# Spin Analysis HOW TO: Relative Luminosity

Sanghwa Park

(Stony Brook Univ.)

# What is the "Relative luminosity"?

- Your observable is some asymmetry for different spin states *a* and *b*, and assuming that the efficiency doesn't have spin dependent:

$$A \equiv \frac{\sigma_a - \sigma_b}{\sigma_a + \sigma_b} = \frac{1}{P_1 P_2} \frac{N_a - R N_b}{N_a + R N_b}$$

- Relative luminosity is defined as: $R = \frac{L_a}{L_b}$

- Although we define different spin patterns and change after each fill to reduce the false asymmetry, relative luminosity still can be a dominant systematic uncertainty source for your analysis.

# Luminosity monitors

- The good luminosity monitors require
  - Minimal to no background
  - Same acceptance as the process we're interested in
  - High statistics
  - No spin dependent
- Traditional PHENIX luminosity monitors are BBC and ZDC.

# Getting started

- There are few ways for getting the bunch by bunch trigger counts.
- Here, we will discuss about two scalers that are commonly used for relative luminosity analysis:
  - GL1p scaler
  - STAR scaler

# GL1p Scaler

- GL1p board counts the number of (live) triggers for each xing, and has 4 scaler inputs.
- The configuration differ Run by Run. For example, in Run13,

| Trigger | GL1-1P Inputs |
|---|---|
| A | BBCLL1 (BBC with 30 cm vertex cut) |
| B | BBCLL1narrow (BBC with 15 cm vertex cut) [Clock on the second board] |
| C | ZDCLL1(narrow) |
| D | ZDCLL1(wide) |

Check the configurations from:

https://www.phenix.bnl.gov/WWW/offline/wikioff/index.php/GL1P_Information

# Caution with configurations/naming

- Although the configuration may changes Run by Run, the database holds the same names.
- One good way is to actually check the sum of the scalers.

```
spin=> \d spin
                    Table "public.spin"
       Column        |            Type             |     Modifiers
---------------------+-----------------------------+--------------------
 runnumber           | integer                     | not null
 fillnumber          | integer                     |
 badrunqa            | integer                     |
 crossingshift       | integer                     |
 polarblue           | real[]                      |
 polarblueerror      | real[]                      |
 polaryellow         | real[]                      |
 polaryellowerror    | real[]                      |
 spinpatternblue     | integer[]                   |
 spinpatternyellow   | integer[]                   |
 bbcvertexcut        | bigint[]                    |
 bbcwithoutcut       | bigint[]                    |
 zdcnarrow           | bigint[]                    |
 zdcwide             | bigint[]                    |
 badbunchqa          | integer[]                   |
 transversxblue      | real                        |
 transversxblueerr   | real                        |
 transversyblue      | real                        |
```

**Scaler counts for each xing (example for run 393888)**

```
-------------------------
 {82425678,0,82884722,85681547,86507334,89376946,87813418,90338568,90922613,90196526,91924876,91657435,87741485,90731192,91248
321,88936174,90935971,89155324,90857369,88374581,92231210,92778712,87882523,88885203,87759645,91010801,87339106,86543789,86140
848,87123269,85399131,86784372,86518268,86792994,84362420,85198792,87235382,85596474,86697220,84928680,88156268,87292972,86401
527,88869132,85282591,84523530,84109114,83595739,86839706,83388463,84546102,86000147,84872245,87475866,87343437,86652259,85344
415,85405856,84426527,83875965,84490180,84571902,84656762,83324213,83428233,85333189,85503647,84082713,86035183,86204244,84481
026,97165517,96144490,98013469,100652518,97311430,98248252,97506719,97999648,93355620,90680146,89715124,89981004,88327640,8912
5281,88693346,90807545,88240236,86905953,84810084,85671788,87134900,85692281,83605887,79545845,83469418,83147724,81059341,8135
7012,82701052,80556763,82611491,79249361,82597763,78956656,79315975,80961745,77679155,78764478,78144793,78080743,835,581,561,1
497,419,390,365,314,319}
```

# Caution with configurations/naming

- Although the configuration may changes Run by Run, the database holds the same names.
- One good way is to actually check the sum of the scalers.

```
spin=> \d spin
                    Table "public.spin"
       Column        |            Type             |     Modifiers
---------------------+-----------------------------+--------------------
 runnumber           | integer                     | not null
 fillnumber          | integer                     |
 badrunqa            | integer                     |
 crossingshift       | integer                     |
 polarblue           | real[]                      |
 polarblueerror      | real[]                      |
 polaryellow         | real[]                      |
 polaryellowerror    | real[]                      |
 spinpatternblue     | integer[]                   |
 spinpatternyellow   | integer[]                   |
 bbcvertexcut        | bigint[]                    |
 bbcwithoutcut       | bigint[]                    |
 zdcnarrow           | bigint[]                    |
 zdcwide             | bigint[]                    |
 badbunchqa          | integer[]                   |
 transversxblue      | real                        |
 transversxblueerr   | real                        |
 transversyblue      | real                        |
 transversyblueerr   | real                        |
 transversxyellow    | real                        |
 transversxyellowerr | real                        |
```

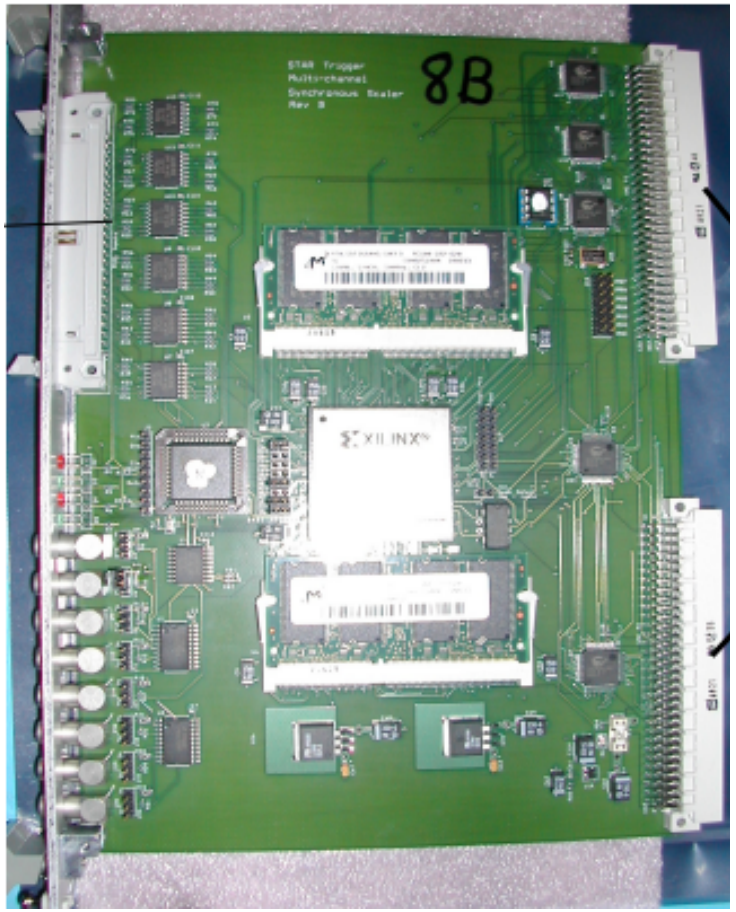
The name doesn't tell you what scaler truly it is. Check the configuration for a given RUN and make sure you know what scaler you are looking at.

- One can use uspin to get the scalers from the DB

```
long long GetScalerBbcVertexCut(int bunch);
long long GetScalerBbcNoCut(int bunch);
long long GetScalerZdcWide(int bunch);
long long GetScalerZdcNarrow(int bunch);
long long GetScaler(int channel,int bunch);
```

# STAR scaler

- PHENIX has another scaler boards, so called STAR scaler (and yes, it's just the name).
- 3 STAR scaler boards with 24+1 inputs for each board.
- Outputs are written in text file and scaler PRDF file for each run.
- Nice documentation including the configuration for each year and example codes by Andrew, Paul and Kieran: https://www.phenix.bnl.gov/WWW/offline/wikioff/index.php/How_to_STAR_Scaler



# STAR scaler

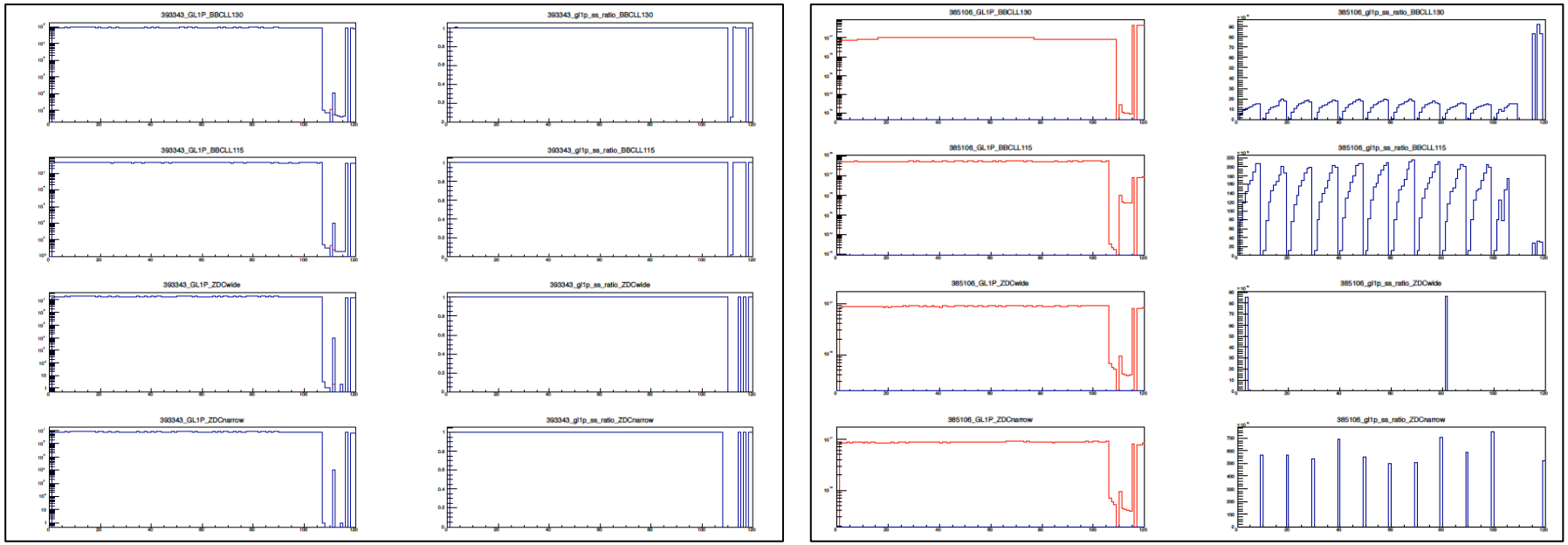
Run13:

Reserved for xing counts

| Scaler Pin | Ping Trigger | Pong Trigger | Pung Trigger |
|---|---|---|---|
| 0 | BeamX_0 | BeamX_0 | MPCN_C_5 |
| 1 | BeamX_1 | BeamX_1 | MPCN_C_4 |
| 2 | BeamX_2 | BeamX_2 | MPCN_C_3 |
| 3 | BeamX_3 | BeamX_3 | MPCN_C_2 |
| 4 | BeamX_4 | BeamX_4 | MPCN_C_1 |
| 5 | BeamX_5 | BeamX_5 | MPCN_C_0 |
| 6 | BeamX_6 | BeamX_6 | ZDC_Wide |
| 7 | PARTITION 1 BUSY | PARTITION 1 BUSY | MPC_N_S_B |
| 8 | PARTITION 1 ACCEPT | SMD_S_L | BBCnovtx |
| 9 | ERT_2x2W | SMD_S_R | BeamX_0 |
| 10 | ERT_2x2E | SMD_S_U | BeamX_1 |
| 11 | ZDCNS | SMD_S_D | BeamX_2 |
| 12 | MPC 4x4C South | SMD_S_H_OR_V | BeamX_3 |
| 13 | MPC 4x4C North | SMD_N_L | BeamX_4 |
| 14 | ZDCN | SMD_N_R | BeamX_5 |
| 15 | ZDCS | SMD_N_U | BeamX_6 |
| 16 | NHIT6 (BBCN>1) | SMD_N_D | PARTITION 1 BUSY |
| 17 | NHIT5 (BBCS>1) | SMD_N_H_OR_V | MPC_N_S_A |
| 18 | NHIT4 (BBCN>0) | NHIT4 | MPCS_C_5 |
| 19 | NHIT3 (BBCS>0) | NHIT3 | MPCS_C_4 |
| 20 | ZDC_Narrow | ZDC_N | MPCS_C_3 |
| 21 | ZDC_Wide | ZDC_S | MPCS_C_2 |
| 22 | BBCLL1_1 | ZDC_Wide (GL1) | MPCS_C_1 |
| 23 | BBCLL1_0 | A_INR (ZDC vtx cut A: ZDCwide via SMD signal path) | MPCS_C_0 |

# Do QA

- Sometimes scalers misbehave, so it's always safe to do some xcheck.
- For example, one can compare the bunch by bunch counts between GL1p and STAR scalers.



# Corrections

- A lot of effort has been made by many ΔG analyzers.
- $A_{LL}^{BBC}$ is checked with ZDC luminosity counting:

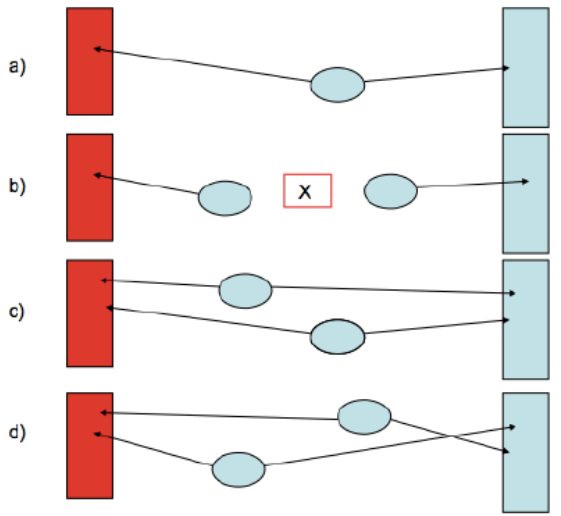
$$A_{LL}^{ZDC/BBC} = \frac{1}{P_B P_Y} \frac{\frac{N_{ZDC}^{++}}{N_{BBC}^{++}} - \frac{N_{ZDC}^{+-}}{N_{BBC}^{+-}}}{\frac{N_{ZDC}^{++}}{N_{BBC}^{++}} + \frac{N_{BBC}^{+-}}{N_{BBC}^{+-}}}$$

- Some corrections you need to consider:
  - Pileup correction: correction to scaler miscount
  - ~~With correction~~: traditionally used to correct ZDC due to its limited vertex reconstruction
  - Residual Rate Correction: introduced to correct residual rate correlation

# Pileup correction

- Scaler over/under counts due to multiple collisions and random coincidence of single diffractive events.
- BBC can only count a single collision, therefore pileup effect needs to be consider in order to get the true counts.

AN1184




- Assuming the number of collisions follows a Poisson distribution, one can derive the relation between observed and true BBC rate as:

$$R_{BBC} = 1 + e^{-\mu\epsilon_{BBC}(1+k_S+k_N)} - e^{\mu\epsilon_{BBC}(1+k_S)} - e^{\mu\epsilon_{BBC}(1+\epsilon_N)}$$

$\mu\varepsilon_{BBC}$: True BBC rate, $k_{S(N)}=\varepsilon_{S(N)}/\varepsilon_{BBC}$

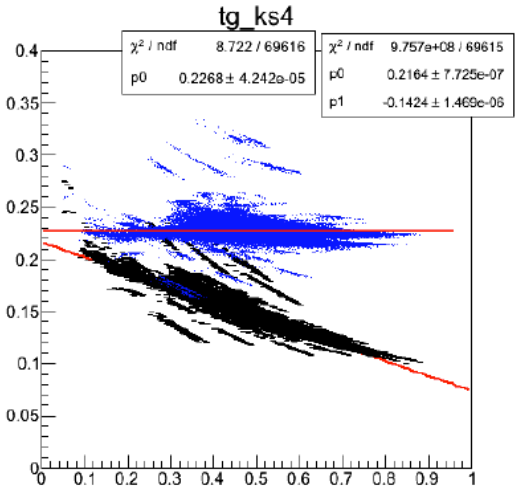
# Getting $k_S$ and $k_N$

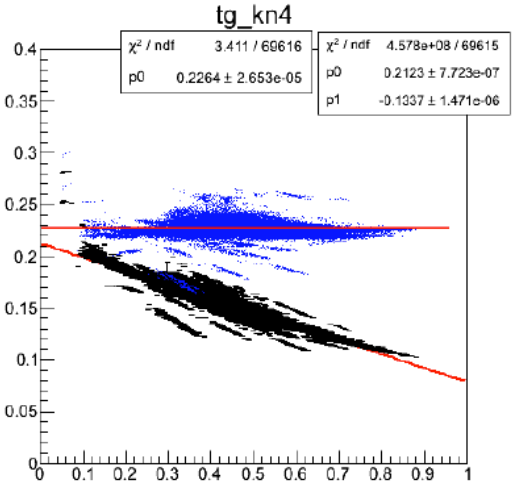
- $\epsilon_{BBC}$: probability that both side of the BBC observe hits.
- $\epsilon_{N(S)}$: probability that only a single side of the BBC observes a hit.
- $\epsilon_0$: probability that no hit is observed in any side of the BBC.

- $1=\varepsilon_{BB}+\varepsilon_N+\varepsilon_S+\varepsilon_0$

($\varepsilon_N$, $\varepsilon_S$ : exclusive probability for single-sided hit)

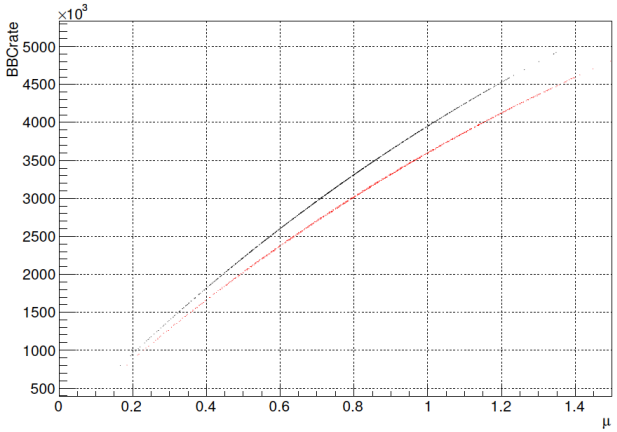
- $\varepsilon_{BB}+\varepsilon_{N(S)}$ : probability for Inclusive hit in single-side
- One can write down the true single-sided rate as:
  - $(\mu\varepsilon_{N(S)})$ = -ln(1-inclusive single rate) - true coincidence rate
- Expected to be rate-independent.



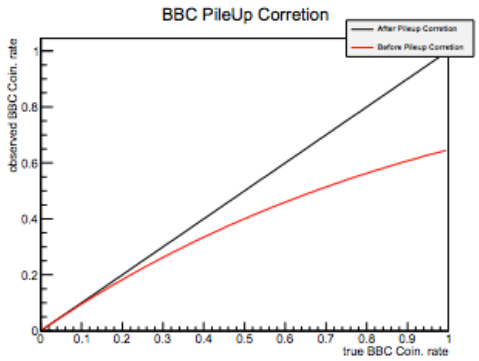



# Pileup correction

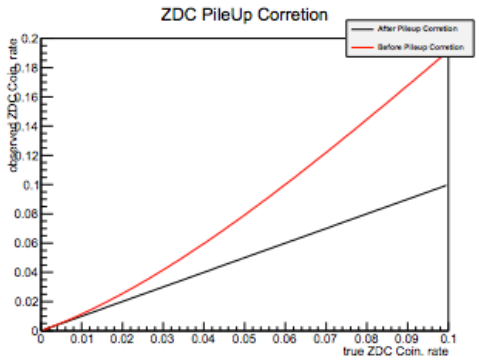
$$R_{BBC} = 1 + e^{-\mu\epsilon_{BBC}(1+k_S+k_N)} - e^{\mu\epsilon_{BBC}(1+k_S)} - e^{\mu\epsilon_{BBC}(1+\epsilon_N)}$$




- Used BBC efficiency as 53% (from Run9 Vernier Scan analysis)
- With $k_S$ and $k_N$ obtained, you can get μ for each run.
- True BBC rate = μ (observed BBC rate)




(a) BBC

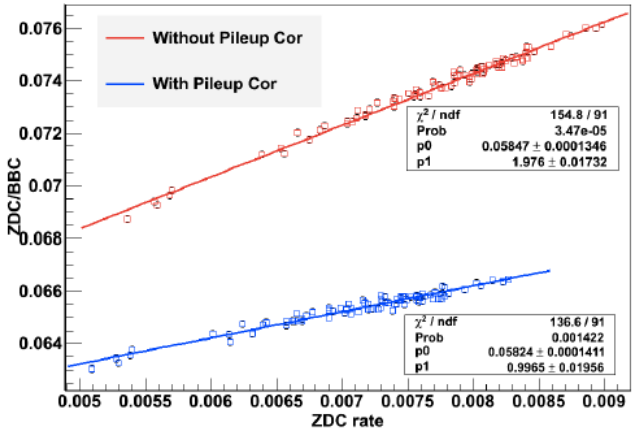



(b) ZDC

- Example of Run13 result: BBC unde-rcounting, ZDC over-counting as the rate increases

# Residual rate correction

- The pileup correction formalism is analytic. It works well for no vertex cut, but not with a vertex cut.
- Even after the pileup correction, residual rate correlation observed



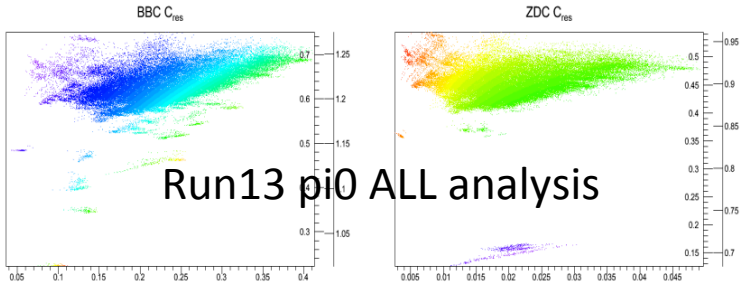

- Introduce a correction factor:

where $f\,R_{true} = R_{true+vtxcut} \times C_{res}$

$$f = \frac{\text{Observed 30cm vertex}_z \text{ scaler count}}{\text{Observed no vertex}_z \text{ scaler count}}$$

$$C_{res} \equiv \frac{1 - \frac{K}{f} R_{obs,vtx}}{(1 - K R_{obs,vtx})} \qquad K \equiv k_S k_N - \frac{1}{2}$$

See AN1184 for details




Run13 pi0 ALL analysis

# Summary

- Relative luminosity analysis has been an important piece for the spin analysis.
- Basic information discussed for the PHENIX luminosity monitoring.
- Corrections for the relative luminosity are introduced, but there are much more details to be discusssed.
- Many resources can be found from ANs and thesis (find some from backup slides).

# Scaler information

- GL1p configuration:

https://www.phenix.bnl.gov/WWW/offline/wikioff/index.php/GL1P_Information

- STAR scaler information

https://www.phenix.bnl.gov/WWW/offline/wikioff/index.php/How_to_STAR_Scaler

# STAR scaler data

- Where to get the STAR scaler data (after the RUN):
  Get it from HPSS (tar file):
  /home/phnxsink/run#/starscaler/starscaler.tar.gz
  The location could be different slightly for some years

- How to get data from HPSS:
  https://www.phenix.bnl.gov/WWW/offline/wikioff/index.php/Data_Carousel

- For some years, you can also find it from local disk:
  /phenix/spin/phnxsp01/sanghwa/StarScalers/data

- The output file should have text files for each board (ping, pong, pung) for each run.

# Resources for systematic studies

- AN1184 (Details for the residual rate correction): http://www.phenix.bnl.gov/WWW/p/forms/info/show_note.php?editkey=an1184
- AN1219 (Run13 relative luminosity for pi0 ALL): http://www.phenix.bnl.gov/WWW/p/forms/info/show_note.php?editkey=an1219
- Mickey's presentation on pileup correction: https://www.phenix.bnl.gov/cdsagenda/askArchive.php?base=agenda&categ=a13407&id=a13407s1t0/moreinfo
- AN1028 (Beam angle study): http://www.phenix.bnl.gov/WWW/p/forms/info/show_note.php?editkey=an1028
- AN953: http://www.phenix.bnl.gov/WWW/p/forms/info/show_note.php?editkey=an953
- Many more...