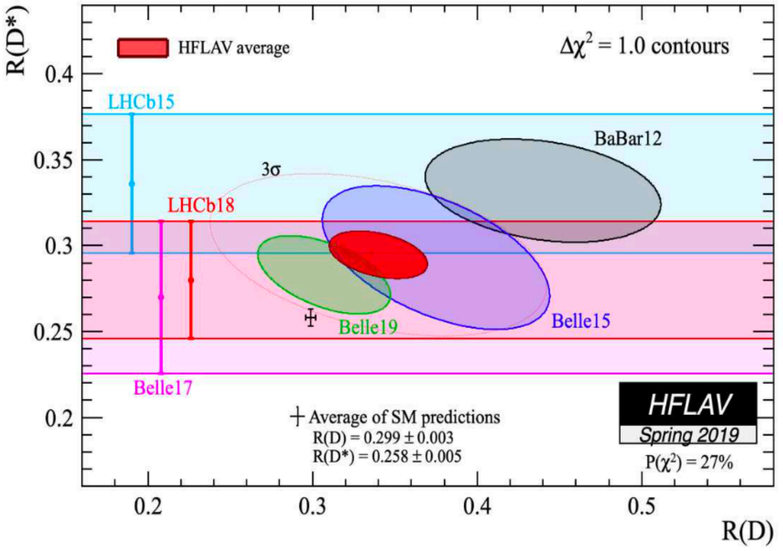
Status of physics analysis, performance studies and tool development

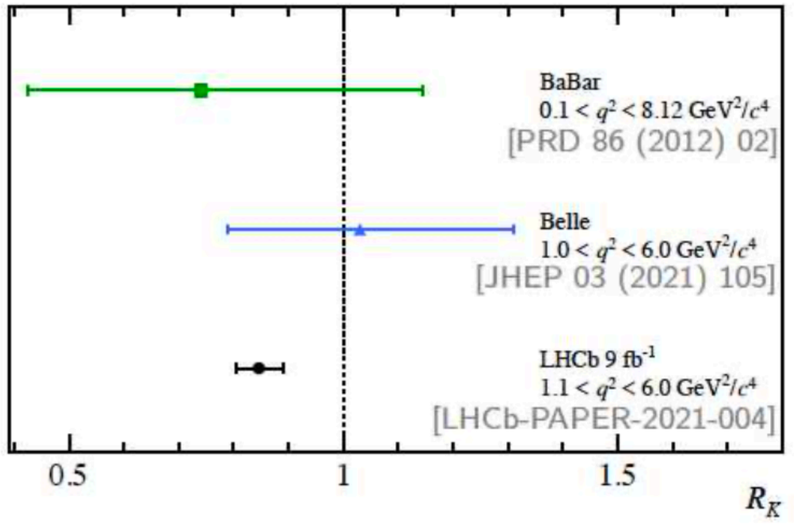
Elisa Manoni (INFN Perugia)
on behalf of Belle II Italian groups

- Belle II on flavour anomalies and beyond
- Highlights on results submitted to journal
- Italian activities
  - Tool development, performance studies, physics analysis
  - 2022 milestones and requests

Belle II Italy - Referee Meeting
September 8th, 2021

Belle II on and beyond flavour anomalies



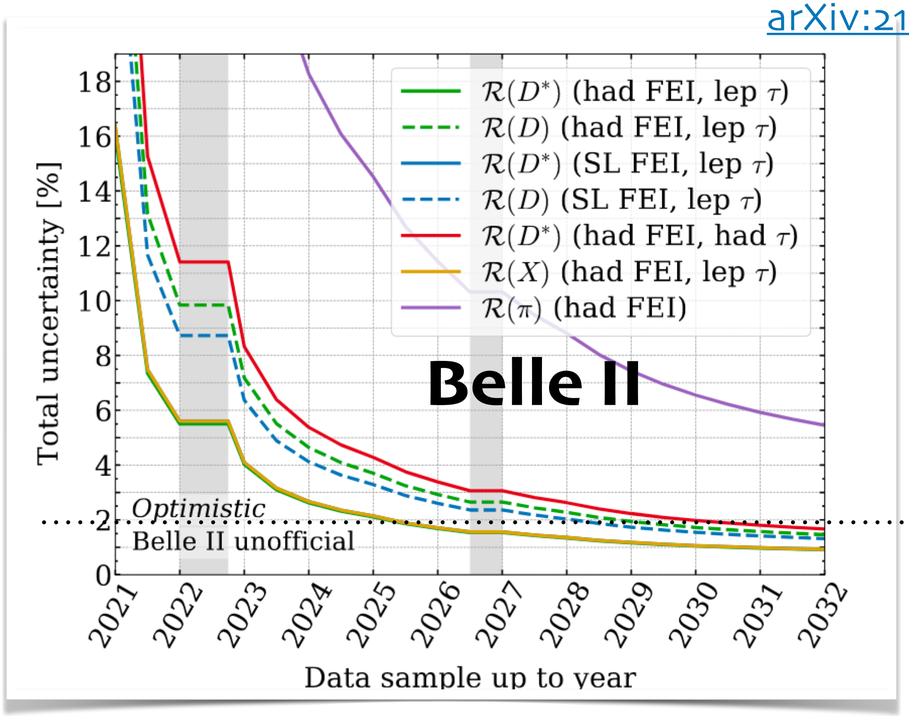


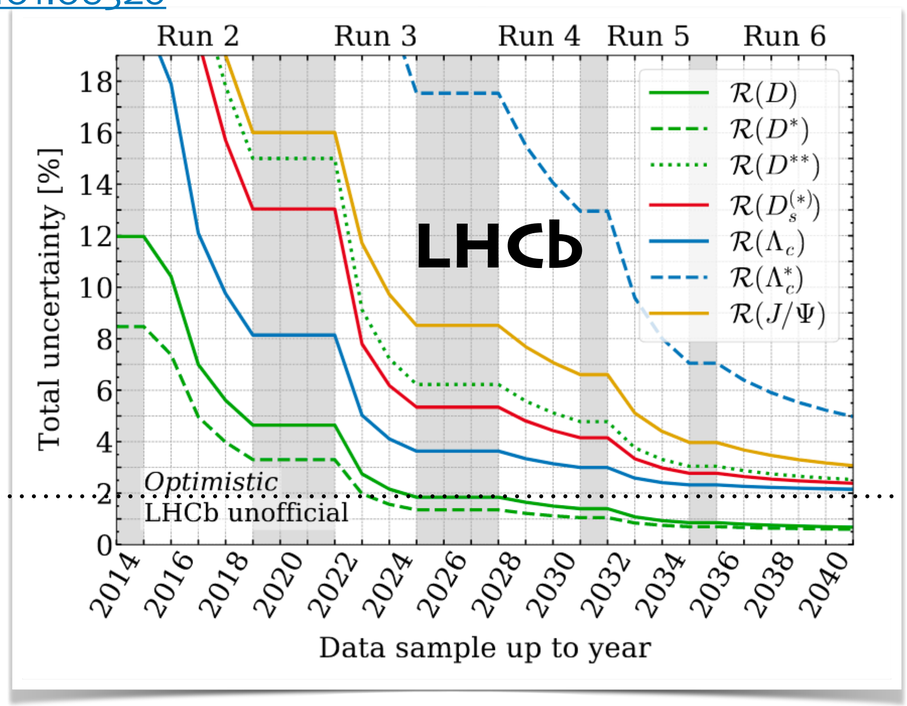
Flavour anomalies: R(D(*))

$$\mathcal{R}(D^{(*)}) = \frac{\mathcal{B}(\bar{B} \to D^{(*)}\tau^-\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D^{(*)}\ell^-\bar{\nu}_\ell)}$$

(where $\ell = e$ and μ)

arXiv:2101.08326

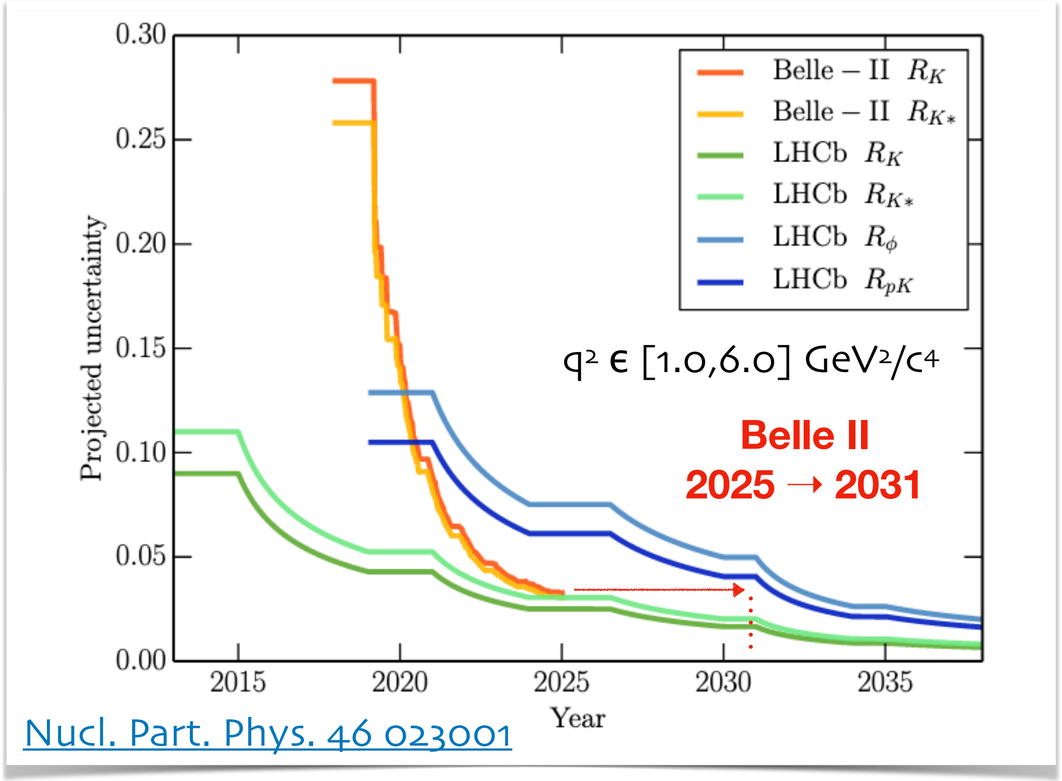




- Plethora of τ/ℓ ratio measurements from LHCb and Belle
- On R(D(*)), (sub)-% level precision can be reached
- Using hadronic tag, Belle II can also perform R(X) measurement, with high stat angular correlations and polarisations measurements also feasible

Flavour anomalies: R(K(*))

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



Nucl. Part. Phys. 46 023001

- Belle II will need ~ 20 ab^{-1} (2025) to confirm anomaly in R(K) at 5σ level, LHCb should be able to do that in the near future
- R(K(*)): LHCb with full luminosity (~2035, 300fb^{-1}) will have better precision in the low q^2 wrt to full BelleII data sample, in the high q^2 BelleII precision et few % level
- Inclusive channel accessible to Belle II

NP models explaining LFU violation: one example

G. Isidori @ "Beyond the anomalies II" workshop

- ***From EFT to simplified models***

Beside direct searches, an essential role is still played by low-energy observables → many visible BSM effects expected, by consistency, virtually in all models addressing the anomalies

Main message: "super-reach" program for LHCb & Belle-II and other low-energy facilities. This program is essential to confirm/disproof the picture and, if confirmed..., to determine the flavor structure of the new sector.

I. EFT-based (model-independent) correlations on a large class of semi-leptonic processes

[$b \to d\,\mu\mu$, $b \to s\,\tau\tau$, $b \to s\,\tau\mu$, $b \to u\,\tau\nu$, ...]

II. Model-dependent correlations for UV-sensitive observables

[$\Delta F=2$, $b \to s\,\nu\nu$, $\tau \to \mu\gamma$, $\tau \to 3\mu$, $\mu N \to eN$, ...]

Competitive/unique in almost all listed modes, one example in the next slides, see backup for more details

Belle II - LHCb Comparison

+ Important contributions on B and D flavour physics from ATLAS, CMS, BESIII.

Belle II
Higher sensitivity to decays with photons and neutrinos (e.g. B→Kνν, μν), inclusive decays, time dependent CPV in B_d, τ physics.

LHCb
Higher production rates for ultra rare B, D, & K decays, access to all b-hadron flavours (e.g. Λ_b), high boost for fast B_s oscillations.

Overlap in various key areas to verify discoveries.

Upgrades
Most key channels will be stats. limited (not theory or syst.).
LHCb scheduled major upgrades during LS3 and LS4.
Belle II formulating a 250 ab^{-1} upgrade program post 2028.

Observable	Current Belle/ Babar	2019 LHCb	Belle II (5 ab^{-1})	Belle II (50 ab^{-1})	LHCb (23 fb^{-1})	Belle II Upgrade (250 ab^{-1})	LHCb upgrade II (300 fb^{-1})
CKM precision, new physics in CP Violation							
$\sin 2\beta/\varphi_1$ ($B\to J/\psi K_S$)	0.03	0.04	0.012	0.005	0.011	0.002	0.003
γ/φ_3	13°	5.4°	4.7°	1.5°	1.5°	0.4°	0.4°
α/φ_2	4°	–	2	0.6°	–	0.3°	–
$\lvert V_{ub}\rvert$ (Belle) or $\lvert V_{ub}\rvert/\lvert V_{cb}\rvert$ (LHCb)	4.5%	6%	2%	1%	3%	<1%	1%
φ_s	–	49 mrad	–	–	14 mrad	–	4 mrad
S_{CP}($B\to\eta' K_S$, gluonic penguin)	0.08	○	0.03	0.015	○	0.007	○
A_{CP}($B\to K_S\pi^0$)	0.15	–	0.07	0.04	–	0.02	–
New physics in radiative & EW Penguins, LFUV							
S_{CP}($B_d\to K^*\gamma$)	0.32	○	0.11	0.035	○	0.015	○
R($B\to K^* l^+l^-$) ($1<q^2<6$ GeV$^2/c^2$)	0.24	0.1	0.09	0.03	0.03	0.01	0.01
R($B\to D^*\tau\nu$)	6%	10%	3%	1.5%	3%	<1%	1%
Br($B\to\tau\nu$), Br($B\to K^*\nu\nu$)	24%, –	–	9%, 25%	4%, 9%	–	1.7%, 4%	–
Br($B_d\to\mu\mu$)	–	90%	–	–	34%	–	10%
Charm and τ							
ΔA_{CP}(KK-ππ)	–	8.5×10^{-4}	–	5.4×10^{-4}	1.7×10^{-4}	2×10^{-4}	0.3×10^{-4}
A_{CP}($D\to\pi^+\pi^0$)	1.2%	–	0.5%	0.2%	–	0.1%	–
Br($\tau\to e\gamma$)	$<120\times10^{-9}$	–	$<40\times10^{-9}$	$<12\times10^{-9}$	–	$<5\times10^{-9}$	–
Br($\tau\to\mu\mu\mu$)	$<21\times10^{-9}$	$<46\times10^{-9}$	$<3\times10^{-9}$	$<3\times10^{-9}$	$<16\times10^{-9}$	$<0.3\times10^{-9}$	$<5\times10^{-9}$

Results on other D & τ modes expected

arXiv: 1808.08865 (Physics case for LHCb upgrade II), PTEP 2019 (2019) 12, 123C01 (Belle II Physics Book)

○ *Possible in similar channels, lower precision*
– *Not competitive.*

Beauty 2020 Phillip URQUIJO 57

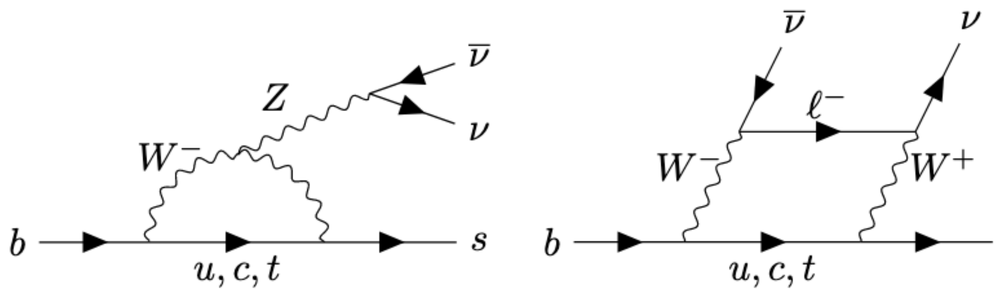
- In many of these channels, preliminary results presented at 2021 conferences
- Highlights on Paolo's talk and more in backup

Latest publications

New journal submission: $B^+ \to K^+ \nu\nu$ (I)

- SM predictions: T. Blake et al, Prog. Part.Nucl. Phys.92, 50 (2017)

$$\mathrm{BR}(B^+ \to K^+ \nu\bar{\nu})_{\mathrm{SM}} = (4.6 \pm 0.5) \times 10^{-6},$$
$$\mathrm{BR}(B^+ \to K^{*+} \nu\bar{\nu})_{\mathrm{SM}} = (8.4 \pm 1.5) \times 10^{-6},$$



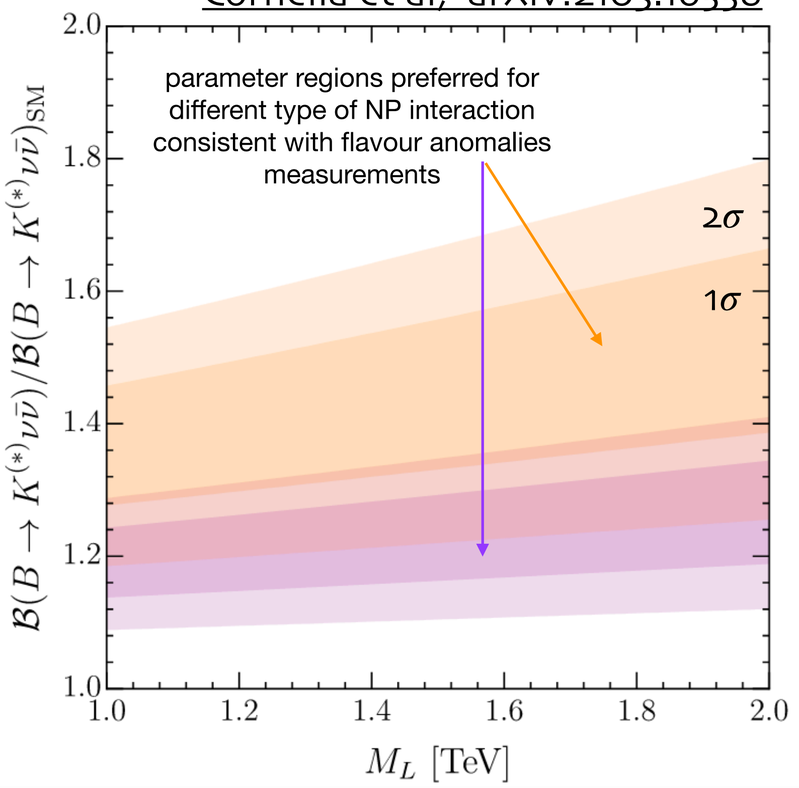
(a) Penguin diagram (b) Box diagram

- Possible enhancement in NP scenarios, e.g. Leptoquark models explaining flavour anomalies

- BaBar and Belle tagged analysis

	UL @ 90% CL (10^{-5})	**Ref**
$B^+ \to K^+ \nu\nu$	1.6	BaBar, HAD+SL TAG, 429 fb^{-1}
$B^+ \to K^{*+} \nu\nu$	4.0	Belle, HAD TAG, 711 fb^{-1}
$B^0 \to K^0 \nu\nu$	2.6	Belle, SL TAG, 711 fb^{-1}
$B^0 \to K^{*0} \nu\nu$	1.8	Belle, SL TAG, 711 fb^{-1}

Cornella et al, arXiv:2103.16558



New journal submission: $B^+ \to K^+ \nu\nu$ (II)

[arXiv:2104.12624 submitted to journal]

NOVEL INCLUSIVE APPROACH on 63 fb^{-1} of BelleII data

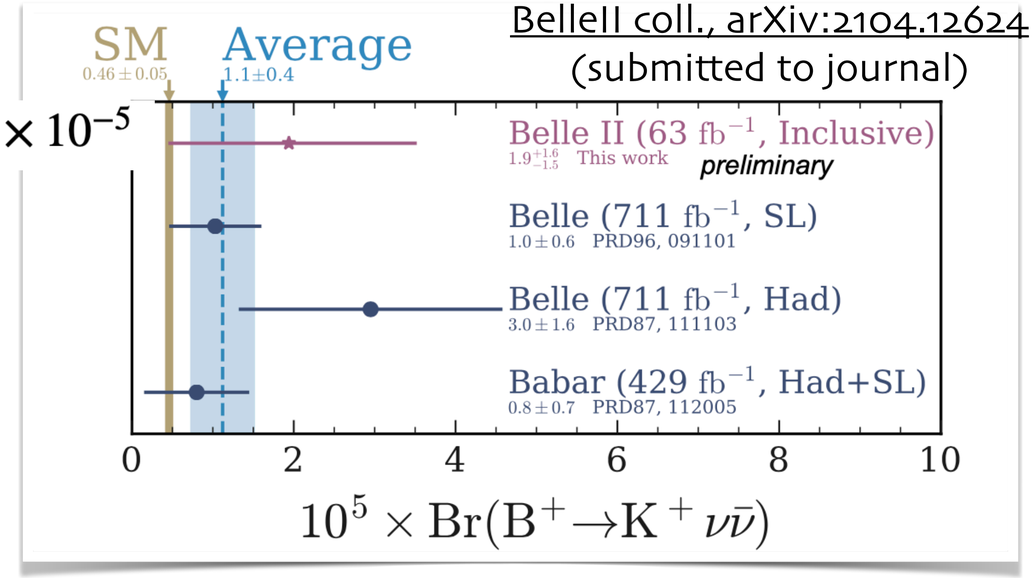
- Signal kaon = highest p_T track, associate remaining tracks and clusters to other B in the event

- No evidence for signal, upper limit on BR using CLs method (assuming SM signal)

$$\mathcal{B}(B^\pm \to K^\pm \nu\bar{\nu}) < (4.1 \pm 0.5) \times 10^{-5} \ @\, 90\,\%\,\mathrm{CL}$$

- Comparing theory and experiments:

$$\mathcal{B}(B^+ \to K^+ \nu\bar{\nu}) = 1.9^{+1.6}_{-1.5} \times 10^{-5}$$



BelleII coll., arXiv:2104.12624 (submitted to journal)

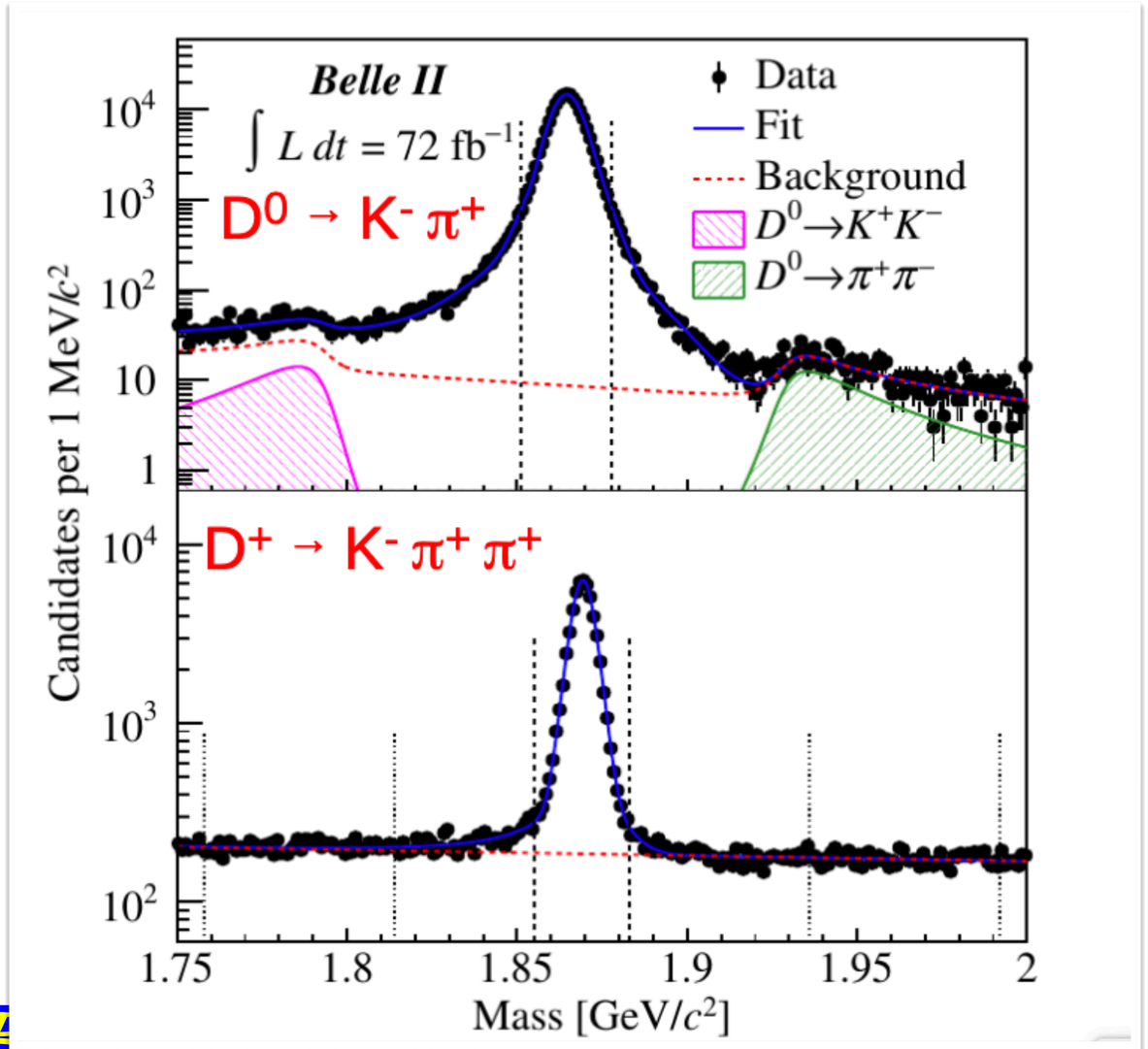
Belle II measurement (~1/10 Belle statistics) in the same ballpark wrt Belle and BaBar ones
[Belle II efficiency ~ 4%, tagged analysis efficiency ~ 0.04%(had tag)-0.2% (sl tag)]

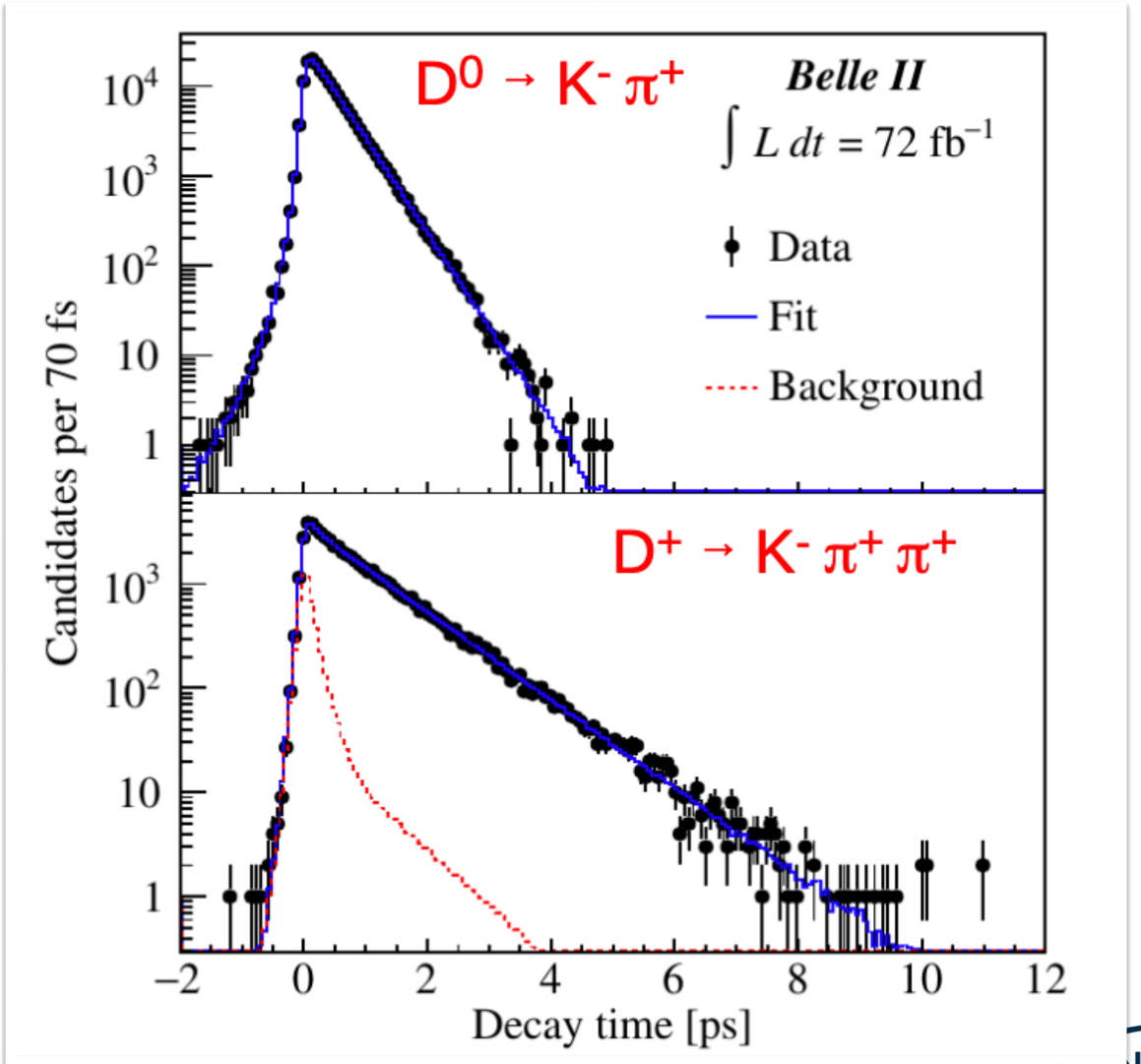
- Room for improvement in K^+ channel, application of inclusive method to other channels in progress

New journal submission: $D^{+/0}$ lifetimes (I)

[arXiv:2108.03216 submitted to journal] **PI+TS et al**

- Use $D^0 \to K^-\pi^+$ and $D^+ \to K^-\pi^+\pi$ from $D^* \to D\pi$ decays





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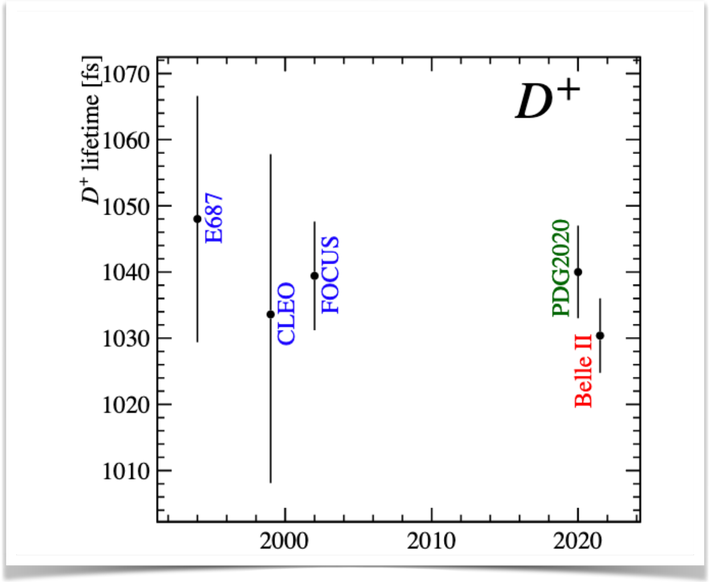
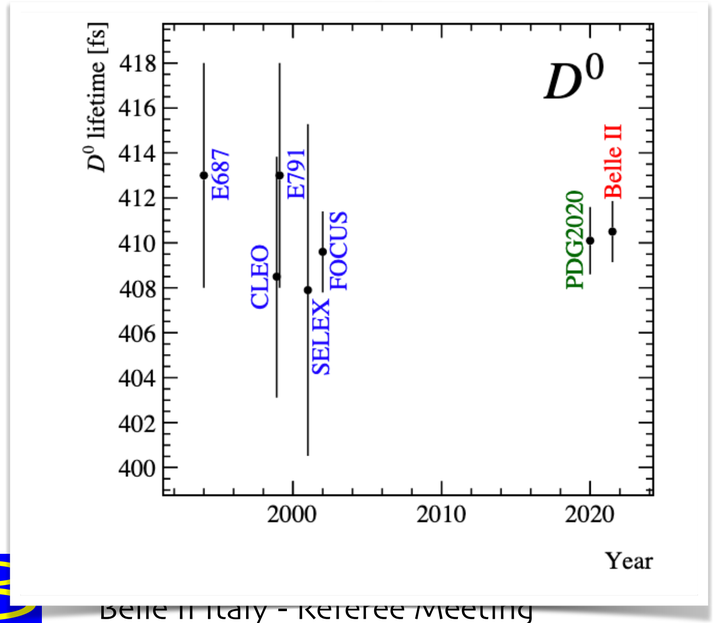




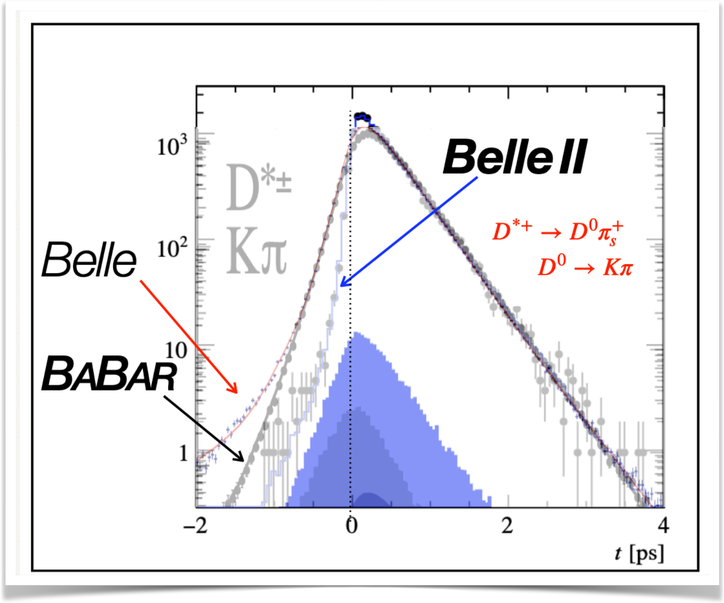
Results:

$$\tau(D^0) = 410.5 \pm 1.1 \pm 0.8\,\text{fs}$$
$$\tau(D^+) = 1030.4 \pm 4.7 \pm 3.1\,\text{fs}$$

$$\tau(D^+)/\tau(D^0) = 2.510 \pm 0.015$$

determined considering correlations between (systematic) uncertainties

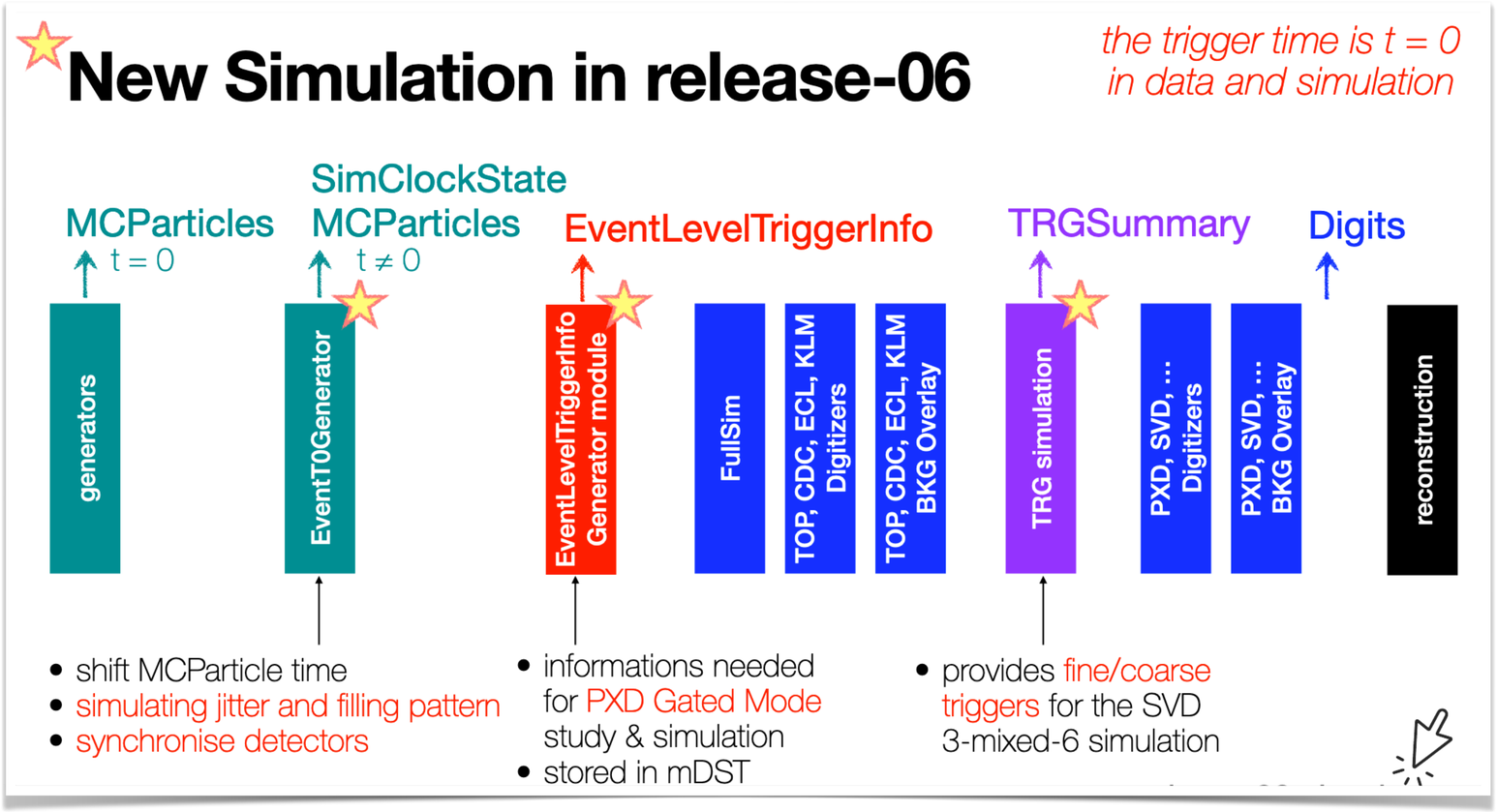
- Most precise measurement to-date, consistent with WA
- Prove excellent Belle II vertexing performances, high-quality calibrations (especially alignment & BeamSpot) and good control of systematic effects → getting ready for TDCPV and mixing analysis



Italian activities: Tools development and physics performance studies

Timing and Event t_0

PI+TO

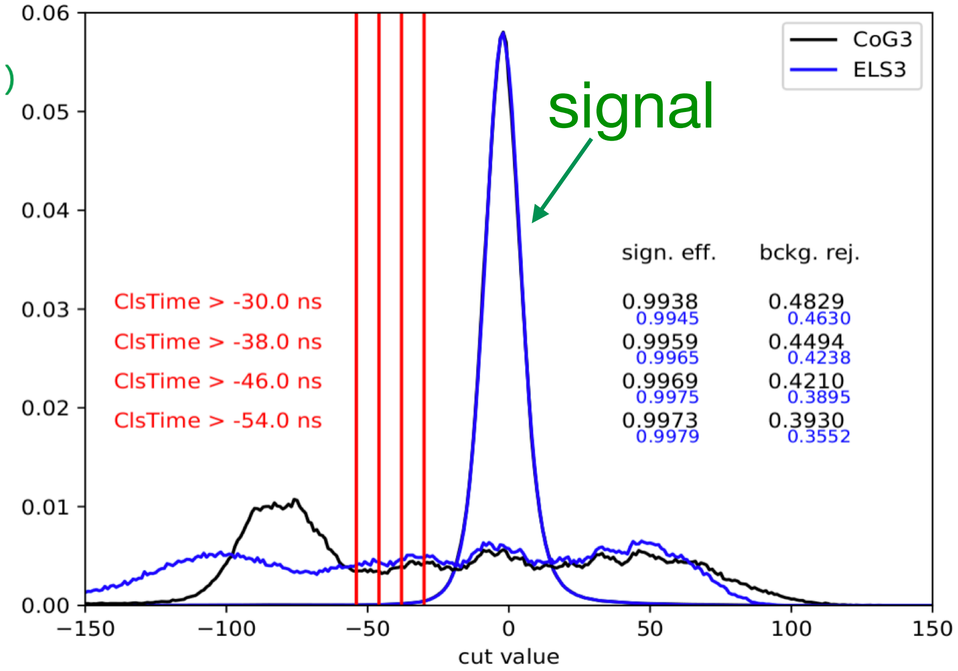


- Timing info is a key ingredient to reject machine background (out-of-time deposits)
- Many improvements in the new release (-06) , e.g. more realistic simulation, additional information at reconstruction level
- Impact on analysis/performances under study

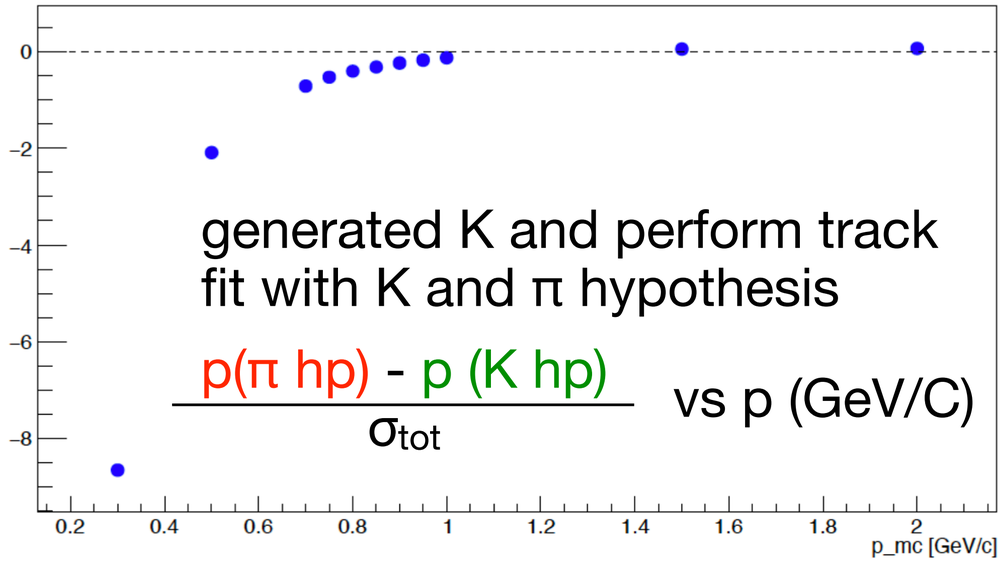
Tracking activities

PI+TO

- Optimise timing-based SVD hit selection
  - reduce fake rate and improve track quality in higher machine background expected with increasing lumi.



- Study track fit with different mass hypothesis in bins of momentum
  - should improve tracking execution time at HLT level by reducing the number of hypothesis mass used in the track fit



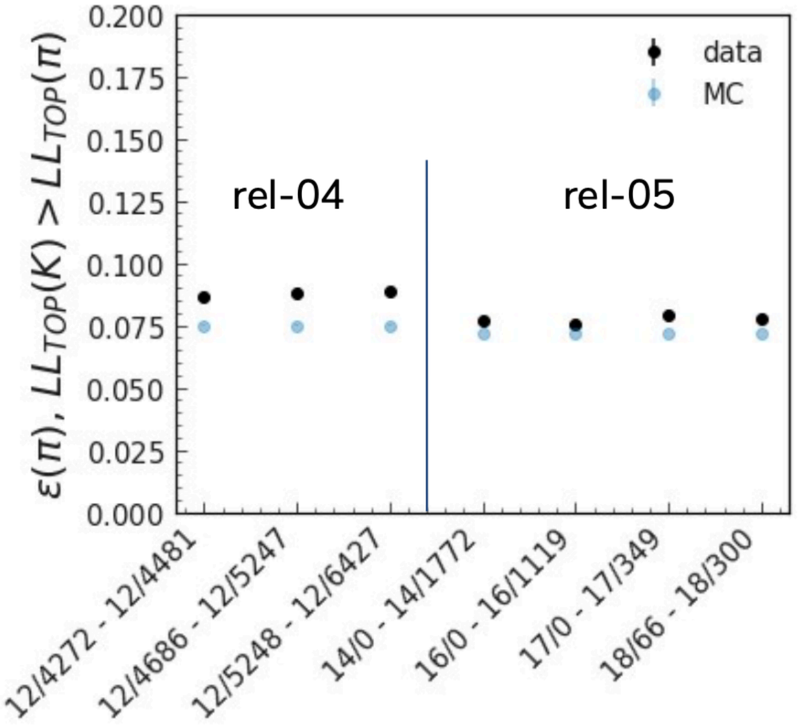
Hadron identification

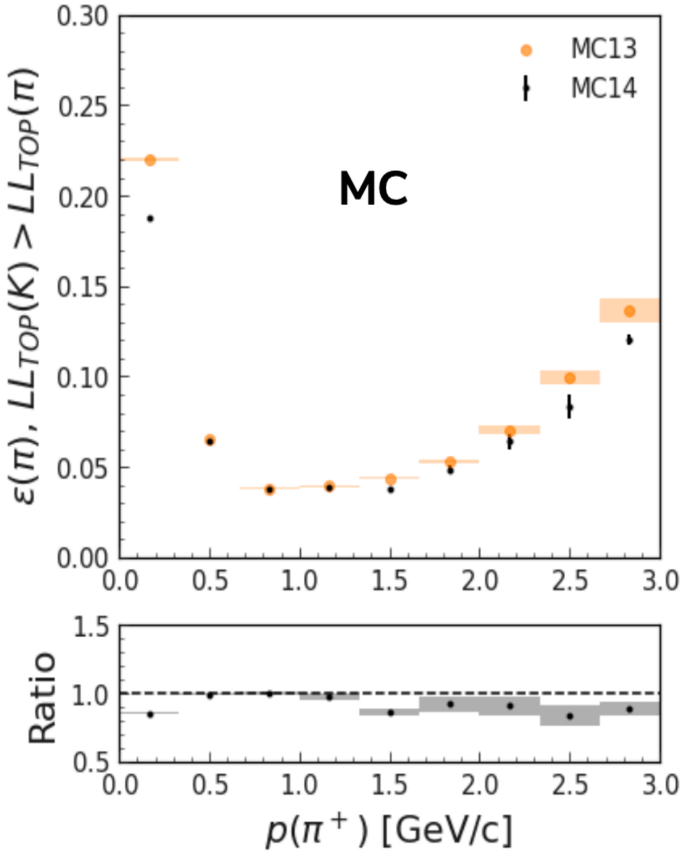
[BELLE2-NOTE-TE-2019-024] TO

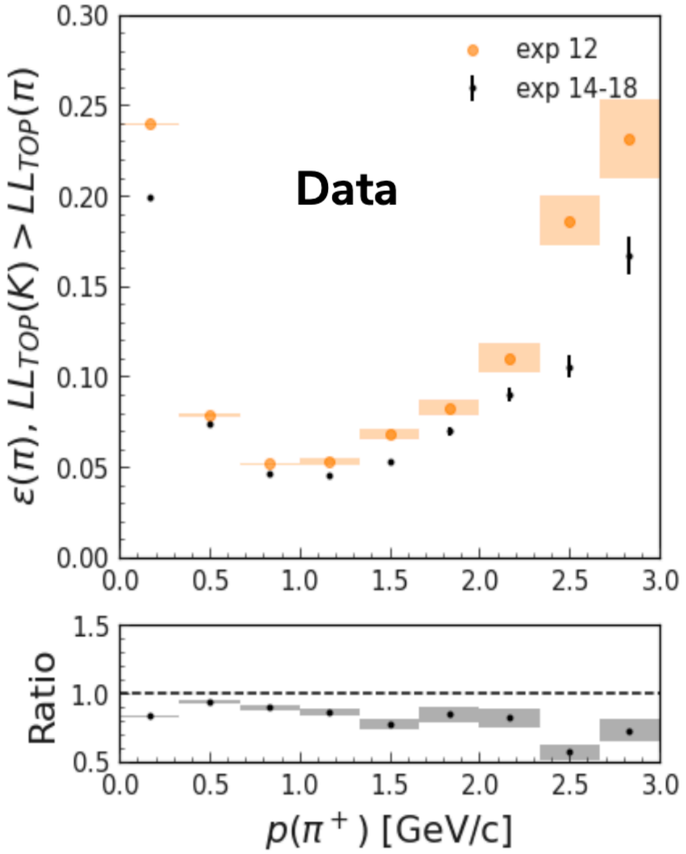
- Performances studies of hadron PID
- pion → kaon misID shown here, similar studies for other mass hypothesis performed

Cut point: LL(K) > LL(π)
Momentum range: 0 < p < 3 GeV

Pion → Kaon mis-id reduced in both data and MC



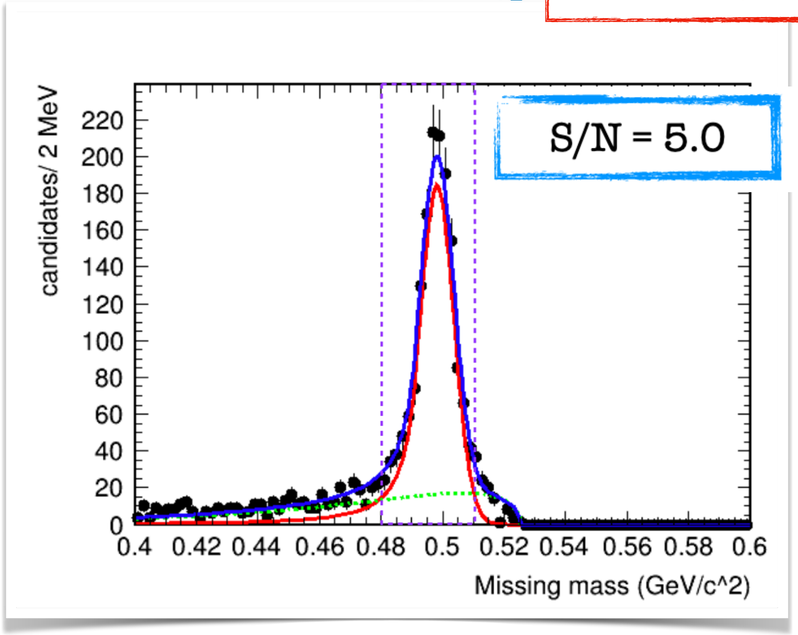




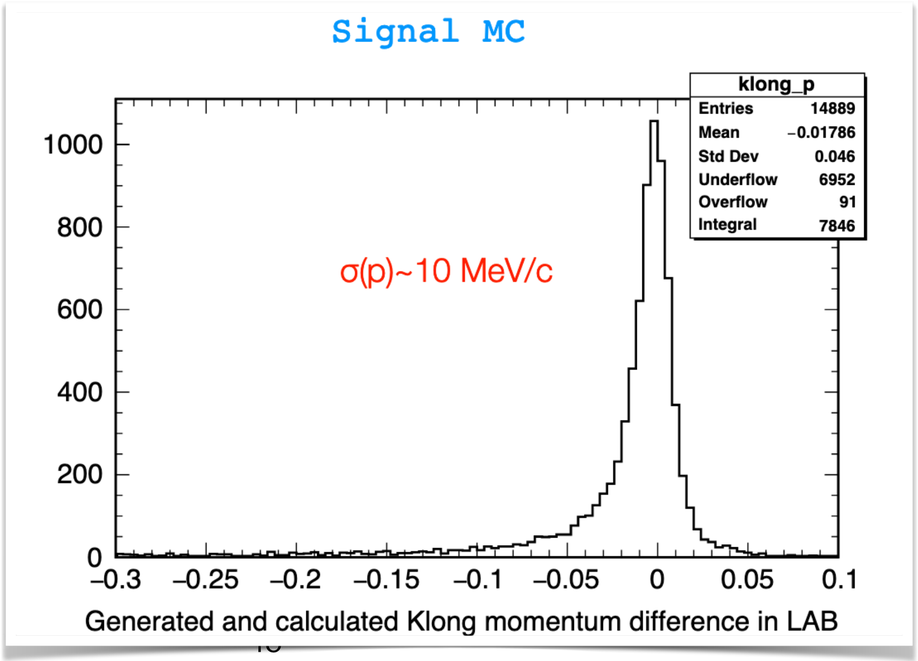
K_L Identification

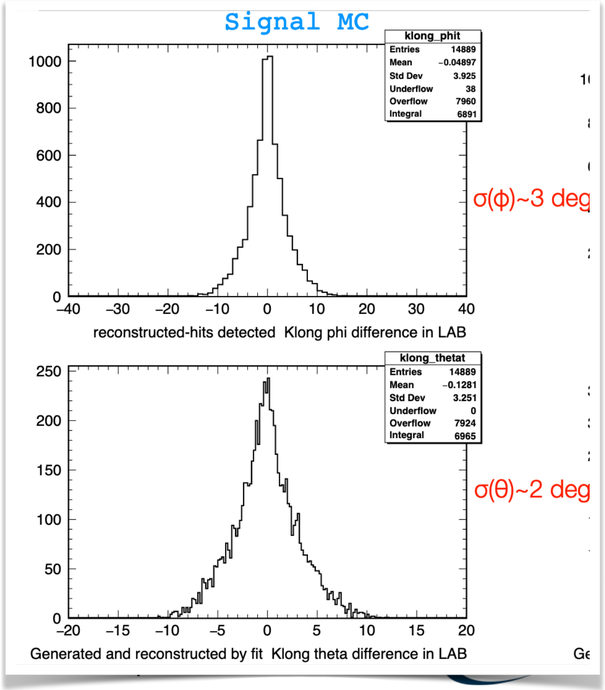
[BELLE2-NOTE-PH-2018-004] **LNF+RM3**

- K_L ID variable computed using a fast BDT
- Study performances of K_L ID by using $e^+e^- \rightarrow \phi\gamma$ with $\phi \rightarrow K_S K_L$ to select unbiased K_L sample
- Good momentum and angular resolution



- Data/MC agreement studies ongoing
- Plan to improve K_L ID tools including additional info from ECL





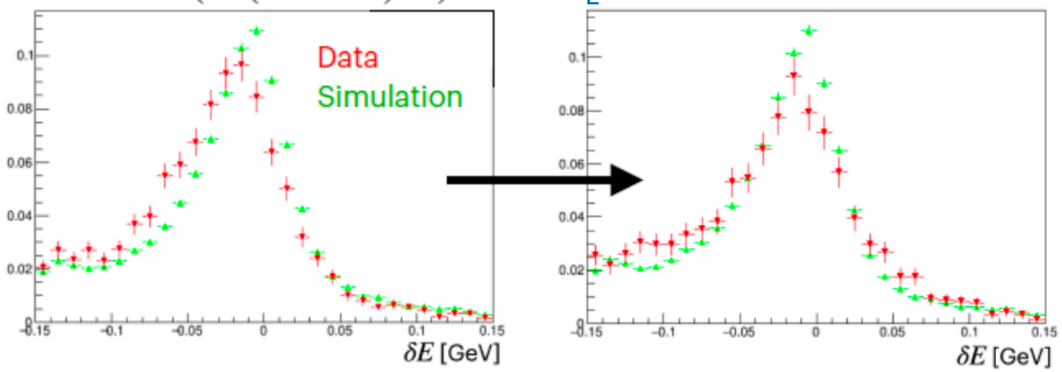
Neutral performance studies from charmless (I)

TS

- BelleII competitive in channels with >1π^0, e.g. π^0 reconstruction chief performance driver for charmless B decay studies
- By-product of charmless analyses, in synergy with neutral performance group

1. Correction of π^0 energy mis-calibration

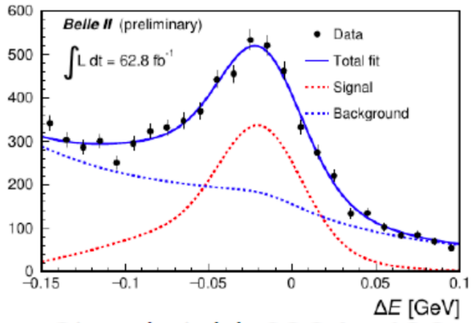
$B^0 \to D^{*-}(\bar{D}^0(K^+\pi^-\pi^0)\pi^-)\pi^+$ [BELLE2-NOTE-TE-2020-011]



photon energy corrections determined by maximising the data-MC agreement of higher-level quantities ($m_{\gamma\gamma}$, ΔE)

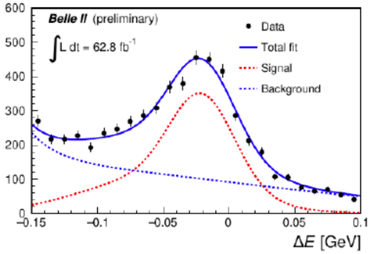
2. Study to improve π^0 standard lists

standard: π^0:charmless reference ($\cos\theta_\rho$<0.75)



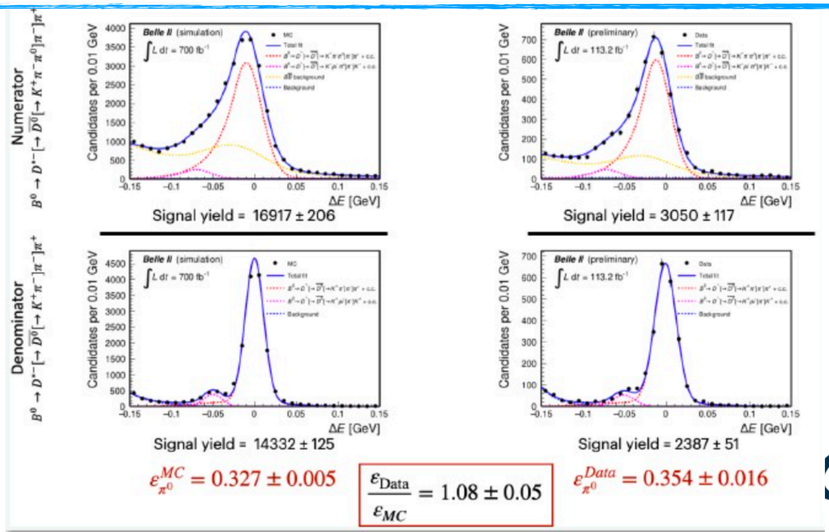
Signal yield: 2904 ± 106
S/√(S+B): 34.5

improved: 0.105 < m(γγ) < 0.15 GeV/c^2 + $\cos\theta_\rho$ < 0.775 + clusterHighestE > 0.05 GeV



Signal yield: 2993 ± 91
S/√(S+B): 38.4

3. Determination of π^0 reconstruction efficiency



$\varepsilon_{\pi^0}^{MC} = 0.327 \pm 0.005$

$\frac{\varepsilon_{\text{Data}}}{\varepsilon_{MC}} = 1.08 \pm 0.05$

$\varepsilon_{\pi^0}^{Data} = 0.354 \pm 0.016$

Instrumental asymmetries

[BELLE2-NOTE-TE-2020-024]

TS

Measurements of CP-violating charge asymmetries $\mathcal{A}_{CP}$.

By-product of charmless analyses, used also by other measurements

$$\mathcal{A} = \mathcal{A}_{CP} + \mathcal{A}_{\text{det}}$$

Observed charge-asymmetry

CP-violating charge-asymmetry

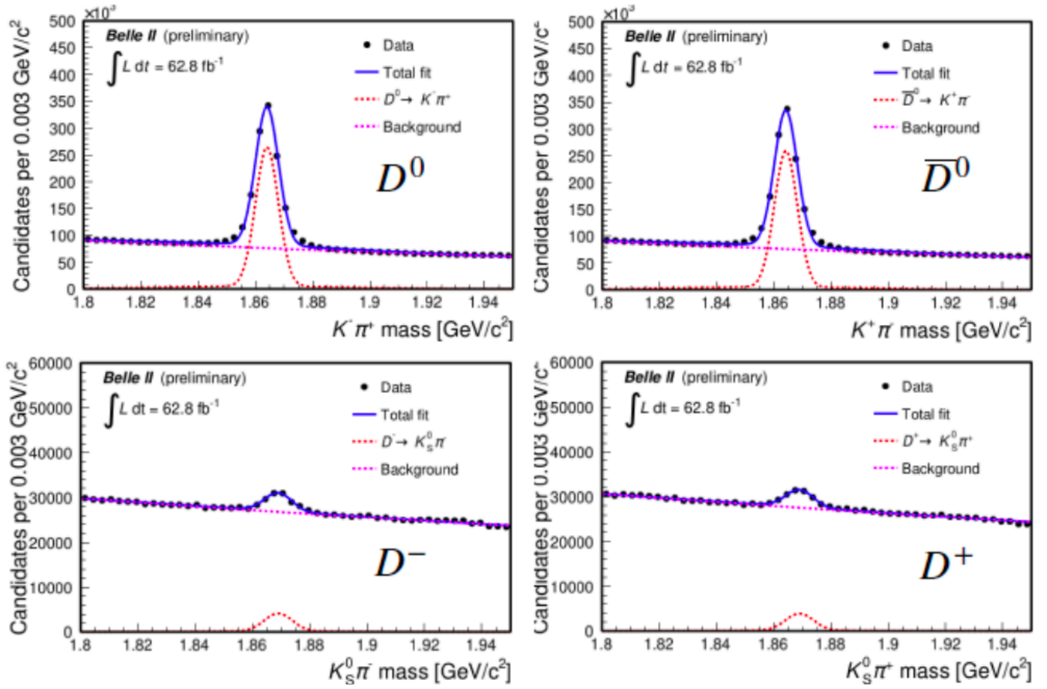
Instrumental charge-asymmetry (due to charge-dependent differences in interaction probabilities, tracking, or PID)

Measure instrumental asymmetries due to charged kaon/pion reconstruction from data using control channels $D^0 \to K^-\pi^+$ and $D^+ \to K^0_S\pi^+$ (expected $\mathcal{A}_{CP} \approx 0$).

$$\mathcal{A}_{\text{det}}(\pi) = \mathcal{A}_{\text{det}}(K^0_S\pi) - \mathcal{A}(K^0_S),$$

$$\mathcal{A}_{\text{det}}(K) = \mathcal{A}_{\text{det}}(K\pi) - \mathcal{A}_{\text{det}}(K^0_S\pi) - \mathcal{A}(K^0_S)$$

Estimate $\mathcal{A}(K^0_S)$ by using the results obtained by the LHCb collaboration (consistent with Belle).

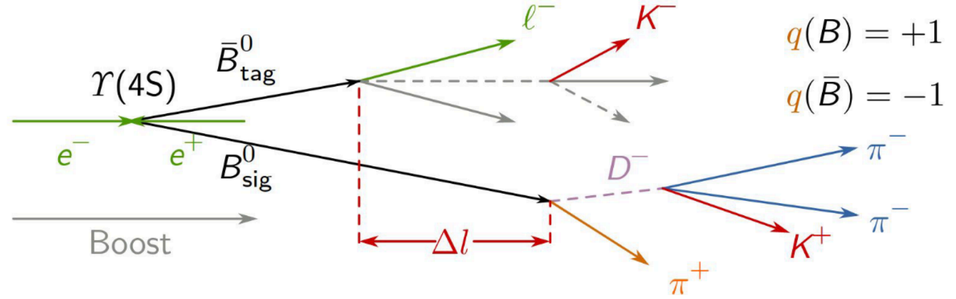


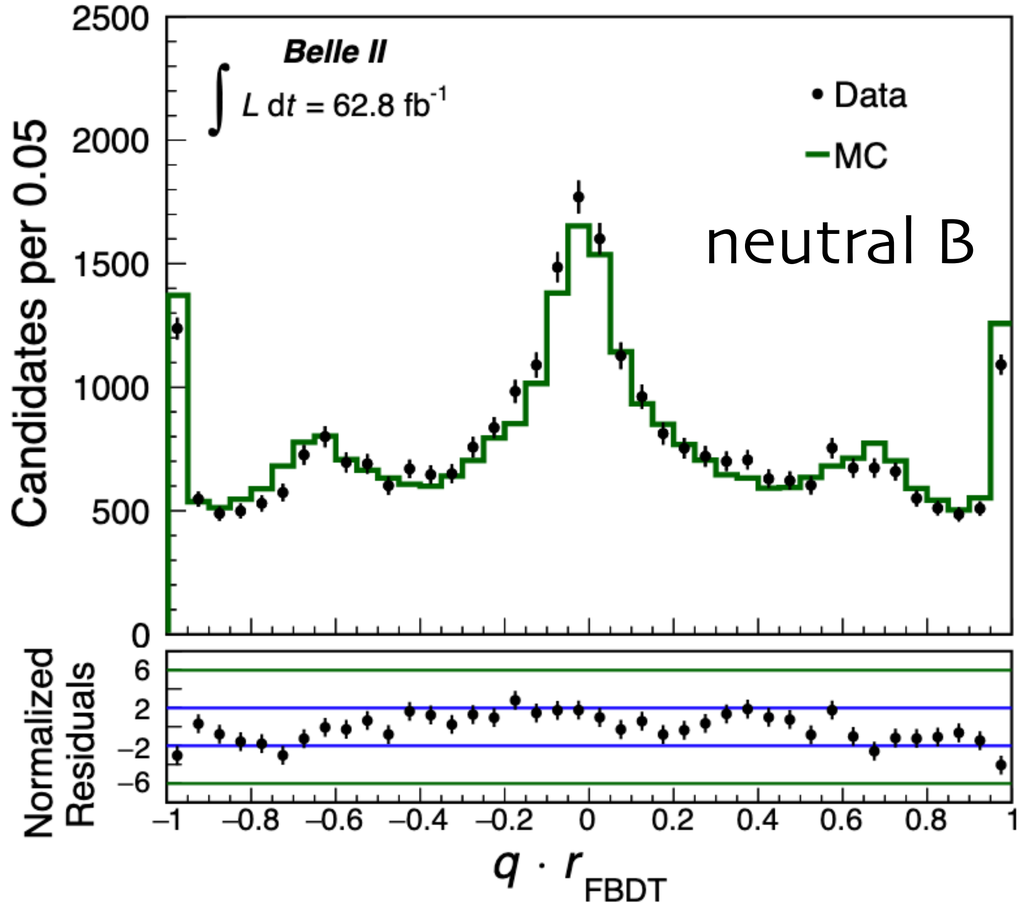
Flavour tagging

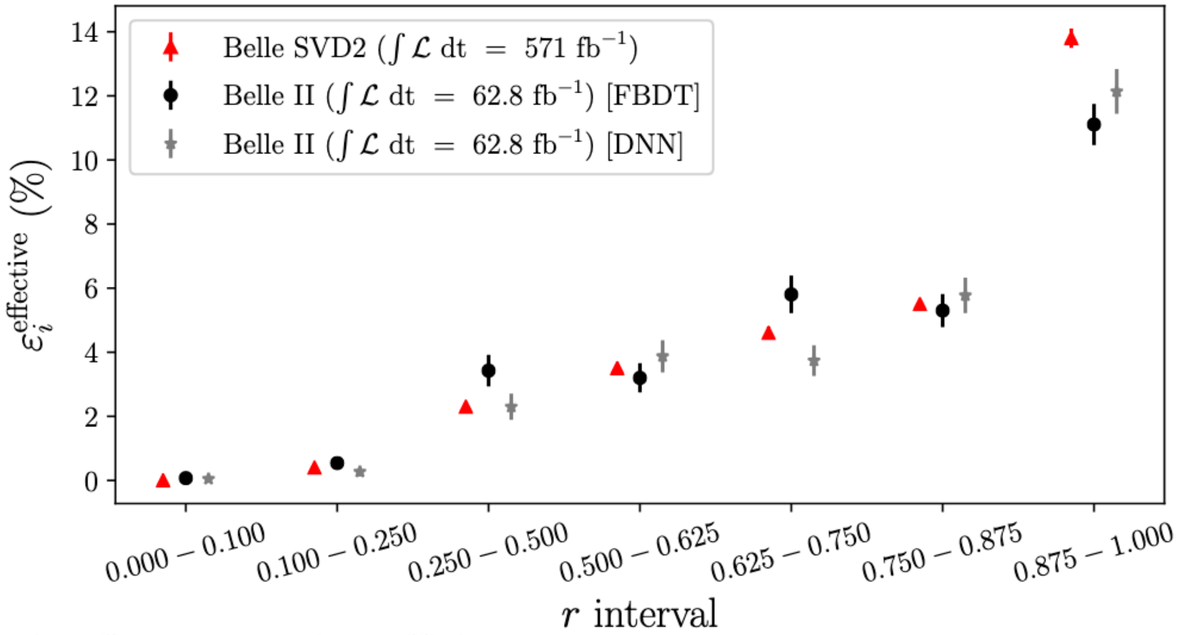
[BELLE2-NOTE-PH-2021-001]
Approved for ICHEP2020

TS

- Essential in many CP-violation and B-mixing analysis sensitive to φ_1/β and φ_2/α







Effective flavour tagging efficiency

$Q = \varepsilon\,(1-2\omega)^2$

Q(Belle II) = (30.0 ± 1.3)%
Q(Belle) = (30.1 ± 0.4)%

Q(Belle MC) = ~ 32.5%

Paper almost ready for submission!

B-counting

BELLE2-NOTE-PH-2021-018
Approved for ICHEP2020

NA + PG

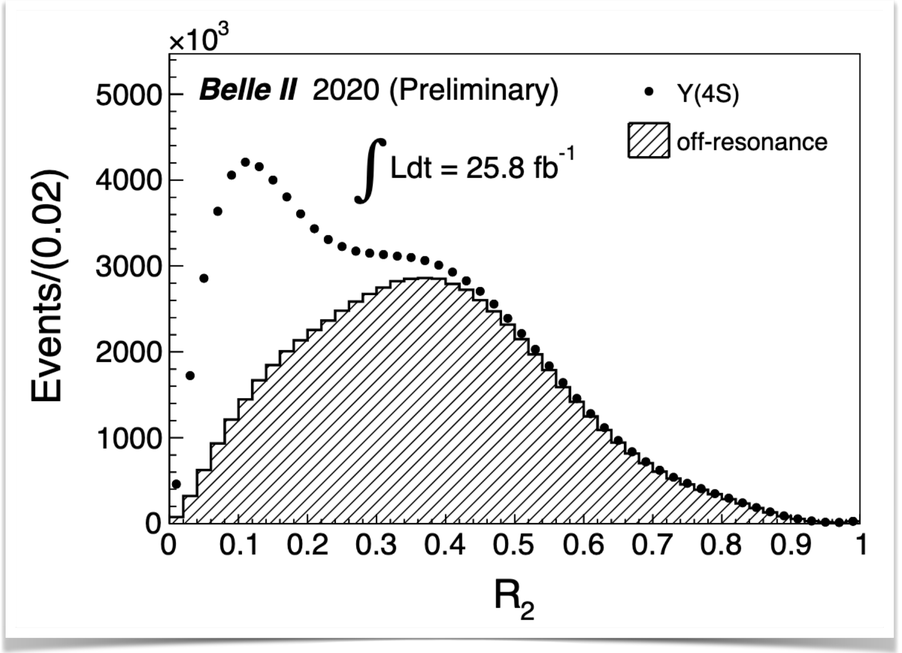
- Count number of BB events produced in the collisions (N_{BB}):
  - used as input in B meson branching fraction measurement
  - Aim to < 1% precision

$$N_{BB} = \left(N_{had}^{on-res} - R_{lumi} \cdot N_{had}^{off-res} \cdot \kappa\right) / \varepsilon_{BB}$$

Number of selected hadronic events in on-peak data

Estimated number of non-BB events in on-peak data

Efficiency of hadronic selection for BB events



	systematics on $N_{B\bar{B}}$ (%)
luminosity measurement	0.9
selection efficiency	0.5
beam energy spread and shift	0.5
tracking efficiency	0.1
trigger efficiency	0.2
Total	1.1

Systematic uncertainties
(stat error currently at 0.3%-level)

- Improvements toward publication: selection to reduce the off-resonance contribution and systematic effects

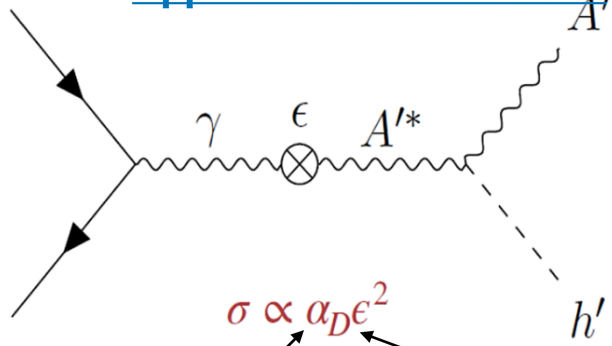
Italian activities: Physics analysis

Search for Dark Higgsstrahlung

BELLE2-NOTE-PH-2020-048
Approved for ICHEP2020

NA + RM3

- Search for a dark Higgs h′, produced in association to a dark photon A′
- Higgsstrahlung process sensitive to dark sector coupling constant α_D
- Analysis focussing on $m_{h'} < m_{A'}$ case with h′→ invisible and A′ → $\mu\mu$

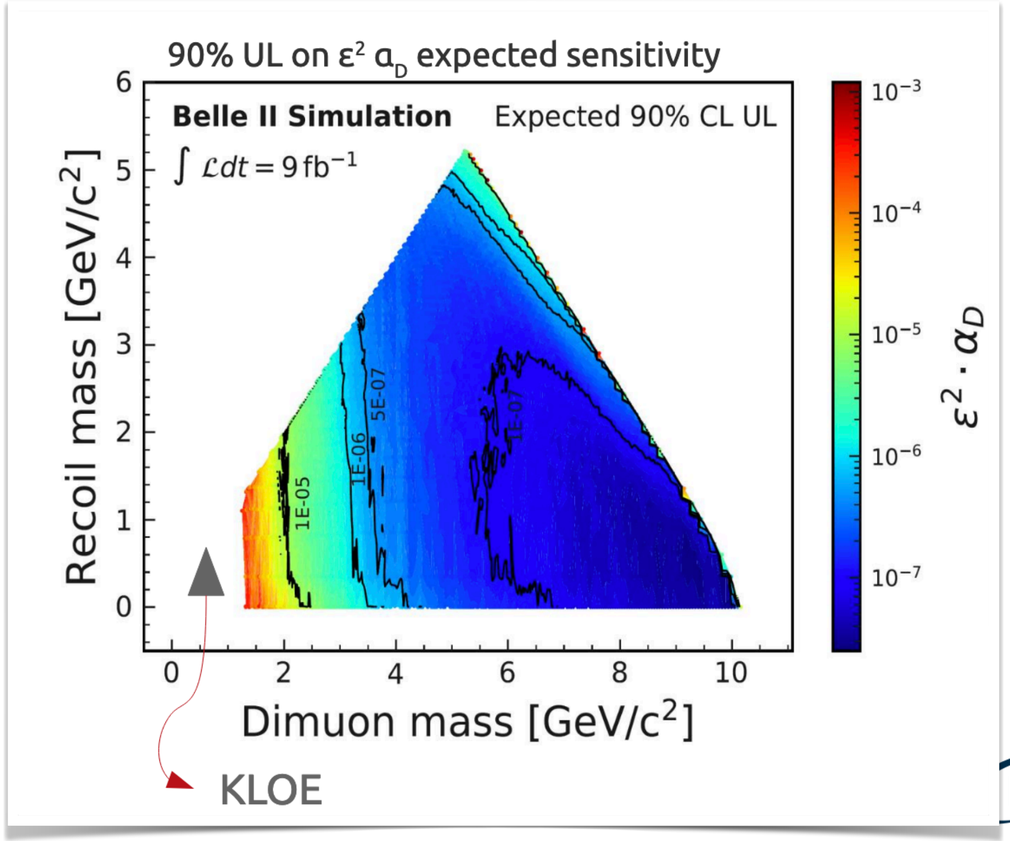


$\sigma \propto \alpha_D \epsilon^2$

dark coupling constant — kinetic mixing parameter

$e^+e^- \to A'^* \to h'A',\ A' \to \mu^+\mu^-$

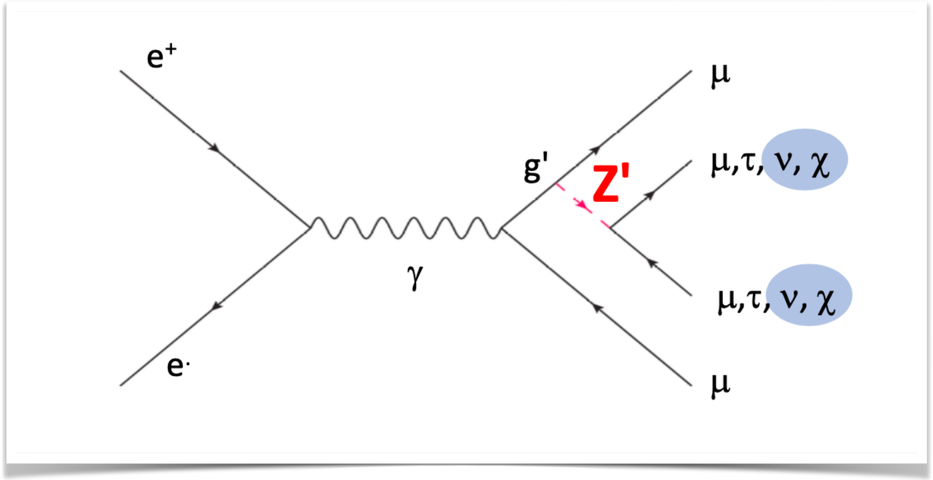
- Expected sensitivity with 9 fb^{-1}
- Analysis in final review stage, one of the next Belle II papers

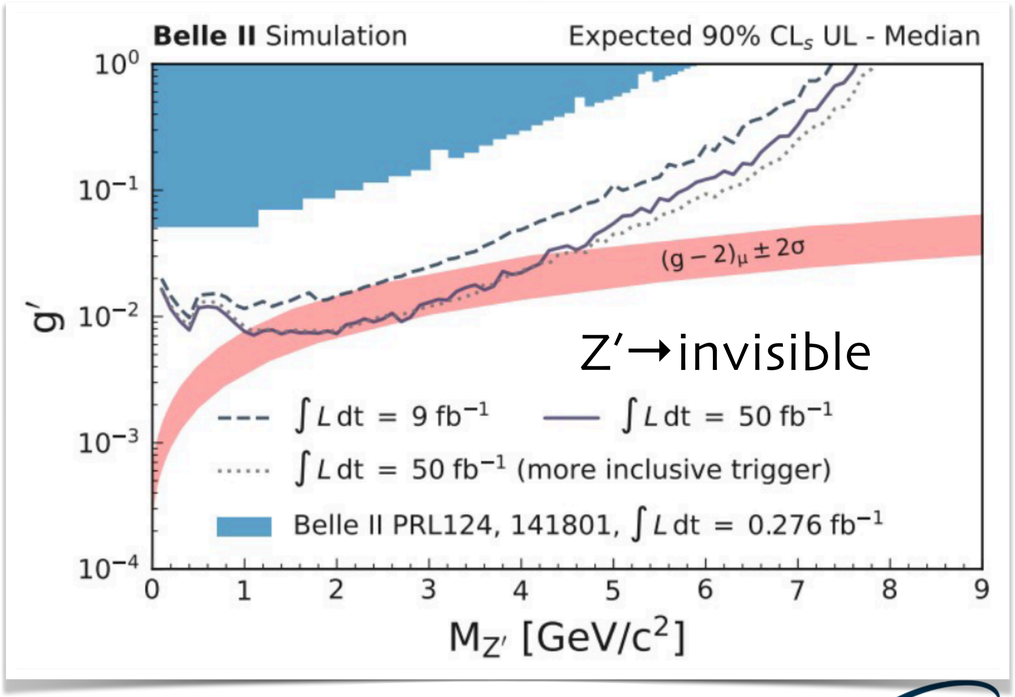


Other dark sector searches

NA +PI+ RM3

- Three topics:
  - Muonic dark force Z′→$\mu\mu$ (4μ final state)
  - Z′→$\tau\tau$ + Leptophilic dark scalar ($2\mu 2\tau$ final state)
  - Z′→ invisible [BELLE2-NOTE-PH-2021-040] (2μ+missing energy final state)
    - update wrt published result (Phys.Rev.Lett. 124 (2020) 14, 141801)
- To be completed during 2022 with at least 80 fb^{-1}



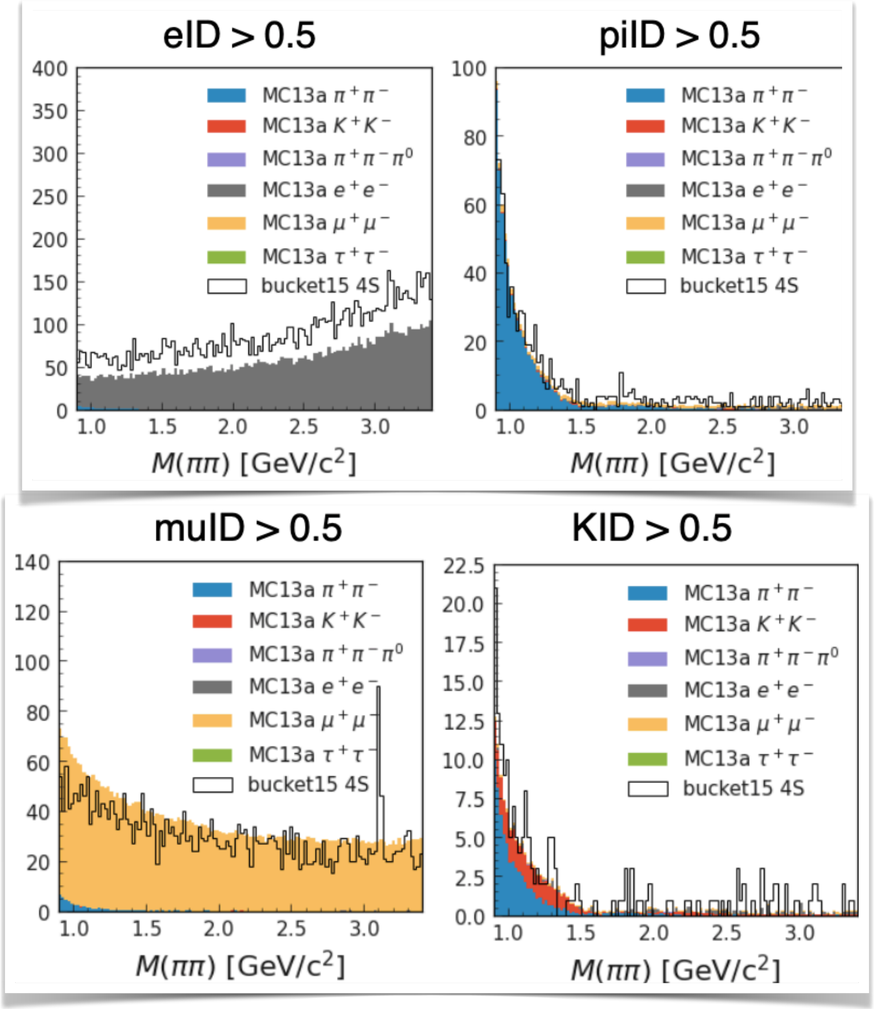


ISR physics & Bottomonium

TO

1. Measure $e^+e^- \to \pi^+\pi^-$ via ISR, aiming for 0.1% precision

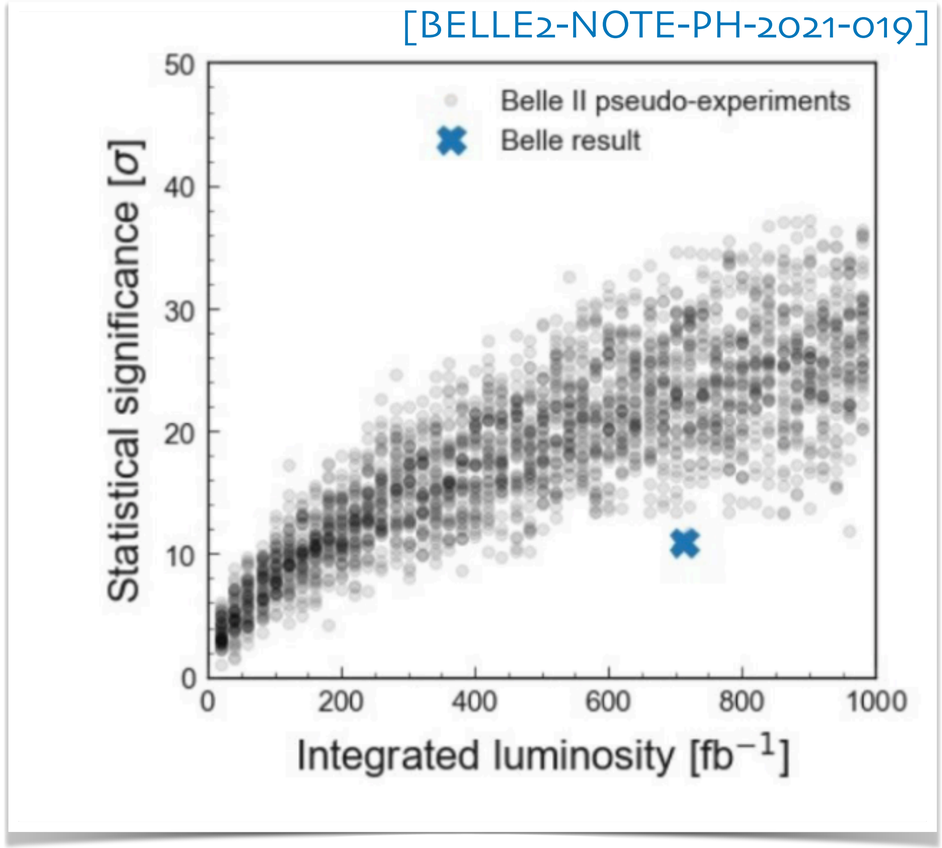
   - PID studies:



2. $\Upsilon(4S) \to \eta h_b(1P)$ rediscovery

   - rediscovery+paving the road for $\Upsilon(10750)$ analysis
   - Analysis improvements and better performances wrt Belle, currently in review

[BELLE2-NOTE-PH-2021-019]

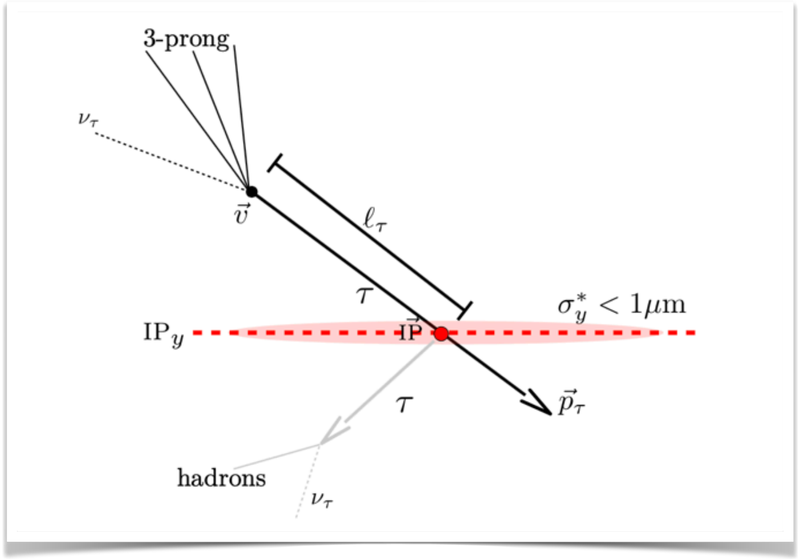


τ lifetime

[BELLE2-NOTE-PH-2020-076]

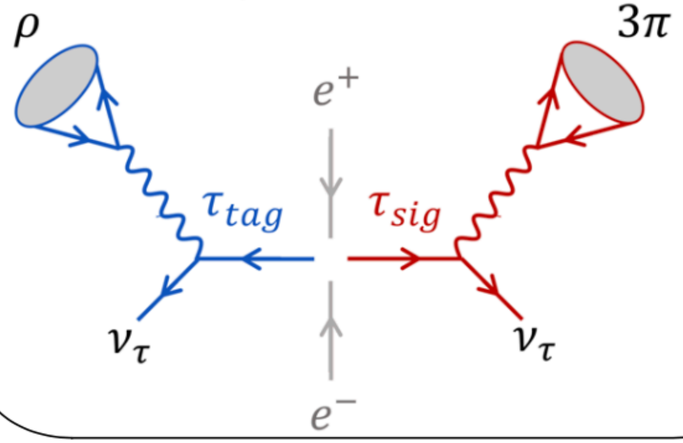
PI+ PG

- Work leading measurement from Belle (PRL 112, 031801 (2014), 711 fb^{-1})
- New analysis technique which exploits smaller beams size and improved vertex performances



Select event topology:

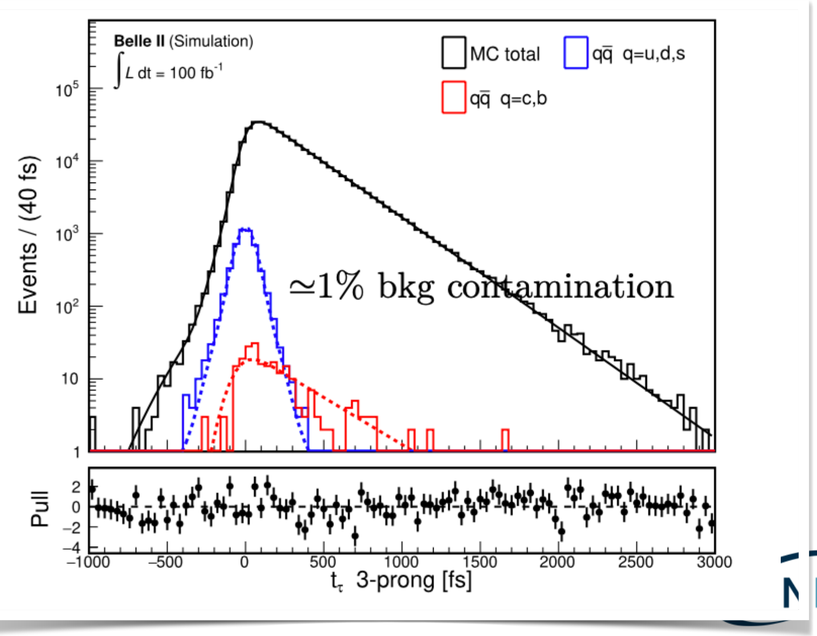
$\tau \to \rho\nu \times \tau \to \pi\pi\pi\nu$



$$t = \ell_{\text{3-prong}} \frac{m_\tau}{|\vec{p}_{\text{3-prong}}|c}$$

From MC study:

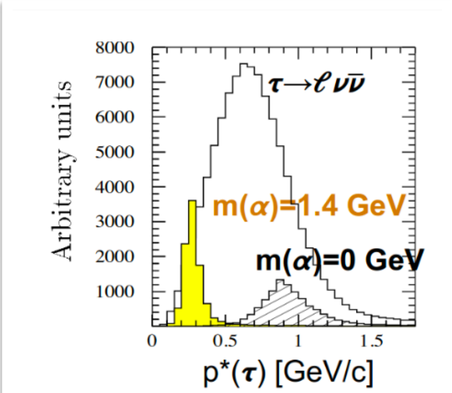
- Same statistical uncertainty of Belle with 100÷200 fb^{-1}



LFV in $\tau \to \ell\alpha$ and $\tau \to \ell\gamma$

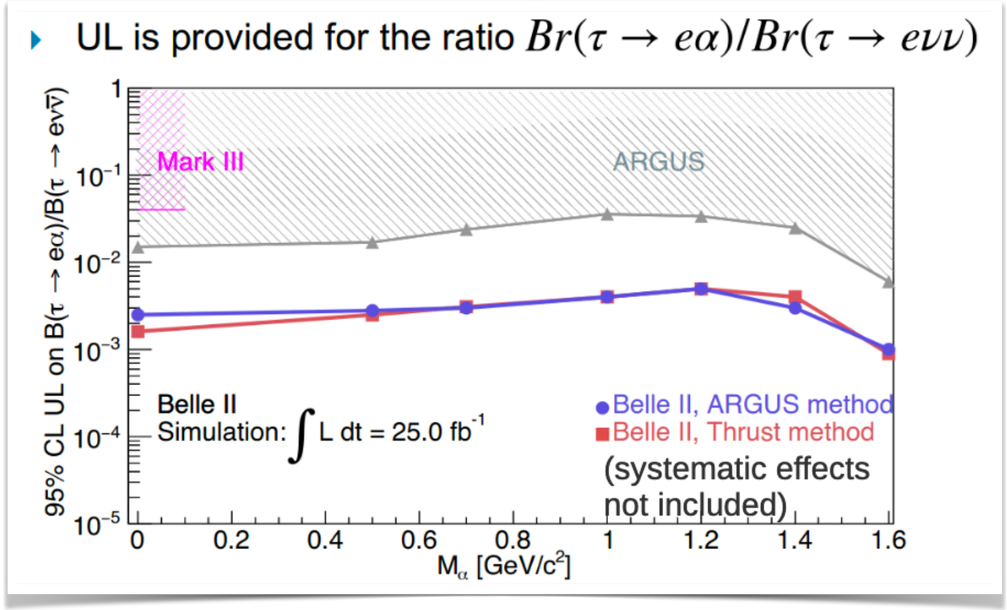
PI

- $\tau \to \ell\alpha$, α being an invisible particle
  - not searched for by BaBar and Belle
  - signal manifests as a peak in the τ momentum computed in pseudo-rest frame
  - internal note being finalised, aiming for unblinding soon



Argus coll., Z.Phys. C68 (1995) 25-2

[BELLE2-CONF-DRAFT-2020-032]
Approved for ICHEP2020



- $\tau \to \ell\gamma$
  - Belle and BaBar searches statistically limited
  - plan to use both 1-prong (τ→ℓνν) and 3-prong (τ→3πν) tag
  - should produce competitive result with pre-shutdown dataset

Multibody B→charmless decays

[BELLE2-NOTE-PH-2021-006]

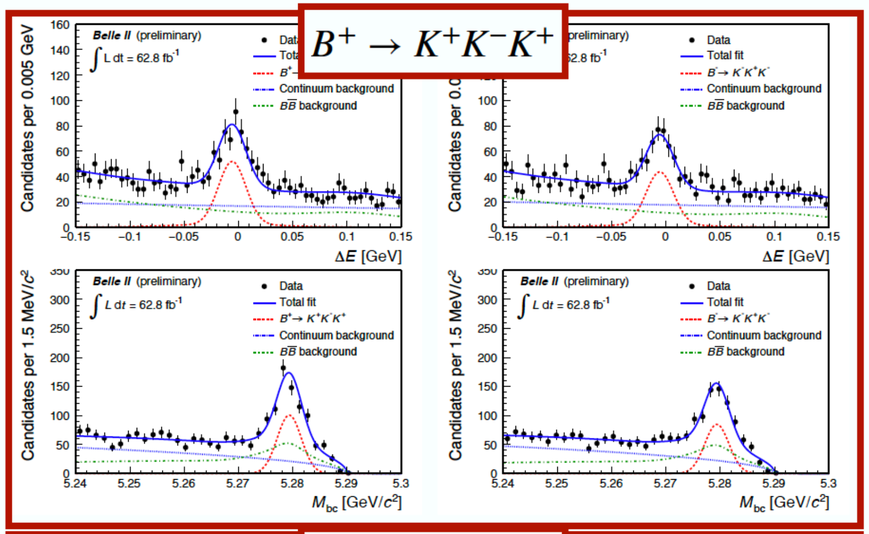
Approved for Moriond2021

Conference note in preparation

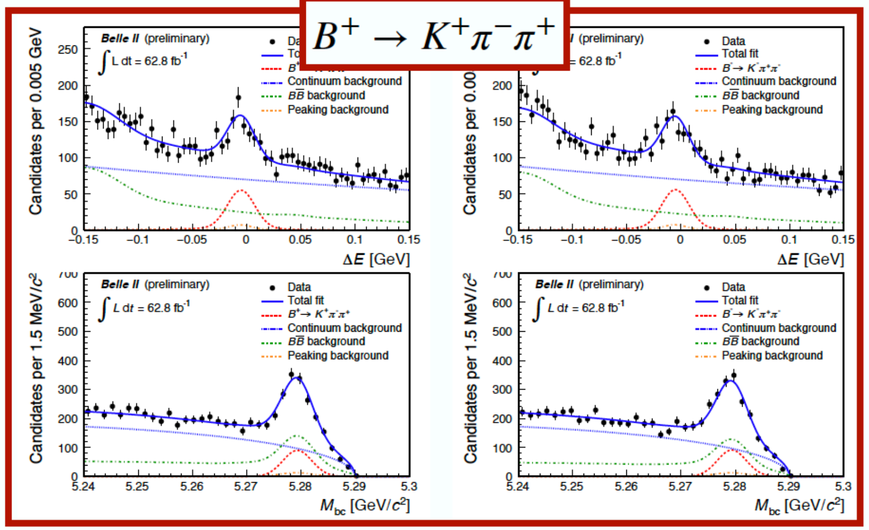
TS

First step towards search of local CPV in Dalitz plots: investigates relative contributions of tree and penguins, and probes non-SM physics.

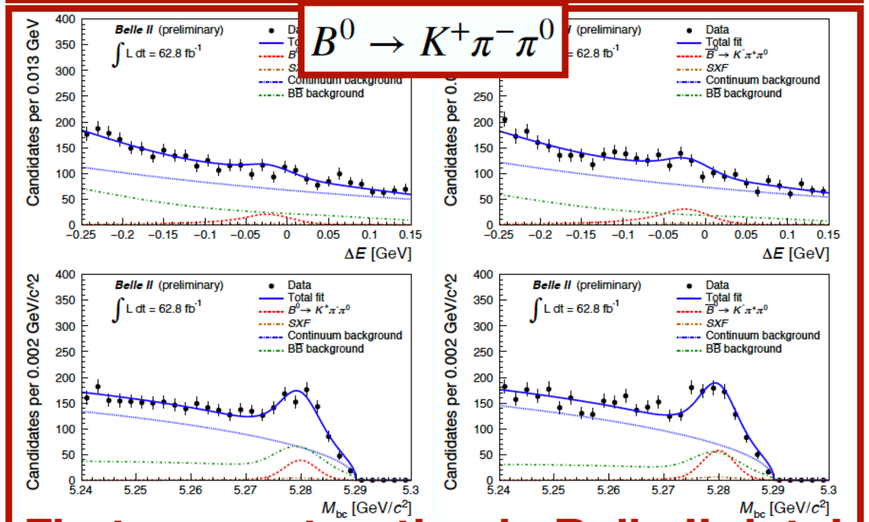
$B^+ \to K^+K^-K^+$



$B^+ \to K^+\pi^-\pi^+$



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



First reconstruction in Belle II data!

$$\mathcal{B}(B^+ \to K^+K^-K^+) = [35.8 \pm 1.6(\text{stat}) \pm 1.4(\text{syst})] \times 10^{-6}$$

$$A_{CP}(B^+ \to K^+K^-K^+) = -0.103 \pm 0.042(\text{stat}) \pm 0.020(\text{syst})$$

$$\mathcal{B}(B^+ \to K^+\pi^-\pi^+) = [67.0 \pm 3.3(\text{stat}) \pm 2.3(\text{syst})] \times 10^{-6}$$

$$A_{CP}(B^+ \to K^+\pi^-\pi^+) = -0.010 \pm 0.050(\text{stat}) \pm 0.021(\text{syst})$$

$$\mathcal{B}(B^0 \to K^+\pi^-\pi^0) = [38.1 \pm 3.5(\text{stat}) \pm 3.9(\text{syst})] \times 10^{-6}$$

$$A_{CP}(B^0 \to K^+\pi^-\pi^0) = 0.207 \pm 0.088(\text{stat}) \pm 0.011(\text{syst})$$

Belle II accesses consistently all channels

$B \to \rho^+ \rho^0$

[BELLE2-NOTE-PH-2021-007]
Approved for Moriond2021
Conference note in preparation

TS

Unique Belle II capability to determine $\alpha/\phi_2 = arg\left[-V_{td}V_{tb}^*/V_{ud}V_{ub}^*\right]$ using $B \to \rho\rho$ decays

Challenges:

- pion-only final state and broad ρ peak
  ⇒ large bckg
- Spin-0 → spin1 + spin-1
  ⇒ angular analysis.

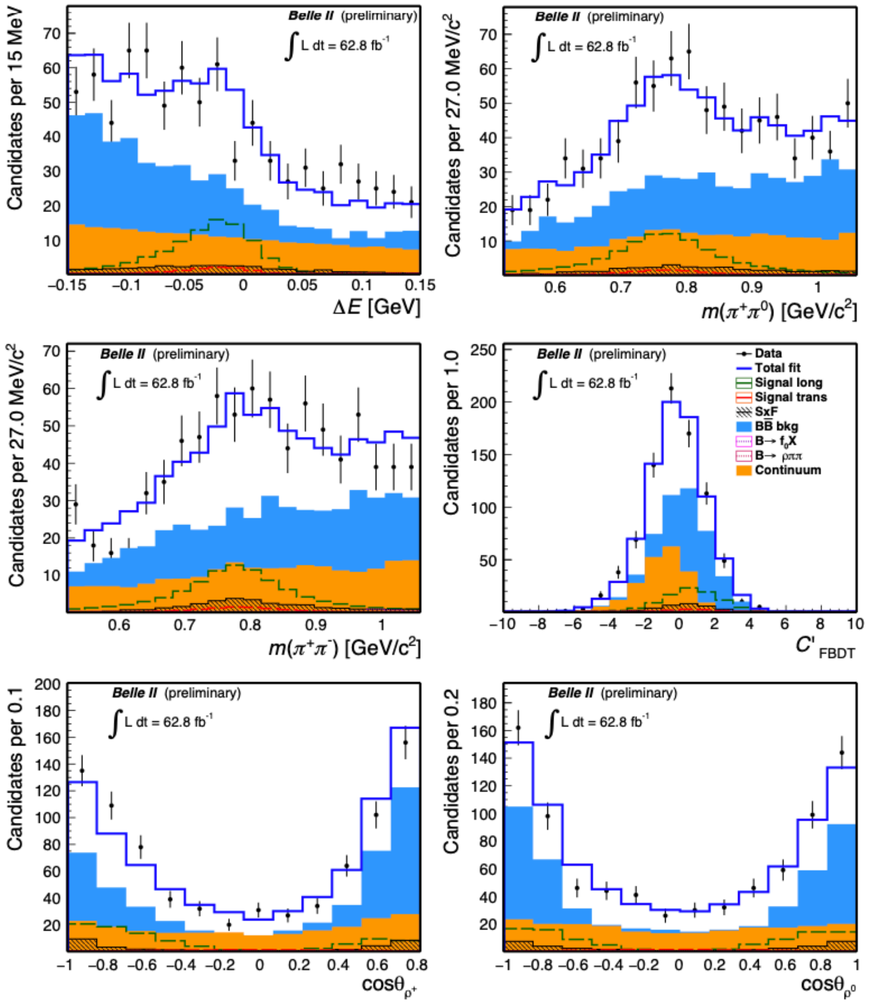
6D fit to extract signal and to measure fraction f_L of decays with longitudinal polarization.

$N = 104 \pm 16$

$\mathcal{B} = [20.6 \pm 3.2(\text{stat}) \pm 4.0(\text{syst})] \times 10^{-6}$

$f_L = 0.936^{+0.049}_{-0.041}(\text{stat}) \pm 0.021(\text{syst})$

20% better precision than Belle on 78 fb^{-1} (PRL 91, 221801 (2003)).



First reconstruction in Belle II data! Surpass early Belle's performance.

B→η'K

[BELLE2-NOTE-PH-2020-053]
Approved for Moriond2021

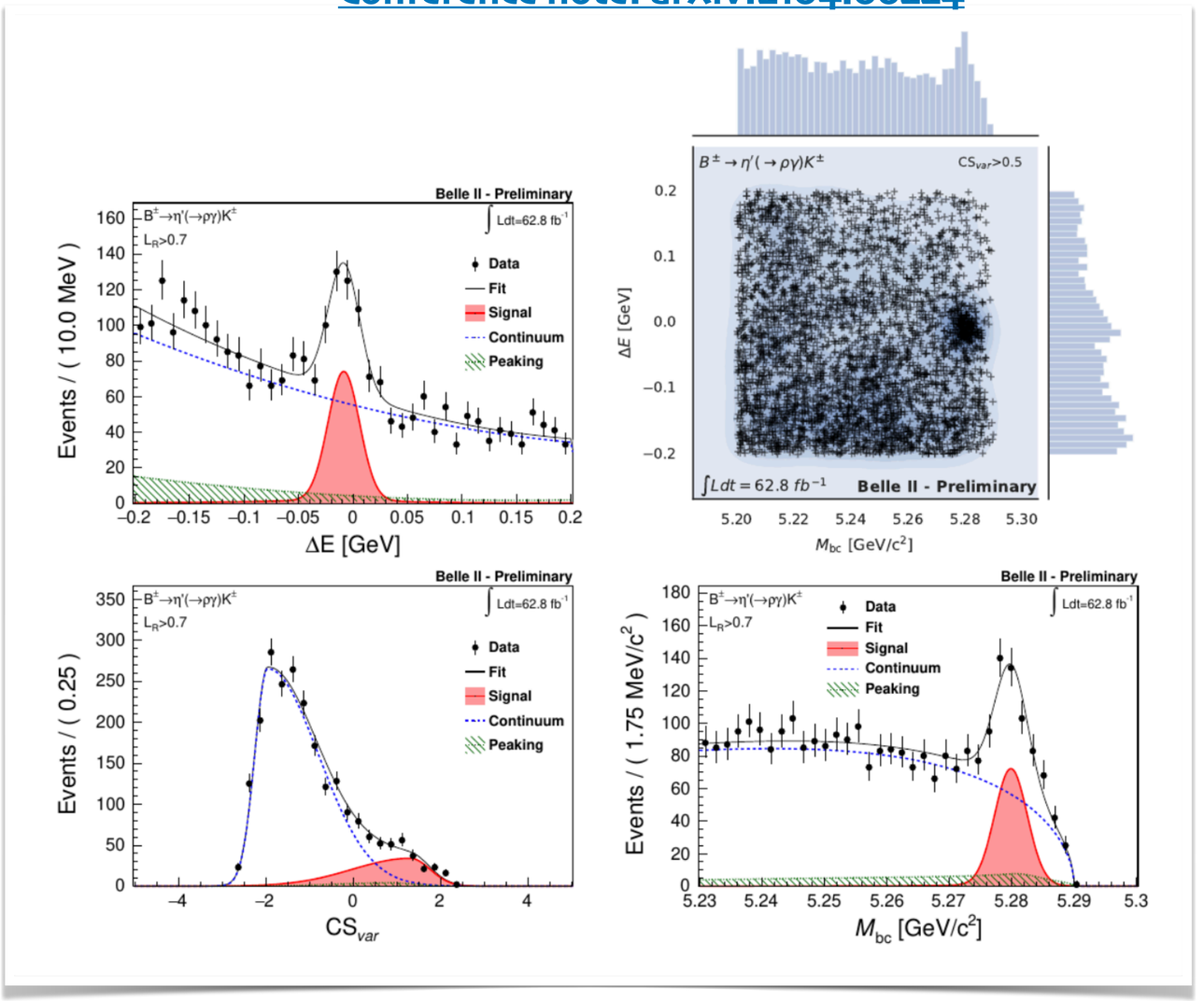
PD

Conference note: arXiv:2104.06224

- Golden channel for detection of NP in TDCPV analysis of penguin modes

$$\mathcal{B}\left(B^{\pm} \to \eta' K^{\pm}\right) = \left(63.4\ ^{+3.4}_{-3.3}\,(\text{stat}) \pm 3.2\,(\text{syst})\right) \times 10^{-6}$$
$$\mathcal{B}\left(B^{0} \to \eta' K^{0}\right) = \left(59.9\ ^{+5.8}_{-5.5}\,(\text{stat}) \pm 2.9\,(\text{syst})\right) \times 10^{-6}$$

- Results consistent with WA
- Next steps:
  - BR measurements including $\eta' K_L$ (should have competitive measurement with statistics collected so far)
  - TDCPV analysis



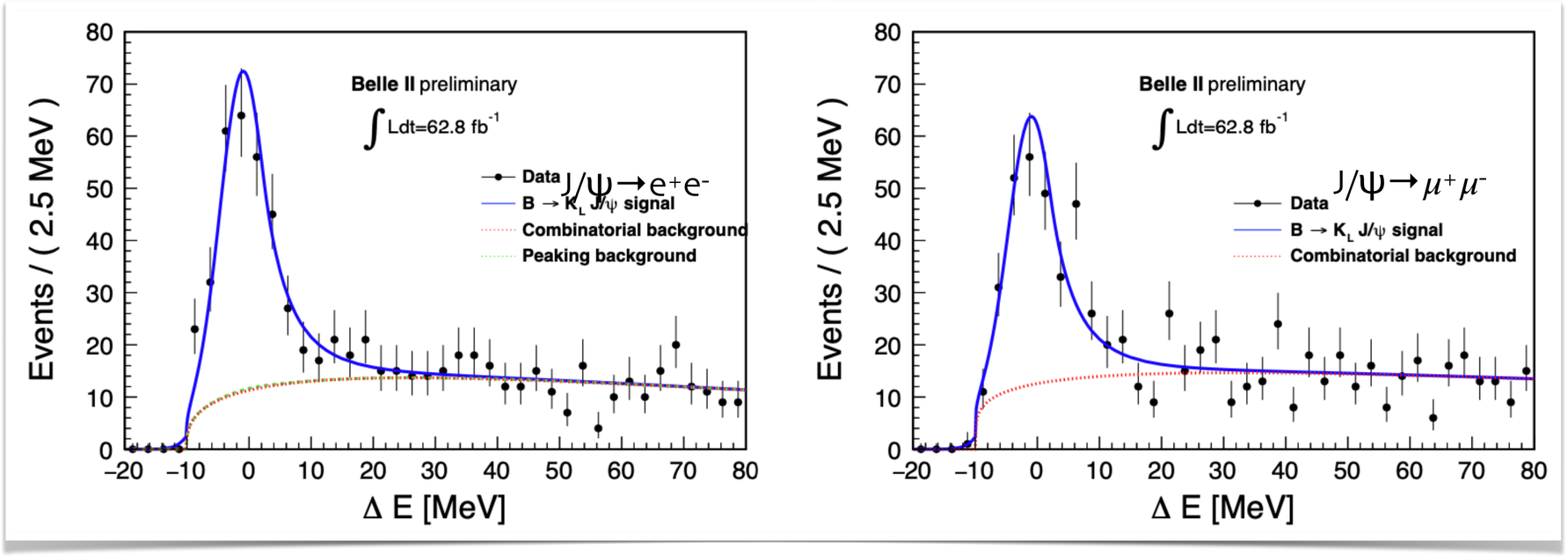
$B \to J/\psi K_L$

[BELLE2-NOTE-PH-2021-003]
Approved for Moriond2021

LNF+RM3

Conference note: arXiv:2106.13547

- Benchmark channel to optimise K_L reconstruction
- Syst error from peaking background evaluated for preliminary result, more detailed study to be performed
- Next step: TDCP analysis



$$N_{\text{sig}}\ (\mu^+\mu^-) = 267 \pm 21(\text{stat}) \pm 28(\text{peaking})$$
$$N_{\text{sig}}\ (e^+e^-) = 226 \pm 20(\text{stat}) \pm 31(\text{peaking}).$$

Similar performances wrt Belle in terms of signal purity

$B \to \tau\nu$ with hadronic tag

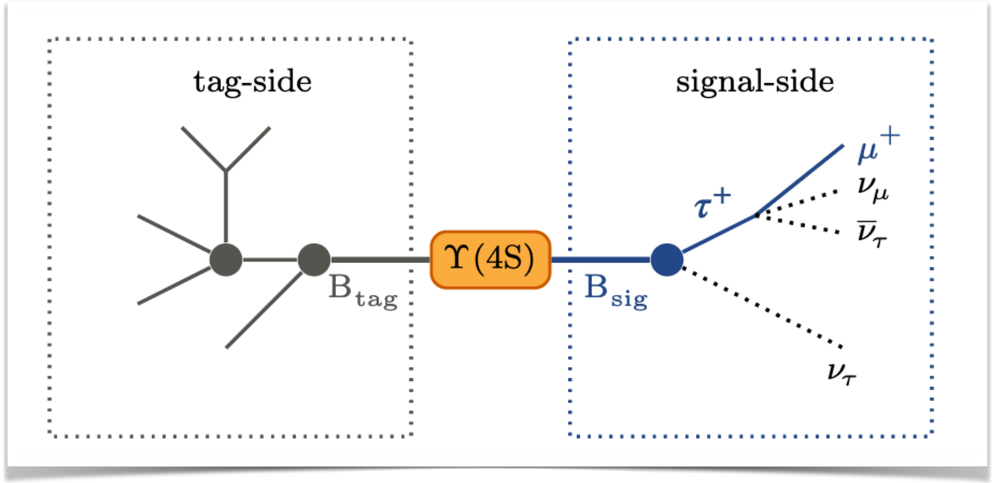
[BELLE2-NOTE-PH-2020-024]
Approved for ICHEP2020

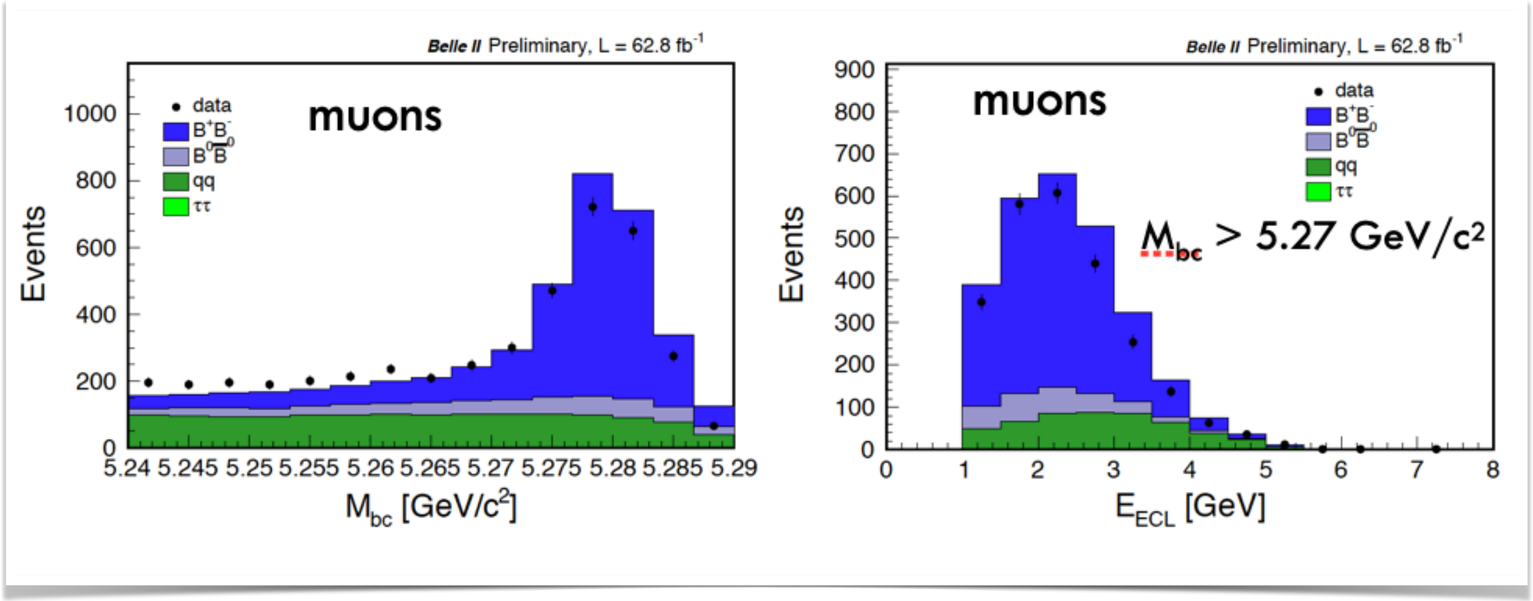
NA + PG

- Measured with full Belle dataset @ 3σ significance, from preliminary studies similar sensitivity expected from BelleII with room for improvement
- Results presented at conference in 2020, test of data/MC agreement on background events for hadronic tagged analysis

Tag side reconstructed in Hadronic modes

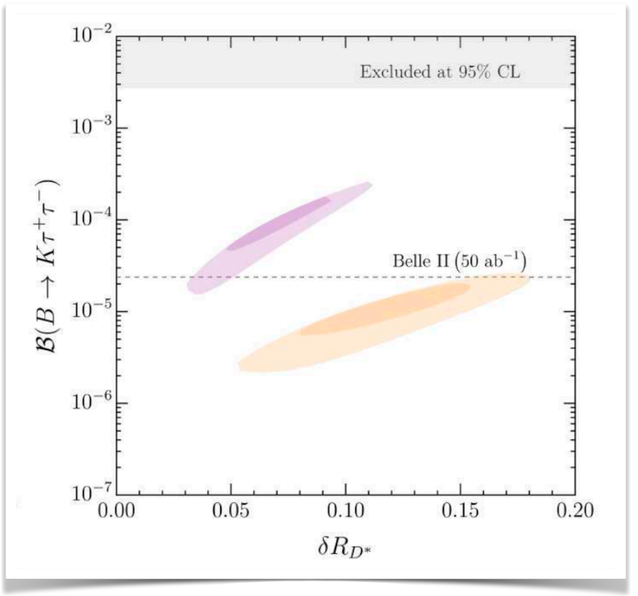
Signal signature searched for in the tag RECOIL



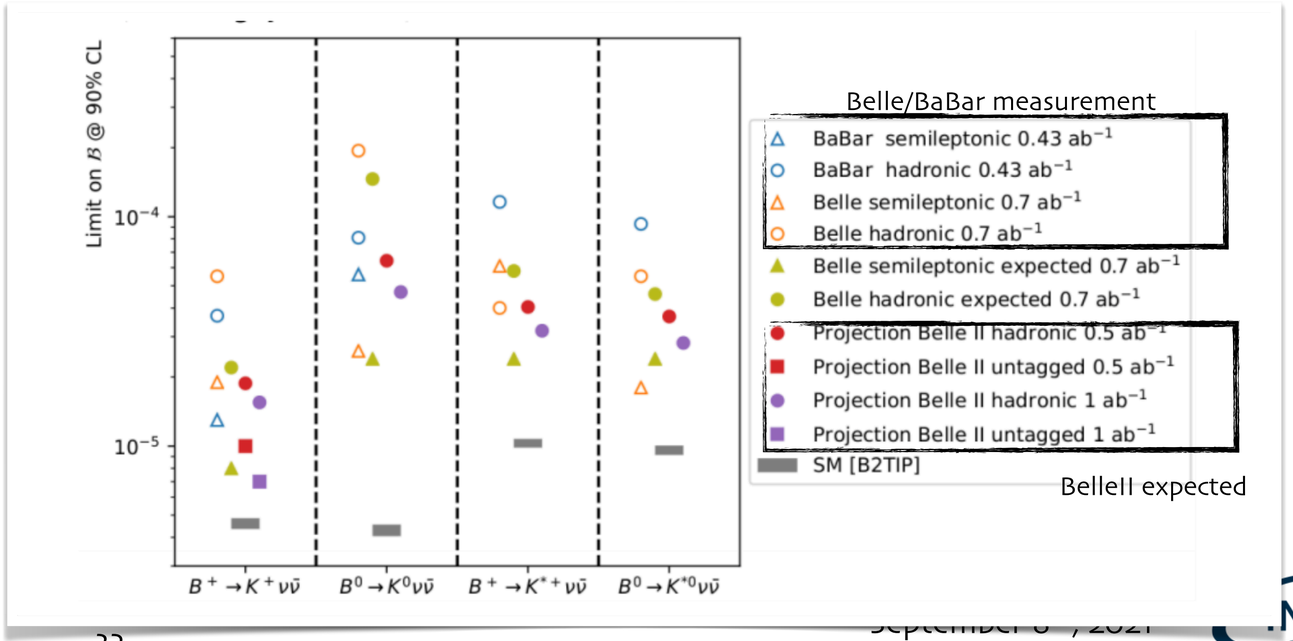


b→sll/$\nu\nu$ transitions

Cornella et al, arXiv:2103.16558



- Enhancement in b→s$\tau\tau$ and b→s$\nu\nu$ foreseen in new physics models explaining R(K$^{(*)}$) and R(D$^{(*)}$) anomalies.
- B→K$^*\tau\tau$ **PG**
  - SM prediction at 10^{-6} level, never searched before
  - Start of MC studies foreseen by the end of 2021
- B→K$^*\nu\nu$ **NA+ PG**
  - Analysis performed using recoil method, hadronic modes reconstructed in the tag side, strategy optimisation ongoing



Stato Milestones 2021

31-12-2021	**Studio di canali di decadimento del mesone B con energia mancante usando il metodo di ricostruzione "Full Event Interpretation" **
31-12-2021	**Misura preliminare della vita media del D0. **
31-12-2021	**Determinazione del numero dei mesoni B prodotti nei campioni di dati sperimentali ufficiali destinati alle analisi di Fisica e studi di performance riguardanti algoritmi di tracciamento, identificazione di particelle e ricostruzione di pioni neutri. **
31-12-2021	**Prime misure di rapporti di decadimento e di violazione della simmetria di CP in stati finali del B con o senza mesoni contenenti quark charm **
31-12-2021	**Finalizzazione di misure di nuova fisica nel settore oscuro **

Internal note with updated results by the end of the year

Submitted to journal!

B counting analysis continuously performed and supported by updated documentation, updated notes on tracking, neutral and PID performances already available, **performance papers** foreseen by first semester of next year

Public conference notes for **branching fraction** measurement on η'**K** and **J/ψ** K_L already available, in approval phase for **branching fraction and CPV asymmetry** in **multibody B→charmless** decays and **branching fraction and angular analysis** in **B→**$\rho^+\rho^0$**.**

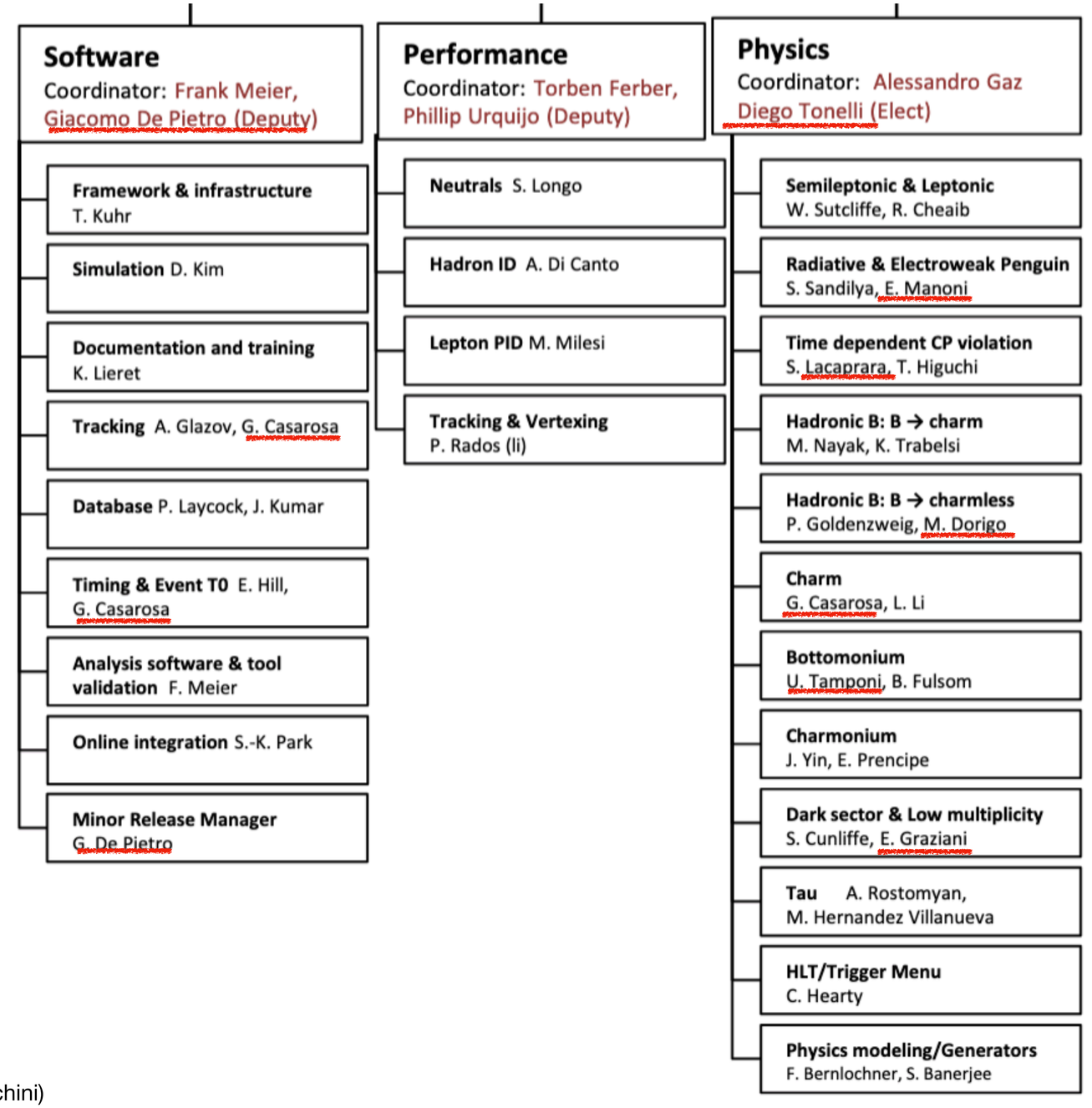
Dark Higgstrahlung close to submission

Responsabilità e richieste 2022

- D. Tonelli Physics coordinator since 1 September 1st, G. De Pietro software coordinator
- 6 physics working group, out of 10, with Italian convener
- Coordination roles also in software (and data production) groups

Sede	Capitolo	Descrizione	Richiesta
PI	missioni	Charm Physics Convener	0
TO	missioni	Bottomonium Convener	5
PI	missioni	Tracking Convener	5
TS	missioni	Charmless hadronic B decays Convener	5
~~TS~~	~~missioni~~	~~Statistics Advisory Convener~~	~~0~~
TS	missioni	Physics Coordinator	30
RM3	missioni	Low multiplicity and Dark sector Convener	5
PD	missioni	Time Dependent CP Violation Convener	5
PG	missioni	Radiative and Electroweak Penguin Convener	5
RM3	missioni	Software coordinator	5
PI	missioni	Timing and Event T0 coordinator	0
PI	missioni	MC processing manager	5
			70

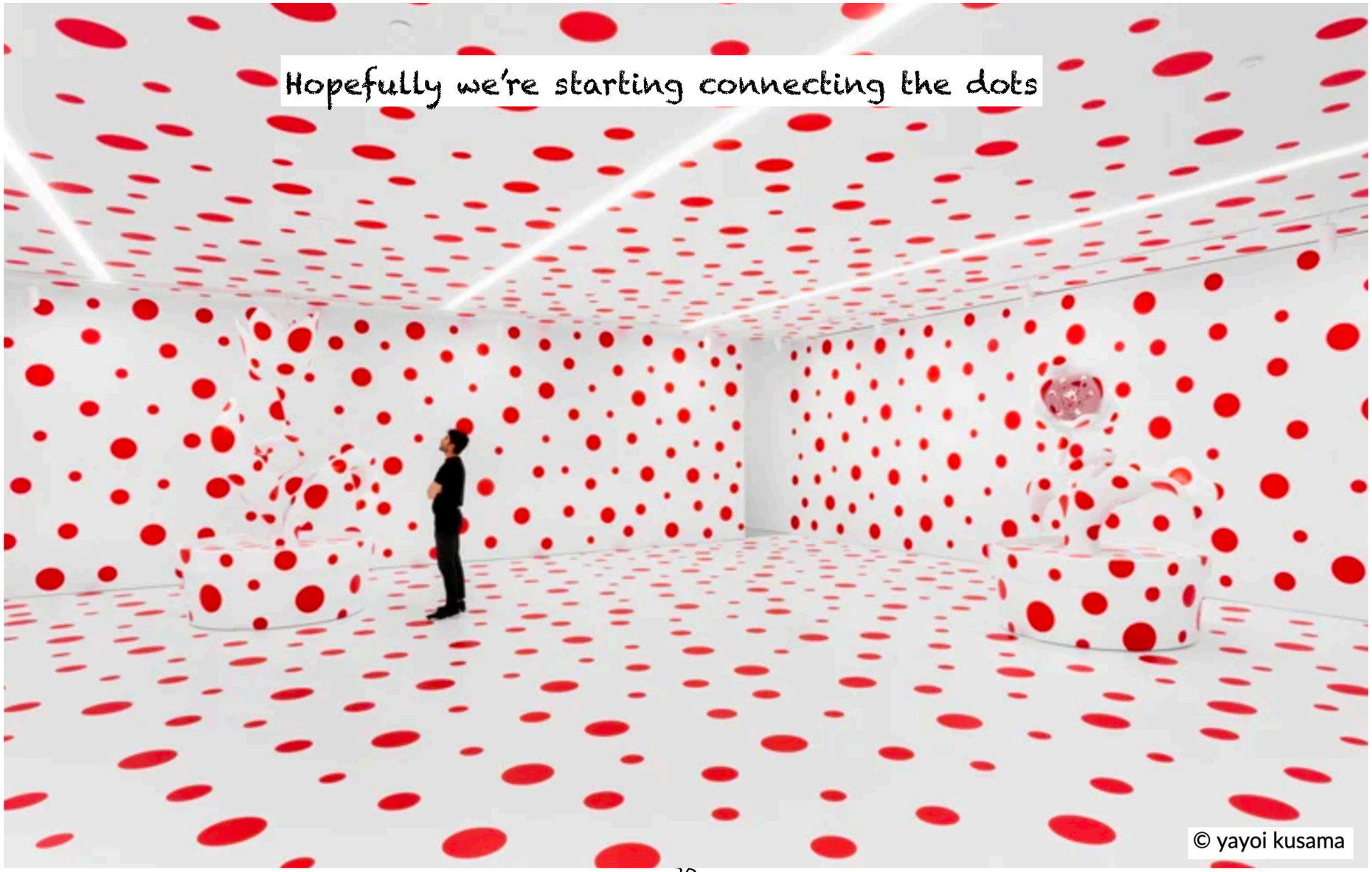
(F. Tenchini)



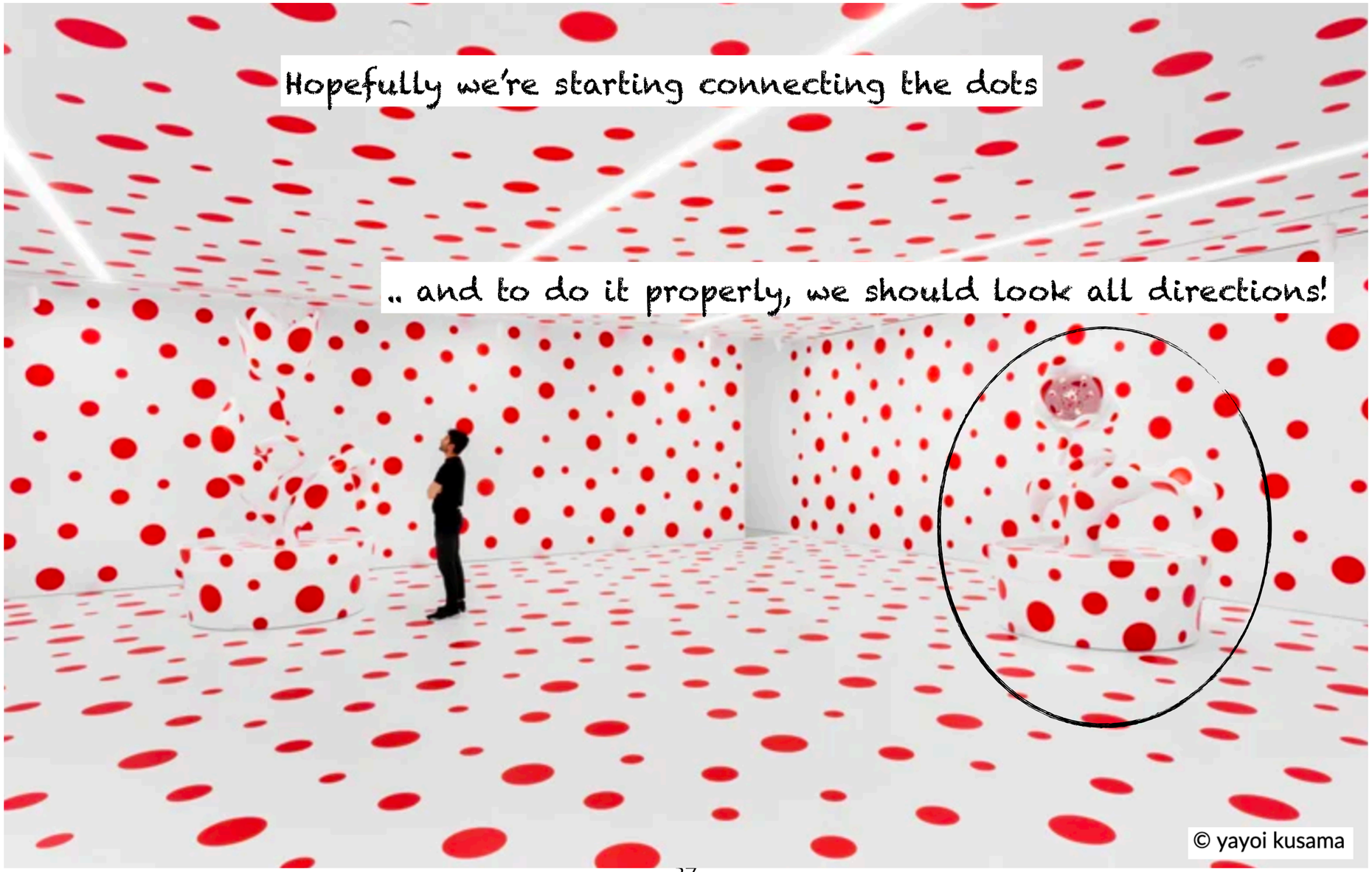
Proposte Milestones 2022

Ricerca di nuova fisica nel settore oscuro, in decadimenti del tau che prevedono violazione del sapore leptonico ed in decadimenti del B con energia mancante nello stato finale.	31-12-2022
Studio di stati composti da quark b ed antiquark b in dati collezionati alla Upsilon(4S) e ad energie superiori.	31-12-2022
Misure di violazione della simmetria CP in transizioni b->sqqbar (q= c, s)	31-12-2022
Misura del numero di coppie BBbar prodotte nelle collisioni alla Upsilon(4S), studi di performance relativi a ricostruzione di pioni neutri, identificazione di particelle cariche ed algoritmi di tracciamento.	31-12-2022
Misure di branching fraction e violazione della simmetria CP in decadimenti del B senza quark charm nello stato finale.	31-12-2022

Summary and conclusions



Summary and conclusions



Summary and conclusions

- Belle II is continuing taking, processing, calibrating, analysing data
- Most of the results achieved so far are still statistically limited, competitive papers benefiting from new ideas and detector/environment features submitted or work-in-progress
  - Strong Italian contributions in both data analysis, software and tool development
    - out of the 5 published physics papers 3 have IT contribution (2 authors, 1 internal review) papers on Flavour tagging and Dark Higgstrahlung in final review phase
    - several responsibility and important analyses/performance studies in hand

Thanks for your attention

Contributi a conferenze con speaker italiani Ottobre 2020 - Settembre 2021

1. XXIV DAQ-BRNS high energy physics symposium (14-18 Dec) , **Alessandro Gaz** ,"The Belle II experiment and first results"
2. Epiphany 2021 (7-10 January 2021), **Stefano Moneta**, "Early Belle II measurements of the tau lifetime"
3. La Thuile 2021 - Les Rencontres des Physiques de la Vallee d'Aoste (9-12 March), **Riccardo Manfredi**, "Measurement of charmless B decays at Belle II"
4. La Thuile 2021 - Les Rencontres des Physiques de la Vallee d'Aoste (9-12 March), **Ezio Torassa**, "Recent Results from Belle II
5. Rencontres de Moriond 2021 - Electroweak Interactions & Unified Theories (20-27 March), **Giacomo De Pietro**, "Dark sector searches at Belle II"
6. MESON 2021 (17-20 May), **Umberto Tamponi** "Quarkonium at Belle II"
7. PHENO2021 (24-26 May), **Sebastiano Raiz** , "Charmless B decays at Belle II" Slides
8. Invisibles workshop 2021 (31 May - 4 June), **Luigi Corona**, "Search for a visible Zo dark boson in mumutautau final state with Belle II"
9. EPS-HEP 2021 (26-30 July), **Marcello Campajola**, "Dark Matter Searches at Belle II, Belle, and BaBar"
10. EPS-HEP 2021 (26-30 July), **Mario Merola**, "Belle II prospects fro Vub and Vcb" Slides
11. EPS-HEP 2021 (26-30 July), , **Mirco Dorigo**, "Charm physics measurements and prospects at Belle and Belle II" Slides
12. EPS-HEP 2021 (26-30 July), , **Gian Luca Pinna Angioni**, "Bottomium-like studies at Belle II (TBC)" Slides
13. 22nd Particles and Nuclei International Conference (PANIC 2021) (5-10 September), **Martina Laurenza** , "Dark sector physics at Belle II"
14. 22nd Particles and Nuclei International Conference (PANIC 2021) (5-10 September), **Elisa Manoni**, "Flavor physics with electroweak penguin and semileptonic decays at Belle and Belle II"
15. NuFact 2021 (The 22nd International Workshop on neutrinos from accelerators) (6-11 September), **Anonio Passeri** , "Belle II status and prospects"
16. 10th International Conference on New Frontiers in Physics (ICNFP 2021) (23 August-2 September), **Paolo Branchini** , "Belle II: status and prospects"
17. Anomalies and Precision in the Belle II era workshop (6-8 September), **Alessandro Gaz** , "Belle II status and prospects"
18. Anomalies and Precision in the Belle II era workshop (6-8 September), **Alberto Martini**, "tau→l phi and tau→ lll Belle II"

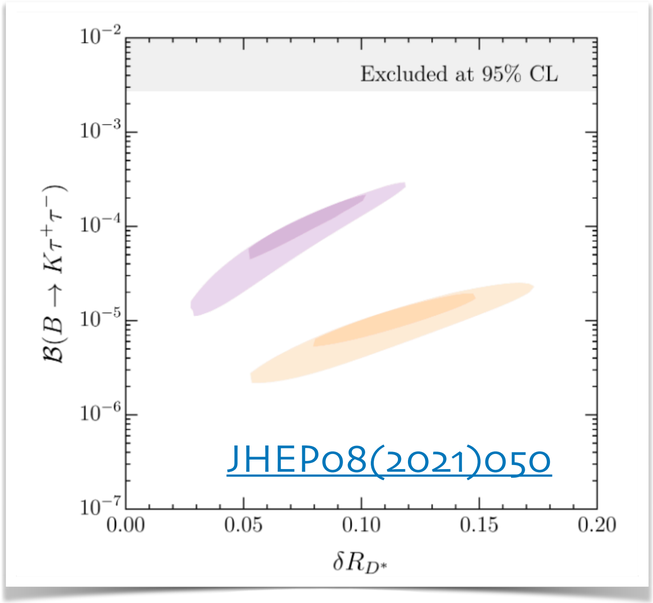
Extra slides

Perspectives on some of the anomalies-related modes

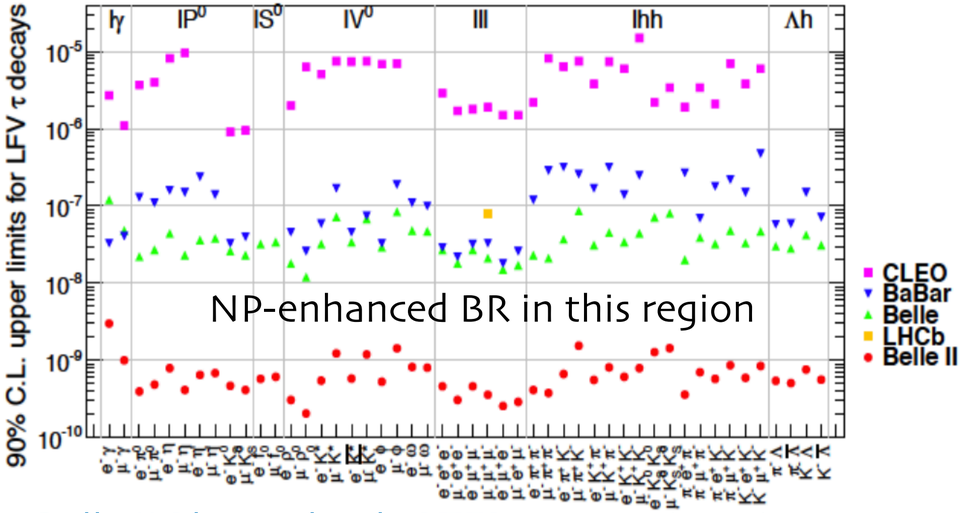
- Charmless B → τ decays:

Observables	Belle 0.71 ab^{-1} (0.12 ab^{-1})	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}
$\mathrm{Br}(B^+ \to K^+\tau^+\tau^-) \cdot 10^5$	< 32	< 6.5	< 2.0
$\mathrm{Br}(B^0 \to \tau^+\tau^-) \cdot 10^5$	< 140	< 30	< 9.6
$\mathrm{Br}(B_s^0 \to \tau^+\tau^-) \cdot 10^4$	< 70	< 8.1	–
$\mathrm{Br}(B^+ \to K^+\tau^\pm e^\mp) \cdot 10^6$	–	–	< 2.1
$\mathrm{Br}(B^+ \to K^+\tau^\pm \mu^\mp) \cdot 10^6$	–	–	< 3.3
$\mathrm{Br}(B^0 \to \tau^\pm e^\mp) \cdot 10^5$	–	–	< 1.6
$\mathrm{Br}(B^0 \to \tau^\pm \mu^\mp) \cdot 10^5$	–	–	< 1.3

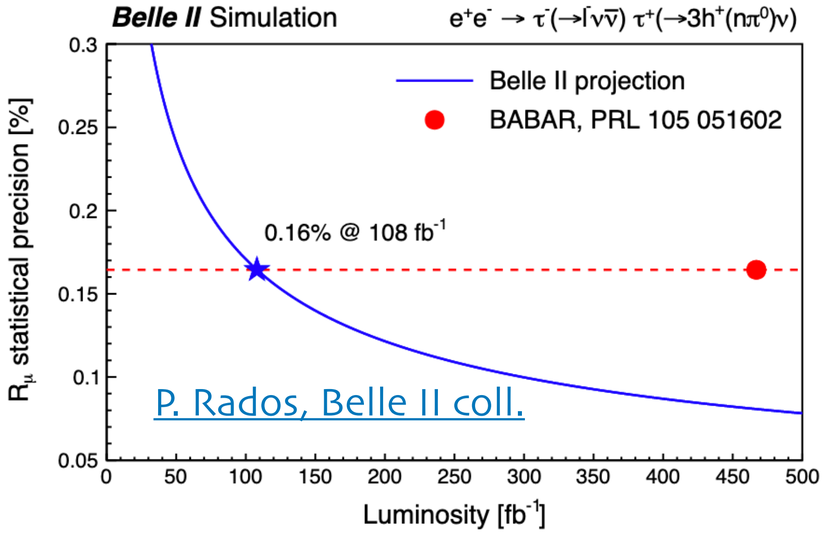
Belle II Physics book, PTEP 2019 12 (2019)



- τ LFV and LFUV searches



Belle II Physics book, PTEP 2019 12 (2019)



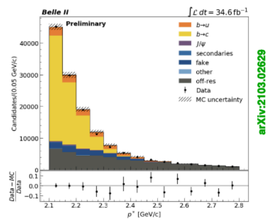
LFU in τ decays: higher τ reconstruction efficiency (4x) wrt BaBar mainly due to due to different PID requirements on tag side

- More on b → s$\nu\nu$ in the next slides

Beyond flavour anomalies: new results and perspectives (I)

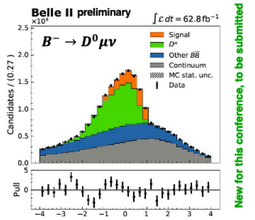
Toward inclusive and exclusive V_{ub} and V_{cb} measurement

Untagged inclusive $X_u \ell \nu$



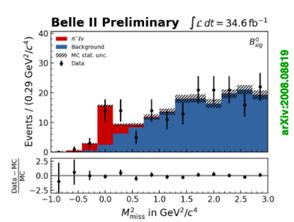
3σ significance for b-u

Untagged exclusive $B \to D^0 \ell \nu$



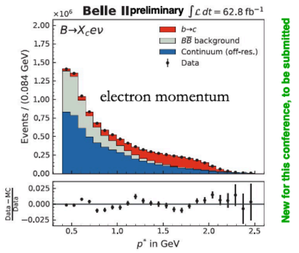
$\mathcal{B}(B^- \to D^0 \ell^- \bar{\nu}_l) = (2.293 \pm 0.053_{\text{stat}} \pm 0.084_{\text{syst}})\%$

FEI hadronic tag excl. $B^0 \to \pi \ell \nu$



$\mathcal{B}(B^0 \to \pi^- \ell^+ \nu_\ell) = (1.58 \pm 0.43_{\text{stat}} \pm 0.07_{\text{sys}}) \times 10^{-4}$

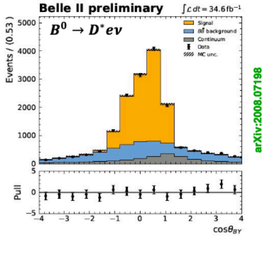
Untagged inclusive $X_c \ell \nu$



$\mathcal{B}(B \to X_c \ell \nu) = (9.75 \pm 0.03(stat) \pm 0.47(syst))\%$

Lepton momentum p* in the CMS

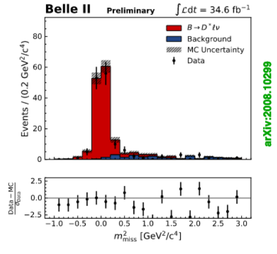
Untagged exclusive $B^0 \to D^* \ell \nu$



$\mathcal{B}(\bar{B}^0 \to D^{*+} \ell^- \bar{\nu}_l) = (4.60 \pm 0.05_{\text{stat}} \pm 0.17_{\text{syst}} \pm 0.45_{\pi_s})\%$

θ_{BY} angle between B and Dℓ system

FEI hadronic tag excl. $B^0 \to D^* \ell \nu$

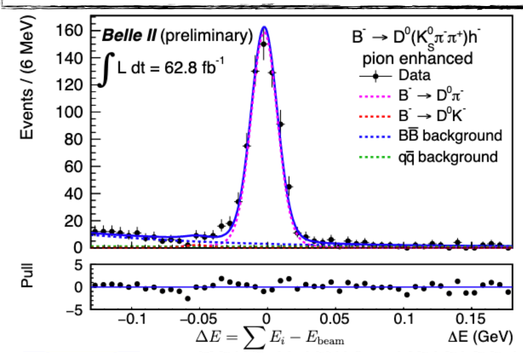


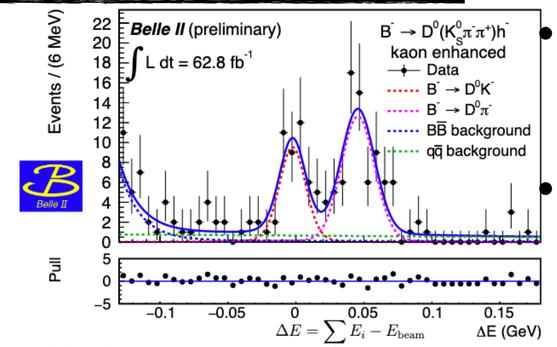
$\mathcal{B}(\bar{B}^0 \to D^{*+} \ell^- \bar{\nu}_l) = (4.51 \pm 0.41_{\text{stat}} \pm 0.27_{\text{syst}} \pm 0.45_{\pi_s})\%$

$m^2_{\text{miss}} = \left(p_{e^+e^-} - p_{B_{\text{tag}}} - p_{D^*} - p_\ell\right)^2$

- Many channels/ technique to measure incl./ excl. V_{ub} and V_{cb}
- Inclusive V_{cb} analysis with new method (q^2 moments) in preparation

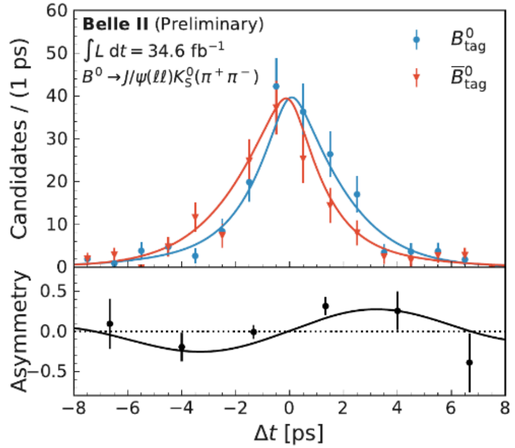
φ_3/γ measurement in $B \to D^{(*)} K$ transitions





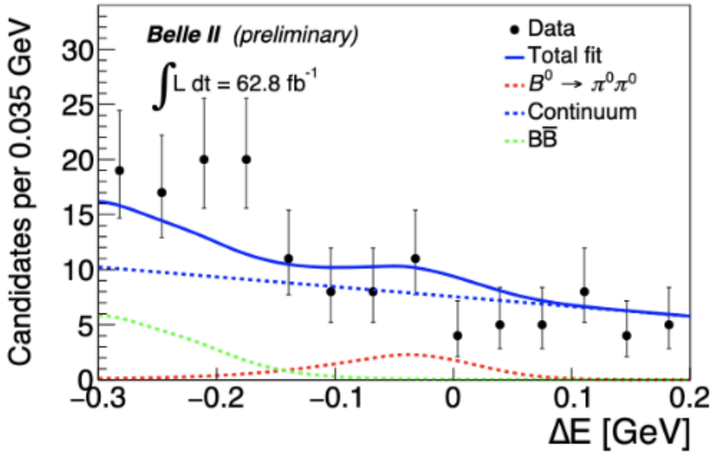
- LHCb will lead precision
- Belle II will contribute with finale states with neutrals
- Belle + Belle II combined measurement in preparation

φ_2/β measurement



- Current precision 0.7°, ~ factor 5 better with 50fb^{-1},
- Will measure K_L channel and penguin polluted modes

toward φ_1/α measurement: $B \to \pi^0\pi^0$

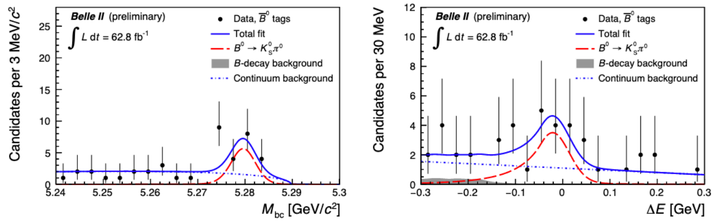


- Current precision 5°, ~ factor 5 better with 50fb-1,
- Unique Belle II capabilities

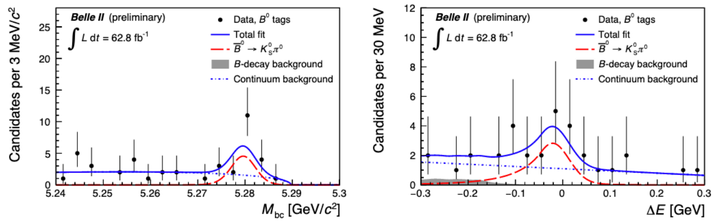
Beyond flavour anomalies: new results and perspectives (II)

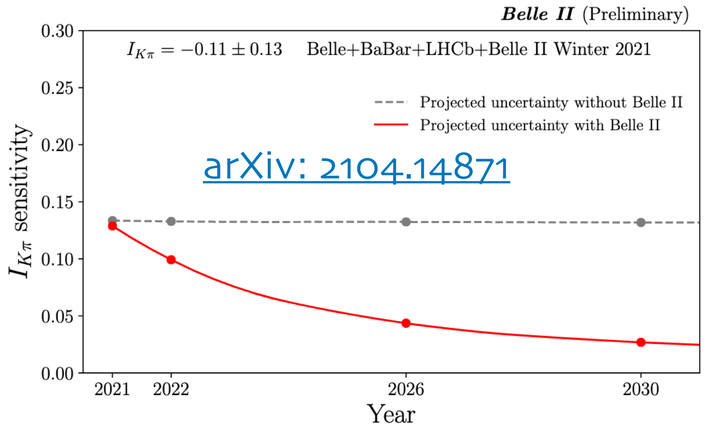
Kπ puzzle

$\overline{B}^0$ tag



B^0 tag

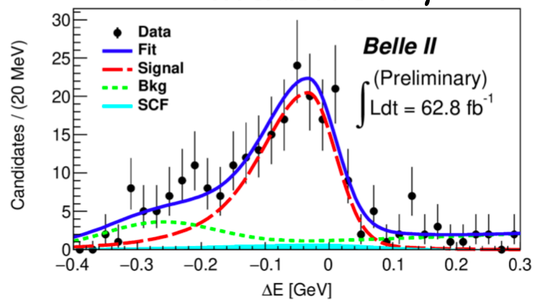




- Belle II can access all charge combinations
- Precision of isospin test limited by $K_S\pi^0$ accessible to Belle II only

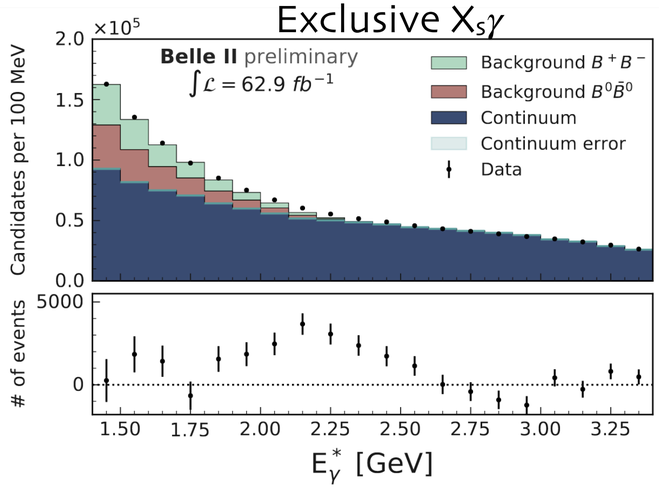
b→sγ

Inclusive $K*\gamma$



(c) $B^+ \to K^{*+}[K^+\pi^0]\gamma$

Exclusive $X_s\gamma$



- Test isospin violation measured at 3.1σ level at Belle in $K*\gamma$
- Inclusive modes unique to Belle II

Moreover:

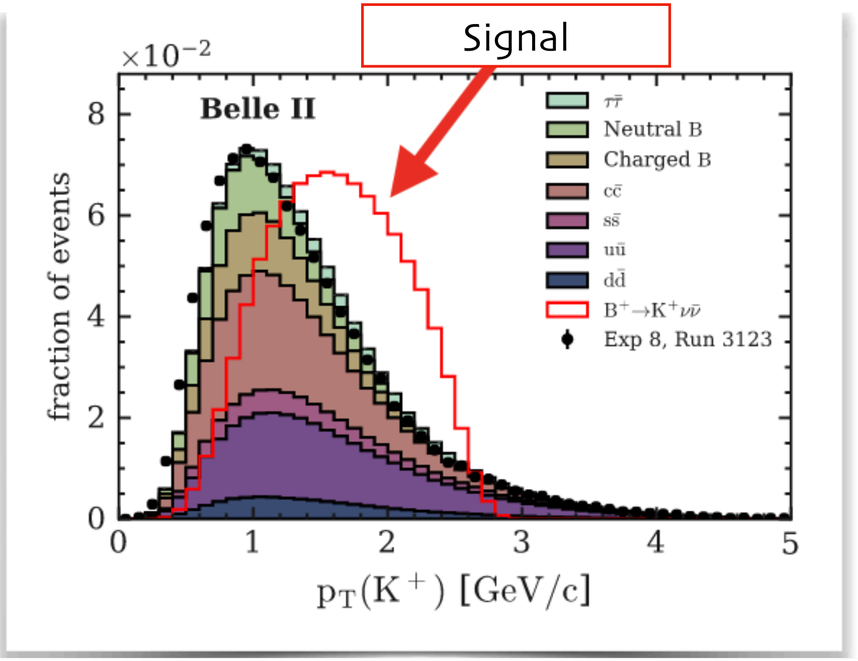
- in the **dark sector**: unique samples due to dedicated trigger lines, with come measurements in some of the channels will start to probe the $(g\text{-}2)_\mu$ favourite band
- in the **charm sector**: "exercising" with D lifetime measurements to get ready for mixing and CPV analyses, competitive in channels with π^0; NP searches (e.g. LFUV, LFV) also in program

New journal submission: $B^+ \to K^+ \nu\nu$ (II)

[arXiv:2104.12624 submitted to journal]

NOVEL INCLUSIVE APPROACH on 63 fb^{-1} of BelleII data:

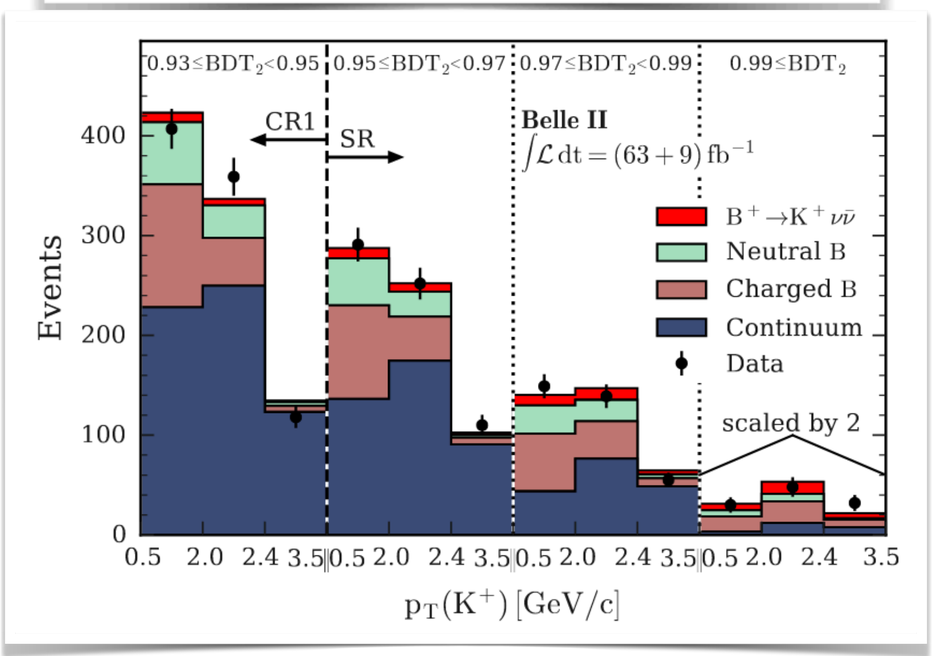
- Signal kaon = highest p_T track
- Associate all other tracks and clusters to other B in the event
- Use multivariate approach (2 BDTs in cascade) based on kinematics, event shape and vertexing variables to suppress background
- Signal efficiency ~ 4.3 % (SM signal)



- Simultaneous maximum likelihood fit in bins of $p_T(K^+)$ and second BDT (BDT_2): signal strength

$$\mu = 4.2^{+2.9}_{-2.8}(\text{stat})^{+1.8}_{-1.6}(\text{syst})$$

consistent with SM exp. (μ=1) at 1 σ
and with bg-only hyp. (μ=0) at 1.3 σ



- Leading systematics: background normalisation uncertainty can be reduced with increasing statistics