Prospects for flavour physics with Belle II

Boštjan Golob
University of Ljubljana/Jožef Stefan Institute
& Belle/Belle II Collaboration

University of Ljubljana

BELLE

Belle II

"Jožef Stefan" Institute

Introduction

Missing energy

(Semi)Inclusive decays

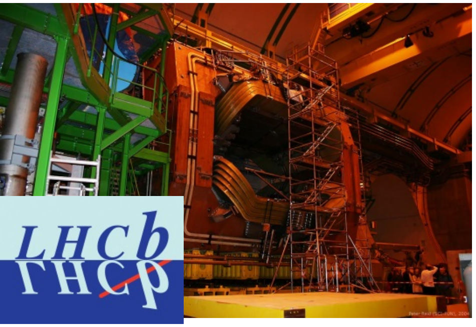
Neutrals

Summary

HIGGS MAXWELL WORKSHOP 2017

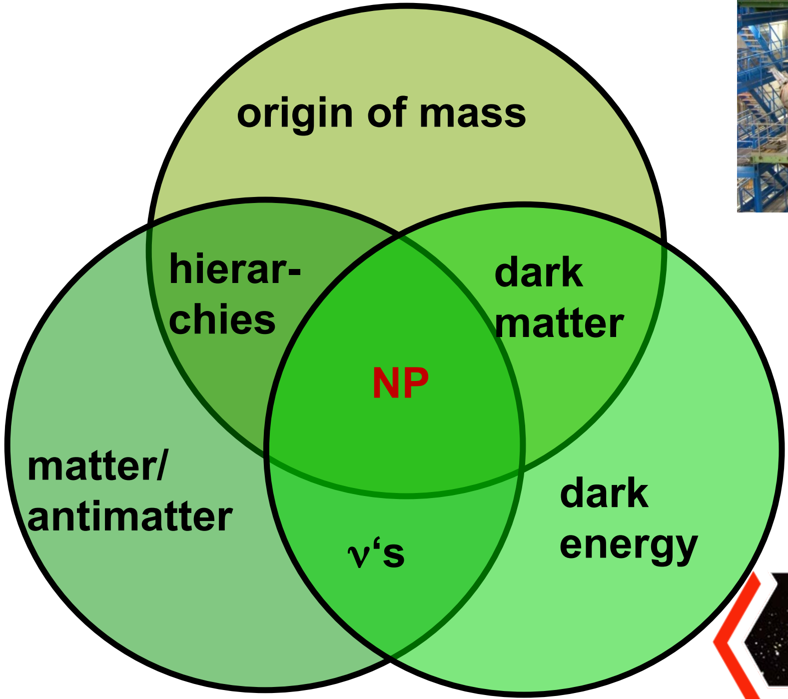
Introduction

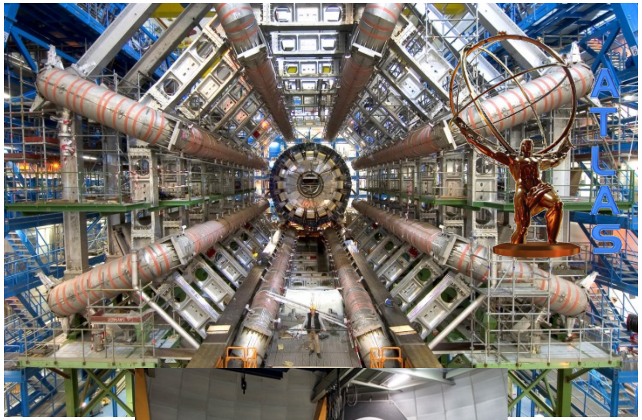
TRIPLE APPROACH
(... TO CONTEPMPORARY HIGH ENERGY PHYSICS)

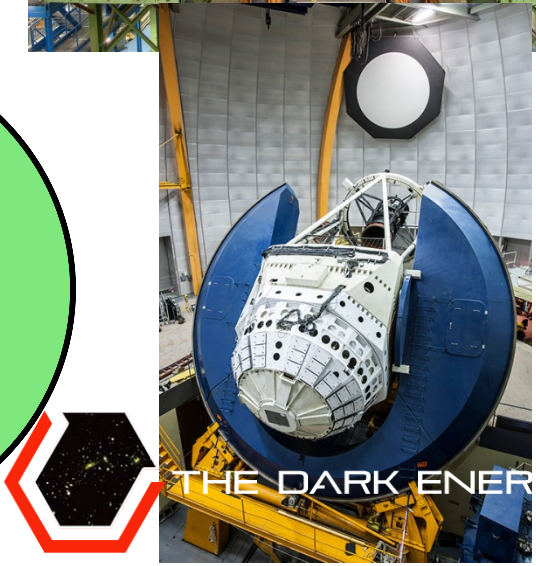


Intensity Frontier

Energy Frontier







Cosmic Frontier

Why Flavor Physics?

Why test the flavor sector of SM?

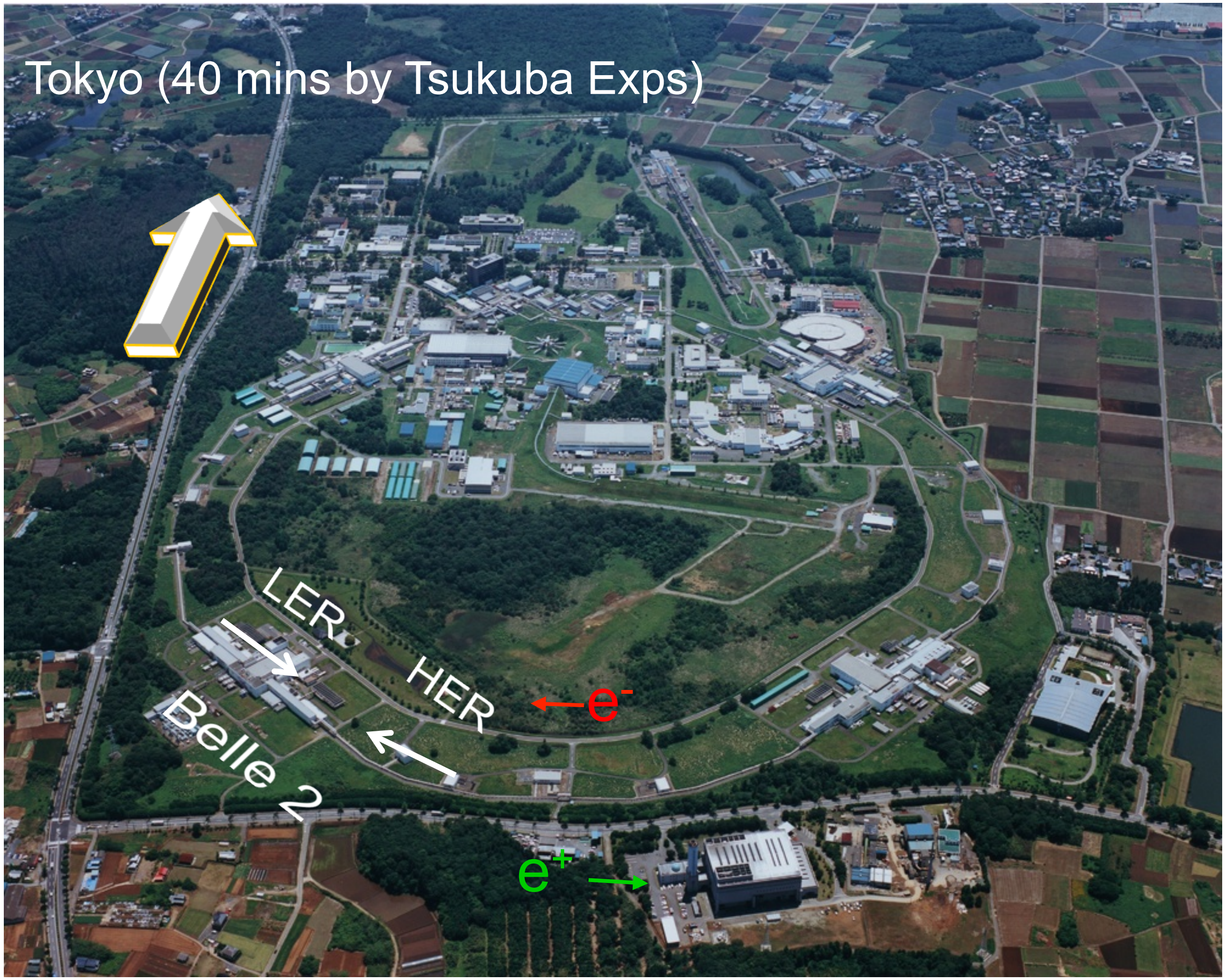
- To confirm the SM (Cabibbo-Kobayashi-Maskawa) picture of quark mixing  2008

- SM is phenomenological description of se energies achieved so far
- Several reasons for NP existence (e.g. to preserve unitarity $M_{Higgs} \sim \mathcal{O}(100\ \mathrm{GeV})$;  2013 only possible through precise cancellation; hierarchy problem solved with Supersymmetry, Extra dimensions, etc.; CP violation is one of necessary conditions for matter dominated Universe; A.D. Sakharov, Pisma Zh. Exp. Teor. Fiz. 5, 3

CPV observed so far in subatomic world not sufficient for observed matter dominance in the Universe)
- Flavor mixing in extensions of SM (CKM matrix or equivalent) can identify nature of NP

Accelerator

"SuperKEKB"



SuperKEKB:

e^- (HER): 7.0 GeV
e^+ (LER): 4.0 GeV

$E_{CMS}=M(\Upsilon(4S))c^2$

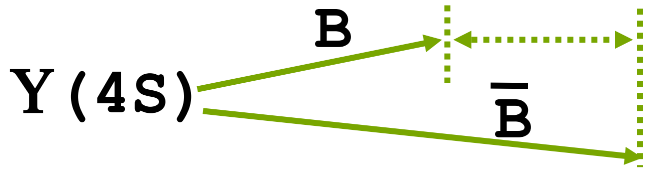
$dN_f/dt = \sigma(e^+e^- \rightarrow f)\,\mathcal{L}$
$\mathcal{L} = 8\text{x}10^{35}\ \text{cm}^{-2}\ \text{s}^{-1}$

Introduction

B Factories

$\sqrt{s}$=10.58 GeV

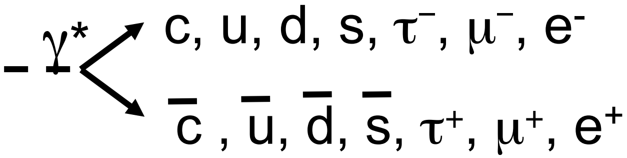
e^+ → Υ(4S) ← e^-



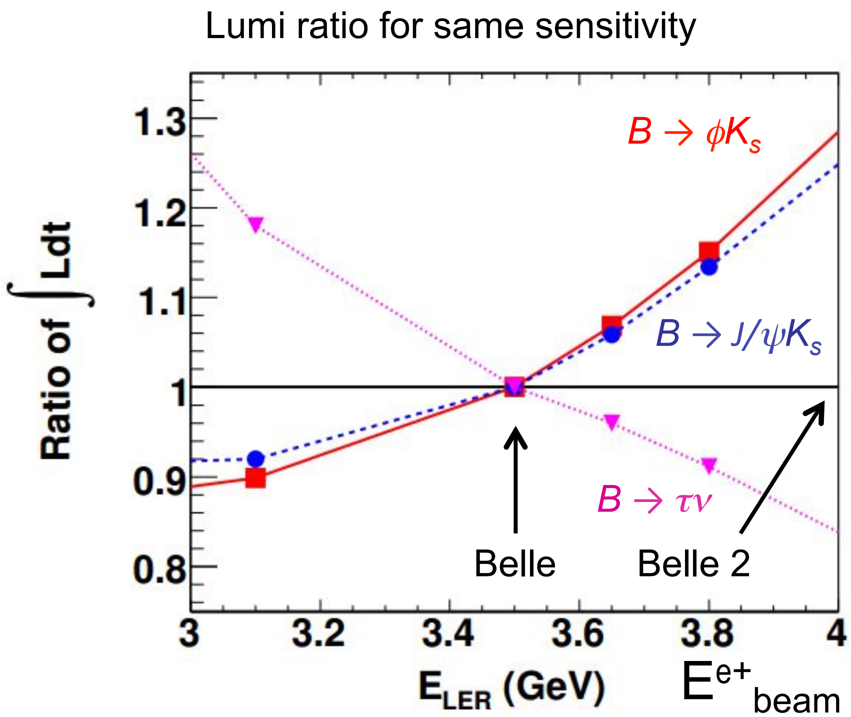
p(e^-)= 7 GeV p(e^+)= 4 GeV

on resonance production
$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B^0\bar{B}^0, B^+B^-$
$\sigma(B\bar{B}) \approx 1.1$ nb
(~1.1x10^9 BB pairs)

continuum production
$\sigma(c\,\bar{c}) \approx 1.3$ nb
(~1.4x10^9 X_cY_c pairs)



Introduction



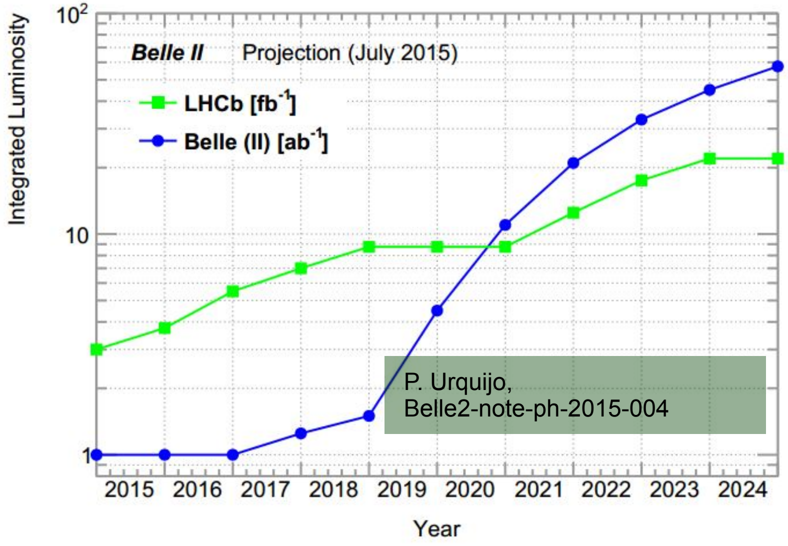
E^{e-}_{beam} from Υ(4S) mass

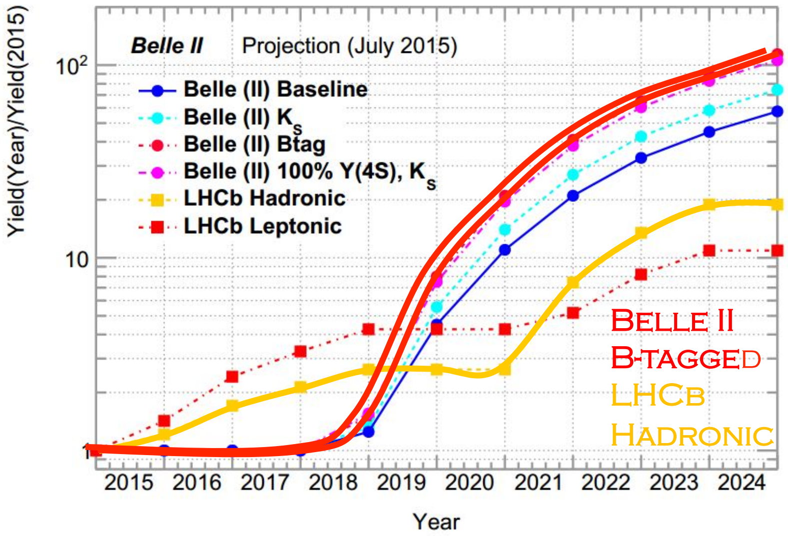
B. Golob, K. Trabelsi, P. Urquijo, Belle2-note-ph-2015-002

Belle 2: improved K_S reconstr.;
improved hadr. B tagging;

LHCb: $\sigma \propto \sqrt{s}$;
run 2 50% less eff. for hadronic triggers than run 1;
run 3 increase eff. for hadr. triggers by 2x w.r.t. run 1;

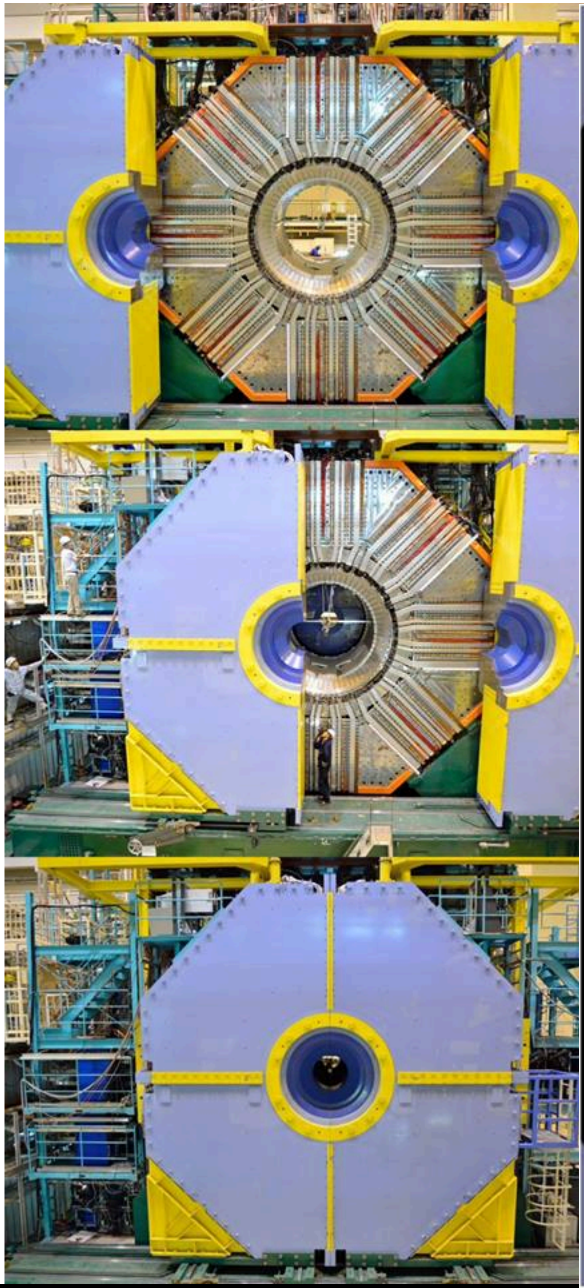
LHCb EPJC 73, 2373

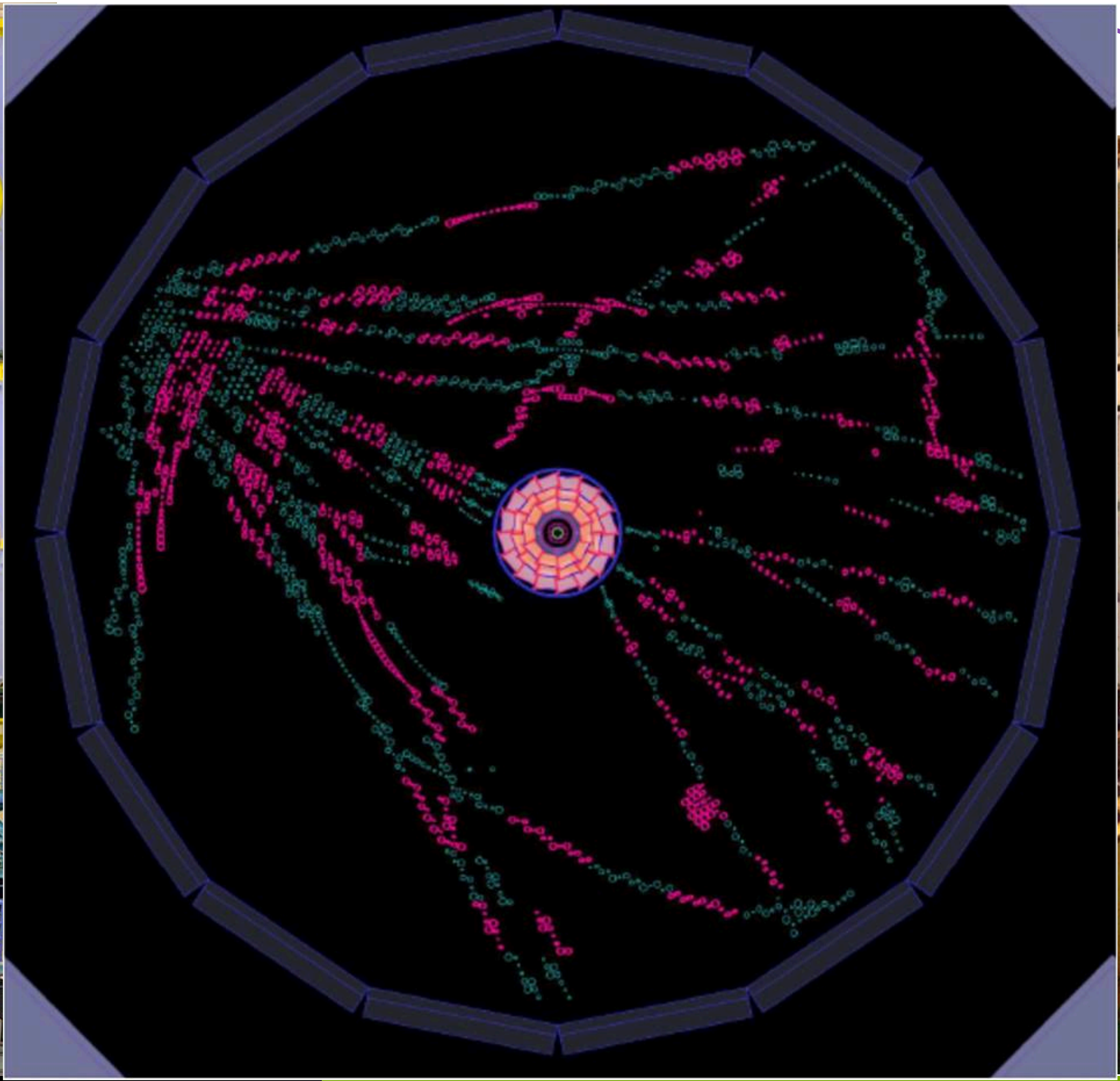




Relative yield increase

Introduction





Subjects

METHODS AND PROCESSES WHERE BELLE 2 CAN PROVIDE IMPORTANT INSIGHT INTO NP COMPLEMENTARY TO OTHER EXPERIMENTS:

E_{MISS}:

$\mathcal{B}(B \to \tau\nu)$, $\mathcal{B}(B \to X_c\tau\nu)$, $\mathcal{B}(B \to h\nu\nu)$,...

(SEMI)INCLUSIVE:

$\mathcal{B}(B \to s\gamma)$, $A_{CP}(B \to s\gamma)$, $\mathcal{B}(B \to sll)$, ...

NEUTRALS:

$S(B \to K_S\pi^0\gamma)$, $S(B \to \eta' K_S)$, $S(B \to K_SK_SK_S)$, $\mathcal{B}(\tau \to \mu\gamma)$, $\mathcal{B}(B_s \to \gamma\gamma)$, ...

DETAILED DESCRIPTION OF PHYSICS PROGRAM AT BELLE 2 IN:

A.G. AKEROYD ET AL., ARXIV: 1002.5012 — Physics at Super B Factory

Super$B$ Progress Reports **Physics** — B. O'LEARY ET AL., ARXIV: 1008.1541

The Physics of the B Factories

ED. A.J. BEVAN, B. GOLOB, TH. MANNEL, S. PRELL, AND B.D. YABSLEY, EUR. PHYS. J. C74 (2014) 3026

B.G.,, K, TRABELSI, P. URQUIJO, BE LLE2-NOTE- PH-2015-002

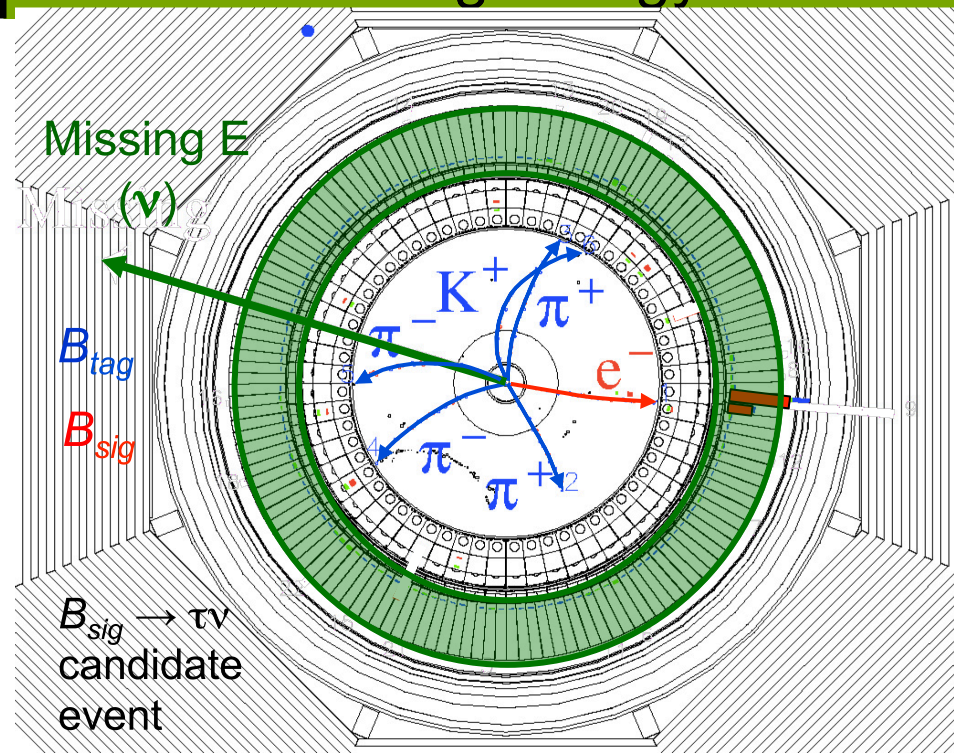
IMPACT OF BELLE II ON FLAVOR PHYSICS

P. URQUIJO, BE LLE2-NOTE- PH-2015-002

BELLE I I - LHCB MEASUREMENT EXTRAPOLATION COMPARISONS

Missing energy

$B \to \tau\nu,\ h\nu\nu,\ X_C\tau\nu, \ldots$

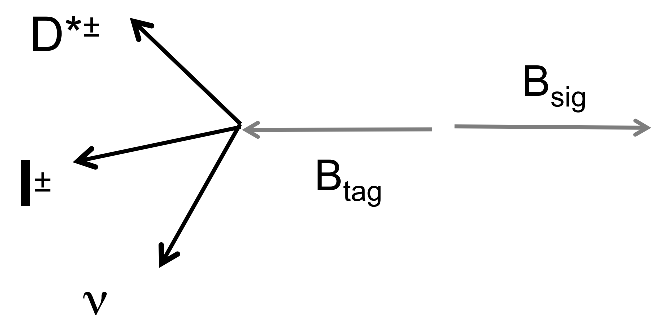


possible to reconstruct events with ν's;

fully (partially) reconstruct B_{tag};
reconstruct $h^{\pm}$ from B_{sig};
no additional energy in EM calorim.;
signal at E_{ECL}~0;

Partial reconstruction (semileptonic tagging):

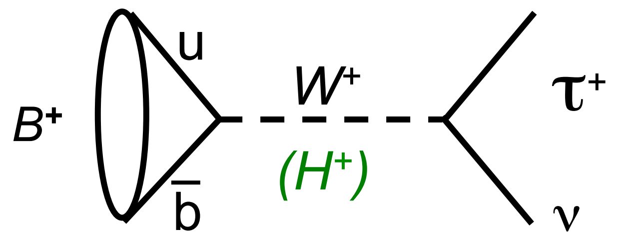
$$\cos\theta_{B\text{-}D^*\ell} \equiv \frac{2E_{\rm beam}E_{D^*\ell} - m_B^2 - M_{D^*\ell}^2}{2|\vec{p}_B|\cdot|\vec{p}_{D^*\ell}|}$$



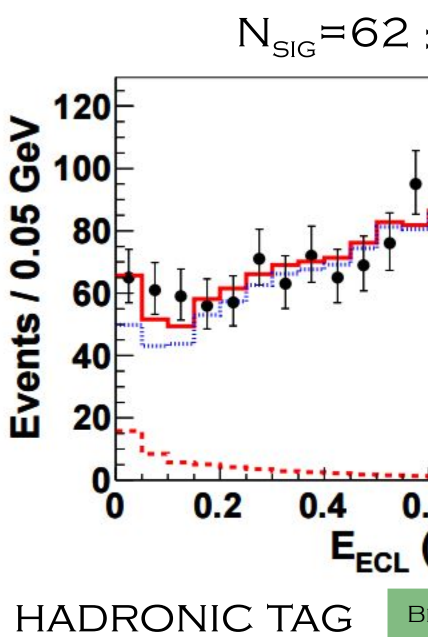
ε_{tag}~1%

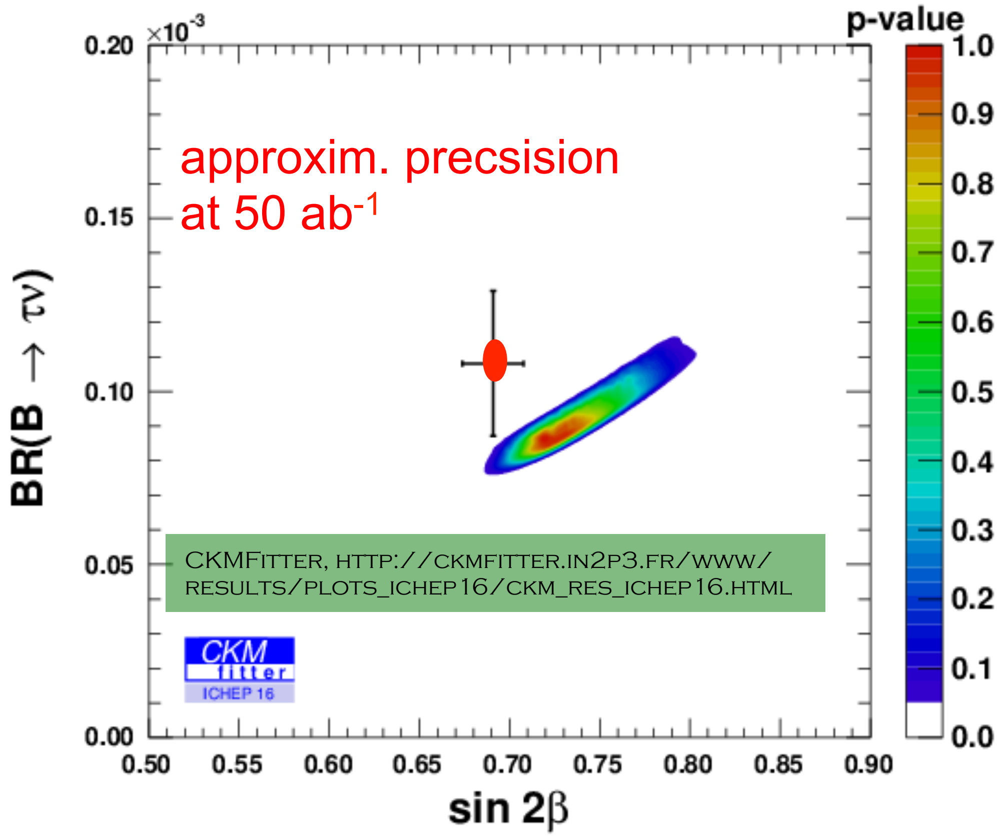
$B \to \tau\nu$

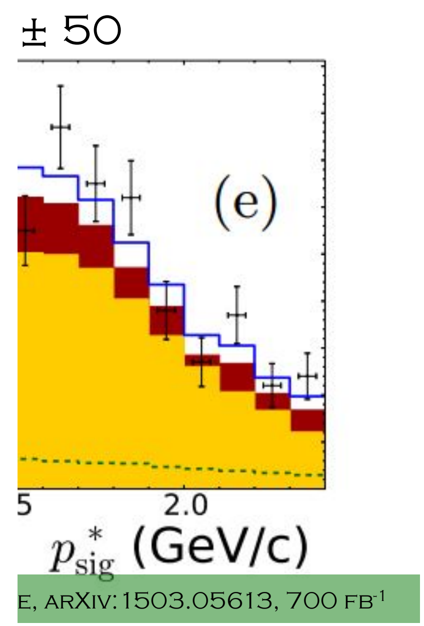
*Does nature have multiple Higgs bosons?**



$$\mathcal{B}(B^+ \to \tau^+\nu) = \mathcal{B}^{SM}(B^+ \to \tau^+\nu)$$







* Key physics questions, T. Browder et al., CERN Courier, August 2016

Missing energy

$B \to D^{*}\tau\nu$

Belle, arXiv:1603.06711, 700 fb[-1]

Are there sources of lepton-flavour violation (LFV) beyond the SM?

R(D$^{(*)}$) = **B**($B \to D^{*}\tau\nu$) / **B**($B \to D^{*} l \nu$) l =e,μ

$R(D)_{SM}$=0.300 ±0.008

H. Na et al., Phys.Rev.D 92, 054410 (2015)

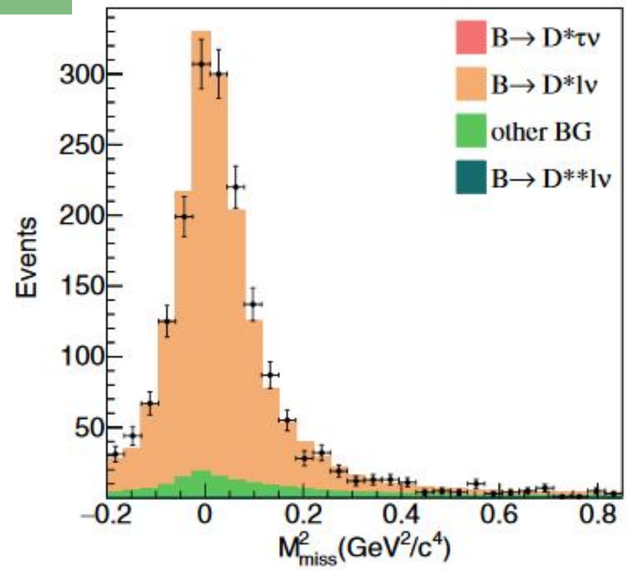
$R(D^{*})_{SM}$ =0.252 ±0.003

S.Fajfer et al., Phys.Rev.D85(2012) 094025

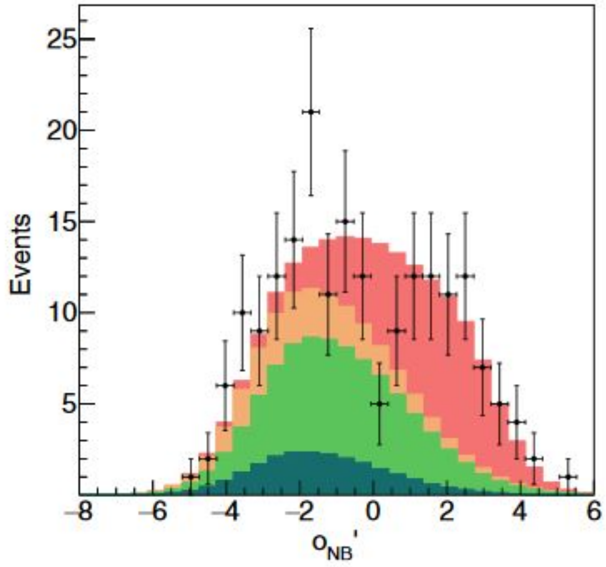
$$M^2_{\rm miss} = (p_{e^+e^-} - p_{\rm tag} - p_{D^{(*)}} - p_\ell)^2/c^2$$

use NN with M^2_{miss}, E_{vis}, $\cos\theta_{B\text{-}D^{*} l}$ ^{sig}.

data sample with low M^2_{miss} used to fit the background contribution



signal is to the right →



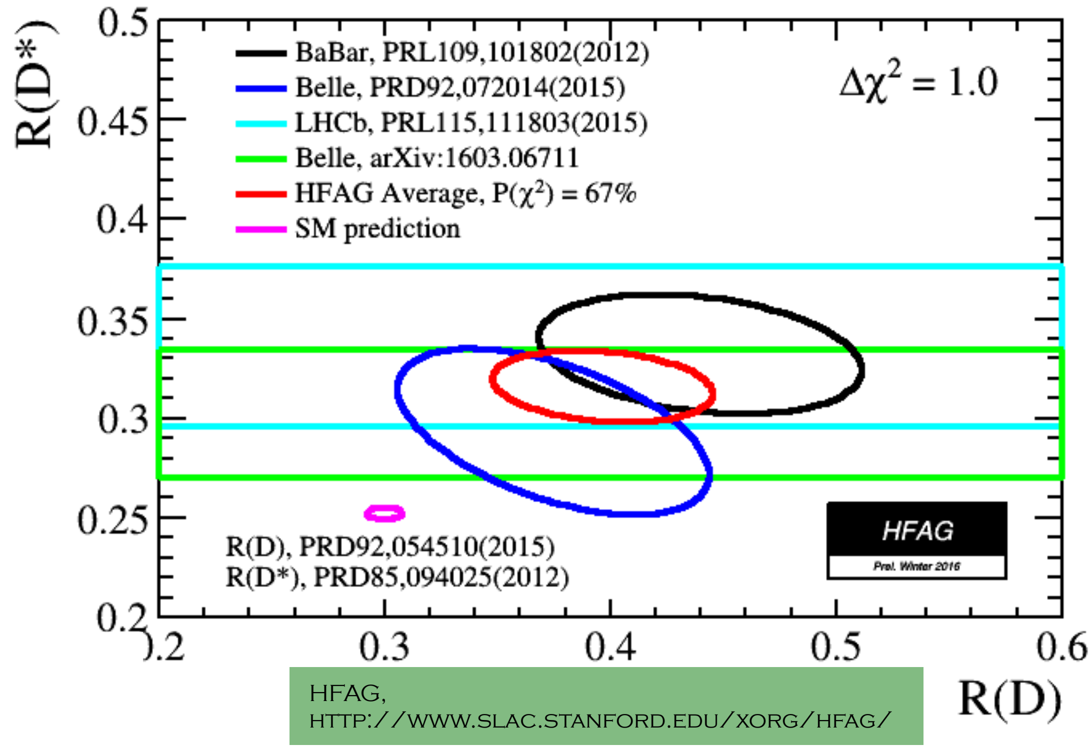
NN output for data with M^2_{miss} > 0.85 GeV^2

Missing energy

$B \to D^* \tau \nu$

R(D*)=0.302±0.030±0.011

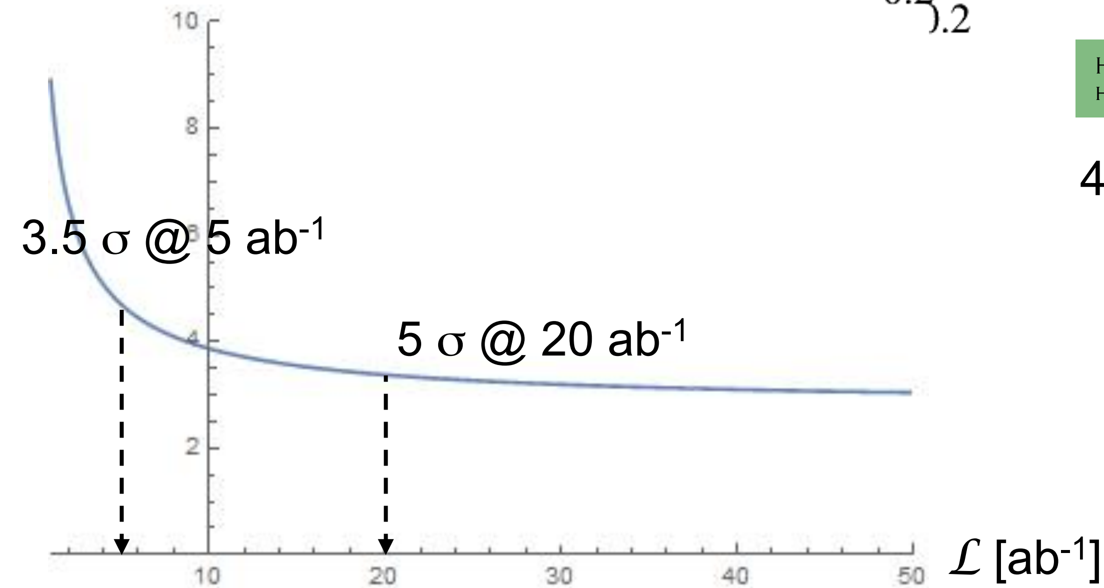
Belle, arXiv:1603.06711, 700 fb-1



HFAG, http://www.slac.stanford.edu/xorg/hfag/

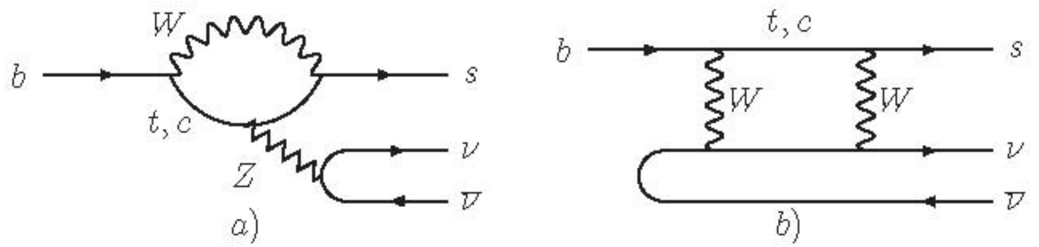
4σ discrepancy with SM

$\sigma(R(D^*))/R(D^{(*)})[\%]$

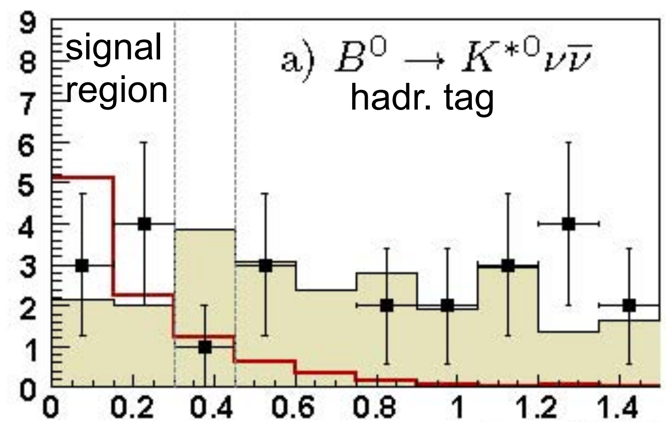


Missing energy

$B \to K^{(*)}\nu\nu$



DOES NATURE HAVE A LEFT–RIGHT SYMMETRY, AND ARE THERE FLAVOUR-CHANGING NEUTRAL CURRENTS BEYOND THE SM?

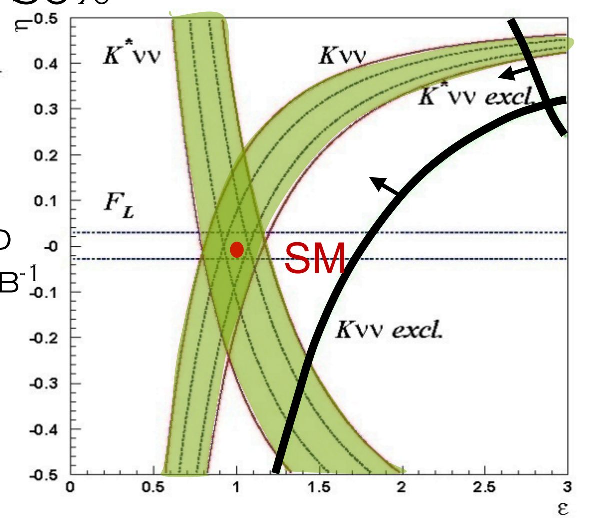


Belle, PRL99, 221802 (2007), 490 fb^{-1}

@ 50 AB^{-1}: BR'S EXPECTED TO BE „MEASURED" TO 30%

$$\frac{-\mathrm{Re}\,(C_L^\nu C_R^{\nu *})}{|C_L^\nu|^2 + |C_R^\nu|^2}$$

APPROX. EXPECTED PRECISION @ 50 AB^{-1}



$$\frac{\sqrt{|C_L^\nu|^2 + |C_R^\nu|^2}}{|(C_L^\nu)^{\mathrm{SM}}|}$$

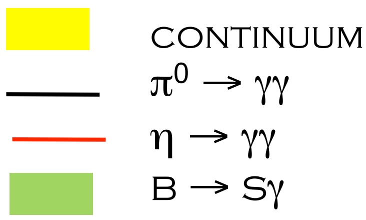
W. ALTMANNSHOFER ET AL., ARXIV:0902.0160

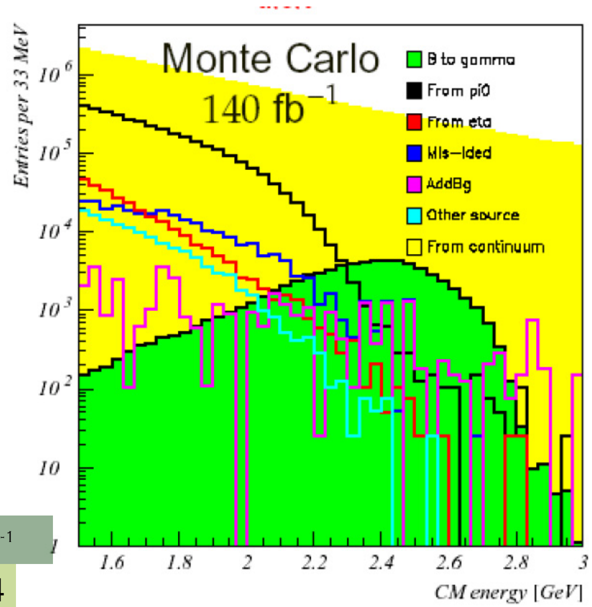
Inclusive

$B \to s(+d)\,\gamma$

Experimental challenge:
huge bkg;
only γ reconstructed in the signal side

1.26 GeV < E < 2.20 GeV

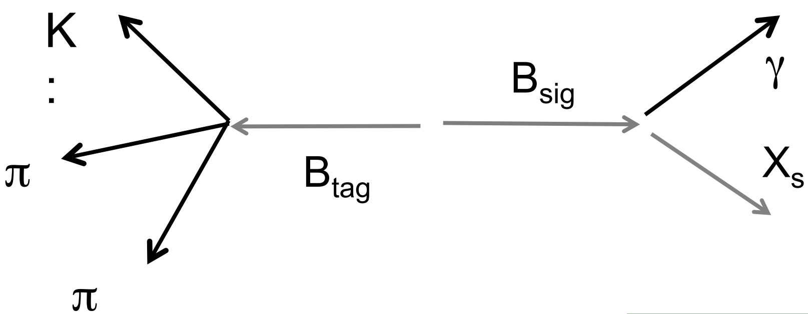


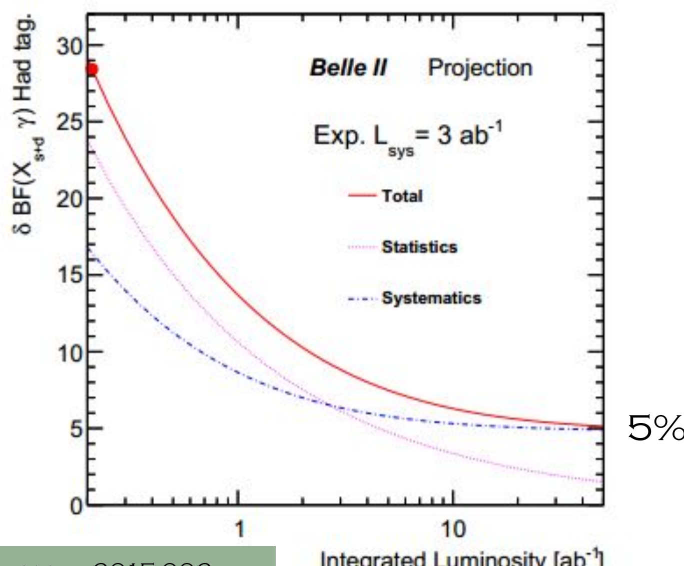


Belle, PRL103, 241801, (2008), 605 fb[-1]

$$Br(B \to X_s \gamma; 1.7\,GeV < E_\gamma) = (3.47 \pm 0.15 \pm 0.40)\cdot 10^{-4}$$

Different method: hadronic tagging (= full reconstruction of B_{TAG});
reduction of system.uncertainty on the account of lower efficiency (ε_{HAD} ~ 0.5%);





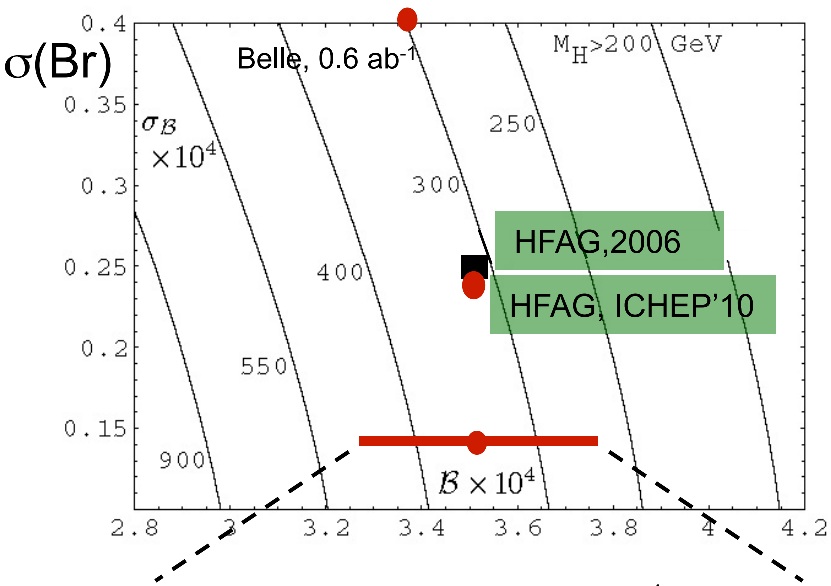
B. Golob, K. Trabelsi, P. Urquijo,, Belle2-note-ph-2015-002

Inclusive

$B \to s(+d)\,\gamma$

Does nature have multiple Higgs bosons?

M. Misiak et al., PRL98, 022002 (2007)



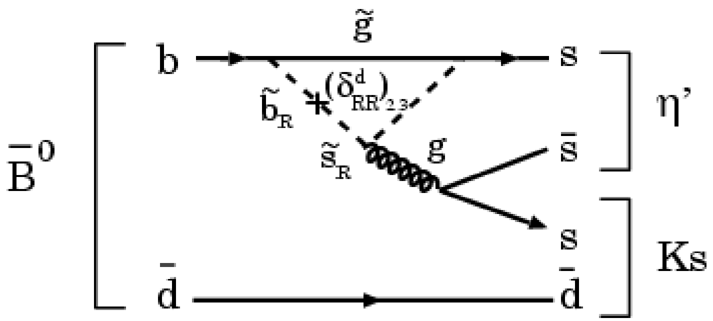
precision @ 50 ab^{-1} &
possible range of central values

CPV in $B \to sq\bar{q}$

Are there new CP-violating phases in the quark sector?

some uncertainties cancel in ΔS

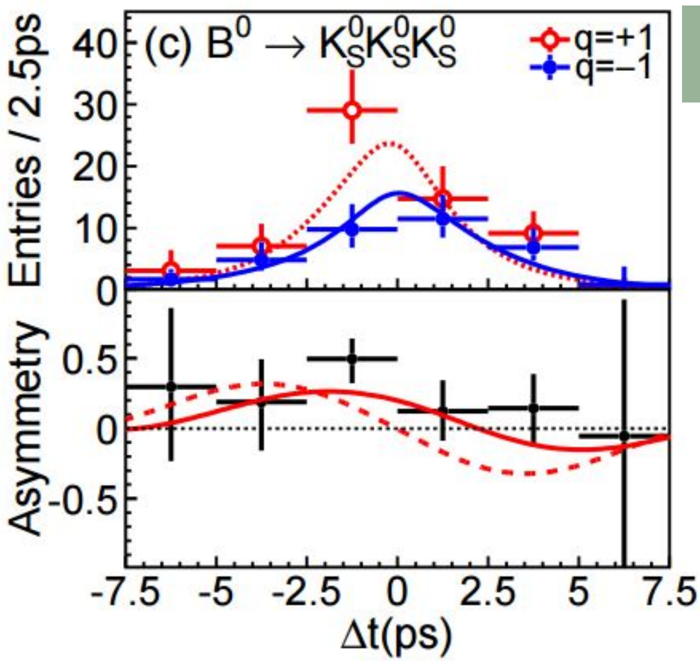
(vtx reconstr., flavor tag, likelihood fit) ;
better K_S eff. with vtx hits - larger vtx radius, 30%);
vtx reconstr. improved with better tracking;



41 new phases in MSSM

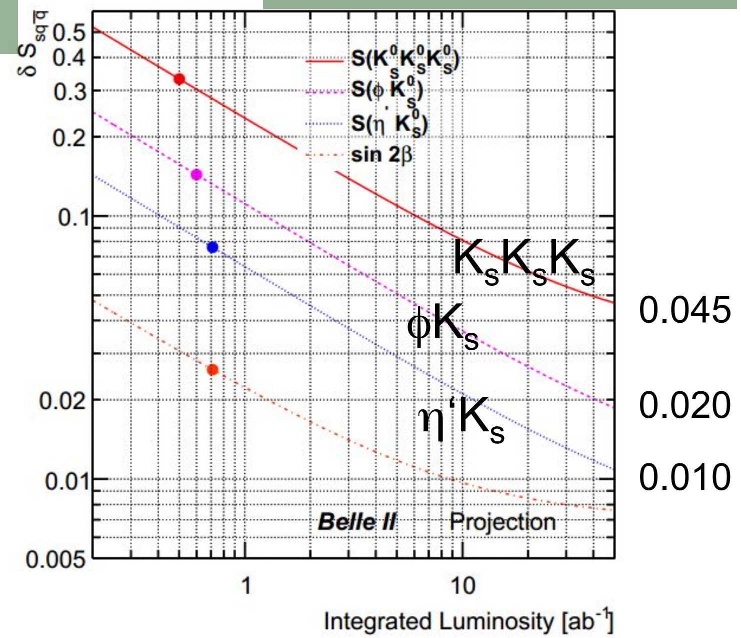
$\Delta S = \sin 2\phi_1^{eff} - \sin 2\phi_1$

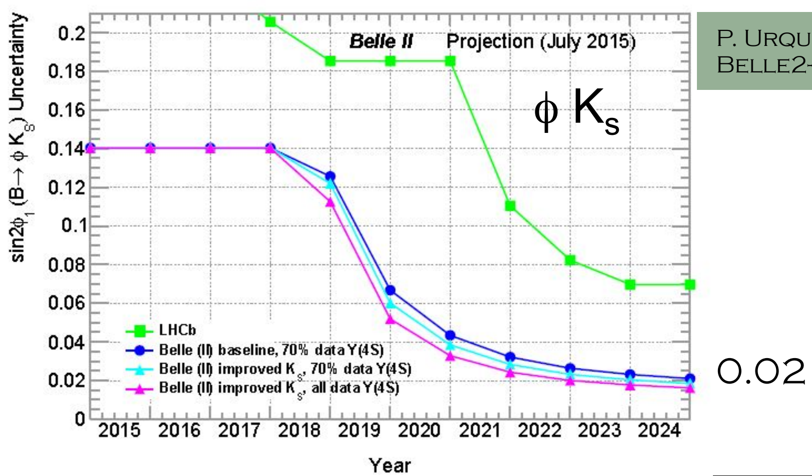
CPV in $B \to s q\bar{q}$



Belle, PRD91, 014011 (2015), 500 fb-1

B. Golob, K. Trabelsi, P. Urquijo, Belle2-note-ph-2015-002





P. Urquijo, Belle2-note-ph-2015-004

typical theory uncertainty
$\sigma(\Delta S^{\eta' K_s}) < \sigma(\Delta S^{\phi K_s}) \sim 0.05$

Why Flavor Physics?

MICHAEL E. PESKIN, FINAL SPEACH OF LEPTON PHOTON 2011

M.E. Peskin, arXiv:1110.3805

IF THE HIGGS BOSON MASS IS ABOVE THE LEP LOWER BOUND OF 114 GEV AND BELOW THE UPPER LIMIT FROM THE LHC ... THE **STANDARD MODEL IS SELF-CONSISTENT** UP TO VERY HIGH ENERGIES, **ALL THE WAY TO THE PLANCK SCALE.** THUS, A POSSIBLE OUTCOME OF THE LHC EXPERIMENTS COULD BE **THE END OF EXPERIMENTAL PARTICLE PHYSICS.**

...

THIS WOULD LEAVE US IN A TERRIBLE SITUATION. **ALL OF THE QUESTIONS** THAT WE HAVE TODAY ABOUT THE PROPERTIES OF PARTICLES WITHIN THE STANDARD MODEL WOULD NOT ONLY BE LEFT UNANSWERED BUT **WOULD BE UNANSWERABLE.**

...

THOSE WHO CHOOSE TO BELIEVE THAT THE STANDARD MODEL IS LITERALLY TRUE SHOULD UNDERSTAND THAT THIS IS WHAT THEY ARE BUYING.

....

THERE IS AN **ALTERNATIVE POINT OF VIEW.**

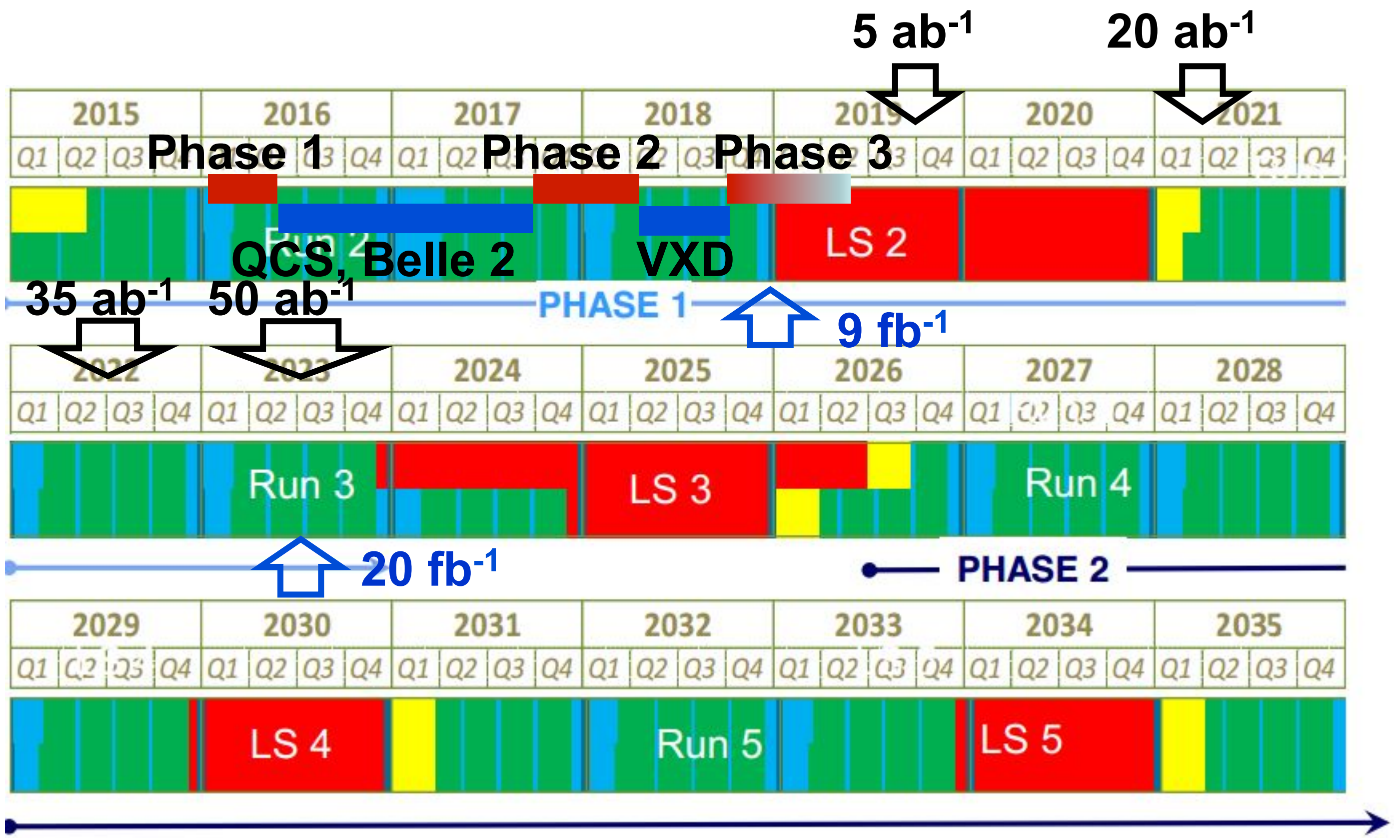
....

THAT POINT OF VIEW IS THE OPTIMISM THAT THE PHYSICS OF THE HIGGS FIELD AND ELECTROWEAK SYMMETRY BREAKING HAS A MECHANISM, ...

ONLY PEOPLE WHO BELIEVE IN IT CAN MAKE THE DISCOVERY THAT IT IS TRUE.

Luminosity Planning

Super KEKB luminosity planning



Phase 1:
w/o QCS
w/o Belle 2

Phase 2:
w/ QCS
w/ Belle 2
(no VXD)

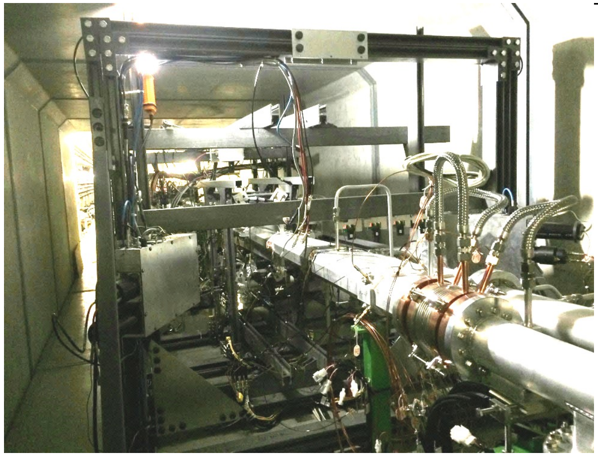
Phase 3:
full Belle 2

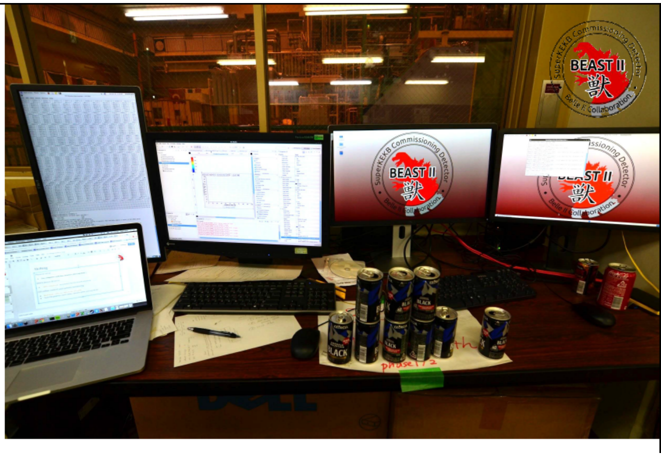
http://lhc-commissioning.web.cern.ch/lhc-commissioning/schedule/LHC%20schedule%20beyond%20LS1%20MTP%202015_Freddy_June2015.pdf

Belle 2 planning

BEAST PHASE I: Simple background commissioning detector (diodes, TPCs, crystals). No final focus (i.e. no luminosity, single beam background studies possible).

Feb – Jun 2016





BEAST PHASE II: More elaborate inner background commissioning detector & full Belle II outer detector. Superconducting final focus, no vertex detectors.

Oct 2017 – Jan 2018

Physics Running

Oct 2018 →

Early running

- need time for calibration of detectors at Υ(4S);
- measurements not requiring sophisticated PID and/or vertex determination;
- maximize impact on existing data samples (e.g. Υ(3S));

Dark matter

$e^+e^- \to \gamma A' \to \gamma \chi\chi$
($M_\chi < M_{A'}/2$)

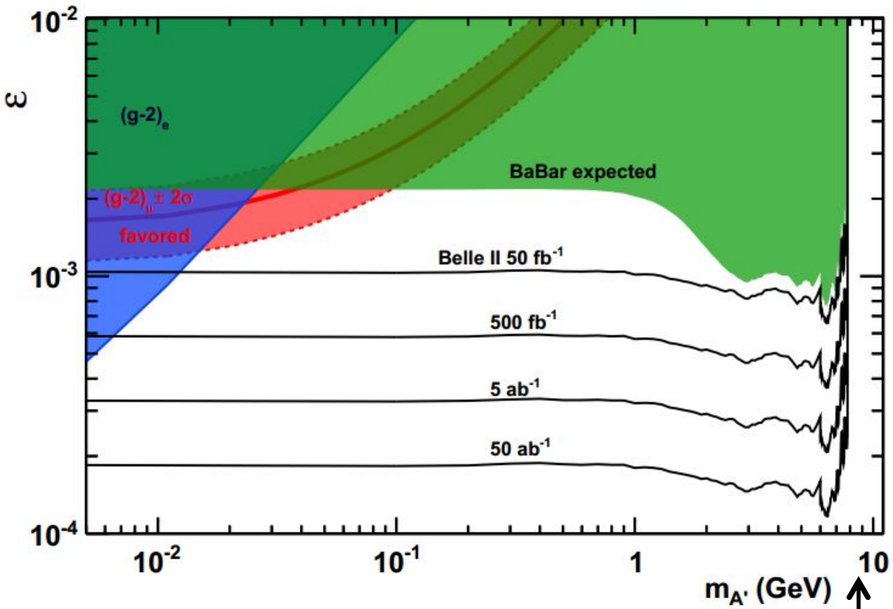
single γ trigger required;
simplified: single γ, $E_\gamma > E_{CUT}$;

high bkg, high trigger rate → low ε

E_{CUT}

main backgrounds:
$e^+e^- \to \gamma e^+e^-$
$e^+e^- \to \gamma\gamma$

A. Bondar et al., Belle2-NOTE-PH-2015-003



ε: γA' coupling

$$M_{A'} < \sqrt{s - 2\sqrt{s}E_{cut}}$$

$B \to \tau\nu$

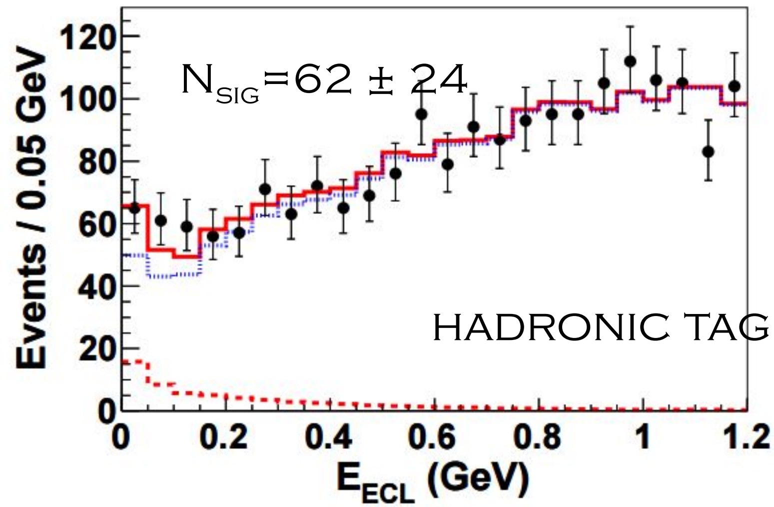
$\mathcal{B}(B^+ \to \tau^+\nu) = (0.72 \pm 0.26 \pm 0.11) \cdot 10^{-4}$

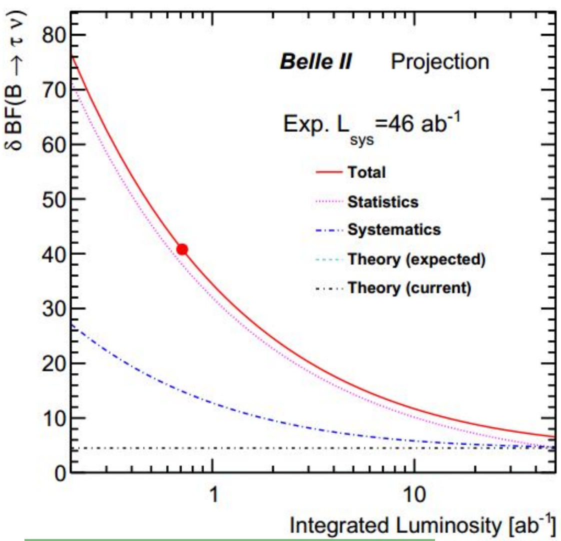
Belle, PRL110, 131801 (2013), 700 fb^{-1}

$\mathcal{B}(B^+ \to \tau^+\nu) = (1.25 \pm 0.28 \pm 0.27) \cdot 10^{-4}$

Belle, arXiv:1503.05613, 700 fb^{-1}

main syst. is reducible: bkg. ECL shape, ε B_{TAG})





P. Urquijo,
BE LLE2-NOTE- PH-2015-002

Projected accuracy on $\mathcal{B}(B^+ \to \tau^+\nu)$

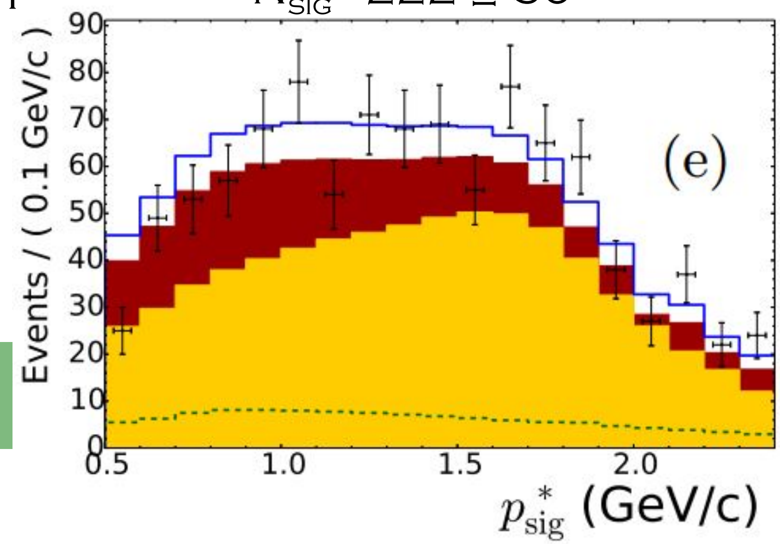
corresponding $|V_{UB}|$ uncertainty (exp.):

semil. tag, 50 ab^{-1}: 4.5%
hadr. tag, 50 ab^{-1}: 3.5%

5×10^{-6}

B. Golob, K. Trabelsi,
P. Urquijo,
Belle2-note-ph-2015-002

N_{SIG}=222 ± 50



SEMIL. TAG

$B \to d\,\gamma$

within SM: $Br(B \to d\gamma) / Br(B \to s\gamma) = (3.8 \pm 0.5) \cdot 10^{-2}$

T. Hurth et al., Nucl.Phys. B704, 56 (2005)

(ratio can be used to determine $|V_{td}/V_{ts}|$)

$Br(B \to s\gamma) = 3.4 \cdot 10^{-4}$

$Br(B \to d\gamma)$ should be measured with an accuracy of ~$2 \cdot 10^{-6}$

sum of exclusive modes: $\sigma(Br(d\gamma)) = (\pm 3 \pm 1) \cdot 10^{-7}$ low X_D mass region

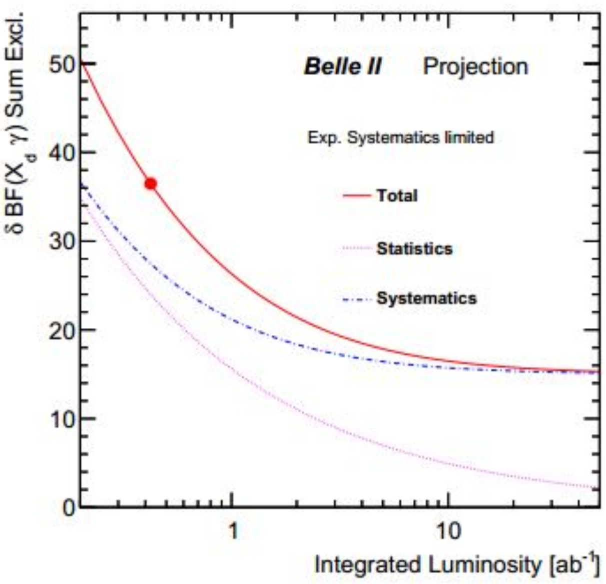
BaBar, PRD82, 051101 (2010), 0.4ab-1

$\sigma(Br(d\gamma)) = (\pm 20 \pm 22) \cdot 10^{-7}$ high X_D mass region

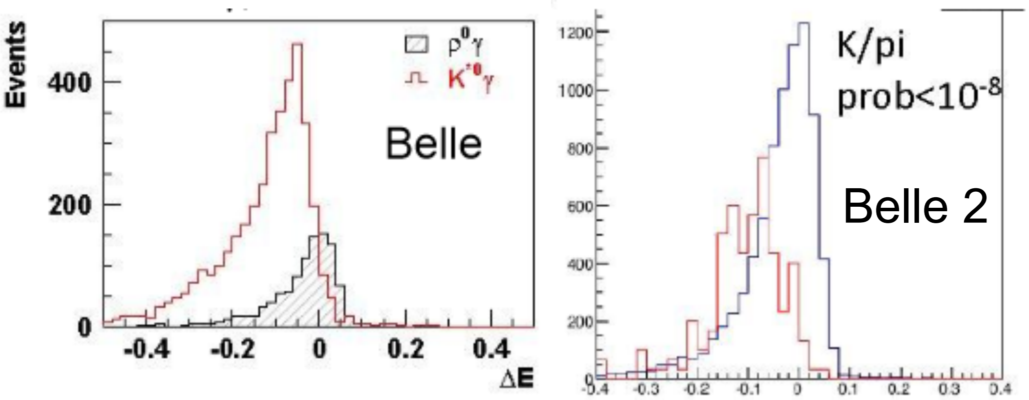
largest syst. uncertainty:
$B \to s\,\gamma$ bkg.;
missing (>= 5 body) modes;

significant improvement necessary

Belle/Belle 2 full simulation:



15%



$B^0 \to K^*(K\pi)\gamma$, $B^0 \to \rho(\pi\pi)\gamma$,
$\Delta E = E_B^* - E_{BEAM}$

$B \to s\gamma$ DCPV

$B \to s\gamma$

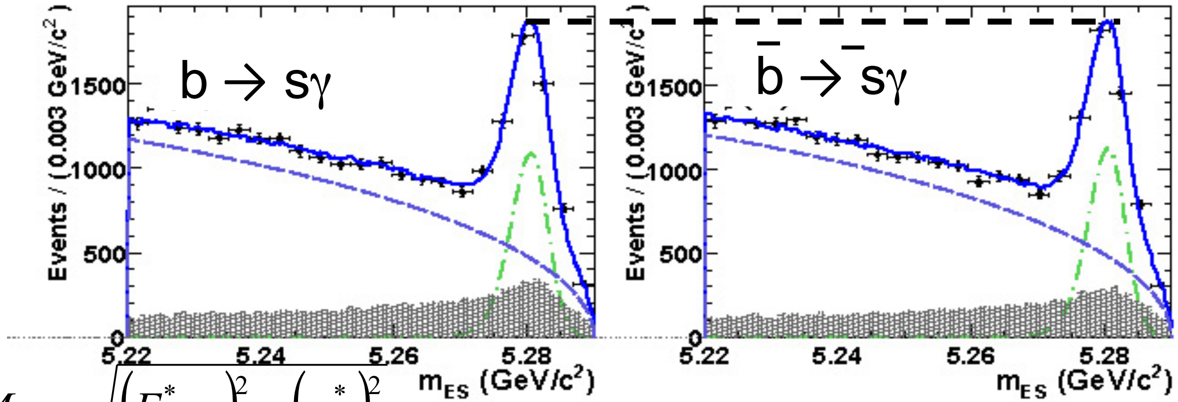
DIRECT CPV

BaBar, PRL101, 171804(2008),350 fb[-1]

$$\frac{N_b - N_{\bar{b}}}{N_b + N_{\bar{b}}} = \langle D \rangle A_{CP} + \Delta D + A_{\det}$$

Semi-inclusive, sum of many exclusive states:

all flavor specific final states;



$$M_{bc} = \sqrt{(E^*_{beam})^2 - (p^*_B)^2}$$

<D>: average dilution due to flavour mistag, ~1

ΔD: difference between flavour mistag for B and B̄, << 1

A_{DET}: detector induced asymmetry

A_{DET}: careful study of K/π asymmetries in (p, θ_{lab}) using *D* decays or inclusive tracks from fragmentation;

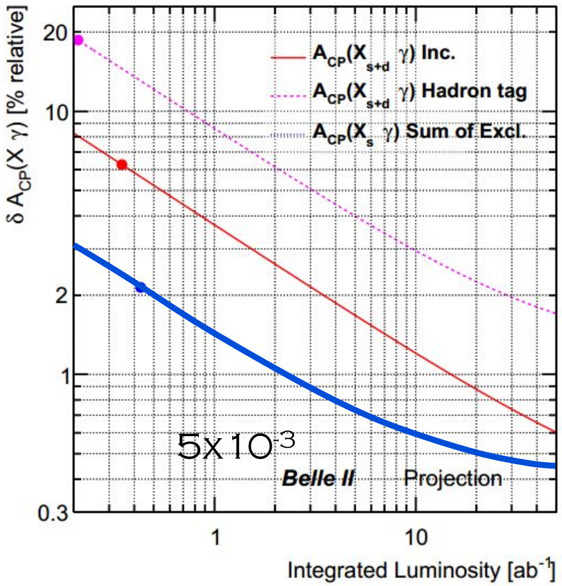
$$A_{CP} = (-0.8 \pm 2.9)\%$$

HFAG, 2014

SM: $A_{CP} \sim (0.44 \pm ^{0.24}_{0.14})\%$

T. Hurth et al., Nucl.Phys. B704, 56 (2005)

lots of work on system.,
→ few 10^{-3}
exp. sensitivity



A. Lenz, Oct 26 morning
L. LiGioi, Oct 26 afternoon
T. Hurth, Nov 14 morning

$B \to s\gamma$ TCPV

$B \to K^* (\to K_S\pi^0)\gamma$ t-dependent CPV

SM:
$S_{CP}^{K^*\gamma} \sim -(2m_s/m_b)\sin2\phi_1 \sim -0.04$

Left-Right Symmetric Models:
$S_{CP}^{K^*\gamma} \sim 0.67 \cos2\phi_1 \sim 0.5$

D. Atwood et al., PRL79, 185 (1997)
B. Grinstein et al., PRD71, 011504 (2005)

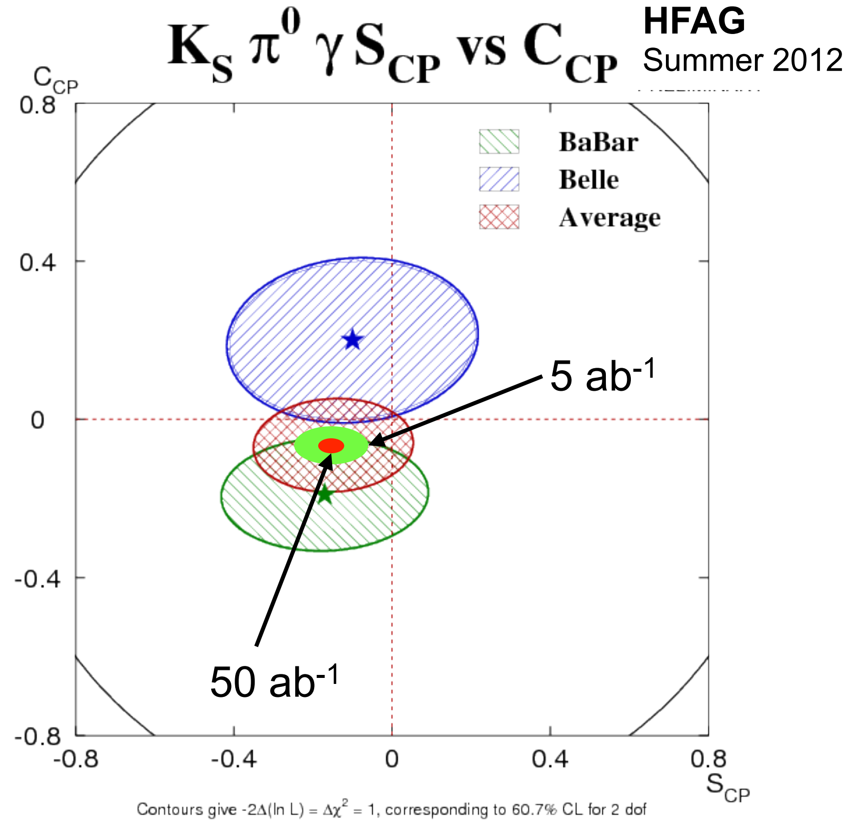
$S_{CP}^{K_S\pi^0\gamma} = -0.15 \pm 0.20$
$A_{CP}^{K_S\pi^0\gamma} = -0.07 \pm 0.12$

HFAG, Summer'12

$\sigma(S_{CP}^{K_S\pi^0\gamma}) = $ 0.09 @ 5 ab^{-1}
0.03 @ 50 ab^{-1}
(~SM prediction)

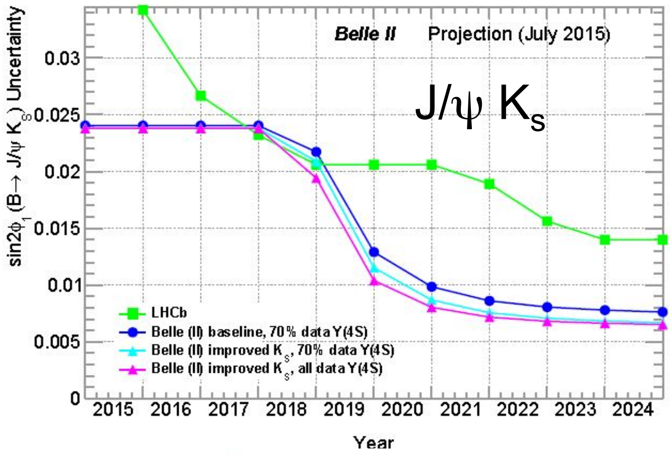
t-dependent decays rate of $B \to f_{CP}$;
S and A: CP violating parameters

$$P(B^0 \to f;\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau}[1 + S_{CP}^f \sin(\Delta m \Delta t) + A_{CP}^f \cos(\Delta m \Delta t)]$$

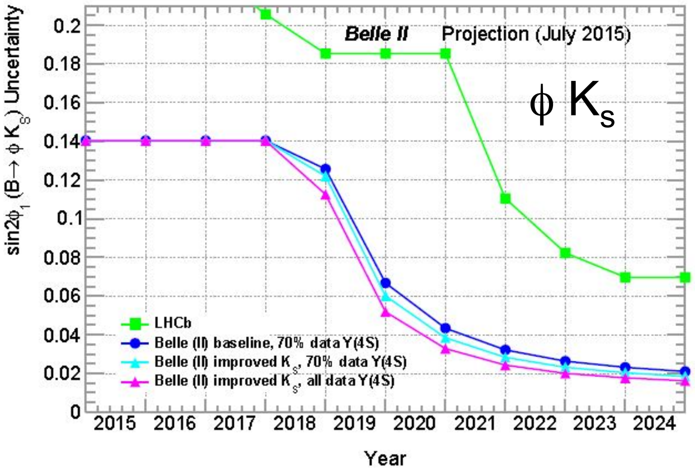


CPV in $B \to SQ\bar{Q}$

B. Golob, K. Trabelsi, P. Urquijo, Belle2-note-ph-2015-002

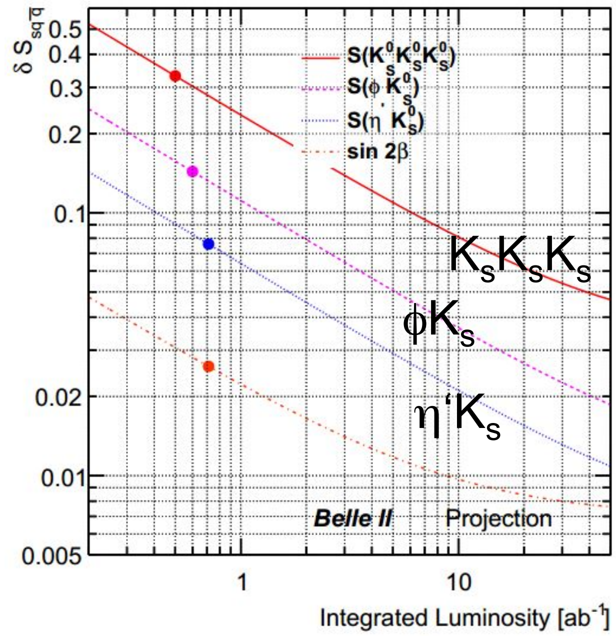


0.007



0.02

P. Urquijo, Belle2-note-ph-2015-004



0.045
0.020
0.010

typical theory uncertainty
$\sigma(\Delta S^{\eta' K_s}) < \sigma(\Delta S^{\phi K_s}) \sim 0.05$

DCPV puzzle

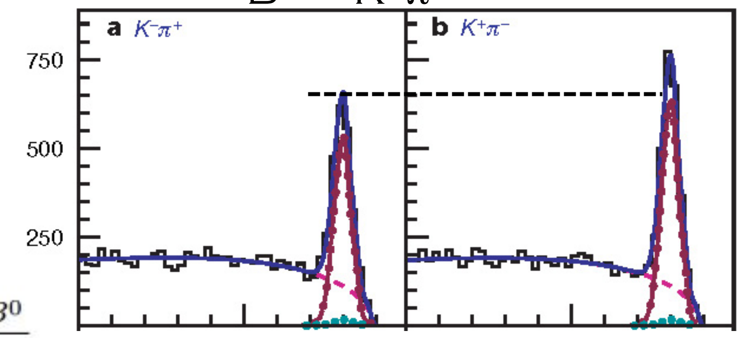
DCPV puzzle:

tree+penguin processes, $B^{+(0)} \to K^+\pi^{0(-)}$

$\Delta A_{K\pi} = A(K^+\pi^-) - A(K^+\pi^0) = -0.147 \pm 0.028$

Belle, Nature 452, 332 (2008), 480 fb^{-1}

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

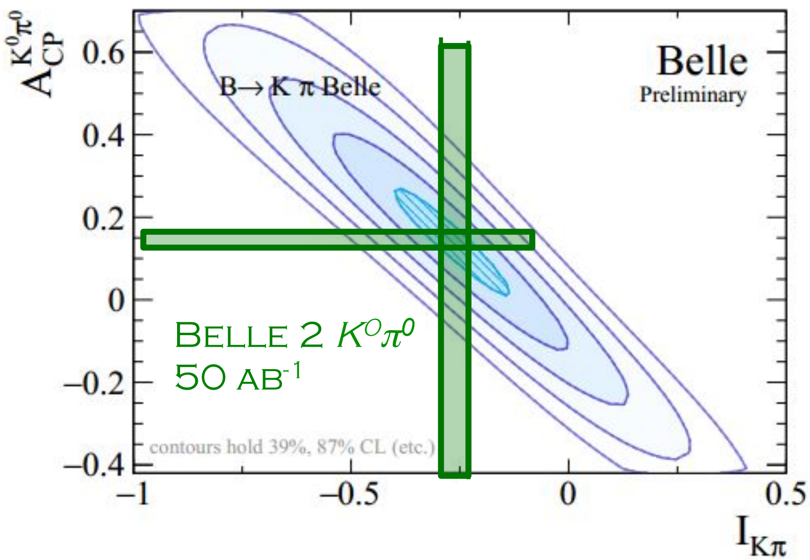


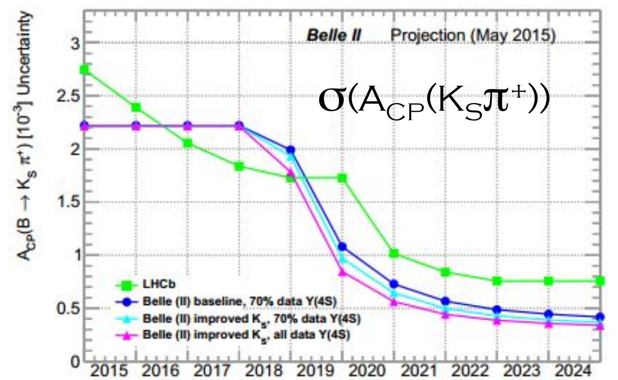
$$I_{K\pi}\,\mathcal{B}(B^0 \to K^+\pi^-)$$

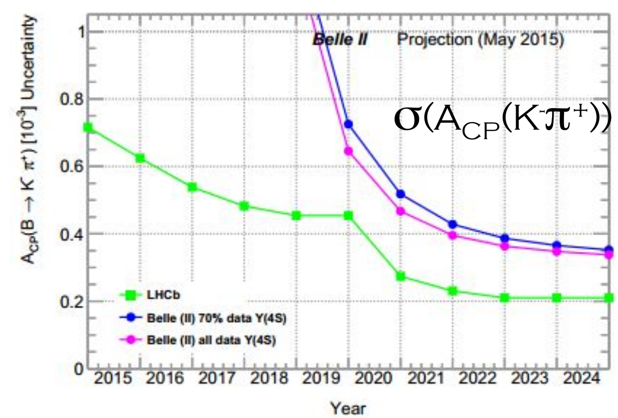
$$= A_{CP}^{K^+\pi^-}\cdot\mathcal{B}(B^0\to K^+\pi^-) + A_{CP}^{K^0\pi^-}\cdot\mathcal{B}(B^+\to K^0\pi^-)\frac{\tau_{B^0}}{\tau_{B^+}}$$

$$- 2A_{CP}^{K^0\pi^0}\cdot\mathcal{B}(B^0\to K^0\pi^0) + 2A_{CP}^{K^+\pi^0}\cdot\mathcal{B}(B^+\to K^+\pi^0)\frac{\tau_{B^0}}{\tau_{B^+}}$$

M. Gronau, PLB627, 82 (2005);
D. Atwood, A. Soni, PRD58, 036005 (1998)







B. Golob, K. Trabelsi, P. Urquijo,, Belle2-note-ph-2015-002

$\tau \to \mu\, \gamma$

Search for $\tau \to \mu\, \gamma$

w/o polarization:
$UL_{90\%}(\mathcal{B}(\tau \to \mu\, \gamma)) \sim 3\text{x}10^{-9}$ @ 50 ab^{-1}

w/ polarization:
factor ~(2-3)x better sensitivity

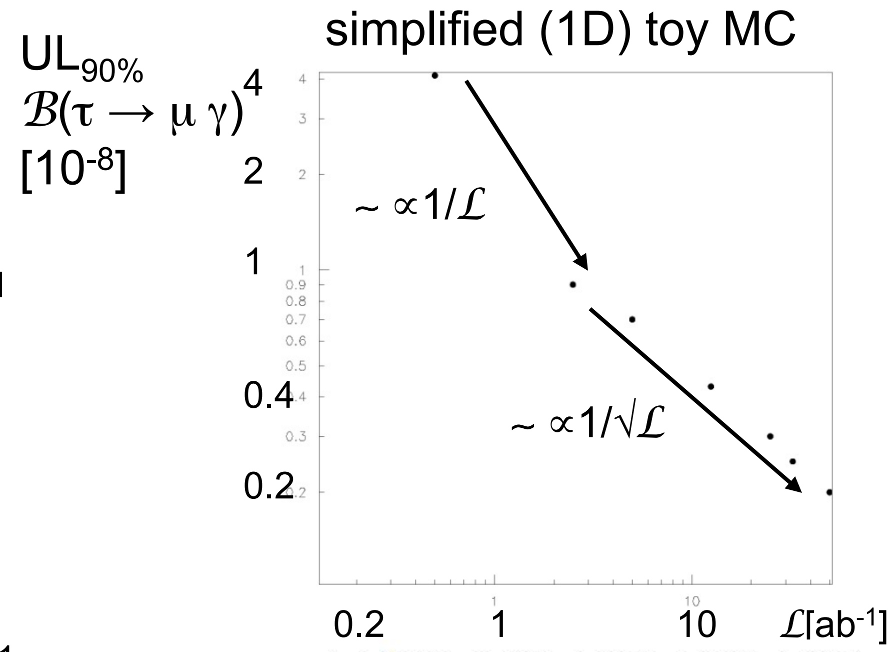
decays $\tau \to 3l,\ l\, h^0$ background free
$UL_{90\%}(\mathcal{B}(\tau \to \mu\, \gamma)) \sim \propto 1/\mathcal{L}$ to ~10ab^{-1}

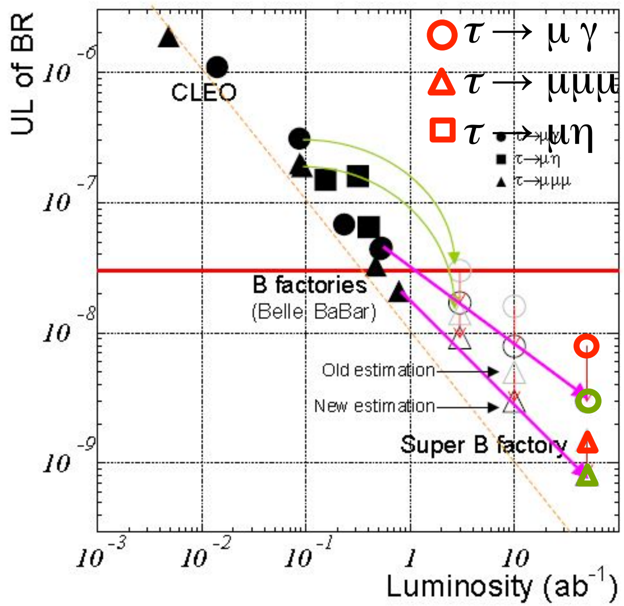
$\mathcal{B}(\tau \to \mu\, \gamma) < 4.4 \cdot 10^{-8}$

Belle, PLB666, 16 (2008), 535 fb^{-1}

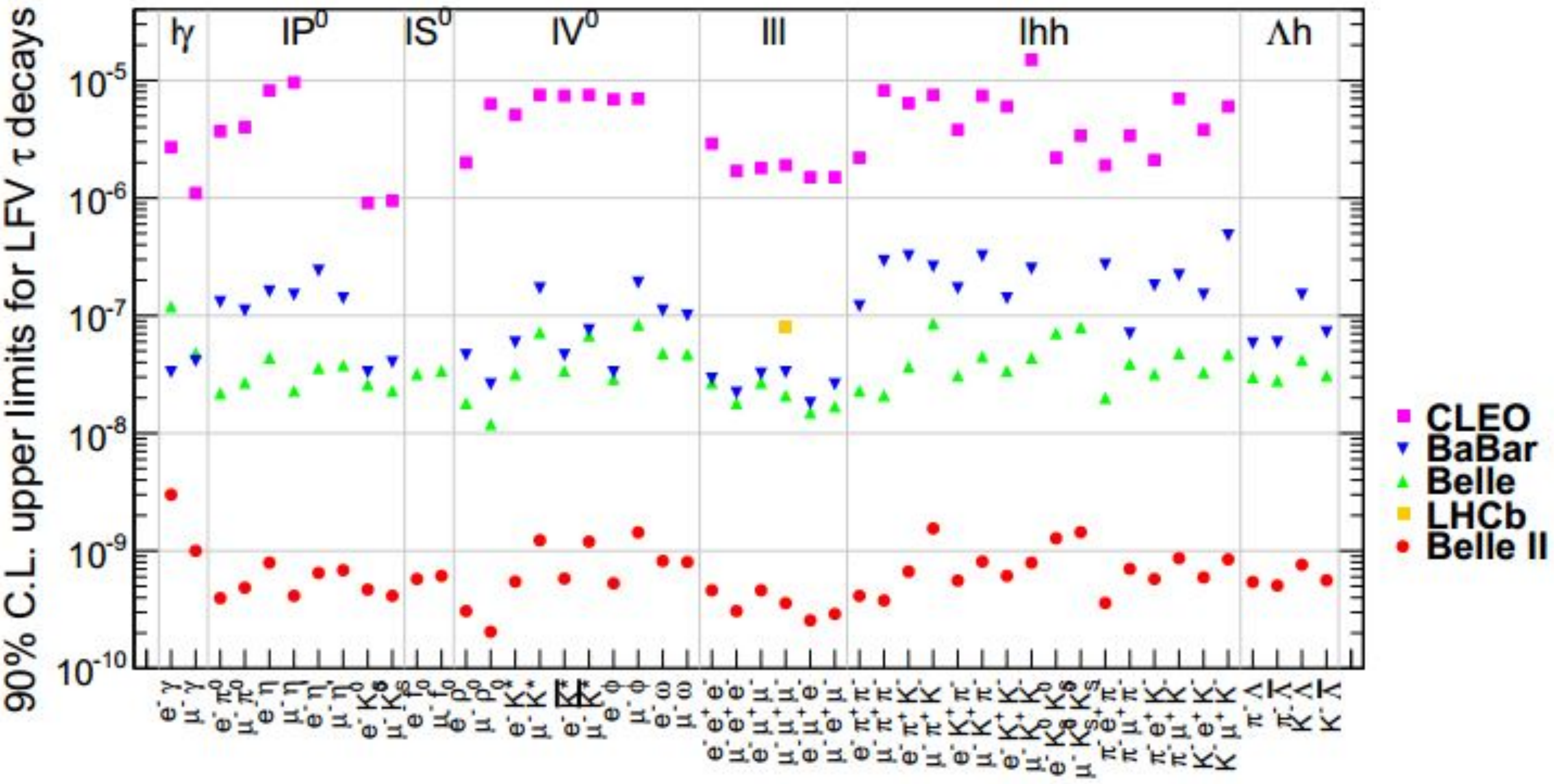
Updated expected sensitivities

K. Inami, PANIC 2011





$\tau \to \mu\,\gamma$



Summary (Belle perspective)

disclaimer: personal statements on importance of ind. processes;

	Observables	Belle or LHCb* (2014)	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}	LHCb 8 fb^{-1} (2018)		LHCb 50 fb^{-1}	
UT angles	$\sin 2\beta$	$0.667 \pm 0.023 \pm 0.012 (0.9°)$	0.4°	0.3°	0.6°	~	0.3°	Depending on $\vert V_{ub}\vert$
	α [°]	85 ± 4 (Belle+BaBar)	2	1				
	γ [°] $(B \to D^{(*)}K^{(*)})$	68 ± 14	6	1.5	4	!	1	„standard candle"
	$2\beta_s(B_s \to J/\psi\phi)$ [rad]	$0.07 \pm 0.09 \pm 0.01^*$			0.025	!	0.009	
Gluonic penguins	$S(B \to \phi K^0)$	$0.90^{+0.09}_{-0.19}$	0.053	0.018	0.2	?	0.04	SM expectation reached
	$S(B \to \eta' K^0)$	$0.68 \pm 0.07 \pm 0.03$	0.028	0.011				
	$S(B \to K^0_S K^0_S K^0_S)$	$0.30 \pm 0.32 \pm 0.08$	0.100	0.033				
	$\beta_s^{\rm eff}(B_s \to \phi\phi)$ [rad]	$-0.17 \pm 0.15 \pm 0.03^*$			0.12	!	0.03	reaching Sm prediction (≤0.02)
	$\beta_s^{\rm eff}(B_s \to K^{*0}\bar{K}^{*0})$ [rad]	–			0.13		0.03	
Direct CP in hadronic Decays	$\mathcal{A}(B \to K^0\pi^0)$	$-0.05 \pm 0.14 \pm 0.05$	0.07	0.04		?		$\sigma(I_{k\pi}) \sim \sigma(A_{K0\pi0})$, $I_{k\pi}$ = -0.27 ±0.14
UT sides	$\vert V_{cb}\vert$ incl.	$41.6 \cdot 10^{-3}(1 \pm 2.4\%)$	1.2%					
	$\vert V_{cb}\vert$ excl.	$37.5 \cdot 10^{-3}(1 \pm 3.0\%_{\rm ex.} \pm 2.7\%_{\rm th.})$	1.8%	1.4%		~		exceeding SM precision
	$\vert V_{ub}\vert$ incl.	$4.47 \cdot 10^{-3}(1 \pm 6.0\%_{\rm ex.} \pm 2.5\%_{\rm th.})$	3.4%	3.0%		!		to reach SM precision
	$\vert V_{ub}\vert$ excl. (had. tag.)	$3.52 \cdot 10^{-3}(1 \pm 10.8\%)$	4.7%	2.4%		!		Probably most precise determination
Leptonic and Semi-tauonic	$\mathcal{B}(B \to \tau\nu)$ [10^{-6}]	$96(1 \pm 26\%)$	10%	5%		~		Depending on $\vert V_{ub}\vert$, current SM ±13%
	$\mathcal{B}(B \to \mu\nu)$ [10^{-6}]	< 1.7	20%	7%				
	$R(B \to D\tau\nu)$ [Had. tag]	$0.440(1 \pm 16.5\%)^\dagger$	5.6%	3.4%		~		current SM precision (~5%) will probably be improved
	$R(B \to D^*\tau\nu)^\dagger$ [Had. tag]	$0.332(1 \pm 9.0\%)^\dagger$	3.2%	2.1%	...	!		To reach SM precision (~1%-2%)
Radiative	$\mathcal{B}(B \to X_s\gamma)$	$3.45 \cdot 10^{-4}(1 \pm 4.3\% \pm 11.6\%)$	7%	6%				
	$A_{CP}(B \to X_{s,d}\gamma)$ [10^{-2}]	$2.2 \pm 4.0 \pm 0.8$	1	0.5				
	$S(B \to K^0_S\pi^0\gamma)$	$-0.10 \pm 0.31 \pm 0.07$	0.11	0.035				
	$2\beta_s^{\rm eff}(B_s \to \phi\gamma)$	–			0.13	!	0.03	
	$S(B \to \rho\gamma)$	$-0.83 \pm 0.65 \pm 0.18$	0.23	0.07				
	$\mathcal{B}(B_s \to \gamma\gamma)$ [10^{-6}]	< 8.7	0.3	–				
Electroweak penguins	$\mathcal{B}(B \to K^{*+}\nu\bar{\nu})$ [10^{-6}]	< 40	< 15	30%				
	$\mathcal{B}(B \to K^+\nu\bar{\nu})$ [10^{-6}]	< 55	< 21	30%				
	C_7/C_9 $(B \to X_s\ell\ell)$	~20%	10%	5%				
	$\mathcal{B}(B_s \to \tau\tau)$ [10^{-3}]	–	< 2	–				
	$\mathcal{B}(B_s \to \mu\mu)$ [10^{-9}]	$2.9^{+1.1}_{-1.0}$*			0.5	!	0.2	to reach SM precision
		20..	20	23	18		27?	

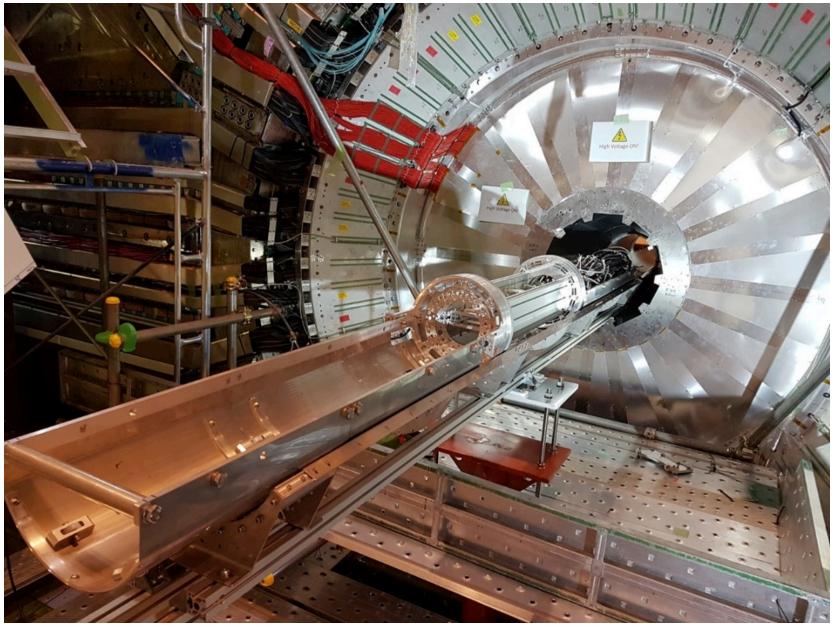
? probably not so interesting because SM value can be reached/tested

~ medium interesting, may depend on other measurements

! important to improve

B. Golob, K. Trabelsi, P. Urquijo, Belle2-note-ph-2015-002

INNER DETECTOR STATUS AS OF FEBRUARY 2017

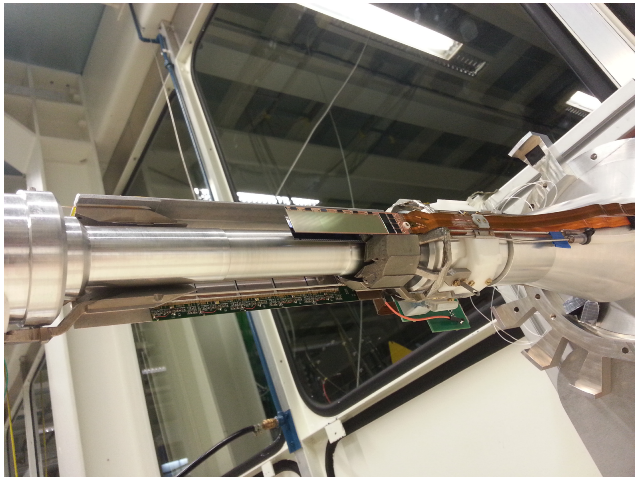


(VXD = SVD+ PXD)

SVD: ~70% OF LADDERS PRODUCED
PXD: SENSOR PRODUCTION ALMOST COMPLETED, ASICS ONGOING

INSTALLATION OF VXD: JULY 2018

VXD practice installation



BUILD UP STEP BY STEP FULL PXD SYSTEM AND THEN TEST WITH BEAM BEFORE TRANSPORT TO KEK.