PHENIX Run 15 ZDC A_N vs. P_T Unfolding

CENuM Workshop II
Online
2020-07-03/(04)

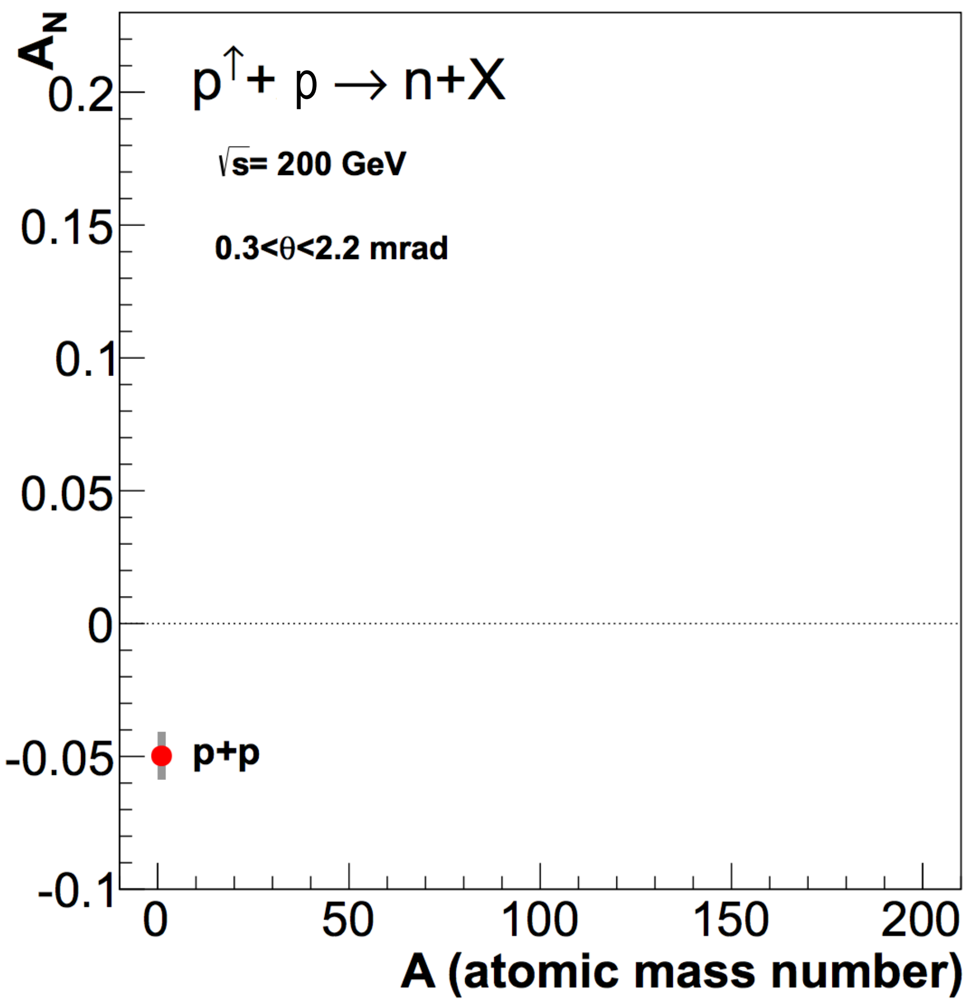
4:00 – 4:15 PM (KST/JST)

Benard Mulilo (KU/RIKEN)

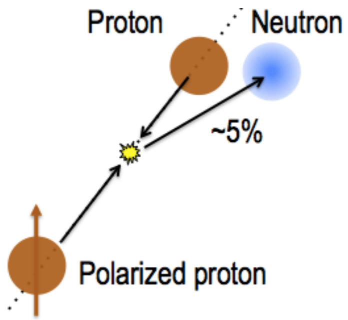
Content

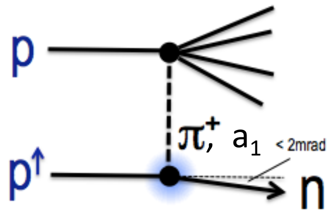
Introduction

Physics Motivation (polarized proton – un polarized proton collisions at 200 GeV)



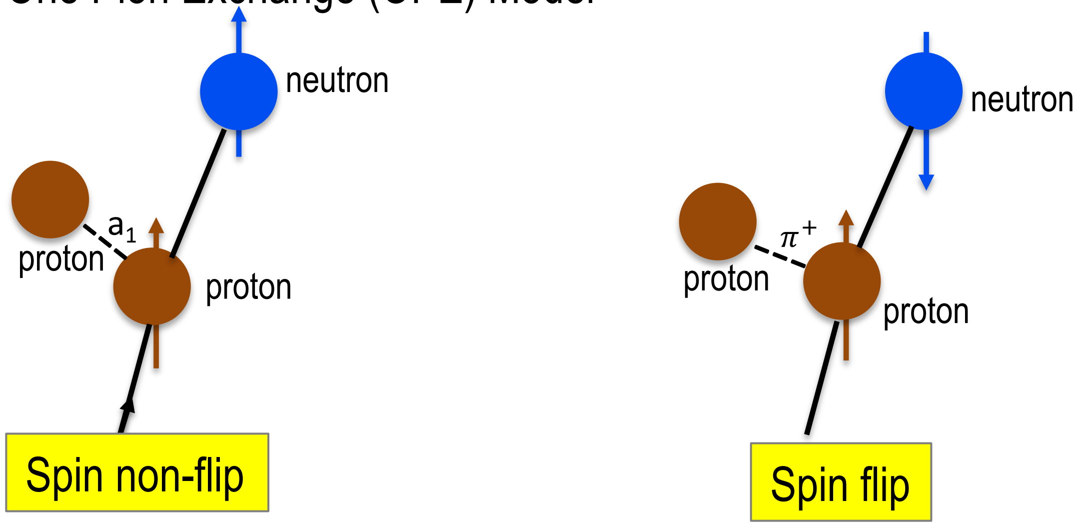
PHENIX Run15 p + p result at 200 GeV





One Pion Exchange (OPE)

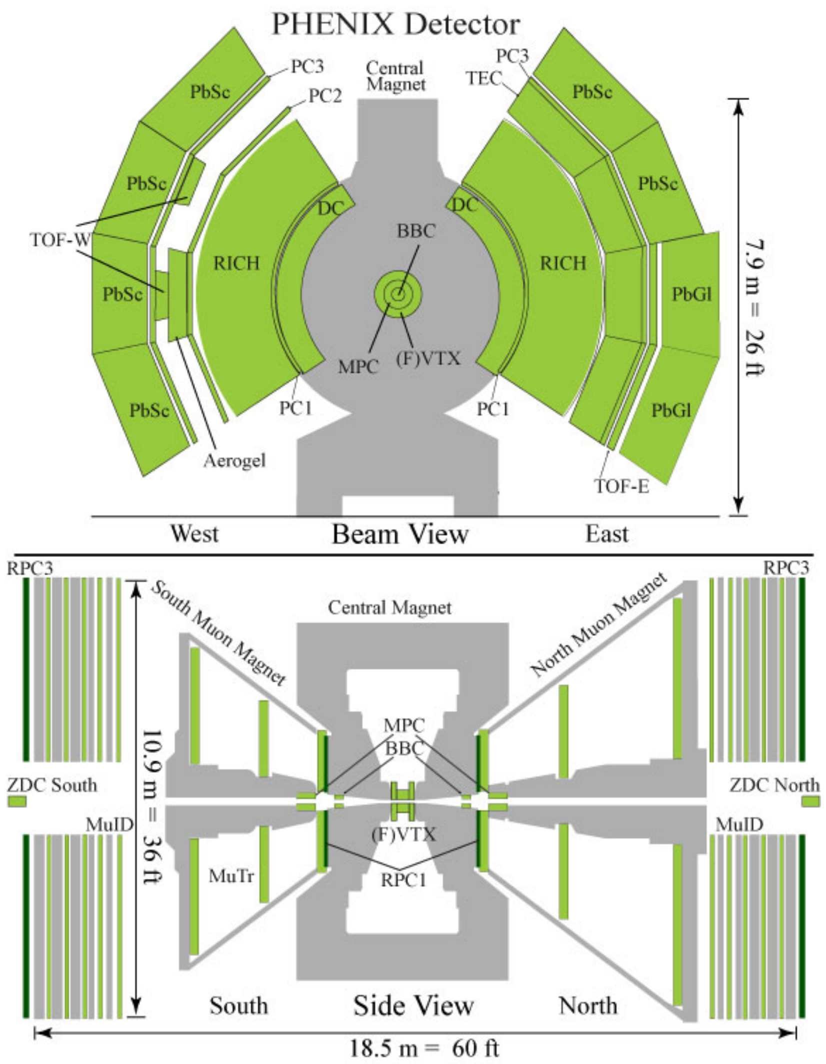
One Pion Exchange (OPE) Model



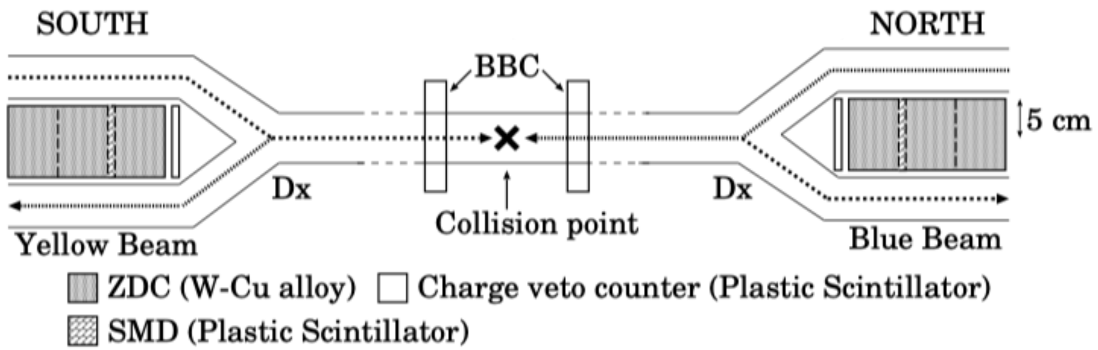
We seek to understand proton spin in terms of A_N vs. true P_T .
This will be the first pp unfolding A_N vs true P_T result at PHENIX.

Introduction

Experimental Procedures (PHENIX Detector – Layout of the PHENIX Zero Degree Calorimeter)



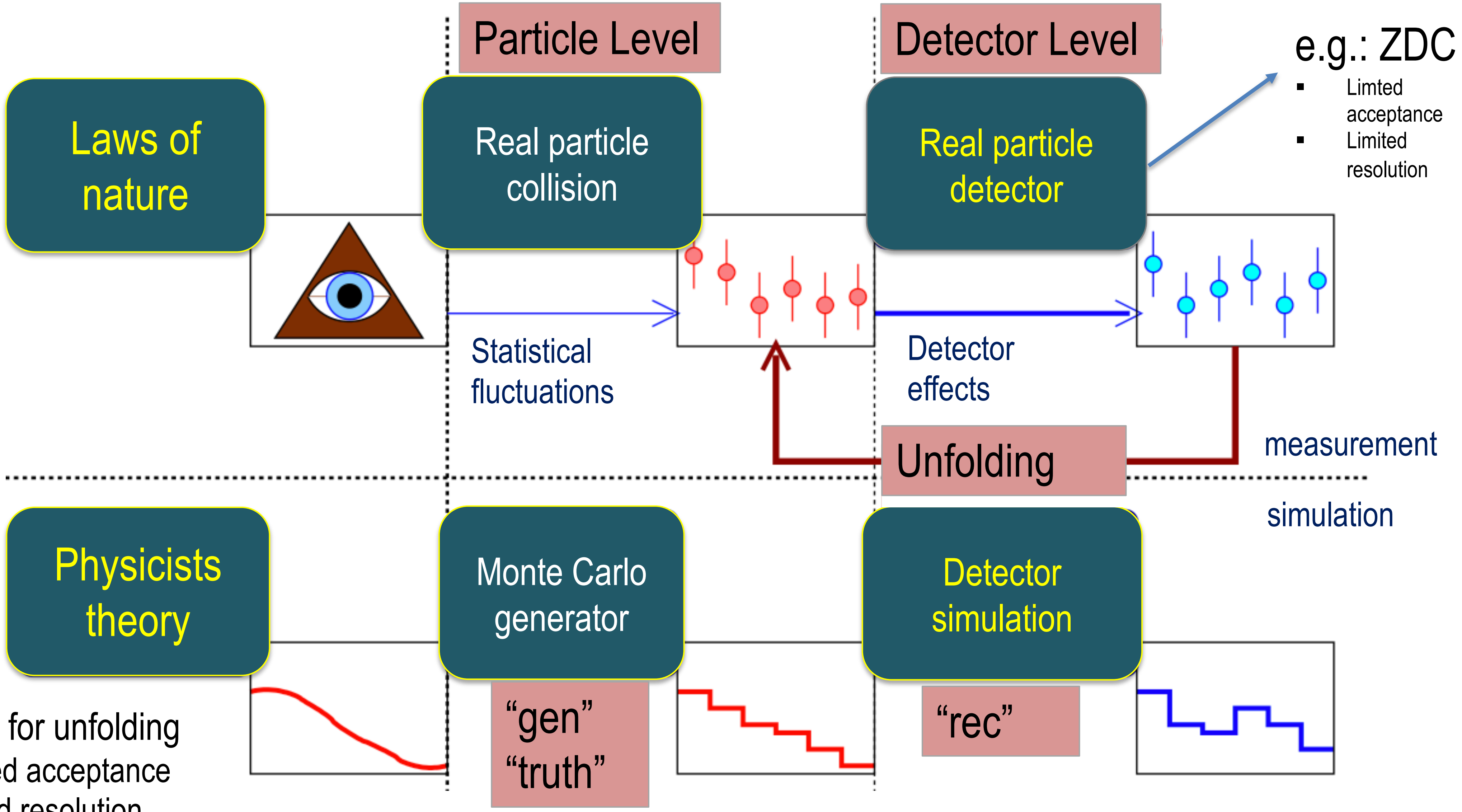
Setup for very forward neutron measurement at PHENIX



Principal components for neutron physics:

◎Zero Degree Calorimeter (neutron measurement)
◎Shower Maximum Detectors (for neutron position measurement)
◎Charge veto counter (charged particles) and BBC (timing)

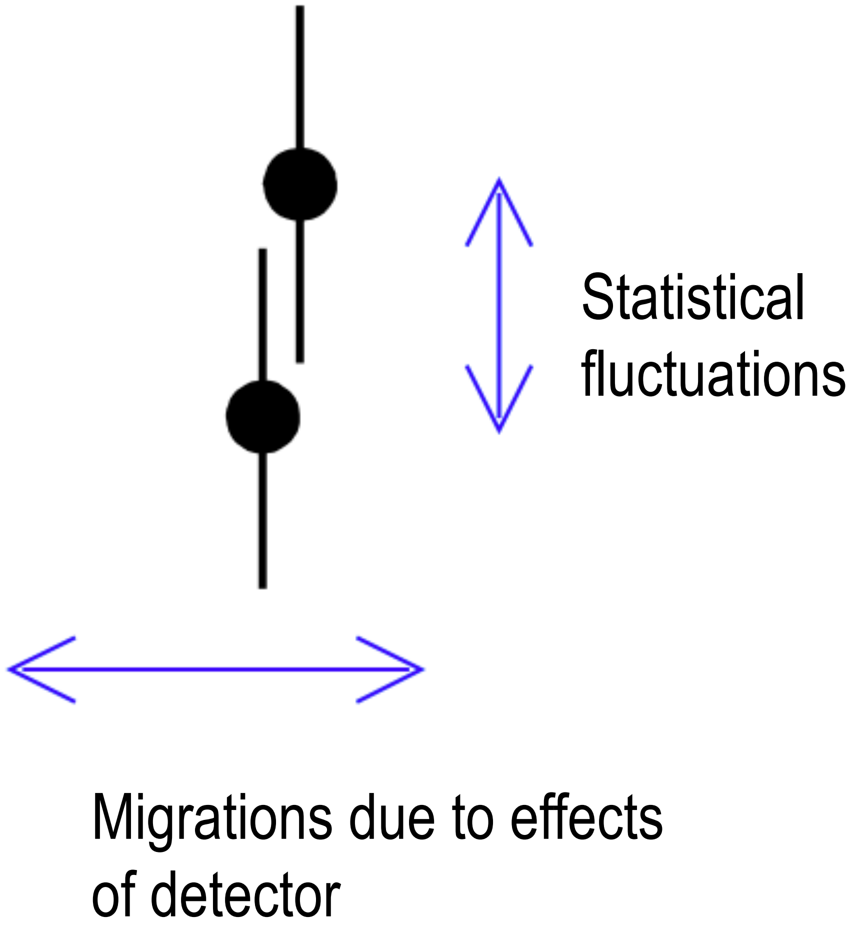
Unfolding Overview and Motivation – Limited Acceptance and Resolution



Reasons for unfolding

- Limited acceptance
- Limted resolution

Unfolding Overview – Statistical fluctuations and migrations due to detector effects



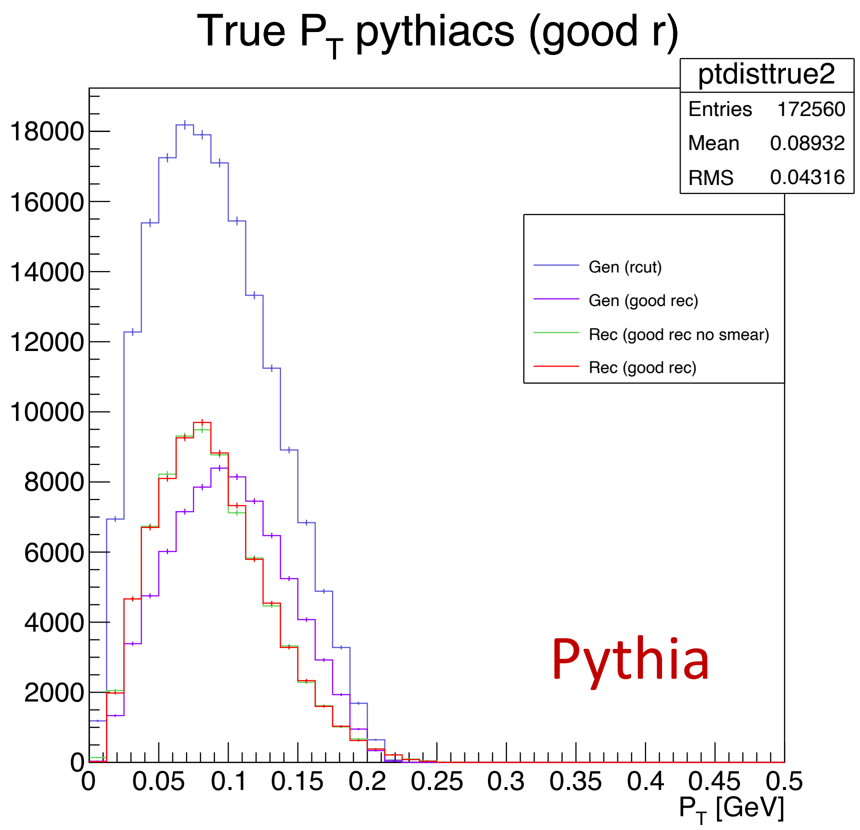
Unfolding:

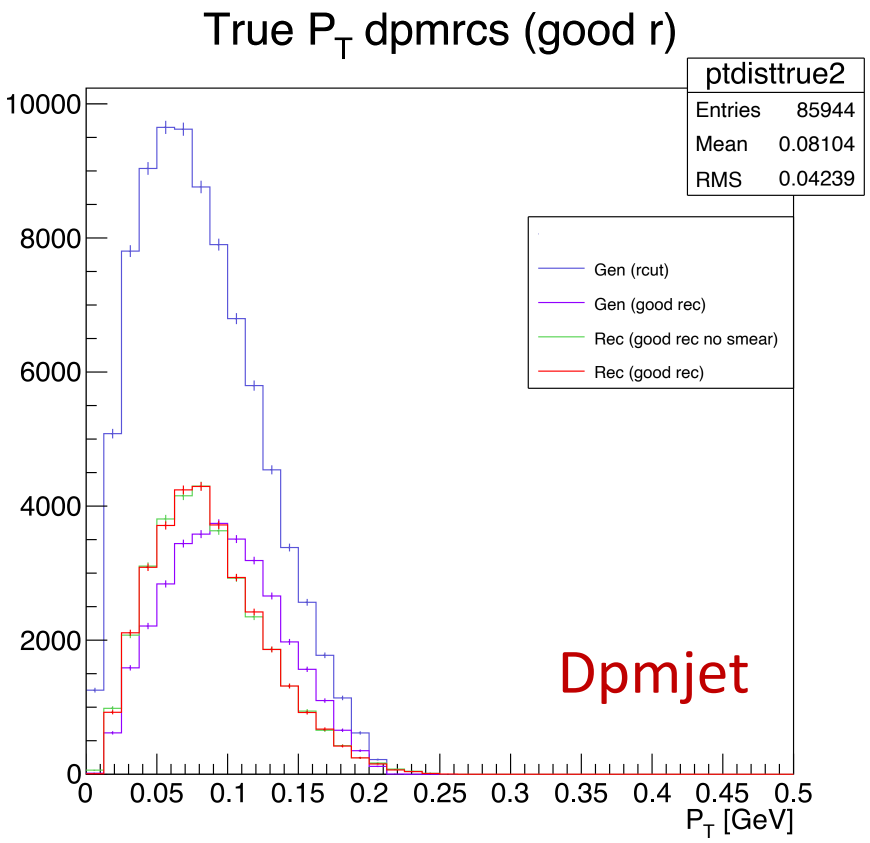
- Used to correct for migration effects in the presence of statistical fluctuations.

Result:

- An estimator of the “truth” distribution.
- Covariance matrix (statistical uncertainties)

Transverse Momentum SVD Unfolding Closure Test Unfolding Input



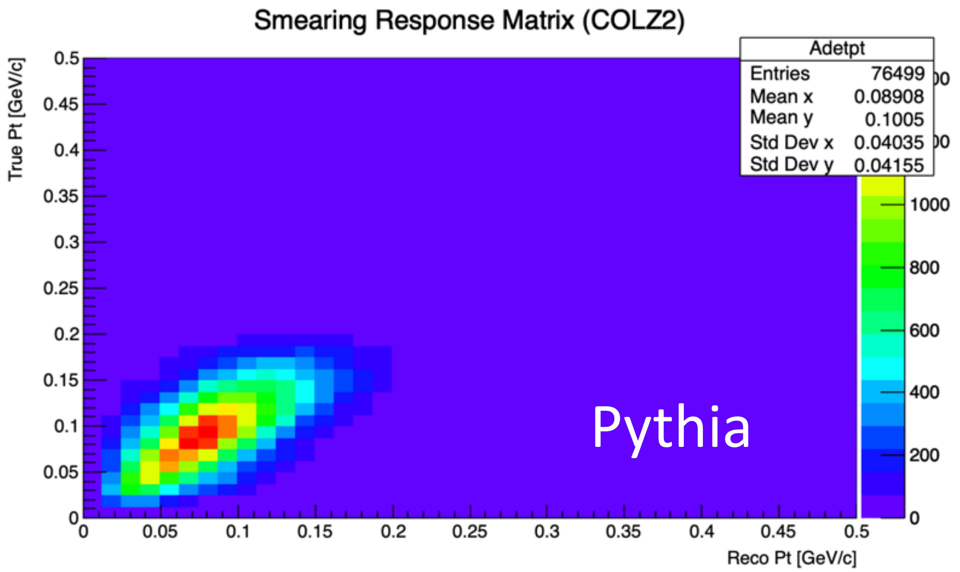


1. Gen (rcut) : Blue line with rmin < 0.5 and rmax < 4.0 cm
2. Gen (good rec): Purple line with cuts: rcut, Emin > 20 GeV and Emax < 120 GeV, EZDC2/EZDCT > 0.03, NxNy >1 fired above Esmdxy = 0.003 GeV
3. Rec (good rec no smear): Green line – no smearing
4. Rec (good rec): Red line – is reconstructed.

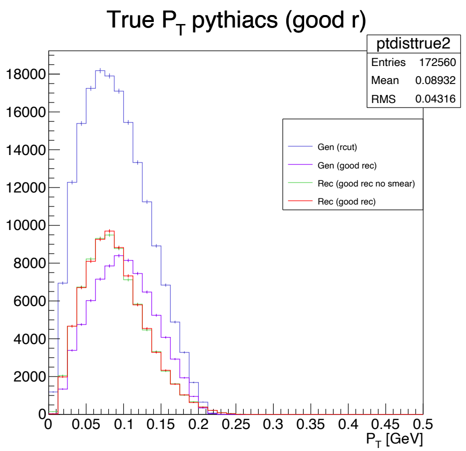
$$P_{T(True)} = \sqrt{px * px + py * py}$$

$$P_{T(Reco)} = \frac{rE_{reco}}{IP\_To\_ZDC}$$ with $r = \sqrt{x_{ev} * x_{ev} + y_{ev} * y_{ev}}$ and IP is the distance from the collision point to ZDC)

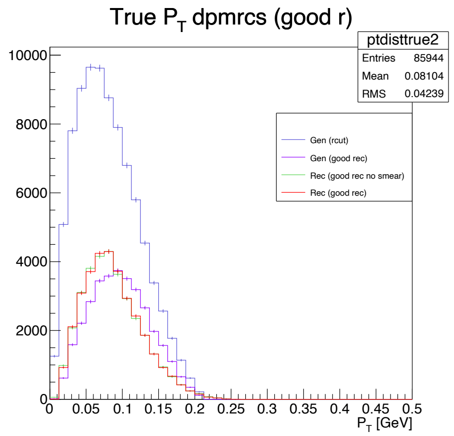
Transverse Momentum SVD Unfolding Closure Test Unfolding Input



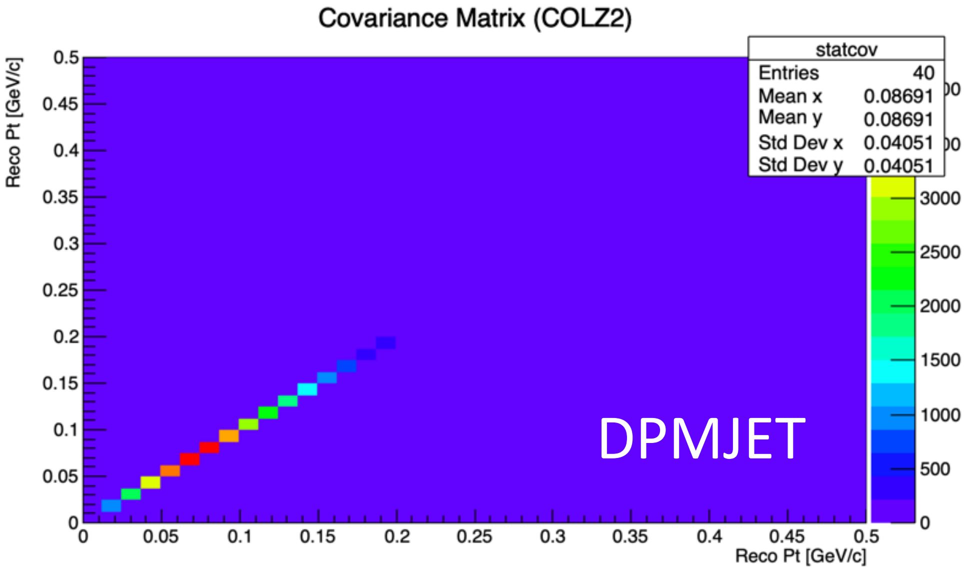
- Detector smearing matrix from pythia Monte Carlo.
- It maps the smeared (reco) pt in red line to the true pt in purple line of Pythia Monte Carlo sample.



Pythia



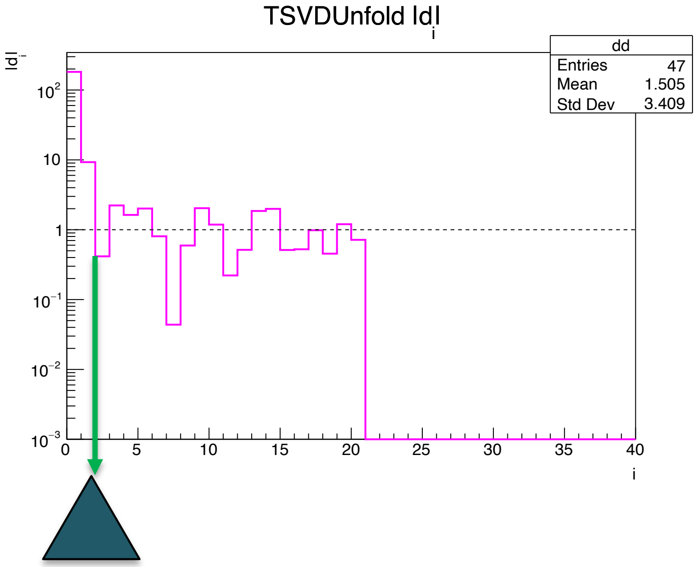
Dpmjet



- Input covariance matrix obtained from the square of the errors of the smeared pt (red line) from dpmjet.
- Unfolding is based on the singular value decomposition(SVD) of detector response matrix.

Transverse Momentum SVD Unfolding Closure Test Unfolding Result

Unfolding is performed with an optimal regularization parameter obtained from a d vector distribution for a regularized system:



$$d_i = z_i^{\tau}\frac{s_i^2+\tau}{s_i}$$, i = 1, ...Nbin

τ = Kreg (regularization parameter)

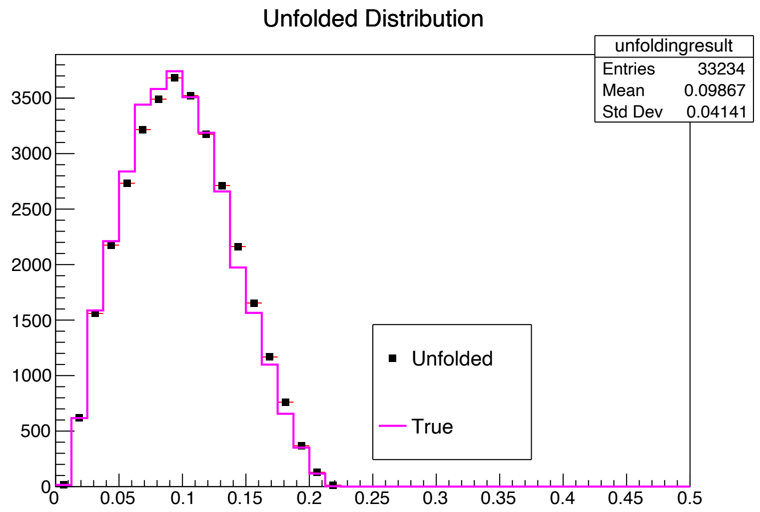
s_i = positive diagonal elements (singular values of response matrix)

τ = nonzero (regularized system)

= zero (non-regularized system), $d_i = s_i . z_i^{(0)}$ (diagonal systems - not useful)

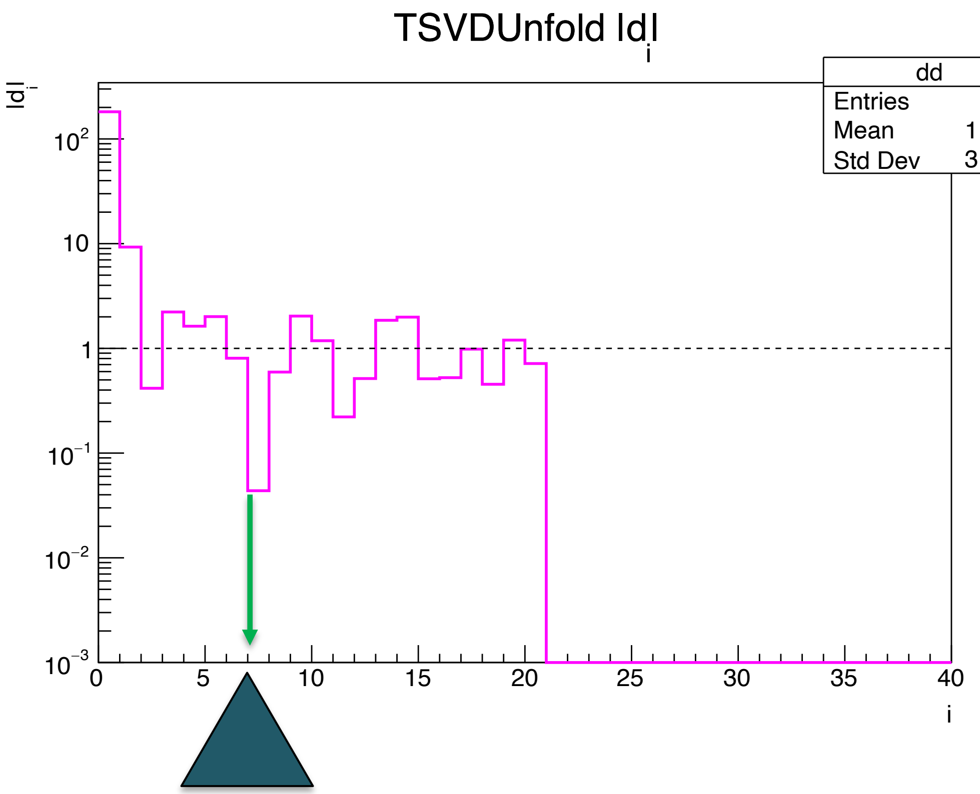
Unfolded the measured pt distribution using regularization parameter = 2

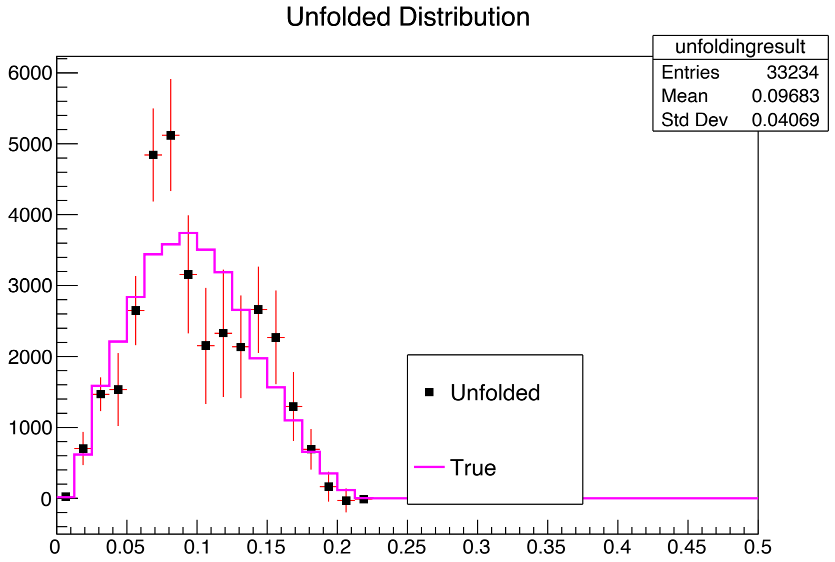
Parameter = 2 gives the best minimum curvature = 0.000007 and is chosen as the optimum value.



Magenta line: True spectrum from dpmjet MC.

Transverse Momentum SVD Unfolding Closure Test Unfolding Result





Unfolded the measured pt distribution using regularization parameter = 7

Regularization parameter = 7 gives a large minimum curvature = 0.343233.
Best minimum curvature should be almost zero but not zero.

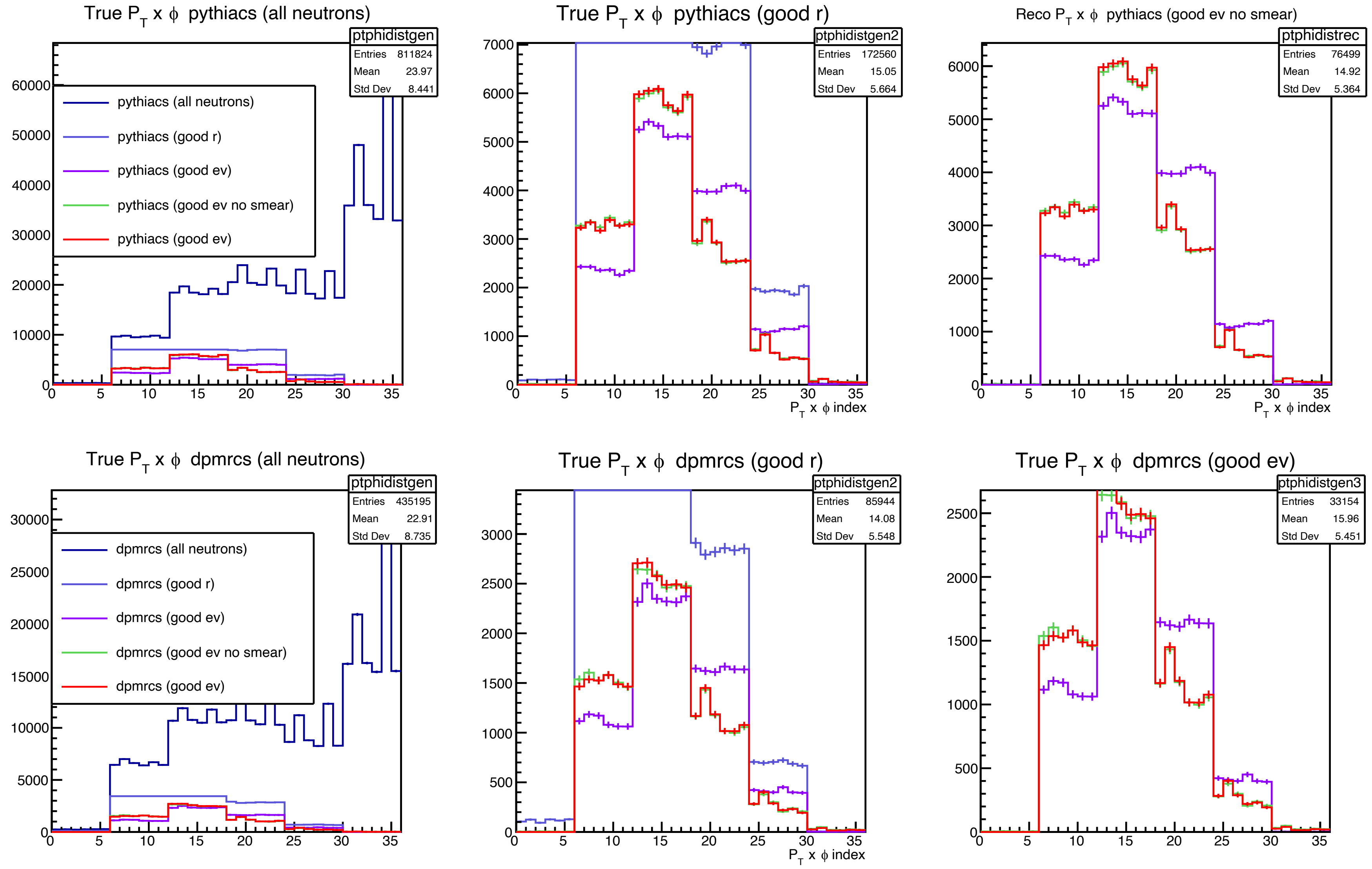
Magenta line: True distribution from dpmjet MC.

Solid black boxes: Unfolded distribution.

Unfolded distribution has been scaled to match the statistics between dpmjet and pythia.

Transverse Momentum and Azimuth SVD Unfolding Closure Test

Unfolding Input

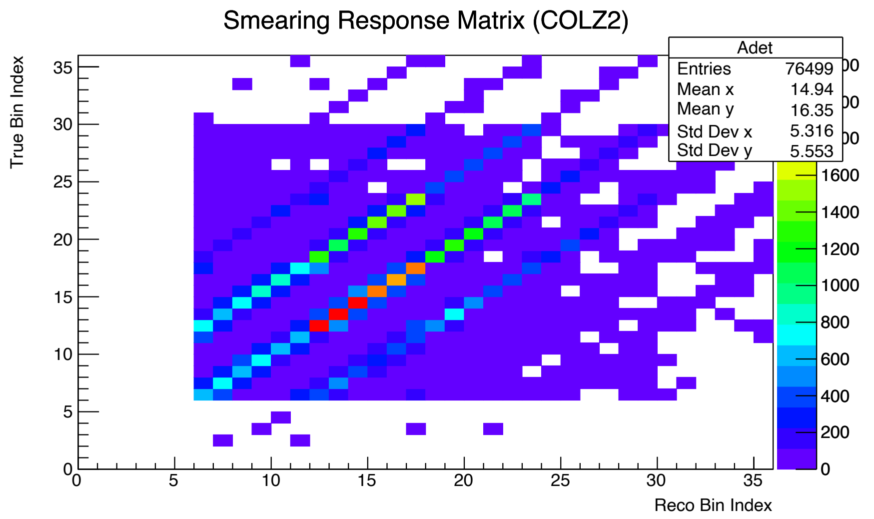


Pythia

Dpmjet

Transverse Momentum and Azimuth SVD Unfolding Closure Test

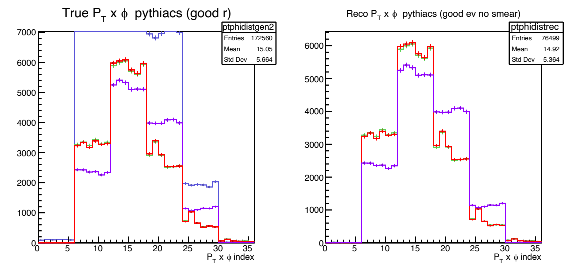
Unfolding Input



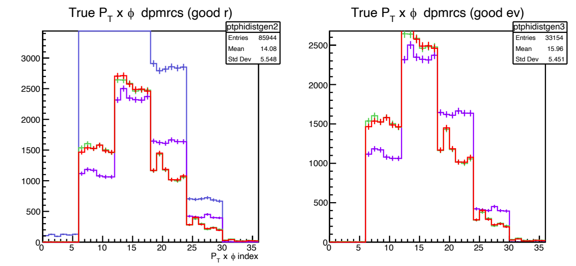
Correlation matrix between true and measured pt in azimuth phi distributions.

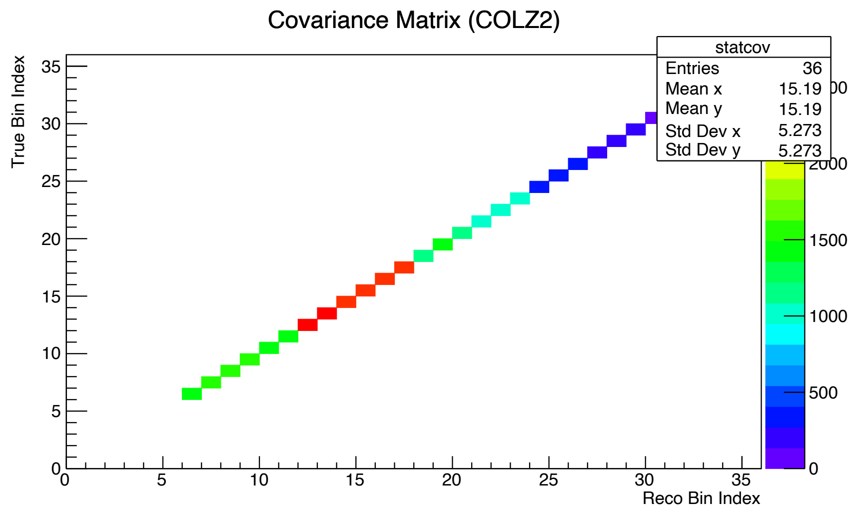
Two variables are being used here pt and phi.

Pythia



Dpmjet

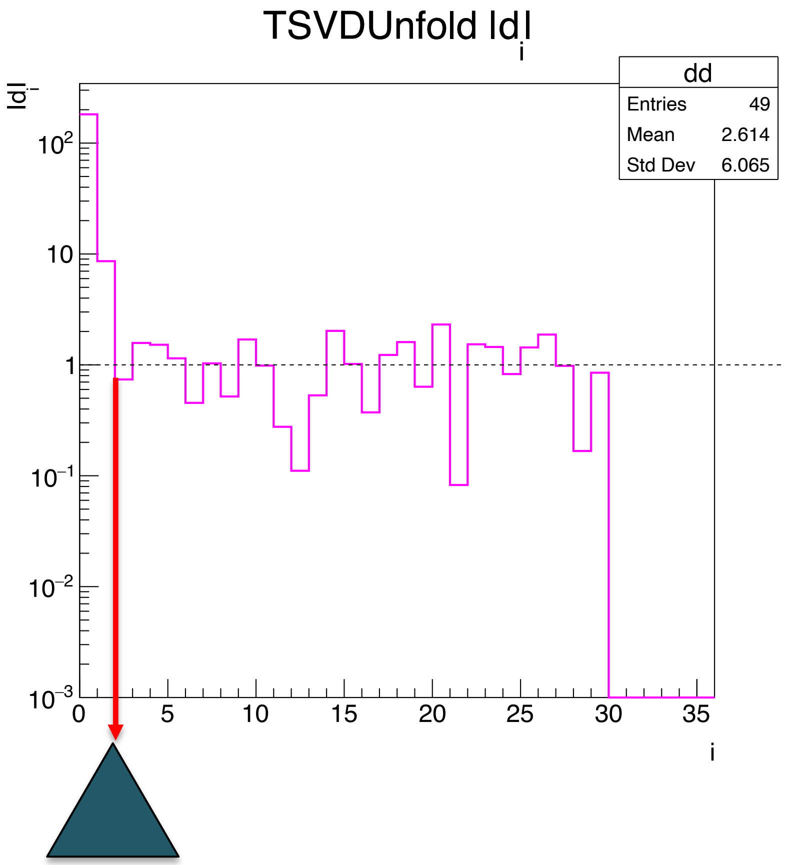


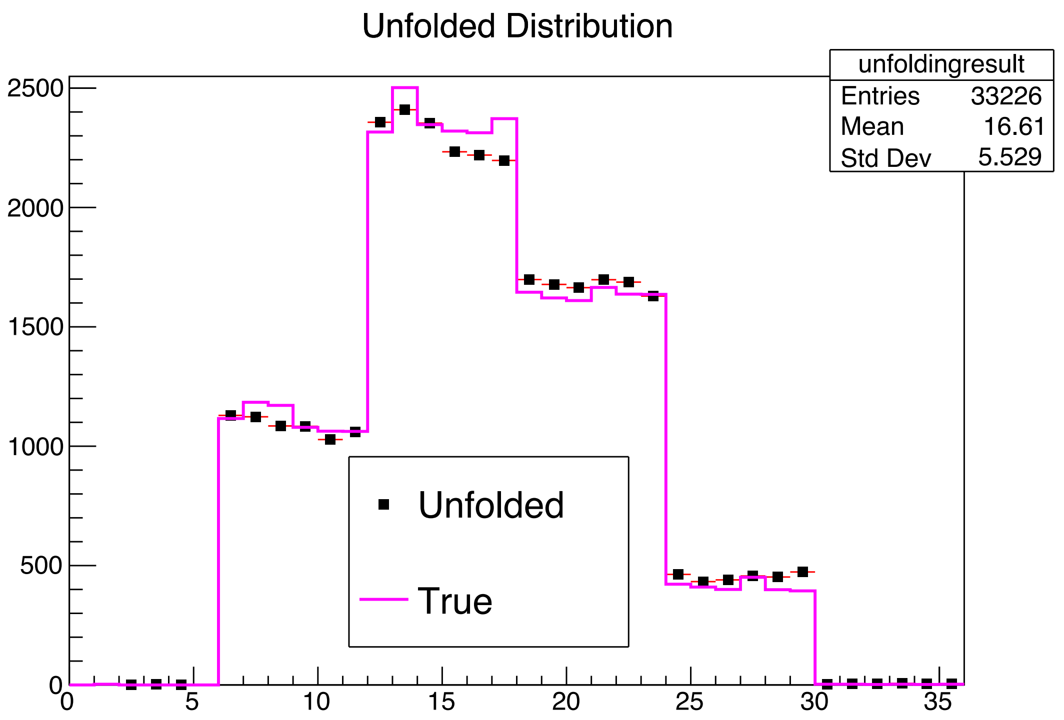


Input covariance matrix obtained from the square of the errors of the reconstructed transverse momentum (pt) distribution (red line) from the Dpmjet Monte Carlo sample.

Transverse Momentum and Azimuth SVD Unfolding Closure Test

Unfolding Result





Unfolded the measured pt distribution using regularization parameter = 2

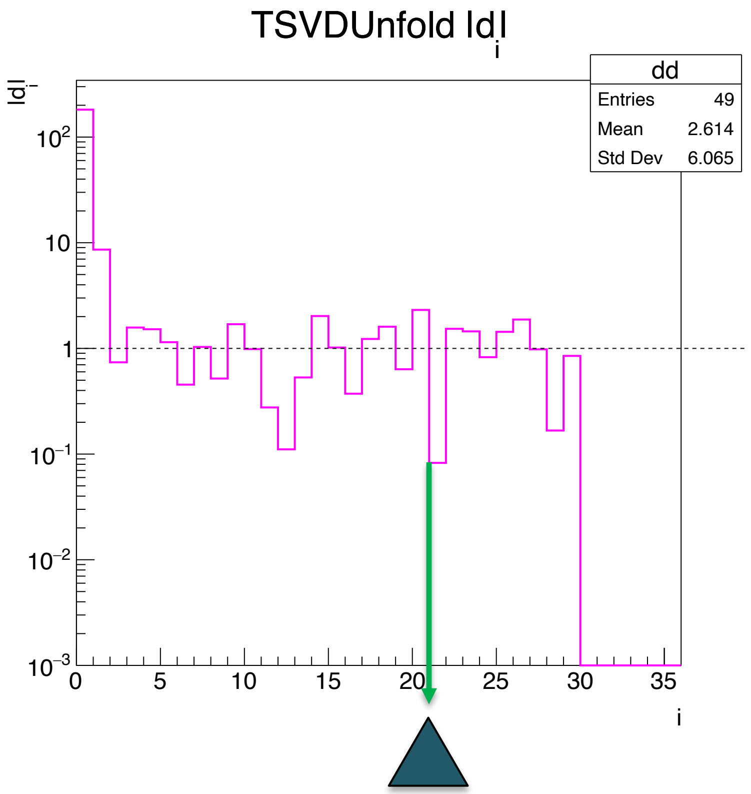
Minimum curvature = 0.000002

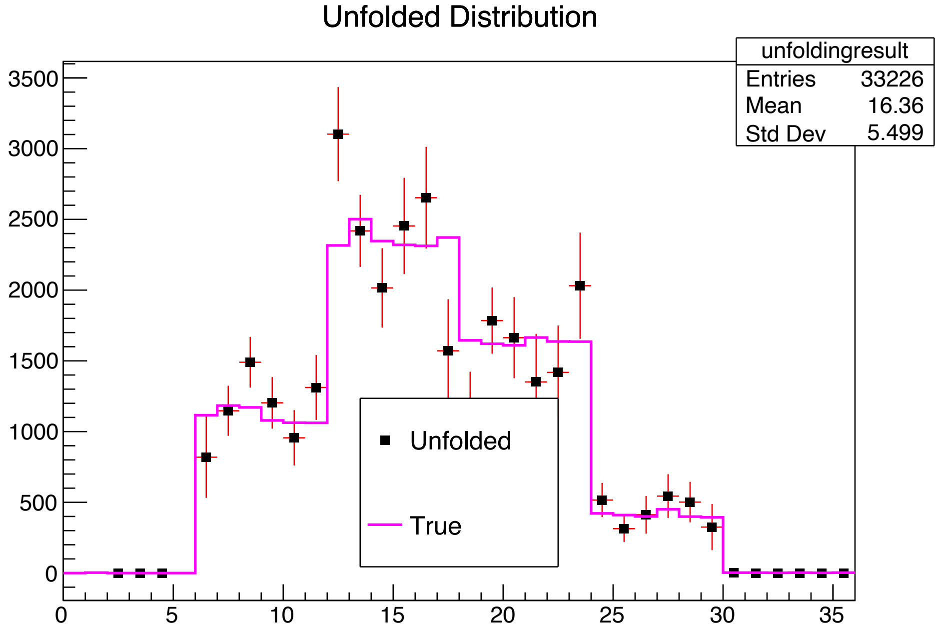
Magenta line: True distribution from dpmjet.

Solid black squares: the unfolded distribution.

Transverse Momentum and Azimuth SVD Unfolding Closure Test

Unfolding Result





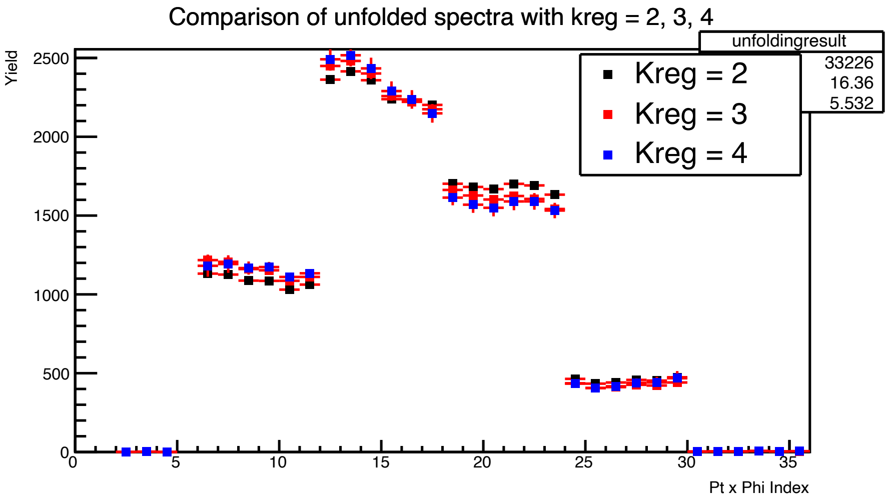
Unfolded the measured pt distribution using regularization parameter = 21 with a minimum curvature equal to 0.583

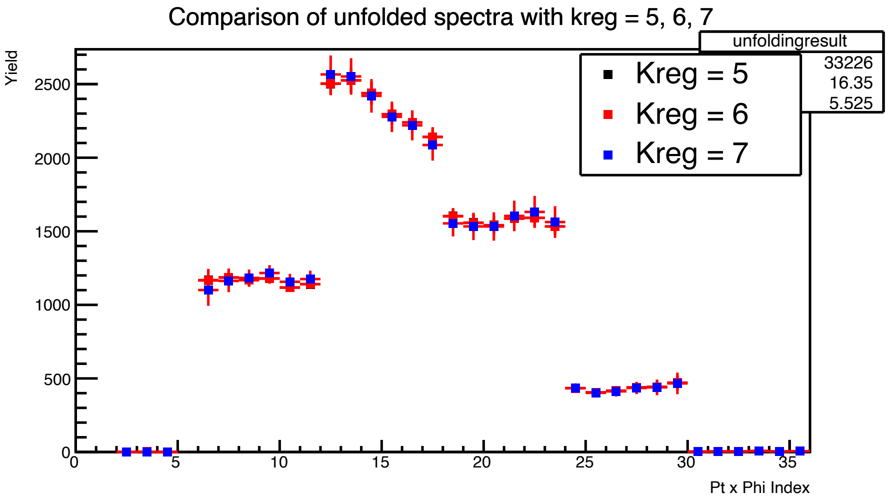
Magenta line: True distribution from dpmjet.

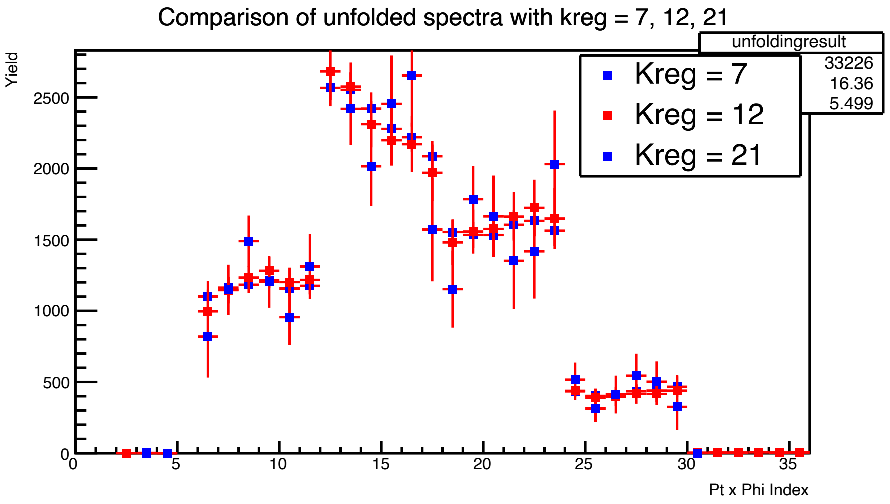
Solid black squares: the unfolded distribution.

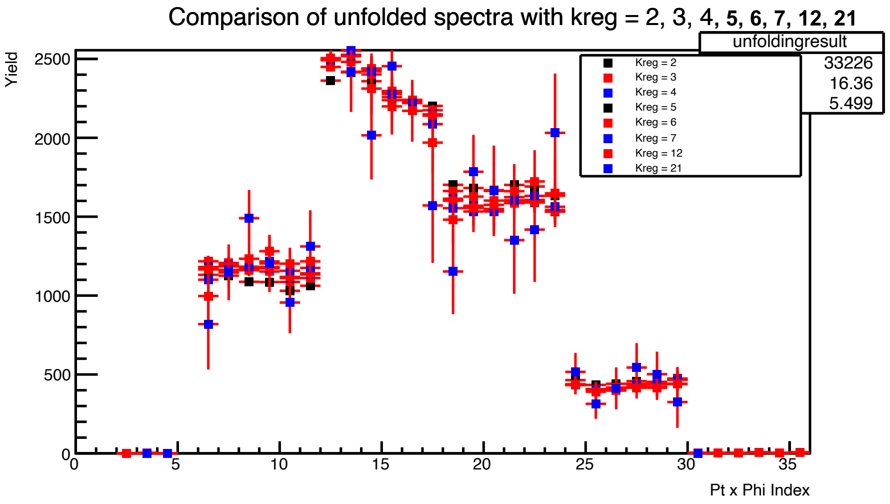
Transverse Momentum and Azimuth SVD Unfolding Closure Test

Unfolding Result









Transverse momentum (P_T) and azimuth (phi) unfolding closure test results – all possible parameter comparison

Transverse Momentum and Azimuth SVD Unfolding Closure Test

Unfolding Result

Summary of all possible kreg values and their coresponding minimum curvature values

Regularization parameter, Kreg	Minimum curvature value determines best optimum regularization parameter, the closer the value to zero the better			
2	1D		2D	
	0.000002	Best value	0.000002	Best value
3			0.000010	
4			0.000201	
5			0.000307	
6			0.000331	
7	0.343233.	~34%	0.009416	
12			0.009416	
21			0.583000	~ 60%

Run 15 neutron asymmetry for inclusive pp collisions in the ZDC – 2D Unfolding

Strategy

To unfold the ZDC neutron asymmetry for inclusive pp collisions run 15 data, one strategy is to:

- Translate the available pt dependent A_N's into yields.
- Apply the 2D unfolding in P_T and azimuth, Φ
- Extract the unfolded asymmetries (A_N's) with systematic uncertainty.

Above strategy requires creation of artificial asymmetries and reweighting procedures of pp One Pion Exchange (OPE) Monte Carlo training sample.

Algorithm

Asymmetry creation and and extraction algorithm is as follows:

Algorithm

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

2. Create spin depended weight according to Taylor series of a polynomial in the form:

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

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

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

Algorithm…

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

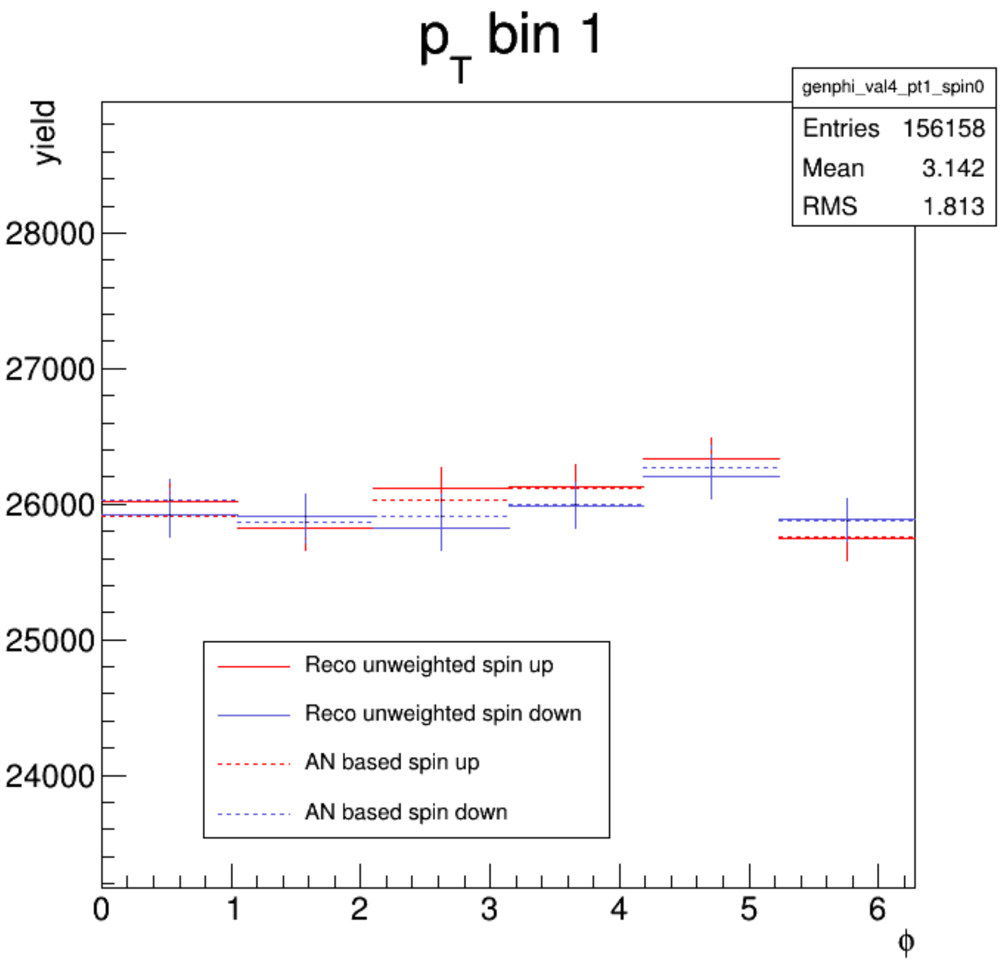
$$\chi^2 = \sum_i \frac{\left(A_{N,i}^{Minjung} - A_{N,i}^{w,reco}\right)^2}{\left(\Delta A_{N,i}^{2,Minjung} + \Delta A_{N,i}^{2,w,reco}\right)}$$

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

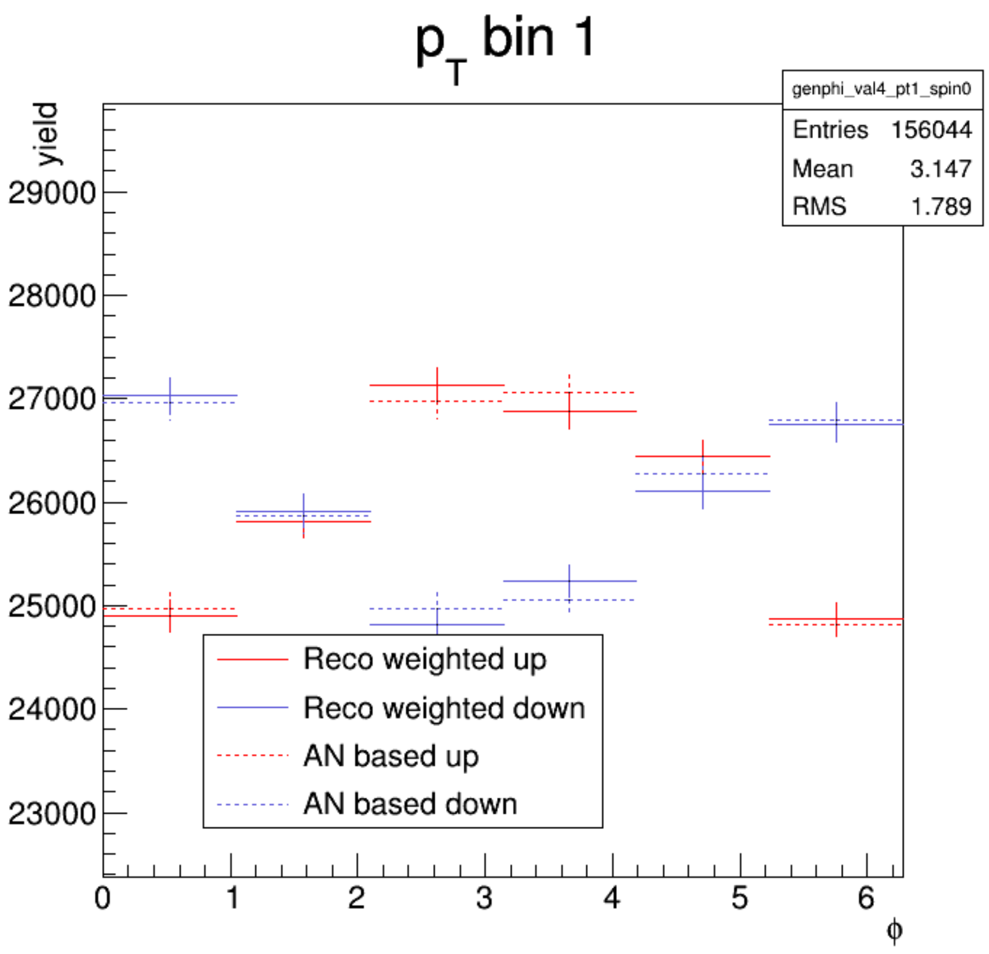
$$A_N = \frac{N_{\Phi\uparrow} - N_{\Phi\downarrow}}{N_{\Phi\uparrow} + N_{\Phi\downarrow}}$$

Unweighted and Weighted Azimuth Distribution – One Pion Exchange (OPE) MC

Unweighted

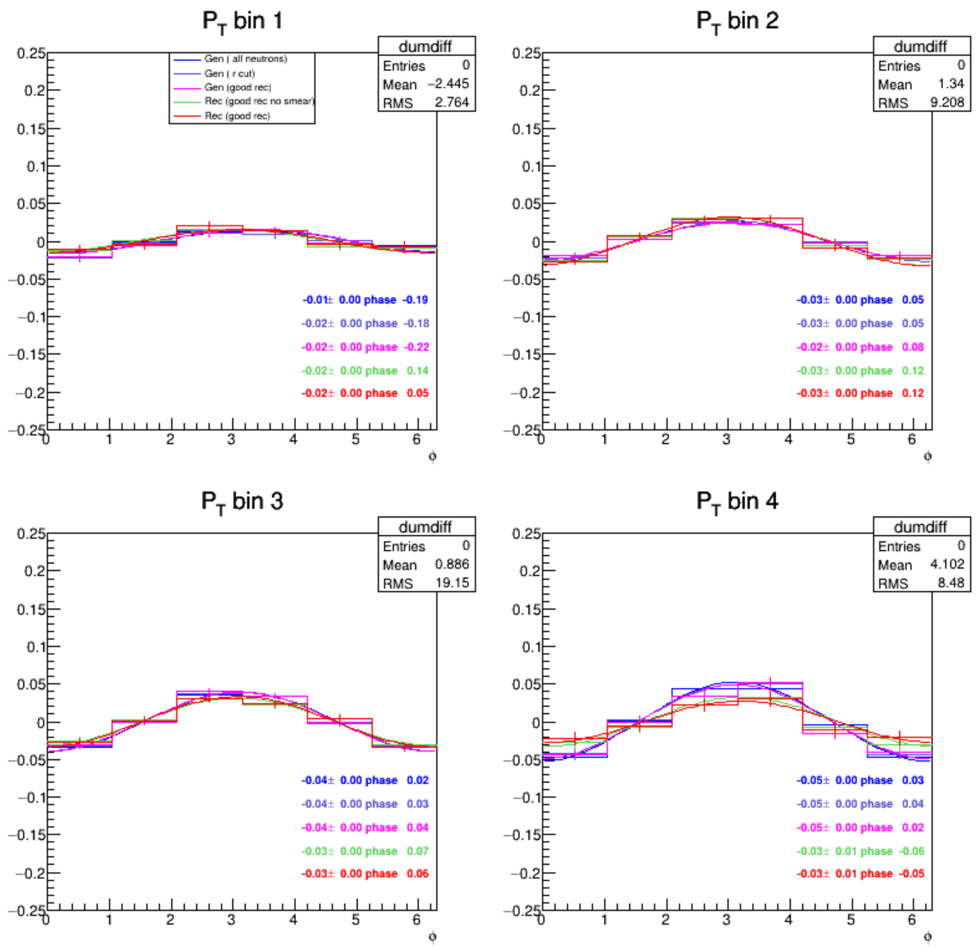


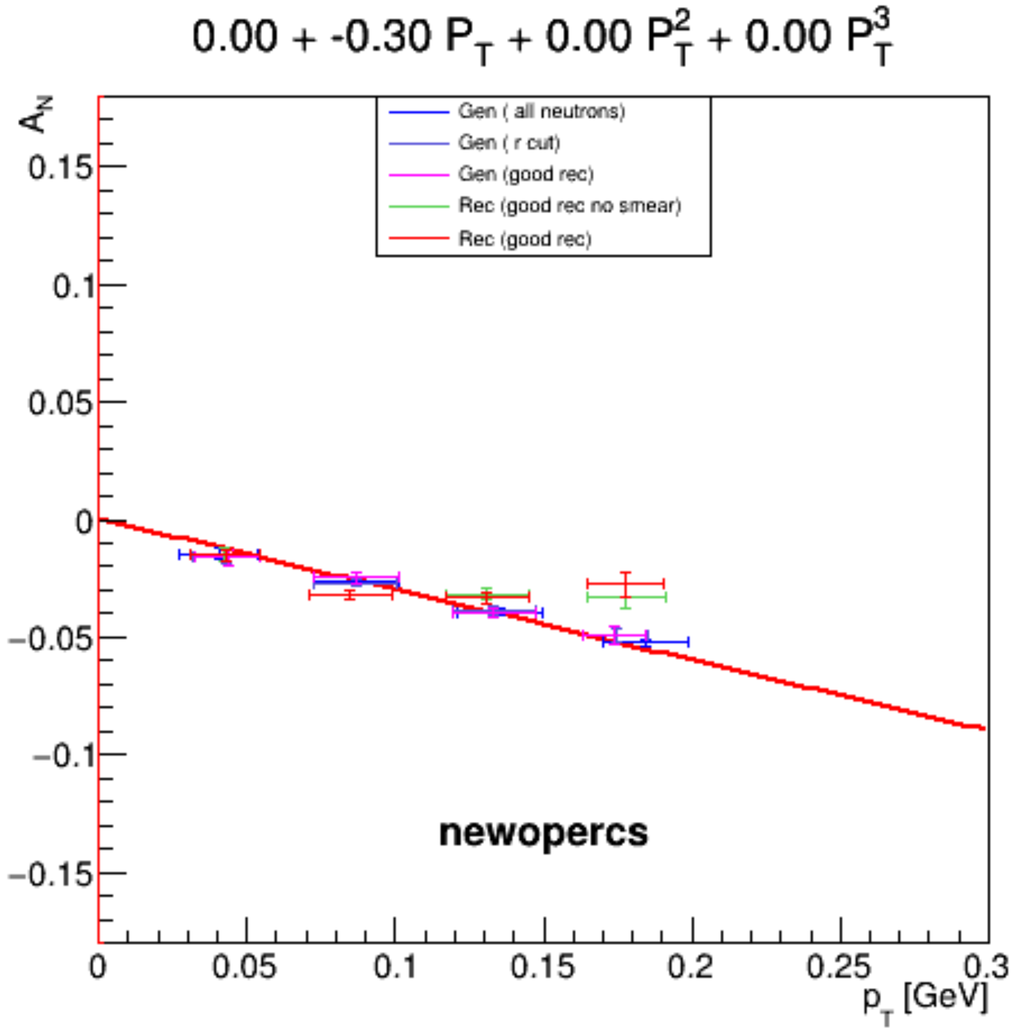
Weighted



A Scan of Created Asymmetries – One Pion Exchange (OPE) MC

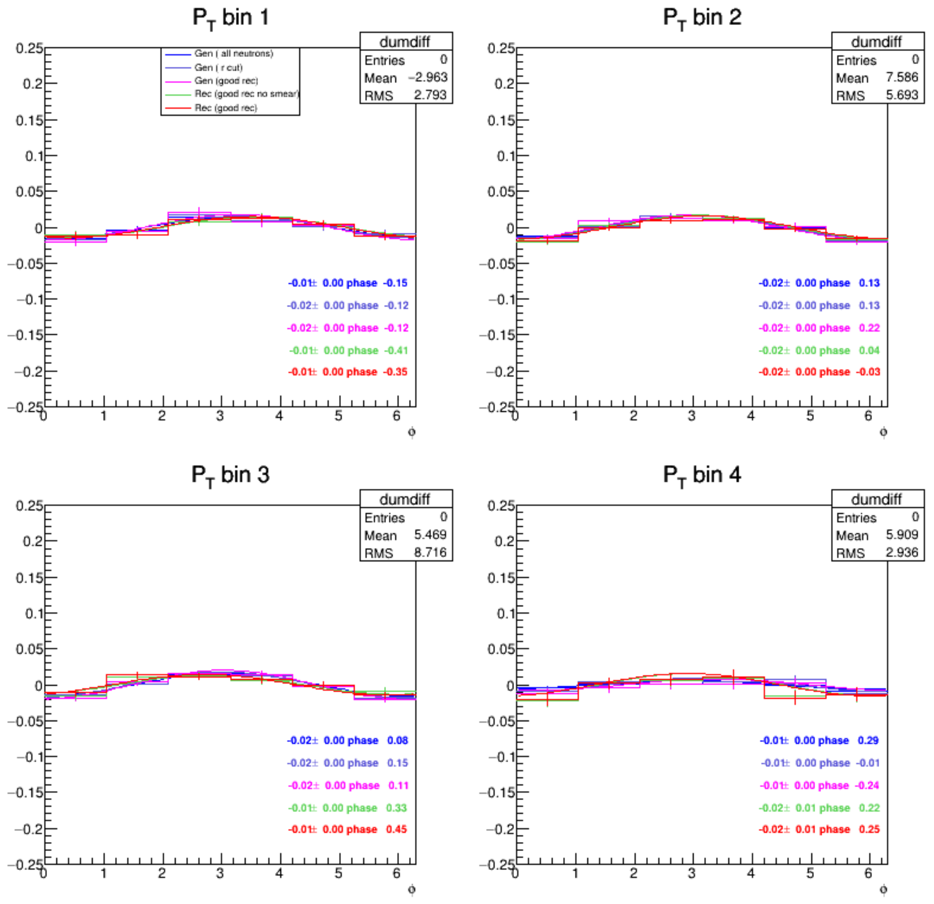
Asymmetry based on linear function

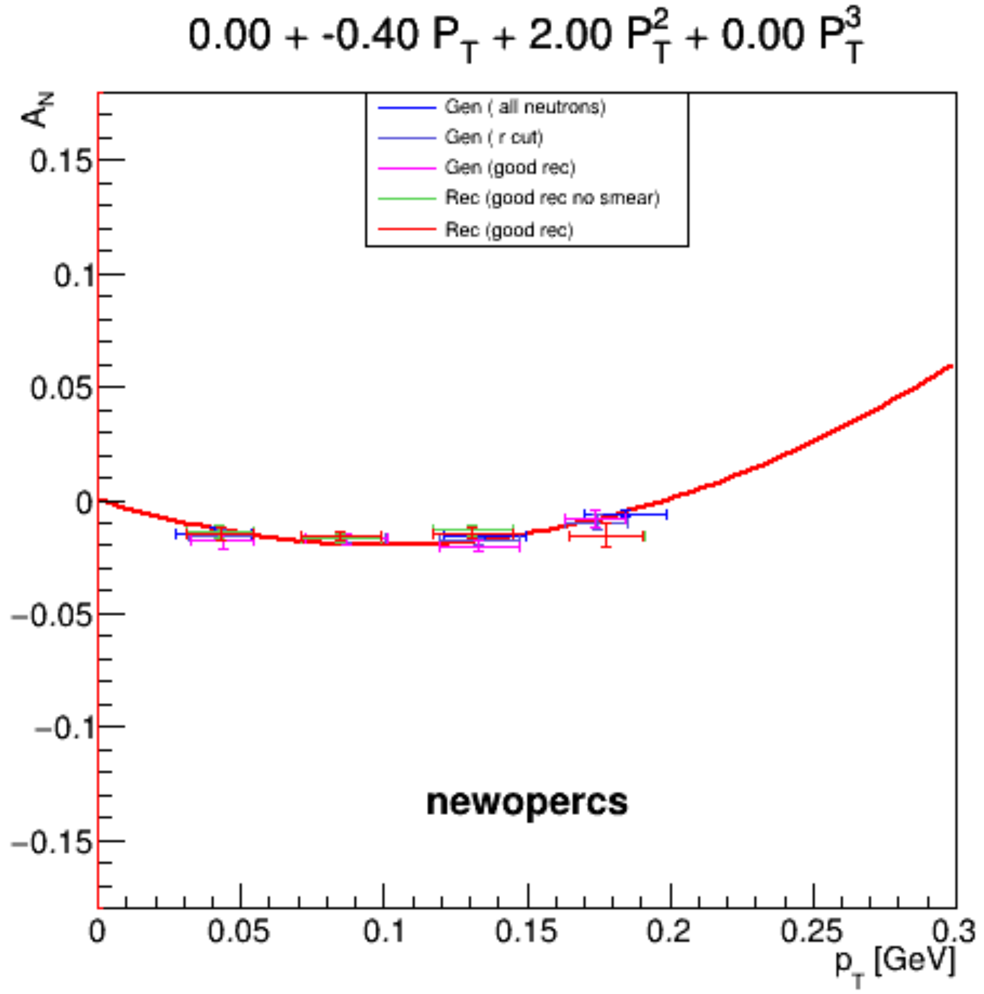




A Scan of Created Asymmetries – One Pion Exchange (OPE) MC

Asymmetry based on quadratic function





Summary

- Closure test works well with a regularization parameter = 2. For regularization parameters > 7 statistical fluctuations become very large. Similar trend is observed in both 1D and 2D unfolding cases.

- Regularization parameters < 7 difference comparison form a good estimate of the unfolding systematic errors.

- Scanned neutron asymmetries for linear and quadratic functions for OPE using parameters chosen intuitively.

- Optimize algorithm by using chi square to scan linear, quadratic and cubic terms over a wide range and determine the best parameters with a minimum chi square between reconstructed asymmetries and experimental data.

Short Term Plan

Period	Task
July 1 ~ July 15	▪ Optimization of weight to mimic the actual pT dependence of pp data using best parameters from Chi-square.
July 16 ~ July 31	▪ Apply best parameters to extract neutron asymmetries that mimic pp experimental data asymmetries and compiling the analysis note.

Working Group

Korea Univ. CENuM Director Prof. B. Hong – Thesis Advisor

RIKEN and RBRC's Dr. H. En'yo (Rad. Lab. Head)

RIKEN and RBRC's Dr. Y. Akiba (Spokesperson - PHENIX)

BNL's Dr. A. Bazilevsky (left) and RIKEN (RBRC)'s Dr. I. Nakagawa(right)

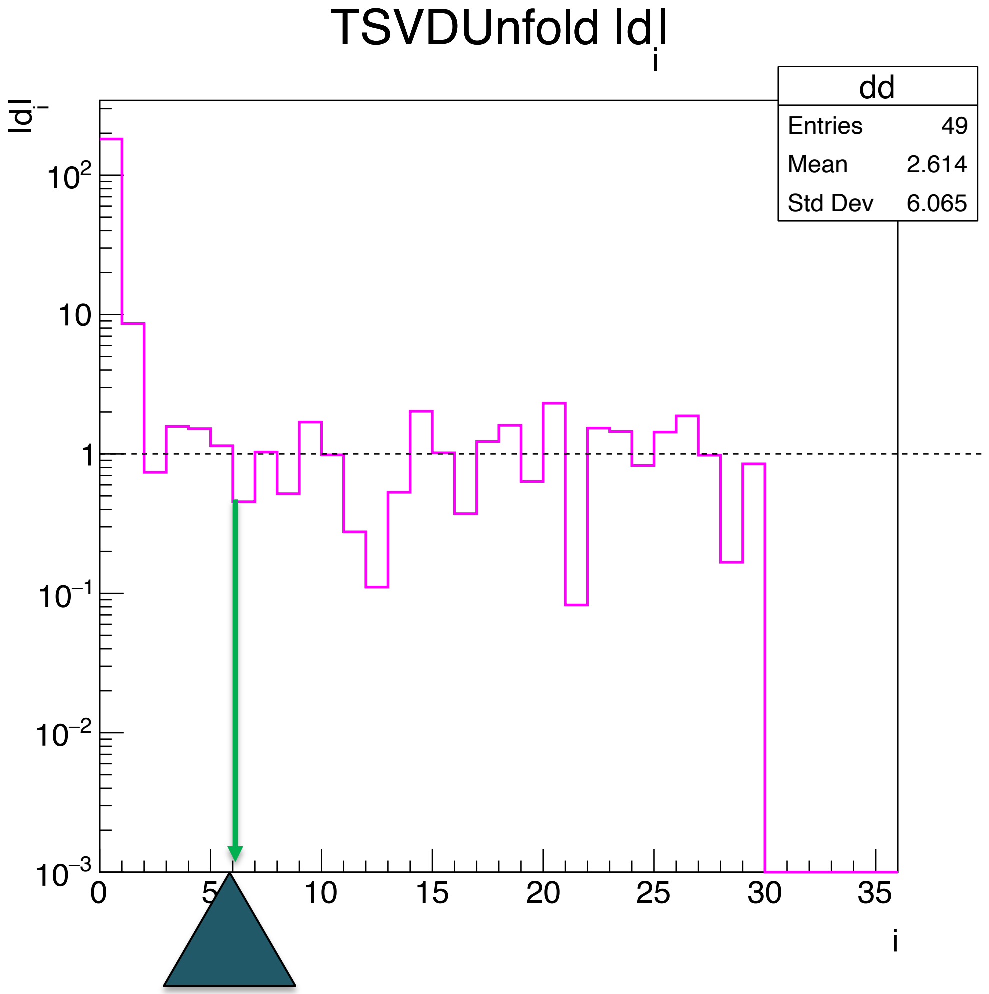
RIKEN and RBRC's Dr. Y. Goto

RIKEN and RBRC's Dr. R. Seidl (Spin PWG Convener)

SBU's Dr. Sanghwa Park (Spin PWG Convener)

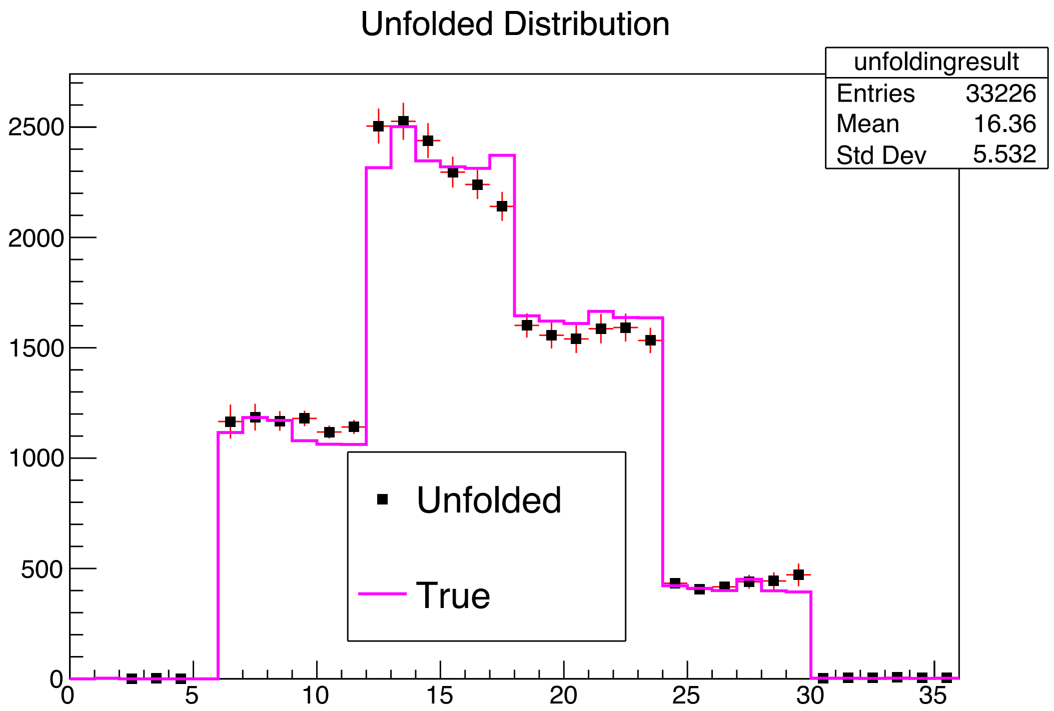
BACKUP

Two-dimensional pt unfolding closure test – Regurization parameter = 6



Unfolded the measured pt distribution using regularization parameter = 6

Minimum curvature = 0.000331

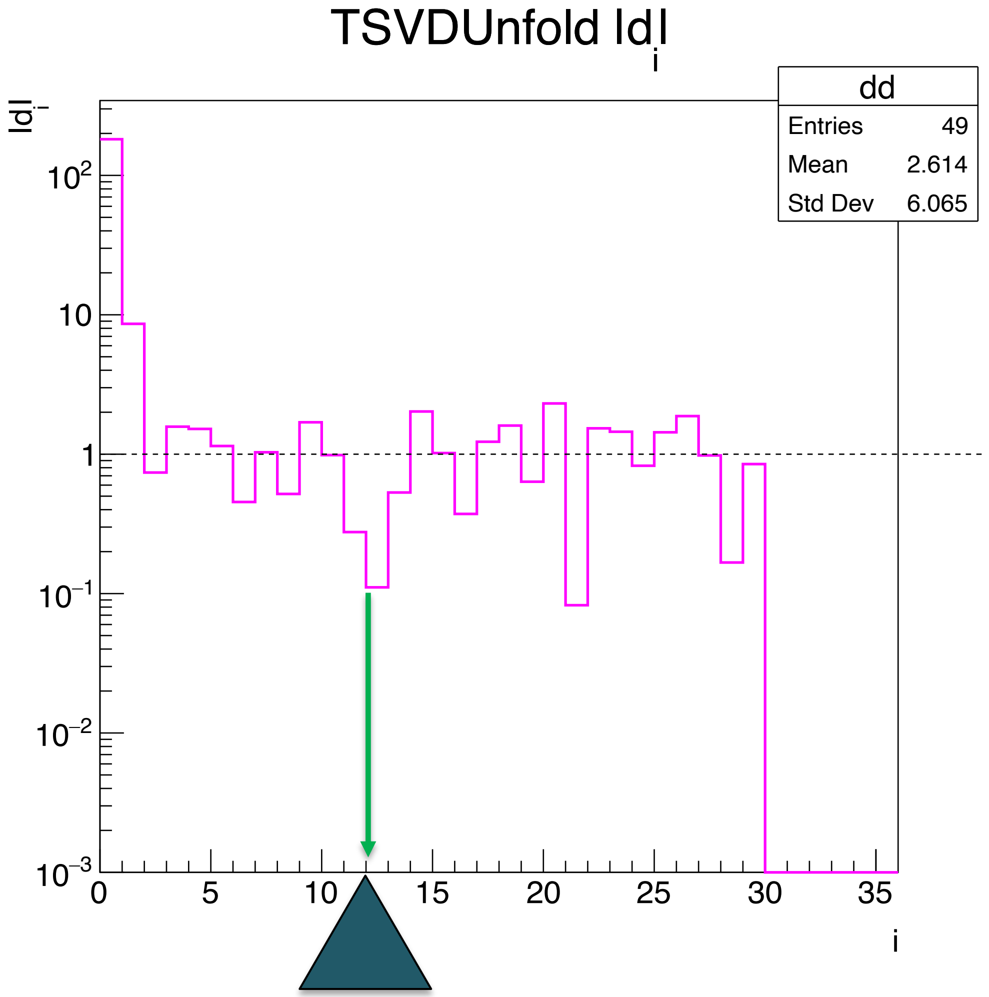


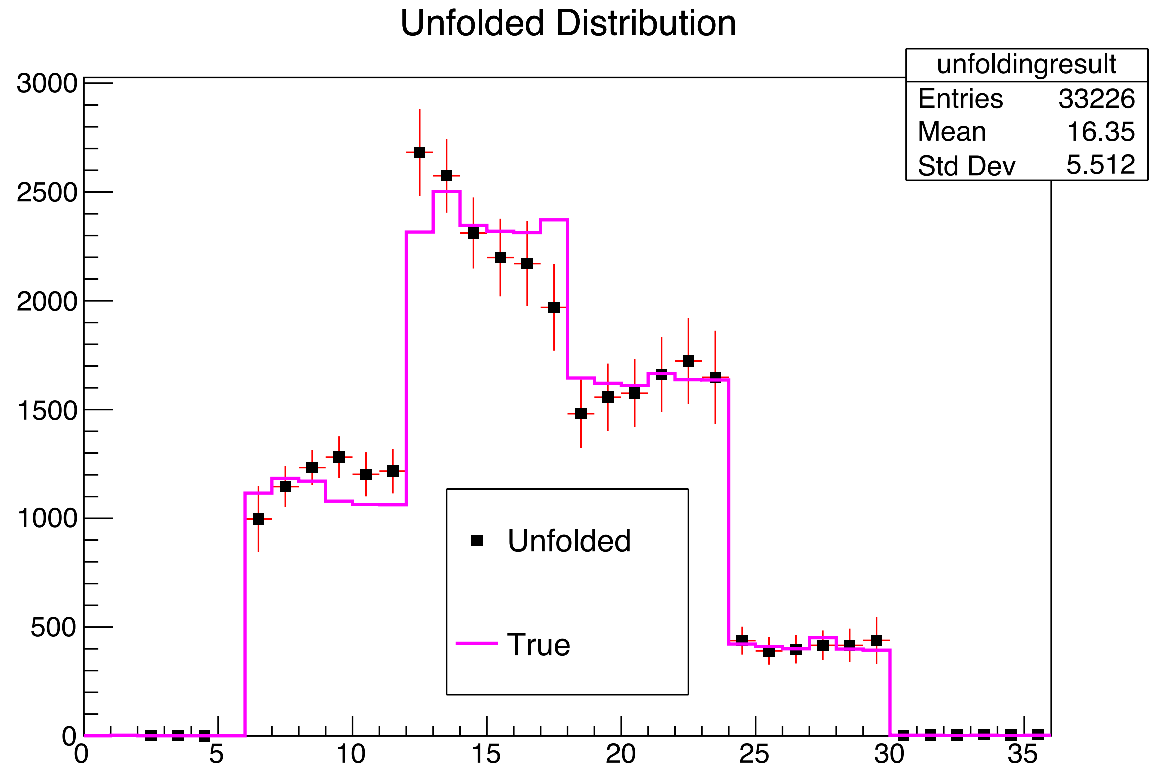
Magenta line: True distribution from dpmjet MC.

Solid black boxes: Unfolded distribution.

Unfolded distribution has been scaled to match the statistics between dpmjet and pythia.

Two-dimensional pt unfolding closure test – Regurization parameter = 12





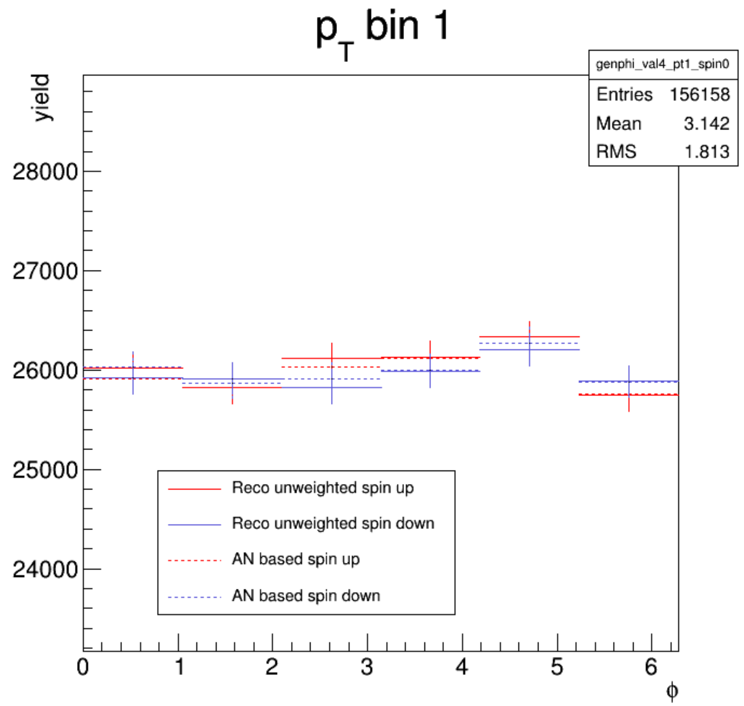
Unfolded the measured pt distribution using regularization parameter = 12
Minimum curvature = 0.009416

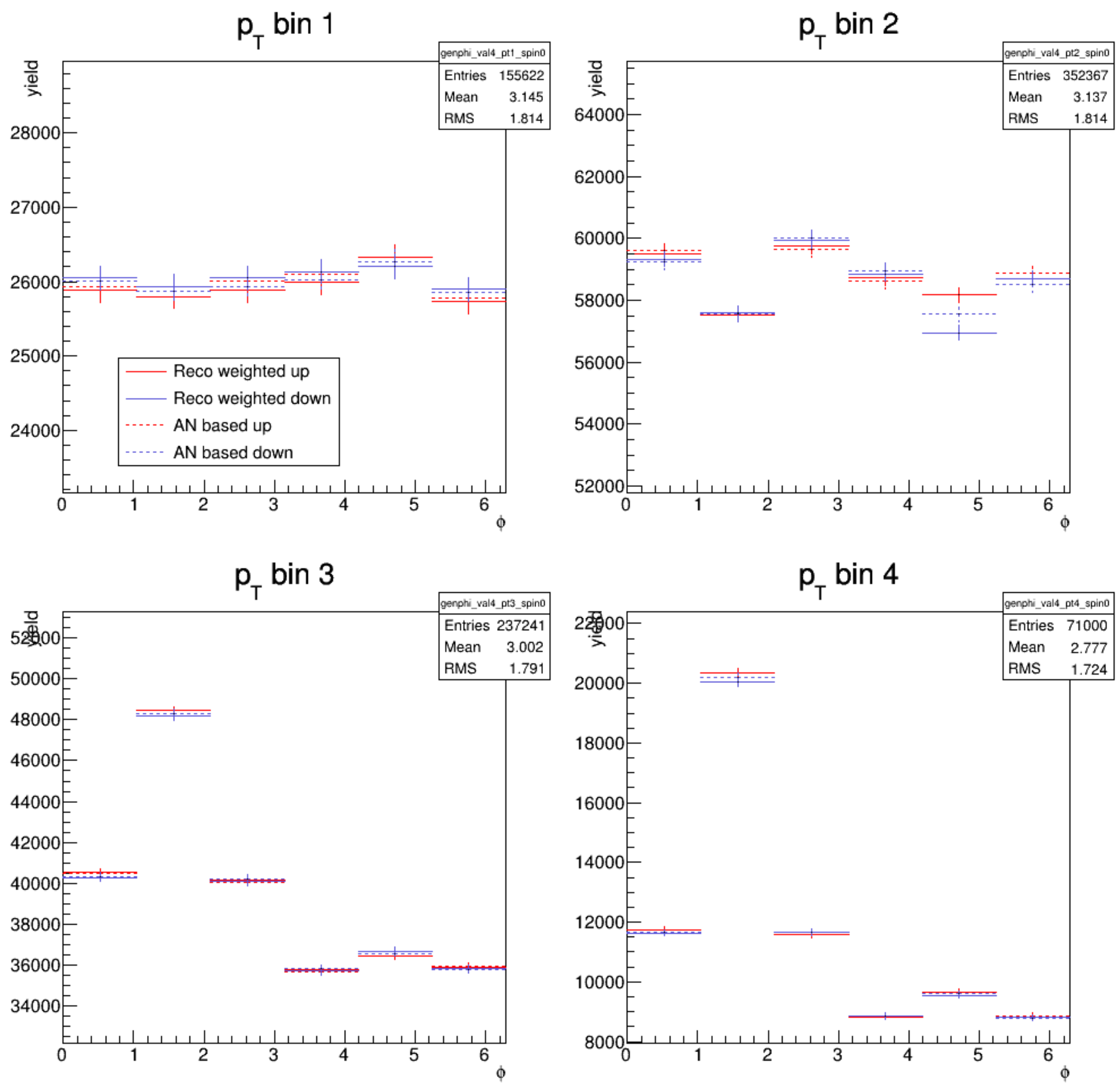
Magenta line: True distribution from dpmjet MC.

Solid black boxes: Unfolded distribution.

Unfolded distribution has been scaled to match the statistics between dpmjet and pythia.

OPE Monte Carlo (Unweighted)

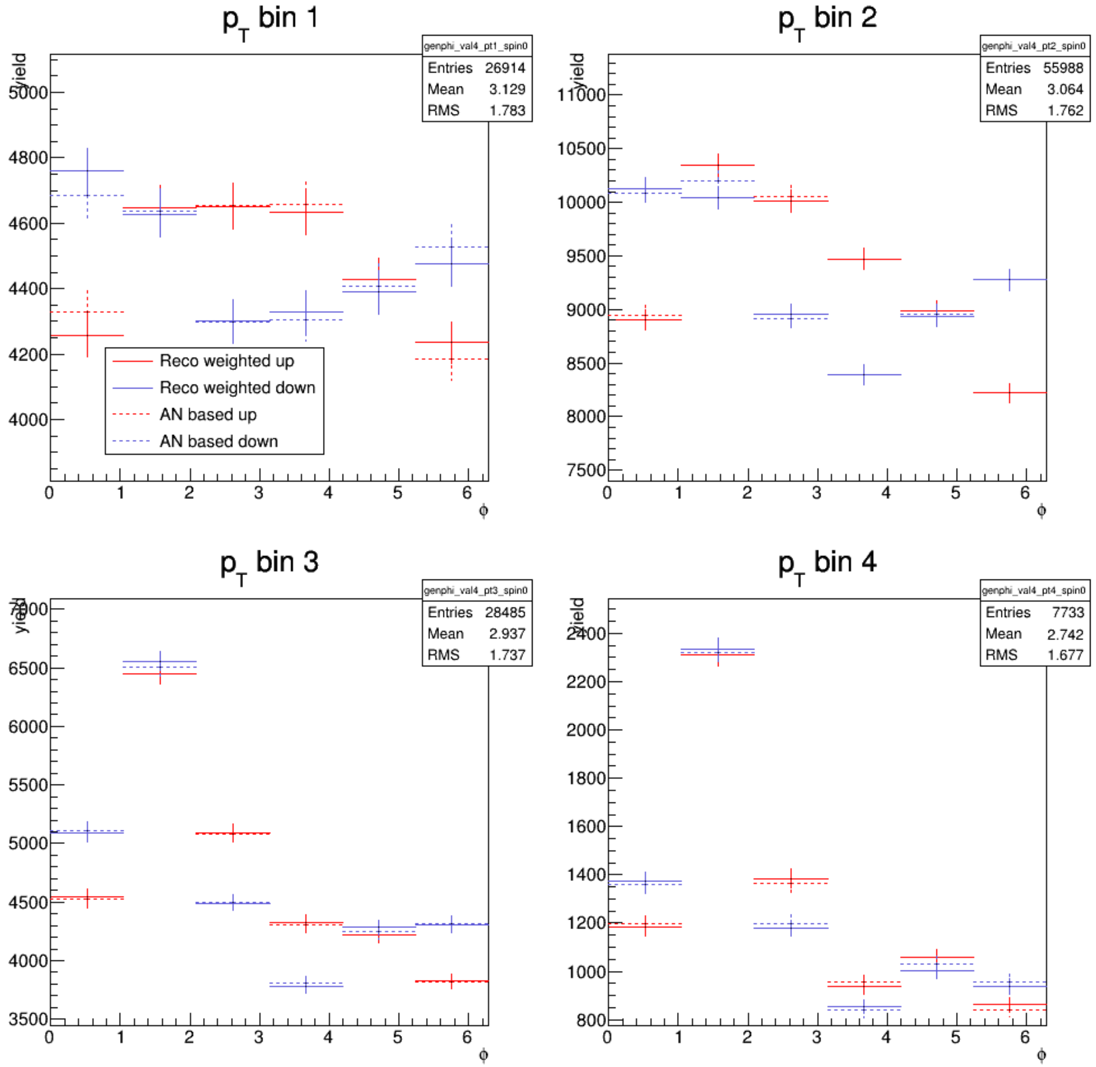




- Reconstructed azimuthal without weight
- Reconstructed azimuthal angle without weight
- Neutron asymmetry (A_N) without weight
- Neutron asymmetry (A_N) without weight

Weighted Monte Carlo

DPMJET



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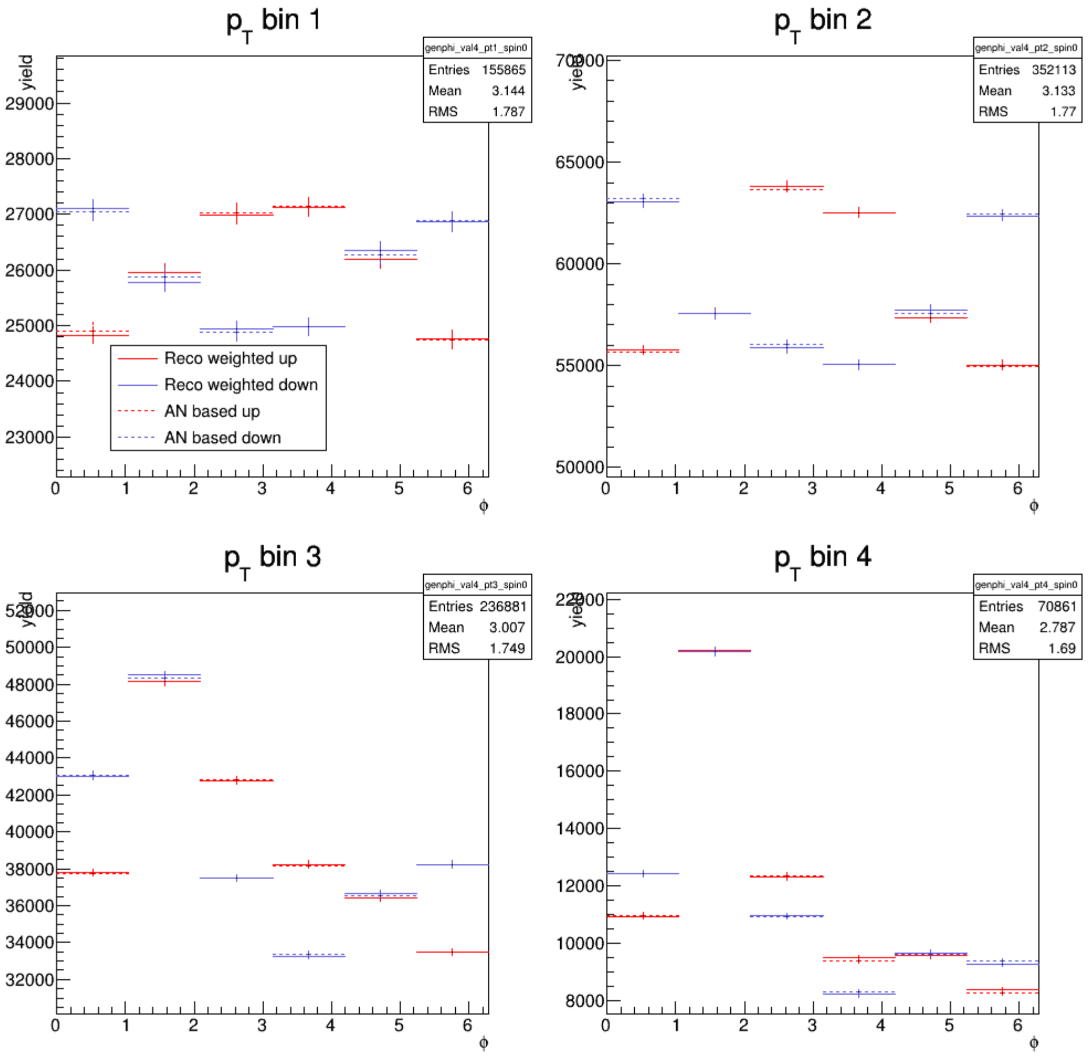
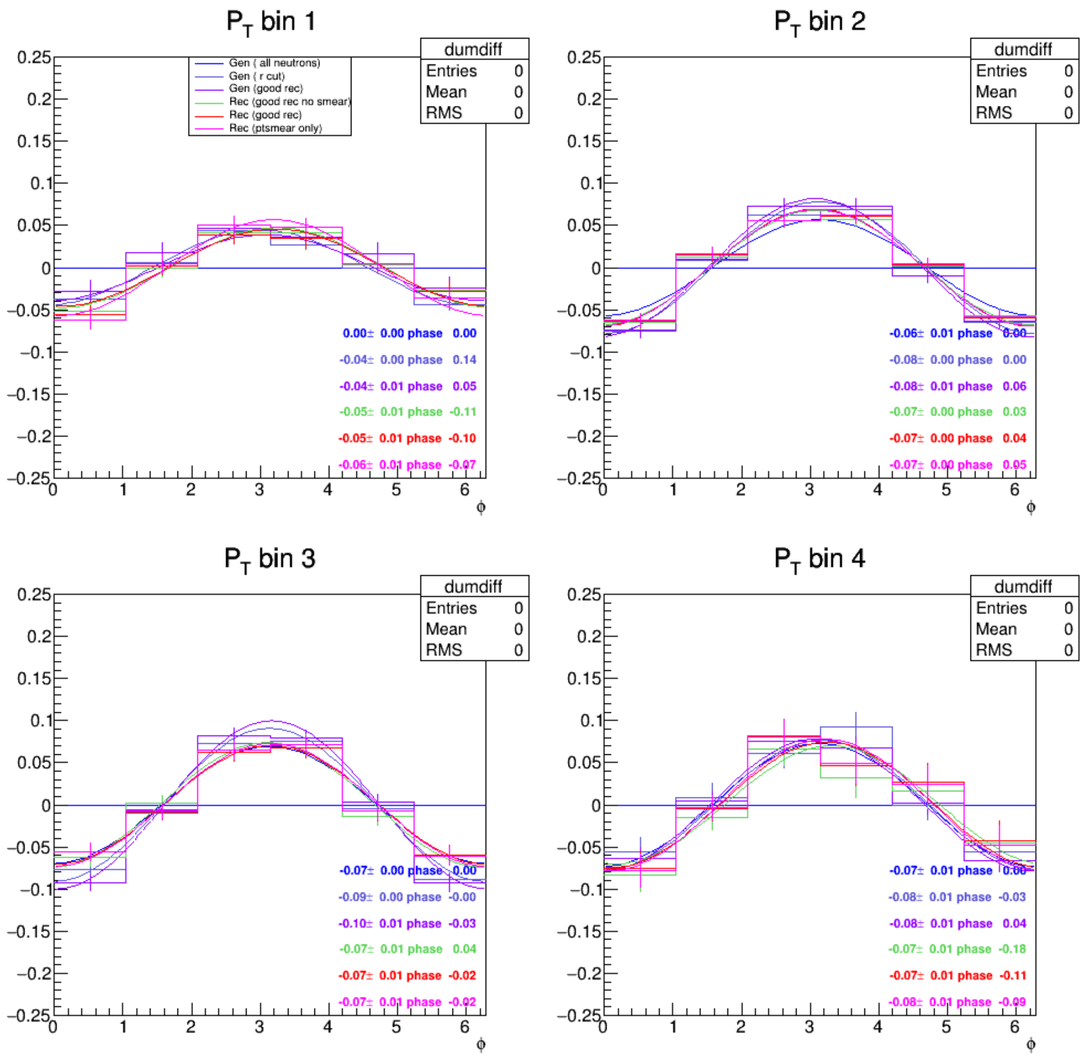


Weighted Monte Carlo

DPMJET



NEWOPERCS