Towards First Physics at Belle II

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HELMHOLTZ ASSOCIATION

Belle II

DESY

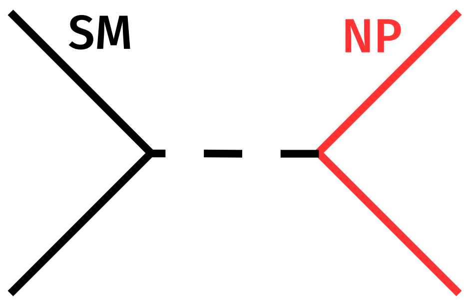
Overview.

- Motivation and Belle at KEKB
- Belle II at SuperKEKB
- Towards for First Physics at Belle II
  - Dark Sector
  - Precision Standard Model
- Conclusions

Motivation for B-Factories: Flavour Frontier.

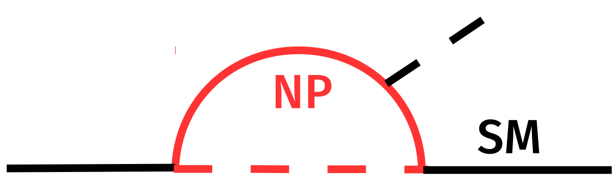
> Energy frontier:

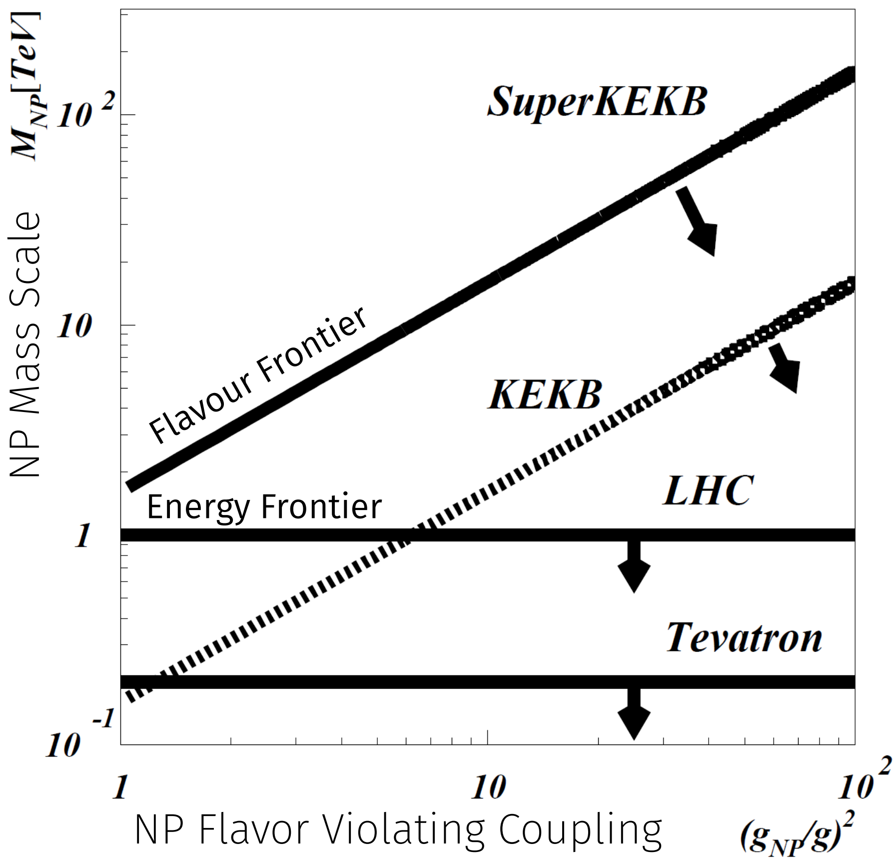
- Production of New Physics (NP) from collisions
- Limited by beam energy



> Flavour frontier:

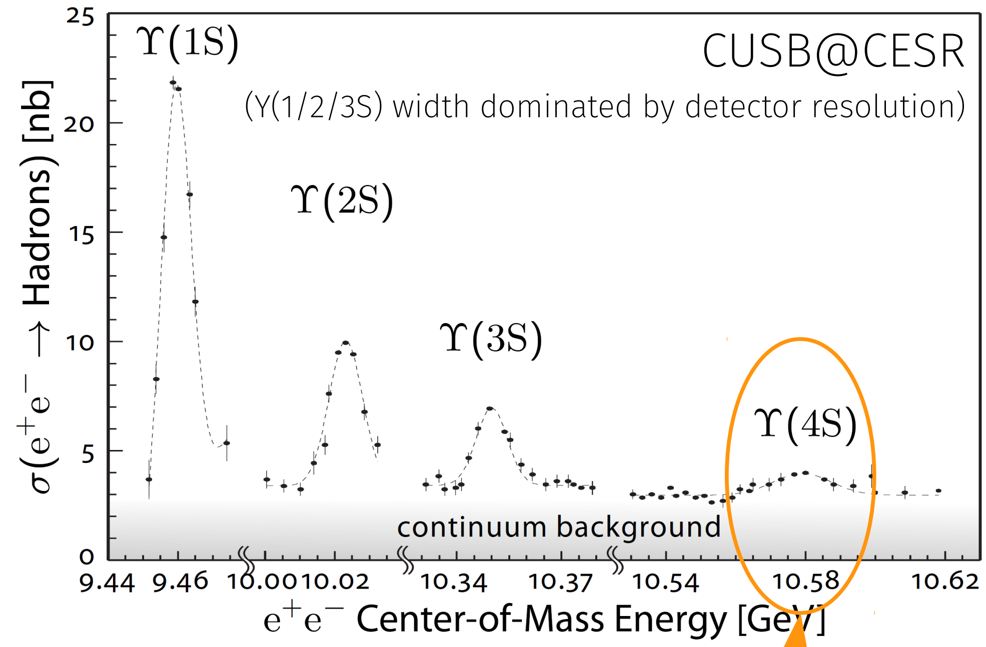
- NP in Virtual processes

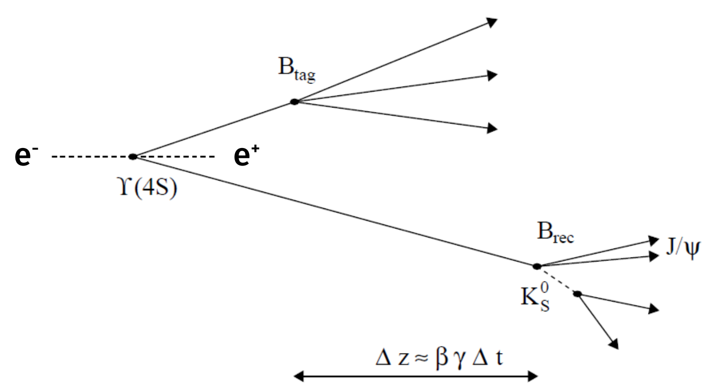




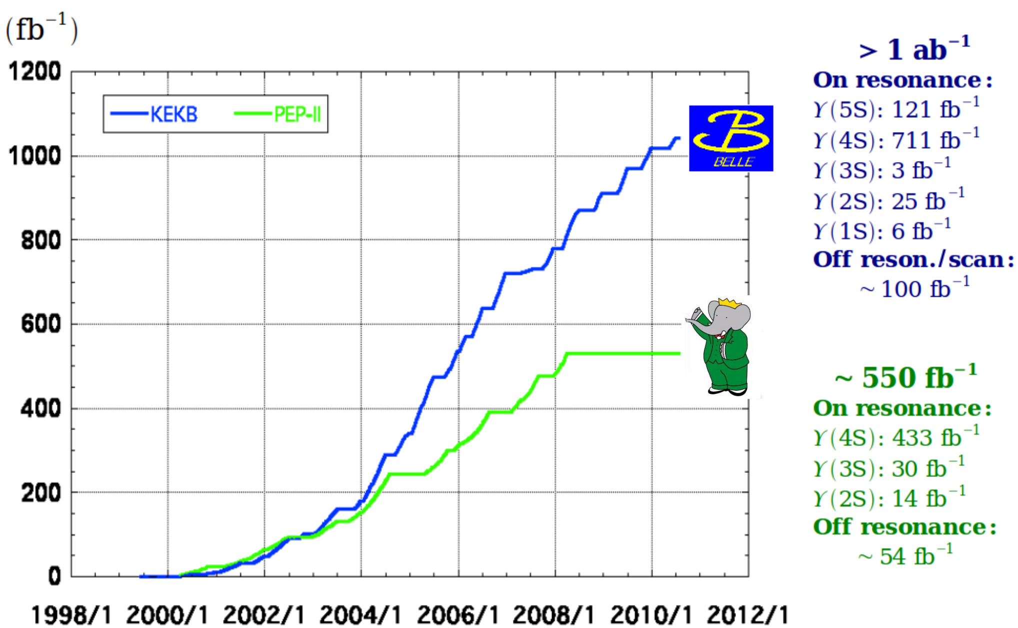
Past B-Factories.

- Belle at KEKB and Babar at PEP-II
- Very high luminosity:
  - ~2x10^{34}/cm^2/s (Belle) (twice the design value)
- Beam energy at Y(nS):
  - **Mainly at E_{CM} = 10.58 GeV**
  - BF Y(4S)→B$\overline{\text{B}}$ > 96%
- Asymmetric beams:
  - 8GeV e$^-$/3.5 GeV e$^+$ (Belle) → Boosted B$\overline{\text{B}}$ pairs





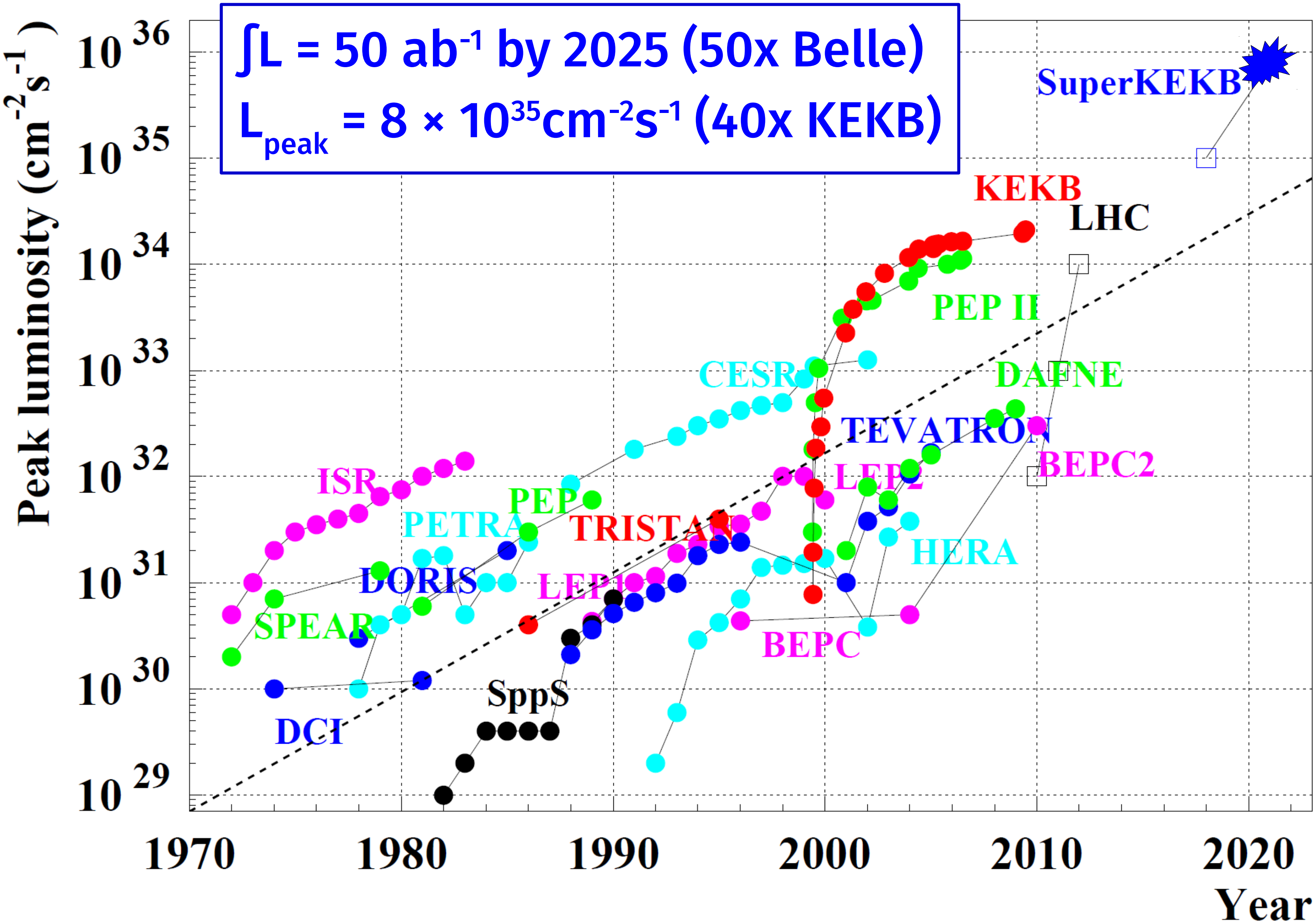
Huge statistics at B-Factories.



Physics process	Cross section [nb]
Y(4S) → BB	1.2
Light quark pairs	2.8
Muon pairs	1.1
Tau pairs	0.9
Bhabha (θ_{lab}>17°)	44
Photon pairs (θ_{lab}>17°)	2.4
Two photon (θ_{lab}>17°)	~80
Total	**~130**

- At Belle:
  - About 772 million $B\bar{B}$ pairs
  - About 500 million tau and muon pairs each
- Many analyses remain statistically limited!

From KEKB to SuperKEKB.

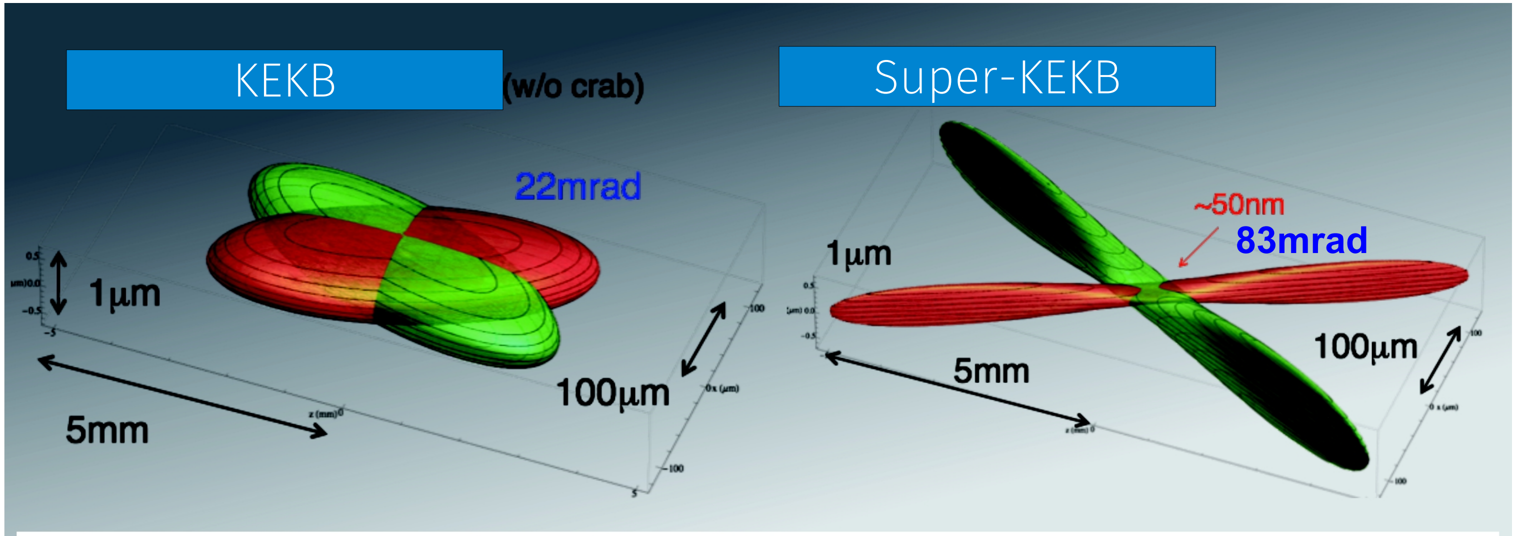


Nano beam scheme.

beam current

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

vertical beta function at IP



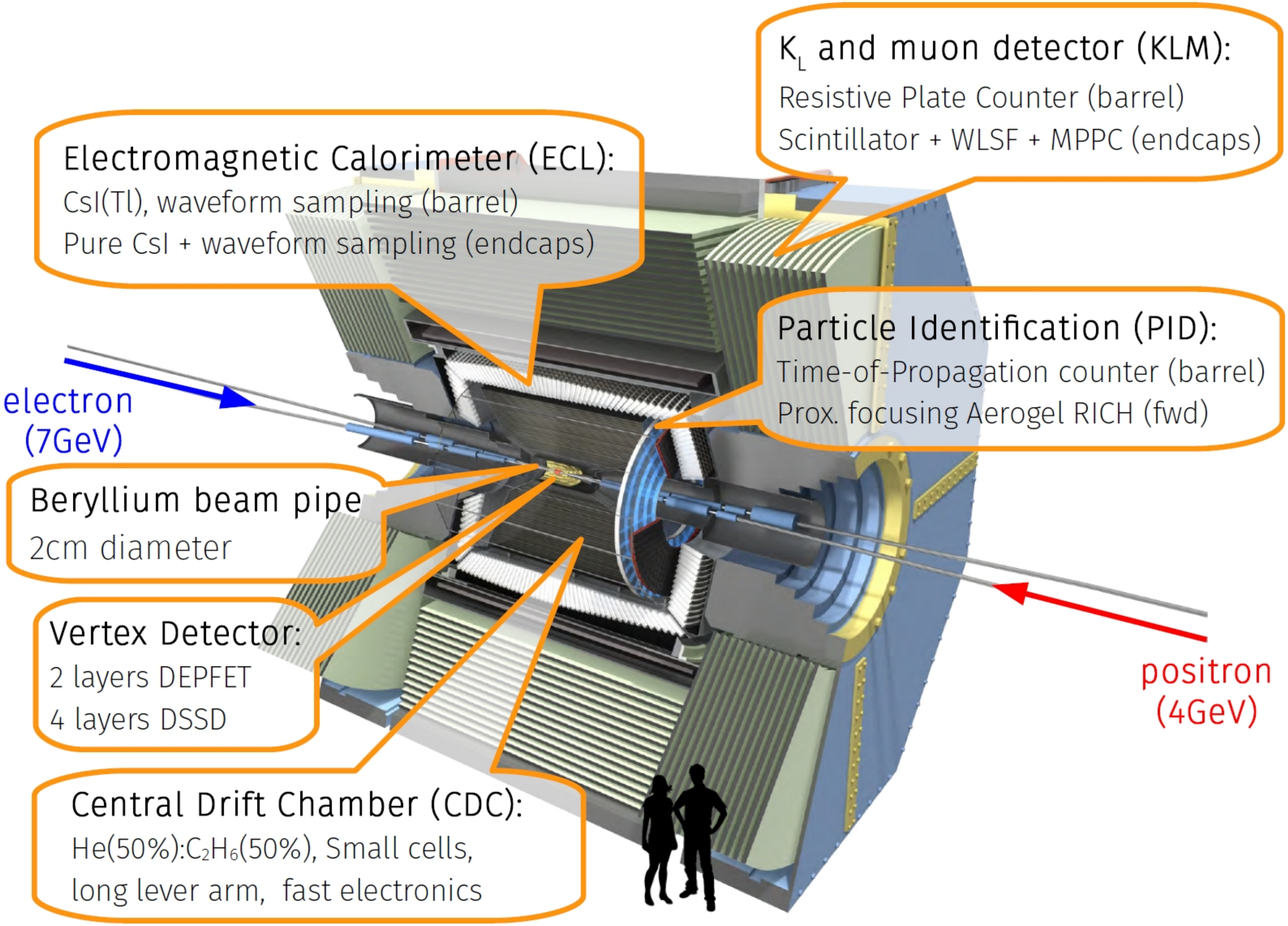
	E (GeV) LER/HER	β*y (mm) LER/HER	β*x (cm) LER/HER	φ (mrad)	I (A) LER/HER	L (cm^{-2}s^{-1})
KEKB	3.5/8.0	5.9/5.9	120/120	11	1.6/1.2	2.1 x 10^{34}
SuperKEKB	4.0/7.0	0.27/0.30	3.2/2.5	41.5	3.6/2.6	80 x 10^{34}

x20

x(2-3)

Belle II at SuperKEKB.

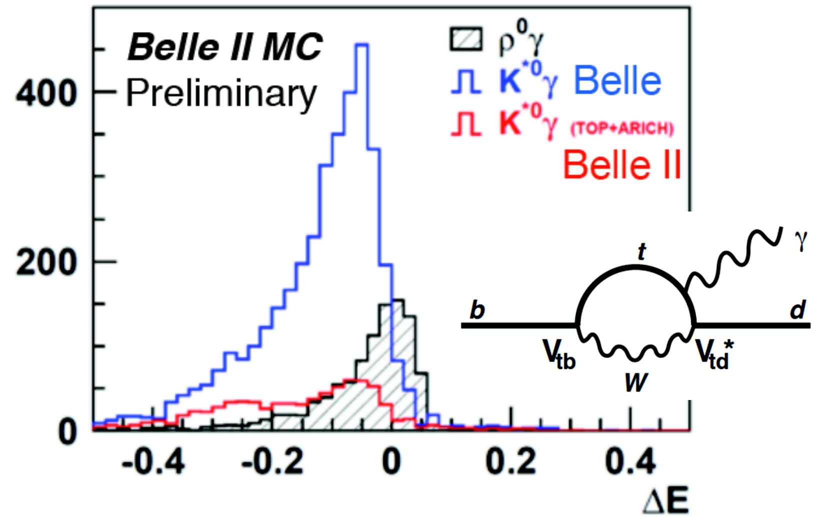
The Present: Belle II at SuperKEKB.



Strength of $e^+e^- \to \Upsilon(4S)$ and Belle II.

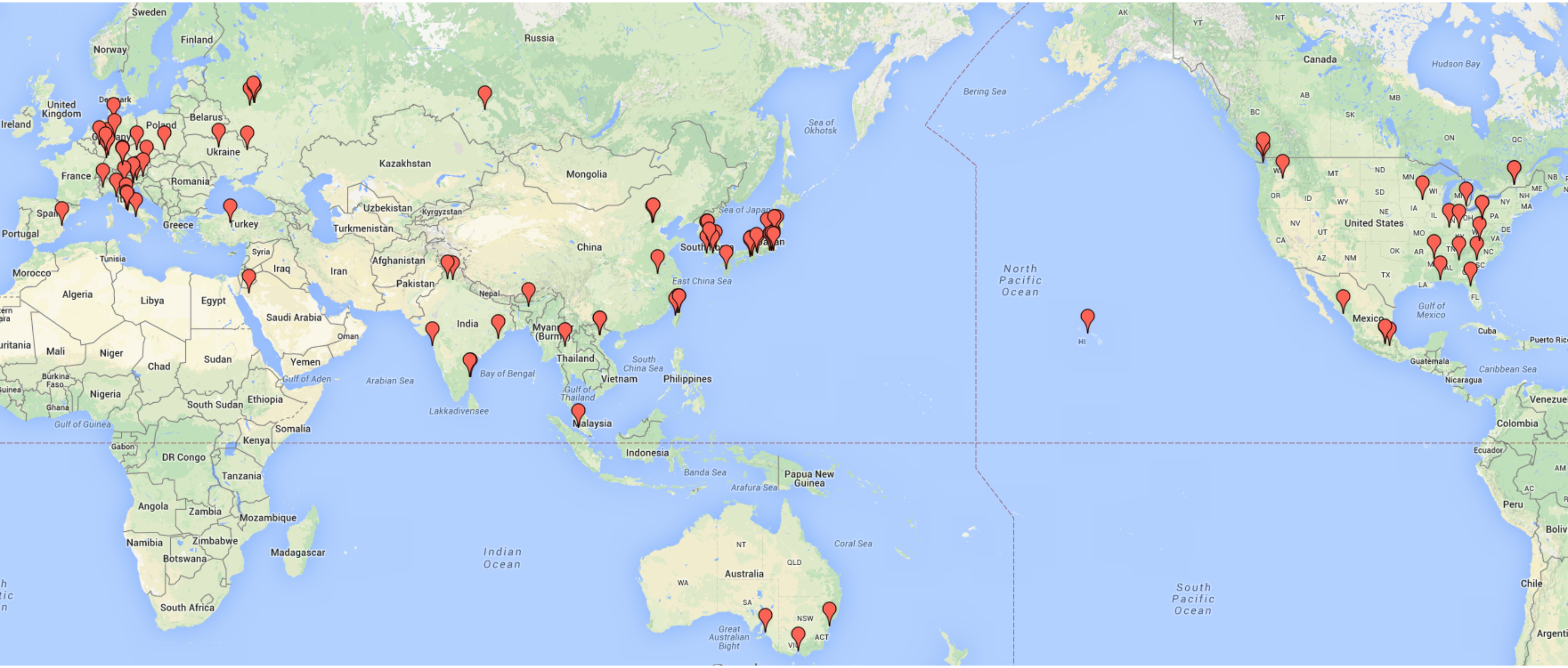
- **>** Full reconstruction of B
  - Modes with multiple neutrinos
  - Inclusive modes
- **>** Hermeticity (90% of 4π)
- **>** Neutral particle reconstruction
  - π^0, K_S^0, K_L^0, η, η', ρ^+,...
- **>** Good PID for μ and e
- **>** High flavour-tagging eff.

vertex reso mit PXD



The Belle II Collaboration.

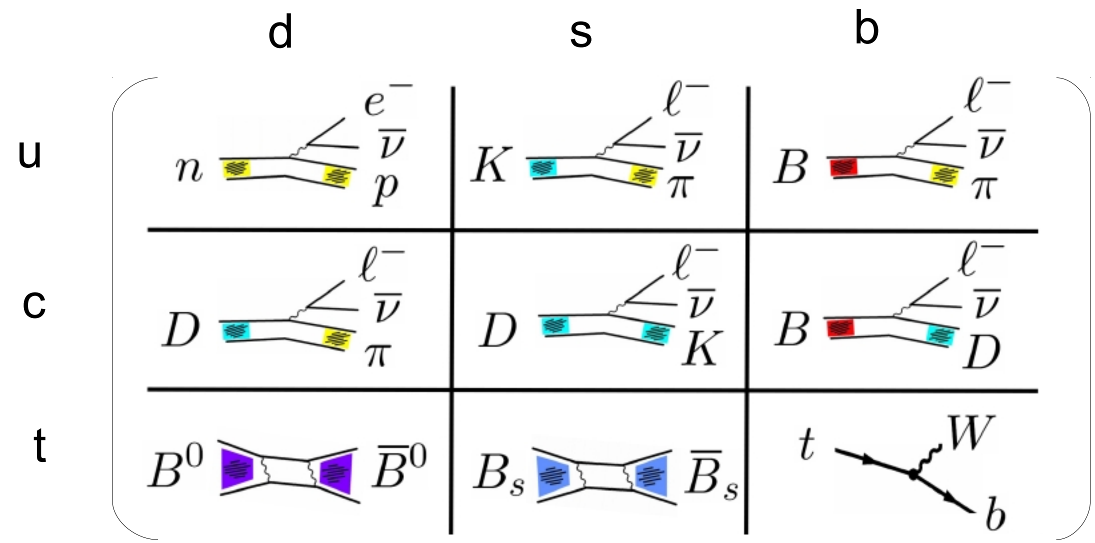
- 626 colleagues, 99 institutes, 23 countries
  (83 colleagues from 11 German institutes)



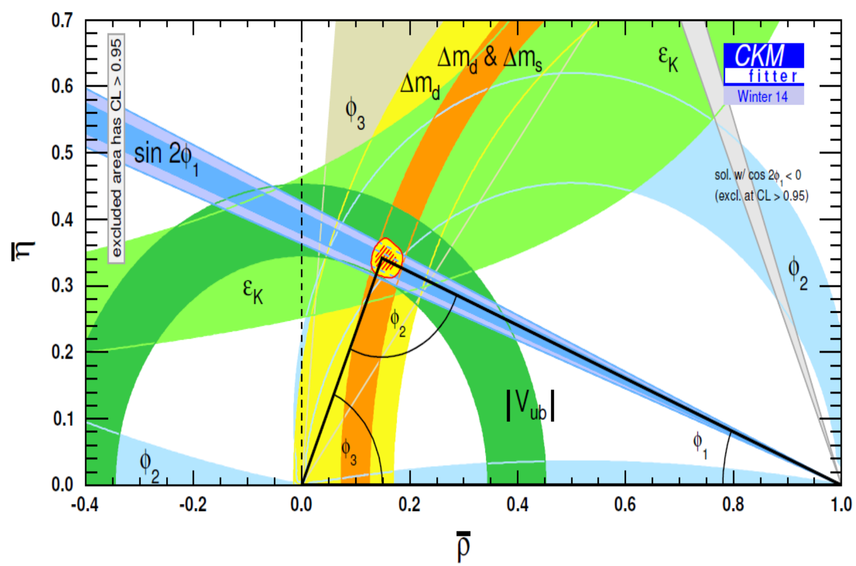
http://belle2.kek.jp

Example: CKM Physics at Belle II.

$V =$



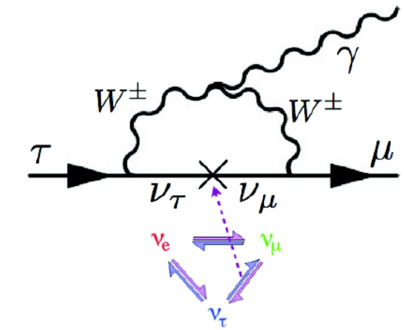
from: S. Descotes-Genon



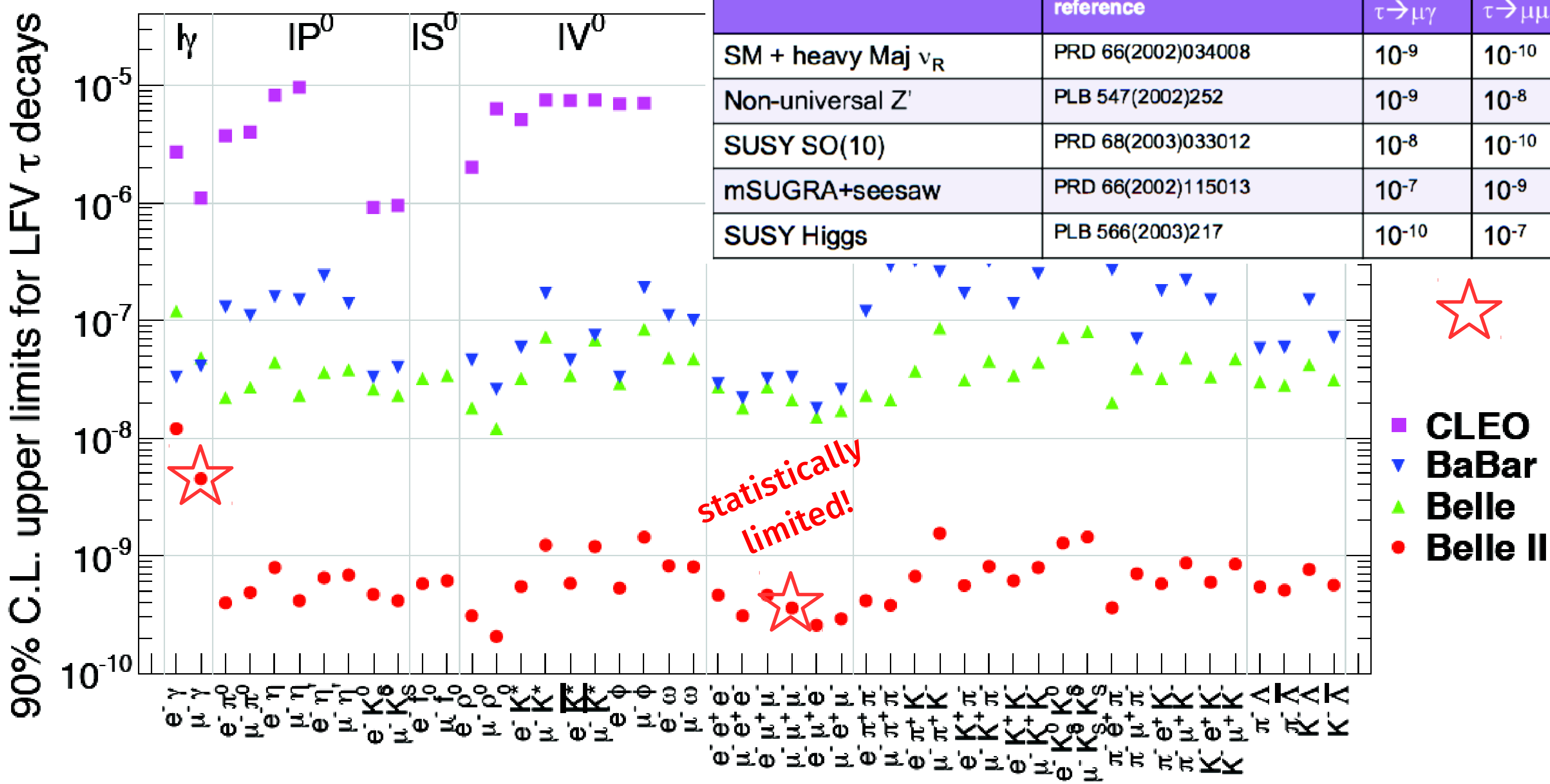
	world average	Belle II exp. ($50ab^{-1}$)
Φ_1 (β)	0.8°	0.4°
Φ_2 (α)	4.0°	1.0°
Φ_3 (γ)	8.5° (Belle: 14.5°)	1.5° statistically limited!

Example: τ Lepton Flavor Violation (LFV) at Belle II.

- LFV is a theoretically clean null test SM: $BF_{SM} \sim 10^{-25} \rightarrow$ New Physics may induce LFV at one loop



	reference	$\tau \rightarrow \mu\gamma$	$\tau \rightarrow \mu\mu\mu$
SM + heavy Maj ν_R	PRD 66(2002)034008	10^{-9}	10^{-10}
Non-universal Z'	PLB 547(2002)252	10^{-9}	10^{-8}
SUSY SO(10)	PRD 68(2003)033012	10^{-8}	10^{-10}
mSUGRA+seesaw	PRD 66(2002)115013	10^{-7}	10^{-9}
SUSY Higgs	PLB 566(2003)217	10^{-10}	10^{-7}



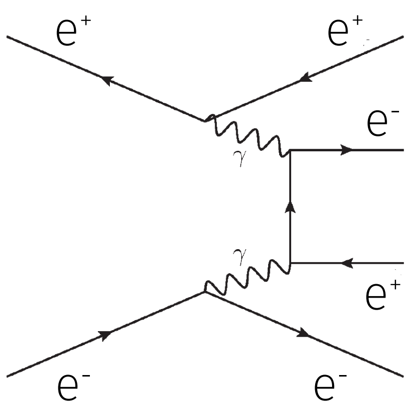
Background: CDC.

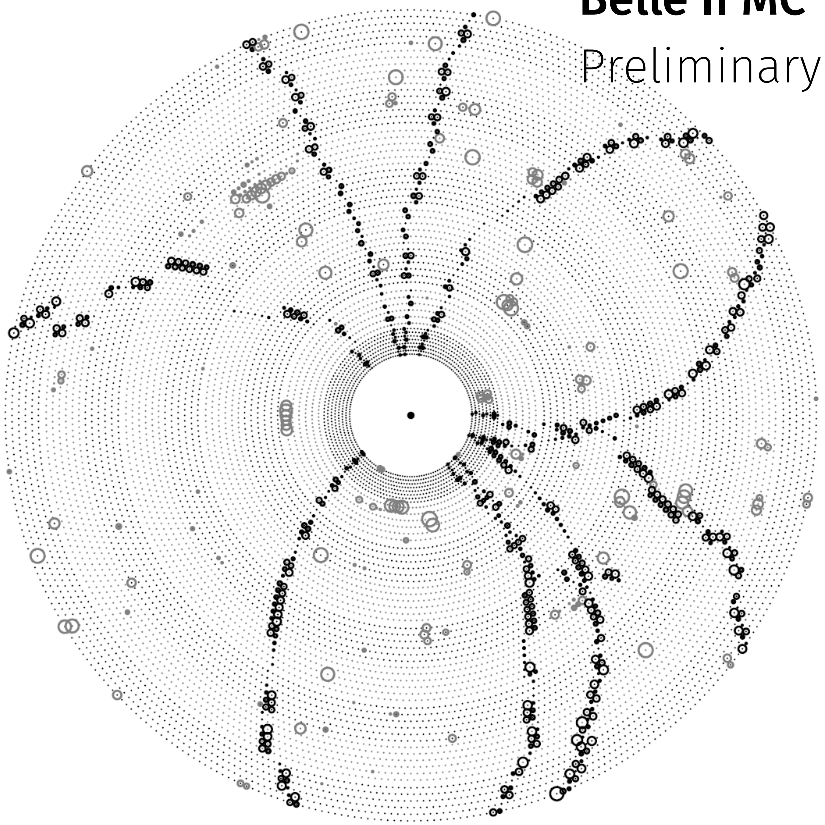
Main background in CDC:

- Radiative Bhabha (scales with L)
- Only small Touschek-increase from increased beam current, largely reduced by collimators

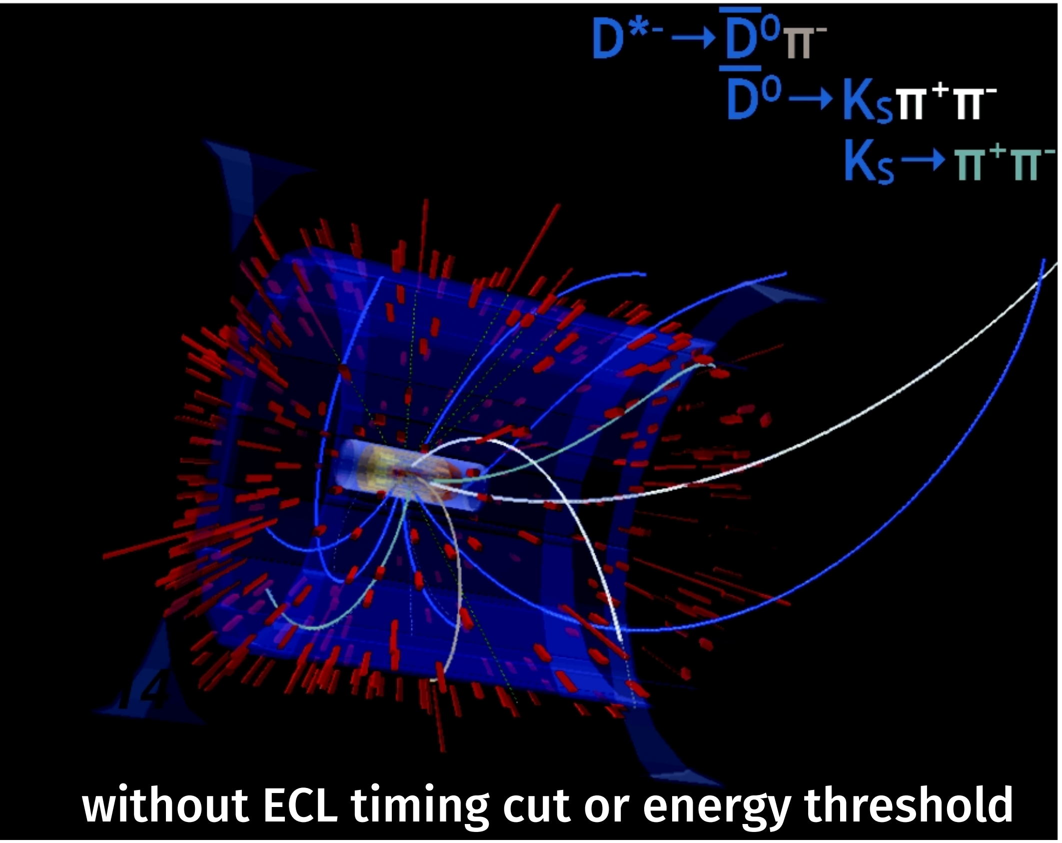
Main background in VTX:

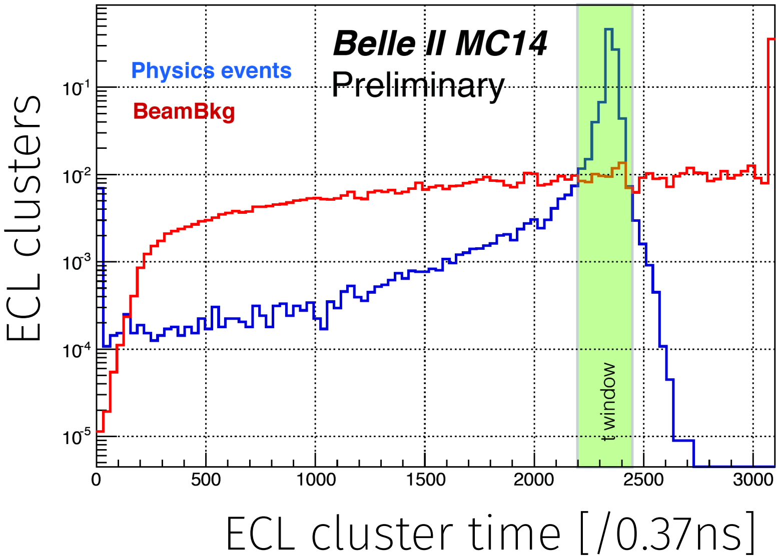
- Two Photon QED





Background: ECL.





Trigger.

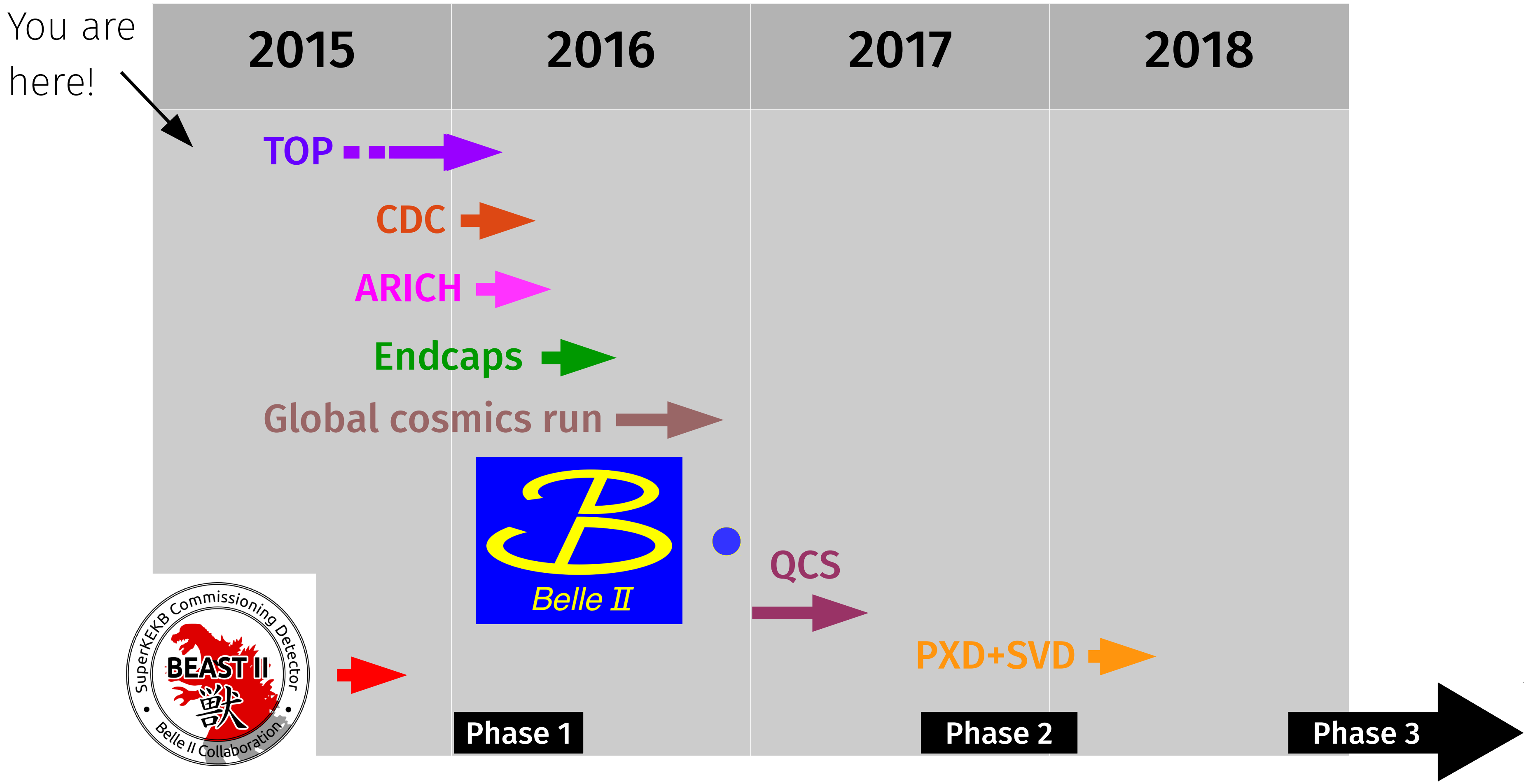
- Two stage trigger:
  - Hardware (L1)
  - Software / Physics Trigger
- Fixed latency: 5μs
- Bunch spacing: 2ns
- >99% efficiency for $B\bar{B}$

	L1 Rate	Physics Rate	Event size
Belle	500 Hz	90 Hz	40kB
Belle II	30 kHz	3-10 kHz	200kB

Physics process	Cross section [nb]	Rate [Hz] @ final L.
$\Upsilon(4S) \to BB$	1.2	960
quark pairs	2.8	2200
Muon pairs	1.1	880
Tau pairs	0.9	720
Bhabha (θ_{lab}>17°)	44	350*
γ pairs	2.4	19*
Two photon	~80	~15000
Total	~130	~20000

*prescaled by 100

Schedule.



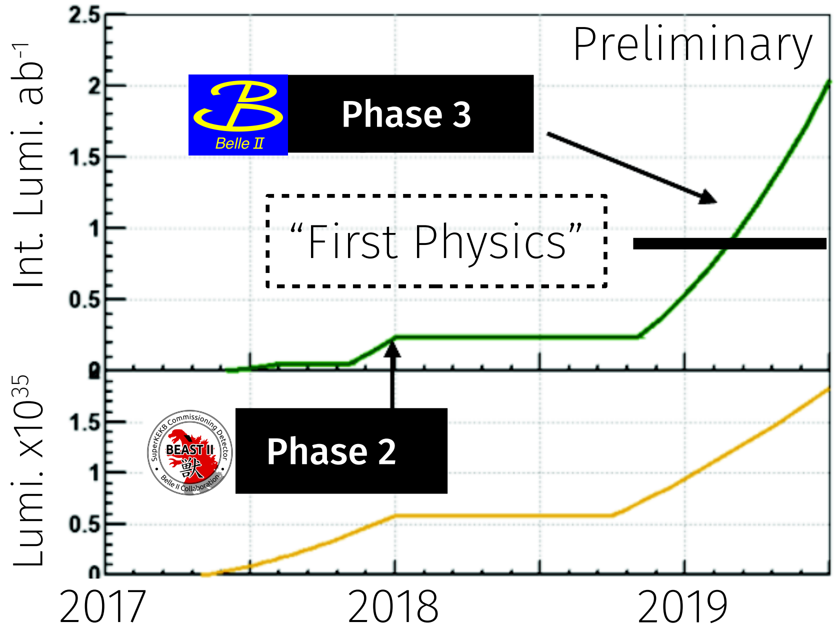
Phase 1: 2016 BEAST/SuperKEKB, cosmics

Phase 2: Mid 2017- Early 2018 BEAST with Partial Belle II

Phase 3: Oct 2018- Full detector

Phase 3: First Physics at Belle II.

- “Maximize original physics research in the first year”
- Possible caveats:
  - PID calibration
  - VXD alignment
  - Backgrounds
- Potential benefits:
  - Looser trigger
  - Different beam energies



- ~300fb^{-1} non-Υ(4S) data in first year (plus similar amount of calibration data at Υ(4S))

Phase 3: First Physics at Belle II.

Experiment	Scans/Off. Res.	$\Upsilon(5S)$ 10876 MeV		$\Upsilon(4S)$ 10580 MeV		$\Upsilon(3S)$ 10355 MeV		$\Upsilon(2S)$ 10023 MeV		$\Upsilon(1S)$ 9460 MeV	
	fb^{-1}	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6
CLEO	17.1	0.4	0.1	16	17.1	1.2	5	1.2	10	1.2	21
BaBar	54	R_b scan		433	471	30	122	14	99	–	
Belle	100	121	36	711	772	3	12	25	158	6	102

> Possible topics for the first year of data taking:

- Bottomonium(like) below and above Υ(4S)
- Energy scans up Υ(6S)
- Light Higgs and **Dark Sector**
- **Preparation of high-precision QED and EW analyses**
- PYTHIA tuning and fragmentation

Light Higgs and the Dark Sector.

Light higgs:

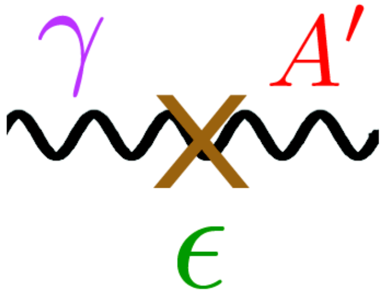
- NMSSM models result in 3 CP-even and 2 CP-odd neutral Higgs bosons
- The lightest Higgs $\mathbf{A^0}$ can have $m_{A0}<2m_b$ (not excluded by LEP): e.g. $\Upsilon(2S) \rightarrow \pi^+\pi^-\Upsilon(1S)$ [$\Upsilon(1S) \rightarrow \gamma A^0[A^0 \rightarrow f\bar{f}]$]
- Belle II: $\Upsilon(2S)$ preferred, slow pion pair trigger needed

Dark Sector:

- Minimal dark matter model: Dark matter particle $\boldsymbol{\chi}$ and a new scalar or gauge boson **A'** as s-channel annihilation mediator ($m_{A'} > 2m_\chi$)
- Additional U(1)' symmetry → "Kinetic Mixing" of massive dark photon A' with the SM photon

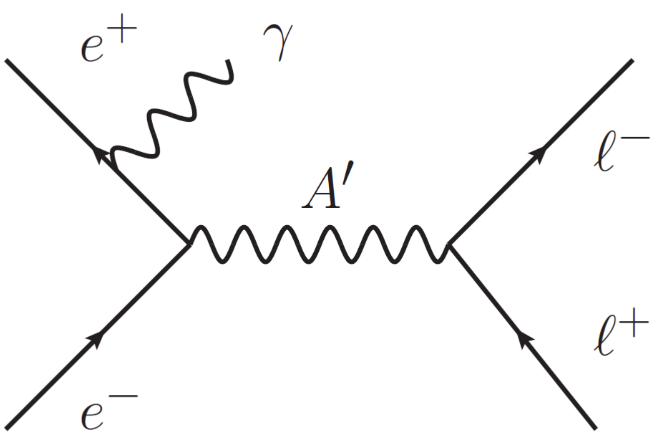
The Dark Photon.

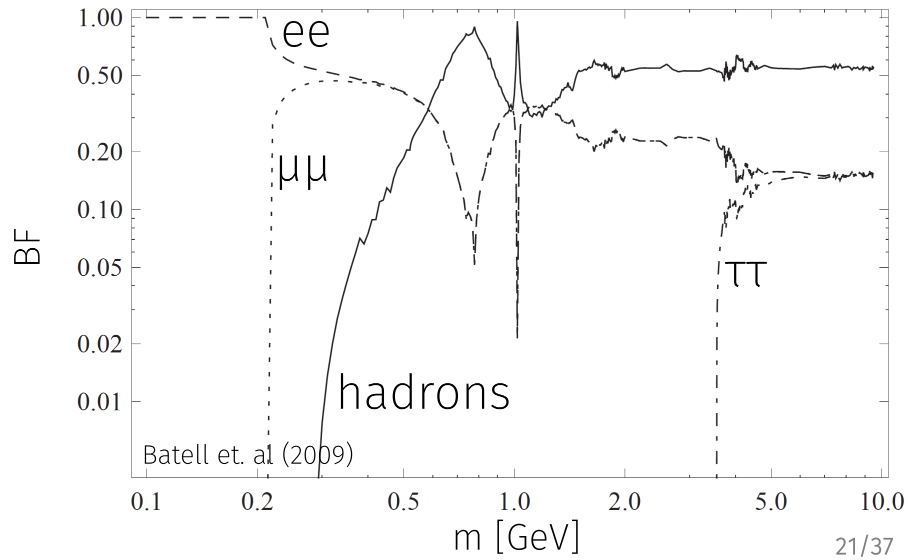
- Kinetic mixing:



$$\Delta\mathcal{L} = \frac{\epsilon}{2} F^{Y,\mu\nu} F'_{\mu\nu}$$

- If A' is the lightest “Dark Sector” particle:
  Annihilation into SM particles, σ proportional to $\alpha\varepsilon^2$





Dark Photon decaying into fermion pairs.

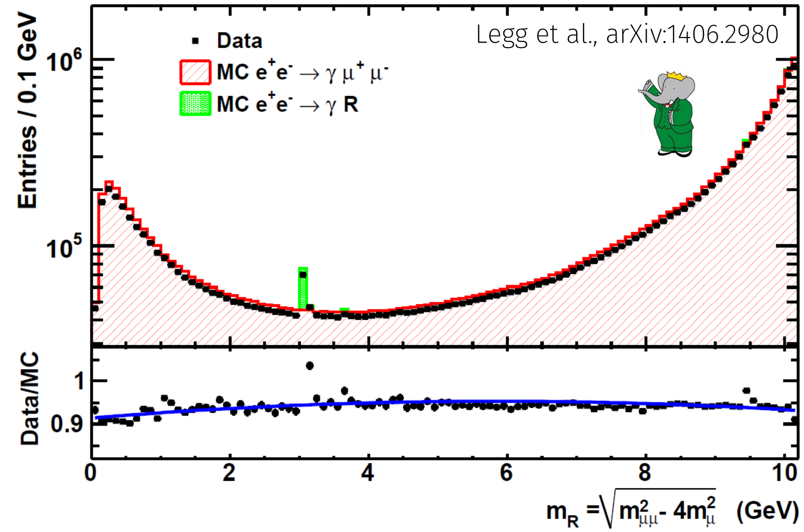
- **Since A' is very narrow:**
  - "Scan" ee → γ_{ISR}A'
- **Signal:**
  - Narrow peak in dilepton (ee or μμ) mass spectrum (dominated by QED)
- **Belle II First Physics:**

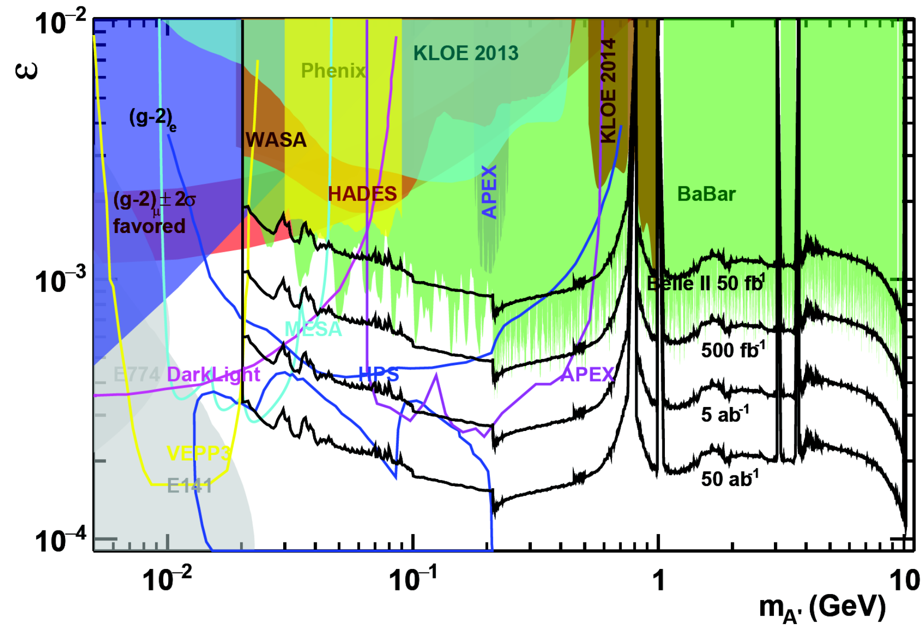
Mass resolution ~0.5

$$\frac{U_\epsilon}{U_\epsilon^0} = \left(\frac{\mathcal{L}^0}{\mathcal{L}}\frac{\Delta_M}{\Delta_M^0}\frac{\epsilon_{\ell\ell}^0}{\epsilon_{\ell\ell}}\right)^{0.25}$$

Trigger efficiency 1.1(μμ)-2(ee)

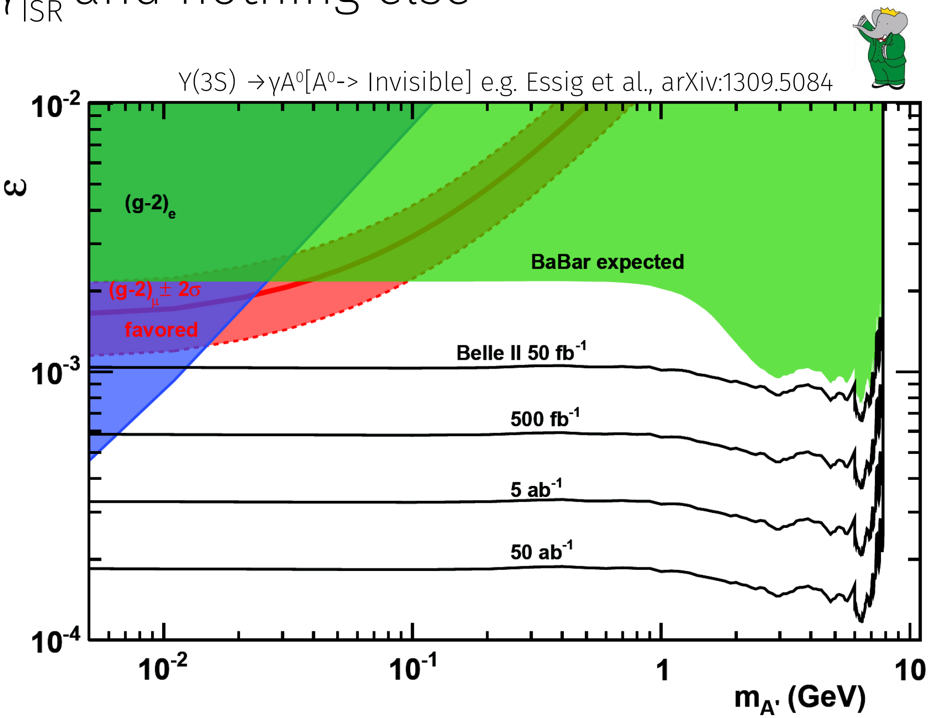
  - Add hadronic final states





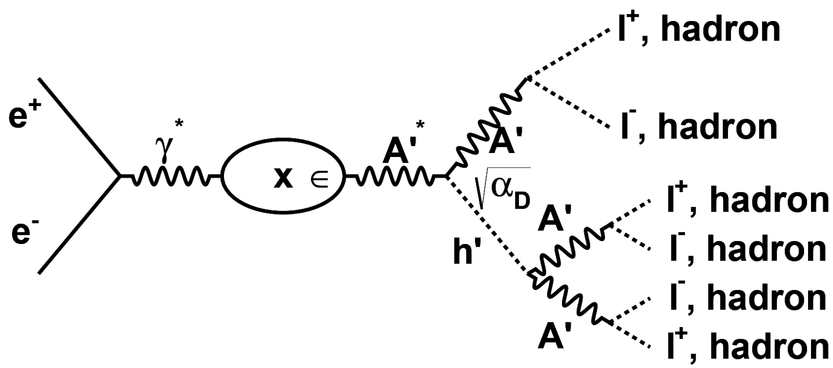
Dark Photon decaying into invisible final state.

- If A' is not the lightest "Dark Sector" particle:
  - $ee \to \gamma_{ISR} A'$, $A' \to \chi\chi$ dominates
- Signal:
  - Single, mono-energetic photon γ_{ISR} and nothing else
- Belle II First Physics: Dedicated "single photon trigger" at E_γ~1GeV
  - Also needed for search of a weakly interacting particle in non resonant $ee \to \gamma\chi\chi$ (via overall γ-rate increase)



Dark Higgs.

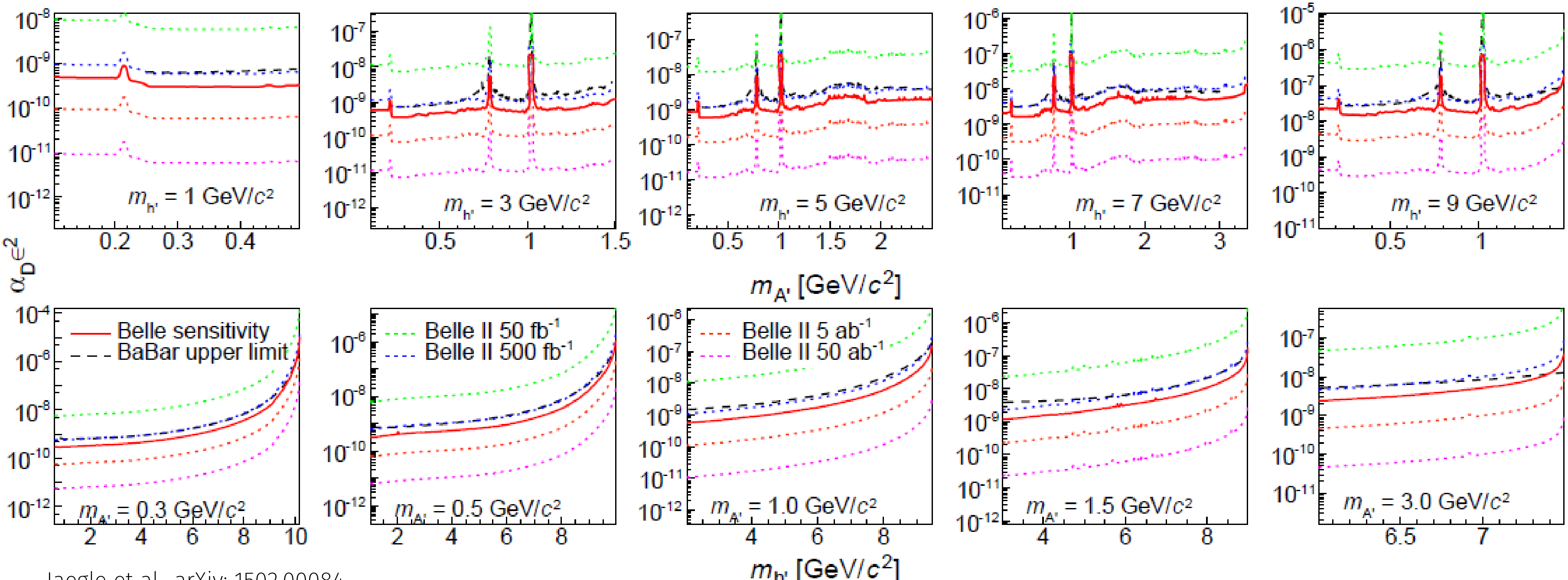
- Dark U(1)' symmetry group spontaneously broken: Adding dark Higgs h' (or several of them...)
- Two couplings involved: α_D and kinetic mixing $\sim\varepsilon^2$
- Dark Higgs-strahlung:



- Case A: $\mathbf{m_{h'} < m_{A'}}$ → h' long lived (decay outside detector), A' → ll or hh
- Case B: $\mathbf{m_{A'} < m_{h'} < 2m_{A'}}$ → h' → A'A'*, six leptons/hadrons
- Case C: $\mathbf{m_{h'} > 2m_{A'}}$ → h' → A'A', six leptons/hadrons

Belle II First Physics:

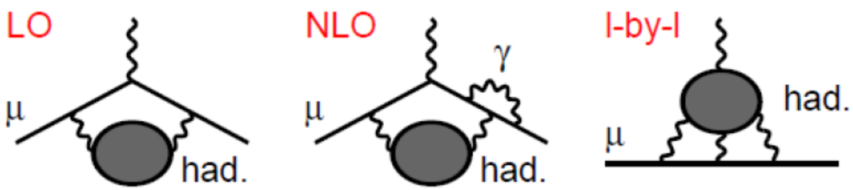
- Case A: Not studied at B factories, new low momentum leptons and missing energy trigger needed
- Case C: Improved mass resolution for finer mass scans



Jaegle et al., arXiv: 1502.00084
Legg et al., arXiv:1202.1313

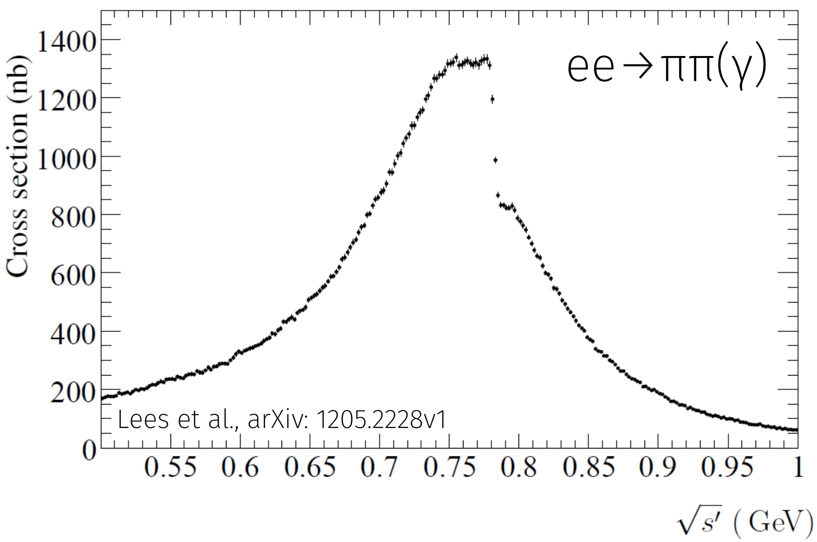
Muon anomalous magnetic moment:

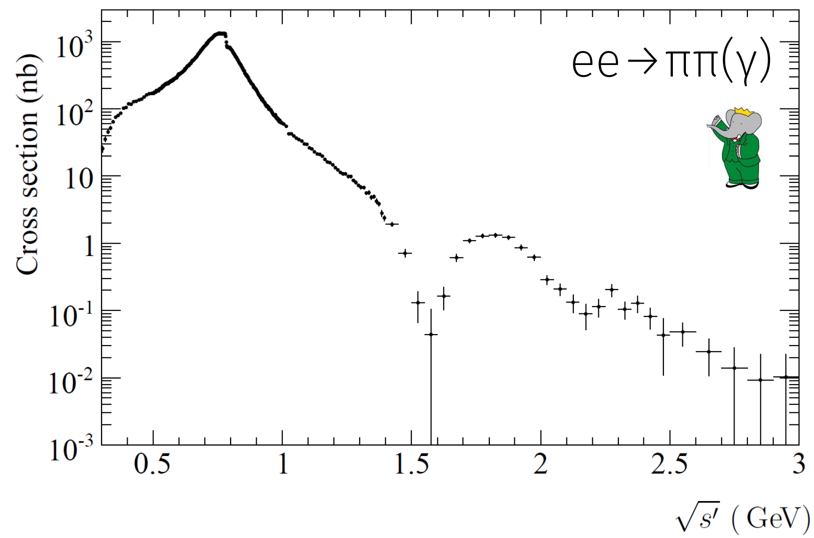
- a_μ^{SM} = (11 659 180.4 ± 4.3 (HVP) ± 2.6 (LBL) ± 0.2 (EW)) x 10^{-10}



$$a_\mu^{\text{had,LO}} = \frac{m_\mu^2}{12\pi^3}\int_{s_{\text{th}}}^{\infty} ds\, \frac{1}{s}\hat{K}(s)\sigma_{\text{had}}(s)$$

Dominant contribution to LO HVP: $\pi^+\pi^-$ (~73% of α_μ^{had})

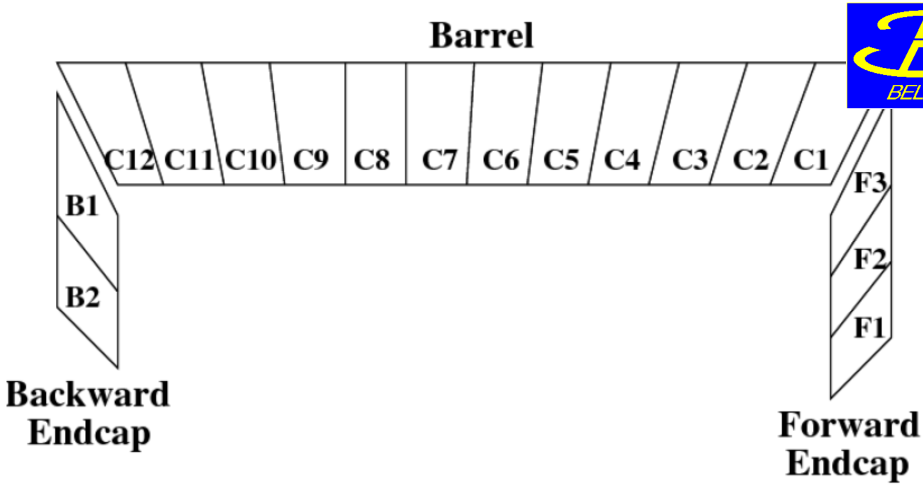


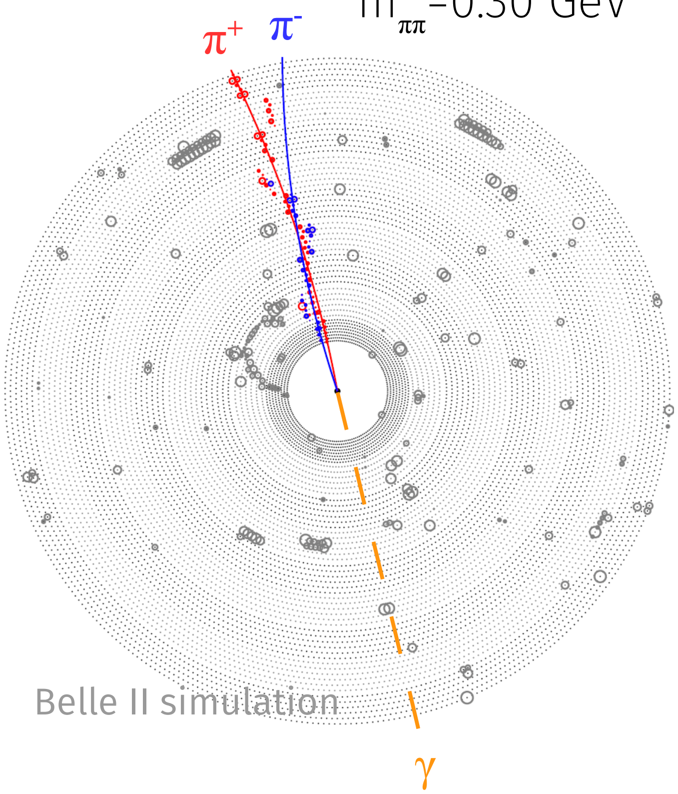


Low Multiplicity Physics at Belle II: ISR physics for g-2.

- Experimental challenge: Total error <1%
  - Correlated track loss, PID, trigger, ...
- Belle: Limited by L1 trigger

  Bhabha veto (E_{ECL}>5 GeV)

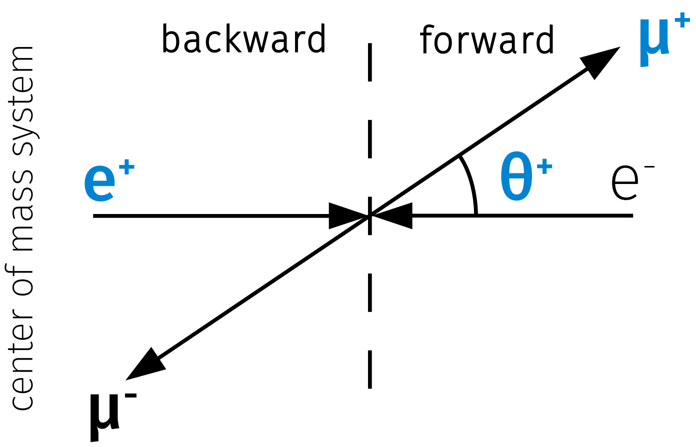


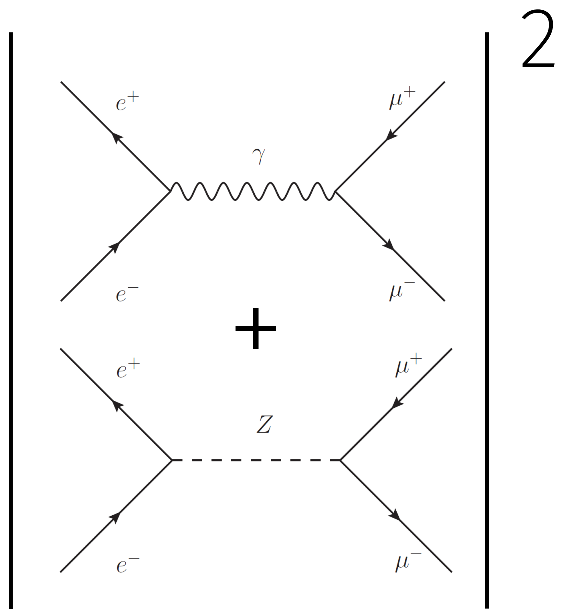


Belle II First Physics:

Optimize electron-vetoed track trigger

- Preferred direction of muons produced in e^+e^- collisions?
  → $A_{FB}=(N_F-N_B)/(N_F+N_B)$
- Born QED predicts symmetric distribution ($N_F=N_B$, $A_{FB}=0$)
- Interference of γ and Z leads to energy dependent asymmetry $A_{FB}<0$ for $s<m_Z^2$





The Standard Model (Born level): ee → μμ.

$$\frac{2s}{\pi}\frac{d\sigma}{d\cos(\theta^*)}\left(e^+e^- \to \mu^+\mu^-\right) =$$

$$\underbrace{|\alpha(s)|^2(1+\cos^2(\theta^*))}_{\sigma^\gamma}$$

$$\underbrace{+\,8\,\mathrm{Re}\left[\alpha^*(s)\chi(s)\left\{\mathcal{G}_{\mathrm{ve}}\mathcal{G}_{\mathrm{v}\mu}(1+\cos^2(\theta^*)) + 2\mathcal{G}_{\mathrm{ae}}\mathcal{G}_{\mathrm{a}\mu}\cos(\theta^*)\right\}\right]}_{\sigma^{\gamma-Z}}$$

$$\underbrace{\begin{matrix} +\;16|\chi(s)|^2[\left(|\mathcal{G}_{\mathrm{ve}}|^2 + |\mathcal{G}_{\mathrm{ae}}|^2\right)\left(|\mathcal{G}_{\mathrm{v}\mu}|^2 + |\mathcal{G}_{\mathrm{a}\mu}|^2\right)(1+\cos^2(\theta^*)) \\ +8\,\mathrm{Re}(\mathcal{G}_{\mathrm{ve}}\mathcal{G}^*_{\mathrm{ae}})\,\mathrm{Re}(\mathcal{G}_{\mathrm{v}\mu}\mathcal{G}^*_{\mathrm{a}\mu})\cos(\theta^*)], \end{matrix}}_{\sigma^Z}$$

with

$$\chi(s) = \rho\frac{G_F}{8\pi\sqrt{2}}\frac{M_Z^2 s}{s - M_Z^2 + i\Gamma_Z M_Z}$$

$$\mathcal{G}_{\mathrm{V}f} = \sqrt{\mathcal{R}_f}\left(T_3^f - 2\sin^2\theta_W^{\mathrm{eff.}}\right)$$

The Standard Model (Born level): ee → μμ.

$$\frac{2s}{\pi}\frac{d\sigma}{d\cos(\theta^*)}\left(e^+e^- \to \mu^+\mu^-\right) =$$

$$\underbrace{|\alpha(s)|^2\boxed{(1+\cos^2(\theta^*))}}_{\sigma^\gamma}$$

$$\underbrace{+\,8\,\mathrm{Re}\left[\alpha^*(s)\chi(s)\left\{\boxed{\mathcal{G}_{\mathrm{ve}}\mathcal{G}_{\mathrm{v}\mu}(1+\cos^2(\theta^*))}+\boxed{2\mathcal{G}_{\mathrm{ae}}\mathcal{G}_{\mathrm{a}\mu}\cos(\theta^*)}\right\}\right]}_{\sigma^{\gamma-Z}}$$

$$\underbrace{+\;16|\chi(s)|^2\left[\boxed{\left(|\mathcal{G}_{\mathrm{ve}}|^2+|\mathcal{G}_{\mathrm{ae}}|^2\right)\left(|\mathcal{G}_{\mathrm{v}\mu}|^2+|\mathcal{G}_{\mathrm{a}\mu}|^2\right)(1+\cos^2(\theta^*))} + \boxed{8\,\mathrm{Re}(\mathcal{G}_{\mathrm{ve}}\mathcal{G}^*_{\mathrm{ae}})\,\mathrm{Re}(\mathcal{G}_{\mathrm{v}\mu}\mathcal{G}^*_{\mathrm{a}\mu})\cos(\theta^*)}\right],}_{\sigma^Z}$$

asymmetric

symmetric

with

$$\chi(s) = \rho\frac{G_F}{8\pi\sqrt{2}}\frac{M_Z^2 s}{s-M_Z^2+i\Gamma_Z M_Z}$$

$$\mathcal{G}_{\mathrm{V}f} = \sqrt{\mathcal{R}_f}\left(T_3^f - 2\sin^2\theta_W^{\mathrm{eff.}}\right)$$

The Standard Model (Born level): ee → μμ.

rho parameter

weak mixing angle

$$\frac{2s}{\pi}\frac{d\sigma}{d\cos(\theta^*)}(e^+e^- \to \mu^+\mu^-) =$$

$$\underbrace{|\alpha(s)|^2(1+\cos^2(\theta^*))}_{\sigma^\gamma}$$

$$\underbrace{+8\,\mathrm{Re}\left[\alpha^*(s)\chi(s)\left\{\mathcal{G}_{\mathrm{ve}}\mathcal{G}_{\mathrm{v}\mu}(1+\cos^2(\theta^*))+2\mathcal{G}_{\mathrm{ae}}\mathcal{G}_{\mathrm{a}\mu}\cos(\theta^*)\right\}\right]}_{\sigma^{\gamma-Z}}$$

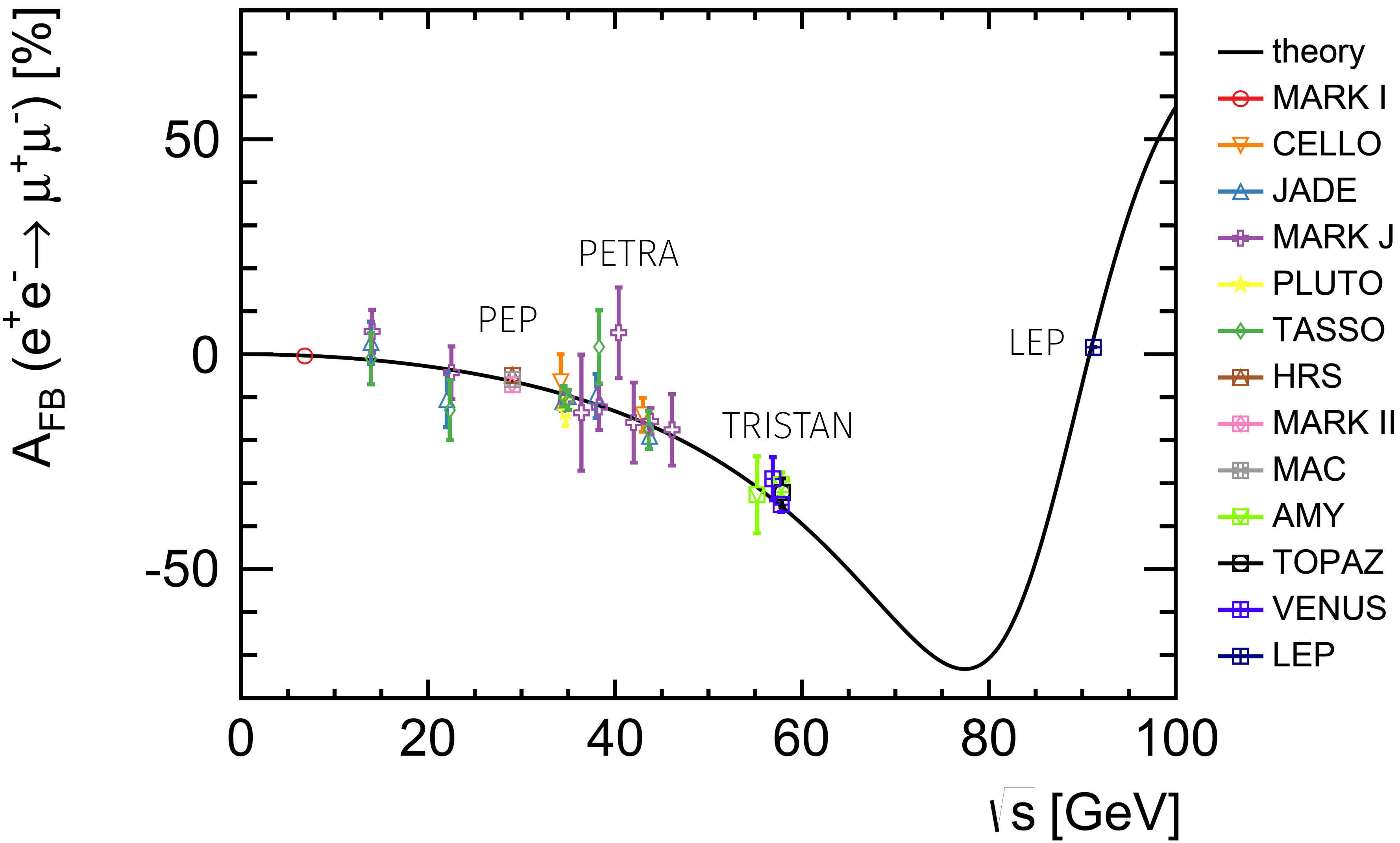
$$\underbrace{\begin{array}{c}+\,16|\chi(s)|^2\left[\left(|\mathcal{G}_{\mathrm{ve}}|^2+|\mathcal{G}_{\mathrm{ae}}|^2\right)\left(|\mathcal{G}_{\mathrm{v}\mu}|^2+|\mathcal{G}_{\mathrm{a}\mu}|^2\right)(1+\cos^2(\theta^*))\right.\\ \left.+8\,\mathrm{Re}(\mathcal{G}_{\mathrm{ve}}\mathcal{G}^*_{\mathrm{ae}})\,\mathrm{Re}(\mathcal{G}_{\mathrm{v}\mu}\mathcal{G}^*_{\mathrm{a}\mu})\cos(\theta^*)\right],\end{array}}_{\sigma^Z}$$

with

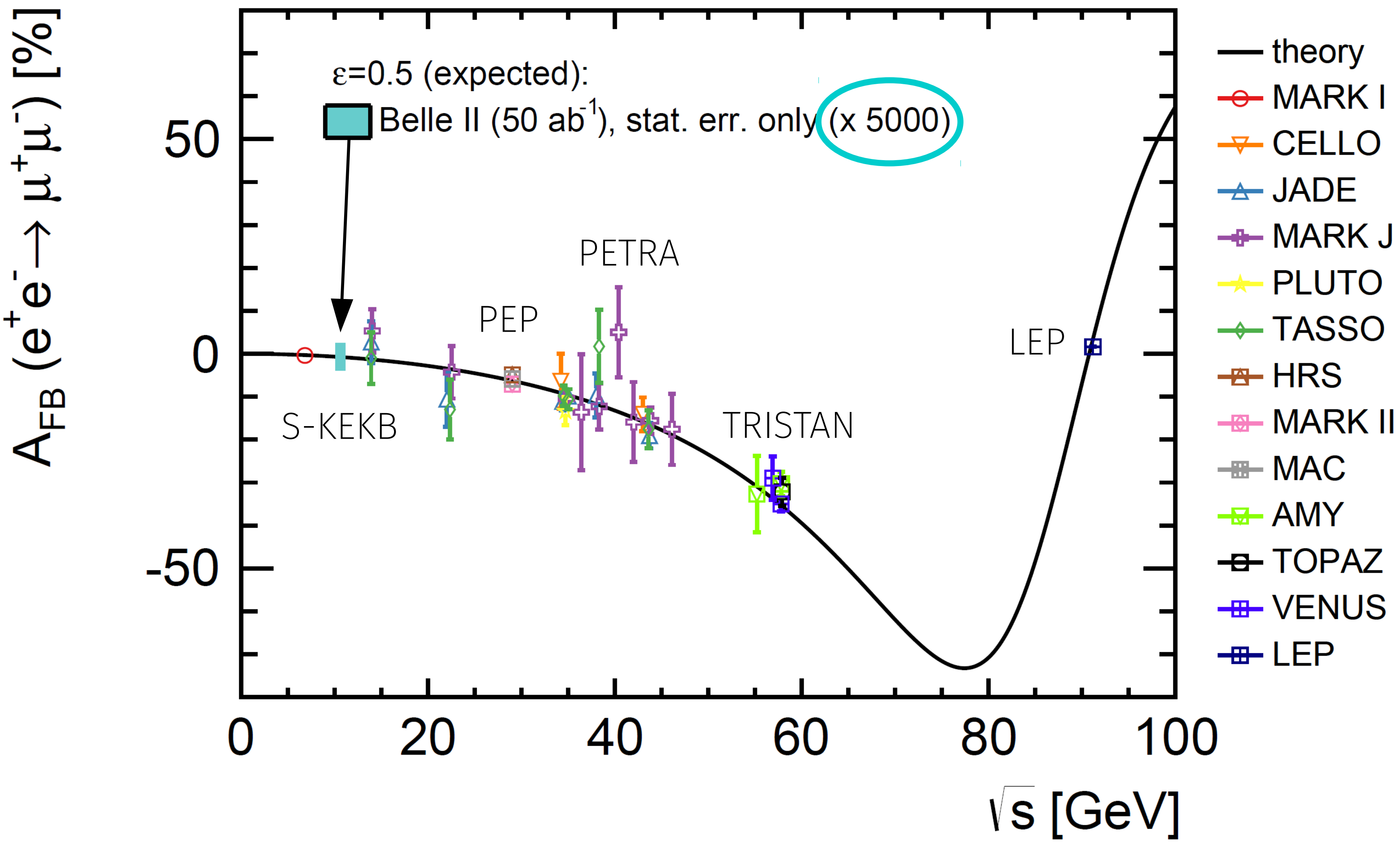
$$\chi(s) = \rho\frac{G_F}{8\pi\sqrt{2}}\frac{M_Z^2 s}{s-M_Z^2+i\Gamma_Z M_Z}$$

$$\mathcal{G}_{\mathrm{V}f} = \sqrt{\mathcal{R}_f}\left(T_3^f - 2\sin^2\theta_W^{\mathrm{eff.}}\right)$$

An asymmetry over energy and time.



An asymmetry over energy and time.



Precision physics far below the Z pole.

Precision measurement at Z pole:

- $A_{FB} \sim g_V^2 g_A^2/(g_V^2+g_A^2)^2$ → Sensitive to the **weak mixing angle** and **ρ**

Precision measurement at Belle II:

- $A_{FB} \sim \rho g_A^2$ (dominated by interference $\sigma_{\gamma Z}$) → Only sensitive to **ρ**
- 50 ab^{-1} yield ~25 billion detected muon pairs at 10.58 GeV CM energy
- Expected statistical uncertainty: $\boldsymbol{\sigma_{abs}(A_{FB}) \approx 10^{-5}}$ with $\boldsymbol{A_{FB\,(EW)} \approx -10^{-2}}$ at Belle II

  → Measurement of weak loop corrections to **ρ**
- Largest corrections and systematics: QED asymmetry (theory: KKMC, ZFITTER, ...) and detector charge asymmetry

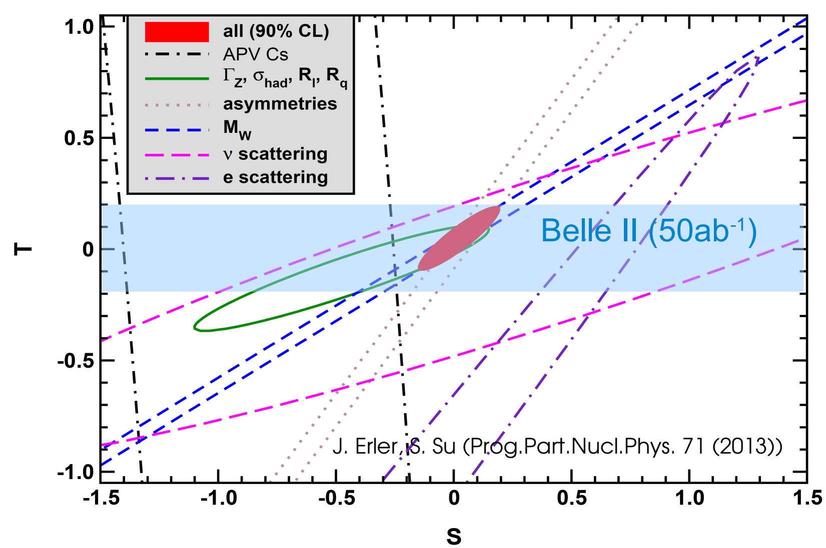
Belle II First Physics:

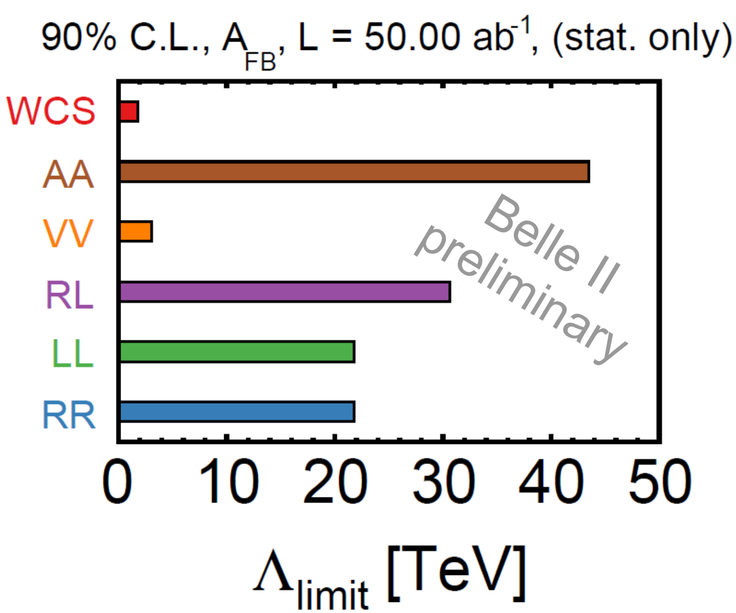
- Fine tuning of two track trigger

Precision physics far below the Z pole.

Oblique parameter T at low energy (complementary to APV):
Isospin violation from different NP loop contributions to Z and W

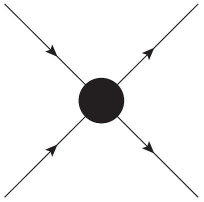
$$\Delta\rho^{\text{new}} = \frac{\hat{\Pi}^{\text{new}}_{WW}(0) - \hat{c}_Z^2 \hat{\Pi}^{\text{new}}_{ZZ}(0)}{M_W^2(1-\Delta\hat{r}_W)} \equiv \frac{\alpha T}{1-\Delta\hat{r}_W} \approx \hat{\alpha}_Z T$$





Contact Interactions at low energy are sensitive to TeV scale NP (involving the second generation)

$$\mathcal{L}_{\text{eff}} = \frac{1}{2}\frac{g^2}{(\Lambda^{\pm})^2} \sum_{i,j=L,R} \eta_{ij}\bar{e}_i\gamma_\mu e_i \bar{f}_j \gamma^\mu f_j$$



Summary.

- Belle II offers high sensitivity to New Physics at the Flavour frontier, largely complementary to LHCb
- Unique data set of non-$\Upsilon(4S)$ data in the first year
- Broad low multiplicity program at Belle II, including Dark Sector and Electroweak Precision
- Significantly improved two track trigger, better Bhabha veto and single photon trigger
- Belle II physics data taking will start 2018

Belle II Theory Interface Platform (B2TIP).

- Joint theory-experiment effort to study the potential impacts of the Belle II program

What's new in Belle II compared to Belle and Babar?
- Efficiencies, precision of hardware
- New software
- New analysis methods
-...

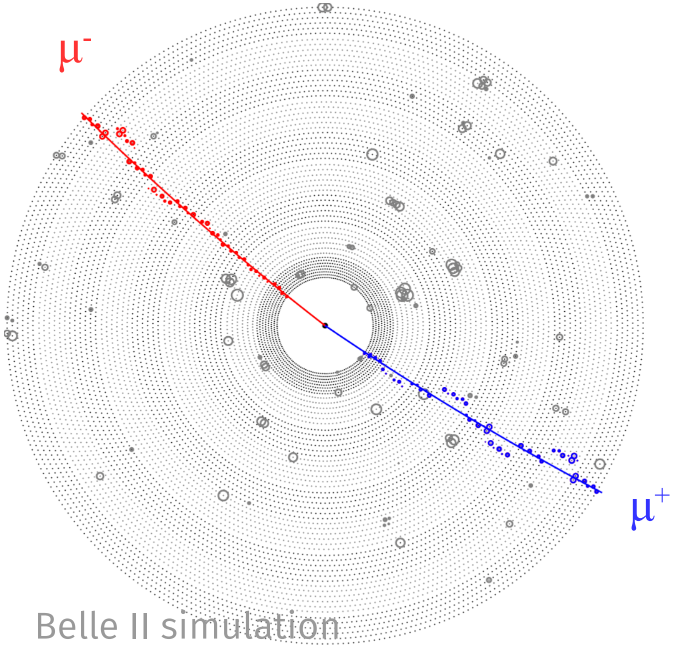
What's new in theory after Belle, Babar and LHCb?
- Progress in QCD
- New Physics models and constraints
- New observables
- ...

NEW IDEAS!

- Next **open** B2TIP workshop: 27.-29.04.2015, Krakau

  http://kds.kek.jp/conferenceDisplay.py?confId=17654

Backup



Backup: Belle II and LHCb.

TABLE XLI: Expected errors on several selected flavour observables with an integrated luminosity of 5 ab^{-1} and 50 ab^{-1} of Belle II data. The current results from Belle, or from BaBar where relevant (denoted with a †) are also given. Items marked with a ‡ are estimates based on similar measurements. Errors given in % represent relative errors.

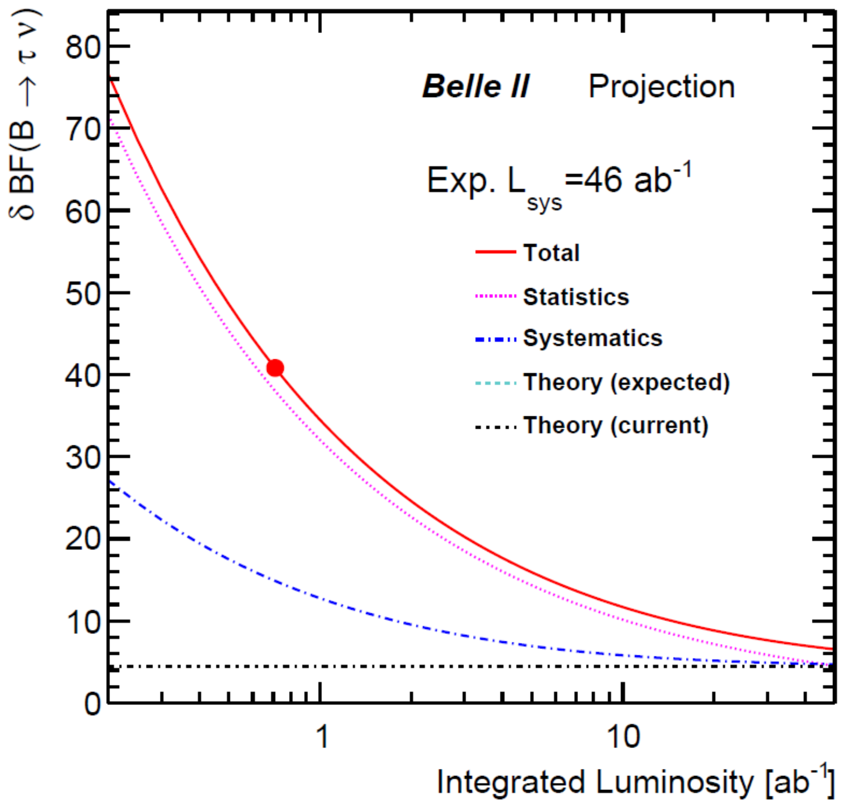
	Observables	Belle or LHCb* (2014)	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}	LHCb 8 fb^{-1}(2018)	LHCb 50 fb^{-1}
UT angles	$\sin 2\beta$	$0.667 \pm 0.023 \pm 0.012 (1.4^\circ)$	0.7°	0.4°	1.6°	0.6°
	α [°]	85 ± 4 (Belle+BaBar)	2	1		
	γ [°] $(B \to D^{(*)} K^{(*)})$	68 ± 14	6	1.5	4	1
	$2\beta_s(B_s \to J/\psi\phi)$ [rad]	$0.07 \pm 0.09 \pm 0.01^*$			0.025	0.009
Gluonic penguins	$S(B \to \phi K^0)$	$0.90^{+0.09}_{-0.19}$	0.053	0.018	0.2	0.04
	$S(B \to \eta' K^0)$	$0.68 \pm 0.07 \pm 0.03$	0.028	0.011		
	$S(B \to K_S^0 K_S^0 K_S^0)$	$0.30 \pm 0.32 \pm 0.08$	0.100	0.033		
	$\beta_s^{\text{eff}}(B_s \to \phi\phi)$ [rad]	$-0.17 \pm 0.15 \pm 0.03^*$			0.12	0.03
	$\beta_s^{\text{eff}}(B_s \to K^{*0}\bar{K}^{*0})$ [rad]	–			0.13	0.03
Direct CP in hadronic Decays	$\mathcal{A}(B \to K^0\pi^0)$	$-0.05 \pm 0.14 \pm 0.05$	0.07	0.04		
UT sides	$\lvert V_{cb}\rvert$ incl.	$41.6 \cdot 10^{-3}(1 \pm 2.4\%)$	1.2%			
	$\lvert V_{cb}\rvert$ excl.	$37.5 \cdot 10^{-3}(1 \pm 3.0\%_{\text{ex.}} \pm 2.7\%_{\text{th.}})$	1.8%	1.4%		
	$\lvert V_{ub}\rvert$ incl.	$4.47 \cdot 10^{-3}(1 \pm 6.0\%_{\text{ex.}} \pm 2.5\%_{\text{th.}})$	3.4%	3.0%		
	$\lvert V_{ub}\rvert$ excl. (had. tag.)	$3.52 \cdot 10^{-3}(1 \pm 10.8\%)$	4.7%	2.4%		
Leptonic and Semi-tauonic	$\mathcal{B}(B \to \tau\nu)$ [10^{-6}]	$96(1 \pm 26\%)$	10%	5%		
	$\mathcal{B}(B \to \mu\nu)$ [10^{-6}]	< 1.7	20%	7%		
	$R(B \to D\tau\nu)$ [Had. tag]	$0.440(1 \pm 16.5\%)^\dagger$	5.6%	3.4%		
	$R(B \to D^*\tau\nu)^\dagger$ [Had. tag]	$0.332(1 \pm 9.0\%)^\dagger$	3.2%	2.1%	...	
Radiative	$\mathcal{B}(B \to X_s\gamma)$	$3.45 \cdot 10^{-4}(1 \pm 4.3\% \pm 11.6\%)$	7%	6%		
	$A_{CP}(B \to X_{s,d}\gamma)$ [10^{-2}]	$2.2 \pm 4.0 \pm 0.8$	1	0.5		
	$S(B \to K_S^0\pi^0\gamma)$	$-0.10 \pm 0.31 \pm 0.07$	0.11	0.035		
	$2\beta_s^{\text{eff}}(B_s \to \phi\gamma)$	–			0.13	0.03
	$S(B \to \rho\gamma)$	$-0.83 \pm 0.65 \pm 0.18$	0.23	0.07		
	$\mathcal{B}(B_s \to \gamma\gamma)$ [10^{-6}]	< 8.7	0.3	–		
Electroweak penguins	$\mathcal{B}(B \to K^{*+}\nu\overline{\nu})$ [10^{-6}]	< 40	< 15	30%		
	$\mathcal{B}(B \to K^{+}\nu\overline{\nu})$ [10^{-6}]	< 55	< 21	30%		
	C_7/C_9 $(B \to X_s\ell\ell)$	~20%	10%	5%		
	$\mathcal{B}(B_s \to \tau\tau)$ [10^{-3}]	–	< 2	–		
	$\mathcal{B}(B_s \to \mu\mu)$ [10^{-9}]	$2.9^{+1.1}_{-1.0}{}^*$			0.5	0.2

Backup: Belle II and LHCb.

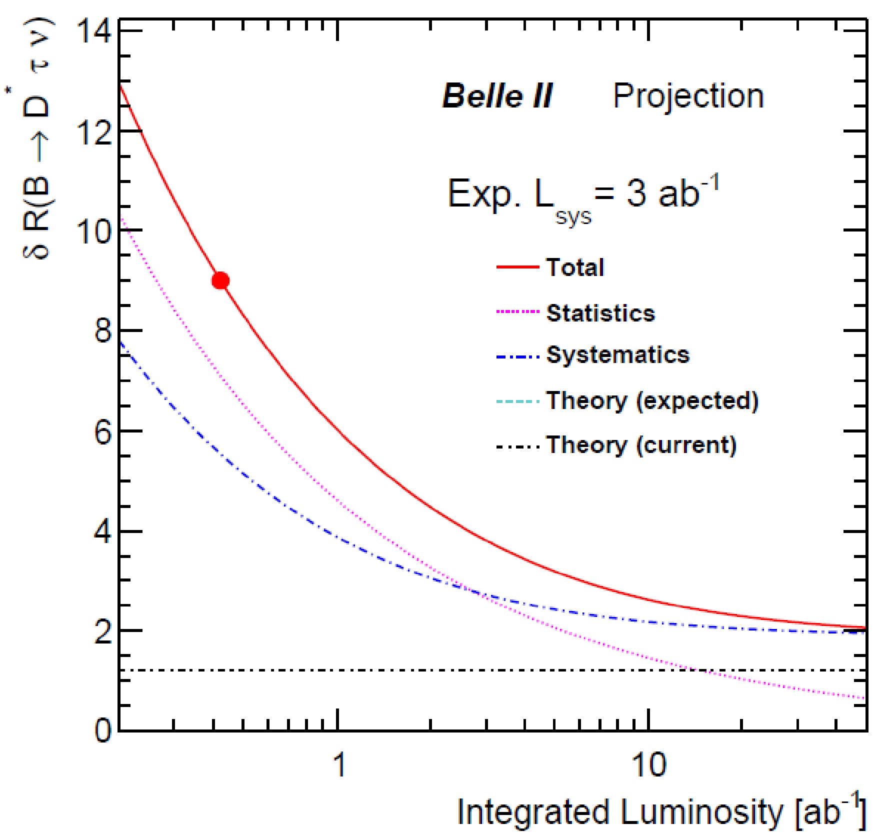
TABLE XLII: Continued from previous page.

	Observables	Belle (2014)	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}	LHCb 2018	LHCb 50 fb^{-1}
Charm Rare	$\mathcal{B}(D_s \to \mu\nu)$	$5.31 \cdot 10^{-3}(1 \pm 5.3\% \pm 3.8\%)$	2.9%	0.9%		
	$\mathcal{B}(D_s \to \tau\nu)$	$5.70 \cdot 10^{-3}(1 \pm 3.7\% \pm 5.4\%)$	3.5%	2.3%		
	$\mathcal{B}(D^0 \to \gamma\gamma)$ [10^{-6}]	< 1.5	30%	25%		
Charm CP	$A_{CP}(D^0 \to K^+K^-)$ [10^{-4}]	$-32 \pm 21 \pm 9$	11	6		
	$\Delta A_{CP}(D^0 \to K^+K^-)$ [10^{-4}]	3.4*			0.5	0.1
	A_Γ [10^{-2}]	0.22	0.1	0.03	0.02	0.005
	$A_{CP}(D^0 \to \pi^0\pi^0)$ [10^{-2}]	$-0.03 \pm 0.64 \pm 0.10$	0.29	0.09		
	$A_{CP}(D^0 \to K_S^0\pi^0)$ [10^{-2}]	$-0.21 \pm 0.16 \pm 0.09$	0.08	0.03		
Charm Mixing	$x(D^0 \to K_S^0\pi^+\pi^-)$ [10^{-2}]	$0.56 \pm 0.19 \pm {}^{0.07}_{0.13}$	0.14	0.11		
	$y(D^0 \to K_S^0\pi^+\pi^-)$ [10^{-2}]	$0.30 \pm 0.15 \pm {}^{0.05}_{0.08}$	0.08	0.05		
	$\lvert q/p \rvert(D^0 \to K_S^0\pi^+\pi^-)$	$0.90 \pm {}^{0.16}_{0.15} \pm {}^{0.08}_{0.06}$	0.10	0.07		
	$\phi(D^0 \to K_S^0\pi^+\pi^-)$ [°]	$-6 \pm 11 \pm {}^{4}_{5}$	6	4		
Tau	$\tau \to \mu\gamma$ [10^{-9}]	< 45	< 14.7	< 4.7		
	$\tau \to e\gamma$ [10^{-9}]	< 120	< 39	< 12		
	$\tau \to \mu\mu\mu$ [10^{-9}]	< 21.0	< 3.0	< 0.3		

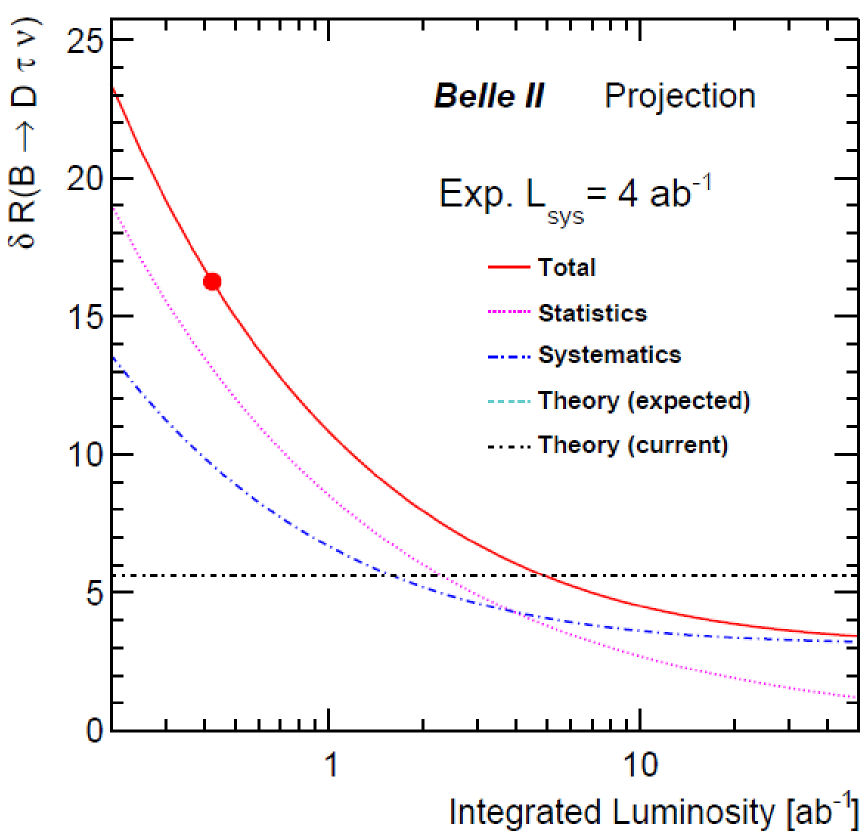
Backup: Belle II: B→τν.



Backup: Belle II B→D*τν and B→Dτν.



(a)$B \to D^* \tau \nu$

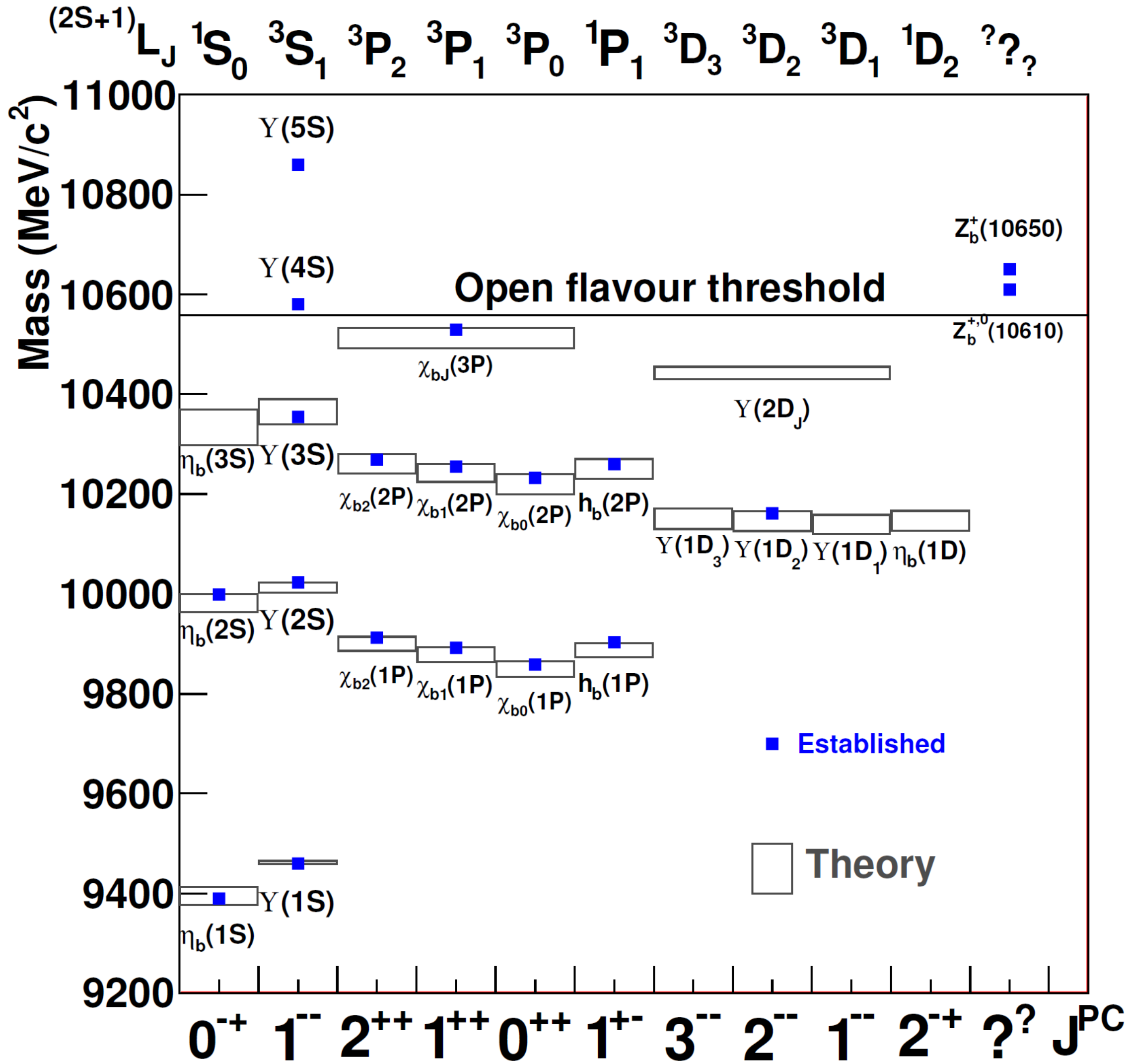


(b)$B \to D \tau \nu$

Backup: First physics "Bottomonium below Υ(4S)".

$\eta_b(1S)$	Resolve discrepancies on the mass and width, based on measurements of radiative transitions.
$\eta_b(2S)$	Independent confirmation of $\Upsilon(2S)$ properties, and tests of hyperfine splitting against theoretical predictions.
$\Upsilon(1^3D_1)$, $\Upsilon(1^3D_3)$	Precise measurement of multi-photon cascade decays to separate $J = 1,\ 3$ (not seen) states from the $J = 2$ (seen) state.
$\Upsilon(1^3D_1)$	Inclusive photon spectra of $\Upsilon(3S)$ decays.
R_b near $\Upsilon(3S)$, $\Upsilon(2^3D_2)$-triplet	Search for unseen $\Upsilon(1D)$ states and the unseen $\Upsilon(2^3D_2)$ triplet via R_b scan methods.
h_b	First observation and resonance characterisation.
Inclusive decays (χ_b, Υ)	Surveys of inclusive hadronic transitions of χ_b and $\Upsilon(2S,\ 3S)$.
Dipion transitions	Surveys of dipion transitions between χ_b states (analogous to Υ).

Backup: First physics "Bottomonium below Υ(4S)".



Backup: First physics "Bottomonium above Υ(4S)".

R_b	Inclusive b cross section as a function of E_{CM} up to $\Upsilon(6S)$
Z_b from scans	Analysis of $\pi + Z_b$ substructure through $\sigma(\Upsilon + 2\pi)$ and $\sigma(h_b(nP) + 2\pi)$ through an E_{CMscan}
Z_b near resonance	Analysis of Z_b charged and neutral from $\Upsilon(6S)$
Tetra quark states	Analysis of radiative or 2π transitions from $\Upsilon(6S)$
Other exotica	Searches for exotic states with single π transitions from $\Upsilon(5S)$ and $\Upsilon(6S)$
$\sigma(B^{(*)}B^{(*)})$ and $\sigma(B_s^{(*)}B_s^{(*)})$	
W_b, X_b	Studies of radiative transitions from $\Upsilon(6S)$ to new bottomonium-like states and χ_{bJ}.
m_b	Accurate determination of m_b via bottomonium sum-rules. Precision tests of discrepancies between pQCD and e^+e^- data near the accelerator threshold region.

Backup: First physics “Bottomonium above Υ(4S)”.