α at the *B* Factories

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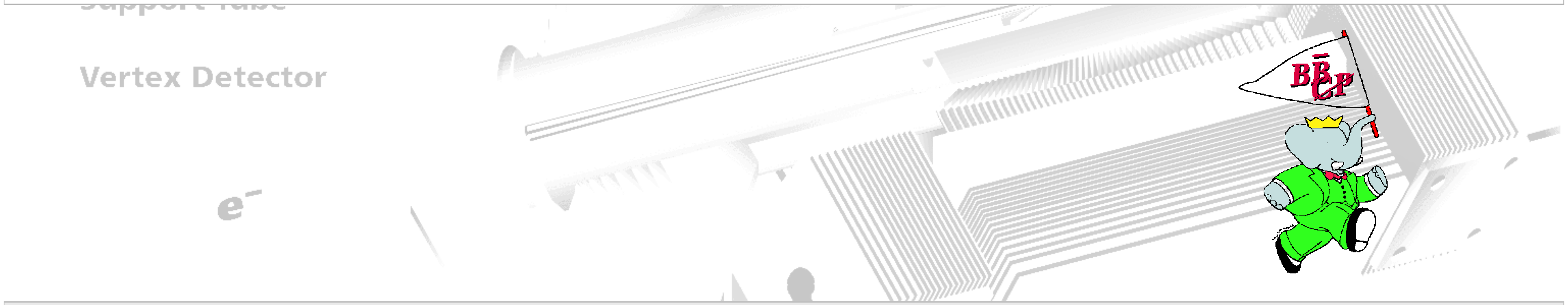

Joint meeting LHCb/theory

CERN – March 11, 2005

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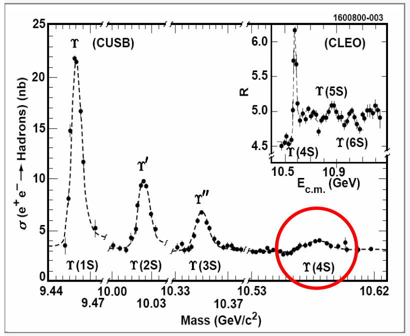
The B_d System $(e^+e^- \to \Upsilon(4S)$ factories)



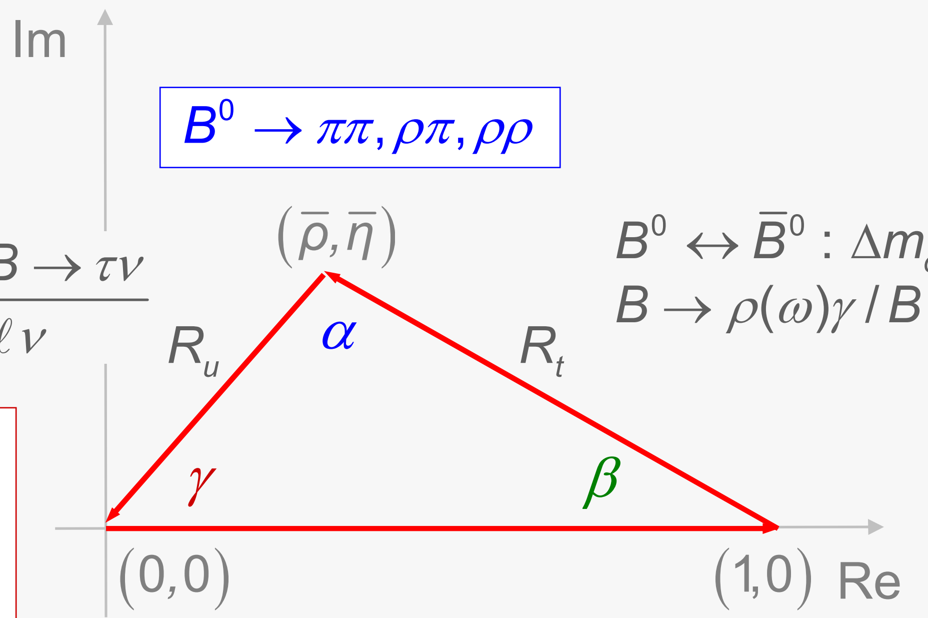
coherent production of $B_d\bar{B}_d$

$B^0 \to \pi\pi, \rho\pi, \rho\rho$

$$\frac{b \to u\ell\nu,\ B \to \tau\nu}{b \to c\ell\nu}$$

$B^0 \leftrightarrow \bar{B}^0 : \Delta m_d$

$B \to \rho(\omega)\gamma \,/\, B \to K^{(*)}\gamma$



$B \to D^{(*)}K^{(*)}$

$B \to D_{K_S^0\pi^+\pi^-}K^{(*)}$

$B^0 \to DK_S^0$, ...

$B^0 \to D^*\pi(\rho)$

$b \to c\bar{c}s$

$B^0 \to J/\psi K_S^0$, ...

$\left(\begin{array}{l} B^0 \to J/\psi \pi^0 \\ B^0 \to D_{(s)}^{(*)+}D^{(*)-} \end{array} \right)$

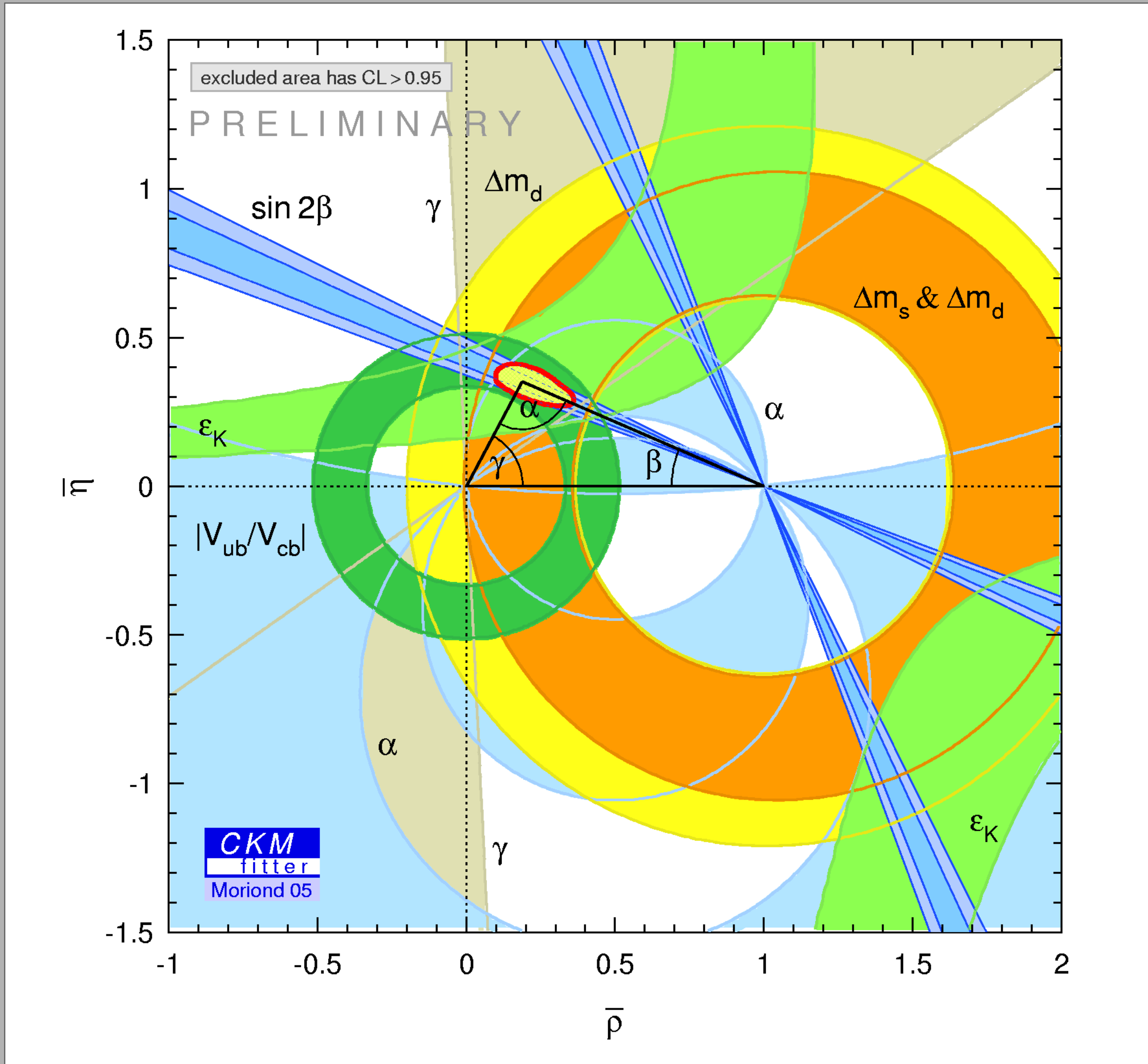
$b \to c\bar{c}d$

$B^0 \to \phi K_S^0$, ...

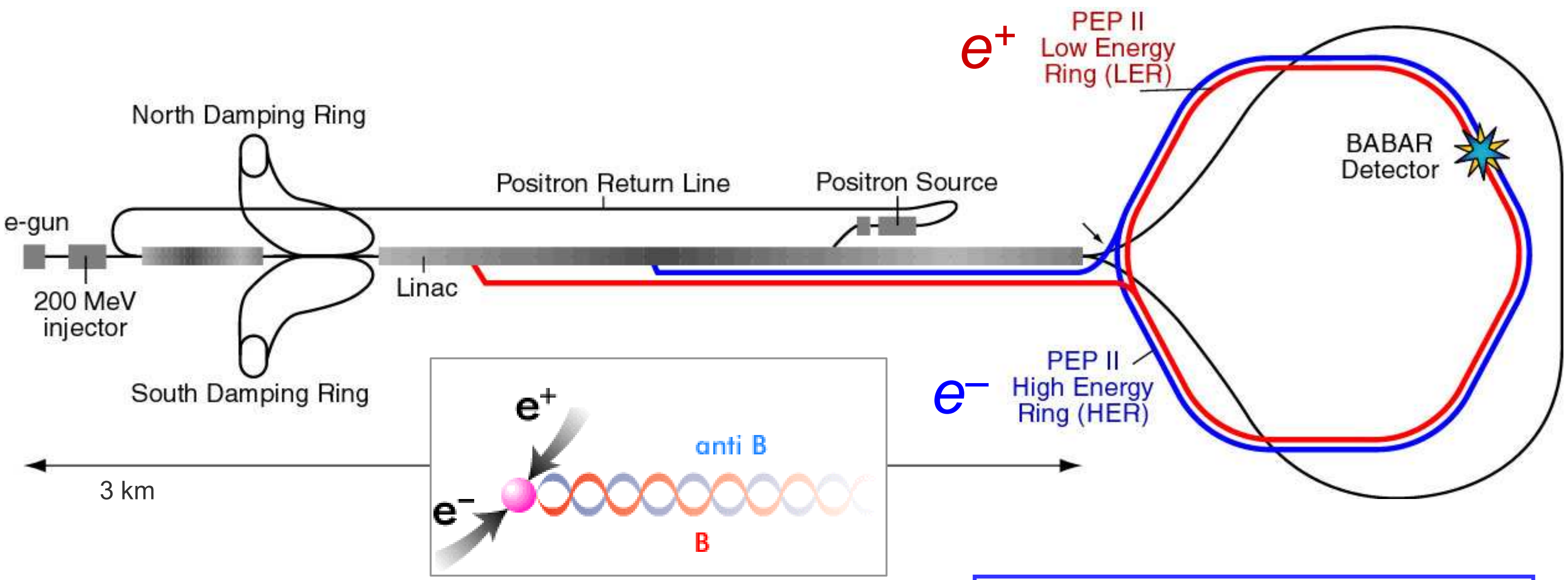
$b \to s\bar{s}s$

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

Today's Metrology



Asymmetric-Energy B Factories : PEP-II and KEKB



9 GeV e^- against 3.1 GeV e^+ :

$$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B}$$

- coherent production of neutral B pair
- boost of $\Upsilon(4S)$ in the laboratory : $\beta\gamma = 0.56$

Quantum coherence : at $\Delta t = 0$, the system is a superposition of :

one B^0 and **one** $\bar{B}^0$

one B_H and **one** B_L

one $B_{CP=+1}$ and **one** $B_{CP=-1}$

Einstein-Podolsky-Rosen phenomenon : measurement of flavor of one meson determines flavor of other meson at same proper time; this property is exploited for the "flavor tagging"

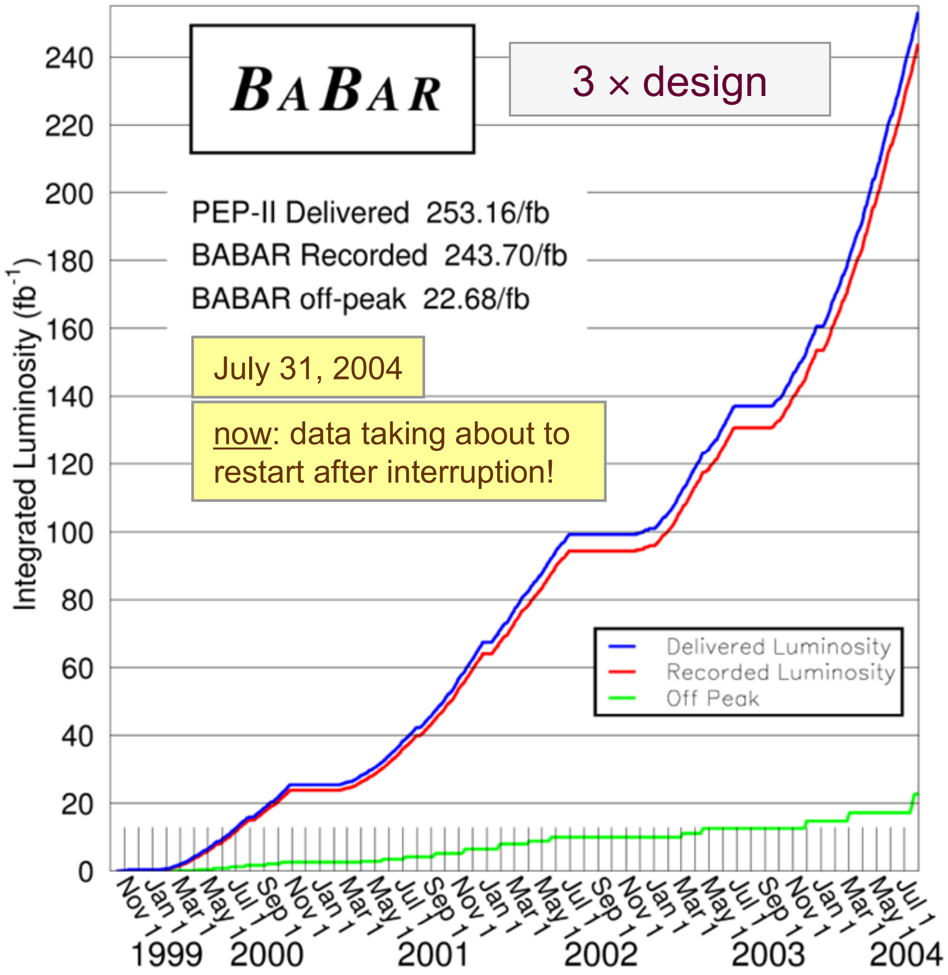
Luminosities

PEP-II records :

Peak luminosity	0.92×10^{34} cm^{-2}s^{-1}
Best shift	246.3 pb^{-1}
Best day	710.5 pb^{-1}
Best 7 days	4.5 fb^{-1}
Best month	16.7 fb^{-1}
Best 30 days	17.0 fb^{-1}
BABAR logged	264.4 fb^{-1}

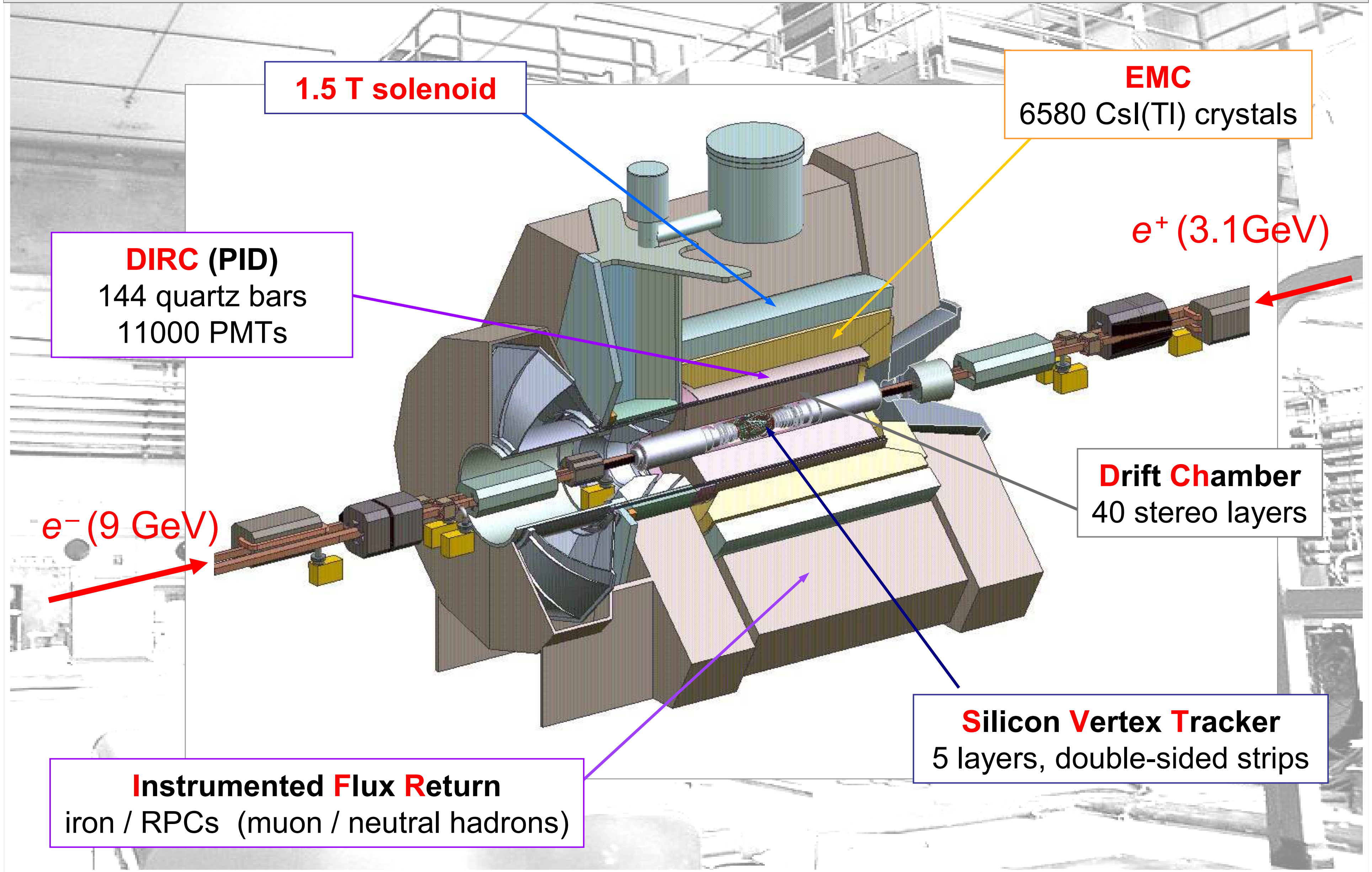
➡ ~261 million $B\bar{B}$ pairs recorded

Belle: ~ 400 million !!! Best peak luminosity at 1.52×10^{34} cm^{-2}s^{-1}



The BABAR Detector

BABAR, NIM A479, 1 (2002)



digression: The three *CP*-Violation phenomena

★ Condition for *CP* invariance : $\left|\langle f_{CP}|H|B^0(t)\rangle\right|^2 = \left|\langle f_{CP}|H|\bar{B}^0(t)\rangle\right|^2, \quad \forall t$

★ Definition of "*CP* parameter" :

$$\lambda_{f_{CP}} = \eta_{f_{CP}} \frac{q}{p} \cdot \frac{\bar{A}_{\bar{f}_{CP}}}{A_{f_{CP}}}$$

← decay amplitude ratio

CP eigenvalue

$\approx e^{-2i\beta}$

★ *CP* invariance requires :

- $|q/p| = 1$ — $\{|B_L\rangle, |B_H\rangle\} = \{|B_{CP=+1}\rangle, |B_{CP=-1}\rangle\}$
- $|\bar{A}_{f_{CP}} / A_{f_{CP}}| = 1$
- $\mathrm{Im}\,\lambda_{f_{CP}} = 0$

$\Rightarrow \lambda_{f_{CP}} = \pm 1$

★ Classification of *CP* violation :

CP-violation phenomena

- *CP* violation in mixing ("indirect") : $|q/p| \neq 1$
- *CP* violation in the decay ("direct") : $|\lambda_{f_{CP}}| \neq 1$
- *CP* violation in interference between mixing and decay : $\mathrm{Im}\,\lambda_{f_{CP}} \neq 0$

digression: Mixing-Induced *CP* Violation (3rd type)

- *CP* Violation due to the interference of decays with and without mixing

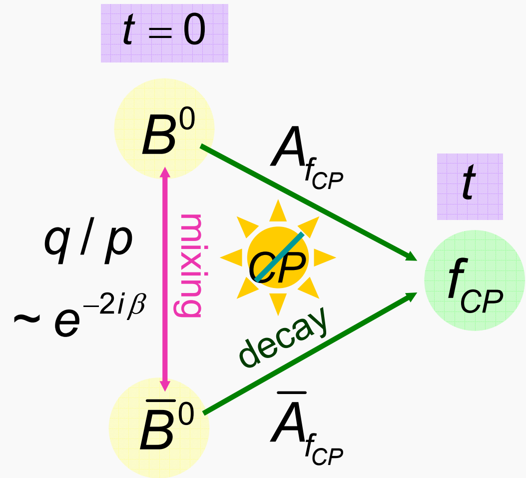
$$\lambda_{f_{CP}} \neq \pm 1 \;\Leftrightarrow\; \mathrm{Prob}(\bar{B}^0(t) \to f_{CP}) \neq \mathrm{Prob}(B^0(t) \to f_{CP})$$

- Time-dependent asymmetry observable

$$A_{f_{CP}}(t) = \frac{\Gamma(\bar{B}^0(t) \to f_{CP}) - \Gamma(B^0(t) \to f_{CP})}{\Gamma(\bar{B}^0(t) \to f_{CP}) + \Gamma(B^0(t) \to f_{CP})}$$

$$= S_{f_{CP}} \sin(\Delta m_d t) - C_{f_{CP}} \cos(\Delta m_d t)$$

with : $= \sin(2\beta)$ and $= 0$ for $b \to c\bar{c}s,\ s\bar{s}s$



avec:

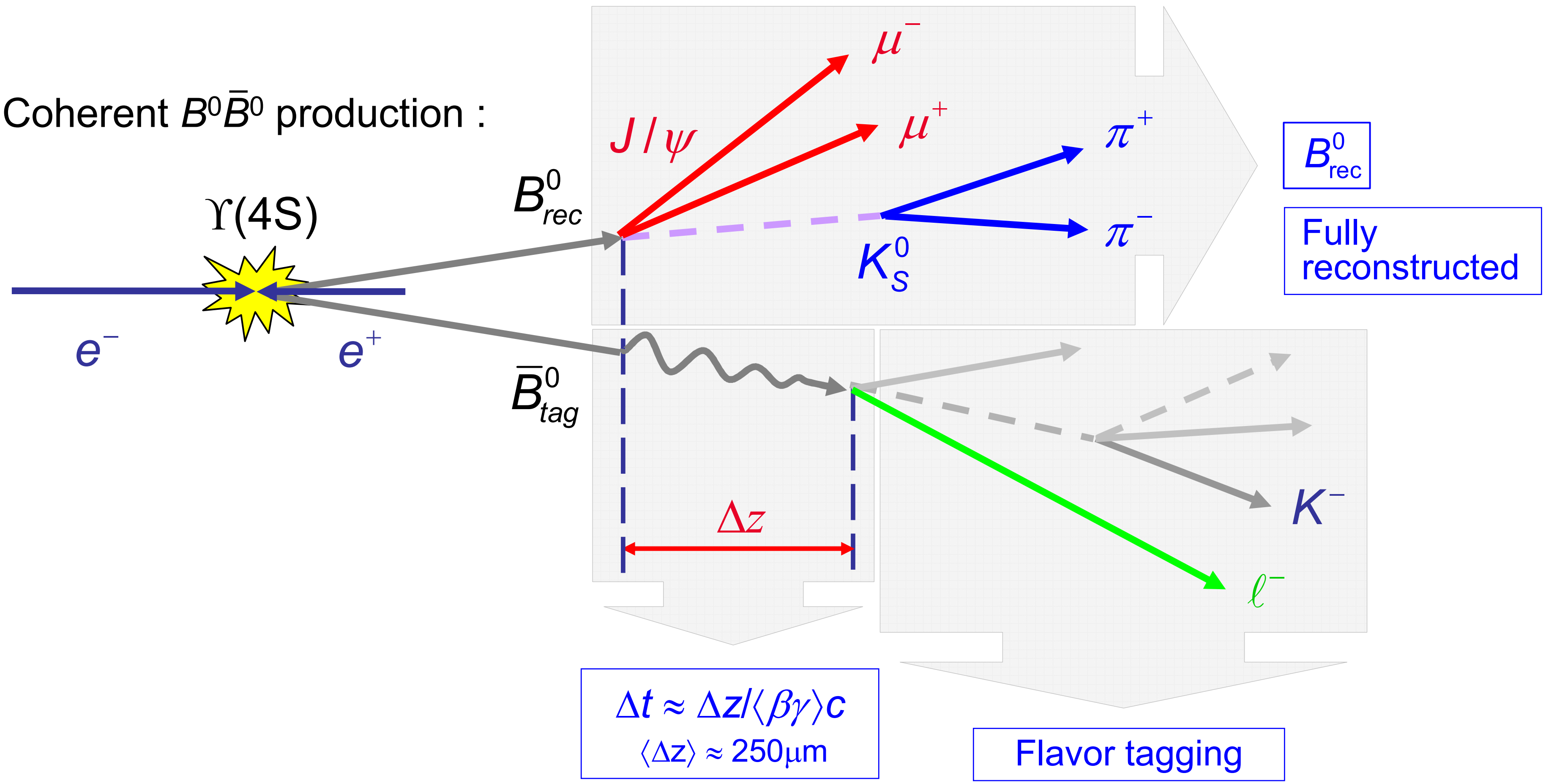
CP observables

$$C_f = \frac{1 - |\lambda_f|^2}{1 + |\lambda_f|^2}$$

$$S_f = \frac{2\,\mathrm{Im}[\lambda_f]}{1 + |\lambda_f|^2}$$

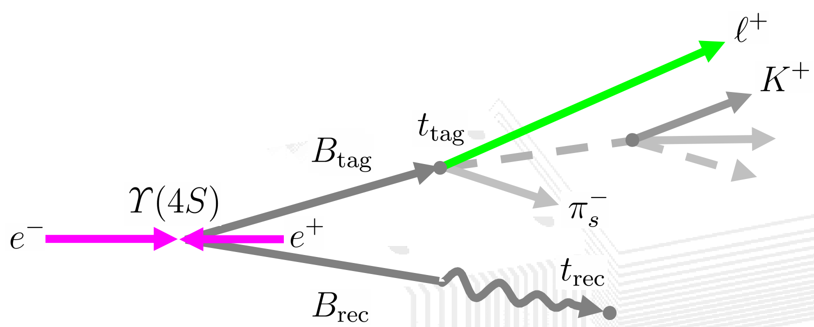
Experimental Technique

Coherent $B^0\bar{B}^0$ production :



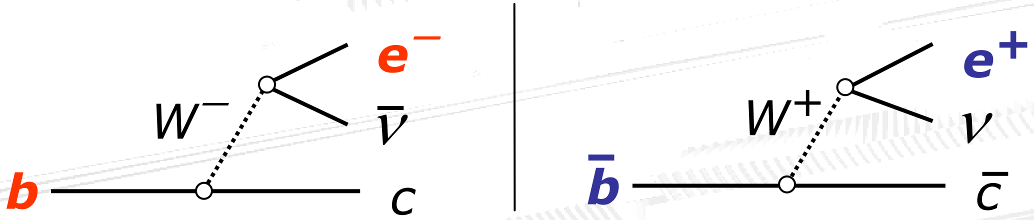
$B^0_{rec} = B^0_{flav}$ (flavor eigenstates)	➡	mixing, lifetime, ...
$B^0_{rec} = B^0_{CP}$ (*CP* eigenstates)	➡	*CP* analysis

digression: Flavor Tagging

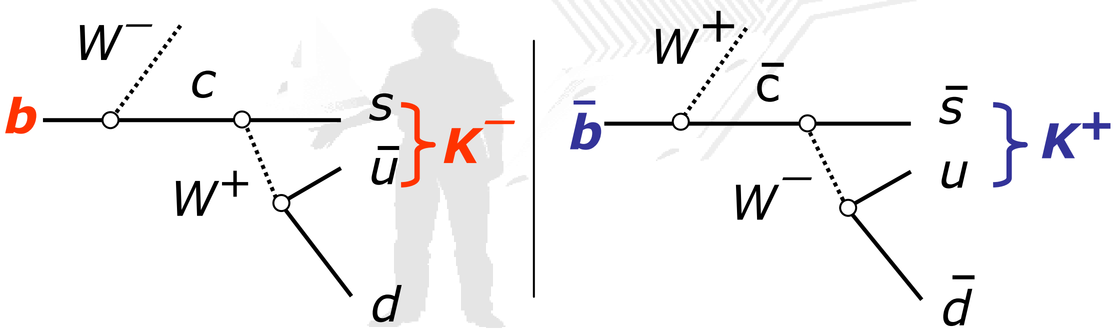


Determine flavor of $B_{\rm tag} \equiv \overline{B_{CP}(\Delta t{=}0)}$ from partial decay products

★ **Leptons :** Cleanest tag. Correct: > 95%



★ **Kaons :** Second best. Correct: 80 – 90%



Full tagging algorithm combines all in neural network

Four categories based on particle content and NN output.

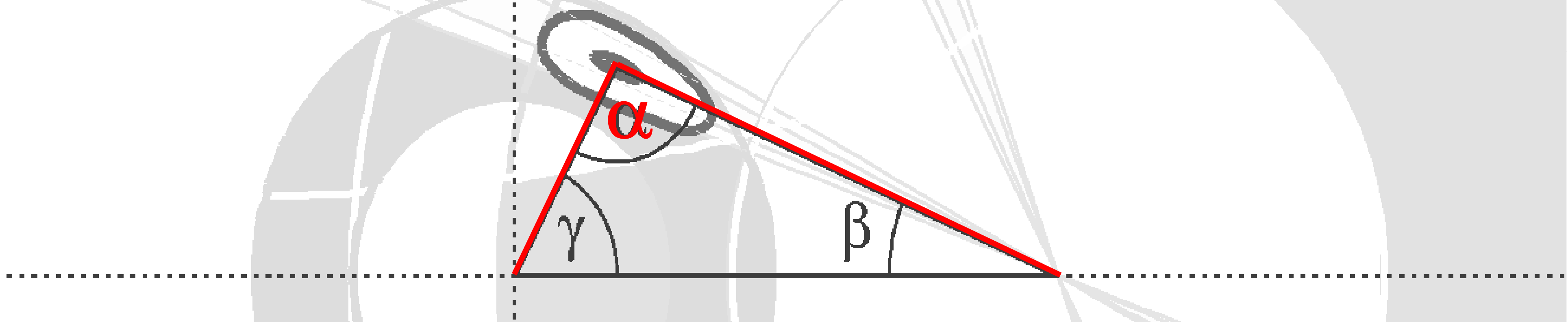
Tagging performance

efficiency *mistag rate*

$$\sum_i \varepsilon_i (1-2\omega_i)^2 = 30.5\%$$

Measurement of the angle α

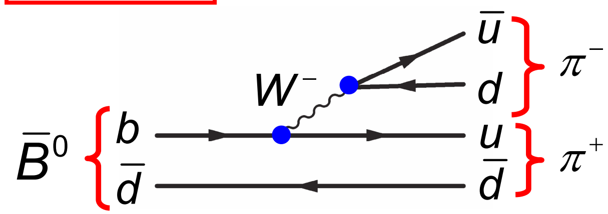
— using charmless *B* decays —



Interference of $b \to u$ decay amplitudes with $B^0\bar{B}^0$ mixing

"Charmless" $b \to u$ Decays

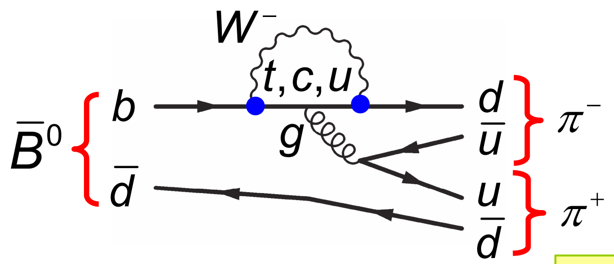
$b \to u\bar{u}d$



Tree : dominant

$\propto V_{ub}V_{ud}^*$

$\propto \lambda^3$



Penguin : competitive ?

$\propto V_{tb}V_{td}^*$

$\propto \lambda^3$

Principal modes :

$B^0 \to \pi^+\pi^-$

$B^0 \to \rho^\pm\pi^\mp$

$B^0 \to \rho^+\rho^-$

Not a *CP* eigenstate

★ If penguin is negligible

$\eta_{h^+h^-} = 1$ for $h = \pi$

$$\lambda_{h^+h^-} = \eta_{h^+h^-} \left(\frac{q}{p}\right)_B \cdot \left(\frac{V_{ub}V_{ud}^*}{V_{ub}^*V_{ud}}\right) = \eta_{h^+h^-} e^{-2i\beta} e^{-2i\gamma} = \eta_{h^+h^-} e^{2i\alpha}$$

$|\lambda_{h^+h^-}| = 1$

$$C_{f_{CP}} = \frac{1 - |\lambda_{h^+h^-}|^2}{1 + |\lambda_{h^+h^-}|^2} \stackrel{!}{=} 0$$

★ Time-dependent *CP* observable

ideal scenario

$$A_{h^+h^-}(t) = S_{h^+h^-} \sin(\Delta m_d t) - C_{h^+h^-} \cos(\Delta m_d t)$$
$$= S_{h^+h^-} \sin(\Delta m_d t) = \sin(2\alpha) \cdot \sin(\Delta m_d t)$$

"Charmless" $b \to u$ Decays : realistic case

★ If "*T*" and "*P*" are of the same order of magnitude :
[Note that *T* and *P* are *complex* amplitudes !]

$$\lambda_{h^+h^-} = \eta_{h^+h^-}\left(\frac{q}{p}\right)_B\left(\frac{e^{-i\gamma}T^{+-}+e^{+i\beta}P^{+-}}{e^{+i\gamma}T^{+-}+e^{-i\beta}P^{+-}}\right)$$

$$= \eta_{h^+h^-}e^{2i\alpha}\left(\frac{1-|P^{+-}/T^{+-}|e^{-i(\alpha-\delta_{+-})}}{1-|P^{+-}/T^{+-}|e^{+i(\alpha+\delta_{+-})}}\right)$$

$$\equiv \left|\lambda_{h^+h^-}\right|e^{2i\alpha_{\rm eff}}$$

where $\delta_{+-} \equiv \theta_{P^{+-}} - \theta_{T^{+-}}$
is the relative strong phase

Direct *CP* violation can occur :

$$|\lambda_{h^+h^-}| \neq 1$$

$$C_{f_{CP}} = \frac{1-|\lambda_{h^+h^-}|^2}{1+|\lambda_{h^+h^-}|^2} \stackrel{!}{\neq} 0$$

★ Time-dependent *CP* observable

realistic scenario

$$A_{h^+h^-}(t) = S_{h^+h^-}\sin(\Delta m_d t) - C_{h^+h^-}\cos(\Delta m_d t)$$

$$= \sqrt{1-C^2_{h^+h^-}}\,\sin(2\alpha_{\rm eff})\cdot\sin(\Delta m_d t) - C_{h^+h^-}\cos(\Delta m_d t)$$

digression: what is the meaning of "*T*" and "*P*" ?

★ Example :

$$A(B^0 \to \pi^+\pi^-) = V_{ud}V_{ub}^*(T + P_u) + V_{cd}V_{cb}^*P_c + V_{td}V_{tb}^*P_t$$

unitarity

$$= \begin{cases} V_{cd}V_{cb}^*(P_c - P_u - T) + V_{td}V_{tb}^*(P_t - P_u - T) & \text{U - convention} \\ V_{ud}V_{ub}^*\boxed{(T + P_u - P_c)} + V_{td}V_{tb}^*\boxed{(P_t - P_c)} & \text{C - convention} \\ V_{ud}V_{ub}^*\boxed{(T + P_u - P_t)} + V_{cd}V_{cb}^*\boxed{(P_c - P_t)} & \text{T - convention} \end{cases}$$

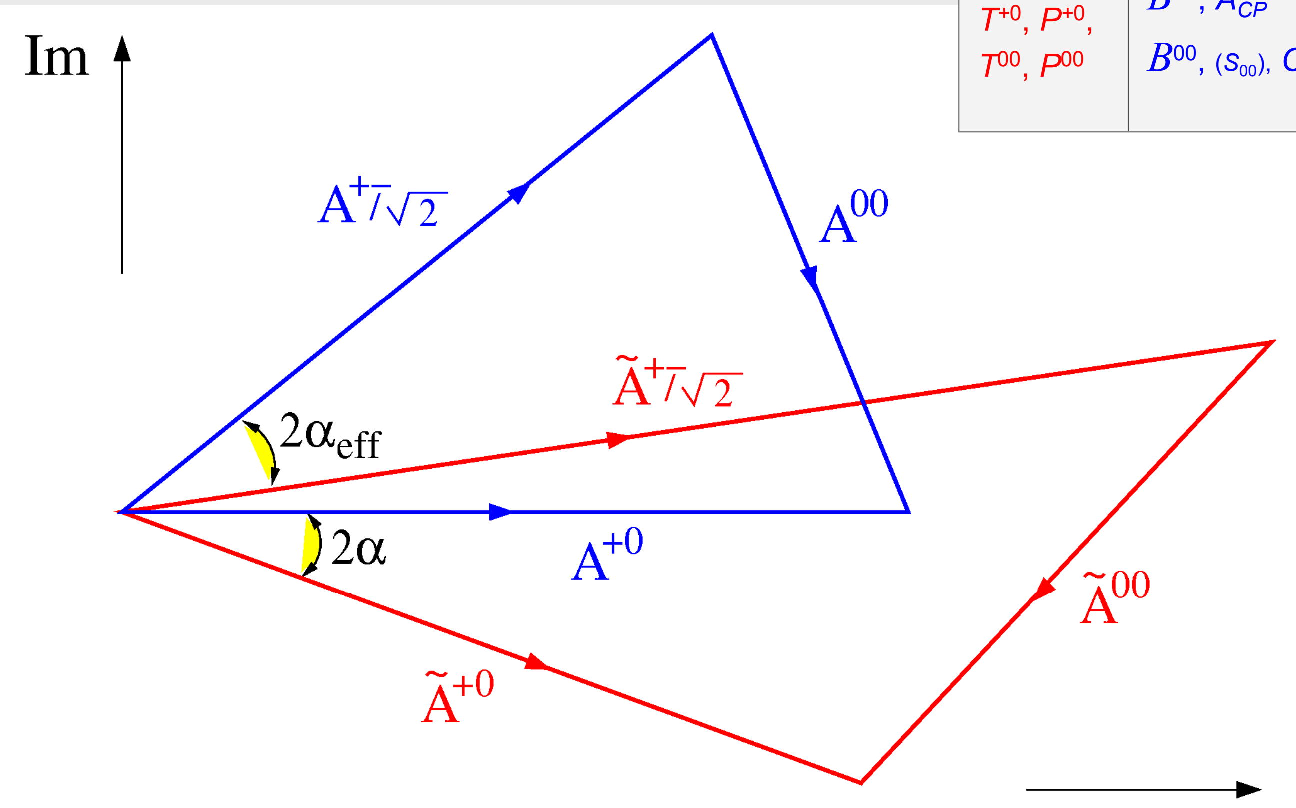
"Tree"

"Penguin"

The "tree" in the (most popular) C - and T - conventions has penguin contributions !

Isospin Analysis for $B \to \pi\pi$, $\rho\rho$

Unknowns	Observables	Constraints	Account
α, T^{+-}, P^{+-}, T^{+0}, P^{+0}, T^{00}, P^{00}	B^{+-}, $S_{\pi\pi}$, $C_{\pi\pi}$ B^{+0}, A_{CP} B^{00}, (S_{00}), C_{00}	2 isospin triangles and one common side	13 unknowns – 7 observ. – 5 constraints – 1 glob. phase = 0 ☺



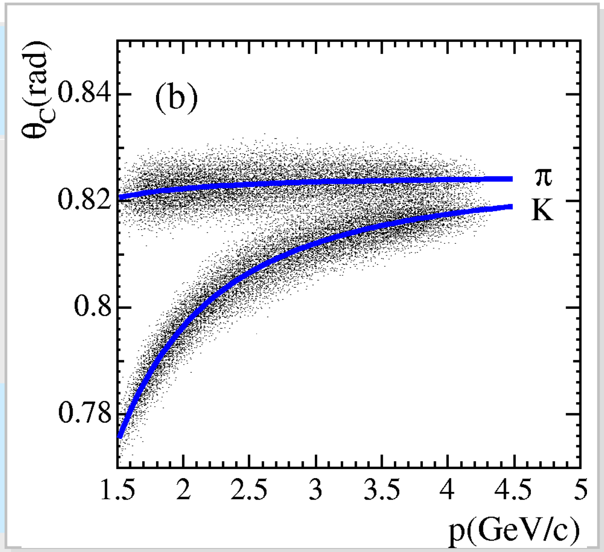
α can be resolved up to an 8-fold ambiguity within $[0,\pi]$

Assumptions:

- neglect EW penguins (shifts α by ~ +2°) penguins
- neglect EM SU(2) breaking
- in $\rho\rho$: Q2B approximation (neglect interference)

Réfs. for SU(2) analyses : **Gronau-London**, PRL, 65, 3381 (1990), **Lipkin *et al.***, PRD 44, 1454 (1991), a.o.

Highlights on Common Analysis Techniques

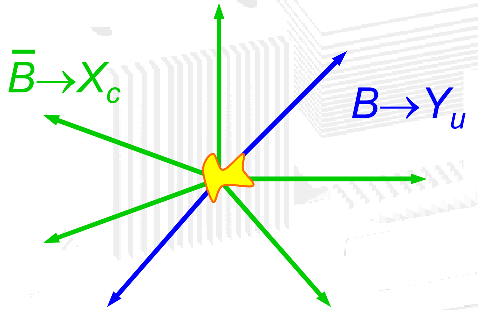


- Strong DIRC Particle ID to separate pions from kaons.
- Event shape monomials (L_0,L_2), and *B* kinematics optimally combined in Multivariate Analyzer [MVA] (Neural Network (NN) or Fisher Discriminant).
- New NN-based *B*-flavor tagging with "*Q*" of 30.5 %
- Unbinned maximum-likelihood fit using beam-energy-substituted *B* mass (m_{ES}), *B*-energy difference (ΔE), the resonance mass and helicity angle, the MVA, and Δt.
- Likelihood components are signal (correctly and misreconstructed), continuum background, charmed and charmless *B*-related backgrounds; as many likelihood-model parameters as possible are determined simultaneously from the fit to reduce systematic errors.
- Tagging-performance parameters and Δt resolution parameters determined simultaneously from fit to fully reconstructed *B* decays to charm.

Reconstructing Rare $b \to u$ Decays

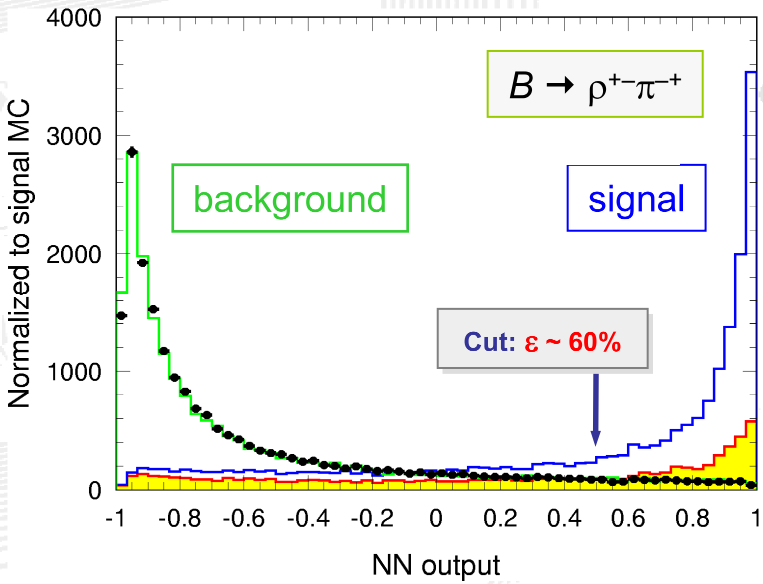
- Suppress continuum, background using event shape variables

$e^+e^- \to \Upsilon(4s) \to B\bar{B}$
B decay ~ in rest event shape spherical



Dominant $e^+e^- \to q\bar{q}$ background is jet-like:

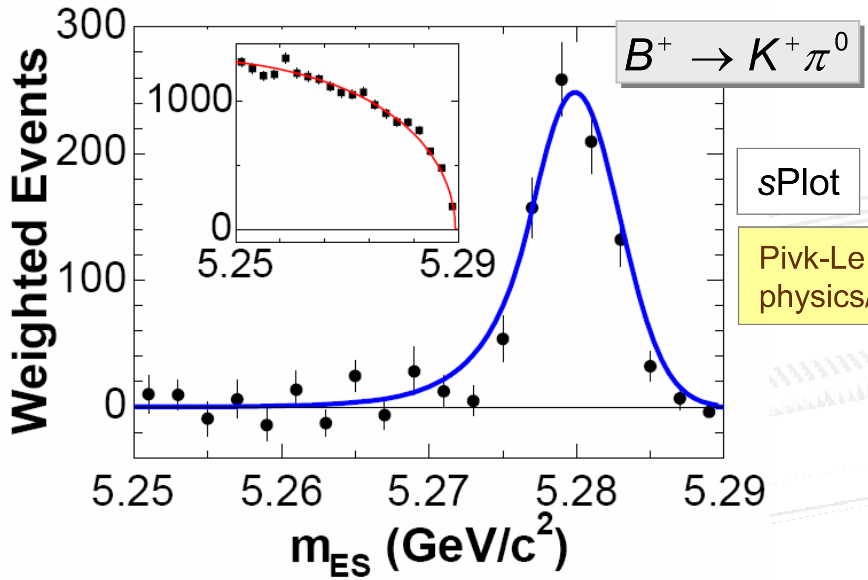
Apply multivariate analyzer techniques:
Neural Network or Fisher Discriminants



- Also: kinematic variables: m_{ES} and ΔE

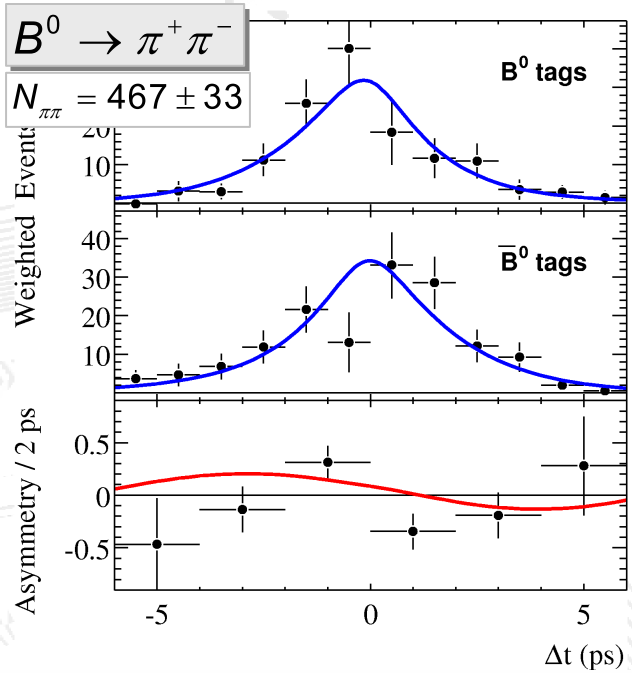
Typical resolution: $\sigma(m_{ES}) \approx$ 2.5 MeV/c^2
$\sigma(\Delta E) \approx$ 25 - 40 MeV

$B \to hh$ Decays: discriminant variables

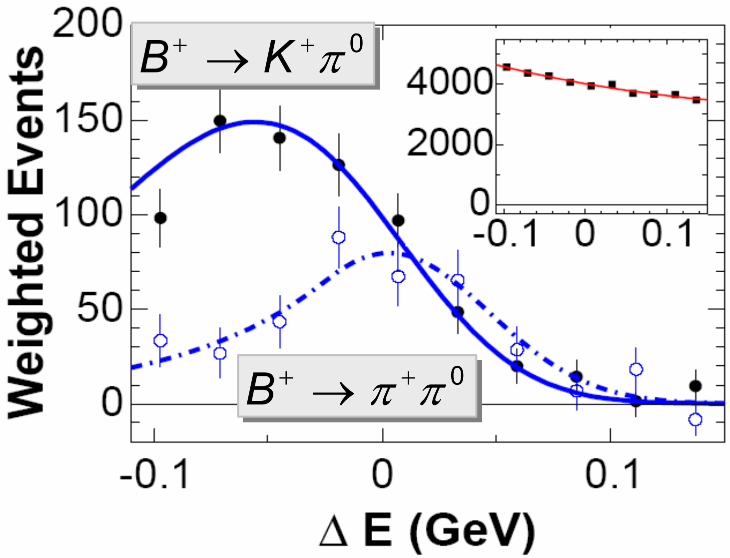


sPlot

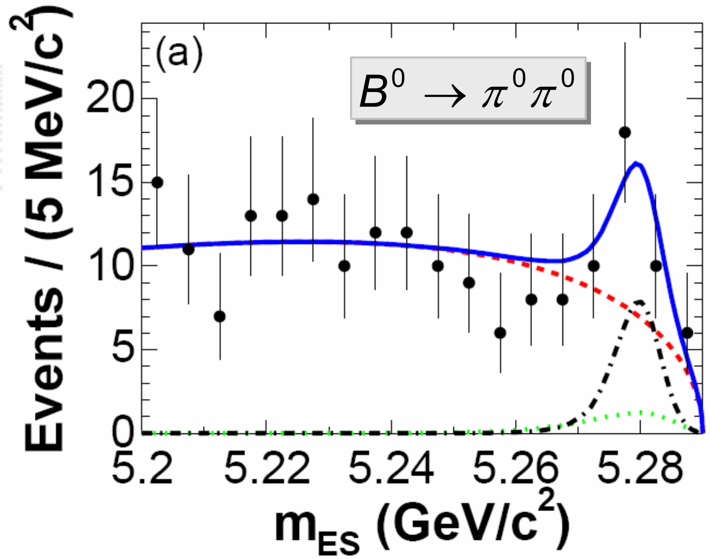
Pivk-Le Diberder
physics/0402083



sPlot



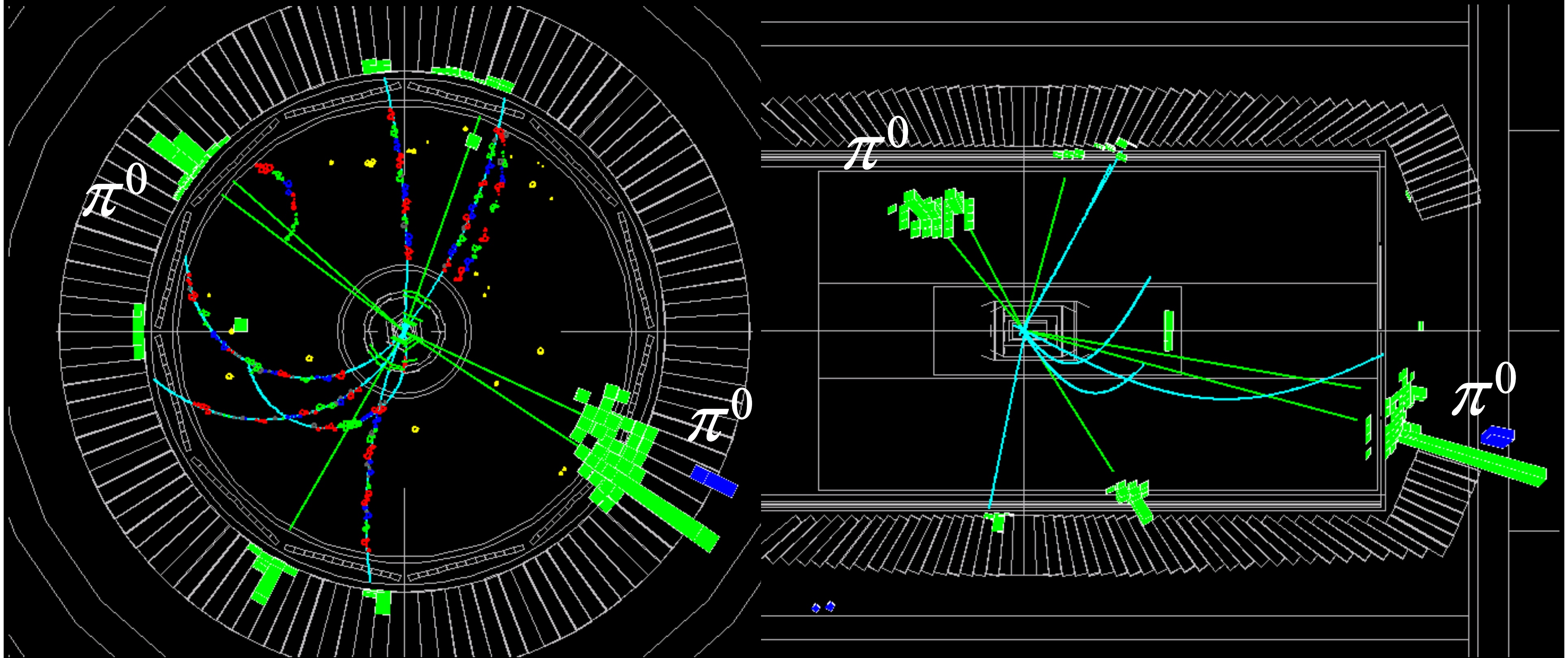
sPlot



SU(2) – Crucial Ingredient : $B \rightarrow \pi^0\pi^0$ (color-suppressed)

A $B^0 \rightarrow \pi^0\pi^0$ candidate

BABAR



$$\mathcal{B}(B^0 \rightarrow \pi^0\pi^0) = (1.51 \pm 0.28) \times 10^{-6} \qquad A_{CP}(B^0 \rightarrow \pi^0\pi^0) = 0.28 \pm 0.39$$

BABAR, hep-ex/0412037
Belle, hep-ex/0408100

Results for $B^0 \rightarrow \pi^+\pi^-$

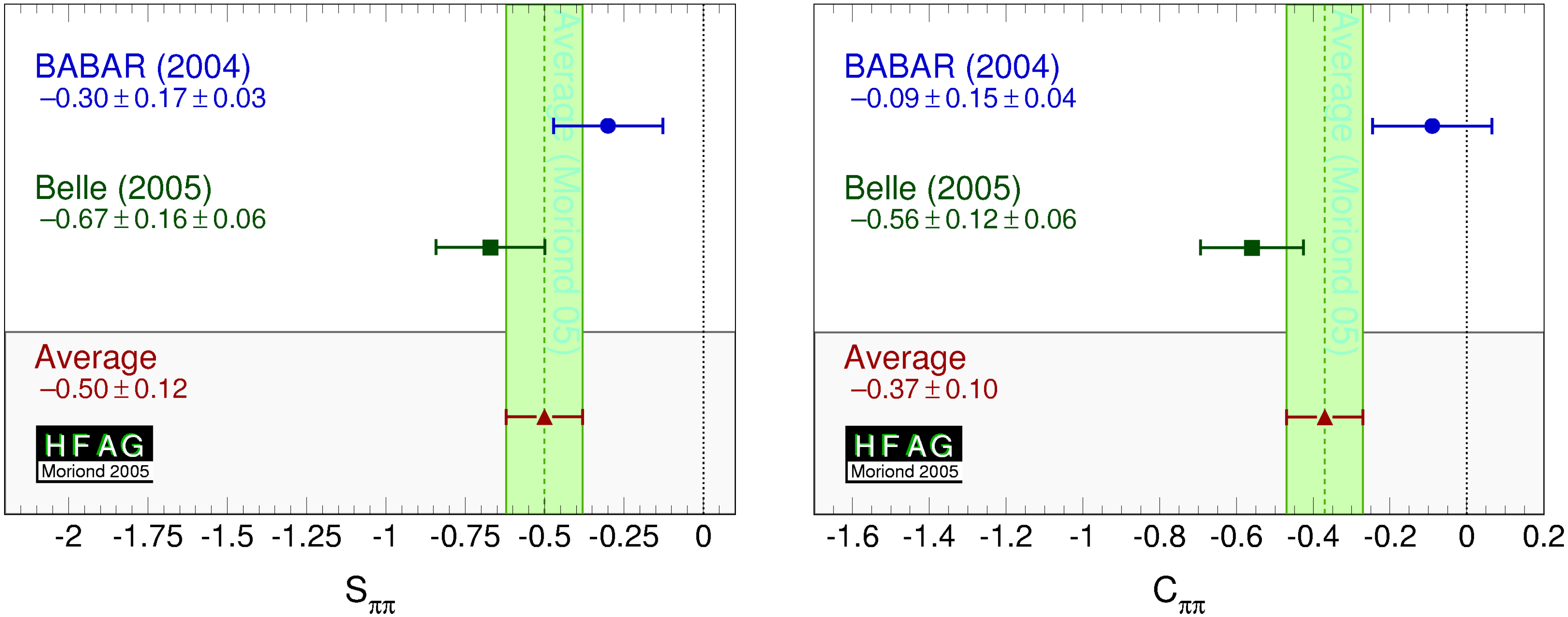
★ Results for the time-dependent analysis :

	BABAR (227m)	Belle (275m)	Average
$S_{\pi\pi}$	–0.30 ± 0.17 ± 0.03	–0.67 ± 0.16 ± 0.06	–0.50 ± 0.12
$C_{\pi\pi}$	–0.09 ± 0.15 ± 0.04	–0.56 ± 0.12 ± 0.06	–0.37 ± 0.10

BABAR, hep-ex/0501071
Belle, hep-ex/0502035

Mediocre (but improved) agreement :

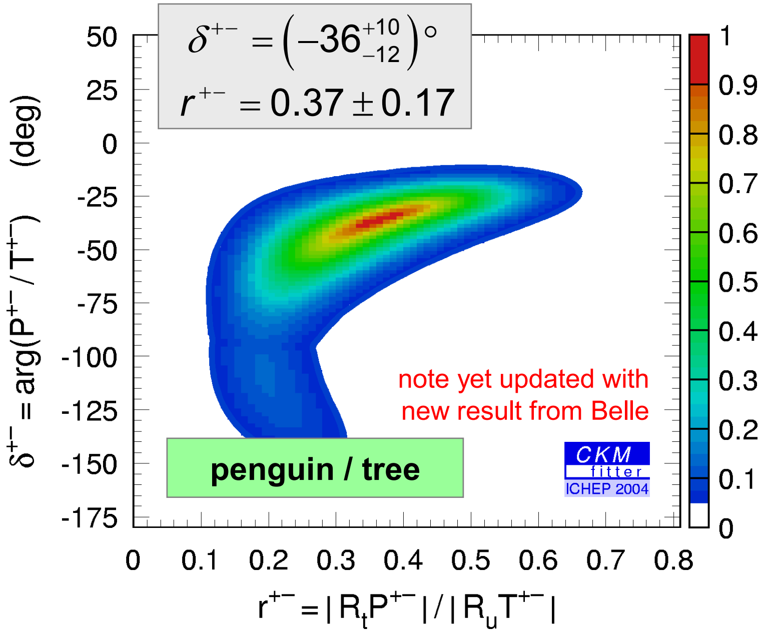
χ^2 = 7.9 (CL = 0.019 ⇒ 2.3σ)



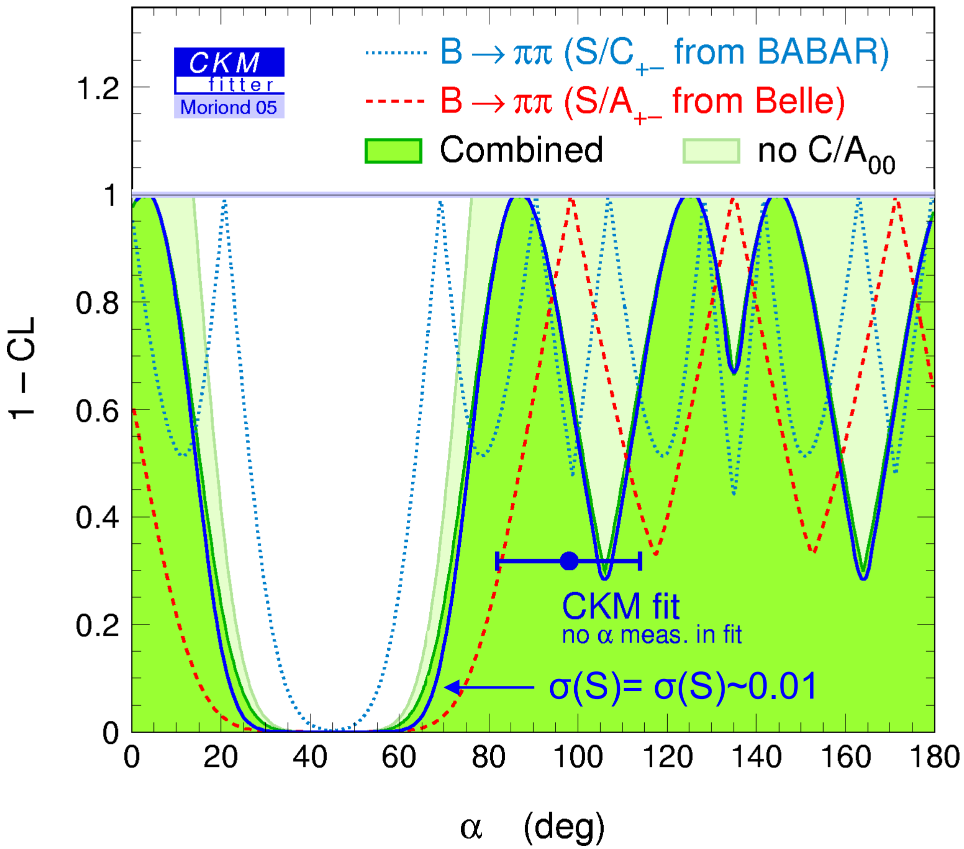
$B^0 \to \pi^+\pi^-$ Isospin Analysis

- χ^2 fit of isospin relations to observables: $\left|\alpha - \alpha_{\rm eff}\right| < 38^\circ$ (90% CL)

BABAR & Belle



BABAR & Belle



- Study decay dynamics ...

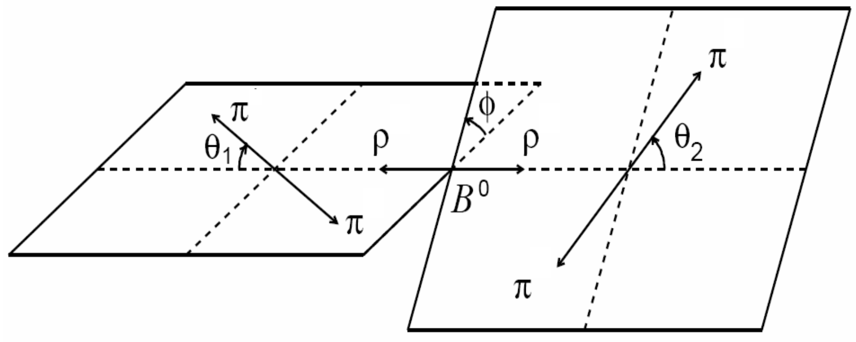
A "surprise" : $B^0 \to \rho^+\rho^-$

★ Branching fractions for the $B \to \rho\rho$ system (WA) :

$\mathcal{B}^{+-} = (30 \pm 6)\times 10^{-6}$, $\mathcal{B}^{+0} = (26.4\,^{+6.1}_{-6.4})\times 10^{-6}$, $\mathcal{B}^{00} < 1.1\times 10^{-6}$ at 90% CL

BABAR, hep-ex/0412067

Note that : a small $\mathcal{B}^{00}/\mathcal{B}^{+0}$ ratio requires small penguins ! [But: $P^{+-} = 0$ would mean that : $\mathcal{B}^{+-}/\mathcal{B}^{+0} = 2$]



★ Experimental complications (I) :

$B \to VV$ can have L_{VV}=0,1,2, with

$CP(L_{VV}$=0,2) = +1 and $CP(L_{VV}$ =1) = –1

Nature's great present : longitudinal polarization dominates ➡ almost no CP dilution

★ Experimental complications (II) :

Dominant mode: $B \to \rho^+\rho^- \to \pi^+\pi^-\pi^0\pi^0 \Rightarrow$ large misreconstruction rate (~ 50%)

The large misreconstruction rate makes the fit vulnerable to biases from correlations and backgrounds

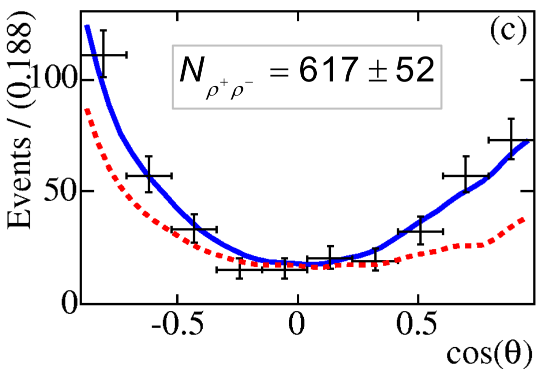
4-body mode and broad, light resonance: large amounts of B-related backgrounds

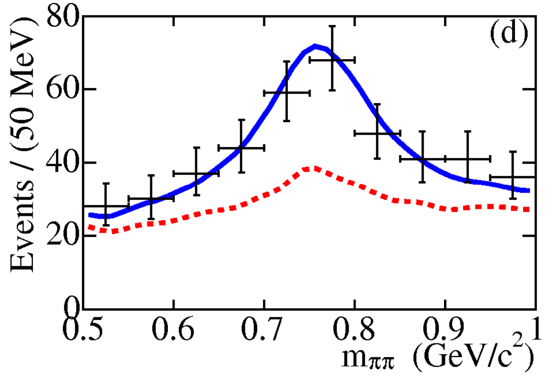
$B^0 \to \rho^+\rho^-$ Isospin Analysis

★ Results : Systematic errors dominated by fit bias and uncertainties on *B*-related backgrounds

BABAR @ Moriond-EW 2005

	BABAR (232m)
f_L	$0.978 \pm 0.014\ ^{+0.021}_{-0.029}$
$S_{\rho\rho,L}$	$-0.33 \pm 0.24\ ^{+0.08}_{-0.14}$
$C_{\rho\rho,L}$	$-0.03 \pm 0.18 \pm 0.09$





★ Isospin analysis :

$$|\alpha - \alpha_{\text{eff}}| < 14^\circ \quad (90\%\ \text{CL})$$

$$\alpha = (100 \pm 13)^\circ$$

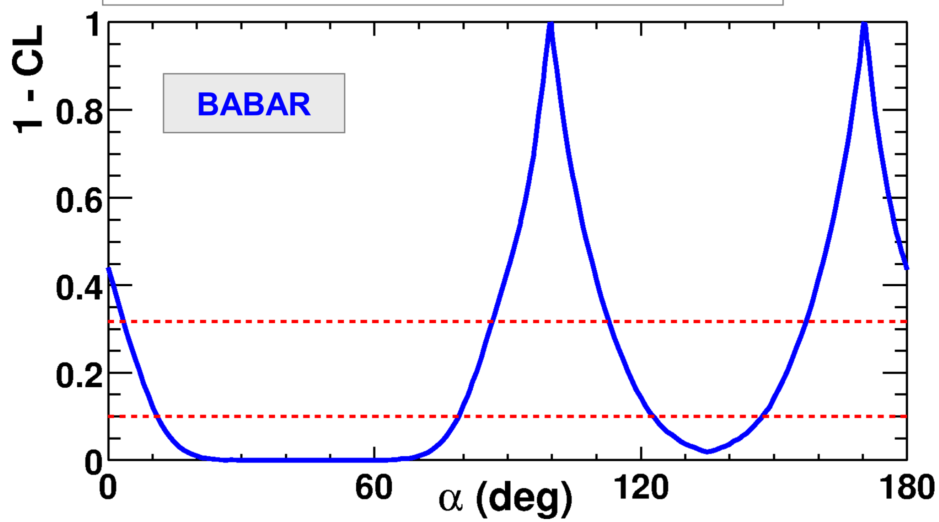
of which 11° is due to penguins

penguin / tree

$\delta^{+-} = (\ldots)^\circ$

$r^{+-} = 0.07^{+0.14}_{-0.07}$

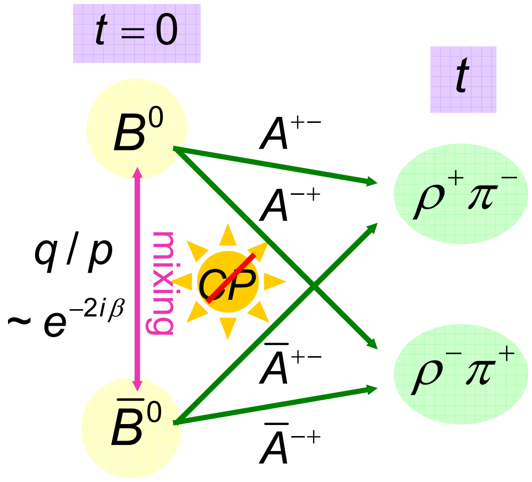
Toy-MC method to derive CL from $\Delta\chi^2$



The $B \to \rho\pi$ System

- Dominant mode $\rho^+\pi^-$ is not a *CP* eigenstate

Aleksan *et al*, Nucl. Phys. B361, 141 (1991)



$$\boxed{A_{\rho^\pm\pi^\mp}(t) = \left(1 \pm A_{CP}\right)\cdot\left(-S_\pm \sin(\Delta m_d t) + C_\pm \cos(\Delta m_d t)\right)}$$

where: $S_\pm = \dfrac{2\ \mathrm{Im}\ \lambda_{\rho^\pm\pi^\mp}}{1+|\lambda_{\rho^\pm\pi^\mp}|^2}$ $\quad C_\pm = \dfrac{1-|\lambda_{\rho^\pm\pi^\mp}|^2}{1+|\lambda_{\rho^\pm\pi^\mp}|^2}$

mixing-induced CPV

direct CPV

$S \equiv S^+ + S^-$ $\quad \Delta S \equiv S^+ - S^-$ $\quad C \equiv C^+ + C^-$ $\quad \Delta C \equiv C^+ - C^-$

strong phase difference

CP-"eigenstateness"

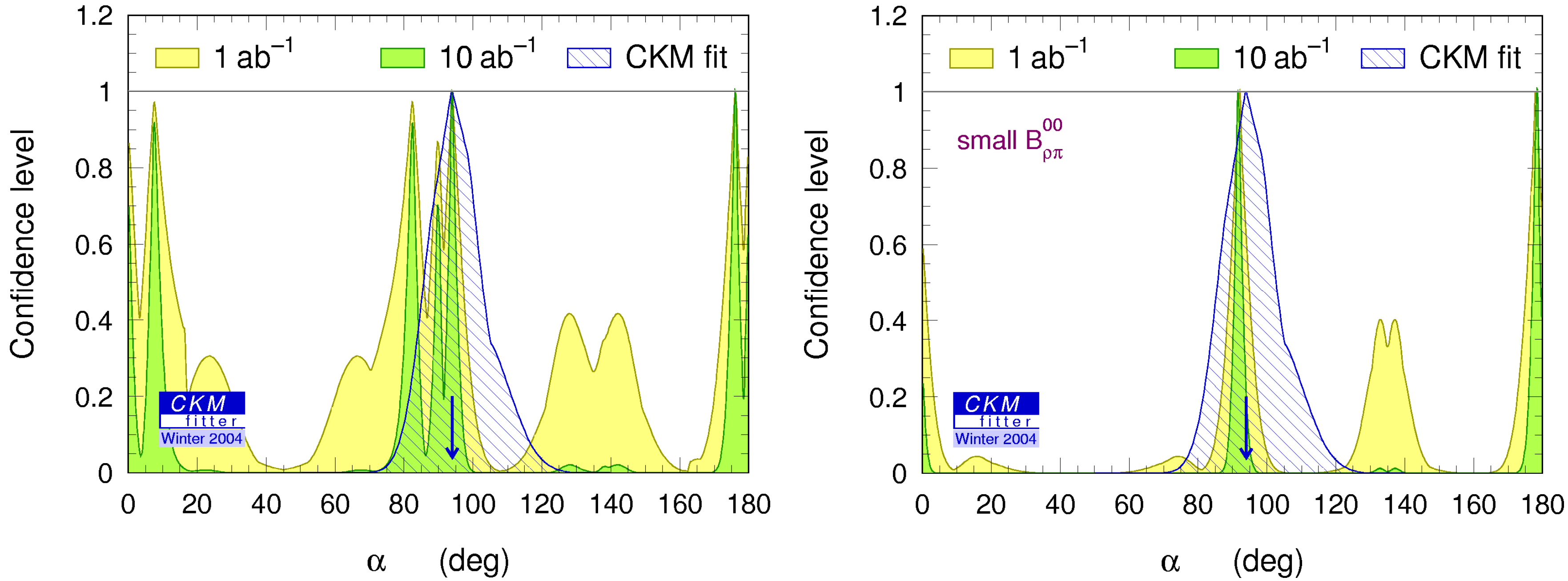
- Pentagon relation between $\rho\pi$ states

Unknowns	Observables	Constraints	Account
α, T^{+-}, P^{+-}, T^{-+}, P^{-+}, T^{+0}, P^{+0}, T^{0+}, P^{0+}, T^{00}, P^{00}	B^{+-}, S, ΔS, C, ΔC, A_{+-} B^{+0}, A_{+0}, B^{0+}, A_{0+} B^{00}, S_{00}, C_{00}	2 SU(2) pentag. $P^{+0} = -P^{0+}$ $P^{+0} \propto f(P^{+-}, P^{-+})$	21 unknowns – 13 observables – 8 constraints – 1 global phase 21 vs. 22 ☺

An Isospin analysis for $B \rightarrow \rho\pi$?

- At present… no useful constraint. How about the future ?

Charles *et al.* hep-ex/0406184

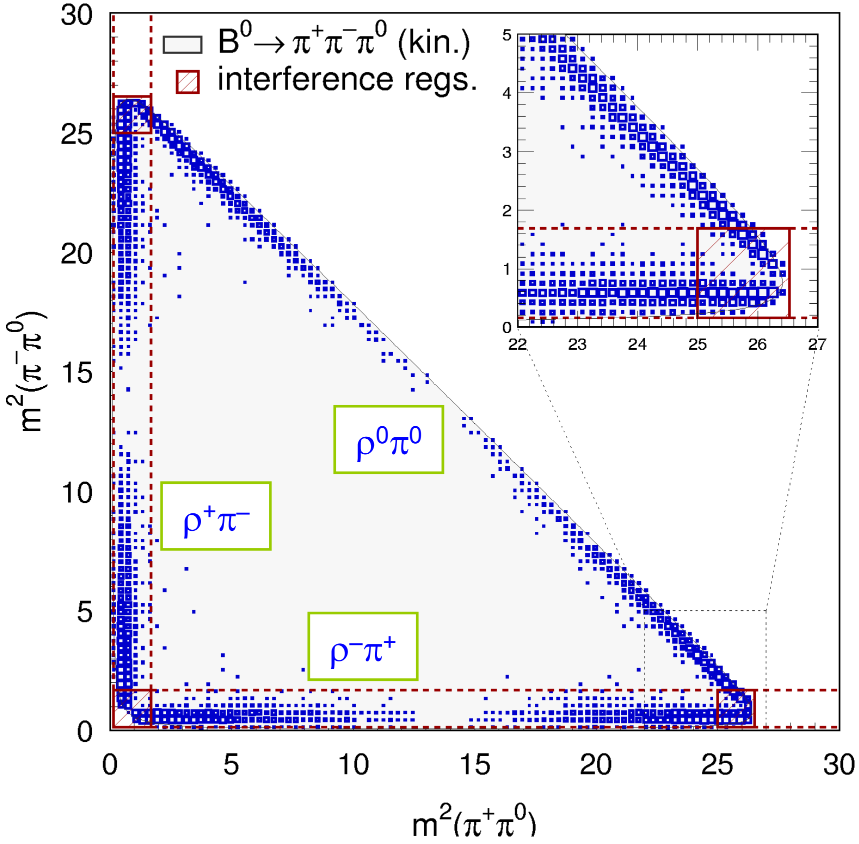


- Very large statistics needed:
  - *quid* systematic errors ?
  - *quid* goodness of the Q2B approximation ?

Dalitz analysis of $B^0 \to (\rho\pi)^0 \to \pi^+\pi^-\pi^0$

- Exploit interference between amplitudes contributing to $B^0 \to \pi^+\pi^-\pi^0$ to simultaneously determine α *and* the strong phases

Snyder-Quinn,
PRD 48, 2139 (1993)



All contributions to $A_{3\pi}$ must be modeled !

Decay amplitudes :

$$A_{3\pi} = f_+ A^{+-} + f_- A^{-+} + f_0 A^{00}$$
$$\bar{A}_{3\pi} = f_+ \bar{A}^{+-} + f_- \bar{A}^{-+} + f_0 \bar{A}^{00}$$

Form factor for ρ resonance (Breit-Wigner)

with : $$A^{ab} = e^{-i\alpha} T^{ab} + P^{ab}$$
$$(q/p)\bar{A}^{ab} = e^{i\alpha} T^{ba} + P^{ba}$$

Time dependence :

$$f_{3\pi} \propto \begin{pmatrix} |A_{3\pi}|^2 + |\bar{A}_{3\pi}|^2 \\ -2\mathrm{Im}\left[\bar{A}_{3\pi} A^*_{3\pi}\right]\sin(\Delta m_d t) \\ +\left(|A_{3\pi}|^2 - |\bar{A}_{3\pi}|^2\right)\cos(\Delta m_d t) \end{pmatrix}$$

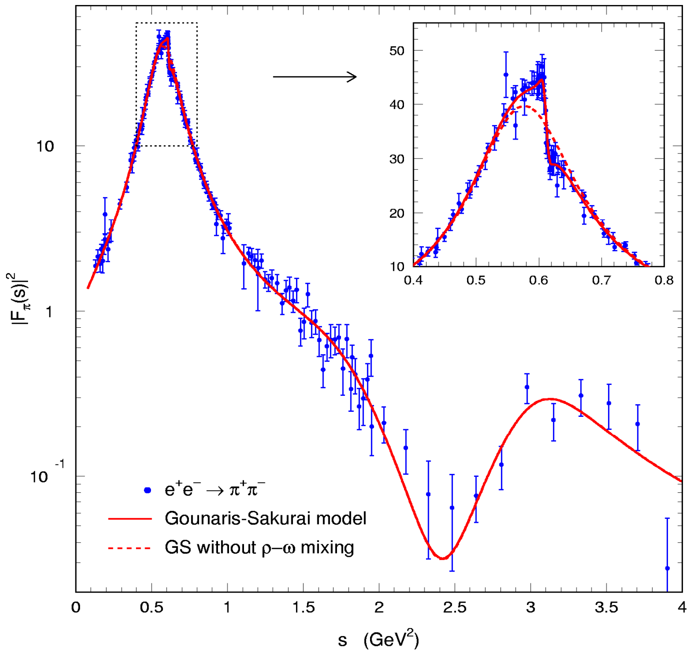
Model Assumptions

- The strong phase difference between the ρ and its radial excitations are independent from the charge of the resonances → SU(2) - tested to very good accuracy with $\tau \to \nu\pi\pi^0$ and $e^+e^- \to \pi^+\pi^-$ data
- The P/T ratio is the same for the ground state and the radial excitations of the ρ → True in naive factorization (same assumptions go into $\rho\pi$ Q2B and $\rho\rho$ analysis)
- The $\rho(770)$ resonance is dominant
- $\rho(1450)$ subdominant, $\rho(1700)$ expected to be not significant
- Scalars like f_0 and σ may be present, expected to be not significant

Assumptions theoretically motivated and necessary to limit no. of fit parameters

$e^+e^- \to \pi^+\pi^-$ data:

Input for the model, but let amplitude of $\rho(1450)$ free in fit



Observables

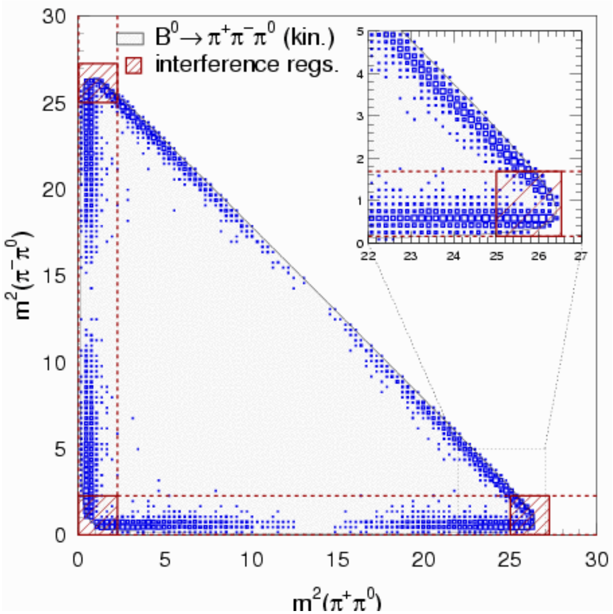
- But… how to fit ? Several problems:
  - Multiple mirror solutions; *Minuit* convergence difficult; *Genetics* algorithm ?
  - amplitude modules and phases are strongly non-Gaussian
  - scan of alpha possible, but what are the results for the other parameters ?
- Much better: fit for the coefficients of the Breit-Wigner bilinears (the “*U*’s and *I*’s”)
  - a single fit contains all the information from the data
  - the coefficients are Gaussian-distributed
  - extract physical parameters (α, P, T, …) in subsequent χ^2 fit to these coefficients

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

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

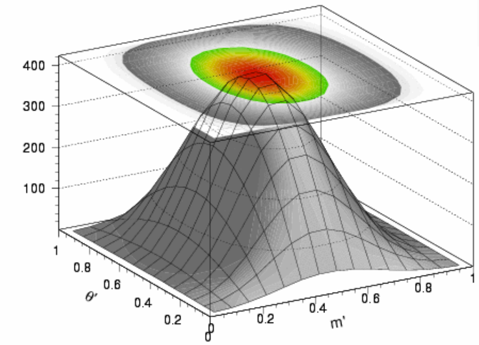
⇒ 11 independent parameters (α, P, T, …) $\rightarrow$ 27 inter-dependent parameters (U,I)
for small $\rho^0\pi^0$, reduces to 16 parameters

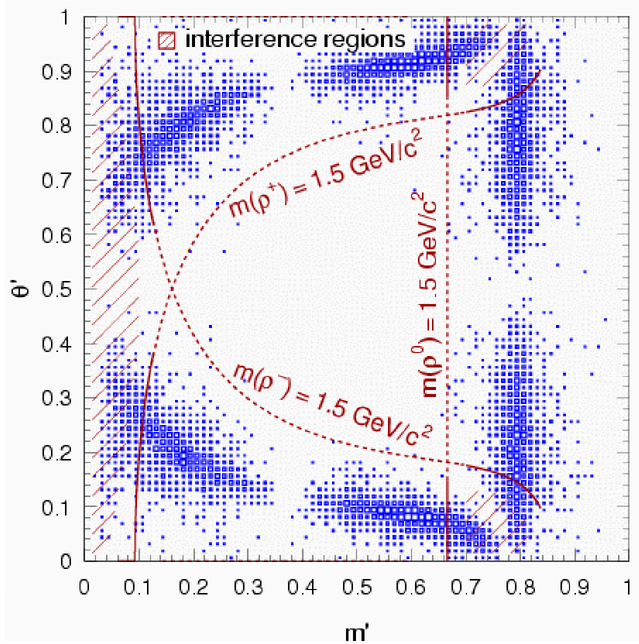
digression: the Square Dalitz Plot



“blow up” the ρ bands and interference regions

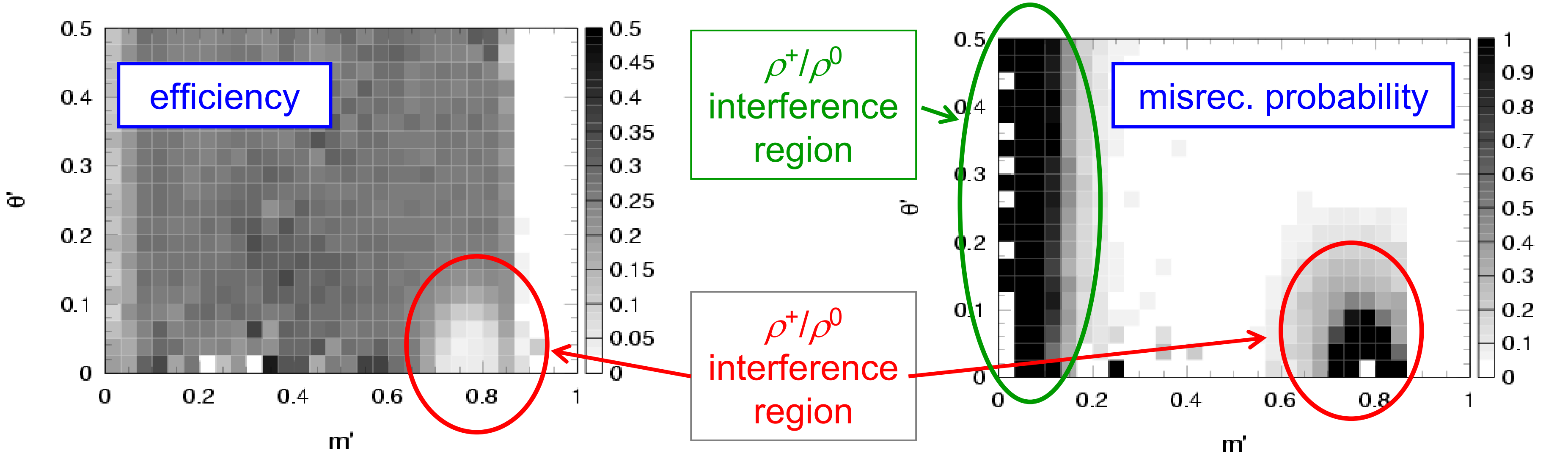
Jacobian:



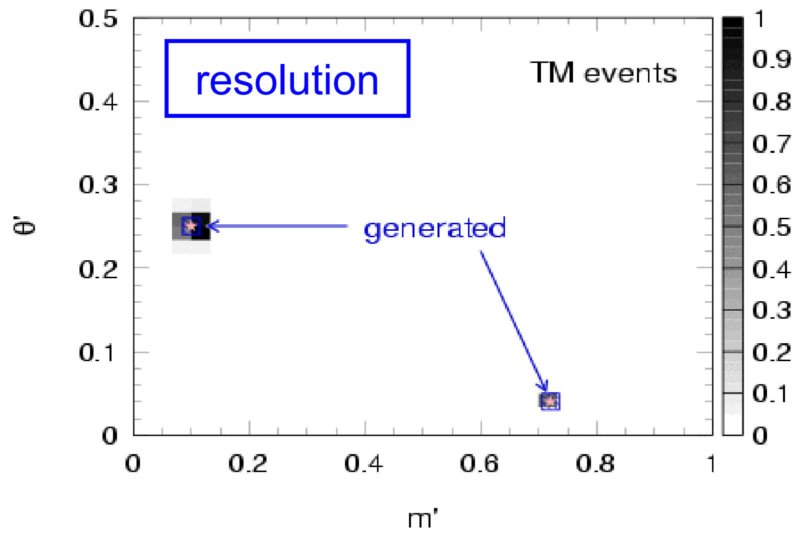


$$\boxed{(m_{+0}^2, m_{-0}^2) \Rightarrow (m', \theta')}$$ where $$\boxed{m' \equiv \frac{1}{\pi}\cos^{-1}\left(\frac{m_{+-} - m_{+-}^{\min}}{m_{+-}^{\max} - m_{+-}^{\min}}\right)}$$ and $$\boxed{\theta' \equiv \frac{\theta_{+-}}{\pi}}$$

digression: Efficiency and Misreconstruction

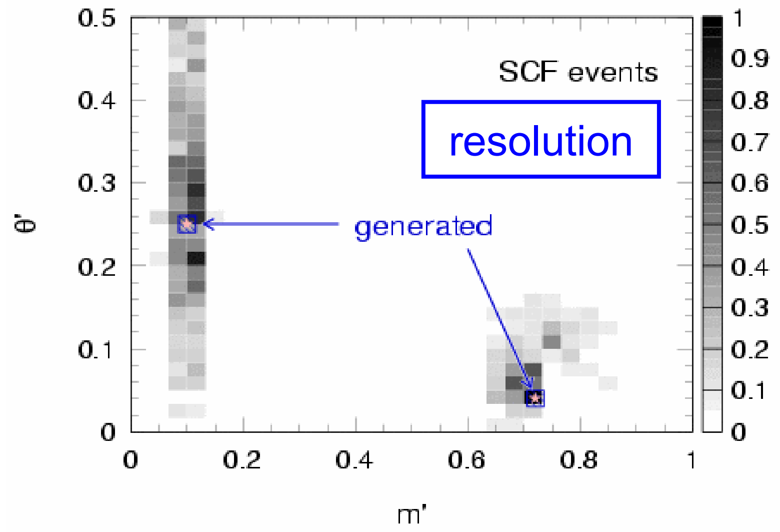


Correctly Reconstructed:

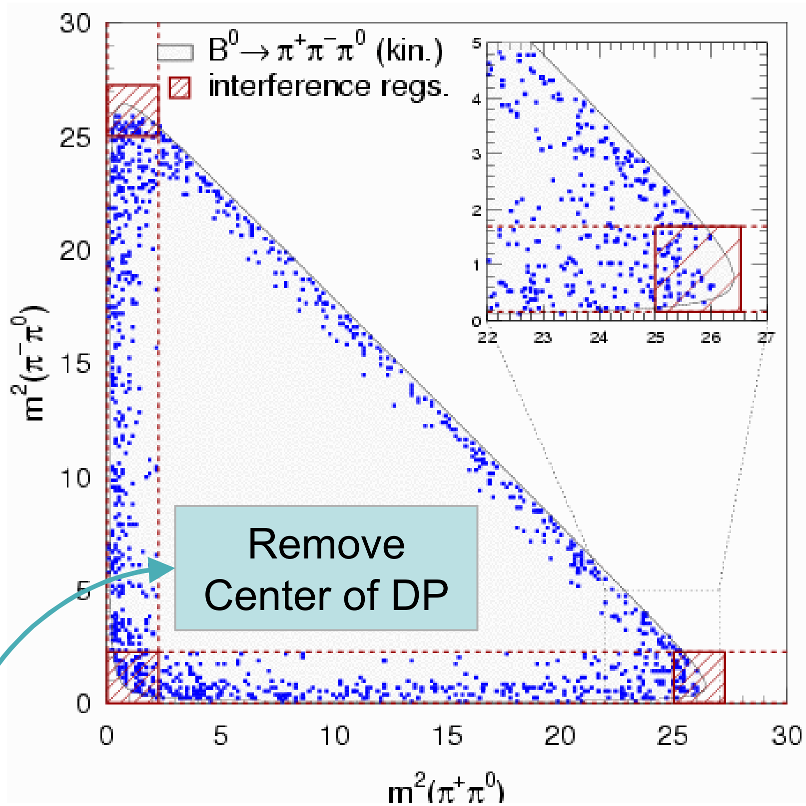


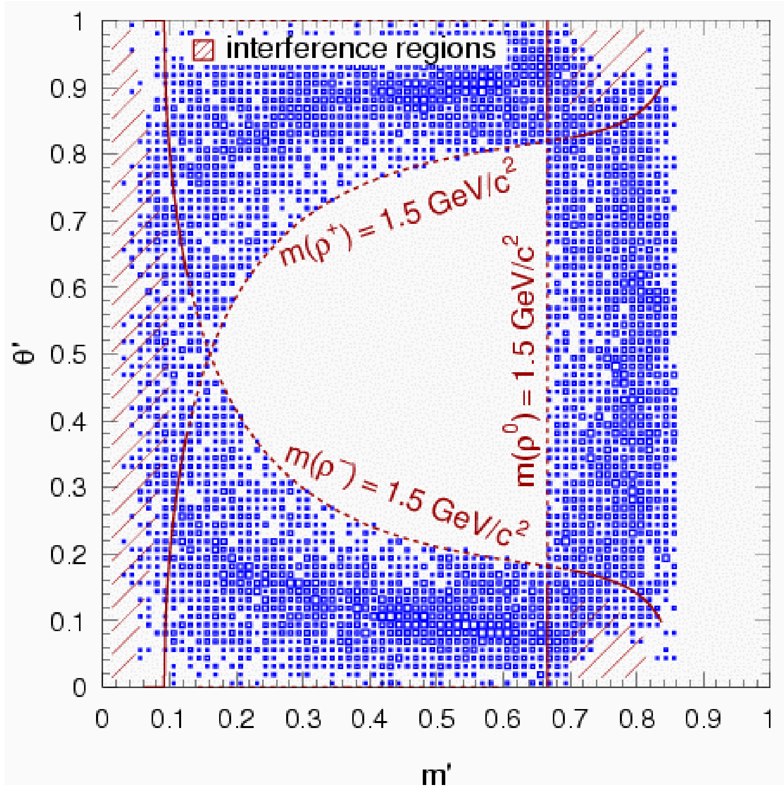
Misreconstructed:

Use 4D Dalitz plot convolution for misreconstructed events



digression: Continuum Background in the Dalitz Plot



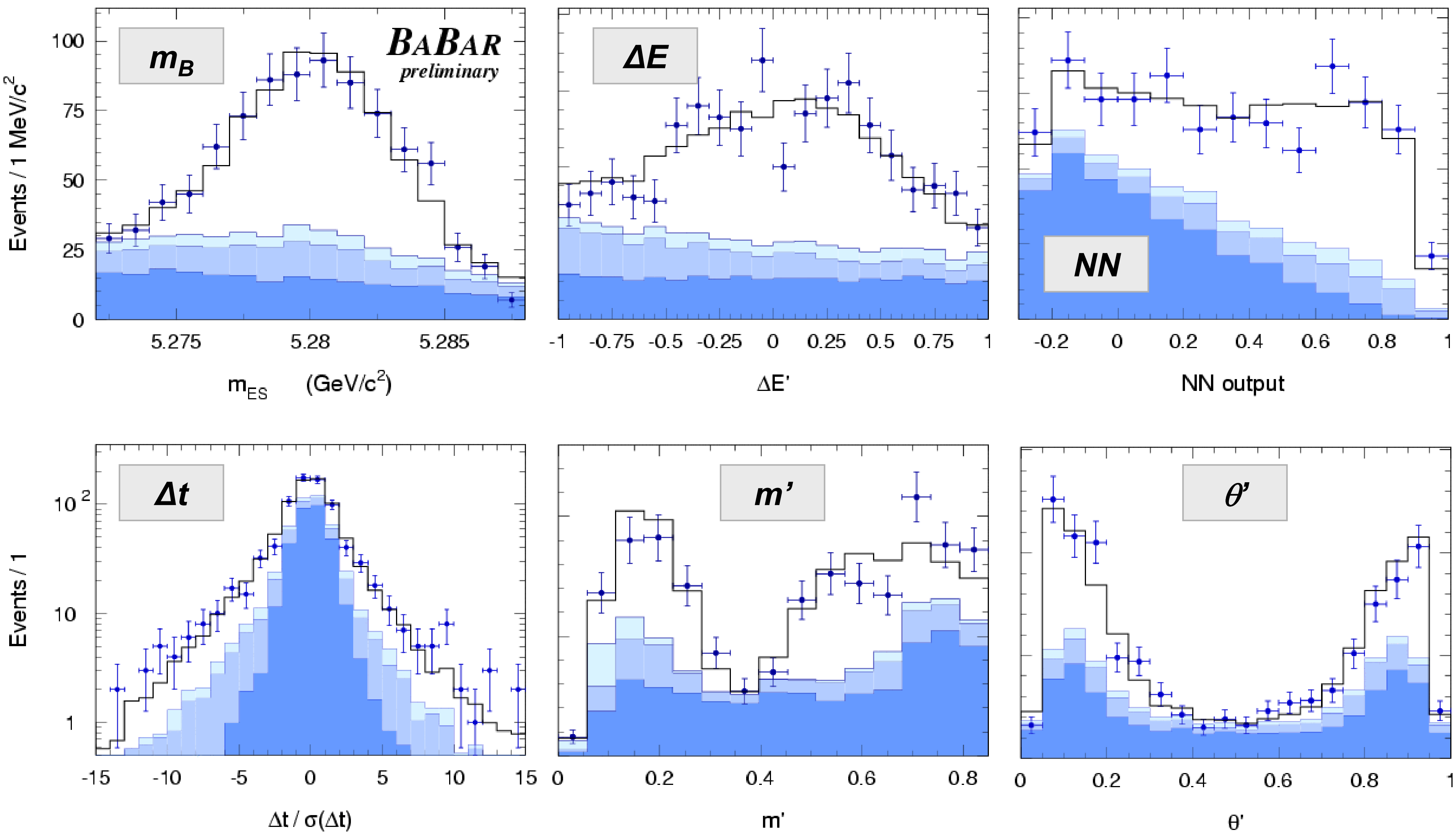


Continuum events obtained from off-resonance runs: no signal !

The DP is correlated with the event shape and hence with the continuum-fighting Neural Network ☹

Fit Projections

$N_{\rho\pi} = 1064 \pm 51$



Fit Results for *U*'s and *I*'s

U_-^+	Coeff. of $\lvert f(\rho^-)\rvert^2$	$1.19 \pm 0.12 \pm 0.03$
I_-	Coeff. of $\lvert f(\rho^-)\rvert^2 \sin(\Delta m \Delta t)$	$-0.19 \pm 0.11 \pm 0.02$
I_+	Coeff. of $\lvert f(\rho^+)\rvert^2 \sin(\Delta m \Delta t)$	$0.06 \pm 0.11 \pm 0.02$
U_-^-	Coeff. of $\lvert f(\rho^-)\rvert^2 \cos(\Delta m \Delta t)$	$0.22 \pm 0.16 \pm 0.05$
U_+^-	Coeff.of $\lvert f(\rho^+)\rvert^2 \cos(\Delta m \Delta t)$	$0.50 \pm 0.17 \pm 0.05$
$U_{+-}^{-,\mathrm{Im}}$	Coeff. of $\mathrm{Im}[f(\rho^+)\, f(\rho^-)^*]\cos(\Delta m \Delta t)$	$0.25 \pm 1.4 \pm 0.3$
$U_{+-}^{-,\mathrm{Re}}$	Coeff. of $\mathrm{Re}[f(\rho^+)\, f(\rho^-)^*]\cos(\Delta m \Delta t)$	$2.0 \pm 1.2 \pm 0.2$
$U_{+-}^{+,\mathrm{Im}}$	Coeff. of $\mathrm{Im}[f(\rho^+)\, f(\rho^-)^*]$	$0.16 \pm 0.70 \pm 0.14$
$U_{+-}^{+,\mathrm{Re}}$	Coeff. of $\mathrm{Re}[f(\rho^+)\, f(\rho^-)^*]$	$-0.26 \pm 0.65 \pm 0.17$
I_{+-}^{Im}	Coeff. of $\mathrm{Im}[f(\rho^+)\, f(\rho^-)^*]\sin(\Delta m \Delta t)$	$-5.2 \pm 1.9 \pm 0.7$
I_{+-}^{Re}	Coeff. of $\mathrm{Re}[f(\rho^+)\, f(\rho^-)^*]\sin(\Delta m \Delta t)$	$-0.3 \pm 2.0 \pm 0.5$
U_0^+	Coeff. of $\lvert f(\rho^0)\rvert^2$	$0.16 \pm 0.05 \pm 0.05$
$U_{+0}^{+,\mathrm{Im}}$	Coeff. of $\mathrm{Im}[f(\rho^+)\, f(\rho^0)^*]$	$0.25 \pm 0.35 \pm 0.18$
$U_{+0}^{+,\mathrm{Re}}$	Coeff. of $\mathrm{Re}[f(\rho^+)\, f(\rho^0)^*]$	$-0.34 \pm 0.39 \pm 0.15$
$U_{-0}^{+,\mathrm{Im}}$	Coeff. of $\mathrm{Im}[f(\rho^-)\, f(\rho^0)^*]$	$0.34 \pm 0.43 \pm 0.17$
$U_{-0}^{+,\mathrm{Re}}$	Coeff. of $\mathrm{Re}[f(\rho^-)\, f(\rho^0)^*]$	$-0.98 \pm 0.44 \pm 0.18$

Q2B
$U_+^+ = 1$

interfering terms
Less sensitive

$\rho^0\pi^0$ terms
Significant, but…

Results of the $B^0 \to (\rho\pi)^0 \to \pi^+\pi^-\pi^0$ Dalitz analysis

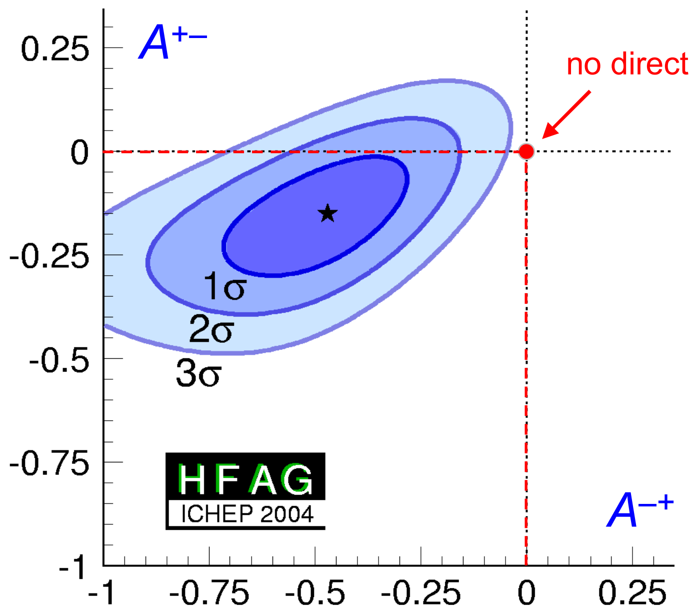
- From the 16 bilinears (U_i, I_i), we determine the physical parameters via a χ^2 fit

- Direct *CP* violation ?

Average : BABAR (213m) & Belle (152m)

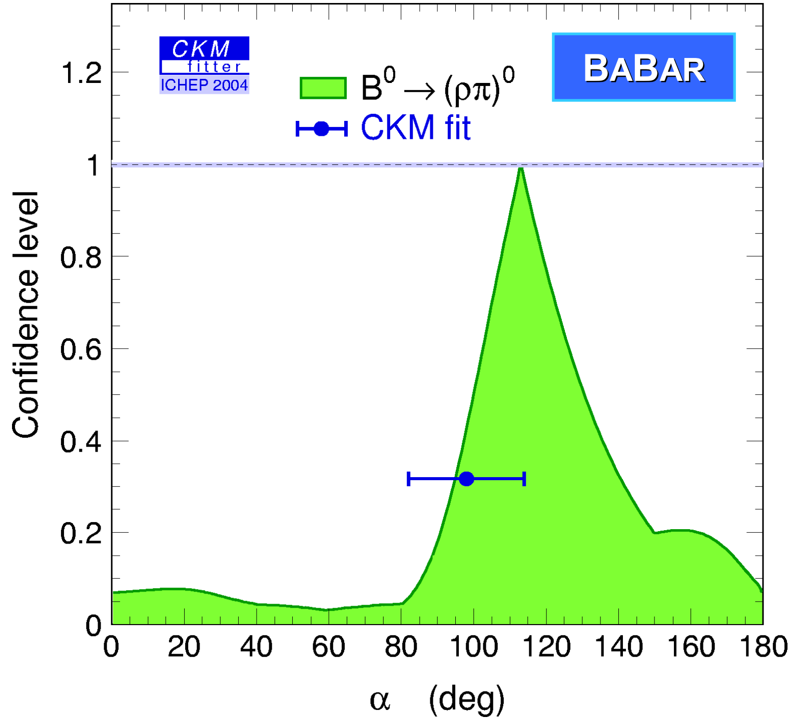
A^{+-} -0.15 ± 0.09	A^{-+} $-0.47^{+0.13}_{-0.14}$

$\Delta\chi^2$(no direct CPV) = 14.5 (CL = 0.00070 ⇒ 3.4σ)



- Parameters : α, $|T^{+-}|$, T^{-+}, T^{00}, P^{+-}, P^{-+}

Scan in α using the bilinears :



BABAR, hep-ex/0408099

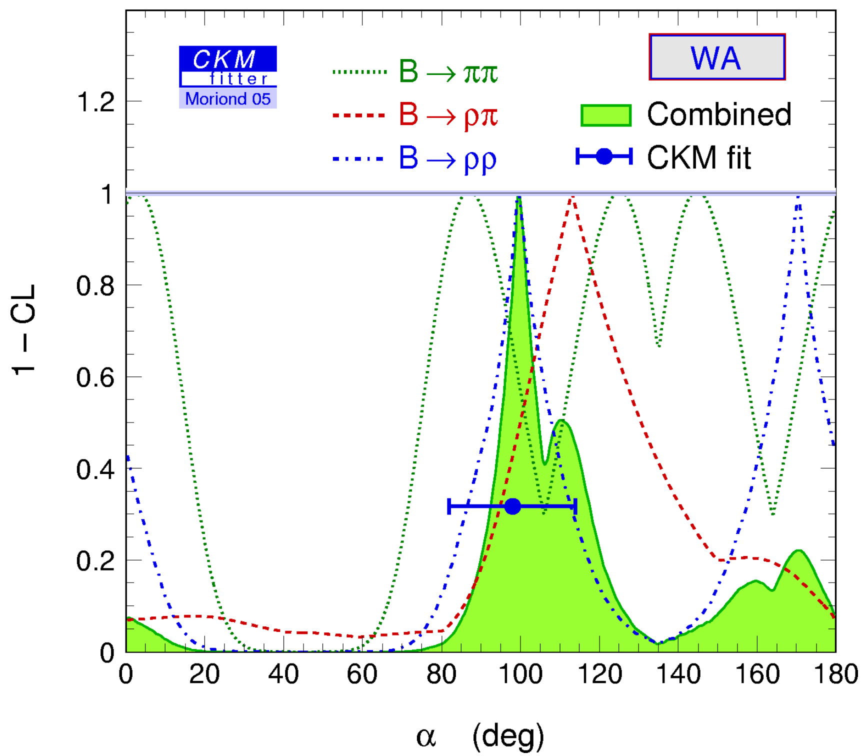
Combination of $\pi\pi$, $\rho\pi$, $\rho\rho$: first measurement of α

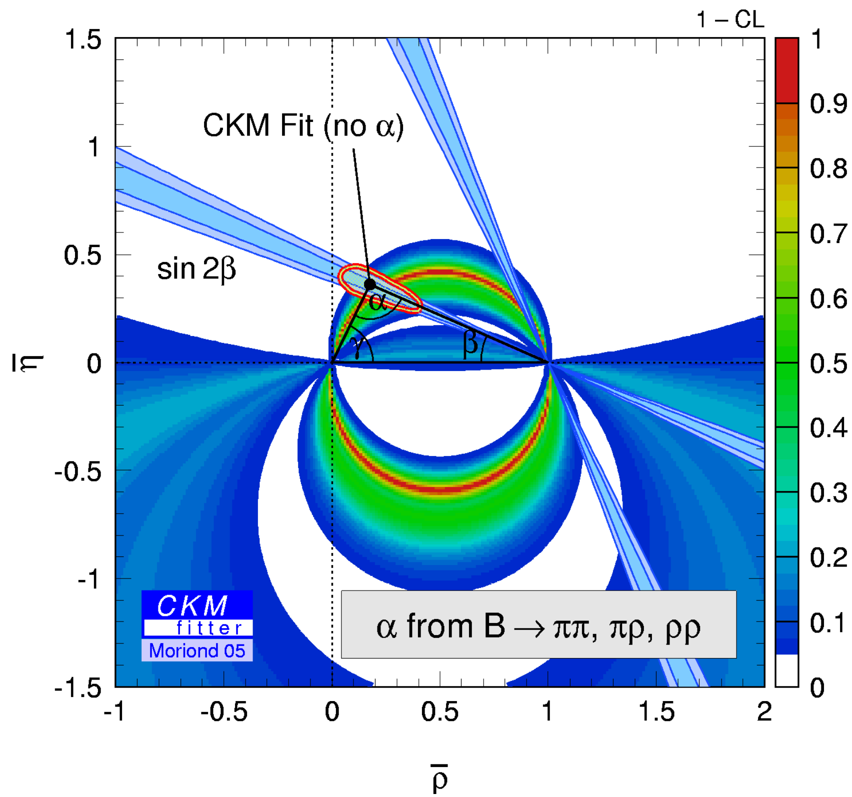
- Combining the three analyses (dominated by $\rho\rho$ and $\rho\pi$) :
  - mirror solution disfavored
  - for the SM solution we find :

$$\alpha_{B\text{-Factories}} = \left[101\,^{+16}_{-9}\right]^\circ$$

  - better precision than CKM fit :

$$\alpha_{\text{CKM}} = \left[98 \pm 16\right]^\circ$$





(1st generation-) *B*-Factories' future …. till ~ 2009

- Expect ~ 4 times more statistics for both BABAR and Belle

- $\pi\pi$ isospin analysis will "rapidly" improve with better $C(\pi^0\pi^0)$ measurements

- $\rho\rho$ isospin analysis, future unclear:
  - bound on penguin pollution only improves with $\sqrt{B(\rho^0\rho^0)}$
  - if discovered, not enough statistics to well measure $C(\rho^0\rho^0)$ and $S(\rho^0\rho^0)$
  - on the other hands: no Belle results yet !
  - at very large statistics, systematics and model-dependence will become an issue

- $\rho\pi$ isospin analysis … not very promising

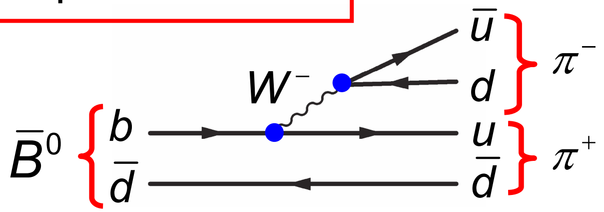
- $\rho\pi$ Dalitz analysis is just at the beginning: very challenging; still much to learn; no Belle result yet; model-dependence IS an issue !

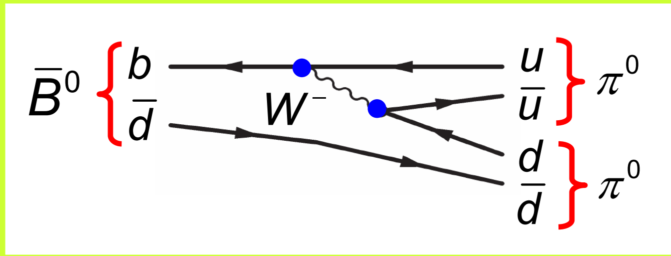
appendix

color suppression

digression : “Color-Suppressed” Amplitudes

Example : $b \to u\bar{u}d$





Famous modes :

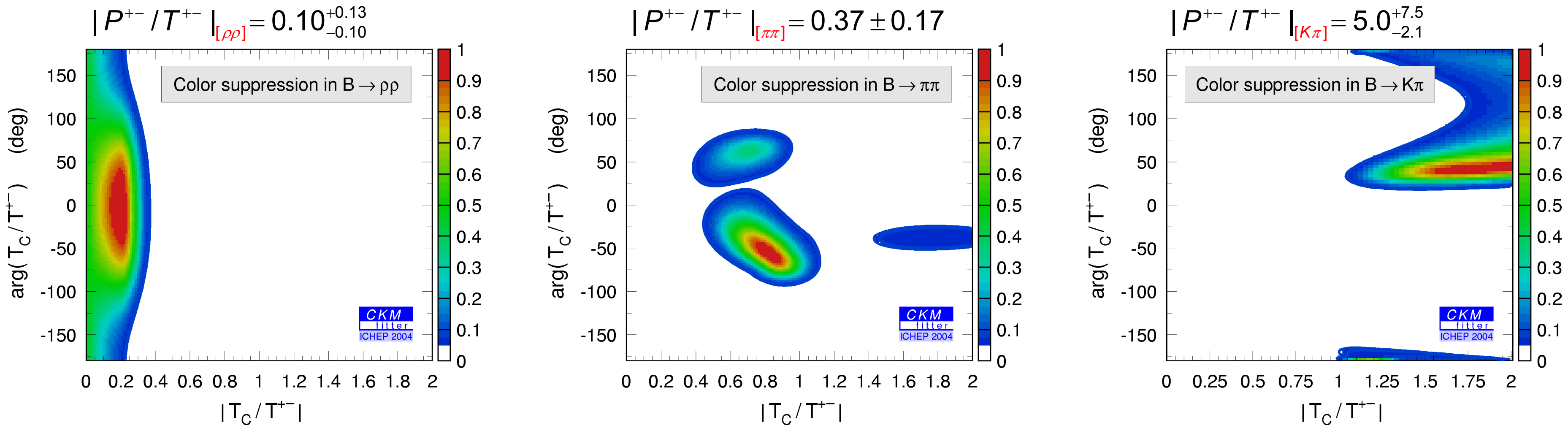
$B^0 \to \pi^0\pi^0$

$B^0 \to \rho^0\pi^0$

$B^0 \to \rho^0\rho^0$

★ The color of the quarks emitted by the virtual W must correspond to the external quark lines to produce color-singlets ➡ suppression by ~$1/N_c$ (naïve!)

[Suppression ≈ verified in $\mathcal{B}(B^0 \to D^0\pi^0)/\mathcal{B}(B^0 \to D^-\pi^+) = (1/10.4)_{exp} \approx (1/N_c)^2$]



➡ important <u>non-factorizable</u> contributions when large penguins !