Belle II Physics Program

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& Belle/Belle II Collaboration

University of Ljubljana
BELLE
Belle II
"Jožef Stefan" Institute

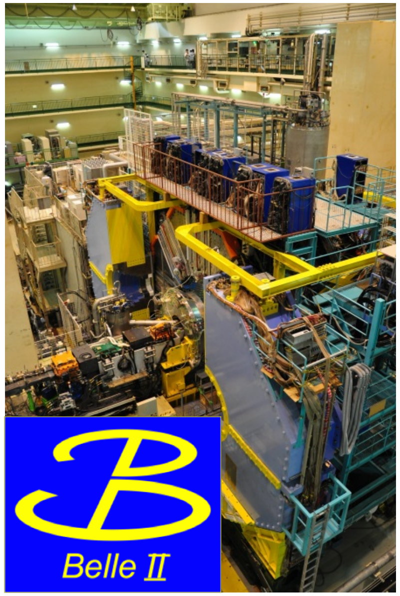
General
(plan, specifics, subjects)

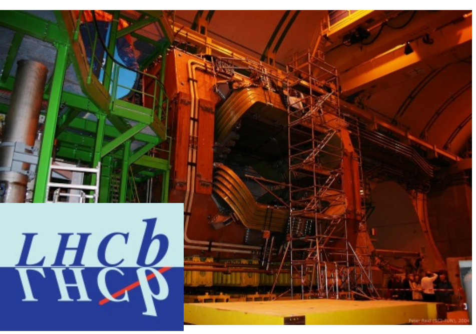
Examples of measurements
(E_{MISS}, neutrals, inclusive)

Summary

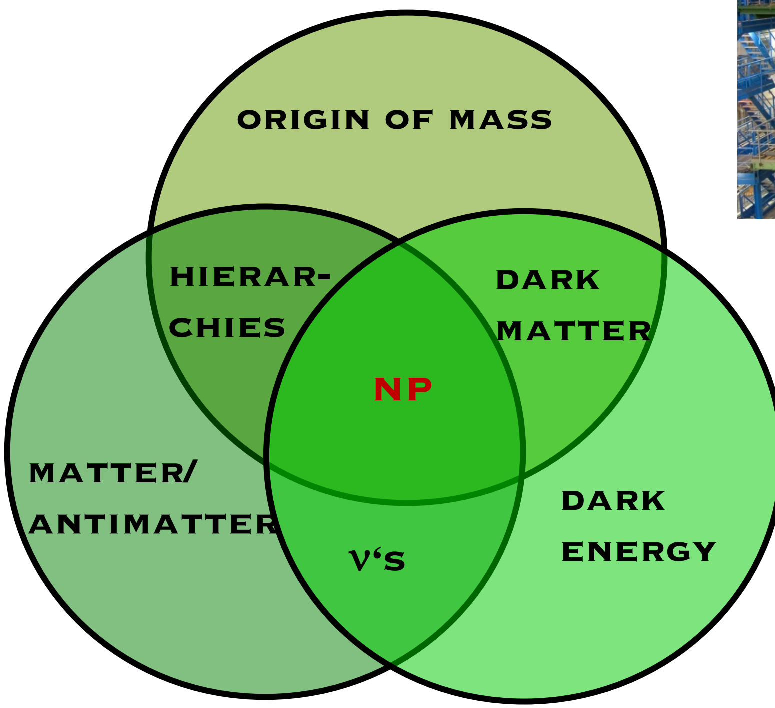
Strategic Workshop in Switzerland
SWICH 2018

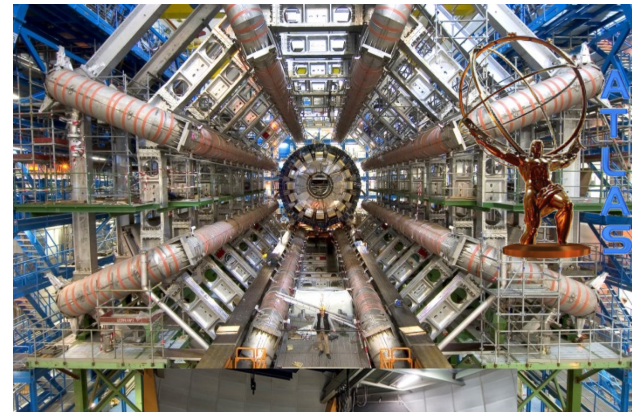
Triple approach
(... to contepmporary high energy physics)

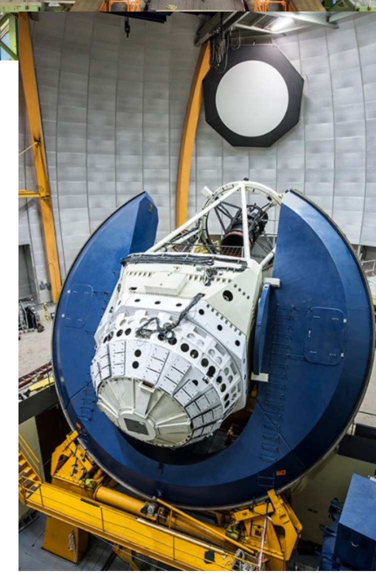




Energy Frontier





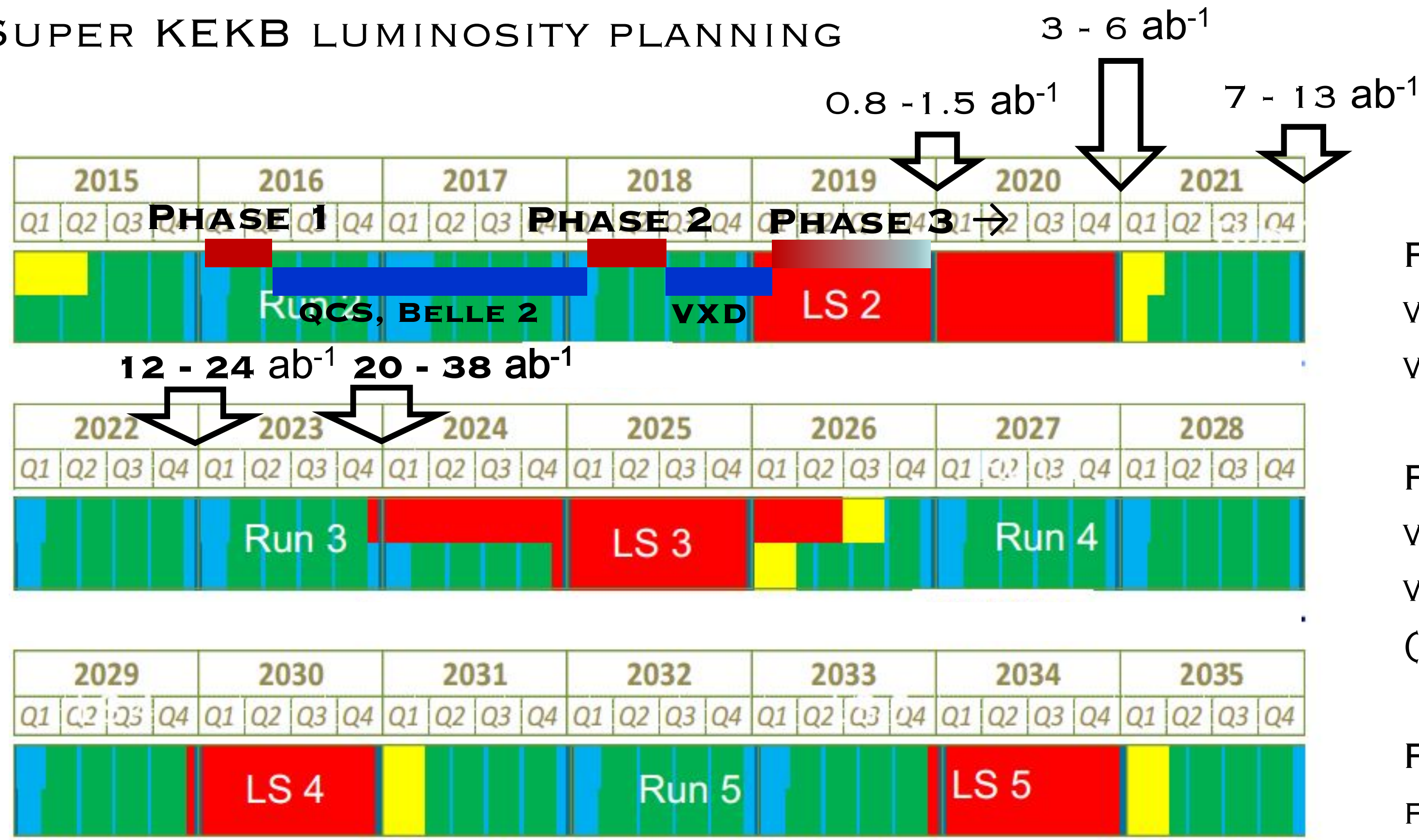


Intensity Frontier

Cosmic Frontier

Plan

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

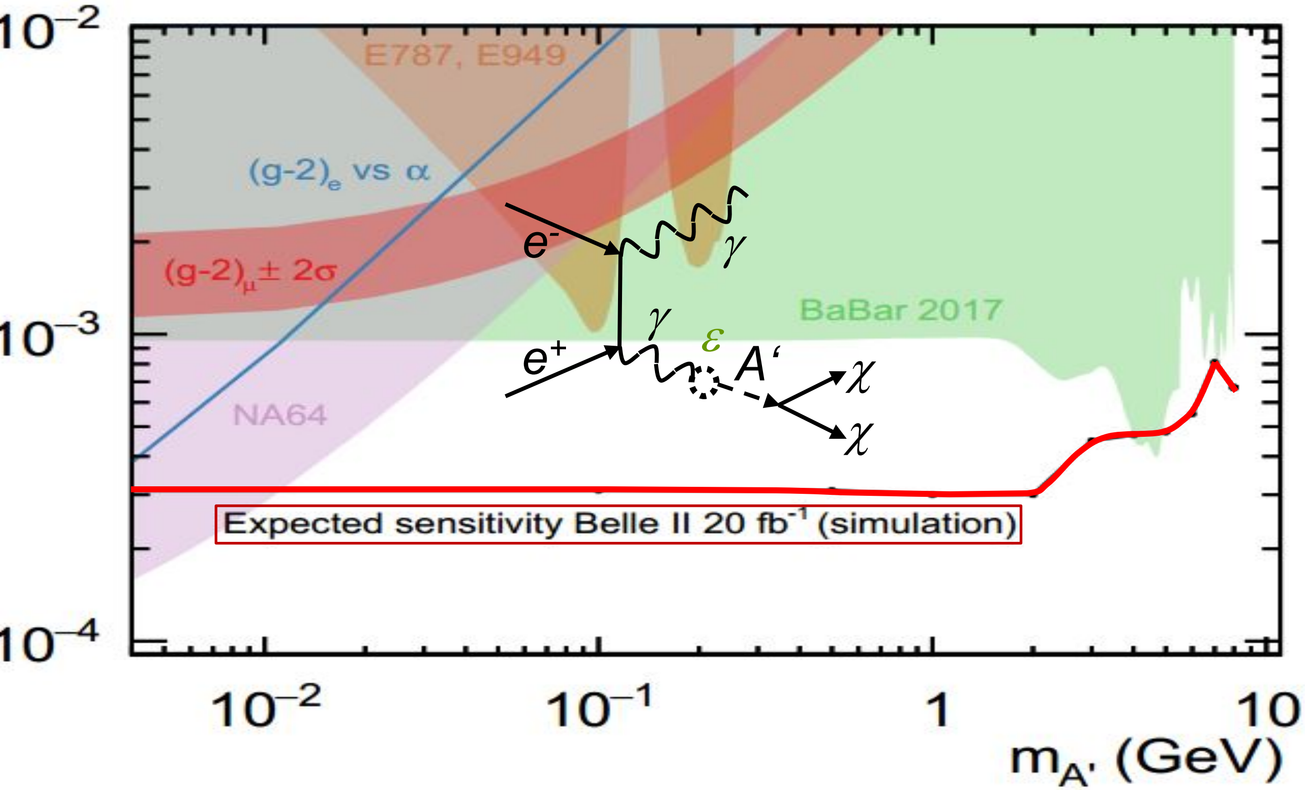
http://lhc-commissioning.web.cern.ch/lhc-commissioning/schedule/LHC%20schedule%20beyond%20LS1%20MTP%202015_Freddy_June2015.pdf
according to Medium Term Plan for 2016-2020, https://cds.cern.ch/record/2053977/files/MTP%202015_FC%205932.pdf

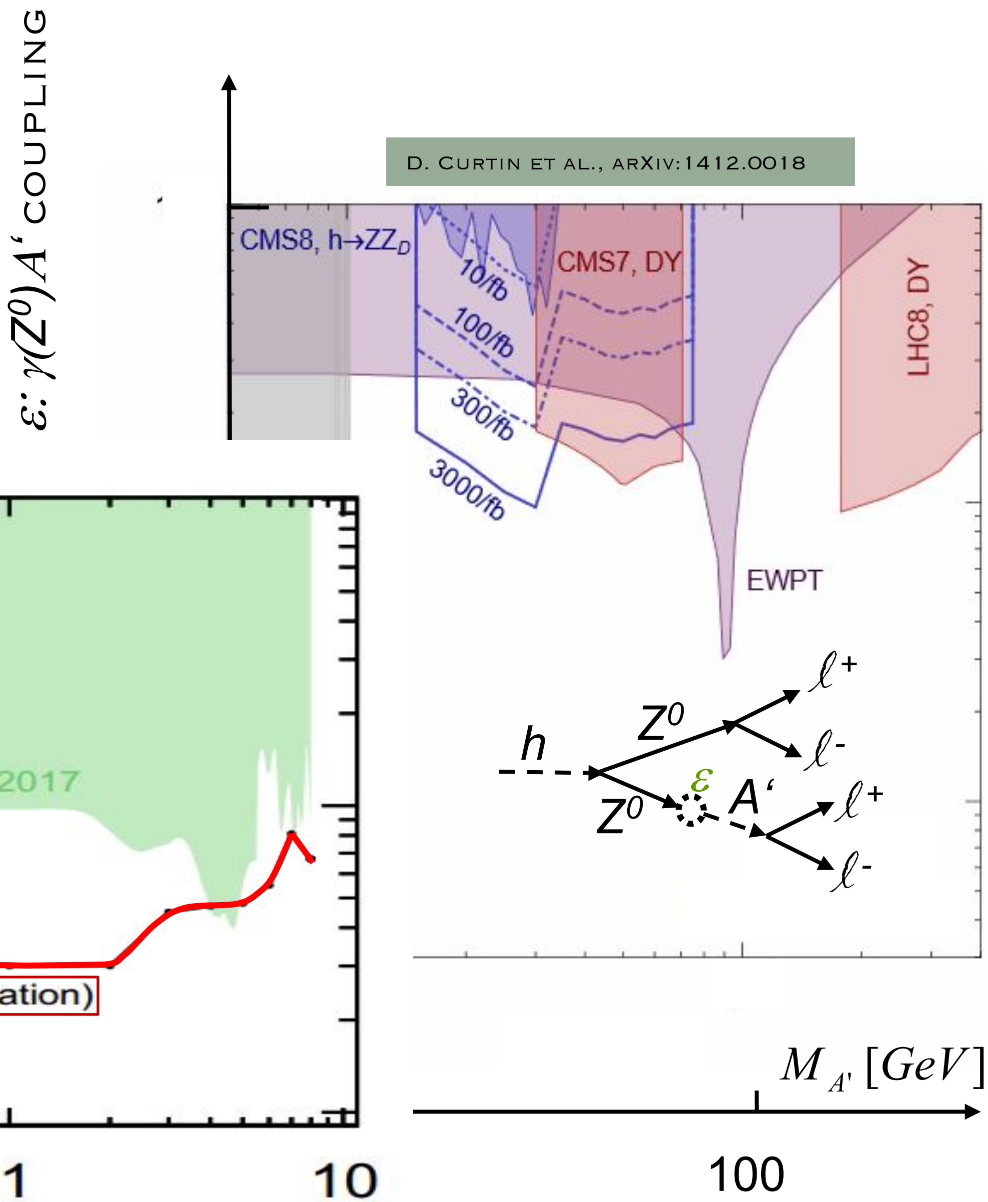
Properties of e^+e^- Colliders (as compared to LHC)

- low energy

A. Bondar et al., Belle2-note-ph-2015-003;
B2TiP report

D. Curtin et al., arXiv:1412.0018





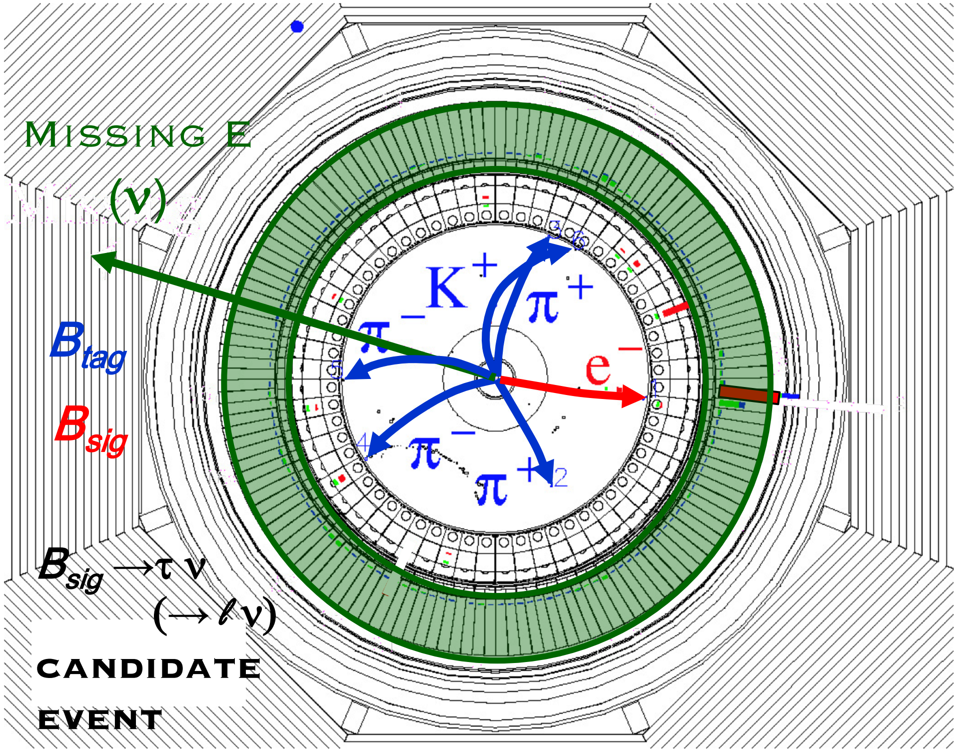
Specifics

Properties of e^+e^- colliders (as compared to LHC)

- low energy
- low trigger rate / Event size (30 kHz 1st level, 10 kHz high level; 300 kB event size)
- low multiplicity ($\mathcal{O}(10)$)
- good hermiticity
- specific methods for full event interpretation (FEI)

fully (partially) reconstruct B_{tag};
$\rightarrow B_{sig}$ 4-momentum known
reconstruct h from e.g.
$B_{sig} \rightarrow \tau(\rightarrow h^{\pm}\nu)\nu$;
no additional energy in EM calorim.;
signal at E_{ECL}~0;

reconstruction of B mesons with invisible particles in final state;
FEI performed using MVA,
ε_{had} ~ 1%, P_{had}~65%
ε_{SL}~ 3%, P_{SL}~30%



Subjects

Methods and processes where Belle 2 can provide important insight into NP complementary to other experiments:

E_{miss}:

$B \to \tau\nu$, $B \to X_c\tau\nu$, $B \to h\nu\nu$, $B \to X_u \ell \nu$, $D_s \to \tau\nu$, $A' \to \chi\chi$,...

(Semi)Inclusive:

$B \to s\ell\ell$, $B \to s\gamma$, $B \to d\gamma$, ...

Neutrals:

$B \to K_S\pi^0\gamma$, $B \to \eta' K_S$, $B \to K_SK_SK_S$, $\tau \to \mu\gamma$, $D^0 \to h^0h^0$, $D^0 \to V\gamma$, $B_s \to \gamma\gamma$, ...

N.B.: at the intensity frontier both, exp. and th. accuracy must ~match in order to be able to spot deviations from SM;

Subjects can be re-ordered into physics topics:

Belle II Physics Groups

Semil. & E_{miss} Decays | Rad. & EW Penguins | t-dependent CPV | Hadronic $b \to c$

Hadronic $b \to$ non-c | $b\bar{b}$ | $c\bar{c}$ | *Charm* | *Low mult. & dark sector*

Subjects

Methods and processes where Belle 2 can provide important insight into NP complementary to other experiments:

Semil. & E_{miss} Decays: inc. & excl. leptonic $b \to c$, $b \to u$ transitions; leptonic B decays; EW penguin decays with ν's; lepton flavor universality & lepton number violations

$B \to \tau\nu$, $B \to X_c\tau\nu$, $B \to X_u \tau \nu$, $B \to \tau\nu$, $B \to h\nu\nu$,…

Rad. & EW Penguins: B meson decays involving FCNC

$B \to s\ell\ell$, $B \to s\gamma$, $B \to d\gamma$, $B_s \to \gamma\gamma$, ...

t-dependent CPV: $\varphi_1, (\beta)$

$B \to J/\psi K_S$, $B \to \eta' K_S$, $B \to K_S K_S K_S$, ...

Hadronic $b \to c$: *direct CPV, φ_3 (γ)*

$B \to D K$, $B \to Dhh'$, $B \to D_s\pi$, ...

Hadronic $b \to$ non-c: *charmless hadronic B decays & DCPV*

$B \to K^0\pi^0$, $B \to \pi^+\pi^0\pi^0$, $B \to \pi^0\pi^0$, $B_s \to K_s K_s$,…

$b\bar{b}$: $\Upsilon(nS)$

$c\bar{c}$: *charmonium(like) states*

Y(4260), X(3872), $\Upsilon(nS) \to XYZ$

Charm: *open charm, decays, oscillations & CPV*

$D_s \to \tau\nu$, $D^0 \to h^0h^0$, $D^0 \to V\gamma$, ...

Low mult. & dark sector: *τ, dark matter searches, $\gamma\gamma$*

$\tau \to \mu\gamma$, $A' \to \chi\chi$,…

Subjects

Methods and processes where Belle 2 can provide important insight into NP complementary to other experiments:

Detailed description of physics program at Belle 2 in:

Physics at Super B Factory — A.G. Akeroyd et al., arXiv: 1002.5012

Super$B$ Progress Reports Physics — B. O'Leary et al., arXiv: 1008.1541

Physics of B Factories — Ed. A.J. Bevan, B. Golob, Th. Mannel, S. Prell, and B.D. Yabsley, Eur. Phys. J. C74 (2014) 3026

Belle II Theory Interface Platfrom (B2TiP) — E. Kou, P. Urquijo eds., to be published in Prog. Theor. Exp. Phys. **New!**

Missing energy

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

Belle, PRD 94, 072007, 700 fb^{-1}

$R(D^{(*)}) = \mathcal{B}(B \to D^*\tau\nu) / \mathcal{B}(B \to D^*\ell\nu)$

ℓ =e,μ Test of Lepton Flavor Universality (LFU)

$R(D)_{SM}$= 0.300 ±0.008

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

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

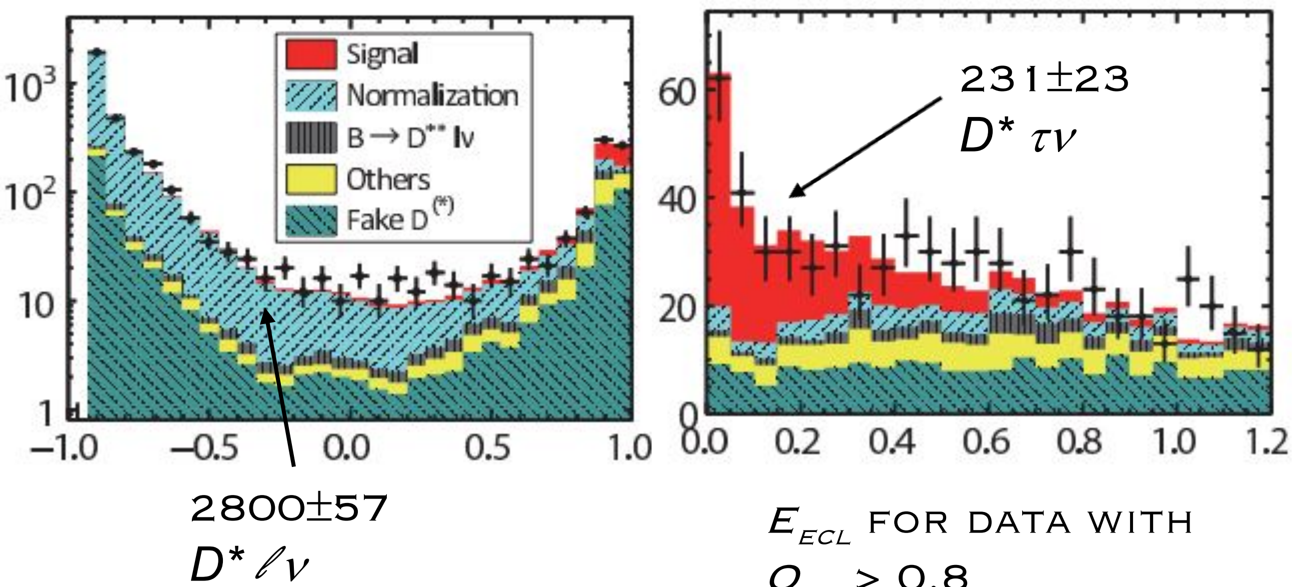
$R(D^*)_{SM}$ = 0.252 ±0.003

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

semil. tag;
use NN with M^2_{miss}, E_{ECL}, $\cos\theta_{B-D^*\ell}^{sig}$.

data sample with low O_{NB} used to fit the background contribution

signal →



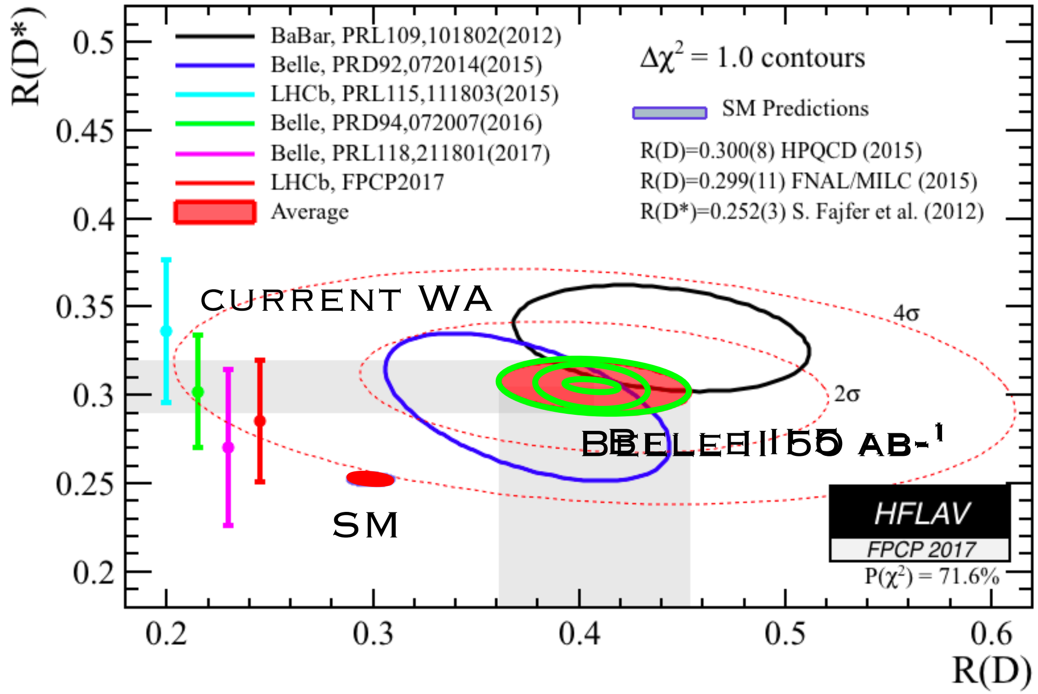
E_{ECL} for data with O_{NB} > 0.8

Missing energy

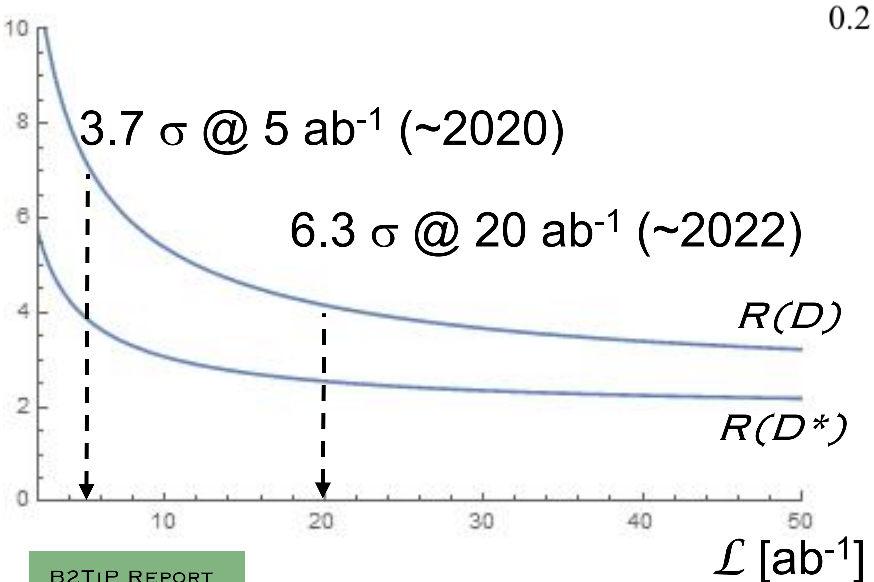
$B \to D^* \tau \nu$

$R(D^*) = 0.302 \pm 0.030 \pm 0.011$

Belle, PRD 94, 072007, 700 fb^{-1}



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



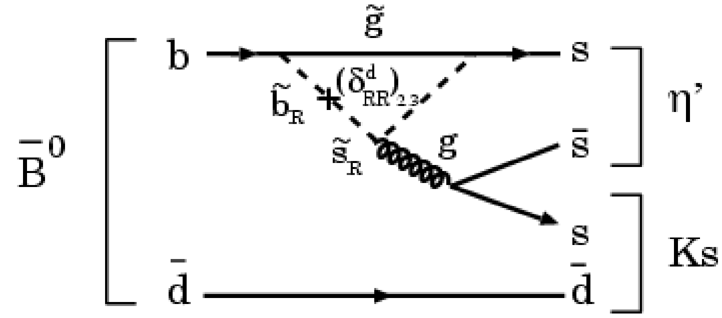
B2TiP Report

combination of tagging methods
($R(D^*)$: had., semil., untagged
$R(D)$: had.)

Neutrals

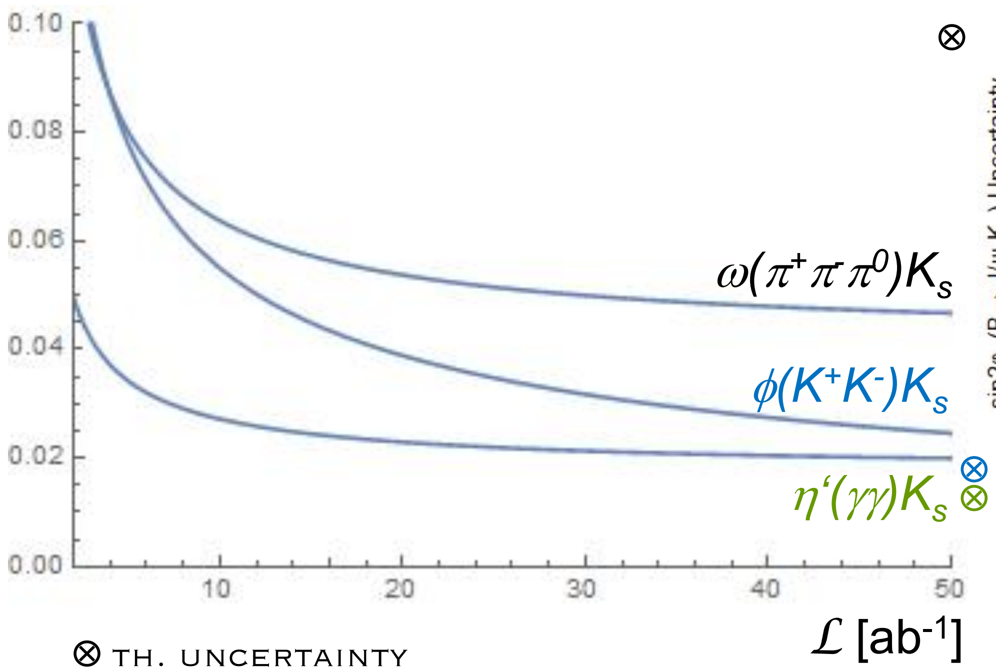
CPV in $B \to sq\bar{q}$

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

$\sigma(\sin 2\phi_1^{eff})$ B2TiP Report

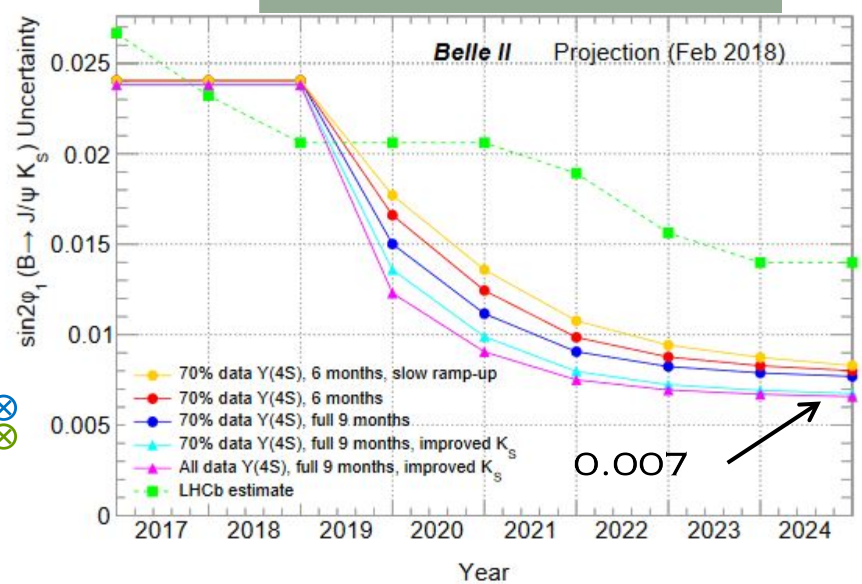


⊗ th. uncertainty

M. Beneke, PLB620,143 (2005)

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

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



$\sigma(\sin 2\phi_1)$ from $B \to J/\psi K_S$

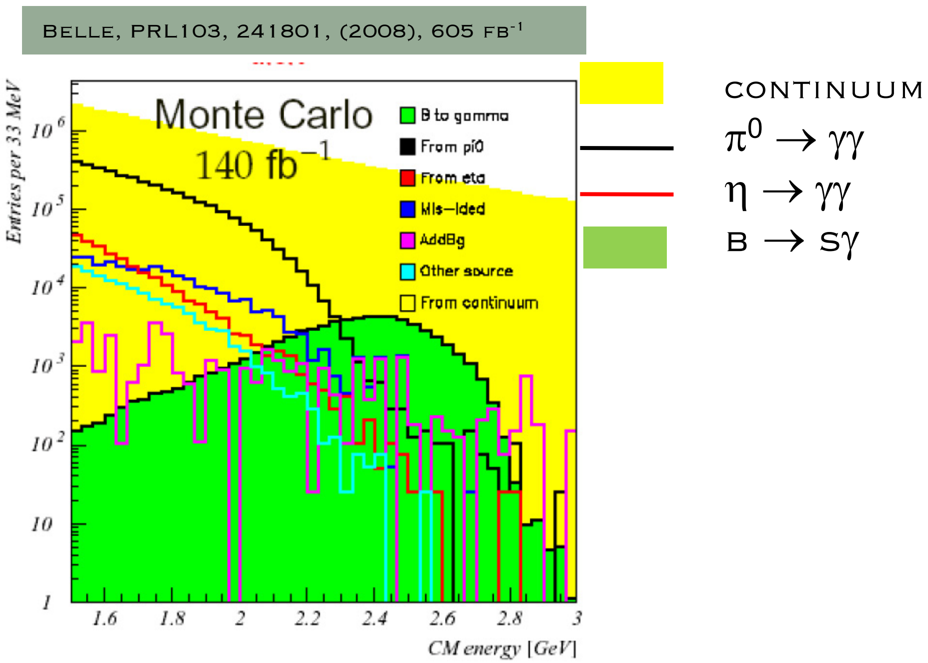
$B \to X_s \ell^+\ell^-$

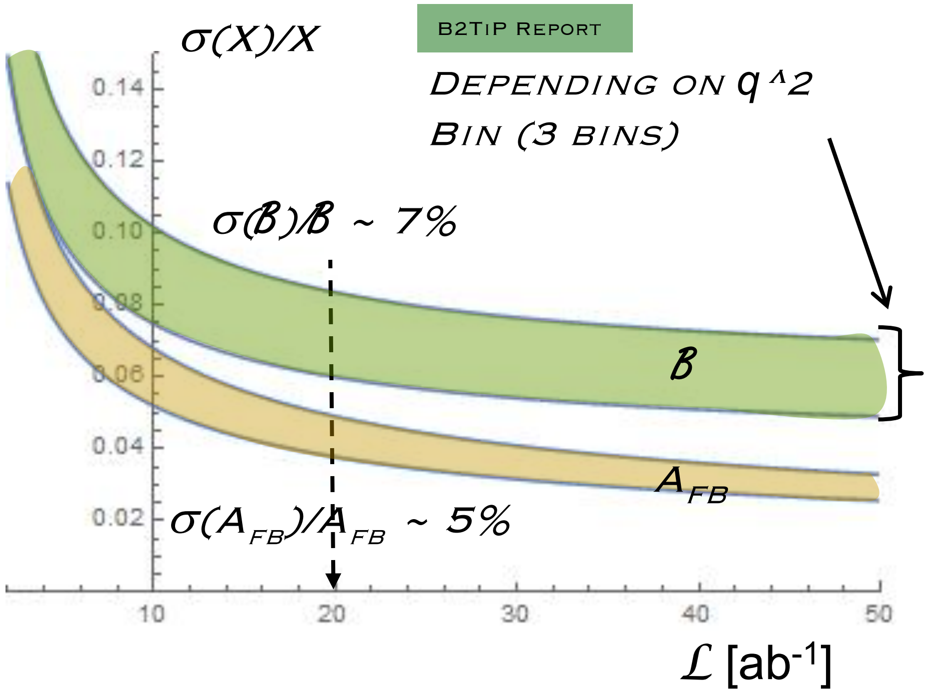
INCLUSIVE MODE: COMPLEMENTARY TO $B \to X_s\gamma$; LOWER HADRONIC UNCERTAINTIES COMPARED TO EXCLUSIVE; COMPLEMENT TO MEAS.'S OF EXCLUSIVE DECAYS;

MAIN BKG'S: $c\bar{c} \to$ SEMIL. DECAYS; $B\bar{B} \to$ SEMIL. B/D DECAYS — CAN BE REJECTED BY E_{miss}

$B \to J/\psi$ ($\Psi(2S)$) X_s — CAN BE REJECTED BY $M(\ell^+\ell^-)$

WITH LARGER STATISTICS FULLY INCLUSIVE STUDY POSSIBLE (AS FOR $B \to X_s\gamma$);
ESTIMATES FOR SUM OF EXCLUSIVE MODES, $M(X_s)<2$ GeV (CAN BE RELAXED);

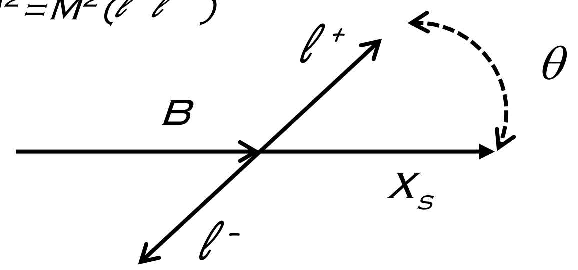




$B \to X_s \ell^+\ell^-$

$\mathcal{B}$ AND DIFF. DECAY DISTRIB. (E.G. IN q^2 & $\cos\theta$) DEPENDING ON WILSON COEFF.'S ($C_{7,9,10}$)

$q^2 = M^2(\ell^+\ell^-)$



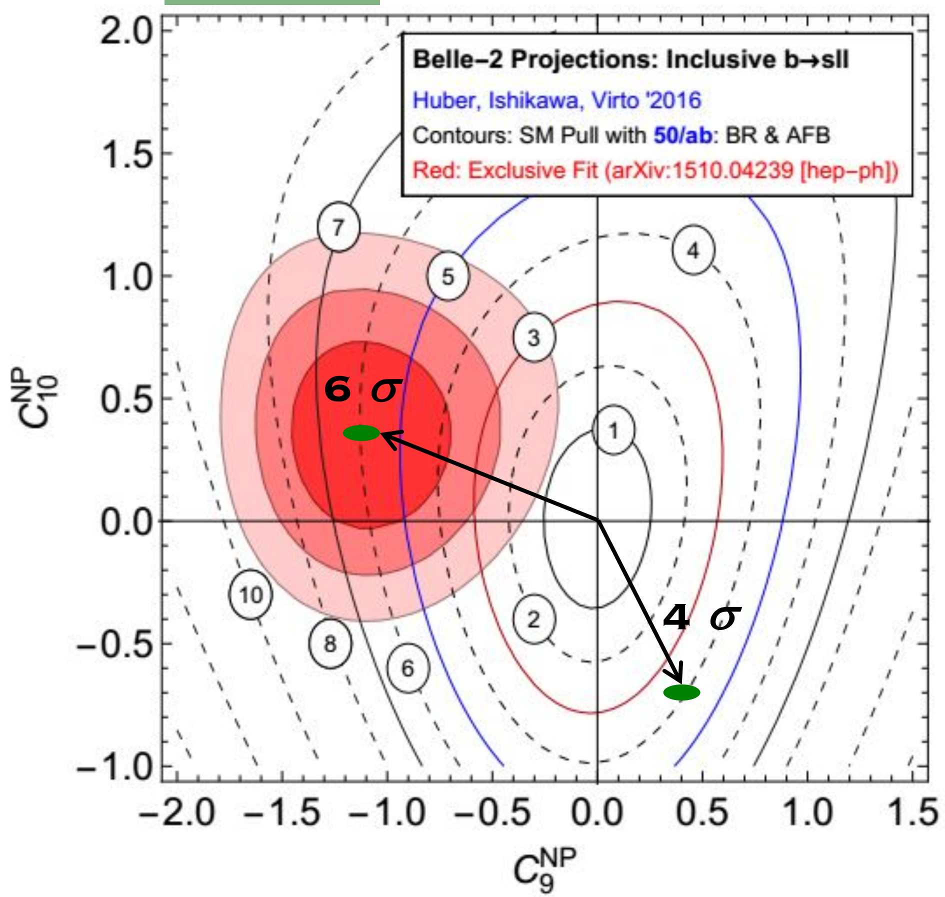
COSTRAINTS ON $C_{9,10}^{NP}$ FROM BELLE II MEASUREMENTS OF $\mathcal{B}$ AND A_{FB} @ 50 AB^{-1}

SM: (0,0)

(N) : N σ CONTOUR

(red ellipse) : FIT TO CURRENT EXCLUSIVE OBSERVABLES

B2TIP REPORT



Summary

	Observables
UT angles	$\sin 2\beta$
	α [°]
	γ [°] $(B \to D^{(*)}K^{(*)})$
	$2\beta_s(B_s \to J/\psi\phi)$ [rad]
Gluonic penguins	$S(B \to \phi K^0)$
	$S(B \to \eta' K^0)$
	$S(B \to K^0_S K^0_S K^0_S)$
	$\beta_s^{\rm eff}(B_s \to \phi\phi)$ [rad]
	$\beta_s^{\rm eff}(B_s \to K^{*0}\bar{K}^{*0})$ [rad]
Direct CP in hadronic Decays	$\mathcal{A}(B \to K^0\pi^0)$
UT sides	$\lvert V_{cb}\rvert$ incl.
	$\lvert V_{cb}\rvert$ excl.
	$\lvert V_{ub}\rvert$ incl.
	$\lvert V_{ub}\rvert$ excl. (had. tag.)
Leptonic and Semi-tauonic	$\mathcal{B}(B \to \tau\nu)$ $[10^{-6}]$
	$\mathcal{B}(B \to \mu\nu)$ $[10^{-6}]$
	$R(B \to D\tau\nu)$ [Had. tag]
	$R(B \to D^*\tau\nu)^\dagger$ [Had. tag]
Radiative	$\mathcal{B}(B \to X_s\gamma)$
	$A_{CP}(B \to X_{s,d}\gamma)$ $[10^{-2}]$
	$S(B \to K^0_S\pi^0\gamma)$
	$2\beta_s^{\rm eff}(B_s \to \phi\gamma)$
	$S(B \to \rho\gamma)$
	$\mathcal{B}(B_s \to \gamma\gamma)$ $[10^{-6}]$
Electroweak penguins	$\mathcal{B}(B \to K^{*+}\nu\bar{\nu})$ $[10^{-6}]$
	$\mathcal{B}(B \to K^{+}\nu\bar{\nu})$ $[10^{-6}]$
	C_7/C_9 $(B \to X_s\ell\ell)$
	$\mathcal{B}(B_s \to \tau\tau)$ $[10^{-3}]$
	$\mathcal{B}(B_s \to \mu\mu)$ $[10^{-9}]$

LHCb „domain“

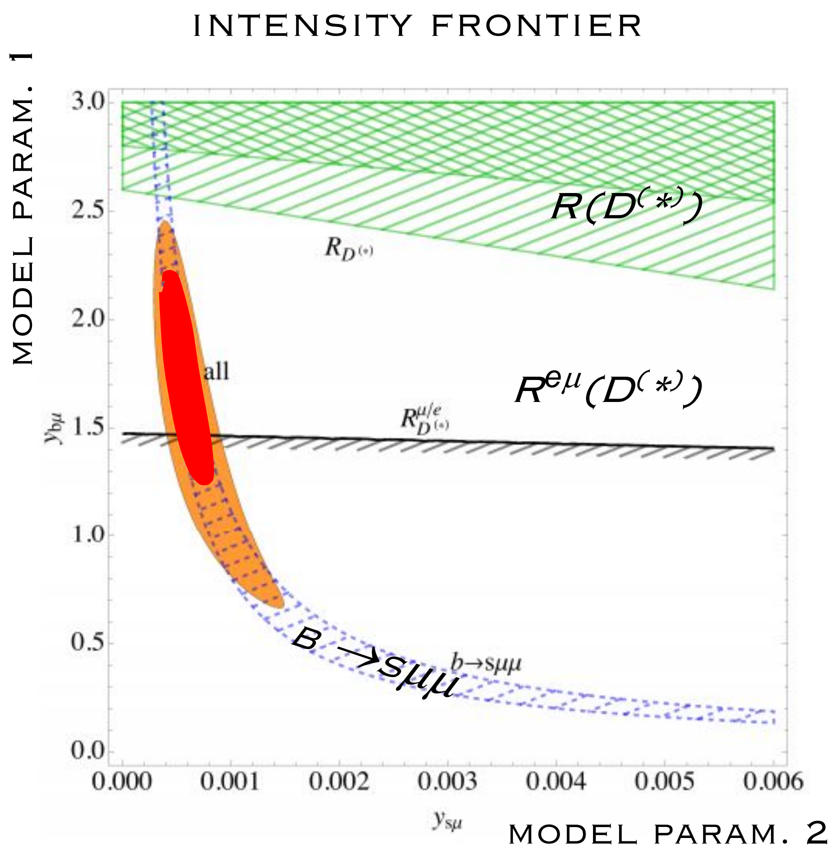
Belle II „domain“

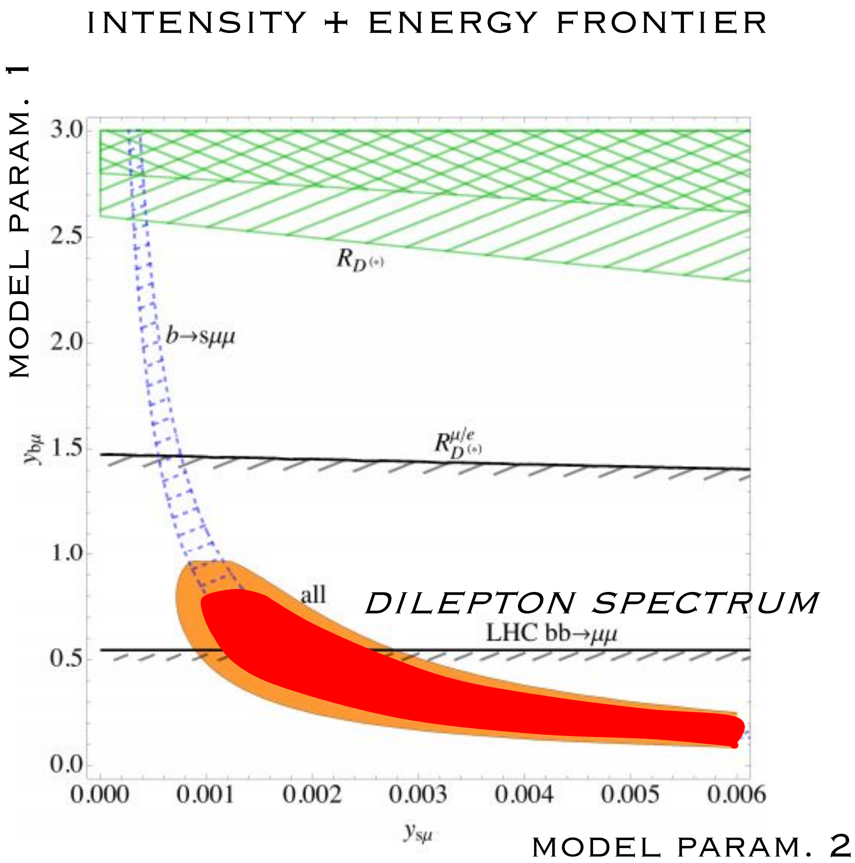
- complementarity!
  not only for „political“ reasons, needed for systematic checks of NP signals and identification of their nature

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

SCALAR LEPTOQUARKS

I. DORSNER ET AL., J. HIGH ENERG. PHYS.2017: 188





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- Intensity frontier exp's able to reach NP mass scales beyond the reach of LHC

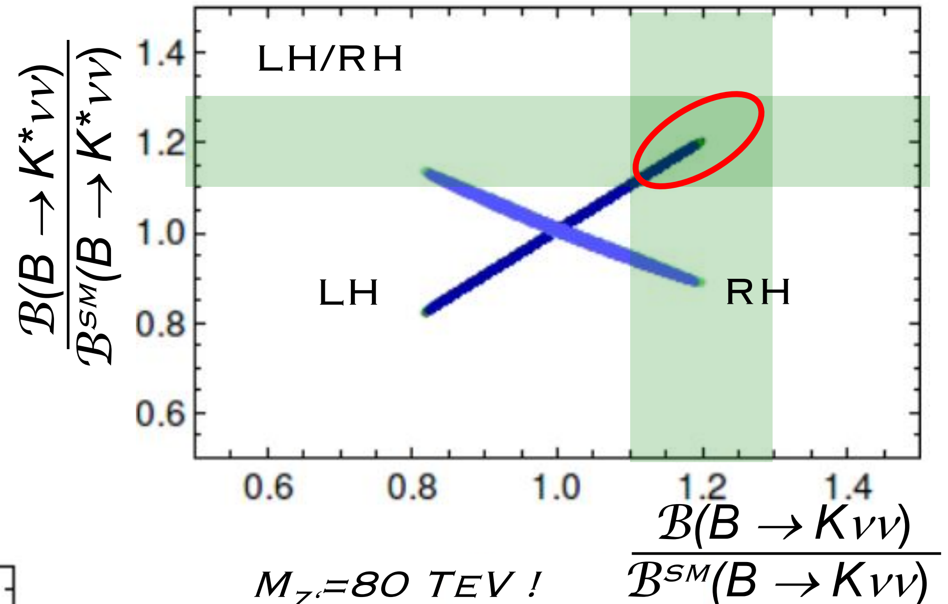
B. Golob, K. Trabelsi, P. Urquijo, Belle2-note-ph-2015-002

SUMMARY

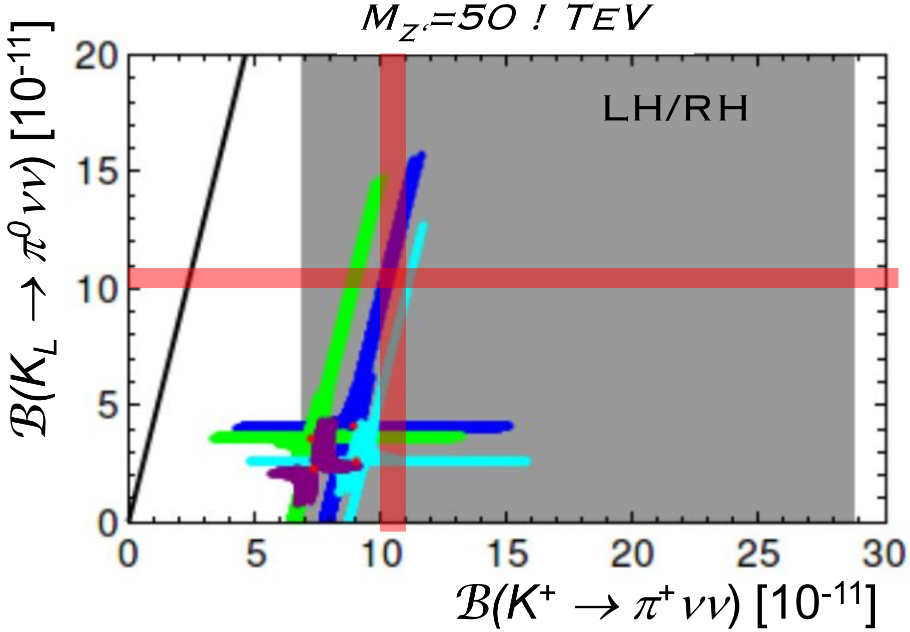
A.J. BURASZ ET AL., JHEP 1411, 121 (2014)

Z' WITH L(R, L+R) COUPLINGS SATISFYING ΔF=2 CONSTRAINTS; EFFECT ON ΔF=1 PROCESSES

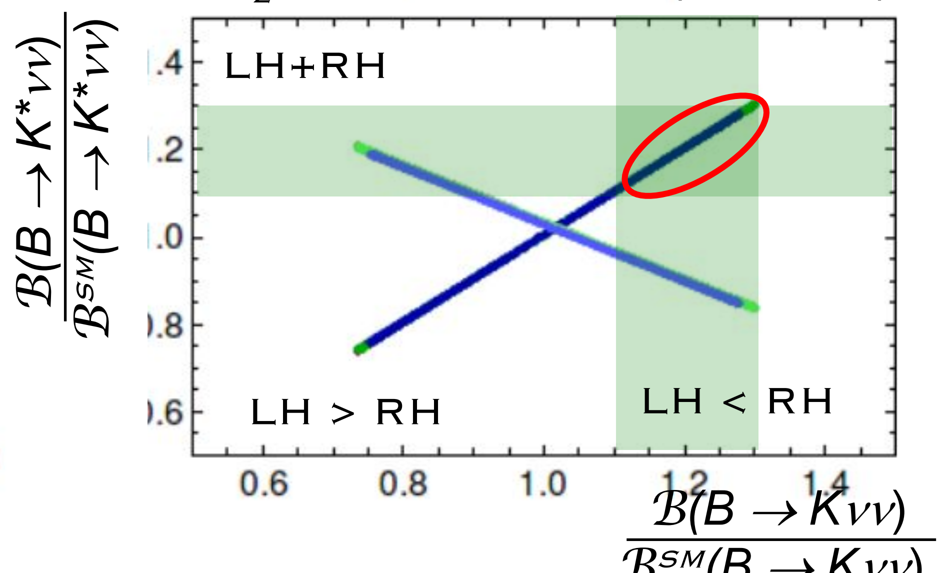
$M_{Z'}$=15 TEV !



$M_{Z'}$=50 ! TEV



$M_{Z'}$=80 TEV !



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

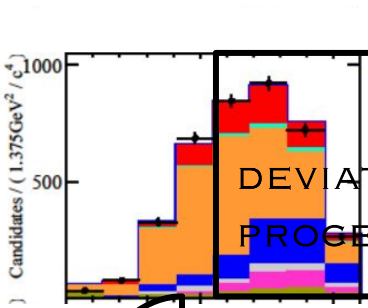
LHCb „domain"

Belle II „domain"

- complementarity!
  not only for „political" reasons, needed for systematic checks of NP signals and identification of their nature
- Intensity frontier exp's able to reach NP mass scales beyond the reach of LHC
- Belle II will in 2019 – ~2025 perform rich program of (very) rare processes (very) sensitive to NP
- eagerly expecting high luminosity datataking with Belle II

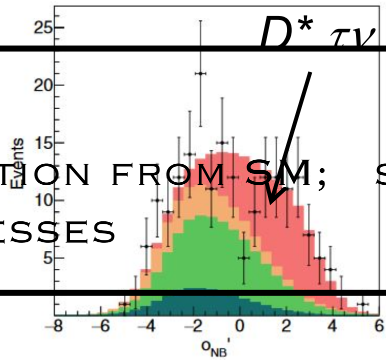
Additional material

LHCb, LHCb-PAPER-2017-017



231±23 $D^* \tau\nu$

Belle, PRD 92, 072014 (2015) 700 fb^{-1}



1273±95 $D^* \tau\nu$

nsity frontier

deviation from SM; systematic tests in related processes

$B \to \pi(\rho)\tau\nu$ (~10%)

$B_c \to J/\psi\tau\nu$ (~10%)

$\Lambda_b \to \Lambda_c\tau\nu$ (~5%)

:

„hope for" accuracy in 2023

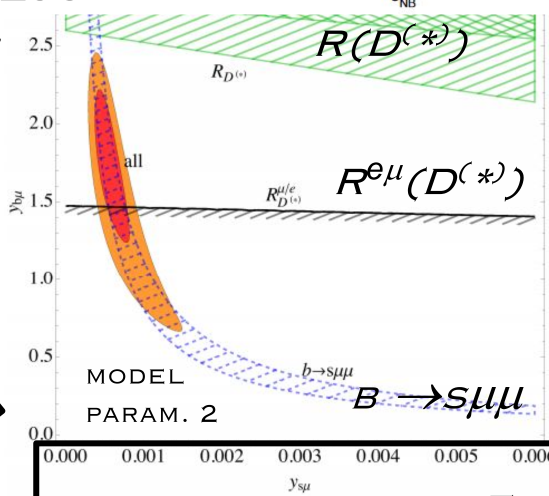
Models

model param. 1

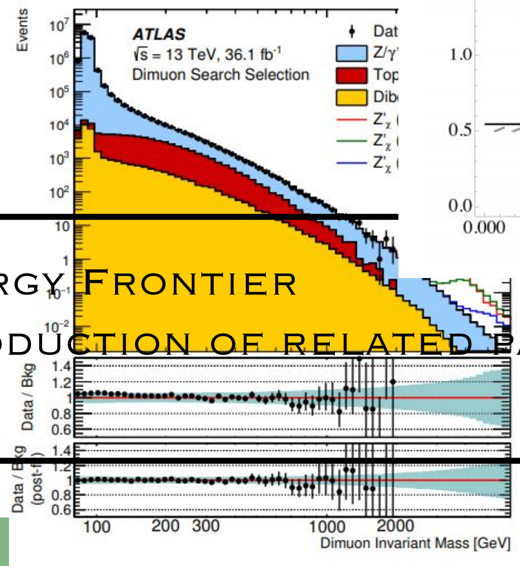
model param. 2

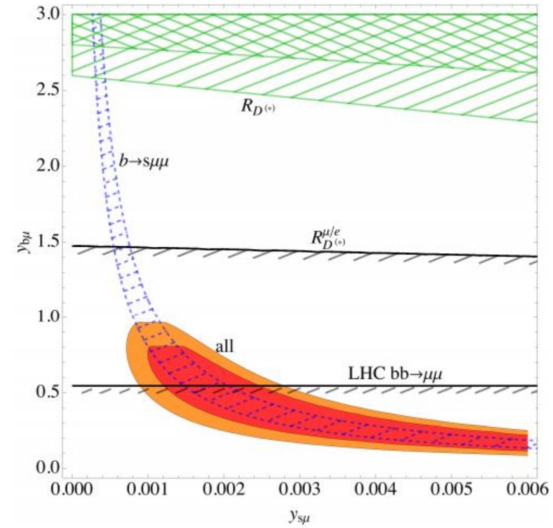
Scalar leptoquarks

I. Dorsner et al., J. High Energ. Phys.2017: 188



dilepton spectrum





Models

Energy frontier

Search for direct production of related particles

ATLAS, DOI: 10.1007/JHEP10(2017)182

Accelerator "SuperKEKB"

SuperKEKB:

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

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

$[M(\Upsilon(1S))c^2, M(\Upsilon(6S))c^2]$

$dN_f/dt = \sigma(e^+e^- \to f)\mathcal{L}$

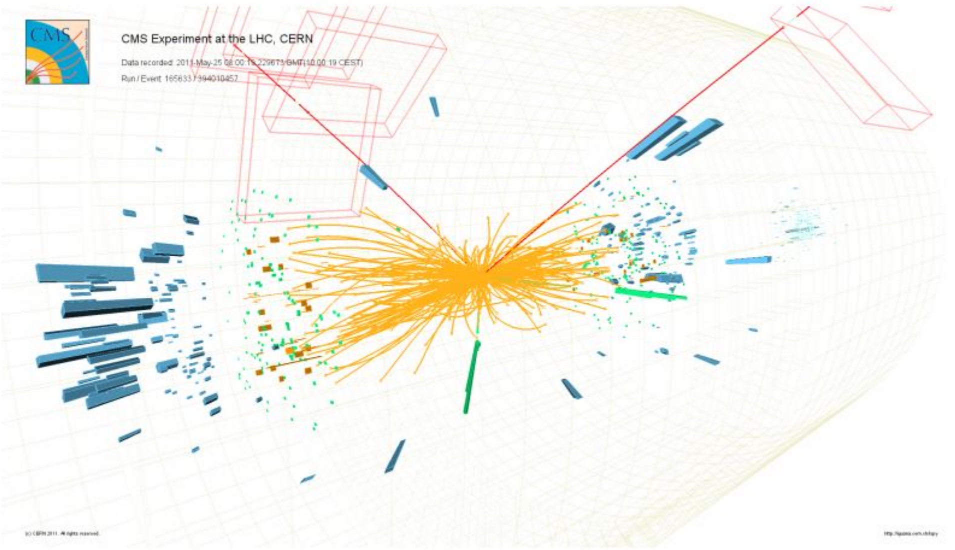
$\mathcal{L} = 8\text{x}10^{35}\ \text{cm}^{-2}\ \text{s}^{-1}$

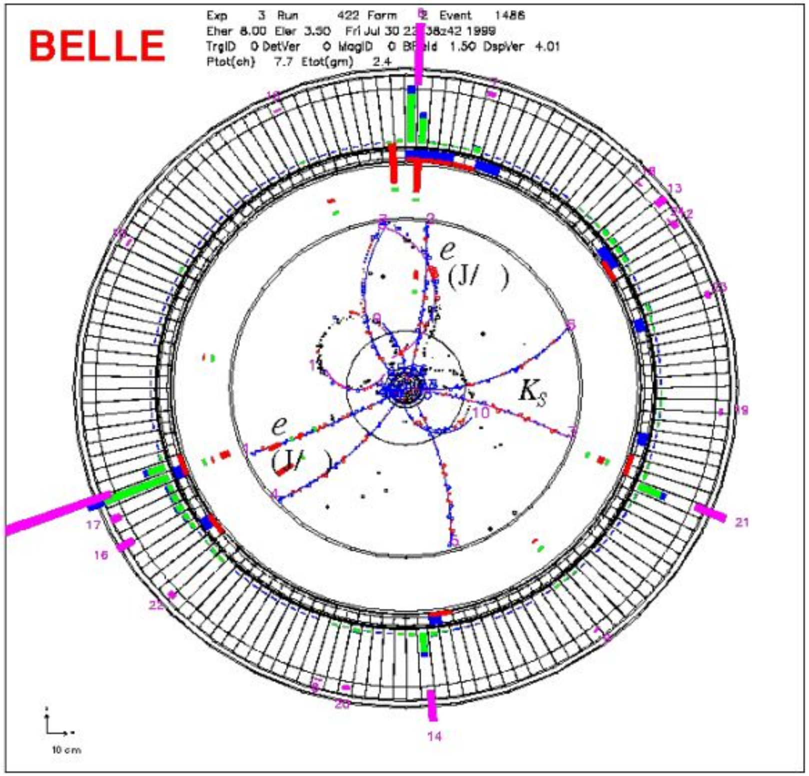
PROPERTIES OF e^+e^- COLLIDERS (AS COMPARED TO LHC)

- LOW ENERGY
- LOW TRIGGER RATE / EVENT SIZE

(30 KHZ 1ST LEVEL, 10 KHZ HIGH LEVEL; 300 KB EVENT SIZE)

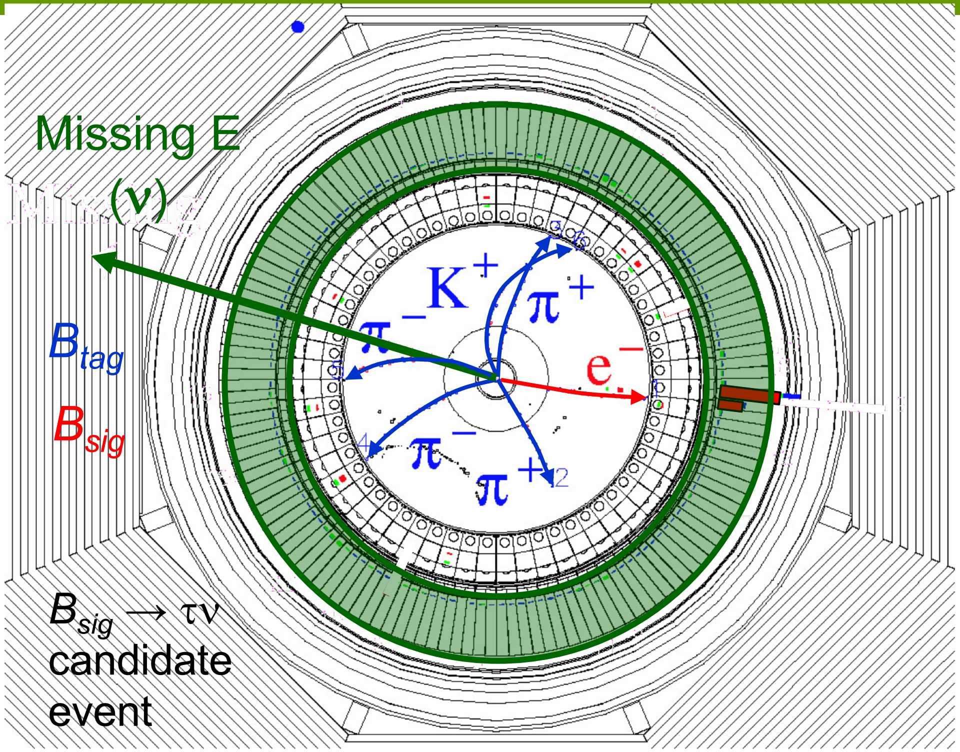
- LOW MULTIPLICITY ($\mathcal{O}$(10))





Semil. tagging

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

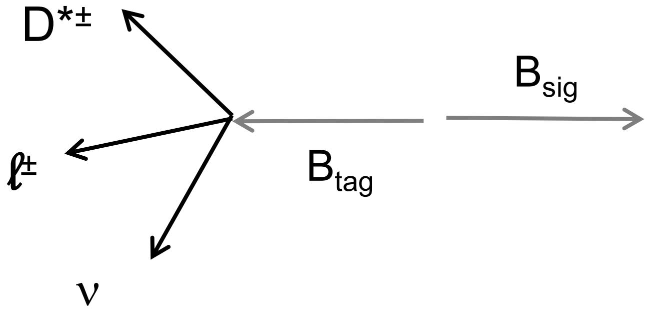


Full reconstruction
(hadronic tagging)

or

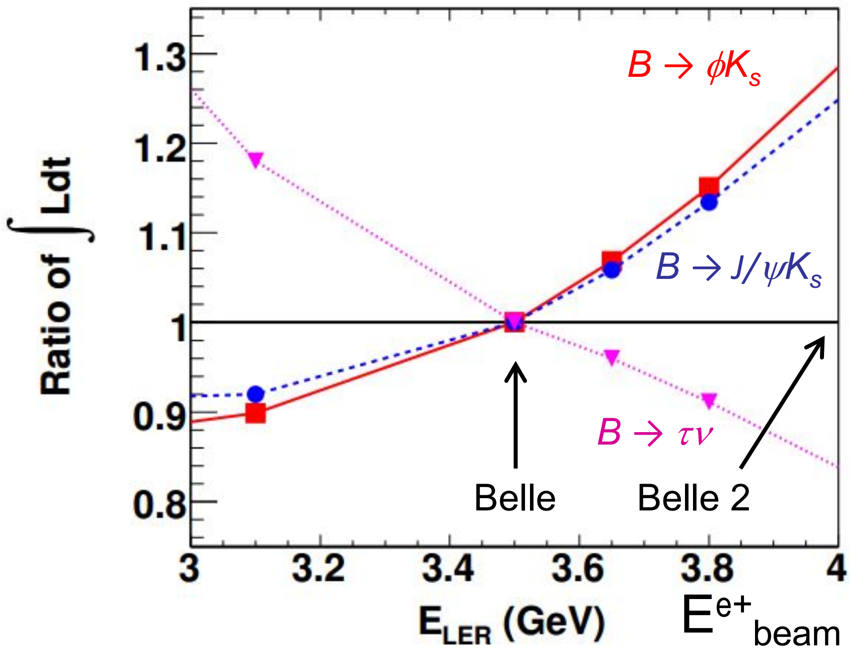
partial reconstruction
(semileptonic tagging):

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



Boost

Lumi ratio for same sensitivity

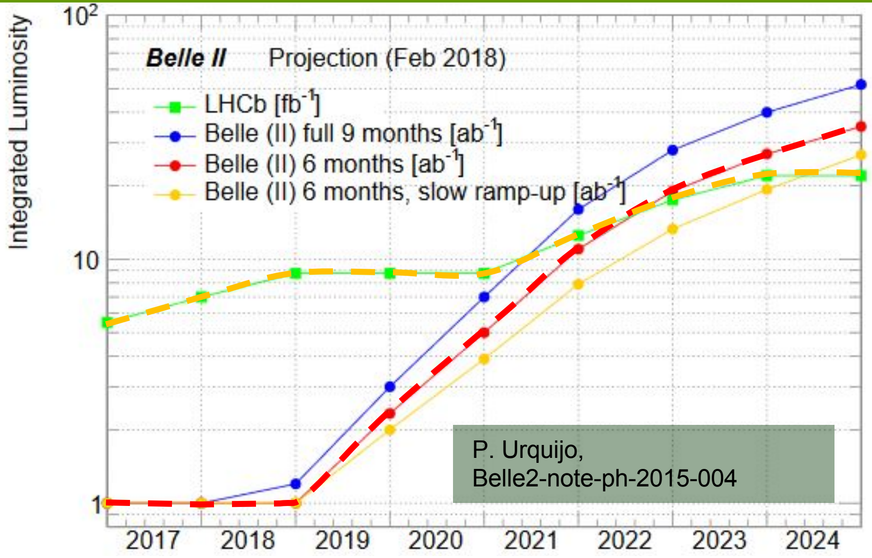


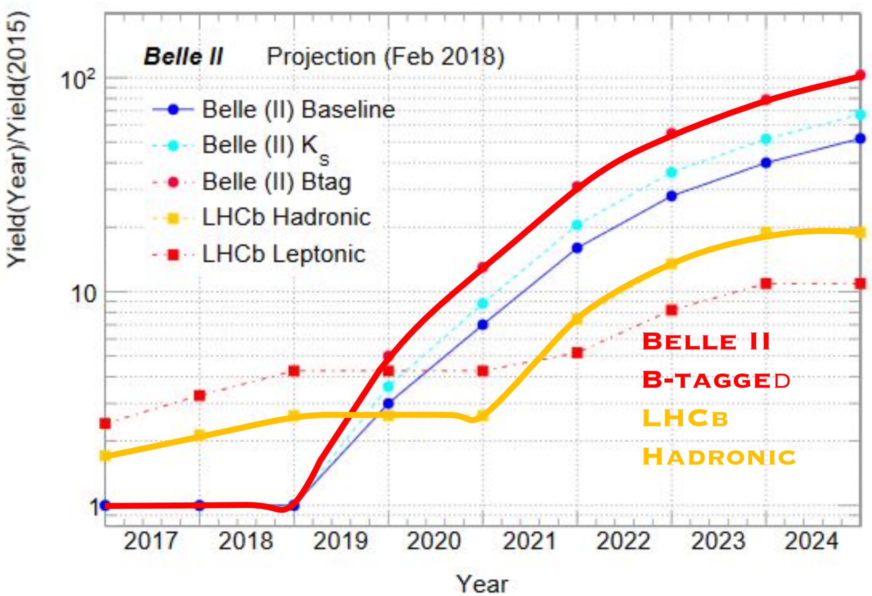
E^{e-}_{beam} from Υ(4S) mass

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



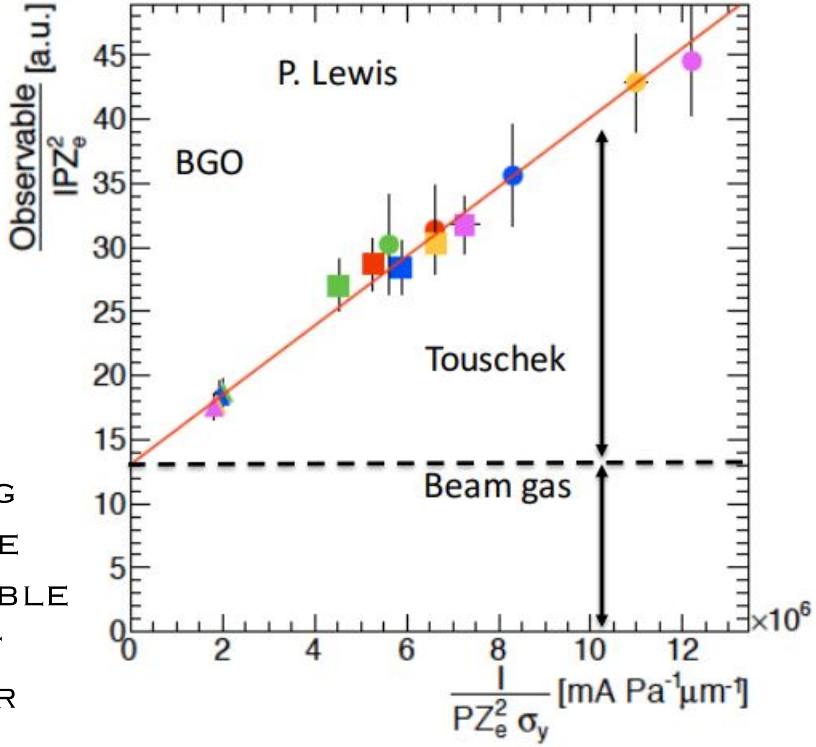


Relative yield increase

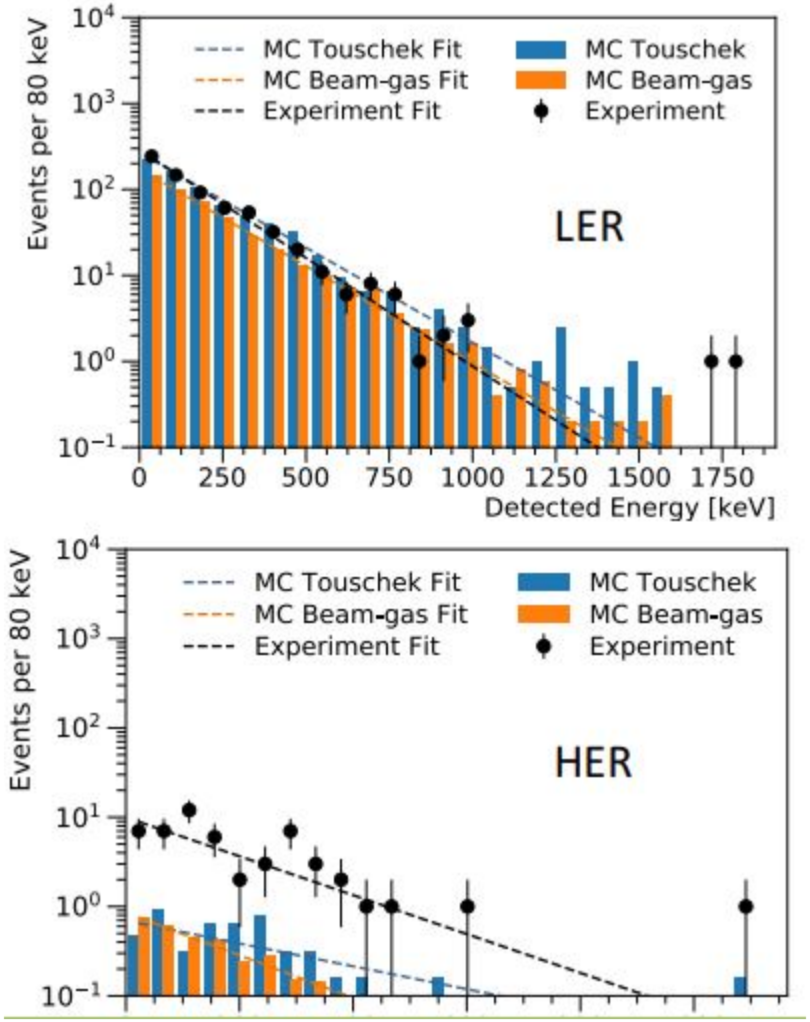
Measurements of beam bkg's in Phase 1

P.M. Lewis et al., arXiv:1802.01366

Separation of Touschek and BeamGas (bremssthralung+Coulomb scattering) contrib.



Spectrum of fast neutrons



Obs.: bkg sensitive observable in Beast detector

P: pressure

Z_e^2: effective atomic number of gas

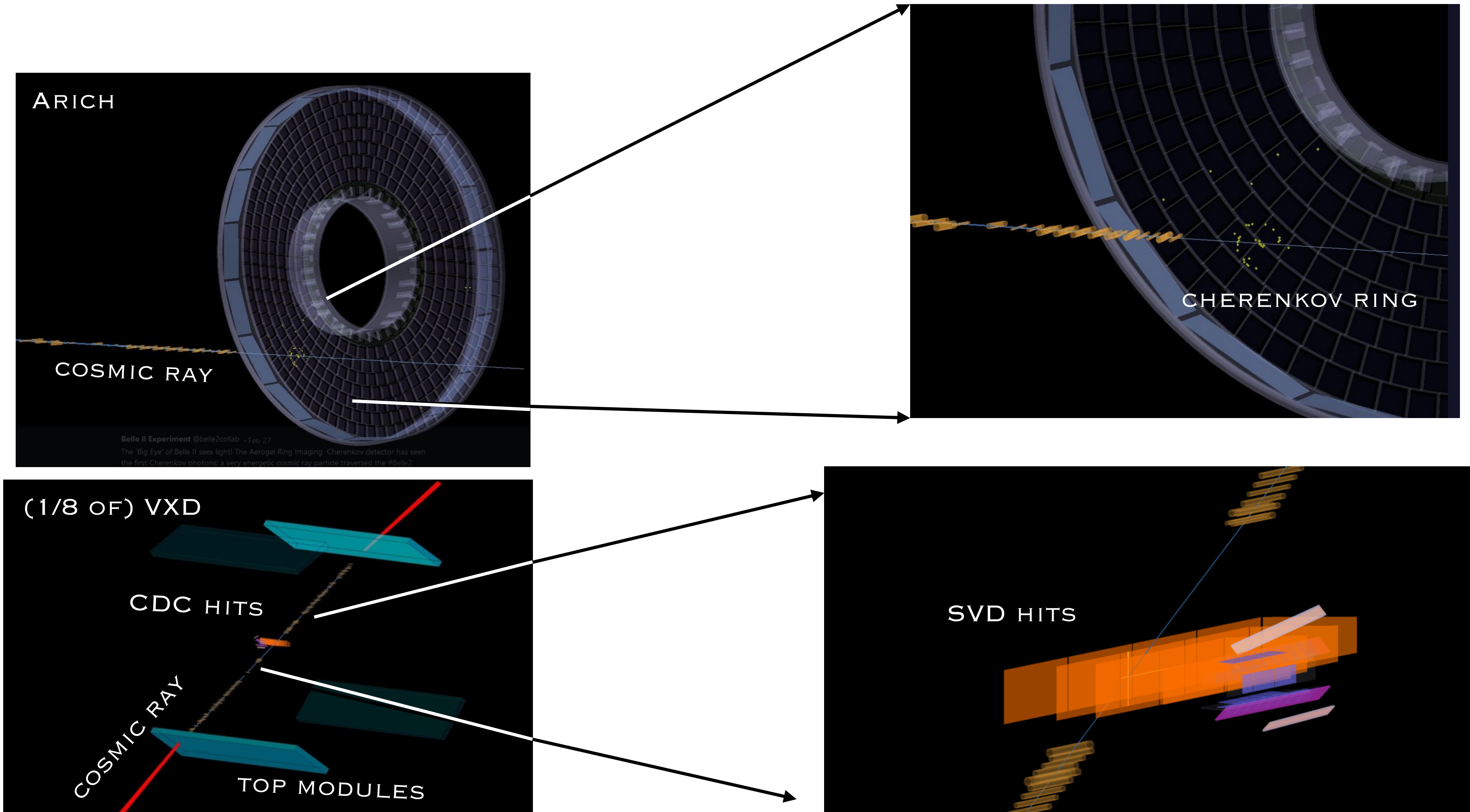
σ_Y: vertical beam dimension

Phase 2

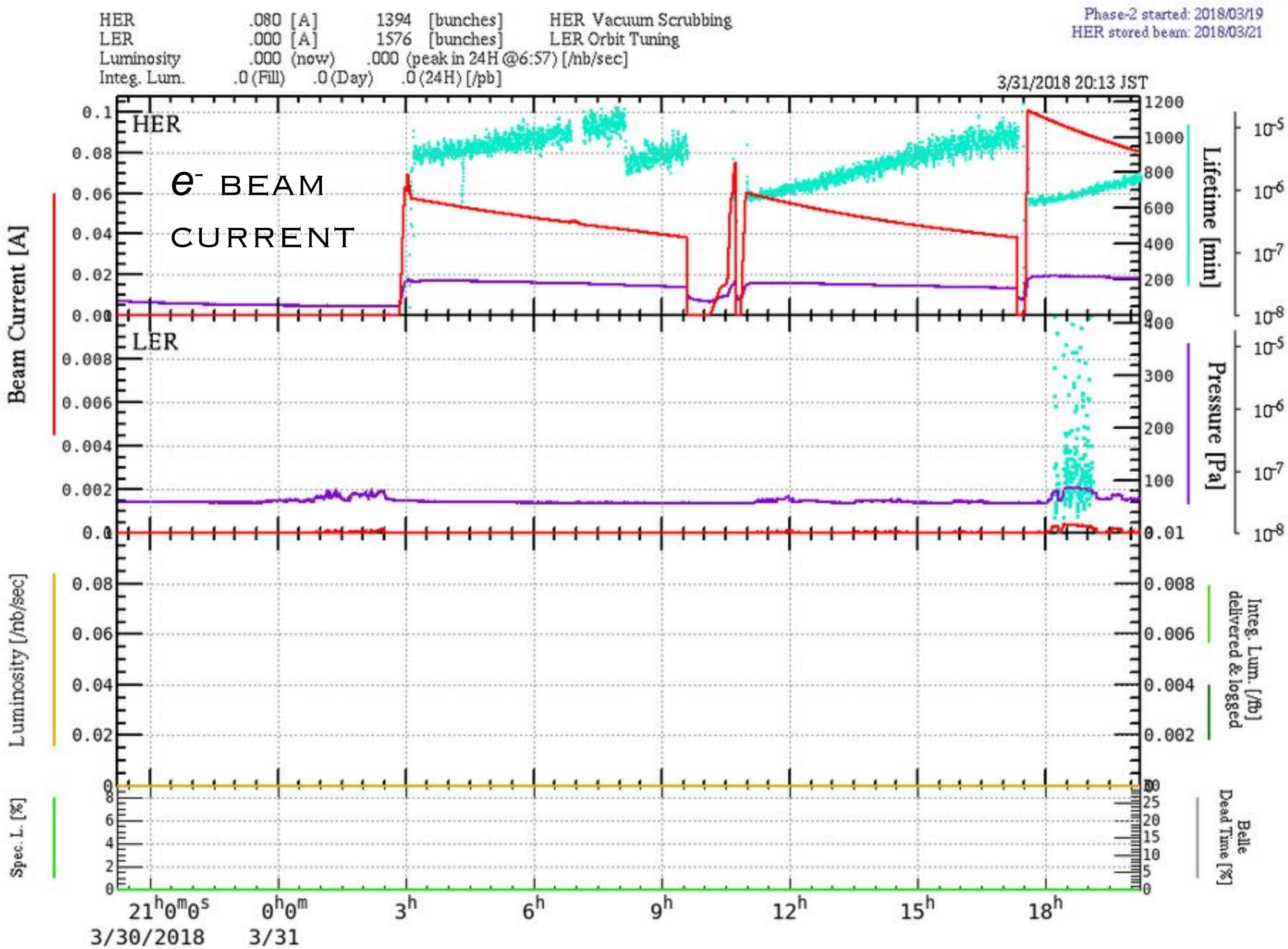
Status:

Phase 2 (full Belle II w/o SVD) started March 19, ongoing until July;

both beams successfully stored, collisions expected in ~ week



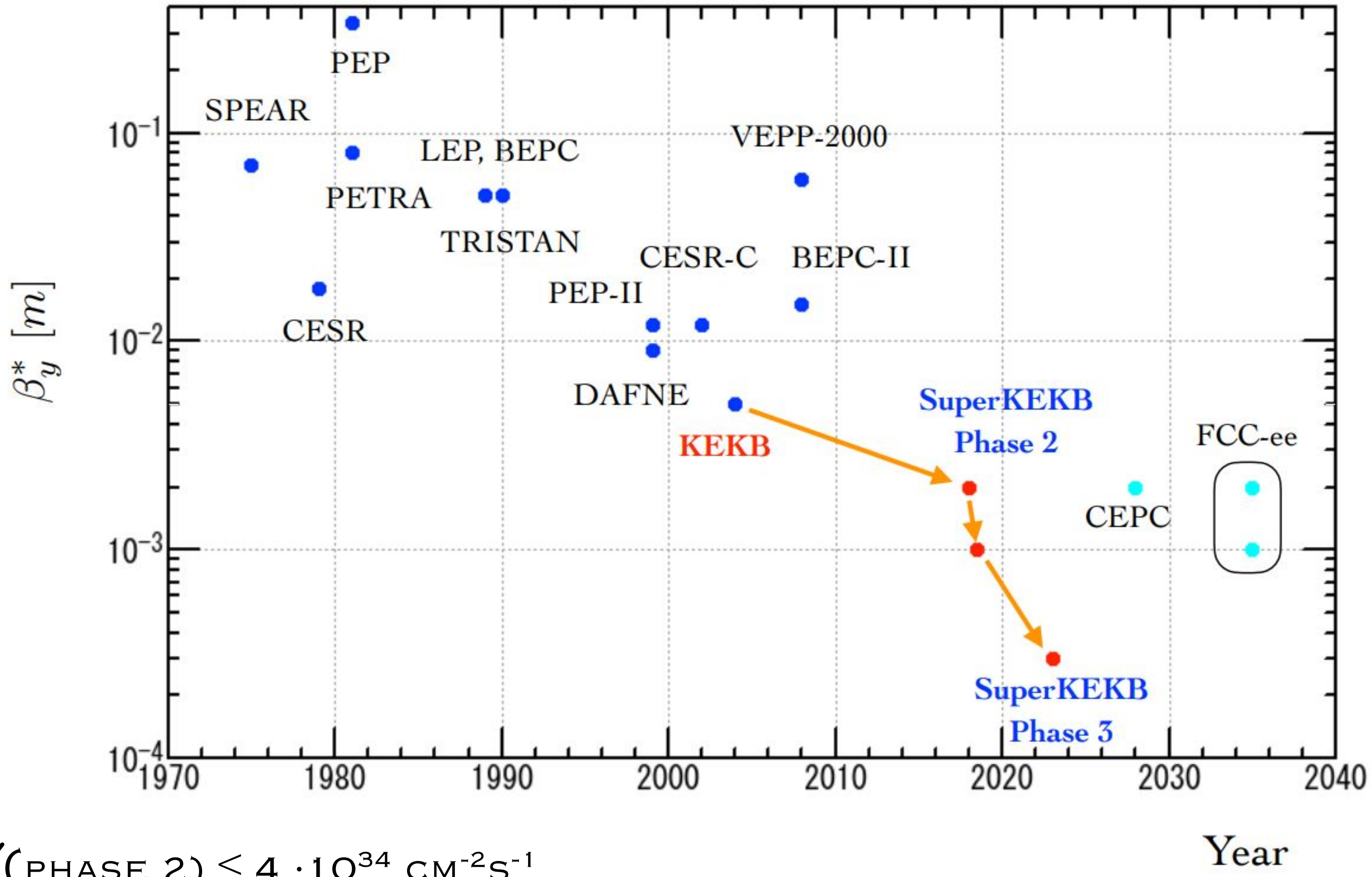
Phase 2 (full Belle II w/o SVD) started March 19



24h SuperKEKB history

both beams successfully stored, no collisions yet

Beam squeezing



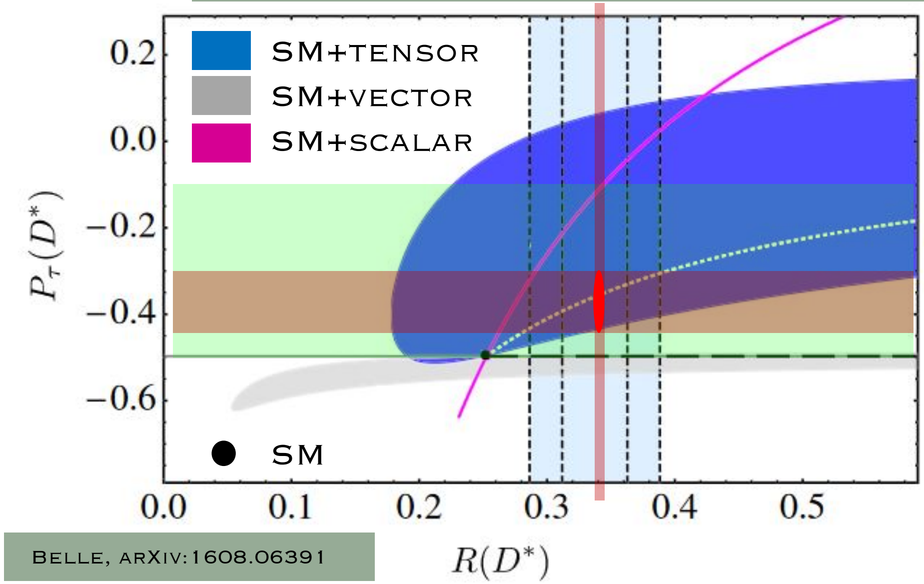
$\mathcal{L}$(phase 2) $\leq 4 \cdot 10^{34}$ cm^{-2}s^{-1}

$\mathcal{L}$(peak KEKB) ~ $2 \cdot 10^{34}$ cm^{-2}s^{-1}

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

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

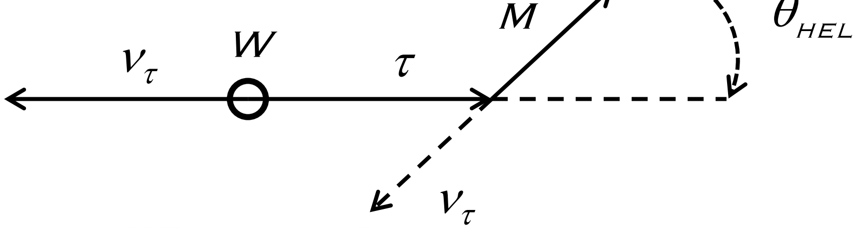
M.Tanaka, R.Watanabe Phys. Rev. D87 (2013), 034028



Belle, arXiv:1608.06391

Belle II, 50 ab^{-1} B2TiP report

Using had. tag & 2-body hadronic τ decays



$$\frac{d\Gamma}{d\cos\theta_{hel}(\tau)} \sim \frac{1}{2}(1 + \alpha P_\tau \cos\theta_{hel}(\tau))$$

$J_M=0,\ \alpha=1$

$J_M=1 \qquad \alpha = \frac{m_\tau^2 - m_M^2}{m_\tau^2 + m_M^2}$

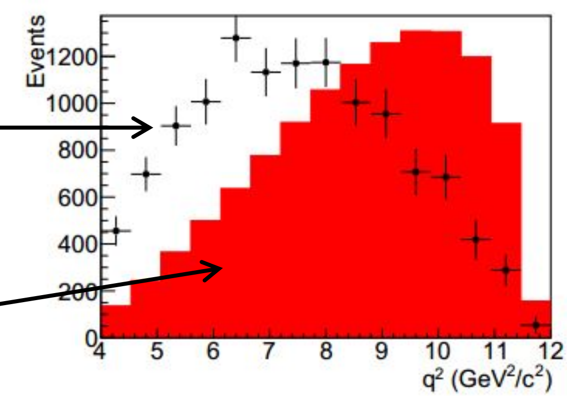
$(M=\rho \Rightarrow \alpha=0.45)$

Also D^* polarization can be measured and can differentiate among NP models

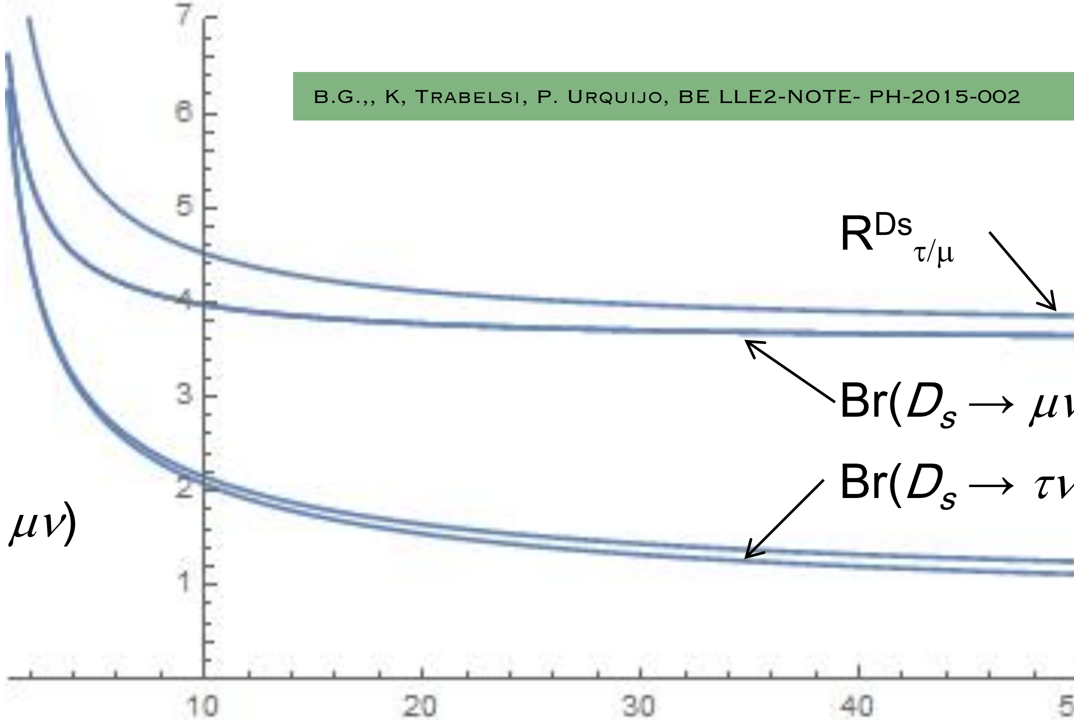
diff. distr.'s also differentiate between SM and NP:

expected data @ 50 ab^{-1}, SM

2HDM type II, $\tan\beta/m_{H\pm}$=0.5(GeV/c^2)$^{-1}$



$D_s \to \ell\, \nu$



$R^{Ds}_{\tau/\mu}$= Br($D_s \to \tau\nu$) / Br($D_s \to \mu\nu$)

Belle, JHEP09, 139 (2013), 900 fb^{-1}

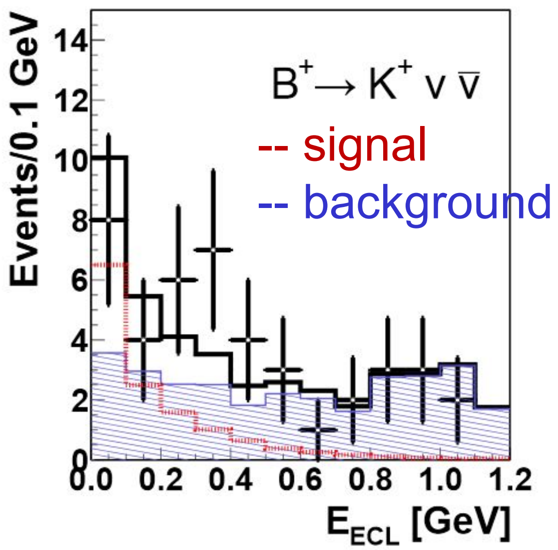
$R^{Ds}_{\tau/\mu}$=10.73 ± 0.69 ± 0.55
$(R^{Ds}_{\tau/\mu})_{SM}$= 9.762 ± 0.031

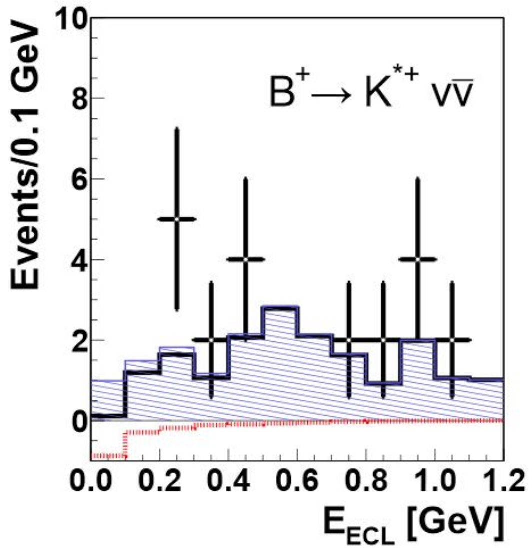
n.b.: $\sigma(R(D^*))/R(D^*)$ ~2.5% @ 20 ab^{-1}

Belle preliminary, arXiv:1303.3719, 711 fb^{-1}

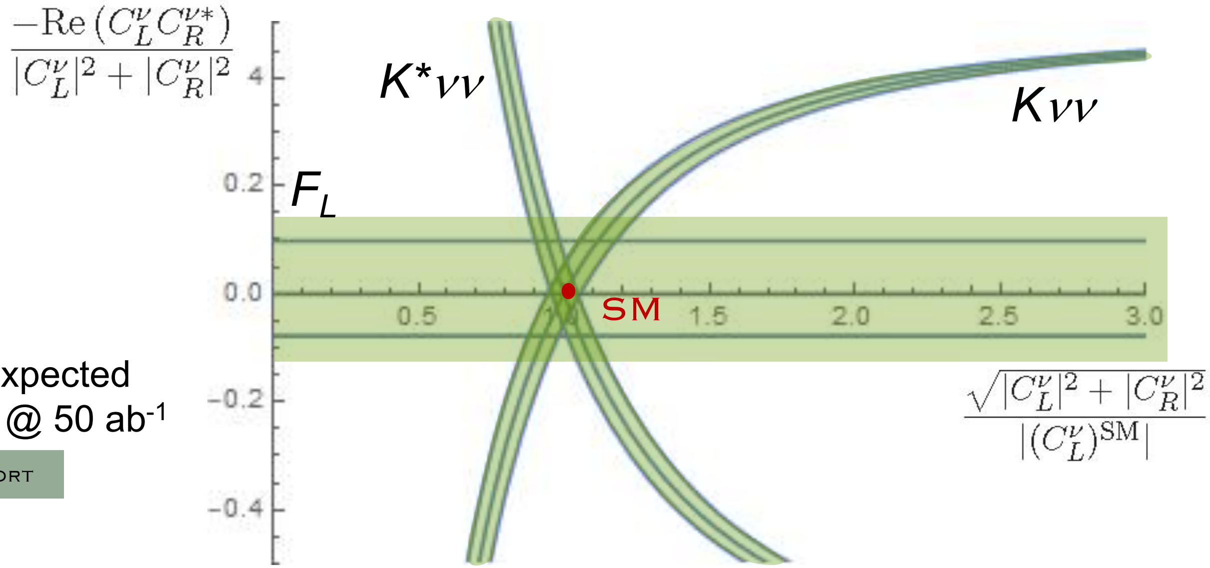
$B \to h\nu\nu$

$\mathcal{B}(B^+ \to K^{(*)}\nu\nu)$ can be measured to ±10% with 50 ab^{-1};
similar accuracy for $B^+ \to K^{*0}\nu\nu$, $B^+ \to K^{*+}\nu\nu$, $B^+ \to K^+\nu\nu$;





combined semil. + had. tag;
limits on right-handed currents



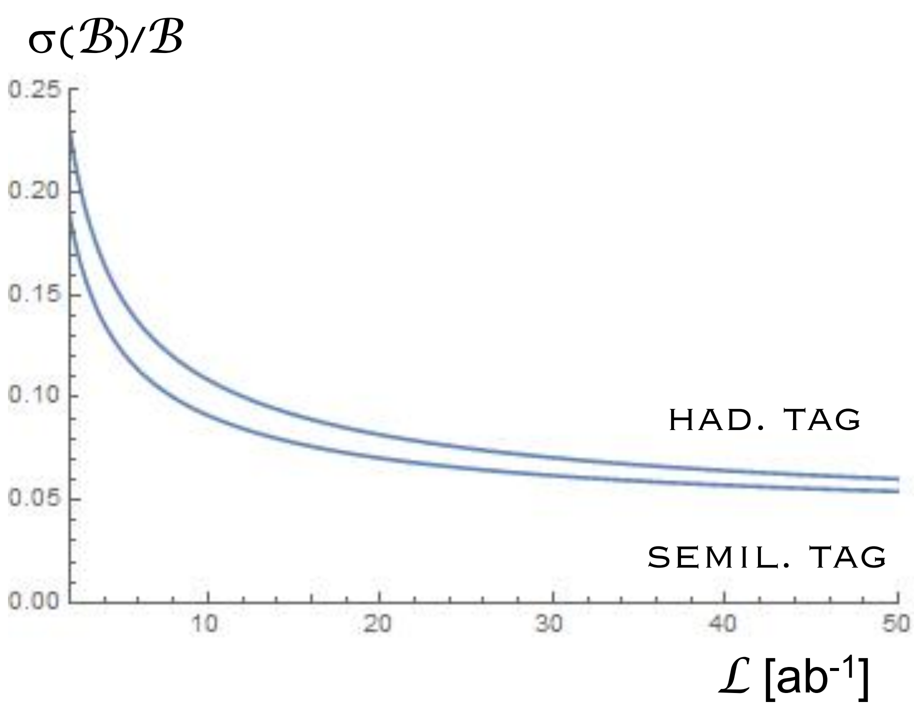
approx. expected precision @ 50 ab^{-1}

B2TIP REPORT

W. Altmannshofer et al., arXiv:0902.0160

$B^+ \to \tau\nu$

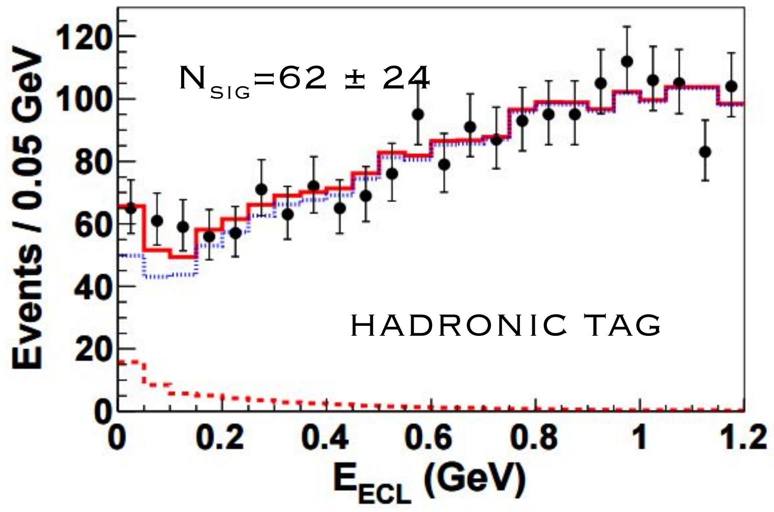
PROJECTED ACCURACY ON $\mathcal{B}(B^+ \to \tau^+ \nu)$

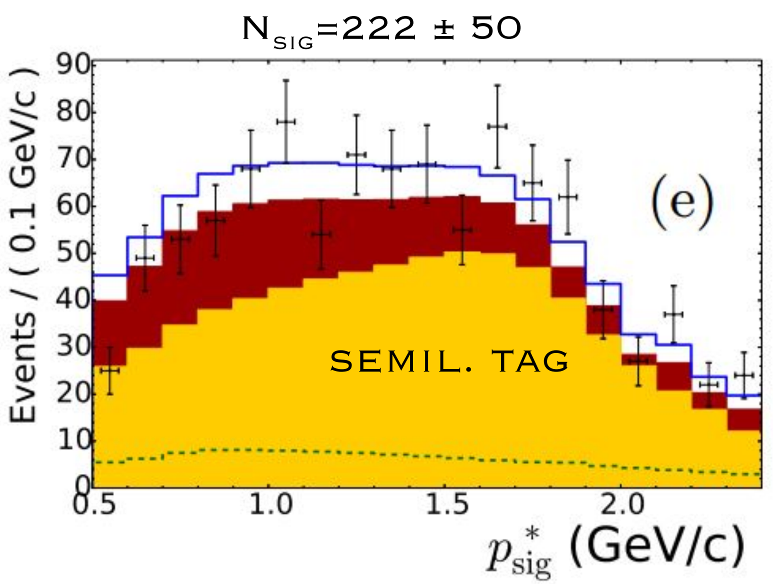


CORRESPONDING $|V_{ub}|$ UNCERTAINTY (EXPERIMENTAL):

SEMIL. TAG, 50 ab^{-1}: ~3%
HADR. TAG, 50 ab^{-1}: ~3%

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





BELLE, ARXIV:1503.05613, 700 fb^{-1}

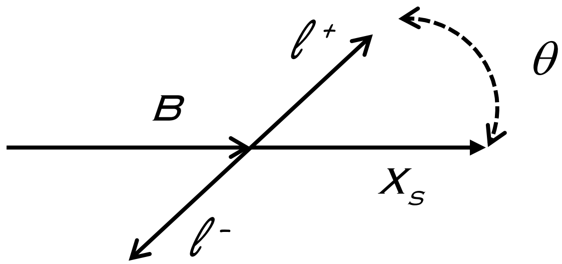
$B \longrightarrow X_s \ell^+\ell^-$

DIFF. DISTRIBUTION

$q^2 = M^2(\ell^+\ell^-)$

$z = \cos\theta$

$s = q^2 / M_b^2$



$$\frac{d^2\Gamma}{dq^2\,dz} = \frac{3}{8}\left[(1+z^2)H_T(q^2) + 2zH_A(q^2) + 2(1-z^2)H_L(q^2)\right]$$

$$\frac{dA_{\rm FB}}{dq^2} = \int_{-1}^{+1} dz\, \frac{d^2\Gamma}{dq^2 dz}\,\mathrm{sgn}(z) = \frac{3}{4}\,H_A(q^2)\,,$$

$$\frac{d\Gamma}{dq^2} = \int_{-1}^{+1} dz\, \frac{d^2\Gamma}{dq^2 dz} = H_T(q^2) + H_L(q^2)$$

$$H_T(q^2) = 2\hat{s}(1-\hat{s})^2\left[\left|C_9 + \frac{2}{\hat{s}}\,C_7\right|^2 + |C_{10}|^2\right]$$

$$H_L(q^2) = (1-\hat{s})^2\left[\left|C_9 + 2\,C_7\right|^2 + |C_{10}|^2\right],$$

$$H_A(q^2) = -4\hat{s}\,(1-\hat{s})^2\ \mathrm{Re}\left[C_{10}\left(C_9 + \frac{2}{\hat{s}}\,C_7\right)\right]$$

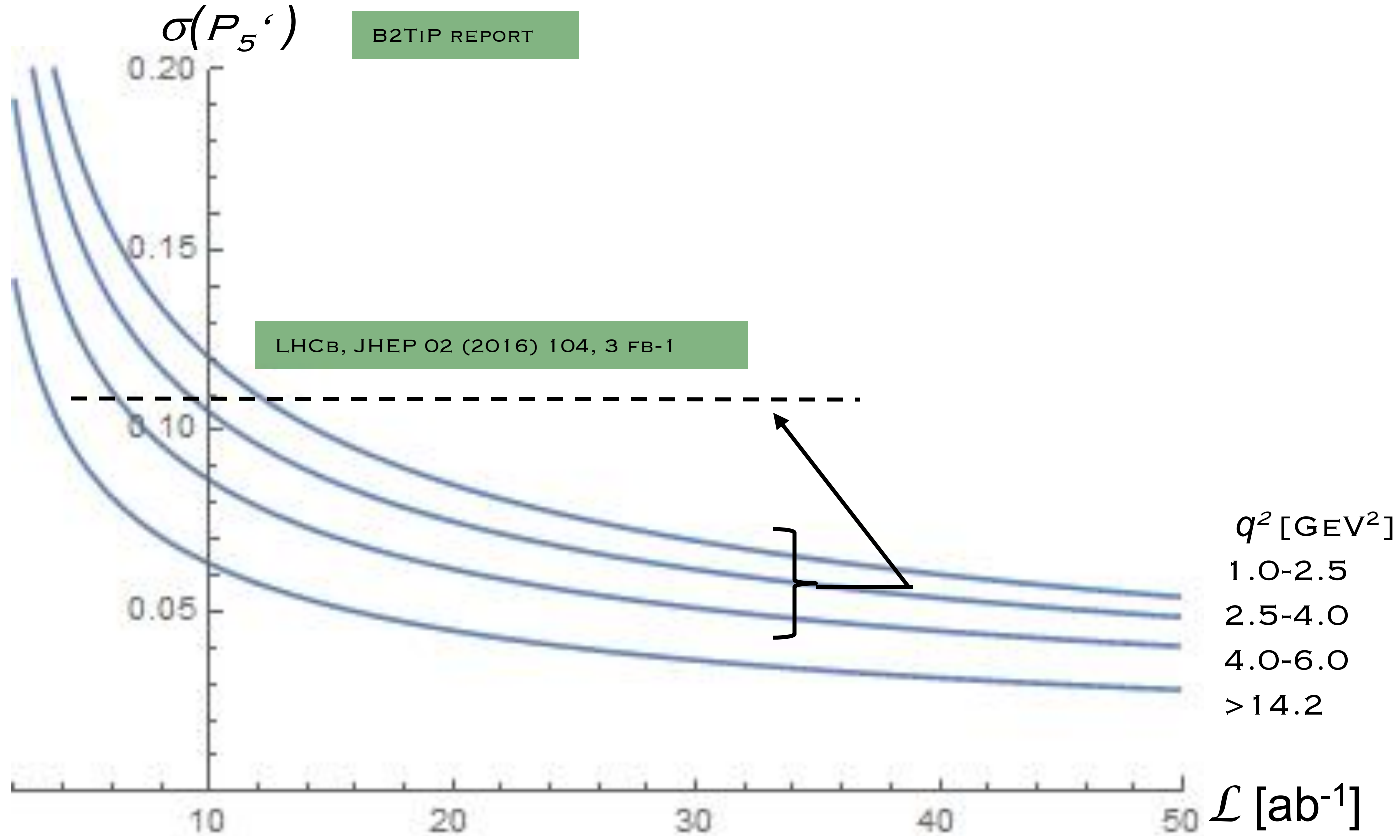
K.S.M. Lee et al., Phys. Rev., D75, 034016 (2007);
A. Ali et al., Phys. Lett., B273, 505 (1991)

$B \longrightarrow K^* \ell^+ \ell^-$

P_5' ACCURACY

$q^2 = M^2(\ell^+ \ell^-)$

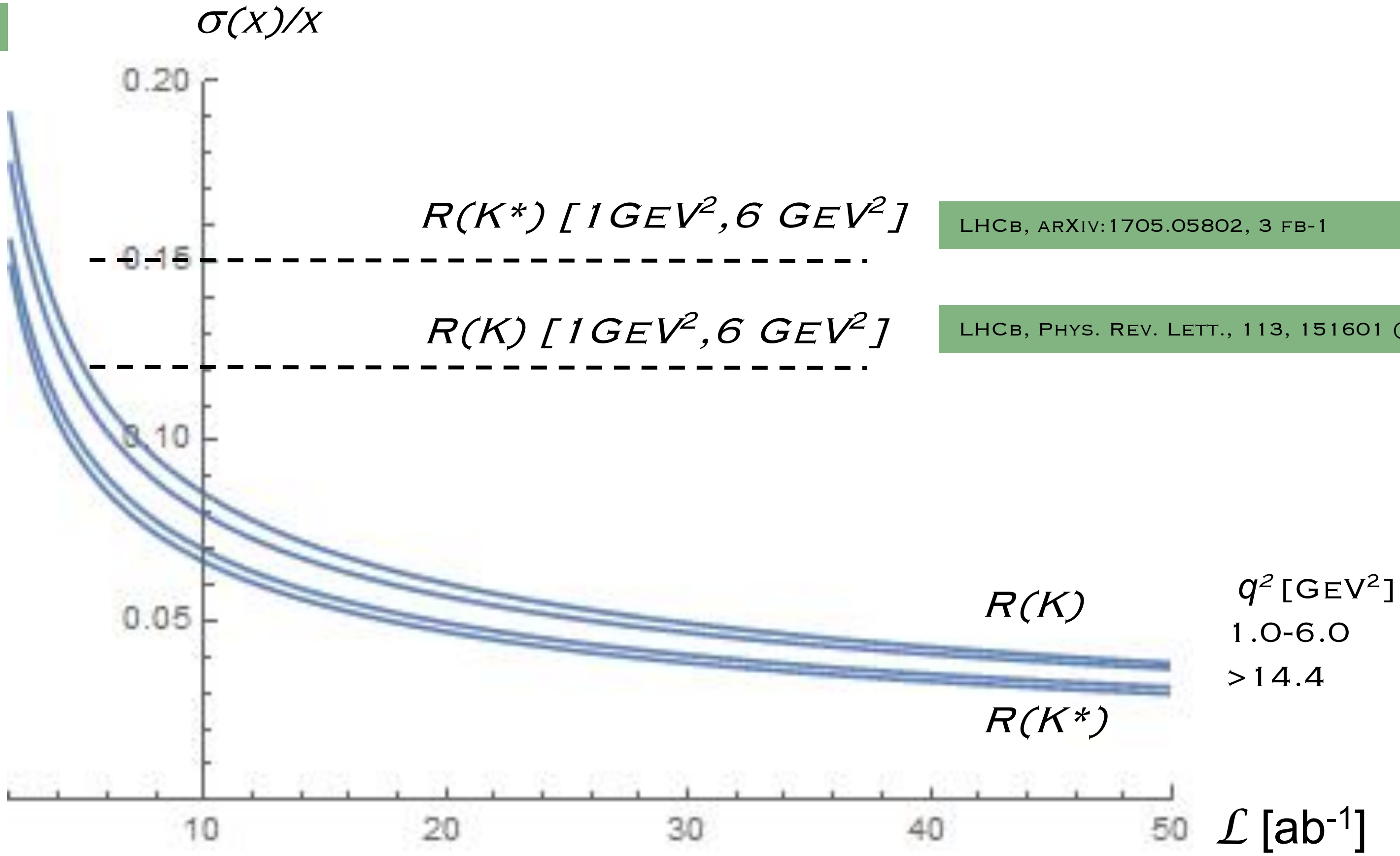
$\ell = e + \mu$



$B \longrightarrow K^{(*)} \ell^+ \ell^-$

R(K), R(K*) accuracy

B2TiP report



LHCb, arXiv:1705.05802, 3 fb-1

LHCb, Phys. Rev. Lett., 113, 151601 (2014), 3 fb-1

$B \to s\tau\tau$

PROBABLY NOT OBSERVED EVEN WITH FULL STAT.;

BR($B \to K^*\tau\tau$) < $2 \cdot 10^{-5}$ @ 50 AB-1 B2TIP REPORT
BR_{SM}($B \to K^*\tau\tau$)~ $1 \cdot 10^{-7}$

COMPARED TO $K^*\nu\nu$ (WITH ADDITIONAL TWO TRACKS FROM τ)

- USING HAD. TAGGING ONLY (TOO MANY ν'S IN SEMIL. TAG)

N($K^*\tau\tau$)/N($K^*\nu\nu$) ~ (ε_{HAD}/(ε_{HAD}+ε_{SL})) [BR($B \to K^*\tau\tau$) / BR ($B \to K^*\nu\nu$)] BR(τ)

~ ½ 10^{-2} 0.1 ~ 5 ·

+ SOME BKG FROM $B \to X_c(\to X_s \ell\nu)\ell\nu$

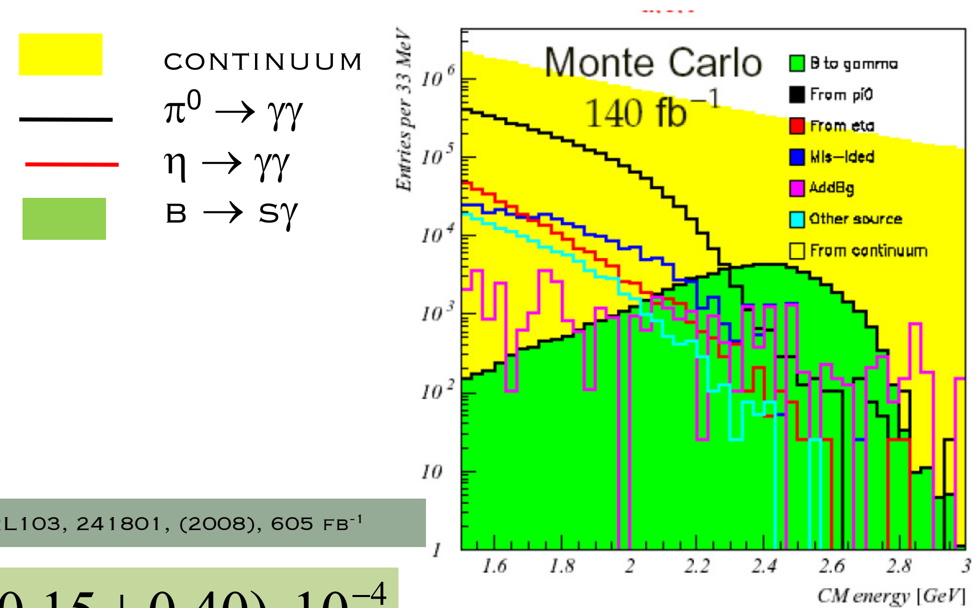
$B \to s(+d)\,\gamma$

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

EXPERIMENTAL CHALLENGE:
HUGE BKG;
ONLY γ RECONSTRUCTED IN THE SIGNAL SIDE

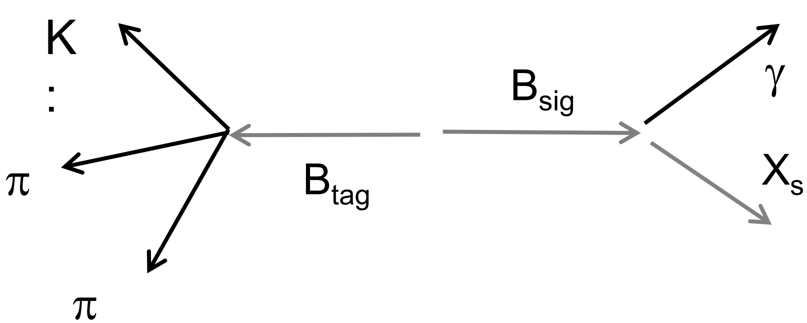
1.26 GeV < E < 2.20 GeV

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 ($\varepsilon_{HAD} \sim 1\%$);



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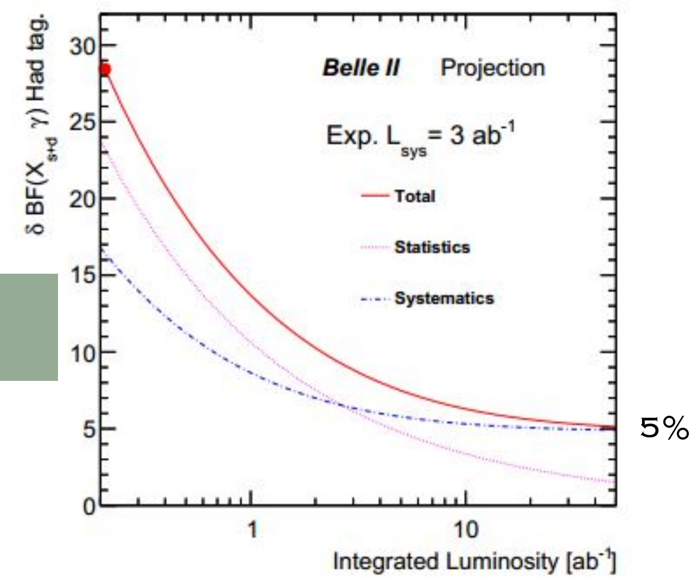
P. URQUIJO,
BELLE2-NOTE-PH-2015-002

SIMILAR ACCURACY WITH SEM. TAG

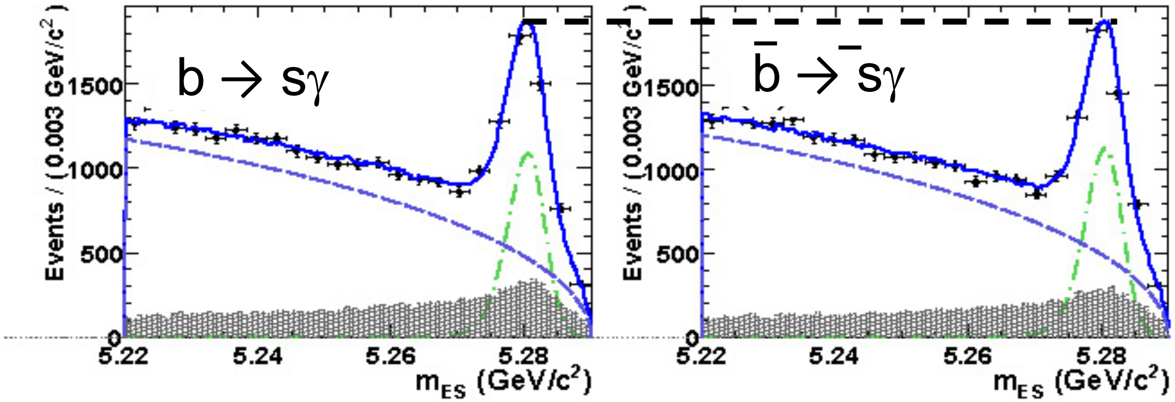


$B \to s\gamma$

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;

$\langle D \rangle$: AVERAGE DILUTION DUE TO FLAVOUR MISTAG, ~1

ΔD: DIFFERENCE BETWEEN FLAVOUR MISTAG FOR B AND $\bar{B}$, << 1

A_{DET}: DETECTOR INDUCED ASYMMETRY

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

HFAG, 2014

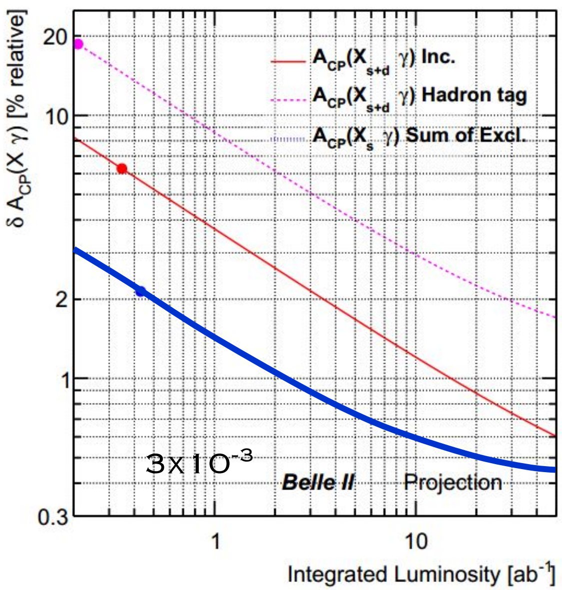
SM: $A_{CP} \sim (0.44 \pm^{0.24}_{0.14})\%$

T. HURTH ET AL., NUCL.PHYS. B704, 56 (2005)

A_{DET}: CAREFUL STUDY OF K/π ASYMMETRIES IN (p, θ_{lab}) USING D DECAYS OR INCLUSIVE TRACKS FROM FRAGMENTATION;

LOTS OF WORK ON SYSTEM.,
→ FEW 10^{-3}
EXP. SENSITIVITY

SEMI-INCLUSIVE METHOD MOST ACCURATE (UNCERTAINTY STAT. DOMINATED)



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$B \to D \gamma$

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 ~$(0.5\ 10^{-2})\ (3.4 \cdot 10^{-4})$ ~$2 \cdot 10^{-6}$

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

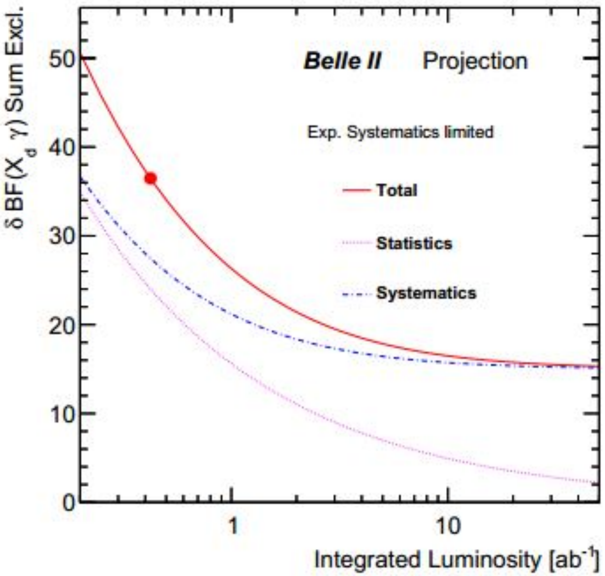
$\sigma(Br(d\gamma)) = (\pm 20 \pm 22) \cdot 10^{-7}$ HIGH X_D MASS REGION

SIGNIFICANT IMPROVEMENT NECESSARY

LARGEST SYST. UNCERTAINTY:

$B \to s\gamma$ BKG.;

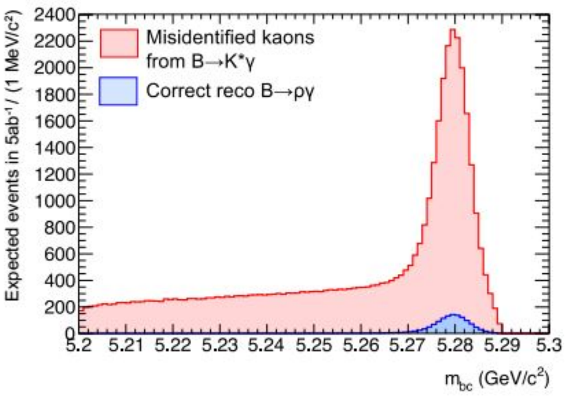
MISSING (>= 5 BODY) MODES;

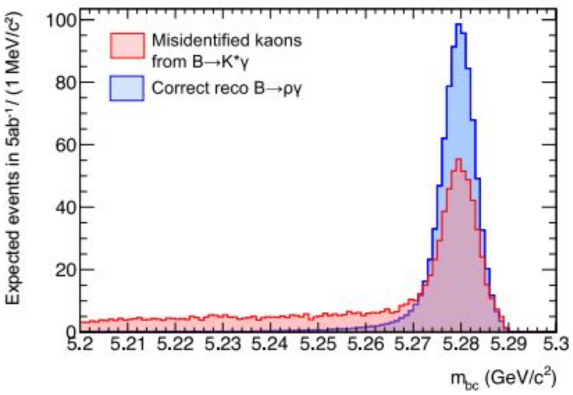


15%

B. GOLOB, K. TRABELSI, P. URQUIJO, BELLE2-NOTE-PH-2015-002

BELLE 2 FULL SIMULATION:





$B^0 \to K^*(K\pi)\gamma$, $B^0 \to \rho(\pi\pi)\gamma$

DCPV puzzle

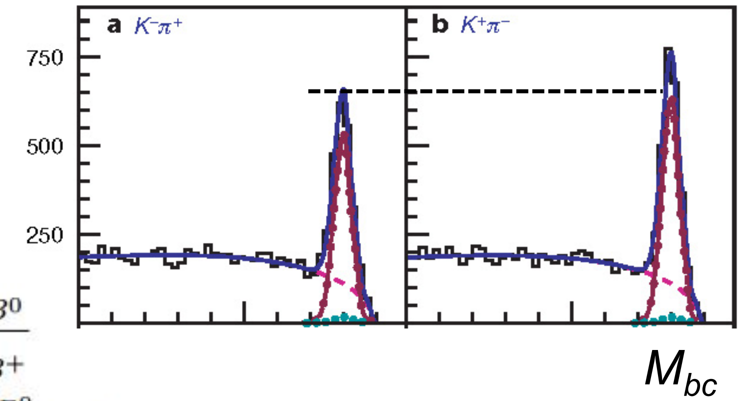
DCPV puzzle:

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}

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

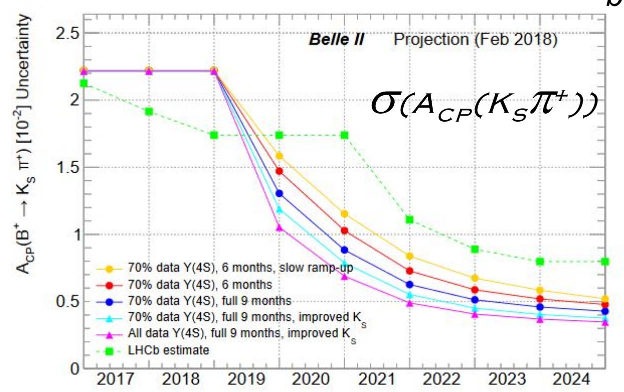


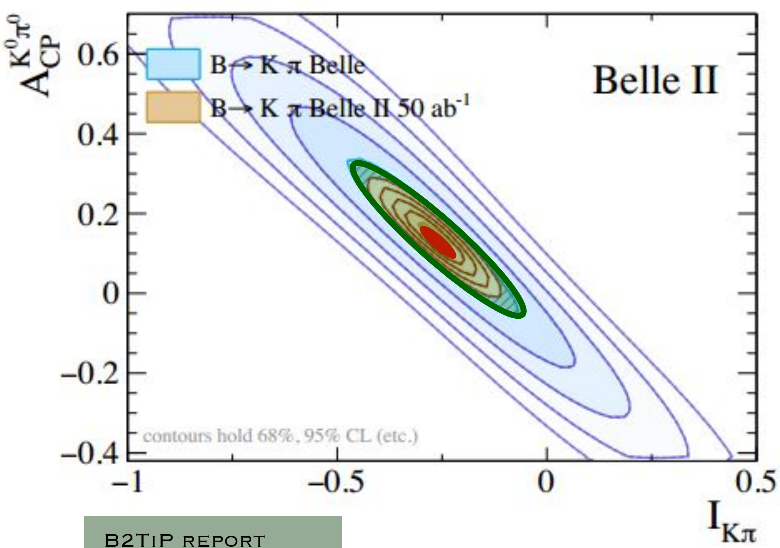
$I_{K\pi}\,\mathcal{B}\,(B^0 \to K^+\pi^-)$

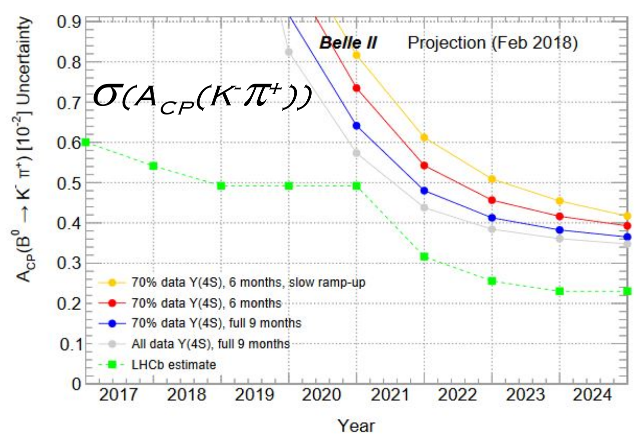
$$= A_{CP}^{K^+\pi^-} \cdot \mathcal{B}(B^0 \to K^+\pi^-) + A_{CP}^{K^0\pi^-} \cdot \mathcal{B}(B^+ \to K^0\pi^-)\frac{\tau_{B^0}}{\tau_{B^+}}$$

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

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







Belle $K^0\pi^0$
Belle II $K^0\pi^0$
50 ab^{-1}

B2TiP report

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

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

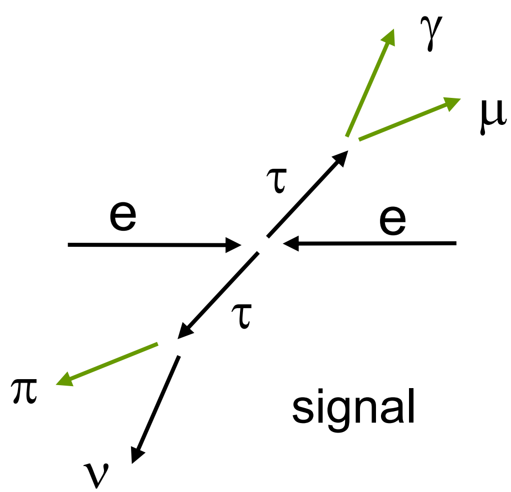
Belle, PLB66, 16 (2008), 535 fb^{-1}

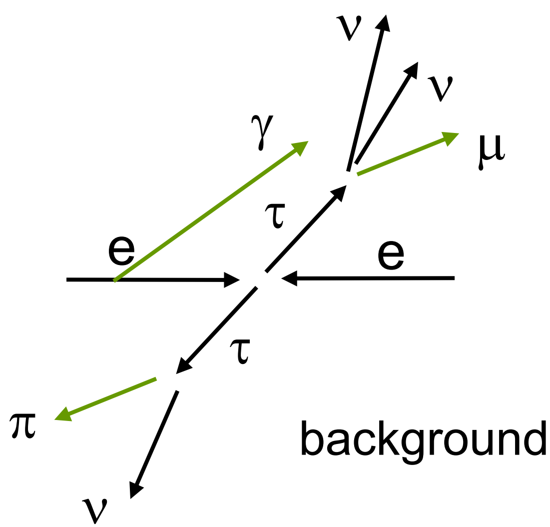
kinematic variables for signal isolation:
$\Delta E = E^{CM}(\mu\gamma) - E^{CM}(beam)$
$M_{inv} = m(\mu\gamma)$

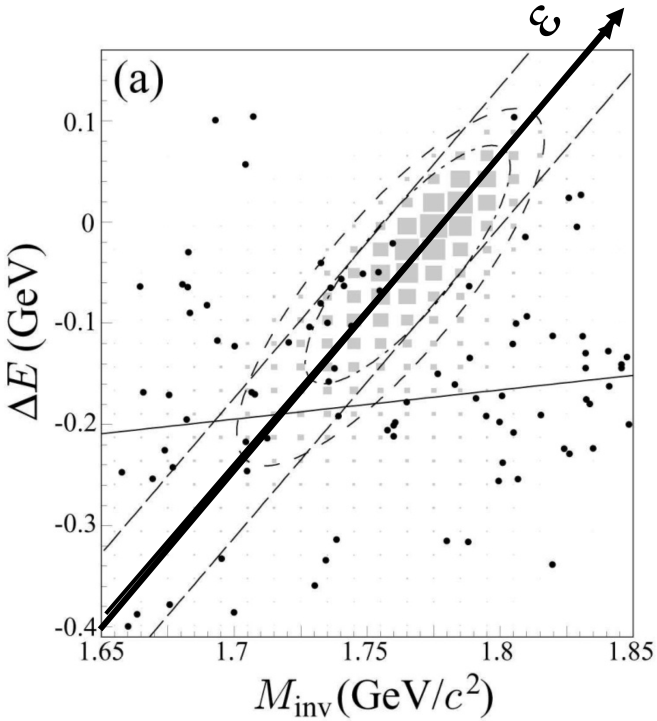
main background from
$ee \to \tau(\mu\nu\nu)\ \tau(\pi\nu)\ \gamma_{ISR}$

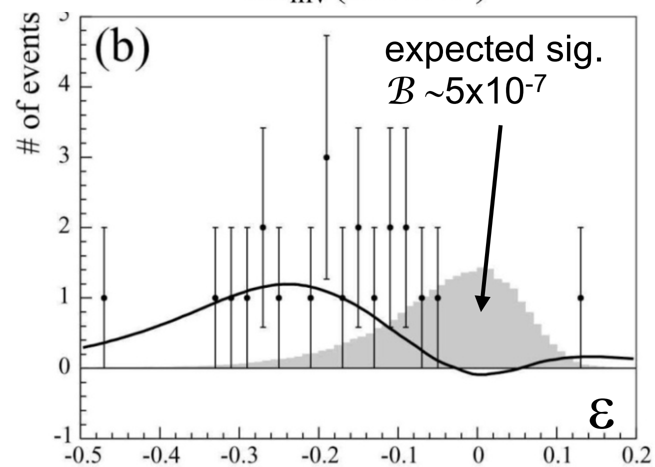
$Br^{UL} \propto 1/\sqrt{\mathcal{L}}$

polarized beam(s) would help









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

w/o polarization:
$UL_{90\%}(\mathcal{B}(\tau \to \mu \gamma)) \sim 2 \times 10^{-9}$ @ 50 ab^{-1}

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

decays $\tau \to 3\ell, \ell h^0$ 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