$D \to K^+K^-\pi^+\pi^-$ strong phase analysis and introduction to TORCH analysis

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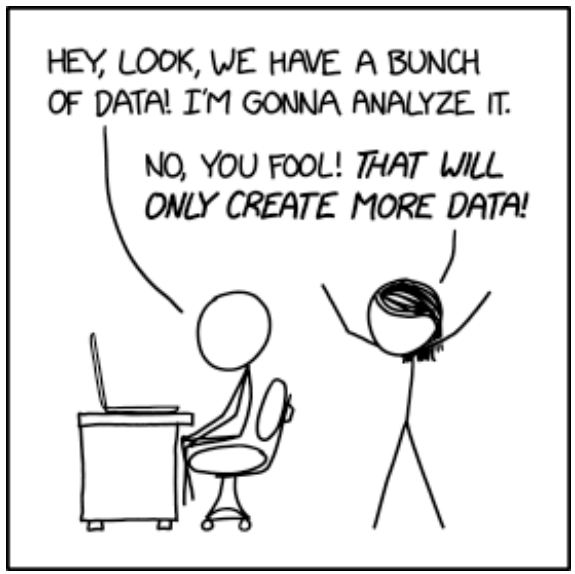
Brief recap of BESIII analysis

What I presented in December:

- BESIII measurement of c_i and s_i in $D^0 \to K^+K^-\pi^+\pi^-$
- Asymmetric uncertainties on s_i using Plugin method
- New review committee, no showstoppers so far

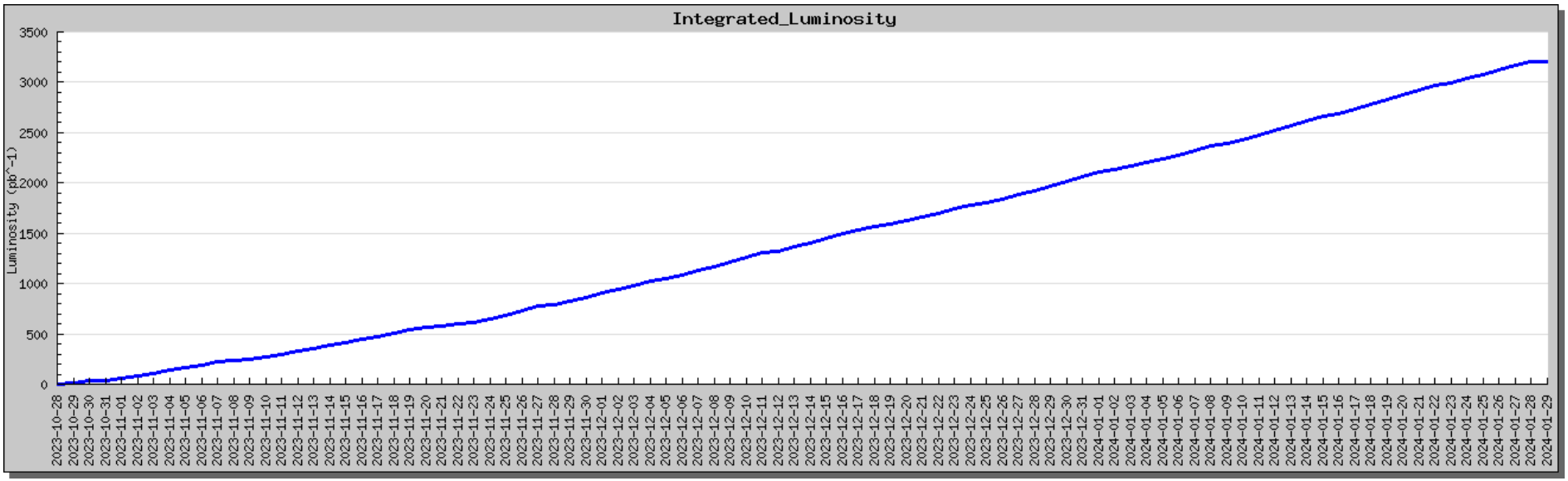


While in review, more BESIII has become available!

Status of BESIII data taking

BESIII will collect $20\,\text{fb}^{-1}$ at $\psi(3770)$:

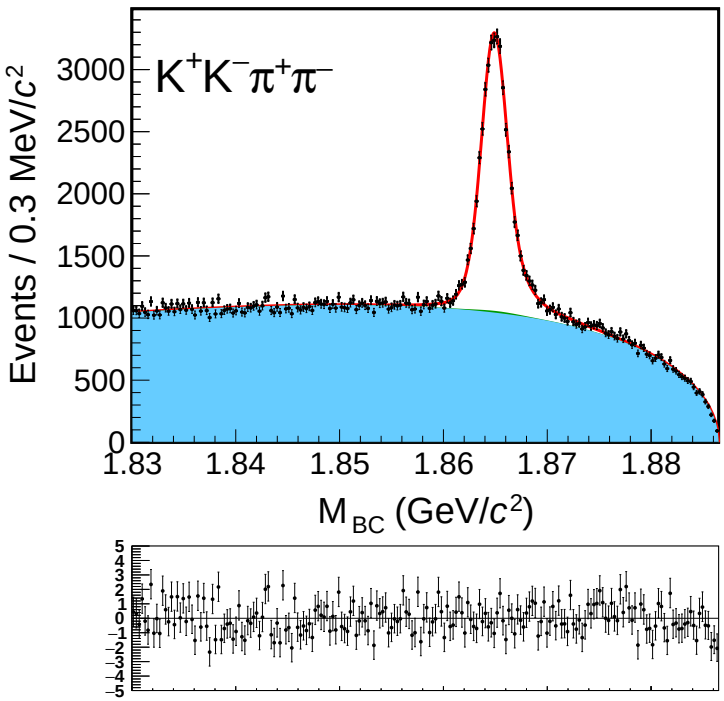
1. 2010-2011: $2.93\,\text{fb}^{-1}$ $\leftarrow$ Measurement of F_+
2. 2021-2022: $4.995\,\text{fb}^{-1}$ $\leftarrow$ Previous presentation
3. 2022-2023: $8.157\,\text{fb}^{-1}$ $\leftarrow$ New stuff!
4. 2023-2024: Data taking ongoing



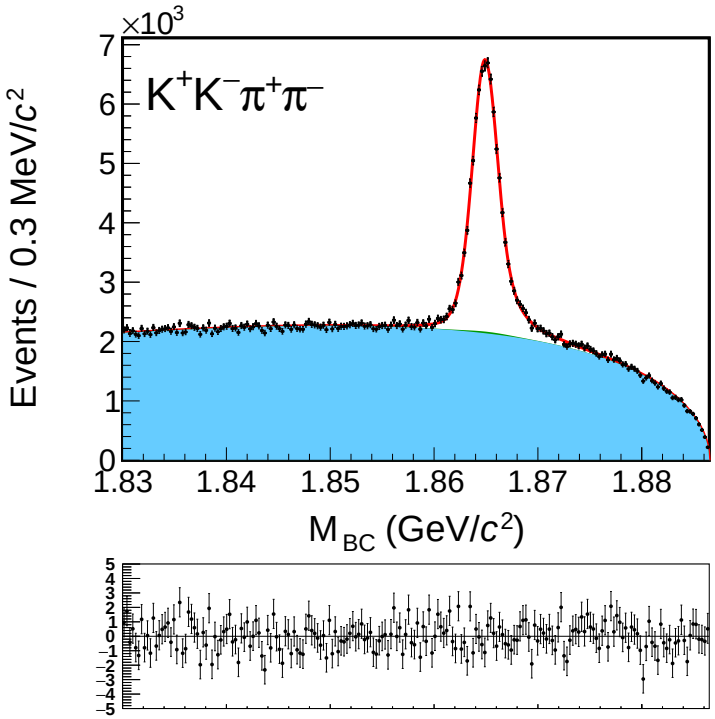
Cross check of $D^0 \to K^+K^-\pi^+\pi^-$ ST yield

Check that ST yield agrees with integrated luminosity

- ST yields used for normalisation
- Expect a factor 2 increase



(a) $N = 29227 \pm 268$



(b) $N = 59057 \pm 380$

Figure 1: Ratio of new and old ST $KK\pi\pi$ yield: 2.021 ± 0.023

Cross check of all ST yields

Check that all other ST yields are consistent

- Combined ratio of ST yields: 2.0256 ± 0.0013
- Ratio of integrated luminosity:
  $2.93 + 4.995 + 8.157/2.93 + 4.995 = 2.029$

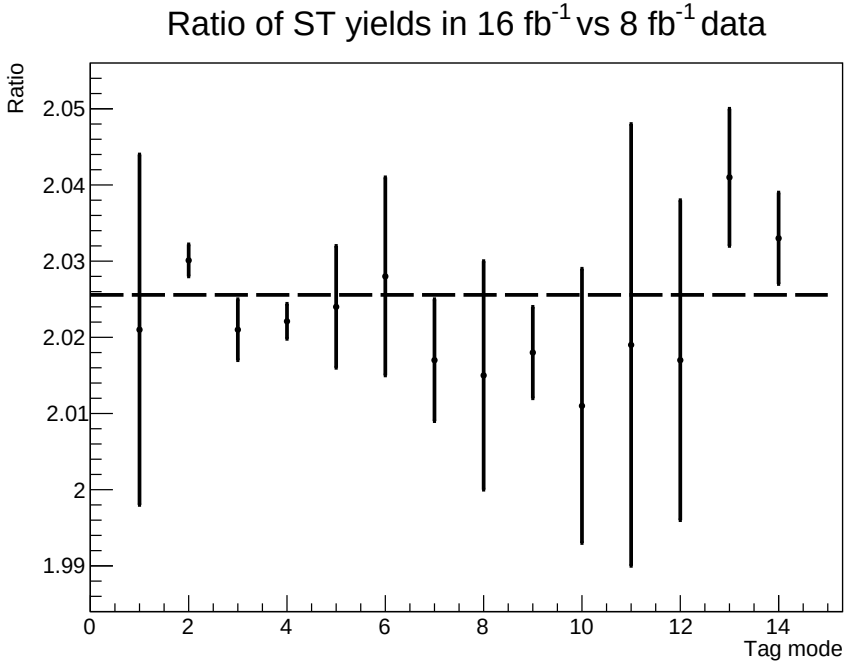
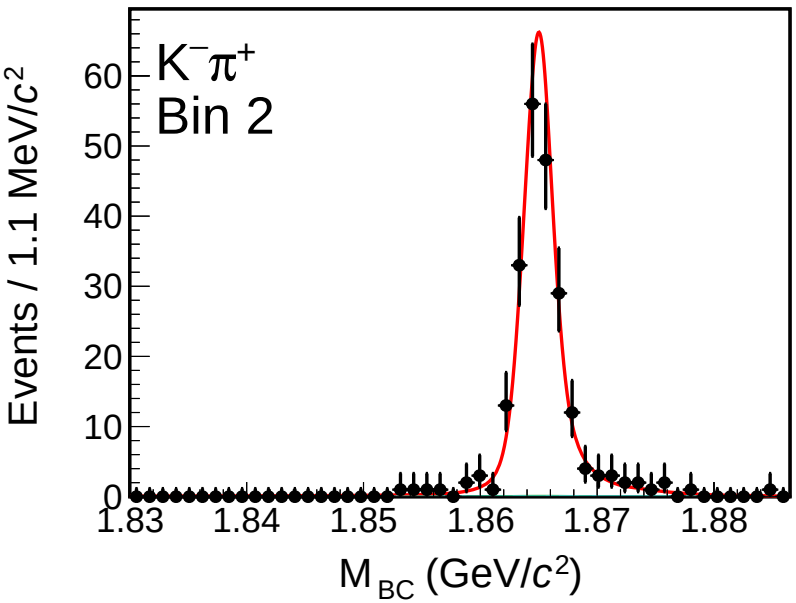


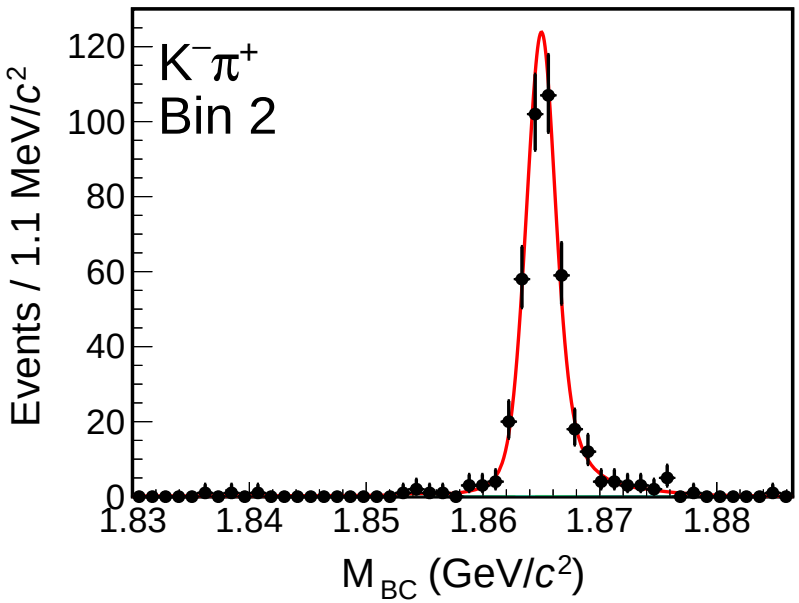
Figure 2: Good agreement!

DT tag yields of $D^0 \to K^+K^-\pi^+\pi^-$ with new data

What about DT yields in phase-space bins?



(a) $N = 211.2^{+15.4}_{-14.8}$

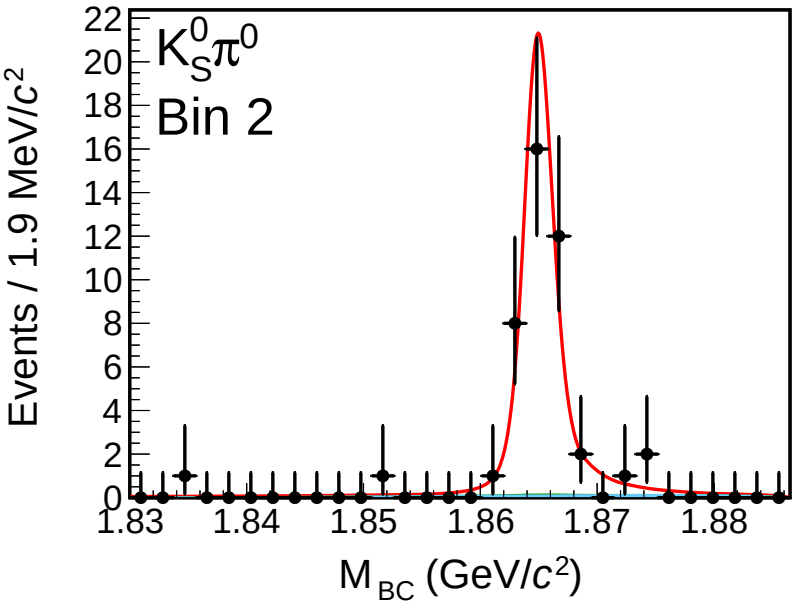


(b) $N = 402.5^{+20.8}_{-20.2}$

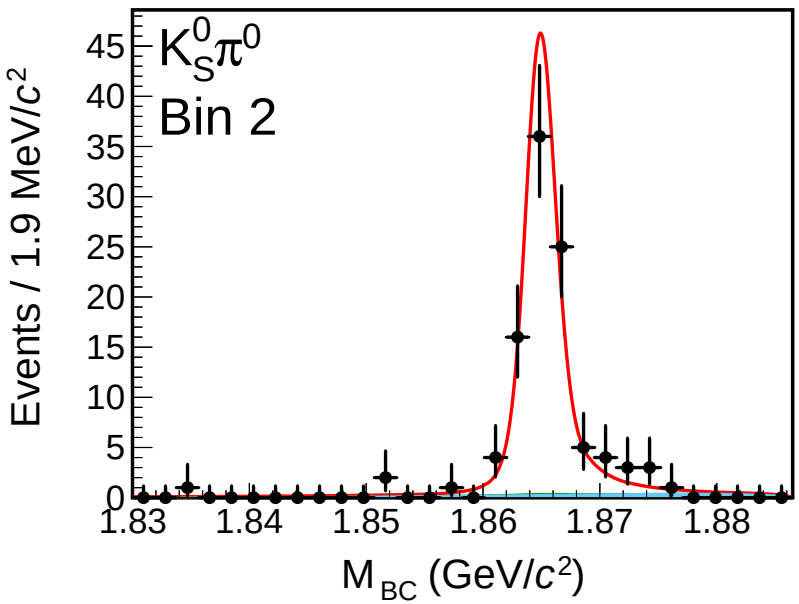
Figure 3: Flavour tag $D \to K\pi$ with $8\,\text{fb}^{-1}$ ($16\,\text{fb}^{-1}$) on the left (right)

DT tag yields of $D^0 \to K^+K^-\pi^+\pi^-$ with new data

Check CP tags, which contain important strong-phase information



(a) $N = 40.4^{+6.8}_{-6.3}$

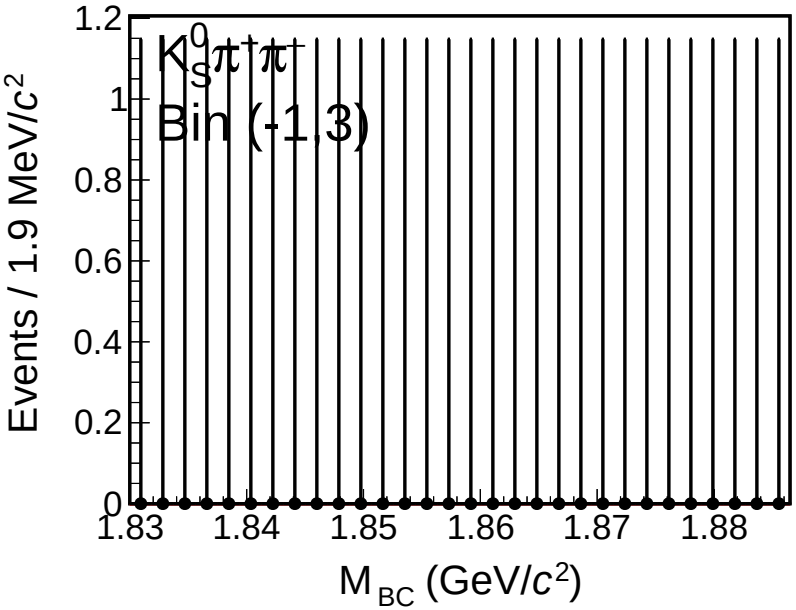


(b) $N = 92.1^{+10.4}_{-9.9}$

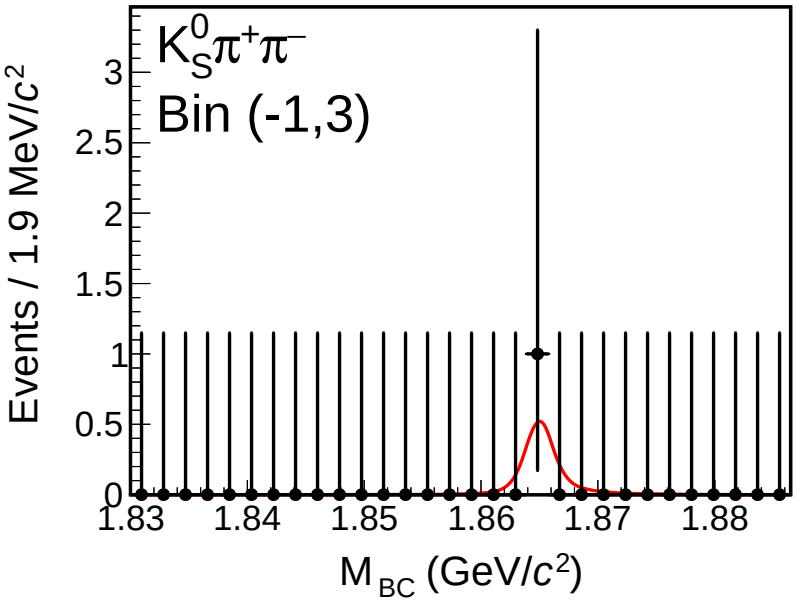
Figure 4: CP tag $D \to K^0_S\pi^0$ with $8\,\text{fb}^{-1}$ ($16\,\text{fb}^{-1}$) on the left (right)

DT tag yields of $D^0 \to K^+K^-\pi^+\pi^-$ with new data

More importantly, what about multi-body tags?



(a) $N = 0.0^{+0.5}_{-0.5}$

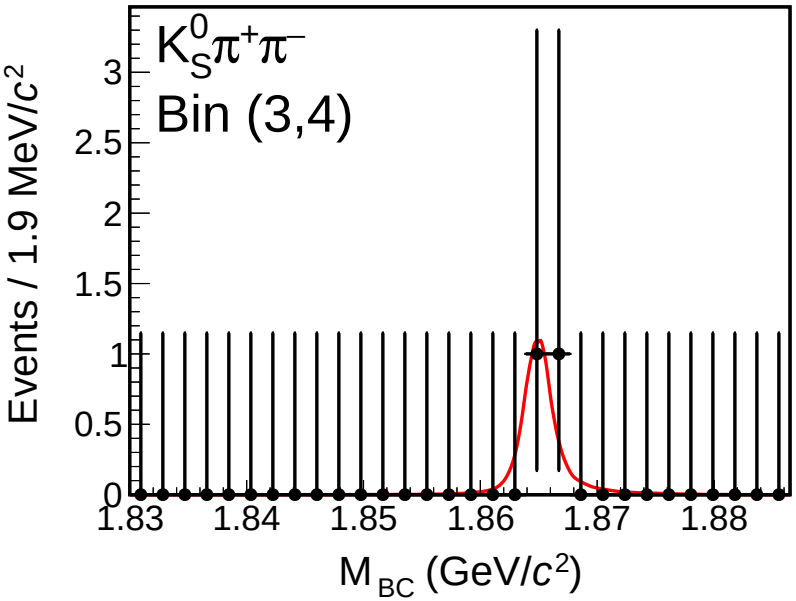


(b) $N = 1.0^{+1.3}_{-0.7}$

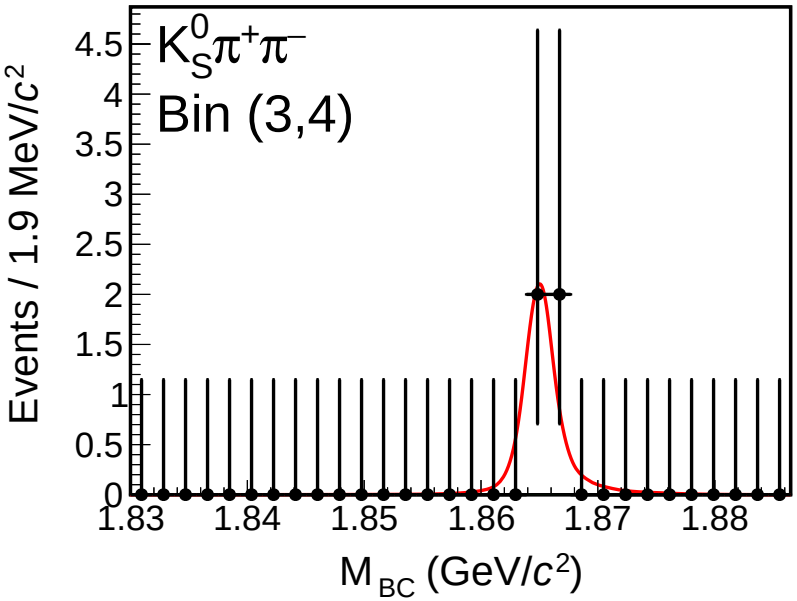
Figure 5: Multi-body tag $D \to K^0_S\pi^+\pi^-$ with $8\,\text{fb}^{-1}$ ($16\,\text{fb}^{-1}$) on the left (right)

DT tag yields of $D^0 \to K^+K^-\pi^+\pi^-$ with new data

More importantly, what about multi-body tags?



(a) $N = 2.0^{+1.8}_{-1.1}$



(b) $N = 4.0^{+2.3}_{-1.7}$

Figure 6: Multi-body tag $D \to K^0_S\pi^+\pi^-$ with $8\,\text{fb}^{-1}$ ($16\,\text{fb}^{-1}$) on the left (right)

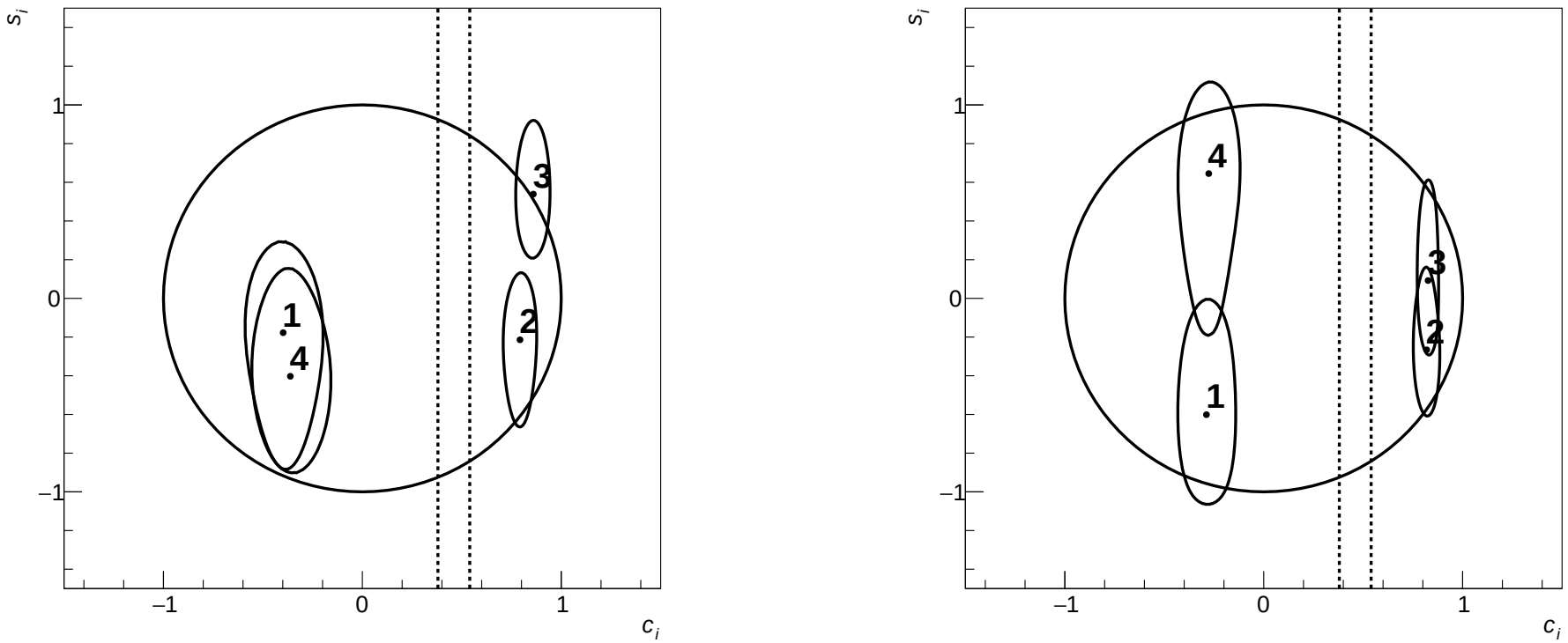
Strong-phase fit with new data

What needs to be updated to fit c_i and s_i?

1. ST and DT yields (done!)
2. Efficiency matrices (work in progress, probably negligible)
   - Don't bother with new MC, just reweight 2022 MC with a factor 13/5
3. Toy studies (work in progress)
4. Tracking and PID efficiency systematics
   - Can probably get away with reusing same numbers

Strong-phase fit with new data

Run fit of c_i and s_i with new ST and DT yields

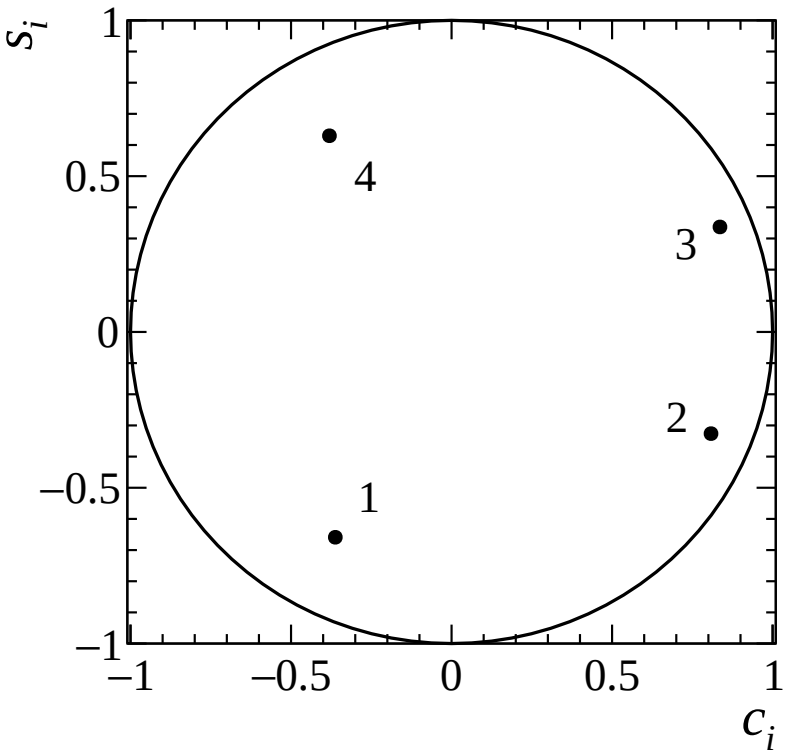


(a) 8 fb^{-1} **(b)** 16 fb^{-1}

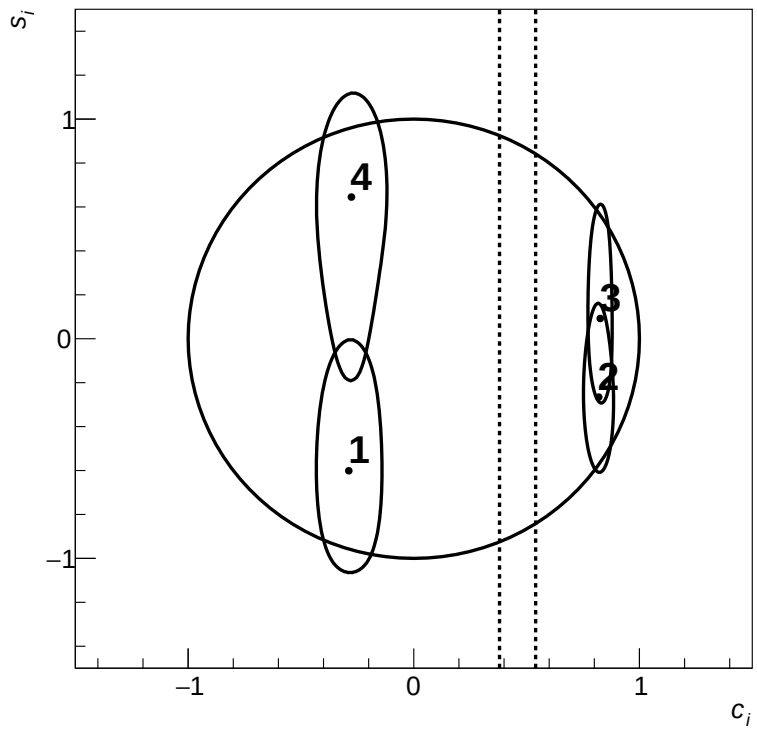
Figure 7: Warning: s_i uncertainties may be very non-Gaussian

Strong-phase fit with new data

New c_i and s_i results are perfectly consistent with model!



(a) Model predictions

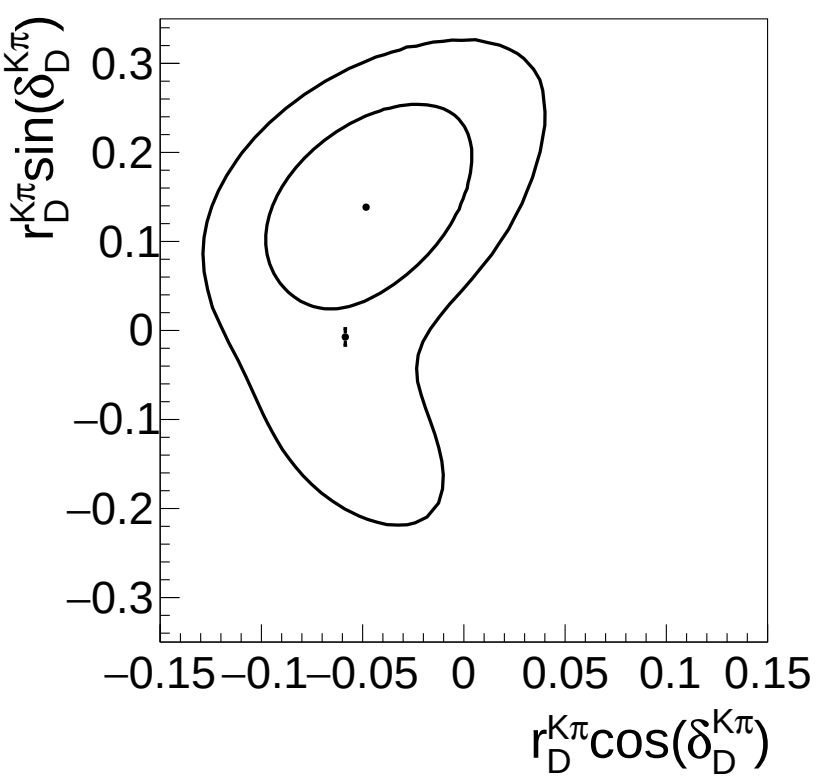


(b) 16 fb^{-1}

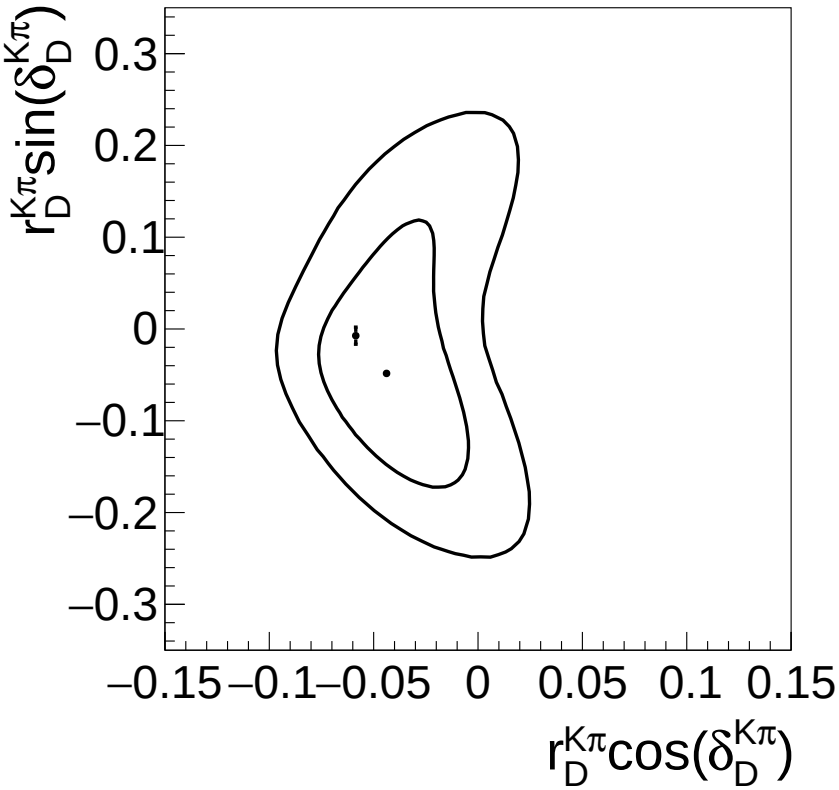
Figure 8: Warning: s_i uncertainties may be very non-Gaussian

Strong-phase fit with new data

What about $\delta_D^{K\pi}$?



(a) 8 fb^{-1}



(b) 16 fb^{-1}

Figure 9: Warning: $r_D^{K\pi}\sin\left(\delta_D^{K\pi}\right)$ uncertainties may be very non-Gaussian

Summary and next steps

In summary:

1. BESIII analysis review is slowly moving forwards
2. New data is available and preliminary results are very promising
3. Aim to include new data without delaying the review process

Summary and next steps

What now? The positive things first:

- Analysis for my thesis is more or less done
- Start preparation of $B^{\pm} \to [h^+h^-\pi^+\pi^-]_D h^{\pm}$ for B2OC review
- Write thesis in parallel (perhaps this plan is too ambitious)

Summary and next steps

What now? The not so positive things last:

- Currently struggling with TORCH analysis...
  1. Timing information is very challenging to interpret
  2. Calibrations are not finalised yet
- I haven't given up (yet), but I'm unsure about including TORCH chapter in my thesis

Thanks for your attention!