Full Event Interpretation: all you need to know

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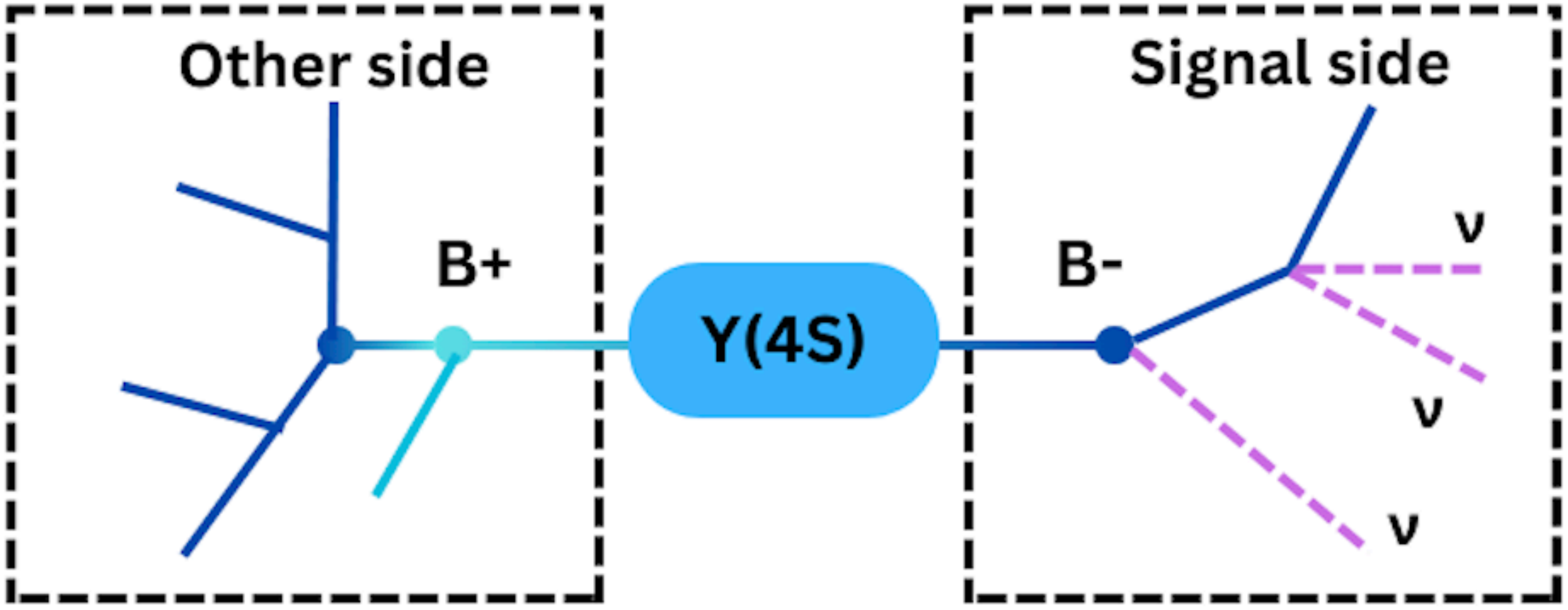
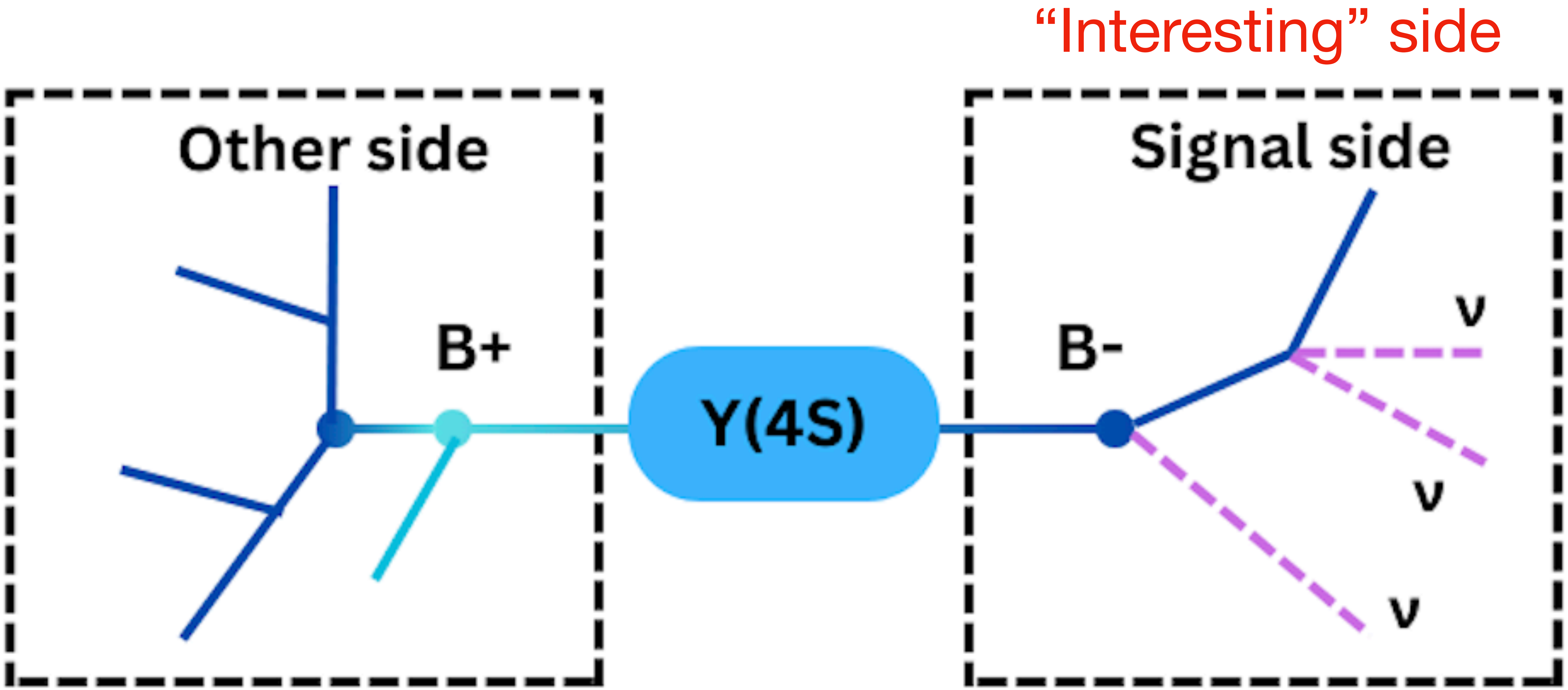
1st Nov, 2023 | Belle II Physics week, KEK



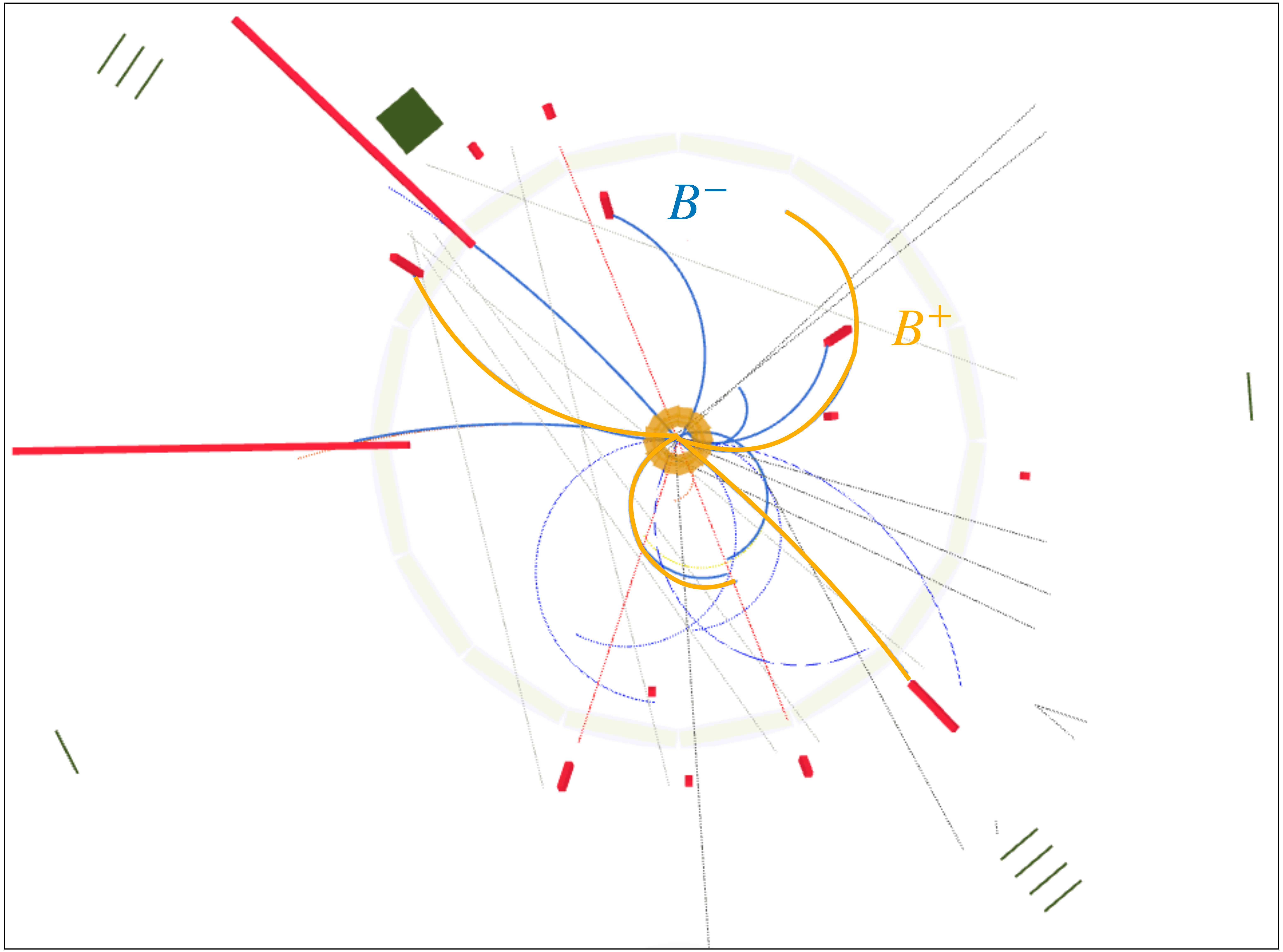
Outline

- **Why?** Purpose of B-tagging
- **How?** How we do at Belle II
- **What?** Tool: FEI
- **Usage of FEI**
- **More knowledge:** calibration/performance/improvements

A typical $B\overline{B}$ event

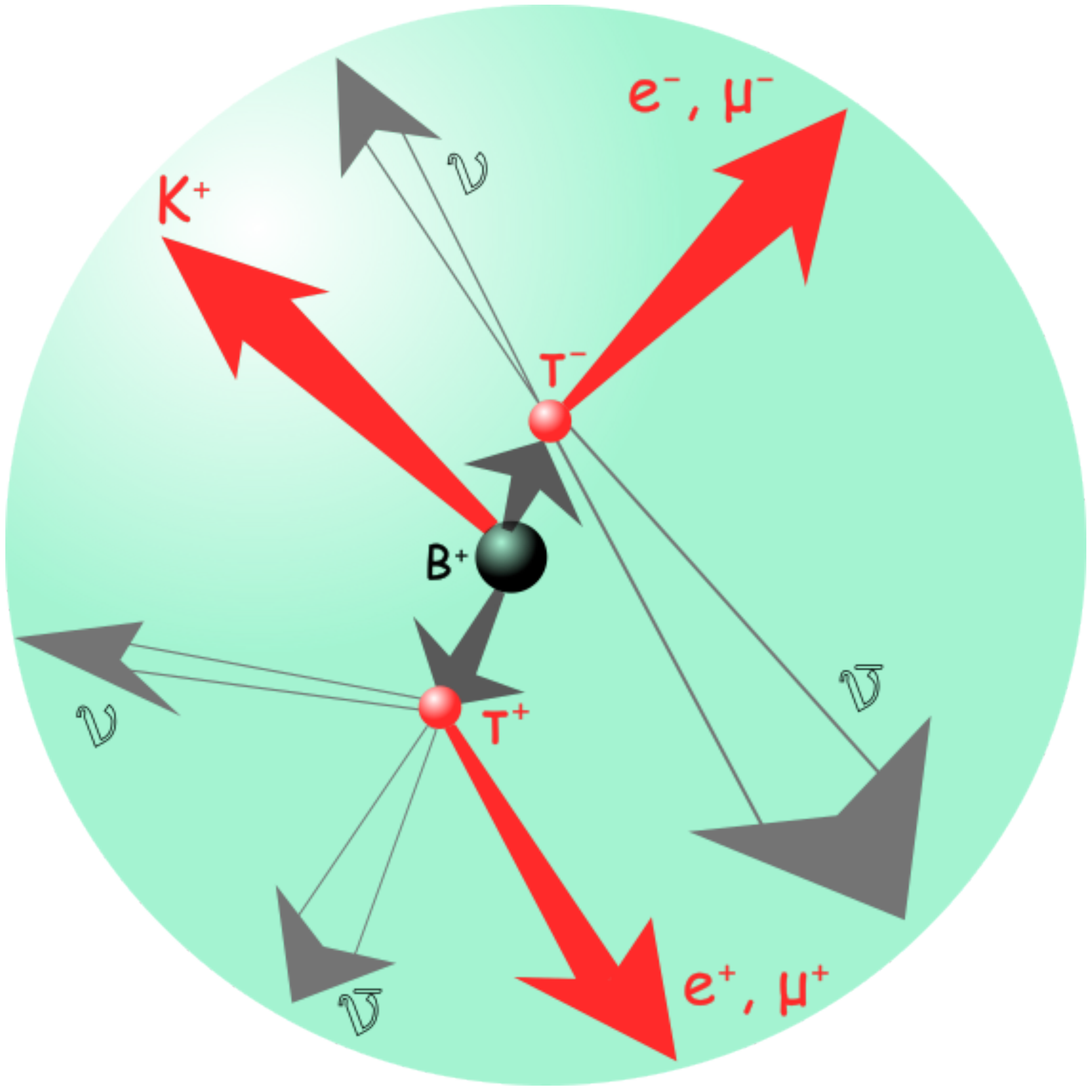


A typical $B\overline{B}$ event (in reality)



Why?

An example of $B^+ \to K^+\tau^-\tau^+$ event



PC: T. Hara

Up to 4 neutrinos in the final state:

Missing energy $\Longrightarrow$ Cannot reconstruct invariant mass or energy of the B

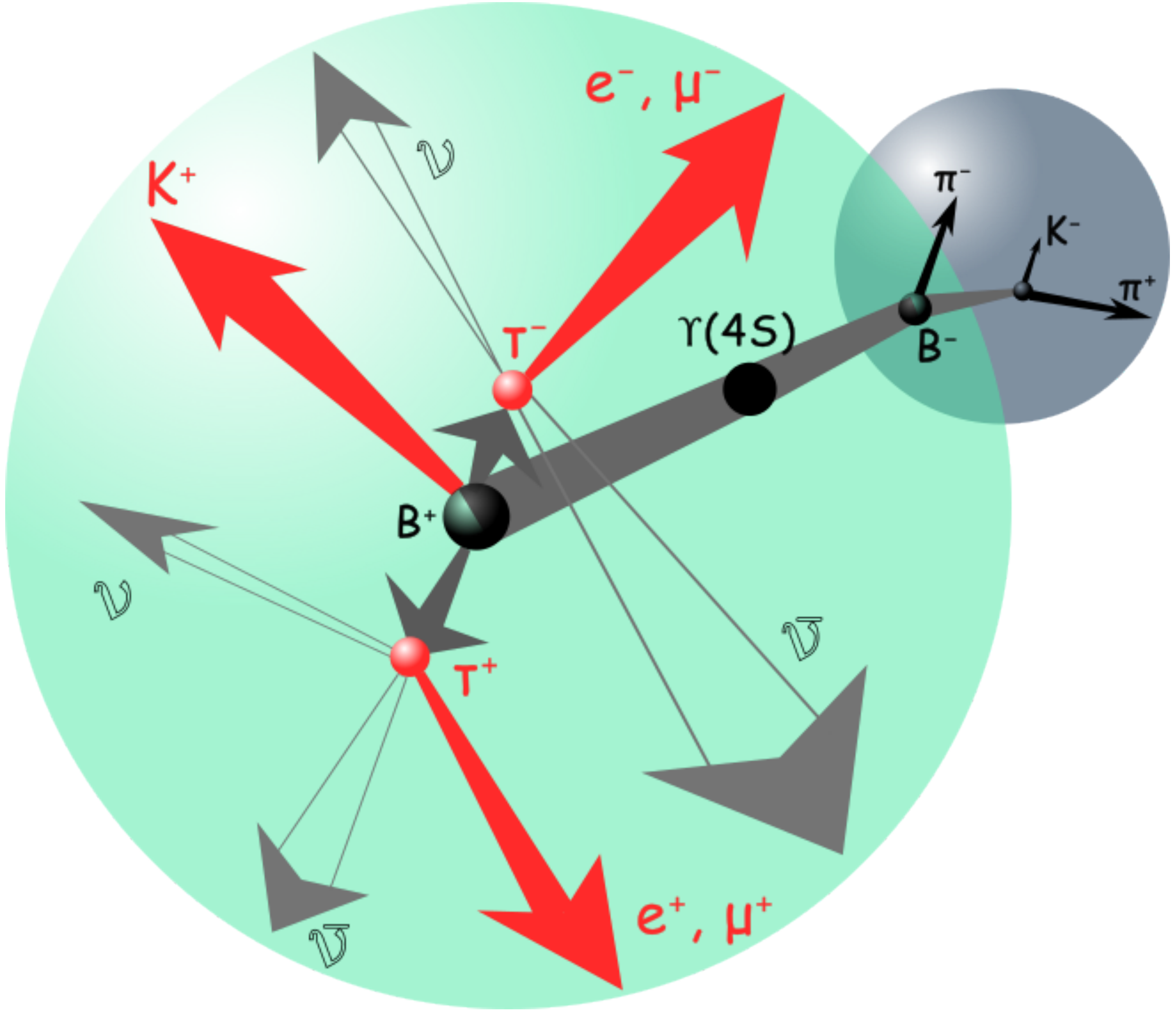
But, we have just two B-mesons in one event, and nothing else: can we use this information?

Why?

Reconstruct the other *B* (B-tag):

$\Longrightarrow$ infer the signal *B* kinematics from B-tag and known beam kinematics

Applicable to all missing-energy decays



PC: T. Hara

Which decays should we reconstruct for the B-tag?

$V_{cb} \gg V_{ub}$

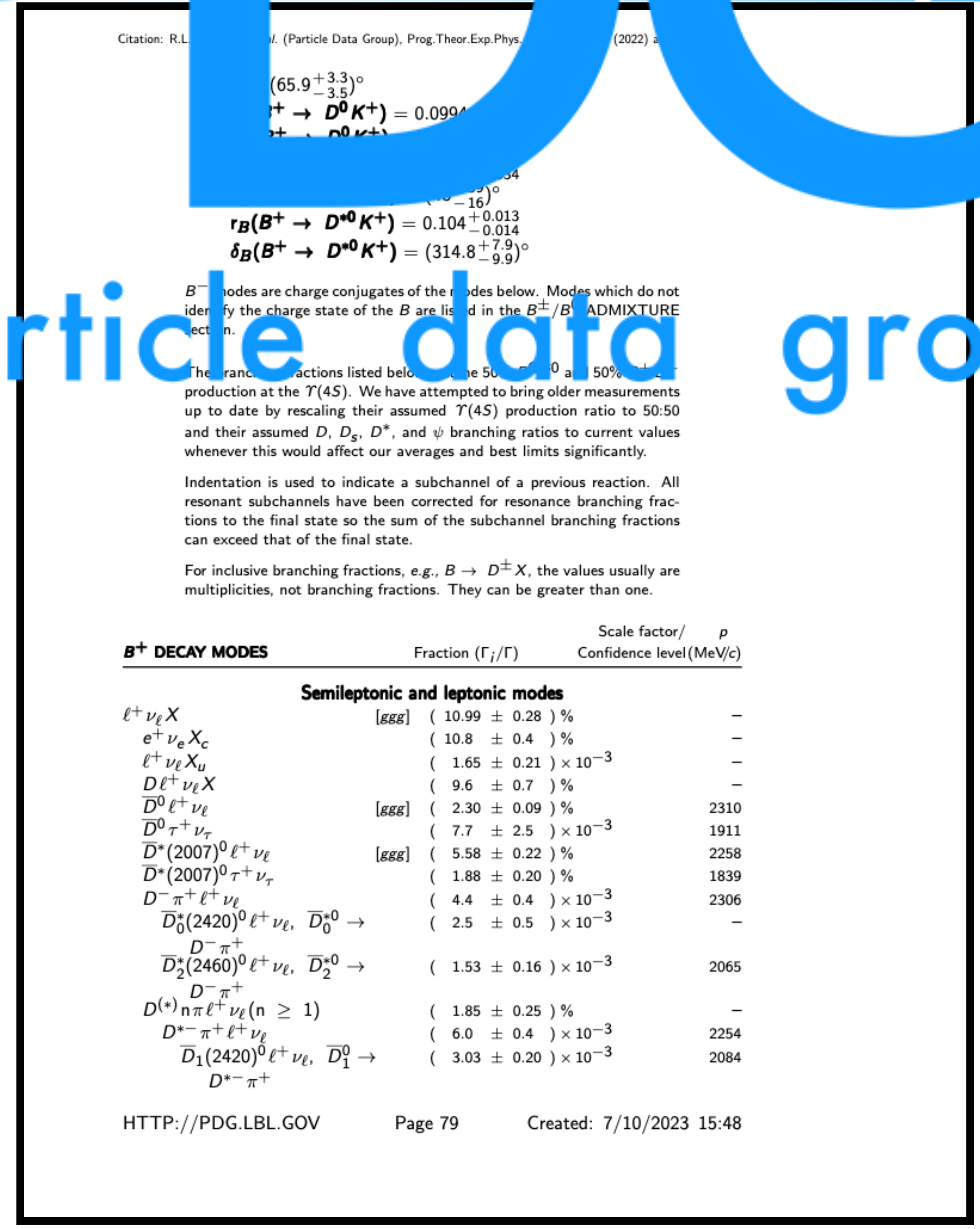
$\mathcal{O}(1000)$ B decays x $\mathcal{O}(100)$ D decays

$\rightarrow \mathcal{O}(10^5)$ possible channels

Mostly, but not always

No problem, we have computers…

But, first let's agree on the *metrics* that should be the objective of the "tagging" algorithm



Citation: R.L. ... (Particle Data Group), Prog.Theor.Exp.Phys. ... (2022) ...

$(65.9^{+3.3}_{-3.5})^\circ$

$\ldots \rightarrow D^0 K^+) = 0.099\ldots$

$r_B(B^+ \rightarrow D^{*0} K^+) = 0.104^{+0.013}_{-0.014}$

$\delta_B(B^+ \rightarrow D^{*0} K^+) = (314.8^{+7.9}_{-9.9})^\circ$

B^- modes are charge conjugates of the modes below. Modes which do not identify the charge state of the B are listed in the $B^\pm/B^0$ ADMIXTURE section.

The branching fractions listed below assume 50% ... and 50% ... production at the $\Upsilon(4S)$. We have attempted to bring older measurements up to date by rescaling their assumed $\Upsilon(4S)$ production ratio to 50:50 and their assumed D, D_s, D^*, and ψ branching ratios to current values whenever this would affect our averages and best limits significantly.

Indentation is used to indicate a subchannel of a previous reaction. All resonant subchannels have been corrected for resonance branching fractions to the final state so the sum of the subchannel branching fractions can exceed that of the final state.

For inclusive branching fractions, *e.g.*, $B \rightarrow D^\pm X$, the values usually are multiplicities, not branching fractions. They can be greater than one.

B^+ DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
Semileptonic and leptonic modes				
$\ell^+ \nu_\ell X$	[ggg]	(10.99 ± 0.28) %		–
$e^+ \nu_e X_c$		(10.8 ± 0.4) %		–
$\ell^+ \nu_\ell X_u$		$(1.65 \pm 0.21) \times 10^{-3}$		–
$D \ell^+ \nu_\ell X$		(9.6 ± 0.7) %		–
$\overline{D}^0 \ell^+ \nu_\ell$	[ggg]	(2.30 ± 0.09) %		2310
$\overline{D}^0 \tau^+ \nu_\tau$		$(7.7 \pm 2.5) \times 10^{-3}$		1911
$\overline{D}^*(2007)^0 \ell^+ \nu_\ell$	[ggg]	(5.58 ± 0.22) %		2258
$\overline{D}^*(2007)^0 \tau^+ \nu_\tau$		(1.88 ± 0.20) %		1839
$D^- \pi^+ \ell^+ \nu_\ell$		$(4.4 \pm 0.4) \times 10^{-3}$		2306
$\overline{D}^*_0(2420)^0 \ell^+ \nu_\ell$, $\overline{D}^{*0}_0 \rightarrow D^- \pi^+$		$(2.5 \pm 0.5) \times 10^{-3}$		–
$\overline{D}^*_2(2460)^0 \ell^+ \nu_\ell$, $\overline{D}^{*0}_2 \rightarrow D^- \pi^+$		$(1.53 \pm 0.16) \times 10^{-3}$		2065
$D^{(*)} n\pi \ell^+ \nu_\ell (n \geq 1)$		(1.85 ± 0.25) %		–
$D^{*-} \pi^+ \ell^+ \nu_\ell$		$(6.0 \pm 0.4) \times 10^{-3}$		2254
$\overline{D}_1(2420)^0 \ell^+ \nu_\ell$, $\overline{D}^0_1 \rightarrow D^{*-} \pi^+$		$(3.03 \pm 0.20) \times 10^{-3}$		2084

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Tagging metrics and objectives

- **High efficiency**: fraction of events that are identified as a tag
- **High Purity**: fraction of identified tags that are "correct"
- **Good kinematic information**: minimise missing/fake

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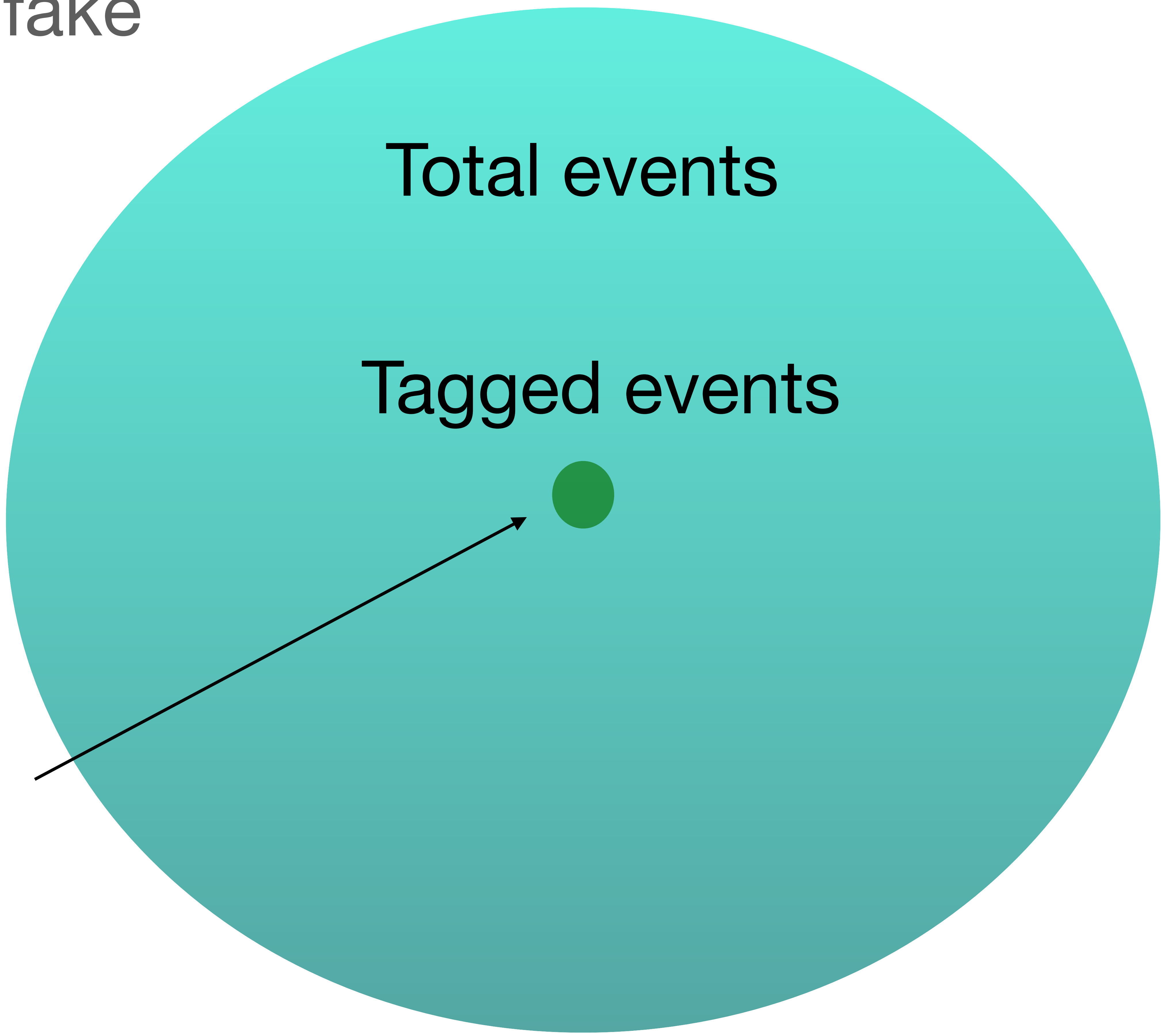

In reality: $\mathcal{O}(1\%)$

Tagging metrics and objectives

- **High efficiency**: fraction of events that are identified as a tag
- **High Purity**: fraction of identified tags that are “correct”
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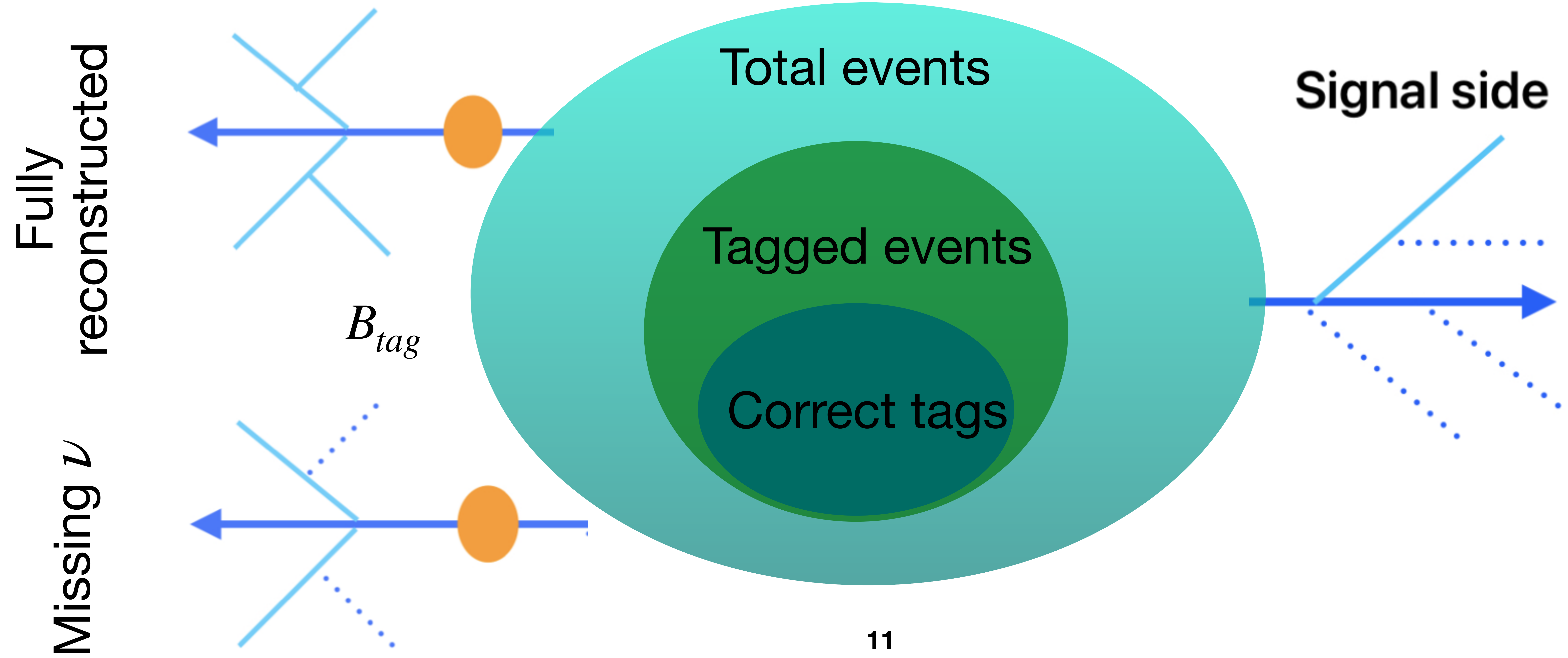
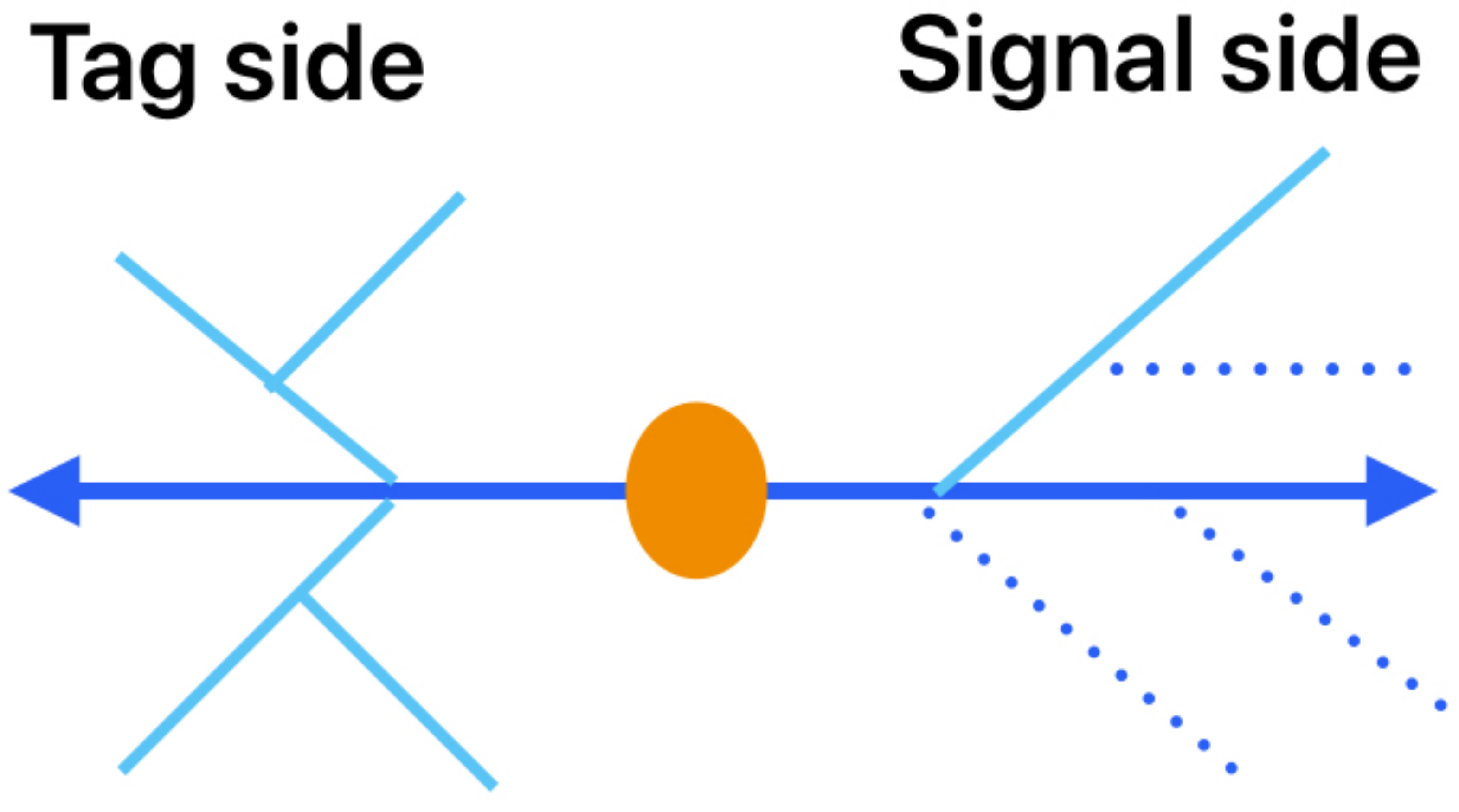
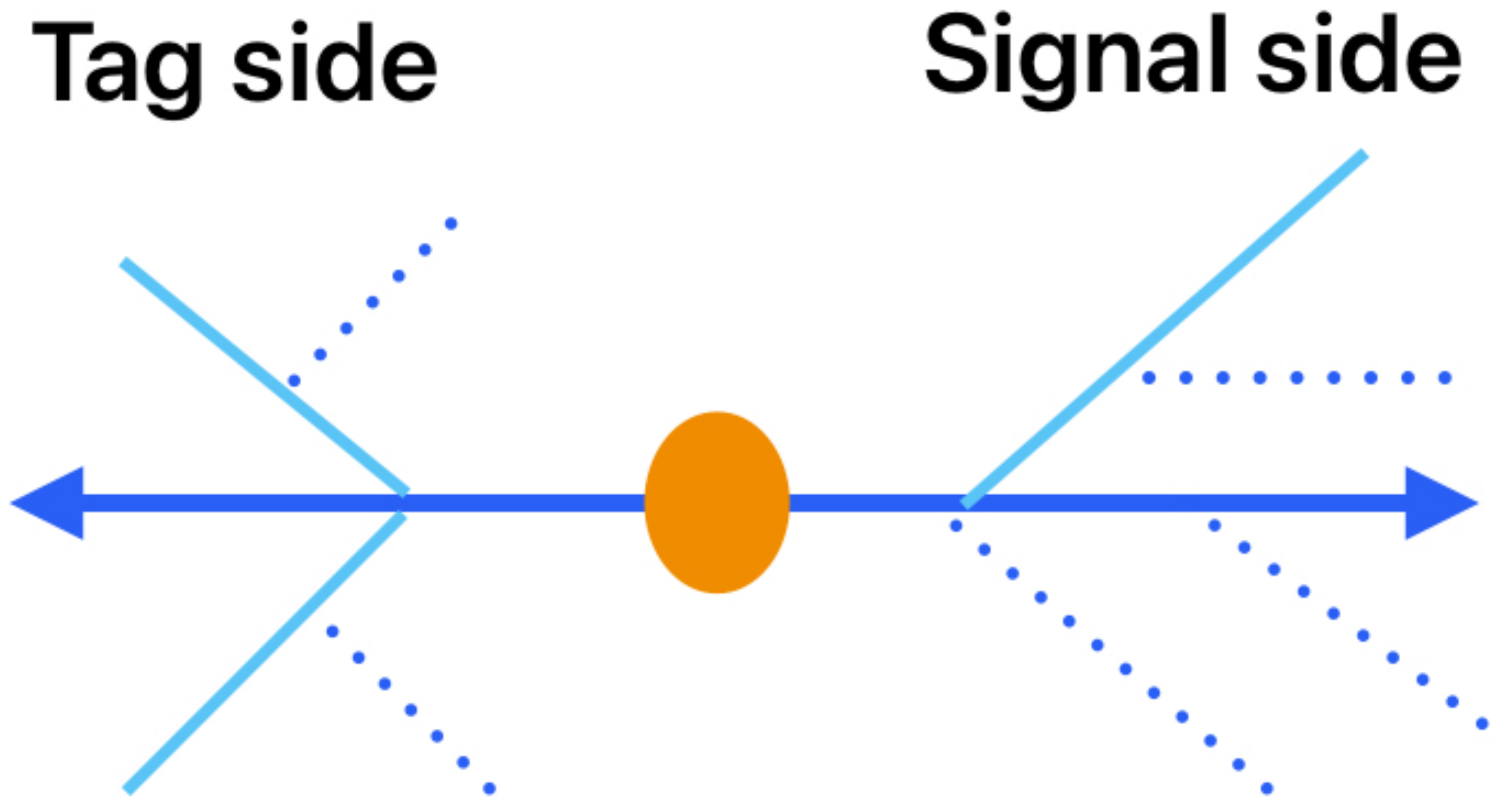


The two tagging types

- **Hadronic tagging**
  - Very low efficiency $< \mathcal{O}(1\%)$
  - High purity $\mathcal{O}(10\%)$
  - Excellent kinematic information



- **Semi-leptonic tagging**
  - Relatively high efficiency $\mathcal{O}(1\%)$
  - Not so good purity
  - Fair kinematic information

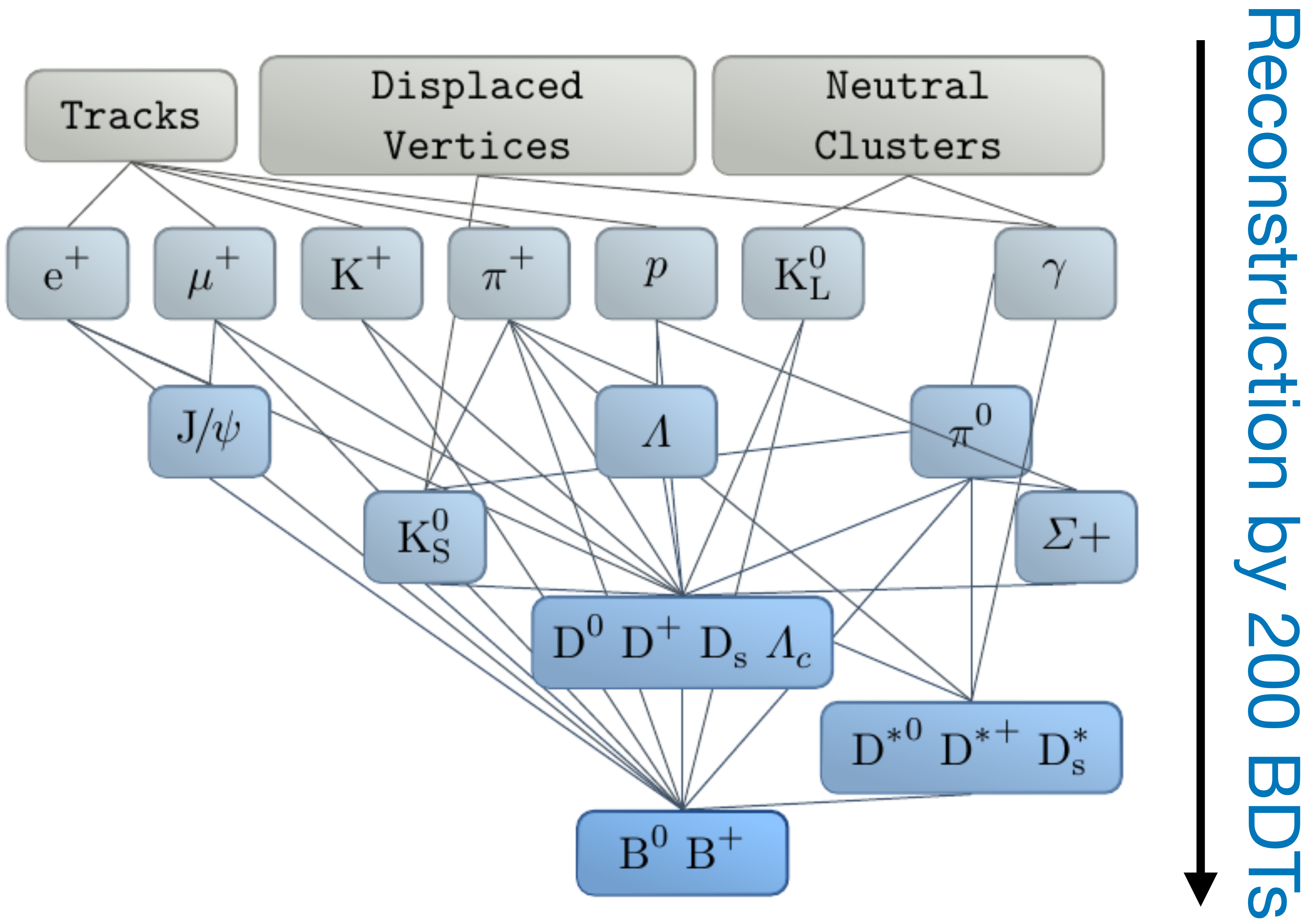


Hadronic

SL

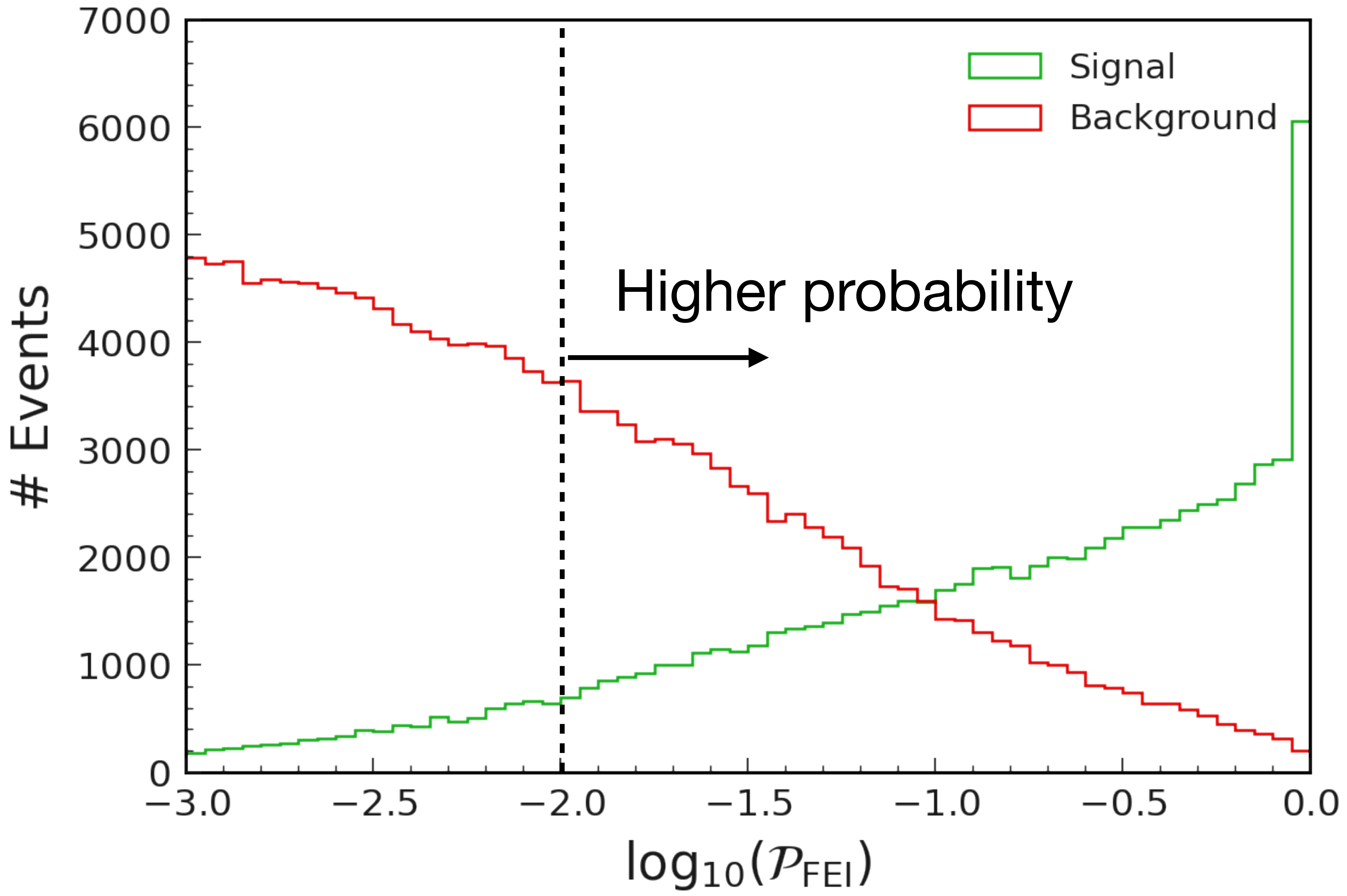
Introduction to FEI

- Hierarchical reconstruction of 10^4 *B* decay chains
- Uses machine learning: over 200 BDTs are trained using simulated samples
- Training inputs: kinematic variables of the decay chains, such as InvM, momentum, ΔE, M_{bc} etc
- *Output*
  - List of tag candidates
  - A probability to have correct reconstruction (signal probability)



[T.Keck et. al, Comput Softw Big Sci (2019) 3: 6]

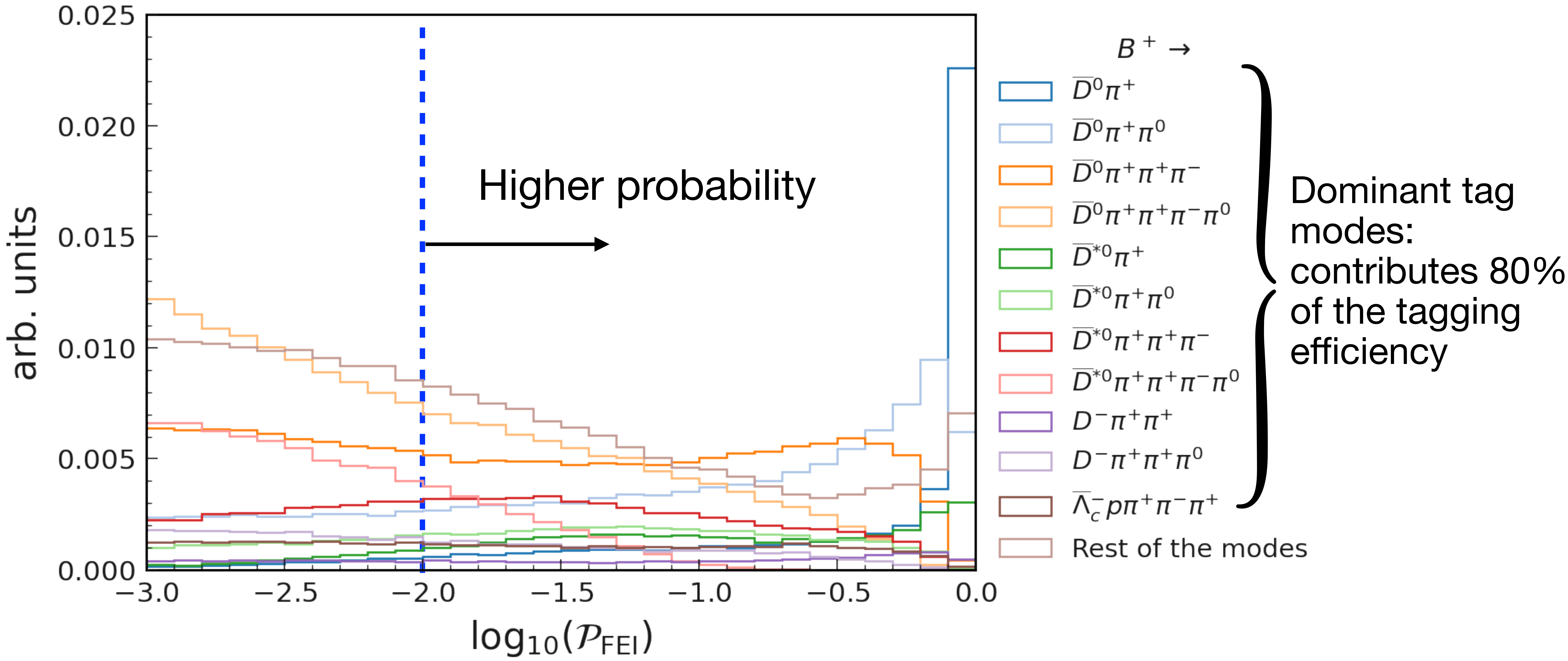
Signal probability



Enhance your purity based on selection on the signal probability

Signal probability: tag-modes

Vidya's thesis
BELLE2-PTHESIS-2023-016

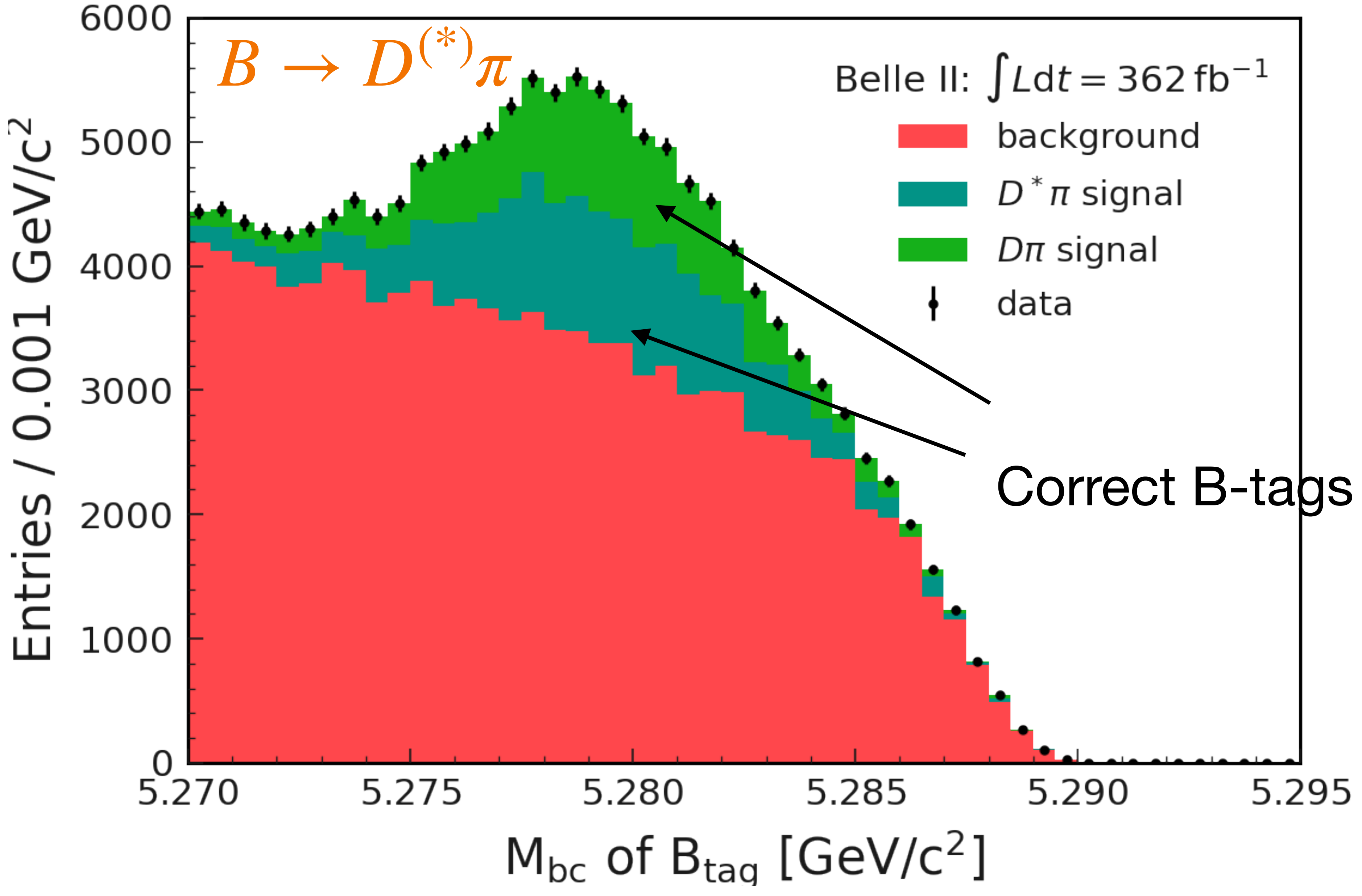


Enhance your purity based on selection on the signal probability

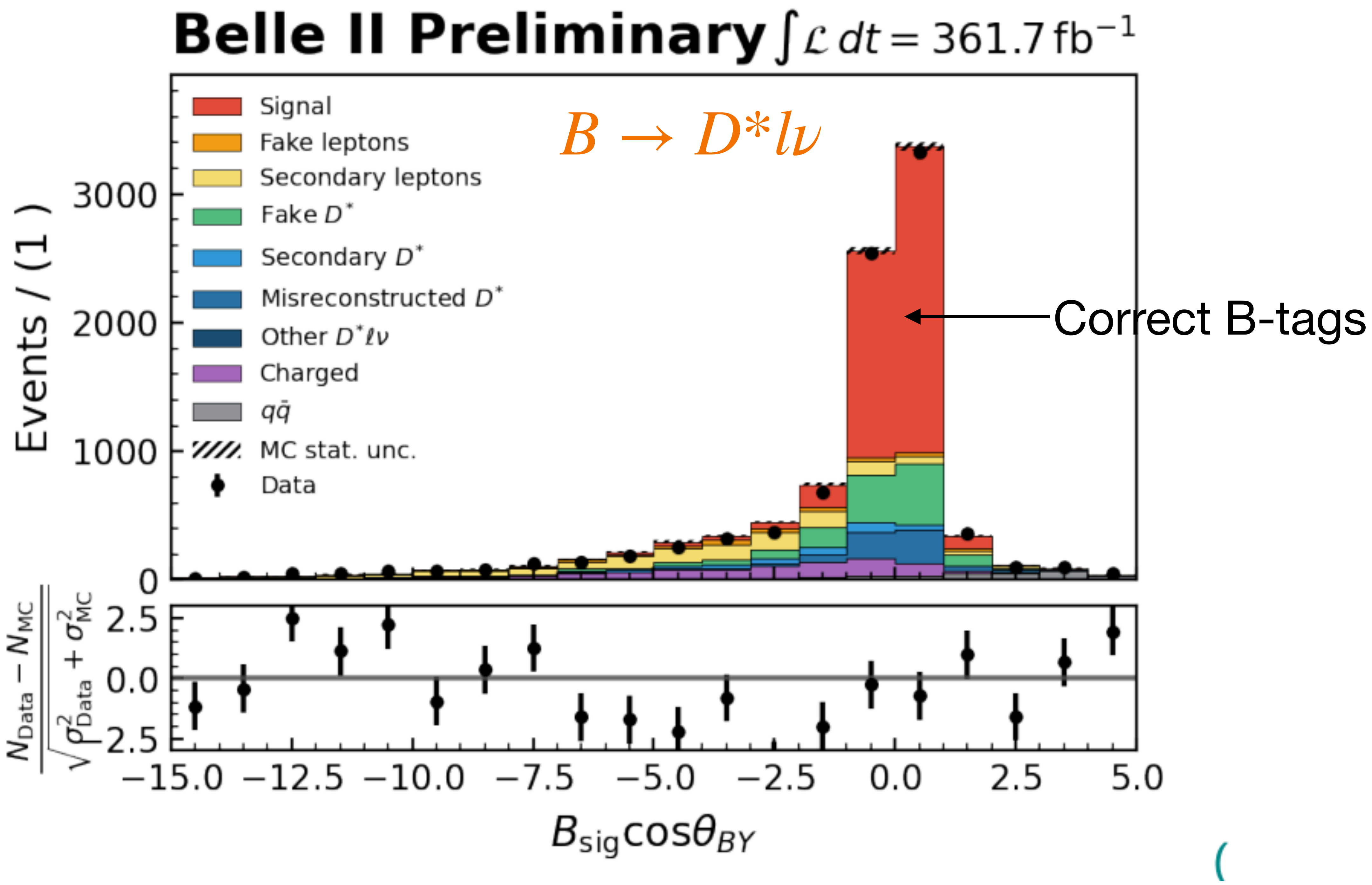
How do we select good tags?

Selection on kinematic variables of the tag side:

Hadronic tag: $\Delta E \sim 0$
and $M_{bc} \sim m_B$

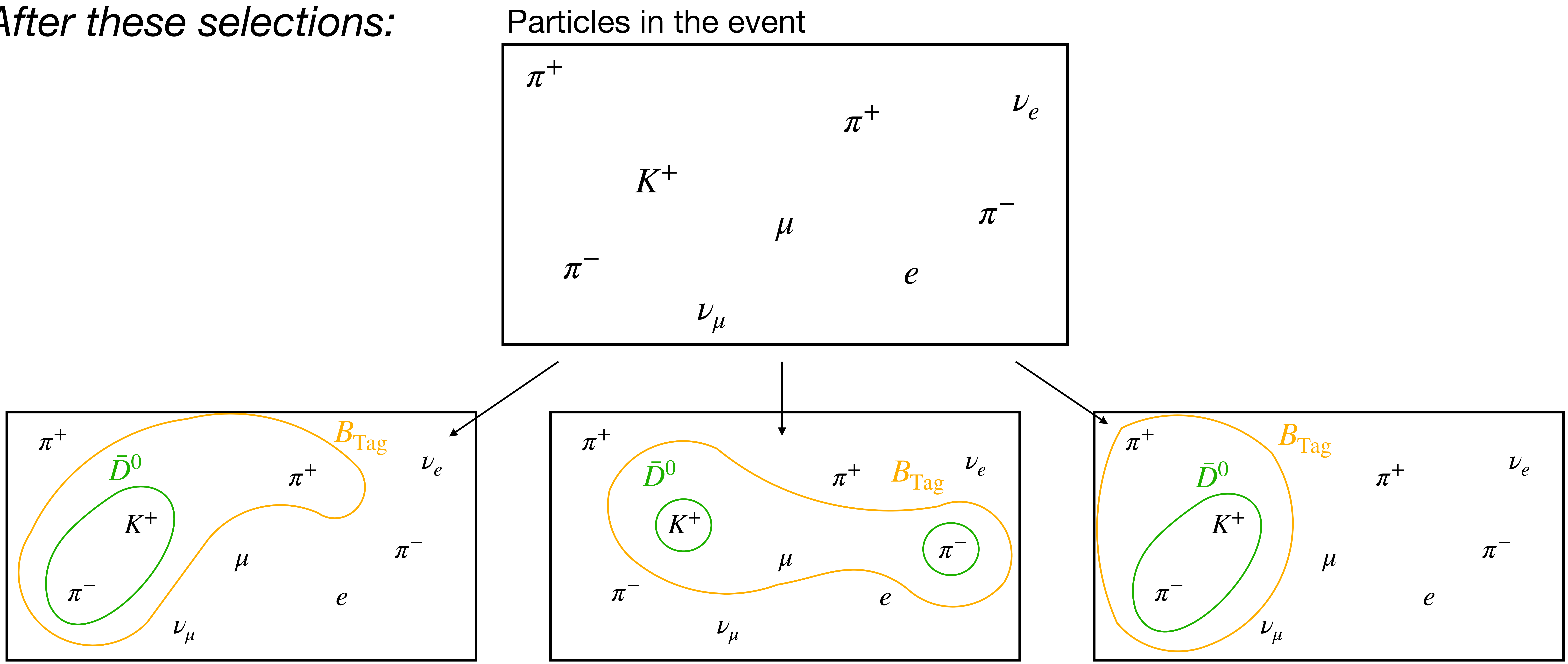


Semileptonic tag:
$\cos\theta_{BY} \in [-1,1]$



Select a best tag

After these selections:

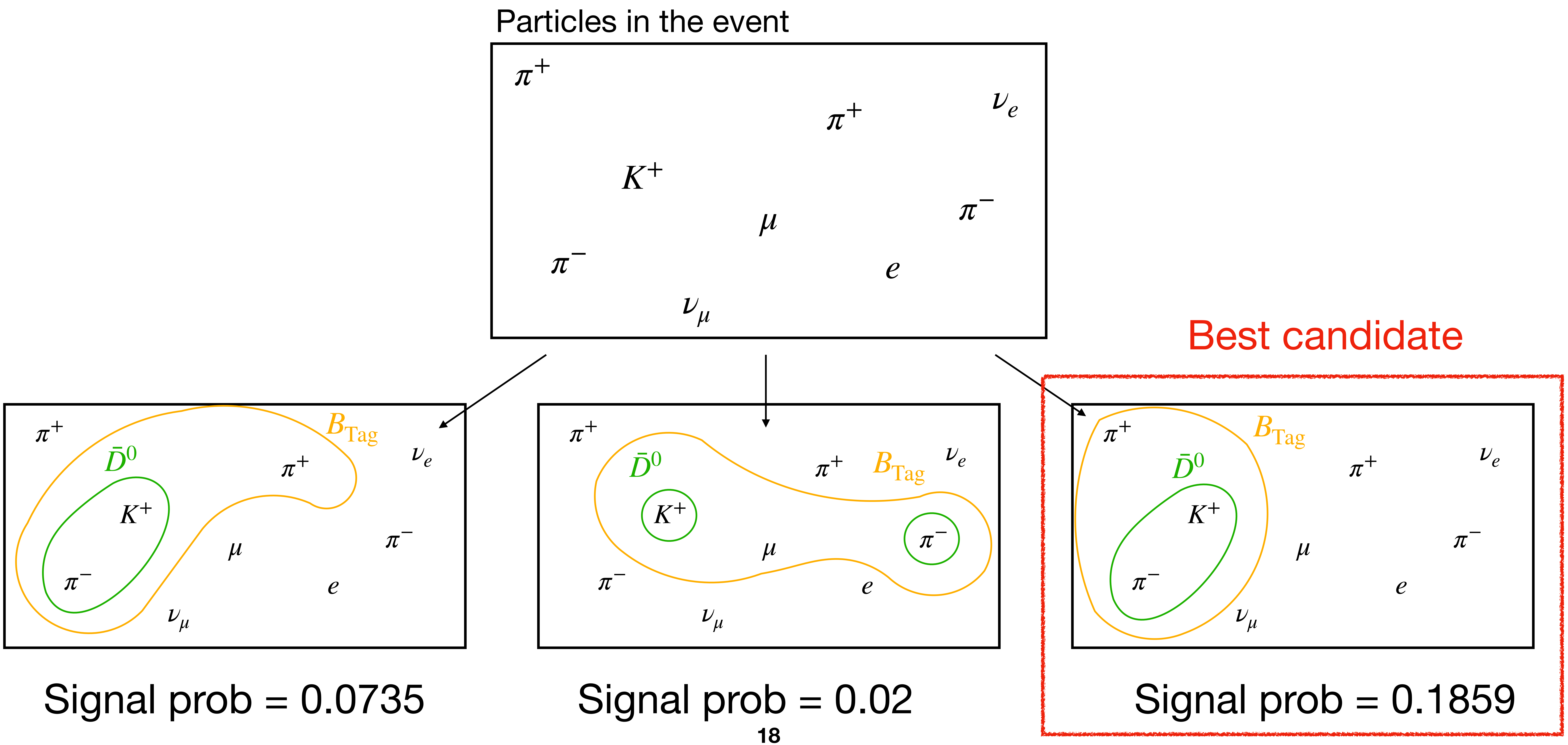


Signal prob = 0.0735

Signal prob = 0.02

Signal prob = 0.1859

Select a best tag



Usage

Training

- **You don't need to train the FEI by yourself, it's already trained and validated.**
- FEI training weights are uploaded directly to the condition database for you to use: formerly done by W. Sutcliffe, now by analysis tools conveners (Yo Sato, Vidya Sagar)
- *What is available now:*
  - MC15ri official training: FEIv4_2022_MC15_light-2205-abys
  - Can be used both for MC15ri and MC15rd

In basf2

Load the FEI

```
# Set up FEI configuration specifying the FEI prefix
configuration = fei.FeiConfiguration(
    prefix=fei_prefix,
    monitor=False
)

# Get FEI path
feistate = fei.get_path(particles, configuration)
```

FEIv4_2022_MC15_light-2205-abys

Get the tag lists you want:

B+:generic
B0:generic

Hadronic tag candidates

B+:semileptonic
B0:semileptonic

Semileptonic tag candidates

Get the variables you want:

Mbc $\longrightarrow M_{bc}$

deltaE $\longrightarrow \Delta E$

extraInfo(SignalProbability) $\longrightarrow \mathscr{P}_{\rm tag}$

extraInfo(decayModeID)

cosThetaBetweenParticleAndNominalB $\longrightarrow \cos\theta_{\rm BY}$

In basf2

Get the variables you want:

`Mbc` $\longrightarrow M_{bc}$

`deltaE` $\longrightarrow \Delta E$

`extraInfo(SignalProbability)` $\longrightarrow \mathscr{P}_{\text{tag}}$

`extraInfo(decayModeID)` →

`cosThetaBetweenParticleAndNominalB` $\longrightarrow \cos\theta_{\text{BY}}$

D channels

```
D0.addChannel(['K-', 'pi+'])
D0.addChannel(['K-', 'pi+', 'pi0'])
D0.addChannel(['K-', 'pi+', 'pi0', 'pi0'])
D0.addChannel(['K-', 'pi+', 'pi+', 'pi-'])
D0.addChannel(['K-', 'pi+', 'pi+', 'pi-', 'pi0'])
D0.addChannel(['pi-', 'pi+'])
D0.addChannel(['pi-', 'pi+', 'pi+', 'pi-'])
D0.addChannel(['pi-', 'pi+', 'pi0'])
D0.addChannel(['pi-', 'pi+', 'pi0', 'pi0'])
D0.addChannel(['K_S0', 'pi0'])
D0.addChannel(['K_S0', 'pi+', 'pi-'])
D0.addChannel(['K_S0', 'pi+', 'pi-', 'pi0'])
D0.addChannel(['K-', 'K+'])
D0.addChannel(['K-', 'K+', 'pi0'])
D0.addChannel(['K-', 'K+', 'K_S0'])
```

0 :	$B^0 \to D^-\pi^+$
1 :	$B^0 \to D^-\pi^+\pi^0$
2 :	$B^0 \to D^-\pi^+\pi^0\pi^0$
3 :	$B^0 \to D^-\pi^+\pi^+\pi^-$
4 :	$B^0 \to D^-\pi^+\pi^+\pi^-\pi^0$
5 :	$B^0 \to \overline{D^0}\pi^+\pi^-$
6 :	$B^0 \to D^-D^0K^+$
7 :	$B^0 \to D^-D^{*0}K^+$
8 :	$B^0 \to D^{*-}D^0K^+$
9 :	$B^0 \to D^{*-}D^{*0}K^+$
10 :	$B^0 \to D^-D^+K^0_S$
11 :	$B^0 \to D^{*-}D^+K^0_S$
12 :	$B^0 \to D^-D^{*+}K^0_S$
13 :	$B^0 \to D^{*-}D^{*+}K^0_S$
14 :	$B^0 \to D^+_sD^-$
15 :	$B^0 \to D^{*-}\pi^+$
16 :	$B^0 \to D^{*-}\pi^+\pi^0$
17 :	$B^0 \to D^{*-}\pi^+\pi^0\pi^0$
18 :	$B^0 \to D^{*-}\pi^+\pi^+\pi^-$
19 :	$B^0 \to D^{*-}\pi^+\pi^+\pi^-\pi^0$
20 :	$B^0 \to D^{*+}_sD^-$
21 :	$B^0 \to D^+_sD^{*-}$
22 :	$B^0 \to D^{*+}_sD^{*-}$
23 :	$B^0 \to J/\psi K^0_S$
24 :	$B^0 \to J/\psi K^+\pi^-$
25 :	$B^0 \to J/\psi K^0_S\pi^+\pi^-$
26 :	$B^0 \to \overline{\Lambda^-_c}p^+\pi^+\pi^-$
27 :	$B^0 \to \overline{D^0}p^+\overline{p^-}$
28 :	$B^0 \to D^-p^+\overline{p^-}\pi^+$
29 :	$B^0 \to D^{*-}p^+\overline{p^-}\pi^+$
30 :	$B^0 \to \overline{D^0}p^+\overline{p^-}\pi^+\pi^-$
31 :	$B^0 \to \overline{D^{*0}}p^+\overline{p^-}\pi^+\pi^-$
32 :	No B^0 FEI decay

0 :	$B^+ \to \overline{D^0}\pi^+$
1 :	$B^+ \to \overline{D^0}\pi^+\pi^0$
2 :	$B^+ \to \overline{D^0}\pi^+\pi^0\pi^0$
3 :	$B^+ \to \overline{D^0}\pi^+\pi^+\pi^-$
4 :	$B^+ \to \overline{D^0}\pi^+\pi^+\pi^-\pi^0$
5 :	$B^+ \to \overline{D^0}D^+$
6 :	$B^+ \to D^+\overline{D^0}K^0_S$
7 :	$B^+ \to D^+\overline{D^{*0}}K^0_S$
8 :	$B^+ \to D^{*+}\overline{D^0}K^0_S$
9 :	$B^+ \to D^{*+}D^{*0}K^0_S$
10 :	$B^+ \to \overline{D^0}D^0K^+$
11 :	$B^+ \to \overline{D^{*0}}D^0K^+$
12 :	$B^+ \to \overline{D^0}D^{*0}K^+$
13 :	$B^+ \to \overline{D^{*0}}D^{*0}K^+$
14 :	$B^+ \to D^+_s\overline{D^0}$
15 :	$B^+ \to \overline{D^{*0}}\pi^+$
16 :	$B^+ \to \overline{D^{*0}}\pi^+\pi^0$
17 :	$B^+ \to \overline{D^{*0}}\pi^+\pi^0\pi^0$
18 :	$B^+ \to \overline{D^{*0}}\pi^+\pi^+\pi^-$
19 :	$B^+ \to \overline{D^{*0}}\pi^+\pi^+\pi^-\pi^0$
20 :	$B^+ \to D^{*+}_s\overline{D^0}$
21 :	$B^+ \to D^+_s\overline{D^{*0}}$
22 :	$B^+ \to \overline{D^0}K^+$
23 :	$B^+ \to D^-\pi^+\pi^+$
24 :	$B^+ \to D^-\pi^+\pi^+\pi^0$
25 :	$B^+ \to J/\psi K^+$
26 :	$B^+ \to J/\psi K^+\pi^+\pi^-$
27 :	$B^+ \to J/\psi K^+\pi^0$
28 :	$B^+ \to J/\psi K^0_S\pi^+$
29 :	$B^+ \to \overline{\Lambda^-_c}p^+\pi^+\pi^0$
30 :	$B^+ \to \overline{\Lambda^-_c}p^+\pi^+\pi^-\pi^+$
31 :	$B^+ \to \overline{D^0}p^+\overline{p^-}\pi^+$
32 :	$B^+ \to \overline{D^{*0}}p^+\overline{p^-}\pi^+$
33 :	$B^+ \to D^0p^+\overline{p^-}\pi^+\pi^-$
34 :	$B^+ \to D^{*0}p^+\overline{p^-}\pi^+\pi^-$
35 :	$B^+ \to \overline{\Lambda^-_c}p^+\pi^+$
36 :	No B^+ FEI decay

FEI skims

Skim code:

Hadronic: 11180500

SL: 11180600

FEI skims are also ready for MC15rd

Skim cuts:

static fei_precuts(path) [source]

Skim pre-cuts are applied before running the FEI, to reduce computation time. This setup function is run by all FEI skims, so they all have the save event-level pre-cuts:

- $n_{\text{cleaned tracks}} \geq 3$
- $n_{\text{cleaned ECL clusters}} \geq 3$
- Visible energy of event (CMS frame) > 4 GeV

We define "cleaned" tracks and clusters as:

- Cleaned tracks (`pi+:FEI_cleaned`): $d_0 < 0.5$ cm, $|z_0| < 2$ cm, and $p_T > 0.1$ GeV * Cleaned ECL clusters (`gamma:FEI_cleaned`): $0.296706 < \theta < 2.61799$, and $E > 0.1$ GeV

					MC15ri	Proc13	Prompt	MC15rd
SL&ME Liaison: @Shanette Anne De Lamotte Prep: BIIDP-5737 Requests: BIIDP-6059	FEI	feiHadronic	11180500	Hadron	Ready* *with ECL cut: release-06-01-10 WITHOUT ECL cut: release-06-01-12	Ready* *with ECL cut: release-06-01-10 WITHOUT ECL cut: release-06-01-12	Ready* *with ECL cut: release-06-01-10 WITHOUT ECL cut: release-06-01-12	Ready* *WITHOUT ECL cut: release-06-01-12
		feiSL	11180600					

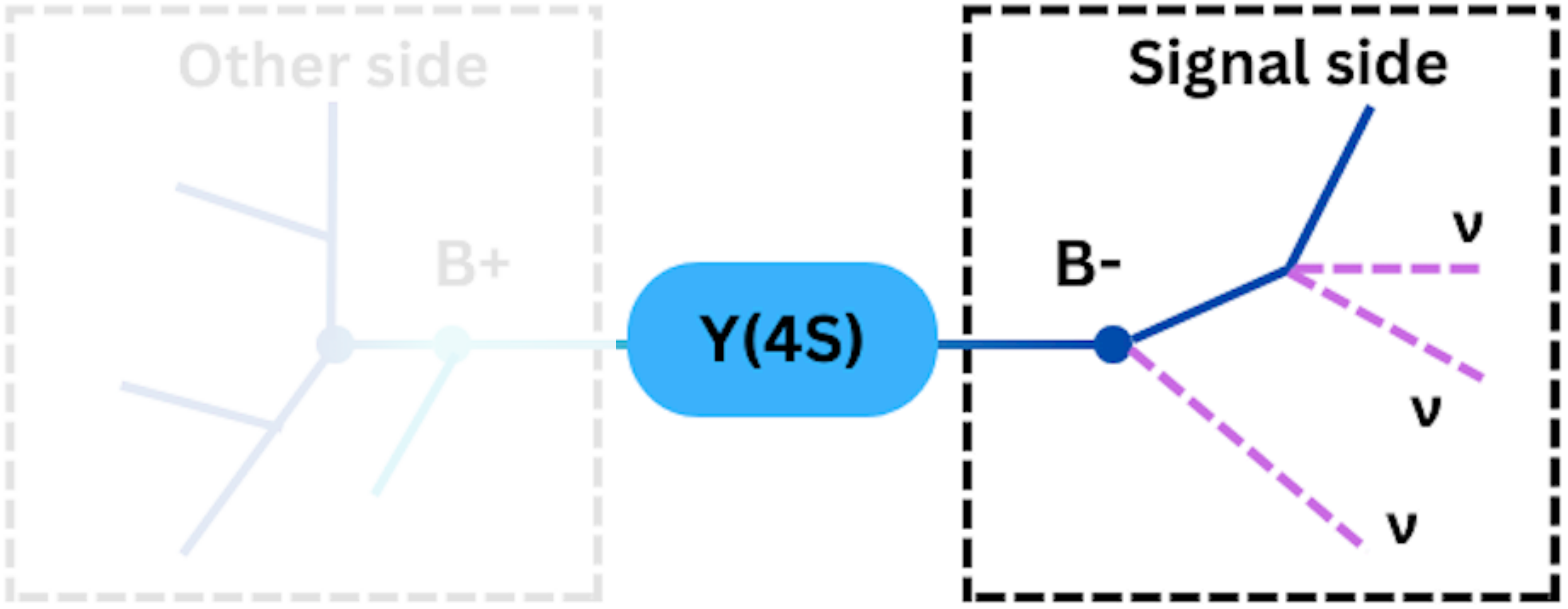
Mind the release!!

In analysis

You have your tag now, what do you do?

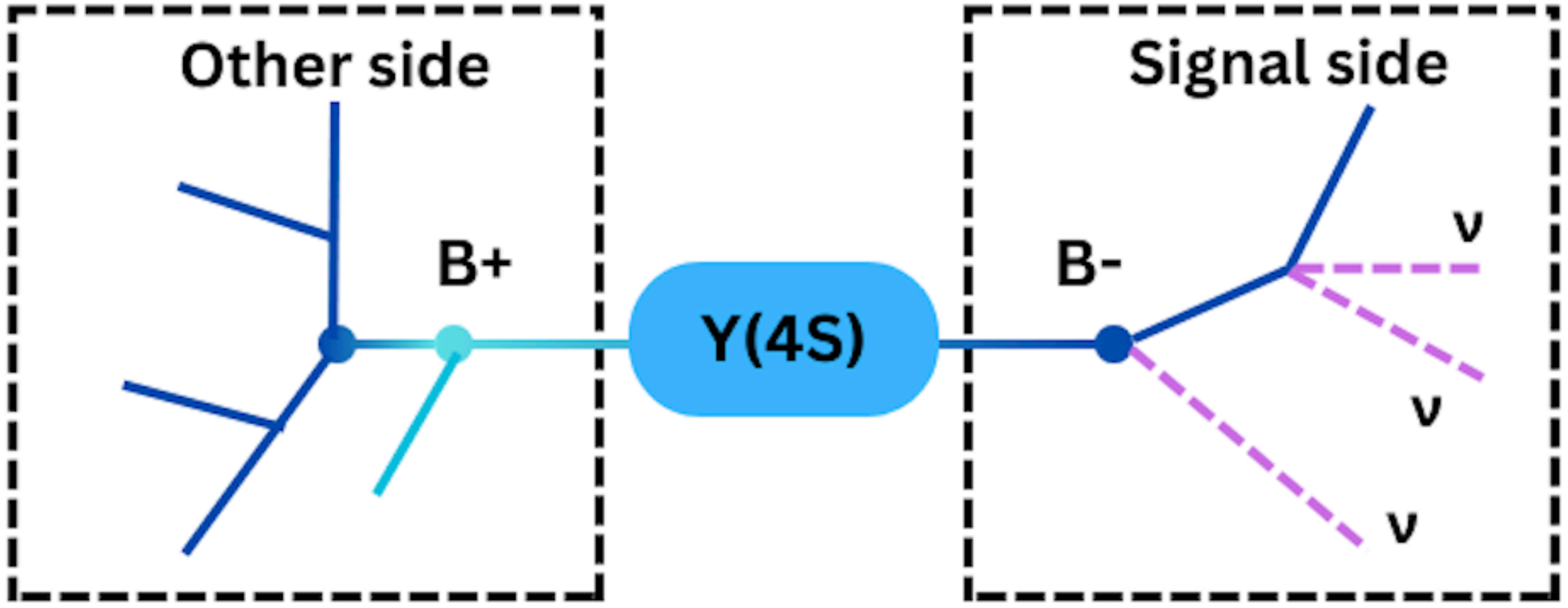
- Build your signal-side B candidate
- Combine tag-side B and signal-side B to form $\Upsilon(4S)$ candidates

Analysis w/o FEI



ε_{Sig}

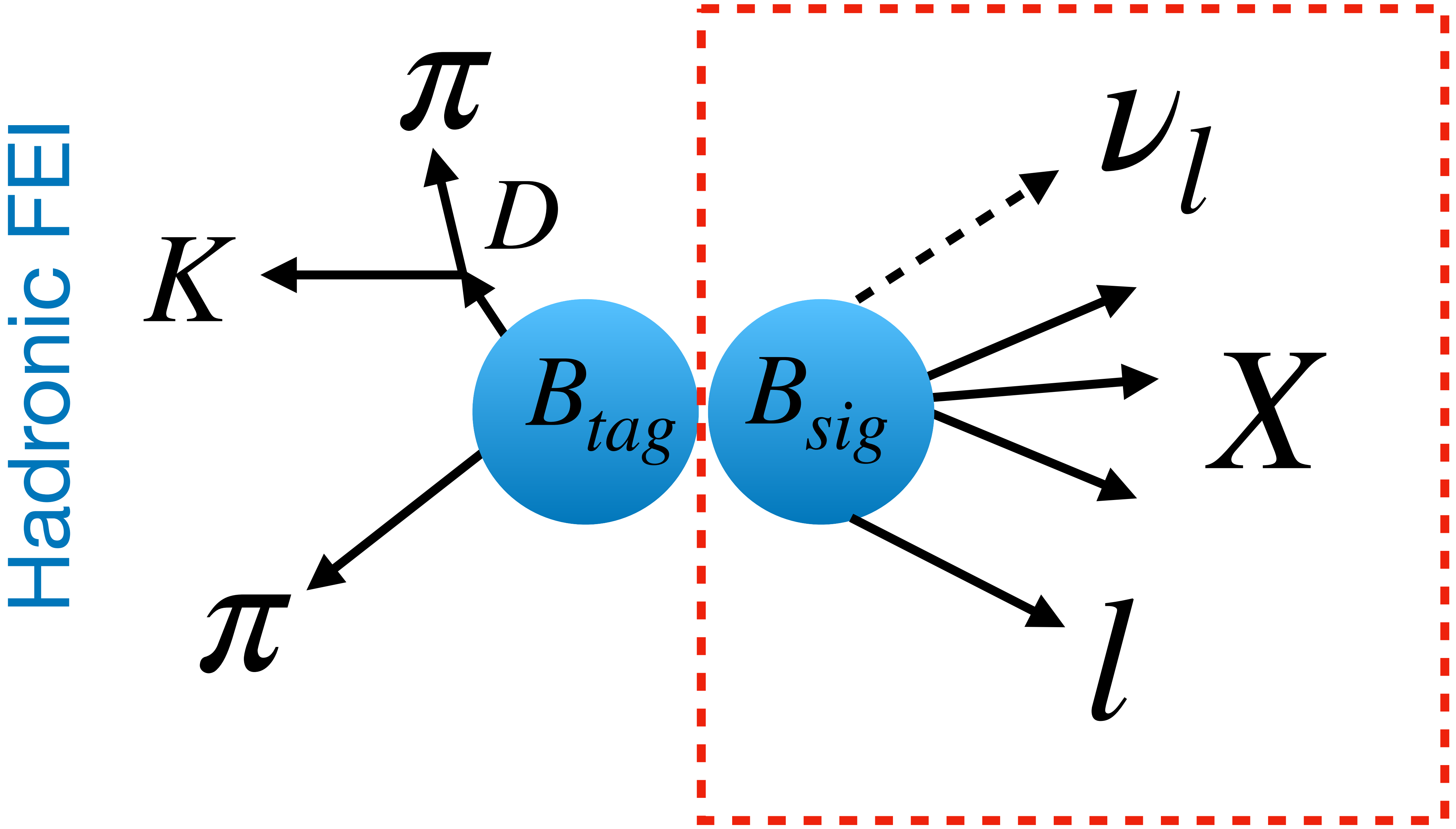
Analysis w/ FEI



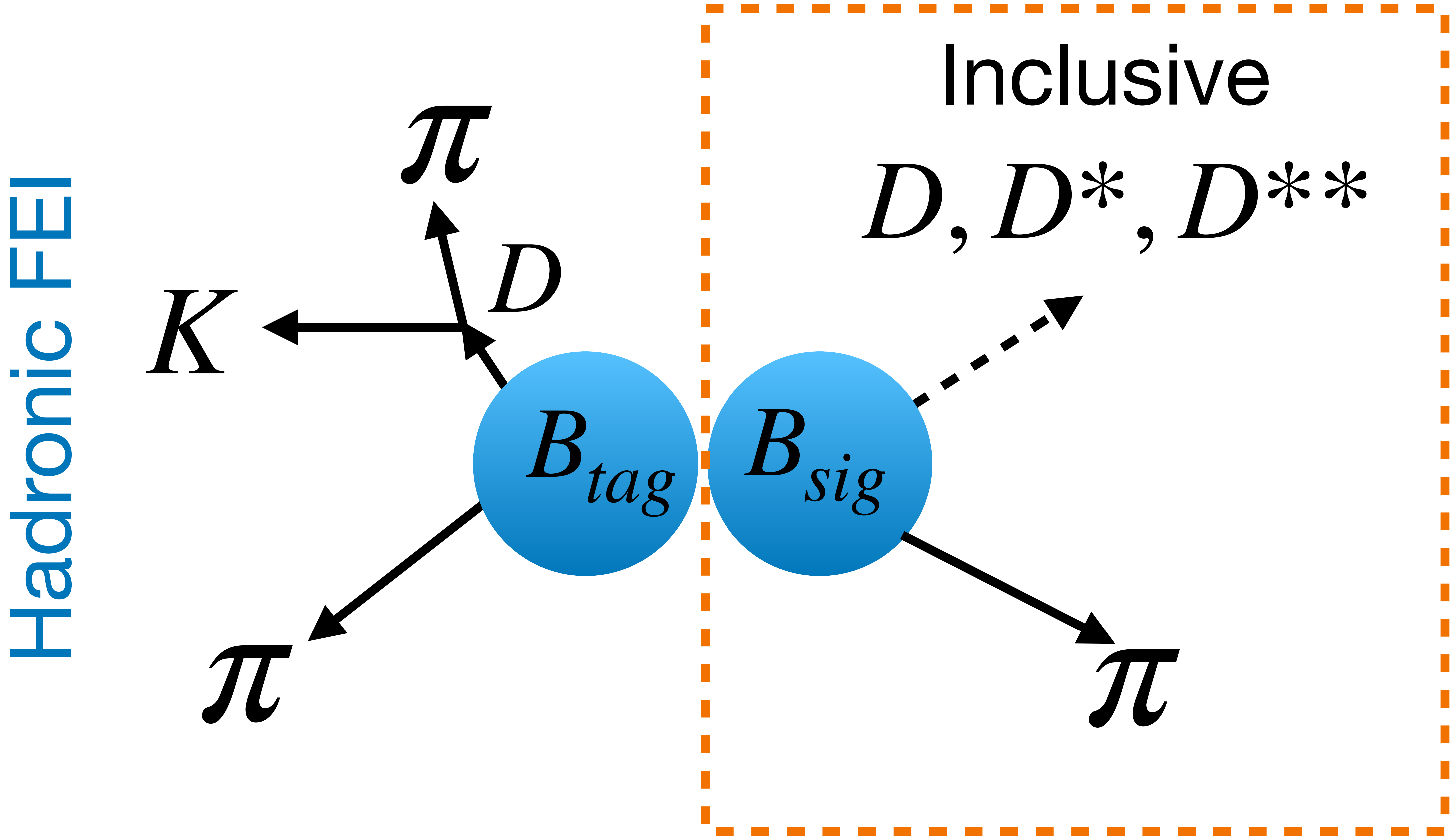
$\varepsilon_{\text{FEI}} \times \varepsilon_{\text{Sig}}$

FEI is trained on MC: needs calibration

Calibration: hadronic tag



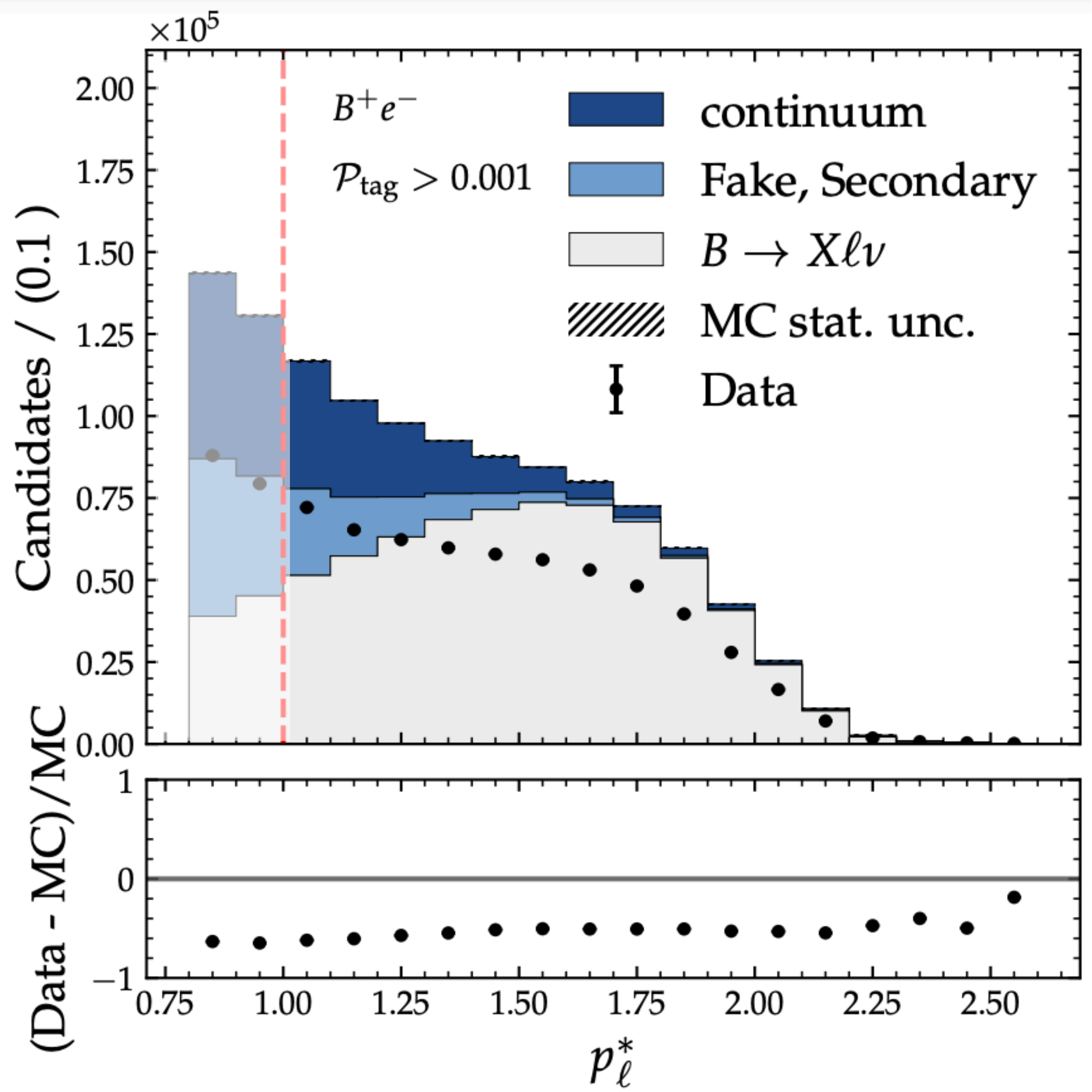
$B \to X_c l \nu$



$B \to D^{(*)}\pi$

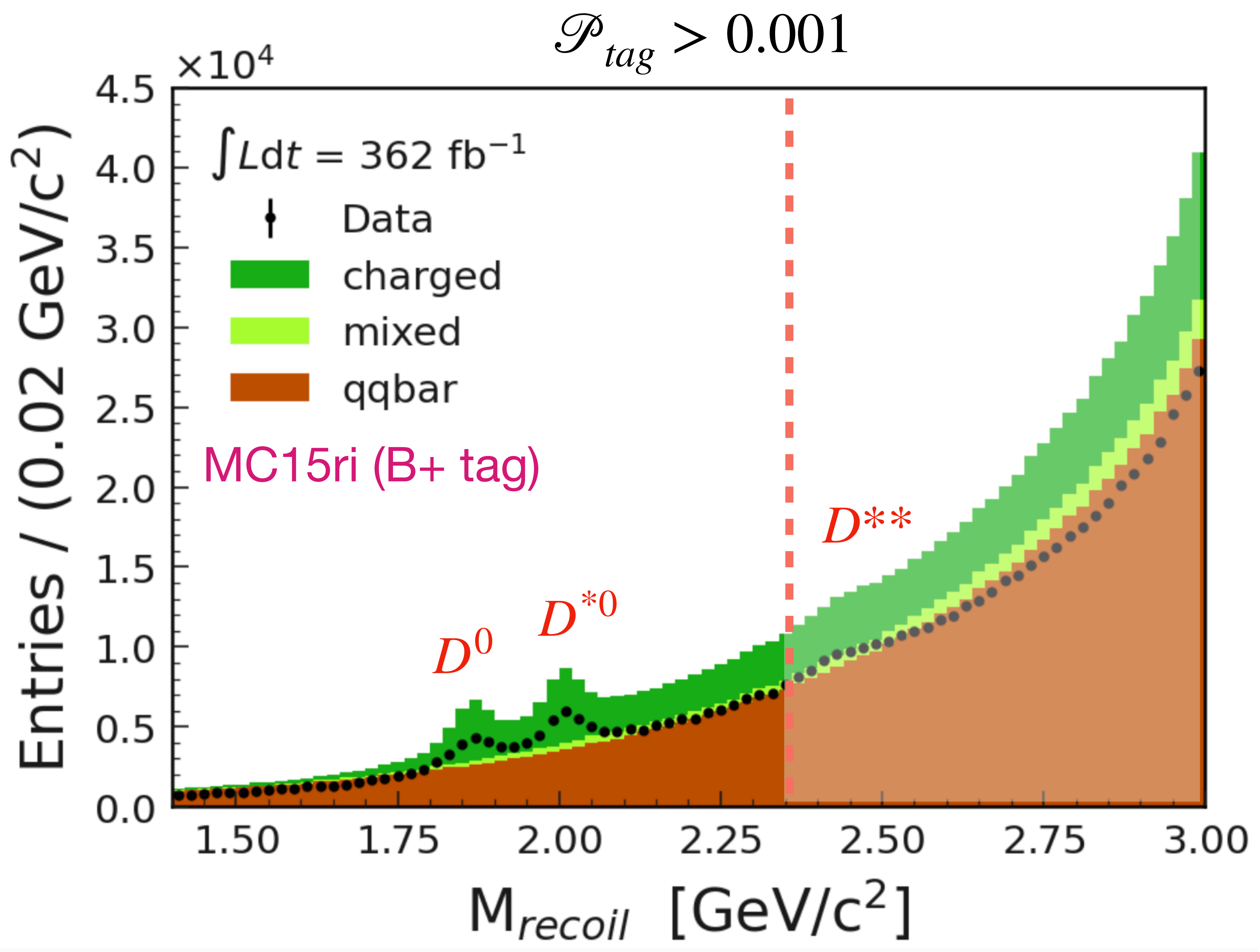
Calibration: hadronic tag

Fit variables



Fit to the lepton momentum in B rest frame: p_l^*

[William, Florian]

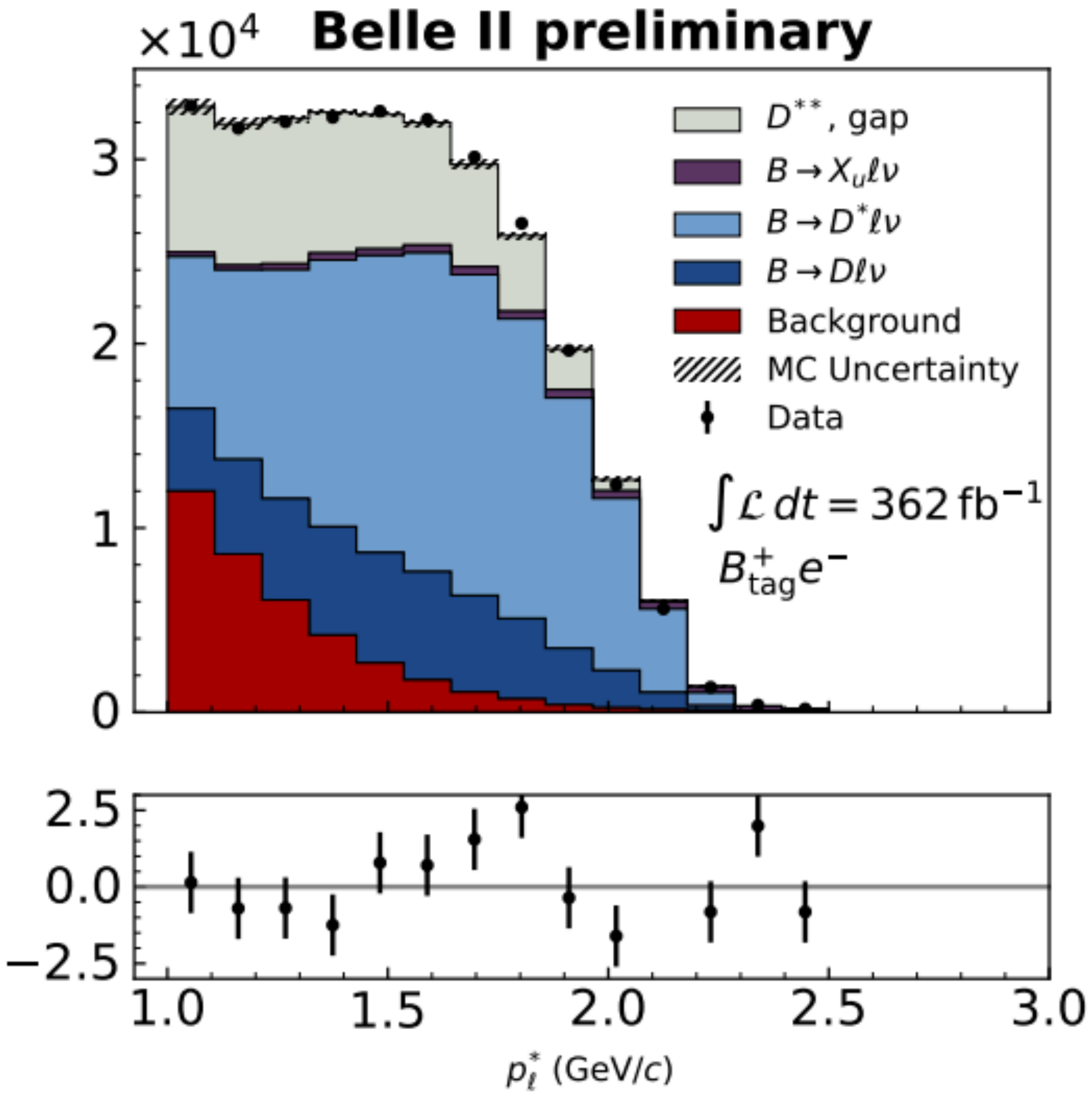


Fit to the recoil mass of B-tag and a pion on the signal side

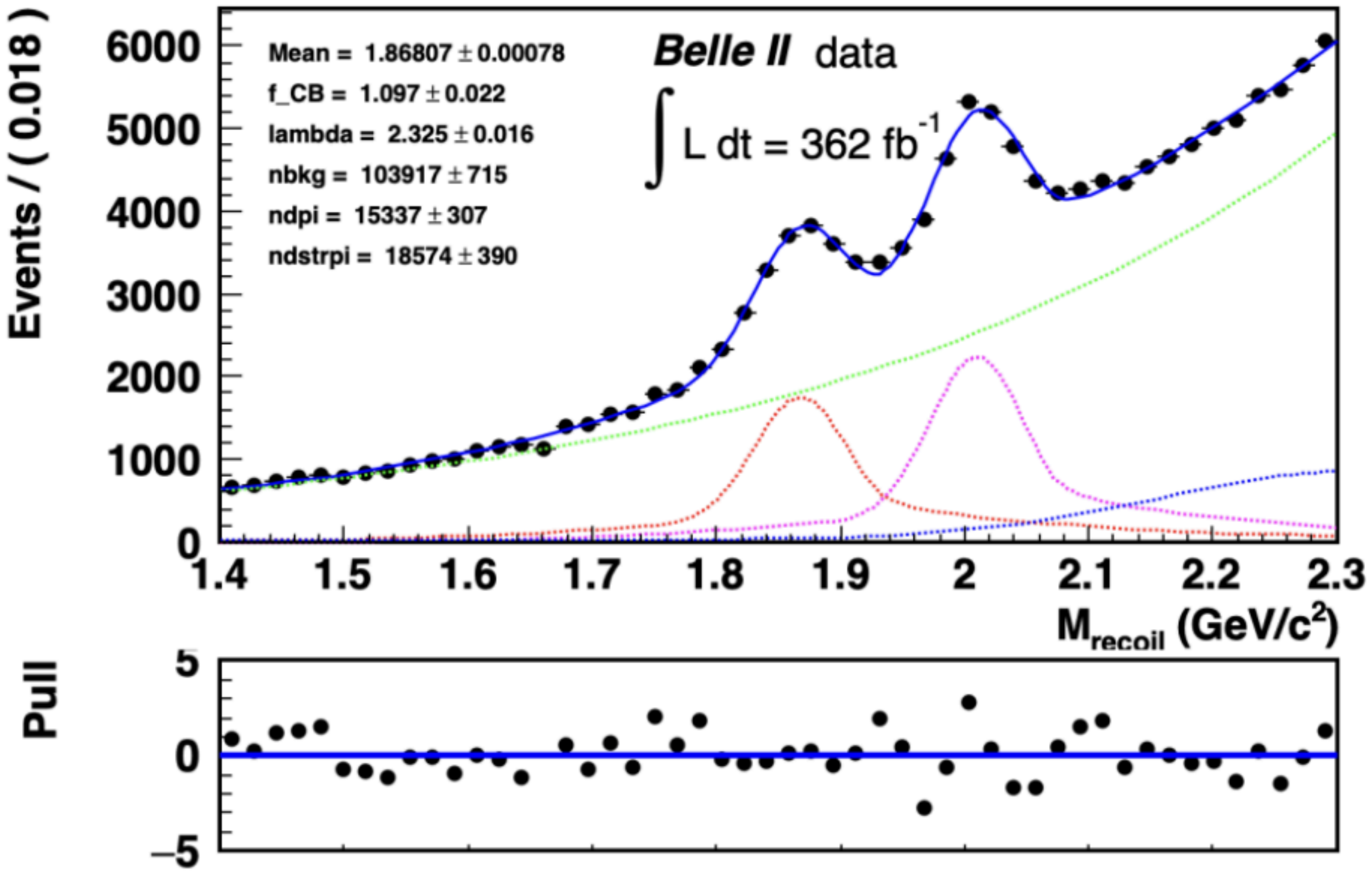
[Karim, Meihong, Niharika, Vidya]

Calibration: hadronic tag

Yield: $\sim 10^5$, High statistics, low purity



Yield: $\sim 10^4$, Low statistics, high purity

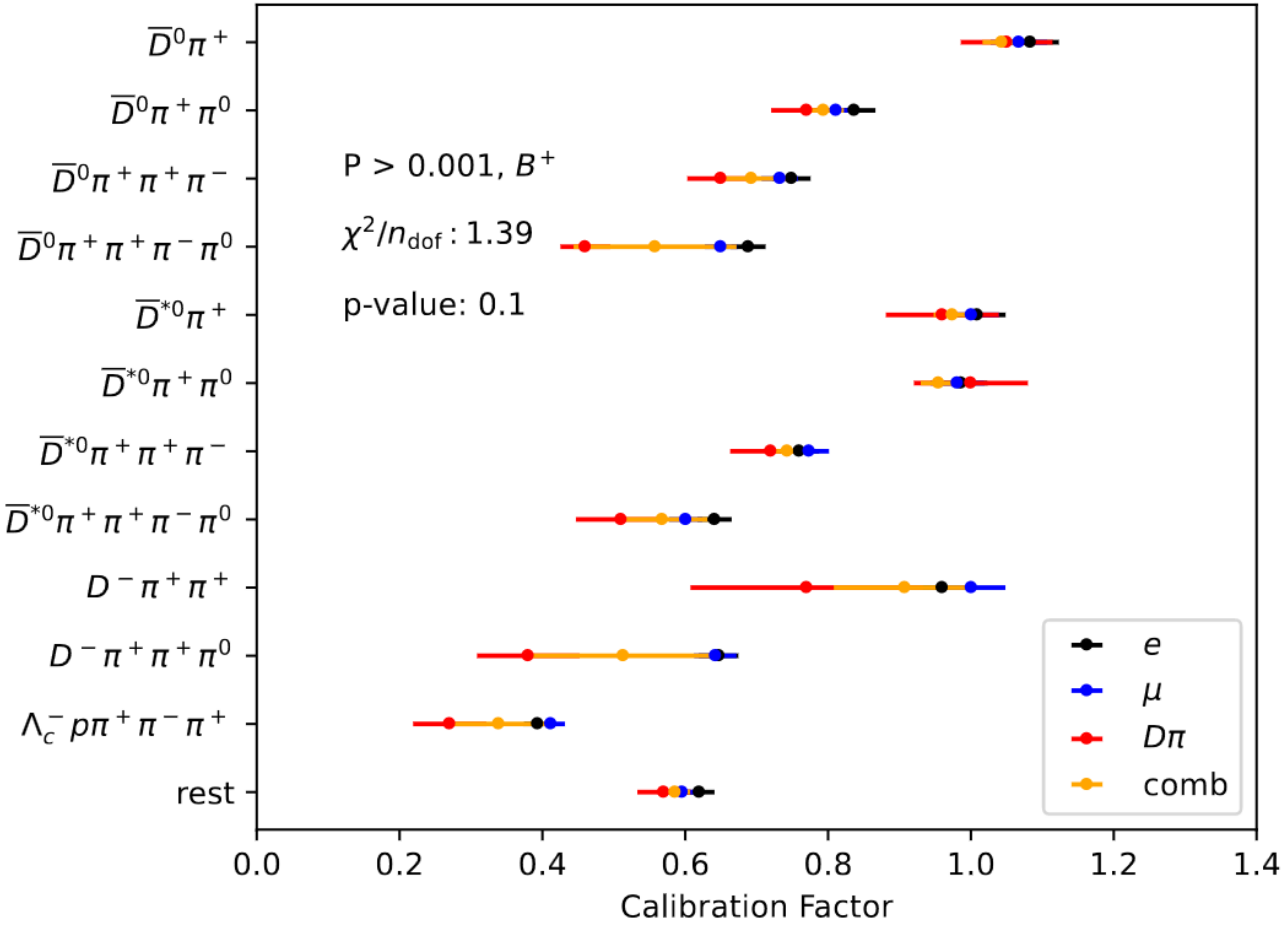


Calibration factors are calculated as ratio of signal yields of data and MC

Calibration: hadronic tag

BELLE2-NOTE-PH-2023-029

Good agreement of CFs despite two orthogonal signal-sides



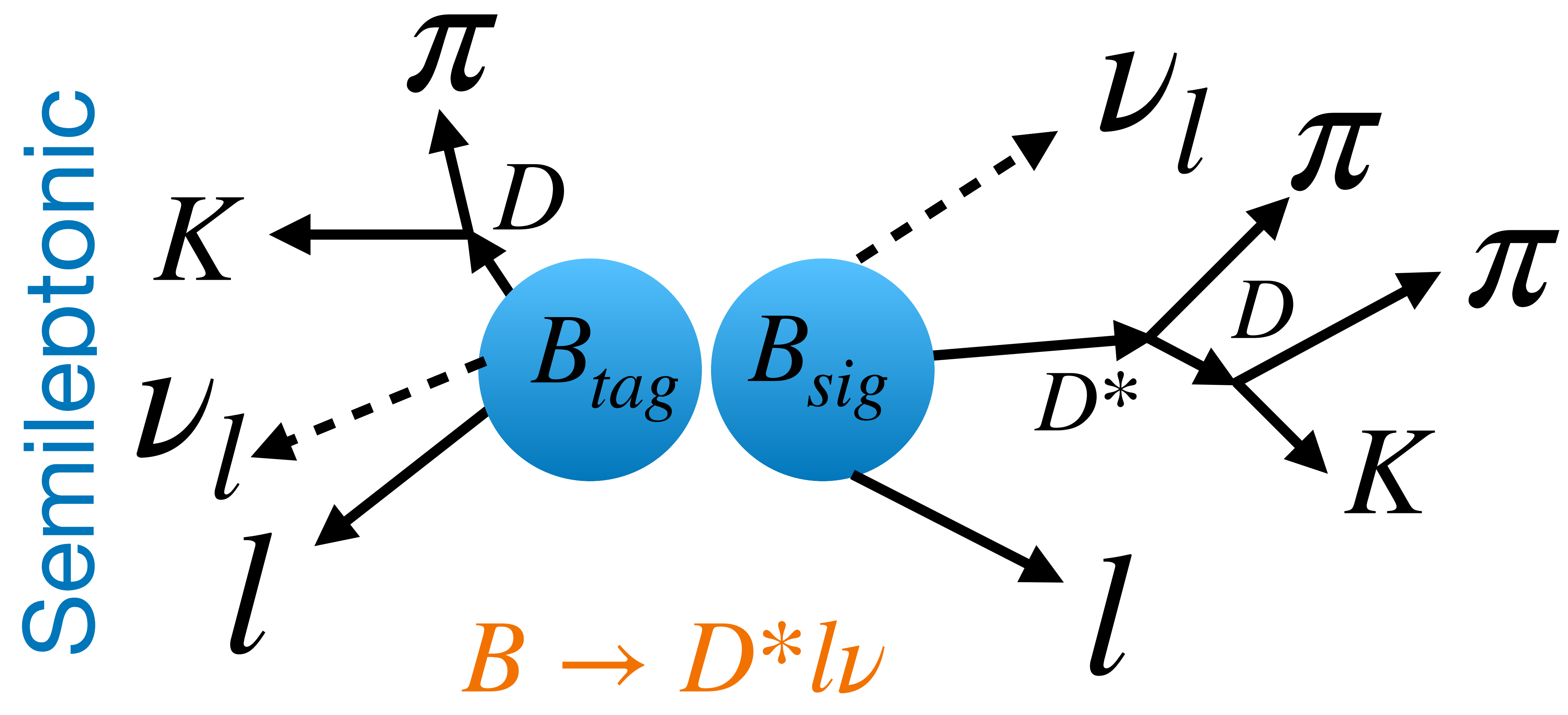
Total CF:
(0.68 ± 0.03)

CFs are ready and available for the analysts to use

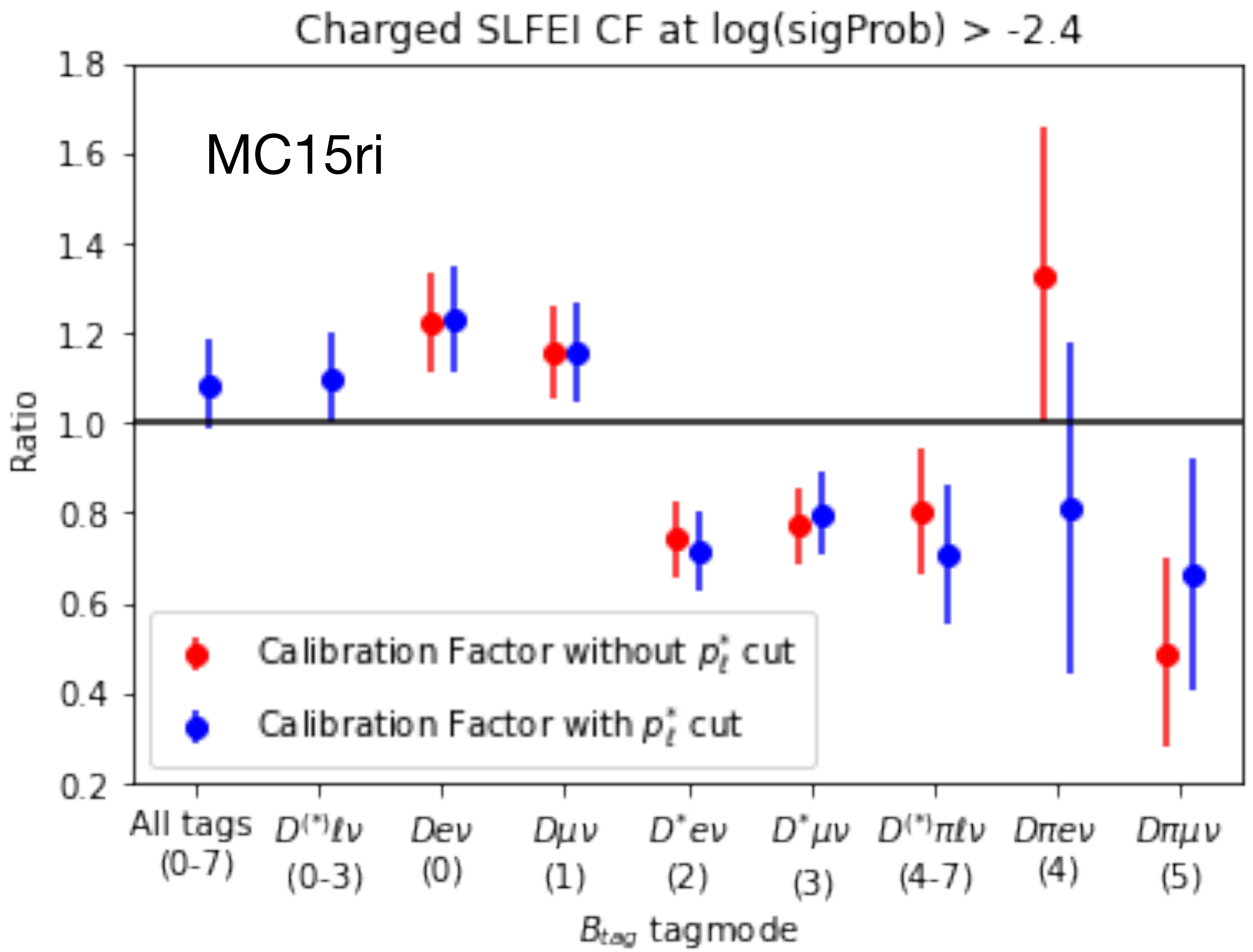
KEKCC: /hsm/belle2/bdata/users/sutclw/fei_calibration/hadronic_FEI_calibration_factors/v1

Calibration: semileptonic tag

[Andre Huang, Kevin Varvell]



Total CF: (1.09 ± 0.10)



CFs are also available for semileptonic tagging

Tag-side selections

FEI-TASK-FORCE

Mode	Cuts post FEI skim	BCS	Signal Probability Working Points
Had Tag	Mbc > 5.27, -0.15 < deltaE < 0.1, cosTBTO < 0.9	Highest extraInfo(SignalProbability)	0.001, 0.01, 0.1
SL Tag	-4 < cosThetaBetweenParticleAndNominalB < 3, cosTBTO < 0.9	Highest extraInfo(SignalProbability)	0.001, 0.01, 0.1

Must use!!

If you use different selections, you need to do the calibration by yourself

ECL Mask:

```
ecl_mask = "[[clusterReg==1] and [E>0.080]] or [[clusterReg==2] and [E > 0.03]] or [[clusterReg==3] and [E > 0.06]]]"\
 "and [clusterNHits > 1.5] and [abs(clusterTiming) < 200] and [0.2967 < clusterTheta < 2.6180]]"
```

Track Mask:

```
track_mask = "[[dr < 2] and [abs(dz) < 4] and [pt > 0.2] and[thetaInCDCAcceptance==1]]"
```

Next generation FEI: improving the metrics

Reference: Vidya's talk at PGM

FEI performance in data

Calculated directly on data

- Calibration factor:

$$\frac{\text{Signal yield in data}}{\text{Signal yield in MC}}$$

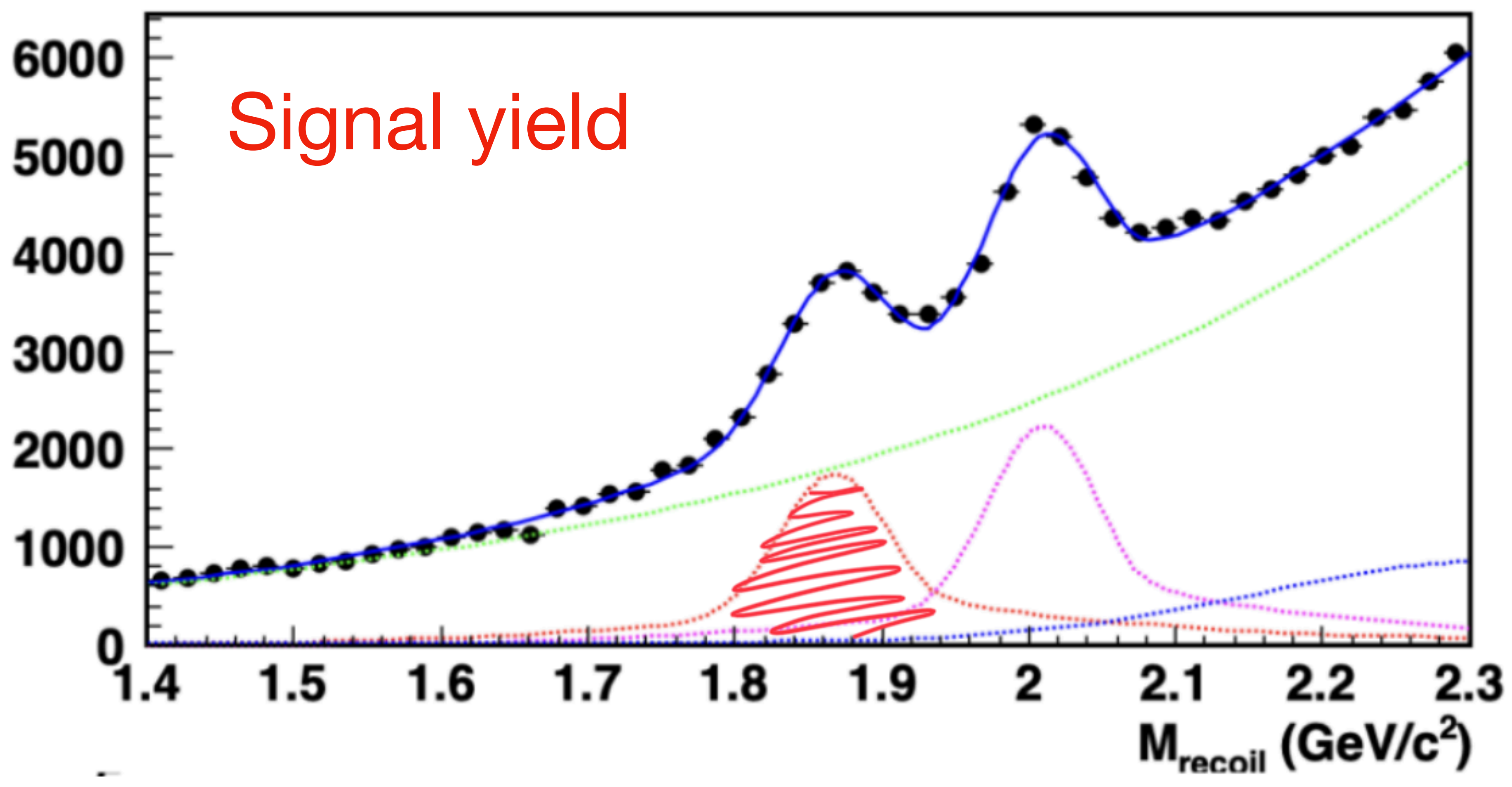
- Purity:

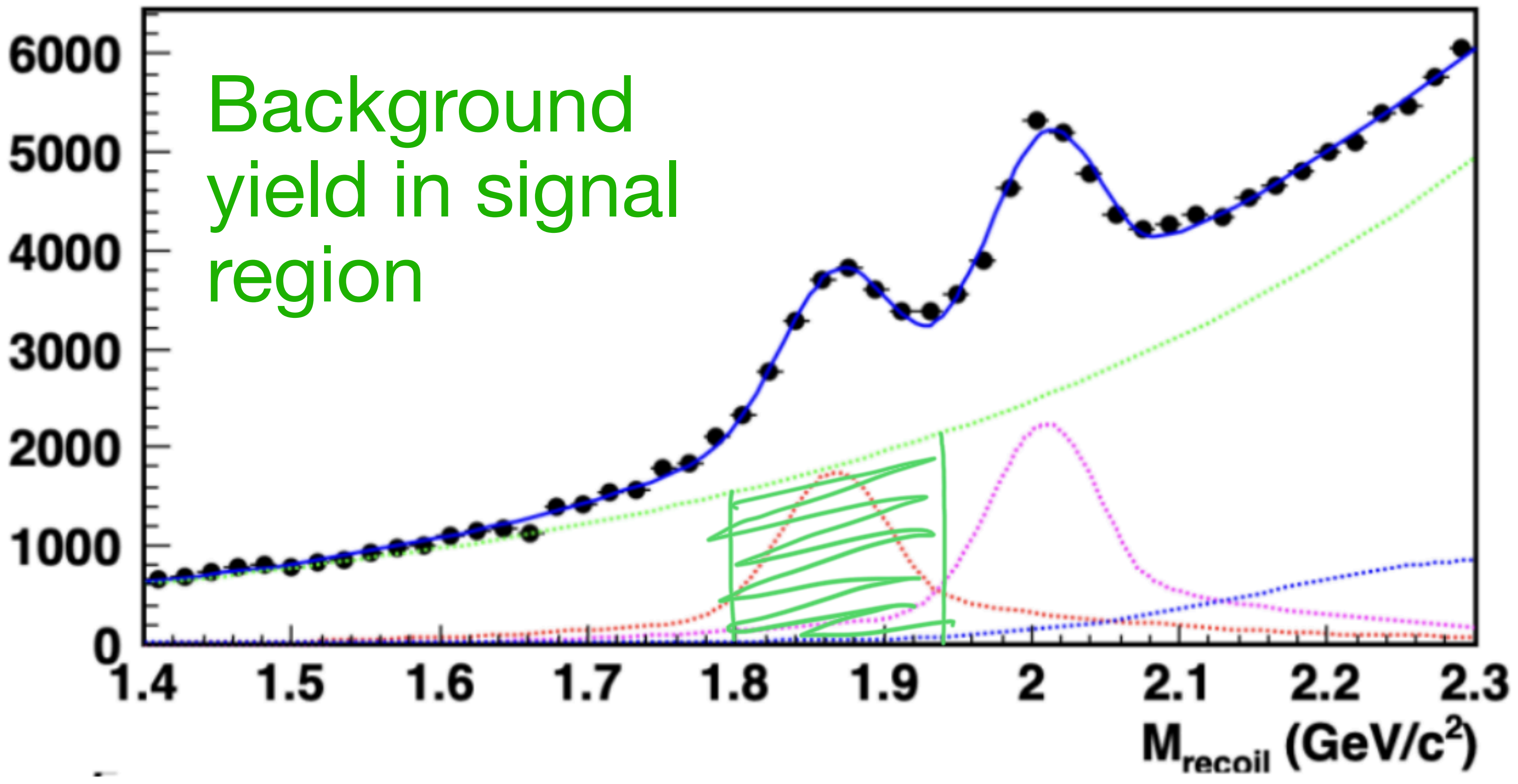
$$\frac{\text{Signal yield}}{\text{Signal yield} + \text{Background yield in signal region}}$$

- Efficiency:

$$\frac{\text{Signal yield}}{n_{BB} \cdot BF_{B\rightarrow D\pi} \cdot \epsilon_{\pi}}$$

n_{BB} → 392.5×10^6, $BF_{B\rightarrow D\pi}$ → PDG, ϵ_{π} → 90%





FEI performance in data: current status

Calculated directly on data

$\mathscr{P}_{sig} > 0.001$

- Calibration factor: **65%**

$$\frac{\text{Signal yield in data}}{\text{Signal yield in MC}}$$

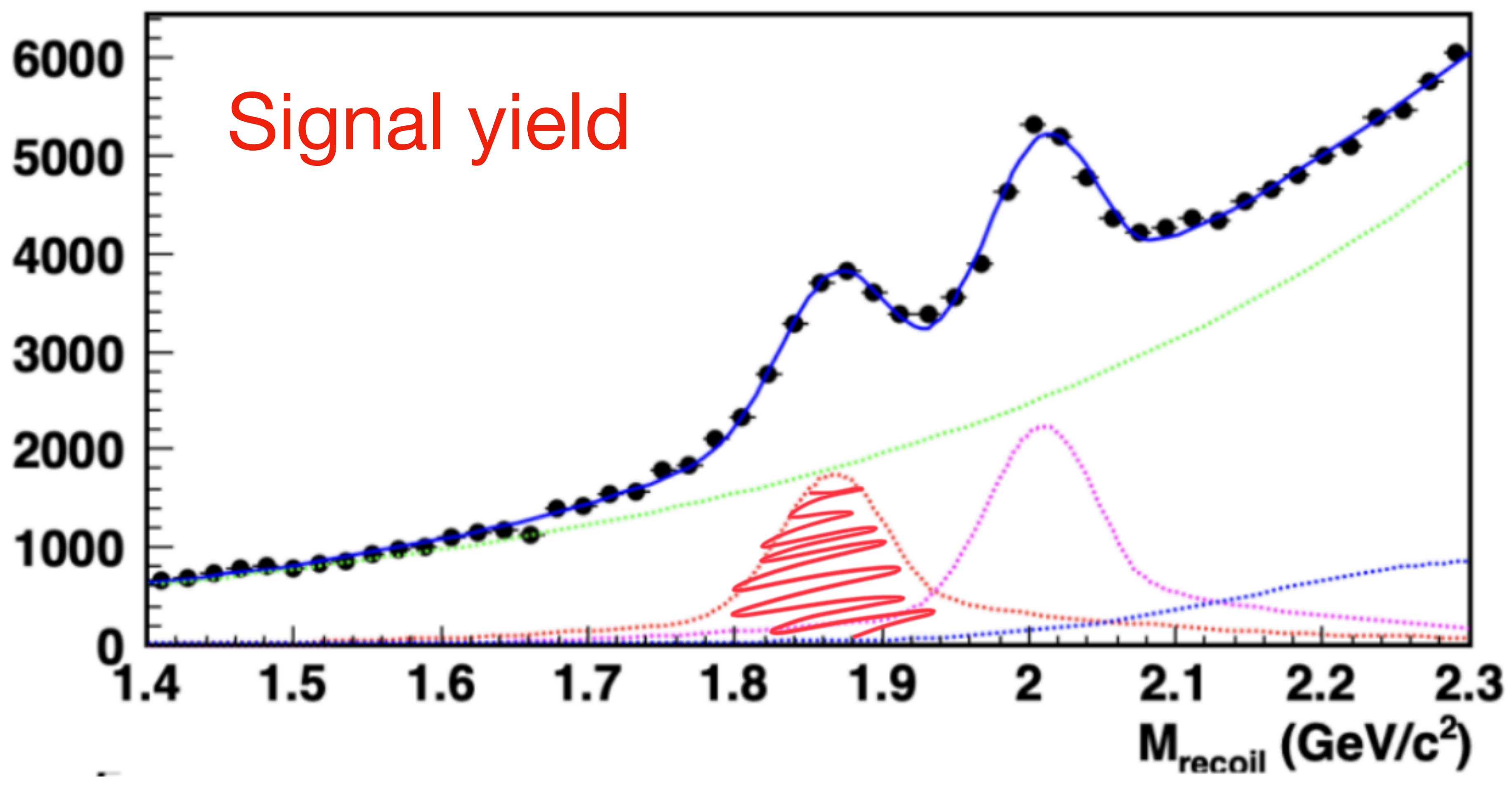
- Purity: **56%**

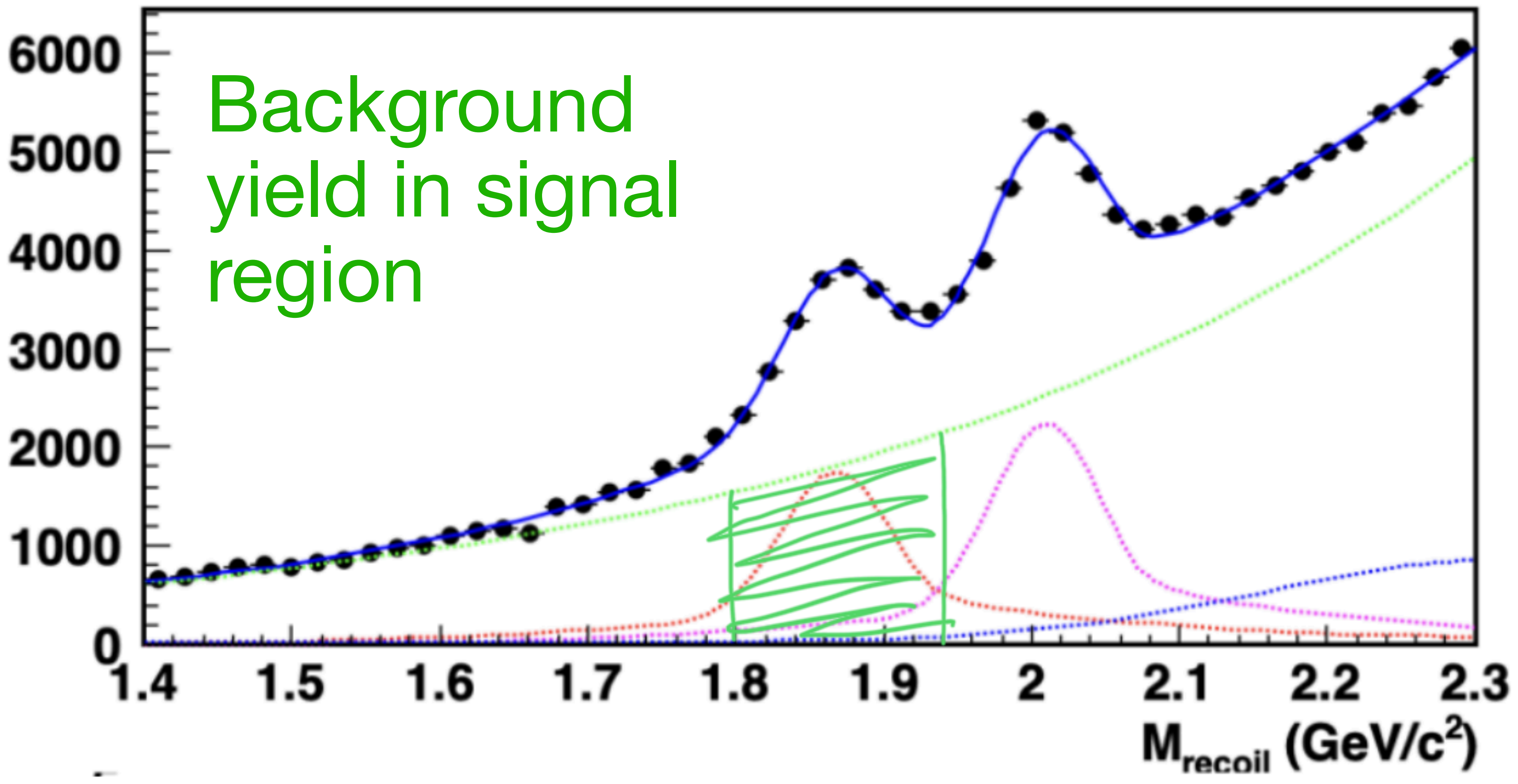
$$\frac{\text{Signal yield}}{\text{Signal yield} + \text{Background yield in signal region}}$$

- Efficiency: **0.93%**

$$\frac{\text{Signal yield}}{n_{BB} \cdot BF_{B \to D\pi} \cdot \epsilon_{\pi}}$$

$n_{BB} \to 392.5 \times 10^6$, $BF_{B \to D\pi} \to$ PDG, $\epsilon_{\pi} \to$ 90%





What affects our current performance?

Calculated directly on data

$\mathscr{P}_{sig} > 0.001$

- Calibration factor: 65%

$$\frac{\text{Signal yield in data}}{\text{Signal yield in MC}}$$

- Purity:

$$\frac{\text{Signal yield}}{\text{Signal yield} + \text{Background yield in signal region}}$$

- Efficiency:

$$\frac{\text{Signal yield}}{n_{BB} \cdot BF_{B\to D\pi} \cdot \epsilon_{\pi}}$$

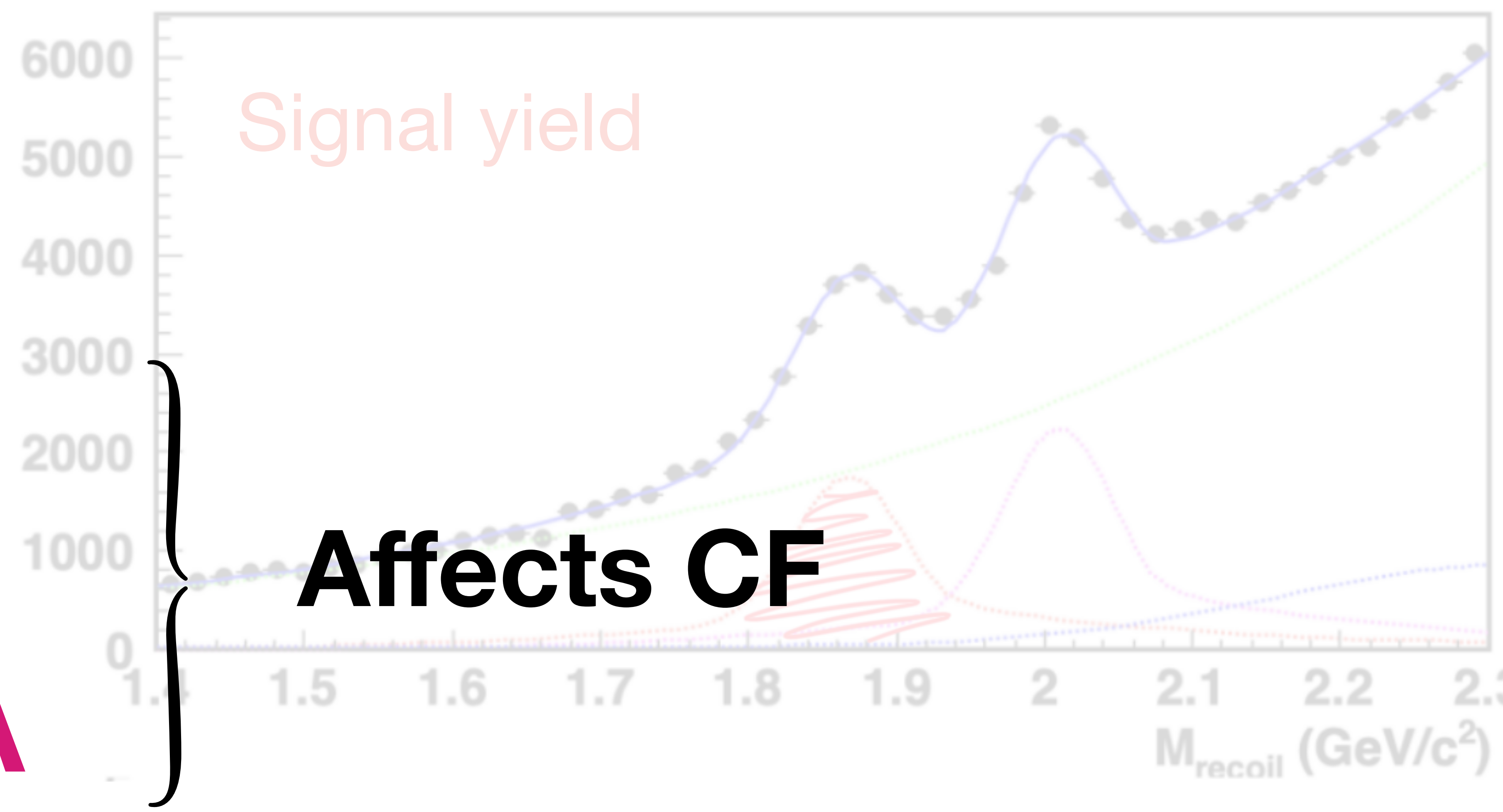
392.5×10^6 ↓ PDG ↓ 90% ↓

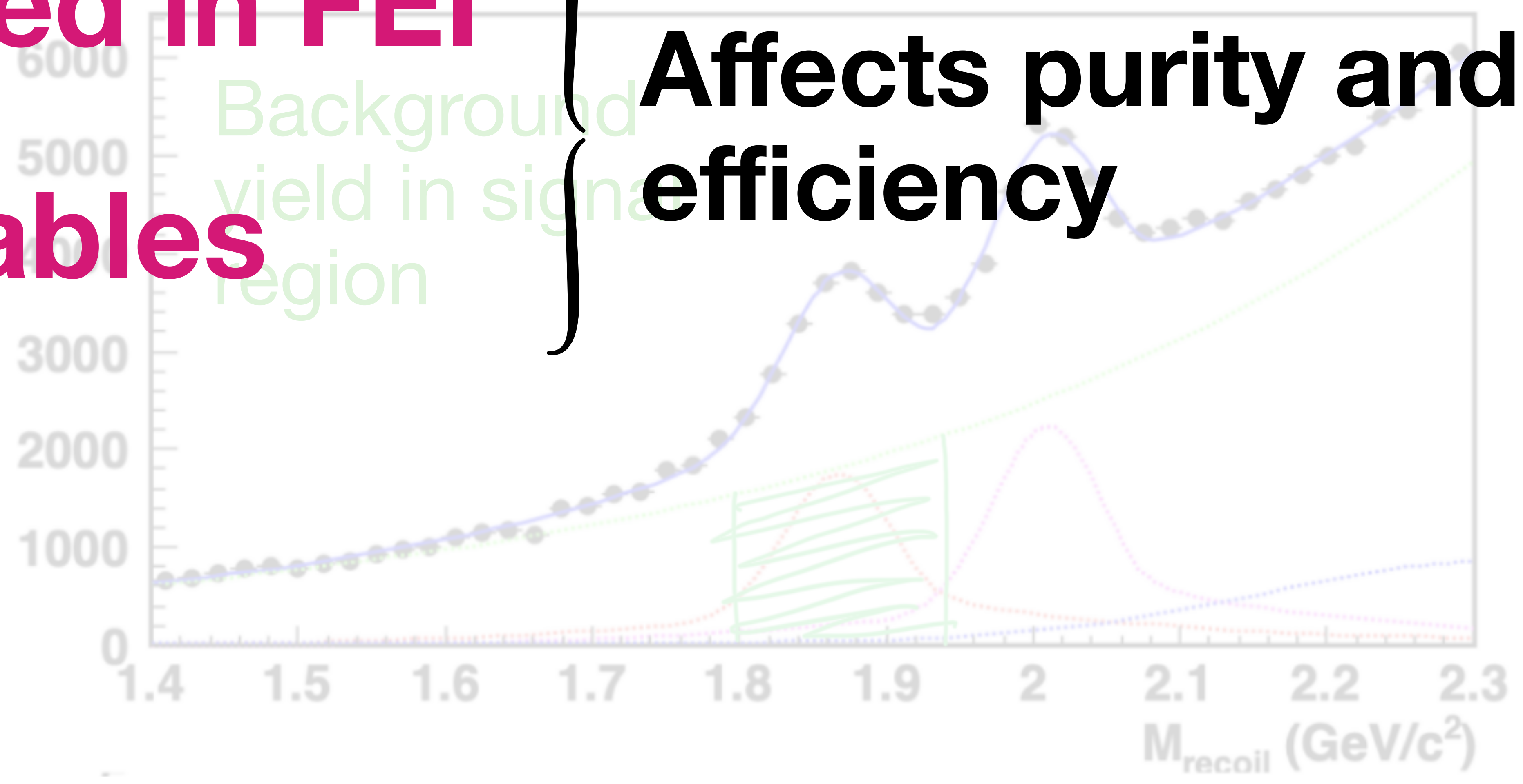
- **Wrong/outdated BFs in MC**
- **Half of the MC is unknown: PYTHIA**

Affects CF

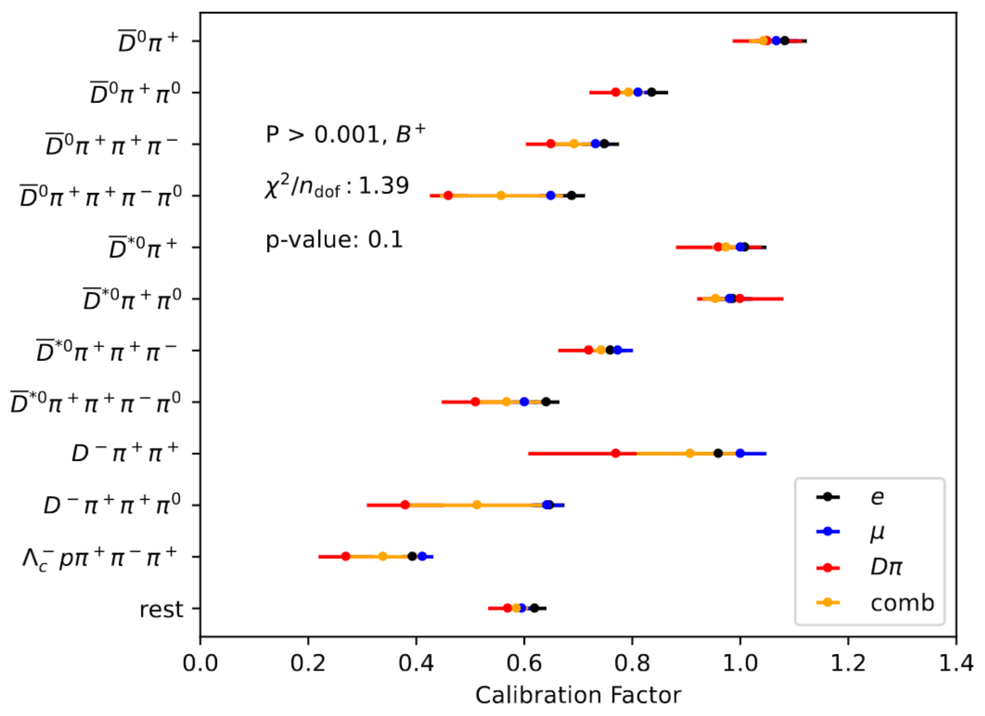
- **Bugs or very loose selections applied in FEI**
- **Wrong choice of input training variables**

Affects purity and efficiency



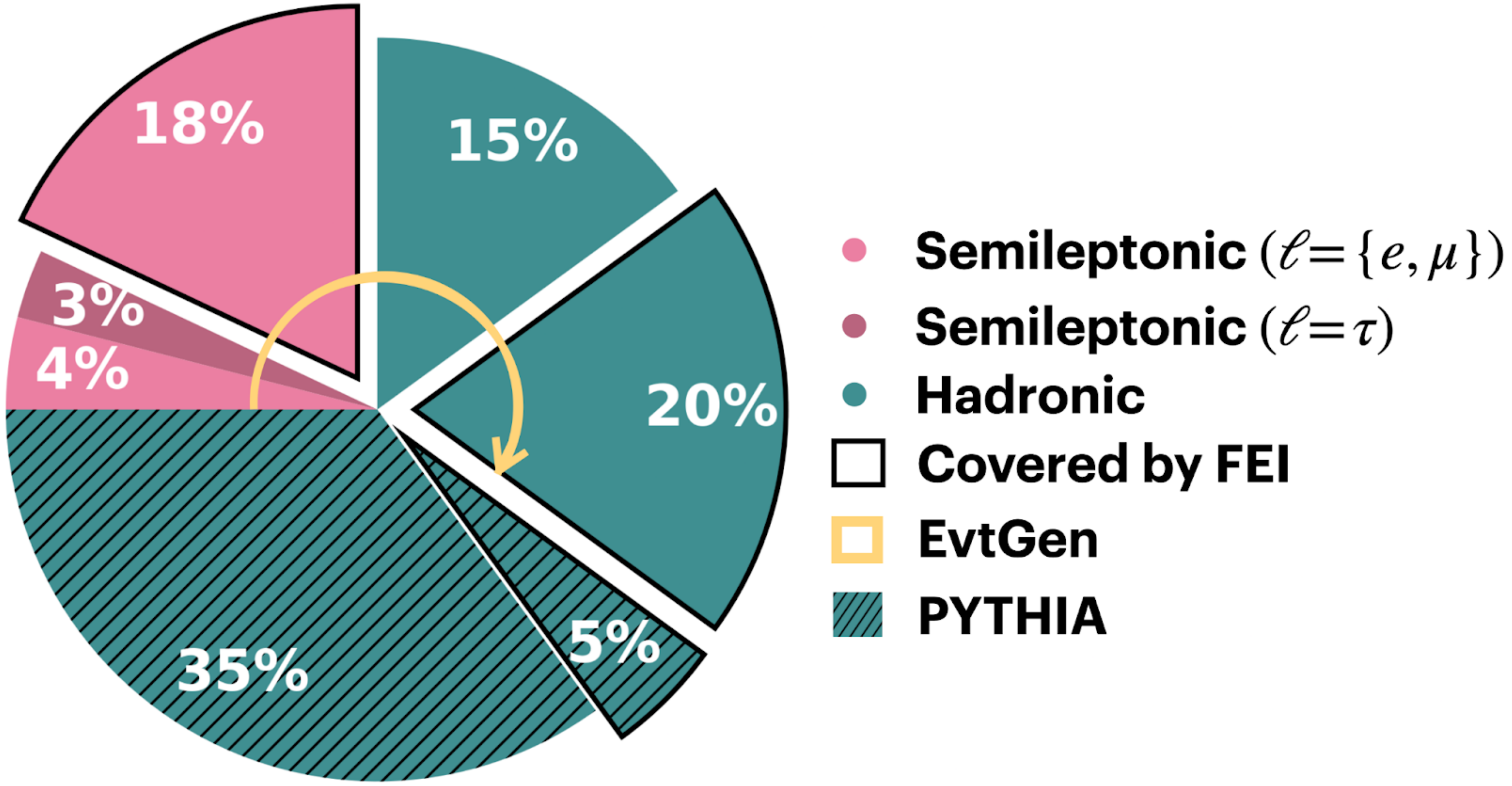


Understanding our MC



Why such large discrepancy with data?

Let's understand our MC…



PC: GdM

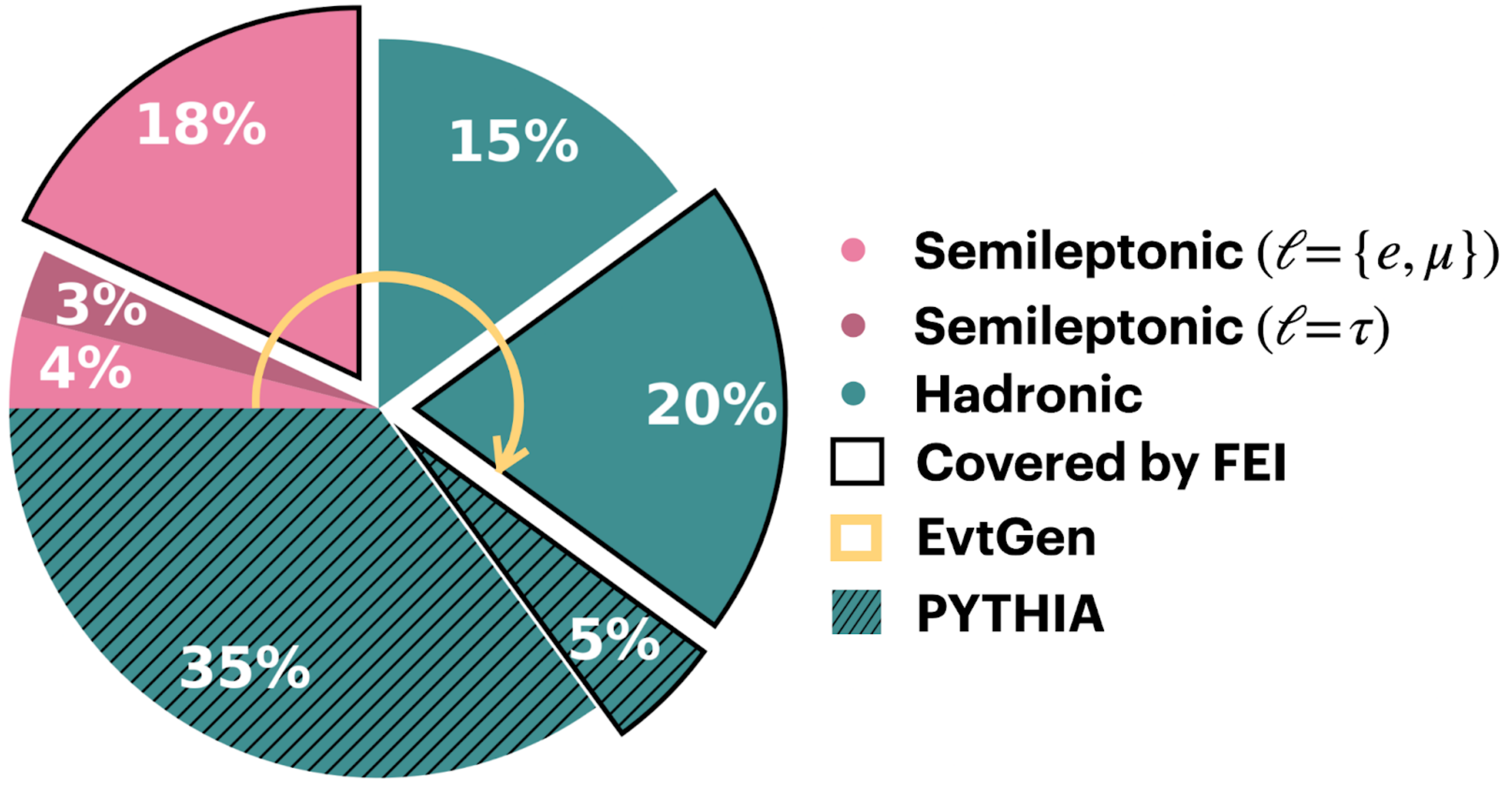
Understanding our MC

Hadronic B-decays: ~75%

Only half of it is measured and the rest is generated by PYTHIA

Most of the known measurements are performed with small data sets

⇒ Large statistical uncertainties.



Poor MC (significantly different from reality/data)

⟹Poor hadronic B-tagging

Understanding $B \to D^{(*)}h$ decays is essential for B-tagging.

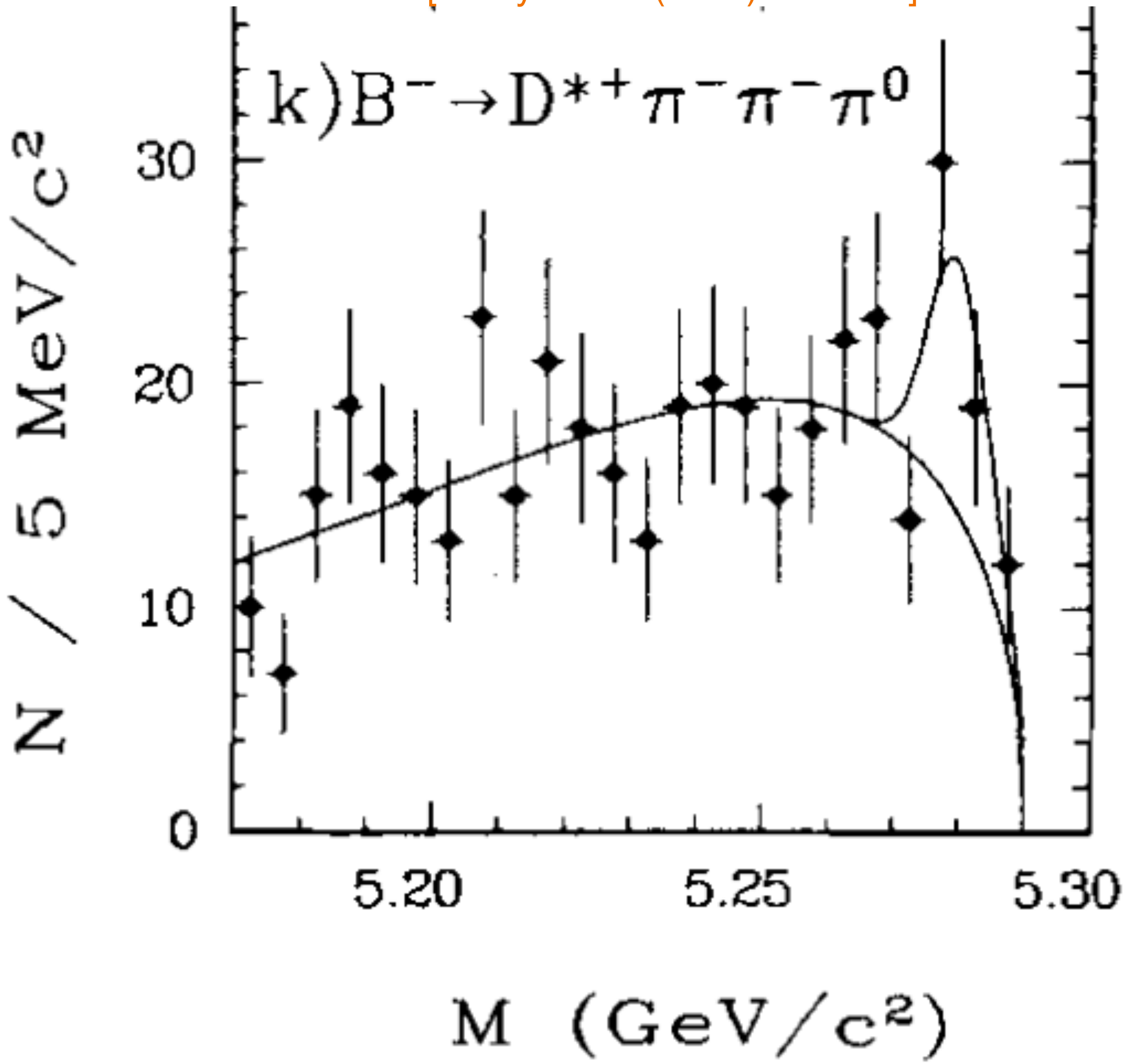
Decays in hadronic B-tagging

ARGUS, 229 pb^{-1}, 33 years ago

Uses M_{bc} as fit variable

$\mathscr{B}$ = (1.5 ± 0.7)%, 47% uncertainty!

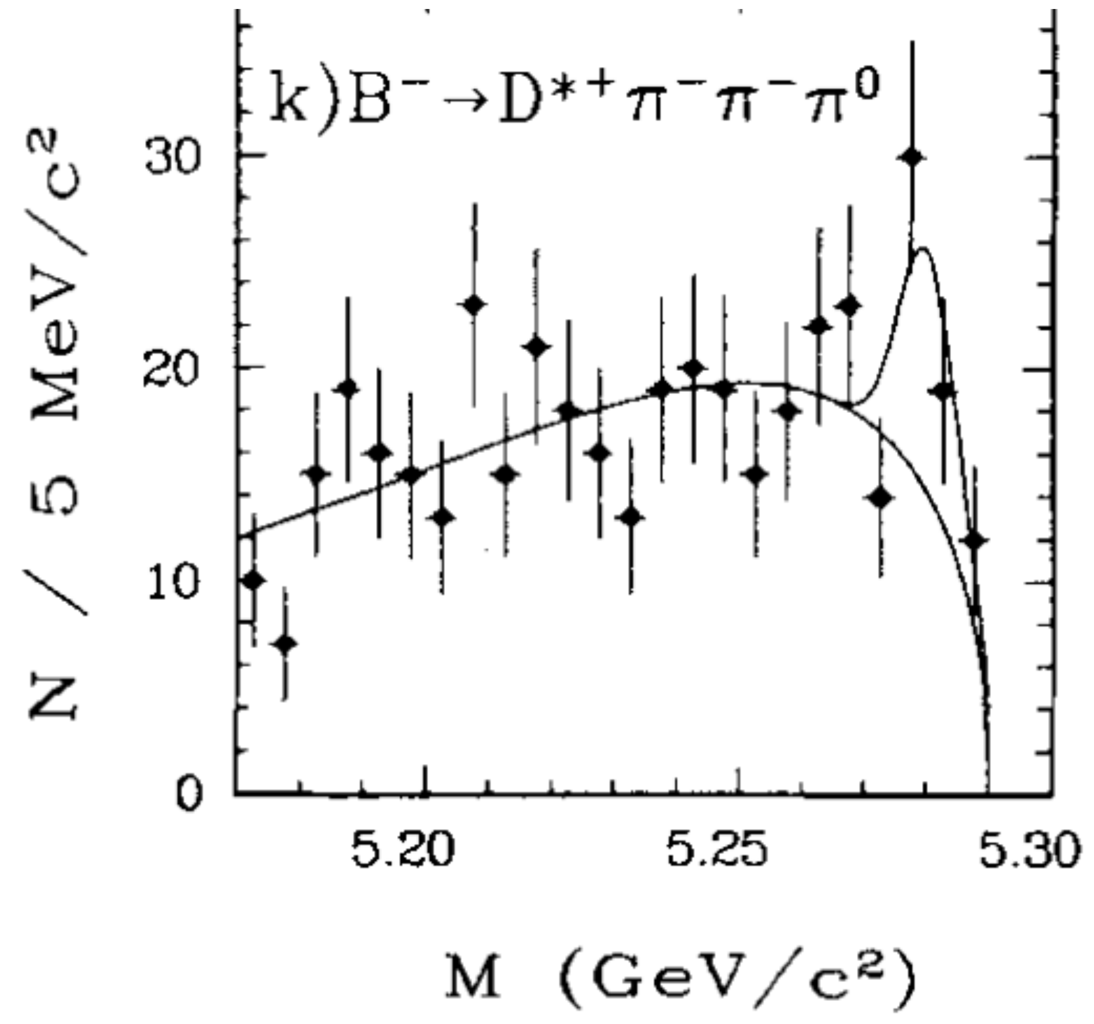
[Z.Phys.C 48 (1990) 543-552]

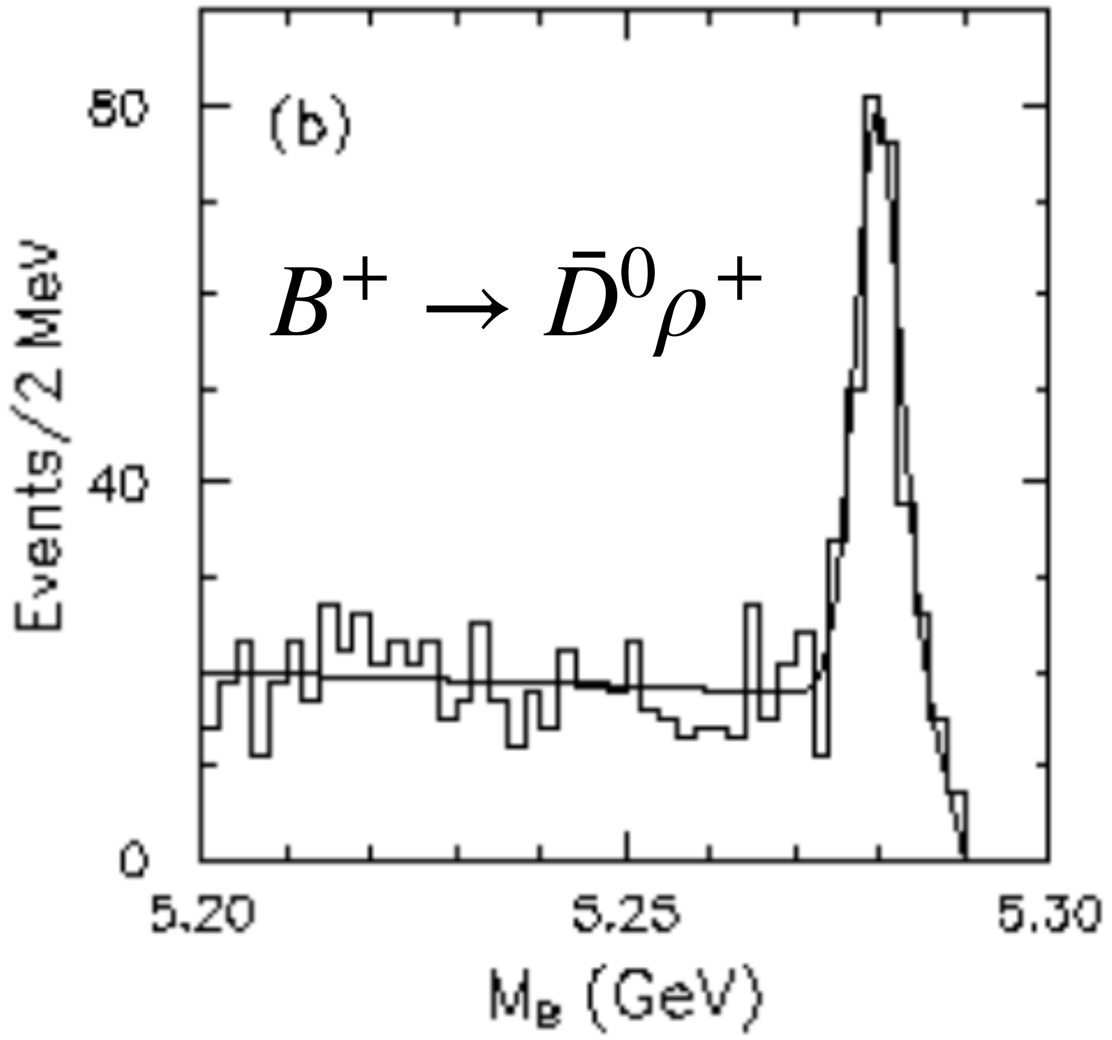


Decays in hadronic B-tagging

ARGUS, 229 pb^{-1}
33 years ago
Uses M_{bc}
$\mathscr{B}$ = (1.5 ± 0.7)%
47% uncertainty!

[Z.Phys.C 48 (1990) 543-552]



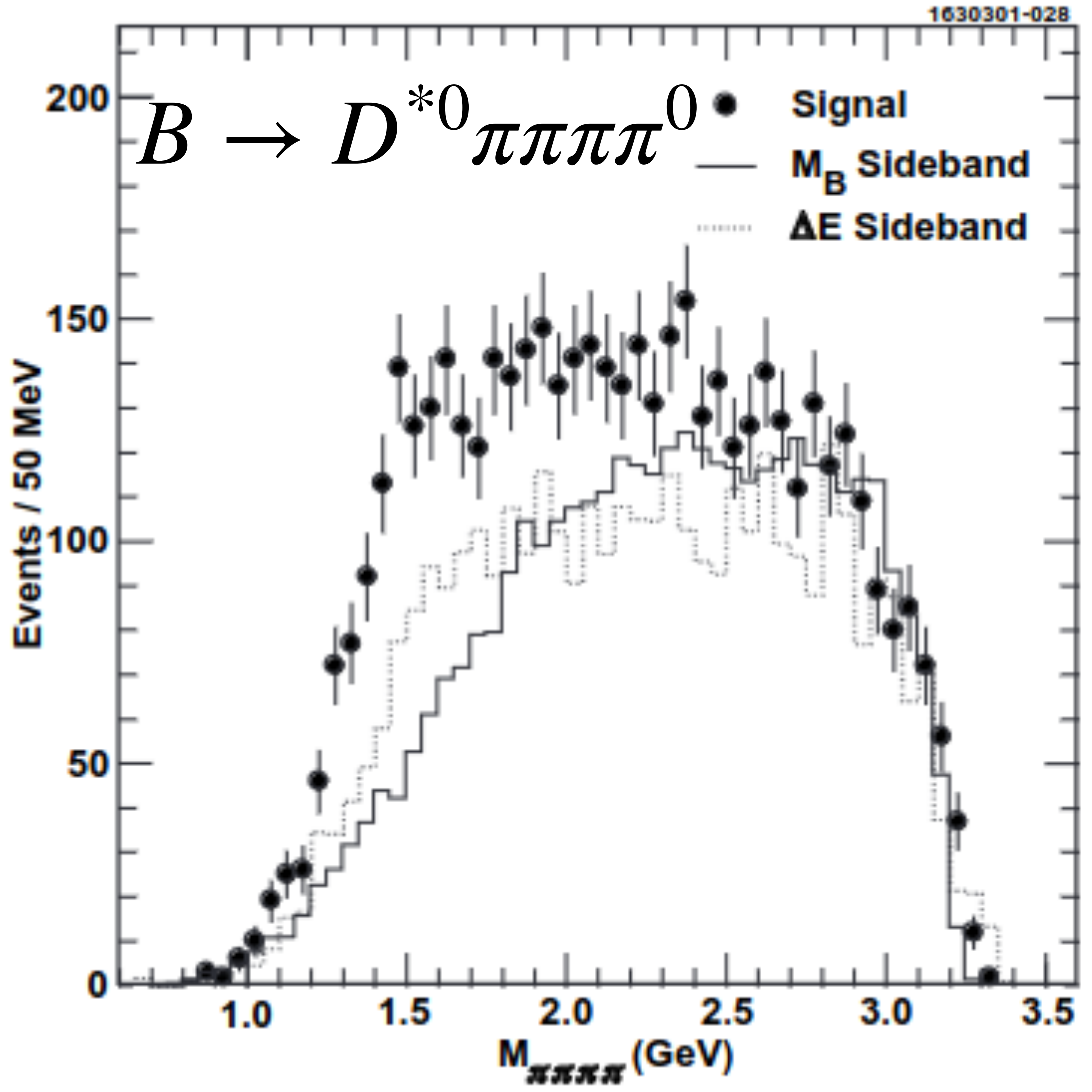


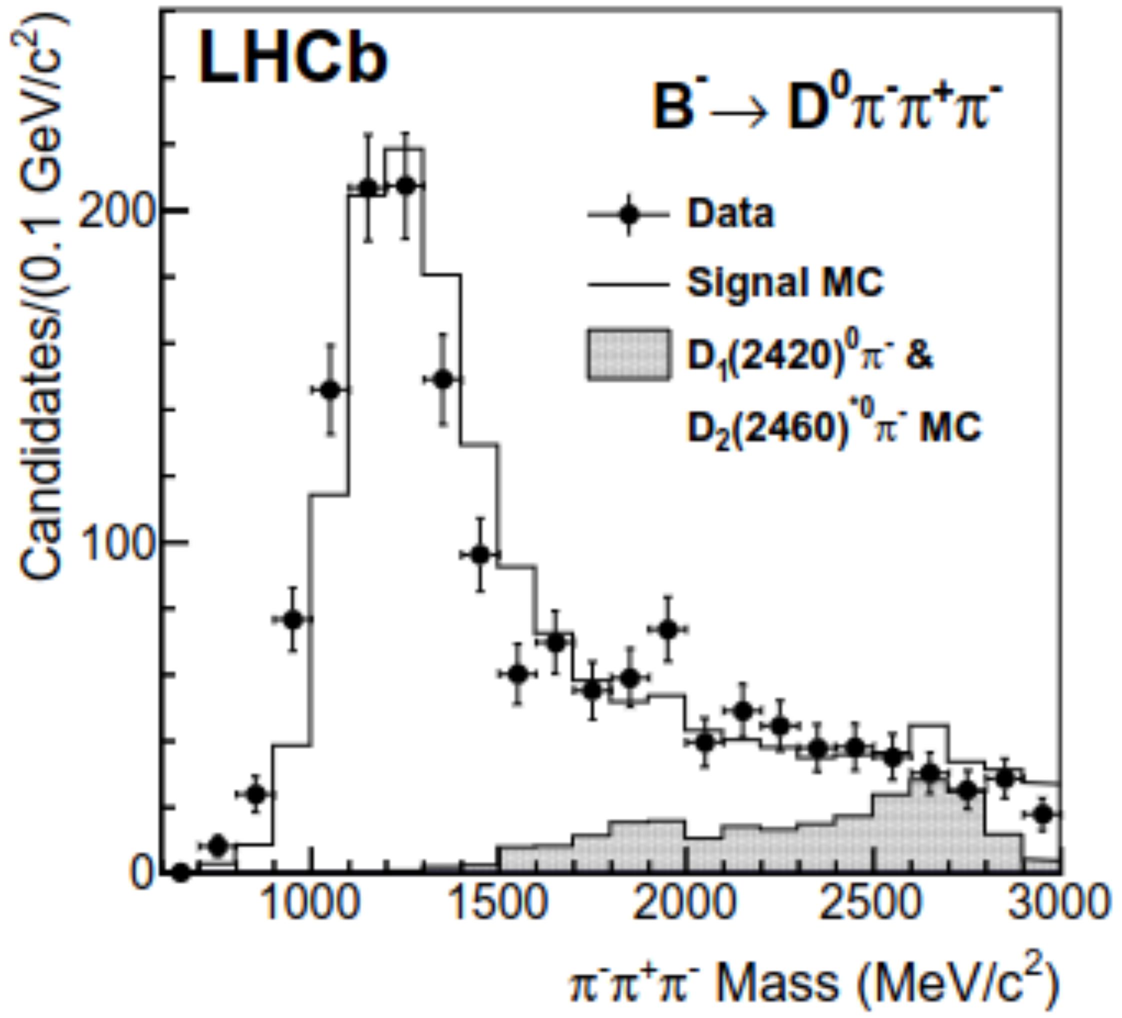
CLEO, 0.89 fb^{-1}
29 years ago
Uses M_{bc}
$\mathscr{B}$ = (1.34 ± 0.18)%
13% uncertainty!

[PRD 50 (1994) 43-68]

CLEO, 9 fb^{-1}
22 years ago
Uses M_{bc}
$\mathscr{B}$ = (1.8 ± 0.4)%
22% uncertainty!

[PRD 64 (2001) 092001]





LHCb, 35 pb^{-1}
12 years ago

But
$\mathscr{B}(B^+ \to \bar{D}^0 a_1^+)$
not provided!

[PRD 84 (2011) 092001]

Updating our MC

[Karim, Meihong, Niharika, Vidya]

Decay model of B mesons is made of explicitly listed decays in DECAY.DEC + ~40% unknown decays modelled by PYTHIA.

Better interpretations of measurements:

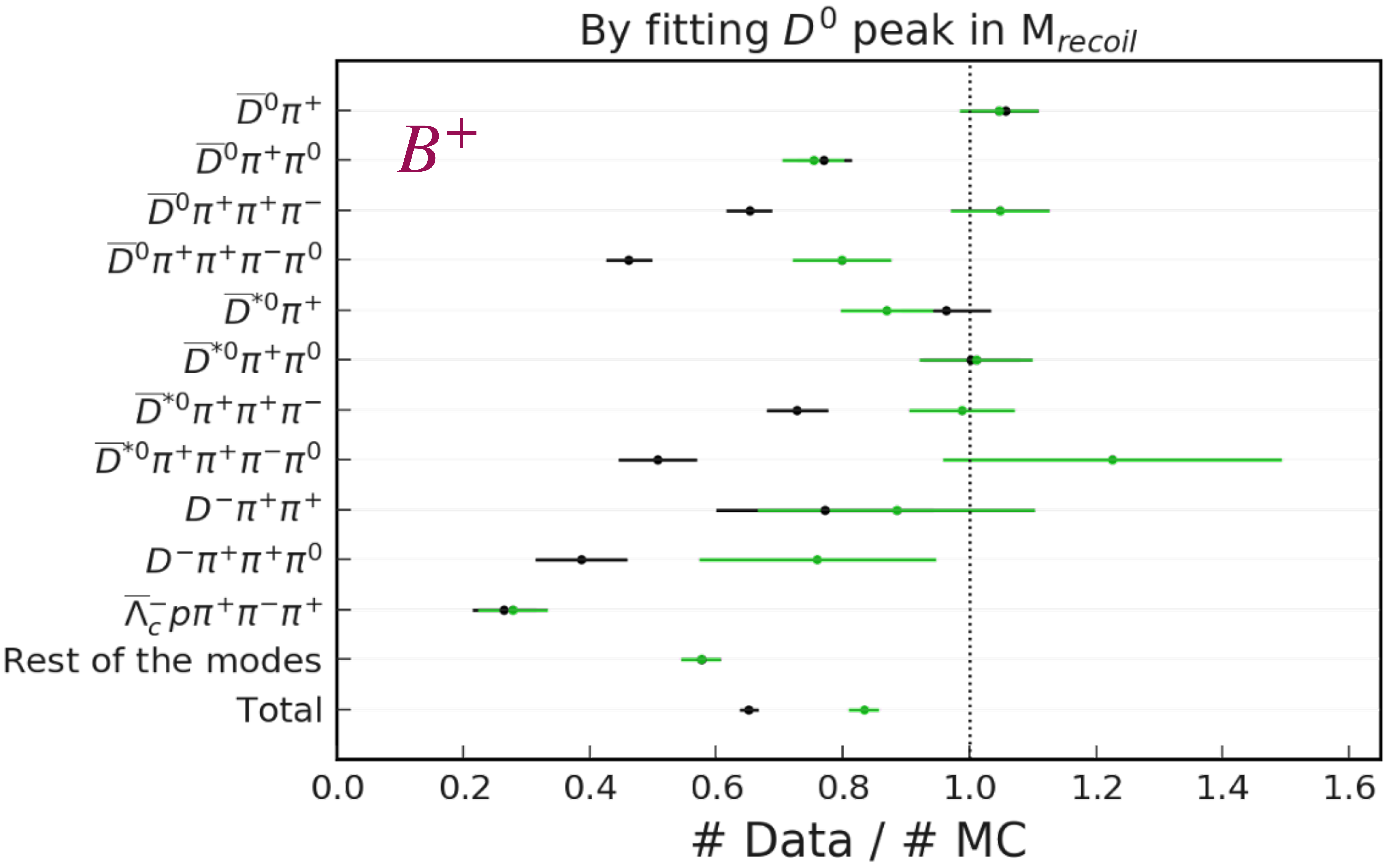
- Correcting misinterpretations of inclusive BF measurement as non-resonant component.
- Avoiding PYTHIA generating additional components
- Updating the decay model of D^{**}
- Removing obviously wrong components

New MC is produced: MC15ri-up and also official for future Belle II production.

MC is first modified based on our best understanding.
And $D\pi$ sample is used to validate.

Updated CF

[Karim, Meihong, Niharika, Vidya]



Old MC

New MC

Yields are getting closer to data

Overall calibration factor: 65% ➡️ 83%

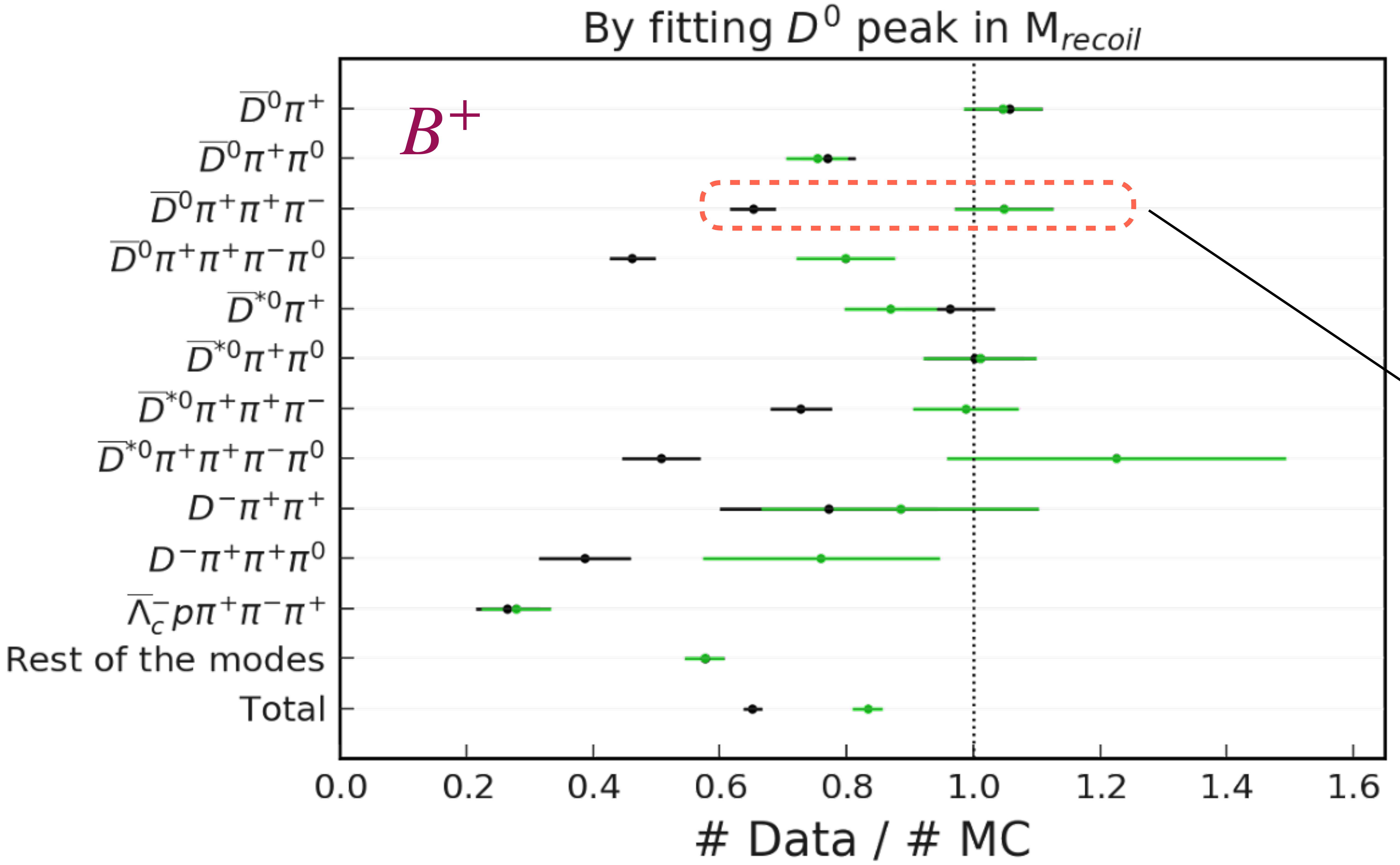
For the top 10 decay modes: 68% ➡️ 92%

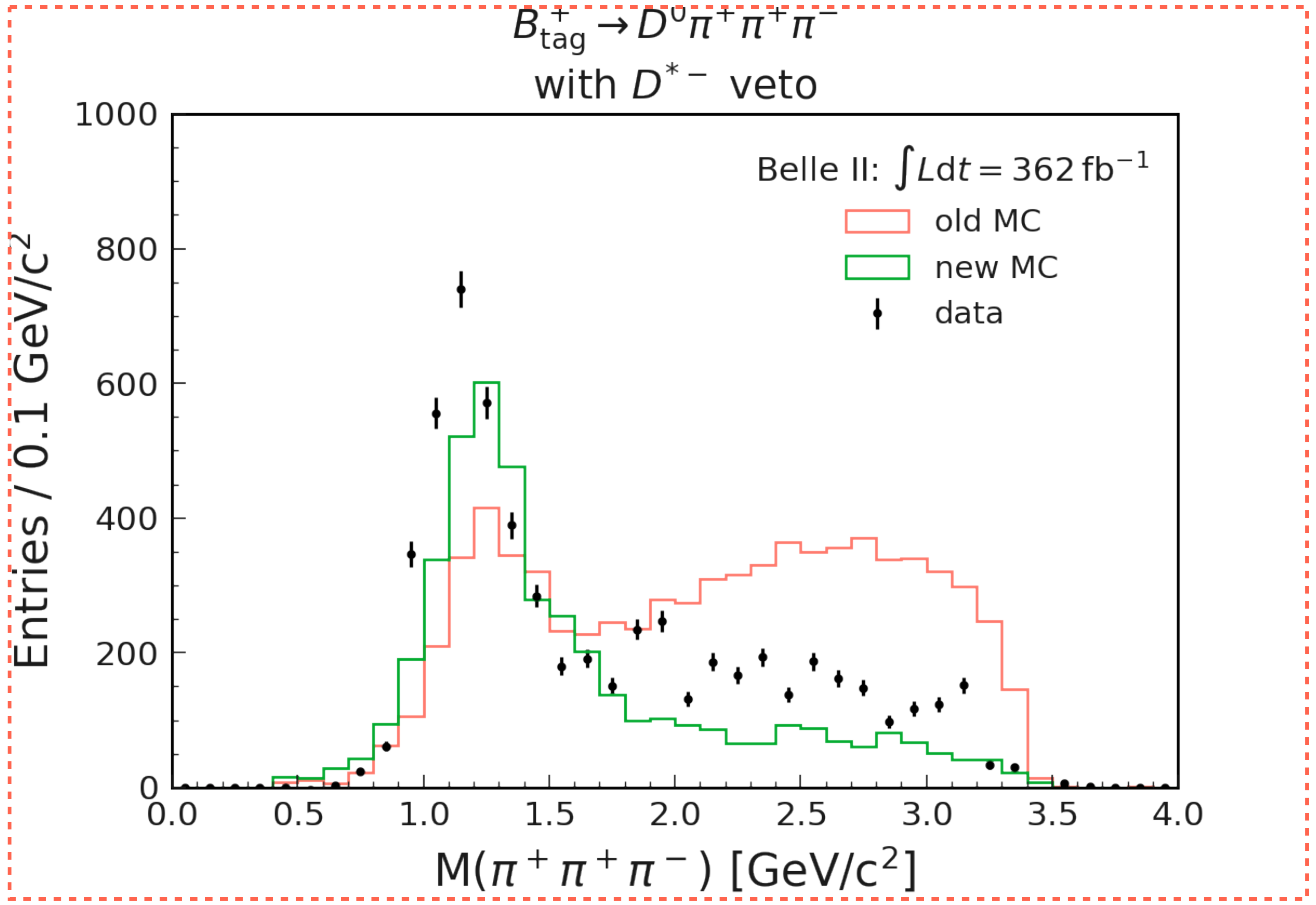
Reminder

MC is first modified based on our best understanding.

And $D\pi$ sample is used to validate.

Decay kinematics improves too…

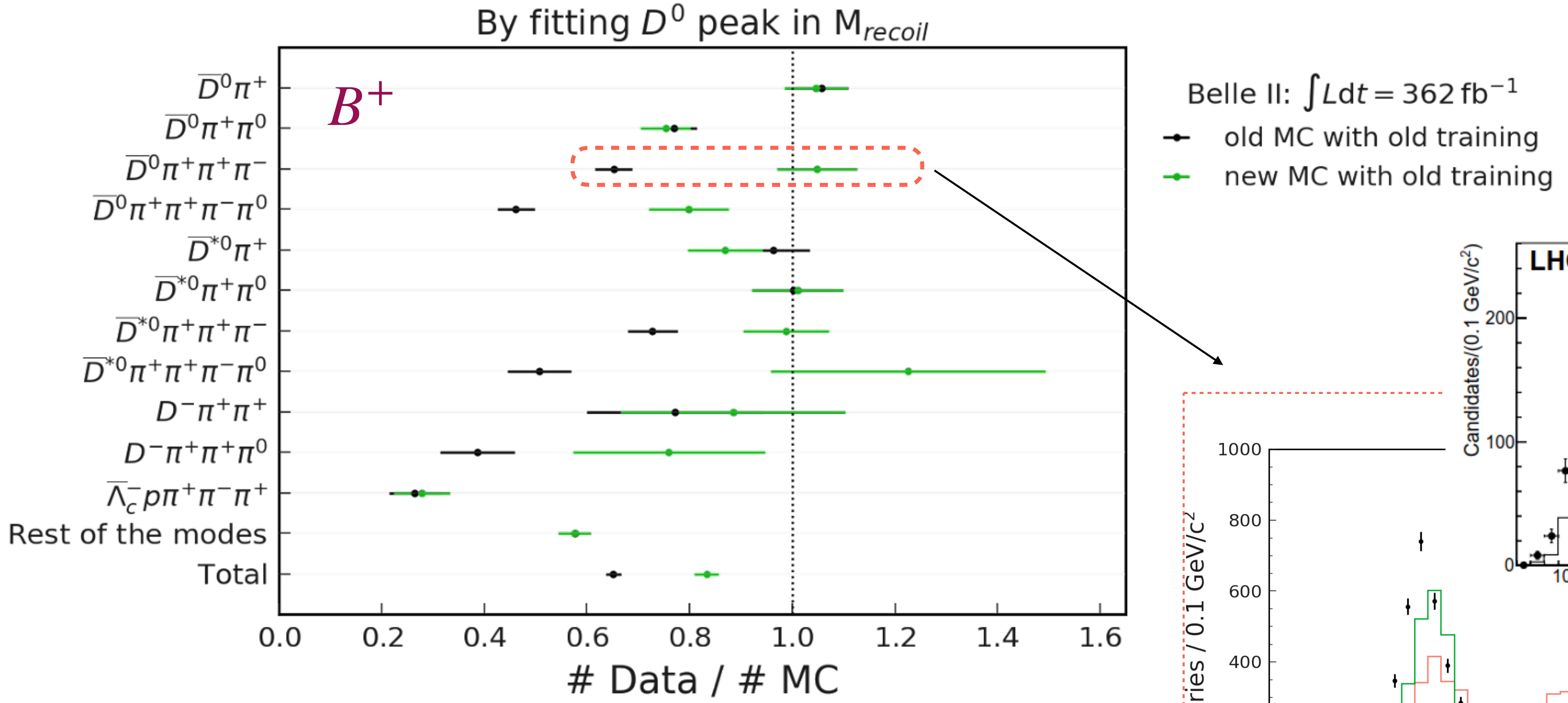


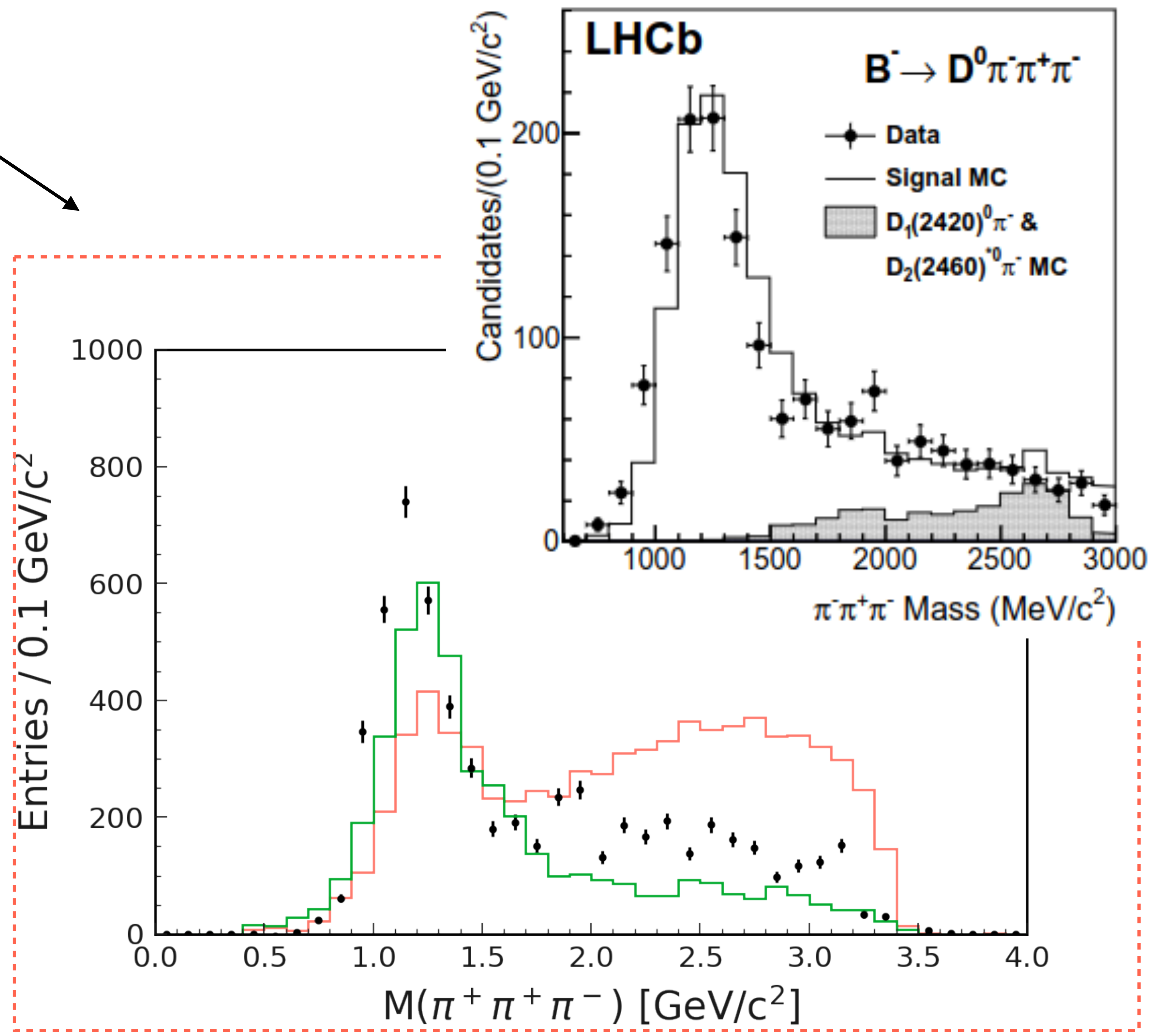


Overall calibration factor: 65% ➡️ 83%

For the top 10 decay modes: 68% ➡️ 92%

Decay kinematics improves too…

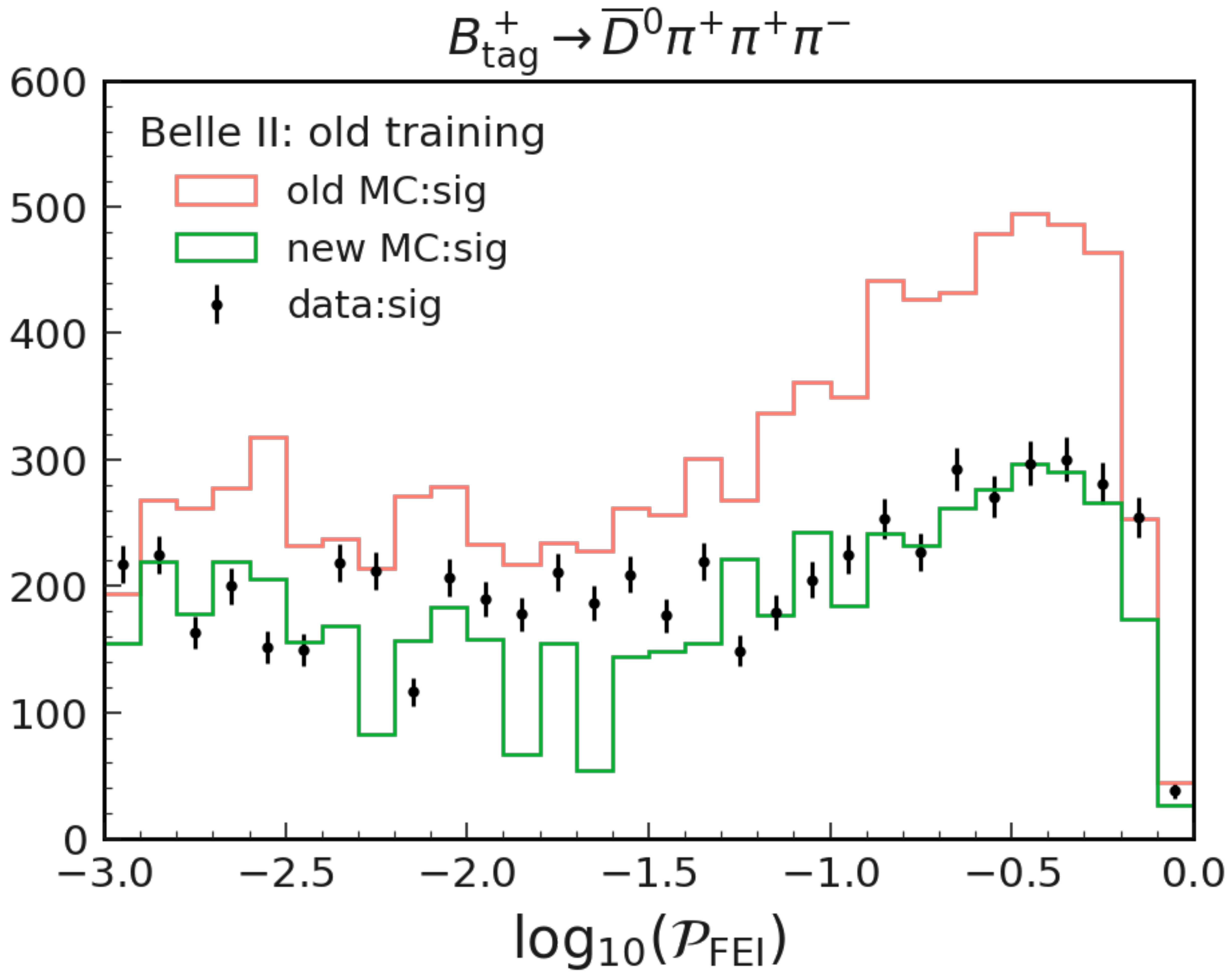




Overall calibration factor: 65% ➡️ 83%

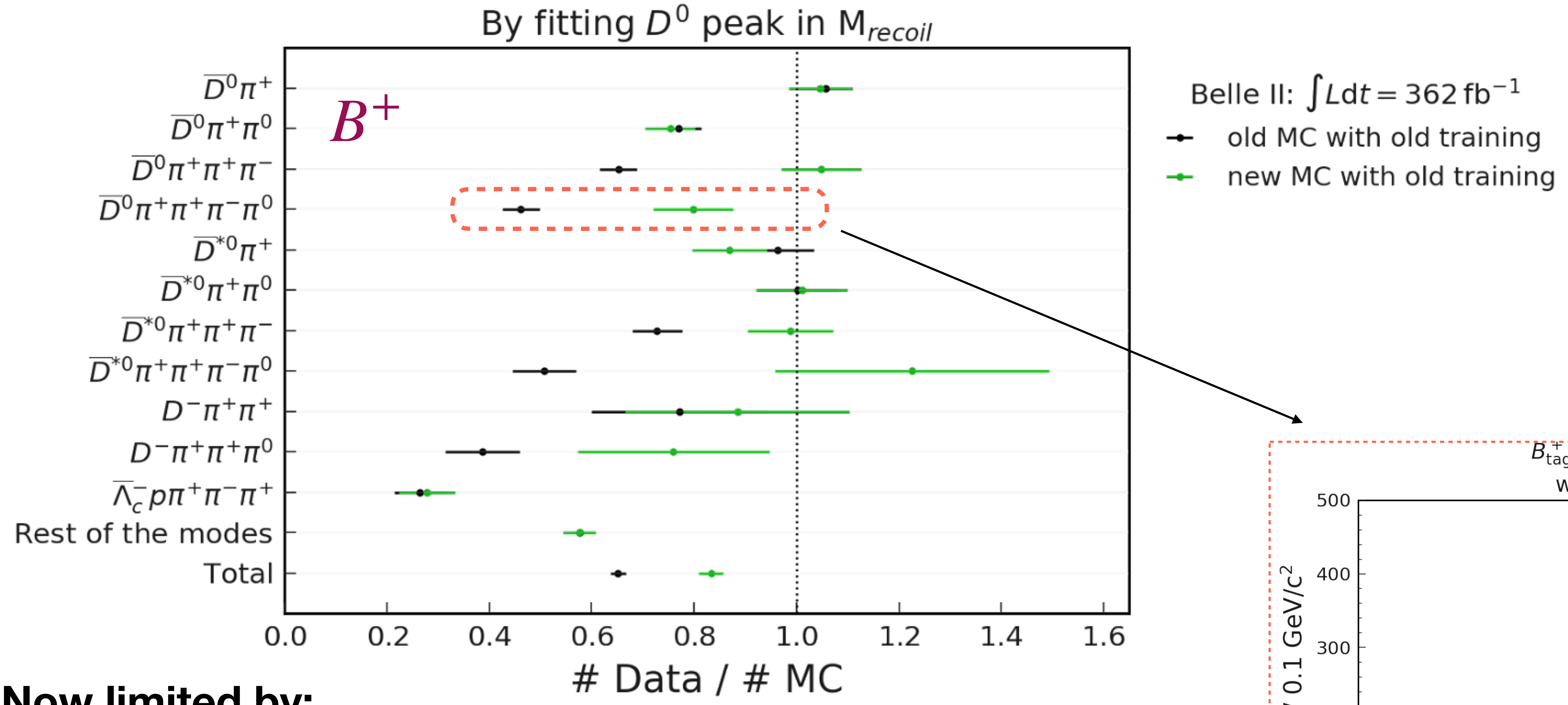
For the top 10 decay modes: 68% ➡️ 92%

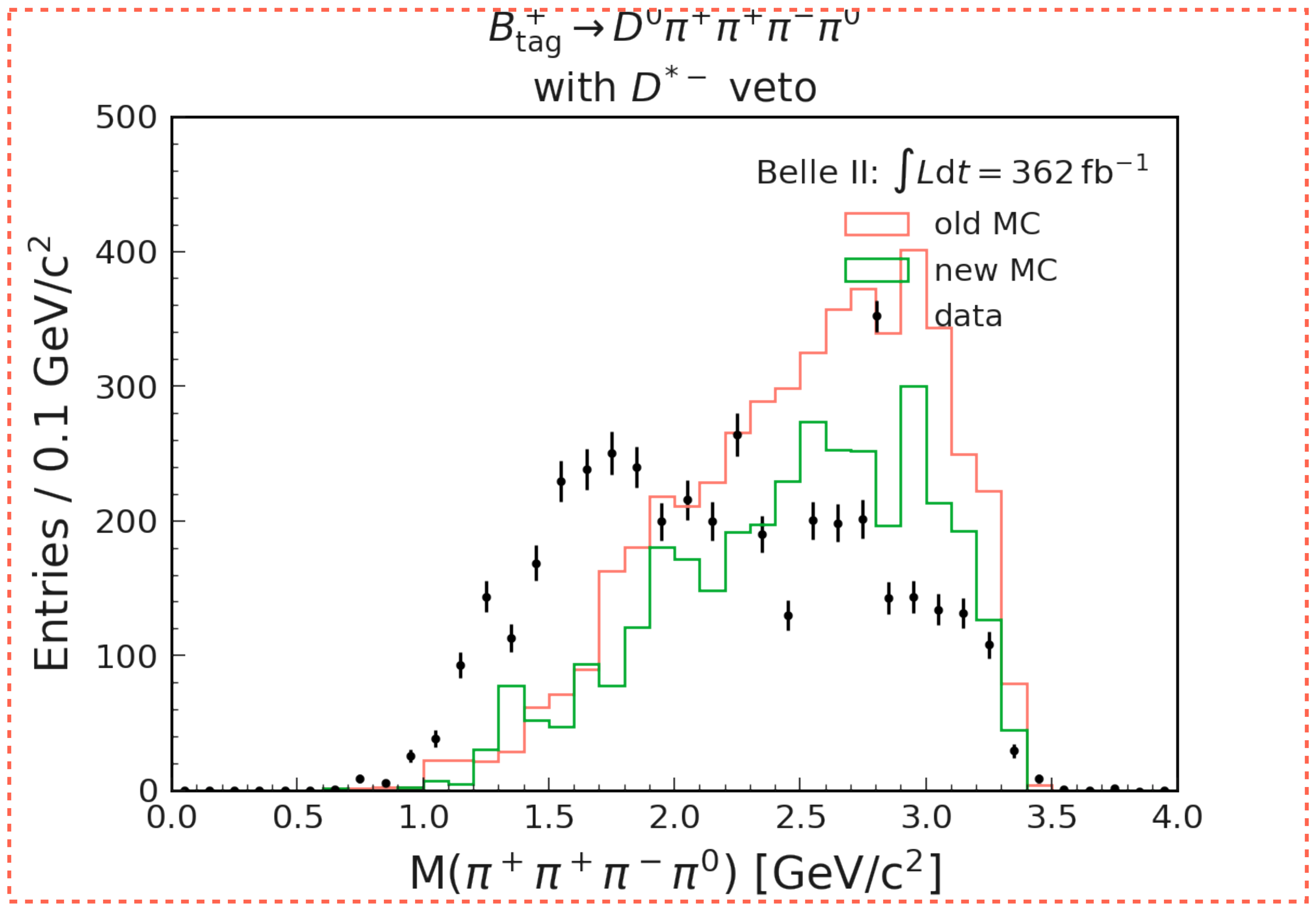
Also, better signal probability..



BDT output is closer to data

What's left: need more measurements..

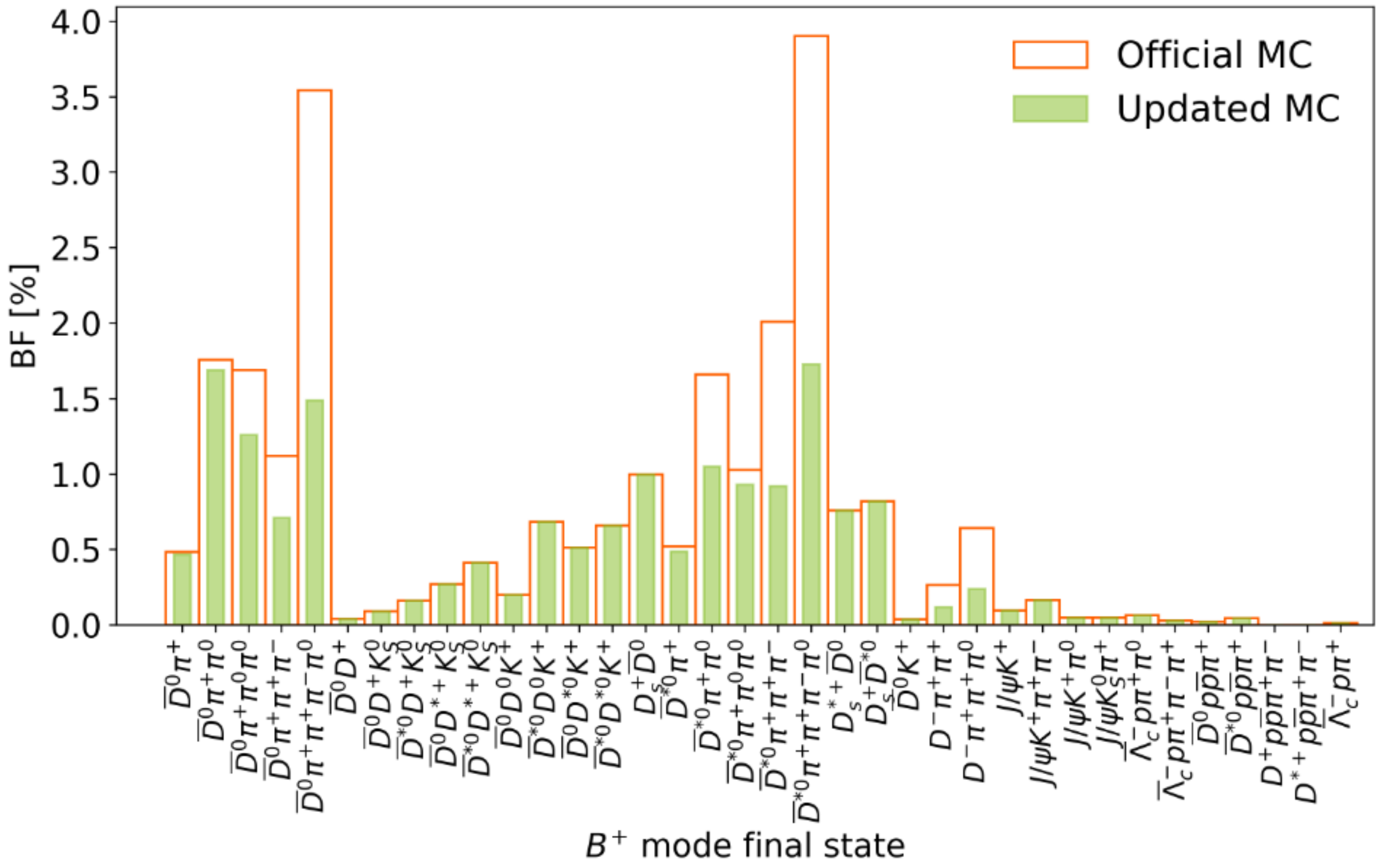


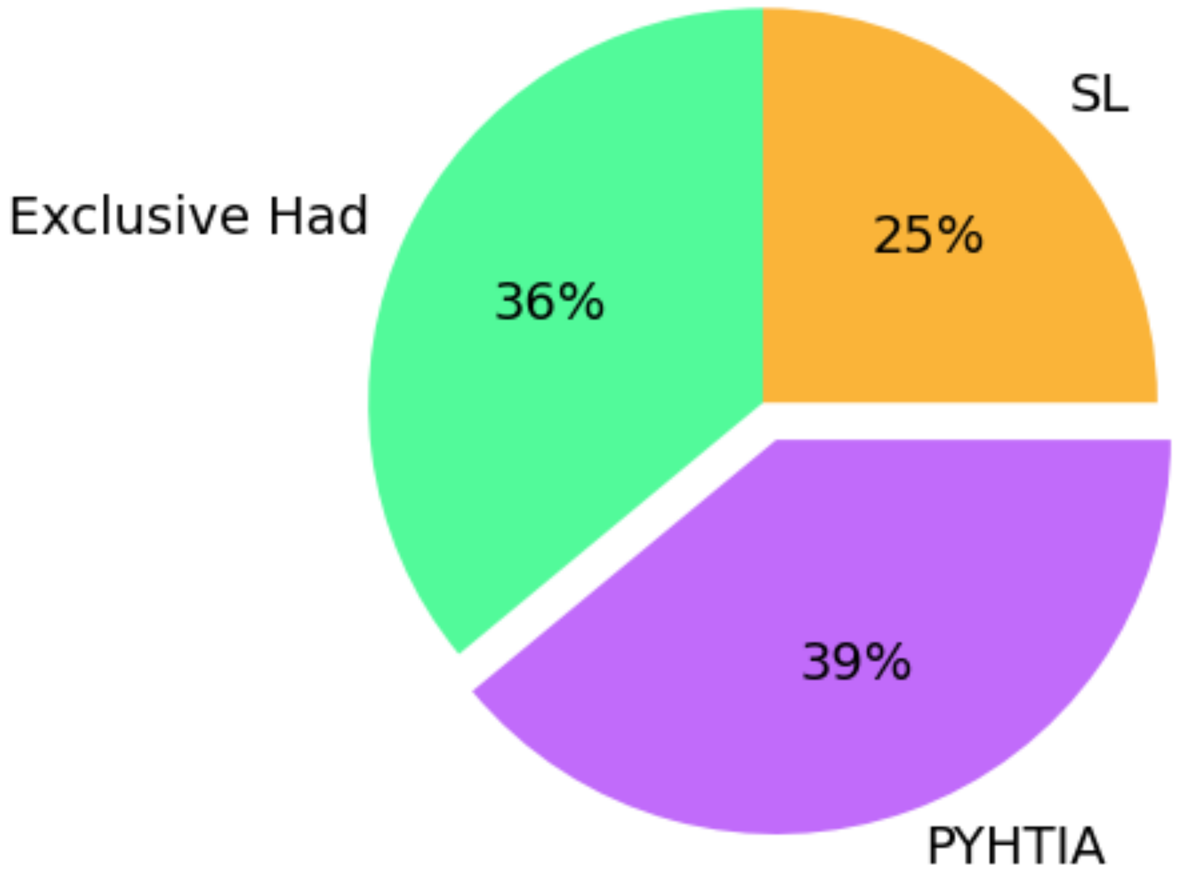


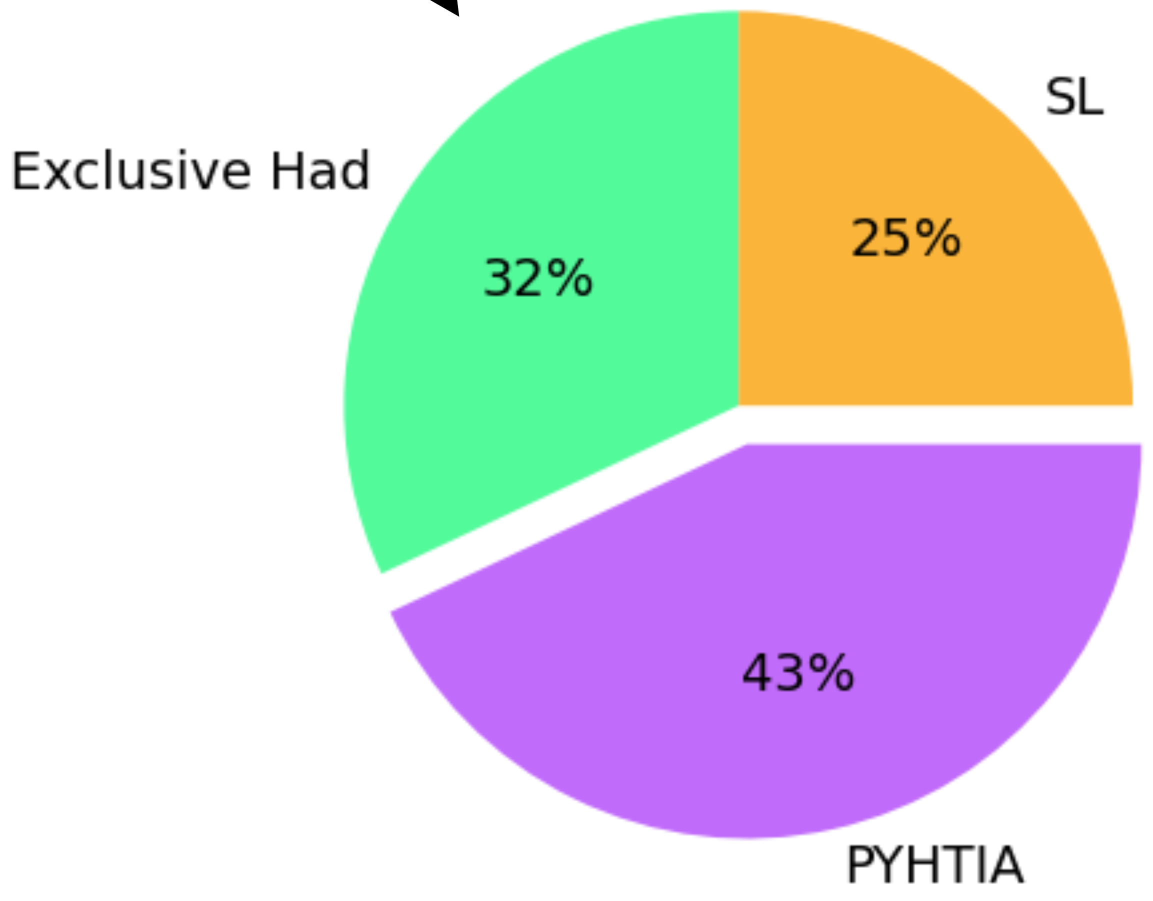
Now limited by:

- Old and statistically limited measurements like $D^0\pi\pi^0$ and $\Lambda_c p\pi\pi\pi$
- And dependance on PYTHIA for $D^{(*)}\pi\pi\pi\pi^0$ which account for $> 15\%$ of the total efficiency.

How does our MC look now



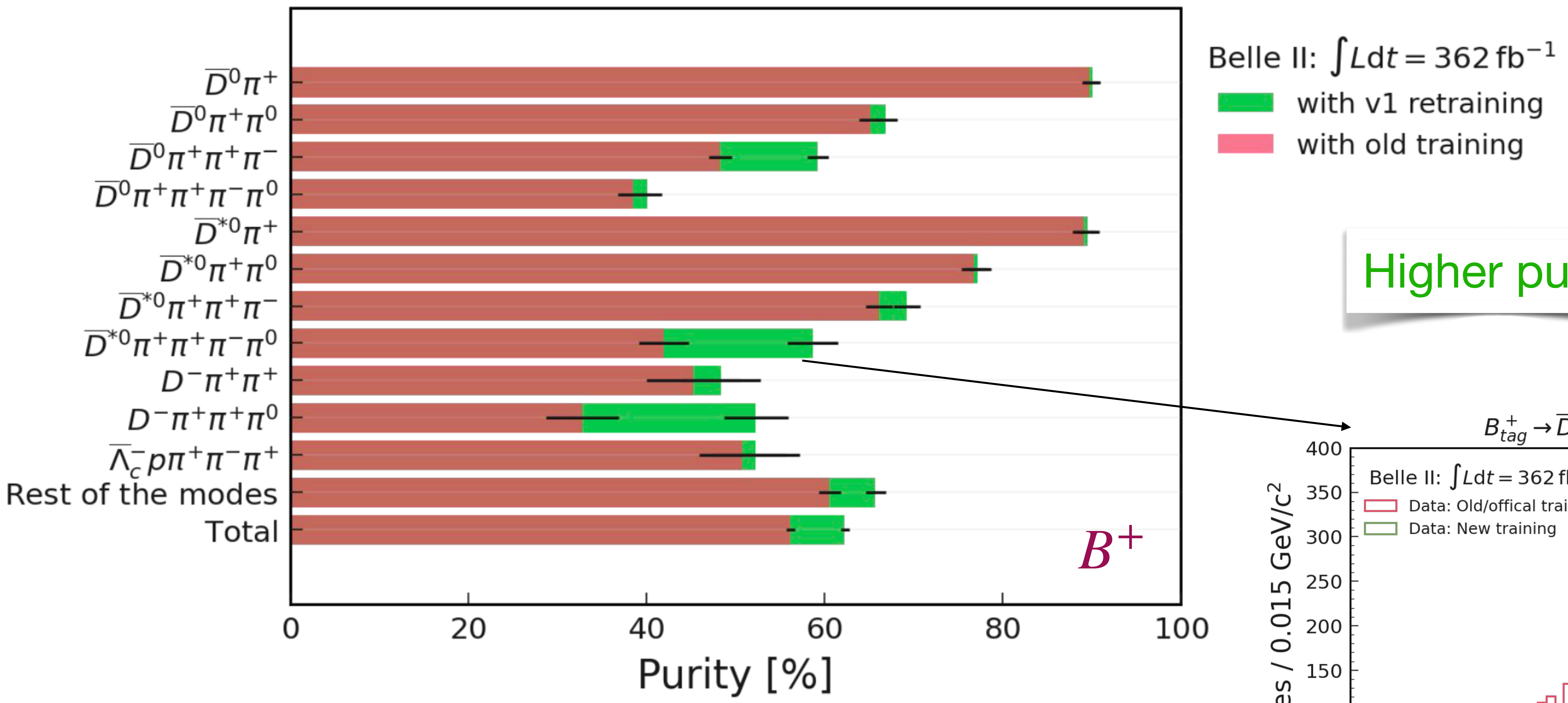




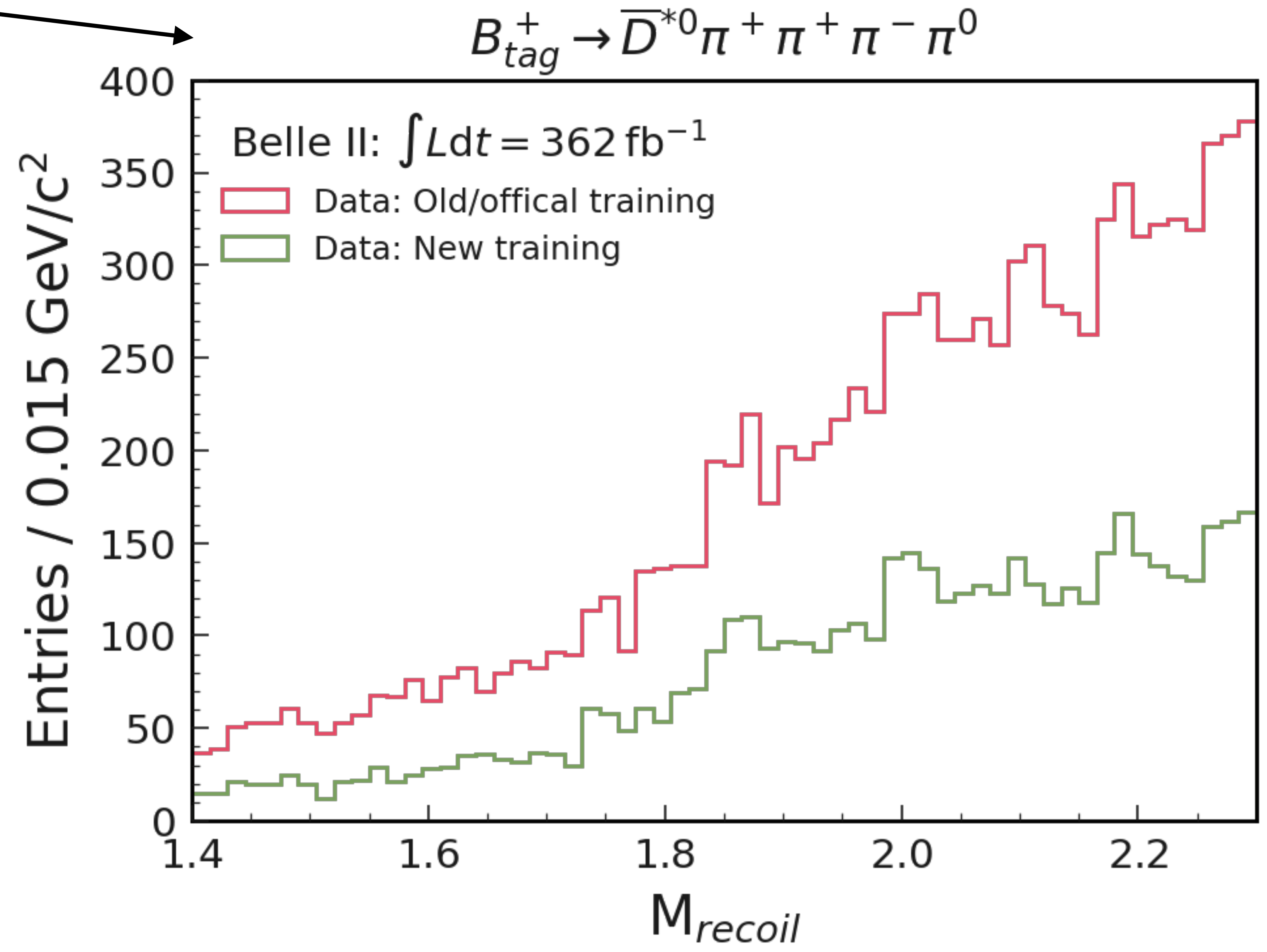
Increase in unknown generated by PYTHIA, but the PYTHIA component of relevant modes decreased

Training with new MC

[Karim, Vidya]



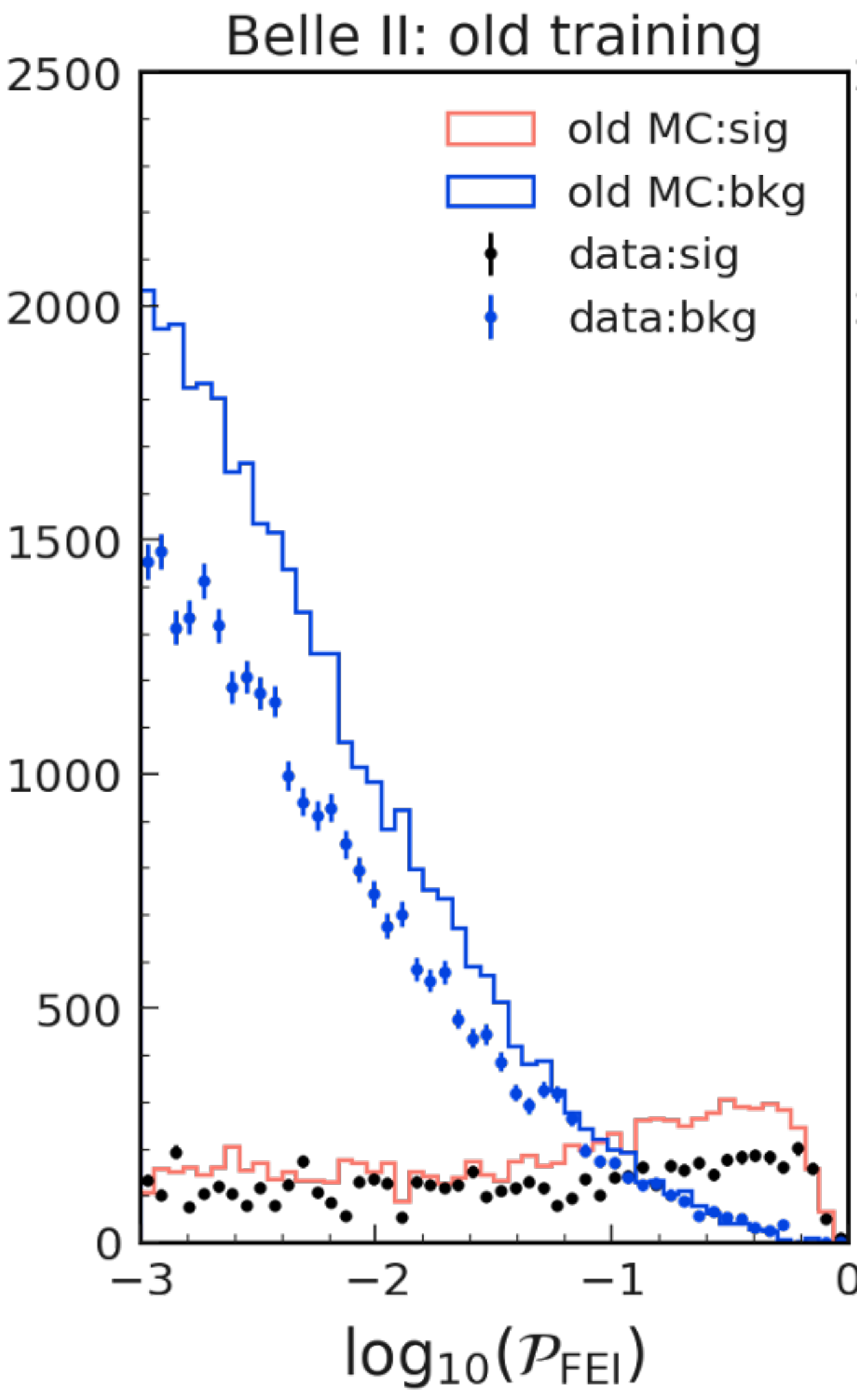
Higher purity

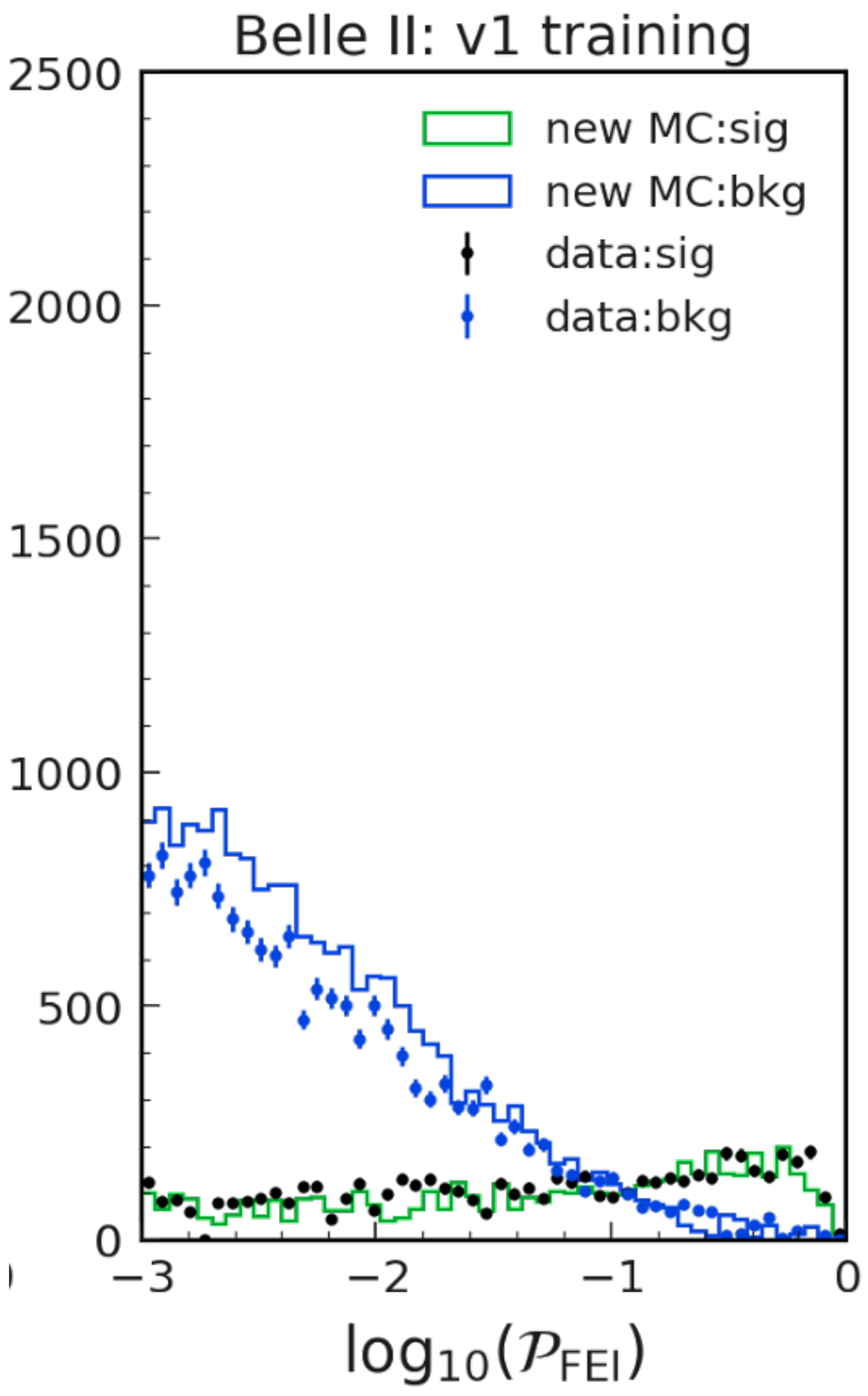


Training with new MC

[Karim, Vidya]

$B^+_{\text{tag}} \to \overline{D}^0 \pi^+ \pi^+ \pi^-$

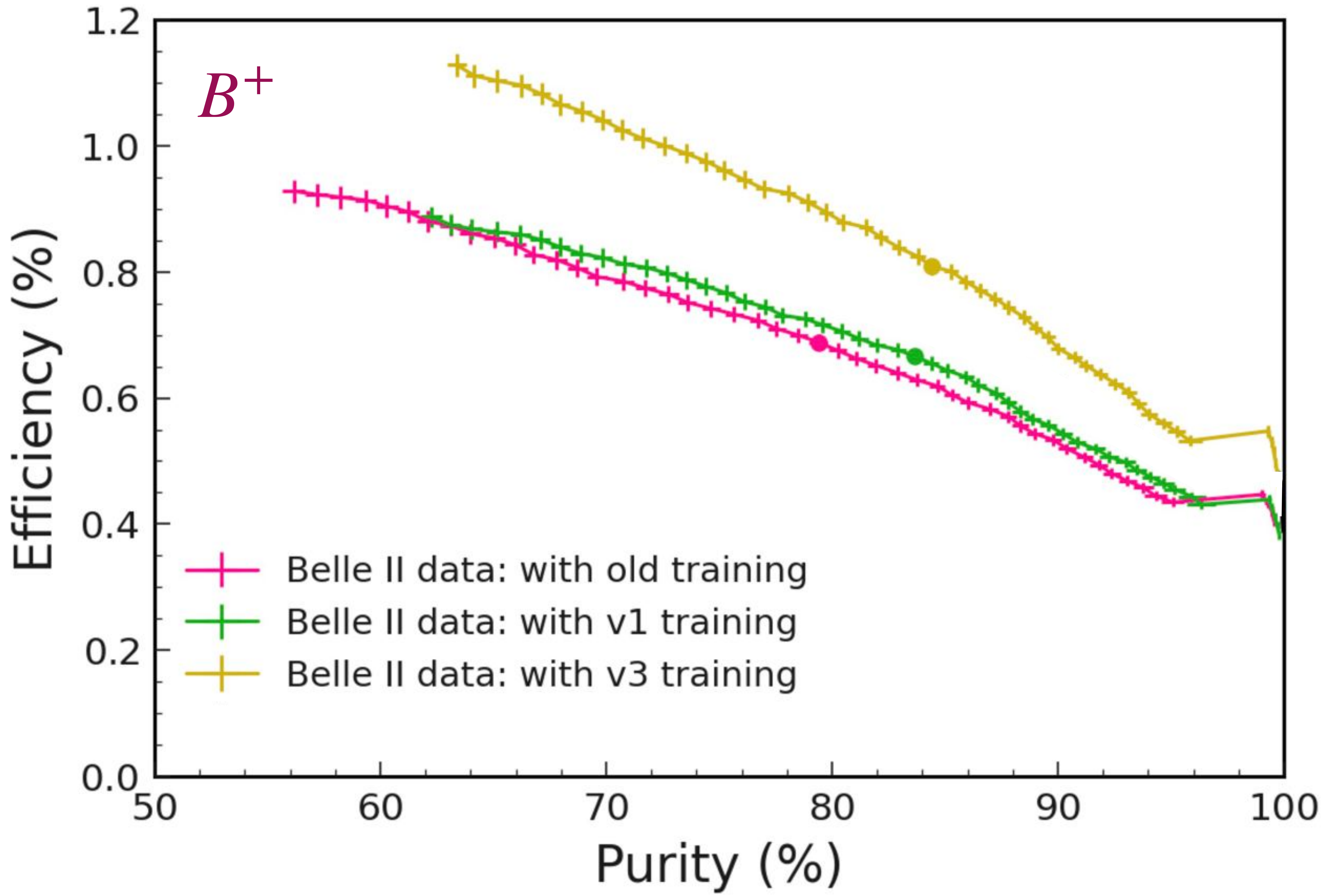




- Background decreases
- Better signal probability agreement both for signal and background

Also, the slow π^0 efficiency is fixed and mass constraint is added.

[Karim, Vidya]



Both efficiency and purity have improved

Training weights publicly available:
light-2205-abys_fei_retrain_3

Overall improvement

- Updated decay model for 11 most efficient B decay modes

  0.65 → 0.81 : **25% ⬆️ in Calibration factor**

- Training with the new MC

  56% → 63% : **12% ⬆️ in purity**

- Loosen the γ preselection and mass-constraint π^0

  0.93% → 1.13% : **21% ⬆️ in efficiency**

Training weights publicly available:
light-2205-abys_fei_retrain_3

Reminder

Vidya@PGM

Timeline for FEI

For winter 2024 conferences :

- Use MC15rd + light-2305-korat (or earlier)
- Use existing training i.e., no improvements
- Skims and calibration available
- Use MC15ri-up for validations

For summer 2024 conferences:

- Use MC15rd-up + light-2307-laperm (or later)
- Retrain with new MC and new precuts i.e., all improvements
- Skimming and calibration should be repeated.

Summary

No summary… ✖

Questions?

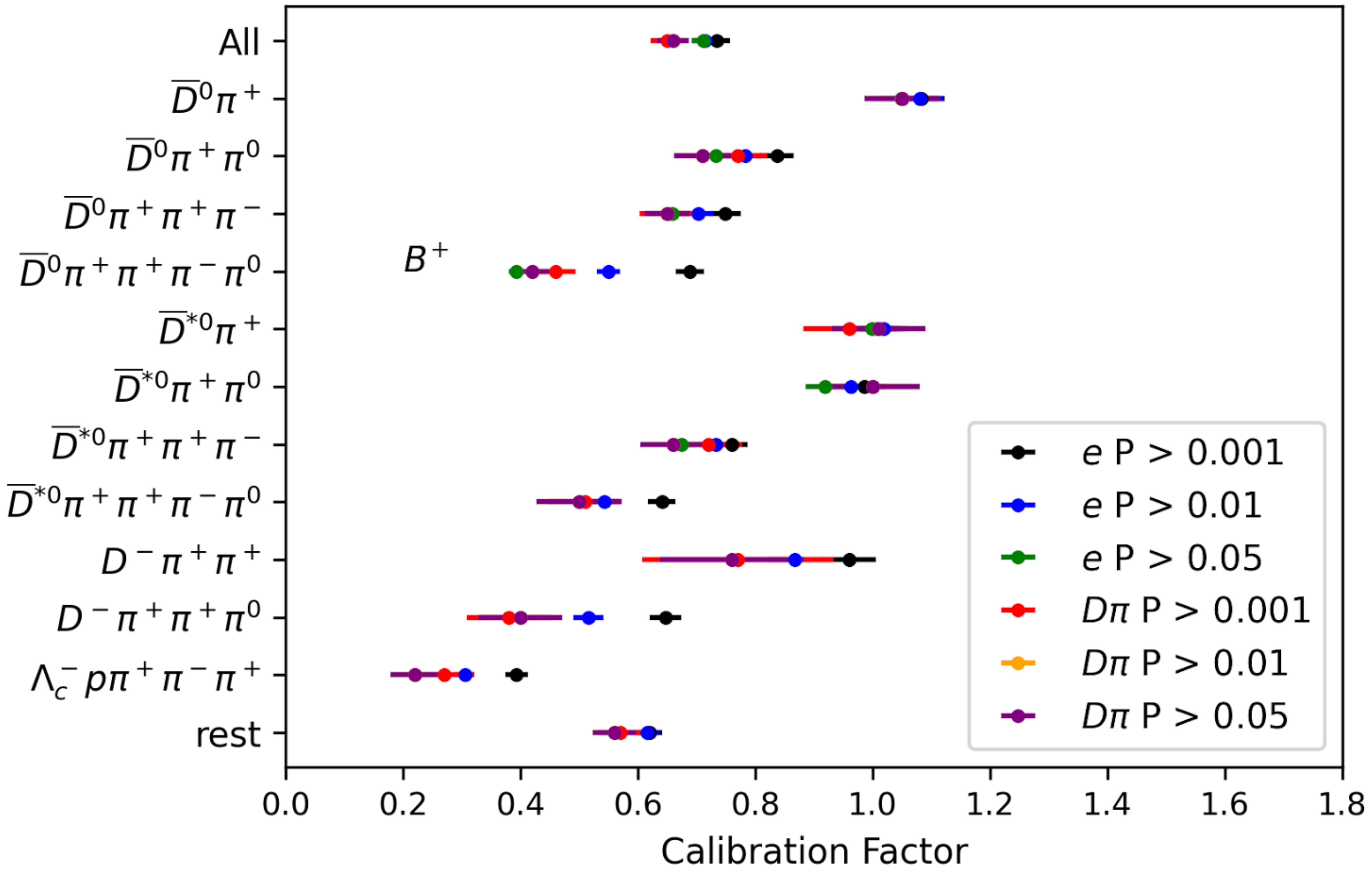
Ask now!!!

or email at:

niharika.rout@ts.infn.it
vidya.vobbilisetti@ijclab.in2p3.fr

Backup

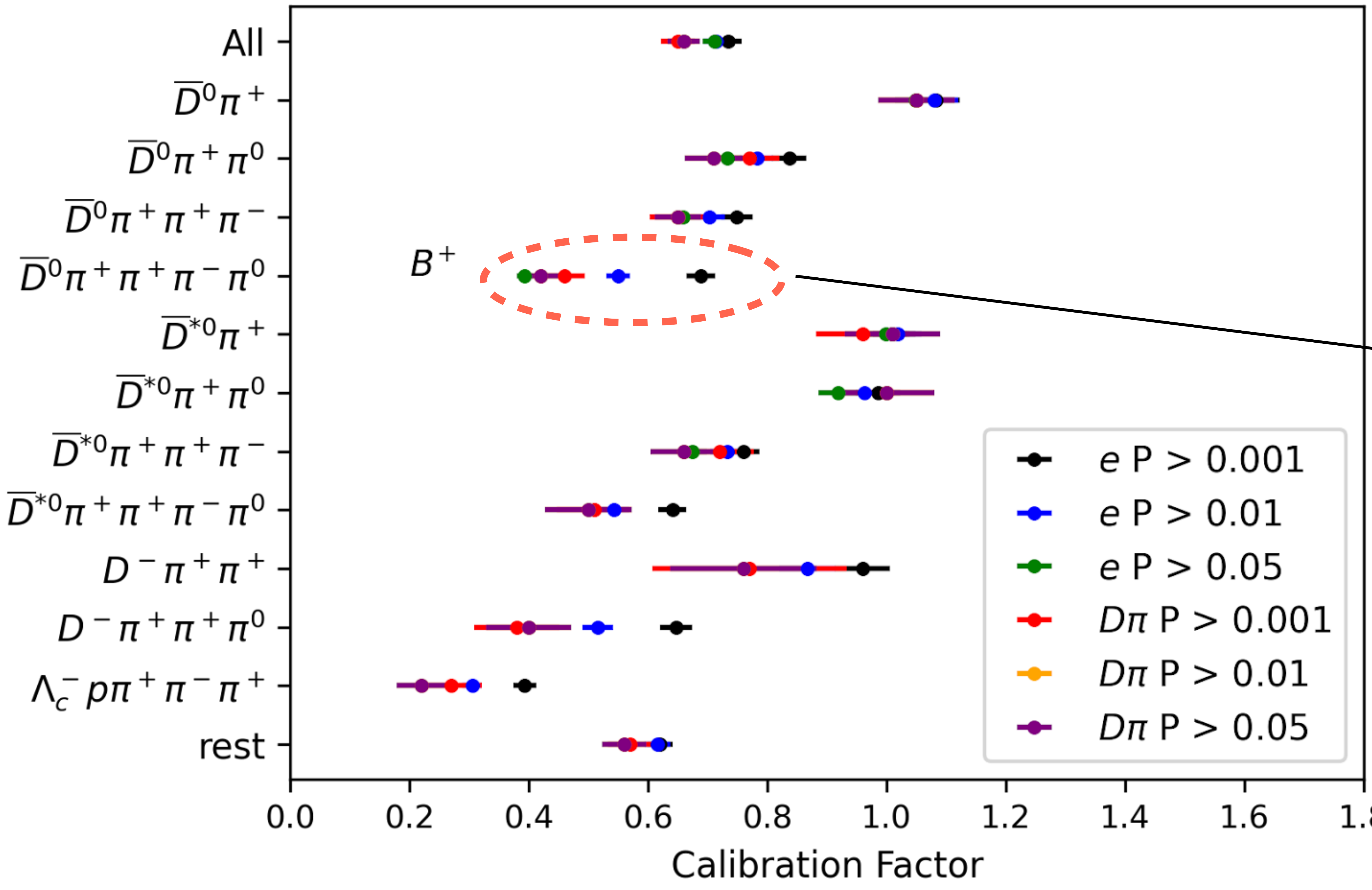
At different sig-prob cuts



The agreement gets better when the sig-prob cut is tighter for the $Xe\nu$ case, i.e, when the purity is better

Backup

At different sig-prob cuts



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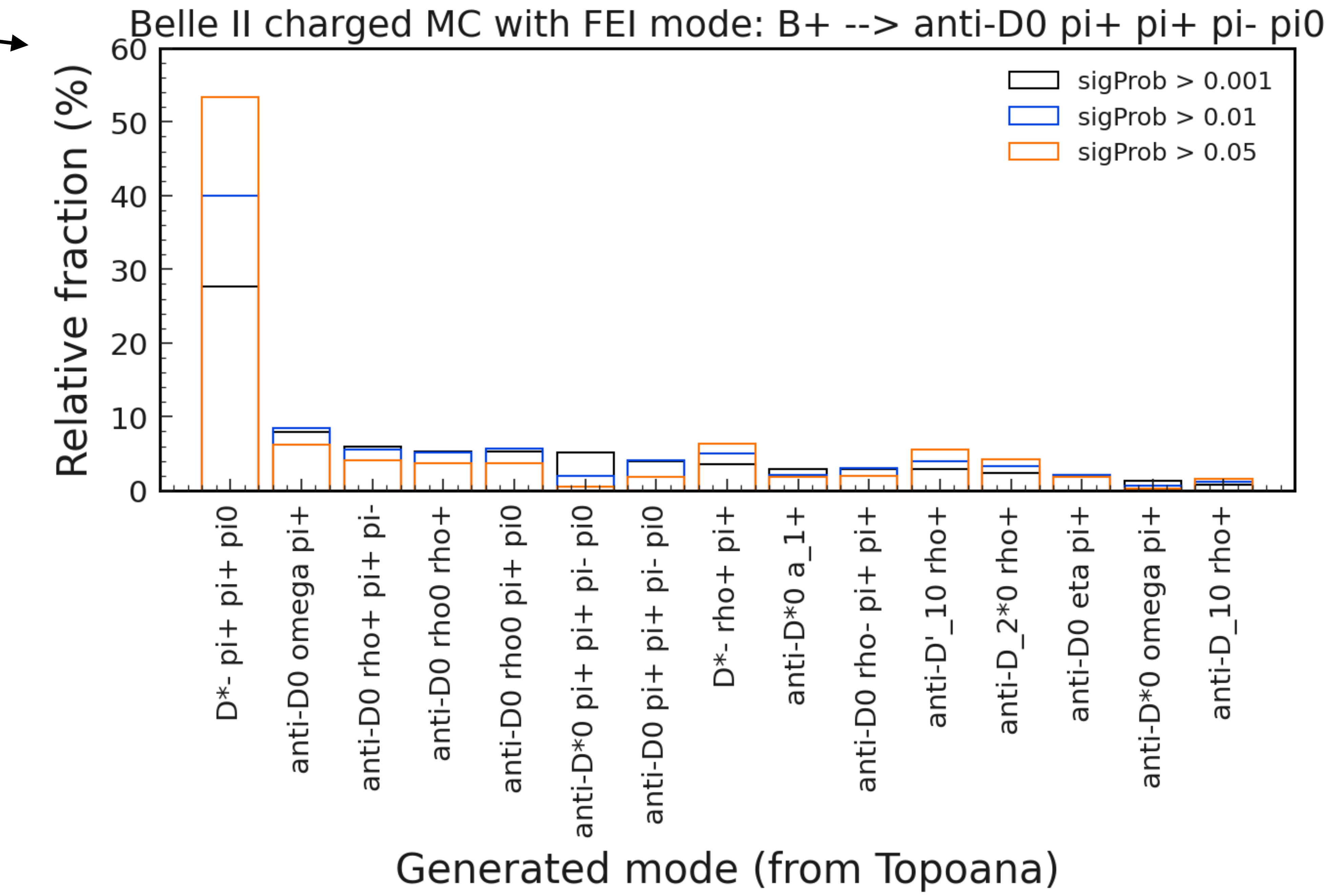
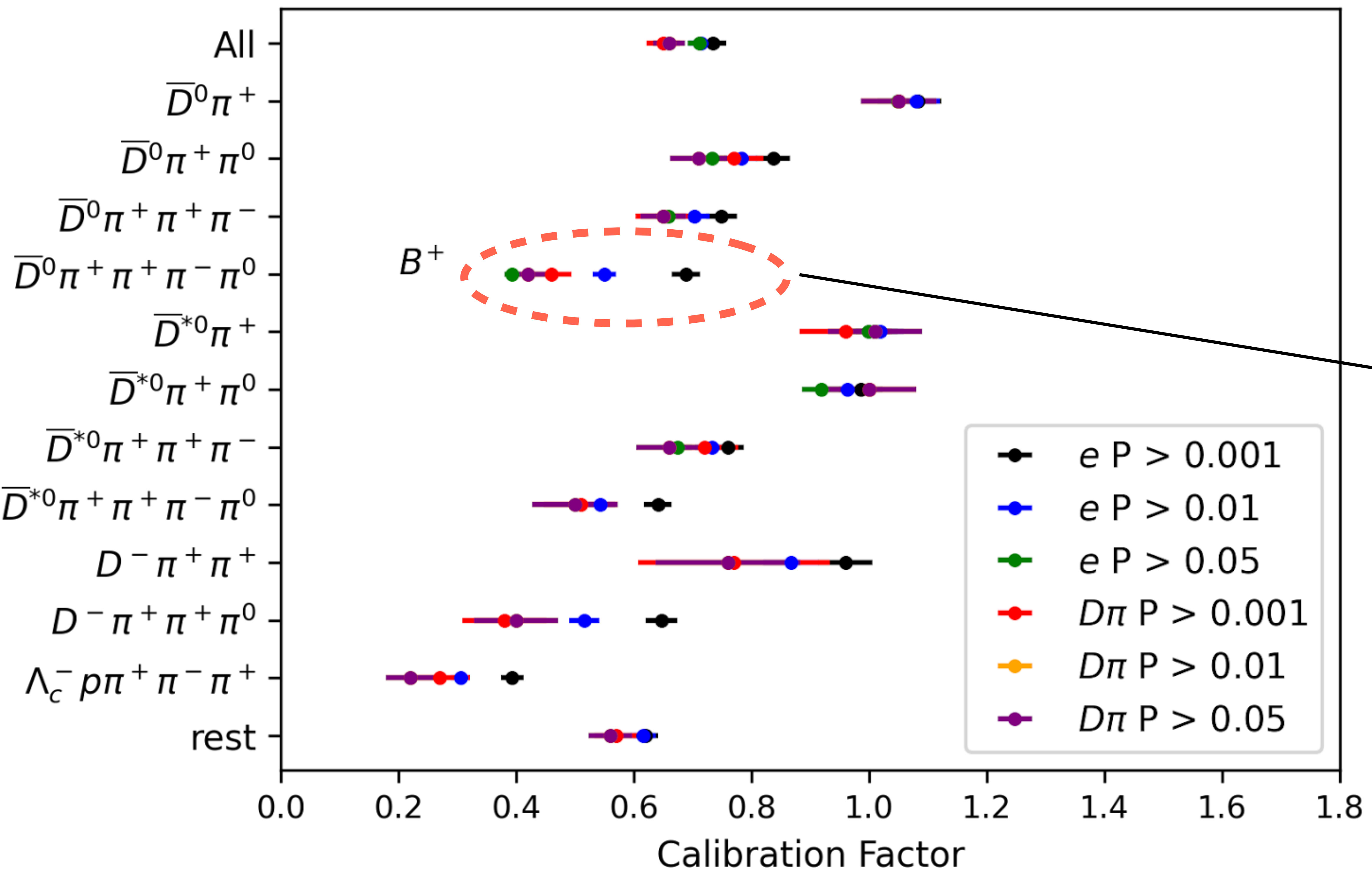
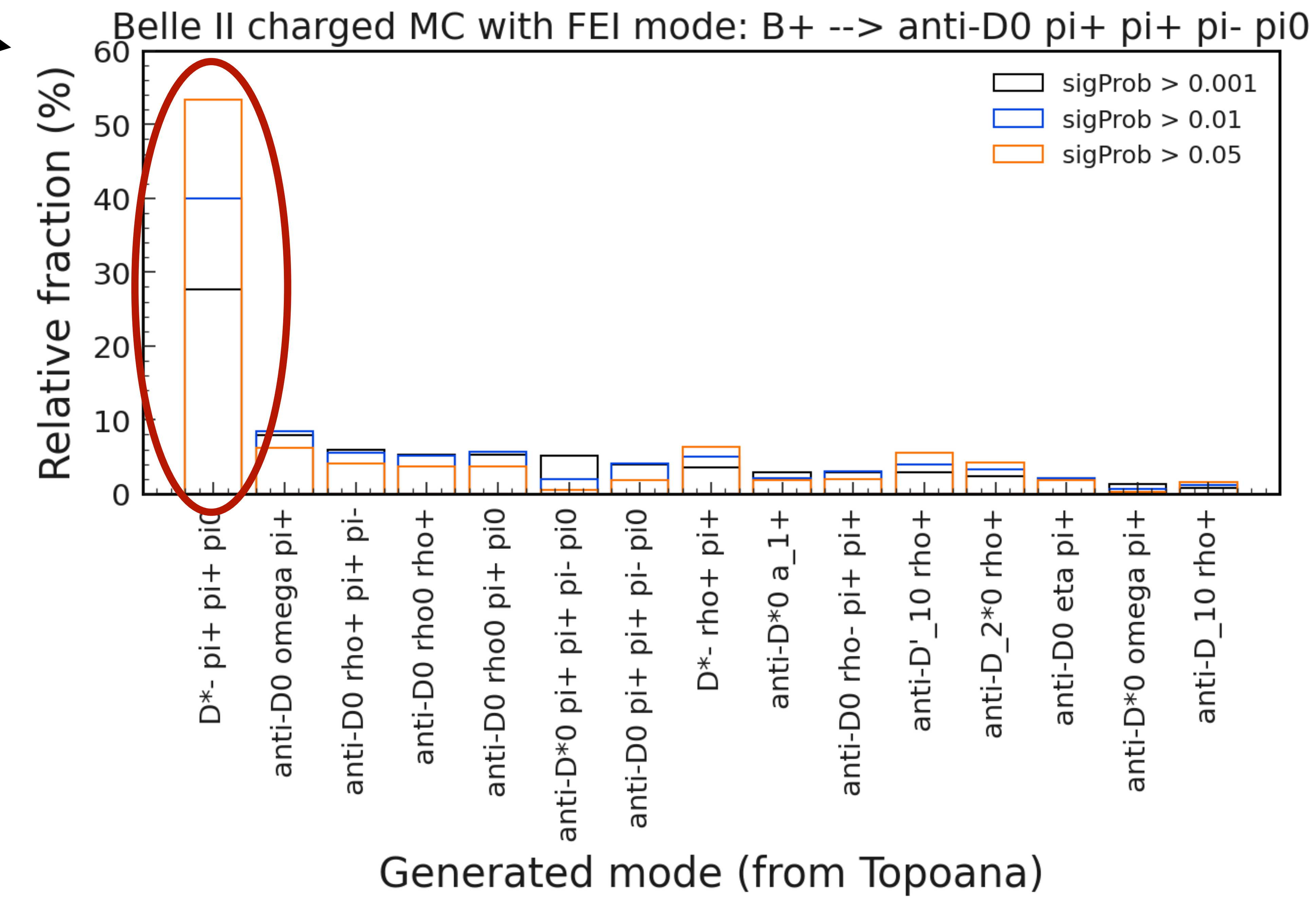


Backup

At different sig-prob cuts



The agreement gets better when the sig-prob cut is tighter for the $Xe\nu$ case, i.e, when the purity is better



Tighter sigProb cut

⇒ higher purity

⇒ Certain components are enhanced than others

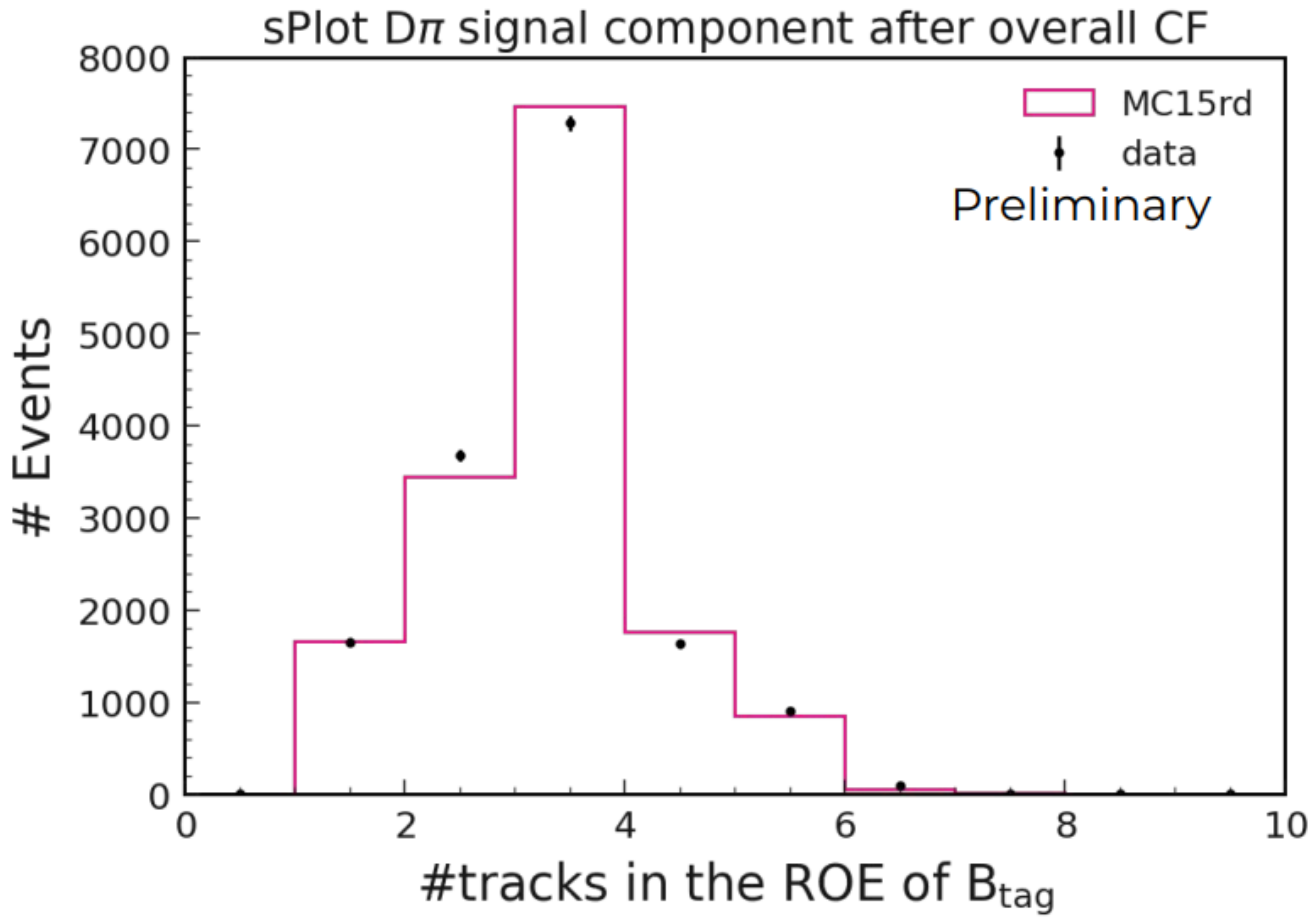
⇒ In this case, the enhanced one is old & bad measurement

⇒ Decreasing the CF

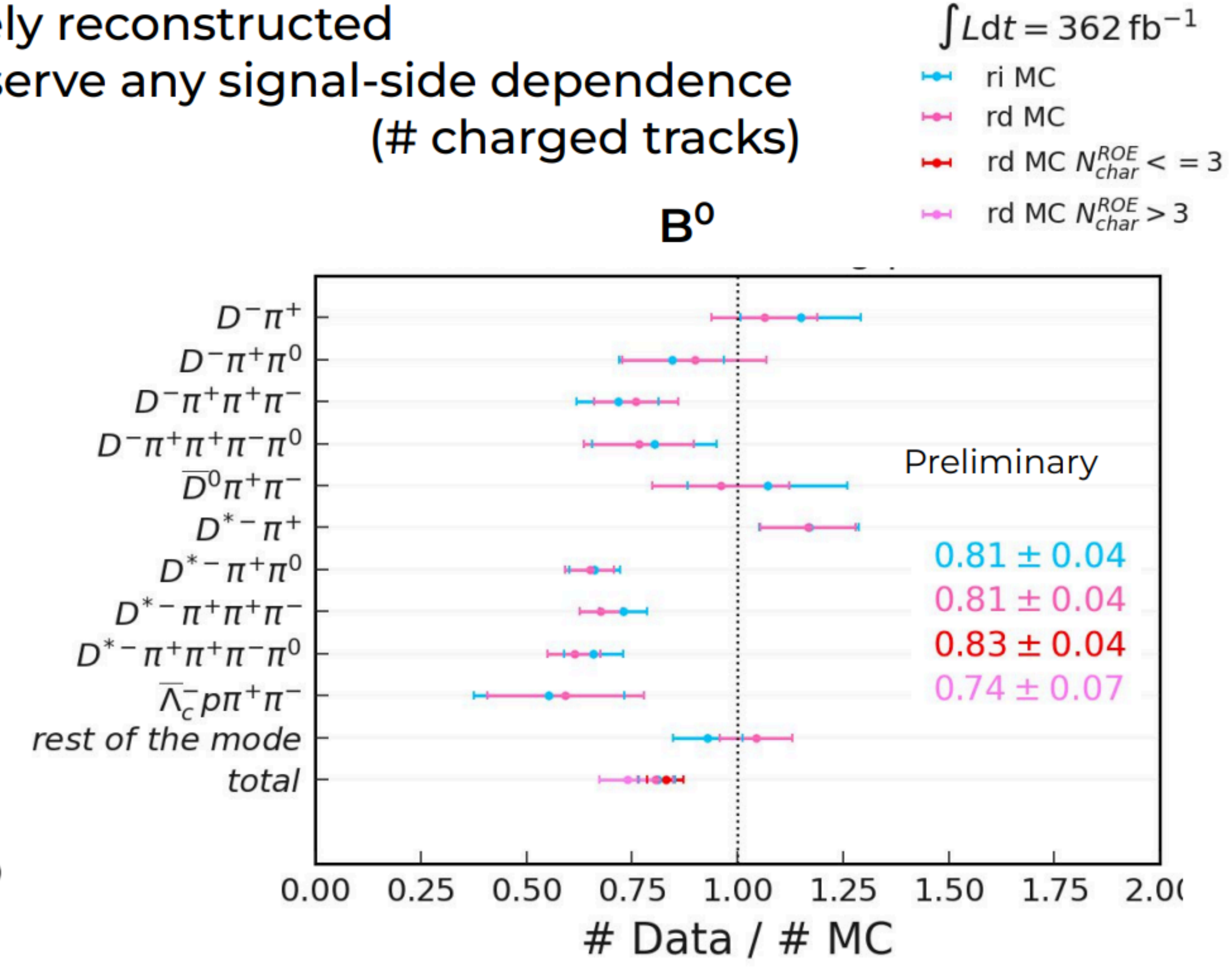
Signal-side dependency

- In Dπ sample, the D meson is inclusively reconstructed
- The ROE of the B_{tag} can be used to observe any signal-side dependence (# charged tracks)

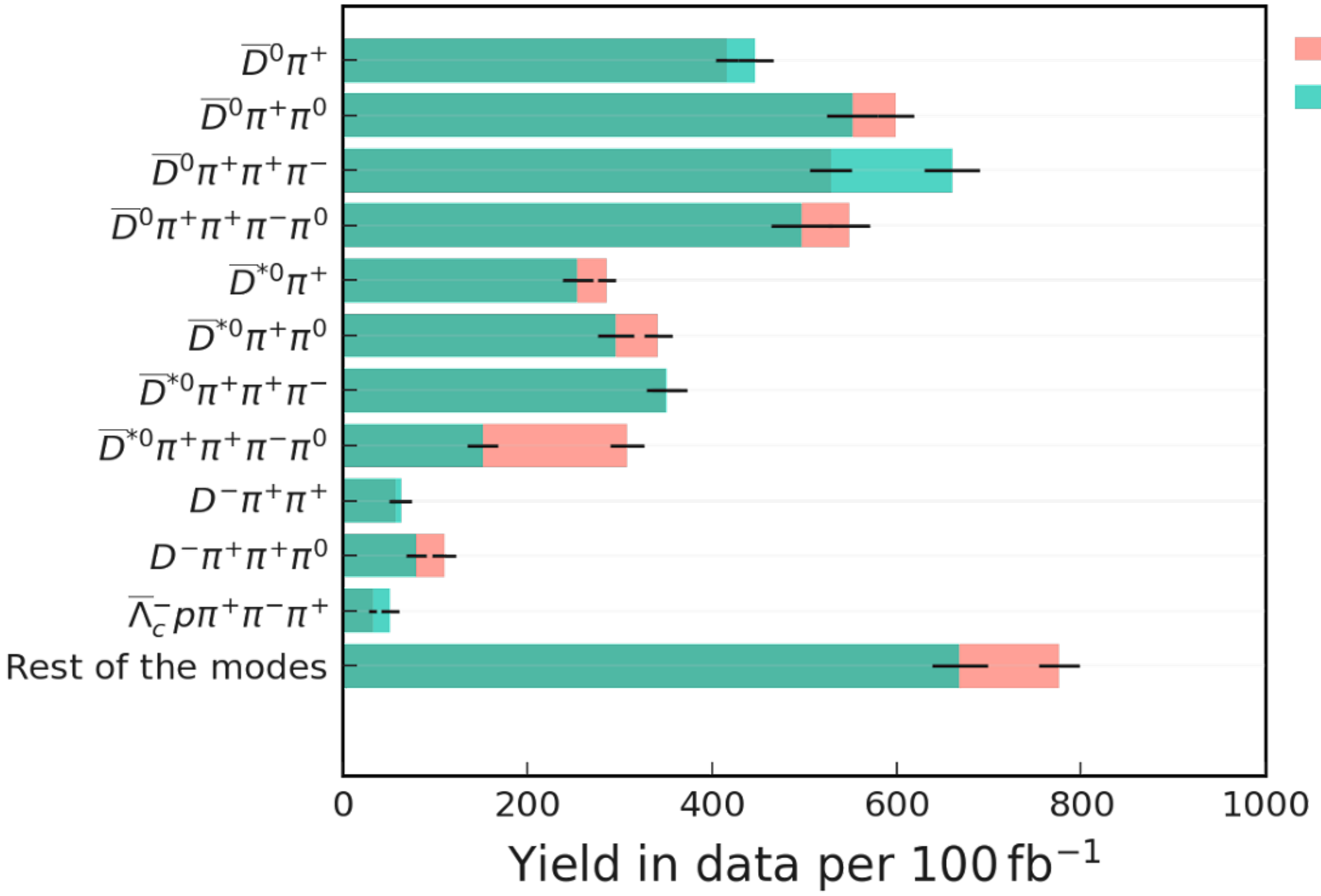
B⁺



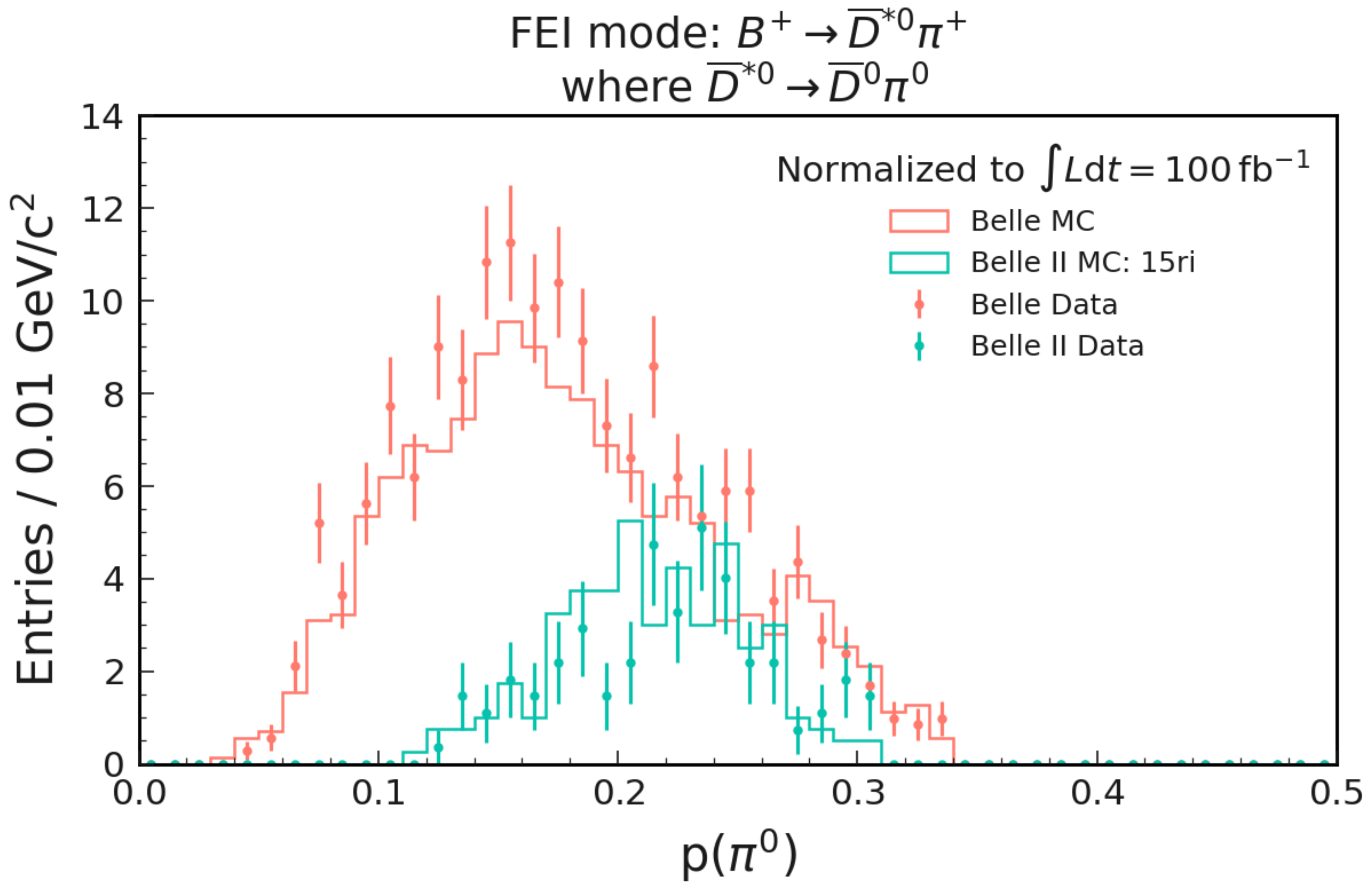
B⁰



Slow π^0s in Belle II FEI



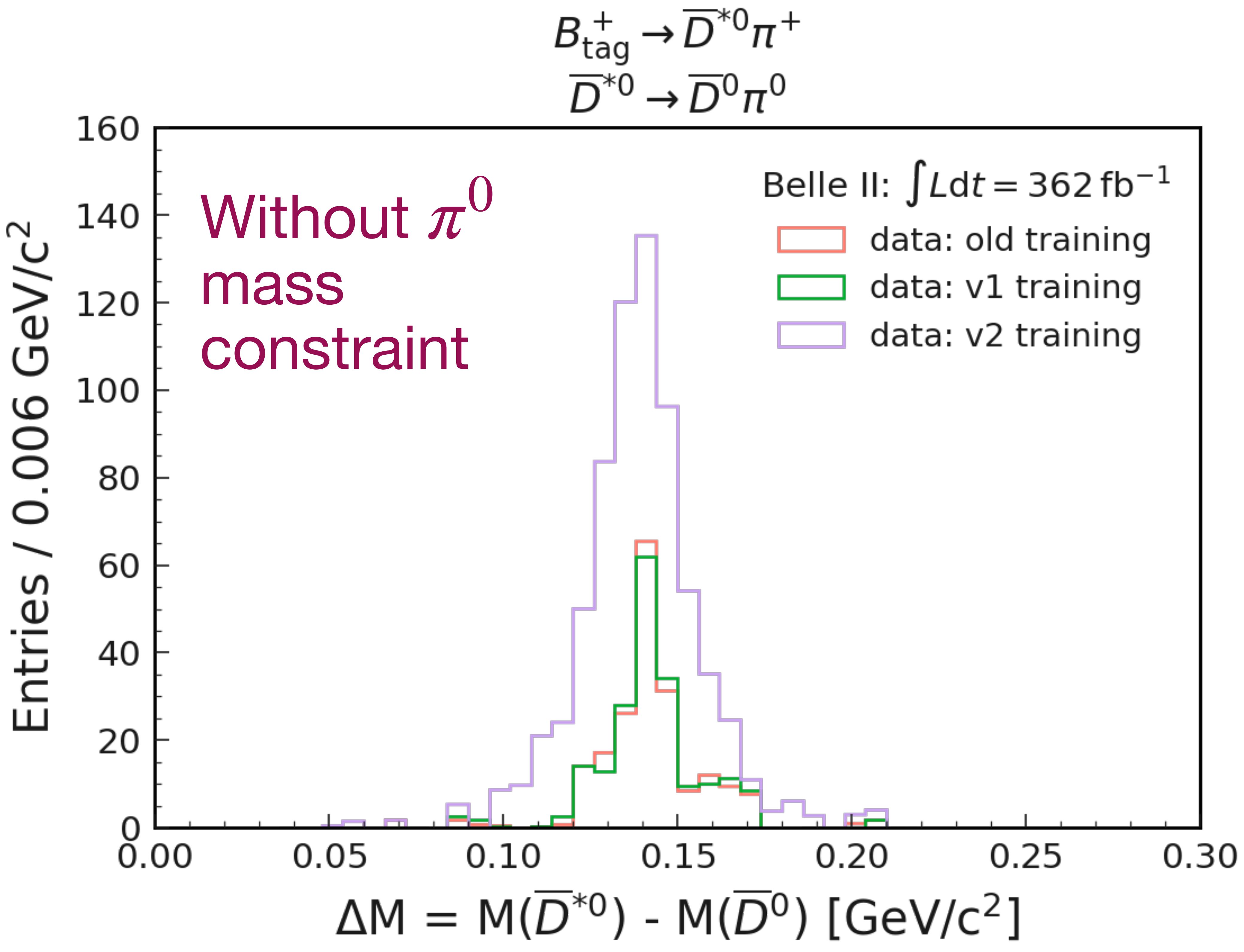
Slow π^0 efficiency suffer at Belle II because of a tighter pre selection on photons

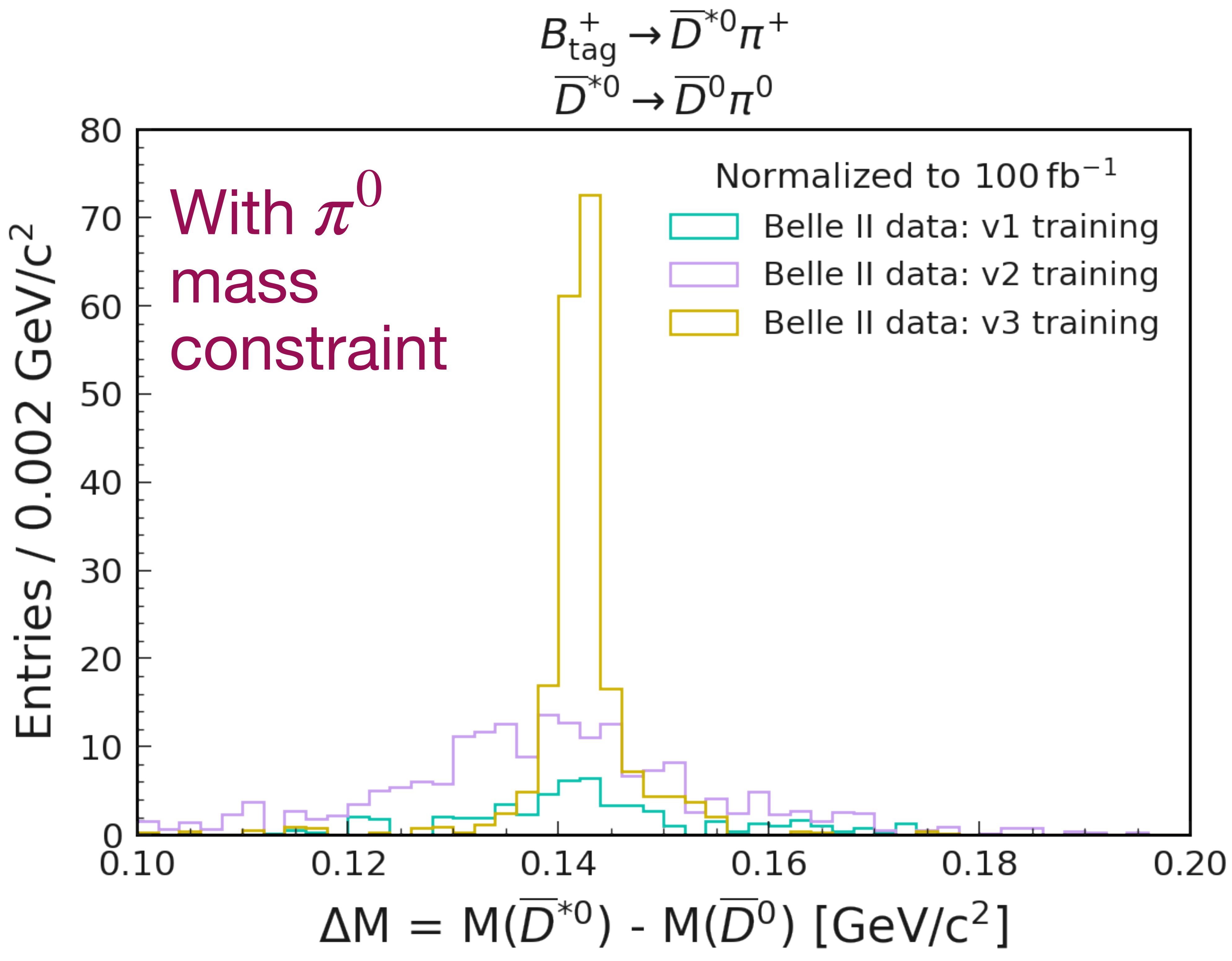


Now unified with Belle selections

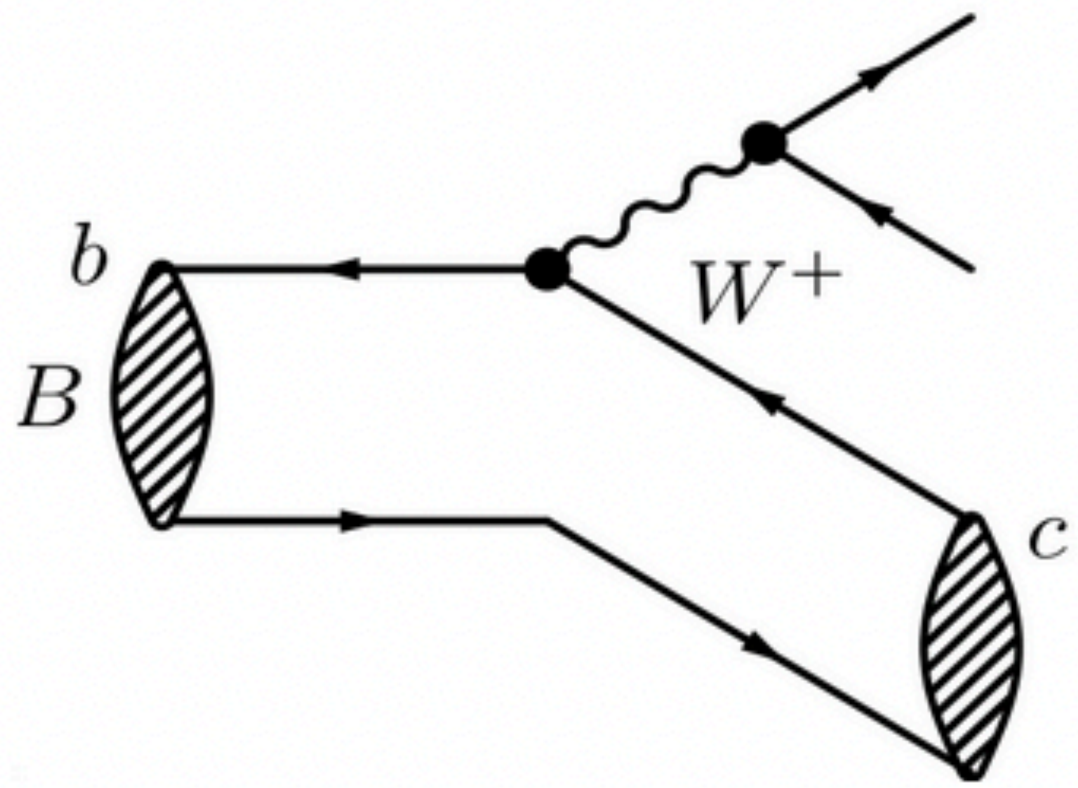
Important for SL-tagging also

Also, there is no mass constraint for π^0 in Belle II





Improvements in the decay table



X = π, ρ, a_1, ωπ, ρππ, ηπ

Y = D, D*, D**

Happens through 2 channels, one with spectator quarks (call Y) and one from the W (call X).

We modified the DECAY table to latest PDG/paper interpretations and this model to see the impact.

Essentially validation, we didn't do any fine-tuning (except set 0 there is no signal*).

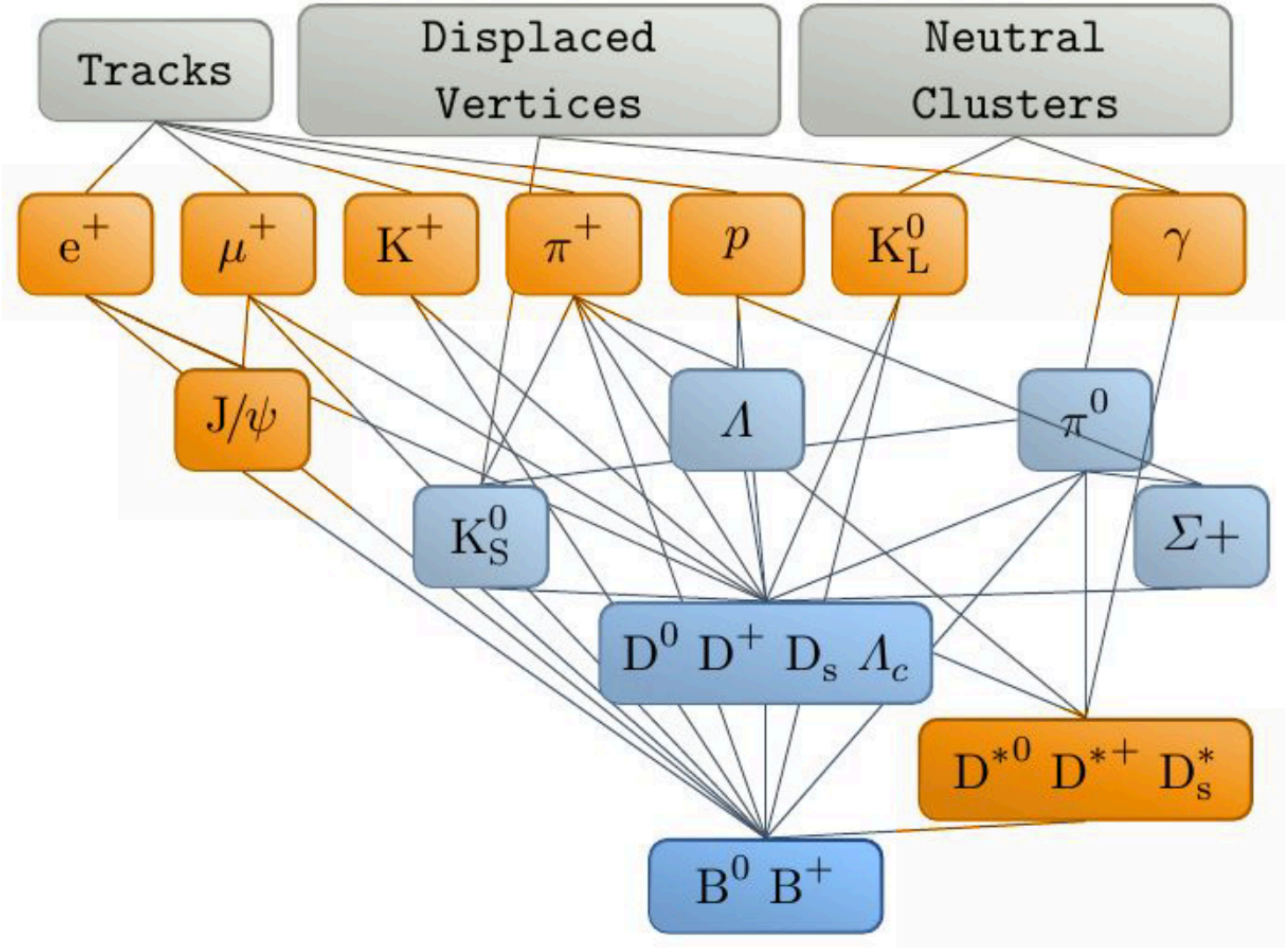
2 primary rules:

- D^0 X: D^{*0} X : D^{**0} X ~= 1 : 1 : 1
  (based on observation from D π^- : D* π^- : D** π^- and D ρ^- : D* ρ^-)
- Y π^- : Y ρ^- : Y a_1^- ~= 1 : 2.5 : 2.5
  (based on predictions and confirmed with τ → h ν decays)

Additional information:

- 3π π^0 is hard to model without some sort of ρ' resonance
  - For **ωπ** we fix from measurements.
  - ηπ is fixed based on predictions to fill SL gap
  - For **ρππ**, we let PYTHIA generate it.
- The fraction of 4 different D** is fixed based on observations.

FEI algorithms: better with cuts



Currently, we have train BDTs for each everything in FEI... even for FSPs!

Unnecessarily duplicating the work of many dedicated performance groups?

Can adopting **standard lists and minimal cuts with standard tools** (like beamBackgroundSuppressionBDT) bring more stability?

Added bonus: Less resource expensive