Quark Flavor Physics from Belle II

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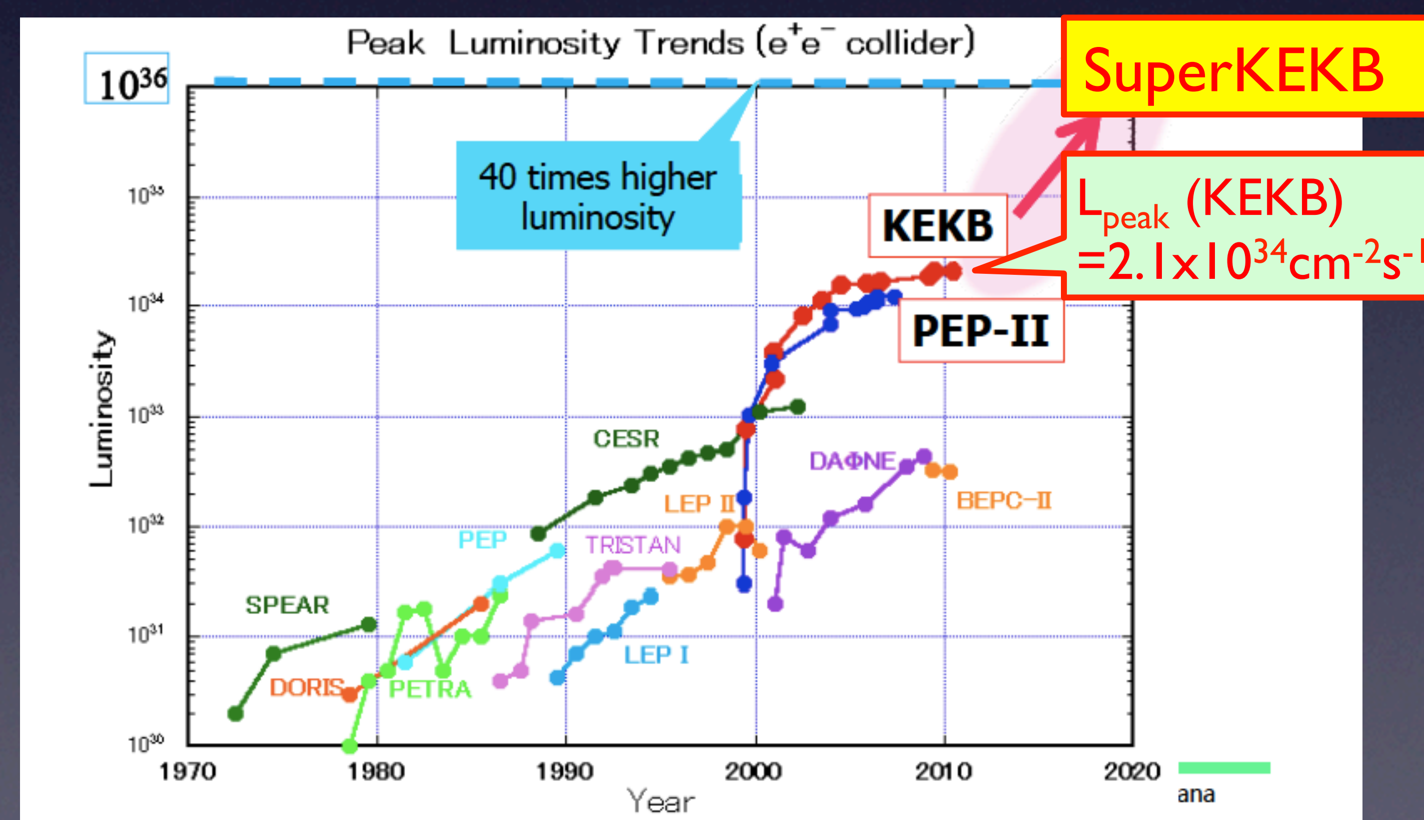
Lattice QCD Meets Experiment 2014 @ Fermilab

SuperKEKB/Belle II

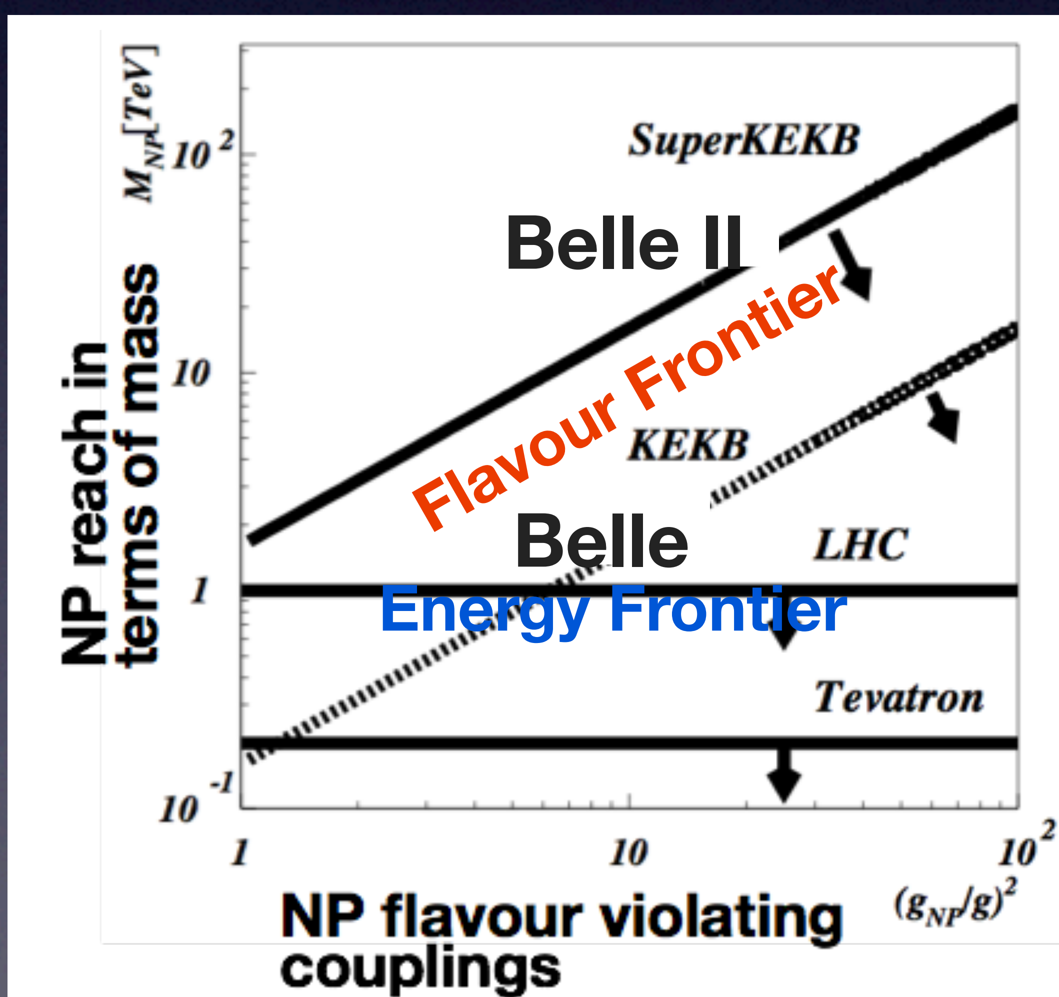
- New intensity frontier facility
- Target luminosity ; $L_{peak} = 8 \times 10^{35} cm^{-2}s^{-1}$
  $L_{int} > 50\ ab^{-1}$ by early 2020's.

$\Rightarrow \sim 10^{10}\ B\bar{B}, \tau^+\tau^-$ and charms per year !



Motivation of Belle II

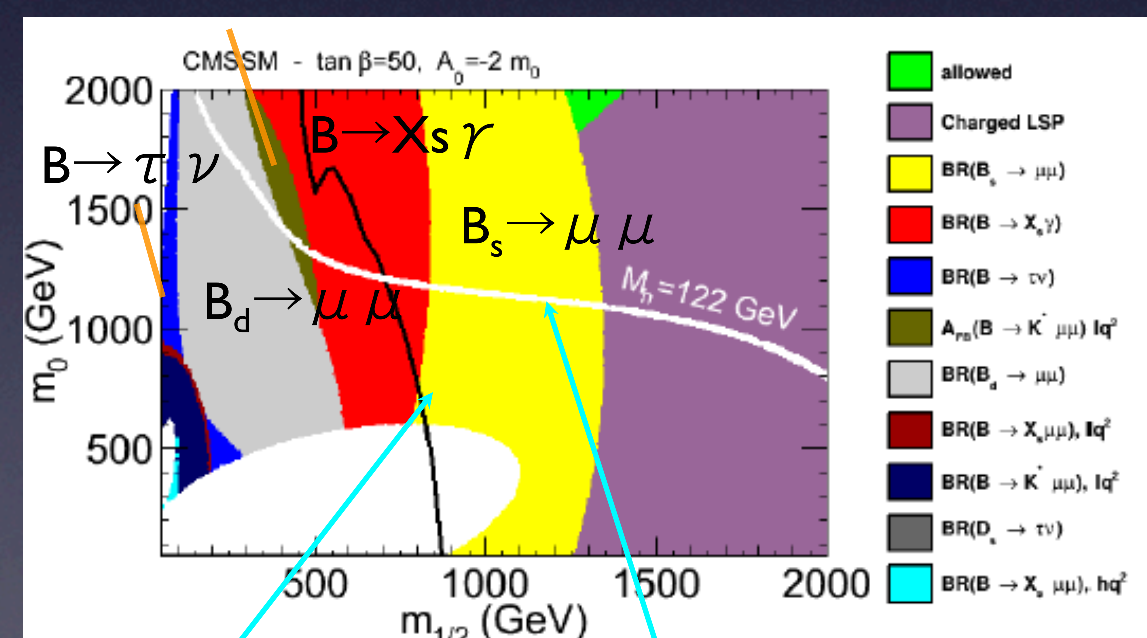
- Search for New Physics through processes sensitive to presence of virtual heavy particles.
- Complementary to direct search at LHC high P_T programs.



Flavour constraints in CMSSM in ($m_{1/2}$, m_0)

[F. Mahmoudi, 1310.2556]

B→K$\mu\mu$



ATLAS SUSY direct search limit w/ 20.3fb^{-1}

Higgs mass can reach 122 GeV

Key Measurements

arXiv:1002.5012

- CPV in b→s penguin decays
- FCNC
- Tauonic decays
- LFV τ decays

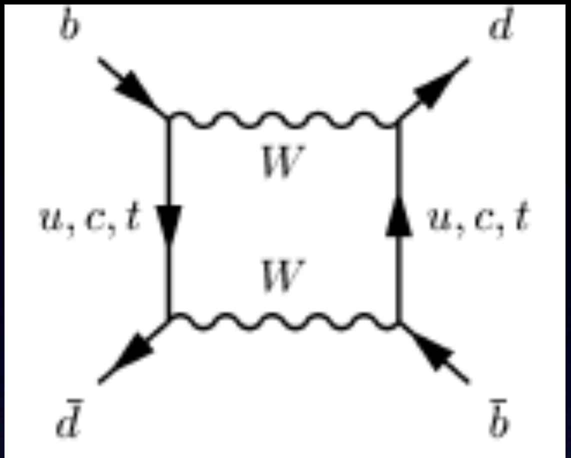
Observable	Belle 2006 (~0.5 ab^{-1})	SuperKEKB (5 ab^{-1})	SuperKEKB (50 ab^{-1})
Hadronic $b \to s$ transitions			
$\Delta S_{\phi K^0}$	0.22	0.073	0.029
$\Delta S_{\eta' K^0}$	0.11	0.038	0.020
$\Delta S_{K^0_S K^0_S K^0_S}$	0.33	0.105	0.037
$\Delta A_{\pi^0 K^0_S}$	0.15	0.072	0.042
$A_{\phi\phi K^+}$	0.17	0.05	0.014
$\phi_1^{eff}(\phi K_S)$ Dalitz		3.3°	1.5°
Radiative/electroweak $b \to s$ transitions			
$S_{K^0_S \pi^0 \gamma}$	0.32	0.10	0.03
$\mathcal{B}(B \to X_s\gamma)$	13%	7%	6%
$A_{CP}(B \to X_s\gamma)$	0.058	0.01	0.005
C_9 from $\overline{A}_{\rm FB}(B \to K^*\ell^+\ell^-)$	-	11%	4%
C_{10} from $\overline{A}_{\rm FB}(B \to K^*\ell^+\ell^-)$	-	13%	4%
C_7/C_9 from $\overline{A}_{\rm FB}(B \to K^*\ell^+\ell^-)$	-		5%
R_K		0.07	0.02
$\mathcal{B}(B^+ \to K^+\nu\nu)$	†† $< 3\ \mathcal{B}_{\rm SM}$		30%
$\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu})$	†† $< 40\ \mathcal{B}_{\rm SM}$		35%
Radiative/electroweak $b \to d$ transitions			
$S_{\rho\gamma}$	-	0.3	0.15
$\mathcal{B}(B \to X_d\gamma)$	-	24% (syst.)	
Leptonic/semileptonic B decays			
$\mathcal{B}(B^+ \to \tau^+\nu)$	3.5σ	10%	3%
$\mathcal{B}(B^+ \to \mu^+\nu)$	†† $< 2.4\mathcal{B}_{\rm SM}$	4.3 ab^{-1} for 5σ discovery	
$\mathcal{B}(B^+ \to D\tau\nu)$	-	8%	3%
$\mathcal{B}(B^0 \to D\tau\nu)$	-	30%	10%
LFV in τ decays (U.L. at 90% C.L.)			
$\mathcal{B}(\tau \to \mu\gamma)$ [10^{-9}]	45	10	5
$\mathcal{B}(\tau \to \mu\eta)$ [10^{-9}]	65	5	2
$\mathcal{B}(\tau \to \mu\mu\mu)$ [10^{-9}]	21	3	1

Ultimate measurements down to theory error !

Precision CKM Measurements

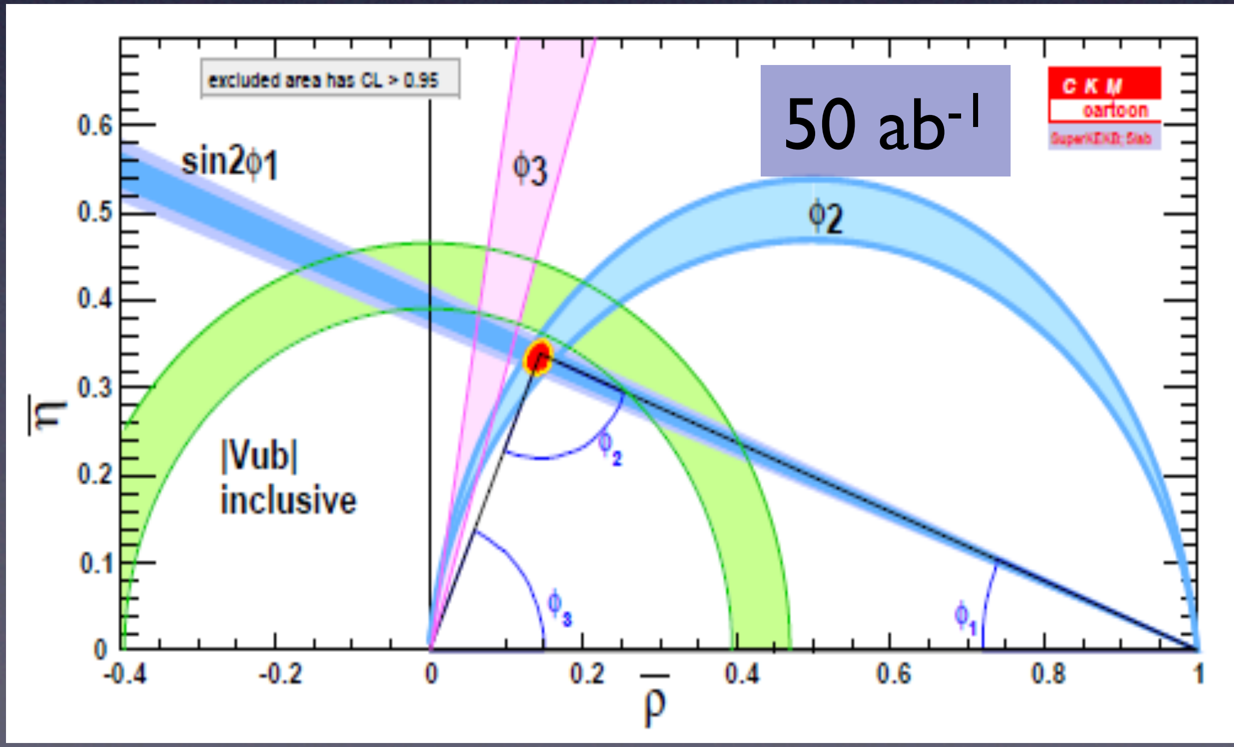
- Comparison between
  - tree-based ; $|V_{ub}| + \phi_3$
  - loop-based ; ϕ_1, ϕ_2, $|V_{td}|$

  $\rightarrow$ NP in loop



- Belle II is unique for $|V_{cb}|$ and $|V_{ub}|$

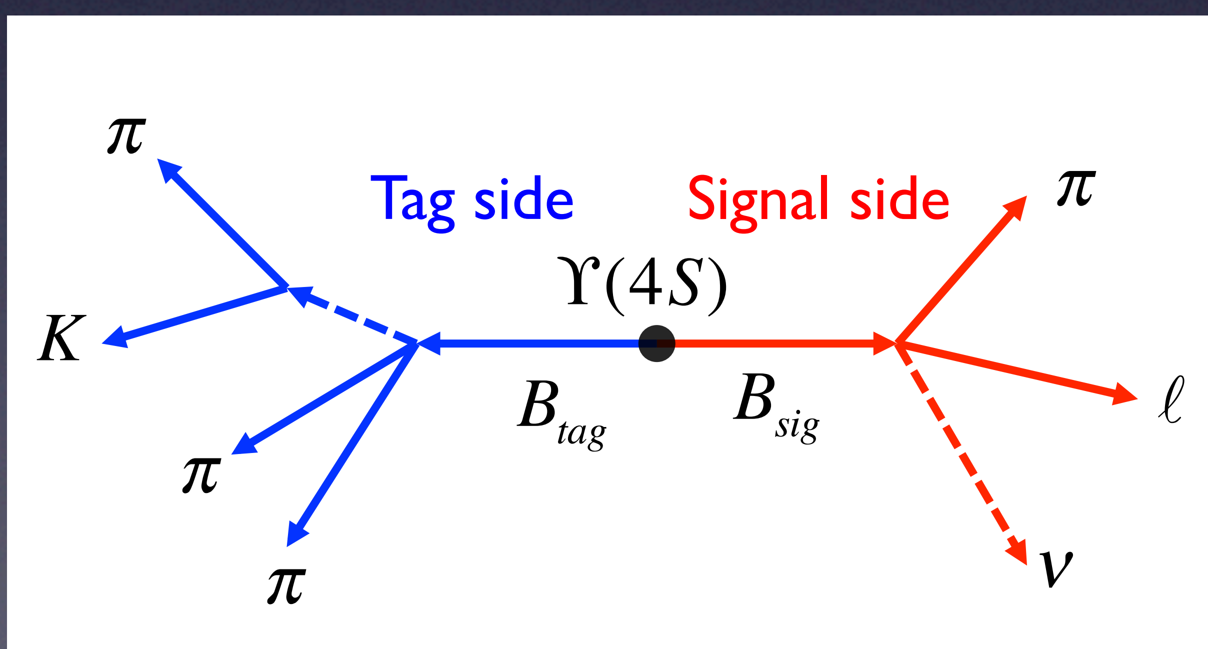
Observable	Belle 2006 ($\sim$0.5 ab^{-1})	SuperKEKB (5 ab^{-1})	SuperKEKB (50 ab^{-1})
Unitarity triangle parameters			
$\sin 2\phi_1$	0.026	0.016	0.012
ϕ_2 ($\pi\pi$)	11°	10°	3°
ϕ_2 ($\rho\pi$)	$68° < \phi_2 < 95°$	3°	1.5°
ϕ_2 ($\rho\rho$)	$62° < \phi_2 < 107°$	3°	1.5°
ϕ_2 (combined)		2°	$\lesssim 1°$
ϕ_3 ($D^{(*)}K^{(*)}$) (Dalitz mod. ind.)	20°	7°	2°
ϕ_3 ($DK^{(*)}$) (ADS+GLW)	-	16°	5°
ϕ_3 ($D^{(*)}\pi$)	-	18°	6°
ϕ_3 (combined)		6°	1.5°
$\|V_{ub}\|$ (inclusive)	6%	5%	3%
$\|V_{ub}\|$ (exclusive)	15%	12% (LQCD)	5% (LQCD)
†††$\bar{\rho}$	20.0%		3.4%
†††$\bar{\eta}$	15.7%		1.7%

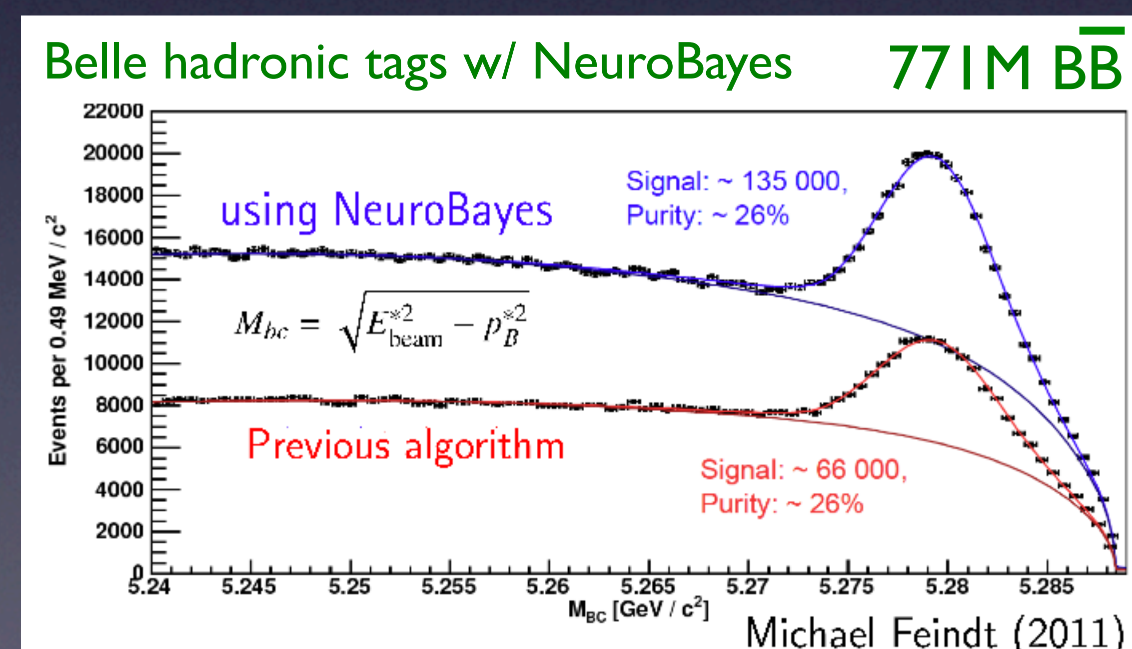


Uniqueness of Belle II

- Fully reconstructed tags to produce “offline B meson beam”.
  - Strong tool for modes with neutrinos

    $B \to X l \nu$, $X \tau \nu$, $\tau \nu$, $K^{(*)} \nu \bar{\nu}$...
- Excellent γ & π^0 detection capability
- $S(K_S^0 \pi^0 \gamma)$, $Br(X_S \gamma)$, $A_{CP}(X_S \gamma)$





NIM A654, 432 (2011)

Lattice QCD and Belle II

- Lattice QCD is important for CKM physics.

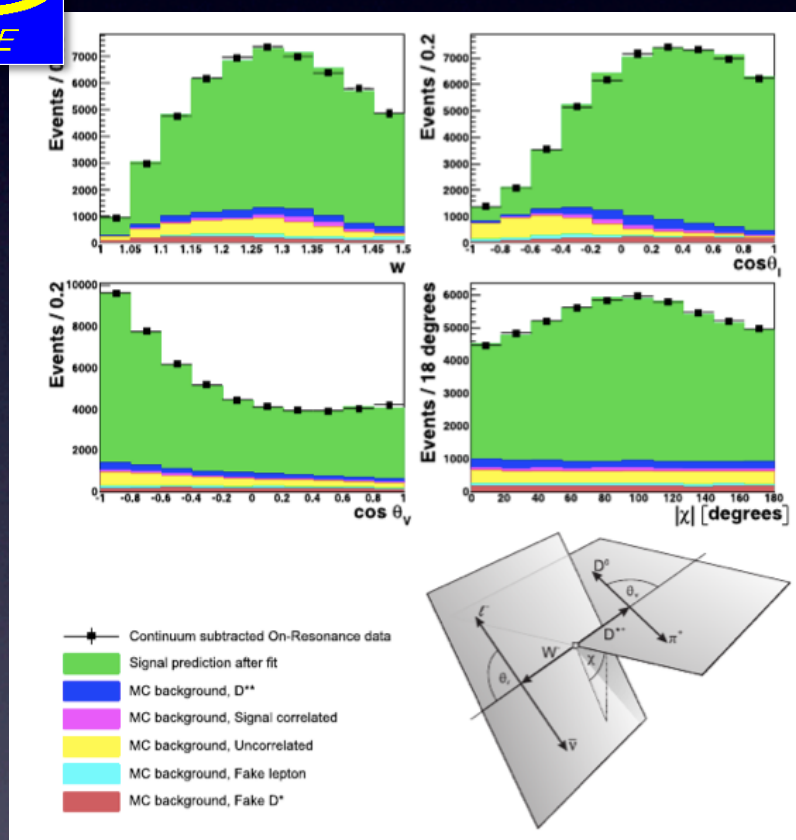
USQCD "Lattice QCD at the Intensity Frontier"
http://www.usqcd.org/documents/13flavor.pdf

Quantity	CKM element	Present expt. error	2007 forecast lattice error	Present lattice error	2018 lattice error
f_K/f_π	$\|V_{us}\|$	0.2%	0.5%	0.5%	0.15%
$f_+^{K\pi}(0)$	$\|V_{us}\|$	0.2%	–	0.5%	0.2%
f_D	$\|V_{cd}\|$	4.3%	5%	2%	$< 1\%$
f_{D_s}	$\|V_{cs}\|$	2.1%	5%	2%	$< 1\%$
$D \to \pi\ell\nu$	$\|V_{cd}\|$	2.6%	–	4.4%	2%
$D \to K\ell\nu$	$\|V_{cs}\|$	1.1%	–	2.5%	1%
$B \to D^*\ell\nu$	$\|V_{cb}\|$	1.3%	–	1.8%	$< 1\%$
$B \to \pi\ell\nu$	$\|V_{ub}\|$	4.1%	–	8.7%	2%
f_B	$\|V_{ub}\|$	9%	–	2.5%	$< 1\%$
ξ	$\|V_{ts}/V_{td}\|$	0.4%	2-4%	4%	$< 1\%$
ΔM_s	$\|V_{ts}V_{tb}\|^2$	0.24%	7–12%	11%	5%
B_K	$\mathrm{Im}(V_{td}^2)$	0.5%	3.5–6%	1.3%	$< 1\%$

- Also for rare decay processes: ex) $B \to K^{(*)} l^+ l^-$, $B \to K^* \gamma$

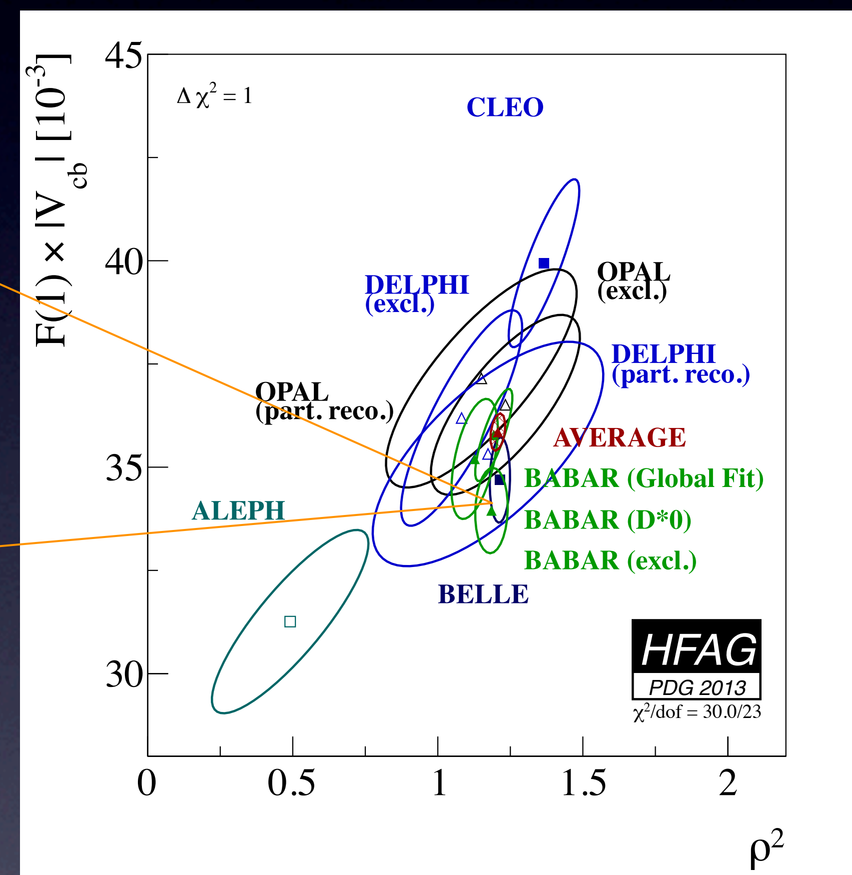
$|V_{cb}|$ at present

- Exclusive $|V_{cb}|$ (relevant to lattice QCD) comes mainly from $B^0 \to D^{*-}\, l^+\, \nu$.
- Precision at the level of ~2%, but slight difference from inclusive (~2σ).



$$\mathcal{F}(1)|V_{cb}| = (34.6 \pm 0.2 \pm 1.0) \times 10^{-3}$$
$$\rho^2 = 1.214 \pm 0.034 \pm 0.009$$
$$R_1(1) = 1.401 \pm 0.034 \pm 0.018$$
$$R_2(1) = 0.864 \pm 0.024 \pm 0.008$$
$$\chi^2/ndf = 138.8/155$$

W. Dungel et al. PRD 82, 112007 (2010)



$|V_{cb}|_{excl} = (39.48 \pm 0.50_{exp} \pm 0.74_{th}) \times 10^{-3}$

$F(1) = (0.908 \pm 0.017)$ [arXiv:1011.2166]

$|V_{cb}|_{incl} = (41.88 \pm 0.73) \times 10^{-3}$

arXiv:1207.1158

- New calculation of F(1) by FNAL/MILC [arXiv:1403.0635]

F(1) = 0.906 (4) (12)

⇒ $|Vcb| = (39.04 \pm 0.49_{exp} \pm 0.53_{QCD} \pm 0.19_{QED}) \times 10^{-3}$

Update of $|V_{cb}|$ from the $\bar{B} \to D^* \ell \bar{\nu}$ form factor at zero recoil with three-flavor lattice QCD

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Abstract

We compute the zero-recoil form factor for the semileptonic decay $\bar{B}^0 \to D^{*+} \ell^- \bar{\nu}$ (and modes related by isospin and charge conjugation) using lattice QCD with three flavors of sea quarks. We use an improved staggered action for the light valence and sea quarks (the MILC asqtad configurations), and the Fermilab action for the heavy quarks. Our calculations incorporate higher statistics, finer lattice spacings, and lighter quark masses than our 2008 work. As a byproduct of tuning the new data set, we obtain the D_s and B_s hyperfine splittings with few-MeV accuracy. For the zero-recoil form factor, we obtain $\mathcal{F}(1) = 0.906(4)(12)$, where the first error is statistical and the second is the sum in quadrature of all systematic errors. With the latest HFAG average of experimental results and a cautious treatment of QED effects, we find $|V_{cb}| = (39.04 \pm 0.49_{\mathrm{expt}} \pm 0.53_{\mathrm{QCD}} \pm 0.19_{\mathrm{QED}}) \times 10^{-3}$. The QCD error is now commensurate with the experimental error.

PACS numbers: 12.38.Gc, 13.20.He, 12.15.Hh

$|V_{cb}|$ Prospect at Belle II

- Tagged measurement of $B \to D^* l\nu$ and $B \to Dl\nu$ will yield $|V_{cb}|$ with a similar level of precision.

→ Require good prediction for F(w) and G(w)

Fit with lattice data at different kinematic points ?

- Improvement in inclusive $|V_{cb}|$ will be far modest.

Expected relative uncertainty in $|V_{cb}|$ from $B \to D^* l\nu$

	Statistical	Systematic (reducible, irreducible)	Total Exp	Theory	Total
$\vert V_{cb}\vert$ exclusive					
711 fb^{-1}	0.6	(2.8, 1.1)	3.1	1.8	3.6
5 ab^{-1}	0.2	(1.1, 1.1)	1.5	1.5	2.2
50 ab^{-1}	0.1	(0.3, 1.1)	1.2	1.0	1.5

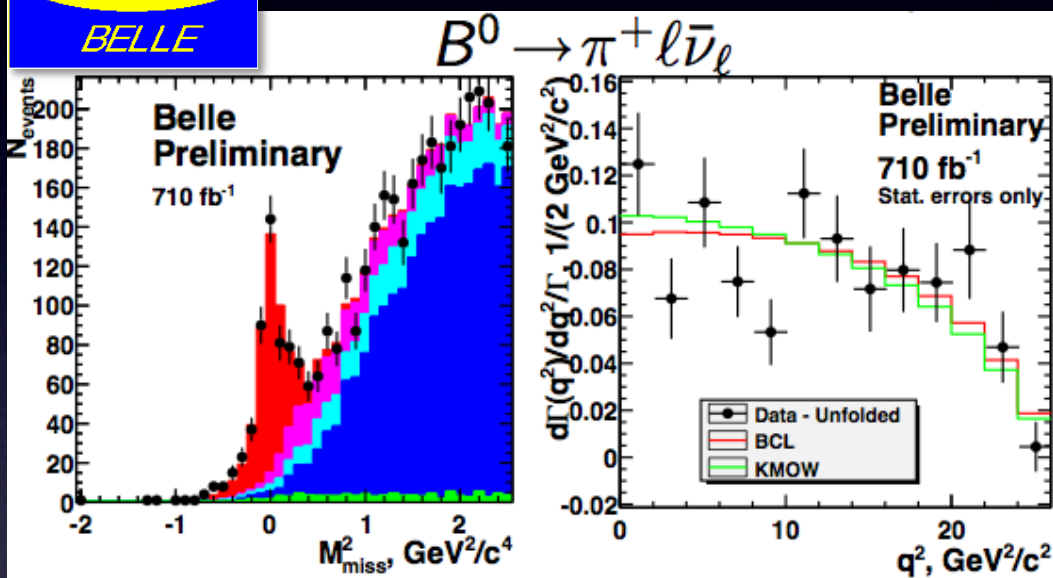
Belle II Internal Note #0021

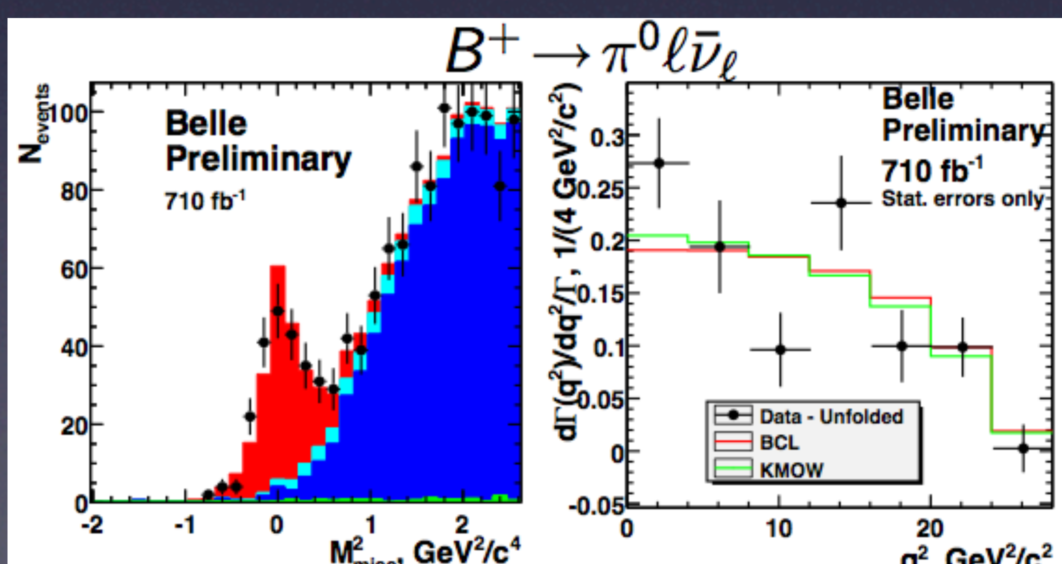
Tracking eff. (statistics limited)

Normalization: $N(\Upsilon(4S))$, $f_{\pm}/f_0$, B^0 lifetime, $Br(D^* \to D^0\pi)$, $Br(D^0 \to K\pi)$

$|V_{ub}|$ at present

- $B \to \pi l \nu$ with hadronic tag





[PRD 88, 032005 (2013)]

- 703/fb of Belle Y(4S) data
- Hadronic tag
- Yield extracted from M^2_{miss} in 13 (7) bins of q^2 for $B^0 \to \pi^+ l \nu$ ($B^+ \to \pi^0 l \nu$)
- Main systematics: tag calibration

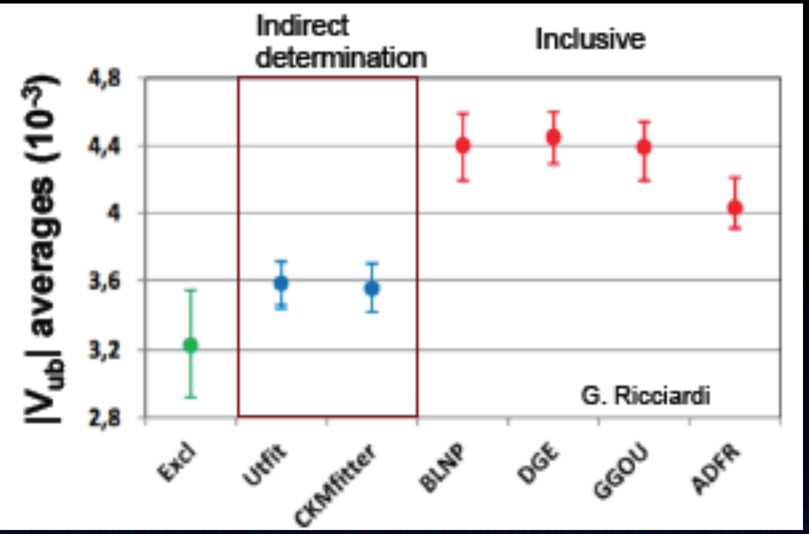
X_u	Yield	$\mathcal{B} \times 10^4$
π^+	461±28	$1.49 \pm 0.09 \pm 0.07$
π^0	230±22	$0.80 \pm 0.08 \pm 0.04$

X_u	Theory	q^2, GeV/c^2	$\lvert V_{ub}\rvert \times 10^3$
π^0	LCSR1	< 12	$3.30 \pm 0.22 \pm 0.09^{+0.35}_{-0.30}$
	LCSR2	< 16	$3.62 \pm 0.20 \pm 0.10^{+0.60}_{-0.40}$
	HPQCD	> 16	$3.45 \pm 0.31 \pm 0.09^{+0.58}_{-0.38}$
	FNAL/MILC	> 16	$3.30 \pm 0.30 \pm 0.09^{+0.36}_{-0.30}$
π^+	LCSR1	< 12	$3.38 \pm 0.14 \pm 0.09^{+0.36}_{-0.32}$
	LCSR2	< 16	$3.57 \pm 0.13 \pm 0.09^{+0.59}_{-0.39}$
	HPQCD	> 16	$3.86 \pm 0.23 \pm 0.10^{+0.66}_{-0.44}$
	FNAL/MILC	> 16	$3.69 \pm 0.22 \pm 0.09^{+0.41}_{-0.34}$

$|V_{ub}|$ Prospect at Belle II

- Belle II should resolve the "$|V_{ub}|$ problem".
- Precision of the tagged $B \to \pi l\nu$ will be similar to the untagged one.

  Can LQCD extend to lower q^2 region ?



- Inclusive $|V_{ub}|$ needs better knowledge on shape function, "cocktail" modelling of $B \to X_u l\nu$, and fragmentation.

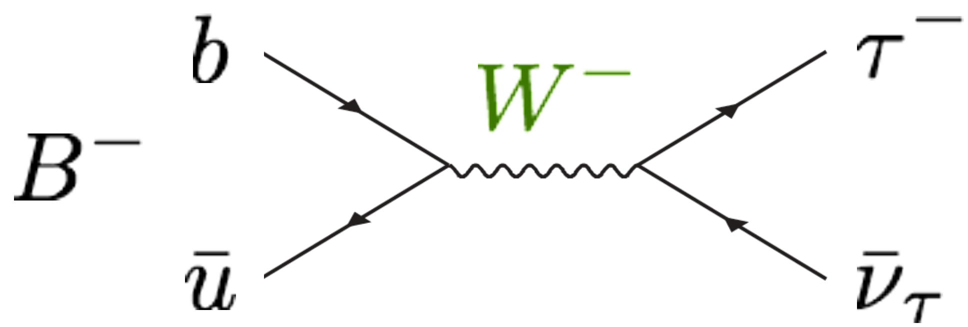
	Statistical	Systematic (reducible, irreducible)	Total Exp	Theory	Total
$\lvert V_{ub}\rvert$ exclusive (had. tagged)					
711 fb^{-1}	5.8	(2.3, 1.0)	6.3	8.7 (2.0)	10.8 (6.6)
5 ab^{-1}	2.2	(0.9, 1.0)	2.6	4.0 (2.0)	4.7 (3.3)
50 ab^{-1}	0.7	(0.3, 1.0)	1.3	2.0	2.4
$\lvert V_{ub}\rvert$ exclusive (untagged)					
605 fb^{-1}	2.7	(2.1, 0.8)	3.5	8.7 (2.0)	9.4 (4.0)
5 ab^{-1}	1.0	(0.8, 0.8)	1.5	4.0 (2.0)	4.2 (2.5)
50 ab^{-1}	0.3	(0.3, 0.8)	0.9	2.0	2.2
$\lvert V_{ub}\rvert$ inclusive					
605 fb^{-1} (old B tag)	4.5	(3.4, 2.3)	6.0	2.5	6.5
5 ab^{-1}	1.1	(1.2, 2.3)	2.8	2.5	3.8
50 ab^{-1}	0.4	(0.4, 2.3)	2.4	2.5	3.4

Belle II Internal Note #0021

Theory error for Inclusive $|V_{ub}|$ uncertainty (2.5% in GGOU 4.5% in BLNP approach)

$B \rightarrow \tau\,\nu$

- Proceed via W-exchange, helicity suppressed.



$$Br(B \rightarrow e\,\nu) \quad 10^{-11}$$
$$Br(B \rightarrow \mu\,\nu) \quad 10^{-7}$$
$$Br(B \rightarrow \tau\,\nu) \quad 10^{-4}$$

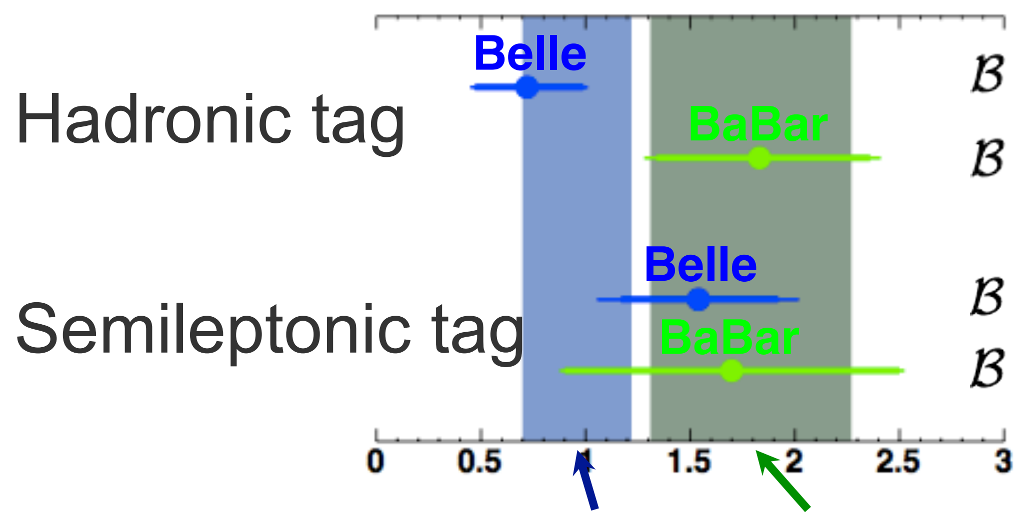
$$\mathcal{B}(B^- \to \ell^- \bar{\nu}) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

- Parameters
  - B decay constant: $f_B = 191 \pm 9\ \mathrm{MeV}$ HPQCD, PDG2012
  - CKM matrix: $|V_{ub}| = (4.15 \pm 0.49) \times 10^{-3}$ $b \to u l \nu$, PDG2012

➡ $Br_{SM}(\tau\nu) = (1.20 \pm 0.25) \times 10^{-4}$

$B \to \tau \nu$

- Both Belle and BaBar provide results with hadronic and semileptonic tags.



Hadronic tag:

$\mathcal{B} = [0.72^{+0.27}_{-0.25}(\mathrm{stat}) \pm 0.11(\mathrm{syst})] \times 10^{-4}$

$\mathcal{B} = [1.83^{+0.53}_{-0.49}(\mathrm{stat}) \pm 0.24(\mathrm{syst})] \times 10^{-4}$

Semileptonic tag:

$\mathcal{B} = [1.54^{+0.38}_{-0.37}(\mathrm{stat})^{+0.29}_{-0.31}(\mathrm{syst})] \times 10^{-4}$

$\mathcal{B} = [1.7 \pm 0.8(\mathrm{stat}) \pm 0.2(\mathrm{syst})] \times 10^{-4}$

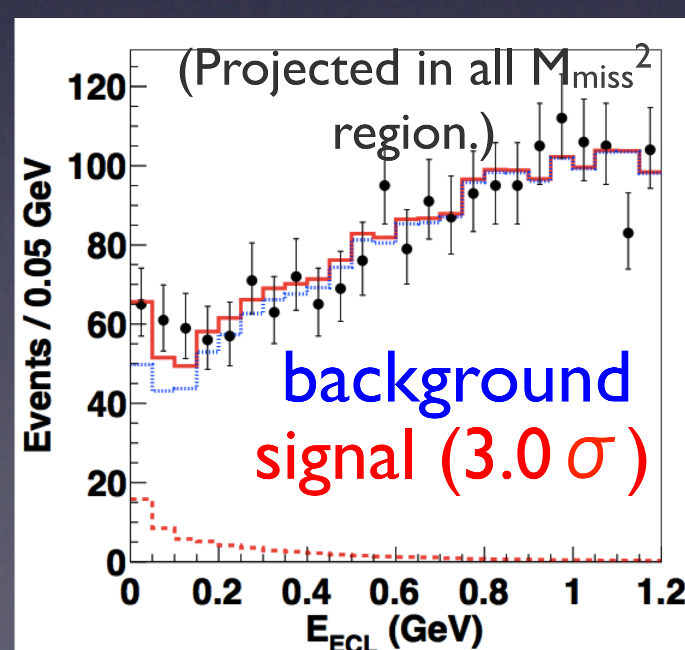
Belle combined: $\mathcal{B}=(0.96\pm0.26)\times10^{-4}$ BaBar combined: $\mathcal{B}=(1.79\pm0.48)\times10^{-4}$

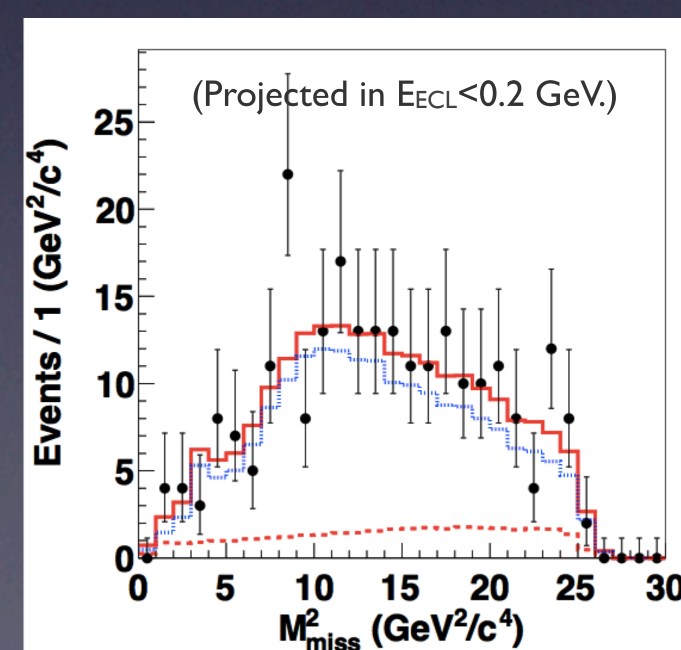
A naive world average: $\mathcal{B}=(1.15\pm0.23)\times10^{-4}$

cf) B=(1.14±0.22)x10-4 [HFAG2013]

Belle hadronic tag
w/ 772M BB (full) data

PRL110, 131801 (2013)





Constraint on Charged Higgs from B→ τ ν

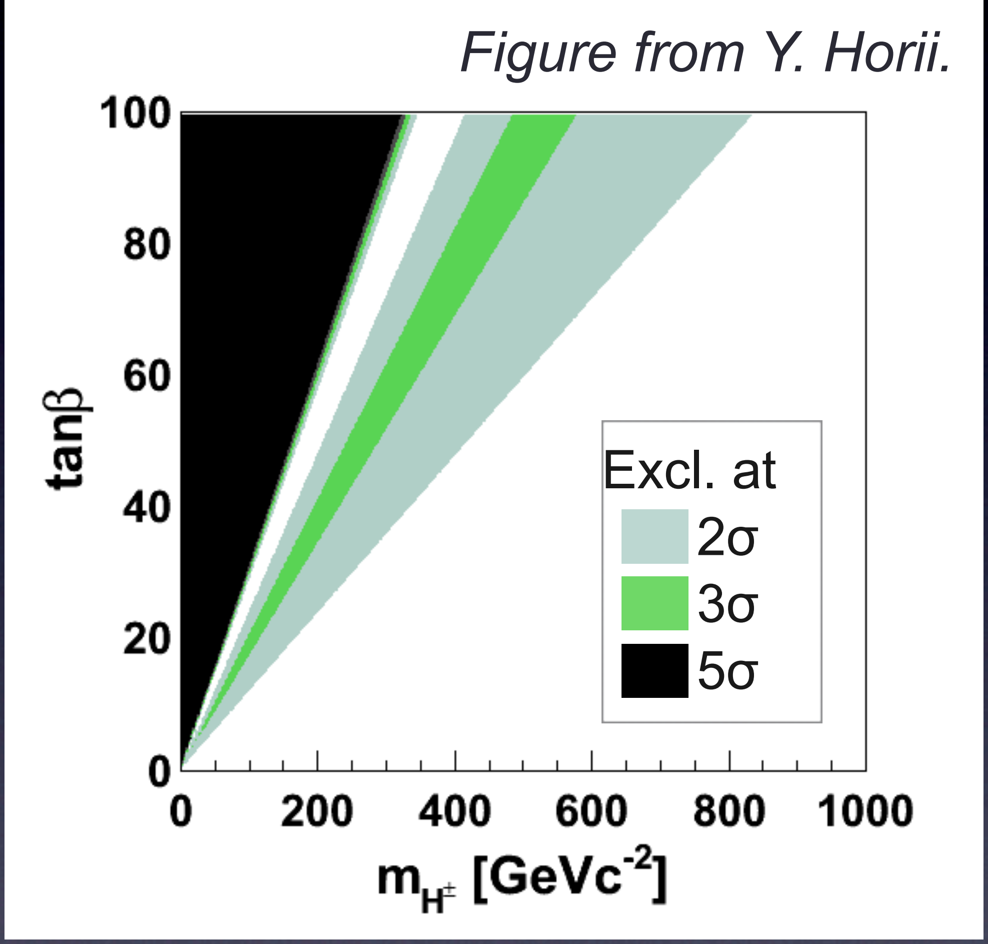
- Assume Type-II 2HDM.

$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{\rm SM} \times r_H$$
$$r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

- Use
  - B(B→ τ ν) = (1.15±0.23)×10^{-4}
  - B(B→ τ ν)$_{SM}$ = (1.11±0.28)×10^{-4}

where B(B→ τ ν)$_{SM}$ is obtained from

  - f_B = (191±9) MeV (HPQCD, PDG2012)
  - $|V_{ub}|$ = (4.15±0.49)×10^{-3} (PDG, PDG2012)



Stringent constraint on tanβ and m_H obtained.

Note: constraint strongly depends on f_B and $|V_{ub}|$.

Prospect at Belle II

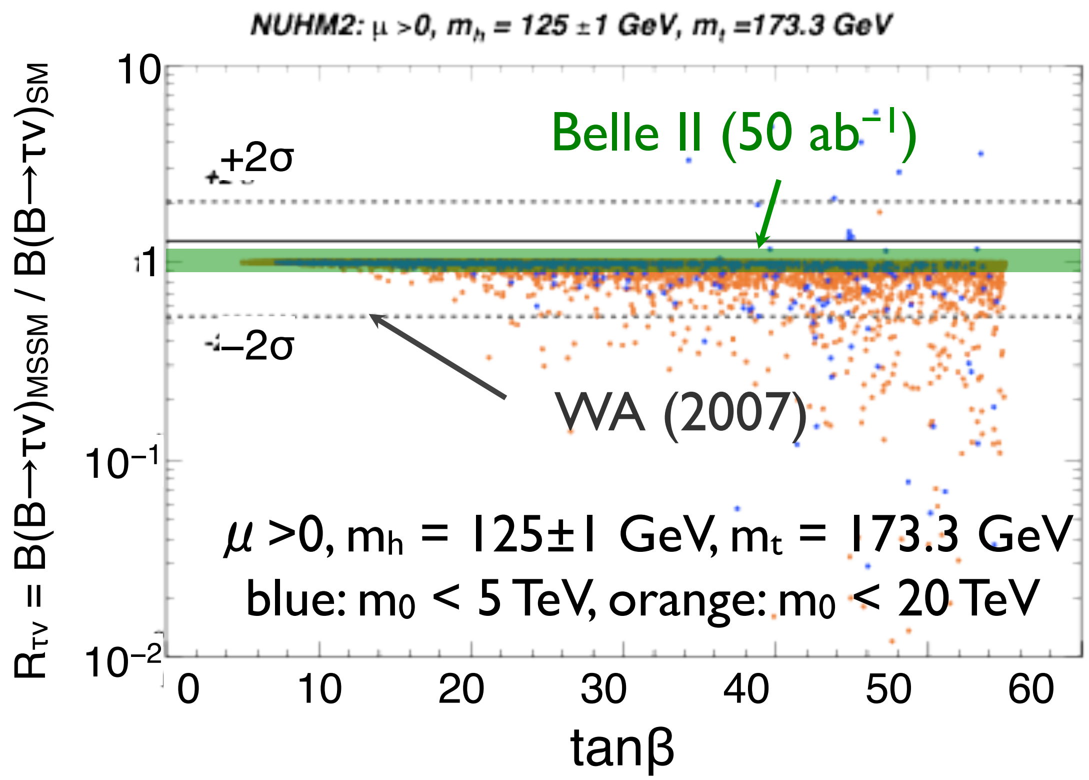
- 7GeV e^- ×4GeV e^+,
- $L_{peak} = 8 \times 10^{35} cm^{-2}s^{-1}$,
- $L_{int} = 50ab^{-1}$

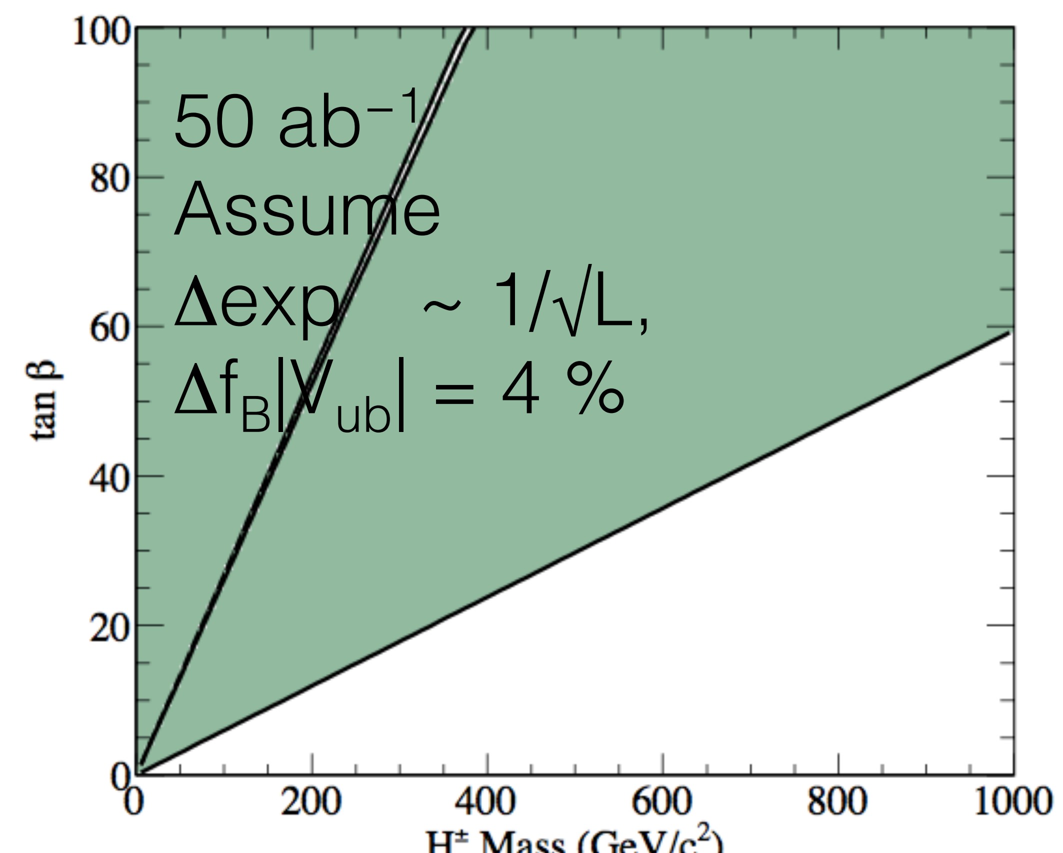
- $B \to \tau\nu$
  - Precision ~ a few %
  - Need better precision for $f_B |V_{ub}|$.

- $B \to \mu\nu$, $e\nu$
  - 5σ observation expected for $B(B\to\mu\nu)_{SM}$ at ~$10\ ab^{-1}$.
  - $O(10^{-8})$ sensitivity at $50\ ab^{-1}$.
  - Interesting to compare w/ $B\to\tau\nu$

2-parameter nonuniversal Higgs model

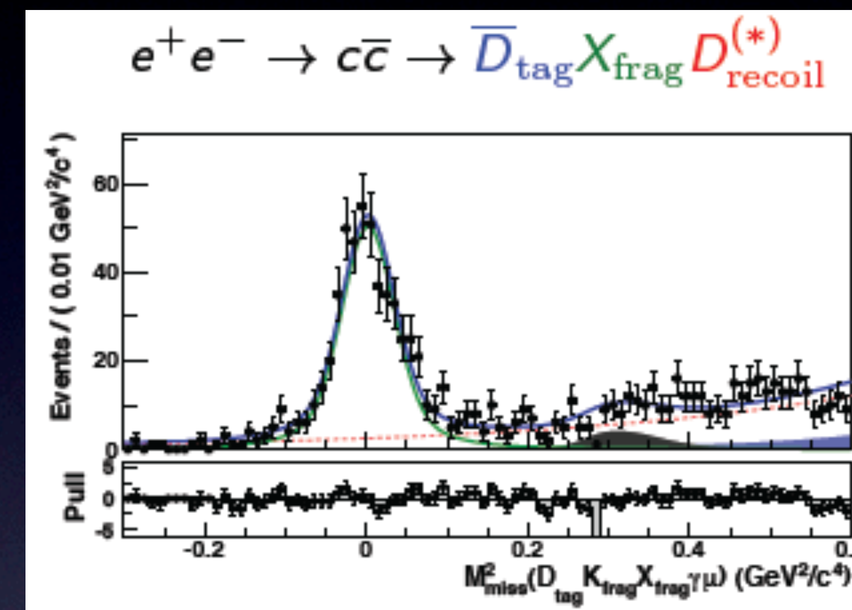
H. Baer, V. Barger, and A. Mustafayev, PRD85, 075010





Prospect for D Leptonic Decays

- Important for both testing the SM and search for NP.
- Belle developed the method to tag D



JHEP 1309, 139 (2013)

	Statistical	Systematic reducible	Systematic irreducible	Total
$\mathcal{B}(D_s \to \mu\nu)$				
913 fb^{-1}	5.3%	0%	3.8%	6.5%
5 ab^{-1}	2.3%	1.6%	0%-0.9%	2.9%
50 ab^{-1}	0.7%	0.5%	0%-0.9%	0.9%-1.3%
$\mathcal{B}(D_s \to \tau\nu)$				
913 fb^{-1}	3.7%	4.4%	3.5%	6.8%
5 ab^{-1}	1.6%	1.9%-2.3%	3.5%-2.2%	3.5%-4.3%
50 ab^{-1}	0.5%	0.6%-0.7%	3.5%-2.2%	2.3%-3.6%

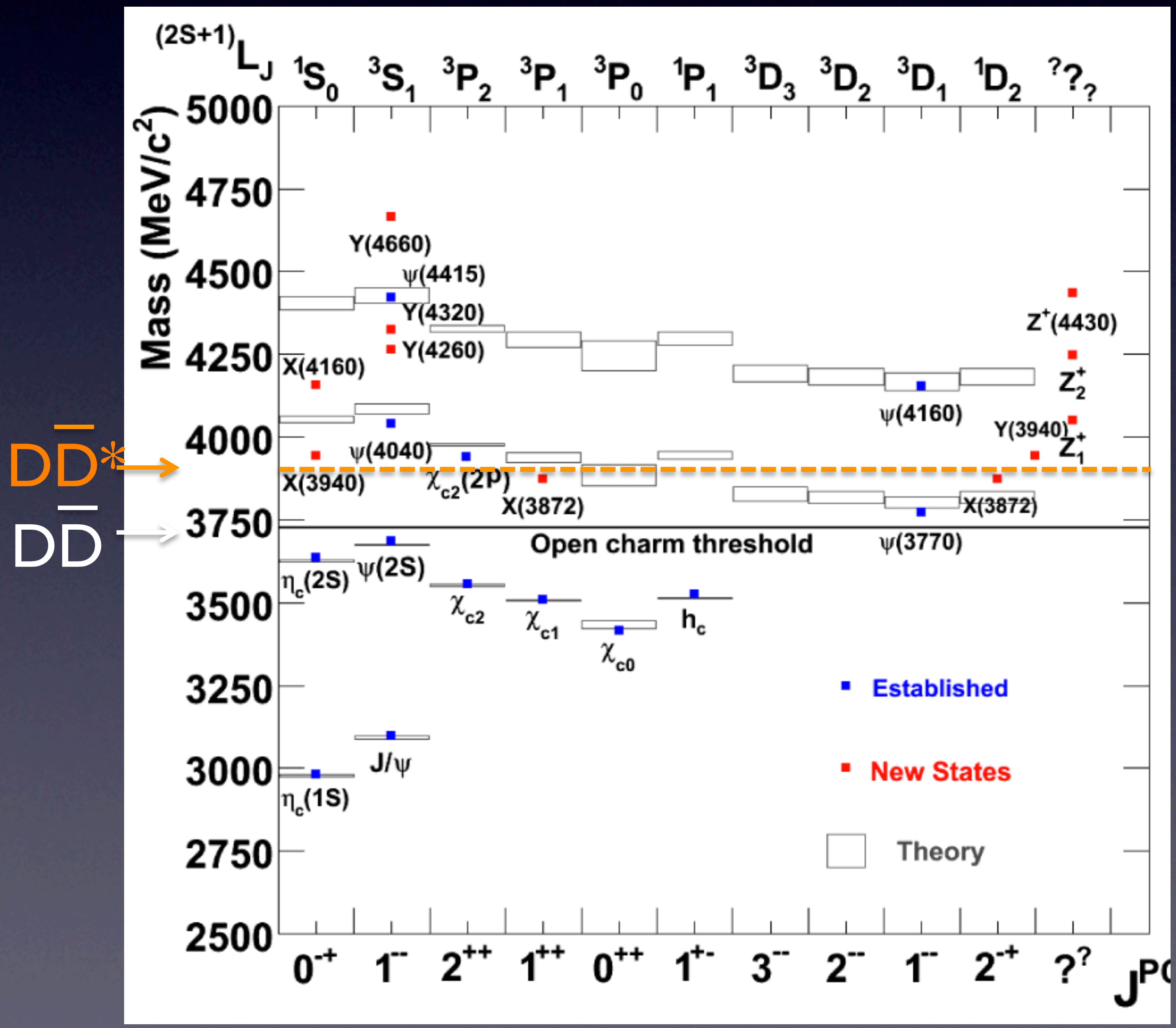
Belle II Internal Note #0021

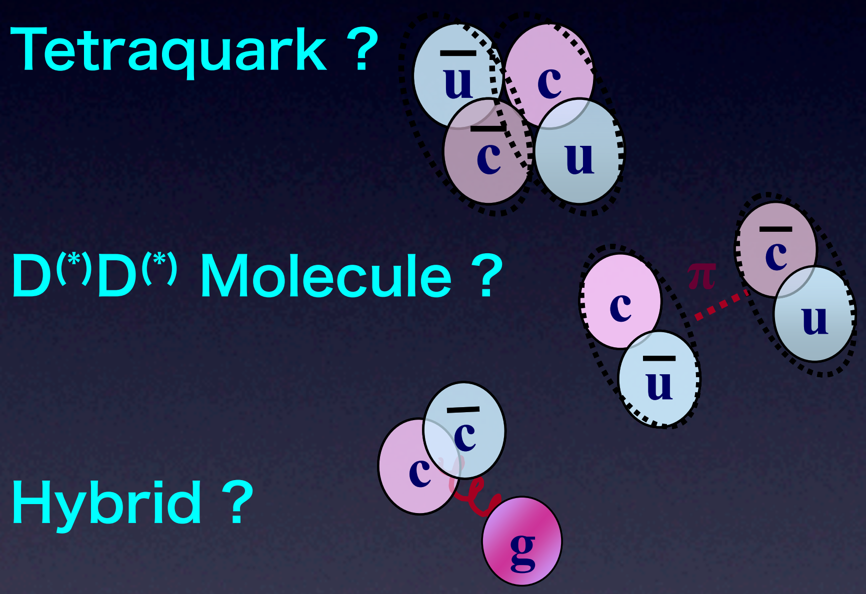
Irreducible error sources

- $Br(\tau \to X)$, $Br(D_S)$, D^0/D^+ fraction in $c\bar{c}$ fragmentation
- Data-MC difference in E_{ECL}(residual energy recorded in EM calorimeter)

Hadron Spectroscopy

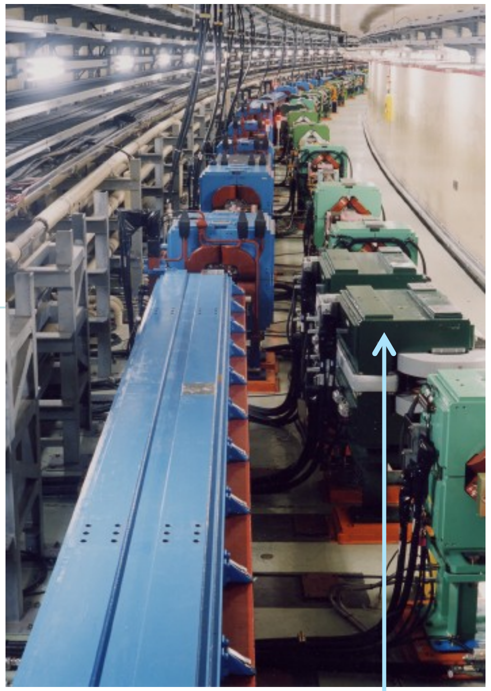
- Many charmonium-like and also bottomonium-like hadrons are observed.
- Many of them do not fit to the mass spectra predicted by the quark model.



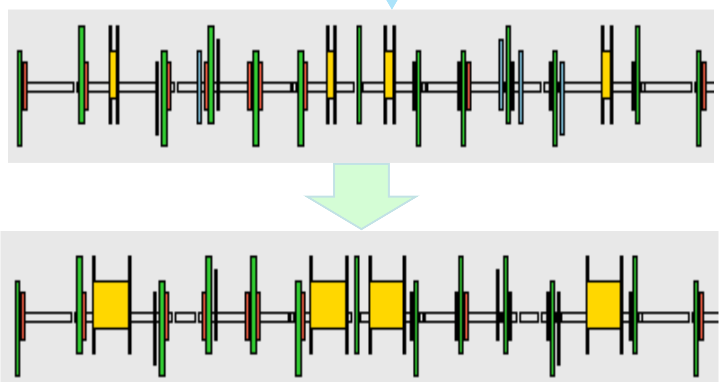


Can lattice QCD explain these states ?

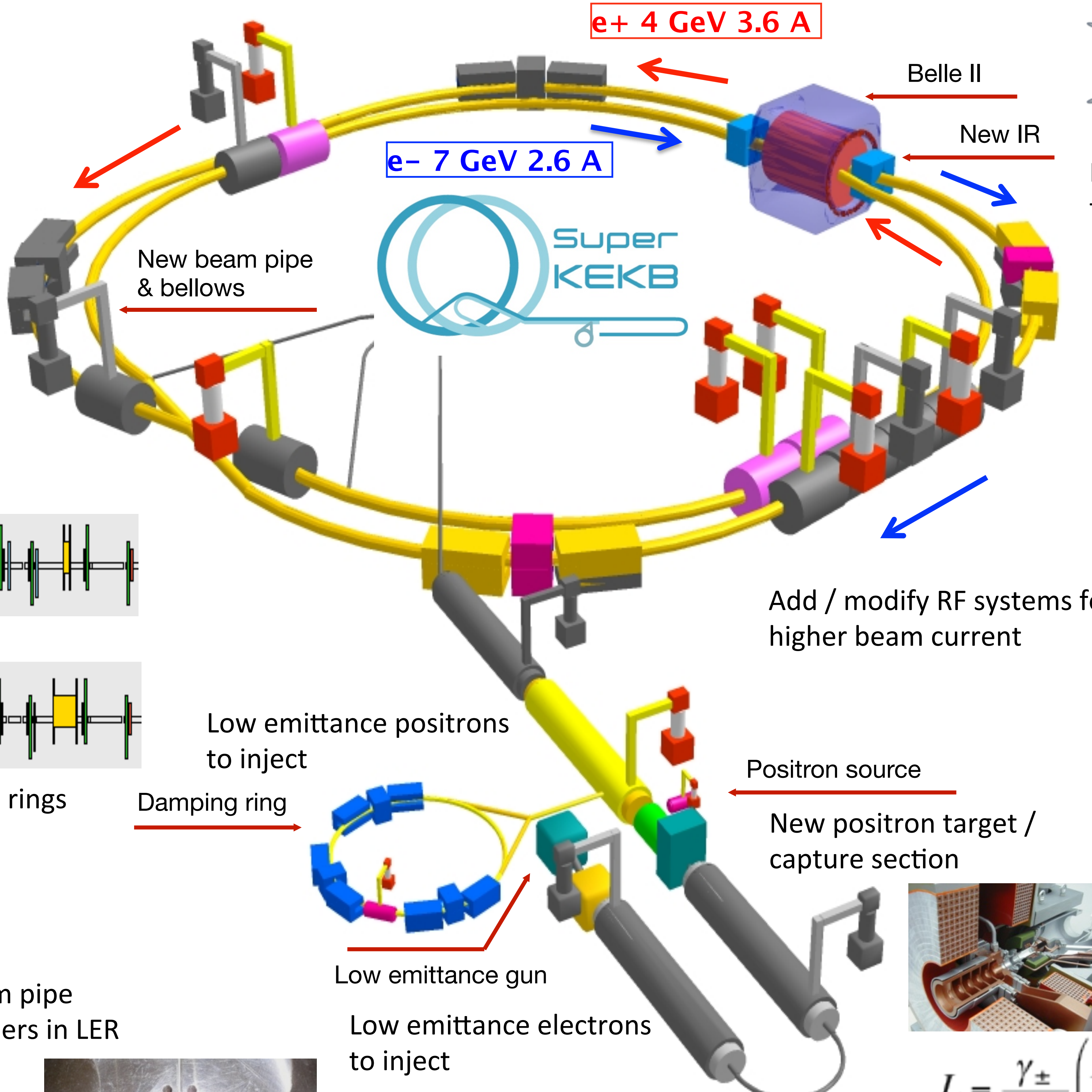
Ex)
Sasa Prelovsek, Luka Leskovec
arXiv:1307.5172



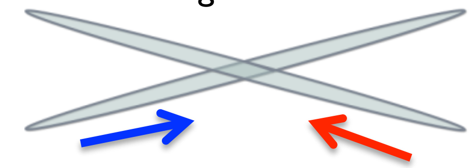
Replace short dipoles with longer ones (LER)



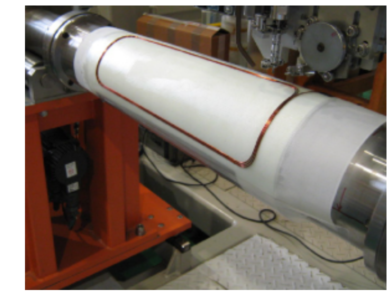
Redesign the lattices of both rings to reduce the emittance



Colliding bunches

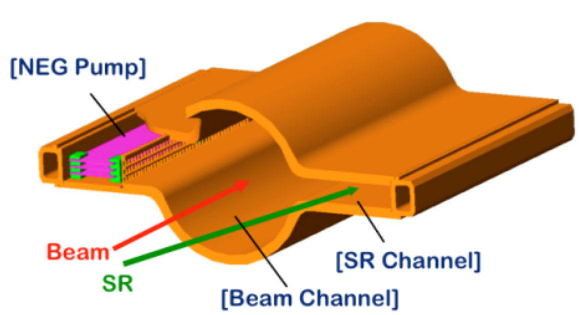


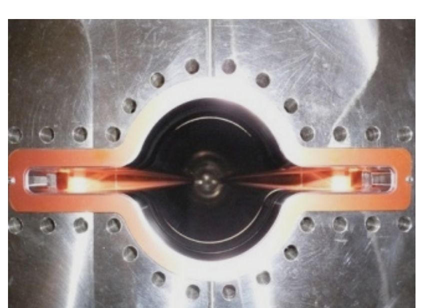
New superconducting final focusing quads near the IP



Add / modify RF systems for higher beam current

TiN-coated beam pipe with antechambers in LER





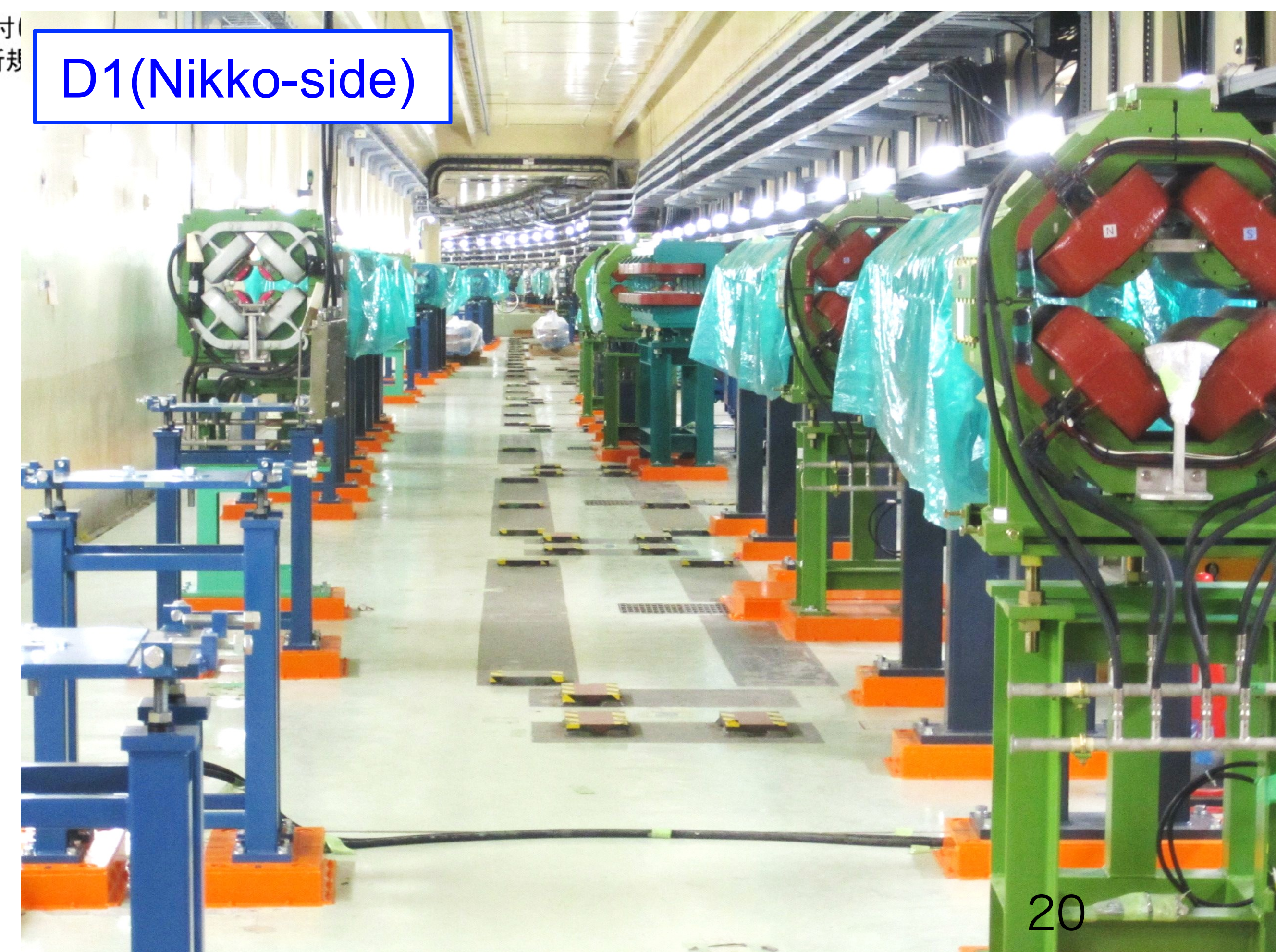
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$

x 40 Gain in Luminosity

Magnets have been installed

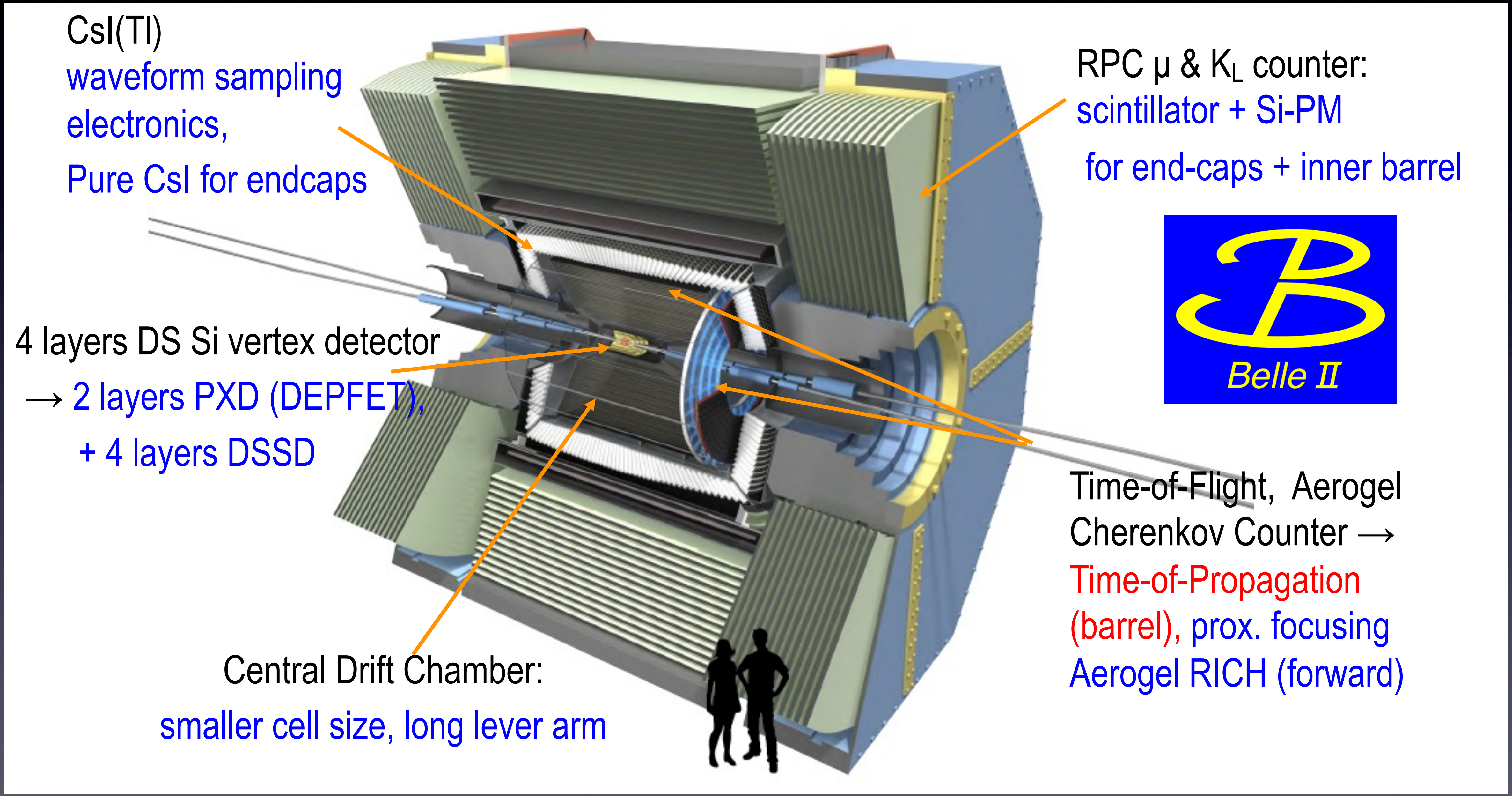
March 2013

（2）KEKB電磁石撤去済
新ビームライン用測量・罫描き 済
ベースプレート設置進行中



Belle II Detector

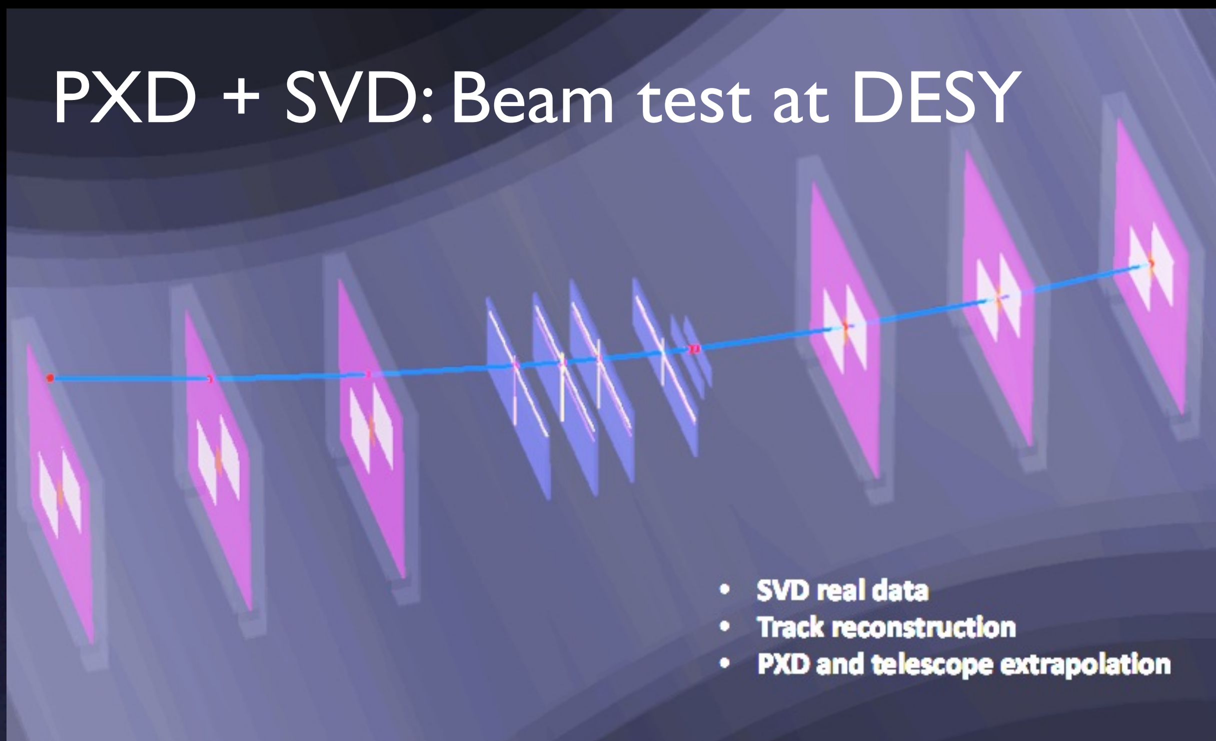
- Deal with higher background (10-20×), radiation damage, higher occupancy, higher event rates (L1 trigg. 0.5→30 kHz)
- Improved performance and hermeticity



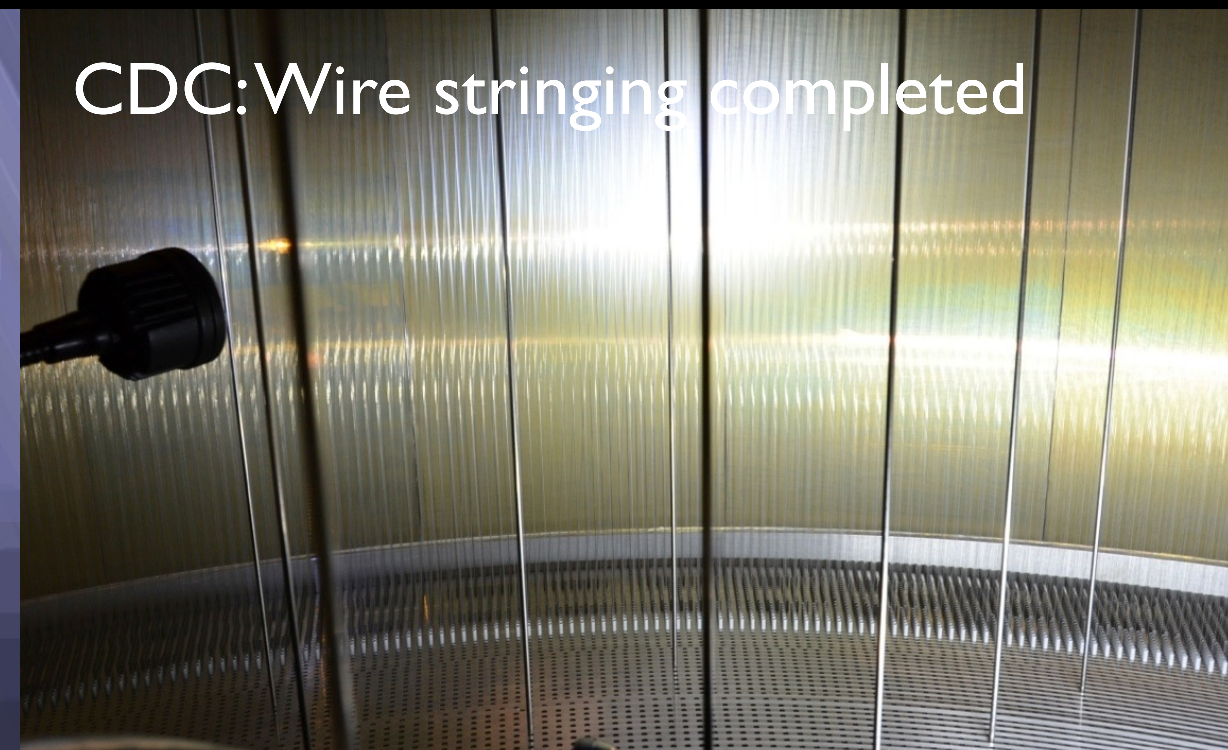
International collaboration from: Saudi Arabia, Australia, Austria, Canada, China, Czech, Germany, India, Italy, Japan, Korea, Malaysia, Mexico, Viet Nam, Poland, Russia, Slovenia, Spain, Taiwan, Thailand, Turkey, USA, Ukraine (Recently joined)

Belle II Progress

PXD + SVD: Beam test at DESY

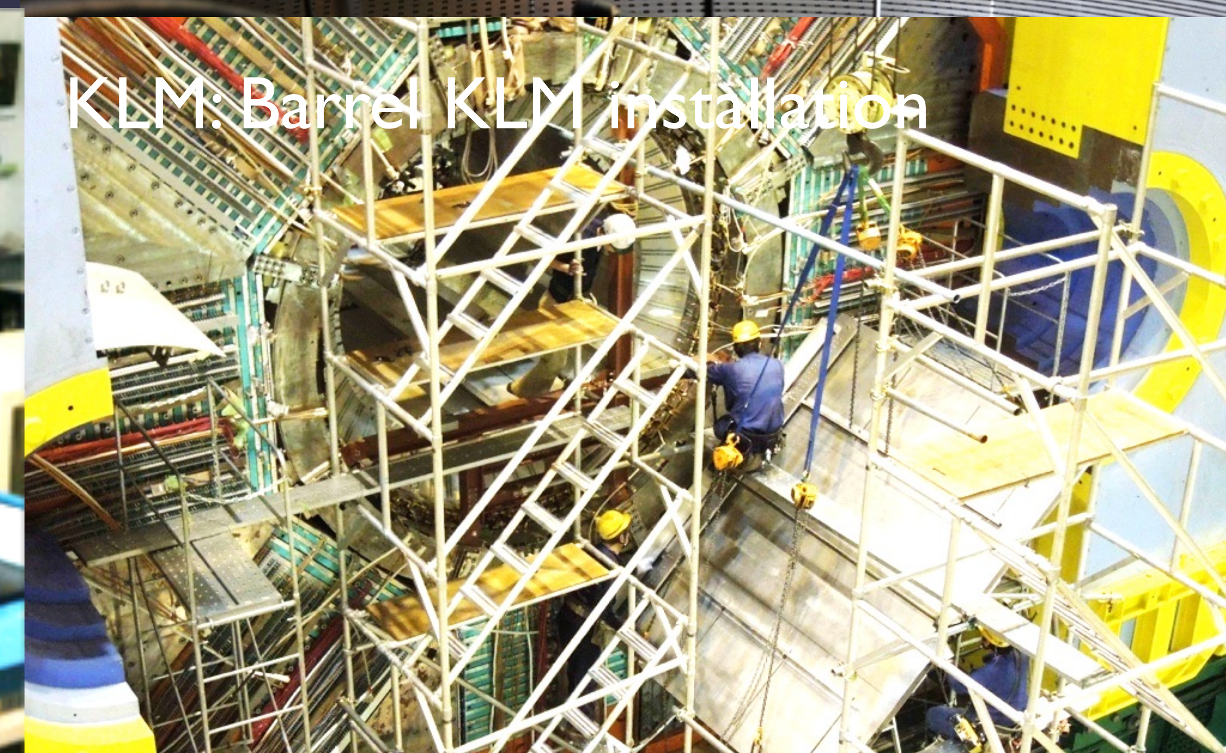


CDC: Wire stringing completed

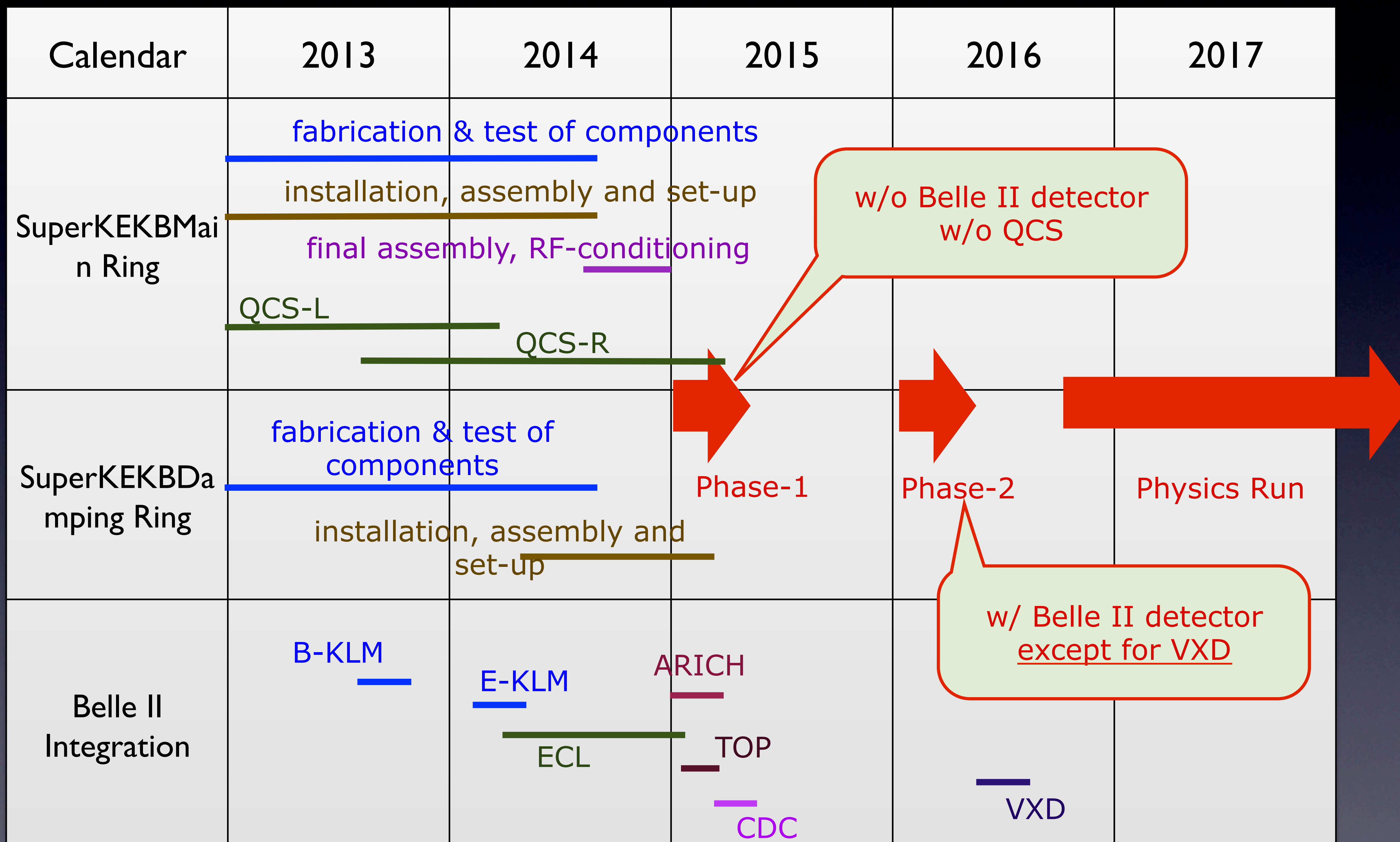


TOP: preproduction of quartz optics

KLM: Barrel KLM installation

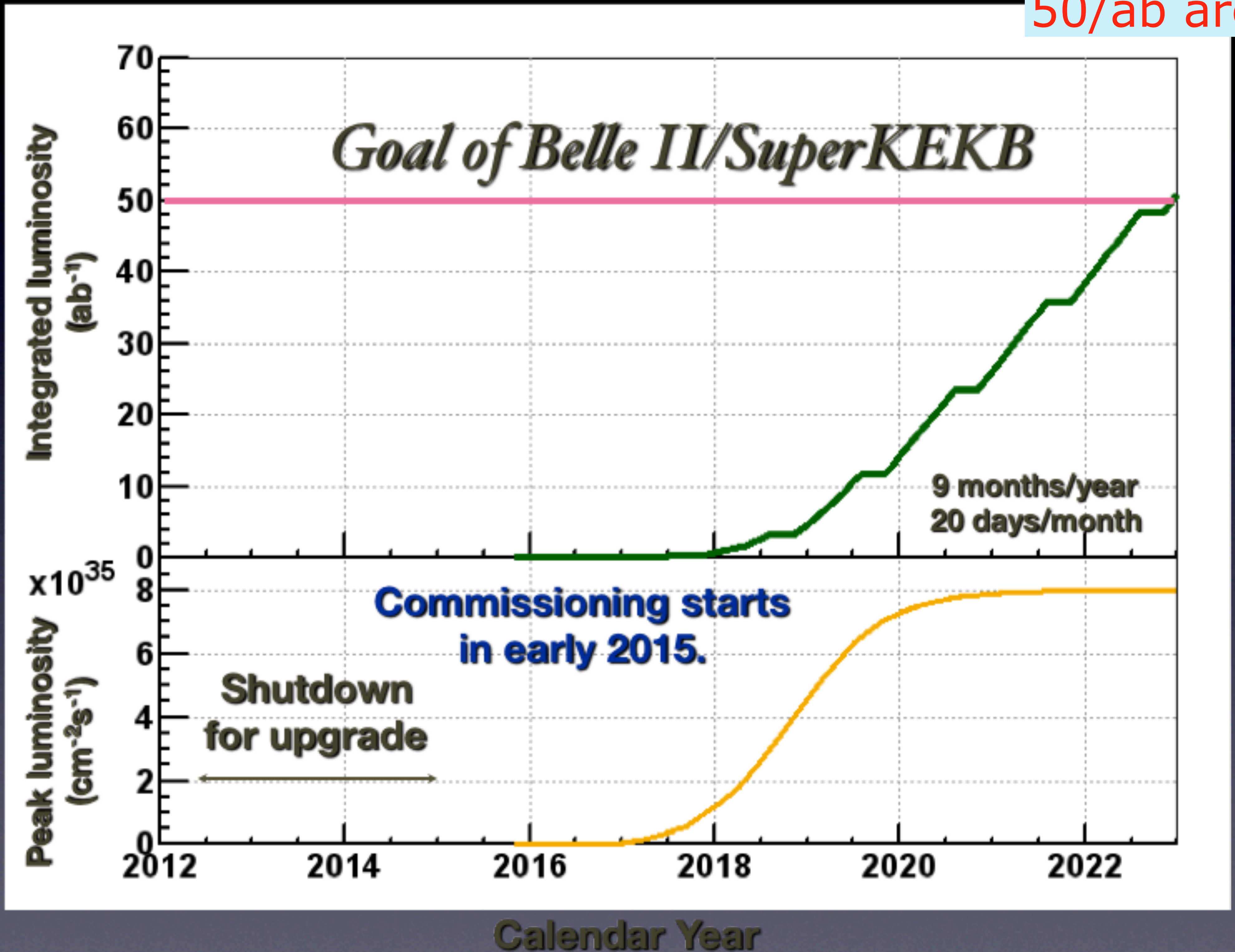


Construction & Commissioning Schedule



Luminosity Projection

50/ab around 2024



Summary

- The Belle II experiment at SuperKEKB aims to find NP with ultimate precision measurement (a few %, typically) of heavy flavor decays ($O(10^{10})$ samples / year).
- Lattice QCD provides crucial inputs to extract physics.
  - Need precise enough calculations timely !
- We will start
  - SuperKEKB commissioning in 2015
  - Belle II physics run in 2016

Let's Keep in Touch !

Backup

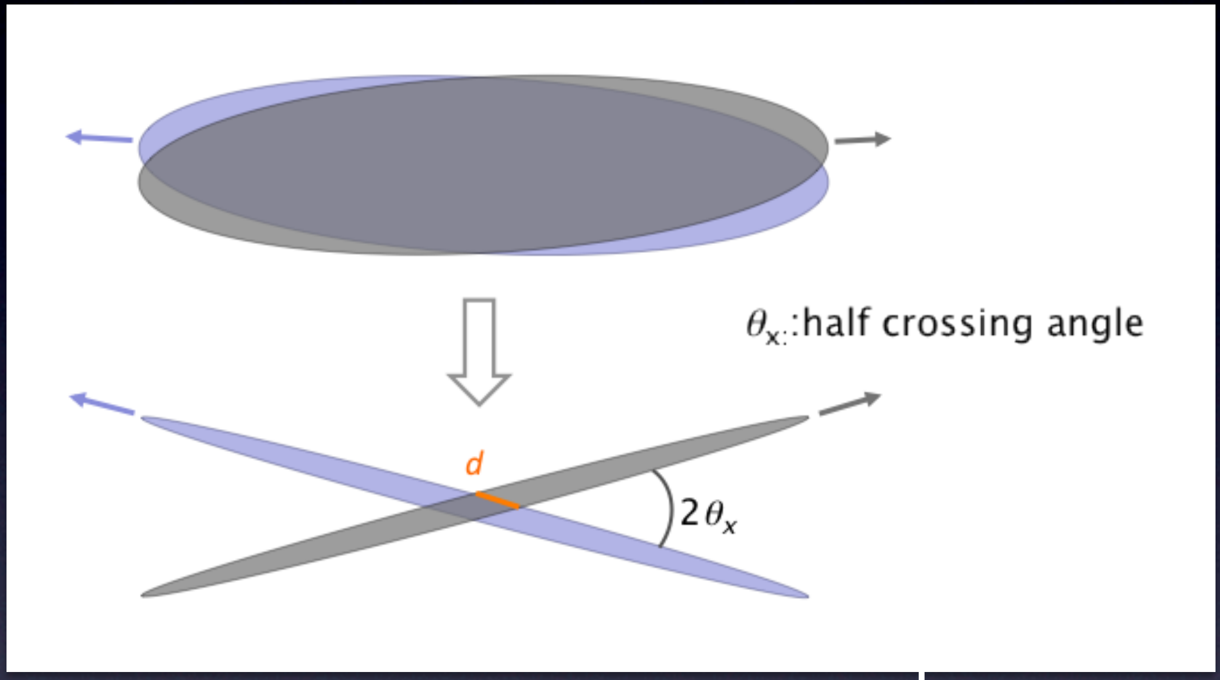
SuperKEKB Accelerator

- Low emittance ("nano-beam") scheme employed

proposed by P.Raimondi

Machine parameters

	SuperKEKB LER/HER	KEKB LER/HER
E(GeV)	4.0/7.0	3.5/8.0
ε_x (nm)	3.2/4.6	18/24
β_y at IP(mm)	0.27/0.30	5.9/5.9
β_x at IP(mm)	32/25	120/120
Half crossing angle(mrad)	41.5	11
I(A)	3.6/2.6	1.6/1.2
Lifetime	~10min	130min/ 200min
L($cm^{-2}s^{-1}$)	80×10^{34}	2.1×10^{34}

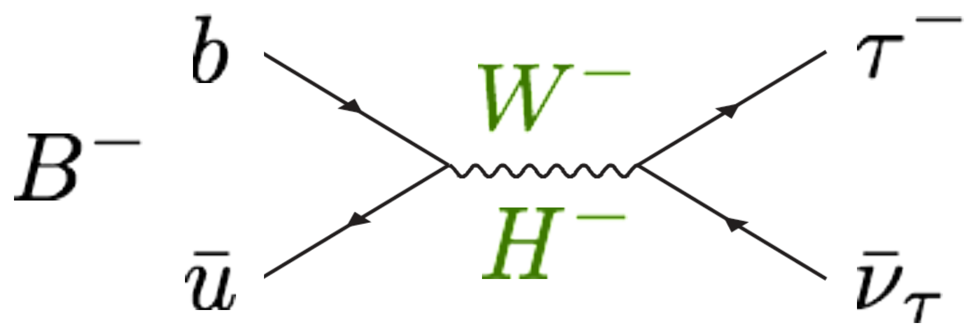


Beam at IP will be squeezed by 1/20.

Beam currents will be doubled.

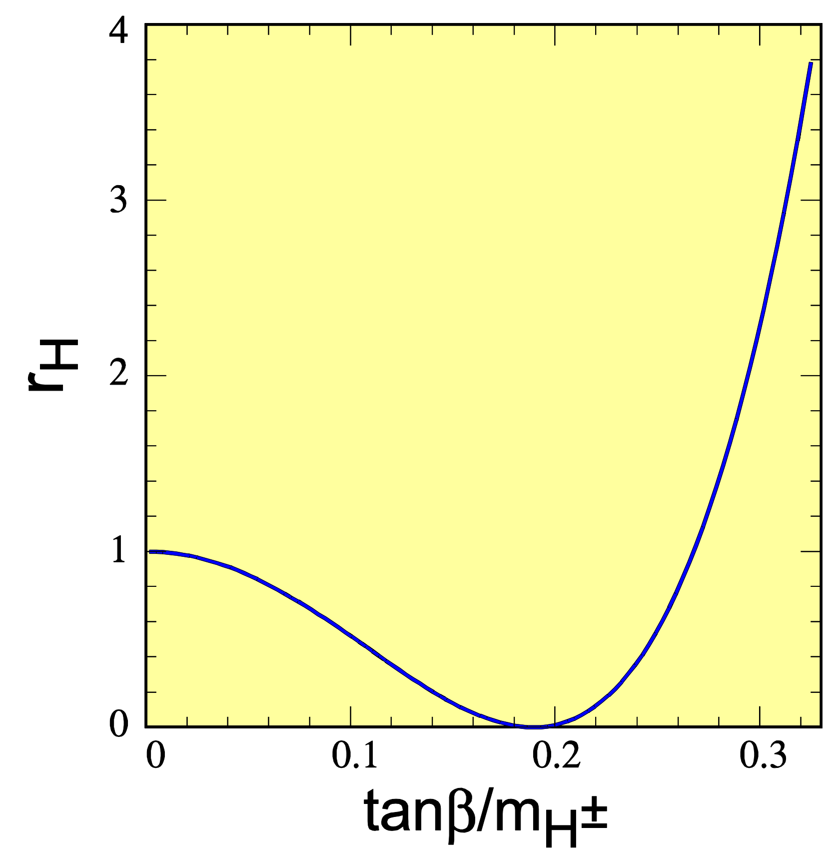
B → τ ν

- Charged Higgs exchange interferes with the helicity suppressed W-exchange.



$$Br = Br_{SM} \times r_H \qquad r_H = \left|1 - g_S\right|^2$$

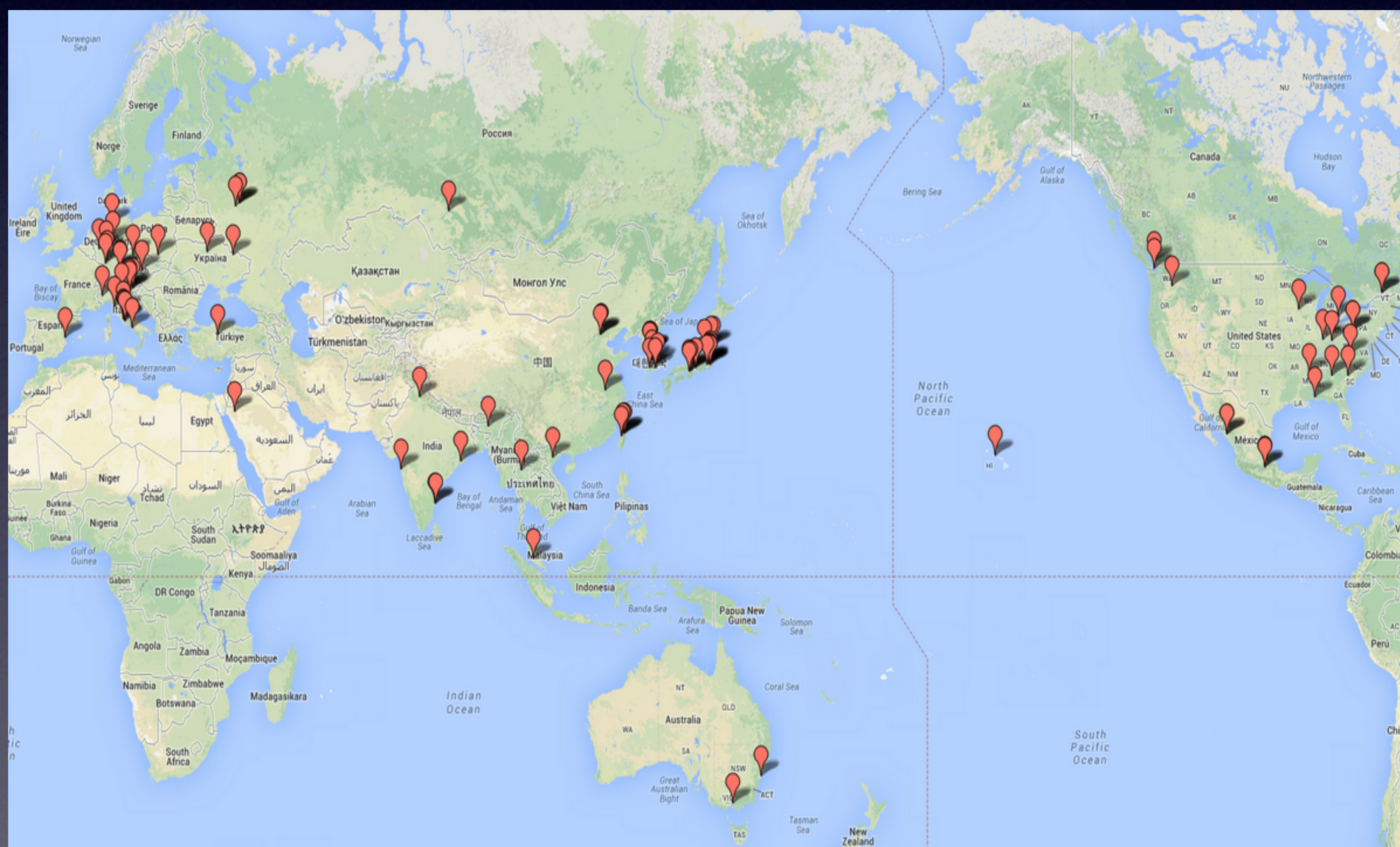
$$r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$



Type II 2HDM, W. S. Hou, PRD 48, 2342 (1993),

Belle II Collaboration

- 23 countries, 95 institutes, 599 collaborators.
  - 13 Institutes / 69 members from US
  - Recent new countries: Canada (4/17), Italy (9/48), Mexico (4/6)



Systematic error for B→D* l ν

TABLE VIII: Systematic errors on $|V_{cb}|$, with the full Belle 711 fb^{-1} data sample, in percent.

	Error on $\lvert V_{cb}\rvert$
Fast track efficiency	2.3
Slow track efficiency	0.8
ρ_{π_s} stability	0.1
Lepton idenficiation	1.1
Norm - D^{**}	0.1
Norm - Signal Corr.	0.1
Norm - Uncorr	0.1
Norm - Fake ℓ	0.0
Norm - Fake D^*	0.0
Norm - Continuum	0.0
D^{**} composition	0.3
D^{**} shape	0.1
$N(\Upsilon(4S))$	0.7 (0.7)
f_{+-}/f_{00}	0.7 (0.4)
B^0 lifetime	0.3 (0.2)
$\mathcal{B}(D^* \to D^0 \pi_s)$	0.4 (0.4)
$\mathcal{B}(D^0 \to K\pi)$	0.6 (0.6)
Systematic Error (red., irred.)	3.0 (2.8, 1.1)

Belle II internal note #0021

Systematic error for B→π l ν

TABLE XI: Systematic errors on the branching fractions of $B \to \pi \ell \nu$ in hadronic tagged and untagged Belle analyses with 711 fb^{-1} and 605 fb^{-1} data samples, respectively. The precision limit for some systematics is given in brackets.

Source	Hadronic tag Error (Limit)	Untagged Error (Limit)
Track reconstruction	0.4	2.0
Hadron identification	–	1.3
Lepton identification	1.0	2.4
Kaon Veto	0.9	
Continuum description	1.0	1.8
Tag Calibration & $N(B\bar{B})$	4.5 (2.0)	2.3 (1.0)
$X_u \ell \nu$ Cross Feed	0.9	0.5 (0.5)
$X_c \ell \nu$ Background	–	0.2 (0.2)
Form Factor Shapes(PDF)	1.1	1.0 (1.0)
Form Factor Background(PDF)	–	0.4 (0.4)
Systematic error (red., irred.)	5.0 (4.6, 2.0)	4.5 (4.2, 1.6)

Belle II internal note #0021

Systematic error for D→l ν, τ ν

Source	$\mu\nu$ [%]	$\tau\nu$ [%]
Normalization	± 2.1	± 2.1
Tag bias	± 1.4	± 1.4
Tracking	± 0.4	± 0.4
Particle ID	± 2.0	± 1.7
Efficiency	± 1.8	± 0.8
Fit model	± 0.2	$^{+3.3}_{-2.9}$
D_s background	± 0.8	± 2.8
τ cross-feed	-	± 0.9
$\mathcal{B}(\tau \to X)$	-	± 0.2
Total syst.	± 3.8	$^{+5.4}_{-5.2}$

TABLE XV: Summary of relative systematic uncertainties for the branching fraction measurements of leptonic D_s decays from [45].

Belle II internal note #0021

Charm Projections

Observables	Belle (2014)	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}	$\mathcal{L}_s$ $[ab^{-1}]$
$\mathcal{B}(D_s \to \mu\nu)$	$5.31 \times 10^{-3}(1 \pm 0.053 \pm 0.038)$	$\pm 2.9\%$	$\pm(0.9\%\text{-}1.3\%)$	> 50
$\mathcal{B}(D_s \to \tau\nu)$	$5.70 \times 10^{-3}(1 \pm 0.037 \pm 0.054)$	$\pm(3.5\%\text{-}4.3\%)$	$\pm(2.3\%\text{-}3.6\%)$	2.5-5
y_{CP} $[10^{-2}]$	$1.11 \pm 0.22 \pm 0.11$	$\pm(0.11\text{-}0.13)$	$\pm(0.05\text{-}0.08)$	5-7.5
A_Γ $[10^{-2}]$	$-0.03 \pm 0.20 \pm 0.08$	± 0.10	$\pm(0.03\text{-}0.05)$	6.5 - 8.5
$A_{CP}^{K^+K^-}$ $[10^{-2}]$	$-0.32 \pm 0.21 \pm 0.09$	± 0.11	± 0.06	15
$A_{CP}^{\pi^+\pi^-}$ $[10^{-2}]$	$0.55 \pm 0.36 \pm 0.09$	± 0.17	$\pm$ 0.06	> 50
$A_{CP}^{\phi\gamma}$ $[10^{-2}]$	$\pm$ 5.6	± 2.5	± 0.8	> 50

- Using Belle results and a rough extrapolation to 50 ab^{-1}:
  - LHCb dominates A_Γ and ΔA_{CP}. BelleII **competitive in x'^2, y' and y_{CP}.**
- Belle II **favourable in A_{CP}** due to symmetric D-meson production; sensitivity would reach 0.03% level.
- Rare modes: ργ, Φγ @ 1% expectation (NP up to 10%)

P. Urquijo @ Belle PAC, Feb.2014