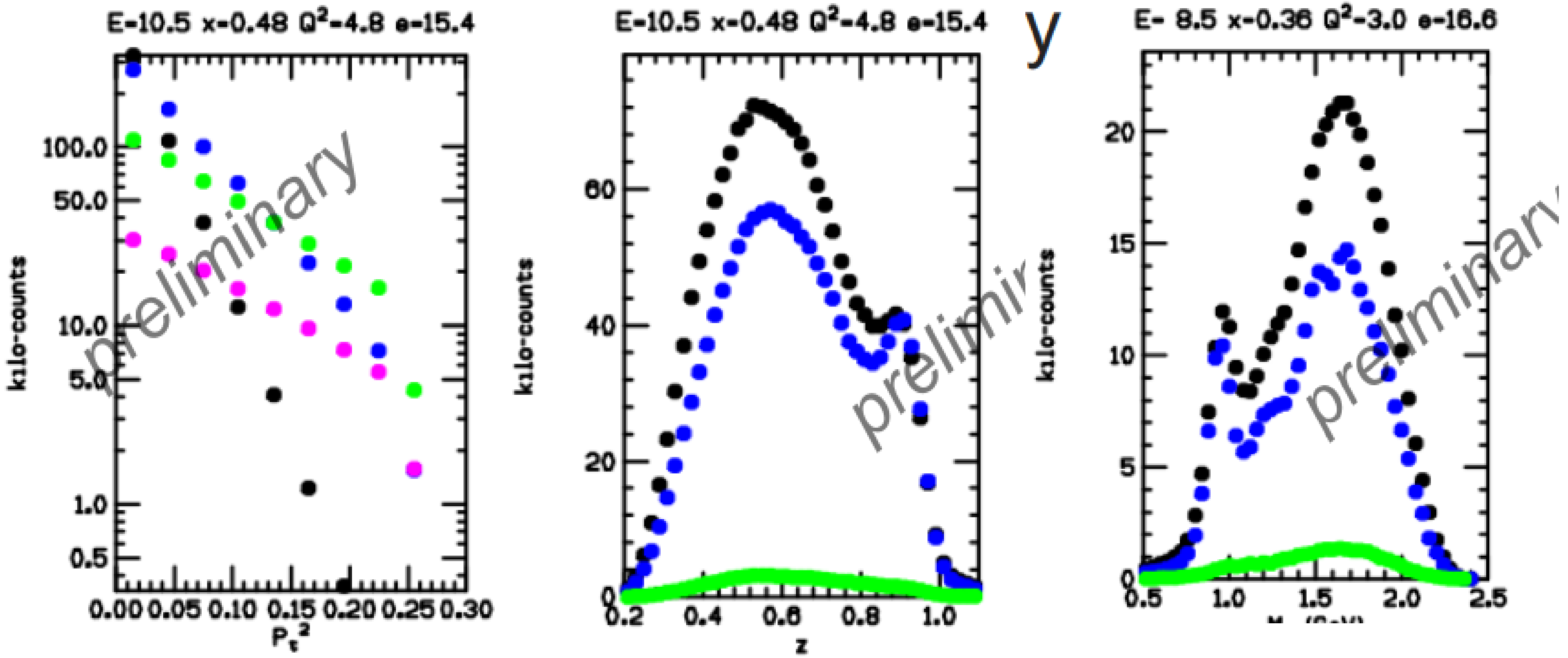
Result: Extraction of raw data yield in bins in x, z, P_T, ϕ, Q^2 binned in several bins that make sense (See proposals / Peter's Analysis)

Yield – Binned in physics variables



Towards Cross Sections – Monte Carlo / Model

Jefferson Lab

- SIMC
  - Acceptance Correction
  - Apply mispointing and Target offsets
  - Compare Elastics
  - Model of physics process
    - Iterate model
- Data To SIMC comparisons
  - Aluminum endcap subtraction
  - Validate Optics, Luminosity, BCM /BPM, tracks, acceptance corrections, pion background subtraction in e-arm, accidental subtraction, blocks dying (also acceptance)
- Extract born cross-section binned in many different kinematic variables

Other Devoted studies not mentioned here:
Helicity Scalers to recover accurate charge and trigger scalers in ~100 runs.
Inclusive analysis Data-to-MC comparisons for dummy thickness and target density fluctuations along with analysis with exclusive pions.
Blocks dying effect on acceptance
Exclusive pion subtraction

All the physics we do with these extracted cross-sections!

Towards Cross Sections Organization of Scripts

- Save your analysis in git (version control)
  - Push up to github regularly
- Several types of analysis script used in the wild:
  - Scripts compiled within CERN ROOT interactively (.L script_name)
  - Make scripts in python / jupyter notebook with pyROOT – harder to version control! Be careful with plot versions.
  - Compile all your scripts as executables using Cmake, add automated test of your scripts using gtest / etc. Version number your scripts in the CMakeLists.txt file. Add optional arguments to run scripts.
- Organize config files, scripts and headers in src, include directories, link ROOTfiles, skimfiles, report files.
  - Config files could be kinematics, cuts, etc.
  - Common block in python / fortran / C++ for loading runlist information
  - Trim down the data in multiple steps! (skimfiles, see next slide)

Organization of Scripts Cont.

- Get away from raw data files as fast as possible
  - Apply good electron cuts, form low level signals / clustering / etc.
  - Combine runs into single kinematics / split kinematics if needed based on similarities
  - Always document your cuts and other information on these 'skim' files or whatever you want to call them.
- It is a lot easier to manipulate a few files of a few GB with low-level physics variables to form higher level physics variables than it is to run through TB of raw data with junk events.
  - You can always go back and run your first analysis phase as needed.
  - Save your personal skimfile output to the mss as needed, 100GB for a pass for a personal use is probably fine. 1TB, probably not too much.
- Don't overwrite raw data files, don't overwrite your output files either. Save each file maybe with an index or tag and save good notes on what that plot of canvases, histograms, etc. are.
  - Save all the plots you show in meetings

Examples of analysis code repositories

- https://github.com/mrcmor100/nps_inclusive
- More advanced repo from Sebastian Seeds, Hall A https://github.com/sebastianseeds/SBS-ana
  - Do better than me (than this repo): Add a README, add comments in code, add functionality and explain how scripts run. Link to ELOG, link to wiki, etc.
  - With the common runlist, build your 'kinematics' instead of hard coding them based on a personal set of text files.
  - Version numbers, etc.

Discussion