

# *Radiative Corrections in B Decays at BaBar*

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*UCSD*

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- Branching fraction measurements
  - Definitions
  - Experimental cuts, *radiative tail*
- Few examples:
  - Hadronic decays
    - $B \rightarrow K l^+ l^-$ ,  $B \rightarrow h^+ h^-$  ( $h=\pi, K$ )

*Other observables (CP asymmetry) not really affected  
(missing radiative tails equivalent to inefficiency)*

# Measuring Branching ratios

*Partial width for a decay channel*

$$\Gamma_n(\omega) = \frac{\text{Phase space } \Phi_n}{2\sqrt{s_n}} |\overline{\mathcal{A}}_n|^2 \underbrace{G_n(\omega)}_{\text{Need to be included in our generator}}$$

$\sqrt{s_n}$  : CM energy

*Weak amplitude*

$\omega$  : parametrization of photon detector resolution (a cut-off)

$$BR(n, \omega) = \frac{\Gamma_n(\omega)}{\Gamma_{tot}}$$

# Yields from Max Likelihood fits

Likelihood fit, model (PDFs) for signal and backgrounds

$$\mathcal{L} = \exp\left(-\sum_i N_i\right) \prod_{j=1} \left[ \sum_i N_i \mathcal{P}_{i,j} \right]$$

$\mathcal{P}(m_{ES}) \cdot \mathcal{P}(\Delta E) \cdot \mathcal{P}(\mathcal{F})$

*yields* →

*B energy measurement with spectrometer* →

$$\Delta E = E_B^* - \frac{\sqrt{s}}{2}$$

- Kinematic variables are most affected by radiative tails.
- Multivariate analysis technique
  - **need to model correctly radiative tail**
    - » **Shape from signal MC, fit parameters from data**
- Selection requirements
  - Cut on  $\Delta E$  (usually  $|\Delta E| < 100(150)$  MeV)
  - **Need to know which fraction of tail is cut away!**
    - » **Signal MC to evaluate efficiency!!!**

$$B^0 \rightarrow h^+ h^- \quad (h = \pi, K)$$

## Back on the envelope estimate (almost)

*F.leDiberder*  
*M.Pivk*

*Total  
radiated  
energy*      *Max  
radiated  
energy*

$$f_{cut}(e_{cut} | \beta, e_{Max}) = \int_{k_{cut}}^1 dk \frac{\beta}{k^{1-\beta}} = 1 - \left( \frac{e_{cut}}{e_{Max}} \right)^\beta$$

Fraction of events  
with radiated energy  
greater than  $e_{cut}$

$$\beta = \mathbf{f}(m_{h^+}, ; m_{h^-})$$

**Could be as large as 10% in  $\pi\pi$  (less in  $K\pi$  and  $KK$ )**

# PHOTOS or not PHOTOS...

- Relevant decays for B physics are **rare**
  - BF error dominated by statistics, not much attention on ‘details’ initially
- First (Run1-Run3) BaBar publication generally *ignore radiative tails* in analysis assumptions
  - *But Bremsstrahlung recovery for electrons*
  - When final state contains (at least) a  $\pi^0$  EMC resolution for **photons** dominates anyway.

*This is not the case anymore!!!*

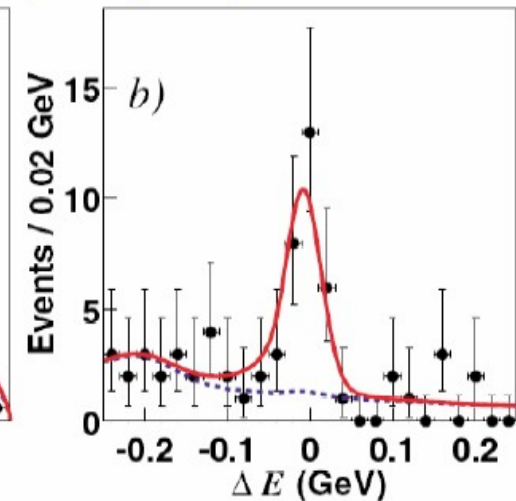
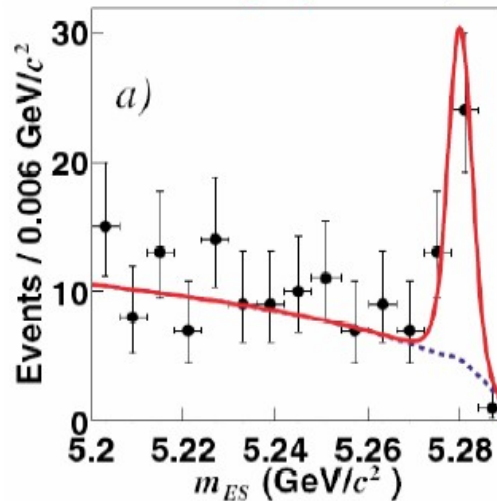
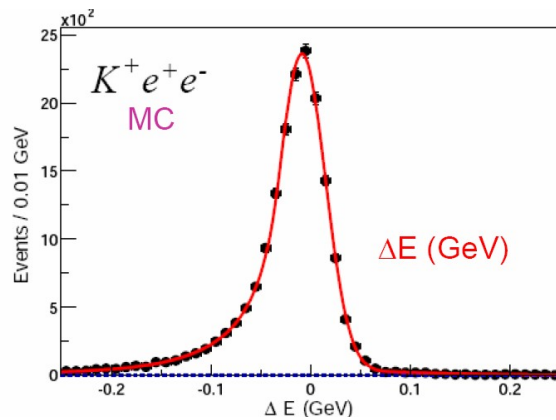
224M BB pairs:  $n_{K^+\pi^-} = 1606 \pm 51$  3% stat error

*Most relevant for ‘charged tracks’ only final states*

# Electron Bremsstrahlung

## BF(B → K l+l-) result

(red) full fit, (blue) all bkg components

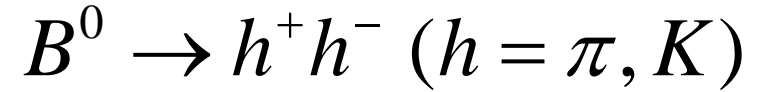


$$\text{BF}(B \rightarrow K l^+l^-) = (0.65 \pm 0.14, 0.13 \pm 0.04) 10^{-6}$$

8.4  $\sigma$  significance [PRL 91, 221802 (2003)]

MC validated on data control sample ( $B \rightarrow J/\psi K$ )

*What about simulation for hadrons?*

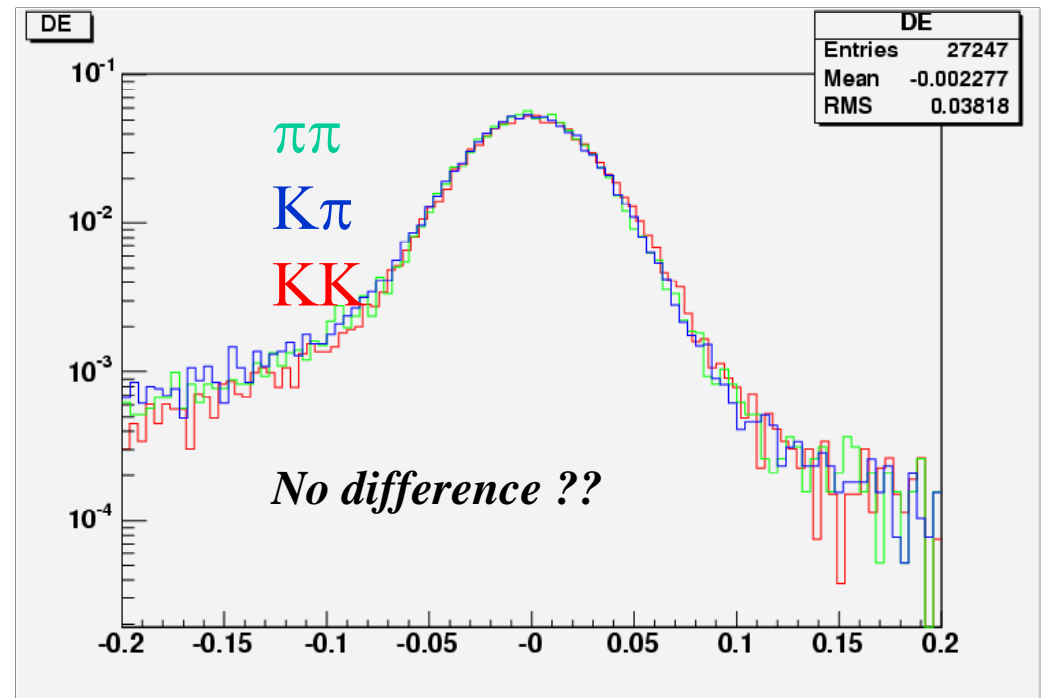
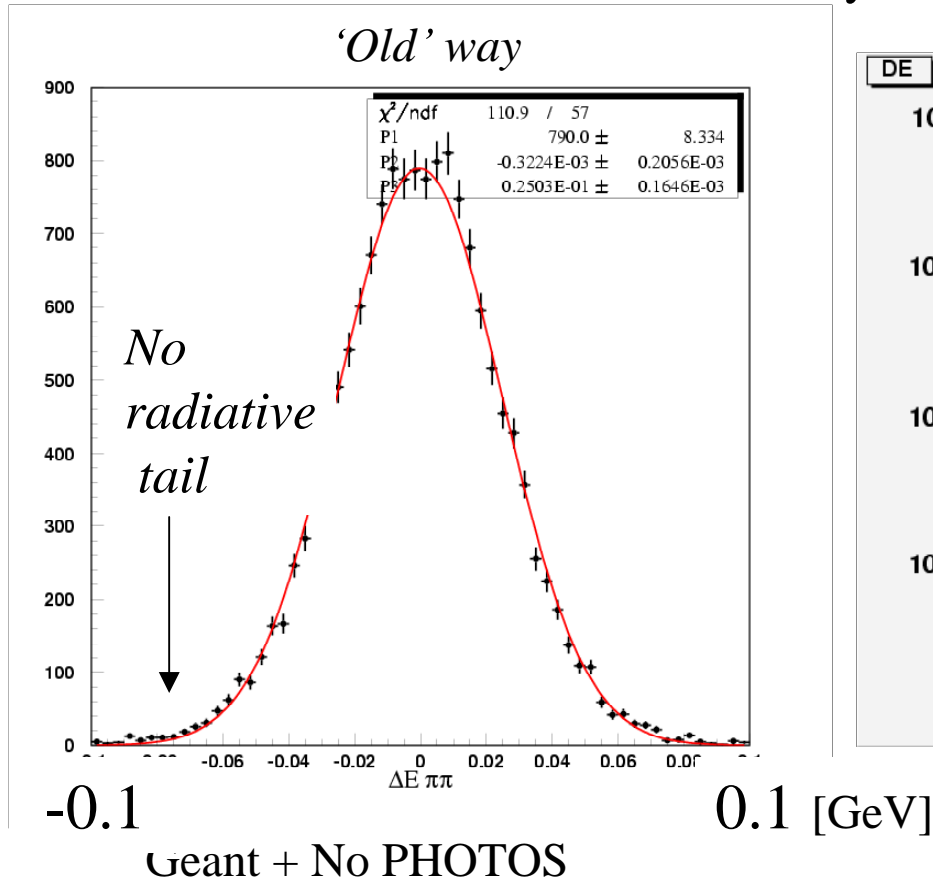


# $\Delta E$ shapes

- Signal PDF

- Core gaussian (track p resolution dominated)
- Radiative tail modeled with Crystal Ball function

$$\frac{\left(\frac{n}{\alpha}\right)^n}{N} \exp\left(-\frac{1}{2}\alpha^2\right) \frac{1}{\left(\frac{\Delta E - \mu}{\sigma} - \frac{n}{\alpha} - \alpha\right)^2}$$



M. Pierini,  
 To be presented  
 At CKM 2005

# An inconsistency?

Charming Penguin  $\sim \lambda^2$

$V_{us} V_{ub}^* \sim \lambda^4$

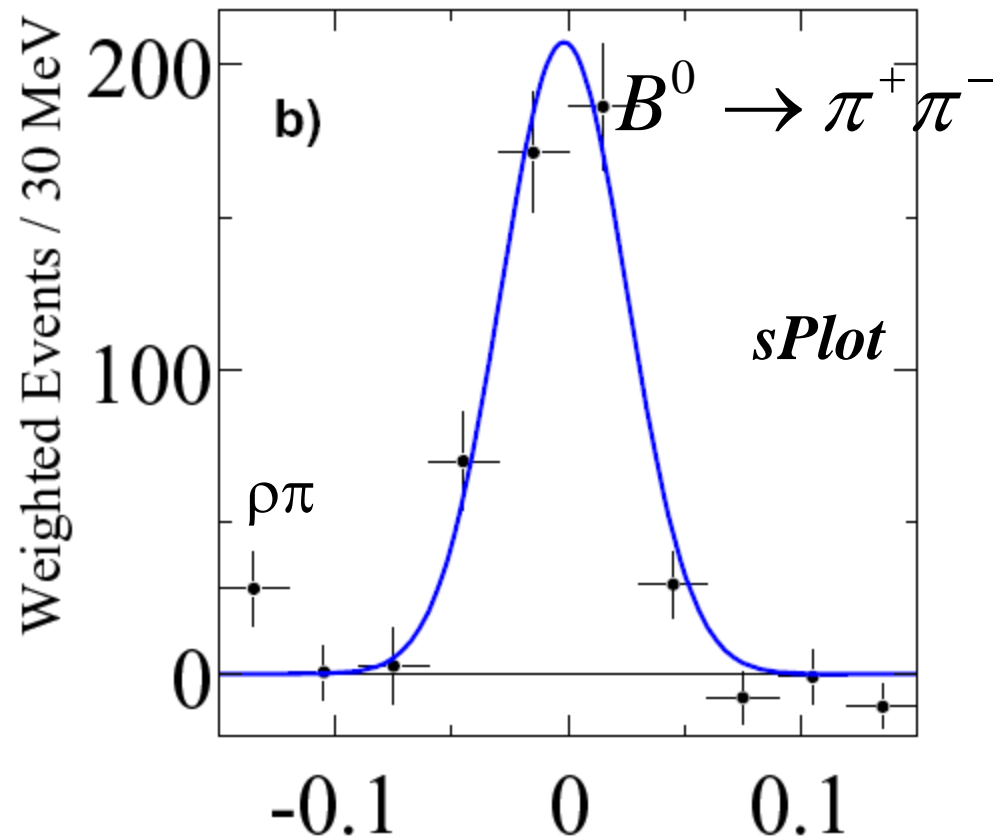
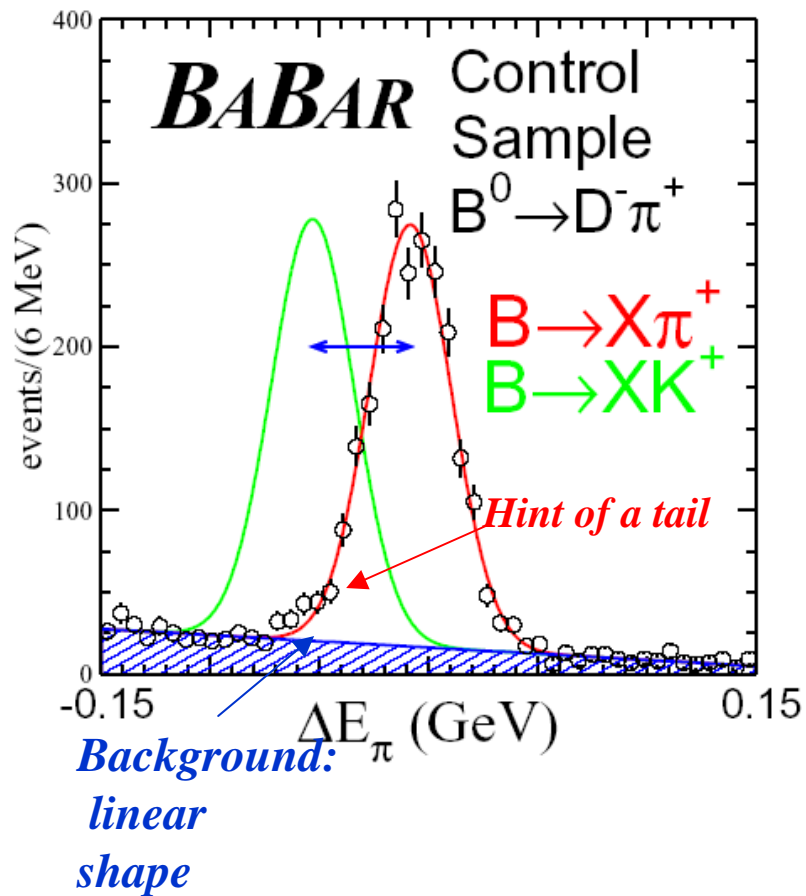
$$\begin{aligned}
 \mathcal{A}(B^0 \rightarrow K^+ \pi^-) &= V_{ts} V_{tb}^* \times P_1(c) - V_{us} V_{ub}^* \times \{E_1 - P_1^{GIM}(u-c)\} \\
 \mathcal{A}(B^+ \rightarrow K^0 \pi^+) &= -V_{ts} V_{tb}^* \times P_1(c) + V_{us} V_{ub}^* \times \{A_1 - P_1^{GIM}(u-c)\} \\
 \sqrt{2} \cdot \mathcal{A}(B^+ \rightarrow K^+ \pi^0) &= V_{ts} V_{tb}^* \times P_1(c) - V_{us} V_{ub}^* \times \{E_1 + E_2 + A_1 - P_1^{GIM}(u-c)\} \\
 \sqrt{2} \cdot \mathcal{A}(B^0 \rightarrow K^0 \pi^0) &= -V_{ts} V_{tb}^* \times P_1(c) - V_{us} V_{ub}^* \times \{E_2 + P_1^{GIM}(u-c)\}
 \end{aligned}$$

Channel	$BR^{\text{th}} \times 10^6$	$BR^{\text{exp}} \times 10^6$	$\mathcal{A}_{\text{CP}}^{\text{th}}$	$\mathcal{A}_{\text{CP}}^{\text{exp}}$
$K^+ \pi^-$	$19.7 \pm 1.1$	$(18.2 \pm 0.8)$	$-0.09 \pm 0.02$	$-0.11 \pm 0.02$
$K^+ \pi^0$	$12.8 \pm 0.6$	$12.1 \pm 0.8$	$-0.04 \pm 0.03$	$0.04 \pm 0.04$
$K^0 \pi^+$	$24.5 \pm 1.0$	$24.1 \pm 1.3$	$0.01 \pm 0.03$	$-0.02 \pm 0.03$
$K^0 \pi^0$	$9.5 \pm 0.6$	$11.5 \pm 1.0$	$0.03 \pm 0.03$	$0.09 \pm 0.16$

2 sigma-ish ?? A slightly larger BF preferred ?

# Cross-feed to background

*Tail hard to catch, can mix with backgrounds*



# BF measurements

*'Old' way*

NO PHOTOS

$$BF(K\pi(\text{soft}\gamma)) = \frac{\text{Fitted yield } N_{K\pi(\text{soft}\gamma)}}{\varepsilon(K\pi(\text{soft}\gamma))N_{BB}}$$

(total number of BB events)

*PDF with*

*no radiation tail*

*(but IN FACT soft photon within resolution included)*

*Need to declare our resolution ( $\omega$ )*

PHOTOS

$$BF(K\pi + K\pi\gamma) = \frac{N_{K\pi+K\pi\gamma}}{\varepsilon(K\pi + K\pi\gamma)N_{BB}}$$

*PDF with*

*correct radiation tail*

*More inclusive observable (good to extract weak interaction physics)*

*PHOTOS could not be accurate enough*

*(missing interference effects, differentiate  $\pi/K$ ).*

*Go back to full QED calculation and validate it.*

*See Elisabetta's talk*

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