Study of Timelike Form Factors Extractions and Two-Photon Effects at PANDA

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Questions

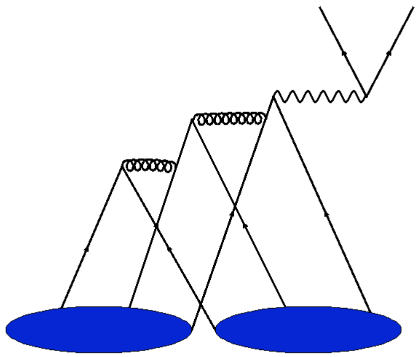
- With what kind of accuracy can one extract G_E and G_M given angular and statistical limitations at PANDA?
- Can one measure two-photon effects in time-like form factor measurements?

Formalism

CM e⁻ angle

Egle Tomasi-Gustafsson, arXiv:nucl-ph:0503001

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



$$\sigma(q^2) = \mathcal{N}\frac{8}{3}\pi\left[2|G_M|^2 + \frac{1}{\tau}|G_E|^2\right]$$

$$\mathcal{N} = \frac{\alpha^2}{4\sqrt{q^2(q^2-4m^2)}}$$

$$|G_M| = \frac{A(N)}{q^4\ln^2(q^2/\Lambda^2)}$$

$$G_E(q^2) = G_M(q^2),\ q^2 = 4m^2$$

$$A(p) = 56.3$$

$$A(n) = 77.15\ \mathrm{GeV}^4$$

$$\Lambda = 0.3\ \mathrm{GeV}$$

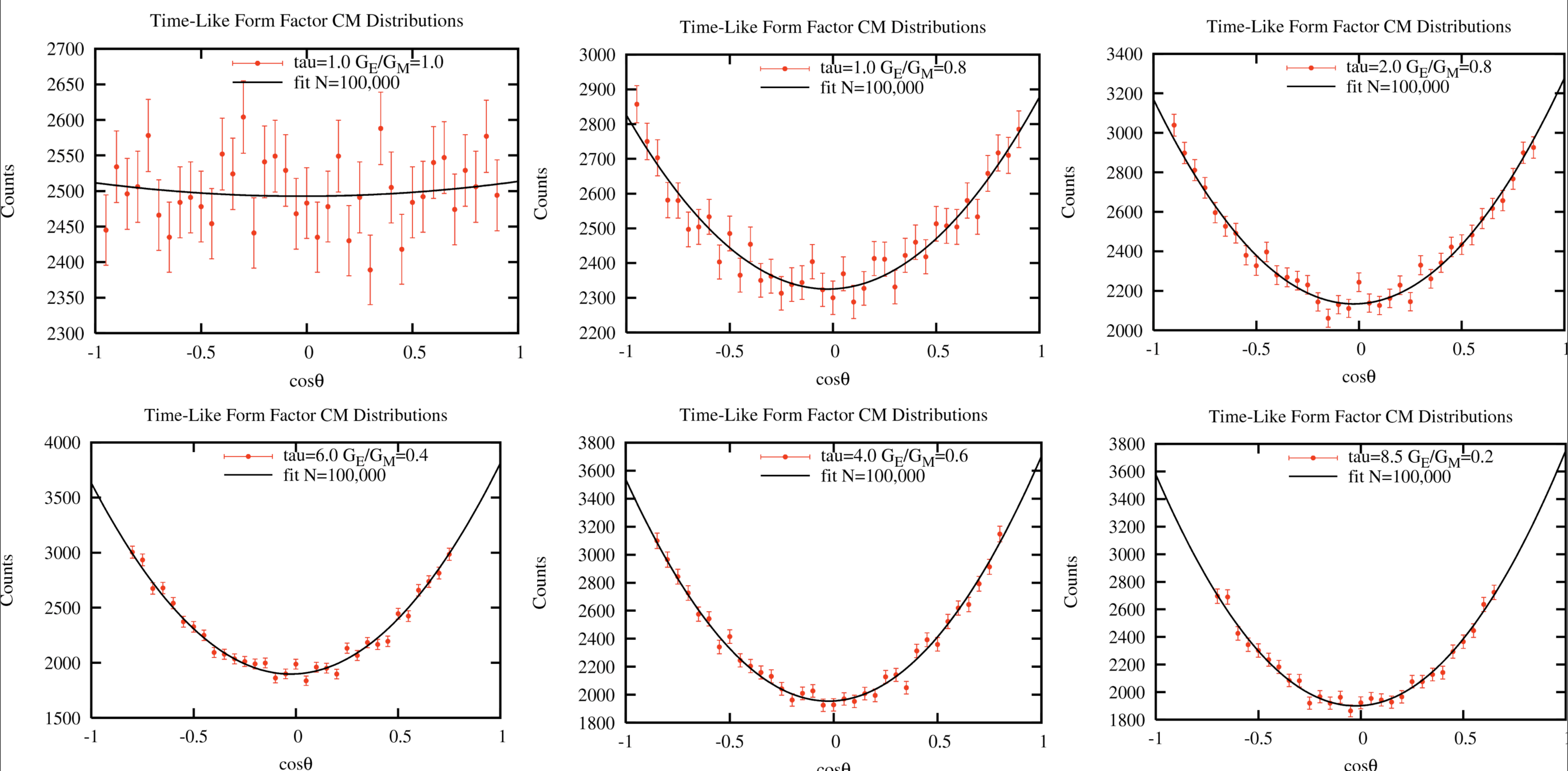
$$\tau = \frac{q^2}{4M^2}$$

Fits to Extract G_E & G_M

Toy Monte Carlo Simulations of e^+e^- FF Events

Experimental cuts of $8^\circ < \theta_{e+,e-}^{lab} < 172^\circ$; N=100,000

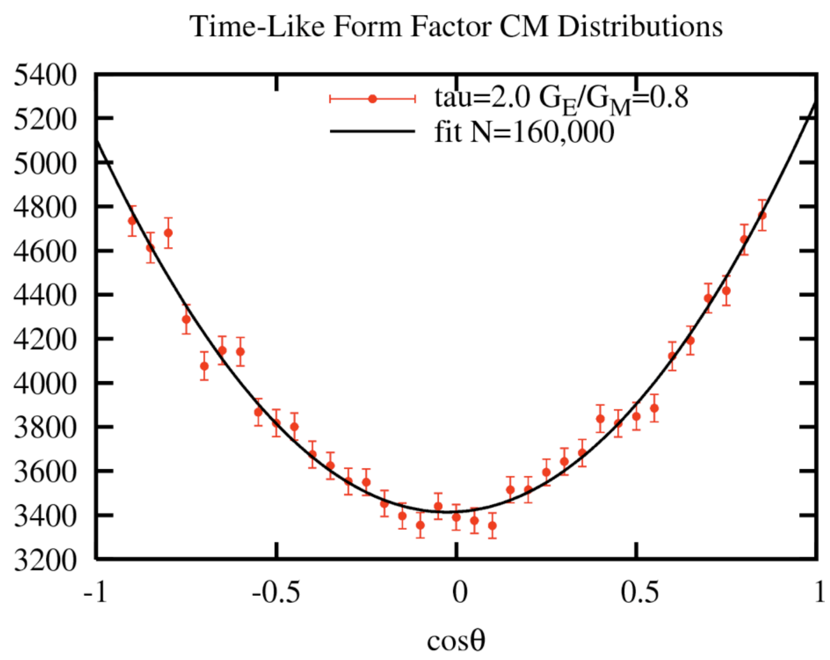
Fits to $u=\cos\theta_{cm}$ of the form $f(u) = a(1+u^2) + b(1-u^2)$

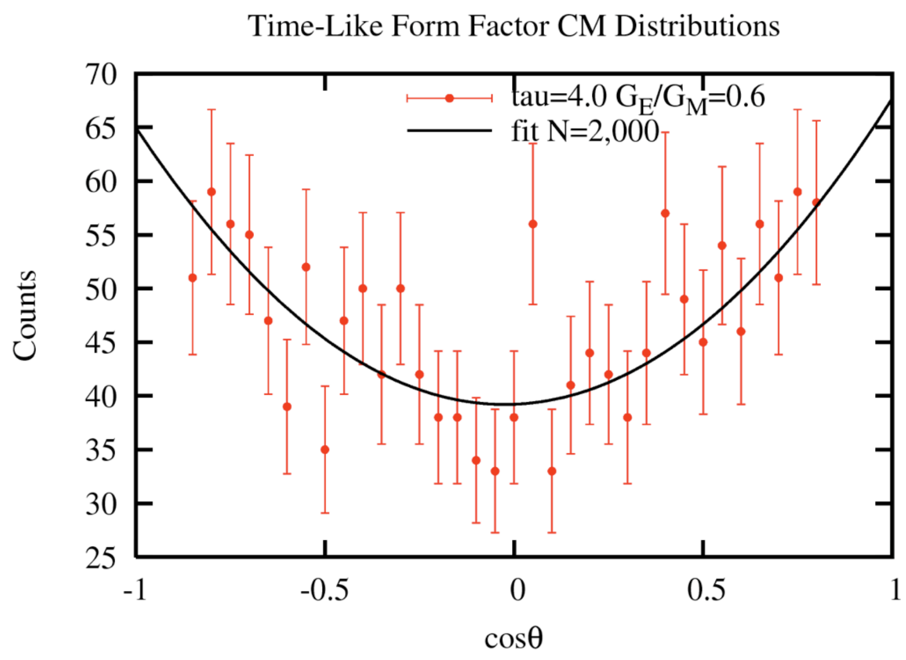


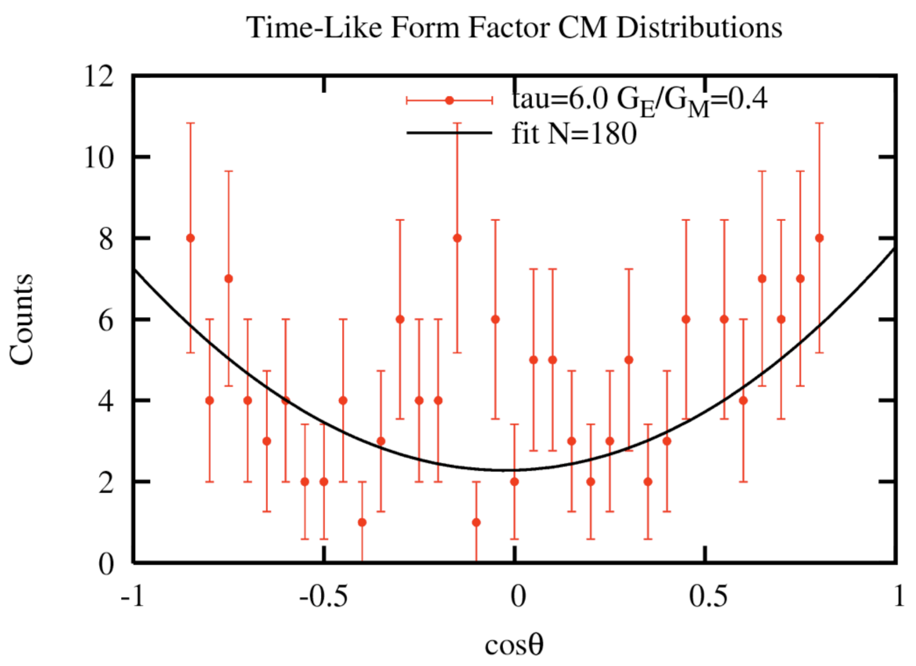
Realistic Counts

τ	Q^2 (GeV^2)	σ (fb)	counts
1.0	3.5	8.39×10^7	1.6×10^8
2.0	7.0	8.07×10^4	1.6×10^5
4.0	14.1	1.02×10^3	2.0×10^3
6.0	21.2	9.04×10^1	1.8×10^2
8.5	30.0	1.12×10^1	2.2×10^1

- Counts assuming 2 fb^{-1} luminosity
- Fits show missing CM angles grow with increasing τ







Fit Summary

No cut in θ_{e-}^{lab}

τ	Q^2 (GeV^2)	G_E/G_M	counts	$G_E^2/G_M^2/\tau$	G_M	G_E
1.0	3.5	1.0	100,000	1.00	1.010(7)	0.980(13)
1.0	3.5	0.8	100,000	0.64	1.010(7)	0.967(20)
2.0	7.0	0.8	100,000	0.32	0.996(7)	1.024(37)
4.0	14.1	0.6	100,000	0.009	1.001(6)	0.96(12)
6.0	21.1	0.4	100,000	0.0267	0.997(6)	1.19(40)
8.5	30.0	0.2	100,000	0.00471	1.008(6)	-1.2(2.0)

$8^o < \theta_{e-}^{lab} < 172^o$

τ	Q^2 (GeV^2)	G_E/G_M	counts	$G_E^2/G_M^2/\tau$	G_M	G_E
1.0	3.5	1.0	100,000	1.00	1.004(9)	0.989(16)
1.0	3.5	0.8	100,000	0.64	1.004(7)	0.990(19)
2.0	7.0	0.8	100,000	0.32	0.997(8)	1.011(39)
4.0	14.1	0.6	100,000	0.009	1.008(9)	0.901(155)
6.0	21.1	0.4	100,000	0.0267	1.005(12)	0.77(66)
8.5	30.0	0.2	100,000	0.00471	0.979(13)	7.8(3.6)
2.0	7.0	0.8	160,000	0.32	1.004(7)	0.988(36)
4.0	14.1	0.6	2,000	0.009	0.924(55)	1.87(92)
6.0	21.1	0.4	180	0.0267	1.13(21)	-17(11)

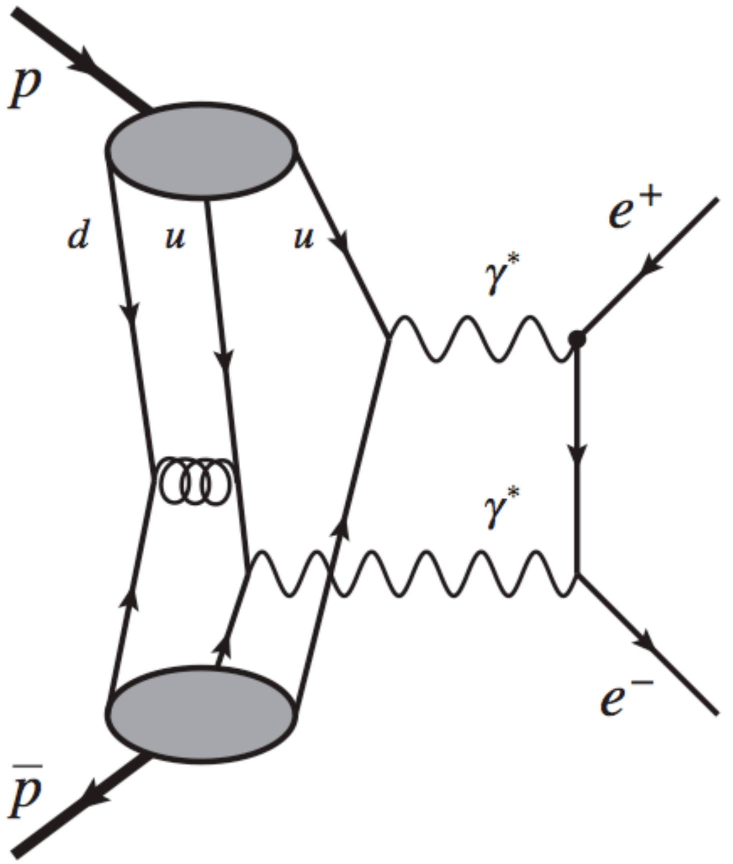
$\int a(1+u^2)du = 8a/3$; $\int b(1-u^2)du = 4b/3$; $u=\cos\theta$;

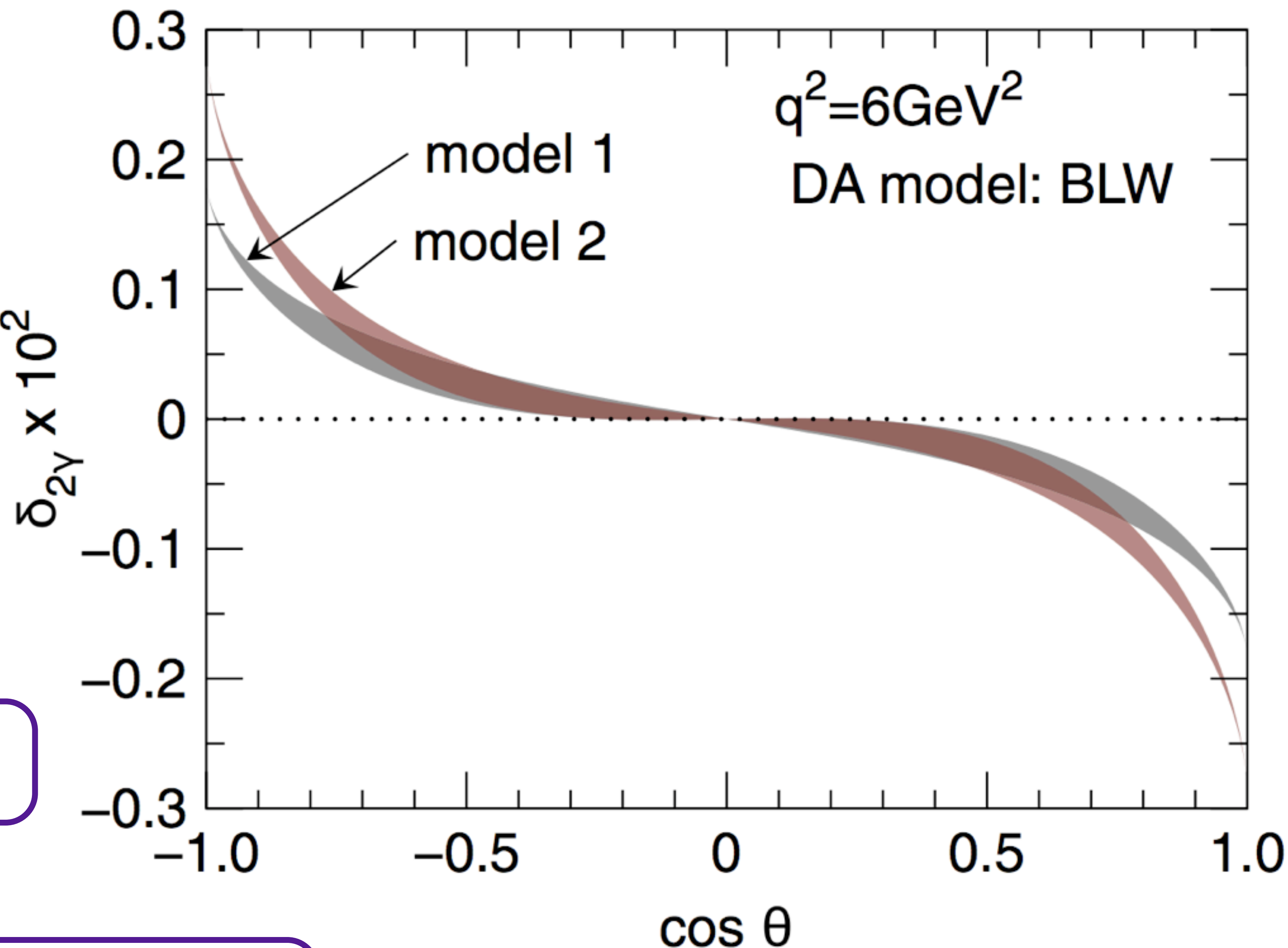
$N = (4/3)(2a+b)/\Delta\cos\theta$; $\Delta\cos\theta=0.05$;

$2a+b = 3N\Delta\cos\theta/4$

2γ Predictions

Guttmann *et al.*, PRD**83**(2011)094021



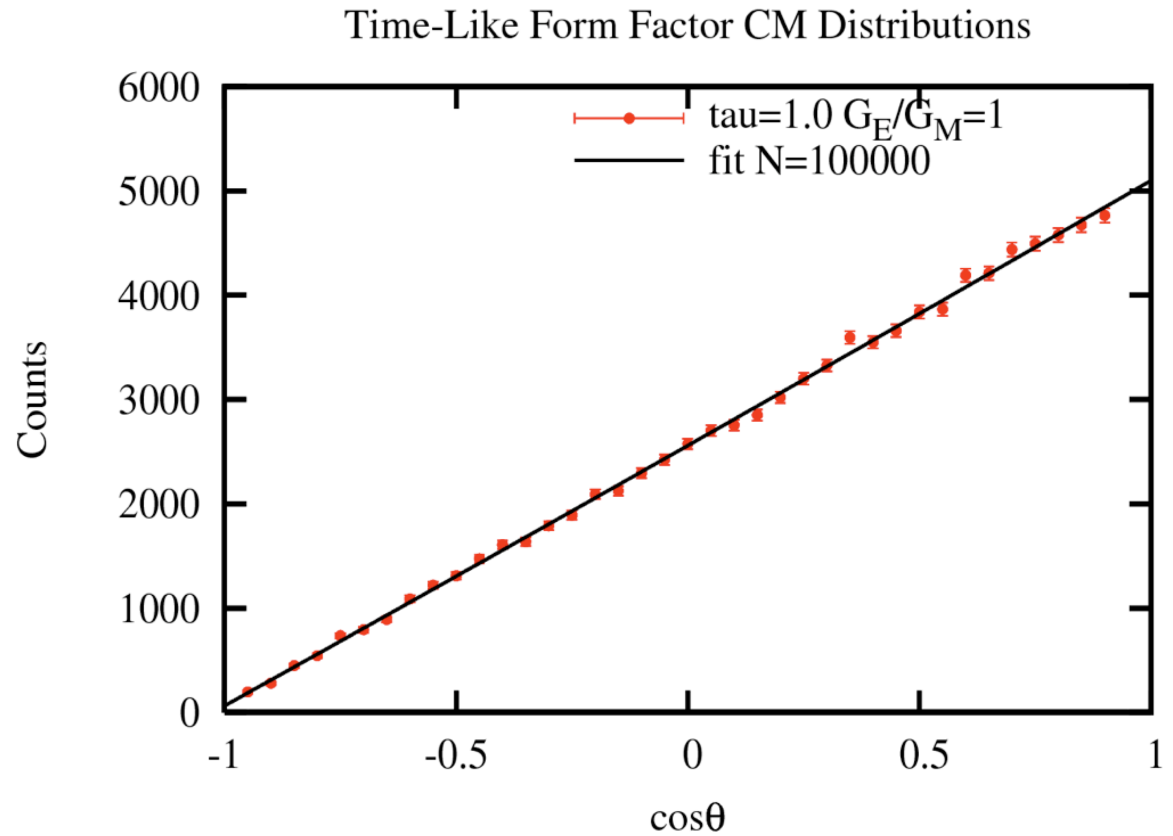


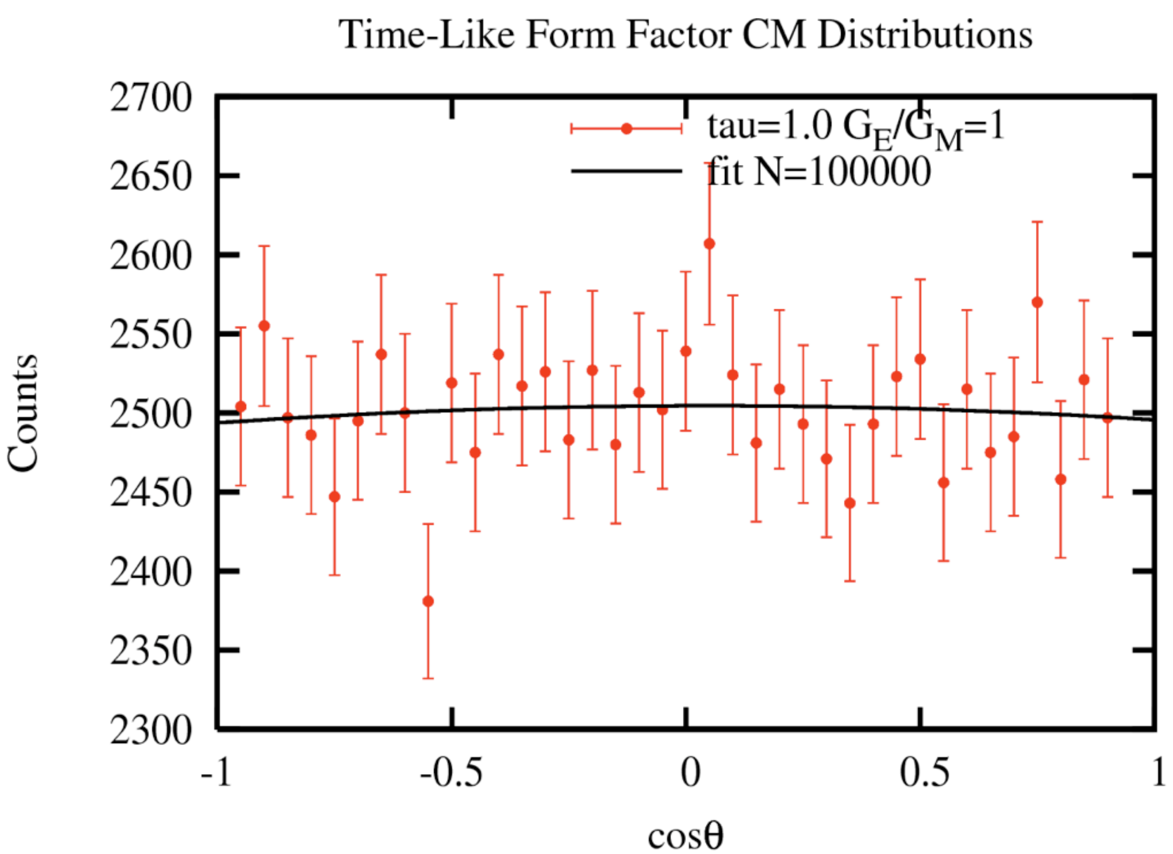
$$d\sigma_{\mathrm{c.m.}} = d\sigma_{\mathrm{c.m.},1\gamma}(1 + \delta_{2\gamma})$$

$$A = (\sigma_{cm}^{fore} - \sigma_{cm}^{aft}) / (\sigma_{cm}^{fore} + \sigma_{cm}^{aft}) = \delta_{2\gamma}$$
$$= (N_{e-} - N_{e+})(\theta) / (N_{e-} + N_{e+})(\theta)$$

(e^- CM angle θ)

Add a Linear Term



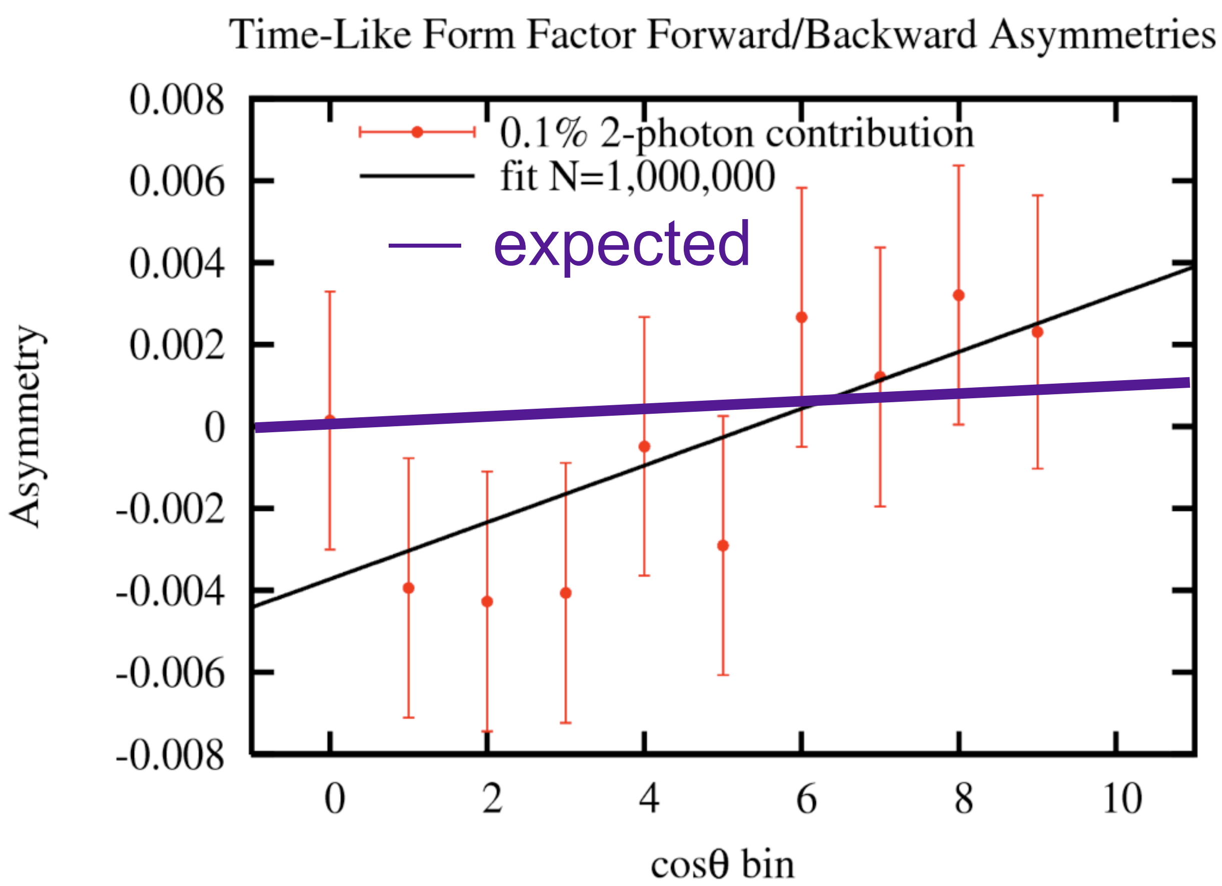


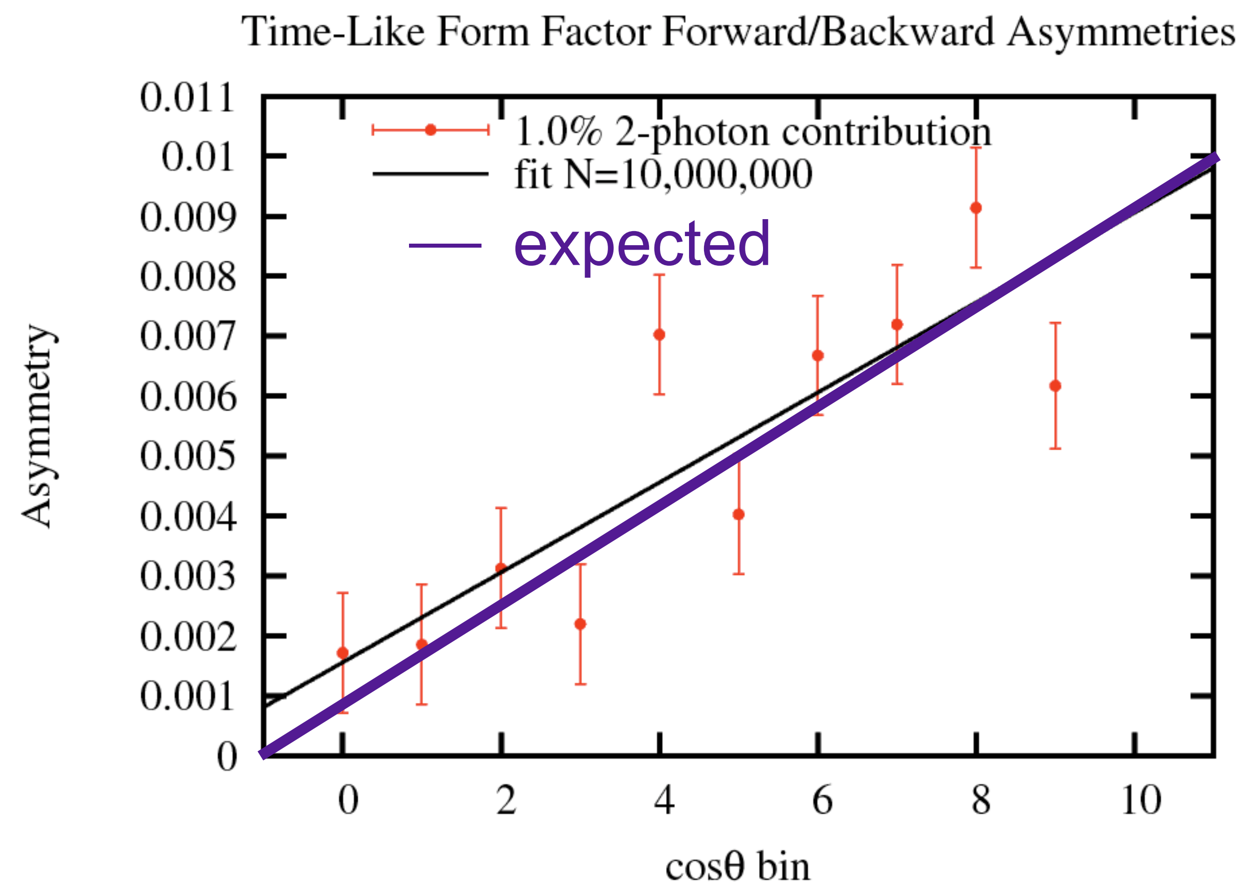
Test of a linear MC distribution to simulate two photon effects

Now allow only 0.1% of the FF events to have a linear angular distribution

Clearly, fitting with a linear term will never be good enough; we need to measure asymmetries

MC Extracted $A_{2\gamma}$





A 0.1% asymmetry due to 2-photon effects will be quite hard to measure at PANDA, but not impossible if one compares e^+ and e^- events in the same detector elements. The asymmetry is really the asymmetry of e^+ and e^- exchange, so one can stably measure mirror-symmetric events.

Conclusions

- Lack of acceptance at low θ increases the errors in form factor extraction as s increases
- A two-photon effect of 0.1% can be measured only at threshold where the event rates are high enough to observe a e^+/e^- asymmetry.
- The toy Monte Carlo can quickly give insight into the effects of acceptance-blockers, such as a polarized target, on e^+e^- measurements.