

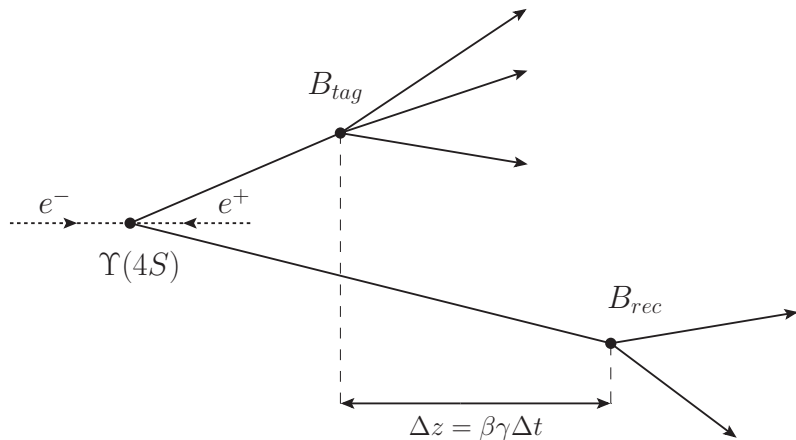
FIRST LOOK AT TIME-DEPENDENT CP VIOLATION USING EARLY BELLE II DATA

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CHARLES UNIVERSITY

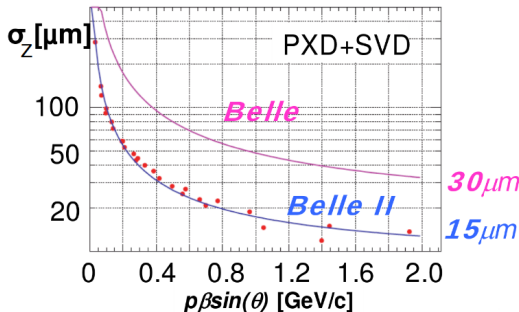
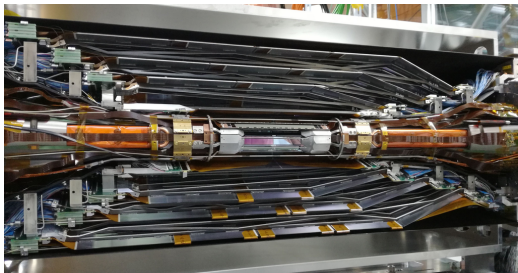




- $\Upsilon(4S)$ mass (10.58 GeV) right above $B^0\bar{B}^0$ production threshold (10.56 GeV) \Rightarrow B -mesons are at \sim rest in the $\Upsilon(4S)$ frame
- Boosted $\Upsilon(4S)$ \Rightarrow boosted B -mesons
- B -mesons are antisymmetrically entangled \Rightarrow when the first one decays, we know the other one is the opposite flavor at $\Delta t = 0$
- If we can measure the time between the two decays and deduce the flavors of the decaying B s, we can analyze time-dependent CPV
- Don't know the precise position of $B\bar{B}$ production, but we can measure where they decay


$$\Delta z = \beta\gamma\Delta t$$

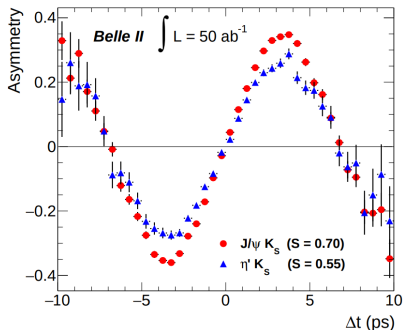
- Vertex positions coming mainly from Pixel Detector (PXD) and Silicon Vertex Detector (SVD)
- PXD
 - $\sim 50 \times 60 \times 75 \mu\text{m}$
 - DEPFET based
 - 1 layer + 1 coming in 2021
 - 14 mm from the beam
- SVD
 - 4 double-sided layers
 - r from 39 to 135 mm
 - $17^\circ < \theta < 150^\circ$
- $\beta\gamma = 0.28$ (2/3 KEKB)



- Most precise determination from tree-level $b \rightarrow c$ processes
- Uncertainty will be dominated by systematics at Belle II (alignment, Δt resolution)
- Independent determination from $b \rightarrow sq\bar{q}$ penguin dominated processes; loops \Rightarrow suppressed, but possible influence of New Physics

Channel	WA	5 ab ⁻¹	50 ab ⁻¹
$J/\psi K_S^0$	0.022	0.012	0.0052
$\eta' K_S^0$	0.06	0.032	0.015
$\Phi' K_S^0$	0.12	0.048	0.020

$\sigma(S)$ at various luminosities (projections)

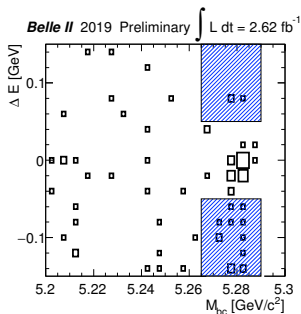
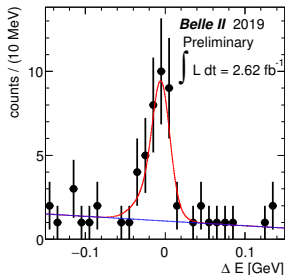


- Golden channel for time-dependent CPV
- Large-ish branching fraction 8.7×10^{-4} (all $B^0 \rightarrow J/\psi K^0$) and negligible contributions of other than $b \rightarrow c\bar{c}s$ tree-level processes
- Measurement of $\sin(2\beta)$ dominated by this channel
- Selection and reconstruction is the first step towards time-dependent CPV measurement

- $B^\pm \rightarrow J/\psi K^\pm$ control channel
- No TD CPV (and no direct CPV) – nice check
- Larger branching fraction

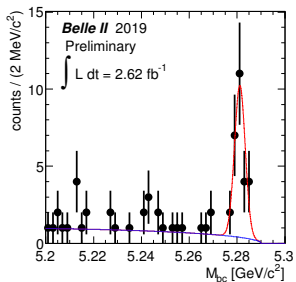
$$\Delta E = E_B^* - E_{\text{beam}}^*$$

$$M_{\text{bc}} = \sqrt{E_{\text{beam}}^{*2} - \mathbf{p}_B^{*2}}$$



- 2D unbinned ML fit
- Shaded regions excluded to suppress $B^0 \rightarrow J/\psi K^{*0}$

Type	Yield
N_{signal}	29.6 ± 5.3
$N_{\text{background}}$	1.6 ± 0.3



- Can be measured via isospin analysis of $B^0 \rightarrow \pi\pi$ and $B^0 \rightarrow \rho\rho$
- B -factories could not measure phase of $B^0 \rightarrow \pi^0\pi^0 \Rightarrow$ eightfold ambiguity in α
- By measuring phase (TDCPV) of $B^0 \rightarrow \pi^0\pi^0$ reduce ambiguity to by $2\times$ or $4\times$ (depends on parameter values)

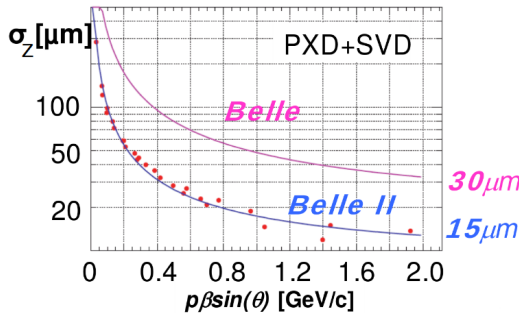
- How to measure B vertices from π^0 s?
 - Dalitz decay $\pi^0 \rightarrow \gamma e^+ e^-$ ($\mathcal{B} \approx 1.2\%$)
 - $\gamma \rightarrow e^+ e^-$ conversion in the beam pipe or PXD
 - Vertex resolution should be only 50% worse than with charged final state (still better than Belle)

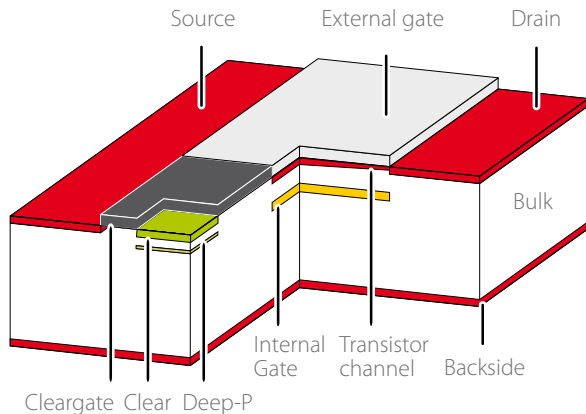
- With full dataset $B^0 \rightarrow \pi\pi$ and $B^0 \rightarrow \rho\rho$ should reach $\sigma(\alpha) \approx 0.6^\circ$

- Belle II is taking data – more info in Tom Browder’s talk from Monday
- First lifetime and mixing results – see Reem Rasheed’s talk
- Time-dependent CPV analyses are in the pipeline
- $B^0 \rightarrow J/\psi K_S^0$ will be the dominant channel in β/ϕ_1 determination
- Belle II should reach sub-degree precision of α/ϕ_2 using $B^0 \rightarrow \pi\pi$ and $B^0 \rightarrow \rho\rho$

THANK YOU!

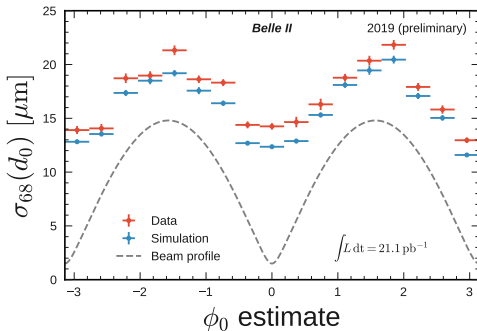
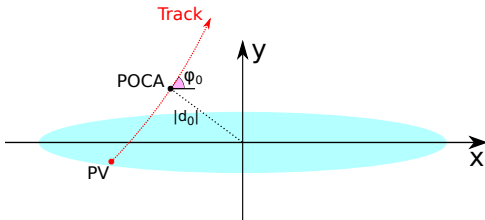
- $\beta\gamma = 0.28$ (2/3 KEKB)





- Integrated amplifier in every pixel
- Fast, low noise, but also fully depleted with large sensitive volume

- Point of closest approach (POCA)
- Gray curve is ellipse with $\sigma_x = 14.8 \mu\text{m}$
 $\sigma_y = 1.5 \mu\text{m}$
values from simulation
- Data from two-track events registered by PXD, SVD and CDC
- Data points are above the curve because of detector resolution



- Many different final states, all including neutrals
- Cleaner theory than other penguin-dominated channels \Rightarrow easier comparison of S to tree-dominated decays
- Statistical uncertainty expected to reach systematics level at $10\text{--}20 \text{ ab}^{-1}$