Measurements of the Relative Phase of Timelike Form Factors GM and GE at PANDA

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Questions

- Time-like form factors G_E and G_M are complex quantities. Can we measure the phase angle between them?
- What implications does this have on polarized target apparatus that obstructs e^+e^- events?

Formalism

Beam(1) & Target(2) Spin

Egle Tomasi-Gustafsson, EPJA**24**(05)419

$$\left(\frac{d\sigma}{d\Omega}\right)(\mathbf{S_1},\mathbf{S_2}) = \left(\frac{d\sigma}{d\Omega}\right)_0 [1+A_y(S_{1y}+S_{2y})+ A_{xx}S_{1x}S_{2x}+A_{yy}S_{1y}S_{2y}+A_{zz}S_{1z}S_{2z}+A_{xz}(S_{1x}S_{2z}+S_{1z}S_{2x})]$$

$$\left(\frac{d\sigma}{d\Omega}\right)_0 A_y = \frac{N}{\sqrt{\tau}}\sin 2\theta Im(G_M G_E^*)$$

$$\left(\frac{d\sigma}{d\Omega}\right)_0 A_{xx} = N\sin^2\theta\left[|G_M|^2 + \frac{1}{\tau}|G_E|^2\right]$$

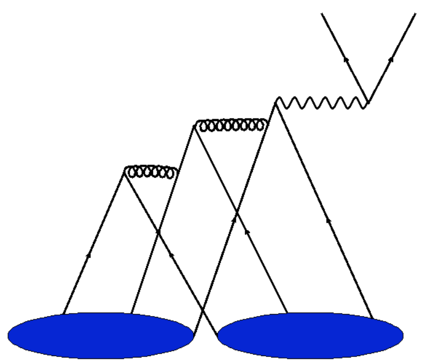
$$\left(\frac{d\sigma}{d\Omega}\right)_0 A_{yy} = -N\sin^2\theta\left[|G_M|^2 - \frac{1}{\tau}|G_E|^2\right]$$

$$\left(\frac{d\sigma}{d\Omega}\right)_0 A_{xz} = \frac{N}{\sqrt{\tau}}\sin 2\theta Re(G_M G_E^*)$$

$$\left(\frac{d\sigma}{d\Omega}\right)_0 A_{zz} = N\left[(1+\cos^2\theta)|G_M|^2 - \frac{1}{\tau}\sin^2\theta|G_E|^2\right]$$

$$\tau = \frac{q^2}{4M^2}$$

$$N = \frac{\alpha^2}{4q^2\sqrt{1-1/\tau}}$$



Transversely Polarized Target

CM angle

Egle Tomasi-Gustafsson, EPJA**24**(05)419

$$\left(\frac{d\sigma}{d\Omega}\right)_0 = N|\bar{G}_M|^2\left[(1+\cos^2\theta)+\rho^2(1-\cos^2\theta)+|S_\perp|\rho\sin 2\theta\sin\Delta\phi\right]$$

$$G_M = \bar{G}_M e^{i\phi_M}$$

$$G_E = \bar{G}_E e^{i\phi_E}$$

$$\Delta\phi = \phi_M - \phi_E \qquad R = \frac{\bar{G}_E}{\bar{G}_M} \qquad \rho = \frac{R}{\sqrt{\tau}}$$

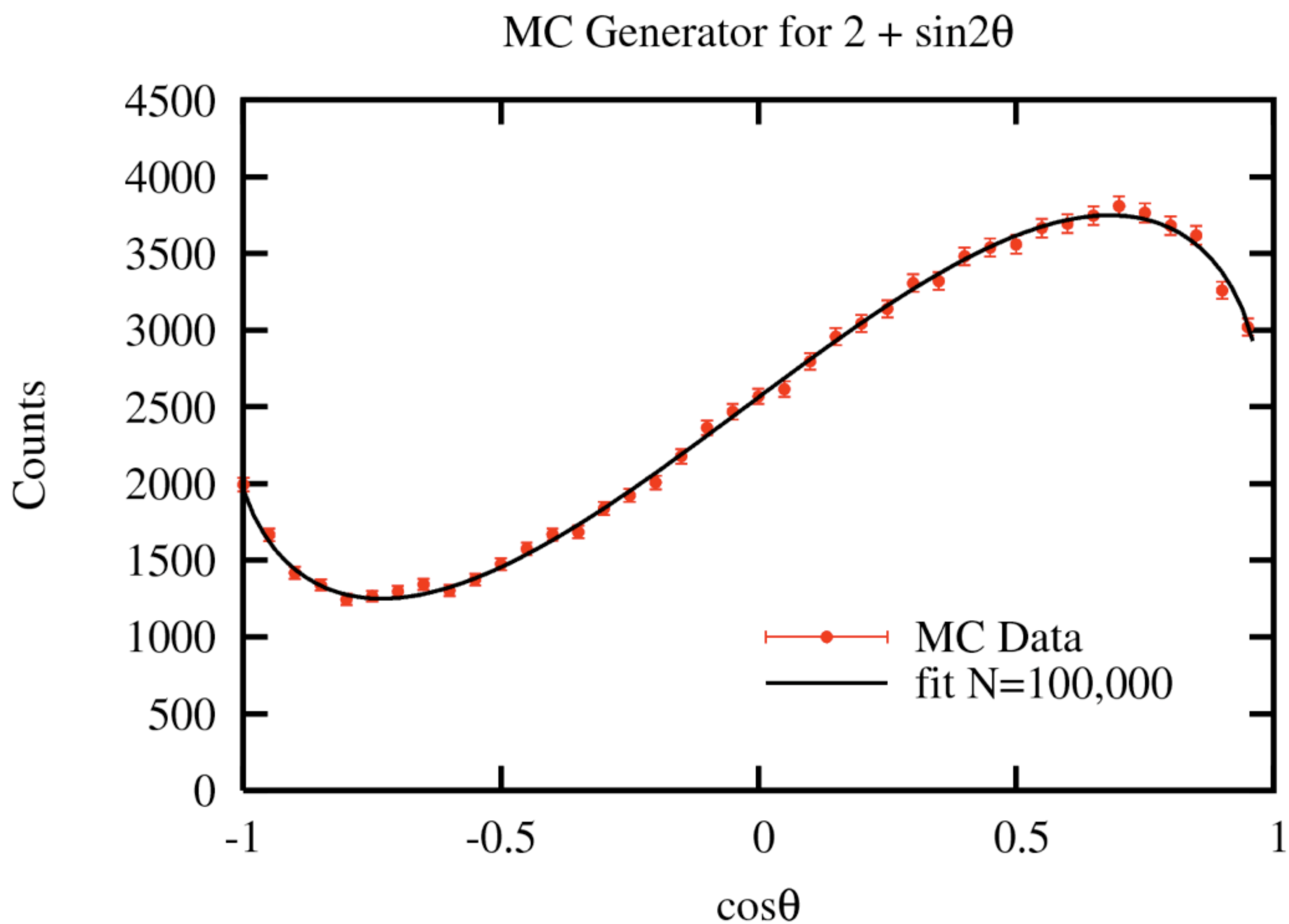
$$A_y = \frac{\sin 2\theta \sin\Delta\phi}{(\rho+\frac{1}{\rho})+(\frac{1}{\rho}-\rho)\cos^2\theta}$$

Because the asymmetry contains a large $\cos^2\theta$ term in the denominator it's probably better to measure cross section differences

$A_y \sim 0.5$ @ $\tau=1$, $R=1$ to ~ 0.08 @ $\tau=6$, $R=0.4$

MC Generator

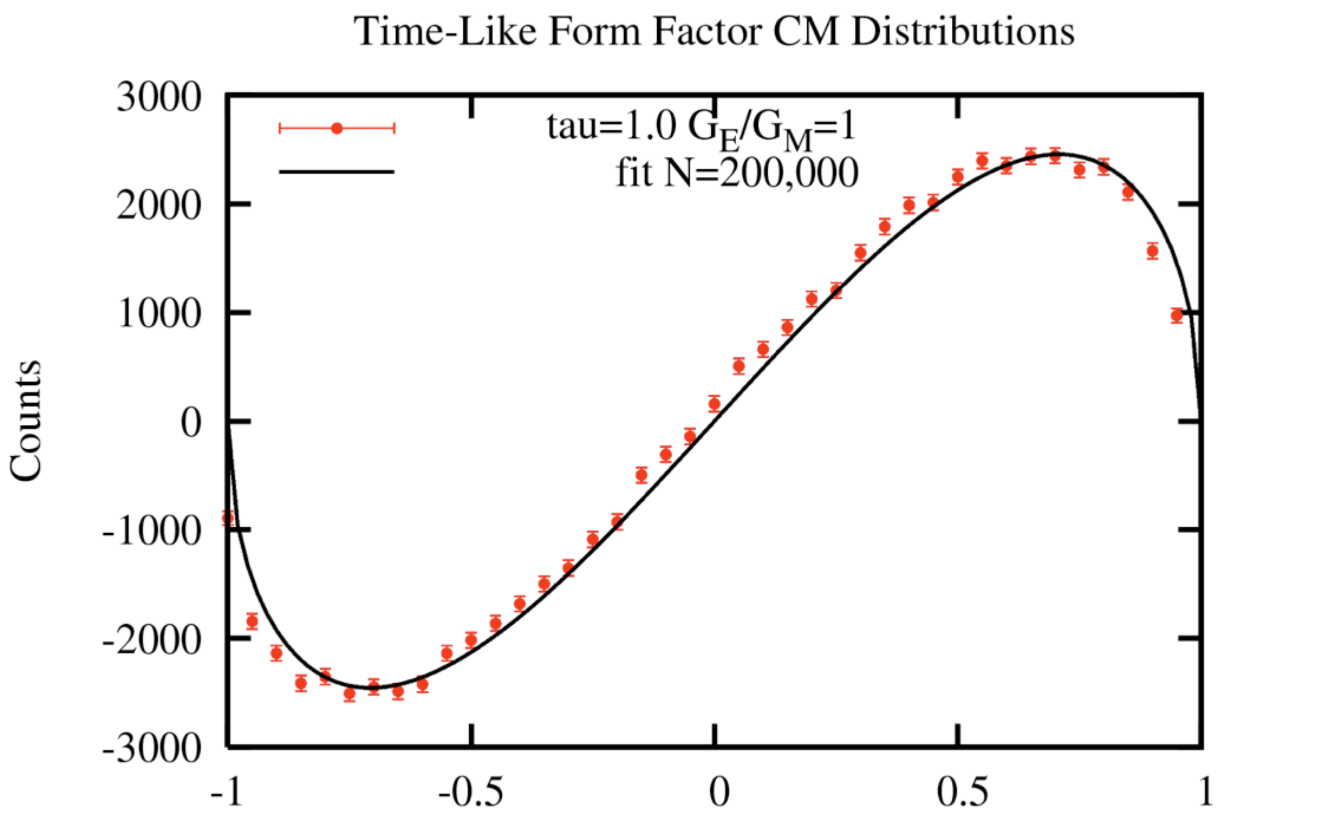
Create a generator for f(θ) = 2+sin2θ

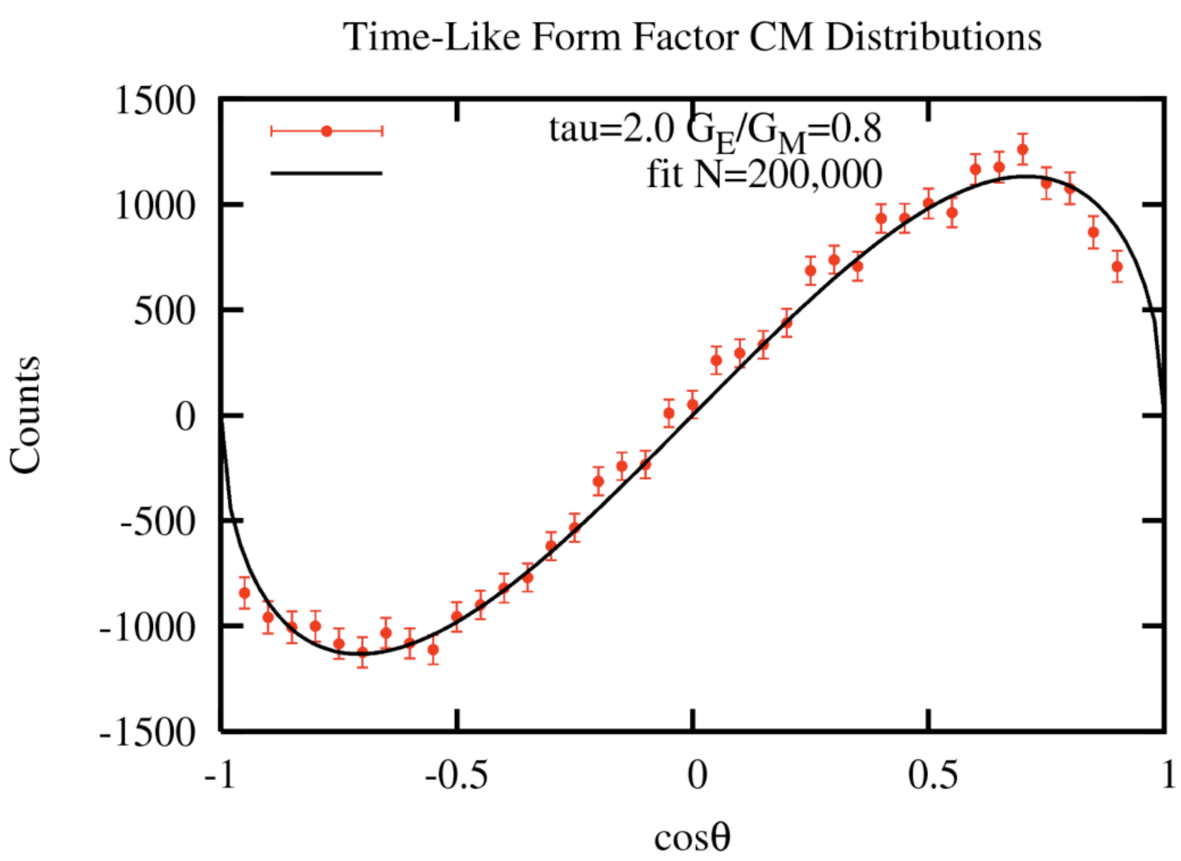


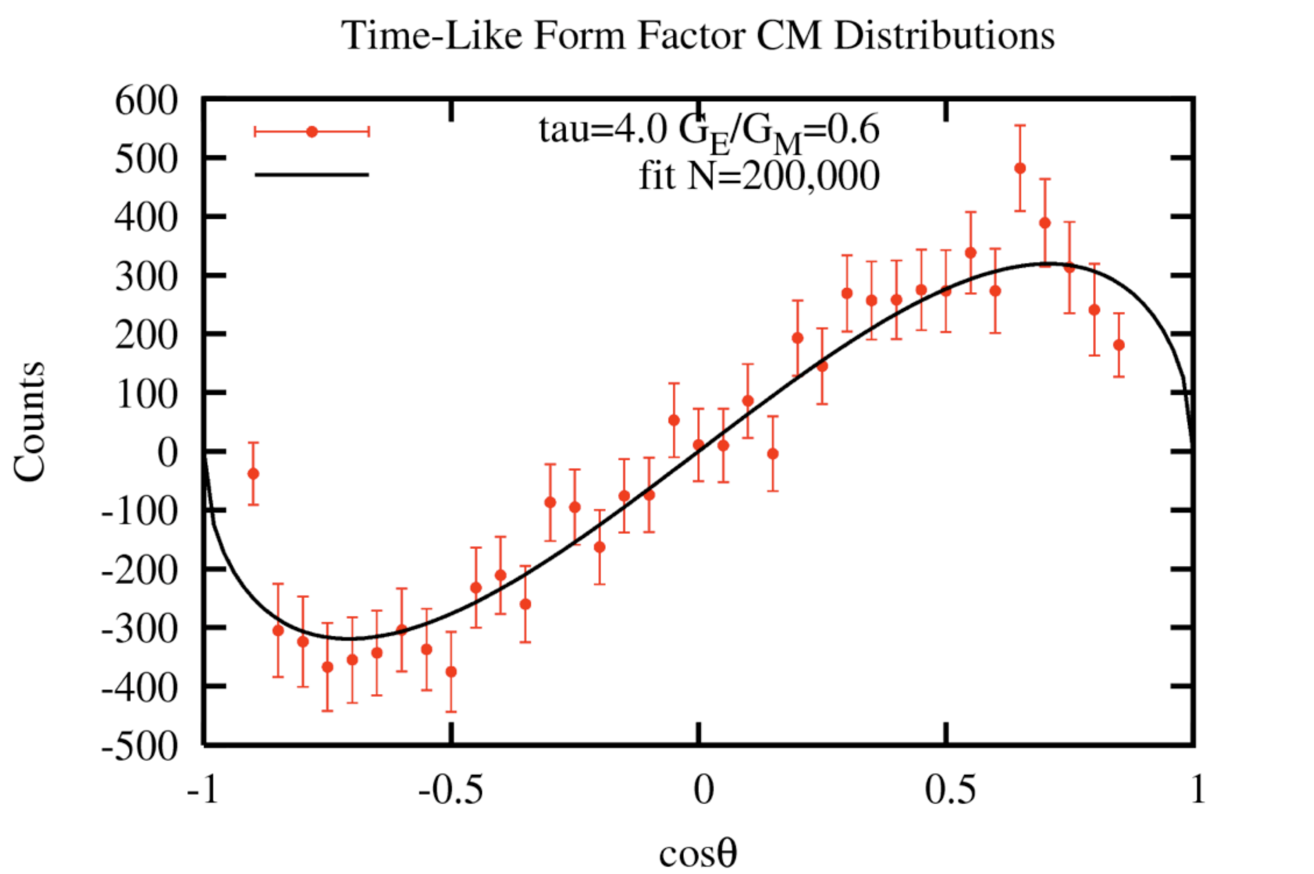
Fits to Extract Δϕ

Toy Monte Carlo Simulations of e^+e^- Δσ Transversely Polarized Events. Experimental cuts of 8° < $\theta_{e+,e-}^{lab}$ < 172°; N=200,000

Fits to $u=\cos\theta_{cm}$ of the form $f(u) = au\sqrt{(1-u^2)}$





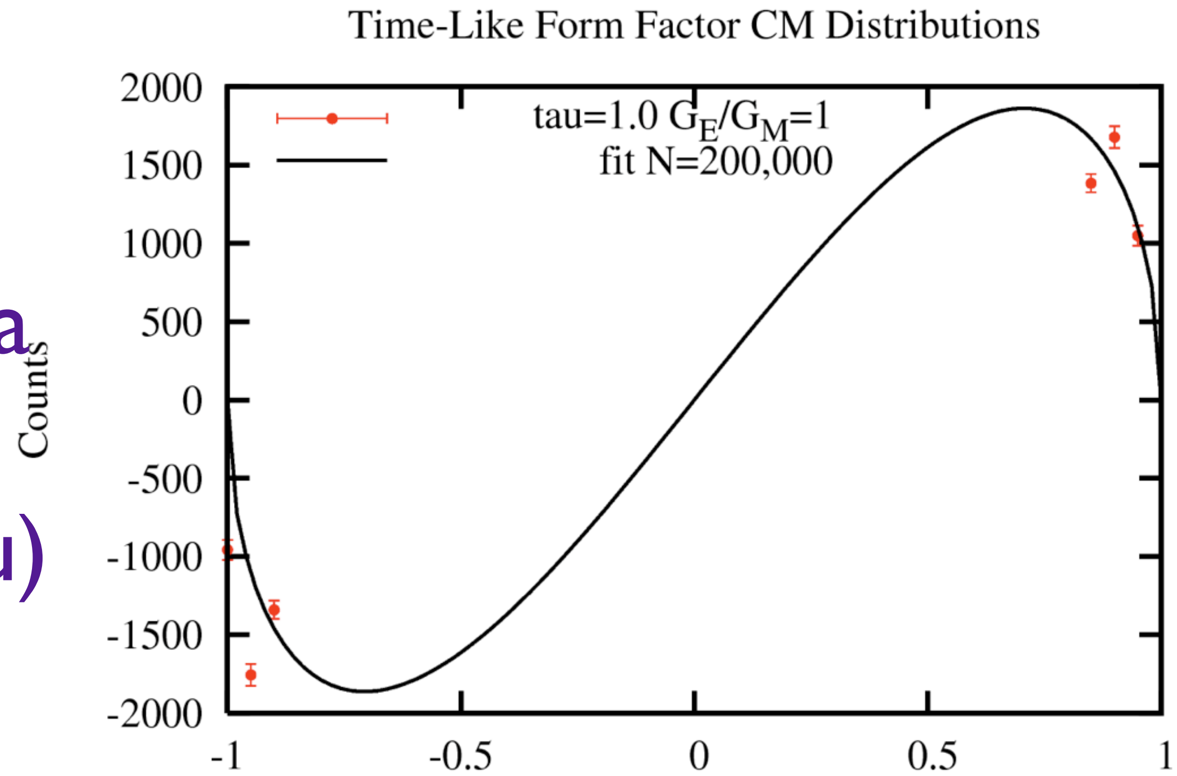


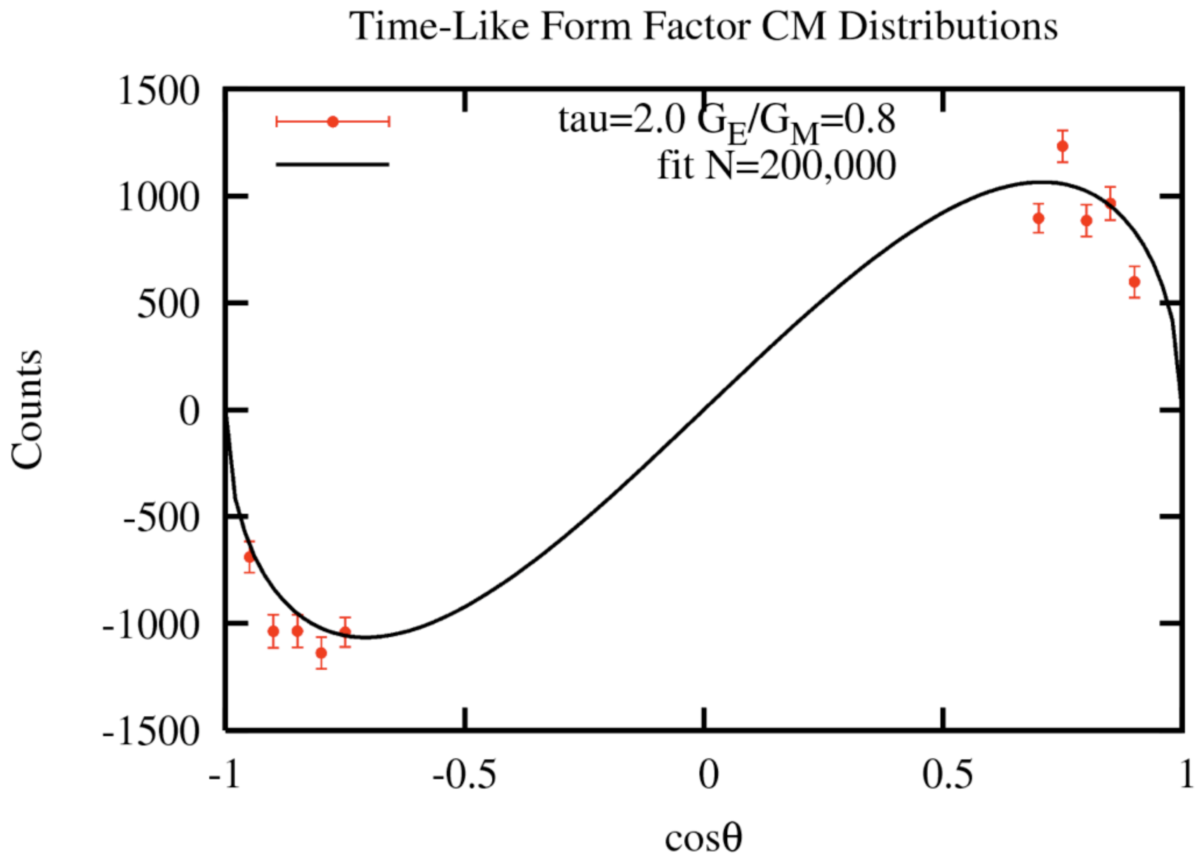
With Target Obstruction

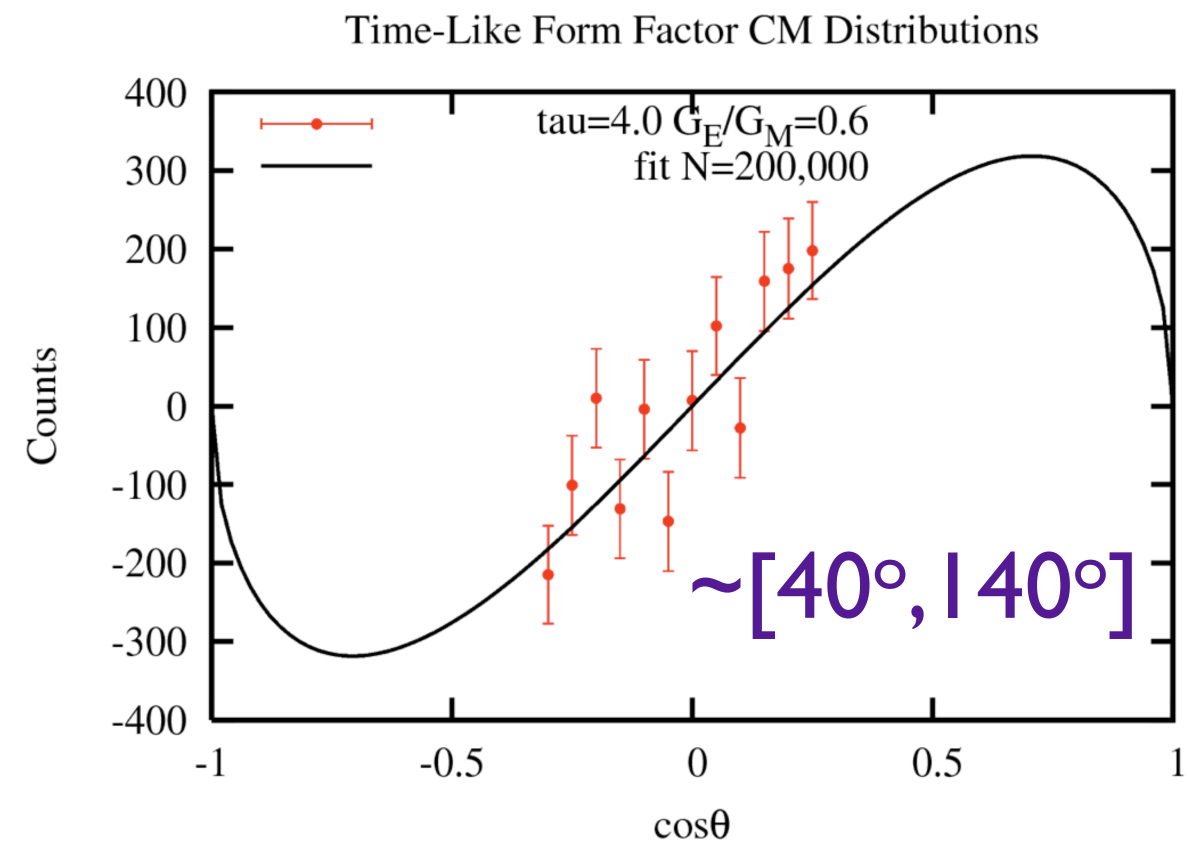
Experimental cuts of $8^\circ < \theta_{e+,e-}^{lab} < 172^\circ$; N=200,000

Exclude [30°,150°] assuming this is obstructed by a flux exclusion tube

Fits to $u=\cos\theta_{cm}$ of the form $f(u) = au\sqrt{(1-u^2)}$







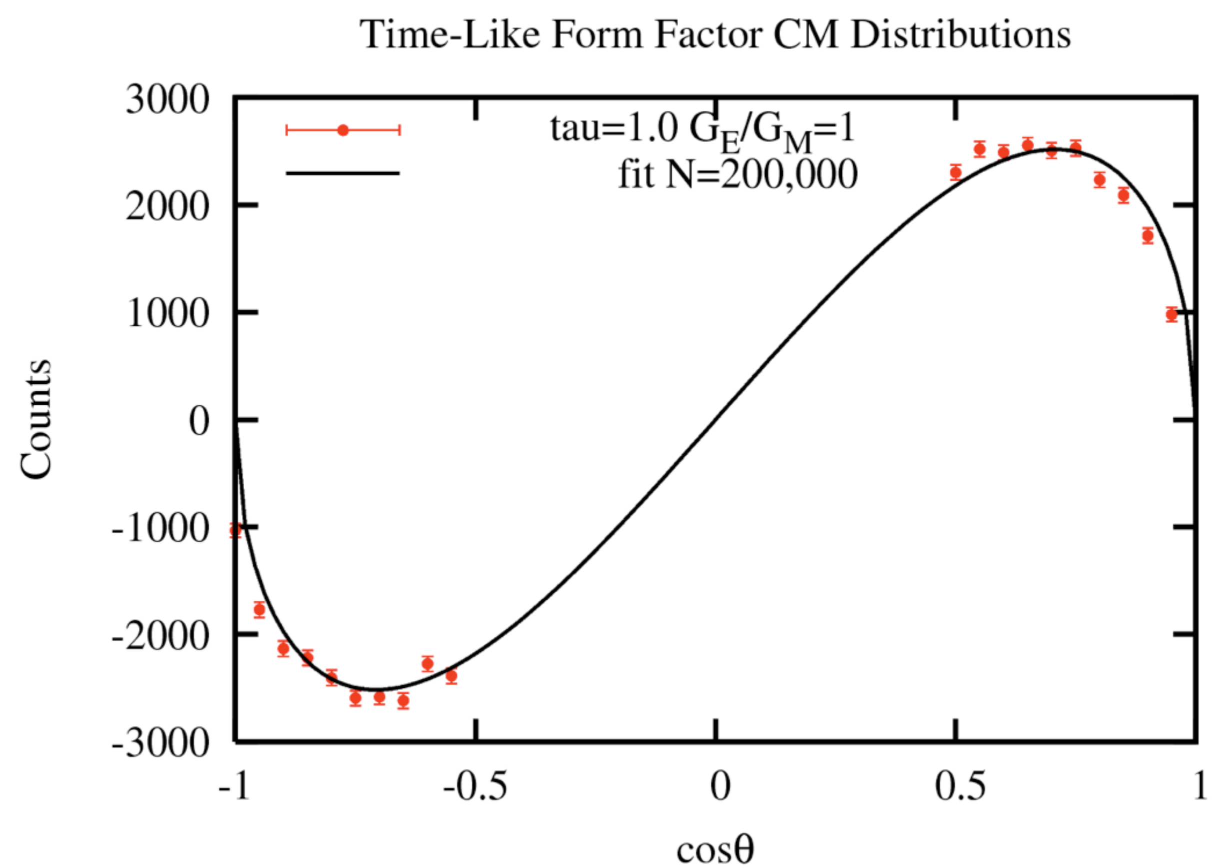
With Target Obstruction

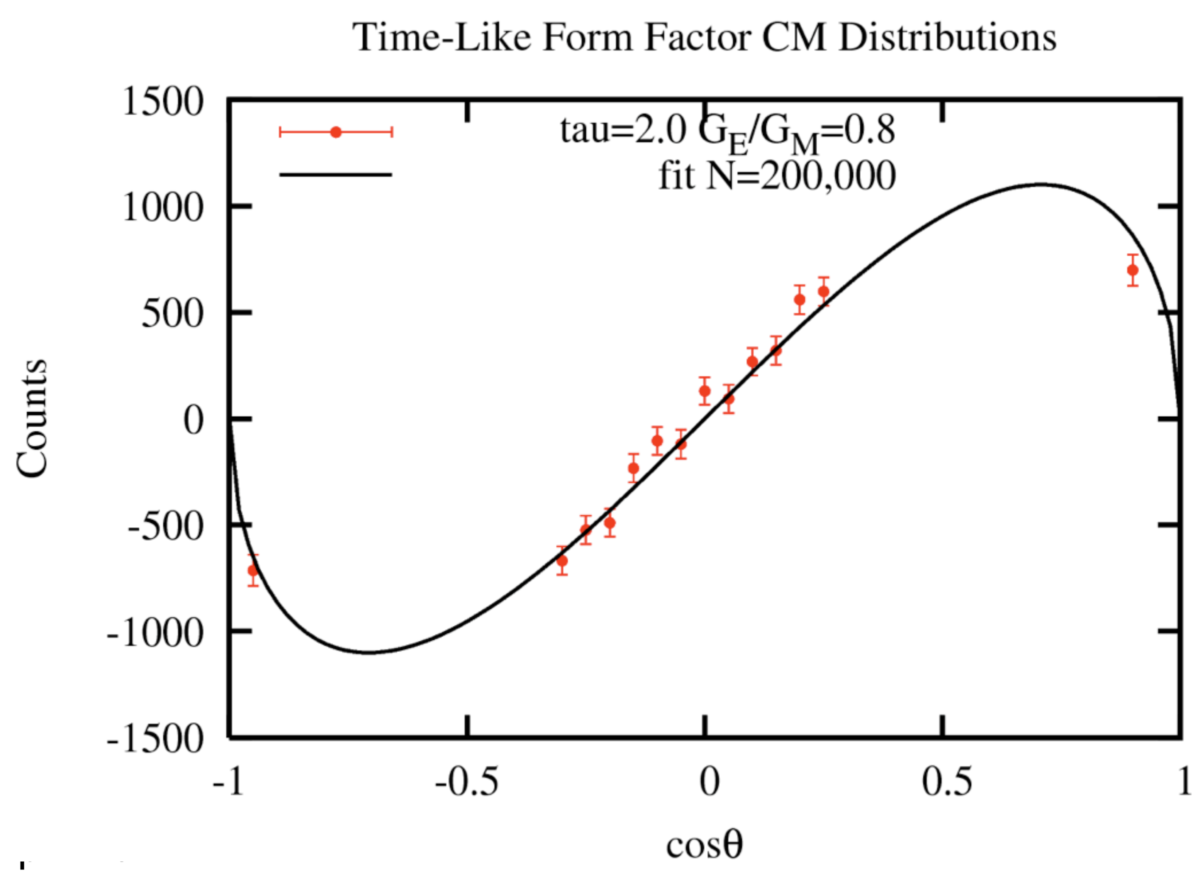
Experimental cuts of 8° < $\theta_{e+,e-}^{lab}$ < 172°; N=200,000

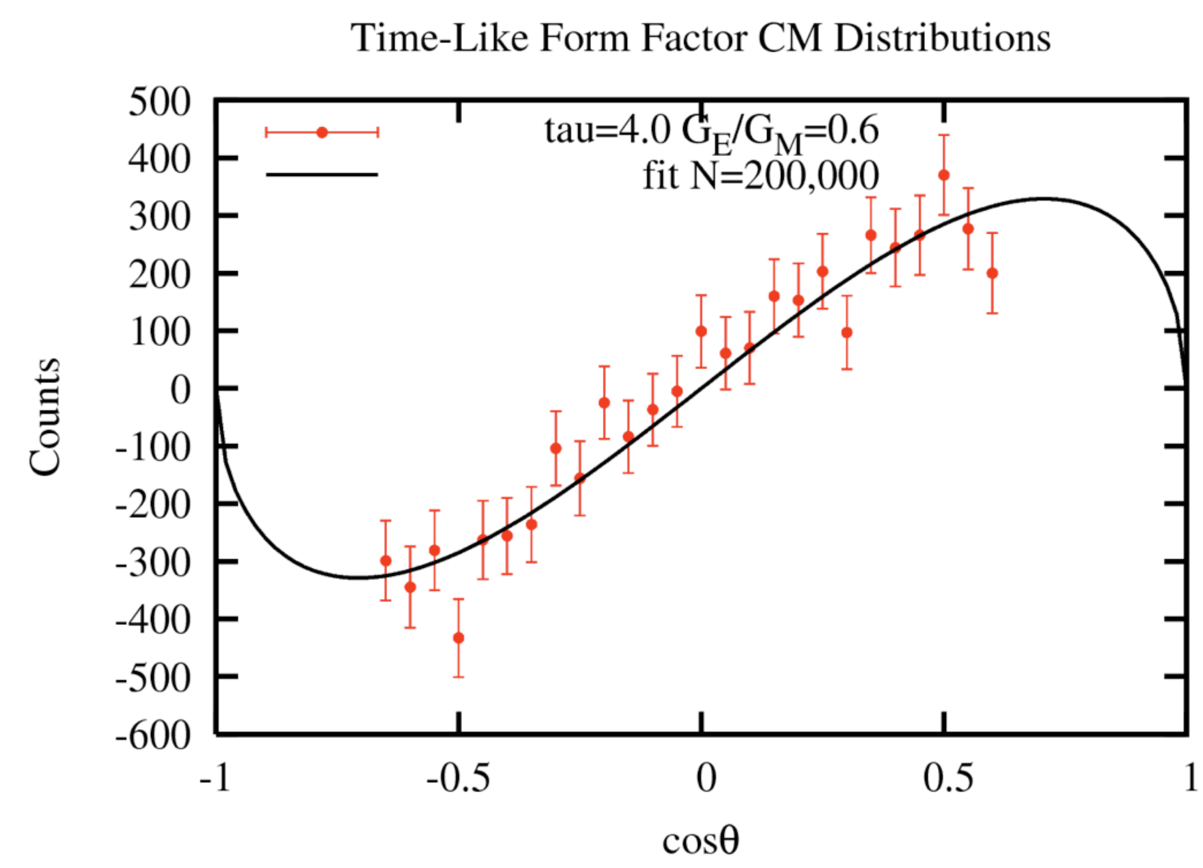
Exclude [60°,120°]

assuming this is obstructed by a flux exclusion tube

Fits to u=cosθ_{cm} of the form f(u) = au$\sqrt{(1-u^2)}$







Realistic Counts

τ	Q^2 (GeV^2)	σ (fb)	Events	MC Events	G_E/G_M	Exclude Nothing	Exclude [30,150]	Exclude [60,120]	60° w/ Dilution
1.0	3.5	8.39×10^7	1.6×10^8	200000	1.0	0.982 (0.020)	0.745 (0.127)	1.007 (0.026)	9%
2.0	7.0	8.07×10^4	1.6×10^5	200000	0.8	1.073 (0.019)	1.009 (0.049)	1.044 (0.055)	19%
4.0	14.1	1.02×10^3	2.0×10^3	200000	0.6	0.984 (0.050)	1.003 (0.201)	0.994 (0.066)	229%

- Assuming phase difference is 90° (*i.e.* maximal signal)
- Polystyrene is $(C_8H_8)_n$; Dilution factor f~ 8/(8x12) = 1/12
- Events for τ=4 are more like 2000; a factor of 100 less

Conclusions

- These toy Monte Carlo results are very preliminary.
- One needs to get as much acceptance as possible with a transversely polarized target
- A 30^{o} limit from a flux exclusion tube is marginal for such a measurement and 60^{o} would be much better.