Update on Statistical Uncertainty of $D^0 \to \pi^+ K^-$ SSA

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Prescription for SSA (and uncertainty) Calculation

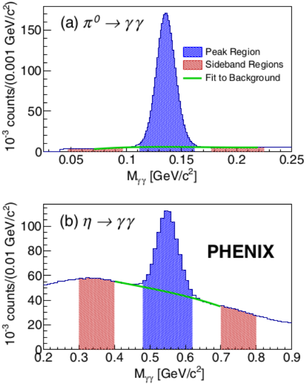


Figure 1: Illustrative plot from PHENIX : π^0 (above) and η (below) from di-photon invariant mass spectra

- Following the standard practice at STAR, PHENIX and COMPASS:
- From invariant mass spectra in azimuthal (ϕ) slices, define signal region (often 2σ around the peak), count total, calculate raw asymmetry (and uncertainty)
- Far from signal peak, count pure background, calculate background asymmetry (and uncertainty)
- Correct 'raw' asymmetry with background asymmetry (and relative contribution) to extract 'signal' asymmetry (and uncertainty)

Now Some Explicit Equations

Transverse Single Spin Asymmetry :

$$A_N(\phi) = \frac{1}{P\langle|cos(\phi)|\rangle} \frac{N(\phi) - \mathcal{R}.N(\phi+\pi)}{N(\phi) + \mathcal{R}.N(\phi+\pi)}$$

where P is beam polarization, $\langle|cos(\phi)|\rangle = \frac{\int_{\phi_1}^{\phi_2} cos(\phi)d\phi}{\phi_2-\phi_1}$ is the average of the cosine of azimuth in the ϕ bin, $\mathcal{R}$ is relative luminosity for opp. pol. dir. of beam, N's are counts in ϕ bins. One can use $N(\phi) = N_L$ and $N(\phi+\pi) = N_R$ for left and right as simplified notation

Statistical Uncertainty of SSA (propagation of error assuming two independent variables $N(\phi)$ and $N(\phi+\pi)$) :

$$\sigma_{A_N}(\phi) = \frac{1}{P\langle|cos(\phi)|\rangle} \frac{2\mathcal{R}.N(\phi).N(\phi+\pi)}{(N(\phi)+\mathcal{R}N(\phi+\pi))^2} \sqrt{(\frac{\sigma_{N(\phi)}}{N(\phi)})^2 + (\frac{\sigma_{N(\phi+\pi)}}{N(\phi+\pi)})^2}$$

Simplifications

Assume $\mathcal{R} \sim 1$, $N(\phi) \sim N(\phi + \pi) = N$ where N is the count of candidates in a ϕ bin ($N = N_{detected}/n$ if you have n bins in azimuth) and assume Poisson distribution of counts (so that $\sigma_N = \sqrt{N}$)

Simplified version of statistical uncertainty of SSA :

$$\sigma_{A_N}(\phi) = \frac{1}{P\langle|cos(\phi)|\rangle} \frac{1}{\sqrt{2N}}$$

Finally : The Signal

Corrected signal SSA :

$$A_N^{Sig}(\phi) = \frac{A_N^{Raw}(\phi) - r.A_N^{Bkg}(\phi)}{1 - r}$$

where $r = \frac{N_{Bkg}}{N_{raw}}$ is background contribution to raw/total count under the signal peak

Corrected signal statistical uncertainty of SSA :

$$\sigma_{A_N^{Sig}}(\phi) = \frac{\sqrt{\sigma^2_{A_N^{Raw}}(\phi) + r^2\sigma^2_{A_N^{Bkg}}(\phi)}}{1 - r}$$

Procedure

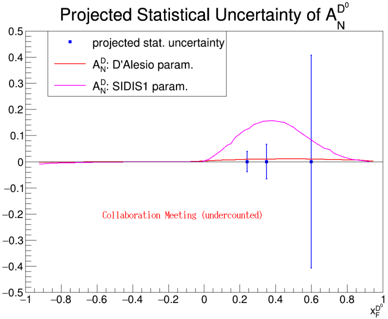
- After background suppression cuts, scale MC counts of signals in x_F bins to get counts in 1 year of data
- Using S/B ratio from analysis (1:8), estimate raw/total and background counts ($N_t = 9N_s$ and $N_b = 8N_s$ respectively) - done because we lack enough bkg MC to get bkg count directly
- For each x_F bin, distribute N_t and N_b in 12 ϕ bins, estimate raw and bakcground uncertainties in each ϕ bin
- For each pair of $(\phi, \phi + \pi)$ bins, extract corrected signal uncertainty $\sigma_{A_N}(\phi)$
- For x_F bin, combine uncertainties for independent measurements in 6 (pairs of left-right) ϕ bins

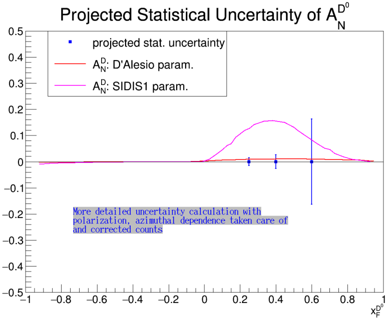
$$\sigma_{A_N}(x_F) = \frac{1}{\sqrt{\sum_{i=1}^{6} \frac{1}{\sigma^2_{A_N}(\phi_i)}}}$$

Calculations

- From 'ideal case' simulation : 4 Million open-charm events $\Rightarrow$ 2 Million $D^0 \to \pi^+ K^-$ (forced decay)
- From cross-sections and 1 year integrated luminosity : 240 Million $D^0 \to \pi^+ K^-$ produced
- A factor of 120 gain over counts from MC - I applied BR again by mistake in last calculation - underestimated signal
- MC analysis signal counts in x_F bins : 2416 $(0.2 \leq x_F \leq 0.3)$, 841 $(0.3 \leq x_F \leq 0.5)$, 22 $(x_F > 0.5)$
- Use 12 equal azimuthal(ϕ) bins and polarization $P = 0.7$
- Statistical Uncertainties in x_F bins : 0.0156, 0.0265, 0.1640

Projected Asymmetry of $A_N^{D^0}$





Statistical uncertainties are for D^0 counts ONLY, whereas calculations are for INCLUSIVE $D/\bar{D}$. So, in a proper comparison, uncertainties will be even shorter (by including $\bar{D}^0$, D^+, D^-).

We get very precise measurement here, but remember this is the 'ideal case' and assumes full statistics of produced counts. Reality will be somewhat different.

Outlook

- A big ‘thank you’ to Igor Denisenko - long discussions with him lead to more careful and more detailed calculation
- Igor will probably demonstrate a parallel method of estimating statistical unceraínty in next physics meeting - following the method of least squares in the pdg statistics chapter - calculating the covariance matrix for a linear combination of two independent functions
- Currently looking at $D^+ \rightarrow \pi^+\pi^+K^-$ reconstruction
- Also looking at a multivariate analysis for the ideal D^0 case with Dimitrije Maletic to see if that can help