Unpolarized Fragmentation Functions at BESIII

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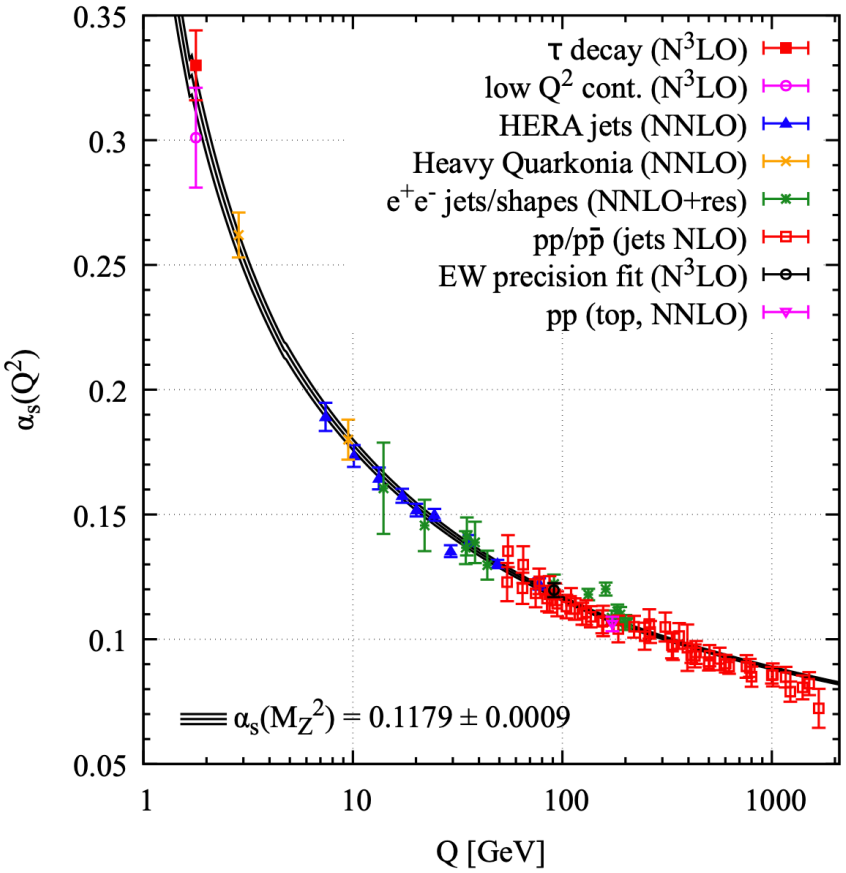
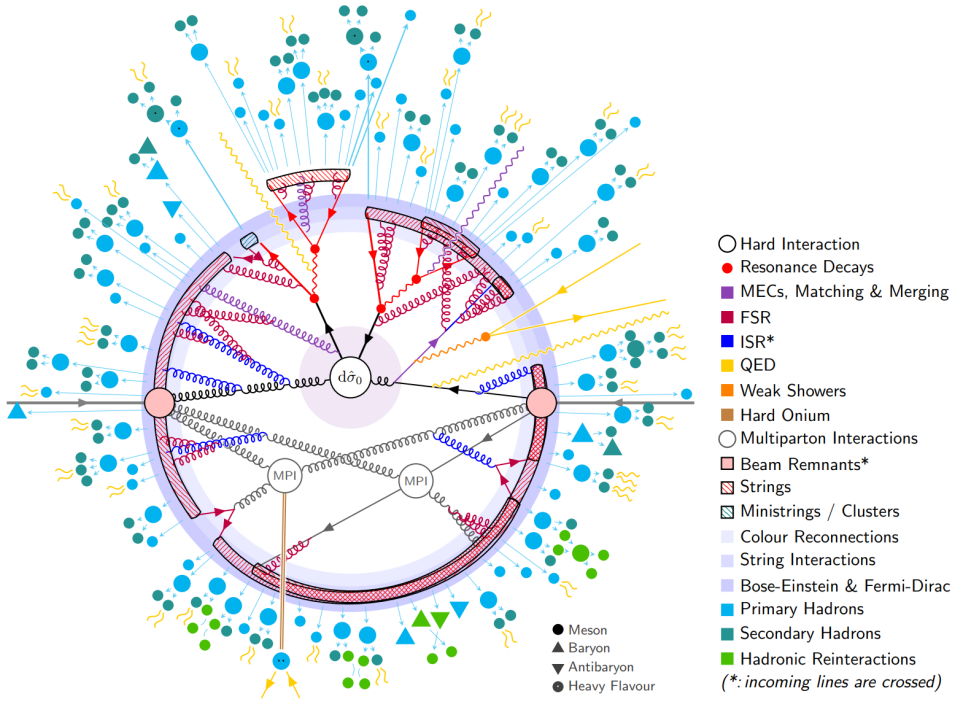
Confinement

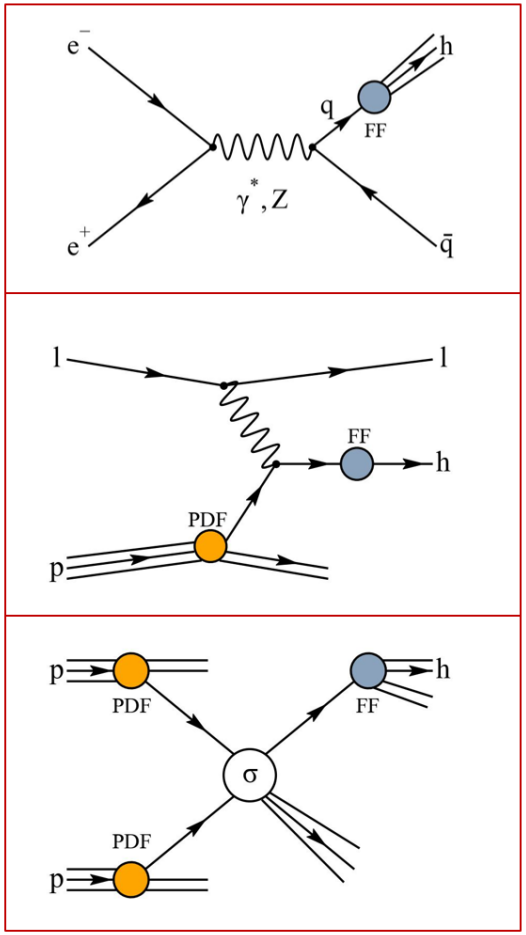




- Confinement, no existing isolated quarks or gluons.
- How to form a hadron? What is hadron structure?

Fragmentation function

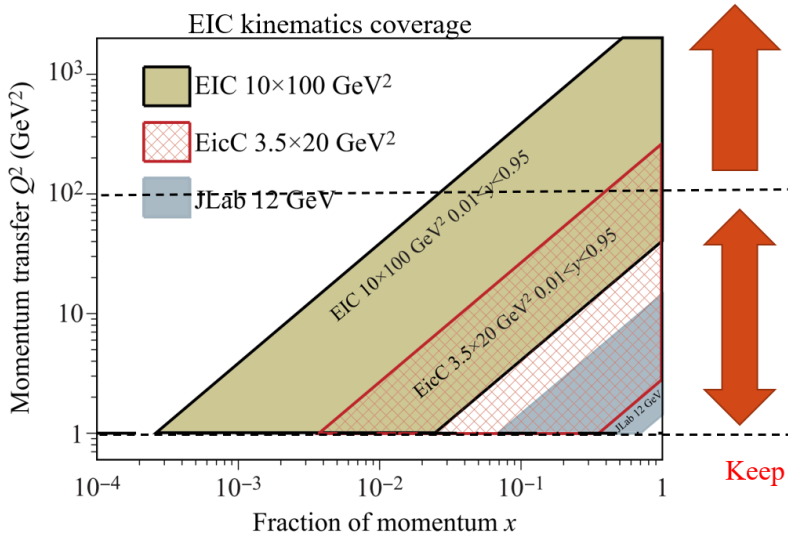
$D_q^h(z)$: describe the fragmentation of an unpolarized quark into an unpolarized hadron, where the hadron carries a fraction $z = 2E_h/\sqrt{s}$ of parton's momentum



INPUT

- $e^+e^- \to hX : \sum_q e_q^2 D(z)$
- $lp \to lhX : \sum_q e_q^2 f_q(x) D(z)$
- $pp \to hX : \sum_{i,j} f_i(x) \otimes f_j \otimes D(z)$

FFs at low energy region is important for EIC&EICC



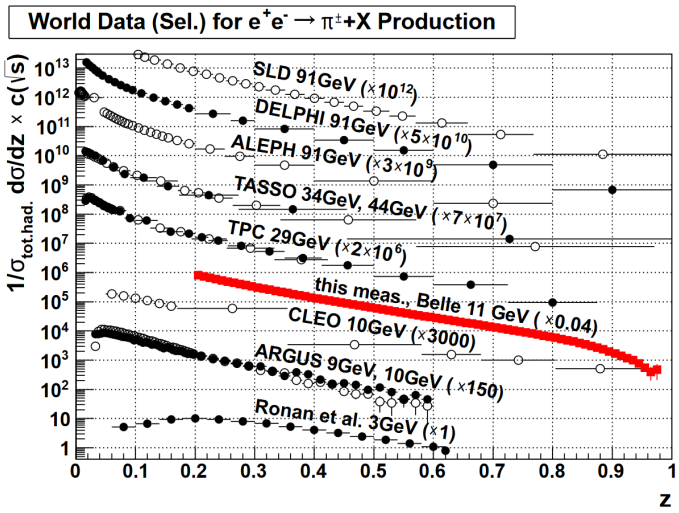
BELLE, BaBar, TASSO, LEP …

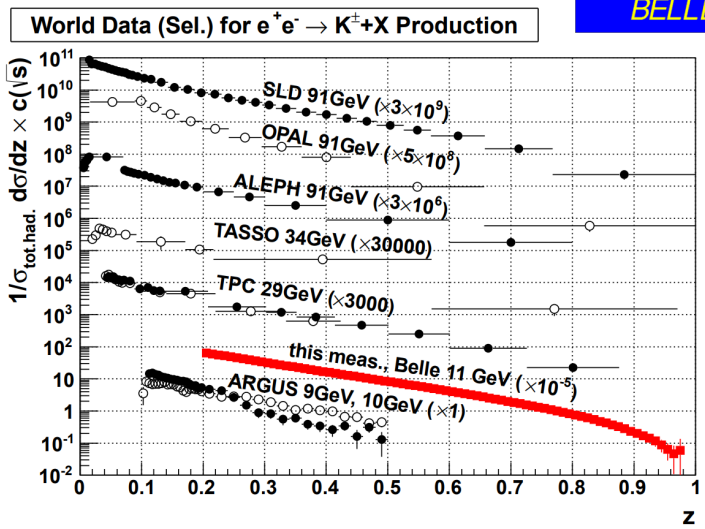
Almost no **precision data** on FF

Keep in mind: QCD evolution is from low to high

World data from e^+e^- experiment

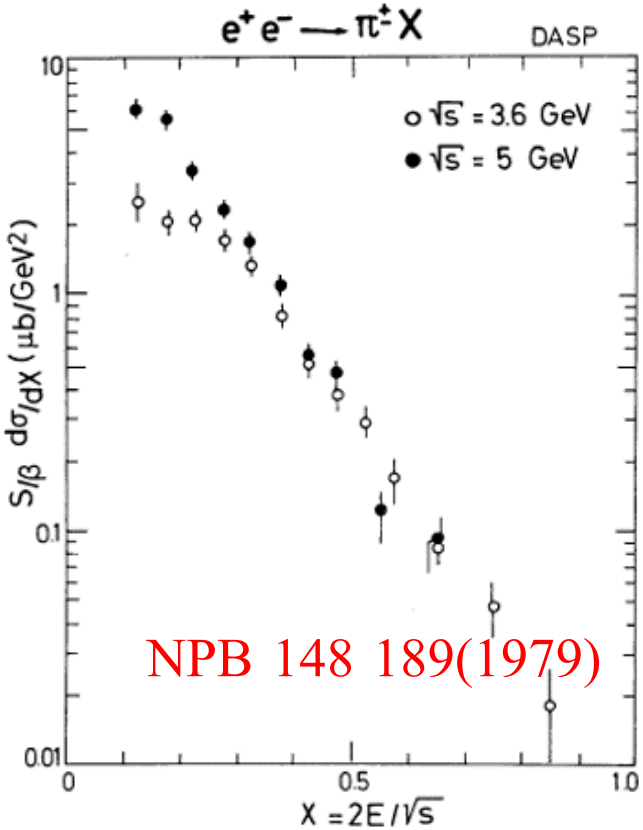
PRL 111 062002(2013)

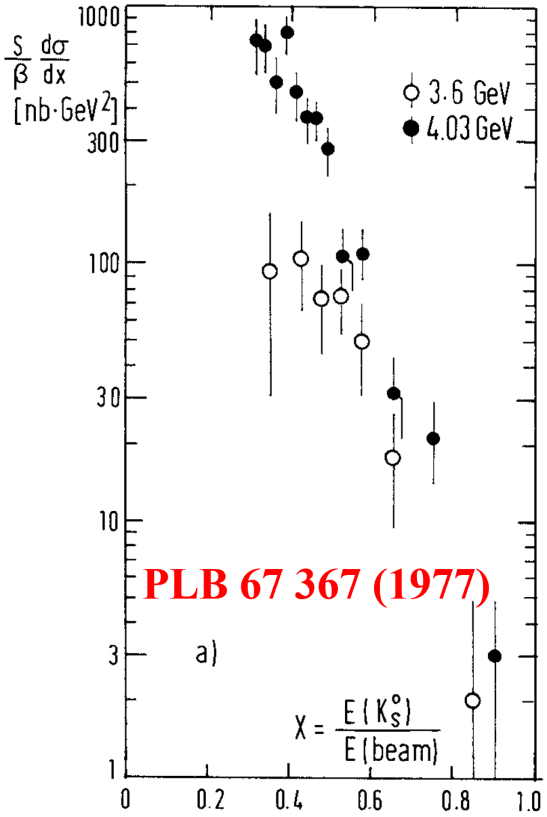




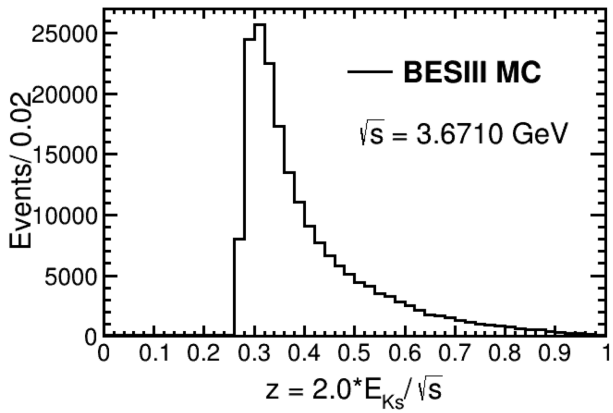
- World data includes charged π, K
- Datasets at low Q^2 range ($\sqrt{s} < 10$ GeV) e^+e^- collision?
- Ronan's result: J/ψ
- Advantage of BESIII: 2.00-4.95 GeV

World data from e^+e^- experiment



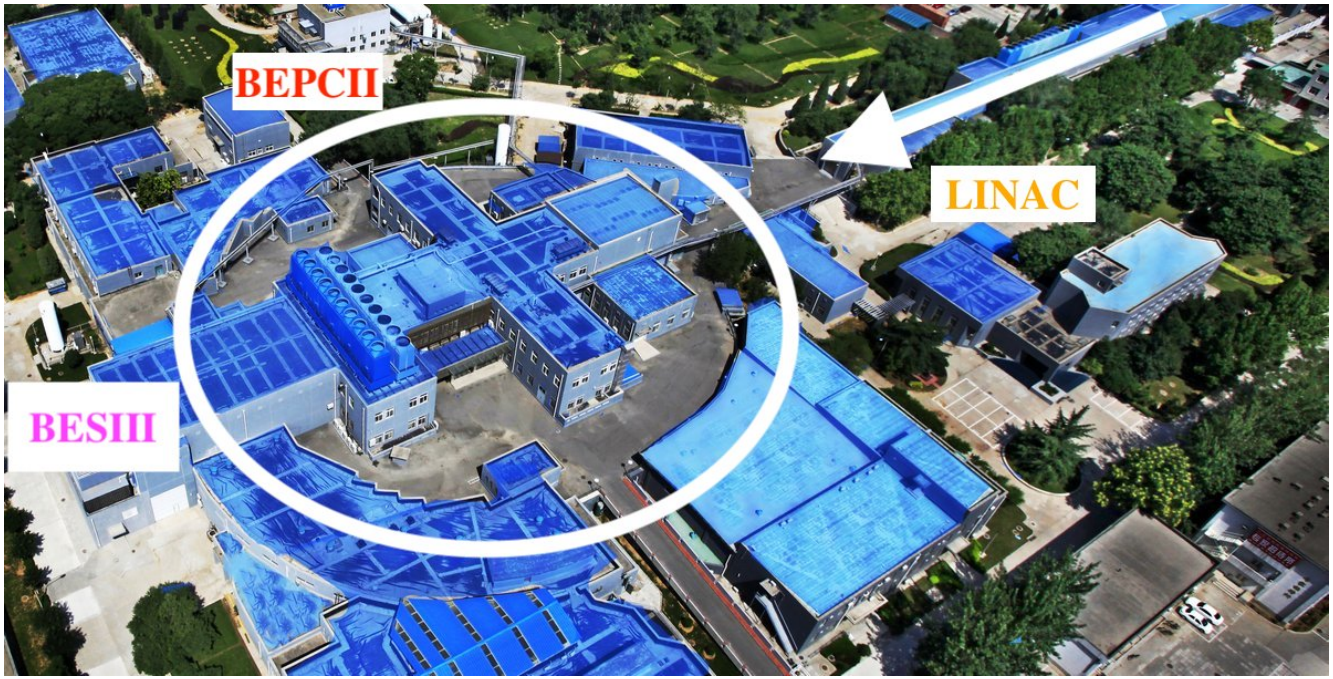


- Charged π @ **DASP**
  - ✓ **~40 years ago**
  - ✓ **stat. uncertainty: 18%**
- K_S^0 **@PLUTO**
  - ✓ **~45 years ago**
  - ✓ **stat. uncertainty: 18-41%**
- **Precision measurement!**
- **Lack data at high** z



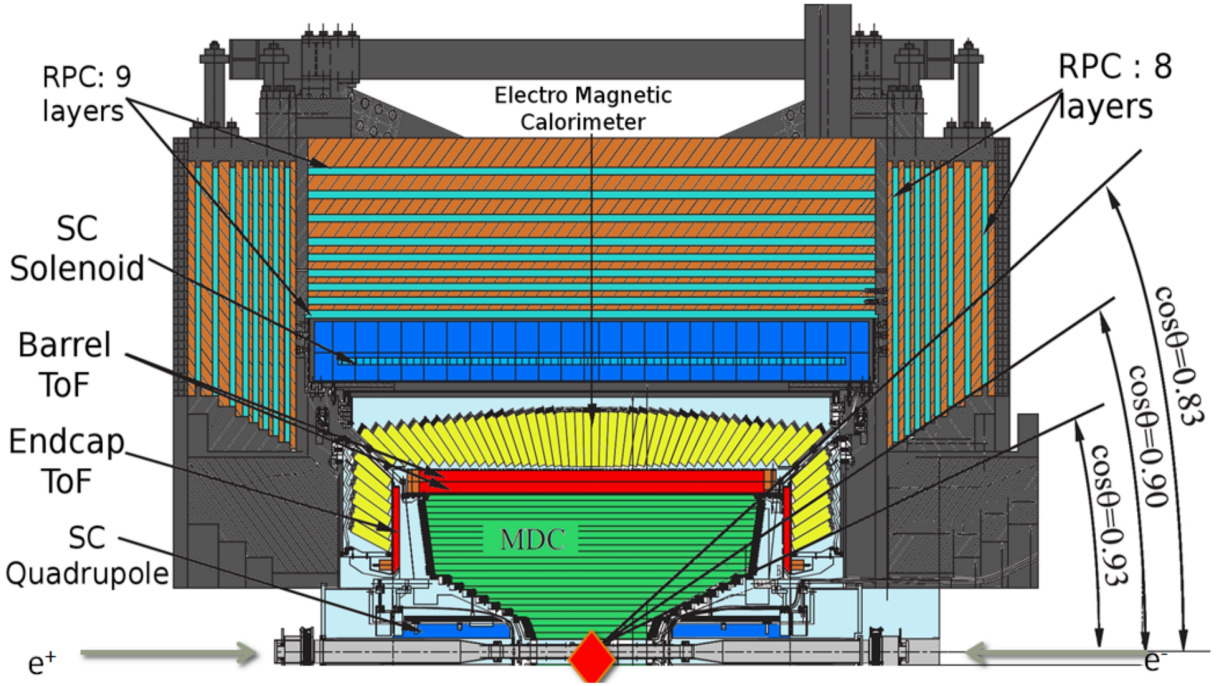
Precision measurement on FFs @ BESIII!

BEPCII



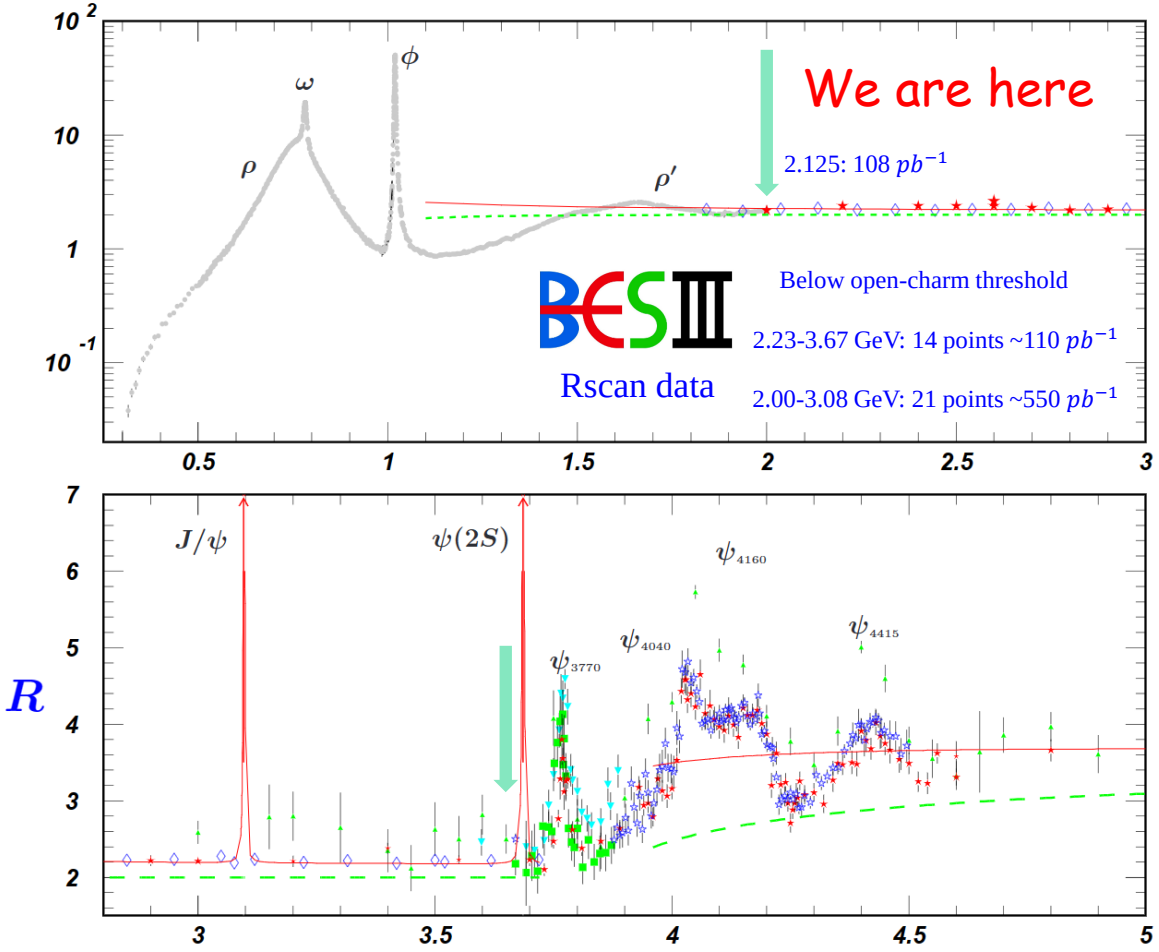
- Beam energy: 1.0-2.475 GeV.
- Luminosity: 1.0×10^{33} cm^{-2}s^{-1} @$\psi(3770)$

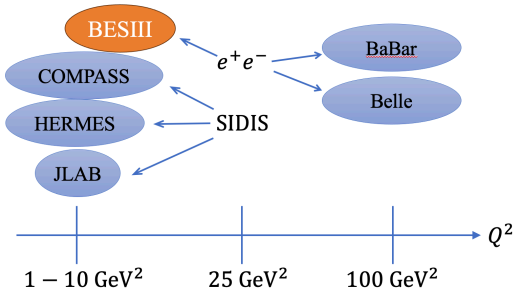
BESIII



- Muon Counter: $\sigma_{xy} < 2$ cm.
- Electromagnetic Calorimeter: $\sigma_E/E = 2.5\%(5\%)$ @ 1 GeV.
- Main Drift Chamber: $\sigma_p/p = 0.5\%$ @ 1 GeV.
- Superconducting Sclenoid: B =1 T.
- Time of Flight: $\sigma_t = 68$ ps(barrel), $\sigma_t = 60$ ps(endcap) 110 ps before 2015.

BESIII data





$\sqrt{s}$(GeV)	$\mathcal{L}_{int.}$(pb^{-1})
2.2324	2.645
2.4000	3.415
2.8000	3.753
3.0500	14.893
3.4000	1.733
3.6710	4.628

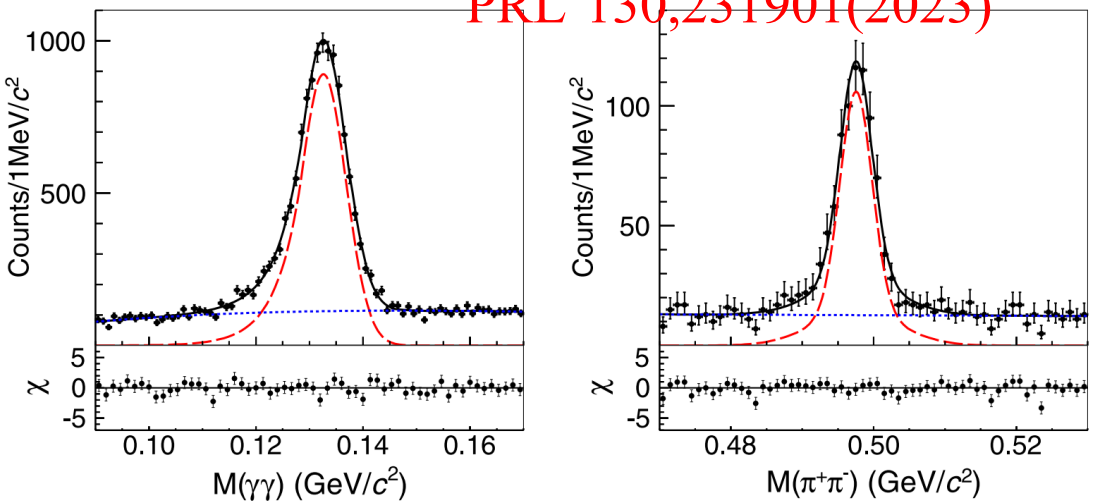
Inclusive π^0/K_S^0 at BESIII

- Experimental observable: $\frac{1}{\sigma_{had}}\frac{d\sigma_{\pi^0}}{dp_{\pi^0}} = f\frac{N_{\pi^0+X}}{N_{had}}\frac{1}{\Delta p_{\pi^0}}$
- Pre-selection same as R-value measurement at BESIII(PRL 128,062004(2022)) (Dr. Christoph's presentation on 16th Oct.)
- Reconstruction:

Good photons → $M(\gamma\gamma)$ → N_{π^0}

Good charged tracks → PID → SecVertexFit → $M(\pi^+\pi^-)$ → $N_{K_S^0}$

PRL 130,231901(2023)



$P \in (0.4, 0.5)$ GeV

$\sqrt{s} = 2.8$ GeV

BESIII Results

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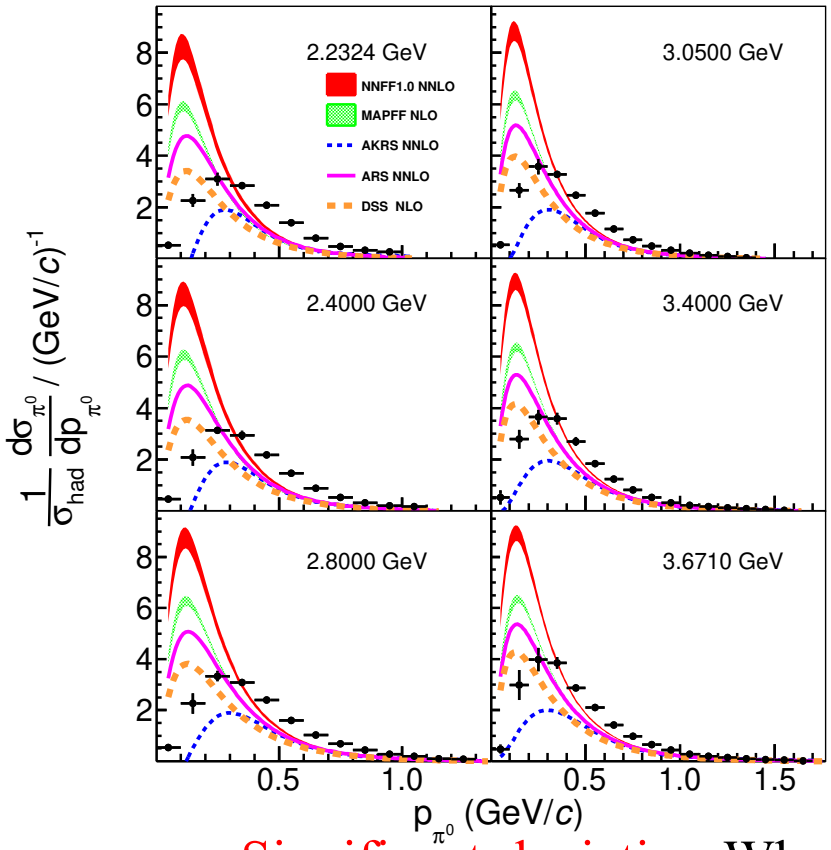
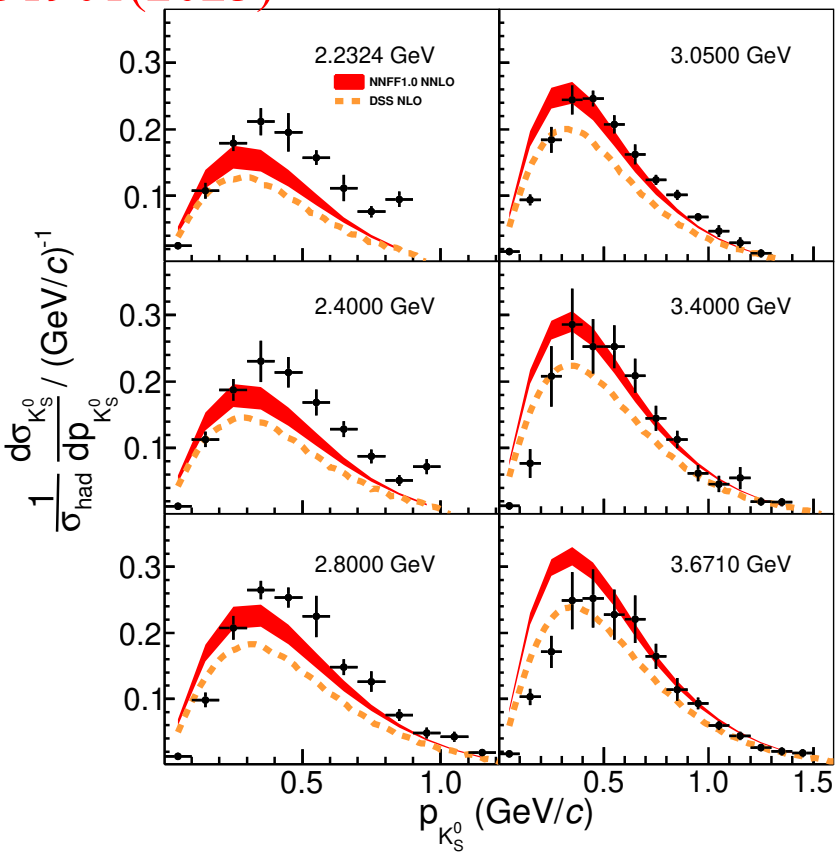
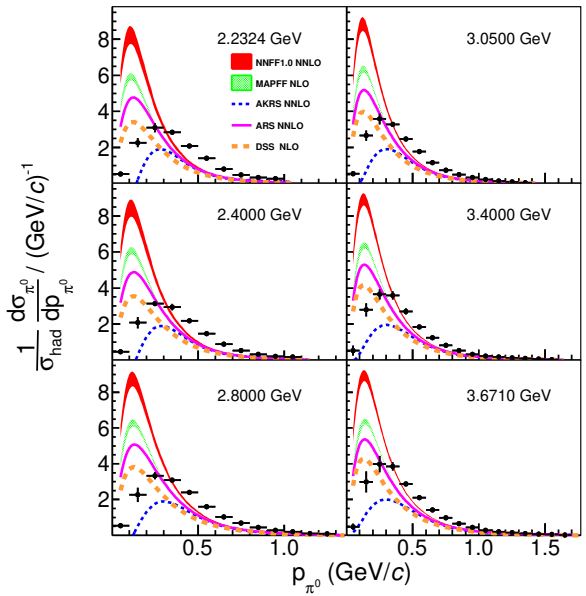


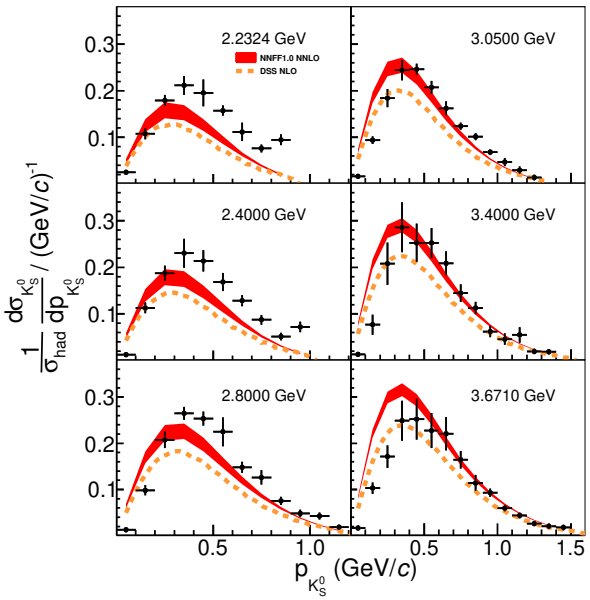


- Significant deviation Why??
  - Experimental side: primary π^0 + π^0 from resonance decay or weak decay???
  - Theory side: leading twist calculation not sufficient at BESIII energy scale? hadron mass effect? large z re-summation? problem in the extrapolation of FFs from high energy data to low-energy scale?

Summary

- The normalized differential cross sections of the $e^+e^- \to \pi^0/K_S^0 + X$ processes has been measured using BESIII data at $5 < Q^2 < 13$ GeV^2.
- z coverage of BESIII results is from 0.1 to 0.9 with a 3% precision at $z \sim 0.4$.
- Large discrepancy with current fragmentation function calculation is observed to depend on both c.m. energy and hadron momentum.



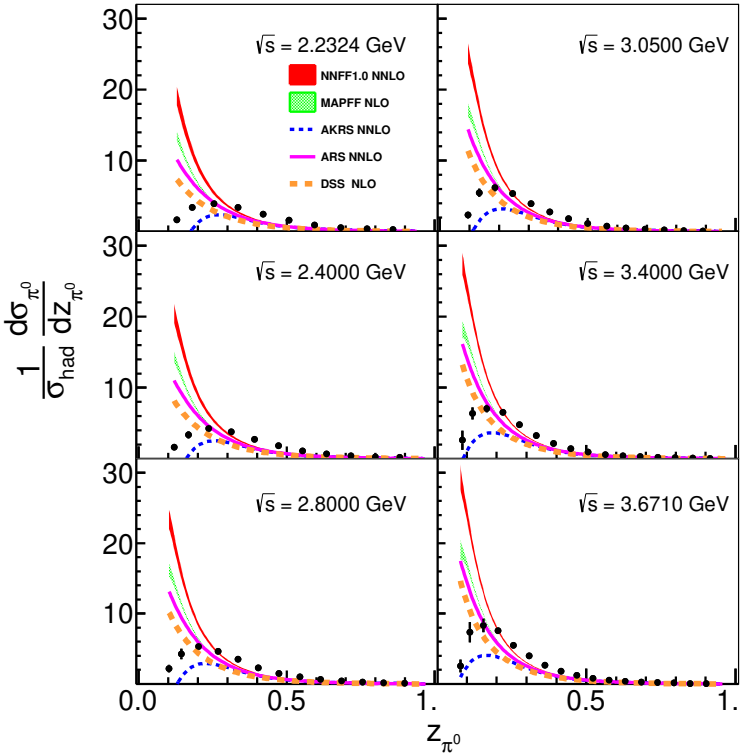


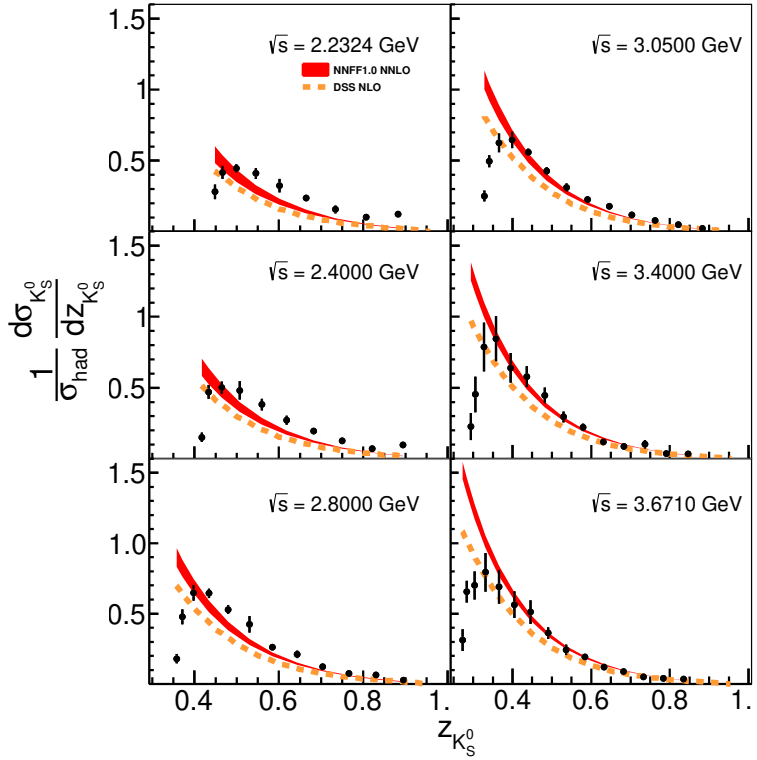
Ongoing researches on unpolarized FFs at BESIII

$e^+e^- \to \pi^\pm/K^\pm + X$	$D^{h/q}(z), D^{h/q}(z,\kappa_T)$
$e^+e^- \to \eta + X$	$D^{h/q}(z)$
$e^+e^- \to \phi/K^*(892) + X$	$D^{h/q}(z)$
$e^+e^- \to (\pi\pi) + X$	$D^{h_1h_2/q}(z, M_h)$
$e^+e^- \to \Lambda(\bar{\Lambda}) + X$	$D_{1T}^{\perp\Lambda/q}(z, p_\perp^2)$
……	

Thanks for your attention!

Backup


√s = 2.2324 GeV
NNFF1.0 NNLO
MAPFF NLO
AKRS NNLO
ARS NNLO
DSS NLO
√s = 3.0500 GeV
√s = 2.4000 GeV
√s = 3.4000 GeV
√s = 2.8000 GeV
√s = 3.6710 GeV
$\frac{1}{\sigma_{had}}\frac{d\sigma_{\pi^0}}{dz_{\pi^0}}$
z_{π^0}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NNFF1.0 NNLO
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√s = 3.4000 GeV
√s = 2.8000 GeV
√s = 3.6710 GeV
$\frac{1}{\sigma_{had}}\frac{d\sigma_{K^0_S}}{dz_{K^0_S}}$
$z_{K^0_S}$