

# Multiplicity Corrections

$J/\psi$  multiplicity dependent production in p+p at 510 GeV

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# Analysis Procedure

- ✓ 1. Dataset Preparation
  - ✓ a. QA
  - ✓ b. event/track selection
- ✓ 2. Signal Extraction

## Event Requirements

$-40 \text{ Vz} < 40 \text{ cm}$   
 $\text{VtxRanking} > 0$

## Track Requirements:

$p_T$	0.2 -> 50 GeV/c
$\eta$	-1.0 -> 1.0
DCA	0 -> 1.5 cm
nHitsFit	20+
nHitsdEdx	11+
nHitsRatio	0.52
$E_{\text{TOW}}/E_{\text{CLU}}$	> 0.5
$n\sigma_{\text{Electron}}$	-1.9 -> 3.0

## Trigger Electron:

$E/p$	0.67 -> 3.33
$m\text{DSMADC} >> 4$	$\geq 18$

## Associate Electron:

$1/\beta$	0.97 -> 1.03
$ m\text{TOFlocalY} $	< 2.0
OR	
$E/p$	0.67 -> 3.33
$m\text{DSMADC} >> 4$	$\geq 18$

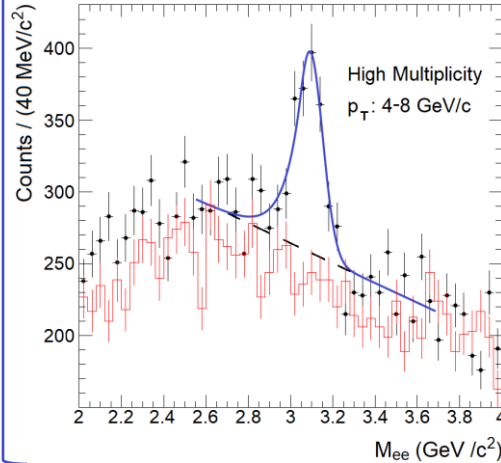
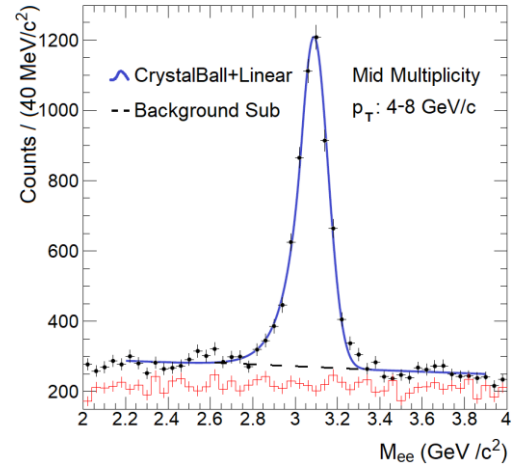
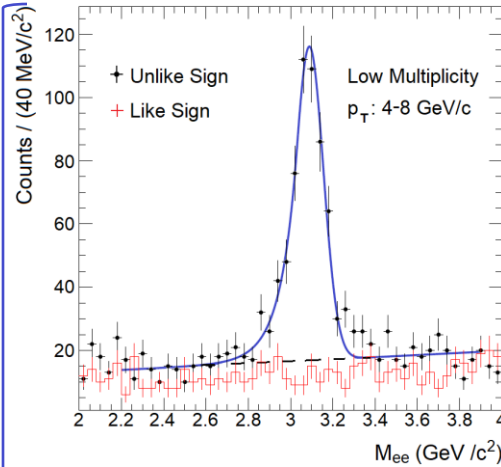
## TOF Multiplicity:

nHitsFit	$\geq 15$
DCA	< 1.5 cm
$\eta$	-1.0 -> 1.0
$p_T$	> 0.2 GeV/c
tofMatchFlag	1

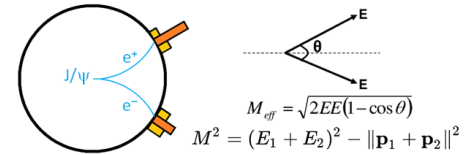
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As shown at HP'23, QM'23



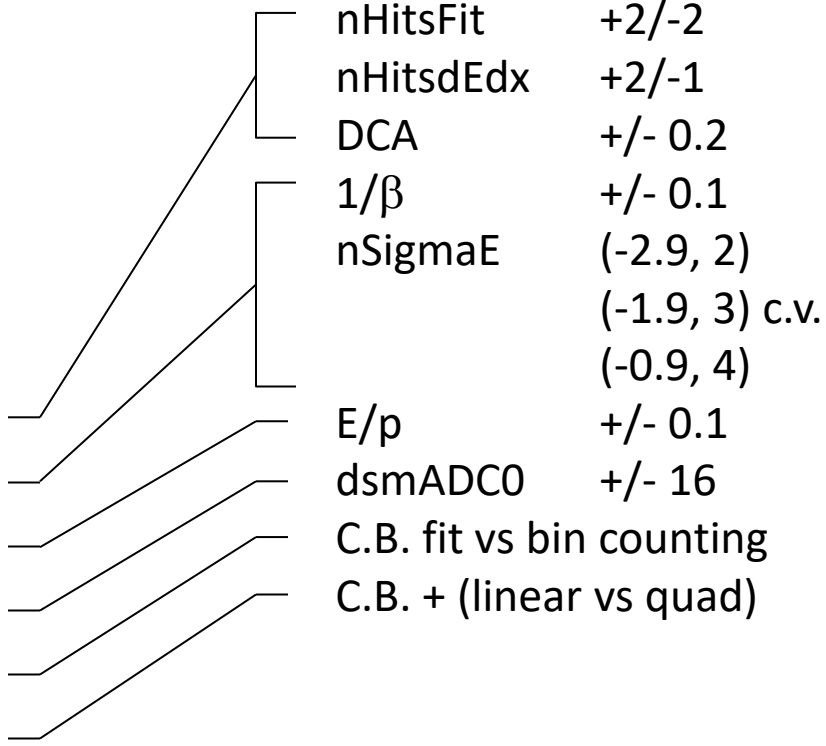
- Method of invariant mass used in di-electron channel



- Subtract like-sign  $e^+ e^-$  pairs from unlike-sign  $e^\pm e^\mp$  pairs
- CrystalBall + linear fit

# Analysis Procedure

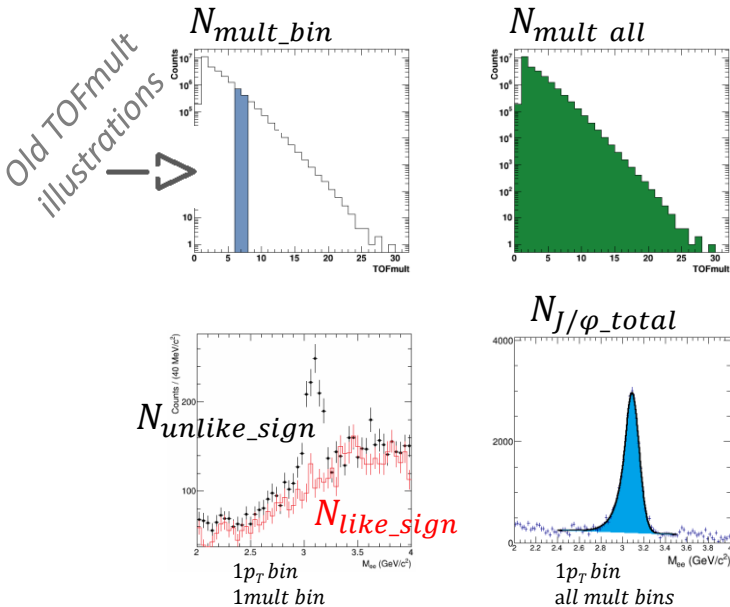
- ✓ 1. Dataset Preparation
  - ✓ a. QA
  - ✓ b. event/track selection
- ✓ 2. Signal Extraction
- 3. Systematic Uncertainties
  - ✓ a. tracking selection
  - ✓ b. PID cut variations
  - ✓ c. E/p cut variations
  - ✓ d. trigger cut variation
  - ✓ e. signal fitting
  - ✓ f. background variation



$$Y_{self\_norm} = \frac{N_{unlike\_sign} - N_{background}}{N_{mult\_bin}} / \frac{N_{J/\phi\_total}}{N_{mult\_total}}$$

**Statistical Uncertainties** are taken as Binomial

$$\sigma_Y = \sqrt{\sum_i \sigma^2}$$



$$1\sigma = \frac{N_{mult\_total}}{N_{mult\_bin} \cdot N_{J/\phi\_total}} \cdot \sigma_{N_{unlike\_sign}}$$

$$2\sigma = \frac{N_{mult\_total}}{N_{mult\_bin} \cdot N_{J/\phi\_total}} \cdot \sigma_{N_{background}}$$

$$3\sigma = \frac{N_{unlike\_sign} - N_{background}}{N_{mult\_bin} \cdot N_{J/\phi\_total}} \cdot \sigma_{N_{mult\_bin}}$$

$$4\sigma = \frac{N_{unlike\_sign} - N_{background}}{(N_{mult\_bin})^2} \cdot \frac{N_{mult\_total}}{N_{J/\phi\_total}} \sigma_{N_{mult\_bin}}$$

$$5\sigma = \frac{N_{unlike\_sign} - N_{background}}{N_{mult\_bin}} \cdot \frac{N_{mult\_total}}{(N_{J/\phi\_total})^2} \sigma_{N_{J/\phi\_total}}$$

# Analysis Procedure

- ✓ 1. Dataset Preparation
  - ✓ a. QA
  - ✓ b. event/track selection
- ✓ 2. Signal Extraction
- 3. Systematic Uncertainties
  - ✓ a. tracking selection
  - ✓ b. PID cut variations
  - ✓ c. E/p cut variations
  - ✓ d. trigger cut variation
  - ✓ e. signal fitting
  - ✓ f. background variation

## 4. Corrections

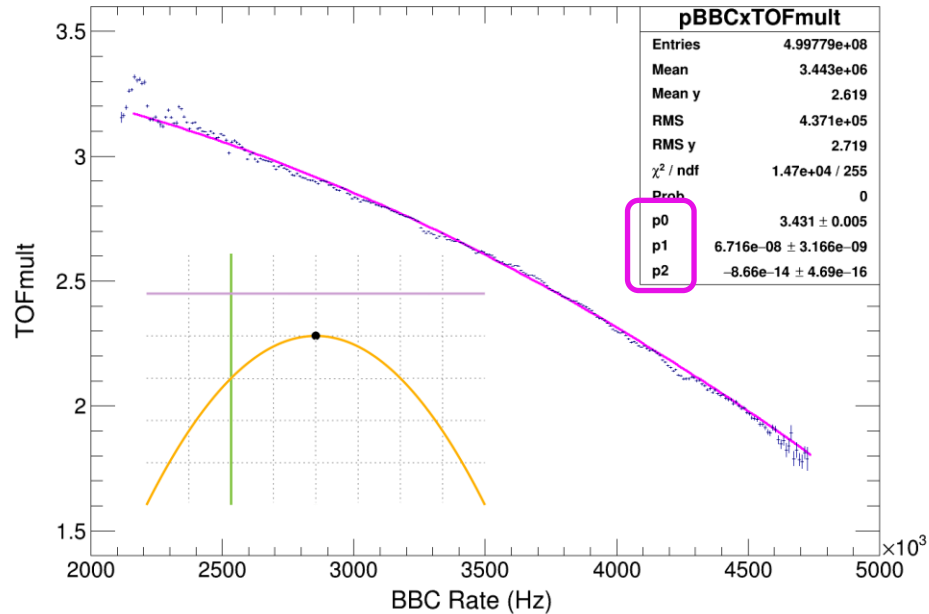
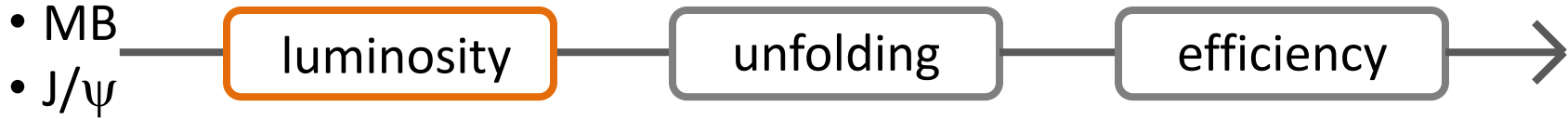
- ✓ a. Luminosity correction
- ✓ b. Unfolding correction
- ✓ c. BBC·MB trigger efficiency
- ✓ d. VPD·MB trigger efficiency \*
- ✓ e. Vertex ranking efficiency
- f. Pythia6 variants

100k Pythia8 MB into zerobias

100k Pythia8 J/ψ into zerobias

$$\epsilon(\text{trig}) = \frac{N_{\text{trigs fired}}}{N_{\text{embedded evts}}}$$

# Correcting TOFmult Yields



# Correcting the multiplicity yields



*Corrects the counts of tracks per event*

$$N_{TOFmult\_bin} \rightarrow N_{mult\_bin}$$

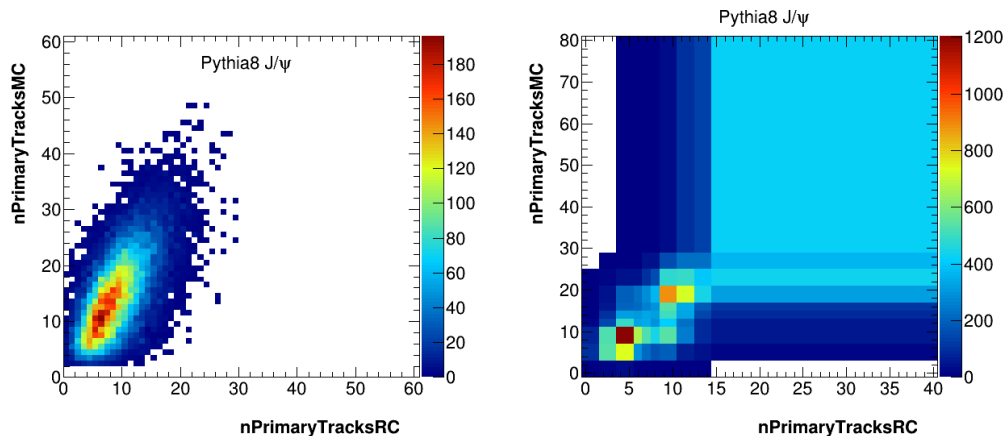


# Correcting the multiplicity yields

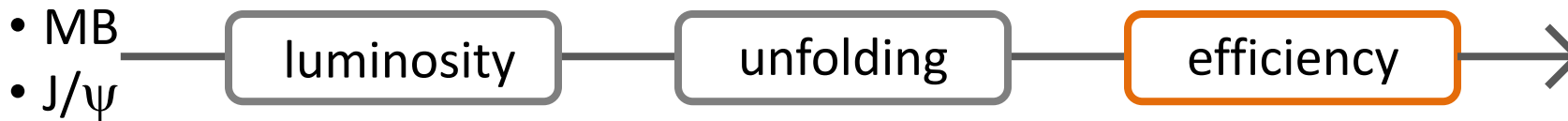


*Corrects the counts of tracks per event*

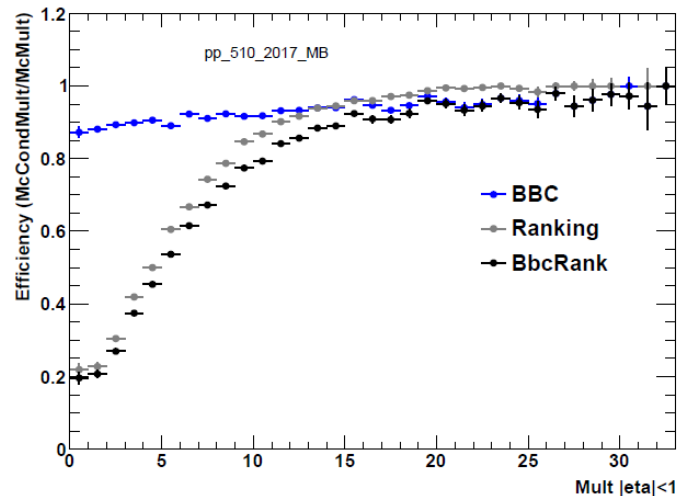
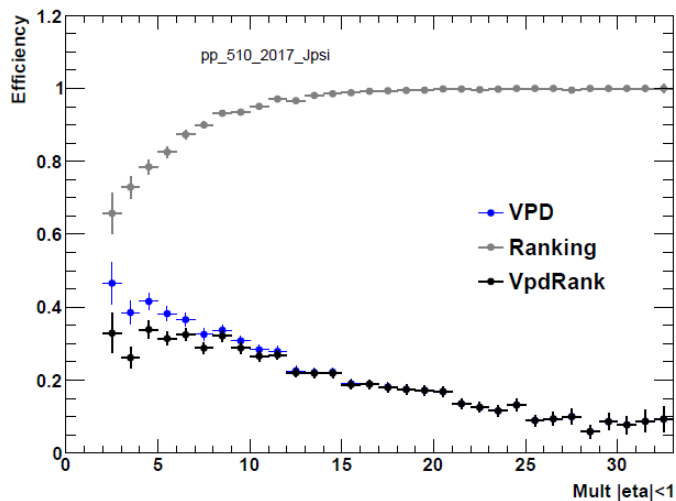
$$N_{TOFmult\_bin} \rightarrow N_{mult\_bin}$$



# Correcting the multiplicity yields



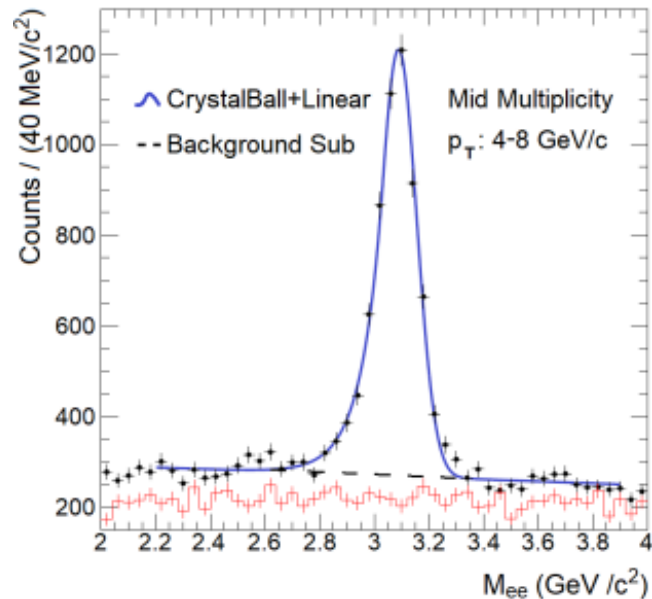
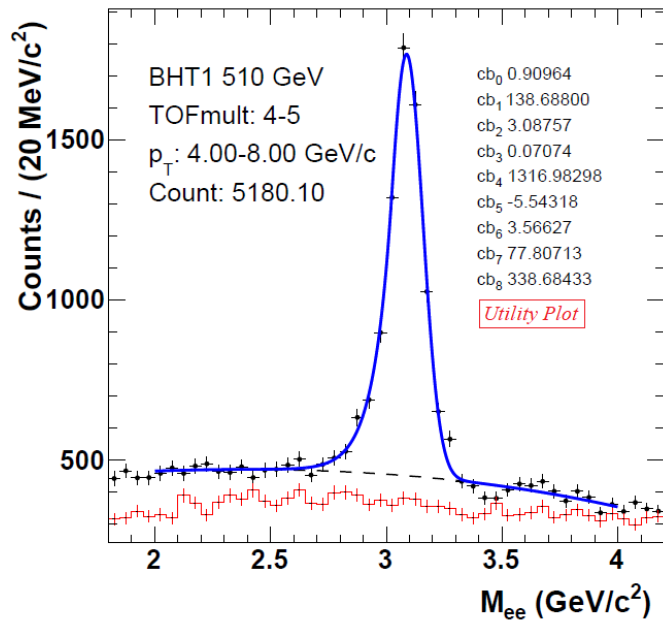
*Corrects the event counts*



# Analysis Procedure

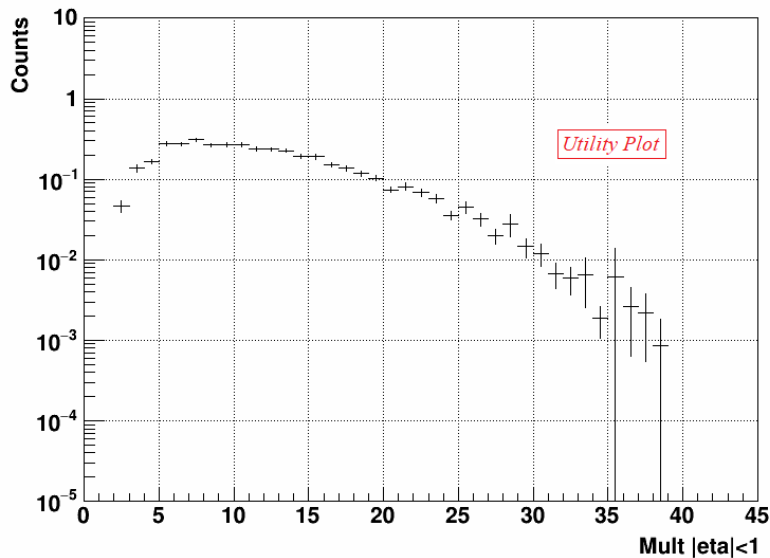
- ✓ 1. Dataset Preparation
  - ✓ a. QA
  - ✓ b. event/track selection
- ✓ 2. Signal Extraction
- 3. Systematic Uncertainties
  - ✓ a. tracking selection
  - ✓ b. PID cut variations
  - ✓ c. E/p cut variations
  - ✓ d. trigger cut variation
  - ✓ e. signal fitting
  - ✓ f. background variation
- 4. Corrections
  - ✓ a. Luminosity correction
  - ✓ b. Unfolding correction
  - ✓ c. BBC·MB trigger efficiency
  - ✓ d. VPD·MB trigger efficiency \*
  - ✓ e. Vertex ranking efficiency
  - f. Pythia6 variants
  - g. Apply VPD trigger eff.
  - h. Numerical crosschecks
  - i. Plot beautification

# Backup

Old Linear background curveNew Cubic background curve

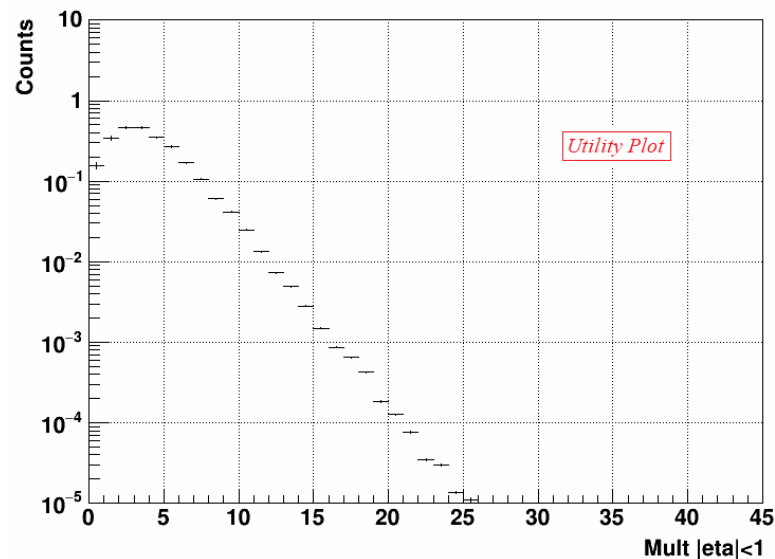
BHT1·(VPD30)

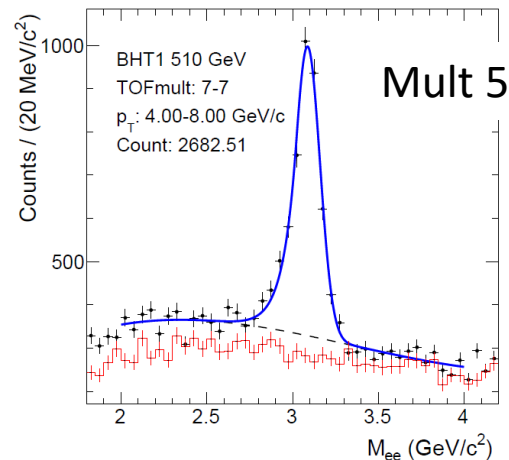
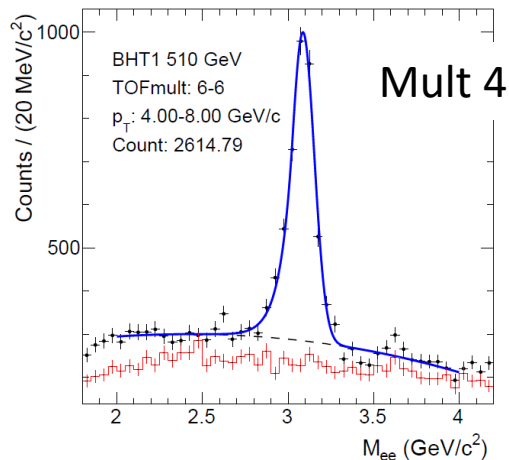
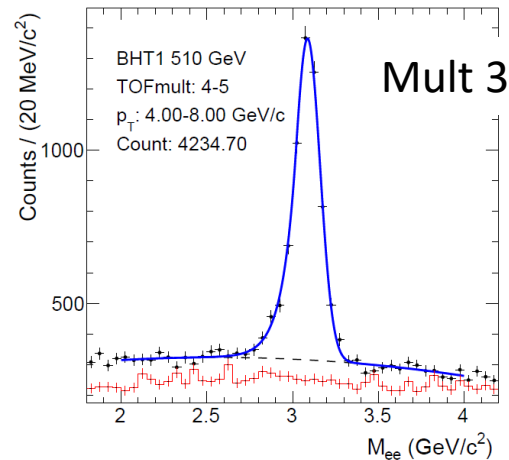
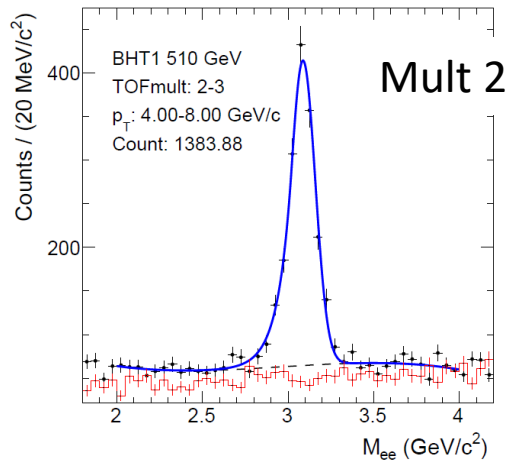
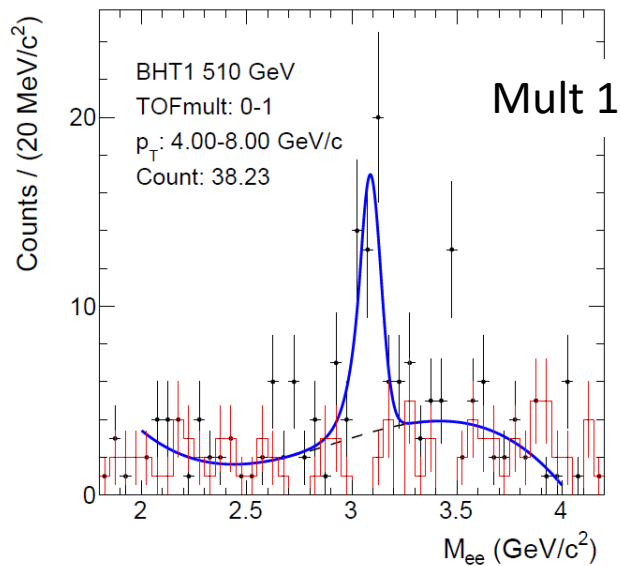
hTOFmult\_lumi\_unfold\_eff

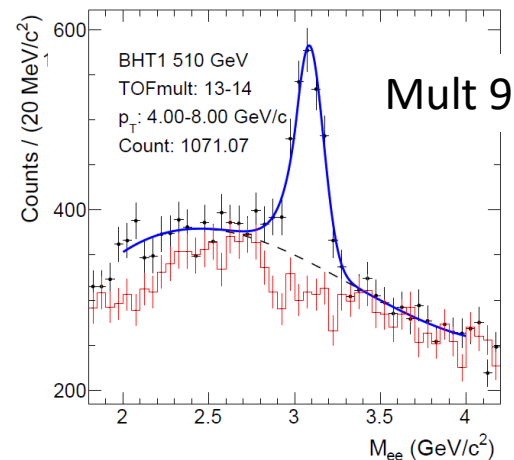
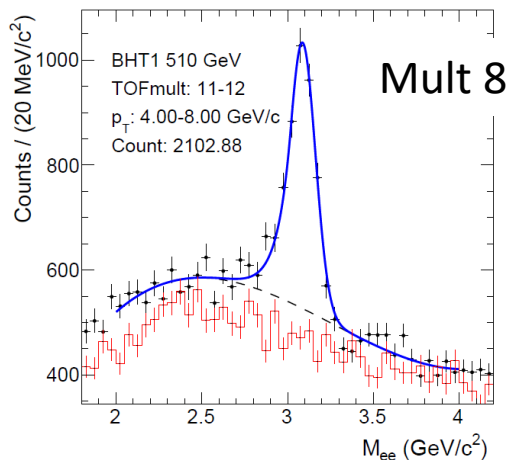
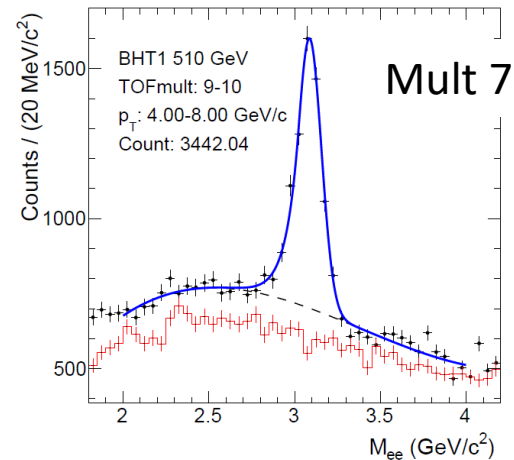
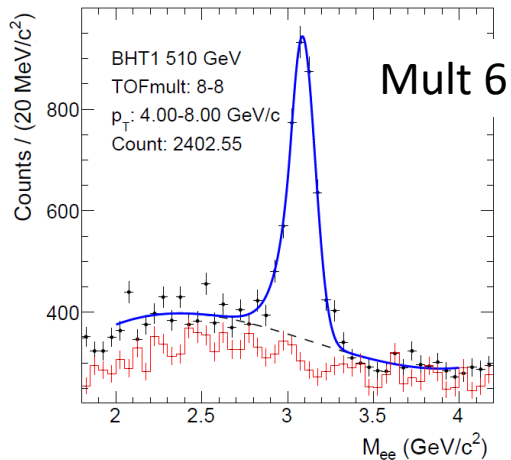
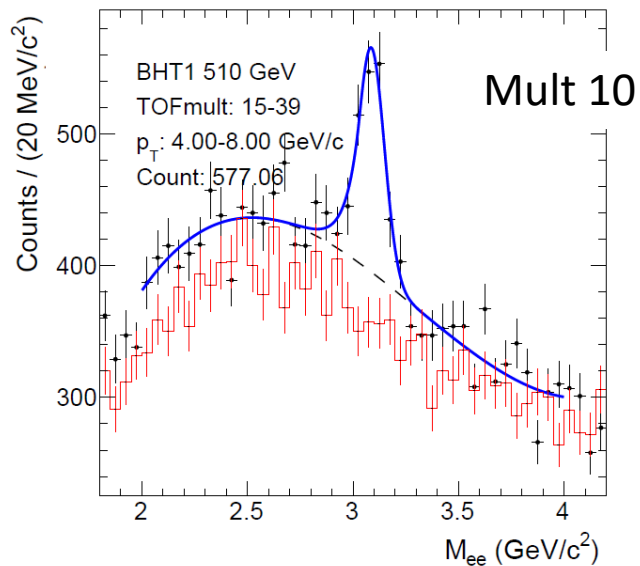


BBC·MB

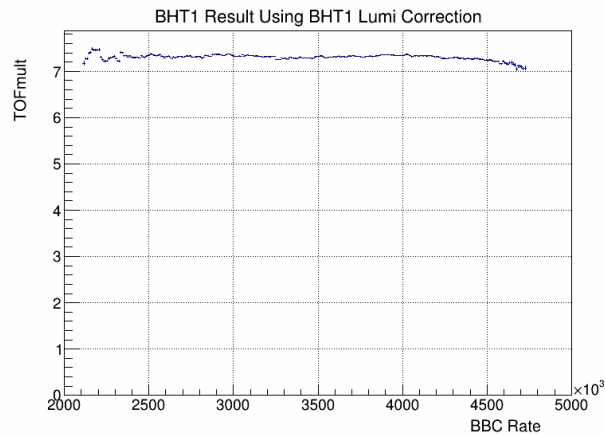
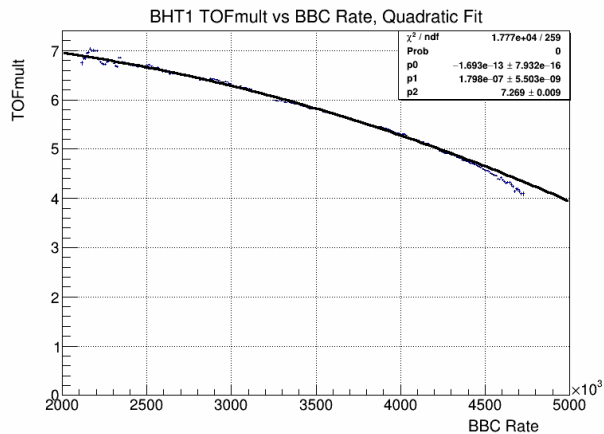
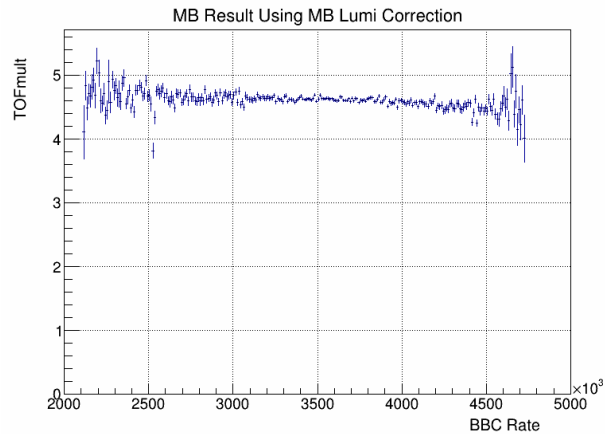
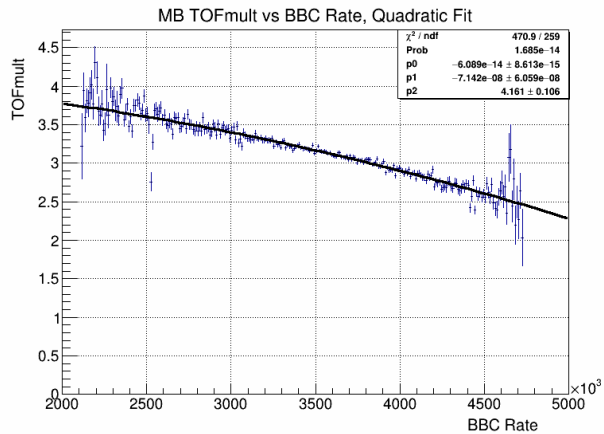
hTOFmult\_lumi\_unfold\_eff









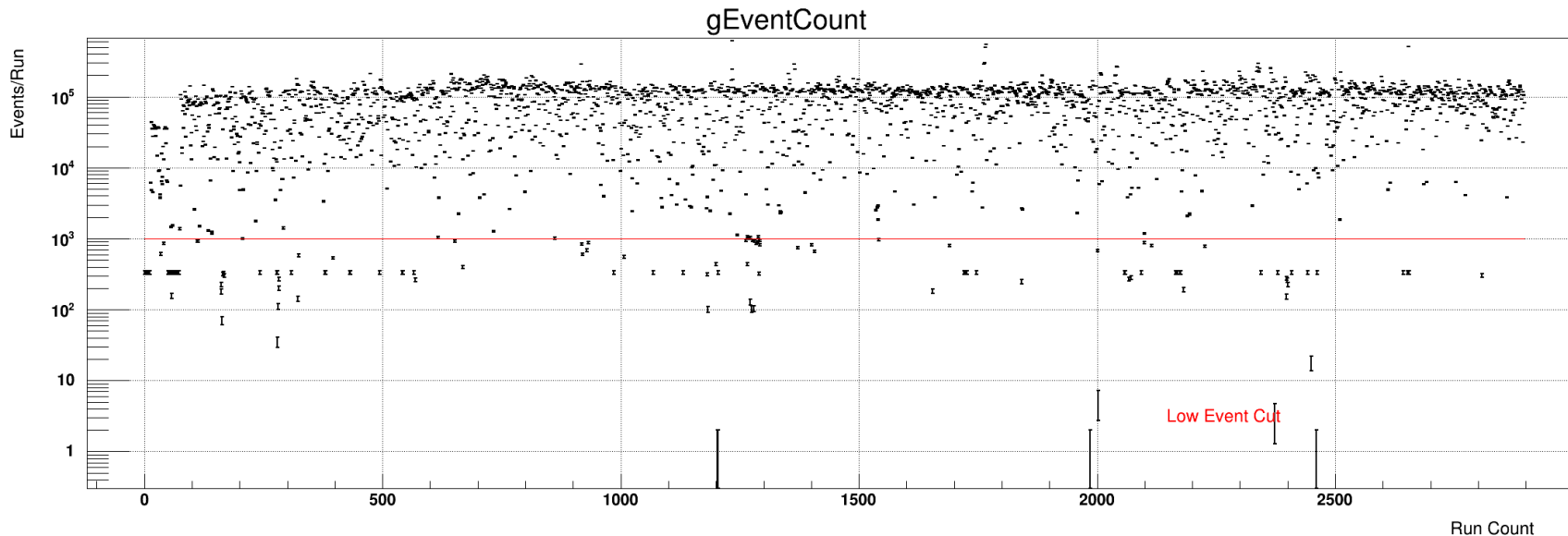


# Analysis Procedure

- ✓ 1. Dataset Preparation
  - ✓ a. QA

## Event QA

- Evt. Count
- <BBC Rate>
- <VPDvz>
- <TPCvx,vy,vz>
- <RefMult>
- <vzDiff>

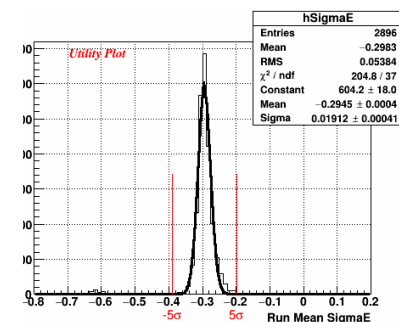
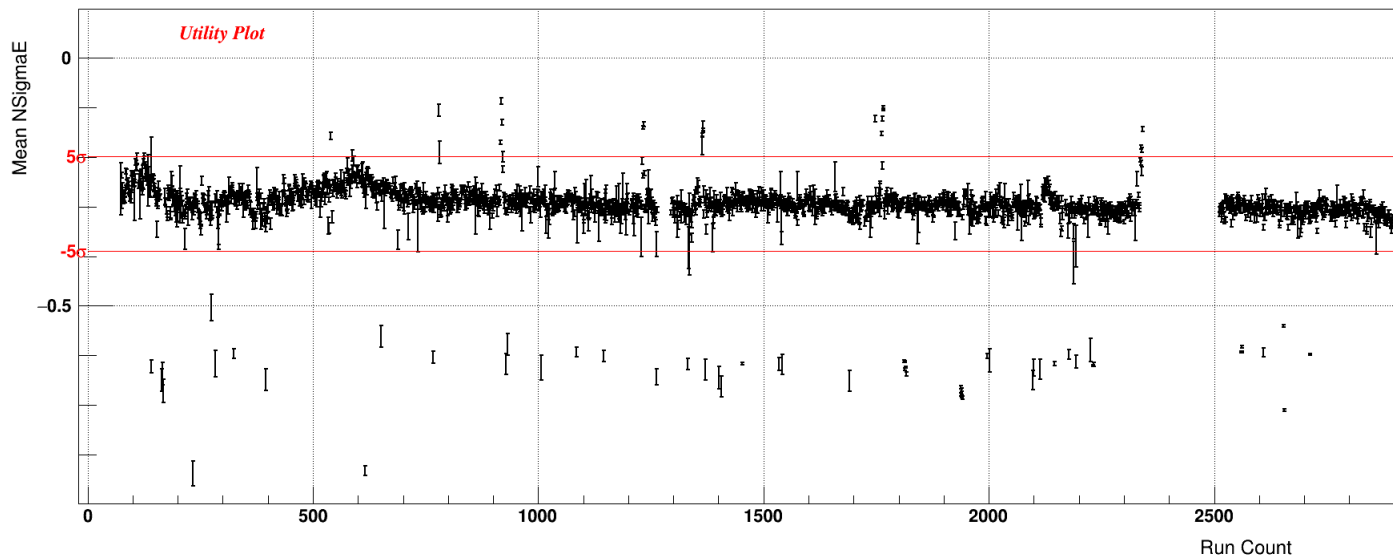


# Analysis Procedure

- ✓ 1. Dataset Preparation
  - ✓ a. QA

## Tracking QA

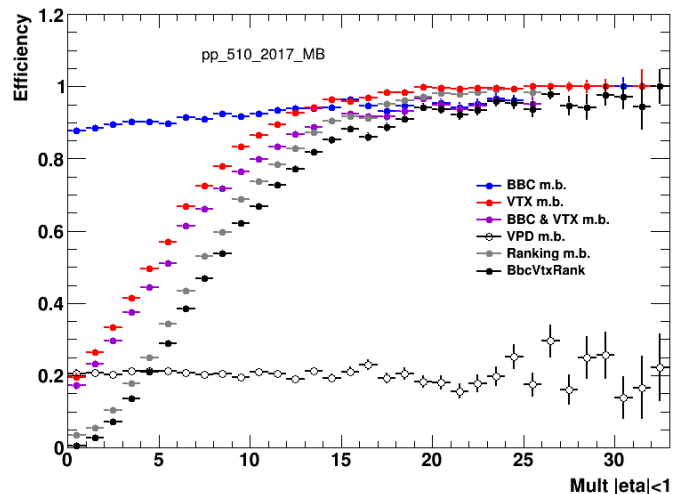
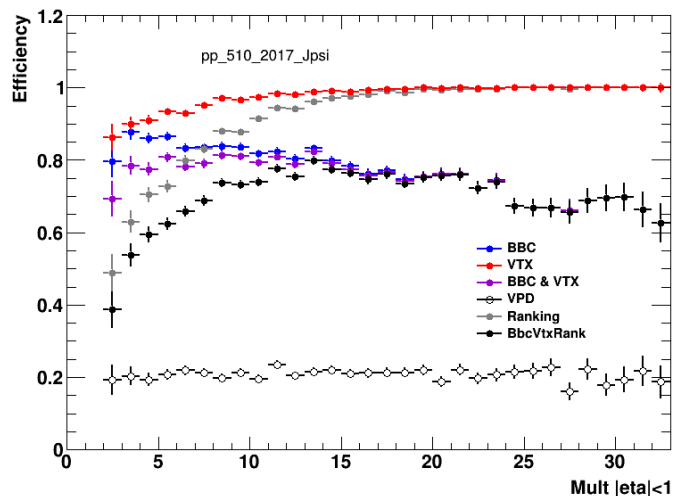
- $\langle p_T \rangle$
- $\langle \Phi \rangle$
- $\langle \text{Eta} \rangle$
- $\langle \text{DCA} \rangle$
- $\langle \text{NGPrimePos} \rangle$
- $\langle \text{NGPrimeNeg} \rangle$
- $\langle \text{NGoodPrime} \rangle$
- $\langle \text{Beta} \rangle$
- $\langle E/p \rangle$
- $\langle \text{NSigmaE} \rangle$
- $\langle \text{NHitsFit} \rangle$
- $\langle \text{NHitsdEdx} \rangle$



# Correcting the multiplicity yields



*Errors found!*



# Correcting the multiplicity yields

- MB
- $J/\psi$

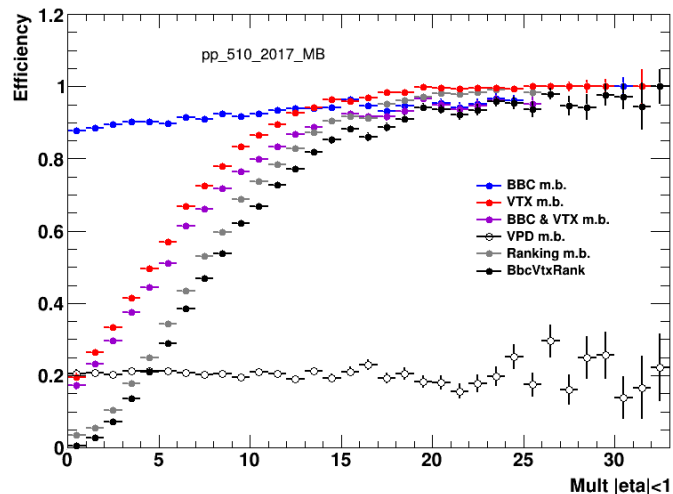
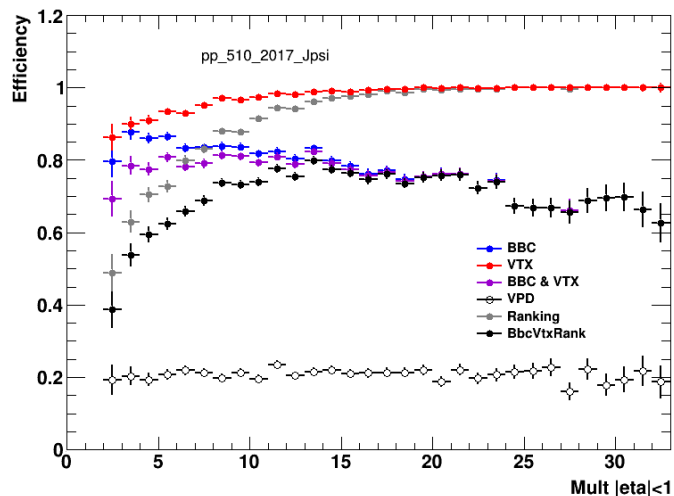
luminosity

unfolding

efficiency

```
bool goodVz = fabs(vz-vzMc)<3.0;
```

*VTX cut is not used on real data!*



# Correcting the multiplicity yields

- MB
- $J/\psi$

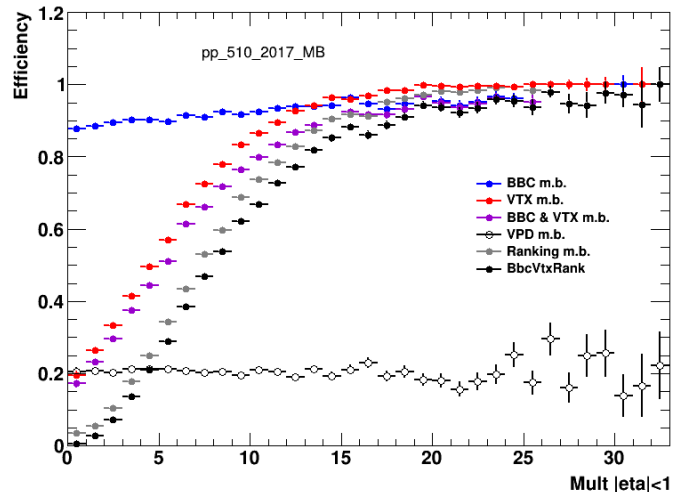
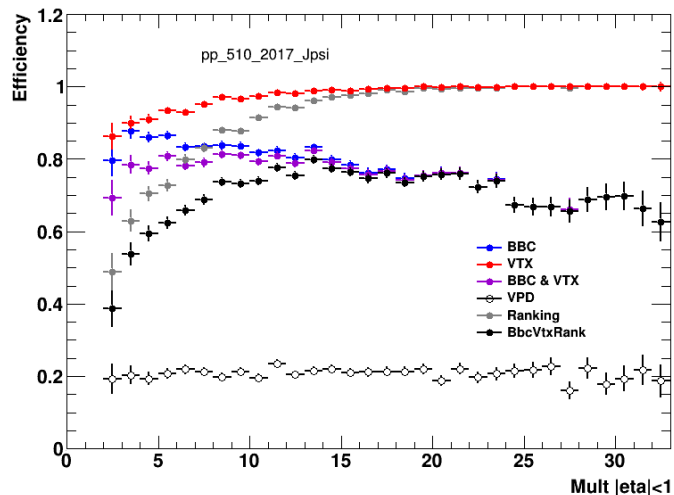
luminosity

unfolding

efficiency

```
bool fireVPD = ( nVpdHit/100 >= 1 ) && ( nVpdHit%100 >= 1); X
bool fireVPD = ( nmcVpdHit/100 >= 1 ) && ( nmcVpdHit%100 >= 1); ✓
```

*No MC hits were incident on VPD?* → *SL21d StBToFSimMaker*

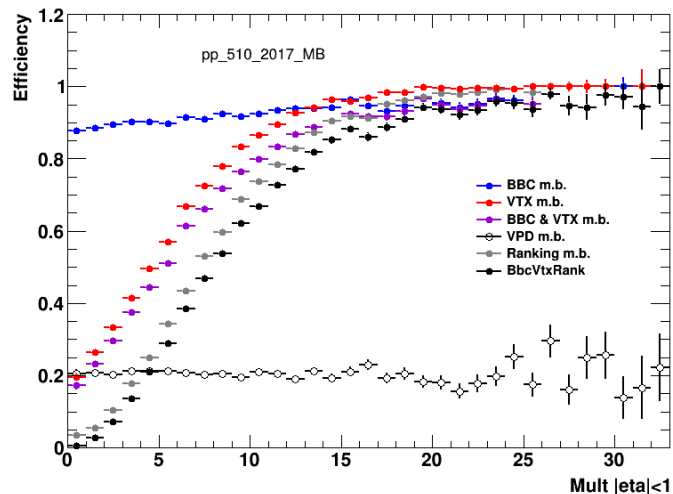
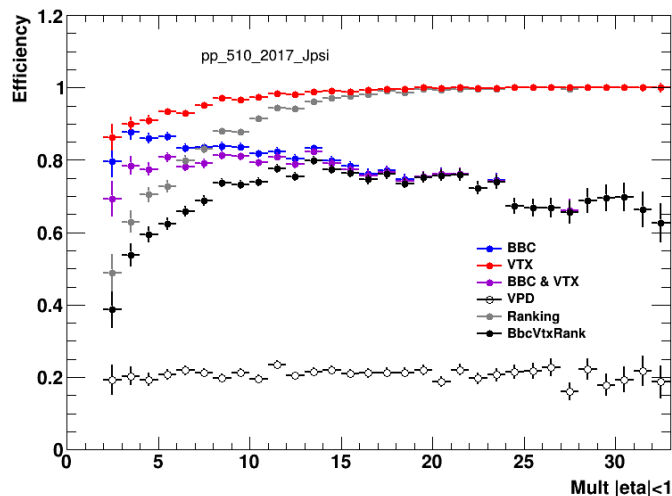


# Correcting the multiplicity yields



Vertex index was wrongly minimized for lowest VzDiff **X**  
 instead use index = 0; **✓**

*No MC hits were incident on VPD?*  $\rightarrow$  *SL21d StBToFSimMaker*



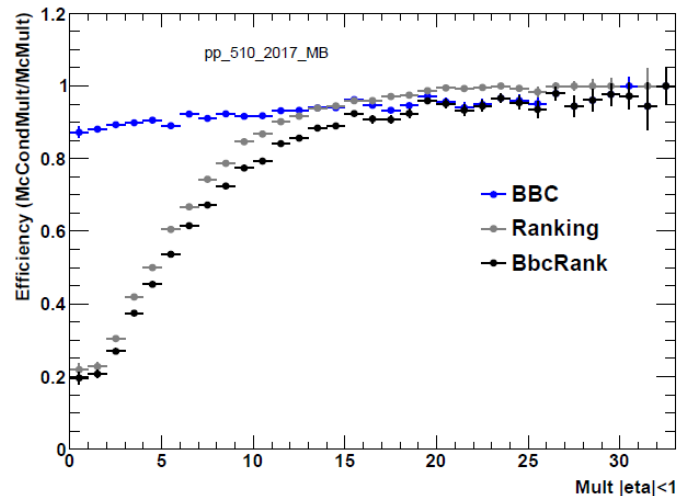
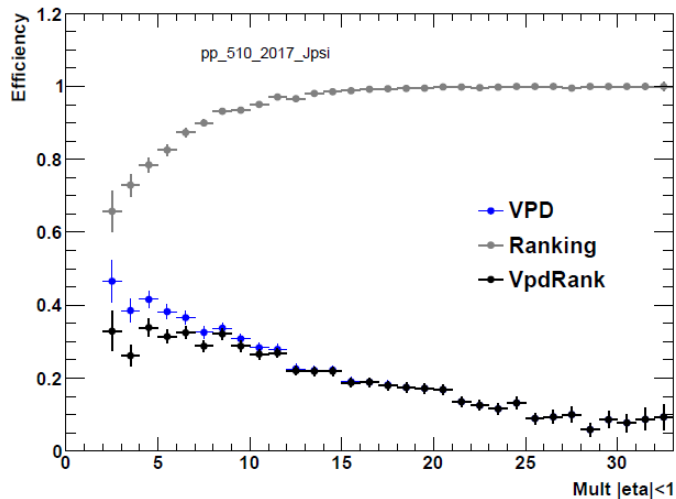
# Correcting the multiplicity yields

- MB
- $J/\psi$

luminosity

unfolding

efficiency





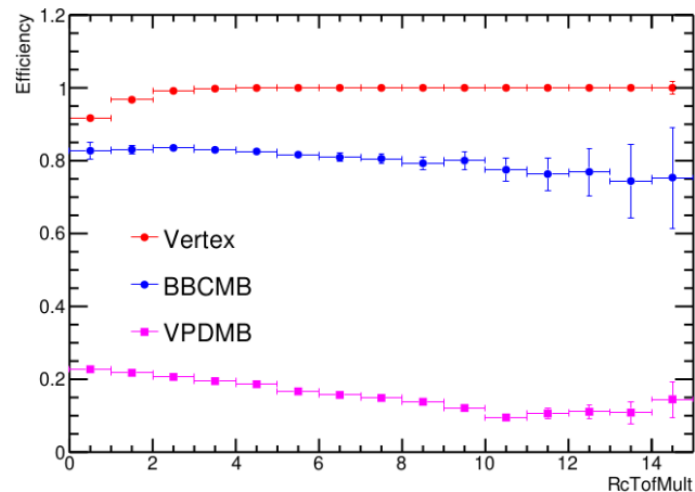
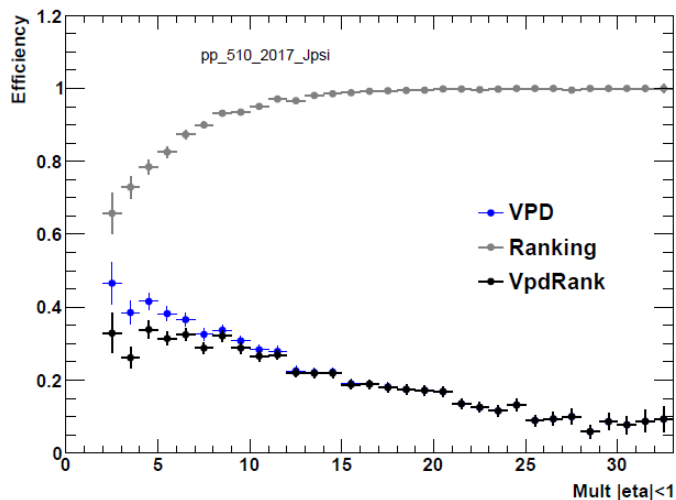
# Correcting the multiplicity yields

- MB
- $J/\psi$

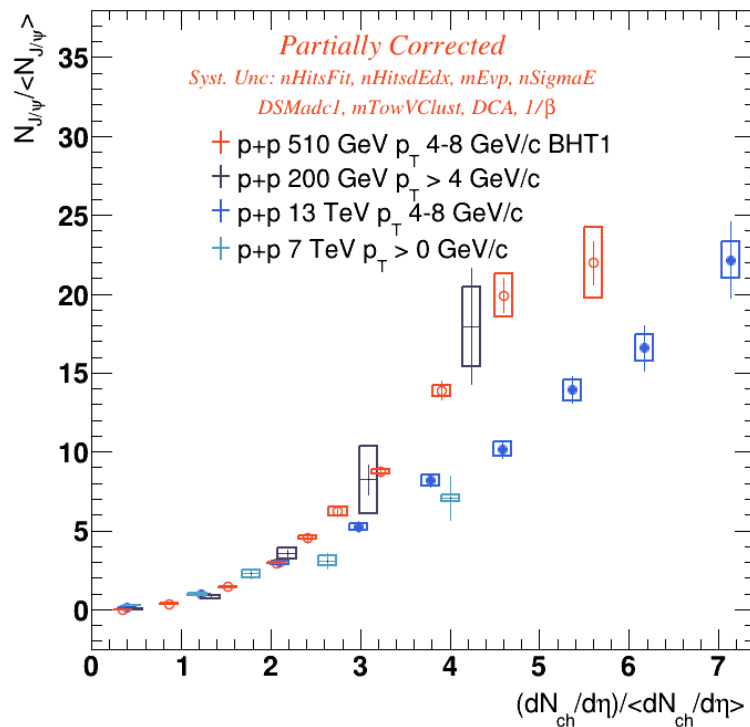
luminosity

unfolding

efficiency



## Self Normalized Yield Plot



- PA name: **Brennan Schaefer**
- PA email address: **brennan.schaefer@lehigh.edu**
- Supervisor email address: **ank220@lehigh.edu**

**Physics Motivation:** Existing measurements from STAR and ALICE that show a faster-than-linear rise in  $J/\psi$  production vs. event multiplicity. Complementing this pQCD calculable process is a new high precision measurement that affords investigation of the influence of multi-parton interactions as an underlying or contributing mechanism.

- Dataset: **pp510GeV**
- Year: **2017**
- Production Tag: **P20ic.SL22b**
- Triggers Used: **MB.VPD30 (570001)**  
**BHT1.VPD30 (570214)**

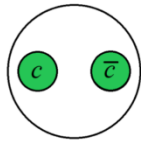
- Embedding Request ID: [20225101](https://drupal.star.bnl.gov/STAR/starsimrequests/2022/Dec/21/Jpsi-ee-pp-510-GeV-2017-BHT1-Trigger)

<https://drupal.star.bnl.gov/STAR/starsimrequests/2022/Dec/21/Jpsi-ee-pp-510-GeV-2017-BHT1-Trigger>

- Good/Bad Run Lists: [Drupal Blog](https://drupal.star.bnl.gov/STAR/blog/bschaefer/QA-BHT1-and-BHT2-datasets)

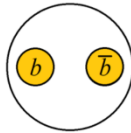
<https://drupal.star.bnl.gov/STAR/blog/bschaefer/QA-BHT1-and-BHT2-datasets>

- QA (before) after: (595M) 382M
- Triggers Used: **MB.VPD30 (570001)**  
**BHT1.VPD30 (570214)**
- ProductionTag: **P20ic.SL22b**
- dsmHotTowers **1, 101, 480, 556, 741, 769, 1086, 1143, 1221, 1239, 1281, 1314, 1476, 1880, 2164, 2165, 2301, 2304, 2314, 2846, 2866, 3494, 3832, 3833, 3834, 3835, 3836, 3839, 3840, 3850, 3856, 3857, 3859, 3876, 3877, 3879, 3880, 3894, 3895, 3899, 3900, 3913, 3914, 3916, 3917, 3920, 3933, 3934, 3935, 3953, 3958, 3959, 3977, 3979, 3980, 3985**



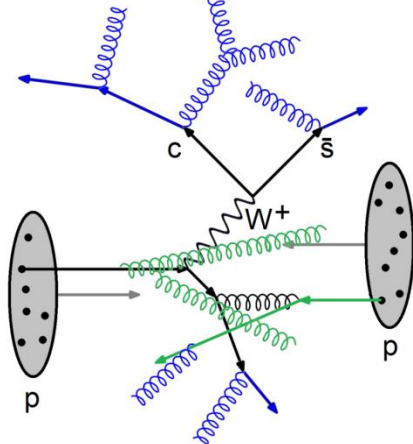
# Backup

## why quarkonia?

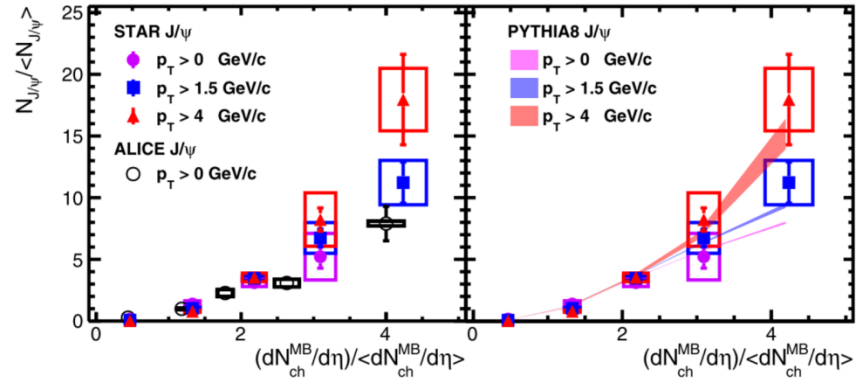
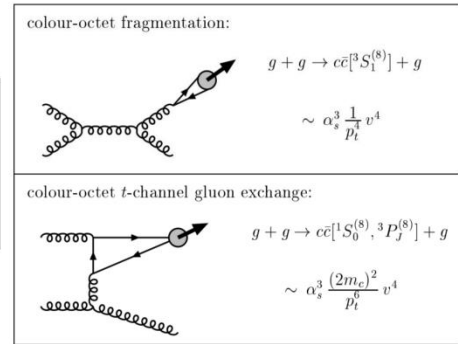
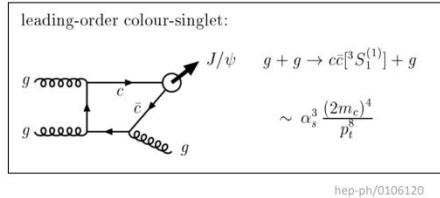


- Non-relativistic *atom-like*
- Clear and precise di-lepton signals
- Flavorless color singlet states
- Produced in hard scattering -> pQCD

### Influence of Multi-Parton Interactions?



### NRQCD @ $\alpha_s^3$



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