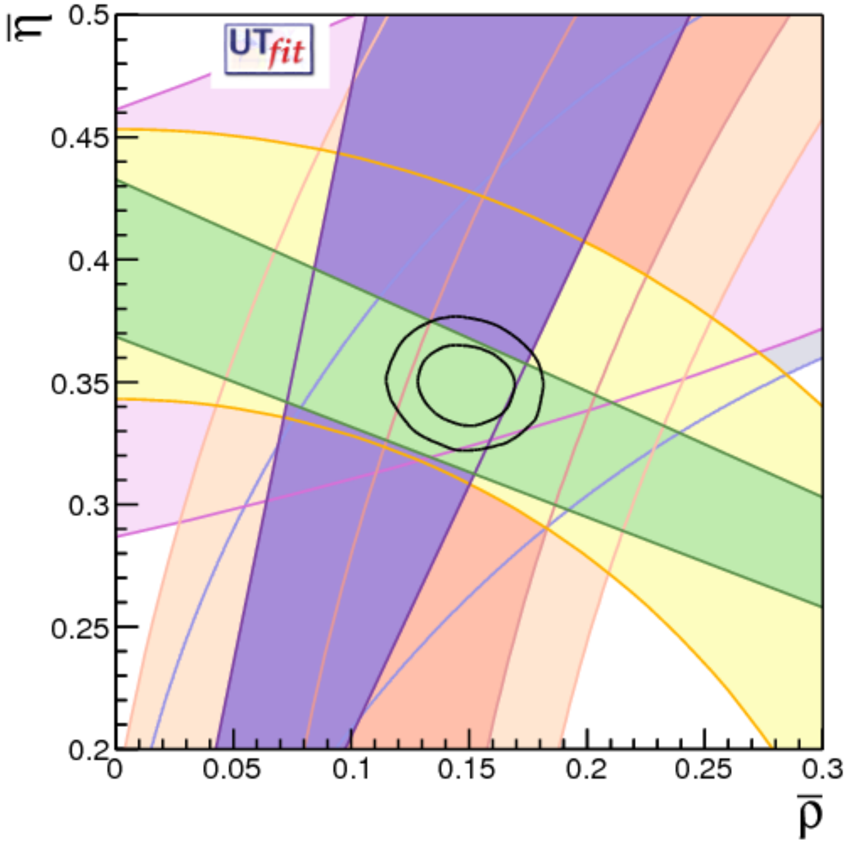
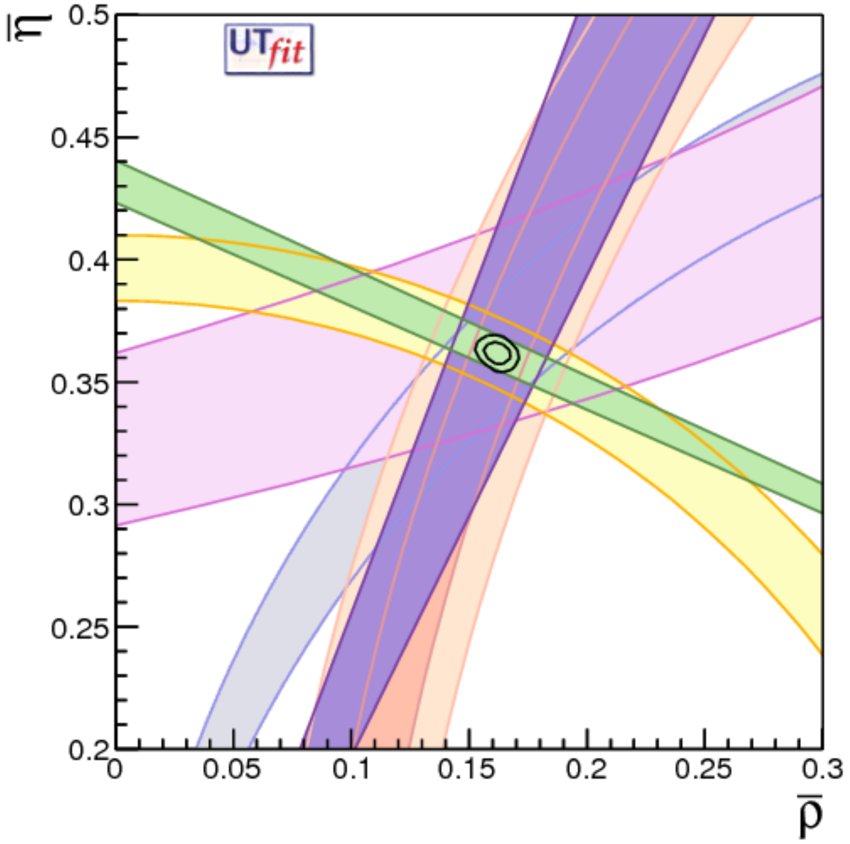
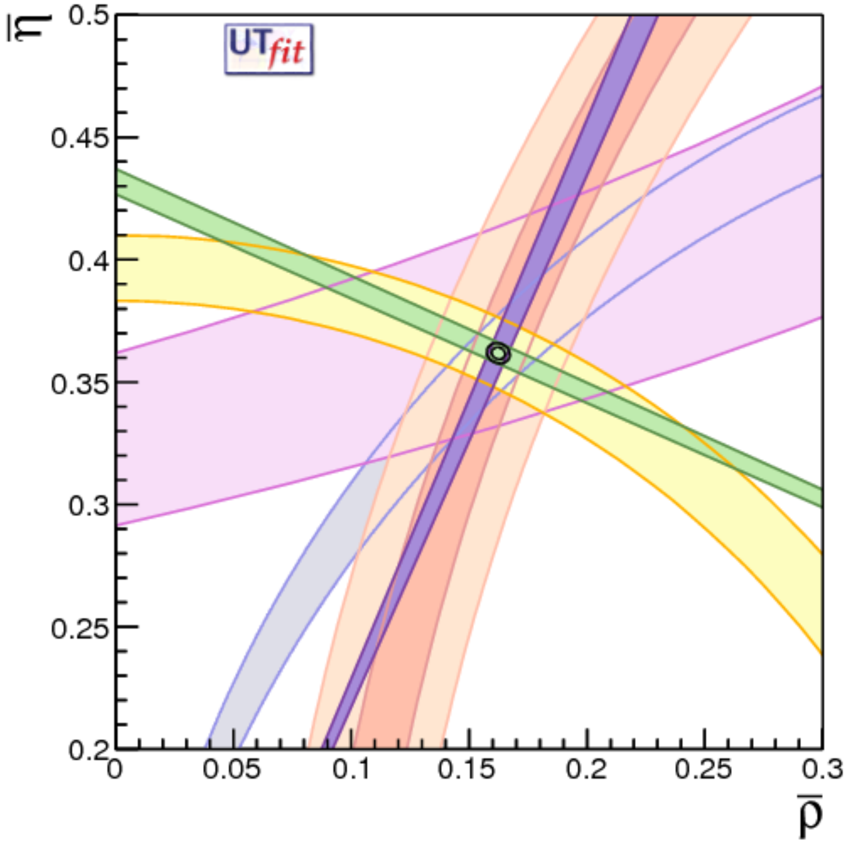
LHCb Upgrade II perspectives physique



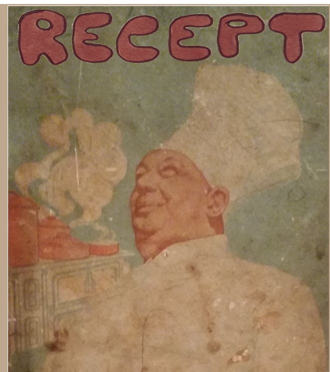




LPNHE
PARIS
European Research Council
Established by the European Commission
V. V. Gligorov pour le groupe LHCb

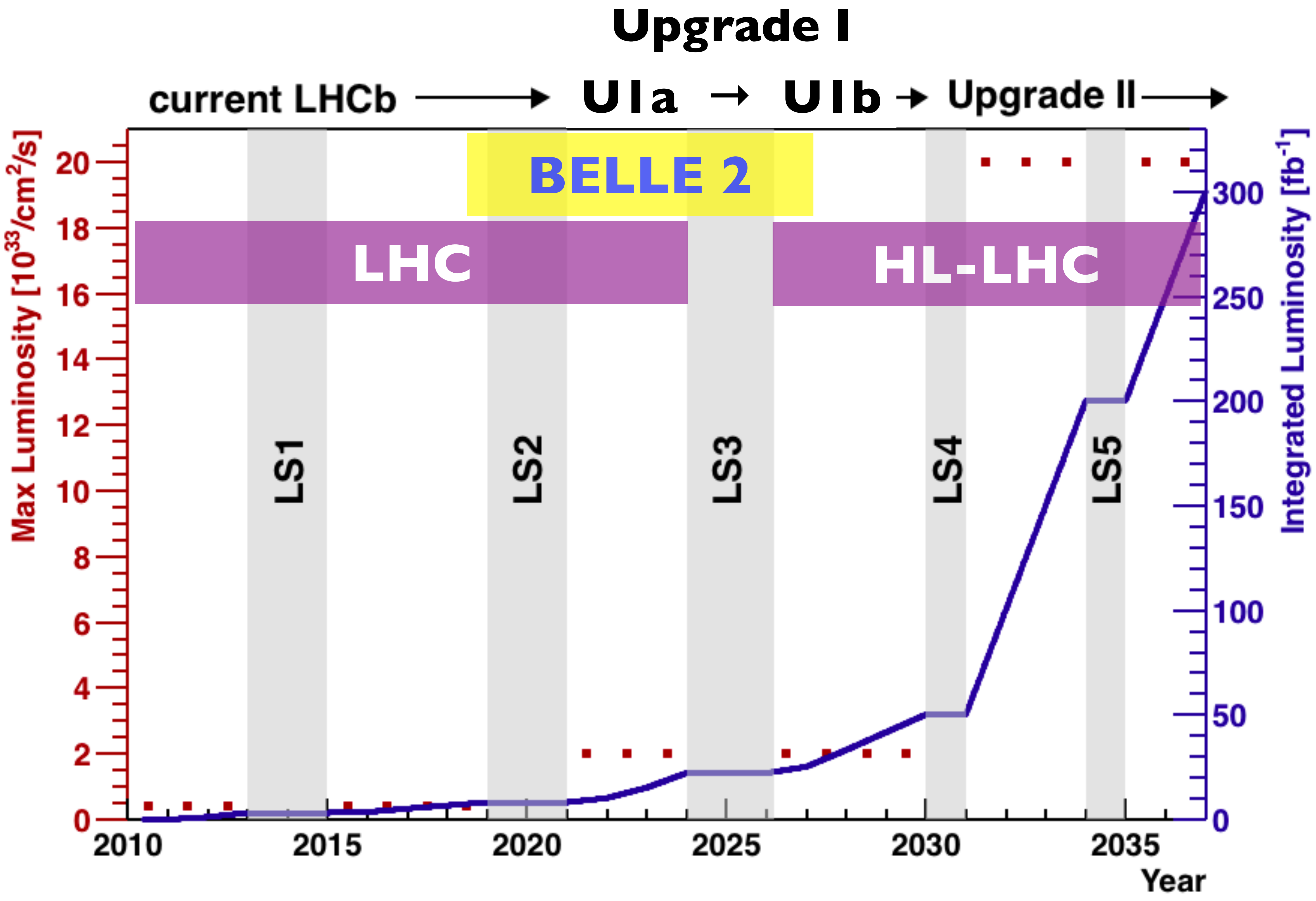
Drawing heavily on (& with many thanks to everyone who contributed to)
https://arxiv.org/abs/1808.08865 & http://arxiv.org/abs/1812.07638

LPNHE biennale, Montpellier, 16.04.2019



LHCb upgrade II plans and timescales

CERN-LHCC-2017-003, CERN-LHCC-2018-027

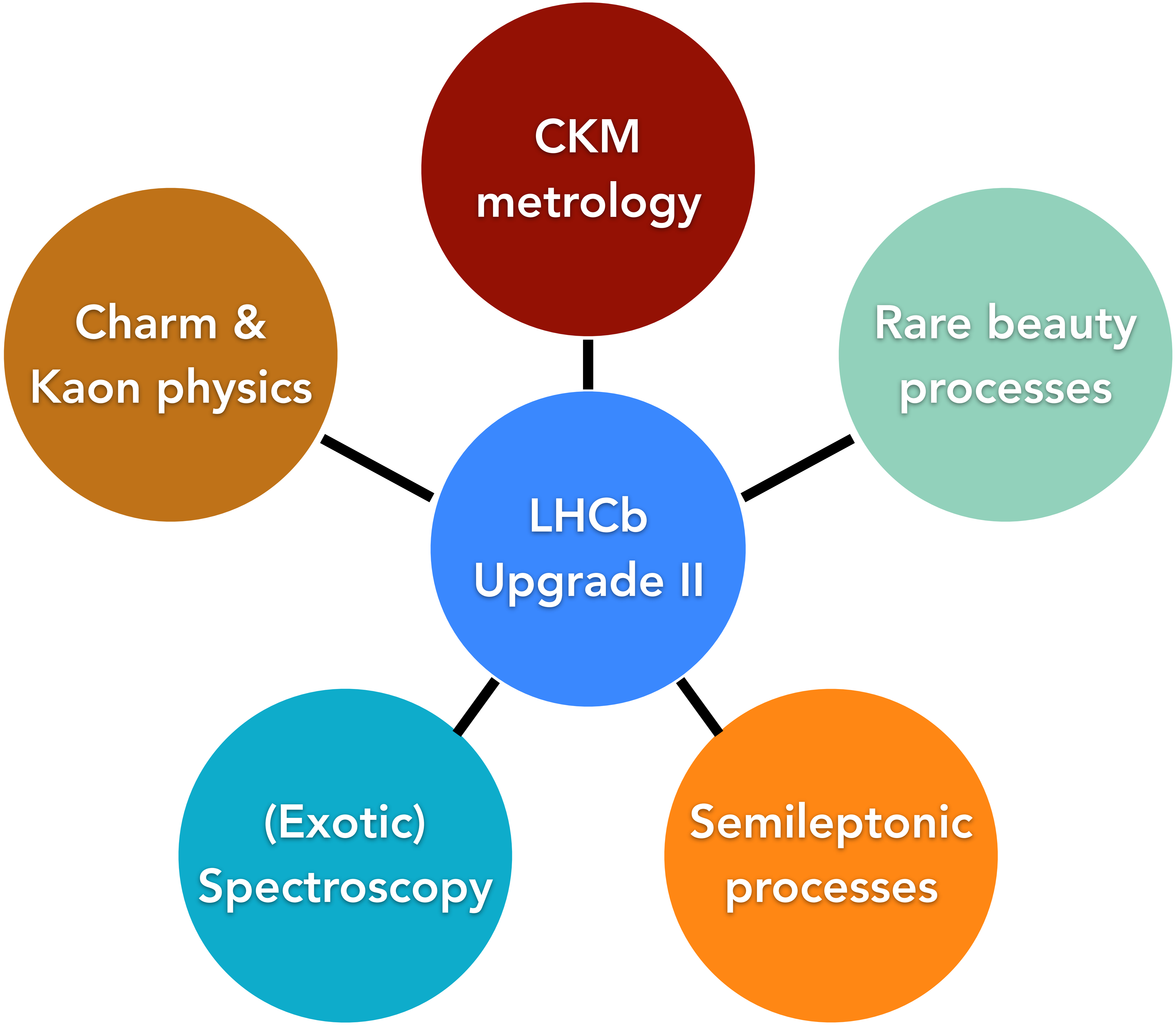


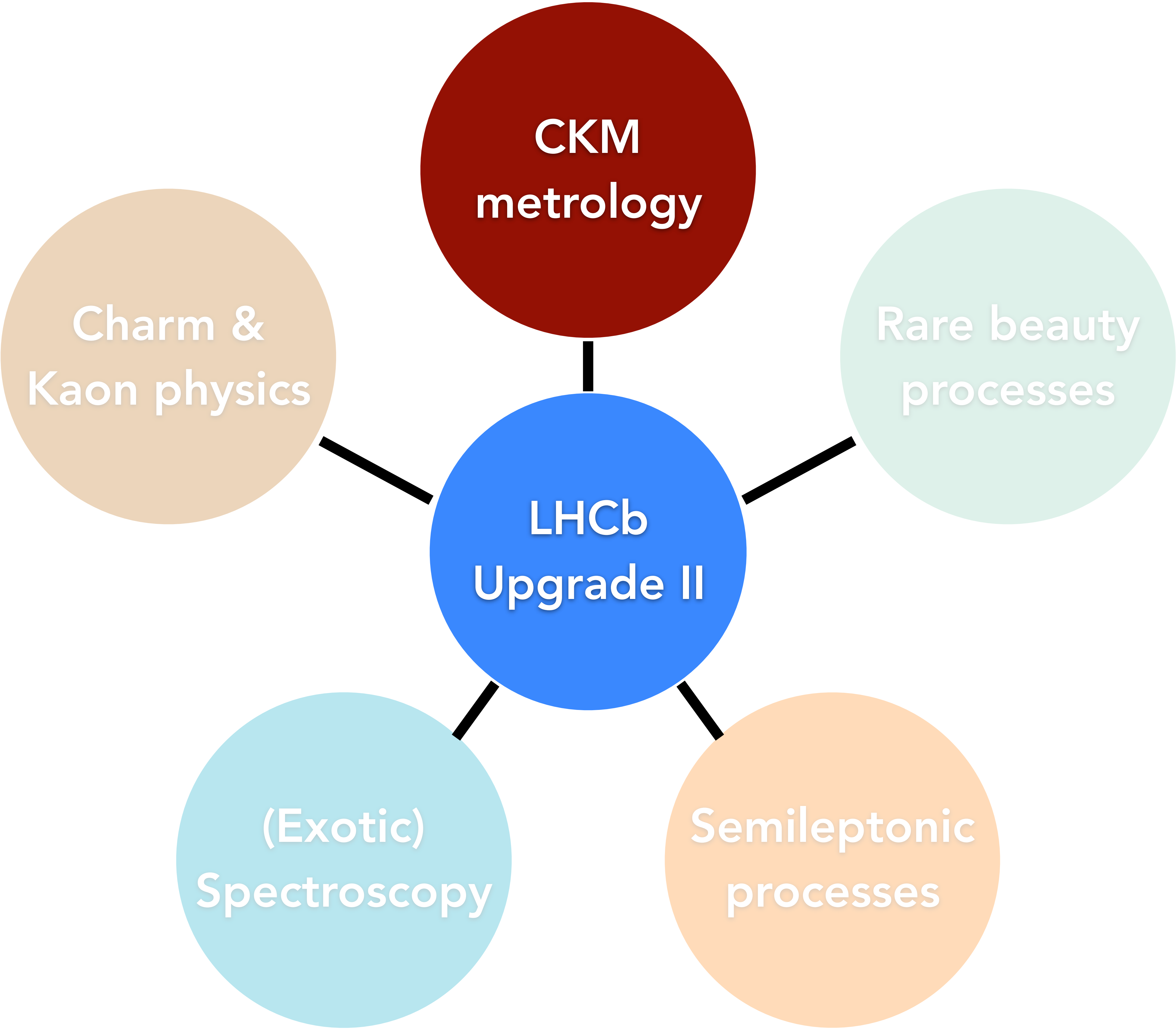
Why a second LHCb upgrade?

1. Key observables which can tell us something about the scale of New Physics won't be theory limited

2. Current LHCb measurements do not generally indicate any fundamental experimental systematics either

3. Unique combination of large integrated luminosity, large cross-section, and relatively short timescale.


CKM metrology
Charm & Kaon physics
Rare beauty processes
LHCb Upgrade II
(Exotic) Spectroscopy
Semileptonic processes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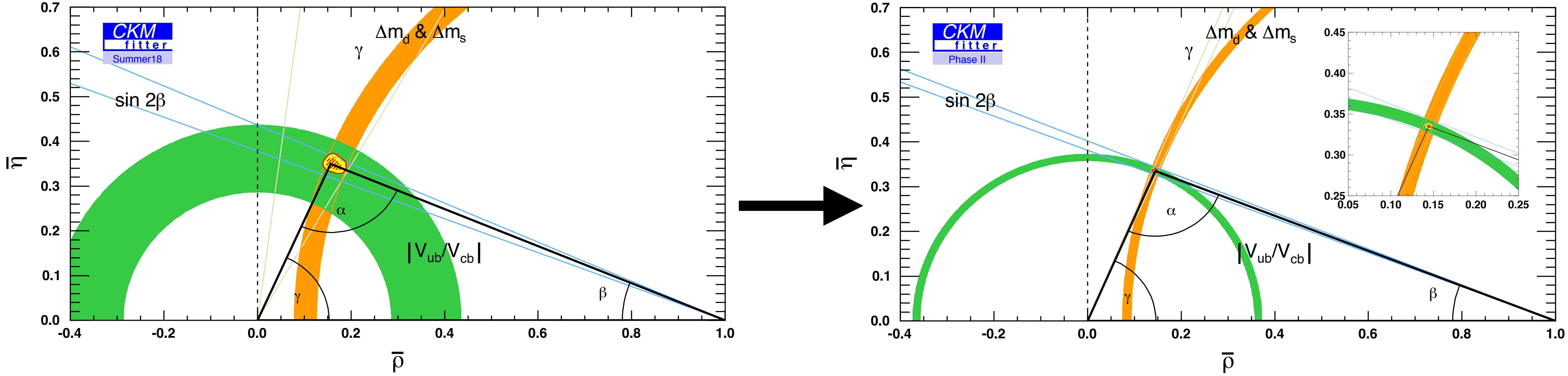
Objective of CKM metrology with LHCb Upgrade II



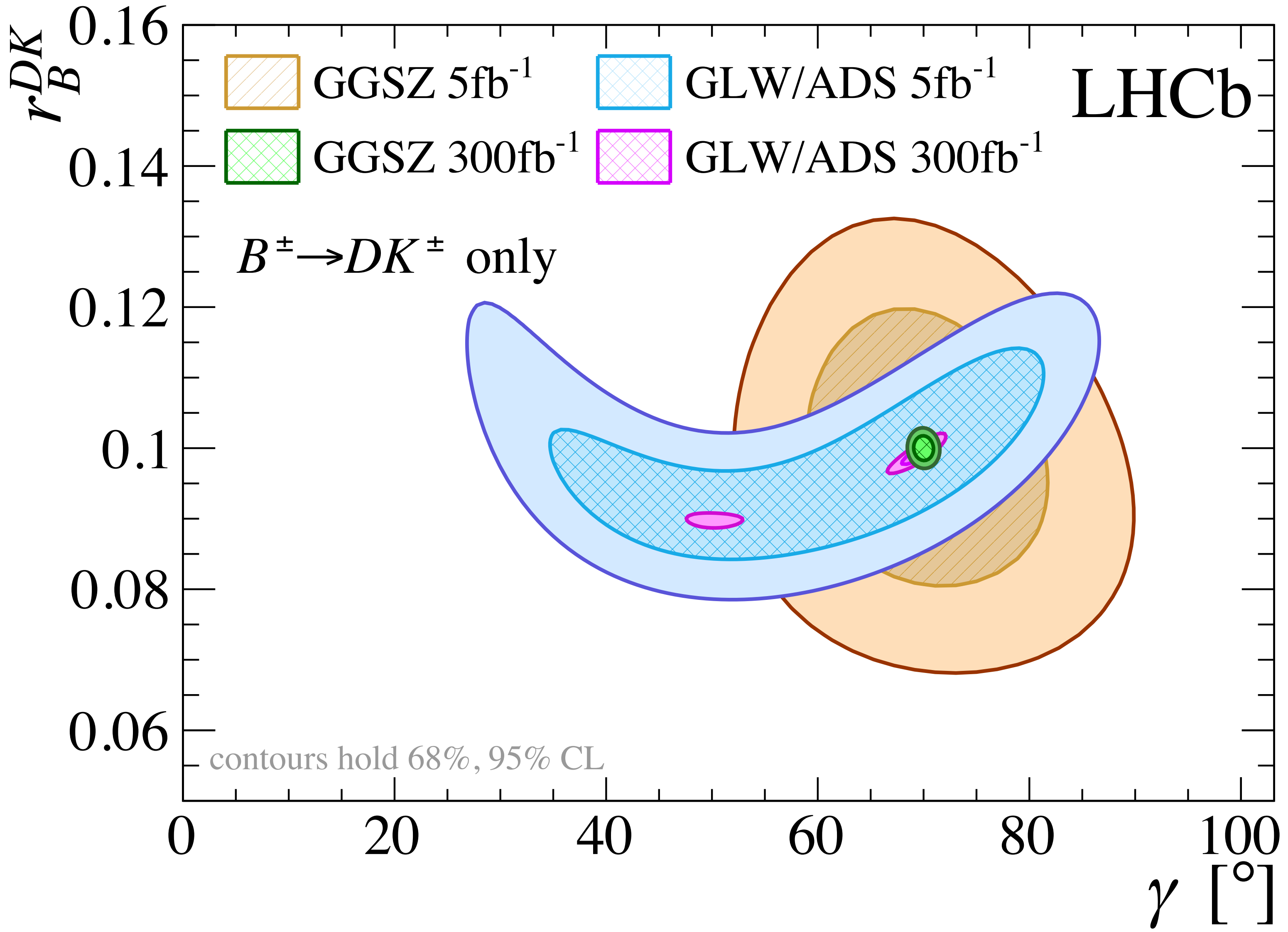
Overconstrain the CKM triangle at <1% level

Objective of CKM metrology with LHCb Upgrade II

Observable	Current LHCb	LHCb 2025	Upgrade II
CKM tests			
γ, with $B_s^0 \to D_s^+ K^-$	$(^{+17}_{-22})^\circ$ [7]	4°	1°
γ, all modes	$(^{+5.0}_{-5.8})^\circ$ [8]	1.5°	0.35°
$\sin 2\beta$, with $B^0 \to J/\psi K_S^0$	0.04 [9]	0.011	0.003
ϕ_s, with $B_s^0 \to J/\psi \phi$	49 mrad [10]	14 mrad	4 mrad
ϕ_s, with $B_s^0 \to D_s^+ D_s^-$	170 mrad [11]	35 mrad	9 mrad
$\phi_s^{s\bar{s}s}$, with $B_s^0 \to \phi\phi$	154 mrad [12]	39 mrad	11 mrad
a_{sl}^s	33×10^{-4} [13]	10×10^{-4}	3×10^{-4}
$\lvert V_{ub}\rvert / \lvert V_{cb}\rvert$	6% [14]	3%	1%

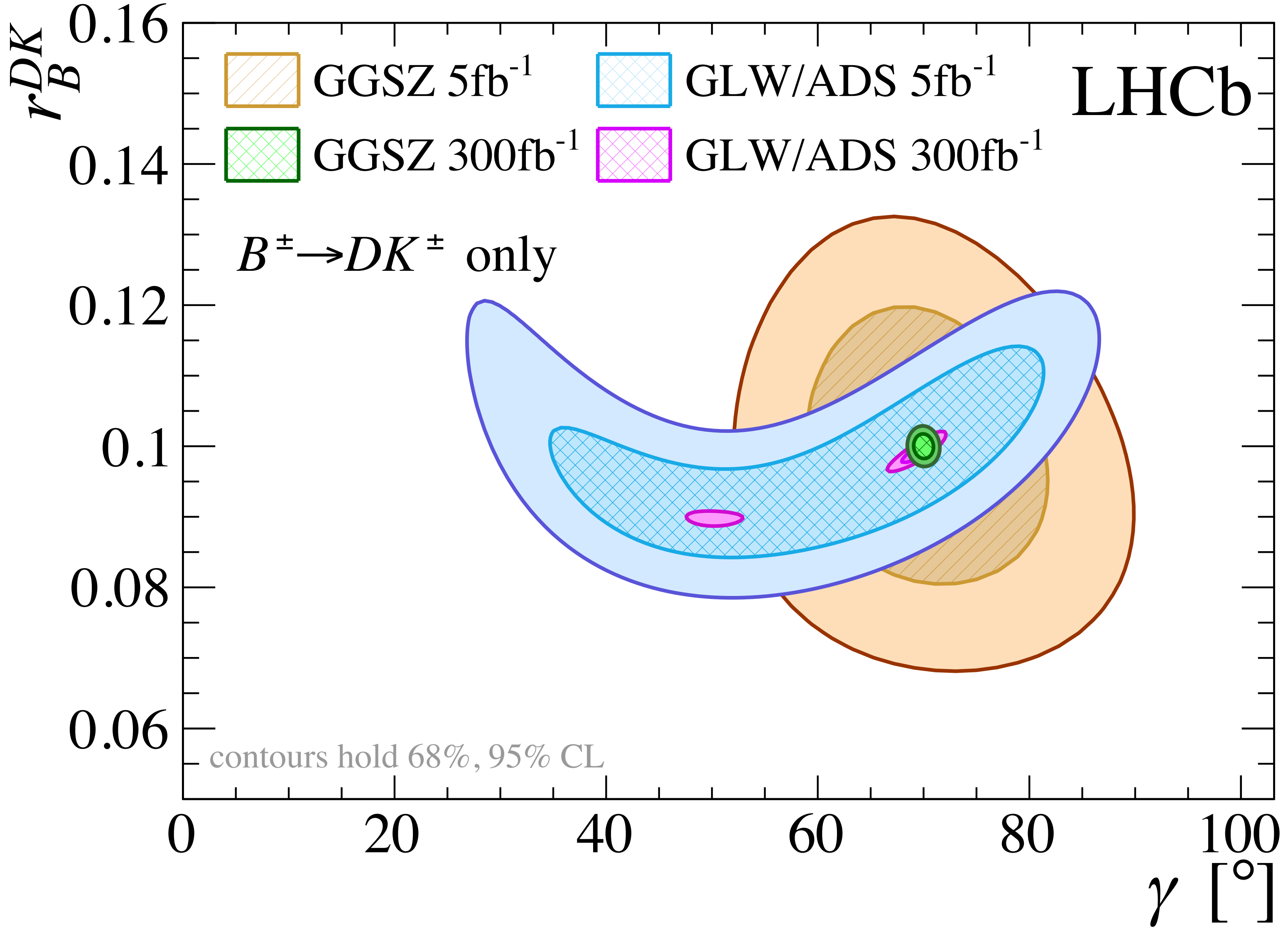
Overconstrain the CKM triangle at <1% level

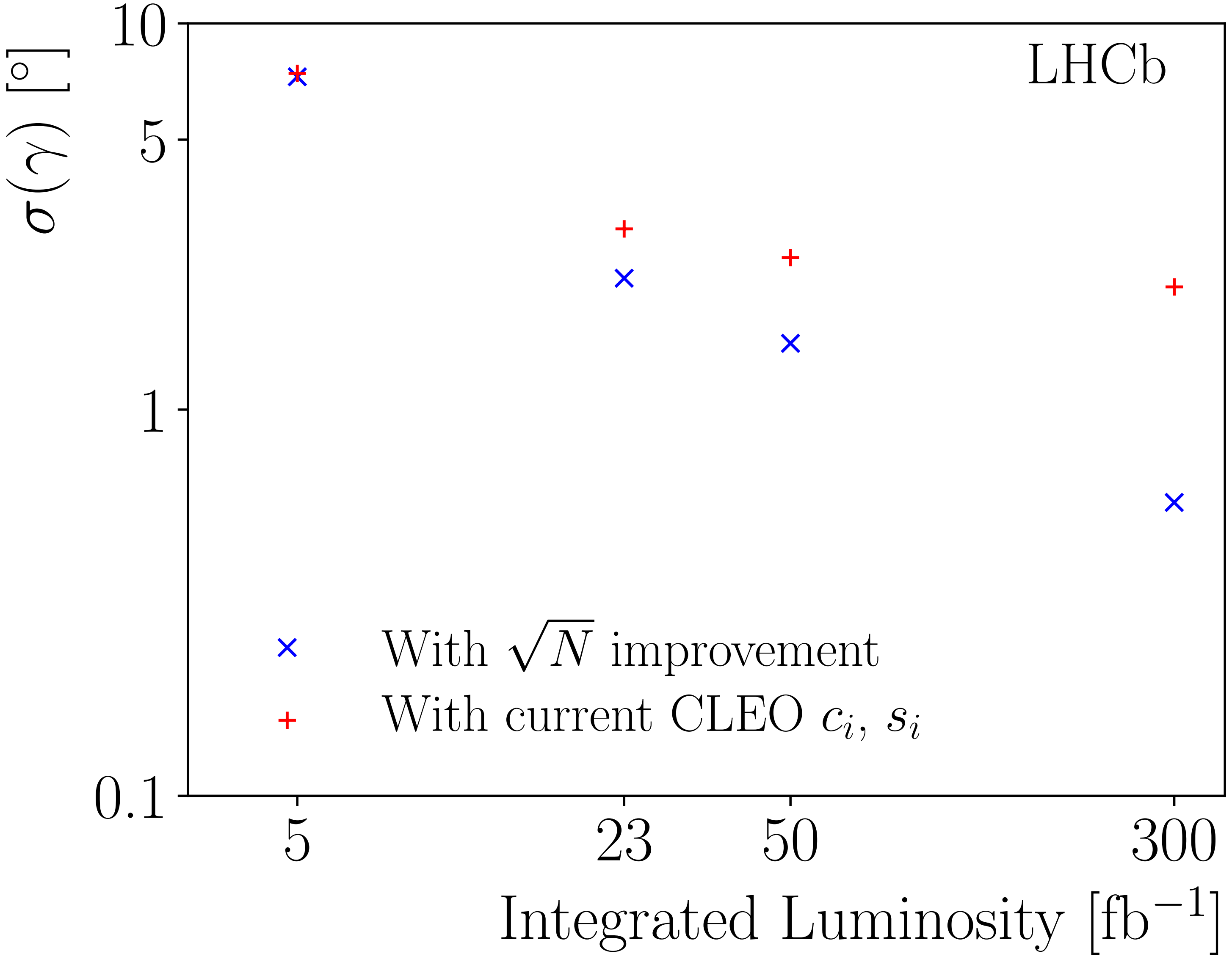
CKM angle γ in Upgrade II



ADS/GLW gives precision, GGSZ & D_sK break ambiguities

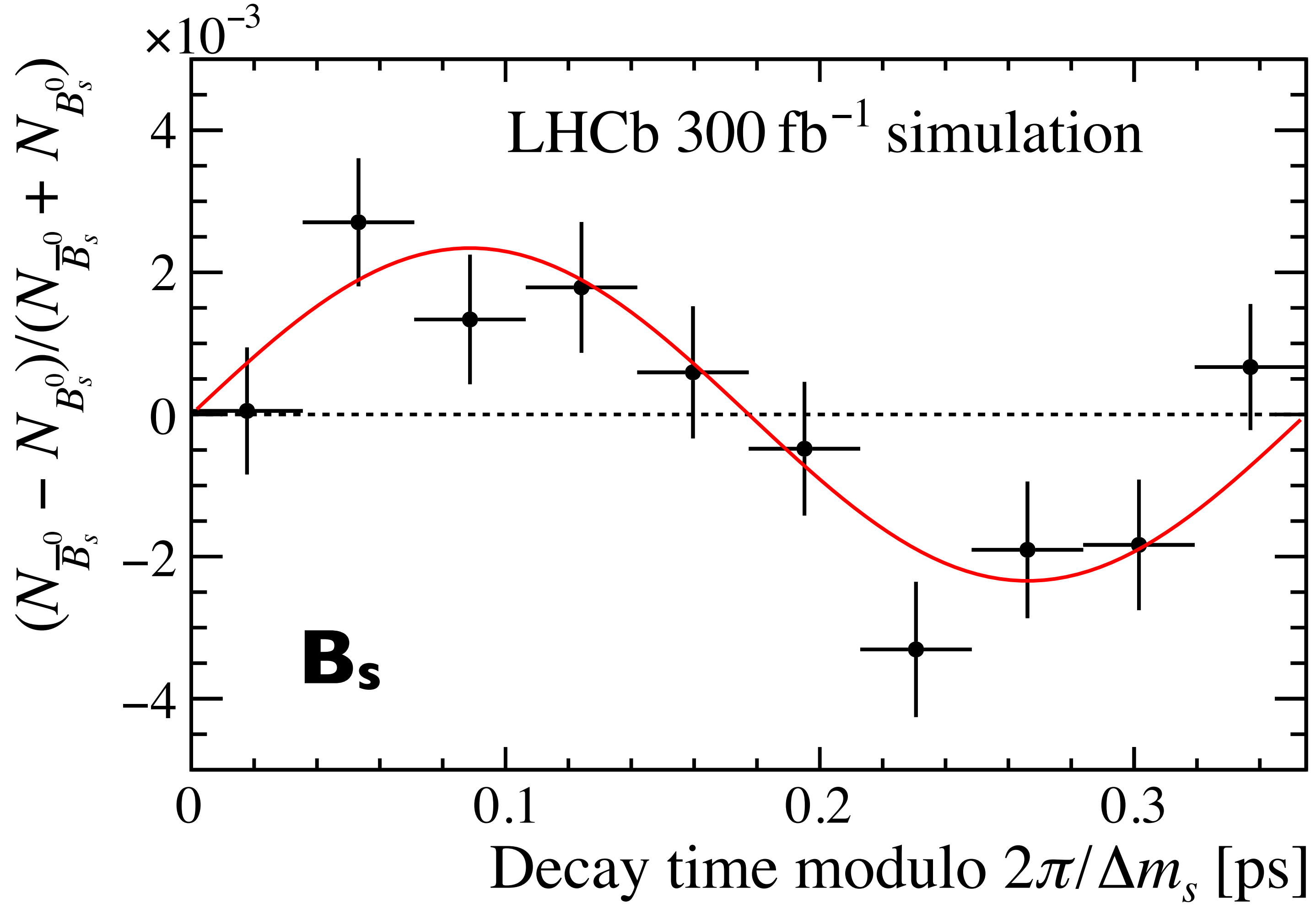
CKM angle γ in Upgrade II

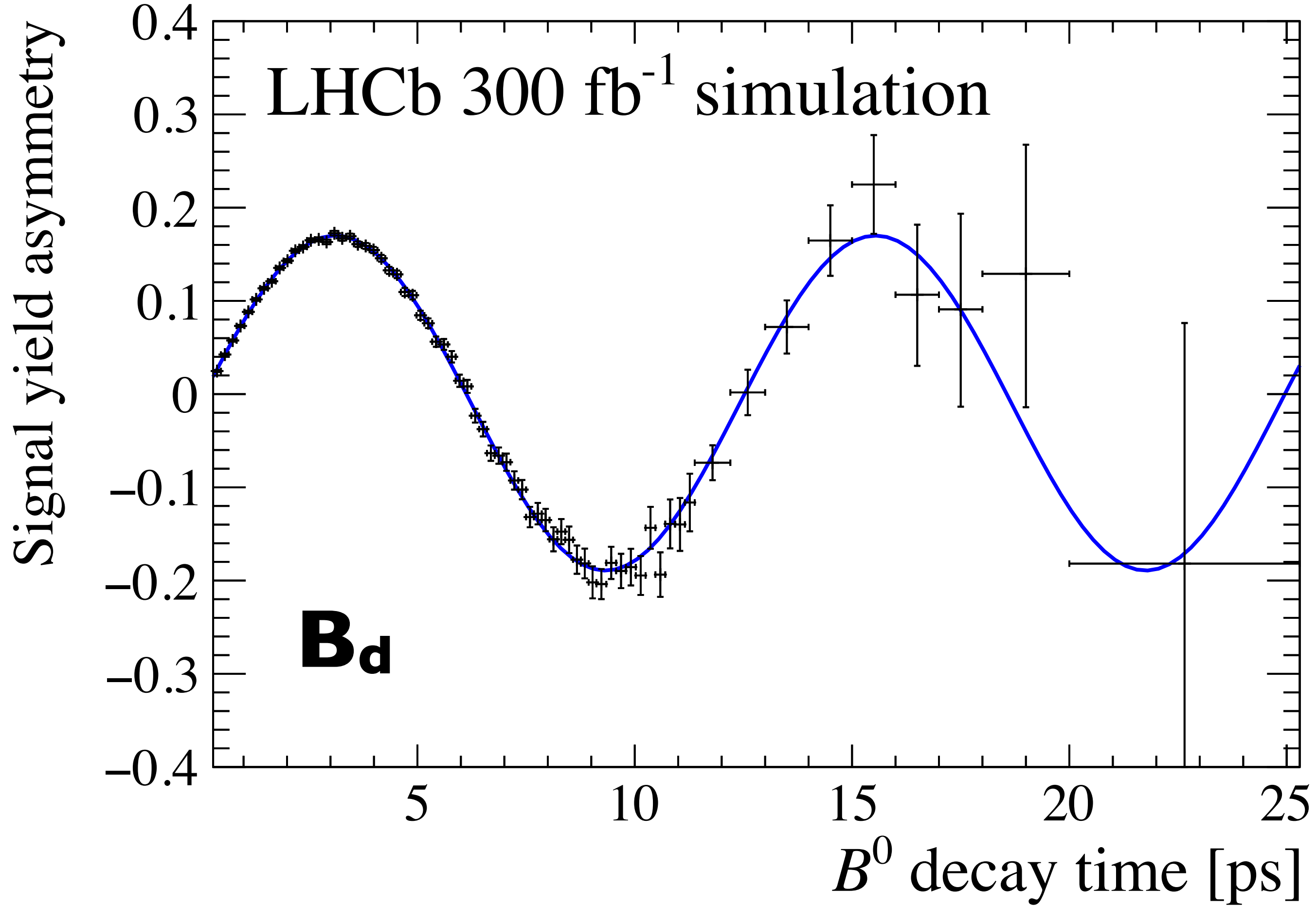




External inputs will be crucial for ultimate GGSZ precision

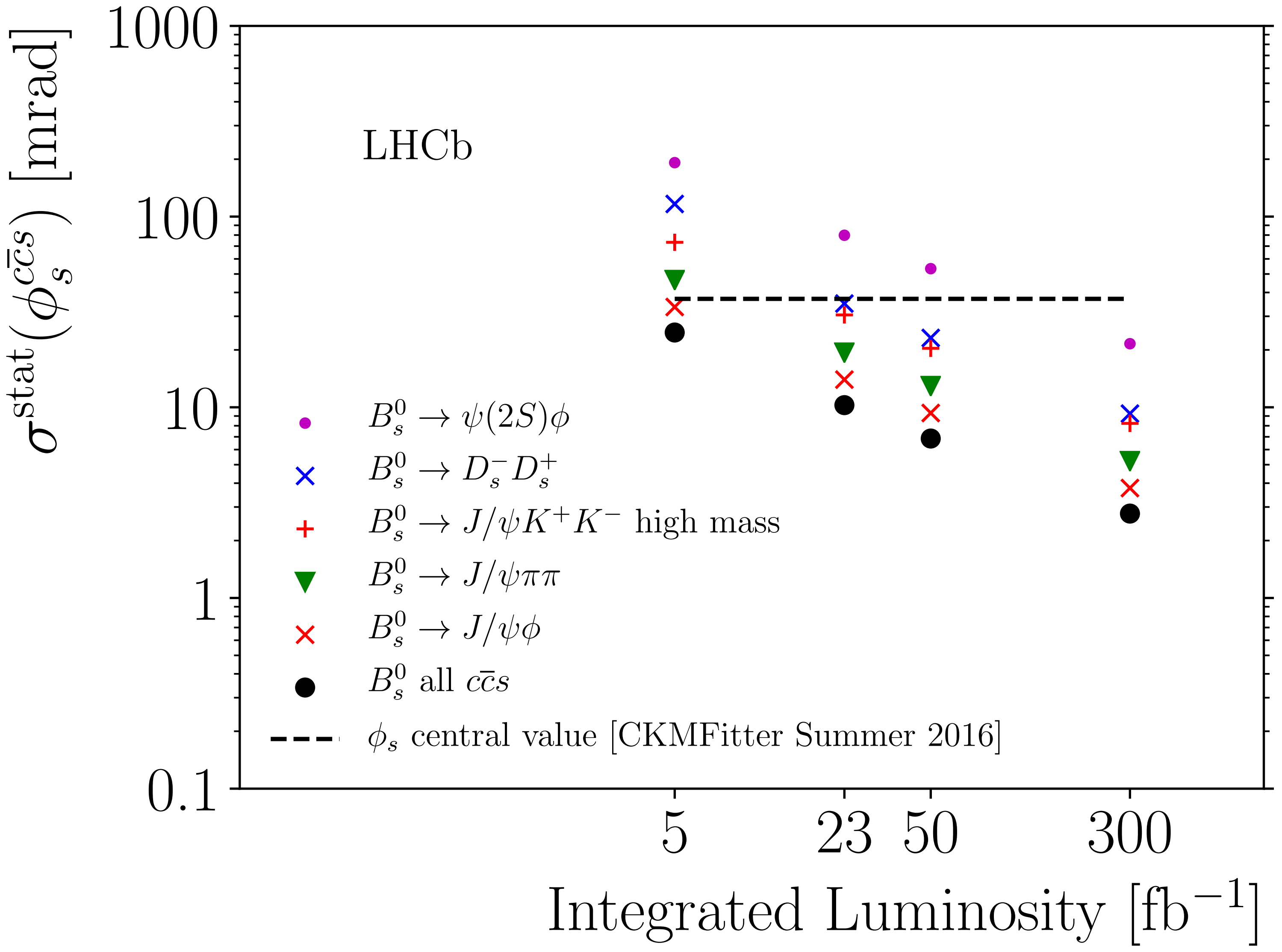
φ_s and Sin2β in Upgrade II

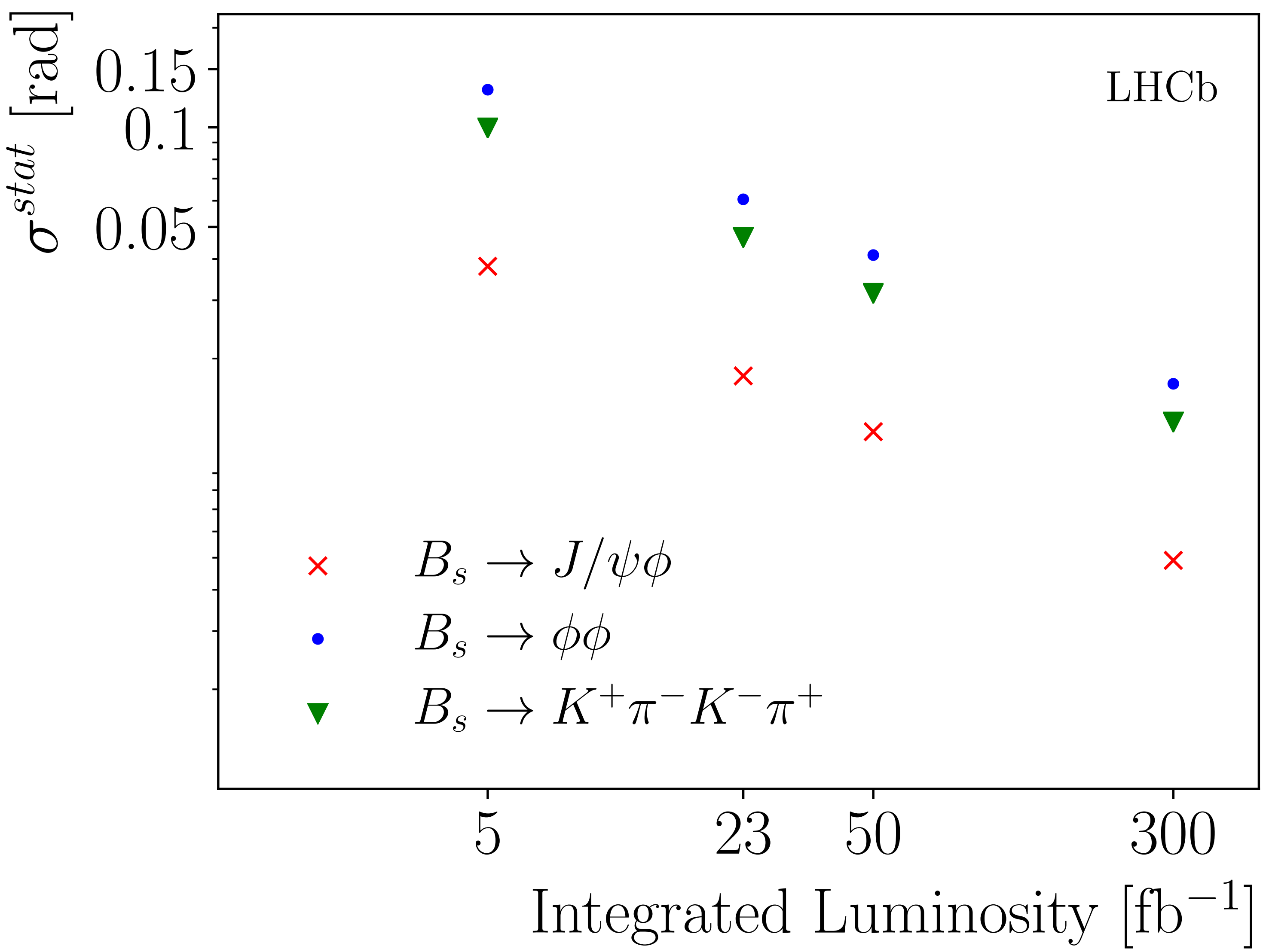




Visually resolve both the B_d and B_s time-dependent CPV!

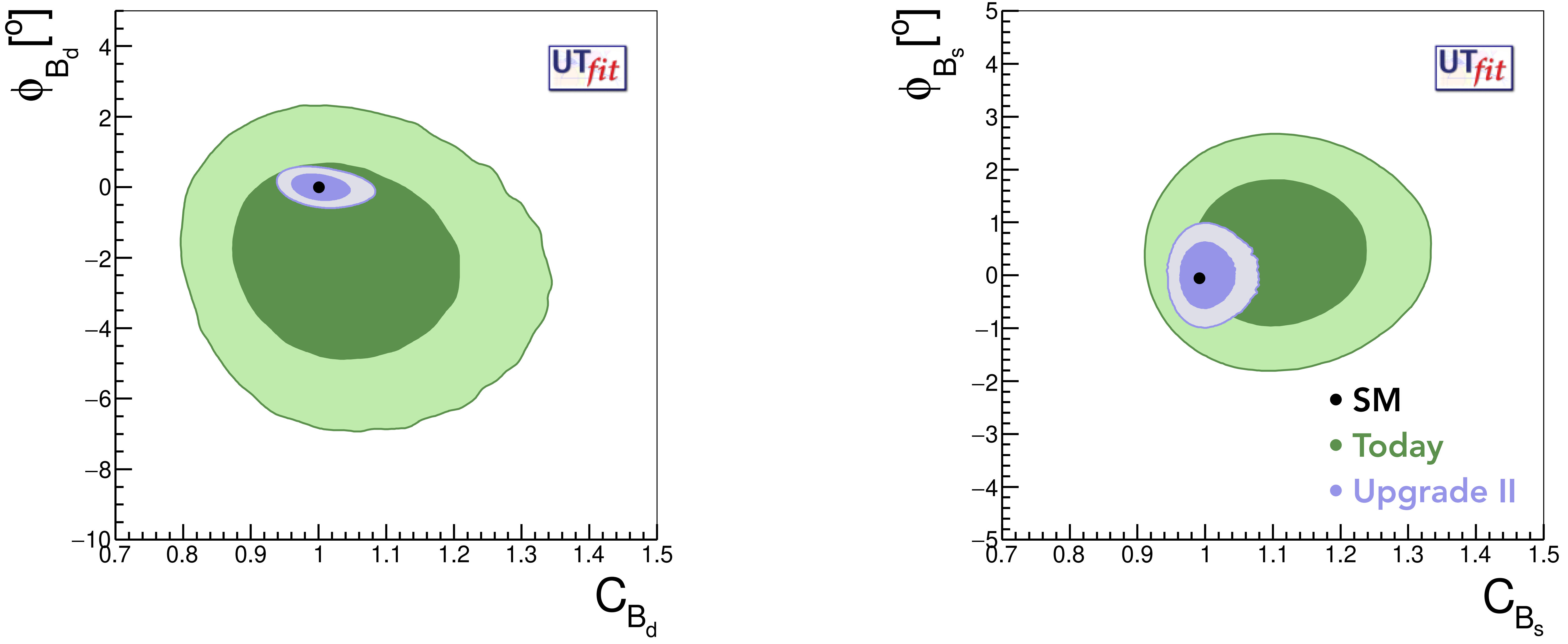
φs and Sin2β in Upgrade II



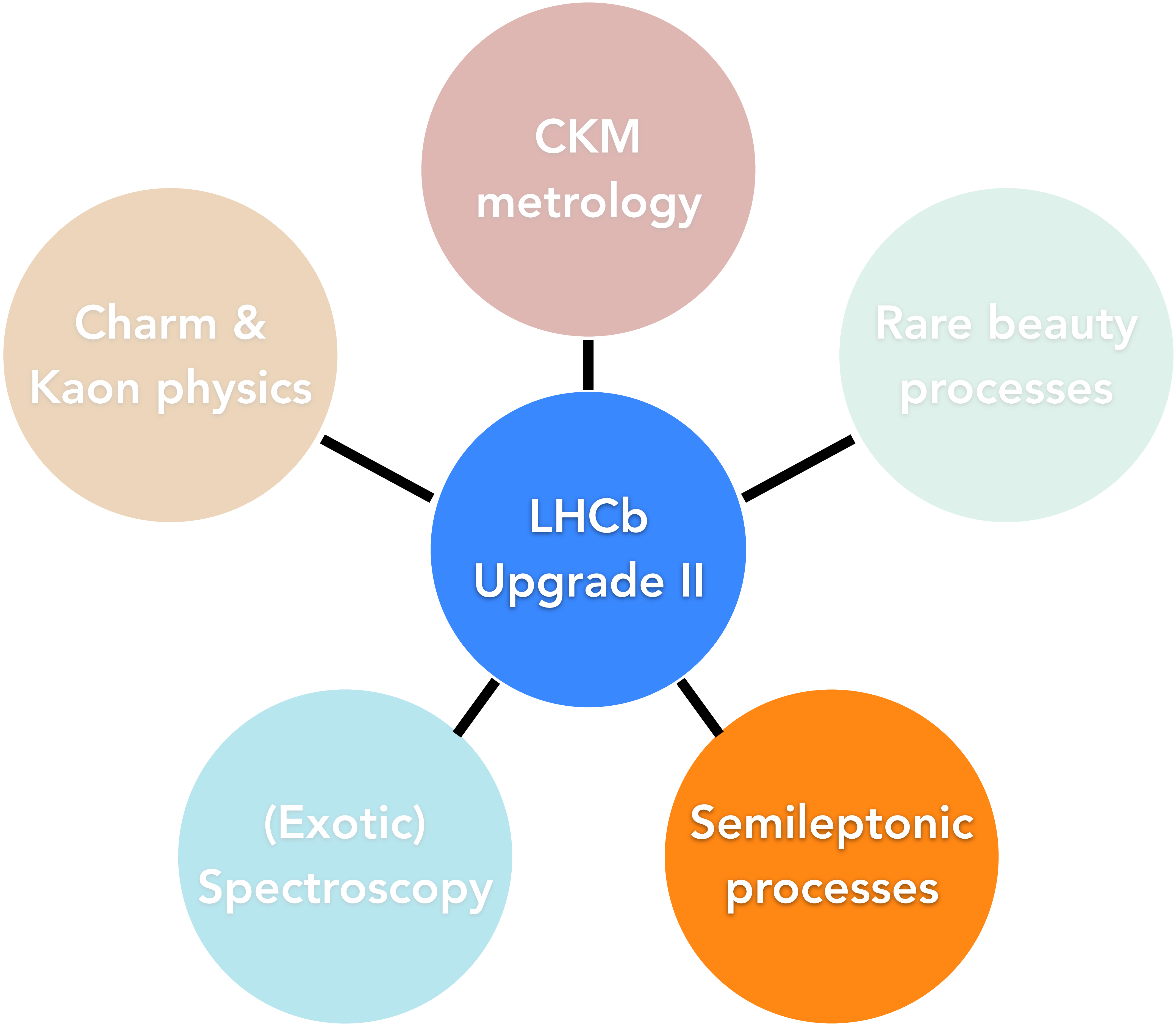


Penguin pollution control vital for interpretation, but wide range of channels accessible @ Upgrade II greatly helps!

Mixing related constraints on NP



Belle II and LHCb Upgrade II combination powerfully constrains the available parameter space for NP in FCNCs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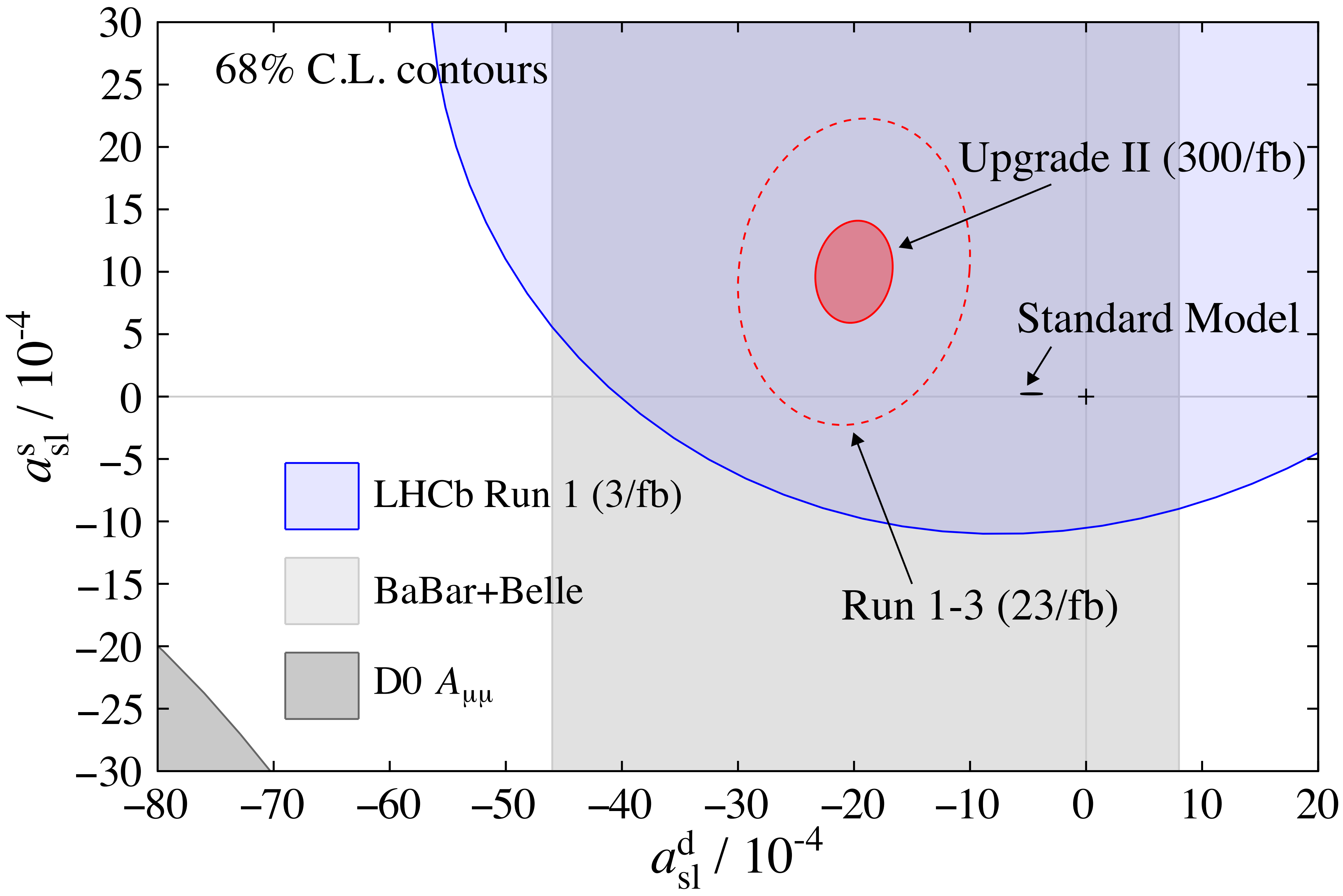
Semileptonic asymmetries

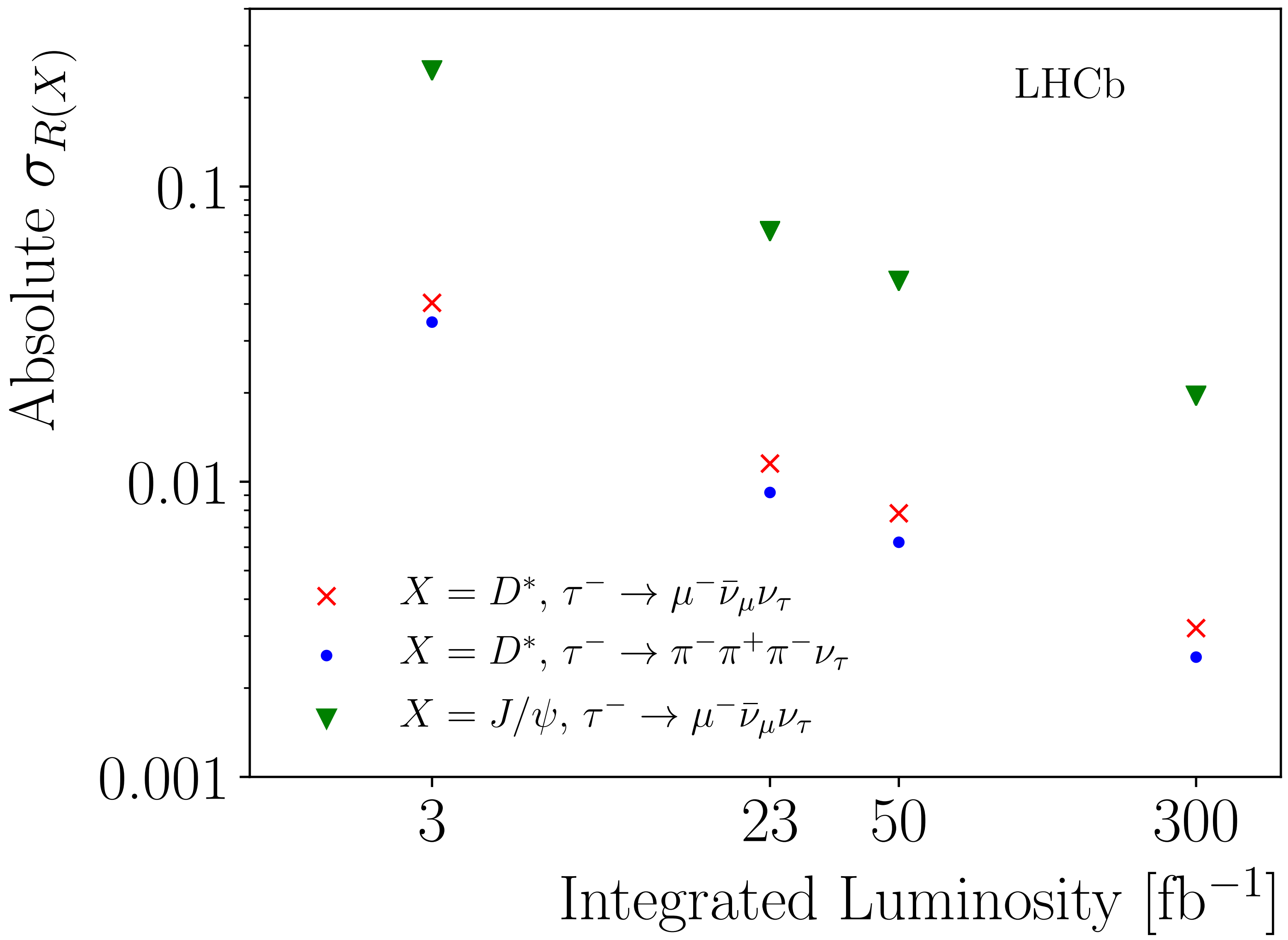


Control K-π detection asymmetries using a combination of high stats MC and tag-and-probe at the 10^{-4} level

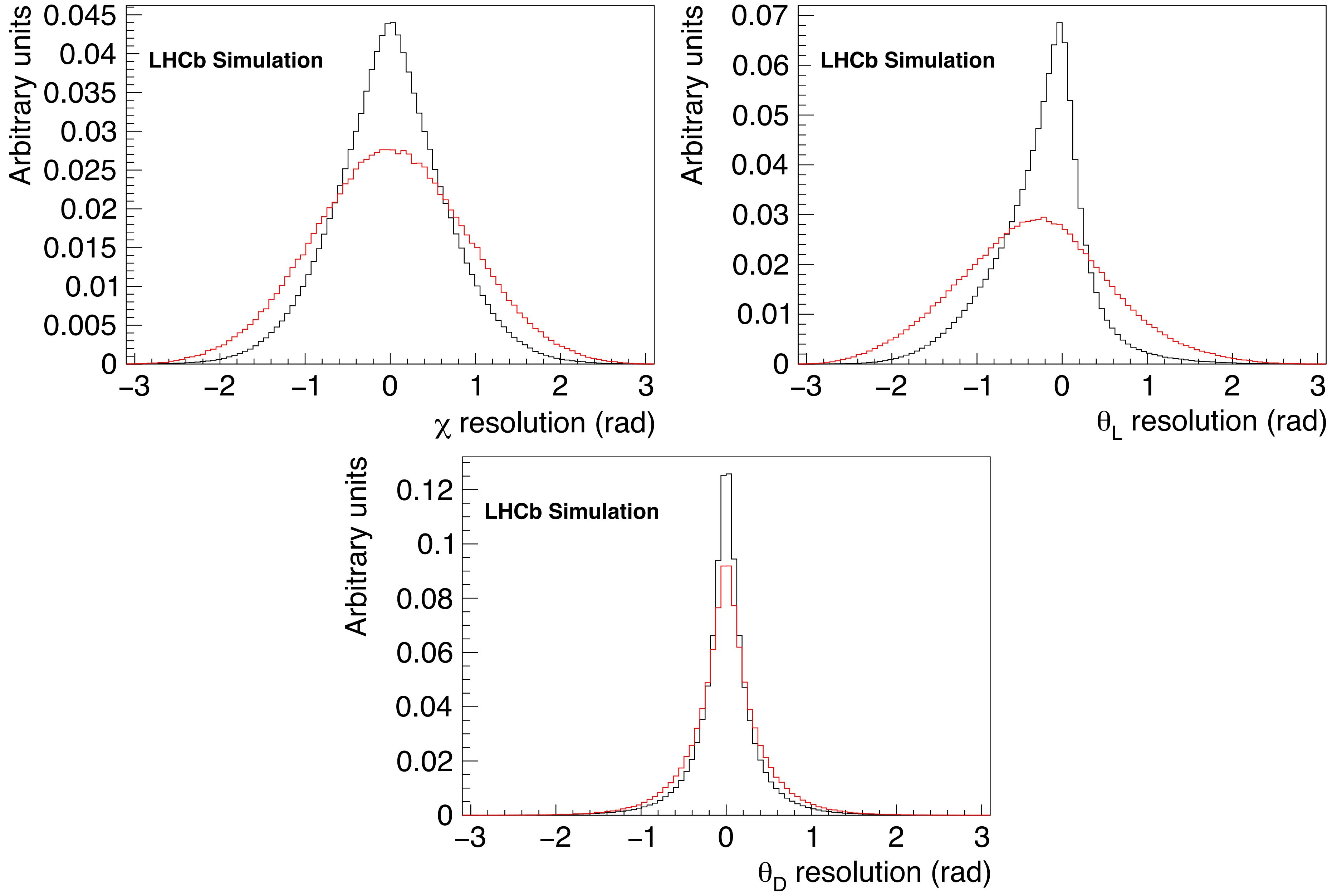
RD* and other lepton-(non)-universal friends

Unique selling point is again the access to all b-hadron species, with complementary experimental and theoretical systematics

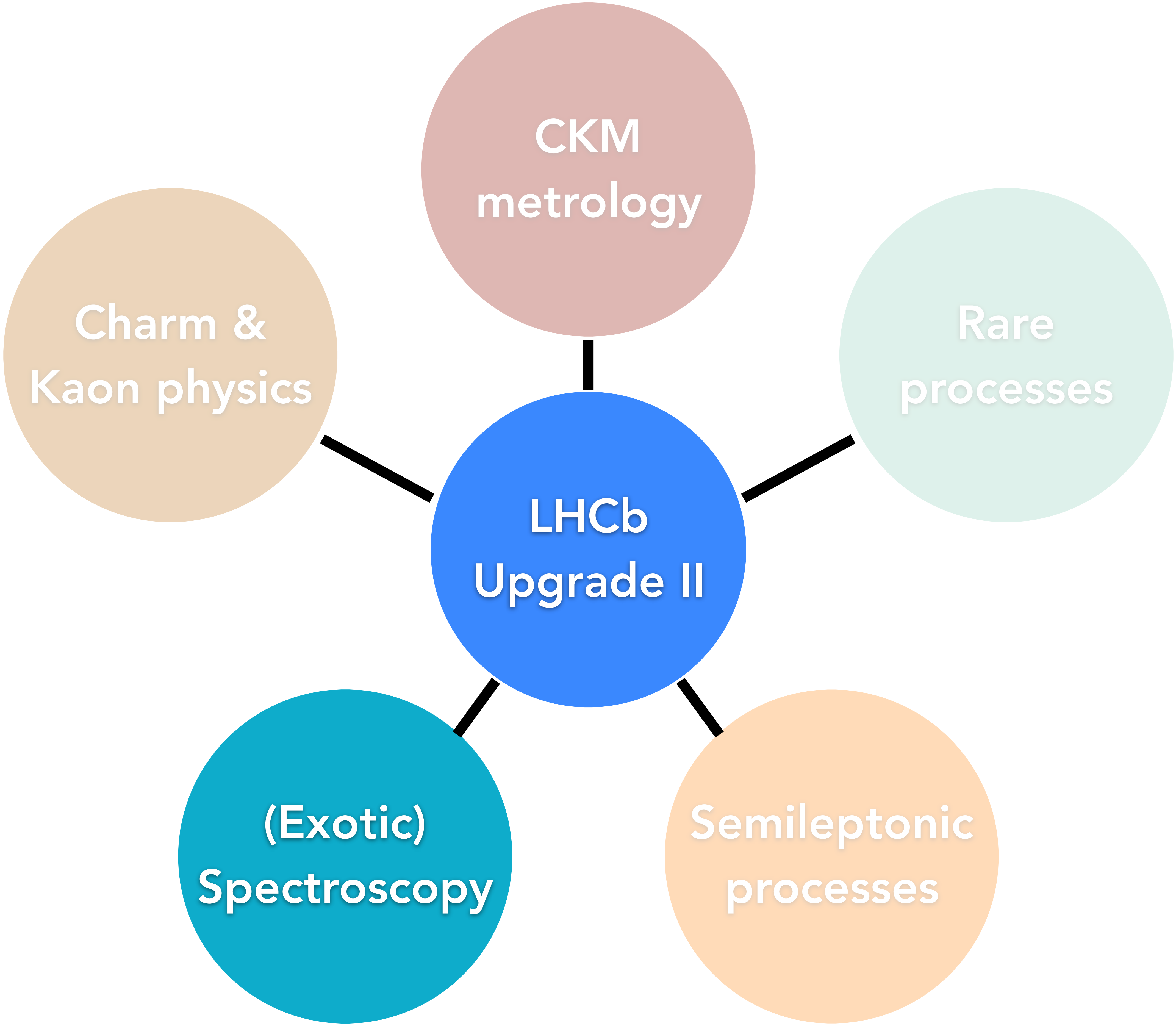
With Upgrade II measurements from $B_c \to J/\psi\tau\nu$ will reach the precision regime



New observables in RD* with Upgrade II



Angular observables *are* resolvable, but Upgrade II statistics needed for precision because of limited resolution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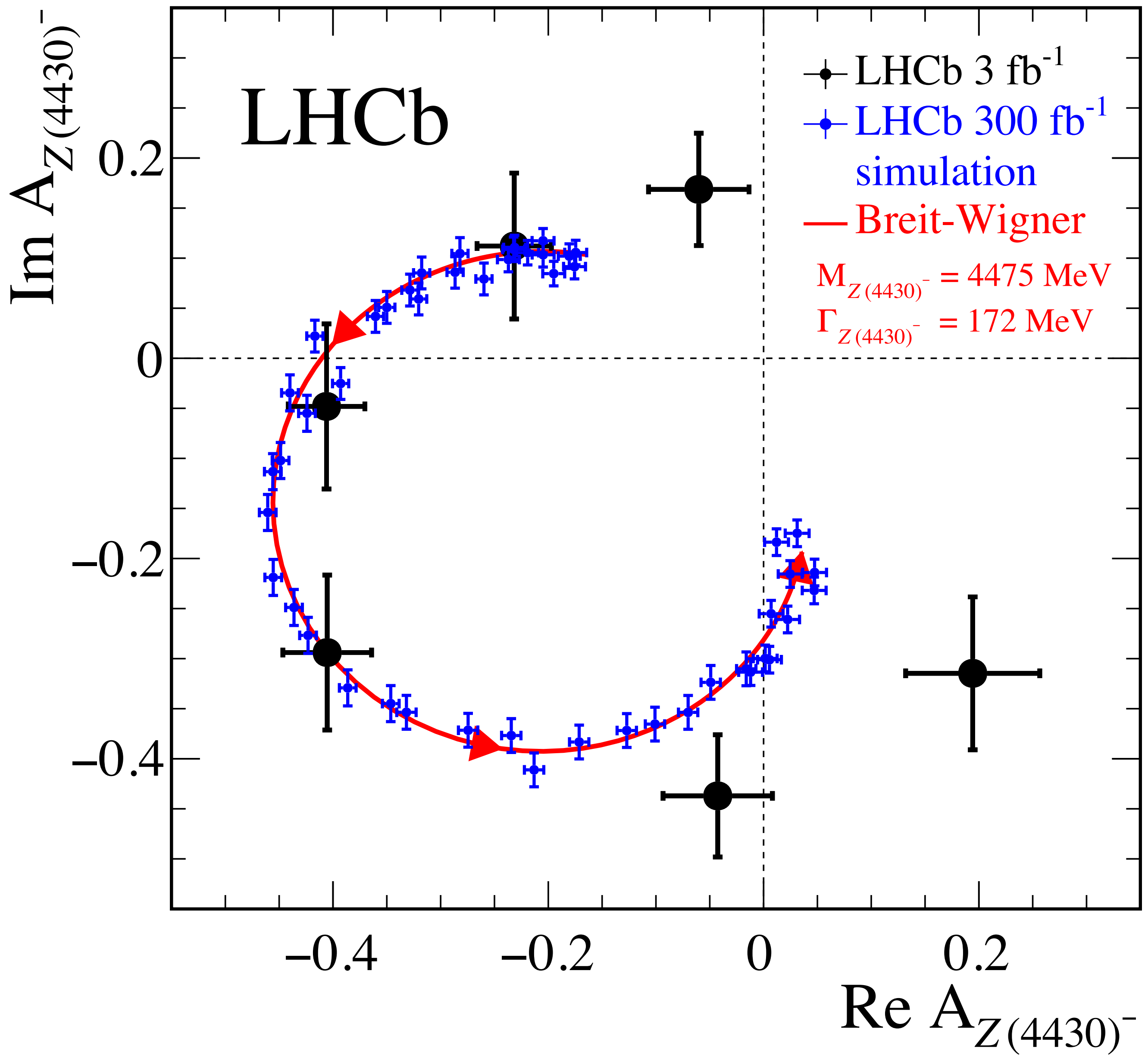
Upgrade II will be an exotica factory!

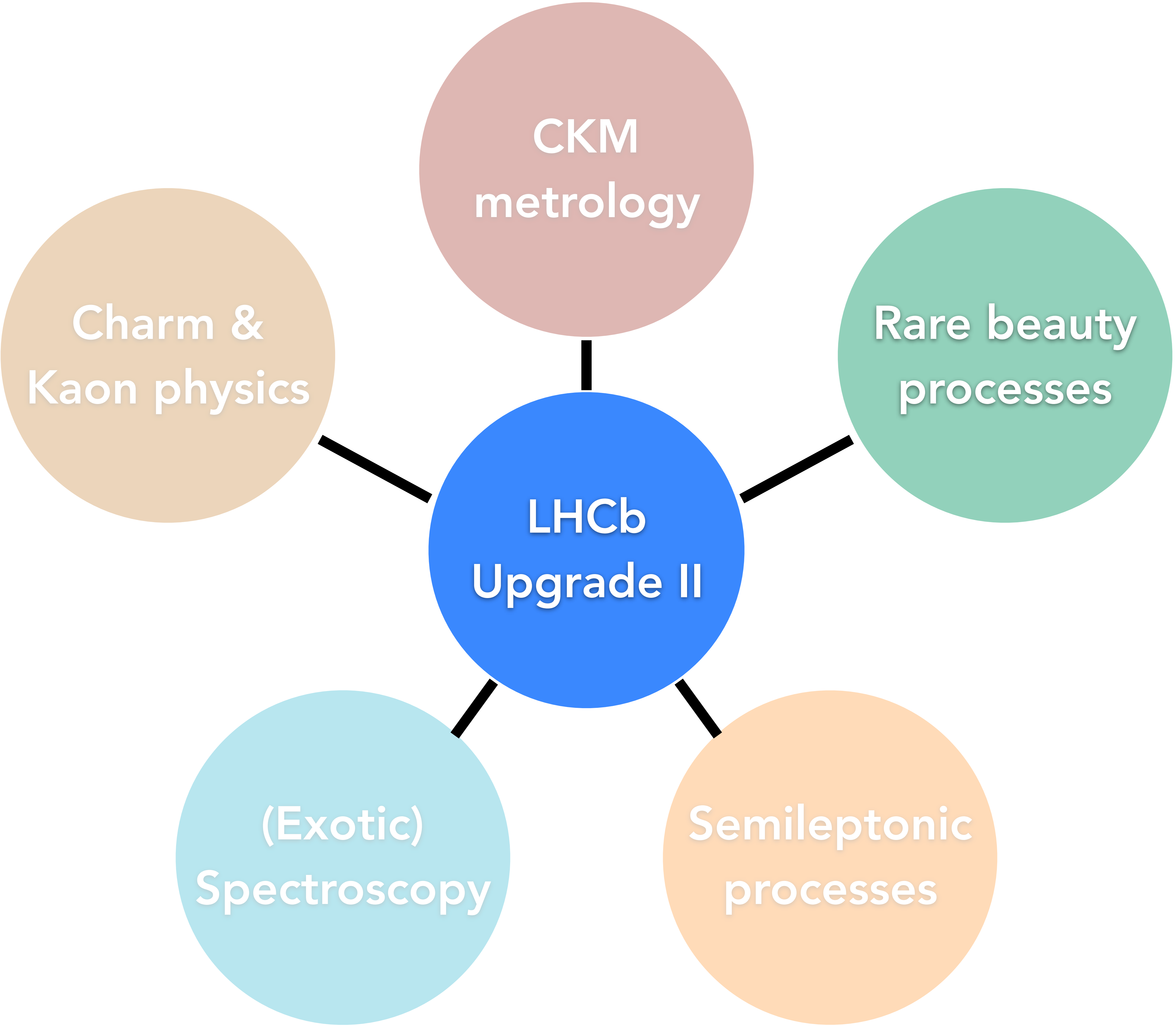
Decay mode	LHCb $23\,\text{fb}^{-1}$	$50\,\text{fb}^{-1}$	$300\,\text{fb}^{-1}$
$B^+ \to X(3872)(\to J/\psi\,\pi^+\pi^-)K^+$	14k	30k	180k
$B^+ \to X(3872)(\to \psi(2S)\gamma)K^+$	500	1k	7k
$B^0 \to \psi(2S)K^-\pi^+$	340k	700k	4M
$B_c^+ \to D_s^+ D^0 \overline{D}{}^0$	10	20	100
$\Lambda_b^0 \to J/\psi\, pK^-$	340k	700k	4M
$\Xi_b^- \to J/\psi\, \Lambda K^-$	4k	10k	55k
$\Xi_{cc}^{++} \to \Lambda_c^+ K^-\pi^+\pi^+$	7k	15k	90k
$\Xi_{bc}^+ \to J/\psi\, \Xi_c^+$	50	100	600

A truly unique reach for all kinds of exotic hadron species.
The main challenge here will be fully processing the data!

Precision physics with exotica



Improvements to the LHCb calorimeter will be critical for accessing the full range of final states and decay modes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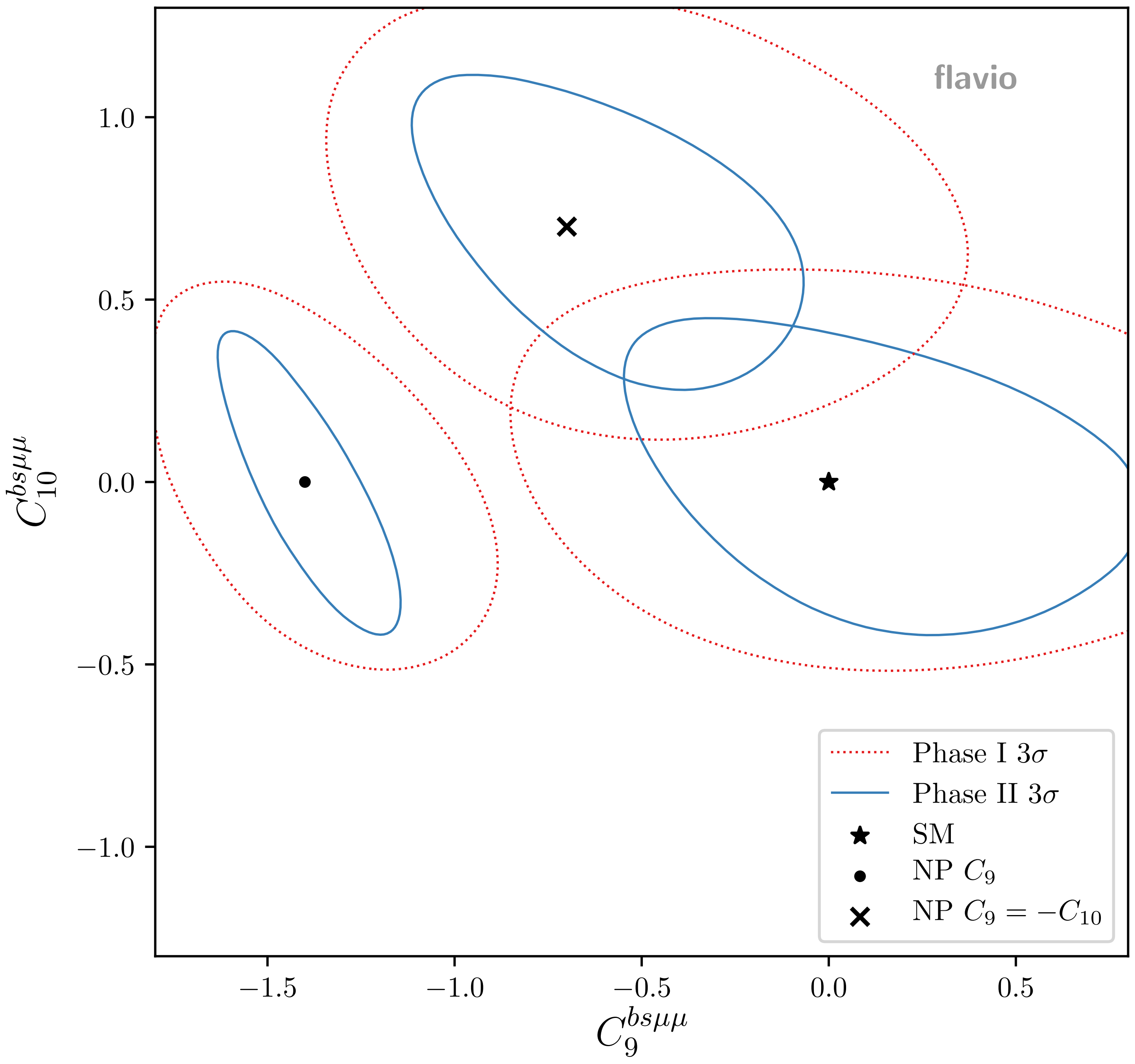
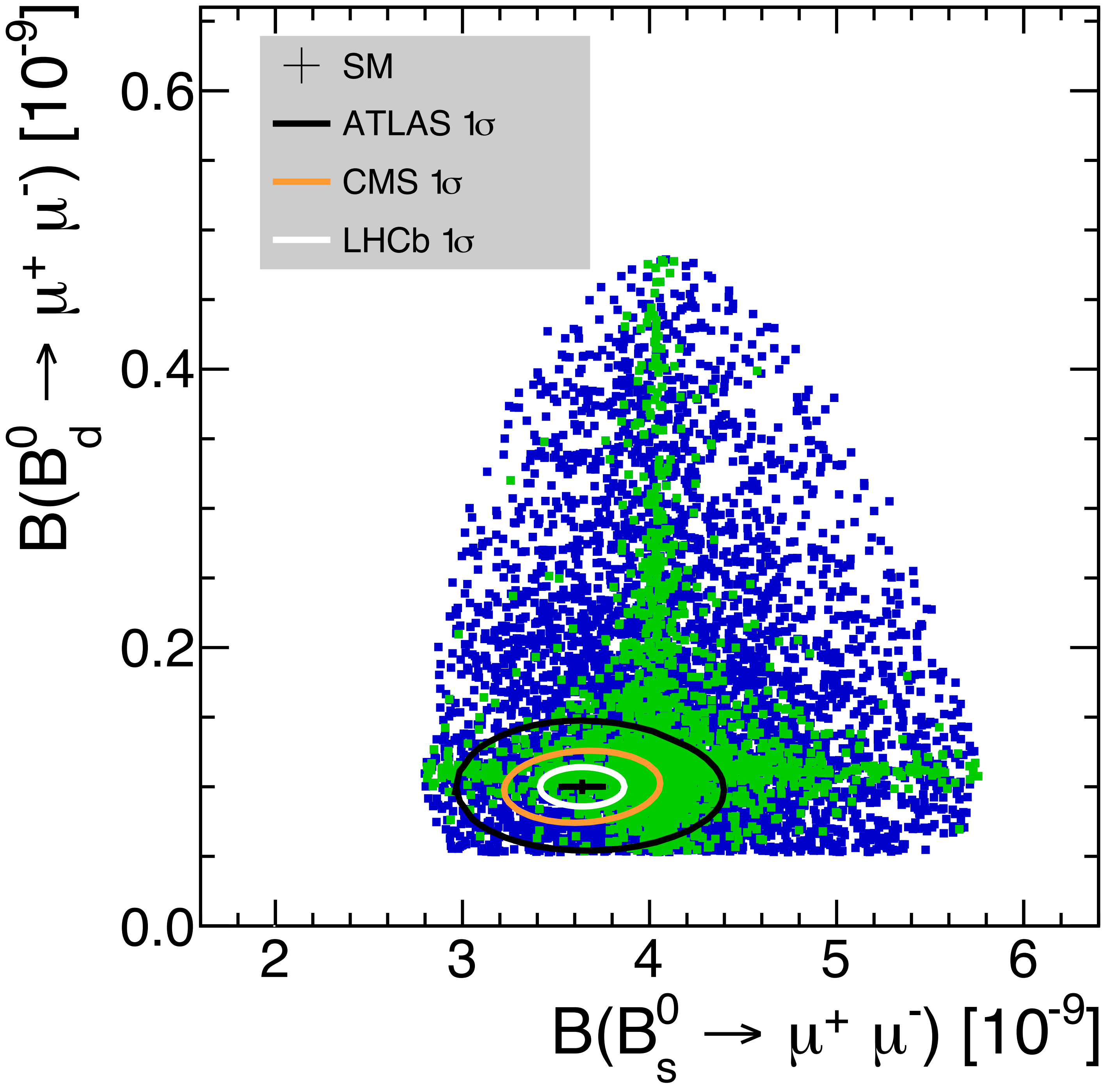
Upgrade II: searching for or characterizing New Physics?

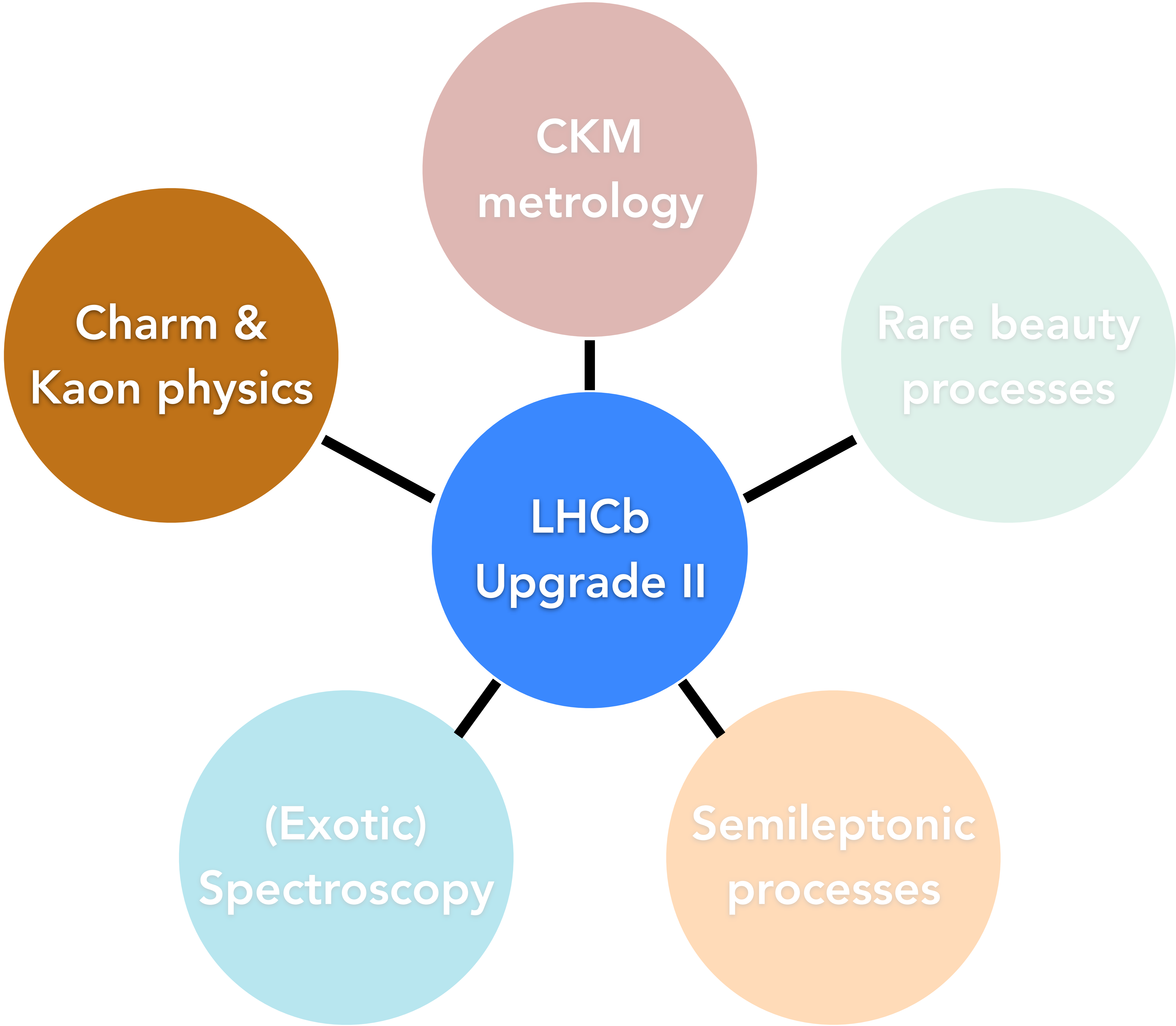




When rare decays aren't rare anymore

Yield	Run 1 result	$9\,\mathrm{fb}^{-1}$	$23\,\mathrm{fb}^{-1}$	$50\,\mathrm{fb}^{-1}$	$300\,\mathrm{fb}^{-1}$
$B^+ \to K^+e^+e^-$	254 ± 29 [5]	1 120	3 300	7 500	46 000
$B^0 \to K^{*0}e^+e^-$	111 ± 14 [6]	490	1 400	3 300	20 000
$B^0_s \to \phi e^+e^-$	–	80	230	530	3 300
$\Lambda^0_b \to pKe^+e^-$	–	120	360	820	5 000
$B^+ \to \pi^+e^+e^-$	–	20	70	150	900
R_X precision	Run 1 result	$9\,\mathrm{fb}^{-1}$	$23\,\mathrm{fb}^{-1}$	$50\,\mathrm{fb}^{-1}$	$300\,\mathrm{fb}^{-1}$
R_K	$0.745 \pm 0.090 \pm 0.036$ [5]	0.043	0.025	0.017	0.007
$R_{K^{*0}}$	$0.69 \pm 0.11 \pm 0.05$ [6]	0.052	0.031	0.020	0.008
R_ϕ	–	0.130	0.076	0.050	0.020
R_{pK}	–	0.105	0.061	0.041	0.016
R_π	–	0.302	0.176	0.117	0.047

Even b→d$\ell\ell$ transitions will be abundant with Upgrade II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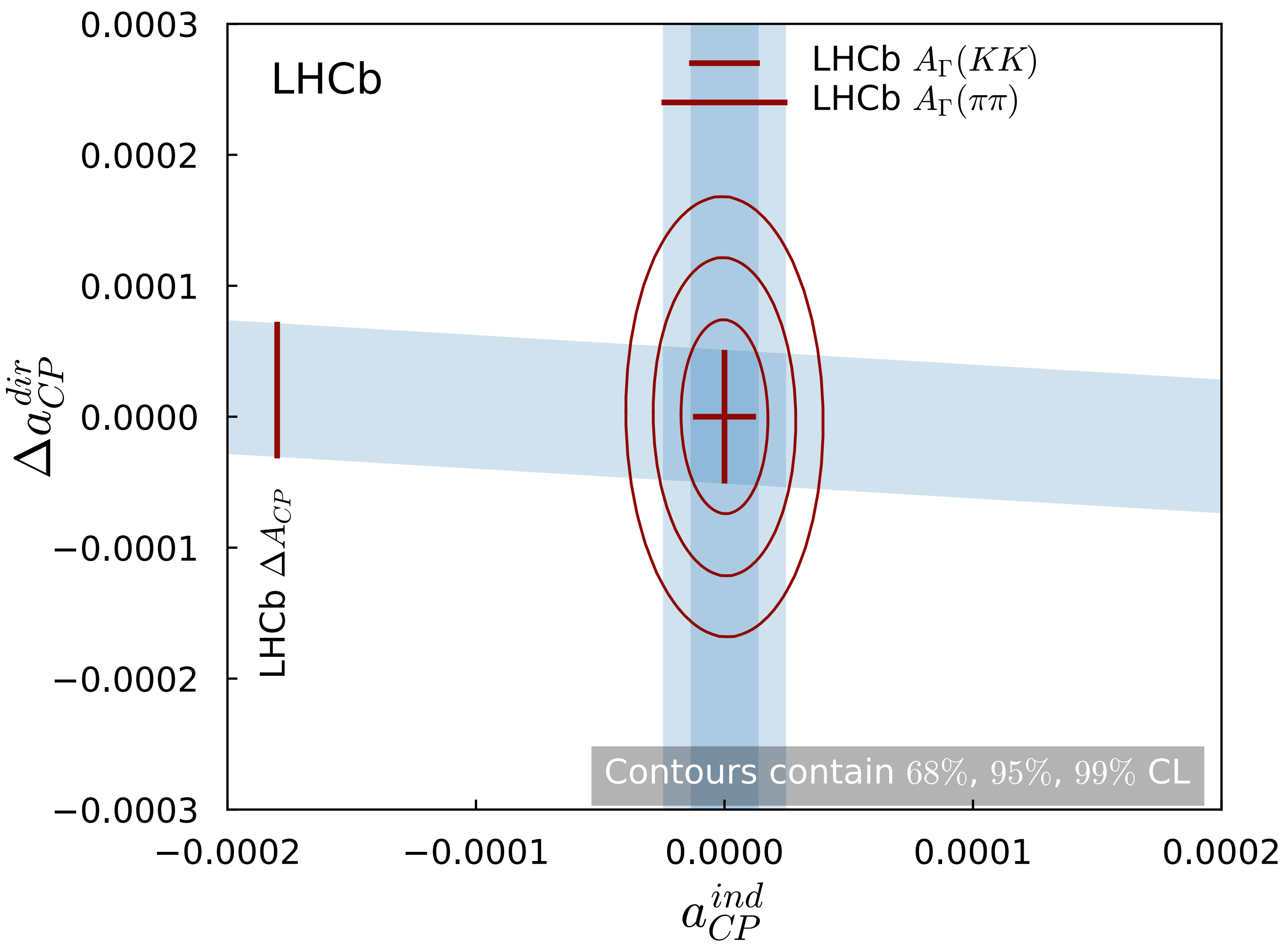
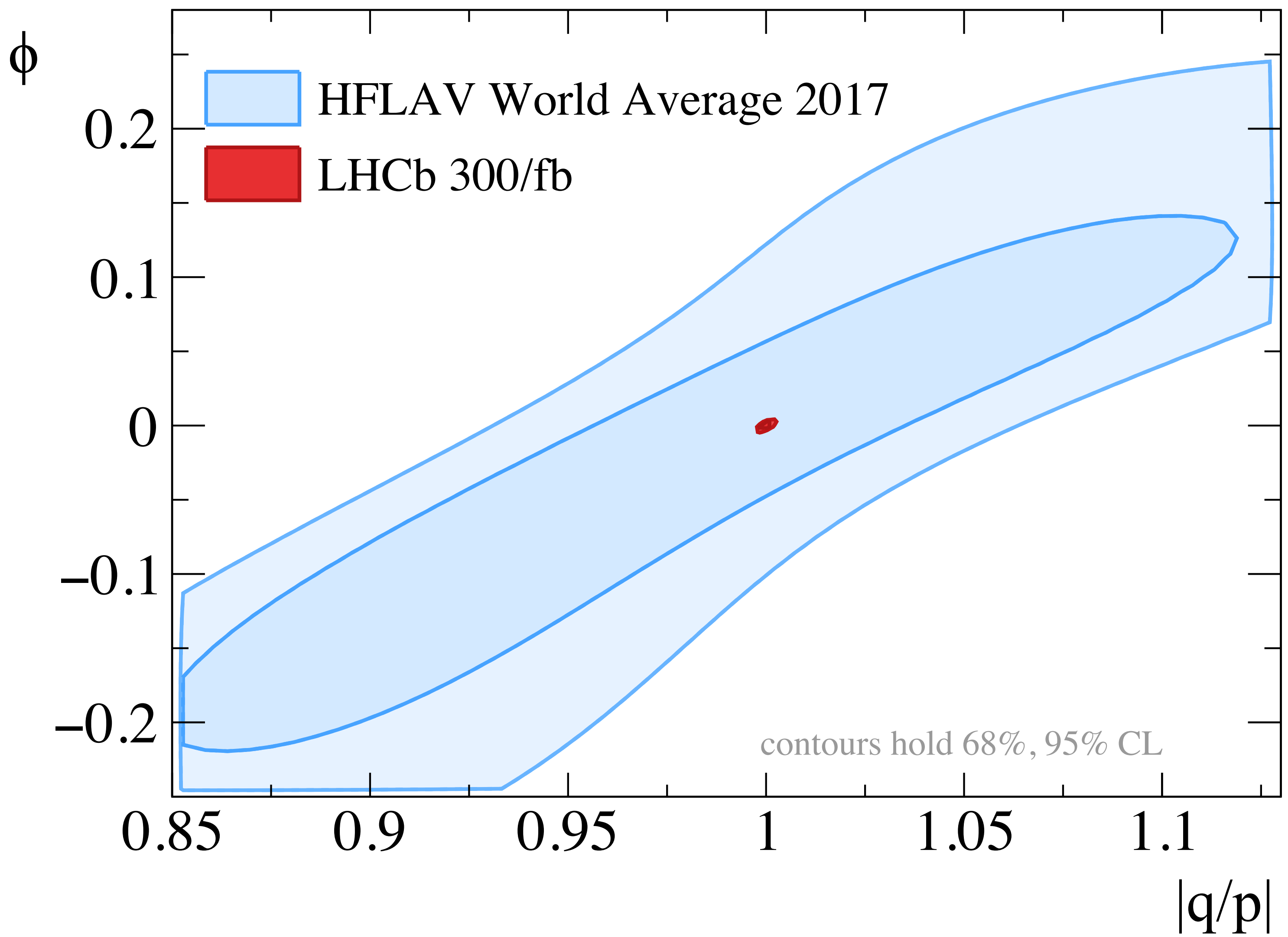
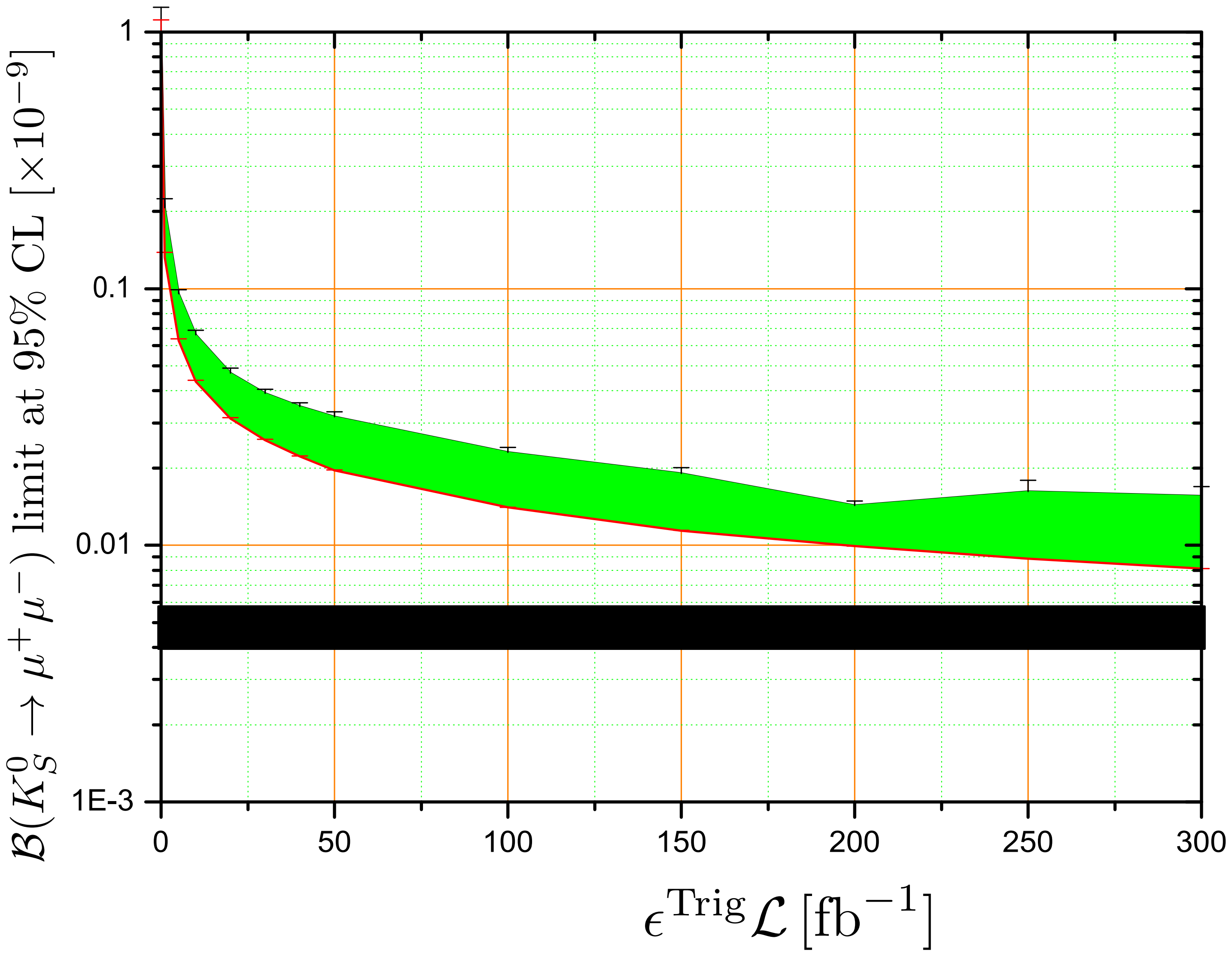
The biggest collider charm factory ever

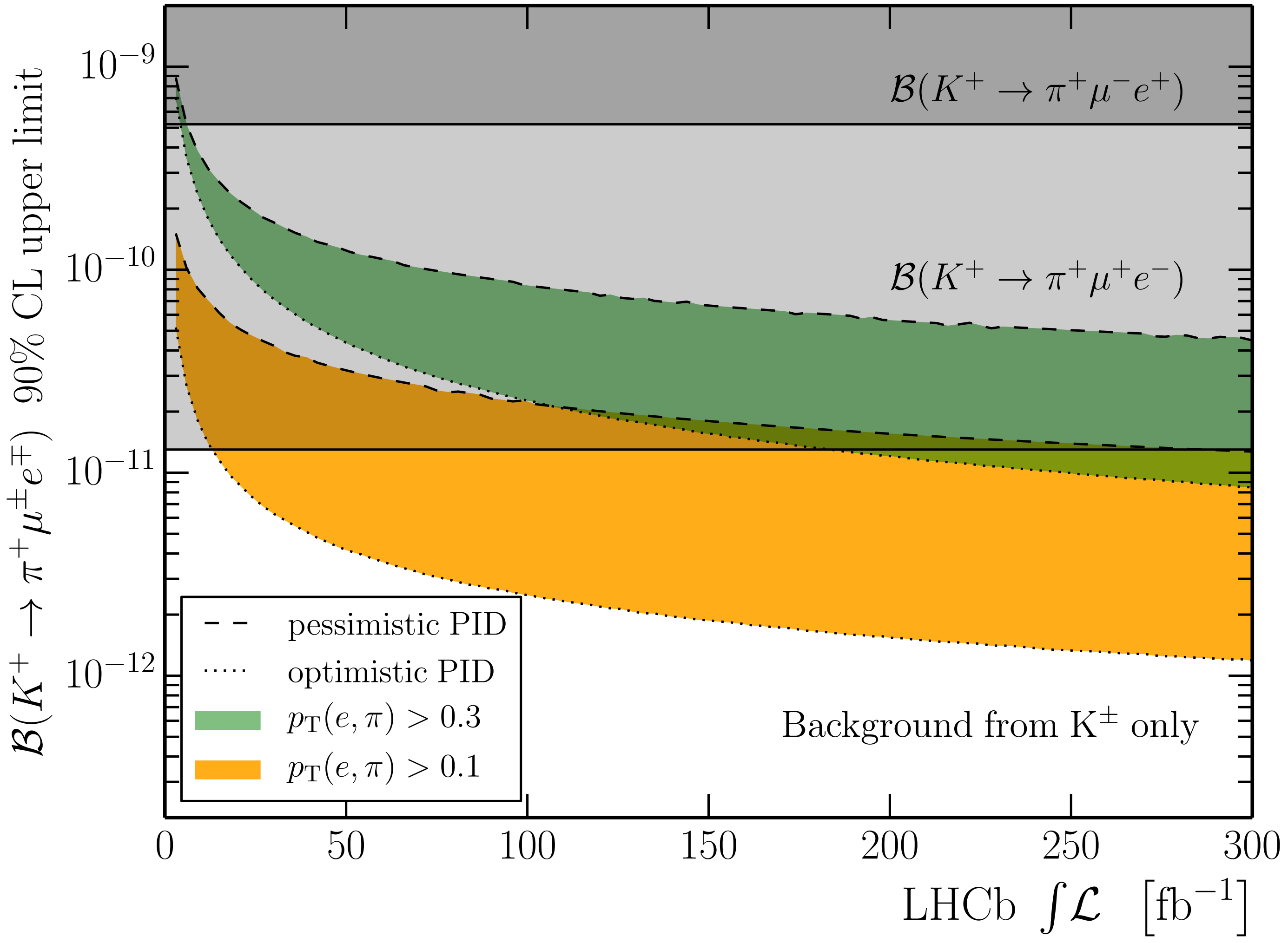




Upgrade II will "see" 10^{15} charm hadrons

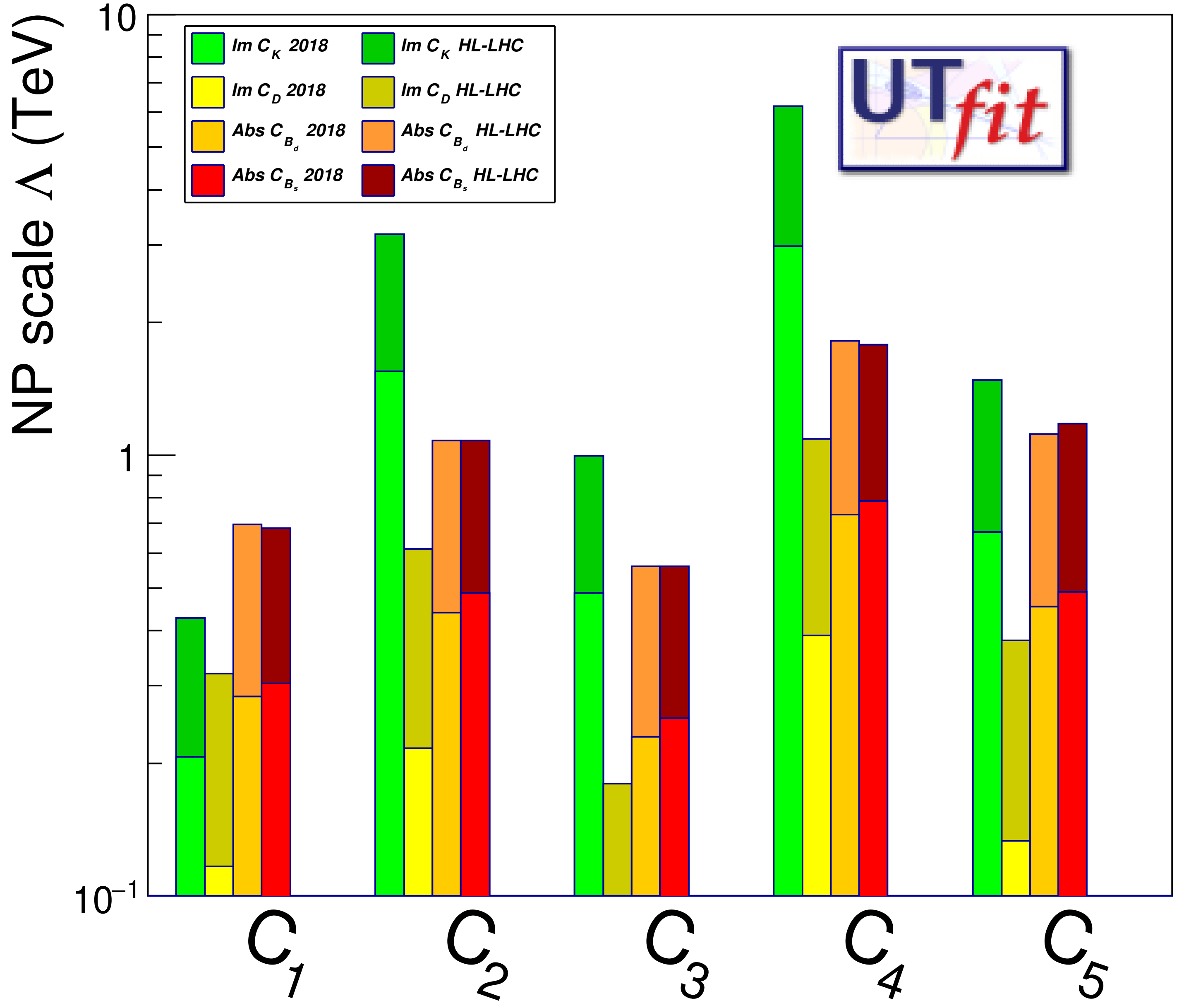
And what about Kaons?





Excellent prospects in both rare decays and LFV

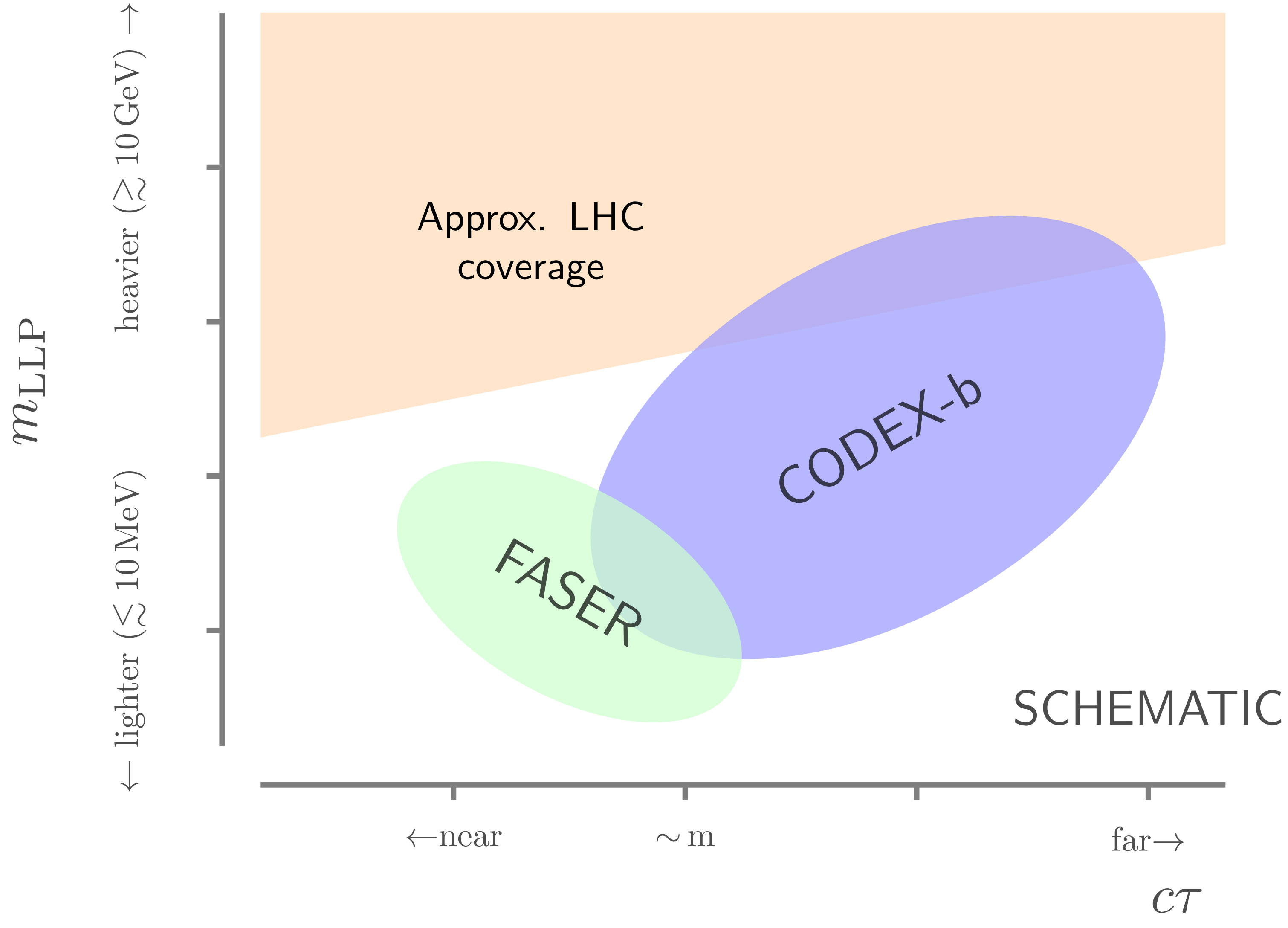
Conclusion

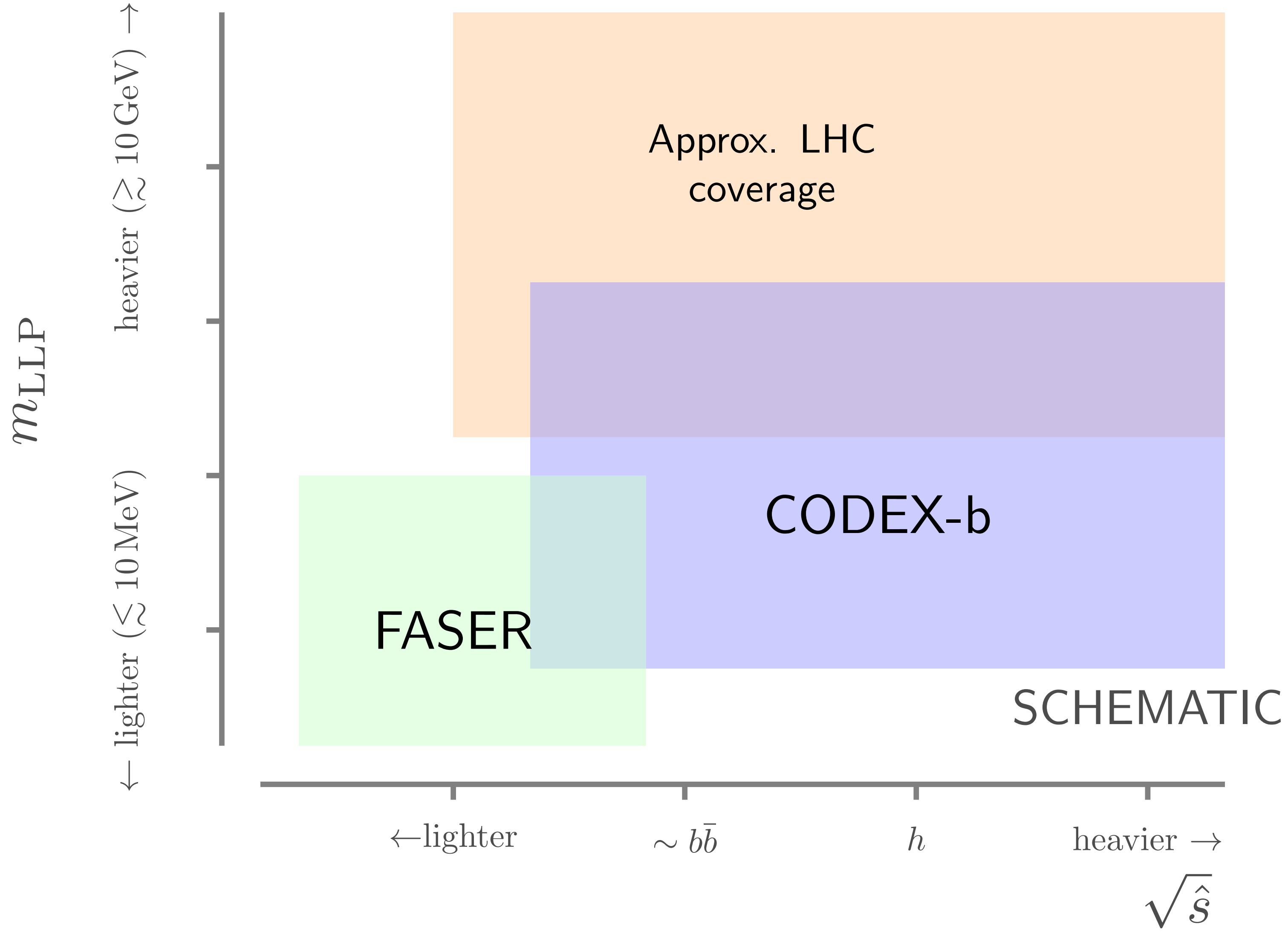


Integrated Luminosity	$3\ \mathrm{fb}^{-1}$	$23\ \mathrm{fb}^{-1}$	$300\ \mathrm{fb}^{-1}$
R_K and R_{K^*} measurements			
$\sigma(C_9)$	0.44	0.12	0.03
$\Lambda^{\text{tree generic}}$ [TeV]	40	80	155
$\Lambda^{\text{tree MFV}}$ [TeV]	8	16	31
$\Lambda^{\text{loop generic}}$ [TeV]	3	6	12
$\Lambda^{\text{loop MFV}}$ [TeV]	0.7	1.3	2.5
$B^0 \to K^{*0}\mu^+\mu^-$ angular analysis			
$\sigma^{\text{stat}}(S_i)$	0.034–0.058	0.009–0.016	0.003–0.004
$\sigma(C'_{10})$	0.31	0.15	0.06
$\Lambda^{\text{tree generic}}$ [TeV]	50	75	115
$\Lambda^{\text{tree MFV}}$ [TeV]	10	15	23
$\Lambda^{\text{loop generic}}$ [TeV]	4	6	9
$\Lambda^{\text{loop MFV}}$ [TeV]	0.8	1.2	1.9

The Upgrade II reach makes it a dream worth chasing

Bonus: CODEX-b!





Voire slides de reunion vendredi pour plus des details

BACKUP