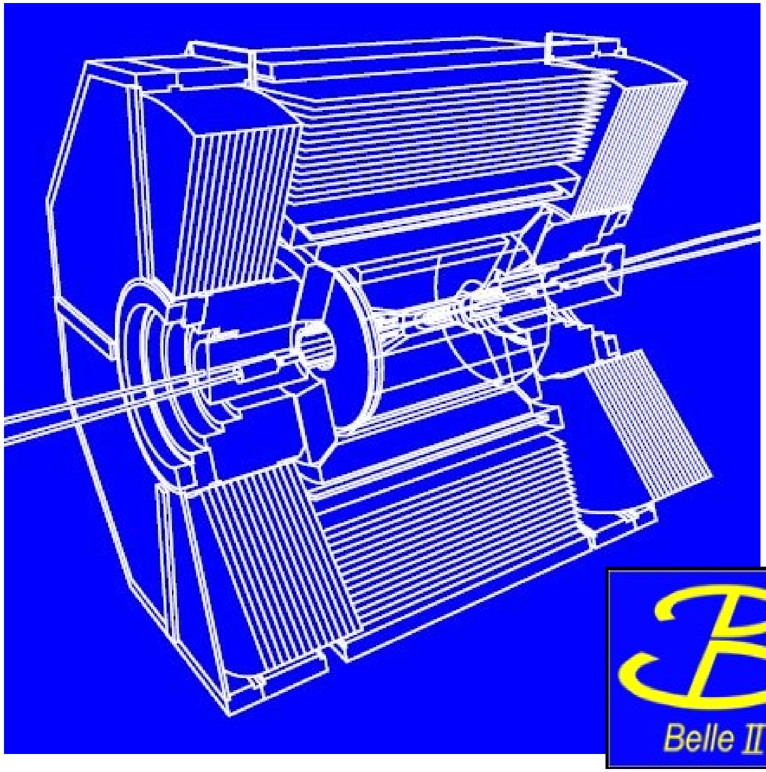
B-tagging for missing energy modes at Belle II

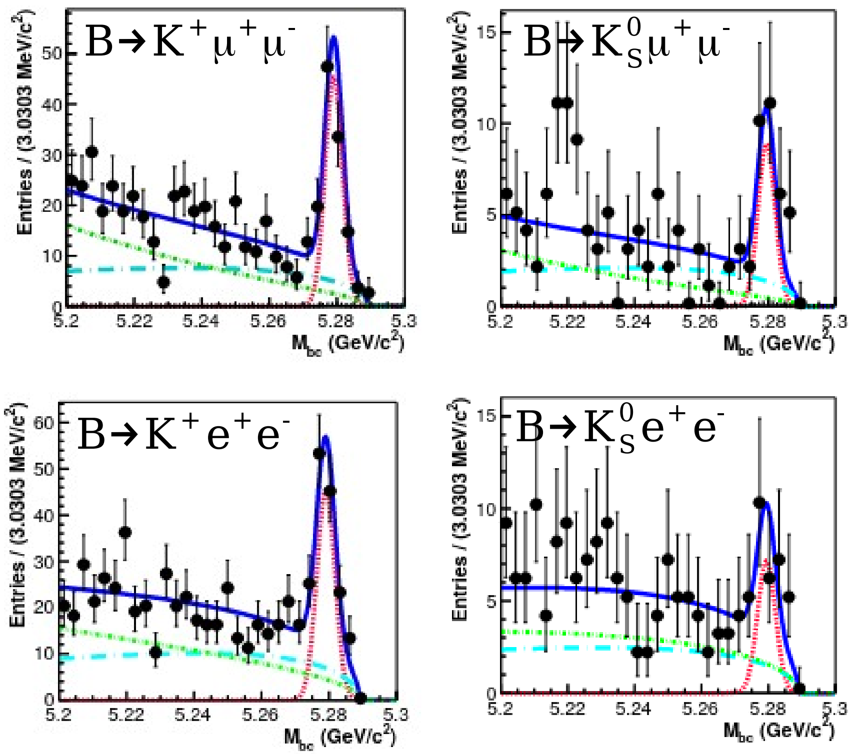


Karim Trabelsi

karim.trabelsi@ijclab.in2p3.fr

2021/10/27

$R_{K^{(*)}}$ at Belle and Belle II



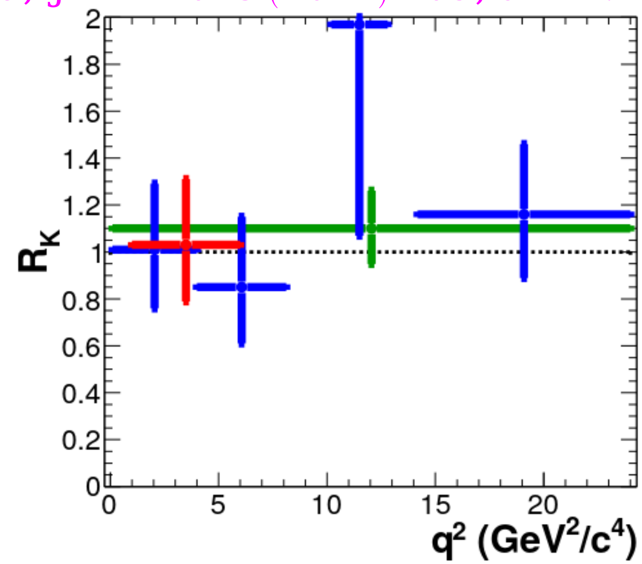
The ''clean'' Lepton Flavor Universality ratio

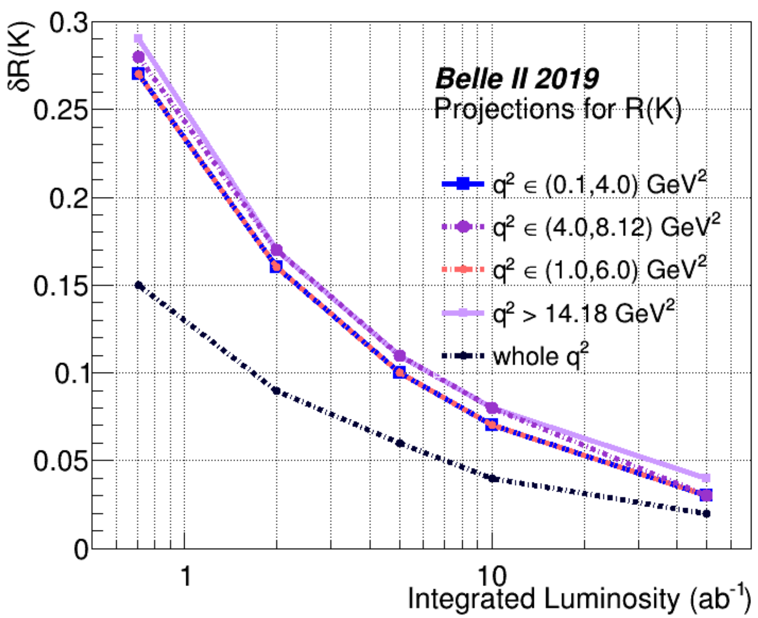
$$R_{K^{(*)}} = \frac{Br(B \to K^{(*)} \mu\mu)}{Br(B \to K^{(*)} e e)}$$

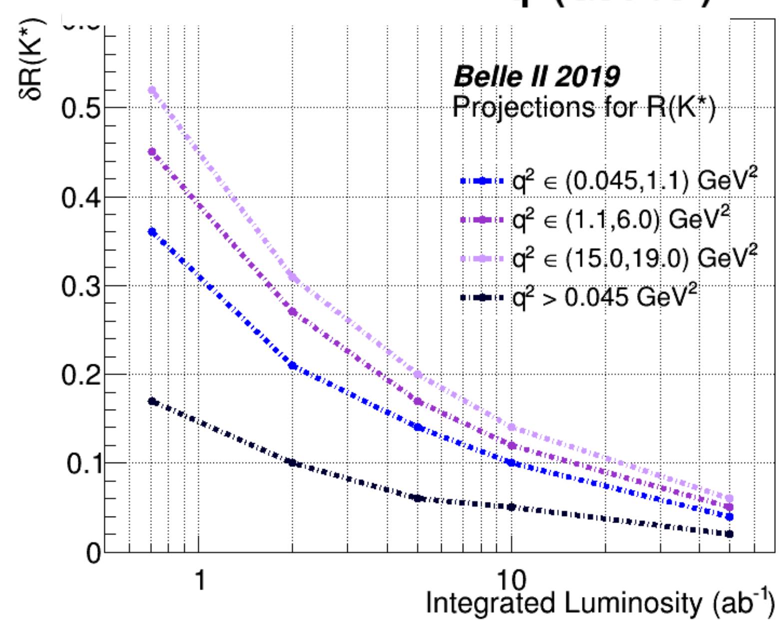
SM prediction very robust: $R_K(SM) = 1$

[up tiny QED and lepton mass effects]

[Belle, JHEP 2013 (2021) 105, arXiv:1908.01848]







Lepton (non) universality using $B \to K^{(*)} l^+ l^-$ decays

Model candidates

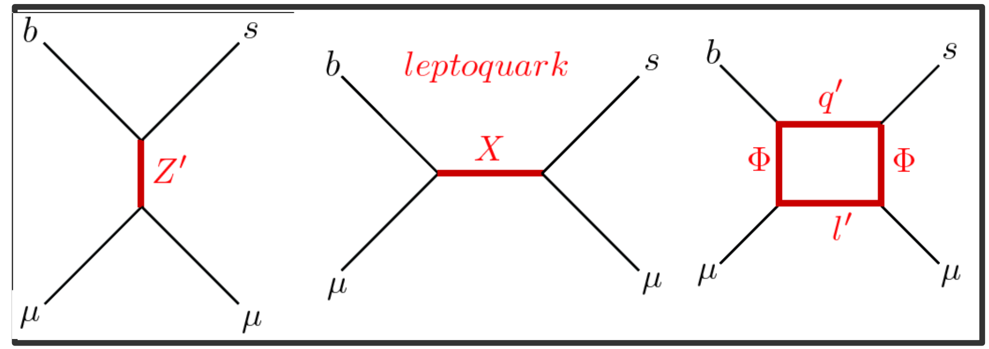
- ✓ Effective operator from Z’ exchange
- ✓ Extra U(1) symmetry with flavor dependent charge

✧ **Models with leptoquarks**

- ✓ Effective operator from LQ exchange
- ✓ Yukawa interaction with LQs provide flavor violation

✧ **Models with loop induced effective operator**

- ✓ With extended Higgs sector and/or vector like quarks/leptons
- ✓ Flavor violation from new Yukawa interactions



Leptoquarks are color-triplet bosons that carry both lepton and baryon numbers

Lot of those models predict also LFV $b \to s e\mu$, $b \to s e\tau$, ...

(see Damir, Sebastien, Olcyr's work)

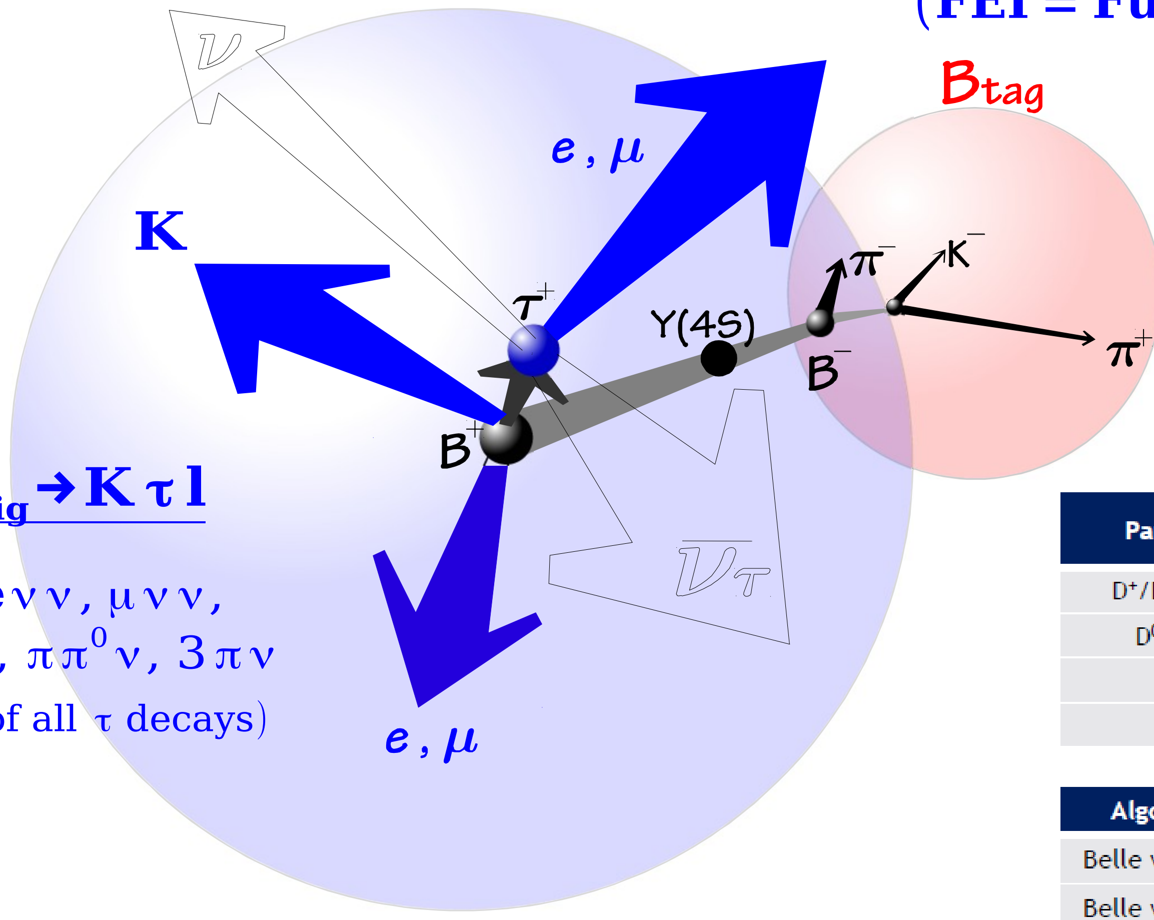
G.Isidori, FPCP 2020: correlations among $b \to s(d) l l'$ within the U(2)-based EFT

	μμ (ee)	ττ	νν	τμ	μe
$b \to s$	R_K, R_{K^*} O(20%)	$B \to K^{(*)} \tau\tau$ → 100×SM	$B \to K^{(*)} \nu\nu$ O(1)	$B \to K \tau\mu$ → 10^{-6}	$B \to K \mu e$???
$b \to d$	$B_d \to \mu\mu$, $B \to \pi \mu\mu$, $B_s \to K^{(*)} \mu\mu$ O(20%) [R_K=R_π]	$B \to \pi \tau\tau$ → 100×SM	$B \to \pi \nu\nu$ O(1)	$B \to \pi \tau\mu$ → 10^{-7}	$B \to \pi \mu e$???

(but the τ is much more challenging...)

Event reconstruction in B→Kτl at B factories

(FEI = Full Event Interpretation)



B_{sig}→Kτl

τ→eνν, μνν,
τ→πν, $\pi\pi^0\nu$, 3πν
(70 % of all τ decays)

B_{tag}

hadronic tag

$B\to D^{(*)}\pi$, $D^{(*)}\rho$...
$\epsilon \sim 0.5\%$

semileptonic tag

$B\to D^{(*)} l \nu X$
$\epsilon \sim 2\%$

Particle	# channels (Belle)	# channels (Belle II)
$D^+/D^{*+}/D_s^+$	18	26
D^0/D^{*0}	12	17
B^+	17	29
B^0	14	26

Algorithm	MVA	Efficiency	Purity
Belle v1 (2004)	Cut based (Vcb)		
Belle v3 (2007)	Cut based	0.1	0.25
Belle NB (2011)	Neurobayes	0.2	0.25
Belle II FEI (2017)	Fast BDT	0.5	0.25

Improvement to tagging efficiency in Belle II

(think about flavour tagging at LHCb...)

physics program related to this activity
$B\to K^{(*)}\tau\tau$, $K^{(*)}\nu\nu$, $D^{(*)}\tau\nu$, τν, μν etc...

$B^+ \to K^+\tau\ell$ SEARCH WITH FEI

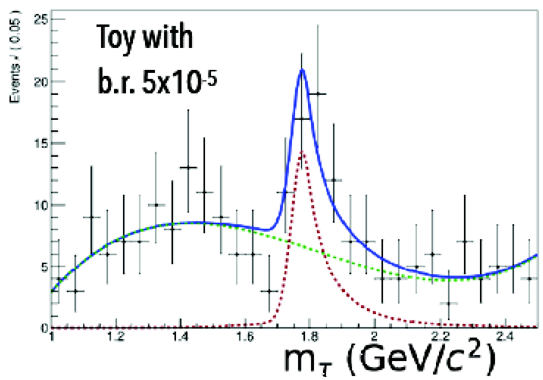
HADRONIC FEI + Belle

Belle Note N.1576

Under refereeing

- $\tau \to \pi/\rho/e/\mu$ decays
- $\ell = \{e, \mu\}$
- MVA is adopted for background suppression
- Fit to m_τ distributions
- Control samples
  $B^+ \to D^-(\to K^+\pi^-\pi^-)\pi^+\pi^+$,
  $B^+ \to J/\psi(\to \ell\ell)K^+$
- Sensitivity $\mathcal{O}(10^{-5})$
  First Belle result!

S. Watanuki (Yonsei U.)
G. de Marino (IJCLab)
K. Trabelsi (IJCLab)



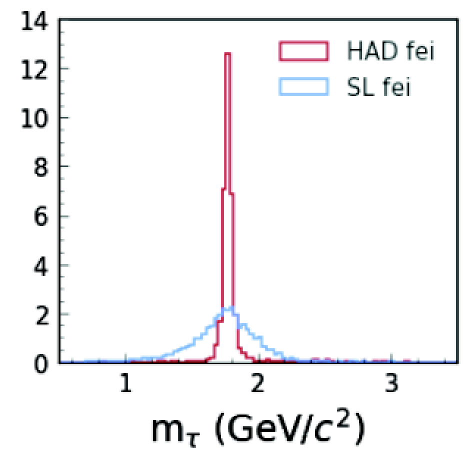
SL FEI

- SL tags: orthogonal sample that can be exploited
- Recoil mass still peaks at m_τ but the resolution is a factor ~2-3 worse

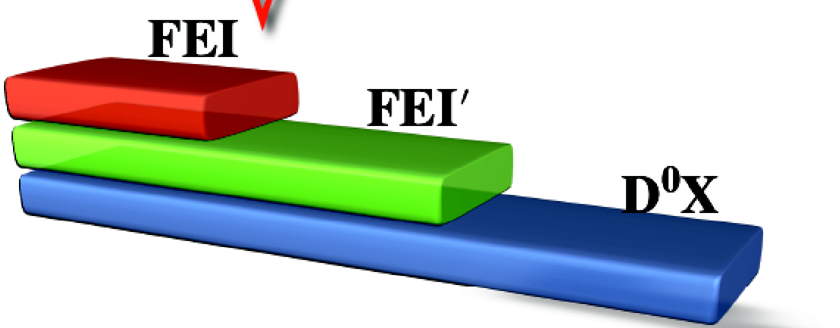
$$m_\tau = [m_B^2 + m_{K\mu}^2 - 2(E_B^* E_{K\mu}^* + |\vec{p}_B^*||\vec{p}_{K\mu}^*|\cos\theta)]^{\frac{1}{2}}$$

E^*_{beam} ; $\sqrt{(E^*_{beam})^2 - m_B^2}$

θ: angle between $\vec{p}^*_{B_{tag}}$ and $\vec{p}^*_{K\mu}$



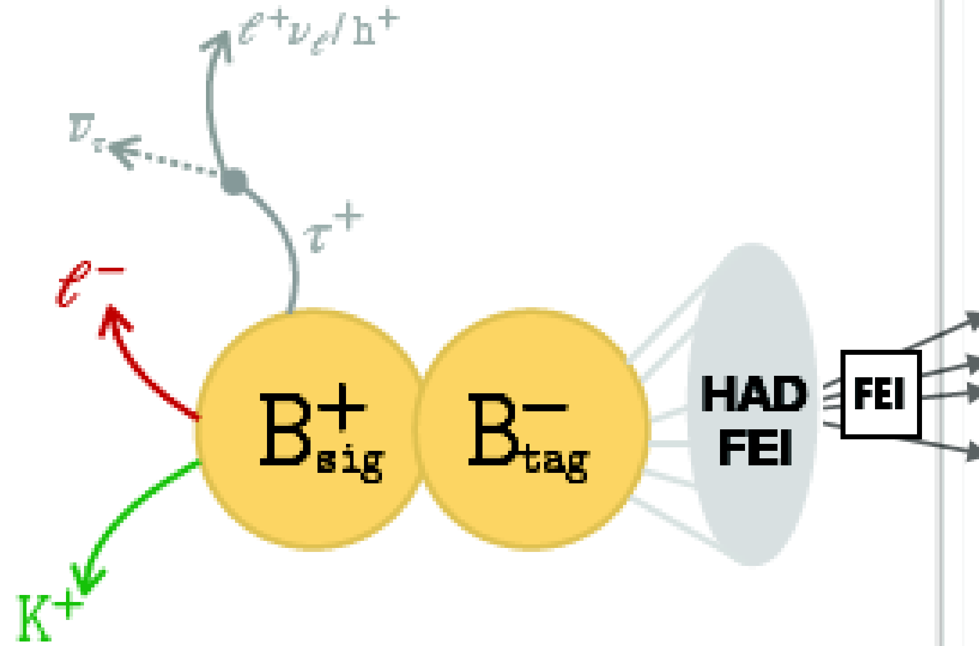
- High efficiency but worse resolution
- → Sensitivity? (higher background level)

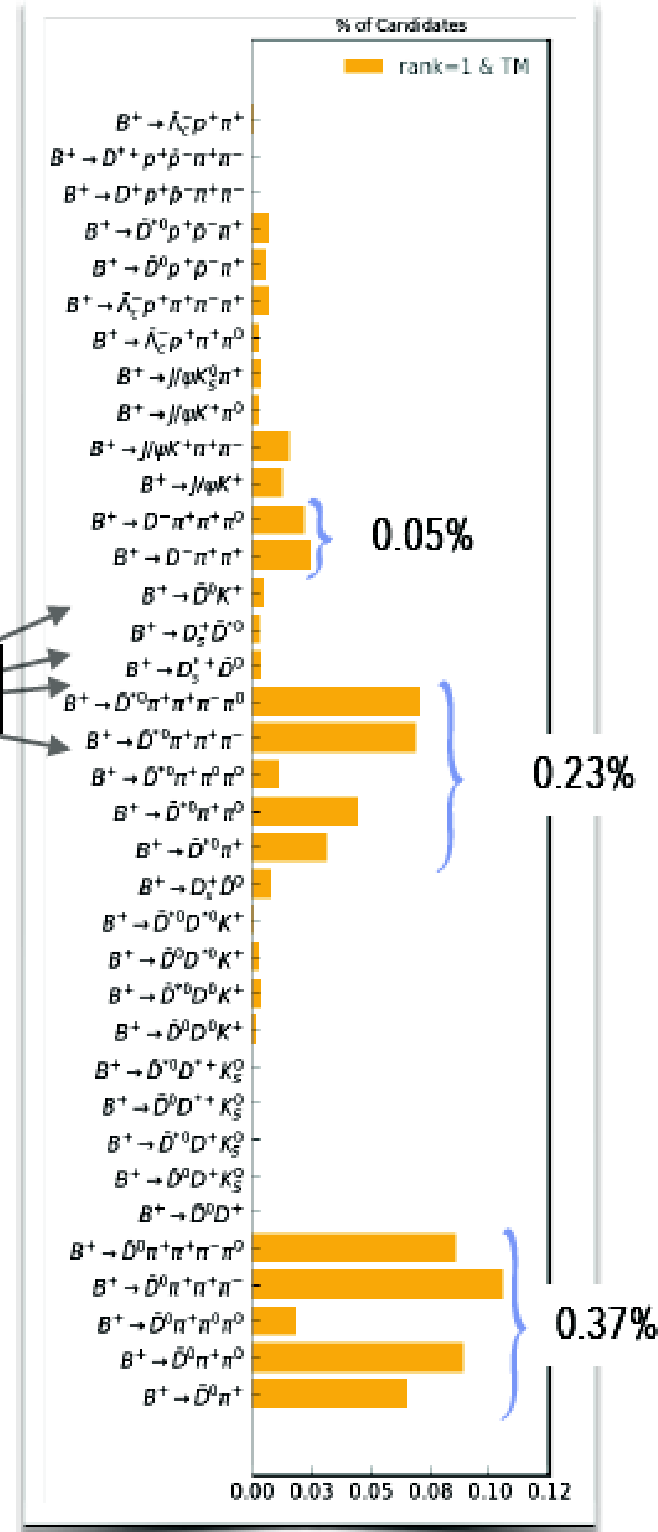


Mode	U.L. (90% CL)	Exp.
$B^+ \to K^+\tau\mu$	4.8×10^{-5}	BABAR
$B^+ \to K^+\tau e$	3.0×10^{-5}	BABAR
$B^+ \to K^+\tau^+\mu^-$	3.9×10^{-5}	LHCb

[BaBar, PRD86, 012004 - LHCb, JHEP 06 (2020) 129]

The other side of missing energy modes are ... often B→charm



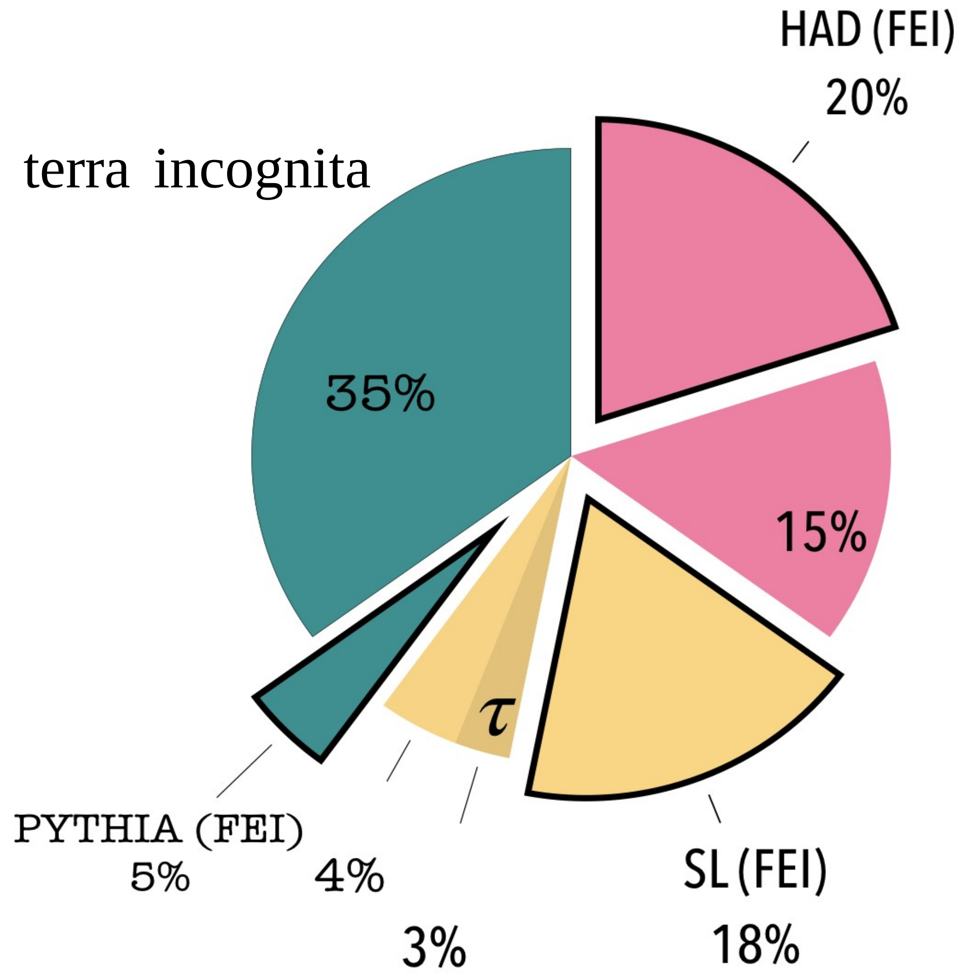


- missing energy modes rely on B-tagging methods
- hadronic FEI relies basically on ~ 10% of the B decays (e.g. charged B)

... completely dominated by $D^{(*)0} n \pi$

⁎ FEI mode
⁎⁎ Partially covered by FEI

EXPLORING $B^{\pm}$ DECAYS *via MC simulation*



- A lot of <u>unexplored and unknown</u> hadronic modes for FEI
- SL decays are almost completely covered by FEI

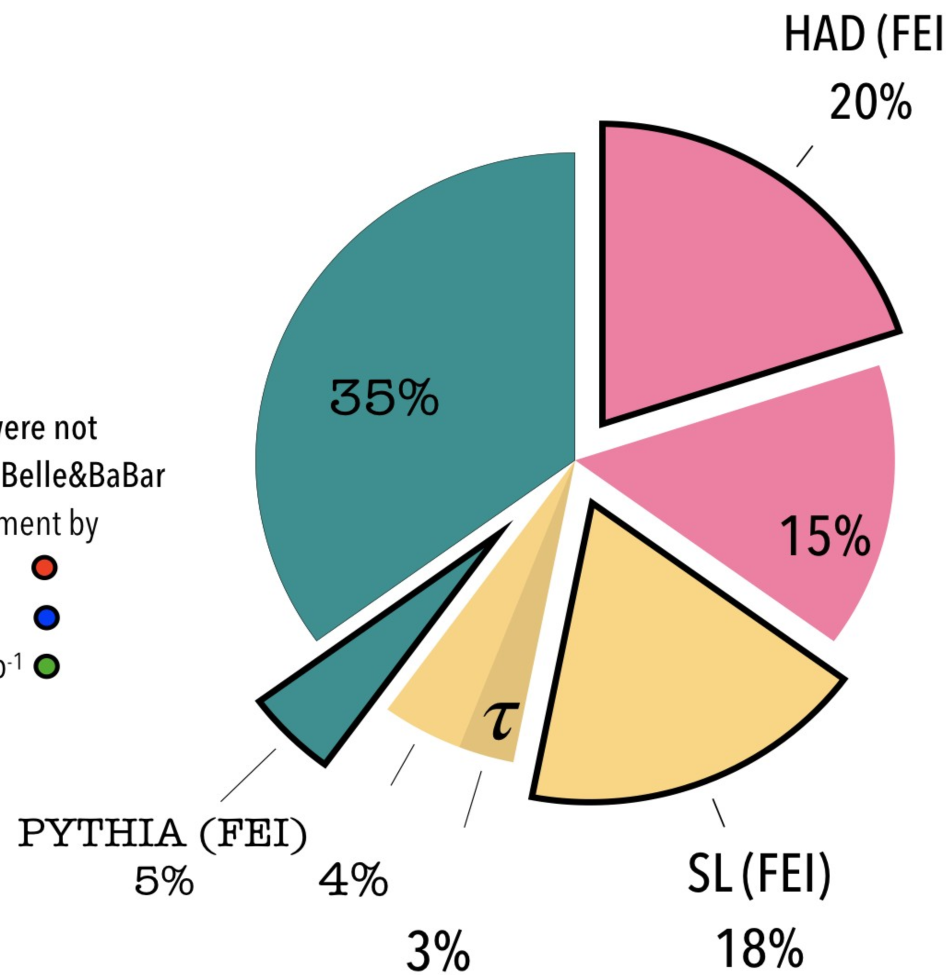
* FEI mode
** Partially covered by FEI

EXPLORING $B^{\pm}$ DECAYS *via MC simulation*

	Decay mode	b.r. (%)	
**	B+ --> anti-D*0 a_1+	1.8716	
*	B+ --> anti-D*0 pi0 pi+ pi+ pi-	1.8497	●
	B+ --> D_s*+ anti-D*0	1.7056	
**	B+ --> anti-D*0 rho+	1.5056	●
**	B+ --> D*- pi0 pi+ pi+	1.5418	●
**	B+ --> anti-D0 rho+	1.2754	●
	B+ --> D'_s1+ anti-D*0	1.1464	
*	B+ --> anti-D*0 pi+ pi+ pi-	1.0581	
*	B+ --> D_s+ anti-D0	1.0060	
*	B+ --> D_s+ anti-D*0	0.8181	
*	B+ --> anti-D*0 D*+ K0	0.8151	
**	B+ --> D_s*+ anti-D0	0.7562	
*	B+ --> anti-D*0 D0 K+	0.6422	
**	B+ --> anti-D*0 pi+ eta	0.6286	
*	B+ --> anti-D0 D*+ K0	0.5441	
*	B+ --> anti-D*0 pi+	0.5532	
*	B+ --> anti-D*0 D*0 K+	0.5230	
**	B+ --> anti-D*0 rho0 rho+	0.5087	
*	B+ --> D*0 anti-D0 K+	0.4822	
*	B+ --> anti-D0 pi+ pi+ pi-	0.4883	
	B+ --> anti-D*0 rho+ omega	0.4581	
**	B+ --> anti-D*0 pi+ omega	0.4309	●
**	B+ --> anti-D*0 pi+ pi- rho+	0.4354	
*	B+ --> anti-D0 pi+	0.4317	
**	B+ --> anti-D0 rho0 pi+	0.4113	
**	B+ --> anti-D0 pi+ omega	0.3834	●
**	B+ --> anti-D*0 pi0 rho0 pi+	0.3766	
	B+ --> D_s*+ anti-D_2*0	0.3630	
	B+ --> anti-D*0 rho+ eta	0.3562	
**	B+ --> anti-D0 a_1+	0.3539	
	B+ --> anti-D*0 pi0 pi+ omega	0.3524	
	B+ --> D'_s1+ anti-D0	0.3177	
**	B+ --> anti-D0 pi0 rho+	0.3155	
*	B+ --> anti-D*0 D+ K0	0.3087	
*	B+ --> anti-D*0 D*+ K*0	0.2845	
	B+ --> anti-D*0 pi+ rho+ rho-	0.2536	
**	B+ --> K*+ psi(4040)	0.2490	

... AND MANY MORE! (Only 1/3 of hadronic modes is shown)

Many b.r.'s were not measured at Belle&BaBar
Old measurement by
CLEO 0.9 fb^{-1} ●
CLEO 9.1 fb^{-1} ●
ARGUS 0.2 fb^{-1} ●

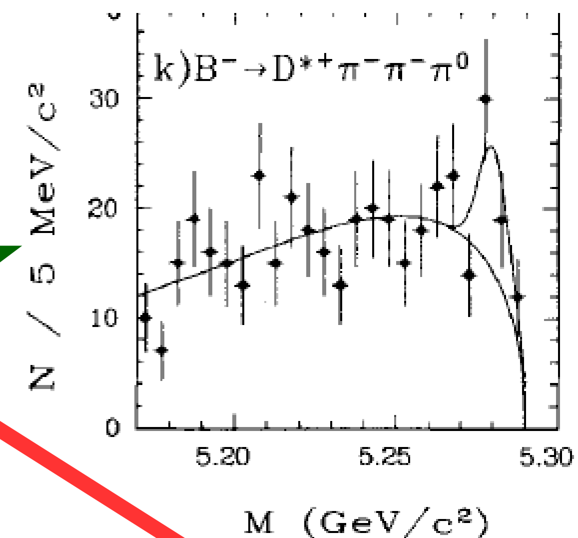


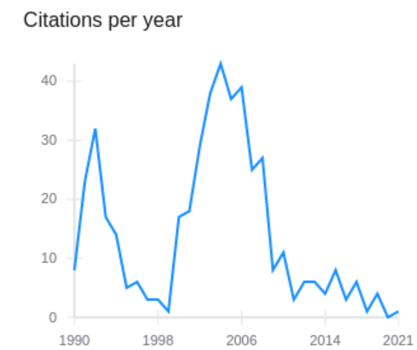
- A lot of <u>unexplored and unknown</u> hadronic modes for FEI
- SL decays are almost completely covered by FEI

Few examples of relevant measurements

	Decay mode	b.r. (%)
* *	B+ --> anti-D*0 a_1+	1.8716
*	B+ --> anti-D*0 pi0 pi+ pi+ pi-	1.8497
	B+ --> D_s*+ anti-D*0	1.7056
* *	B+ --> anti-D*0 rho+	1.5056
* *	B+ --> D*- pi0 pi+ pi+	1.5418
* *	B+ --> anti-D0 rho+	1.2754
	B+ --> D'_s1+ anti-D*0	1.1464
*	B+ --> anti-D*0 pi+ pi+ pi-	1.0581
*	B+ --> D_s+ anti-D0	1.0060
*	B+ --> D_s+ anti-D*0	0.8181
*	B+ --> anti-D*0 D*+ K0	0.8151
* *	B+ --> D_s*+ anti-D0	0.7562
*	B+ --> anti-D*0 D0 K+	0.6422
* *	B+ --> anti-D*0 pi+ eta	0.6286
*	B+ --> anti-D0 D*+ K0	0.5441
*	B+ --> anti-D*0 pi+	0.5532
*	B+ --> anti-D*0 D*0 K+	0.5230
* *	B+ --> anti-D*0 rho0 rho+	0.5087
*	B+ --> D*0 anti-D0 K+	0.4822
*	B+ --> anti-D0 pi+ pi+ pi-	0.4883
	B+ --> anti-D*0 rho+ omega	0.4581
* *	B+ --> anti-D*0 pi+ omega	0.4309
* *	B+ --> anti-D*0 pi+ pi- rho+	0.4354
*	B+ --> anti-D0 pi+	0.4317
* *	B+ --> anti-D0 rho0 pi+	0.4113
* *	B+ --> anti-D0 pi+ omega	0.3834
* *	B+ --> anti-D*0 pi0 rho0 pi+	0.3766
	B+ --> D_s*+ anti-D_2*0	0.3630

ARGUS, Z.Phys.C 48 (1990) 543-552





Many b.r.'s were not measured at Belle&BaBar

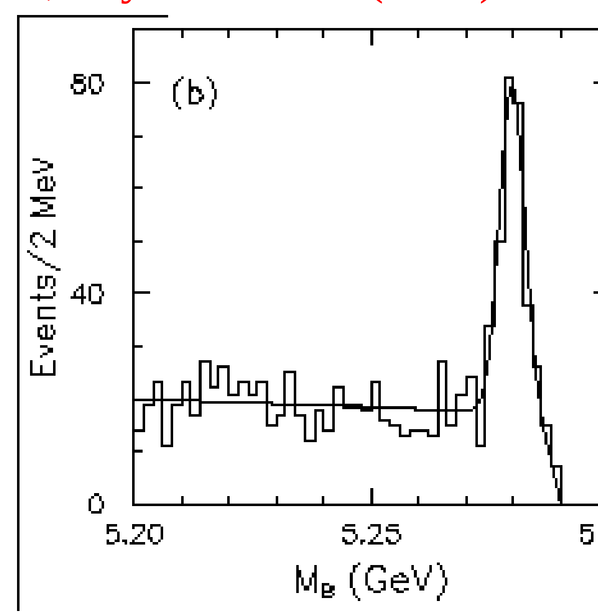
Old measurement by

CLEO 0.9 fb^{-1}

CLEO 9.1 fb^{-1}

ARGUS 0.2 fb^{-1}

CLEO, Phys.Rev.D 50 (1994) 43-6



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

- $B \to D^{(*)} \pi \eta$ modes at few 10^{-3} ?

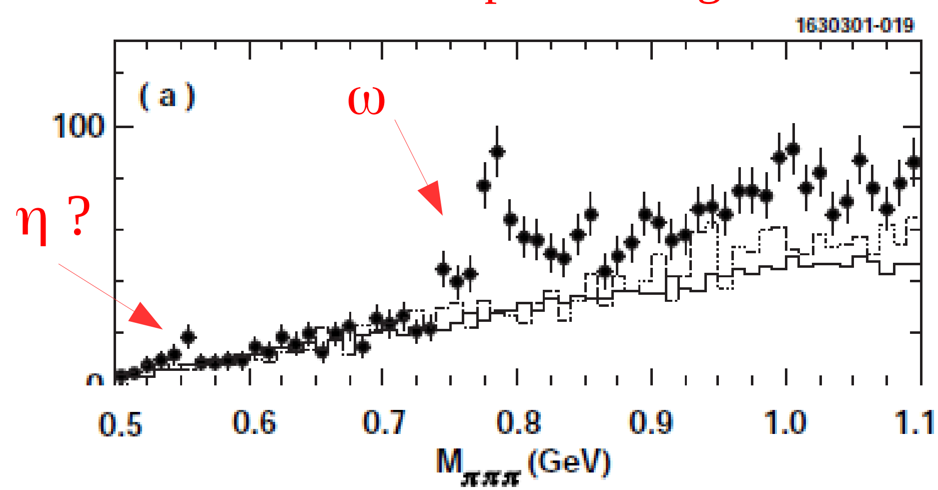
⇒ related to recent paper on lepton moments ??

⇒ $B \to D^{(*)} \pi \eta$ modes ⇒ SL gap modes $(B \to D^{(*)} \eta l \nu$

	Decay mode	b.r. (%)	
∗ ∗	B+ --> anti-D*0 a_1+	1.8716	
∗	B+ --> anti-D*0 pi0 pi+ pi+ pi-	1.8497	● (blue)
	B+ --> D_s*+ anti-D*0	1.7056	
∗ ∗	B+ --> anti-D*0 rho+	1.5056	● (blue)
∗ ∗	B+ --> D*- pi0 pi+ pi+	1.5418	● (green)
∗ ∗	B+ --> anti-D0 rho+	1.2754	● (red)
	B+ --> D'_s1+ anti-D*0	1.1464	
∗	B+ --> anti-D*0 pi+ pi+ pi-	1.0581	
∗	B+ --> D_s+ anti-D0	1.0060	
∗	B+ --> D_s+ anti-D*0	0.8181	
∗	B+ --> anti-D*0 D*+ K0	0.8151	
∗ ∗	B+ --> D_s*+ anti-D0	0.7562	
∗	B+ --> anti-D*0 D0 K+	0.6422	
∗ ∗	B+ --> anti-D*0 pi+ eta	0.6286	
∗	B+ --> anti-D0 D*+ K0	0.5441	
∗	B+ --> anti-D*0 pi+	0.5532	
∗	B+ --> anti-D*0 D*0 K+	0.5230	
∗ ∗	B+ --> anti-D*0 rho0 rho+	0.5087	
∗	B+ --> D*0 anti-D0 K+	0.4822	
∗	B+ --> anti-D0 pi+ pi+ pi-	0.4883	
	B+ --> anti-D*0 rho+ omega	0.4581	
∗ ∗	B+ --> anti-D*0 pi+ omega	0.4309	● (blue)
∗ ∗	B+ --> anti-D*0 pi+ pi- rho+	0.4354	
∗	B+ --> anti-D0 pi+	0.4317	
∗ ∗	B+ --> anti-D0 rho0 pi+	0.4113	
∗ ∗	B+ --> anti-D0 pi+ omega	0.3834	● (blue)
∗ ∗	B+ --> anti-D*0 pi0 rho0 pi+	0.3766	
	B+ --> D_s*+ anti-D_2*0	0.3630	

Decay	$\mathcal{B}(B^+)$	$\mathcal{B}(B^0)$
$B \to D \ell^+ \nu_\ell$	$(2.4 \pm 0.1) \times 10^{-2}$	$(2.2 \pm 0.1) \times 10^{-2}$
$B \to D^* \ell^+ \nu_\ell$	$(5.5 \pm 0.1) \times 10^{-2}$	$(5.1 \pm 0.1) \times 10^{-2}$
$B \to D_1 \ell^+ \nu_\ell$	$(6.6 \pm 1.1) \times 10^{-3}$	$(6.2 \pm 1.0) \times 10^{-3}$
$B \to D_2^* \ell^+ \nu_\ell$	$(2.9 \pm 0.3) \times 10^{-3}$	$(2.7 \pm 0.3) \times 10^{-3}$
$B \to D_0^* \ell^+ \nu_\ell$	$(4.2 \pm 0.8) \times 10^{-3}$	$(3.9 \pm 0.7) \times 10^{-3}$
$B \to D_1' \ell^+ \nu_\ell$	$(4.2 \pm 0.9) \times 10^{-3}$	$(3.9 \pm 0.8) \times 10^{-3}$
$B \to D \pi\pi \ell^+ \nu_\ell$	$(0.6 \pm 0.9) \times 10^{-3}$	$(0.6 \pm 0.9) \times 10^{-3}$
$B \to D^* \pi\pi \ell^+ \nu_\ell$	$(2.2 \pm 1.0) \times 10^{-3}$	$(2.0 \pm 1.0) \times 10^{-3}$
$B \to D \eta \ell^+ \nu_\ell$	$(4.0 \pm 4.0) \times 10^{-3}$	$(4.0 \pm 4.0) \times 10^{-3}$
$B \to D^* \eta \ell^+ \nu_\ell$	$(4.0 \pm 4.0) \times 10^{-3}$	$(4.0 \pm 4.0) \times 10^{-3}$
$B \to X_c \ell^+ \nu_\ell$	$(10.8 \pm 0.4) \times 10^{-2}$	$(10.1 \pm 0.4) \times 10^{-2}$

⇒ but also looking closer at $D^{*0}\pi\pi\pi\pi^0$'s analysis of CLEO [hep-ex/0103021] with only 9/fb we can observe it or put a stringent limit



Main priorities (focusing on charged B modes)

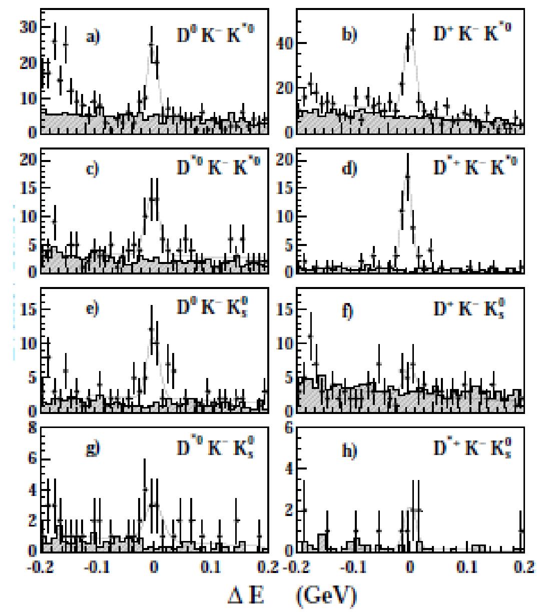
- $B^- \rightarrow D^0 \pi^+ \pi^- \pi^+$: measure $D^0 a_1^+$, $D^0 \rho^0 \pi^-$, $D^0 \pi^+ \pi^- \pi^+$ NR
- Modes with one π^0 :
  - $D^0 \rho^+$, OLD (CLEO $0.9\,\mathrm{fb}^{-1}$)
  - $D^{*-} \pi^+ \pi^+ \pi^0$, OLD (ARGUS $0.25\,\mathrm{fb}^{-1}$)
  - $D^- \pi^+ \pi^+ \pi^0$, never measured (guessed in DECAY.DEC file)
  - $D^{(*)0} \pi^+ \pi^+ \pi^- \pi^0$, OLD (CLEO $9\,\mathrm{fb}^{-1}$)
- Modes with η (PYTHIA), $D^{(*)0} \eta \pi^+$ (link to SL gap filled with $D^{(*)0} \eta l^+ \nu$)
- ... also DKK^*...

...and also add B^0 modes

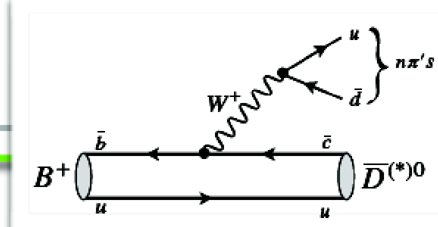
crucial for FEI hadronic modes:
- better modeling = optimal result
- new modes = higher efficiency

but also important for inclusive tagging
.... trained on MC

Observation of $B \rightarrow D^{(*)} K^- K^{0(*)}$ decays
A. Drutskoy et al, hep-ex/0207041 [29 fb^{-1}]



BEYOND FEI - DIRECTIONS (I)



- $B \to K\tau\ell$ **is the ideal mode to exploit B-tagging improvements - unique case with** m_τ **as variable of signal extraction**

- Multi-pion modes
  - **Improve MC modelling**

    - PHSP model often not accurate (intermediate resonances)

    - Wrong interpretation of PDG b.r.'s (double counting) - Resonant vs. NR e.g. $\overline{D}^0\pi^+\pi^+\pi^-$

    - Large uncertainty on high-b.r. decay modes

    ⇓

  - **FEI' = Re-trained FEI**

    + new modes

    $D^{*0}D_s^{*+}$ (1.7)

    $D^{*-}\pi^+\pi^+\pi^0$ (1.8)

    $\overline{D}^{(*)0}K^{(*)+}K^{(*)0}$ (~0.5)

⇐ Request measurements from BtoCharm @ Belle II!

$D^{*-}\pi^+\pi^+\pi^0$ (ARGUS 0.2 fb-1)

$\overline{D}^{*0}\pi^+\pi^+\pi^-\pi^0, \overline{D}^{*0}\rho^+, \overline{D}^{(*)0}\pi^+\omega$ (CLEO 9.1 fb-1)

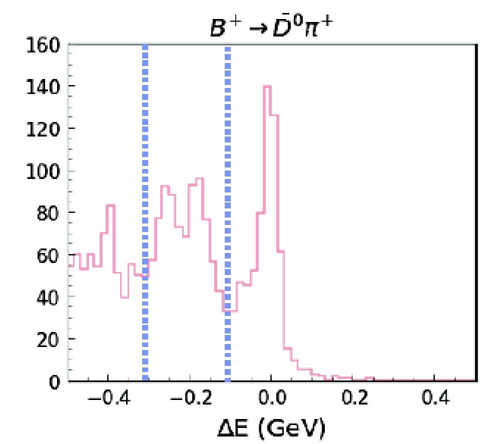
$\overline{D}^0\rho^+$(CLEO 0.9 fb-1)

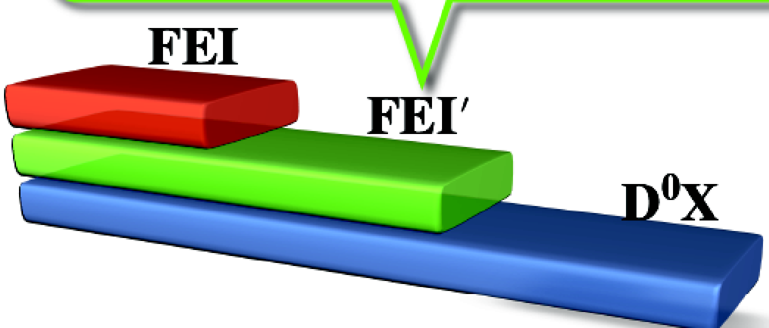
$D^-\pi^+\pi^+\pi^0$ (guessed in DECFILE)

$\overline{D}^{(*)0}\pi^+\eta$ (Appear as PYTHIA decays but also SL `gap')

+ 'Recycling'

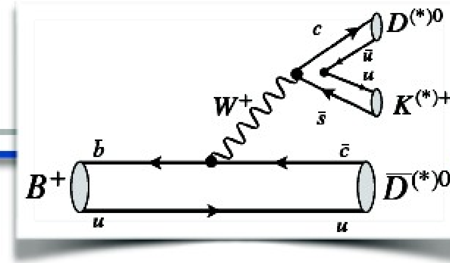
- Decays with D* are lost as soon as one γ or π^0 is missing
- Select the ΔE~-0.2 GeV region with known shift (missing γ or π^0) → recoil mass is still fine!

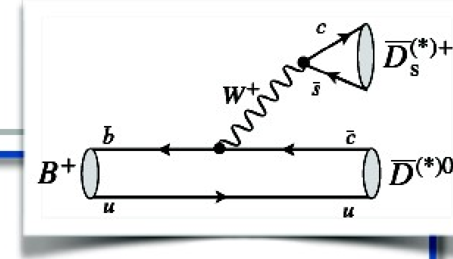


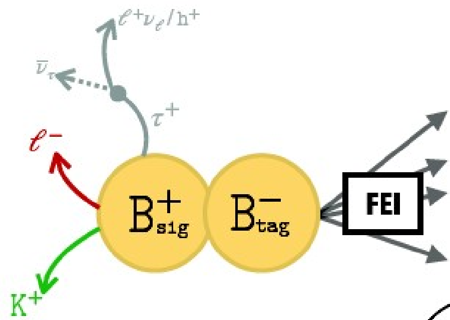


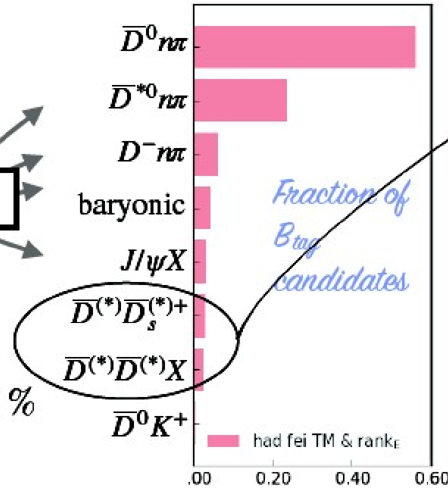
A better MC modelling is anyway beneficial for the training of FEI and any tagging algorithms (even inclusive ones!)

BEYOND FEI -DIRECTIONS (II)









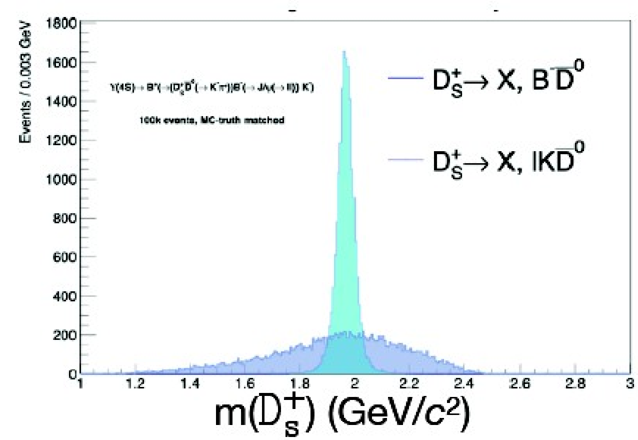
$\varepsilon_{FEI} \sim 0.03\,\%$

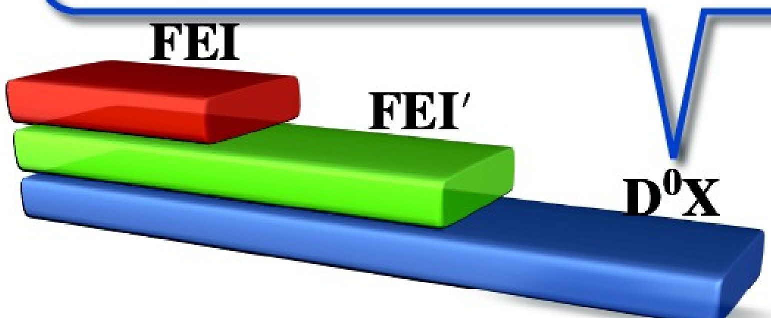
Double charm modes give small `FEI' contribution, despite the high branching ratios ($DD_sX \sim 8\,\%$, $DDKX \sim 5\,\%$) because of the full reconstruction of 2 D mesons

$\varepsilon_{FEI}(D^0) \times \varepsilon_{FEI}(D_s^+)$

$\sim 10\%$ $\sim 3\%$

Avoid reconstructing both D's. Instead D^0X tagging where X has specific properties (i.e. # kaons, invariant mass etc.)



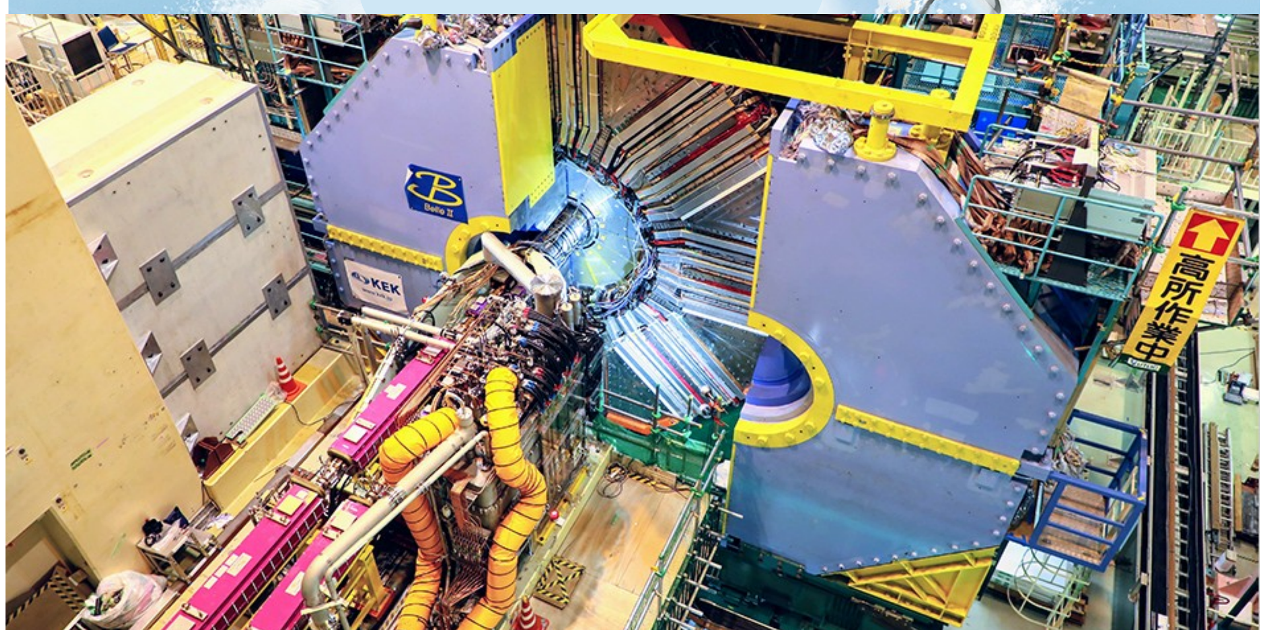


- **Semi-inclusive approach for higher tagging efficiency**

Summary

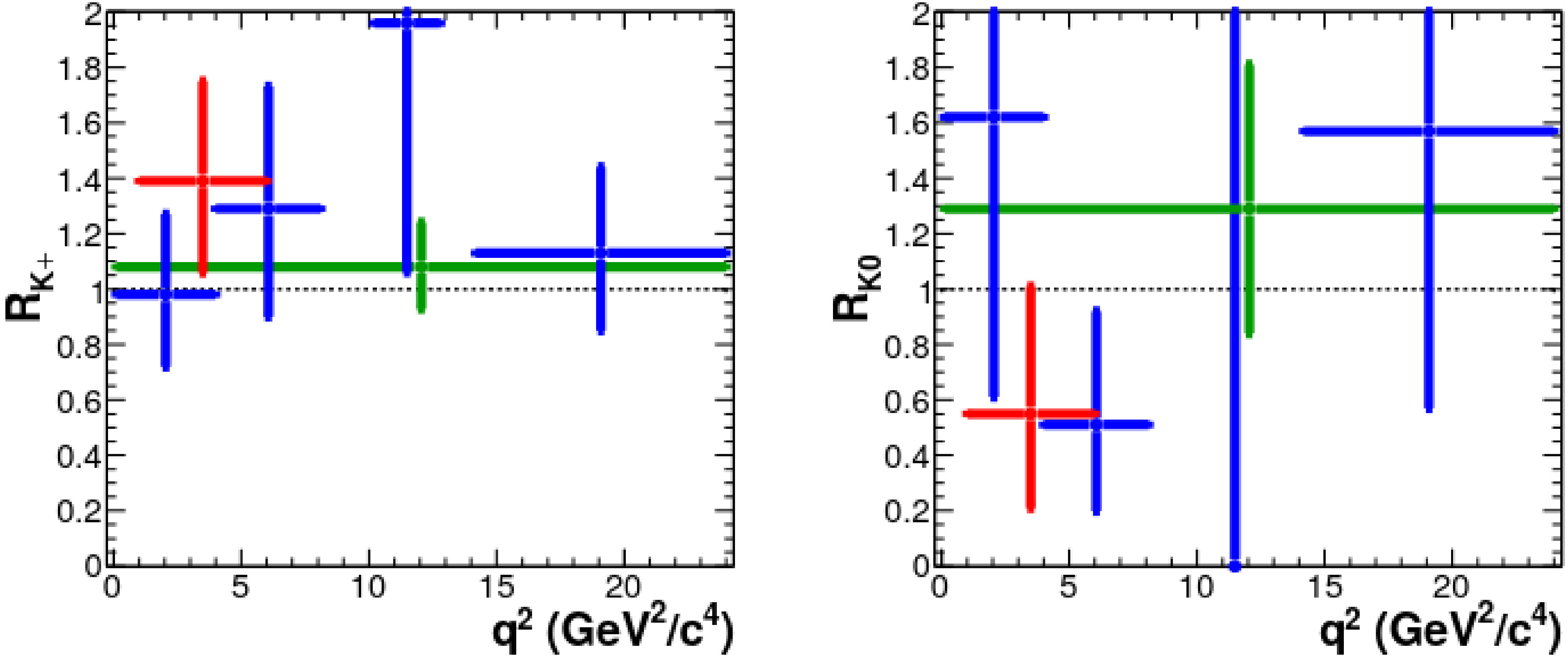
- $B \to K \tau l$ modes are the ideal environment to explore B-tagging
- The ''$B \to \tau$'' team
  S. Watanuki (IJCLab → Yonsei U.)
  G. de Marino
  V. Bertacchi (CPPM) cs-tag
  V.S. Vobbilisetti ($B \to K \tau \tau$)
  K. Trabelsi
  - Better modelling is beneficial for the training of tagging algorithms (also inclusive ones!)
  - New modes ⇒ higher efficiency
- Neutral B's
  $B^0 \to K^0_S \tau l$ [S.Sandilya, Vismaya V.S. - Hyderabad]
  $B^0 \to \tau l$ [M.Liu - Fudan's PhD student at IJCLab for 2 years]


LE MYSTÈRE DES PINGOUINS
ペンギン・ハイウェイ
penguin highway

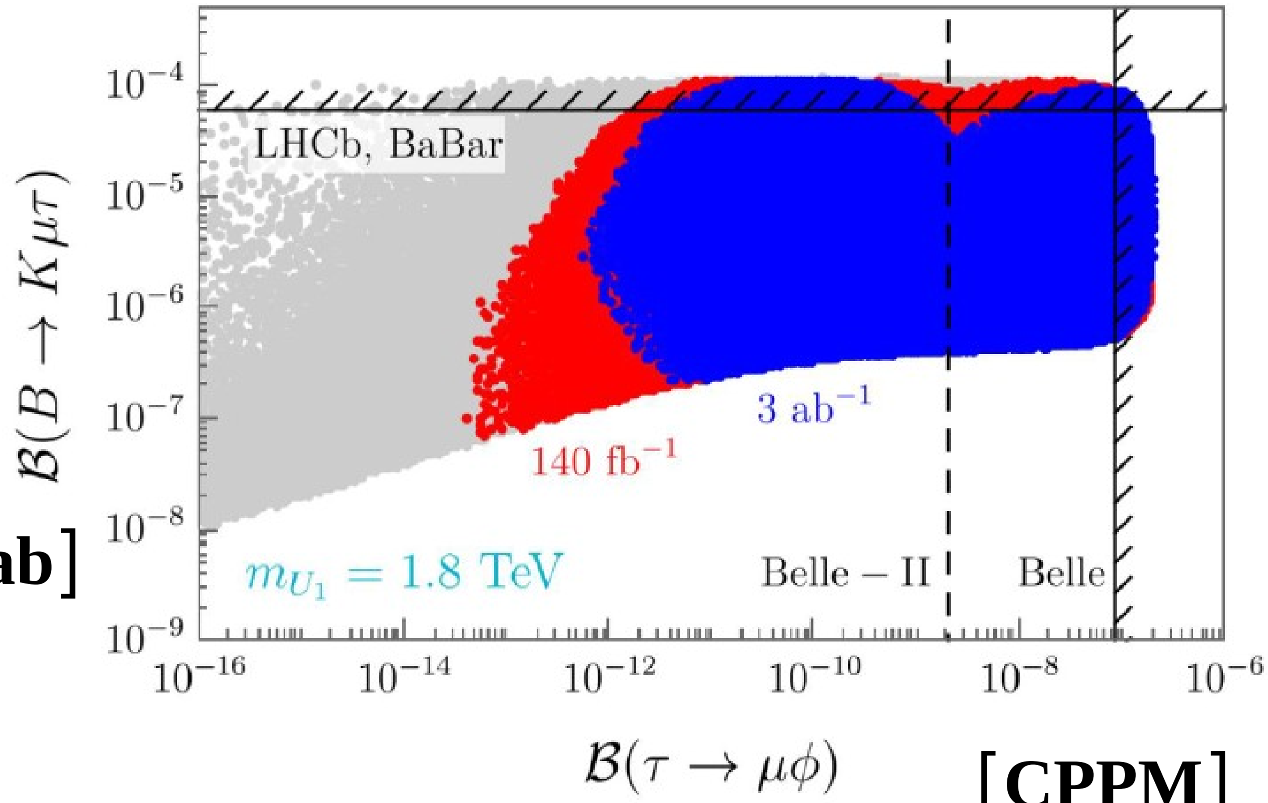

KEK
高所作業中

$R_{K^{(*)}}$ at Belle

[Belle, JHEP 2013 (2021) 105, arXiv:1908.01848]



Nice complementarity

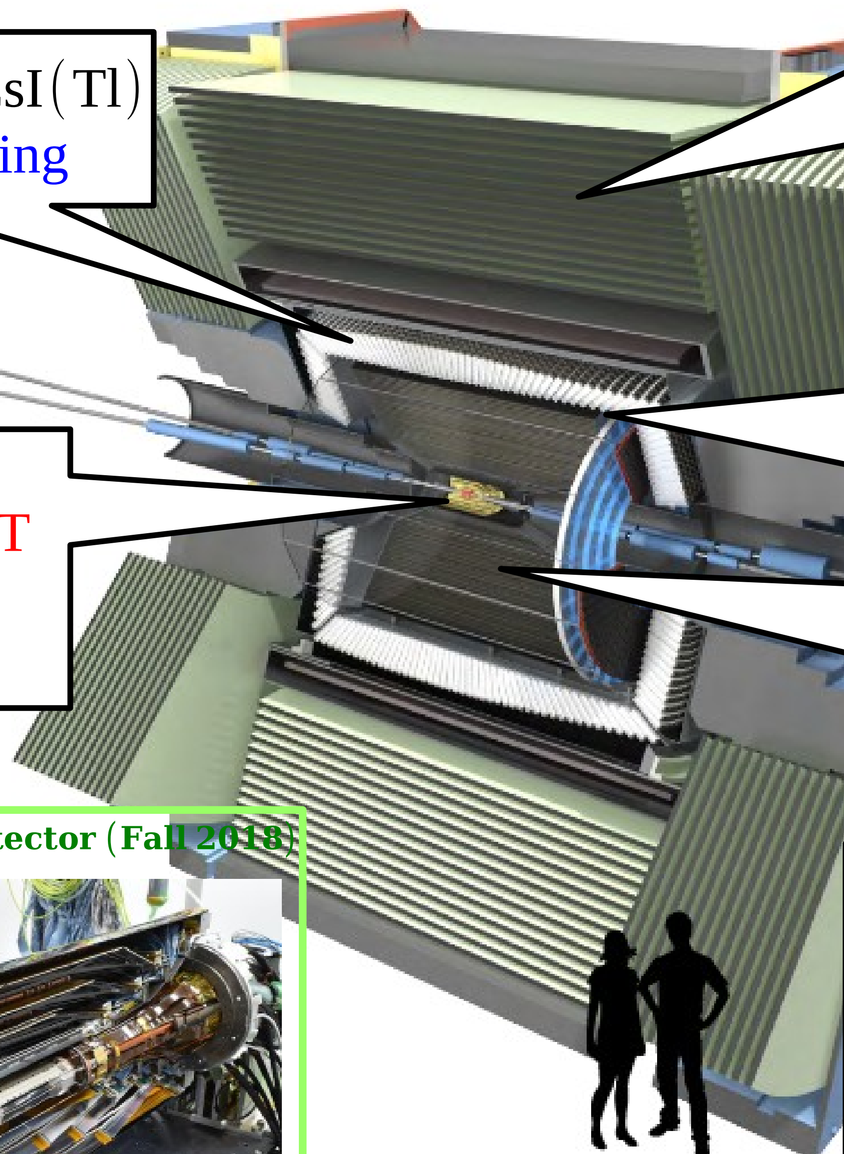


[IJCLab]

[CPPM]

A. Angelescu et al., arXiv:2103.12504v2 (21 Apr 2021)

Belle II detector



EM Calorimeter: CsI(Tl)
waveform sampling

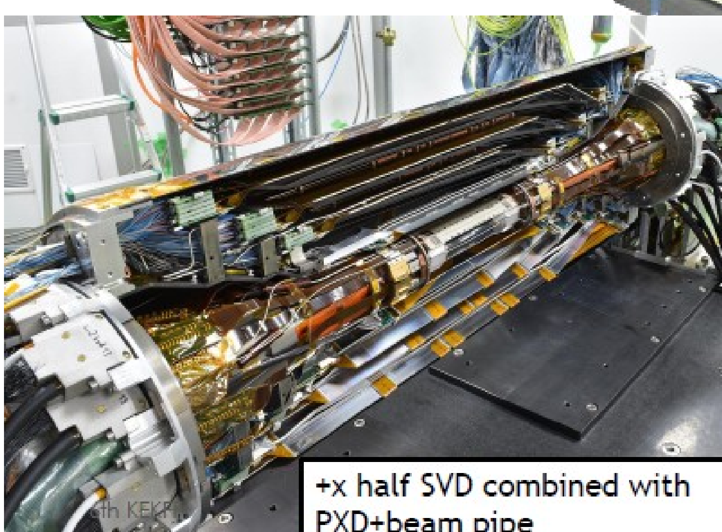
K_L and muon detector
Resistive Plate Counter (barrel)
Scintillator + WLSF + MPPC (endcaps)

Particle Identification
Time-Of-Propagation counter (barrel)
Prox. focusing Aerogel RICH

Vertex Detector
1/2 layers DEPFET
+
4 layers DSSD

Central Drift Chamber
He (50%):C_2H_6 (50%)
small cells, long level arm, fast electronics

Installation of Vertex Detector (Fall 2018)



on-going DAQ upgrade
(to be installed in 2020-2021)
PCIe40 board, capable of reading via high speed optical links and to write to computer at rate of 100 Gb/s:
limited number of boards (20) enough **to read entire Belle II detector**
(P.Robbe, D.Charlet et al)

considering now VTX upgrade (2025 or later)
(also luminometer LumiBelle2, P.Bambade et al)

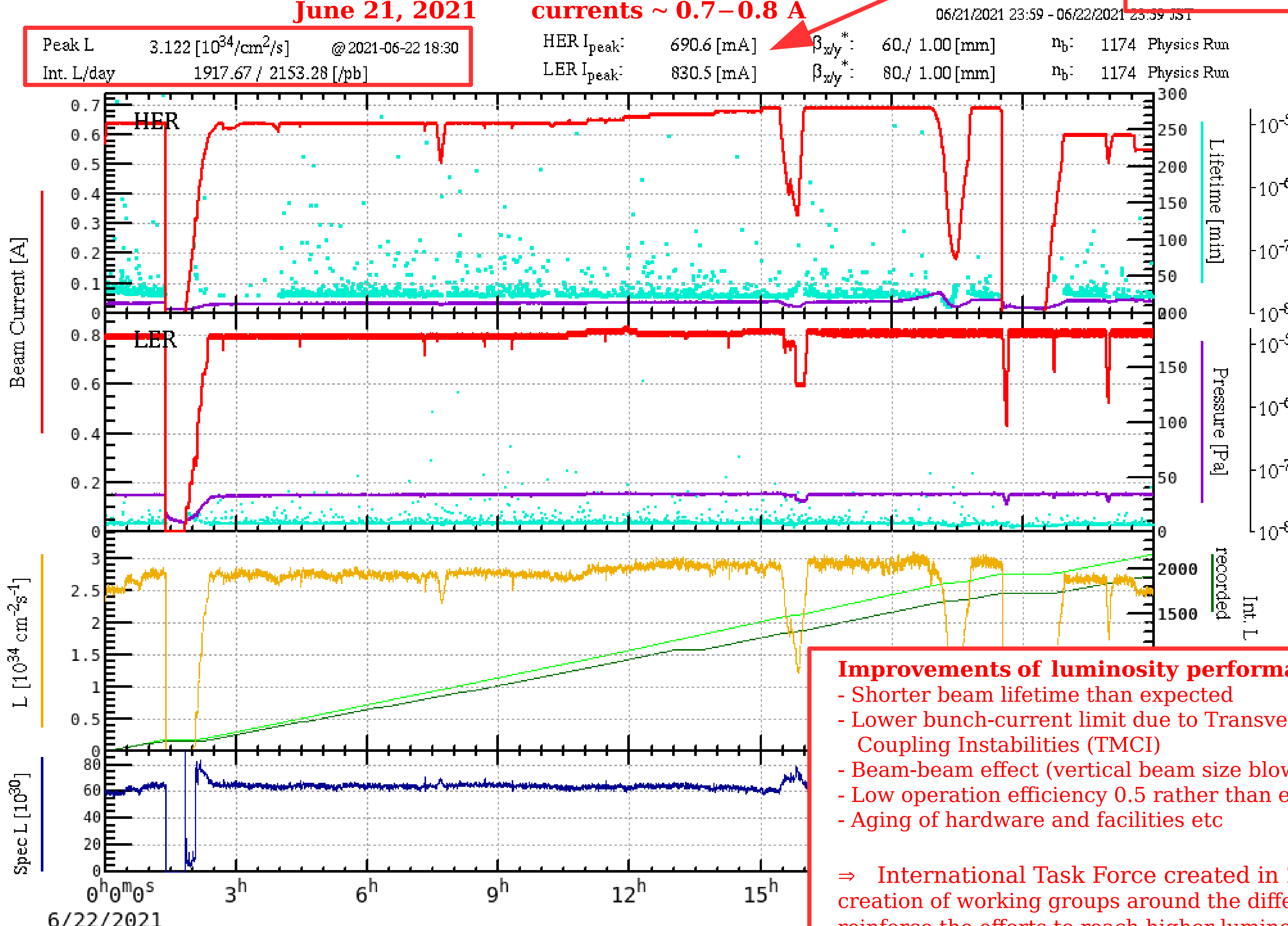
News about Belle II

- despite difficult conditions, continued to take data since March 2020 ! yes, no excuse… will be of little value around here…

3.1×10^{34}/cm^2/s ! ~2 fb^{-1} per day

June 21, 2021 **currents ~ 0.7−0.8 A**

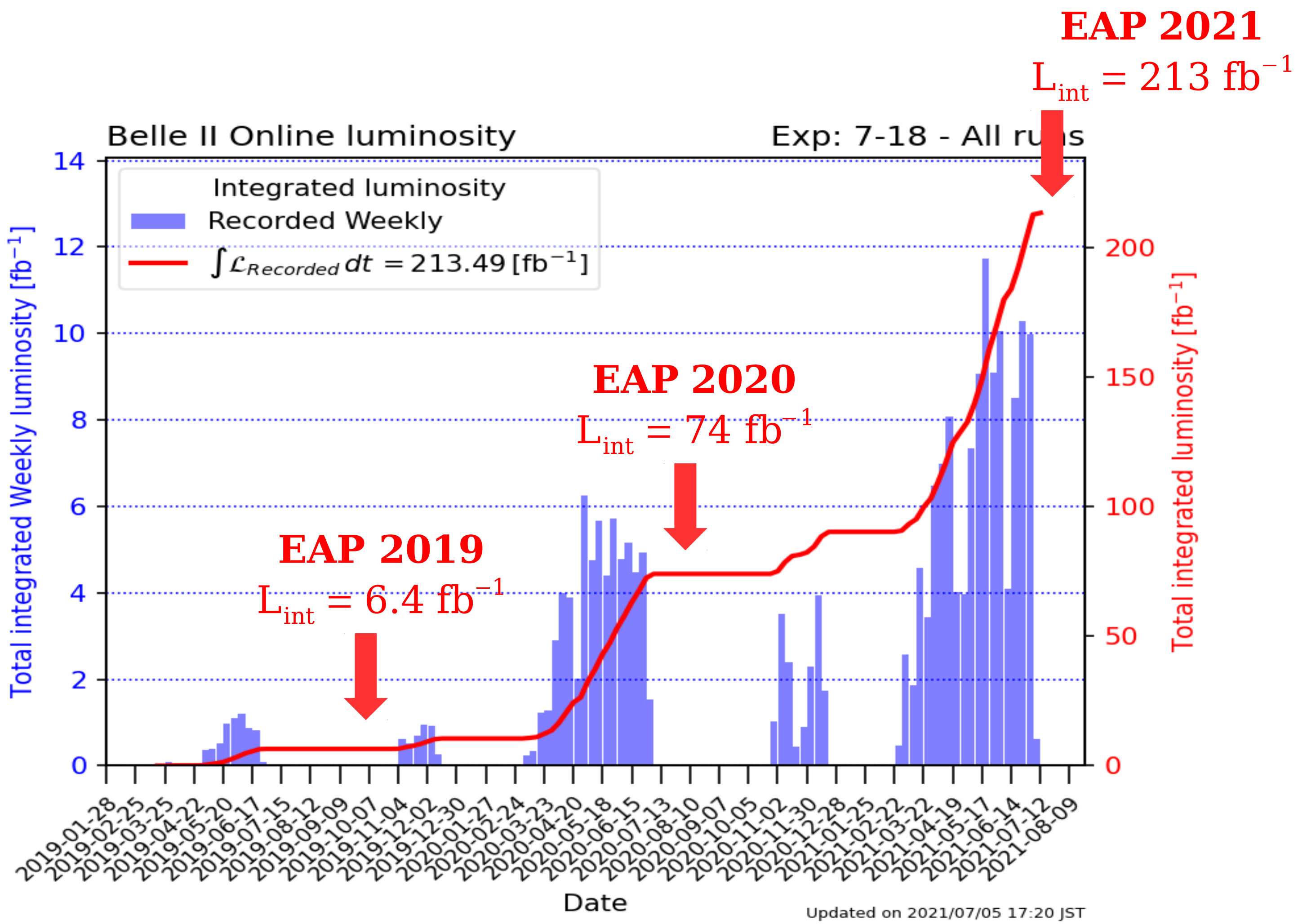
record of KEKB/Belle
2.1×10^{34}/cm^2/s currents > 1 A
record of PEPII/BaBar
1.2×10^{34}/cm^2/s currents > 2 A



Improvements of luminosity performance needed
- Shorter beam lifetime than expected
- Lower bunch-current limit due to Transverse Mode Coupling Instabilities (TMCI)
- Beam-beam effect (vertical beam size blow-up)
- Low operation efficiency 0.5 rather than expected 0.65
- Aging of hardware and facilities etc

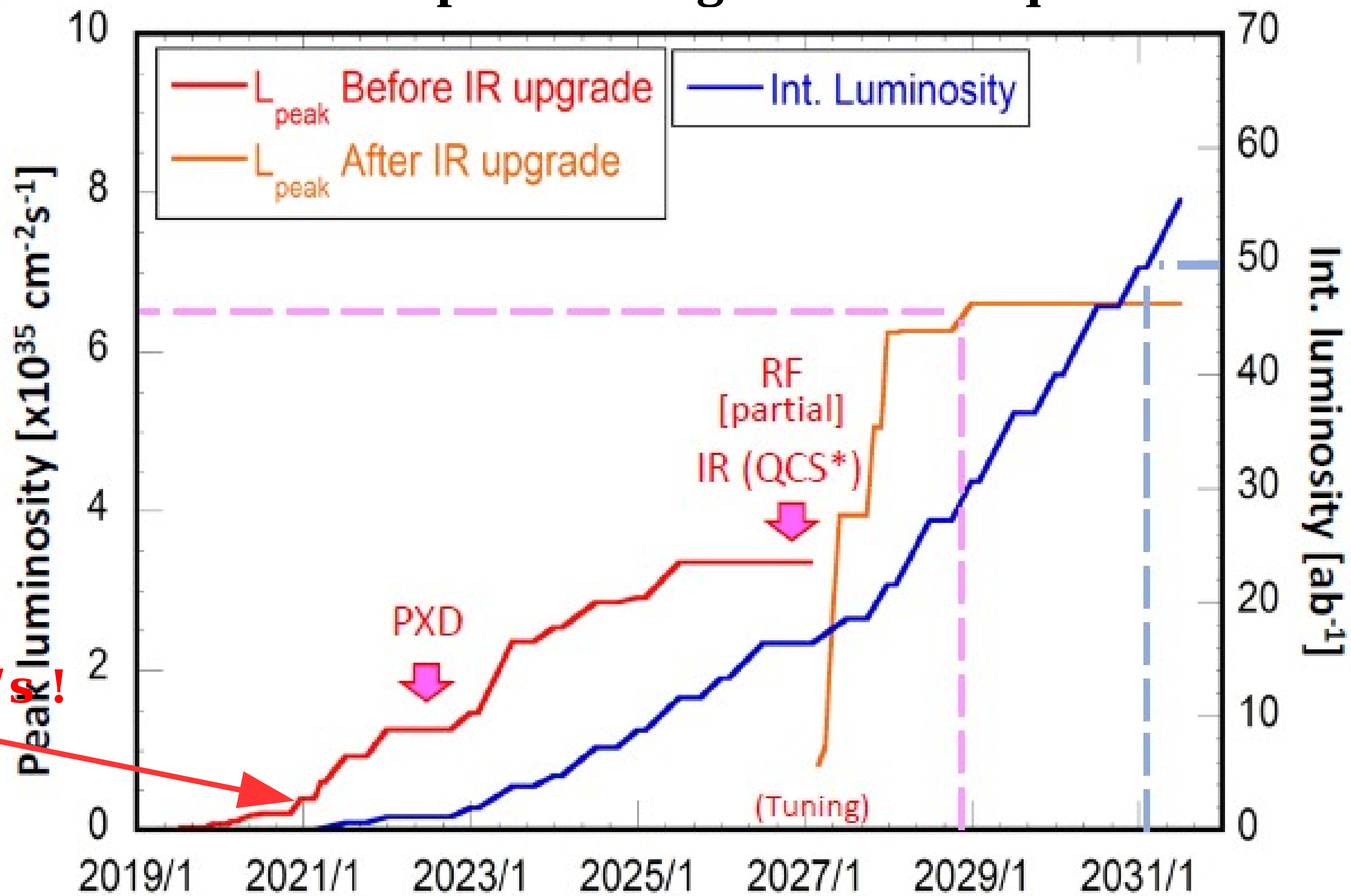
⇒ International Task Force created in 2021
creation of working groups around the different SKEKB issues
reinforce the efforts to reach higher luminosity by 2022

News about Belle II



Calendrier de Belle II

la vie n'est pas un long fleuve tranquille...



$3\times10^{34}/cm^2/s$!

By summer 2022: $\sim$1 ab^{-1}

complete PXD (2 layers) installed in end of 2022 (or a bit later)

(replace some TOP PMT)

→ **...et d'opportunites**

2026: collider upgrade (QCS+RF) → installation upgraded detector

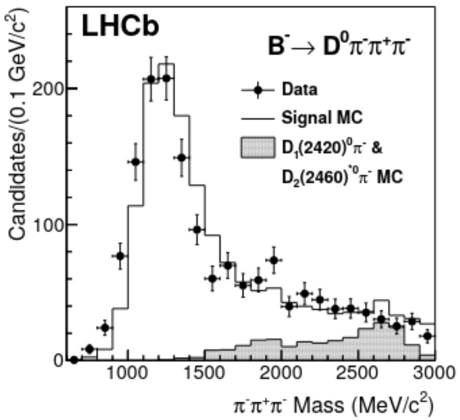
2031: 50 ab^{-1}

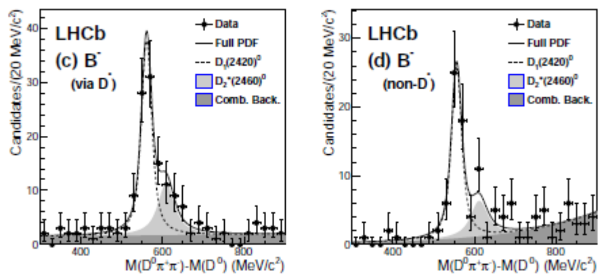
→ SuperKEKB with polarized beams

writing White Paper (A.Martens for polarimety part)

$B \to D^0 \pi^+ \pi^- \pi^+$

Phys.Rev.D 84 (2011) 092001



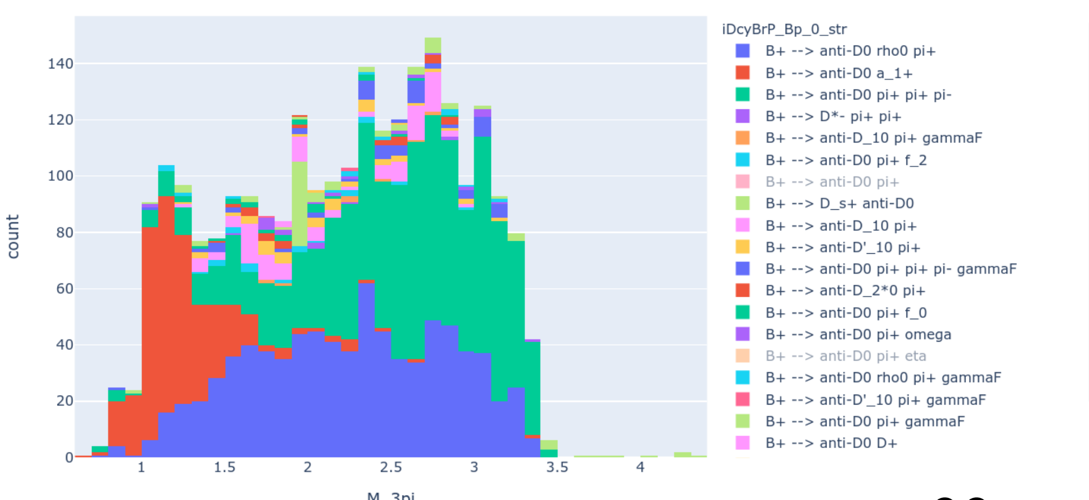


$$\mathcal{B}(\overline{B}^0 \to D_1(2420)^-\pi^+,\ D_1(2420)^- \to D^+\pi^-\pi^+) = (1.3 \pm 0.3^{+0.2}_{-0.3}) \times 10^{-4}$$
$$\mathcal{B}(B^- \to D_1(2420)^0\pi^+,\ D_1(2420)^0 \to D^0\pi^-\pi^+) = (6.3 \pm 0.9 \pm 0.9) \times 10^{-4}$$
$$\mathcal{B}(B^- \to D_1(2420)^0\pi^+,\ D_1(2420)^0 \to D^{*+}\pi^-) = (5.8 \pm 1.0 \pm 0.9) \times 10^{-4}$$
$$\mathcal{B}(B^- \to D_1(2420)^0\pi^+,\ D_1(2420)^0 \to D^0\pi^+\pi^-)_{\text{non}-D^*} = (2.5 \pm 0.4 \pm 0.4) \times 10^{-4}$$
$$\mathcal{B}(B^- \to D_2^*(2460)^0\pi^+,\ D_2^*(2460)^0 \to D^{*+}\pi^-) = (2.5 \pm 0.7 \pm 0.4) \times 10^{-4}$$

- but no $D a_1$ result, neither $D\rho\pi$, $D3\pi$ NR

⇒ $D\rho\pi$, $D3\pi$ NR results in PDG are from CLEO (0.9 fb^{-1})

⇒ used in our (Belle/Belle II) DECAY file



$\Gamma(B^+ \to \overline{D}^0\pi^+\pi^+\pi^-)/\Gamma(B^+ \to \overline{D}^0\pi^+)$ — Γ_{106}/Γ_{49}

VALUE	DOCUMENT ID	TECN	COMMENT
1.2 ± 0.4	**OUR FIT** Error includes scale factor of 3.7.		
1.27 ±0.06 ±0.11	AAIJ 2011E	LHCB	pp at 7 TeV

References:

AAIJ 2011E PR D84 092001 Measurements of the Branching Fractions for $B_{(s)} \to D_{(s)}\pi\pi\pi$ and $\Lambda_b^0 \to \Lambda_c^+\pi\pi\pi$

$\Gamma(B^+ \to \overline{D}^0\pi^+\pi^+\pi^-$ nonresonant$)/\Gamma_{\text{total}}$ — Γ_{108}/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
0.0051 ±0.0034 ±0.0023	[1] BORTOLETTO 1992	CLEO	$e^+e^- \to \Upsilon(4S)$

[1] BORTOLETTO 1992 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

References:

BORTOLETTO 1992 PR D45 21 Inclusive and Exclusive Decays of B Mesons to Final States Including Charm and Charmonium Mesons

$\Gamma(B^+ \to \overline{D}^0\pi^+\rho^0)/\Gamma_{\text{total}}$ — Γ_{109}/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
0.0042 ±0.0023 ±0.0020	[1] BORTOLETTO 1992	CLEO	$e^+e^- \to \Upsilon(4S)$

[1] BORTOLETTO 1992 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

References:

BORTOLETTO 1992 PR D45 21 Inclusive and Exclusive Decays of B Mesons to Final States Including Charm and Charmonium Mesons

$\Gamma(B^+ \to \overline{D}^0 a_1(1260)^+)/\Gamma_{\text{total}}$ — Γ_{110}/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
0.0045 ±0.0019 ±0.0031	[1] BORTOLETTO 1992	CLEO	$e^+e^- \to \Upsilon(4S)$

[1] BORTOLETTO 1992 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

References:

BORTOLETTO 1992 PR D45 21 Inclusive and Exclusive Decays of B Mesons to Final States Including Charm and Charmonium Mesons