b -> s TRANSITIONS: SUSY AROUND THE CORNER?

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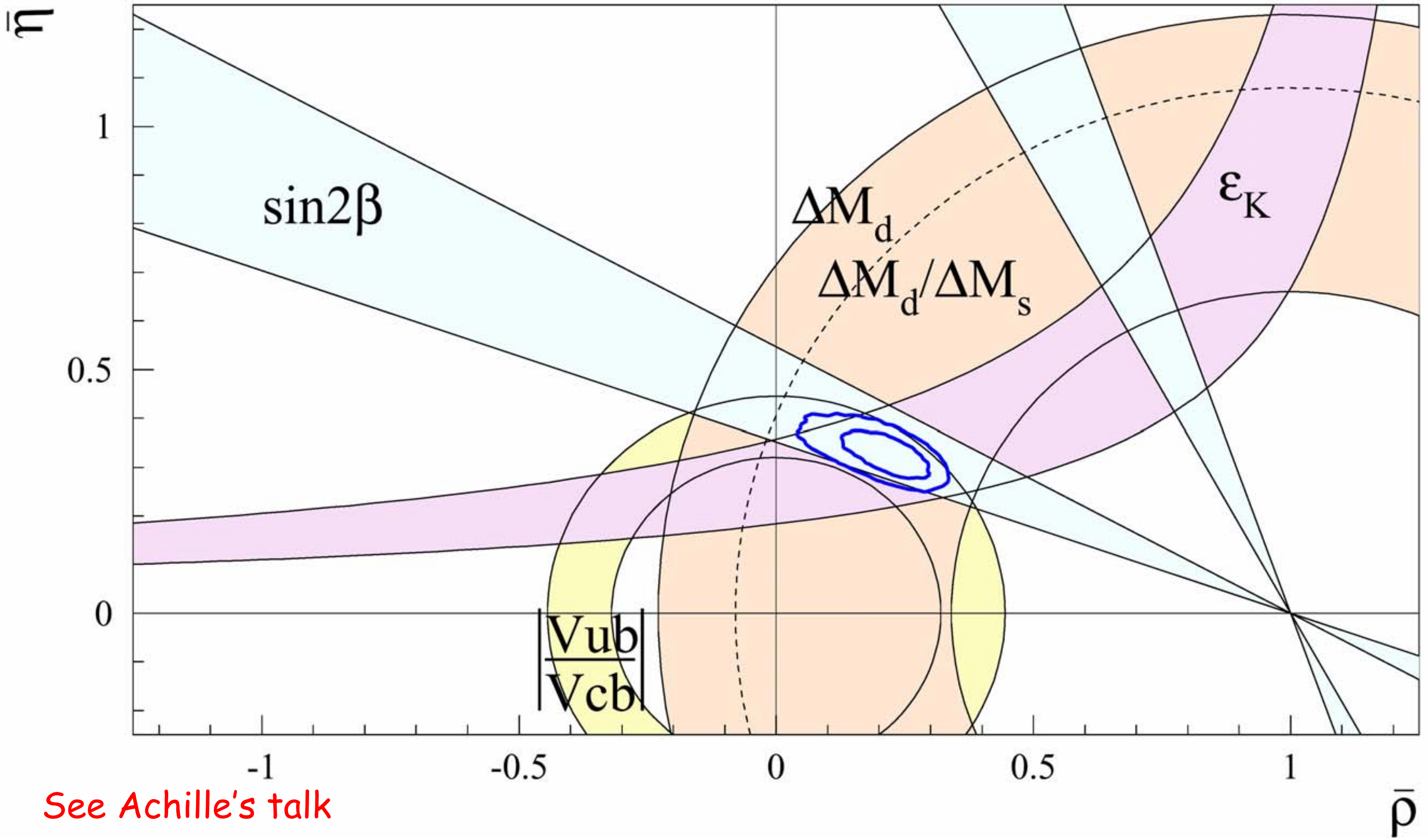
- Why SUSY in b -> s transitions ?
  (NP in UT fits)
- A model-independent analysis:
  - Ingredients
  - Results
- Conclusions & Outlook

Why NP (SUSY) in b -> s ?



See Achille's talk

Why NP (SUSY) in b->s ? (cont'd)

- NP in s -> d or b -> d transitions is
  - Strongly constrained by the UT fit
  - "Unnecessary", given the great success and consistency of the fit (see Achille's talk)
- NP in b -> s transitions is
  - Much less (un-) constrained by the UT fit
  - Natural in many flavour models, given the strong breaking of family SU(3)
  - Hinted at by ν's in SUSY-GUTs (Moroi; Chang, Masiero & Murayama; Hisano & Shimizu)

New Physics in CKM fits

Assume: (Ciuchini, Franco, Lubicz, Parodi, Stocchi & L.S.)

- NP only enters at the loop level;
- NP either in $\Delta S=2$, $\Delta B=2$ ($\Delta S=0$) or $\Delta B=\Delta S=2$

We parameterize the New Physics mixing amplitudes in a simple general form:

Soares, Wolfenstein;
Grossman, Nir, Worah; ...

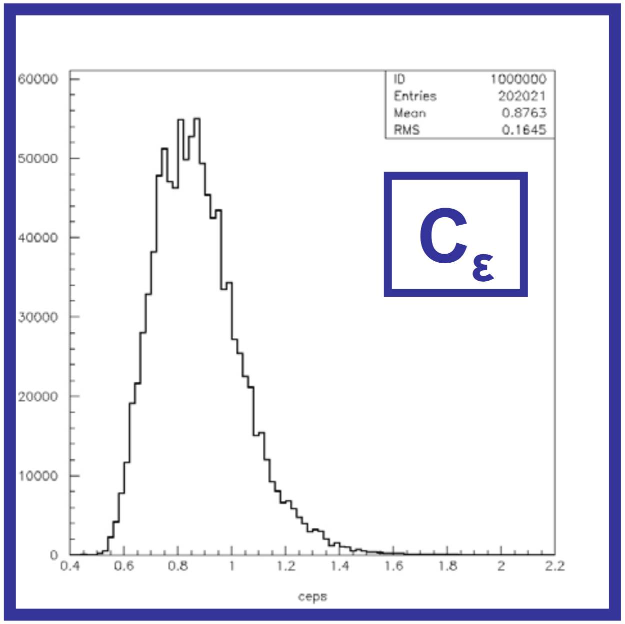
$$M_q = C_q\, e^{2i\varphi_q} (M_q)^{SM} \quad \text{for } B_q\text{–}\bar{B}_q \text{ mixing}$$

$$\mathrm{Im}(M_K) = C_\varepsilon\, \mathrm{Im}(M_K)^{SM} \quad \text{for } K\text{–}\bar{K} \text{ mixing}$$

→ **We introduce 4 real coefficients:** $\{C_d, \varphi_d\}$, C_s, C_ε

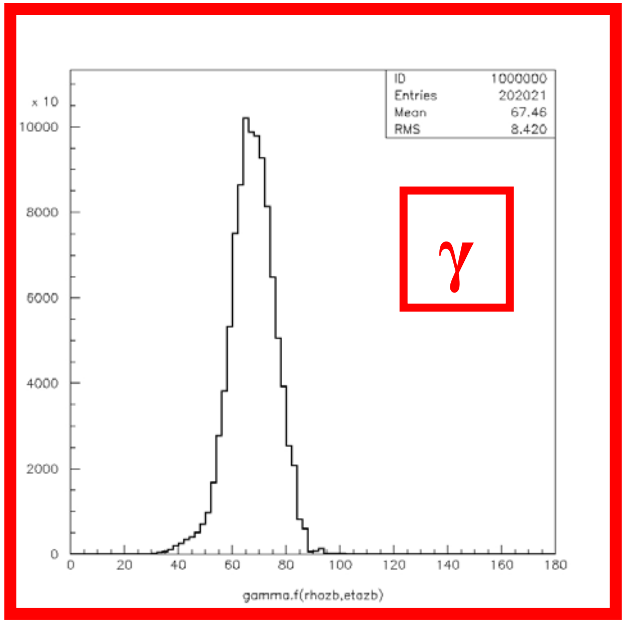
New Physics in $K-\bar{K}$ mixing

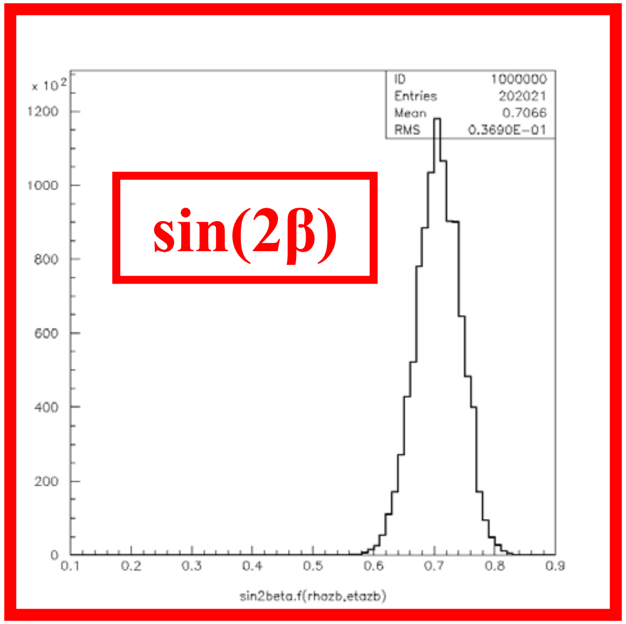
$$\varepsilon_K = C_\varepsilon \, (\varepsilon_K)^{SM}$$



$$C_\varepsilon = 0.86 \,^{+0.17}_{-0.14}$$

CFLPSS

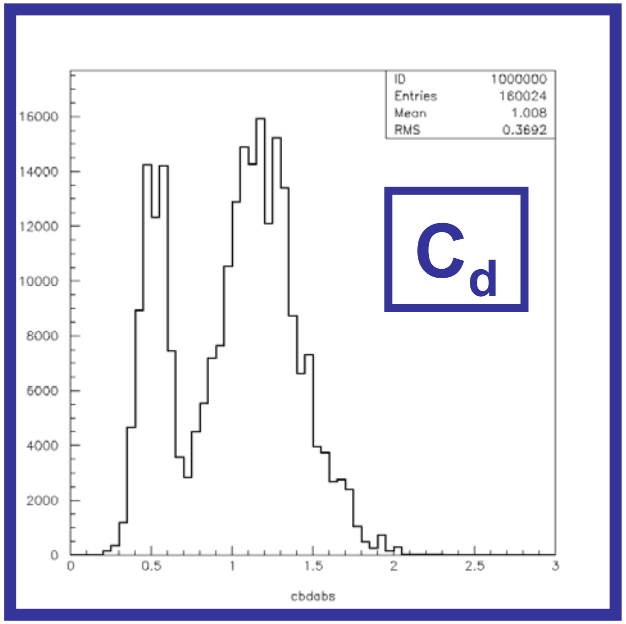


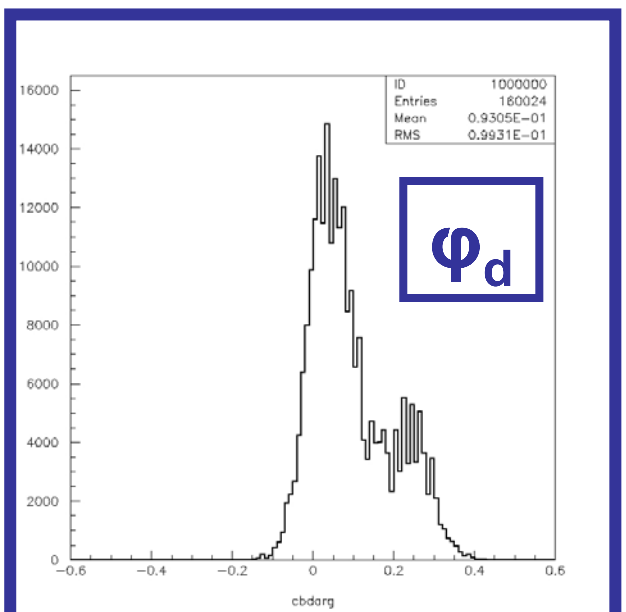


New Physics in B_d–$\overline{B}_d$ mixing

$$\Delta m_d = C_d\,(\Delta m_d)^{SM}$$

$$A(J/\psi\ K_S) \sim \sin 2(\beta+\varphi_d)$$





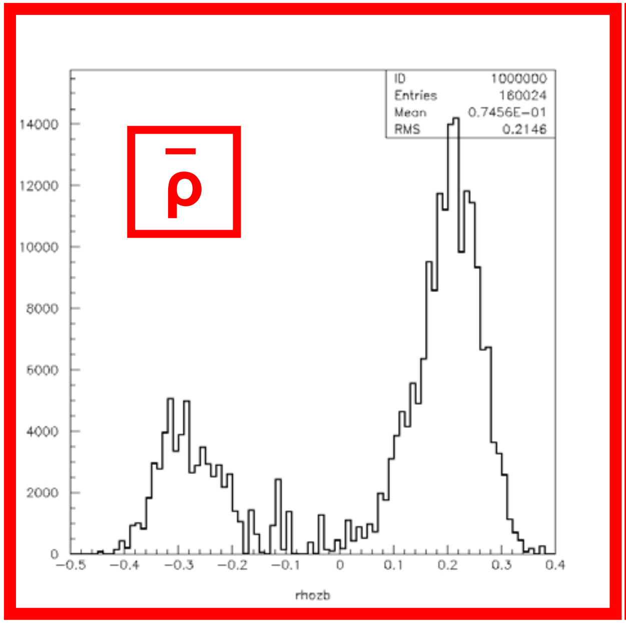
With φ_d only determined up to a trivial twofold ambiguity:

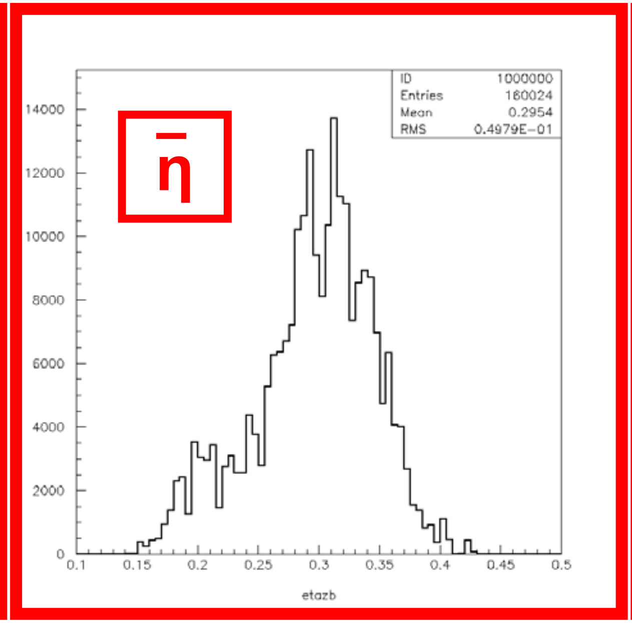
$$\beta+\varphi_d \rightarrow \pi-\beta-\varphi_d$$

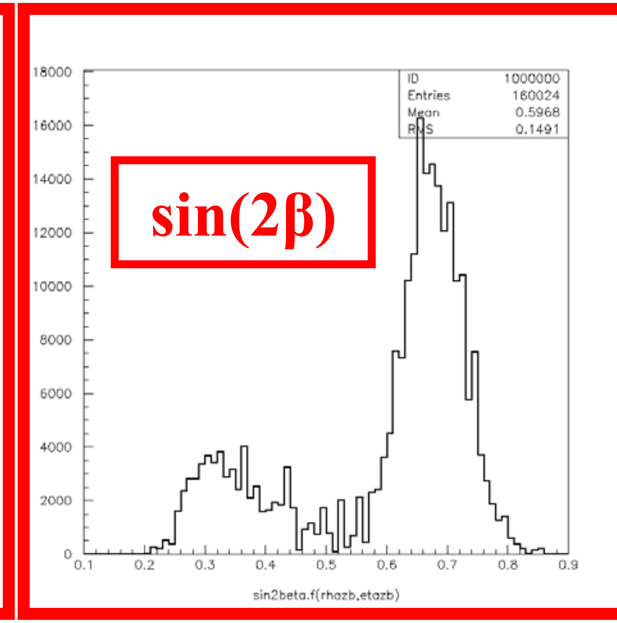
i.e. $\varphi_d' = \pi-2\beta-\varphi_d$

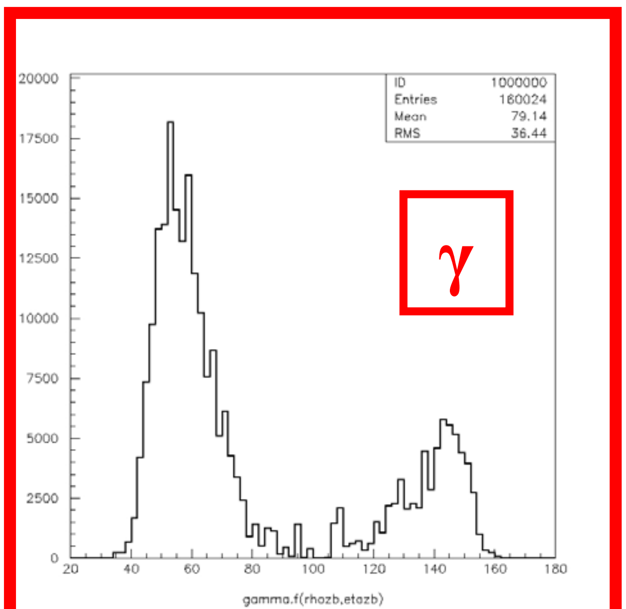
Corresponding to opposite signs of $\cos 2(\beta+\varphi_d)$

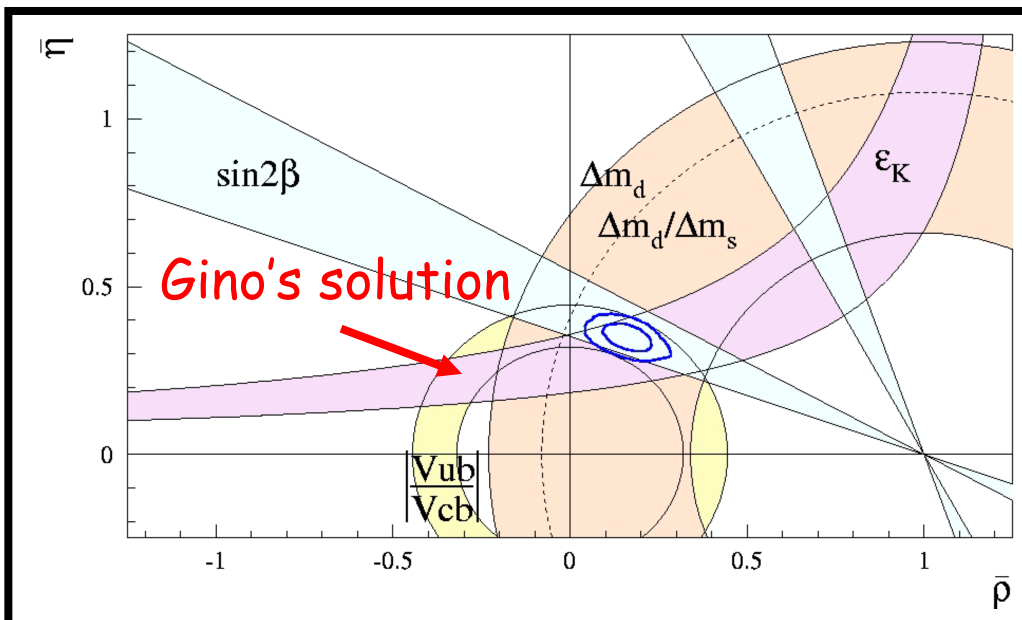
CFLPSS


ρ̄
ID 1000000
Entries 160024
Mean 0.7456E−01
RMS 0.2146
rhozb


η̄
ID 1000000
Entries 160024
Mean 0.2954
RMS 0.4979E−01
etazb


sin(2β)
ID 1000000
Entries 160024
Mean 0.5968
RMS 0.1491
sin2beta.f(rhozb,etazb)


γ
ID 1000000
Entries 160024
Mean 79.14
RMS 36.44
gamma.f(rhozb,etazb)

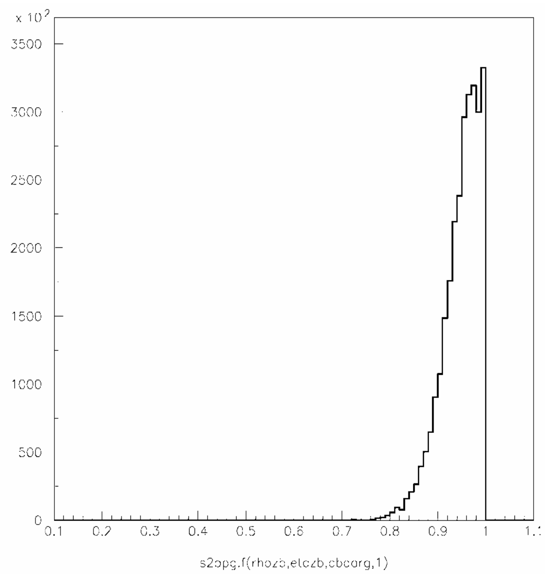

η̄
sin2β
Δm_d
Δm_d/Δm_s
ε_K
Gino's solution
|Vub/Vcb|
ρ̄

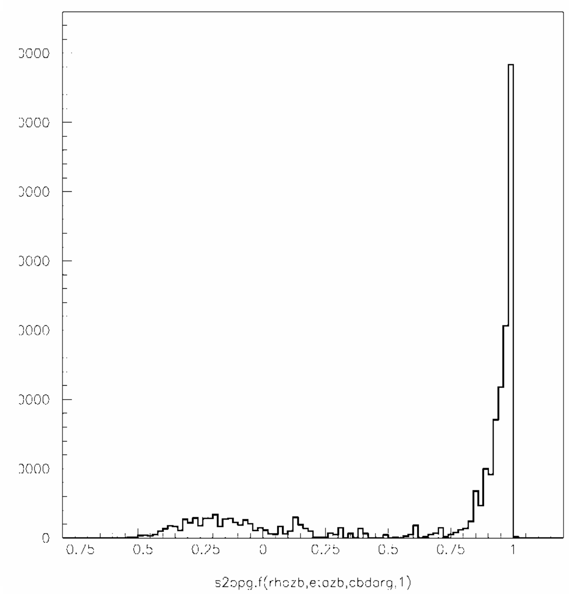
CFLPSS

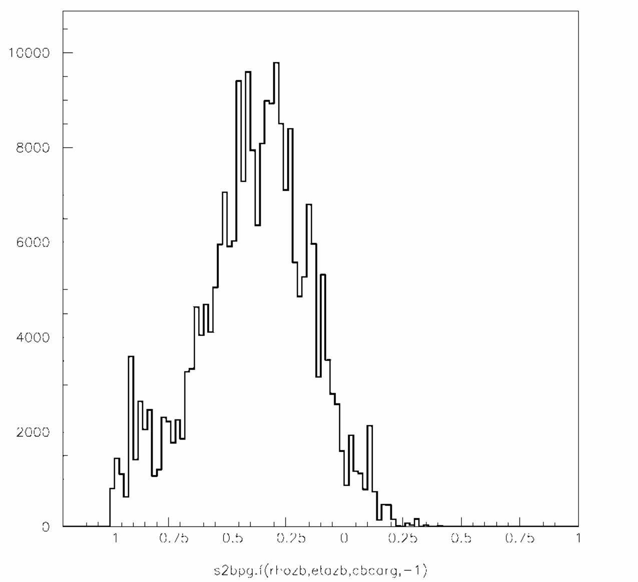
Can we get rid of Gino's solution?

P.d.f. for $\sin(2(\beta+\varphi_d)+\gamma)$:

CFLPSS







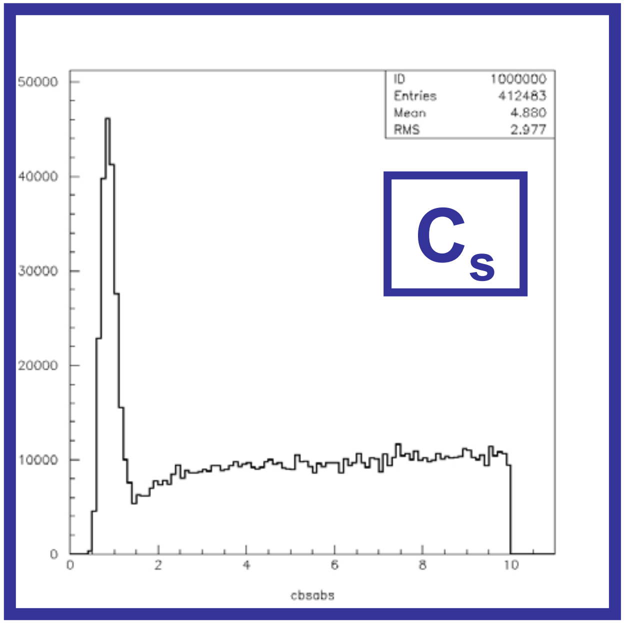
SM

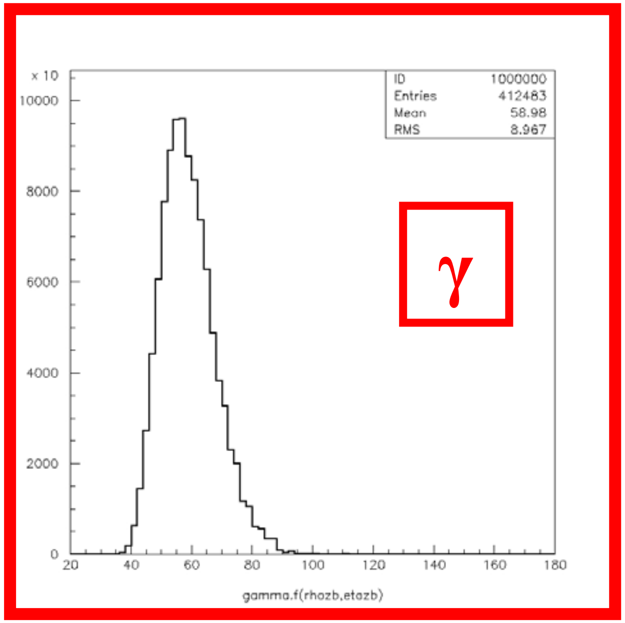
$\cos 2(\beta+\varphi_d) > 0$

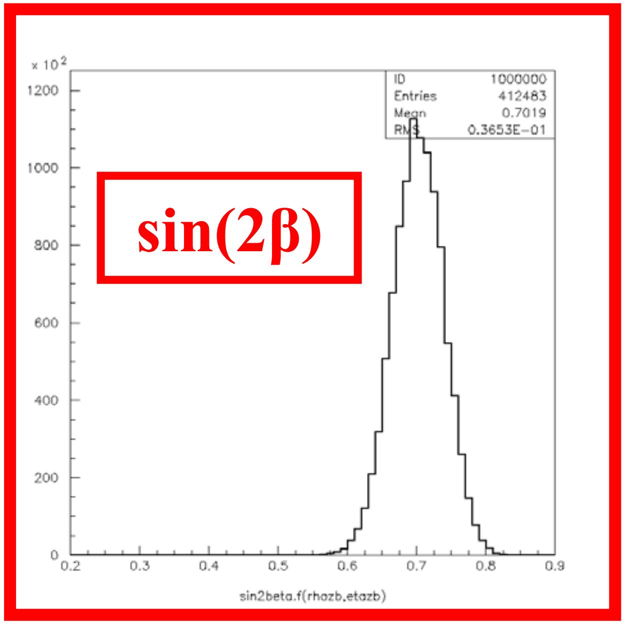
$\cos 2(\beta+\varphi_d) < 0$

New Physics in B_s–$\overline{B}_s$ mixing

$\Delta m_s = C_s (\Delta m_s)^{SM}$







CFLPSS

In the lack of an experimental determination of Δm_s, C_s can be arbitrarily large…

Why NP (SUSY) in b->s ? (cont'd)

Experimental informations:

- Large BR's of b->s charmless modes: B->$K^{(*)}\pi$, B->η' K, B->Φ K, ...
- Time-dependent CP asymmetries:

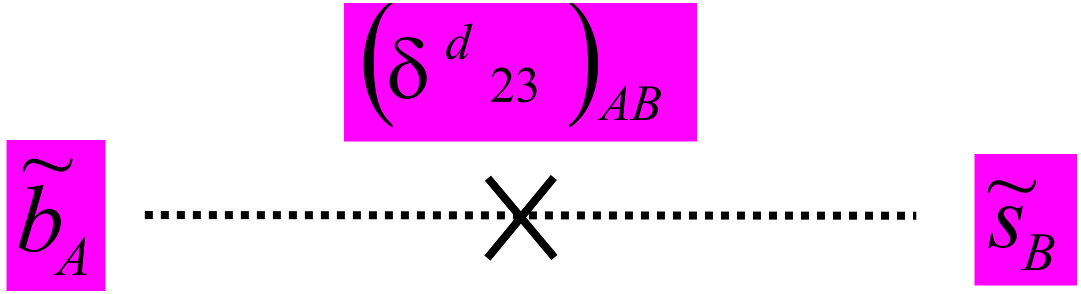
	BaBar	Belle
$S_{K\Phi}$	$-0.18\pm0.51\pm0.07$	$-0.73\pm0.64\pm0.22$
$C_{K\Phi}$	$-0.80\pm0.38\pm0.12$	$0.56\pm0.41\pm0.16$
$S_{\eta'K}$	$0.02\pm0.34\pm0.03$	$0.71\pm0.37\pm0.06$
$C_{\eta'K}$	$0.10\pm0.22\pm0.03$	$-0.26\pm0.22\pm0.04$

Plus rate CP asymmetries in B -> K π channels

Our analysis: ingredients

Ciuchini, Franco, Masiero & L.S.

- We consider a MSSM with generic soft SUSY-breaking terms, but
  - dominant gluino contributions only
  - mass insertion approximation



four insertions AB=LL, LR, RL, RR

Our analysis: ingredients (cont'd)

- We compute @ NLO (except for SUSY matching):
  - b -> s γ (BR and A_{CP})
  - b -> s $l^+ l^-$
  - ΔM_s (with lattice QCD matrix el. from Becirevic et al.)
  - B -> Φ K_S (BR and time-dependent asymmetry coefficients $S_{\Phi K}$, $C_{\Phi K}$)
  - B_S -> J/ΨΦ (time-dep asymmetry $S_{J/\Psi\,\Phi}$)
  - B -> K π (BR's and direct CP asymmetryes)

Related work: Bertolini, Borzumati & Masiero; Ciuchini et al.; Barbieri & Strumia; Abel, Cottingham & Wittingham; Kagan; Borzumati et al.; Besmer, Greub & Hurth; Lunghi & Wyler; Causse; Hiller; Khalil & Kou; Kane et al.; Harnik et al.; Baek; Hisano & Shimizu; +RPV…

On the sensitivity of B->KX decays to SUSY contributions

Various sources of SUSY effects in the decay amplitudes:

- Leading power in $1/m_b$
  - the chromomagnetic operator: In QCD factorization, it appears as an α_s correction
    - the one-loop proof of factorization does not apply to this term
    - other power-suppressed terms may be numerically of the same size
- m_b-suppressed corrections
  - Cabibbo-enhanced terms: which mechanism?
    - penguin annihilation (BBNS) $\Rightarrow$ *moderate* sensitivity to SUSY
    - charming penguins $\Rightarrow$ *no* sensitivity to SUSY

We use the *improved* QCD factorization ($\rho_A < 8$) to maximize the sensitivity to SUSY but, in any case, hadronic uncertainties are not fully under control

Our analysis: ingredients (cont'd)

- Constraints on b-> s transitions:

$$BR(B \to X_S \gamma) = (3.29 \pm 0.34) \times 10^{-4}$$
$$A_{CP}(B \to X_S \gamma) = (-0.02 \pm 0.04)$$
$$BR(B \to X_S l^+ l^-) = (6.1 \pm 1.4 \pm 1.3) \times 10^{-6}$$
$$\Delta M_S > 14.4\ \mathrm{ps}^{-1} \qquad BR(B \to K\pi)$$

perform a MonteCarlo analysis, studying clustering in Re δ, Im δ plane. Use CKM angles from standard UT fit (see Achille's talk).

Our analysis: ingredients (cont'd)

- Input parameters:

ρ = 0.173 ± 0.046 (G)

η = 0.357 ± 0.027 (G)

$F_\pi(0)$ = 0.27 ± 0.08 (F)

$F_K/F_\pi(0)$ = 1.20 ± 0.10 (F)

Λ_{BBNS} = 0.35 ± 0.15 (F)

μ = 5.0 ± 2.5 (F)

$\rho_{A,H}$ = 4.0 ± 4.0 (F)

$\Phi_{A,H}$ = $\pi \pm \pi$ (F)

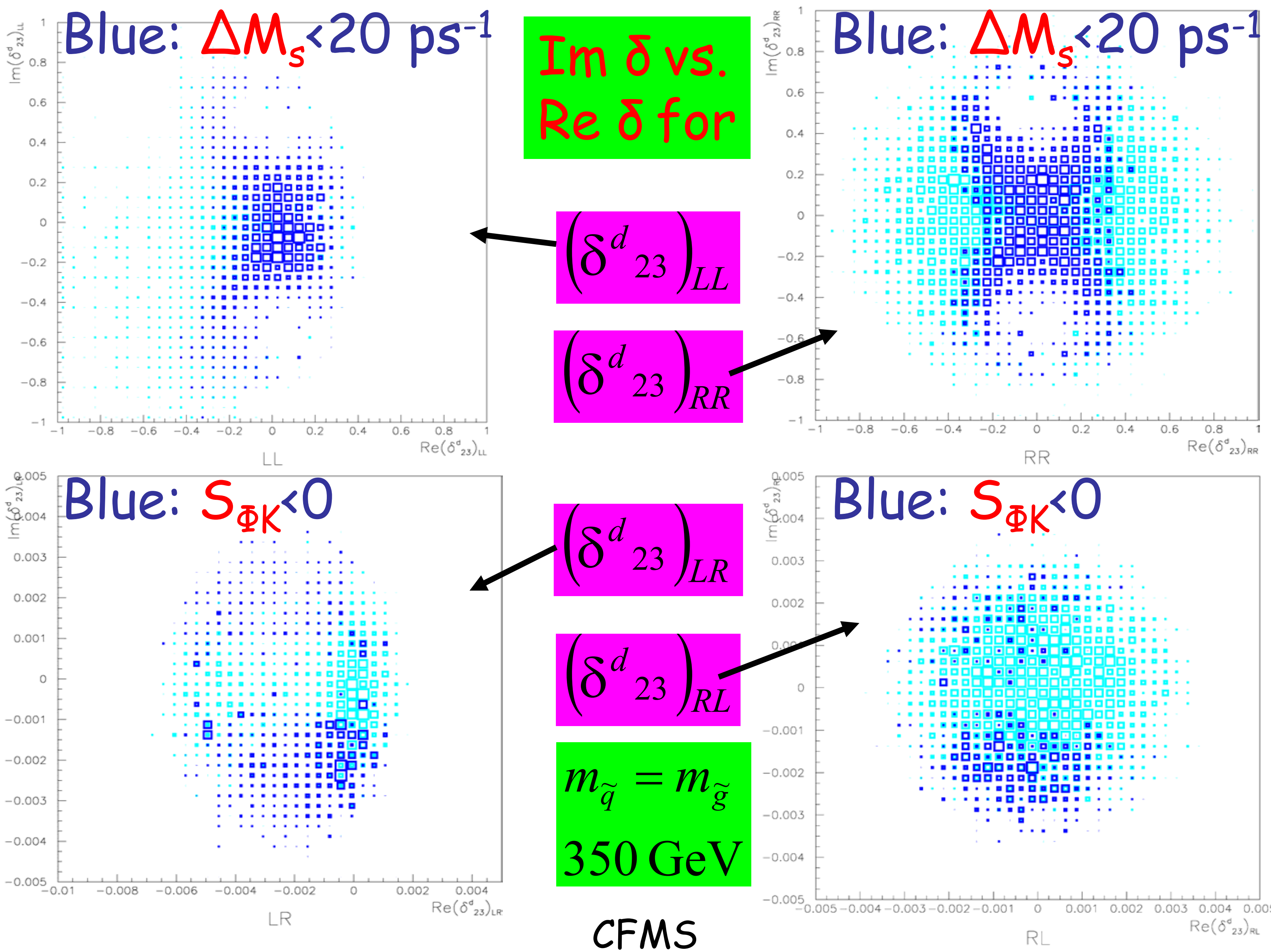
B_1^{RI} = 0.87 ± 0.11 (F)

B_2^{RI} = 0.82 ± 0.10 (F)

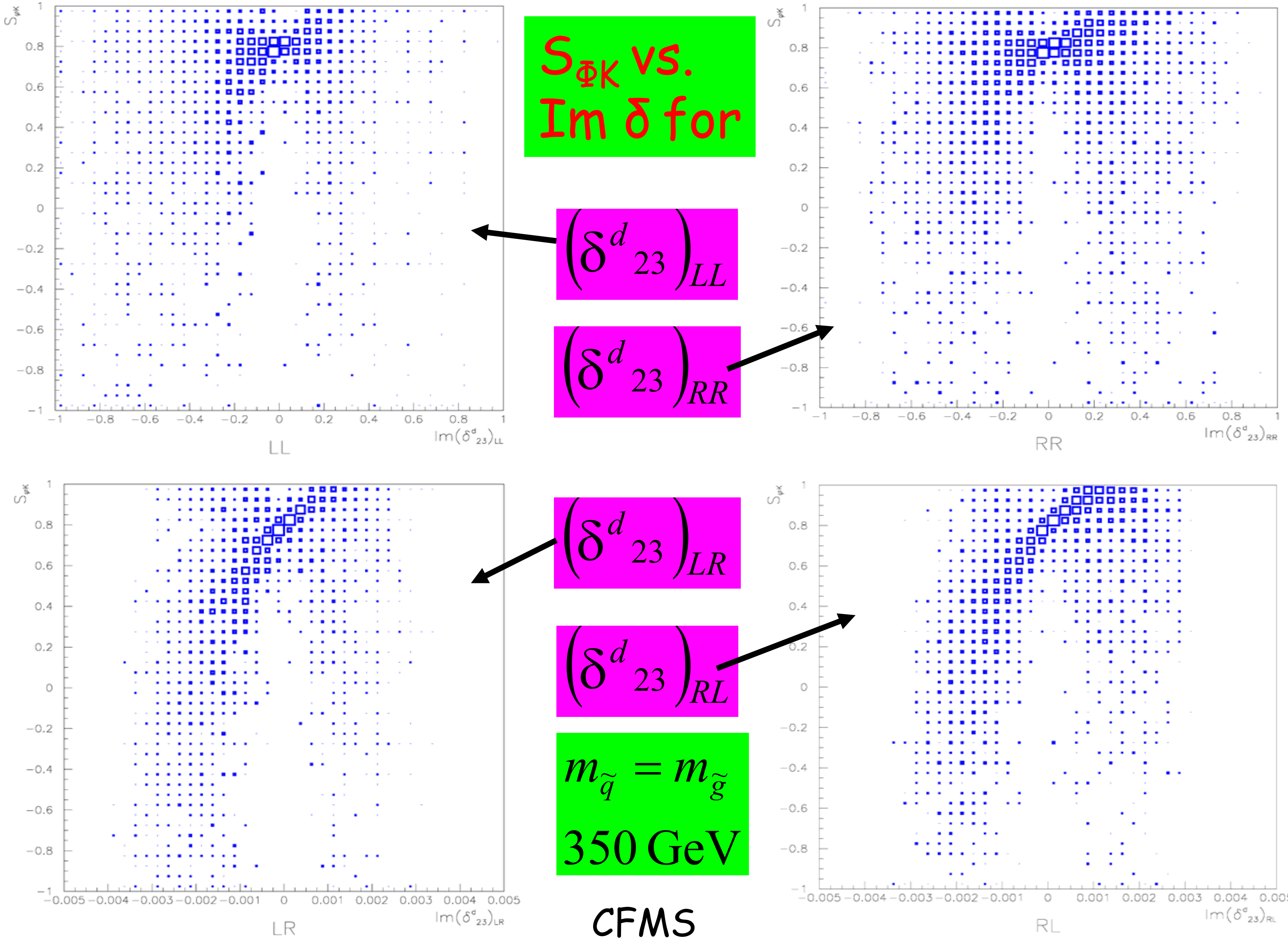
B_3^{RI} = 1.02 ± 0.15 (F)

B_4^{RI} = 1.16 ± 0.14 (F)

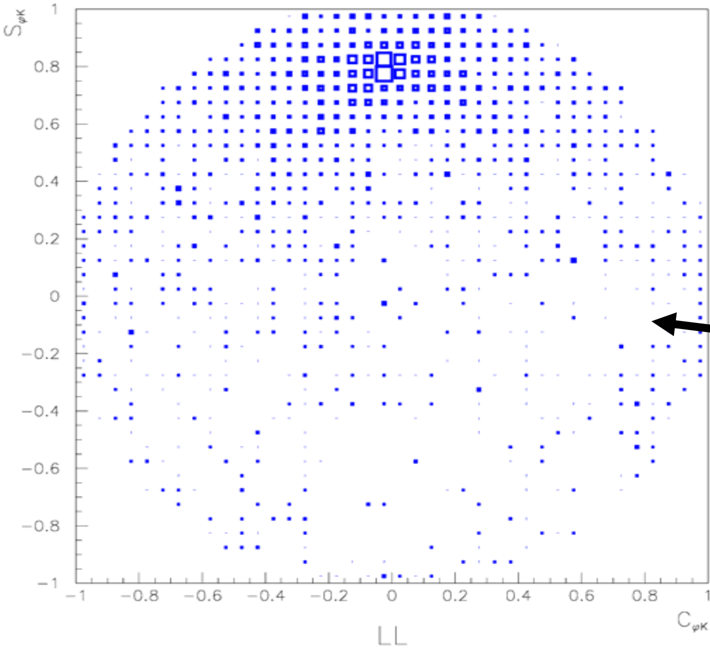
B_5^{RI} = 1.91 ± 0.21 (F)


Blue: ΔM_s<20 ps^-1
Blue: ΔM_s<20 ps^-1
Im δ vs. Re δ for
(δ^d_23)_LL
(δ^d_23)_RR
Blue: S_ΦK<0
Blue: S_ΦK<0
(δ^d_23)_LR
(δ^d_23)_RL
m_q̃ = m_g̃
350 GeV
Im(δ^d_23)_LL
Re(δ^d_23)_LL
LL
Im(δ^d_23)_RR
Re(δ^d_23)_RR
RR
Im(δ^d_23)_LR
Re(δ^d_23)_LR
LR
Im(δ^d_23)_RL
Re(δ^d_23)_RL
RL

CFMS

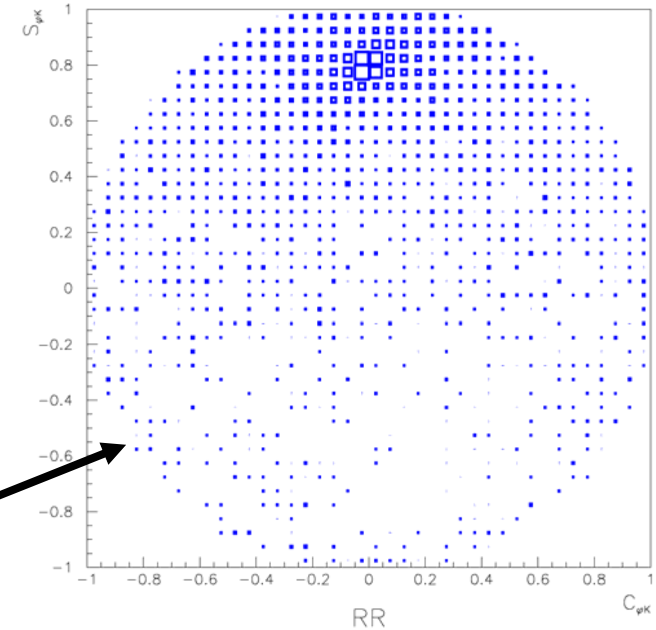


$S_{\Phi K}$ vs. Im δ for
$(\delta^d{}_{23})_{LL}$
$(\delta^d{}_{23})_{RR}$
$(\delta^d{}_{23})_{LR}$
$(\delta^d{}_{23})_{RL}$
$m_{\tilde{q}} = m_{\tilde{g}}$
350 GeV
LL
$Im(\delta^d{}_{23})_{LL}$
RR
$Im(\delta^d{}_{23})_{RR}$
LR
$Im(\delta^d{}_{23})_{LR}$
RL
$Im(\delta^d{}_{23})_{RL}$
$S_{\phi K}$
CFMS

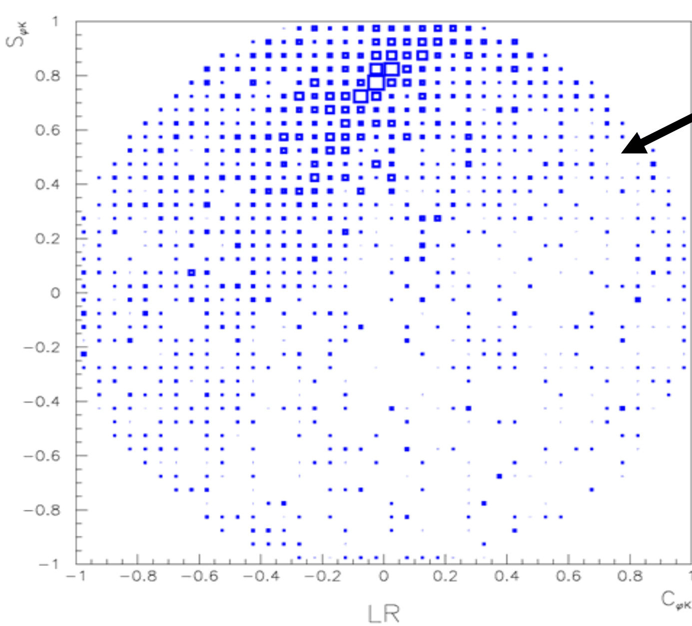


$S_{\Phi K}$ vs. $C_{\Phi K}$ for

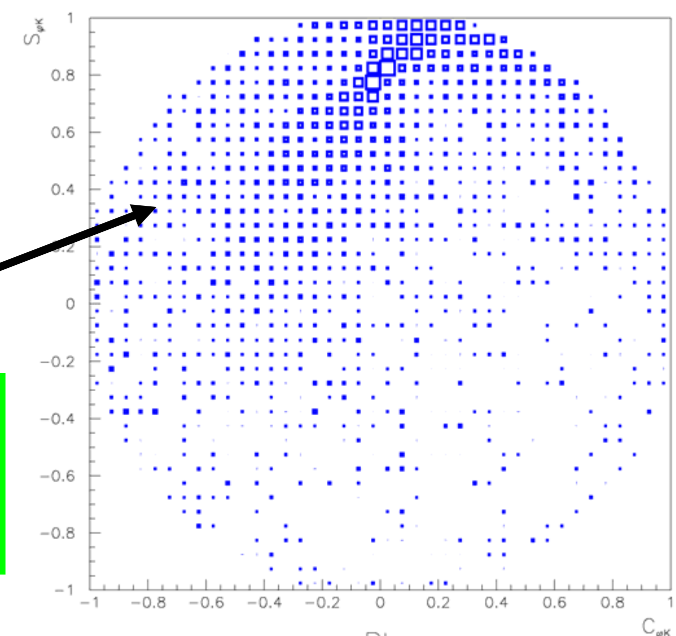
$\left(\delta^d{}_{23}\right)_{LL}$



$\left(\delta^d{}_{23}\right)_{RR}$



$\left(\delta^d{}_{23}\right)_{LR}$



$\left(\delta^d{}_{23}\right)_{RL}$

$m_{\tilde{q}} = m_{\tilde{g}}$

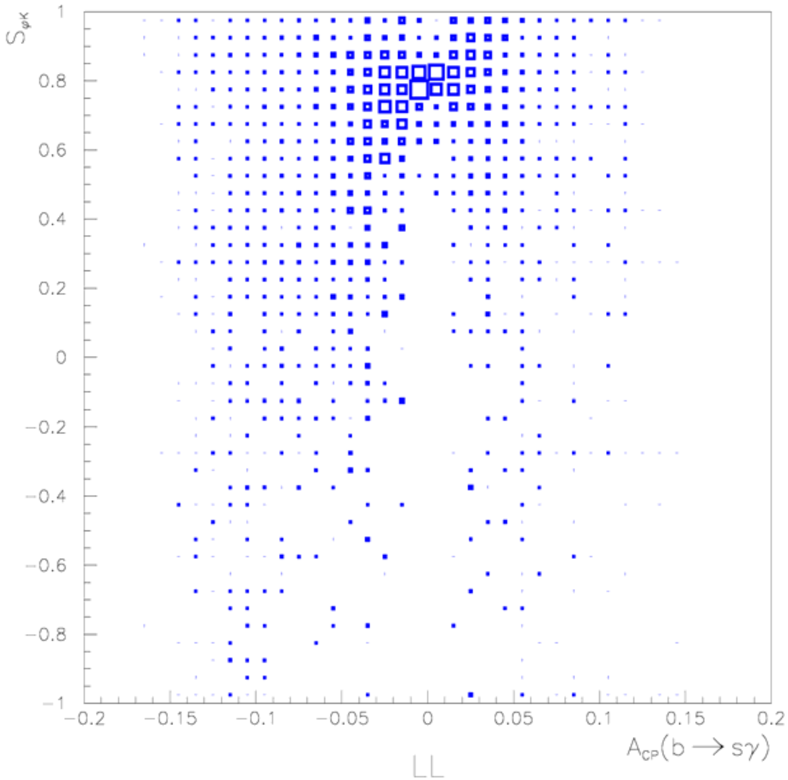
350 GeV

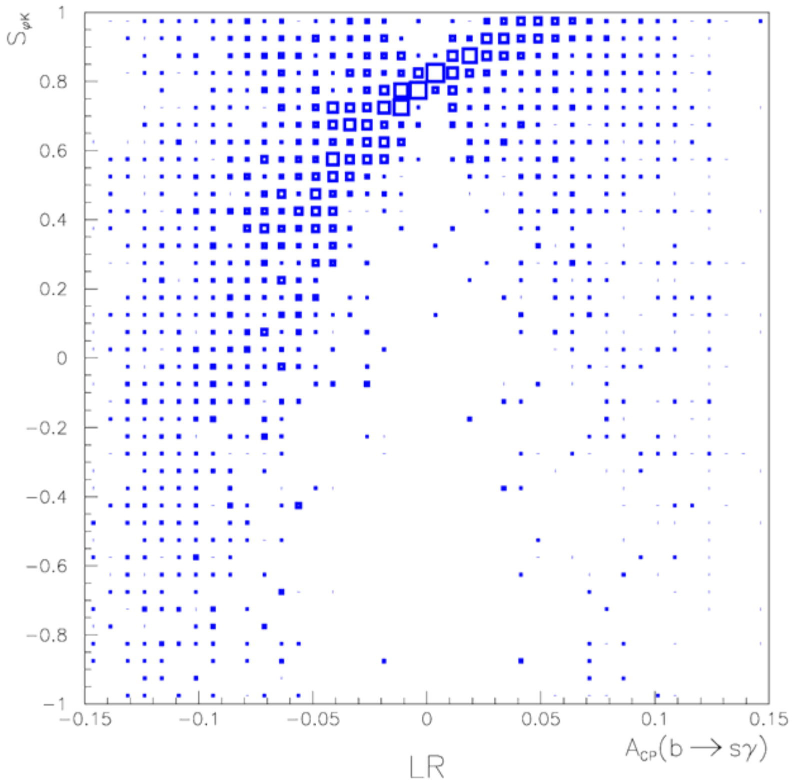
CFMS

$S_{\Phi K}$ vs $A_{CP}(b\to s\gamma)$

$m_{\tilde{q}} = m_{\tilde{g}}$

350 GeV

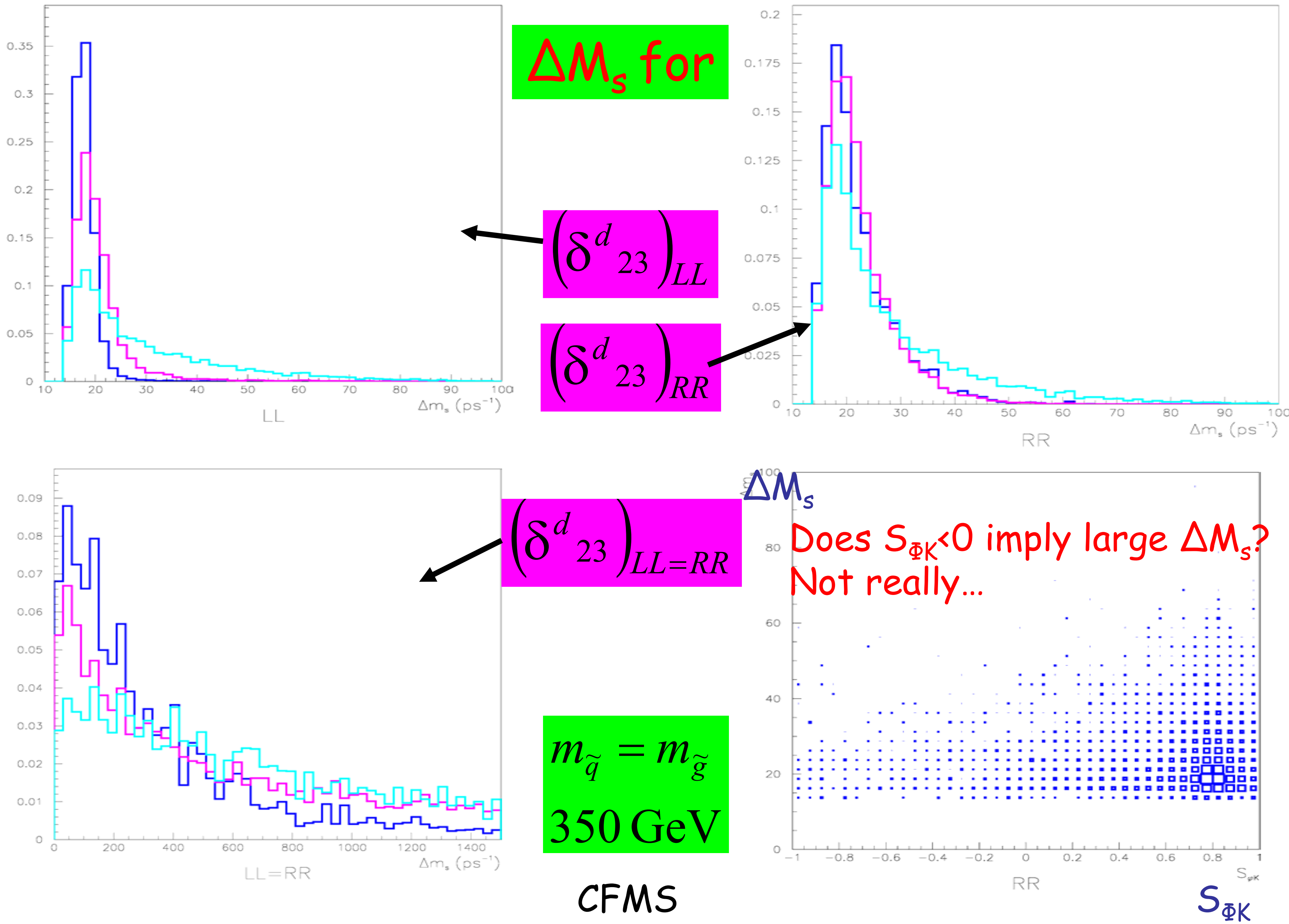




$\left(\delta^{d}{}_{23}\right)_{LL}$

CFMS

$\left(\delta^{d}{}_{23}\right)_{LR}$

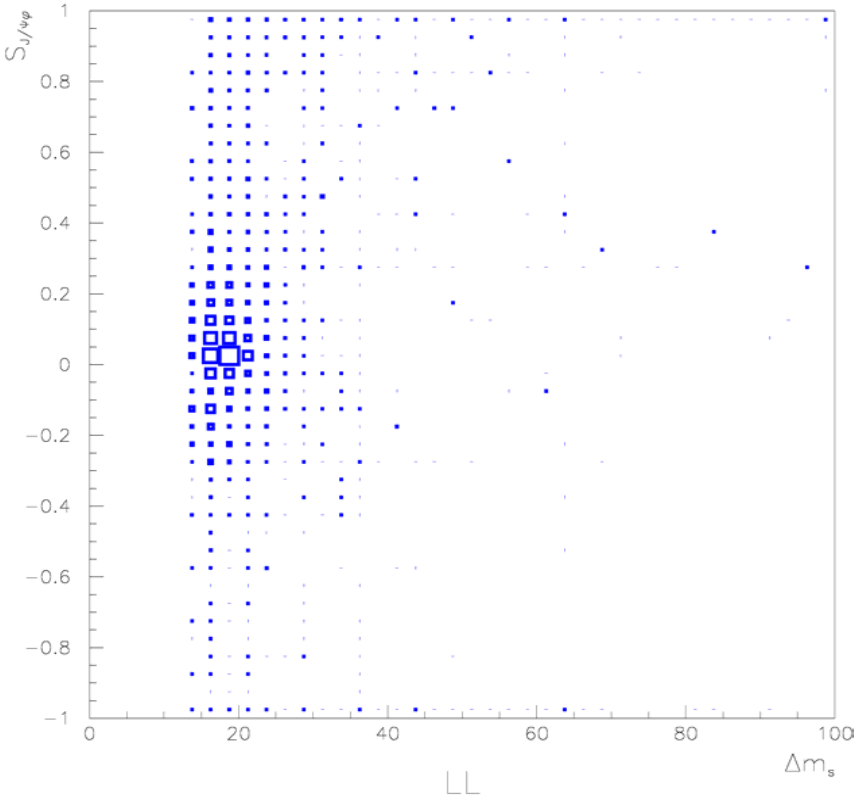


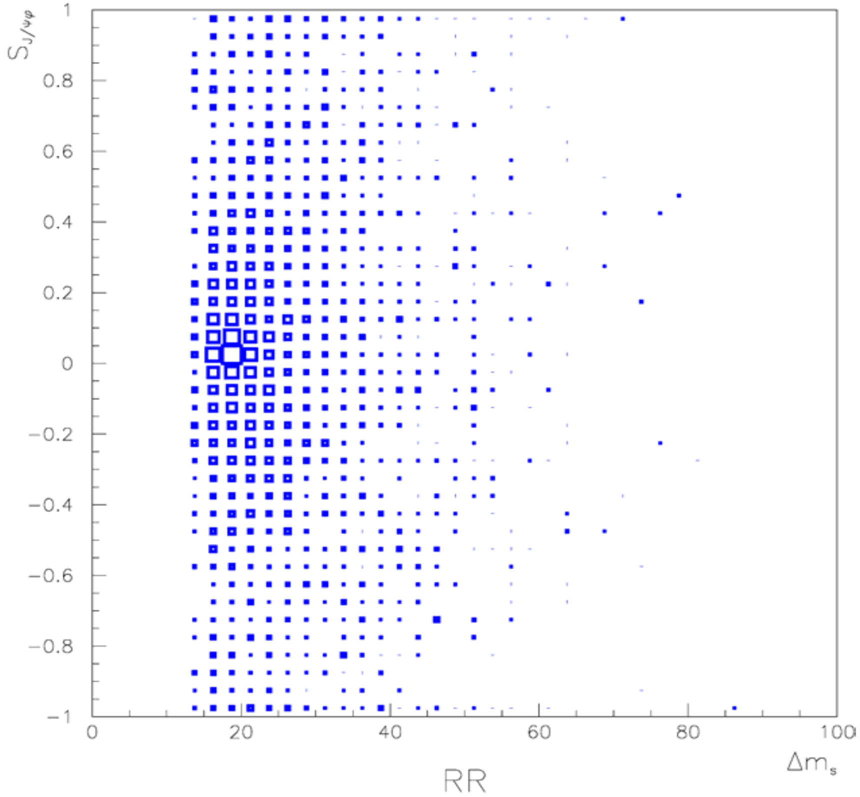
ΔM_s for
(δ^d_23)_LL
(δ^d_23)_RR
(δ^d_23)_LL=RR
LL
RR
LL=RR
Δm_s (ps^-1)
ΔM_s
Does S_ΦK<0 imply large ΔM_s?
Not really…
m_q̃ = m_g̃
350 GeV
CFMS
S_φK
S_ΦK

$S_{J/\psi\Phi}$ vs ΔM_s

$m_{\tilde{q}} = m_{\tilde{g}}$

350 GeV





$\left(\delta^d{}_{23}\right)_{LL}$

CFMS

$\left(\delta^d{}_{23}\right)_{RR}$

Conclusions

- Many independent th and exp motivations for SUSY in b->s transitions:
  - Consistency of SM UT fit
  - Possible deviations from SM in $S_{\Phi K}$, $C_{\Phi K}$
  - Flavour Symmetries
  - SUSY GUTs + neutrino oscillations
- In the presence of NP, $S_{\Phi K}$, $C_{\Phi K}$ suffer from sizable hadronic uncertainties

Conclusions (cont'd)

- At present, SUSY models with $\left(\delta^d{}_{23}\right)_{LL\text{ or }RR} \approx O(10^{-1})$ or $\left(\delta^d{}_{23}\right)_{LR\text{ or }RL} \approx O(10^{-3})$ and 350 GeV squark/gluinos can reproduce all exp data including deviations from SM in $S_{\Phi K}$, $C_{\Phi K}$
- Future data on rare B decays and ΔM_s will allow us to test the SM and SUSY
- Interesting correlations with other observables in B physics and LFV