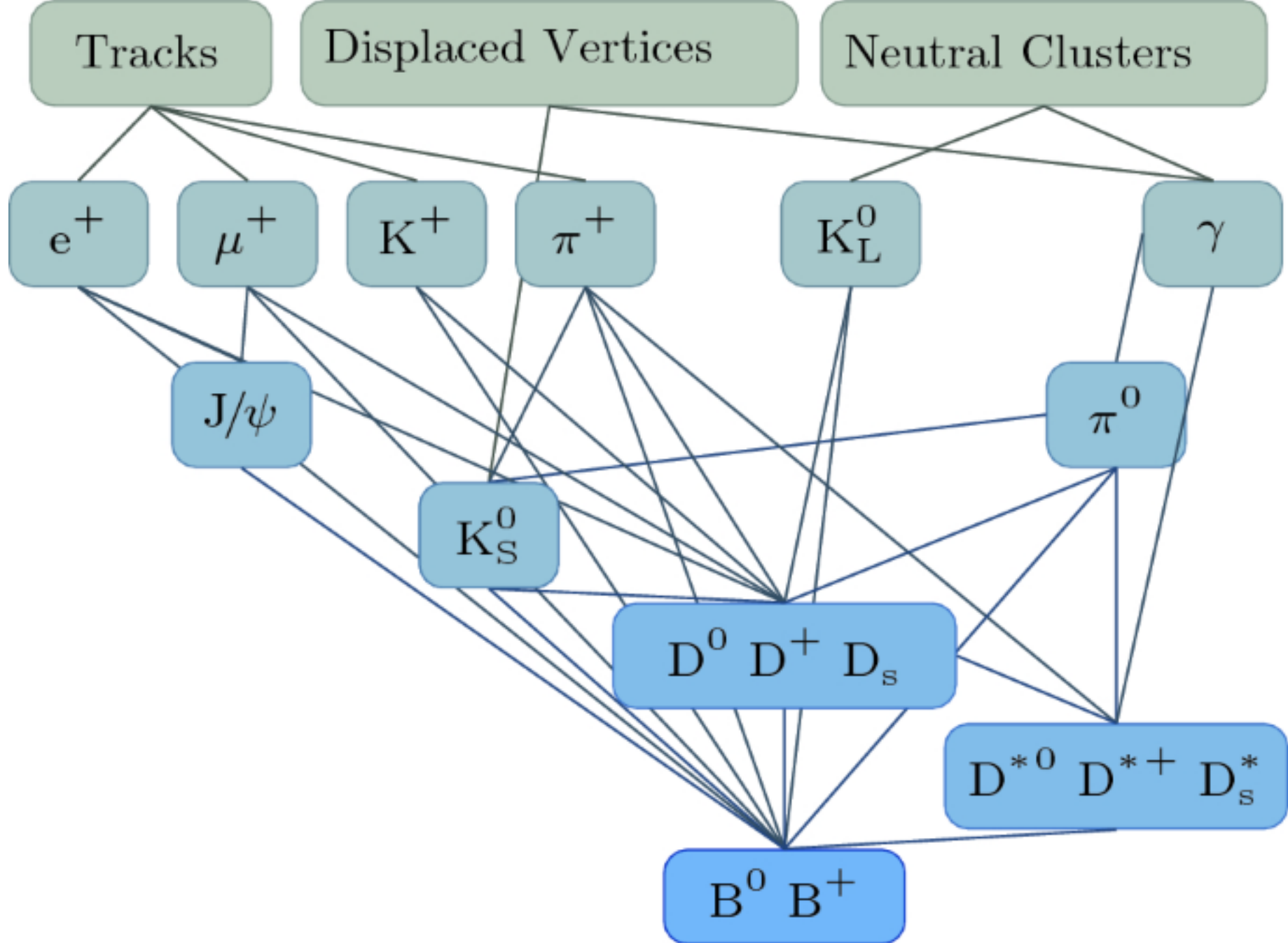
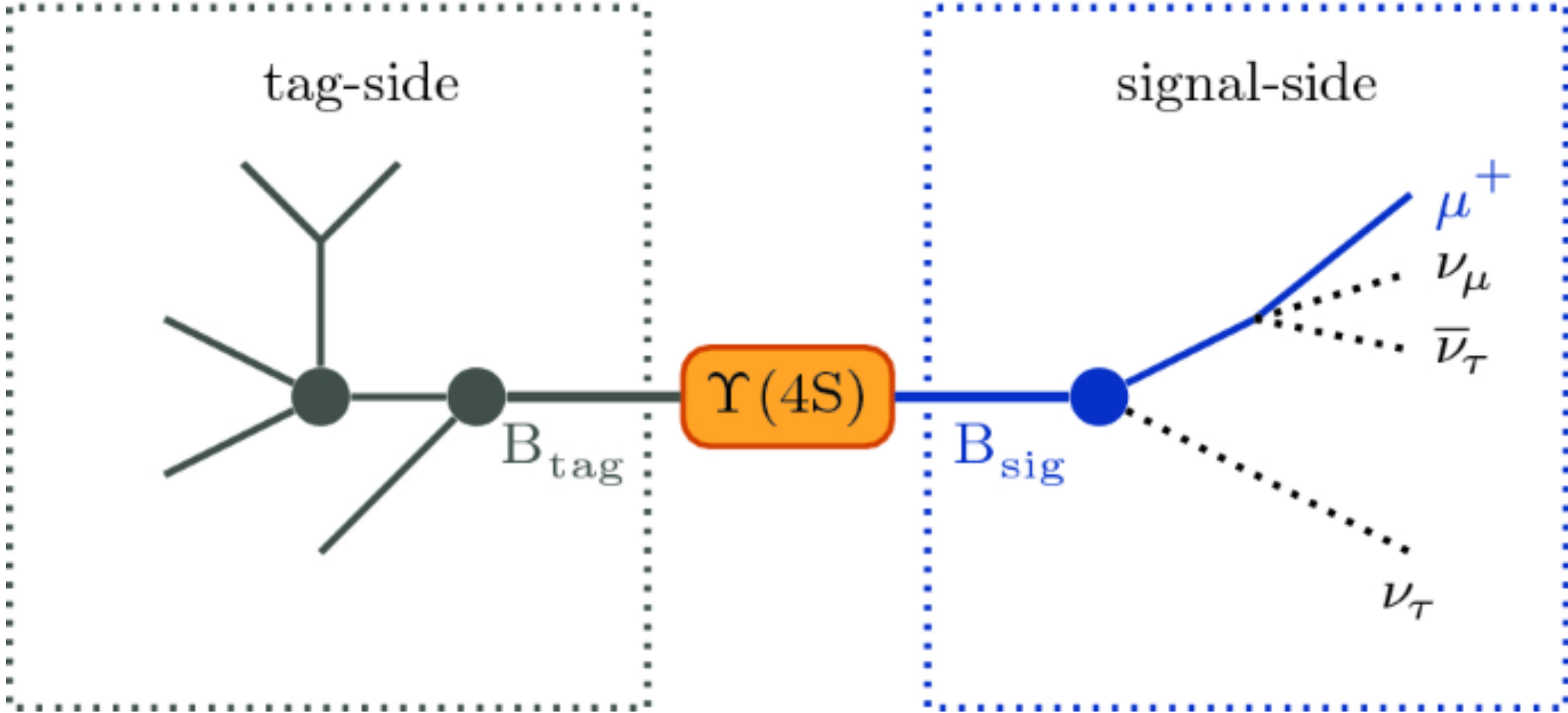


FEI Calibration study at Belle II

Niharika Rout

Motivation

- Many interesting missing energy analyses
- Relies on the tagging tools
- **FEI**: heavily used tagging tool at Belle II



Employs over 200 BDTs to reconstruct over 10000 B decay chain

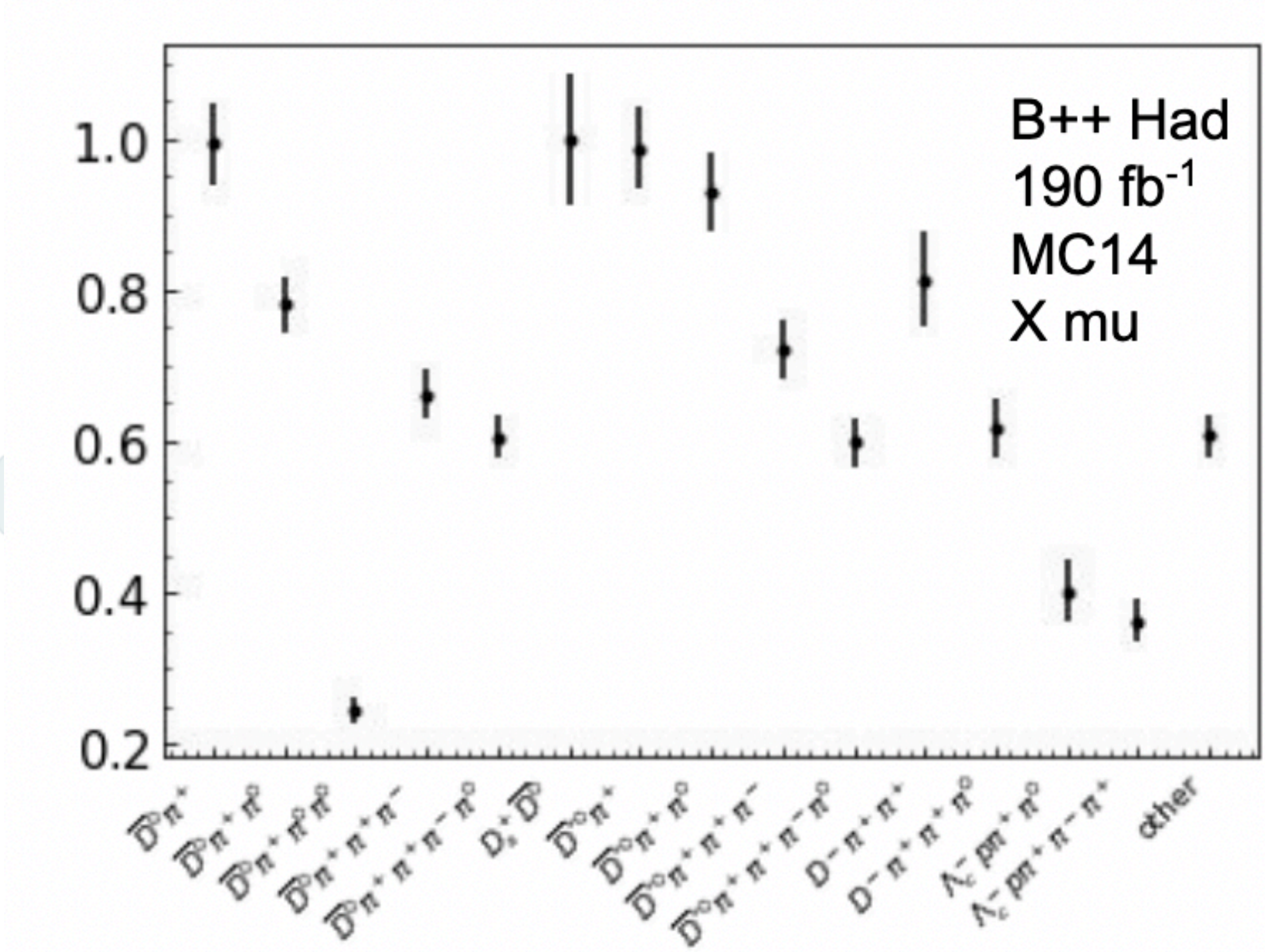
Depends on MC samples for the training of the BDT

Incorrect MC description gives large FEI calibration/correction factor

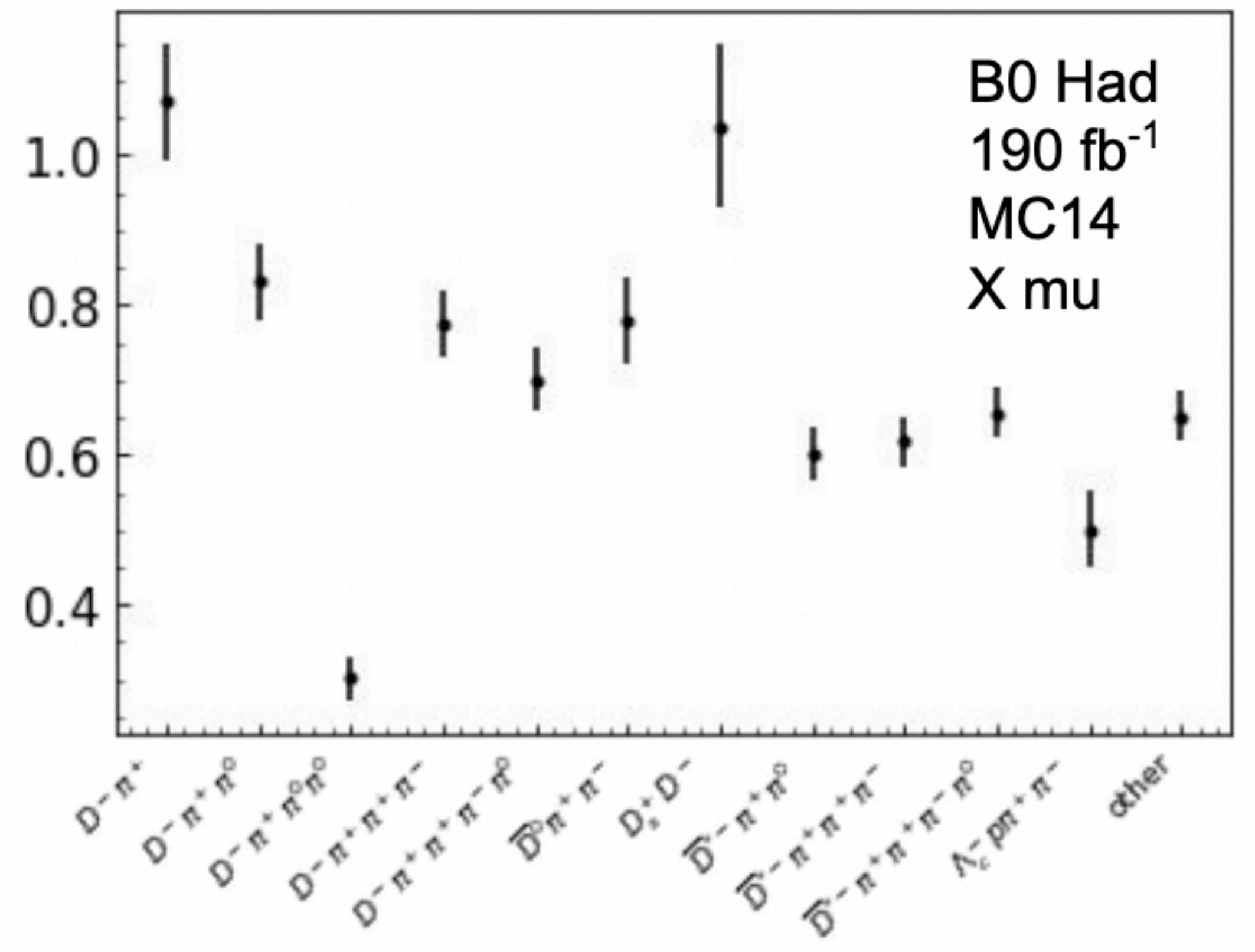
Hadronic FEI

- Many interesting missing energy analyses

tag-side [Physics performance@B2GM](#)



$B^0 B^+$



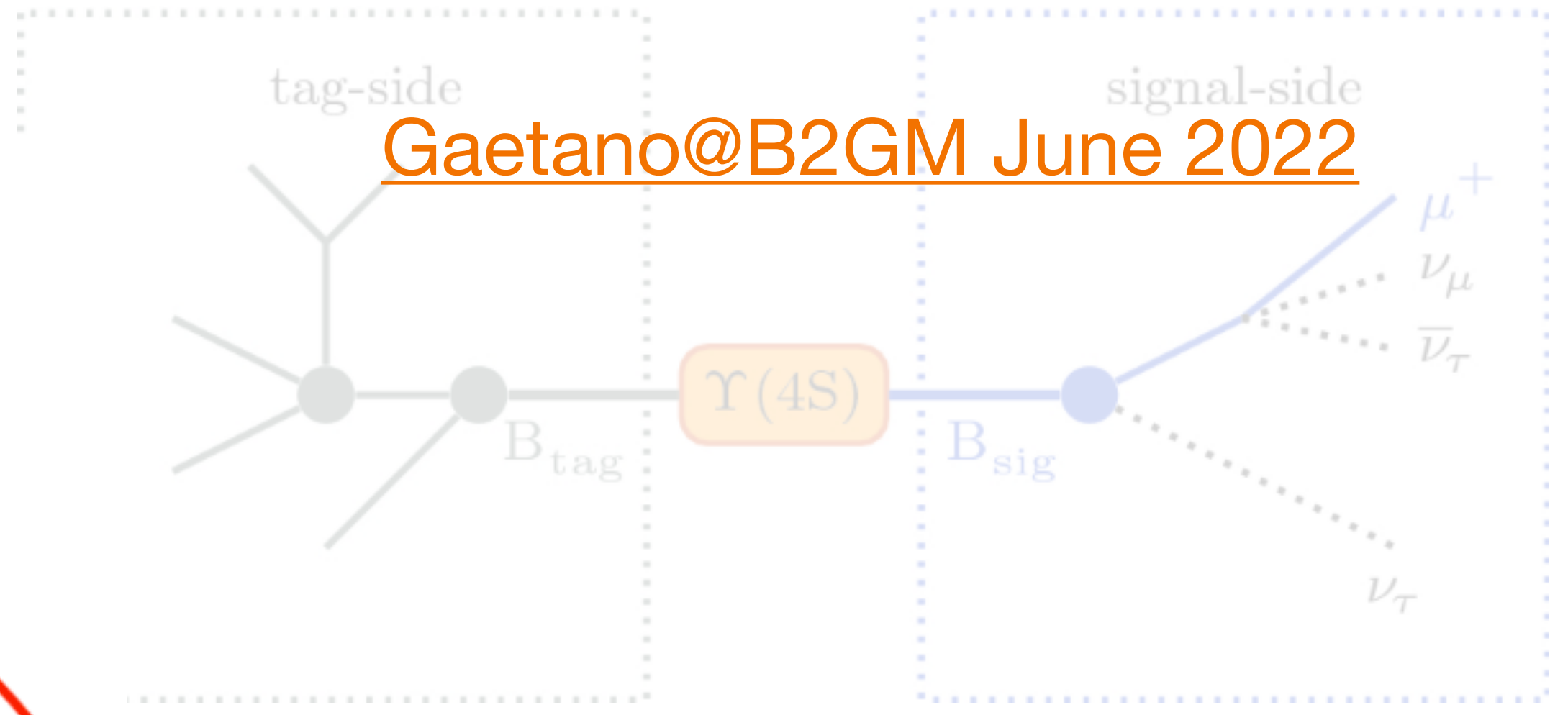
incorrect MC description gives large ϵ_{cal} calibration factor

Hadronic FEI

- Many interesting missing energy analyses

Limiting factor : $\epsilon_{tag} < 1\%$!

- Relic
- FEI:



over 200 BDTs to reconstruct over 12 modes out of 36 makes 90% of the total efficiency $D^{(*)} n\pi$

The results shown later are based on these modes only!

Method

Partial reconstruction for more statistics!

[Vidya sagar @ BHadronicMeeting](#)

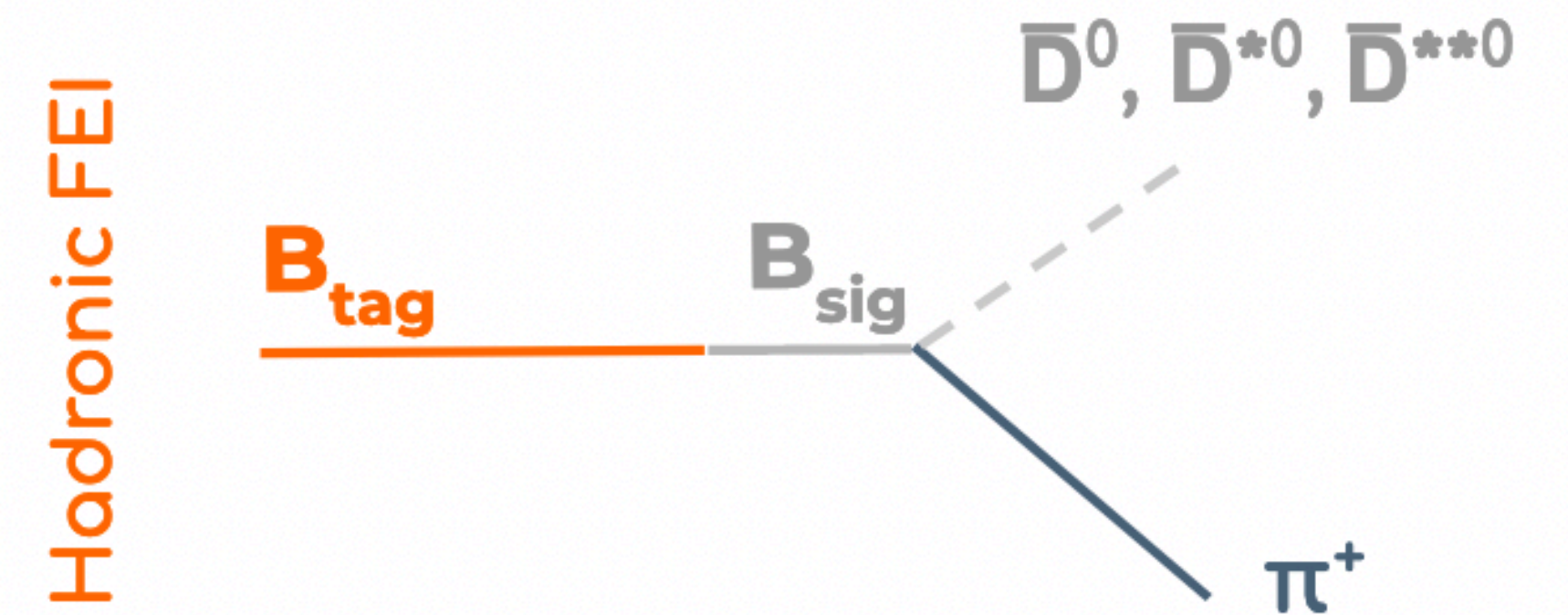
In CM frame of $\Upsilon(4S)$:

$$\vec{p}_{B_{sig}} = -\vec{p}_{B_{tag}}$$

$$\vec{p}_X = \vec{p}_{B_{sig}} - \vec{p}_{\pi^+}$$

$$E_X = E_{beam} - E_{\pi^+}$$

$$M_{recoil} = M_X = \sqrt{E_X^2 - p_x^2}$$

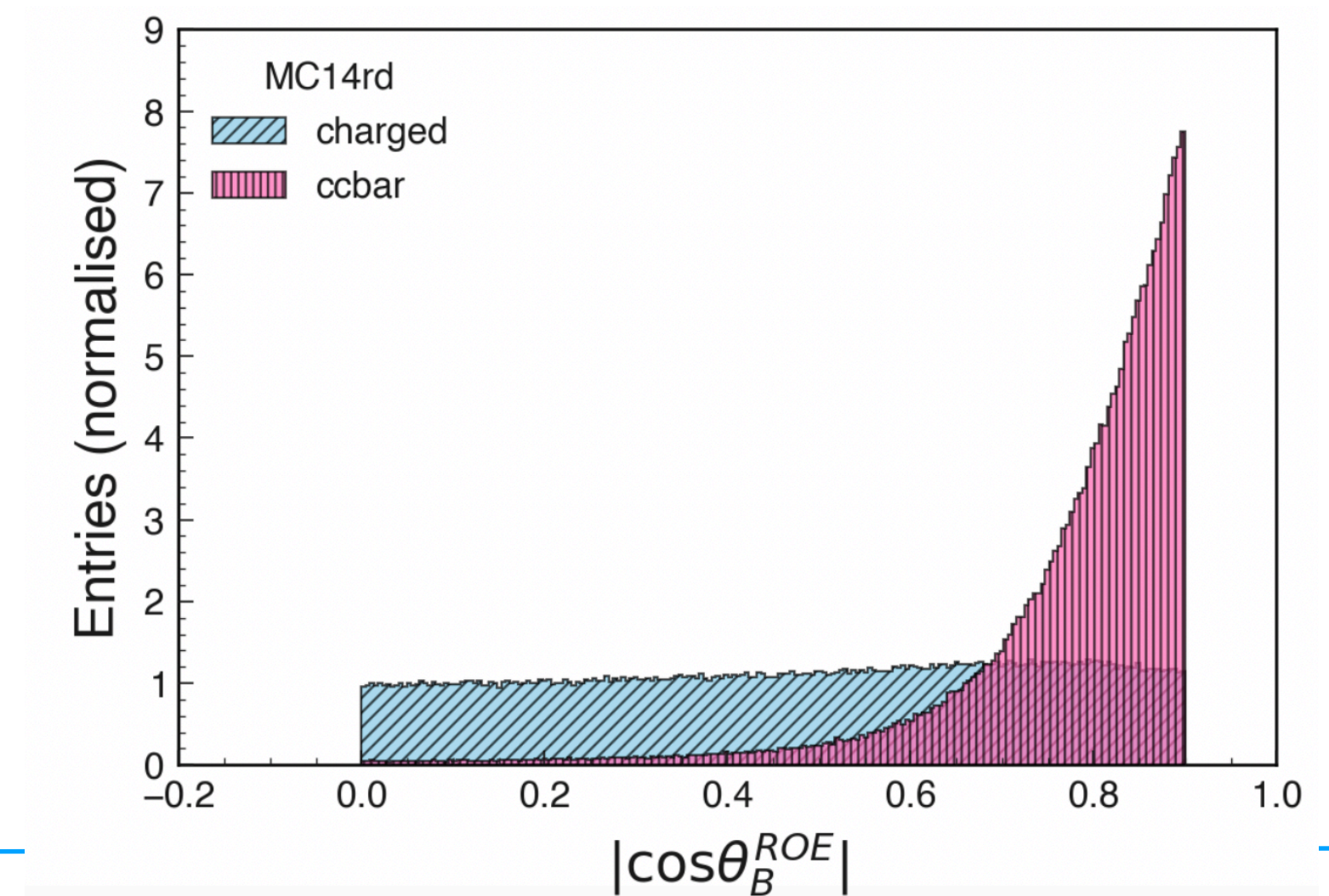
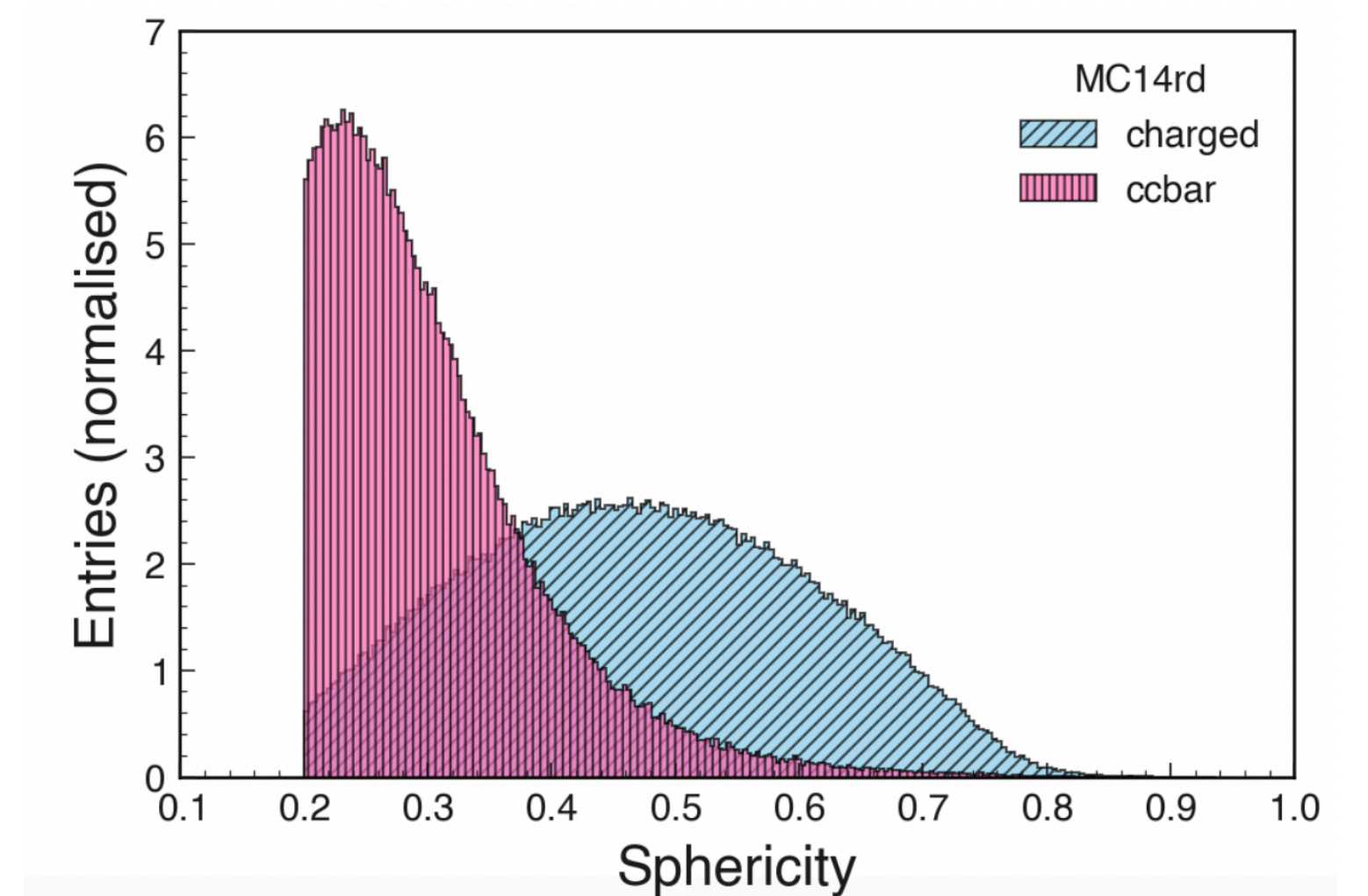


We can look for D^0, D^{*0} and even D^{**0} in the recoil mass of a fully reconstructed B and a π^\pm

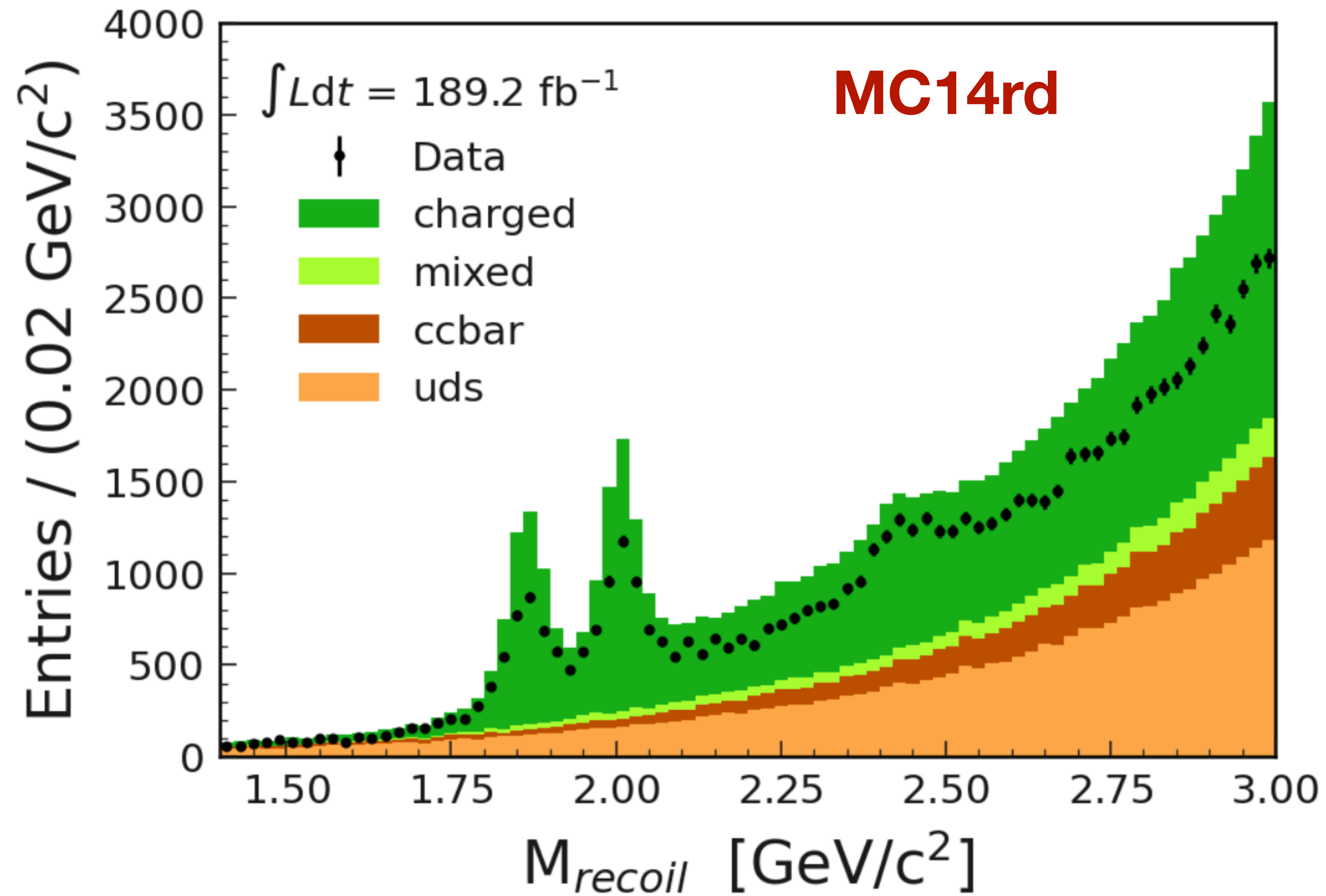
Event selection

- **Event:** sphericity > 0.2
- **Tracks:** $\text{abs}(d0) < 1$ and $\text{abs}(z0) < 3$ and $\text{thetaInCDCAcceptance}$
- **Kinematics:** $\text{mbc} > 5.27$ and $\text{abs}(\text{deltaE}) < 0.05$ and $\text{signalProbability} > 0.001$
- **Continuum suppression:** $\text{costheta} < 0.9$
- **π tracks:** track selection + $\text{kid} < 0.9$ and $\text{muid} < 0.9$ and $\text{eid} < 0.9$
- **BCS selection:** max of (pi_CMS_p) and (FEI_sig_prob)

FEI tag: FEIv4_2021_MC14_release_05_01_12



M_{recoil}



Signal window of $D^{(*)}$

D^0

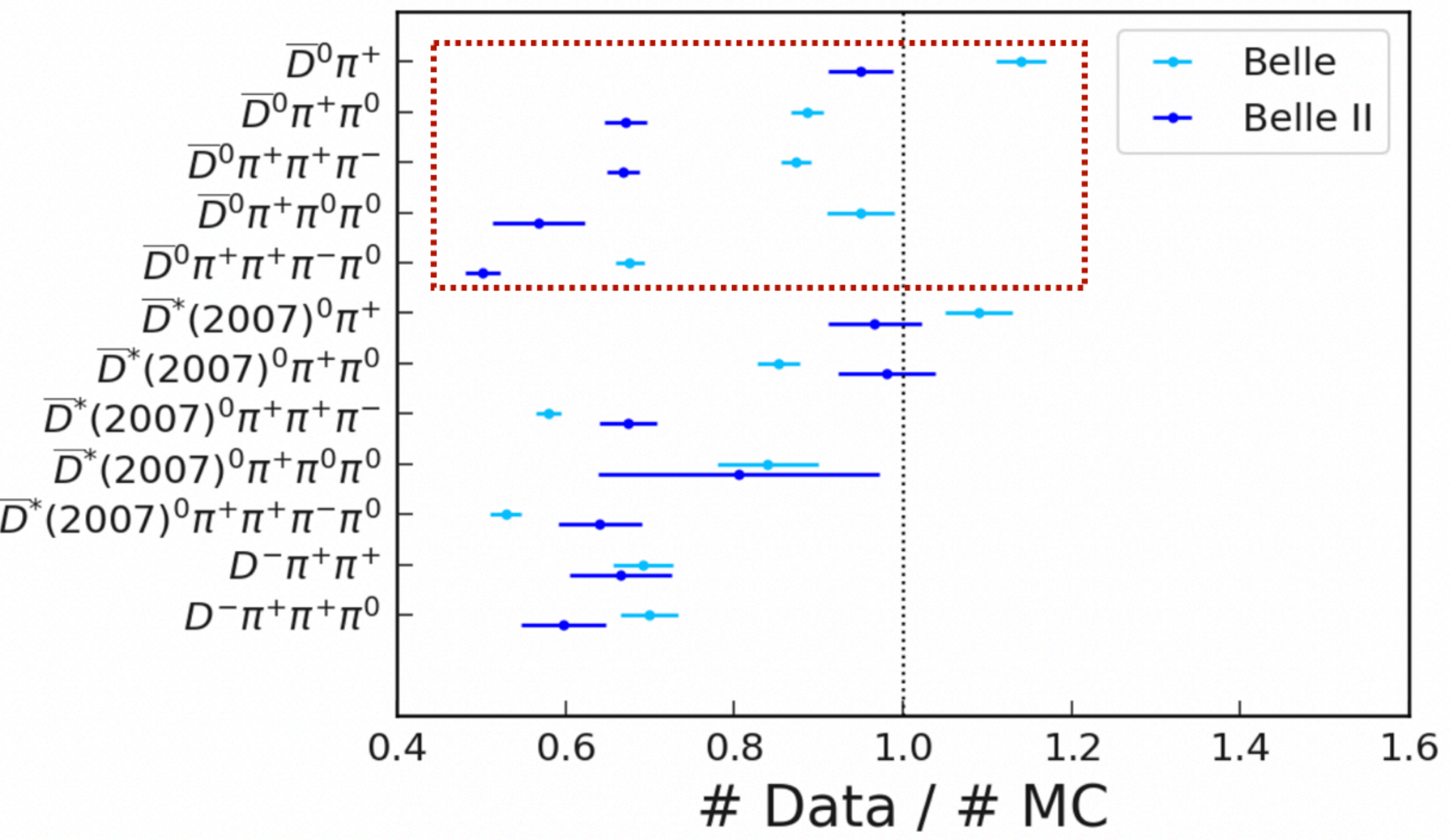
M_{recoil}	Data/MC
[1.84, 1.88]	0.64
[1.82, 1.90]	0.66
[1.80, 1.92]	0.70

D^{*0}

M_{recoil}	Data/MC
[1.98, 2.02]	0.66
[1.95, 2.05]	0.71
[1.92, 2.10]	0.73

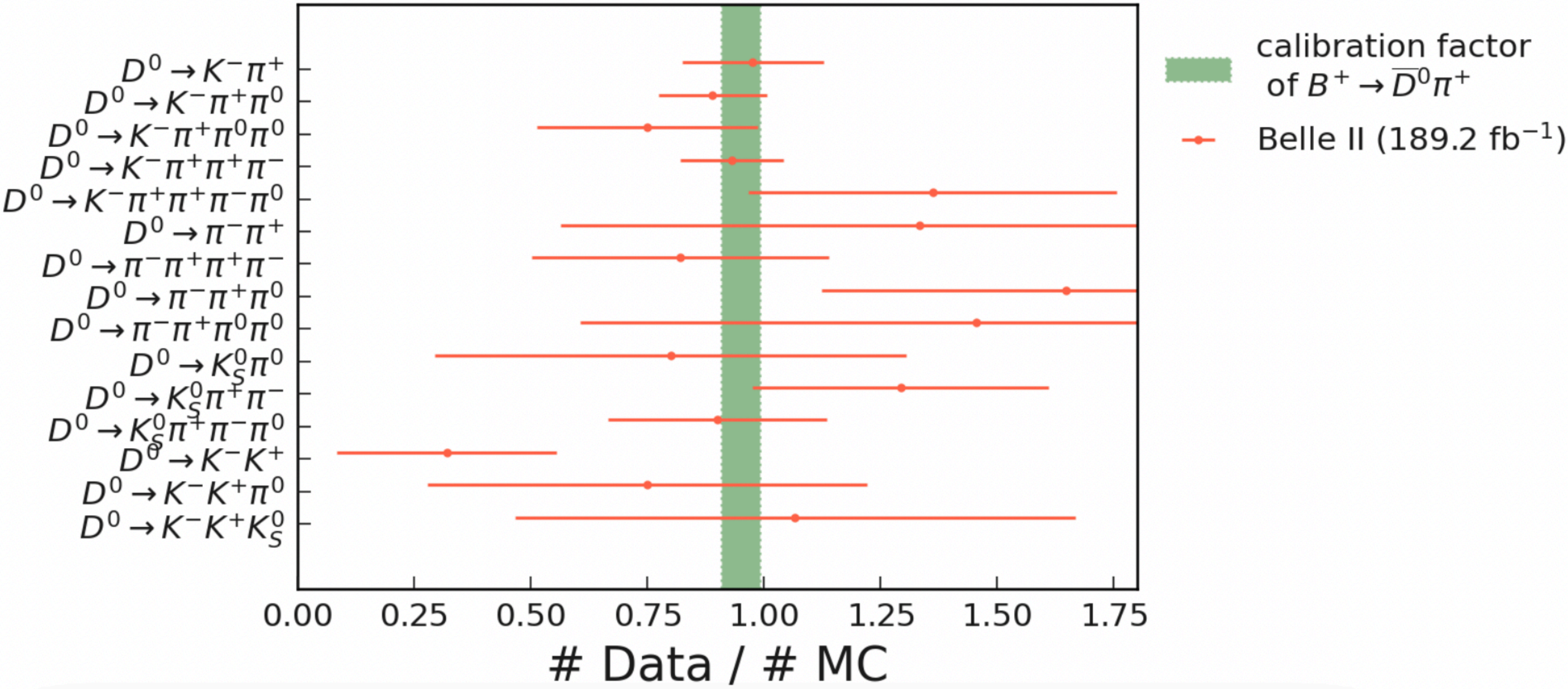
Overall calibration factor obtained using this method ~ 0.65

FEl: mode by mode



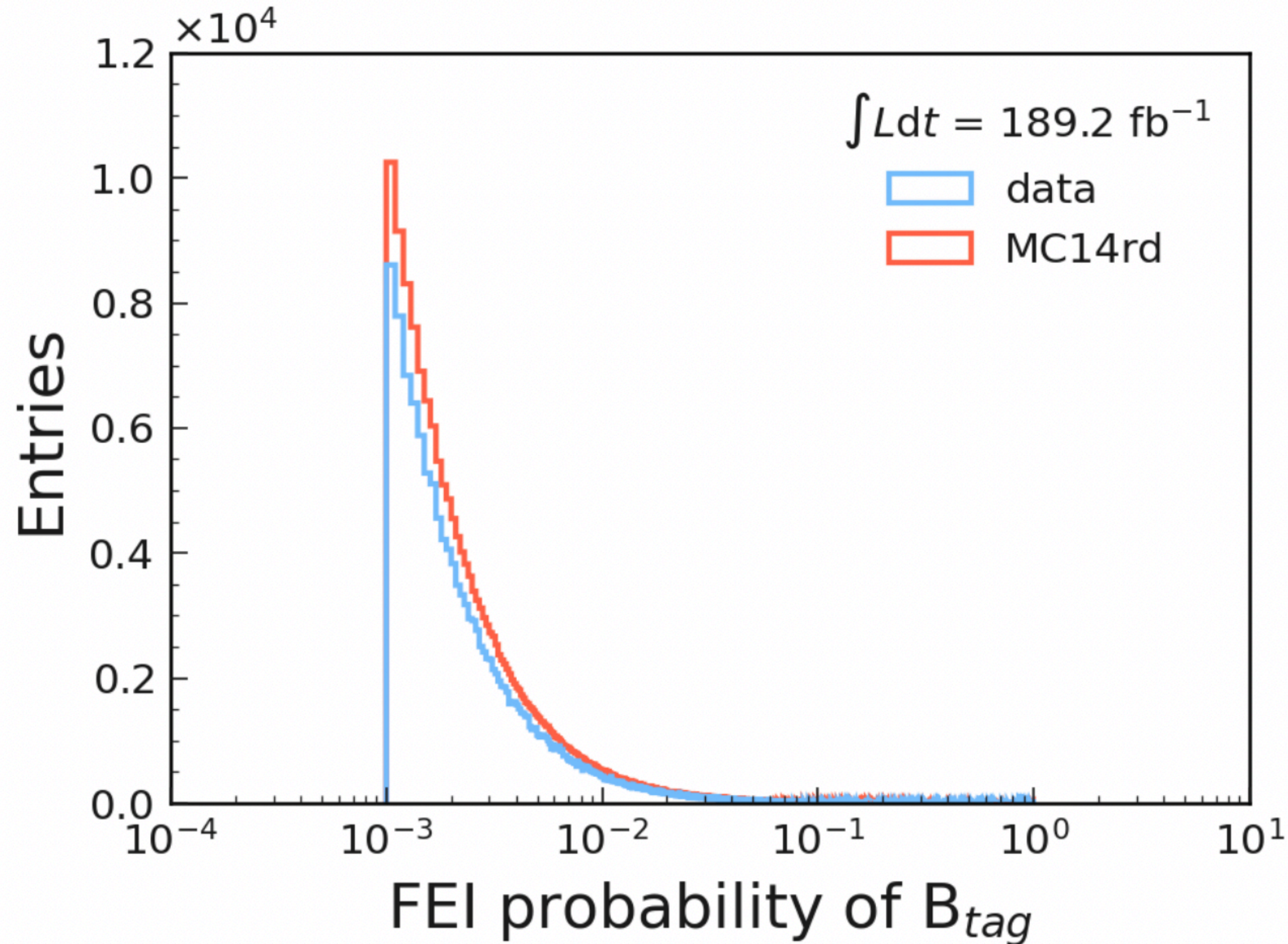
- Belle calibration factor is ~ 0.8
- **Belle II: 0.65; why so low at Belle II?**
- Most of the differences are in $D^0 n \pi$ channels

Further investigations



Looked at calibration factors at D-level; nothing suspicious!

Further investigations



- FEI probability is used in the BCS selection along with pion momentum
- Data-MC comparison looks fine

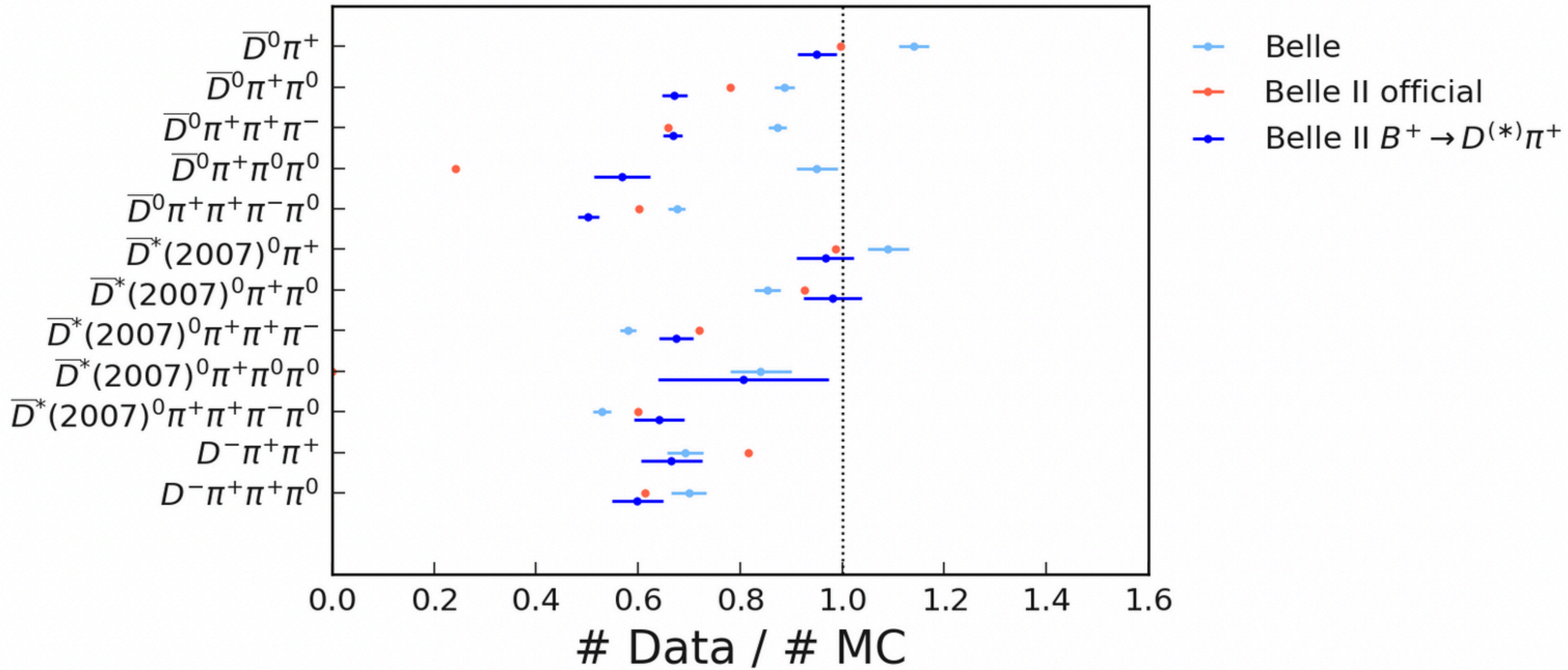
Branching ratio check

Mode	Belle (%)	Belle II (%)
$D\pi\pi^0$	1.76	1.74
$D\pi\pi^0\pi^0$	1.69	1.56
$D\pi\pi\pi$	1.12	1.38
$D\pi\pi\pi\pi^0$	3.54	3.42

[BELLE2-NOTE-PH-2022-002](#)

- The difference in the calibration factor for $D\pi\pi\pi$ makes sense (~30% difference in BR between Belle and Belle II)
- Need to study other 3 modes!

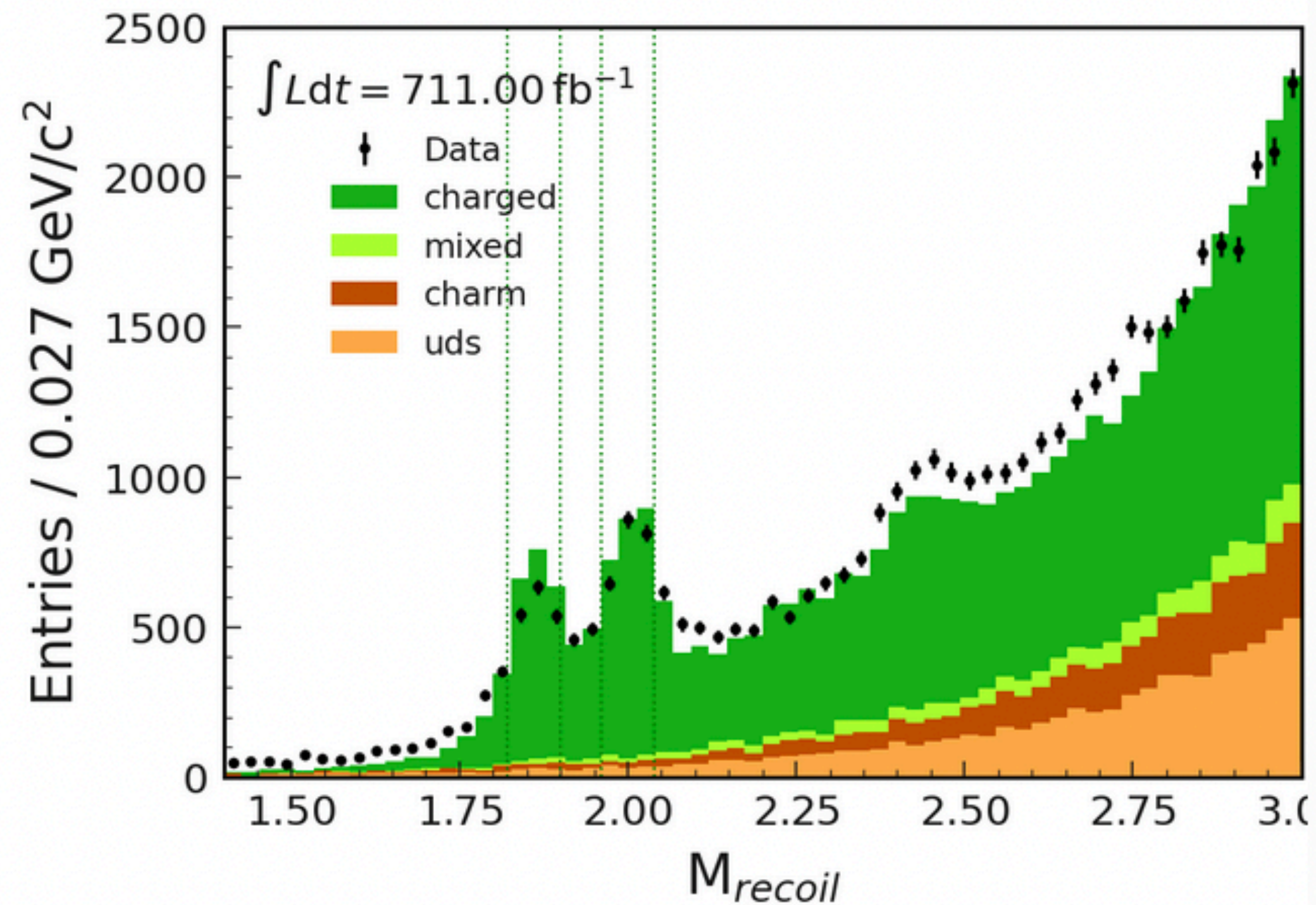
Comparison with official values



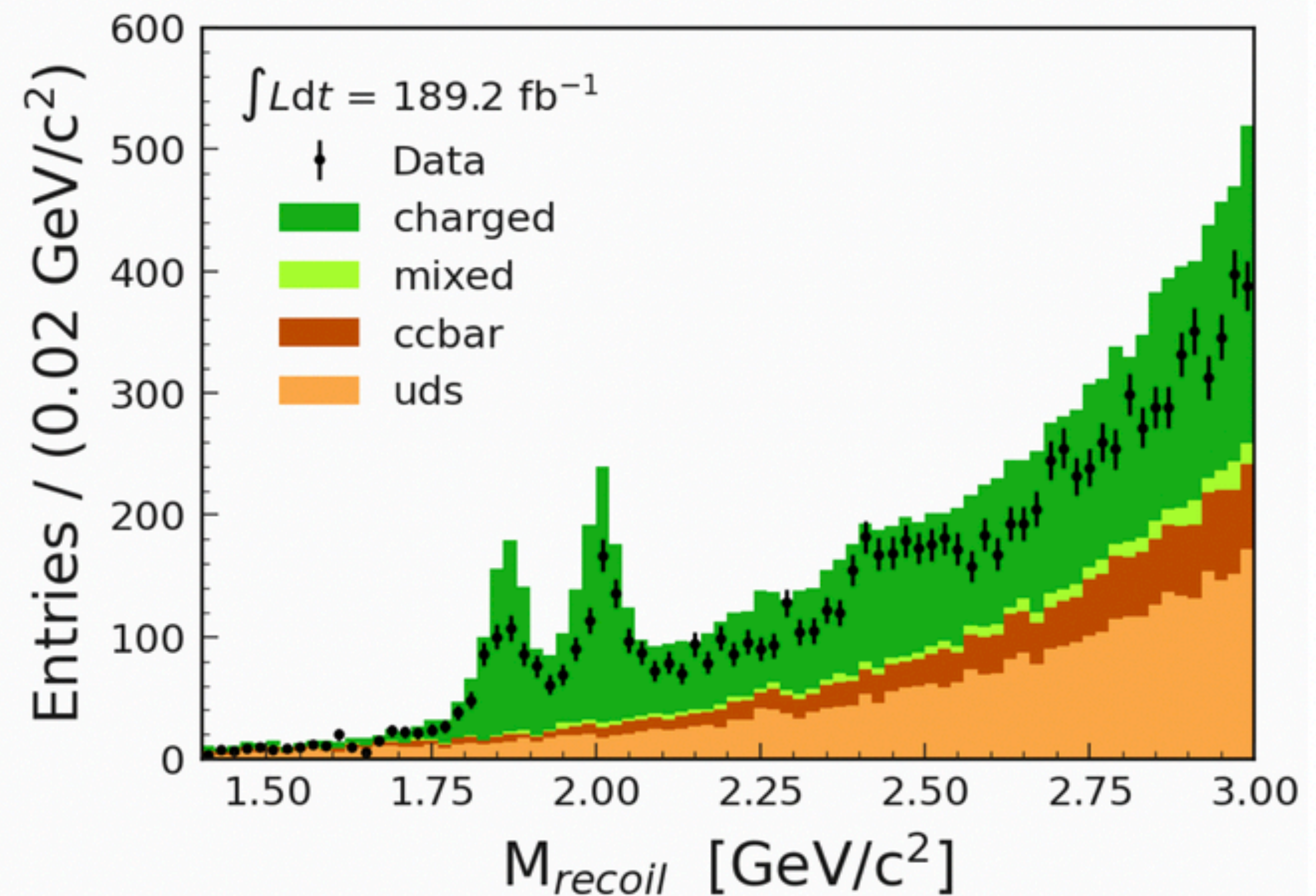
Comparison with Belle: M_{recoil}

FEl mode: $B^+ \rightarrow \bar{D}^0 \pi^+ \pi^0$

Belle (Official MC)
Calibration factor: 0.89 ± 0.02



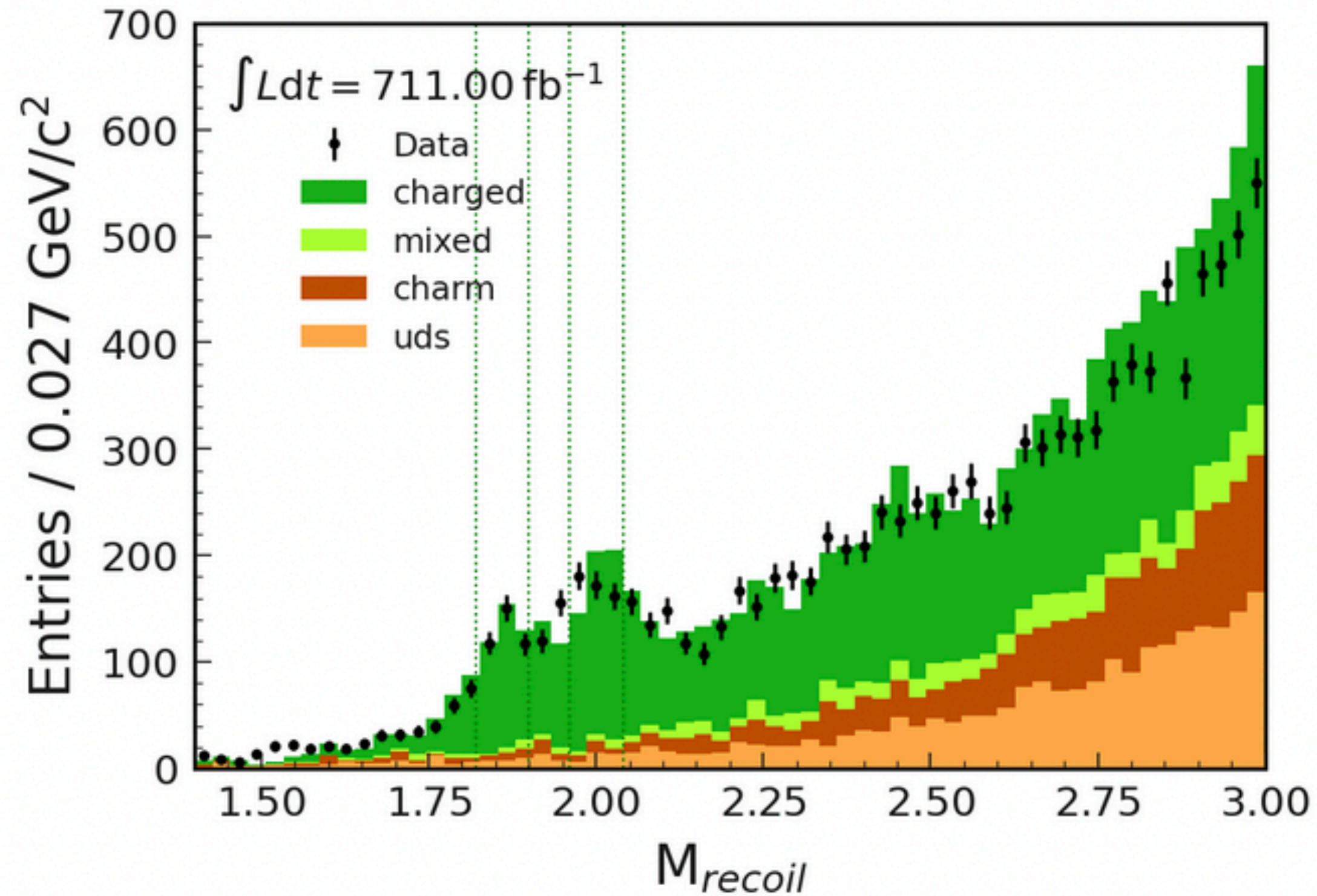
Belle II (MC14rd)
Calibration factor: 0.67 ± 0.02



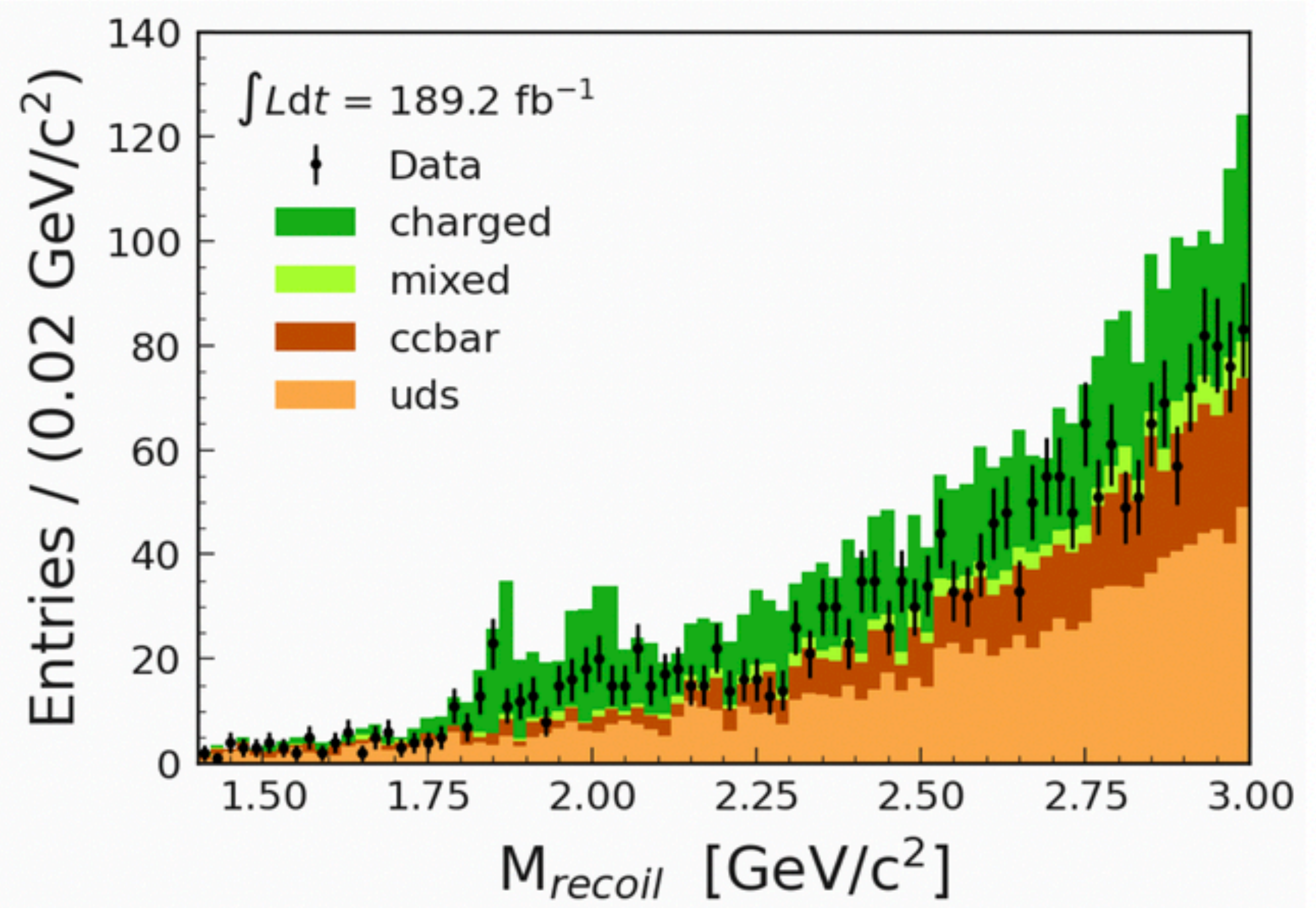
- Resolution is better at Belle II
- uds background level is very high!

FEI mode: $B^+ \rightarrow \bar{D}^0 \pi^+ \pi^0 \pi^0$

Belle (Official MC)
Calibration factor: 0.95 ± 0.04



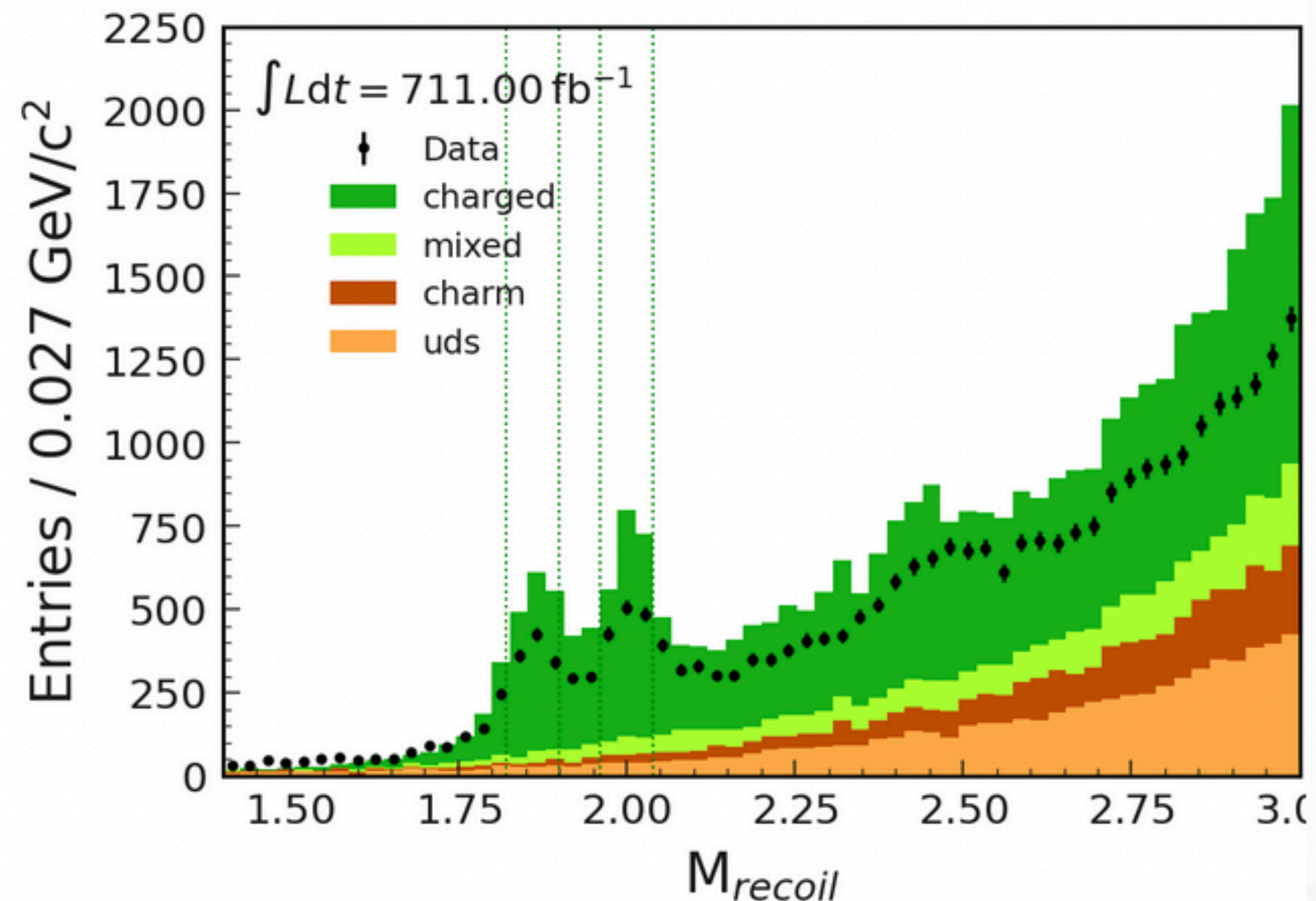
Belle II (MC14rd)
Calibration factor: 0.57 ± 0.05



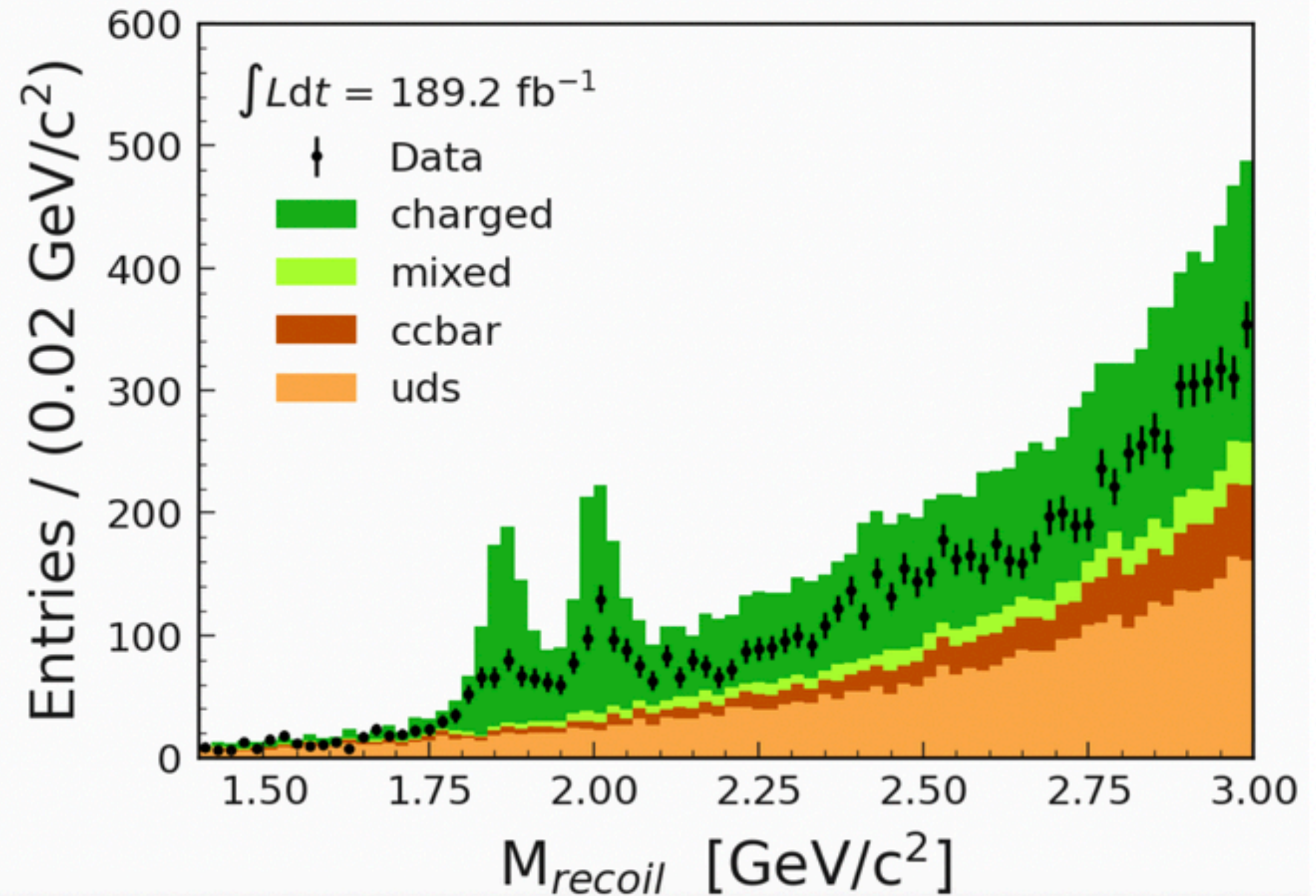
- Low statistics!
- uds background level is very high!

FEI mode: $B^+ \rightarrow \bar{D}^0 \pi^+ \pi^- \pi^+ \pi^0$

Belle (Official MC)
Calibration factor: 0.68 ± 0.02

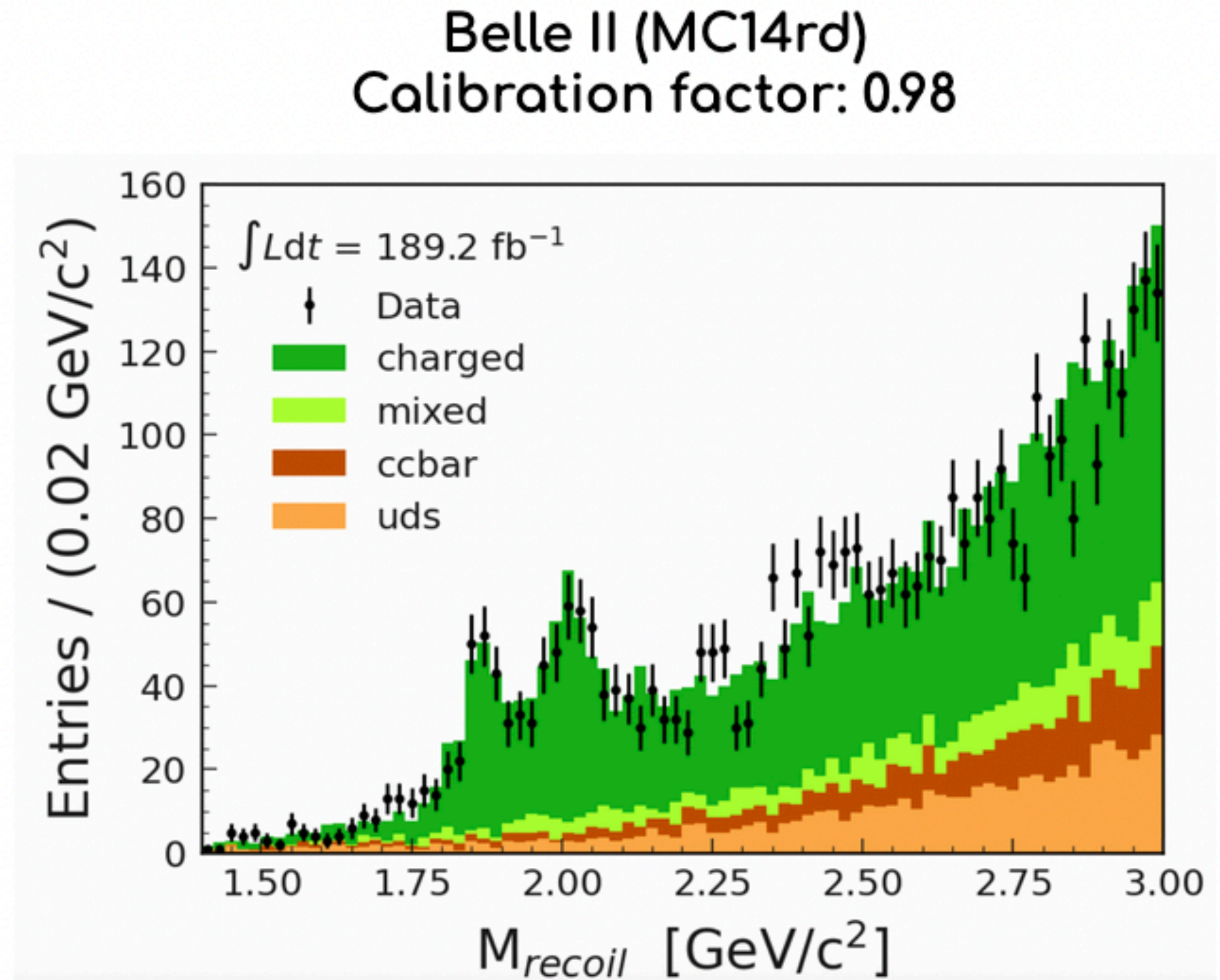
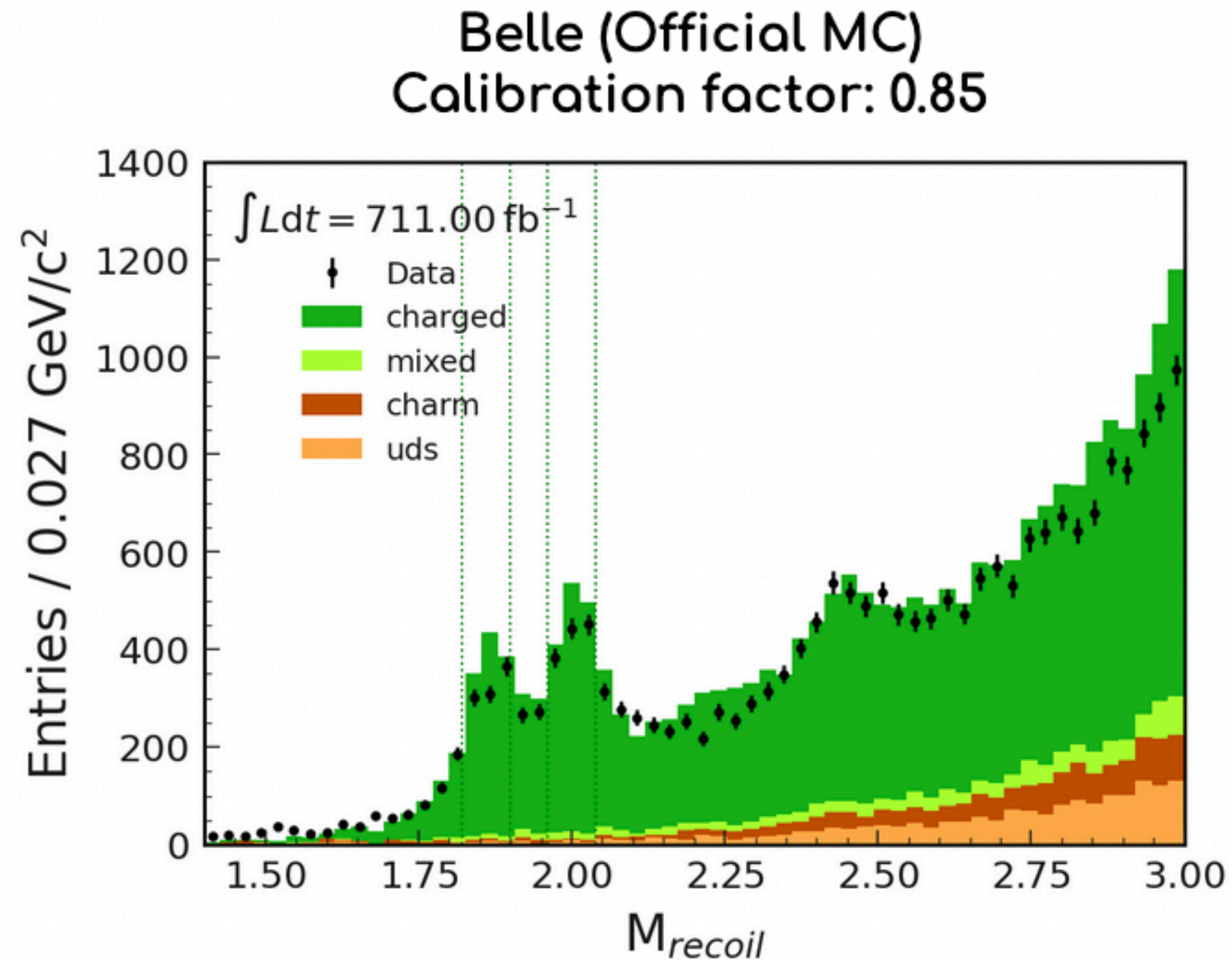


Belle II (MC14rd)
Calibration factor: 0.50 ± 0.02



- Resolution is better at Belle II
- uds background level is very high!

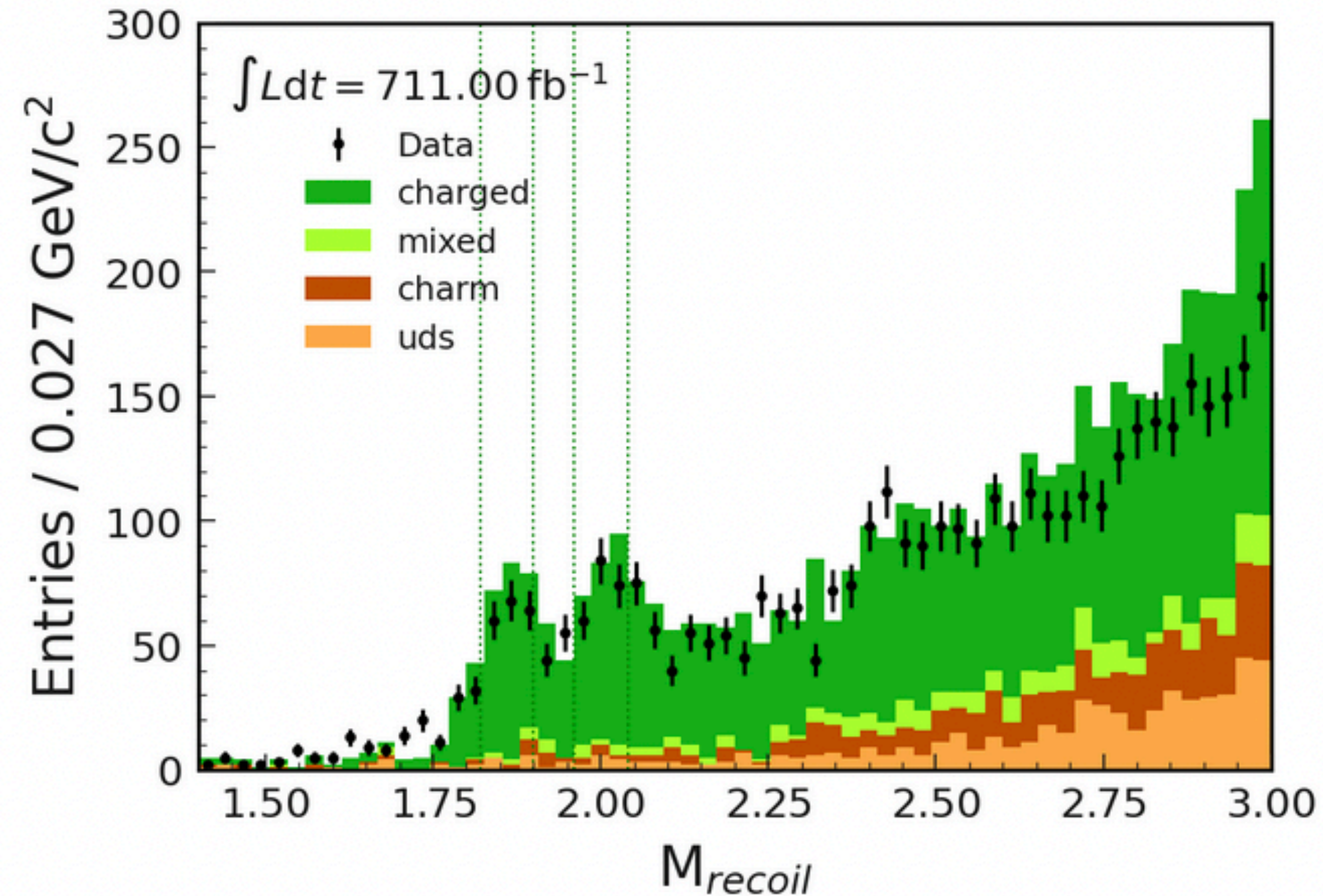
FEI mode: $B^+ \rightarrow \bar{D}^{*0} \pi^+ \pi^0$



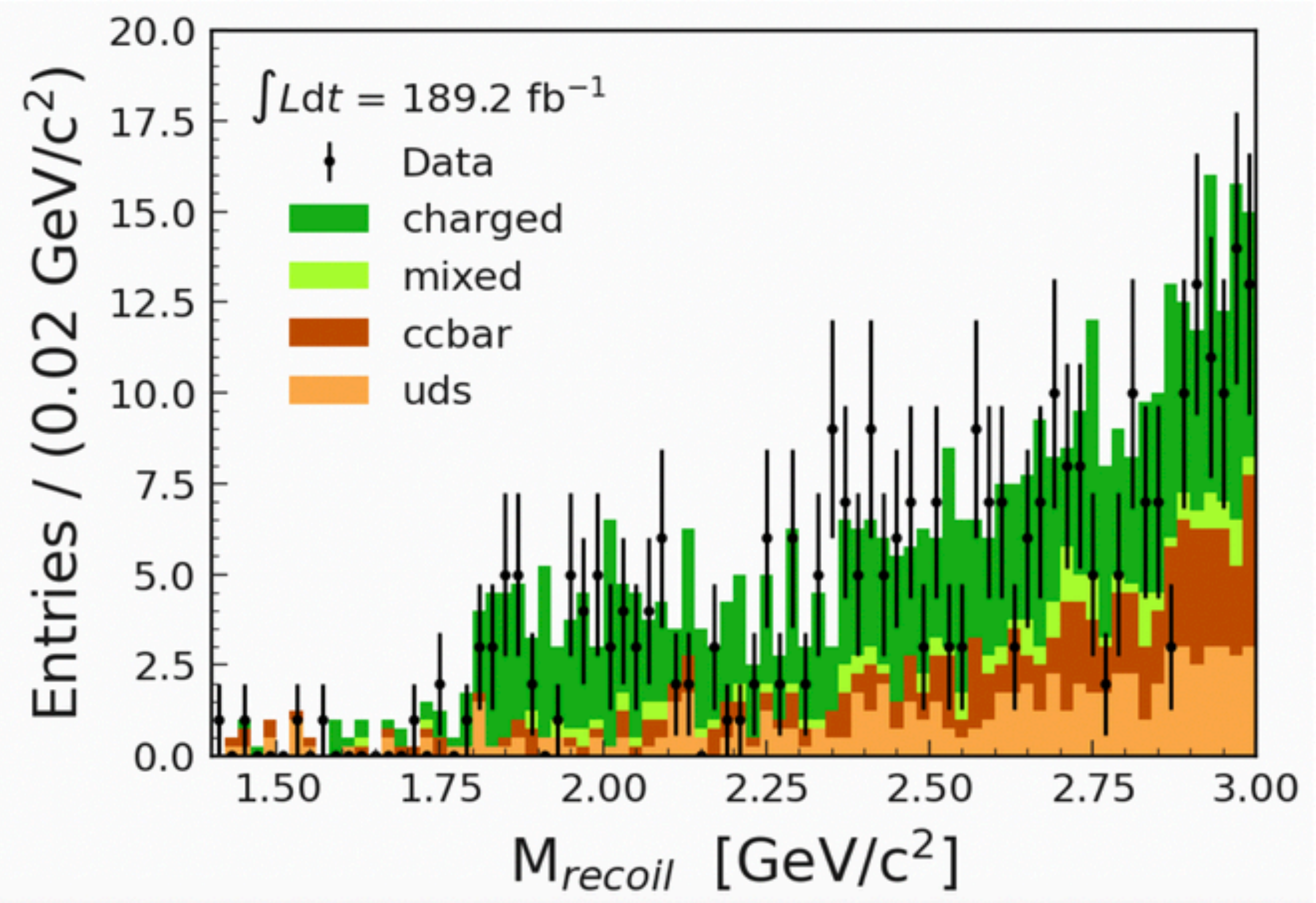
- Resolution is better at Belle II
- Background level is low as compared to D modes

FEI mode: $B^+ \rightarrow \bar{D}^{*0} \pi^+ \pi^0 \pi^0$

Belle (Official MC)
Calibration factor: 0.84



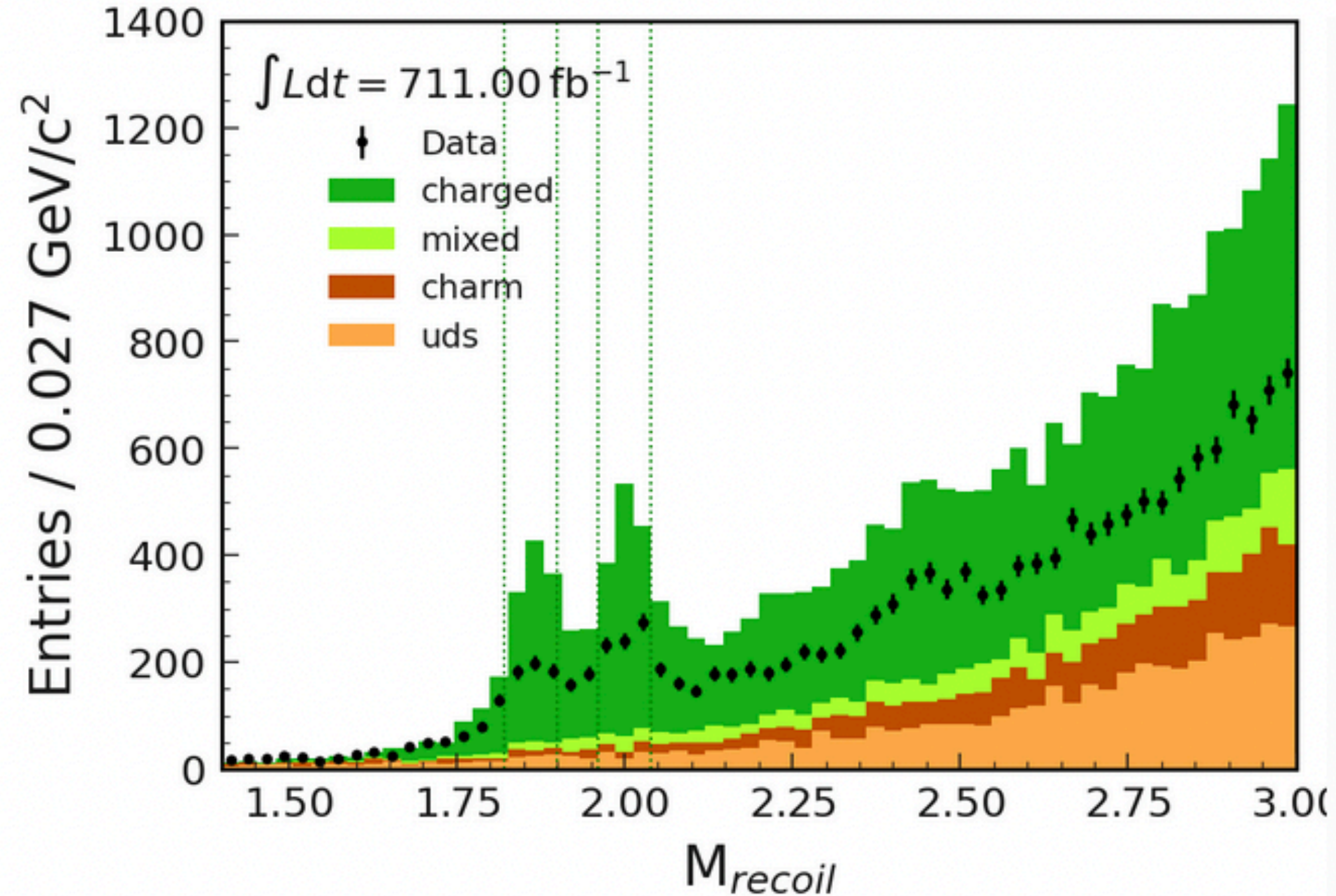
Belle II (MC14rd)
Calibration factor: 0.81



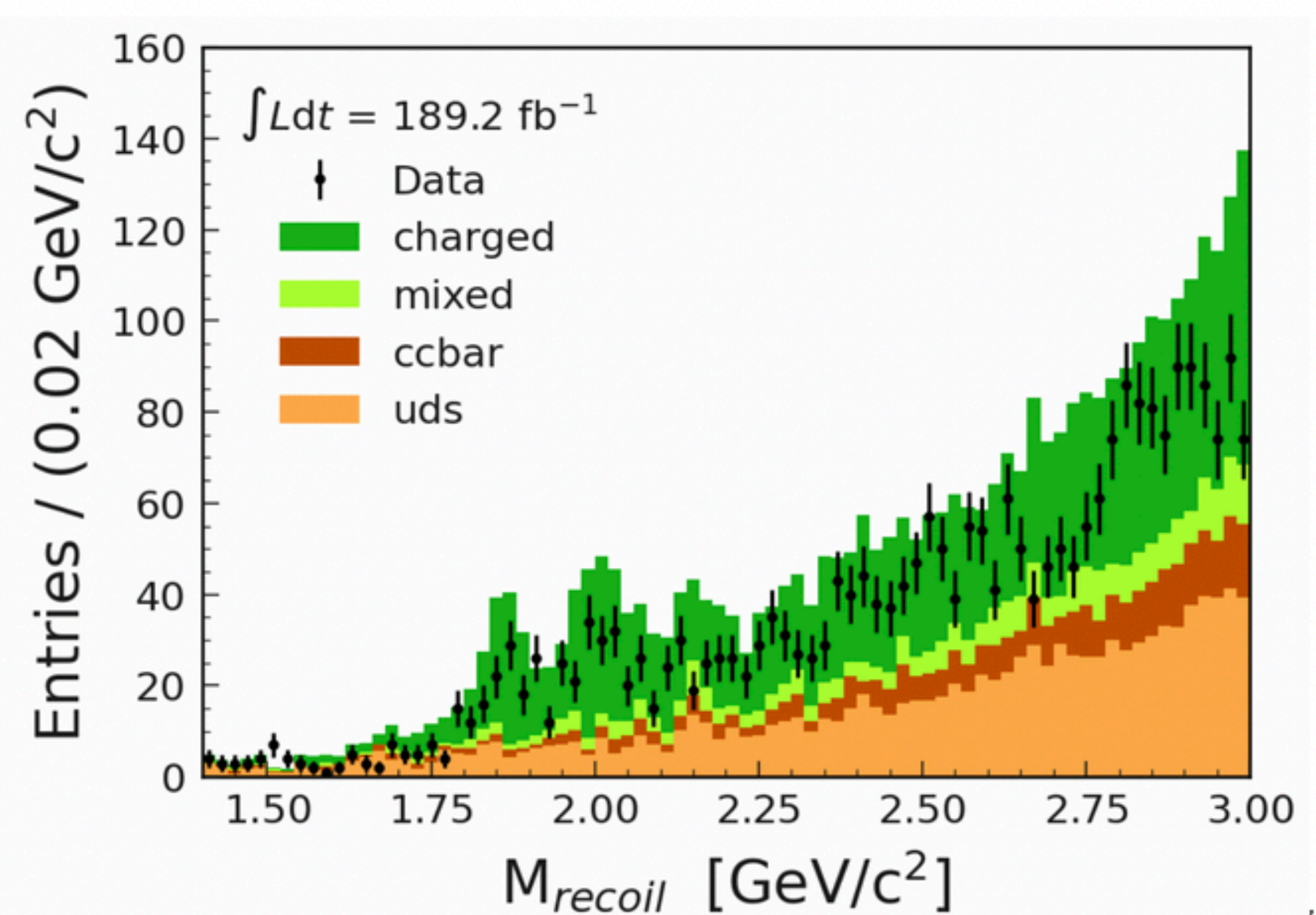
- Low statistics: no conclusion!

FEI mode: $B^+ \rightarrow \bar{D}^{*0} \pi^+ \pi^- \pi^+ \pi^0$

Belle (Official MC)
Calibration factor: 0.53

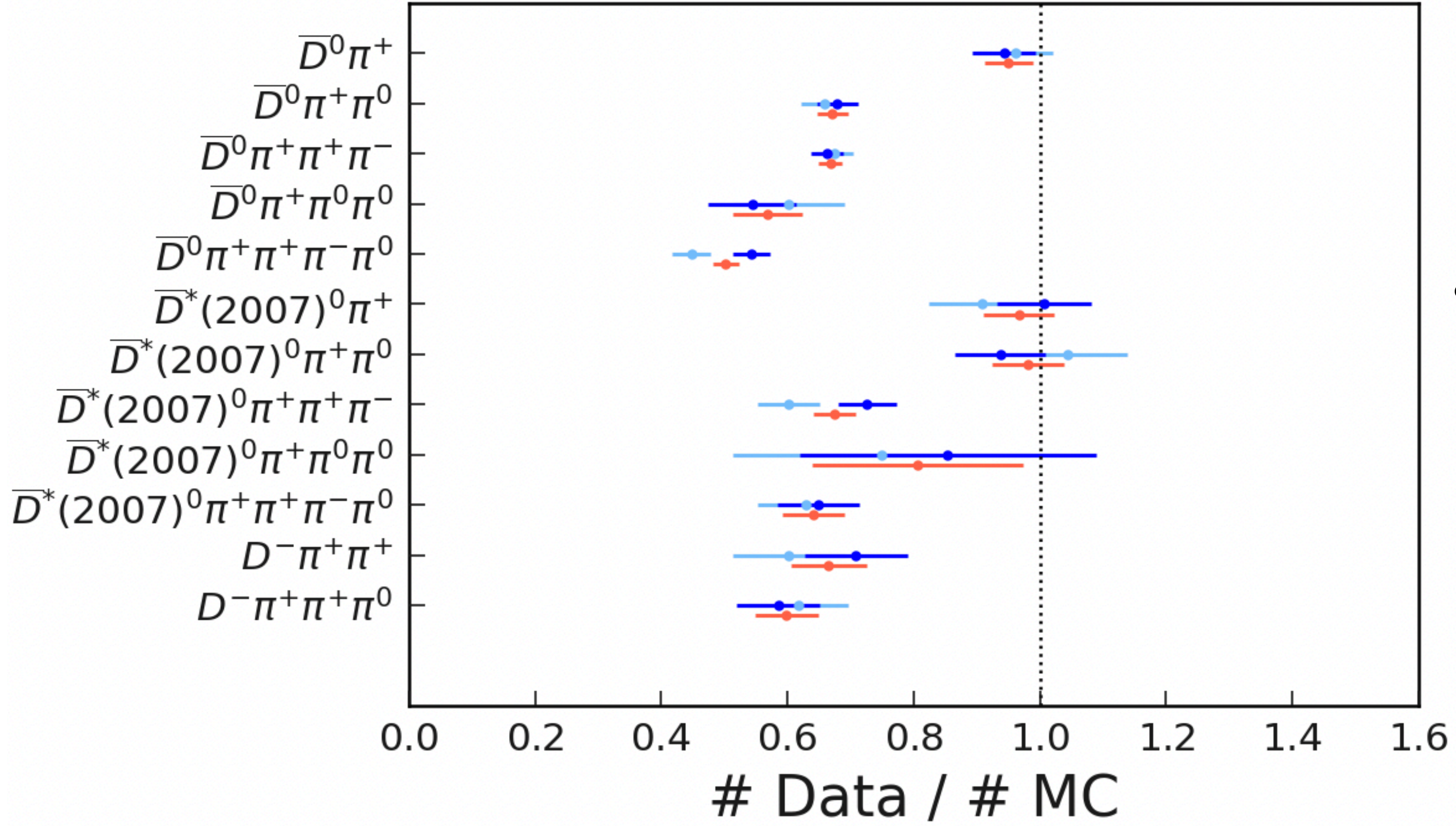


Belle II (MC14rd)
Calibration factor: 0.64



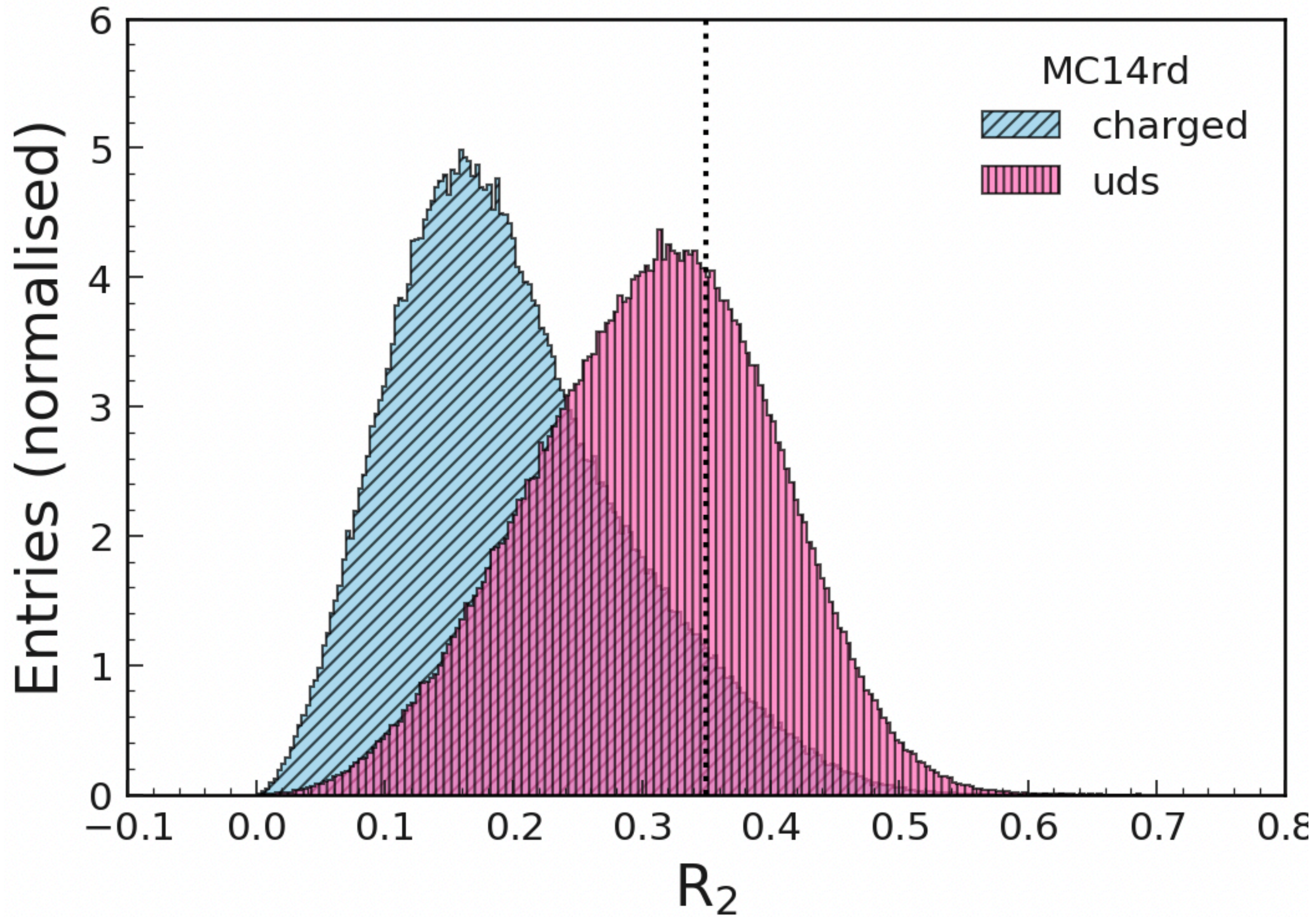
- High multiplicity mode
- Background level is low as compared to D modes, but still high

Check in different signal region of D and D*



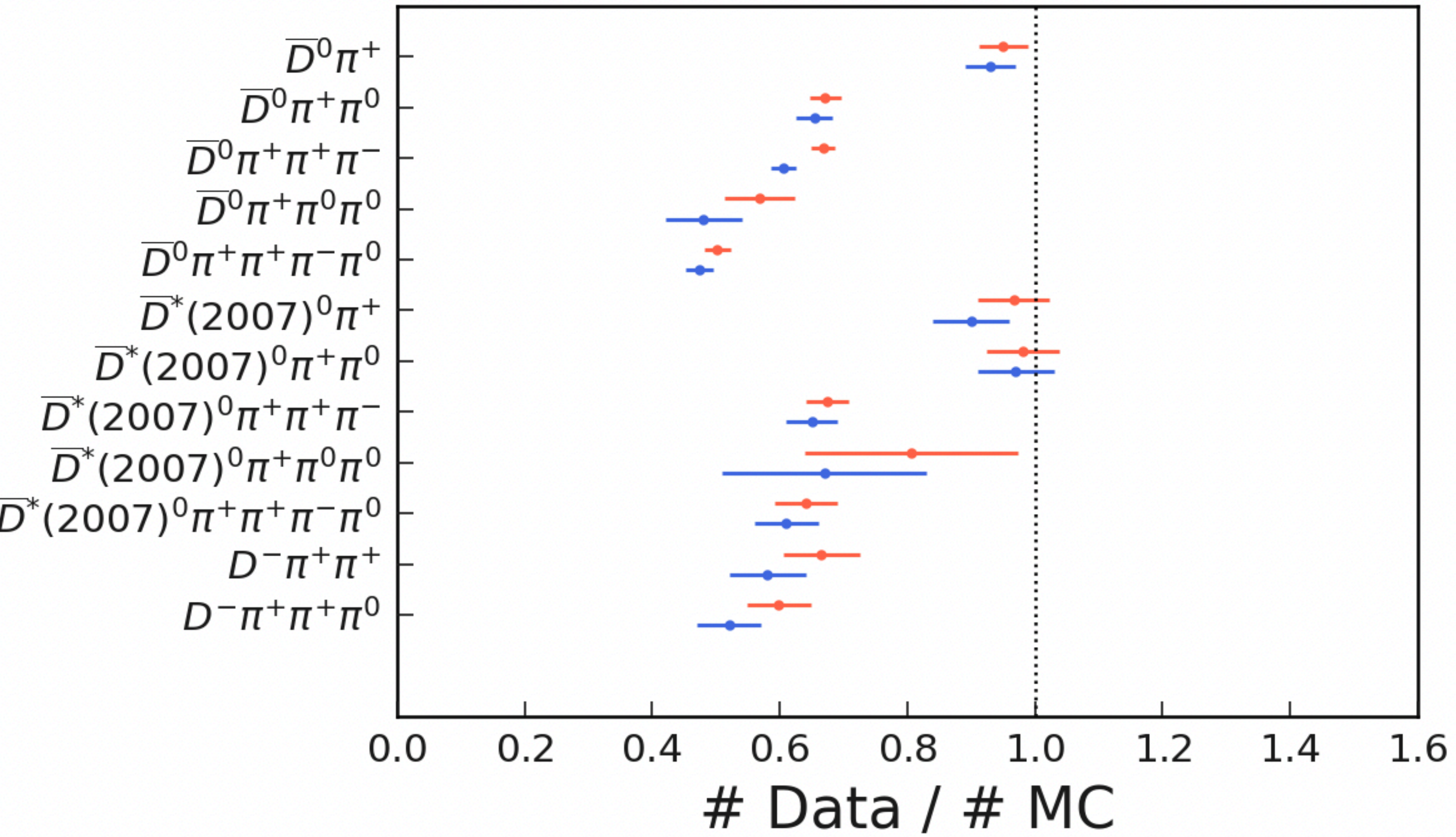
- The calibration factor in D* region is slightly better as compared to D region although the background level in this region is high?

Further optimisation of continuum at Belle II



$R_2 < 0.35$

Further optimisation of continuum at Belle II



$\int L dt = 189.2 \text{ fb}^{-1}$

— without R2 cut

— with R2 cut

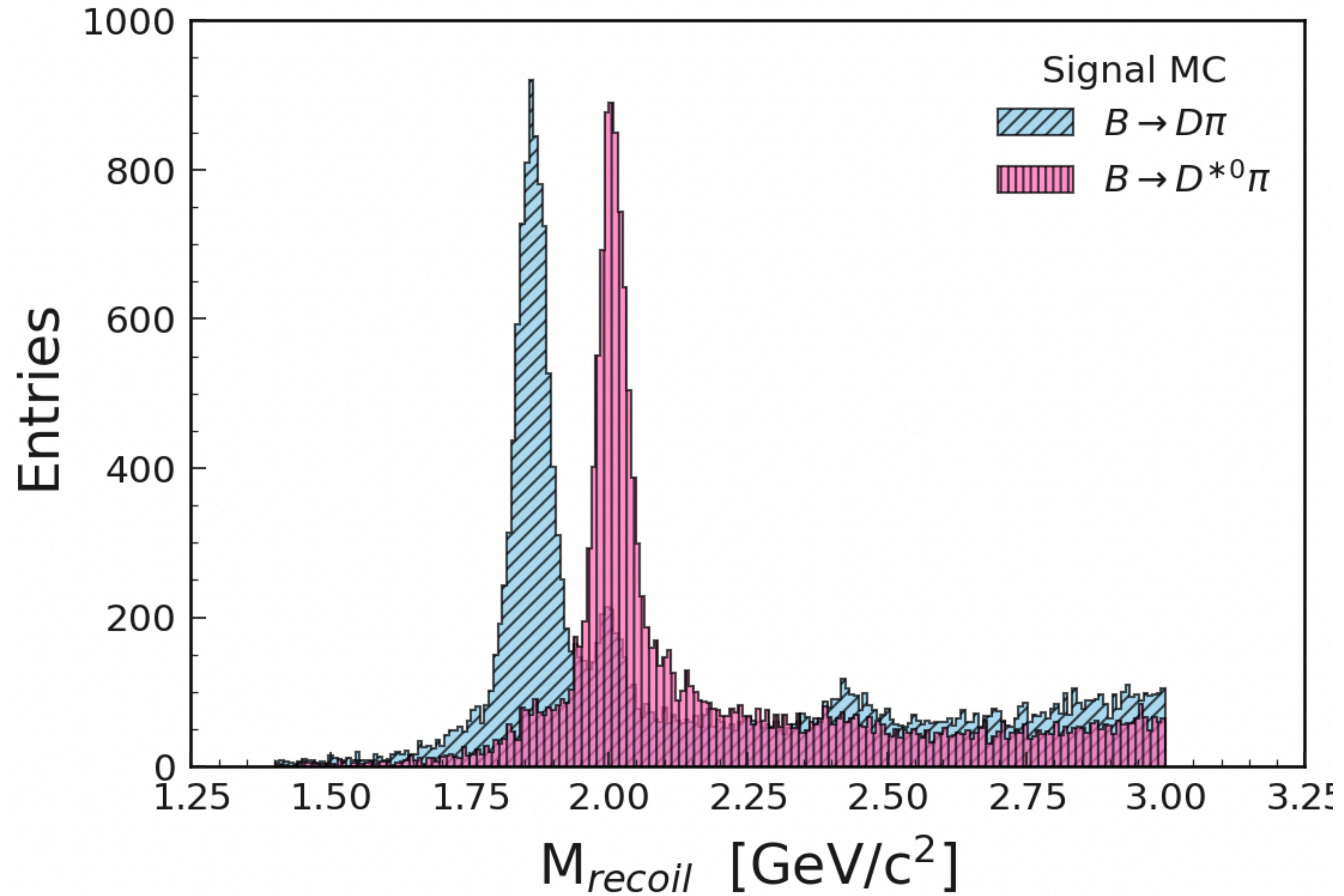
- With R2 selection the factors get worse!
- Any suggestion what to check next?

Study with new MC

New MC

- The changes are made only to the charged MC
- The changes are taken from the BELLE2-NOTE-PH-2022-002 [[Vidya sagar @ BHadronicMeeting](#)]
- Generated signal MC of $B \rightarrow D\pi$ and $B \rightarrow D^{*0}\pi$: one side decays to signal and other side decays generically (new MC)
- The number of events generated are equivalent to luminosity of the MC14rd MC used for studying (753.64 fb⁻¹) times the BR of the decay.
 - $B \rightarrow D\pi$: 3542108 events
 - $B \rightarrow D^{*0}\pi$: 3692836 events

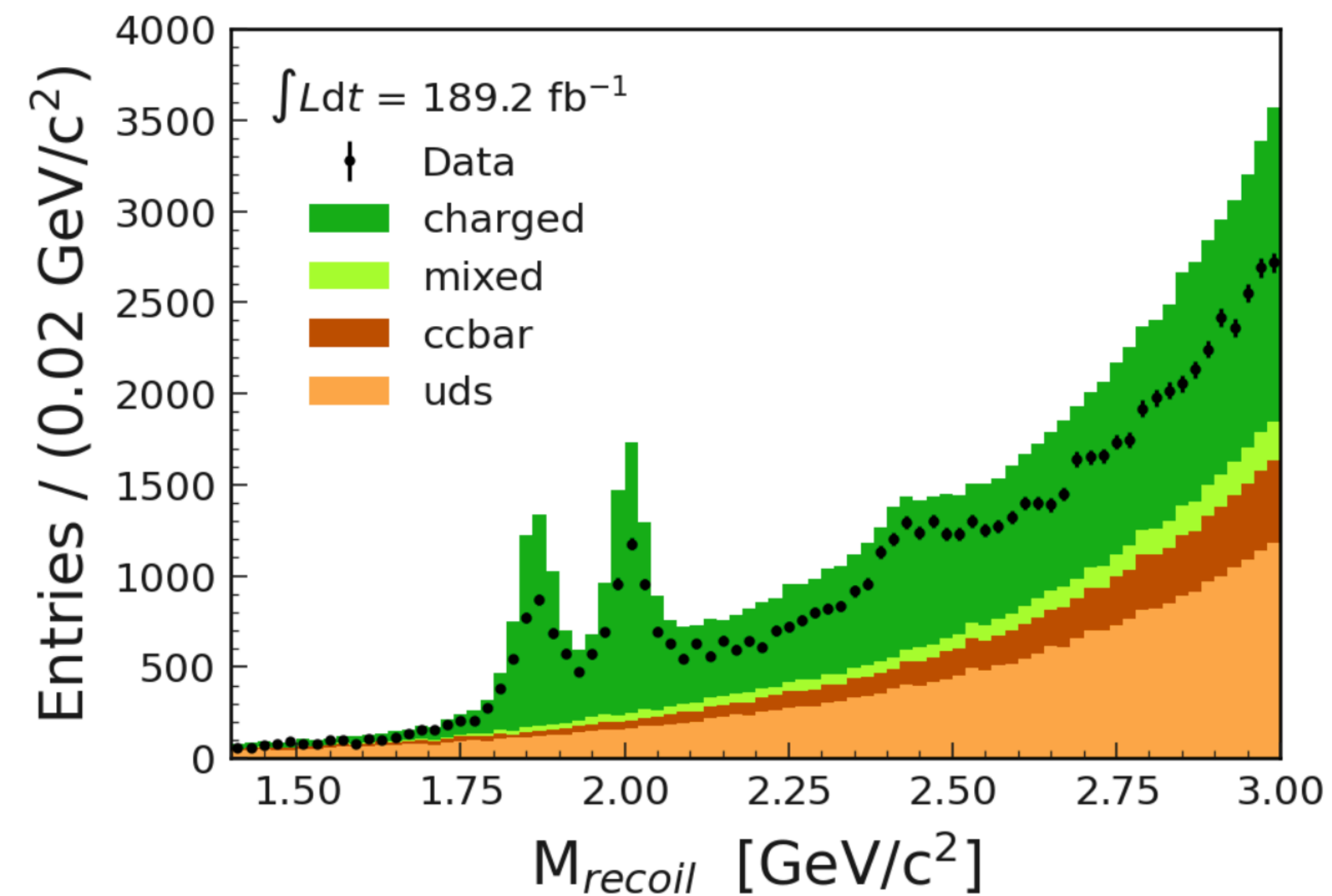
M_{recoil} in signal MC



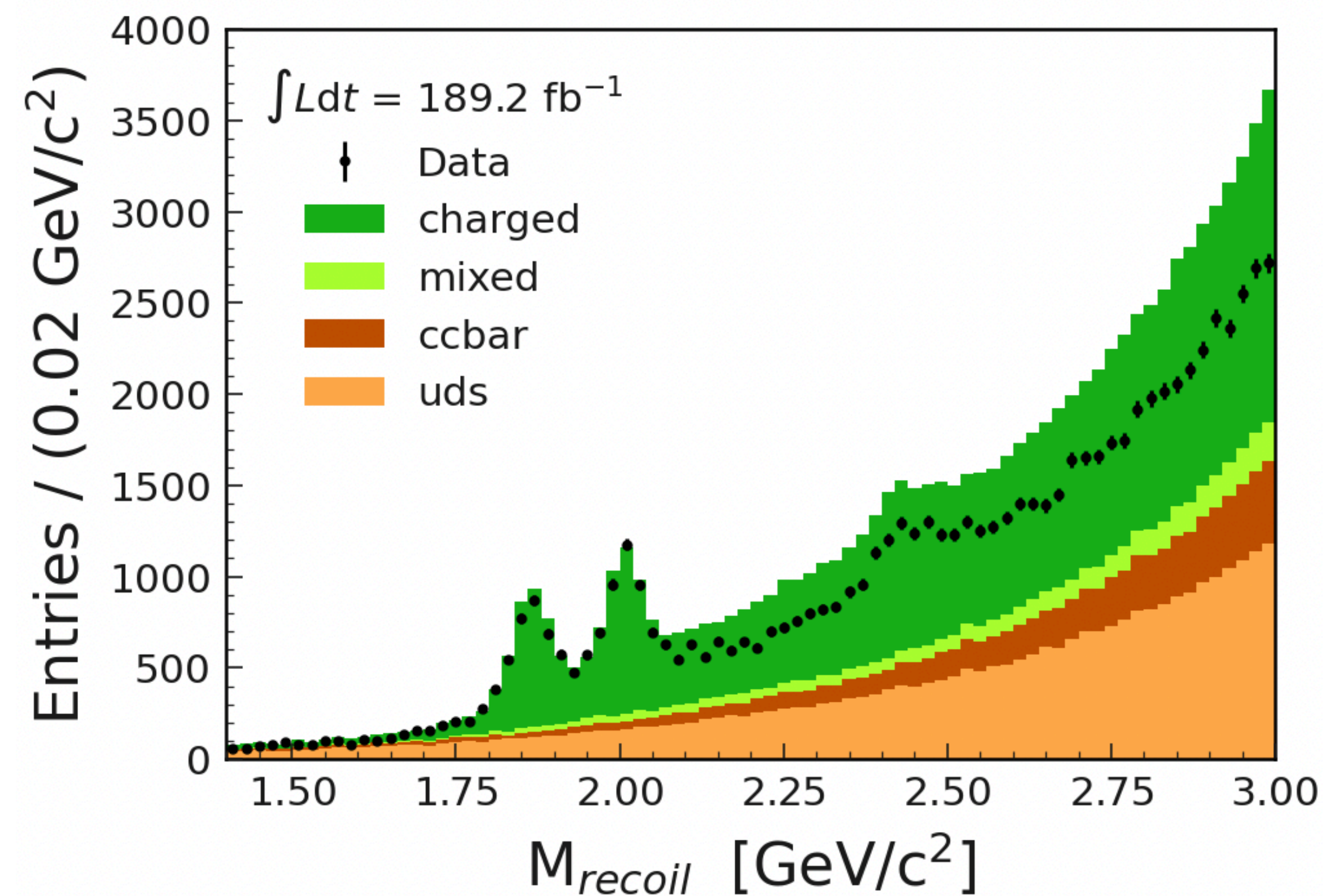
M_{recoil}

- Removed $D\pi$ and $D^{*0}\pi$ events from MC14rd sample and inserted events from signal MC sample

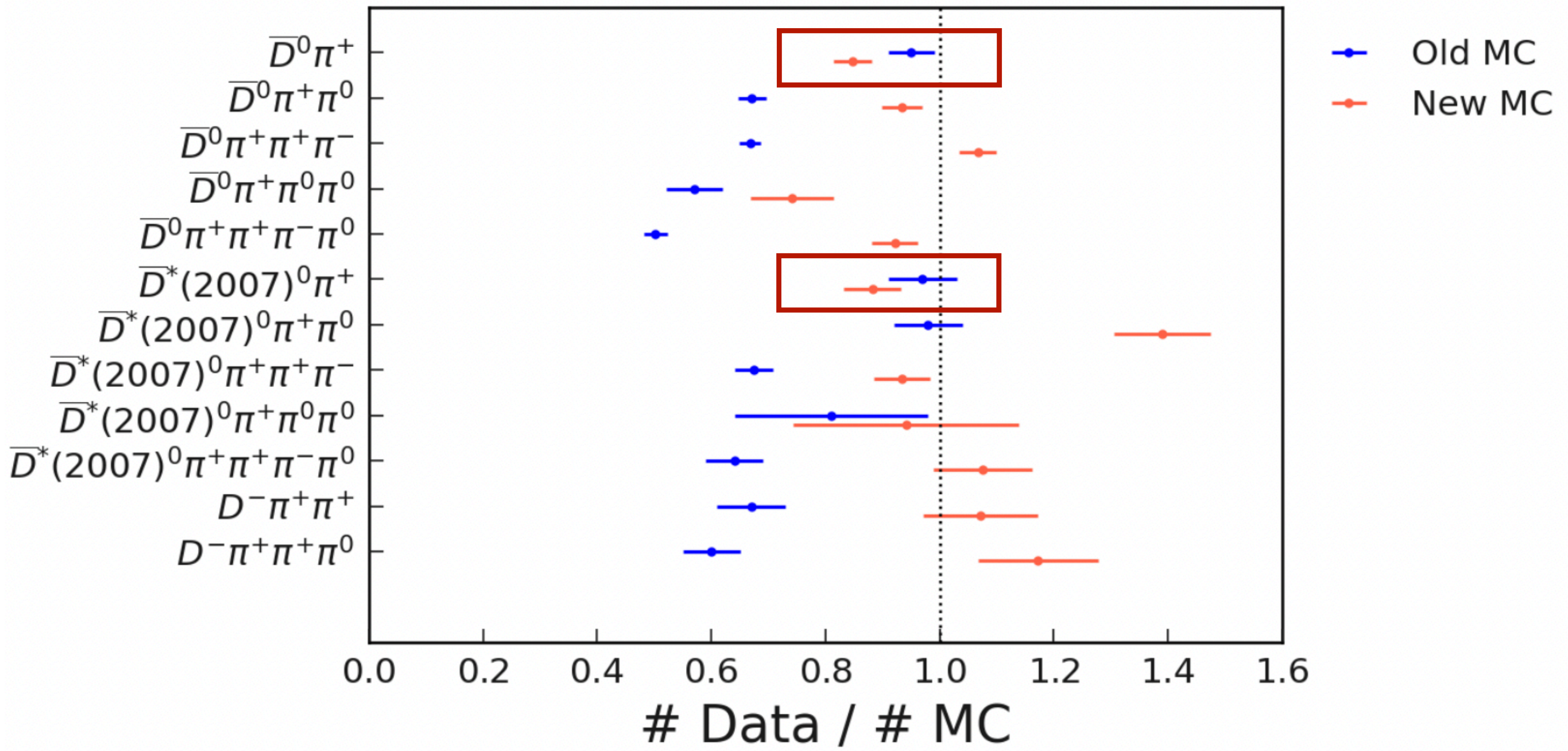
Before



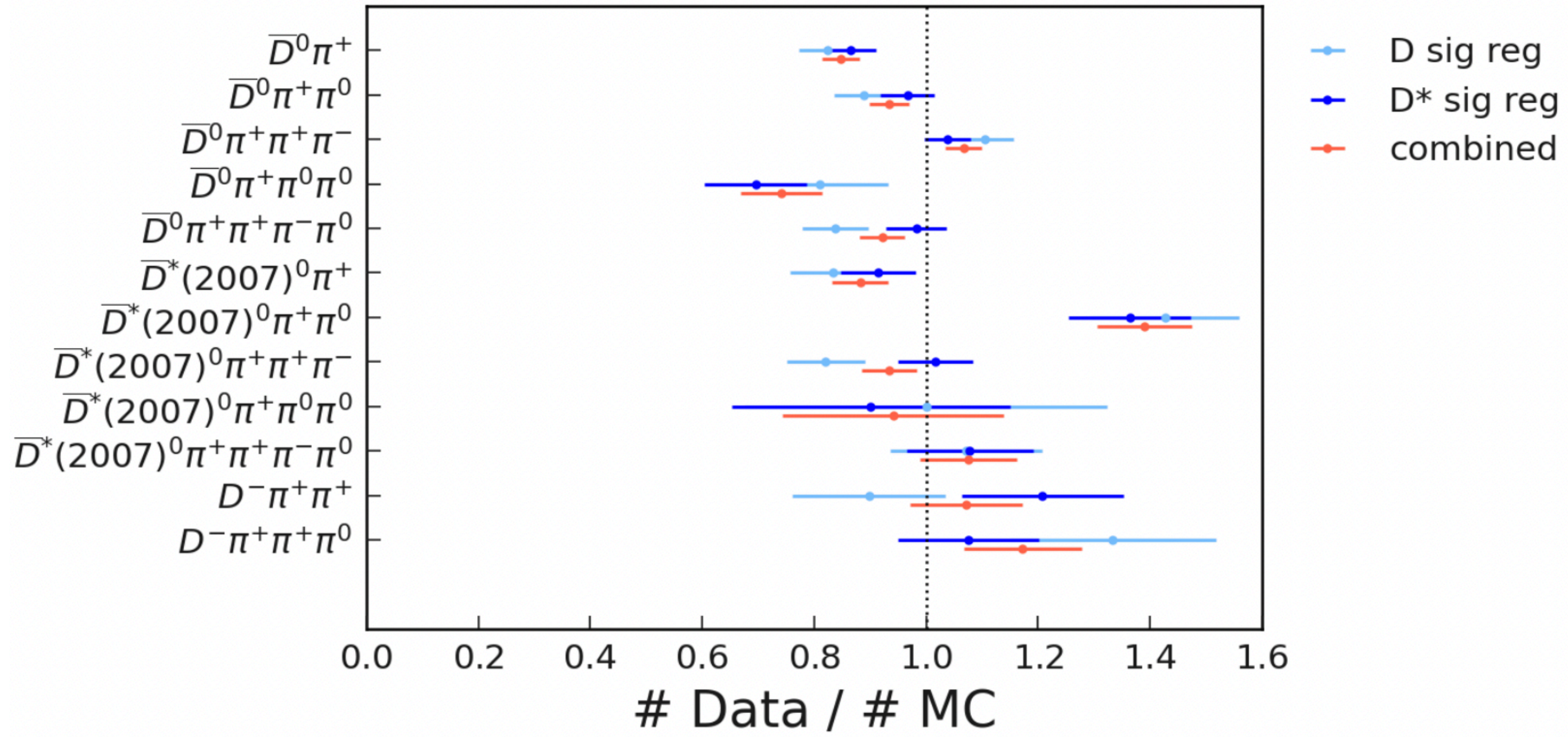
After



Calibration factors

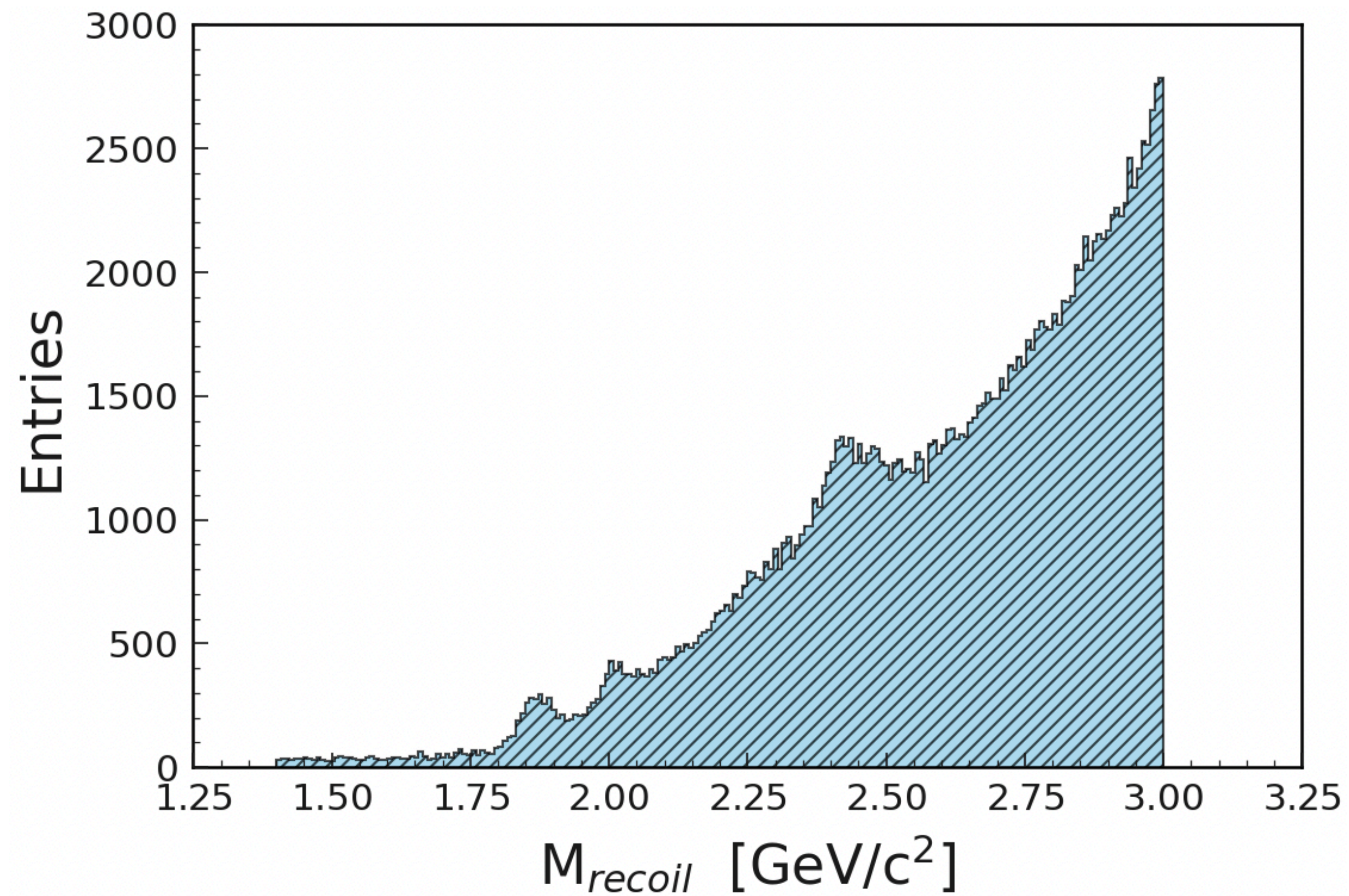


Calibration factors: new MC



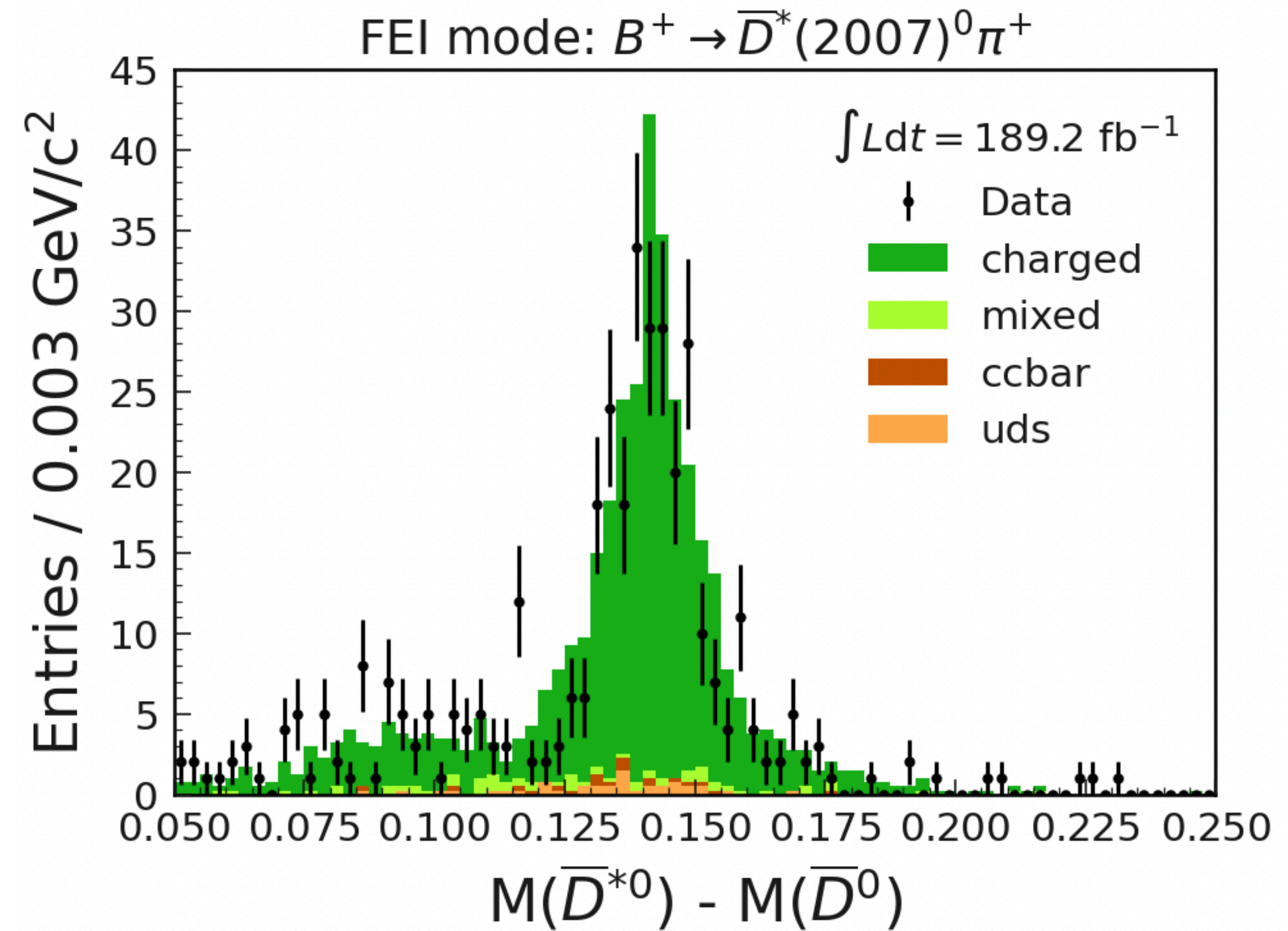
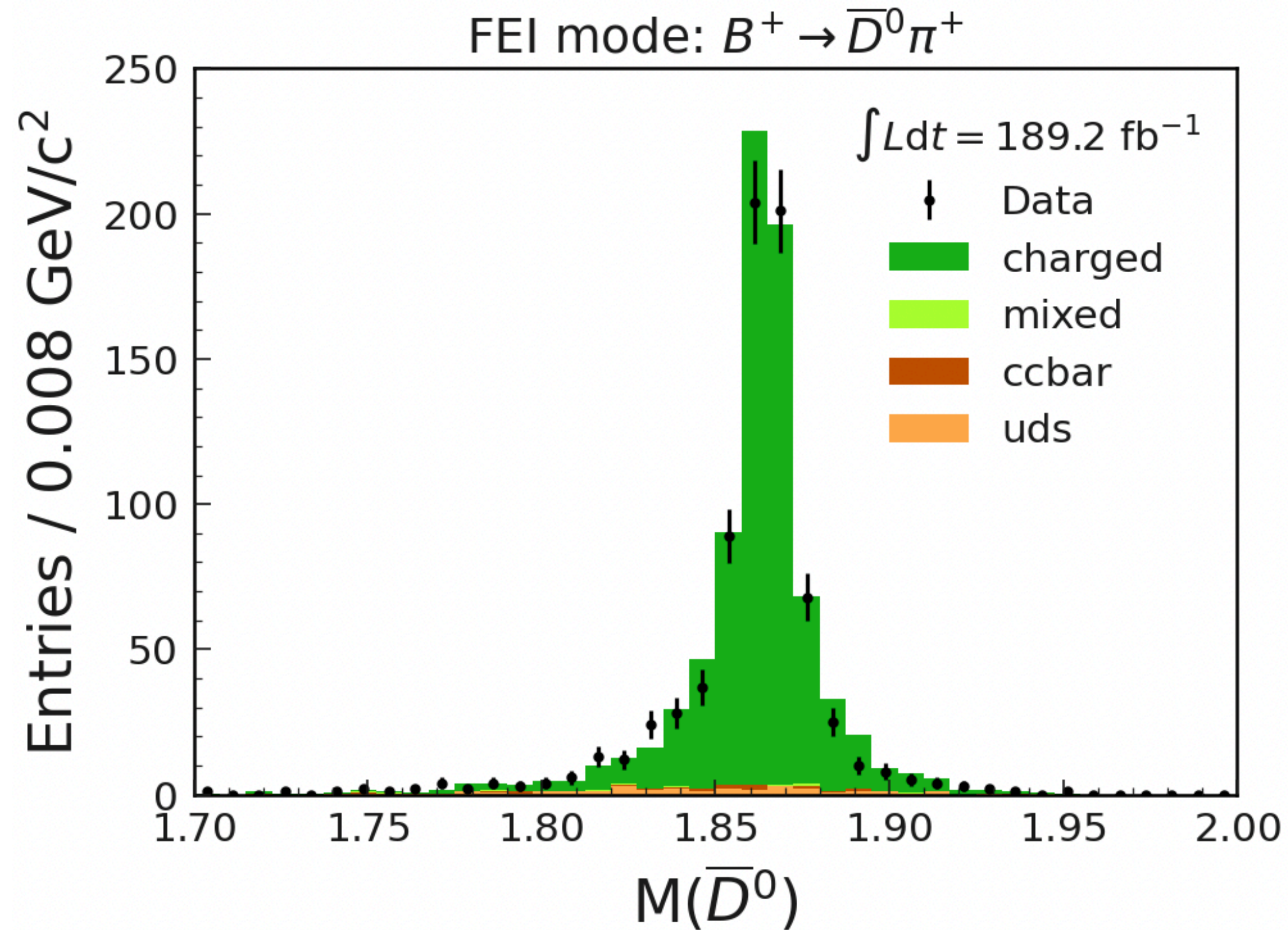
Backup

- M_{recoil} after removing the $D\pi$ and $D^*\pi$ events: old MC14rd



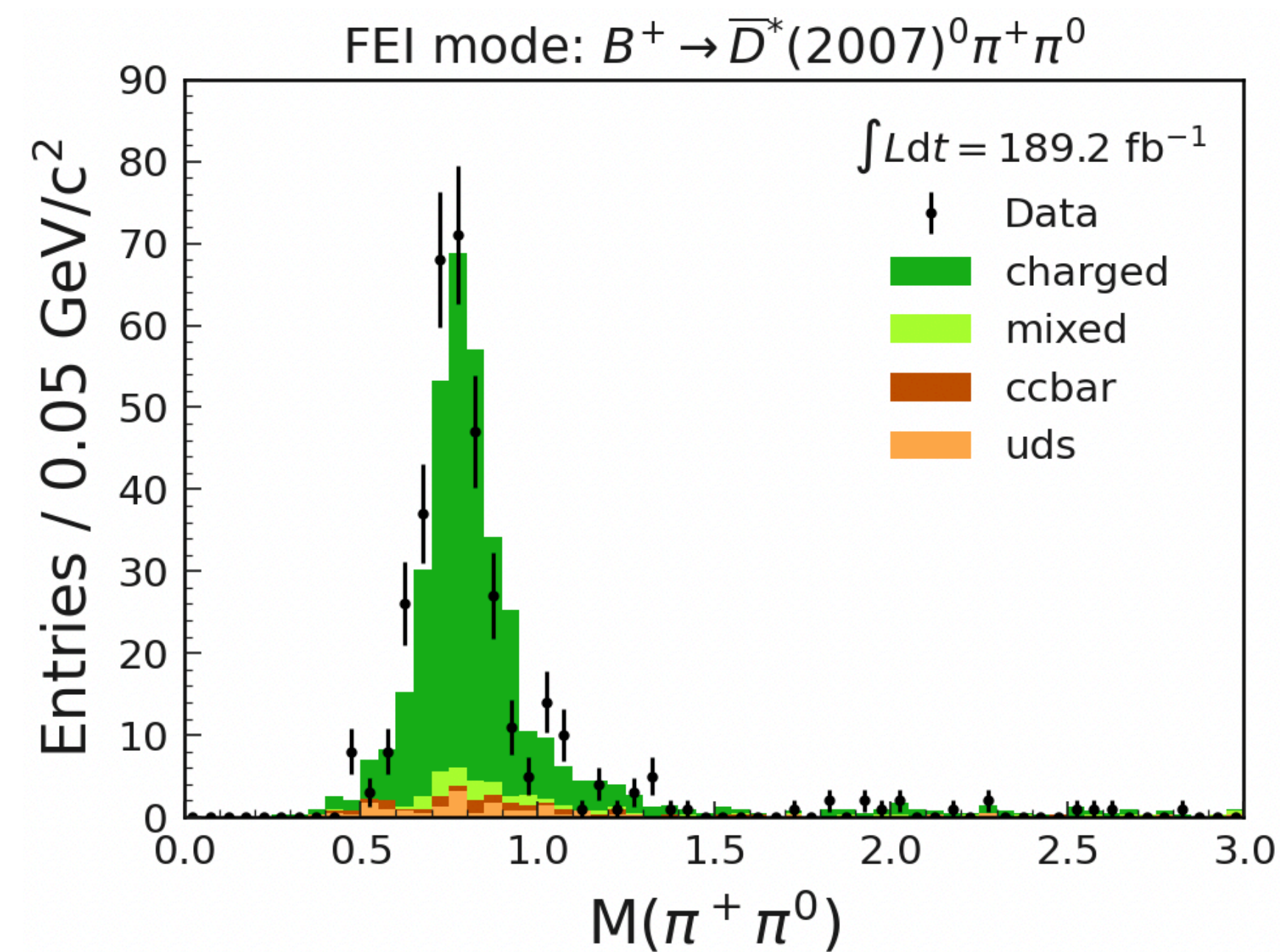
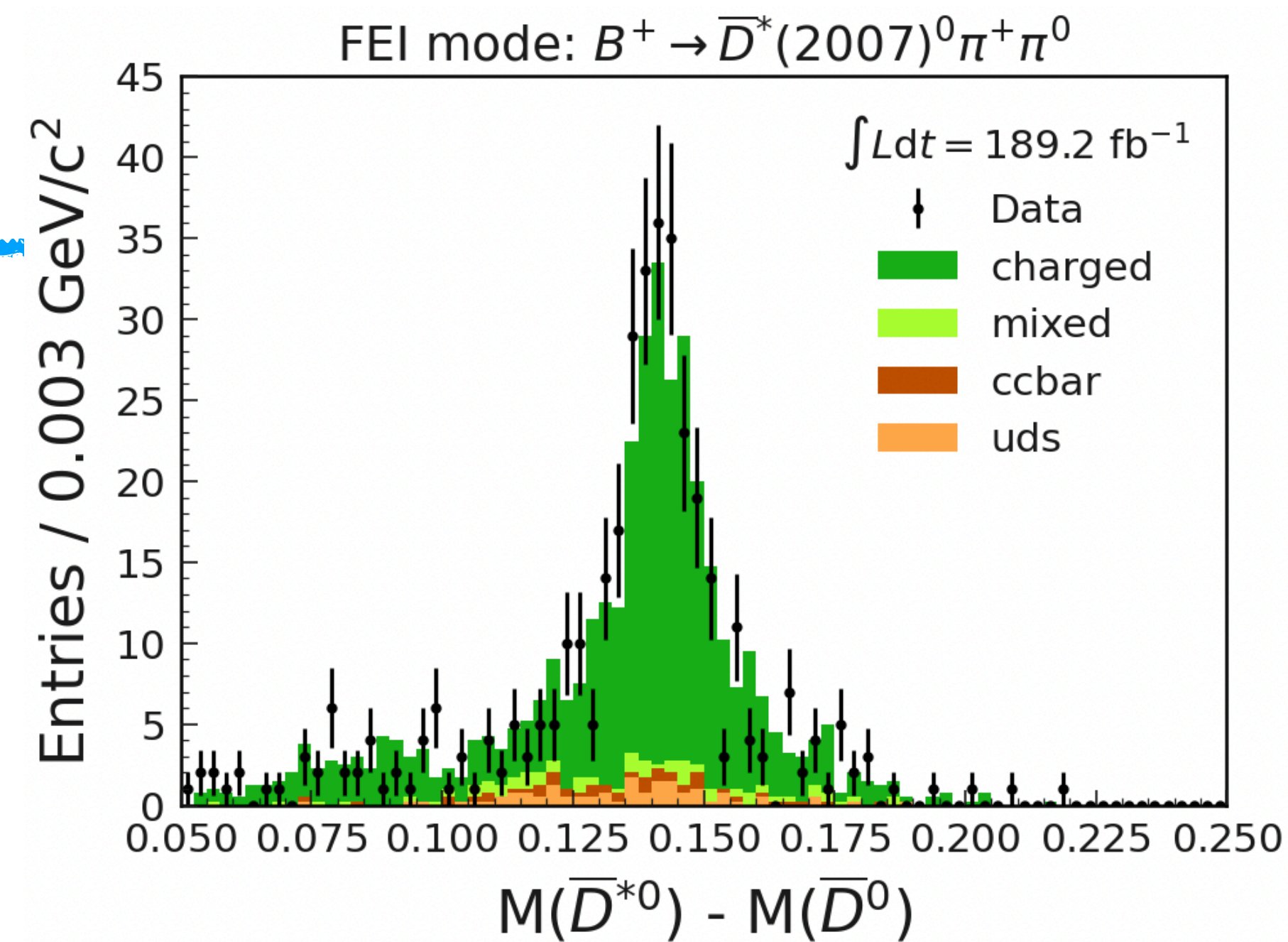
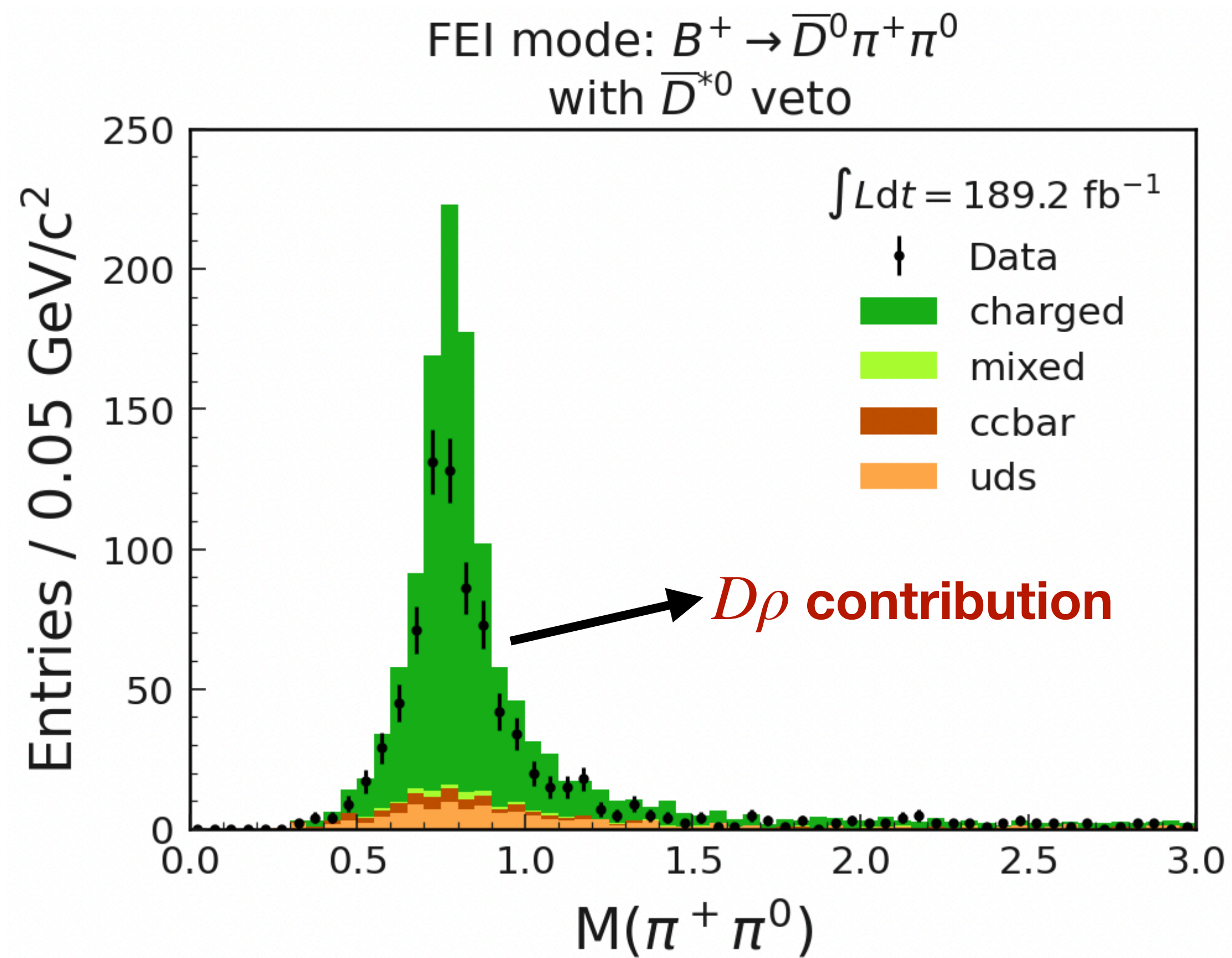
FEl: mode by mode study

$$B^+ \rightarrow \bar{D}^{0(*)} \pi^+$$



- The ΔM resolution is very bad!
- And there are lots of background events! → Not sure if the obtained calibration factors are correct.

$$B^+ \rightarrow \bar{D}^{0(*)} \pi^+ \pi^0$$



Next steps

- Look at other FEI modes
- Apply the proposed corrections to Belle II MC and see if the calibration factors are close to one.