Unfolding P_T dependence of A_N for Forward Neutron Production in Polarized p + p Collisions at Sqrt(s) = 200 GeV

Spin PWG Meeting
2020/07/30
9:00 AM (KST/JST)

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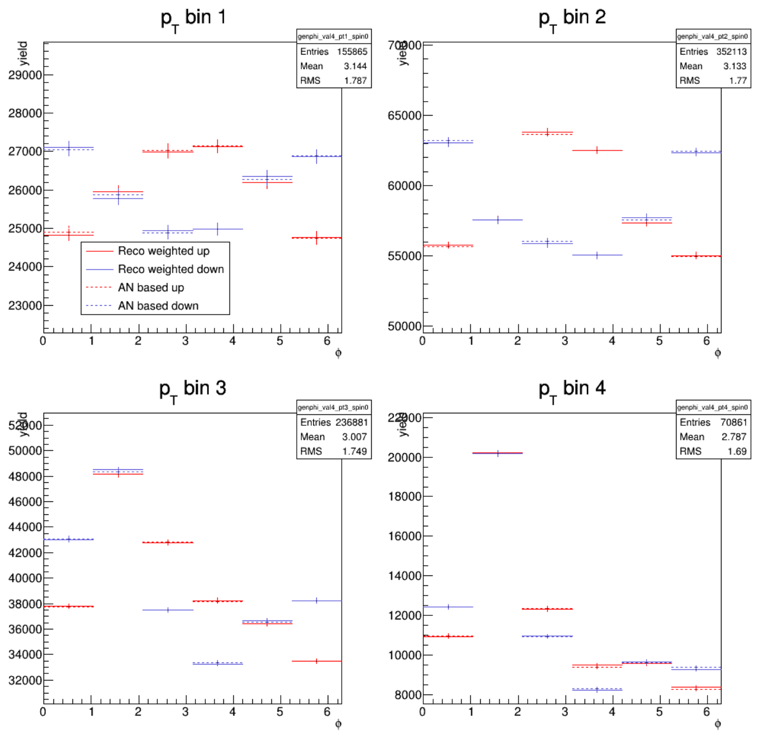
Last Update in Spin PWG Meeting - Asymmetry Extraction Strategy

[2020-06-18 (9 AM, JST/KST)]

- **Translation**: Measured Asymmetries (Minjung) are translated into 2D yields.
- **Unfolding**: Unfolding of the two-dimensional yields is executed.
- **Extraction**: Unfolded asymmetries obtained based on the unfolded yields by calculating asymmetries.



(Minjung's)

P_T dependent A_N's → translate into 2D yields → Unfold → Get unfolded A_N's

Asymmetry Weighting and Extraction - Different Functional Forms

For MC sample:

- Create spin up or down state (ispin 0, 1) for each event.

Create spin dependent weight according to some functional form:

- Polynomial (w_{pol3}) function:

$$w_{pol3} = 1 + \left(a + b * P_{T,T} + c * P_{T,T}^2 + d * P_{T,T}^3\right) * \cos(\Phi_{T,T} + spin * \pi)$$

- Power function (w_{pow}) :

$$w_{pow} = 1 + \left(\alpha + \beta * P_{T,T}^{\gamma}\right) * \cos(\Phi_{T,T} + spin * \pi)$$

- Exponential function (w_{exp}):

$$w_{exp} = 1 + \left(\omega + \sigma * \left(1 - \exp\left(\eta * P_{T,T}\right)\right)\right) * \cos(\Phi_{T,T} + spin * \pi)$$

a = constant part

b = linear part scanned over a wide range $b_{min} < b < b_{max}$

c = quadratic part scanned over a wide range between $c_{min} < c < c_{max}$

d = cubic part scanned over a wide range between $d_{min} < d < d_{max}$

s = spin (↑↓)

$P_{T,T}$ is the true transverse momentum and $\Phi_{T,T}$ is the true azimuthal angle distributions.

f = $\alpha, \beta, \gamma, \omega, \sigma, \eta$ are parameters.

Use these weights based on generated variables in all events and reconstructed variables, etc.…

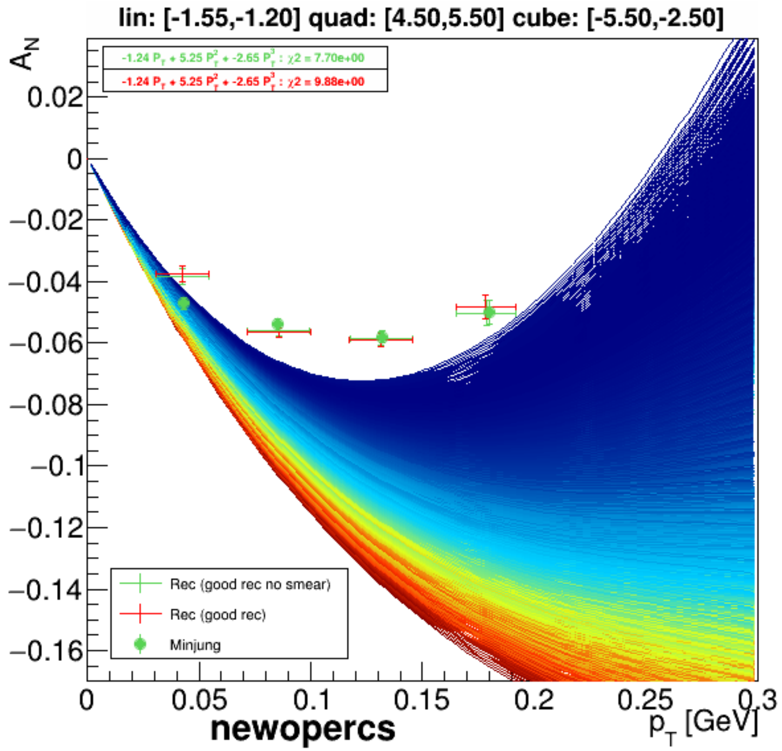
Asymmetries and Best Parameter Scanning – Minimum Chi-Square Search

Calculate Chi-Square based on reconstructed asymmetries and experimental data asymmetries (Minjung):

$$\chi^2_{min} = \sum_i \frac{(A_{N,i}^{Minjung} - A_{N,i}^{wgt,reco})^2}{\Delta A_{N,i}^{2,Minjung} + \Delta A_{N,i}^{2,wgt,reco}}$$

Best parameter is found (i.e. parameter with lowest Chi-Square for each functional form).

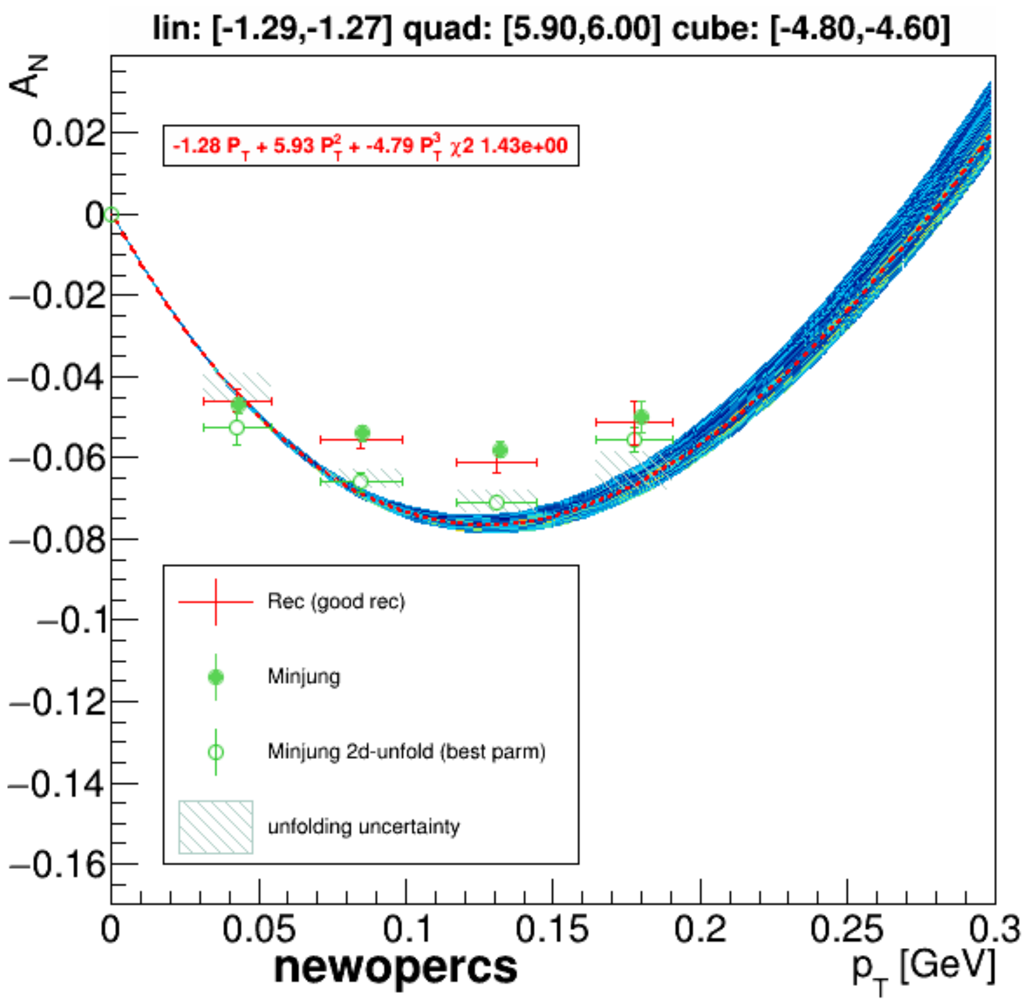
Reconstructed Asymmetries and Minimum Chi-Square Search – Coarse Scanning



- Green points: introduced asymmetries based on reco variables without crosstalk (not required)
- Red points: Introduced asymmetries based on smeared reco variables.
- Before unfolding, need best Chi-Square (minimum Chi-Square) .
- Zoom in (coarse scanning to fine scanning) to find best minimum one.

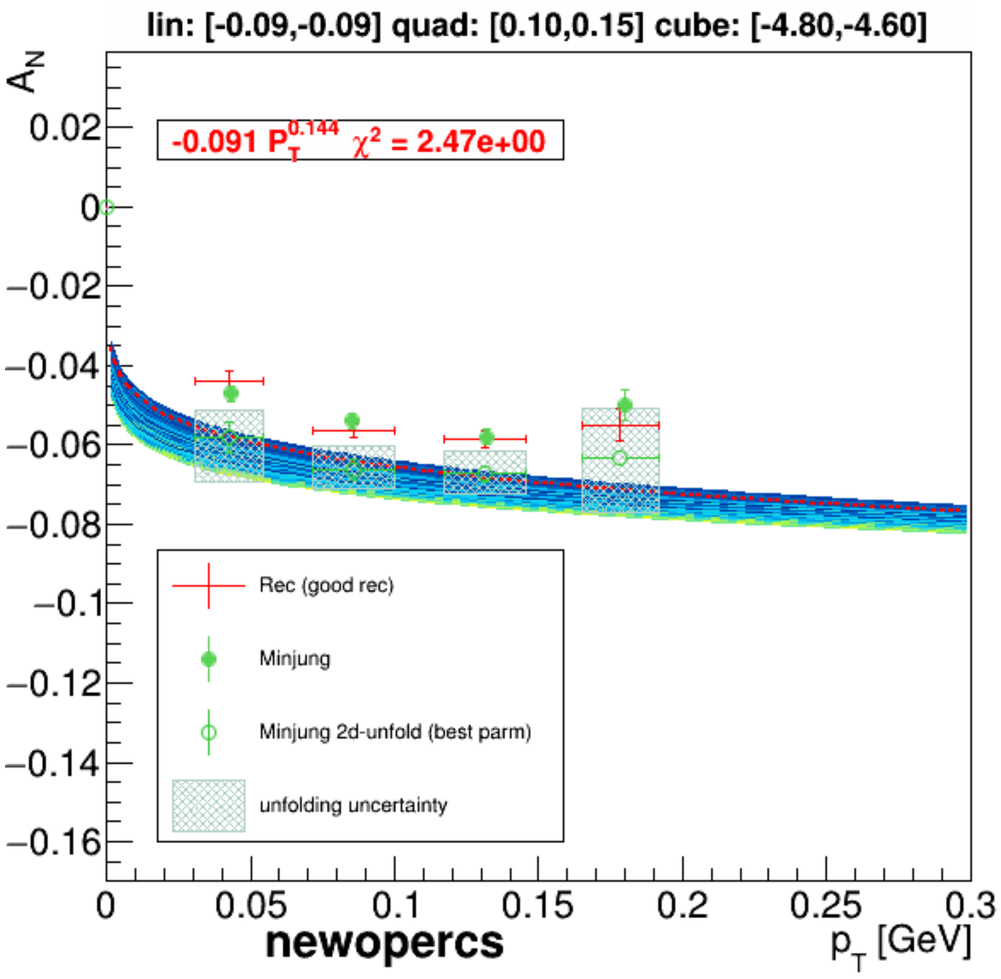
Reconstructed A_N's	Linear			Quadratic			Cubic			Chi-Square (best)
	Min	Max	Best	Min	Max	Best	Min	Max	Best	
Green cross	-1.55	-1.20	-1.24	4.50	5.50	5.25	-5.5	-2.50	-2.65	7.70
Red cross	-1.25	-1.20	-1.24	4.50	5.50	5.25	-5.5	-2.50	-.265	9.88

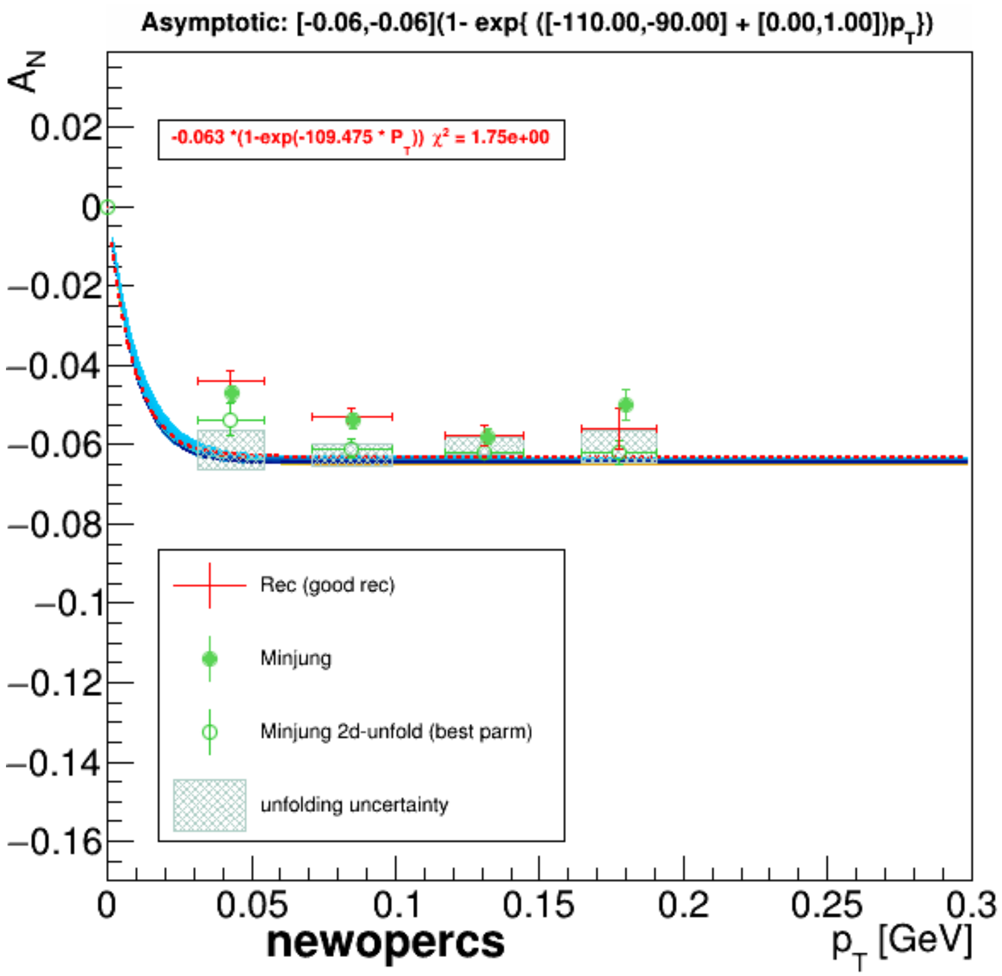
Asymmetries based on a 3rd order polynomial (pol3) function – Fine Scanning



- ❑ Fine scanning around best value based on Pol3.
- ❑ Shaded curve obtained from the spread of all unfolded A_N's
- ❑ Red broken line is best parametrization in range used for the unfolding (input curve).

Fine Scanning for other Functional Forms – Power Law and Exponential

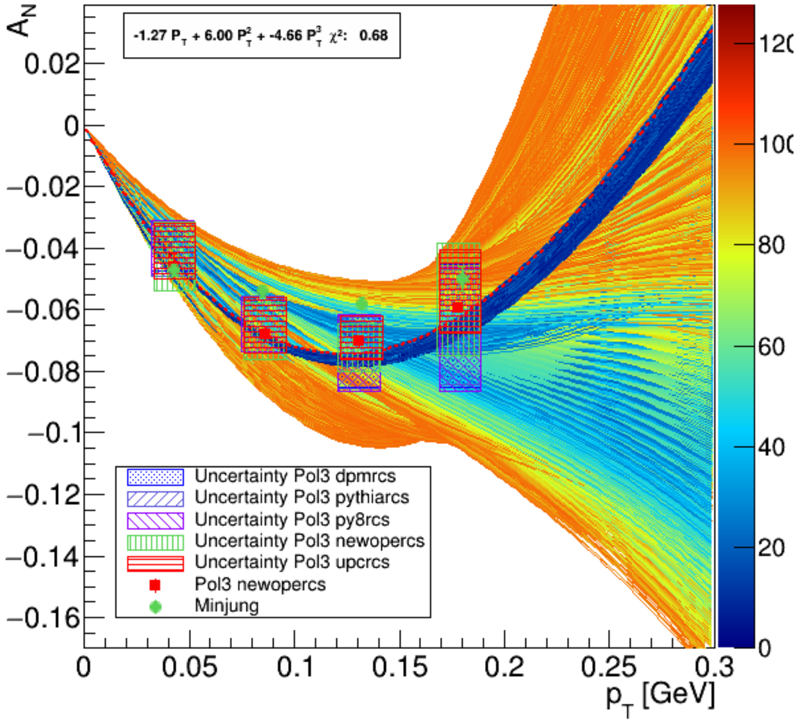




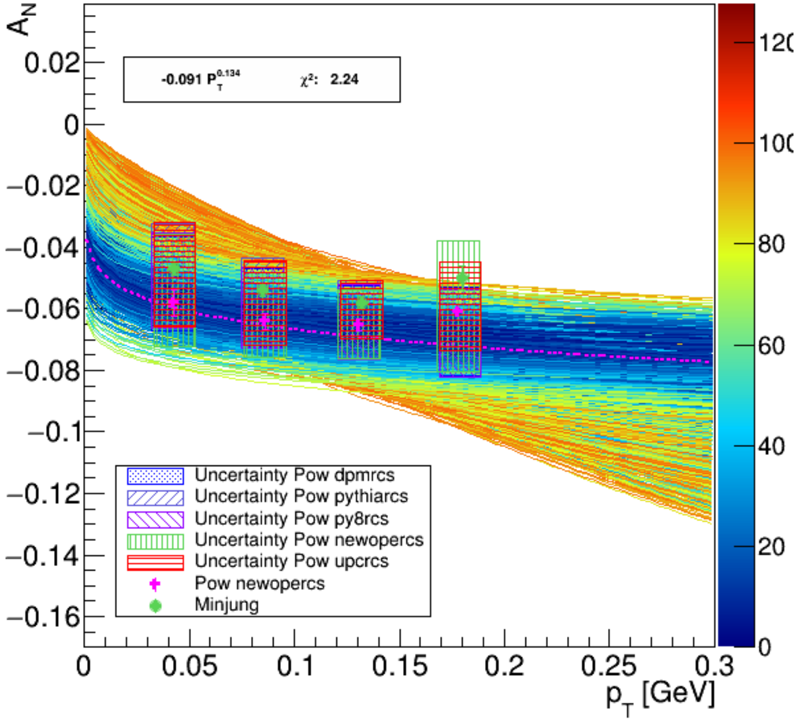
Both functions with somewhat larger Chi-Square than polynomial function (i.e. less flexible)

All Three Parameterizations with Coarse and Fine Scanning Ranges

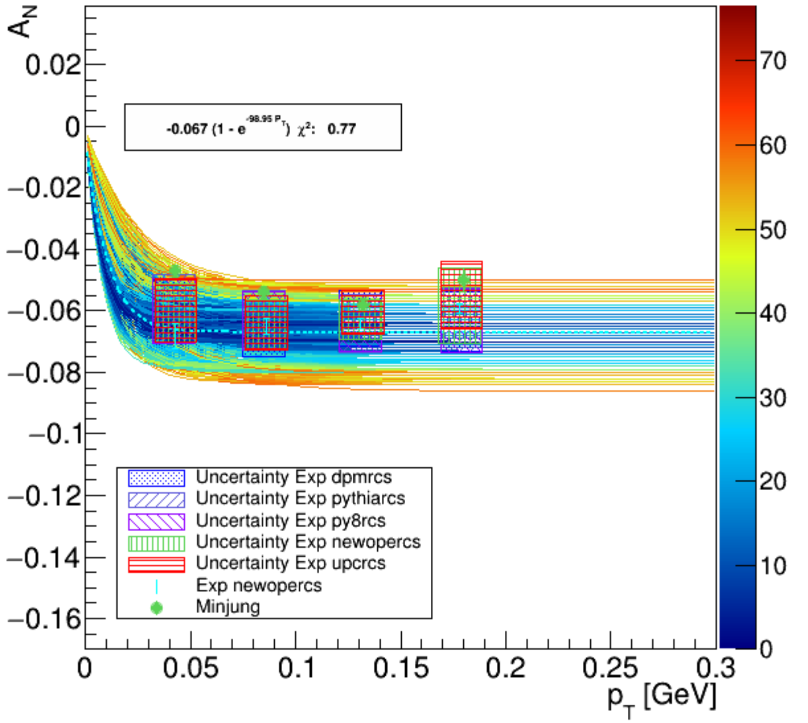
Pol3 dependence



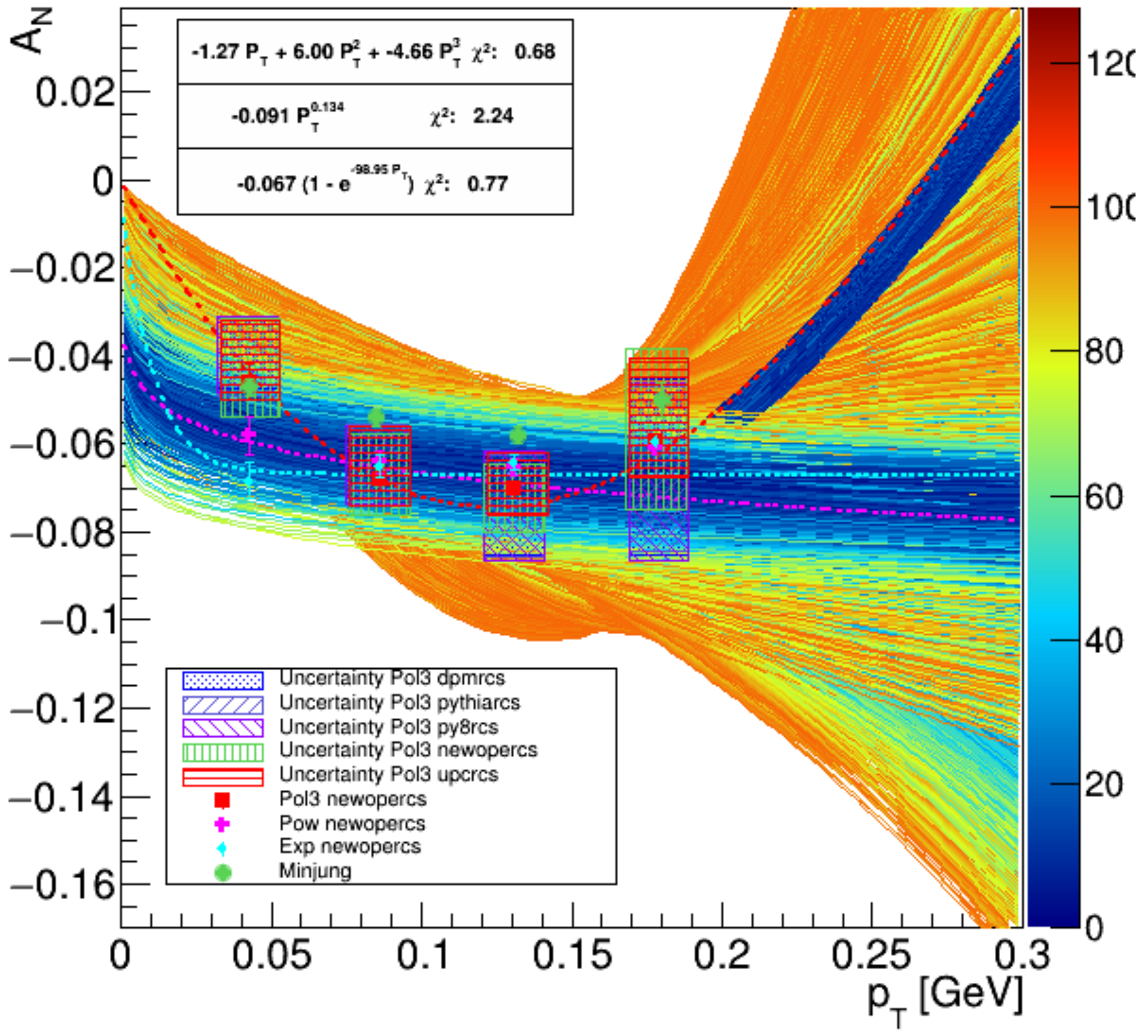
Power law dependence



1-exp dependence



Unfolded Asymmetries – Pol3, Power & Exponential Dependendence



- Unfolded asymmetries for both coarse and fine ranges.

  All show reasonable χ^2 in comparison to measured asymmetries (Minjung).

- Pol3 Chi2 = 0.68 : b = -1.27, c = 6.00, d = -4.66

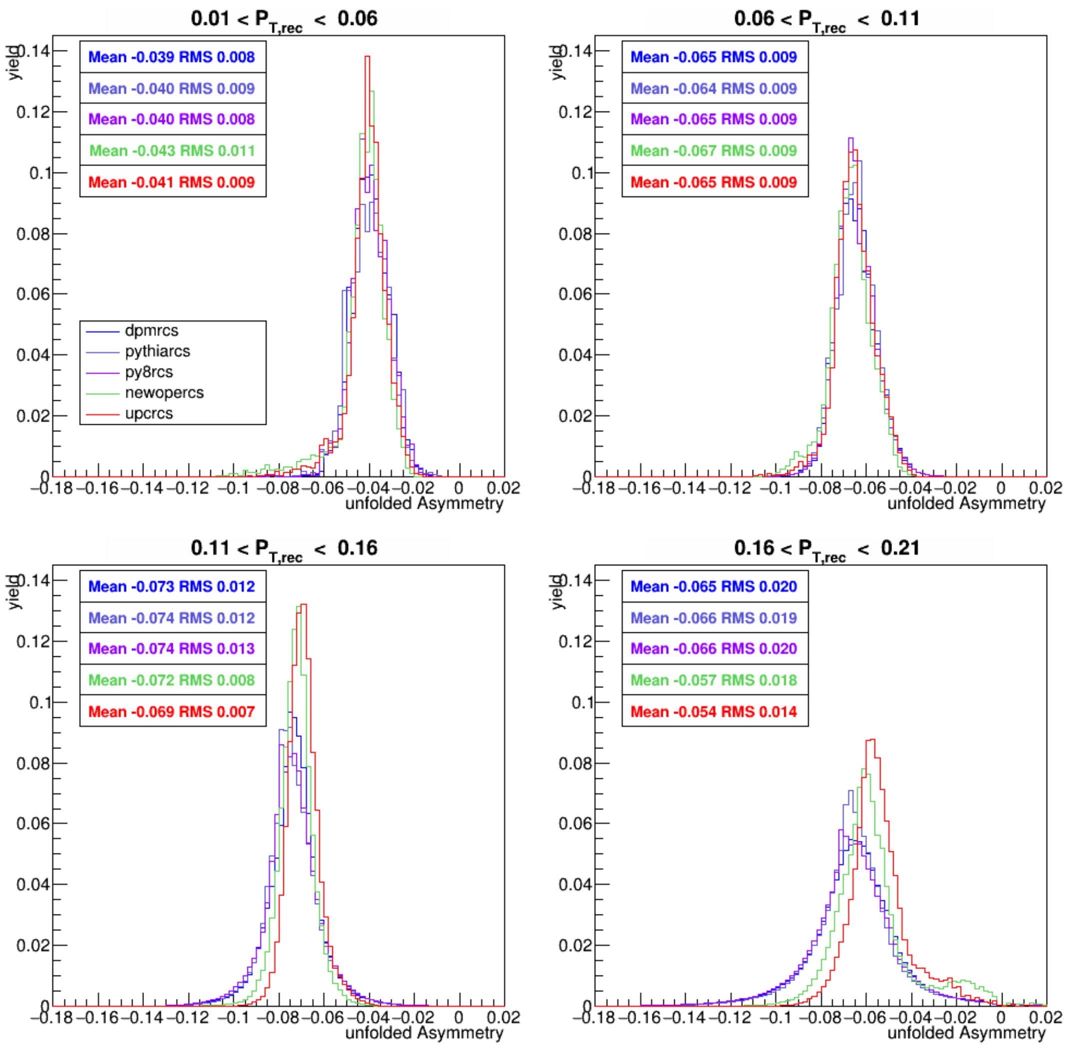
- Powr Chi2 = 2.24 : b = -0.091, c = +0.134

- Expo Chi2 = 0.77 : b = -0.067, f = -98.95

  Lowest unfolded result for each parameterization displayed as points.

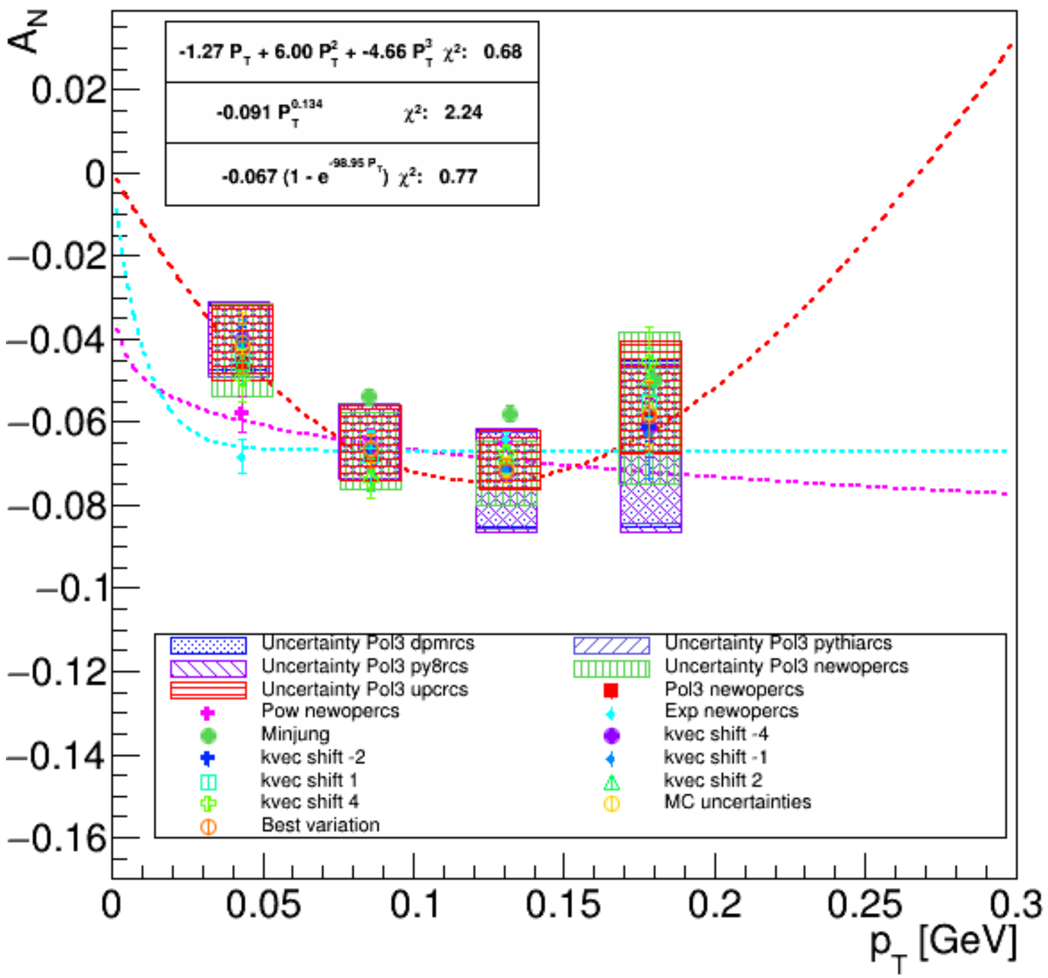
- RMS ranges of unfolded points shown for all the MCs - Dpmjet, Pythia6, Pythia8, Ope & Upc for polynomial.

Variation of Unfolded Asymmetry Results for all Monte Carlo Samples



- Distributions of unfolded asymmetries for Dpmjet, Pythia6, Pythia8, Ope and Upc MC samples.
- Spread of unfolded results for all MC's more prominent in higher pt bins.
- The width of the RMS is to be assigned as systematic uncertainties – next slide.

Unfolded Inclusive Result Summary with Systematic Uncertainties



- ❖ Variation of best regularization parameter in the TSVD unfolding (kvec shifts→ $\pm1, \pm2, \pm4$).
- ❖ Addition of uncertainties due to MC statistical uncertainties in unfolding covariance matrix via GetAdetCovMatrix (MC uncertainties).
- ❖ Repetition of best parametrization many times (best variation).
- ❖ Systematic uncertainties show the mean and Root Mean Square (RMS) for all MC repetitions.

Summary:

- ❖ Unfolding worked reasonably well with best parametrization.
- ❖ Enhancement of asymmetries has been observed.

Systemeatic Uncertainties studied via:

- ❖ Variation of best regularization parameter for the unfolding.
- ❖ Response matrix (MC uncertainties).
- ❖ Repetition of the best parametrizations.

- ❖ Systematic uncertainties display the mean and RMS for all MC repetitions.

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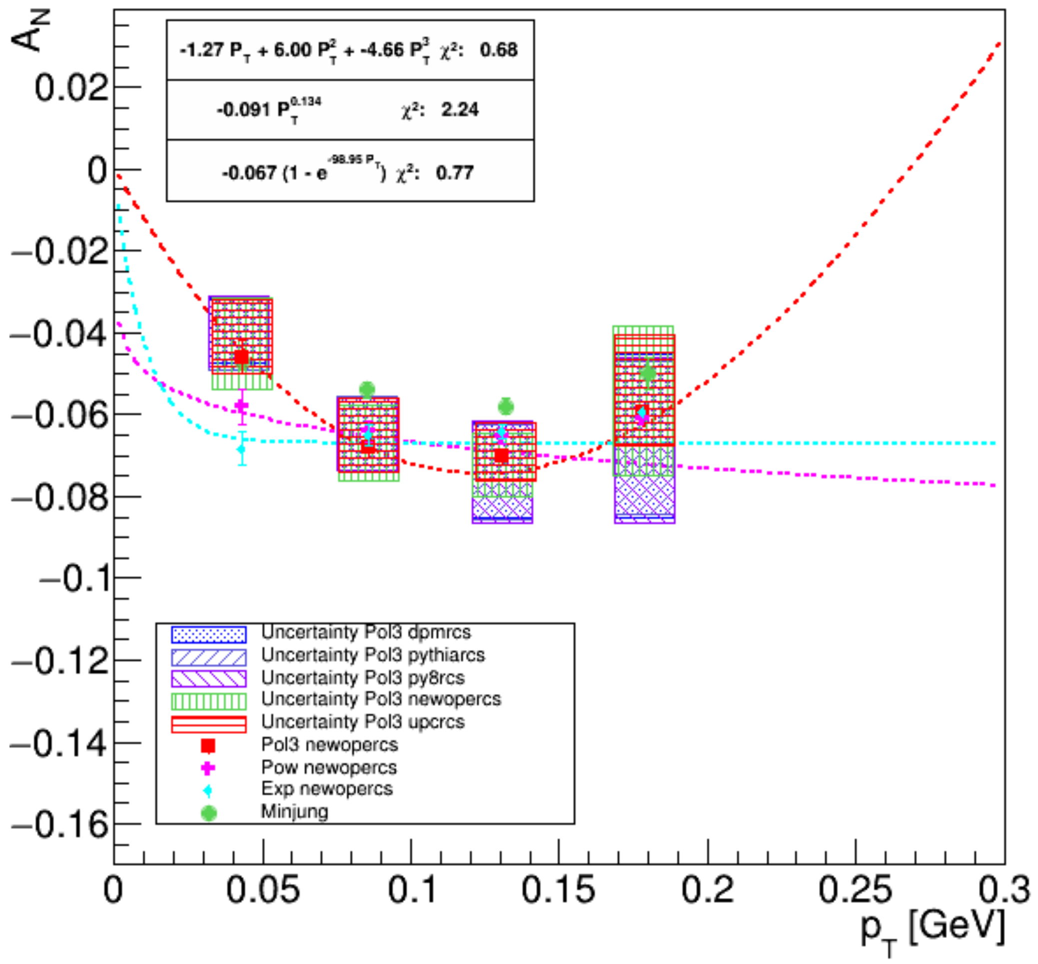
BACKUP

Overall Unfolded Inclusive Result - Polynomial, Power & Exponential



- Overall unfolded asymmetry result

  Best Chi-Square and parameters:

- Pol3 Chi2 = 0.68 : b = -1.27, c = 6.00, d = -4.66
- Powr Chi2 = 2.24 : b = -0.091, c = +0.134
- Expo Chi2 = 0.77 : b = -0.067, f = -98.95

  All show reasonable χ^2 with respect to Minjung's asymmetry results.

  MC uncertainties:
- Shown for Pol3 Dpmjet, Pythia6, Pythia8, Ope & Upc.

Algorithm

1. Create two spin states using TRandom Number Generator:
   Spin up (0)
   Spin down (1)

2. Create spin depended weight:

$$w = 1 + \left(a + b * P_{T,T} + c * P_{T,T}^{2} + d * P_{T,T}^{3}\right) cos(\varphi_T + spin * \pi)$$

the parameters are:
a = constant
b = linear
c = quadratic
d = cube
spin * pi = phase shift
spin = 0 (up)
1 (down)

Note: Other functional forms can also be scanned and tried to describe data asymmetries.

Algorithm…

3. Scan parameters for different functional forms over a wide range using chi-square based on the reconstructed asymmetries from pp collision monte carlo samples and run 15 pp asymmetry results (Minjung's result) to find the best parameter, i.e. parameter with lowest,

$$\chi^2 = \sum_i \frac{\left(A_{N,i}^{Minjung} - A_{N,i}^{w,reco}\right)^2}{\left(\Delta A_{N,i}^{2,Minjung} + \Delta A_{N,i}^{2,w,reco}\right)}$$

4. Extract the asymmetry using the best Chi-squared parameters,

$$A_N = \frac{N_{\Phi\uparrow} - N_{\Phi\downarrow}}{N_{\Phi\uparrow} + N_{\Phi\downarrow}}$$