

Measurement of SuperKEKB Electron Beam Polarization through Tau Forward-Backward Polarization Asymmetry

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CAP 2019

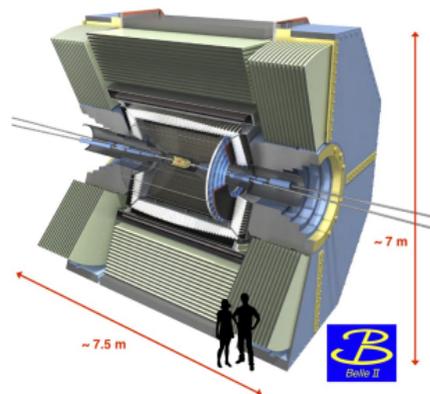
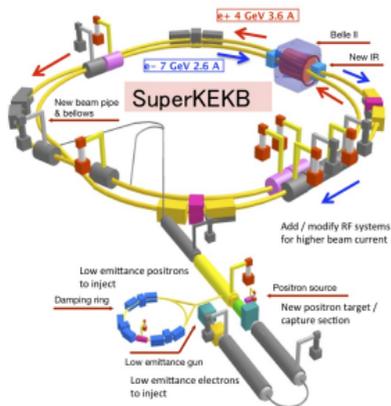
June 4, 2019



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SuperKEKB and Belle II

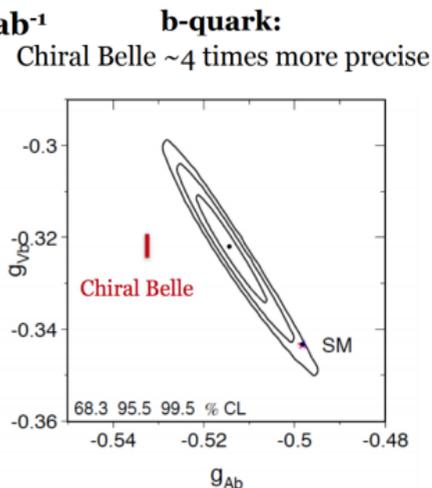
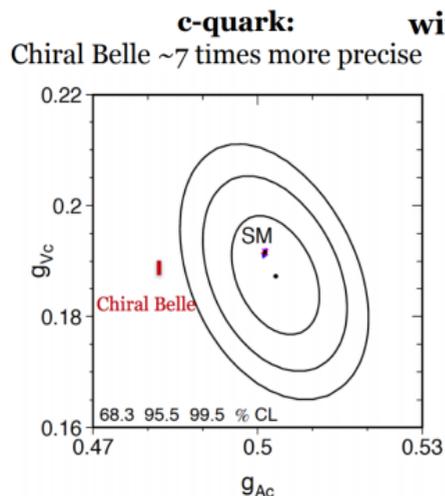
- SuperKEKB and Belle II are upgrades to the previously existing KEKB and Belle respectively
- SuperKEKB is designed to deliver a record $8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
- See Dr. Racha Cheaib's talk tomorrow morning for more details



Beam Polarization as a SuperKEKB Upgrade

- A polarized electron beam would allow Belle II to make many precise measurements of electro-weak parameters. Including A_{LR} for e, μ, τ, c, b

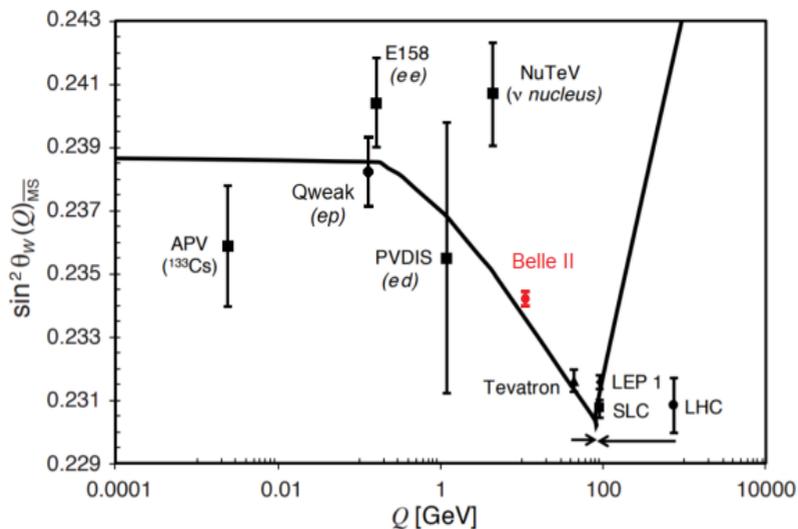
$$A_{LR} = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} = \frac{4}{\sqrt{2}} \left(\frac{G_{FS}}{4\pi\alpha Q_f} \right) g_A^e g_V^f \langle Pol \rangle \propto T_3^f - 2Q_f \sin^2 \theta_W$$



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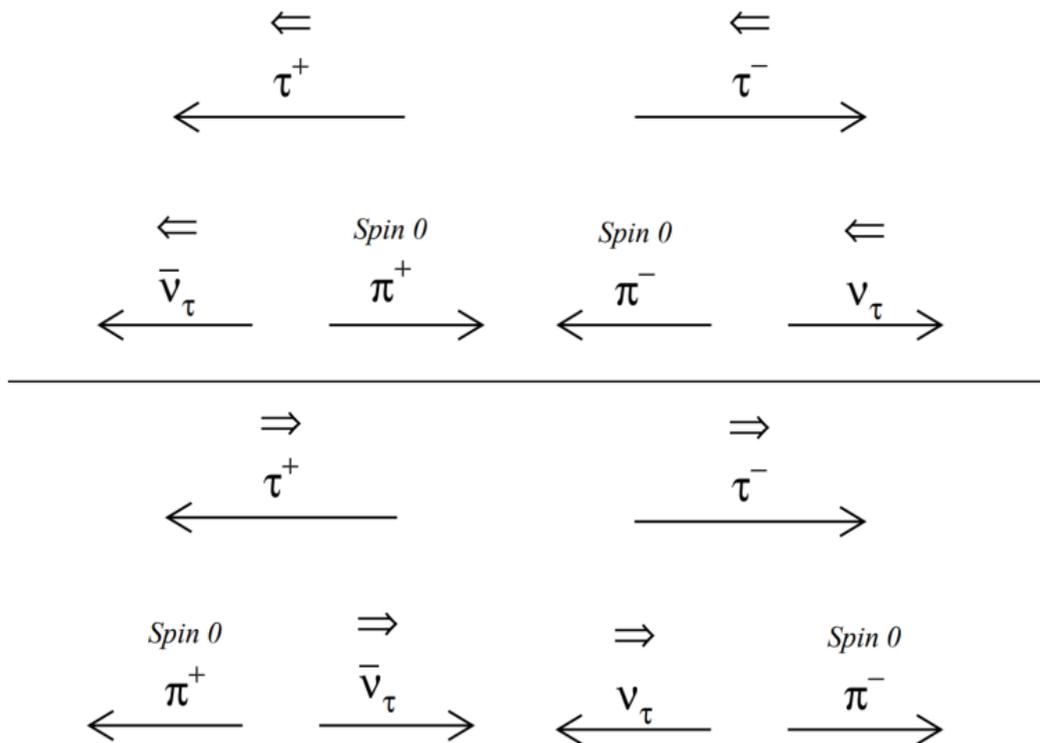
Beam Polarization as a SuperKEKB Upgrade

- Adding electron polarization to SuperKEKB would involve 3 separate hardware projects
 - A circularly polarized laser source to produce longitudinally polarized electrons
 - Beam rotators to rotate the beam perpendicular for transport and longitudinal for collision
 - Compton polarimeter to measure polarization after rotation

To maximize precision, beam polarization needs to be known at the IP

Measuring Beam Polarization with Tau Decays

- The τ decay, $\tau \rightarrow \pi\nu$, provides a powerful technique to measure polarization.

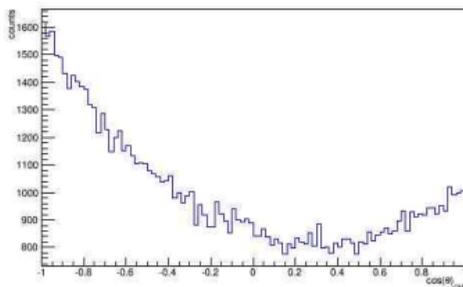


Simulating Tau Decays

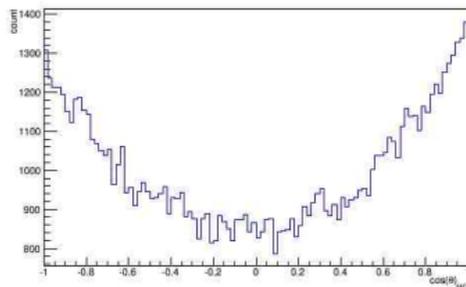
- Using the KK2F generator¹ many $e^+e^- \rightarrow \tau^+\tau^- \rightarrow \pi^+\pi^-\nu_\tau\bar{\nu}_\tau$ events are produced for each beam polarization

$\pi^- \cos \theta$ distributions

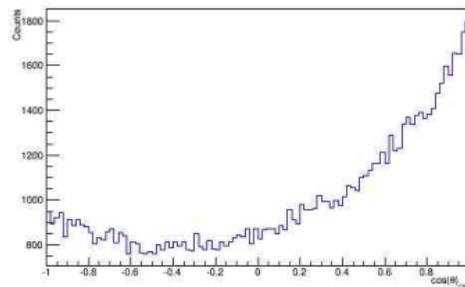
Negative Polarization



No Polarization



Positive Polarization



¹S. Jadach, B.F.L. Ward, Z. Was; Computer Physics Communications, Volume 130, Issue 3, 2000, Pages 260-325, [https://doi.org/10.1016/S0010-4655\(00\)00048-5](https://doi.org/10.1016/S0010-4655(00)00048-5).

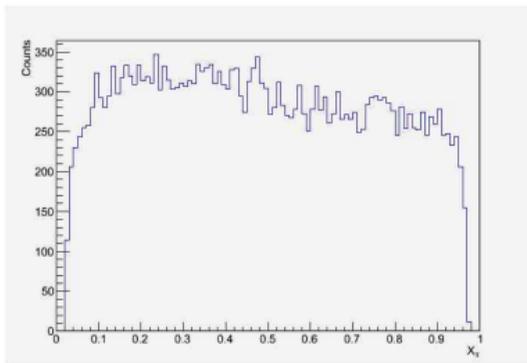
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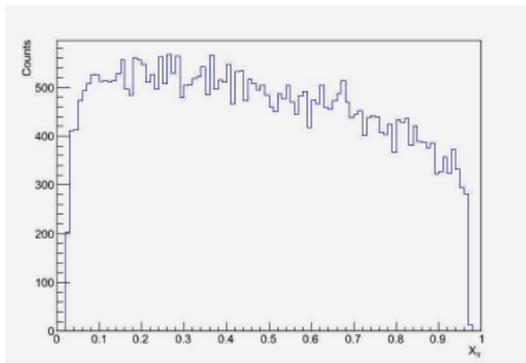
X_π distributions for no polarization

$$X_\pi \equiv P_\pi/E_b$$

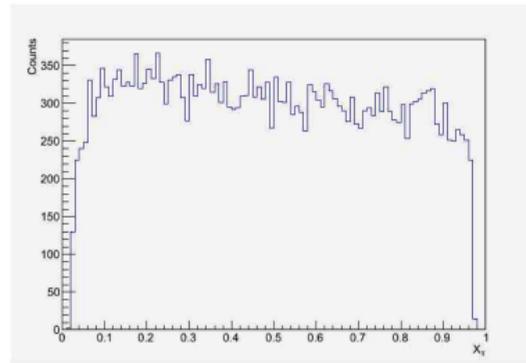
$-1 < \cos\theta < -0.5$



$-0.5 < \cos\theta < 0.5$



$0.5 < \cos\theta < 1$



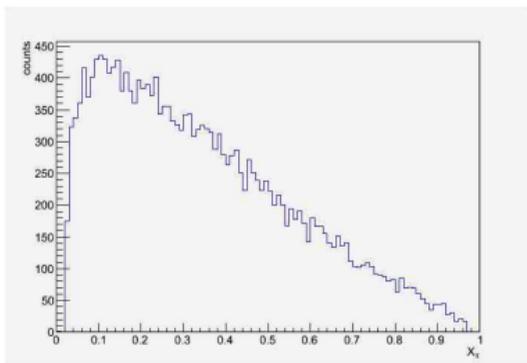
Simulating Tau Decays

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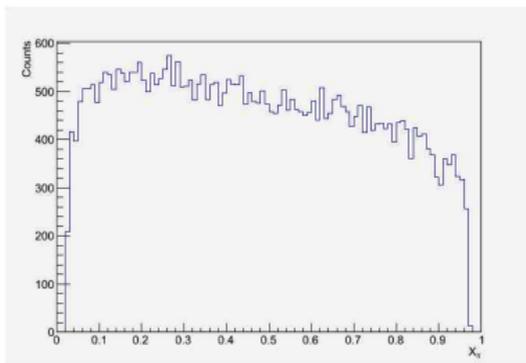
X_π distributions for positive polarization

$$X_\pi \equiv P_\pi/E_b$$

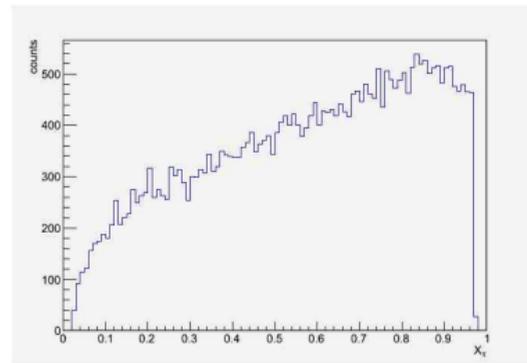
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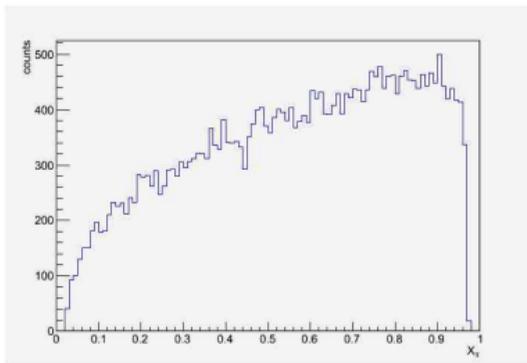
Simulating Tau Decays

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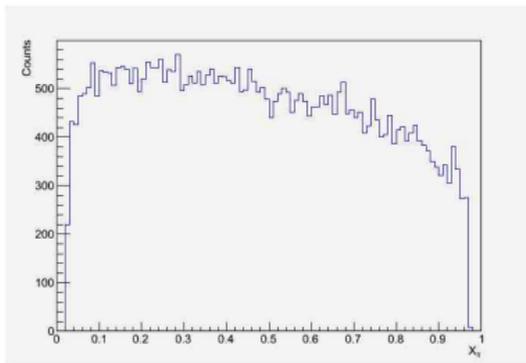
X_π distributions for negative polarization

$$X_\pi \equiv P_\pi/E_b$$

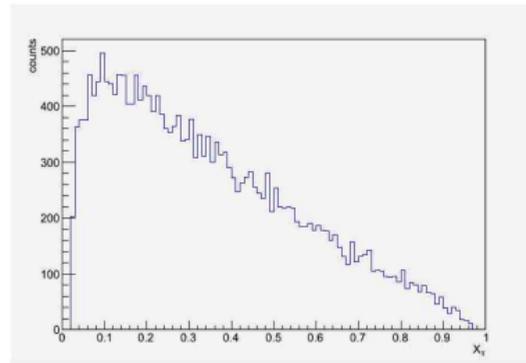
$-1 < \cos\theta < -0.5$



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$0.5 < \cos\theta < 1$



BaBar

- While Belle II is collecting data, BaBar has 531 fb^{-1} of data
- This corresponds to 500 million $e^+e^- \rightarrow \tau^+\tau^-$ events
 - 5.8 million $\tau^+\tau^- \rightarrow \pi^+\pi^-\nu_\tau\bar{\nu}_\tau$
- The PeP-II beam at BaBar was unpolarized, but a measurement will still give insight into the precision achievable with polarized beams
- Generating BaBar MC to obtain templates for each polarization state
 - Many sources of signal
 - $\tau^\pm \rightarrow \pi^\pm\nu_\tau$
 - $\tau^\pm \rightarrow \pi^\pm\pi^0\nu_\tau$
 - Multiple background sources
 - $\tau^\pm \rightarrow \mu^\pm\nu_\mu\nu_\tau$
 - $e^+e^- \rightarrow \mu^+\mu^-$
- MVA being trained to optimize these factors

Conclusion

- Beam polarization at SuperKEKB would allow for world leading electro-weak measurements
- Tau decays provide a powerful tool for measuring beam polarization at the interaction point
- A measurement of A_{LR} has been made with the generator level data
- BaBar MC with polarized beams is in the process of being produced

Thank You