First look at isolated Photon AN (statistics projection with data)

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Motivation

- The PPG12 group has released a preliminary result on the isolated photon cross section.
- Would be great to start to look into exploring the isolated photon A_N, leveraging their isolation + shower shape analysis method and double side band method for background subtraction
- I am currently calculating A_N and estimating the statistical precision using the available CaloDSTs (ana468). (~ 35% of the full Physics Calo data set)
- This is the **first look** at measuring the isolated photon A_N; further systematic studies, background estimation, and cross-checks are required.
- **Special thanks** to the JET TG / PPG12 team (Yeonju, Shuhang, Jaebeom, etc.) for their invaluable support in providing the dataset and assisting with isolated photon extraction.

Isolated Photon

Data set: CaloGoldenRun DSTs produced with ana468 tag + Spin QA applied to filter out bad-spin runs (~600 runs used in total)
- need to be revisited to address the condor issue on my side.

Photon selection: Same isolation cut and tight shower shape cut as used in **PPG12** (isolated photon cross section in pp)

Isolation cut isolation cone of radius $\Delta R = 0.3$

$$E_{\mathrm{T}}^{\mathrm{iso}} < 1.08128 + 0.0299107 \cdot E_{\mathrm{T}}^{\mathrm{reco}}$$

Same pre-selection & Tight Shower shapes cut used for following slides

Pre-selection
E11/E33 < 0.98
$0.6 <$ et1 < 1.0
$0.8 <$ E32/E35 < 1.0
weta_cogx < 0.6
Tight
$0 <$ weta_cogx $< 0.15 + 0.006 \cdot E_{\mathrm{T}}^{\gamma}$
$0 <$ wphi_cogx $< 0.15 + 0.006 \cdot E_{\mathrm{T}}^{\gamma}$
$0.4 <$ E11/E33 < 0.98
$0.9 <$ et1 < 1.0
$0.92 <$ E32/E35 < 1.0
Non-tight
Pass the pre-selections, Fails at least two of the five tight requirements

Table 4: Photon identification criteria

Asymmetry calculation: Run-averaged relative luminosity and polarization values from PPG07 were used

Isolated Photon w/o background subtraction

Background estimation is necessary for asymmetry calculation

Below is equation from PHENIX direct photon TSSA paper : PRL 127, 162001 (2021)

$$A_N^{\gamma_{iso}} = \frac{A_{raw}^{\gamma} - r^{BG} A_N^{BG}}{1 - r^{BG}}$$

We need to evaluate the background fraction (r^{BG}), and subtract the asymmetry from the background (A_N^{BG})

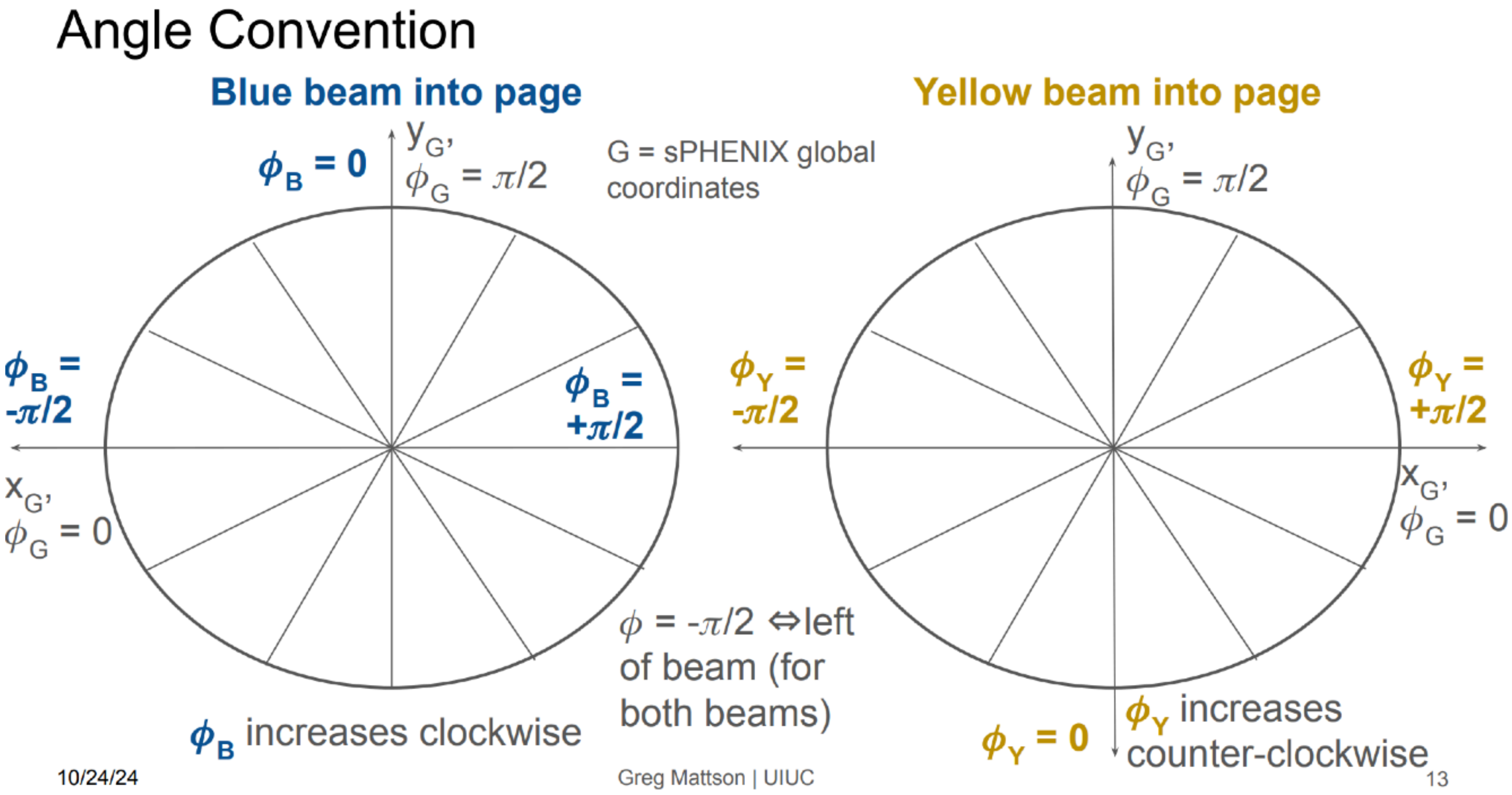
I had some discussions with Sasha, and we actually can assume A_N^{BG} = 0, since neutral mesons are the dominant background sources and are known to be consistent with zero, as how PHENIX did in direct photon TSSA analysis.

The statistical uncertainty must include the background fractions, as they directly affect the statistical error. *(Next step)*

→ We will estimate the background fractions (i.e., the purity) using data-driven double-sideband method.

Angle Convention

In order to prevent the angle convention, following PGG07 beam dependence conversion for asymmetry calculation



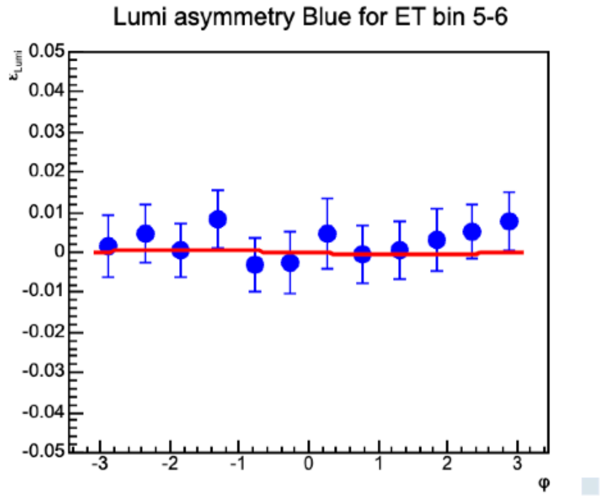

```
phi_B = cluster_phi - TMath::Pi() / 2.0;
if (phi_B < -TMath::Pi())
    phi_B += 2.0 * TMath::Pi();
phi_Y = cluster_phi + TMath::Pi() / 2.0;
if (phi_Y > TMath::Pi())
    phi_Y -= 2.0 * TMath::Pi();
```

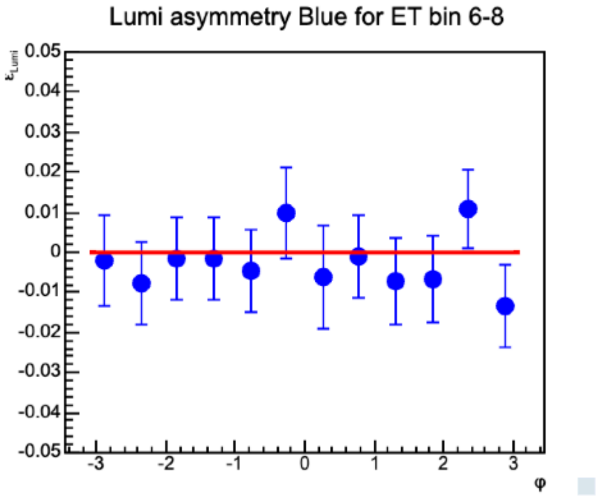
Simple calculation

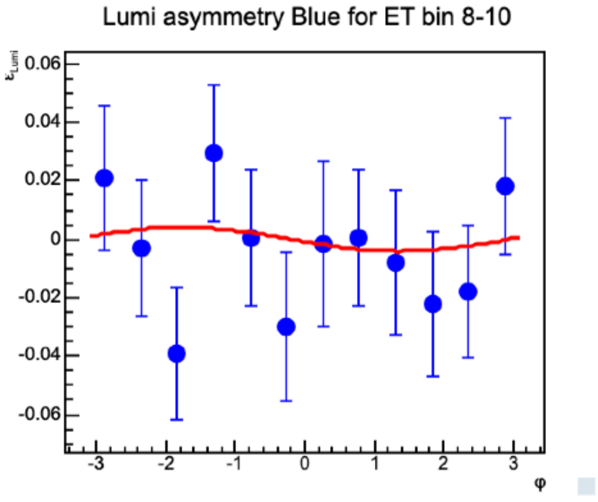
$$\phi_B = \phi_G - \frac{\pi}{2}, [-\pi/2, \pi/2]$$

$$\phi_Y = \phi_G + \frac{\pi}{2}, [-\pi/2, \pi/2]$$

Raw asymmetry calculation(Blue Beam)

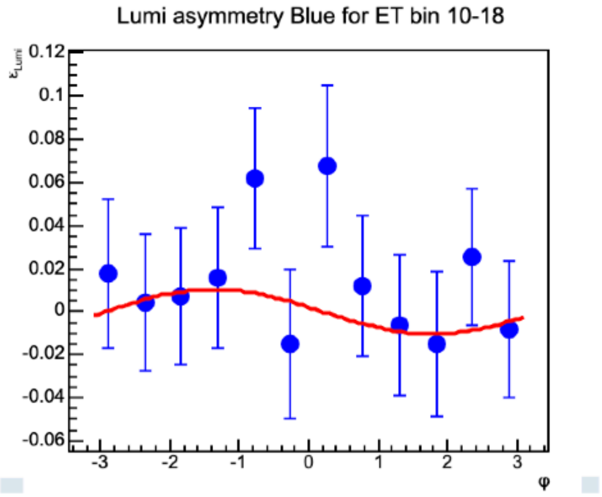


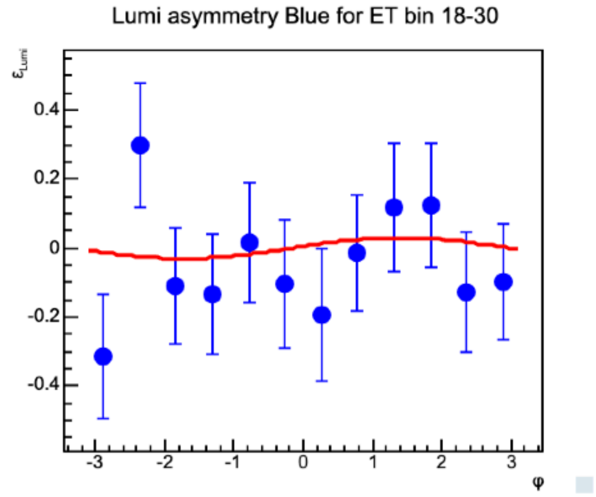




List of cuts

Isolation cut
+ tight shower shape cut
+ |zvtx| < 50cm
+ MBD N hits >1
+ MBD S hits >1





Fitting function : -[0]*sin(x-[1])

[0] -> raw asymmetry

p_T bins follow previous PHENIX for apple-to-apple comparison

1^{st} [5,6]

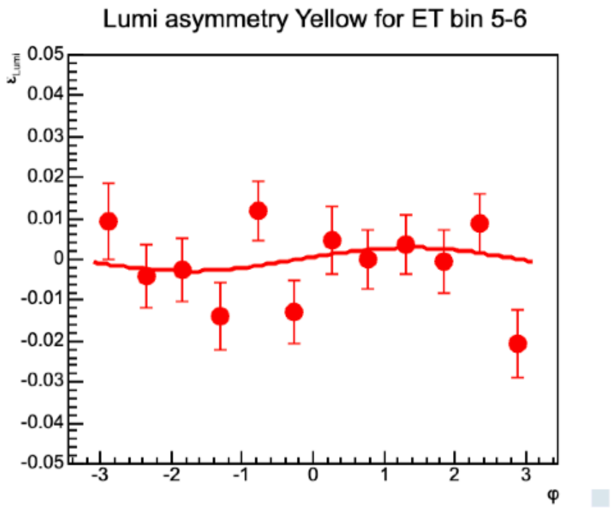
2^{nd} [6,8]

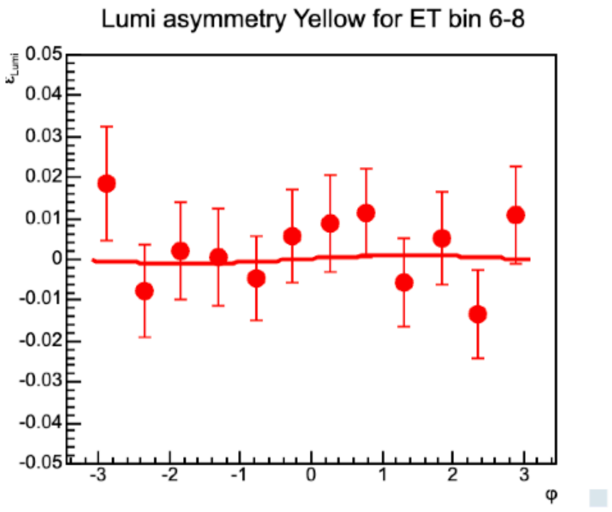
3^{rd} [8,10]

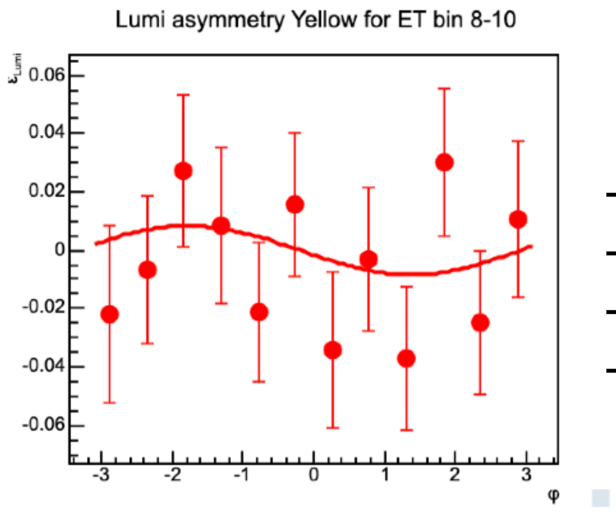
4^{th} [10,18]

5^{th} [18,30] - NEW

Raw asymmetry calculation(Yellow Beam)







List of cuts

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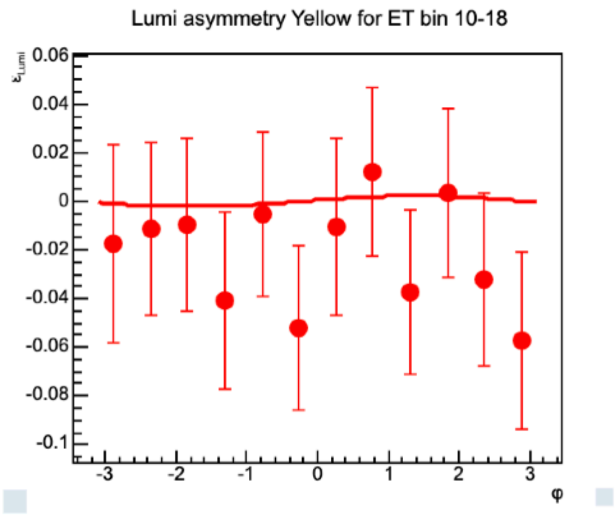

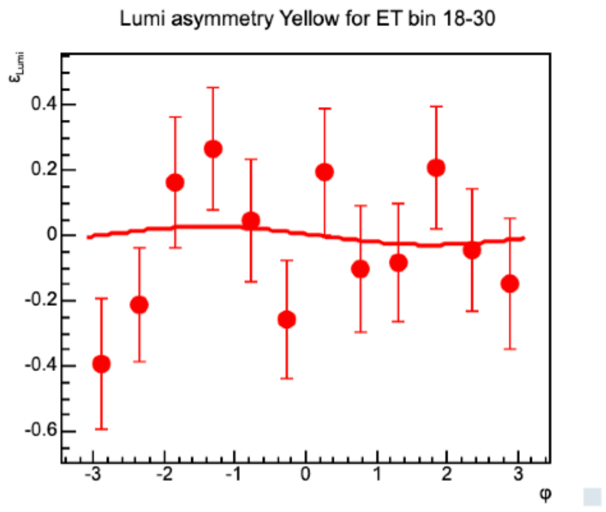

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[0] -> raw asymmetry

p_T bins follow previous PHENIX for apple-to-apple comparison

1^{st} [5,6]
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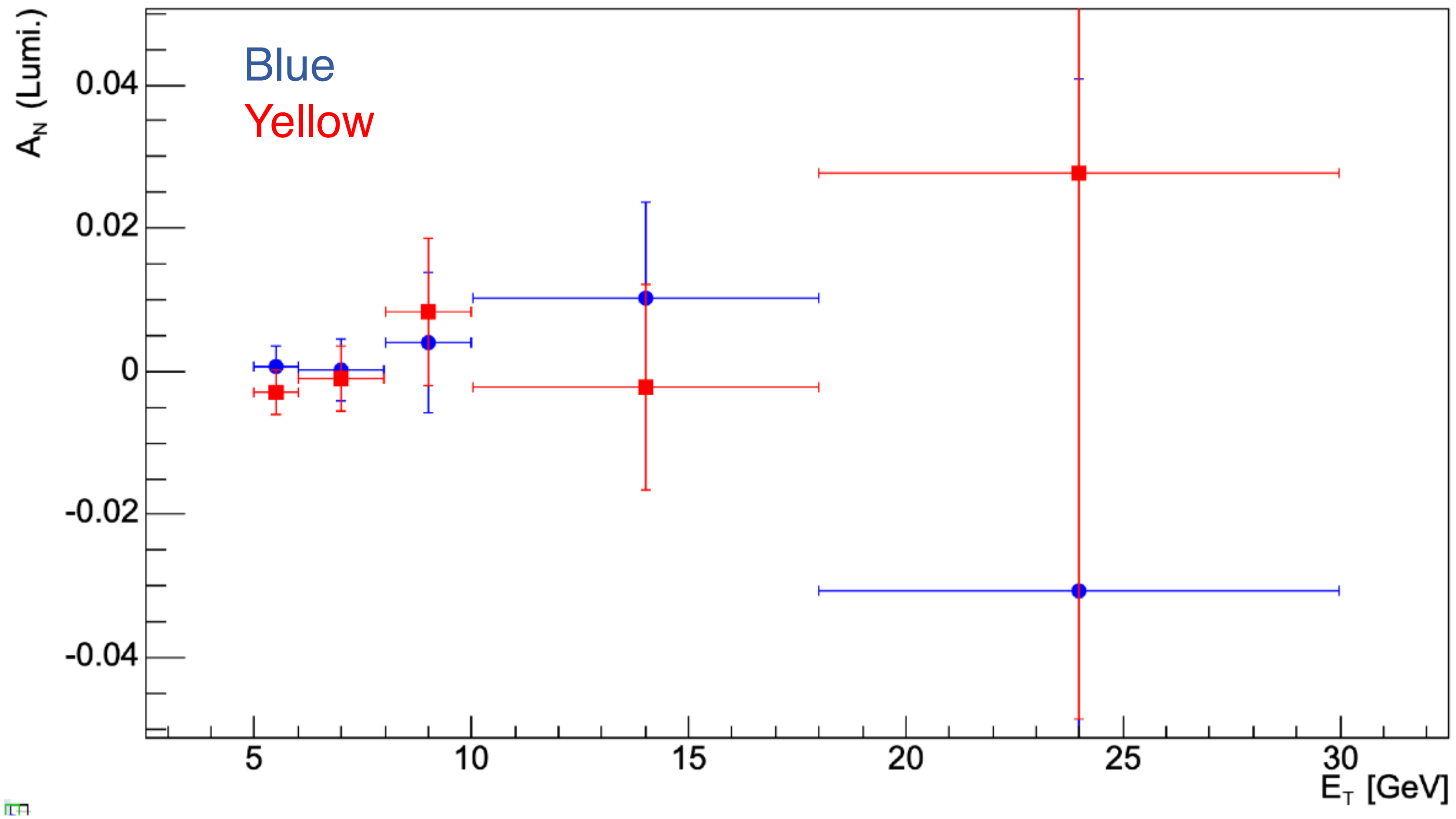
5^{th} [18,30] - NEW

Bellow / Yellow TSSA of iso. Photon



1^{st} [5,6] 2^{nd} [6,8] 3^{rd} [8,10] 4^{th} [10,18] 5^{th} [18,30] - NEW

Isolated cut
+ lzvtxl < 50cm
+ tight cut
Blue/Yellow separated

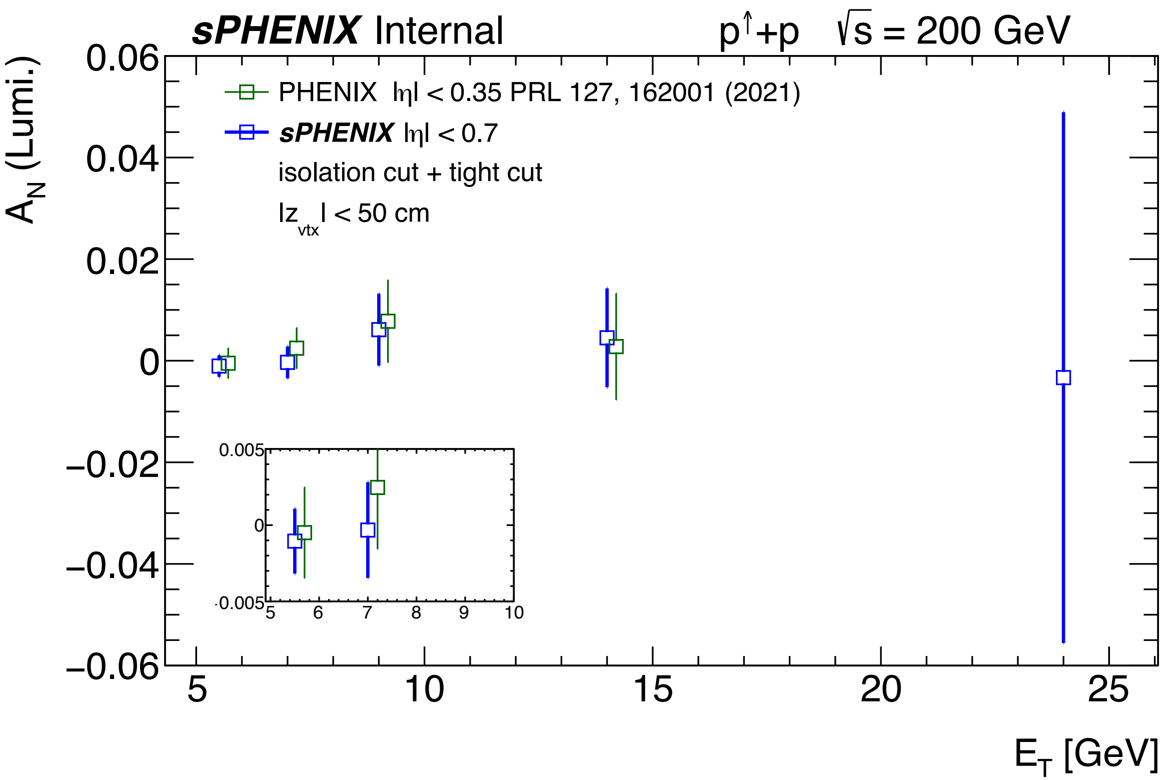
Rel.Lumi. Blue : 0.998
Rel Lumi. Yellow : 0.998
Blue Pol : 0.486
Yellow Pol : 0.455

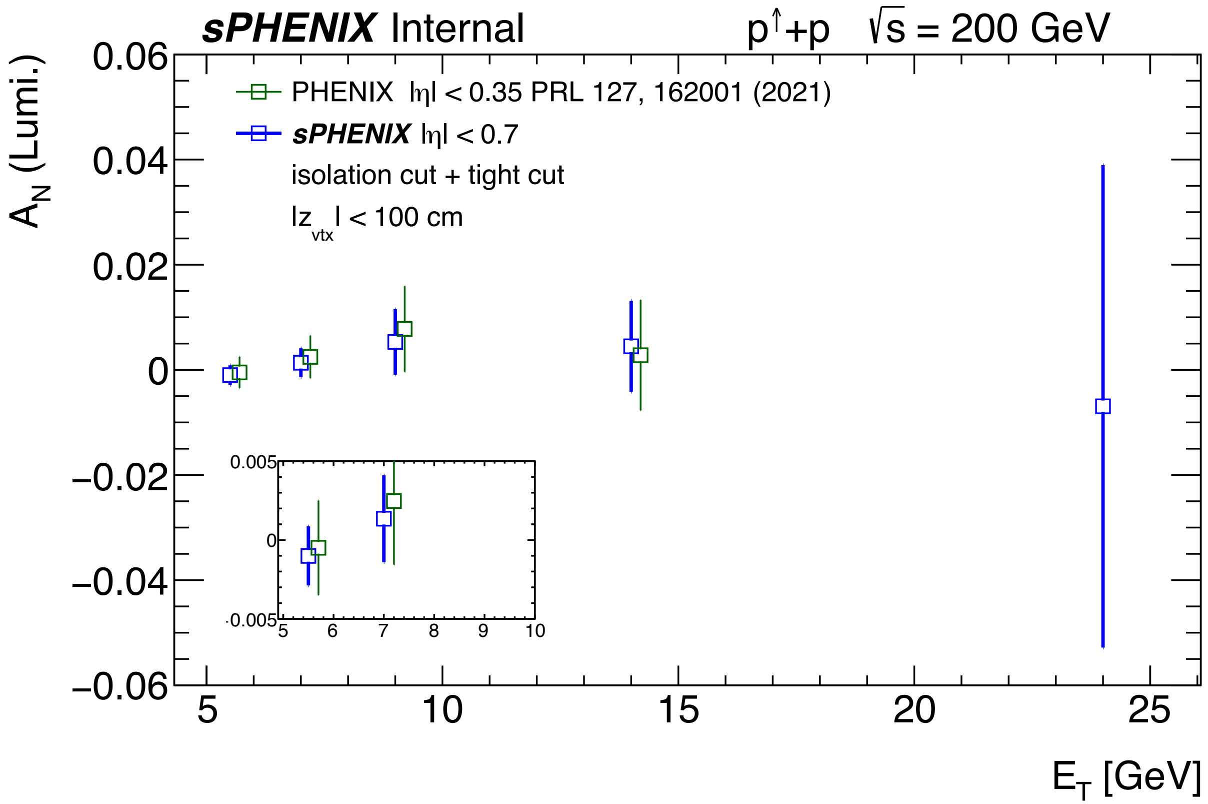
Rel.Lumi and Pol values are referred to PPG07

(Can be recalculated)

First look at TSSA of isolated Photon

Statistics comparison for different z-vertex cut



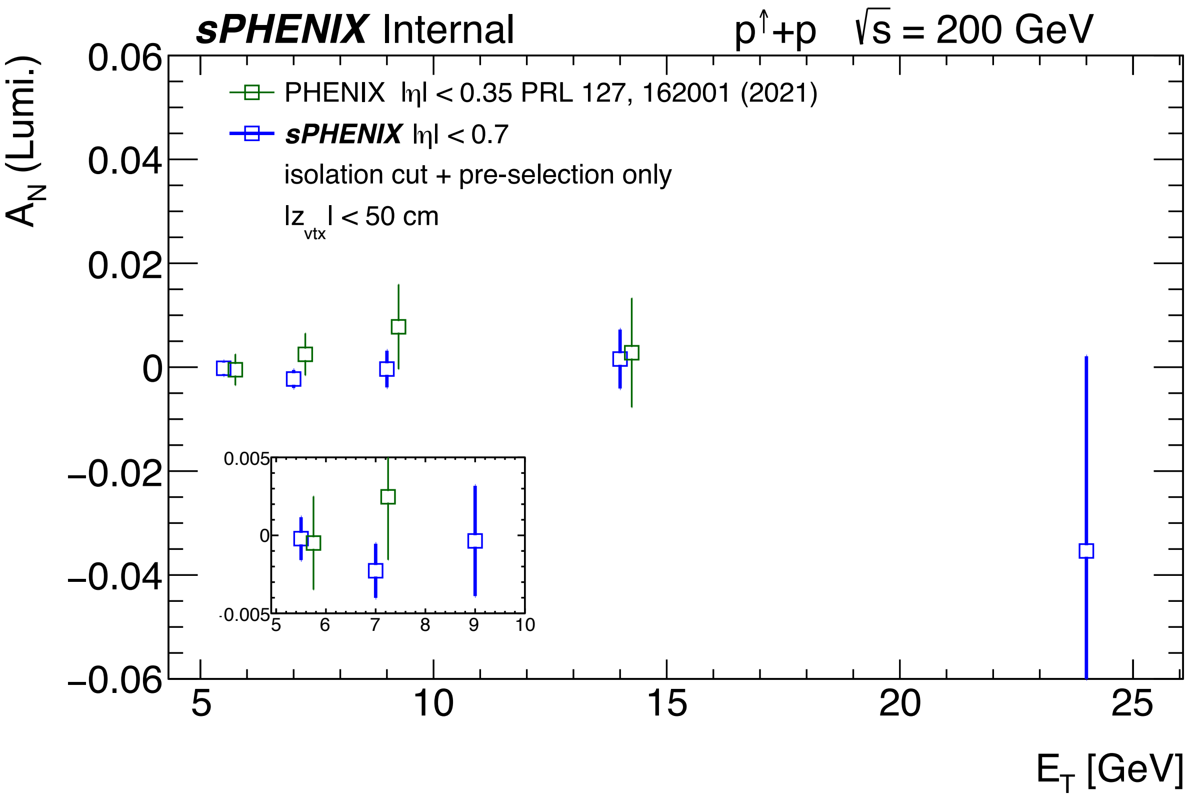


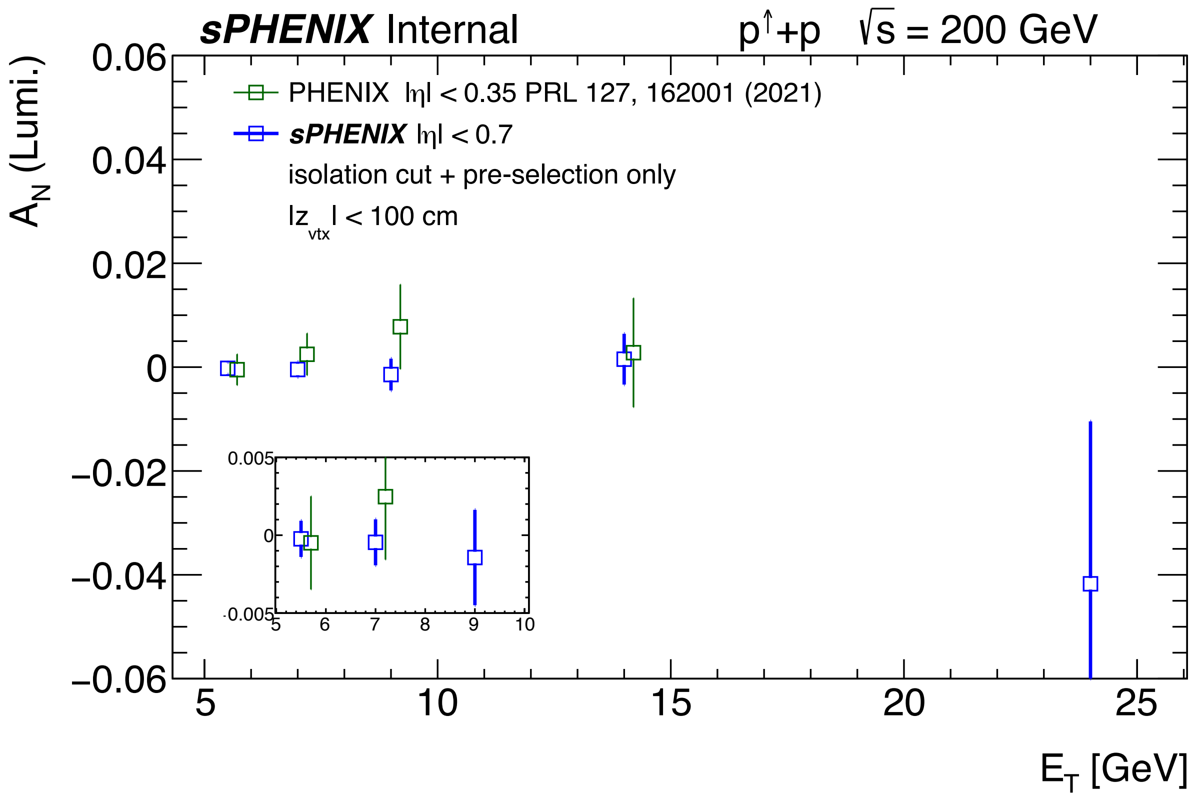
p_T bins same for sPHENIX and PHENIX; PHENIX points are shifted by +0.5 in E_T

1^{st} [5,6] 2^{nd} [6,8] 3^{rd} [8,10] 4^{th} [10,18] 5^{th} [18,30] - NEW

First look at TSSA of isolated Photon

Statistics comparison for different z-vertex cut with pre-selection shower shape cut





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1^{st} [5,6] 2^{nd} [6,8] 3^{rd} [8,10] 4^{th} [10,18] 5^{th} [18,30] - NEW

Summary / Plan

Summary

From current dataset, I tried to evaluate the asymmetry w/o background subtraction

- isolation cut and shower shape cuts are used which is well established from cross-section measurement

Plan

Checking the GoodRunList

- Starting from the CaloGoodList + Spin QA -> Checking list of DSTs(Good to double check with

Background subtraction/ purity estimation to correct the statistics estimation

- Performing double side band method, estimating purity with Zvtx<30cm cuts

BACKUP

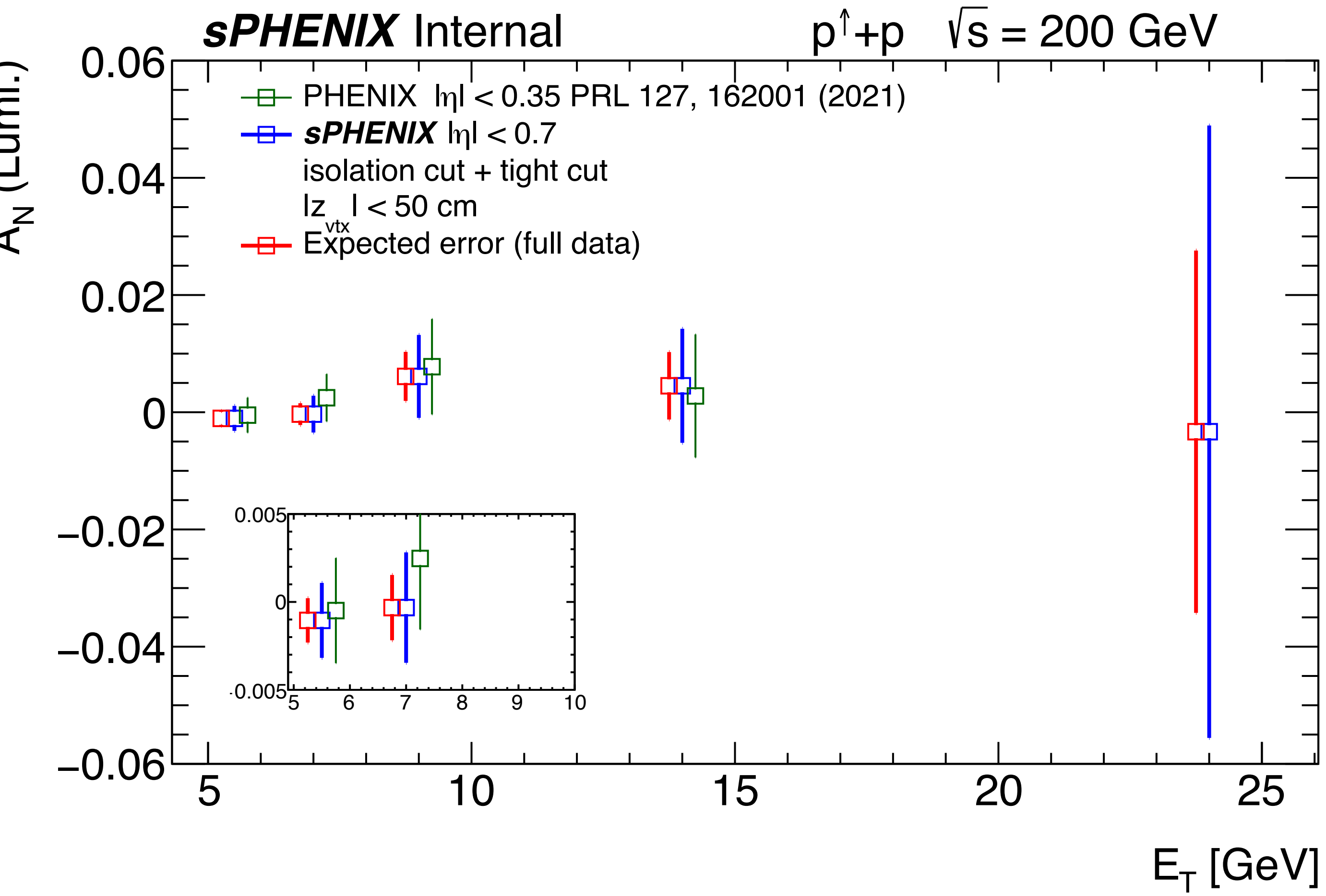
Estimation with Full dataset

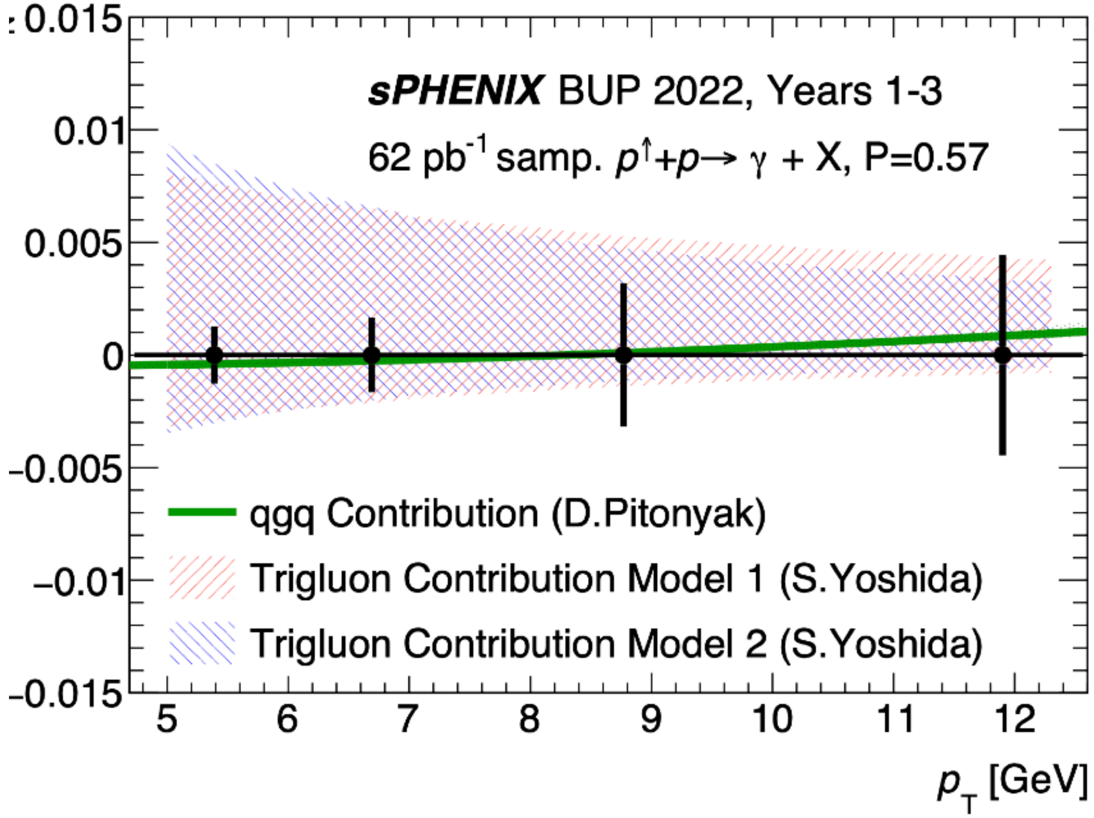
Production tag ana468, has only 30 ~ 35% of full dataset.(as far as I know; might be wrong)
Very rough stat estimation with full dataset, just re-scaling stat uncertainty

Estimation with Full dataset(tight cut)

Production tag ana468 contains approximately 35% of the full dataset.

A very rough statistical estimation for the full dataset is obtained by scaling the current statistical uncertainties, assuming the present data corresponds to 35% of the total.





Shower shape variables/isolation energy

weta_cogx
Energy-weighted second moment in the η direction
Measures the spread of energy in η. Prompt photons tend to have smaller values.
wphi_cogx
Energy-weighted second moment in the ϕ direction
Measures the spread in ϕ. A smaller value indicates a more localized shower.
E11/E33
Energy of central tower / energy in 3×3 tower cluster
Indicates how concentrated the energy is at the center of the cluster.
et1
Symmetry parameter using 4 towers around the cluster center
Measures energy symmetry. A value close to 1 implies uniform distribution.
E32/E35
Energy in 3×2 region / energy in 3×5 region (η×ϕ)
Captures how much energy is confined in a narrow region.

Pre-selection
$E11/E33 < 0.98$ $0.6 <$ et1 < 1.0 $0.8 < E32/E35 < 1.0$ weta_cogx < 0.6
Tight
$0 <$ weta_cogx $< 0.15 + 0.006 \cdot E_T^{\gamma}$ $0 <$ wphi_cogx $< 0.15 + 0.006 \cdot E_T^{\gamma}$ $0.4 < E11/E33 < 0.98$ $0.9 <$ et1 < 1.0 $0.92 < E32/E35 < 1.0$
Non-tight
Pass the pre-selections, Fails at least two of the five tight requirements

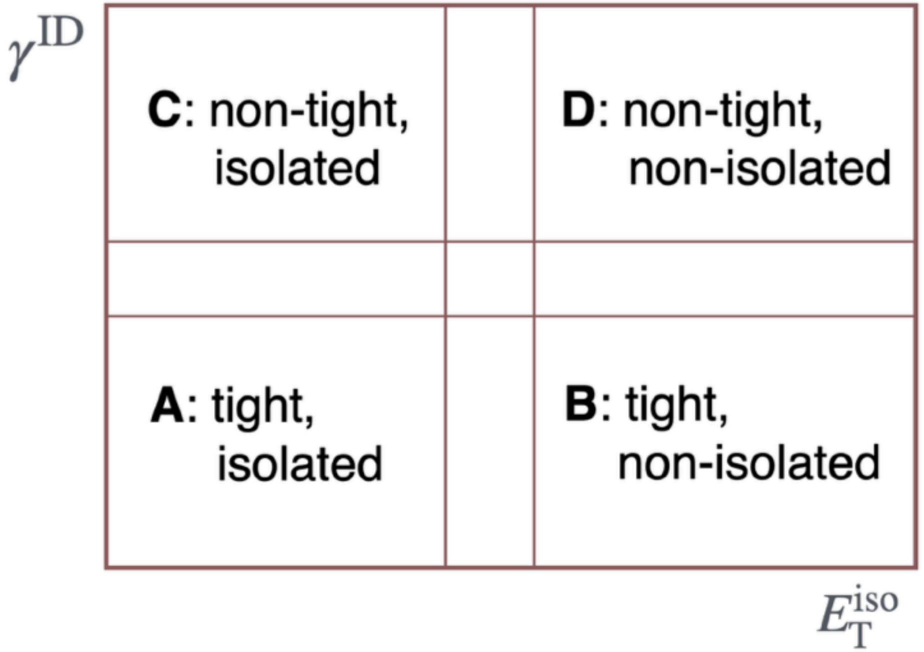
Table 4: Photon identification criteria

Isolation Energy E_T^{iso}
Sum of E_T in EMCal + Inner/Outer HCal towers inside the cone, excluding the photon cluster itself

Double Side band method

Region Definitions

- A: Tight ID + Isolated → Signal + Background
- B: Tight ID + Non-isolated → Background-enriched
- C: Non-tight ID + Isolated → Background-enriched
- D: Non-tight ID + Non-isolated → Pure Background



Under the assumption that the isolation cut is largely uncorrelated with shower shape cut variables

-> Background is factorizable

-> The ratio of background clusters in region C over D should be similar to the ratio of background in region A over B.

Therefore, the amount of the signal $N^{A,data}_{signal}$ is :

$$N^{A,data}_{signal} = N^{A,data}_{raw} - N^{B,data}_{raw} \frac{N^{C,data}_{raw}}{N^{D,data}_{raw}}$$

$$N^{X,data}, \quad X \in \{A, B, C, D\}$$

is number of reconstructed signal clusters in region X