

Belle II Status

before first collisions



Racha Cheaib
University of Mississippi

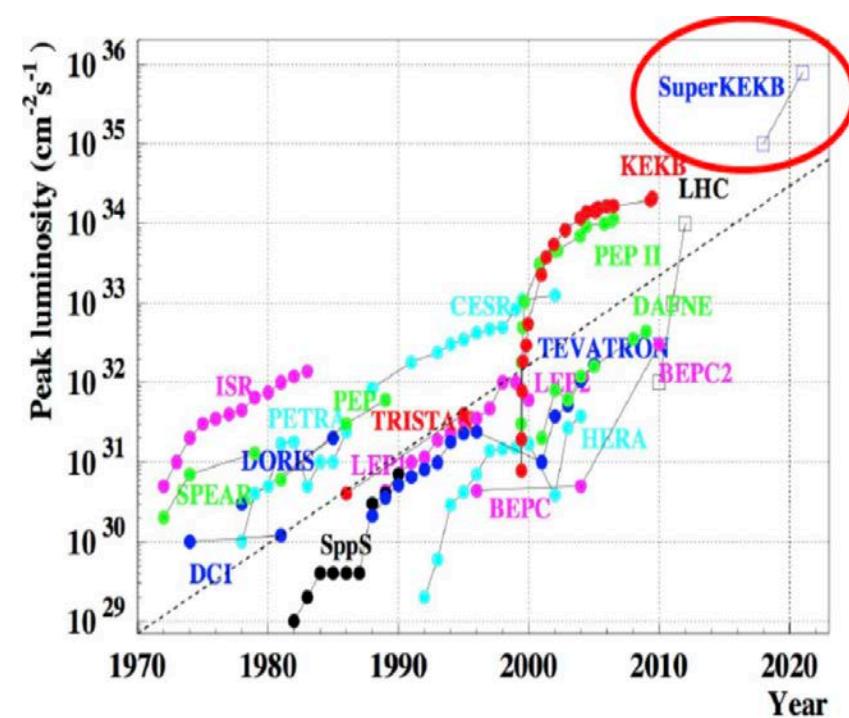
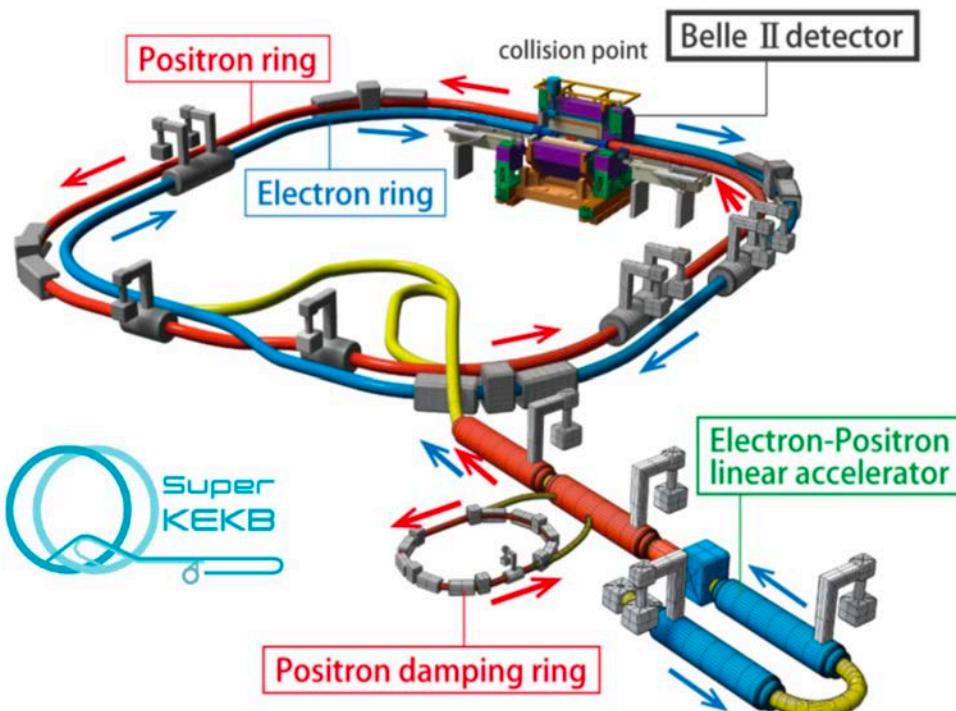
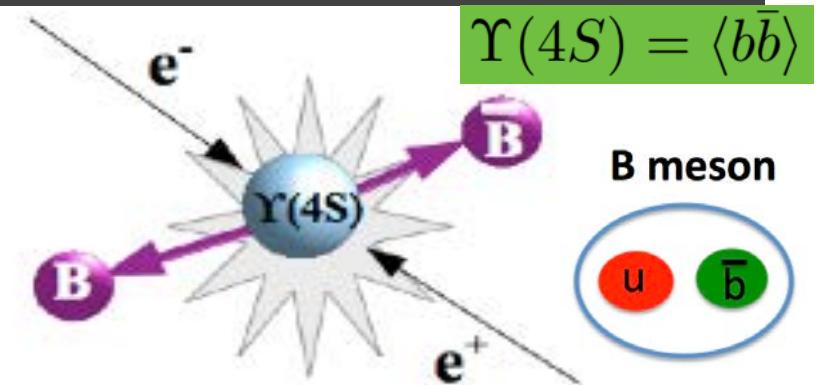
Rencontres de Moriond
March 10 -17th, 2018





What are Belle II and SuperKEKB?

- A B-meson factory in Tsukuba, Japan.
- Electrons and positrons are collided at $\Upsilon(4S)$ energy.
- Upgrade of KEKB and Belle to higher luminosities

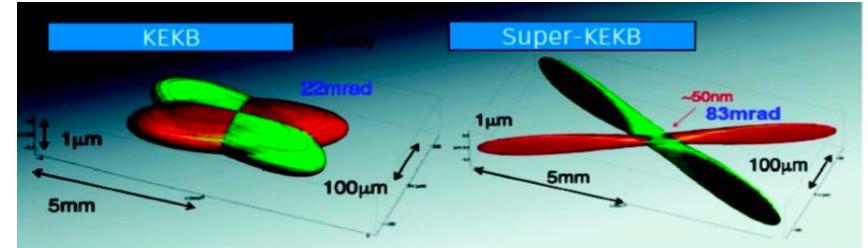




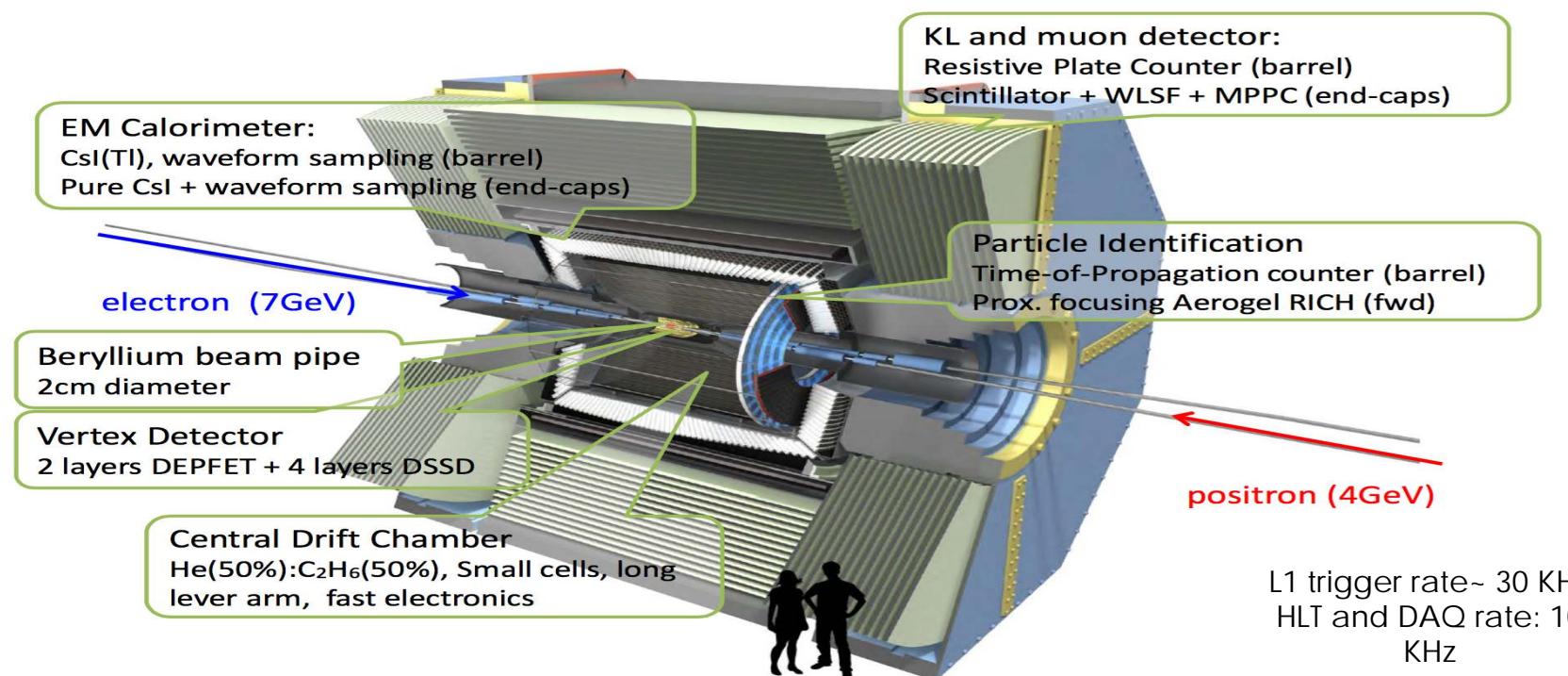
How Belle II?

- SuperKEKB: increase luminosity by a factor of 40

- 20 x smaller vertical beam size
- 2-3 x beam current



- Improve detector to handle large background levels





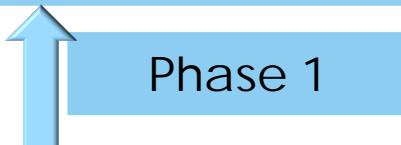
Current Status :

2016

2017

2018

2019



Phase 1

arXiv:1802.01366

Beam on, no collisions.
Basic accelerator tuning.
Commissioning with BEAST II.





Current Status :

2016

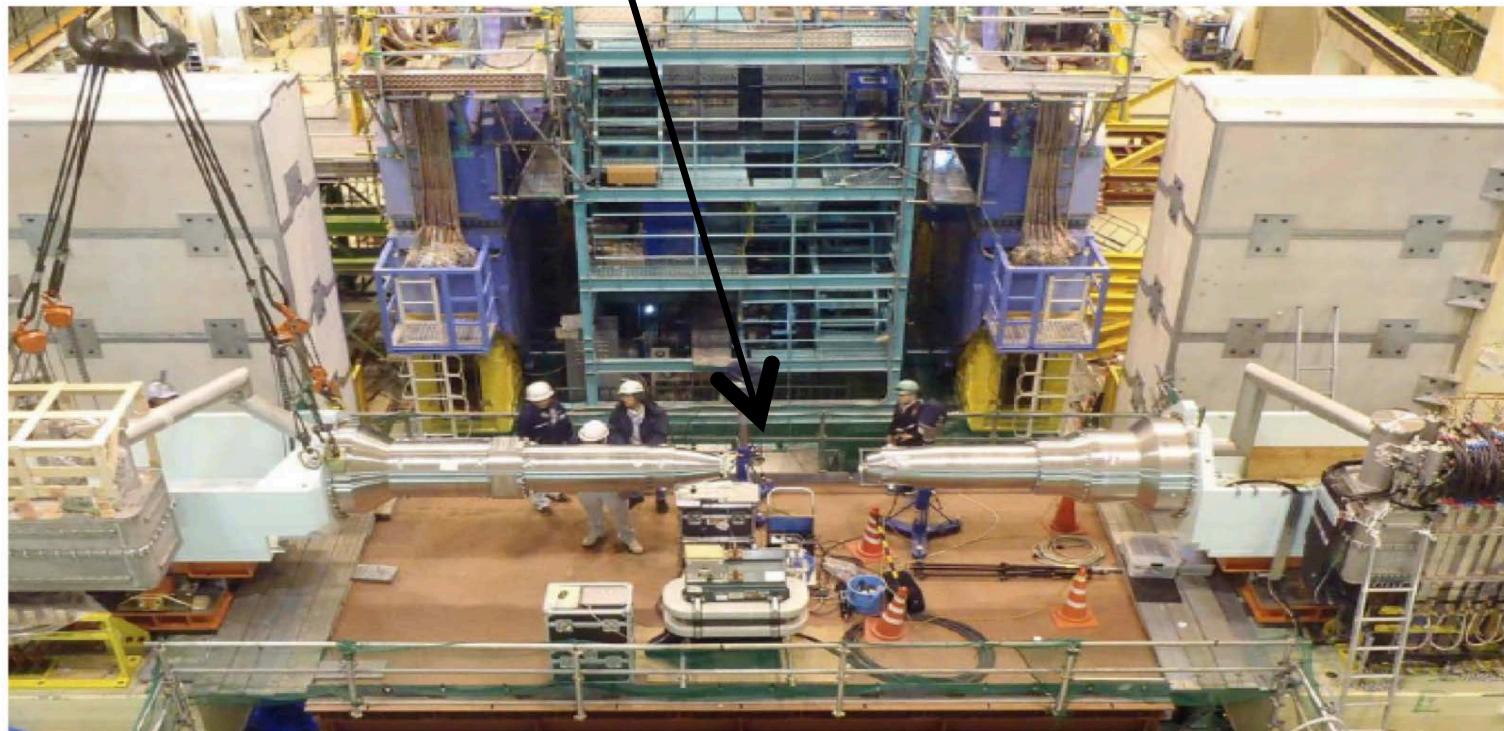
2017

2018

2019

Phase 1

Install final focusing magnets (QCS)





Current Status :

2016

2017

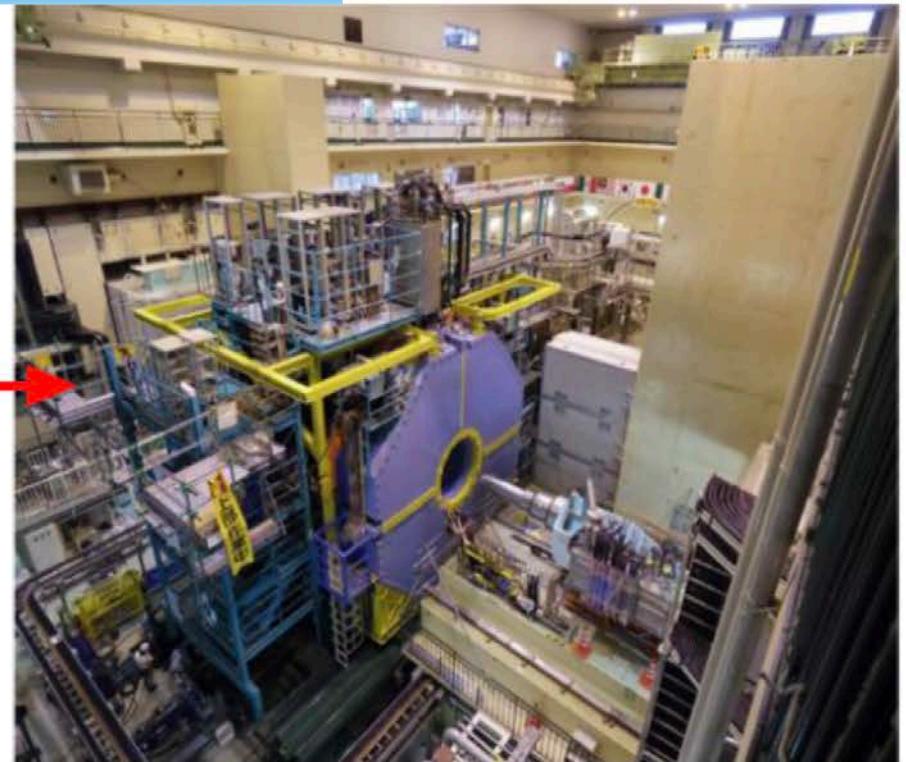
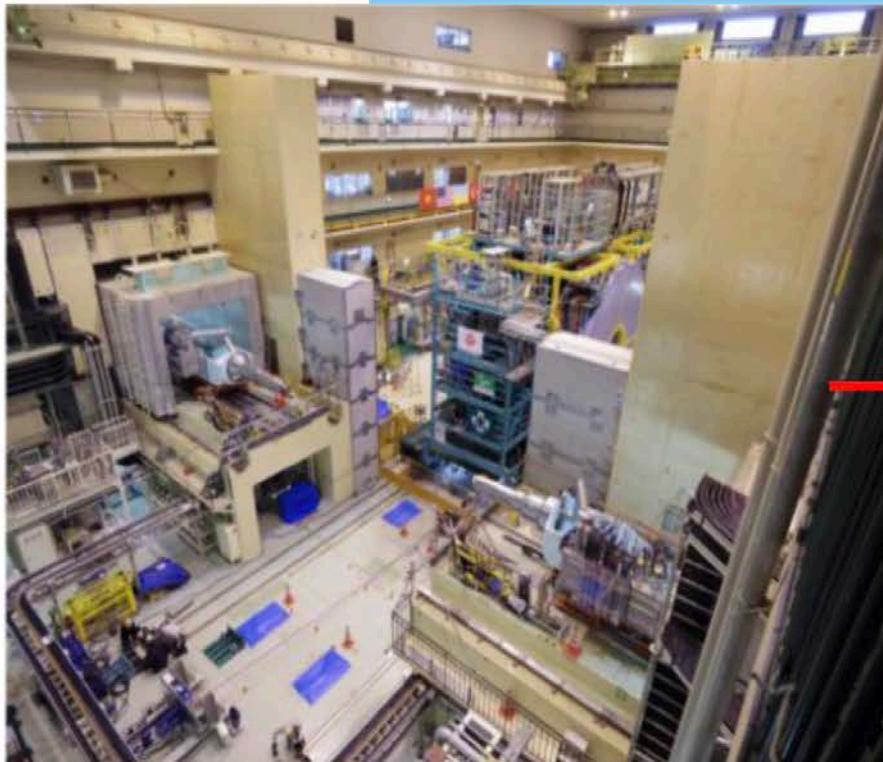
2018

2019

Phase 1



Belle II detector installation (TOP,
CDC) and roll-in .





Current Status :

2016

2017

2018

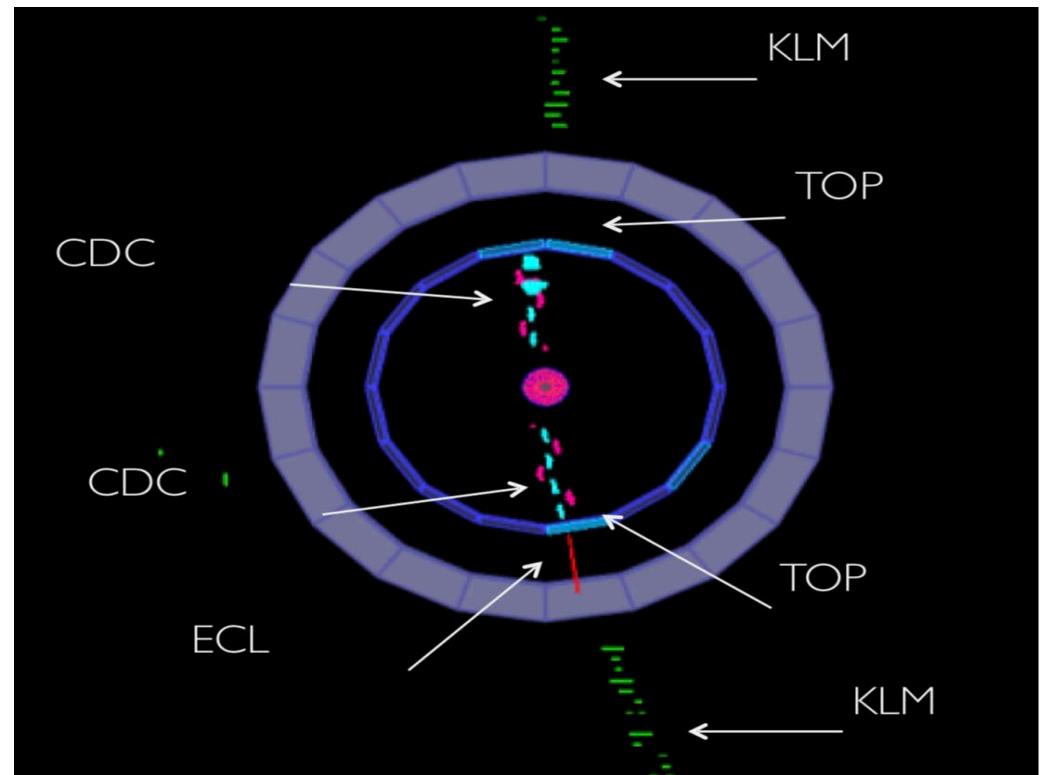
2019

Phase 1



Belle II global cosmics run (July-August)

- Established 1.5 T magnetic field
- Readout integration of installed sub-detectors central DAQ in progress.





Current Status :

2016

2017

2018

2019

Phase 1

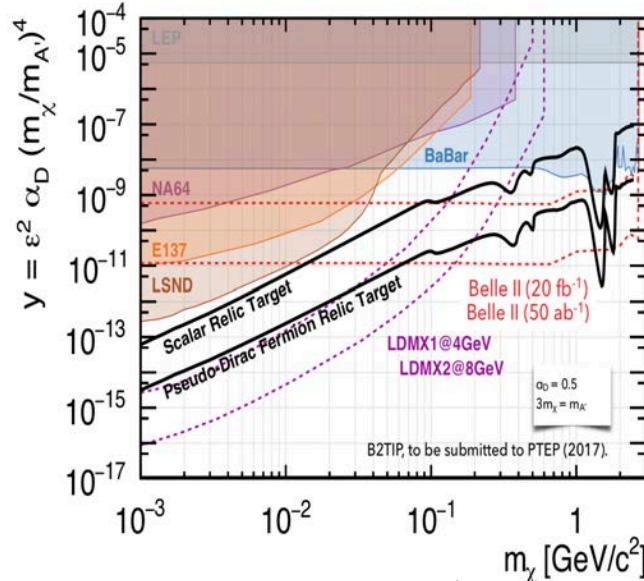
Phase 2

Phase 3

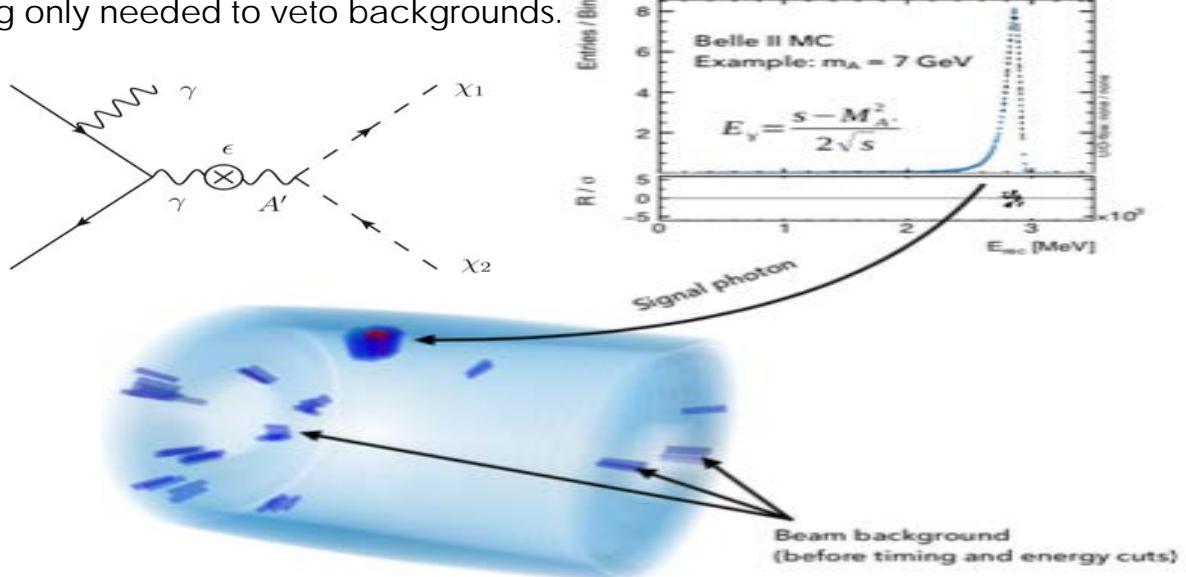
April 2018: Beam collisions with QCS.
VXD not yet installed
Expected luminosity: 20 fb^{-1}

Early Physics topics: Dark photon searches

Requires low energy single photon trigger
Tracking only needed to veto backgrounds.



B2TIP, to be submitted to PTEP (2018).



Racha Cheaib, University of Mississippi



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2017

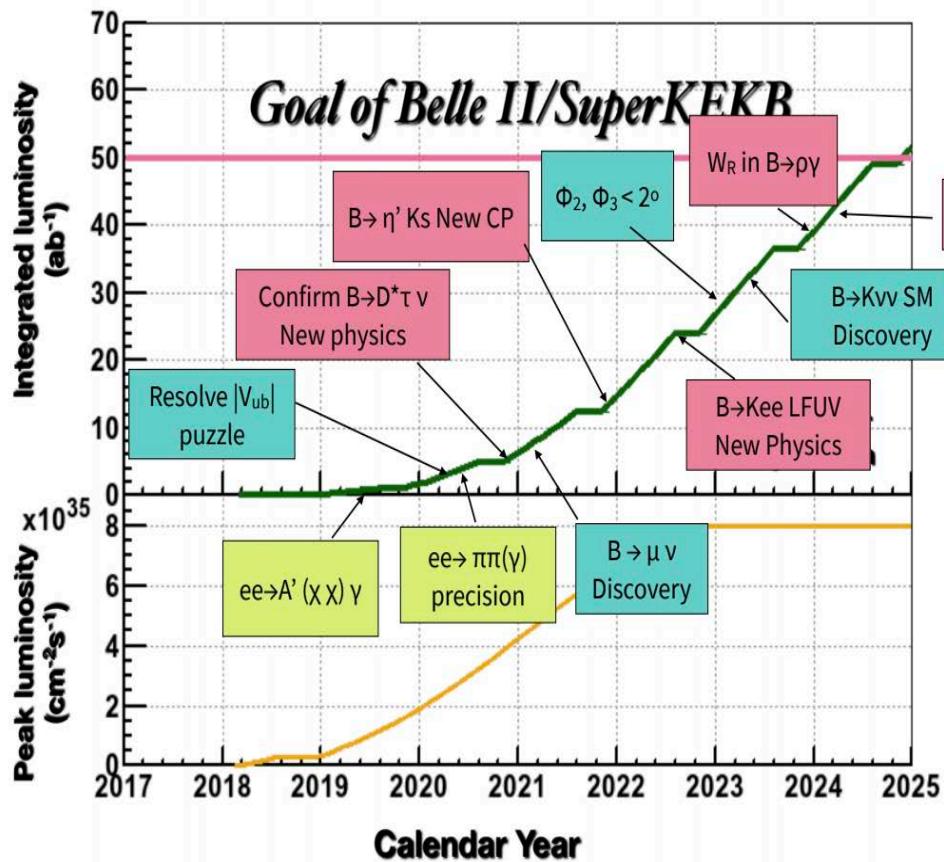
2018

2019

Phase 1

Phase 2

Phase 3



Physics run with VXD
Luminosity target: $80 \times 10^{35} \text{ cm}^2/\text{s}$
Target sample: 50 ab^{-1}

- B-physics:
 - CPV: $B \rightarrow J/\psi K_s^0, \phi K^0$
 - Rare B decays: $B \rightarrow K\bar{v}v, K\tau^+\tau^-$
 - Semi-leptonic B decays
- Lepton flavour violation:
 - $\tau \rightarrow \mu\gamma$
- Charm Physics: D-mixing

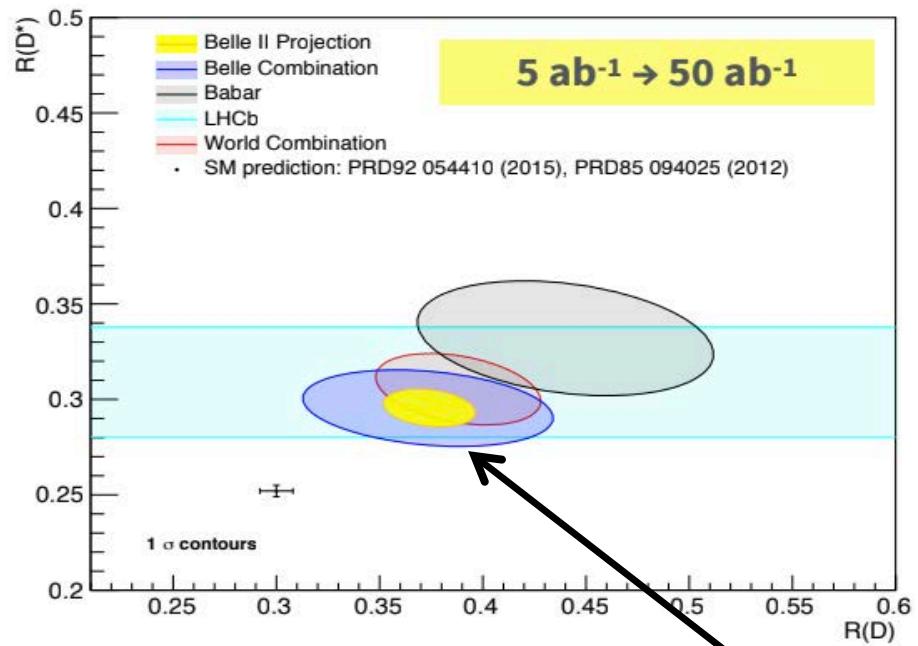
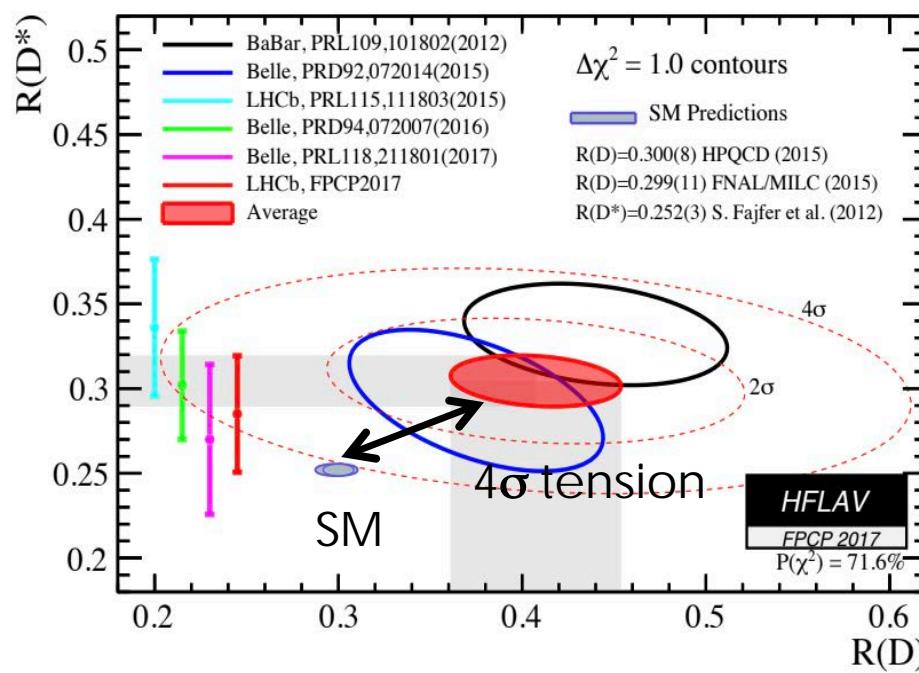
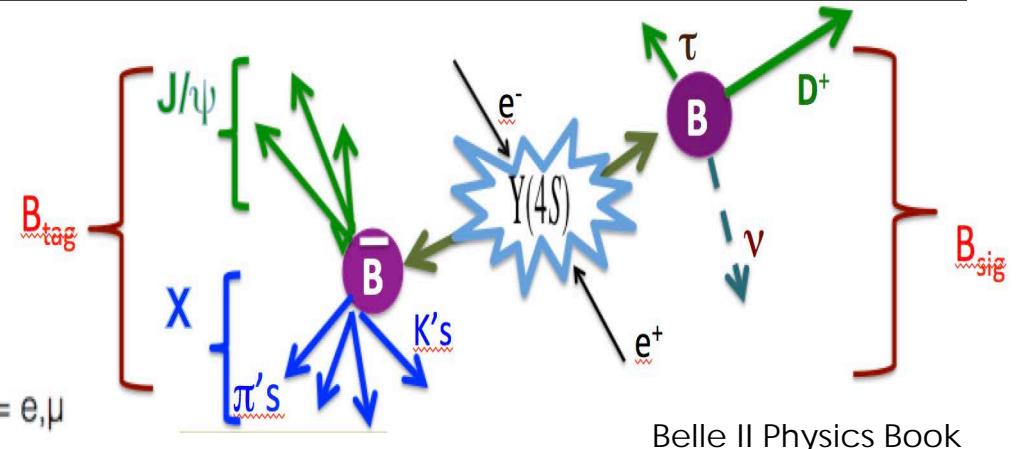
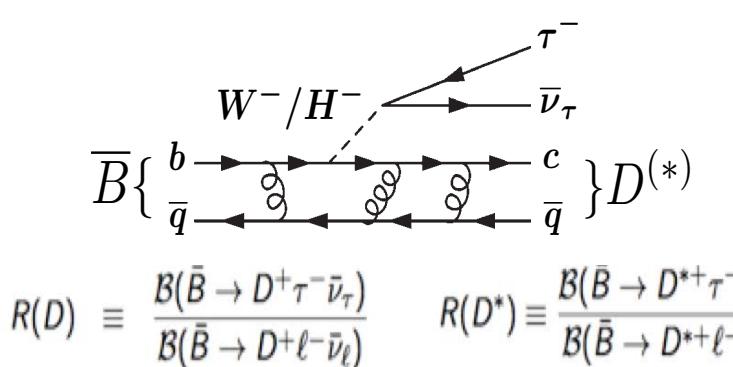




Physics agenda

CHEF'S CHOICE

$R(D)$ and $R(D^*)$

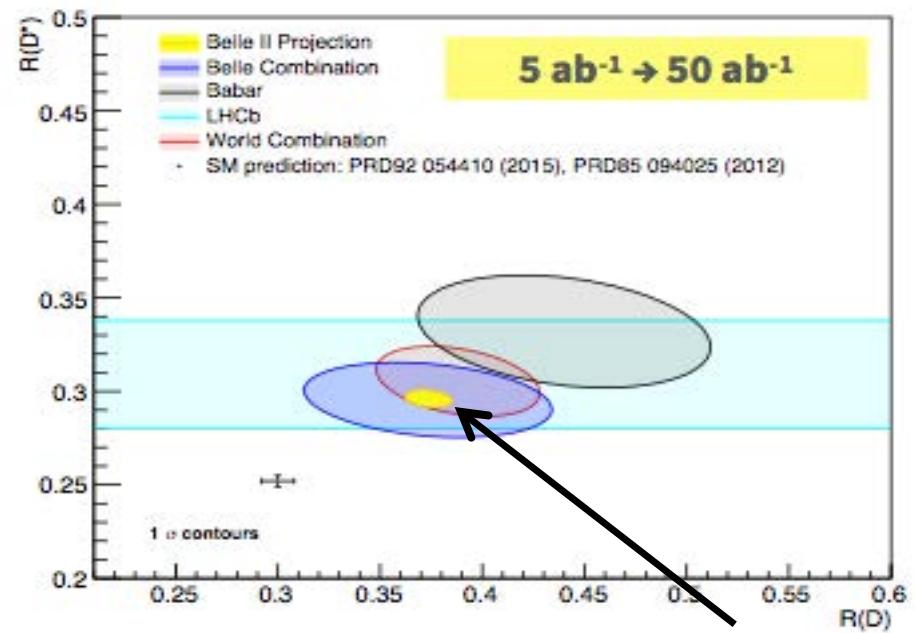
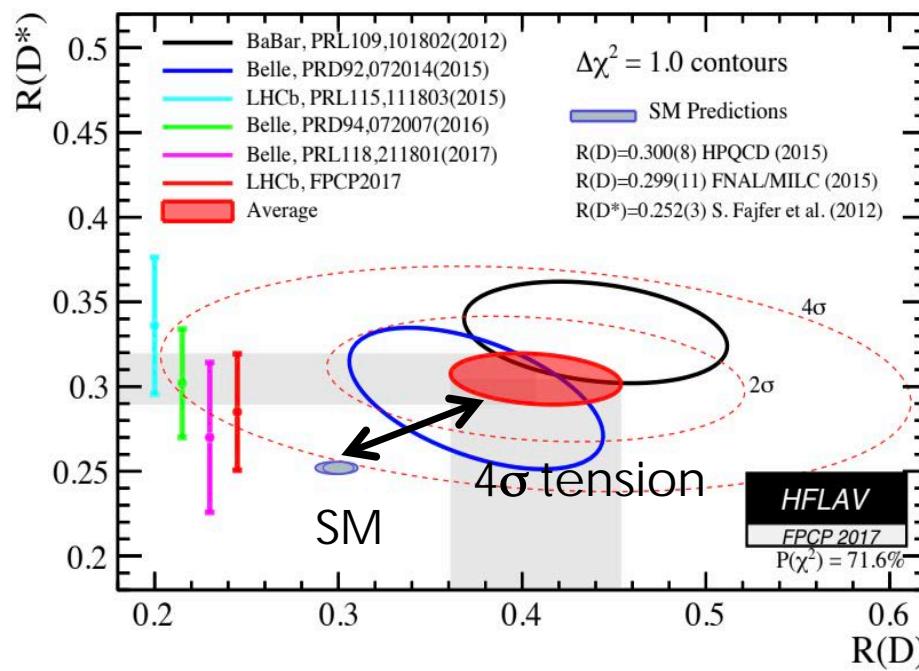
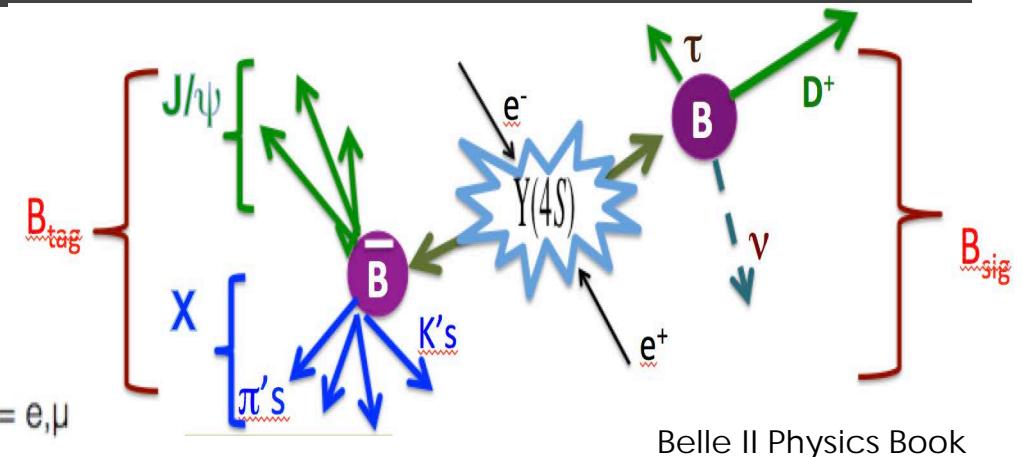
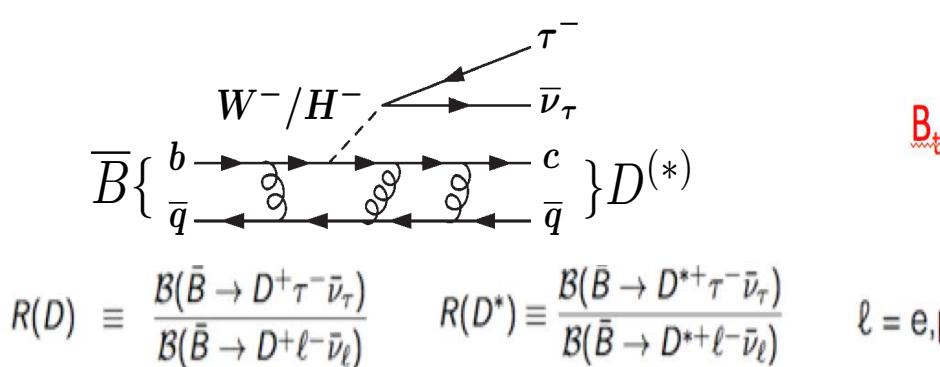




Physics agenda

CHEF'S CHOICE

$R(D)$ and $R(D^*)$



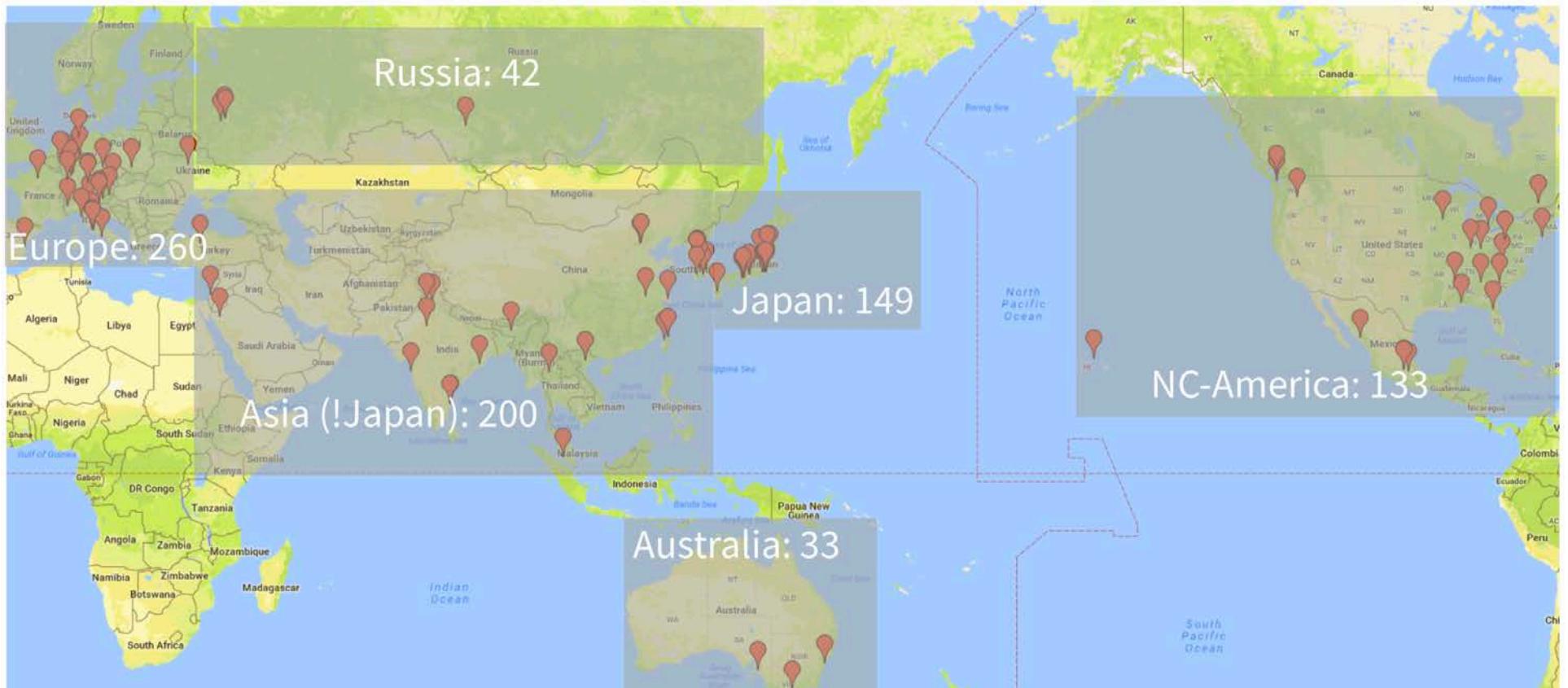


Excitement:

- ❑ First beams circulating later in March!!!!
- ❑ Belle II Phase 2 data is only a couple of months away.
 - ❑ Dark sector , Bottomonium.
- ❑ Belle II Phase 3 data will strongly contribute to the present understanding of B-anomalies and much more.
- ❑ Stay tuned!

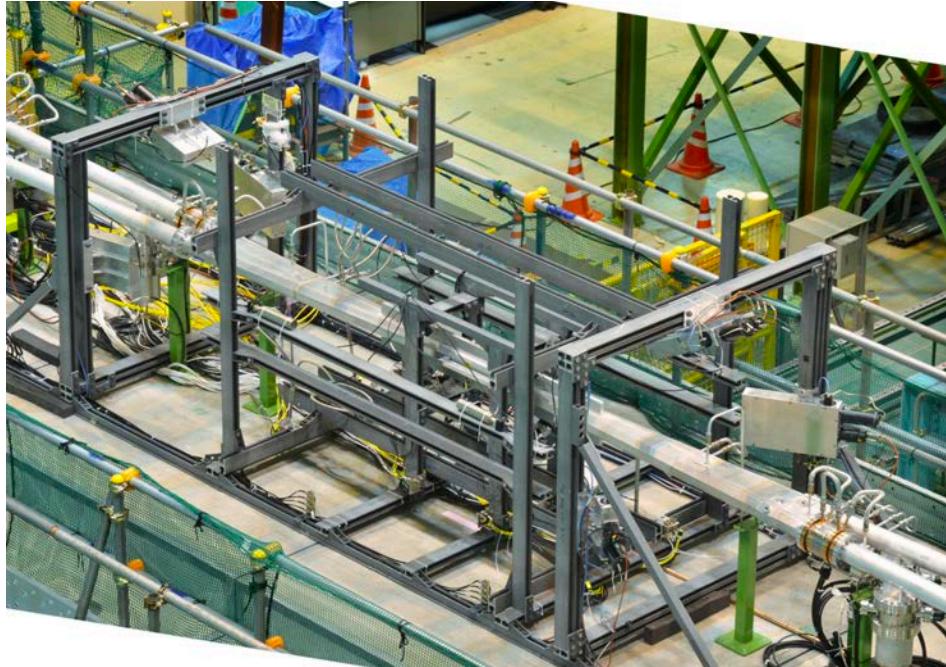


Belle-II collaboration



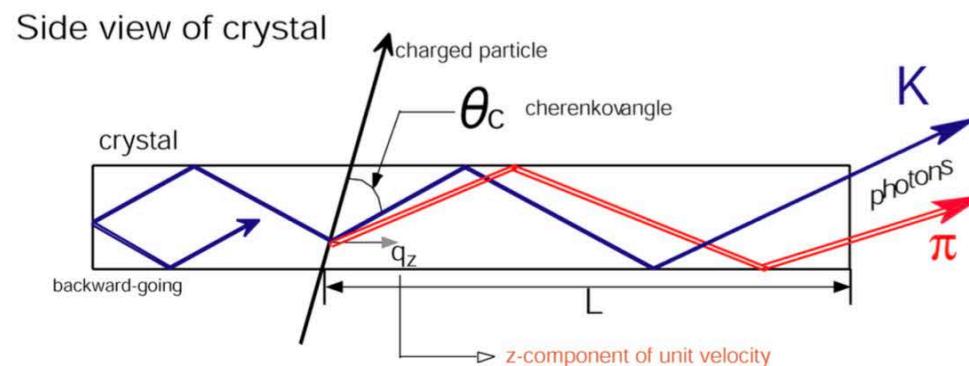
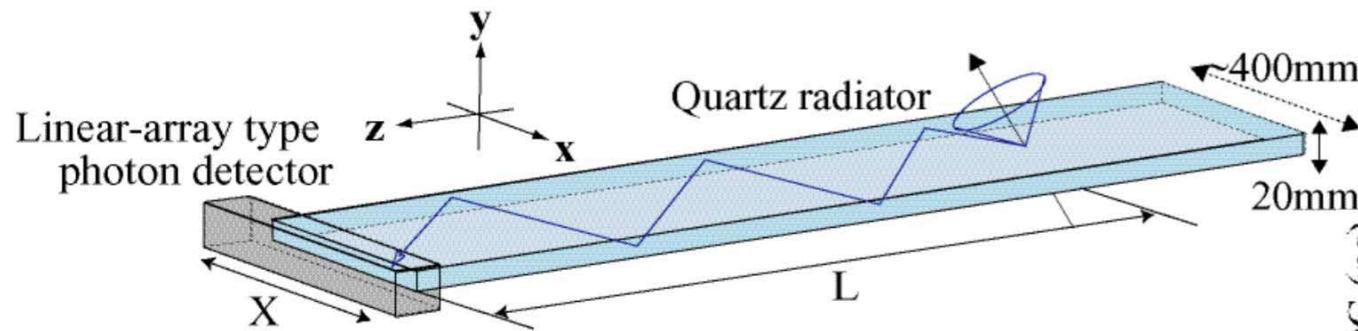
BEAST-:II

- Belle-II commissioning detector to provide diverse real-time measurements of beam conditions.
- Phase-2 operation from Feb. to July, 2018
- Belle-II will generate a large amount of beam backgrounds:
 - Touschek scattering: Coulomb scattering between 2 particles in the same bunch
 - Beam-gas: scattering off residual gas atoms in the beam pipe
 - Synchotron radiation: photons emitted when electrons are bent by magnetic fields.



sensor	number	location	unique measurement
Belle II PXD	2 ladders	VXD	in-situ occupancy, full Belle II tracking, vertexing
Belle II SVD	4 ladders	VXD	
diamond sensors	8 diamonds	VXD	ionizing dose in VXD → BEAM abort
FANGS "LHC style" silicon pixel sensors	3 arms 15 chips	VXD	MIPs & x-rays > 10 keV @ 40 MHz → Synchrotron x-ray spectrum
CLAWS Scintillators w/ SiPMTs	2 ladders	VXD	X-rays or track counting w/ 1-ns timing → injection background
PLUME "ILC style" silicon pixels sensor	2 ladders	VXD	Two-sided silicon pixels → tracklets w/ pointing
Micro-TPC nuclear recoil detectors	8	VXD dock	fast neutrons: rate, directional & spectral information
He-3 tube neutron detectors	4	VXD dock	thermal neutrons: rate
Scintillators	40+40	around QCS	X-ray and total loss distribution versus position, → collimator adjustment
PIN diodes		around QCS	amount of beam background around QCS → collimator adjustment
FPGA	2	beam pipe	
LYSO-ECL	4+4	ECL	

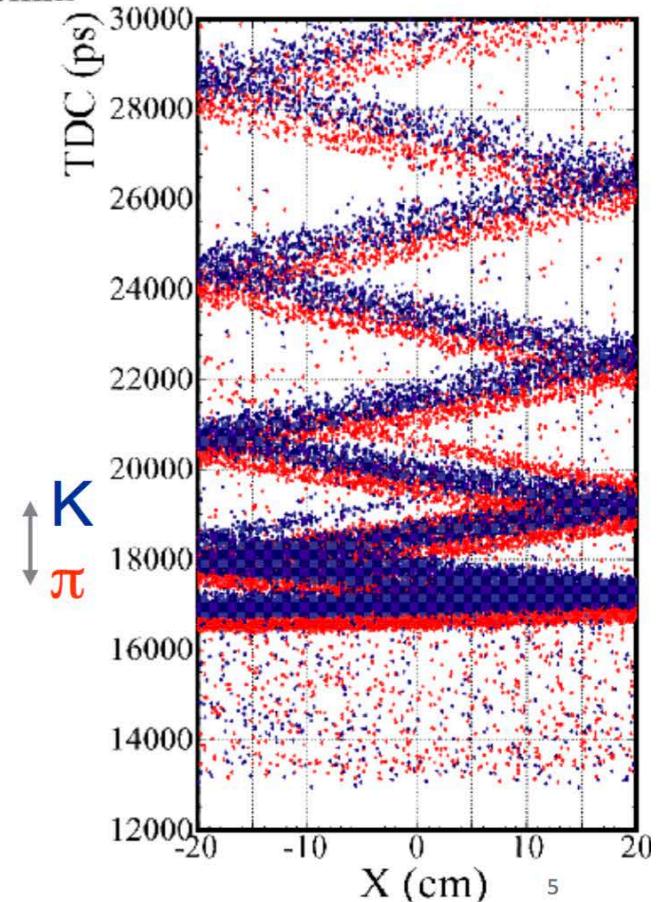
TOP



Different opening angles for the same momentum

- Measure x-y position (5 mm) of photons (**imaging**)
- Measure precise (40 ps) time of arrival of photons (**time-of-propagation**); TOF from IP works additively

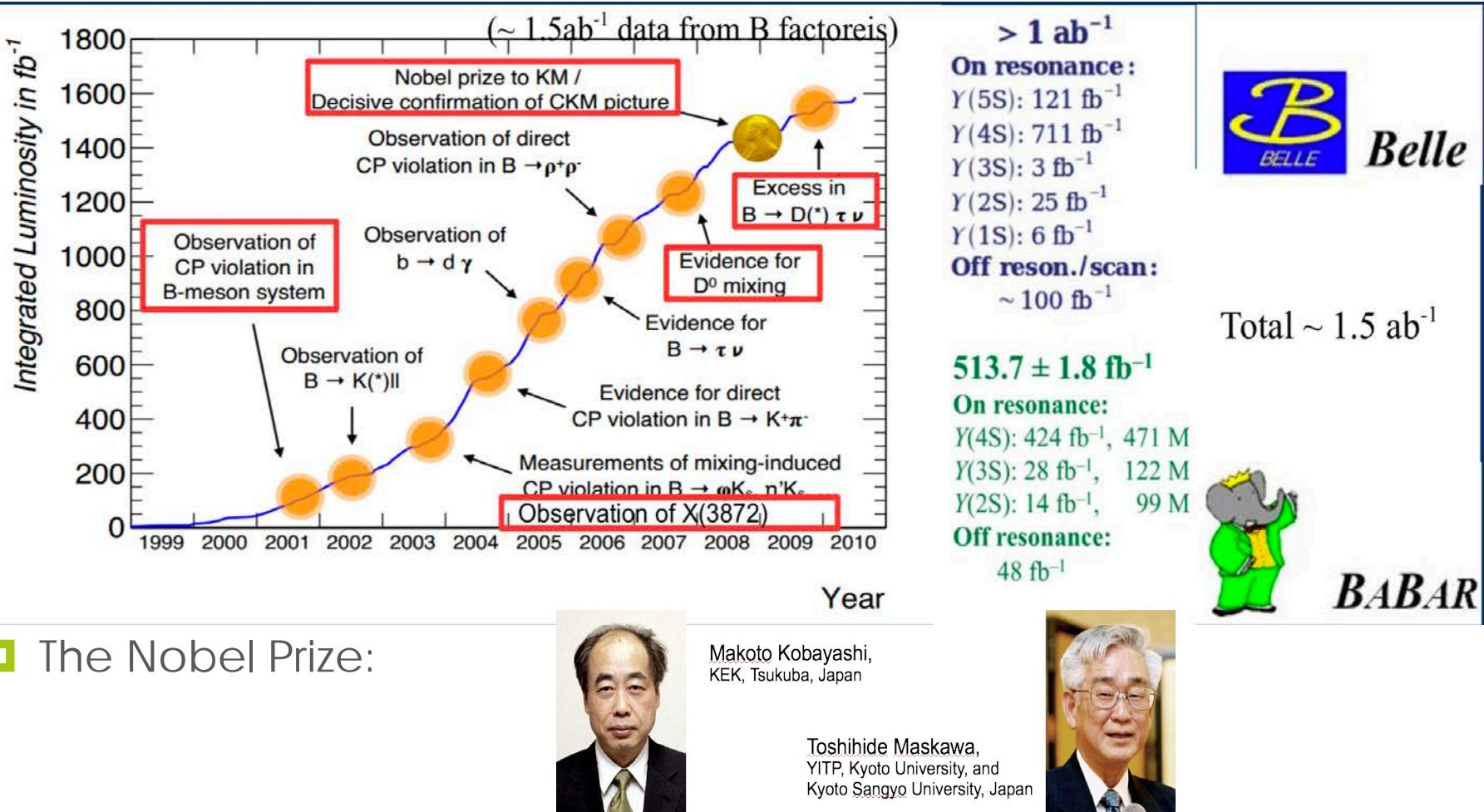
Simulation
2GeV/c, $\theta=90$ deg.





Why Belle II?

- Previous B-factories have been very successful:



- The Nobel Prize:



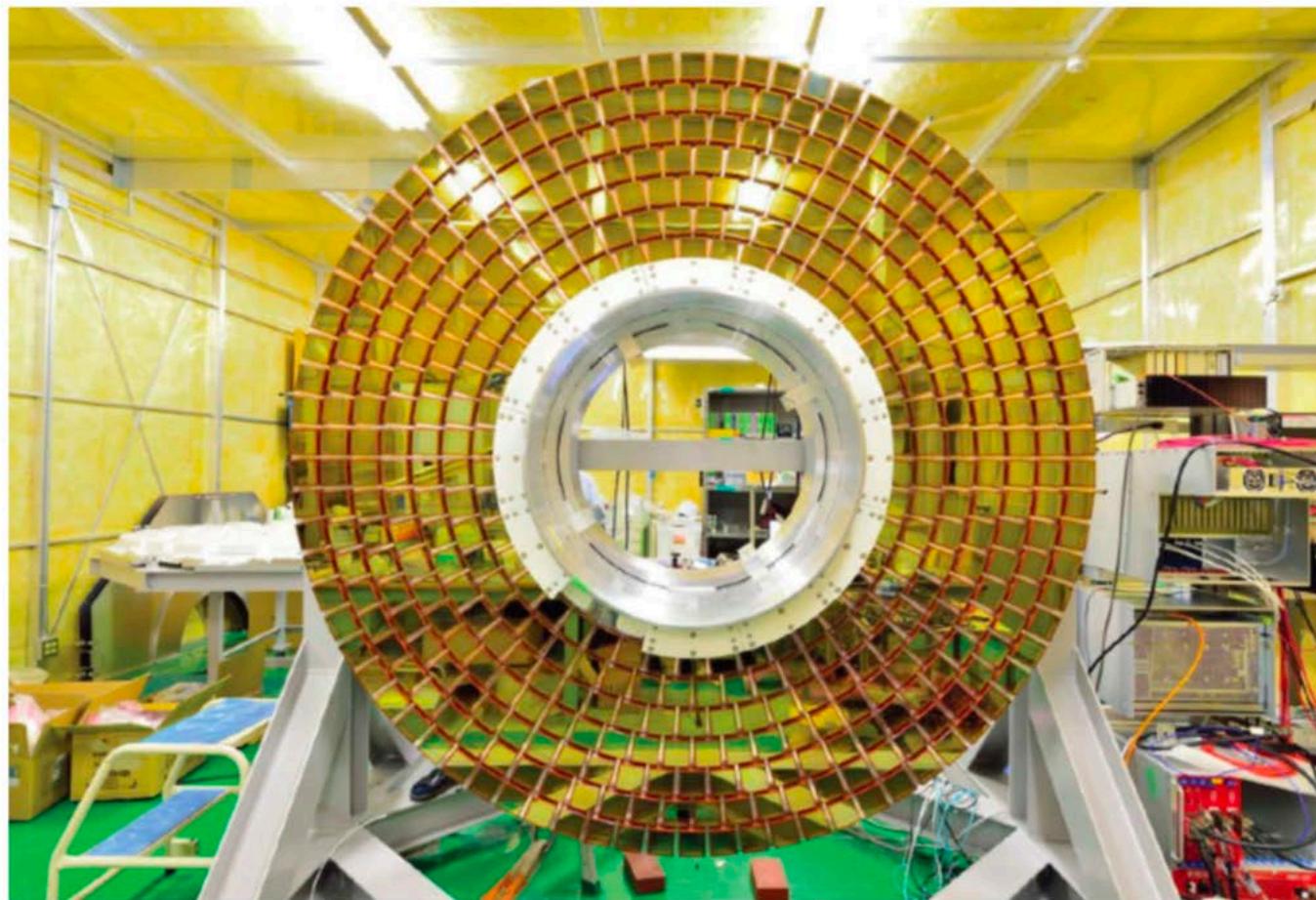
Makoto Kobayashi,
KEK, Tsukuba, Japan



Toshihide Maskawa,
YITP, Kyoto University, and
Kyoto Sangyo University, Japan

- Complementary to LHC.

ARICH:





Intensity vs. Energy:

KEK B $e^+ e^-$ collider
Detectors: Belle-2
 $3-7 \text{ GeV} \sim 10^9 \text{ eV}$
Focus on specific
energy range for
precision
measurements.

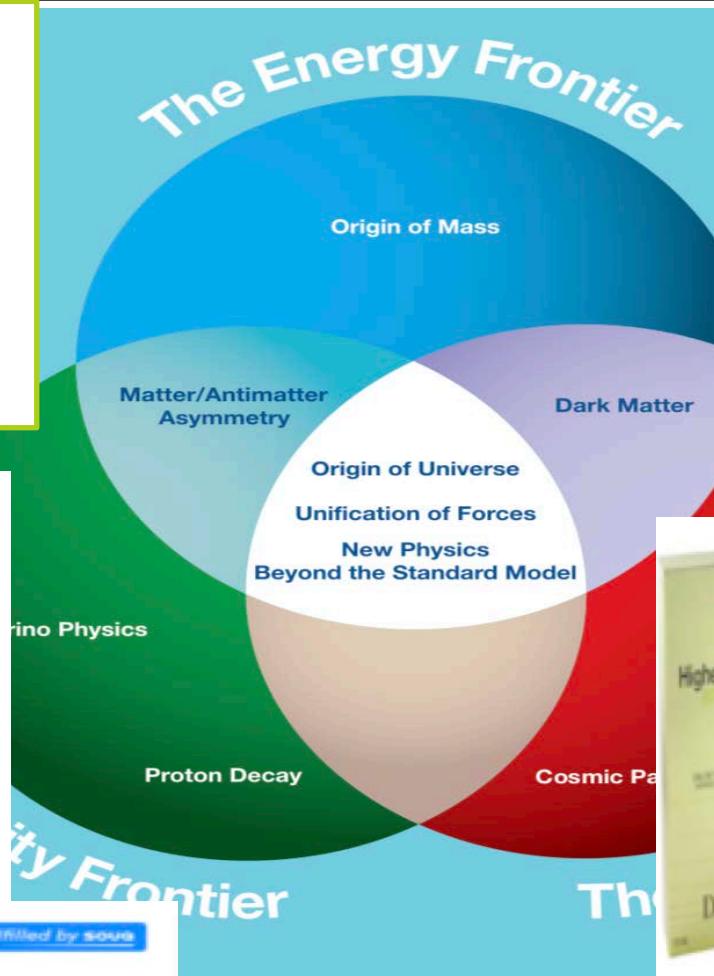


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Large Hadron Collider
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Detectors: ATLAS, LHCb
 $13 \text{ TeV} \sim 10^{13} \text{ eV}$
High energy to search for
new particles and physics



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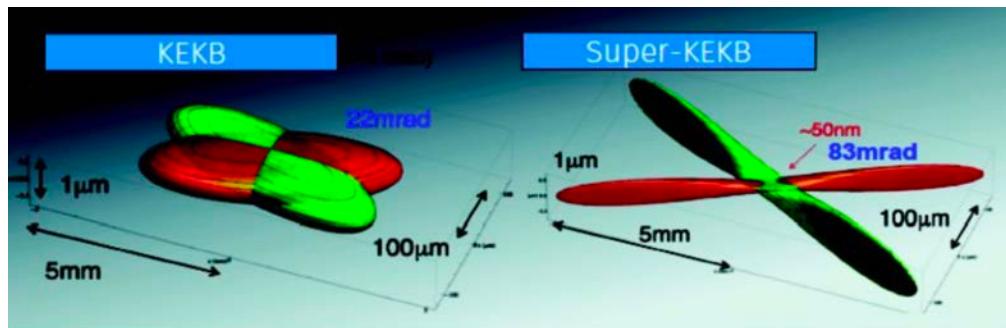
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ADD TO CART

Complementary frontiers in particle physics!

How Belle-II?

- SuperKEKB: increase luminosity by a factor of 40
 - 20 x smaller vertical beam size: "World's most complicated superconducting magnet system."
 - 2-3 x beam current



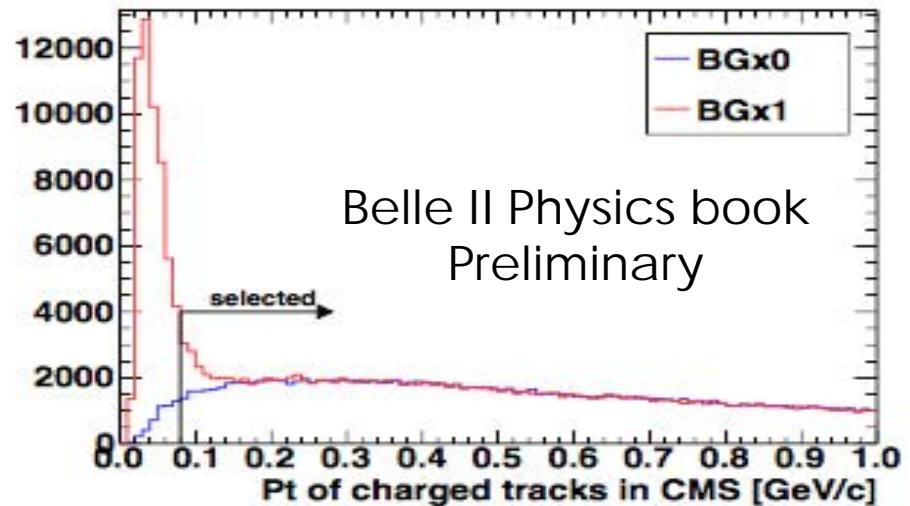
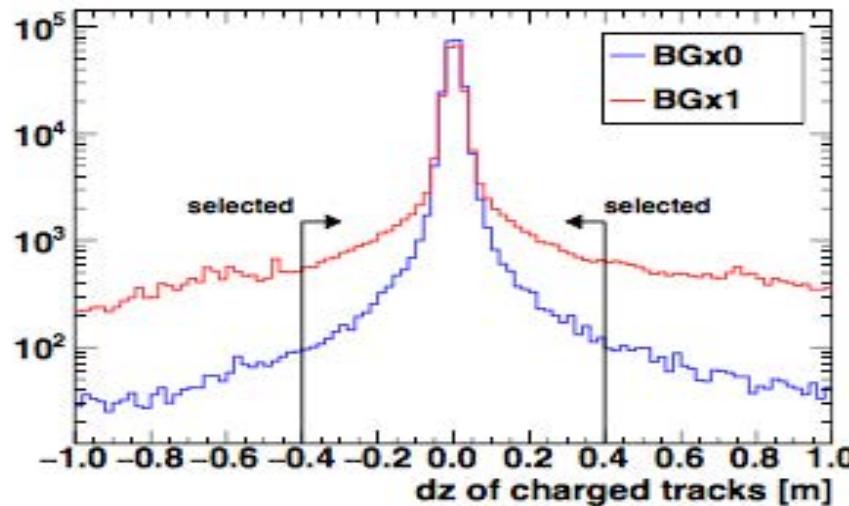
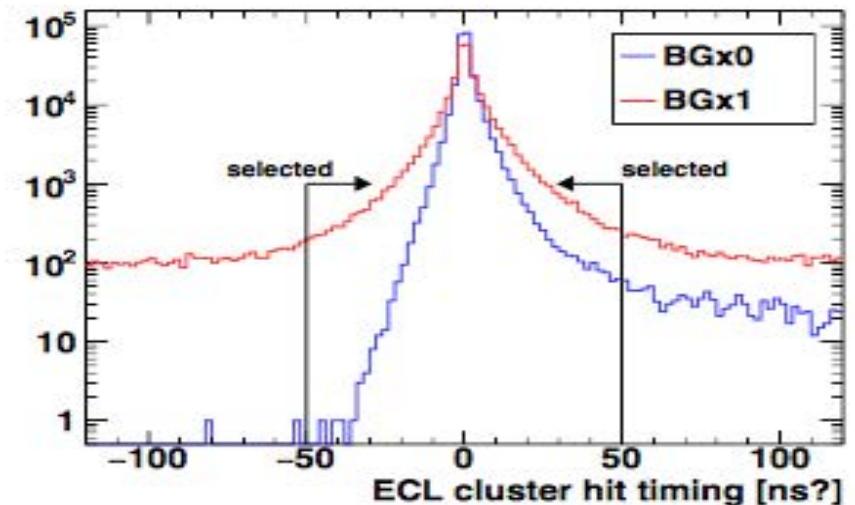
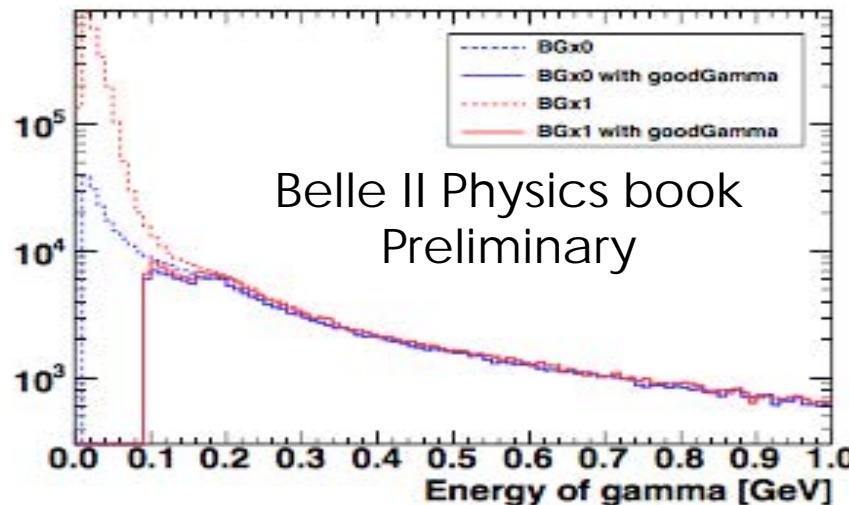
$$\mathcal{L} = \frac{\gamma_{e^\pm}}{2er_e} \left(1 + \frac{\sigma_y^*}{\sigma_x^*}\right) \frac{I_{e^\pm} \xi_y^{e^\pm}}{\beta_y^{*e^\pm}} \left(\frac{R_L}{R_{\xi_y}}\right)$$

beam current

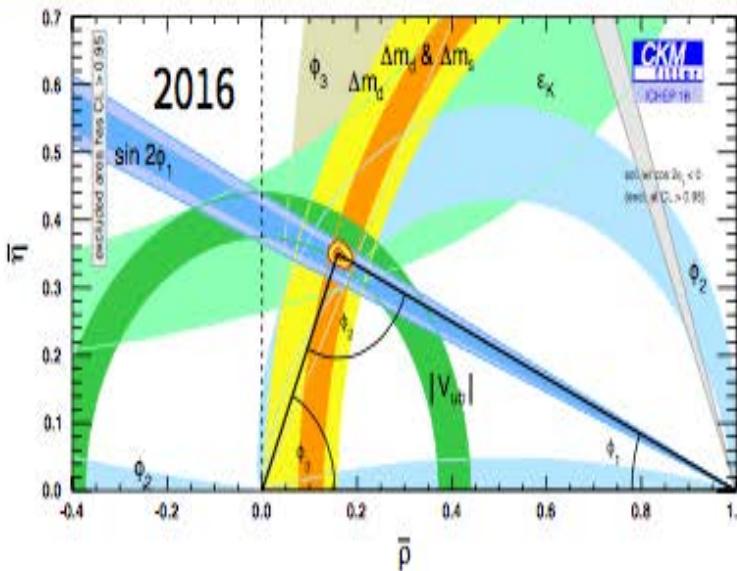
beam size at IP geometrical factor

Parameter	KEKB (LER/HER)	SuperKEKB (LER/HER)
Energy (GeV)	3.5/8.0	4.0/7.0
β_y (mm)	5.9/5.9	0.27/0.30
β_x (cm)	120/120	3.2/2.5
Current (A)	1.6/1.2	3.6/2.6
Luminosity($\text{cm}^{-2}\text{s}^{-1}$)	2.1×10^{34}	80×10^{34}

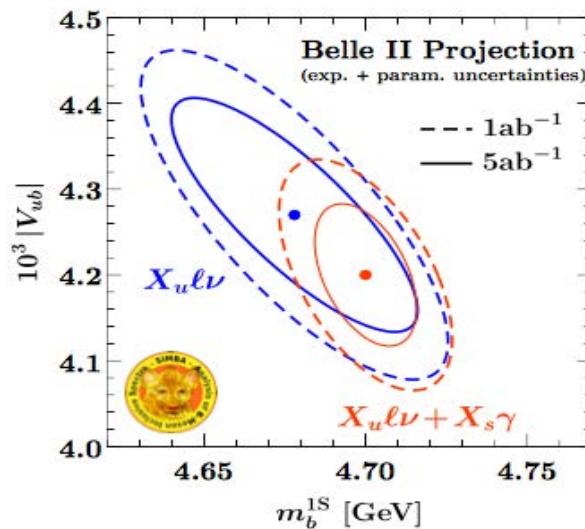
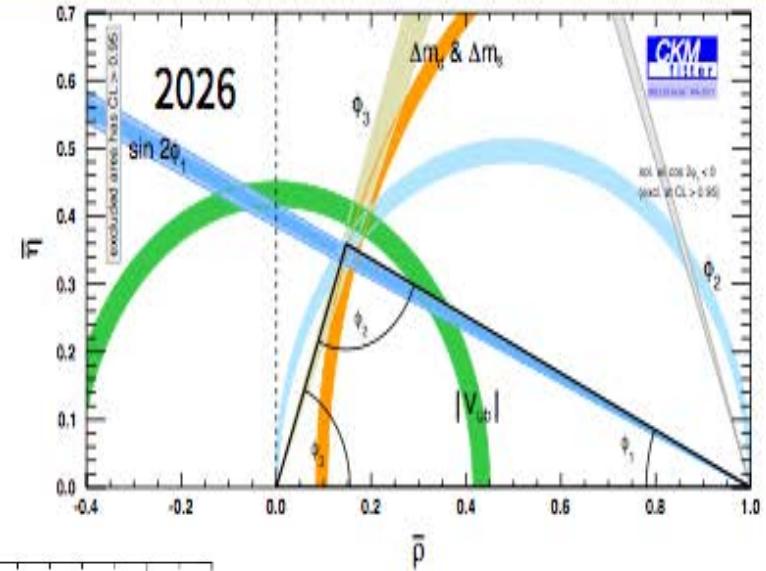
Beam Backgrounds:



V_{ub} and CKM Matrix:



$\Phi_3 \sim 1-1.5^\circ$ at
LHCb & Belle II
 $|V_{ub}| \sim 1.2\%$
Belle II

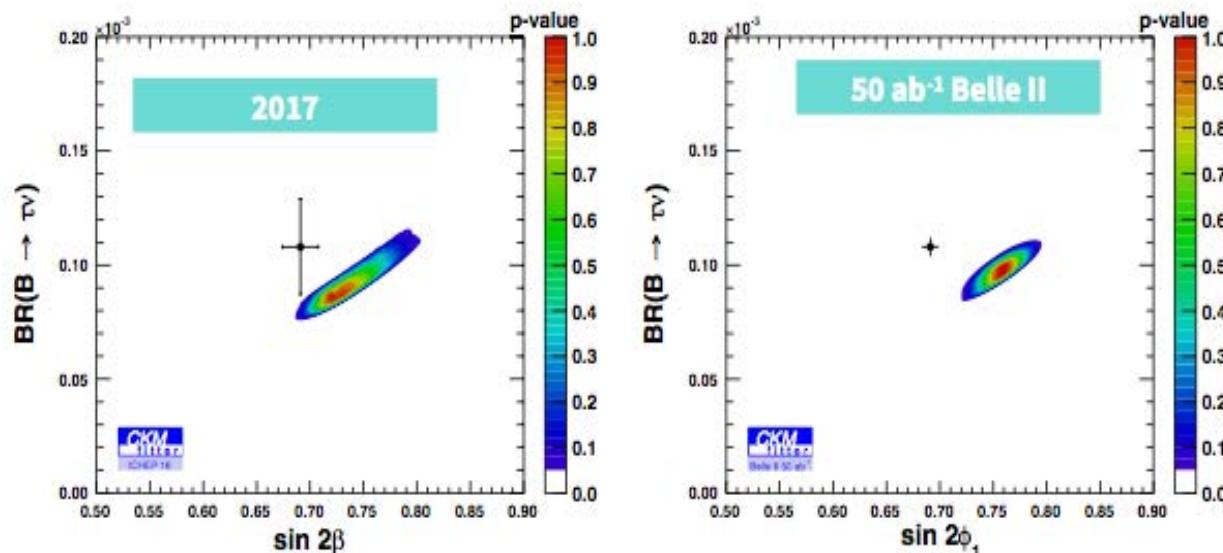


No theoretical
uncertainties

Belle II Physics book
Preliminary

$B \rightarrow l\nu$:

$$B_\tau = (7.7 \pm 0.6) \times 10^{-5}, \quad B_\mu = (3.5 \pm 0.3) \times 10^{-7}, \quad B_e = (8.1 \pm 0.6) \times 10^{-12}.$$



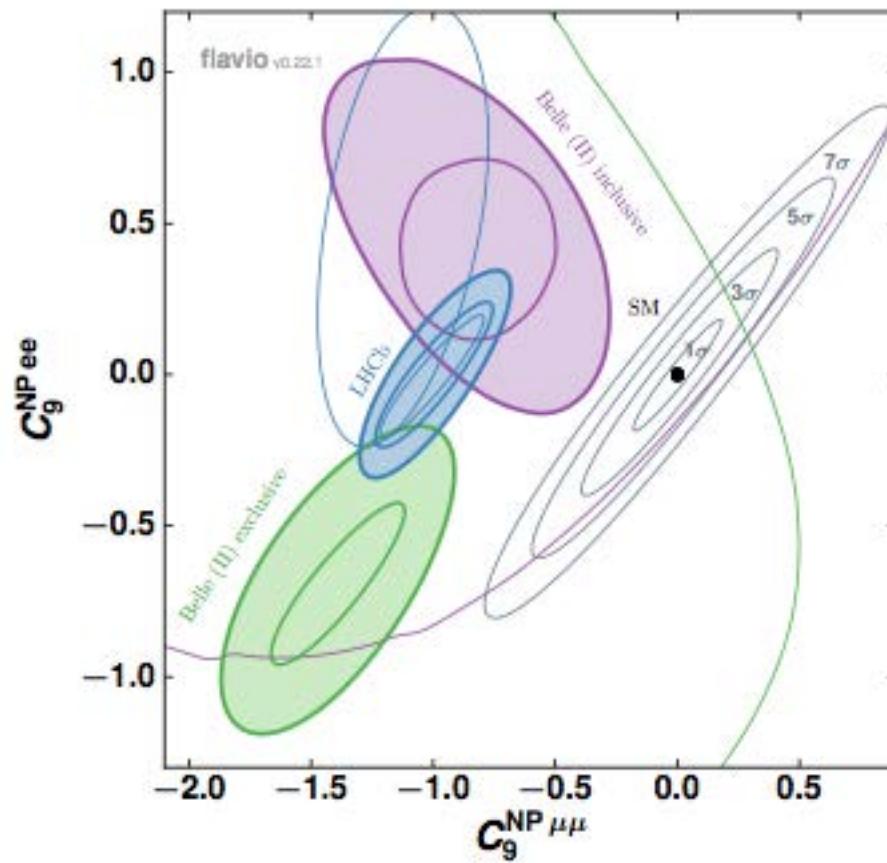
B_τ : 10% precision with 5ab-1 and 3% with 50 ab-1.
 $B\mu$: discovery by 5-6%

ℓ	\mathcal{B}_{SM}	711 fb^{-1}	5 ab^{-1}	50 ab^{-1}
τ	$(7.71 \pm 0.62) \times 10^{-5}$	61179 ± 5031	430231 ± 35378	4302312 ± 353781
μ	$(3.46 \pm 0.28) \times 10^{-7}$	275 ± 23	1933 ± 159	19333 ± 1590
e	$(0.811 \pm 0.065) \times 10^{-11}$	0.0064 ± 0.0005	0.0453 ± 0.0037	0.4526 ± 0.0372

Belle II Physics book
Preliminary

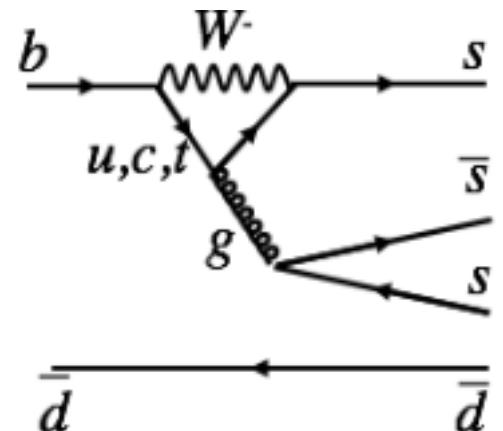
R(K) and R(K^{*})

Measurement of both muon and electron modes possible.
Dominant systematic error: 0.4% lepton ID.
With 20 fb⁻¹, R(K) and R(K^{*}) anomaly should be confirmed.



$B \rightarrow K^* \gamma$

- $b \rightarrow s$ time dependent CP violation dominated by new physics contributions.



Channel	WA (2017)		5 ab^{-1}		50 ab^{-1}	
	$\sigma(S)$	$\sigma(A)$	$\sigma(S)$	$\sigma(A)$	$\sigma(S)$	$\sigma(A)$
◆ $J/\psi K^0$	0.022	0.021	0.012	0.011	0.0052	0.0090
★ ϕK^0	0.12	0.14	0.048	0.035	0.020	0.011
★ $\eta' K^0$	0.06	0.04	0.032	0.020	0.015	0.008
◆ ωK_S^0	0.21	0.14	0.08	0.06	0.024	0.020
(★) $K_S^0 \pi^0 \gamma$	0.20	0.12	0.10	0.07	0.031	0.021
◆ $K_S^0 \pi^0$	0.17	0.10	0.09	0.06	0.028	0.018

- ★ Full study based on Belle II simulation
- ◆ Extrapolation of Belle/BaBar results

Belle II Physics book
Preliminary

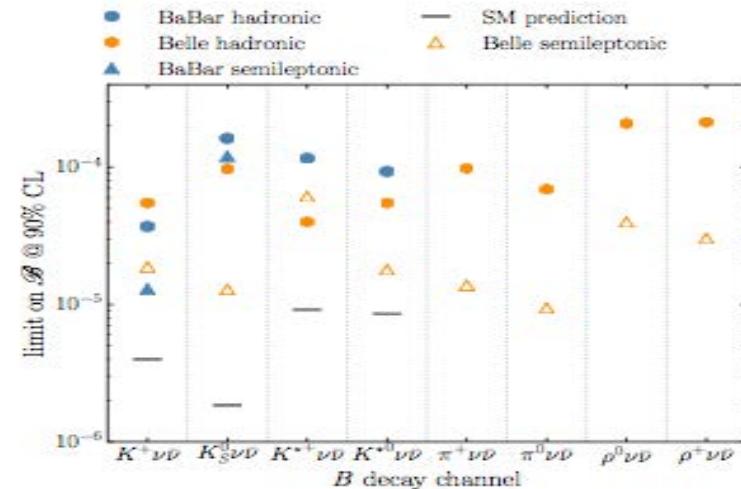
$B \rightarrow K^* \nu \bar{\nu}$

- Previously measured by Belle and BaBar.
- Best limits by Belle semi-leptonic tagging analysis.
- Belle II will zoom in on the branching fraction and provide a powerful NP search.
- Expect 5σ discovery with 20 ab^{-1} .

Belle II Physics book

Preliminary

Observables	Belle 0.71 ab^{-1} (0.12 ab^{-1})	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}
$\text{Br}(B^+ \rightarrow K^+ \nu \bar{\nu})$	$< 450\%$	30%	11%
$\text{Br}(B^0 \rightarrow K^{*0} \nu \bar{\nu})$	$< 180\%$	26%	9.6%
$\text{Br}(B^+ \rightarrow K^{*+} \nu \bar{\nu})$	$< 420\%$	25%	9.3%
$F_L(B^0 \rightarrow K^{*0} \nu \bar{\nu})$	—	—	0.079
$F_L(B^+ \rightarrow K^{*+} \nu \bar{\nu})$	—	—	0.077
$\text{Br}(B^0 \rightarrow \nu \bar{\nu}) \times 10^6$	< 14	< 5.0	< 1.5
$\text{Br}(B_s \rightarrow \nu \bar{\nu}) \times 10^5$	< 9.7	< 4.5	< 1.5



Dark photon: $e^+e^- \rightarrow \gamma A'$, $A' \rightarrow l^+l^-$

