Long-range two-particle correlations in DIS with CLAS12

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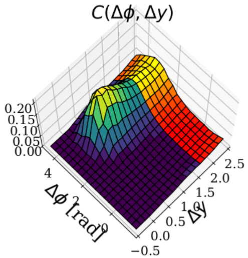
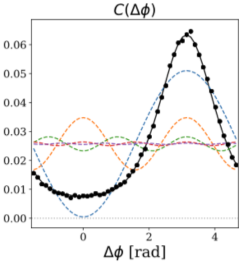
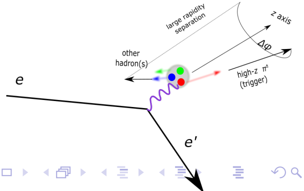






Intro

- Correlations between particles with large rapidity separation can be used to study correlations that occur early on in a reaction.
- Here we investigate the correlations in the azimuthal separation $\Delta\phi$ between pairs of particles produced in SIDIS reactions in CLAS12.
- Similar studies have been investigating:
  - *pp*, *p*Pb, and PbPb at the LHC[1] and RHIC.
  - e^+e^- at ALEPH (recently published)[2]
  - *ep* at HERA (ongoing analysis)[3]
- Large acceptance at CLAS12 makes it well suited for analogous studies

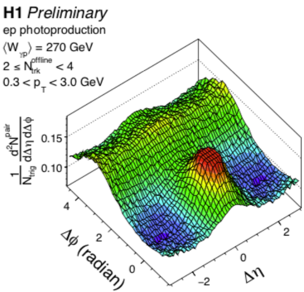
[1] JHEP 09, 091 (2010), 1009.4122; Phys. Lett. B718, 795 (2013), 1210.5482; Phys. Rev. Lett. 116, 172302 (2016), 1510.03068

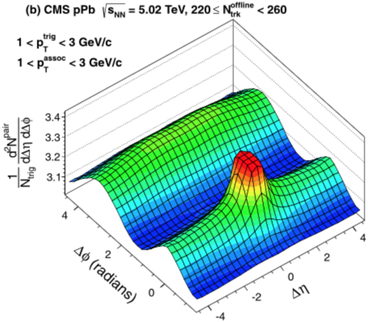
[2] https://doi.org/10.1016/j.nuclphysa.2018.09.018

[3] "Search for collectivity in e-p collisions with H1", Submitted to Initial Stages 2021, Israel

Intro (continued)

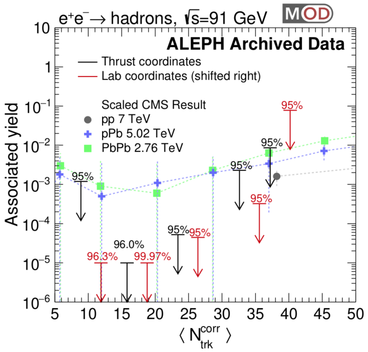
- A common feature is a peak at $\Delta\phi = \pi$ at both large and small rapidity separation.
- Another possible feature is a secondary peak (the "ridge") at $\Delta\phi = 0$, persisting at large rapidity separation.
  - A ridge has been observed in CMS at high track multiplicity, and predicted by some theoretical models
  - Upper limits have been set/are being set at ALEPH and HERA.



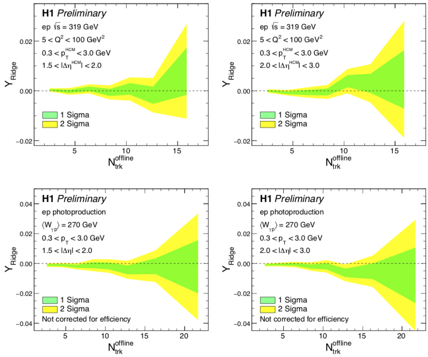


"Ridge" Analysis Upper Limits (Existing data for small systems)

ALEPH[4]



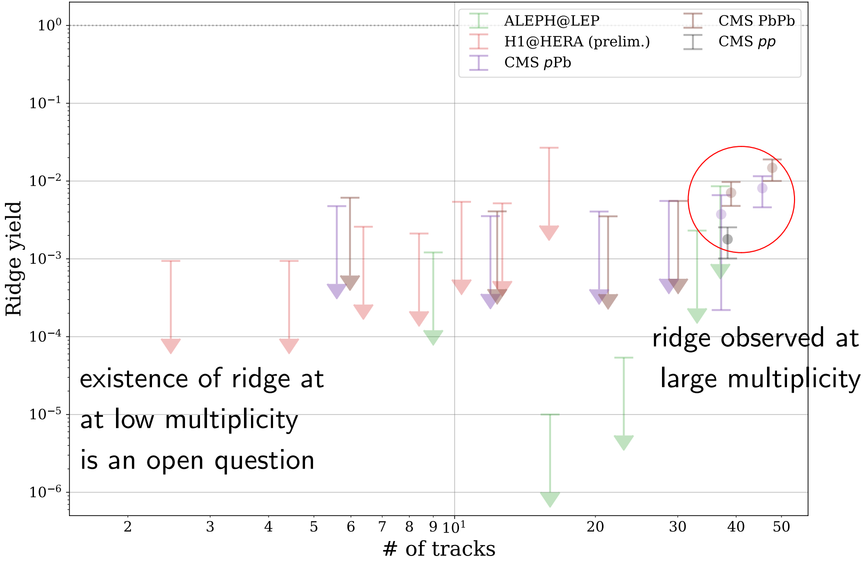
HERA[5]



[4] https://doi.org/10.1016/j.nuclphysa.2018.09.018

[5] "Search for collectivity in e-p collisions with H1", Submitted to Initial Stages 2021, Israel, 10-15 January, 2021

Ridge-yield existing limits



Data/Event Selection (1/2)

- DSTs from RGA fall 2018, entire inbending dataset (outbending will be included later)[6]
- Tuples made using the following cuts:
- Electron ID:
  - EC fraction: $E_{\mathrm{EC}}/p > 0.17$
  - PCAL energy > 0.07 GeV
  - Vertex position: between -13 and 12 mm
  - > 2 photoelectrons in HTCC.
  - DC and PCAL fiducial.
  - The particle's charge is negative.
- Electron kinematics (DIS):
  - $Q^2 > 1\ \mathrm{GeV}^2/c^2$
  - $W > 2\ \mathrm{GeV}/c^2$
  - $y_e \equiv \nu/E < 0.85$

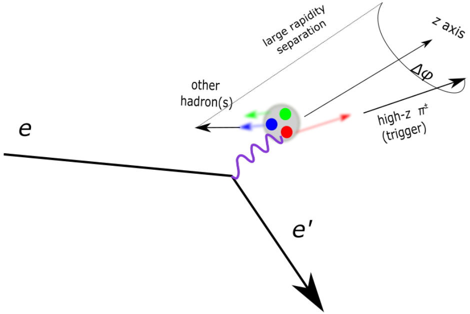
[6] `/lustre/expphy/cache/clas12/rg-a/production/recon/fall2018/torus-1/pass1/v0/dst/`

Data/Event Selection (2/2)

- Hadron ID:
  - $|\texttt{chi2pid}| < 2.5$
  - $|\Delta v_z| < 20$ mm
  - $|\Delta t_{\mathrm{corr}}| < 0.3$ ns
  - fiducial cuts in DC.
- Dihadron events require a high-z pion as the "trigger" particle: $z \equiv E_h/\nu > 0.4$.
- For analysis, we require additional cuts:
  - $p_t > 0.3$ GeV for both particles in CM frame.
  - for πp events, remove events in which $m_X(ep \to e\pi X) < 1.665$ GeV (this corresponds to the Δ baryon mass, plus ≈3 sigma resolution)

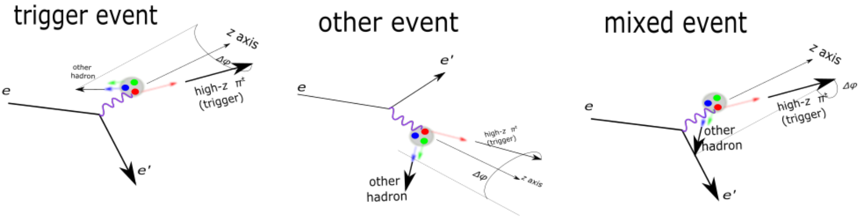
Definitions

- Trigger particle: a high z pion. Not to be confused with event trigger
- Results are presented in the CM frame:
  - rotated so that outgoing electron is in xz plane, and z axis is along momentum transfer
  - boosted so that the proton+virtual photon are at rest (CM).
  - $\Delta\phi$ difference in azimuth between hadrons in this frame
  - Δy difference in rapidity ($y = \frac{1}{2} \ln \frac{E+p_z}{E-p_z}$)



Event mixing

- Event mixing is performed to correct for pair-acceptance effects and produce correlation functions
- Each trigger is paired with one of the hadrons in a different event.
- The kinematic variables that depend on the virtual photon kinematics are recalculated.
- Likewise difference variables $\Delta\phi$ and Δy are recalculated.

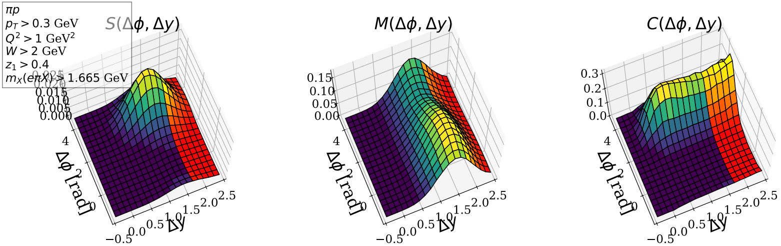


Same/mixed event yields and correlation function

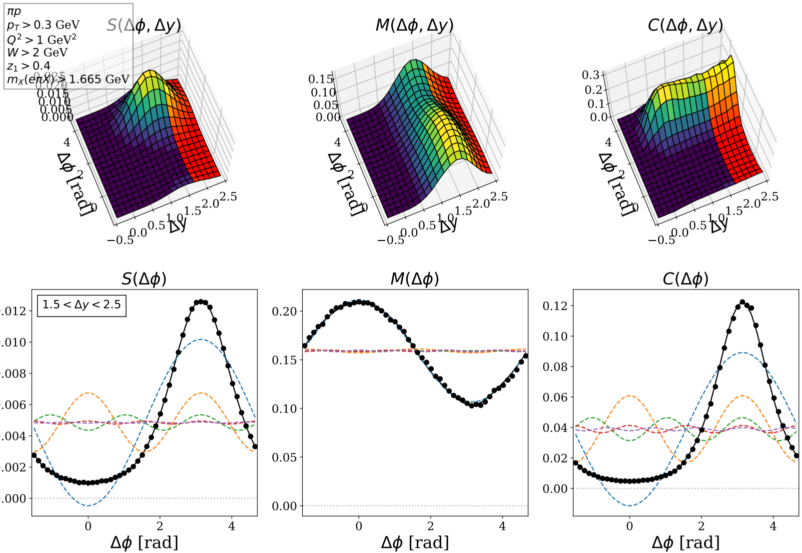
- Same event yield: $S(\Delta\phi, \Delta y) = \frac{1}{N_{\mathrm{trig}}} \frac{dN^{\mathrm{same}}}{d\Delta\phi d\Delta y}$
- Mixed event yield: $M(\Delta\phi, \Delta y) = \frac{1}{N_{\mathrm{tot}}^{\mathrm{mix}}} \frac{dN^{\mathrm{mix}}}{d\Delta\phi d\Delta y}$
- Correlation function: $C(\Delta\phi, \Delta y) = \frac{S(\Delta\phi, \Delta y)}{M(\Delta\phi, \Delta y)}$
- Correlation function (1D projection):

$$C(\Delta\phi) = \frac{\int_{\Delta y_{\mathrm{min}}}^{\Delta y_{\mathrm{max}}} d\Delta y [S(\Delta\phi, \Delta y)]}{\int_{\Delta y_{\mathrm{min}}}^{\Delta y_{\mathrm{max}}} d\Delta y [M(\Delta\phi, \Delta y)]}$$

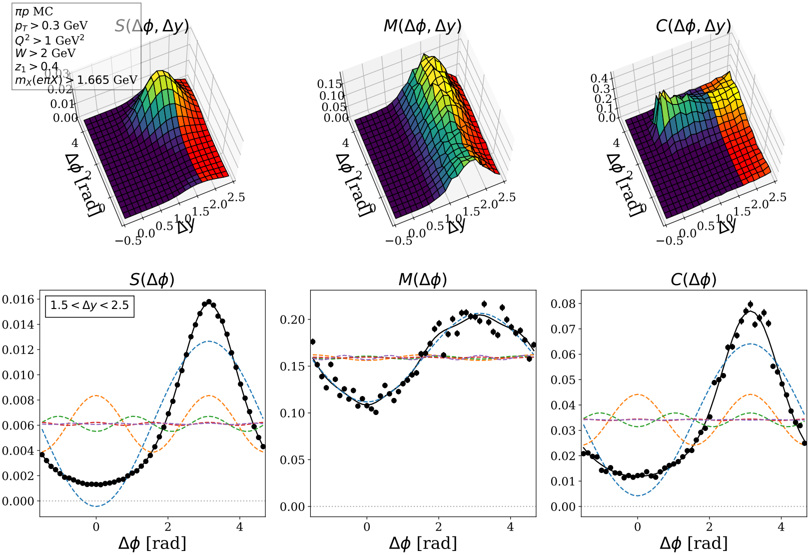
  - for this analysis, we use $1.5 < \Delta y < 2.5$ for our projection range.



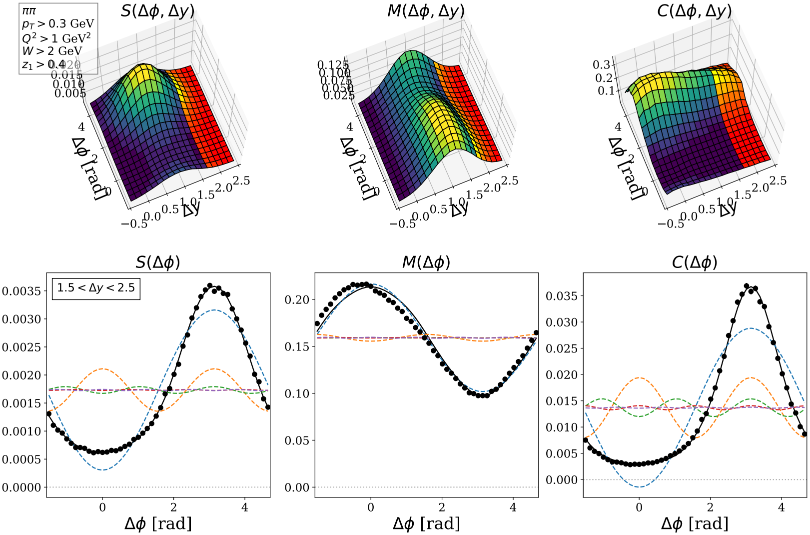
Correlation function from πp events



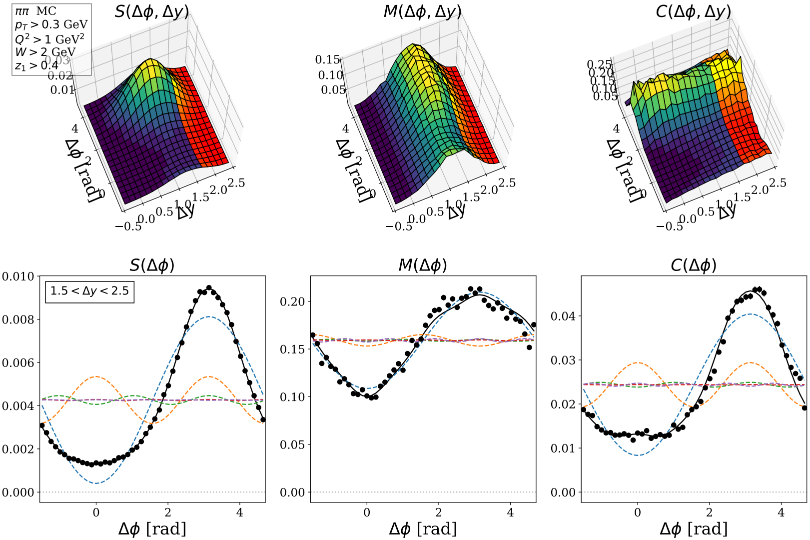
Correlation function from πp events (Monte Carlo)



Correlation function from $\pi\pi$ events

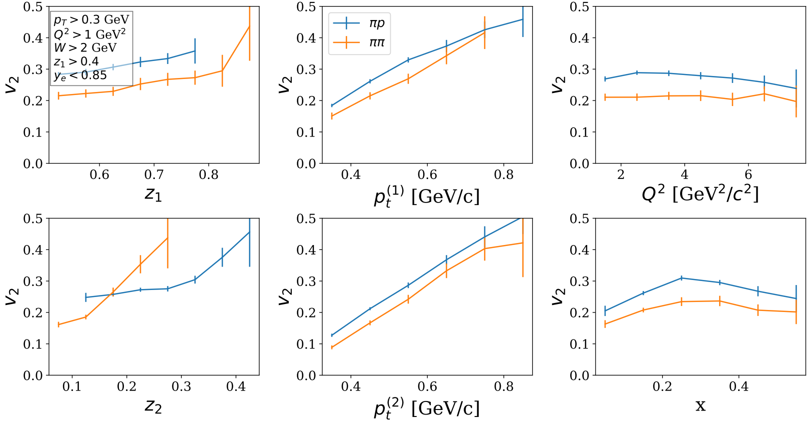


Correlation function from $\pi\pi$ events (Monte Carlo)

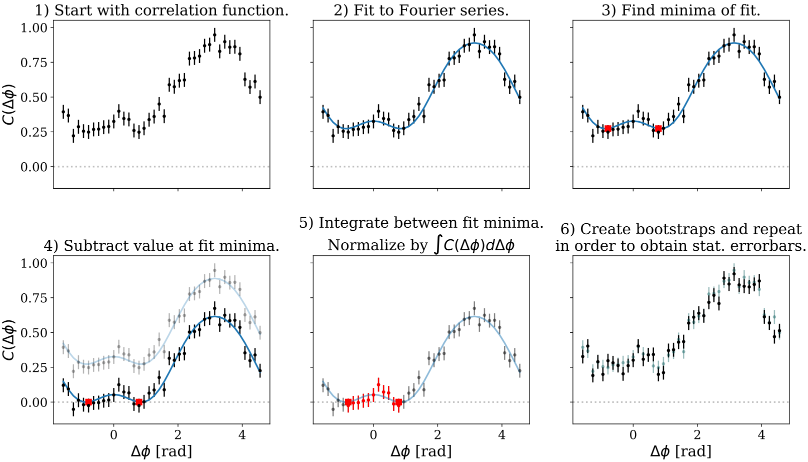


Fourier transform of correlation function and V_2

- A Fourier transform is performed on the correlation function: $C(\Delta\phi) = A(1 + 2\sum_n V_n \cos(n\Delta\phi))$
- These Fourier components can in principle be compared with structure-function predictions.
- V_2 is plotted below:



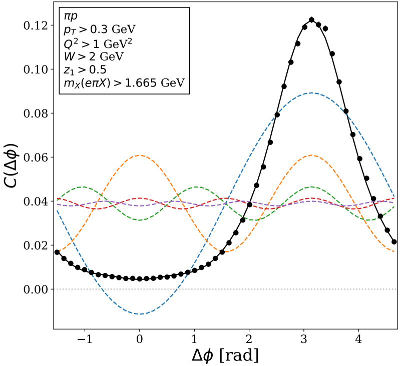
Ridge-yield procedure[7]

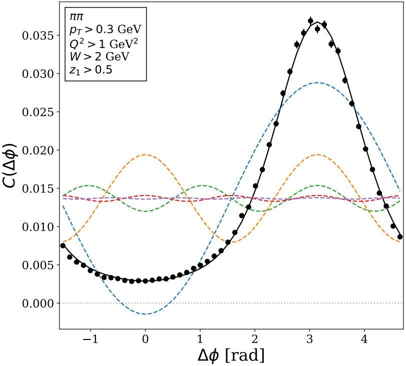


[7] Demonstrated for pseudo-data with an exaggerated ridge

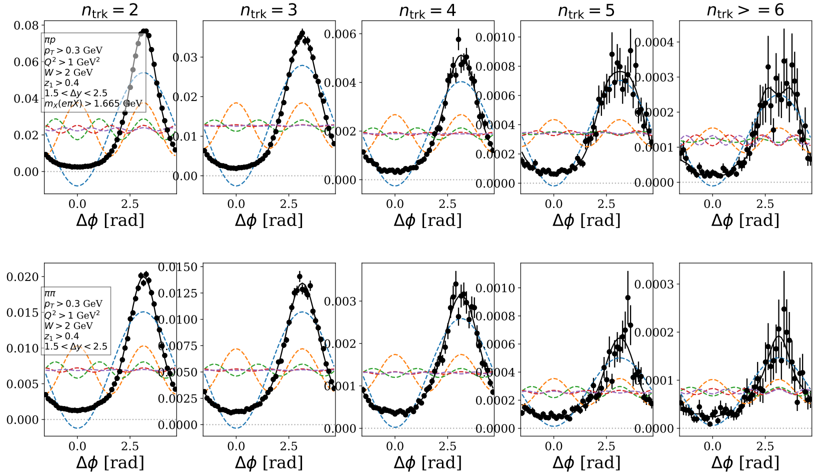
Ridge-yield at CLAS12

- Without binning any other variables, the yield for our CLAS12 data is zero, since the fit has a minimum at $\Delta\phi = 0$ (see below) so the integration range vanishes.
- However, we can separate our data into bins by kinematics and/or n_{tracks} in order to set exclusion regions



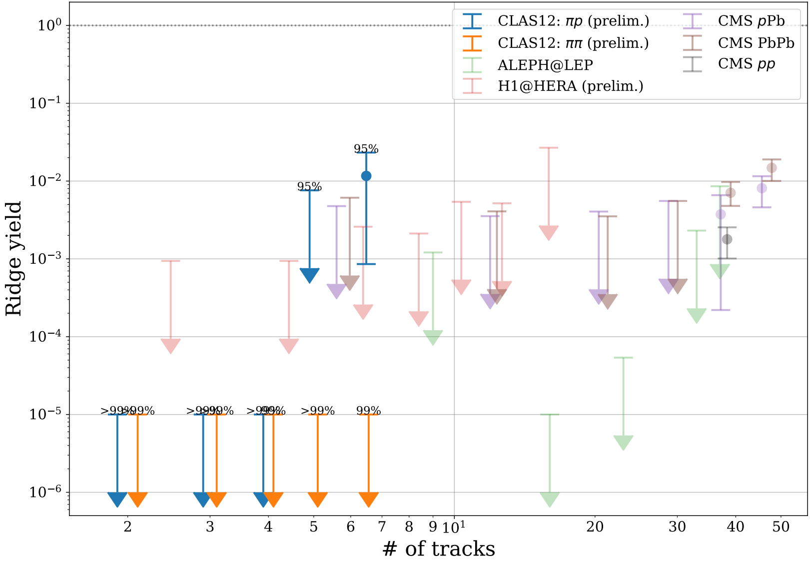


Correlation functions at CLAS-12 vs ntracks



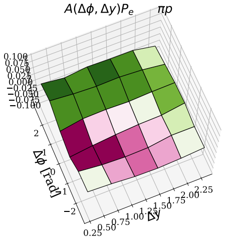
No ridge found... use bootstrap to set upper limits...

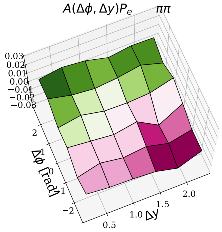
Add CLAS-12 to ridge-yield search: Small-Systems Frontier

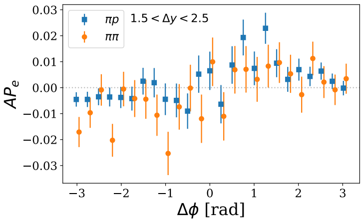


Polarization asymmetry

- We are also investigating the asymmetry of the same-event yield with respect to the beam helicity; $A = \frac{S_+ - S_-}{S_+ + S_-} / P_e$





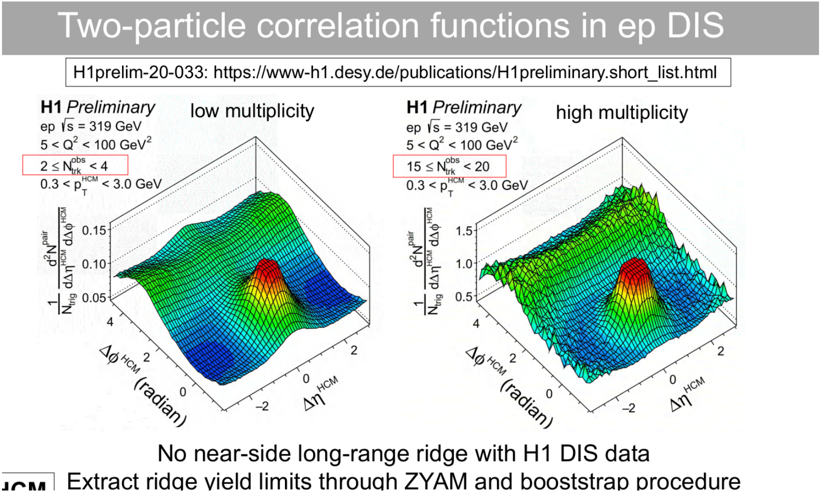


Conclusions

- Azimuthal correlations in rapidity-separated πp and $\pi\pi$ pairs are a useful tool to study structure and fracture phenomena
- Fourier decomposition may be performed on the $\Delta\phi$ spectrum.
- Ridge-yield analyses can test models that predict the "ridge" feature.
- CLAS12 is well suited for such analyses due to its large acceptance and high luminosity.
- We can use this *ep* scattering data from RGA as a reference for nuclear-target measurements.
- Plan forward:
  - Include outbending data (in addition to inbending)
  - Loosen p_t (and possibly other) cuts to further increase statistics in ridge yield analysis
  - Determine systematic errors.

Backup Slides

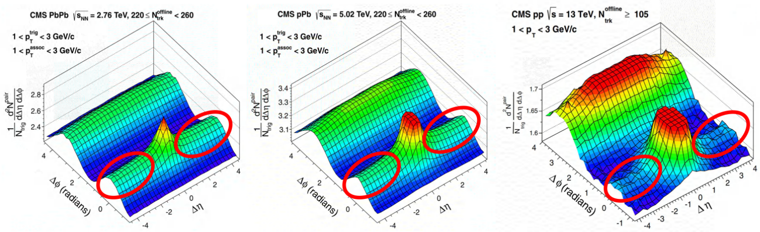
correlations in H1@HERA



Ridge at CMS

Collectivity in small system

PLB 724 (2013) 213–240; PRL 116, 172302 (2016)



Collectivity as a probe of parton correlation:

Lots of evidence of collectivity in high multiplicity pp and pPb collisions, similar to heavy-ion collisions attributed to the perfect liquid nature of QGP

What about even smaller system?

Ridge yield at CLAS-12 vs ntracks (mc=pink)