Extracting the beam asymmetry Σ from data (bins in $(E_\gamma, \cos\theta)$)

Event yield asymmetries (binned in ϕ)

$$A(\phi) = \frac{N^\perp - N^\parallel}{p_\gamma^\parallel N^\perp + p_\gamma^\perp N^\parallel} = \Sigma \cos(2(\alpha^\parallel - \phi))$$

Event based fit (unbinned in ϕ)

$$\begin{aligned}-\ln\mathcal{L} = &\sum_{i=1}^{n} -\ln(p_{\text{prompt}}(\phi_i, p_{\gamma,i}, \Sigma, a_1 \ldots a_4, b_1 \ldots b_4)) + \\ &\sum_{j=1}^{m} -\ln\left(p_{\text{sideband}}(\phi_j, p_{\gamma,j}, \Sigma^{\text{bkg}}, a_1^{\text{bkg}} \ldots a_4^{\text{bkg}}, b_1^{\text{bkg}} \ldots b_4^{\text{bkg}})\right)\end{aligned}$$

toy MC: generate events that follow pdfs ($\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}$) of $N^\parallel, N^\perp$ and $p_{\text{prompt}}, p_{\text{sideband}}$

Investigating toy MC fit results

χ^2 **fits**: investigate *normalized residuals* $\xi = \frac{\Sigma_{\text{estimated}} - \Sigma_{\text{true}}}{\text{err}(\Sigma_{\text{estimated}})}$,
$\rightarrow$ "good" fit yields $\xi \sim \mathcal{N}(0,1)$
bayesian fits:

a. add up posteriors $p(\Sigma|y_i)$ to combined posterior $P(\Sigma|y_0,\ldots,y_{9999})$ (mixture model)
   $\rightarrow$ expect $P(\Sigma|y_0,\ldots,y_{9999}) \sim \mathcal{N}(\Sigma_{\text{true}},\sigma)$
b. build "normalized residuals" $\Xi = \sum_{i=0} \frac{p(\Sigma|y_i) - \Sigma_{\text{true}}}{\text{std}(p(\Sigma|y_i))}$
   $\rightarrow$ expect $\Xi \sim \mathcal{N}(0,\mathcal{O}(1))$

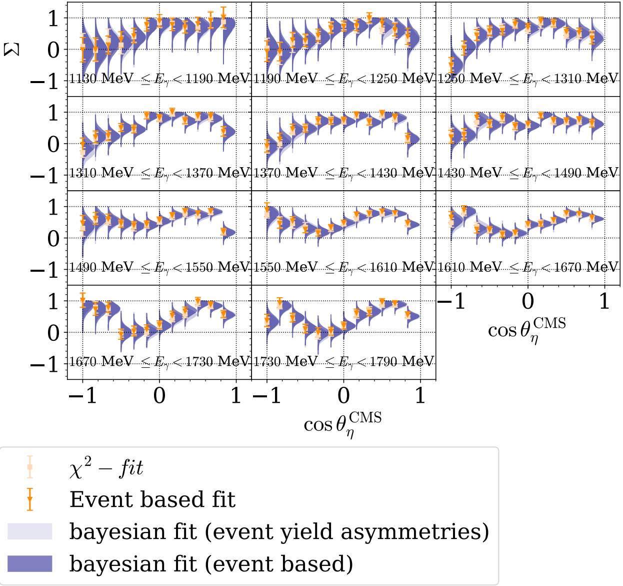
also check χ^2 distribution and MCMC diagnostics

Fit results

statistics of η final state:

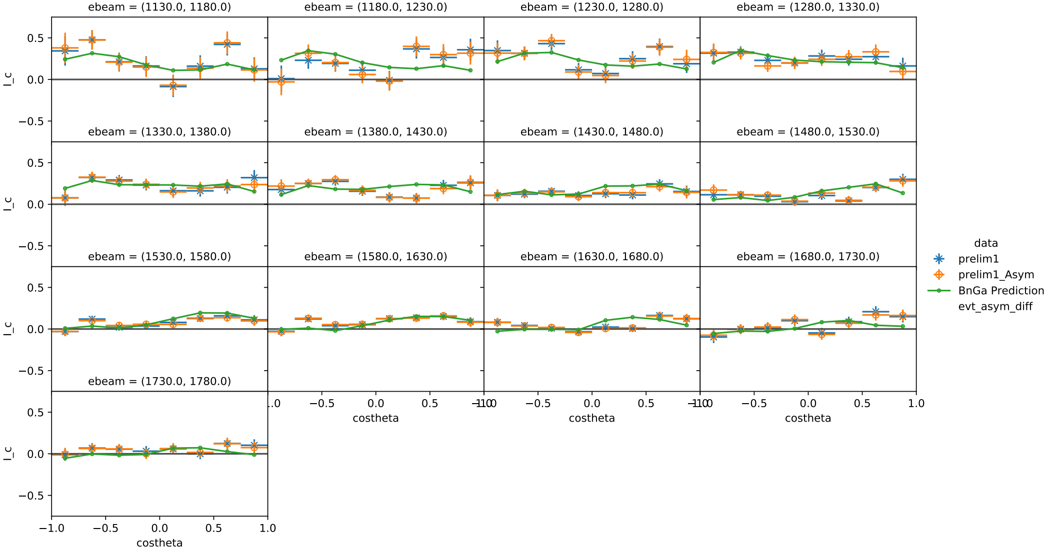
- 10000 toy bins
- $p_\gamma^{\parallel} = 0.25, p_\gamma^{\perp} = 0.3,\ \Sigma = 0.3$
- $n_{\text{events}}^{\parallel} \sim \text{Pois}(800),\ n_{\text{events}}^{\perp} \sim \text{Pois}(1000)$

Results

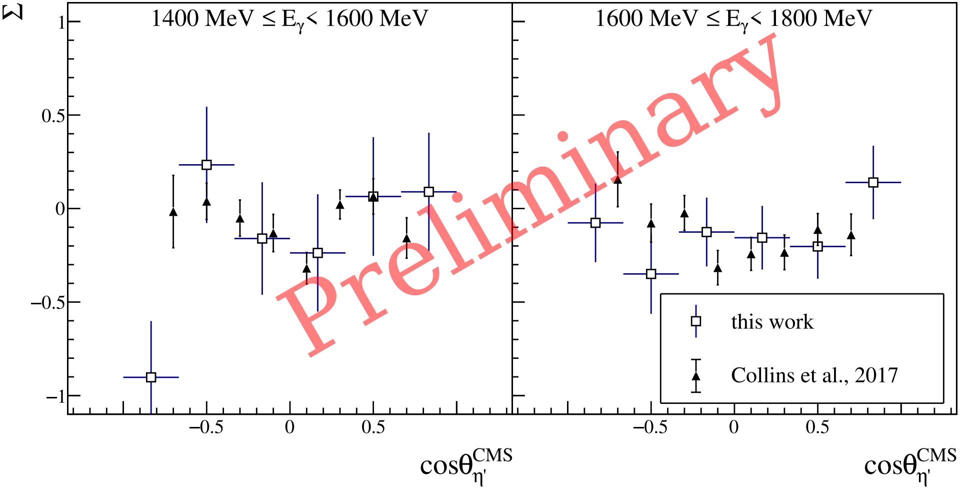


Σ
1130 MeV $\le E_\gamma <$ 1190 MeV
1190 MeV $\le E_\gamma <$ 1250 MeV
1250 MeV $\le E_\gamma <$ 1310 MeV
1310 MeV $\le E_\gamma <$ 1370 MeV
1370 MeV $\le E_\gamma <$ 1430 MeV
1430 MeV $\le E_\gamma <$ 1490 MeV
1490 MeV $\le E_\gamma <$ 1550 MeV
1550 MeV $\le E_\gamma <$ 1610 MeV
1610 MeV $\le E_\gamma <$ 1670 MeV
1670 MeV $\le E_\gamma <$ 1730 MeV
1730 MeV $\le E_\gamma <$ 1790 MeV
$\cos\theta_\eta^{\mathrm{CMS}}$
$\chi^2 - fit$
Event based fit
bayesian fit (event yield asymmetries)
bayesian fit (event based)

Σ in $\gamma p \to p2\pi^0$



Σ in $\gamma p \to p\eta'$



To Do

extract Σ using unbinned maximum likelihood fit for η'

apply BAYESIAN approach

consider bkg contaminations in results of $\Sigma_{\eta'}$, study toy MC