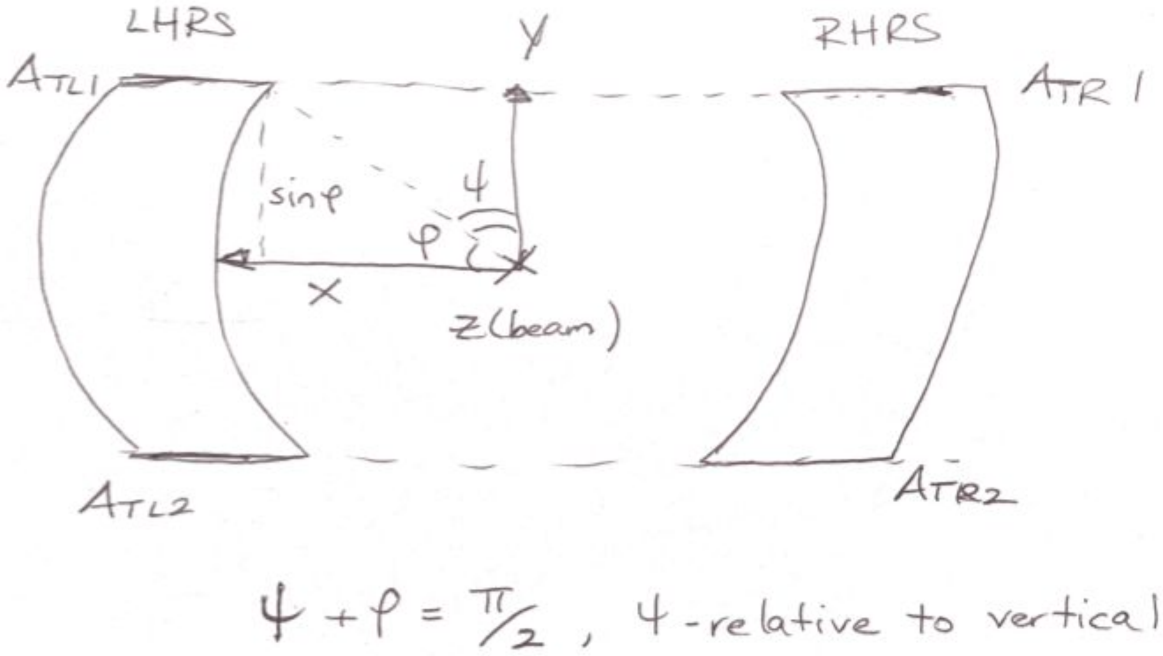
Intro to A_T Corrections

A_T Detector Picture



Four A_T detectors to monitor transverse (horizontal) polarization (Up/Down)

Azimuthal Angle

Vertical $A_T \propto \cos\varphi$ Horizontal $A_T \propto \sin\varphi$

φ is azimuth relative to horizontal, Ψ is azimuth relative to vertical

$$\cos(\Psi) = \sin(\varphi) \equiv \frac{\pm\theta_{tg}}{\sqrt{\theta_{tg}^2 + \sin^2\theta_o \pm 2\phi_{tg}\tan\theta_o + \sec^2\theta_o\phi_{tg}^2}}$$

$$\sin(\Psi) = \cos(\varphi) \equiv \frac{\sqrt{\sin^2\theta_o \pm 2\phi_{tg}\tan\theta_o + \sec^2\theta_o\phi_{tg}^2}}{\sqrt{\theta_{tg}^2 + \sin^2\theta_o \pm 2\phi_{tg}\tan\theta_o + \sec^2\theta_o\phi_{tg}^2}}$$

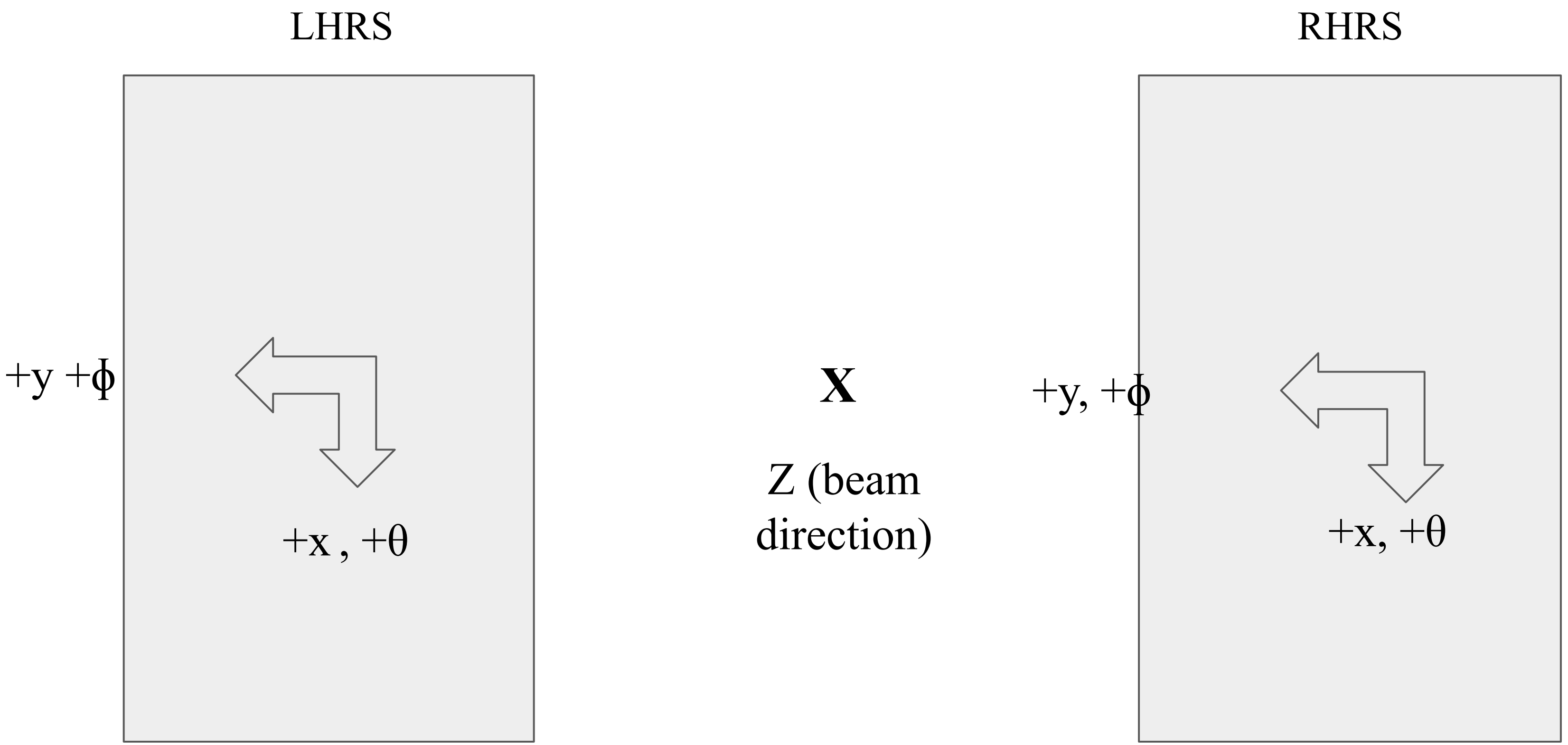
+ sign for LHRS, - sign for RHRS

θ_o - spectrometer central angle

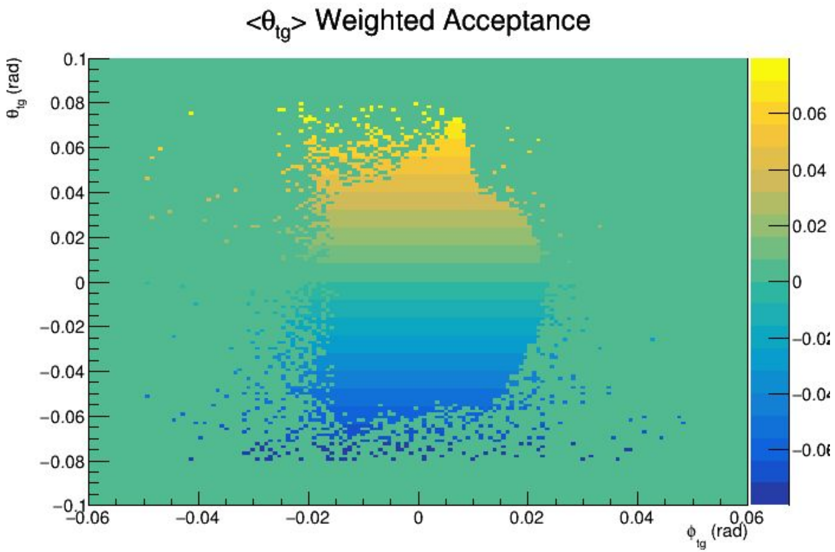
θ_{tg} - vertical angle , ϕ_{tg} - horizontal angle

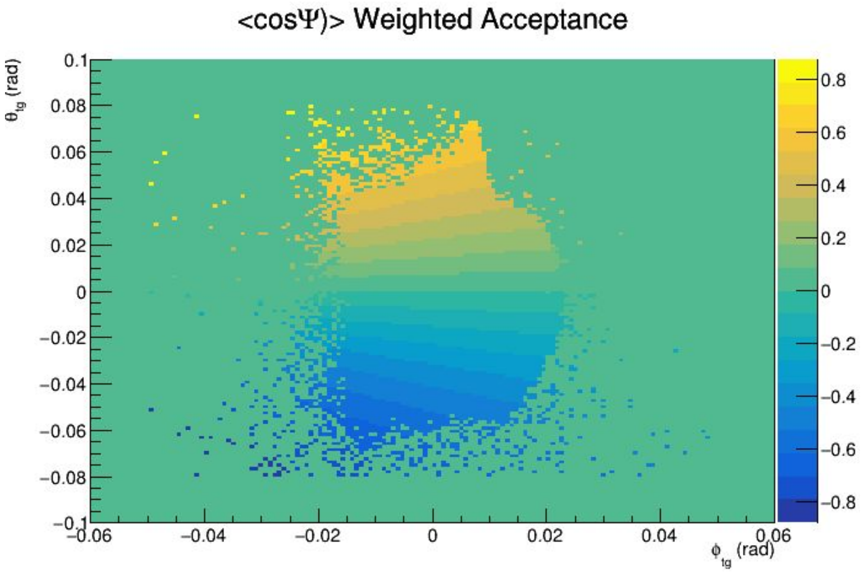
cos (ψ) correlated with θ_{tg} and sin(ψ) correlated ϕ_{tg}

Transport Coordinate System



Acceptance

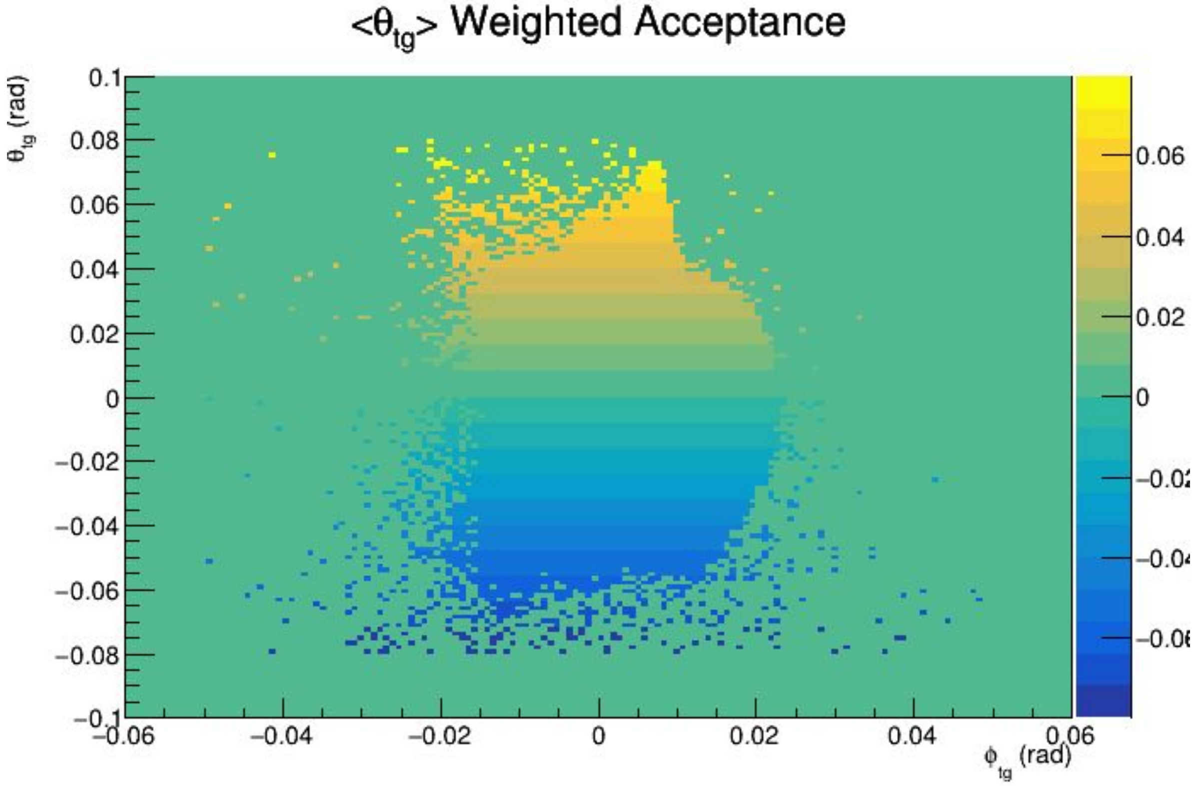




Toward negative φ_{tg} is beam center

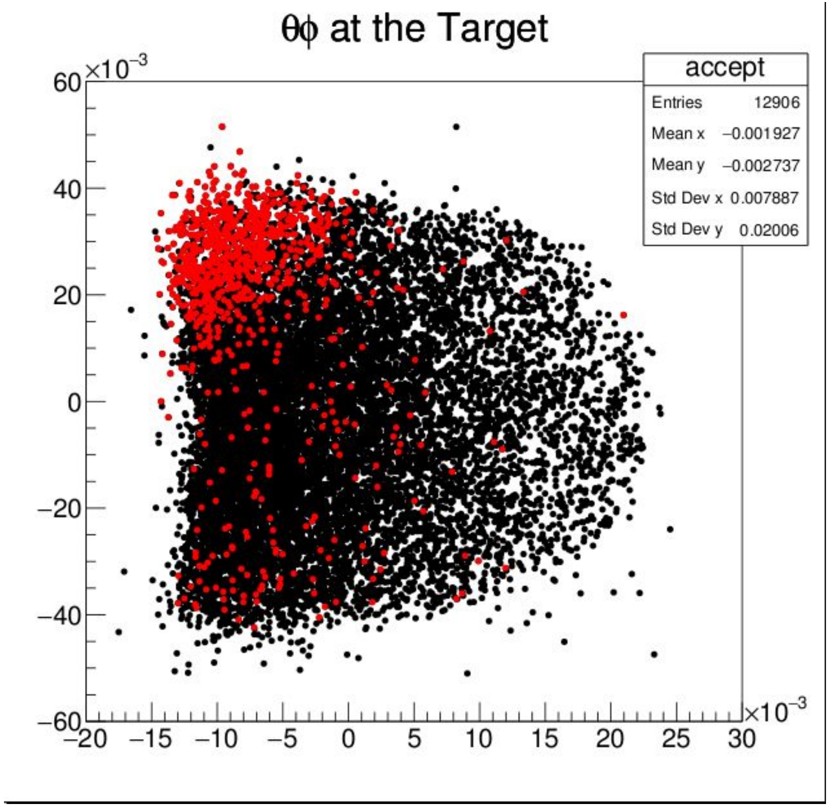
θ_{tg} up/down (Horizontal Pol), φ_{tg} left/right (Vertical Pol)

Acceptance

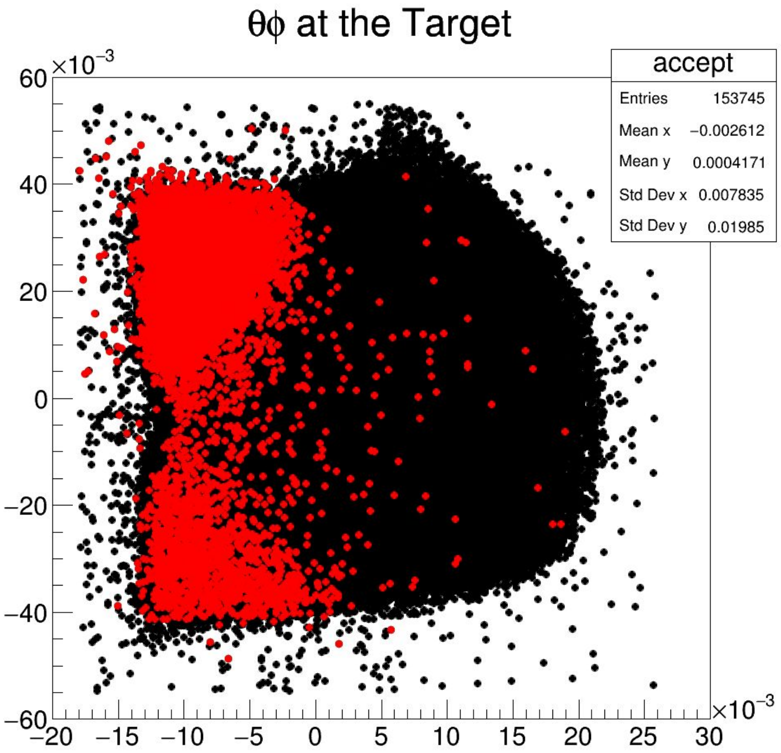


- Events at the top/bottom are A_T enhanced. Those events are more sensitive to A_T compared to events at the center of the acceptance.
- **At main detector, would like $\langle\theta_{tg}\rangle = 0$. Main detectors not sensitive to horizontal A_T**
- A_T detectors to accept events at top/bottom of acceptance.

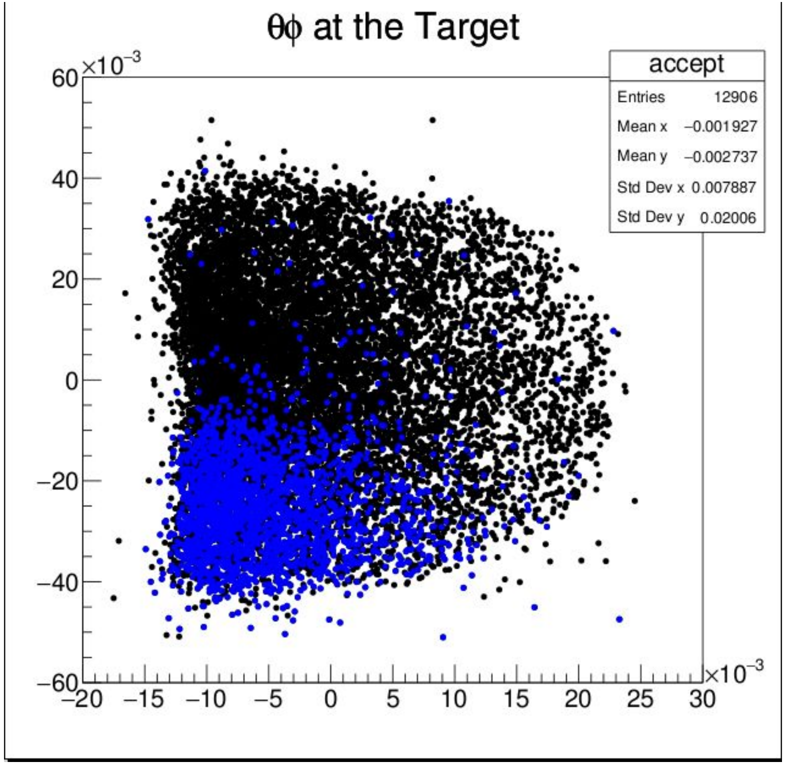
PREX (LHRS) A_T In



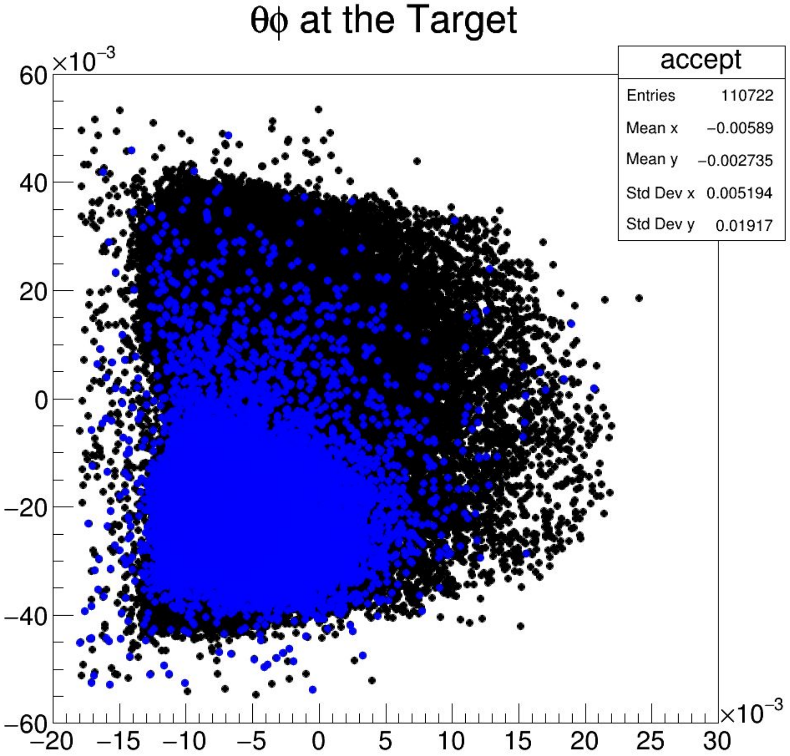
CREX (LHRS) A_T In



PREX (LHRS) A_T Out



CREX (LHRS) A_T Out



Definitions

Integrating Mode

$A_{m,usl}$ - reg_asym_usl_mean

$A_{PV,usl} = A_{m,usll}$ - $A_{TV,usl}$ - $A_{TH,usl}$

Same expressions for upstream right and A_T detectors as well as various combinations

Counting Mode

A_T Ansatz $A_n = \frac{A}{Z}\hat{A}_n\sqrt{Q^2}$

$$A_{PV,usl} = P_L \hat{A}_{PV} Q^2_{usl}$$

$$A_{TV,usl} = P_V \frac{A}{Z}\hat{A}_n\sqrt{Q^2_{usl}} < \phi_{tg} >$$

$$A_{TH,usl} = P_H \frac{A}{Z}\hat{A}_n\sqrt{Q^2_{usl}} < \theta_{tg} >$$

Q^2, $<\theta>$, $<\phi>$ are from counting

Hatted quantities for dimensional analysis

Vertical Transverse Polarization

Perfect spectrometer has $\cos(\varphi) = 1$ on LHRS and -1 on RHRS

Purely vertically polarized beam, $A_{m,usl} \sim -A_{m,usr}$

$<\phi_{tg}>_{usl}$ and $<\phi_{tg}>_{usr}$ have opposite sign

$$A_{m,usl} = P_L \hat{A_{PV}} Q^2_{usl} + P_V \frac{A}{Z} \hat{A}_n < \phi_{tg} >_{usl} + P_H \frac{A}{Z} \hat{A}_n < \theta_{tg} >_{usl}$$

$$A_{m,usr} = P_L \hat{A_{PV}} Q^2_{usr} + P_V \frac{A}{Z} \hat{A}_n < \phi_{tg} >_{usr} + P_H \frac{A}{Z} \hat{A}_n < \theta_{tg} >_{usr}$$

We will take the average and double difference

Vertical Transverse Polarization

$$Q^2_{usavg} = \frac{Q^2_{usl} + Q^2_{usr}}{2}, \quad Q^2_{usdd} = \frac{Q^2_{usl} - Q^2_{usr}}{2}$$

$$A_{m,usavg} = P_L \hat{A_{PV}} Q^2_{usavg} + P_V A_n \frac{<\phi_{tg}>_{usl} + <\phi_{tg}>_{usr}}{2} + P_H A_n \frac{<\theta_{tg}>_{usl} + <\theta_{tg}>_{usr}}{2}$$

$$A_{m,usdd} = P_L \hat{A_{PV}} Q^2_{usdd} + P_V A_n \frac{<\phi_{tg}>_{usl} - <\phi_{tg}>_{usr}}{2} + P_H A_n \frac{<\theta_{tg}>_{usl} - <\theta_{tg}>_{usr}}{2}$$

Term sensitive to P_H is suppressed in double difference.

If $Q^2_{usl} \neq Q^2_{usr}$, we must correct for it

Vertical Transverse Polarization

$$A_{m,usavg} =_L \hat{A_{PV}} Q^2_{usavg} + P_V A_n \frac{<\phi_{tg}>_{usl} + <\phi_{tg}>_{usr}}{2} + P_H A_n \frac{<\theta_{tg}>_{usl} + <\theta_{tg}>_{usr}}{2}$$

$$A_{m,usdd} - A_{PV,usdd} \approx P_V A_n \frac{<\phi_{tg}>_{usl} - <\phi_{tg}>_{usr}}{2}$$

Now we measured A_n for a purely vertically polarized beam so we have

$$A^T_{m,usavg} = P_V A_n \frac{<\phi_{tg}>_{usl} + <\phi_{tg}>_{usr}}{2}$$

$$A^T_{m,usdd} = P_V A_n \frac{<\phi_{tg}>_{usl} - <\phi_{tg}>_{usr}}{2}$$

$$\frac{A^T_{m,usavg}}{A^T_{m,usdd}} = \frac{<\phi_{tg}>_{usl} + <\phi_{tg}>_{usr}}{<\phi_{tg}>_{usl} - <\phi_{tg}>_{usr}} \equiv \xi$$

ξ is left/right apparatus asymmetry

Vertical Transverse Polarization

$$A_{m,usavg} =_L \hat{A_{PV}} Q^2_{usavg} + P_V A_n \frac{<\phi_{tg}>_{usl} + <\phi_{tg}>_{usr}}{2} + P_H A_n \frac{<\theta_{tg}>_{usl} + <\theta_{tg}>_{usr}}{2}$$

$$A_{m,usdd} - A_{PV,usdd} \approx P_V A_n \frac{<\phi_{tg}>_{usl} - <\phi_{tg}>_{usr}}{2}$$

$$\frac{A^T_{m,usavg}}{A^T_{m,usdd}} = \frac{<\phi_{tg}>_{usl} + <\phi_{tg}>_{usr}}{<\phi_{tg}>_{usl} - <\phi_{tg}>_{usr}} \equiv \xi$$

ξ measured in integrated mode. We cross check with counting data to show those measurements are within error

Vertical Transverse Polarization Correction

Correction to A_{PV} due to vertical transverse polarization

$$A_{TV,usavg} = A_{m,usdd,corr}\xi, \quad A_{m,usdd,corr} = A_{m,usdd} - A_{PV,usdd}$$

Magnitude of P_V given by

$$\frac{P_V}{P} = \frac{A_{m,usdd,corr}}{A^T_{m,usdd}}$$

$$A_{m.usl} - A_{TV,usl} = A_{PV,usl} + \mathbf{A_{TH,usl}}$$

$$A_{m.usr} - A_{TV,usr} = A_{PV,usr} + \mathbf{A_{TH,usr}}$$

Horizontal Transverse Polarization

Four A_T detectors to monitor transverse polarization

$$A_{m,atl1} = P_L \hat{A_{PV}} Q^2_{atl1} + P_V A_n < \phi_{tg} >_{atl1} + P_H A_n < \theta_{tg} >_{atl1}$$

$$A_{m,atl2} = P_L \hat{A_{PV}} Q^2_{atl2} + P_V A_n < \phi_{tg} >_{atl2} + P_H A_n < \theta_{tg} >_{atl2}$$

$$A_{m,atr1} = P_L \hat{A_{PV}} Q^2_{atr1} + P_V A_n < \phi_{tg} >_{atr1} + P_H A_n < \theta_{tg} >_{atr1}$$

$$A_{m,atr2} = P_L \hat{A_{PV}} Q^2_{atr2} + P_V A_n < \phi_{tg} >_{atr2} + P_H A_n < \theta_{tg} >_{atr2}$$

Different combinations can suppress the vertical transverse or vice versa

Recall that $<\phi>_{LHRS}$ opposite sign with $<\phi>_{RHRS}$

Horizontal Transverse Polarization (LHRS)

Recall that $<\phi>_{LHRS}$ opposite sign with $<\phi>_{RHRS}$

Recall that each A_T isolates events at top/bottom of acceptance

$<\theta_{tg}>_{atl1}$ and $<\theta_{tg}>_{atl2}$ have opposite signs

Consider double difference of A_Ts on LHRS (same for RHRS) - vertical transverse suppressed

$$A_{m,atldd} \approx P_L \hat{A_{PV}} \frac{Q^2_{atl1} - Q^2_{atl2}}{2} + P_H A_n \frac{<\theta_{tg}>_{atl1} - <\theta_{tg}>_{atl2}}{2}$$

$$A_{m,uslcorr} \equiv A_{m,usl} - A_{TV,usl} = P_L \hat{A_{PV}} Q^2_{usl} + P_H A_n < \theta_{tg} >_{usl}$$

Horizontal Transverse Polarization (LHRS)

$$A_{m,atldd} \approx P_L \hat{A_{PV}} \frac{Q^2_{atl1} - Q^2_{atl2}}{2} + P_H A_n \frac{<\theta_{tg}>_{atl1} - <\theta_{tg}>_{atl2}}{2}$$

$$A_{m,uslcorr} \equiv A_{m,usl} - A_{TV,usl} = P_L \hat{A_{PV}} Q^2_{usl} + P_H A_n < \theta_{tg} >_{usl}$$

Subtract Q^2 dependence for A_T double difference

$$A_{m,atldd,corr} \equiv A_{m,atldd} - A_{PV,atldd} = P_H A_n \frac{<\theta_{tg}>_{atl1} - <\theta_{tg}>_{atl2}}{2}$$

$$A_{TH,usl} = P_H A_n < \theta_{tg} >_{usl}$$

Horizontal Transverse Polarization Correction

Corrections due to transverse polarization

$$A_{TH,usl} = \frac{A_{m,atldd,corr}}{\xi_{LHRS}}, \quad A_{TH,usr} = \frac{A_{m,atrdd,corr}}{\xi_{RHRS}}$$

$$\xi_{LHRS} = \frac{<\theta_{tg}>_{atl1} - <\theta_{tg}>_{atl2}}{2<\theta_{tg}>_{usl}}, \quad \xi_{RHRS} = \frac{<\theta_{tg}>_{atr1} - <\theta_{tg}>_{atr2}}{2<\theta_{tg}>_{usr}}$$

We have two Independent measurements of horizontal transverse polarization

One for each arm

Q^2 Differences

$$A_{PV,usl} = A_{m,usl} - A_{TH,usl} - A_{TV,usl} = P_L \hat{A_{PV}} Q^2_{usl}$$

$$A_{PV,usr} = A_{m,usr} - A_{TH,usr} - A_{TV,usr} = P_L \hat{A_{PV}} Q^2_{usr}$$

Consider the average and double difference

$$A_{PV,usdd} = A_{PV,usavg} \frac{Q^2_{usdd}}{Q^2_{usavg}}$$

Correction due to Q^2 difference