

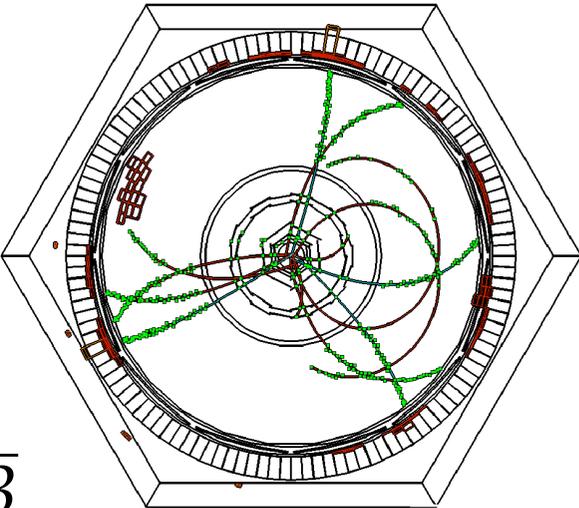
B Physics & *Dark Matter*

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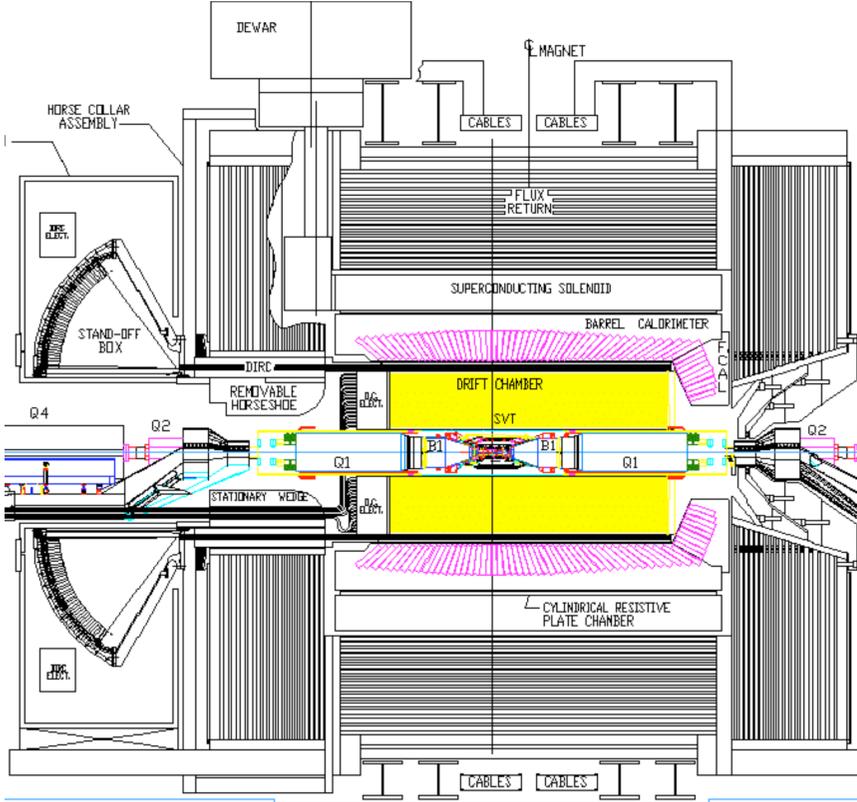
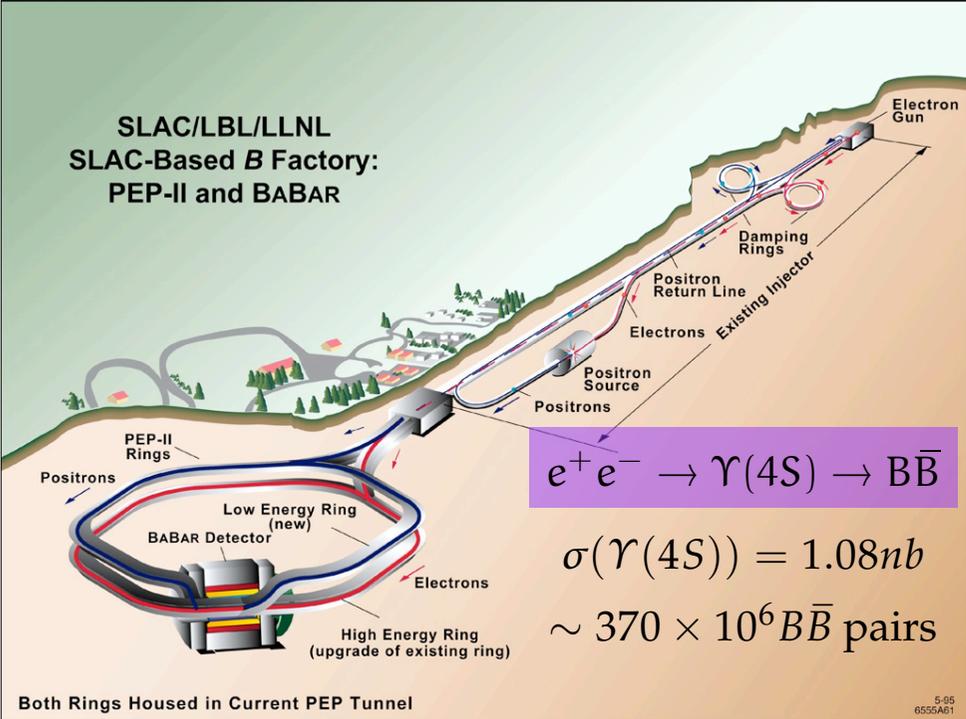
Dark Matter
FROM THE COSMOS TO THE LABORATORY

Connection: B Physics \Rightarrow Dark Matter ?



Dark Matter detection problematic

- Direct Detection
 - B meson mass = 5.28 GeV
 - produce two B's: $e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B}$
 - Over 20% of B decays have a ν
 - Detectors are not fully hermetic



Invisible decays

$$e^+ e^- \rightarrow \Upsilon(3S) \rightarrow \Upsilon(1S) \pi^+ \pi^-$$

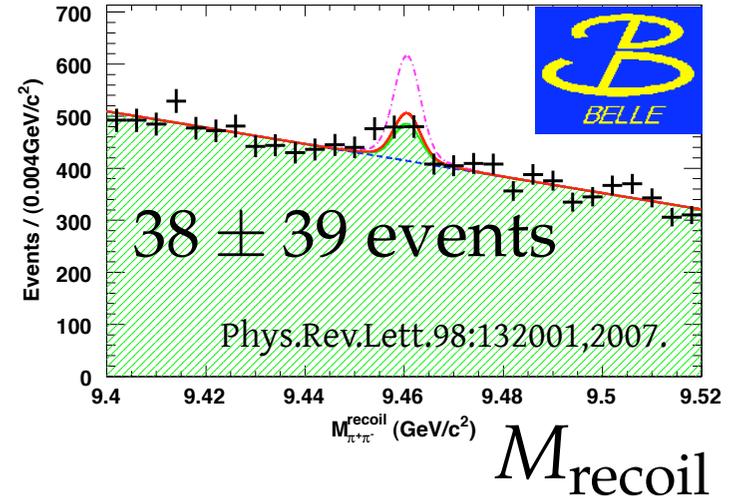
$\Upsilon(1S)$

McElrath, Phys.Rev.D72:103508,2005.

$$\sigma(f\bar{f} \rightarrow \chi\chi) \simeq \sigma(\chi\chi \rightarrow f\bar{f})$$

$$\sigma(\Upsilon(1S) \rightarrow \chi\chi) = f_{\Upsilon(1S)}^2 M_{\Upsilon(1S)} \sigma(b\bar{b} \rightarrow \chi\chi)$$

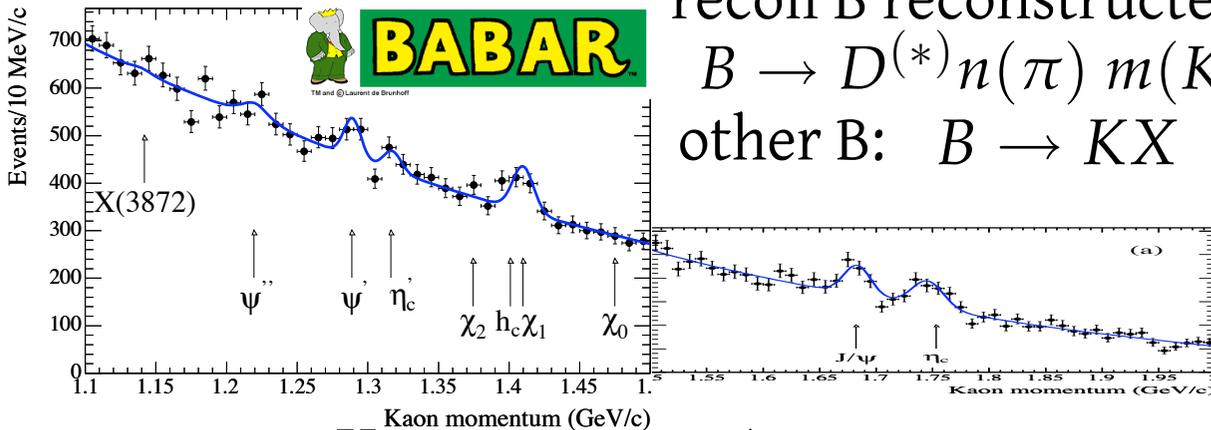
$$\sigma(\Upsilon(1S) \rightarrow \chi\chi) \simeq 0.41\%$$



$$\mathcal{B}(\Upsilon(1S) \rightarrow \text{invisible}) < 0.25\%$$

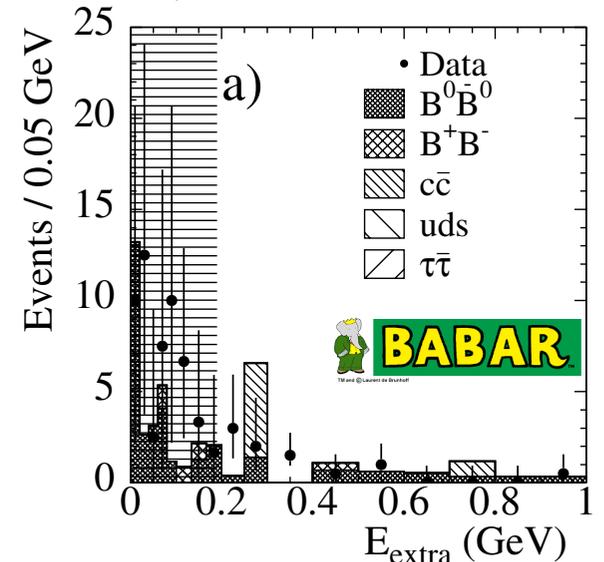
B

Phys.Rev.Lett.96:052002,2006.



Kaon momentum

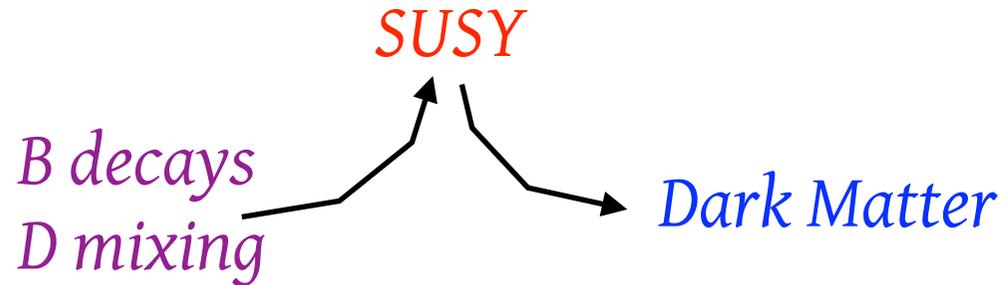
Phys.Rev.Lett.93:091802,2004.



$$\mathcal{B}(B \rightarrow \text{invisible}) < 2.2 \times 10^{-4}$$

Connection: B Physics \Rightarrow Dark Matter ?

■ Indirect Means



■ Measurements sensitive to **SUSY** or **New Physics**

- $b \rightarrow s\gamma$

- $B \rightarrow \tau\nu$

- $B \rightarrow D^{(*)}\tau\nu$

- $D^0 \leftrightarrow \bar{D}^0$ mixing

I will not cover:

- $b \rightarrow s$ Penguin CP violation

- Δm_s

- $B_{(s)} \rightarrow \mu^+\mu^-$

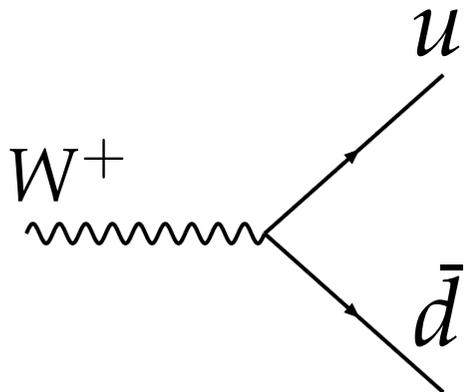
- $\tau \rightarrow \mu\gamma$

Flavor Changing Neutral Currents

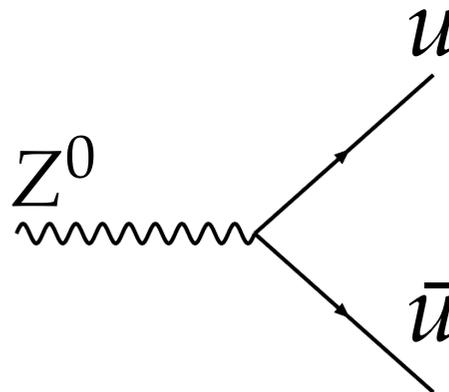
Quarks	u up	c charm	t top	Force Carriers
	d down	s strange	b bottom	
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	
Leptons	e electron	μ muon	τ tau	γ photon
				g gluon
				Z Z boson
				W W boson

Flavor \rightarrow

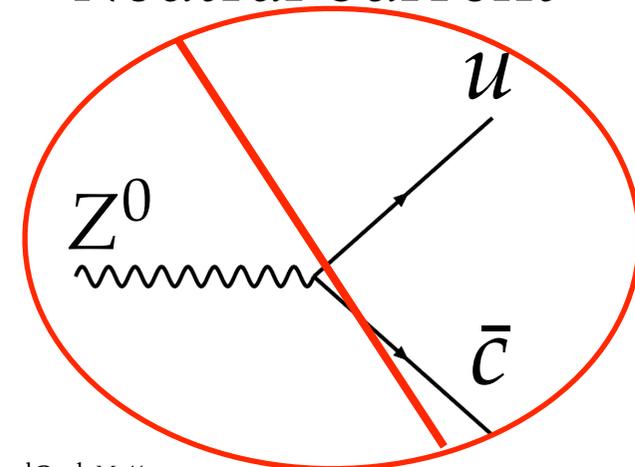
Charged Current



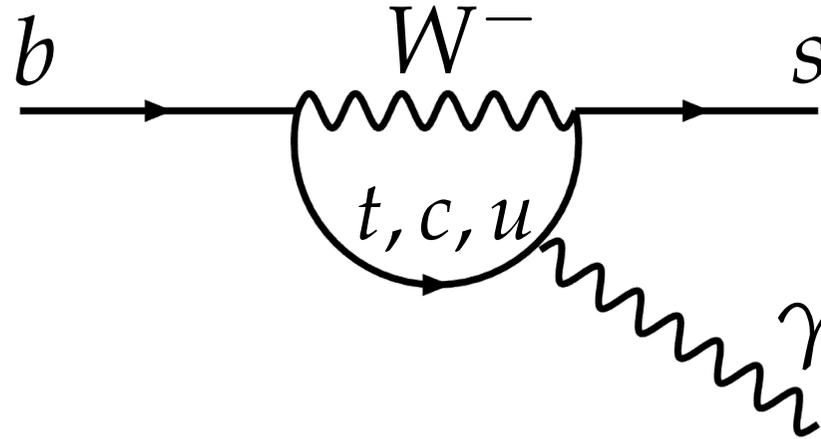
Neutral Current



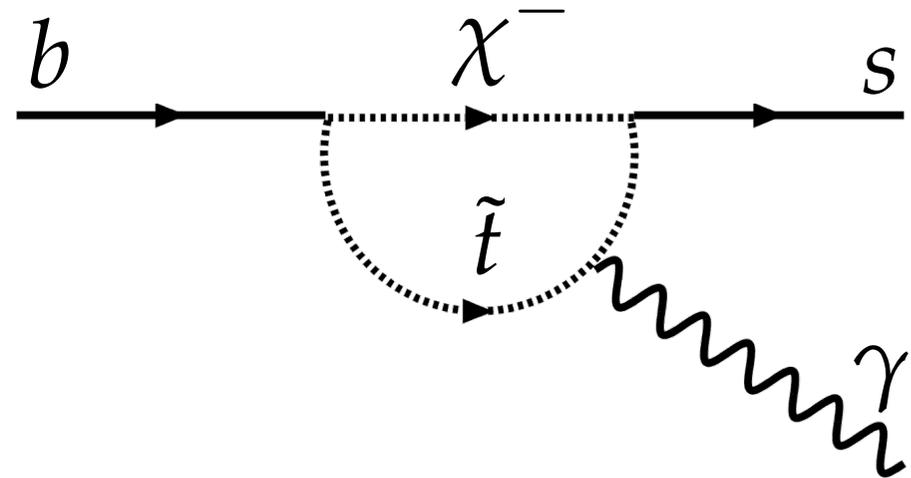
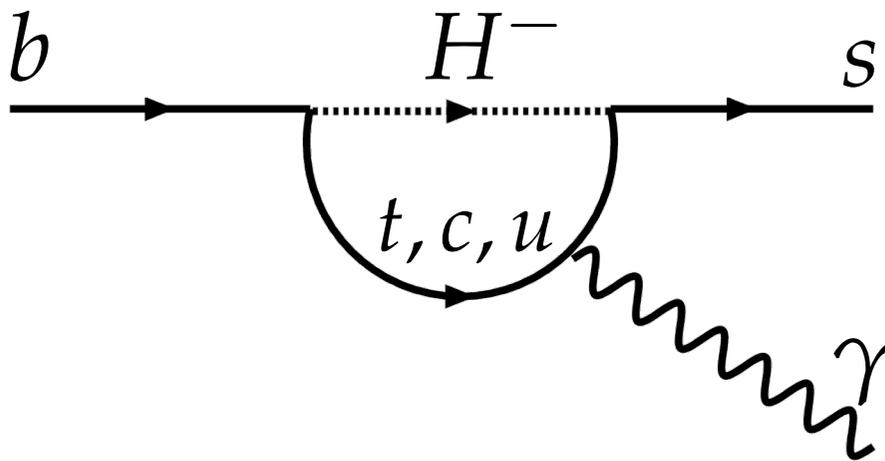
Flavor Changing Neutral Current



Penguin Diagrams



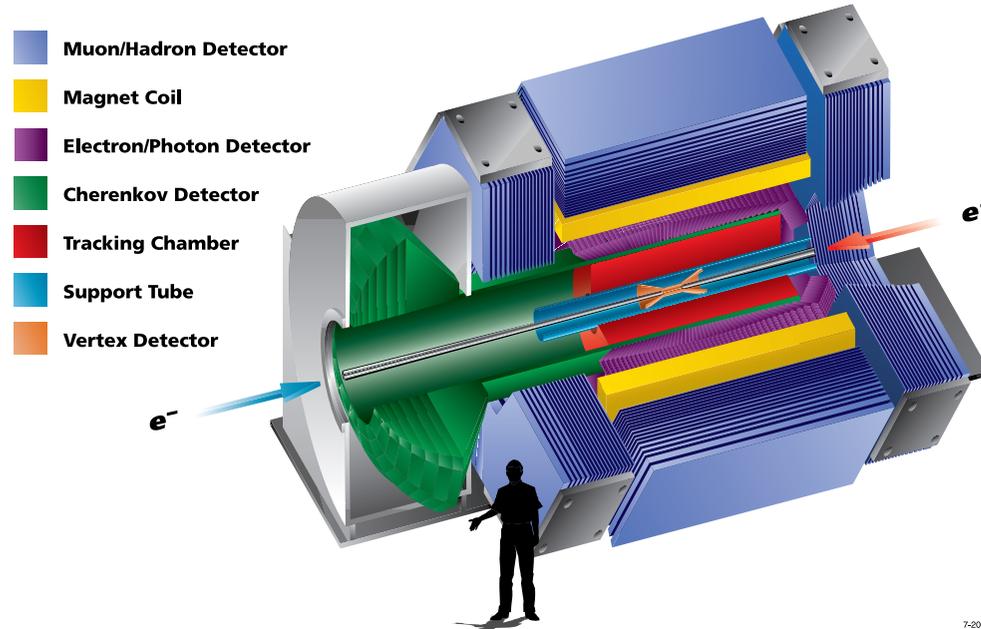
Standard Model has FCNC
at the one-loop level



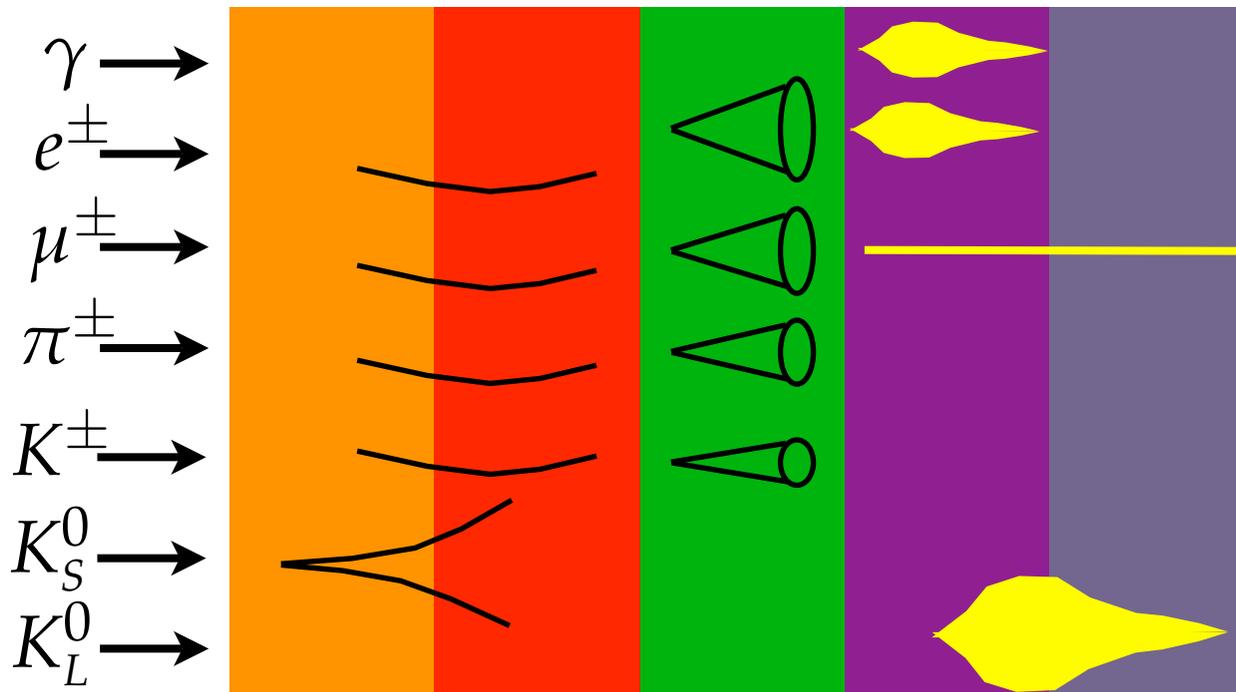
Charged Higgs and Charginos also yield
FCNC at the one-loop level

BABAR Schematic

BABAR Detector

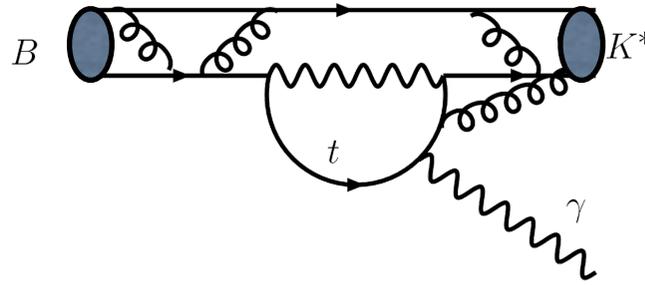
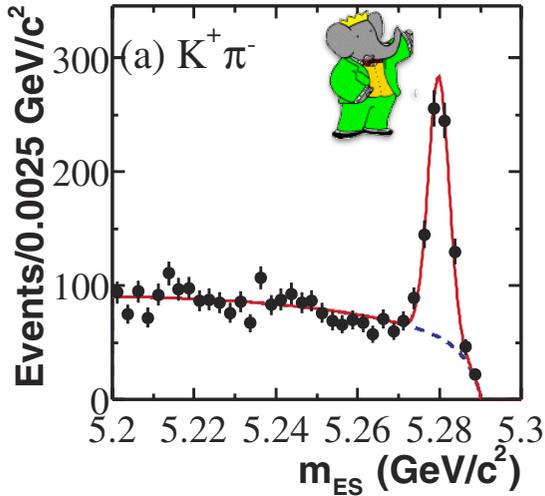


7-2000
6558A1



Inclusive vs. Exclusive decays

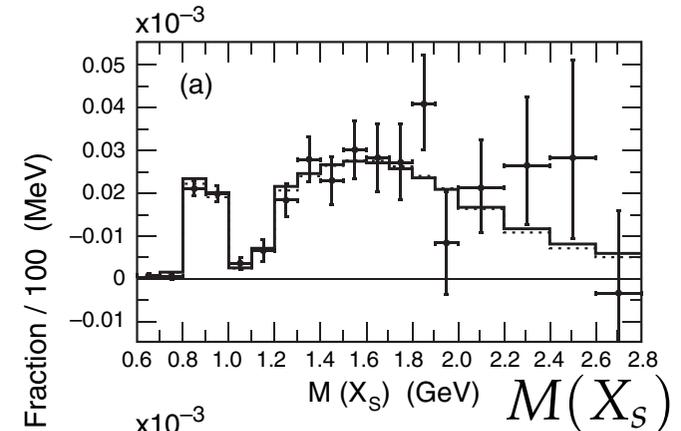
$$B^0 \rightarrow K^{*0} \gamma$$



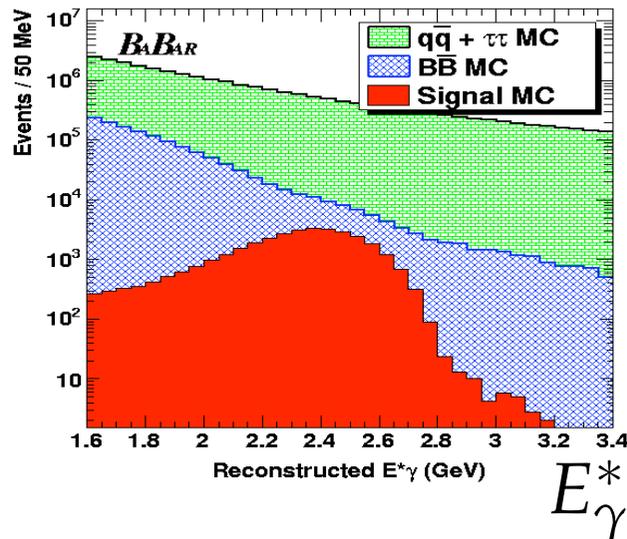
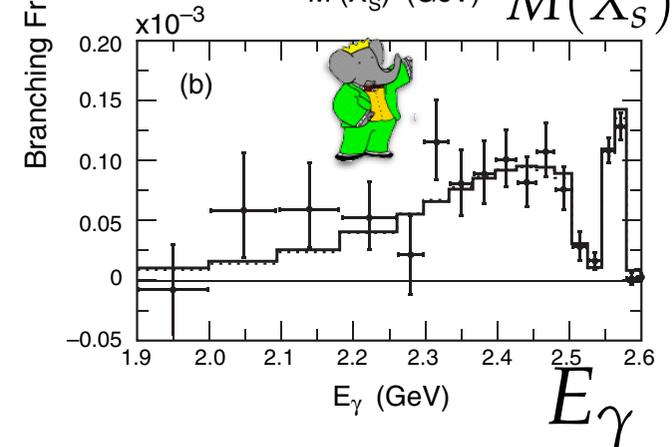
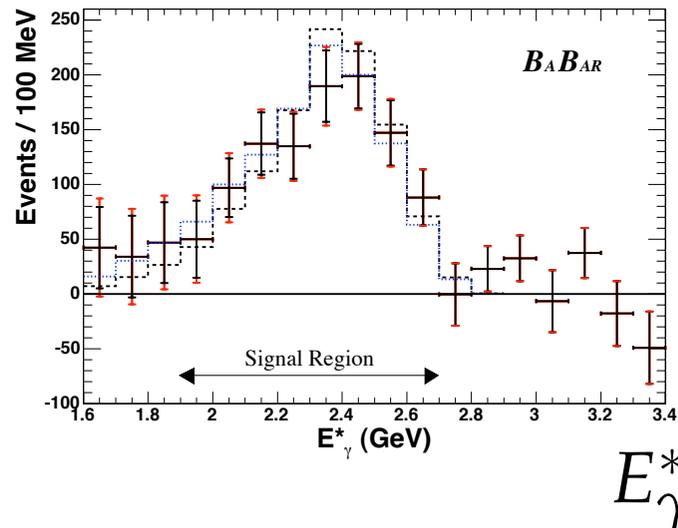
$$B \rightarrow X_s \gamma$$

sum 38 different hadronic states X_s

Phys. Rev. D 72, 052004 (2005)



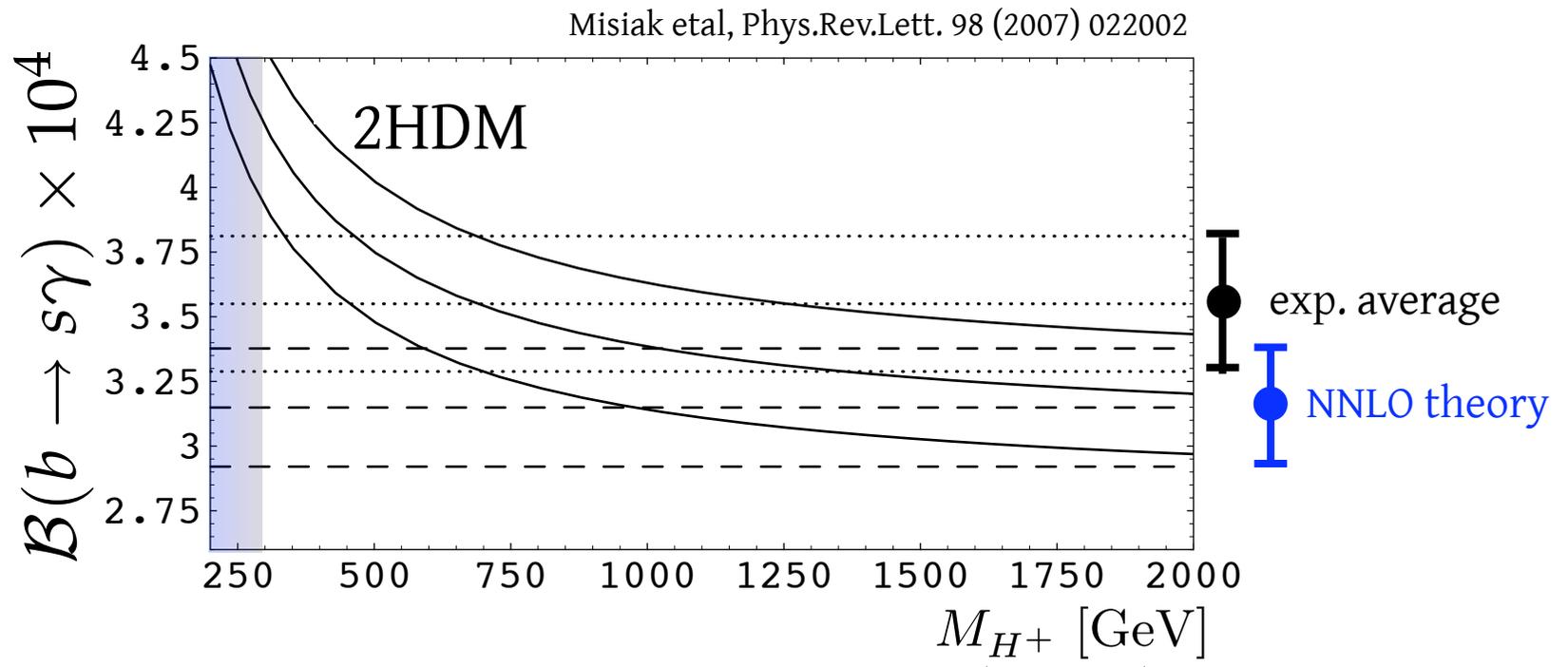
PRL 97, 171803 (2006)



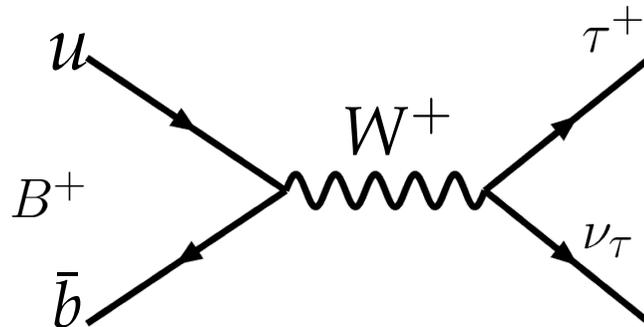
Theory vs. Experiment - and 2HDM

$$\Phi_d = \begin{pmatrix} \phi_1^0 \\ \phi_1^- \end{pmatrix} \quad \Phi_u = \begin{pmatrix} \phi_2^+ \\ \phi_2^0 \end{pmatrix}$$

$$\tan \beta = \frac{\langle \Phi_u \rangle}{\langle \Phi_d \rangle}$$



$$B^\pm \rightarrow \tau^\pm \nu_\tau$$



$$\tau \rightarrow e \nu_e \nu_\tau$$

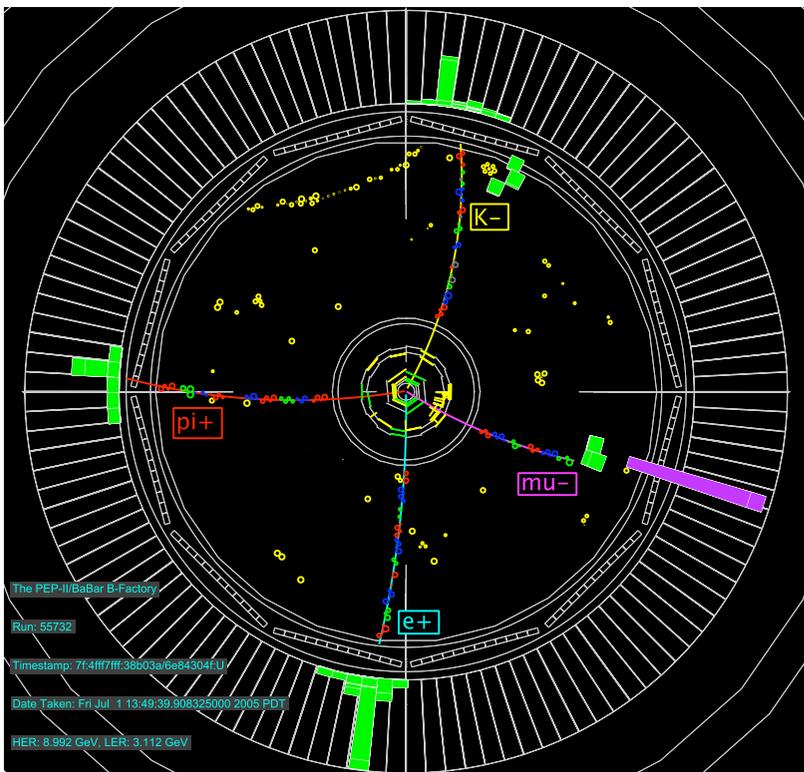
$$\mu \nu_\mu \nu_\tau$$

$$\pi \nu_\tau$$

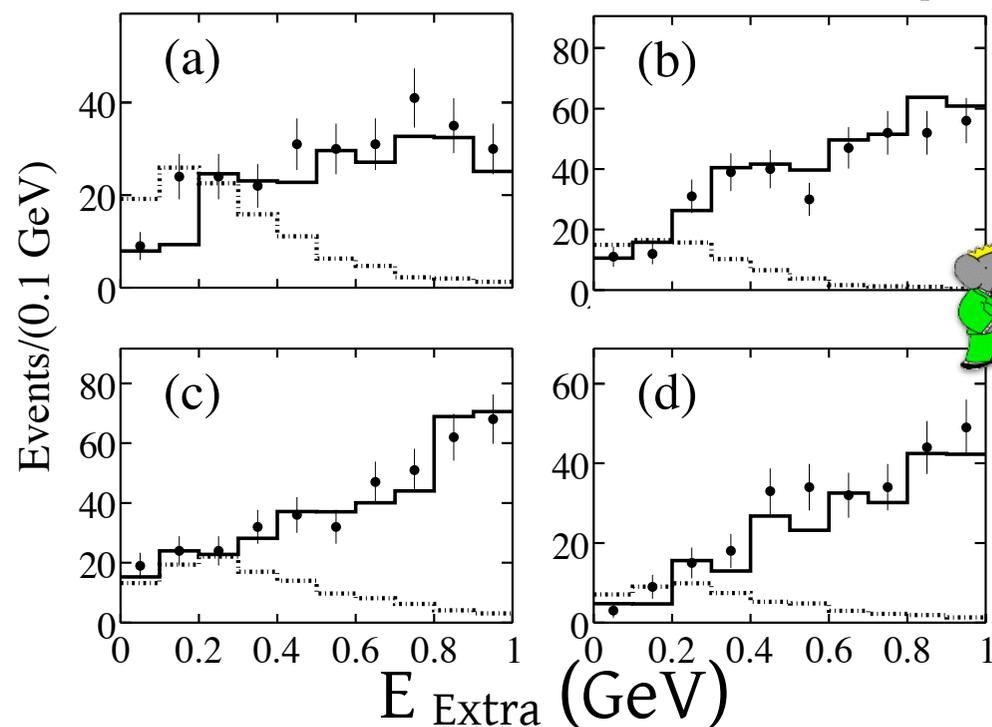
$$\pi \pi^0 \nu_\tau$$

$$\mathcal{B}(B_u \rightarrow \tau \nu)^{\text{SM}} = \frac{G_F^2 m_B m_\tau^2}{8\pi} \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B.$$

reconstruct $B^- \rightarrow D^0 \mu^- \bar{\nu}_\mu$ look at remainder of the event for the τ



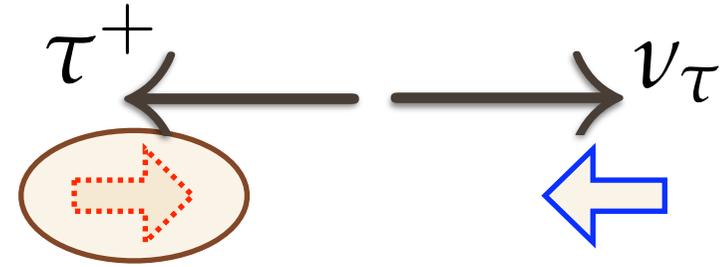
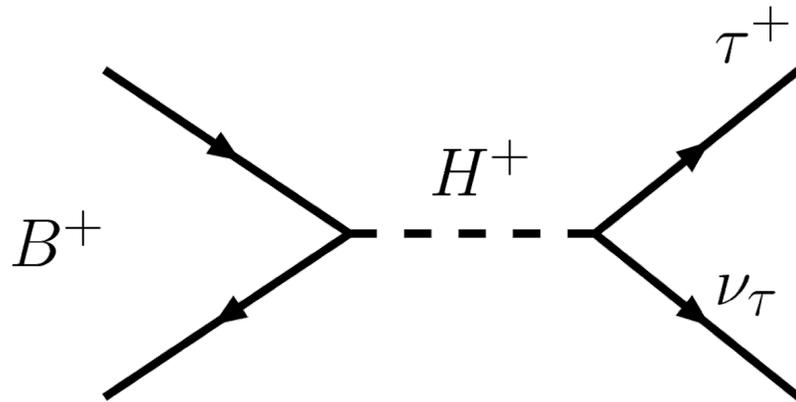
arXiv:0705.1820v1 [hep-ex]



BABAR average of semileptonic and hadronic tags

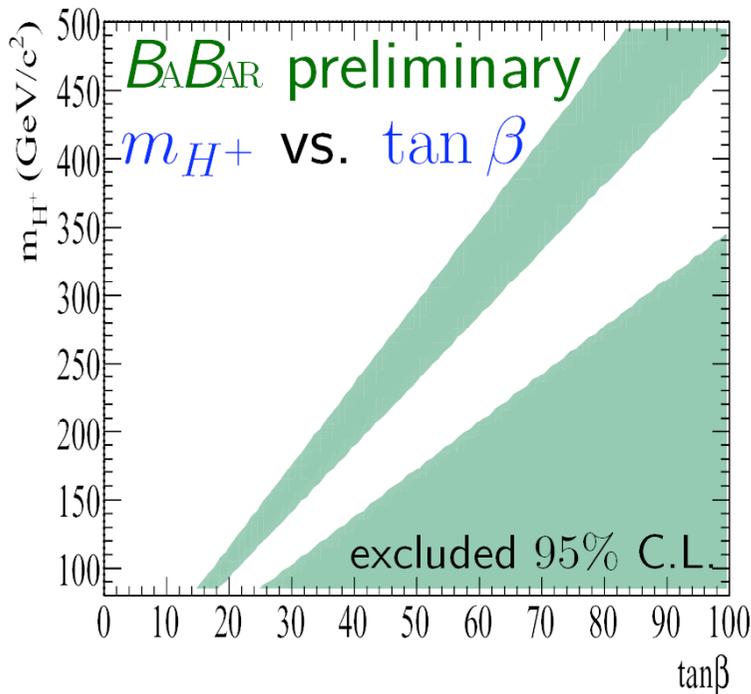
$$\mathcal{B}(B^+ \rightarrow \tau^+ \nu_\tau) = (1.20 \pm 0.39 \pm .37) \times 10^{-4}$$

$B^\pm \rightarrow \tau^\pm \nu_\tau$ Charged Higgs limits



$$\mathcal{B}(B \rightarrow \tau \nu) = \mathcal{B}_{SM} \times \left[1 - \left(\frac{m_B^2}{m_{H^\pm}^2} \right) \tan^2 \beta \right]^2$$

see Isidori & Paradisi
Phys.Lett. B639 (2006) 499-507



$$\mathcal{B}(B^+ \rightarrow \tau^+ \nu_\tau) = (1.20 \pm 0.39 \pm .37) \times 10^{-4}$$

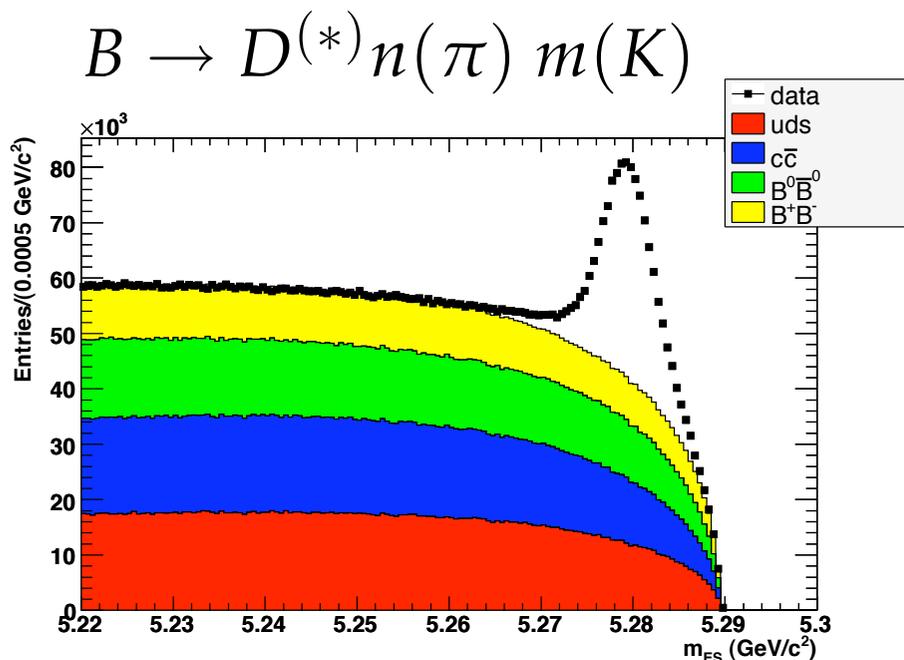


$$\mathcal{B}(B^+ \rightarrow \tau^+ \nu_\tau) = 1.79^{+0.56}_{-0.49} {}^{+0.39}_{-0.46} \times 10^{-4}$$

SM prediction

$$\mathcal{B}(B^+ \rightarrow \tau^+ \nu_\tau) = (0.73 \pm 0.11) \times 10^{-4}$$

$$B \rightarrow D^{(*)} \tau \nu$$



arXiv:0707.2758v1 [hep-ex]

$$\mathcal{B}(B \rightarrow D \tau^- \bar{\nu}_\tau) = (0.90 \pm 0.26 \pm 0.11 \pm 0.06)\%$$

$$\mathcal{B}(B \rightarrow D^* \tau^- \bar{\nu}_\tau) = (1.81 \pm 0.33 \pm 0.11 \pm 0.06)\%,$$

SM calculations Chen & Geng JHEP 0610:053,2006

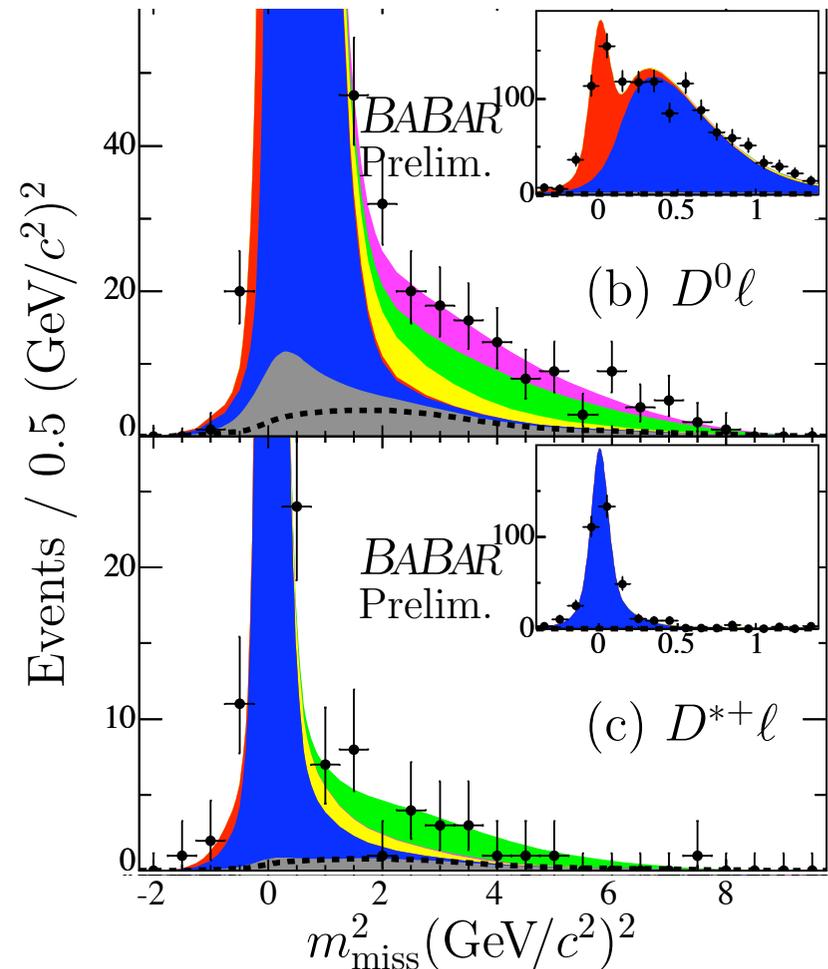
$$\mathcal{B}(\bar{B}^0 \rightarrow D^+ \tau^- \bar{\nu}_\tau) = (0.69 \pm 0.04)\%$$

$$\mathcal{B}(\bar{B}^0 \rightarrow D^{*+} \tau^- \bar{\nu}_\tau) = (1.41 \pm 0.07)\%;$$

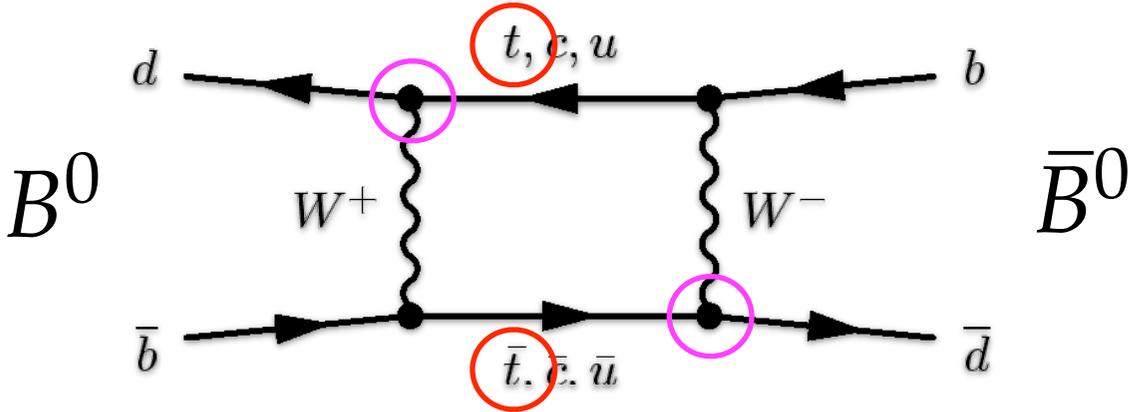
reconstruct $D^{(*)}$

$$\tau \rightarrow e \nu \nu \text{ or } \tau \rightarrow \mu \nu \nu$$

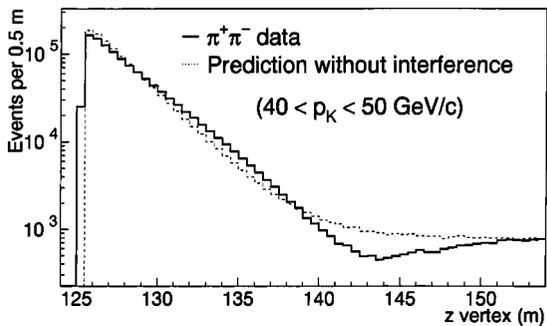
large $B \rightarrow D^{(*)} \ell \nu$ background



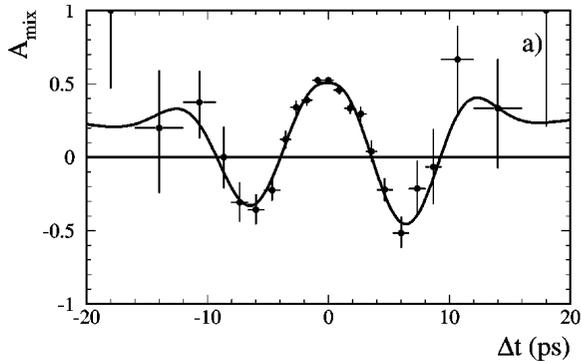
Meson Mixing



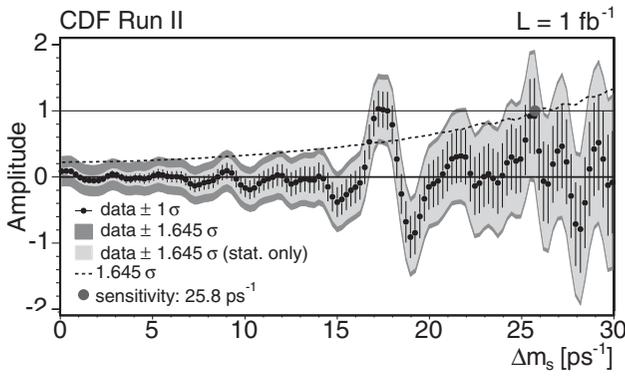
K^0



B^0



B_S

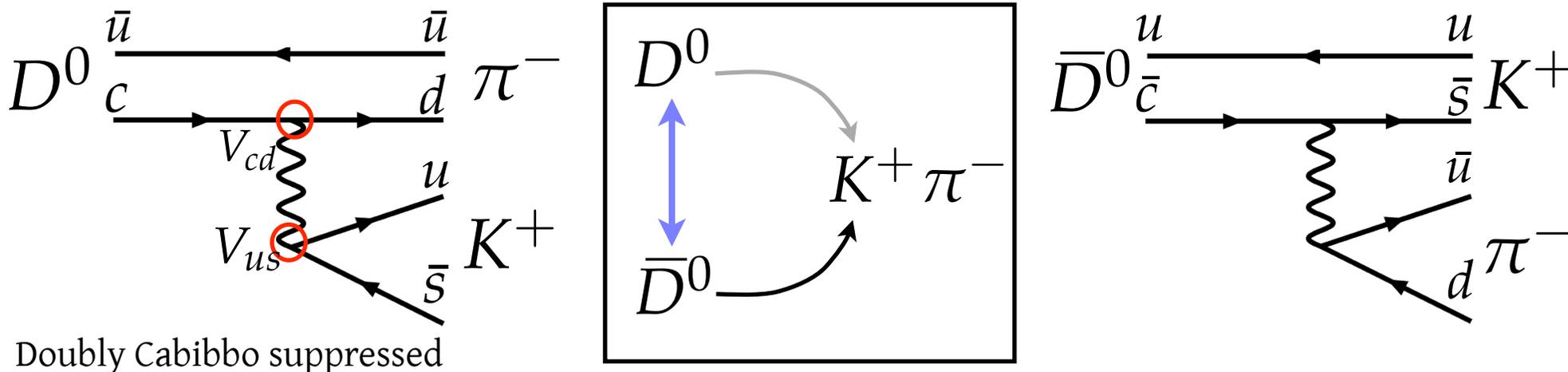


$$\frac{\Delta m_{K^0}}{\Gamma_{K_S^0}} = 0.474$$

$$\frac{\Delta m_{B_d}}{\Gamma} = 0.776$$

$$\frac{\Delta m_{B_S}}{\Gamma} = 25.5$$

D mixing



probability to produce a D^0 that decays as a \bar{D}^0

$$f_{\text{Mixed}}(t) = \frac{e^{-t/\tau}}{4\tau} \{ \cosh(\Delta\Gamma t/2) - \cos(\Delta m t) \}$$

$$A(D^0 \xrightarrow{\Delta m} \bar{D}^0 \rightarrow K^+ \pi^-) + A(D^0 \xrightarrow{\text{DCSD}} K^+ \pi^-)$$

$$f_{\text{Mixed}}(t) \sim e^{-t/\tau} \left\{ r_D + \sqrt{r_D} y' t + \frac{(x'^2 + y'^2)}{4} (t/\tau)^2 \right\}$$

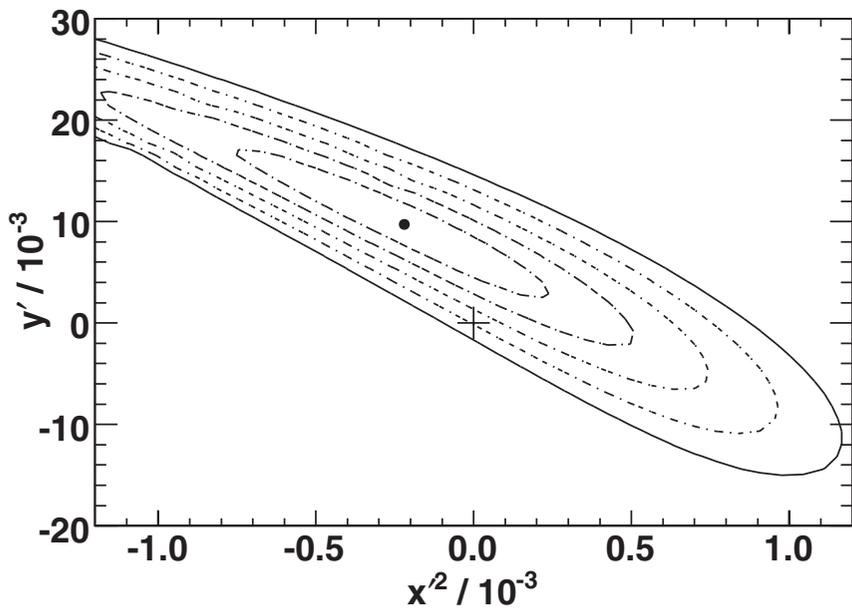
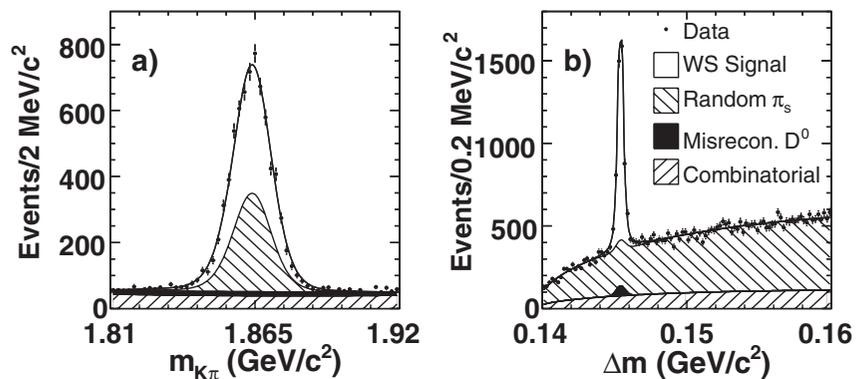
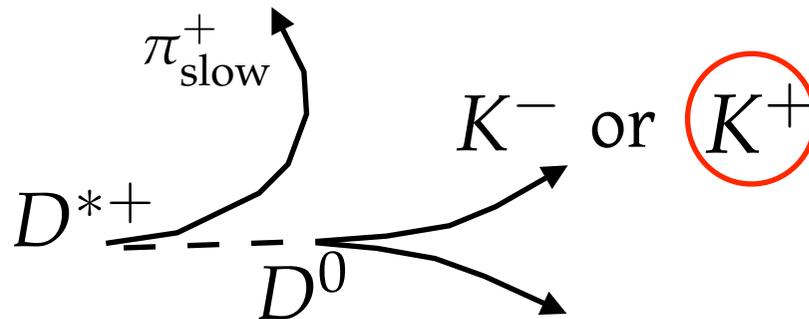
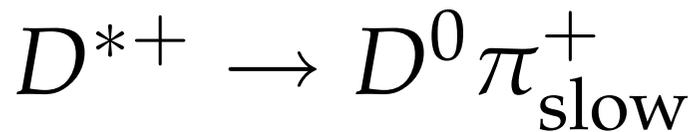
$$x = \Delta m / \Gamma$$

$$x' = x \cos \delta + y \sin \delta$$

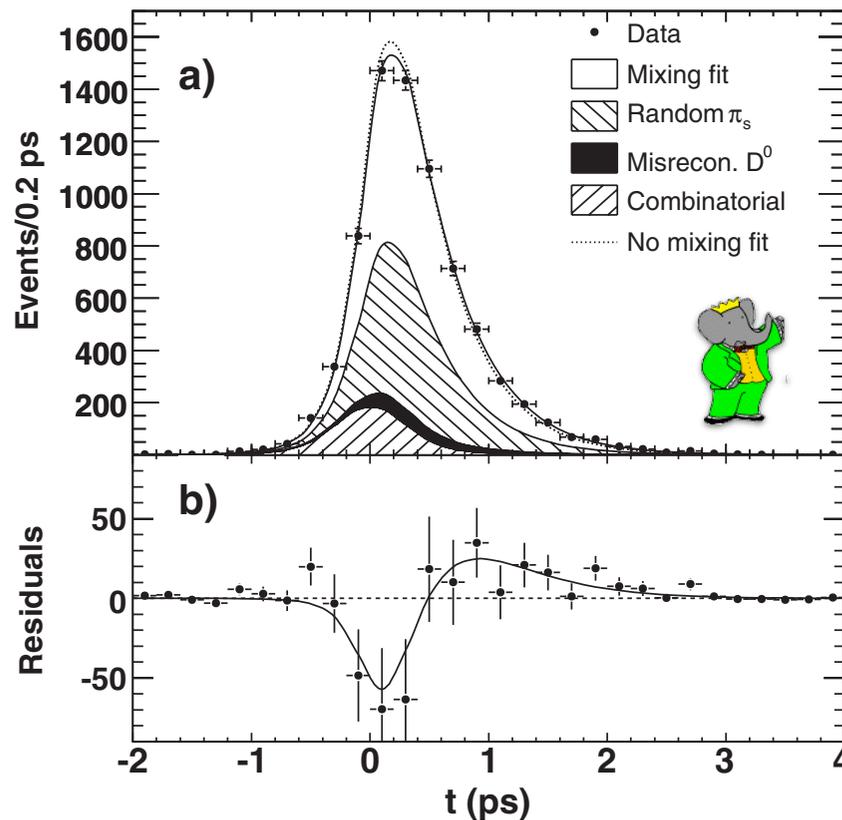
$$y = \Delta\Gamma / 2\Gamma$$

$$y' = y \cos \delta - x \sin \delta$$

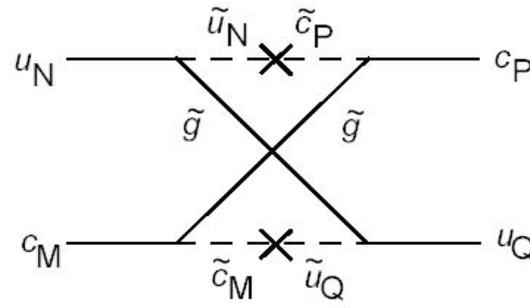
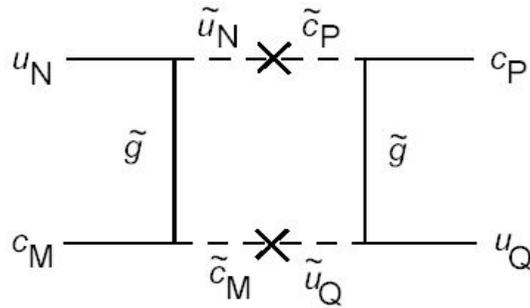
D Mixing



PRL 98, 211802 (2007)



D Mixing and SUSY limits

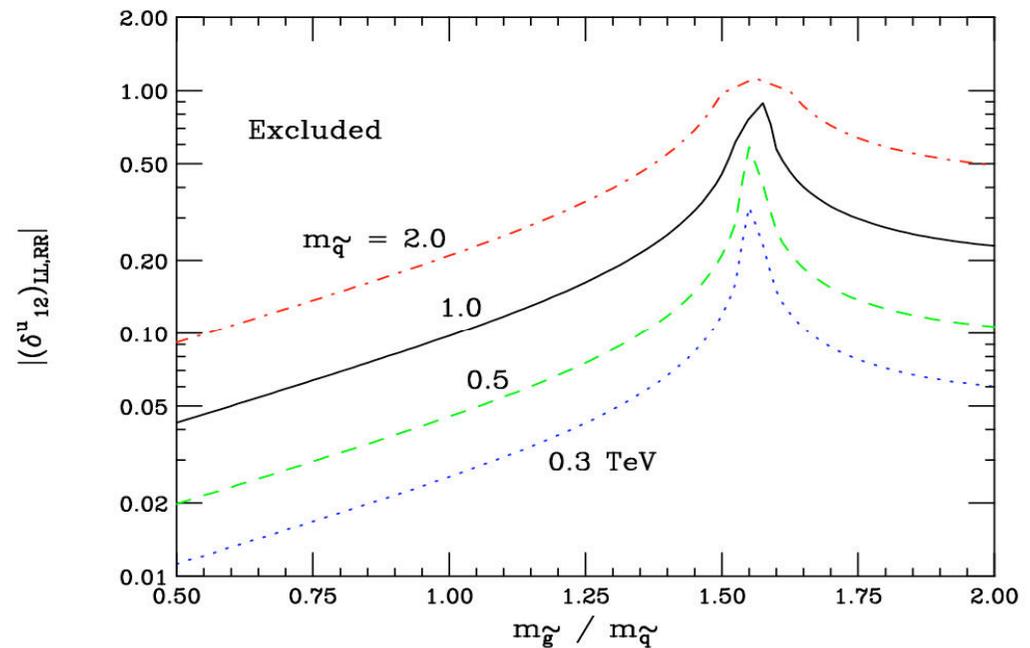


courtesy J. Hewitt

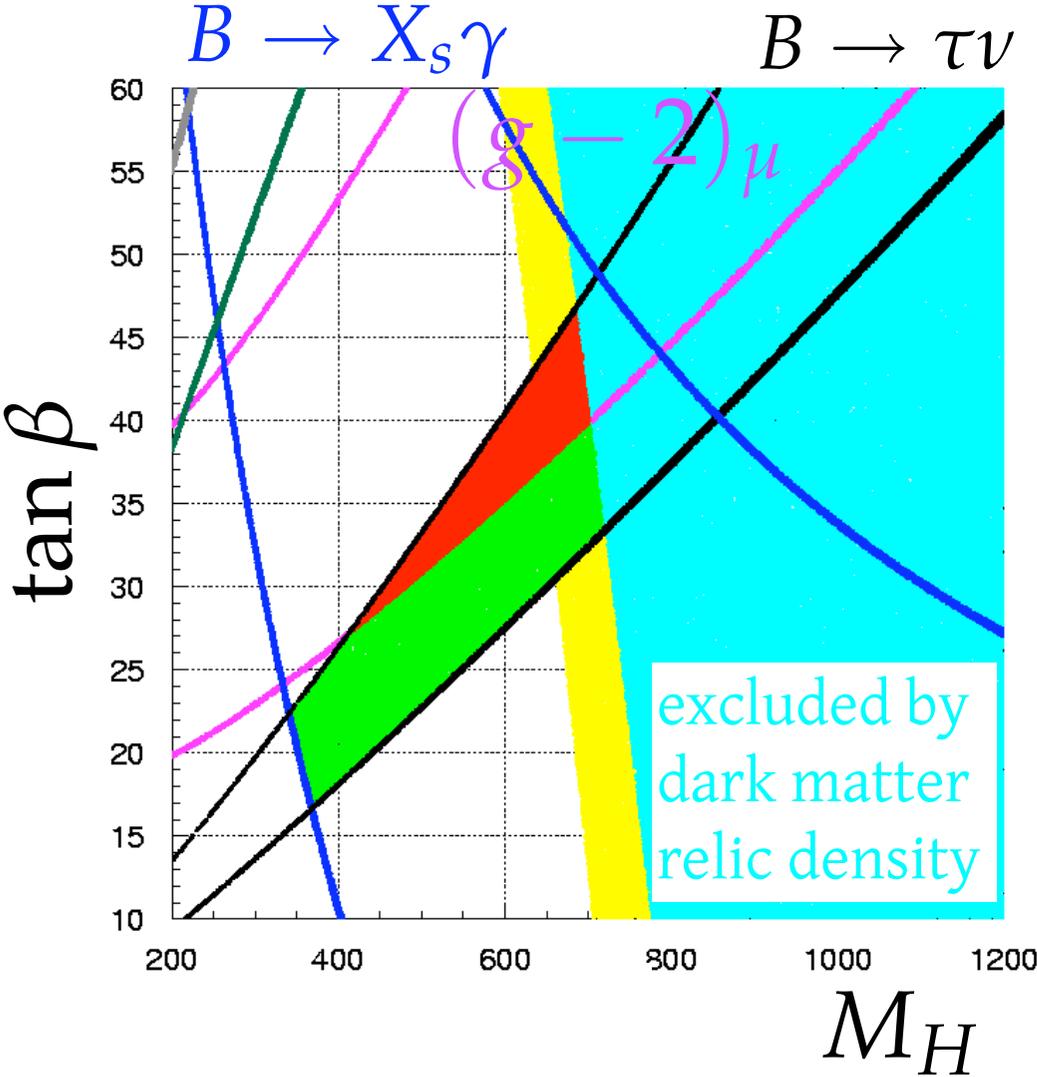
see J. Hewitt et al arXiv:0705.3650

$$(\delta_{ij})_{MN} = \frac{(V_M \tilde{M}^2 V_N^\dagger)_{ij}}{m_{\tilde{q}}^2}$$

bounds size of u-squark
and c-squark
mass difference



SUSY limits



from Isidori et al arXiv:hep-ph/0703035v2

B Factory future

