Measurements of two-particle correlations in e^+e^- collisions at 91 GeV with ALEPH archived data

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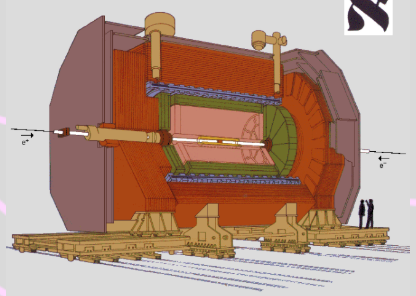

JETSCAPE Workshop, Texas A&M University

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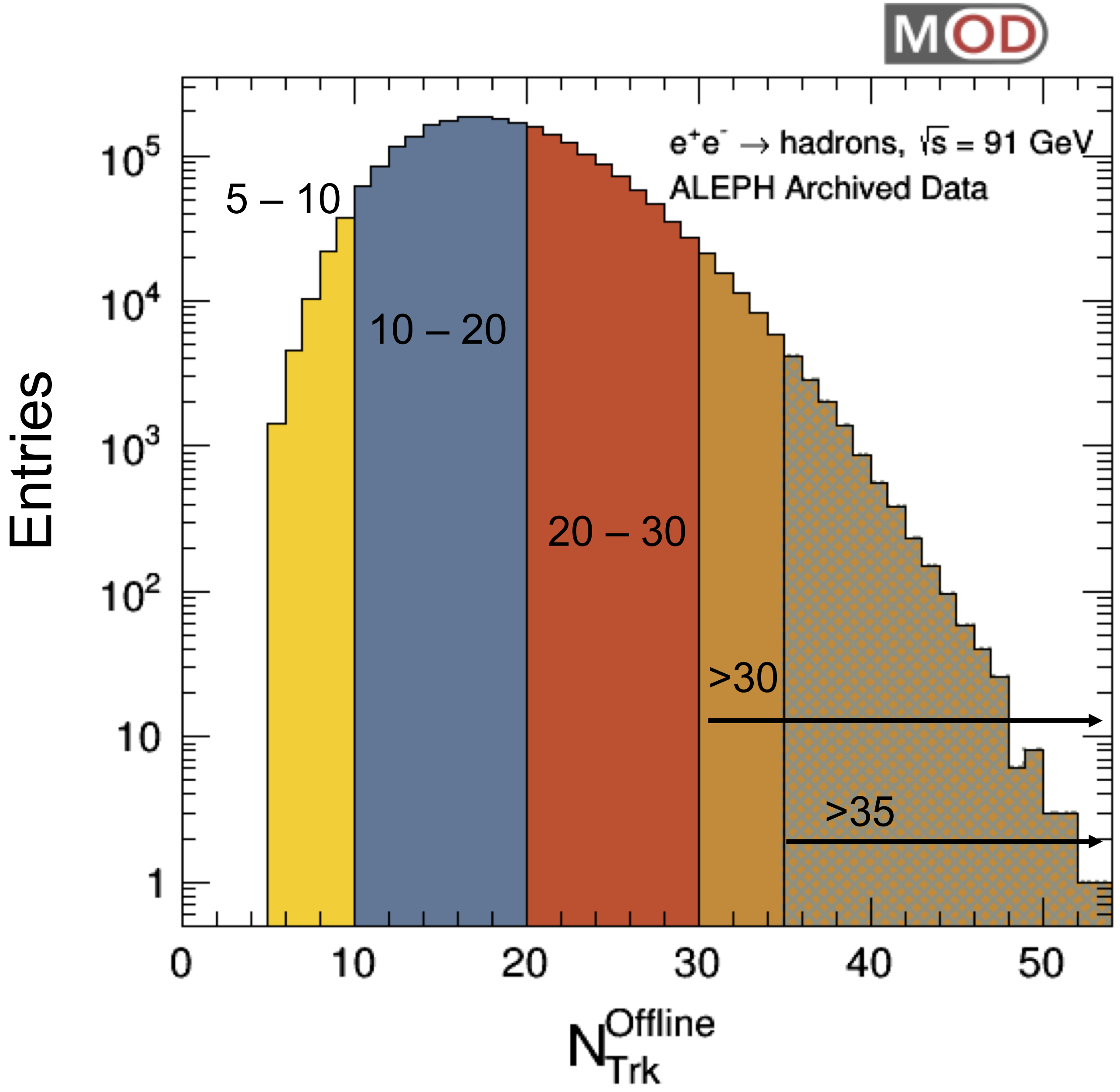
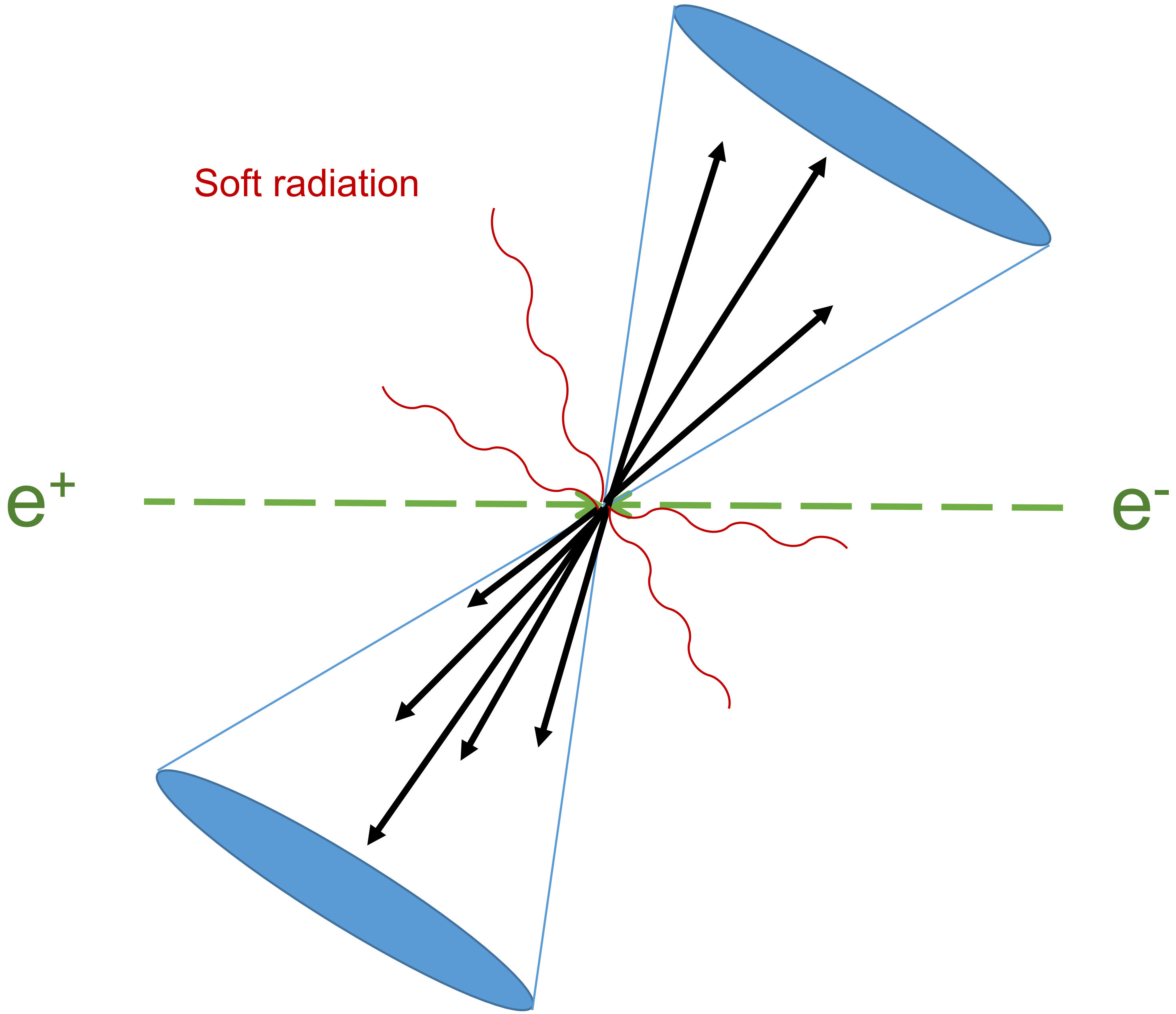
Motivation

- Origin of ridge observed in small systems is still uncertain:
  - Initial state effect (CGC)
  - Final state effect due to mini-QGP
  - …
- Complications from the complexity of hadronic events
  - Hadronic structure
  - Gluon initial state radiation
  - Beam remnants
- e^+e^- allows us to study high multiplicity events with well-defined initial conditions

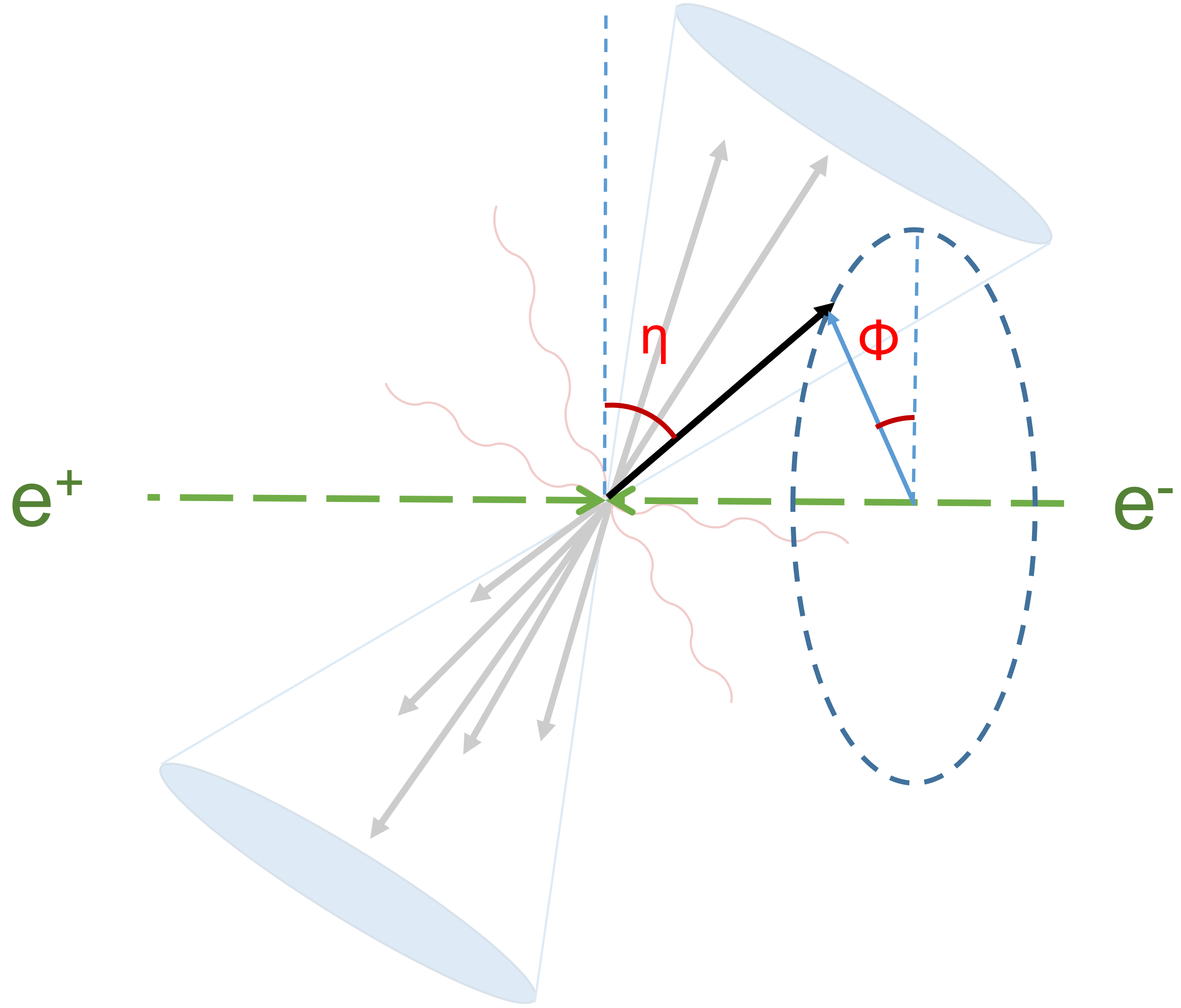


Beam Coordinates (I)



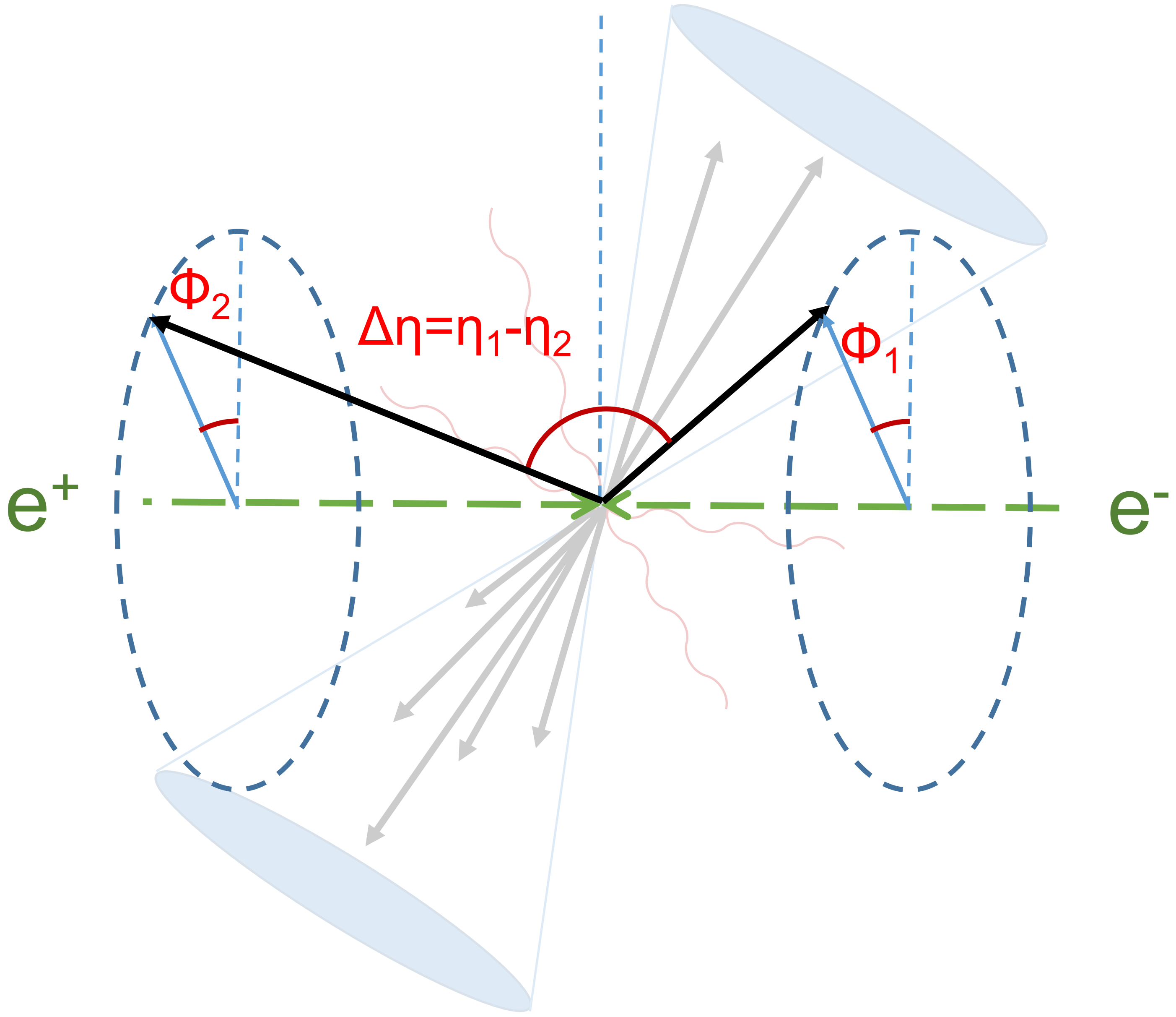
- Repeat measurement performed in pp, pA and AA collisions

Beam Coordinates (II)



- Repeat measurement performed in pp, pA and AA collisions
- Pseudorapidity (η) and azimuthal angle (Φ) are calculated with respect to the beam pipe

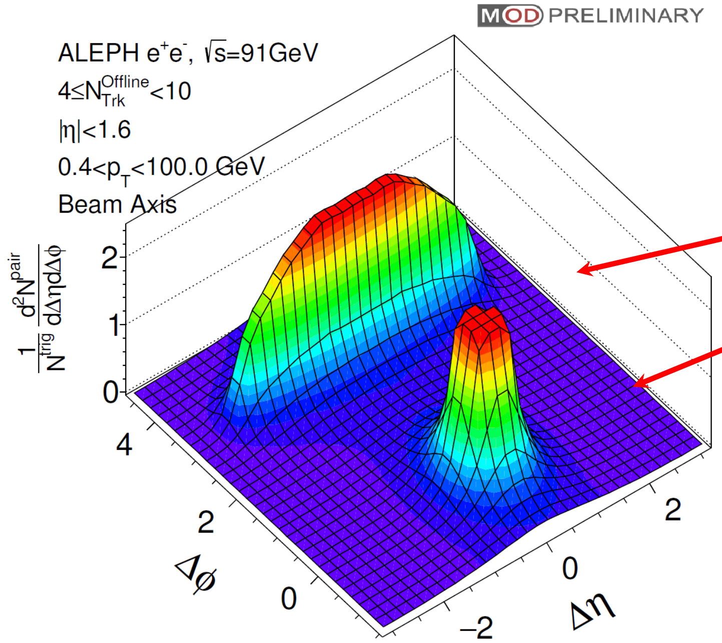
Beam Coordinates (III)



- Repeat measurement performed in pp, pA and AA collisions
- Pseudorapidity (η) and azimuthal angle (Φ) are calculated with respect to the beam pipe
- Search for enhanced number of charged particle pairs with large Δη and small ΔΦ
- Sensitive to pressure driven expansion of the medium in the direction perpendicular to the beam axis

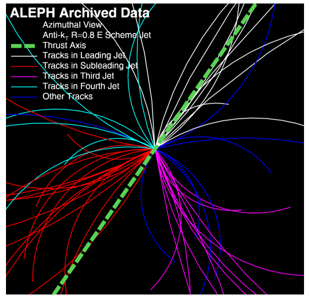
Two-Particle Correlation Function (I)

Signal pair distribution: same event pairs



$$S(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2N^{same}}{d\Delta\eta d\Delta\phi}$$

Event 1

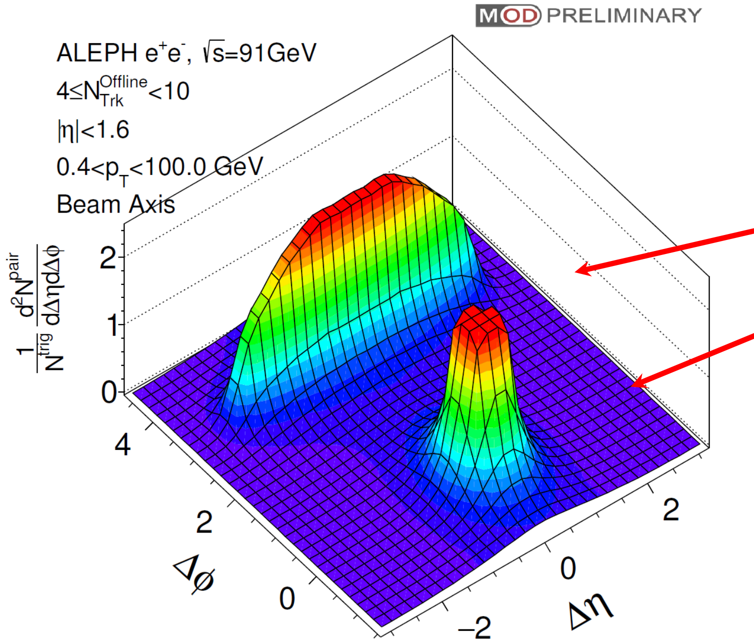


$\Delta\eta = \eta_1 - \eta_2$

$\Delta\varphi = \varphi_1 - \varphi_2$

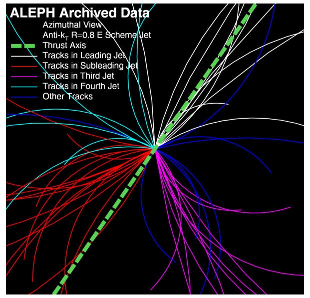
Two-Particle Correlation Function (II)

Signal pair distribution: same event pairs

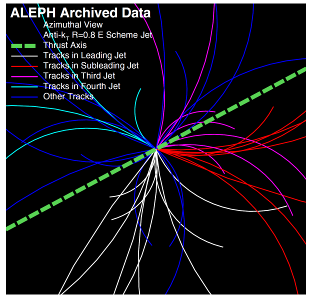


$$S\left(\Delta\eta,\Delta\phi\right)=\frac{1}{N_{trig}}\frac{d^2N^{same}}{d\Delta\eta d\Delta\phi}$$

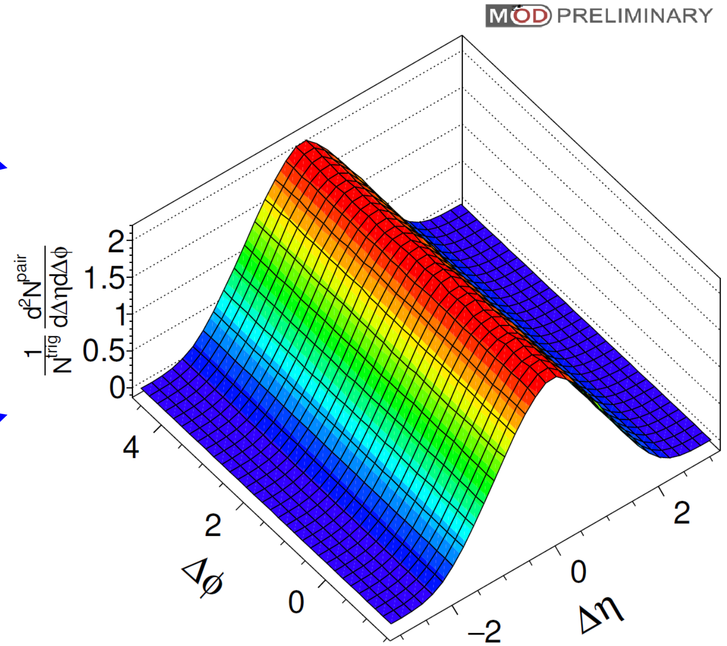
Event 1



Event 2



Background pair distribution: mixed event pairs



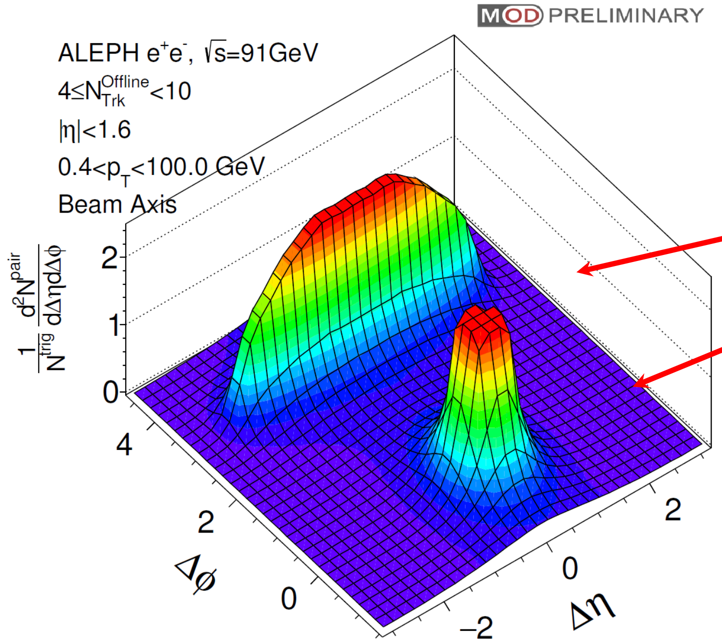
$$B\left(\Delta\eta,\Delta\phi\right)=\frac{1}{N_{trig}}\frac{d^2N^{mix}}{d\Delta\eta d\Delta\phi}$$

$\Delta\eta = \eta_1 - \eta_2$

$\Delta\varphi = \varphi_1 - \varphi_2$

Two-Particle Correlation Function (III)

Signal pair distribution: same event pairs



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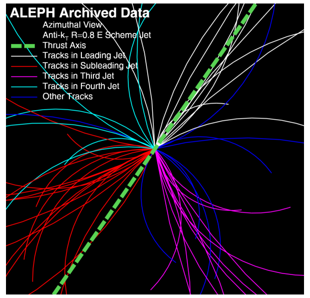
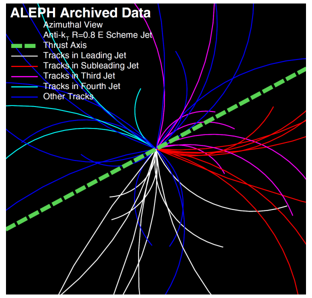
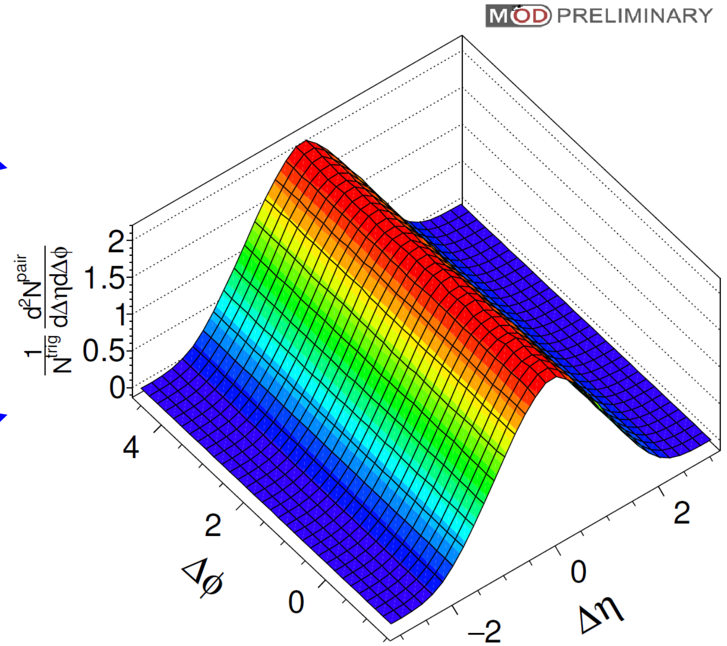


Event 2



Background pair distribution: mixed event pairs



$$B\left(\Delta\eta,\Delta\phi\right)=\frac{1}{N_{trig}}\frac{d^2N^{mix}}{d\Delta\eta d\Delta\phi}$$

Associated hadron yield per trigger:

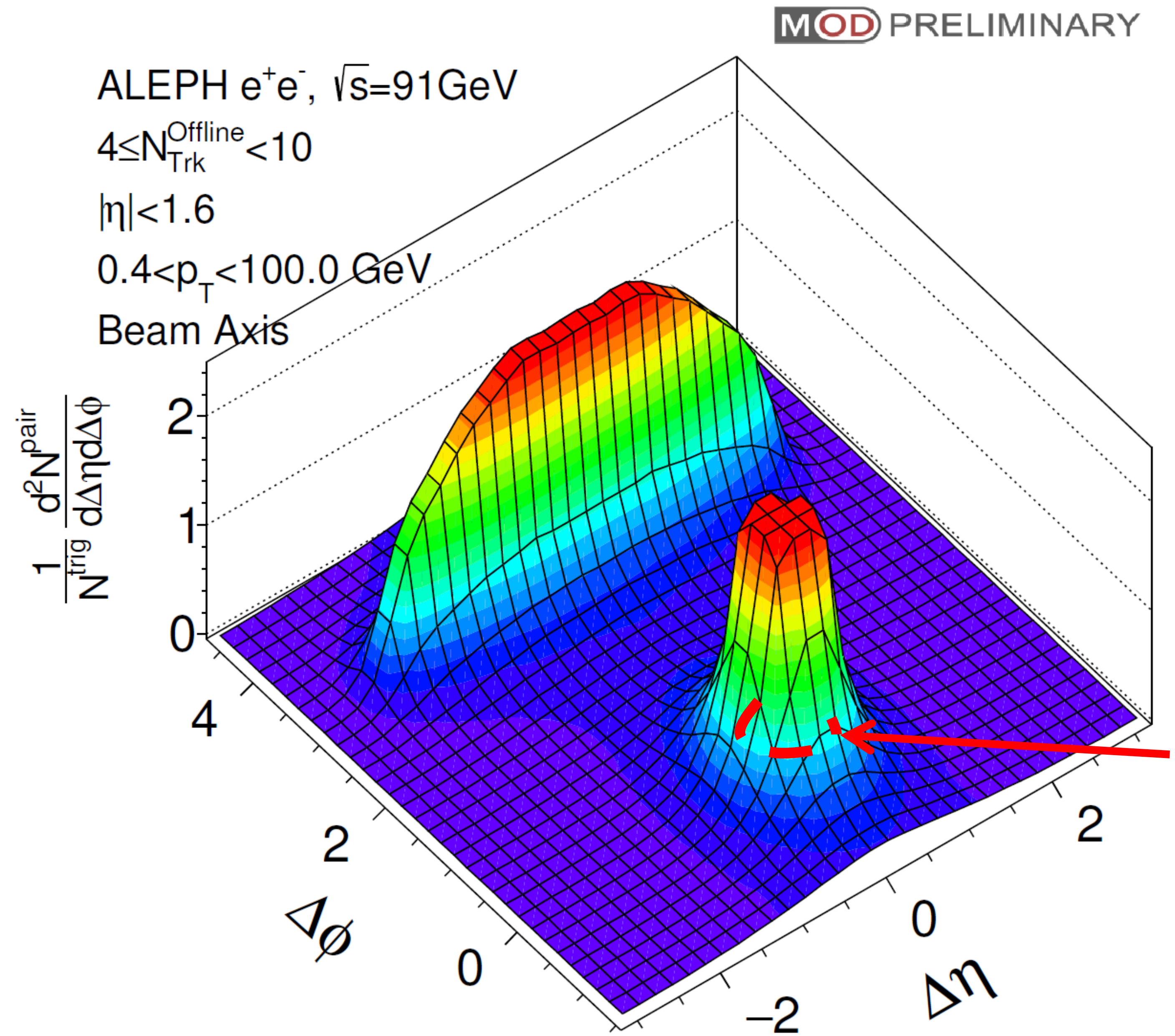
$$\frac{1}{N_{trig}}\frac{d^2N^{pair}}{d\Delta\eta d\Delta\phi}=B\left(0,0\right)\times\frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)}$$

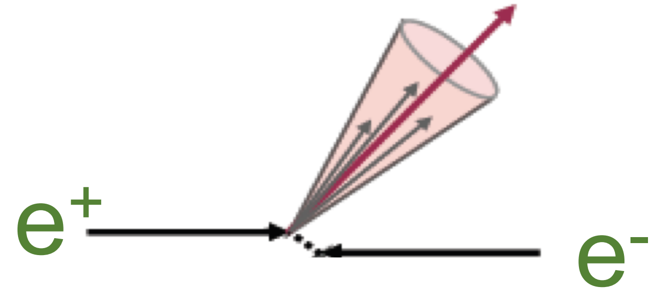
$\Delta\eta = \eta_1-\eta_2$

$\Delta\varphi = \varphi_1-\varphi_2$

Signal Correlation Function (I)

$$S(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2 N^{same}}{d\Delta\eta d\Delta\phi}$$

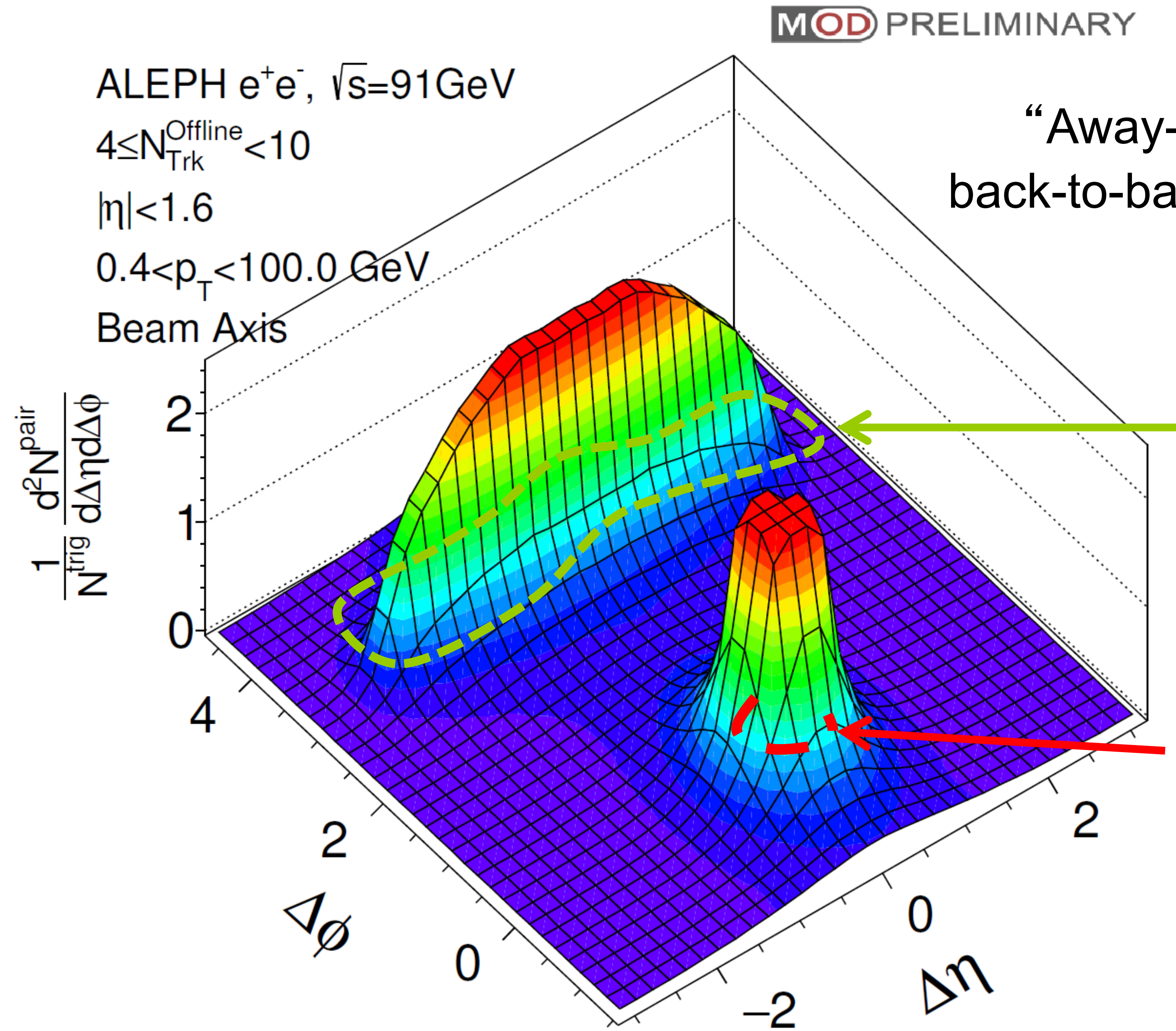




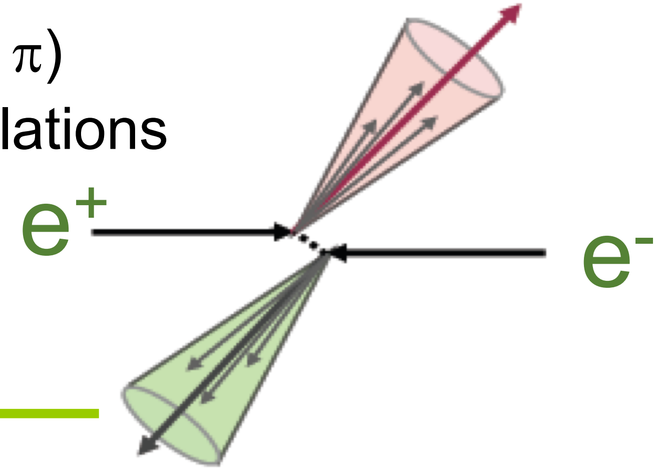
"Near-side" (Δϕ, Δη ~ 0) correlations from single jets

Signal Correlation Function (II)

$$S(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2 N^{same}}{d\Delta\eta d\Delta\phi}$$

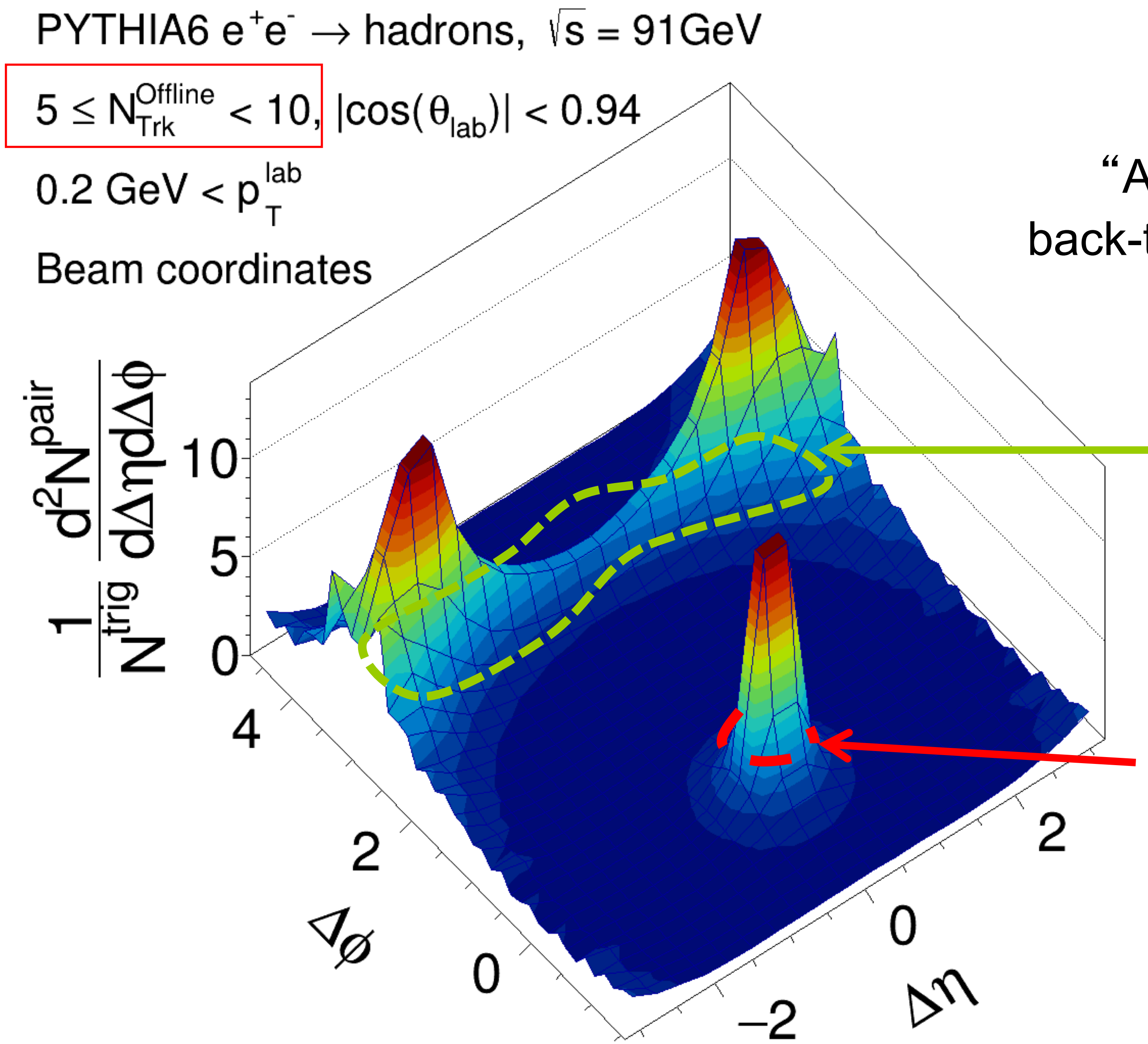


"Away-side" ($\Delta\phi \sim \pi$)
back-to-back jet correlations

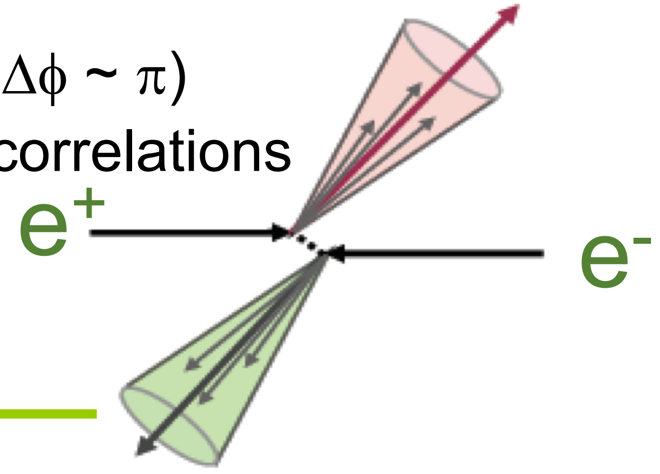


"Near-side" ($\Delta\phi$, $\Delta\eta \sim 0$)
correlations from single jets

Beam Axis Correlation Function (I)



"Away-side" ($\Delta\phi \sim \pi$)
back-to-back jet correlations

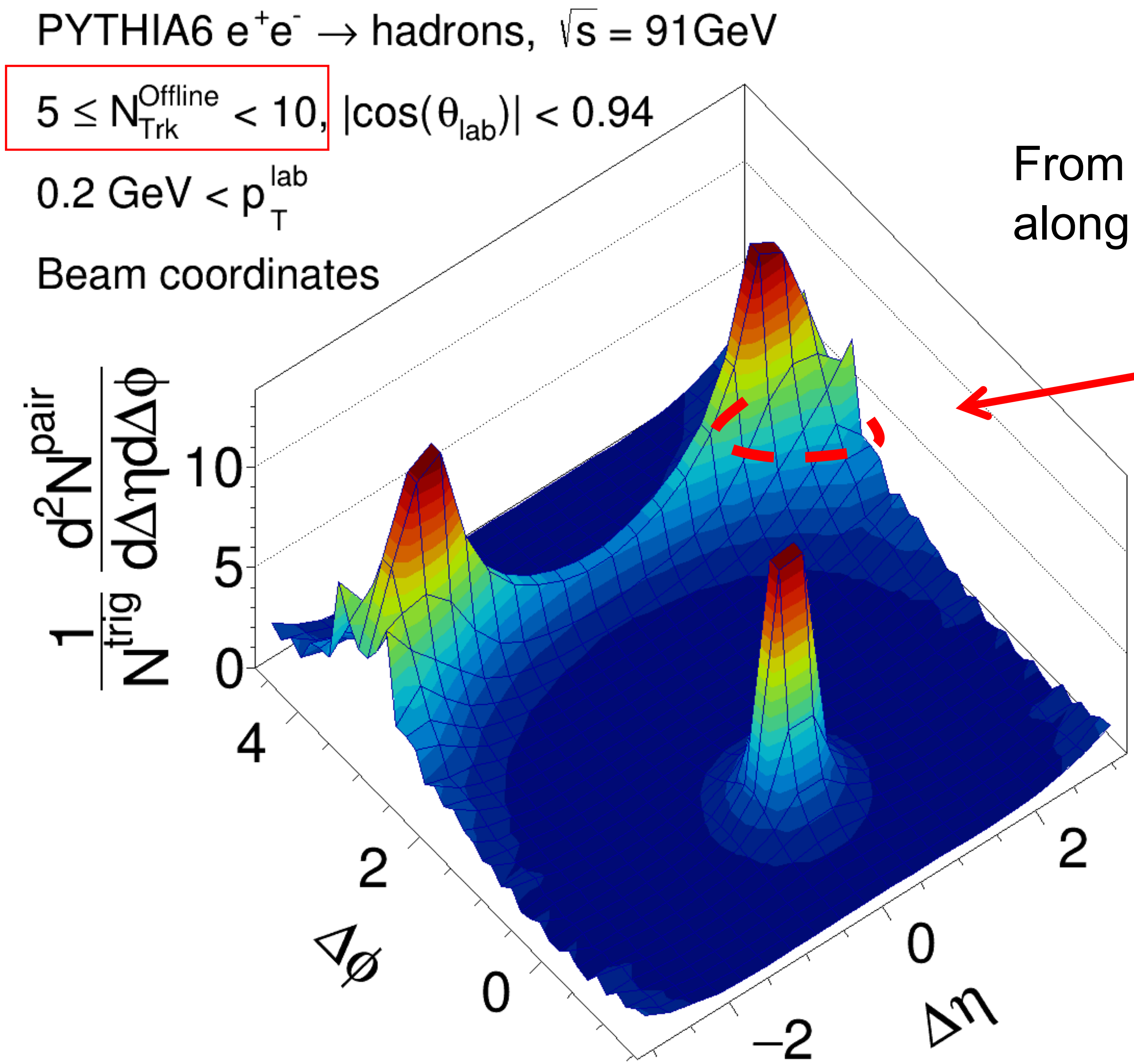


Associated hadron yield per trigger:

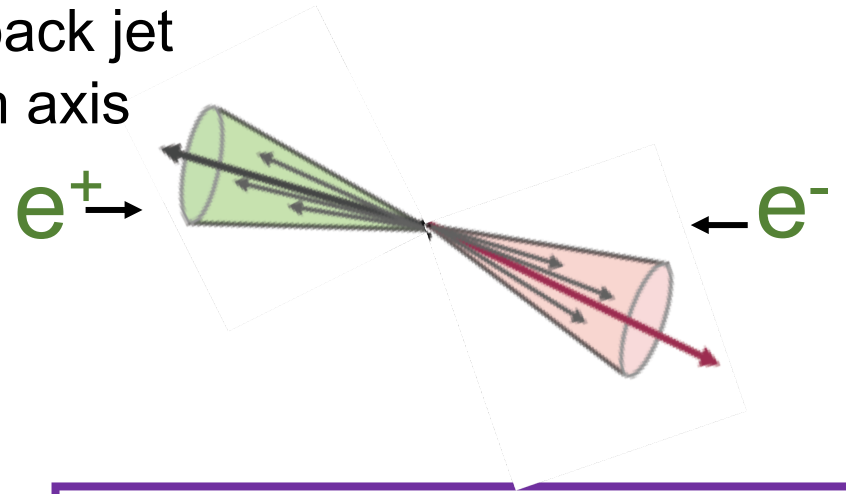
$$\frac{1}{N_{trig}} \frac{d^2 N^{pair}}{d\Delta\eta d\Delta\phi} = B(0,0) \times \frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)}$$

"Near-side" ($\Delta\phi$, $\Delta\eta \sim 0$)
correlations from single jets

Beam Axis Correlation Function (II)



From back-to-back jet along the beam axis



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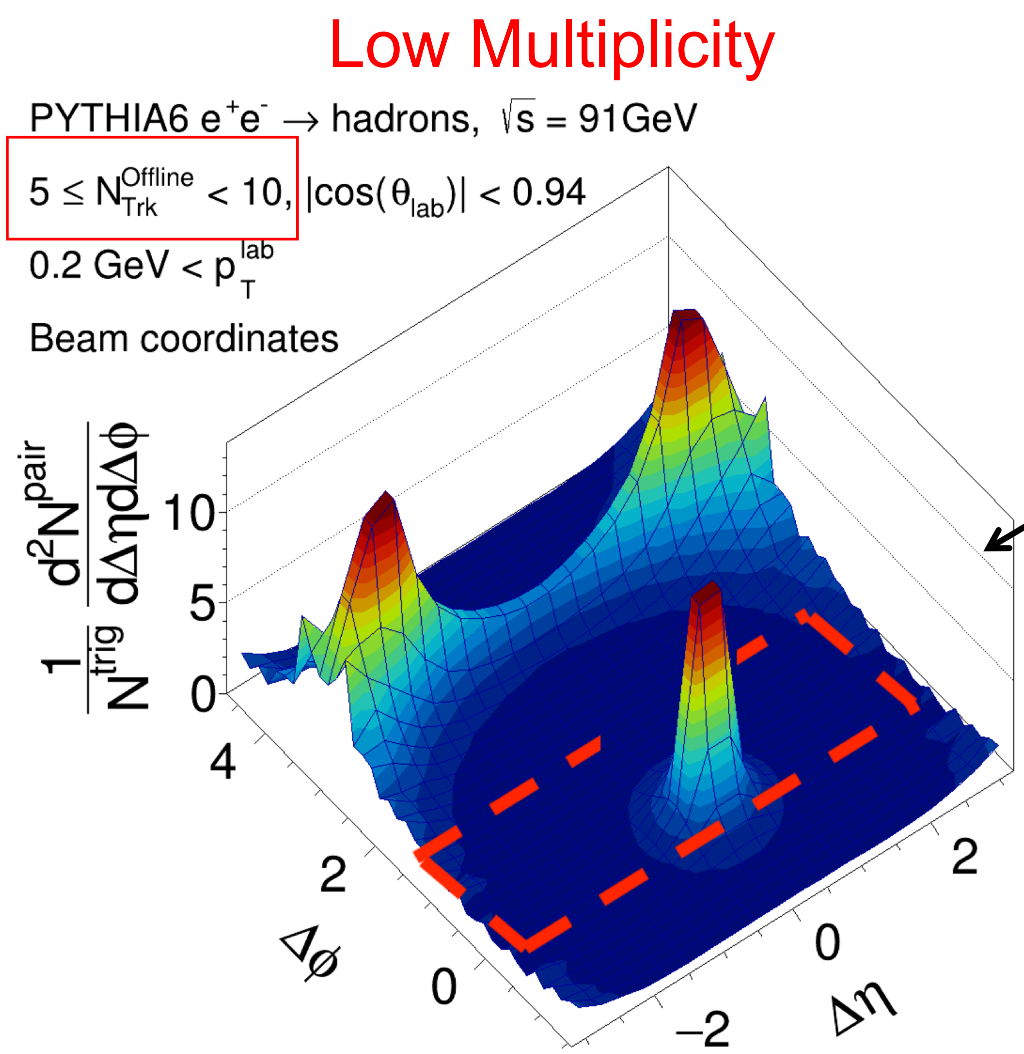
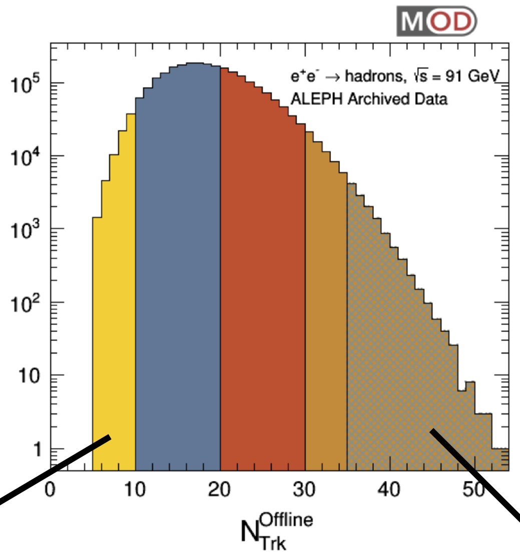
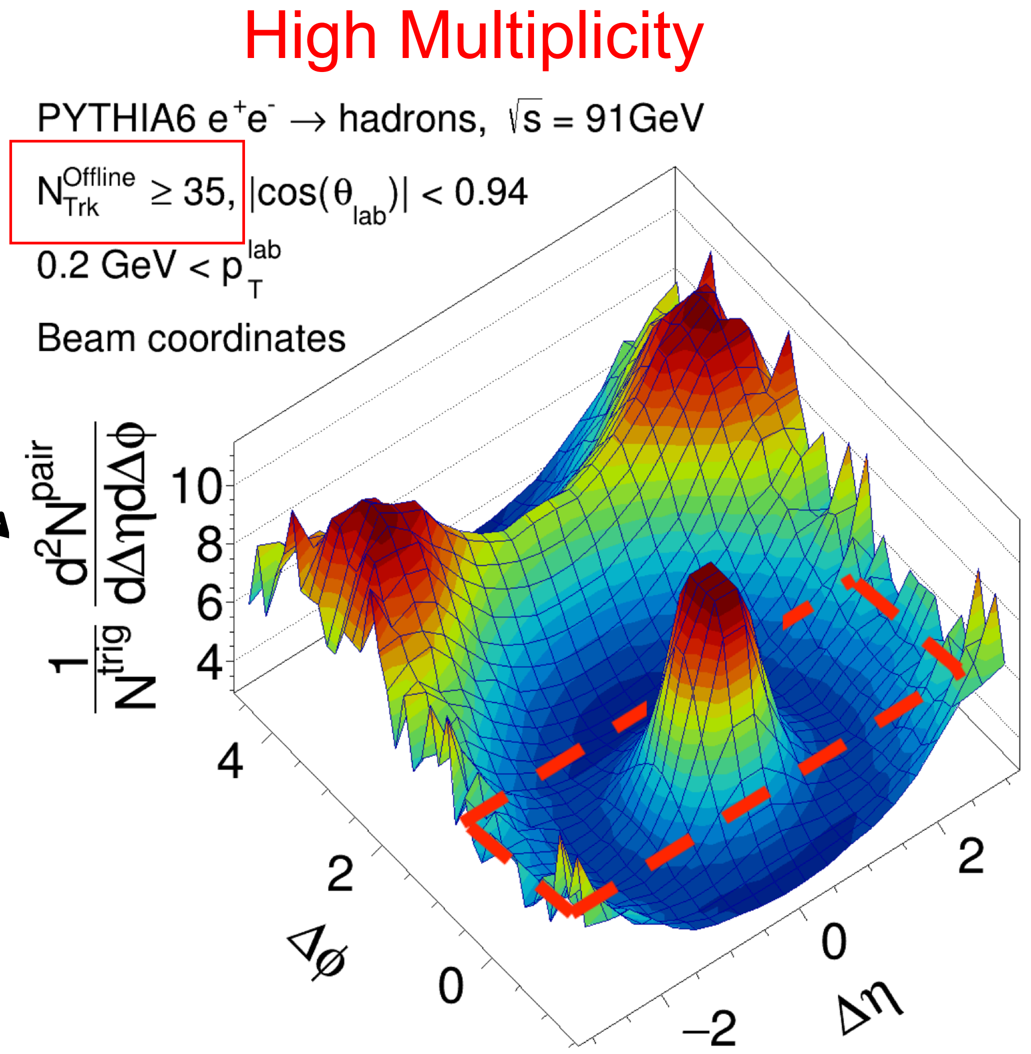
"Near-side" ($\Delta\phi$, $\Delta\eta \sim 0$) correlations from single jets

Beam Axis Correlation Function (III)

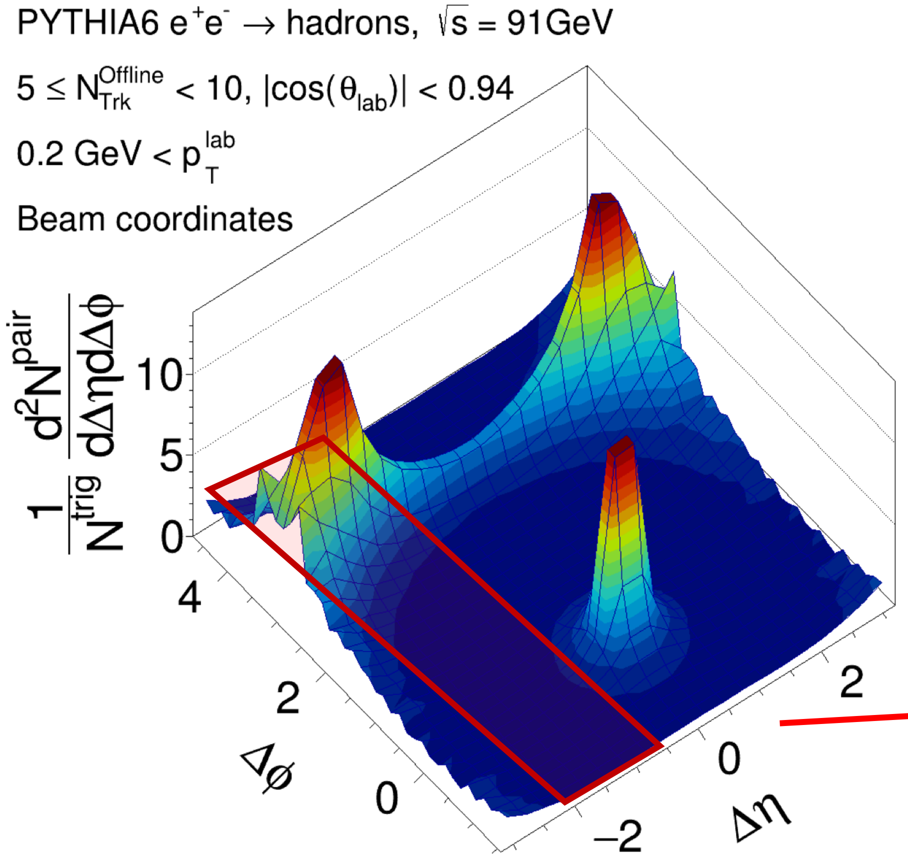




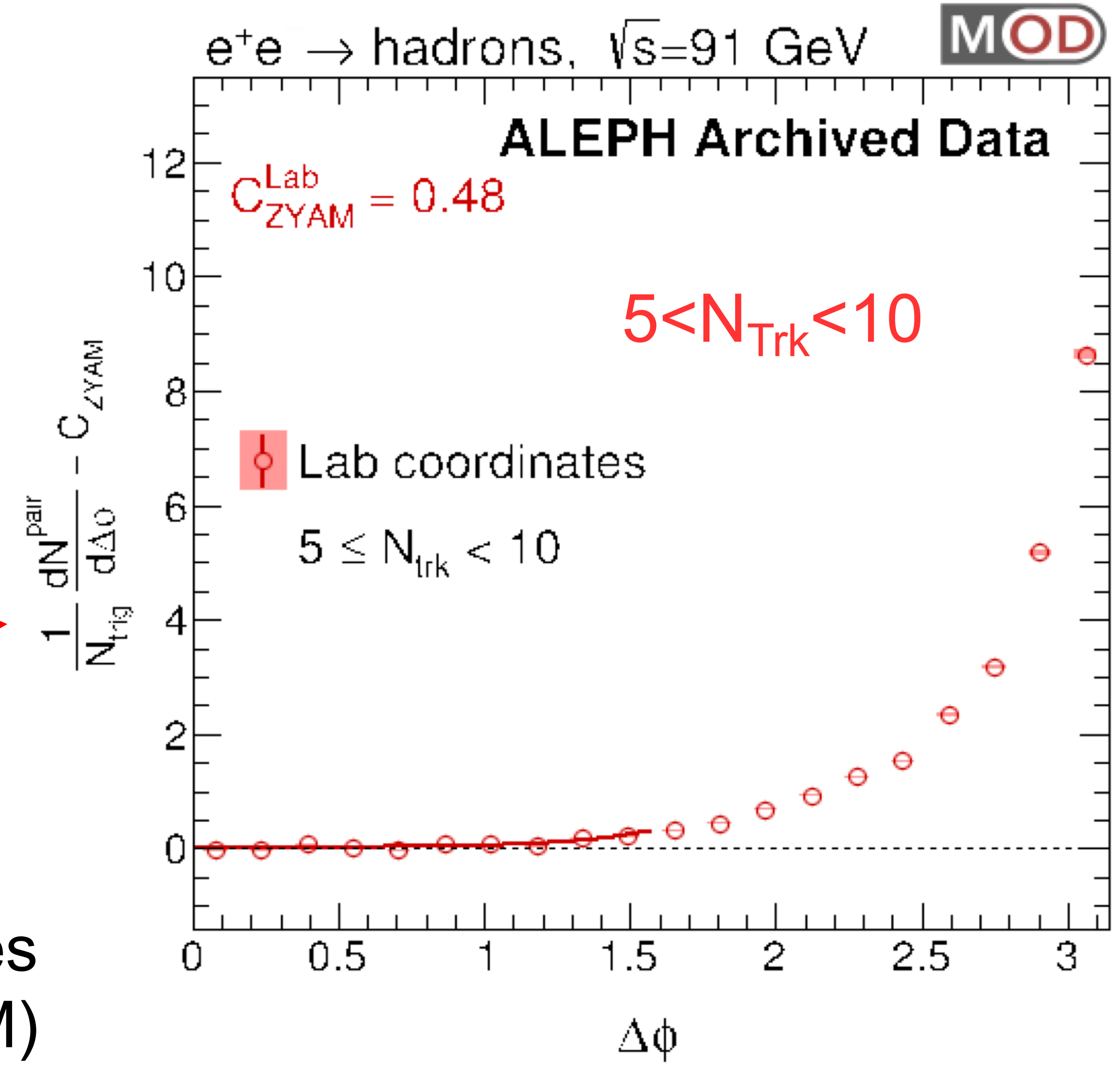


No clear near side ridge structure observed at small $\Delta\Phi$ and large $\Delta\eta$

Projection (I)

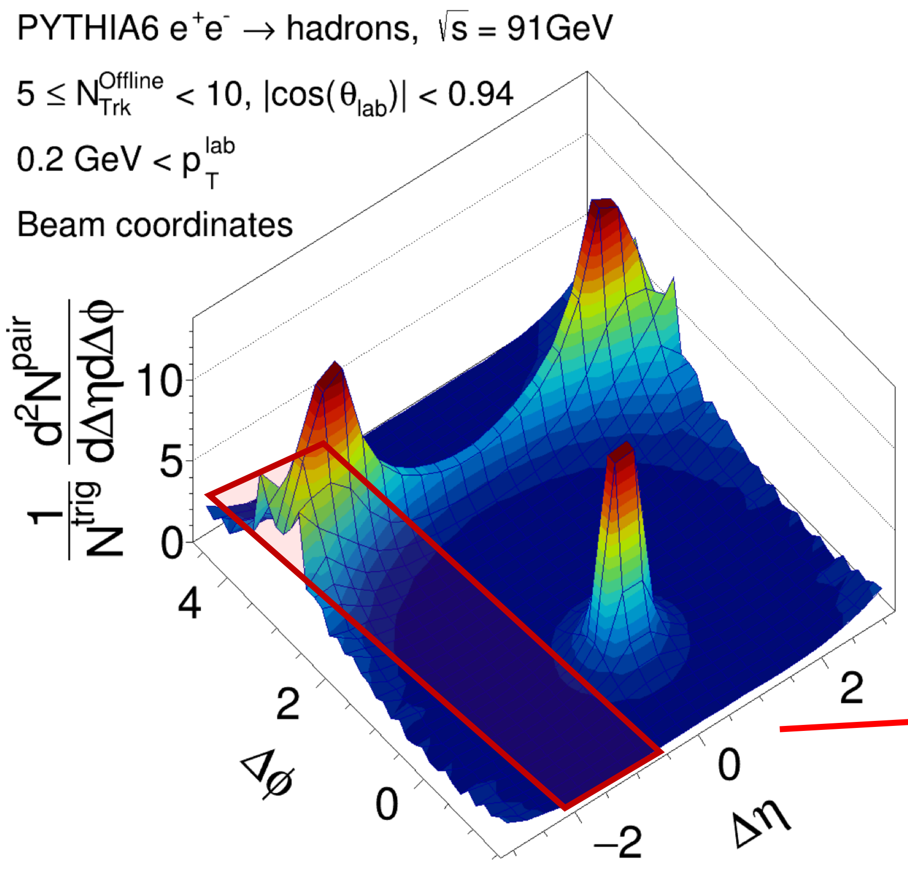


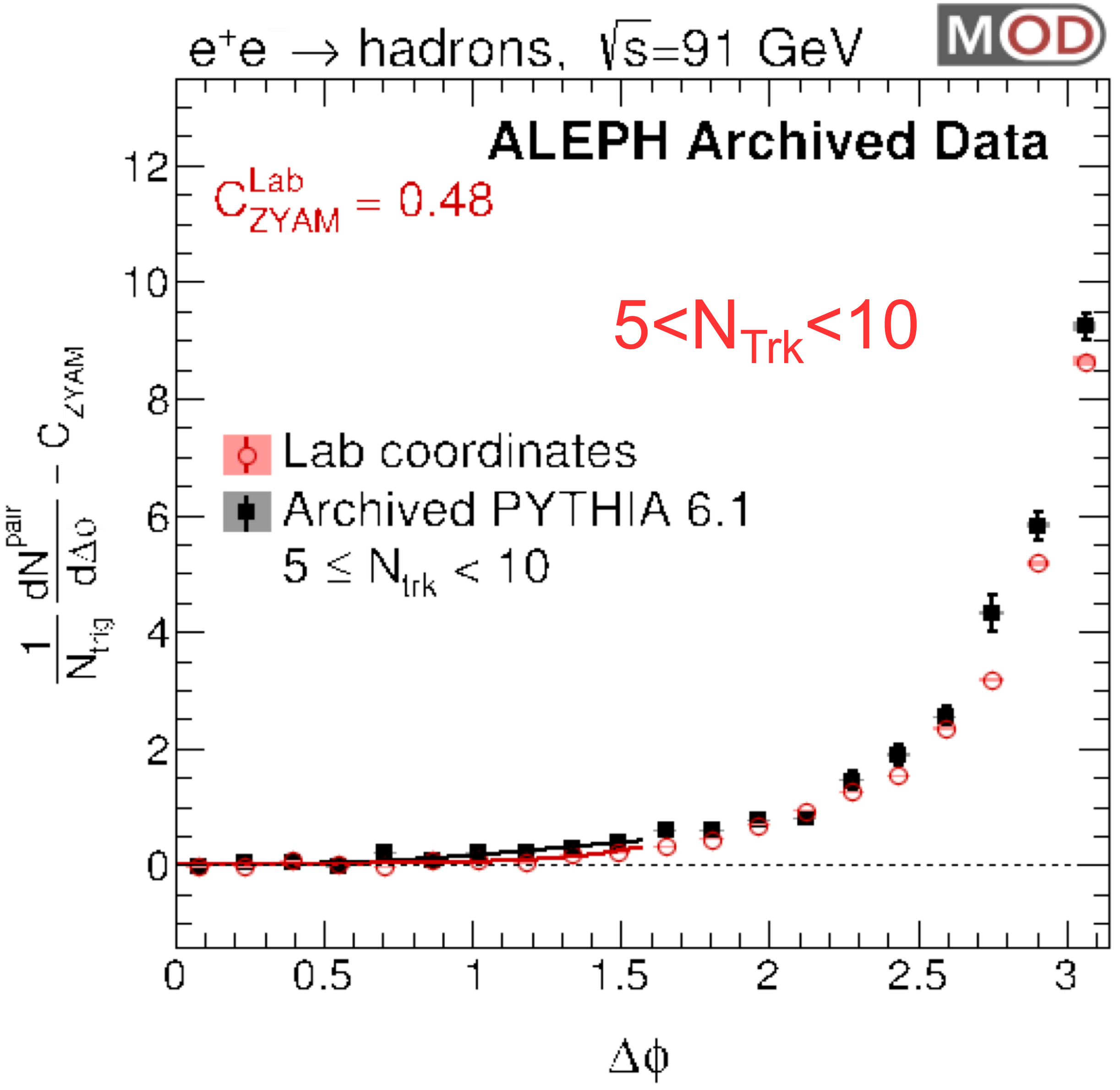
Projection



- Project $1.6<|\Delta\eta|<3.2$ into 1D plot
- Fit data from $0<|\Delta\Phi|<\pi/2$ with Fourier series
- Subtract off "zero yield at minimum" (ZYAM)

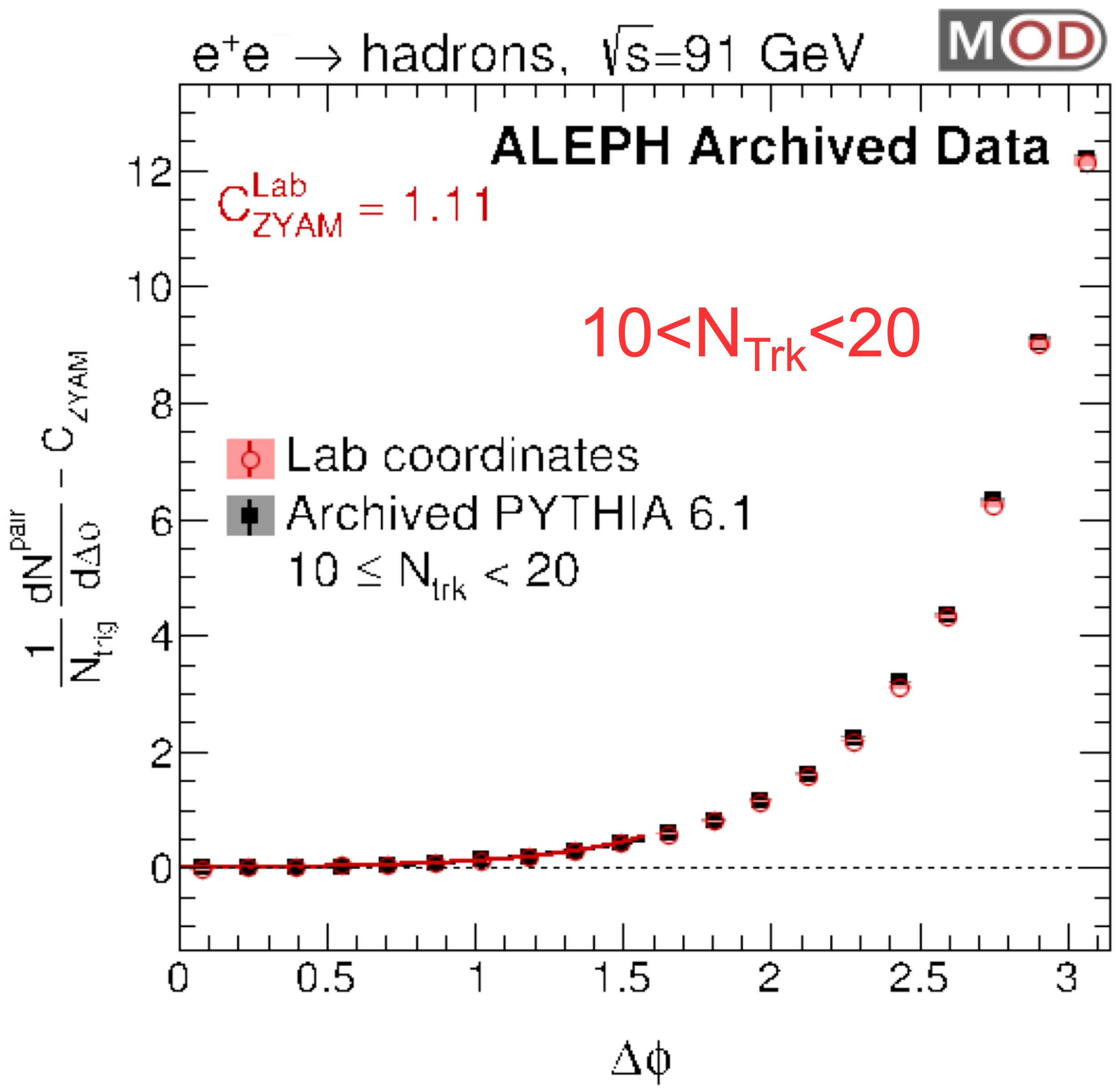
Projection (II)

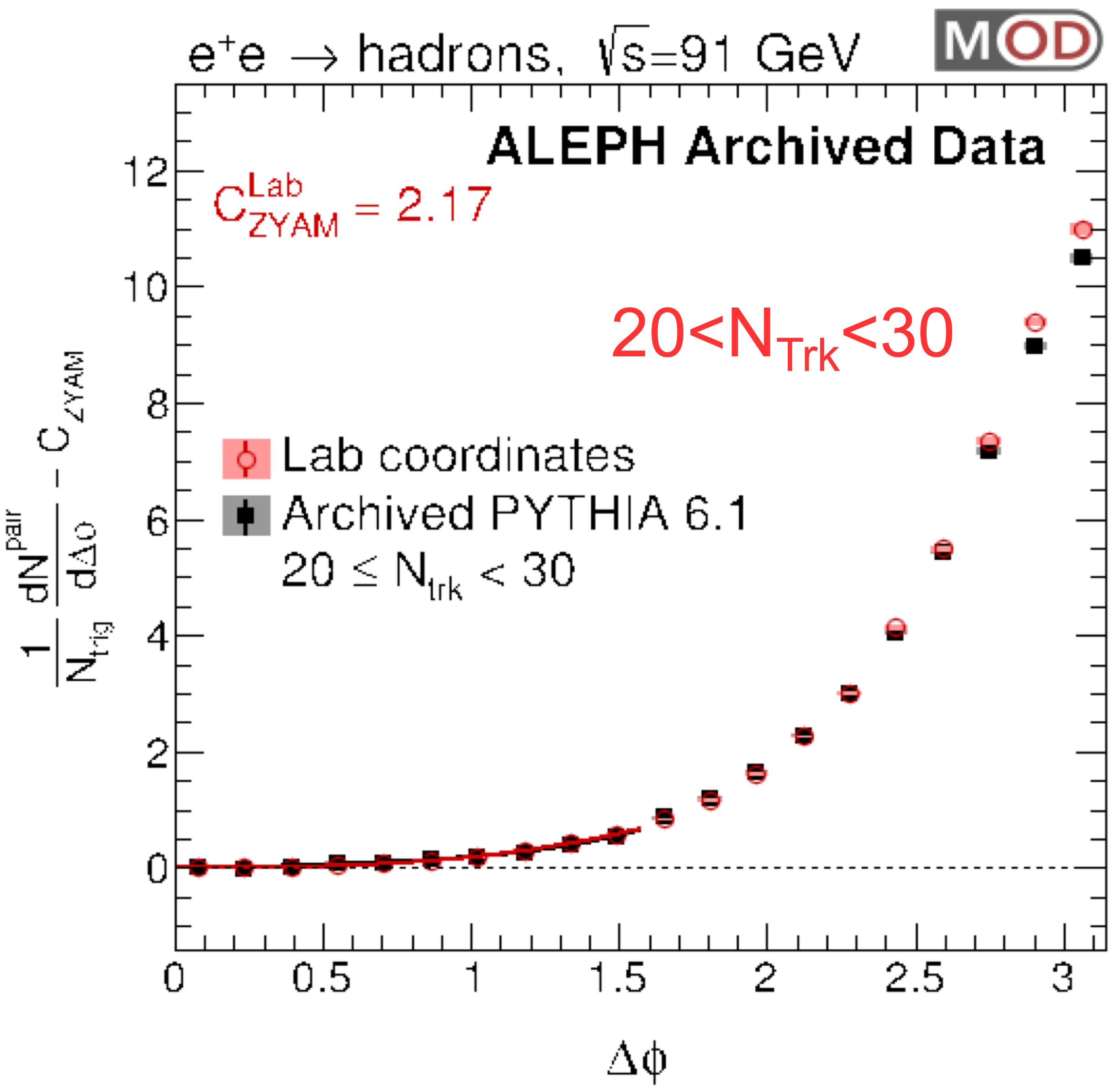




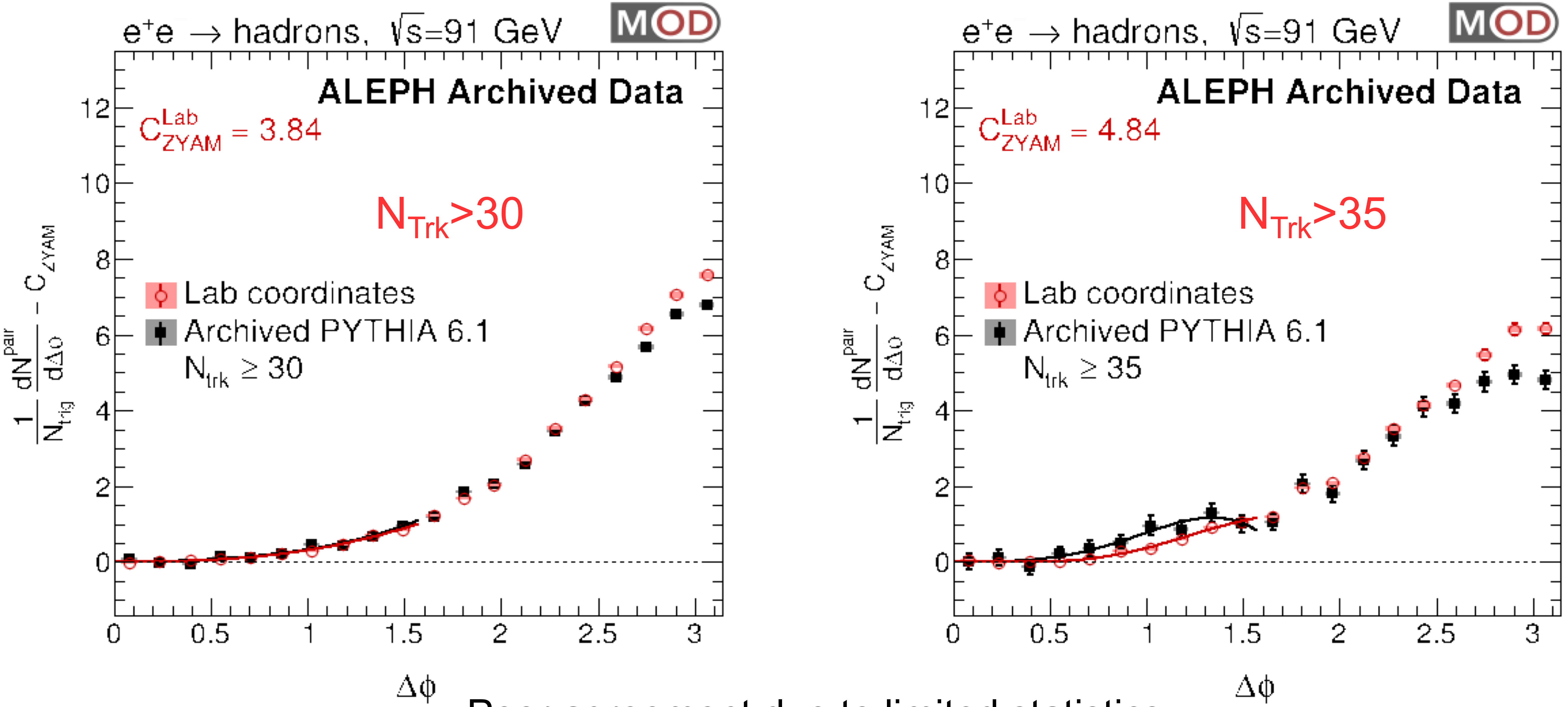
- Good agreement between PYTHIA6 and Data with some discrepancy at large ΔΦ
- No ridge observed!

Higher Multiplicities (I)



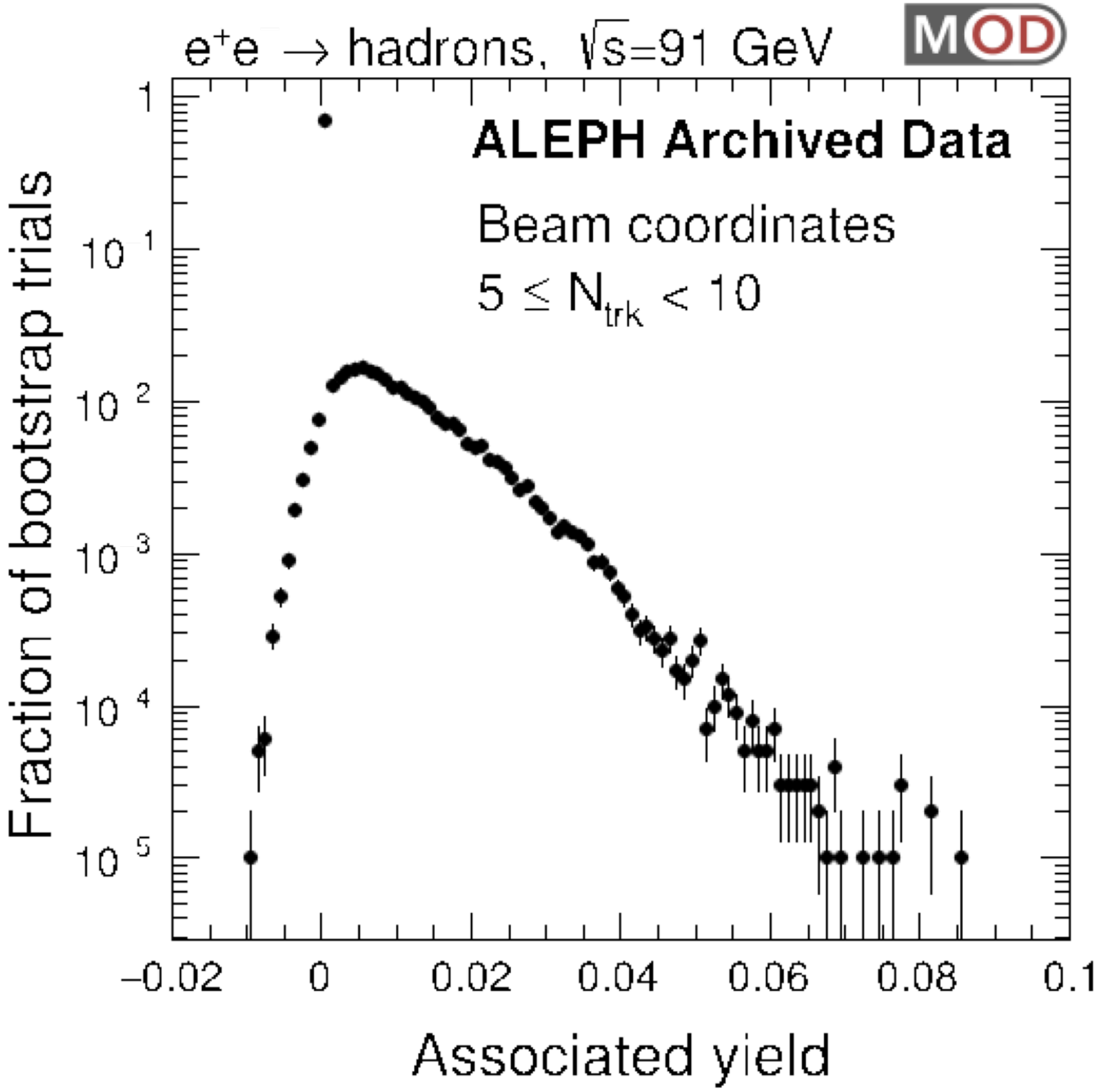


Higher Multiplicities (II)



Poor agreement due to limited statistics

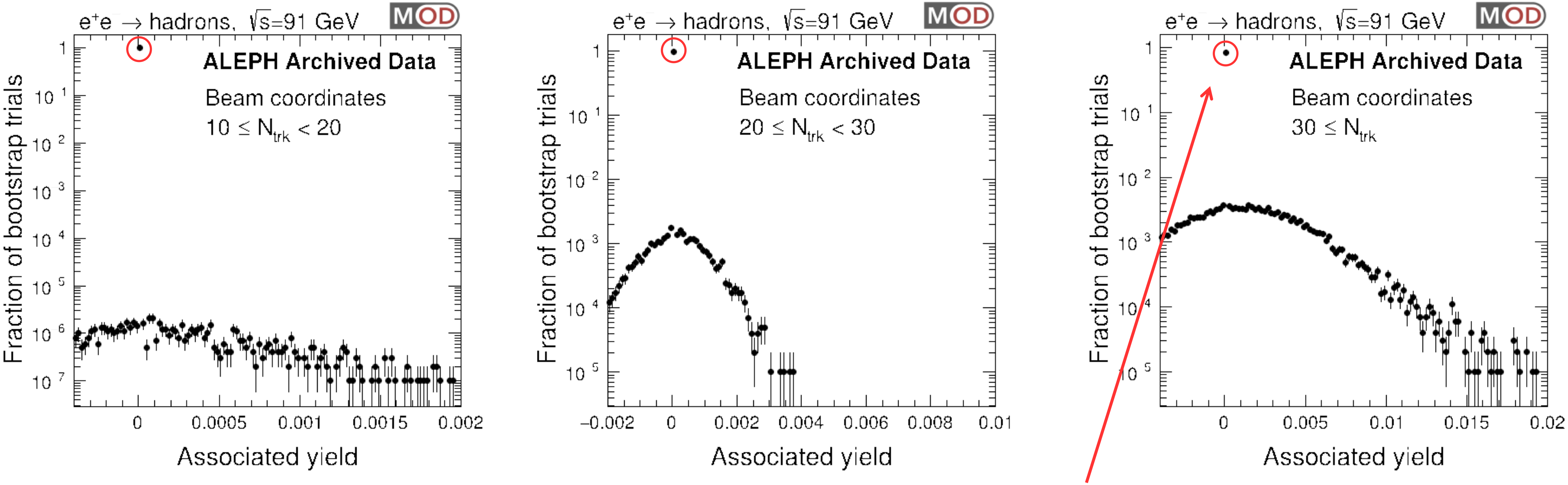
Setting a limit (I)



- Vary data within uncertainties to create pseudo-data sets
  - Randomly sample from Gaussian with μ = yield and σ = error
- Repeat fit + ZYAM subtraction
- Integrate over near-side yield

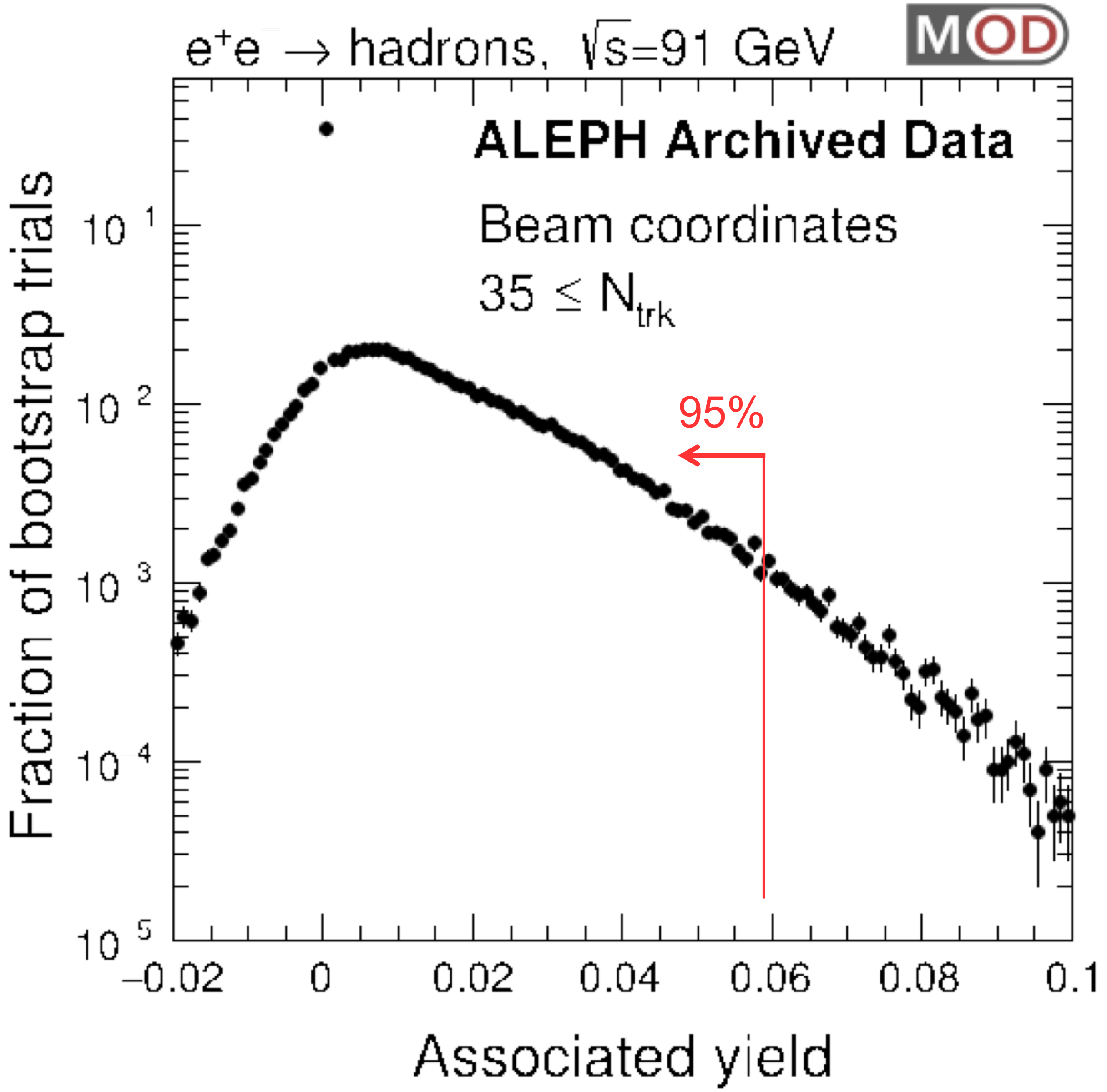
Note: It is possible to create negative yields through a combination of statistical fluctuations in the samples and fits

Setting a limit (II)



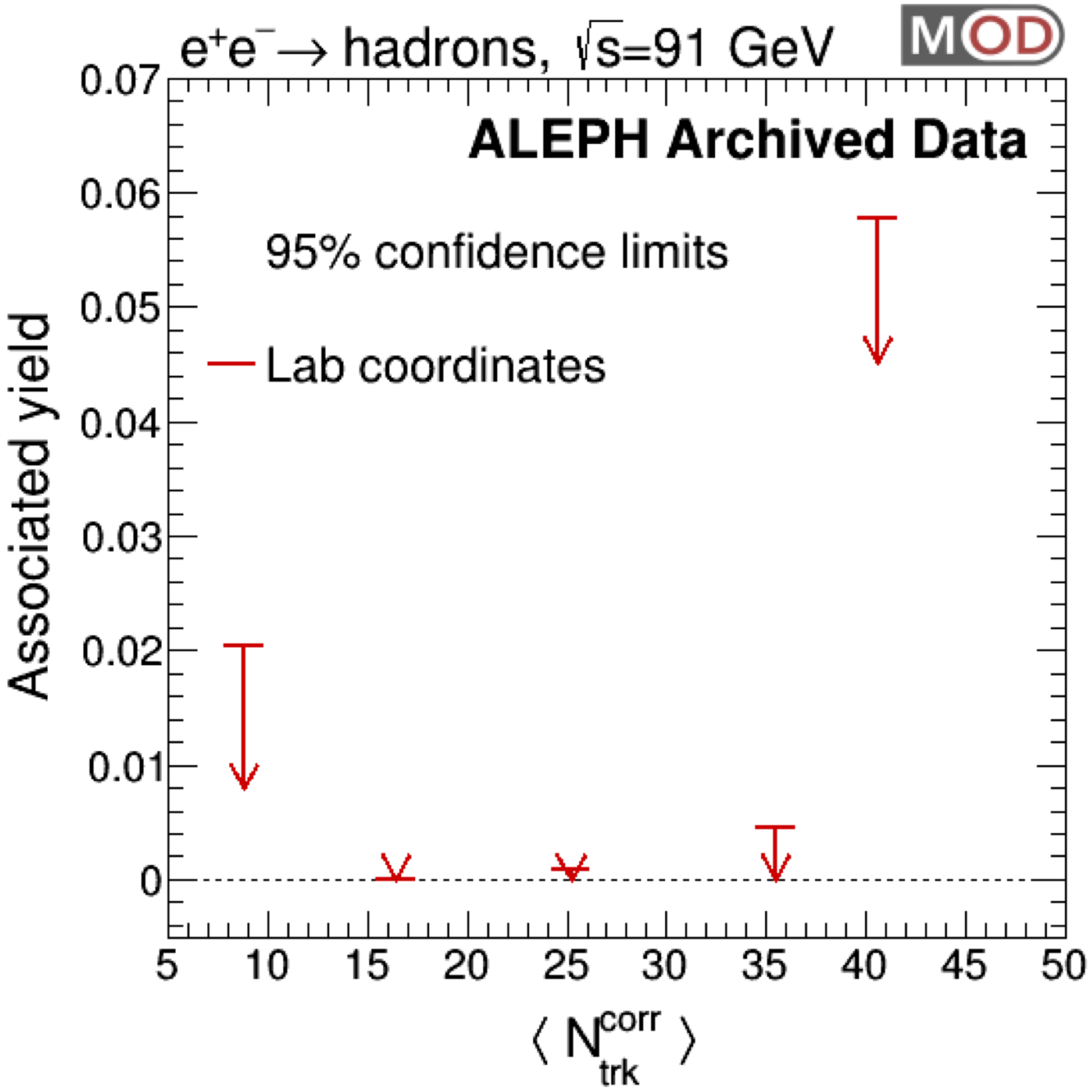
Majority of trials have no associated yield because their fits predominantly have a minimum at 0

Setting a limit (III)



- Vary data within uncertainties to create pseudo-data sets
  - Randomly sample from Gaussian with μ = yield and σ = error
- Repeat fit + ZYAM subtraction
- Integrate over near-side yield
- Find value that contains 95% of our trials

Setting a limit (IV)



- Vary data within uncertainties to create pseudo-data sets
  - For each point randomly sample from Gaussian with μ equal to the yield and σ equal to the error
- Repeat fit + ZYAM subtraction
- Integrate over near-side yield
- Find value that contains 95% of our trials
- Stringent limit for beam-axis analysis

Summary

- The first two-particle correlation analysis performed with e^+e^- collisions in bins of event multiplicity up to ~50
- Beam coordinates
  - No evidence of a final-state effect causing a near side ridge in the probed multiplicity ranges
  - This serves as an important reference for the pp, pA, and AA collision results
- Data preservation projects are valuable for future scientific collaboration and investigation!!

Acknowledgement

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We would like to thank **Wei Li**, **Maxime Guilbaud, Wit Busza** and **Yang-Ting Chen** for the useful discussions on the analysis.

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Backup

Charged Particle Multiplicity