Measurement of the branching fraction of $B \to \overline{D}^{(*)} K^- K^{(*)0}$ and $B \to D^{(*)} D_s^-$ decays using the 2019-2022 Belle II data sample

Belle II

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

GDR-InF annual workshop 2023

INTENSITY frontier GDR-InF

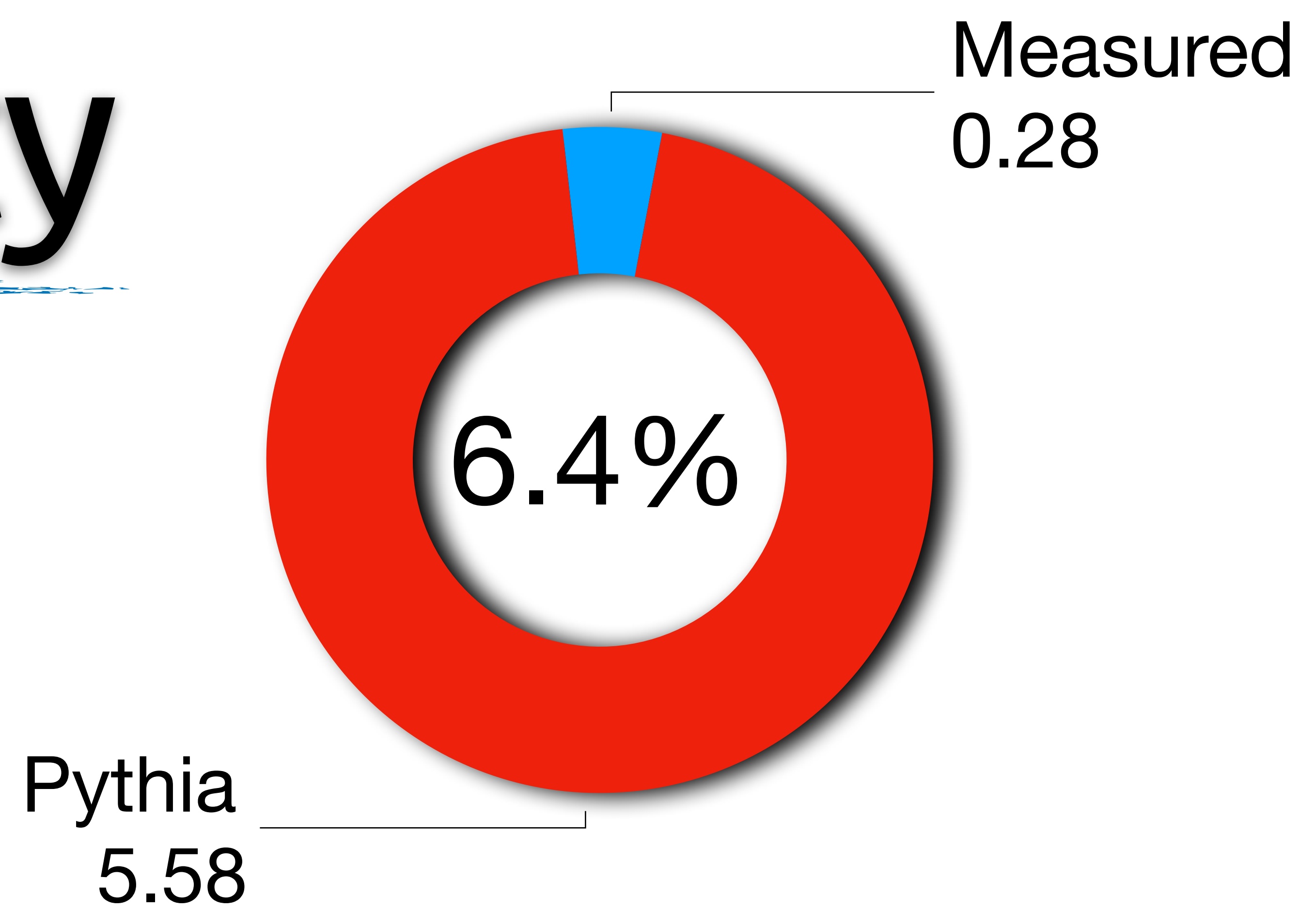
CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE CPPM

Valerio Bertacchi, Karim Trabelsi

Mont Sainte-Odile, 7 November 2023

erc European Research Council Established by the European Commission

Motivations: the DKK opportunity



- The DKK sector is **mostly unexplored**
  - In Belle II MC: $(B^+ \to DKK) \simeq 6\,\%$ (where $D = D^{\pm,0,*}$, $K = K^{\pm,0,*}$)
  - Measurements from a single paper [Belle, Phys.Lett.B,542(2002)]
    29.4 fb^{-1}, 5 modes (BR=0.28%)
  - The remaining is generated by Pythia

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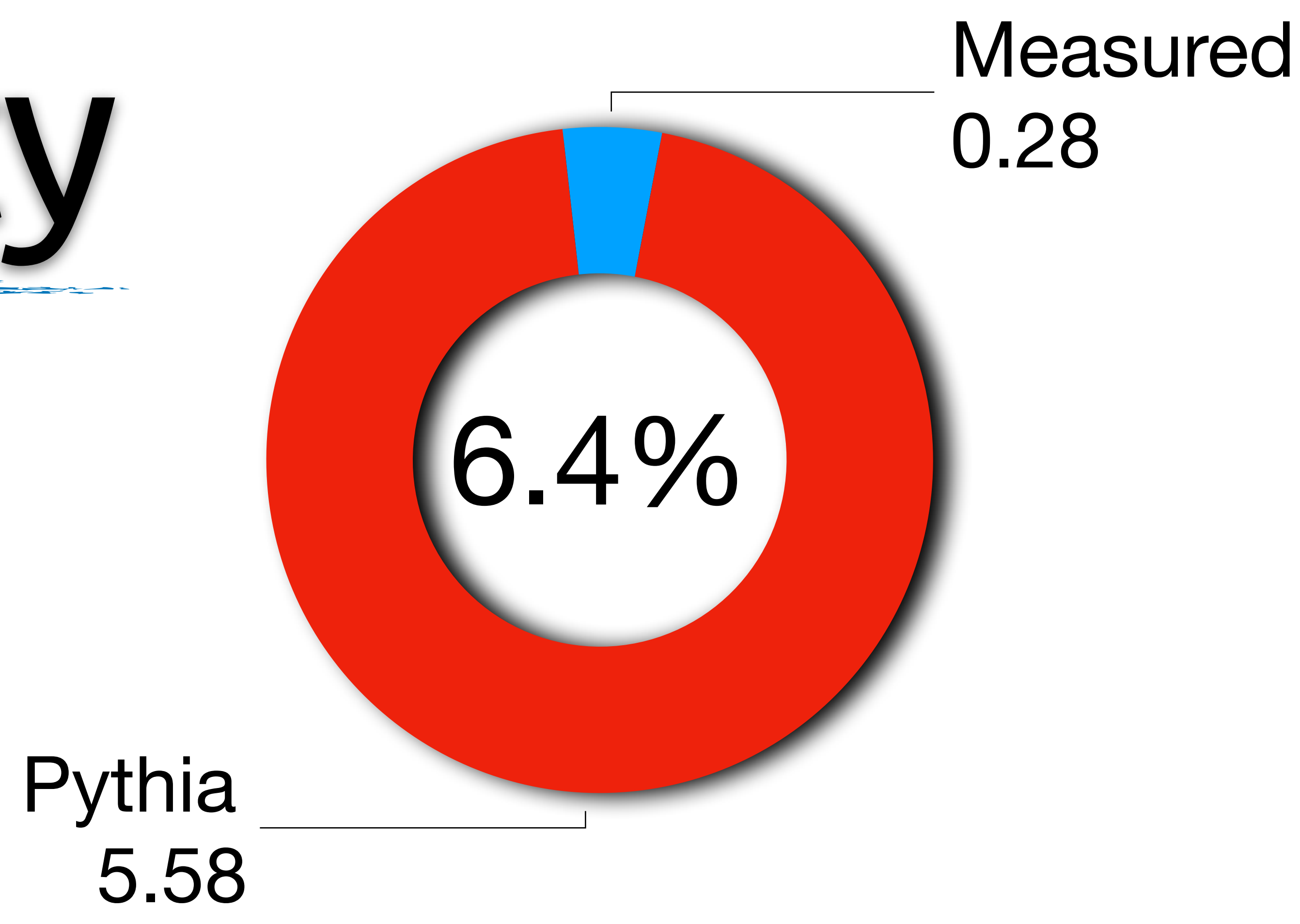

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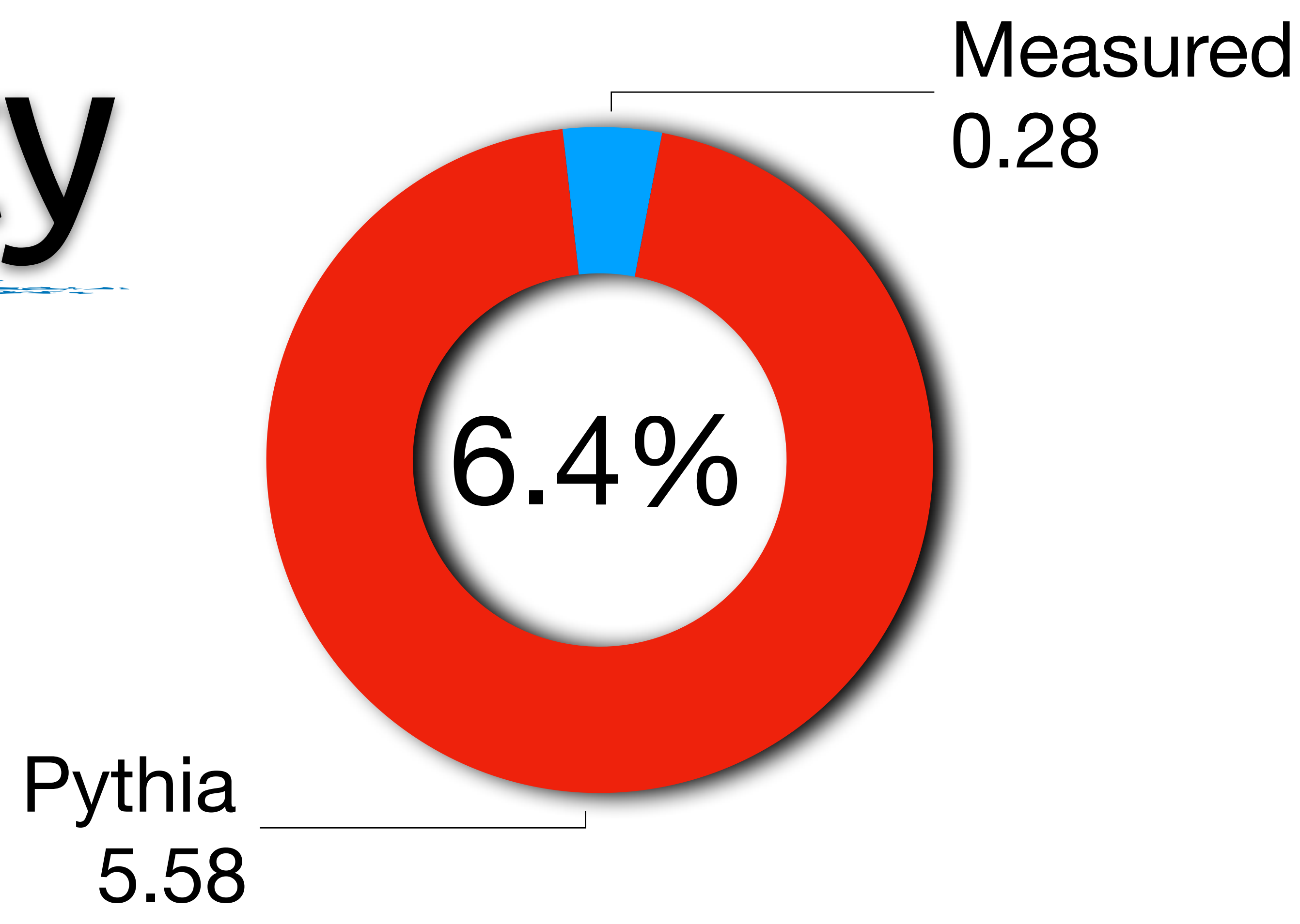

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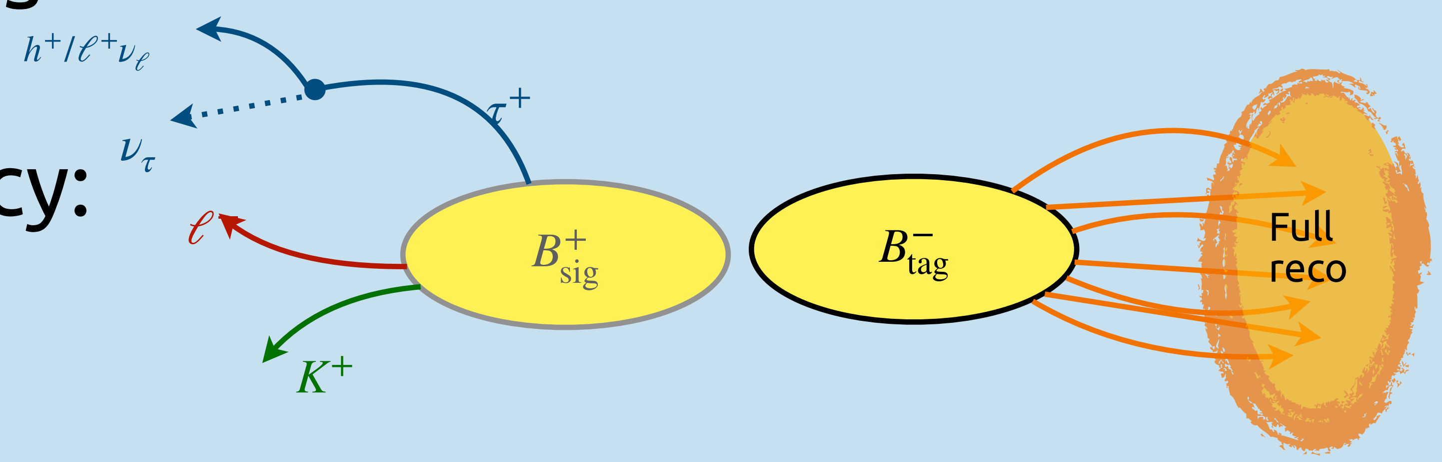
- A better knowledge of this sector can be very useful to **extend the b-tagging modes**
  - **Hadronic B-tagging:** full reconstruction of the tag side using $B \to$ hadron modes
  - Anly a **small set of modes** contributes to the hadronic Belle II b-tagging efficiency:
    - $B \to D^{(*)}(n)\pi^{\pm}$, $B \to D^{(*)}(n)\pi^{\pm}\pi^{0}$, n<4
  - $B \to DKK$ modes has very hight purity: their contribution to b-tagging can be relevant
    - semi-inclusive approaches ($B \to DKKX$) can also be developed, obtained result similar to semileptonic B-tagging



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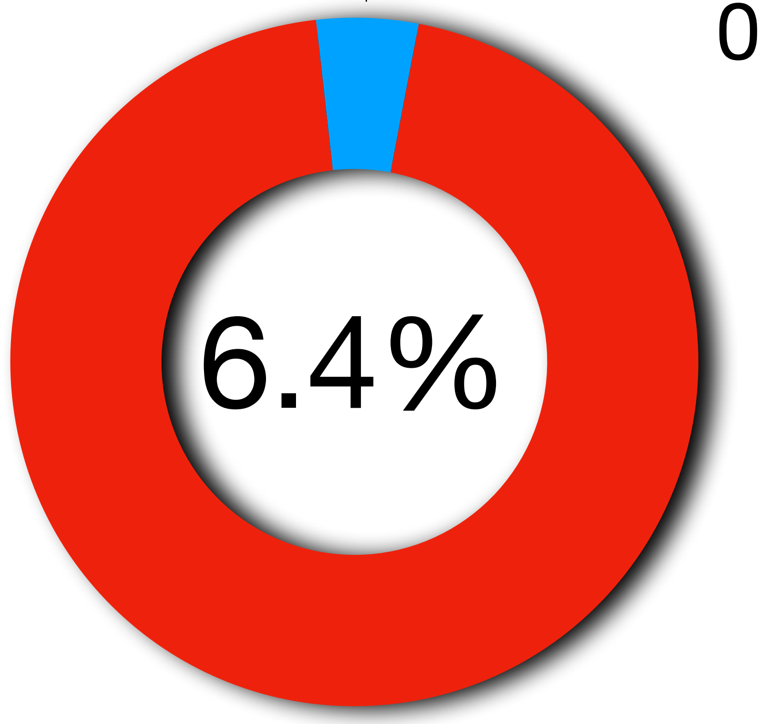

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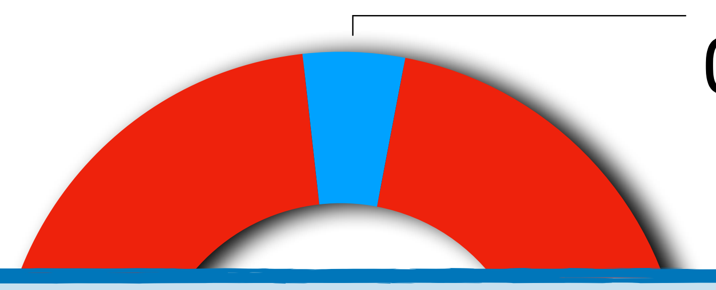
- A better knowledge of this sector can be very useful to **extend the b-tagging modes**

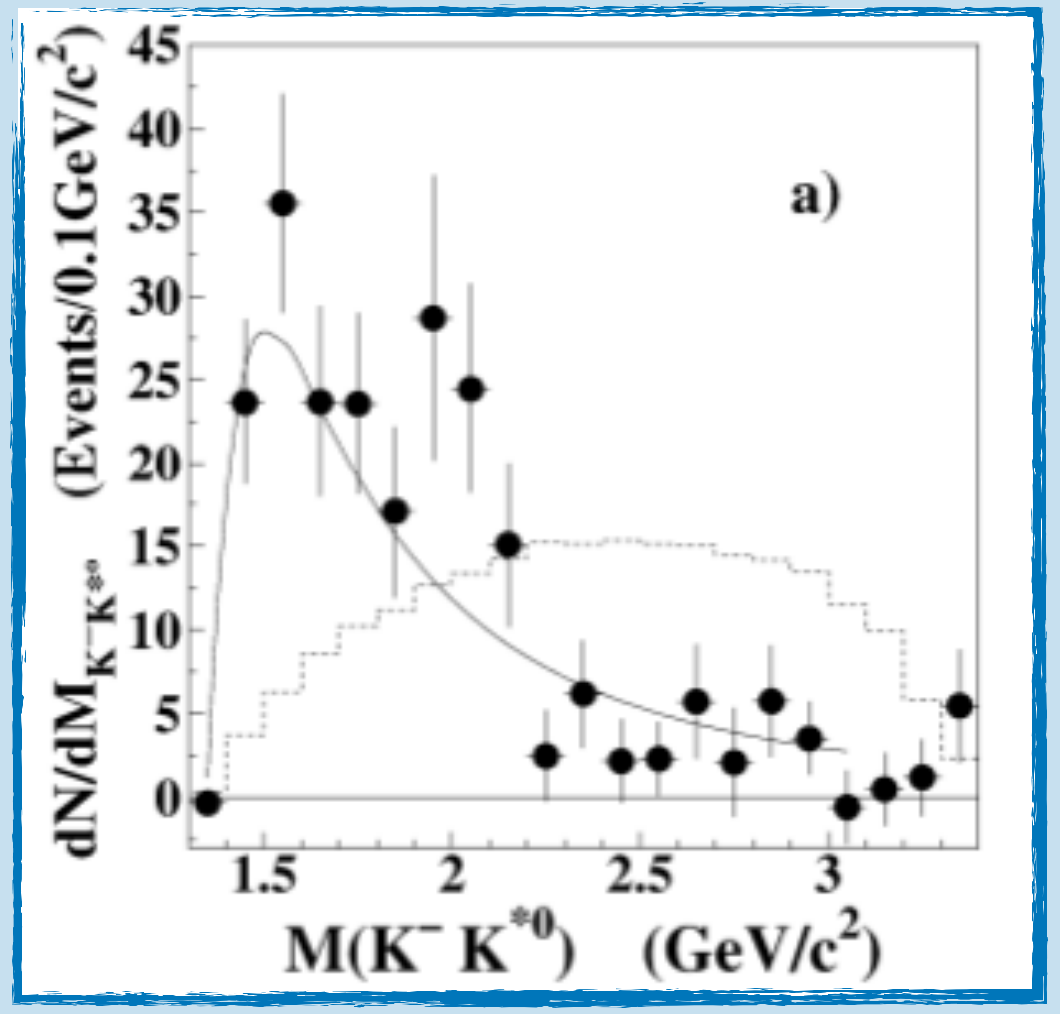
- The Belle II integrated luminosity (362 fb^{-1}) already recorded allows:
  - to improve over the Belle measurement with **higher precision**
  - to **observe additional 3 new** $B \to DKK^0_S$ modes (2-3 sigmas in Belle paper)
  - to **understand the resonant contribution** $(a_1, \rho' ...)$ of this class of decays
  - to perform the world best measurement of the four $B \to D_s^- D^{(*)}$ channels

Motivations: the DKK opportunity

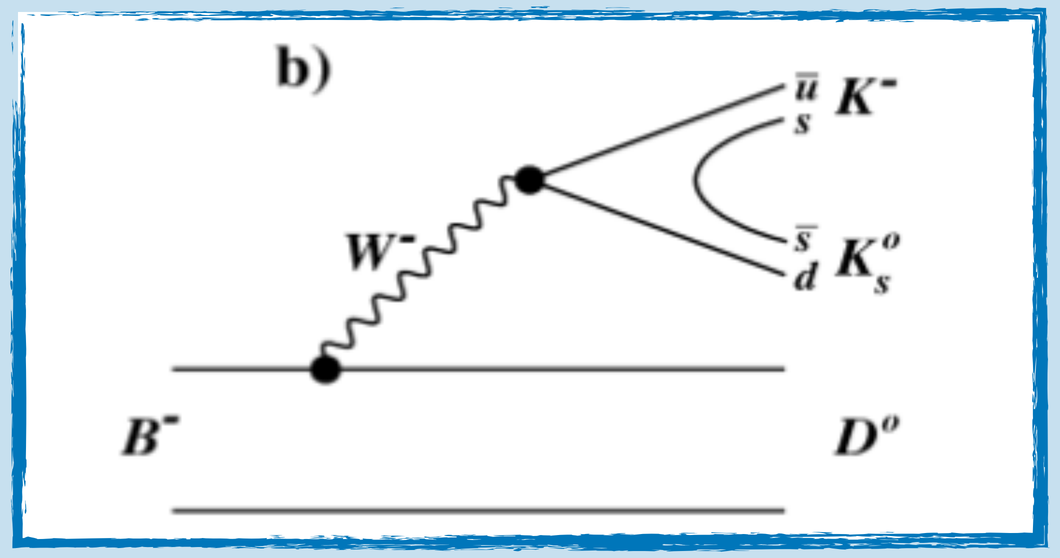


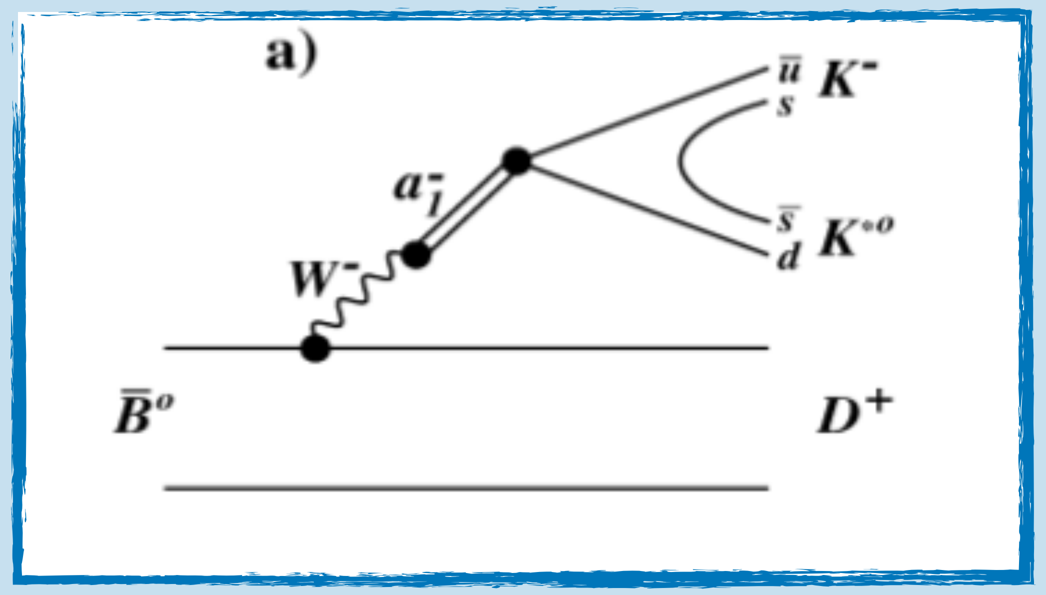
Belle studied the $K^{-}K^{*0}$ **mass distribution**

- far from 3 body phase-space
- compatible with resonant $a_1^- \to K^- K^{*0}$ resonance
- angular analysis $K^- K^{*0}$: $J^P = 1^+$ (agrees with a_1)
- Also $m(K^- K^0_S)$ far from phase-space



[Belle, Phys.Lett.B,542(2002)]





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Analysis strategy

- **Efficiency** as a 2D map $\varepsilon(m_{K-K^{(*)}}, m_{D^{(*)}K^{(*)}})$
- **Signal yield:** ΔE fit: signal + background ($q\overline{q}, B\overline{B}$...), where $\Delta E = E_B^* - \sqrt{s}/2$
- **Branching Fractions:**
  - Event by event efficiency correction, as a function of $(m_{K-K^{(*)}}, m_{D^{(*)}K^{(*)}})$
  - $$\mathscr{B} = \frac{1}{2f_{+-,00}N_{B\overline{B}} \cdot \mathscr{B}(\text{inter})} \cdot \sum_{i \in \text{ bins}} \frac{N_i^{\text{reco}}}{\varepsilon_i},$$

bkg-subtracted and efficiency corrected yield (i=bins of efficiency map)

- **Invariant Masses/angular variables:**
  - s-Plot is performed on the required variable: $\Delta E \times \text{Var}$ --> Var bkg free
  - Event by event efficiency Correction, as a function of $(m_{K-K^{(*)}}, m_{D^{(*)}K^{(*)}})$

Studied decay channels

$B^- \to D^0 K^- K^{*0}$
$\overline{B}^0 \to D^+ K^- K^{*0}$
$B^- \to D^{*0} K^- K^{*0}$
$\overline{B}^0 \to D^{*+} K^- K^{*0}$
$B^- \to D^0 K^- K_S^0$
$\overline{B}^0 \to D^+ K^- K_S^0$
$B^- \to D^{*0} K^- K_S^0$
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  - s-Plot is performed on the required variable: $\Delta E \times \text{Var}$ --> Var bkg free
  - Event by event efficiency Correction, as a function of $(m_{K^-K^{(*)}}, m_{D^{(*)}K^{(*)}})$

- Preliminary result presented in Moriond '23
  - Only the K_S^0 modes were studied
  - Efficiency correction function of $m(KK_S^0)$ only
- arXiv:2305.01321

Studied decay channels

$B^- \to D^0 K^- K^{*0}$
$\overline{B}^0 \to D^+ K^- K^{*0}$
$B^- \to D^{*0} K^- K^{*0}$
$\overline{B}^0 \to D^{*+} K^- K^{*0}$
$B^- \to D^0 K^- K_S^0$
$\overline{B}^0 \to D^+ K^- K_S^0$
$B^- \to D^{*0} K^- K_S^0$
$\overline{B}^0 \to D^{*+} K^- K_S^0$

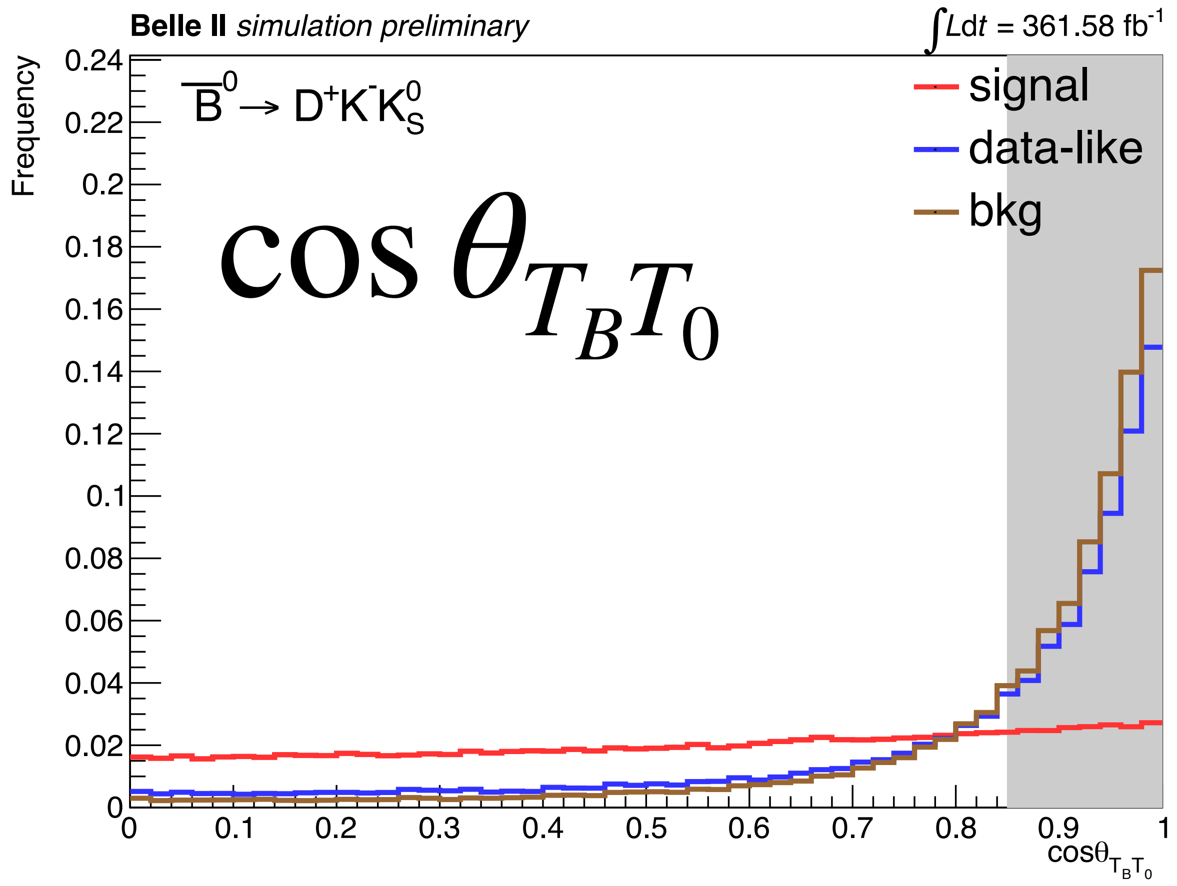
Reconstruction and selection

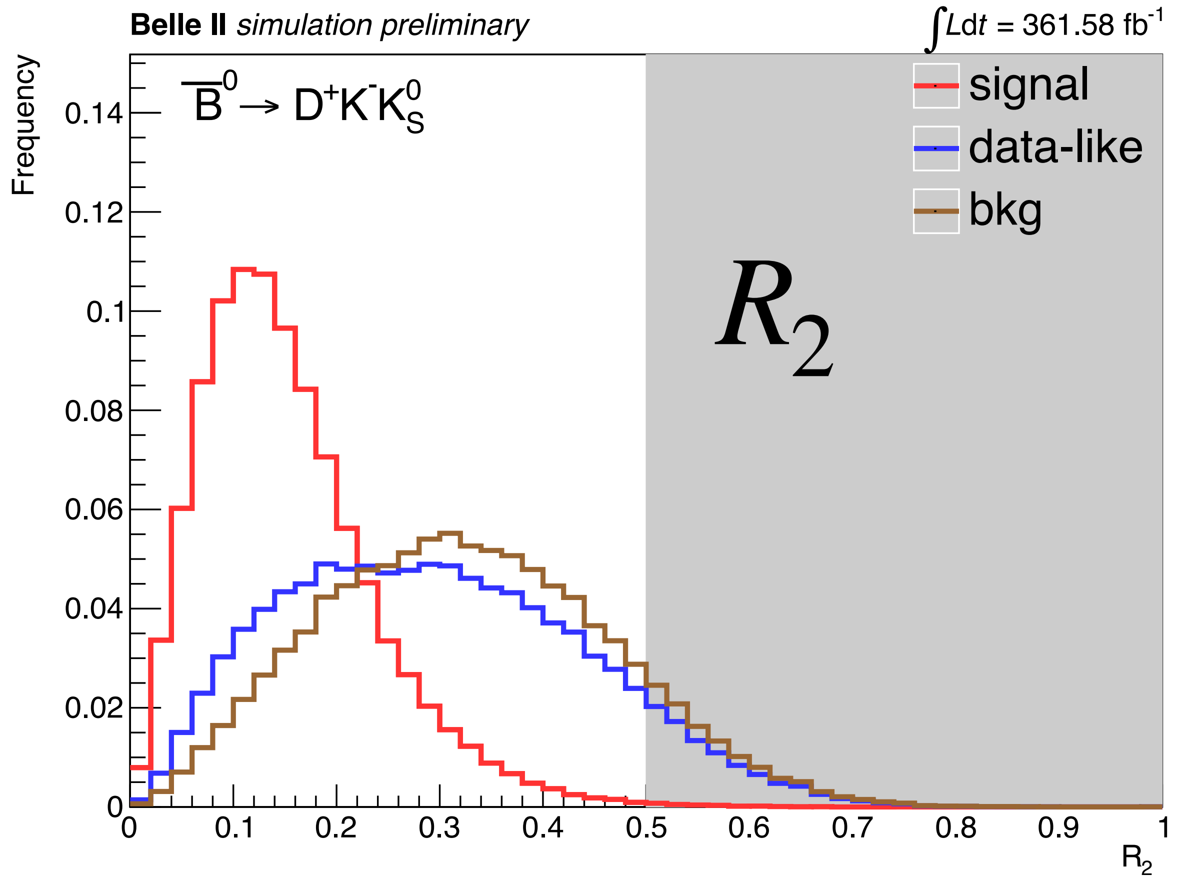
Decay chain

$B \to D^{(*)} K^- K^{(*)0}_{(S)}$

- $K^0_S \to \pi^+\pi^-$
- $K^{*0} \to K^+\pi^-$
- $D^0 \to K^-\pi^+$
- $D^+ \to K^-\pi^+\pi^+$
- $D^{*0} \to D^0\pi^0$
  - $\pi^0 \to \gamma\gamma$
- $D^{*+} \to D^0\pi^+$

$B\bar{B}$ and $q\bar{q}$ suppression



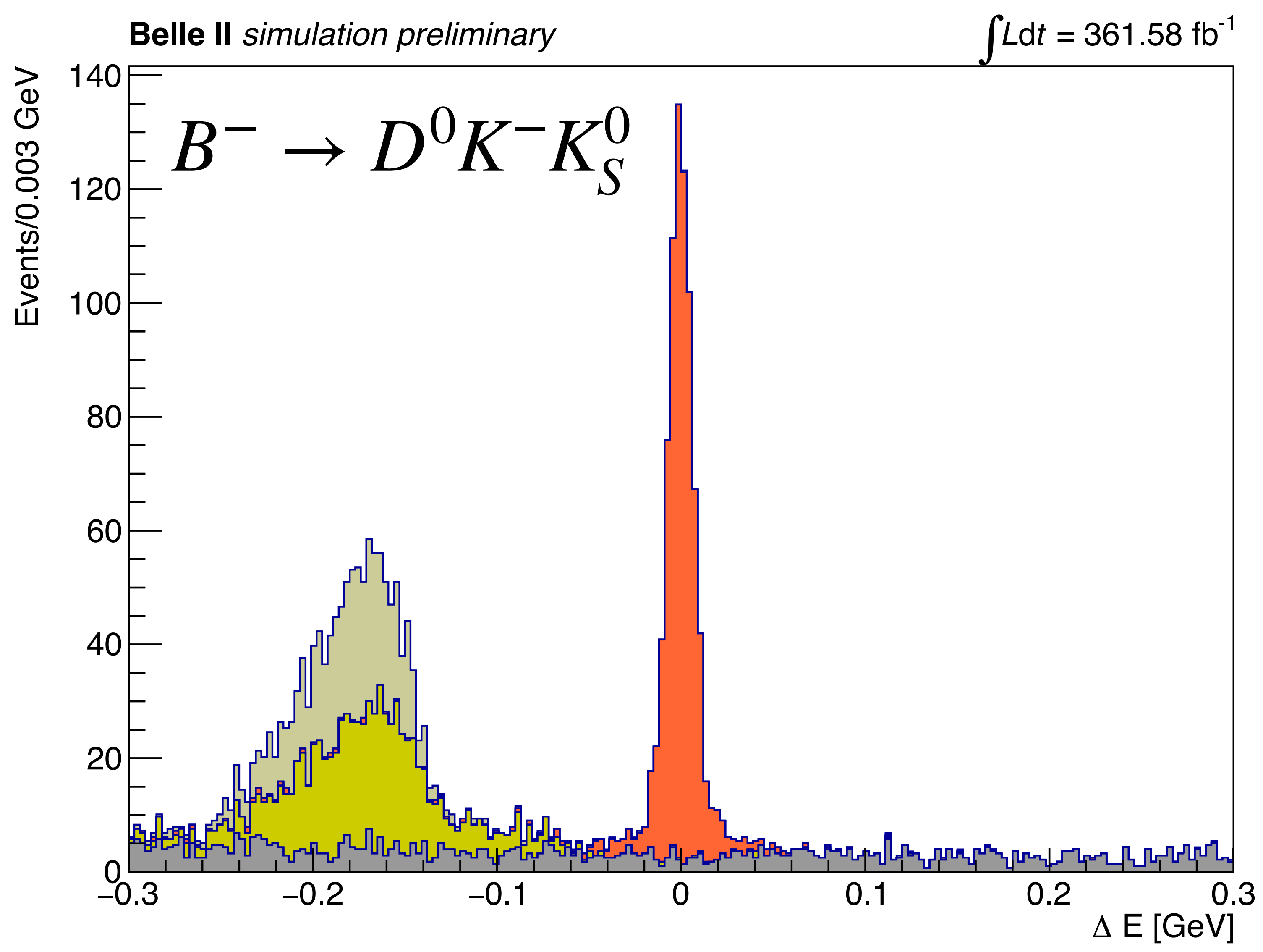


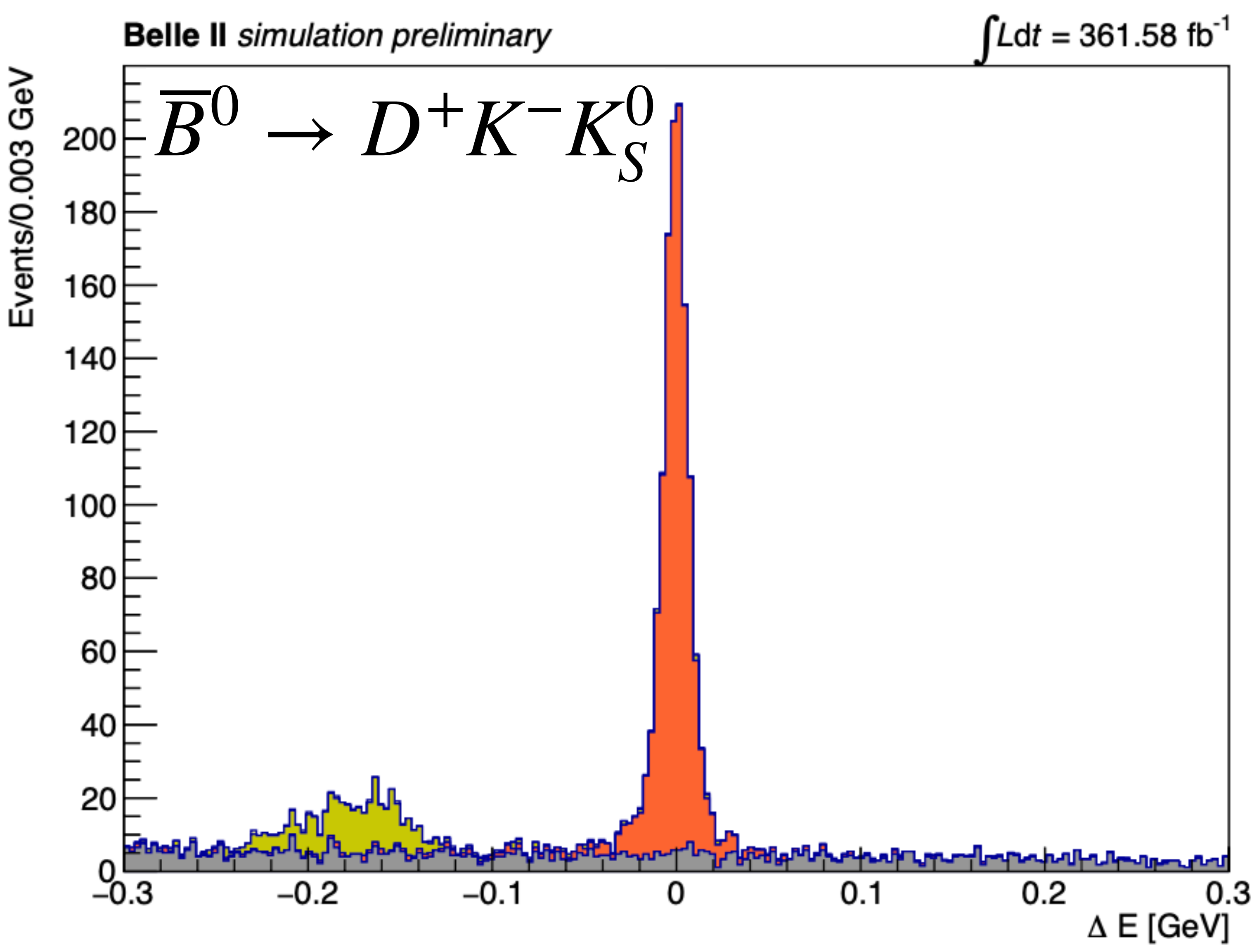
- ...
- ... [see backup for full details and definitions]

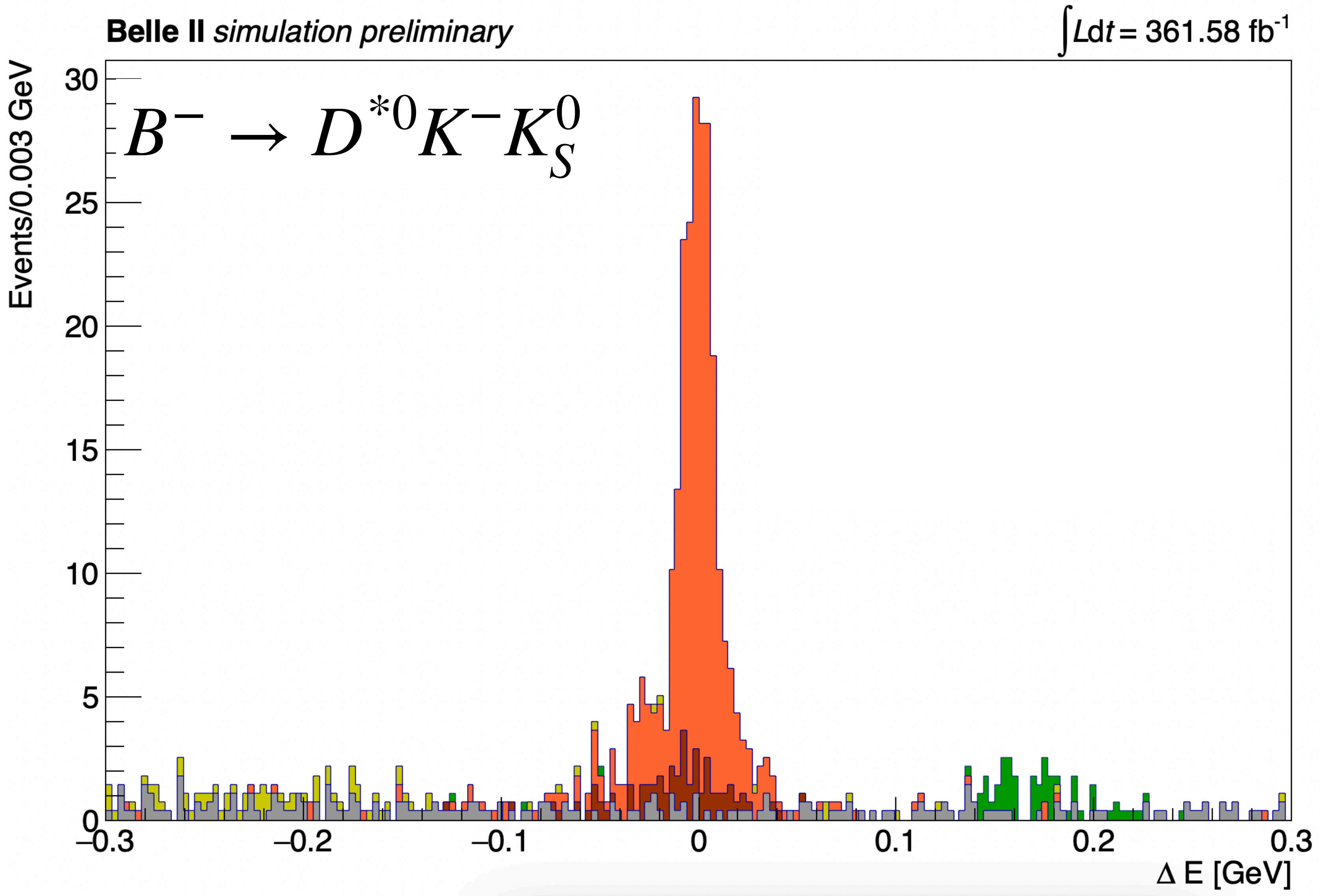
- $M_{bc} = \sqrt{(\sqrt{s}/2)^2 - \vec{p}_B^{*2}} > 5.272$ GeV
- $B \to DD_s^-(\to KK)$ **veto**: $\Rightarrow |m_{D_s} - m_{KK}| > 20$ MeV
- **Best candidate selection:** $\min|M_{bc} - M_B|$
- $|M^{\text{reco}}_{K^*} - M^{\text{PDG}}_{K^*}| < 50$ MeV

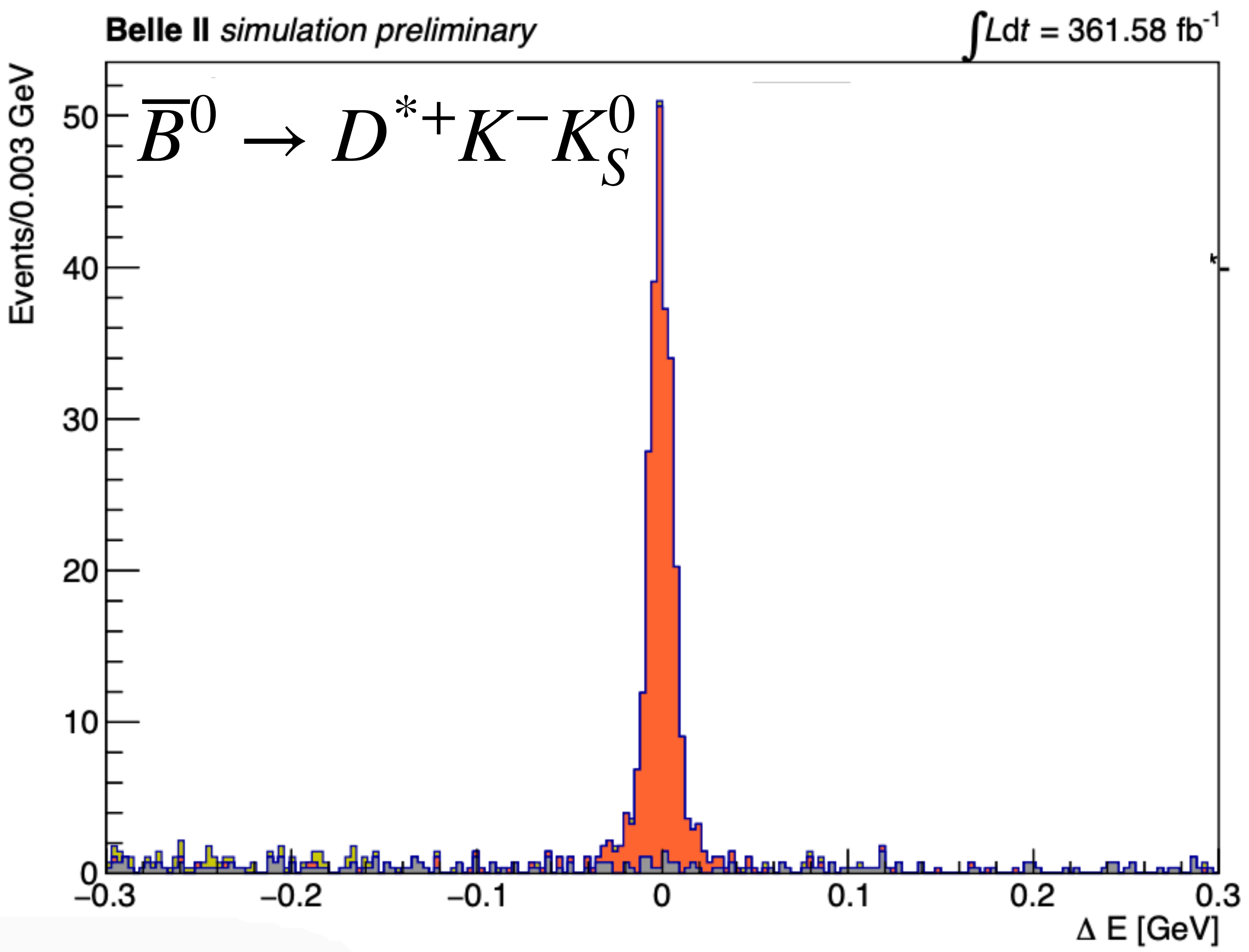
Reconstructed sample composition - K_S^0 channels

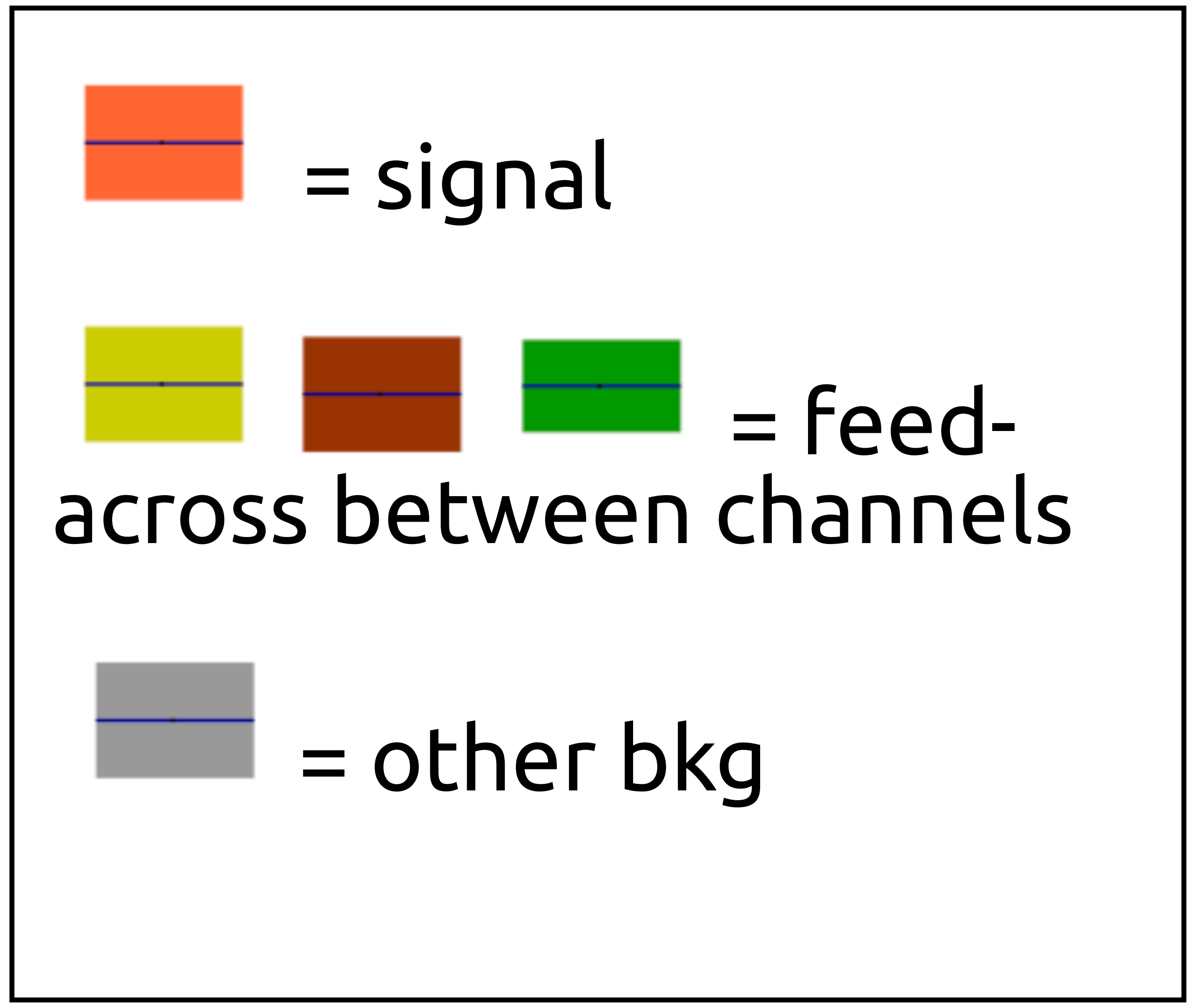
[MC Simulation]







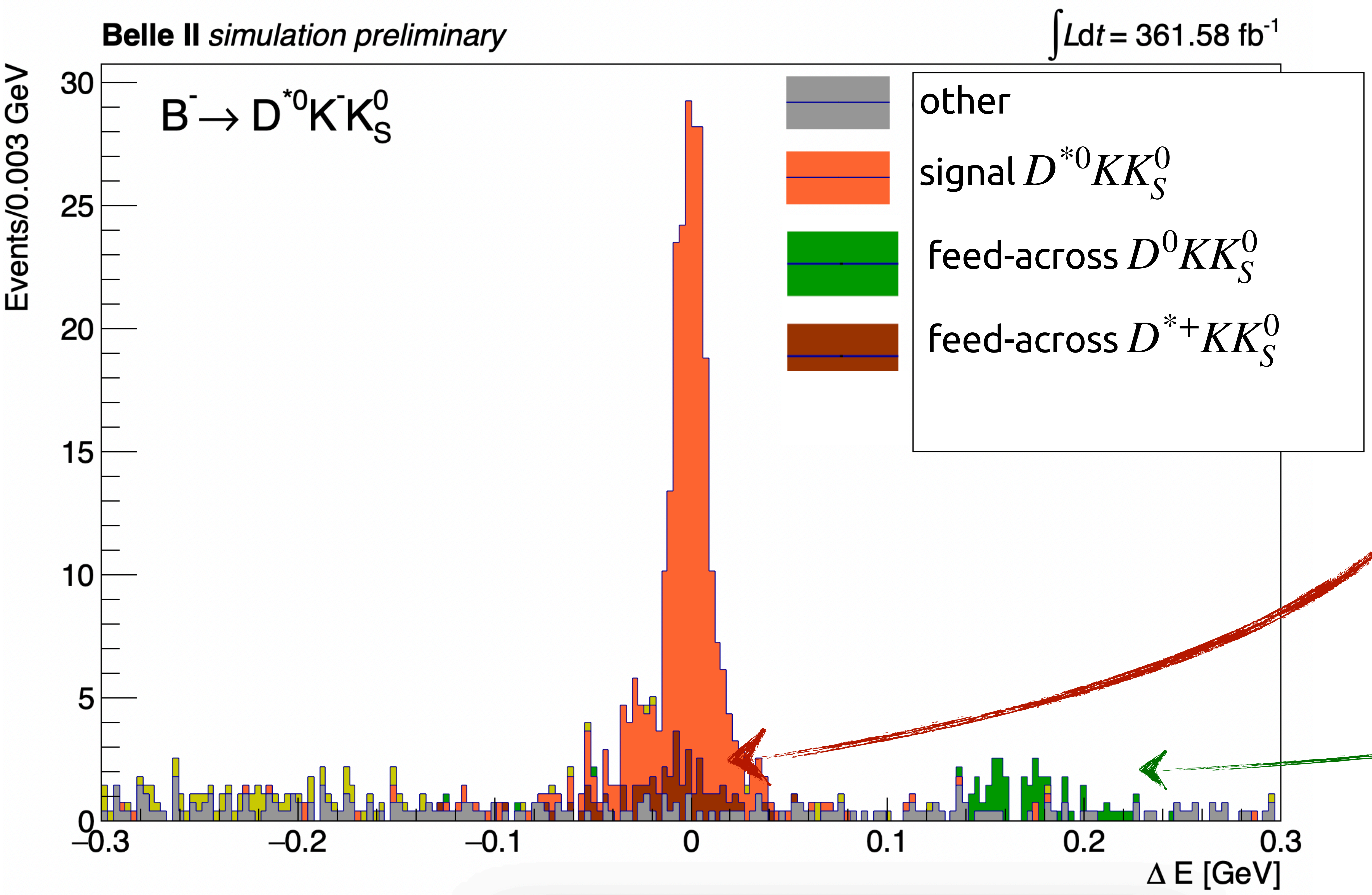




- all the channels are very clean
- some off-peak feed across
- only in $D^{*0}KK_S^0$ has a peaking bkg *[next slides]*

Peaking background in $B^- \to D^{*0} K^- K_S^0$

[MC Simulation]



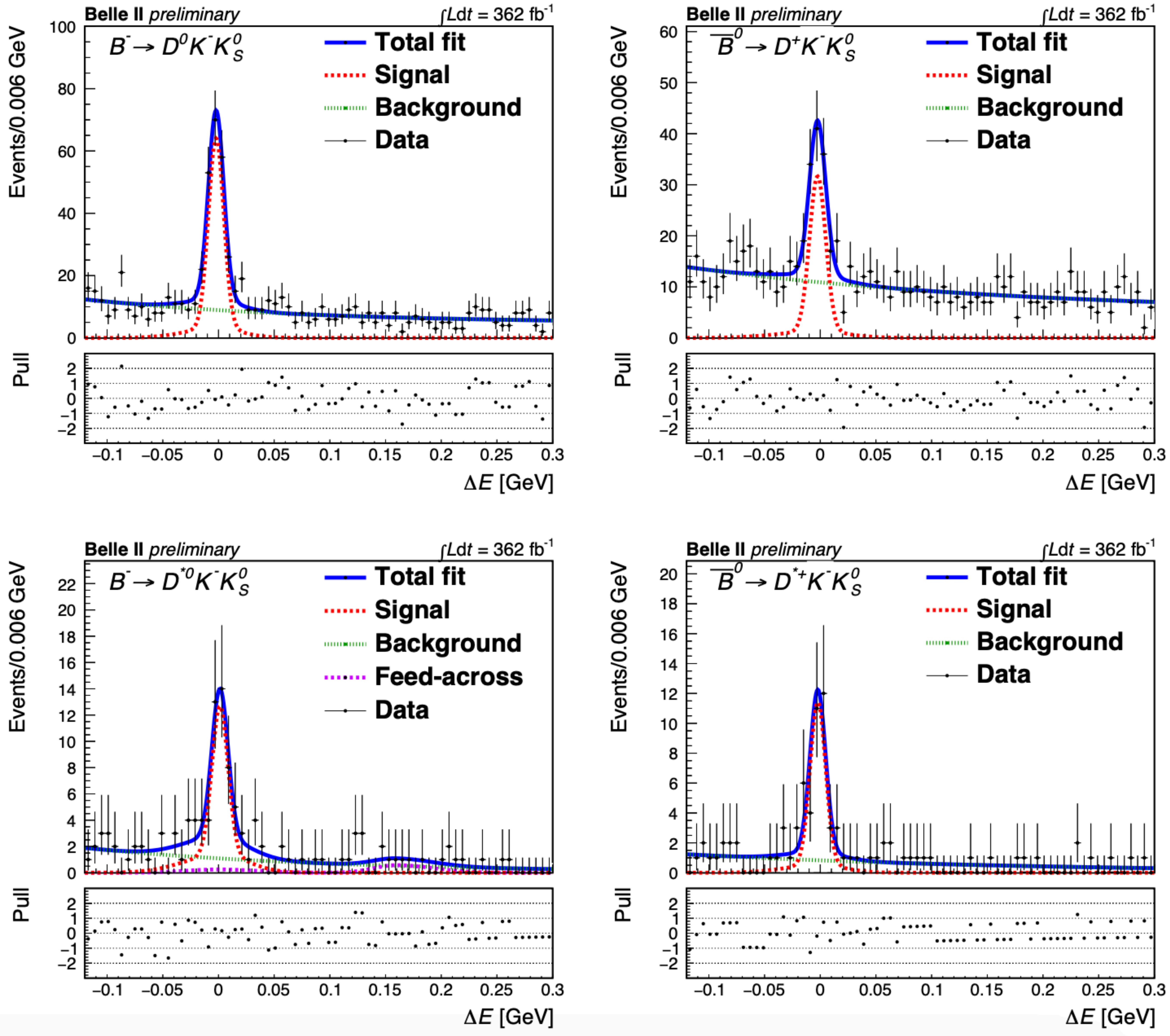
- peaking feed across from $D^{*+}KK_S^0$ (lost π^+ and added a wrong π^0)
- yield estimated using:

$$N^{\rm bkg}_{D^{*+}} = \frac{BR(\overline{B}^0 \to D^{*+}K^-K_S^0)}{BR(B^- \to D^0K^-K_S^0)} \cdot N^{\rm bkg}_{D^0}$$

- *[More details in backup]*

Yield extraction (K_S^0 channels)

[Data - 362 fb^{-1}]



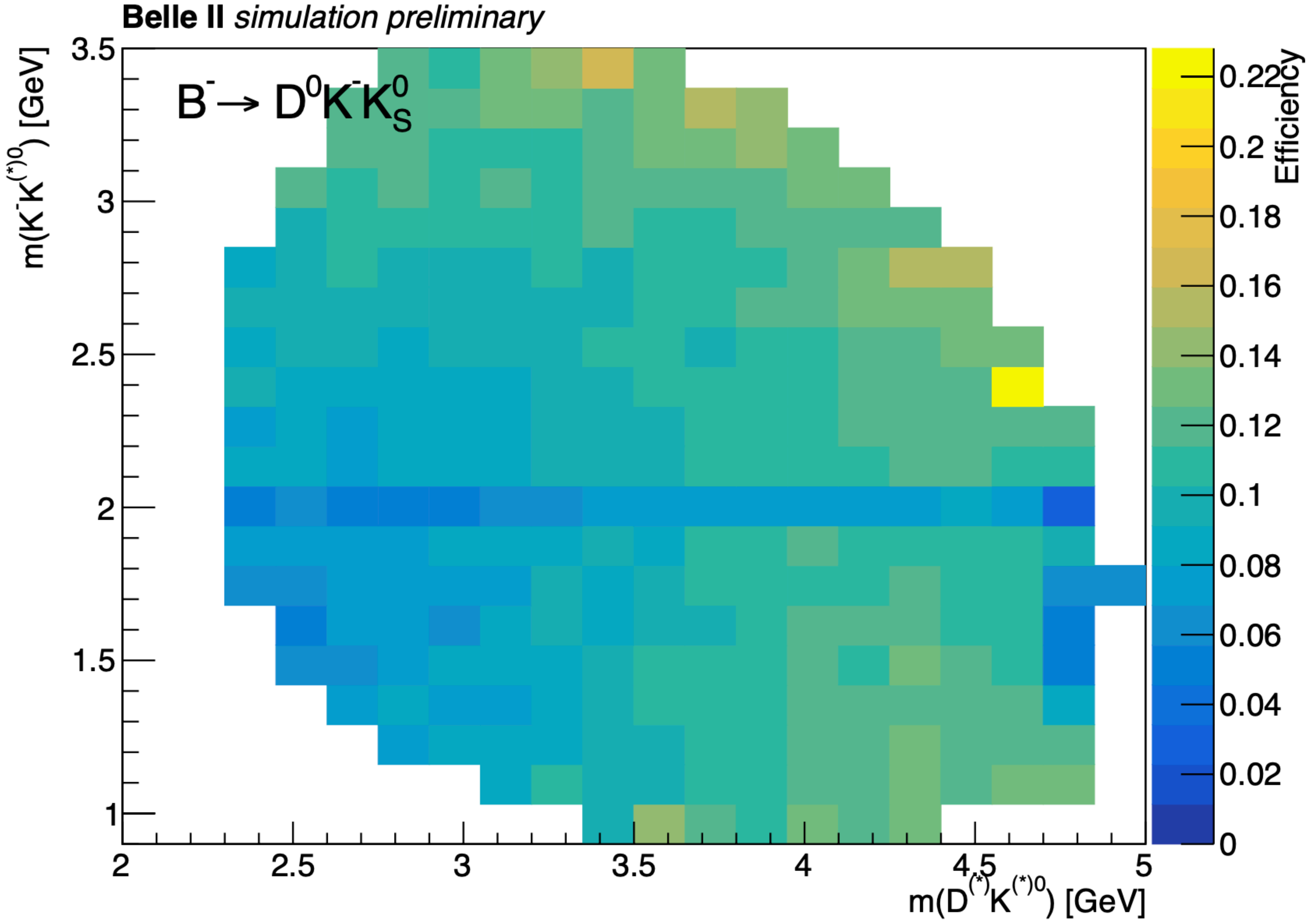
- **Signal**: gaussian+asymmetric gaussian
- **Bkg**: exponential+constant
- Dedicated peaking bkg channels and $D^{*0}KK_S^0$ channel
- Result preliminary validated on MC and with 10^3 toys

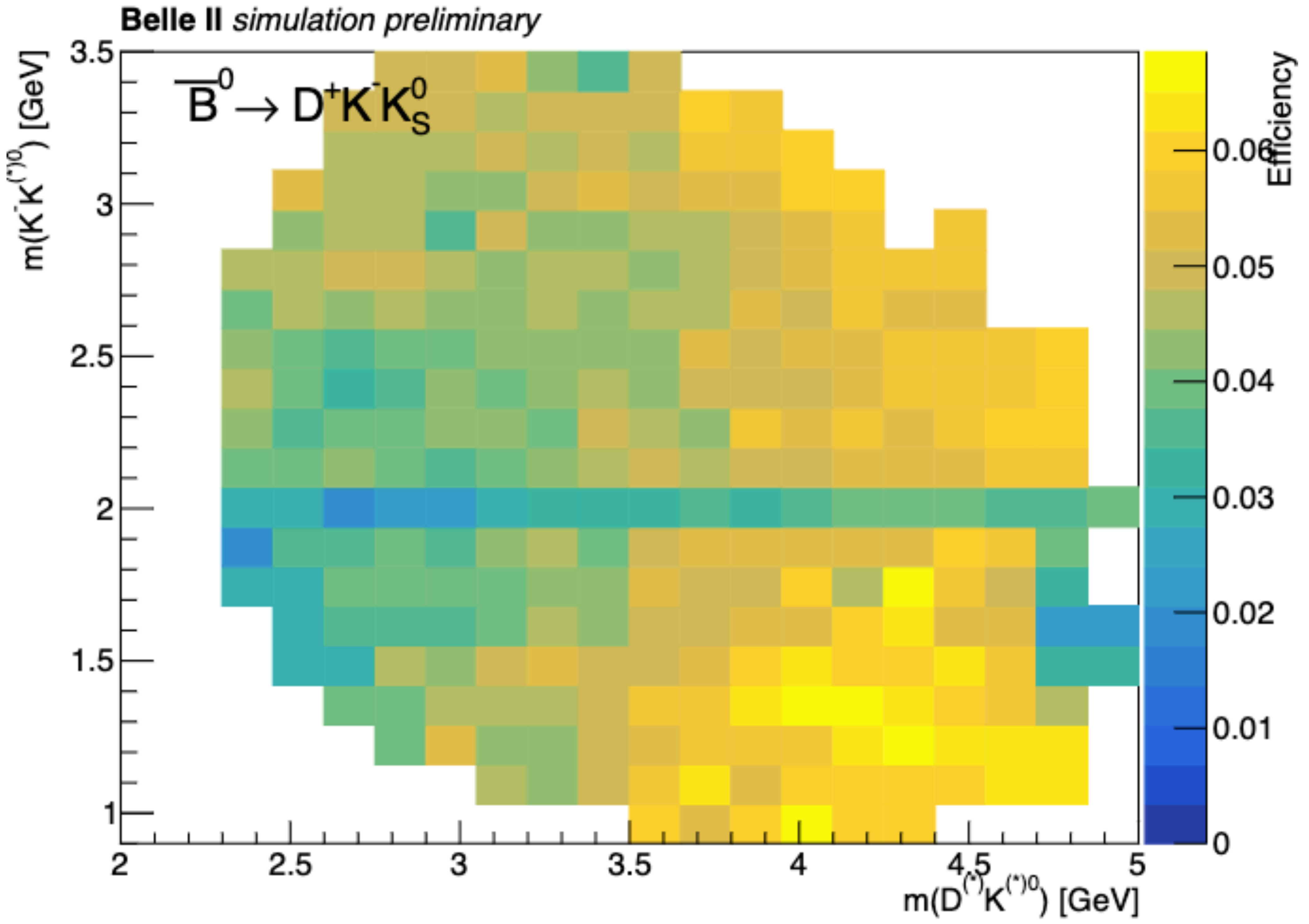
[from arXiv:2305.01321]

Efficiency estimation

[MC Simulation]

- Estimated using signal MC
- differential in $\varepsilon(m_{K-K^{(*)}}, m_{D^{(*)}K^{(*)}})$ --> to be independent from the Dalitz model of the MC
- Two examples of the maps:





Branching fractions and syst. unc. (K_S^0 channels)

[Data - 362 fb^{-1}]

Channel	Yield	Integrated $\varepsilon^{\text{corr.}}$	$\mathcal{B}$ [10^{-4}]	Significance (σ)	Belle measurement ($n\sigma$)
$B^- \to D^0 K^- K_S^0$	209 ± 17	0.1034 ± 0.0001	$1.84 \pm 0.16 \pm 0.10$	18	$2.75 \pm 0.7 \pm 0.15$ (5.5)
$\overline{B}^0 \to D^+ K^- K_S^0$	105 ± 14	0.0480 ± 0.0001	$0.83 \pm 0.12 \pm 0.05$	10	$0.8 \pm 0.4 \pm 0.15$ (2.6)
$B^- \to D^{*0} K^- K_S^0$	50 ± 9	0.0415 ± 0.0001	$1.46 \pm 0.27 \pm 0.12$	8	$2.6 \pm 1.35 \pm 0.6$ (2.5)
$\overline{B}^0 \to D^{*+} K^- K_S^0$	37 ± 7	0.0408 ± 0.0001	$0.91 \pm 0.19 \pm 0.06$	9	$1.0 \pm 0.75 \pm 0.2$ (2.5)

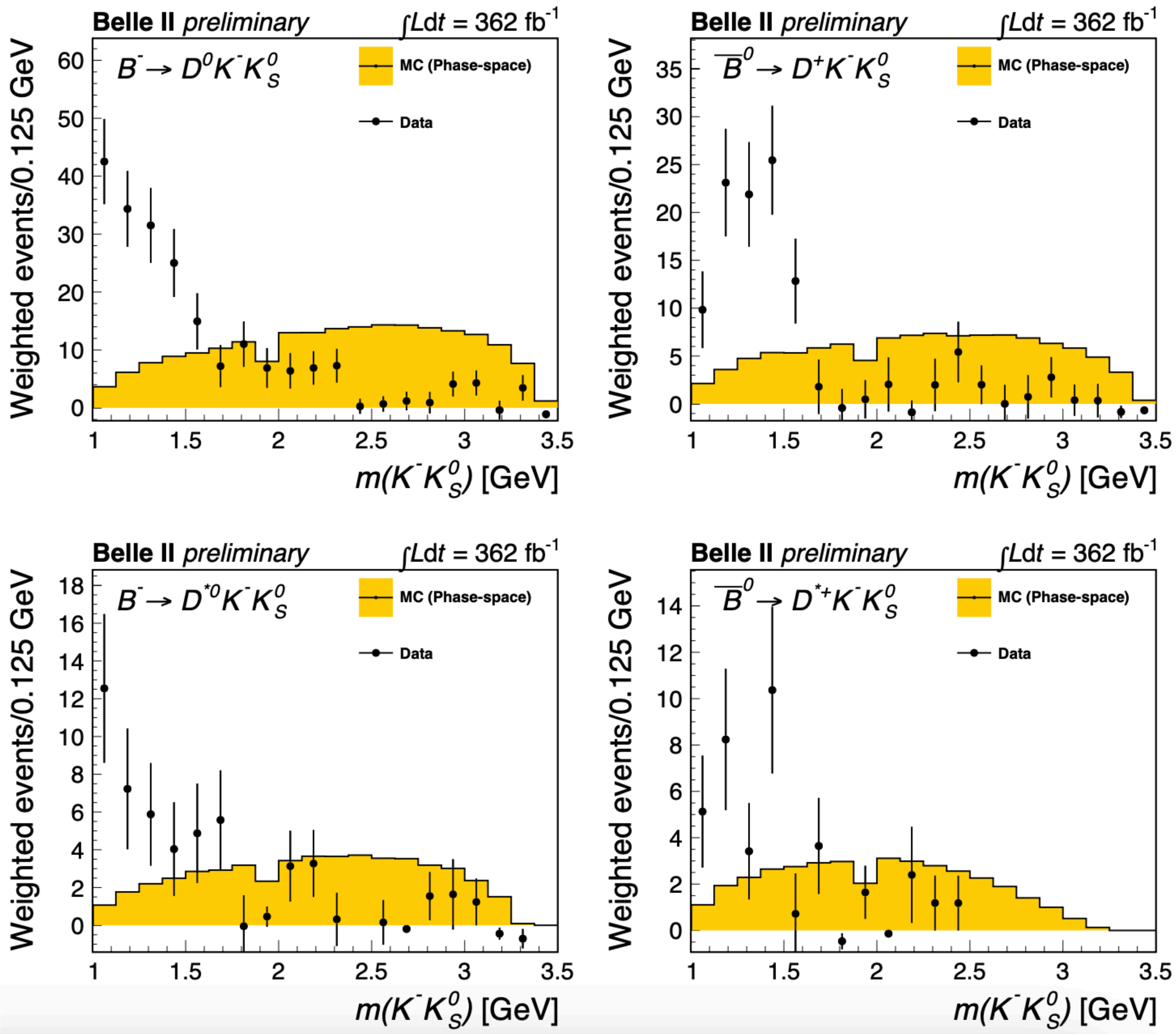
Source	$D^0 K^- K_S^0$	$D^+ K^- K_S^0$	$D^{*0} K^- K_S^0$	$D^{*+} K^- K_S^0$
Eff. - MC sample size	0.8	1.5	1.7	1.6
Eff. - tracking	0.7	1.0	0.7	1.0
Eff. - π^+ from D^{*+}	-	-	-	2.7
Eff. - K_S^0	3.6	3.6	3.8	3.4
Eff. - PID	1.3	1.5	0.5	0.6
Eff. - π^0	-	-	5.1	-
Signal model	1.5	3.4	2.9	2.6
Bkg model	0.8	1.1	<0.1	0.7
$DKK\pi$ bkg	-	-	-	-
D^{*0} peaking bkg	-	-	<0.1	-
$N_{B\overline{B}}$, $f_{+-,00}$	2.7	2.8	2.7	2.8
Intermediate $\mathcal{B}$s	0.7	1.7	1.6	1.1
Total systematic	5.2	6.5	7.9	6.2
Statistical	8.8	14.5	18.2	20.6

- Observation of **3 new decay** channels
- All channels are **statistically limited**
- highlighted dominant systematic uncertainties

[from arXiv:2305.01321]

Invariant masses (K_S^0 channels)

[Data - 362 fb^{-1}]

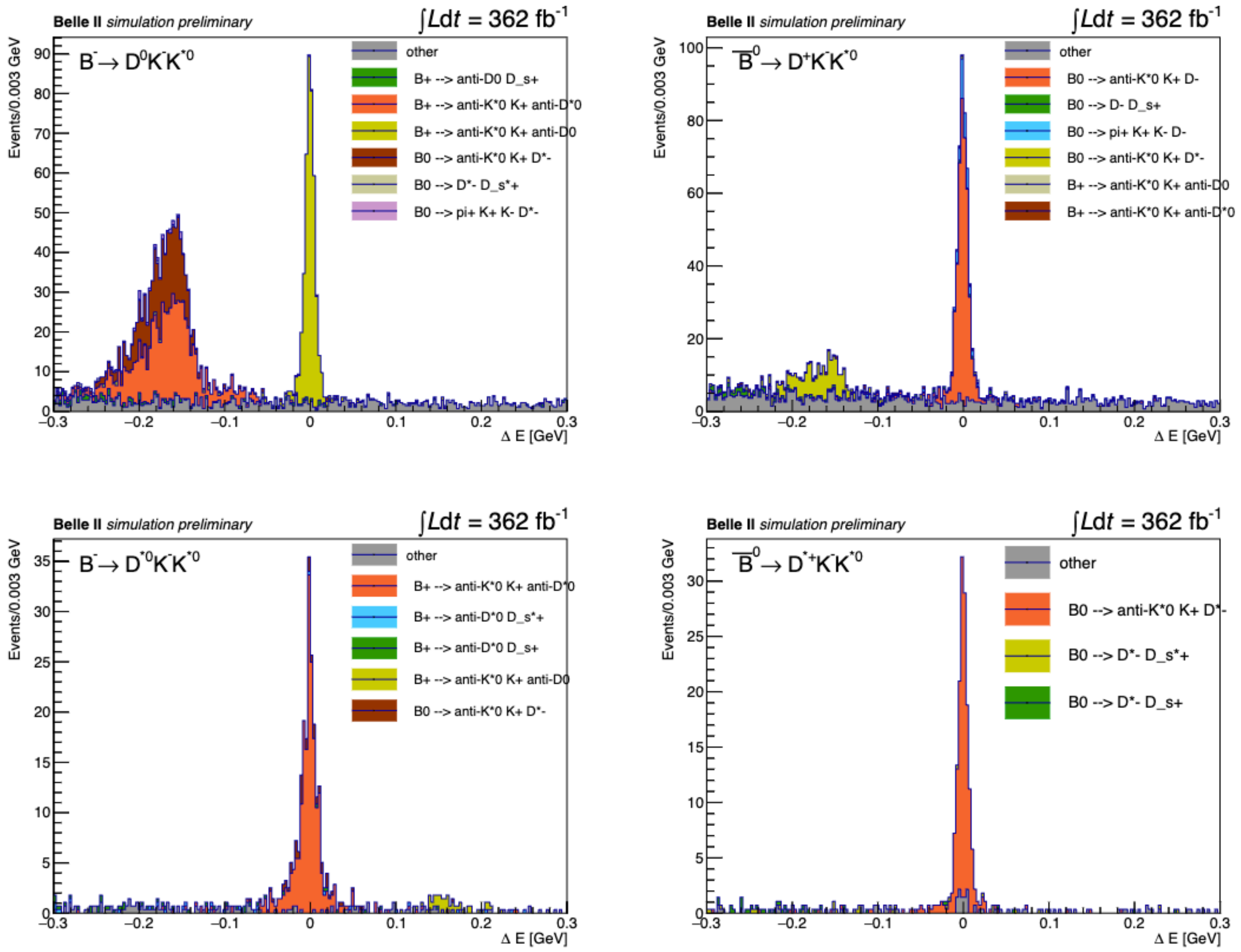


- Clear **discrepancy with phase-space** distribution (from MC)
- Can be compatible with a low-mass **resonance** ρ'-like (See for instance: *[arXiv:2201.06881]*)
- *NB: Efficiency correction not applied in the $m(KK_S^0)$ shown here*

[from arXiv:2305.01321]

Reconstructed sample composition - K^{*0} channels

[MC Simulation]

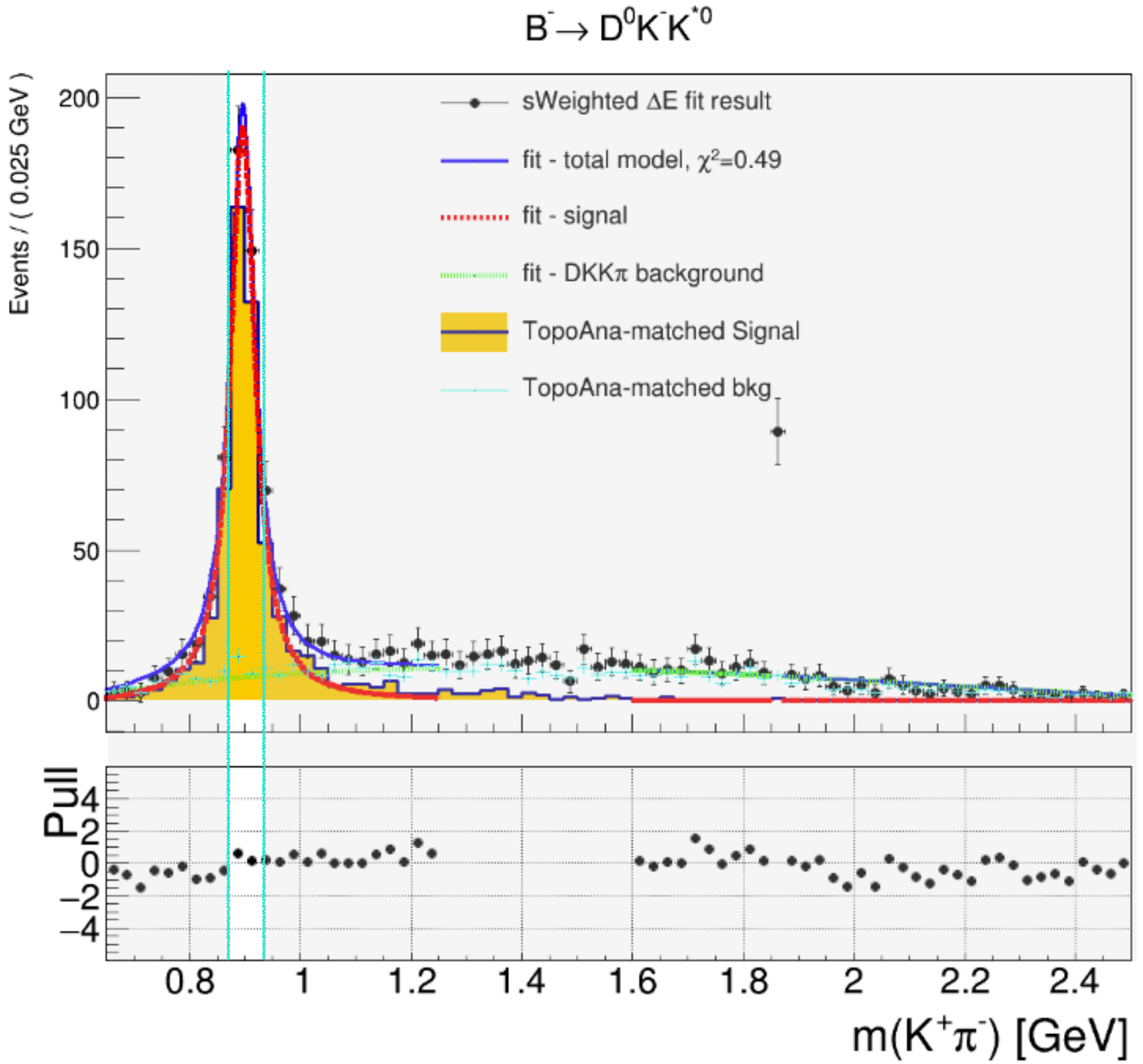


- all the channels are very clean
- some off-peak feed across
- All the channels have a $B \to DKK\pi$ peaking bkg *[next slides]*
- The $D^{*0}KK^{*0}$ has an additional peaking bkg, likewise the K_S^0 case

$B \to DKK\pi$ background

[MC Simulation]

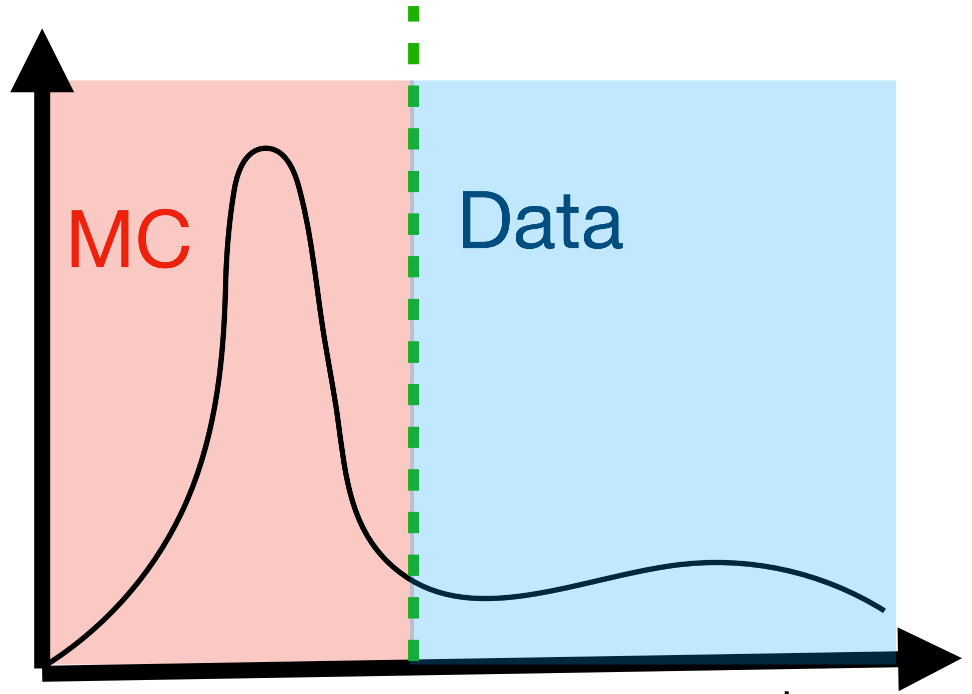
- Do not apply the cut in $m(K^+\pi^-)$
- **perform a fit in ΔE** to separate $q\bar{q}/B\bar{B}$ bkg
- **use the sPlot to obtain the $m(K^+\pi^-)$** distribution, free from $q\bar{q}/B\bar{B}$ bkg
- **fit the resulting $m(K^+\pi^-)$** distribution
  - Signal: BW phase-space corrected, with mean=$m_{K^{*0}}$ and free width
  - Bkg: 3rd degree Chebyshev polynomial (parameters fixed)
  - veto on $m(K^+\pi^-) \approx m_D$ for $B \to D^{(*)}DK$ + veto [1.25 GeV,1.60 GeV] for additional K* resonances
- **Extract the fraction** $R_{NR} = N_{DKK\pi}/N_{DKK^*}$ in signal region (under the K* peak)
- applying the cut $|m(K^+\pi^-) - m_{K^*}| < 50$ MeV
- **Perform the ΔE fit**, including the NR $DKK\pi$ component



$B \to DKK\pi$ background: results

[MC Simulation]

- NR fraction estimated on MC
- Since we know that the MC is not-realistic, we also use **data in the $m(K^*)$ sideband** merged with data in signal region to obtain a more reliable expectation (value never used only for systematic uncertainties estimation)
- Only statistical error shown

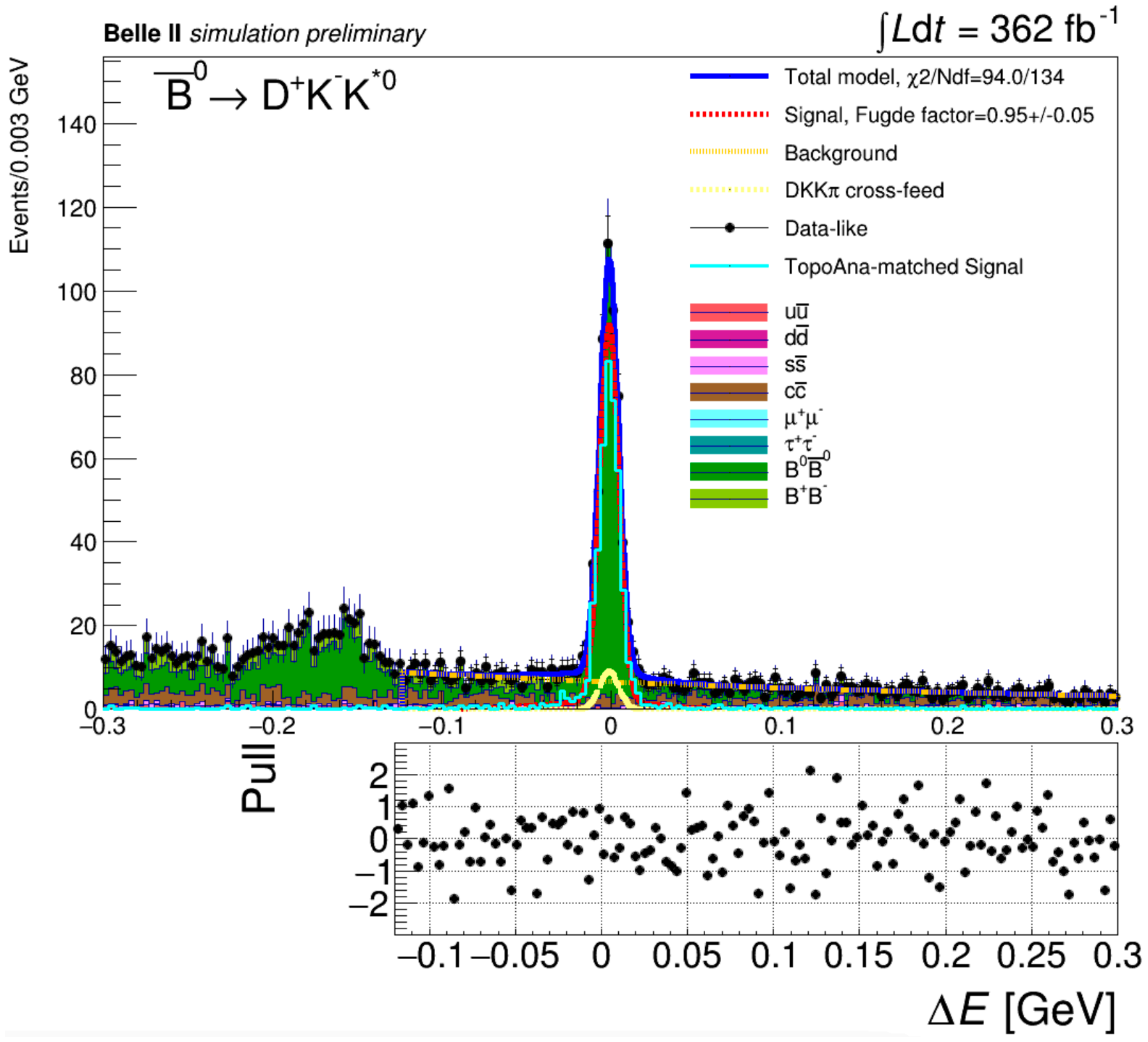


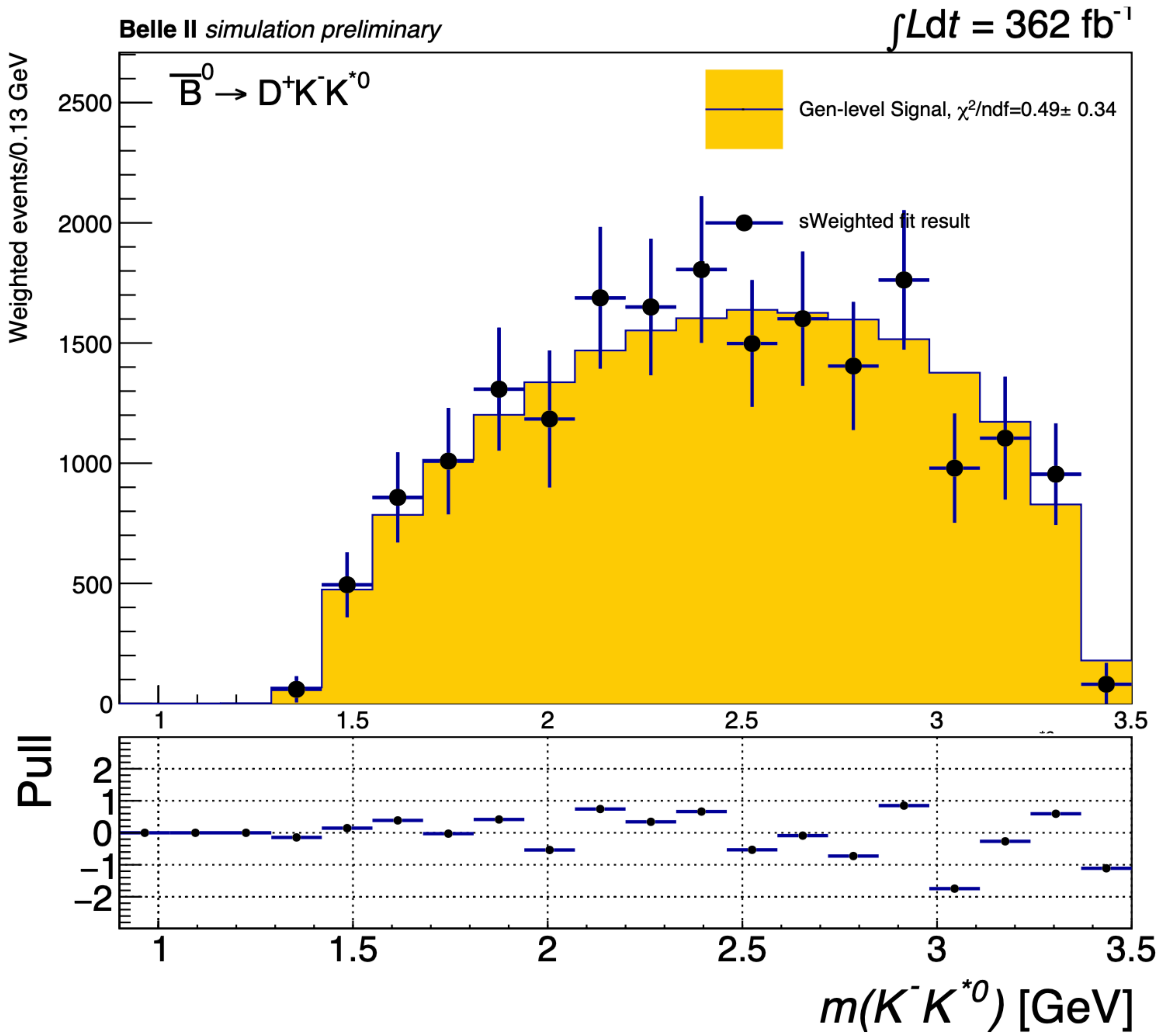
Channel	Non-resonant fraction (MC) [%]	Non-resonant fraction (Data-sideband) [%]
$B^- \to D^0 K^- K^{*0}$	7.0 ± 0.7	2.2 ± 0.4
$\bar{B}^0 \to D^+ K^- K^{*0}$	9.0 ± 0.8	0.5 ± 0.4
$B^- \to D^{*0} K^- K^{*0}$	4.8 ± 0.8	1.4 ± 0.5
$\bar{B}^0 \to D^{*+} K^- K^{*0}$	7.6 ± 1.3	2.4 ± 0.8

$B \to DKK^{*0}$ channels

[MC Simulation]

Channel	Yield	TopoAna-matched Yield	Integrated ε	$\mathcal{B}$ $[10^{-4}]$	Monte Carlo $\mathcal{B}$ $[10^{-4}]$
$B^- \to D^0 K^- K^{*0}$	454 ± 22	422 ± 21	0.0499 ± 0.0001	$8.86 \pm 0.45 \pm 0.41$	8.07 ± 0.06
$\overline{B}^0 \to D^+ K^- K^{*0}$	475 ± 23	447 ± 21	0.0243 ± 0.0001	$8.54 \pm 0.44 \pm 0.41$	8.83 ± 0.06
$B^- \to D^{*0} K^- K^{*0}$	195 ± 16	200 ± 14	0.0194 ± 0.0001	$14.87 \pm 1.27 \pm 1.14$	14.93 ± 0.09
$\overline{B}^0 \to D^{*+} K^- K^{*0}$	148 ± 12	149 ± 12	0.0180 ± 0.0001	$12.40 \pm 1.2 \pm 0.63$	13.00 ± 0.08





- Good agreement with the expected values
- modelled also the $DKK\pi$ non-resonant bkg
- **efficiency corrected** $m(KK^{*0})$ distributions

Angular analysis

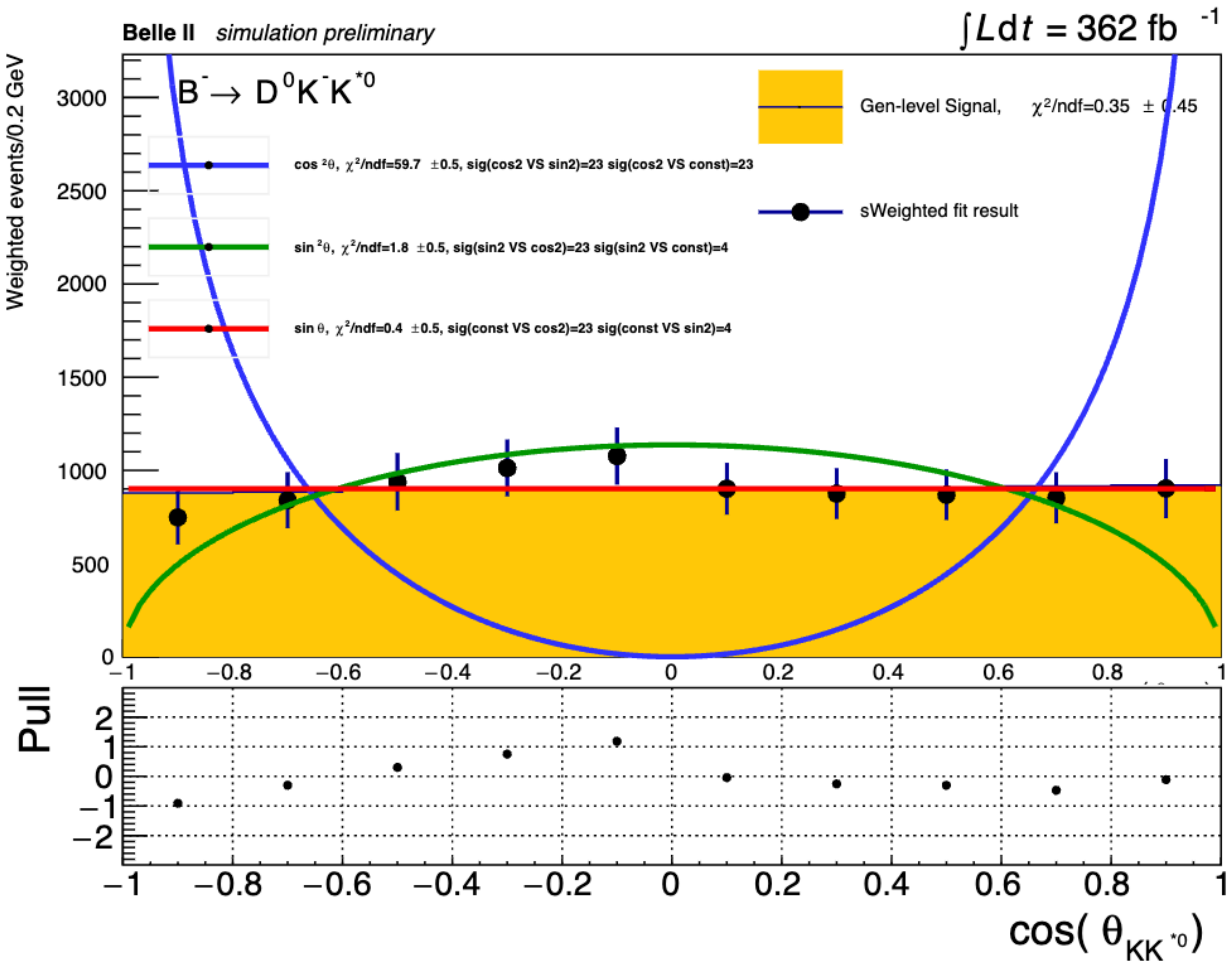
[MC Simulation]

- Validated with generator level distribution from signal MC (normalized to the same integral)
- Tested all the spin-pairity hypothesis of Belle
- NB: the generic MC is phase space

from Belle paper

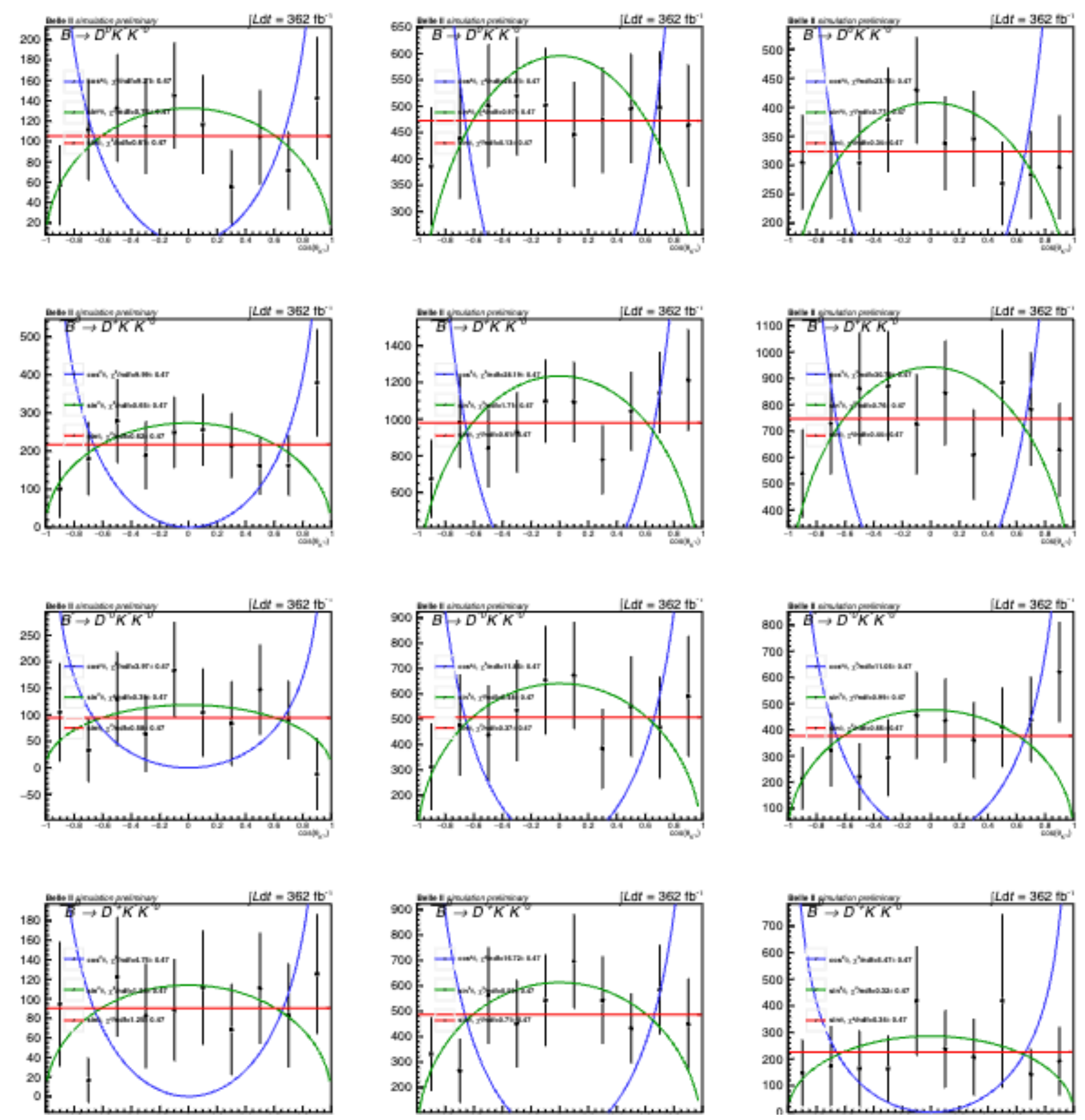
The angular distributions of the $K^- K^{*0}$ system with $J^P = 0^-, 1^-, 1^+$. The values of χ^2/n.d.f. were obtained from fits to the experimental angular distributions (see Fig. 4)

	D meson modes		D^* meson modes		Sum
J^P	θ_{KK}	θ_{K^*}	θ_{KK}	θ_{K^*}	χ^2/n.d.f.
0^-	const	$\cos^2\theta_{K^*}$	const	$\cos^2\theta_{K^*}$	71.7/16
1^-	$\sin^2\theta_{KK}$	$\sin^2\theta_{K^*}$	–	–	37.3/ 8
1^+	const	const	const	const	20.7/16



- + differential in bin of mKK

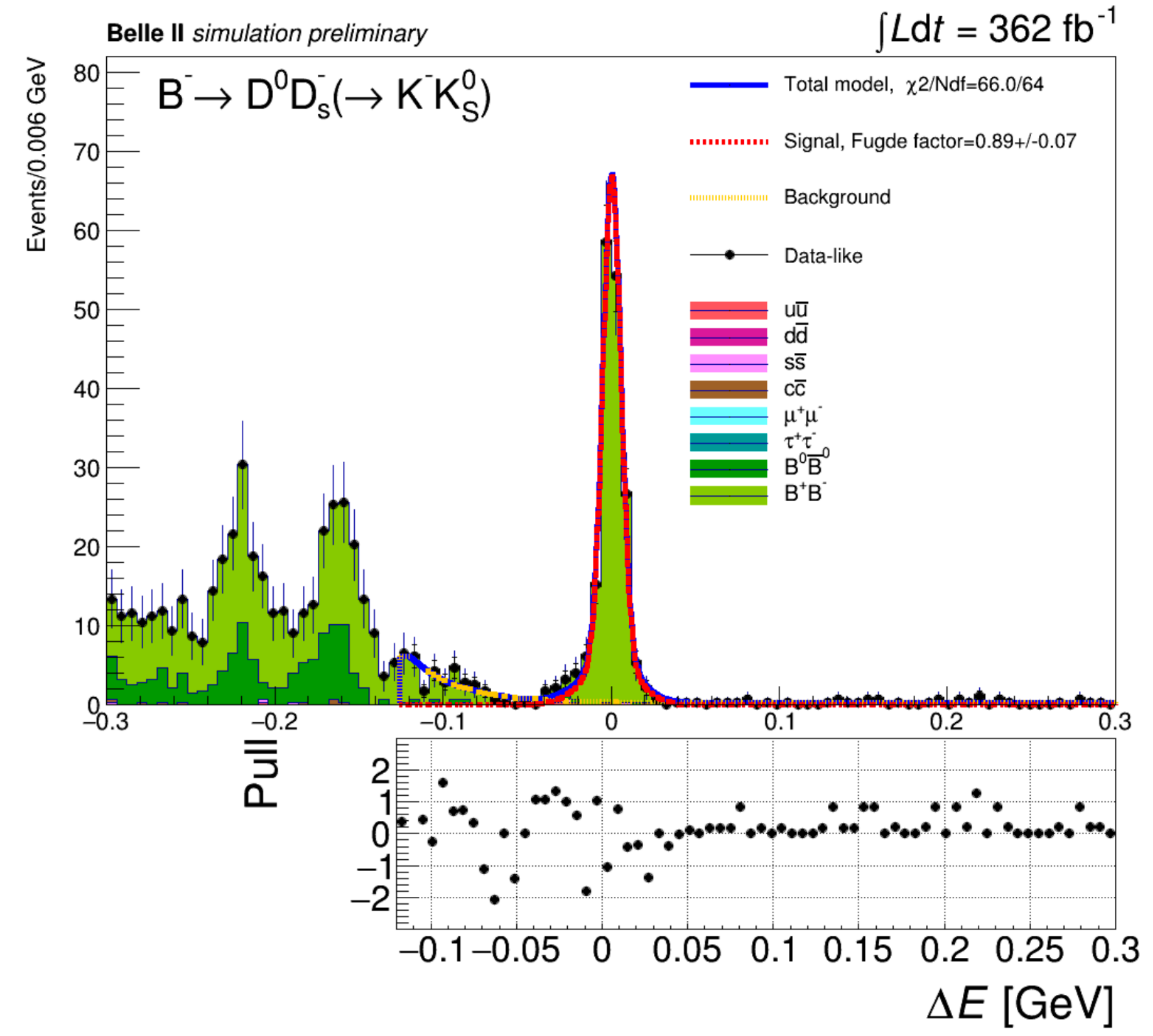
0.9-1.7 GeV 1.7-2.6 GeV 2.6-3.5 GeV

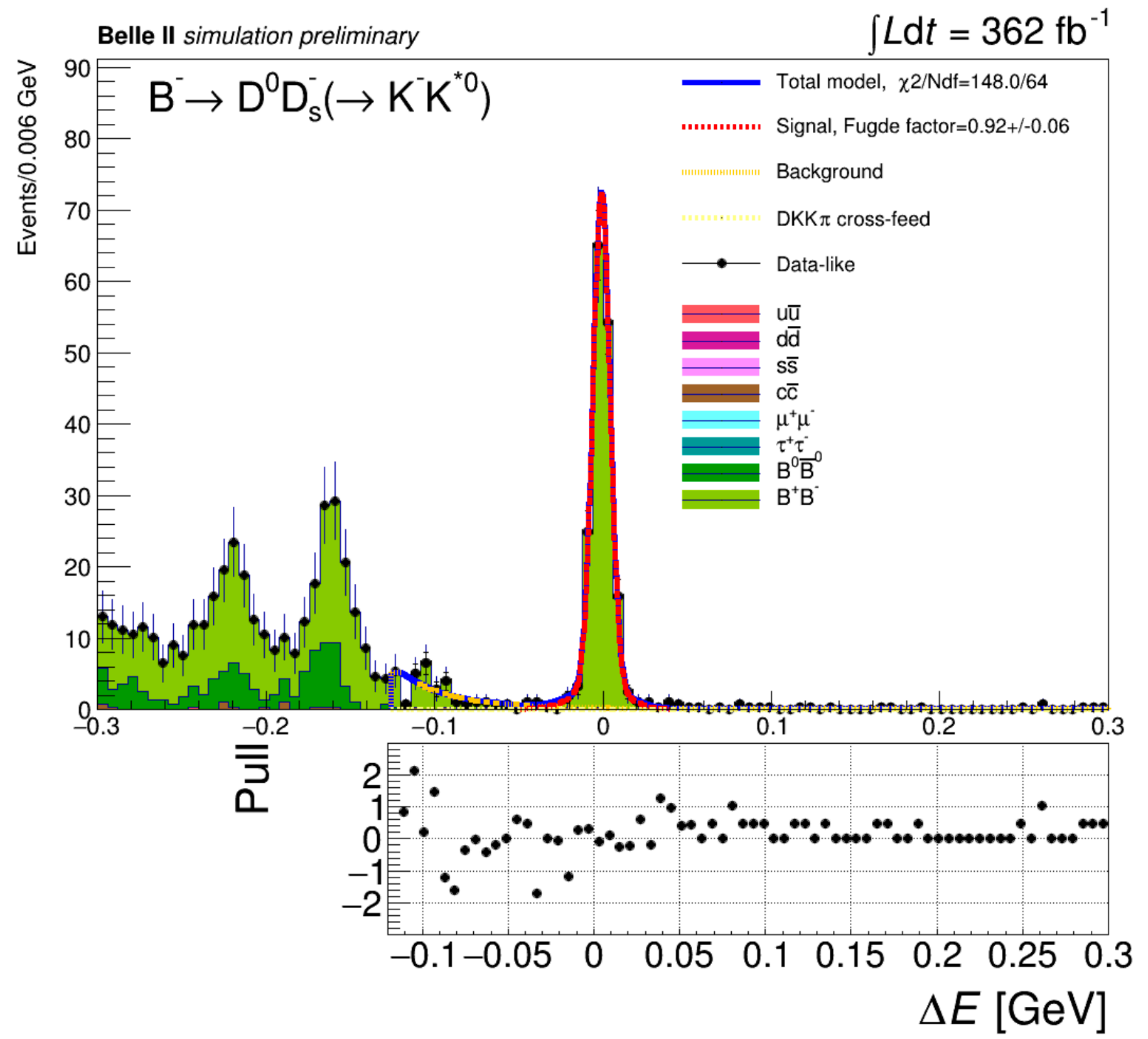


Control channel: $B \to D^{(*)} D_s^-(\to K^- K^{(*)0}_{(S)})$

[MC Simulation]

- Pro: very **clean** channel, **no Pythia**, same **efficiency**
- Cons: lower yield ($BR(D_S^- \to K^- K_S^0) \simeq 1.5\,\%$)
- Reconstruction: reverted the cut
  $|m_{D_s} - m_{KK}| > 20 \text{ MeV} \longrightarrow |m_{D_s} - m_{KK}| < 20 \text{ MeV}$
- Result: branching fraction statistically limited, with **precision compatible with the world average**





Branching fractions

Channel	Yield	Average $\varepsilon(K^{*0}/K_S^0)$	$\mathcal{B}$ $[10^{-4}]$	World average $\mathcal{B}$ $[10^{-4}]$
$B^- \to D^0 D_s^-$	343 ± 19	$0.011/0.05$	$96 \pm 5 \pm 4$	90 ± 9
$\overline{B}^0 \to D^+ D_s^-$	333 ± 19	$0.06/0.02$	$82 \pm 5 \pm 4$	72 ± 8
$B^- \to D^{*0} D_s^-$	90 ± 11	$0.04/0.02$	$99 \pm 12 \pm 7$	82 ± 17
$\overline{B}^0 \to D^{*+} D_s^-$	88 ± 10	$0.05/0.02$	$81 \pm 9 \pm 4$	80 ± 11

Conclusions

- 8 $B \to D^{(*)}KK_{(S)}^{(*)0}$ channels: **5 *(expected)* world best measurement**, **3 new observations**
  - Interesting resonant structures in K_S^0 channels observed
  - Resonant structures in K^{*0} channels expected (from Belle)
- 4 $B \to D^{(*)}D_s^-$ channels: **4 *(expected)* world best measurements**, statistically limited
- *Status:* the analysis is within the internal review phase, the result will be submitted to the journal and public presented **in the next months**

BACKUP SLIDES

Previous measurements (Belle)

[Belle, Phys.Lett.B,542(2002)]

Decay mode	BR (10^{-4})	Signif. (σ)
$B^- \to D^0 K^- K^{*0}$	$7.5 \pm 1.3 \pm 1.1$	8.0
$\overline{B}^0 \to D^+ K^- K^{*0}$	$8.8 \pm 1.1 \pm 1.5$	10.4
$B^- \to D^{*0} K^- K^{*0}$	$15.3 \pm 3.1 \pm 2.9$	6.7
$\overline{B}^0 \to D^{*+} K^- K^{*0}$	$12.9 \pm 2.2 \pm 2.5$	9.5
$B^- \to D^0 K^- K^0$	$5.5 \pm 1.4 \pm 0.8$	5.5

Decay mode	BR (10^{-4})	Signif. (σ)
$\overline{B}^0 \to D^+ K^- K^0$	$1.6 \pm 0.8 \pm 0.3$	2.6
$B^- \to D^{*0} K^- K^0$	$5.2 \pm 2.7 \pm 1.2$	2.5
$\overline{B}^0 \to D^{*+} K^- K^0$	$2.0 \pm 1.5 \pm 0.4$	2.5

$\mathscr{L}_{int=}$=29.4 fb^{-1}

Full reconstruction and selection

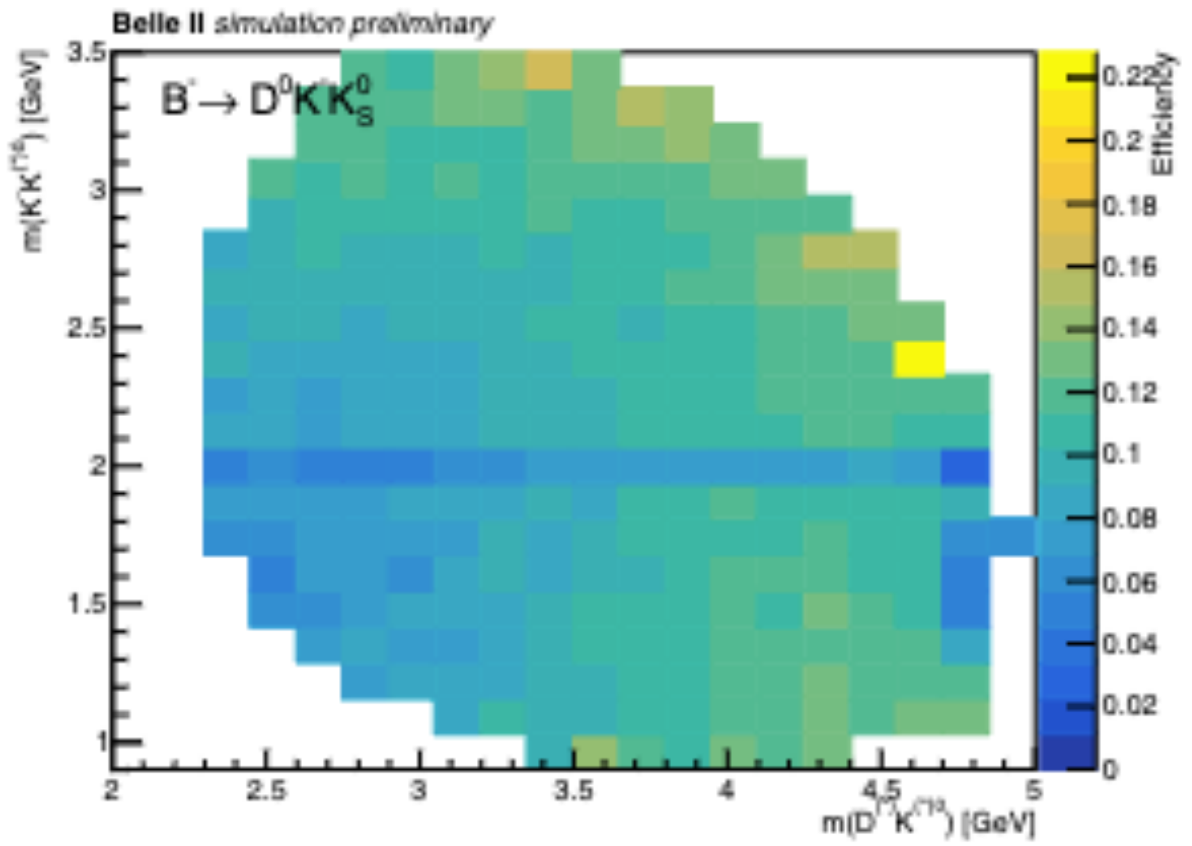
- K^+: $\mathrm{PID}(K) > 0.6$
- π^+: $\mathrm{PID}(\pi) > 0.6$
- γ: `eff40_May2020Fit` collection
  $T_{cluster} < 100$ ns
  hadronicSplitOffSuppression>0.1
- π^0 :
  pi0:`eff40_May2020Fit` collection
  $|m^{reco}_{\pi^0} - m^{PDG}_{\pi^0}| < 15$ MeV
- K^0_S :
  `K_S0:merged` collection
  $|m^{reco}_{K^0_S} - m^{PDG}_{K^0_S}| < 10$ MeV (3σ)
  $R_{\pi\pi-\mathrm{IP}} > 0.4$ cm
  $\cos\theta > 0.8$, θ= angle between $\vec{p}_{K^0_S}$ and $\vec{v}_{K^0_S}$
- $K^{*0} \to K^+\pi^-$
  with $|M^{\mathrm{reco}}_{K^*} - M^{\mathrm{PDG}}_{K^*}| < 50$ MeV
- $D^+ \to K^-\pi^+\pi^+$, $D^0 \to K^-\pi^+$
  with $|M^{\mathrm{reco}}_{D} - M^{\mathrm{PDG}}_{D}| < 15$ MeV (3σ)
  mass and vertex kinematic fit
- $D^{*+} \to D^0\pi^+$
  with $|M^{\mathrm{reco}}_{D^*} - M^{\mathrm{PDG}}_{D^*}| < 1.5$ MeV (3σ)
- $D^{*0} \to D^0\pi^0$
  with $|M^{\mathrm{reco}}_{D^*} - M^{\mathrm{PDG}}_{D^*}| < 3$ MeV (3σ)

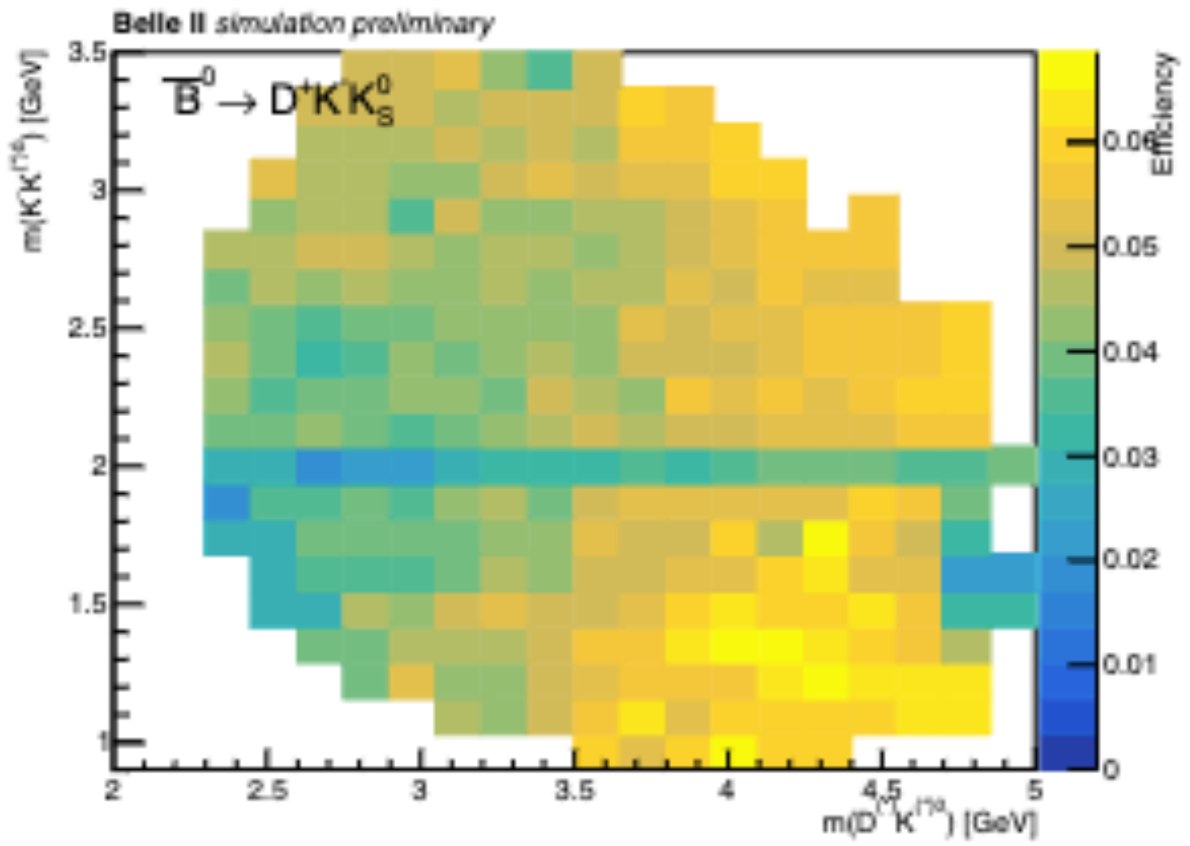
- $M_{bc} > 5.272$ GeV
- -0.12 GeV $< \Delta E < 0.3$ GeV
- $B \to DD_s^-(\to KK)$ **bkg suppression:** $\Rightarrow$
  $|m_{D_s} - m_{KK}| > 20$ MeV (4σ)
- $q\bar{q}$ **and** $B\bar{B}$ **backgrounds suppression:**
  - $R_2 = \mathrm{FWM}(2)/\mathrm{FWM}(0) < 0.5$ (FWM=fox-wolfram moment)
  - $|\cos\theta_{T_BT_0}| < 0.85$, where $\theta_{T_BT_0}$= angle between B thrust axis and the thrust axis of the ROE (rest-of-event)
  - $|\cos\theta_{p_Bp_{\mathrm{beam}}}| < 0.9$, where $\theta_{p_Bp_{\mathrm{beam}}}$= angle between B momentum and beam direction
- **Best candidate selection:** $\min|M_{bc} - M_B|$

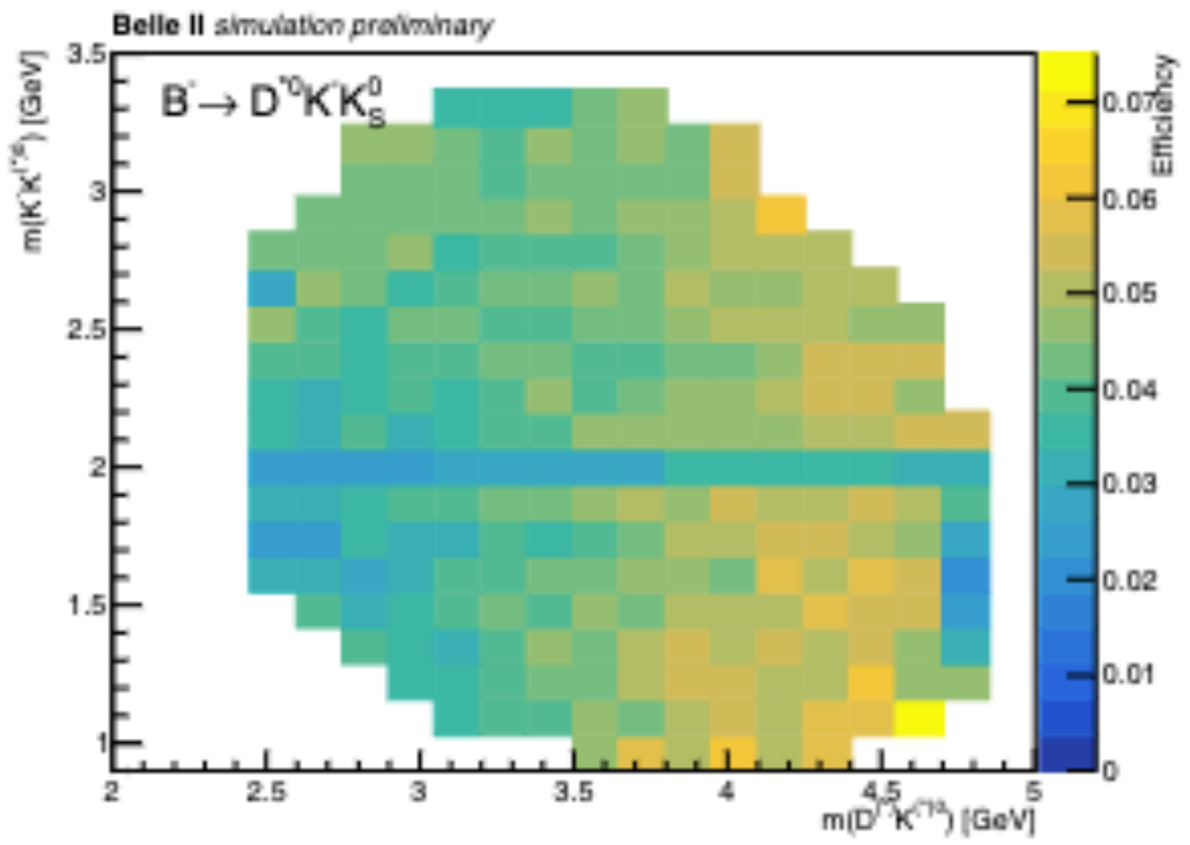
Efficiency - all the maps

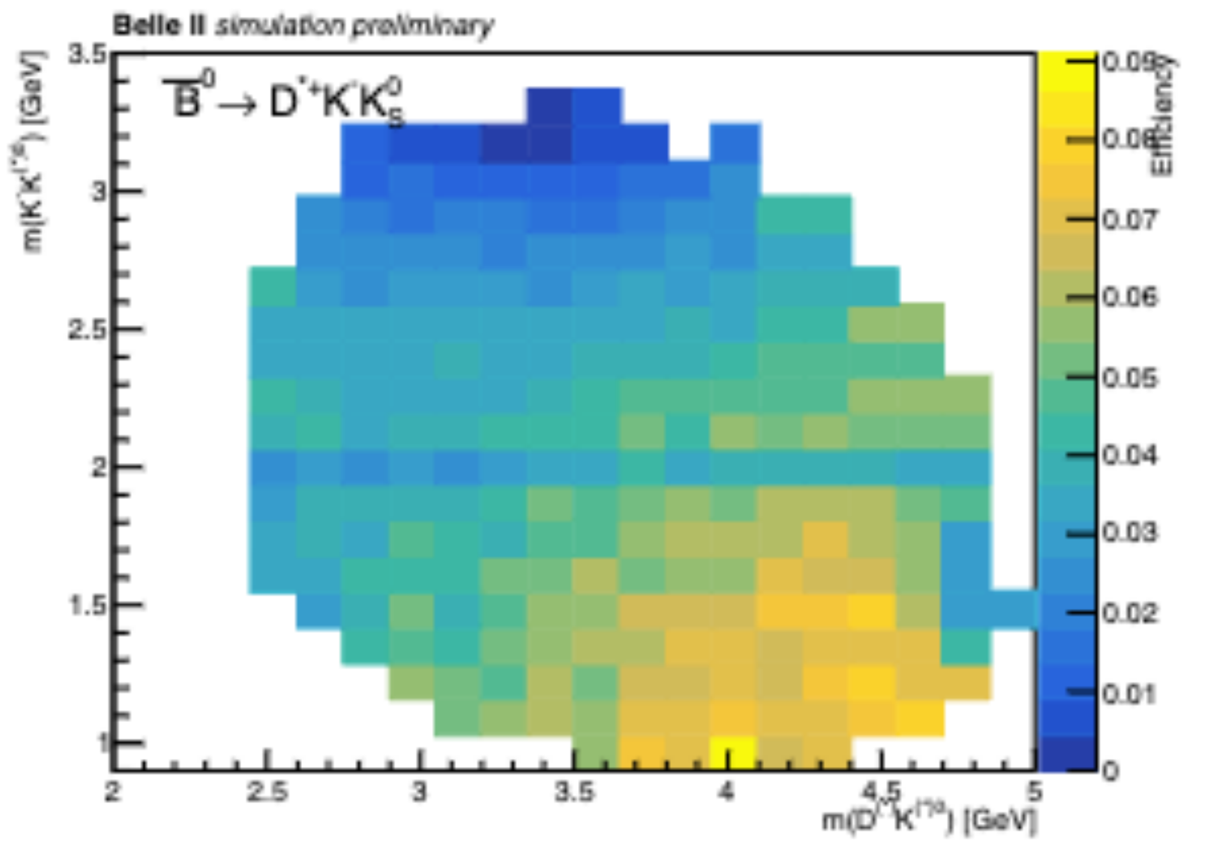
[MC Simulation]

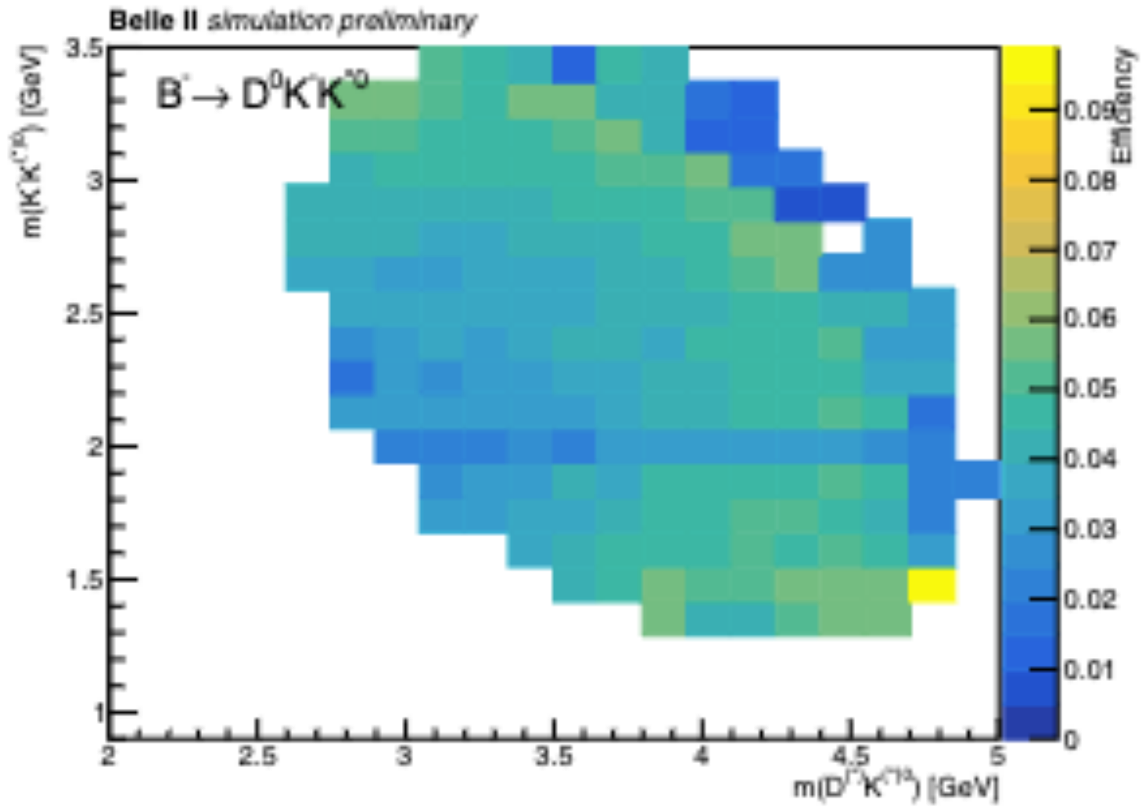
NB: z scale is not the same

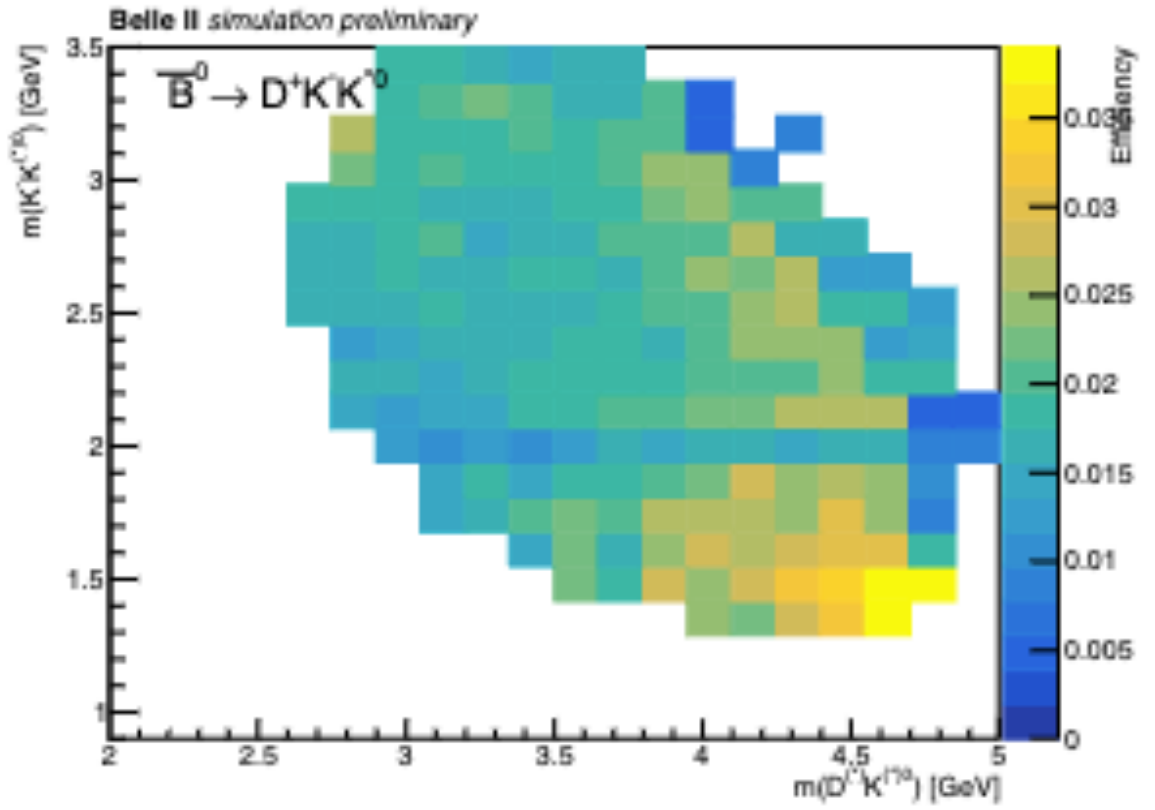


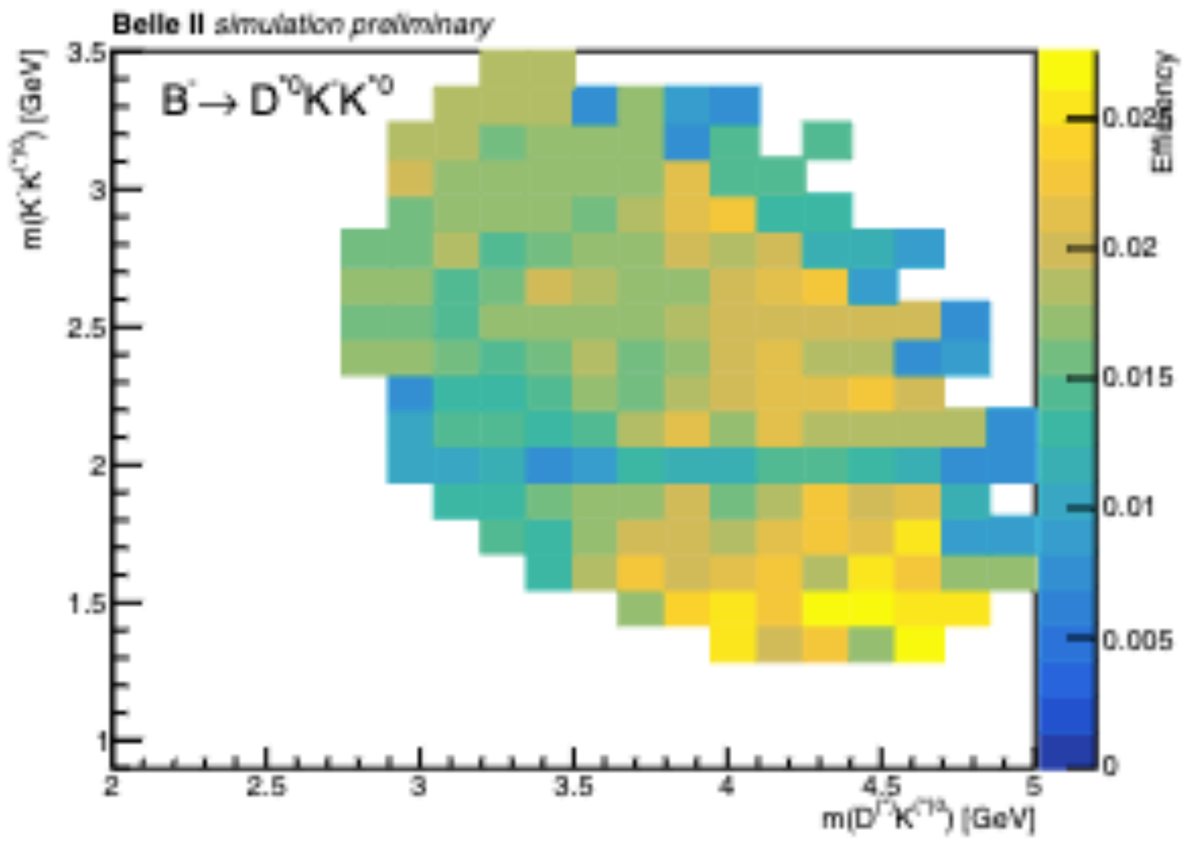


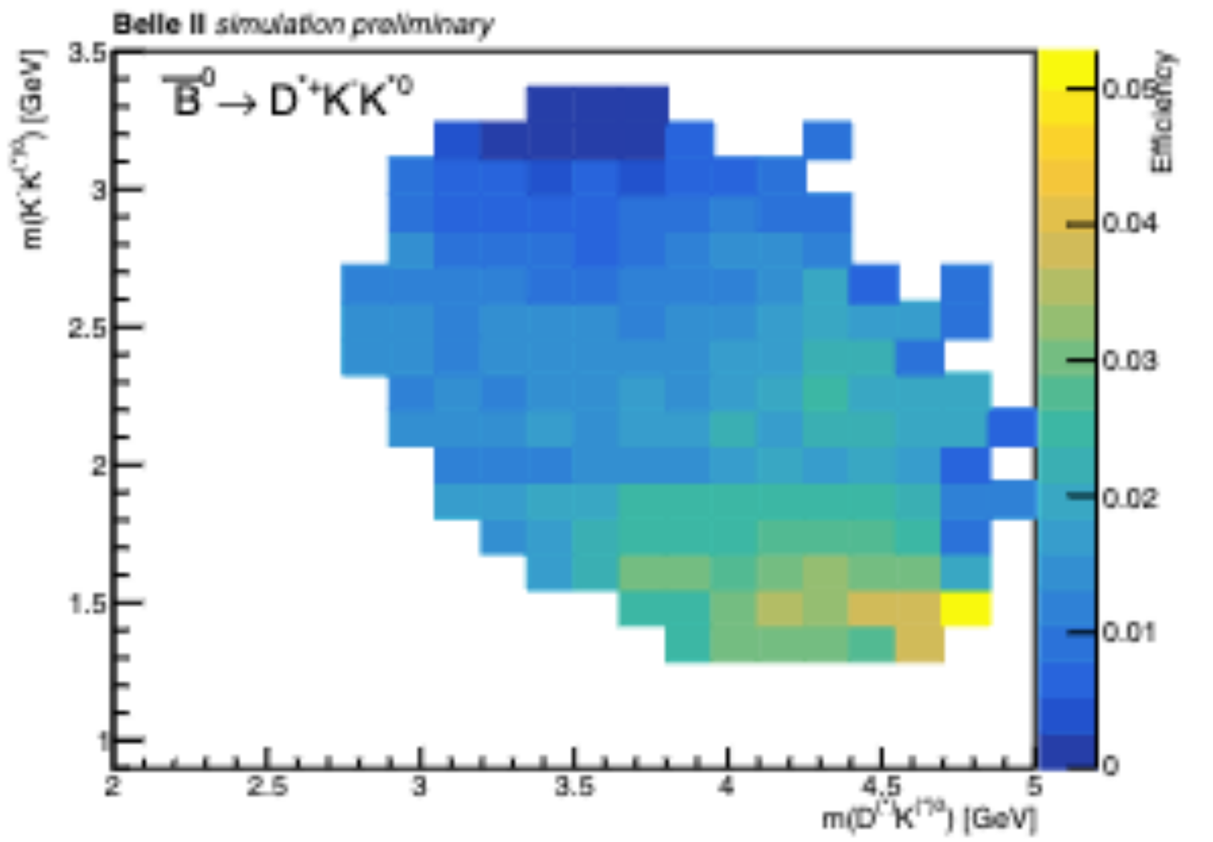






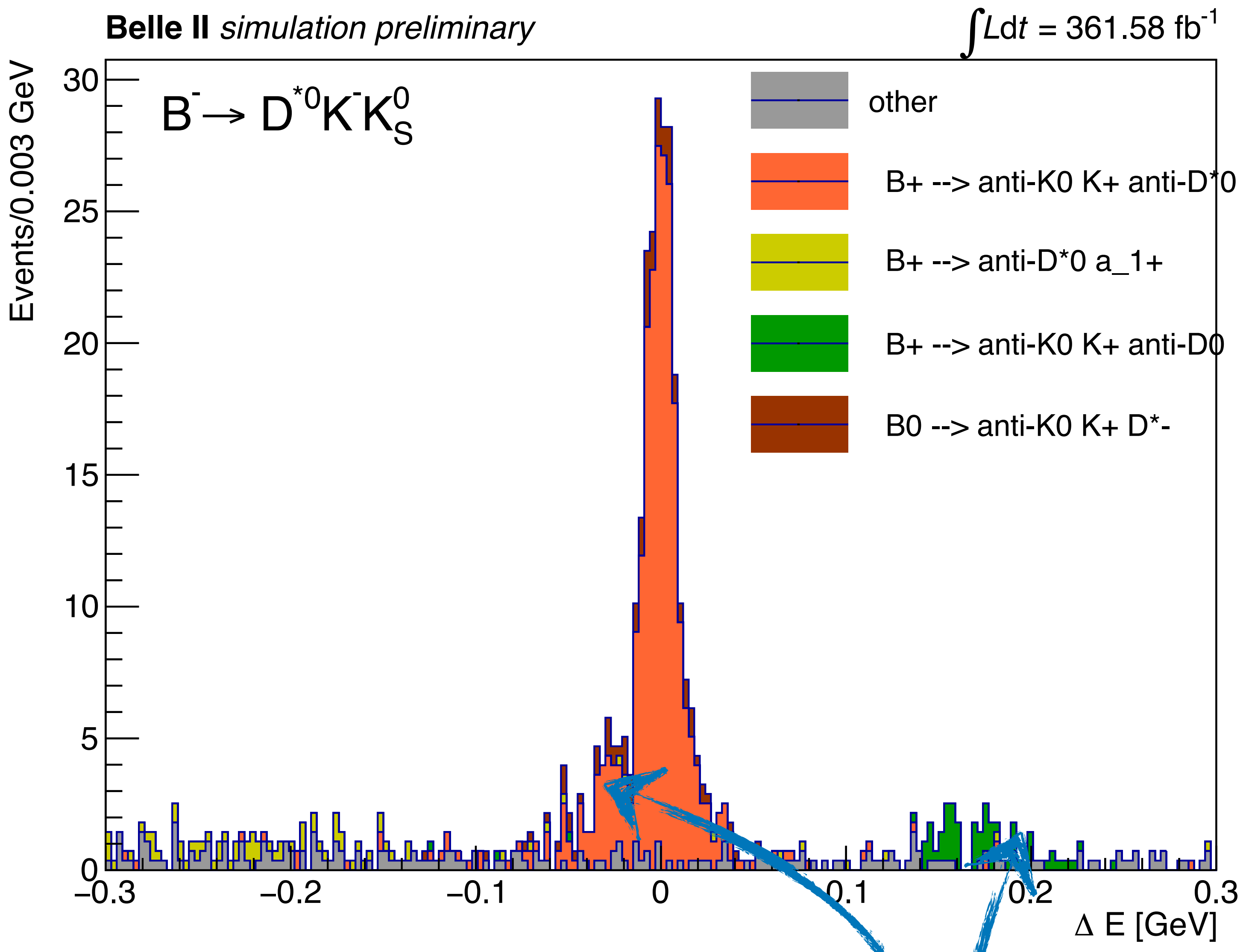






$B^- \to D^{*0} K^- K^0_S$ sample composition

[MC Simulation]



$$N^{\mathrm{bkg}}_{D^0} \propto BR(B^- \to D^0 K^- K^0_S)\varepsilon_{B^- \to D^0 K^- K^0_S} \cdot f_{\pi^0}, \quad (2)$$

where ε is the efficiency and f_{π^0} is the probability of wrong π^0 association. For the $\overline{B}^0 \to D^{*+}K^-K^0_S$ feed-across instead we have:

$$N^{\mathrm{bkg}}_{D^{*+}} \propto BR(\overline{B}^0 \to D^{*+}K^-K^0_S)\varepsilon_{\overline{B}^0 \to D^0 K^- K^0_S \text{ from } \overline{B}^0 \to D^{*+}K^-K^0_S} \cdot f_{\pi^0}, \quad (3)$$

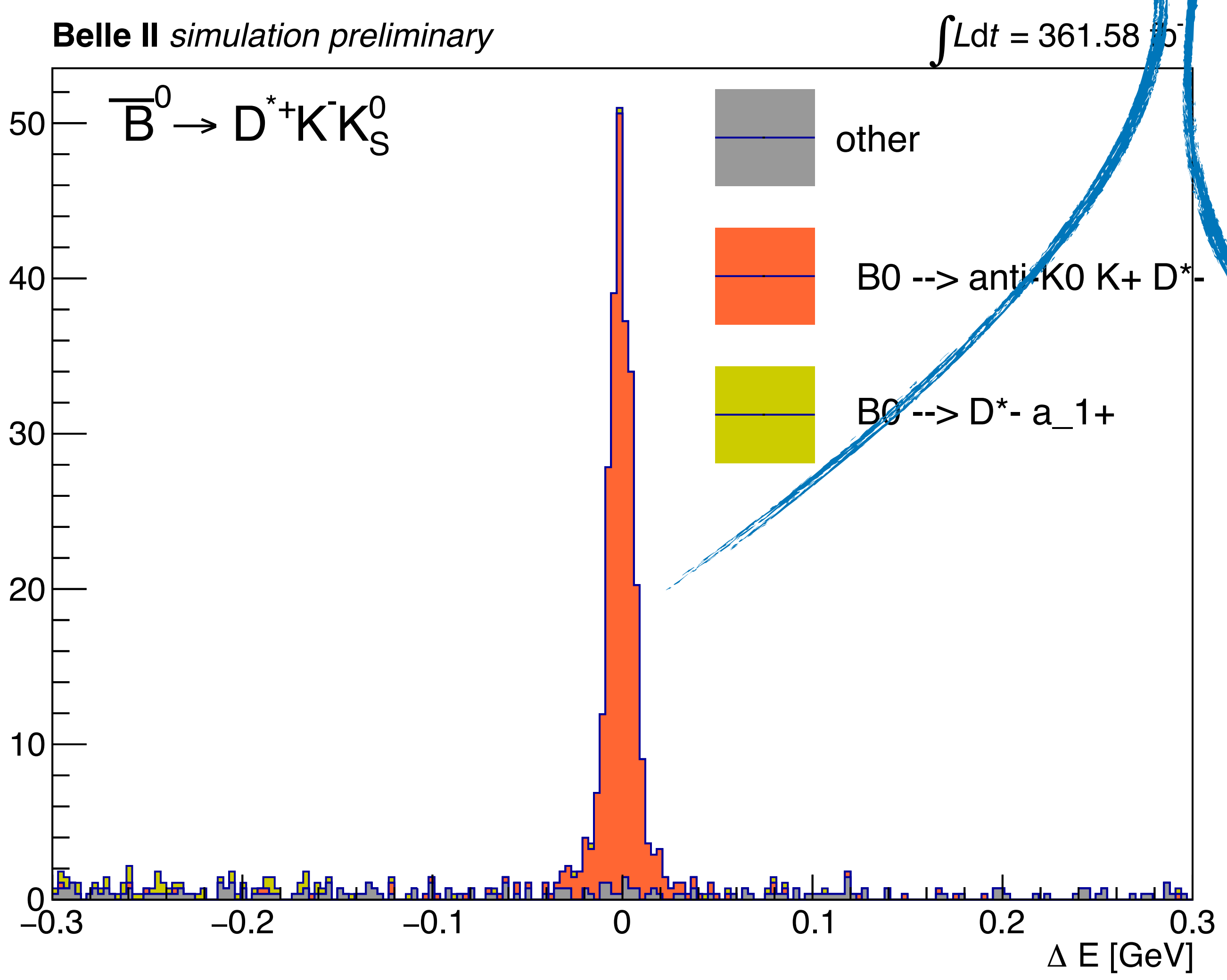
Assuming now:

$$\varepsilon_{\overline{B}^0 \to D^0 K^- K^0_S \text{ from } \overline{B}^0 \to D^{*+}K^-K^0_S} = \varepsilon_{B^- \to D^0 K^- K^0_S}, \quad (4)$$

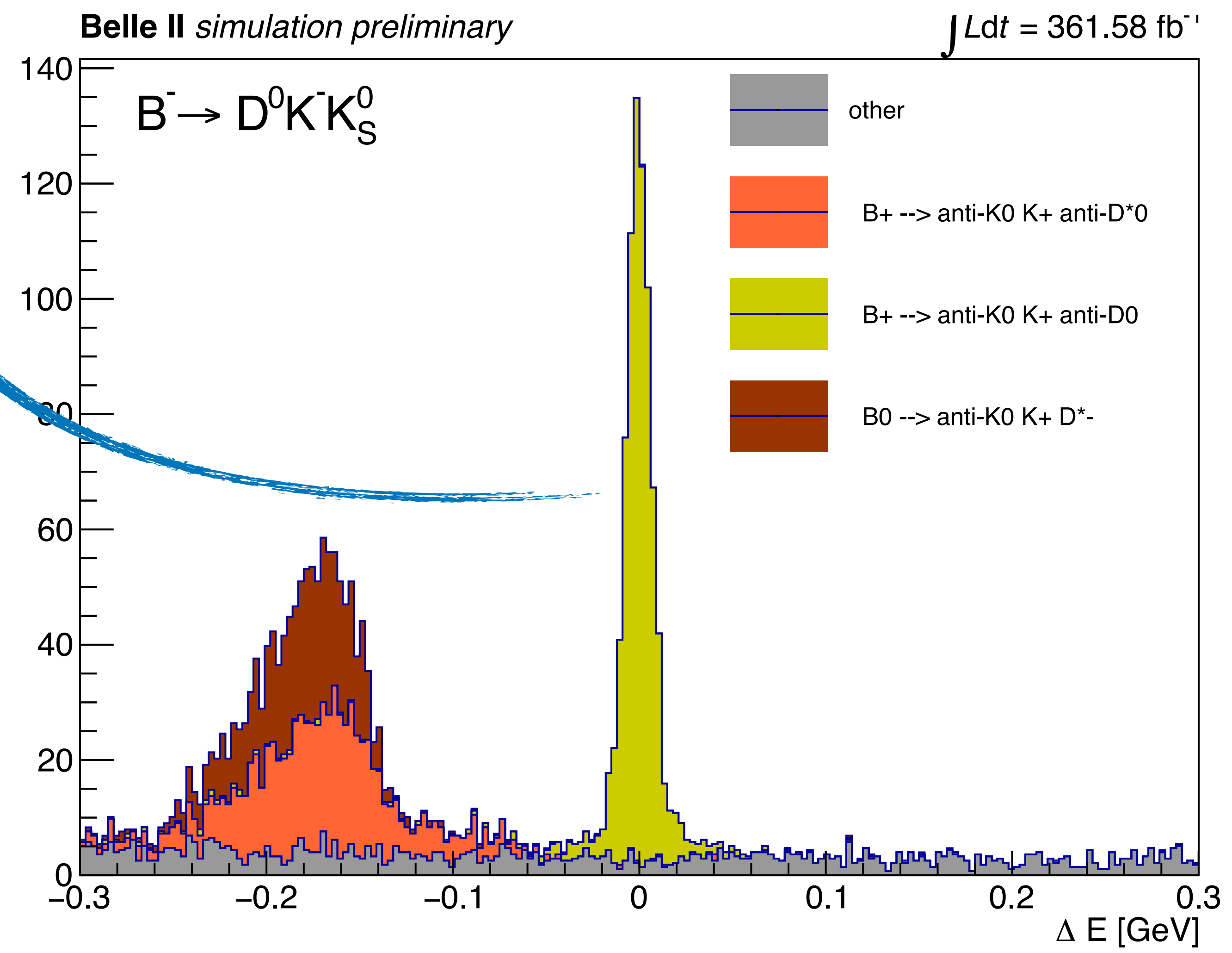
we have:

$$N^{\mathrm{bkg}}_{D^{*+}} = \frac{BR(\overline{B}^0 \to D^{*+}K^-K^0_S)}{BR(B^- \to D^0 K^- K^0_S)} \cdot N^{\mathrm{bkg}}_{D^0}. \quad (5)$$

Syst. unc. on this (110%/90% based on signal MC)



Peaking bkg: feed across of $D^{*+}KK^0_S$



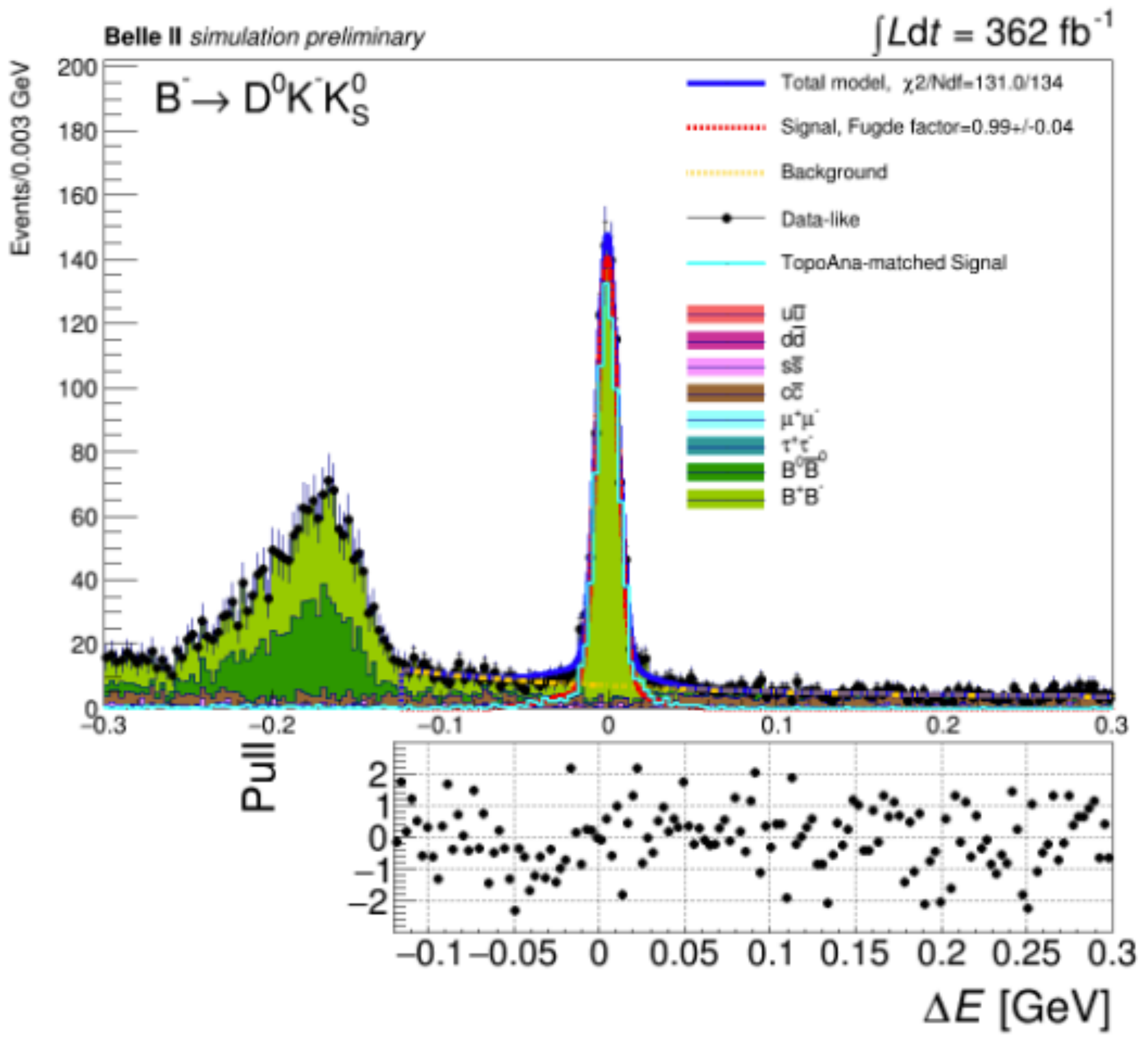
shifted bkg: feed across of $D^0KK^0_S$

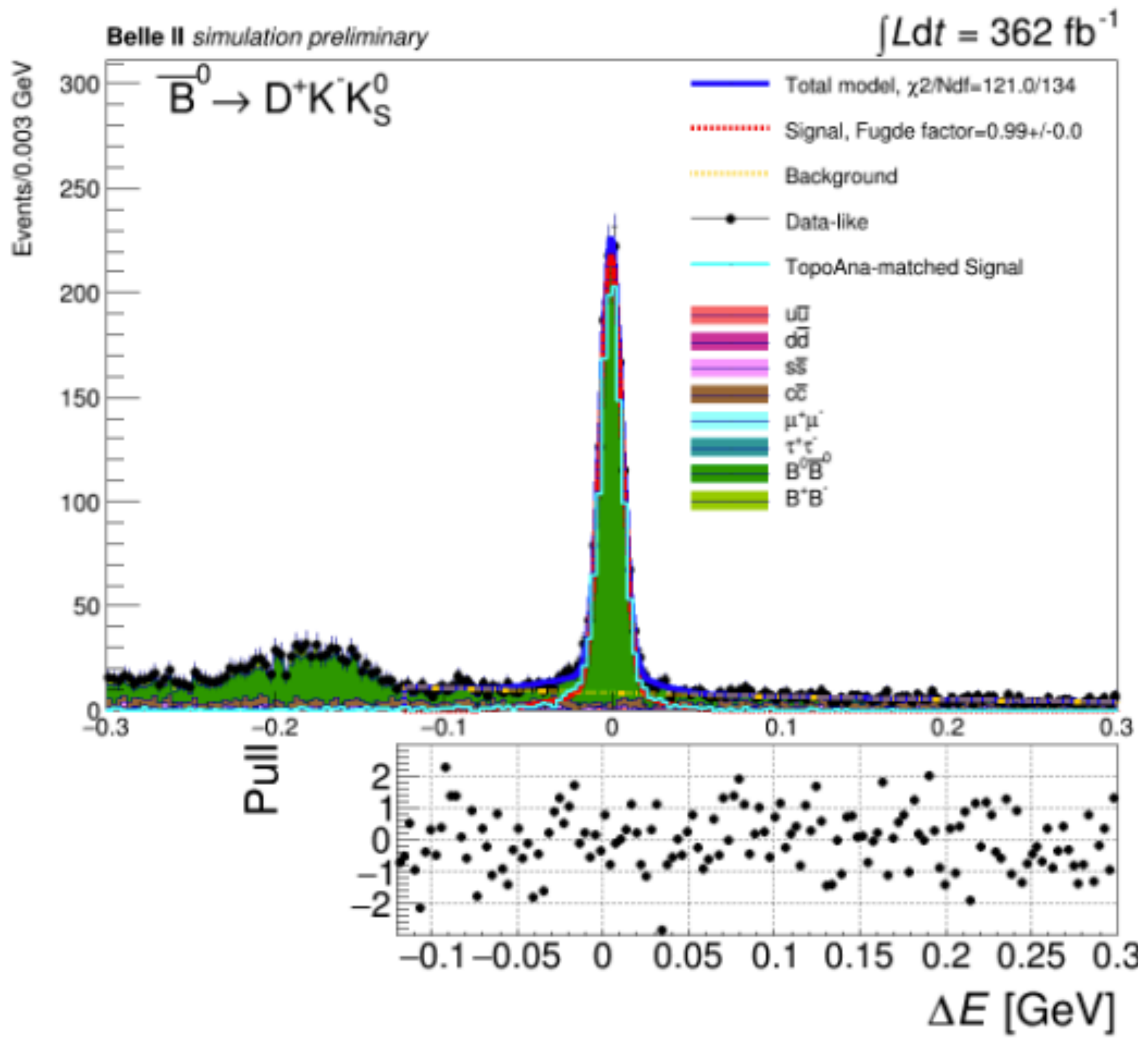
Fit model

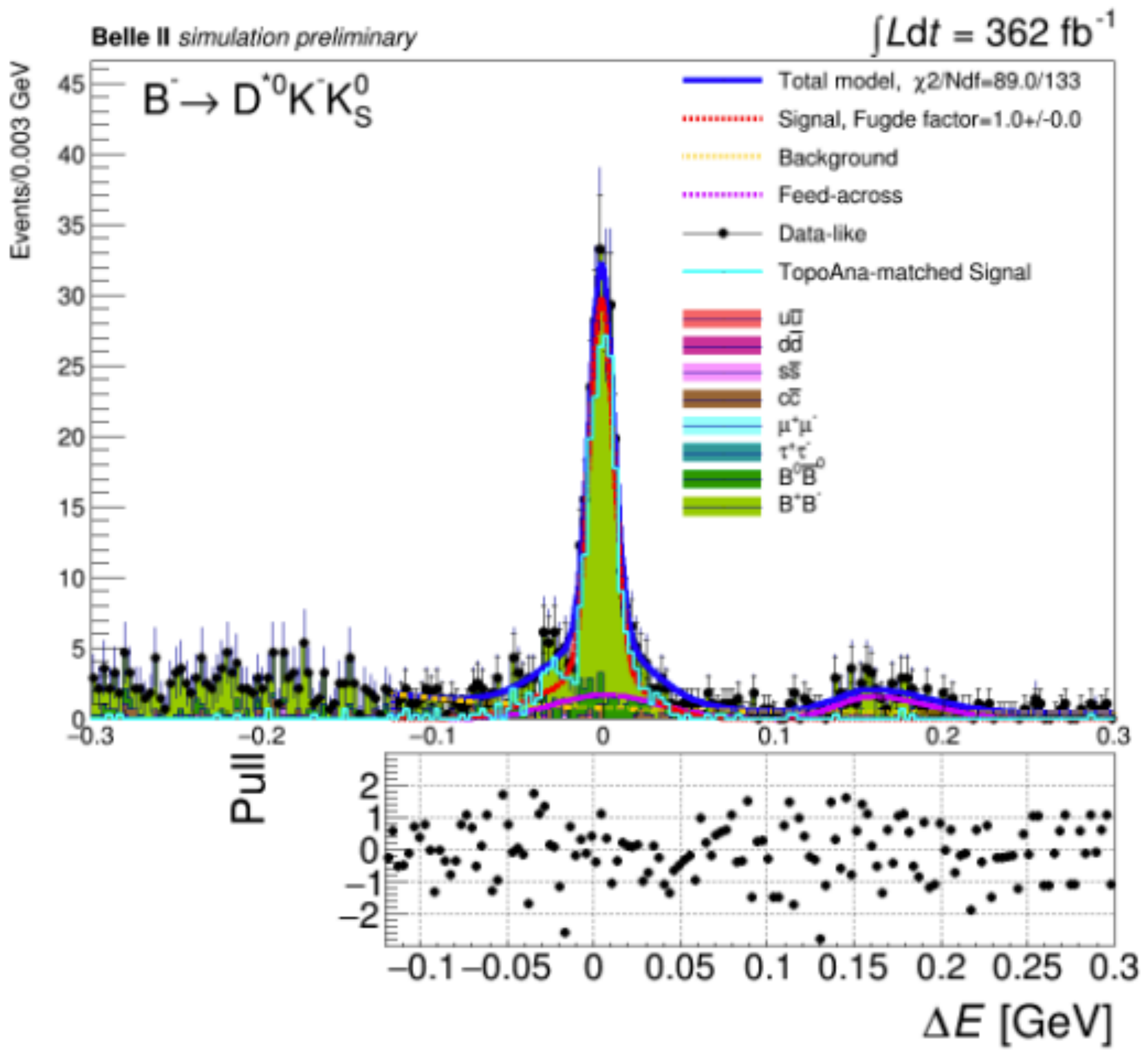
	D^0, D^+, D^{*+}	D^{*0}
K_S^0	• **Signal** sum of: - **Core Gaussian:** fixed width, free mean - **Tail Gaussian:** asymmetric fixed widths, mean=core Gaussian mean - Ratio Core/Tail fixed from MC - Free parameters: total yield, common mean, **fudge factor** (multiply the core width, fixed from D0 channel) • **Background:** exponential+constant (3 free parameters)	• **Signal:** as other mode (core Gaussian+tail Gaussian) • **Background**: as other mode (exponential+constant) • **D0 feed across:** asymmetric gaussian (widths fixed from MC, $\mu = \mu_{\text{signal}} + \Delta\mu$ fixed, yield free) • **D*+ feed across:** asymmetric gaussian (fixed width, mean 0, yield constrained from assumption)
K^{*0}	• **Signal**: same as K_S^0 modes - Free fudge factors • **Background**: same as K_S^0 modes + gaussian with width and mean as the core one, and yield constrained by R_{NR}	• **Signal**: same as $D^{*0}K^-K_S^0$ • Free fudge factor • **Background**: same as $D^{*0}K^-K_S^0$ + gaussian with width and mean as the core one, and yield constrained by R_{NR}

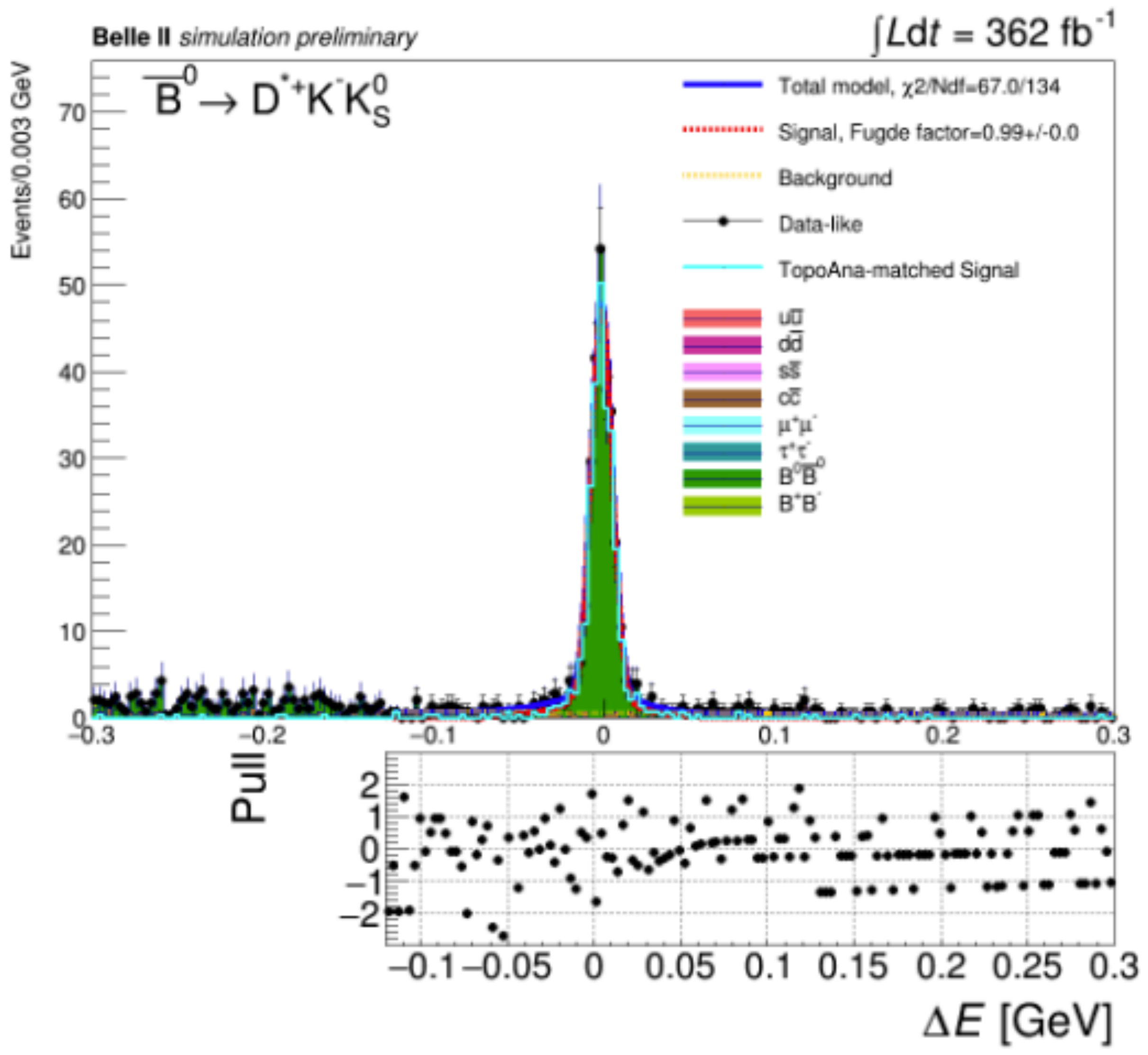
Yield extraction

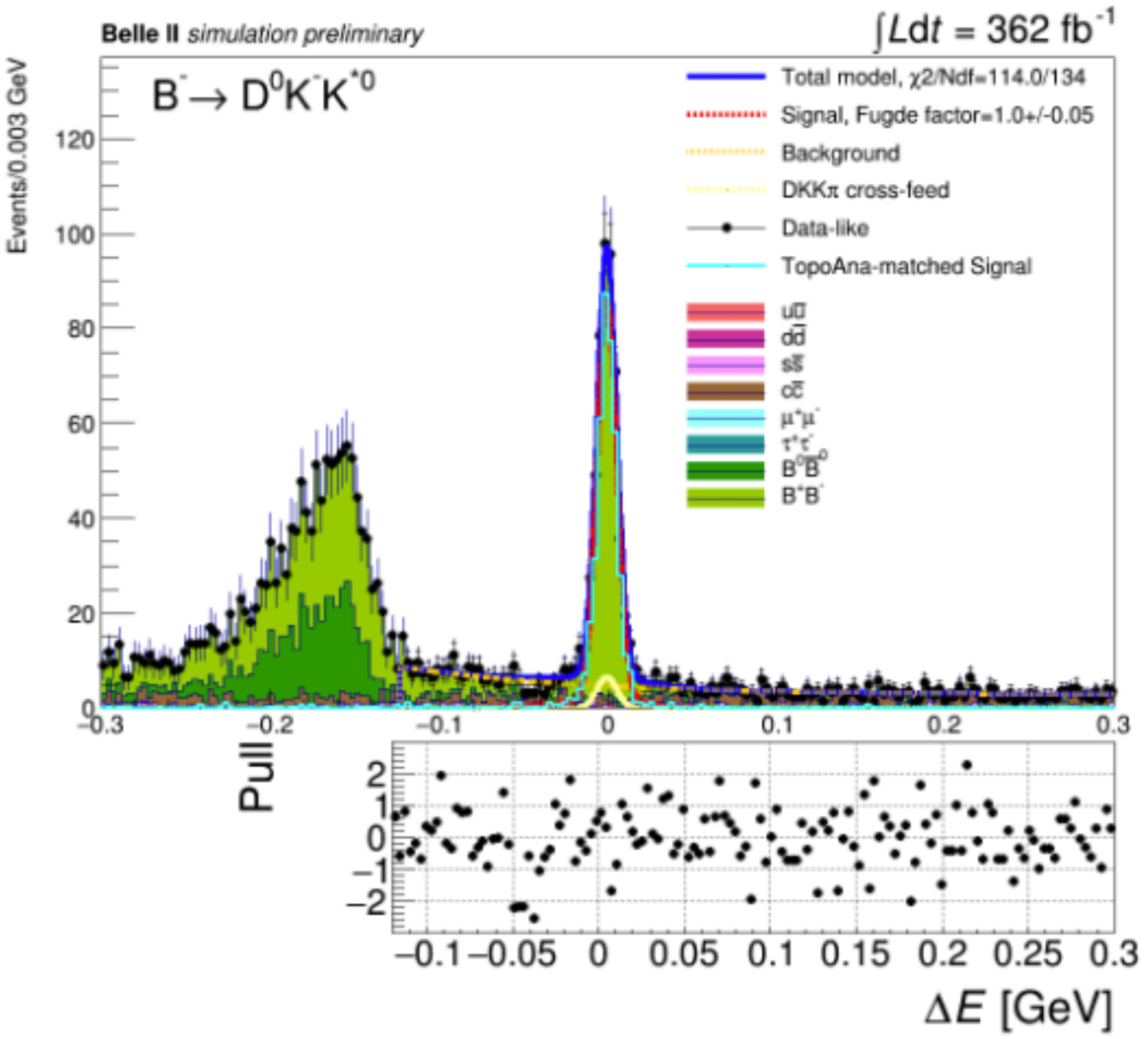
[MC Simulation]

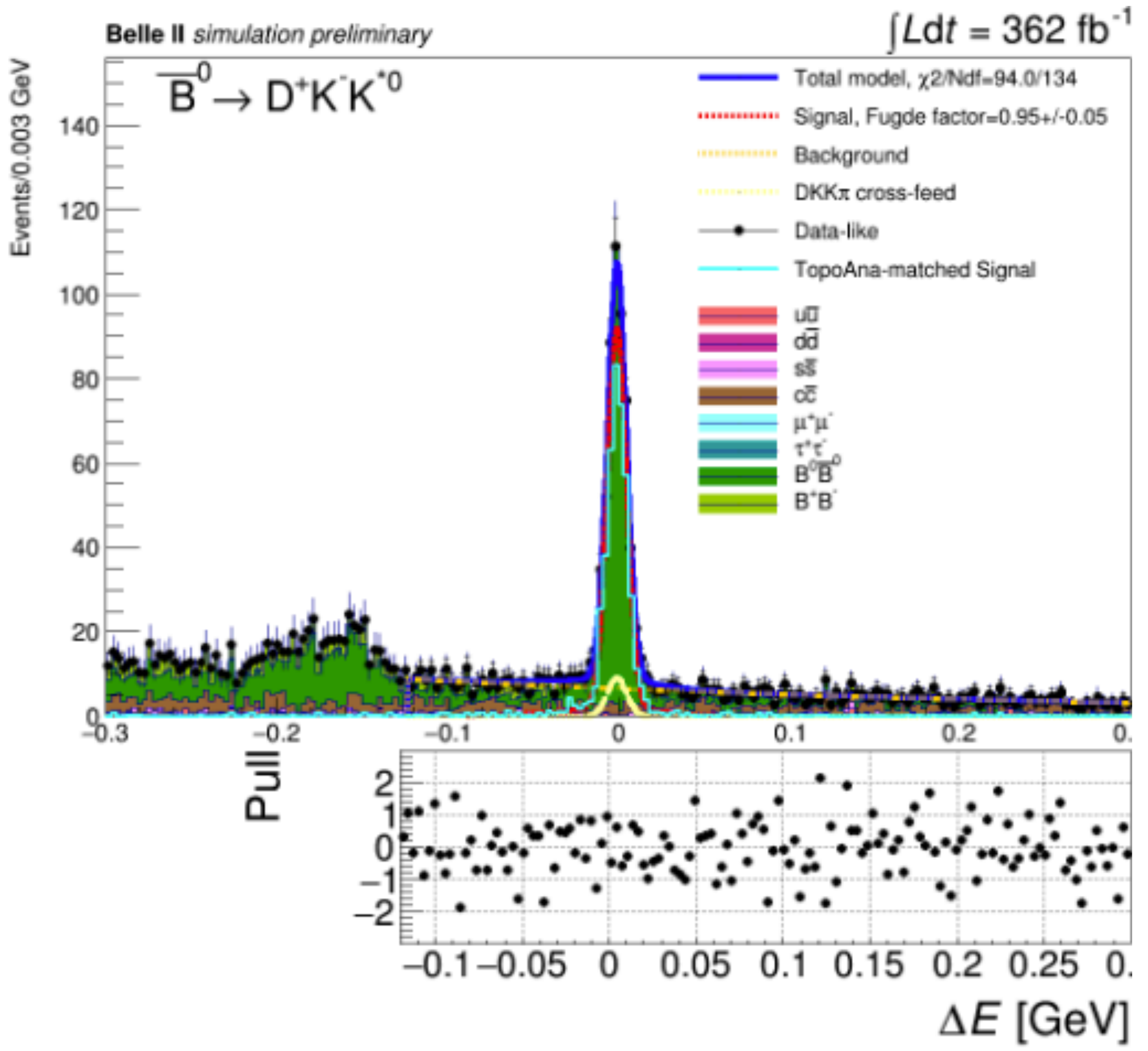


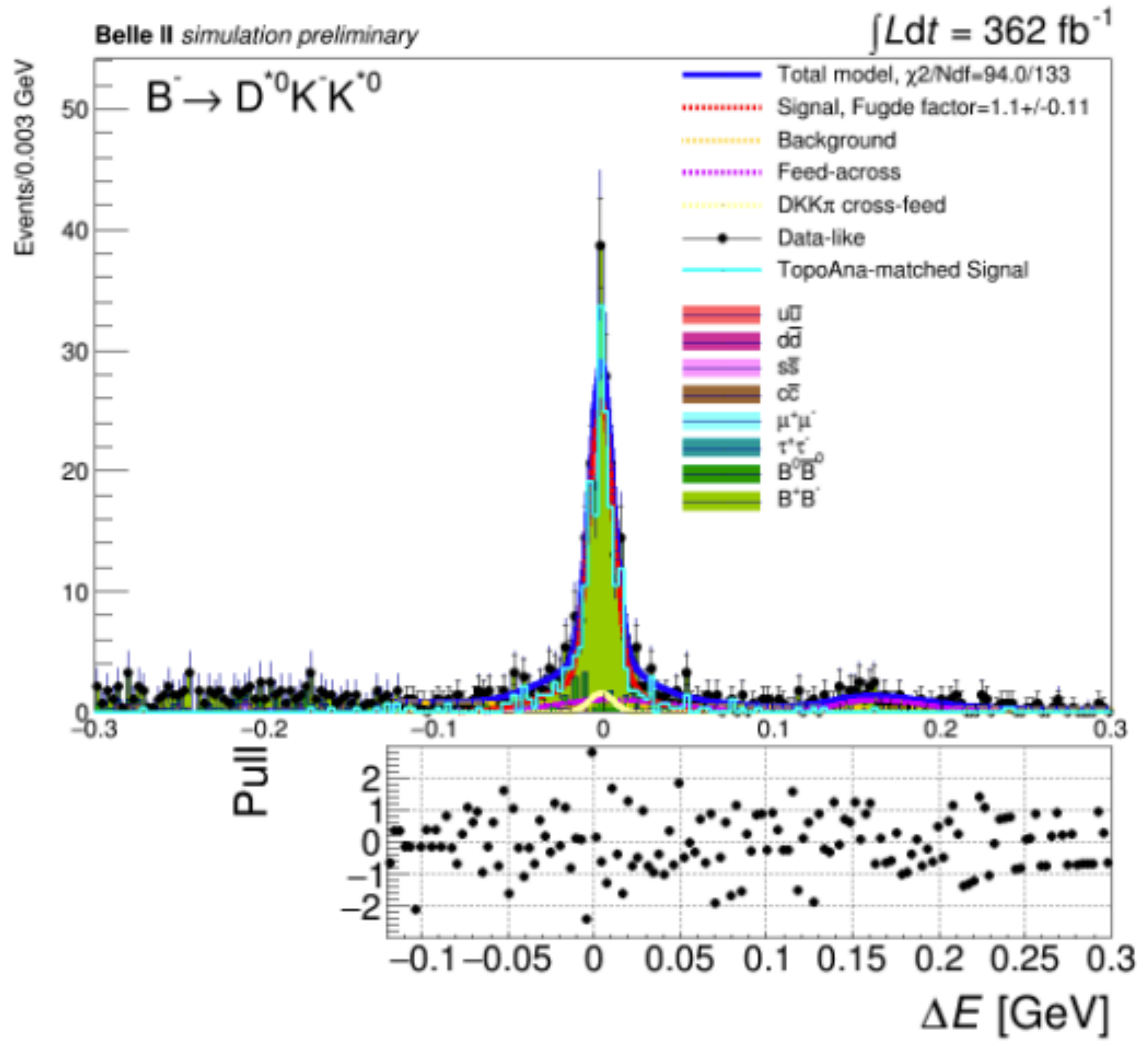


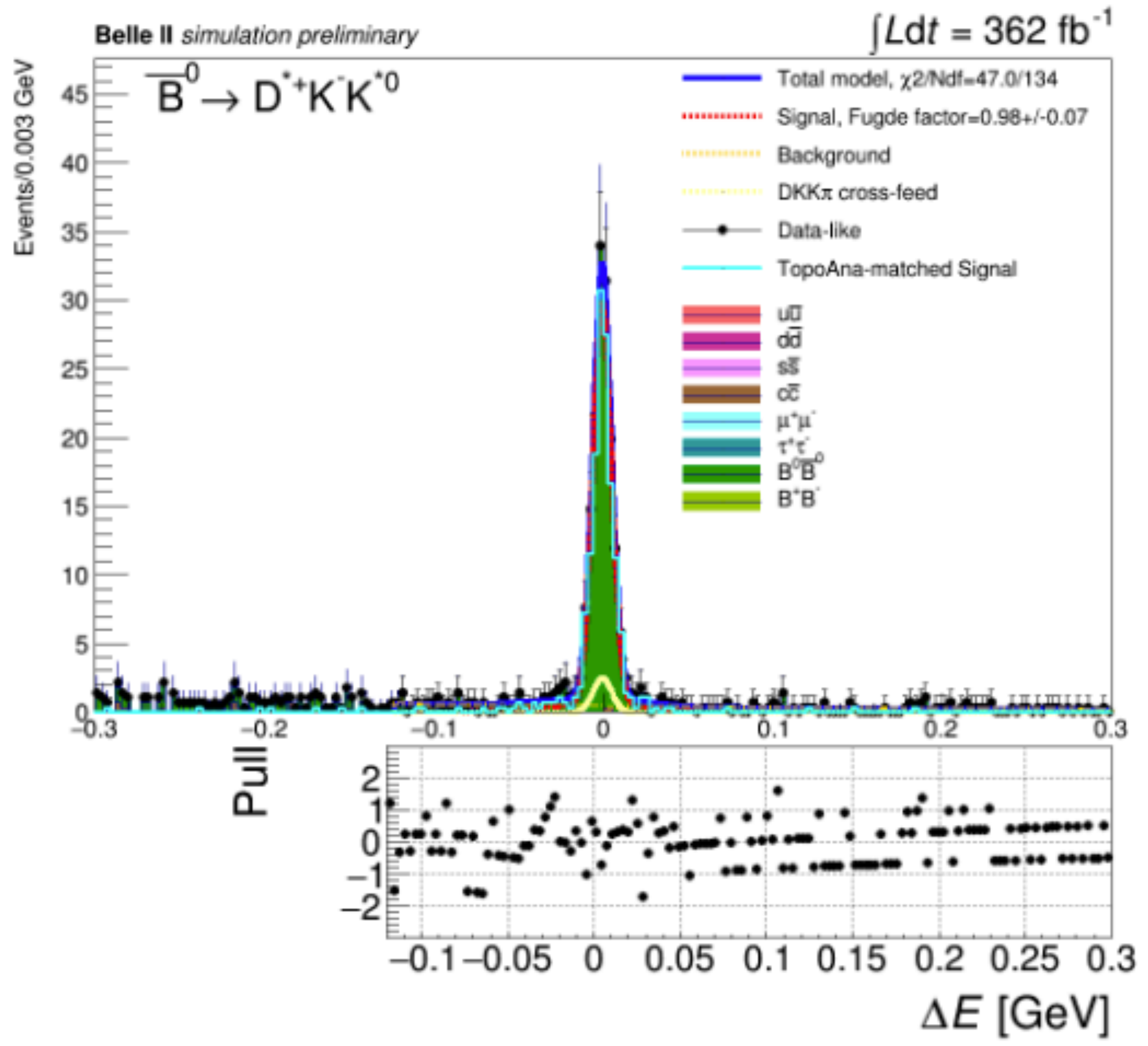










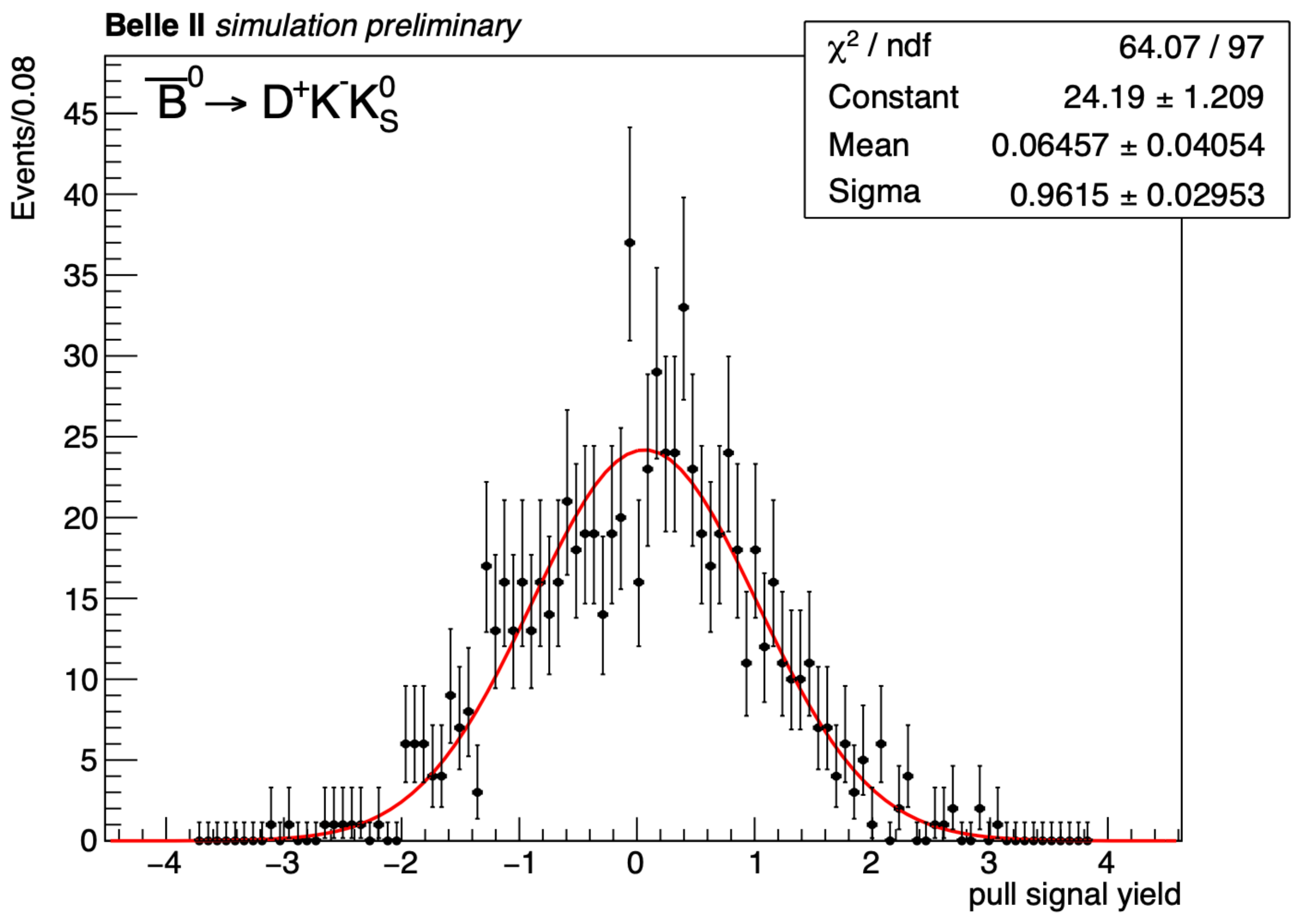


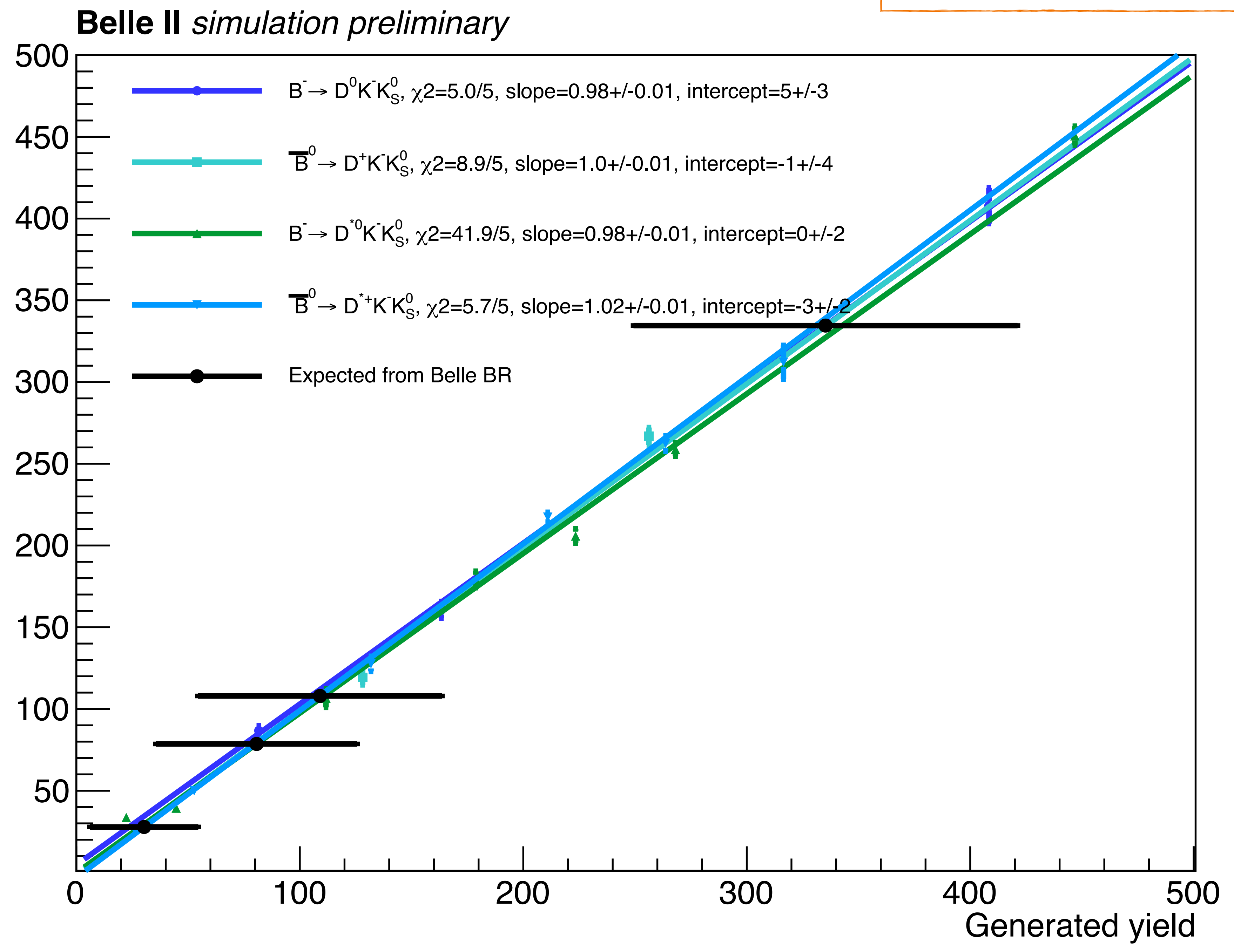
Yield extraction: Toys validation

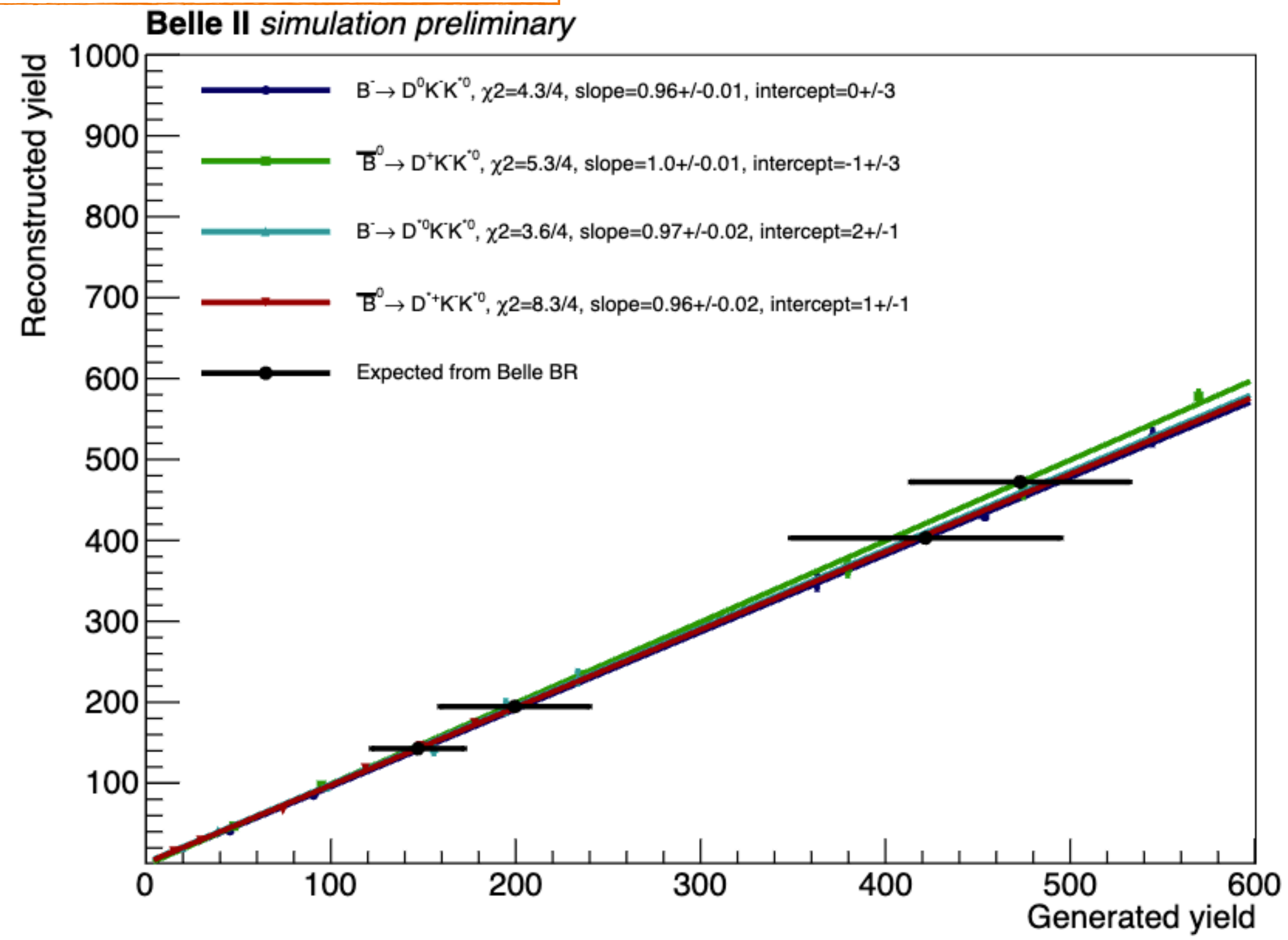
[MC Simulation]

- Generated 10^3 toys from generic MC fit PDF
- Scaled the signal yield of generic MC fit in the range [0.1,2] to test linearity
- No discrepancy from linear trend observed

zoom in the range [0.1,0.5 MC]







Systematic uncertainties

[MC Simulation]

[Relative systematic uncertainties in %]

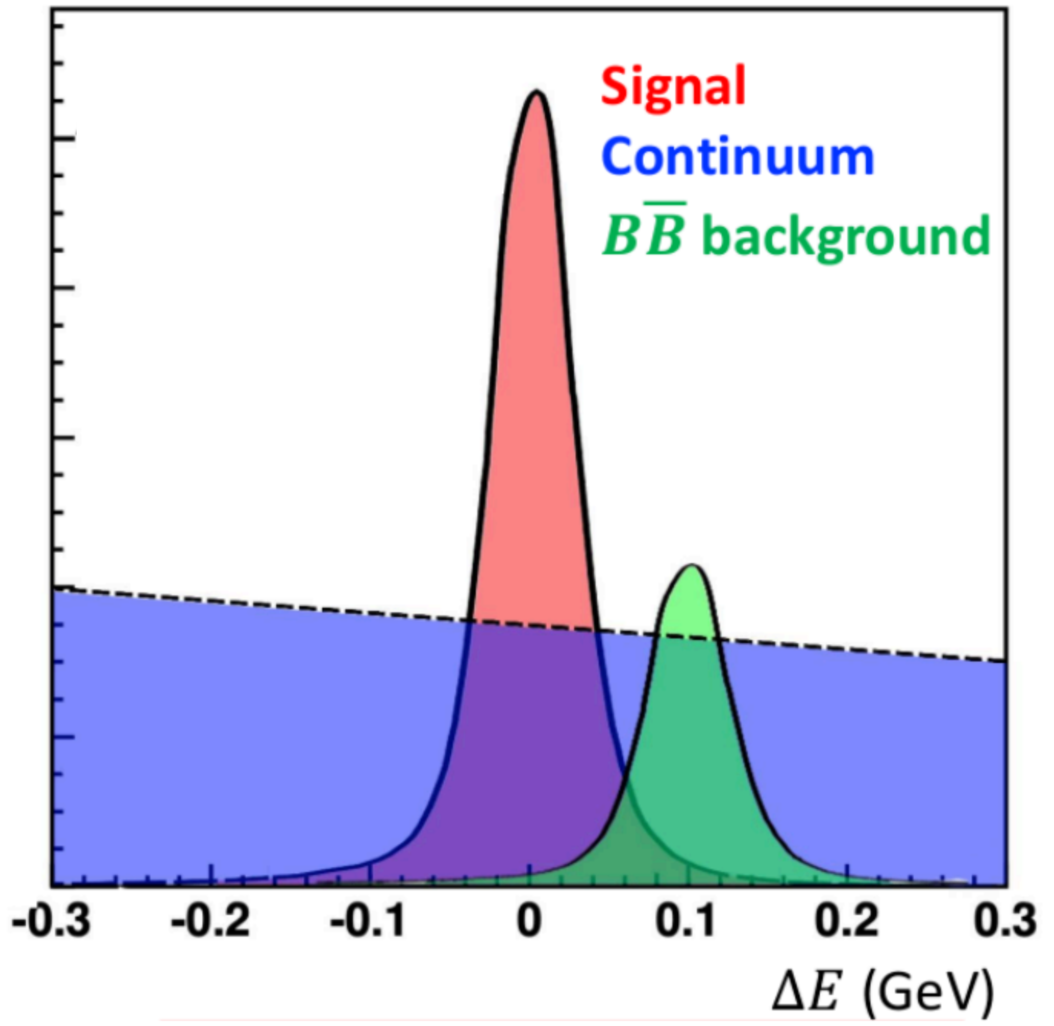
Source	$D^0K^-K^0_S$	$D^+K^-K^0_S$	$D^{*0}K^-K^0_S$	$D^{*+}K^-K^0_S$	$D^0K^-K^{*0}$	$D^+K^-K^{*0}$	$D^{*0}K^-K^{*0}$	$D^{*+}K^-K^{*0}$
Eff. - MC sample size	0.3	0.5	0.6	0.6	0.5	0.7	0.9	1.2
Eff. - tracking	0.7	1.0	0.7	1.0	1.0	1.2	1.0	1.2
Eff. - π^+ from D^{*+}	-	-	-	2.7	-	-	-	2.7
Eff. - K^0_S	4.3	4.5	4.0	4.1	-	-	-	-
Eff. - PID	1.4	1.7	0.5	0.7	3.7	3.1	1.7	2.0
Eff. - π^0	-	-	5.4	-	-	-	5.7	-
Signal model	0.7	1.4	3.0	1.2	0.8	0.7	2.6	0.6
Bkg model	1.3	0.4	0.6	0.1	1.6	0.05	0.02	0.1
D^{*0} peaking bkg	-	-	2.2	-	-	-	2.0	-
$DKK\pi$ bkg	-	-	-	-	1.2	0.5	0.6	1.4
$N_{B\overline{B}}$, $f_{+-,00}$	2.7	2.8	2.7	2.8	2.7	2.8	2.7	2.8
Intermediate $\mathcal{B}$s	0.7	1.7	1.6	1.1	0.8	1.7	1.6	1.1
Total systematic	5.9	6.1	8.4	6.1	4.6	4.9	7.6	5.1
Statistical	3.9	3.1	8.0	6.9	5.1	5.1	8.5	9.7
Exp. stat. (Belle).	5.9	8.9	9.5	12.3	5.1	5.1	8.5	9.7

Source	$B^- \to D^0 D_s^-$	$\overline{B}^0 \to D^+ D_s^-$	$B^- \to D^{*0} D_s^-$	$\overline{B}^0 \to D^{*+} D_s^-$
Eff. - MC sample size	<0.1	<0.1	<0.1	<0.1
Eff. - tracking	0.8	1.0	0.8	1.0
Eff. - π^+ from D^{*+}	-	-	-	2.7
Eff. - K^0_S	1.7	1.8	1.7	1.8
Eff. - PID	1.9	2.0	1.2	1.3
Eff. - π^0	-	-	5.1	-
Signal model	<0.1	0.3	0.9	0.4
Bkg model	0.6	0.6	0.2	<0.1
D^{*0} peaking bkg	-	-	0.5	-
$N_{B\overline{B}}$, $f_{+-,00}$	2.7	2.8	2.7	2.8
Intermediate $\mathcal{B}$s	1.8	2.1	2.0	1.8
Total systematic	4.3	4.6	6.6	4.9
Statistical	5.8	5.7	14.2	11.0

B-Factory basics

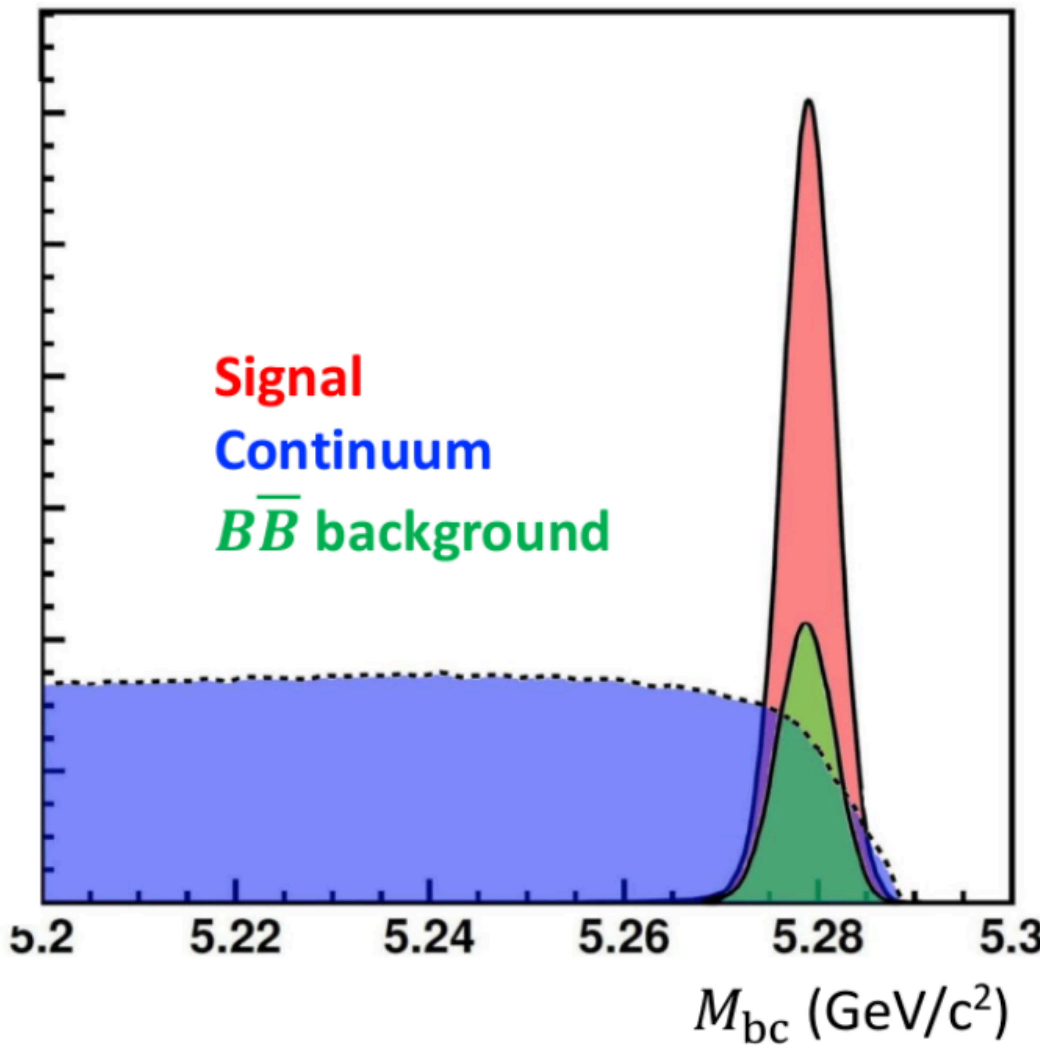
- $\sqrt{s} = m(\Upsilon(4S)) = 10.58\ \text{GeV} \simeq 2m_B \Rightarrow$ constrained kinematics
- Hermetic detector $\Rightarrow$ complete event reconstruction

$\Delta E = E_B^* - \sqrt{s}/2$



Expected $\Delta E \simeq 0$

$M_{bc} = \sqrt{(\sqrt{s}/2)^2 - \vec{p}_B^{*2}}$



Expected $M_{bc} \simeq m_B$

- Asymmetric collider $\Rightarrow$ Boost of center-of-mass
- Excellent vertexing performance ($\sigma \sim 15\ \mu\text{m}$)
- coherent $B\overline{B}$ pairs production
- Excellent flavour tagging performance

$\Rightarrow$ measurement of Δt for time dependent CP violation (TDCPV)