Muon Acceptance for Timelike Form Factors in PANDA

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Questions

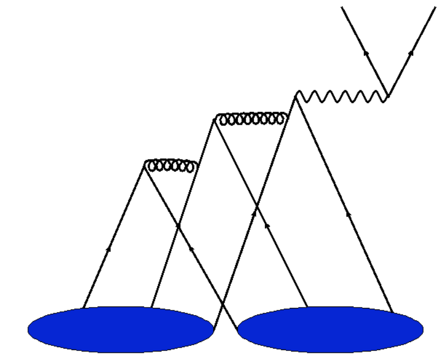
- What coverage in center-of-mass (CM) angles will the muon counters in PANDA cover?
- Can one detect a single muon (or electron) instead of a pair to measure G_E and G_M?

Formalism

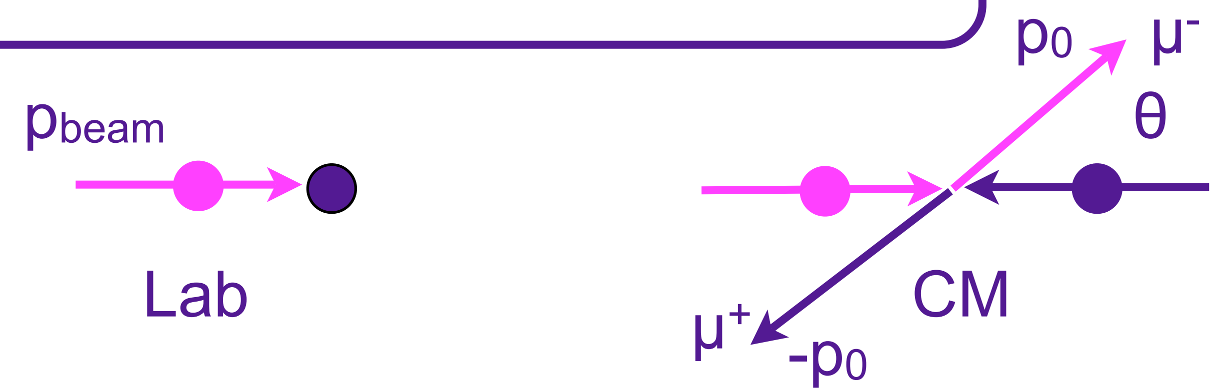
CM e$^-$ angle

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

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



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



Muon acceptance: 1°<θ_{lab}<124°

$$s = q^2 = 2M(E_{\text{beam}} + M)$$

$$\beta = \frac{p_{\text{beam}}}{E_{\text{beam}} + M}$$

$$\gamma = \frac{1}{\sqrt{1-\beta^2}}$$

$$E_{\text{beam}} = \sqrt{M^2 + p_{\text{beam}}^2}$$

$$p_0 = \frac{\sqrt{s}}{2} \qquad (m = 0)$$

$$(p_{e^-})_{\text{CM}} = (p_0, p_0\sin\theta, 0, p_0\cos\theta)$$

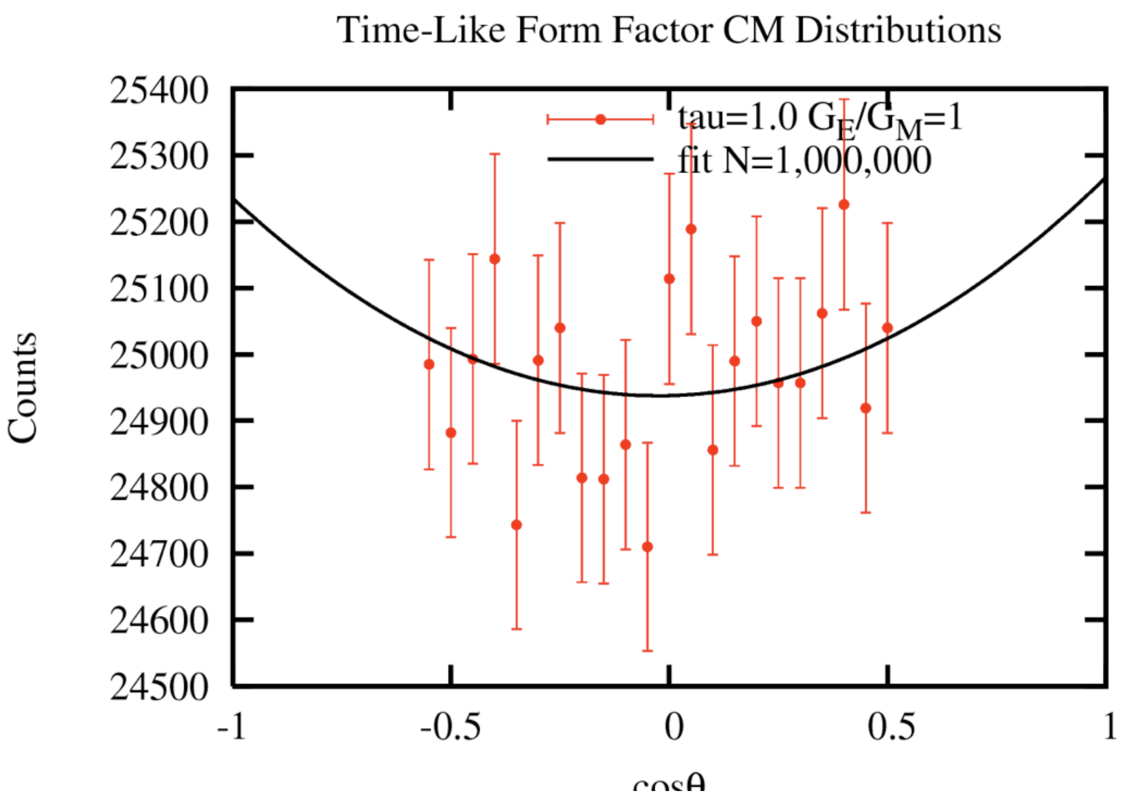
$$(p_{e^+})_{\text{CM}} = (p_0, -p_0\sin\theta, 0, -p_0\cos\theta)$$

$$(p_{e^-})_{\text{lab}} = (\gamma p_0 + \gamma\beta p_0\cos\theta, \sin\theta, 0, \gamma p_0\cos\theta + \gamma\beta p_0)$$

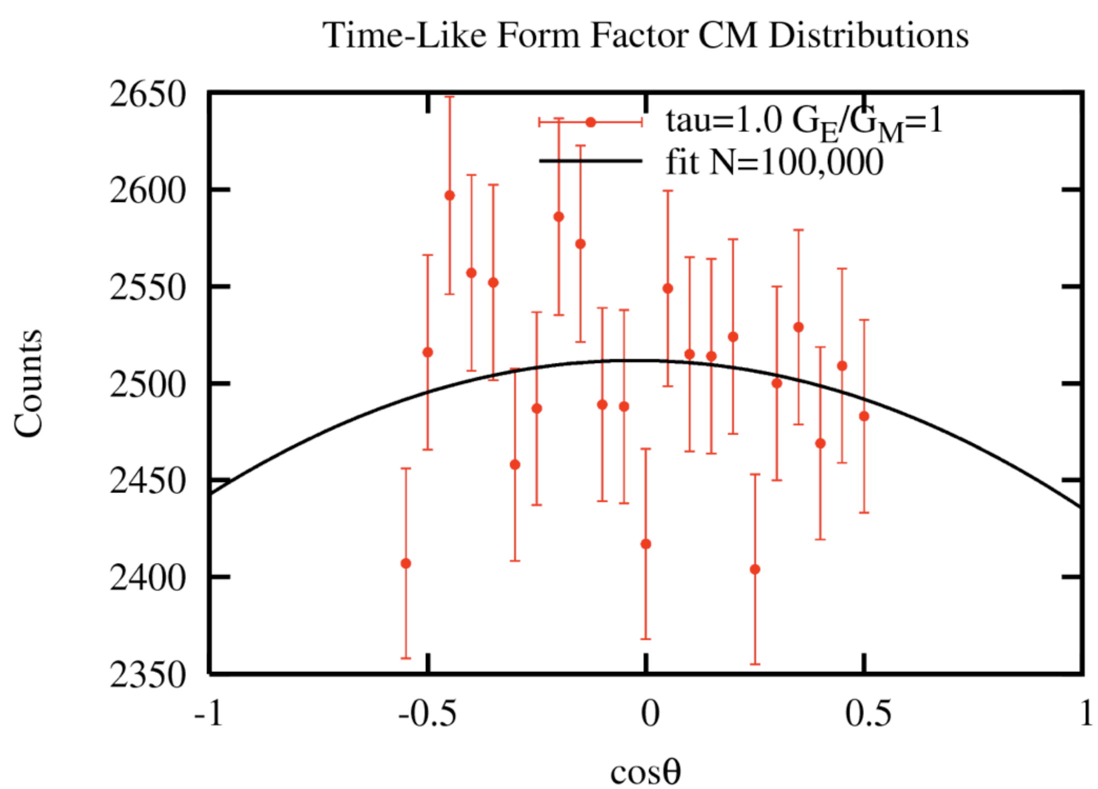
$$(p_{e^+})_{\text{lab}} = (\gamma p_0 - \gamma\beta p_0\cos\theta, -\sin\theta, 0, -\gamma p_0\cos\theta + \gamma\beta p_0)$$

Simulated Acceptance 1

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

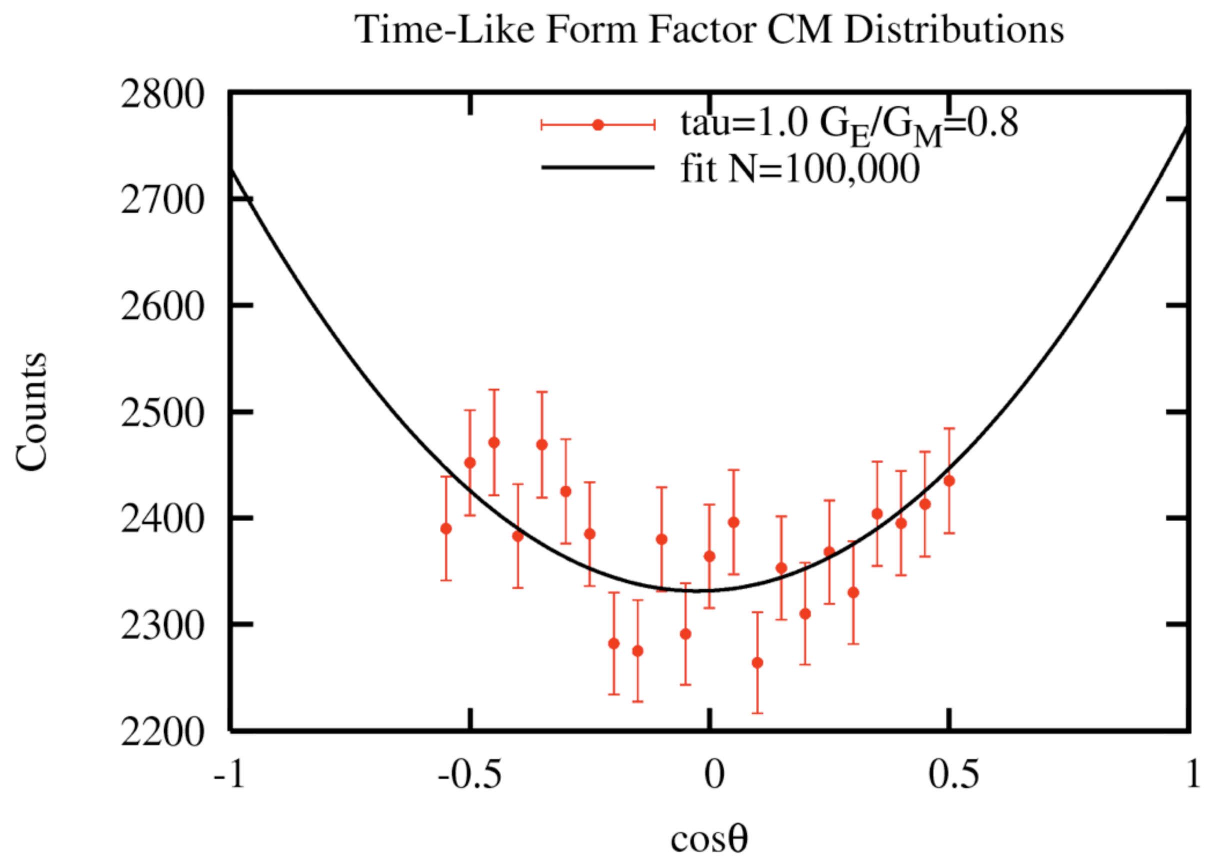



```
degrees of freedom (ndf) : 20
rms of residuals      (stdfit) = sqrt(WSSR/ndf)      : 0.868683
variance of residuals (reduced chisquare) = WSSR/ndf : 0.75461

Final set of parameters            Asymptotic Standard Error
=======================            ==========================

a               = 12625.5          +/- 147.4        (1.168%)
b               = 12312.2          +/- 180.1        (1.463%)


correlation matrix of the fit parameters:

               a      b
a              1.000
b             -0.984  1.000
```

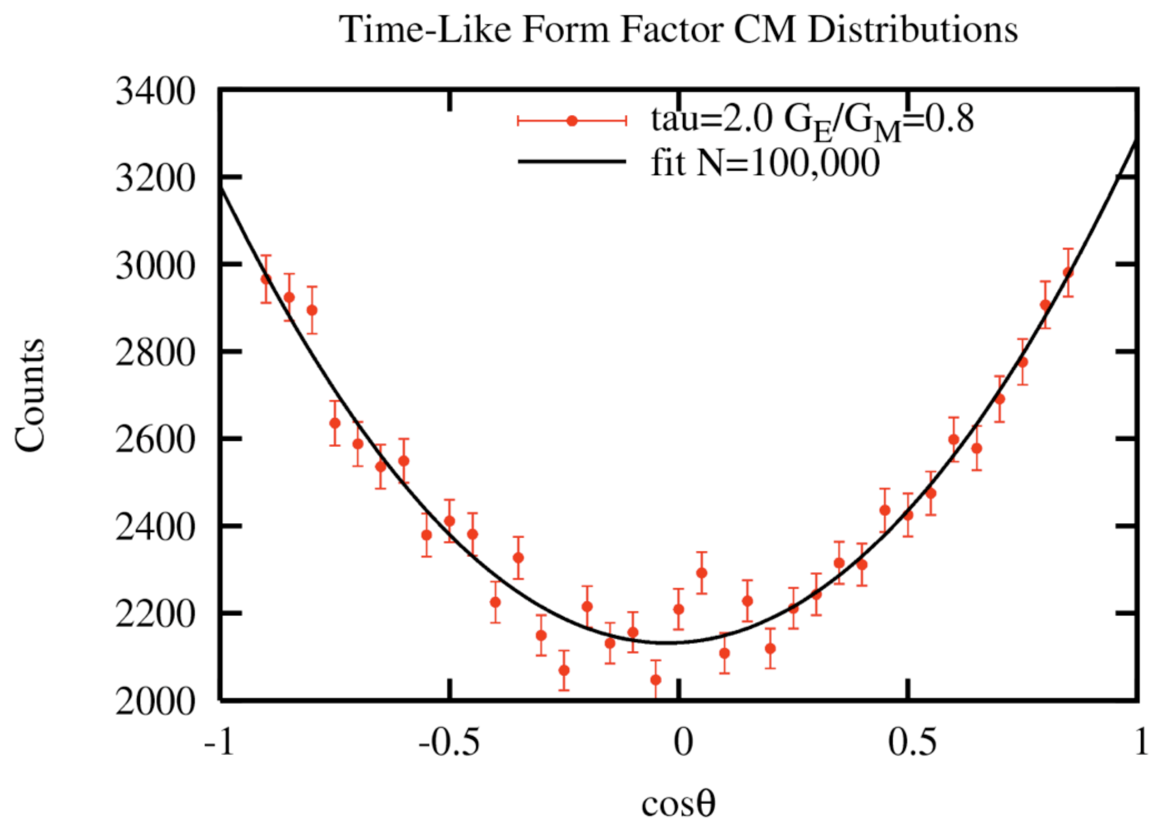



```
degrees of freedom (ndf) : 20
rms of residuals      (stdfit) = sqrt(WSSR/ndf)      : 1.08991
variance of residuals (reduced chisquare) = WSSR/ndf : 1.1879

Final set of parameters            Asymptotic Standard Error
=======================            ==========================

a               = 1219.56          +/- 58.36        (4.786%)
b               = 1292.22          +/- 71.34        (5.521%)


correlation matrix of the fit parameters:

               a      b
a              1.000
b             -0.984  1.000
```

Simulated Acceptance 2

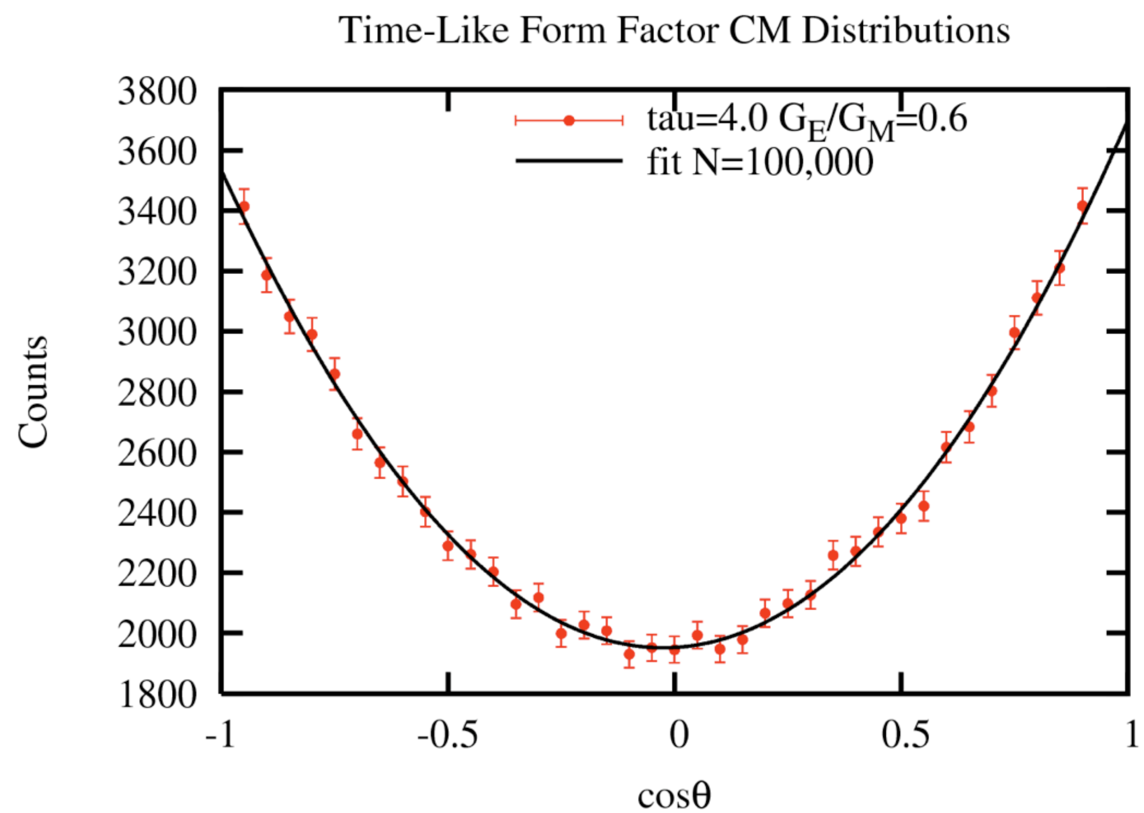



```
degrees of freedom (ndf) : 20
rms of residuals      (stdfit) = sqrt(WSSR/ndf)      : 1.00944
variance of residuals (reduced chisquare) = WSSR/ndf : 1.01897

Final set of parameters            Asymptotic Standard Error
=======================            ==========================

a               = 1374.64          +/- 53.02        (3.857%)
b               = 956.702          +/- 64.6         (6.752%)


correlation matrix of the fit parameters:

               a      b
a              1.000
b             -0.984  1.000
```

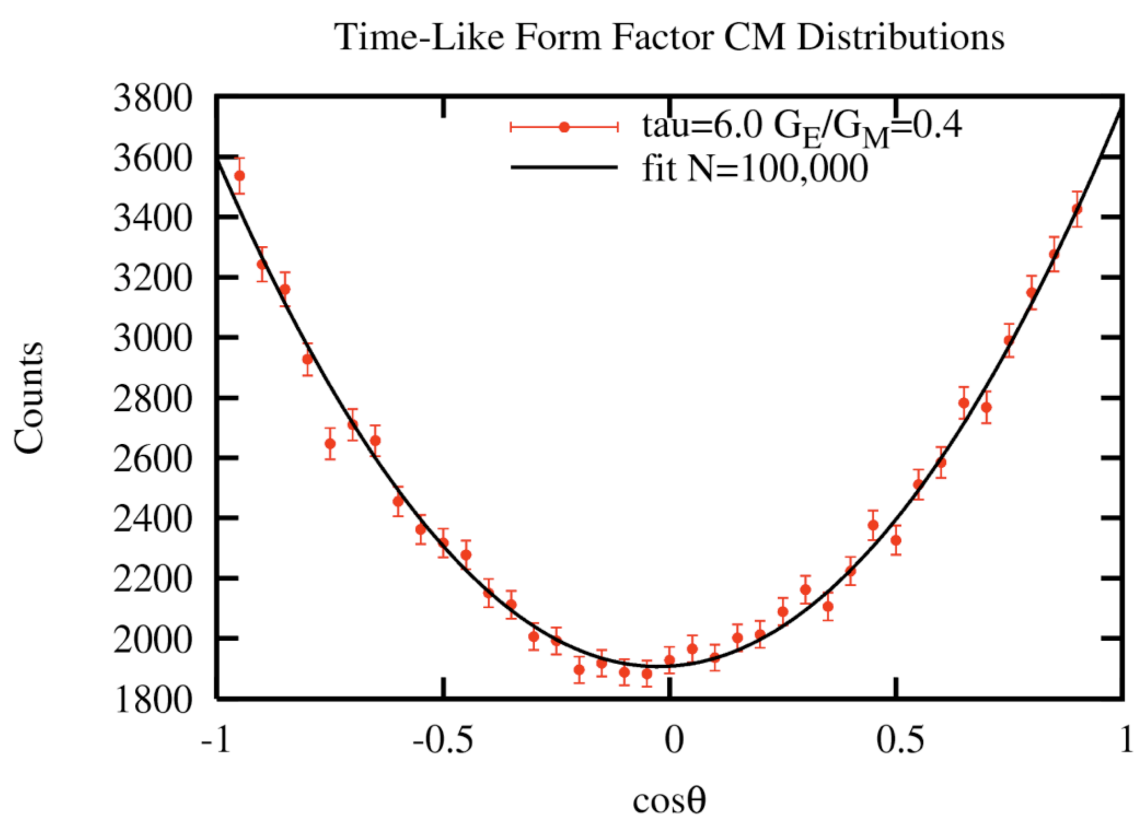



```
degrees of freedom (ndf) : 34
rms of residuals      (stdfit) = sqrt(WSSR/ndf)      : 1.23035
variance of residuals (reduced chisquare) = WSSR/ndf : 1.51376

Final set of parameters            Asymptotic Standard Error
=======================            ==========================

a               = 1616.63          +/- 17.07        (1.056%)
b               = 514.901          +/- 27.38        (5.317%)


correlation matrix of the fit parameters:

               a      b
a              1.000
b             -0.885  1.000
```

Simulated Acceptance 3

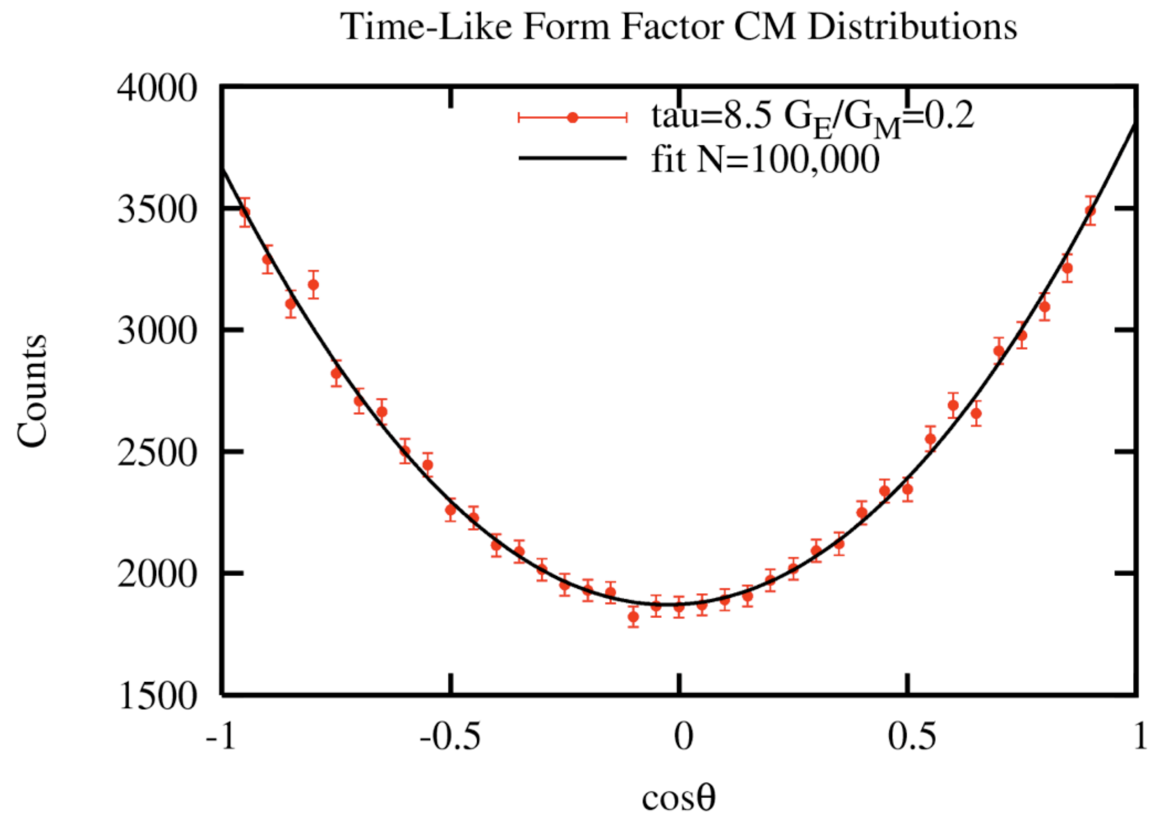



```
degrees of freedom (ndf) : 36
rms of residuals      (stdfit) = sqrt(WSSR/ndf)      : 0.691037
variance of residuals (reduced chisquare) = WSSR/ndf : 0.477532

Final set of parameters            Asymptotic Standard Error
=======================            ==========================

a               = 1807.07          +/- 8.497        (0.4702%)
b               = 144.32           +/- 13.85        (9.598%)


correlation matrix of the fit parameters:

                a      b
a               1.000
b              -0.865  1.000
```

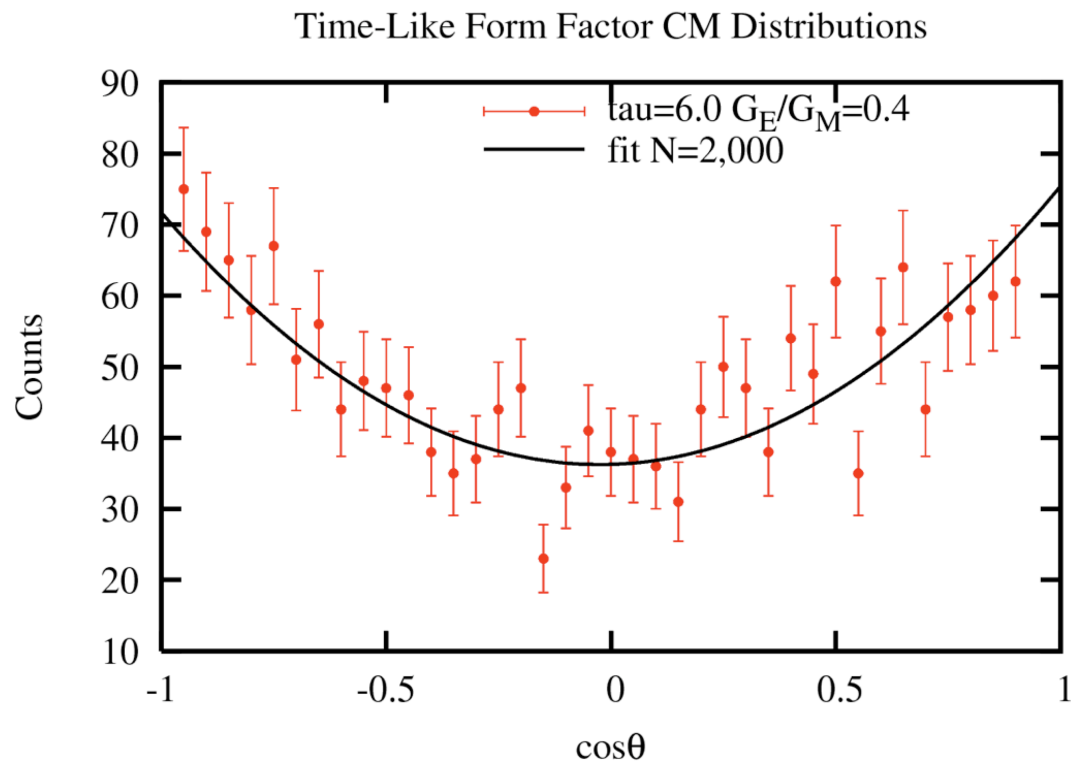



```
degrees of freedom (ndf) : 36
rms of residuals      (stdfit) = sqrt(WSSR/ndf)      : 1.07421
variance of residuals (reduced chisquare) = WSSR/ndf : 1.15393

Final set of parameters            Asymptotic Standard Error
=======================            ==========================

a               = 1839.98          +/- 13.25        (0.7201%)
b               = 66.7062          +/- 21.48        (32.2%)


correlation matrix of the fit parameters:

                a      b
a               1.000
b              -0.866  1.000
```

Simulated Acceptance 4

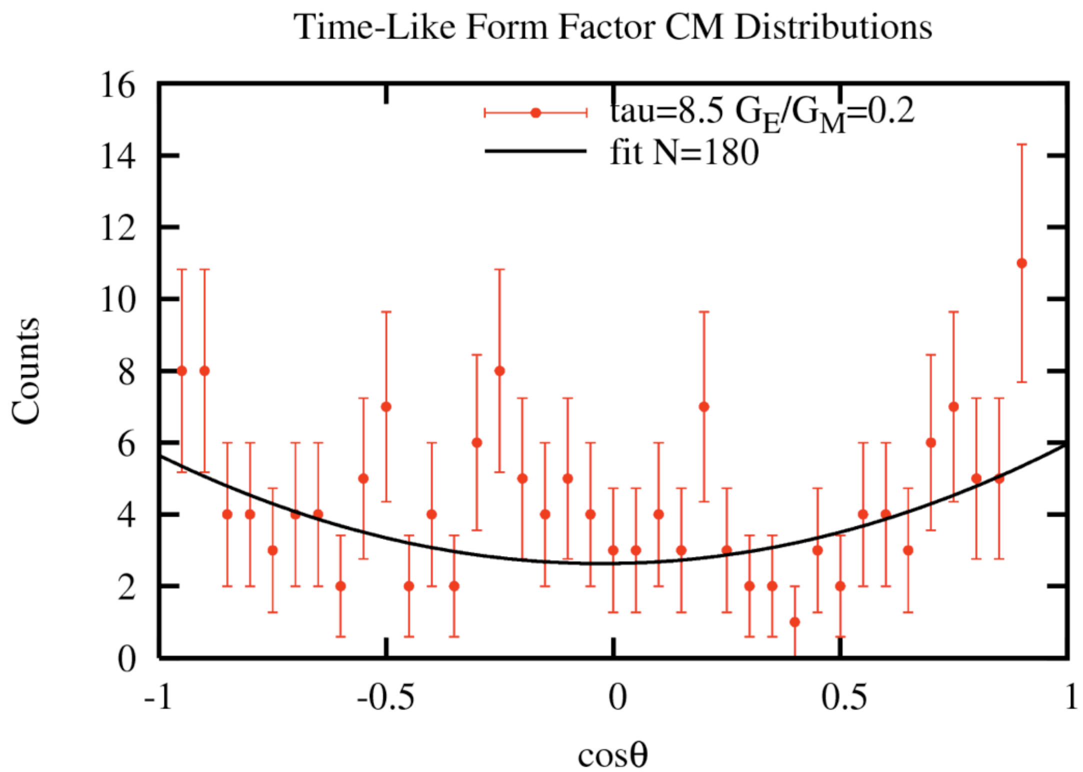



```
degrees of freedom (ndf) : 36
rms of residuals      (stdfit) = sqrt(WSSR/ndf)      : 0.916857
variance of residuals (reduced chisquare) = WSSR/ndf : 0.840628

Final set of parameters            Asymptotic Standard Error
=======================            ==========================

a               = 1879.84          +/- 11.34        (0.6031%)
b               = -9.33121         +/- 18.27        (195.8%)


correlation matrix of the fit parameters:

               a      b
a              1.000
b             -0.867  1.000
```

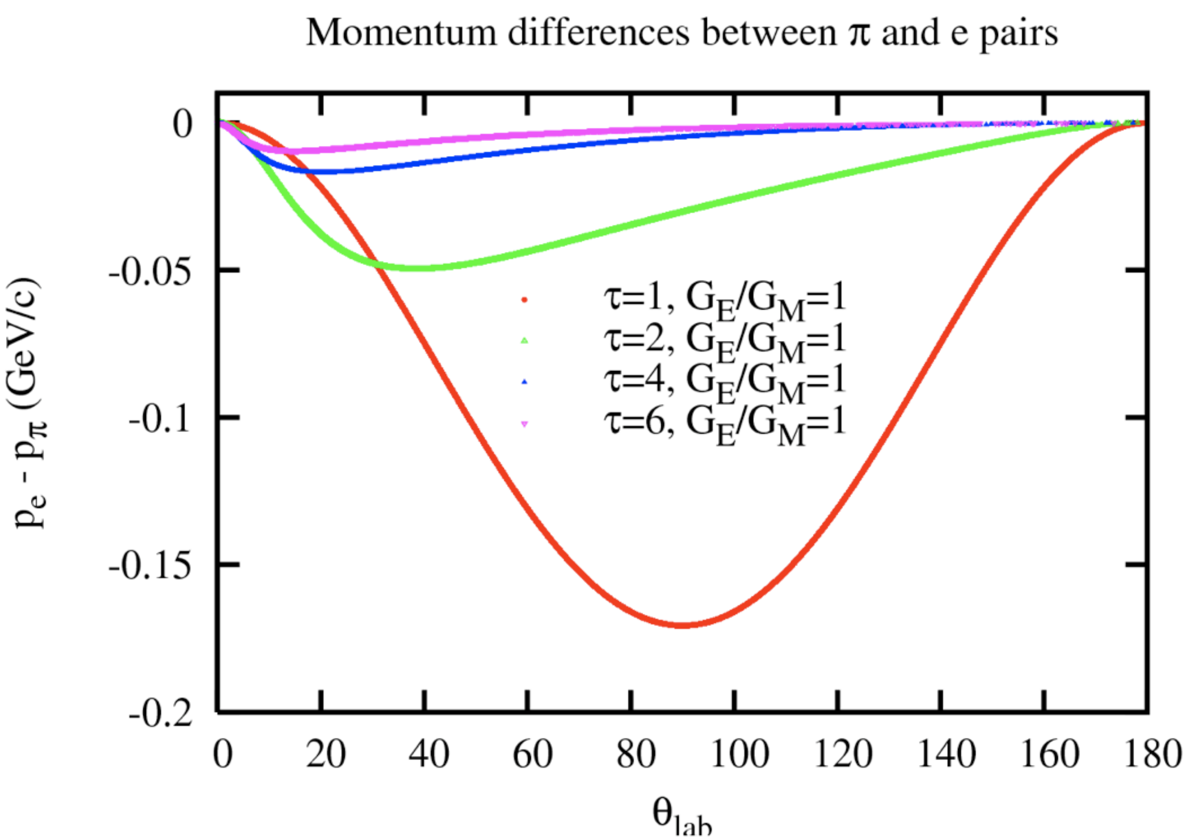



```
degrees of freedom (ndf) : 36
rms of residuals      (stdfit) = sqrt(WSSR/ndf)      : 1.07704
variance of residuals (reduced chisquare) = WSSR/ndf : 1.16001

Final set of parameters            Asymptotic Standard Error
=======================            ==========================

a               = 36.7716          +/- 1.853        (5.04%)
b               = -0.532456        +/- 2.979        (559.4%)


correlation matrix of the fit parameters:

               a      b
a              1.000
b             -0.866  1.000
```

Simulated Acceptance 5




```
degrees of freedom (ndf) : 36
rms of residuals      (stdfit) = sqrt(WSSR/ndf)      : 0.925413
variance of residuals (reduced chisquare) = WSSR/ndf : 0.856389

Final set of parameters            Asymptotic Standard Error
=======================            ==========================

a               = 2.90031          +/- 0.482        (16.62%)
b               = -0.26995         +/- 0.7881       (291.9%)


correlation matrix of the fit parameters:

                a      b
a               1.000
b               -0.891  1.000
```



There is little hope to resolve exclusive e^+e^- events from exclusive $\pi^+\pi^-$ events. The graph to the left shows the difference in momenta as a function of lab angle for different beam energies, assuming all energy goes into the pair. Only at threshold does one see momentum differences as large as 100 MeV. Hence, one must measure pairs, not single particles, to identify time-like form factors.

Conclusions

- Near threshold, $\tau=1$, acceptance is limited to CM angles around 90^o.
- Already at $\tau=2$ the CM acceptance is very good for two muons.
- Because the electron and pion momenta at fixed θ (for exclusive pairs) are imperceptibly different, one must measure electron pairs rather than a single electron. One may, however, be able to measure a single muon if all pions from exclusive pairs can be effectively eliminated in the muon counters.