Longitudinal Spin Structure of the Proton in Run Group C

Derek Holmberg
11-20-25

Jefferson Lab

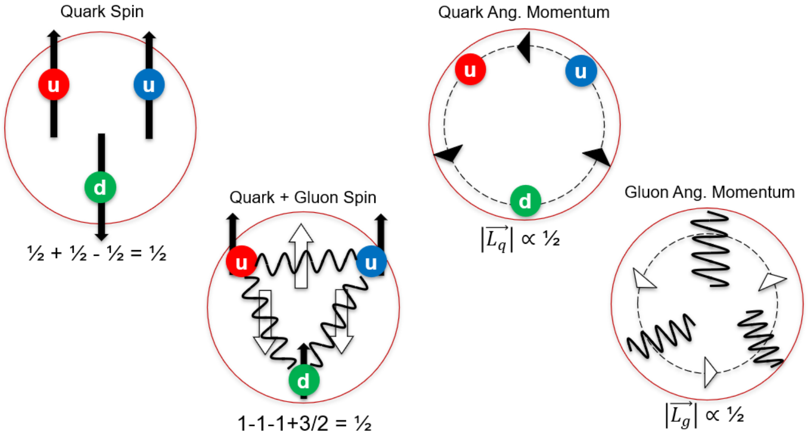
William & Mary
CHARTERED 1693

clas
CEBAF Large Acceptance Spectrometer

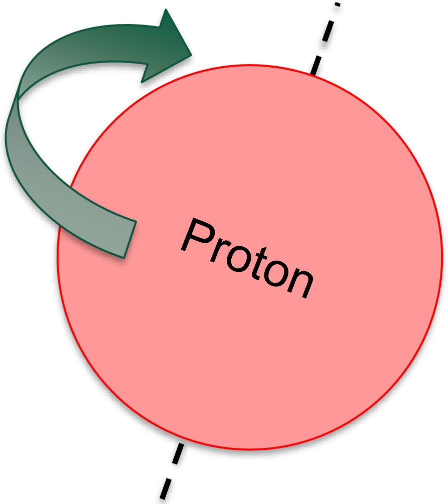
CLAS Collaboration Meeting November 18-21

Where Does the Proton Spin Come From?

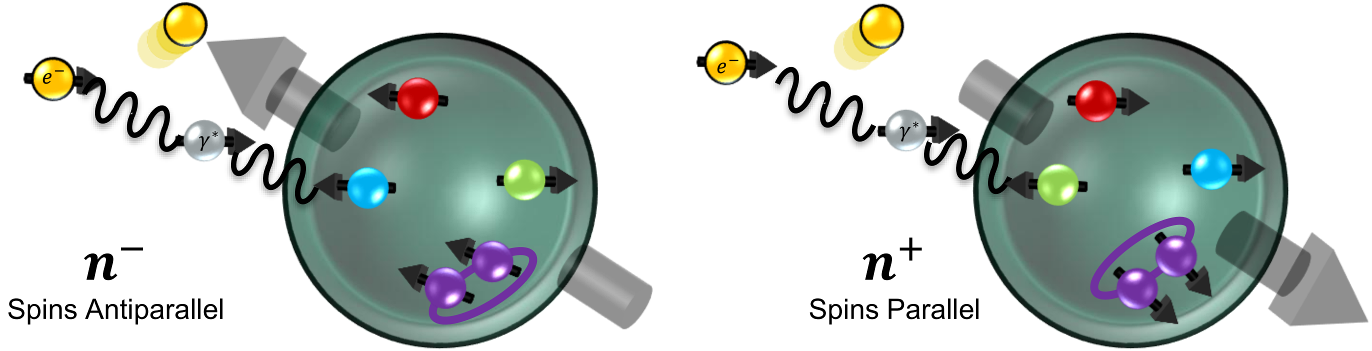
- Total proton spin $\frac{1}{2} = quark\ spin + gluon\ spin + quark\ orbital\ momentum + gluon\ orbital\ momentum$
- Quark spin contribution depends on polarized parton distribution functions (PDFs)
- **Polarized PDF**: $\Delta q_i(x) = q_i^{\uparrow}(x) - q_i^{\downarrow}(x)$
- $g_1(x) \approx \frac{1}{2}\Sigma_i e_i^2 \Delta q_i(x) \propto \frac{1}{2}\left[\frac{4}{9}\Delta u(x) + \frac{1}{9}\Delta d(x) + \frac{1}{9}\Delta s(x) + \cdots\right]$
- Measure structure functions through polarized electron-proton scattering



Proton total spin $|\hat{S}| = \hbar/2$



Polarized *ep* Scattering



- Protons are polarized either parallel or antiparallel to the beam electrons' spins
- Deep inelastic scattering (DIS): electrons scatter off individual quarks ($Q^2 > 1\ \mathrm{GeV}^2, \quad W > 2\ \mathrm{GeV}$)
- Scattering conserves spin (angular momentum), so any asymmetry between $n^{\pm}$ is related to spin structure

$$A_{||}(x, Q^2) = \frac{n^- - n^+}{n^- + n^+} = D\big(A_1(x, Q^2) + \eta A_2(x, Q^2)\big)$$

- With $A_1, A_2 =$ virtual photon asymmetries

$$A_1(x, Q^2) \propto \frac{g_1(x, Q^2)}{F_1(x, Q^2)} \approx \frac{\Sigma_i e_i^2 \Delta q_i(x, Q^2)}{\Sigma_i e_i^2 q_i(x, Q^2)}$$

Run Group C Experimental Setup

- Ran from June 2022 to March 2023 for 80 PAC days (120 scheduled)
- RG-C data divided into five run periods:
  - Summer 2022: Inbending (Negative Solenoid and Torus)
    - Runs 16128 – 16772
  - Fall 2022: Inbending (Negative Solenoid and Torus)
    - Runs 16859 – 17183
  - Fall 2022: Inbending (Positive Solenoid, Negative Torus)
    - Runs 17188 – 17408
  - Spring 2023: Inbending (Negative Solenoid and Torus)
    - Runs 17482 – 17768
  - Spring 2023: Outbending (Negative Solenoid, Positive Torus)
    - Runs 17769 – 17811
- Used several target types:
  - Frozen ammonia targets: NH_3 for protons, ND_3 for deuterons
  - Carbon foil targets
  - Polyethylene (and deuterated polyethylene) foil targets
  - Empty targets (both filled with liquid helium and completely empty)
- Generate polarized protons (deuterons) with RG-C polarized target

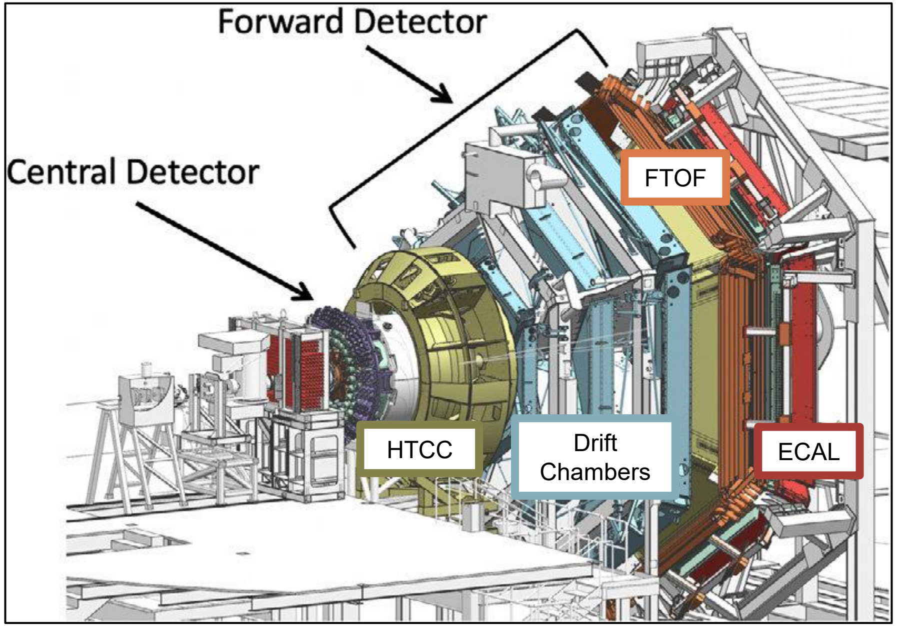
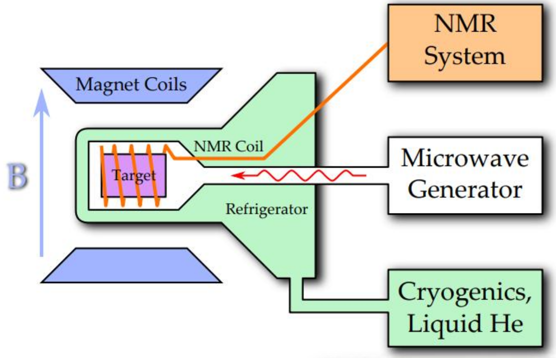
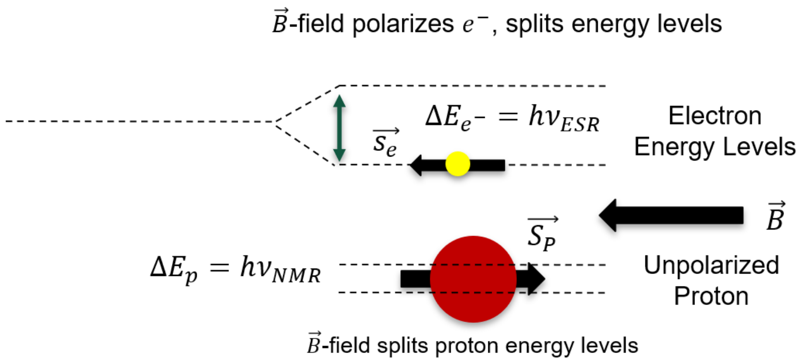


Diagram of CLAS12 Detector, Ziegler et. al.

Run Group C Experimental Setup

- Generate polarized protons (deuterons) with RG-C polarized target
- Ammonia crystals, polarized via dynamic nuclear polarization (DNP)
- Cool to ~1 K in a 5 T field generated by solenoid, where free electrons almost completely polarize
- Using microwaves with a frequency of $\nu_{ESR} \pm \nu_{NMR}$ (~140 GHz), transfer electron polarization to the protons (or deuterons)
- ~90% for protons, ~40% for deuterons





Ammonia crystals unexposed to beam (left), crystals after beam exposure (right). Purple color from paramagnetic centers.

Electron PID Cuts

- Inclusive electron scattering: $ep \to eX, \quad ed \to eX$
- Forward Detector: DC, ECAL, HTCC
- Electron Event Builder PID:
  - Negative track in the DC
  - $E_{PCAL} > 60\ \mathrm{MeV}$
  - Photoelectrons in HTCC $nphe > 2$
- Deep inelastic kinematic cuts:
  - $Q^2 > 1\ \mathrm{GeV}^2, W > 2\ \mathrm{GeV},$
  - $E' > 2.6\ \mathrm{GeV}$ (minimize radiative effects)
- Fiducial cuts (work in progress):
  - Summer: $-9\ \mathrm{cm} < V_Z < 1\ \mathrm{cm}, |V_{X,Y}| < 2\ \mathrm{cm}$
  - Fall & Spring: $-7.5\ \mathrm{cm} < V_Z < 2.5\ \mathrm{cm}, |V_{X,Y}| < 2\ \mathrm{cm}$
  - $5° < \theta < 40°,\ |\chi^2_{PID}| < 3$
  - Region-dependent drift chamber edge cuts:
    - EdgeR1 > 4 cm, EdgeR2 > 5 cm, EdgeR3 > 8 cm
  - Working on ECAL fiducial cuts based on L-strips
    - PCAL Lv, Lw > 9 cm (based on RG-A fiducial studies)
- QADB cuts for all run periods

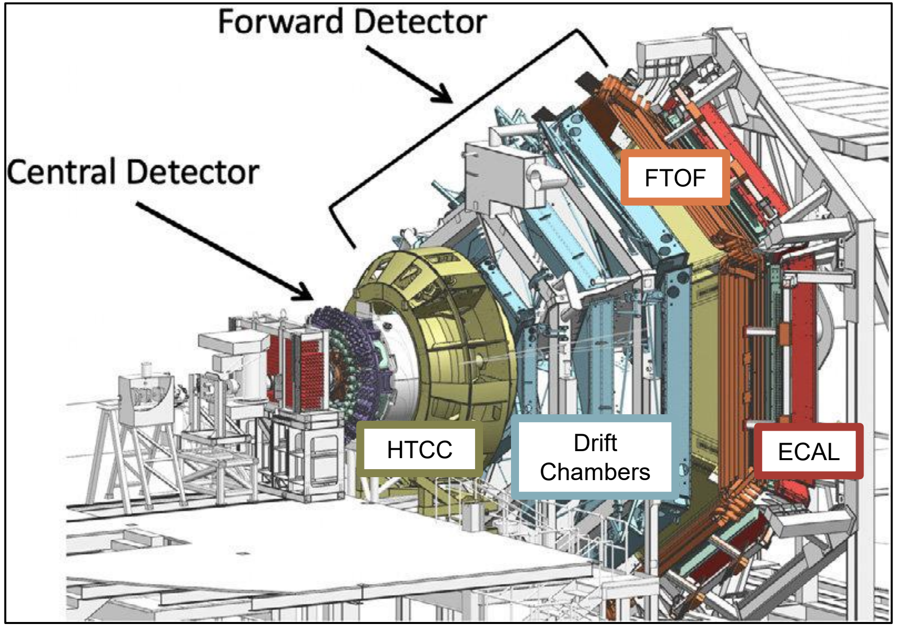
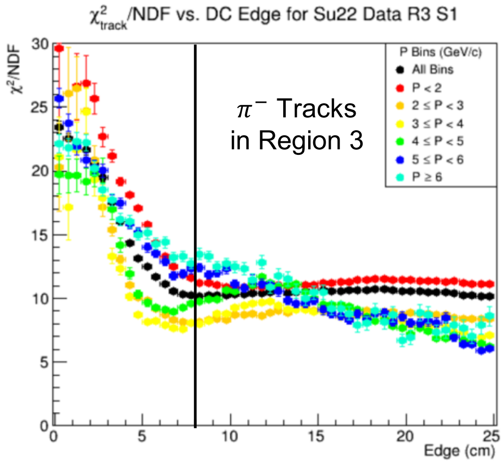
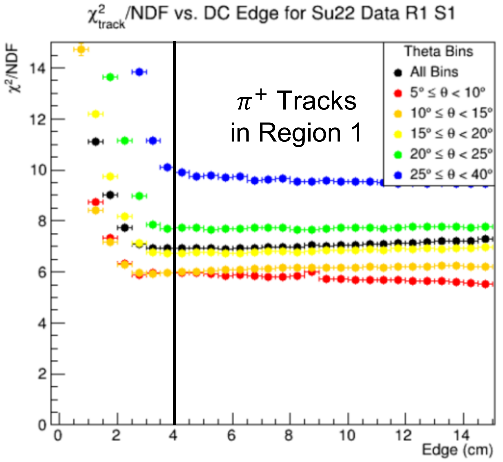


Diagram of CLAS12 Detector, Ziegler et. al.

Electron PID Cuts

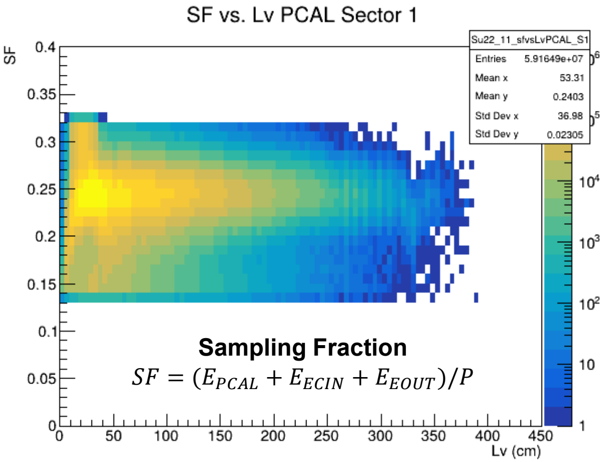
- Inclusive electron scattering: $ep \rightarrow eX, \quad ed \rightarrow eX$
- Forward Detector: DC, ECAL, HTCC
- Electron Event Builder PID:
  - Negative track in the DC
  - $E_{PCAL} > 60 \text{ MeV}$
  - Photoelectrons in HTCC $nphe > 2$
- Deep inelastic kinematic cuts:
  - $Q^2 > 1 \text{ GeV}^2, W > 2 \text{ GeV},$
  - $E' > 2.6 \text{ GeV}$ (minimize radiative effects)
- Fiducial cuts (work in progress):
  - Summer: $-9 \text{ cm} < V_Z < 1 \text{ cm}, |V_{X,Y}| < 2 \text{ cm}$
  - Fall & Spring: $-7.5 \text{ cm} < V_Z < 2.5 \text{ cm}, |V_{X,Y}| < 2 \text{ cm}$
  - $5° < \theta < 40°, \ |\chi^2_{PID}| < 3$
  - Region-dependent drift chamber edge cuts:
    - EdgeR1 > 4 cm, EdgeR2 > 5 cm, EdgeR3 > 8 cm
  - Working on ECAL fiducial cuts based on L-strips
    - PCAL Lv, Lw > 9 cm (based on RG-A fiducial studies)
- QADB cuts for all run periods

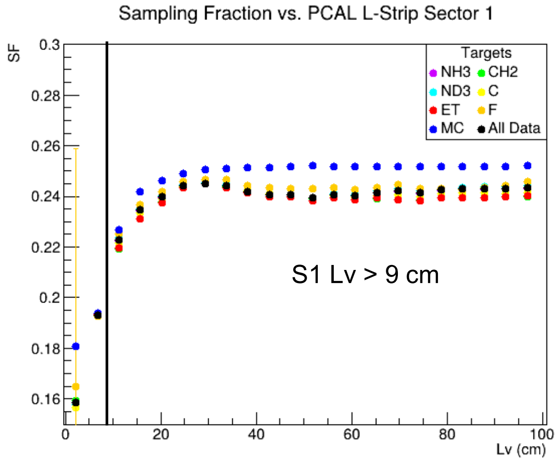




Electron PID Cuts

- Inclusive electron scattering: $ep \rightarrow eX, \quad ed \rightarrow eX$
- Forward Detector: DC, ECAL, HTCC
- Electron Event Builder PID:
  - Negative track in the DC
  - $E_{PCAL} > 60$ MeV
  - Photoelectrons in HTCC $nphe > 2$
- Deep inelastic kinematic cuts:
  - $Q^2 > 1\ \text{GeV}^2, W > 2\ \text{GeV},$
  - $E' > 2.6$ GeV (minimize radiative effects)
- Fiducial cuts (work in progress):
  - Summer: $-9\ \text{cm} < V_Z < 1\ \text{cm}, |V_{X,Y}| < 2\ \text{cm}$
  - Fall & Spring: $-7.5\ \text{cm} < V_Z < 2.5\ \text{cm}, |V_{X,Y}| < 2\ \text{cm}$
  - $5° < \theta < 40°, \ |\chi^2_{PID}| < 3$
  - Region-dependent drift chamber edge cuts:
    - EdgeR1 > 4 cm, EdgeR2 > 5 cm, EdgeR3 > 8 cm
  - Working on ECAL fiducial cuts based on L-strips
    - PCAL Lv, Lw > 9 cm (based on RG-A fiducial studies)
- QADB cuts for all run periods





Unpolarized Background and Beam-Target Polarization

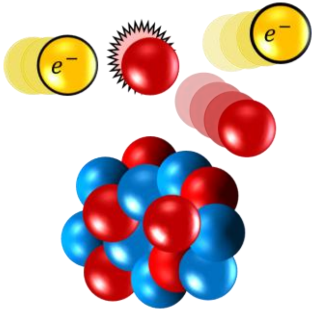
- Unpolarized background: N, Al, He nuclei in target/bath
- Reduces measured $A_{||}$, and cannot be removed with vertex/kinematic cuts
- Quantified using a dilution factor D_F

$$D_F = \frac{Y_H}{Y_{Ammonia}} = \frac{3\sigma_H \ell_H \rho_H}{(3\sigma_H + \sigma_N)\ell_A \rho_A + \sigma_{He}\ell_{He}\rho_{He} + \sigma_{Al}\ell_{Al}\rho_{Al}}$$

- Imperfect polarization of beam electrons and target particles: $P_b P_t$

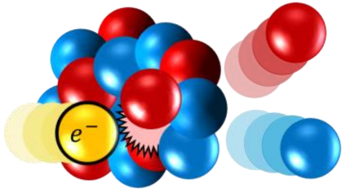
- Dividing $A_{||}$ by D_F and $P_b P_t$ accounts for the background

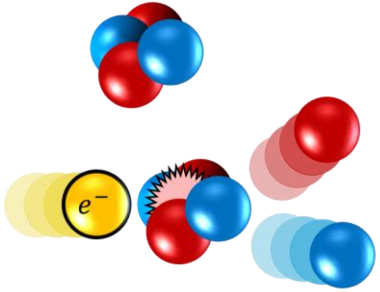
$$A_{||,phys} = \frac{A_{||,raw}}{D_F P_b P_t} \propto A_1$$



Ideal ep Scattering

N, Al Nuclei Scattering



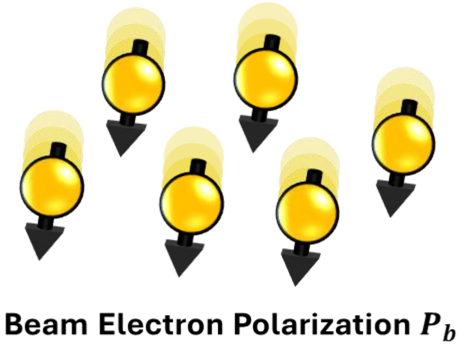


Liquid He Scattering

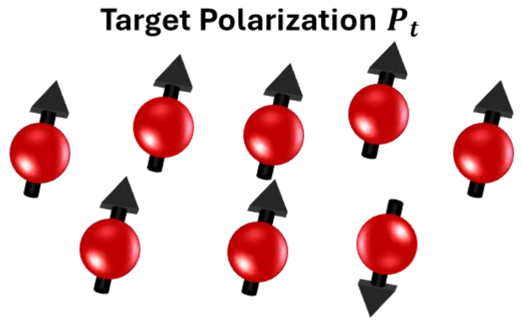
Unpolarized Background and Beam-Target Polarization

- Unpolarized background: N, Al, He nuclei in target/bath
- Reduces measured $A_{||}$, and cannot be removed with vertex/kinematic cuts
- Quantified using a dilution factor D_F

$$D_F = \frac{Y_H}{Y_{Ammonia}} = \frac{3\sigma_H \ell_H \rho_H}{(3\sigma_H + \sigma_N)\ell_A \rho_A + \sigma_{He}\ell_{He}\rho_{He} + \sigma_{Al}\ell_{Al}\rho_{Al}}$$



- Imperfect polarization of beam electrons and target particles: $P_b P_t$

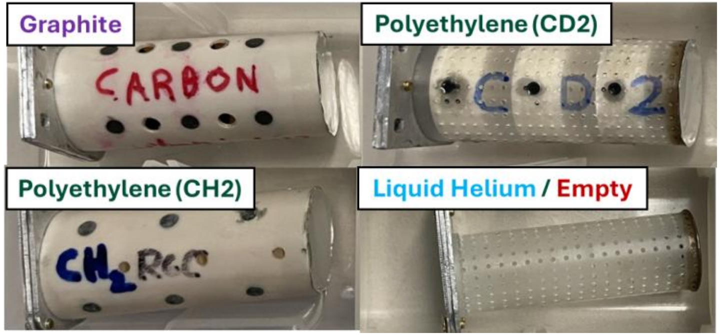


- Dividing $A_{||}$ by D_F and $P_b P_t$ accounts for the background

$$A_{||,phys} = \frac{A_{||,raw}}{D_F P_b P_t} \propto A_1$$

Calculating the Dilution Factor

- Advantageous to write D_F in terms of scattering counts from background targets instead of cross sections
- Counts from the targets are functions of the cross sections
- Using information from all targets, write the yields in terms of scattering counts



- $n_A(\sigma_{Al}, \sigma_{He}, \sigma_C, \sigma_H)$, where $\frac{7}{6}\sigma_C \approx \sigma_N$
- $n_{MT}(\sigma_{Al}, \sigma_{He})$, $n_C(\sigma_{Al}, \sigma_{He}, \sigma_C)$
- $n_{CH}(\sigma_{Al}, \sigma_{He}, \sigma_C, \sigma_H)$, $n_F(\sigma_{Al})$

- Solving for the yields and rewriting the D_F:

$$D_F(x, Q^2) = P_F \frac{C_1 n_C + C_2 n_{MT} + C_3 n_{CH} + C_4 n_F}{C_5 n_A}$$

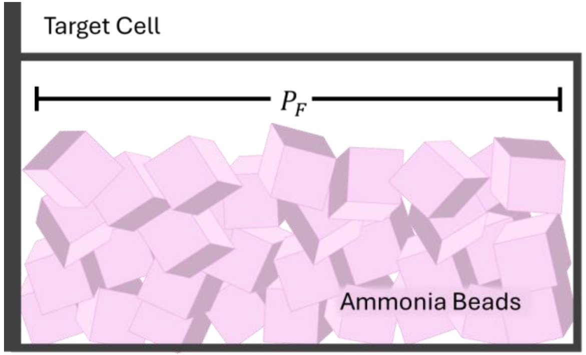
- Packing fraction P_F is the target volume fraction occupied by the ammonia crystals

$$P_F(x, Q^2) = \frac{D_1(n_A - n_{MT})}{D_2 n_{MT} + D_3 n_C + D_4 n_{CH} + D_5 n_F}$$

$C_i, D_i \propto \ell_i, \rho_i$ of target materials

Calculating the Dilution Factor

- Advantageous to write D_F in terms of scattering counts from background targets instead of cross sections
- Counts from the targets are functions of the cross sections
- Using information from all targets, write the yields in terms of scattering counts
- $n_A(\sigma_{Al}, \sigma_{He}, \sigma_C, \sigma_H)$, where $\frac{7}{6}\sigma_C \approx \sigma_N$
- $n_{MT}(\sigma_{Al}, \sigma_{He})$, $n_C(\sigma_{Al}, \sigma_{He}, \sigma_C)$
- $n_{CH}(\sigma_{Al}, \sigma_{He}, \sigma_C, \sigma_H)$, $n_F(\sigma_{Al})$



- Solving for the yields and rewriting the D_F:

$$D_F(x, Q^2) = P_F \frac{C_1 n_C + C_2 n_{MT} + C_3 n_{CH} + C_4 n_F}{C_5 n_A}$$

- Packing fraction P_F is the target volume fraction occupied by the ammonia crystals

$$P_F(x, Q^2) = \frac{D_1(n_A - n_{MT})}{D_2 n_{MT} + D_3 n_C + D_4 n_{CH} + D_5 n_F}$$

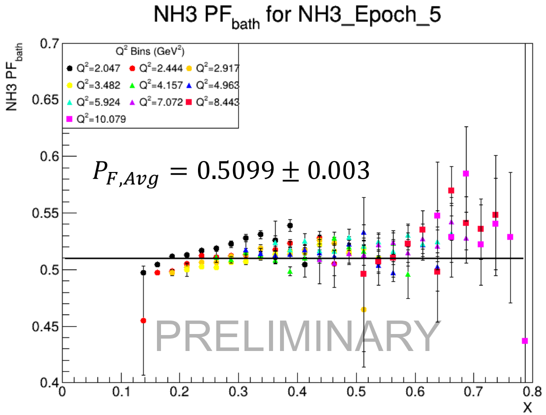
$C_i, D_i \propto \ell_i, \rho_i$ of target materials

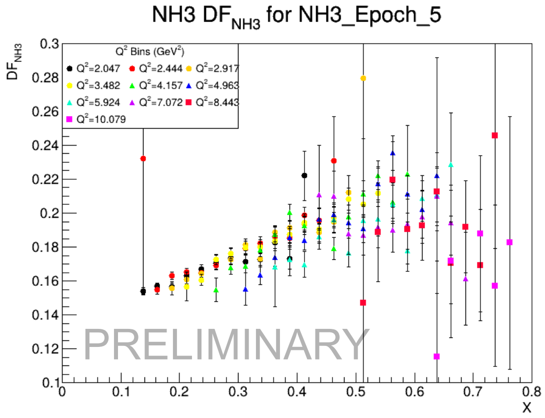
Calculating the Dilution Factor

- Two methods are used to calculate the dilution factor: a data-driven method and a model of the dilution factor

- Data-driven method:
  - Measure n_A n_{MT} n_C n_{CH} n_F from the data
  - Use these values to calculate a value of P_F for each x, Q^2 bin
  - Calculate a weighted average of all P_F
  - Use this $P_{F,avg}$ as an input to calculate D_F for each x, Q^2 bin
  - Requires a radiation length correction to empty n_{MT} and foil n_F counts (haven't found a suitable model yet)

- Modeled dilution factor:
  - From modeled structure functions, "build" each target and simulate the counts n_A n_{MT} n_C n_{CH} n_F coming from the target
  - Accounts for EMC effect, fermi motion, and radiative corrections to be built-in to the model
  - Helps estimate D_F in low-statistics regions
  - Model is tuned to fit experimentally measured D_F and P_F





Preliminary Results

- Calculated preliminary D_F for the RGC dataset
- Datasets are broken up into different “epochs” that have different packing fractions
- D_F binned in x for each epoch
- Once D_F are calculated, use them to get $P_b P_t$

Summer 2022 Runs

Epoch 2: Runs 16137 – 16178
Epoch 3: Runs 16211 – 16260
Epoch 4: Runs 16318 – 16357
Epoch 5: Runs 16658 – 16674
Epoch 6: Runs 16675 – 16695
Epoch 7: Runs 16709 – 16738
Epoch 8: Runs 16742 – 16752
Epoch 9: Runs 16753 – 16766
Epoch 10: Runs 16767 – 16772

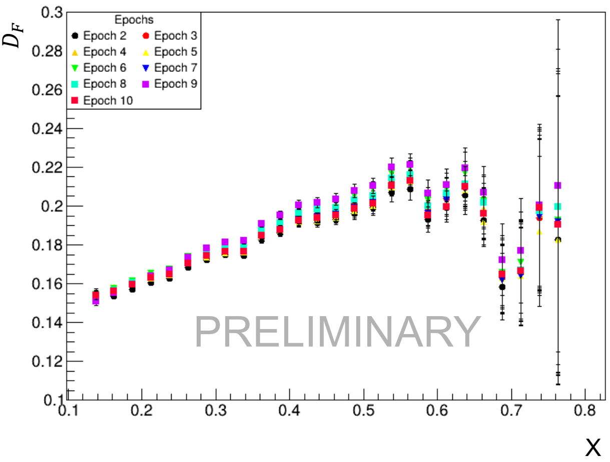
Fall 2022 Runs

Epoch 11: Runs 16983 – 16993
Epoch 12: Runs 16695 – 17032
Epoch 13: Runs 17067 – 17102
Epoch 14: Runs 17144 – 17161
Epoch 15: Runs 17162 – 17169
Epoch 16: Runs 17188 – 17214
Epoch 17: Runs 17215 – 17225
Epoch 18: Runs 17353 – 17368
Epoch 19: Runs 17371 – 17382

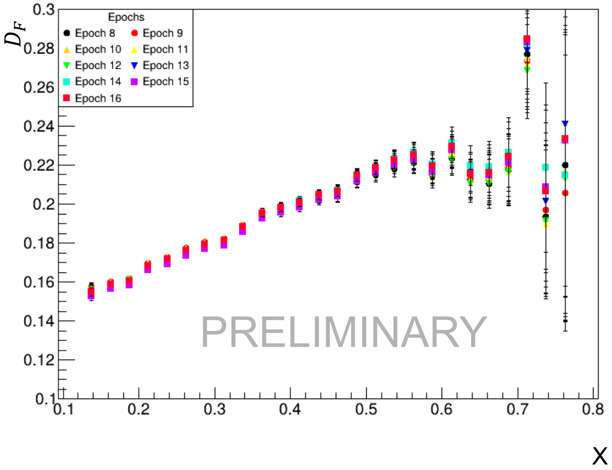
Spring 2023 Runs

Epoch 20: Runs 17575 – 17597
Epoch 21: Runs 17598 – 17611
Epoch 22: Runs 17720 – 17741
Epoch 23: Runs 17748 – 17762
Epoch 24: Runs 17769 – 17778
(Epoch 24 is outbending)

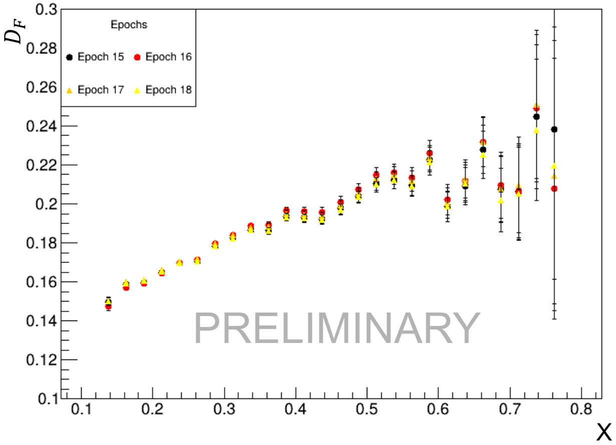
Summer 2022 D_F Data



Fall 2022 D_F Data

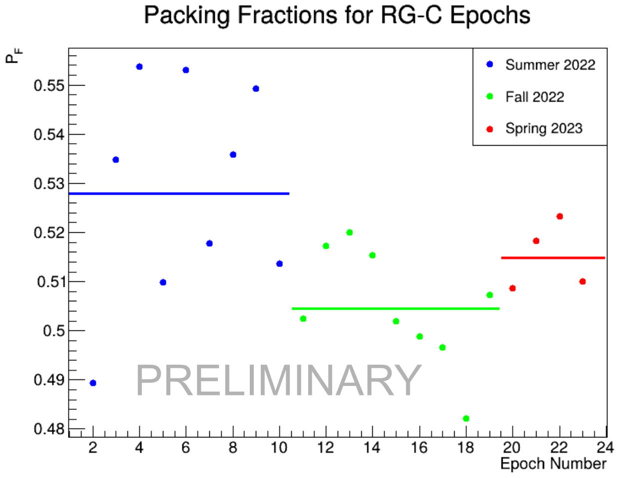


Spring 2023 D_F Data



Preliminary Results

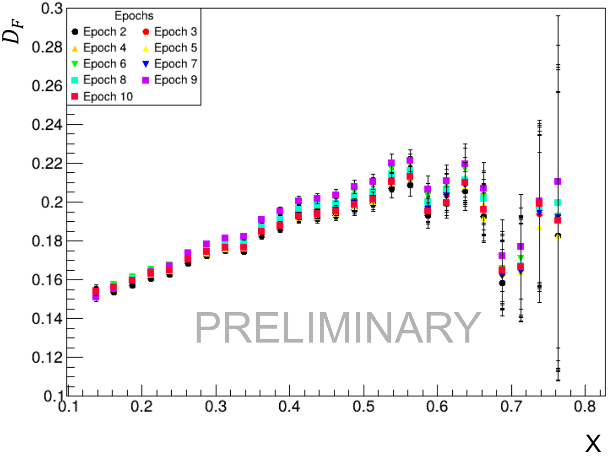
- Calculated preliminary D_F for the RGC dataset
- Datasets are broken up into different “epochs” that have different packing fractions
- D_F binned in x for each epoch
- Once D_F are calculated, use them to get $P_b P_t$



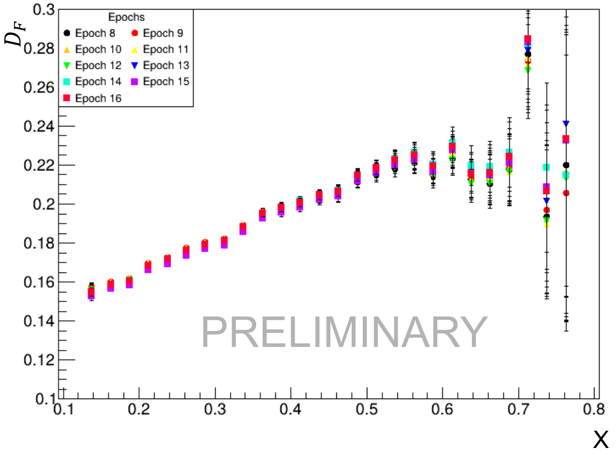
Weighted Average P_F Per Run Period:

Summer 2022 $P_F = 0.5280 \pm 0.0001$
Fall 2022 $P_F = 0.5045 \pm 0.0001$
Spring 2023 $P_F = 0.5149 \pm 0.0001$

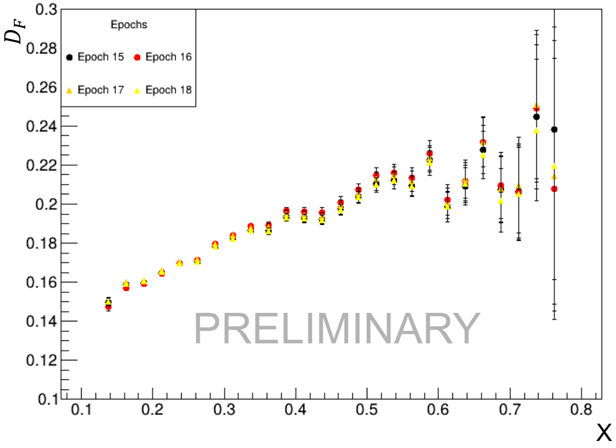
Summer 2022 D_F Data



Fall 2022 D_F Data



Spring 2023 D_F Data



Beam-Target Polarization Calculations

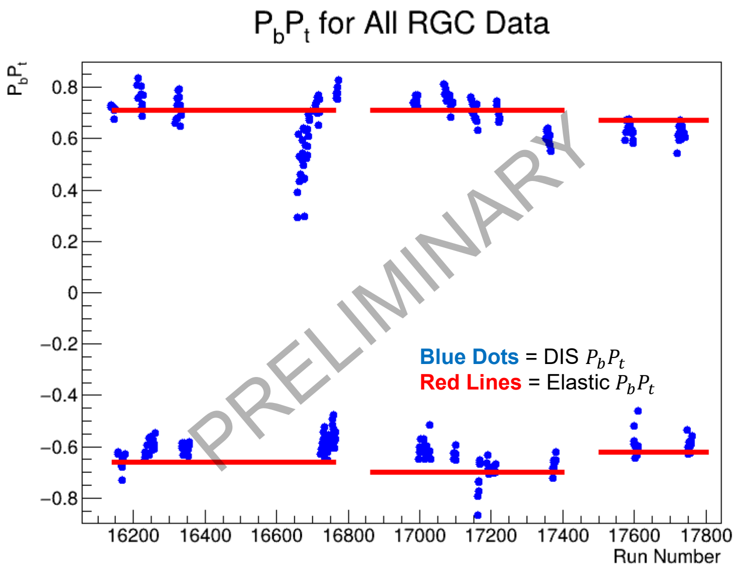
$$A_{||,phys} = \frac{A_{||,raw}}{D_F P_b P_t} \quad \Rightarrow \quad P_b P_t = \frac{A_{||,raw}}{D_F A_{||,phys}}$$

- Use a model to calculate $A_{||,phys}$
- For DIS $P_b P_t$, calculated over x, Q^2 bins using $A_{th} = D(A_1 + \eta A_2)$, with values of D, η, A_1, A_2 come from S. Kuhn 's model
- Model is a parameterized fit to existing world data
- Calculated through the maximum likelihood method:

$$P_b P_t = \frac{\sum_{x,Q^2\ bins} D_{F,i} A_{th,i} \left(n_i^- - n_i^+\right)}{\sum_{x,Q^2\ bins} D_{F,i}^2 A_{th,i}^2 \left(n_i^- + n_i^+\right)}$$

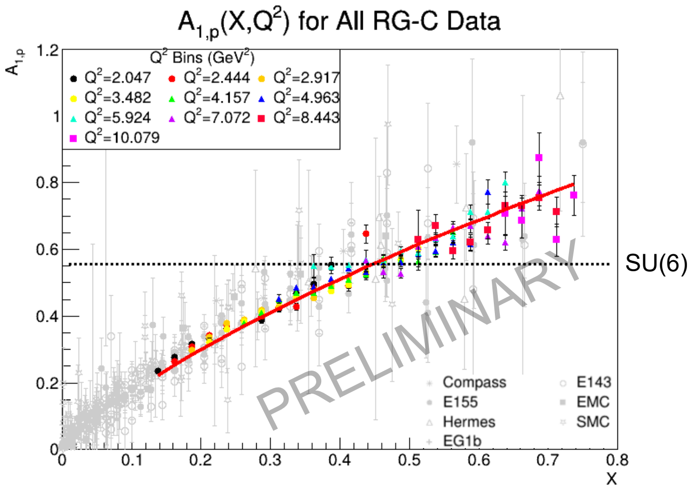
- Values of $P_b P_t$ were also calculated for RGC data using exclusive elastic $ep \rightarrow e'p'$ scattering (Noemie Pilleux)
- Elastic asymmetry parameterized by Arrington et. al.

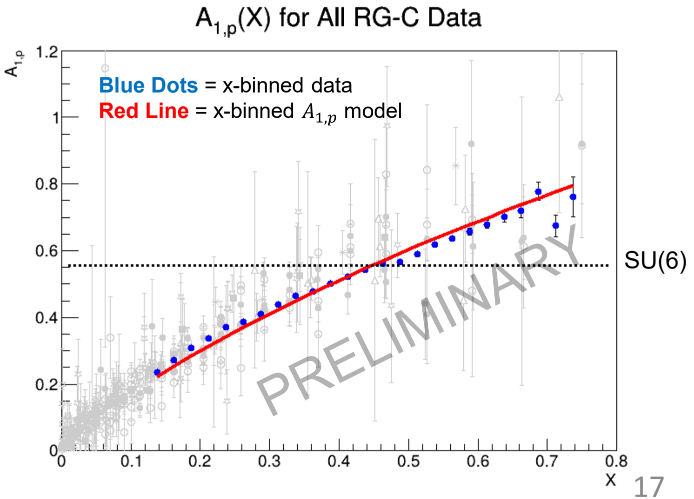
- Normalize DIS $P_b P_t$ to elastic $P_b P_t$ using $f \sim P_b P_{t\,elastic} / P_b P_{t\,DIS,avg}$
- However, since there are corrections required for both DIS and Elastic (polarized nitrogen, D_F normalization, etc.), the results shown for $A_{1,p}$ will use just the DIS results from this slide



Preliminary Results

- To calculate $A_{1,p}$, rearrange $A_{||,phys} = D(A_1 + \eta A_2)$
- $A_1 = A_{||,phys}/D - \eta A_2$, with D, η, A_2 from S. Kuhn's model
- Values of η, A_2 are small for DIS kinematics, so smaller effects from model
- Spring 2023 data excludes outbending runs
- Data fluctuates around model values of $A_{1,p}$
- Currently, we don't have data-driven $A_{1,d}$ results due to issues with calculating the ND3 D_F



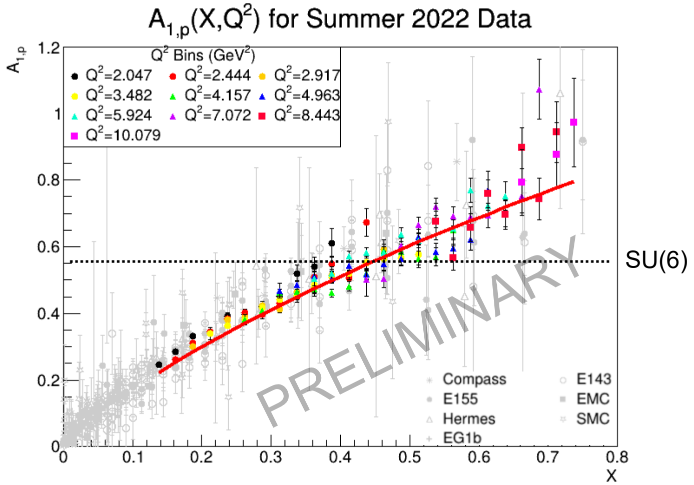


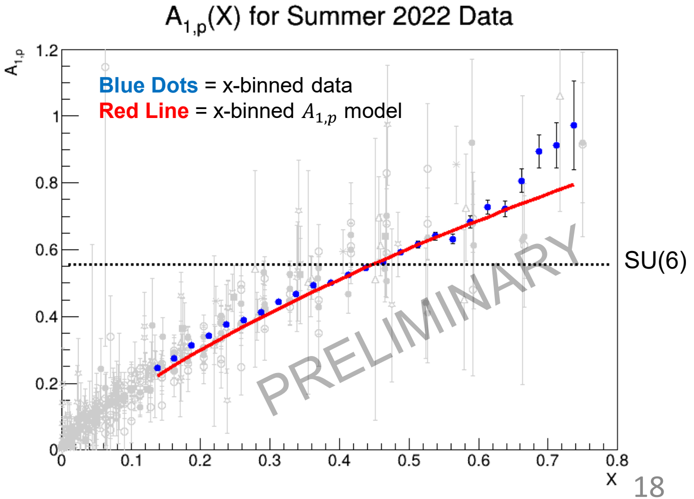
Preliminary Results

- To calculate $A_{1,p}$, rearrange $A_{||,phys} = D(A_1 + \eta A_2)$
- $A_1 = A_{||,phys}/D - \eta A_2$, with D, η, A_2 from S. Kuhn's model
- Values of η, A_2 are small for DIS kinematics, so smaller effects from model
- Spring 2023 data excludes outbending runs

- Data fluctuates around model values of $A_{1,p}$

- Currently, we don't have data-driven $A_{1,d}$ results due to issues with calculating the ND3 D_F



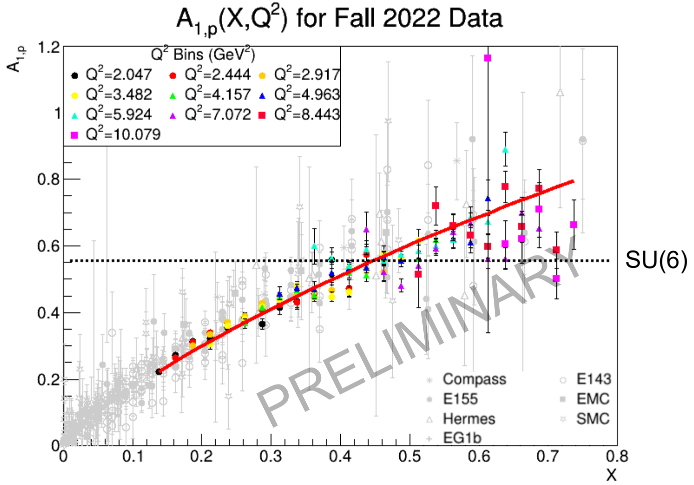


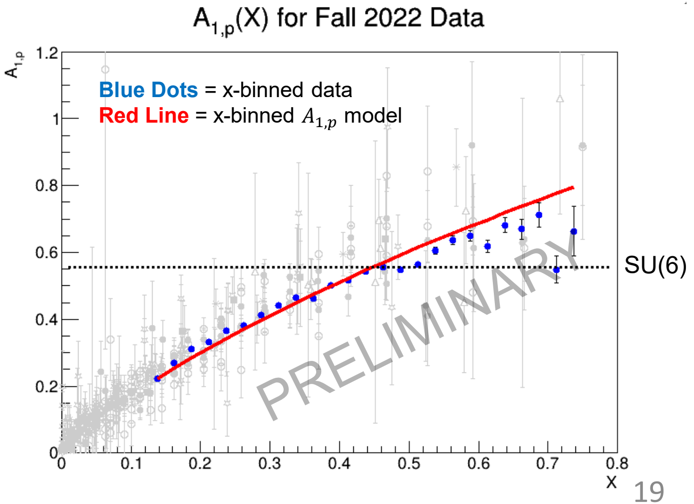
Preliminary Results

- To calculate $A_{1,p}$, rearrange $A_{||,phys} = D(A_1 + \eta A_2)$
- $A_1 = A_{||,phys}/D - \eta A_2$, with D, η, A_2 from S. Kuhn's model
- Values of η, A_2 are small for DIS kinematics, so smaller effects from model
- Spring 2023 data excludes outbending runs

- Data fluctuates around model values of $A_{1,p}$

- Currently, we don't have data-driven $A_{1,d}$ results due to issues with calculating the ND3 D_F



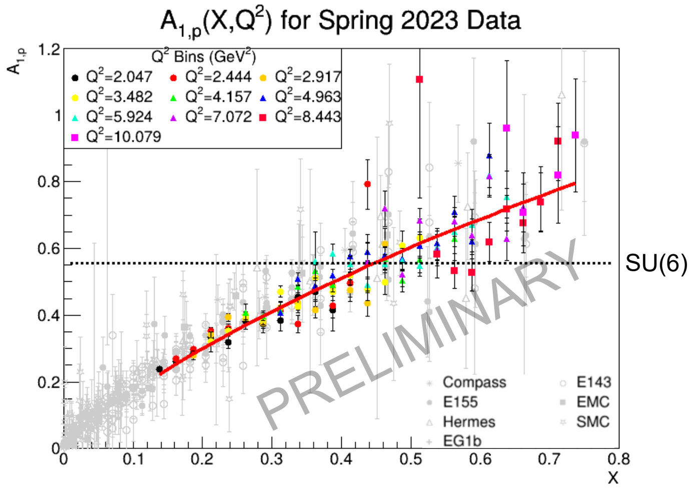


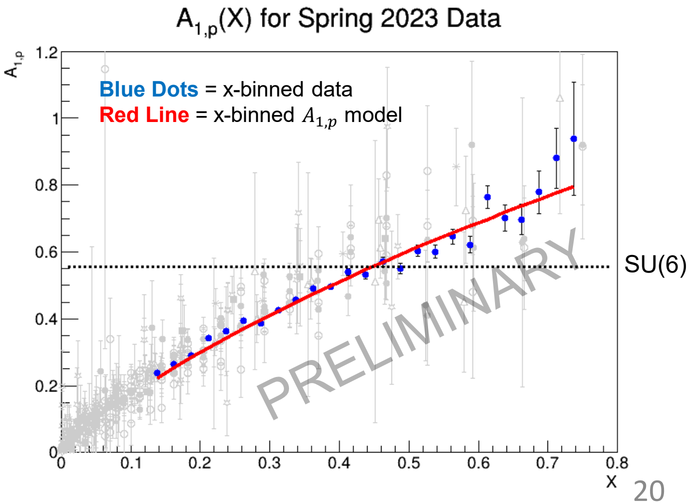
Preliminary Results

- To calculate $A_{1,p}$, rearrange $A_{||,phys} = D(A_1 + \eta A_2)$
- $A_1 = A_{||,phys}/D - \eta A_2$, with D, η, A_2 from S. Kuhn's model
- Values of η, A_2 are small for DIS kinematics, so smaller effects from model
- Spring 2023 data excludes outbending runs

- Data fluctuates around model values of $A_{1,p}$

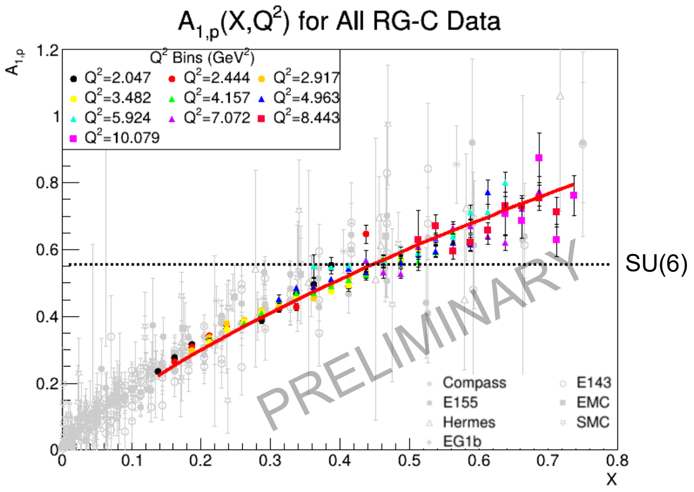
- Currently, we don't have data-driven $A_{1,d}$ results due to issues with calculating the ND3 D_F

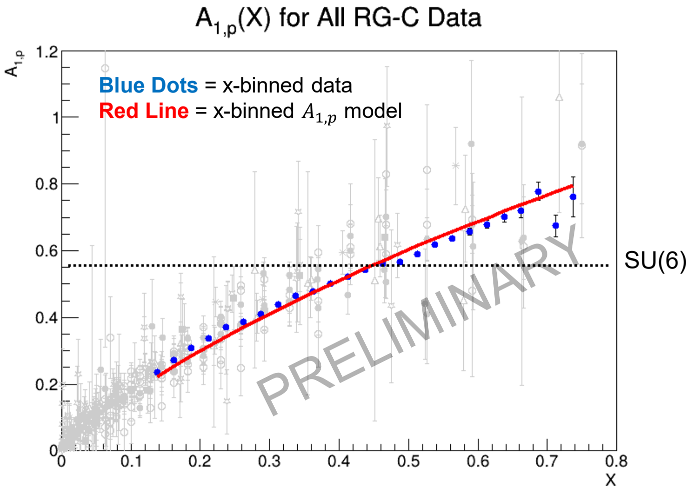




Work Left To Do

- Incorporate radiation length corrections to n_{MT}, n_F counts
- Correct $P_b P_t$ for polarized ^{14}N in target
- Finalize the D_F model-driven approach
- Finalize ECAL fiducial cuts and implement sampling fraction (SF) vs. momentum cuts
- Any Questions?





Backup Slides

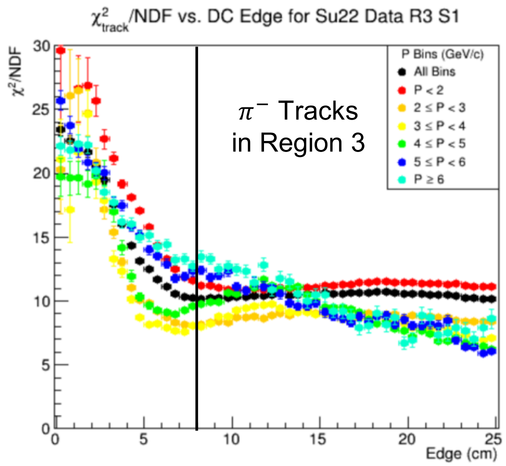
- DC and ECAL fiducial cuts
- Thermal expansion corrections to targets
- All D_F and P_F for NH3 targets across all x, Q^2 bins
- All D_F and P_F for ND3 targets across all x, Q^2 bins

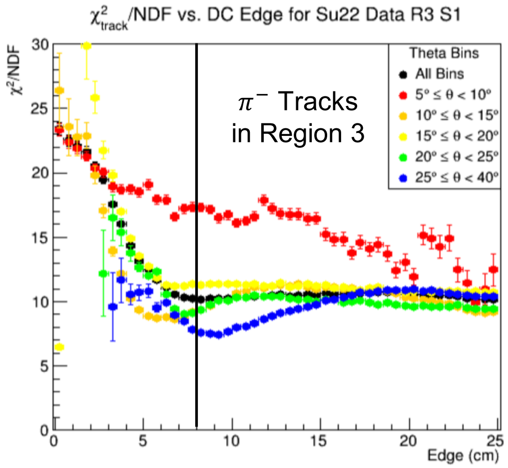
Determining Cuts For DC

- The DC fiducial cuts based on average χ^2_{track}/NDF vs. edge variable of track
- Cuts selected qualitatively based on where average χ^2 rises relative to the rest of the distribution
- Analyzed separately for inbending and outbending data using π^+, π^-
- Tracks binned in polar scattering angle θ, momentum P

- Iterative procedure for making cuts:
  1. First, make cuts for Region 3 using inbending data and cuts for Region 1 using outbending data
  2. After Region 1 and 3 cuts are applied, look at Region 2 and make cuts for inbending and outbending

- Checked for each sector in each region
- No momentum, θ-dependent cuts
- Vertex cuts applied
  - Summer 2022: $-9\text{ cm} \leq V_Z \leq 1\text{ cm}, |V_{X,Y}| < 2\text{ cm}$
  - Fall 2022 & Spring 2023: $-7.5\text{ cm} \leq V_Z \leq 2.5\text{ cm}, |V_{X,Y}| < 2\text{ cm}$



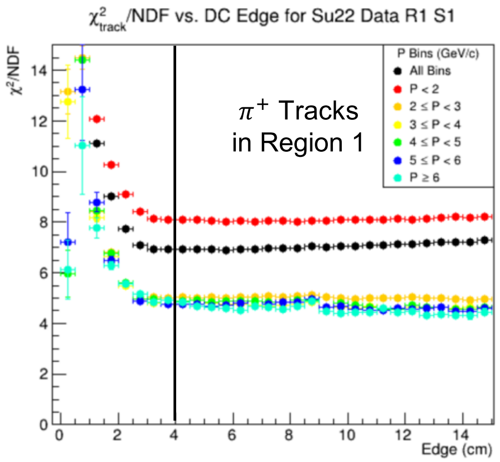


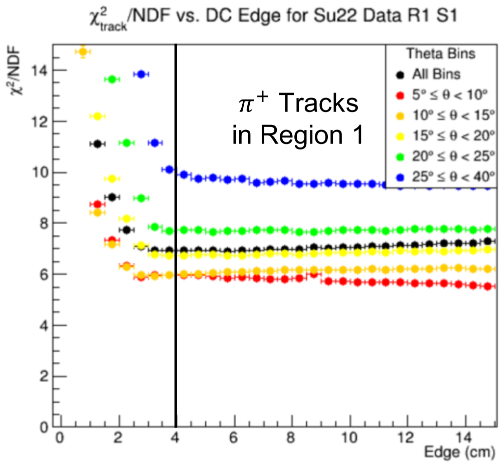
Determining Cuts For DC

- The DC fiducial cuts based on average χ^2_{track}/NDF vs. edge variable of track
- Cuts selected qualitatively based on where average χ^2 rises relative to the rest of the distribution
- Analyzed separately for inbending and outbending data using π^+, π^-
- Tracks binned in polar scattering angle θ, momentum P

- Iterative procedure for making cuts:
    1. First, make cuts for Region 3 using inbending data and cuts for Region 1 using outbending data
    2. After Region 1 and 3 cuts are applied, look at Region 2 and make cuts for inbending and outbending

- Checked for each sector in each region
- No momentum, θ-dependent cuts
- Vertex cuts applied
    - Summer 2022: $-9 \text{ cm} \leq V_Z \leq 1 \text{ cm}, |V_{X,Y}| < 2 \text{ cm}$
    - Fall 2022 & Spring 2023: $-7.5 \text{ cm} \leq V_Z \leq 2.5 \text{ cm}, |V_{X,Y}| < 2 \text{ cm}$





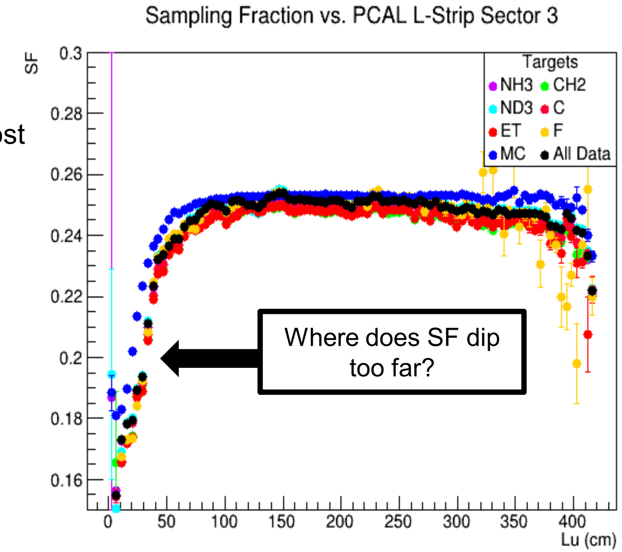
ECAL Fiducial Cuts

- ECAL fiducial cuts are based on the sampling fraction: energy deposited by a particle in the calorimeter
- Sampling fraction $\boldsymbol{SF} = (\boldsymbol{E_{PCAL}} + \boldsymbol{E_{ECIN}} + \boldsymbol{E_{OUT}})/\boldsymbol{P}$, where E_i = energy deposited in each region of ECAL and P = momentum
- Sampling fraction is a key quantity in electron PID, since electrons have a distinguishable energy profile ($SF \approx 24\%$)
- Distinguishes electrons from minimally ionizing particles (MIPs), like π^- or π^+

- Goals of ECAL fiducial cut:

1. Make an "edge" cut on each region of ECAL based on where SF efficiency is lost
   - Close to the edge, the entire EM shower may not be contained, reducing SF
   - If SF is too low, it's more difficult to distinguish electrons from MIPs

2. Identify inefficient regions of ECAL as well as dead PMT channels
   - Make sure that inefficient regions are identified and removed
   - Check that all removed channels are cut from the Monte Carlo

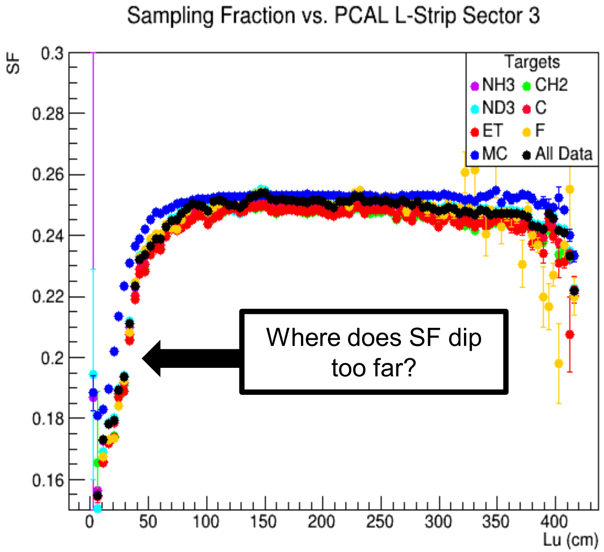


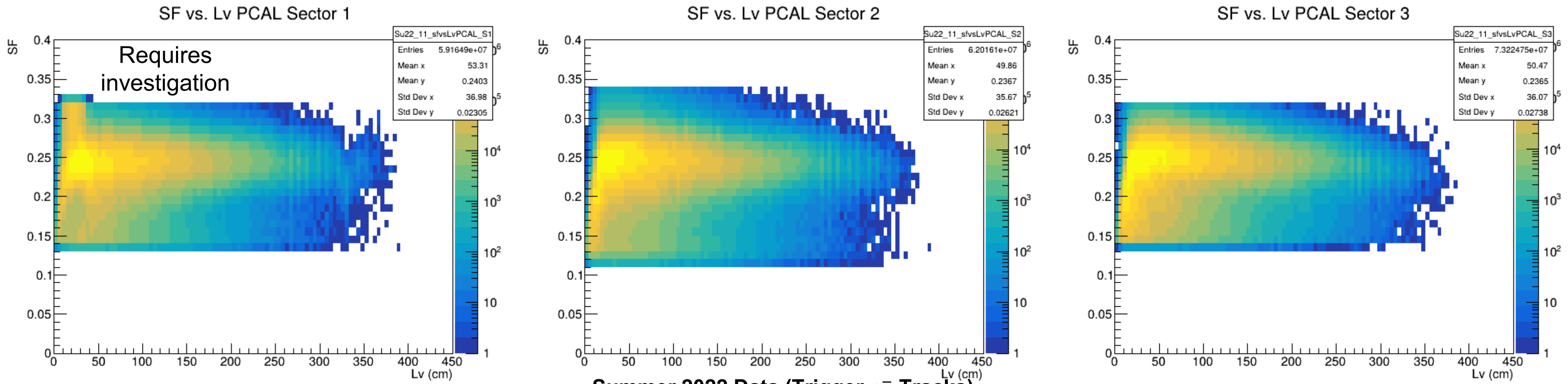
ECAL Fiducial Cuts

- ECAL fiducial cuts are based on the sampling fraction: energy deposited by a particle in the calorimeter
- Sampling fraction $\boldsymbol{SF} = (\boldsymbol{E_{PCAL}} + \boldsymbol{E_{ECIN}} + \boldsymbol{E_{OUT}})/\boldsymbol{P}$, where E_i = energy deposited in each region of ECAL and P = momentum
- Sampling fraction is a key quantity in electron PID, since electrons have a distinguishable energy profile ($SF \approx 24\%$)
- Distinguishes electrons from minimally ionizing particles (MIPs), like π^- or π^+

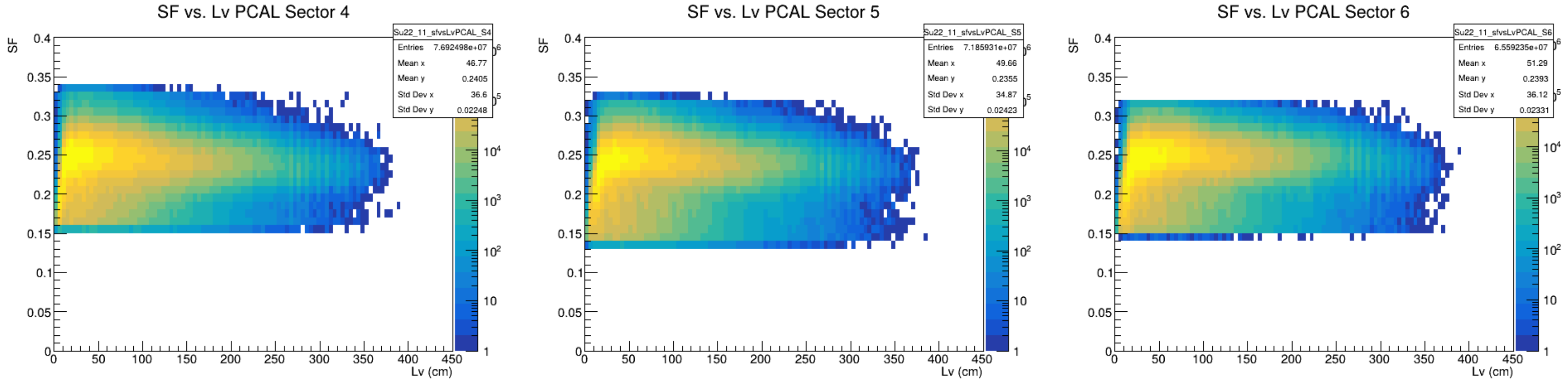
- For now, I'm using the RG-A "loose" fiducial cuts for electrons in the PCAL: Lw, Lv > 9 cm
- More analysis is necessary for unstable SF in sector 1

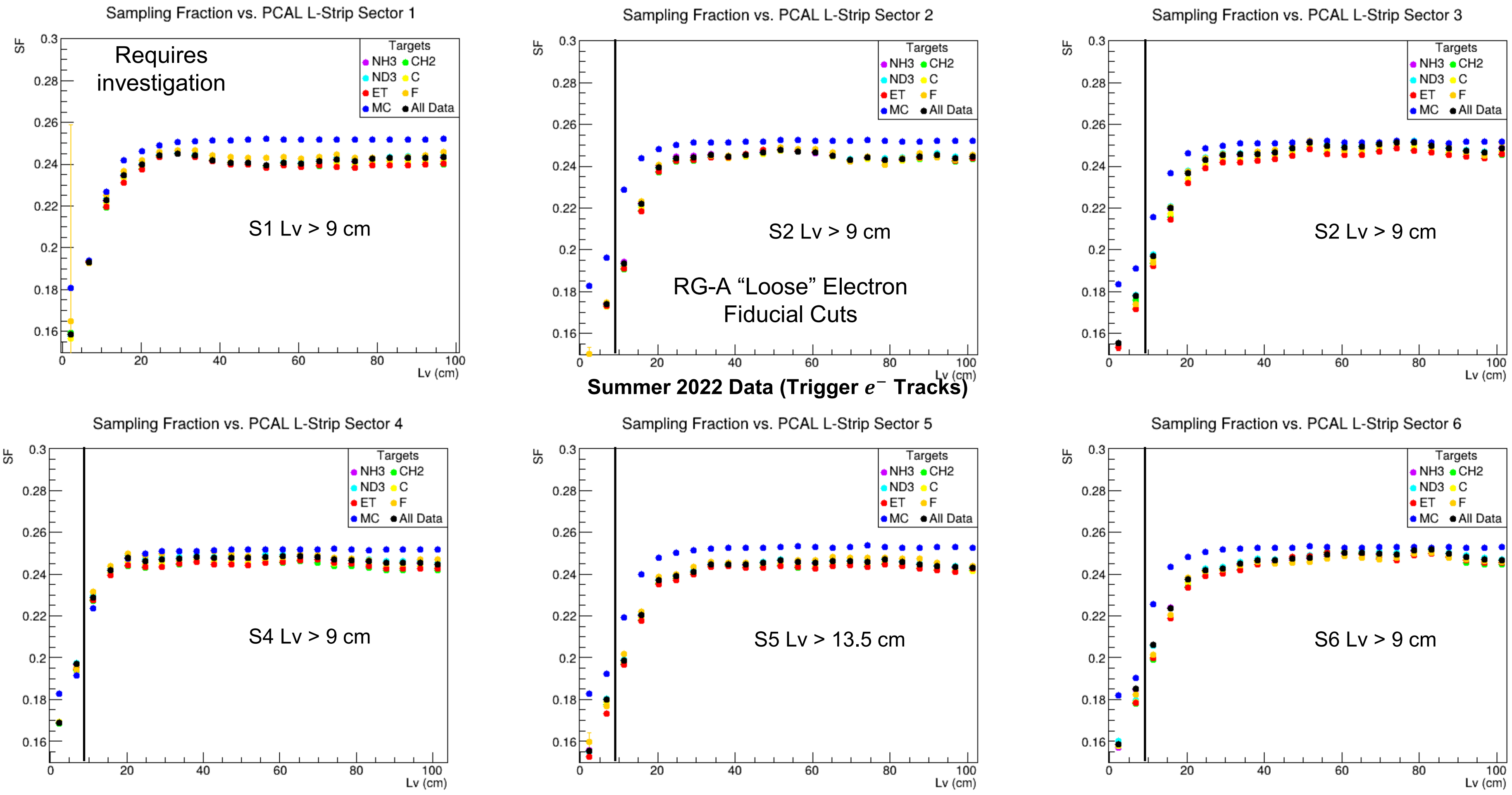
- Trigger electron data only
  - My vertex cuts: $|V_{x,y}| < 2$ cm (all data sets), -8 cm $< V_Z <$ 2 cm for Summer 2022, -10 cm $< V_Z <$ 0 cm for Fall 2022 and Spring 2023 (needs to be updated)
  - My drift chamber fiducial cuts: EdgeR1 > 4 cm, EdgeR2 > 5 cm, EdgeR3 > 8 cm
  - Electron momentum > 2.6 GeV/c

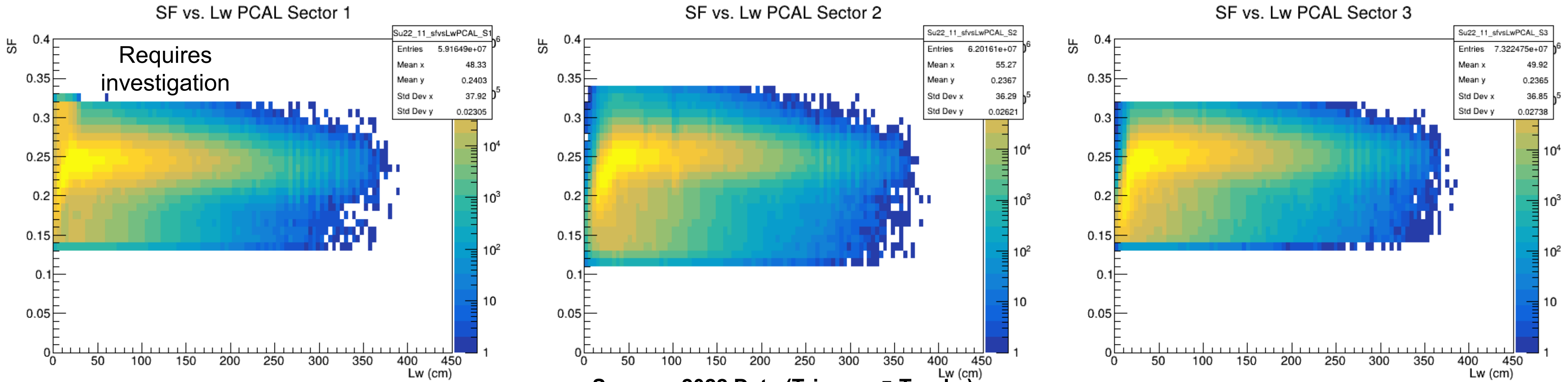




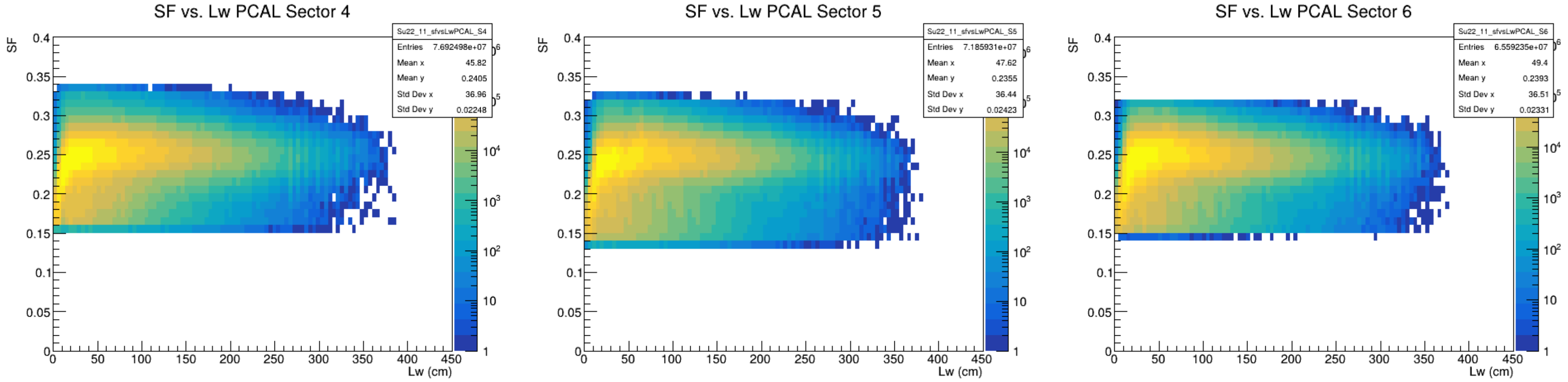
Summer 2022 Data (Trigger e^- Tracks)

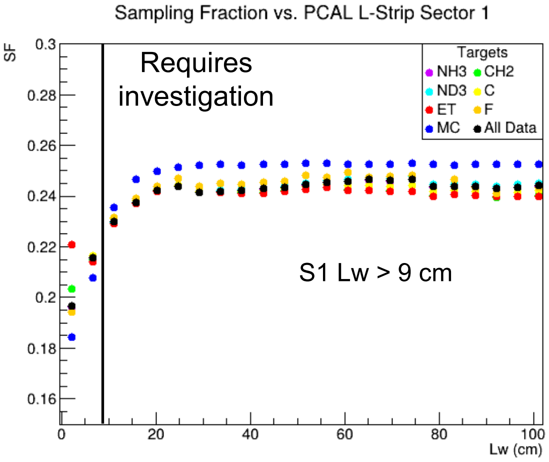


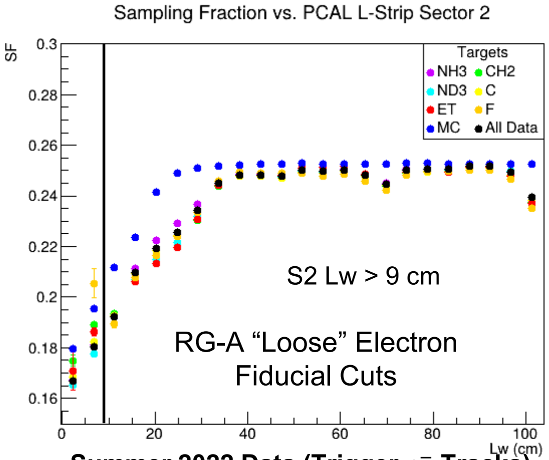

Sampling Fraction vs. PCAL L-Strip Sector 1
Requires investigation
S1 Lv > 9 cm
Sampling Fraction vs. PCAL L-Strip Sector 2
S2 Lv > 9 cm
RG-A “Loose” Electron Fiducial Cuts
Sampling Fraction vs. PCAL L-Strip Sector 3
S2 Lv > 9 cm
Summer 2022 Data (Trigger e^- Tracks)
Sampling Fraction vs. PCAL L-Strip Sector 4
S4 Lv > 9 cm
Sampling Fraction vs. PCAL L-Strip Sector 5
S5 Lv > 13.5 cm
Sampling Fraction vs. PCAL L-Strip Sector 6
S6 Lv > 9 cm
Targets
NH3
CH2
ND3
C
ET
F
MC
All Data
SF
Lv (cm)

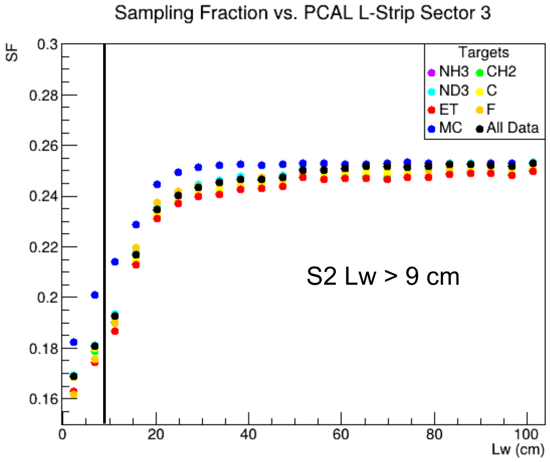


Summer 2022 Data (Trigger e^- Tracks)

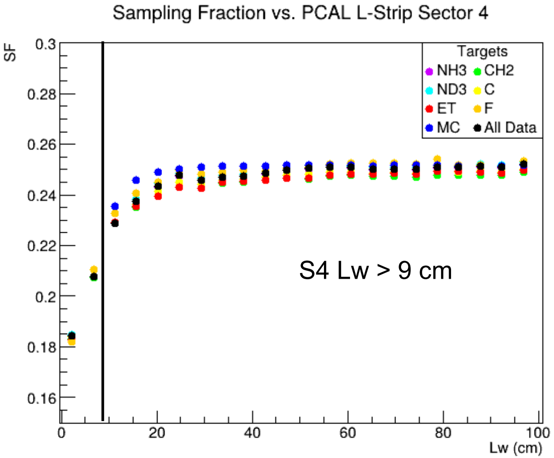


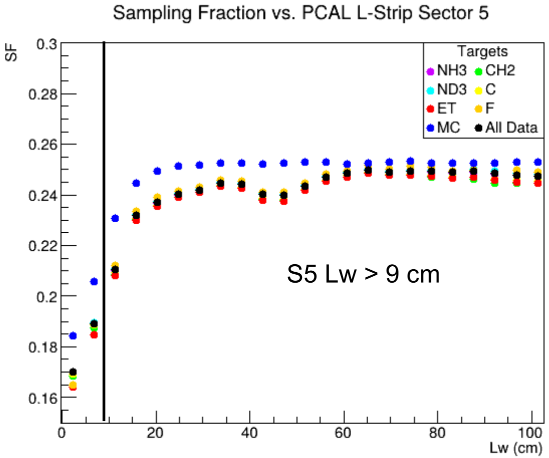


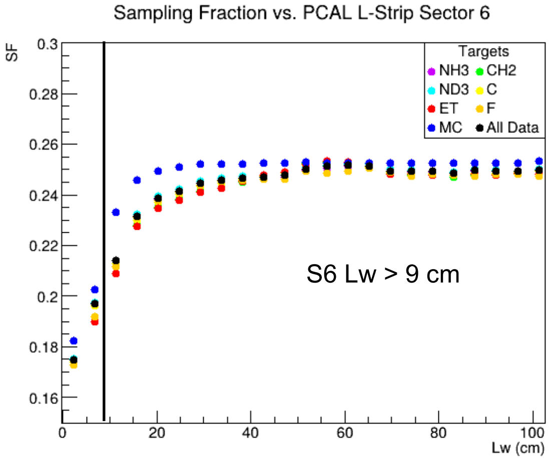




Summer 2022 Data (Trigger e^- Tracks)

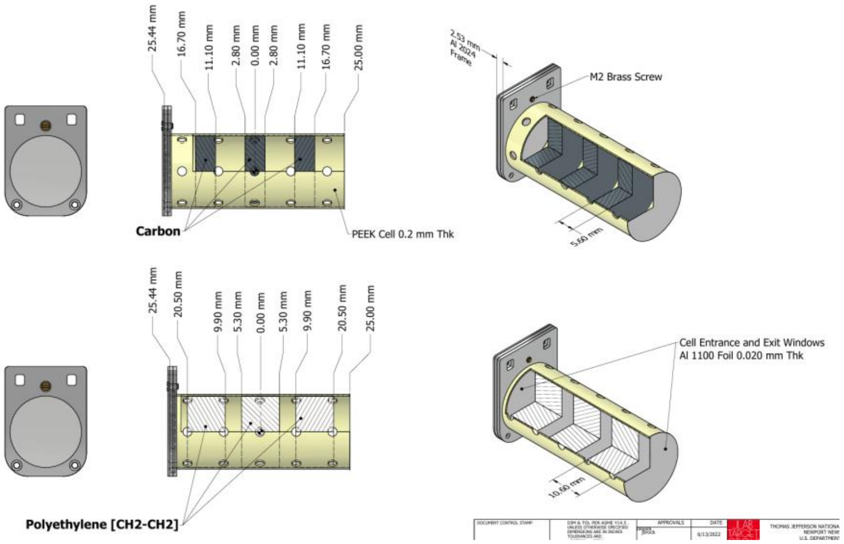


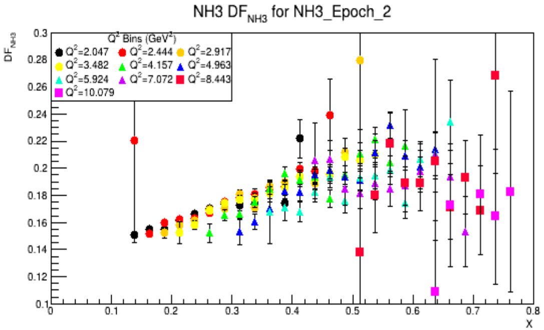


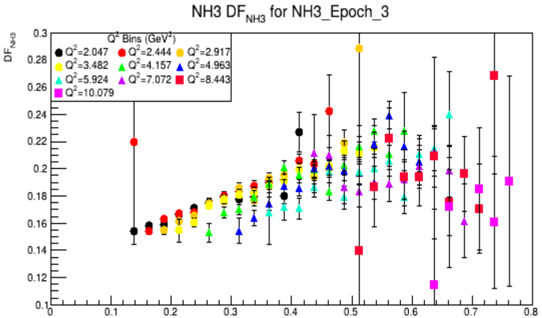


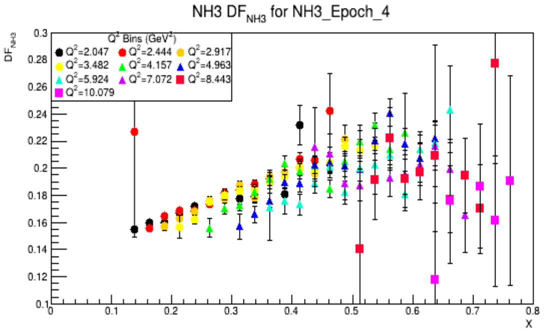
Thermal Contraction of Targets

- Studying the impact of thermal contraction of the target cells on the dilution factor
- Carbon, CH2, CD2 targets' geometry measured at room temperature, cooled to ~1K, so there's some contraction of target length
- Modulate the sizes of the targets as follows:
  - $\ell_C * (1 - dL_C/L_C)$, with dL_C/L_C = 0.5%
  - $\ell_{CH} * (1 - dL_{CH}/L_{CH})$, with dL_{CH}/L_{CH} = 2.1%
  - $\ell_{CD} * (1 - dL_{CH}/L_{CH})$
  - $L * (1 - 0.018)$ (for Teflon contraction, 1.8%)
  - $\rho_C/(1 - dL_{CH}/L_{CH})^3$
  - $\rho_{CH}\ /(1 - dL_{CH}/L_{CH})^3$
  - $\rho_{CD}/(1 - dL_{CH}/L_{CH})^3$
  - ρ_A, ρ_D are unchanged

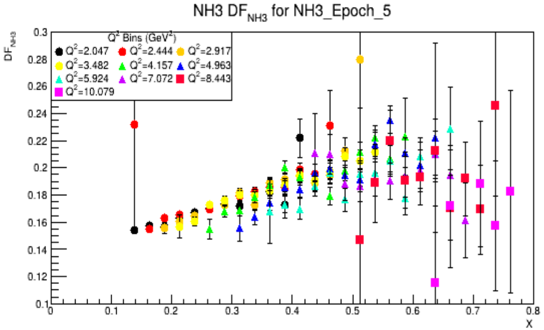


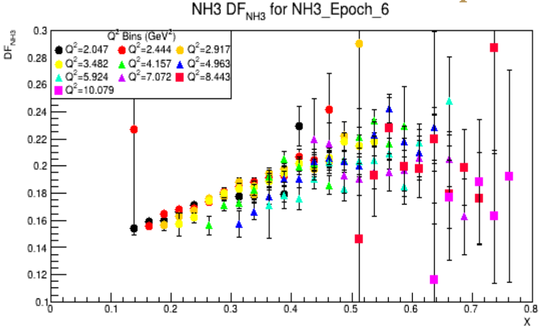


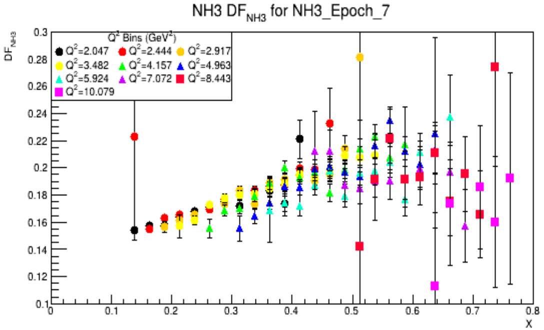


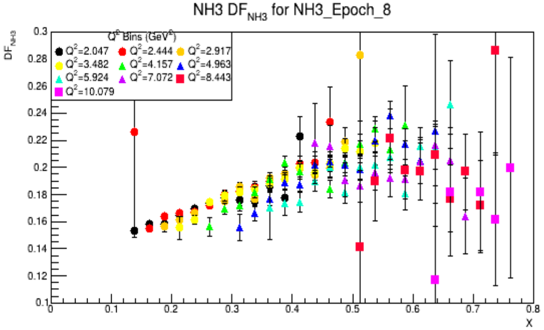


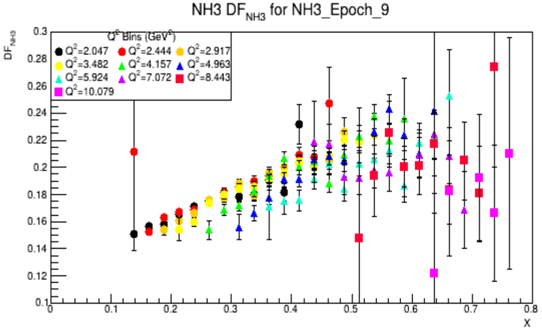
Summer 2022 D_F

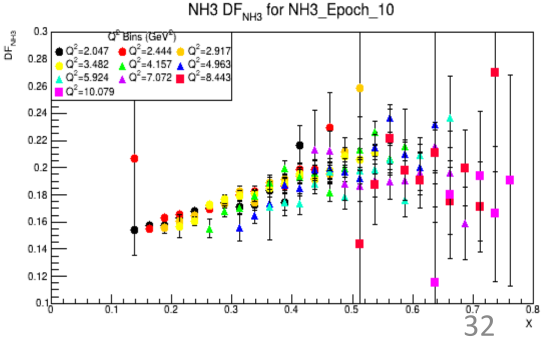


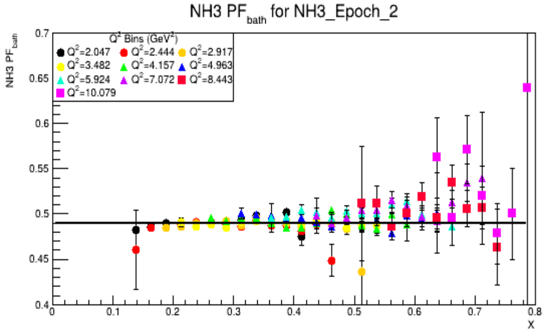


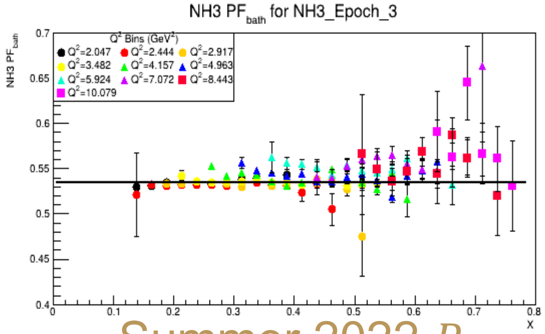


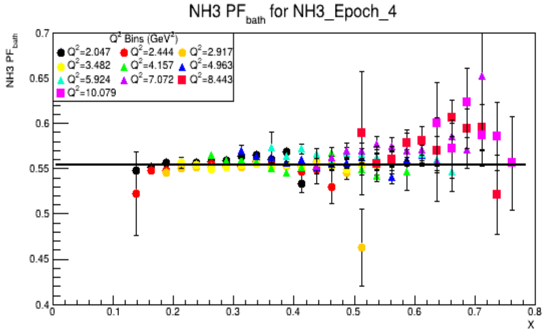




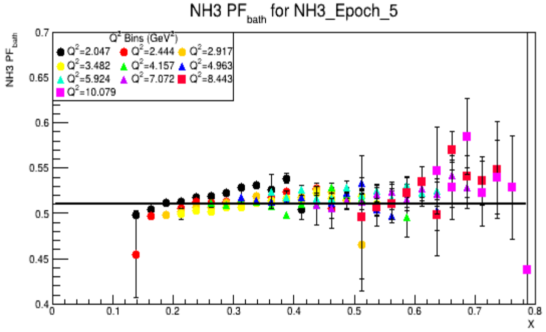


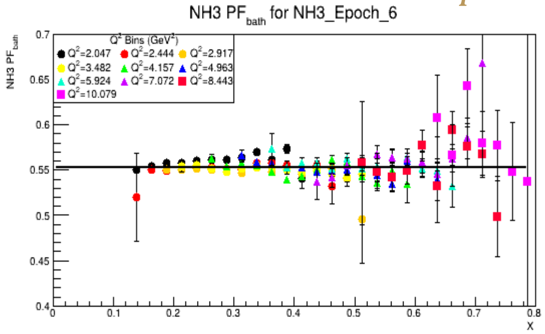


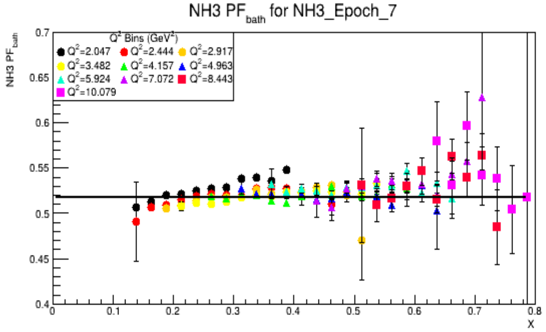


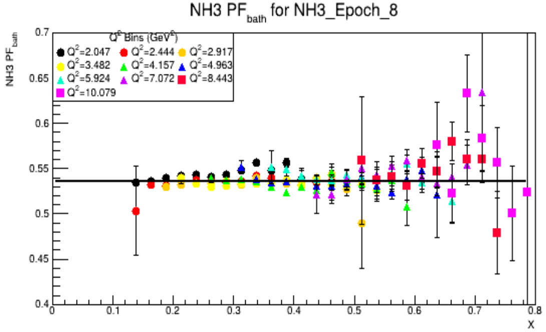


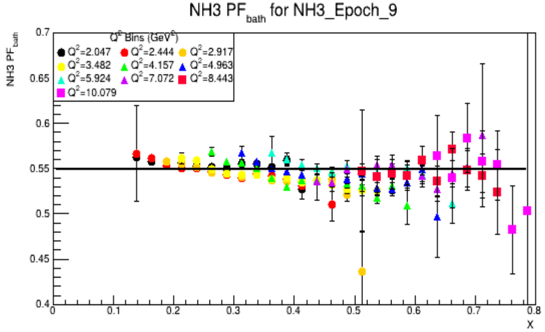
Summer 2022 P_F

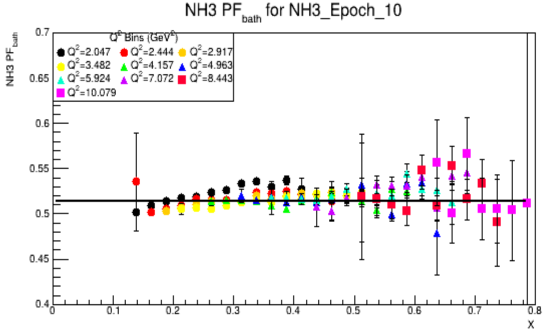




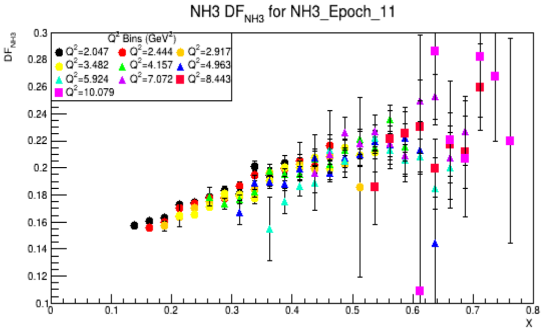


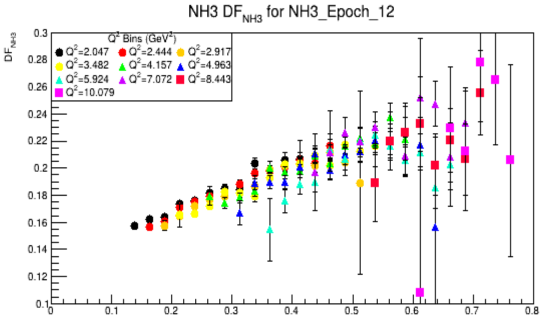


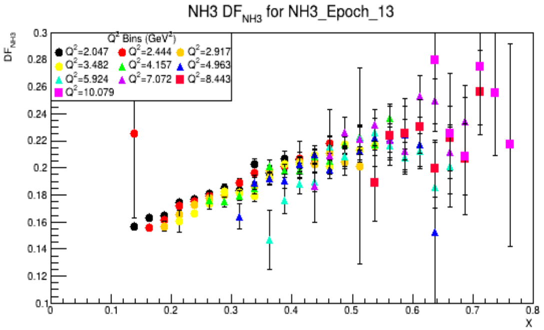


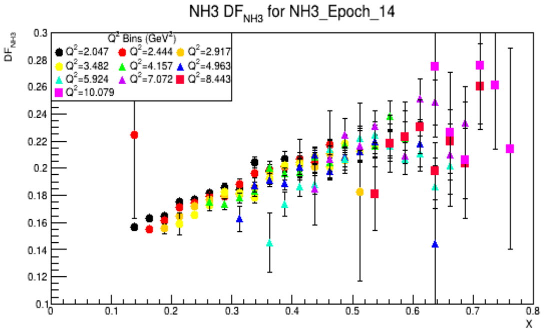


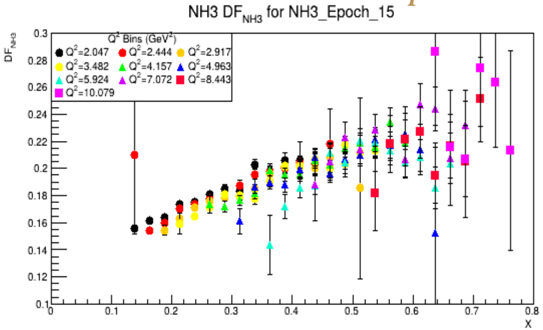
Fall 2022 D_F

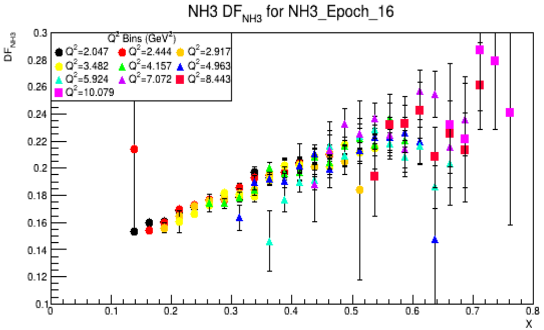

NH3 DF_NH3 for NH3_Epoch_11
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079
DF_NH3
x

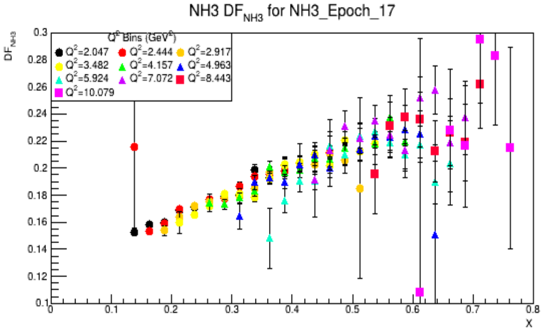

NH3 DF_NH3 for NH3_Epoch_12
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079
DF_NH3
x

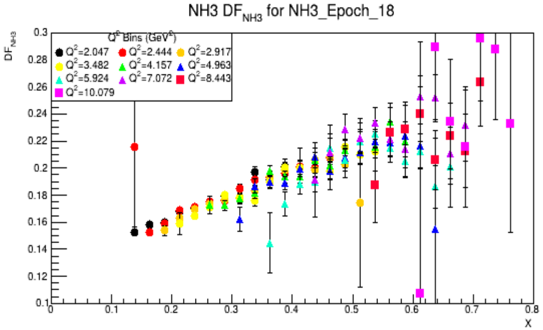

NH3 DF_NH3 for NH3_Epoch_13
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079
DF_NH3
x

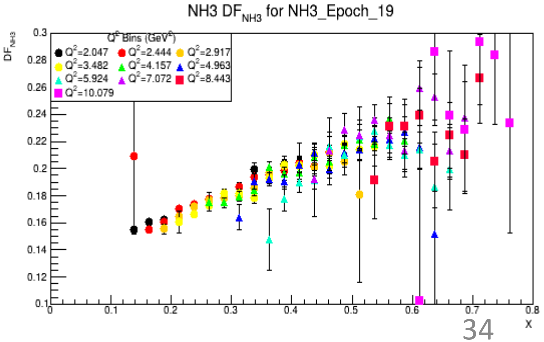

NH3 DF_NH3 for NH3_Epoch_14
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079
DF_NH3
x


NH3 DF_NH3 for NH3_Epoch_15
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079
DF_NH3
x

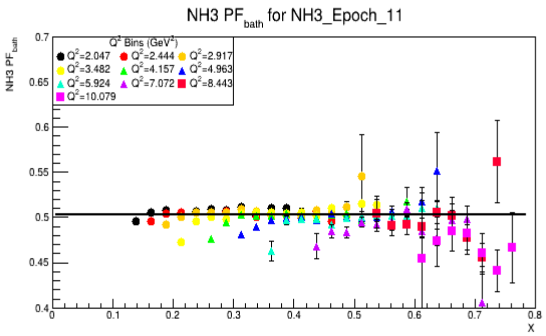

NH3 DF_NH3 for NH3_Epoch_16
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079
DF_NH3
x

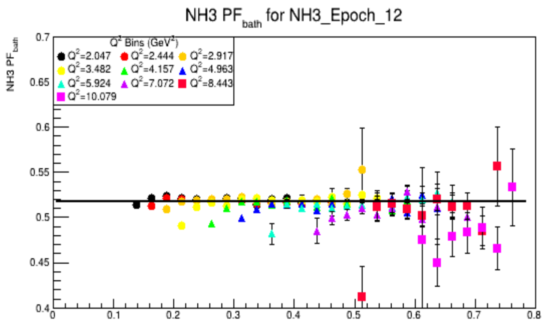

NH3 DF_NH3 for NH3_Epoch_17
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079
DF_NH3
x

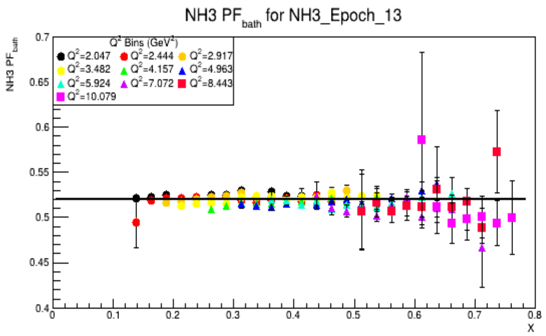

NH3 DF_NH3 for NH3_Epoch_18
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079
DF_NH3
x

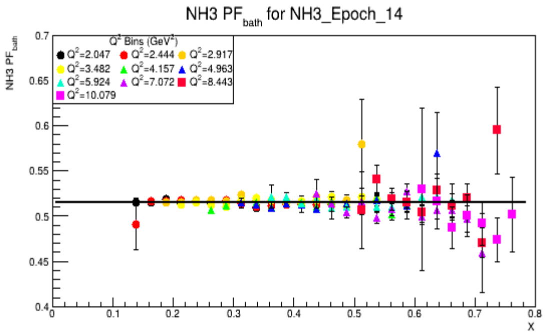

NH3 DF_NH3 for NH3_Epoch_19
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079
DF_NH3
x

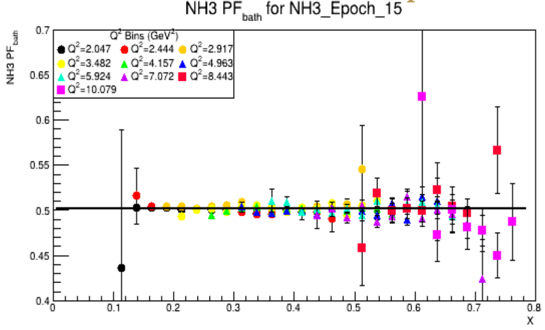
Fall 2022 P_F

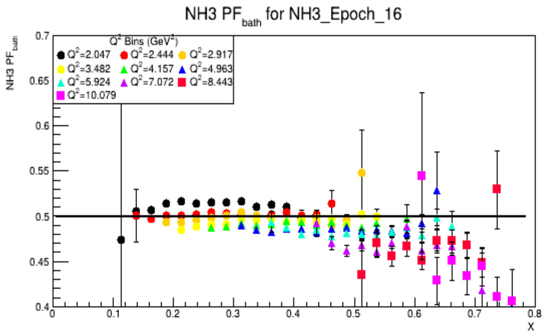

NH3 PF_bath for NH3_Epoch_11
NH3 PF_bath
x
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079

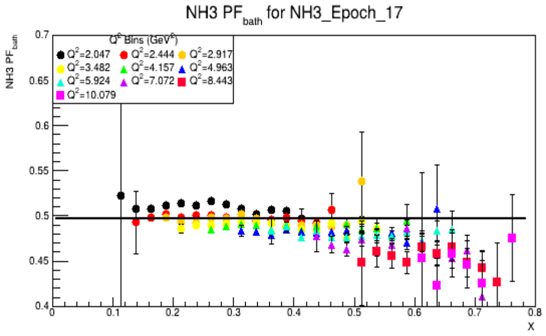

NH3 PF_bath for NH3_Epoch_12
NH3 PF_bath
x
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079

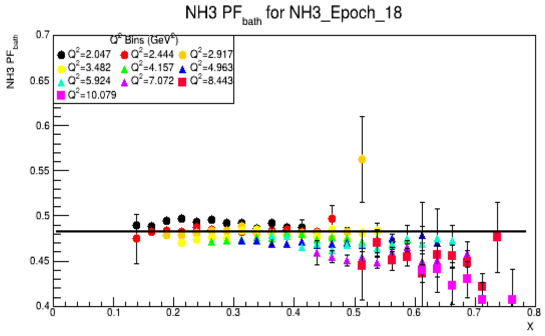

NH3 PF_bath for NH3_Epoch_13
NH3 PF_bath
x
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079

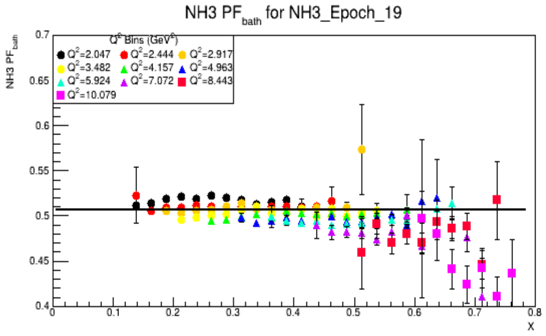

NH3 PF_bath for NH3_Epoch_14
NH3 PF_bath
x
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079

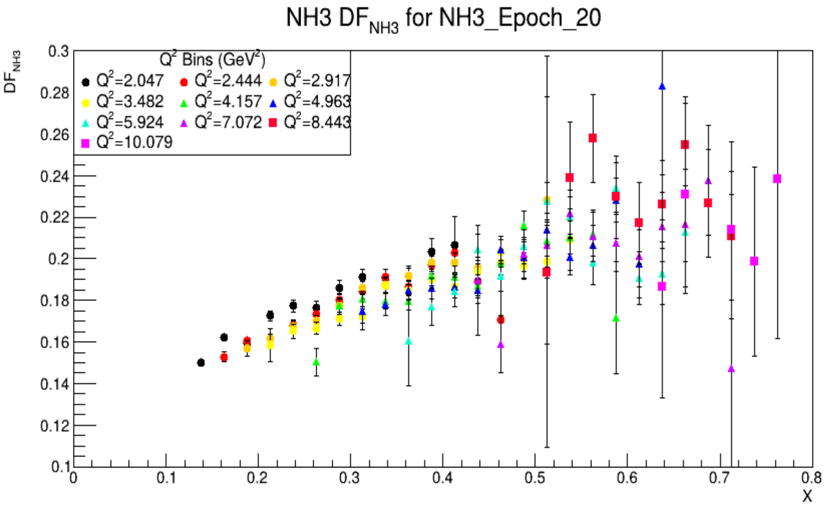

NH3 PF_bath for NH3_Epoch_15
NH3 PF_bath
x
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079

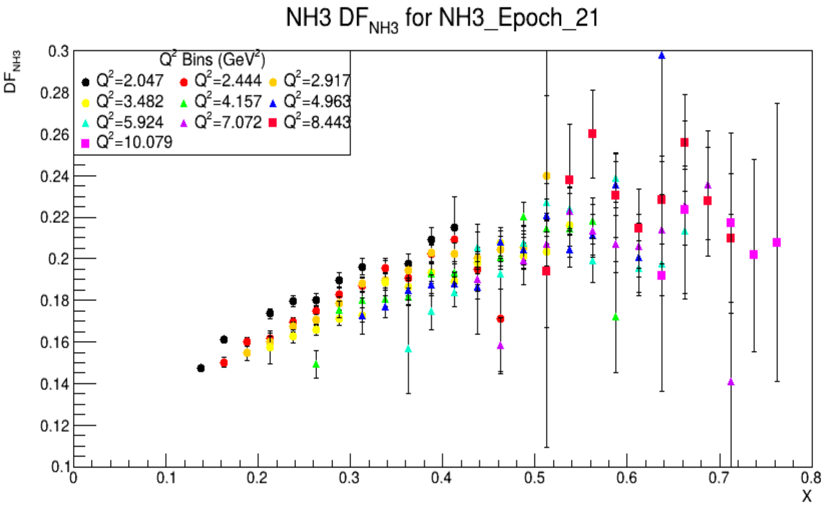

NH3 PF_bath for NH3_Epoch_16
NH3 PF_bath
x
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079


NH3 PF_bath for NH3_Epoch_17
NH3 PF_bath
x
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079

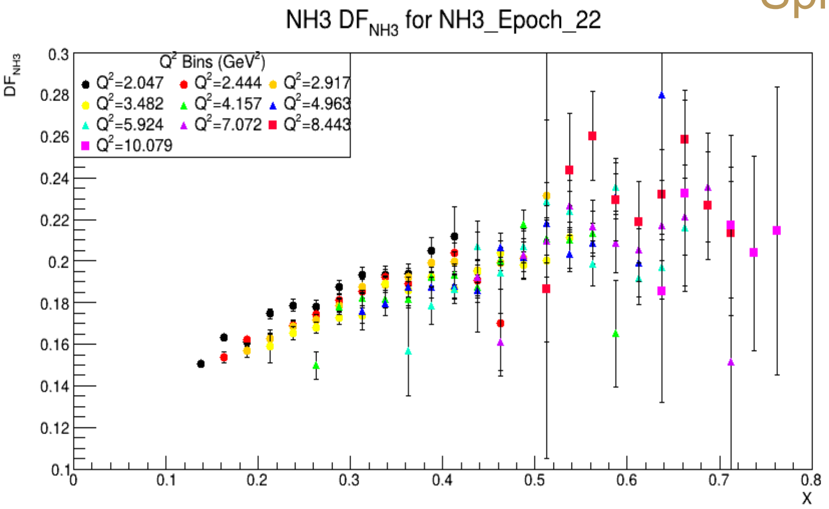

NH3 PF_bath for NH3_Epoch_18
NH3 PF_bath
x
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079

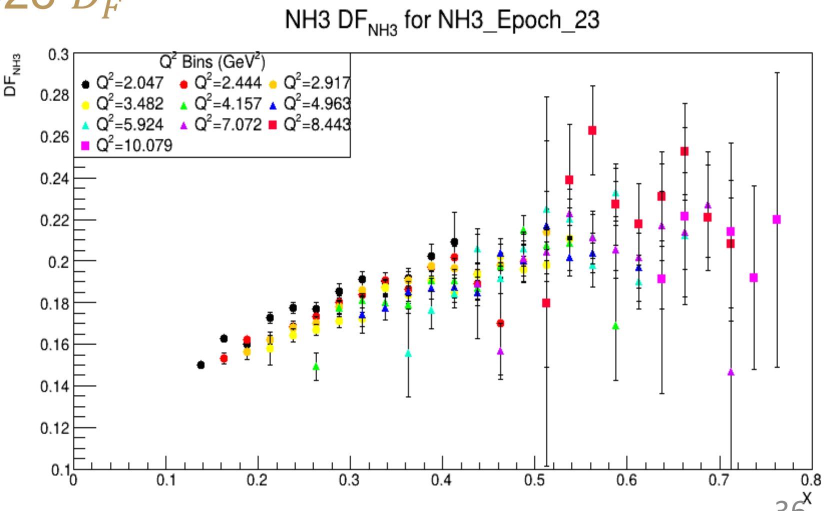

NH3 PF_bath for NH3_Epoch_19
NH3 PF_bath
x
Q² Bins (GeV²)
Q²=2.047 Q²=2.444 Q²=2.917
Q²=3.482 Q²=4.157 Q²=4.963
Q²=5.924 Q²=7.072 Q²=8.443
Q²=10.079





Spring 2023 D_F





Spring 2023 P_F