Study of $\tau^+ \to \pi^+\pi^0\overline{\nu}_\tau$ and $\tau^+ \to K^+\pi^0\overline{\nu}_\tau$ at STCF

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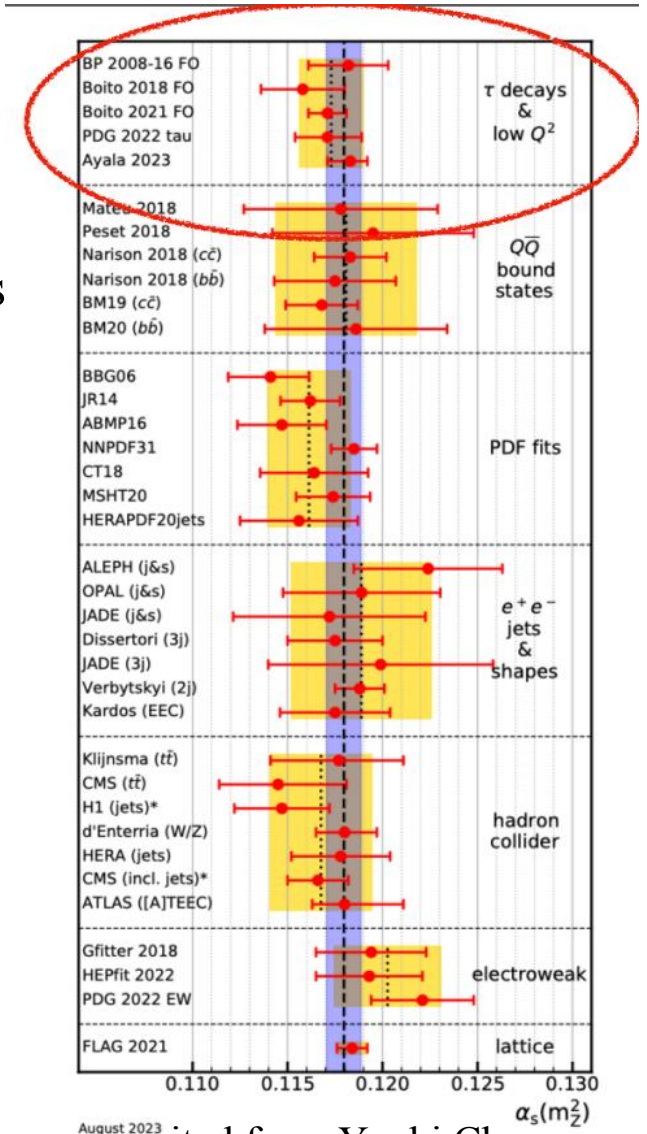
Outline

- Motivation
- MC sample
- $\tau^+ \to \pi^+\pi^0\overline{\nu}_\tau$
  - Event selection
  - Branching fraction measurement
- $\tau^+ \to K^+\pi^0\overline{\nu}_\tau$
  - Event selection
  - Branching fraction measurement
- Summary

Motivation

- The strong coupling constant α_s is a fundamental parameter of the Standard Model (SM) of particle physics and Quantum Chromodynamics (QCD). Measuring the branching ratio of $\tau^+ \to \pi^+\pi^0\overline{\nu}_\tau$ the decay process provides significant experimental input for determining α_s .
- The τ lepton is the sole lepton with a mass large enough to decay into hadrons. Its decays to hadronic final states occur via W - exchange, and the decay rates to final states containing a strange quarkare suppressed by the factor $(|V_{us}|/|V_{ud}|)^2$.
- Given a value of m_s ,$|V_{us}|$ can be determined with unprecedented precision from the inclusive sum of the branching fractions of $\tau^+ \to K^+\pi^0\overline{\nu}_\tau$.



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MC sample

$\sqrt{s}$= 3.773 GeV

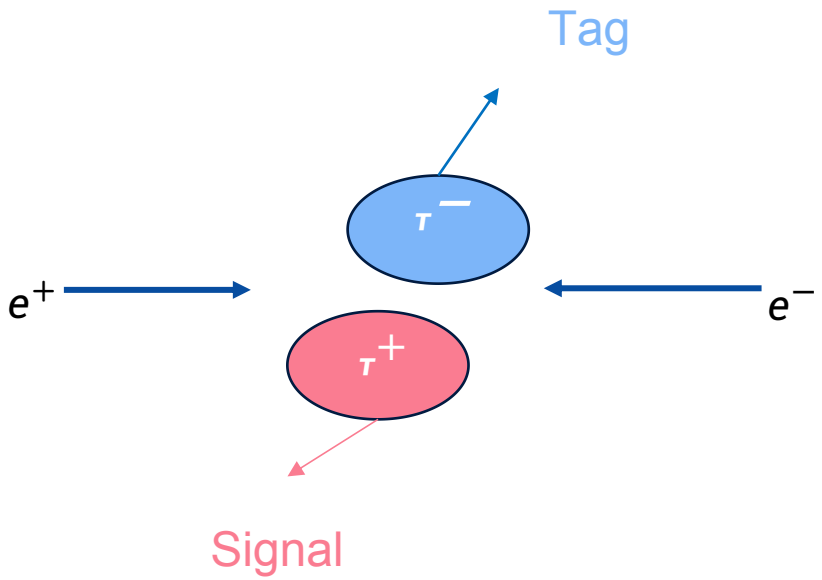
- 400,000 signal MC
- signal MC Generator model: tauhadnu.

$\sqrt{s}$= 4.260 GeV

- 3,000, 000 Inclusive ditau MC
- Inclusive ditau MC Generator model: madgraph5＋pythia8.
- signal MC : from ditau inclusive MC.

MC sample

Double tag method



Tag: $\tau^- \to e^- \nu_\tau \overline{\nu}_e$

Signal: 1. $\tau^+ \to \pi^+ \pi^0 \overline{\nu}_\tau$, $\pi^0 \to \gamma\gamma$

2. $\tau^+ \to K^+ \pi^0 \overline{\nu}_\tau$, $\pi^0 \to \gamma\gamma$

$$B(\tau^+ \to \pi^+ \pi^0 \overline{\nu}_\tau / \tau^+ \to K^+ \pi^0 \overline{\nu}_\tau) = \frac{N_{sig}}{2N_{\tau\tau}\varepsilon B(\tau^- \to e^- \nu_\tau \overline{\nu}_e) B(\pi^0 \to \gamma\gamma)}$$

N_{sig}: Signal yields

ε : $\tau^- \to e^- \nu_\tau \overline{\nu}_e$ and $\tau^+ \to \pi^+ \pi^0 \overline{\nu}_\tau$ / $\tau^+ \to K^+ \pi^0 \overline{\nu}_\tau$ efficiency

$$\tau^+ \rightarrow \pi^+\pi^0\overline{\nu}_\tau$$

Event selection

- Charge tracks

V_{xy}<1cm, $|V_z|$ <10cm

cosθ<0.93;

- Photon selection

E_γ> 0.025 GeV in the barrel section

E_γ> 0.050 GeV in the end cap

0 ≤ TDC ≤ 14(×50ns)

$N_\gamma \geq 2$

- π^0 Reconstruction

χ^2<200(1-c kinematic)

- PID requirement

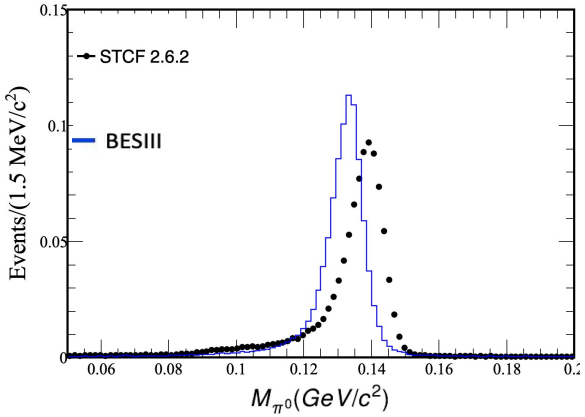
Using PID system: Global PID

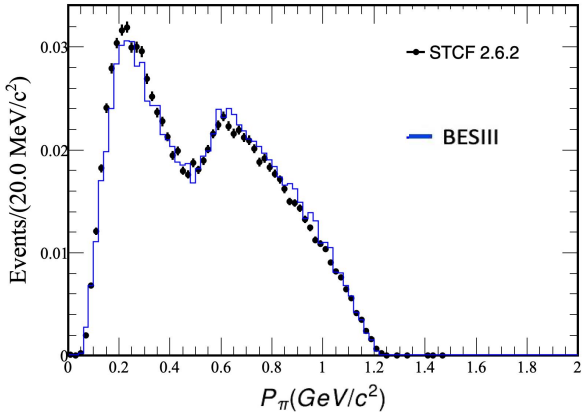
e :$Prob_e > Prob_\pi; Prob_e > Prob_K$

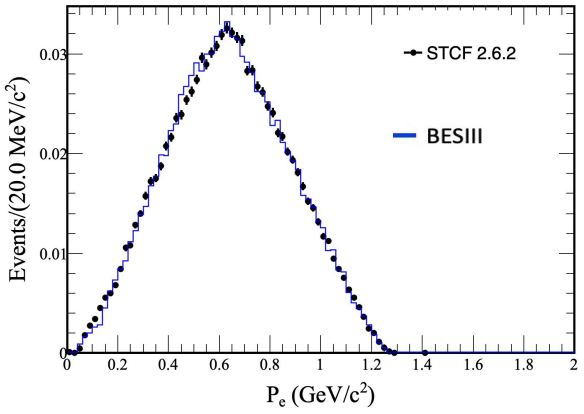
π :$Prob_\pi > Prob_e; Prob_\pi > Prob_K$

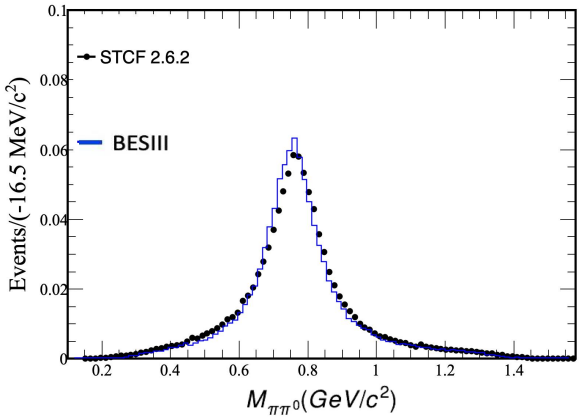
$N_\pi = 1, N_e = 1$

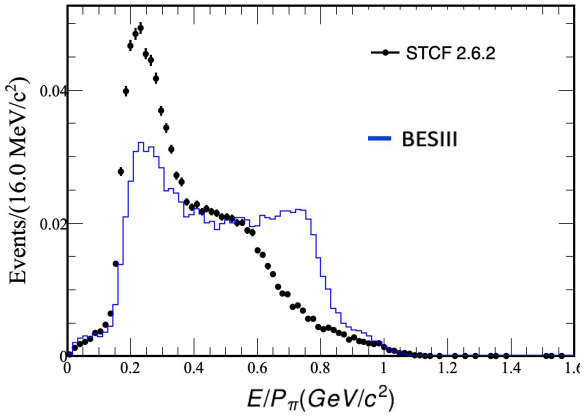
Compare with BESIII at $\sqrt{s}$ = 3.773 GeV

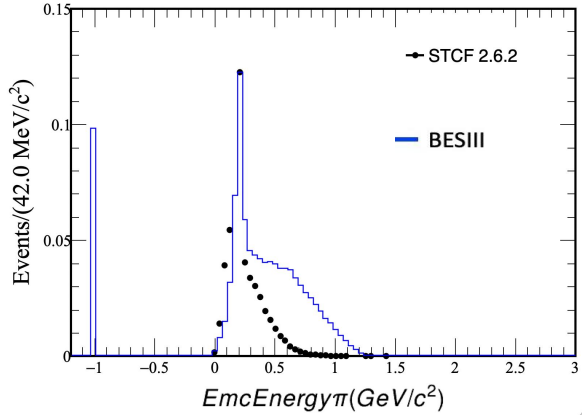


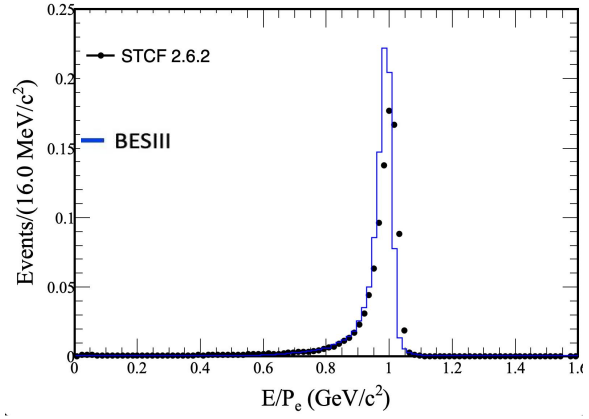


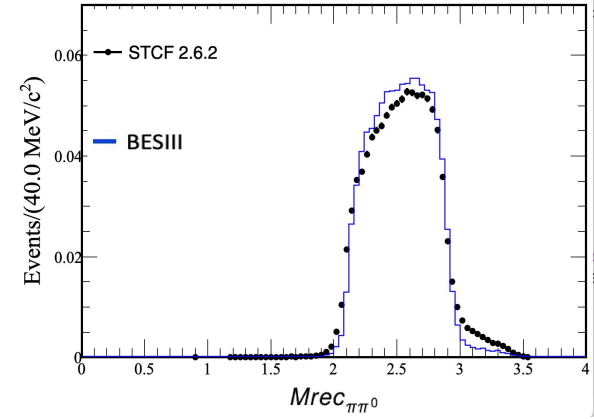




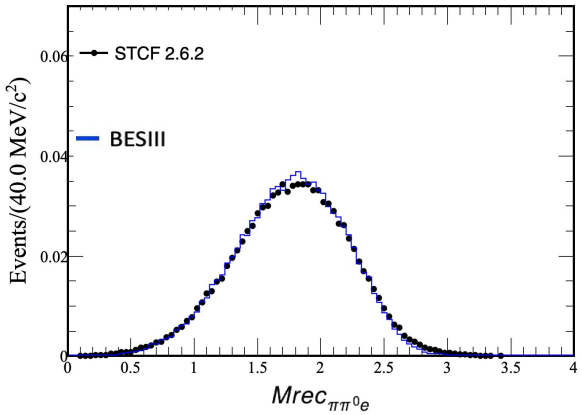


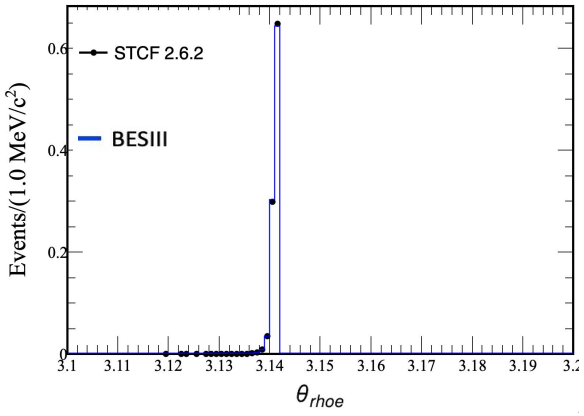






Compare with BESIII at $\sqrt{s}$ = 3.773 GeV

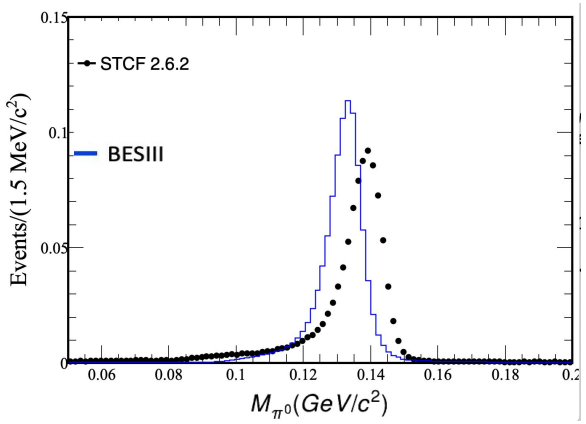


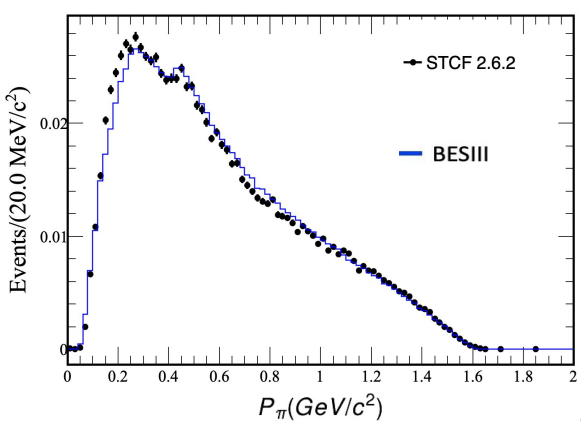


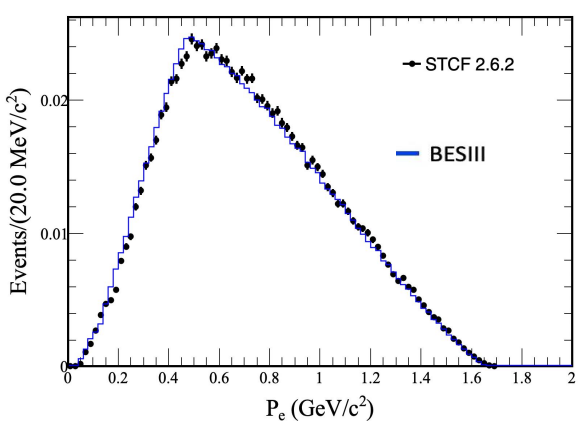
Compare with BESIII at $\sqrt{s}$ = 3.773 GeV

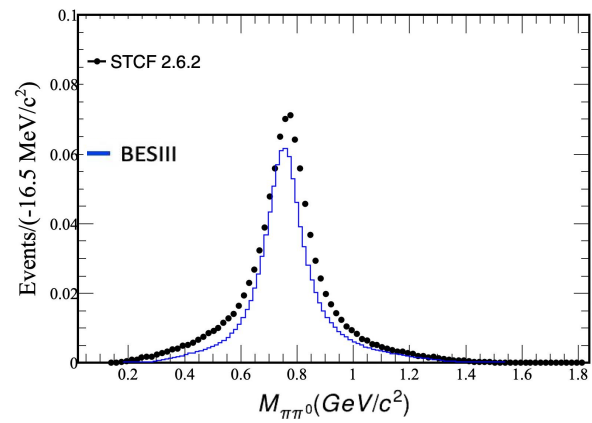
	SigMC num	Efficiency	BESIII efficiency
No cut	108515	55.08%	50.24%
$0.12 < m(\pi^0) < 0.15$	82454	41.85%	43.94%
$\frac{E}{P}(\pi) < 0.9$, $0.8 < \frac{E}{P}(e) < 1.05$	70372	35.72%	39.18%
$P_e < 1.2$ $P_\pi < 1.2$	69968	35.52%	39.00%
$exN(\gamma) = 1, N(\pi^0) = 1$	65830	33.42%	30.36%
the(rhoe)<3.1413	43965	22.32%	20.63%
$2 < mrec(\pi\pi^0) < 3$, $0.5 < mrec(\pi\pi^0 e) < 2.8$	43424	22.04%	20.47%

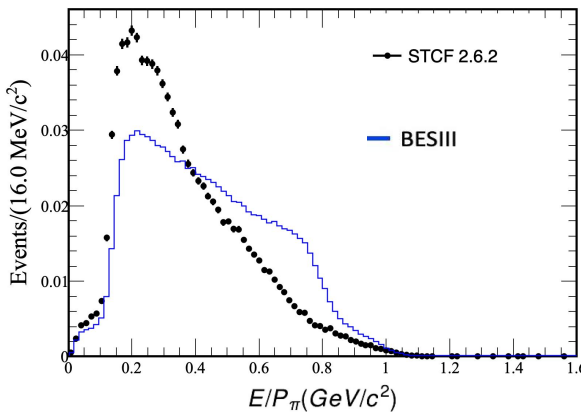
Compare STCF at $\sqrt{s}$ = 4.260 GeV with BESIII at $\sqrt{s}$ = 4.270 GeV

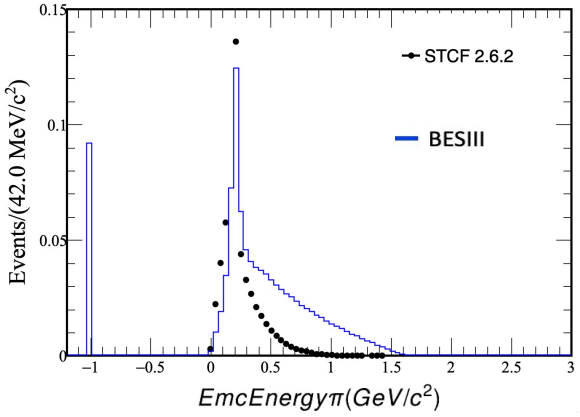


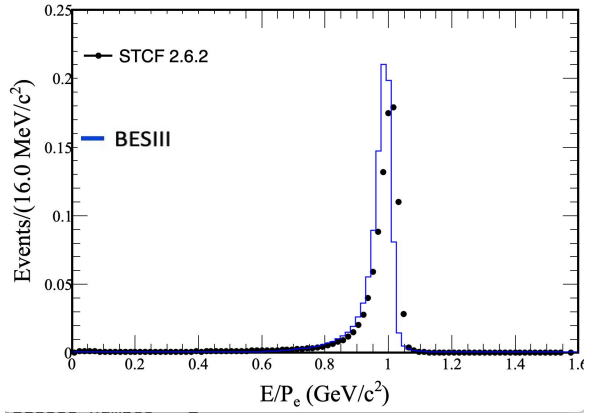


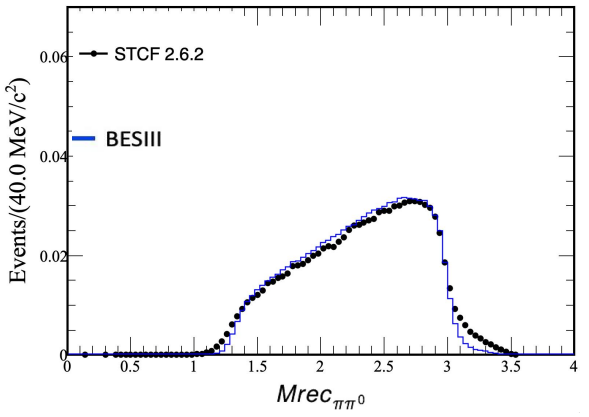




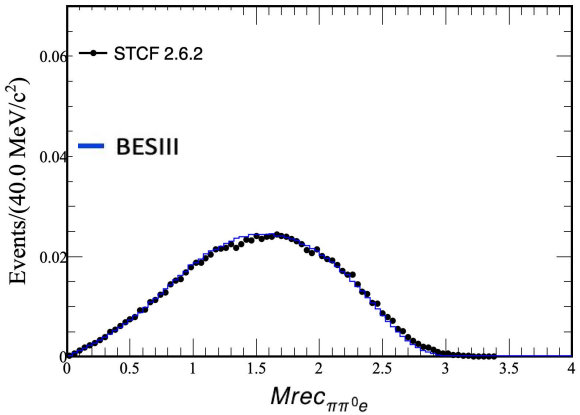


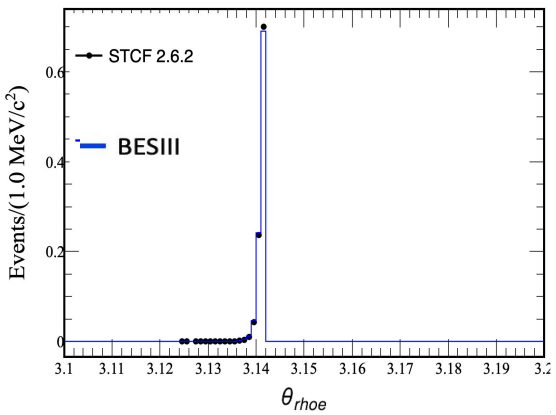






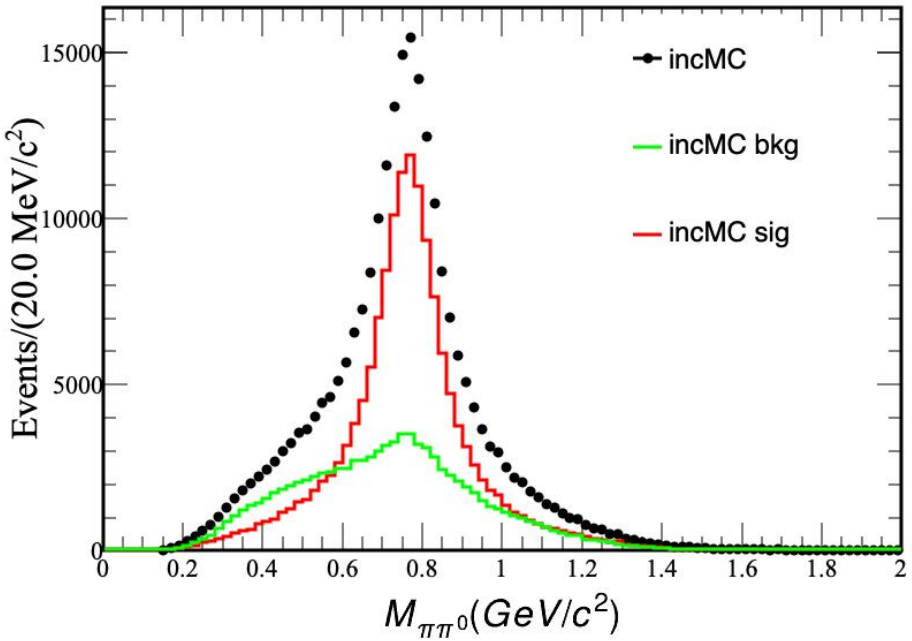
Compare STCF at $\sqrt{s}$ = 4.260 GeV with BESIII at $\sqrt{s}$ = 4.270 GeV



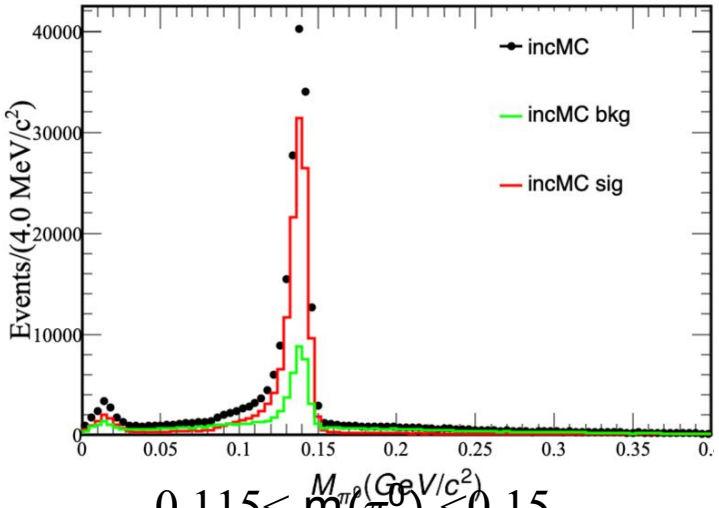


Signal selection criteria

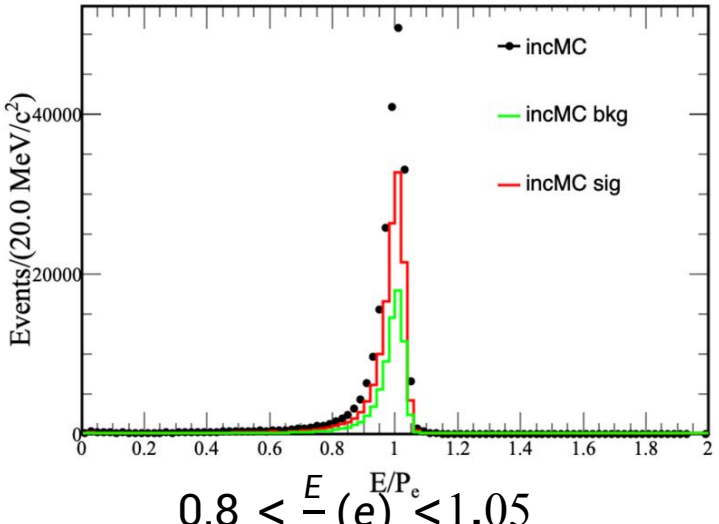
At $\sqrt{s} = 4.26\ GeV$, $\mathrm{m}(\pi^+\pi^0)$ is used to identify semileptonic decay, combined tag and signal selection .



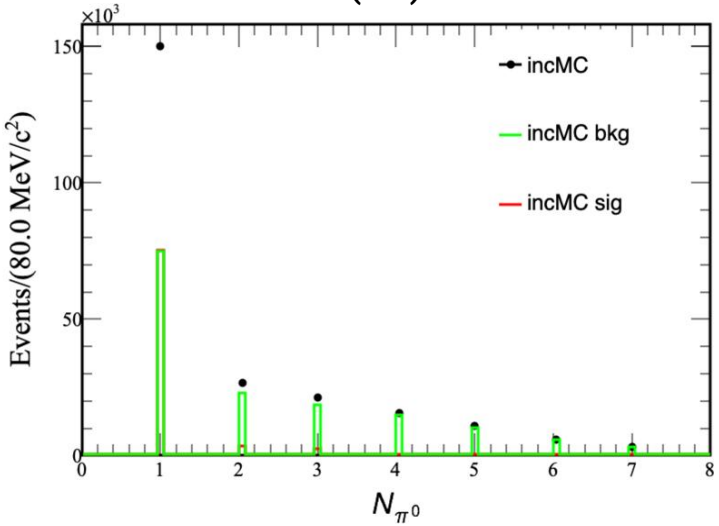
Event selection



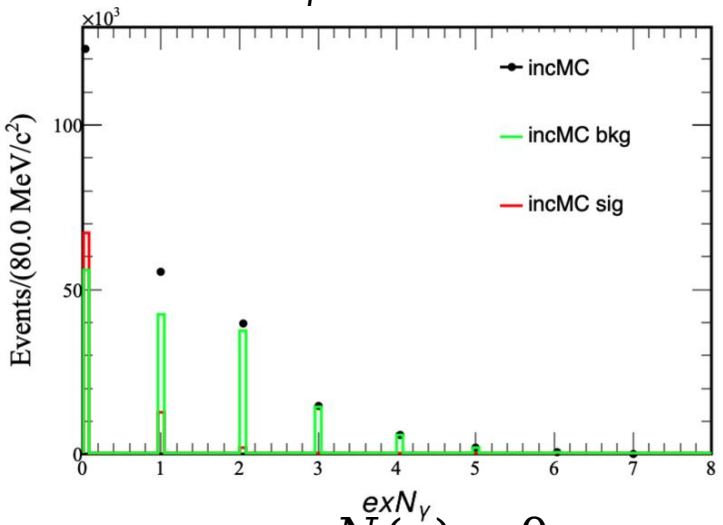
$0.115 < m(\pi^0) < 0.15$



$0.8 < \frac{E}{P}(e) < 1.05$

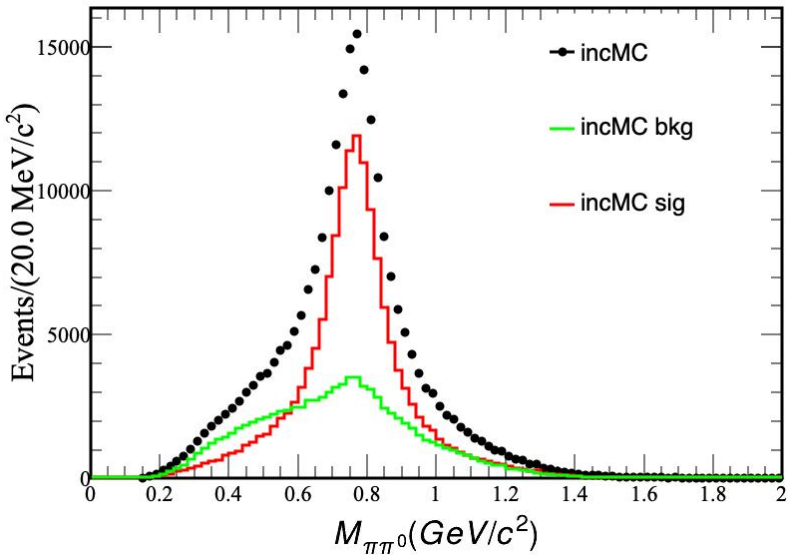


$N(\pi^0)=1$



$exN(\gamma) = 0$

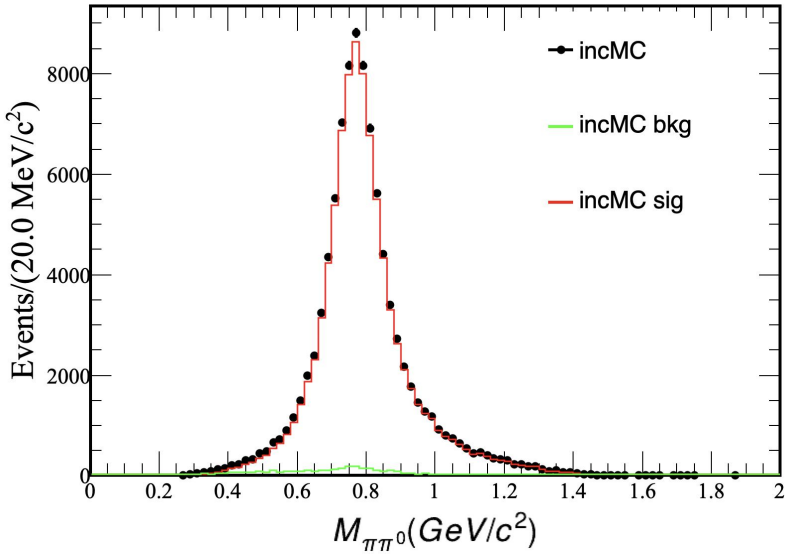
Signal selection criteria



$0.115 < m(\pi^0) < 0.15$,

$0.8 < \frac{E}{P}(e) < 1.05$,

$N(\pi^0)=1$, $exN(\gamma) = 0$



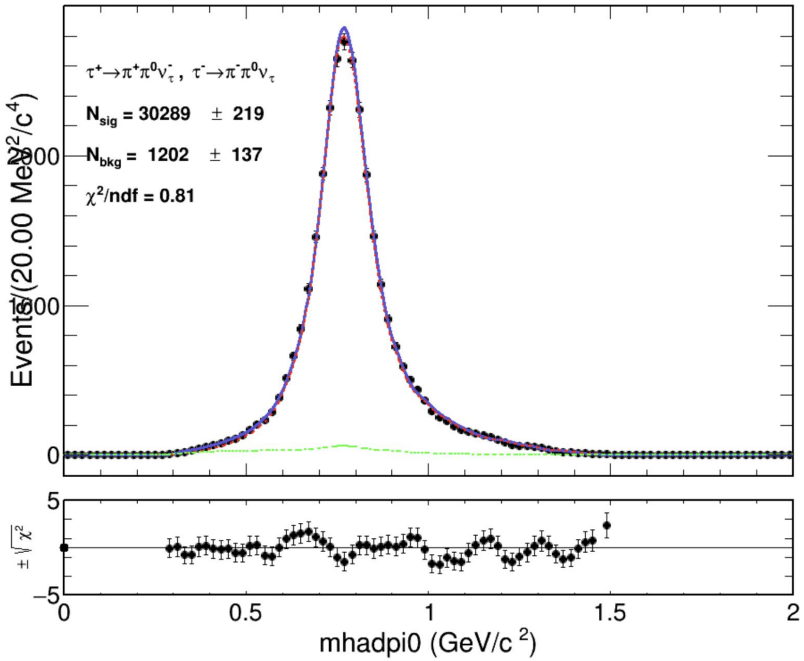
Event selection

	ditau sigMC num	Efficiency	BESIII efficiency	ditau bkgMC num	bkg ratio
No cut	151492	55.7%	48.3%	90351	37.4%
$0.115 < m(\pi^0) < 0.15$	116461	42.8%	45.0%	35756	23.5%
$0.8 < \frac{E}{P}(e) < 1.05$	100881	37.1%	40.8%	28160	21.8%
$N(\pi^0) = 1,\ exN(\gamma) = 0$	92117	33.9%	31.1%	3350	3.5%

Signal Fit

$\sqrt{s}$= 4.260 GeV

- Signal shape: From 2,000,000 ditau inclusive MC;
- Background shape: From 2,000,000 ditau inclusive MC;
- Data:1,000,000 ditau inclusive MC serve as data.



Calculation details

- $B(\tau^+ \to \pi^+\pi^0\overline{\nu}_\tau) = \frac{N_{sig}}{2N_{\tau\tau}\varepsilon B(\tau^- \to e^-\nu_\tau\overline{\nu}_e)B(\pi^0 \to \gamma\gamma)}$

  where $\varepsilon \pm \varepsilon_{err} = \varepsilon \pm \frac{\sqrt{N_{sel}}}{N_{gen}}$

- $input\ sys. = B(\tau^+ \to \pi^+\pi^0\overline{\nu}_\tau) \times \sqrt{(\frac{B_{(\tau^- \to e^-\nu_\tau\overline{\nu}_e)err}}{B_{(\tau^- \to e^-\nu_\tau\overline{\nu}_e)}})^2 + (\frac{B_{(\pi^0 \to \gamma\gamma)err}}{B_{(\pi^0 \to \gamma\gamma)}})^2}$

  $stat. = B(\tau^+ \to \pi^+\pi^0\overline{\nu}_\tau) \times \sqrt{(\frac{N_{sigerr}}{N_{sig}})^2 + (\frac{\varepsilon_{err}}{\varepsilon})^2}$

Parameter	value
$B_{(\tau^- \to e^-\nu_\tau\overline{\nu}_e)}$	0.1782 ± 0.0004
$B_{(\pi^0 \to \gamma\gamma)}$	0.9880 ± 0.00034

- Measurement result

	data volume	Bf(%)	stat.	input sys./sys.
Our work (4.260 GeV)	1,000,000 MC	25.39	0.21(0.83%)	0.06(0.24%)
	Estimated cumulative retrieval 1ab^{-1}	25.39	0.0036(0.01%)	0.06(0.24%)
ALEP	––	25.47	0.097(0.38%)	0.085(0.33%)
Belle	––	25.24	0.01(0.04%)	0.39(1.55%)

$$\tau^+ \rightarrow K^+\pi^0\overline{\nu}_\tau$$

Event selection

- The Event selection for charge tracks , π^0reconstruction and photon selection in process of $\tau^+ \to K^+\pi^0\overline{\nu}_\tau$ are the same as for the previous channel.
- PID requirement:

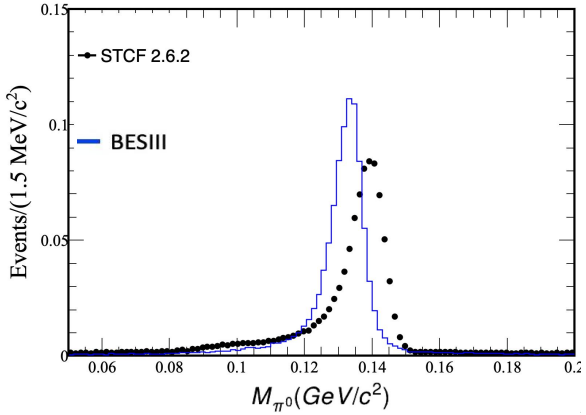
  Using PID system: Global PID

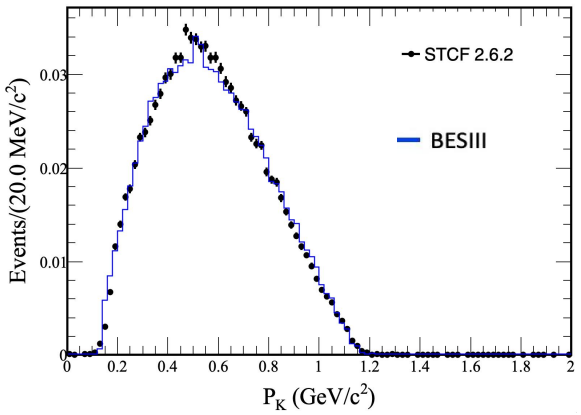
  e :$Prob_e$>$Prob_\pi$;$Prob_e > Prob_K$;

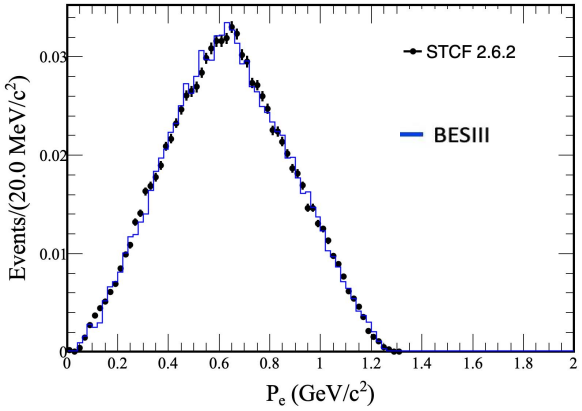
  K :$Prob_K$>$Prob_e$;$Prob_K > Prob_\pi$;

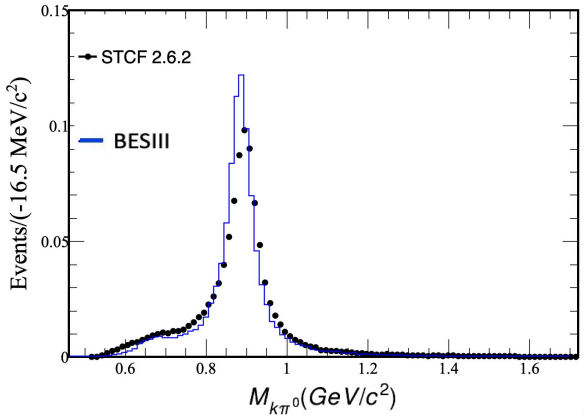
  N_K =1, N_e = 1

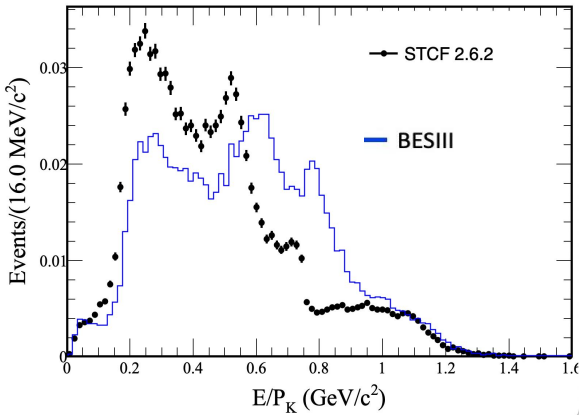
Compare with BESIII at $\sqrt{s}$ = 3.773 GeV

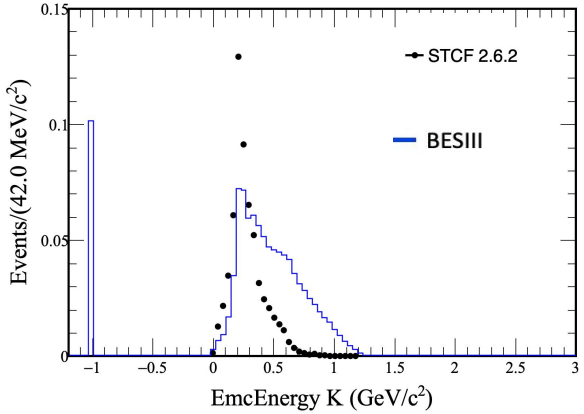


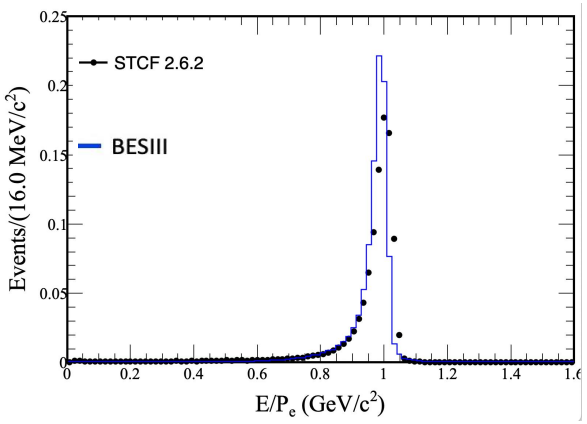


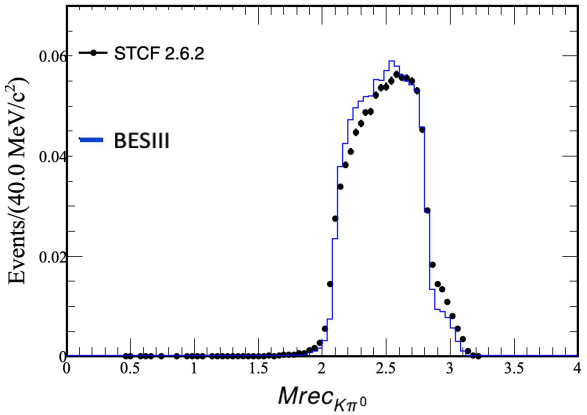




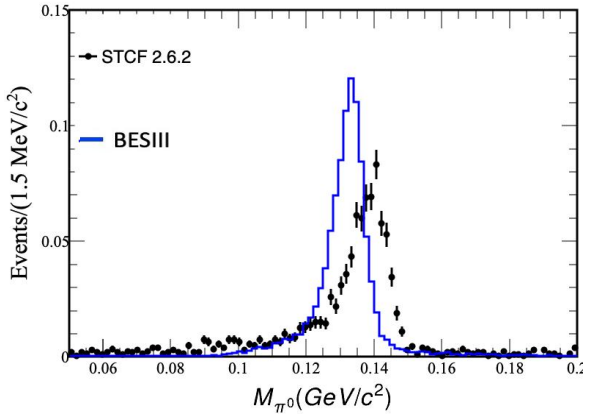


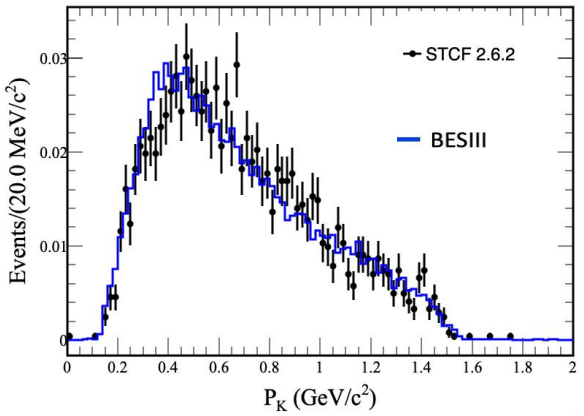


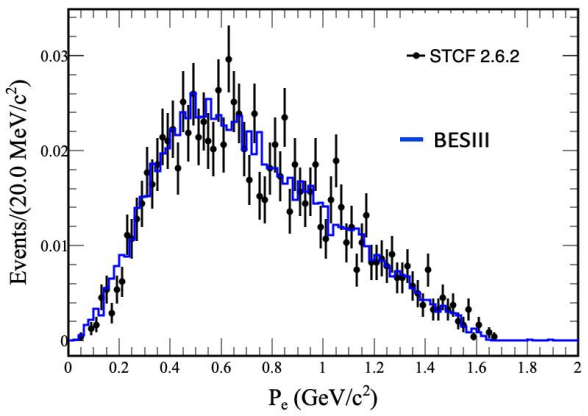


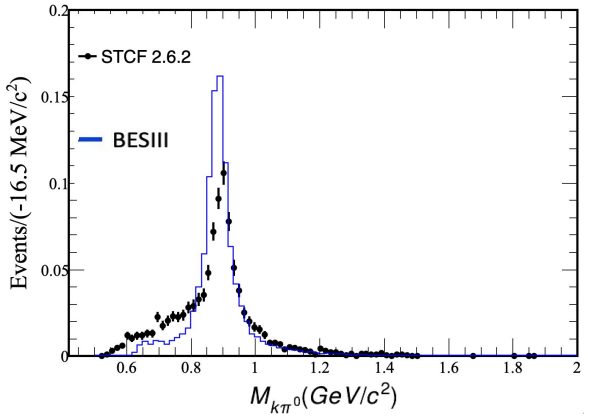


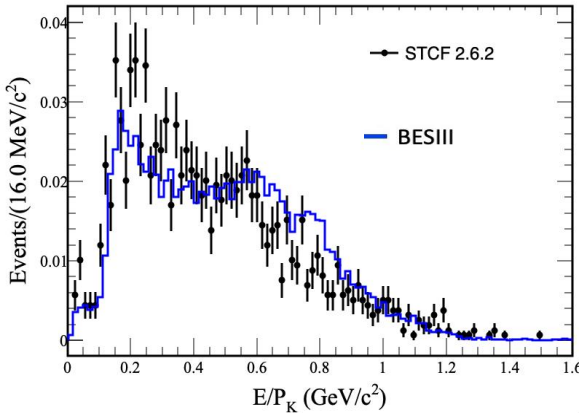
Compare STCF at $\sqrt{s}$ = 4.260 GeV with BESIII at $\sqrt{s}$ = 4.270 GeV

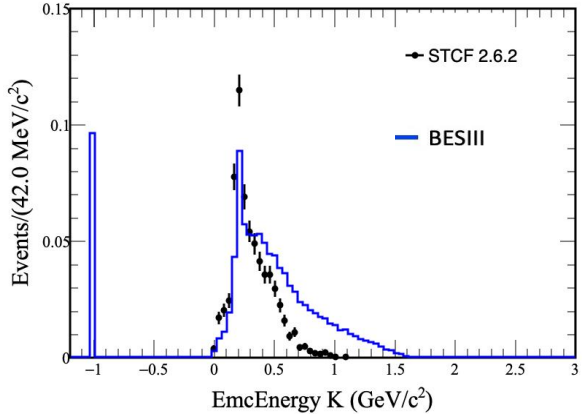


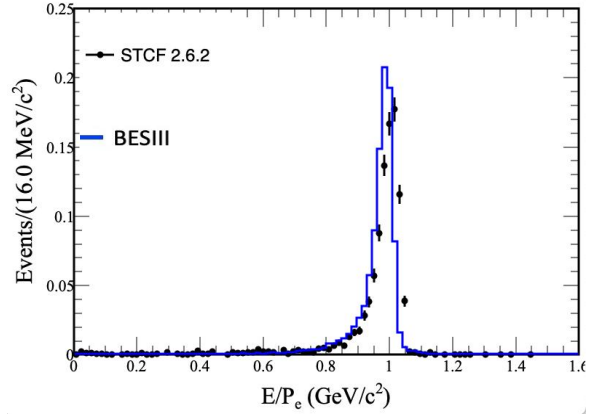


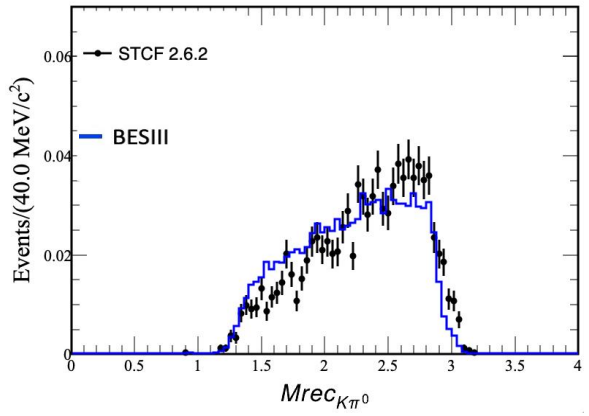






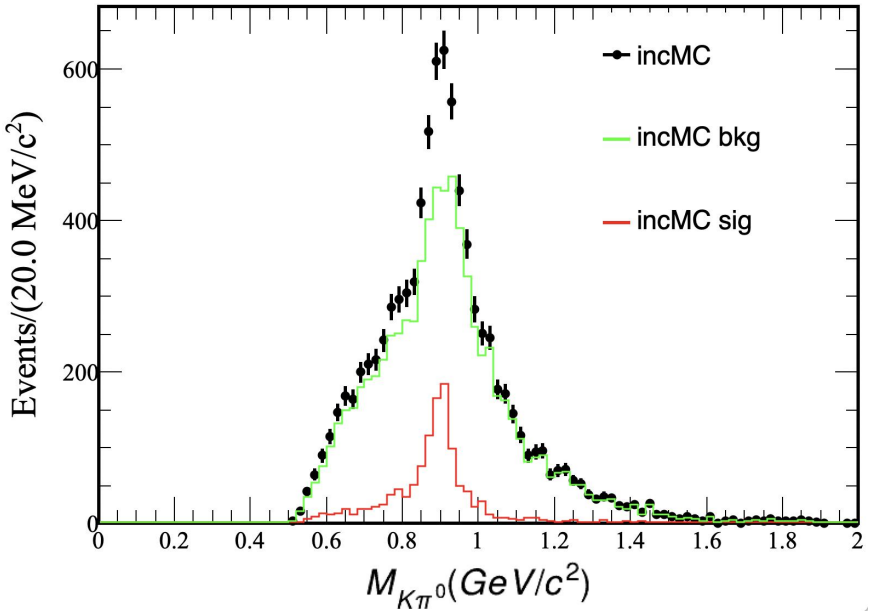


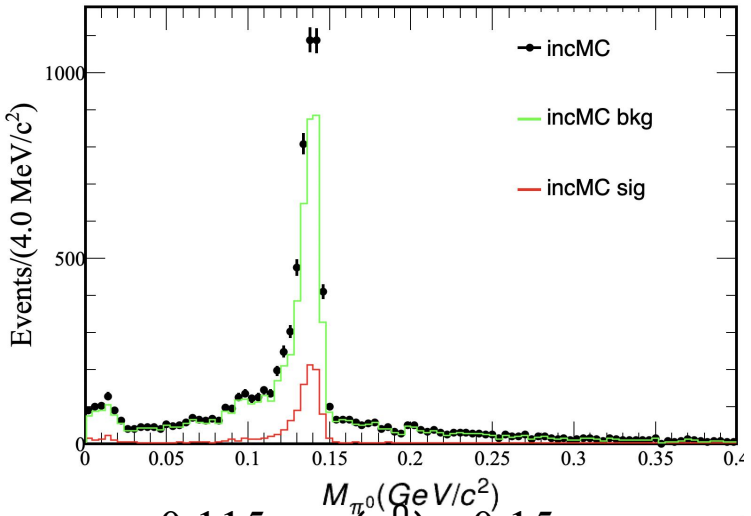




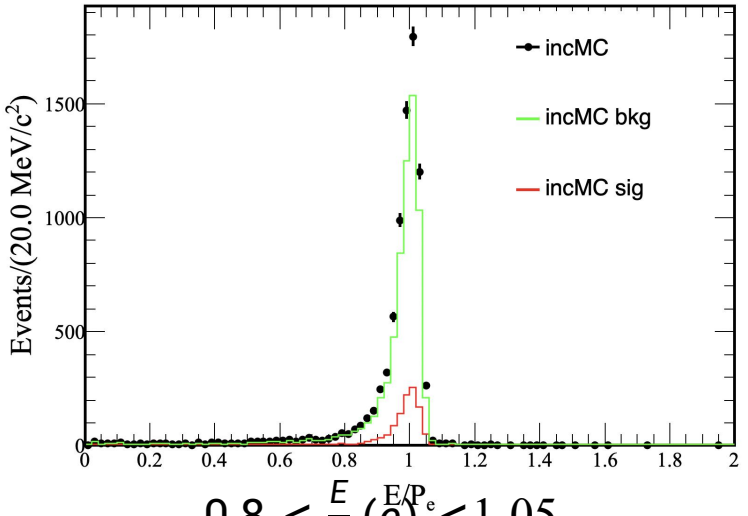
Signal selection criteria

At $\sqrt{s} = 4.26\ GeV$, $\mathrm{m}(\mathrm{K}^+\pi^0)$ is used to identify semileptonic decay, combined tag and signal selection

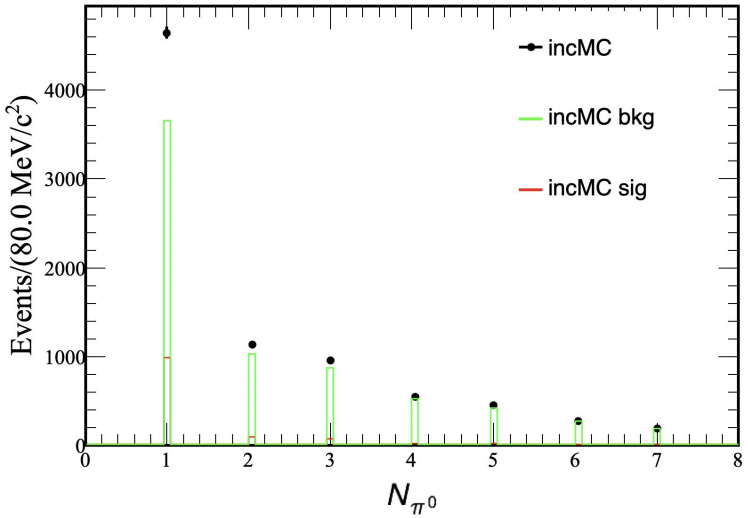




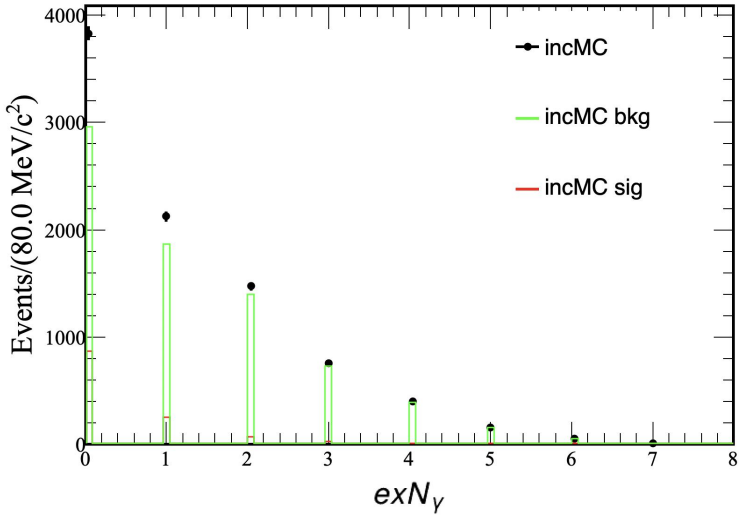
$0.115 < m(\pi^0) < 0.15$



$0.8 < \frac{E}{P}(e) < 1.05$

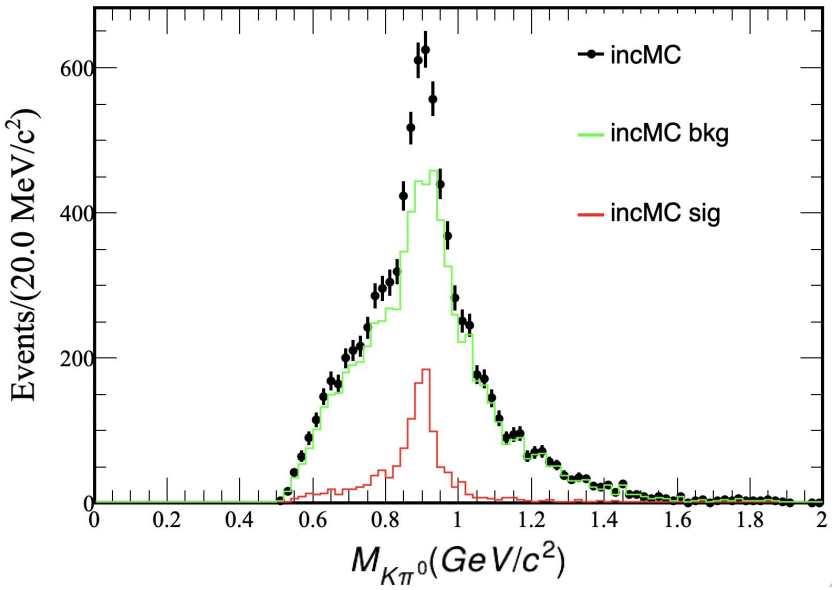


$N(\pi^0)=1$



$exN(\gamma) = 0$

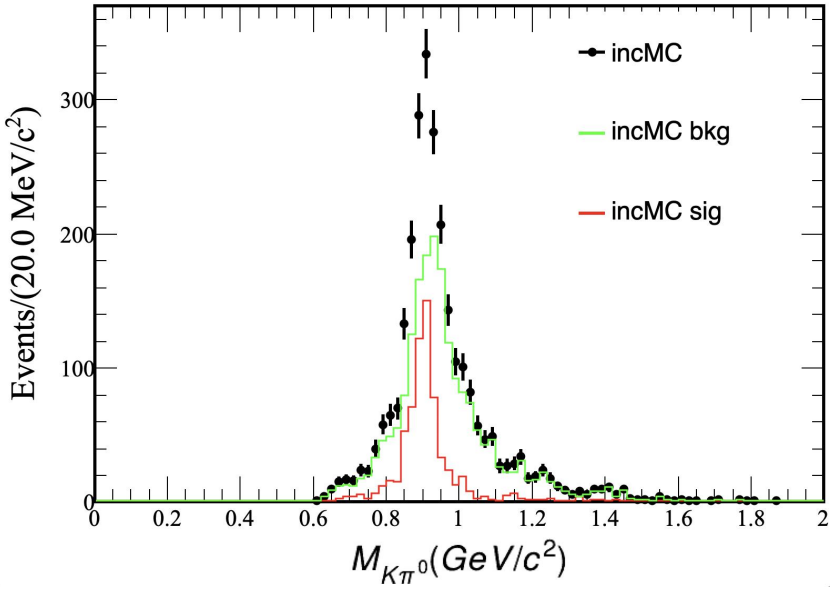
Signal selection criteria



$0.12 < m(\pi^0) < 0.15$,

$0.8 < \frac{E}{P}(e) < 1.05$,

$N(\pi^0)=1$, $exN(\gamma) = 0$



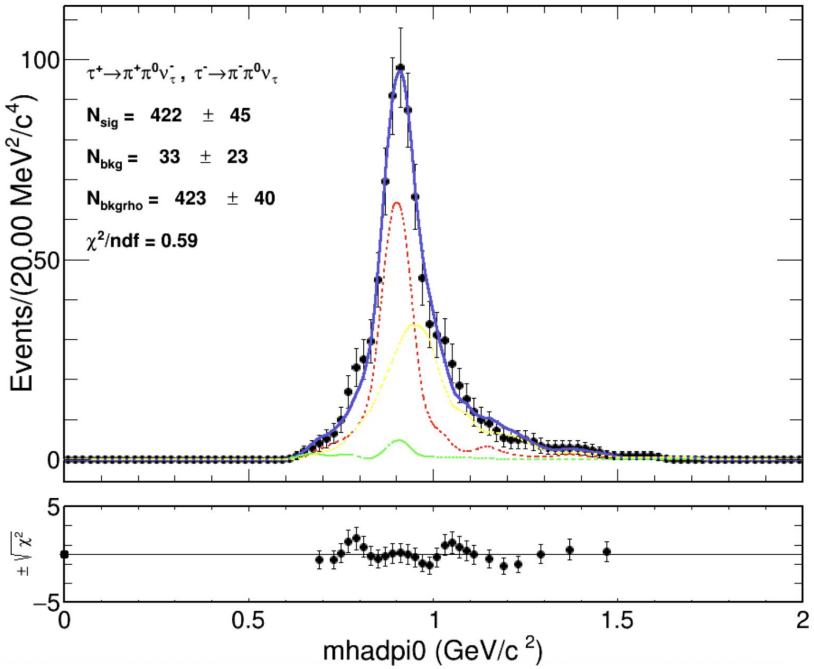
Event selection

	ditau sigMC num	Efficiency	BESIII efficiency	ditau bkgMC num	bkg ratio
No cut	1233	37.59%	41.7%	7560	85.98%
$0.115 < m(\pi^0) < 0.15$	892	24.07%	37.9%	3805	81.01%
$0.8 < \frac{E}{P}(e) < 1.05$	781	20.92%	34.3%	3173	80.25%
$N(\pi^0) = 1,\ exN(\gamma) = 0$	689	16.86%	22.3%	1983	74.21%

Signal Fit

$\sqrt{s}$= 4.260 GeV

- Signal shape: From 2,000,000 ditau inclusive MC;
- Background shape: From 2,000,000 ditau inclusive MC;
- Data:1,000,000 ditau inclusive MC serve as data.



Measurement result

	data volume	Bf(10^{-3})	stat.	input sys./sys.
Our work (4.260GeV)	1,000,000 MC	2.91	0.32(11%)	0.006(0.21%)
	Estimated cumulative retrieval $1ab^{-1}$	2.91	0.0054(0.19%)	0.006(0.21%)
BABR	––	4.16	0.03(0.72%)	0.18(4.33%)
ALEP	––	4.71	0.59(12.53%)	0.23(4.88%)
CLEO	––	4.44	0.26(5.86%)	0.24(5.41%)

Summary

- We have compared the BESIII results at $\sqrt{s}$ = 3.773 GeV and $\sqrt{s}$ = 4.26 GeV. Apart from significant differences in the distributions of $\mathrm{m}(\pi^0)$, $E/P(hadron)$, and the emcenergy of hadron , the distributions of other variables are relatively similar.
- We have also measured the branching fractions of the decay $\tau^+ \to \pi^+\pi^0\overline{\nu}_\tau$ and $\tau^+ \to K^+\pi^0\overline{\nu}_\tau$ at $\sqrt{s}$ = 4.26 GeV.

Next to do

- To use more MC samples.
- To estimate the strong coupling constant and $|V_{us}|$.