WGVI Summary

WG VI: Angles from penguin dominated B(s,d) decays

Conveners
T. Gershon, L. Silvestrini, Th. Feldmann

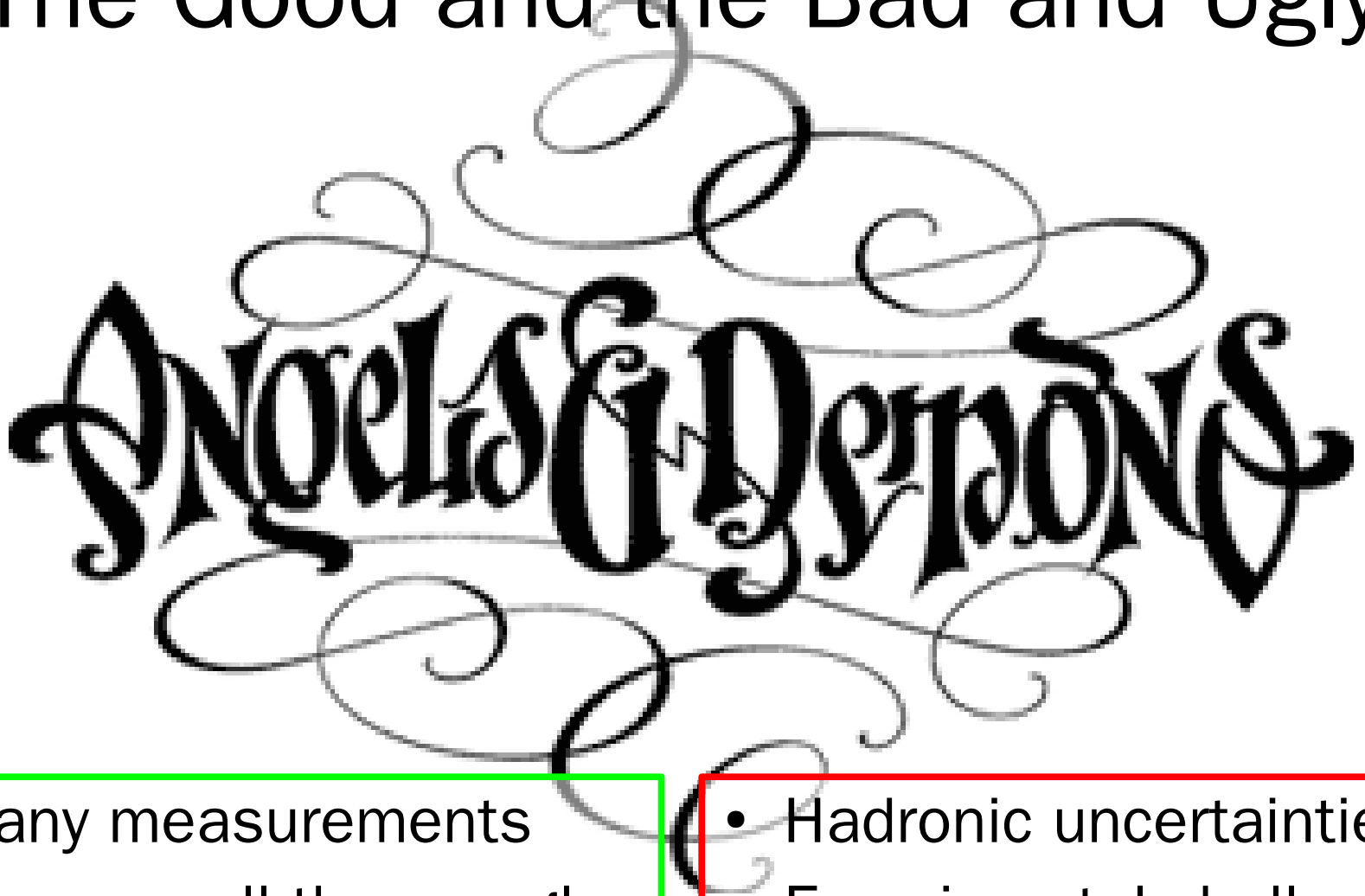
WGVI Summary

WG VI: A… B(s,d)

WG VI: Angles from charmless B decays

Conveners
T. Gershon, L. Silvestrini, Th. Feldmann

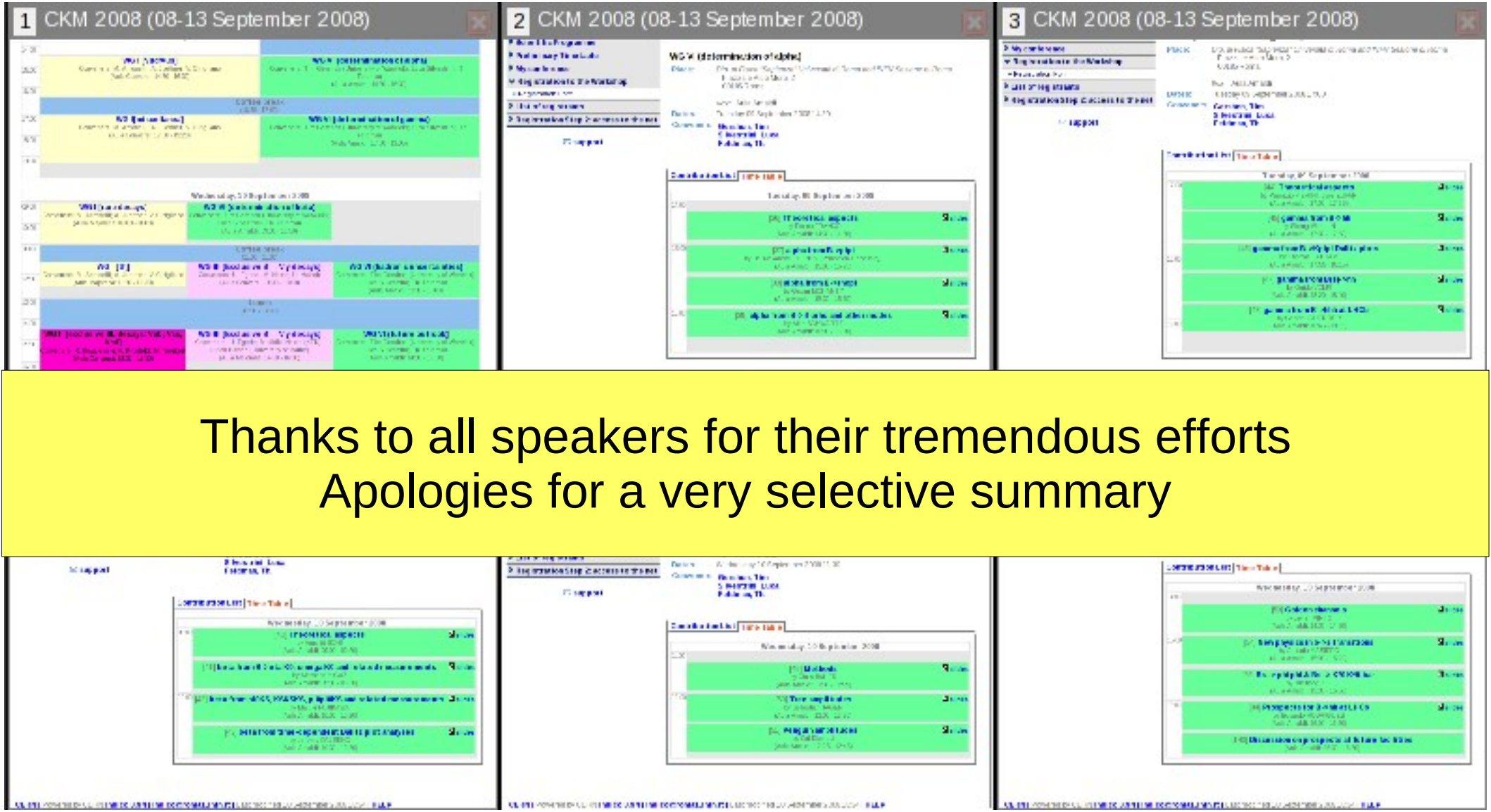
The Good and the Bad and Ugly



- Many measurements
- Measure all three angles
- Sensitive to new physics

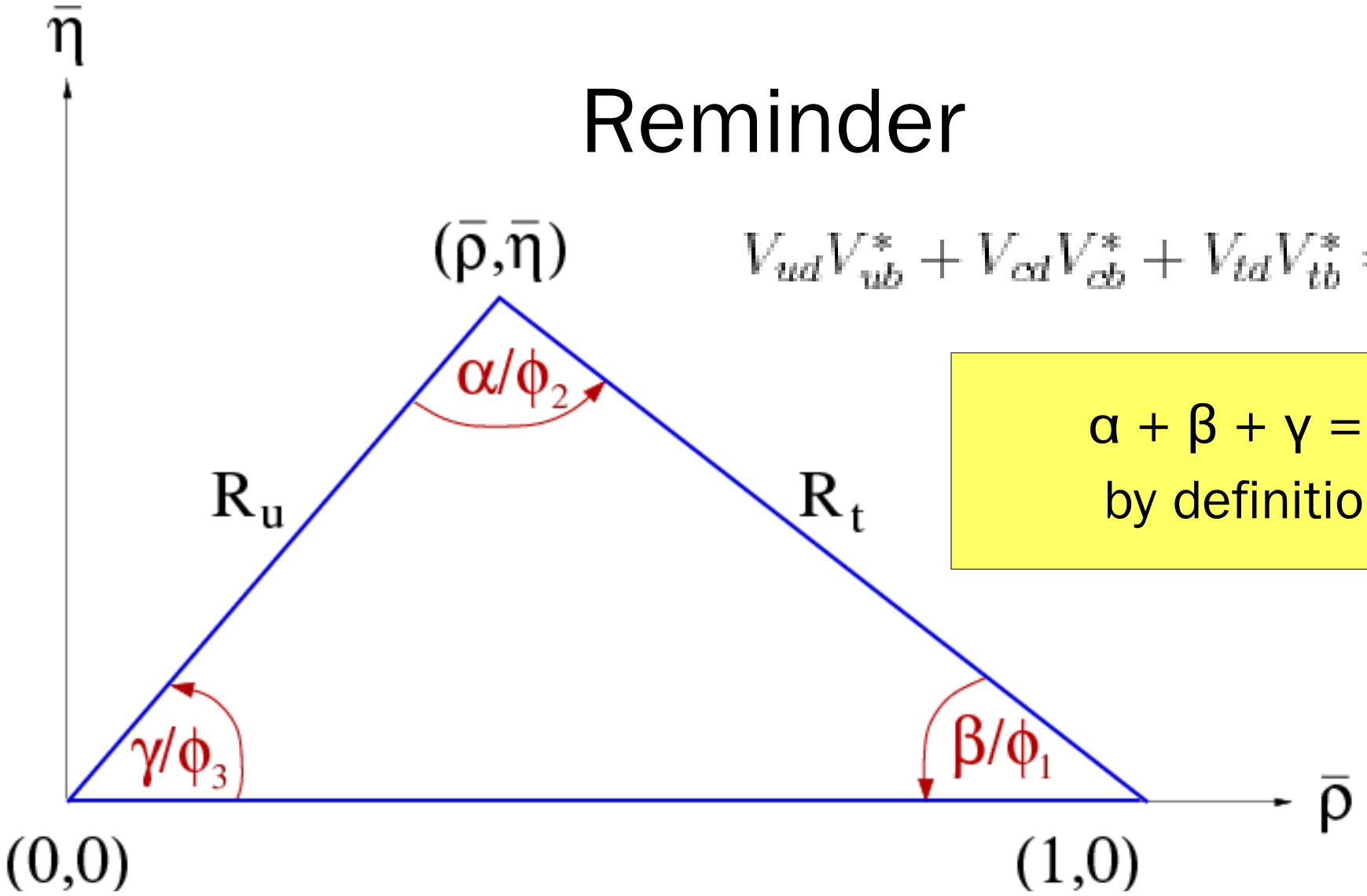
- Hadronic uncertainties
- Experimental challenges

Many, many excellent talks



Thanks to all speakers for their tremendous efforts
Apologies for a very selective summary

Reminder



$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0,$$

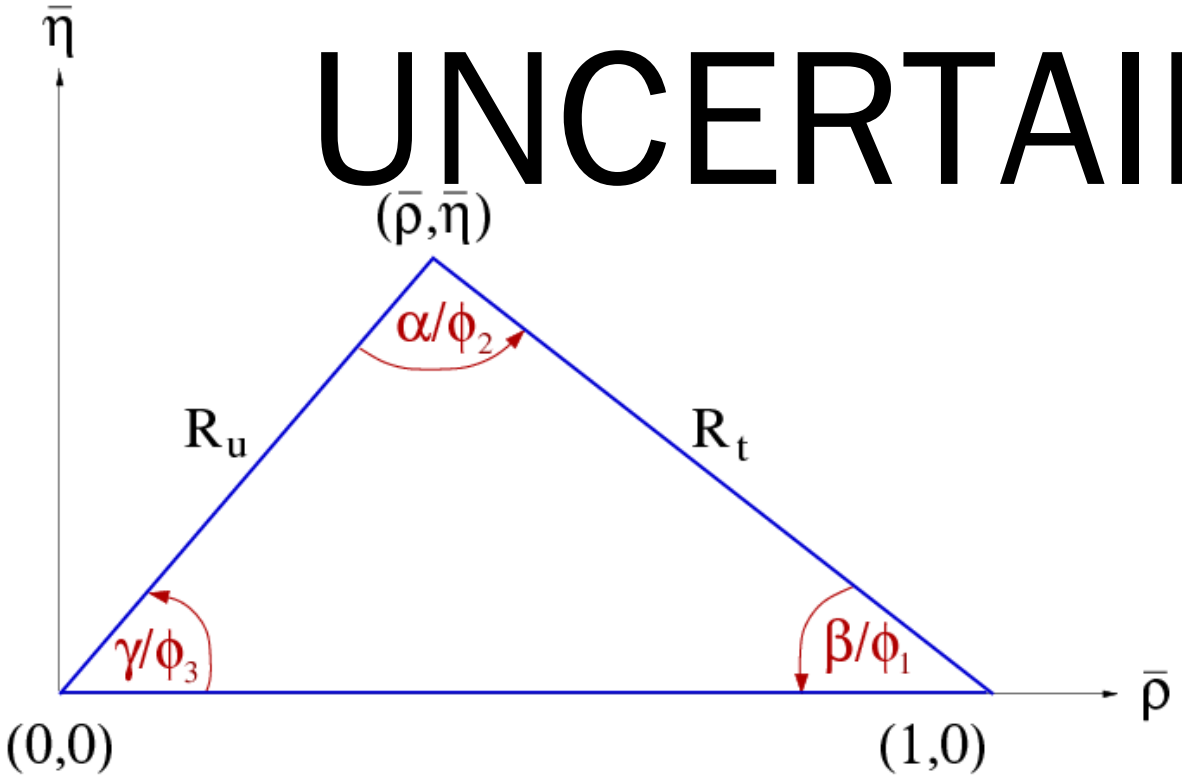
α + β + γ = π
by definition

$$\alpha \equiv \phi_2 = \arg\left[-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right], \quad \beta \equiv \phi_1 = \arg\left[-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right], \quad \gamma \equiv \phi_3 = \arg\left[-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right]$$

Wednesday, 10 September 2008

11:00	[49] **Methods** by Chris BAUER (Aula Amaldi: 11:30 - 11:55)	slides
12:00	[50] **Tree amplitudes** by Sebastian JAGER (Aula Amaldi: 12:00 - 12:20)	slides
	[51] **Penguin amplitudes** by Cai-Dian LU (Aula Amaldi: 12:25 - 12:45)	slides

HADRONIC UNCERTAINTIES



theory primers [Bauer, Franco, Pierini, Jäger]

- symmetries and topological amplitudes
  $1/N_c$ arguments

- factorization ($1/m_b$ expansion -> SCET)

  different phenomenological assumptions:
  - SCET/BPRS
  - QCDF/BBNS
  - pQCD

Comparison

	BPRS	QCDF	PQCD
Expansion in $\alpha_s(\mu_i)$?	No	Yes	Yes
Singular convolutions	N/A	New parameters	"Unphyiscal" k_T
Charm Loop?	Non-perturbative	Perturbative	Perturbative
Number of parameters	Most	Middle	Least
How conservative?	Most	Middle	Least

hadronic uncertainties

[Jäger, Lü, Pierini]

Status of theoretical calculations:

- tree amplitudes:
  - ➔ colour allowed:
    only small corrections to naive factorization
  - ➔ colour suppressed:
    NLO vertex corrections almost cancel LO
    dominated by spectator effects
  - ➔ annihilation:
    $1/m_b$-suppressed
    uncertain (non-factorizable effects)

Tree amplitudes

- 1/N expansion (only counting rules)
- Λ_{QCD}/m_B expansion (QCDF/SCET; pQCD): computation of important pieces possible

	$a_1/T/E_1$	$a_2/C/E_2$	α_4^u	$b_1/E/A_2$	$b_2/A/A_1$
1/N	1	1/N	1/N	1/N	1 [?]
Λ/m_B	1	1	1	Λ/m_B	Λ/m_B

- QCD light-cone sum rules: partly complementary set of calculable amplitudes; constrain "inputs" to Λ/m_B
- SU(3) [U-spin] relates $\Delta D=1$ and $\Delta S=1$: e.g. trees in πK from $\pi\pi$; penguins in ρp from ρK^*, etc. (m_s/Λ_{QCD} corrections; annihilation contamination)

JÄGER

hadronic uncertainties

[Jäger, Lü, Pierini]

Status of theoretical calculations:

- penguin amplitudes:

  differing results in BBNS/BPRS/pQCD:
  - ➔ chirally enhanced penguin
  - ➔ annihilation penguin
  - ➔ charm(ing) penguin

  - ✗ treatment of non-factorizable $1/m_b$ effects ?

Non-factorizable penguins

	Charmming penguin	Chiral enhanced penguin	Annihilation penguin
BBNS/ QCDF	Perturbative, small	Big	nonperturbative model parameters, large phases
pQCD	Perturbative, small	Big	Big, perturbative large phases
BPRS/ SCET	Big, non-perturbative fit parameter	Not known	perturbative

Hadronic Uncertainties

- Need to understand subleading effects in order to interpret several interesting measurements
  - $\Delta A_{CP}(K\pi)$
  - ϕK^* polarization
  - $\Delta S(\phi K_S$, *etc.*)
  - Large BR($B^0 \to \pi^0\pi^0$)
- Hoped for breakthrough has not (yet) occurred
  - High energy scales of LHC attractive for theorists too
- Need LHCb data to inspire future theory developments
- Focus on theoretically clean &/or data-driven methods

Tuesday, 09 September 2008

17:00

[44] **Theoretical aspects** slides
by Maurizio PIERINI; Jure ZUPAN
(Aula Amaldi: 17:00 - 17:25)

[45] **gamma from B->hh** slides
by Sheng-Wen LIN
(Aula Amaldi: 17:30 - 17:50)

18:00

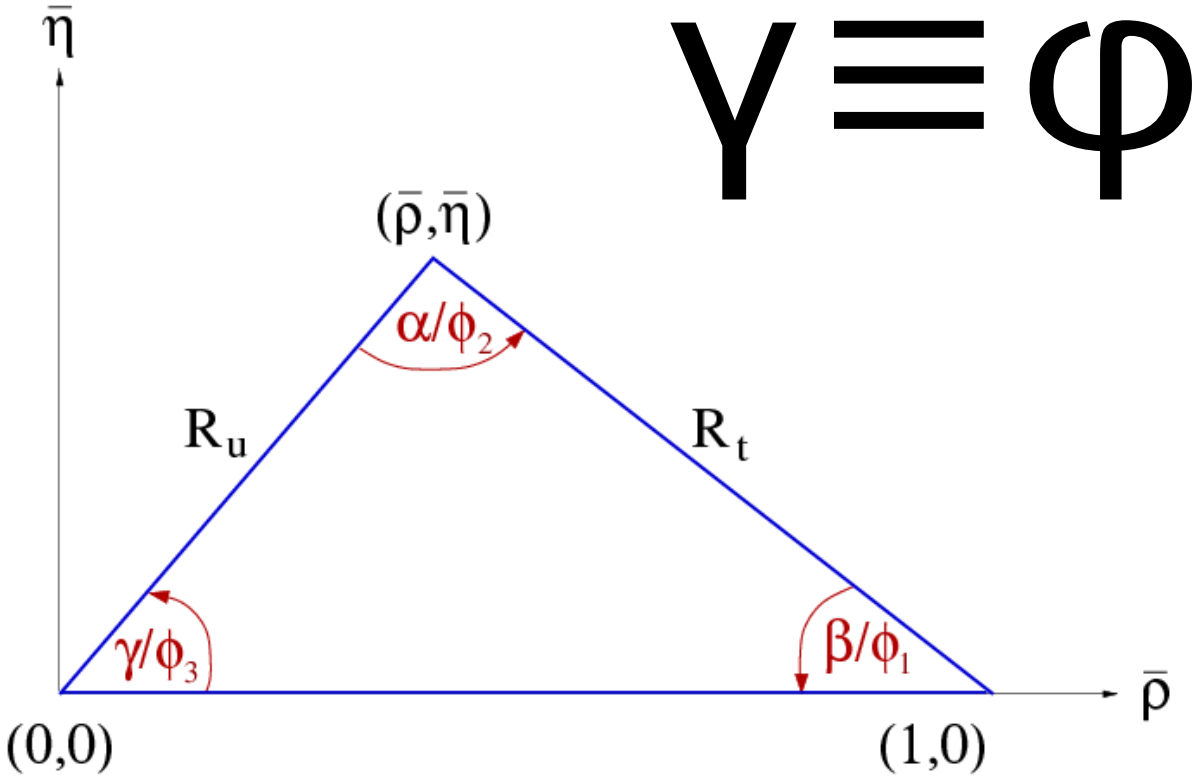
[46] **gamma from B->Kpipi Dalitz plots** slides
by Thomas LATHAM
(Aula Amaldi: 17:55 - 18:15)

[47] **gamma from B(s)->hh** slides
by Guido VOLPI
(Aula Amaldi: 18:20 - 18:40)

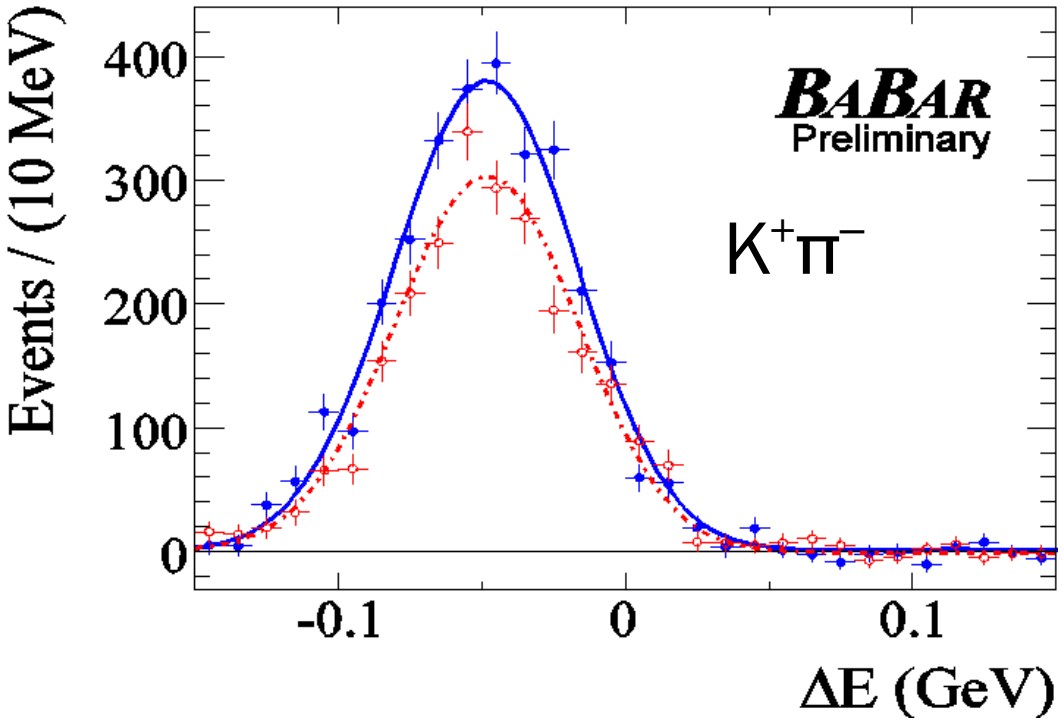
19:00

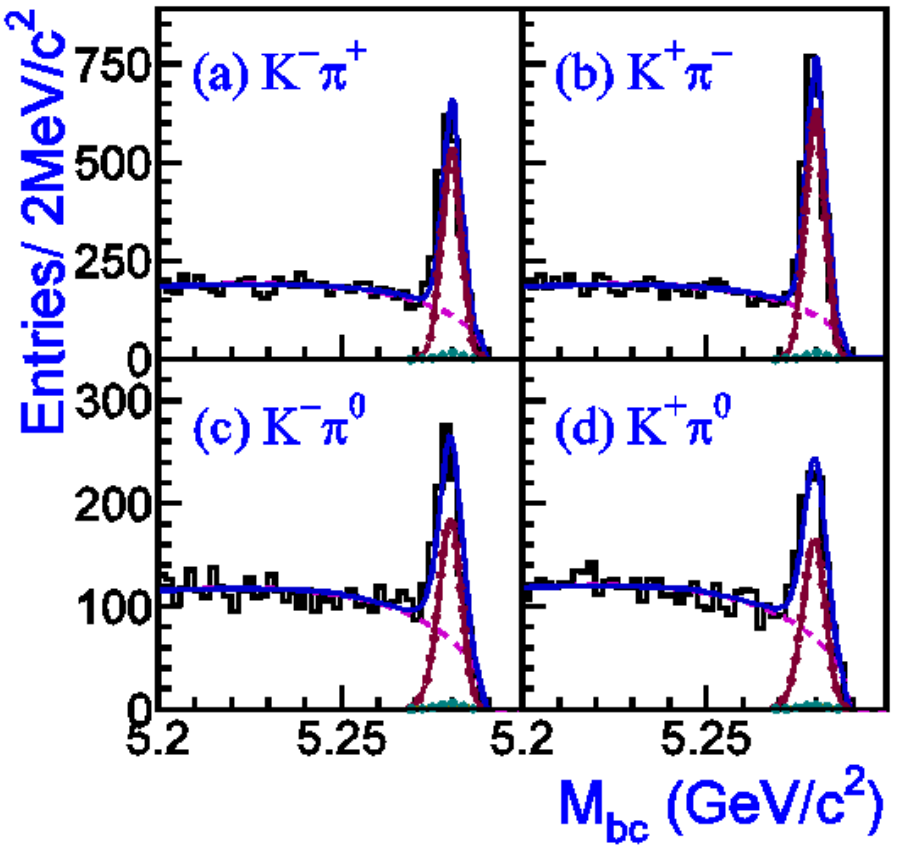
[48] **gamma from B->hhh at LHCb** slides
by Gabriel GUERRER
(Aula Amaldi: 18:45 - 19:05)

$\gamma \equiv \phi_3$

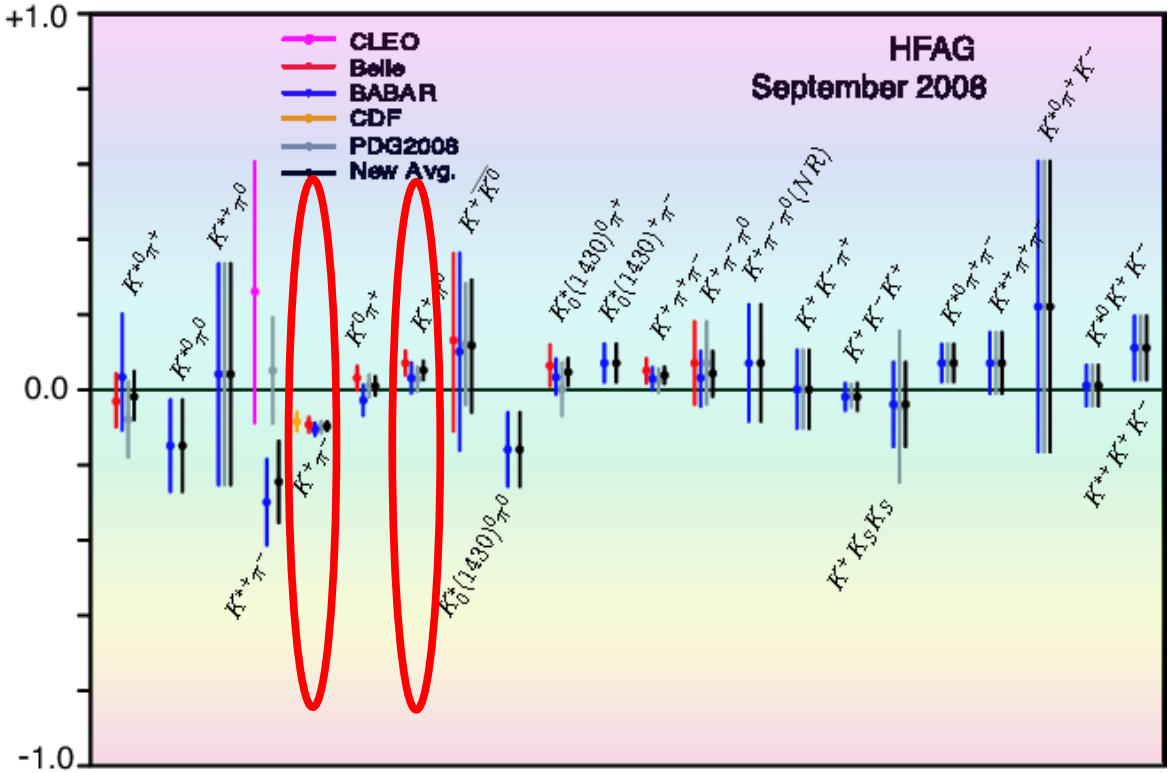


$\Delta A_{CP}(K\pi)$





$\Delta A_{CP}(K\pi)$



RPP#	Mode	PDG2008 Avg.	BABAR	Belle	CLEO	CDF	New Avg.
98	$K^+\pi^-$	-0.101 ± 0.015	$-0.107 \pm 0.016^{+0.006}_{-0.004}$	$-0.094 \pm 0.018 \pm 0.008$	$-0.04 \pm 0.16 \pm 0.02$	$-0.086 \pm 0.023 \pm 0.009$	$-0.098^{+0.}$
208	$K^+\pi^0$	0.027 ± 0.032	$0.030 \pm 0.039 \pm 0.010$	$0.07 \pm 0.03 \pm 0.01$	$-0.29 \pm 0.23 \pm 0.02$		0.050 ± 0.02

$\Delta A_{CP}(K\pi)$

The experimental measurements

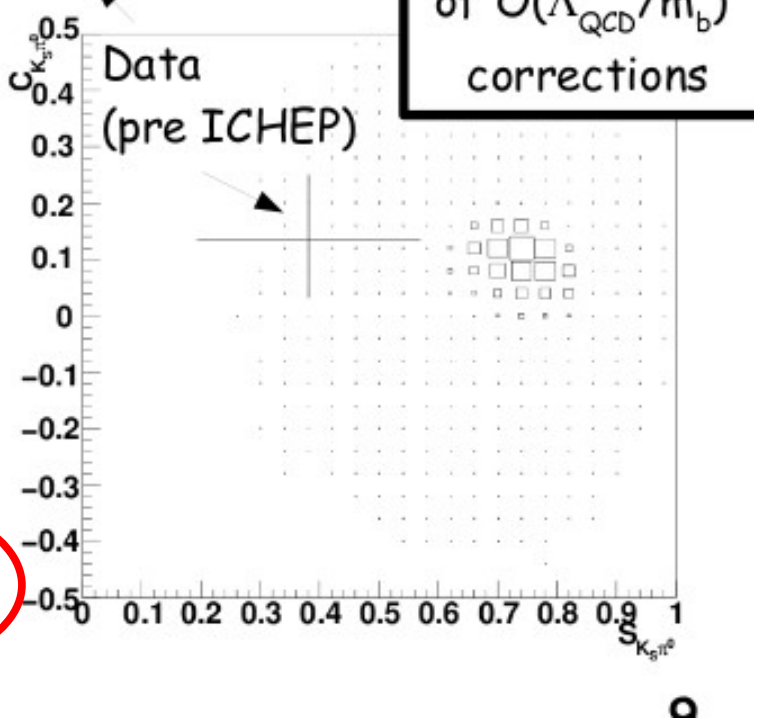
Decay Mode	$BR^{exp} \times 10^6$	$\mathcal{A}_{CP}^{exp} = -C$	S
$K^+\pi^-$	19.4 ± 0.6	-0.097 ± 0.012	–
$K^+\pi^0$	12.9 ± 0.6	0.050 ± 0.025	–
$K^0\pi^+$	23.1 ± 1.0	0.009 ± 0.025	–
$K^0\pi^0$	9.9 ± 0.6	-0.14 ± 0.11	0.38 ± 0.19

Fit predictions not very precise

	global fit	fit prediction
$BR(K^+\pi^-) \times 10^6$	19.6 ± 0.5	20.1 ± 1.0
$BR(K^+\pi^0) \times 10^6$	12.7 ± 0.5	12.4 ± 0.7
$BR(K^0\pi^+) \times 10^6$	23.7 ± 0.8	24.6 ± 1.2
$BR(K^0\pi^0) \times 10^6$	9.2 ± 0.4	8.6 ± 0.6
$\mathcal{A}_{CP}(K^+\pi^-)$	-0.094 ± 0.012	0.01 ± 0.07
$\mathcal{A}_{CP}(K^+\pi^0)$	0.041 ± 0.023	-0.03 ± 0.06
$\mathcal{A}_{CP}(K^0\pi^+)$	0.014 ± 0.020	0.04 ± 0.05
$C(K_S\pi^0)$	0.11 ± 0.03	0.10 ± 0.04
$S(K_S\pi^0)$	0.72 ± 0.04	0.74 ± 0.04
ΔA_{CP}	0.135 ± 0.025	0.060 ± 0.068

Better ...

SM prediction in presence of $O(\Lambda_{QCD}/m_b)$ corrections

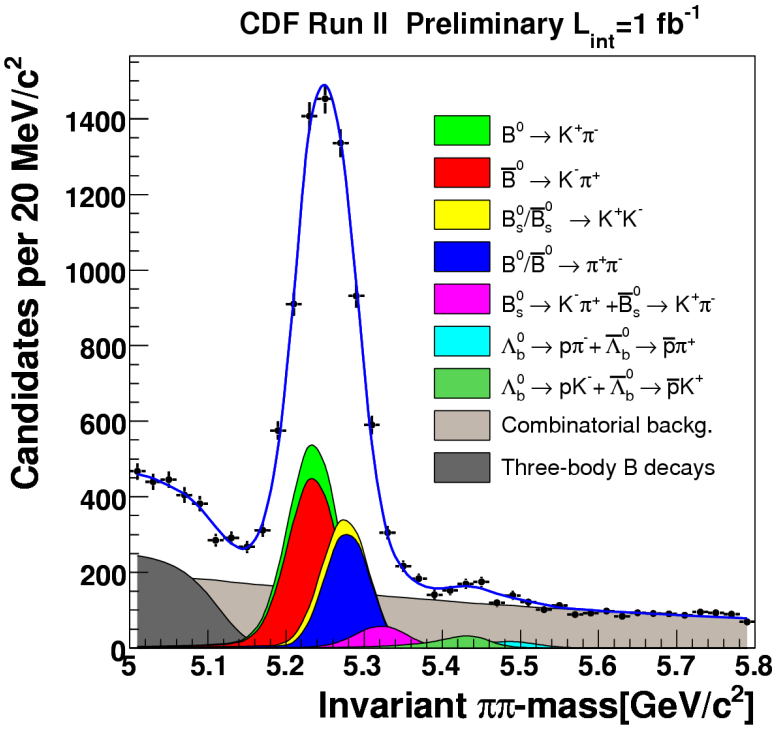


PIERINI, many others

Bs and other results from CDF

Determination of sample composition provides

1. Observation of new Bhh mode: Bs→Kπ
2. First observation of $\Lambda_b \rightarrow ph$ decays: $\Lambda_b \rightarrow p\pi$ and $\Lambda_b \rightarrow pK$
3. Unique sample of $B_s \rightarrow KK$
4. B-factories-like samples of $B_d \rightarrow \pi\pi$ and $B_d \rightarrow K\pi$



A wealth of measurements is extracted

1. BR($B_s \rightarrow K\pi$) and ACP($B_s \rightarrow k\pi$)
2. Improved BR($B_s \rightarrow KK$)
3. BR($\Lambda_b \rightarrow p\pi$) and ACP($\Lambda_b \rightarrow p\pi$)
4. BR($\Lambda_b \rightarrow pK$) and ACP($\Lambda_b \rightarrow pK$)

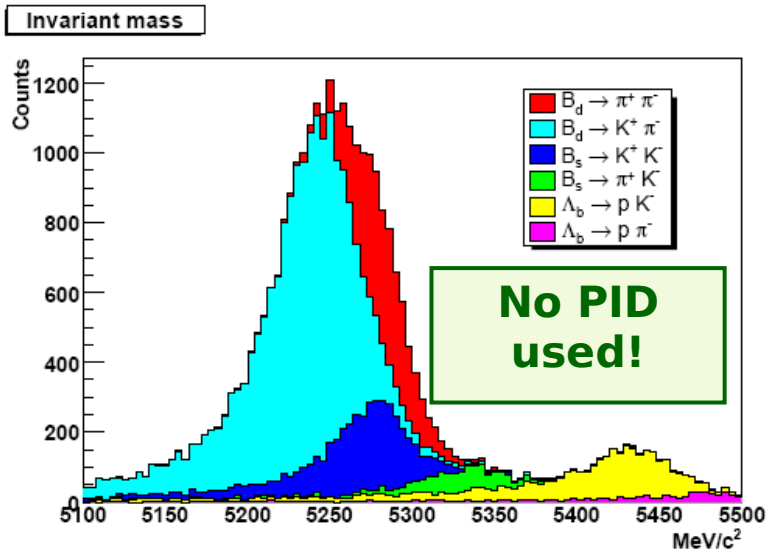
Constraints on gamma!

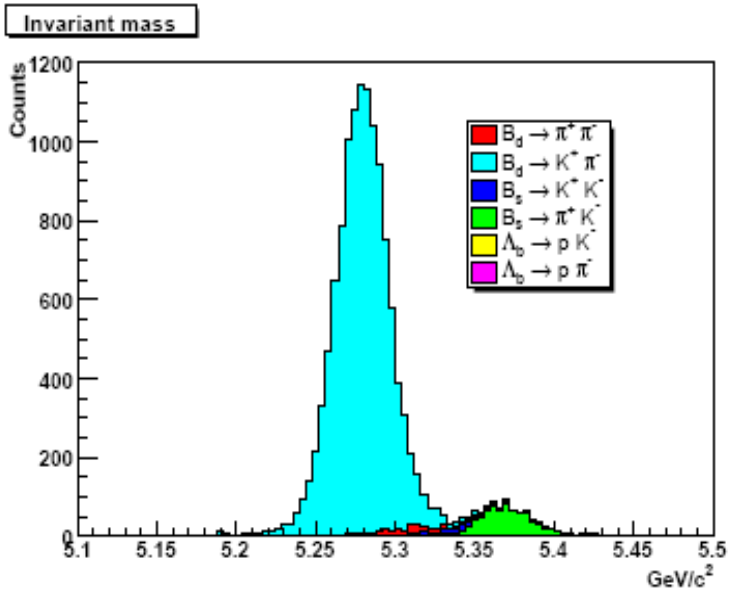
All BR are measured relative to the reference mode $B_d \rightarrow K\pi$ to cancel common systematic uncertainties

VOLPI

How Will it Look for LHCb?

LHCb Note 2007-059





Latest Monte Carlo studies agree with these predictions

	$B \to \pi\ \pi$	$B \to K\pi$	$B_s \to KK$	$B_s \to \pi\ K$
yields	36k	140k	36k	10k
B/S	0.5	0.15	< 0.06	1.9

Kππ Dalitz plot techniques

Ciuchini, Pierini, Silvestrini, 2006; Gronau, Pirjol, Soni, JZ, 2006, 2007

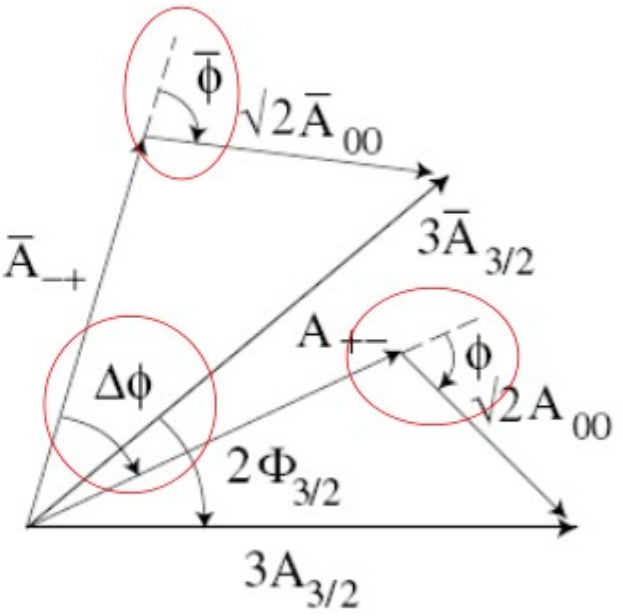
- relative phases of $B \to K^*\pi$ amplitudes from $B \to K\pi\pi$
- no penguins in: $3A_{3/2} = A(K^{*+}\pi^-) + \sqrt{2}A(K^{*0}\pi^0)$
- in the limit of zero EWP

$$\gamma = \Phi_{3/2} \equiv -1/2 \times \arg\left(\bar{A}_{3/2}/A_{3/2}\right)$$

- with EWP ($C = -0.27 = 3(C_9 + C_{10})/(2\lambda^2(C_1 + C_2))$)

$$\boxed{\bar{\eta} = \tan\Phi_{3/2}\left[\bar{\rho} + C[1 - 2\mathrm{Re}(r_{3/2})] + \mathcal{O}(r_{3/2}^2)\right]}$$

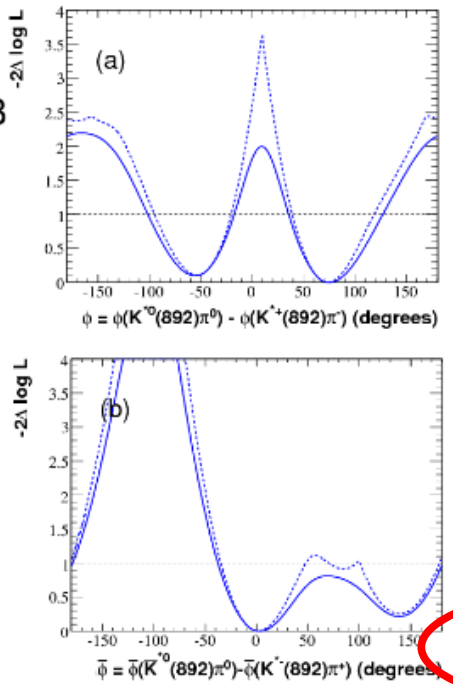
  - for $K\pi$: $r_{3/2} = 0$ in SU(3) limit
  - $r_{3/2}$ correction to this Neubert-Rosner shift
    - $r_{3/2} < 0.05$ using naive factorization
    - $r_{3/2} = 0.054 \pm 0.045 \pm 0.023$ using SU(3)



Kππ Dalitz plot results

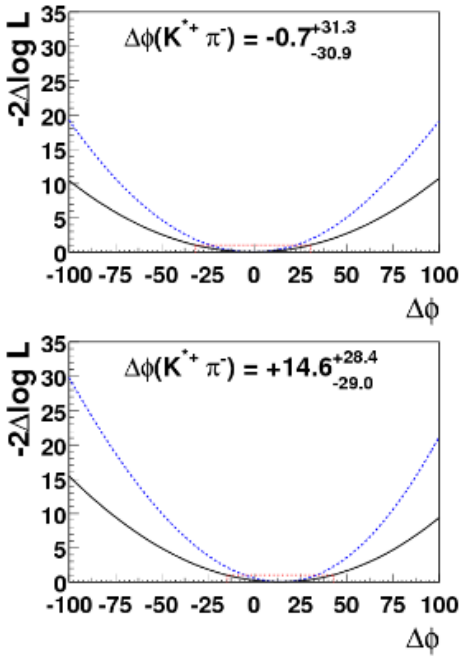
$K\pi\pi^0$ (BaBar)

- BABAR results from 232 million BB
- Accepted by PRD
  - arXiv:0711.4417 [hep-ex]
- Scans opposite show the results for ϕ and $\bar{\phi}$
- Presence of multiple solutions reduces precision of constraint
- Preliminary BABAR results on 454 million BB indicate much better separation between solutions
  - Likelihood scans of phase differences not yet completed
  - arXiv:0807.4567 [hep-ex]



$K_S\pi\pi$ (BaBar + Belle)

- A new Belle preliminary result from 657 million BB:
  $\Delta\phi = (-1 \pm {}^{24}_{23} \pm 11 \pm 18)°$
  (errors are stat, syst, model)
- A second, almost degenerate, solution:
  $\Delta\phi = (+15 \pm {}^{19}_{20} \pm 11 \pm 18)°$
- Difference between solutions is interference between $K_0^{*\pm}(1430)$ and NR
- These again include the $B^0\bar{B}^0$ mixing phase (-2β)
- Apparent disagreement with the BABAR results



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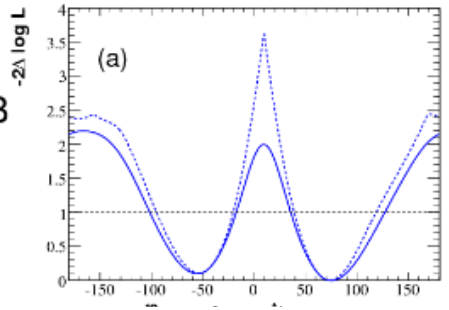

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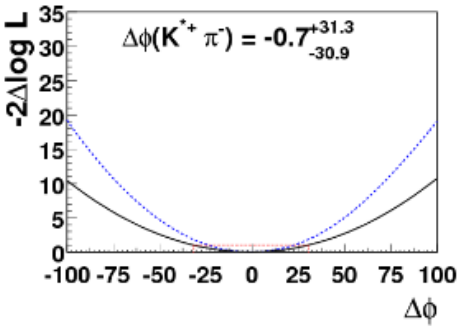
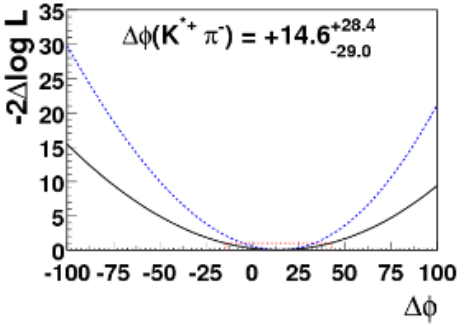
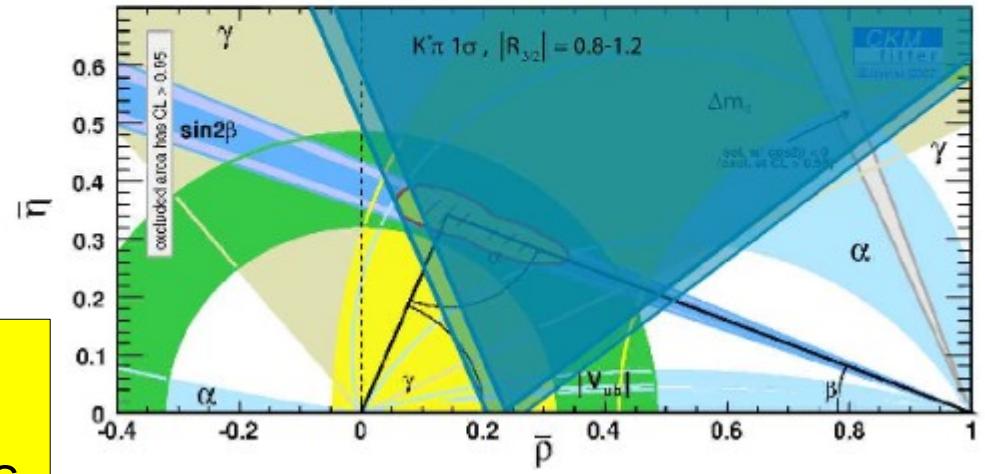




- CKM constraint in presence of EW penguins is:

$$\bar{\eta} = \tan\Phi_{3/2}\left[\bar{\rho} - 0.24 \pm 0.03\right]$$



Constraint does not include latest results

Prospects for LHCb

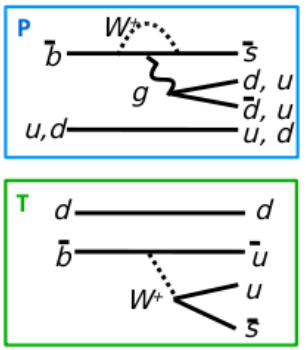
- $B^0 \to K\pi\pi^0$ will be difficult → use a different method
- One nominal year of LHCb data on $B^+ \to K\pi\pi$
  - 2 orders of magnitude more events than the B factories!

γ : B+ → K+π+π- and B0 → K_Sπ+π-

dominant contributions for K* resonance

B+ → K*0 π+ : **Vbt V*ts** P

B0 → K*+ π- : Vbt V*ts P + Vbu V*us T



1st step: amplitude analysis of charged B

- extracts B+ : Vbt V*ts ∝ a $e^{i\delta}$
  B- : V*bt Vts ∝ a $e^{i\delta}$
  which should be equal in absence of weak phase
- parameters are extracted relative to B+ → χc0 K+ which should have same contribution in neutral decay, allowing comparison of parameters

- the ability of measuring γ is related to it's own value and the ratio **r** = **T** / **P** in B0 → K* π
- we can measure **r**
- conflicting theoretical predictions
  Beneke,Neubert Nucl. Phys **B675**, 333(2003)
  Buras et al, Phys. Rev.Lett **92** 101804 (2004)

Monte Carlo test

- 100 samples of 100k B0 events
- no background nor acceptance included
- inputs inspired by BaBar
- input $\gamma = 69^\circ$, r = 0.45
- extracts $\gamma = 69^\circ \pm 5^\circ$

γ Summary

- Kπ system remains interesting
  - results are tantalizing but hadronic uncertainties remain
  - need better data on $K_S\pi^0$ – Super Flavour Factory
- Kππ based methods provide additional information
  - can control hadronic uncertainties
  - first results available, expect updates from B factories
  - looking good for LHCb

Wednesday, 10 September 2008

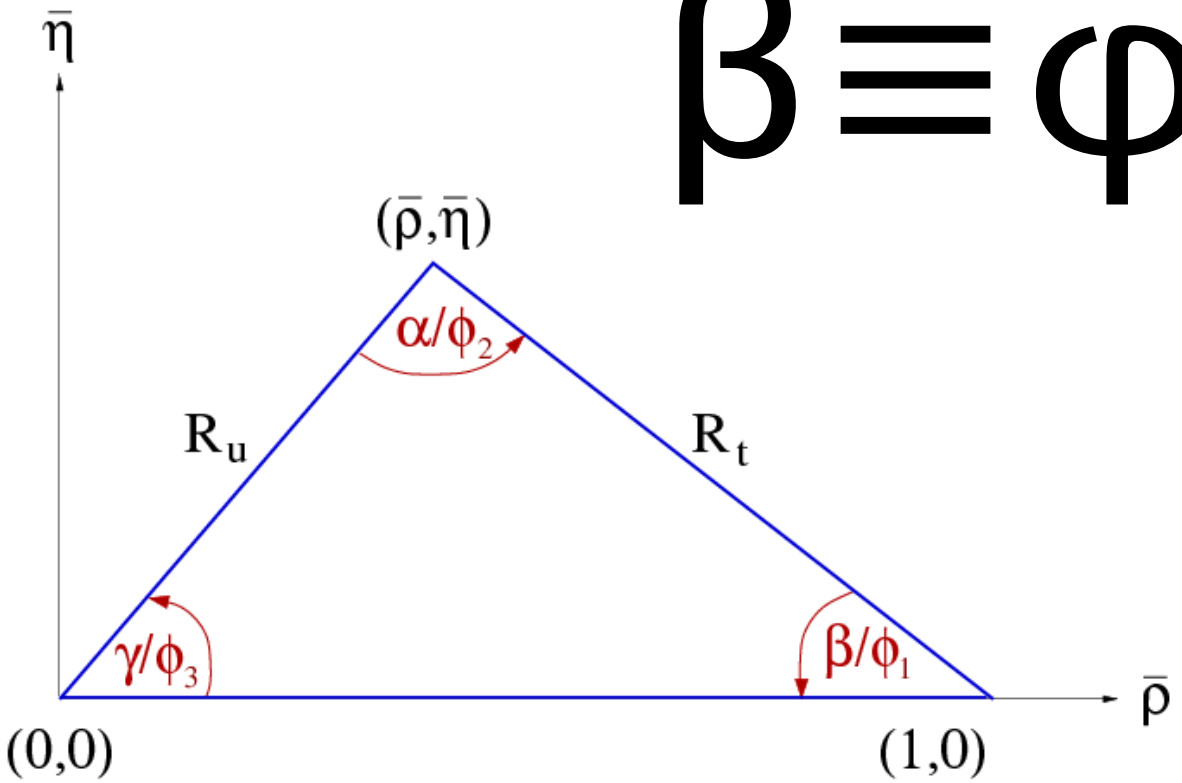
09:00 [40] **Theoretical aspects** slides
by Amarjit SONI
(Aula Amaldi: 09:00 - 09:20)

[41] **beta from B->eta'K0, omega K0 and related measurements** slides
by Alessandro GAZ
(Aula Amaldi: 09:30 - 09:50)

10:00 [42] **beta from pi0KS, KSKSKS, pi0pi0KS and related measurements** slides
by Miyuki FUJIKAWA
(Aula Amaldi: 10:00 - 10:20)

[43] **beta from time-dependent Dalitz plot analyses** slides
by Jeremy DALSENO
(Aula Amaldi: 10:30 - 10:50)

$$\beta \equiv \varphi_1$$



ΔS in Hadronic b→s Penguin Dominated Decays

Browder,Gershon,Pirjol,AS,Zupan,arXiv:0802.3201(RMP)

Some More on ΔS

- **ΔS REMAINS an EXCELLENT TEST**
- **Sign of ΔS theoretically NOT fully reliable though in most model calculations and for most modes ΔS is positive**

- ***CONCLUSIVE evidence for NP demands |ΔS| >0.10 IN some of the CLEAN modes (though whichever |ΔS|)***

TABLE VIII Expectations for ΔS_f in three cleanest modes.

Model	ϕK^0	$\eta' K^0$	$K_S K_S K^0$
QCDF+FSI[a]	$0.03^{+0.01}_{-0.04}$	$0.00^{+0.00}_{-0.04}$	$0.02^{+0.00}_{-0.04}$
QCDF[b]	0.02 ± 0.01	0.01 ± 0.01	
QCDF[c]	0.02 ± 0.01	0.01 ± 0.02	
SCET[d]		-0.019 ± 0.009 -0.010 ± 0.010	
pQCD[e]	0.02 ± 0.01		

[a]Cheng *et al.* (2005a,b) [b]Beneke (2005)
[c]Buchalla *et al.* (2005) [d]Williamson and Zupan (2006)
[e]Li and Mishima (2006)

Message: Don't take theory errors too "literally"

Both experiments now using time-dependent Dalitz pot analyses

$B^0 \to \phi K_S$

BaBar

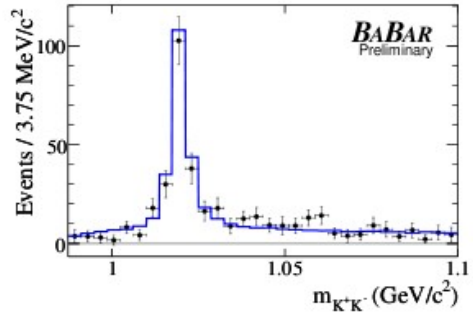
Time-dependent DP fit to low mass, $m_{K^+K^-} < 1.1$ GeV

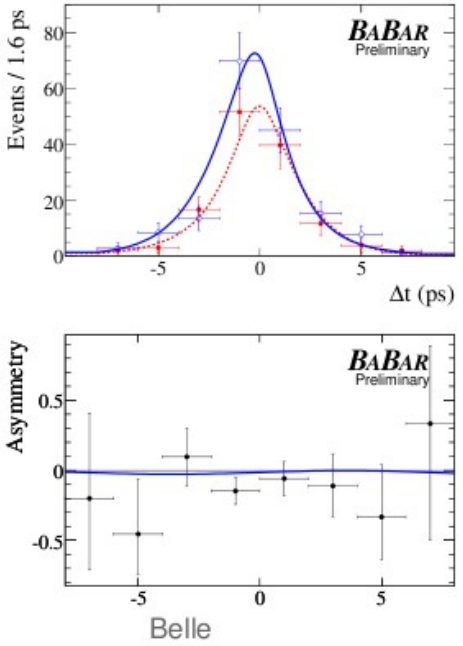
Amplitudes and phases fixed from full DP fit, except $\phi(1020)$

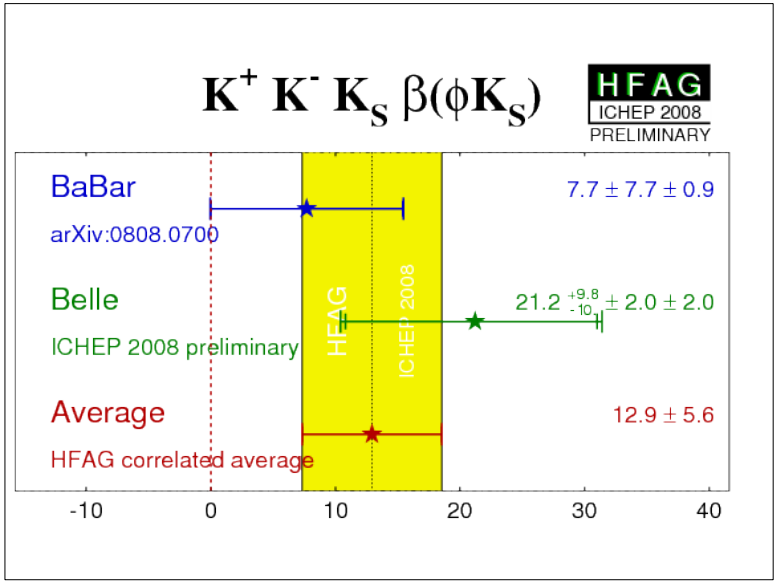
Separate $f_0(980)$ and $\phi(1020)$ CP parameters

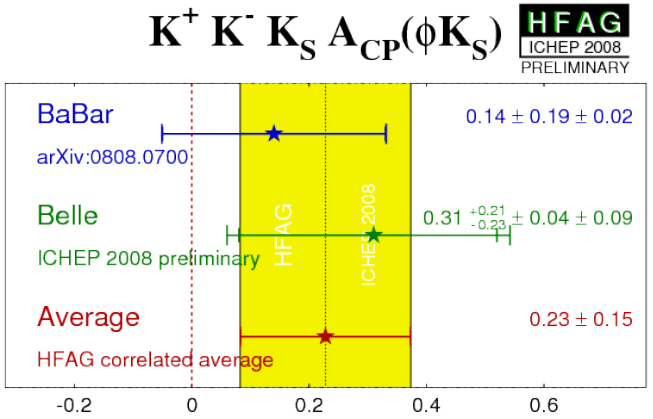
Other CP parameters set to zero

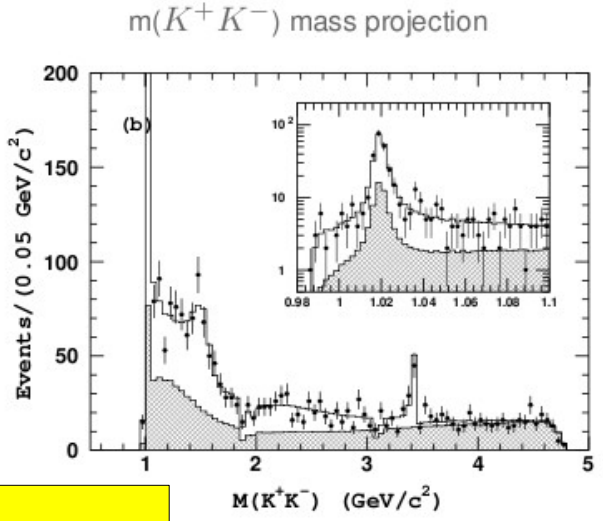
Signal yield: 421 ± 25 events

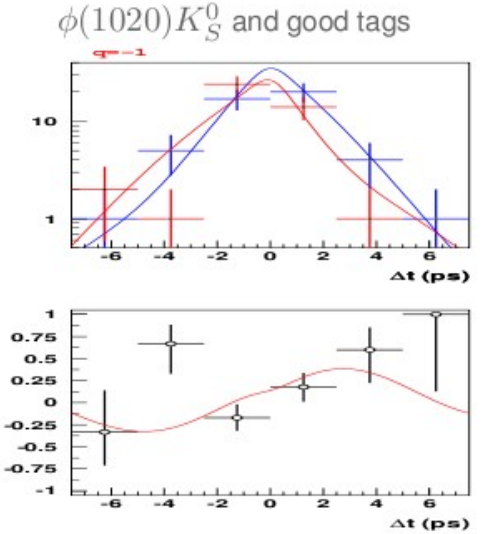






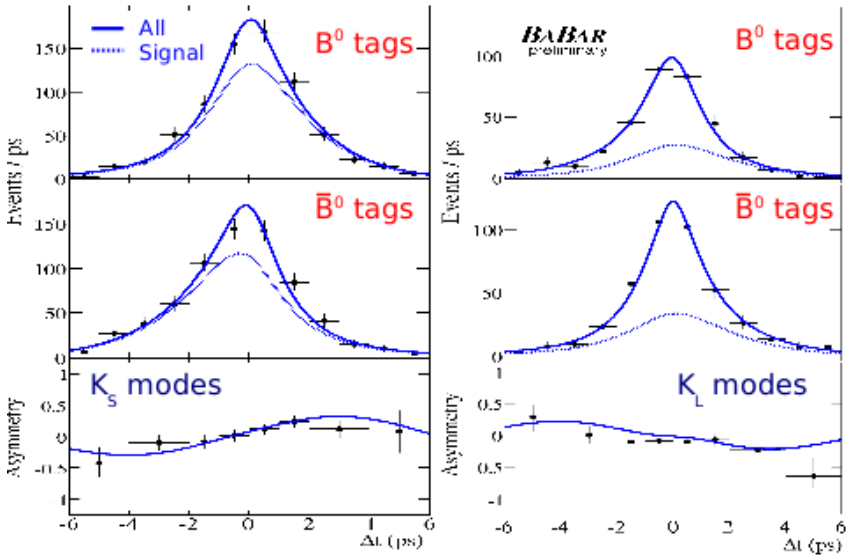






DALSENO

$B^0 \to \eta' K_S$

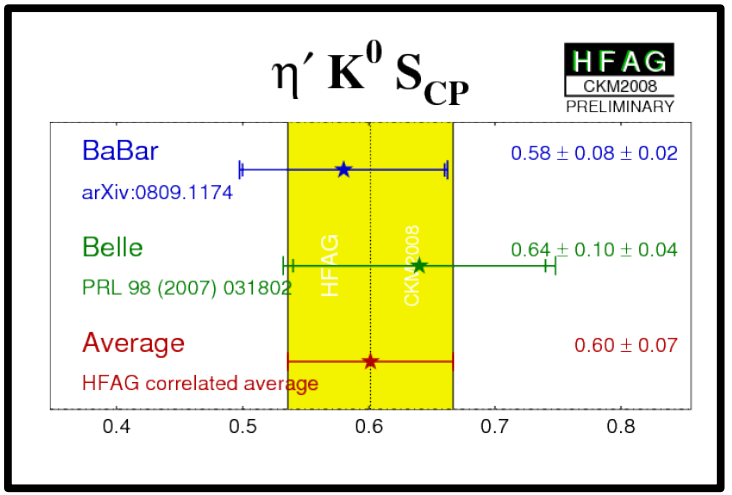


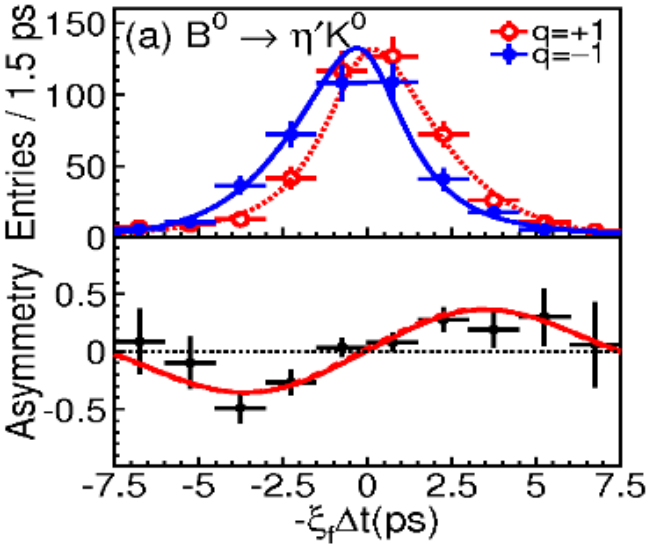
Maximum Likelihood fit separately to K_S and K_L modes:

$$-\xi_{\eta' K_S} S_{\eta' K_S} = 0.53 \pm 0.08 \pm 0.02$$
$$C_{\eta' K_S} = -0.11 \pm 0.06 \pm 0.02$$
$$-\xi_{\eta' K_L} S_{\eta' K_L} = 0.82 \pm 0.19 \pm 0.02$$
$$C_{\eta' K_L} = 0.09 \pm 0.14 \pm 0.02$$

Final results computed through scans of $-2 \ln \mathcal{L}$:

Methods to constrain ΔS using SU(3) related modes appear to be reaching limitations



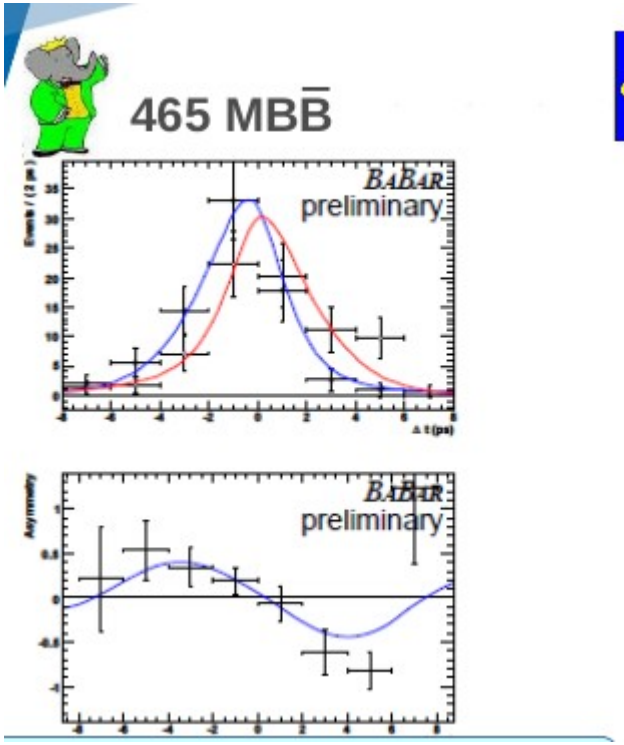


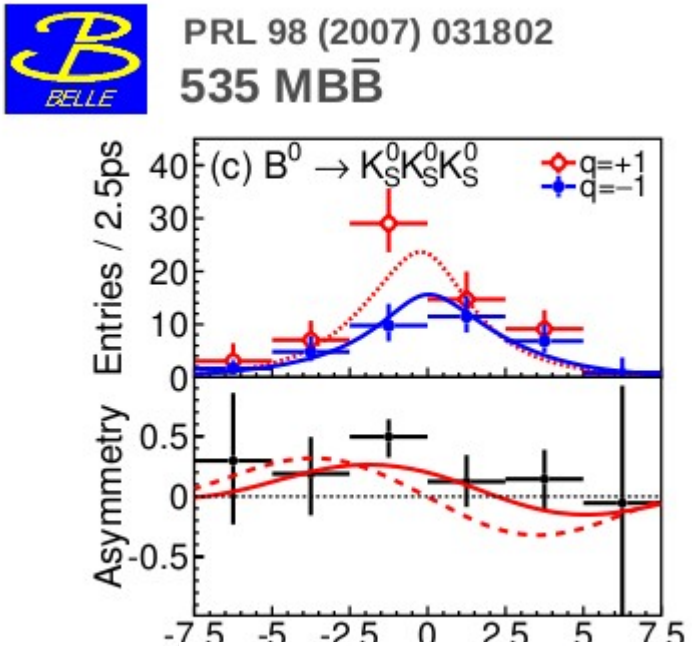
Maximum Likelihood fit simultaneously to K_S and K_L:

$$-\xi_{\eta' K^0} S_{\eta' K^0} = 0.64 \pm 0.10 \pm 0.04$$
$$C_{\eta' K^0} = 0.01 \pm 0.07 \pm 0.05$$

GAZ

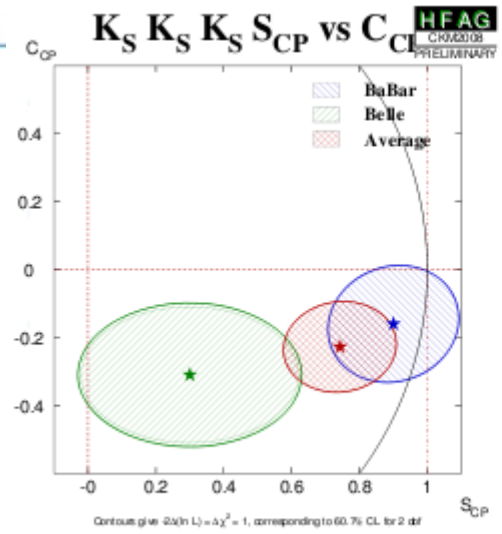
$B^0 \to K_S K_S K_S$





FUJIKAWA

(preliminary)
BABAR RESULTS
NEW FOR CKM2008



$C_{CP} = -\mathcal{A}$

BaBar	$-0.16 \pm 0.17 \pm 0.03$
Belle	$-0.31 \pm 0.20 \pm 0.07$
Average	-0.23 ± 0.13

$\sin 2\phi_1^{\text{eff}} = -S$

BaBar	$0.90 \pm {}^{0.20}_{0.18} \pm {}^{0.04}_{0.03}$
Belle	$0.30 \pm 0.32 \pm 0.08$
Average	0.74 ± 0.17

$B^0 \to K^0\pi^0$

Mode of special interest: $\pi^0 K_S$

Beneke

Cheng, Chua, AS

Buchalla, Hiller, NiR, RAZ

BABAR $\Delta S \sim -.12 \pm .20$

BELLE $\sim 0.0 \pm .31$

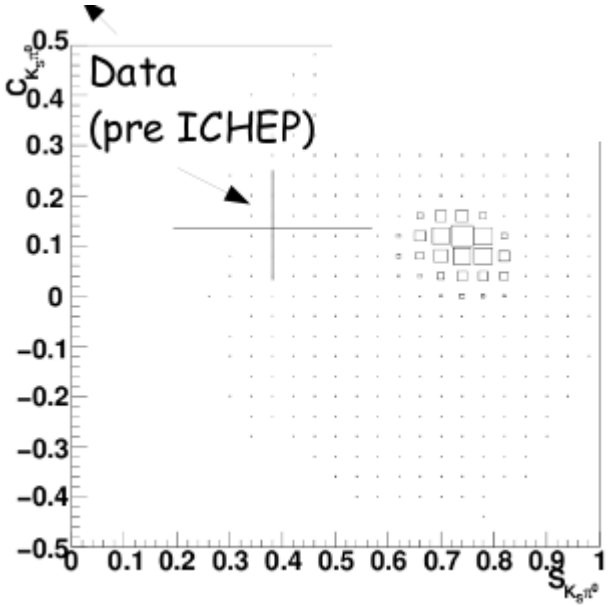
$\Delta S_{\pi^0 K_S}$

$.07^{+.05}_{-.04}$ (.12, .15)

$.04 \pm .02 \pm .03$

$.052^{+.042}_{-.031}$

See Paoti Chang talk ICHEP 08



More on $\pi^0 K_S$

- However, Isospin povides useful relations amongs the 4 K π modes which may lead to useful constraints
- An interesting exampleFleischer, Jager, Pijol, Zupan, arXiv: 0806.2900

$\simeq 26$

$$S_{\pi^0 K_S} = 0.99^{+0.01}_{-0.07}\big|_{\rm exp.}{}^{+0.000}_{-0.001}\big|_{R_{T+C}}{}^{+0.00}_{-0.10}\big|_{R_q}{}^{+0.00}_{-0.06}\big|_{\gamma}$$

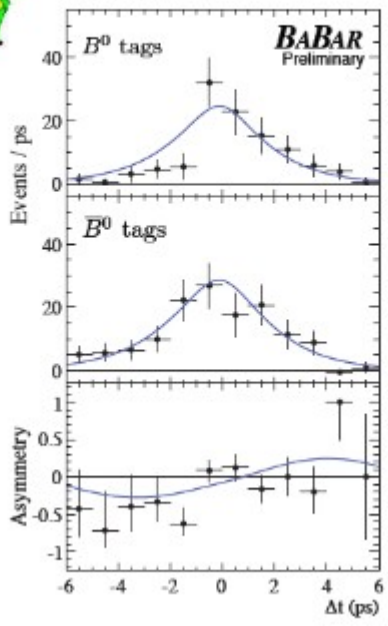
See also Gronau + Rosner arXiv: 0807.3080

Fits prefer large values of $S(K_s\pi^0)$

SONI, PIERINI

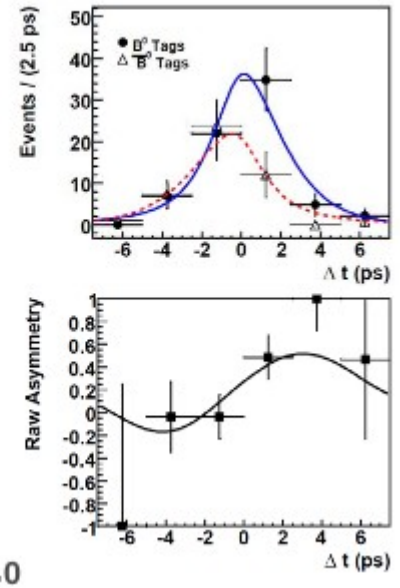
$B^0 \to K_S \pi^0$

465 MBB̄

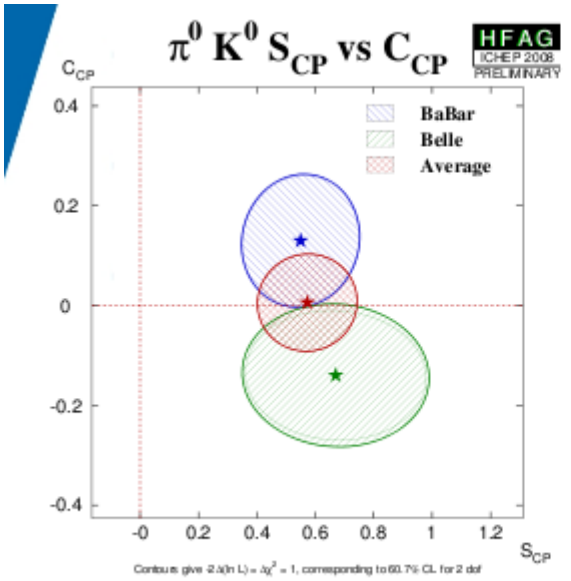


$K_S\pi^0$

657 MBB̄



$K_S\pi^0+K_L\pi^0$



FUJIKAWA

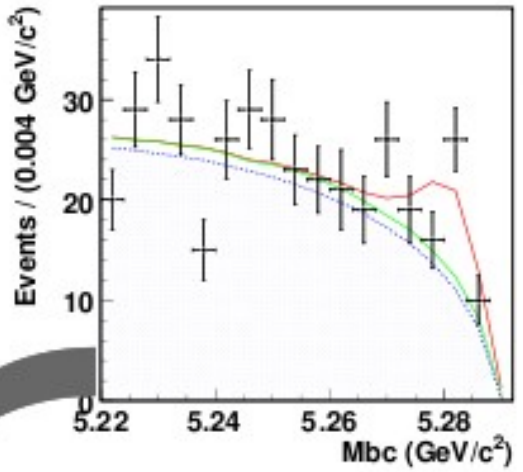
$\sin 2\phi_1^{eff} = S$

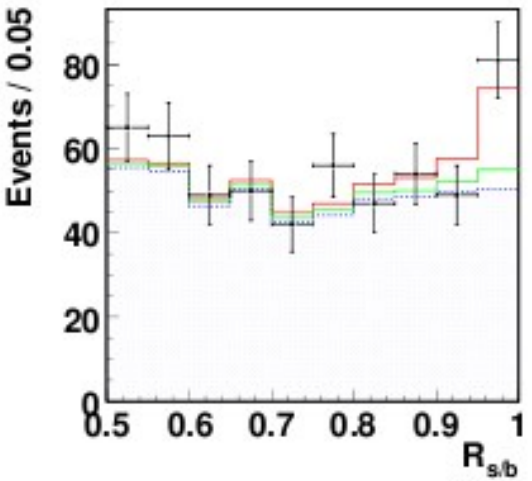
BaBar	$0.55 \pm 0.20 \pm 0.03$
Belle	$0.67 \pm 0.31 \pm 0.06$
Average	0.57 ± 0.17

$C_{CP} = -\mathcal{A}$

BaBar	$0.13 \pm 0.13 \pm 0.03$
Belle	$-0.14 \pm 0.13 \pm 0.06$
Average	0.01 ± 0.10

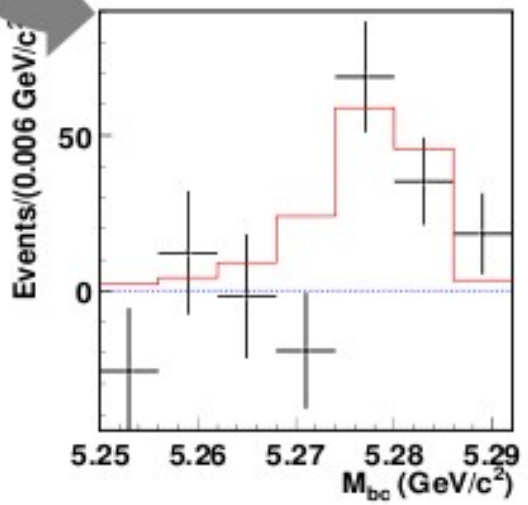
$B^0 \to K_L \pi^0$ (!!!)





657 MB$\bar{B}$

Background subtraction



- First measurement
- M_{bc} calculated from direction of K_L cluster
- $K_L \pi^0$ signal

  285 ± 52 (stat) ± 57 (syst)

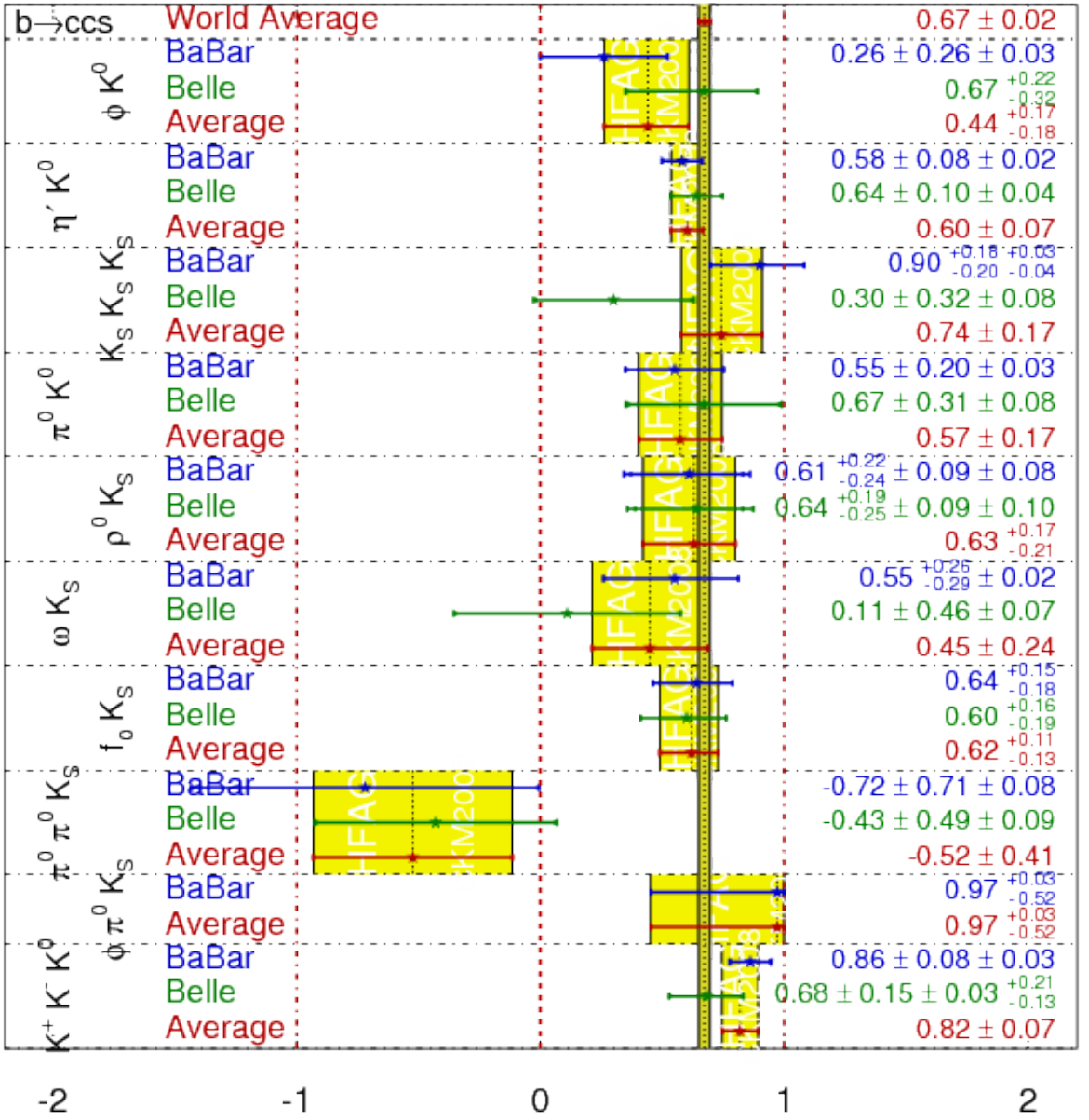
  3.7σ (including systematics)

HFAG COMPILATION

$\sin(2\beta^{\text{eff}}) \equiv \sin(2\phi_1^{\text{eff}})$

HFAG CKM2008 PRELIMINARY

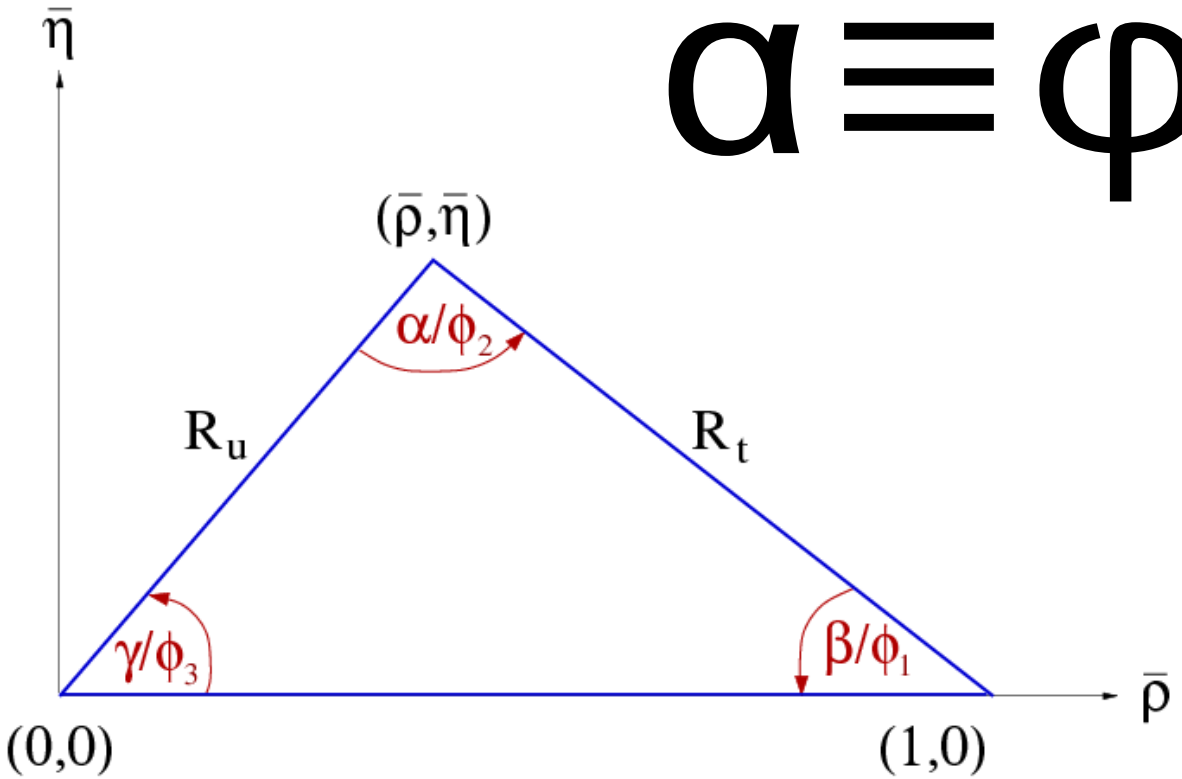
- Huge effort from B factories to clarify hints of trends / deviations in previous measurements
  - eg. Dalitz plot analyses
- Situation today is quite different to the past
- (Put your own conclusion here)



Tuesday, 09 September 2008

14:00	[36] **Theoretical aspects** slides by Enrico FRANCO (Aula Amaldi: 14:30 - 14:50)
15:00	[37] **alpha from B->pipi** slides by Dr. Alexandre TELNOV (Princeton University) (Aula Amaldi: 15:00 - 15:20)
	[38] **alpha from B->rhopi** slides by Gagan MOHANTY (Aula Amaldi: 15:30 - 15:50)
16:00	[39] **alpha from B->rhorho and other modes** slides by Alan SCHWARTZ (Aula Amaldi: 16:00 - 16:20)

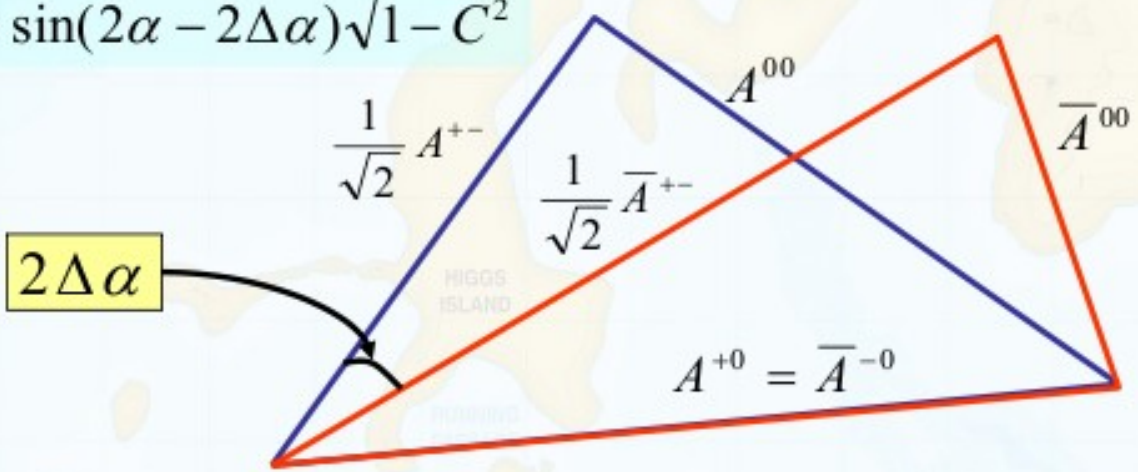
$$\alpha \equiv \varphi_2$$



The Gronau-London Method

M. Gronau, D. London, Phys. Rev. Lett. **65**, 3381 (1990)

$$S = \sin(2\alpha - 2\Delta\alpha)\sqrt{1-C^2}$$



$$A^{+-} = A(B^0 \to \pi^+\pi^-)$$
$$\overline{A}^{+-} = A(\overline{B}^0 \to \pi^+\pi^-)$$
$$A^{00} = A(B^0 \to \pi^0\pi^0)$$
$$\overline{A}^{00} = A(\overline{B}^0 \to \pi^0\pi^0)$$
$$A^{+0} = A(B^+ \to \pi^+\pi^0)$$
$$\overline{A}^{-0} = A(B^- \to \pi^-\pi^0)$$

4-fold ambiguity in $2\Delta\alpha$: either triangle can flip up or down

$$A_{\pi\pi} = e^{+i\gamma}T + e^{-i\beta}P$$
$$\overline{A}_{\pi\pi} = e^{-i\gamma}T + e^{+i\beta}P$$

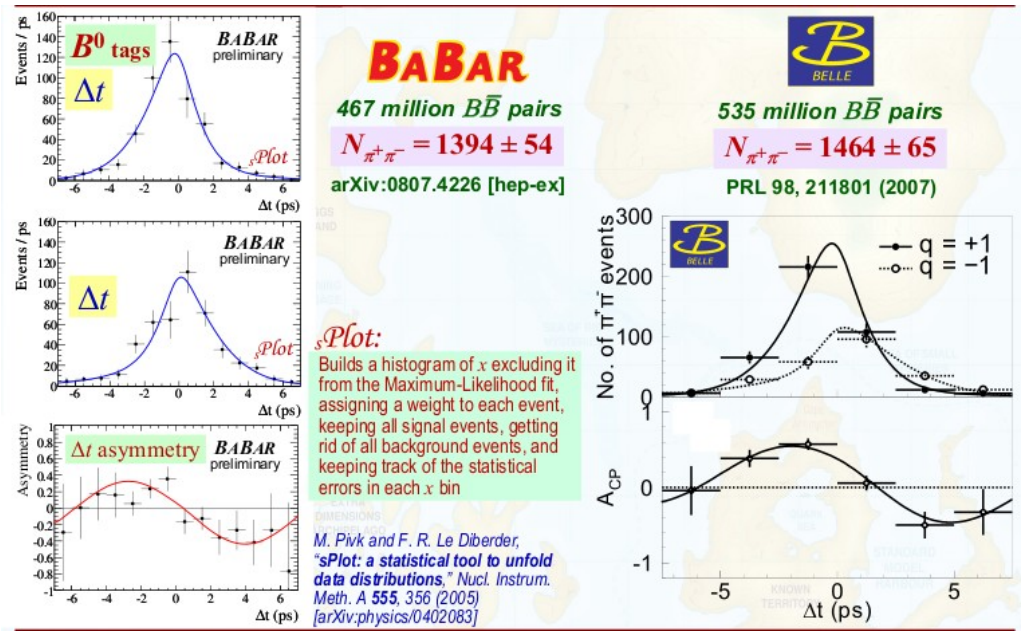
Neglecting EW penguins, ± 0 is a pure tree mode, and so the two triangles share a common side:

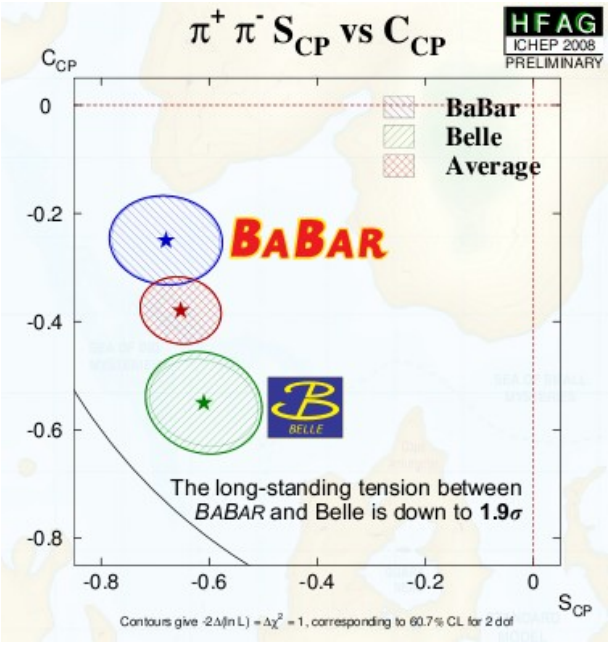
$$A(B^+ \to \pi^+\pi^0) = \overline{A}(B^- \to \pi^-\pi^0)$$

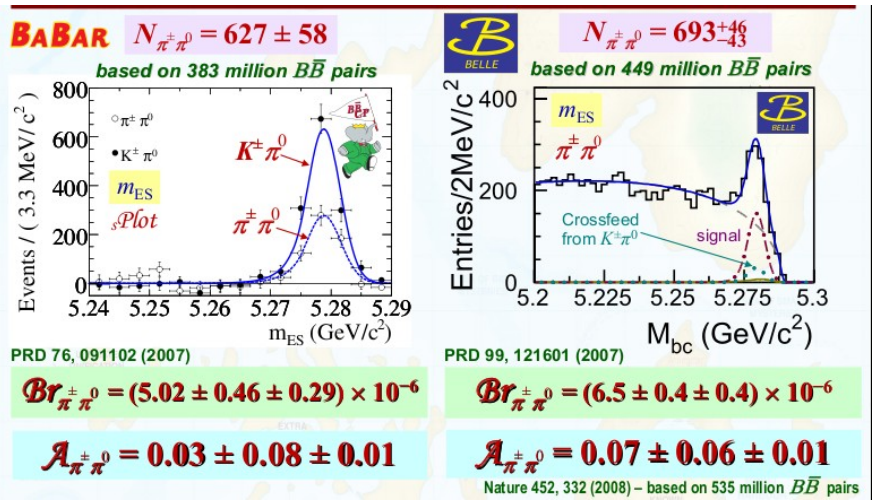
$$A^{+0} = \frac{1}{\sqrt{2}}A^{+-} + A^{00}$$
$$\overline{A}^{-0} = \frac{1}{\sqrt{2}}\overline{A}^{+-} + \overline{A}^{00}$$

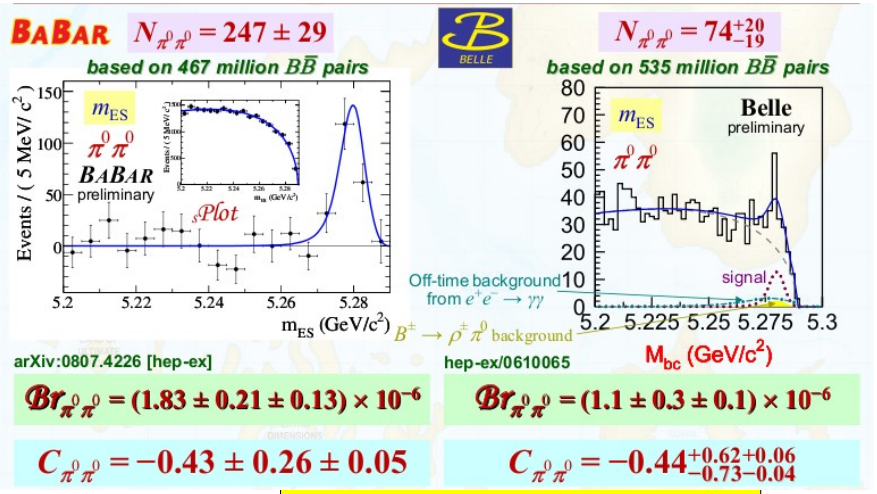
Other (small) issues: $\Delta I = 5/2$ and $\pi^0/\eta/\eta'$ mixing corrections

Measurements in the ππ System

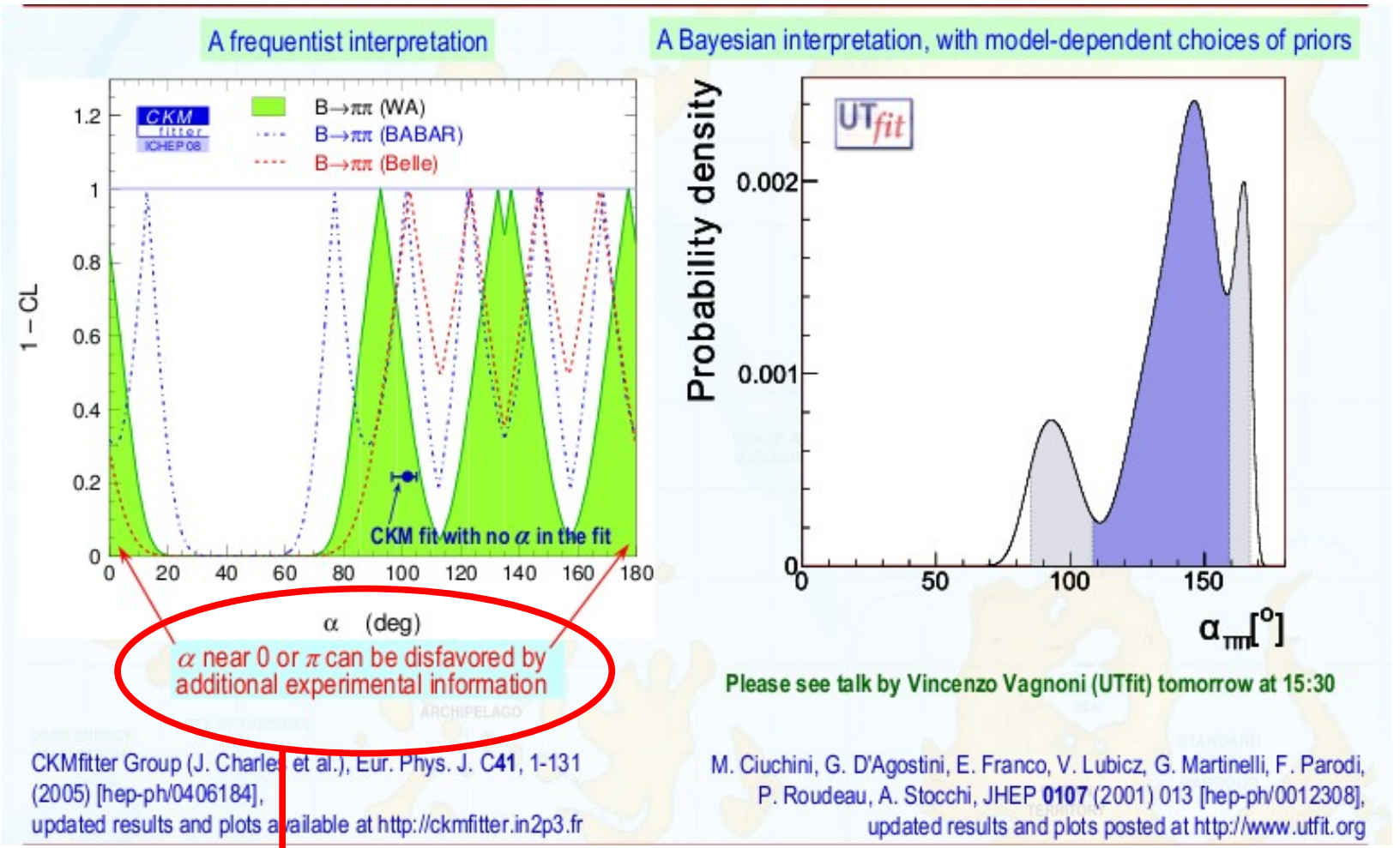








Putting it Together



Very important disclaimer! … Why?

TELNOV

The Zero Solution

- GL method does not use any knowledge about penguin contribution (except isospin)
  - neither magnitude nor phase
  - insensitive to isospin conserving new physics
- But, we do know

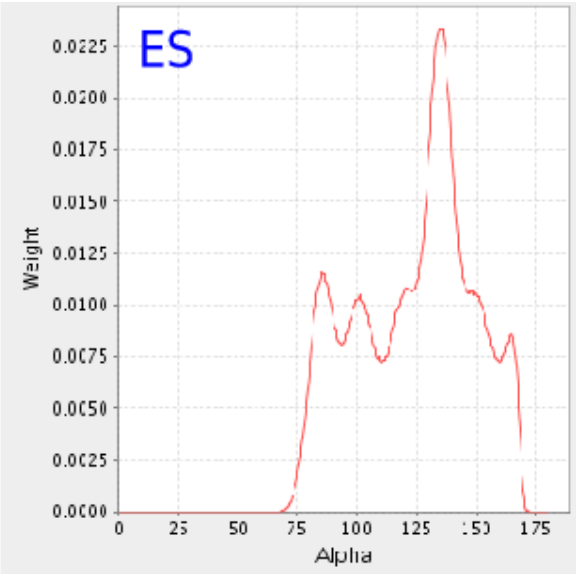
$$A_{\pi\pi} = \frac{2|P||T|\sin(\delta)\sin(\alpha)}{|P|^2+|T|^2+2|P||T|\cos(\delta)\cos(\alpha)}$$

(using unitarity)

- Non-zero direct CP violation in $B\to\pi\pi \Rightarrow \alpha \neq 0$
  - (or hadronic parameters → infinity)

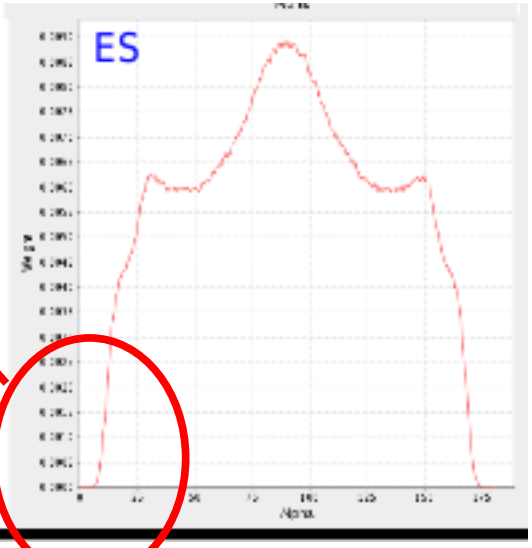
Bayesian Implementation

- Use priors that enforce limitations on the magnitude of |P|/|T|
- Even without using $S_{\pi\pi}$ in the fit, still exclude $\alpha = 0$



Try removing experimental information on S^{+-} :

The Result change completely, the cut on the hadronic parameter is less effective.



FRANCO

The ρρ System

- **If $m_{\rho 1} \neq m_{\rho 2}$ wave function can be antisymmetric** Falk et al., PRD 69, 011502 (2004)

  ⇒ **l=1 allowed, isospin relations do not hold**

  But measurements are stable when decreasing allowed Δm region

- **electroweak penguin can have I=2**

  ⇒ **isospin relations do not hold**

  But no sign of direct CP asymmetry in $B^+ \to \rho^+\rho^0$ decays

- **final state is VV, L=1 possible and has opposite CP (-1)**

  ⇒ **uncertainty in measuring S, must also measure polarization**

  (⇒ **isospin relations hold separately for long., trans. perp., trans. par. states)**

  Polarization has been measured: $f_L \approx 1$
  (consistent with factorization)
  Kagan, PLB 601, 151 (2004)

Measurements in the ρρ System

349 fb^{-1}

unbinned extended ML fit to M_{bc}, ΔE, $m_{\pi\pi^+}$, $\cos\theta_+$, $m_{\pi\pi^-}$, $\cos\theta_0$, x_{NN}, Δt :

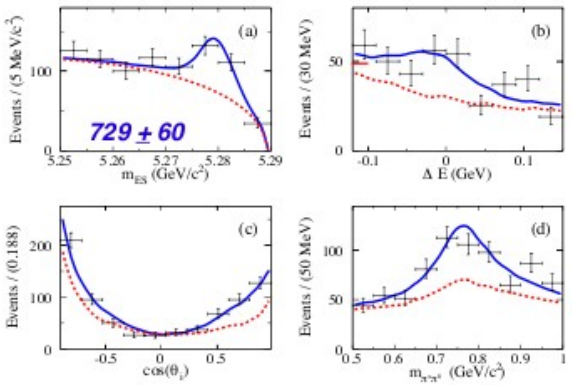
$B_{\rho^+\rho^0} = (25.5 \pm 2.1\ ^{+3.6}_{-3.9}) \times 10^{-6}$

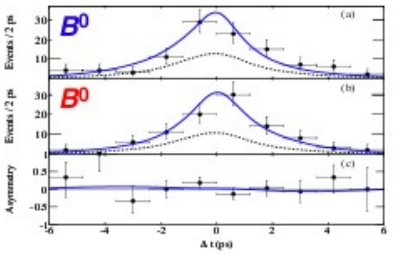
no PDF for non-resonant $B \to \rho\pi\pi$

$f_L = 0.992 \pm 0.024\ ^{+0.026}_{-0.013}$

$A_{\rho\rho} = -0.01 \pm 0.15 \pm 0.06$

$S_{\rho\rho} = -0.17 \pm 0.20\ ^{+0.05}_{-0.06}$



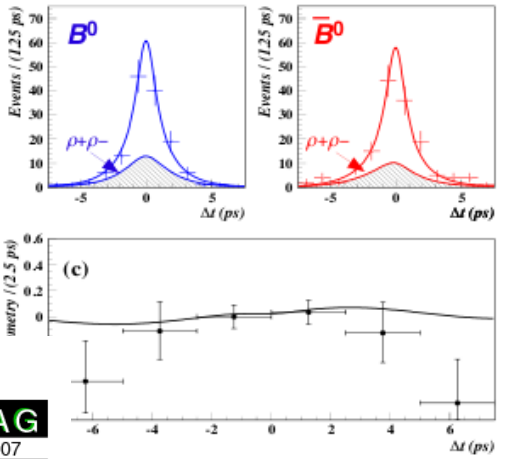


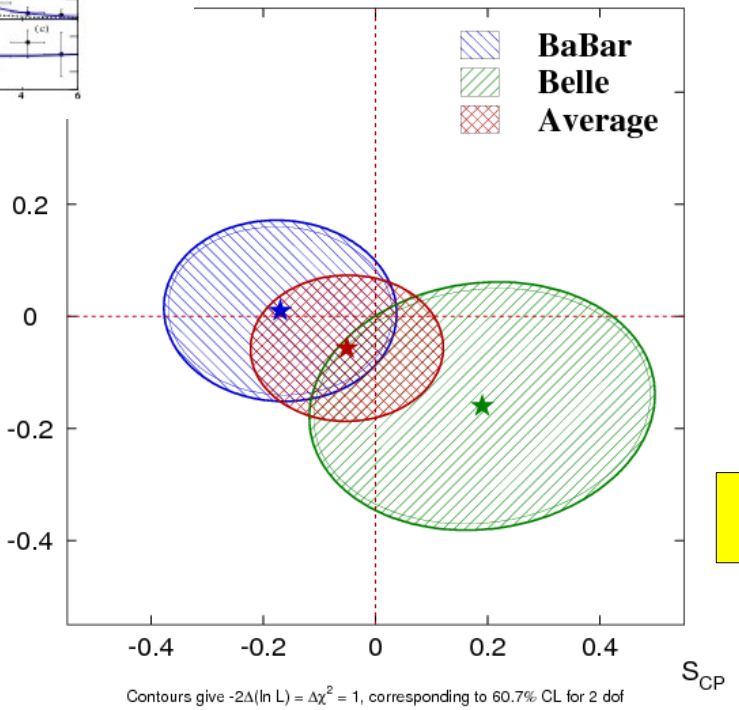
492 fb^{-1}

Also: reduce qq suppression cut, include qq PDF into ML fit (70% increase in ε, 12% decrease in errors)

$A_{\rho\rho} = 0.16 \pm 0.21 \pm 0.08$

$S_{\rho\rho} = 0.19 \pm 0.30 \pm 0.08$





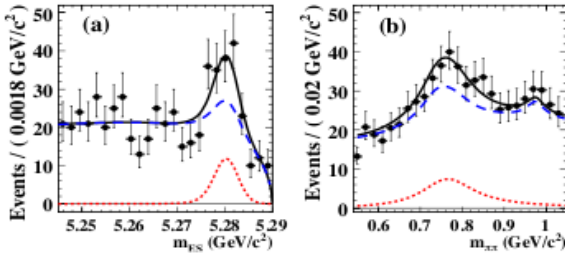
SCHWARTZ

Measurements in the ρρ System

423 fb^{-1}

$(0.55< m_{\pi\pi-1}< 1.05)$ x $(0.55 < m_{\pi\pi-2}< 1.05)$

unbinned extended ML fit to M_{bc}, ΔE, $m_{\pi\pi}$, $\cos\theta_1$, $m_{\pi\pi}$, $\cos\theta_2$, x_{NN}, Δt, $\sigma_{\Delta t}$:



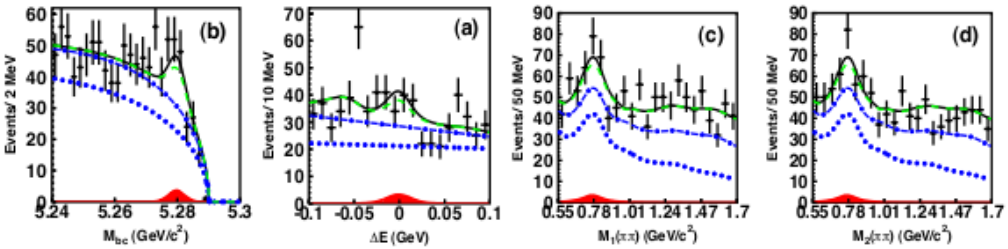
Mode	yield	significance (σ)	branching fraction (10^{-6})
$\rho^0\rho^0$	99^{+35}_{-34}	3.1	$0.92 \pm 0.32 \pm 0.14$
$\rho^0\pi^+\pi^-$	-12^{+39}_{-35}	-	< 8.7
$\pi^+\pi^-\pi^+\pi^-$	8^{+30}_{-25}	-	< 21.1

$F_L = 0.75^{+0.11}_{-0.14} \pm 0.04$

$A_{\rho\rho} = -0.2 \pm 0.8 \pm 0.3$

$S_{\rho\rho} = 0.3 \pm 0.7 \pm 0.2$

605 fb^{-1}



Mode	yield	significance (σ)	branching fraction (10^{-6})
$\rho^0\rho^0$	24.5^{+24}_{-22}	1.0	$0.4 \pm 0.4^{+0.2}_{-0.3}$
$\rho^0\pi^+\pi^-$	112.5^{+67}_{-66}	1.3	$5.9^{+3.5}_{-3.4} \pm 2.7$
$\pi^+\pi^-\pi^+\pi^-$	161.2^{+61}_{-59}	2.5	$12.4^{+4.7}_{-4.6}{}^{+2.1}_{-1.9}$

- BaBar – evidence for $B^0 \rightarrow \rho^0\rho^0$
- Belle – consistent with zero
- Differences in analysis (ππ mass window)
  - To be resolved in future updates

Measurements in the ρπ System

Three-body differential decay rate:

$$d\Gamma[B^0(\overline{B}^0) \to \pi^+\pi^-\pi^0] = \frac{1}{(2\pi)^3}\frac{|A_{3\pi}|^2}{32m^3_{B^0}}dm^2_+ dm^2_-$$

Decay amplitude

DP variables

For a decay tagged as $B^0(+)$ or $\overline{B}^0(-)$:

$$\left|A^{\pm}_{3\pi}\right|^2 \propto \left[1 \mp \frac{|A_{3\pi}|^2-|\overline{A}_{3\pi}|^2}{|A_{3\pi}|^2+|\overline{A}_{3\pi}|^2}\cos(\Delta m_d \Delta t) \pm \frac{2\,\mathrm{Im}(\frac{q}{p}A^*_{3\pi}\overline{A}_{3\pi})}{|A_{3\pi}|^2+|\overline{A}_{3\pi}|^2}\sin(\Delta m_d \Delta t)\right]$$

$A_{3\pi}(m^2_+, m^2_-) = \sum_\kappa f_\kappa(m^2_+, m^2_-)\, A_\kappa$

27 Bilinear coefficients (U, I) – determine from the data fit:

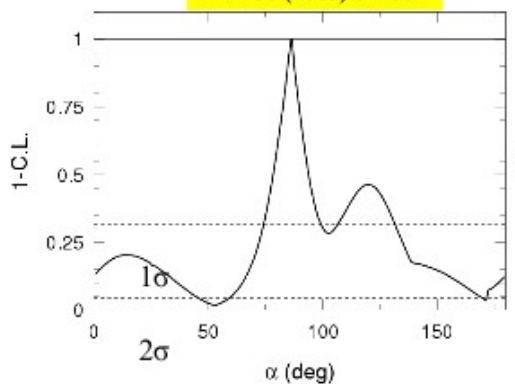
$$|A_{3\pi}|^2 \pm |\overline{A}_{3\pi}|^2 = \sum_{\kappa\in\{+,-,0\}} |f_\kappa|^2 U^{\pm}_\kappa + 2\sum_{\kappa<\sigma\in\{+,-,0\}} (\mathrm{Re}[f_\kappa f^*_\sigma]U^{\pm,\mathrm{Re}}_{\kappa\sigma} - \mathrm{Im}[f_\kappa f^*_\sigma]U^{\pm,\mathrm{Im}}_{\kappa\sigma})$$

PRD 62 (2000) 054002

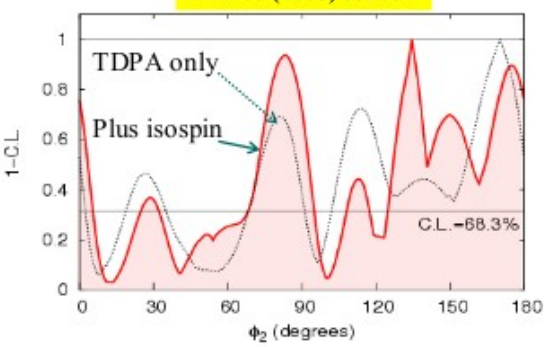
$$\mathrm{Im}\left(\frac{q}{p}A^*_{3\pi}\overline{A}_{3\pi}\right) = \sum_{\kappa\in\{+,-,0\}} |f_\kappa|^2 I_\kappa + \sum_{\kappa<\sigma\in\{+,-,0\}} (\mathrm{Re}[f_\kappa f^*_\sigma]I^{\mathrm{Im}}_{\kappa\sigma} + \mathrm{Im}[f_\kappa f^*_\sigma]I^{\mathrm{Re}}_{\kappa\sigma})$$

4

PRD 76 (2007) 012004



PRD 77 (2008) 072001



BABAR measures:

- $\alpha = \left(87\ ^{+45}_{-13}\right)^\circ$
- $\delta = (37 \pm 37)^\circ$

$\delta = \arg\left(A^{-*}A^{+}\right)$

For Belle:

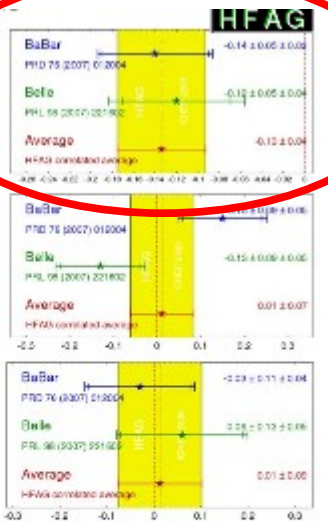
- $68^\circ < \varphi_2 < 95^\circ$ at 68.3% C.L.
- Using BF and A_{CP} values of $B^+ \to \rho^0\pi^+$ and $\rho^+\pi^0$

13

Direct CP violation @ 3σ

ed

$$A^{CP}_{\rho\pi} = \frac{U^+_+ - U^+_-}{U^+_+ + U^+_-}$$



$$C = \frac{1}{2}\left(\frac{U^-_+}{U^+_+} + \frac{U^-_-}{U^+_-}\right)$$

$$S = \left(\frac{I_+}{U^+_+} + \frac{I_-}{U^+_-}\right)$$

$$\Delta C = \frac{1}{2}\left(\frac{U^-_+}{U^+_+} - \frac{U^-_-}{U^+_-}\right)$$

$$\Delta S = \left(\frac{I_+}{U^+_+} - \frac{I_-}{U^+_-}\right)$$

BABAR: $+0.39 \pm 0.09 \pm 0.09$

Belle: $+0.36 \pm 0.10 \pm 0.05$

BABAR: $-0.01 \pm 0.14 \pm 0.06$

Belle: $-0.08 \pm 0.13 \pm 0.05$

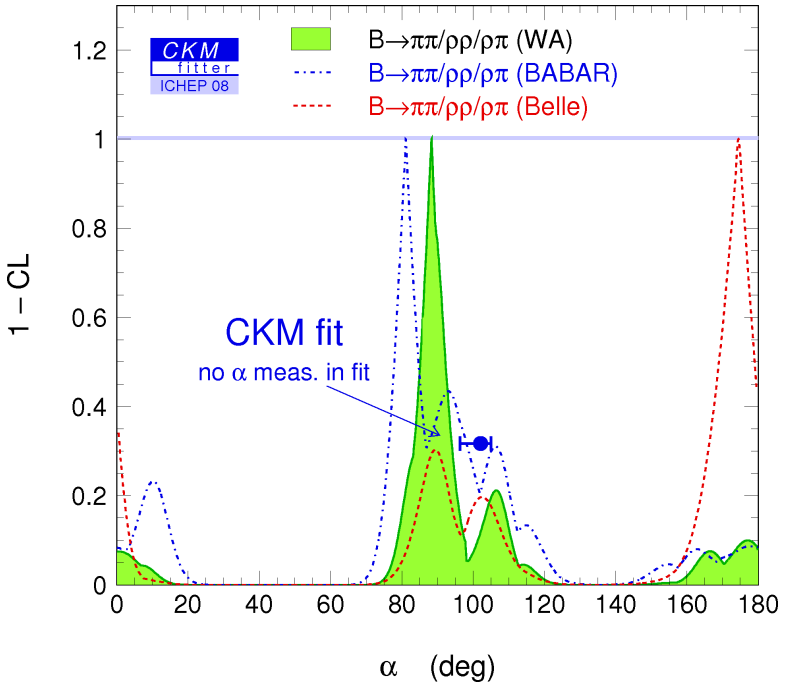
$\rho^0\pi^0$ mode also obtained

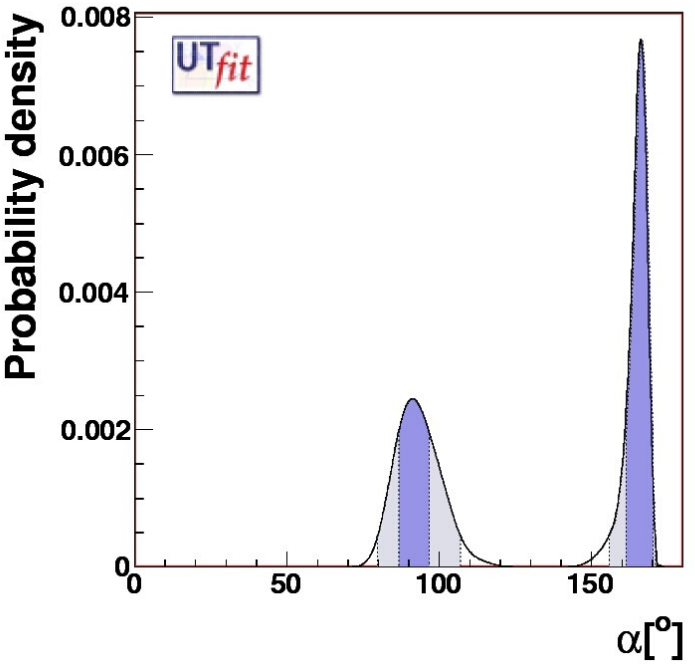
12

ary

MOHANTY

α Summary



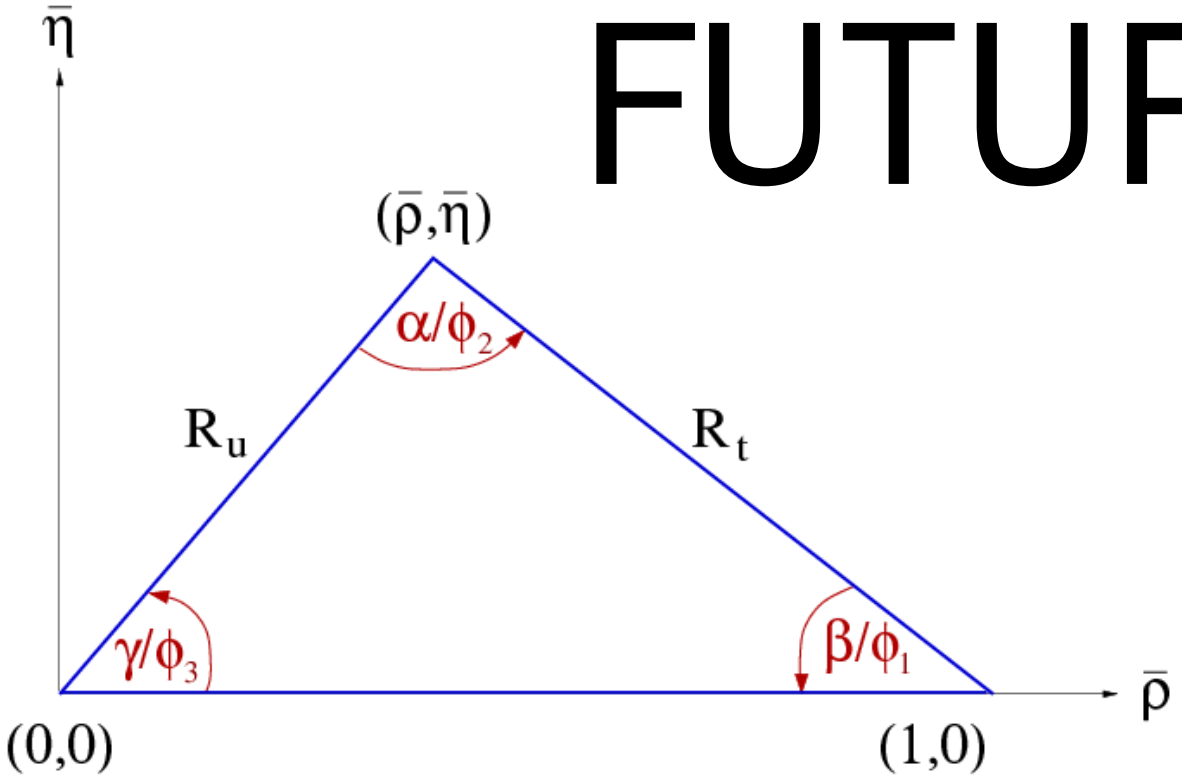


- SM solution (near 90˚) allowed, uncertainty ~ 8˚
- LHCb can contribute for ρπ, $\rho^0\rho^0$
- Focus on theoretically clean methods, but can reduce uncertainty with additional assumptions (eg. SU(3))
- |P|/|T| is crucial parameter

Wednesday, 10 September 2008

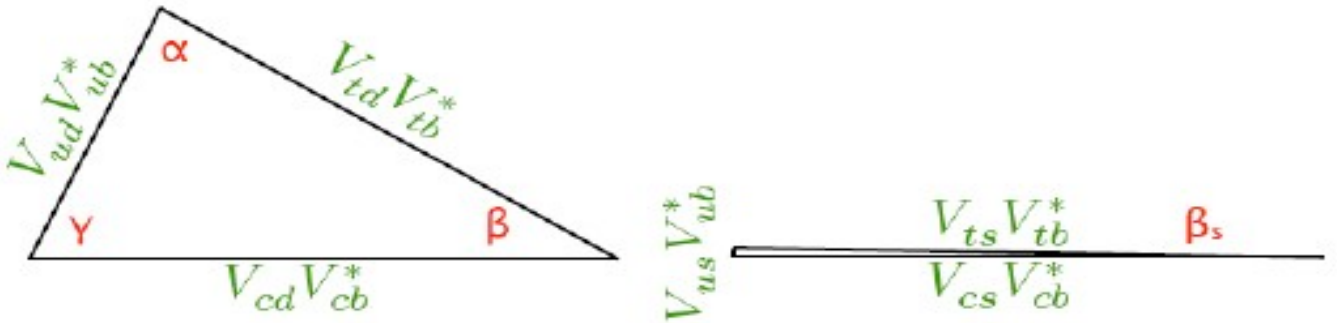
14:00	[53] **Golden channels** slides by Javier VIRTO (Aula Amaldi: 14:30 - 14:50)
15:00	[54] **New physics in b->s transitions** slides by Antonio MASIERO (Aula Amaldi: 15:00 - 15:20)
	[56] **Bs -> phi phi & Bs -> K*0 K*0-bar** slides by Yuehong XIE (Aula Amaldi: 15:30 - 15:50)
16:00	[84] **Prospects for B->hh at LHCb** slides by Eduardo RODRIGUES (Aula Amaldi: 16:00 - 16:20)
	[143] **Discussion on prospects at future facilities** (Aula Amaldi: 16:30 - 16:50)

FUTURE



b → s: why new physics there?

- **b → d much constrained (see UT determination)**



- **b → s still allows for a non-negligible amount of new physics (at least at the 15 -20% level), in particular in CP violating phenomena**

- **Large 2 – 3 mixing in the neutrino sector ;**
  - **correspondence to b_R → s_R in the 5-plet of SU(5)**

- **Hints for new physics in b → s transition (SUSY, 4th generation, warped extra-dimensions, new Z', etc.)**

MASIERO + NP breakout session

Hadronic b→s penguins Golden or Not Golden?

- $B_d \to \phi K_S$ (Theory)

- SU(3): [Grossman,Isidori,Worah'98 , Grossman,Ligeti,Nir,Quinn'03, ..]

$$|\Delta S_{\phi K_S}| < \sqrt{2}\,\lambda\left(\sqrt{\frac{BR(B^+ \to \phi\pi^+)}{BR(B_d \to \phi K_S)}} + \sqrt{\frac{BR(B^+ \to K^{*}K^+)}{BR(B_d \to \phi K_S)}}\right) + \mathcal{O}(\lambda^2) \lesssim 0.3$$

- QCDF: $0.01 < \Delta S_{\phi K_S} < 0.05$ [Beneke'05]

(safe minimal QCDF input + BR : $0.03 < \Delta S_{\phi K_S} < 0.06$ [Virto'07])

QCDF + FSI : $\Delta S_{\phi K_S} = 0.03^{+0.01}_{-0.04}$ [Cheng,Chua,Soni'05]

- GP: $\Delta S_{\phi K_S} = 0 \pm 0.09$ [Silvestrini'07]

- $B_d \to \phi K_S$ (Experiment)

- Current (*) : $\Delta S^{c\bar{c}s}_{\phi K_S} = -0.29 \pm 0.18$ [HFAG,BaBar,Belle'07]

- LHC: $2fb^{-1} : N \sim 920,\ 0.3 < B/S < 1.1,\ \sigma_S \sim 0.23$

$10fb^{-1} : \sigma_S \sim 0.10$ [Xie, LHCb-2007-130]

- SuperB: $75ab^{-1} : \sigma_S \sim 0.02$!! [SuperB CDR '07]

GOLDEN

- $B_d \to \eta' K_S,\ \pi^0 K_S$ (Theory)

	QCDF	SCET	GP
$\Delta S_{\eta' K_s}$	[0.00-0.03]	-0.019±0.008 -0.010±0.010	-0.007±0.054
$\Delta S_{\pi^0 K_s}$	[0.02-0.015]	0.077±0.030	0.024±0.059

[Beneke'05 , Williamson,Zupan'06 , Silvestrini'07]

- SU(2) --> $\Delta S_{\pi^0 K_S} = 0.31^{+0.03}_{-0.18}$ [Fleischer,Jäger,Pirjol,Zupan '08]

- $B_d \to \eta' K_S,\ \pi^0 K_S$ (Experiment)

	Current	LHC	SuperB ($75ab^{-1}$)
$\Delta S_{\eta' K_s}$	-0.11±0.08	?	$\sigma_S \sim 0.01$
$\Delta S_{\pi^0 K_s}$	-0.13±0.21	?	$\sigma_S \sim 0.02$

[BaBar'08 , SuperB CDR'07]

GOLDEN

$B_s \to VV$

- $B_s \to K^{0*}\bar{K}^{0*}$ (Theory)

- QCDF: [Beneke, Rohrer, Yang '06]

BR (10^{-6})	A_{CP} (%)	$\phi_{\parallel}$ (deg)	f_L	A^0_{CP} (%)
$9.1^{+0.5\ +11.3}_{-0.4\ -6.8}$	1^{+2}_{-1}	-34^{+110}_{-62}	63^{+42}_{-29}	$11^{+3\ +7}_{-3\ -17}$

- Similar results from pQCD [Ali et al.'07]

- From $BR(B_s \to K^{0*}\bar{K}^{0*})$ and QCDF input:

$$BR^L_s \gtrsim 3 \cdot 10^{-5} \quad \Rightarrow \quad (S^L_{K^*K^*} - 0.051) < \sin 2\beta_s < (S^L_{K^*K^*} - 0.037)$$

also in SM: $C^L_{K^*K^*} = 0.000 \pm 0.014\ , \quad S^L_{K^*K^*} = 0.004 \pm 0.018$

[Descotes-Genon, Matias, Virto '07]

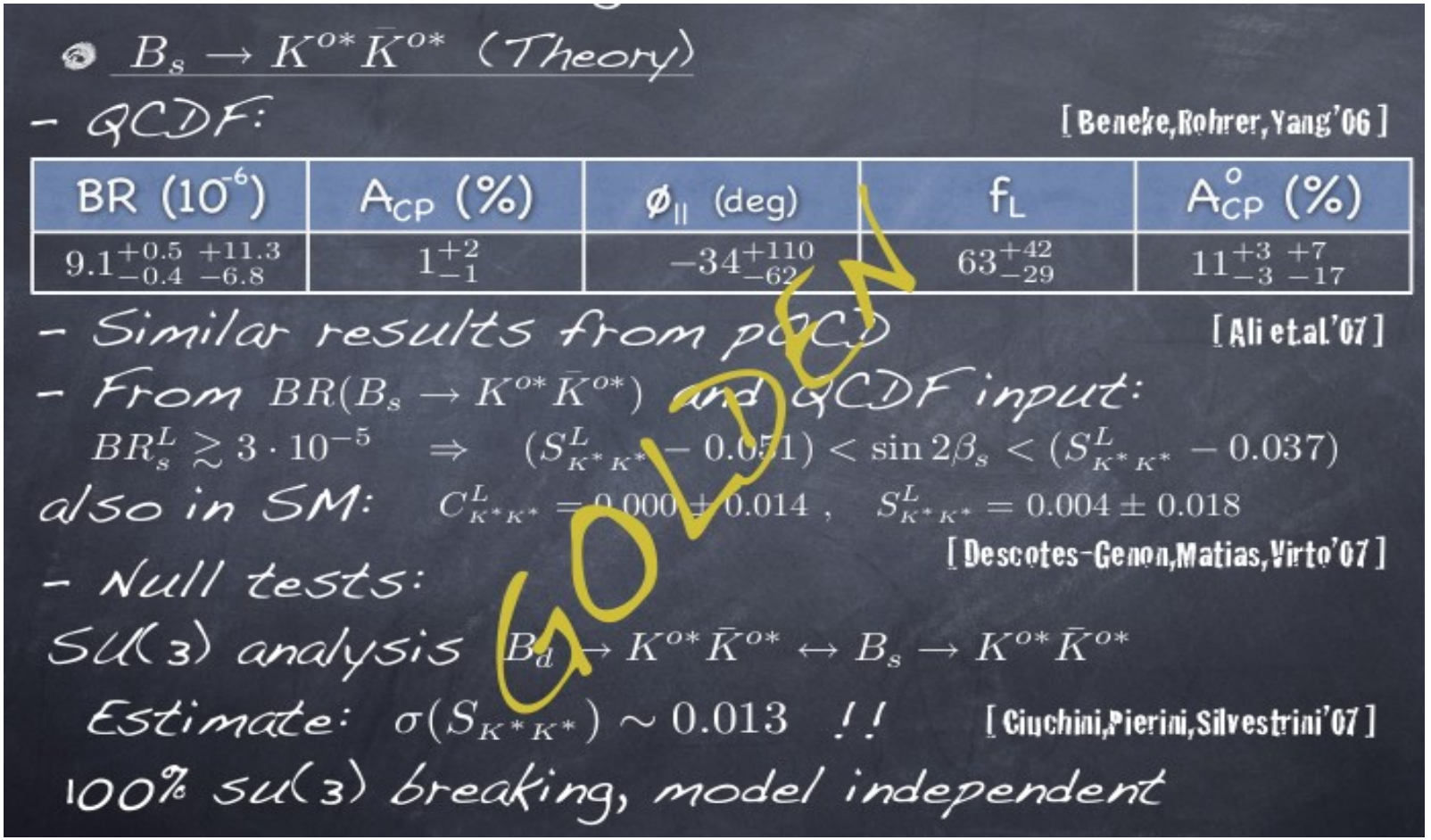
- Null tests:

writing $A(B_s -> f) = V_{tb}V_{ts}P_t + V_{ub}V_{us}P_u$

we have: $S_f = \sin(2\beta_s - 2\beta_s) + \mathcal{O}(\lambda^2) = 0 + \mathcal{O}(\lambda^2)$

Also $B_s \to \varphi\varphi$

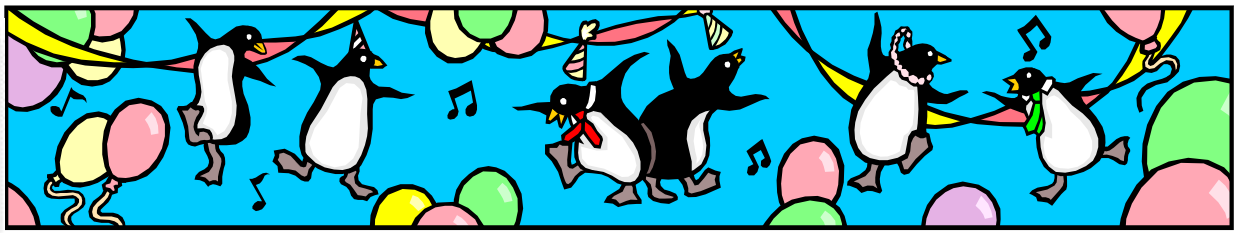
$B_s \to VV$



Also $B_s \to \varphi\varphi$

Prospects for LHCb

- $B_s \to \phi\phi$ and $B_s \to K^{*0}\overline{K}^{*0}$ provide a new window into CP violation in hadronic b → s penguins
- Updated study shows LHCb can achieve a resolution of $\Delta(\text{“}\phi_s\text{”}) \approx 0.125$ in $B_s \to \phi\phi$ with 2 fb^{-1} (1 nominal year), making it an ideal place to search for the anticipated unexpected physics
- Study of $B_s \to K^{*0}\overline{K}^{*0}$ is progressing well in LHCb
- LHCb is about to take over the penguin world!



LHCb = penguin party?

Need to study effects of contributions from nonresonant or other decays

XIE

Exciting times to be alive

THE Sun

Thursday, September 11, 2008

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Success! The world hasn't ended

By STAFF REPORTER

Published: 10 Sep 2008

ADD YOUR COMMENTS

WE are all still here!

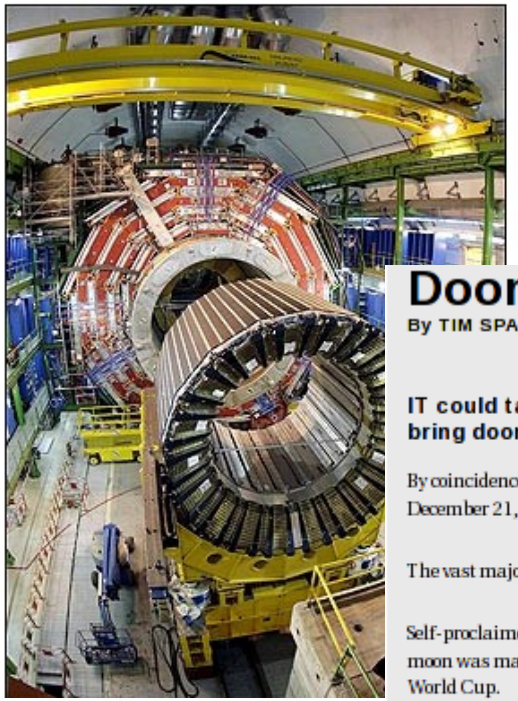
The world's most powerful physics experiment is well and truly under way.

Scientists cheered as a beam of proton particles completed their first circuit of the 27km long Large Hadron Collider (LHC).

At 8.30am today, the machine which some fear could create a giant black hole capable of swallowing the planet was switched on.

Dr Lyndon Evans, known as Lyn, is leader of the Large Hadron Collider project at the Geneva-based European Organisation for Nuclear Research (CERN).

The white-haired Welshman showed few signs of stress, however, even finding time for a small joke when the machine took a second



Remarkable new physics prediction!

Doom in 4 years

By TIM SPANTON

IT could take four years for the experiment to bring doomsday, say some scientists.

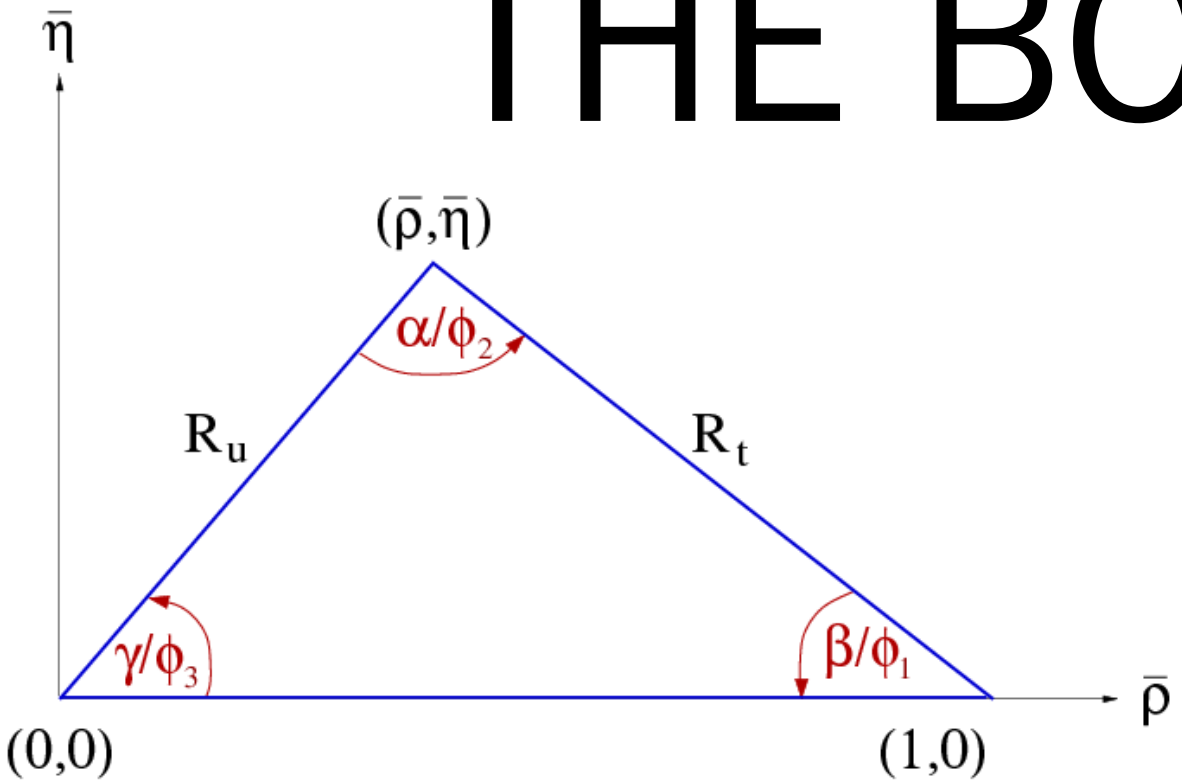
By coincidence the ancient Mayan calendar finishes then — on December 21, 2012.

The vast majority of experts say it won't happen.

Self-proclaimed experts used to believe the world was flat, the moon was made of cheese and England would win the 2006 World Cup.

Scientist Otto Rossler tried to get the European Court to ban the tests. He warns: "Nothing will happen for at least four years. Then the weather will change completely, wiping out life. There will be a Biblical Armageddon."

THE BOOK


$\bar{\eta}$
$(\bar{\rho},\bar{\eta})$
α/ϕ_2
R_u
R_t
γ/ϕ_3
β/ϕ_1
$\bar{\rho}$
(0,0)
(1,0)

The Book

- All contributors to the WG welcome to contribute
  - Including some who could not be in Rome
- We have identified individuals to make the first drafts of sections (5 pages per section)
  - Theory primers — Bauer, Jäger
  - α — Telnov, Schwartz
  - β — Soni, (Dalseno)
  - γ — Zupan, Latham
- Other WG members will serve as reviewers
- First drafts by mid-October please!

Congratulations to the organizers (especially Riccardo) for a fantastic workshop … and more!