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

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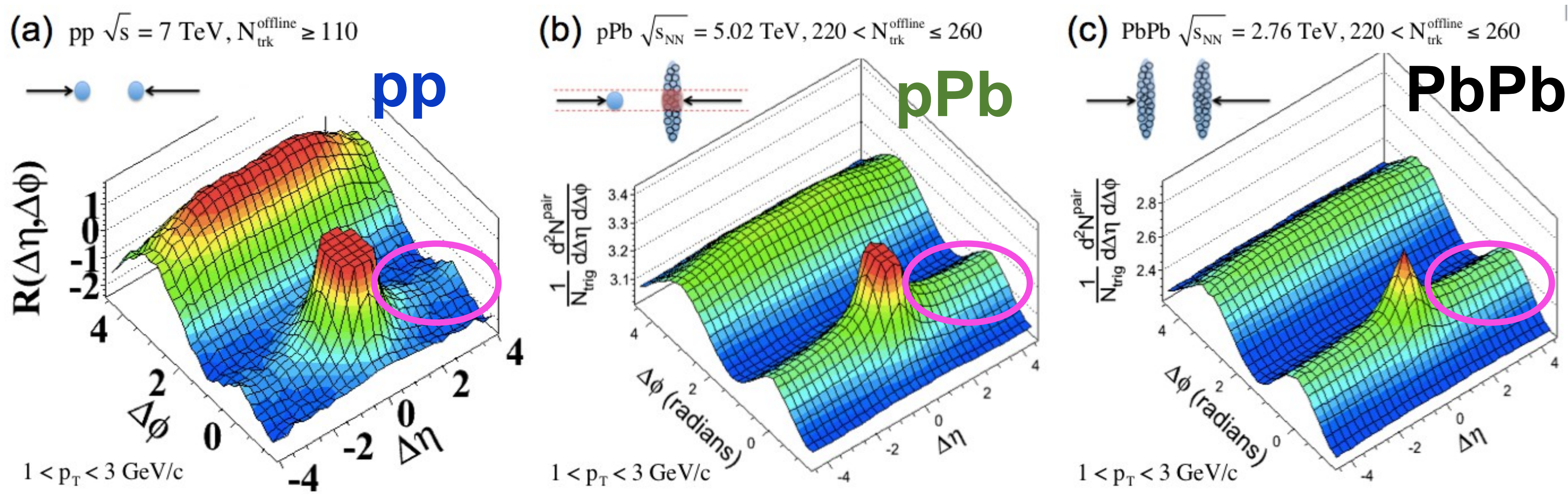
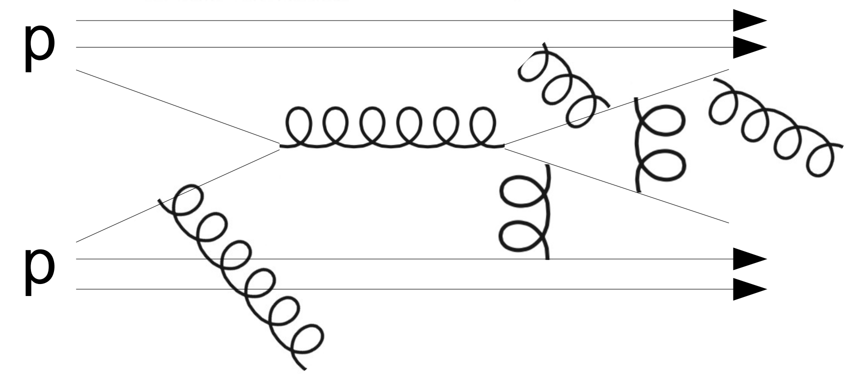
Introduction



- Origin of ridge in small systems still uncertain
  - Initial state effect (CGC)
  - Flowing mini Quark Gluon Plasma
  - MPIs
  - "Escape" mechanism
- Complications from complexity of hadronic events
  - Hadron structure
  - Gluon ISR
  - Beam remnants



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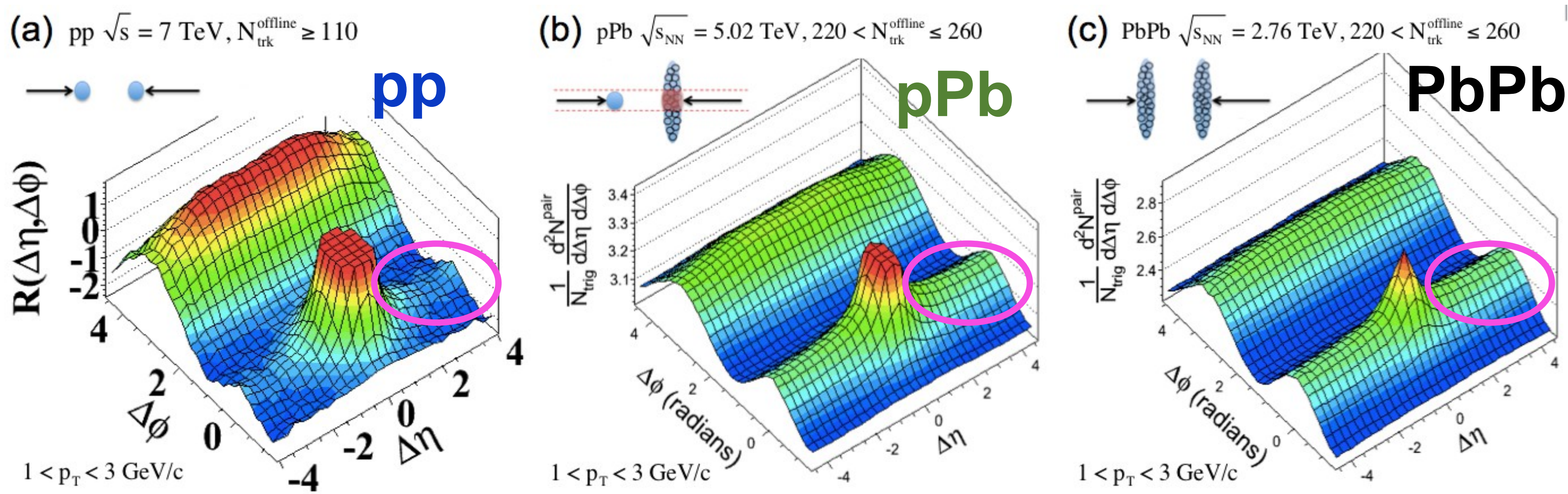

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  - Hadron structure
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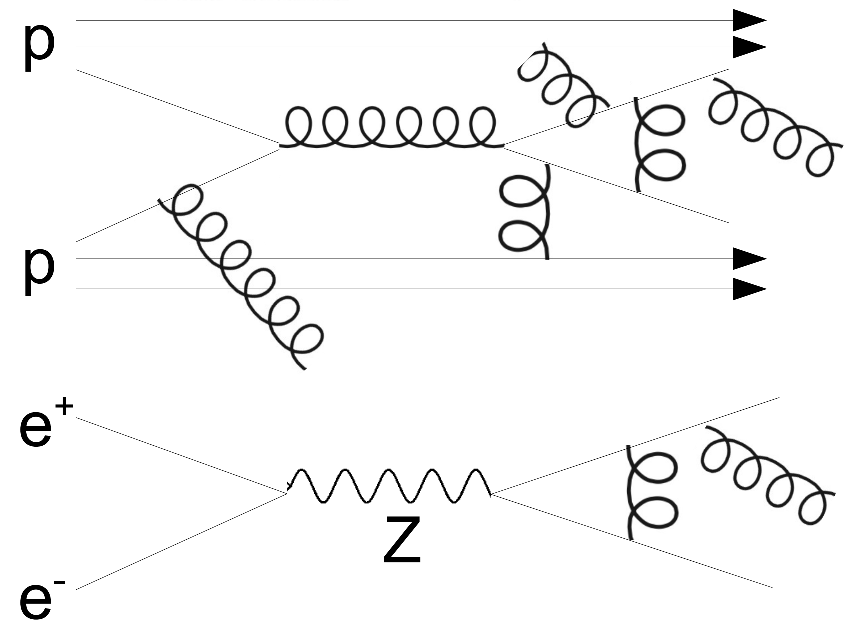
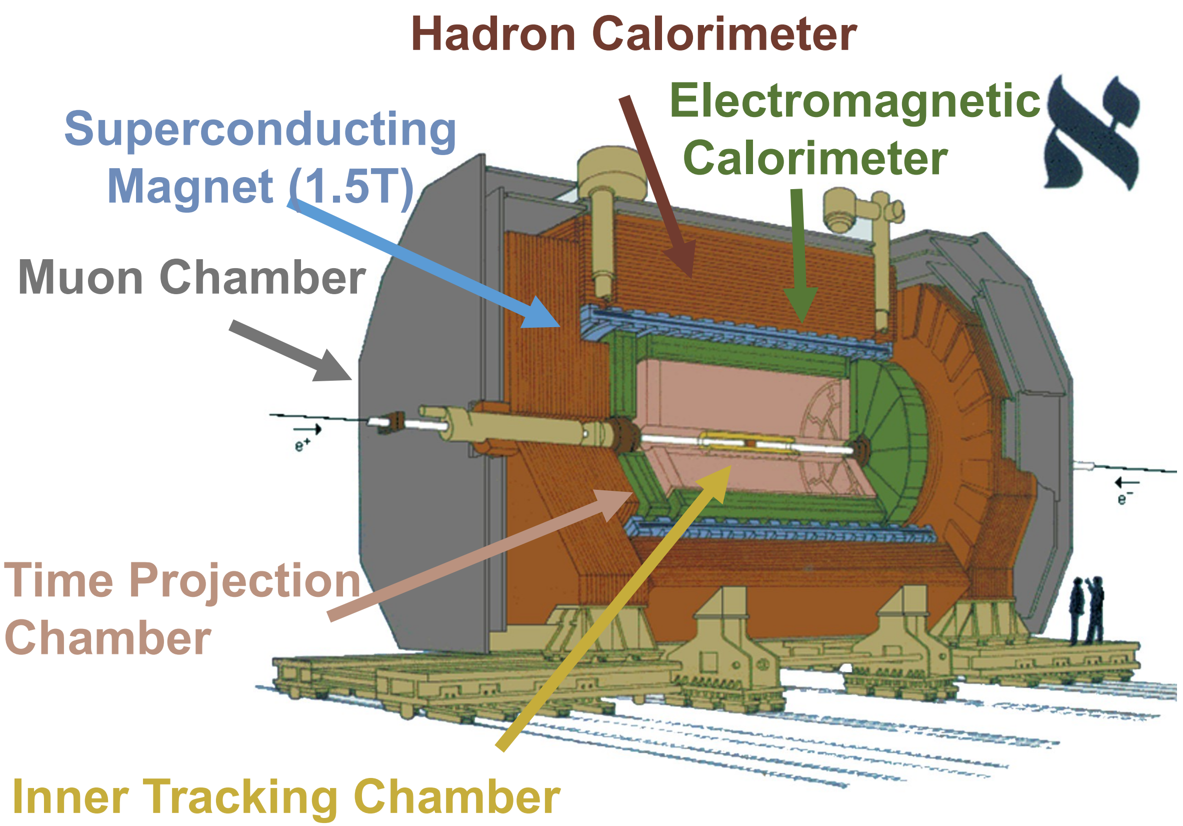
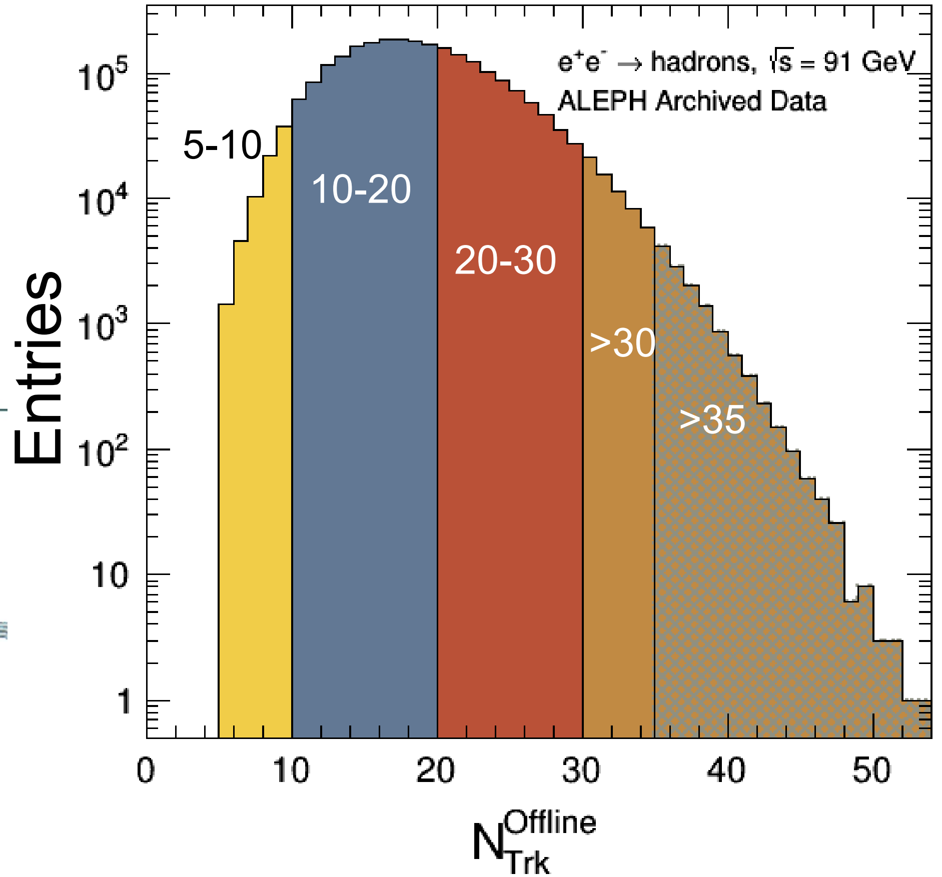
  - Beam remnants
- e^+e^- allows us to study high-multiplicity events with well-defined initial-conditions



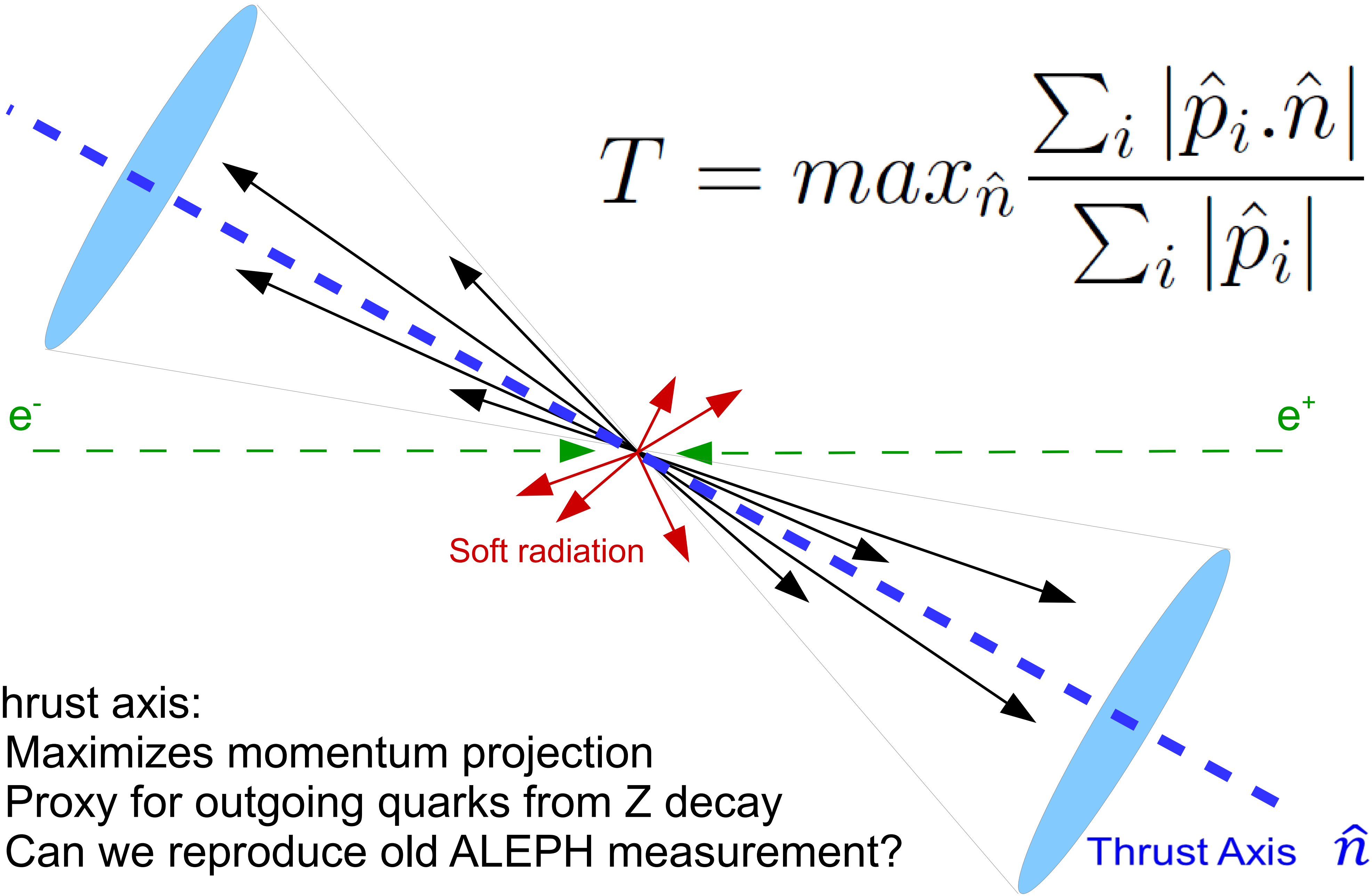
The ALEPH Detector





- LEP1 e^+e^- data at Z pole (91 GeV)
- Data archived as list of energy-flow objects
- Charged particle multiplicities up to 50
  - p_T>0.2 GeV and $|\eta|$<1.74
- Calorimeters used for event shape variables

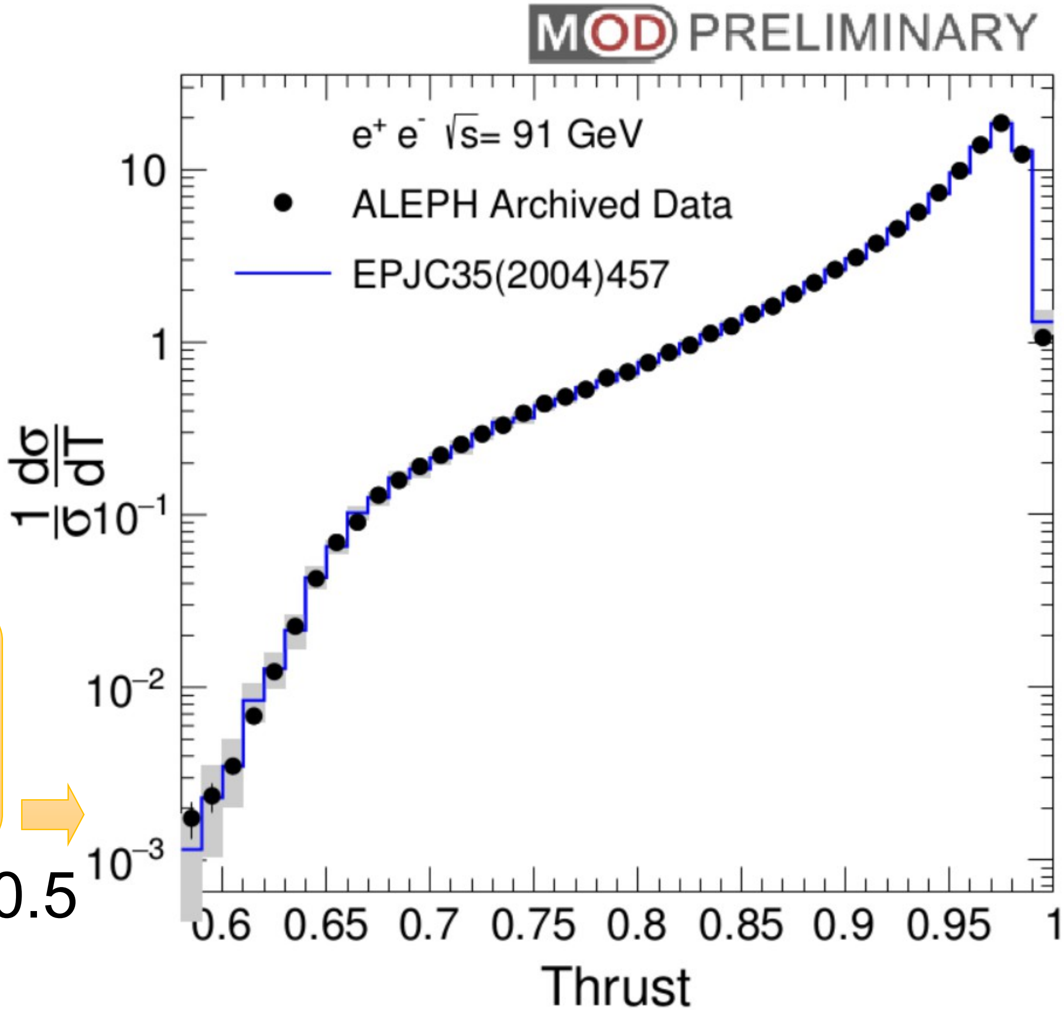
Thrust Axis definition



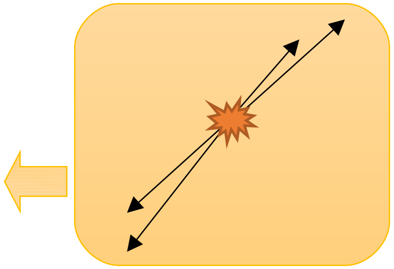
$$T = max_{\hat{n}} \frac{\sum_i |\hat{p}_i . \hat{n}|}{\sum_i |\hat{p}_i|}$$

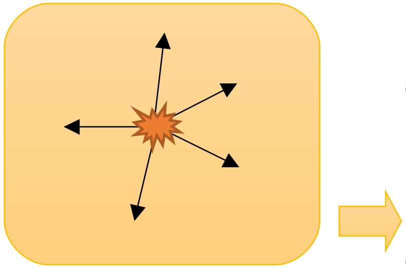
- Thrust axis:
  - Maximizes momentum projection
  - Proxy for outgoing quarks from Z decay
  - Can we reproduce old ALEPH measurement?

Unfolded Thrust Distribution



Pencil-like: T~1

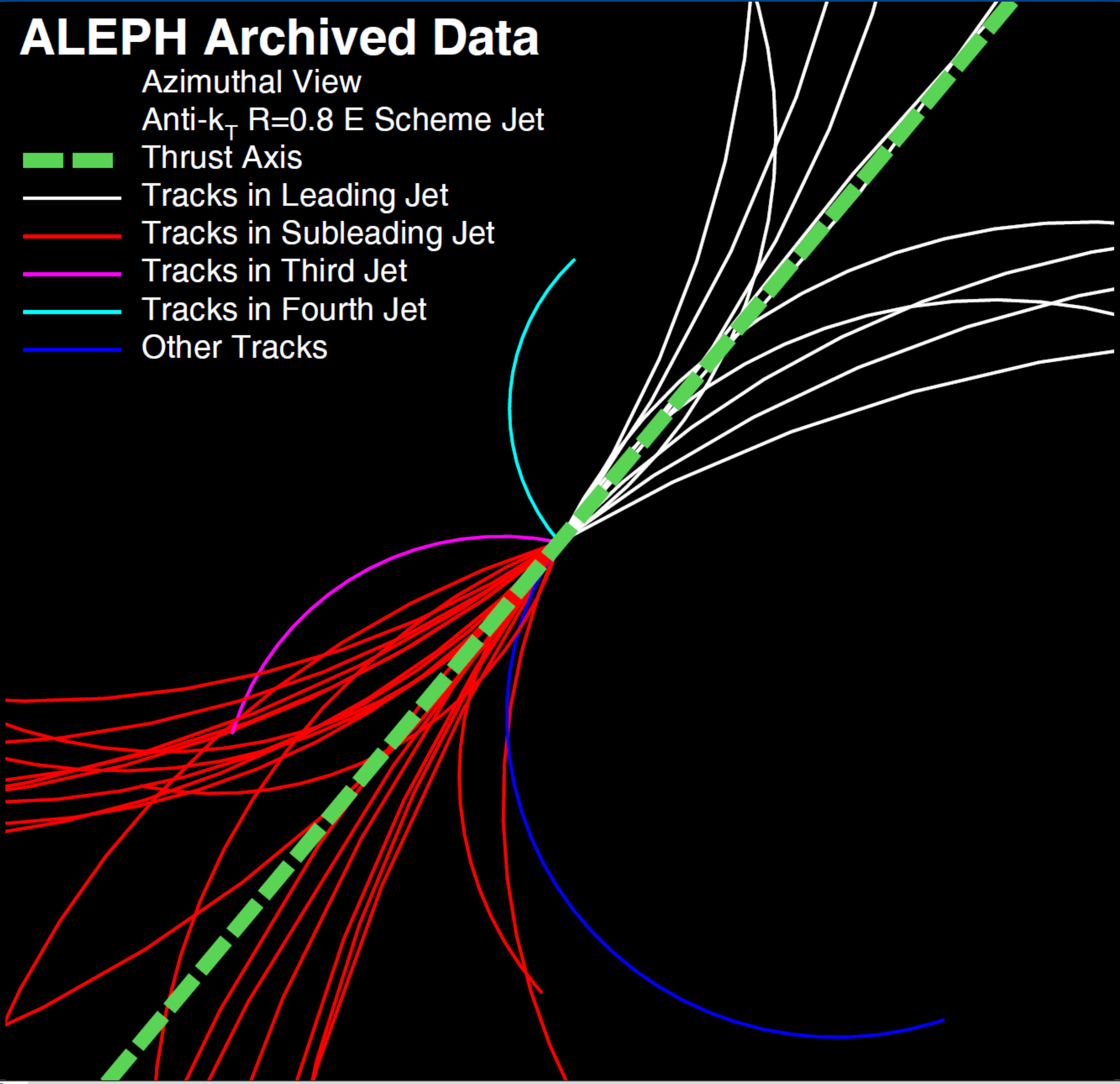




Spherical: T~0.5

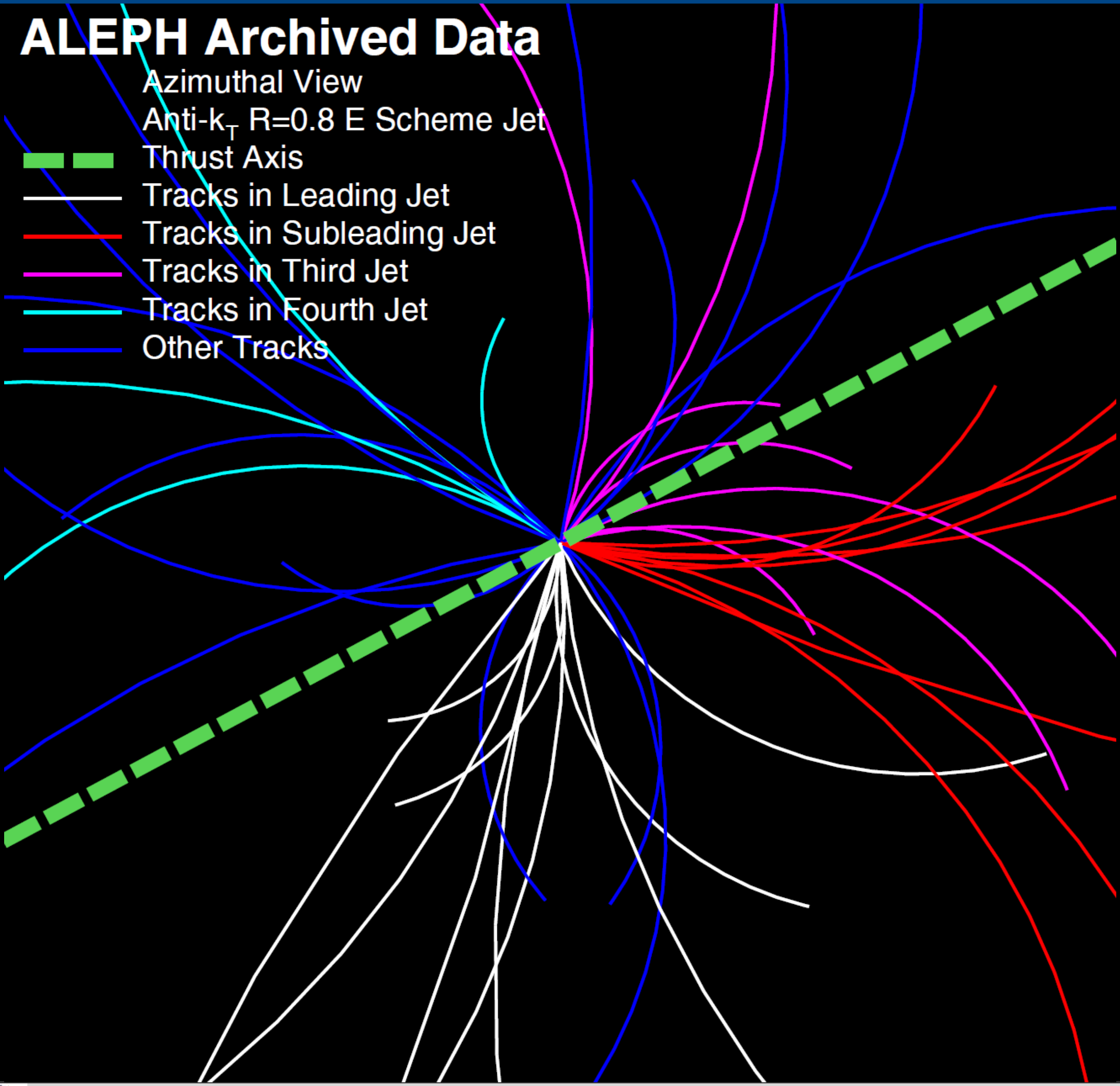
- Able to reproduce existing measurements with archived data!
- Most events are dijet-like
- But what about high-multiplicity events?

High Multiplicity e^+e^- Event (1)



39 tracks
T = 0.98

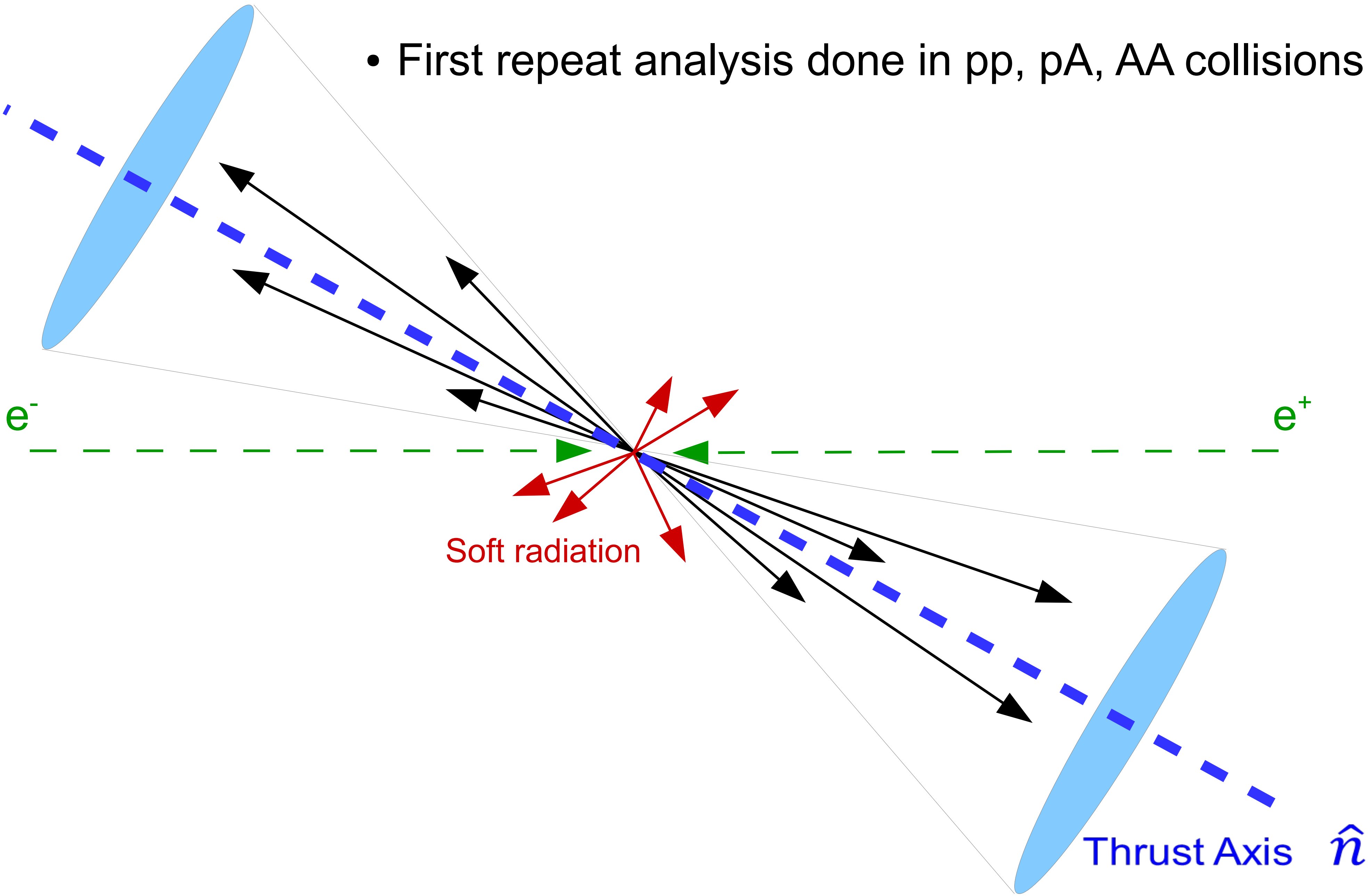
High Multiplicity e^+e^- Event (2)



44 tracks
T = 0.57

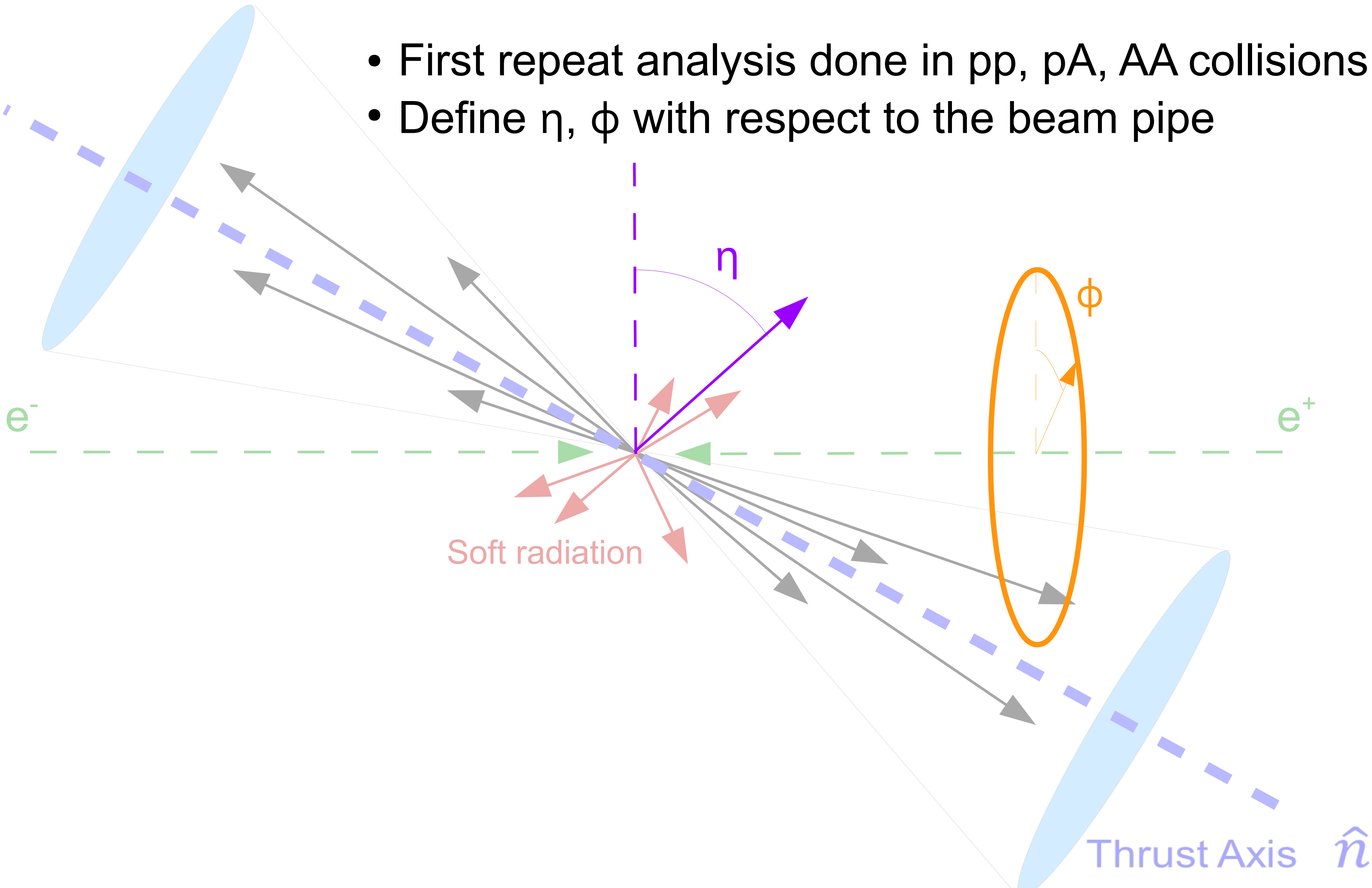
Beam-axis coordinates

- First repeat analysis done in pp, pA, AA collisions



Beam-axis coordinates

- First repeat analysis done in pp, pA, AA collisions
- Define η, ϕ with respect to the beam pipe



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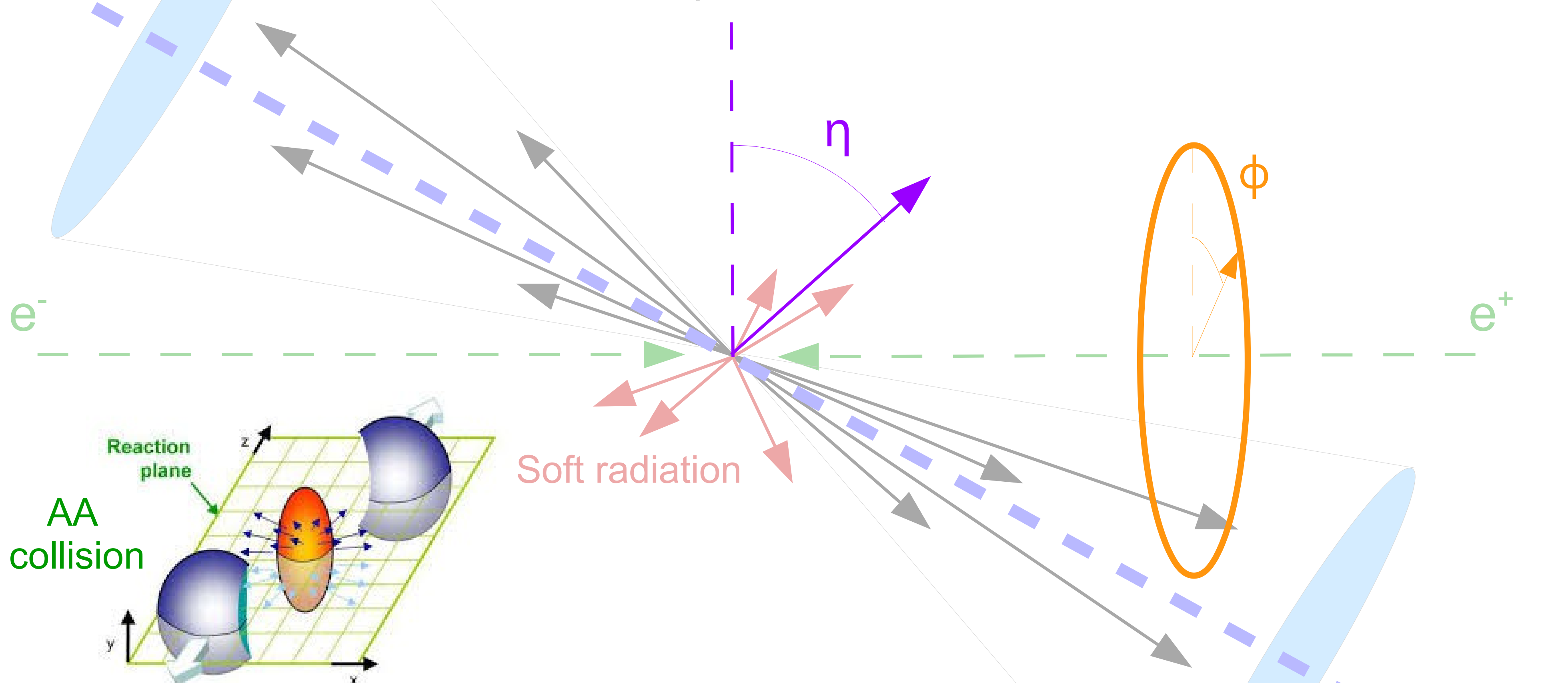
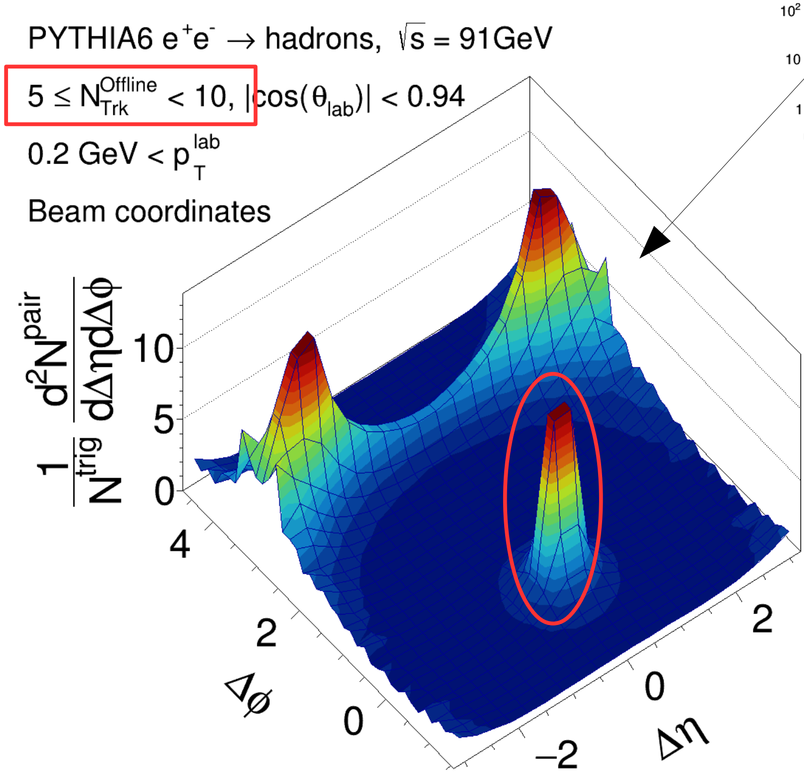


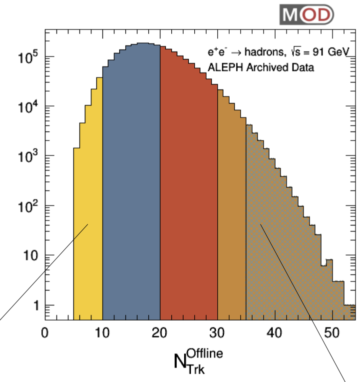
- Look for near-side ridge in two-particle correlation
  - Large Δη, small Δϕ
- Sensitive to expansion of 'mini-QGP' perpendicular to beam axis

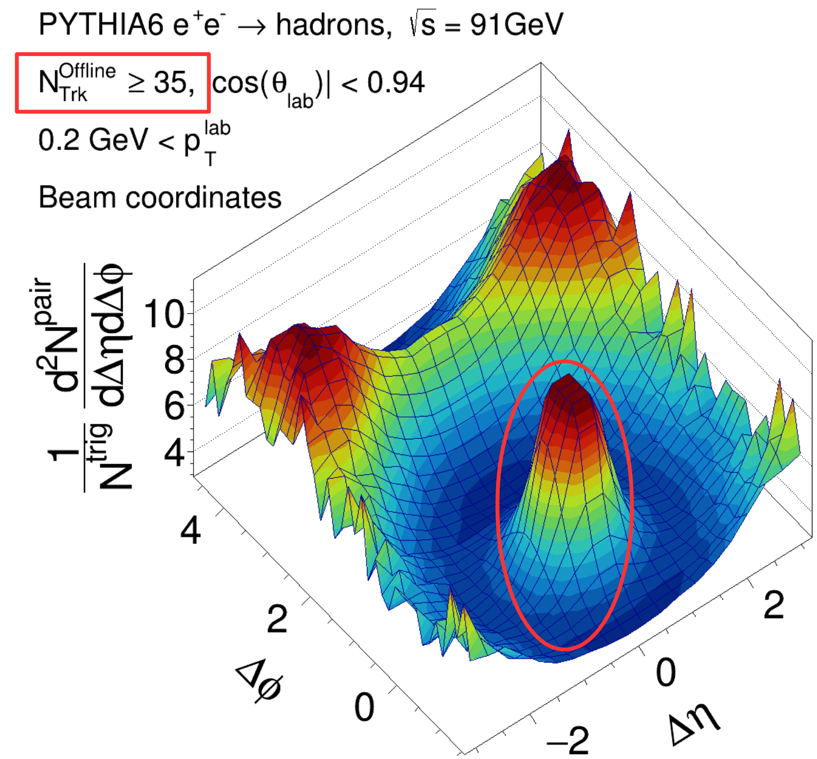
Beam-axis two-particle correlation

Low Multiplicity

High Multiplicity



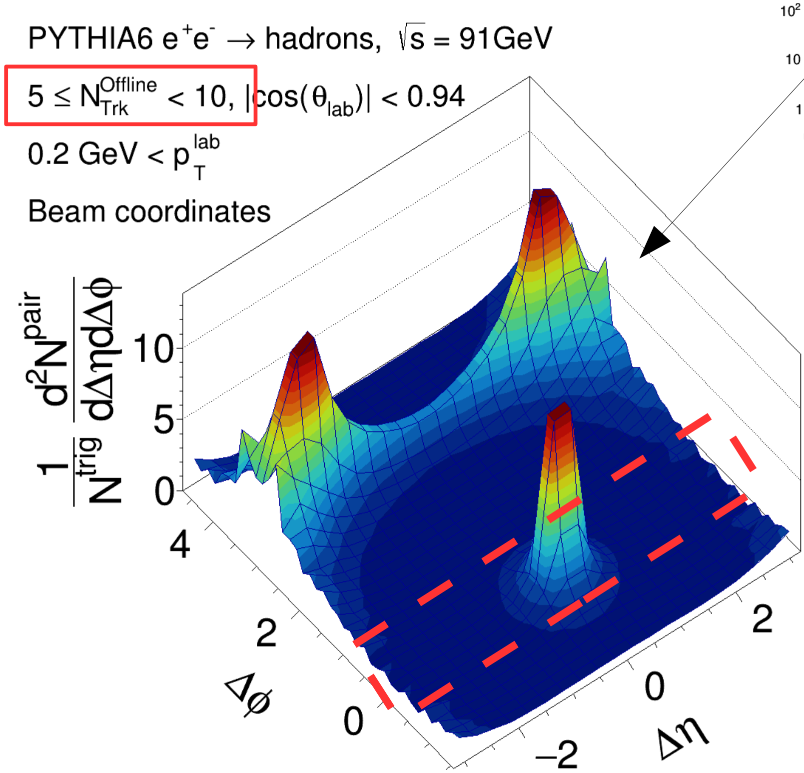


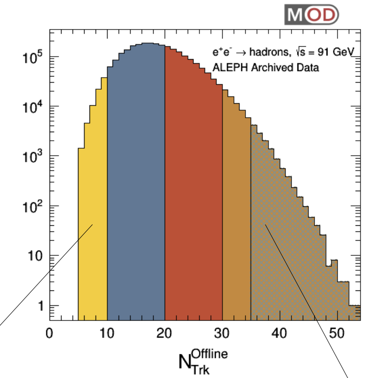


- Clear jet peak at $(\Delta\eta, \Delta\phi) = (0,0)$

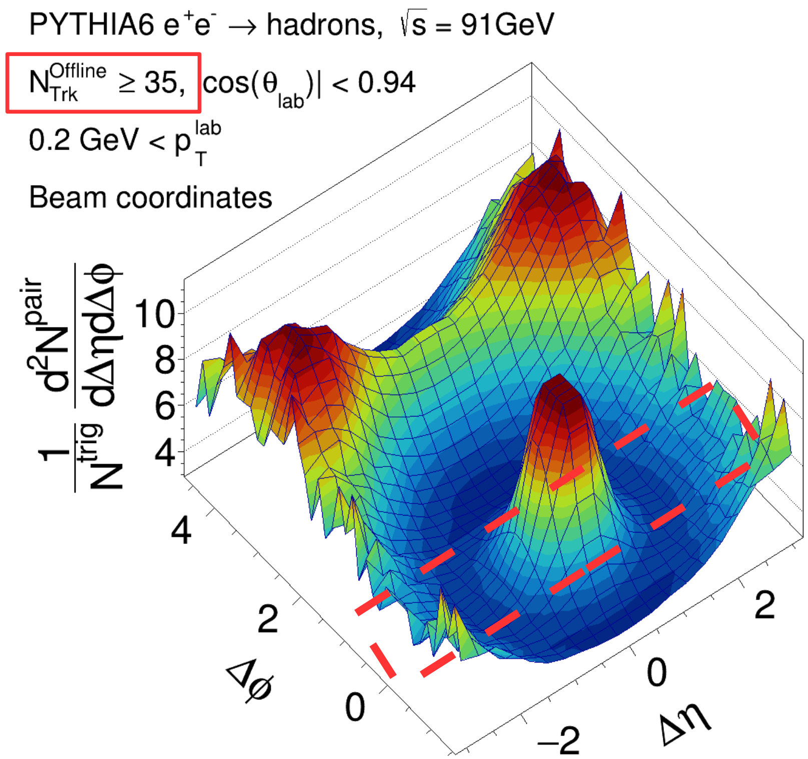
Beam-axis two-particle correlation

- Low Multiplicity





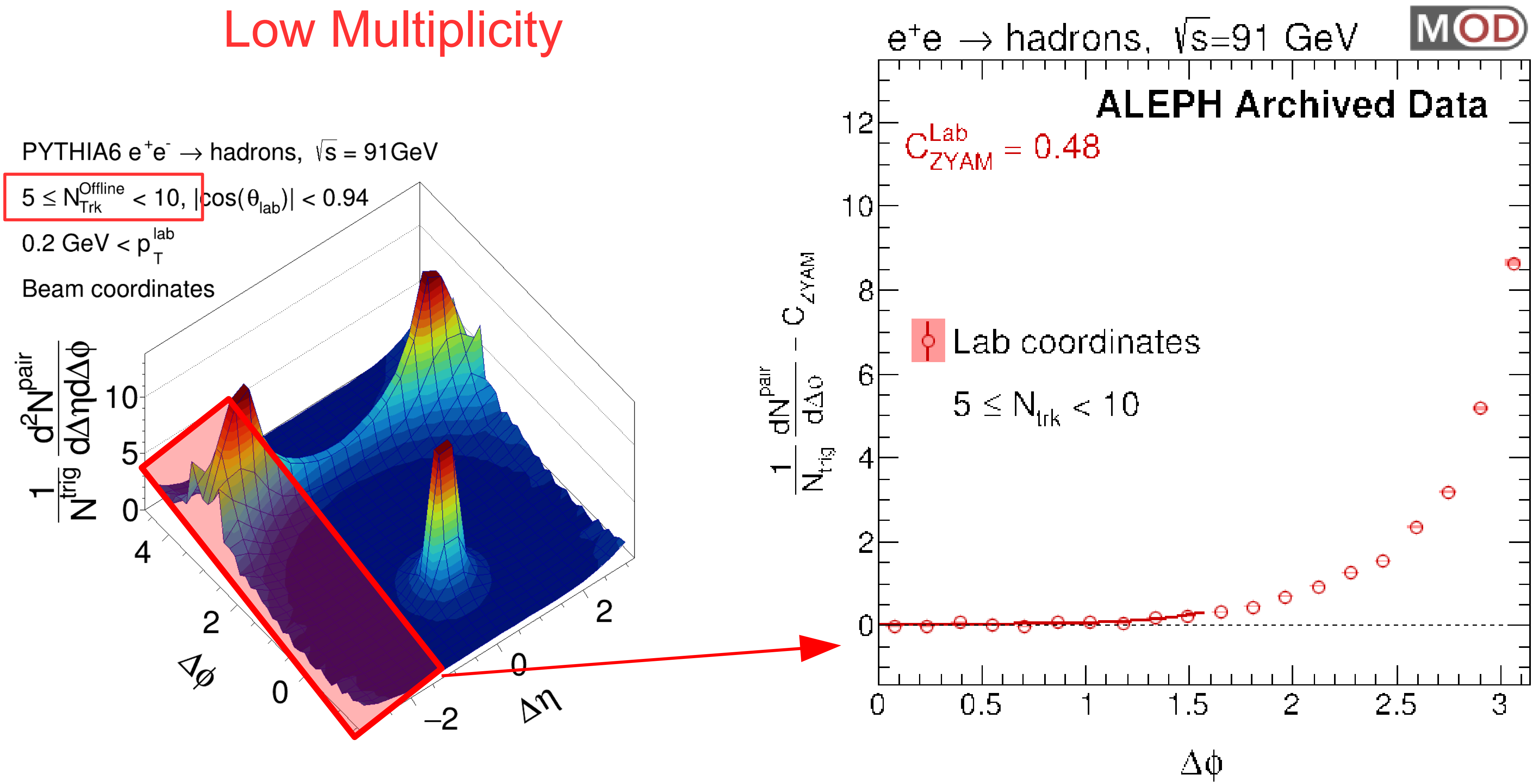
High Multiplicity



- Clear jet peak at $(\Delta\eta,\Delta\phi) = (0,0)$
- No clear near-side ridge

Projection

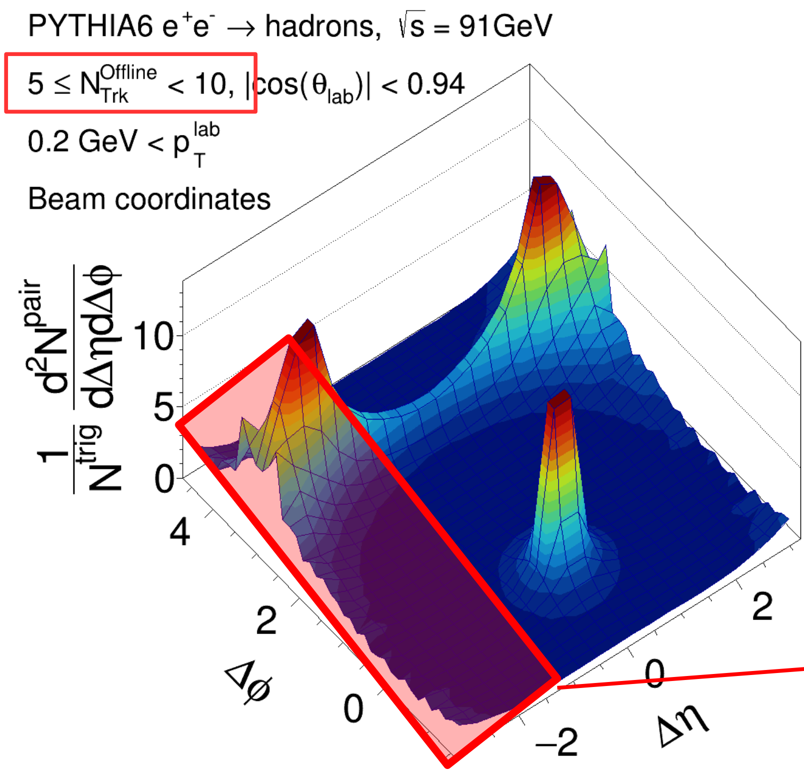
Low Multiplicity

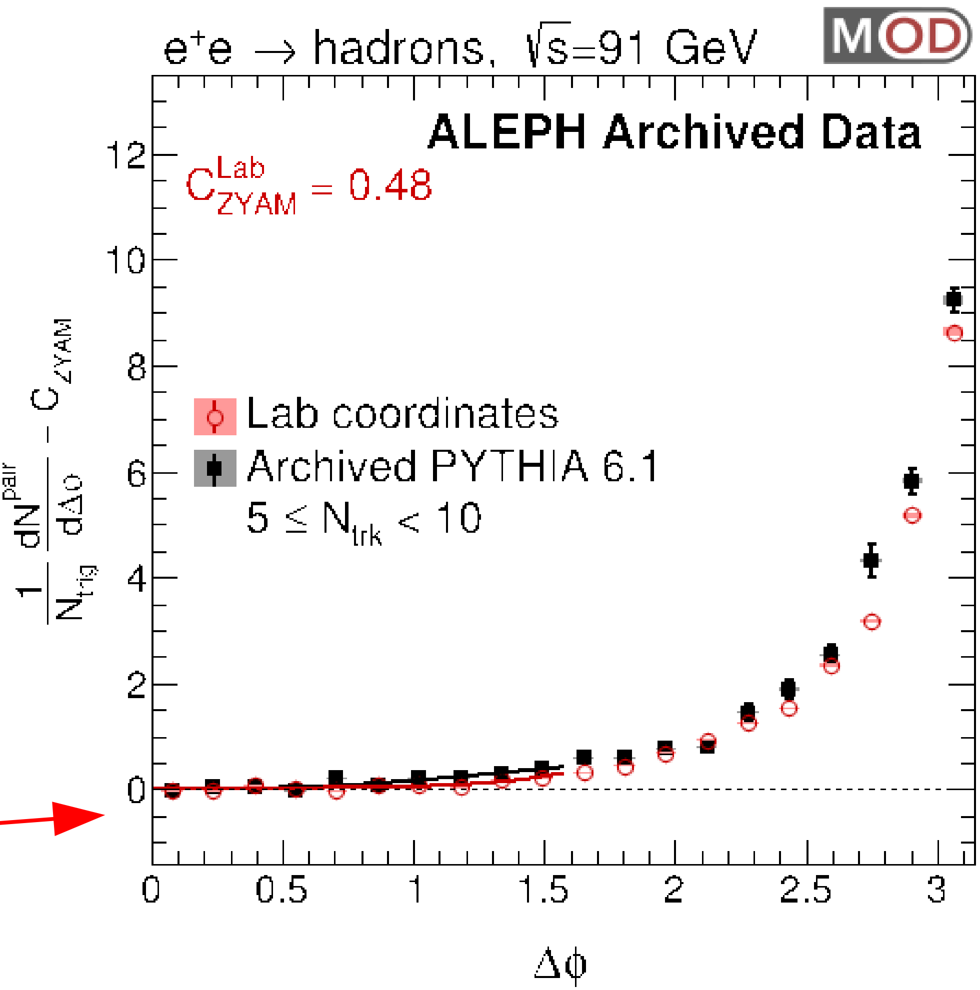


- Project $1.6<|\Delta\eta|<3.2$ into a 1D plot
- Fit data from $0<|\Delta\phi|<\pi/2$ with Fourier series
- Subtract off the 'zero yield at minimum' (ZYAM)

Projection

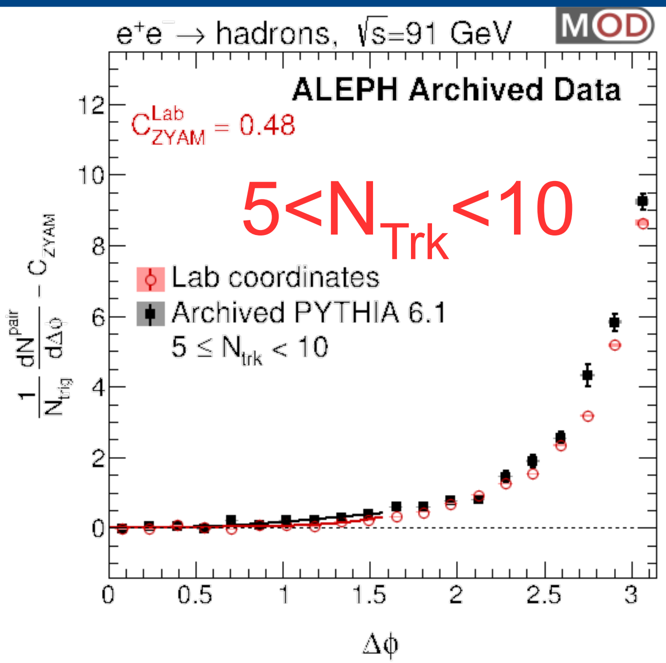
Low Multiplicity

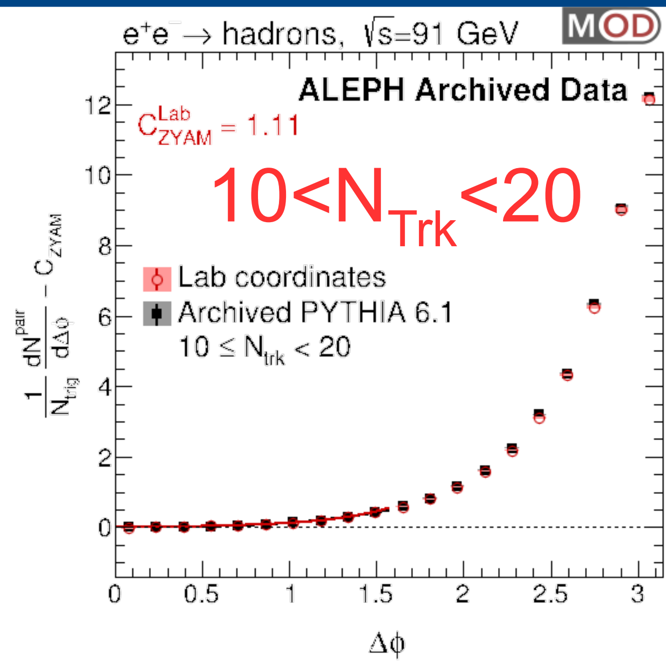


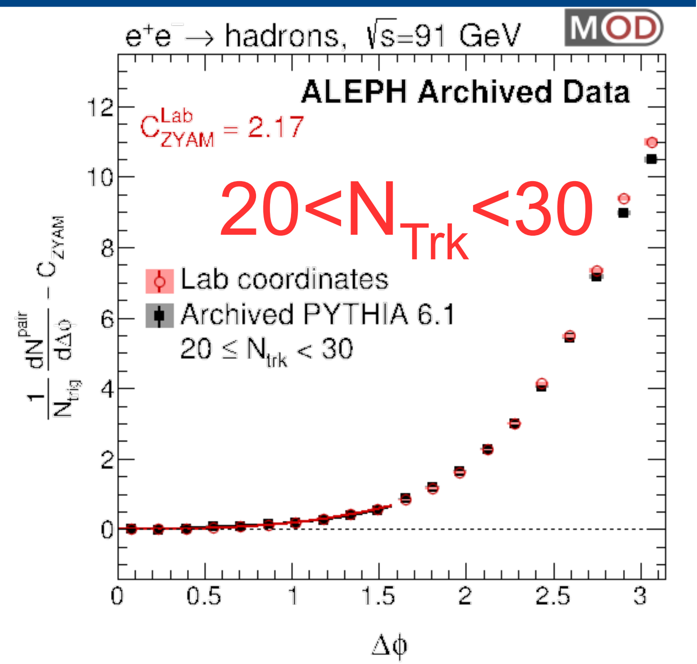


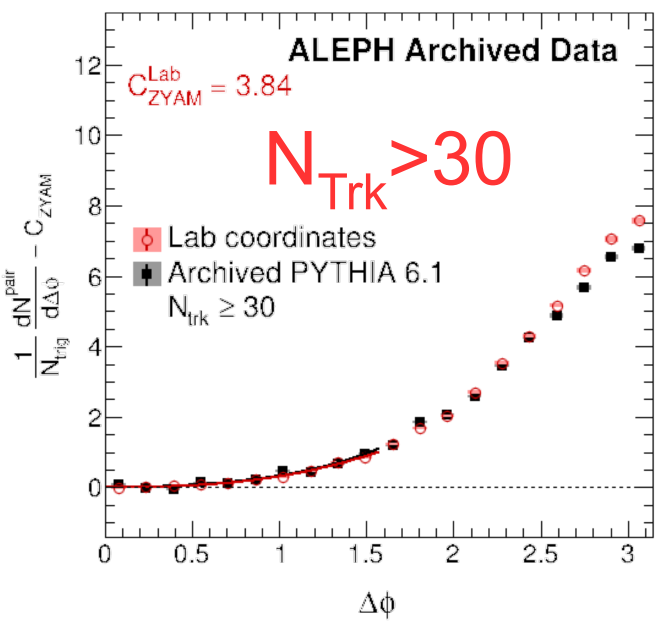
- Very similar to archived PYTHIA 6.1 predictions

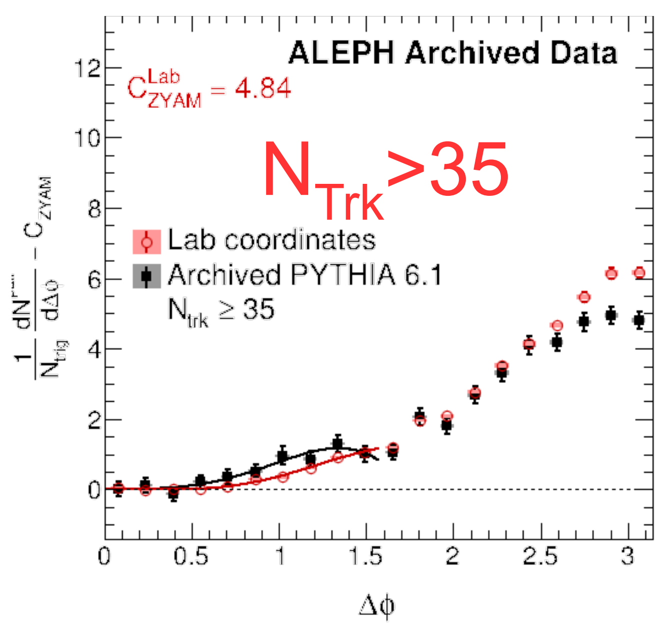
Going to higher multiplicities...







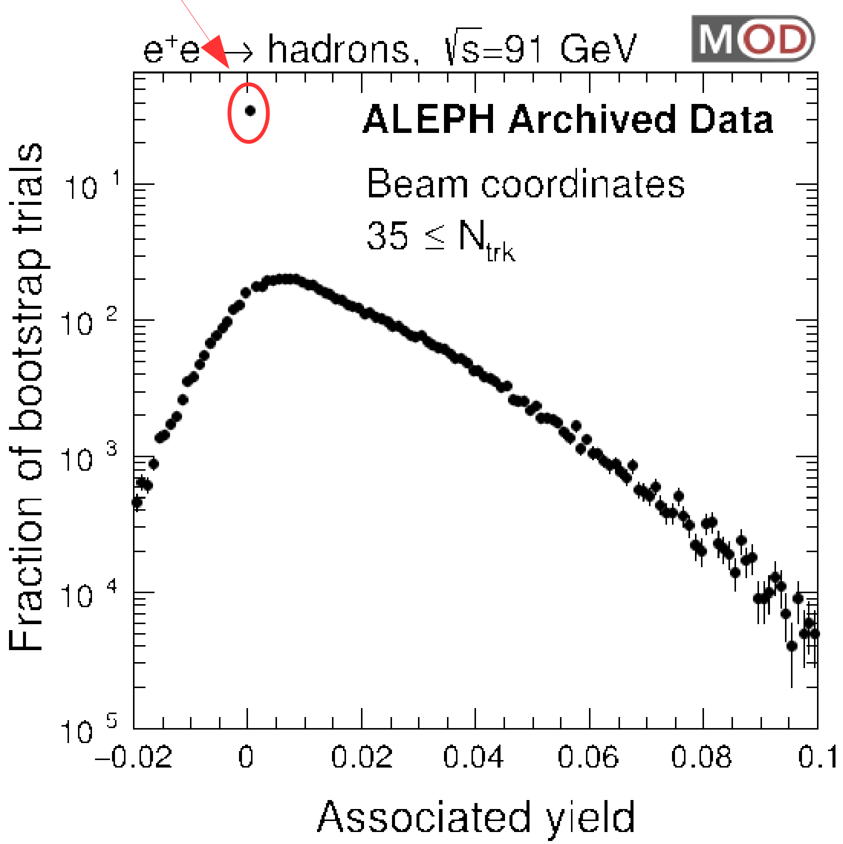




- No ridge observed!
- Agreement with PYTHIA6 is excellent for 10-20 multiplicity bin
- Some discrepancy at large $\Delta\phi$

Setting a limit

- Vary data within uncertainties to create pseudodata sets
- Repeat fit + ZYAM, integrate any near-side yield
- Majority of trials have no associated yield



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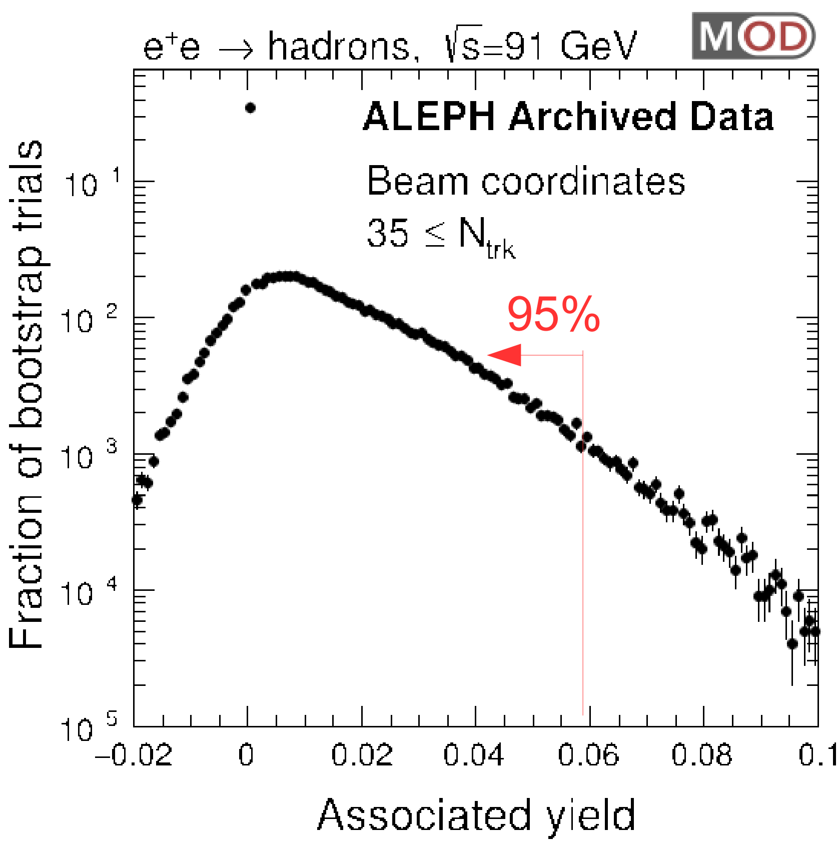

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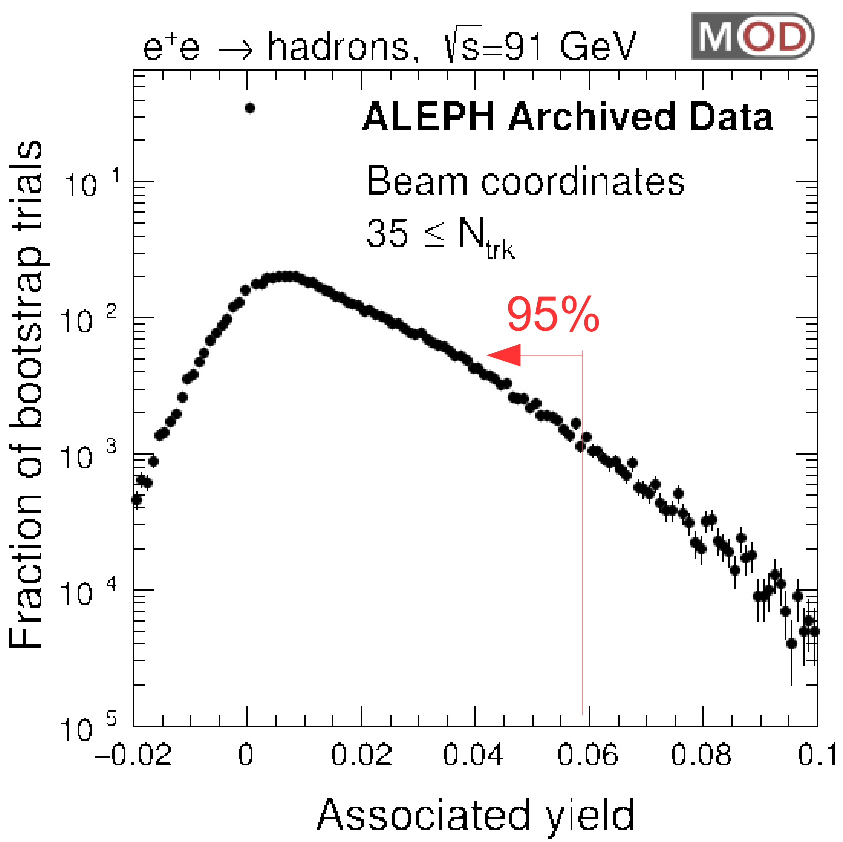
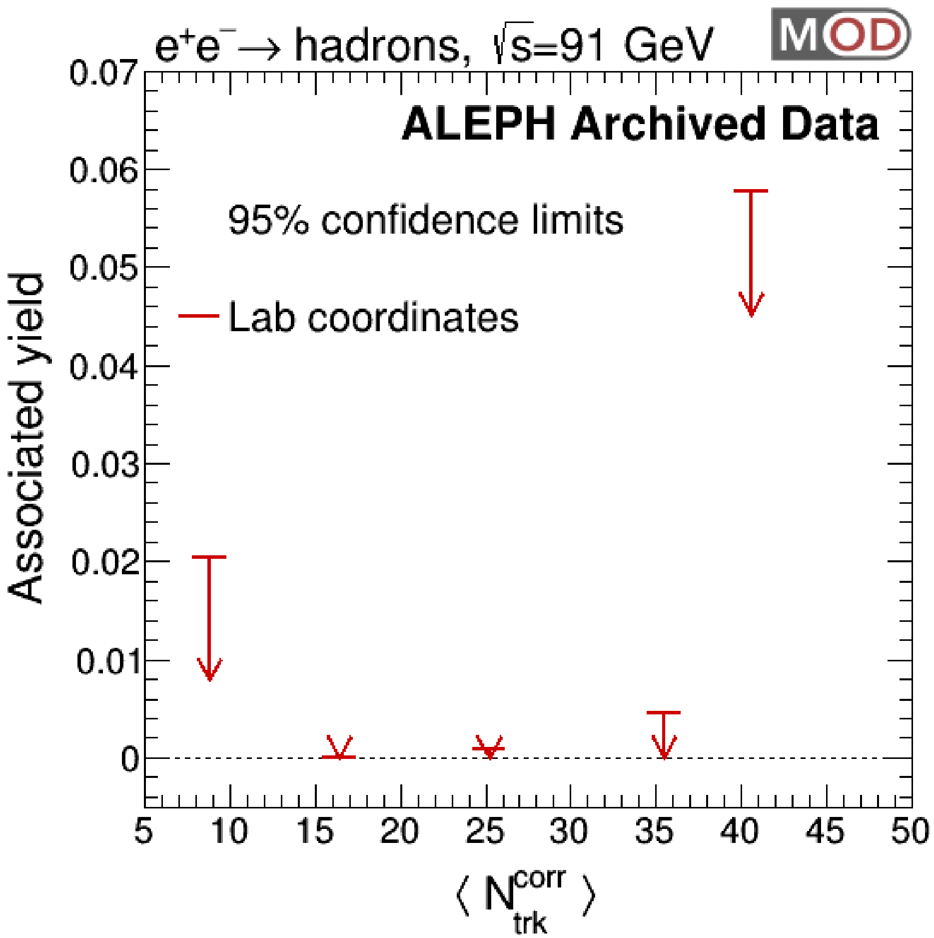
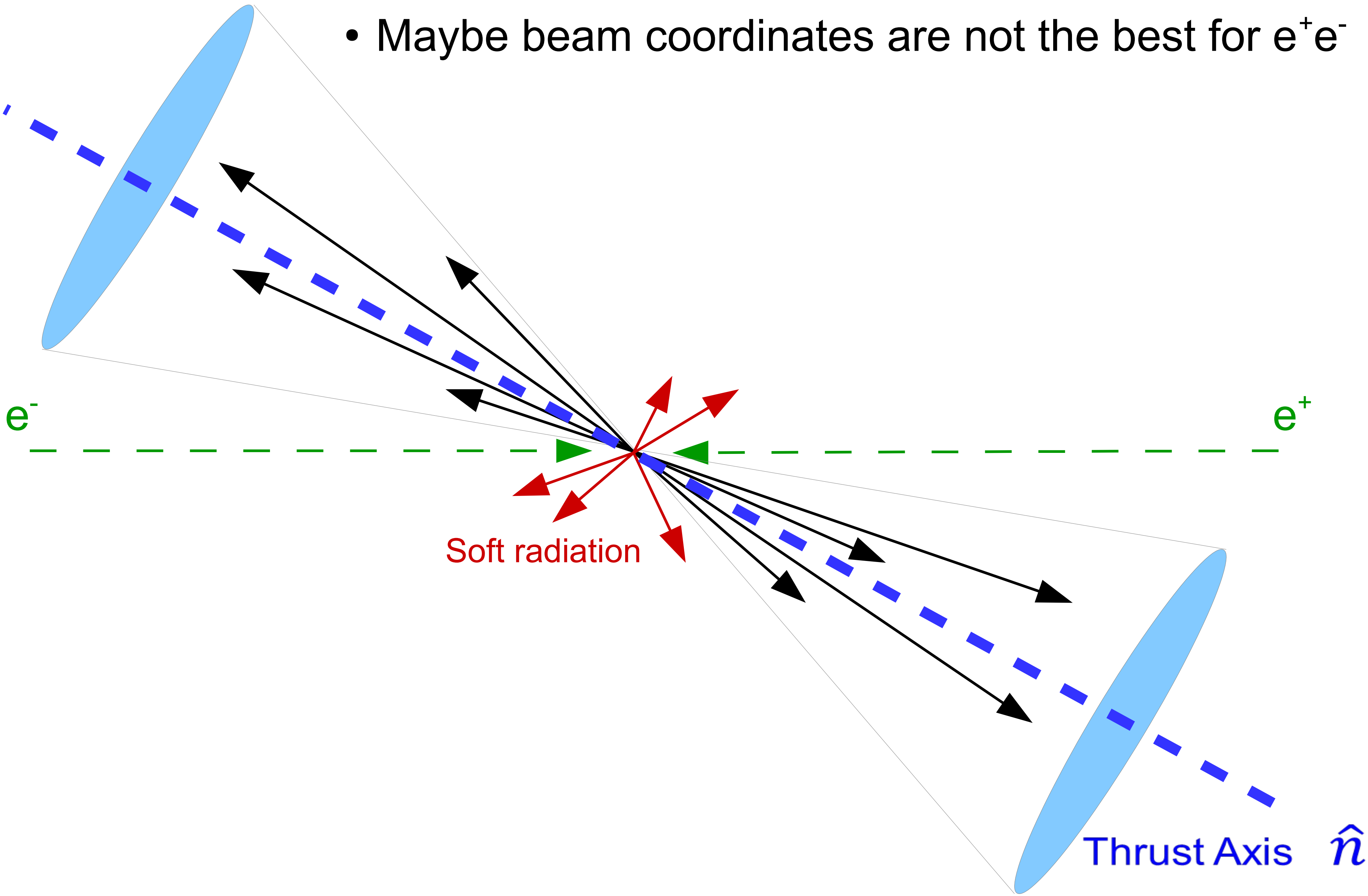
- Stringent limit for beam-axis analysis





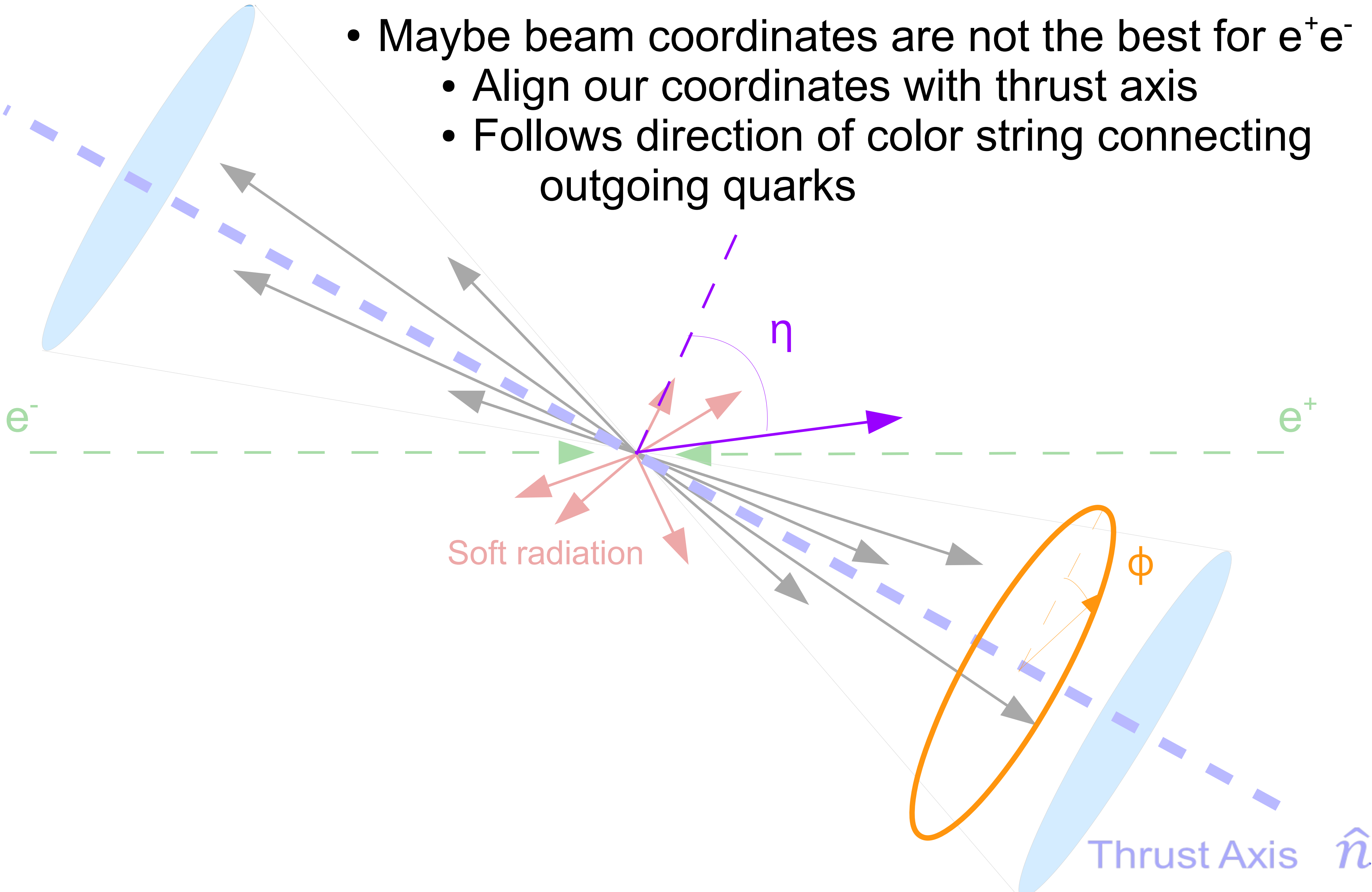
Thrust-axis coordinates

- Maybe beam coordinates are not the best for e^+e^-



Thrust-axis coordinates

- Maybe beam coordinates are not the best for e^+e^-
  - Align our coordinates with thrust axis
  - Follows direction of color string connecting outgoing quarks



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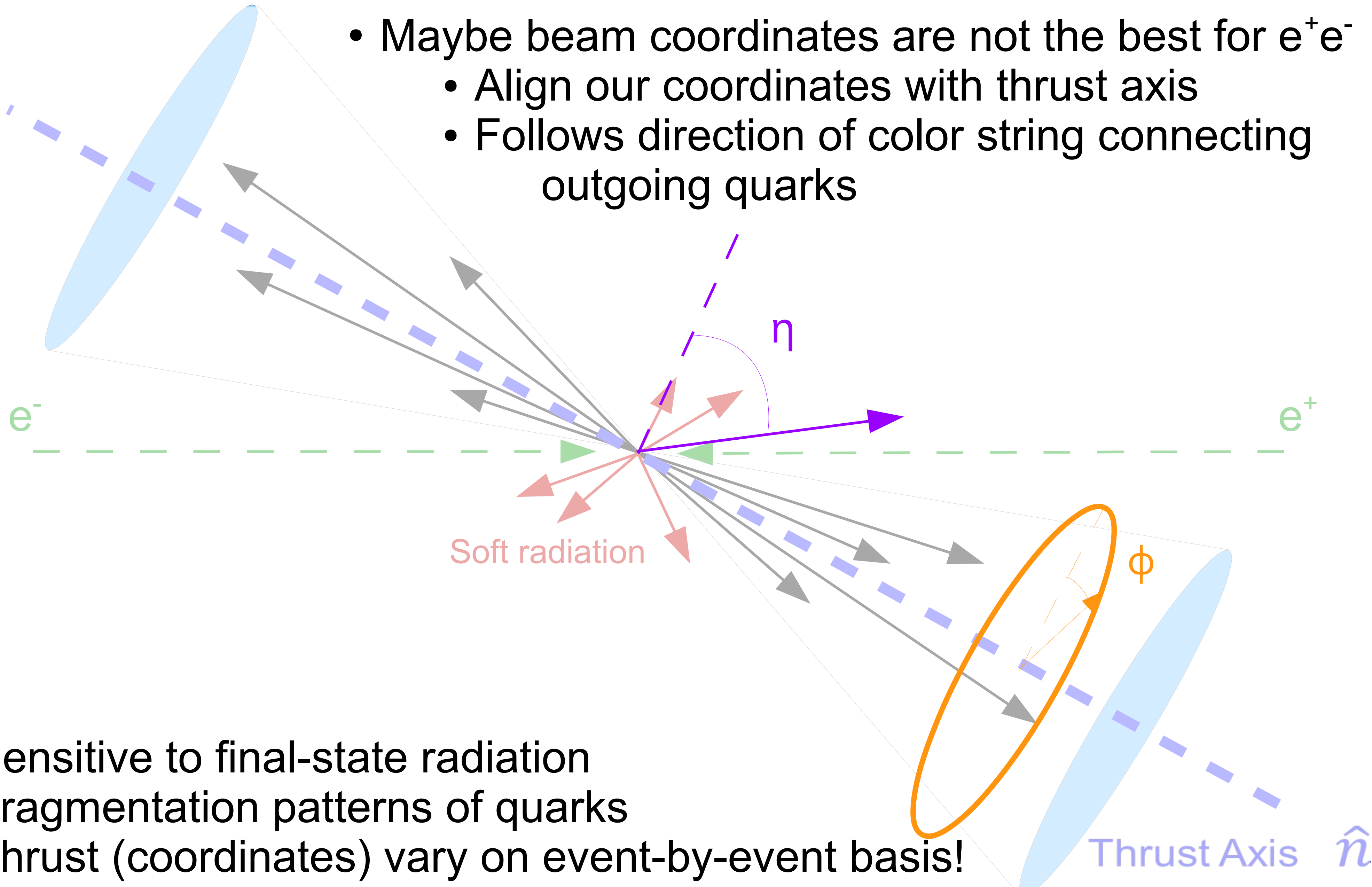
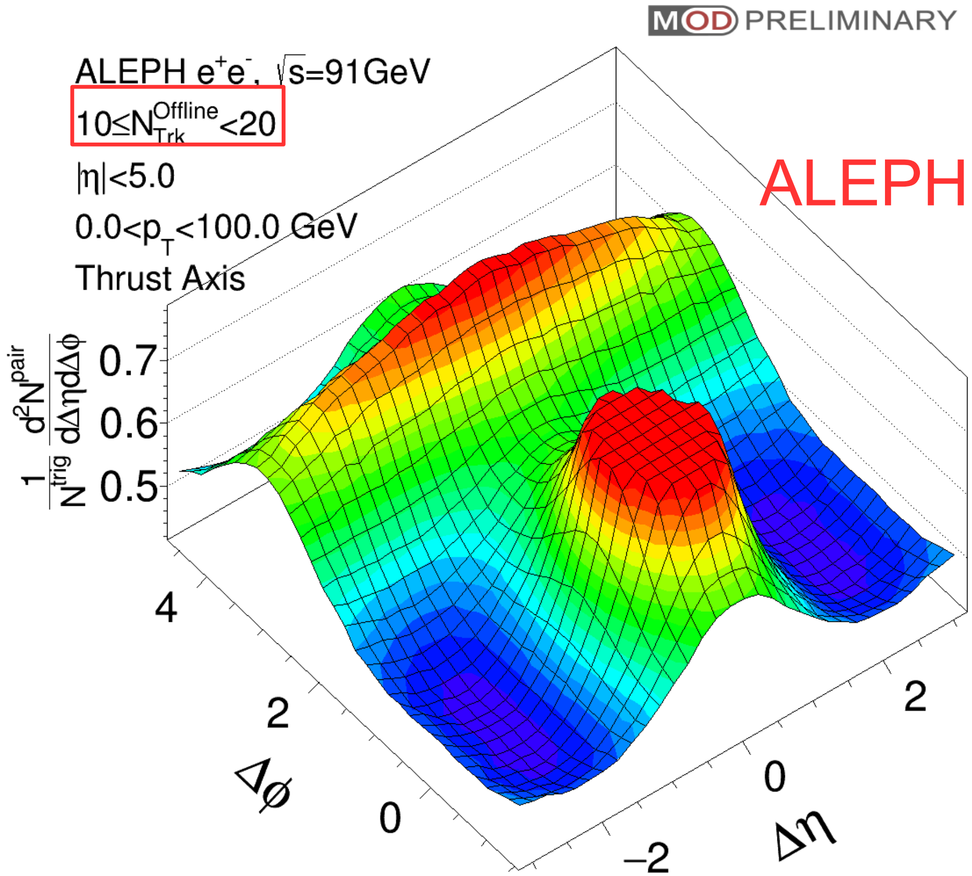
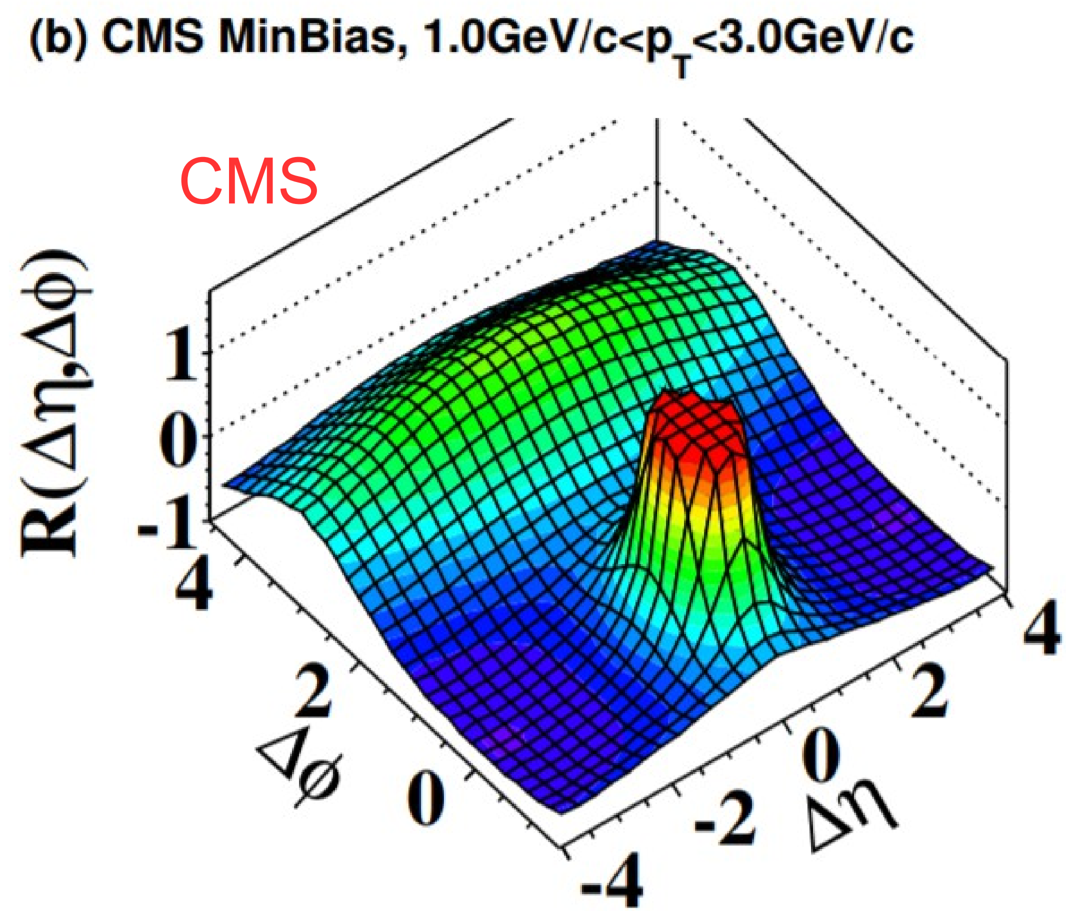


- Sensitive to final-state radiation
- Fragmentation patterns of quarks
- Thrust (coordinates) vary on event-by-event basis!

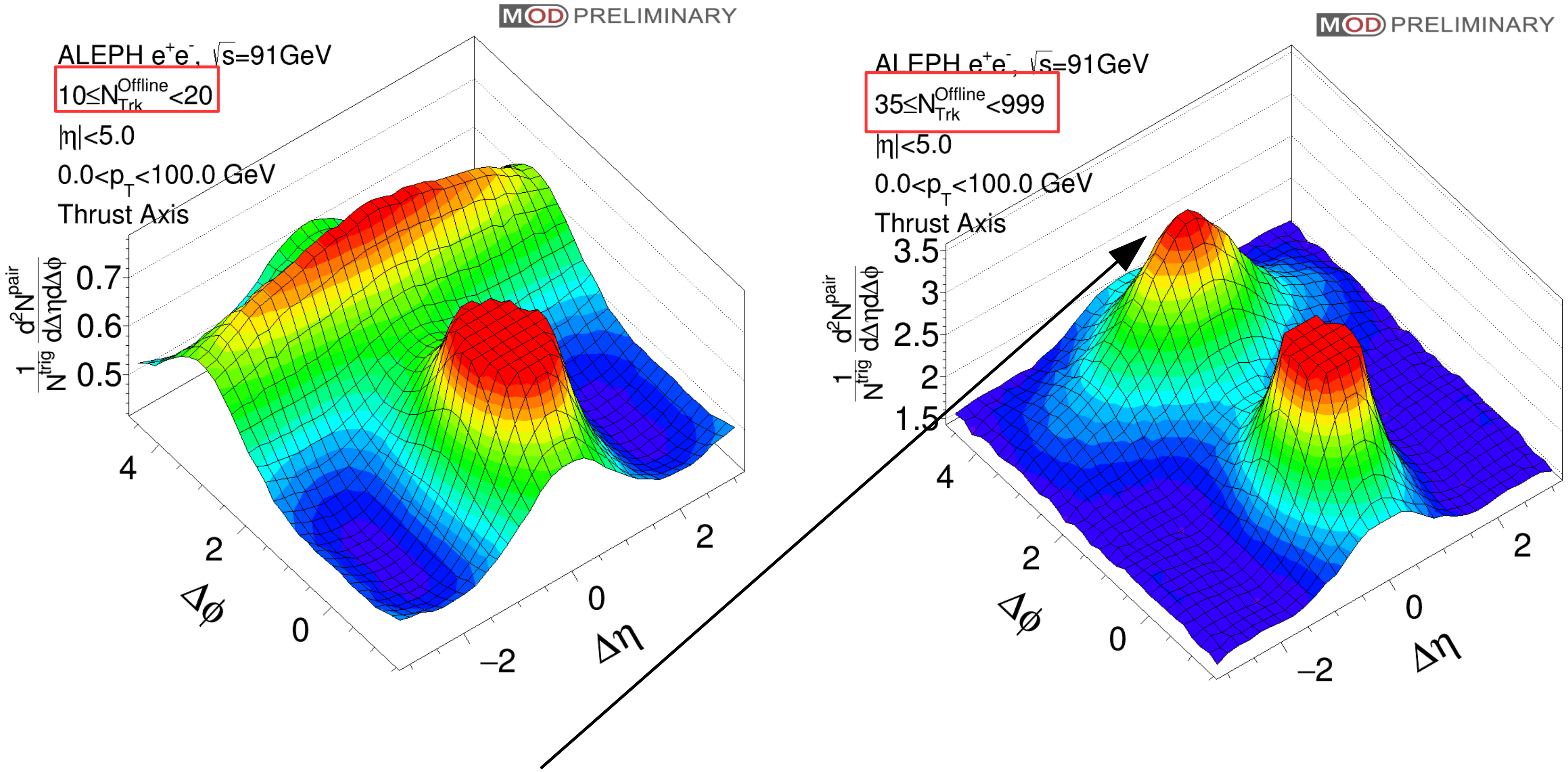
Correlation with thrust axis





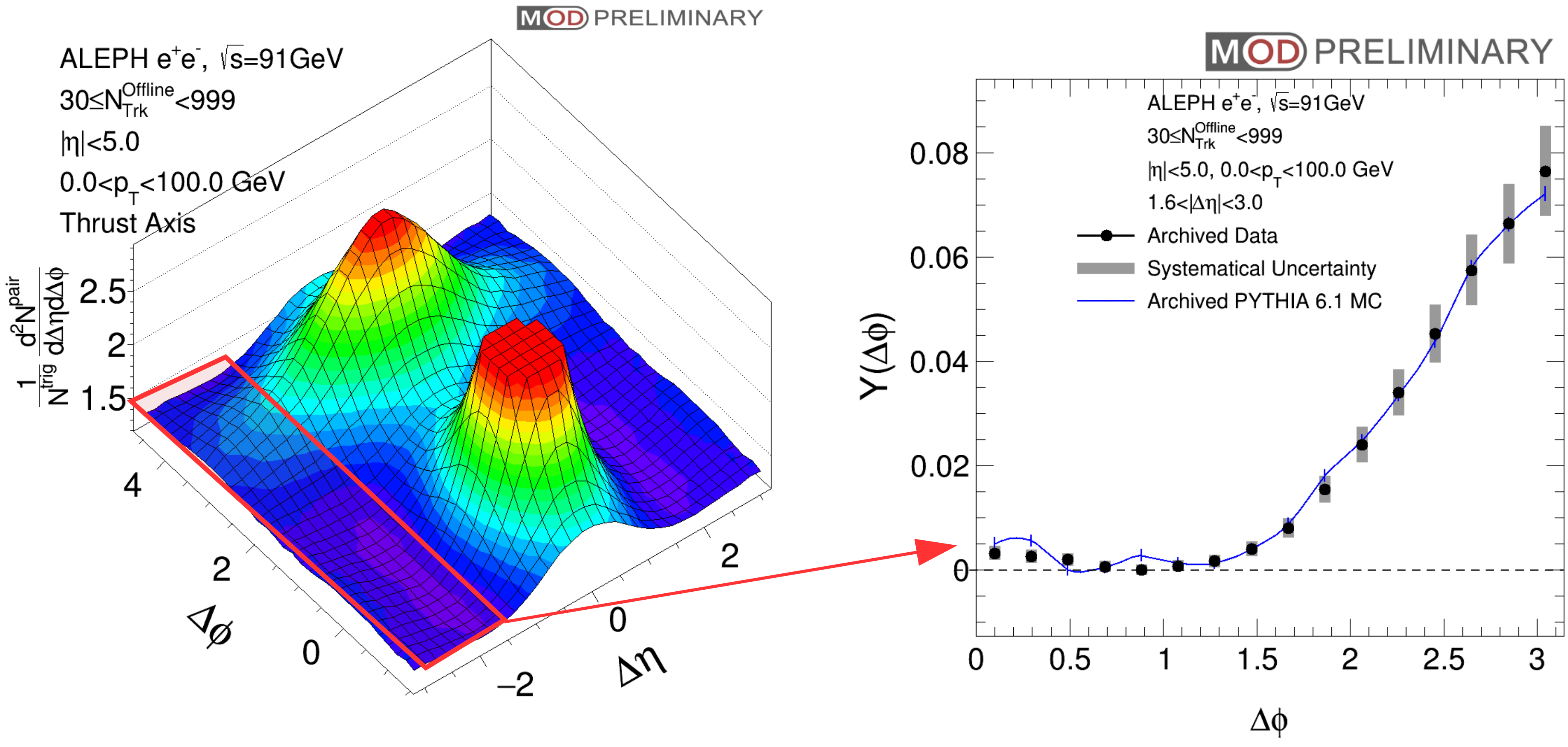
- Correlation function shape qualitatively similar between pp and e^+e^-
- Many caveats, but interesting to think about mapping:
  - pp beam axis to e^+e^- thrust axis
  - pp forward production to e^+e^- dijet constituents

Correlation with thrust axis



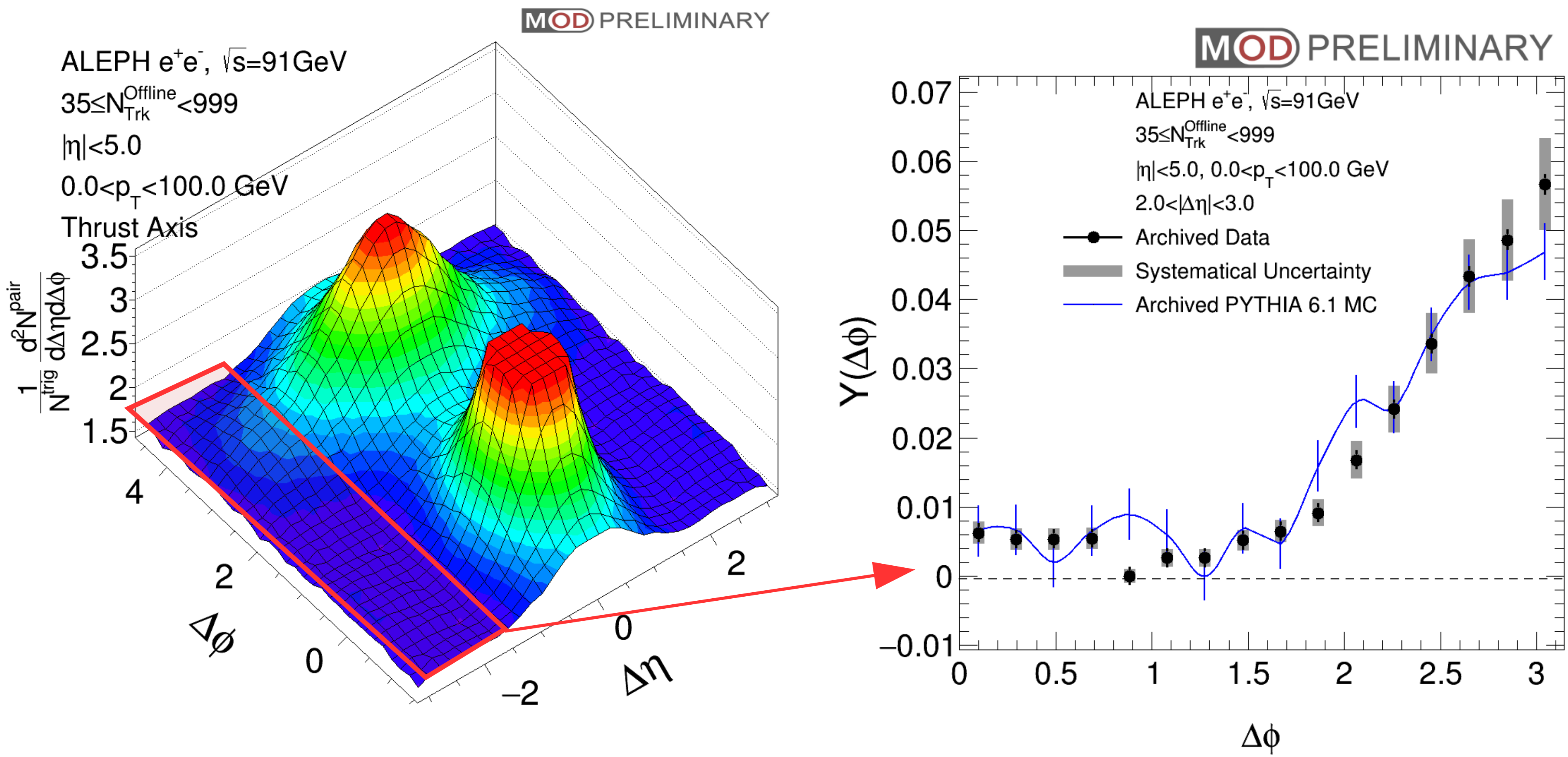
- Narrower away-side peak in high-multiplicity events
- Toy-event studies indicate this could be due to increased multi-jet events

Thrust axis projection N_{trk}>30



- Projection into Δϕ + ZYAM shows data in agreement with PYTHIA 6
- Small hint of near-side ridge, but sensitive to details of thrust reconstruction
  - ZYAM with fit + yield extraction still ongoing

Thrust axis projection N_{trk}>35



- Projection into $\Delta\phi$ + ZYAM shows data in agreement with PYTHIA 6
- Small hint of near-side ridge, but sensitive to details of thrust reconstruction
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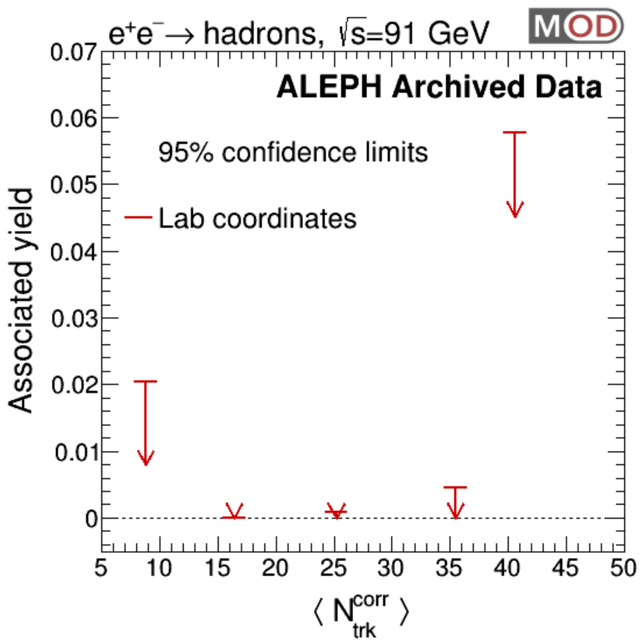
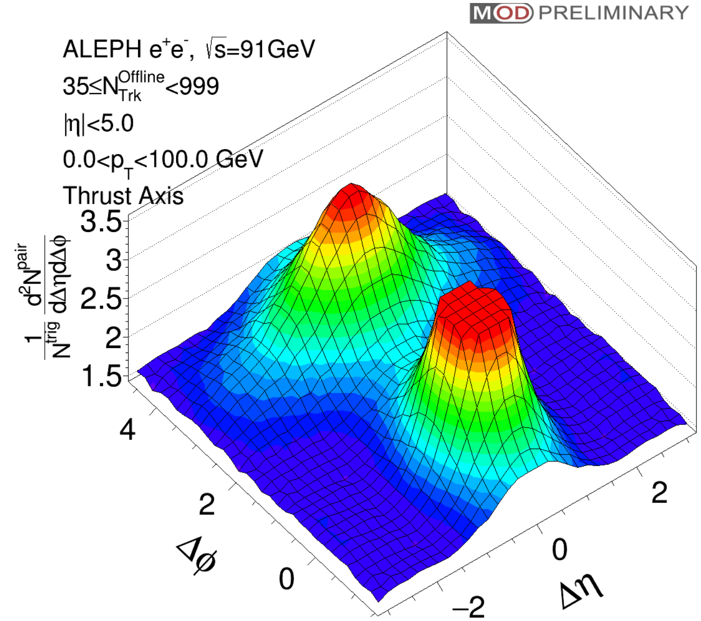
Summary

- First two-particle correlation analysis in e^+e^- collisions performed in bins of multiplicity up to ~50
- Beam coordinates:
  - No significant ridge signal observed and confidence limits reported
- Thrust coordinates:
  - No significant difference observed between LEP1 data and PYTHIA6
  - Associated yield calculation still ongoing
- No evidence for a final-state effect causing near-side ridge in the multiplicity ranges probed
  - Important reference for pp, pA, AA collisions
- *Data preservation projects are valuable for future scientific collaboration and investigation*





Acknowledgement

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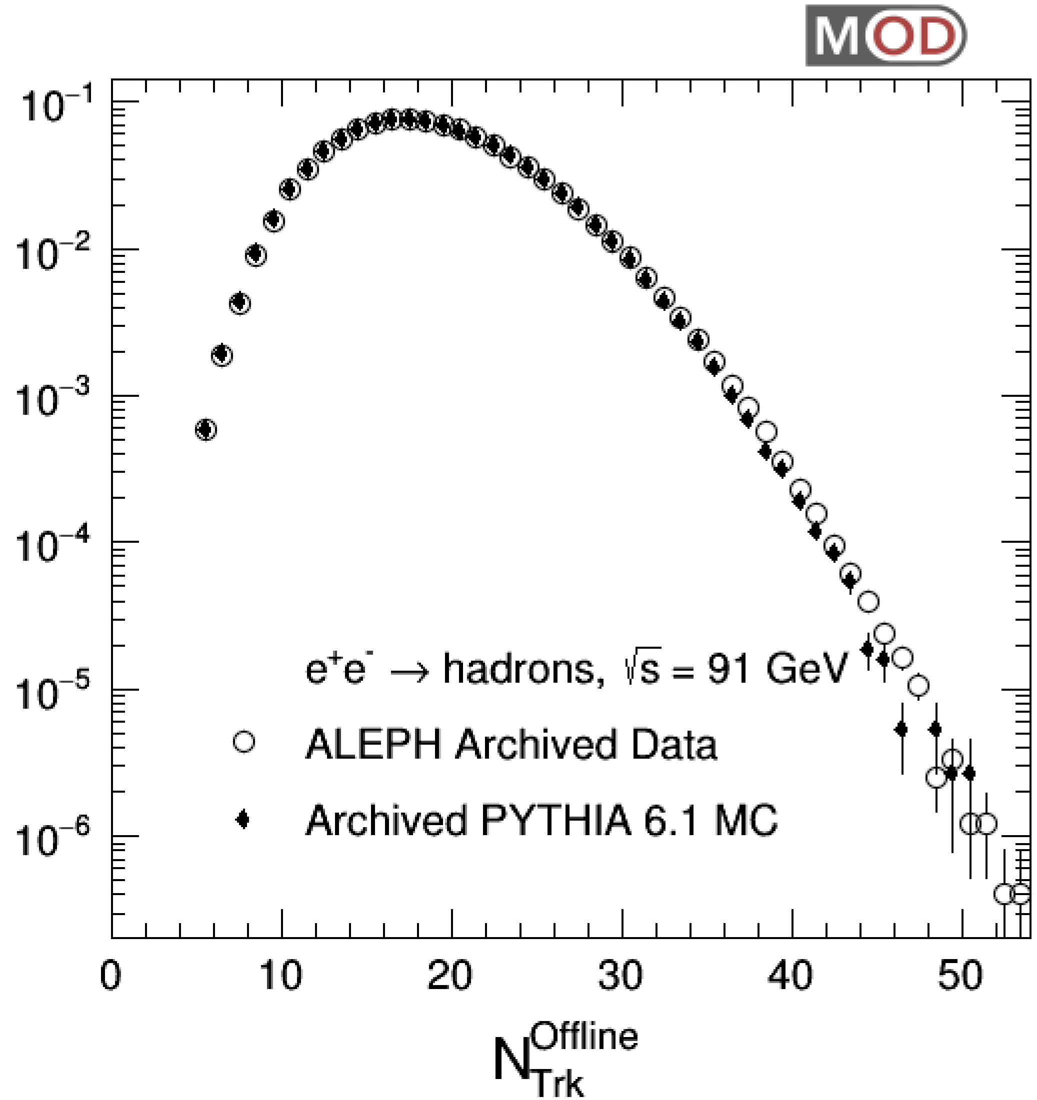
We would like to thank **Wei Li**, **Maxime Guilbaud, Wit Busza** and **Yang-Ting Chen** for the useful discussions on the analysis.

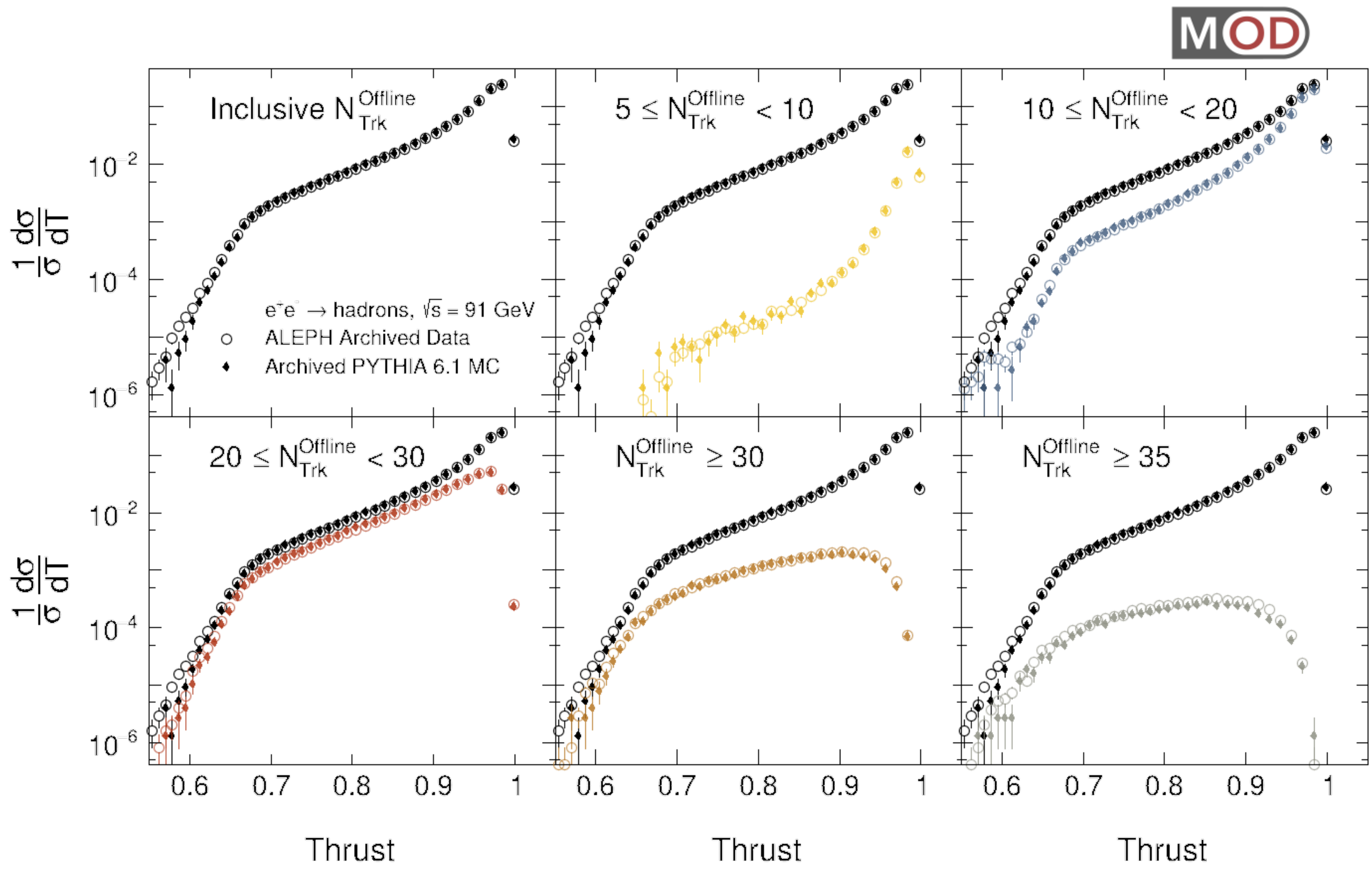
The MIT group's work was supported by US DOE-NP

Backup

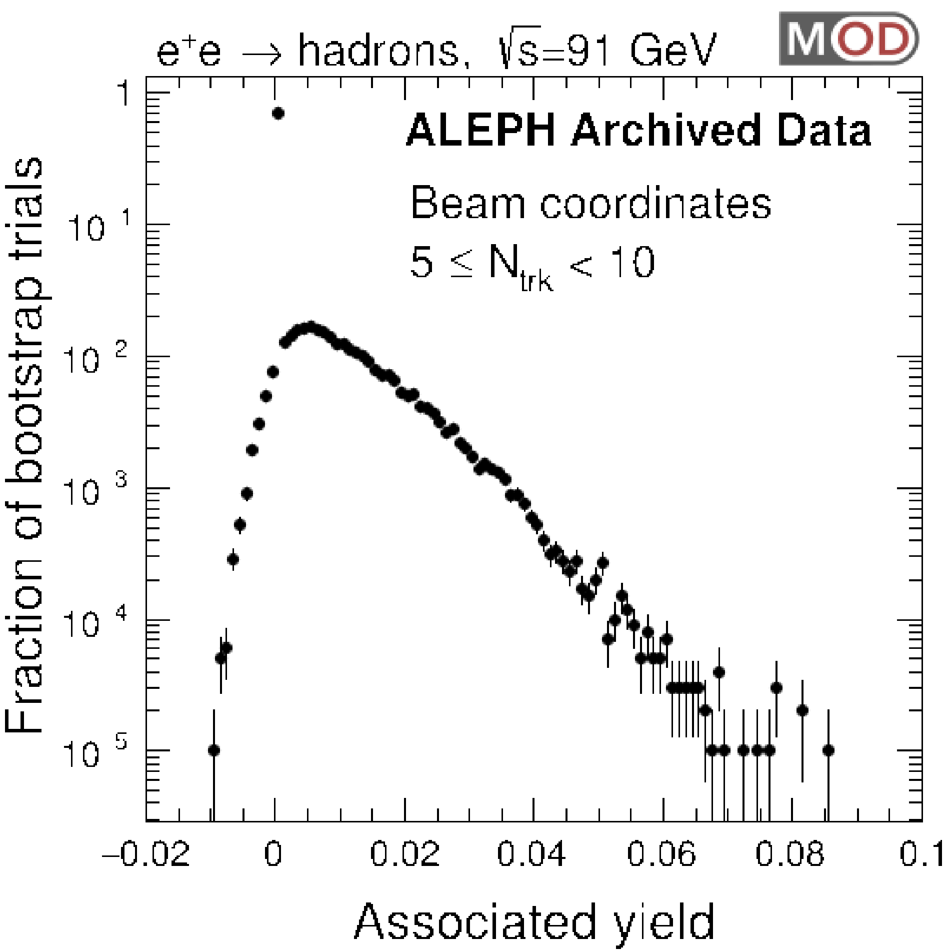
Multiplicity comparison

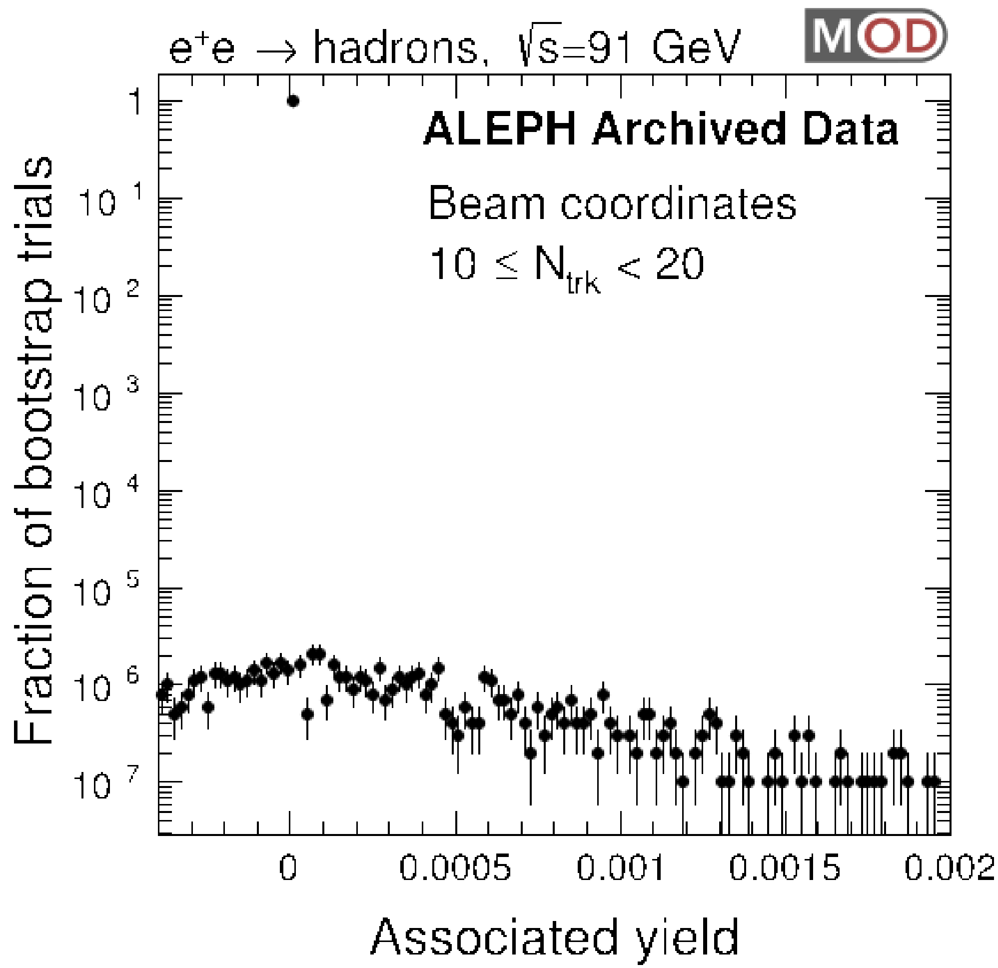


Thrust vs multiplicity



Pseudodata sets





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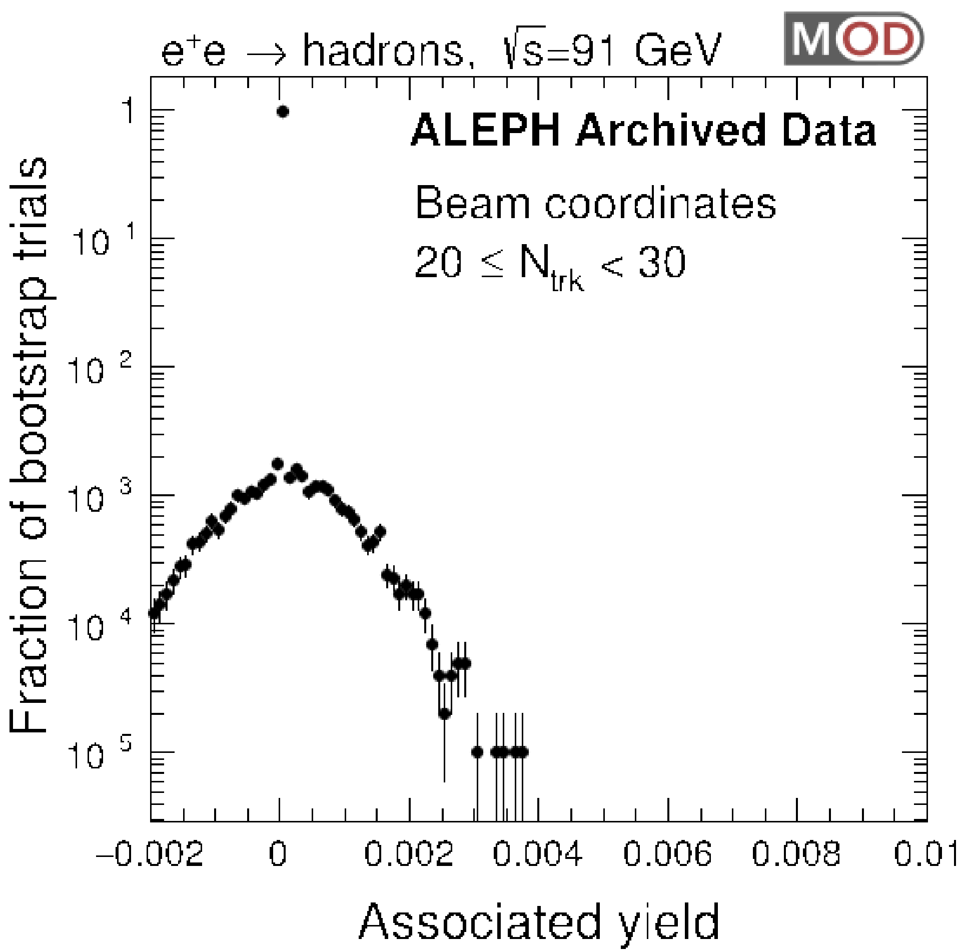

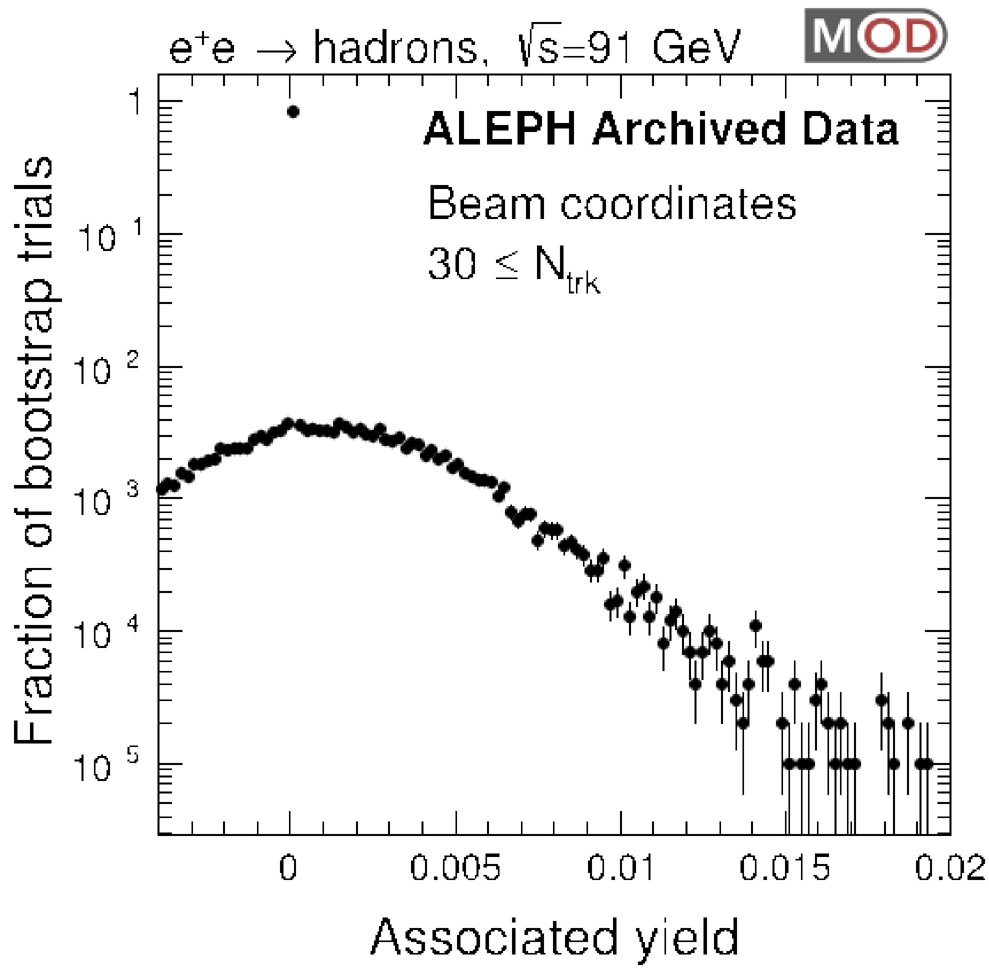

Beam axis correlation functions