Physics Program at SuperKEKB

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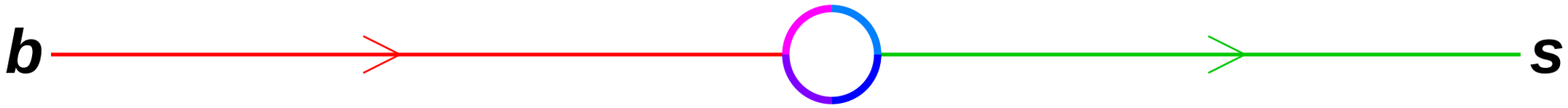
SM does not tell much about flavor

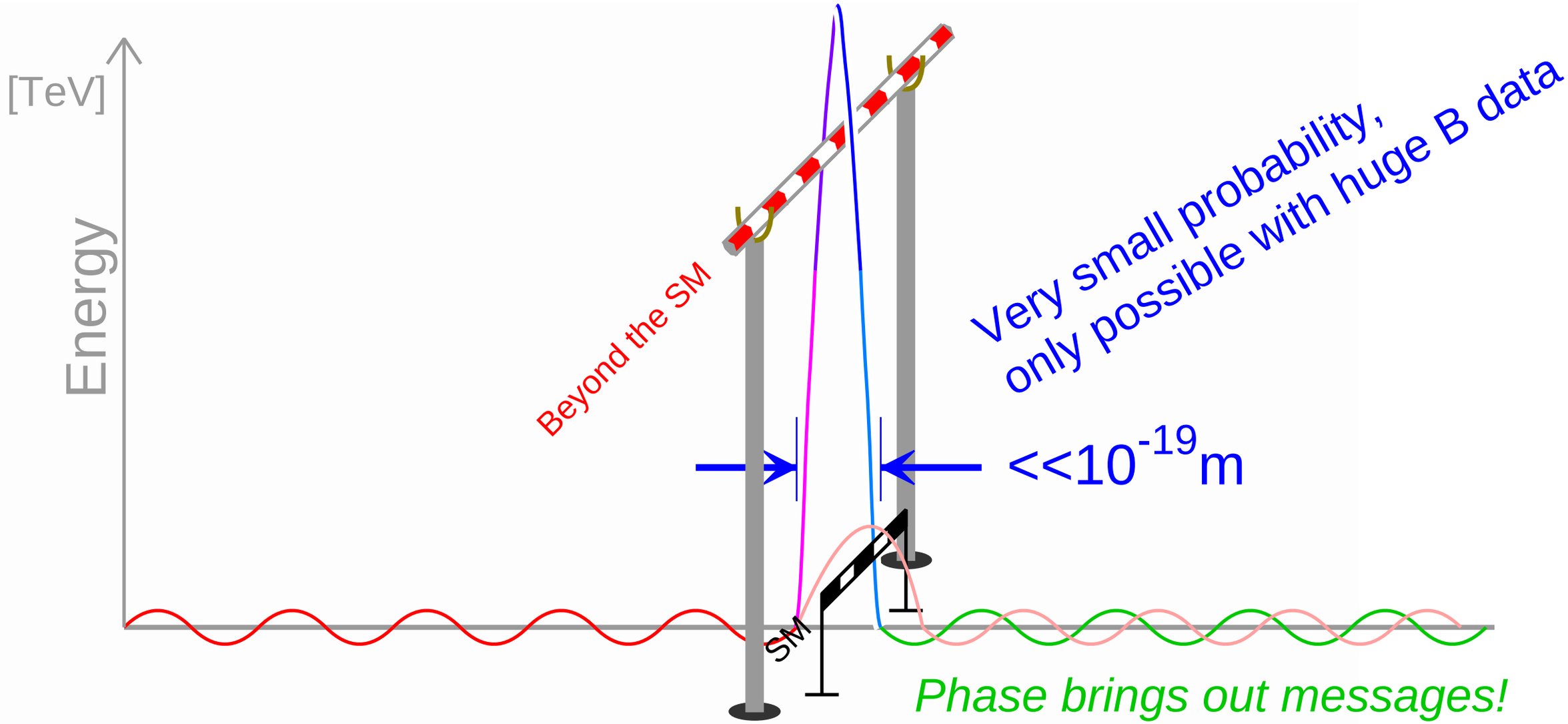
- Why three generations?
- What determines the mass and mixing pattern?
- How antimatter disappeared in the universe?

Questions remain unanswered even if SUSY is found at LHC, or even if upgraded KEKB finds new physics...

BUT, step-by-step experimental approach in flavor physics is definitely needed to address these grand questions
— hopefully keys are in new physics beyond the SM

"Quantum effect" beyond the SM



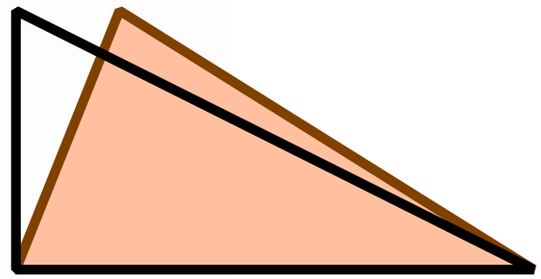


Cabibbo-Kobayashi-Maskawa Matrix

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Effective BSM contribution?

$$+ \begin{pmatrix} \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \end{pmatrix}$$



Unitarity triangle with and without BSM

MSSM down-type squark mass matrix

$$
\begin{pmatrix}
m^2_{\tilde{d}_L} & m_d(A_d - \mu\tan\beta) & (\Delta^d_{12})_{LL} & (\Delta^d_{12})_{LR} & (\Delta^d_{13})_{LL} & (\Delta^d_{13})_{LR} \\
 & m^2_{\tilde{d}_R} & (\Delta^d_{12})_{RL} & (\Delta^d_{12})_{RR} & (\Delta^d_{13})_{RL} & (\Delta^d_{13})_{RR} \\
 & & m^2_{\tilde{s}_L} & m_s(A_s - \mu\tan\beta) & (\Delta^d_{23})_{LL} & (\Delta^d_{23})_{LR} \\
 & & & m^2_{\tilde{s}_R} & (\Delta^d_{23})_{RL} & (\Delta^d_{23})_{RR} \\
 & & & & m^2_{\tilde{b}_L} & m_b(A_b - \mu\tan\beta) \\
 & & & & & m^2_{\tilde{b}_R}
\end{pmatrix}
$$

mass insertion approximation (MIA): $(\delta^d_{ij})_{AB} = \dfrac{(\Delta^d_{ij})_{AB}}{\tilde{m}^2}$

$b \to s$ transition ($ij = 23$)

- CPV phase in $b \to s$
- $B \to X_s\gamma$ branching fraction
- B_s mixing

$b \to d$ transition ($ij = 13$)

- CPV phase in $b \to d$
- $B \to X_d\gamma$ branching fraction
- B_d mixing

Two key measurements

Non-SM !@#$% from B meson decay

Lepton ?:&|=* violation in τ decay

!@#$% maybe phase, ?:&|=* maybe flavor, but could be anything else

Or. . . seven key measurements

- Non-SM CP phase: High precision $b \to s$ penguin studies
- Charged Higgs: searches in $B^+ \to \tau^+\nu$ and $B \to D^{(*)}\tau^+\nu$
- Non-SM right-handed current: $B \to K^*\gamma$ CPV
- Inclusive measurements: $b \to s\gamma$, $b \to d\gamma$, $b \to s\ell^+\ell^-$ (A_{FB}), V_{ub}
- Loop vs tree: high precision unitarity triangle measurement
- Lepton flavor violation: searches in high statistics τ decays
- NP search in up-quark sector: CPV in D-D mixing

+ Bonus

- Hunt for new particles: 4-quark states and more?
- Endless list: More rare B decays, B_s at $\Upsilon(5S)$, more D decays, continuum, $\gamma\gamma$, ISR. . .
- Jackpot?: anything not thought of yet. . .

Now it's time to look more closely at the physics strategy

- Today, need more focus on early stage of upgraded KEKB, to maximize physics output with 3 or 5 ab^{-1}
- $10\ \text{ab}^{-1}$ would tell us the direction of Flavor Physics — Goal of current roadmap
- $50\ \text{ab}^{-1}$ would allow us to study Flavor Physics of BSM towards the systematics/theory limits (not in the roadmap yet)

First Step	Second Step	Third Step
Completion of SM First hint of BSM?	Confirmation of BSM More hints on BSM	Flavor physics on BSM
$\int \mathcal{L} = 3\ \text{ab}^{-1}$	$\int \mathcal{L} = 10\ \text{ab}^{-1}$	$\int \mathcal{L} = 50\ \text{ab}^{-1}$

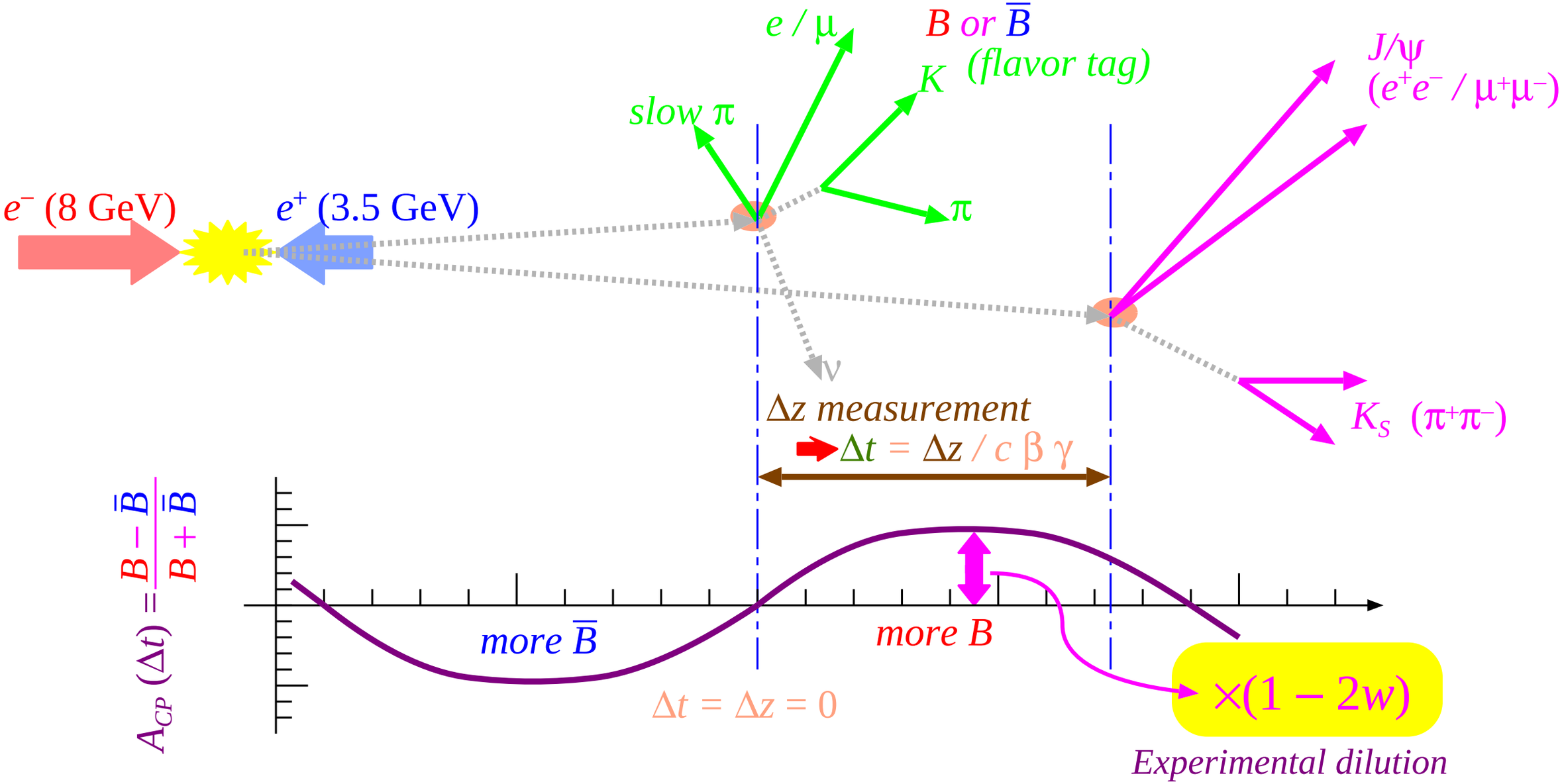
Assumptions

- Main physics and detector target is for 50 ab^{-1} with $\times 20$ background (to get prepared!)
- Most of the studies have assumed the current Belle detector (it'll be a good assumption)
  - It is indeed a good detector, little room to improve
    PID (TOP/ARICH) — esp. to reduce fake rate
    Larger SVD — esp. for K^0_S vertexing
    Ultra-small beampipe/pixel — not for the day one
    Hermeticity — no feasible idea yet to boost it
    Software — tracking, calibration, . . .
  - Other improvements just to cancel beam background
    (or slightly worse at the moment with $\times 20$ background)
- As for the first stage, the Belle detector would do better! (with $\times 5$ background)

Non-SM CP phase

High precision $b \to s$ penguin studies

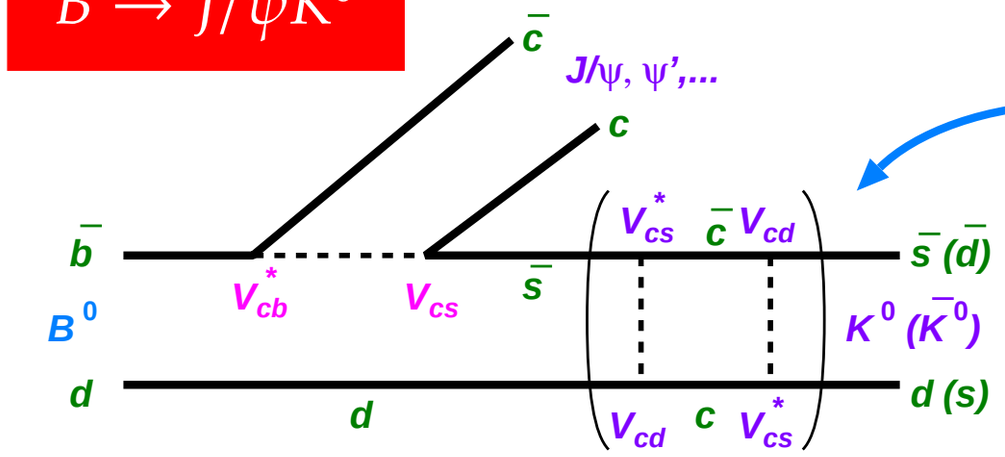
Time-dependent CPV measurement



$$A_{CP}(\Delta t) = -\xi_f \mathcal{S} \sin(\Delta m \Delta t) + \mathcal{A} \cos(\Delta m \Delta t)$$

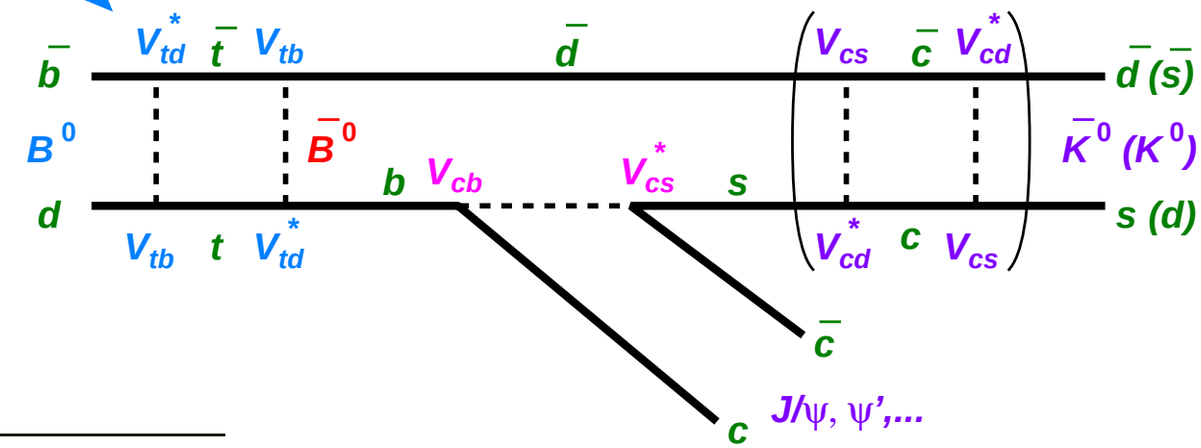
CPV in tree: the SM reference point

$B \to J/\psi K^0$



Complex interference term at $t \neq 0$ due to the weak phase difference,

$\phi_1 = \pi - \arg(V_{tb}^* V_{td} / V_{cb}^* V_{cd})$

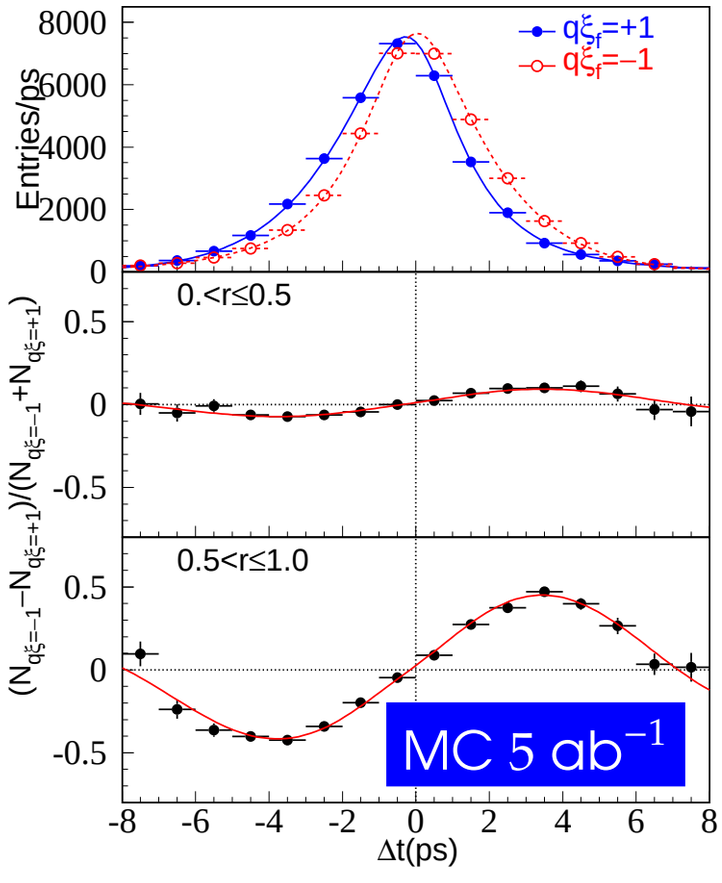


	stat	syst (reducible)	syst (irreducible)
0.5 ab^{-1}	0.031	0.012	
3 ab^{-1}	0.013	0.005	0.012
10 ab^{-1}	0.007	0.003	

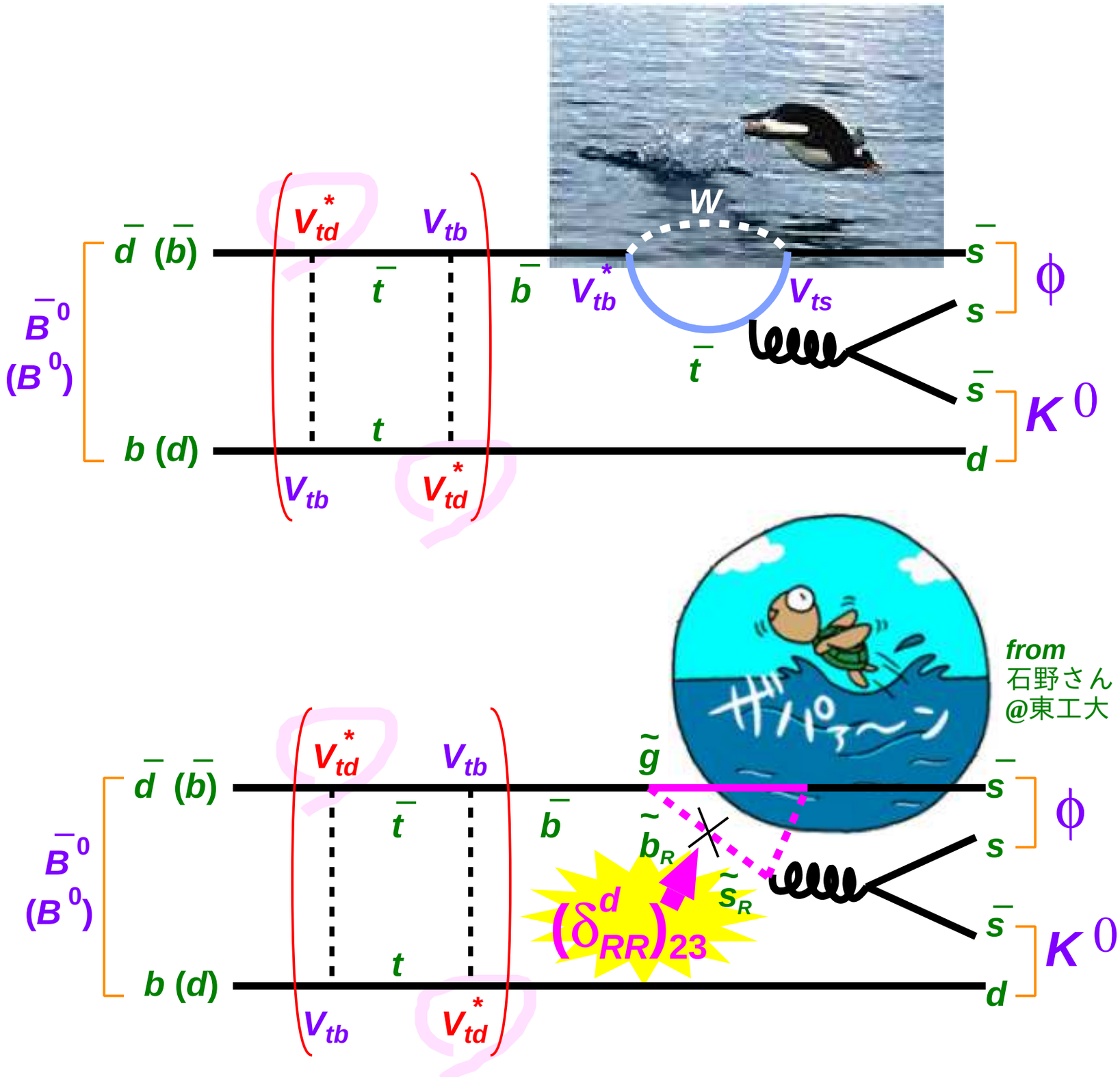
At 3 ab^{-1}, already syst. error = stat. error!

Irreducible errors:

IP profile	0.007
vtx selection	0.006
alignment	0.006
Δz bias	0.004



$b \to s$: a BSM probe



In SM
CPV phase$=\phi_1$
(equals to $J/\psi K_S^0$)

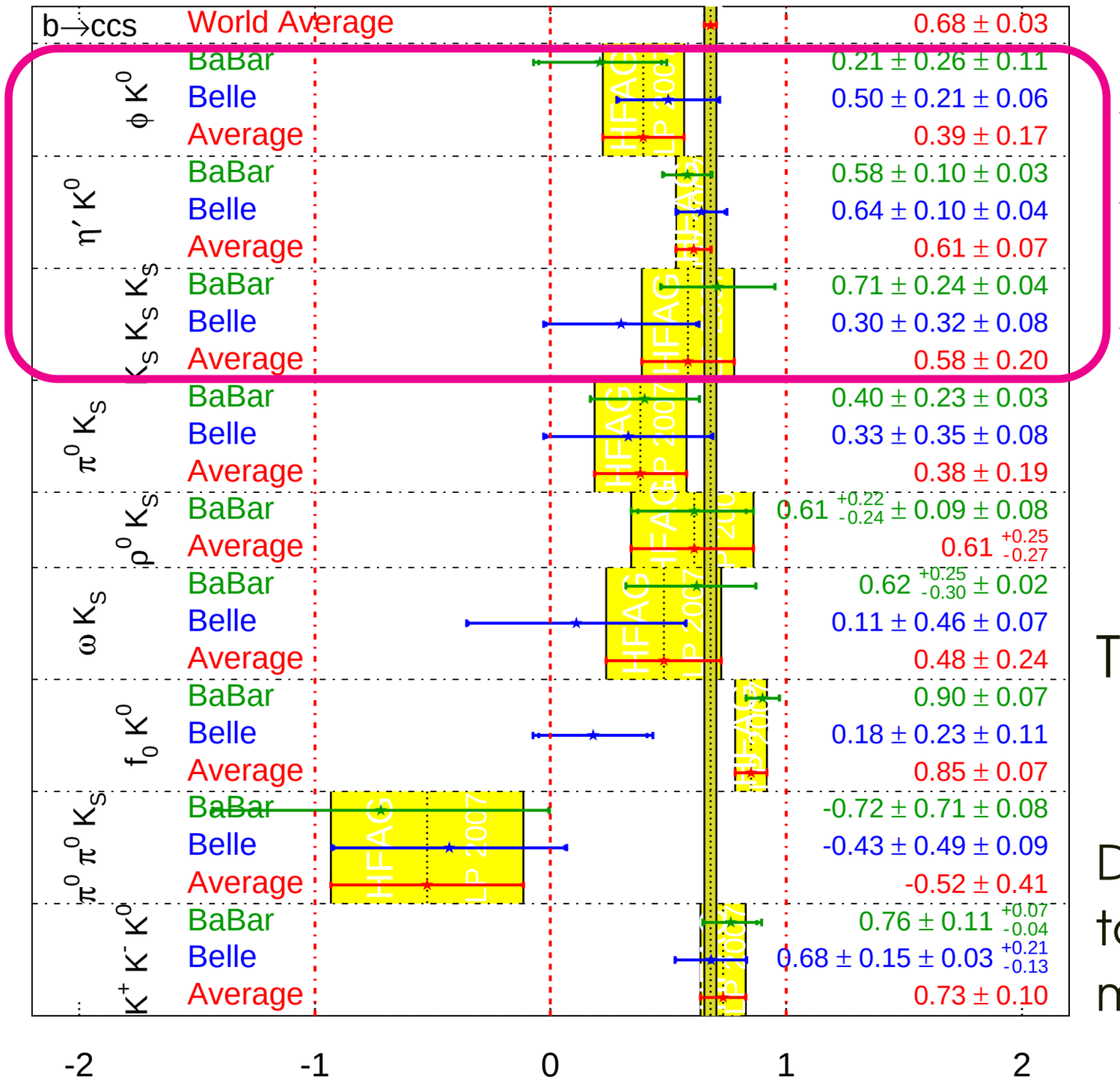
$\phi_1 + \phi_{\rm NP}$?

$\mathcal{S} \neq \sin 2\phi_1$

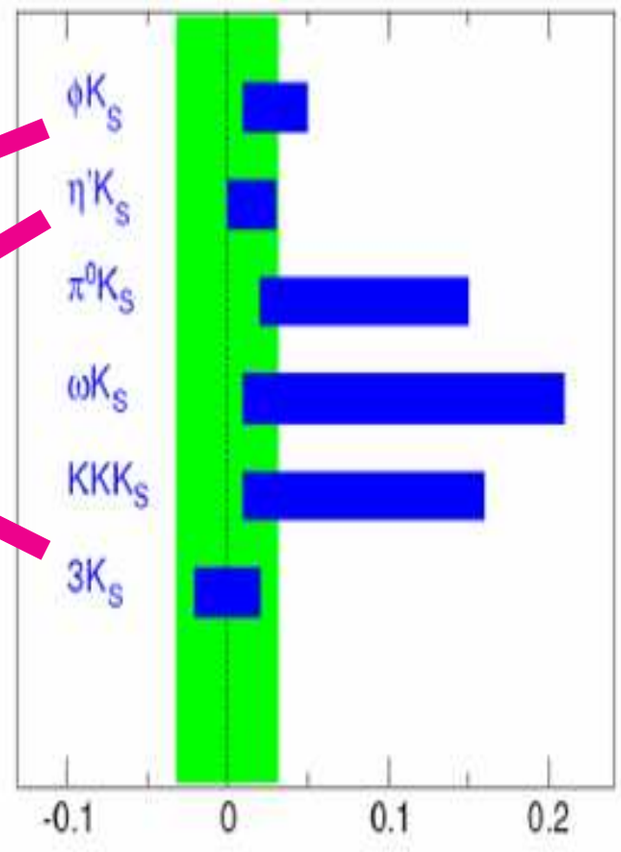
$b \to s$ CPV: now

$$\sin(2\beta^{\rm eff}) \equiv \sin(2\phi_1^{\rm eff})$$

HFAG LP 2007 PRELIMINARY



ΔS in QCDF



Three golden modes

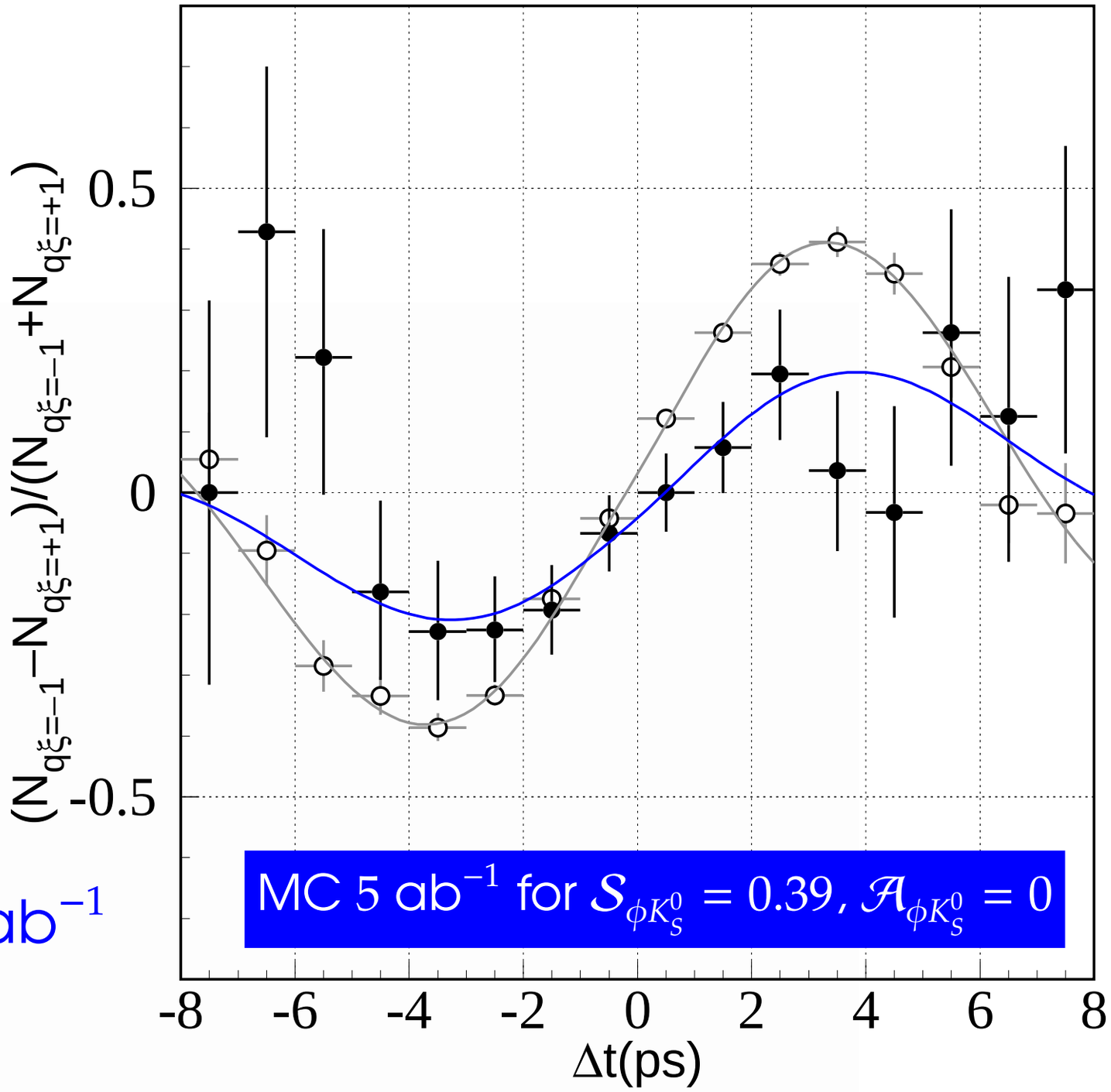
$\delta S_{\rm theo} \sim 0.02$

Definitely need more data to pin down the difference mode by mode.

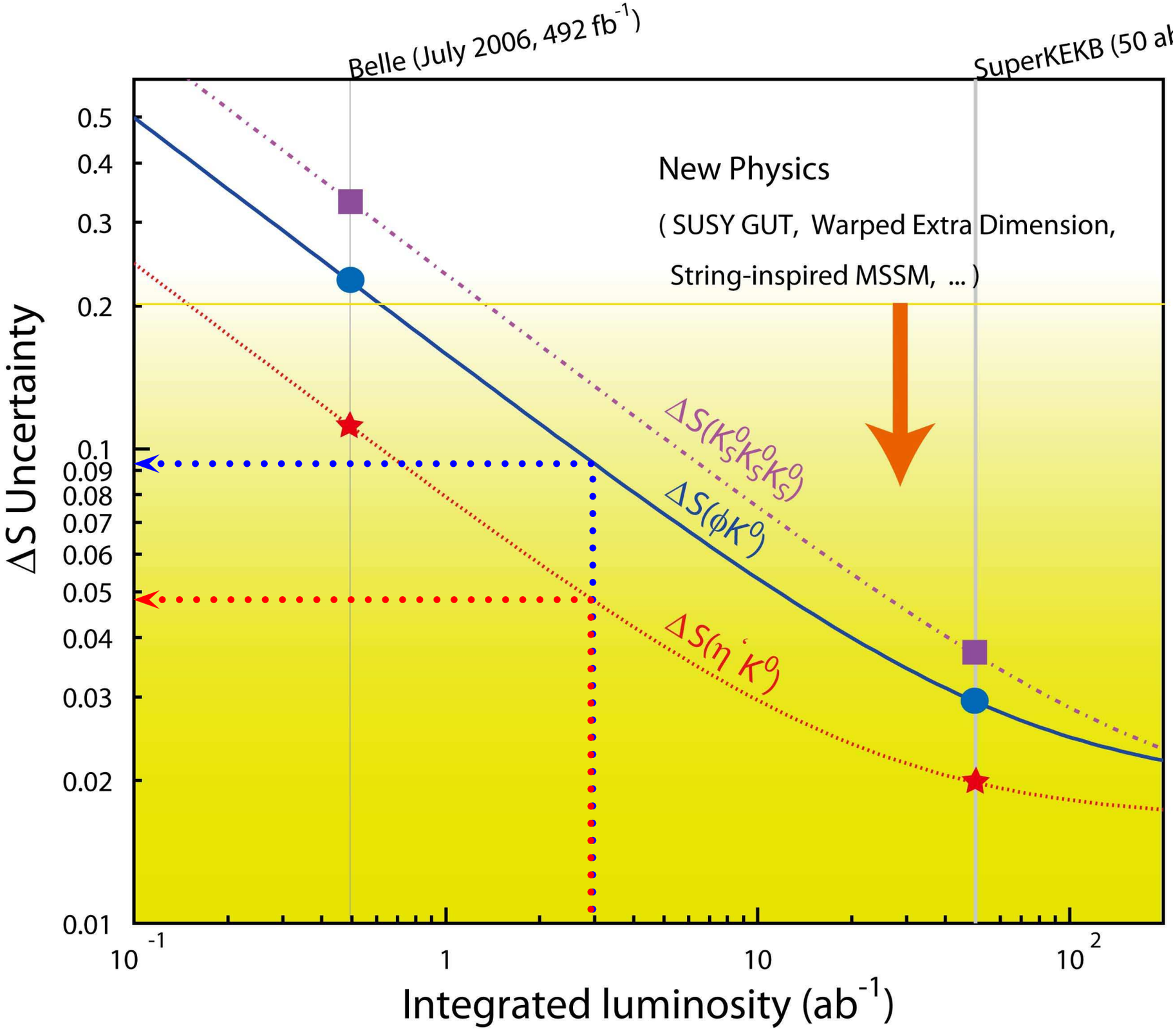
For 3 ab^{-1}

	N(event)	$\sigma_{\rm stat}(S)$
ϕK^0_S	1860	0.094
ϕK^0_L	720	0.230
ϕK^0	2580	0.086
$\eta' K^0_S$	8640	0.043
$\eta' K^0_L$	2760	0.097
$\eta' K^0$	11400	0.039
$K^0_S K^0_S K^0_S$	1140	0.129

$\Delta S > 3\sigma$ already with 3 ab^{-1}
for the current $S_{\phi K^0} = 0.39$



Projection



Stat. error dominant until $\gg 10$ ab^{-1}

50 ab^{-1} will bring us to the theory limit of $\delta\mathcal{S} \sim 0.03$!

Reducing stat. error helps a lot

Possible improvements

- Reconstructed decay chains (now)

  $\eta'_{\rho\gamma}K_S^{+-}$, $\eta'_{\gamma\gamma}K_S^{+-}$, $\eta'_{3\pi}K_S^{+-}$, $\eta'_{\rho\gamma}K_S^{00}$, $\eta'_{\gamma\gamma}K_S^{00}$; $\eta'_{\gamma\gamma}K_L$, $\eta'_{3\pi}K_L$

  $(\eta'_{\rho\gamma} \to \rho^0\gamma,\ \eta'_{\gamma\gamma} \to \pi^+\pi^-\eta(\to\gamma\gamma),\ \eta'_{3\pi} \to \pi^+\pi^-\eta(\to\pi^+\pi^-\pi^0)$

  $\phi_{+-}K_S^{+-}$, $\phi_{SL}K_S^{+-}$, $\phi_{+-}K_S^{00}$; $\phi_{+-}K_L$ $(\phi_{+-} \to K^+K^-,\ \phi_{SL} \to K_S^{+-}K_L)$

  $K_S^{+-}K_S^{+-}K_S^{+-}$, $K_S^{+-}K_S^{+-}K_S^{00}$ $(K_S^{+-} \to \pi^+\pi^-,\ K_S^{00} \to \pi^0\pi^0)$

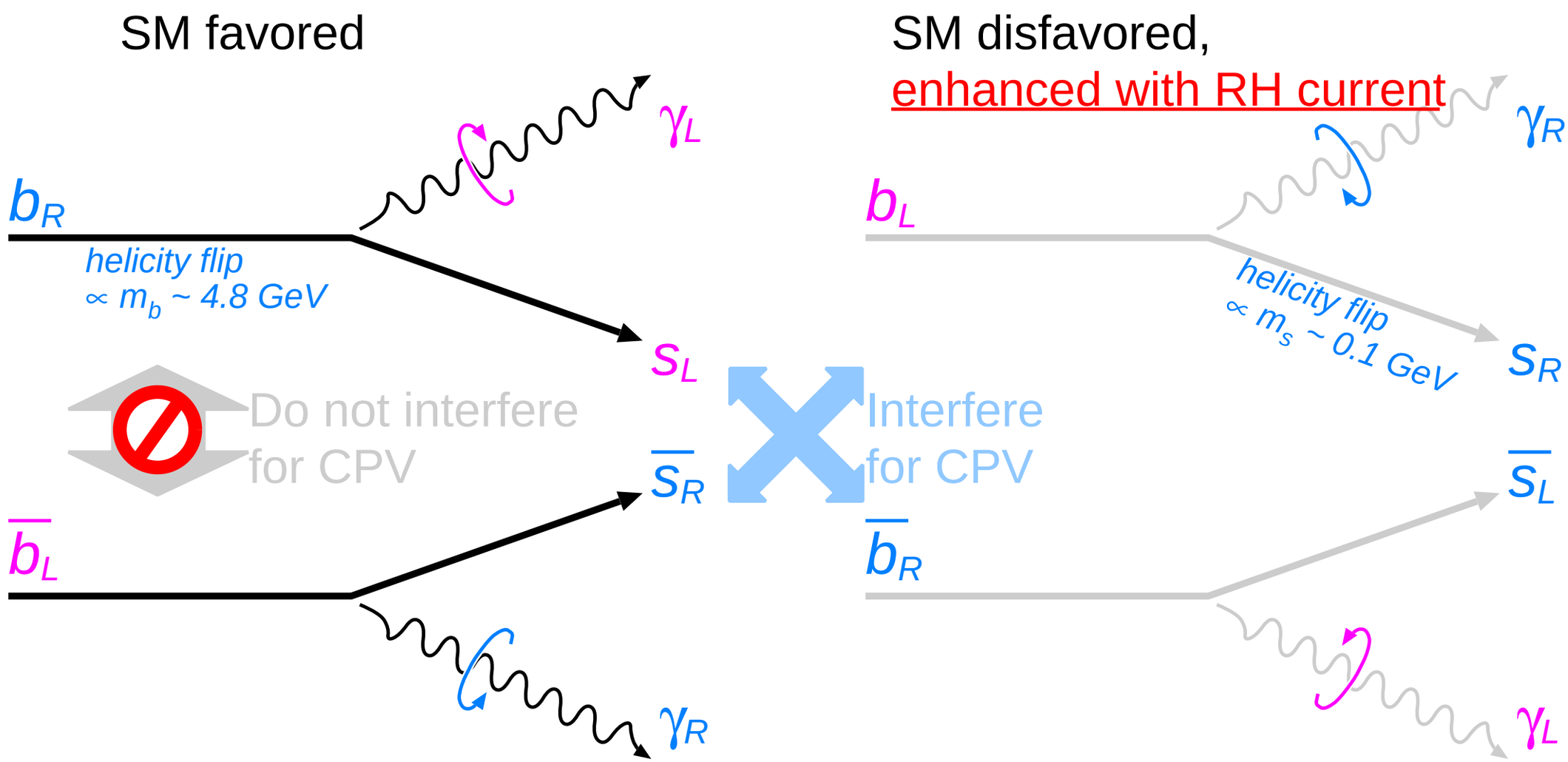
  More modes could be included with more data

- Reconstruction efficiencies
  - Less background with a better PID
- Flavor tag effective efficiencies
  - Kaon id
  - Low-momentum muon id
  - Slow pion from D^{*+}

Efforts should be made to increase every additional 5–10%

Non-SM right-handed current
time-dependent $b \to s$ CPV

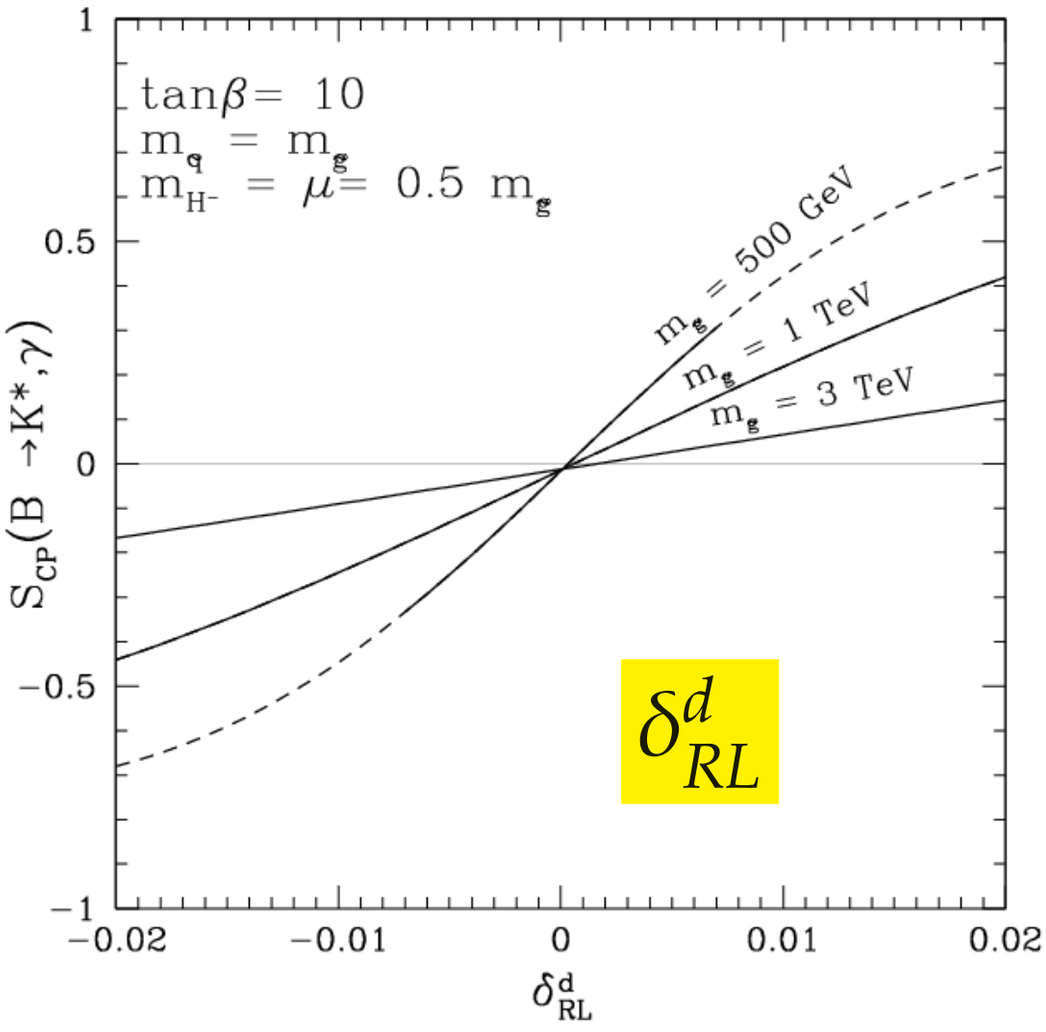
Right-handed current

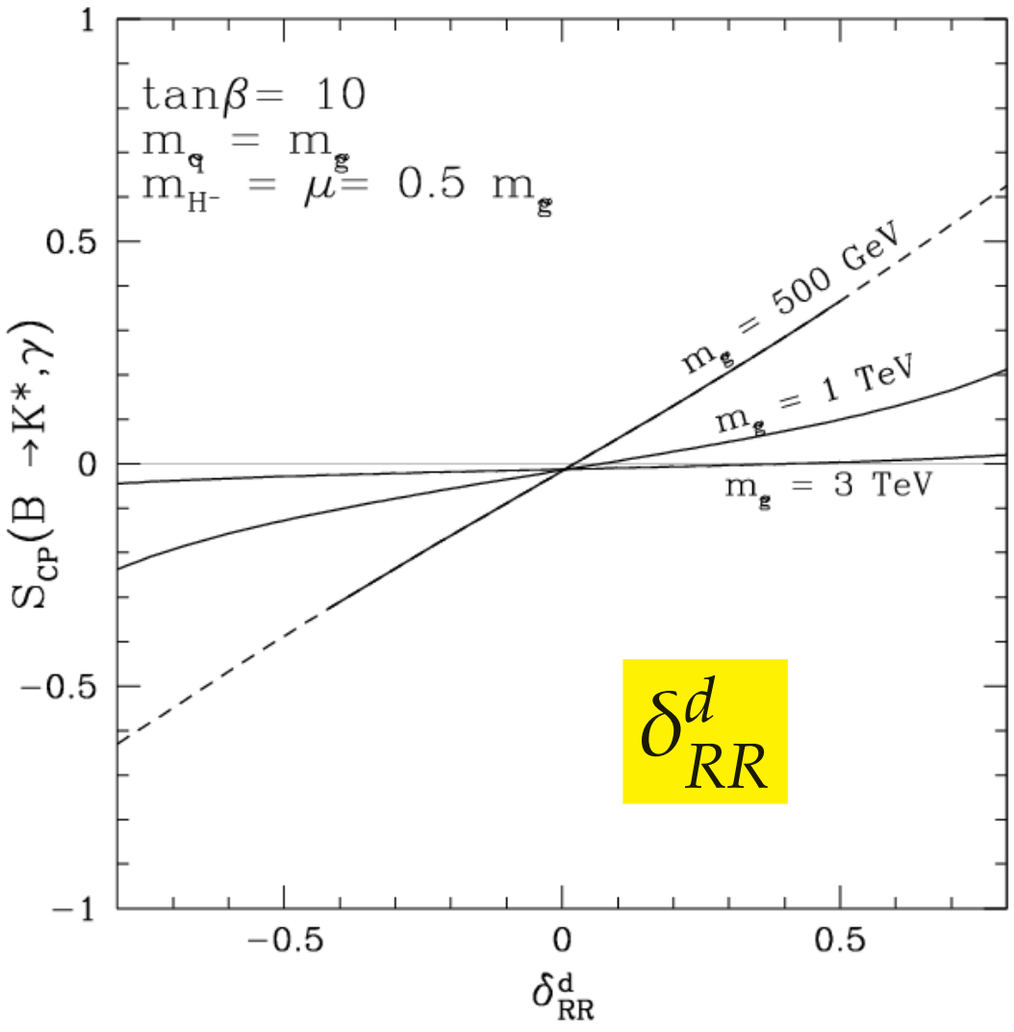


- CPV in SM expected to be $S \sim -\frac{2m_s}{m_b}\sin 2\phi_1$ = a few %
  CPV will enhanced in the presence of RH current
- Direct photon helicity measurement: extremely difficult
  (possible with $\gamma \to e^+e^-$ conversion with 50+ ab^{-1})
- s quark helicity is hard to measure (e.g., in $K\pi\pi\gamma$ final state)

Right-handed current in BSM

- SUSY in general mixing framework (Foster-Okumura-Roszkowski)





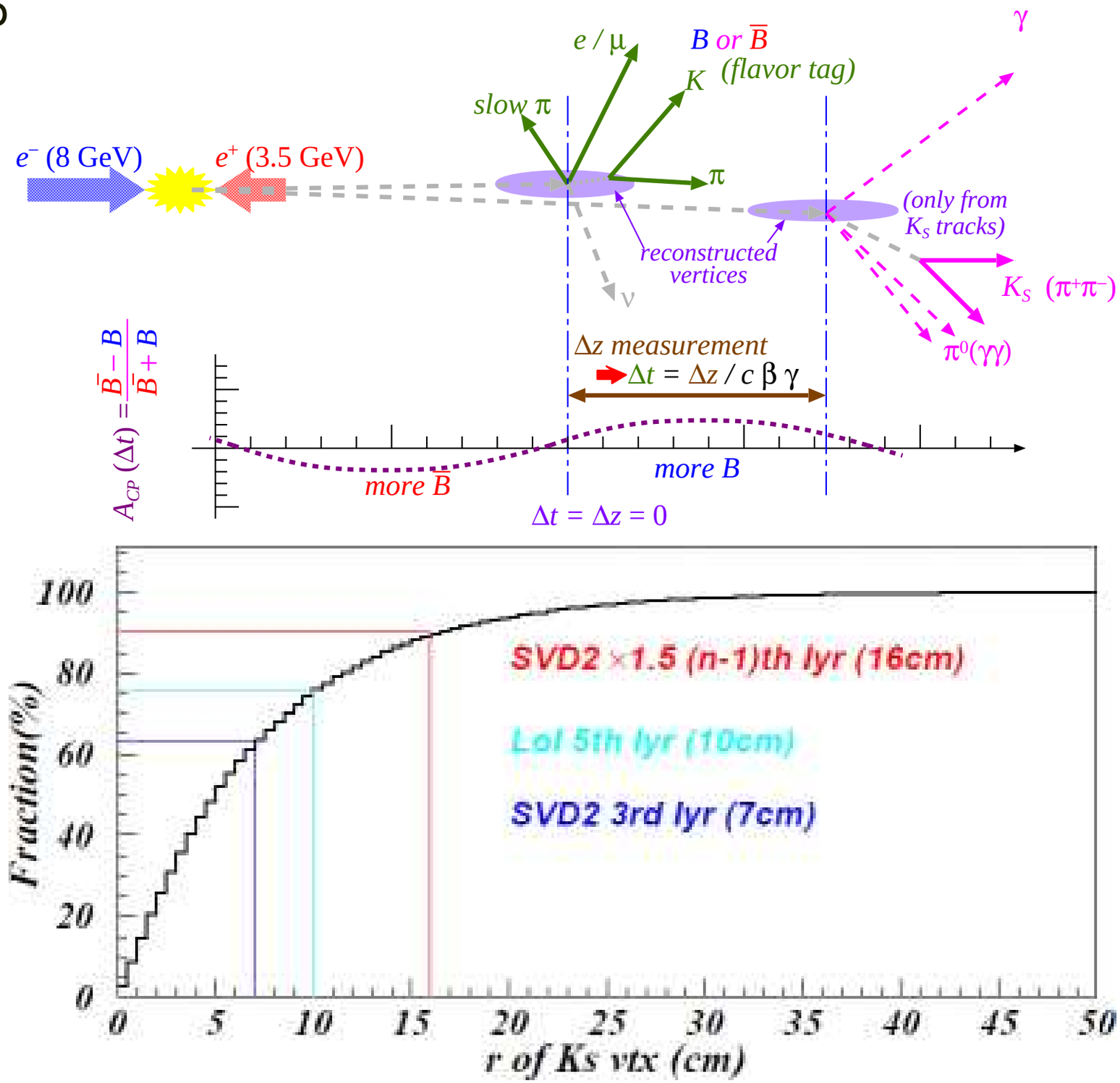
(constraints on $B \to X_s\gamma$, B_s mixing are taken into account)

- $O(1)$ effect is also possible in left-right symmetric model, warped extra dimesion...

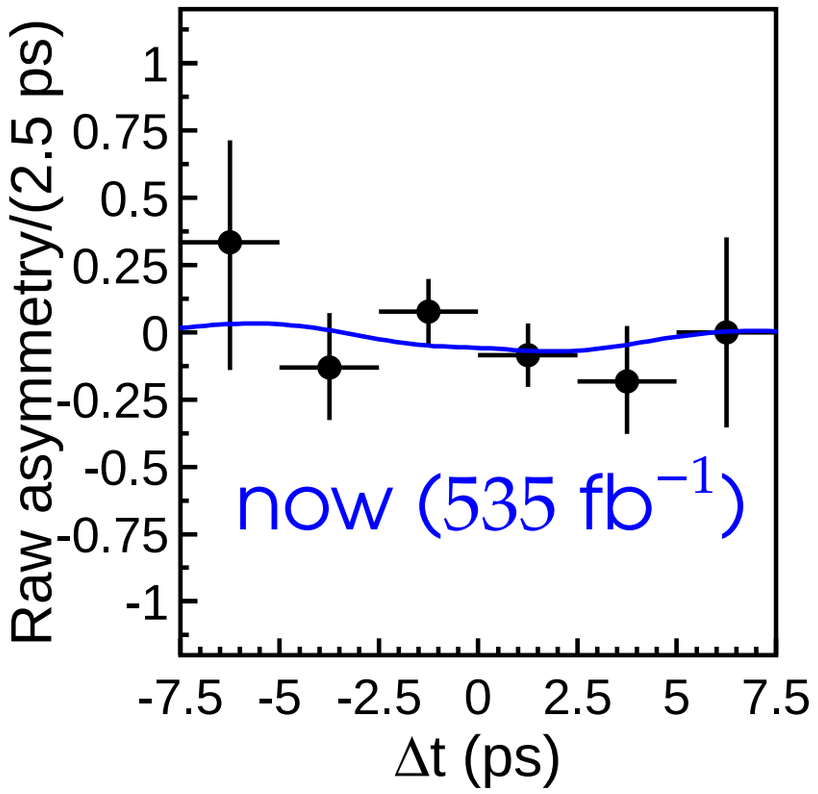
Time dependent CPV in $B \to K^0_S \pi^0 \gamma$

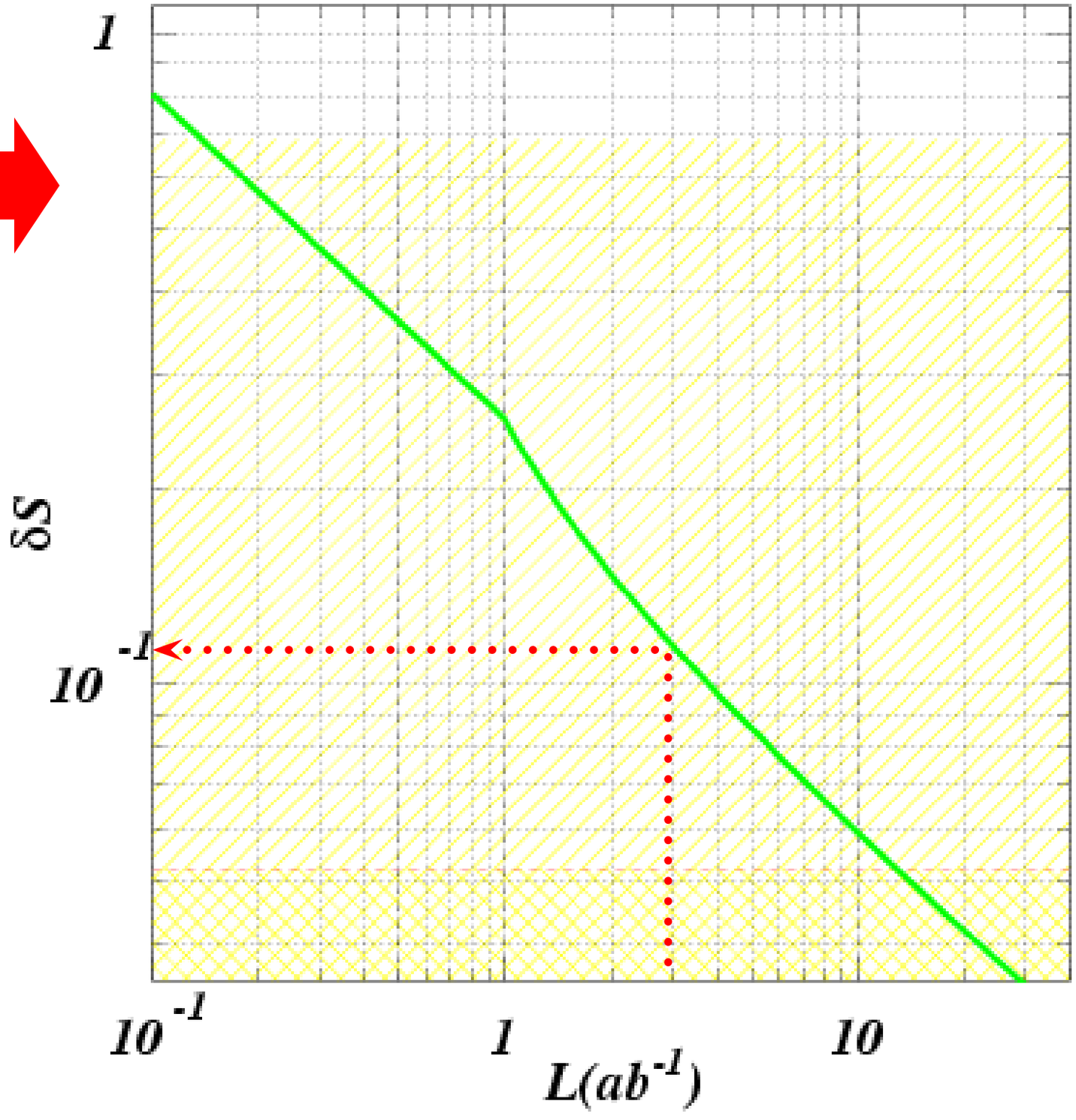
- B vertex from off-IP K^0_S decay
- K^0_S has to decay inside the SVD volume

worthwhile enlarging the SVD volume only for this measurement



$B \to K^0_S \pi^0 \gamma$ prospects





- 3 ab^{-1} $\Rightarrow \delta S \sim 0.11$
  (10 ab^{-1} $\Rightarrow \delta S \sim 0.06$)
  SVD enlarging is taken into account
- Stat. error dominated

More modes

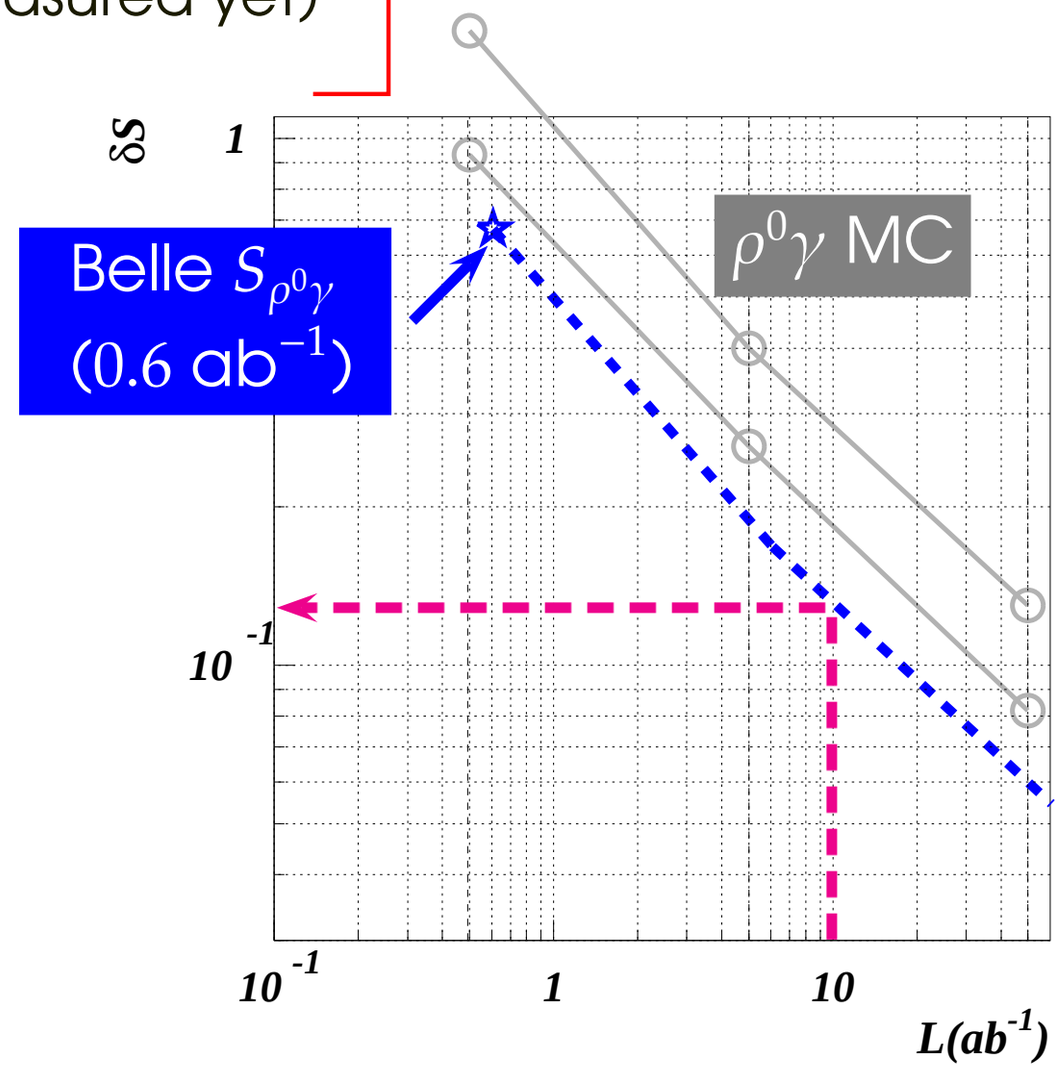
- $B \to K^0_S \eta\gamma$
  $\mathcal{B} = 10.3 \times 10^{-6}$
- $B \to K^0_S \phi\gamma$ (neutral mode not measured yet)
  $\mathcal{B} \sim 3.5 \times 10^{-6}$ (clean signal)
- $B \to K_1(1270)^0\gamma$ (neutral mode not measured yet)
  $\mathcal{B} \sim 43 \times 10^{-6}$ (large $\mathcal{B}$)
  CP($K^0_S\rho$) vs non-CP($K^{*+}\pi^-$)

All these modes should be tried

- $B \to \rho\gamma$ and $\omega\gamma$
  SM predicts $\mathcal{S} = 0$
  need non-SM CPV phase
  in non-SM RH $b \to d$

  $\mathcal{B} \sim 1 \times 10^{-6}$, already tried:
  $\mathcal{S}_{\rho^0\gamma} = -0.83 \pm 0.65 \pm 0.18$ (0.6 ab^{-1})

  ➡ $\delta\mathcal{S} = 0.13$ with 10 ab^{-1}

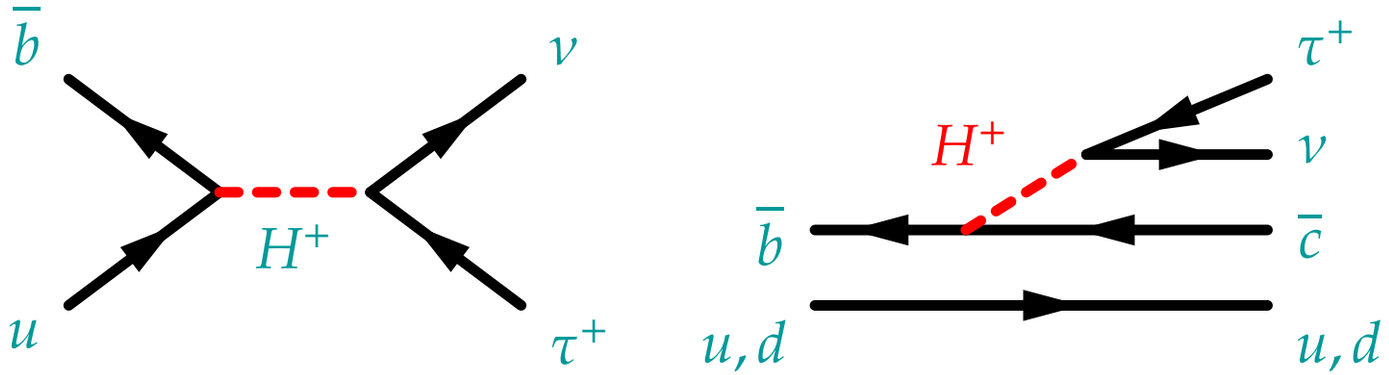


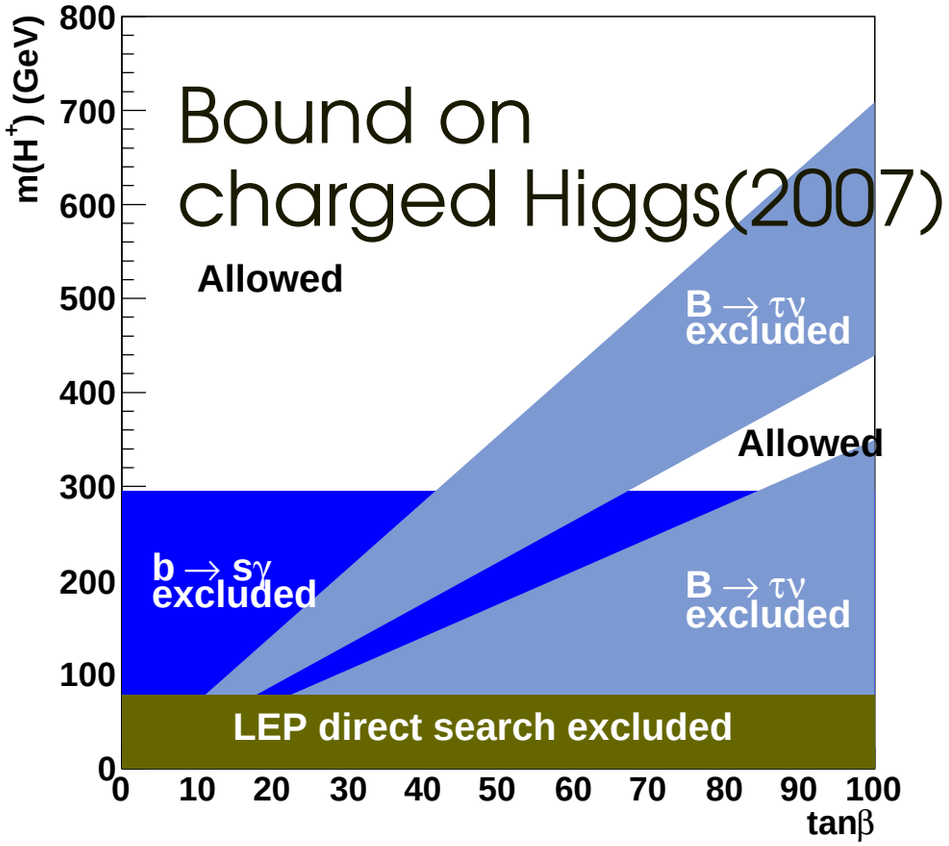
Charged Higgs

searches in $B^+ \to \tau^+\nu$ and $B \to D^{(*)}\tau^+\nu$

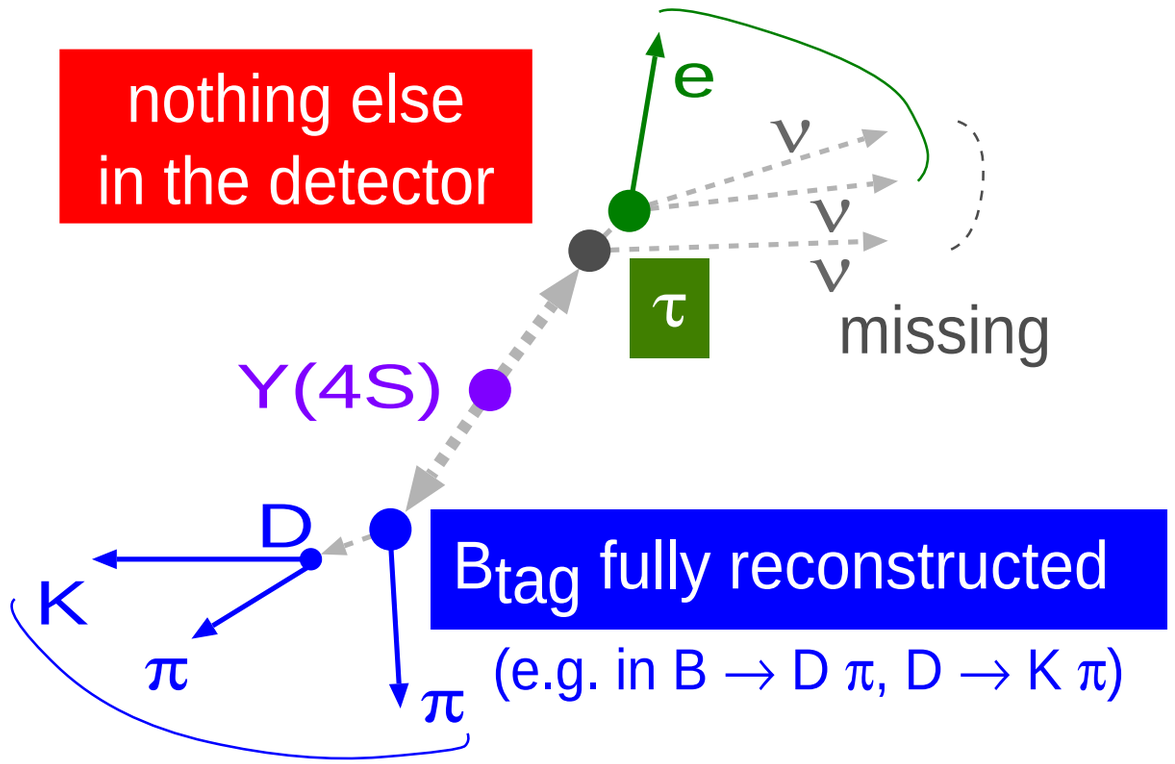
Charged Higgs

- Needed in many BSM
- Appears in a tree diagrams:
  $B^+ \to \tau^+\nu, B \to D\tau^+\nu$
  (also in loops: $b \to s\gamma$)





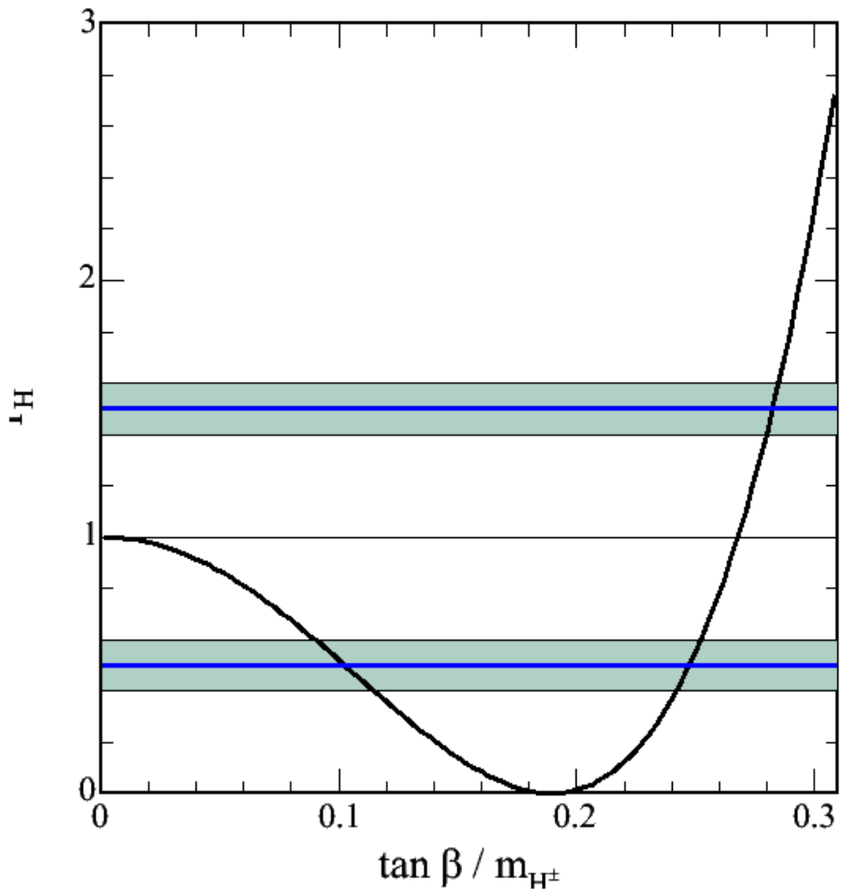
- More than one neutrino, full reconstruction of other B

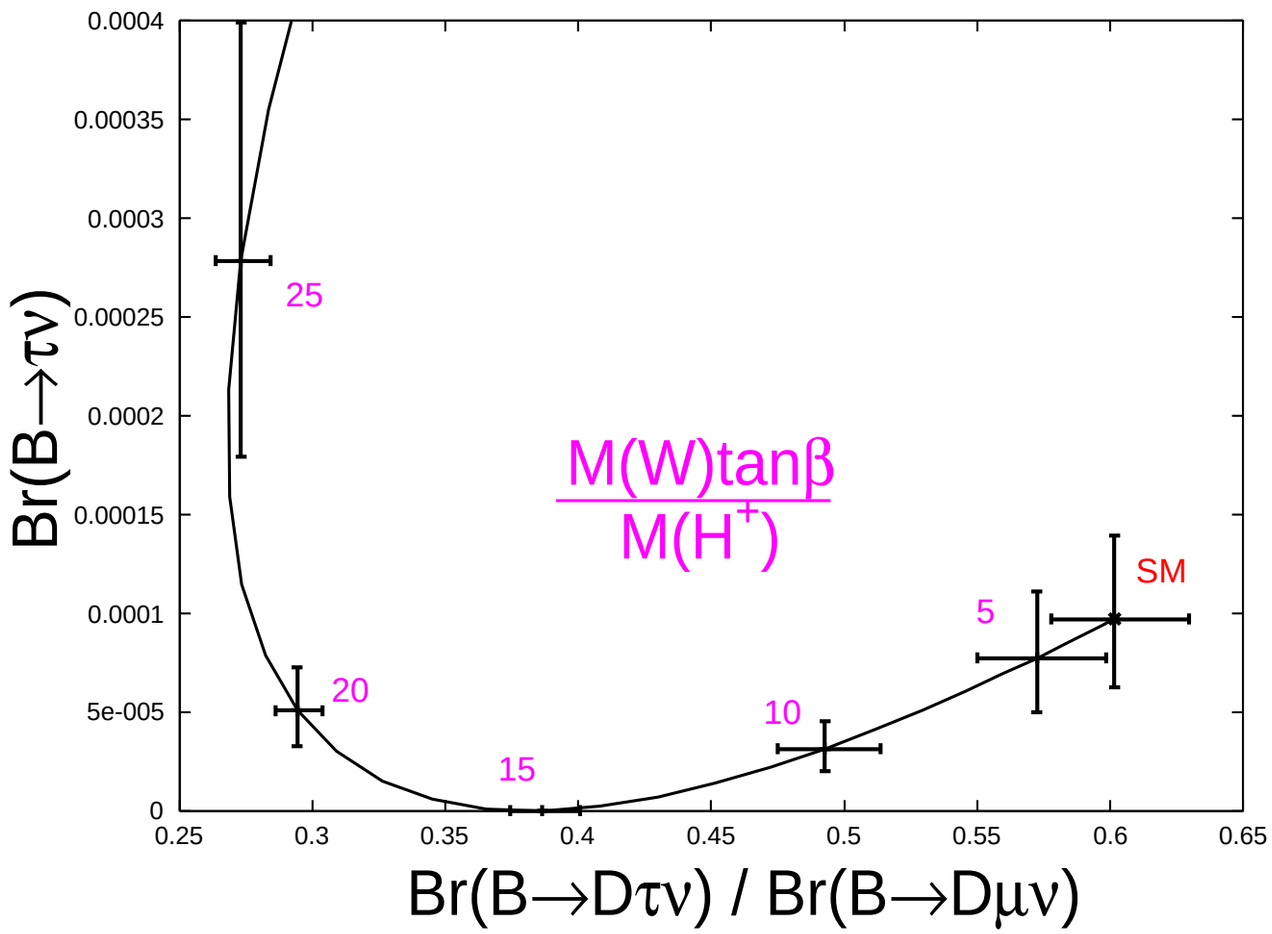


$B^+ \to \tau^+\nu$ and $B \to D\tau^+\nu$

$$r_H = \frac{\mathcal{B}(B^- \to \tau^-\bar{\nu}_\tau)}{\mathcal{B}_{\rm SM}(B^- \to \tau^-\bar{\nu}_\tau)} \neq 1$$ ➡ m_{H^+} / tan β measurement

- Two-fold ambiguity if $r_H < 1$ — solvled with $B \to D\tau^+\nu$
- Universality between b-u-H^+ coupling and b-c-H^+ coupling (and b-t-H^+ couplina from LHC)

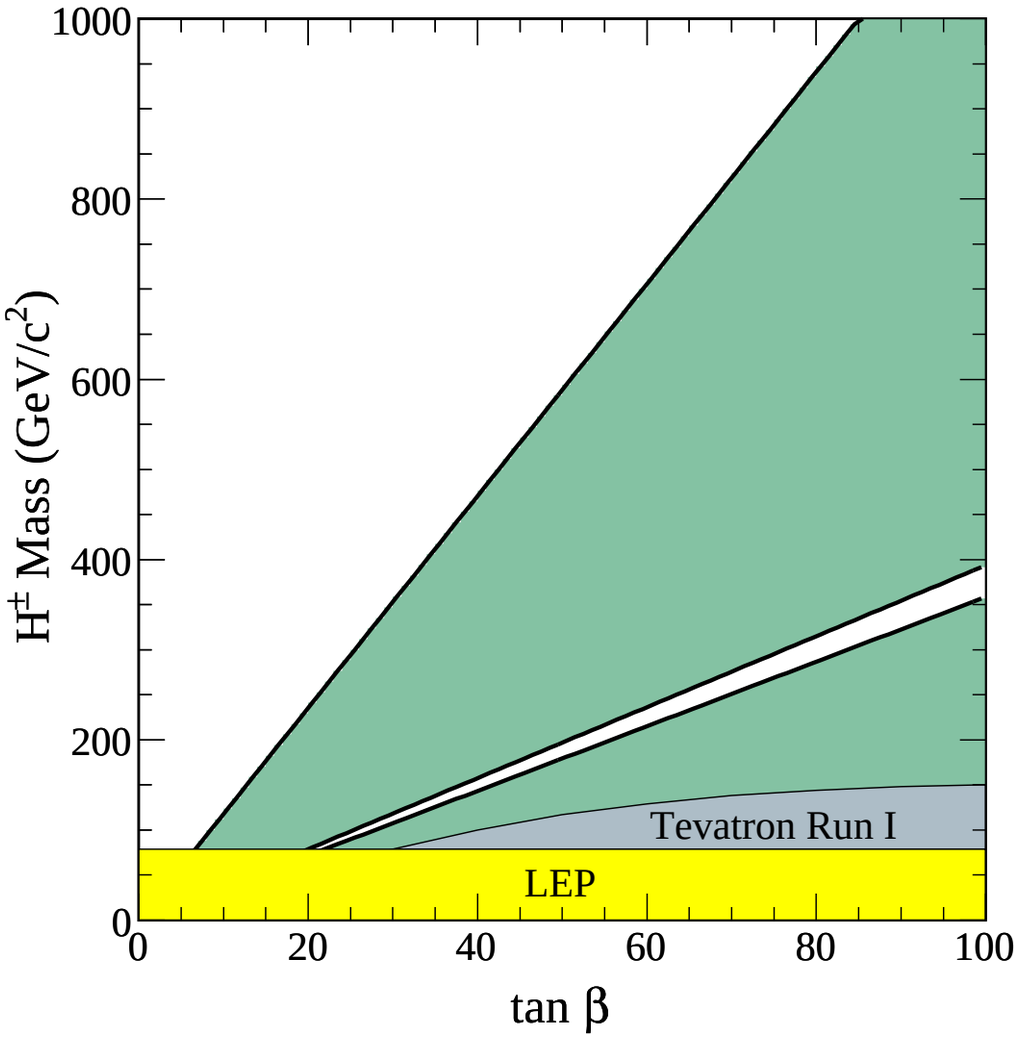




(Cannot be done at LHC nor LHCb)

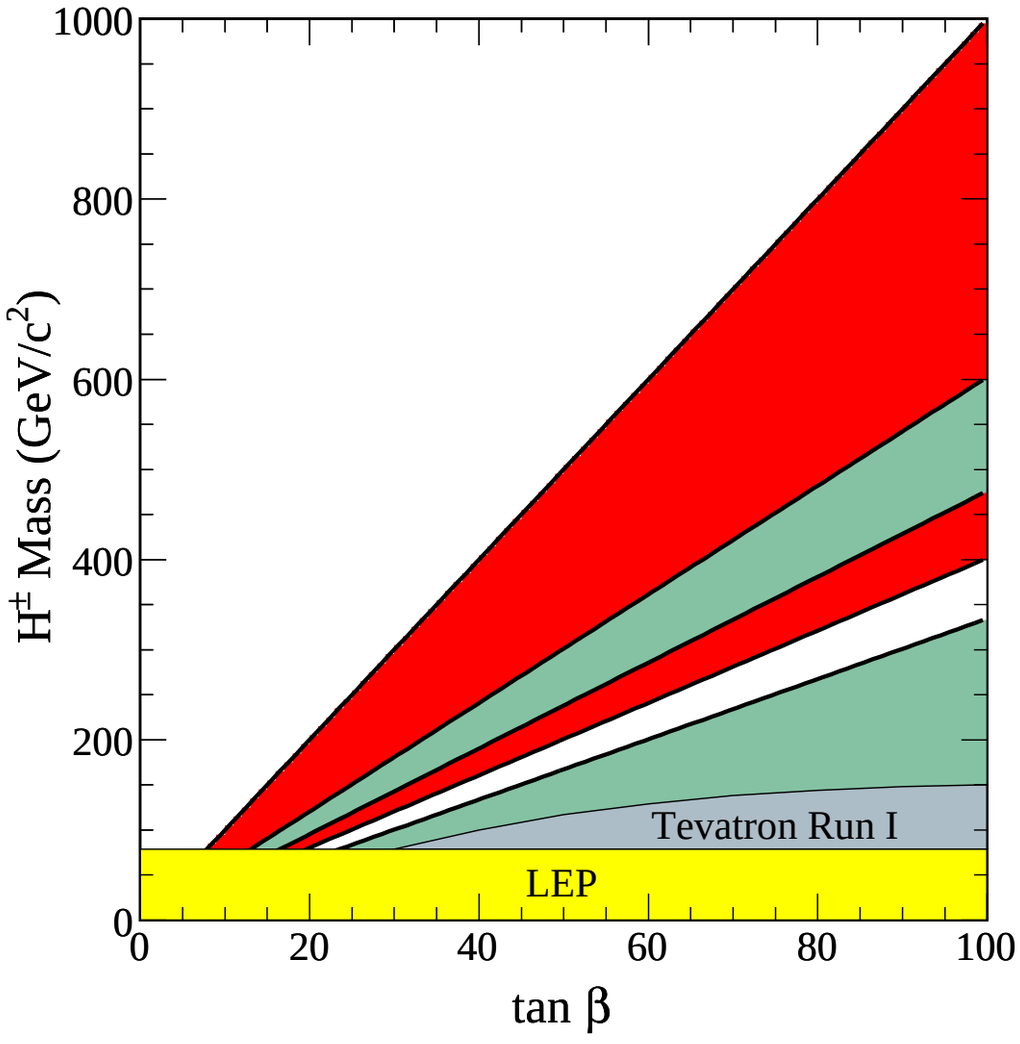
$B^+ \to \tau^+\nu$ at 5 ab^{-1}

Excluded region



or, Discovery region

(outside the current excluded region)



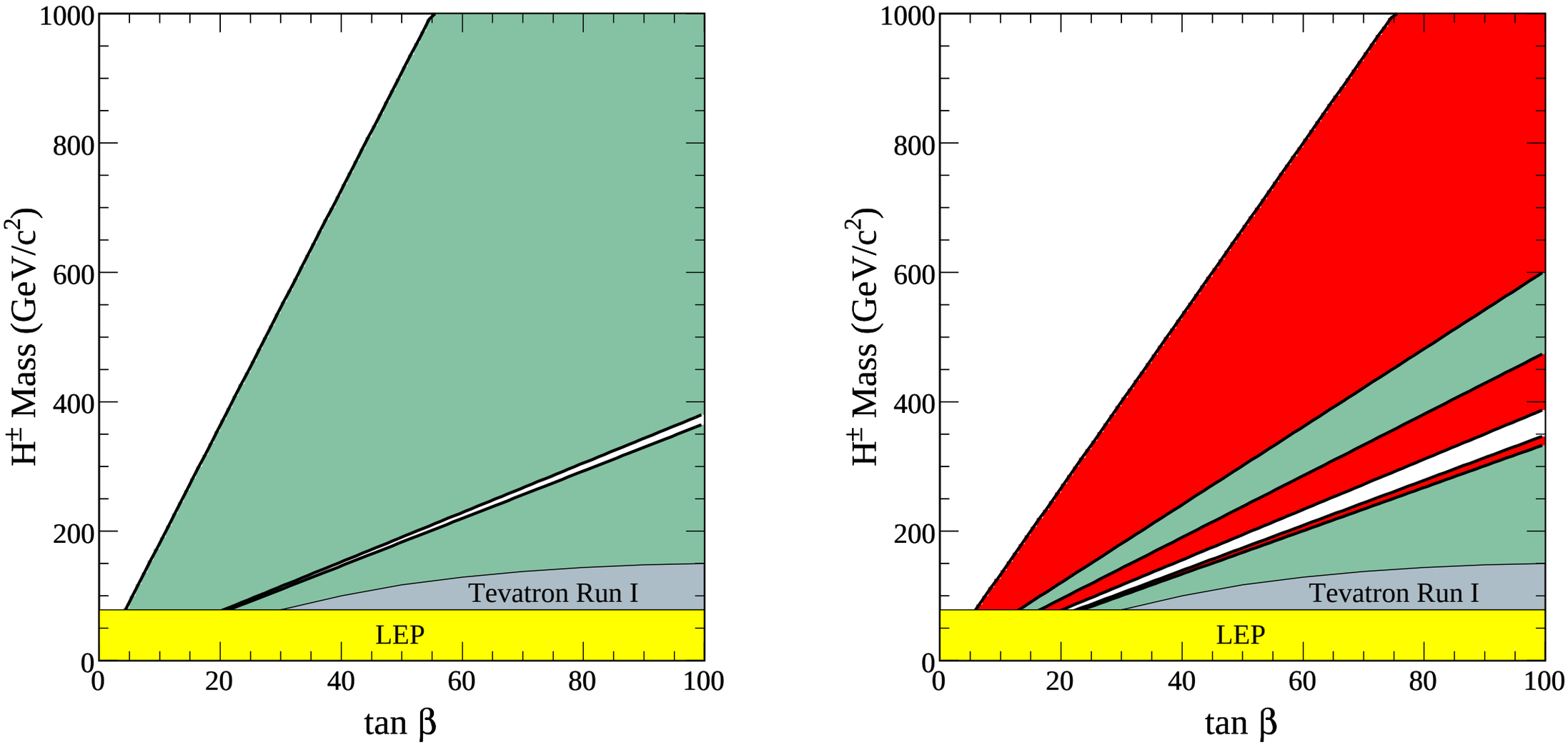
- Similar limit from $B \to D^{(*)}\tau^+\nu$
- Searches up to $m_{H^+} \sim$ several 100 GeV for large $\tan\beta$
  (need more data for smaller $\tan\beta$)

$B^+ \to \tau^+\nu$ at 50 ab^{-1}

Excluded region

or, Discovery region

(outside the current excluded region)



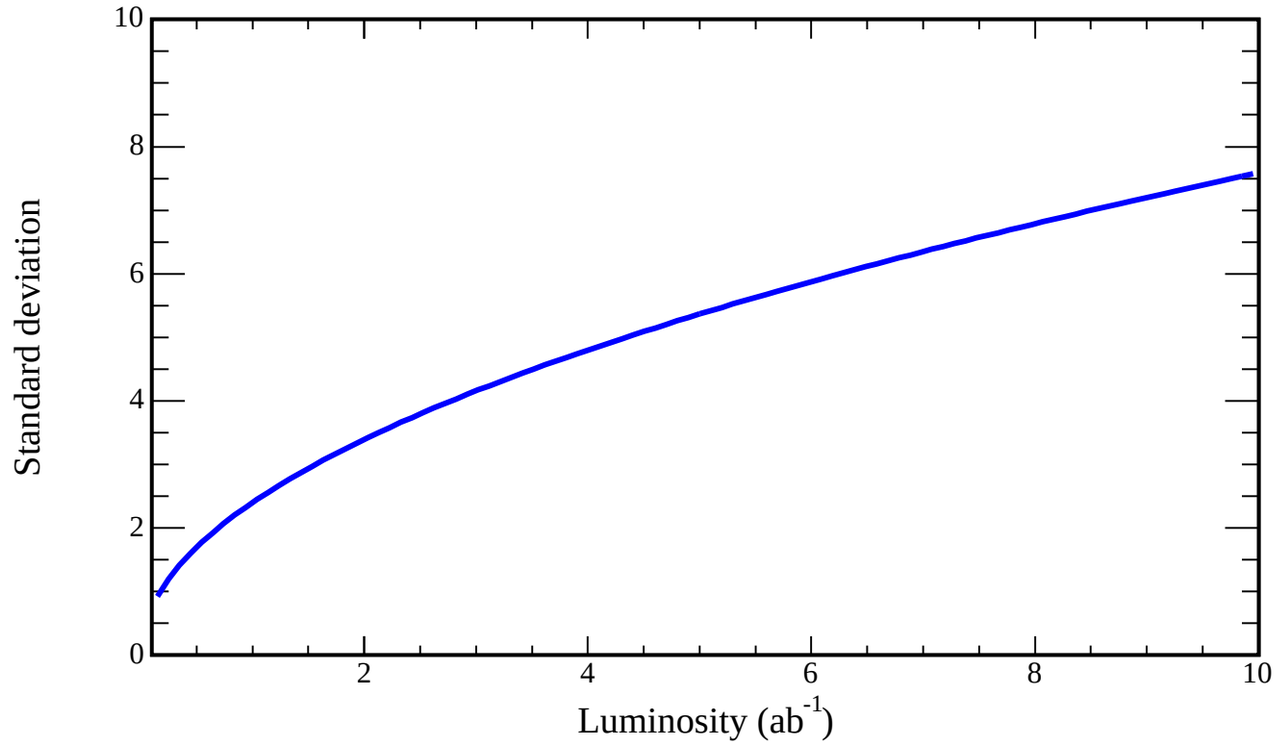
- Similar limit from $B \to D^{(*)}\tau^+\nu$
- Searches up to $m_{H^+} \sim$ several 100 GeV for large $\tan\beta$
  (need more data for smaller $\tan\beta$)

$B^+ \to \mu^+\nu$

- Full reconstruction is not needed — high efficiency
  Straightforward analysis — less worry on beam background

- $B^+ \to \mu^+\nu$ is a good discovery channel with a few ab^{-1}

$$\mathcal{B}_{\rm SM}(\tau\nu) = 1.6 \times 10^{-4}$$
$$\mathcal{B}_{\rm SM}(\mu\nu) = 7.1 \times 10^{-7}$$
$$\mathcal{B}_{\rm SM}(e\nu) = 1.7 \times 10^{-11}$$



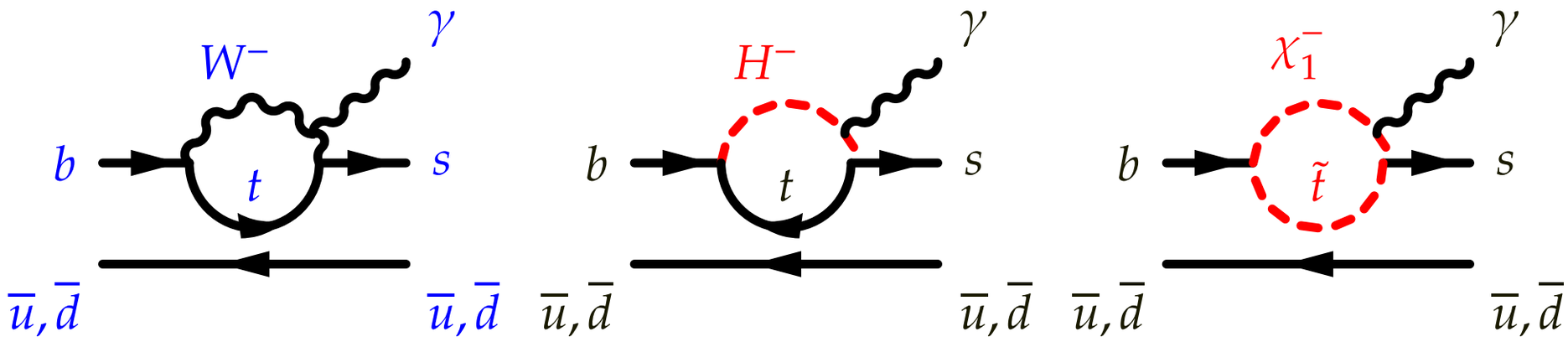
3σ at 1.6 ab^{-1}
5σ at 4.3 ab^{-1}

- Yet another universality test
  $R_H^{\tau\nu}$ vs $R_H^{\mu\nu}$ — should be equal for the charged Higgs

Inclusive measurements

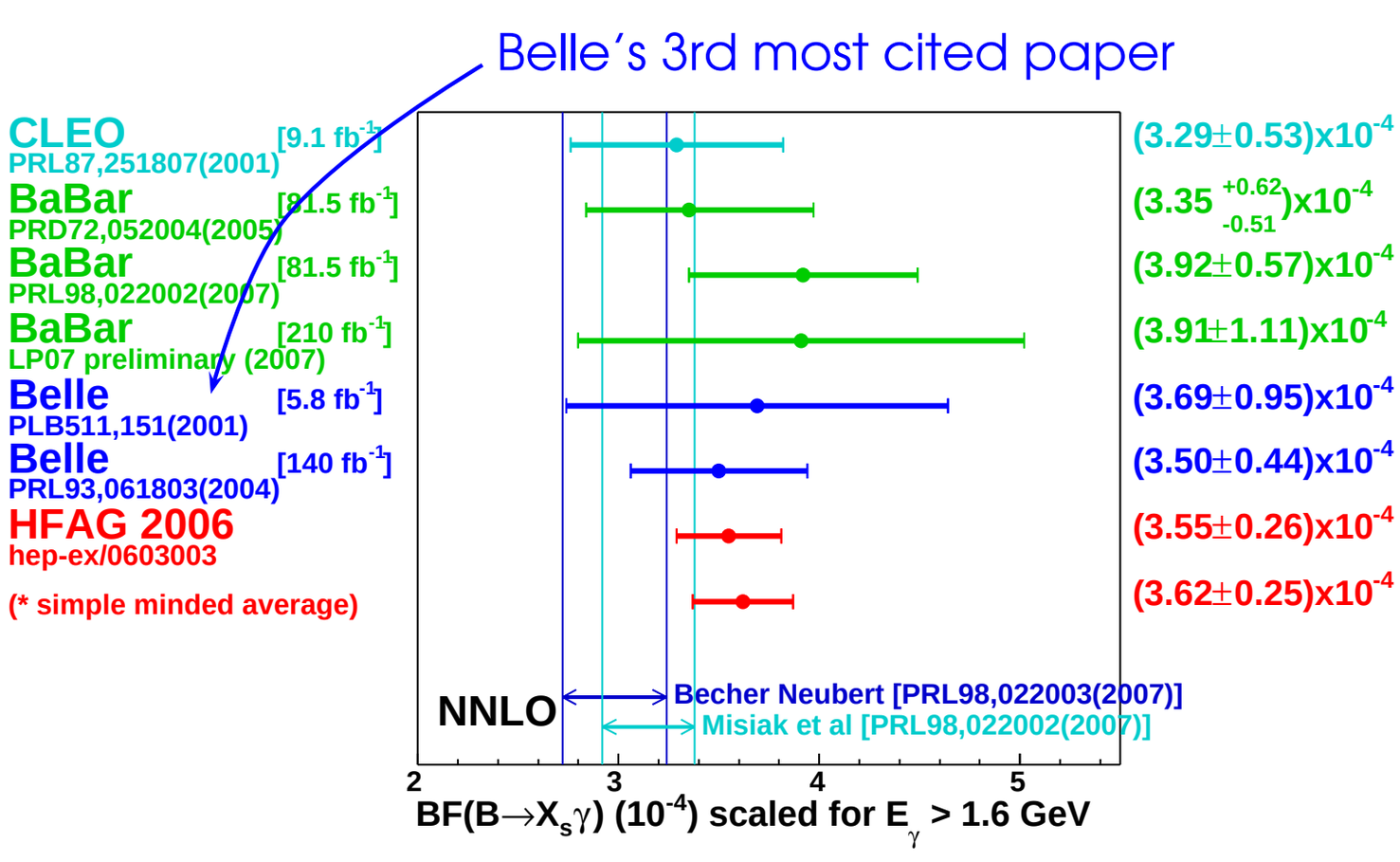
$B \to X_s\gamma$, $B \to X_s\ell^+\ell^-$

$b \to s\gamma$



- Charged Higgs would always increase $\mathcal{B}$
- Other SUSY contribution could cancel

Treasure box to constrain many BSM scenarios



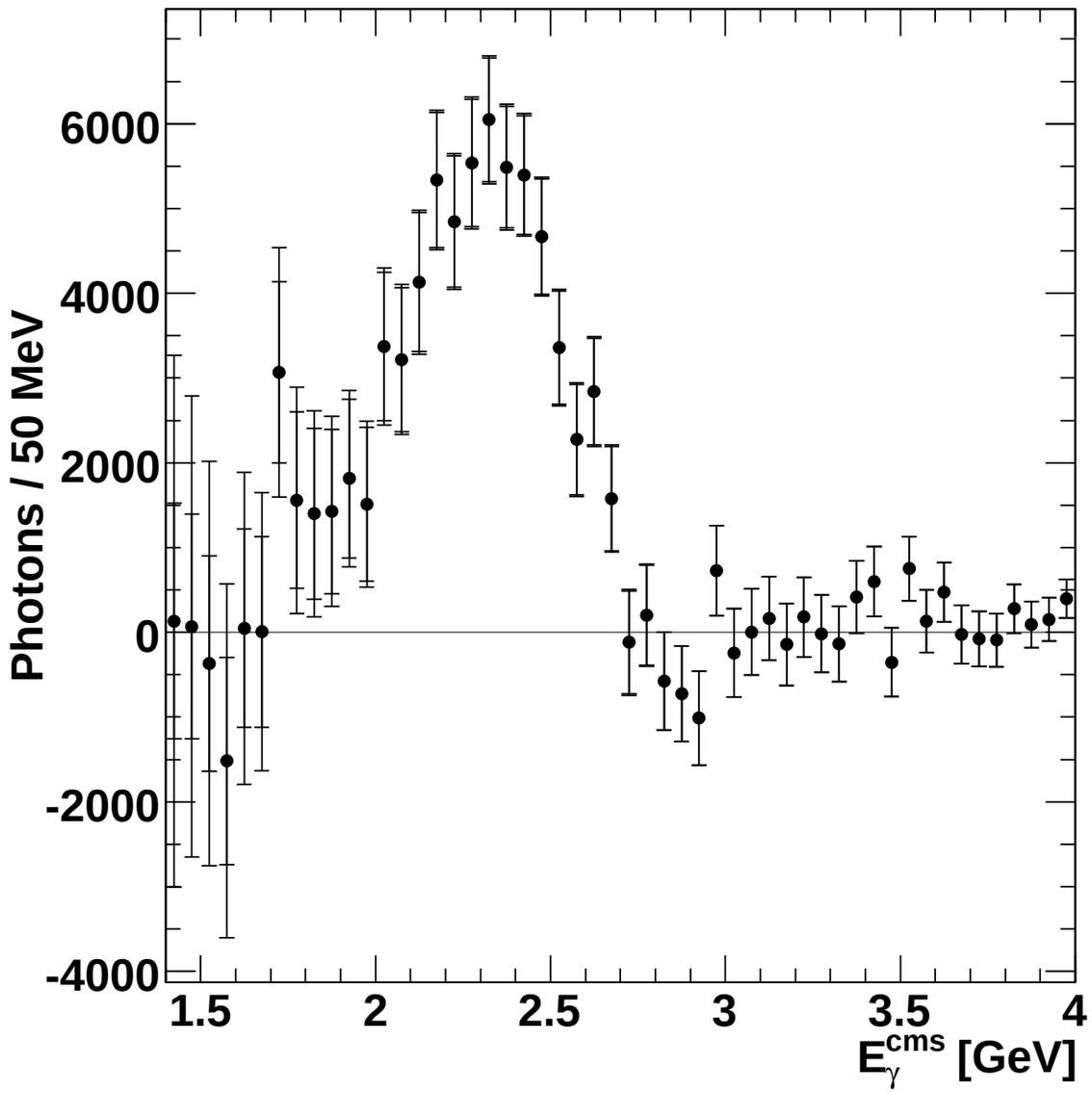
Experimental $\mathcal{B}$ is slightly higher than theory

[new development in theory: NNLO]

New $b \to s\gamma$ result

- Fully inclusive $B \to X_s\gamma$
- Full dataset (605 fb^{-1})
- Same analysis technique with improvements
- $E_\gamma^{\rm min} = 1.7$ GeV

Preliminary!



$$\mathcal{B}(B \to X_s\gamma; 1.7\ \text{GeV}) = (3.31 \pm 0.16 \pm 0.37) \times 10^{-4}$$

$\mathcal{B}(B \to X_s\gamma; 1.8\ \text{GeV}) = (3.24 \pm 0.15 \pm 0.24) \times 10^{-4}$ (new)

$\mathcal{B}(B \to X_s\gamma; 1.8\ \text{GeV}) = (3.38 \pm 0.31 \pm 0.30) \times 10^{-4}$ (previous 140 fb^{-1})

(more details in A.Limosani, Moriond EW 2008, hep-ex in preparation)

$b \to s\gamma$ prospects

- To lower the E_γ cut

  1.8 GeV with 140 fb^{-1} (lowest for some time)

  1.7 GeV preliminary with 605 fb^{-1} (new record)

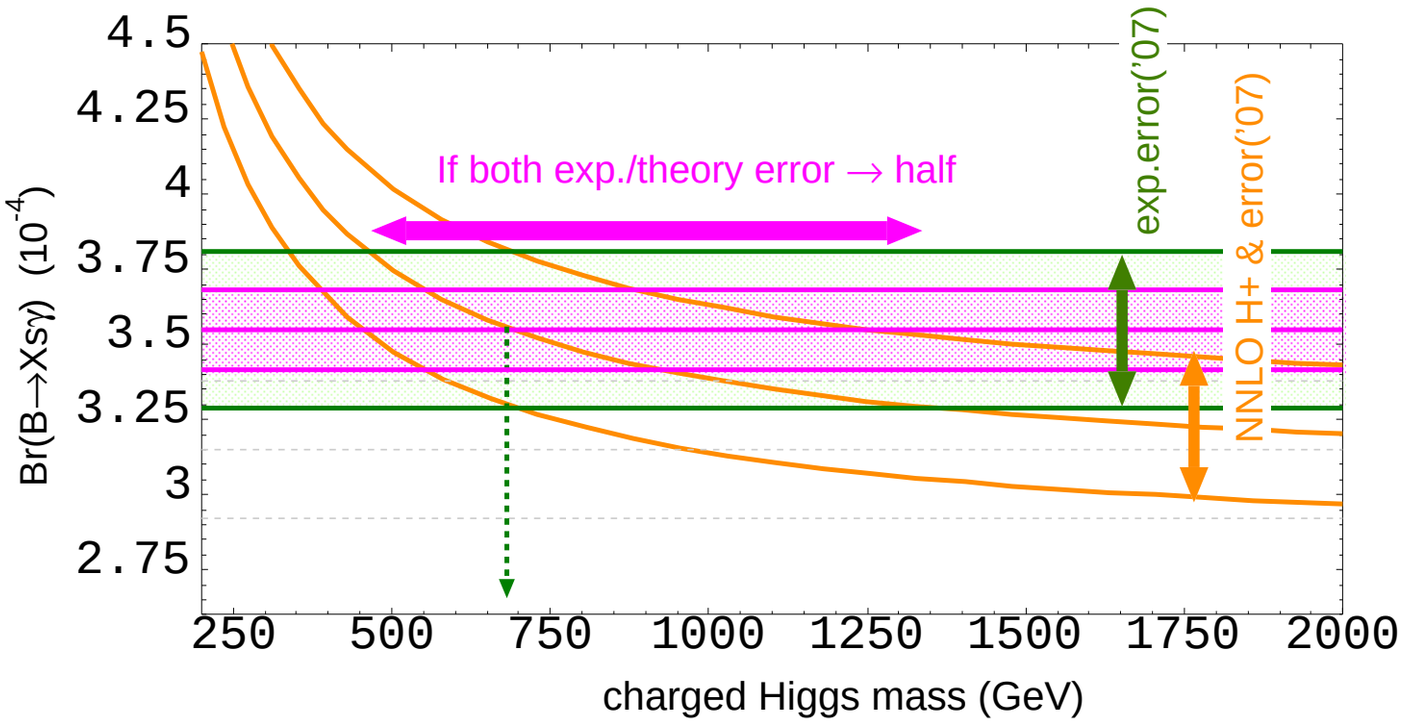
  1.6 GeV is possible with the first a few ab^{-1} data

  (so far we observe that this is a statistics issue, need 10% off-resonance)

- Full reconstruction analysis:

  No need of off-resonance, 5 ab^{-1} for the current stat. error

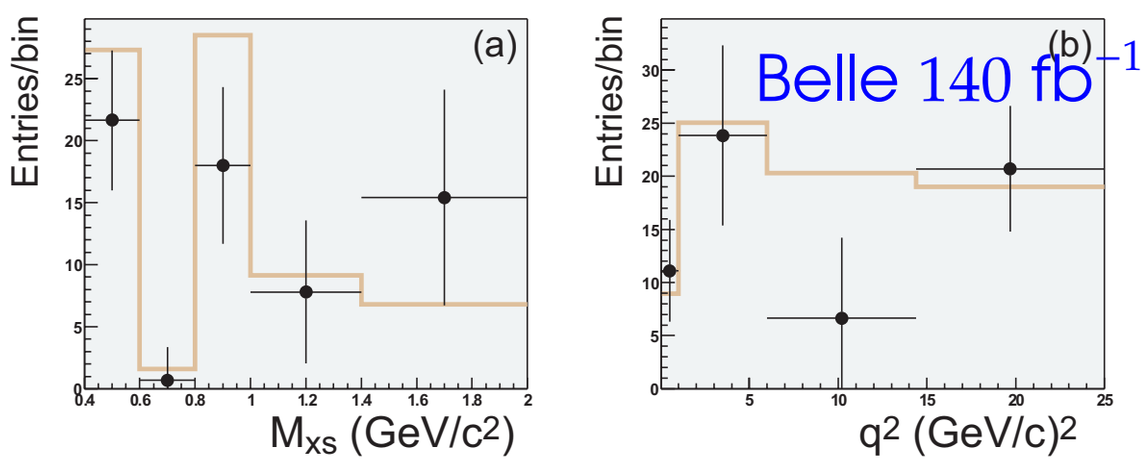
- No $\tan\beta$ dependence, comparison with $B^+ \to \tau^+\nu$



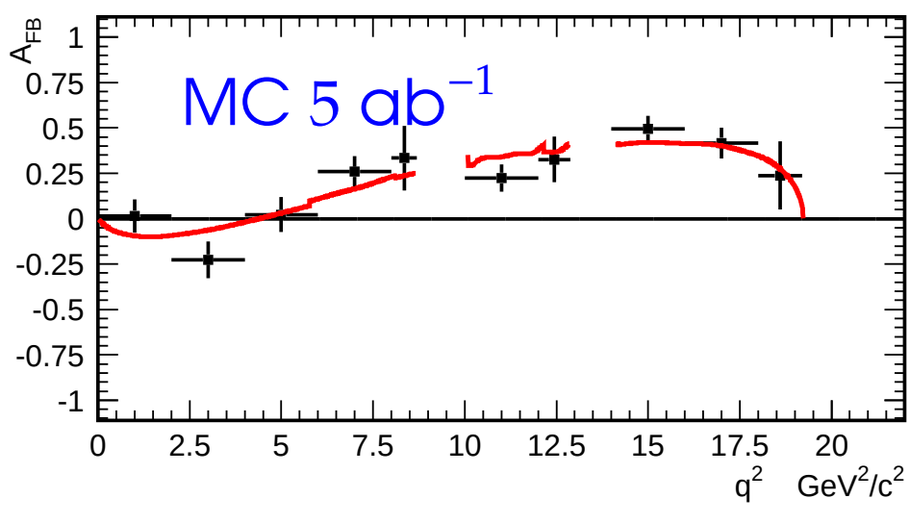
$b \to s\ell^+\ell^-$ prospects

- Many observables — BF, q^2 spectrum, A_{FB}, A_{CP}, ...
  to classify new physics with 3 types of interactions
  (3 Wilson coefficients, C_7, C_9 and C_{10} for corresponding operators)
- Exclusive mode ($B \to K^*\ell^+\ell^-$) — probably done at LHCb
  (form factor uncertainty would be irreducible)
- Inclusive measurement
  - Sum of exclusive (up to 140 fb^{-1} so far)
  - Fully inclusive (extremely difficult according to very early MC study)

(no inclusive A_{FB} study yet, for any ab^{-1})



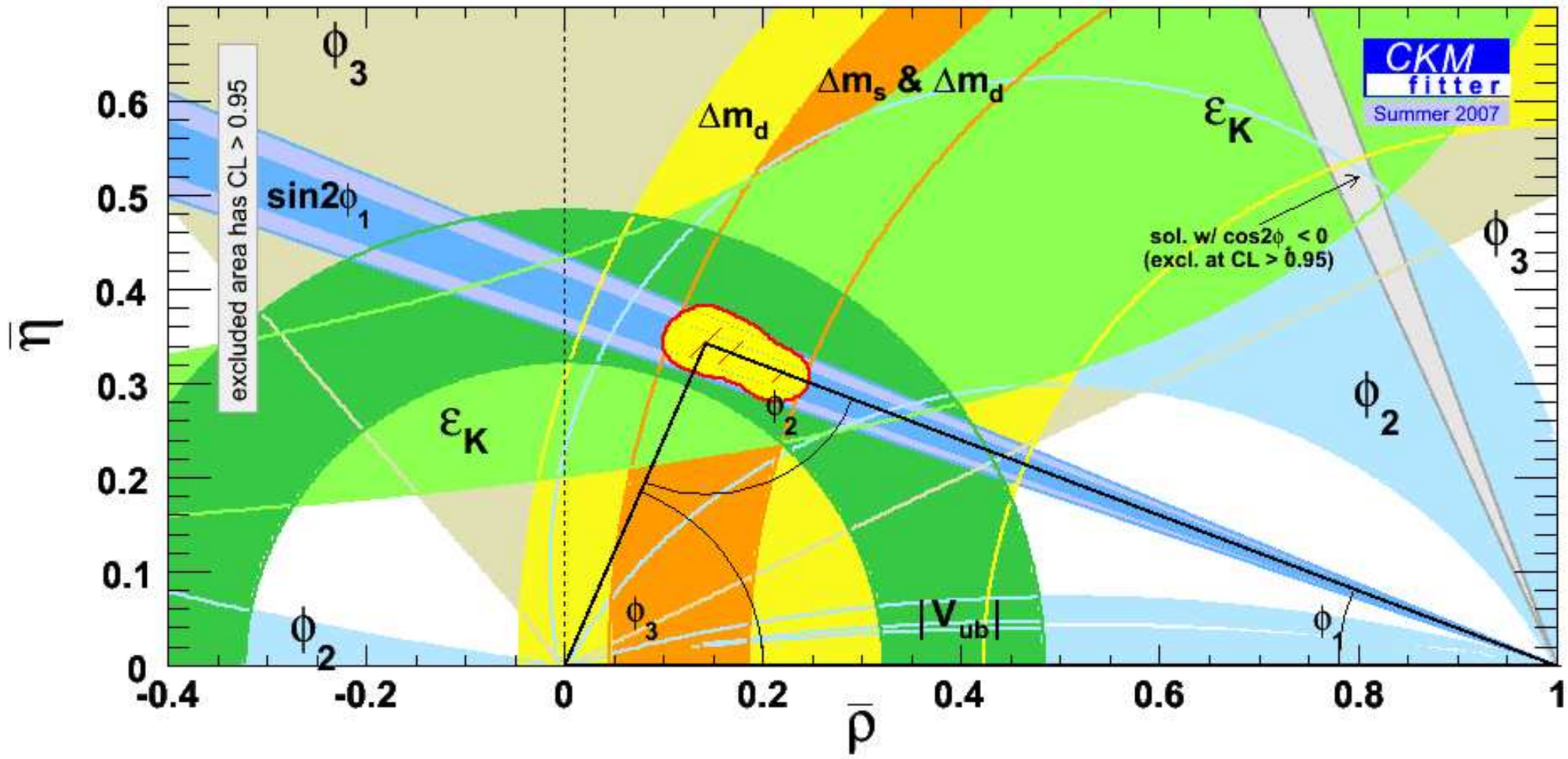
(inclusive $B \to X_s\ell^+\ell^-$)



(exclusive $A_{FB}(B \to K^*\ell^+\ell^-)$)

Loop vs tree

high precision unitarity triangle measurement



Loop

ϕ_1 from $B \to J/\psi K^0_S$

$|V_{td}|$ from B_d and B_s mixing

Tree

$|V_{ub}|$ from $b \to u\ell^-\overline{\nu}$

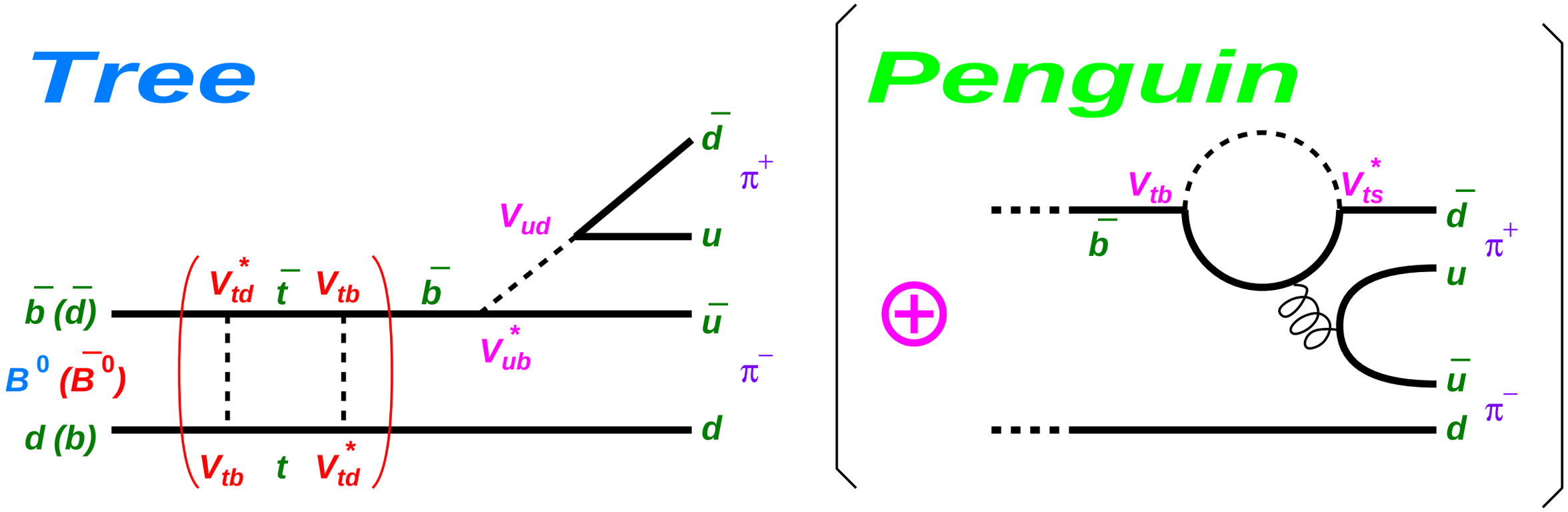
ϕ_3 from $B \to DK$

$|V_{cb}|$ from $b \to c\ell^-\overline{\nu}$ defines the unit

ϕ_2 from $B \to \pi\pi$ is mixture of loop and tree

Ideal strategy: compare Loop vs Tree, cross-check with ϕ_2

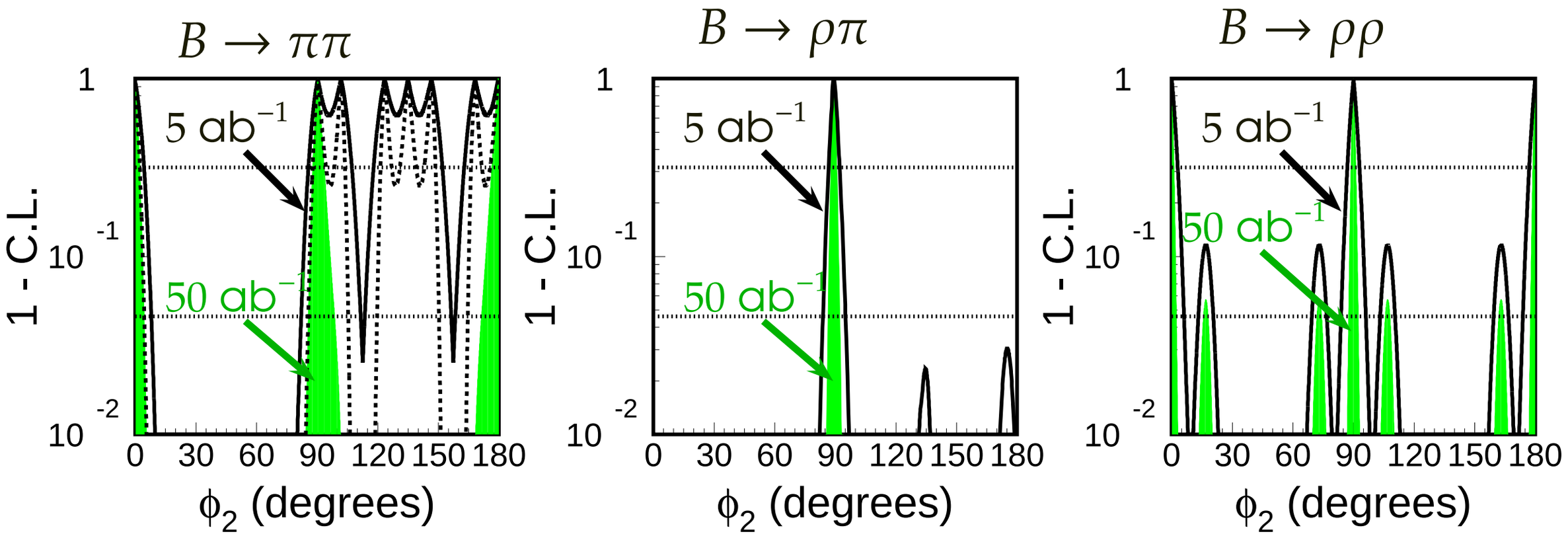
ϕ_2 from $B \to \pi\pi$



$$\arg(V_{ub}V_{us}^*) \neq \arg(V_{tb}V_{ts}^*) \; !$$

- $\mathcal{S} = \sin 2\phi_2$ if no penguin pollution
- Isospin analysis — measure all branching fractions and A_{CP} for $B^0 \to \pi^+\pi^-$, $B^{\to}\pi^0\pi^0$ and $B^\pm \to \pi^\pm\pi^0$

ϕ_2 from $B \to \pi\pi$, $\rho\pi$ and $\rho\rho$

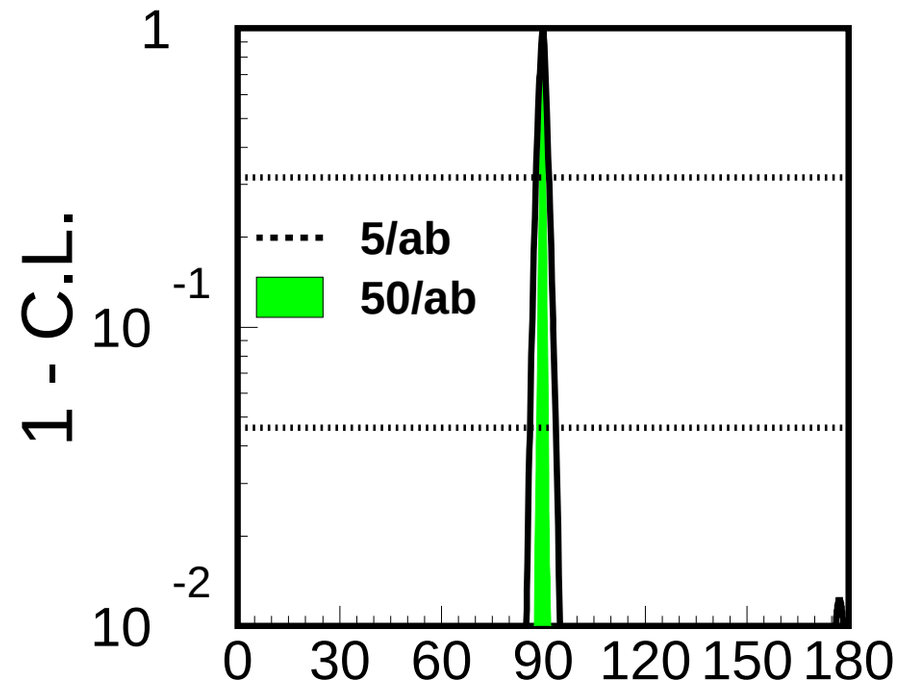


- $\pi\pi$ and $\rho\rho$: time dependent isospin analysis
  Need to measure $\mathcal{B}$ and A_{CP} of $(+-)$, (± 0), (00) combinations in addition to $\mathcal{S}$

  (sensitivity also depends on central values)
- $\rho\pi$: time dependent Dalitz analysis
  Less multi-fold ambiguity, need details of higher resonances

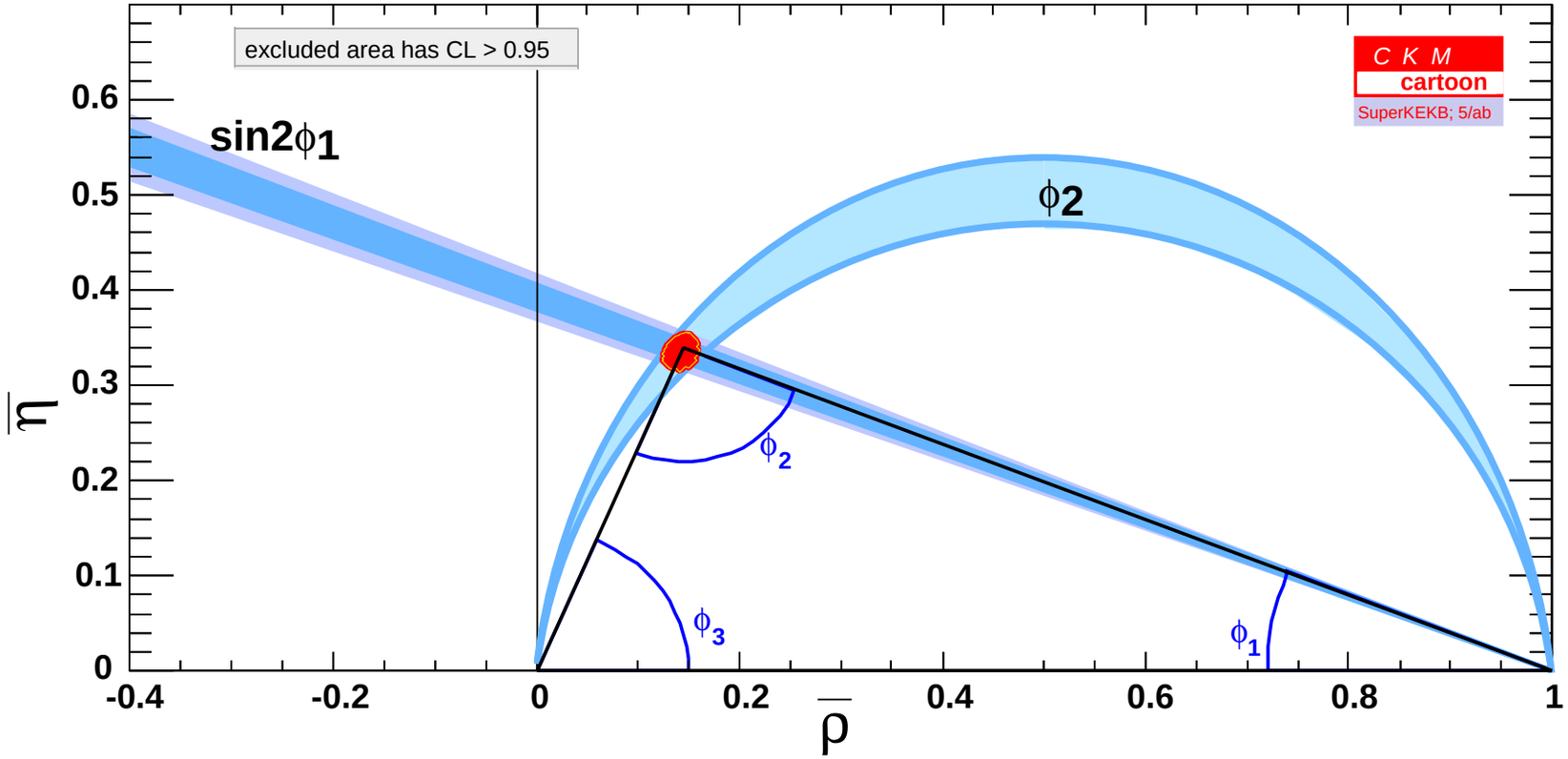
ϕ_2 combined

- Combined: 2° error ($5\ \mathrm{ab}^{-1}$)
  (1° error ($50\ \mathrm{ab}^{-1}$))
  if all results align



Reference point on $(\bar{\rho}, \bar{\eta})$!

($\delta \sin 2\phi_1 = 0.016$, $\phi_1 = 21.4°$, $\phi_2 = 90°$ at $5\ \mathrm{ab}^{-1}$)



Note: theory/isospin error not included, but free from LQCD!

ϕ_3

Methods

- tCPV of $B \to D^{*\pm}\pi^{\mp}$ ($\sin(2\phi_1 + \phi_3)$)
- $B^{\pm} \to D_{CP}K^{\pm}$ (GLW method)
- $B^{\pm} \to D_{\mathrm{DCSD}}K^{\pm}$ (ADS method)
- $B^{\pm} \to D^0K^{\pm}$, $D^0 \to K^0_S\pi^+\pi^-$ Dalitz analysis

	$5\ \mathrm{ab}^{-1}$	$50\ \mathrm{ab}^{-1}$	
$B \to D^{*\pm}\pi^{\mp}$	18°	6°	(depends on the value of r)
GLW + ADS	16°	5°	
Dalitz	7°	2.5°	(need charm-factory data)
All combined	6°	2°	

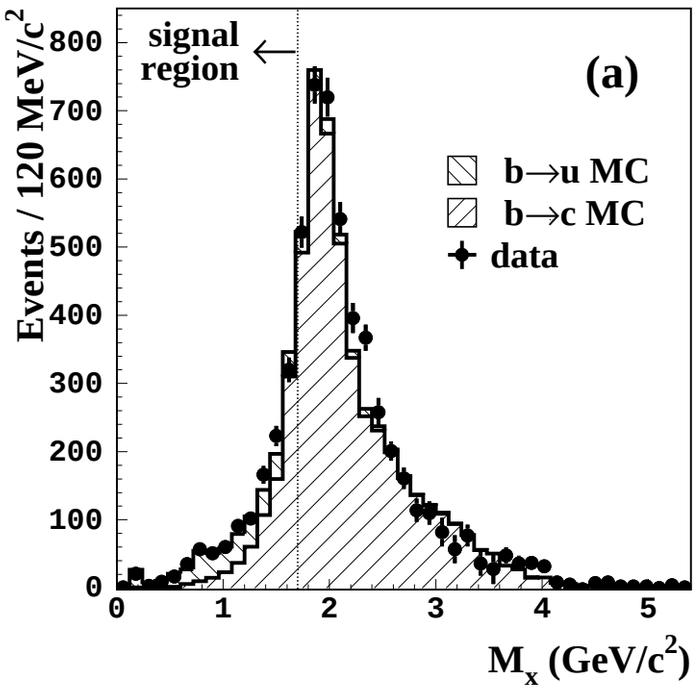
(cf. LHCb ($10\ \mathrm{fb}^{-1}$ / 2013) — $\delta\phi_3 \sim 2^\circ$ from D_sK (5°), ADS (4°), GLW (4°), Dalitz (5°))

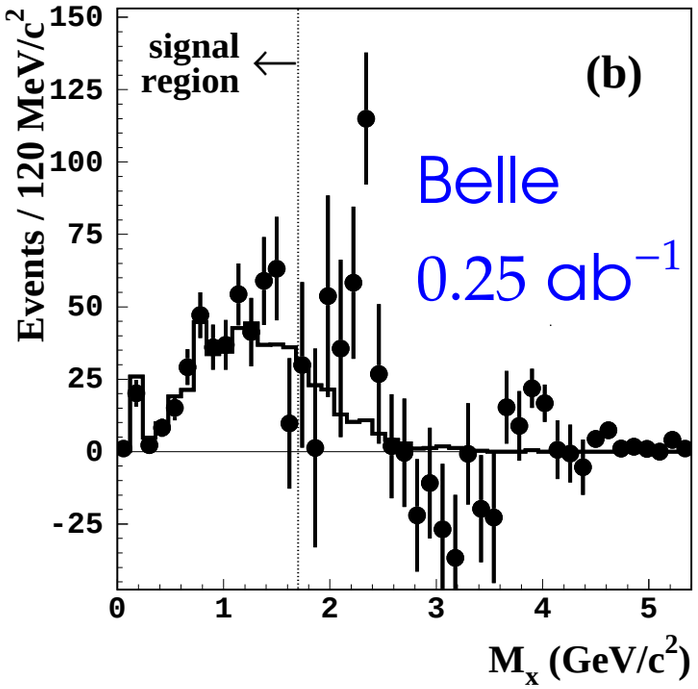
V_{ub} (inclusive measurement)

$|V_{ub}| = (3.98 \pm 0.15_{\rm exp} \pm 0.30_{\rm theo}) \times 10^{-4}$ — (Jan.7,2008 HFAG)

$8.3\% = \pm 2.0_{\rm stat} \pm 2.5_{\rm exp} \pm 1.8_{\rm b2cmodel} \pm 1.1_{\rm b2umodel} \pm 6.3_{\rm HQEparam} \pm 0.4_{\rm SFfunc} \pm 0.7_{\rm subSF} \pm 3.6_{\rm matching} \pm 1.4_{\rm WA}$

- Full-recon tag with M_X cut for a better background handle
  expected experimental error $\sim 3\%$ at 5 ab^{-1}
- HQE parameters to be reduced from $b \to c\ell^-\overline{\nu}$
  expected theory error $\sim 5\%$ at 5 ab^{-1}





Need to include higher M_X to reduce theory error
Not really stat. limited!

Larger dataset will help
to study $b \to c$ background

(theory field is also VERY active)

V_{td}

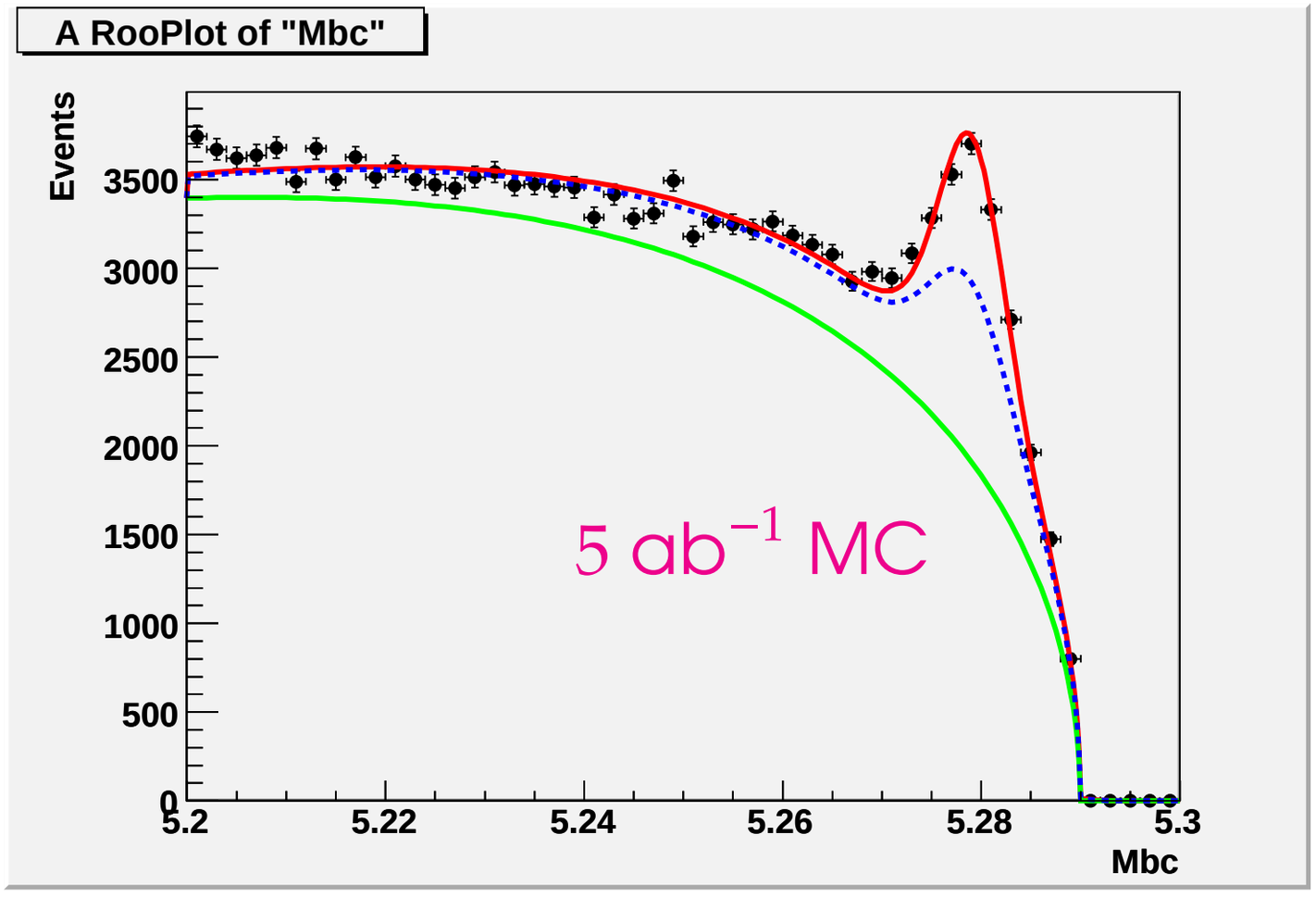
- Exclusive $B \to \rho\gamma$ — $\delta\mathcal{B}(\rho^0\gamma) \sim 9\%$, $\delta\mathcal{B}(\rho^+\gamma) \sim 12\%$ at 5 ab^{-1}
  (but no way to reduce form-factor error $\sim 25\%$ for $|V_{td}/V_{ts}|$)

- Inclusive $B \to \rho\gamma$ would be possible, $\delta\mathcal{B} \sim 24\%$ at 5 ab^{-1}
  (theory error has to be also taken into account)

Efficiency 2.9%

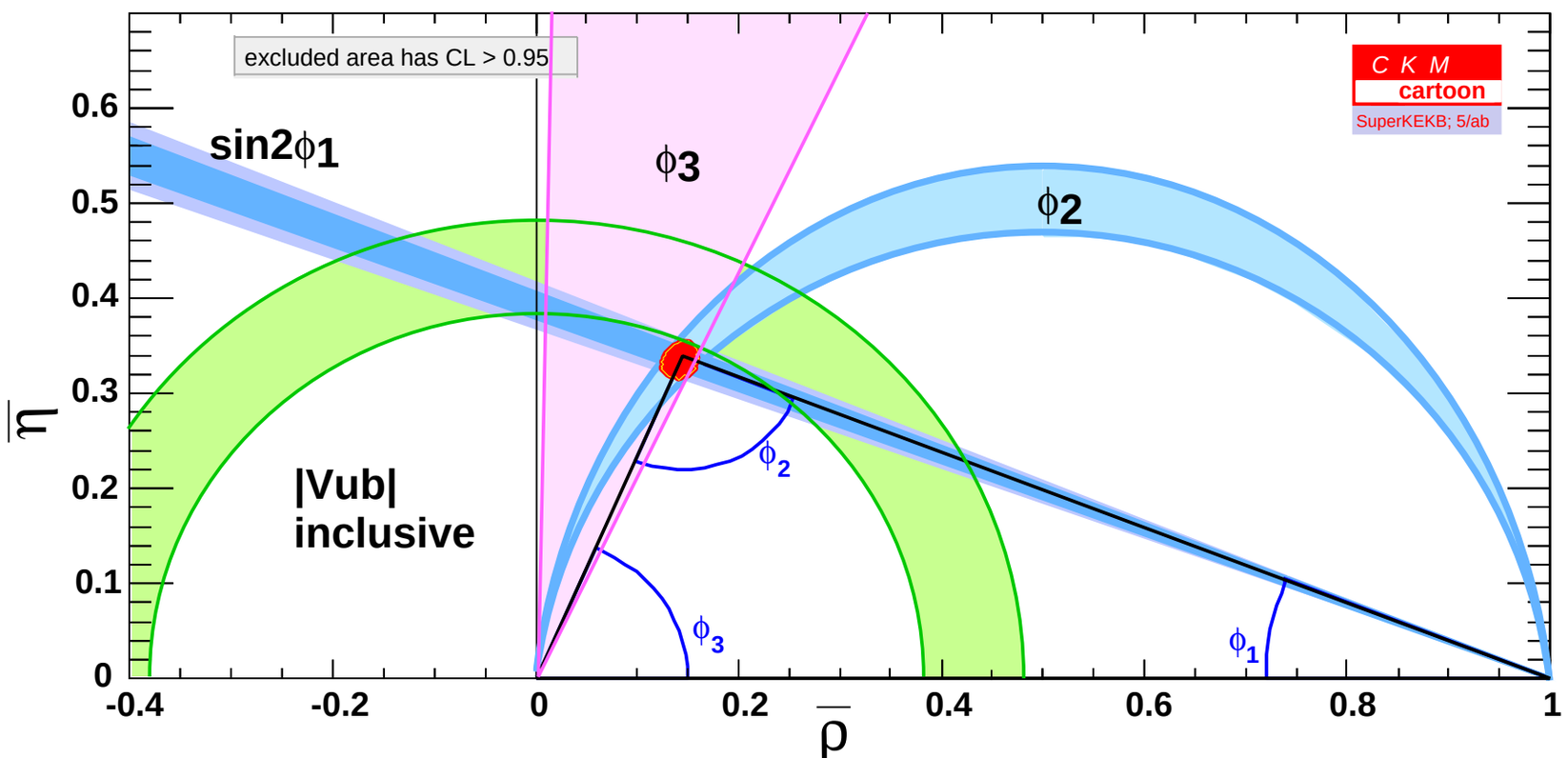
$\pm 20\%$ uncertainty from $b \to s\gamma$

Error sources:
- Stat.: 5%
- Fit.: 21%
- Model: 10%
- Total: 24%



Unitarity Triangle at $5\ \mathrm{ab}^{-1}$

- V_{ub} from inclusive $b \to u\ell^-\overline{\nu} \Rightarrow \delta = 6\%$
- ϕ_3 from $B \to DK \Rightarrow \delta = 6^\circ$ with $5\ \mathrm{ab}^{-1}$ (LHCb maybe doing better)
- $|V_{td}|$ from $B \to X_d\gamma \Rightarrow$ theory error?
  ($\Delta m_s/\Delta m_b$ measurement would be still better — Lattice?)
- Upgraded KEKB alone gives interesting constraints
  Lattice QCD will help to further reduce errors
  (V_{ub} from exclusive, V_{td} from $B \to \rho\gamma$)

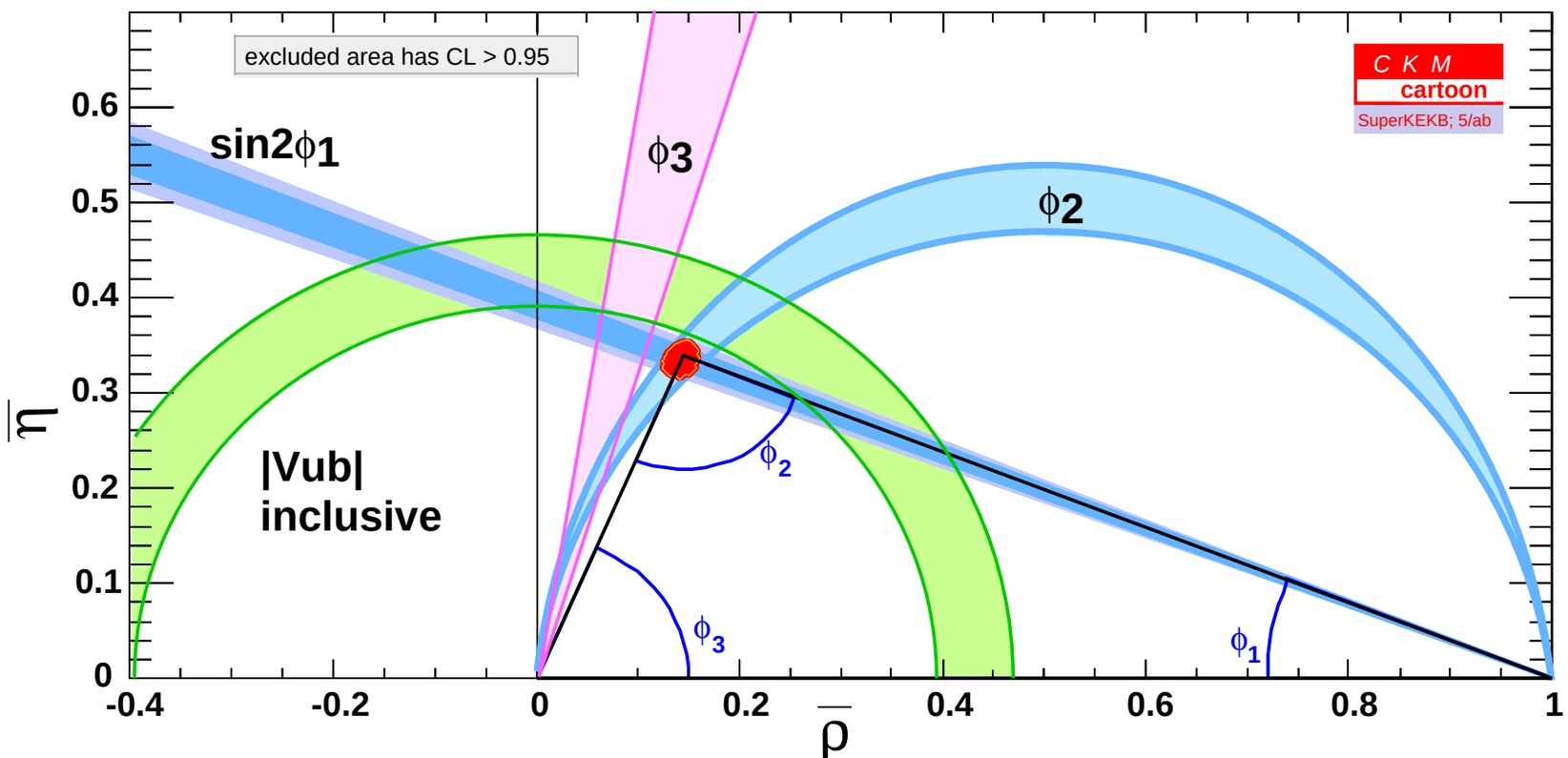


Errors for $5\ \mathrm{ab}^{-1}$
(with no LQCD info)

Central values
from 2007 averages

Unitarity Triangle at 50 ab^{-1}

- V_{ub} from inclusive $b \to u\ell^-\overline{\nu} \Rightarrow \delta = 4\%$
- ϕ_3 from $B \to DK \Rightarrow \delta = 2^\circ$ with 50 ab^{-1} (LHCb maybe doing better)
- $|V_{td}|$ from $B \to X_d\gamma \Rightarrow$ theory error?
  ($\Delta m_s/\Delta m_b$ measurement would be still better — Lattice?)
- Upgraded KEKB alone gives interesting constraints
  Lattice QCD will help to further reduce errors
  (V_{ub} from exclusive, V_{td} from $B \to \rho\gamma$)

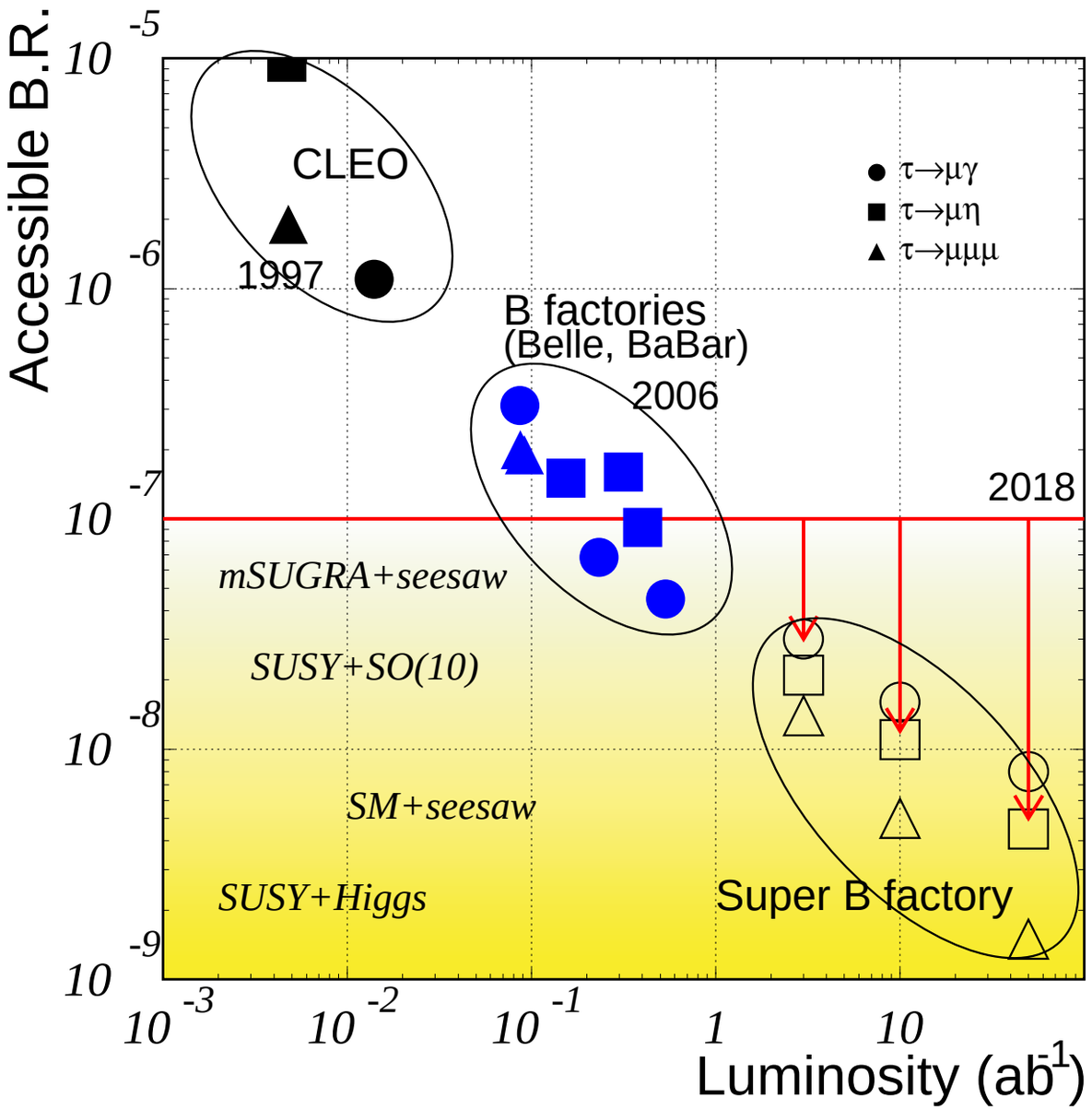


Errors for 50 ab^{-1}
(with no LQCD info)

Central values
from 2007 averages

Lepton flavor violation
searches in high statistics τ decays

τ lepton flavor violation (LFV)

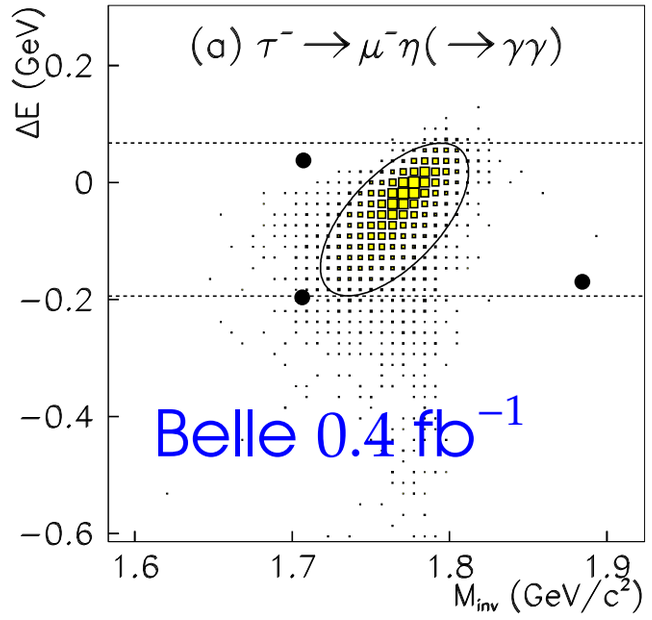


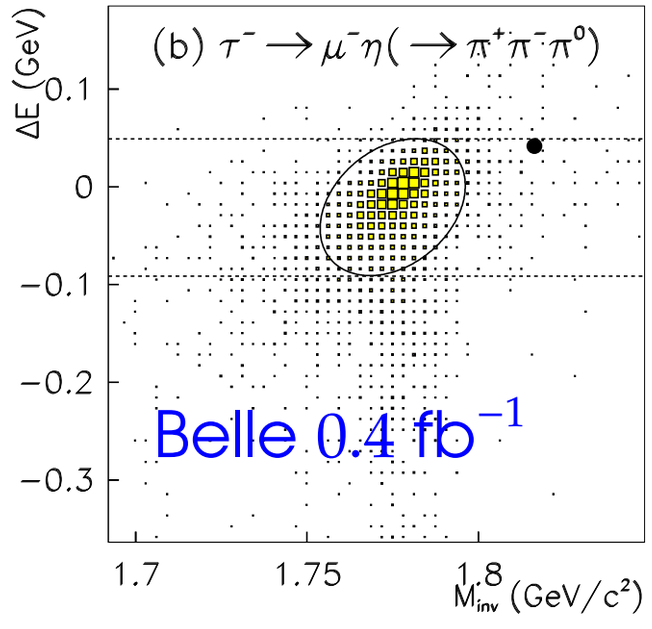
- Quark mixing ➡ KM
- Neutrino mixing ➡ MNS
- Charged lepton — LFV?
  - LFV through neutrino mixing is extremely small: e.g. $\mathcal{B}(\tau \to \mu\gamma) \sim 10^{-54}$
  - BSM scenarios (SUSY, etc) generates LFV: SUSY SO(10) $\sim 10^{-8}$, sSUGRA + seesaw $\sim 10^{-7}$
- Many modes to search (those including lepton number violation with and without $B - L$)

Searches down to $\sim 10^{-8}$ with 3–10 ab^{-1}

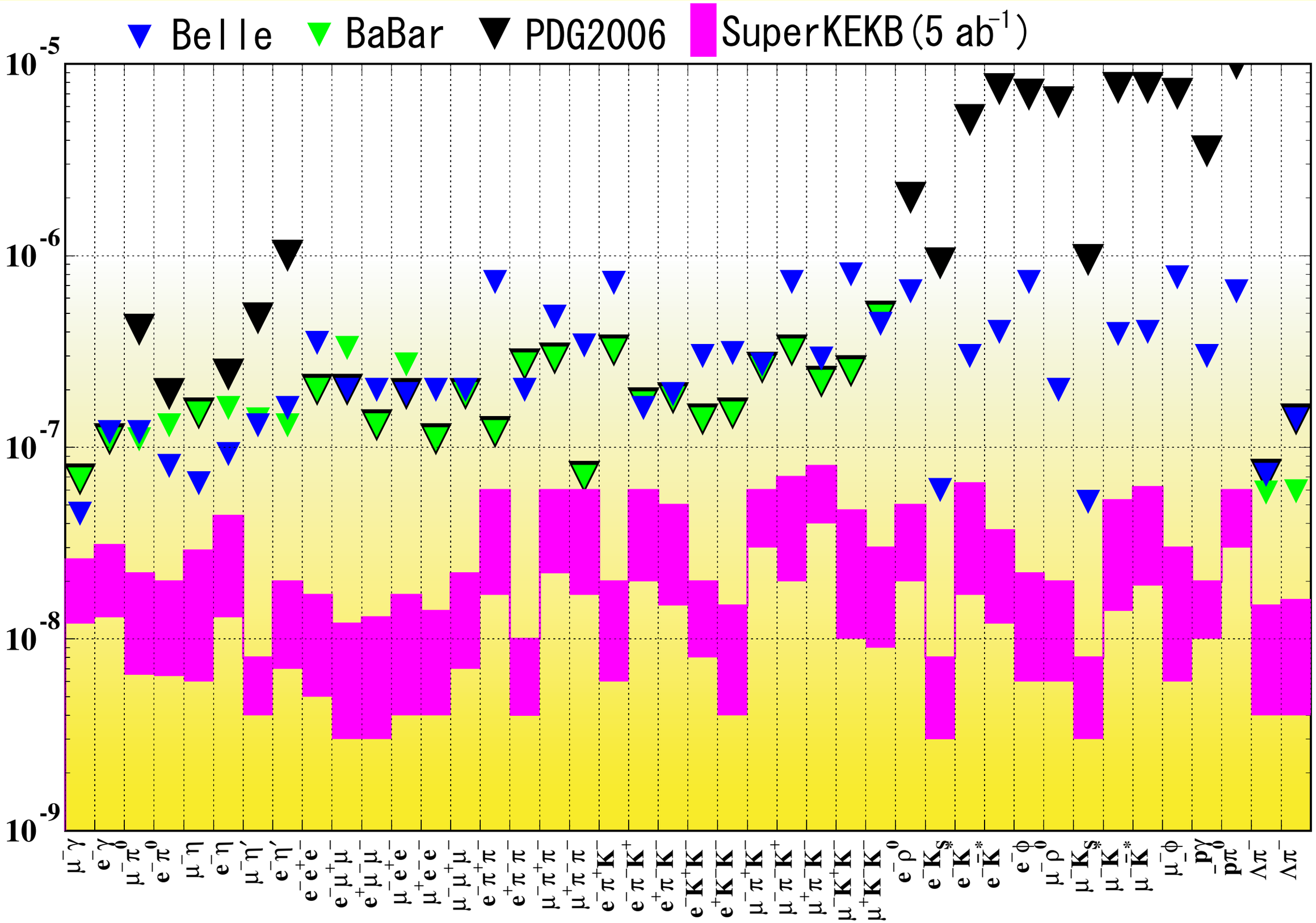
Analysis and prospects

- $\tau^- \to \ell^- \gamma$ modes
  - Not background free
    (such as $e^+e^- \to \tau^+\tau^-\gamma$)
  - limit scales with $1/\sqrt{\mathcal{L}}$
- $\tau^- \to \ell^- h^0$ and $\tau^- \to \ell^-\ell^+\ell^-$ modes
  - background free at least till ~ 1 ab^{-1}
    (too little background now)
  - limit scales with $1/\mathcal{L}$
- Concerns
  - Photon energy resolution is the key in $\tau \to \ell\gamma$ modes
  - Trigger: low multiplicity trigger as of now will be kept





Many τ LFV possibilities ($5\ \mathrm{ab}^{-1}$)



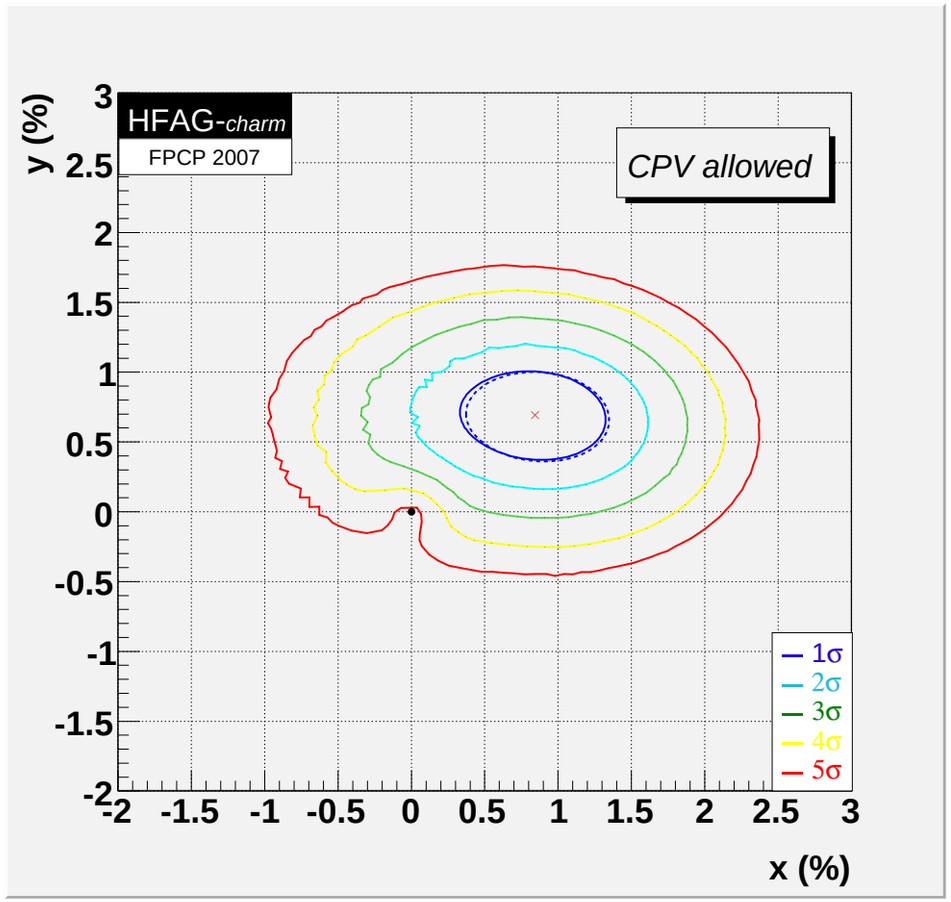
Charm physics

CP violation in up-quark sector

$D^0\overline{D}^0$ CPV

- $x = (0.84\,^{+0.32}_{-0.34})\%$, $y = (0.69 \pm 0.21)\%$ are larger than SM, but not incompatible
- It could also be non-SM effect… to confirm, search for CPV (only 10^{-4} in SM)

$$A_\Gamma = \frac{\Gamma(\overline{D}^0 \to K^+K^-) - \Gamma(D^0 \to K^+K^-)}{\Gamma(\overline{D}^0 \to K^+K^-) + \Gamma(D^0 \to K^+K^-)} = \frac{1}{2}A_M y\cos\phi - x\sin\phi$$



latest world average ($> 5\sigma$)

now: $A_\Gamma = (0.1 \pm 3.0 \pm 1.5) \times 10^{-3}$ (0.5 ab^{-1})

➡ $\delta A_\Gamma \sim 10^{-3}$ with 5 ab^{-1} for $D \to K^+K^-$

Dalitz analysis mode ($D \to K^0_S\pi\pi$) will be equally sensitive to CPV

Summary

many summary lines have to be included
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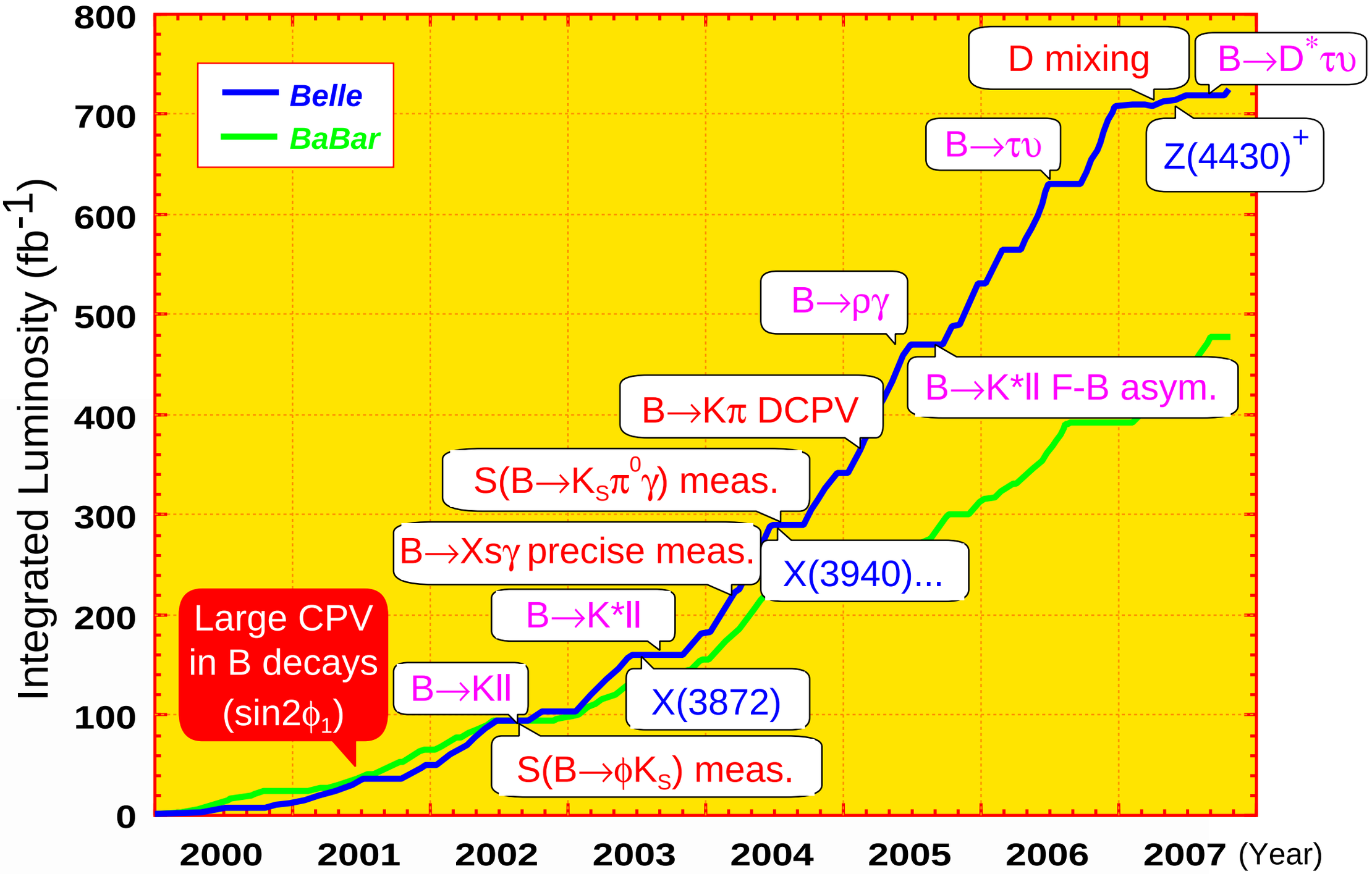
Summary

- Key measuments are already very exciting with 3–5 ab^{-1}
  - $b \to s$ penguin: mode-by-mode CPV with $\delta S < 0.1$
  - Extensive test on charged Higgs
  - RH current search with $\delta S \sim 0.1$
  - Inclusive measurements: $b \to s\gamma$, $b \to s\ell^+\ell^-$, ...
  - Precise ϕ_2 ($\delta = 2°$) provides a reference point $(\overline{\rho}, \overline{\eta})$
  - LFV τ decay search range down to 10^{-8}
  - CPV in D decays
- Many other physics potentials (not discussed)
  - $B \to K\nu\overline{\nu}$ and other rare decays
  - New particles, and more and more and more...
- Meanwhile let's push hard for 50 ab^{-1} or more

Backup

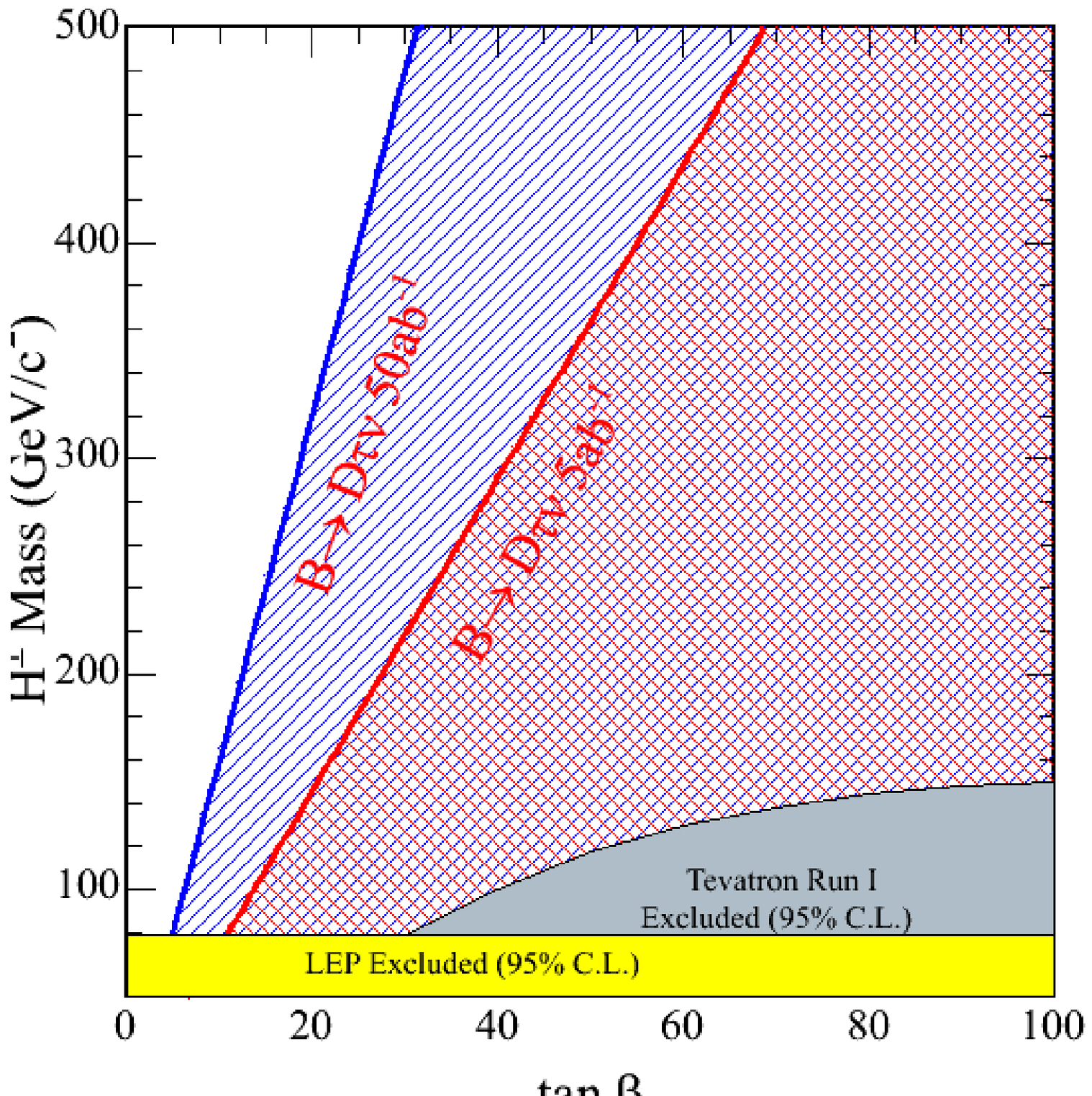
backup backup backup backup backup backu



Belle has established the needed decays/techniques

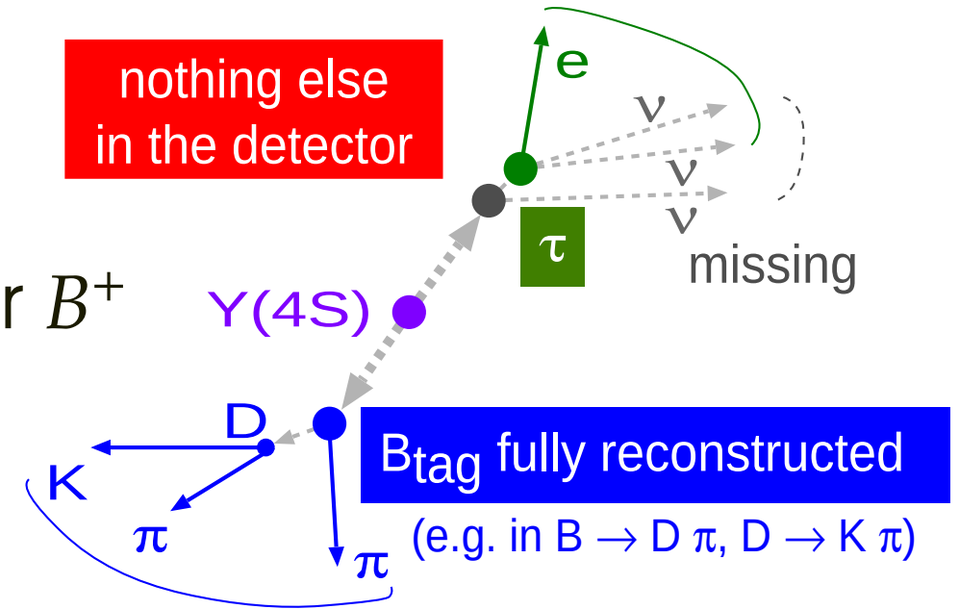
- Decay modes: $b \to s\ell^+\ell^-$, $b \to d\gamma$, $B^+ \to \tau^+\nu$, $B \to D^*\tau^+\nu$
- Phases: time-dependent CPV in $b \to s$, $b \to s\gamma$

$B \to D\tau^+\nu$ at 5 and 50 ab^{-1}



Prospects on full reconstruction

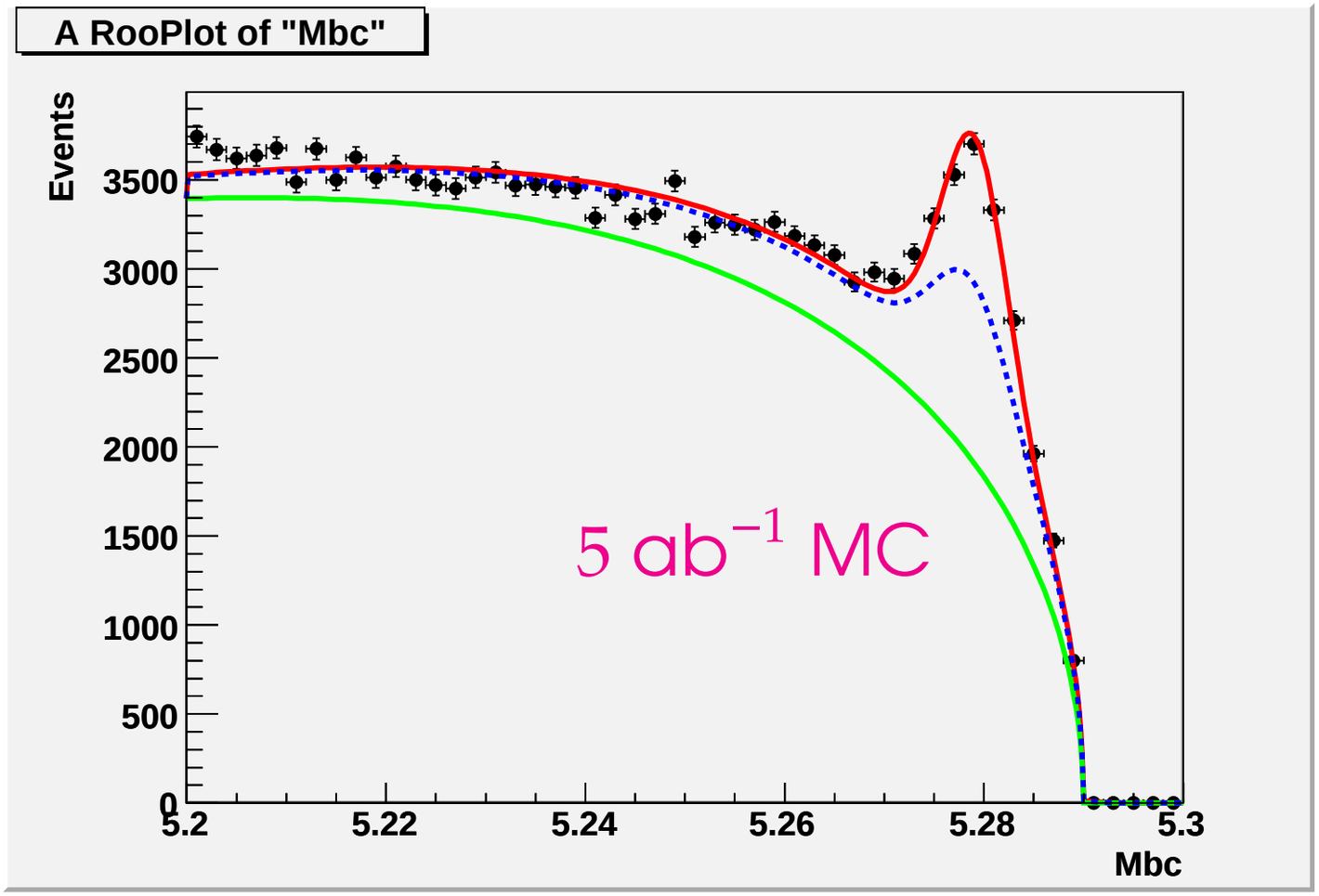
- Latest Belle code
  - Modes: $D^{(*)}(\pi^+, \rho^+, a_1^+, D_s^{(*)+})$
  - Efficiency: 0.09% for B^0, 0.15% for B^+
- Problems
  - Not an ultimate approach
    (χ^2 based best-candidate selection)
  - Slow $\pi^\pm$ recovery with SVD tracker
- At upgraded KEKB
  - Beam background: worries in soft photon, π^0, $\pi^\pm$
  - Soft photon reconstruction:
    — Less material in front of CsI
    — More beam background pile-up



Full reconstruction code is now being revisited

$B \to X_d\gamma$ at 5 ab^{-1}

- Efficiency 2.9%
- A fit result:
  $\Rightarrow \Upsilon = 4249 \pm 224 \pm 888$
- $b \to s\gamma$ component
  ±20% uncertainty
- Error sources:
  Stat.: 5%
  Fit.: 21%
  Model: 10% (not in Y)
  Total: 24%



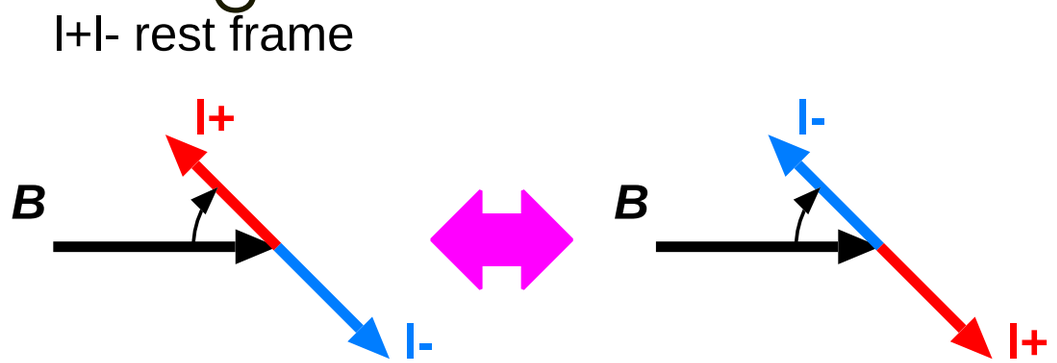
$B \to X_d\gamma$ seems to be possible with 5 ab^{-1}!

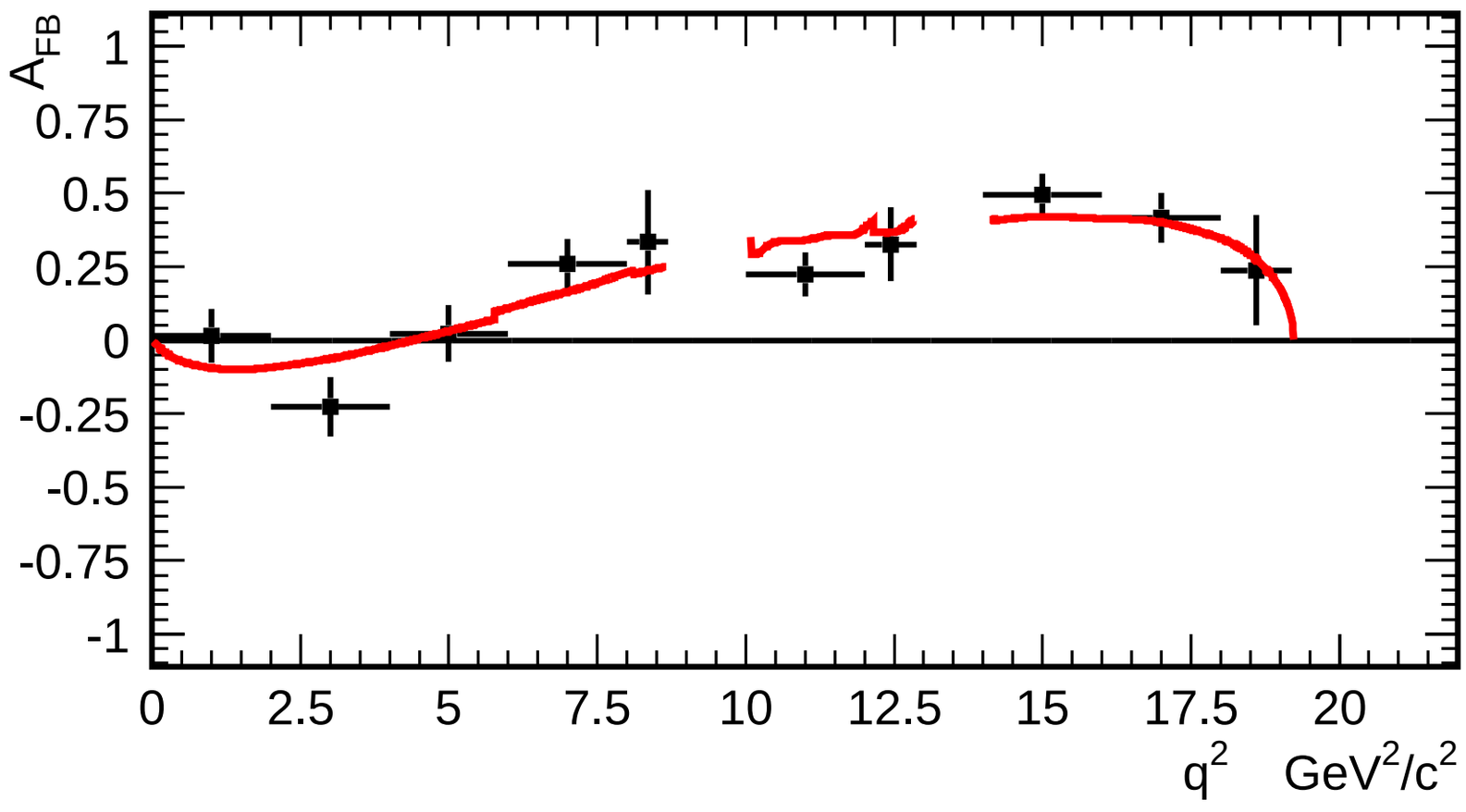
(still challenging, systematic error could be quite different in reality)

$A_{FB}(B \to K^* \ell^+ \ell^-)$ at 5 ab^{-1}

- Sensitive to C_9 and C_{10} Wilson coefficients
- Full (q^2, θ) fit with SM q^2 dist with leading coefficients only (A_9 and A_{10})
- $\delta A_9/A_9 \sim 11\%$
  $\delta A_{10}/A_{10} \sim 13\%$ at 5 ab^{-1}

  (i.e., $\delta A_9/A_9 \sim \delta A_{10}/A_{10} \sim 4\%$ at 50 ab^{-1})





LHCb?

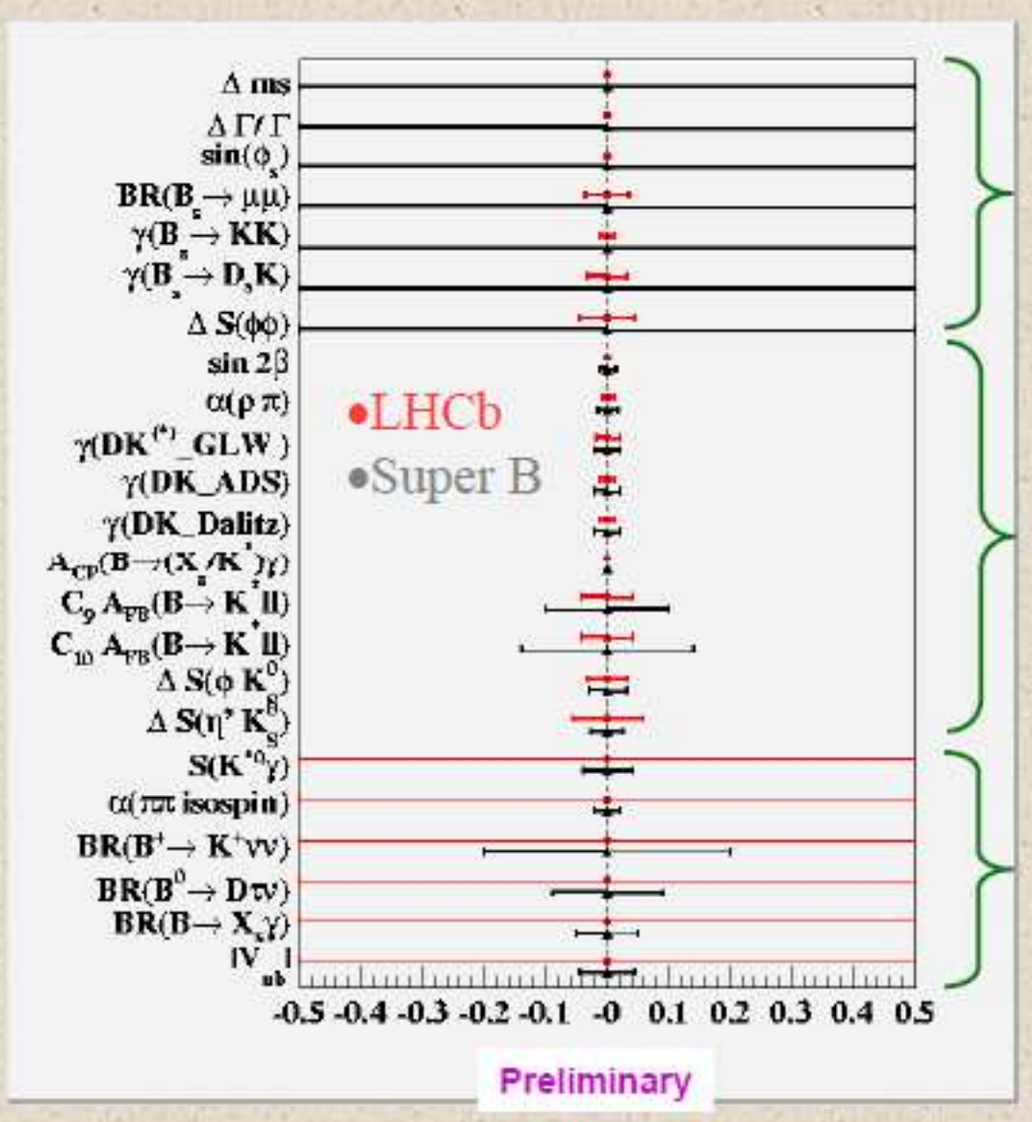
S. Stone

Super B factory and Super-LHCb

Sensitivity Comparison ~2020

Super-LHCb 100 fb^{-1} vs Super-B factory 50 ab^{-1}

SuperB numbers from M Hazumi - Flavour in LHC era workshop; LHCb numbers from Muheim



Bs

Common

No IP
Neutrals, ν

- This plot is made by our LHCb friend.
- LHCb: 10/fb
- Super-LHCb: 100/fb

Quite complementary to each other!

56

Beam-background

- Vertex (SVD)
  - Fast readout chip (APV25)
  - Eventually monolithic pixel
- Drift chamber (CDC)
  - Larger SVD radius
  - small cell to shorten drift time
- Calorimeter (ECL)
  - Sampling readout + wave form analysis
  - Pure CsI (endcap only, costly...)
- Muon, K_L^0 (KLM)
  - RPC to scintillator tile

All these efforts
just to compensate