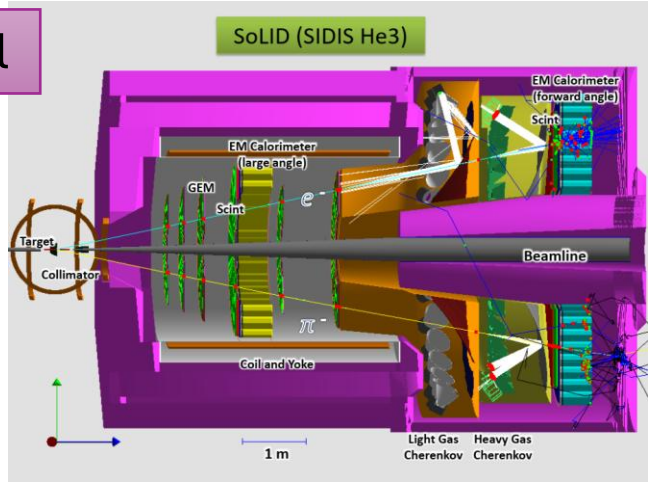
SoLID Lite
SIDIS He3 projection and design and simulation

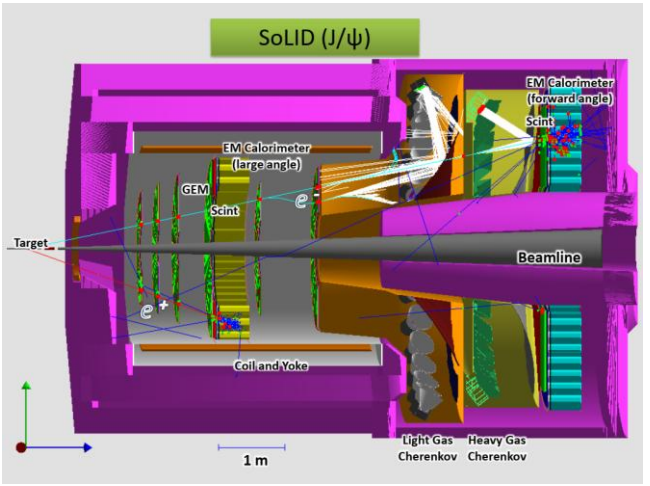
Zhiwen Zhao

SoLID Lite option (preliminary)

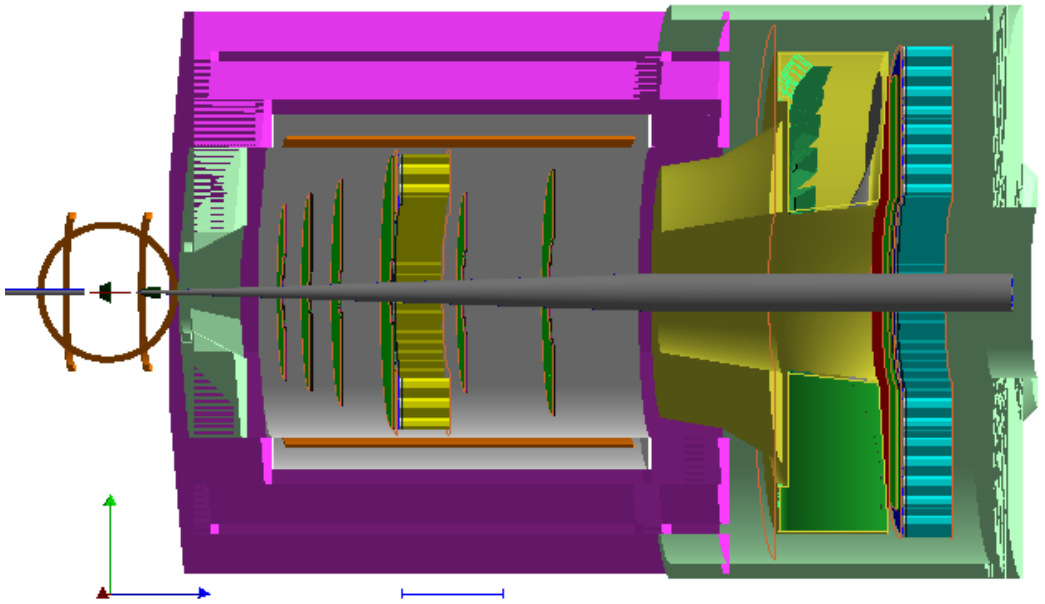
- SoLID full with forward angle (FA) and large angle (LA) detectors
- SoLID lite option (“4seg24degFA+LA”)
  - Works for both Jpsi and SIDIS
  - Reduce FA into 4 segments of 24 deg each while keeping LA full
  - Solenoid magnet using unmodified LEO iron (purple) for JPsi, then add front piece and endcap (green) for SIDIS
  - One Cherenkov with CO2, maybe reuse sPHENIX ECAL

SoLID full

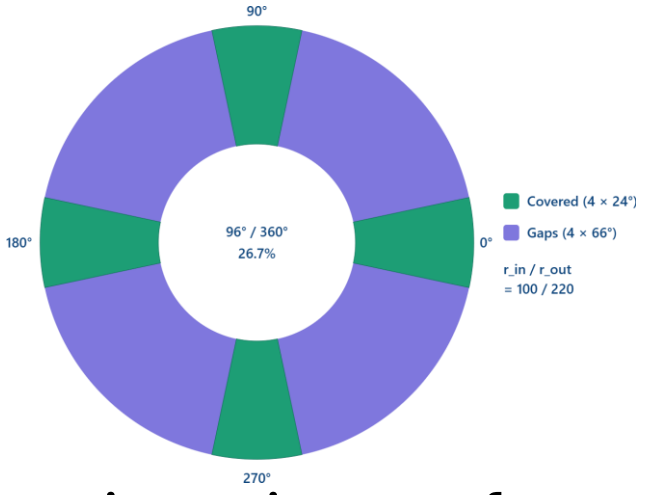




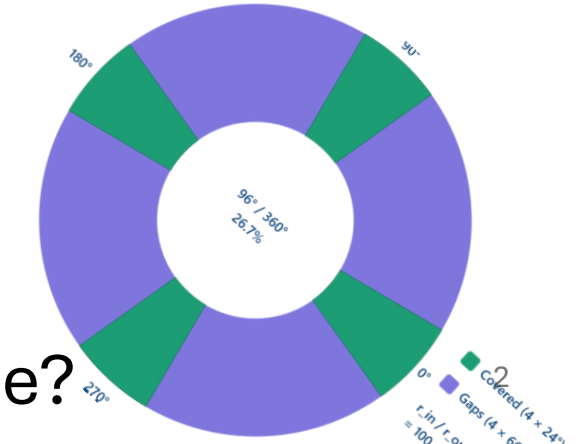
Two stages of magnet



4seg24degFA



engineering preference?



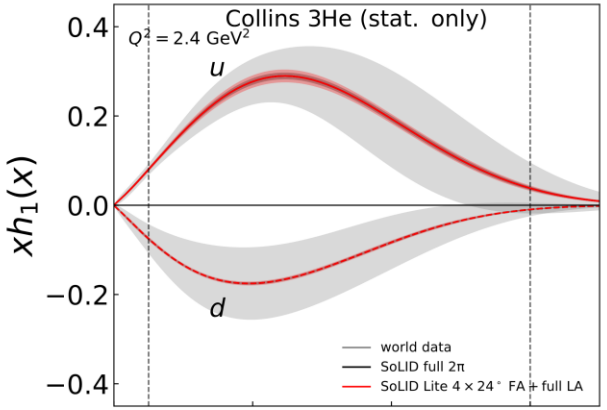
SoLID lite SIDIS He3

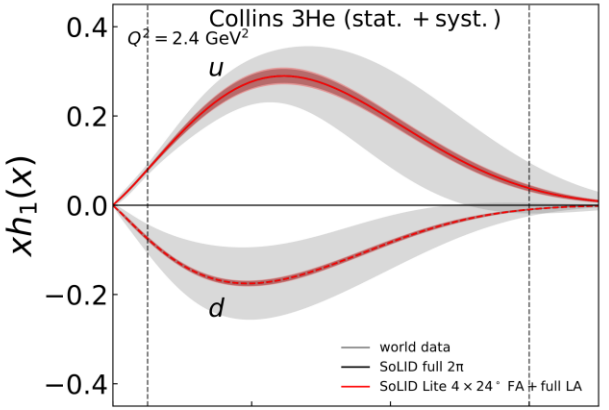
$$A_{UT}^{h}(\phi_h,\phi_S)=\frac{2}{P_T^1+P_T^2}\cdot\frac{\sqrt{N_1(\phi_h,\phi_S)N_2(\phi_h,\phi_S+\pi)}-\sqrt{N_1(\phi_h,\phi_S+\pi)N_2(\phi_h,\phi_S)}}{\sqrt{N_1(\phi_h,\phi_S)N_2(\phi_h,\phi_S+\pi)}+\sqrt{N_1(\phi_h,\phi_S+\pi)N_2(\phi_h,\phi_S)}}$$

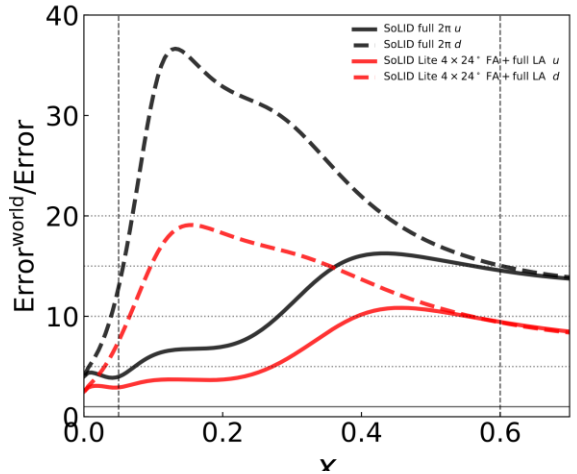
- things to consider
  - Keep phi 180 deg detector symmetry to minimize systematic uncertainty for the A_UT
  - FA is critical to have hadron detection
- Configuration (4seg24degFA+LA)
  - 4 segments of 24 deg in phi for FA
  - 24 deg segment means 2 sectors of Cherenkov and EC modules behind should be a bit larger
  - positive and negative pions will have difference acceptance in phi due to solenoid field. They are assumed to be same for now and more detailed simulation needed later
  - 4*24/360=0.27 of FA in area ratio, related to cost
  - LA remains full

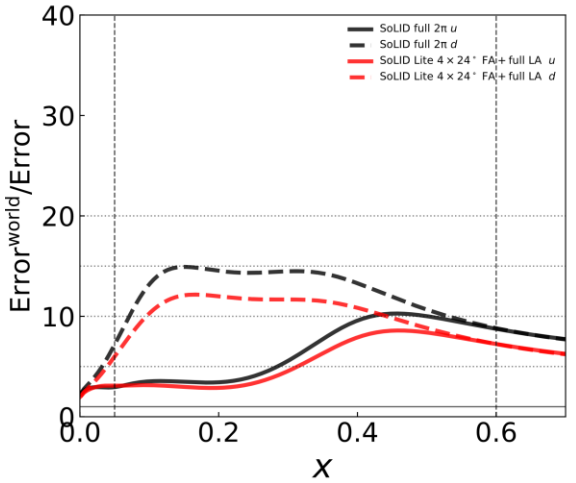
SoLID lite SIDIS He3, Transversity

- Compare TMD fitting error for SoLID full and lite with same binning and stat error only
- Assume 4x lumi, the same as SBS target and current
- Error ratio reduced by ~2x

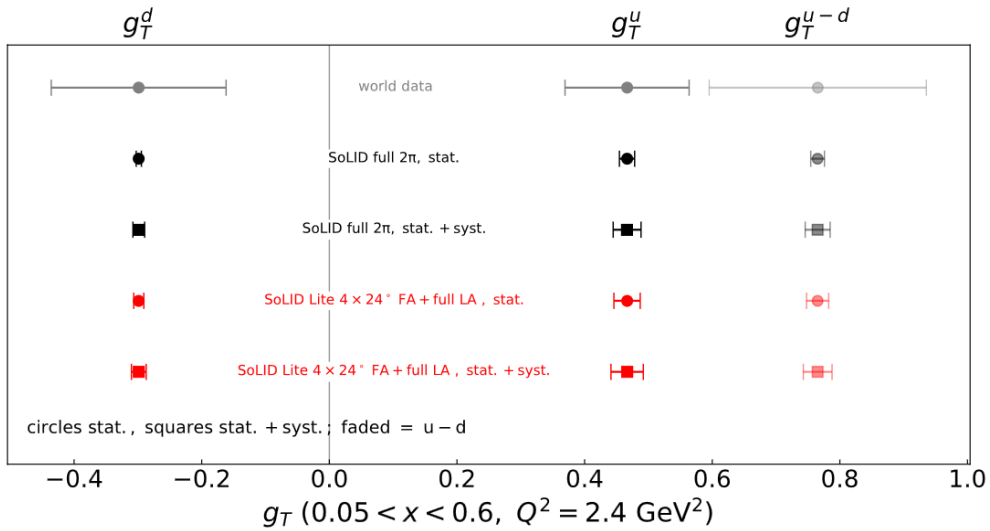


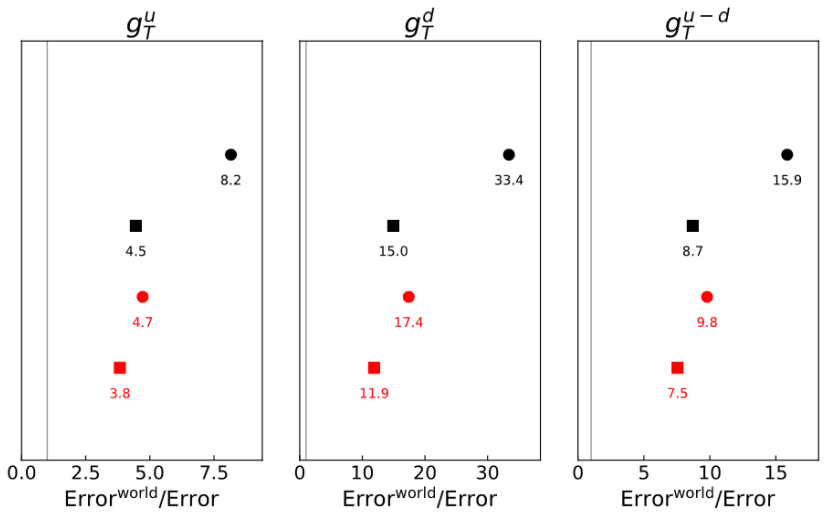






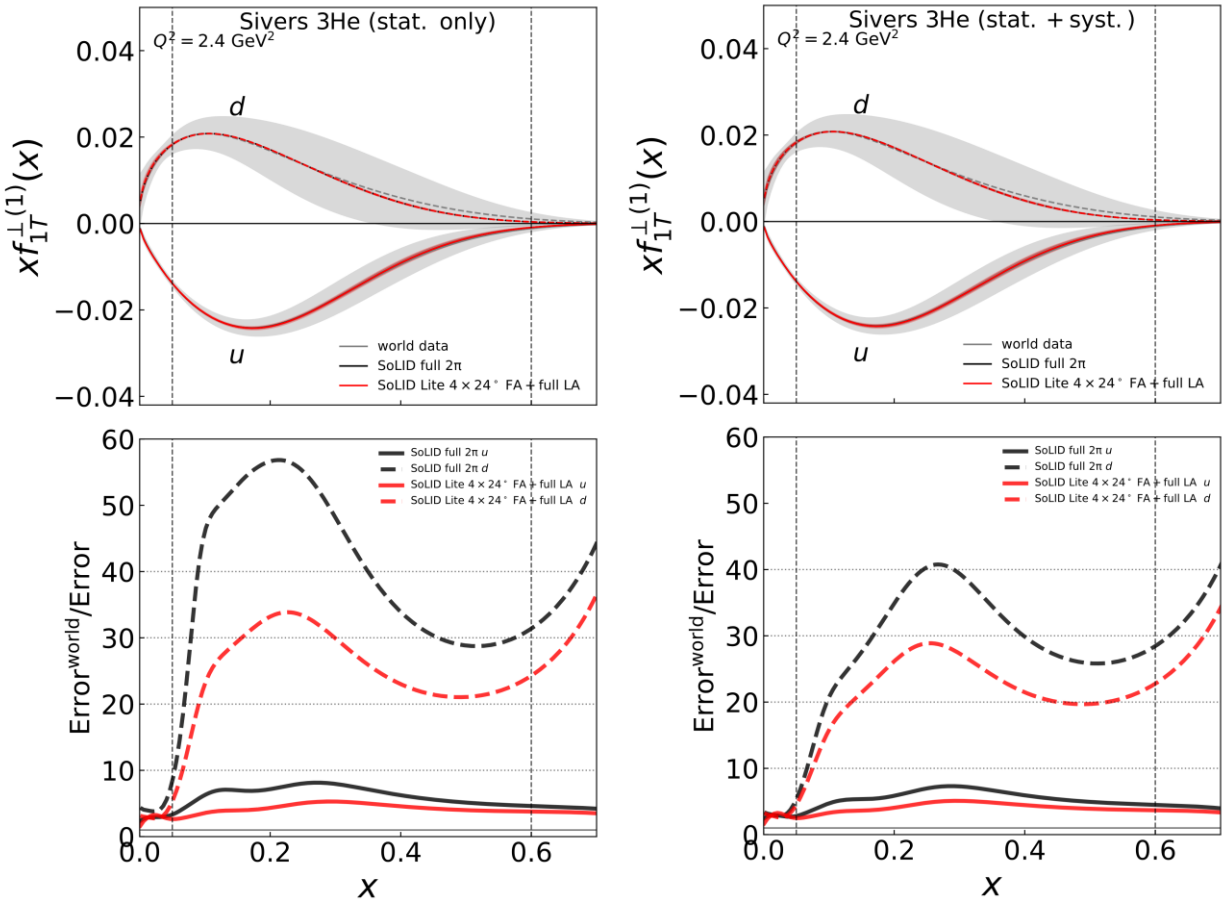
SoLID Lite uses the same bins as full 2π, and 4× lumi





SoLID lite SIDIS He3, Sivers

- Compare TMD fitting error for SoLID full and lite with same binning and stat error only
- Assume 4x lumi, the same as SBS target and current
- Error ratio reduced by ~2x



SoLID Lite uses the same bins as full 2π, and 4× lumi

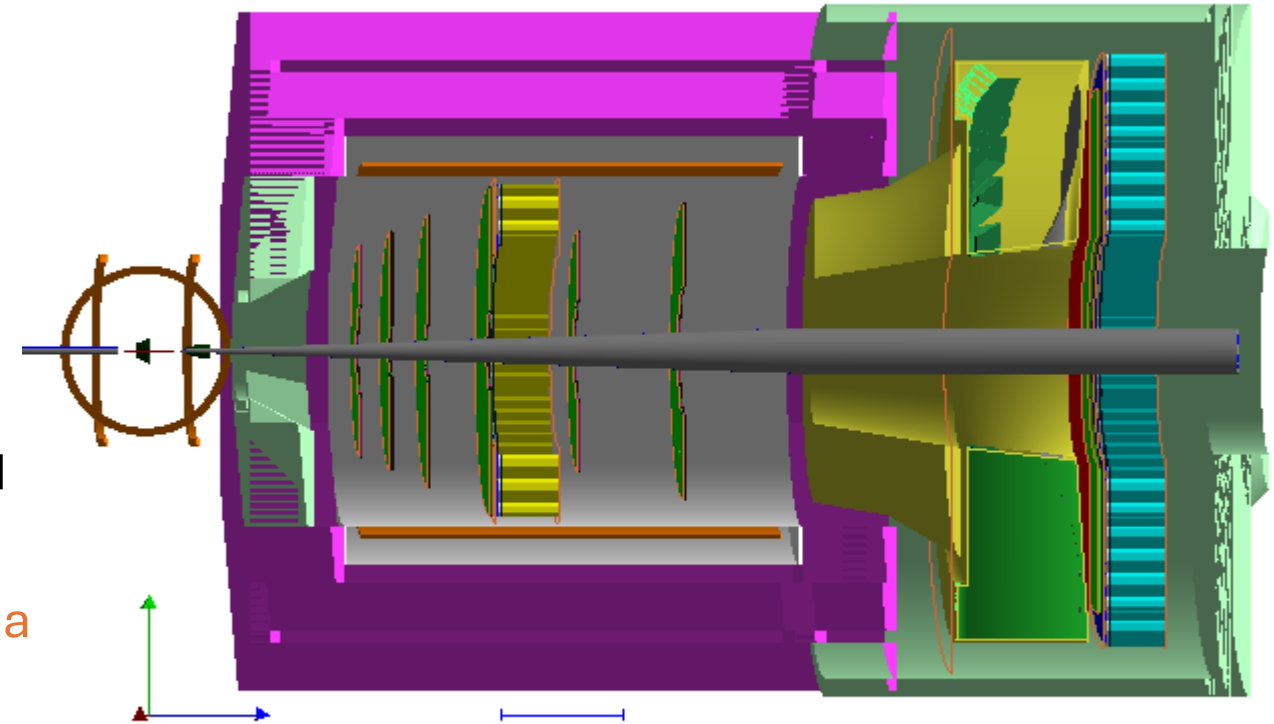
SoLID Lite uses the same bins as full 2π, and 4× lumi

SoLID He3 projection todo list

- Update world data from 2015 to latest
- Treating syst uncertainty not bin-by-bin in fitting
- Optimize binning with lite option
- Checking projection on other observables
- Iterate with new simulation

Possible stages and detector changes

- Start with JPsi+DDVCS
  - use solenoid magnet with unmodified CLEO iron (purple)
  - muon detector with 3 layer of iron doesn't affect field and force much
- Then SIDIS
  - add front piece (green) to prevent field leak at target location
  - add endcap cylinder and/or bottom and/or use muon detector iron and/or a small endcap nose for force balance
- Then PVDIS
  - No need of front piece, but SIDIS magnet can still be the starting point because Bz is better contained within solenoid
  - Baffle need redesign or optimization



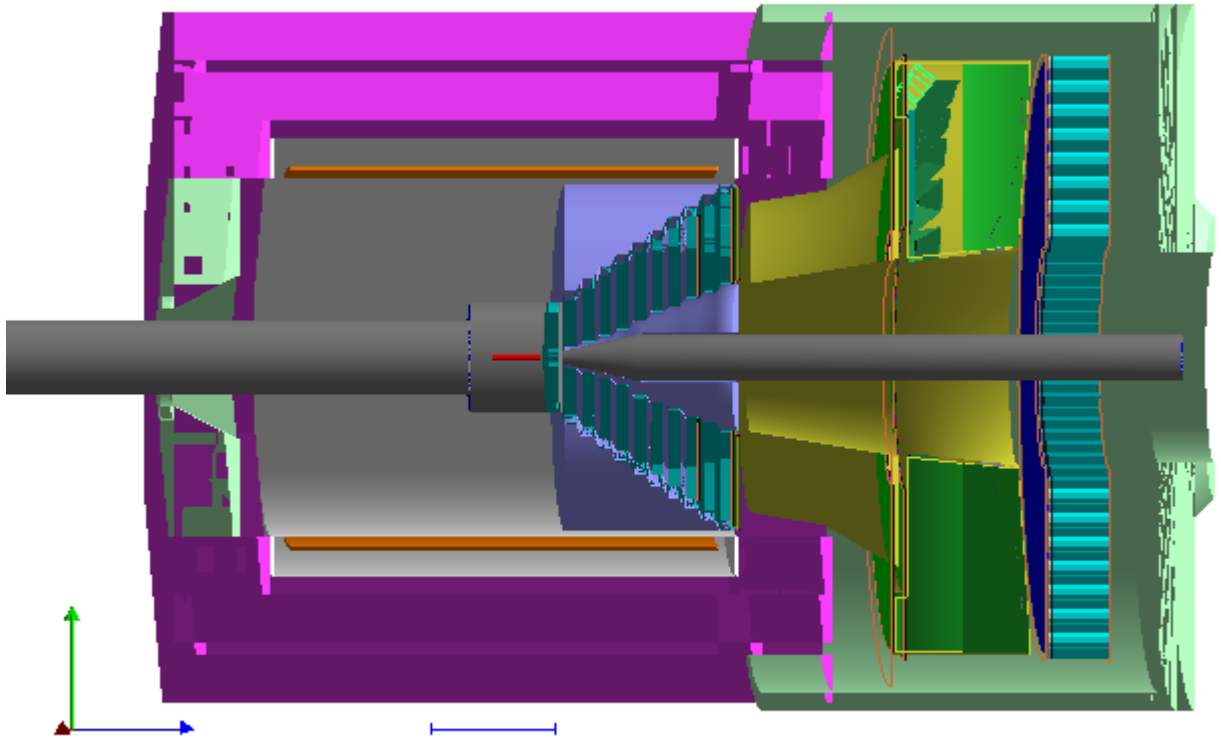
- nominal max forward angle from target center z=-350cm changes from 15.4 to 13.6deg. LA can compensate
- one Cherenkov with CO2
- No heavy gas Cherenkov
- No MRPC, need SPD as TOF
- maybe reuse sPHENIX ECAL or others

Jpsi/sidis design and simulation todo list

- Jpsi
  - new field map (2D) basically ready
  - Adjust CO2 Cherenkov and use existing ECAL
  - new simulation to produce new acceptance
  - Iterate with new ECAL
  - Final tuning with 3D map
- SIDIS He3
  - Adjust new magnet iron for field shielding and force and then new 2D map
  - Adjust cell window collimator
  - check CO2 Cherenkov and existing ECAL
  - new simulation to produce new acceptance
  - Iterate with new ECAL
  - Final tuning with 3D map

Possible stages and detector changes

- Start with JPsi+DDVCS
  - use solenoid magnet with unmodified CLEO iron (purple)
  - muon detector with 3 layer of iron doesn't affect field and force much
- Then SIDIS
  - add front piece (green) to prevent field leak at target location
  - add endcap cylinder and/or bottom and/or use muon detector iron and/or a small endcap nose for force balance
- Then PVDIS
  - No need of front piece, but SIDIS magnet can still be the starting point because Bz is better contained within solenoid
  - Baffle need redesign or optimization



- nominal max angle from target center z=10cm changes from 54.7 to 35.9deg, physics acceptance reduced for the 40cm long full target
- one Cherenkov with CO2 (redesign optics?)
- maybe reuse sPHENIX ECAL or others
- move Cher and ECAL upstream ~0.5m to optimize coverage

pvdis design and simulation todo list

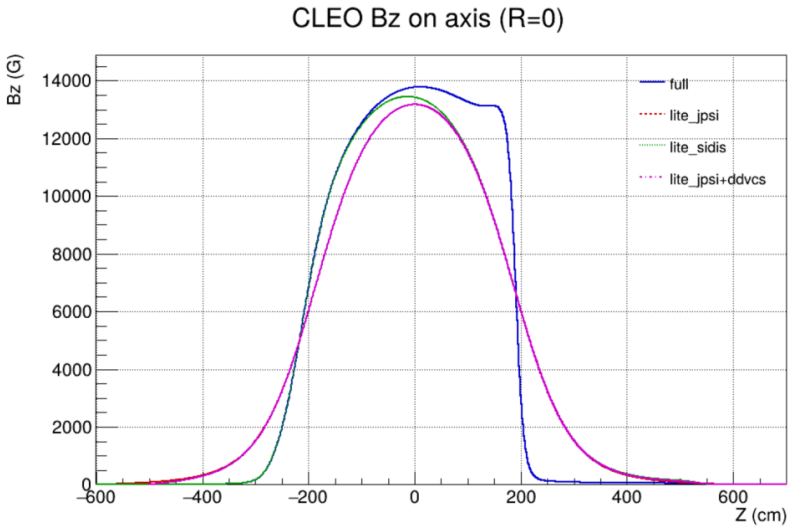
- pvdis
  - Use jpsi magnet or sidis magnet iron 2D map and optimize baffle accordingly
  - Adjust CO2 Cherenkov (likely optics) and existing ECAL
  - new simulation to produce new acceptance
  - Iterate with new ECAL
  - Final tuning with 3D map

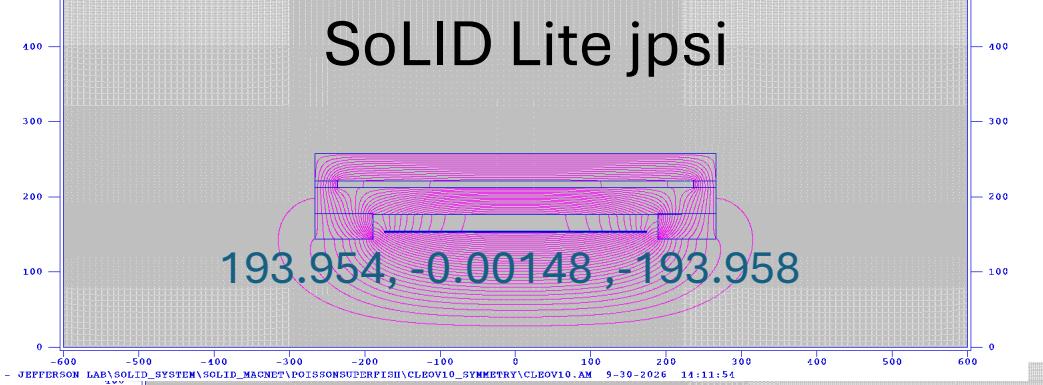
Explore no baffle option?

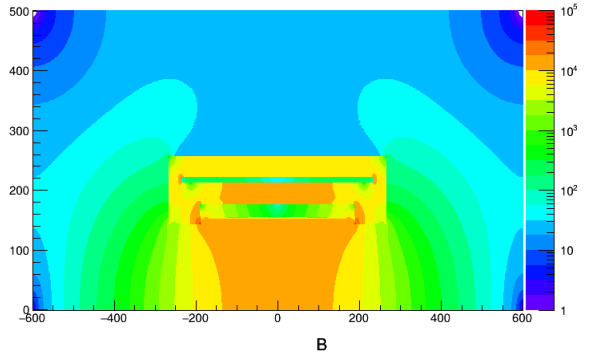
- Acceptance through existing baffle ~1/3, so 3x lumi w baffle = 1xlumi w/o baffle in term of e- DIS rate
- Baffle blocks photons from target (direct photon and pi0 decay), also pi- (1/3) and pi+ (100%)
- If we put pb/w slit near max field bending at solenoid boundary z=~200cm to block only photons and running at lower lumi, what would PID/tracking/trigger be?

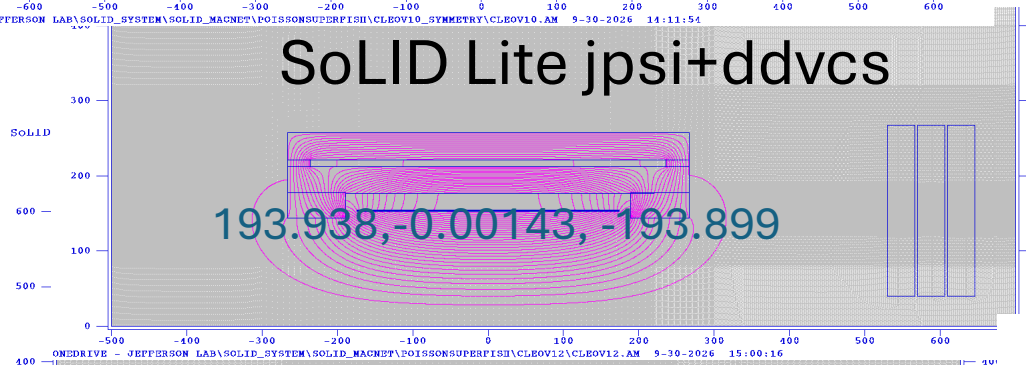
Field study

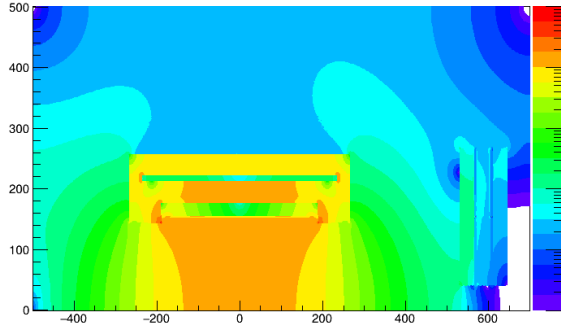
- Here are only 2D maps by POISSON as a test. 3D maps study needs TOSCA
- using unmodified CLEO iron only reduce Bz field at z=0 from 1.38T to 1.32T, but field integral changes more
- For sidis setup, without endcap nose
  - field diffuse more broadly
  - force is not balanced on coil. (force at left edge, middle, right edge are shown in metric ton)
- HGC PMT location still remain ~100G for all cases
- DDVCS muon detector iron doesn't affect jpsi setup, and may help SIDIS setup as flux return

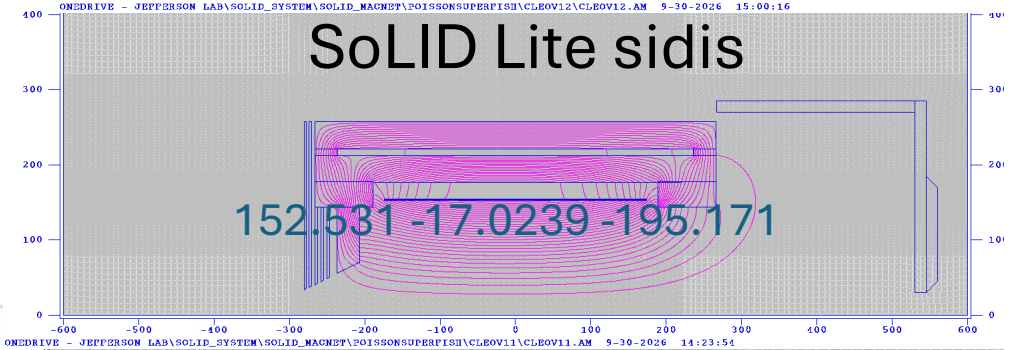


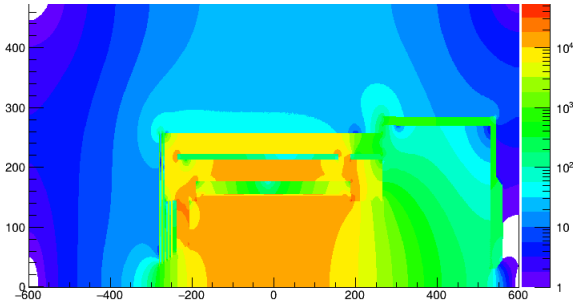


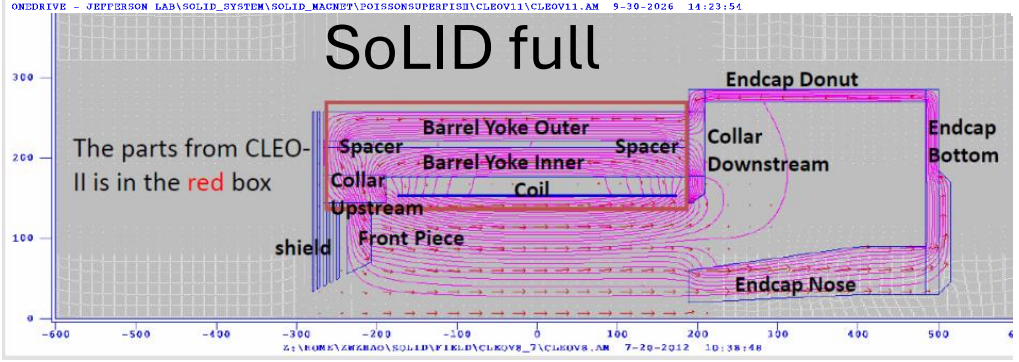


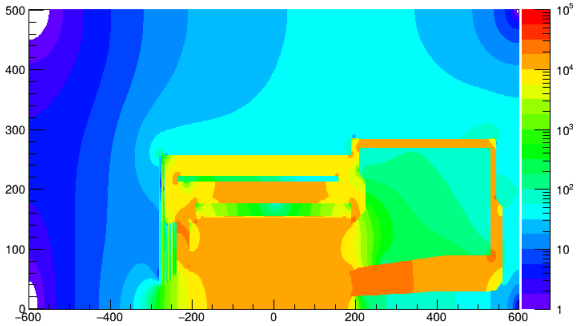












Field bending

We have 1.5 safety factor in Weizhi's tracking resolution

- Simple field integral for electron along straight lines
- Momentum resolution may be reduced by 20-30% according to absolute field integral

z(-350,200)cm

Angle	Map	Signed integral (T·m)	Abs. integral (T·m)	Bend, 2 GeV/c	Bend, 5 GeV/c
8°	full	-0.9629	0.9629	+8.27°	+3.31°
8°	lite_jpsi	-0.5634	0.7346	+4.84°	+1.94°
8°	lite_sidis	-0.5682	0.7406	+4.88°	+1.95°
13°	full	-1.1443	1.3129	+9.83°	+3.93°
13°	lite_jpsi	-0.9063	1.2983	+7.78°	+3.11°
13°	lite_sidis	-0.9137	1.3074	+7.85°	+3.14°

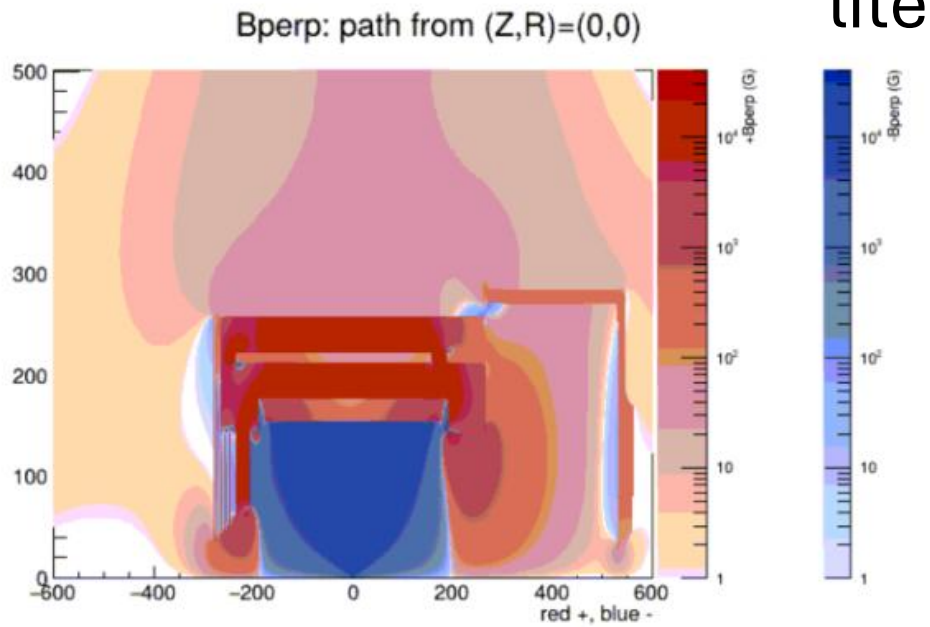
z(0,400)cm

Angle	Map	Signed integral (T·m)	Absolute integral (T·m)	Bend at 2 GeV/c	Bend at 5 GeV/c
22°	full	-1.1917	1.2445	+10.23°	+4.09°
22°	lite_jpsi	-0.5179	0.8476	+4.45°	+1.78°
22°	lite_sidis	-0.5254	0.8484	+4.51°	+1.81°
35°	full	-1.1434	1.7737	+9.82°	+3.93°
35°	lite_jpsi	-0.8531	1.5746	+7.33°	+2.93°
35°	lite_sidis	-0.8524	1.5850	+7.32°	+2.93°

Field bending

- At solenoid boundary z=~200cm, B_perp reverse sign
- pvdis baffle needs redesign as field integral weaken by 15-40%

lite SIDIS

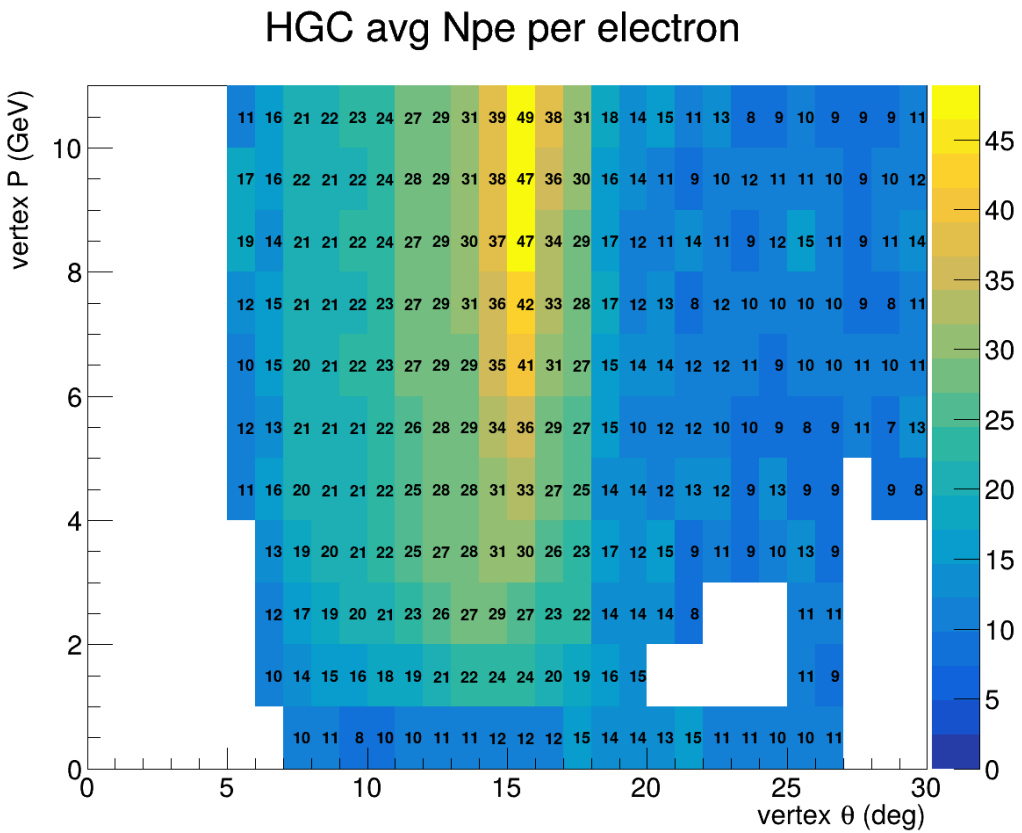


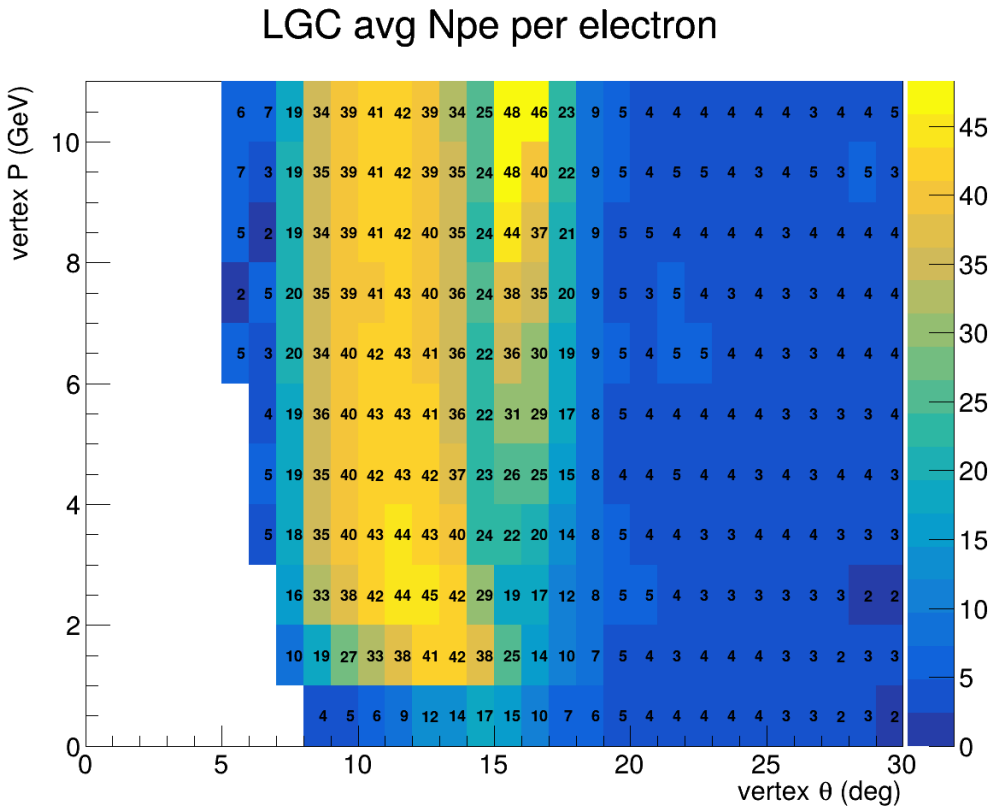
z(0,200)cm

Angle	Map	Signed integral (T·m)	Abs. integral (T·m)	Bend, 2 GeV/c	Bend, 5 GeV/c
22°	full	−1.1242	1.1242	+9.66°	+3.86°
22°	lite_jpsi	−0.6782	0.6873	+5.83°	+2.33°
22°	lite_sidis	−0.6824	0.6914	+5.86°	+2.34°
35°	full	−1.4027	1.5144	+12.05°	+4.82°
35°	lite_jpsi	−1.1274	1.2960	+9.68°	+3.87°
35°	lite_sidis	−1.1338	1.3026	+9.74°	+3.89°

HGC using CO2 gas (SIDIS He3)

- Fill HGC using CO2 gas instead of C4F8, then comparing it to LGC
- HGC (1m gas length) as e detector has about ½ Npe than LGC (~2m gas length)
  - With a 1m extension, it can have similar Npe like LGC
- HGC optics works for e in SIDIS and jpsi case and more studies need to optimize it



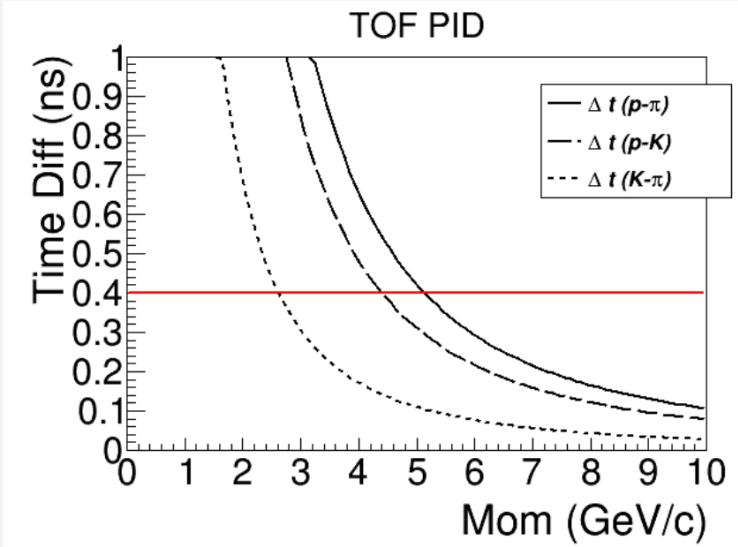


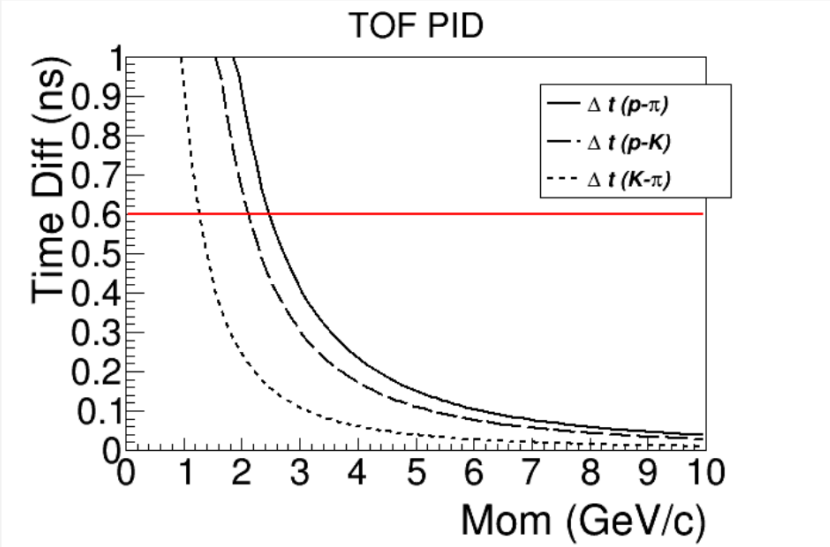
One Cherenkov for e/pi

- use HGC full tank
  - Easy to add more sectors later
  - Side walls would block lights or create background when particle bending in phi, 4 small tanks only if budget is limited
  - Moving 0.5 upstream would save room, may need adjust optics
  - existing HGC optics using CO2 (mainly mirror) likely won't work for PVDIS
  - Any big change can't be permanent if we want to reuse it with heavy gas at original location again
- To increase Npe, add 1m extension or increase CO2 pressure to 1.7atm with lower pion threshold or a bit of both
- a minimum design
  - 4 of 24deg thin tanks
  - 4*2*9=72 MAPMT
  - 4*2=8 mirrors for jpsi/SIDIS
  - Maybe side wall with flat mirrors as well if partial tank
  - Reuse parts, maybe except the thin tanks, when expand into more sectors

TOF PID with SPD (no 100ps MRPC at FA)

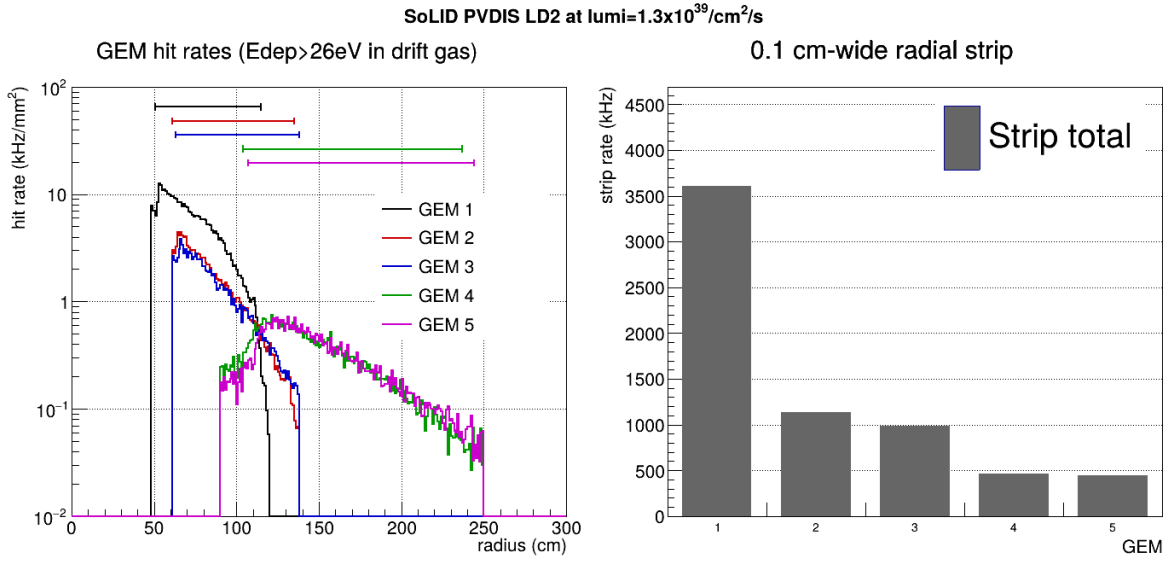
- Jpsi/SIDIS TOF flight distance ~8m/3m at FA/LA
- At FA, pi/K can be separated up to 2.5-3GeV
  - 2.5GeV for SPD 200ps time resolution and 2 sigma
  - 3GeV for SPD 150ps time resolution and 2 sigma
- At LA, pi/K can be separated up to 1.5-2GeV
  - 1.5GeV for SPD 200ps time resolution and 2 sigma
  - 2GeV for SPD 150ps time resolution and 2 sigma

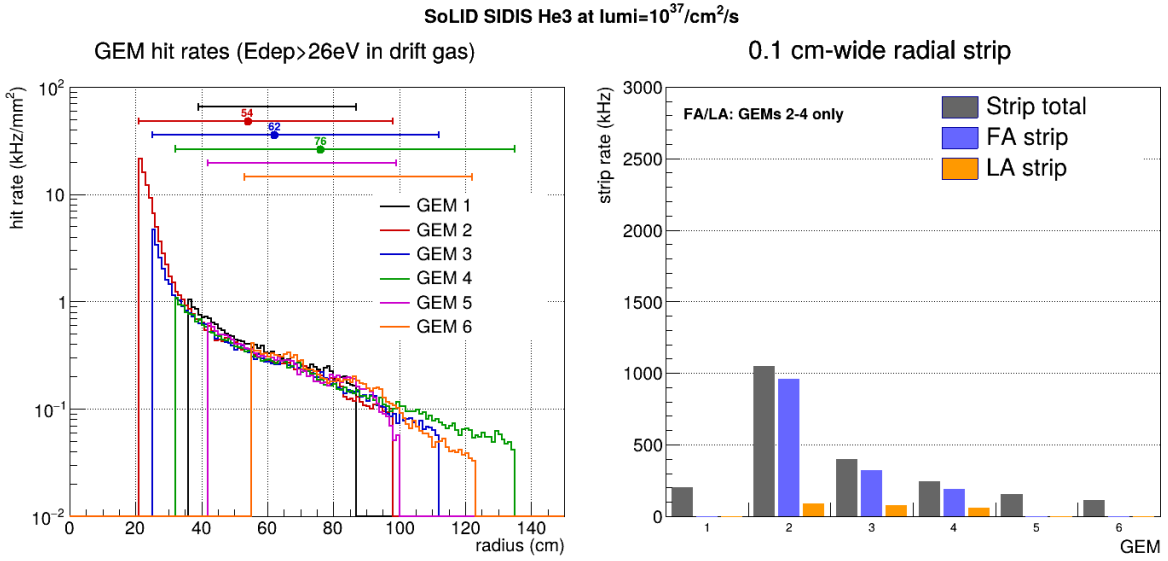


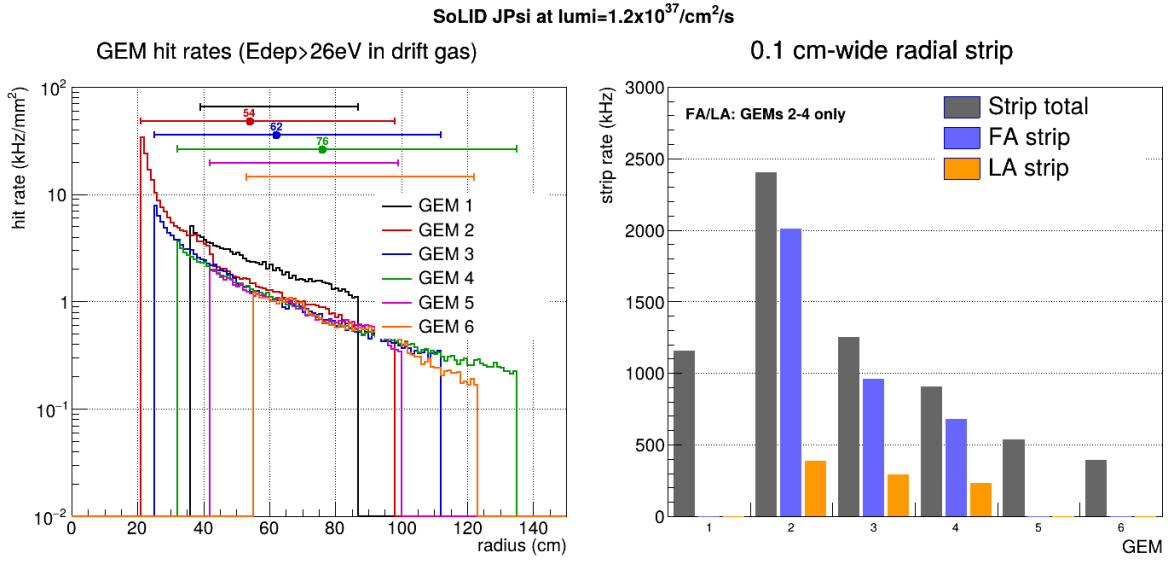


SoLID full GEM rate and lumi increase

- For SIDIS/Jpsi
  - GEM 2,3,4 are shared between FA and LA and rate is mostly from FA
  - GEM 2 has highest rate at FA inner radius.
  - For LA only, GEM 1 become highest
  - we hope to have jpsi go 2x lumi, sidis he3 go 4x lumi, when FA is included, and increase even more if only LA is included
  - according to tracking experience, using segmented strips would help
  - separating GEM 2,3,4 FA part and moving them further downstream would help (field integral from vertex doesn't change much)
  - More studies are needed
- For PVDIS
  - GEM 1 has highest rate, segmented strip is needed



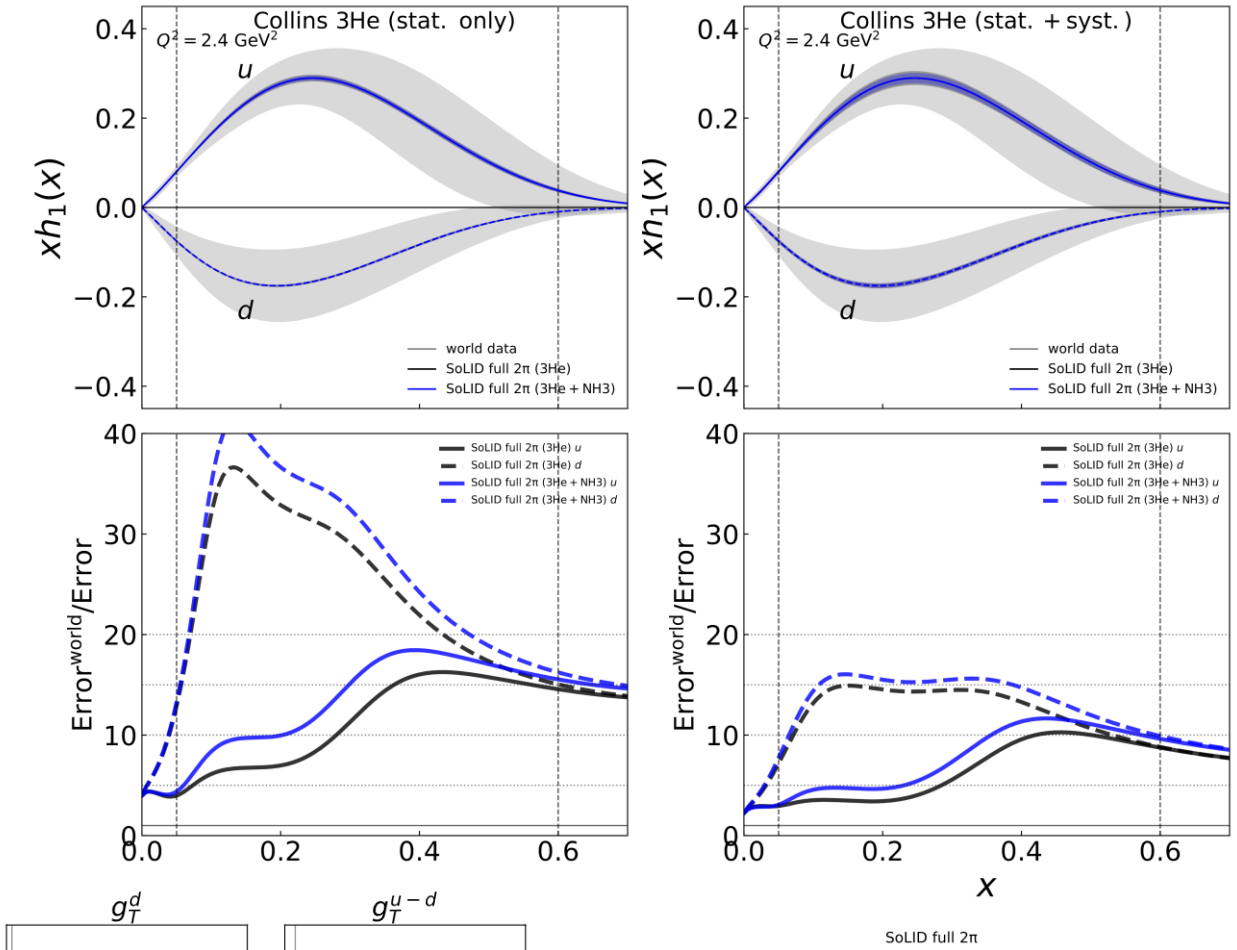


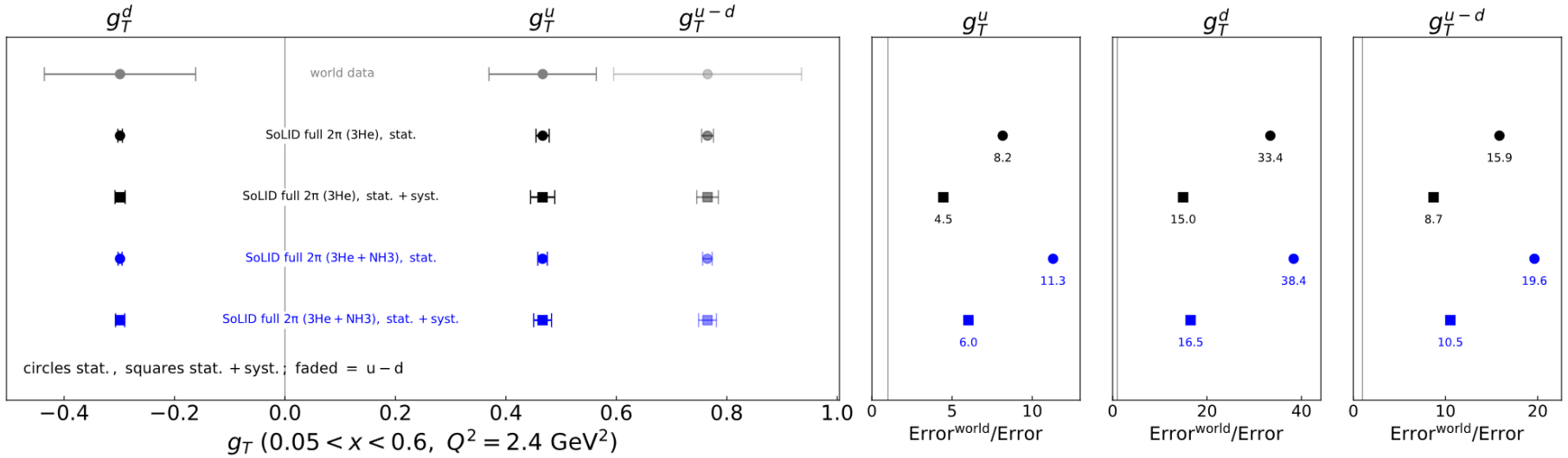


backup

SoLID full SIDIS, Transversity

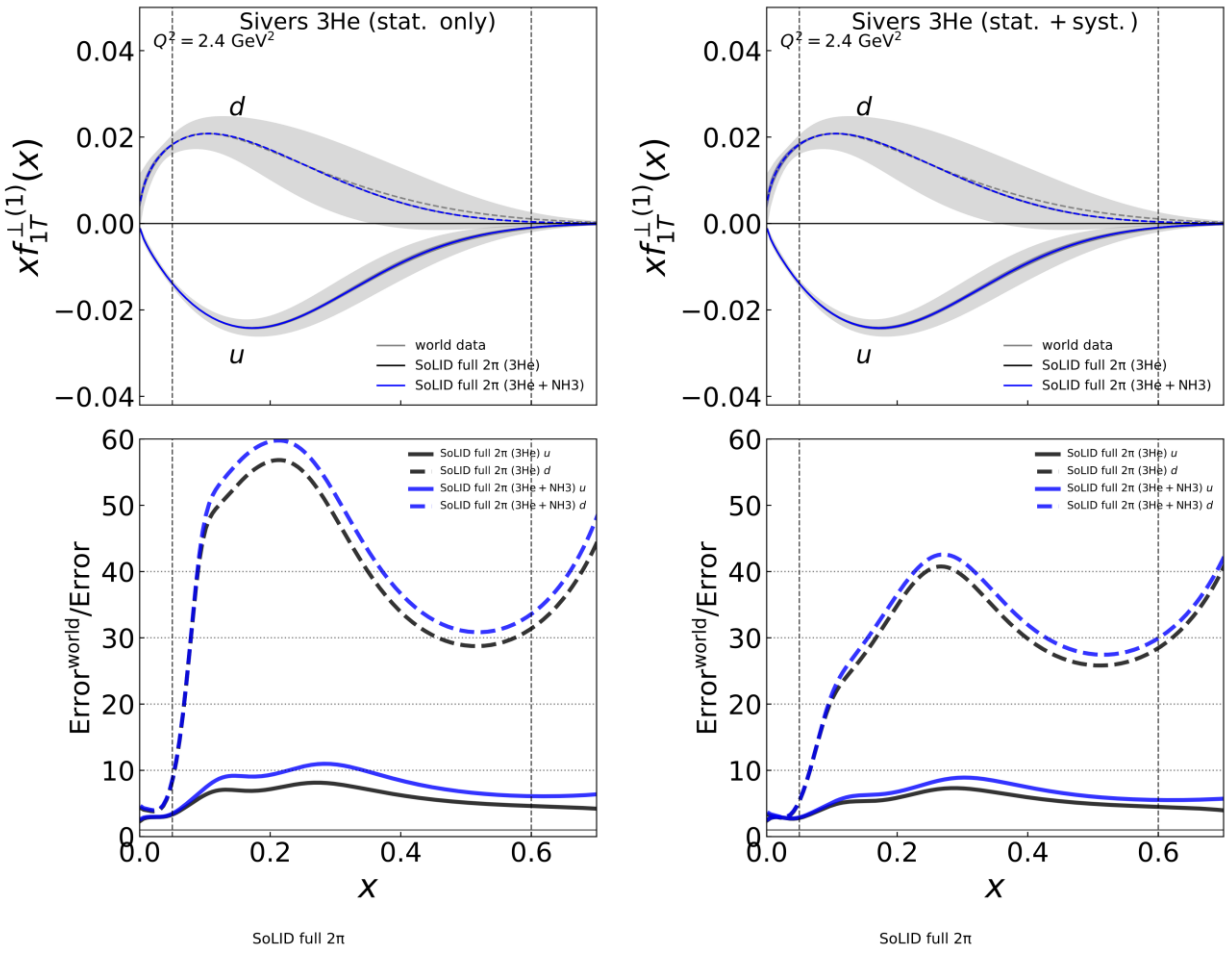
- Compare TMD fitting error for SoLID full He3 and NH3





SoLID full SIDIS, Sivers

- Compare TMD fitting error for SoLID full He3 and NH3



SoLID Lite option consideration

- General
  - Less detector coverage means less trigger rate below daq limit
  - background for LA are not limited, and the limit is for GEM occupancy at most inner radius of FA
  - a rough guideline, detector cost reduce to 30%
- Jpsi setup
  - For decay pair, LA is critical for physics coverage and FA adds more kinematic reach
  - If full LA, increase lumi by 5x, roughly factor 2 loss in counts and less coverage
  - If full LA + some FA, increase lumi by 2x, roughly factor 3-4 loss in counts but same coverage
- DDVCS setup
  - For e-, LA is more important than FA. muon coverage to be explored
  - Best as run group with jpsi
- SIDIS He3
  - Need 180 phi detector symmetry to minimize systematic uncertainty.
  - FA is critical to have hadron detection
  - If 4segment of 24deg sector for both FA and LA, increase lumi by 4x, roughly factor 3-5 loss in counts but same coverage
  - If further adding full LA, increase lumi by 4x, more coverage at higher Q2 and x
- SIDIS NH3
  - No need of 180 phi detector symmetry because target transverse field breaks it
  - FA is critical to have hadron detection
  - Limit is on beam current 100nA which the target can take
  - reuse He3 setup or rearrange? Need study with phi cut
- PVDIS
  - More coverage more counts
  - daq may not be the limit, but beam current is? and tracking?

SoLID and SBS kinematics

SBS SIDIS He3 2026 PAC update

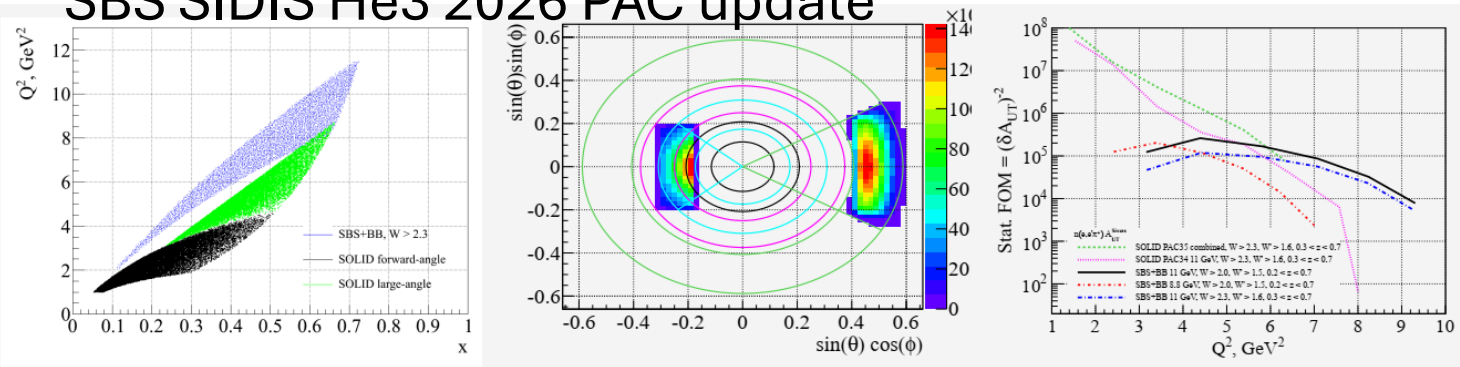
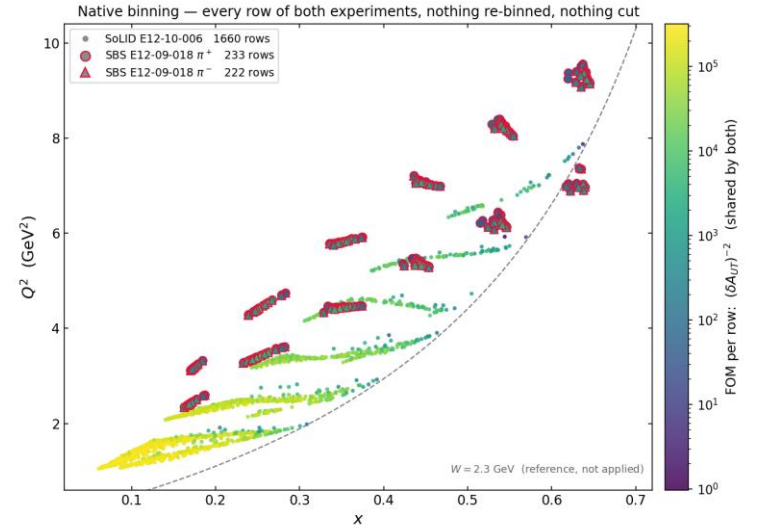


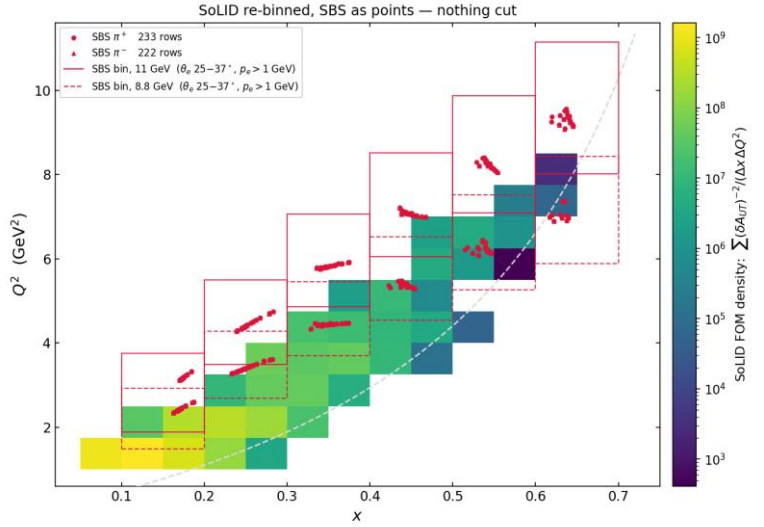
FIG. 3. Comparison between E12-09-018 and SoLID (^{3}He) in terms of x, Q^2 coverage at 11 GeV (left), polar and azimuthal angular acceptance (middle), and statistical figure-of-merit (right) as a function of Q^2, as presented to PAC38 [1]. In the middle plot, the green (cyan) circles indicate the BigBite (SBS) polar angle acceptance, with corresponding lines from the origin indicating the respective azimuthal coverages (around the beamline). The color scale is proportional to the distribution of DIS electrons (SIDIS hadrons) within the two-arm acceptance. The pink (black) circles indicate the polar-angle coverage of the SoLID large-angle (forward-angle) detectors, with approximate 2π azimuthal coverage. The right-hand plot shows figure-of-merit comparisons between SoLID and E12-09-018 as a function of Q^2.

- Beam time
  - SBS has 40/20 day, SoLID has 48/21 days, at 11GeV/8.8GeV respectively
- Beam current
  - SBS has 40uA, SoLID has 15uA
- target length
  - SBS has 60cm, SoLID has 40cm
- Target pol in beam
  - SBS 60%, SoLID 60%
- Angle
  - SBS e- theta 25-37deg by BB, hadron theta around 14deg by SBS

- At same beam energy, SoLID and SBS don't overlap in Q2 vs x
- The kinematic plots on the right will be remade with scattered points instead of binned data



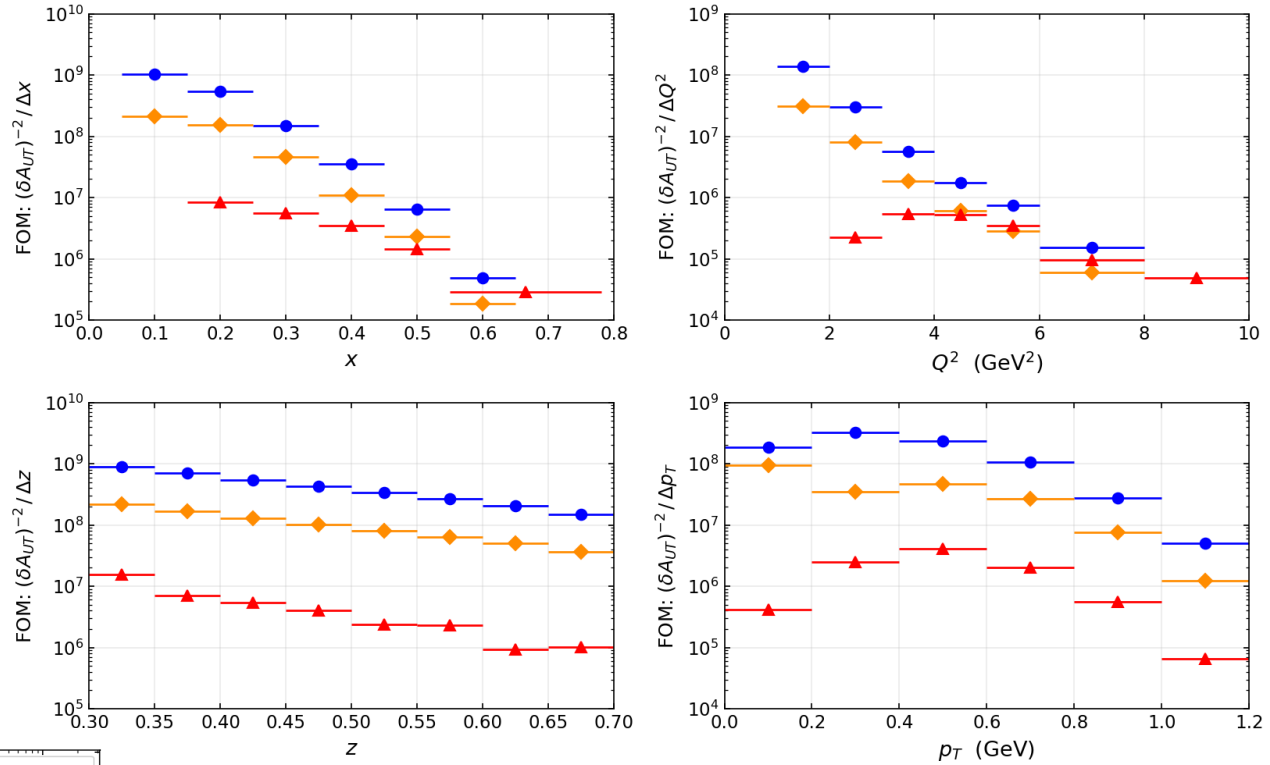
FOM for both; the crimson edge marks SBS. SoLID: adaptive bins filling the plane. SBS: 13 (x, Q^2) cells, each streak one cell spread by its (z, p_T)

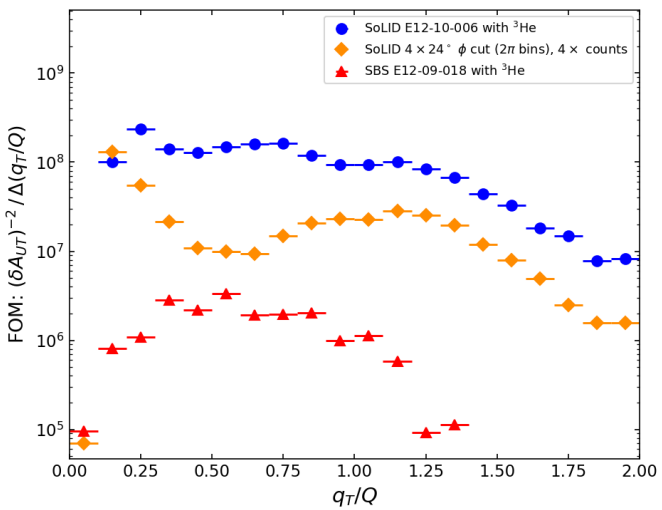


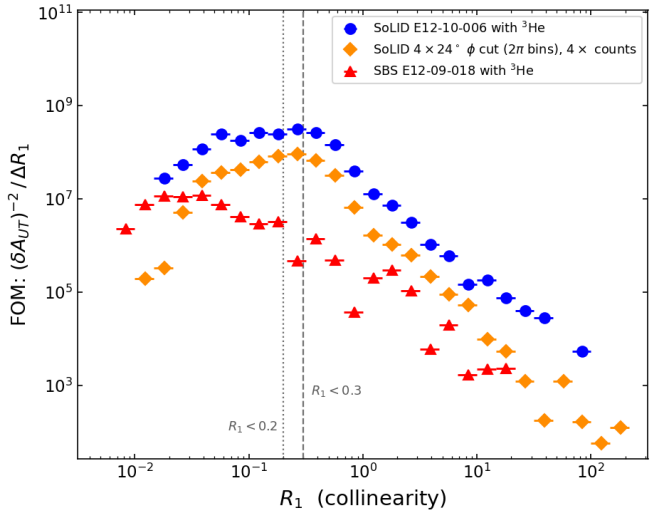
SoLID on the 0.05 x 0.75 grid as a density; SBS rows at their own positions, no FOM shown. Boxes are the SBS cells: x in 0.1 steps, Q^2 from the $\theta_e = 25 - 37°$ and $p_e > 1$ GeV acceptance at each beam energy. $W = 2.3$ GeV drawn for reference, not applied.

SoLID and SBS kinematics

- q_T = P_t/z = P_H/z
  - P_t defined in lab frame, target nucleon at rest
  - P_H defined in Breit frame, virtual photon at rest, target nucleon and hadron opposite
- The kinematic plots will be remade with scattered points instead of binned data



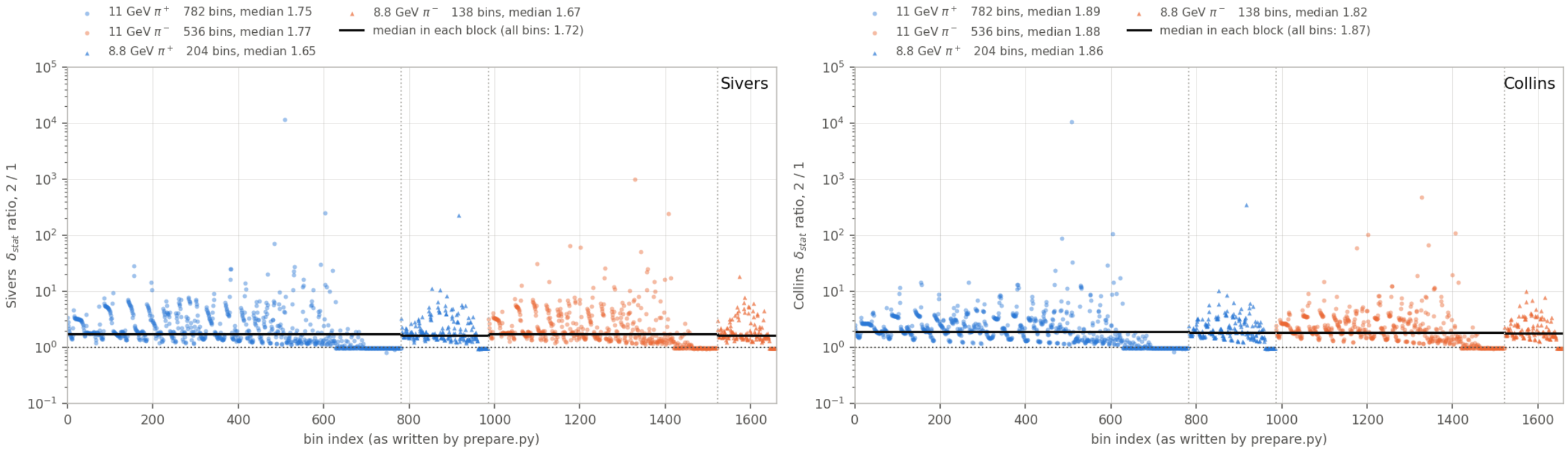




statistical errors only
$W > 2.3$ GeV, $W' > 1.6$ GeV, $0.3 < z < 0.7$, $1 < Q^2 < 8$ GeV^2, $p_T < 1.6$ GeV

SoLID full and lite stat error comparison

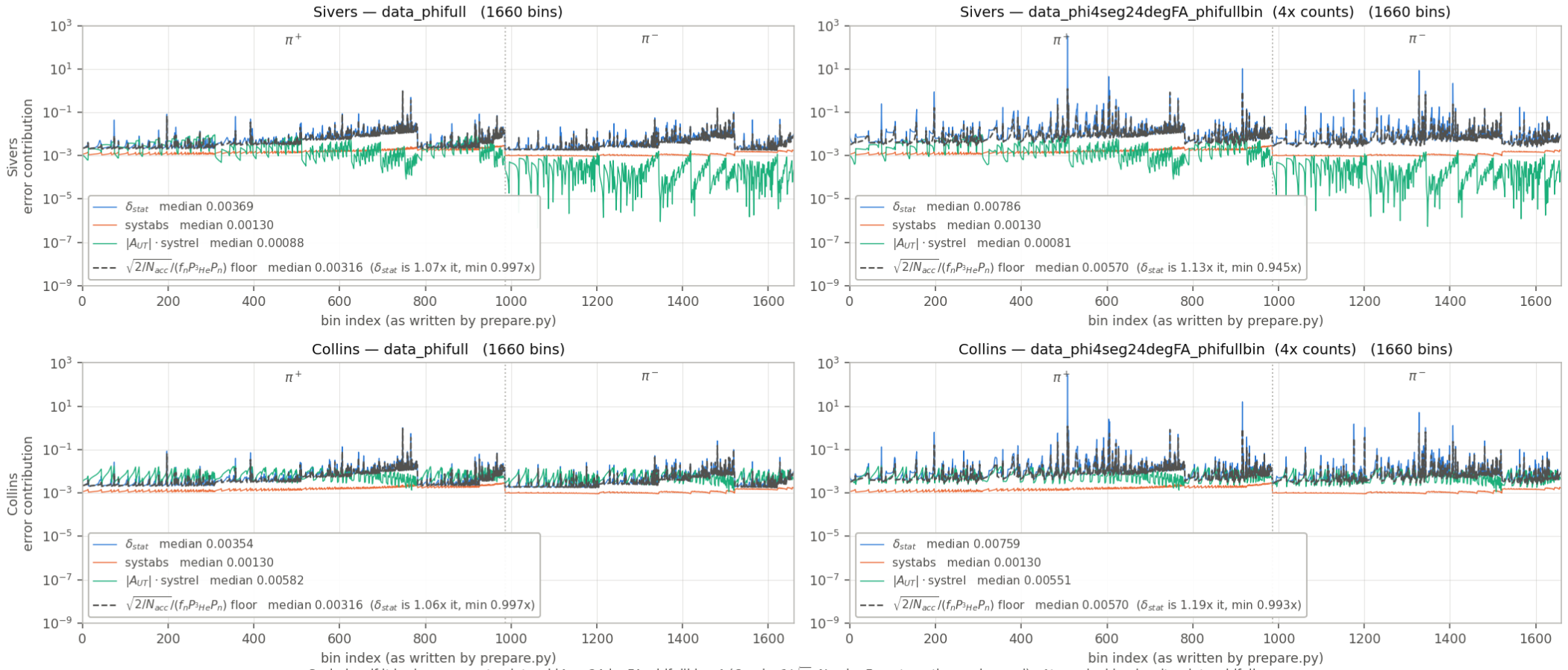
Statistical error ratio per bin, all bins — 2 = data_phi4seg24degFA_phifullbin (4x counts) over 1 = data_phifull (1660 shared bins)
below the dotted line the second configuration is the more precise; why each bin sits where it does: README, 'Why the statistical error differs'



Scaled as if it had more counts: data_phi4seg24degFA_phifullbin x4 (δ_{stat} by $1/\sqrt{F}$, N_{acc} by F, systematics unchanged). At nominal luminosity: data_phifull.
δ_{stat} and systabs both carry the same $1/(f_n \cdot 0.6 \cdot 0.86)$ scaling: kinematic-dependent dilution f_n, target polarisation $P_{^3He} = 0.6$, effective neutron polarisation $P_n = 0.86$.
$|A_{UT}| \cdot$ systrel does not — systrel is the quadrature of the relative uncertainties alone (3% target pol, 5% nuclear, 2.5% radiative, 3% diffractive meson, 0.2% random coincidence).

SoLID full and lite stat error comparison

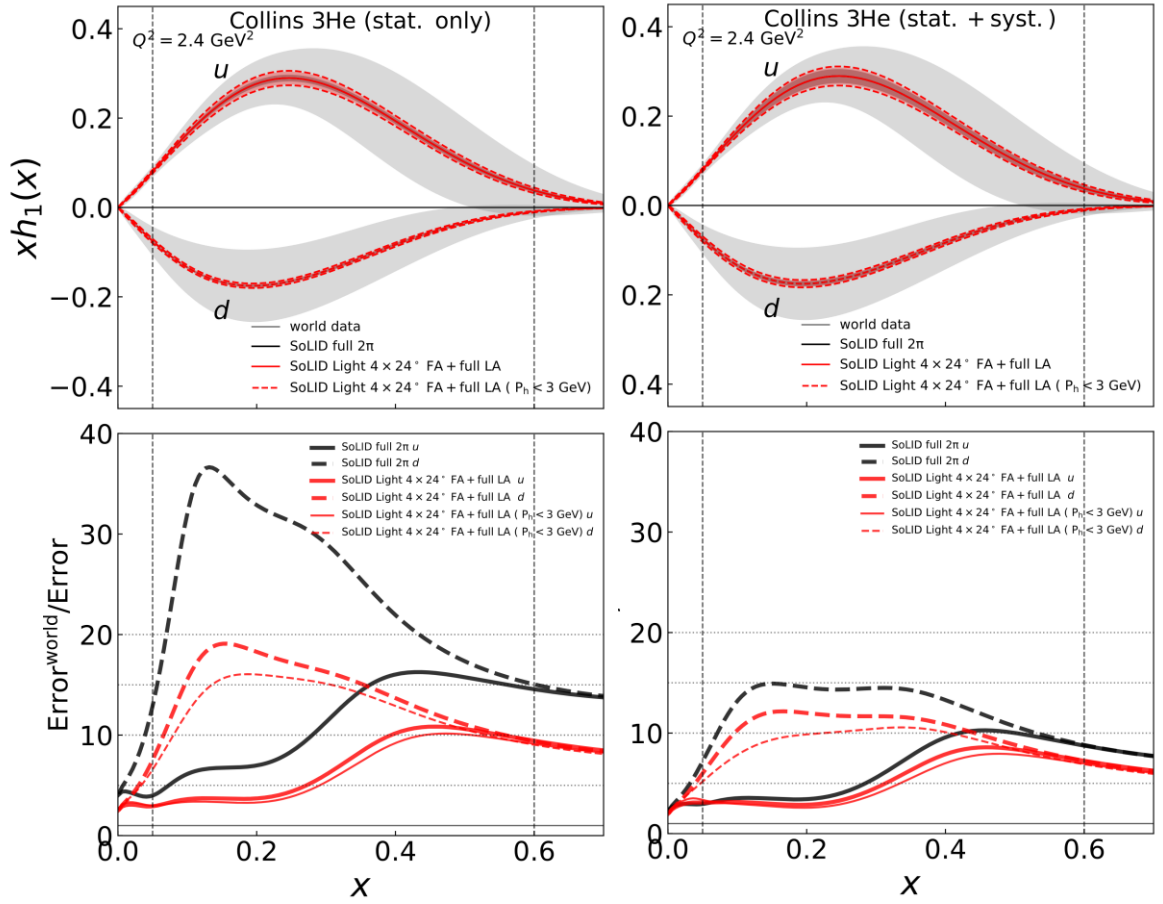
The three terms of error_tot, per bin — $error_tot^2 = \delta_{stat}^2 + systabs^2 + (A_{UT}\, systrel)^2$
absolute values; one shared log axis 1e-09-1e+03 covering every panel, nothing clipped (the bottom decades are empty, for the legend)



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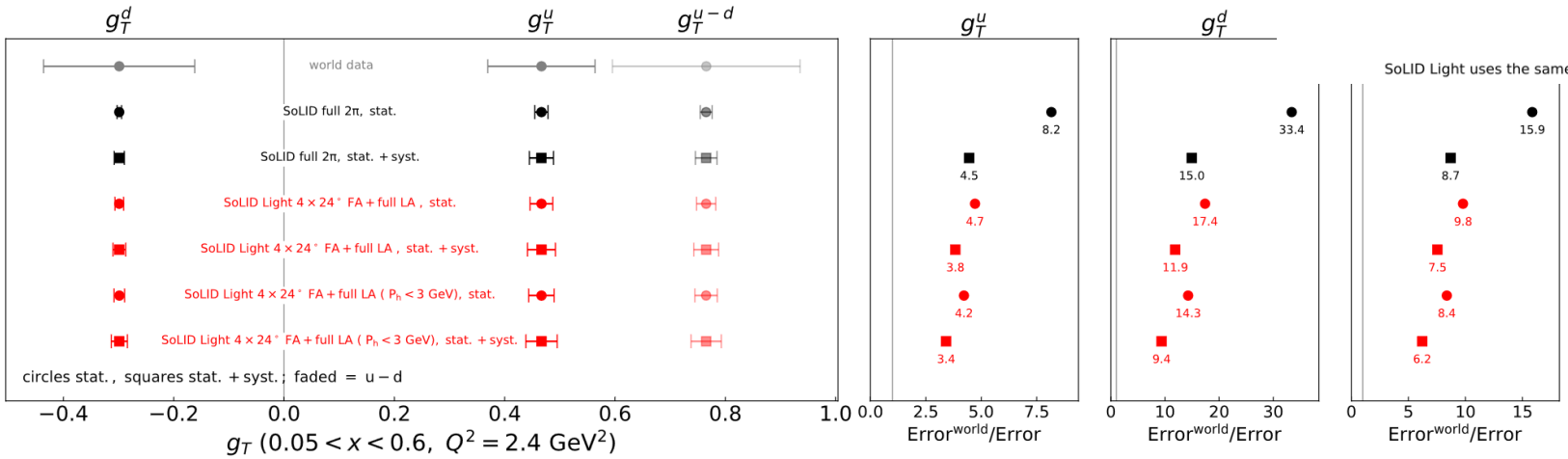
SoLID lite SIDIS He3, Transversity

- Compared with SoLID full with same binning for stat error only
- Assume 4x lumi, the same as SBS target and current
- GEM with segmented strips and adjustment to reduce occupancy
- Error ratio reduced by ~2x and P<3GeV cut impact is small



SoLID Light uses the same bins as full 2π, and 4× lumi

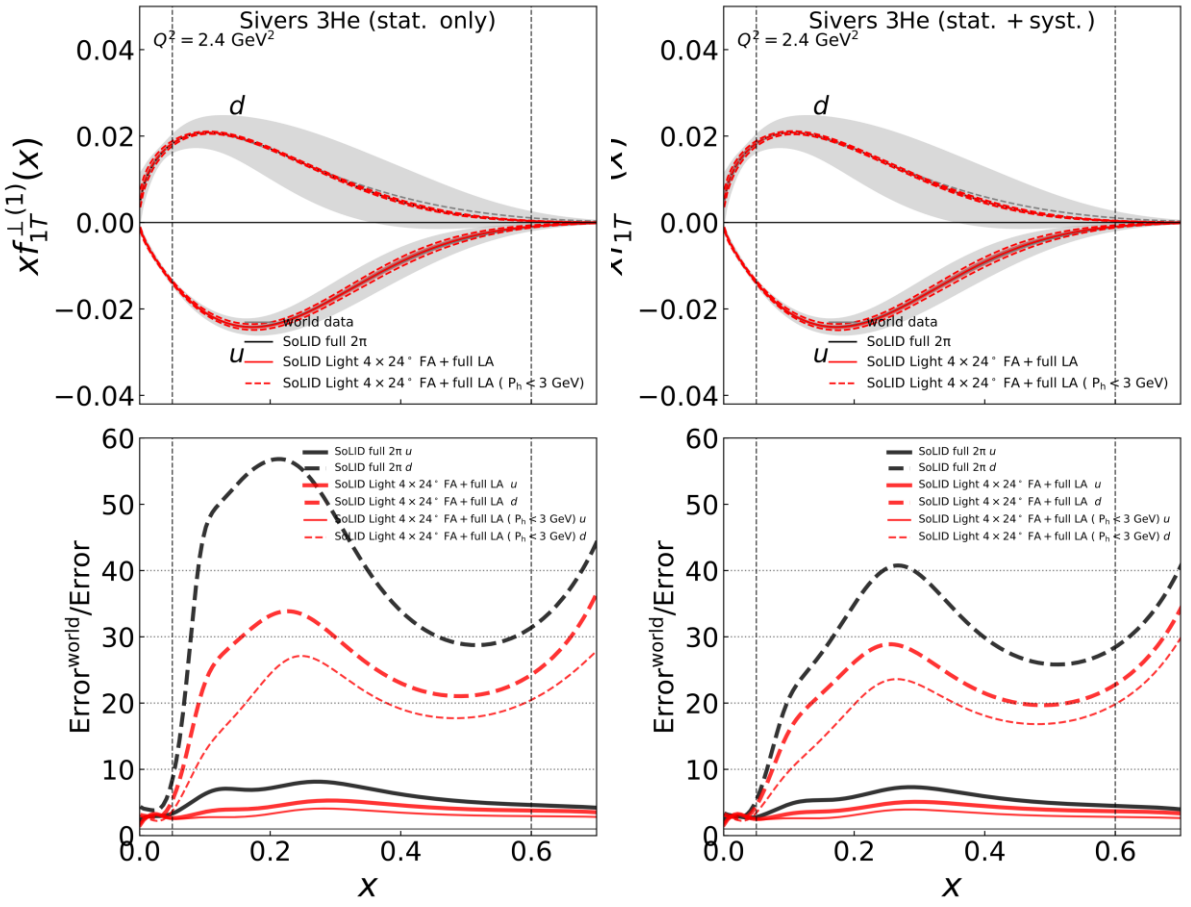
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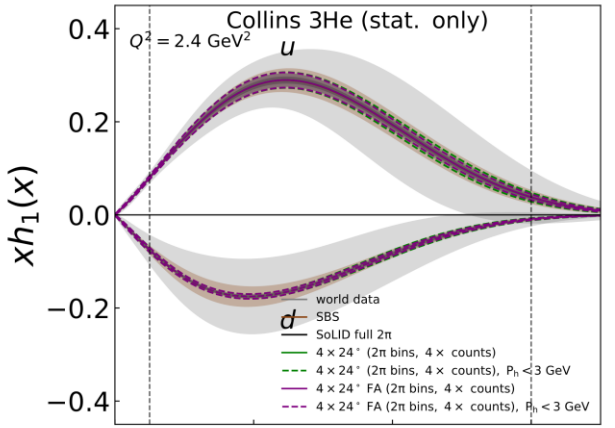


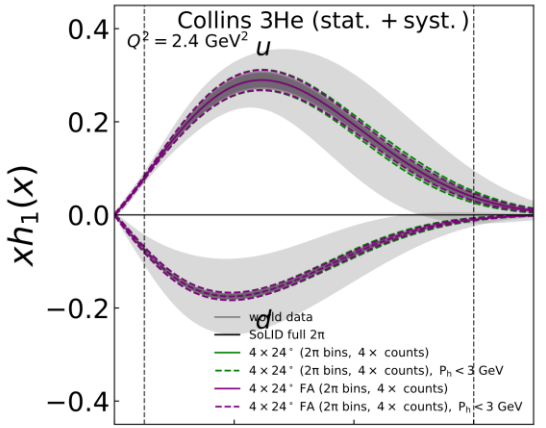
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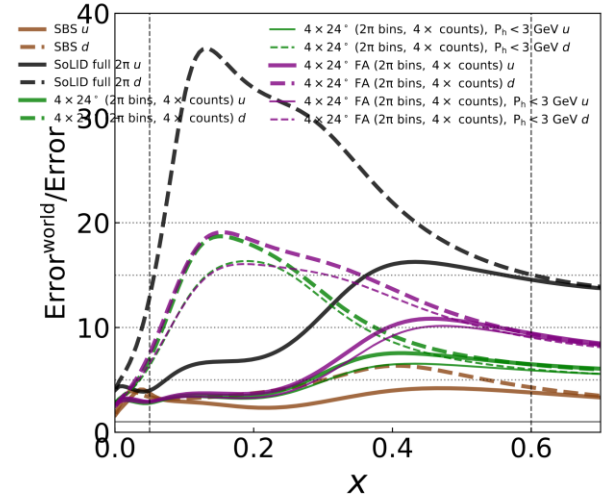
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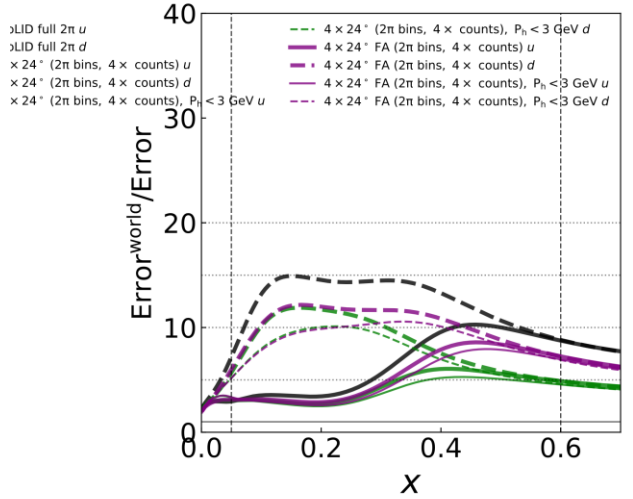
SoLID lite SIDIS He3 (P_h<3GeV)

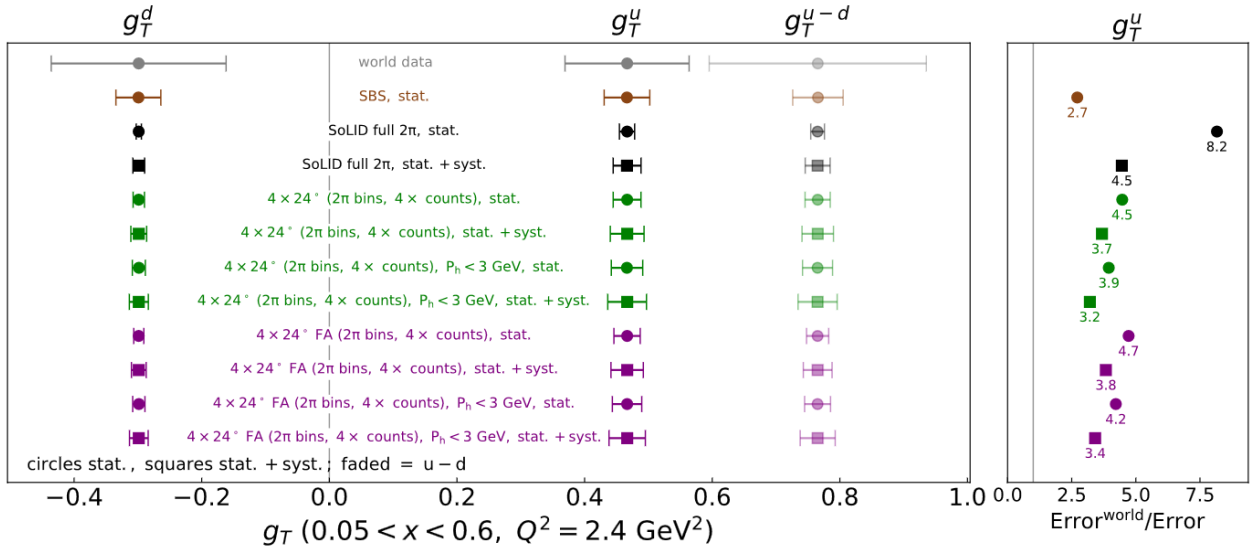
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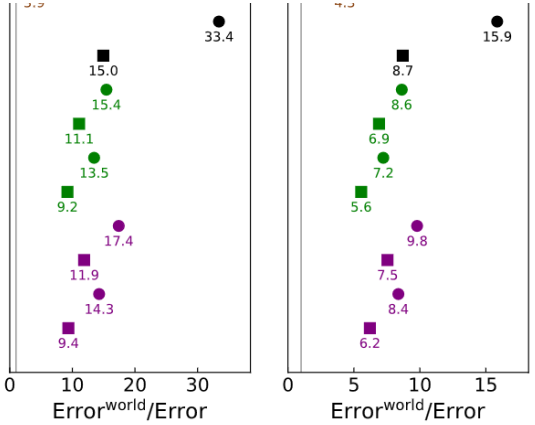






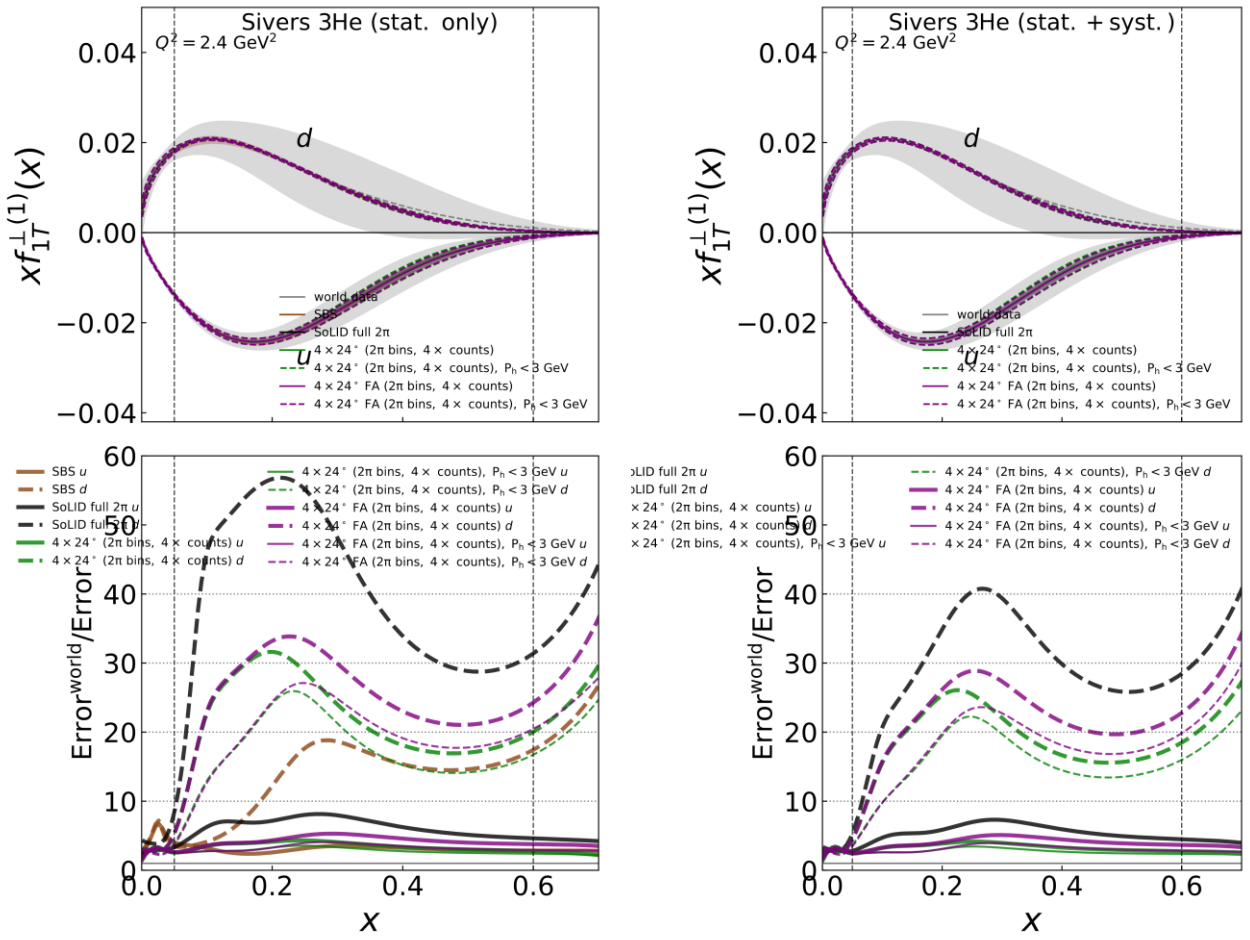






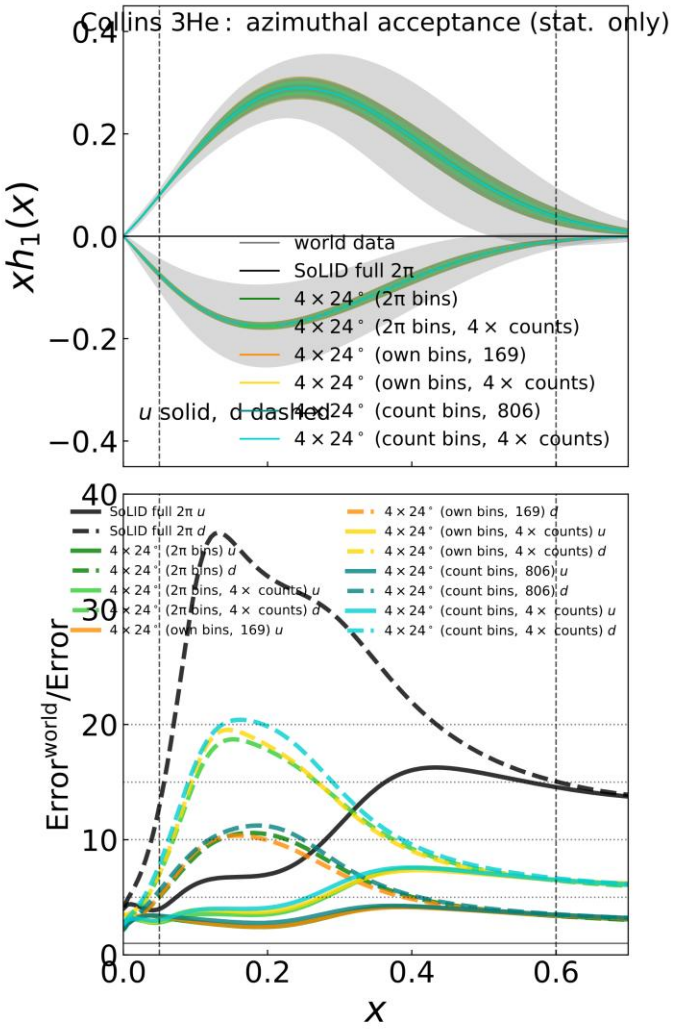
SoLID lite SIDIS He3 (P_h<3GeV)

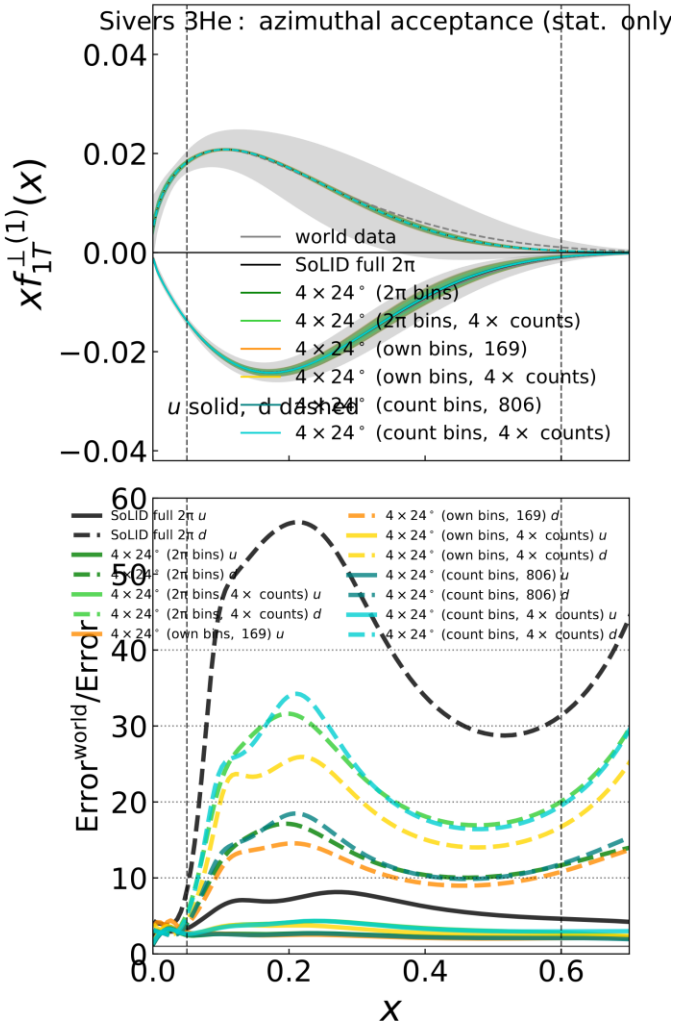
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SoLID lite x4counts and binning

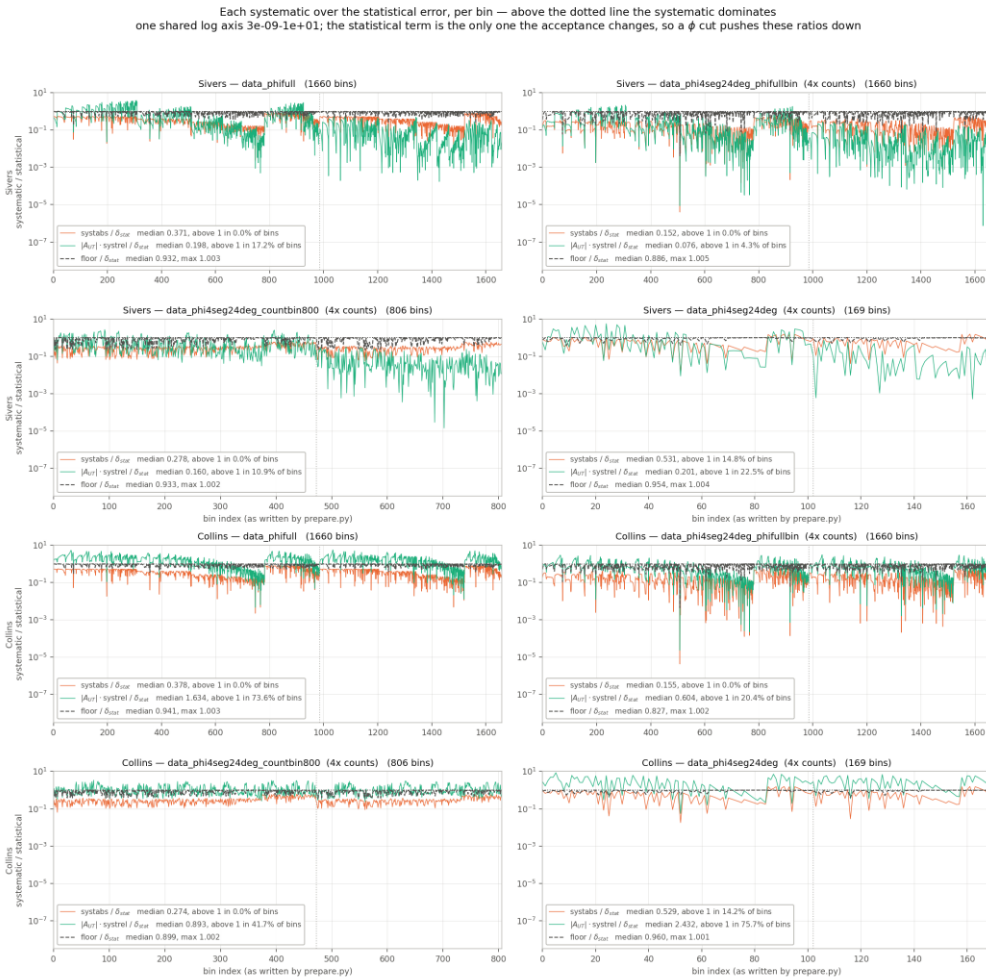
- Increase beam current and target length for SoLID lite to match SBS. It will have 4x luminosity comparing to SoLID full pol 1e36/cm2/s
- x4counts will improve error ratio by roughly 80%
- Different binning have similar result

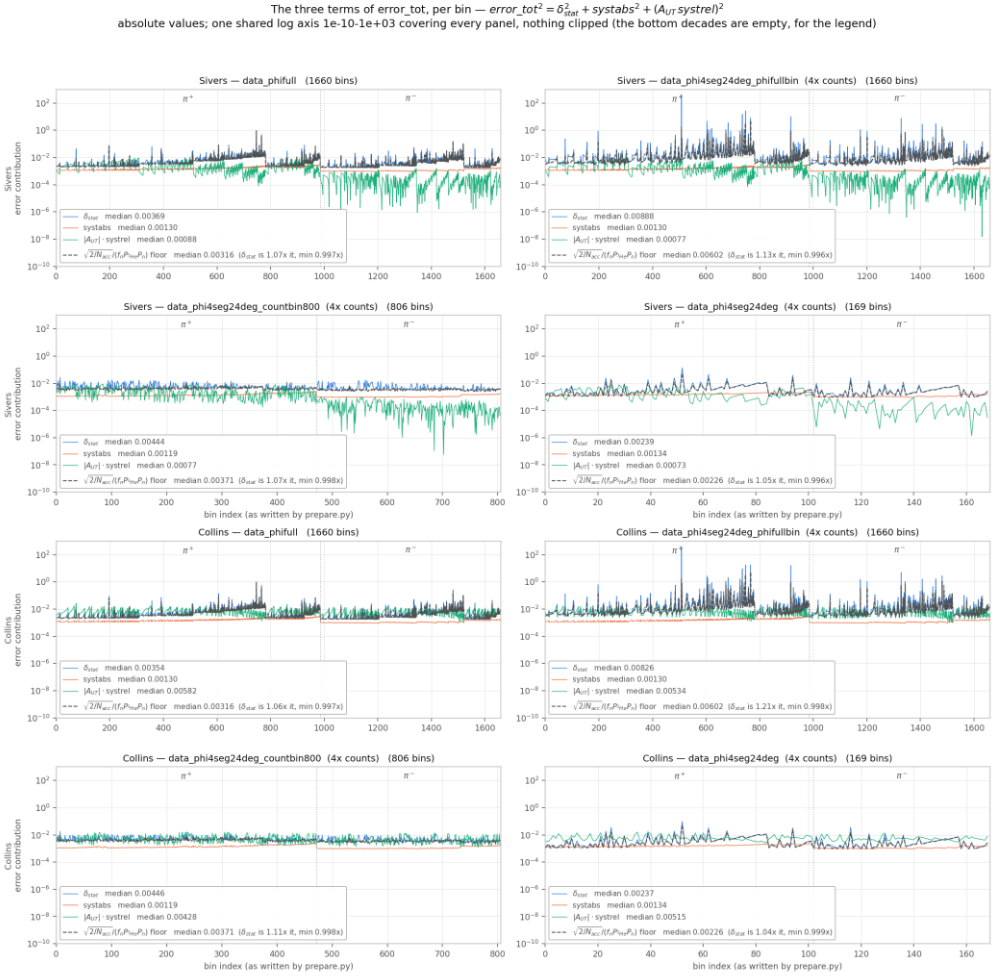




SoLID error budget x4counts

- Different binning choice to match errors of stat, syst_abs, AUT*syst_rel
- Currently we use same bining condition for both collins and sivers. but the model has AUTsivers<AUTcollins in general and different for pi+ and pi-. So it may be best to bin them differently in the future and understand model depandance
- Too few bins won't show true distribution, too many bins would make stat too large than syst
- Currently syst is assumed to be bin independent. So it has 1/N_bins dilution for error propagation when binning changes and makes fitting with stat+syst results can't be compared over binning changes. It would need to consider bin correlation in the future
- I hope Tianbo's new fitting code will improve on binning choice and bin correlation



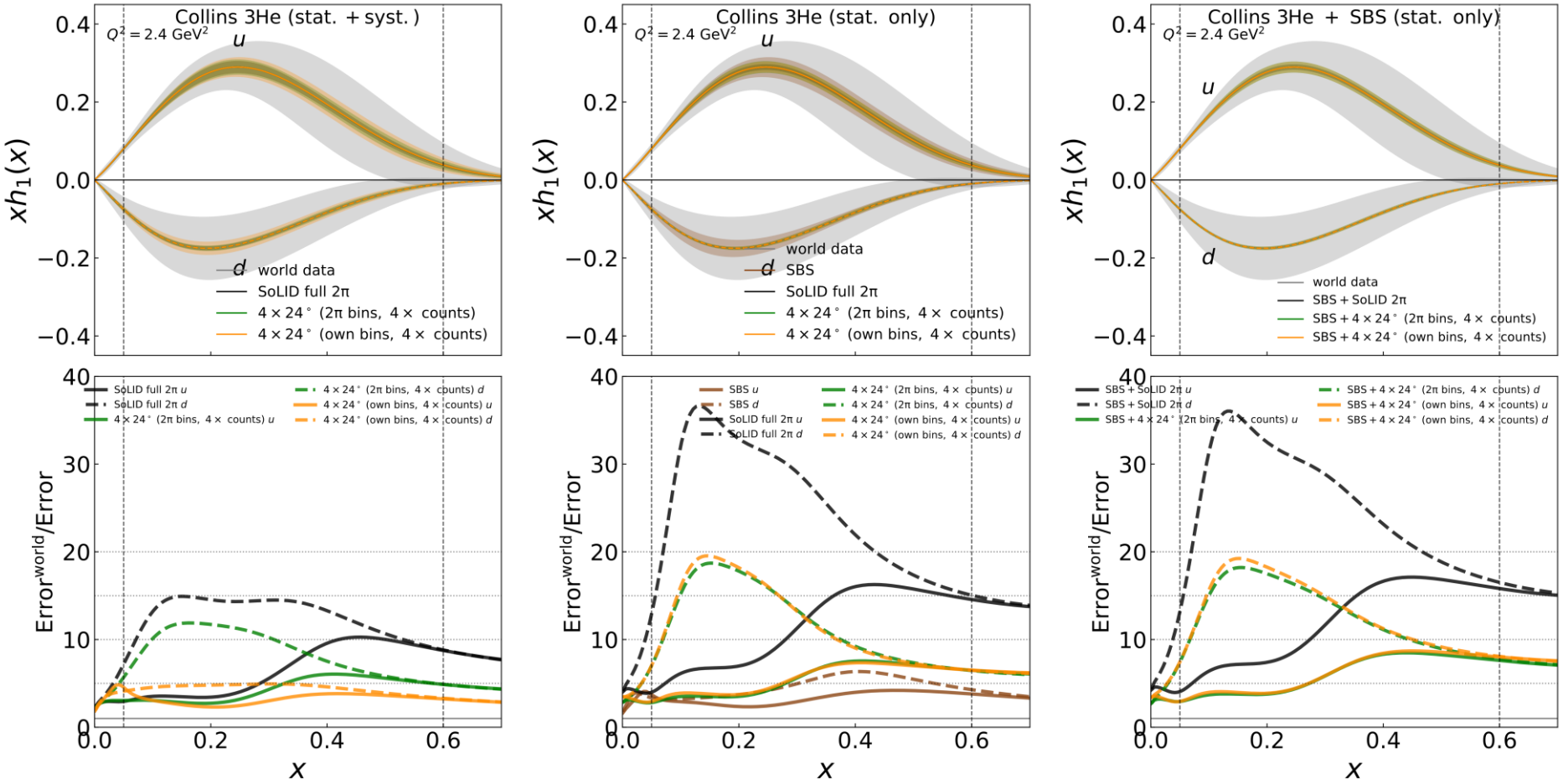


SoLID and SBS, Transversity

- The transversity and sivers models used only have parameters related to x, the fitting error ratio doesn't depend on Q2
- SBS high Q2 and x data for transversity are suppressed by depolarization factor epsilon^2. This is not true for sivers which doesn't have depolarization factor

separated

Combined

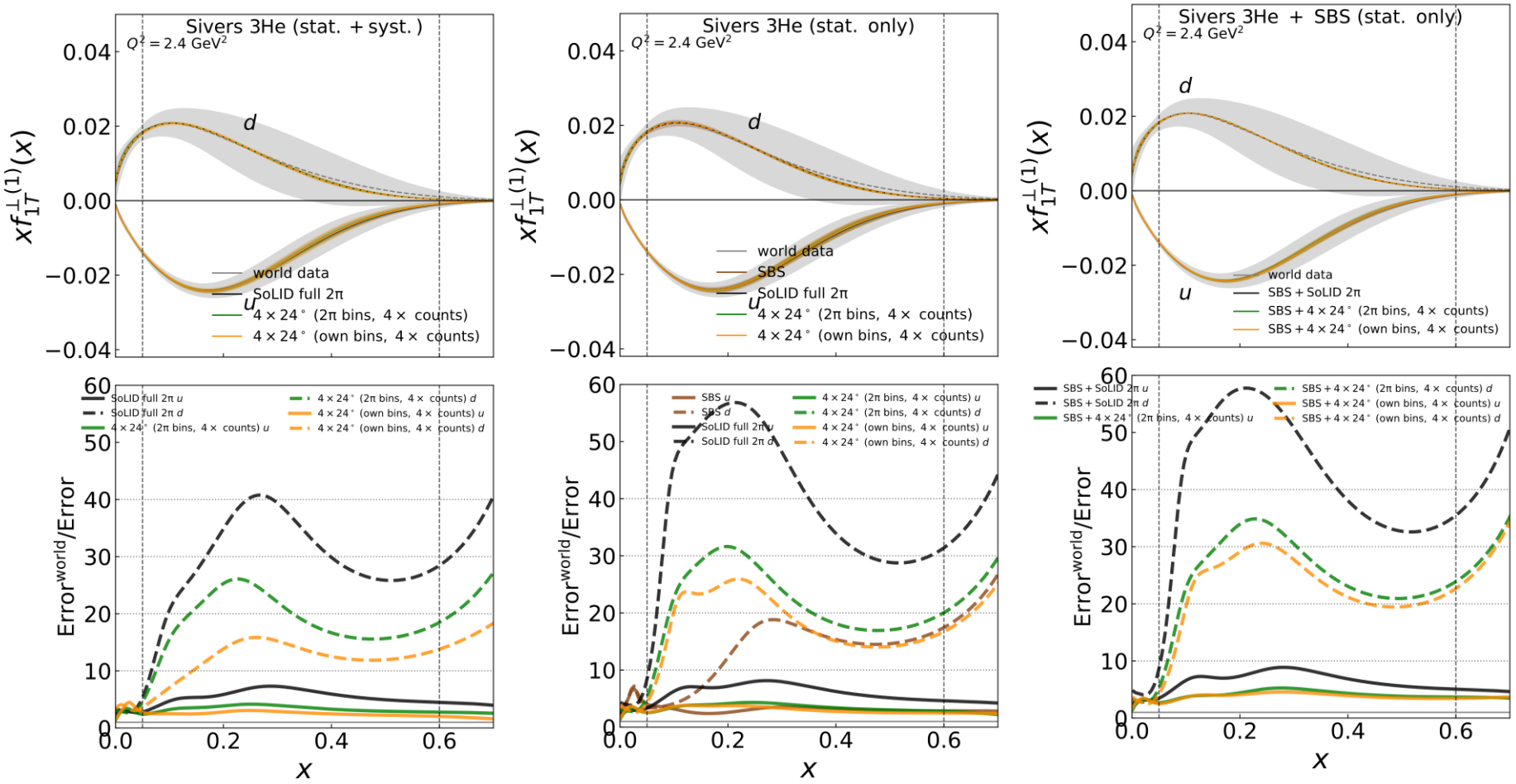


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SoLID and SBS, R1<0.3

