Extracting the angle γ of the unitarity triangle from $B_{d,s} \to J/\psi\,\eta$ decays

Experimental prospects for $B_{d,s} \to J/\psi\,\eta$ and $B_{d,s} \to \eta\,\ell^+\ell^-$

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- CP violation and rare decays – motivation:
  - CKM picture of CP violation correct/ sufficient? Measurement in many channels allow overdetermination of CKM elements.
  - Rare decays ($BR < 10^{-5}$) involving loops at lowest order sensitive to contributions from higher mass scales. Measured decay distributions possible at high-statistics machines.

- Presented here:
  - CP violation in $B_{d,s} \to J/\psi\, \eta$ allows determination of γ.
  - The rare decay $B_s \to \eta\, \ell^+ \ell^-$ is accessible at LHC to join in the search for heavy new physics particles.

CP violation in $B_{d,s} \to J/\psi\,\eta$:

EXPERIMENT:

$a_{CP} = \frac{|A(t)|^2 - |\bar{A}(t)|^2}{|A(t)|^2 + |\bar{A}(t)|^2}$

$\Rightarrow \mathcal{A}_{CP}^{dir}$ and $\mathcal{A}_{CP}^{mix}$

THEORY:

Quark Topologies:

$\Rightarrow A_{d,s} \propto (1 - a_{d,s} e^{i\theta_{d,s}} e^{i\gamma})$

But a_s CKM suppressed

$\Rightarrow$ Only a_{CP} for B_d mode can be used to extract γ.

BUT:

Need one more observable.

CP averaged rate depends on normalization.

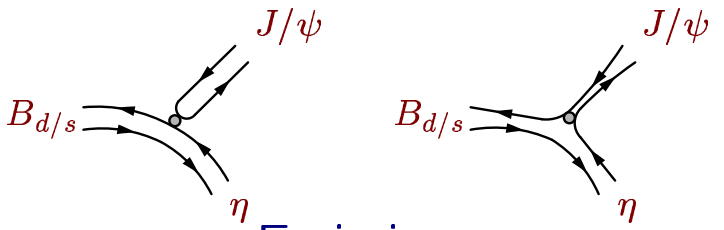
CP averaged rate for B_s mode with SU(3) symmetry

$\Rightarrow$ normalization.

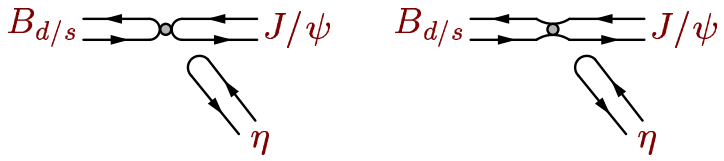
$\Rightarrow \gamma$

Quark Topologies in $B_{d,s} \to J/\psi\,\eta$

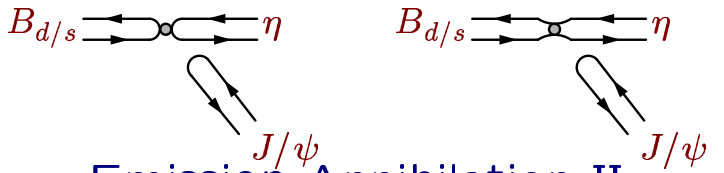
Disconnected Type Connected Type



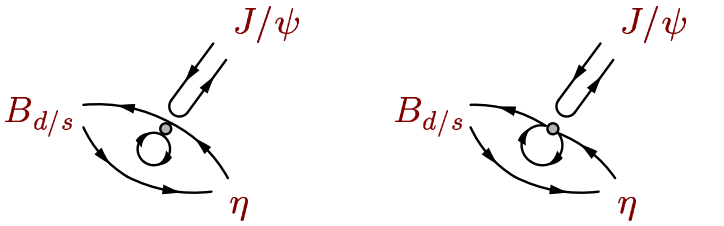
Emission



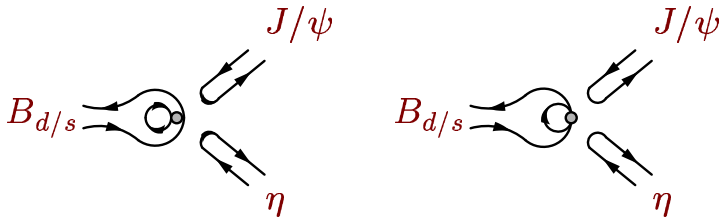
Emission Annihilation I



Emission Annihilation II

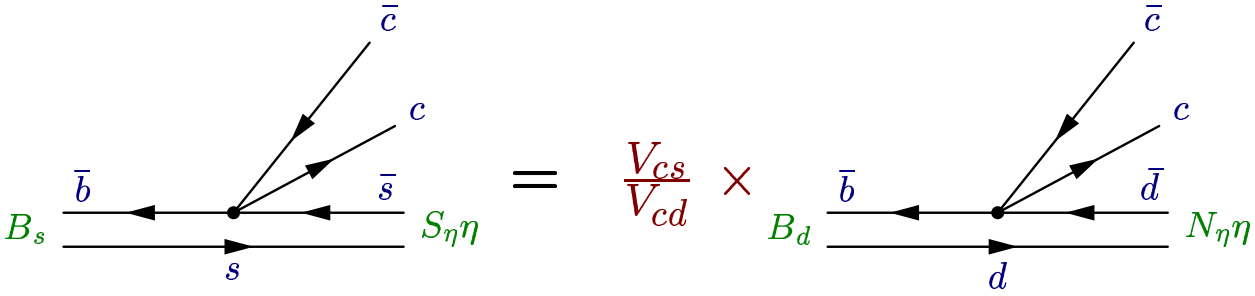


Penguin Emission



Double Penguin Annihilation

Estimating amplitudes with U-spin relations:



- Strong interaction assumed SU(3) flavour symmetric in the decay amplitude.
- Input: Measured BR for $B_d \to J/\psi\, K_S$ (CLEO). LCSR Form factors for $B \to K$ (Ali et al.)
- Dependence on η mixing angle.

Branching Ratios for $B_{d,s} \to J/\psi\, \eta$ and $B_{d,s} \to \eta\, \ell^+\ell^-$

	$\theta_P = -10°$	$\theta_P = -20°$
$B_d \to J/\psi\, \eta$	4.1×10^{-6}	1.6×10^{-6}
$B_s \to J/\psi\, \eta$	8.3×10^{-4}	9.5×10^{-4}
$B_d \to \eta\, \mu^+\mu^-$	2.8×10^{-9}	1.1×10^{-9}
$B_s \to \eta\, \mu^+\mu^-$	4.6×10^{-7}	5.2×10^{-7}

- Uncertainties
  - SU(3) breaking $\approx 10\% - 20\%$ in amplitudes.
  - For $B \to \eta\, \mu^+\mu^-$ - form factors $\Rightarrow \pm 20\%$ in BR.

Reconstructed $B_{d,s} \to J/\psi\,\eta$ events per year:

	$B_d \to J/\psi\,\eta$	$B_s \to J/\psi\,\eta$
HERA-B (untagged, /yr)		
$\theta_P = -10°$	35	1.4×10^3
$\theta_P = -20°$	15	1.6×10^3
CDF II (untagged, 2fb^{-1})		
$\theta_P = -10°$	250	9.5×10^3
$\theta_P = -20°$	100	1.1×10^4
ATLAS (tagged, 30fb^{-1})		
$\theta_P = -10°$	1.5×10^4	6.0×10^5
$\theta_P = -20°$	5.5×10^3	7.5×10^5
η not reconstructed ($\to$ factor $10\% - 20\%$)		

- Extraction of γ does not require B_s tagging.
- HERA-B running at full luminosity.
- CDF II: +50% with e^+e^- trigger
  +40% with relaxed muon trigger.
- $N(B_d)/N(B_s)$ taken ≈ 5
- K_S reconstruction efficiency taken ≈ 0.4
- $\to$ B_d mode probably only accessible at ATLAS.

Reconstructed $B_{d,s} \to \eta\, \ell^+\ell^-$ events

	$B_d \to \eta\, \mu^+\mu^-$	$B_s \to \eta\, \mu^+\mu^-$
CDF II (2 fb^{-1})		
$\theta_P = -10°$	< 5	90
$\theta_P = -20°$	< 2	110
ATLAS (30 fb^{-1})		
$\theta_P = -10°$	< 10	250
$\theta_P = -20°$	< 5	275
η not reconstructed ($\to$ factor 10% – 20%)		

- $N(B_d)/N(B_s)$ taken ≈ 5
- K^* reconstruction efficiency taken ≈ 0.5
- $\to$ B_d mode probably inaccessible, but possibilities for B_s.