



# Prospects of CKM elements $|V_{cs}|$ and decay constant $f_{D_s^+}$ in $D_s^+ \rightarrow l^+ \nu_l$ decay at STCF



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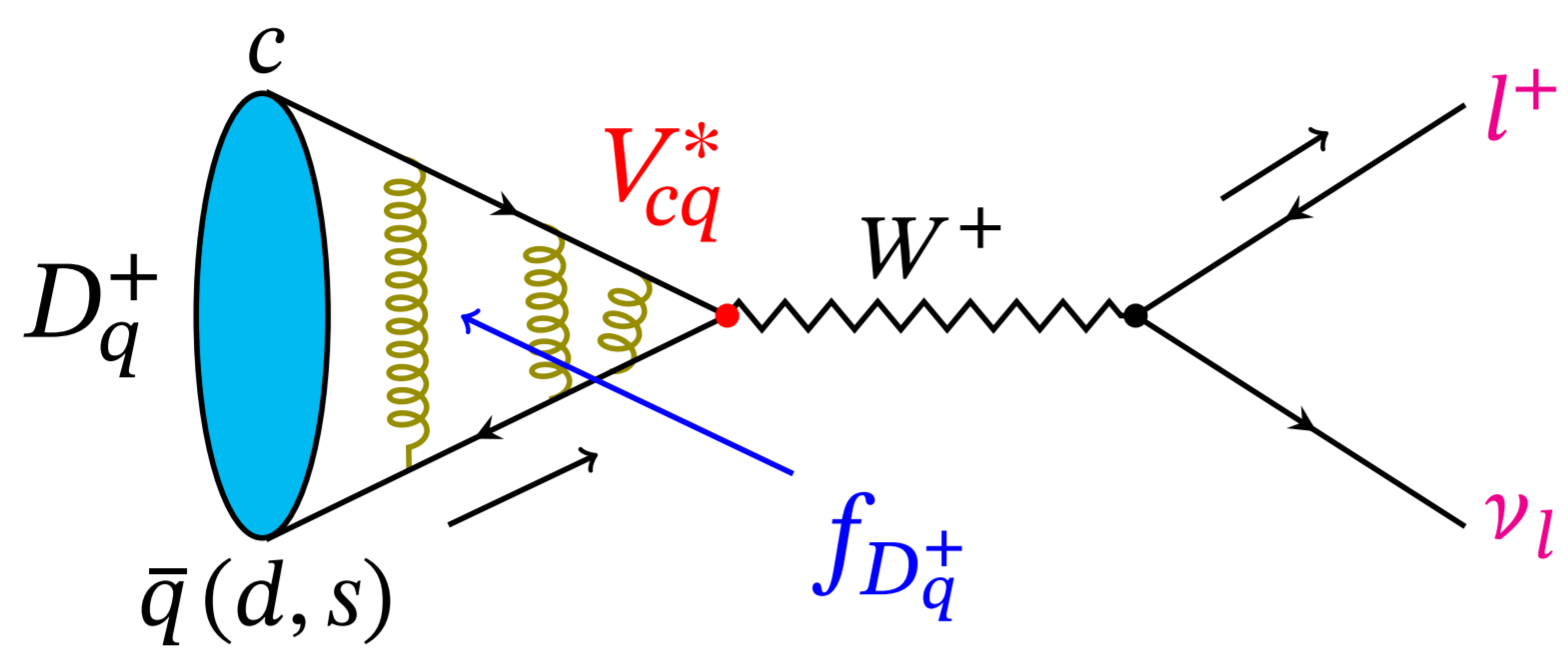
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## Introduction

In the SM

•  $D_s$  pure leptonic decay:

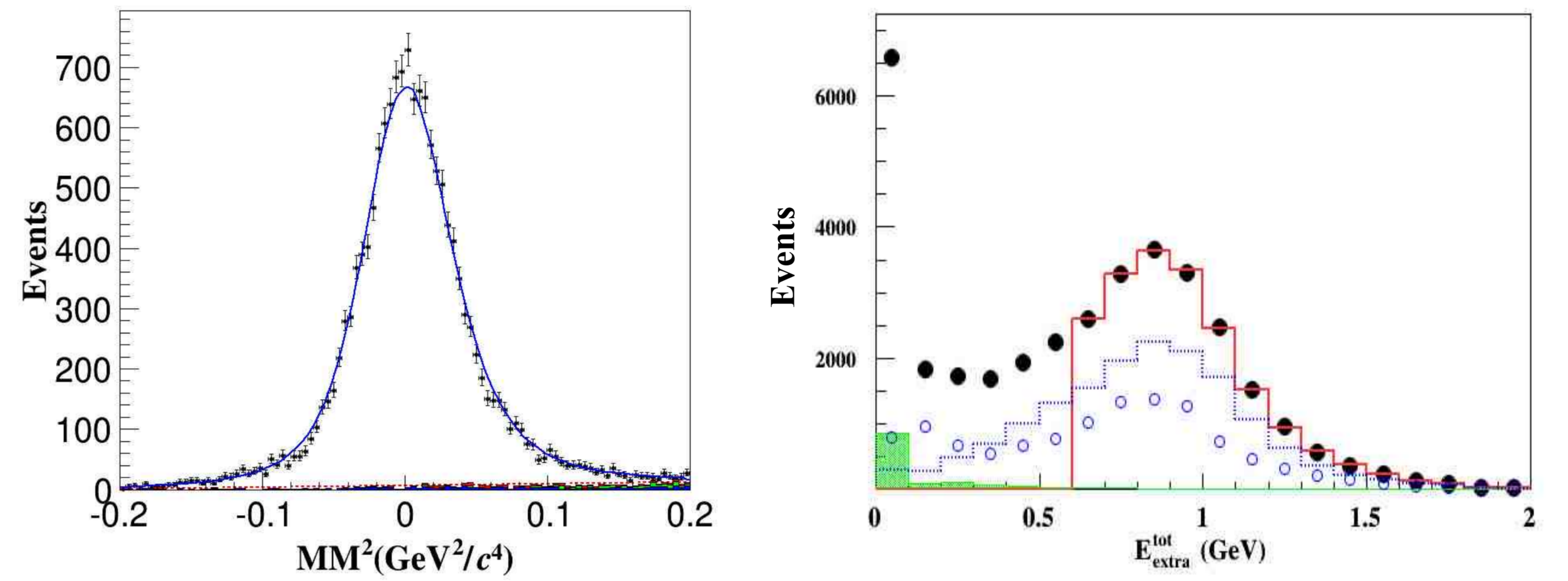


$$\Gamma(D_s^+ \rightarrow l^+ \nu_l) \propto |f_{D_s^+}|^2 \cdot |V_{cs}|^2$$

- Precise measurements of  $f_{D_s^+}$  and  $|V_{cs}|$  are essential to probe new physics beyond the Standard Model (SM).
- Up-to-date results of  $|V_{cs}|$  and  $f_{D_s^+}$  are still limited by statistics uncertainty in the measurement of  $D_s^+ \rightarrow l^+ \nu_l$ .
- Future precise measurement of  $D_s^+ \rightarrow l^+ \nu_l$  is critical to calibrate various theoretical calculations of  $f_{D_s^+}$  and test the unitarity of the CKM matrix.

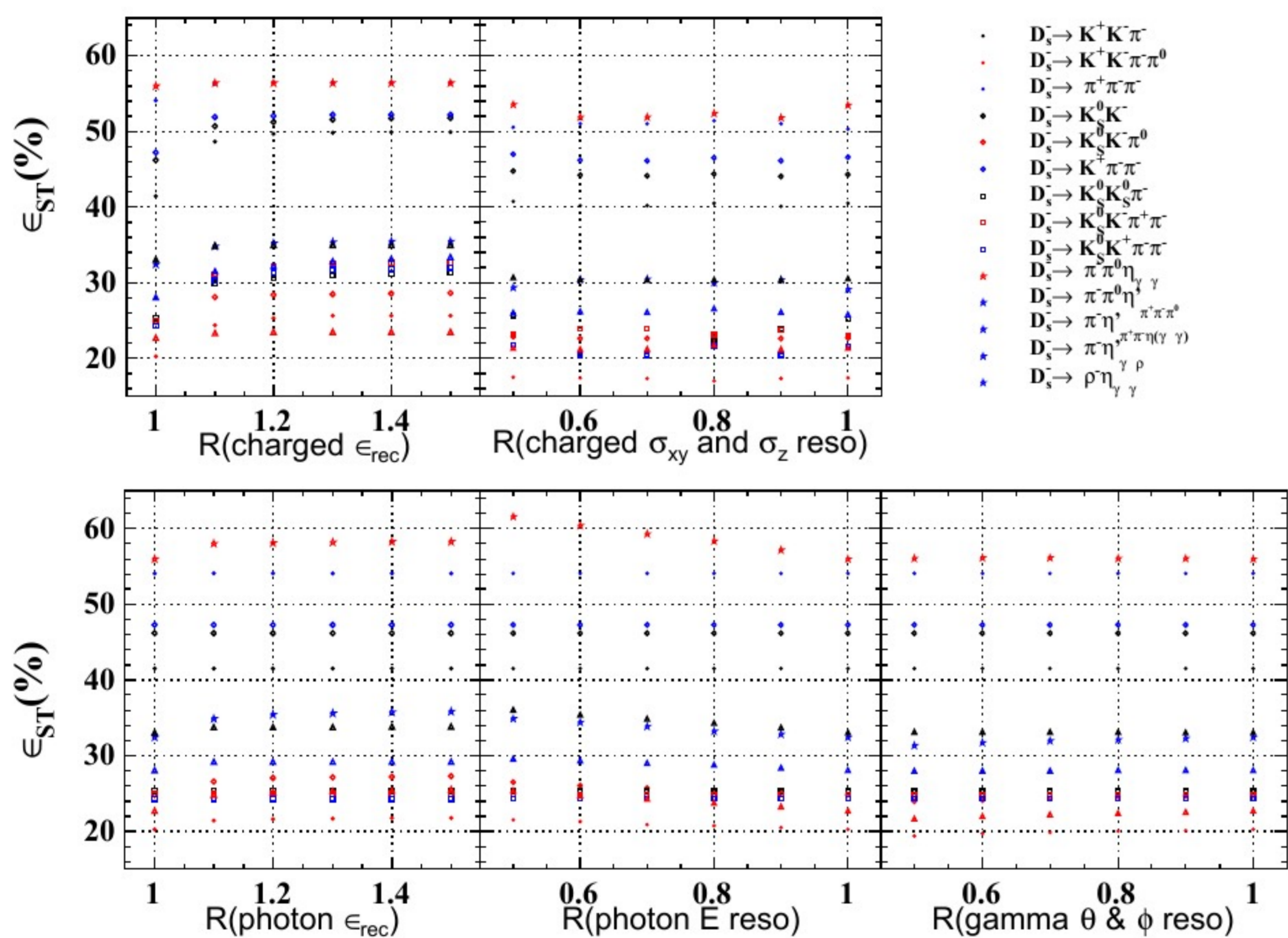
## Analysis of $D_s^+ \rightarrow l^+ \nu_l$

$e^+e^- \rightarrow D_s^+ D_s^-$  0.1 ab<sup>-1</sup> @4.009GeV



- Analysis method is **double tag method**.
- 14 single tags are reconstructed, whose total Branch fraction is  $(30.57 \pm 1.05) \times 10^{-2}$ .
- The branch fraction is  $(5.61 \pm 0.05) \times 10^{-3}$  by  $D_s^+ \rightarrow \mu^+ \nu_\mu$ . The branch fraction is  $(5.49 \pm 0.06) \times 10^{-2}$  by  $D_s^+ \rightarrow \tau^+ \nu_\tau$ .
- Statistical sensitivity of BF is **2.7 times** better than BESIII.

## Optimization of $D_s^+ \rightarrow \mu^+ \nu_\mu$



- Optimized response of tracking efficiency for low momentum charged pion is **72.19%** at  $p_T = 0.1 \text{ GeV}/c$ .
- Detection efficiency of photons is **97.32%** at 0.2 GeV.
- $\pi/k$  mis-identification rate of **1%** with the PID performance.
- $\pi/\mu$  mis-identification rate of **3%** with the MUD performance.
- Detection efficiency for ST is increased by a factor of **1.1 to 1.2**.
- Efficiency for selecting  $D_s^+ \rightarrow \mu^+ \nu_\mu$  is increased by a factor of **1.3**.

## Results of $D_s^+ \rightarrow l^+ \nu_l$

Combined results from these BESIII measurements and PDG values

Experiment	Reference	$f_{D_s^+}$ [MeV]
ETM(2+1+1)	PRD91(2015)054507	247.2±4.1
FMILC(2+1+1)	PRD98(2018)074512	249.9±0.4
FLAG19(2+1+1)	arXiv:1902.08191 [hep-lat]	249.9±0.5
HFLAV18	EPJCS1(2021)226	254.5±3.2
CLEO	PRD79(2009)052002, $\tau_\nu$	251.8±11.2±5.3
CLEO	PRD80(2009)112004, $\tau_\nu$	257.0±13.3±5.0
CLEO	PRD79(2009)052001, $\tau_\nu$	277.1±17.5±4.0
BaBar	PRD82(2010)091103, $\tau_{\mu\nu}$	244.6±8.6±12.0
Belle	JHEP09(2013)139, $\tau_{\mu\nu}$	261.1±4.8±7.2
BESIII 0.482 fb <sup>-1</sup>	PRD94(2016)072004, $\mu\nu$	245.5±17.8±5.1
CLEO	PRD79(2009)052001, $\mu\nu$	256.7±10.2±4.0
BaBar	PRD82(2010)091103, $\mu\nu$	264.9±8.4±7.6
Belle	JHEP09(2013)139, $\mu\nu$	248.8±6.6±4.8
BESIII 3.19 fb <sup>-1</sup>	PRL122(2019)071802, $\mu\nu$	253.0±3.7±3.6
BESIII 6.32 fb <sup>-1</sup>	arXiv:2102.11734 [hep-ex], $\mu\nu$	249.8±3.0±3.8
BESIII 6.32 fb <sup>-1</sup>	arXiv:2102.11734 [hep-ex], $\tau_\nu$	249.7±6.0±4.2
BESIII 6.32 fb <sup>-1</sup>	arXiv:2105.07178 [hep-ex], $\tau_\nu$	251.6±5.9±4.9
STCF 0.1 ab <sup>-1</sup>	arXiv:2110.08864v1 [hep-ex], $\tau_\nu$	256.3±0.5
STCF 0.1 ab <sup>-1</sup>	arXiv:2109.14969 [hep-ex], $\mu\nu$	255.8±0.4

Experiment	Reference	$ V_{cs} $
CKMfitter	PJC41(2005)1	0.973394±0.000096
ETM(2+1+1)	PRD91(2015)054507	1.014±0.024
FMILC(2+1+1)	PRD98(2018)074512	1.000±0.016±0.003
FLAG19(2+1+1)	arXiv:1902.08191 [hep-lat]	1.004±0.002±0.016
HFLAV18	EPJCS1(2021)226	0.969±0.01
CLEO-c	PRD79(2009)052002, $\tau_\nu$	0.988±0.044±0.022
CLEO-c	PRD80(2009)112004, $\tau_\nu$	1.009±0.052±0.021
CLEO-c	PRD79(2009)052001, $\tau_\nu$	1.088±0.069±0.018
BaBar	PRD82(2010)091103, $\tau_{\mu\nu}$	0.956±0.036±0.056
Belle	JHEP09(2013)139, $\tau_{\mu\nu}$	1.025±0.019±0.029
BESIII 0.482 fb <sup>-1</sup>	PRD94(2016)072004, $\mu\nu$	0.944±0.063±0.027
CLEO-c	PRD79(2009)052001, $\mu\nu$	1.007±0.040±0.018
BaBar	PRD82(2010)091103, $\mu\nu$	1.040±0.033±0.031
Belle	JHEP09(2013)139, $\mu\nu$	0.976±0.026±0.021
BESIII 3.19 fb <sup>-1</sup>	PRL122(2019)071802, $\mu\nu$	0.985±0.014±0.014
BESIII 6.32 fb <sup>-1</sup>	arXiv:2102.11734 [hep-ex], $\mu\nu$	0.973±0.012±0.016
BESIII 6.32 fb <sup>-1</sup>	arXiv:2102.11734 [hep-ex], $\tau_\nu$	0.973±0.009±0.014
STCF 1.0 ab <sup>-1</sup>	arXiv:2110.08864v1 [hep-ex], $\tau_\nu$	0.998±0.003
STCF 0.1 ab <sup>-1</sup>	arXiv:2109.14969 [hep-ex], $\mu\nu$	0.996±0.002

$$\mu^+ \nu_\mu \quad f_{D_s^+} = 255.8 \pm 0.4 \text{ MeV} \quad \tau^+ \nu_\tau \quad f_{D_s^+} = 256.3 \pm 0.5 \text{ MeV}$$

$$|V_{cs}| = 0.996 \pm 0.002 \quad |V_{cs}| = 0.998 \pm 0.003$$

$$R_{\tau/\mu} = \frac{\bar{\Gamma}(D_s^+ \rightarrow \tau^+ \nu_\tau)}{\bar{\Gamma}(D_s^+ \rightarrow \mu^+ \nu_\mu)} = 9.79 \pm 0.05$$

## Summary

- ◆ Unprecedented precision to be achieved at STCF will provide a precise calibration of QCD and a rigorous test of SM.
- ◆ Accuracy of LFU test can be improved obviously experimentally, which makes it promise to search for the new physics beyond SM.