Towards First Physics at Belle II

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Matter To The Deepest, Ustron, 16.09.2015

HELMHOLTZ ASSOCIATION

Belle II

DESY

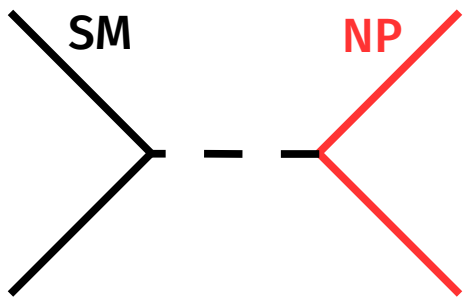
Overview.

- First Generation of B-Factories
- Belle II at SuperKEKB
- Towards First Physics at Belle II
- B2TIP – Belle II Theory Interface Platform
- Conclusions

Motivation for Belle II: Flavour Frontier.

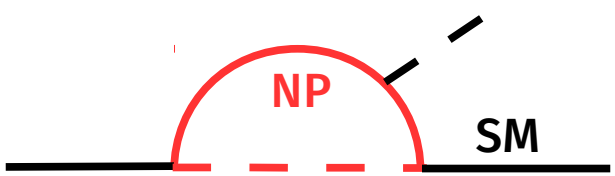
Energy frontier:

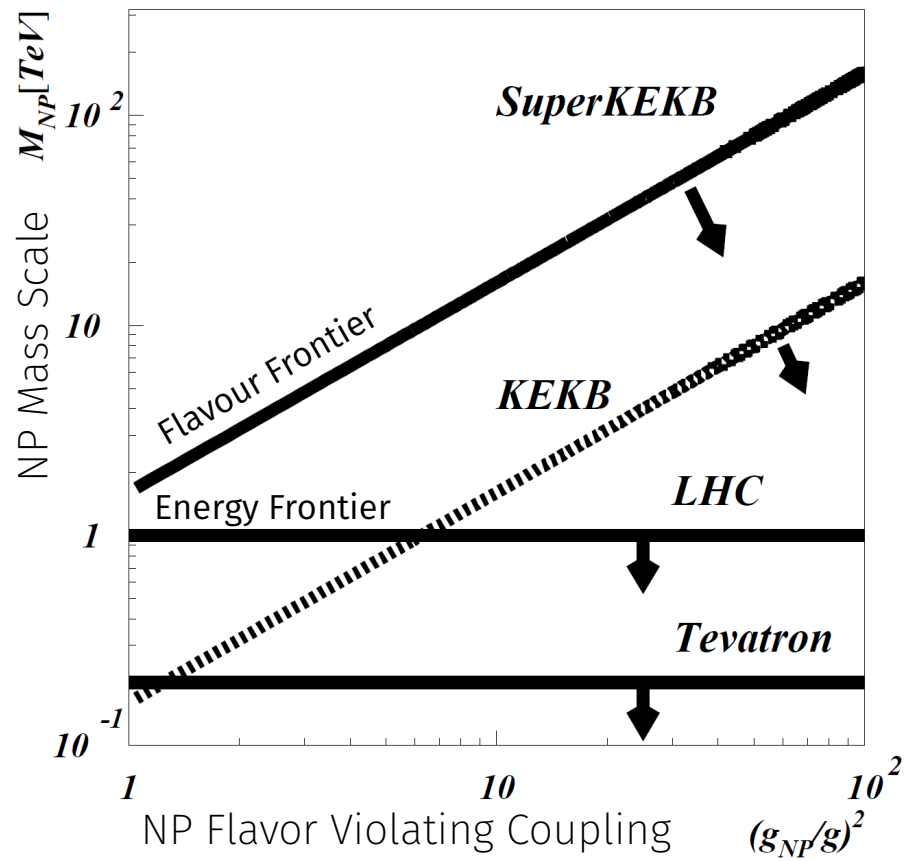
- Production of New Physics (NP) from collisions
- Limited by beam energy



Intensity frontier:

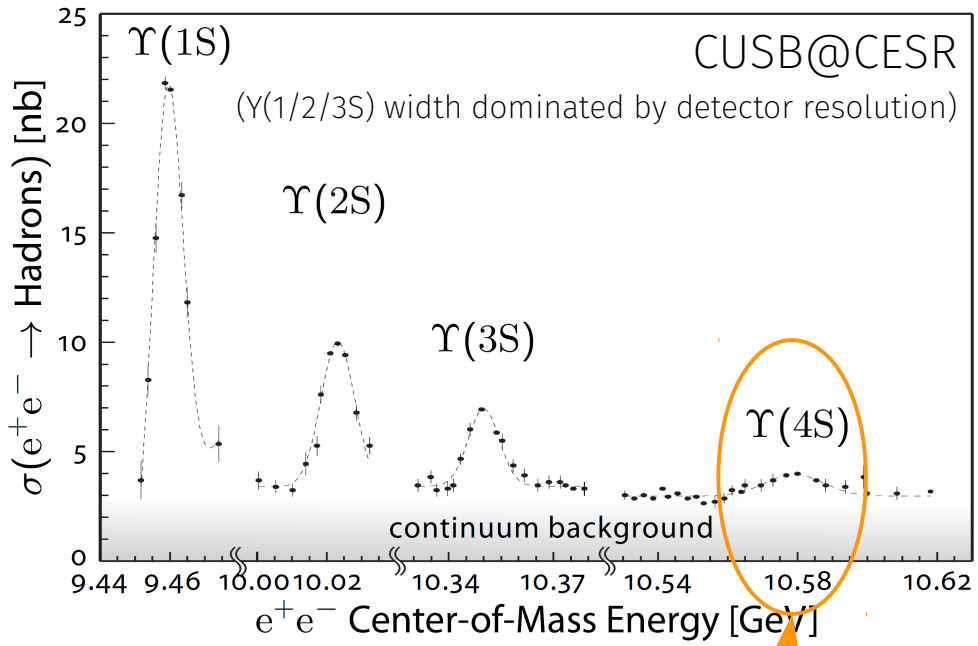
- NP in Virtual processes

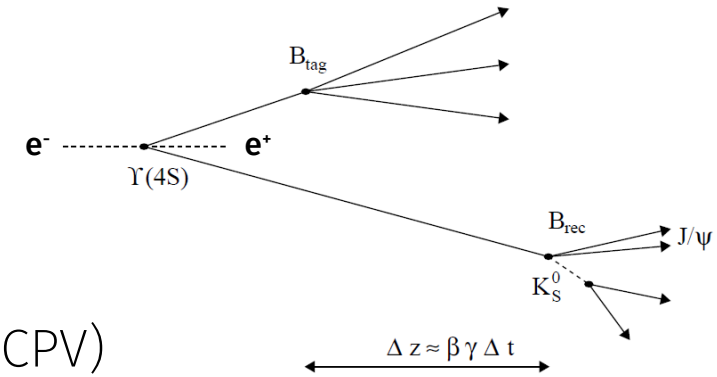




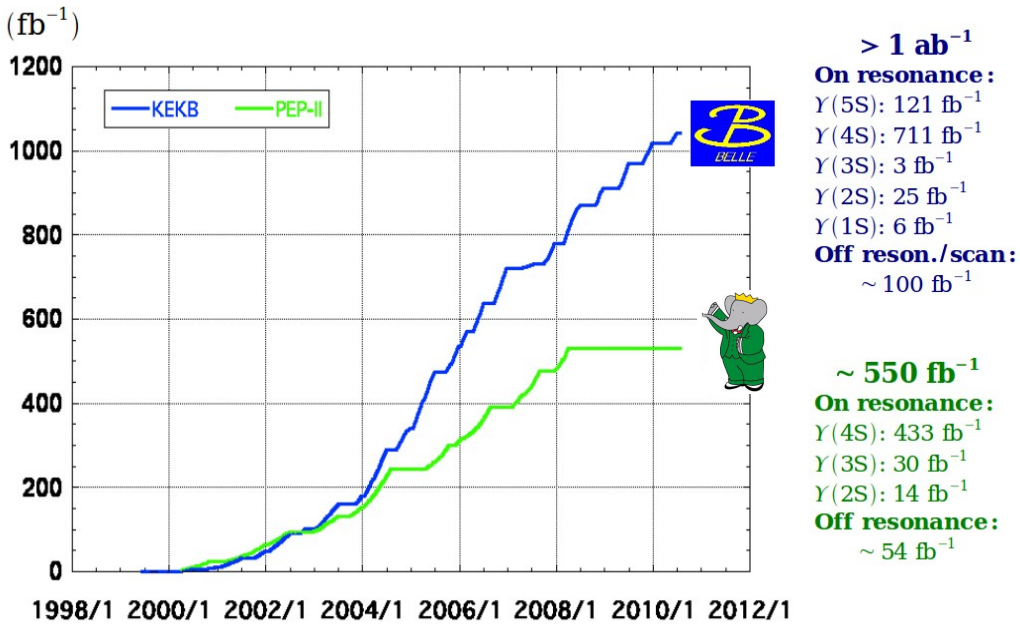
First generation of B-Factories.

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





First generation of 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**

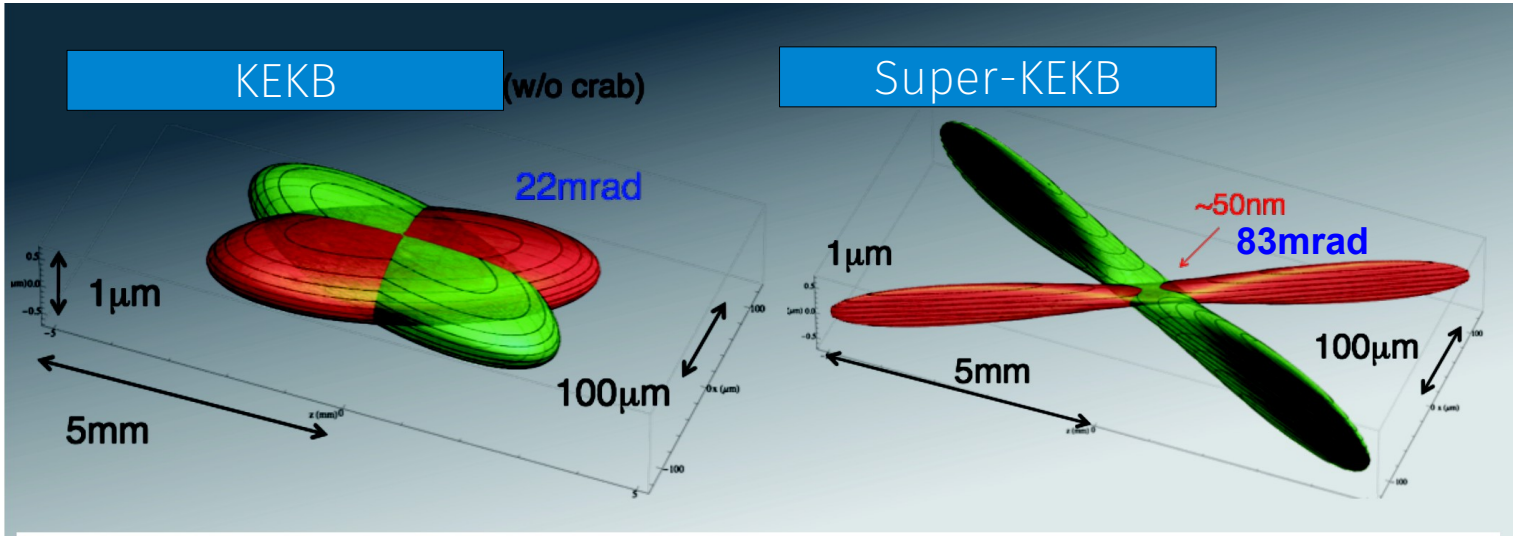
- At Belle:
  - About 772 million $B\bar{B}$ pairs
  - About 900 million tau and muon pairs each
- Still many analyses remain statistically limited

Nano beam scheme at SuperKEKB.

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

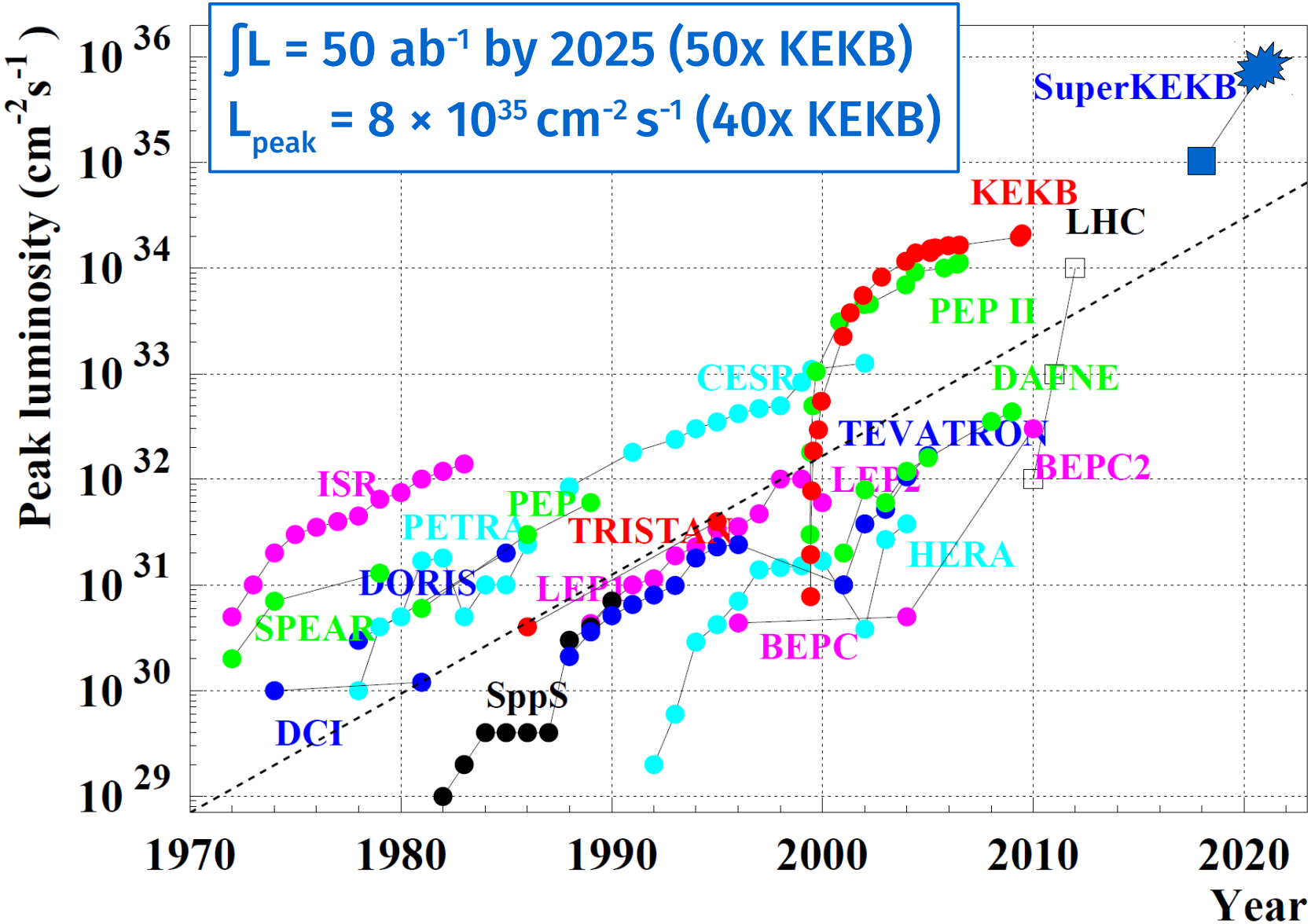


	E (GeV) LER/HER	β^*_y (mm) LER/HER	β^*_x (cm) LER/HER	φ (mrad)	I (A) LER/HER	L ($cm^{-2}s^{-1}$)
KEKB	3.5/8.0	5.9/5.9	120/120	11	1.6/1.2	2.1×10^{34}
SuperKEKB	4.0/7.0	0.27/0.30	3.2/2.5	41.5	3.6/2.6	80×10^{34}

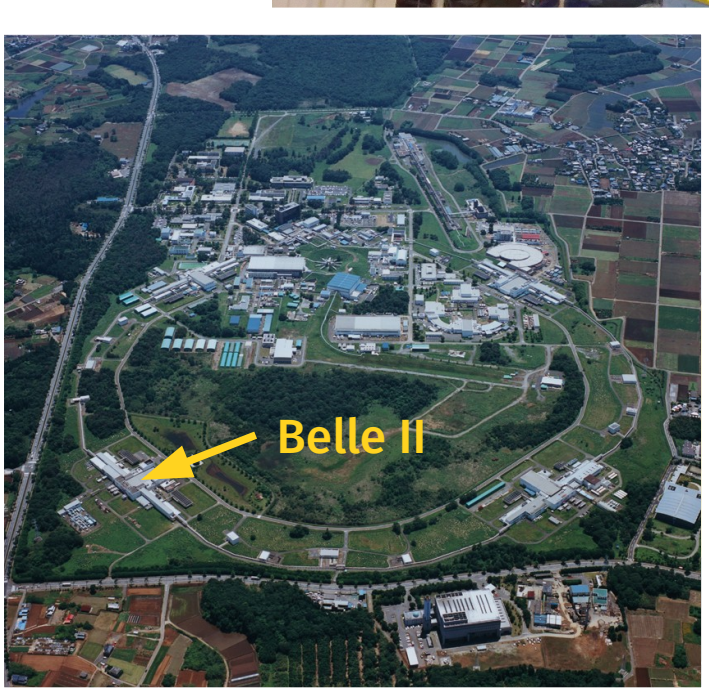
factor 20

factor 2-3

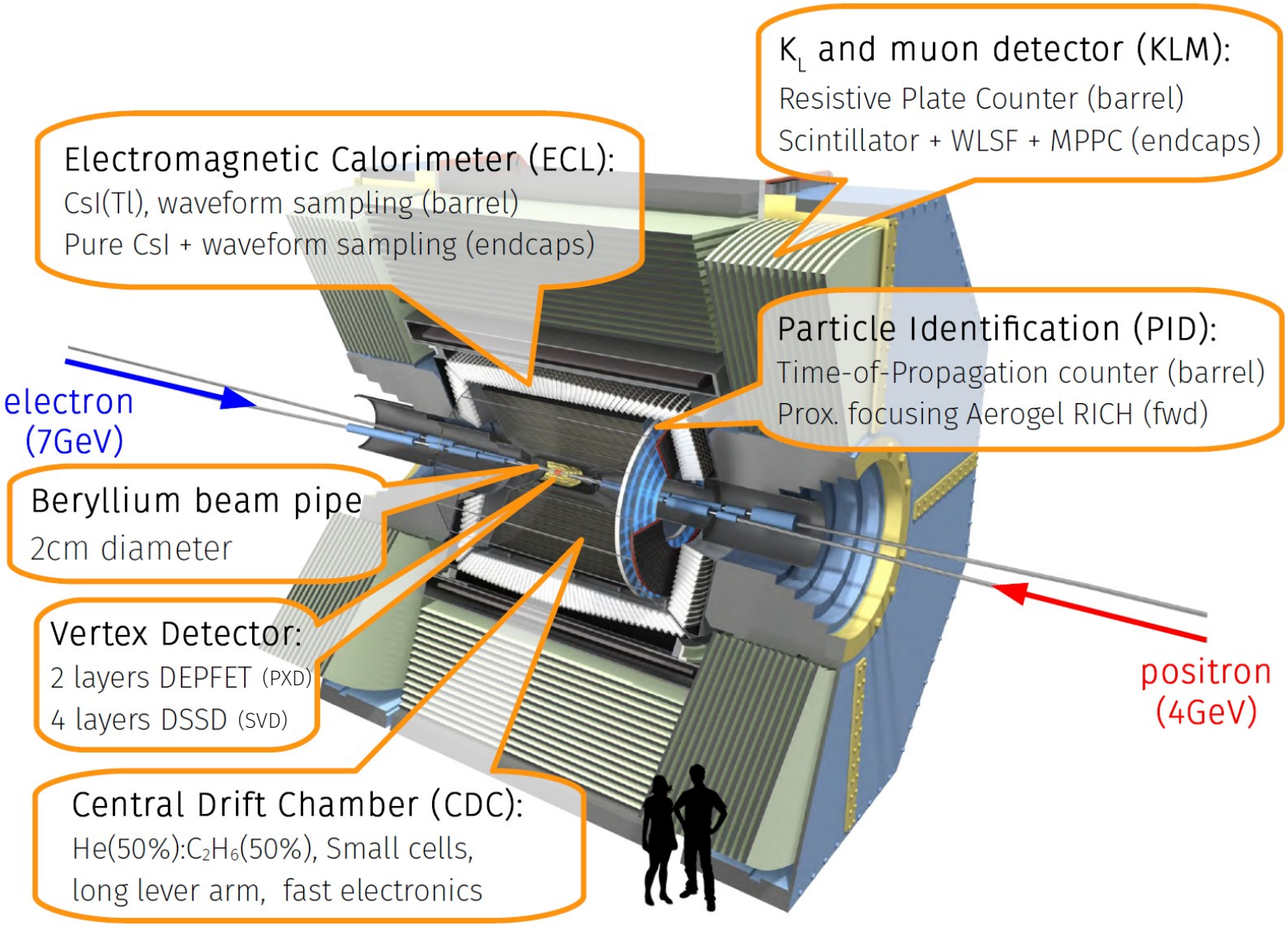
From KEKB to SuperKEKB.



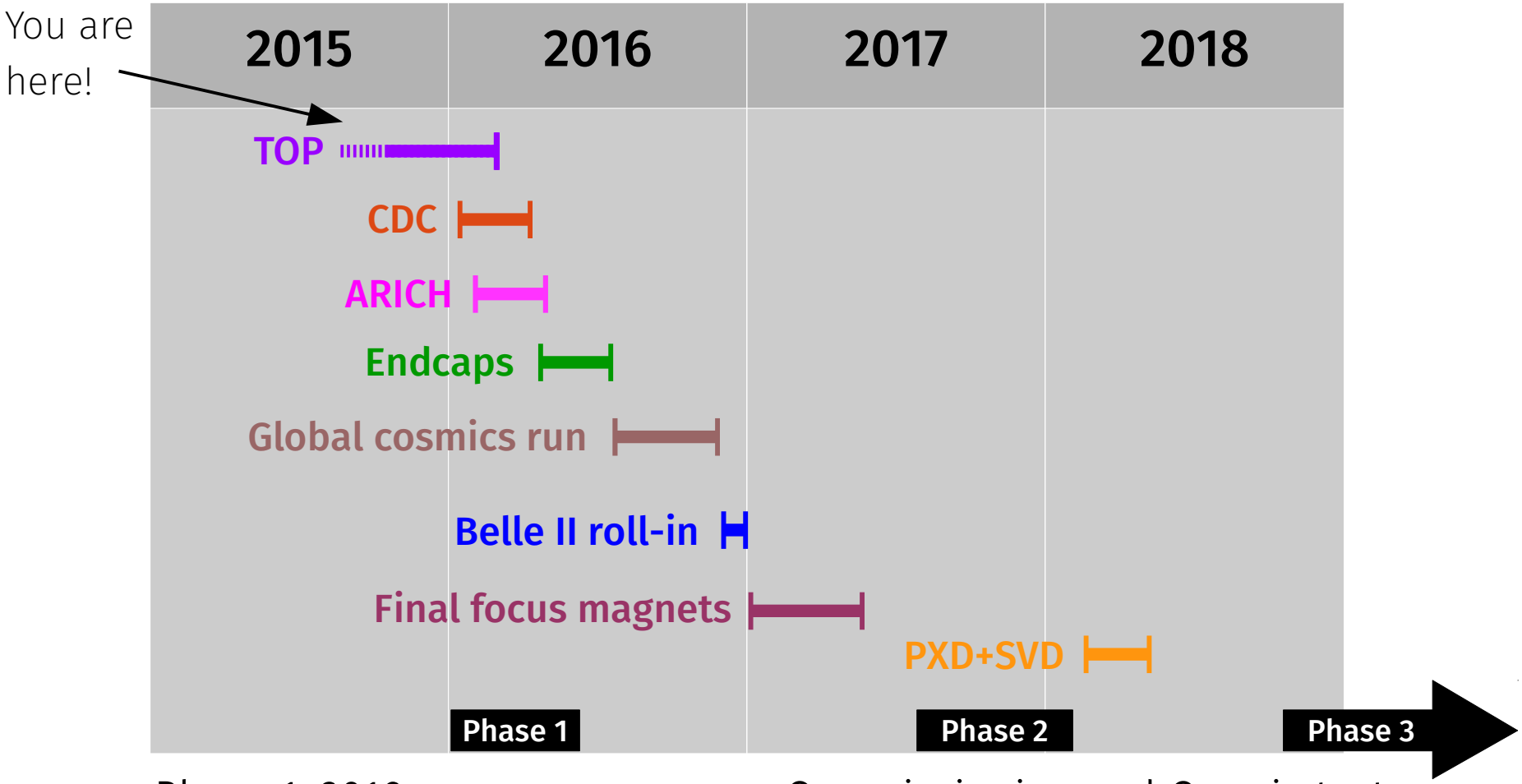
Belle II Detector at SuperKEKB.



Detector Upgrade: Belle II at SuperKEKB.



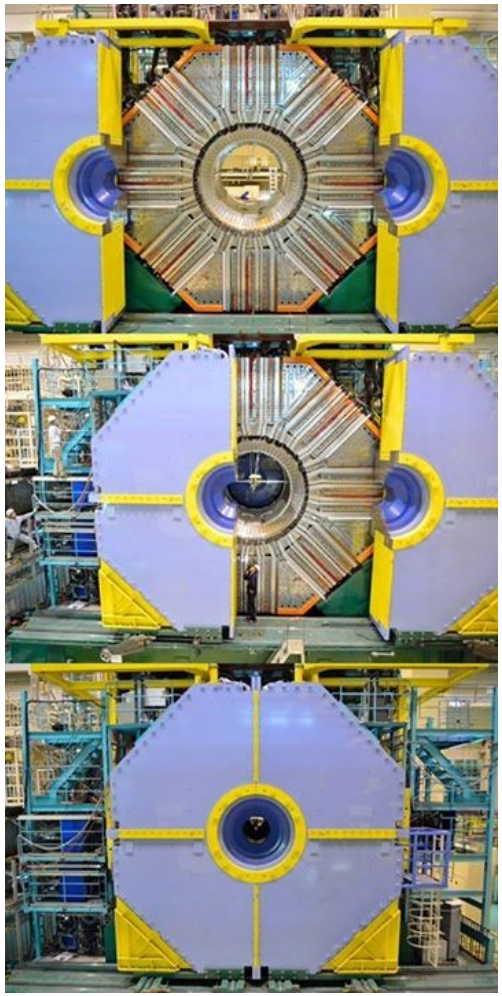
Schedule.



Phase 1: 2016	Commissioning and Cosmic test
Phase 2: Mid 2017- Early 2018	Commissioning and physics with partial Belle II detector
Phase 3: Oct 2018-2024(+)	Physics with full Belle II detector

Schedule.

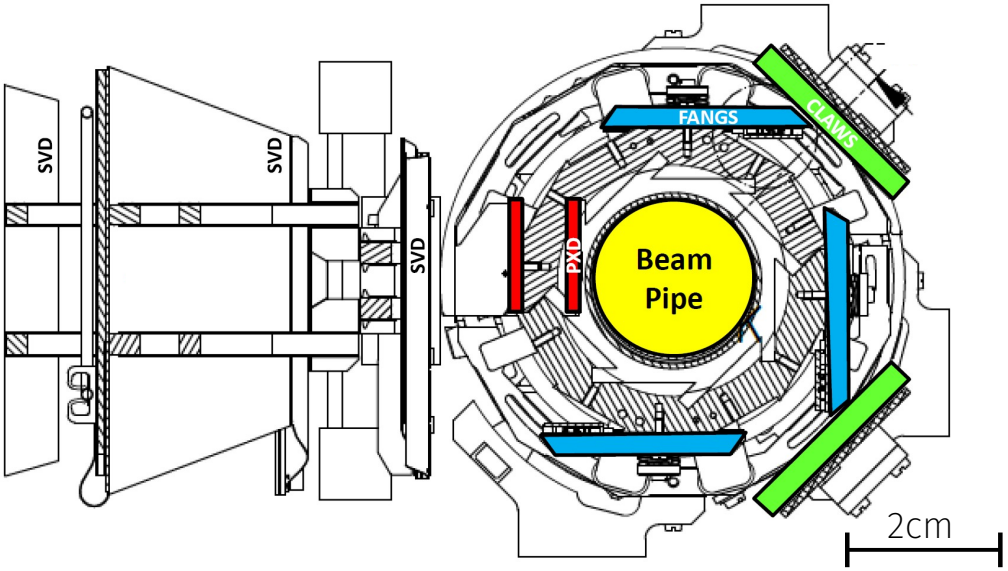
Preparation of the
Belle II solenoid test



Interaction region for Phase 1

Towards First Physics: Phase 2.

- Mid 2017: Belle II without nominal vertex detectors but with final calorimeter, drift chamber, etc.
- Main goals:
  - Measure beam bkg.
  - Tune accelerator
- Conditions (expected):
  - E_{CMS}=10.58GeV
  - L_{int} = (0-300) fb^{-1} ~ only 1/3 Belle



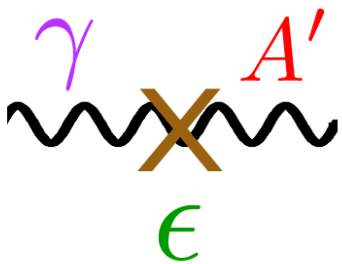
→ Unique physics with that dataset possible?

Towards First Physics: Dark Photon.

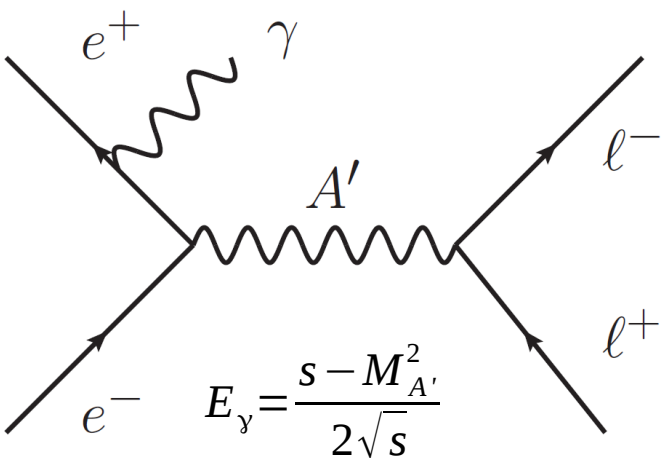
- Dark Photon motivated by dark matter, g-2 anomaly...
- Minimal dark matter model: Dark matter particle χ and a new scalar or gauge boson A' as s-channel annihilation mediator ($m_{A'} > 2m_\chi$)

*Holdom, Phys. Lett B166, 1986

- Additional U(1)' symmetry → "Kinetic Mixing"* of massive dark photon A' with the SM photon

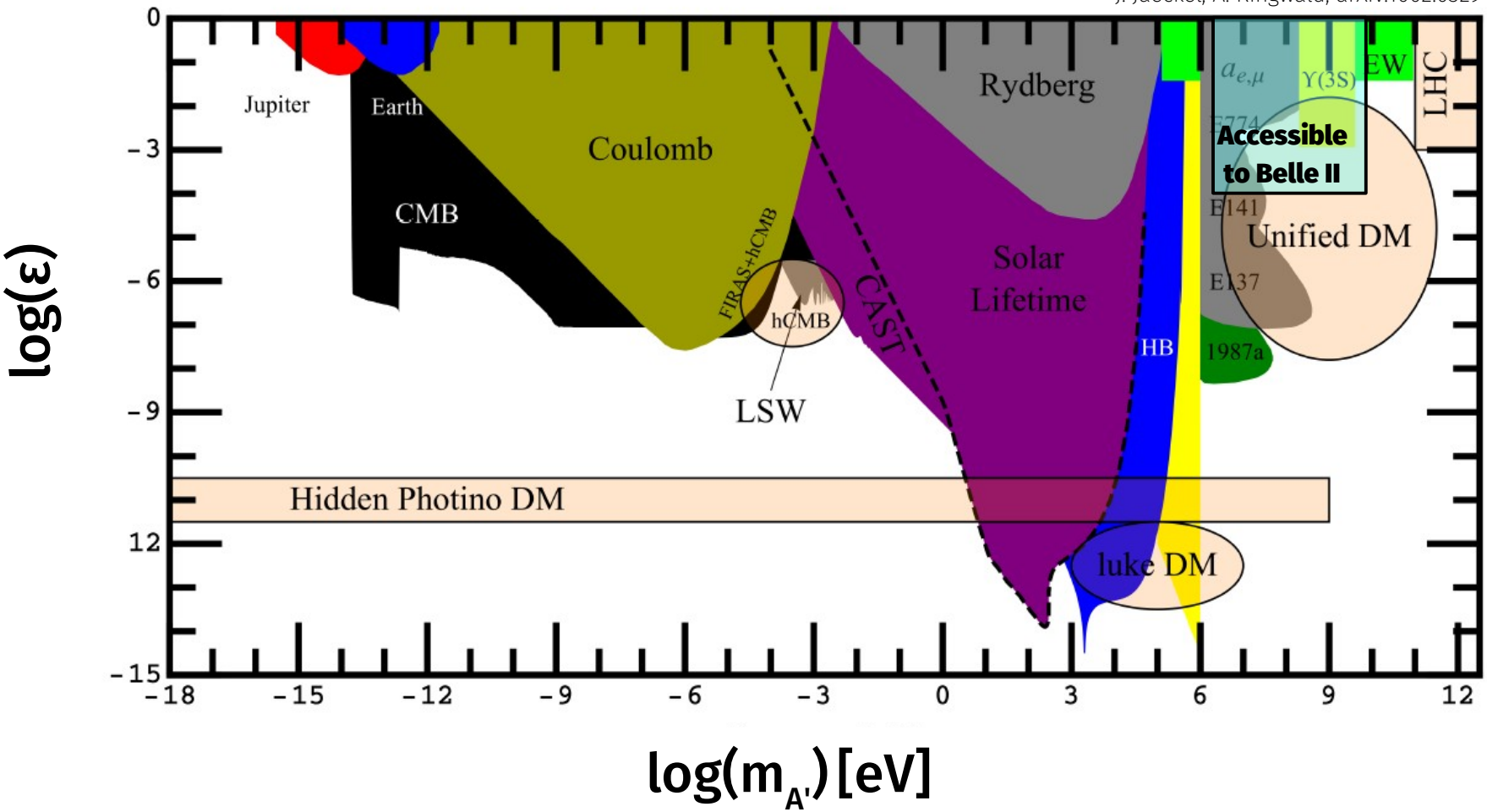


$$\Delta\mathcal{L} = \frac{\epsilon}{2} F^{Y,\mu\nu} F'_{\mu\nu}$$



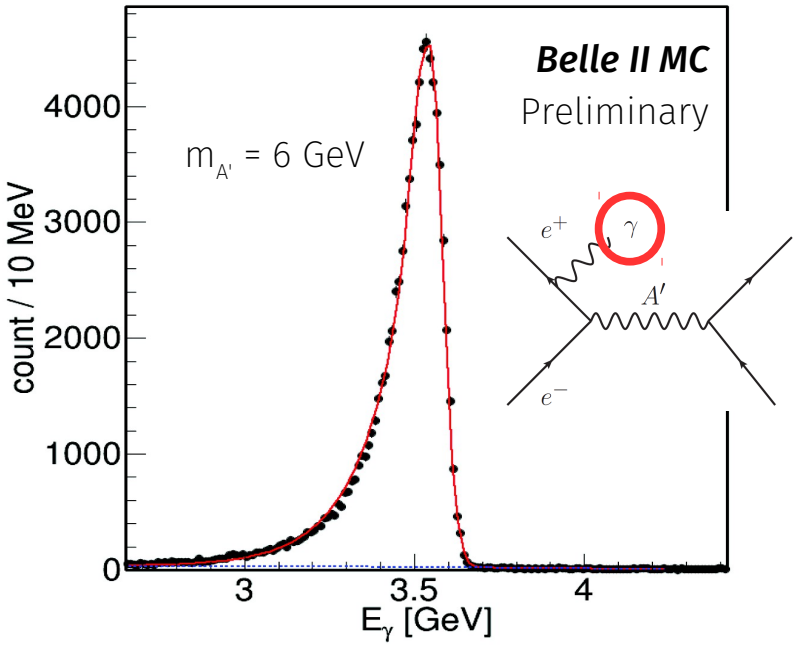
Towards First Physics: Dark Photon.

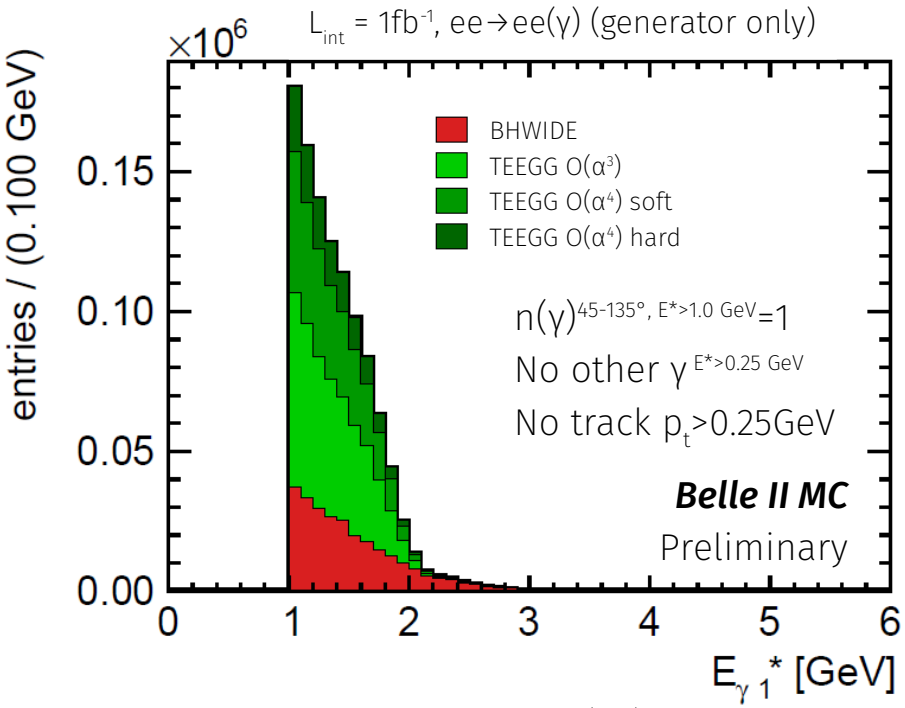
J. Jaeckel, A. Ringwald, arXiv:1002.0329



Towards First Physics: Dark Photon decay to invisible.

- If A' is not the lightest DM particle:
  Decay into dark matter dominates: $ee \to A'\gamma$, $A' \to \chi\bar{\chi}$
- SM background: $ee \to ee(\gamma)$ and $ee \to \gamma\gamma$

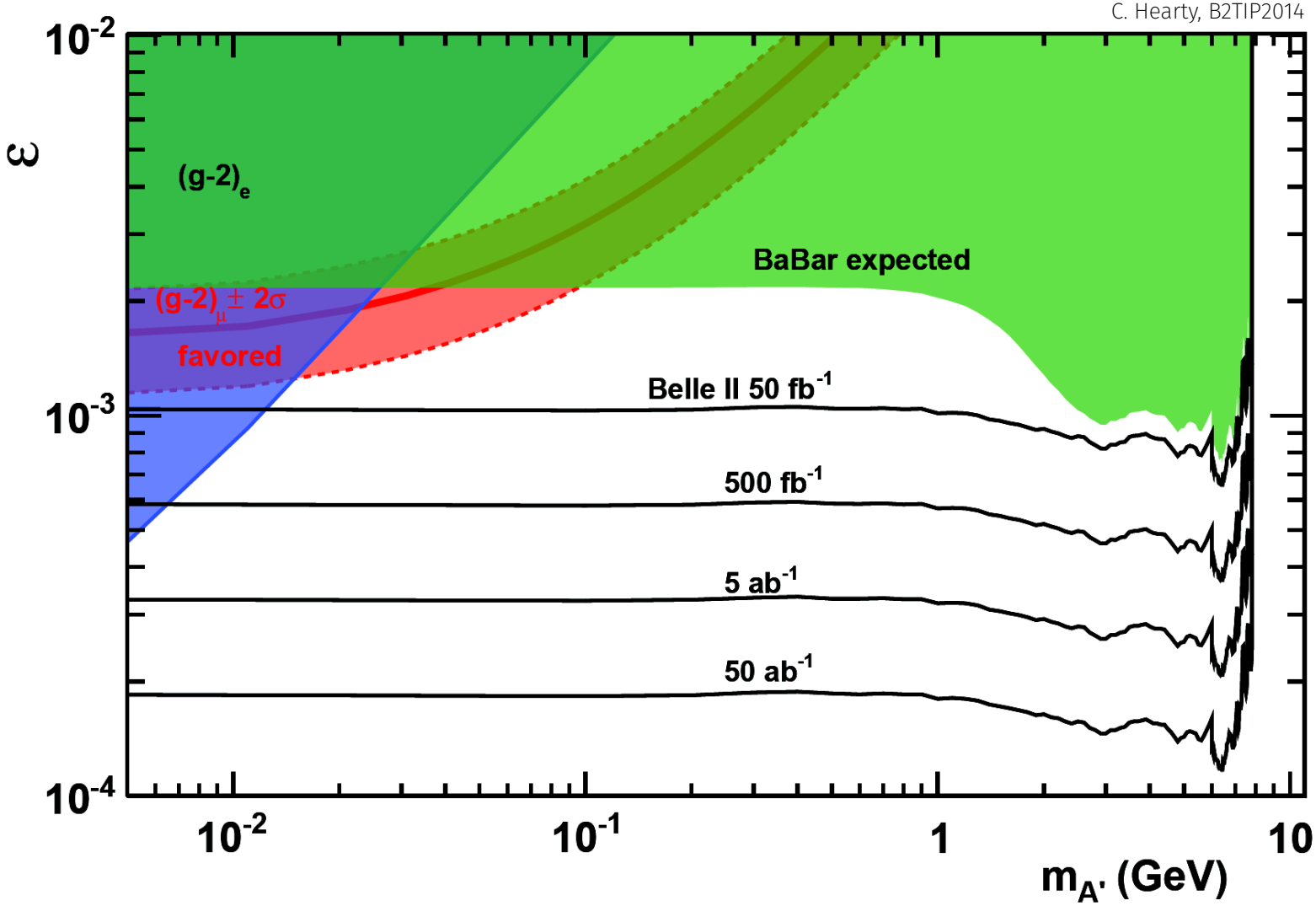




BHWIDE: Jadach et al., Phys. Lett. B 390, 298 (1997)
TEEGG: Karlen, Nucl. Phys. B289, 23 (1987)

Towards First Physics: Dark Photon decay to invisible.

Y(3S) →γA⁰[A⁰-> Invisible], BABAR-CONF-08/019, arXiv: 0808.0017
limit: e.g. Essig et al., arXiv: 1309.5084
C. Hearty, B2TIP2014



Towards First Physics: Planned Low Multiplicity Trigger.

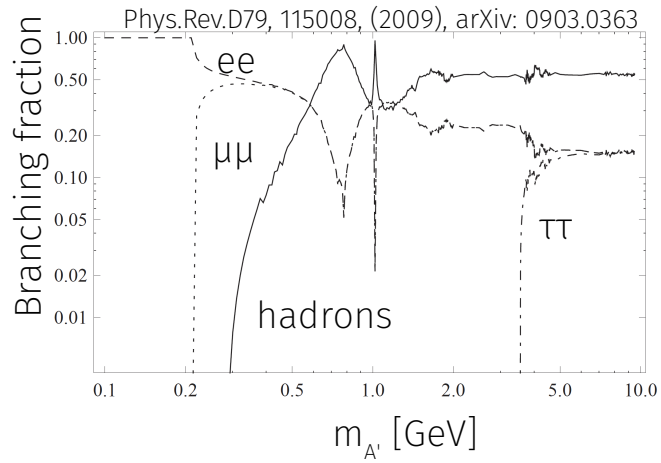
- Two stage trigger: Hardware (L1) + Software (HLT)
- Fixed latency: 5μs, Bunch spacing: 2ns, ε>99% for $B\overline{B}$

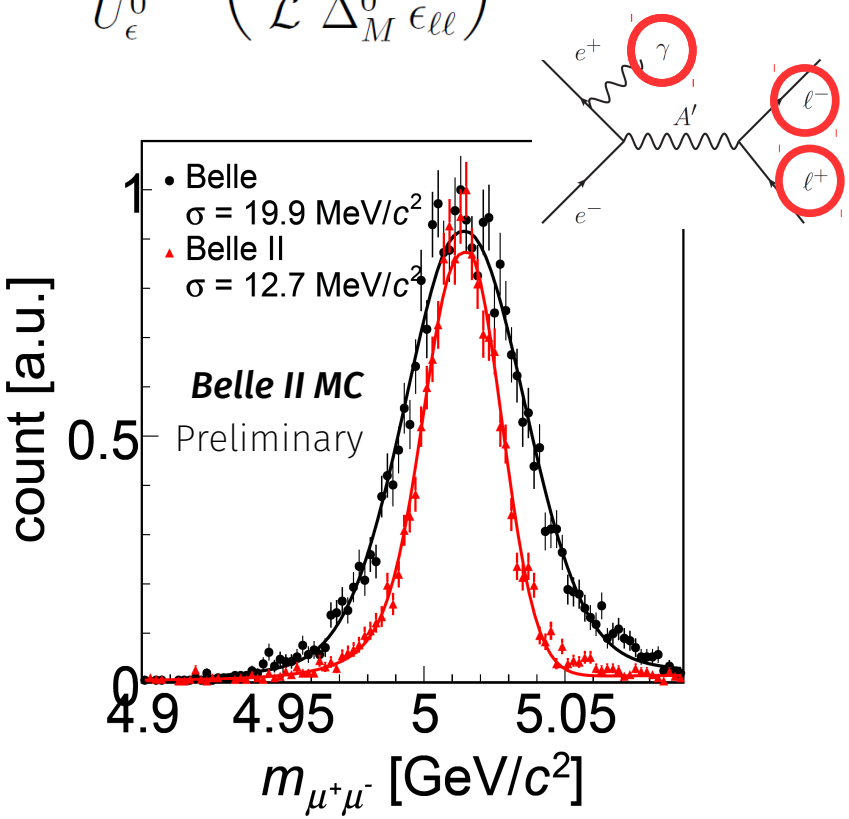
Single Photon	Bhabha	ISR (e.g. ππγ)	Two track
	Belle: •f(θ) veto •fix prescales		**Belle:** •CDC+KLM •CDC+TOF
Belle II: Calorimeter (ECL): •~1 GeV barrel •~2 GeV endcap	**Belle II:** •f(θ, φ) 'pure' veto •'efficient' accept •f($\theta^{+/-}$) prescales	**Belle II:** •1 ECL ~0.5GeV and ≥1 track (back to back)	**Belle II:** •CDC only •KLM only •Single track

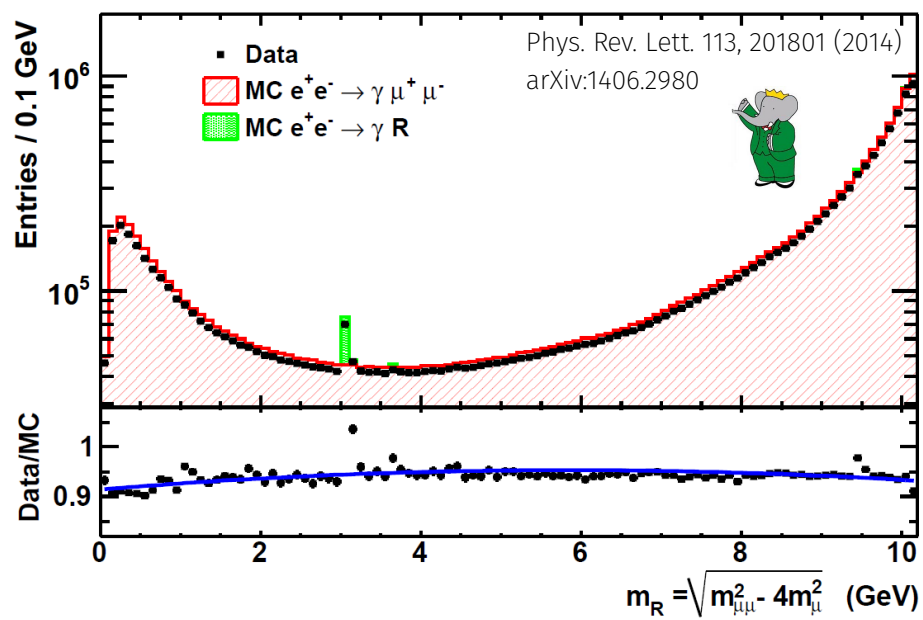
Towards First Physics: Dark Photon decay to visible.

- If A' is the lightest DM particle: Decay into SM matter dominates

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

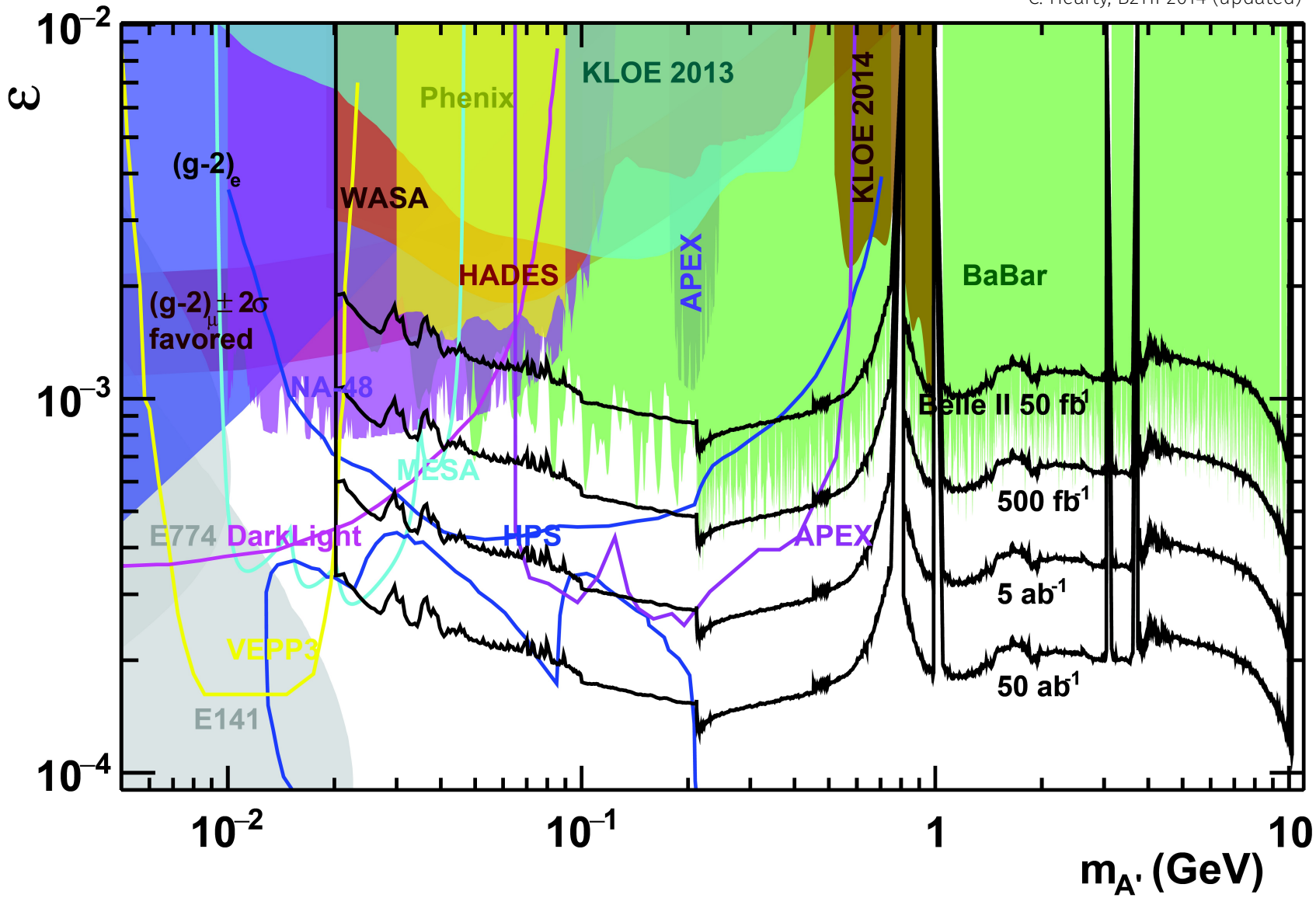






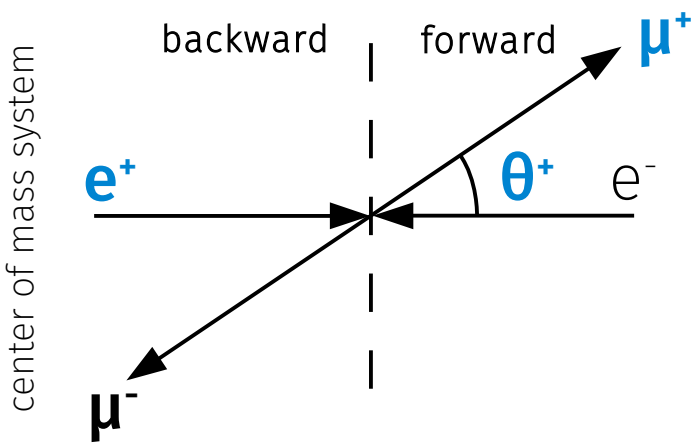
Towards First Physics: Dark Photon decay to visible.

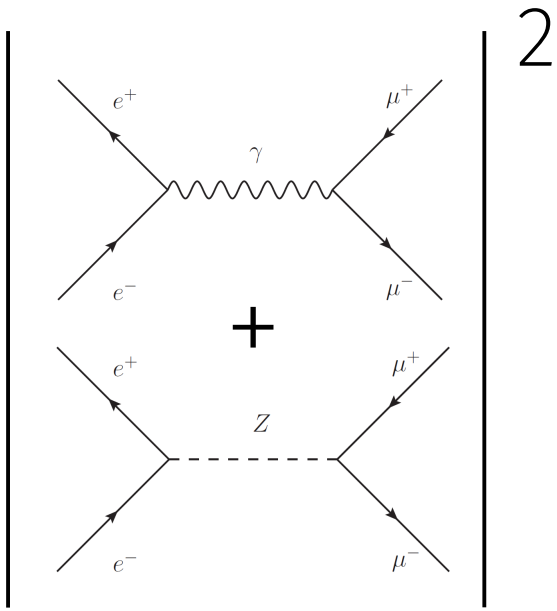
C. Hearty, B2TIP2014 (updated)



Low Multiplicity Physics at Belle II: AFB.

- Preferred direction of muons produced in e^+e^- collisions?
  $\rightarrow A_{FB}=(N_F-N_B)/(N_F+N_B)$
- 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 $s<m_Z^2$





Low Multiplicity Physics at Belle II: AFB.

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

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

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

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

with

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

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

Low Multiplicity Physics at Belle II: AFB.

asymmetric

symmetric

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

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

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

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

with

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

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

Low Multiplicity Physics at Belle II: AFB.

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

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

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

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

with

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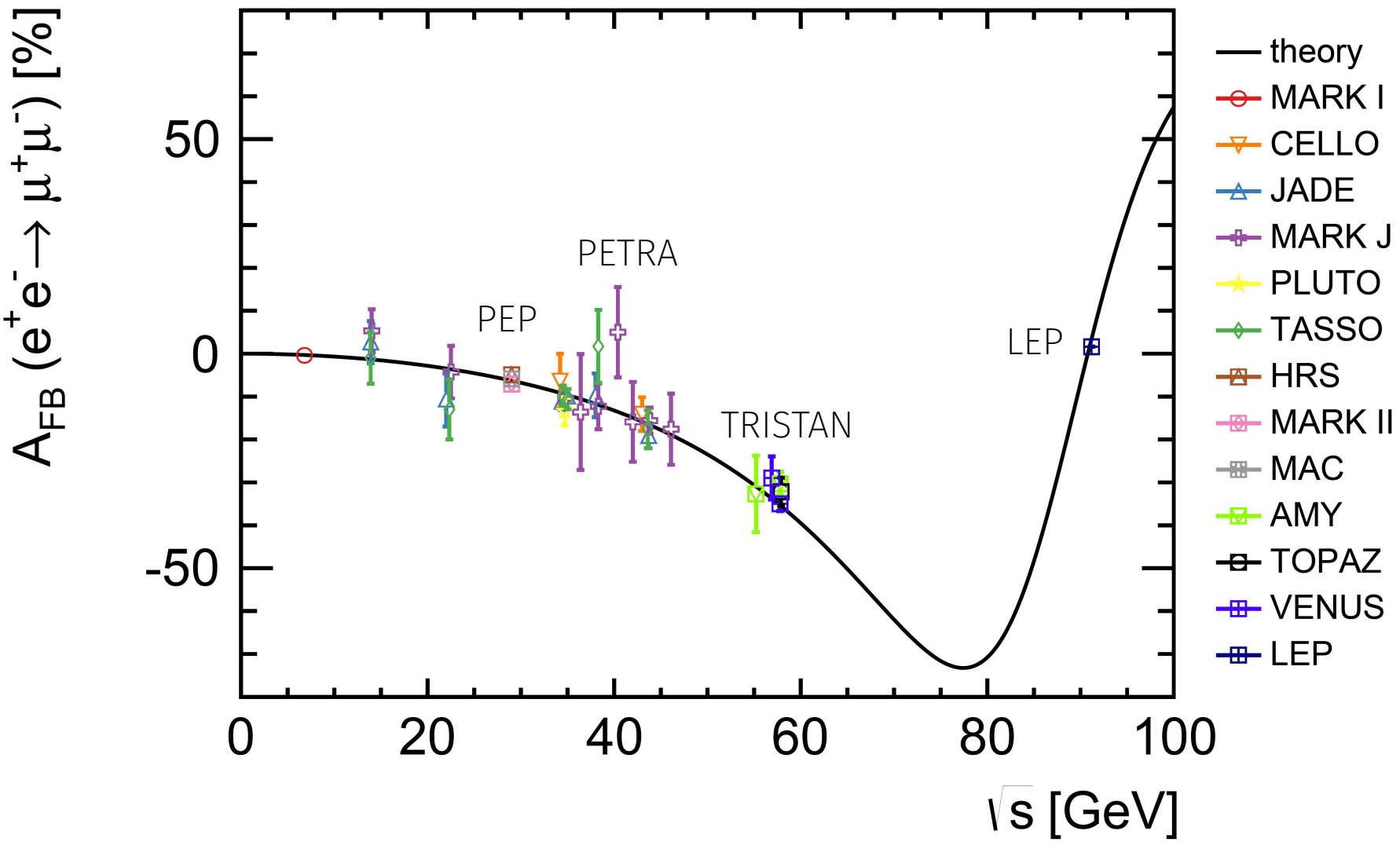
$$\mathcal{G}_{\mathrm{V}f} = \sqrt{\mathcal{R}_f}\left(T_3^f - 2\sin^2\theta_W^{\mathrm{eff.}}\right)$$

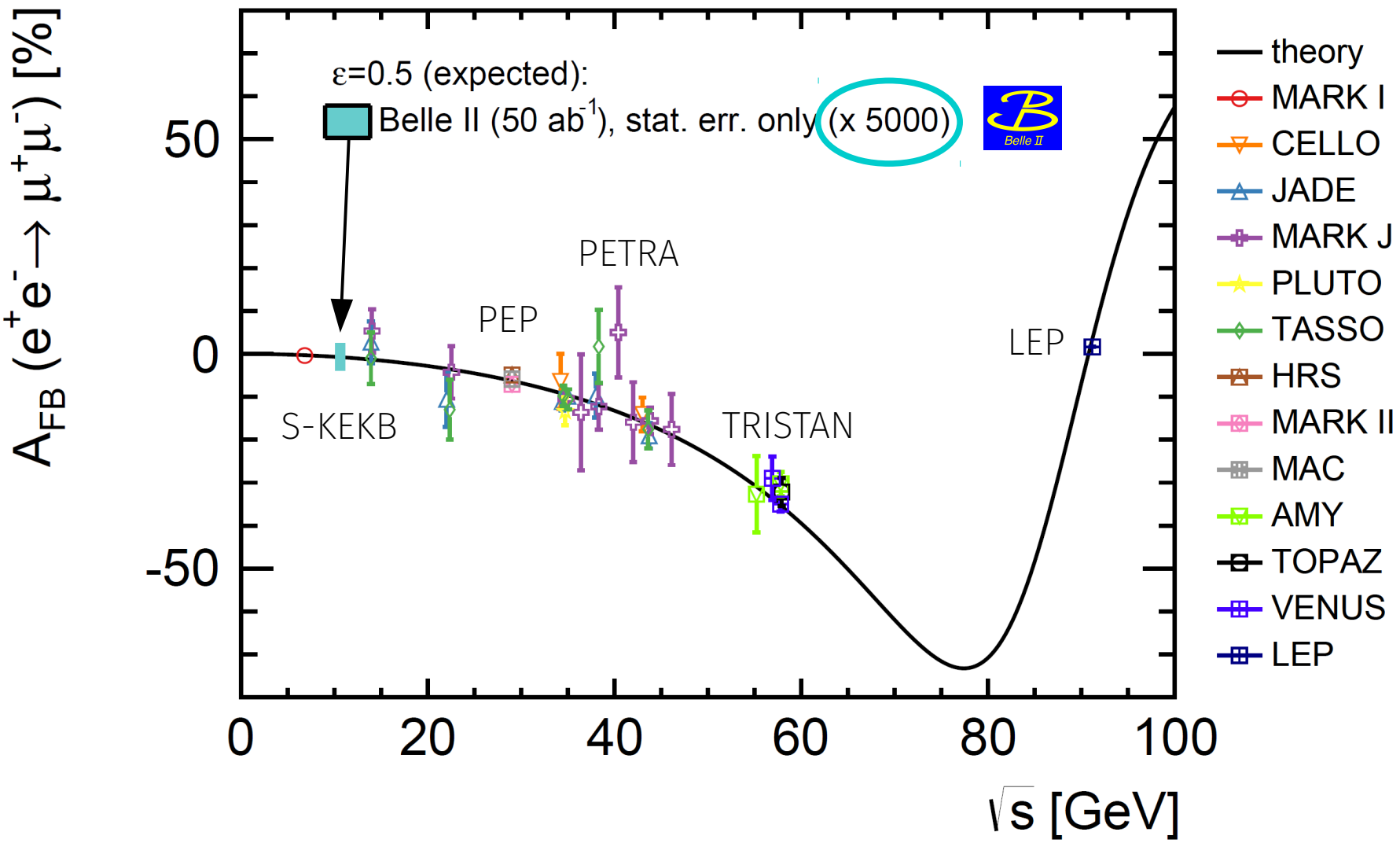
ρ parameter

weak mixing angle

Low Multiplicity Physics at Belle II: AFB.



Low Multiplicity Physics at Belle II: AFB.



Low Multiplicity Physics at Belle II: AFB.

- 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 (~25 billion μ-pairs):
  - $A_{FB} \sim \rho g_A^2$ (dominated by interference $\sigma_{\gamma Z}$) → Only sensitive to **ρ**
  - 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: ZFITTER*, KKMC**, ...) and detector charge asymmetry

*Bardin et al., Comput.Phys.Commun. 133, 229 (2001)
Bardin et al., Comput.Phys.Commun. 174, 728 (2006)
**Jadach et al., Comput.Phys.Commun. 130, 260-325 (2000)
Jadach et al., Phys. Rev. D63, 113009 (2001)

- Under study:
  - Fine tuning of two track trigger (single track trigger are crucial)
  - For extraction of **ρ** from measured A_{FB}: ISR-FSR interference?

Belle II Theory Interface Platform (B2TIP).

- Joint theory-experiment effort to study the potential impacts of the Belle II program
- Eight physics WGs + one “New Physics” WG
- Topics covered in this talk:
  WG8 “Tau, low multiplicity and electroweak”
- KEK Green report (~400 pages) end of 2016

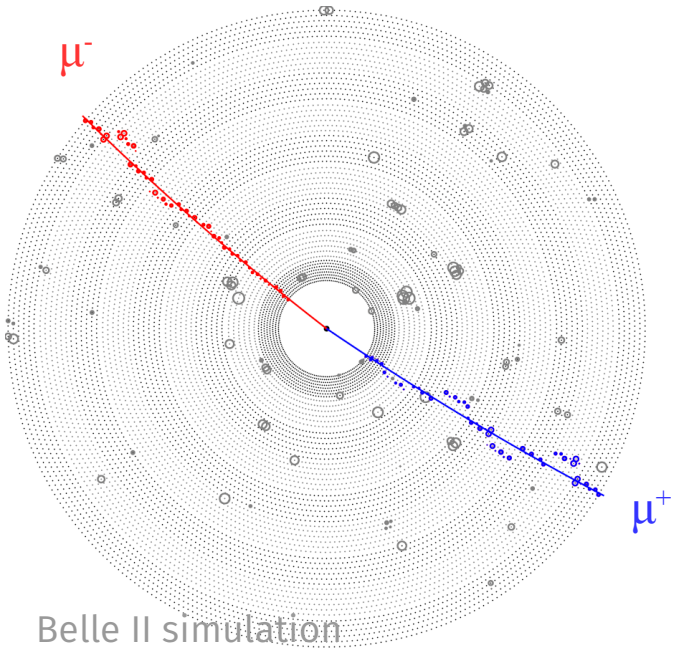
Next open B2TIP meeting: 28.-29.10.2015, KEK (Japan)

https://kds.kek.jp/indico/event/19103/

Summary.

- Belle II offers high sensitivity to New Physics at the Flavour frontier, largely complementary to LHCb
- Broad low multiplicity program at Belle II, including Dark Sector, ISR and Electroweak Precision Physics
- Significantly improved two track trigger, better Bhabha veto and single photon trigger planned
- Belle II physics data taking will start 2018, first data with partial detector in 2017

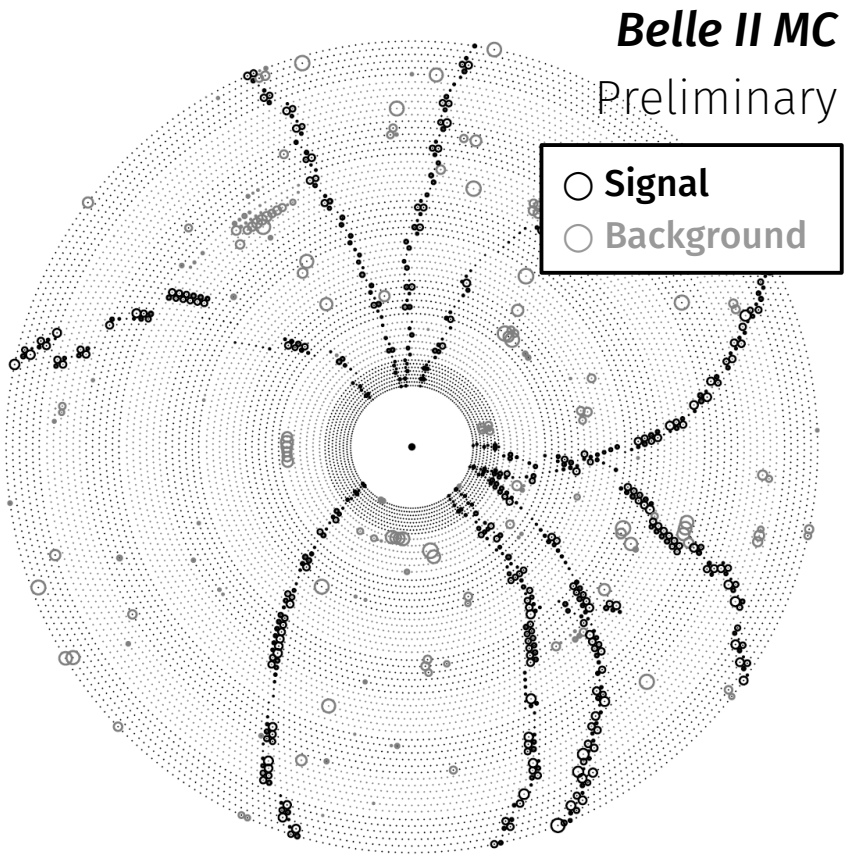
Backup



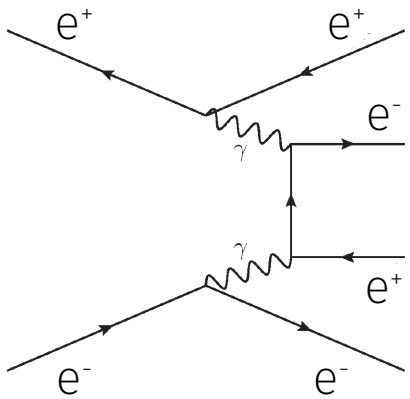
Backup: Background for Tracking Detectors.

- Main background in Central Drift Chamber:
  - Radiative Bhabha and Touschek

    → **Huge effort to reduce backgrounds by collimators and shielding**



- Main background in VTX:
  - Two Photon QED



Backup: Belle II and LHCb.

PRELIMINARY

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*	Belle II		LHCb	
		(2014)	5 ab^{-1}	50 ab^{-1}	8 fb^{-1}(2018)	50 fb^{-1}
UT angles	$\sin 2\beta$	$0.667 \pm 0.023 \pm 0.012(0.9°)$	0.4°	0.3°	0.6°	0.3°
	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		
	$S(B \to K^0_S K^0_S K^0_S)$	$0.30 \pm 0.32 \pm 0.08$	0.100	0.033		
	$\beta_s^{\rm eff}(B_s \to \phi\phi)$ [rad]	$-0.17 \pm 0.15 \pm 0.03^*$			0.12	0.03
	$\beta_s^{\rm eff}(B_s \to K^{*0}\bar{K}^{*0})$ [rad]	–			0.13	0.03
Direct CP in hadronic Decays	$\mathcal{A}(B \to K^0\pi^0)$	$-0.05 \pm 0.14 \pm 0.05$	0.07	0.04		
UT sides	$\lvert V_{cb}\rvert$ incl.	$41.6 \cdot 10^{-3}(1 \pm 2.4\%)$	1.2%			
	$\lvert V_{cb}\rvert$ excl.	$37.5 \cdot 10^{-3}(1 \pm 3.0\%_{\rm ex.} \pm 2.7\%_{\rm th.})$	1.8%	1.4%		
	$\lvert V_{ub}\rvert$ incl.	$4.47 \cdot 10^{-3}(1 \pm 6.0\%_{\rm ex.} \pm 2.5\%_{\rm th.})$	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		
	$S(B \to K^0_S\pi^0\gamma)$	$-0.10 \pm 0.31 \pm 0.07$	0.11	0.035		
	$2\beta_s^{\rm eff}(B_s \to \phi\gamma)$	–			0.13	0.03
	$S(B \to \rho\gamma)$	$-0.83 \pm 0.65 \pm 0.18$	0.23	0.07		
	$\mathcal{B}(B_s \to \gamma\gamma)$ $[10^{-6}]$	< 8.7	0.3	–		
Electroweak penguins	$\mathcal{B}(B \to K^{*+}\nu\bar{\nu})$ $[10^{-6}]$	< 40	< 15	30%		
	$\mathcal{B}(B \to K^+\nu\bar{\nu})$ $[10^{-6}]$	< 55	< 21	30%		
	C_7/C_9 $(B \to X_s\ell\ell)$	~20%	10%	5%		
	$\mathcal{B}(B_s \to \tau\tau)$ $[10^{-3}]$	–	< 2	–		
	$\mathcal{B}(B_s \to \mu\mu)$ $[10^{-9}]$	$2.9^{+1.1}_{-1.0}{}^*$			0.5	0.2

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Backup: Belle II and LHCb.

PRELIMINARY

	Observables	Belle or LHCb* (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		
	$\Delta A_{CP}(D^0 \to K^+K^-)$ $[10^{-3}]$	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		
	$\phi(D^0 \to K_S^0\pi^+\pi^-)$ $[^\circ]$	$-6 \pm 11 \pm {}^{4}_{5}$	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		

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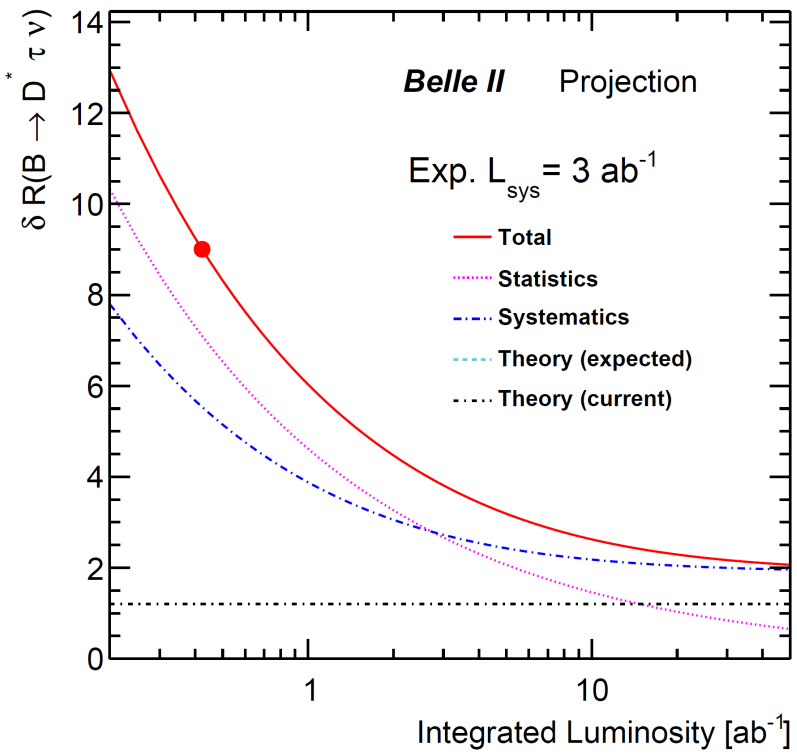
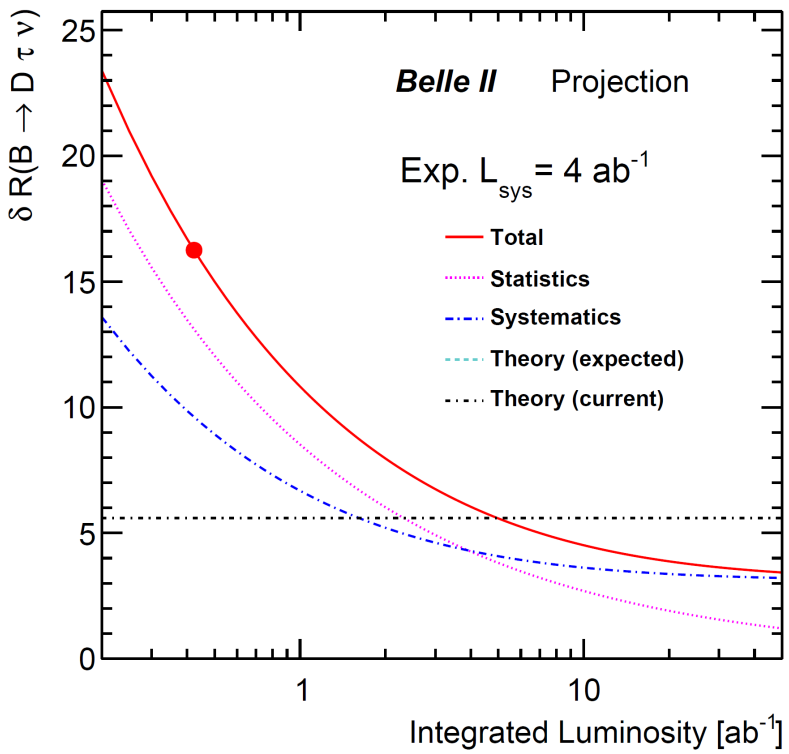
Backup: Belle II B→D*τν and B→Dτν.

PRELIMINARY



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



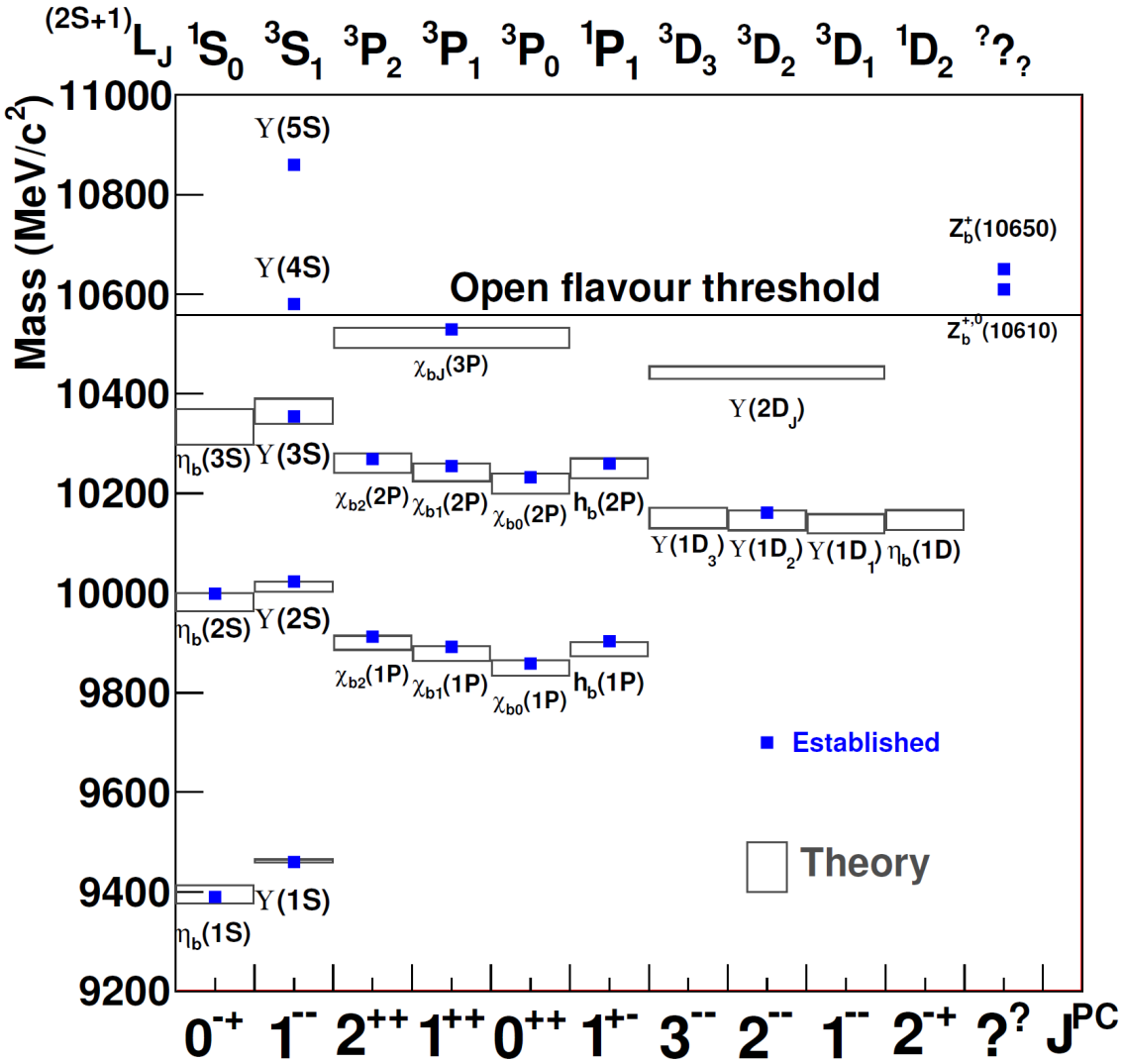
(b)$B \to D \tau \nu$

BELLE2-NOTE-PH-2015-002

Backup: First physics "Bottomonium below Y(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)”.

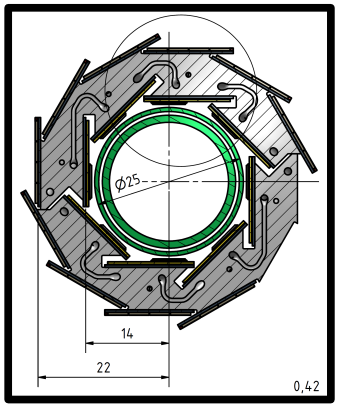


Backup: First physics "Bottomonium above Y(4S)".

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.

Belle II Vertex Detectors

- 2 layers of DEPFET pixel detectors (PXD)
- 4 layers of double-sided silicon strip detectors (SVD)



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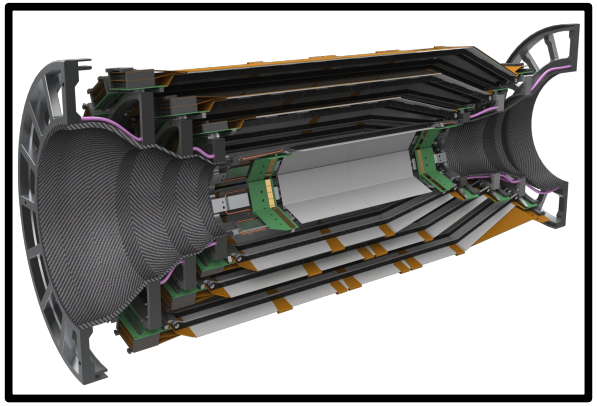

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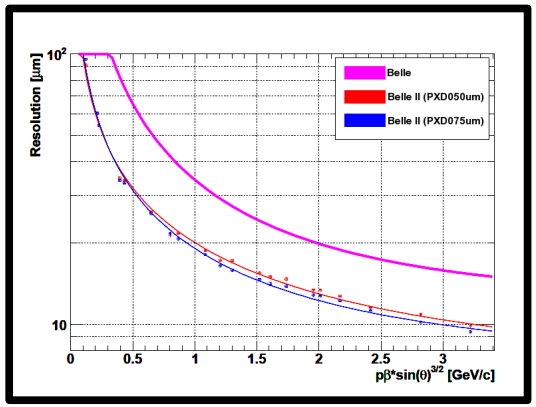


PXD
0.21% X_0/layer

pixel: 50x55/85μm
thickness: 75μm

hit time resolution: 20μs

SVD
0.55% X_0/layer

shaping time: 20ns
hit time resolution: 3ns

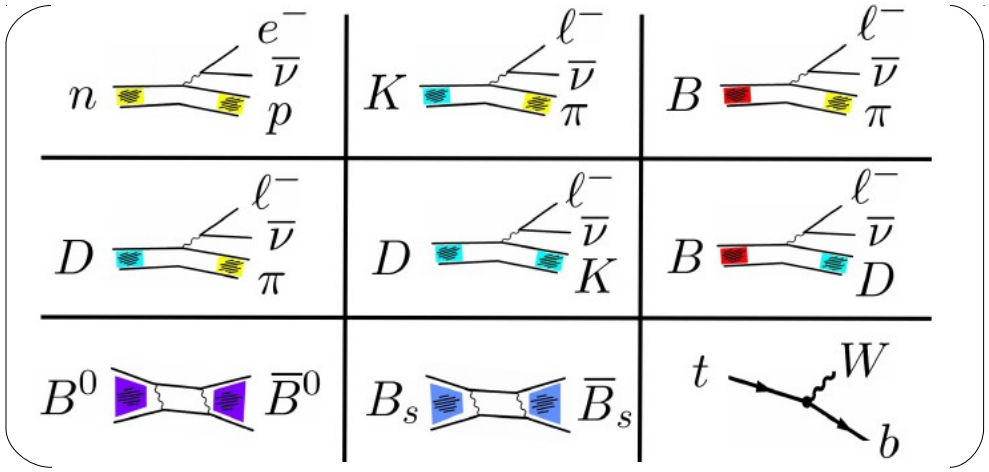
PXD + SVD = VXD

Z vertex resolution two times better than Belle

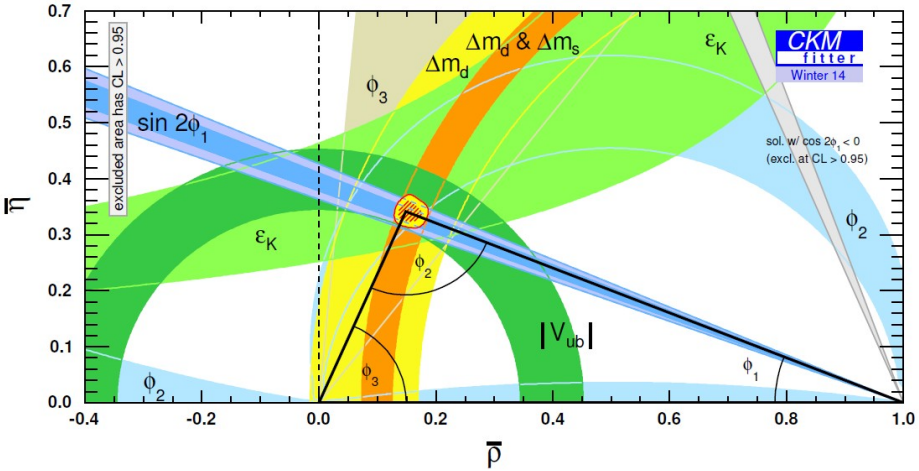
Improved K_s efficiency (e.g. $B \rightarrow K_s K_s K_s$, ...)

Example: Precision CKM Metrology at Belle II.

$$V_{CKM} = \begin{array}{c|ccc} & d & s & b \\ \hline u & n \to p\, e^- \bar{\nu} & K \to \pi\, \ell^- \bar{\nu} & B \to \pi\, \ell^- \bar{\nu} \\ c & D \to \pi\, \ell^- \bar{\nu} & D \to K\, \ell^- \bar{\nu} & B \to D\, \ell^- \bar{\nu} \\ t & B^0 \leftrightarrow \bar{B}^0 & B_s \leftrightarrow \bar{B}_s & t \to W\, b \end{array}$$



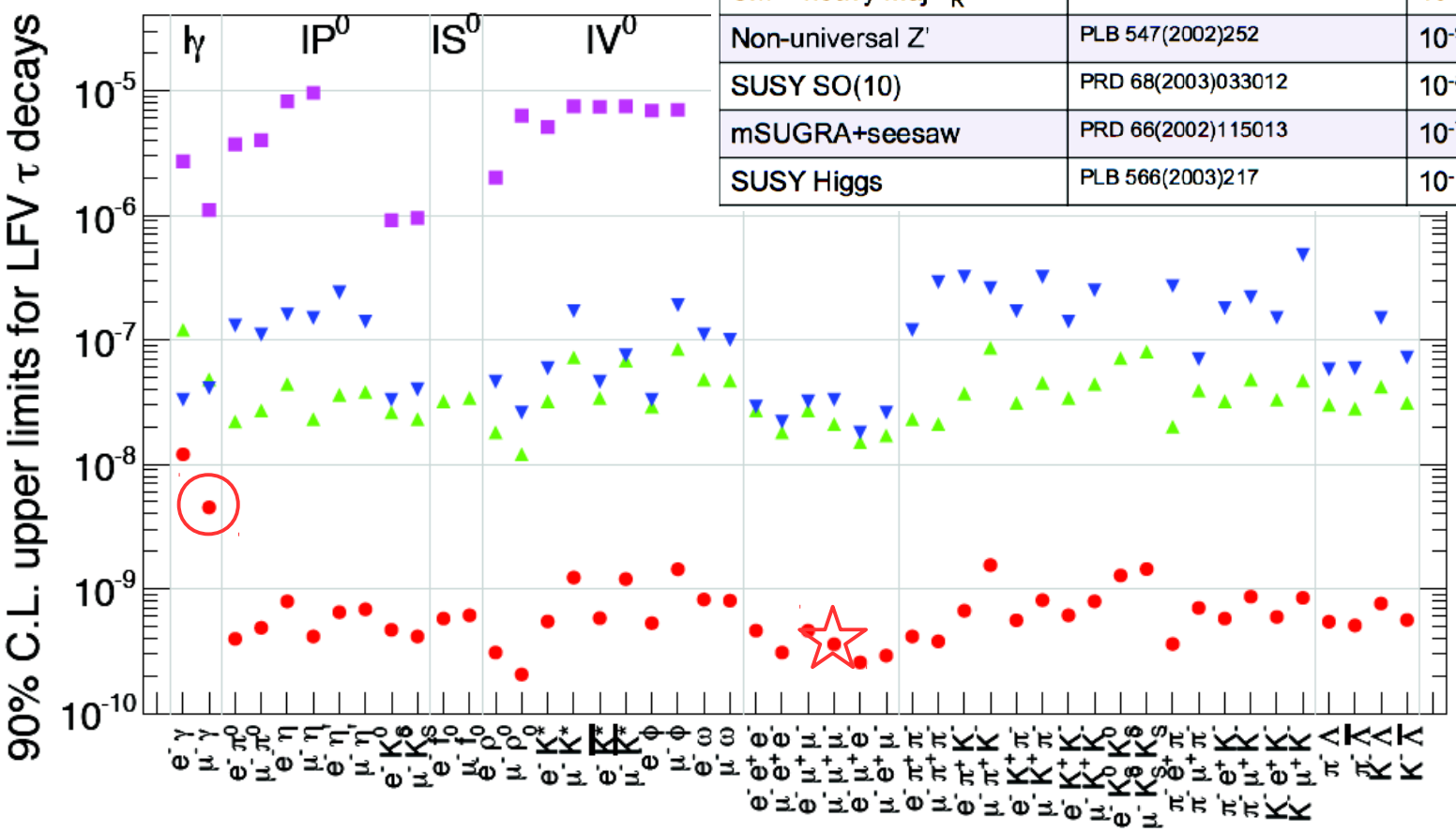
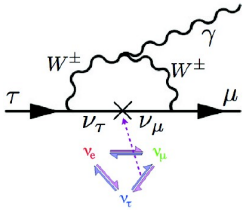
from: S. Descotes-Genon



	World average	Belle II exp. ($50ab^{-1}$)
$\Phi_1(\beta)$	±0.8°	±0.4°
$\Phi_2(\alpha)$	±4.0°	±1.0°
$\Phi_3(\gamma)$	±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 of the SM: $BF_{SM} \sim 10^{-25}$ → NP may induce LFV at one loop

	reference	$\tau \to \mu\gamma$	$\tau \to \mu\mu\mu$
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}