MC Study of Direct Photon Production and Asymmetries at SPD

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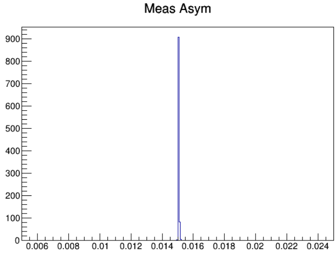
Asymmetry Measurement and Background Corrections

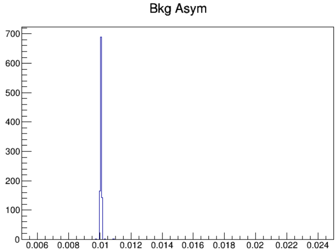
- Single photons from (mostly) π^0 decays are the largest source of bkg for direct photons
- In every bin (p_T or x_F), $A_N = \frac{1}{P}\frac{N^+ - RN^-}{N^+ + RN^-}$
- CDR suggests MC based study to determine bkg fraction and subtracting $N_{prompt} = N_\gamma - k \times N_{\pi^0}$
- MC does not replicate (background) asymmetry, so, correction factor from cross-section is constant (same for both configuration of beam polarization N^+, N^-)
- For a given bin : $N_{prompt} = N_\gamma(1 - r)$, r being the background fraction
- Bin-by-bin asymmetry being a ratio, subtraction of a constant factor cancels, resulting in no correction for asymmetry

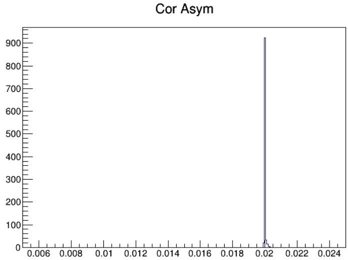
Asymmetry Measurement and Background Corrections

- Proper way of correction is not by statistically subtracting background count, but background asymmetry
- Asymmetry : $A_N^{signal} = \frac{A_N^{measured} - r \times A_N^{background}}{1-r}$
- Uncertainty : $\sigma_{signal} = \frac{\sqrt{(\sigma^2_{measured} + r^2 \times \sigma^2_{background}}}{1-r}$
- Toy MC with assumed signal and background asymmetries and background fractions used to demonstrate the correction
- Uniform random variables (one for signal, one for background) to divide counts with a given asymmetry
- Next two slides show raw measured, background and statistically corrected asymmetries for two different signal to background ratios

Demonstration : Signal to Background = 1:1

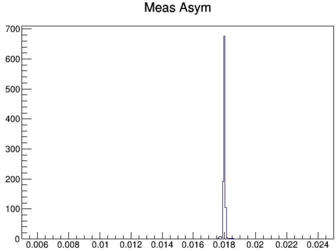


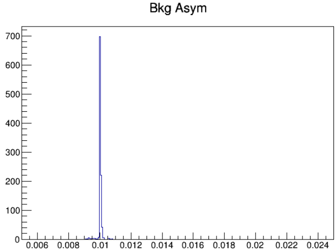


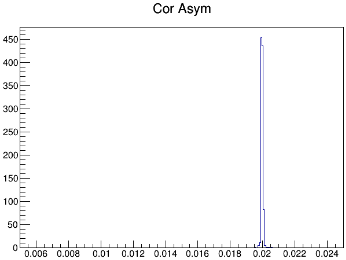


- signal to background = 1:1
- (assumed) true signal asymmetry = 2%
- (assumed) background asymmetry = 1%
- $\frac{\delta A_N}{A_N} = 25\%$

Demonstration : Signal to Background = 4:1







- signal to background = 4:1
- (assumed) true signal asymmetry = 2%
- (assumed) background asymmetry = 1%
- $\frac{\delta A_N}{A_N} = 10\%$

Pythia 8 MinBias and Prompt Photon Production

- Produced 1 billion events with Pythia 8 minimum bias, normalized to 1 year of data (integrated luminosity 1 fb^{-1})
- Counted π^0, η, photons decayed from π^0, η
- Assumed single photon survival prob $\sim 91\%$
- Based on survival prob. removed photons from reconstructed π^0, η
- Counted background single photon if not reconstructed and it survived

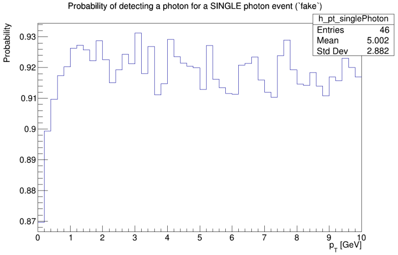


Figure 1: single γ survival prob. from Andrei Maltsev using SPDRoot. Takes care of conversions before ECal and missing acceptance/gaps

Photon Counts

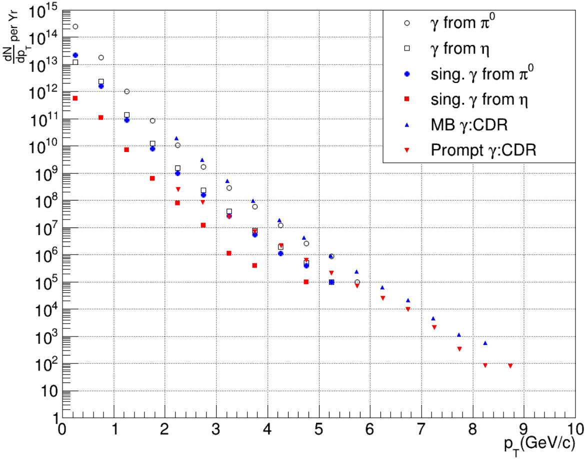
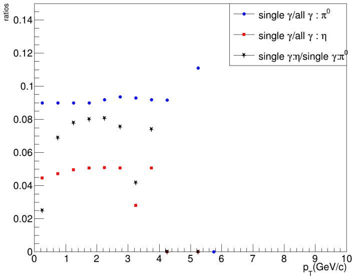
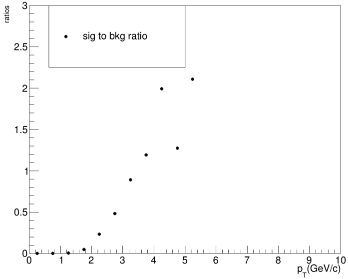


Figure 2: photon counts from MinBias simulation

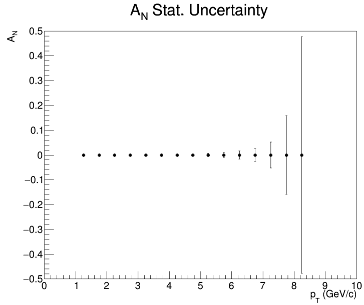
Relevant Photon Ratios

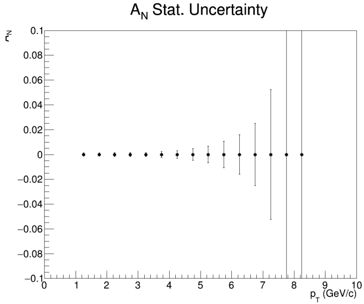




- My sim slightly undercounts total MB photons shown in CDR
- My sim was statistics starved and high p_T bins were not populated
- However, the ratios show steady patterns : $\sim 9\%$ photons from π^0 decays survive as background
- $\sim 4-5\%$ photons from η decays survive as background
- Among background photons, contribution from η is $\sim 6-7\%$
- Important : signal:background $\sim 1:1$ and better from $\sim p_T = 3$ GeV/c onwards

Statistical Uncertainties





- Using formula for propagating statistical uncertainties on Slide 3
- Used CDR estimations of Prompt Photons and MB Photons ($\sim 9\%$ of them survive as background from this study)
- Only statistical uncertainties of prompt photons and background photons propagated (no systematic uncertainty assumed)
- Warning : remember signal/background ratio. Measurments are decent only in high $p_T > 3$ GeV/c bins

A Footnote

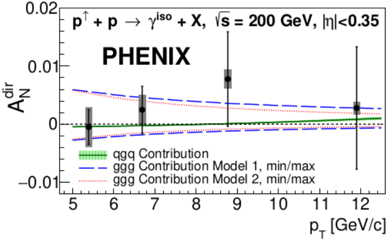


Figure 3:
https://arxiv.org/abs/2102.13585v1
Recent PHENIX direct photon A_N result submitted to PRL

- In their calculation, they assume background $A_N^{bkg} = 0$ as for mid-rapidity π^0 A_N is compatible to zero

A Footnote : continued

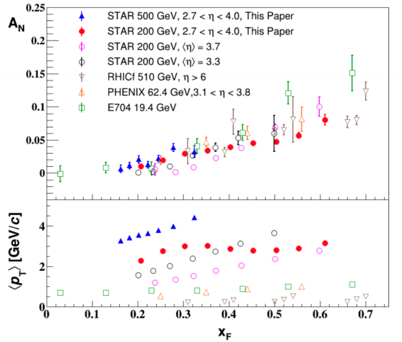


Figure 4:
https://arxiv.org/abs/2012.11428
Recent STAR π^0 A_N results compared to others, not published yet

- However, at forward rapidity, A_N of background can be comparable to what we expect for prompt photons and therefore signal/background ratio and proper corrections are important

Longitudinal Asymmetry : Update

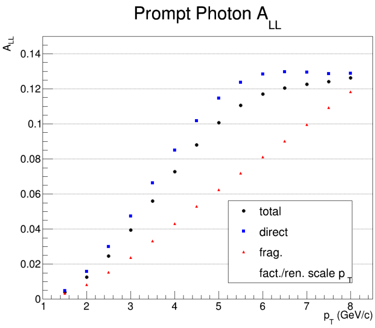


Figure 5: Prompt photon A_{LL} : courtesy of Werner Vogelsang

- Werner Vogelsang recently kindly provided calculations of A_{LL} for us
- $\sqrt{s} = 27$ GeV, $-3 \leq y \leq 3$.
- NNPDF3.0 unpolarized PDF, DSSV 2014 polarized PDF
- factorization/renormalization scale $= p_T$
- Rodolfo Sassot will use these with our projected uncertainties for 1 fb^{-1} integrated luminosity for their Weighted MC technique to find the effect on $\Delta g(x)$
- Waiting for computing time in grid

Next Steps : For Prompt Photons

- Submit batch jobs to generate enough statistics to populate high p_T bins
- Some hitches for running new SPDRoot. Once fixed, use SPDRoot for MB and direct photons MC to study background of prompt photons
- Isolation cut (restriction of energy in a cone around leading photon) are useful for higher energy measurements. Study carefully what it can do for us to reduce background and/or fragmentation photons