The 21st International Symposium on Spin Physics (Spin2014)
Oct. 20-24, 2014, Beijing, China

Measurement of Collins Asymmetry in Inclusive Production of Pion Pairs at BESIII

GUAN Yinghui

(E-mail: guanyh@ihep.ac.cn)

Institute of High Energy Physics (IHEP, CAS)

(on behalf of the BESIII collaboration)

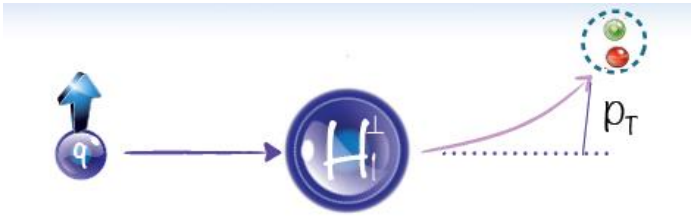
Institute of High Energy Physics
Chinese Academy of Sciences

BESIII

Outline

- **Introduction**
  - **Collins Fragmentation Function**
  - **BEPCII and BESIII**
- **Analysis Overview**
  - **Analysis method**
  - **Extraction of the Collins asymmetry**
  - **Preliminary results: asymmetries *vs.* pion fractional energies**
- **Summary and Outlook**

Collins Fragmentation Function(FF)



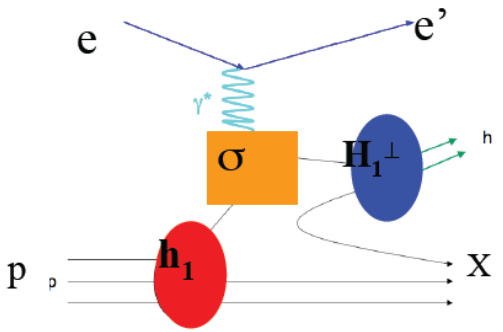
J. C. Collins, Nucl.Phys. B396, 161 (1993)

$$D_{hq^\uparrow}(z, P_{h\perp}) = D_1^q(z, P_{h\perp}^2) + H_1^{\perp q}(z, P_{h\perp}^2)\frac{(\hat{\mathbf{k}} \times \mathbf{P}_{h\perp}) \cdot \mathbf{S}_q}{zM_h},$$

D_1: the unpolarized FF
H_1: Collins FF
→ describes the fragmentation of a transversely polarized quark into a spinless hadron *h*.
→ depends on $z = 2E_h/\sqrt{s}$, $\mathbf{P}_{h\perp}$
→leads to an azimuthal modulation of hadrons around the quark momentum.

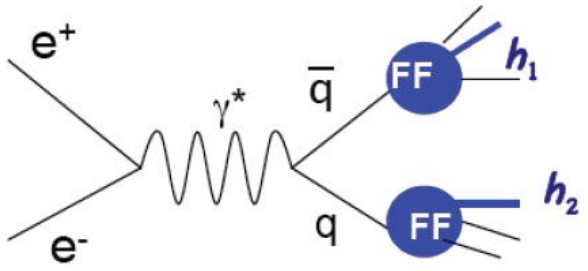
SIDIS

Transversity ⊗ Collins FF



e+ e-

Collins FF ⊗ Collins FF

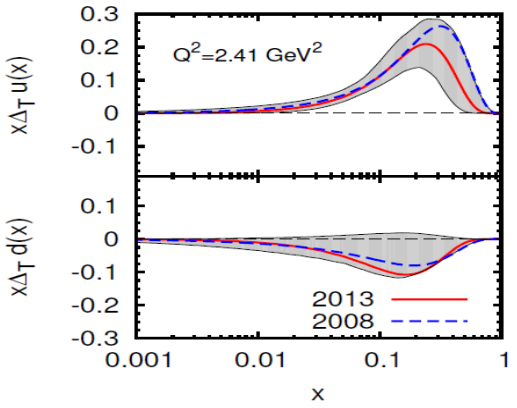


Global Analysis on Collins FF

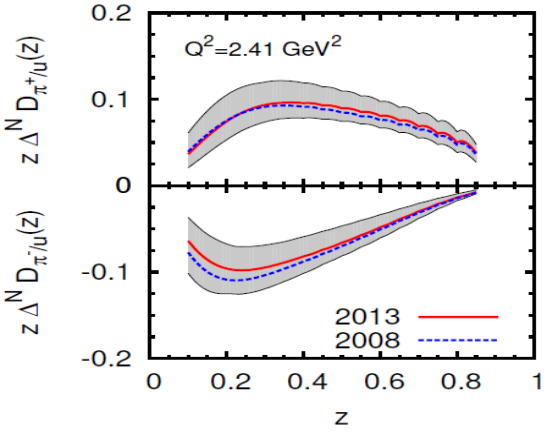
Anselmino et al., PRD 87, 094019 (2013)

Using data from HERMES, COMPASS, Belle

Transversity

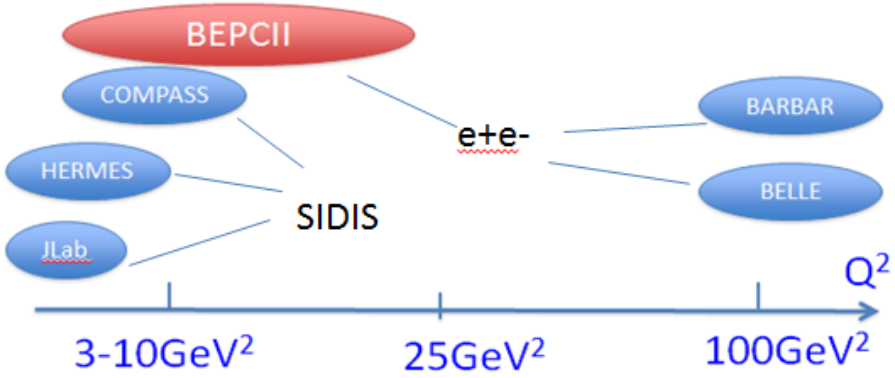


Collins pion FF



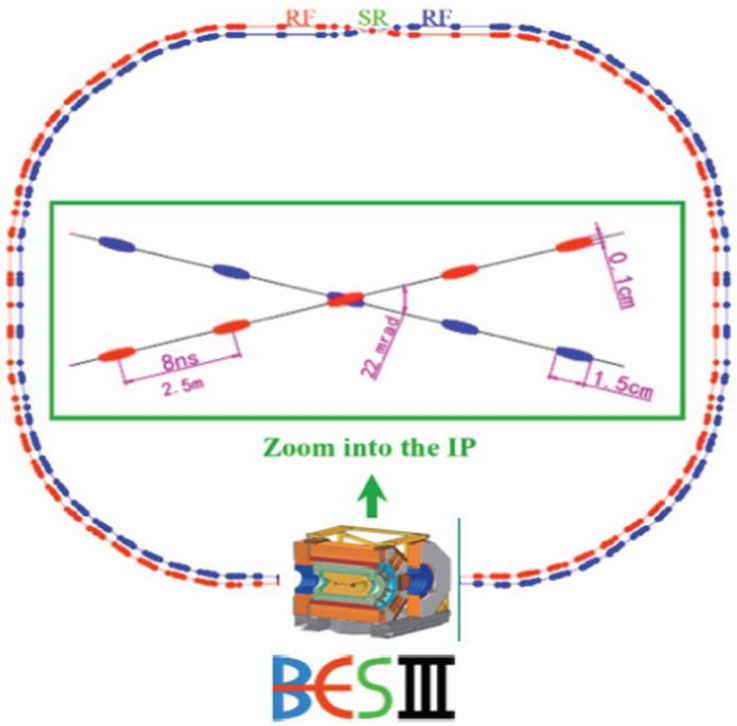
- The Q^2 evolution of Collins FFs was assume the same as that for the unpolarized FF, and this has not be validated.
- Low Q^2 data from e+e- collider is useful.
- **BEPCII**
  - Similar Q^2 coverage with SIDIS.
  - Predication in

    PRD 88. 034016 (2013) P. Sun, F. Yuan

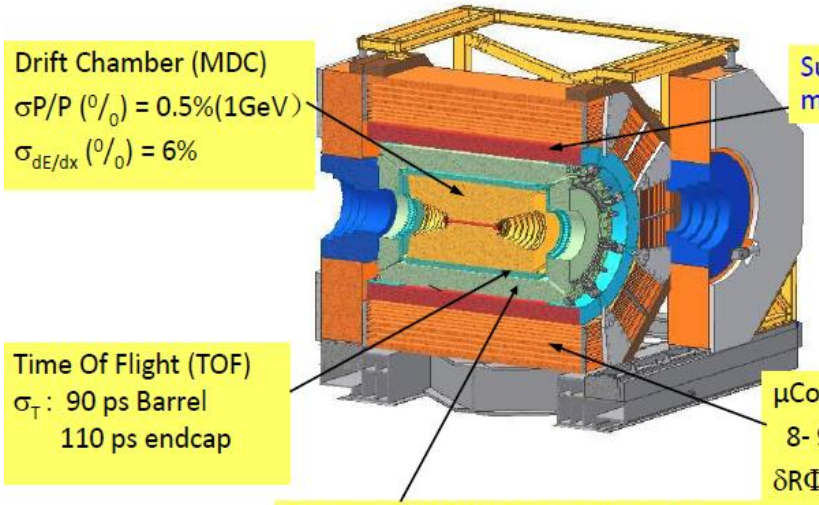


BEPCII and BESIII

Beijing Electron Positron Collider-II (BEPCII)



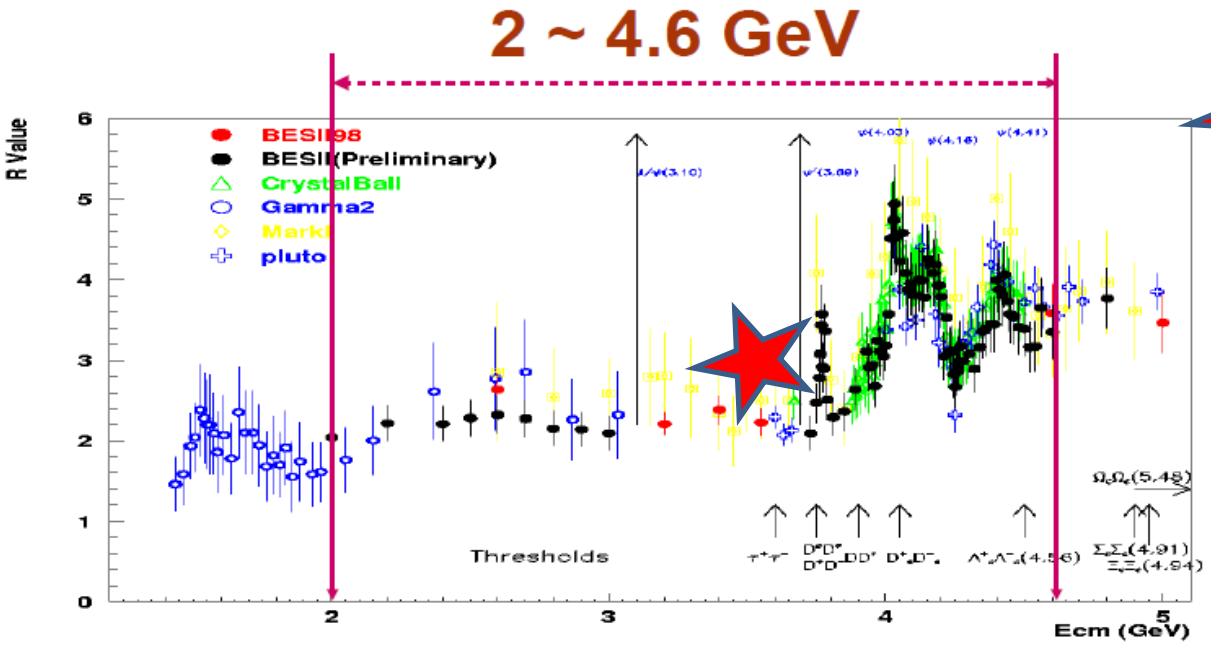
NIM A614, 345 (2010)



Large acceptance: 93% *4π

- e+e- symmetric collider, unpolarized beams
- Beam energy: 1.0-2.3GeV (Q: ~2.0-4.6GeV)
- Achieved luminosity: 0.7×10^{33} $cm^{-2}s^{-1}$@3.773GeV

Data Sample and Event Selection



- ~62 pb $^{-1}$ @3.65GeV
- Continuum region
- Few backgrounds!

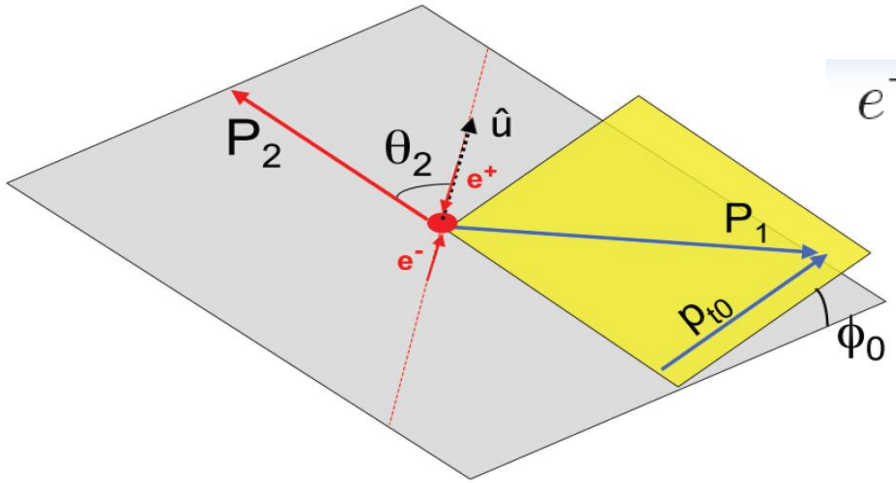
- Number of charged tracks >=3
- Number of charged pion>=2
- $N_{electron}$ =0 to suppress Bhabha
- The total visible energy E_{vis}>1.5GeV.

For the charged π

- $0.3< z=2E_h/\sqrt{s} <0.9$
- open angle >120^o to select back-to-back pion-pair. Also suppress $M_{\pi\pi}$ resonance.

The Reference Frame

D. Boer Nucl.Phys.B806:23,2009



$$e^+e^- \to q\,\bar{q} \to h_1\,h_2\,X$$

$$\sigma \sim 1 + \frac{\sin^2\theta_2}{1+\cos^2\theta_2}\cos(2\phi_0)\mathcal{F}\left[\frac{H_1^\perp(z_1)\bar{H}_1^\perp(z_2)}{D_1(z_1)\bar{D}_1(z_2)}\right]$$

$$\mathcal{F}[X] = \sum_{q\bar{q}}\int [2\hat{\mathbf{h}}\cdot\mathbf{k_{T1}}\hat{\mathbf{h}}\cdot\mathbf{k_{T2}} - \mathbf{k_{T1}}\cdot\mathbf{k_{T2}}]$$

$$d^2\mathbf{k_{T1}}d^2\mathbf{k_{T2}}\,\delta^2(\mathbf{k_{T1}}+\mathbf{k_{T2}}-\mathbf{q_T})X$$

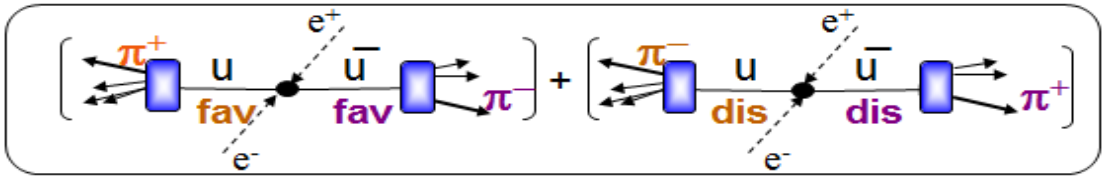
$$k_{Ti} = z_i\,p_{Ti}$$

- **Collins effect: cosine modulation.**

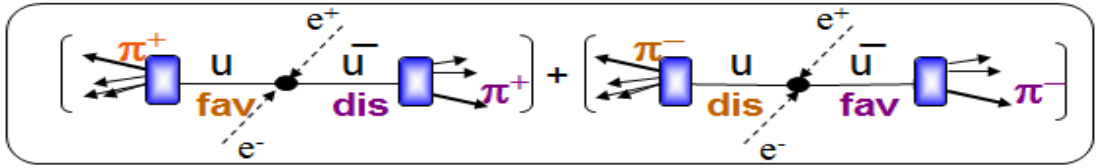
Product of Two Collins FFs

- **Favored** fragmentation process describes the fragmentation of a quark of flavor q into a hadron with a valence quark of the same flavor: i.e.: u→π+, d→π-
- **Disfavored** for d→π^+, u→π^-

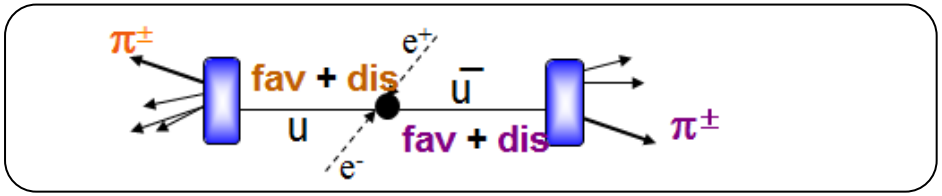
Unlike-sign pairs= **U**:
$\pi^{\mp}\pi^{\pm}$: (fav x fav)+(dis x dis)



Like-sign pairs = **L**:
$\pi^{\pm}\pi^{\pm}$: (fav x dis)+(dis x fav)

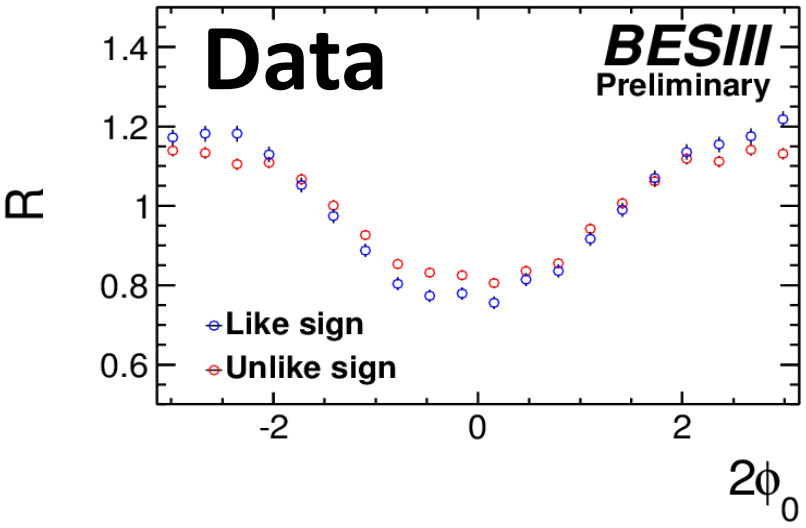


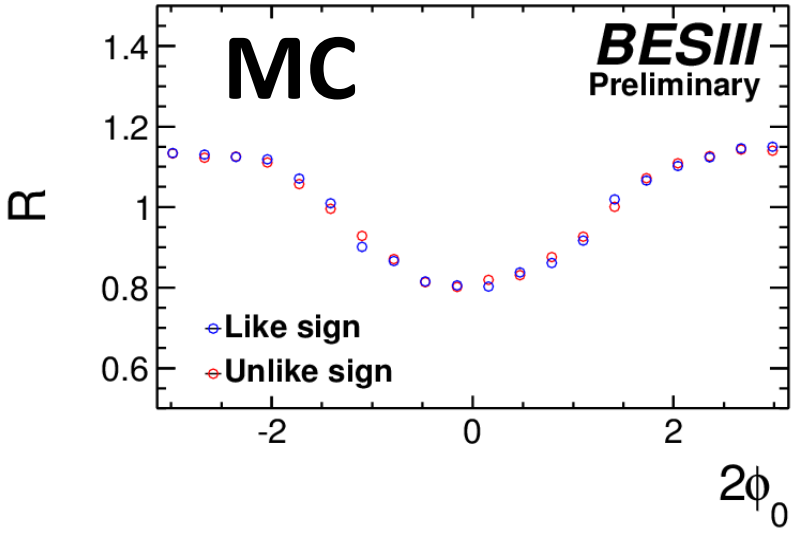
All charged pairs= **C (U+L)**:
ππ: (fav + dis)x(fav + dis)
$\pi=\pi^{\pm}$



- **All charged pion pairs are divided into:**
  - **Unlike-sign pairs ($\pi^+\pi^-$)**
  - **Like-sign pairs ($\pi^+\pi^+$ and $\pi^-\pi^-$)**
  - **All Charged pairs ($\pi\,\pi$)**

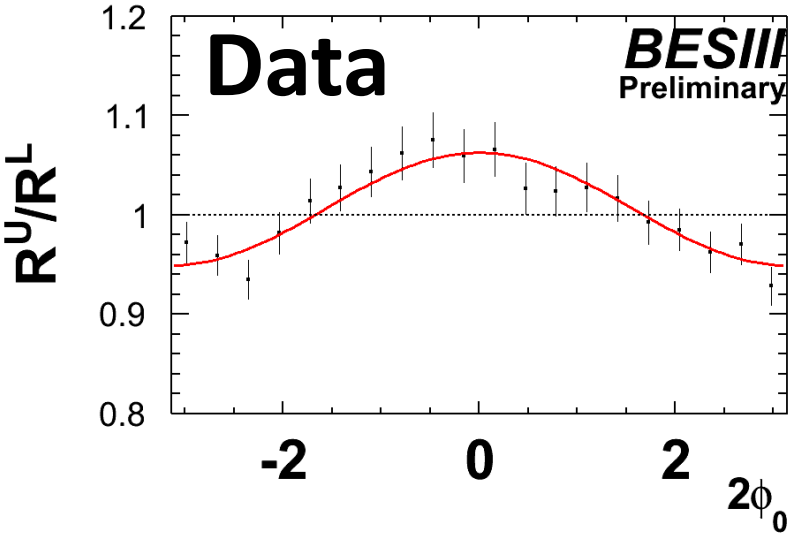
$2\phi_0$ Raw Distribution

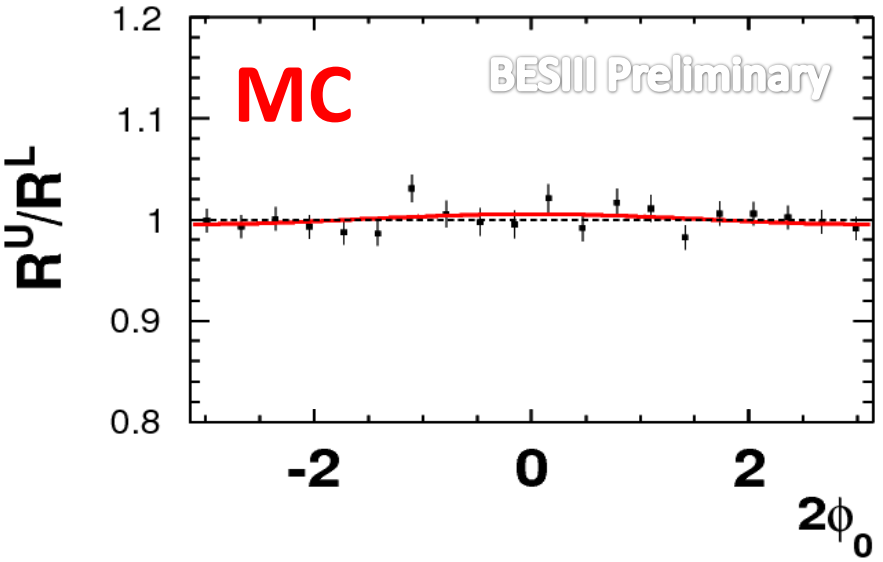




- **The normalized ratio** $R := \frac{N(2\phi_0)}{\langle N_0 \rangle}$
  - **For Charged, Unlike-sign and Like-sign pairs, we have R^U, R^C , R^L**
- **Raw $2\phi_0$ distributions are subjected to the limited acceptance and non-uniform efficiencies of the detector!**
- **The MC simulation does not include the Collins effect.**
- **Small deviations in Like and Unlike in data indicate asymmetries.**

Double Ratio



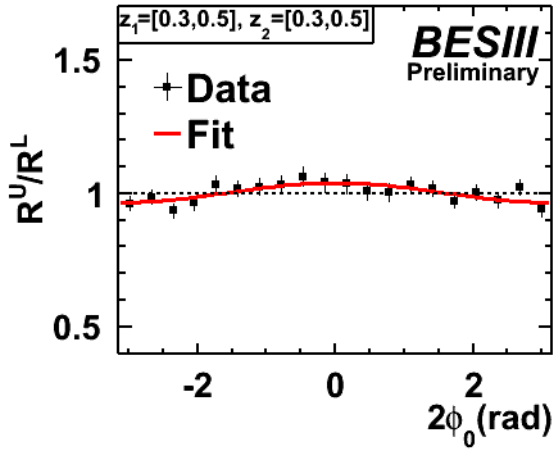


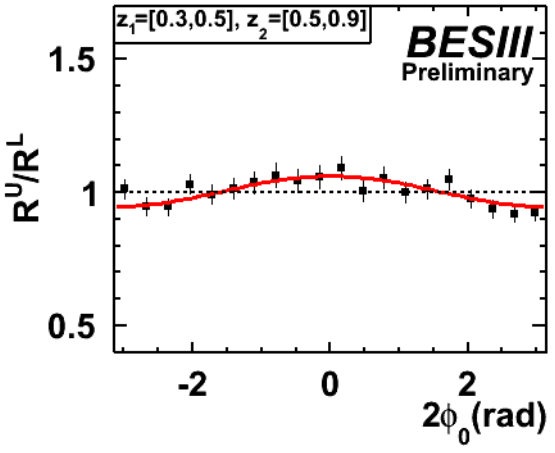
- **Acceptance effects and radiation effects can be reduced by performing the ratio of Unlike/Like sign pion pairs (R^U/R^L) or Unlike/Charged pairs (R^U/R^C)**

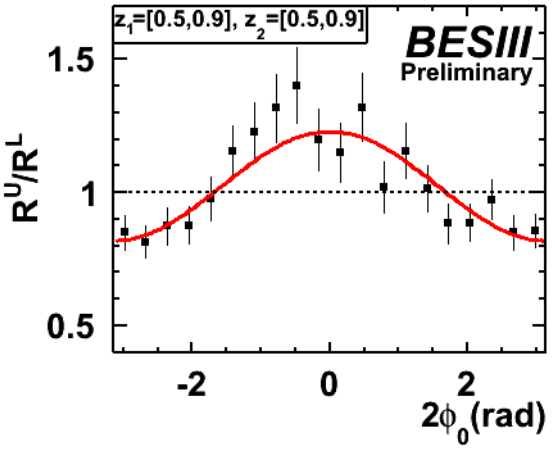
$$\frac{R^U}{R^L} \simeq 1 + \frac{\sin^2\theta}{1+\cos^2\theta}\cos(2\phi_0)(G^U - G^L) \qquad \frac{R^U}{R^C} \simeq 1 + \frac{\sin^2\theta}{1+\cos^2\theta}\cos 2\phi_0 (G^U - G^C)$$

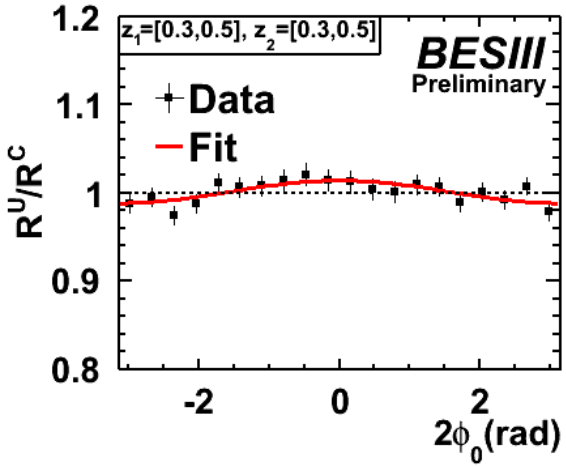
- **DRs are fitted by** $\frac{R^U}{R^{L(C)}} = a\cos(2\phi_0) + b,$
- **$A_{UL(C)} = \frac{a}{b}$ represents the asymmetries of interest.**

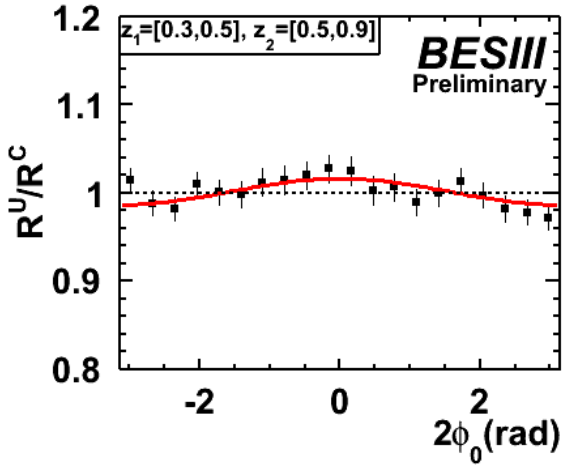
Fit to DR in Different z Bin

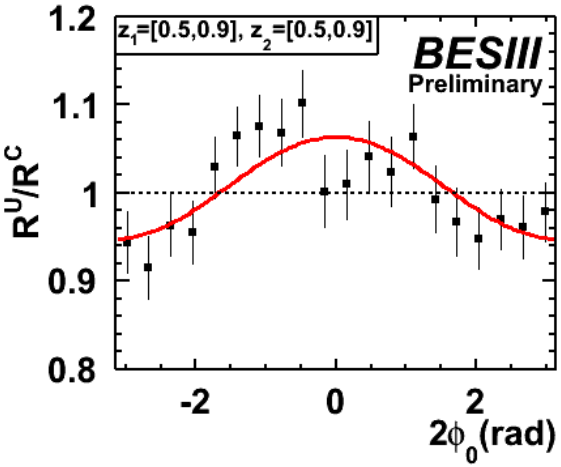






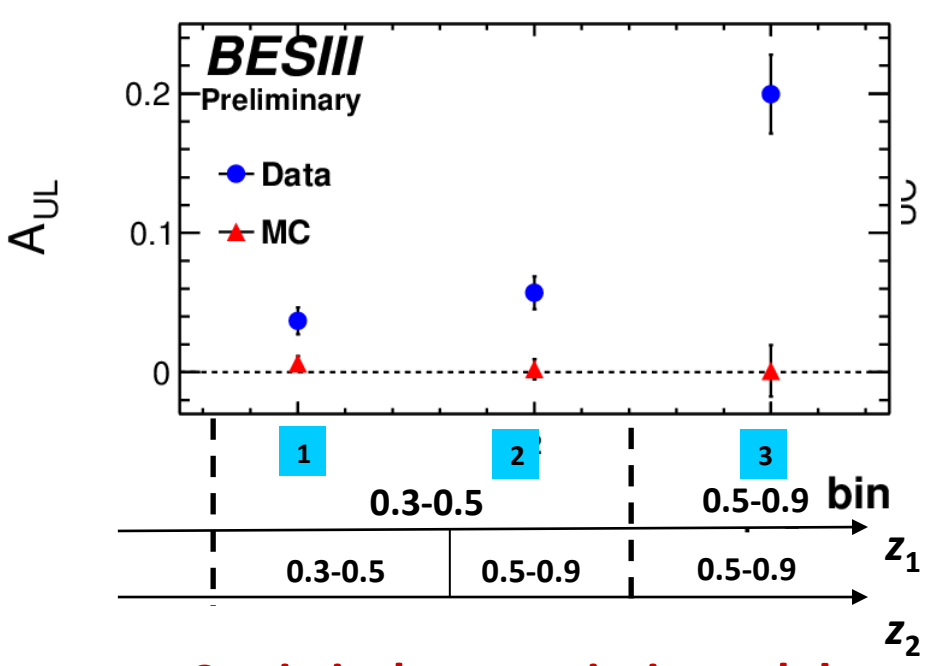


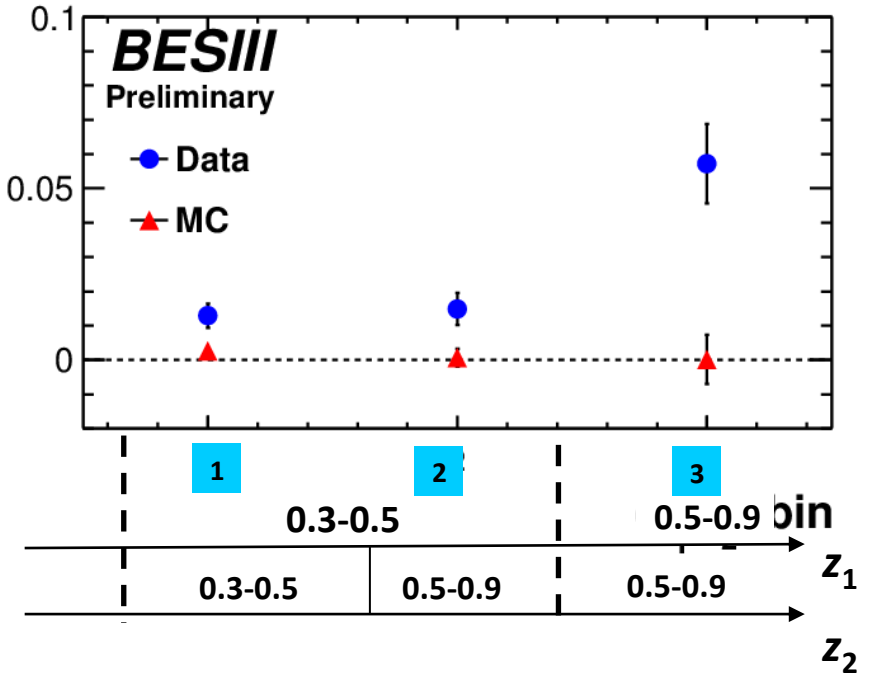




- **Only three symmetrized z-bins, due to the limited statistics.**

Z-dependence Asymmetries





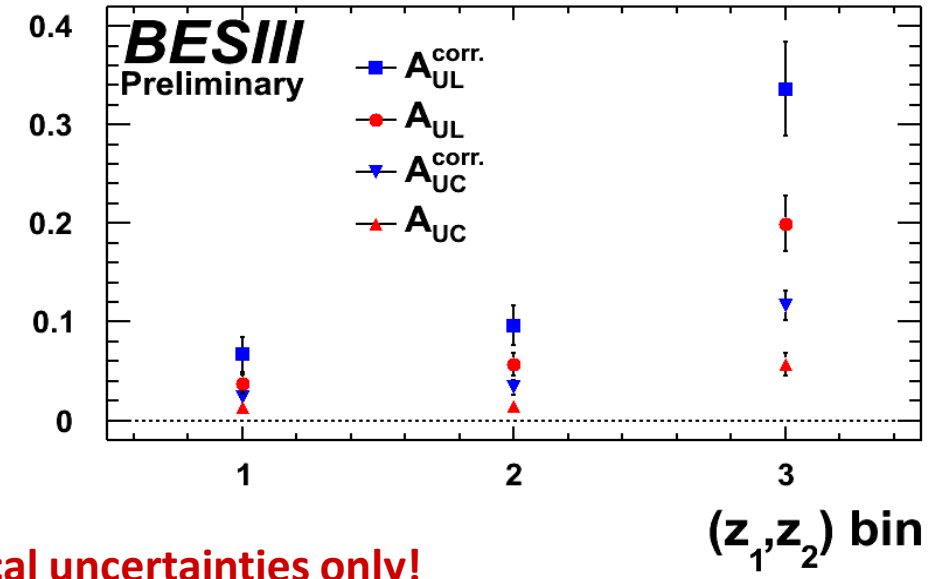
- **Statistical uncertainties only!**

- **Data show nonzero A_{UL} and A_{UC}.**
- **The MC simulation does not include the Collins effect. Zero asymmetries in MC indicate that detector effects are reduced to a negligible level.**

R_{mis} Correction

- **Mis-combination problem: without identifying jets, pions from the same quark fragmentation may be combined. This dilutes the asymmetries of interest.**
- **Estimation of the combined rate R_{mis} relies on MC. (Pythia 6.2)**
- **Measured Asymmetries are corrected by**

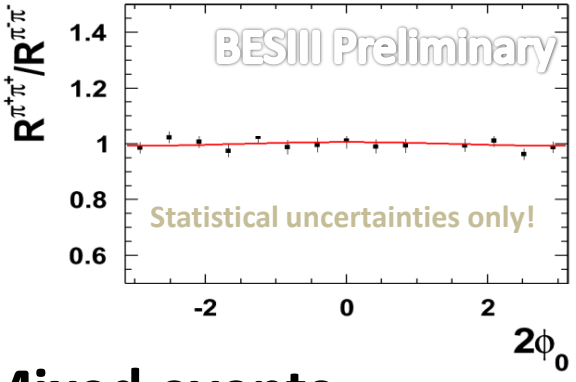
$$A^{corr.} = \frac{A^{mea.}}{(1 - R_{\rm mis})}$$



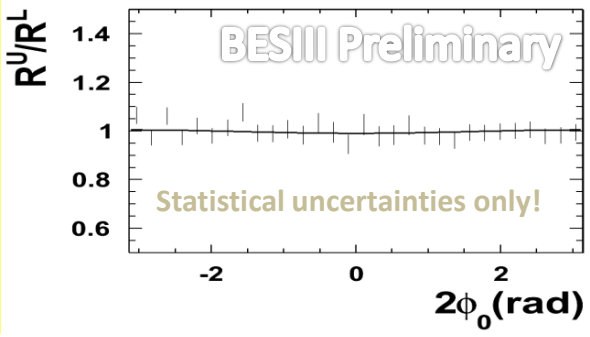
- **Statistical uncertainties only!**

Zero Test in Data

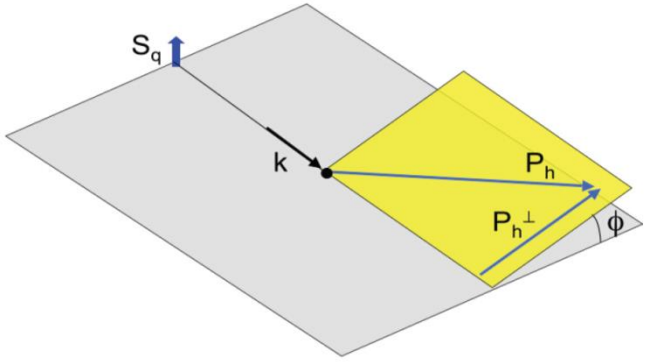
- Check efficiency differences of π^+ and π^-, make sure DR can cancel detection effects.



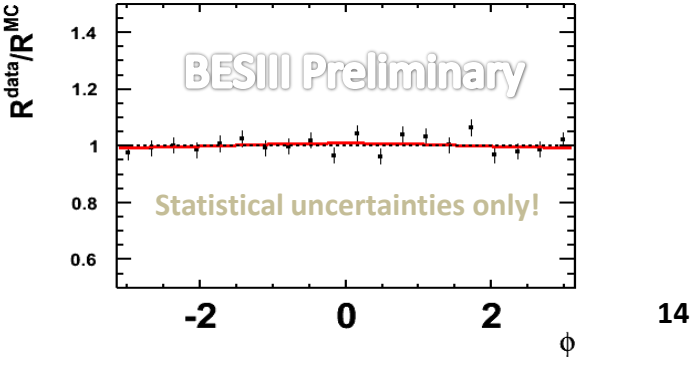
- Mixed events
  - Combine two π from different events in data. Zero asymmetry is expected.



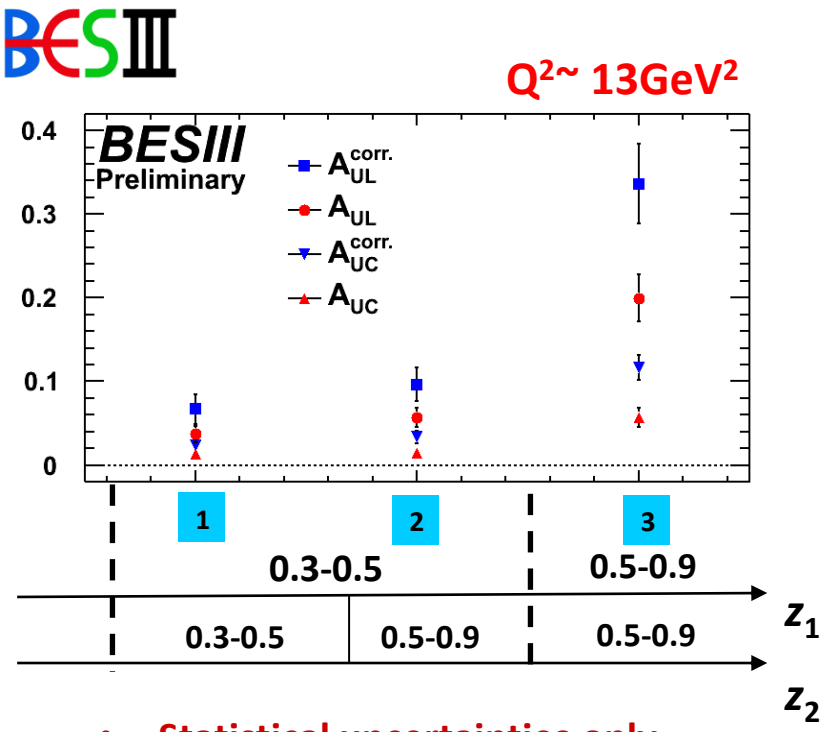
- Single Spin Asymmetry(SSA)



  - Thrus axis is assumed as the direction of the initial quark
  - With unpolarized beam, zero SSA is expected. To cancel efficiencies, R^{data}/R^{MC} was used.

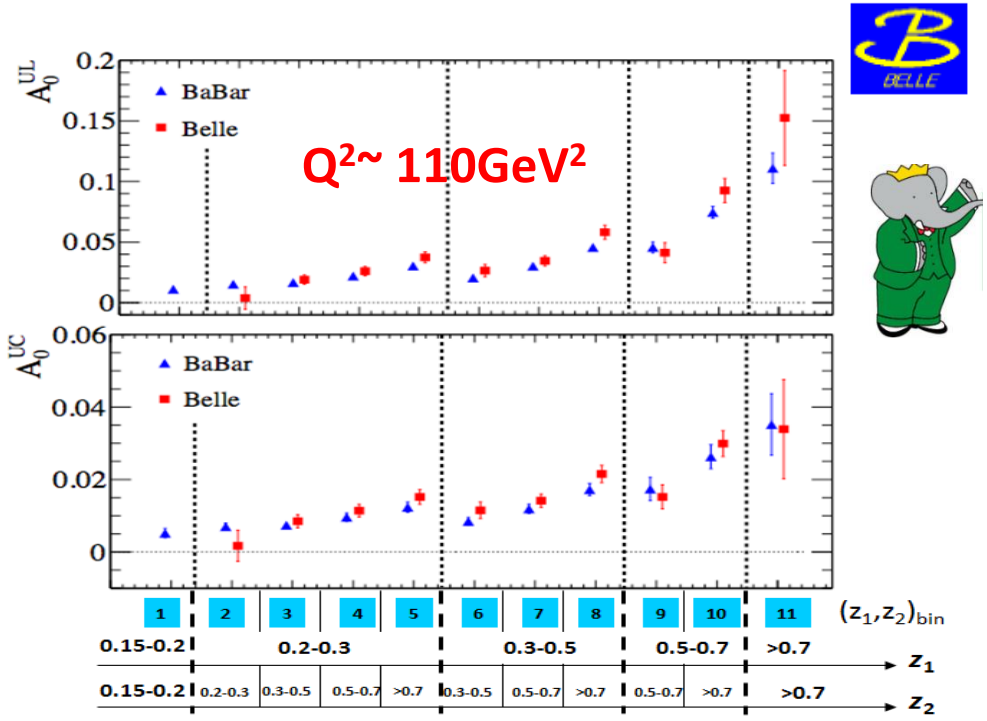


Collins Asymmetries in Different Q^2



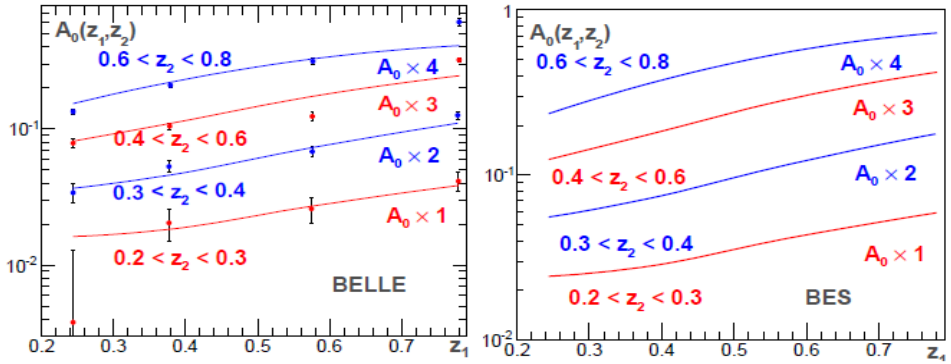
Q^2~ 13GeV^2

- Statistical uncertainties only.



- The measured Collins asymmetries at BESIII is larger than those at higher Q^2 at B factories.
- This trend accords with predictions in PRD 88. 034016 (2013).

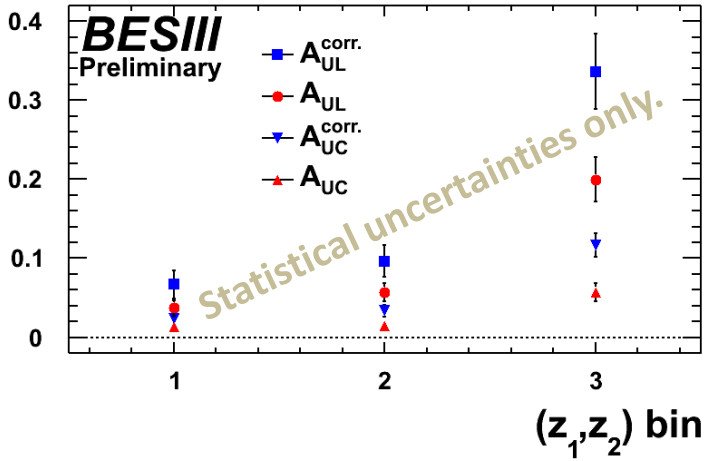
➢ Theoretical prediction PRD 88. 034016 (2013)



Q^2~ 110GeV^2 Q^2~ 20GeV^2

Summary and Outlook

- **Collins effects measurement is implemented using BESIII data @3.65GeV.**
  - **Nonzero Collins asymmetries were observed.**



- **Outlook**
  - **Potential of data above charm threshold can be explored.**
  - **BESIII plans to take more data $\sqrt{s}$<3.6GeV, which will improve precision of this measurement.**

Acknowledgement

- **We would like to thank Jianping Ma, Feng Yuan, Peng Sun, Xiaodong Jiang and D. Boer for helpful discussions!**

Thanks for your attention!