PHENIX Data Analysis Status and Prospect

Benard Mulilo
KU/RIKEN

RBRC Group Meeting
Feb. 12, 2019 @ 9AM JST

Content

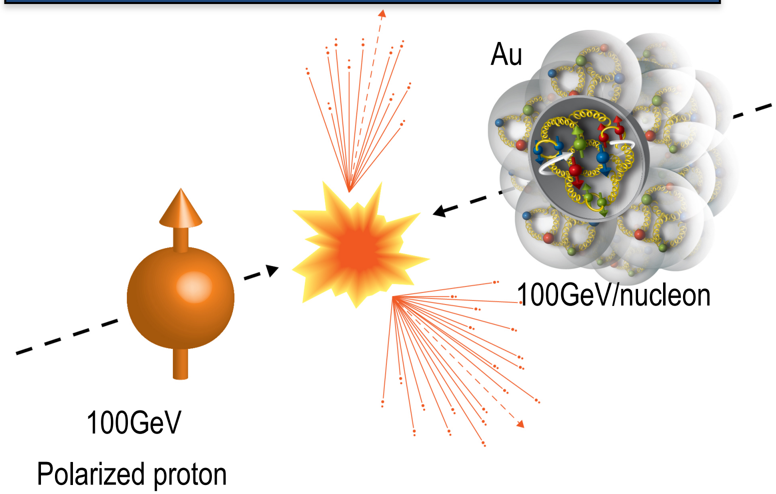
Slide 2

- ⌘ Data set and overview
- ⌘ One-dimensional P_T unfolding analysis
- ⌘ Two-dimensional ($\mathbf{P_T}$, Φ) unfolding analysis
- ⌘ Prospect and analysis schedule

Data Set and Overview[1]

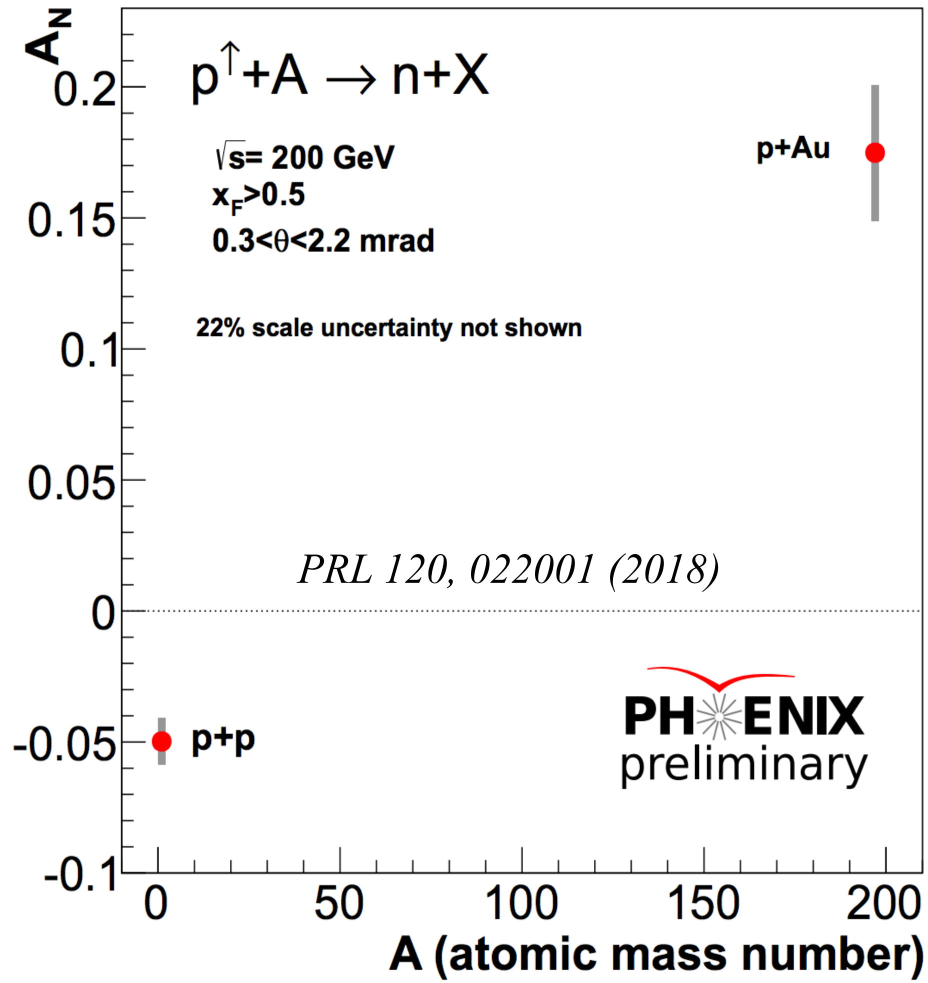
Slide 3

PHENIX Run15 (2015) Data Set



Nucleus	# of proton	# of neutron
p	1	0
Au	79	118

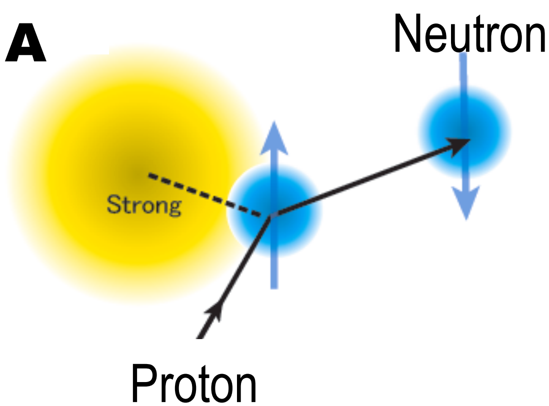
◎ QED process (Hypothesis)

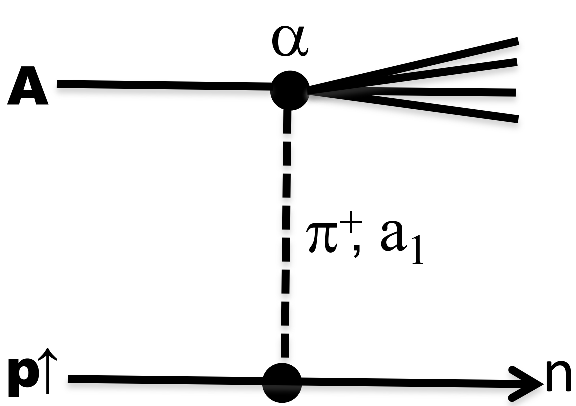


Data Set and Overview[3]

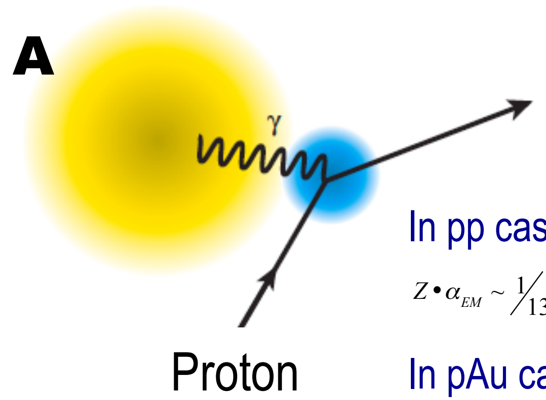
Slide 4

Strong (hadronic)





Primakoff (Electromagnetic)

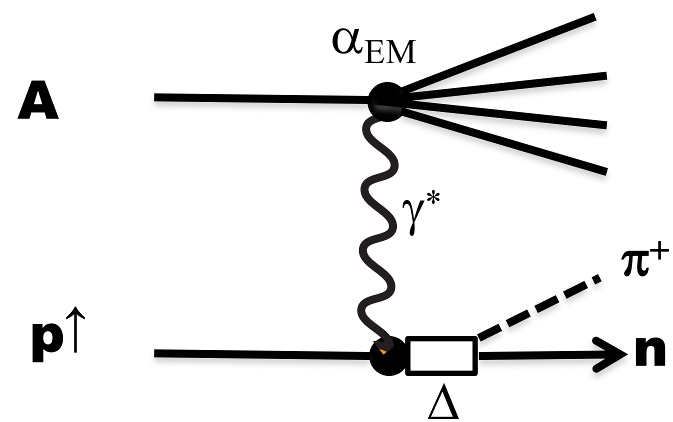


In pp case:

$Z \bullet \alpha_{EM} \sim {}^{1}\!/_{137}$

In pAu case:

$Z \bullet \alpha_{EM} \sim {}^{79}\!/_{137}$



One-dimensional P_T Unfolding Analysis

Unfolding

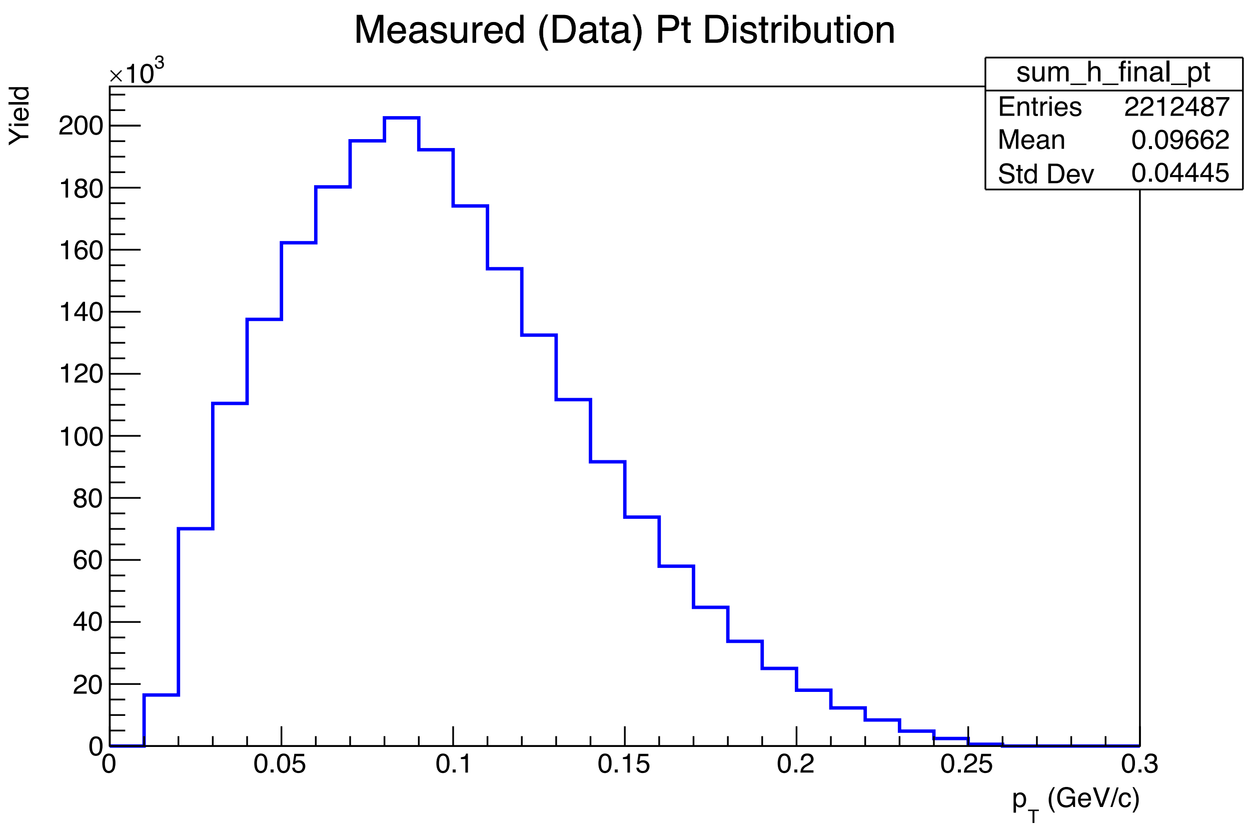
- Measurements in high energy physics (HEP) are usually affected by various detector effects such as the resolution, efficiency, etc.
- Unfolding technique removes these effects and recovers the true spectrum.

Inputs to singular value decomposition (SVD) object

- Data
- Covariance matrix
- True spectrum
- Reconstructed spectrum (Reco)
- Detector response (smearing) matrix

Unfolding Input – Measured P_T Spectrum

① Data to unfold: Run 15 inclusive pAu transverse momentum data at $\sqrt{s_{NN}} = 200$ GeV.



Unfolding Input – Reco P_T Spectrum

② Reco spectrum: pAu reconstructed P_T spectrum from a combination of UPC (EM) + DPMJET (HAD) MC training samples. This is a hypothesis.

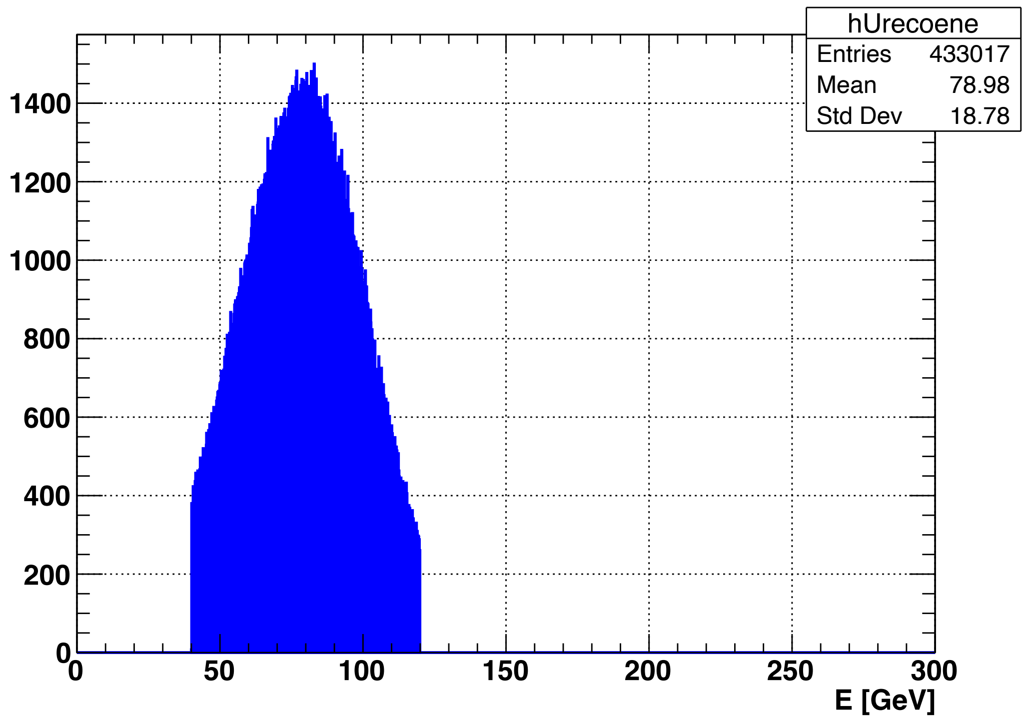
Neutron Selection Cuts

Following cuts were utilized for neutron identification and rejection of photon events. Same cuts were applied to experimental data:

- ZDC energy: 40 < E < 120 and 2^{nd} ZDC energy/ZDC total energy > 0.03 (i.e. non-zero 2^{nd} ZDC energy)
- Acceptance cut: 0.5 < r < 4.0 cm
- SMD multiplicity: Nx/Ny >= 2 fired SMD strips.
- That is Nx and Ny > 1 fired strips above SMD threshold E = 0.003 GeV.

Unfolding Input – Reco P_T Spectrum

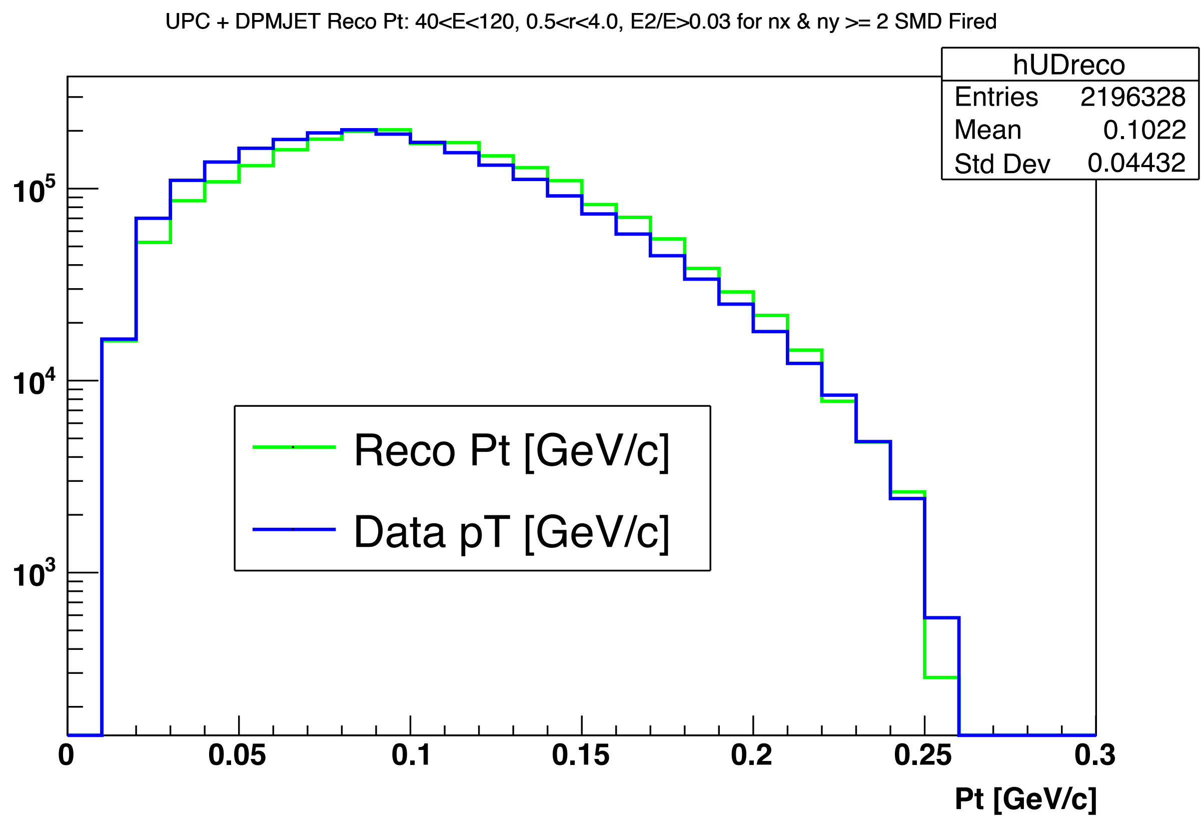
ZDC Total Energy Cut Check



⌘ ZDC total energy: 40 < E < 120 and 2nd ZDC energy/ZDC total energy > 0.03 cuts

Unfolding Input – Reco P_T Spectrum

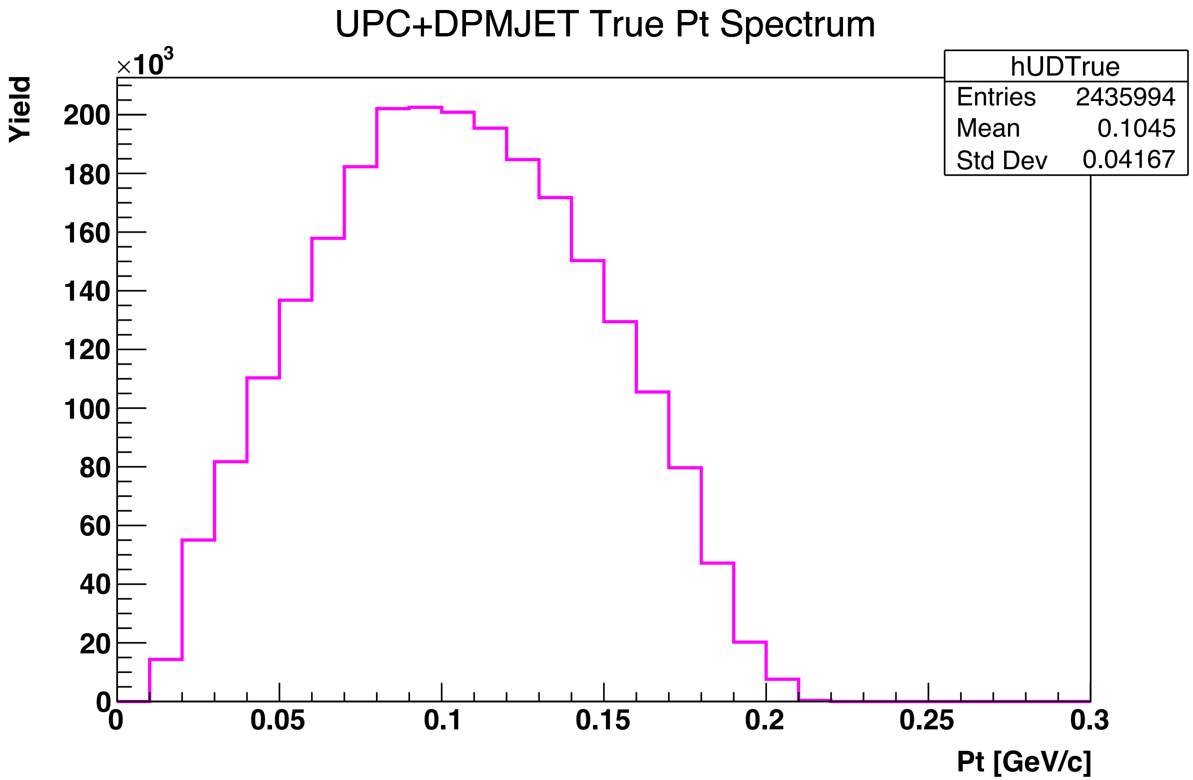
Slide 9



Unfolding Input – True P_T Distribution

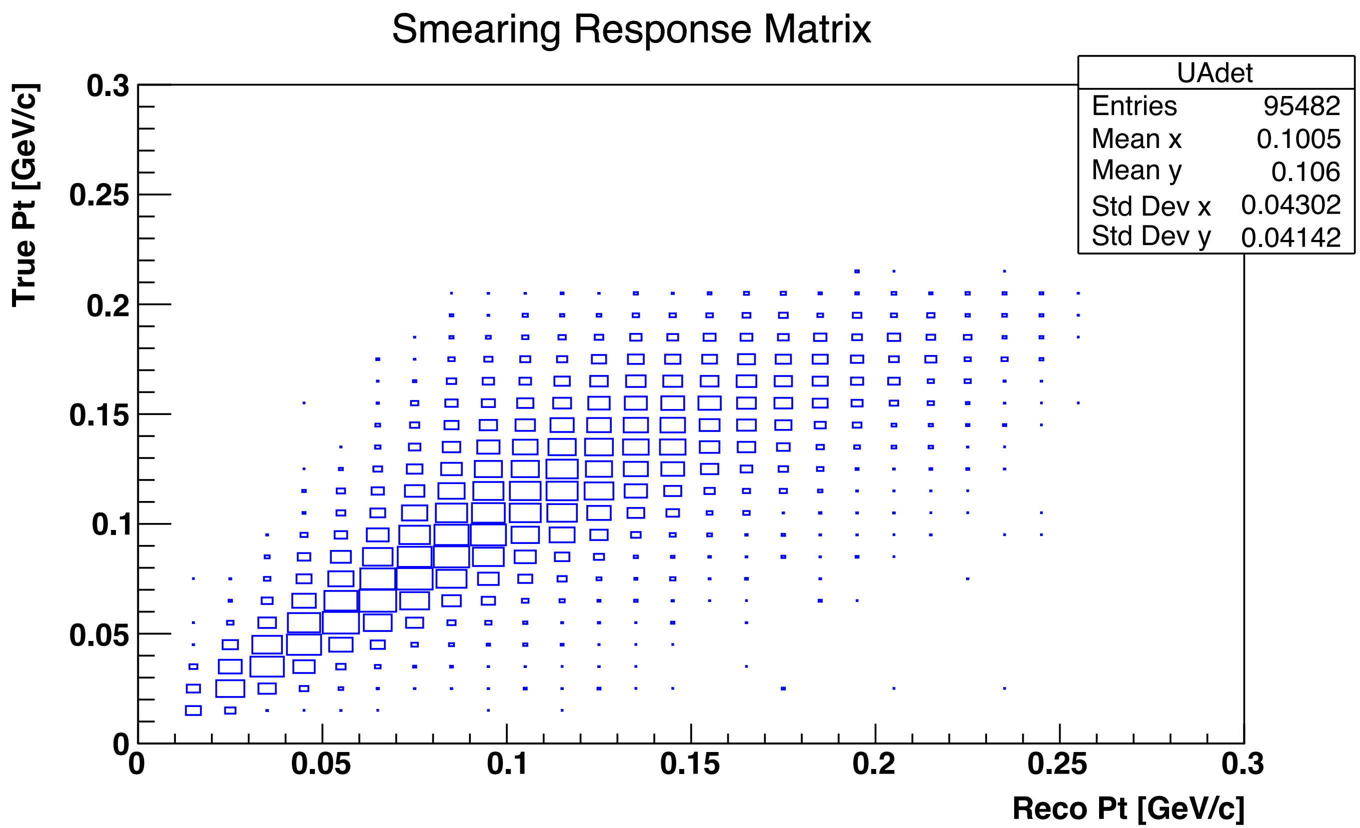
③ True spectrum:

True P_T spectrum from addition of UPC (EM) + DPMJET (HAD) MC samples.



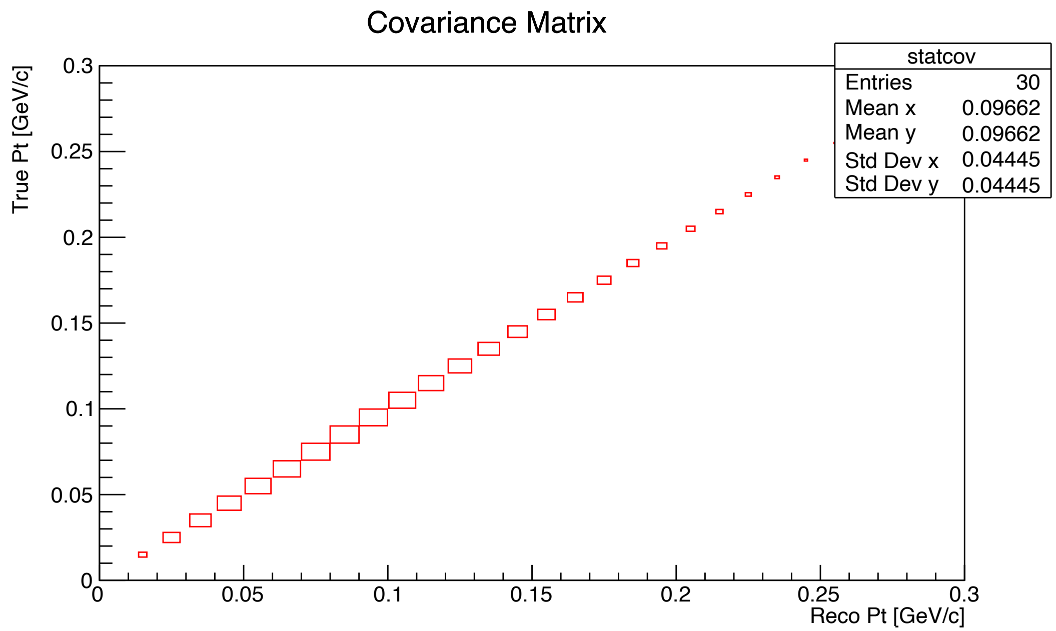
Unfolding Input – Response Matrix

④ Detector response matrix: 2D plot extracted from the Reco and True P_T spectra of MC.



Unfolding Input – Covariance Matrix

⑤ Covariance matrix: 2D histogram extracted from the measured P_T spectrum.



Finally created a TSVDUnfold object to perform unfolding of the data distribution.

```
TSVDUnfold *tsvdunf = new TSVDUnfold( hdata, statcov, hUDreco, hUDTrue, UAdet )
```

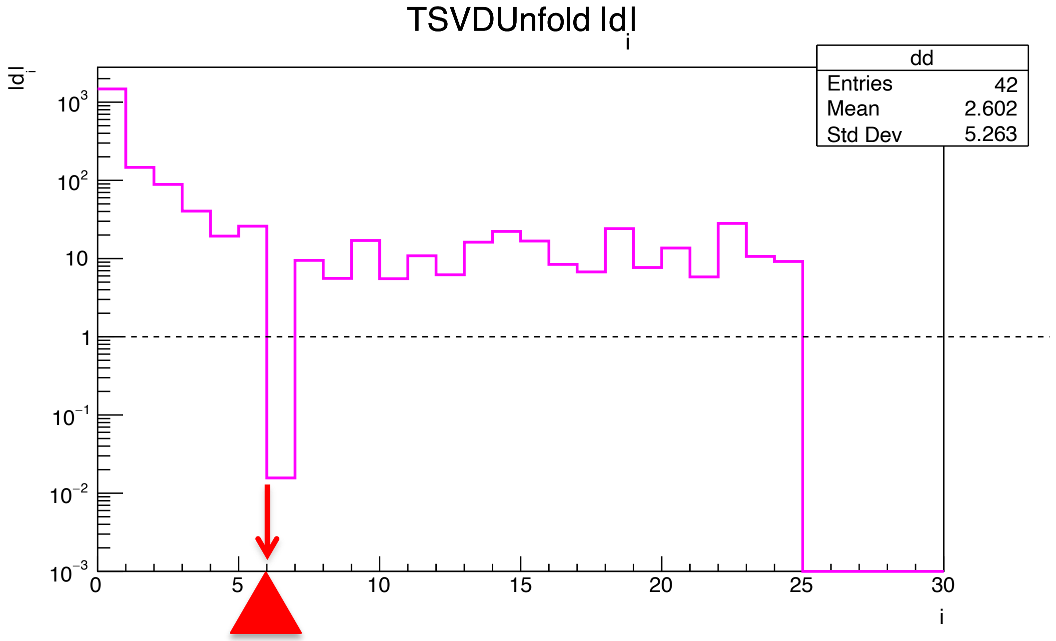
FLAG = ON

1 2 3 4 5

Unfolding Output – Regularization Parameter

Slide 13

- Performed unfolding with the regularization parameter (kreg = 6 as optimum).

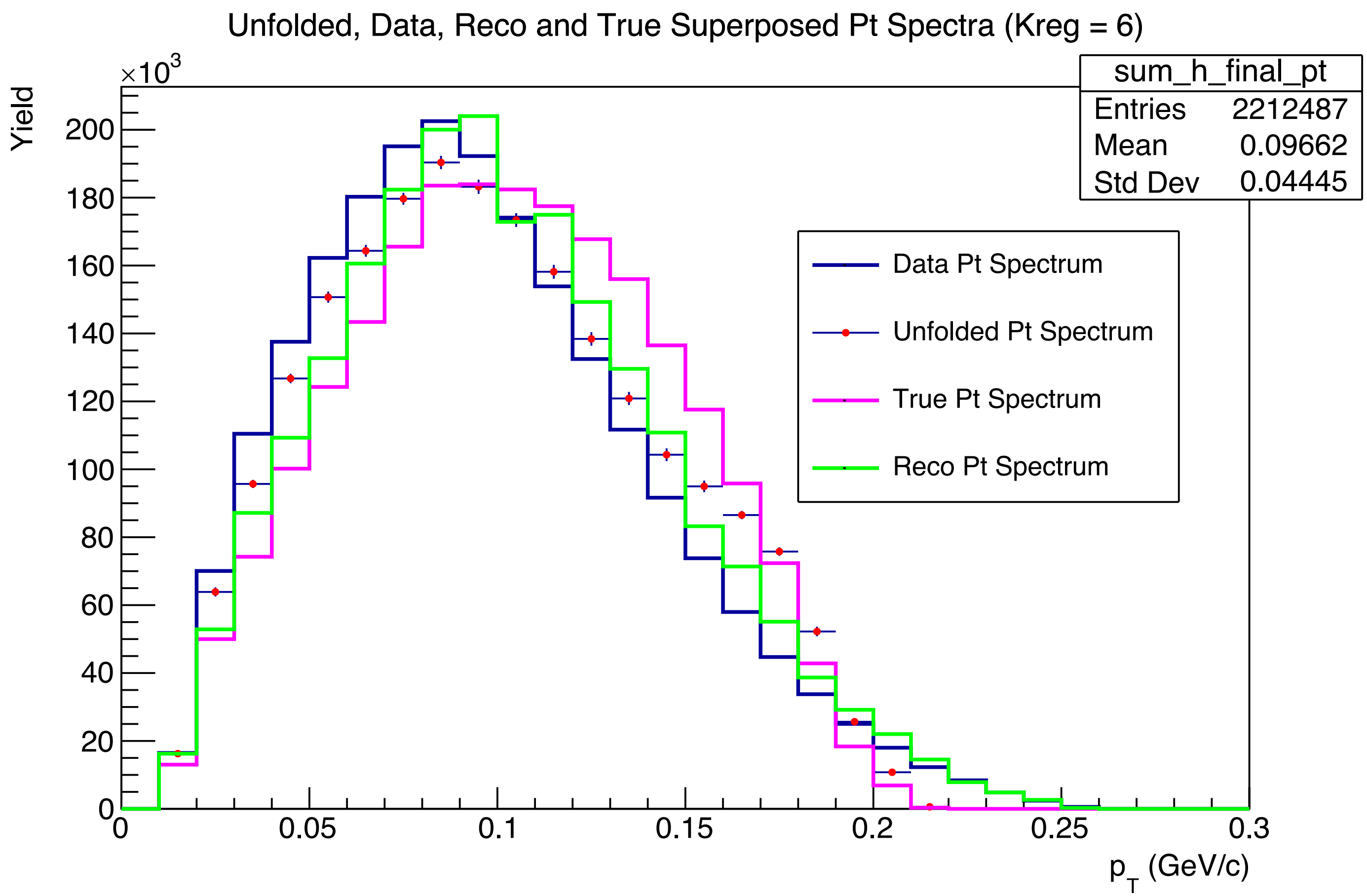


- This distribution helps us cross-check the quality of our unfolding regularization.

- Regularization is chosen as the point where | d_i | stops being statistically significant.
- This is the point where the regularization (kreg) is considered most optimal.

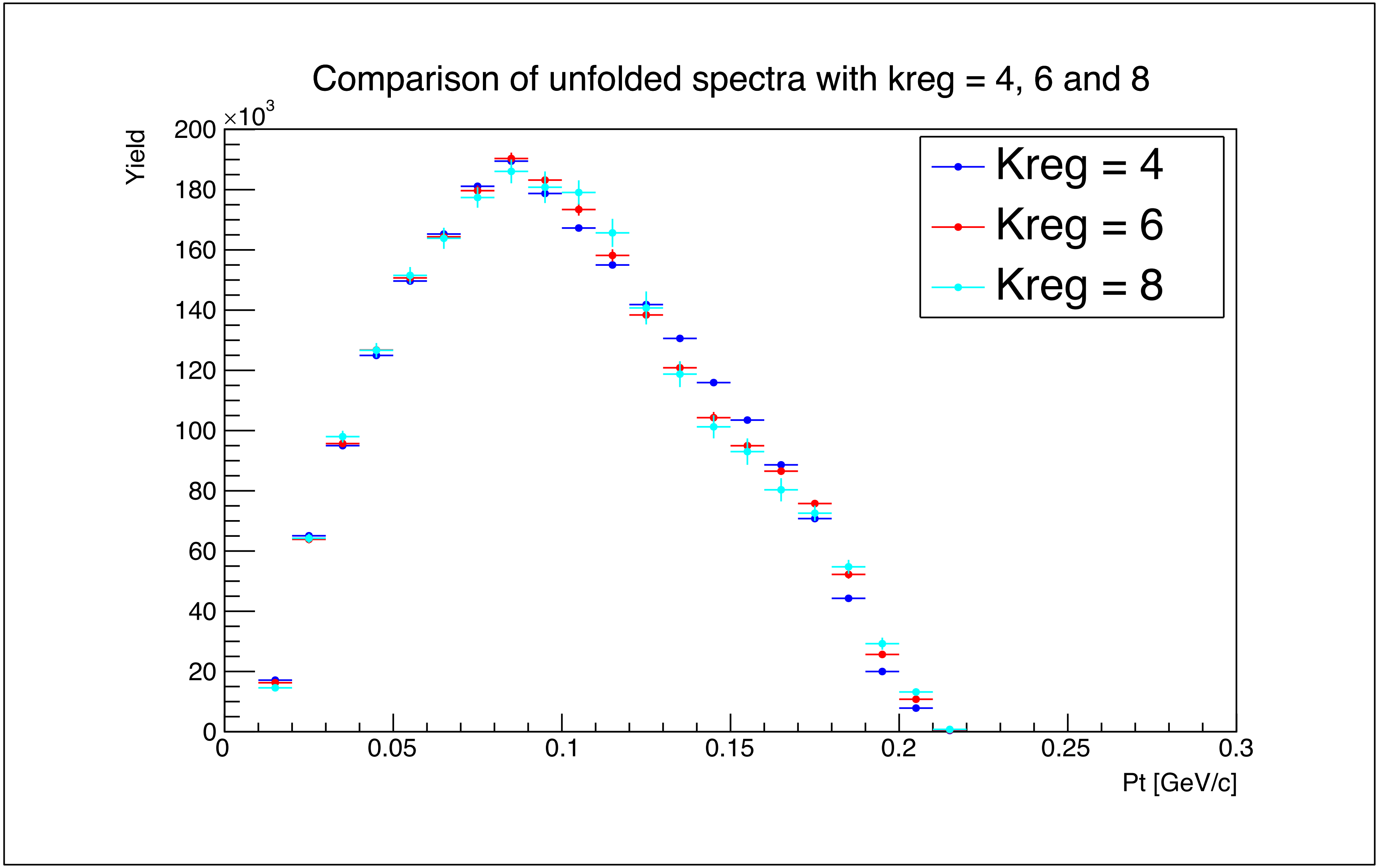
Unfolding Output – Unfolded P_T Distribution

Slide 14



Unfolding Output – Unfolded P_T Distribution

Slide 15



RIKEN Nishina Center Acc. Progress Report [One page only]

Unfolding the transverse momentum distribution for very forward neutron production in pAu collisions at $\sqrt{s_{NN}} = 200$ GeV

B. Mulilo,[*1,*2] for the PHENIX collaboration

The PHENIX collaboration measured that when a transversely polarized proton with spin up collides with unpolarized proton at $\sqrt{s_{NN}} = 200$ GeV, they generate neutrons predominantly to the right[1]. In 2011, theorists explained this result in terms of the interference of pion and a_1 reggeon exchanges[2]. But in 2015 using run 15 pAu data, we observed that when a polarized proton collides with a gold nucleus at $\sqrt{s_{NN}}$ = 200 GeV, they generate more neutrons to the left[3] contrary to theoretical predictions[2]. This nuclear dependence of the asymmetry (A_N) has, therefore, attracted a massive interest in nuclear physics.

To explore the nature of the proton spin further, we are now studying A_N as as a function of the true transverse momentum (Pt). We begin with an understanding that our measurements are limited by known effects such as the detector resolution and detection efficiency among others. Our technique is, therefore, to employ a method known as unfolding to remove these known effects and recover the true distribution.

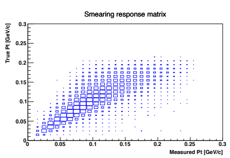


Fig. 1. Smearing response matrix mapping the binned true Pt spectrum to the measured spectrum.

We proceed by parametrizing measurement effects using the response matrix in Fig.1 from Monte Carlo[4]. What this matrix does is to map the binned true spectrum in the Magenta line onto the measured spectrum in the Green line of Fig.2. For the measured and true distribution bins R_i and T_j, respectively, the smearing matrix element S_{ij} gives the fraction of entries from bin T_j that end up being reconstructed in bin R_i.

The unfolding has been performed using the singular value decomposition method[5] contained in CERN's ROOT toolkit. Since our smearing matrix is not perfectly diagonal, we unfolded with a parameter, alias Kreg[5], which determines the regularization of the unfolding. The unfolded spectrum was the distribution corresponding to an optimum Kreg = 6 as depicted in Fig.2. In the vicinity of optimum Kreg, we expect the unfolded distributions to behave normally, so we compared neighboring Kreg 3 and 4 to the optimum Kreg = 6 and the result was as expected as shown in Fig.3.

We are now extending the ideas of the one dimensional unfolding to two dimensional unfolding of Pt in azimuth Φ. The unfolded spectrum will then be used to calculate A_N as a function of the unfolded Pt and we will finally be able to draw further conclusions about the the nature of the proton spin.

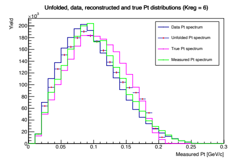


Fig. 2. Superposition of the experimental data, unfolded, true and measured Pt distributions.

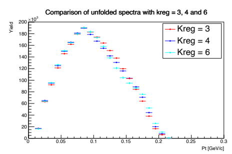


Fig. 3. Unfolded spectra with various parameters.

- - - - -

References
1) A. Adare et al. Phys. Rev. D88 (2013) 032006.
2) B. Z. Kopeliovich et al. Phys. Rev. D84 (2011) 114012
3) A. Aidala et al. Phys. Rev. Lett. 120, 022001 (2018)
4) G. Mitsuka Phys. Rev. C 95, 044908 (2017)
5) Nucl. Instr. Meth. A372, 469 (1996)[hep-ph/9509307]

*1 RIKEN Nishina Center
*2 Department of Physics, Korea University

Contribution Form > Finished

Your manuscript has been sent to the RIKEN Nishina Center Accelerator Progress Report Editorial Committee.

Once the manuscript is confirmed by the editorial committee, a confirmation mail will be sent to the contributor.

In case the manuscript needs to be revised, inform the Editorial Committee after receiving the confirmation mail.
Do not re-submit via web site.

RIKEN Nishina Center Accelerator Progress Report Editorial Committee
E-mail: progress@ribf.riken.jp

Japanese

Go to APR TOP

Have another manuscript to send?
Go to Contribution form top.

English

Go to APR TOP

Have another manuscript to send?
Go to Contribution form top.

- CLIP MAIL -

2D (P_T, Φ) Unfolding for Asymmetry Calculations

Preparation of the true and reconstructed transverse momenta distributions in azimuth, Φ.

True and reconstructed transverse momentum distributions (GeV/c):

- P_T bins = 4 bins
- Minimum P_T = 0.0
- Maximum P_T = 0.3
- P_T bin width = 0.075
- P_T slices = $0.0<P_T<0.075$ (bin 1), $0.075<P_T<0.150$ (bin 2), $0.150<P_T<0.225$ (bin 3), $0.225<P_T<0.300$ (bin 4)

True and reconstructed azimuth, Φ (radians):

- Φ bins = 6 bins
- Minimum Φ = -3.14 (-Pi)
- Maximum Φ = +3.14 (+pi)
- Φ bin width = 1.05
- Φ slices = $-(3.14< \Phi <2.10)$ (bin 1), $-(2.10< \Phi <1.05)$ (bin 2), $-(1.05< \Phi <0.0)$ (bin 3), $0.0< \Phi <1.05$ (bin 4), $1.05< \Phi<2.10$ (bin 5) and $2.10< \Phi<3.15$ (bin 6)

Current Tasks

Slide 18

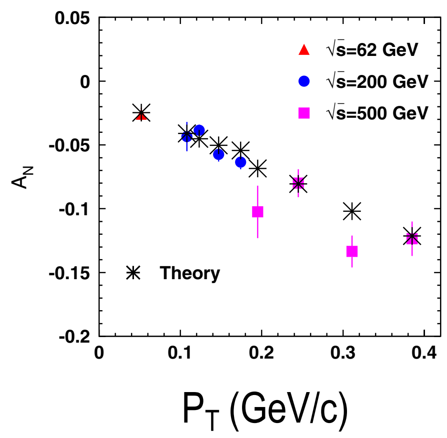
- Converting two-dimensional to one-dimensional P_T in Φ distribution and construct the smearing response matrix input to the TSVD unfolding (current priority)

- Apply the unfolding using ROOT's singular value decomposition (SVD) method incorporated in CERN's ROOT analysis toolkit.

Analysis Prospect

- Reconstruct P_T - dependence of A_N distribution

PRD84,114012(2011)
$p^{\uparrow} + p$
Reference



- Compute systematic uncertainties associated with the A_N vs. P_T

Analysis Schedule (So Compact)

Below is the analysis schedule for tasks remaining after the 1D unfolding results shown in this presentation. The schedule is too compact to finish all remaining tasks this year, 2020.

TIMELINE	ANALYSIS TASKS	STATUS
Nov. 2019	Monte Carlo tuning to match data	Checked
Nov. 2019	Disable single SMD hit event and get rid of spikes	Checked
Nov. 2019	Azimuthal distribution health check of UPC_A_N+0.2	Checked
Dec. 2019	Convert 2D(P_T, Φ) into 1D preparation for 1D unfolding	Here now
Dec-Jan 2020	P_T, Φ 1D unfolding	current
Jan-Feb 2020	Stability check of unfolding matrix using MC	current
Feb-Mar 2020	Unfolding experimental data	current
Mar. 2020	Calculate A_N as a function of P_T	Pending
Mar. 2020	Backgrounds and systematic uncertainty	Pending
Apr. 2020	Preliminary	Pending
May-Jul 2020	Paper draft	Pending
Aug. 2020	Paper submission	Pending
Aug-Oct 2020	Thesis writing	Pending
Dec. 2020	Defense	Pending

Analysis Schedule (Tentative)

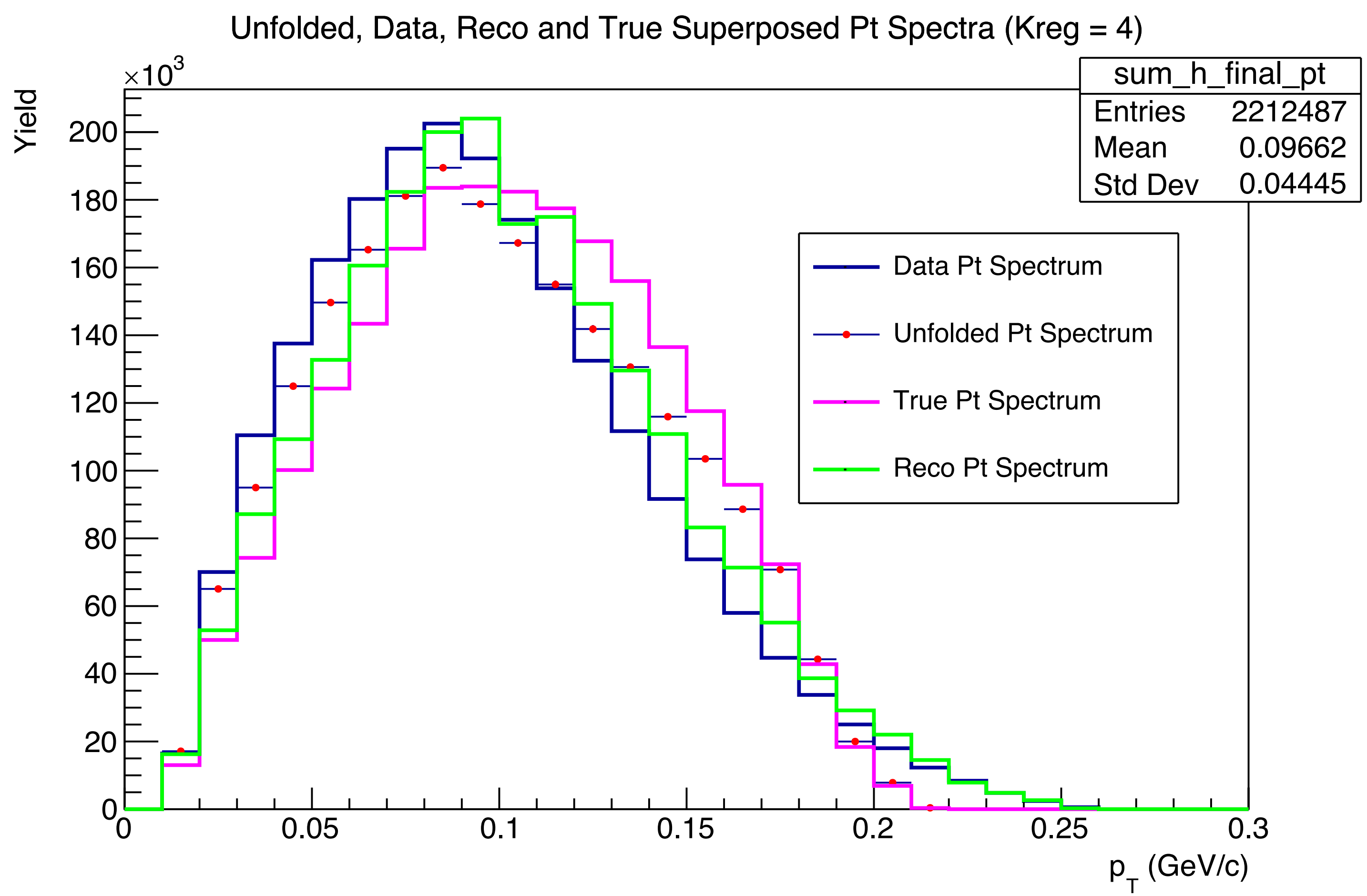
If there will be positive feedback from the University of Zambia? Tentative but more realistic

TIMELINE	ANALYSIS TASKS	STATUS
Jan. 2020	Convert 2D (P_T, Φ) into 1D hist prepartion for unfolding	Now here
Mar. 2020	$P_{T\text{-}\Phi}$ 1D unfolding and stability check of unfolding matrix	Pending
Aug. 2020	Unfolding the experimental data and calculation of $A_N(P_T)$	Pending
Dec. 2020	Study the background and systematic uncertainty and get preliminary	Pending
Jun. 2021	Prepartion and submission of the paper draft	Pending
Dec. 2021	Defending thesis and completion of the Ph.D requirements.	Pending

BACKUP

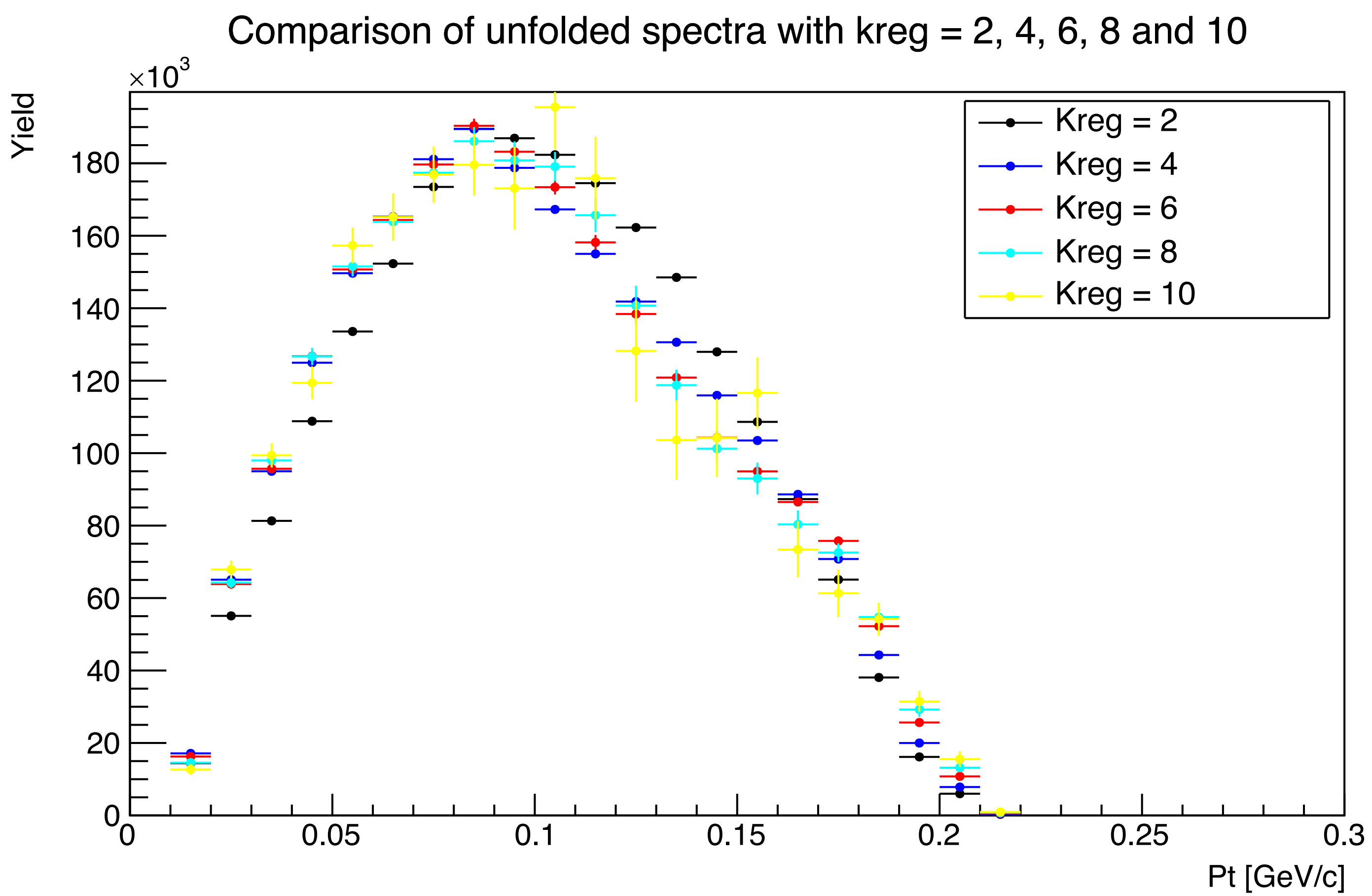
Unfolding Output – Unfolded P_T Distribution

Slide 1



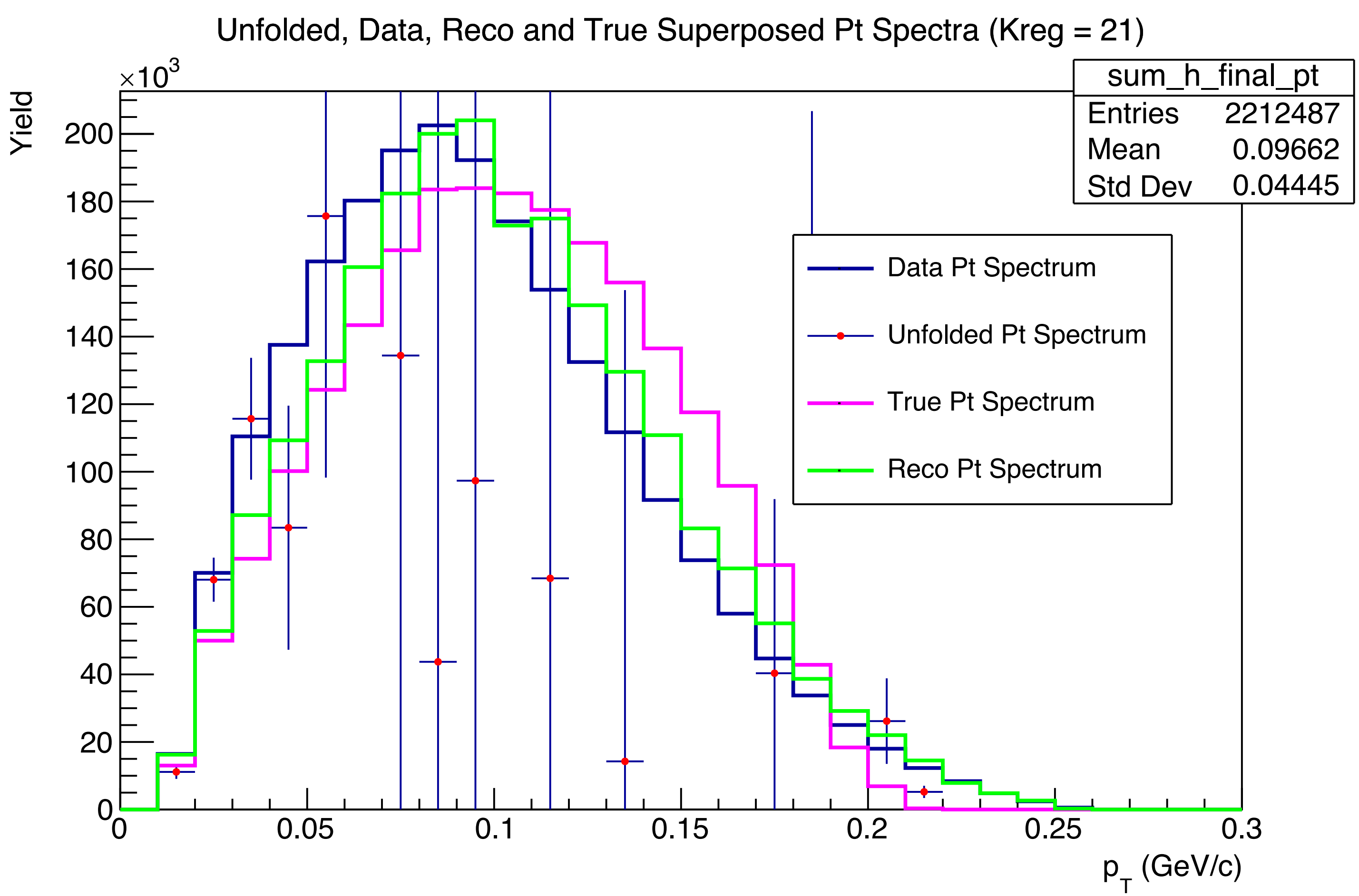
Unfolding Output – Unfolded P_T Distributions

Slide 2



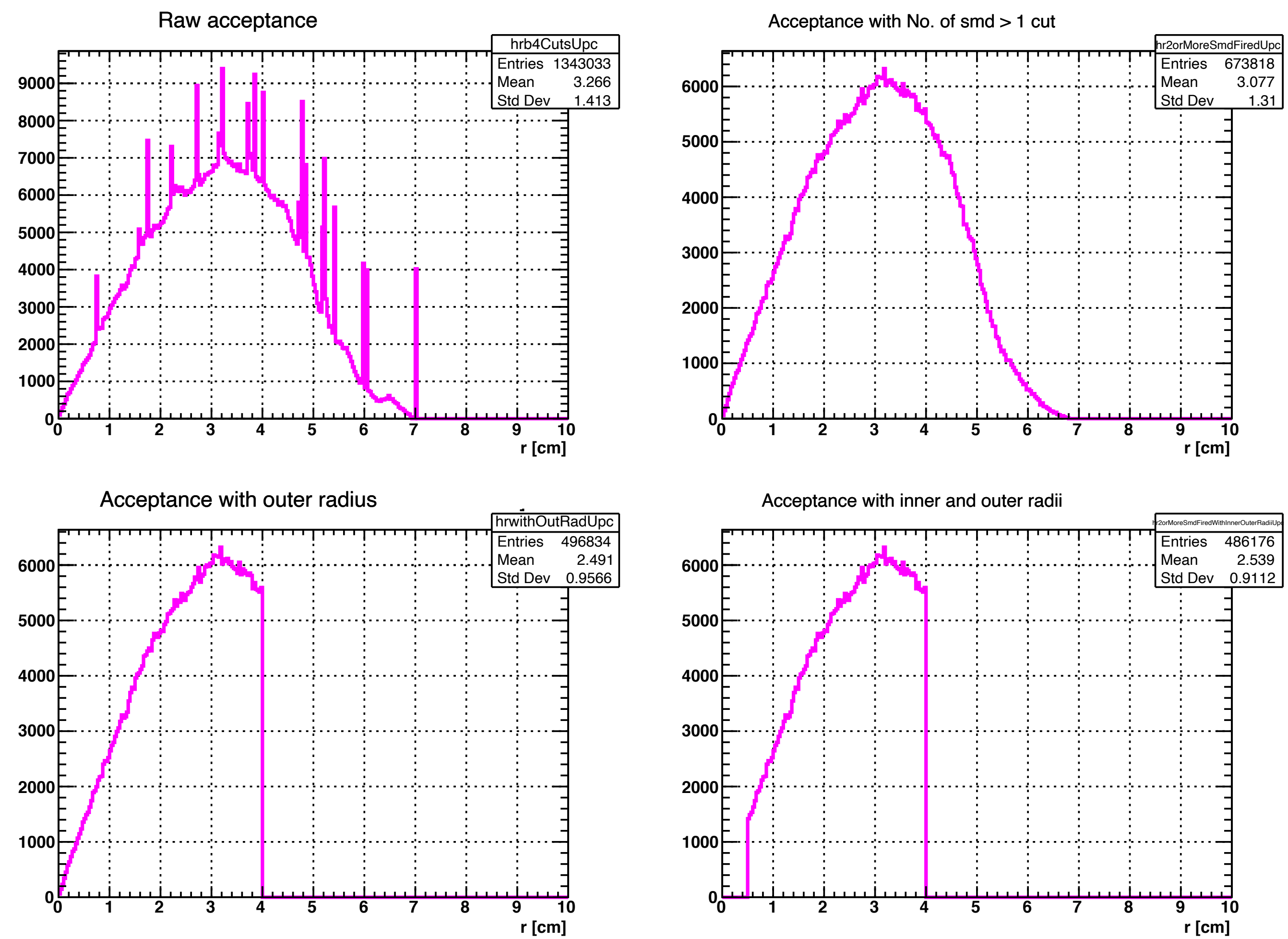
Unfolding Output – Unfolded P_T Distribution

Slide 3



Acceptance Cut Check

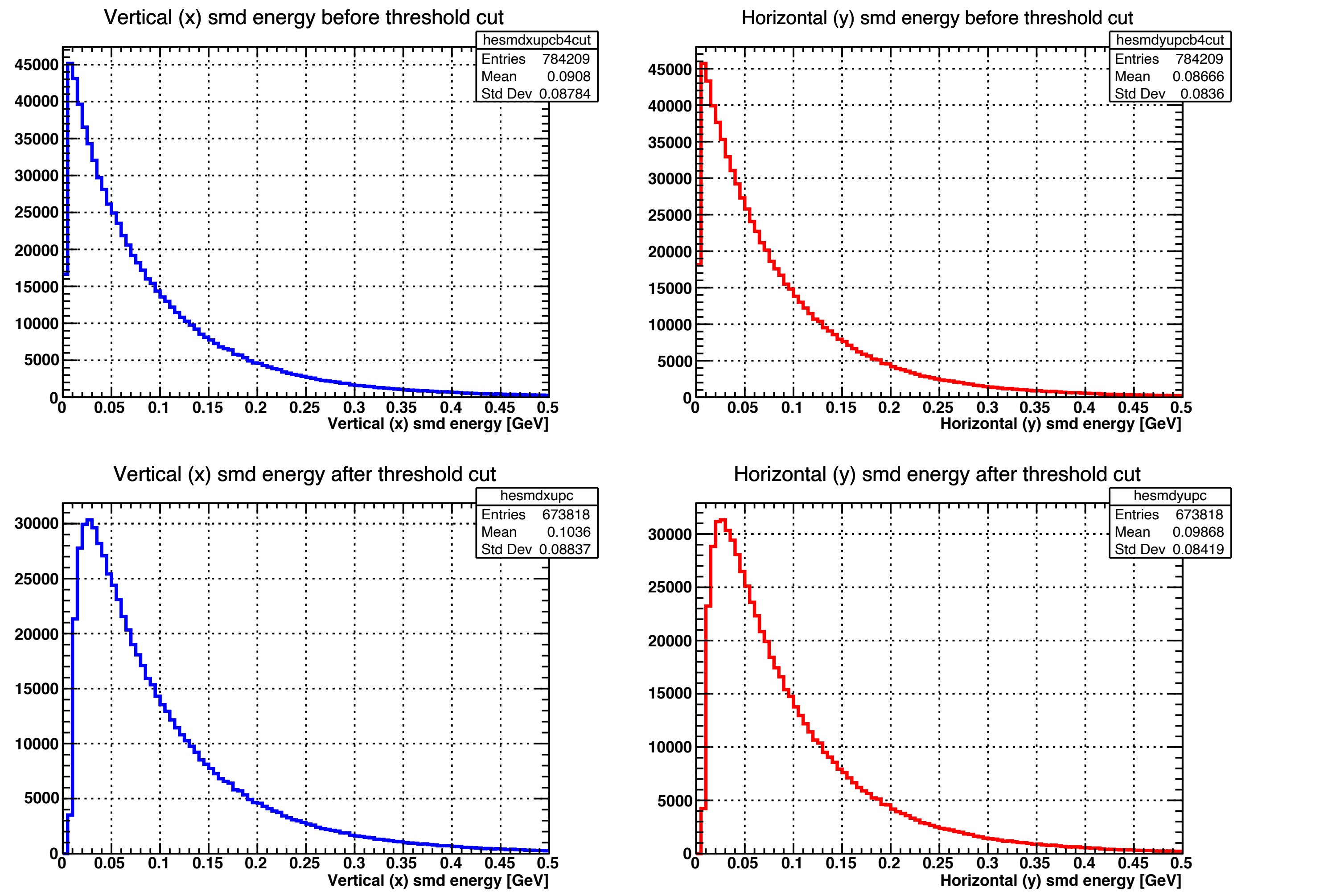
Slide 4



⌘ Inner and outer radii > 0.5 cm and < 4.0 cm cuts, respectively are applied as shown in the bottom right side panel.

SMD Energy Check

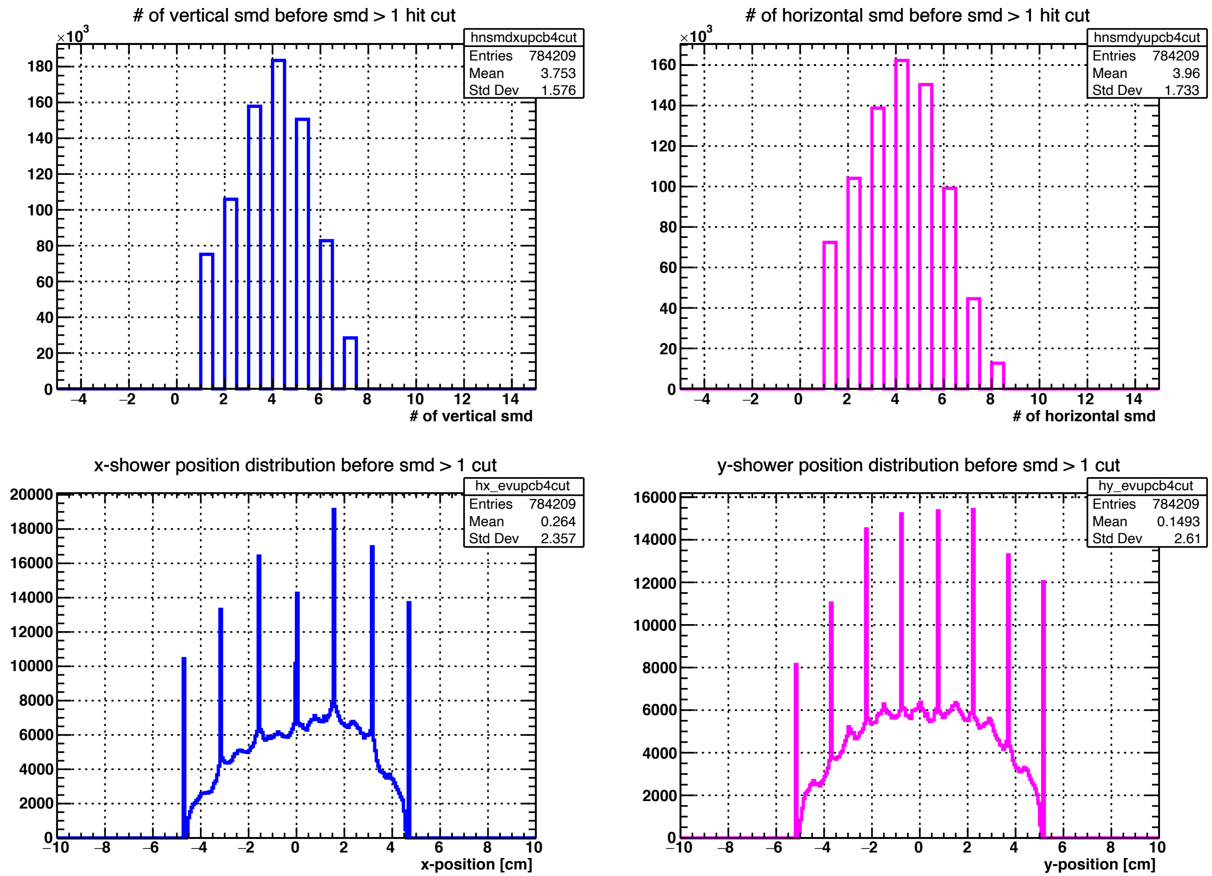
Slide 5



SMD XY Position Check

Slide 6

- Top panels depict # of fired vertical, Nx, (left) and horizontal, Ny, (right) smd before applying Nx(Ny) > 1 hit cut.

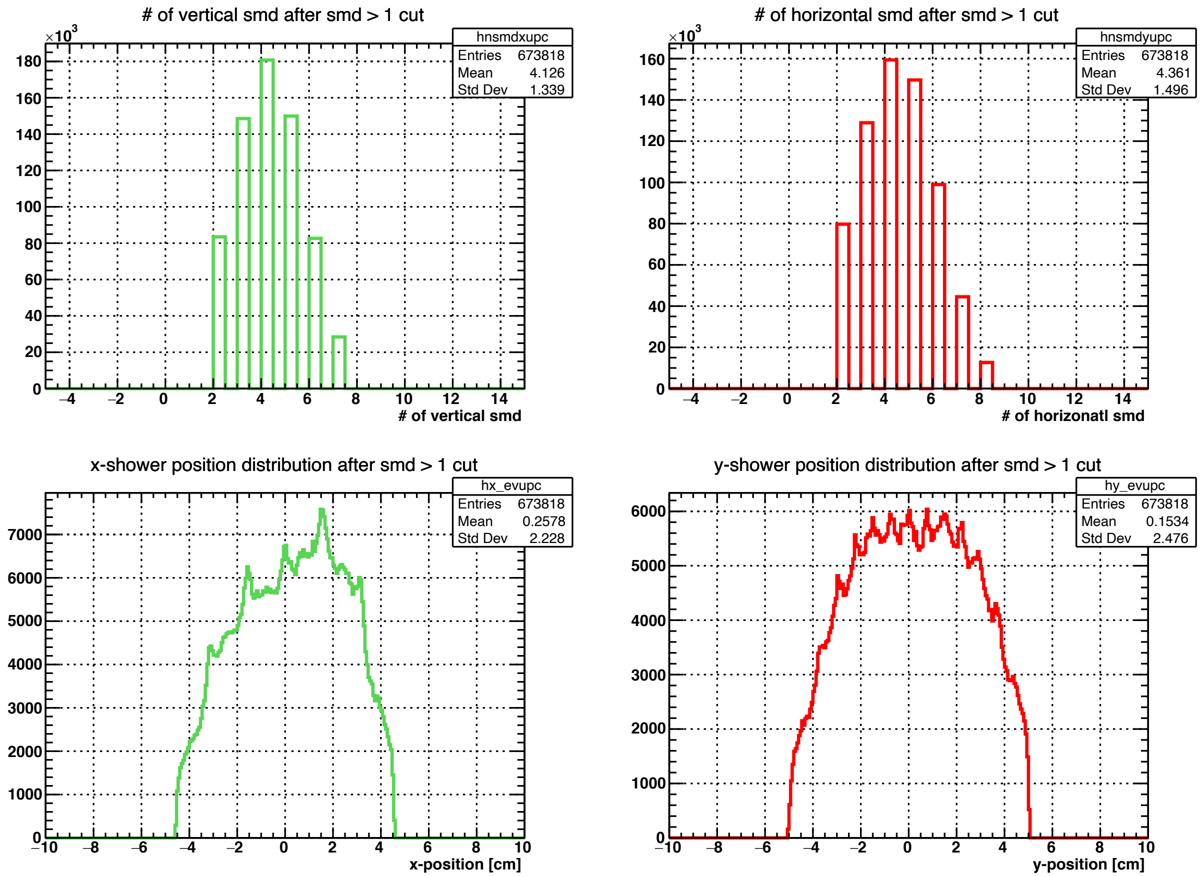


- Bottom panels are x (left) and y (right) particle position distributions before smd cut, Nx && Ny > 1 fired strips above SMD threshold, E = 0.003 GeV is applied. The spikes x = 7 and y = 8 are smd strips.

SMD XY Position Check

Slide 7

- Top panels display the number of vertical, Nx, (left) and horizontal, Ny, (right) smd after applying Nx(Ny) > 1 hit cut.



- Bottom panels are x (left) and y (right) particle position distributions after smd cut Nx/Ny > 1 fired strips above the SMD threshold, E = 0.003 GeV is applied. The SMD spikes in the x and y distributions have now been eliminated.