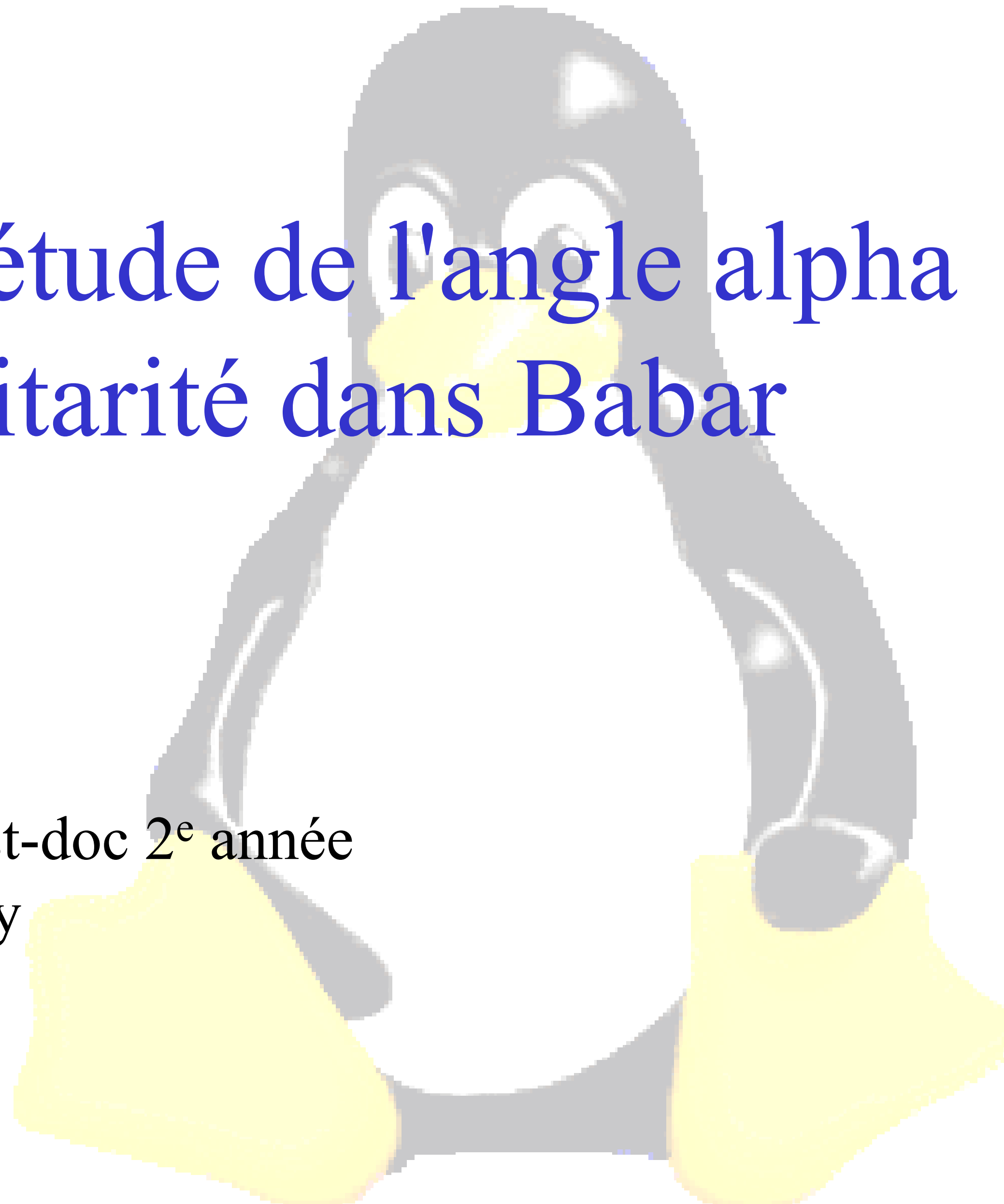
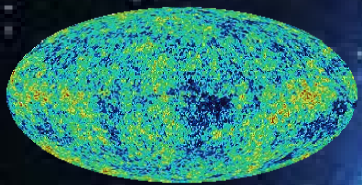


Violation de CP et étude de l'angle alpha du triangle d'unitarité dans Babar

Marc Escalier, post-doc 2e année
Dapnia/SPP/Saclay

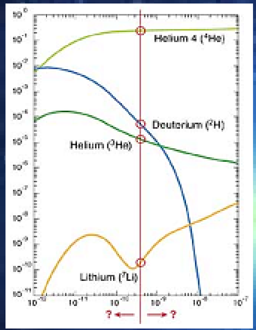
Pourquoi étudier la violation de CP ?

D'où venons-nous ?
Pourquoi existons-nous ?



1965, Penzias, Wilson, 3K

qté/10^6 H



ρ mat. ord.

Asymétrie matière/antimatière

1967, Sakharov:
violation CP

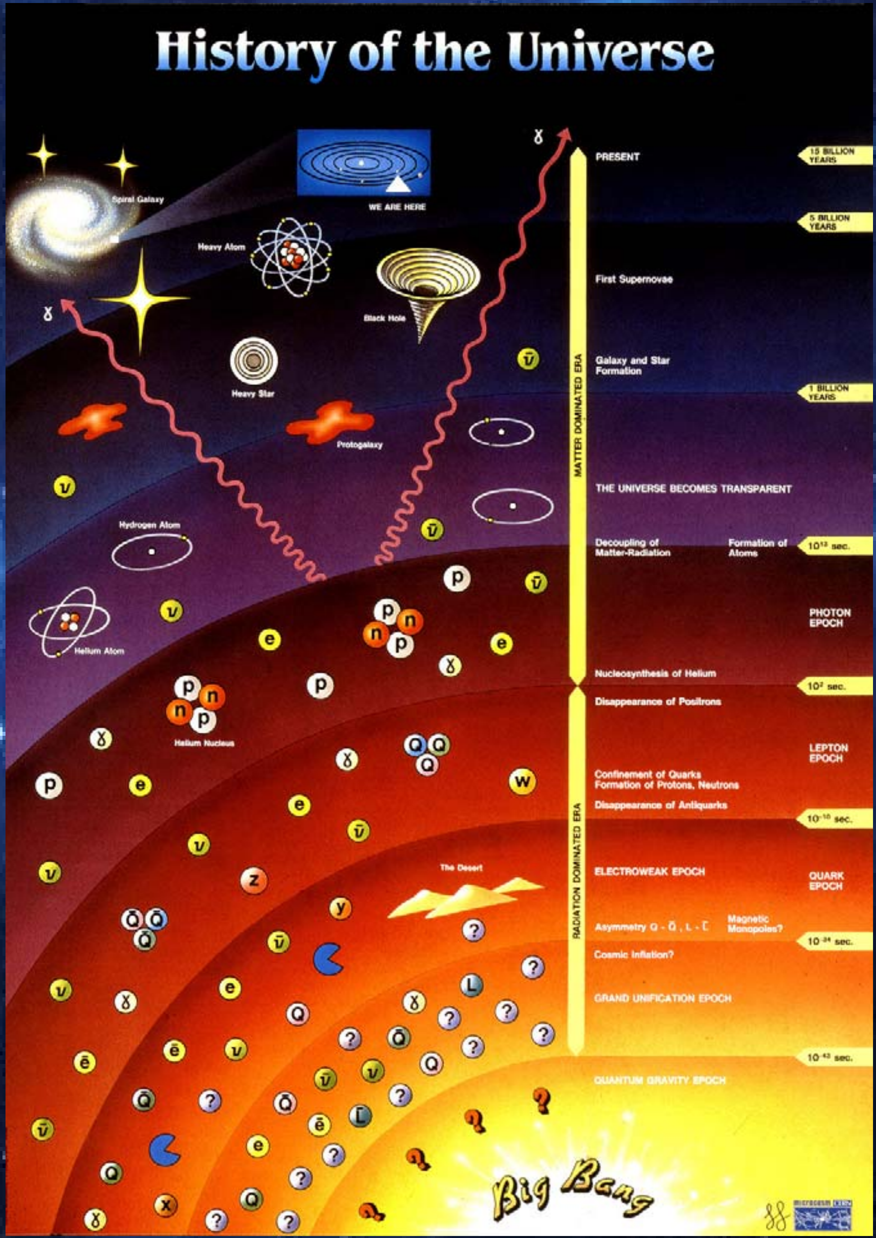
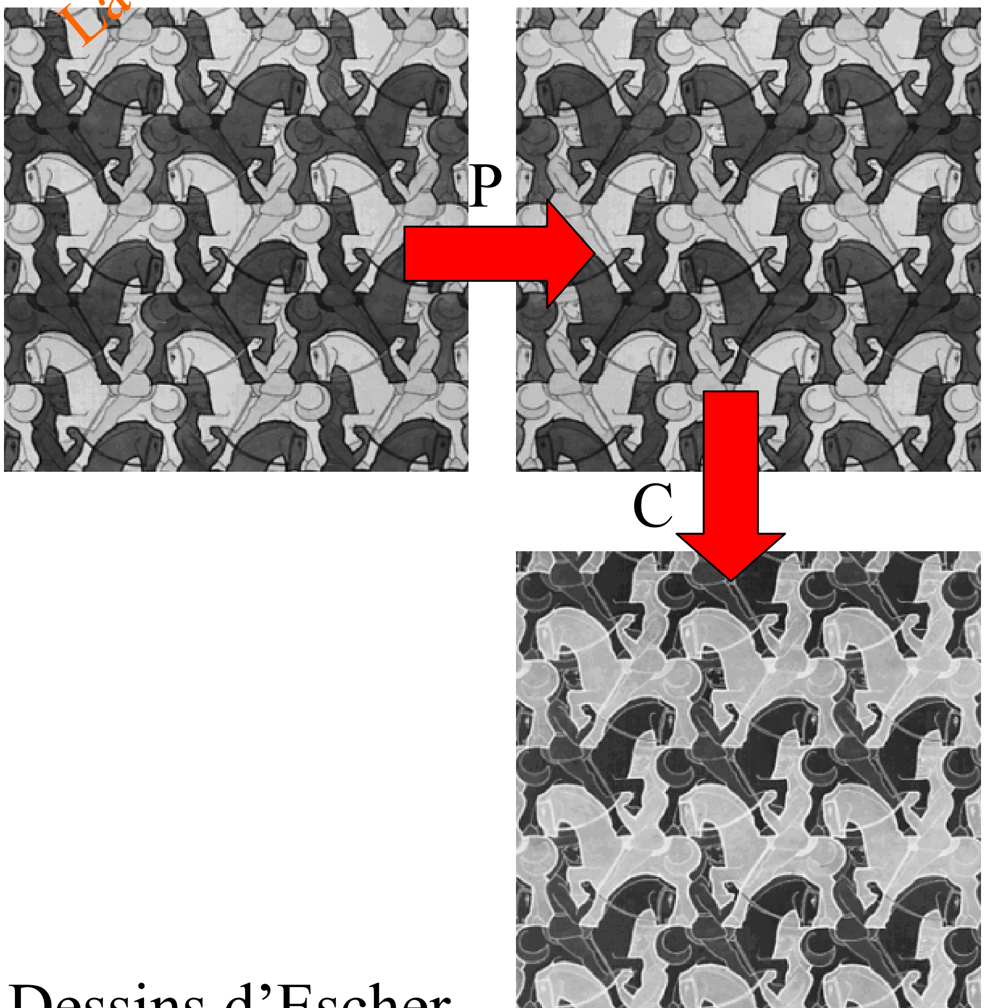
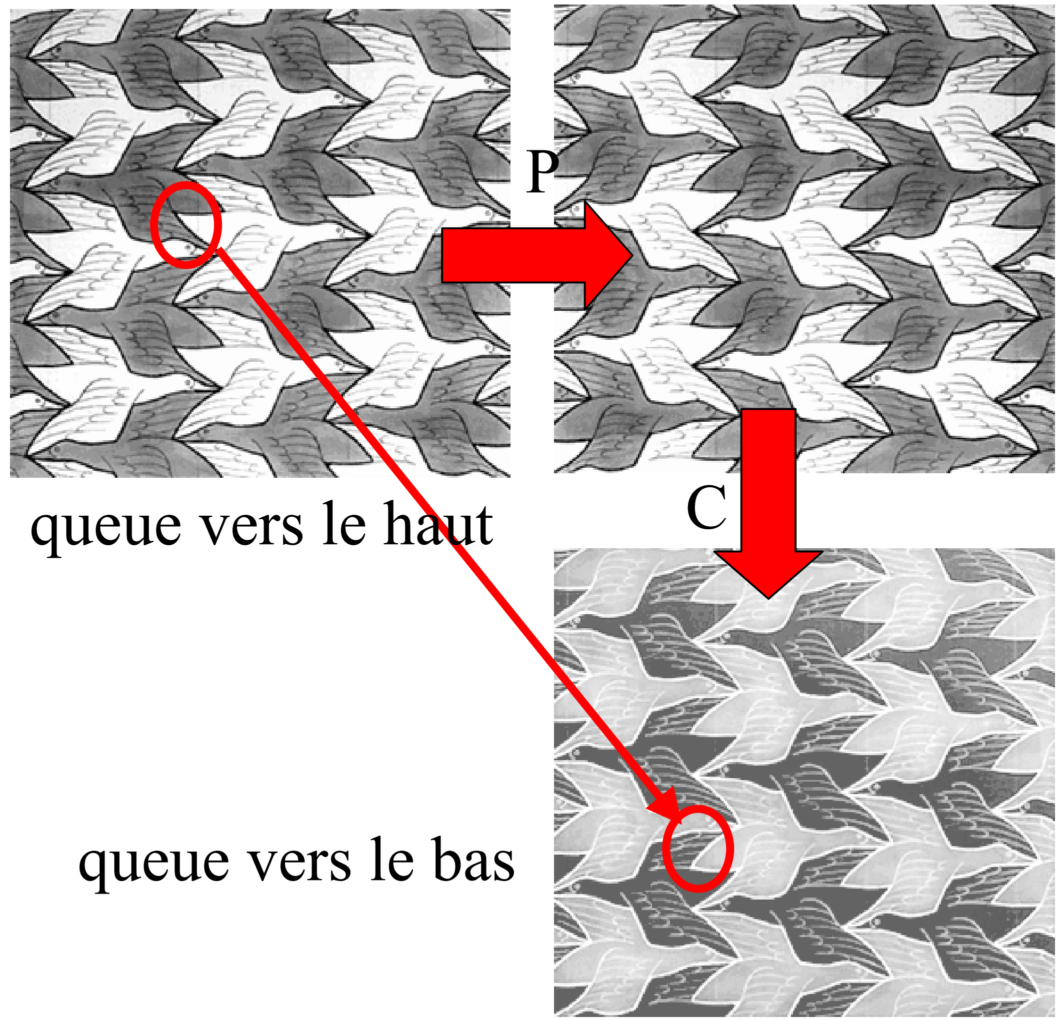


Illustration de violation de CP

La violation de CP

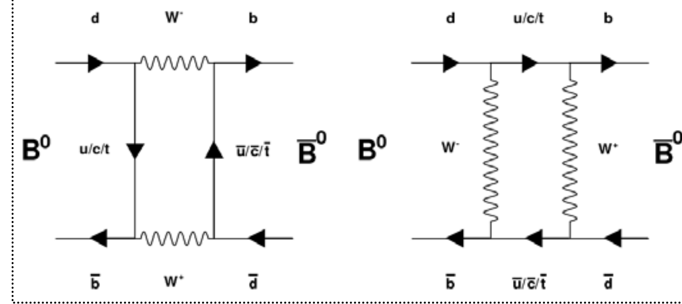


oie blanche:



Dessins d’Escher

La violation de CP



- Conjugaison **C**: Q → -Q
- Parité : **P** (x,y,z) → (-x,-y,-z)
- Inversion temps: **T** t → -t

- directe (« désintégration »)

$P(B \rightarrow f) \neq P(\bar{B} \rightarrow \bar{f})$

$B^0 \longrightarrow f$

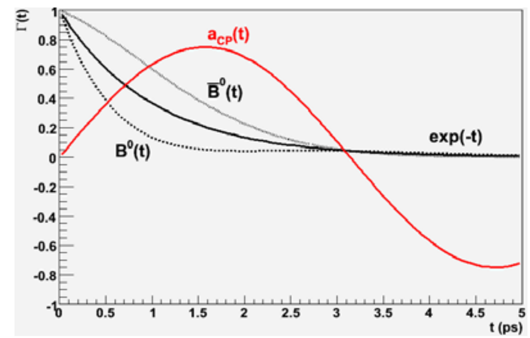
$\bar{B}^0 \overset{\neq}{\longrightarrow} \bar{f}$

- indirecte (« mélange »)

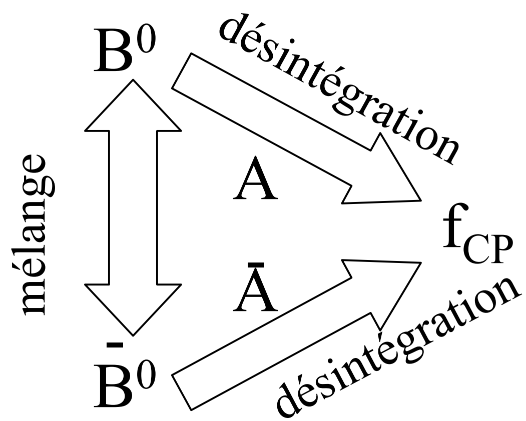
$P(B \rightarrow \bar{B}) \neq P(\bar{B} \rightarrow B)$

$B^0 \longrightarrow \bar{B}^0$

$\bar{B}^0 \overset{\neq}{\longrightarrow} B^0$



- interf. entre désintégrations avec et sans mélange



Histoire violation CP

1949, Powell puzzle τ/θ

1954, Lüders, Pauli, Schwinger : CPT conservé

balbutiements

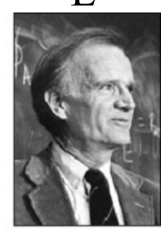
1956, Lee, Yang, tester conservation P
(<1957, P, C, T dites « conservés »)

1957: Wu, violation P dans ^{60}Co

Violation P

<1964: CP « ~~conservé~~ »:CP pair: $K_S \rightarrow \pi^+\pi^-$, CP impair: $K_L \rightarrow \pi^+\pi^-\pi^0$

1964, Christenson, Cronin, Fitch, Turlay



violation CP indirecte/mélange dans kaons neutres
$K_L \rightarrow \pi^+\pi^-$ ($\sim 10^{-3}$)

Violation CP

>1964, CPT conservé, C, P, CP violé par interaction faible

~~CP~~: principe fondamental ou « accident » ?

- fondamental → <u>indépendamment du mélange</u>

K

1998: violation T dans kaons neutres CPLEAR

(1993), 1999: violation CP directe dans kaons neutres (NA31, E731), KTEV, NA48

- fondamental → <u>d'autres systèmes</u>

1975, Pais, Treiman: prédiction ~~CP~~ faible dans saveurs lourdes (c, b) (mélange seul)

B

1981, Bigi, Carter, Sanda: prédiction ~~CP~~ >> dans interférence désintégration B → J/ψ K_S avec et sans mélange, possibilité mesure sin 2β

1987, Oddone, proposition usines à B asymétriques (f(t)) (1ères collisions, 1999)

2001: violation CP interférence, B neutres $B^0 \to J/\psi\, K_S$ Babar, Belle

2004: violation CP directe dans B neutres $B^0 \to K^+\pi^-$ Babar, Belle

Principales mesures de violation de CP

1973: Kobayashi, Maskawa, mélange quarks : (+Cabbibo 1963)

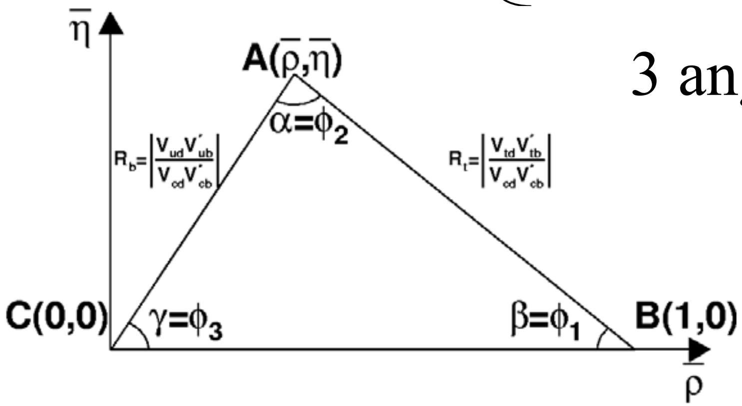
état propre interaction faible $\neq$ état propre masse

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

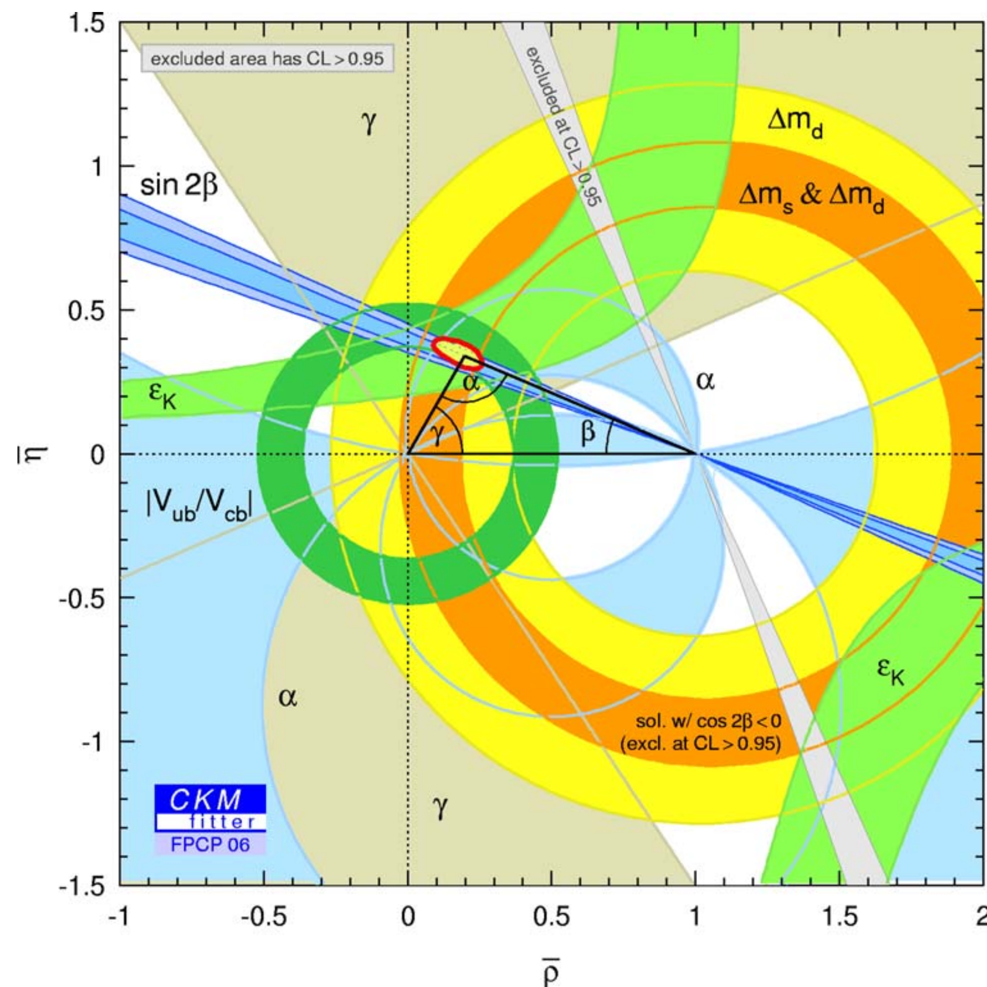
Présence d'une phase
→violation CP

La matrice CKM et le triangle d'unitarité

V_{CKM}, unitaire $\begin{cases} V^\dagger V = 1 & \rightarrow \text{triangle d'unitarité} \\ VV^\dagger = 1 & V_{ub}^* V_{ud} + V_{cb}^* V_{cd} + V_{tb}^* V_{td} = 0 \end{cases}$



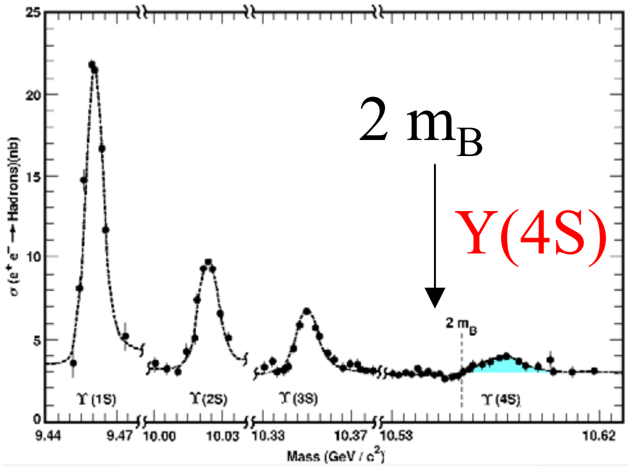
3 angles: α, β, γ

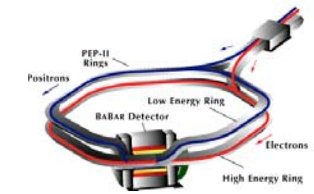


- $\alpha = 92.6^{+10.7}_{-9.3}$ °
- $\beta = 21.7 + 1.3 - 1.2$ ° ⟶ précis
- $\gamma = 62 + 38/-24$ °

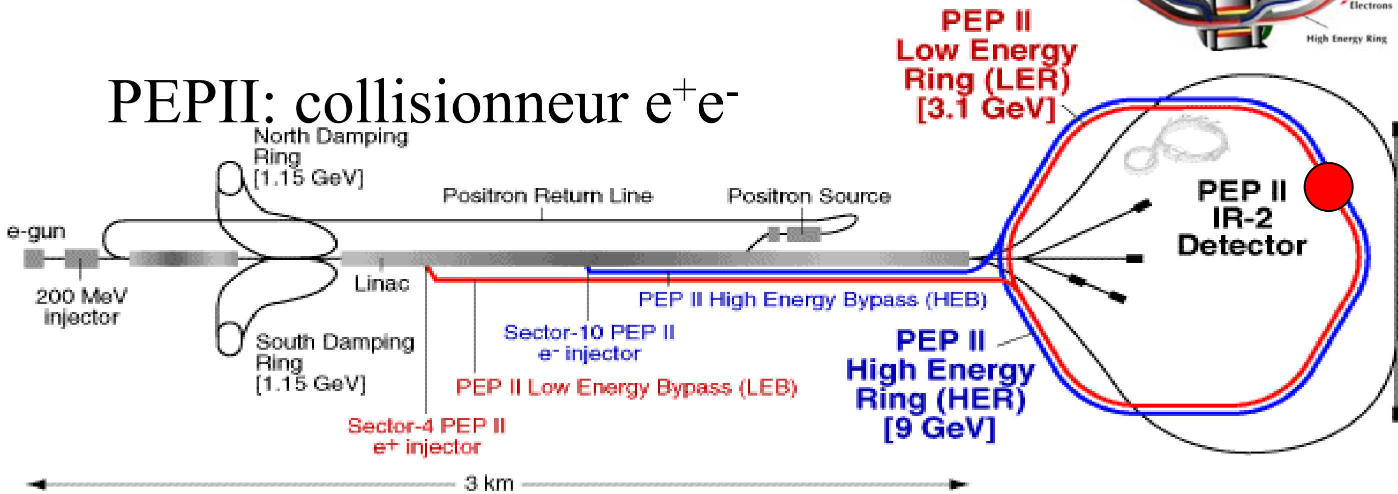
β: précis: mesurer avec méthodes ≠
→nouvelle physique ?
γ & α: modes rares, (plus de stat)

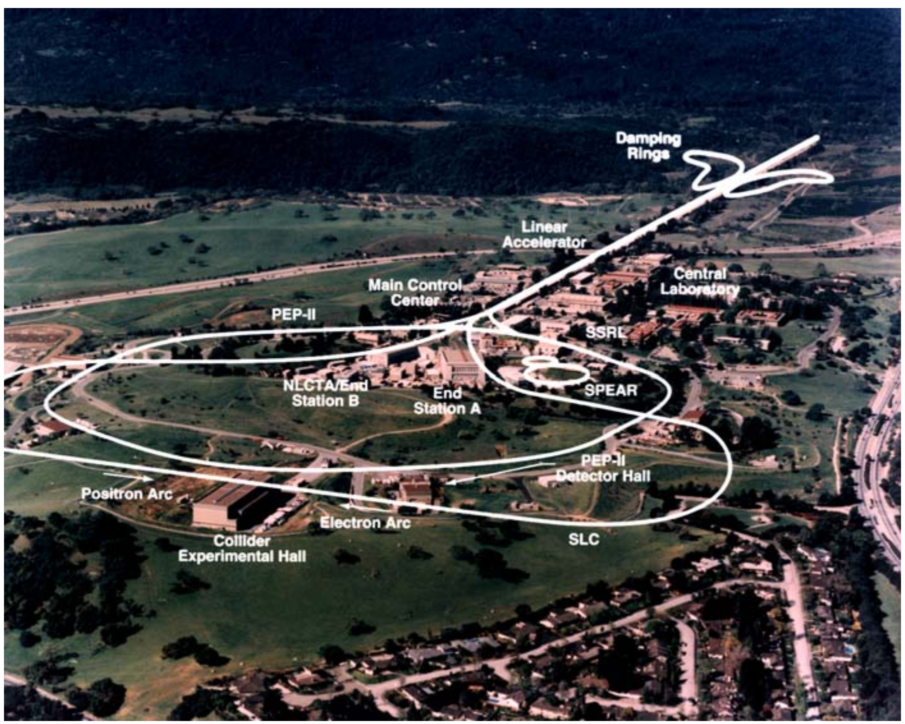
Expérience Babar

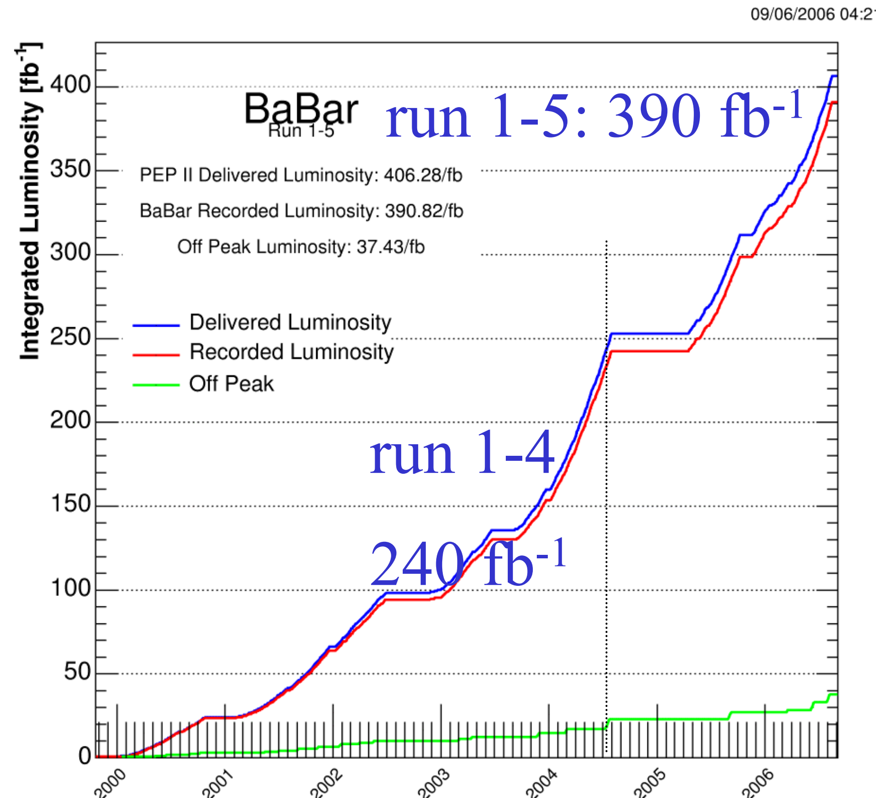




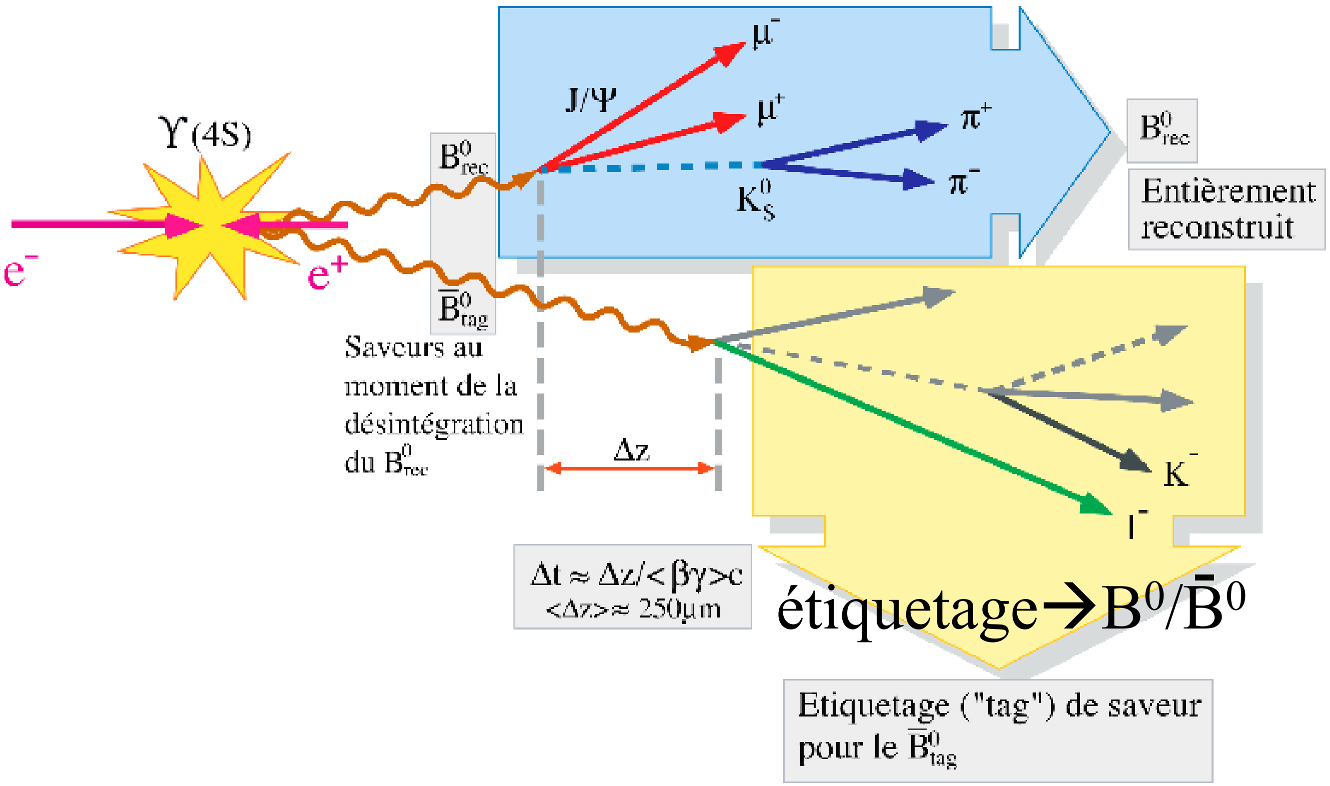
PEPII: collisionneur e^+e^-



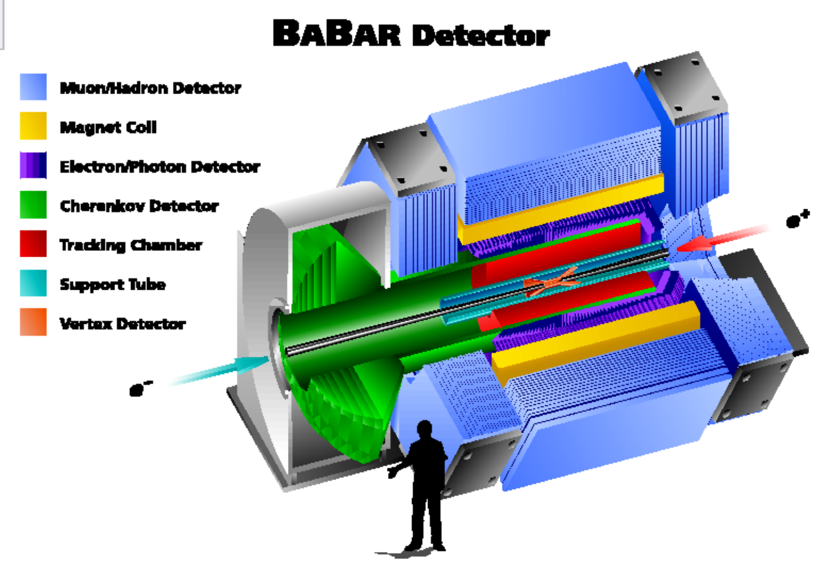




formalisme



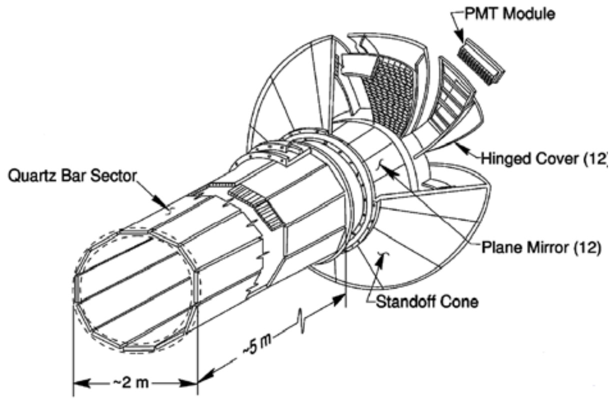
- Détecteur de vertex (SVT)
- Chambre à dérive (DCH)
- Détecteur Cerenkov (DIRC)
- Calorimètre électromagnétique (EMC)
- Aimant supraconducteur
- Retour de flux instrumenté (IFR)

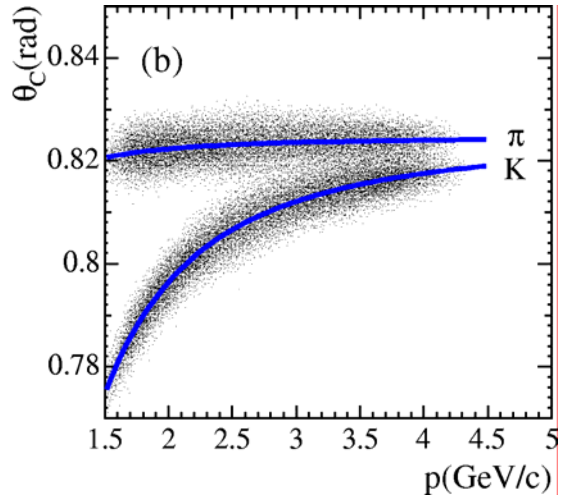


Signal selection

- Hadron ID→π/K separation

DIRC : Cerenkov angle





+dE/dx using DCH

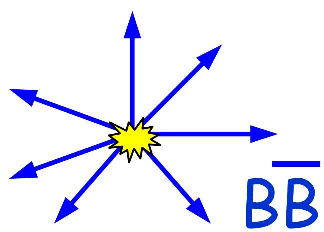
- Kinematical identification with
  - -Beam energy substituted mass
  - -Energy difference

$$m_{\mathrm{ES}} = \sqrt{E_{\mathrm{beam}}^{*2} - p_B^{*2}}$$

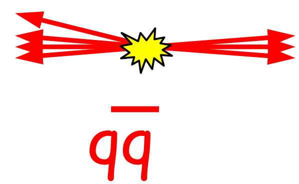
$$\Delta E = E_B^* - E_{\mathrm{beam}}^*$$

- Event-shape variables: neural network

'Spherical'



Jet



+mass-helicities

Extraction des paramètres

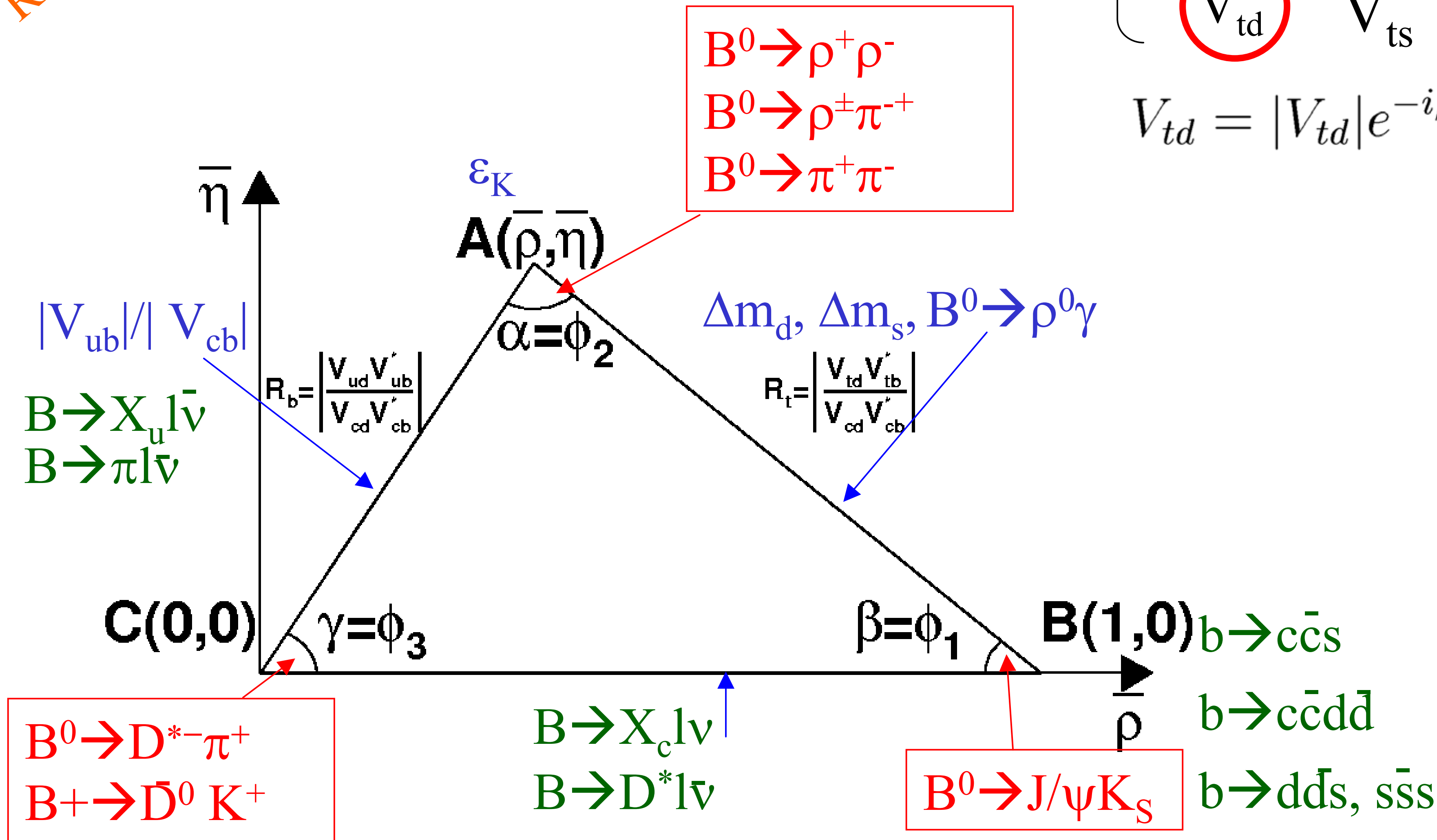
Revue analyses

- module élém matrice, + autr. contraintes
- angles: a_{CP}
- rapport des côtés: mélange B, $b \rightarrow u l \nu$

$$V_{ub} = |V_{ub}| e^{-i\gamma}$$

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$V_{td} = |V_{td}| e^{-i\beta}$$

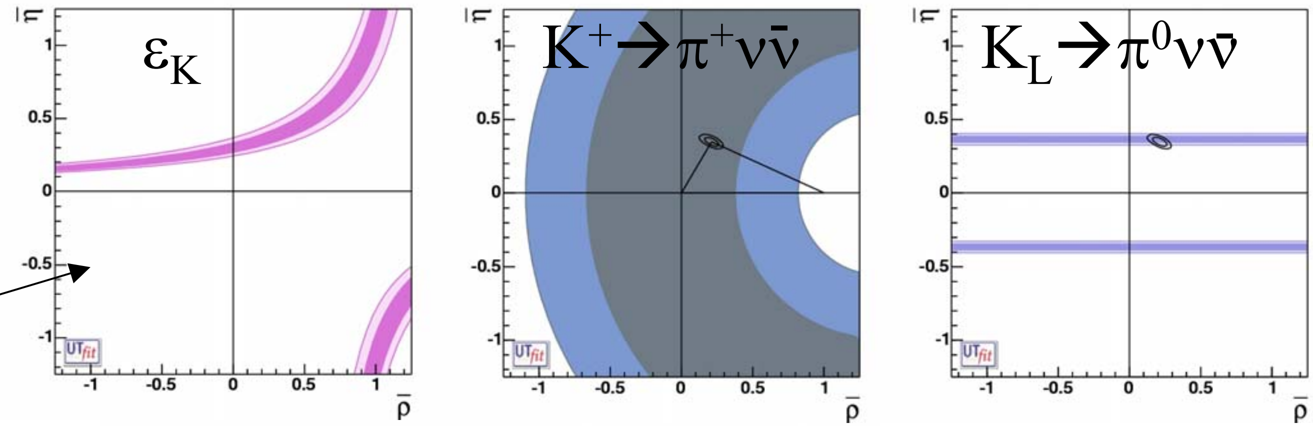


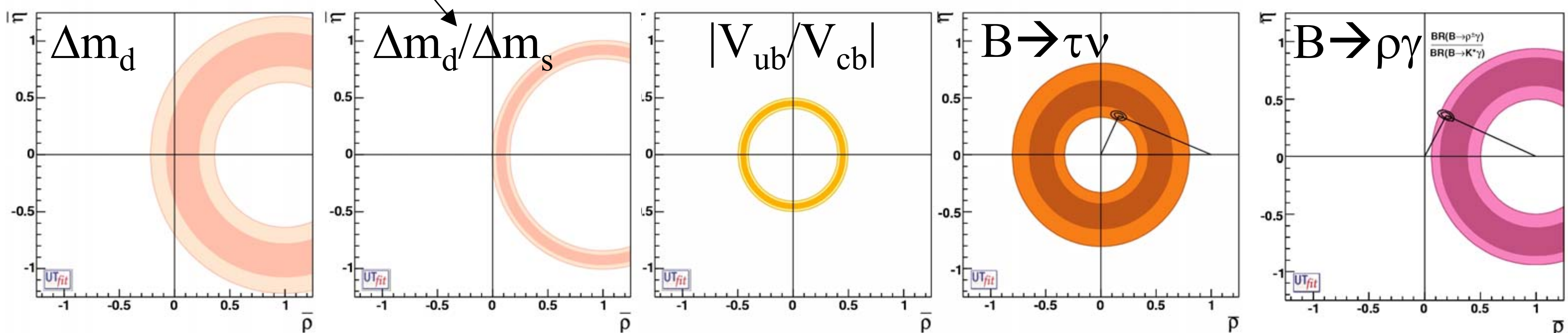
Mesures

(+ autres analyses)

- Mesures directes: V_{ij}

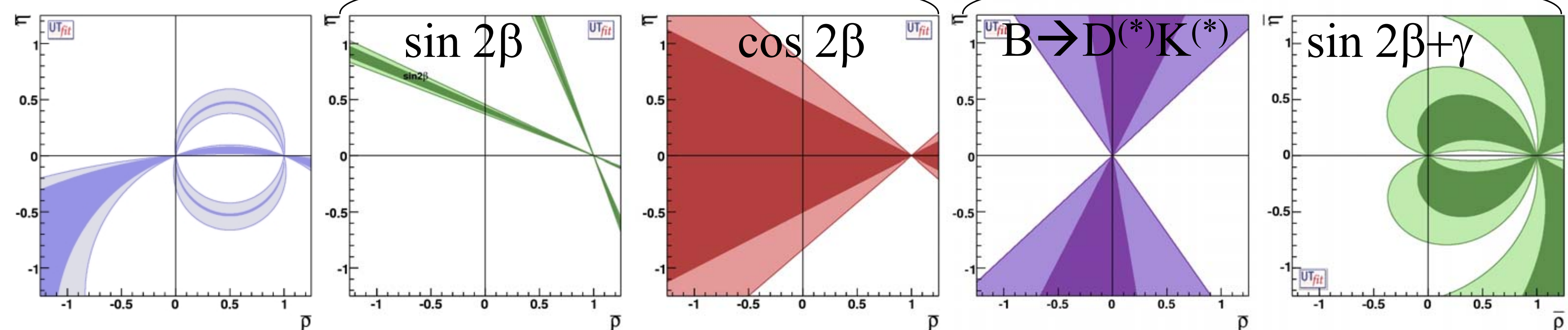
  (non dans Babar)





- Mesure des angles

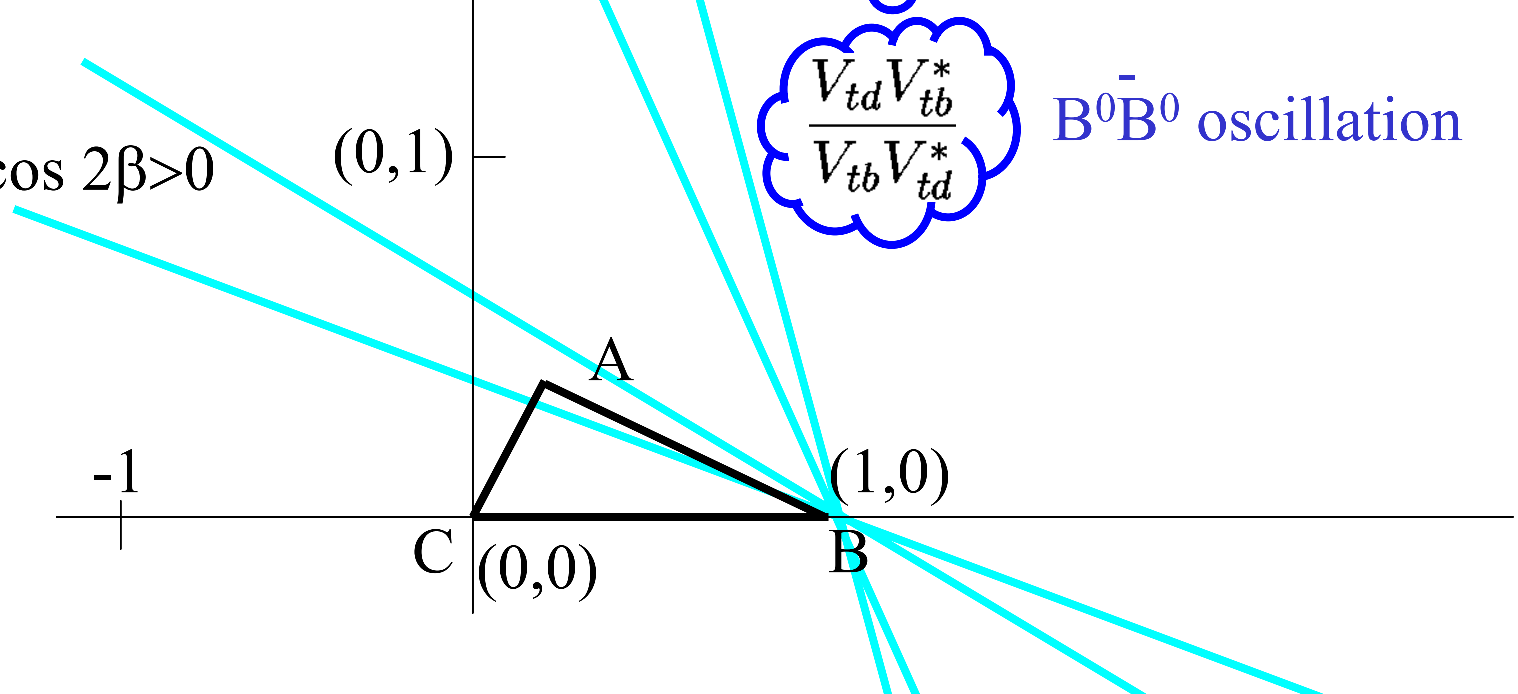
α β γ

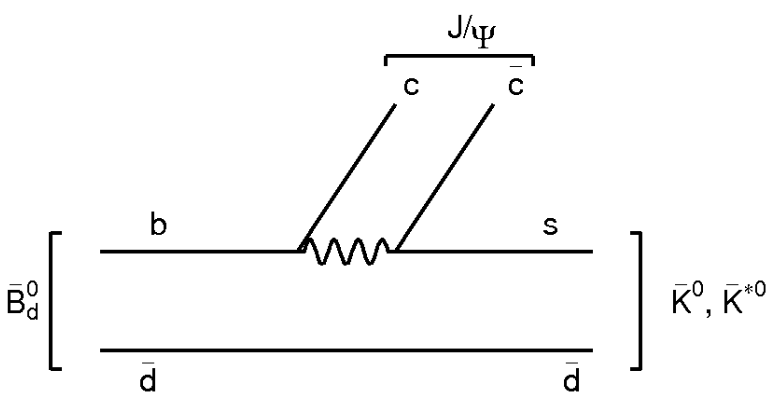


β

$$\beta = arg\left(-\frac{V_{cd}V_{cb}^*}{V_{tb}^*V_{td}}\right)$$

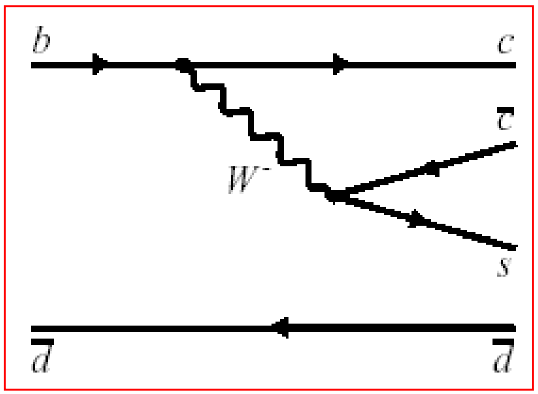
$$V_{td} = |V_{td}|e^{-i\beta}$$

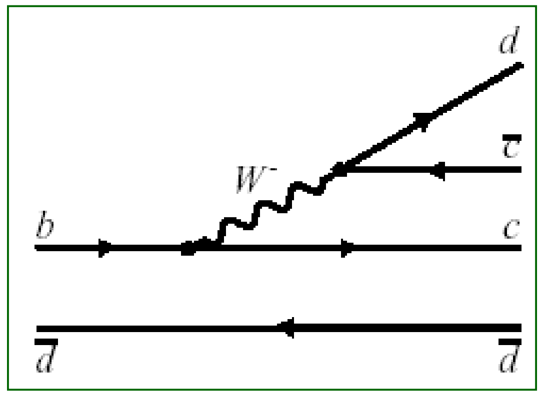


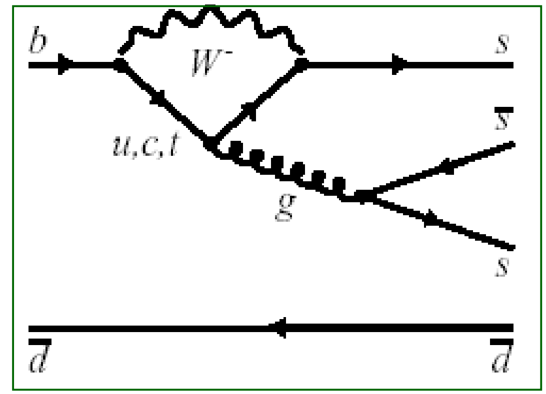


➔B➔J/Ψ K_S

$b \to c\bar{c}s$	$b \to c\bar{c}d$	$b \to d\bar{d}s$, $s\bar{s}s$
charmonium	charm et charmonium	dominé pingouin
dominé arbre	présence pingouin	dominé pingouin







$J/\psi K_S^0$ (canal en or)

$\psi(2S)K_S^0, \chi_{c1}K_S^0, \eta_c K_S^0$

$J/\psi K_L^0$

$J/\psi K^{*0}(K^{*0} \to K_S^0\pi^0)$

$D^{*+}D^-, D^+D^-$

$J/\psi\pi^0, D^{*+}D^{*-}$

$\phi K^0, K^+K^-K_S^0,$

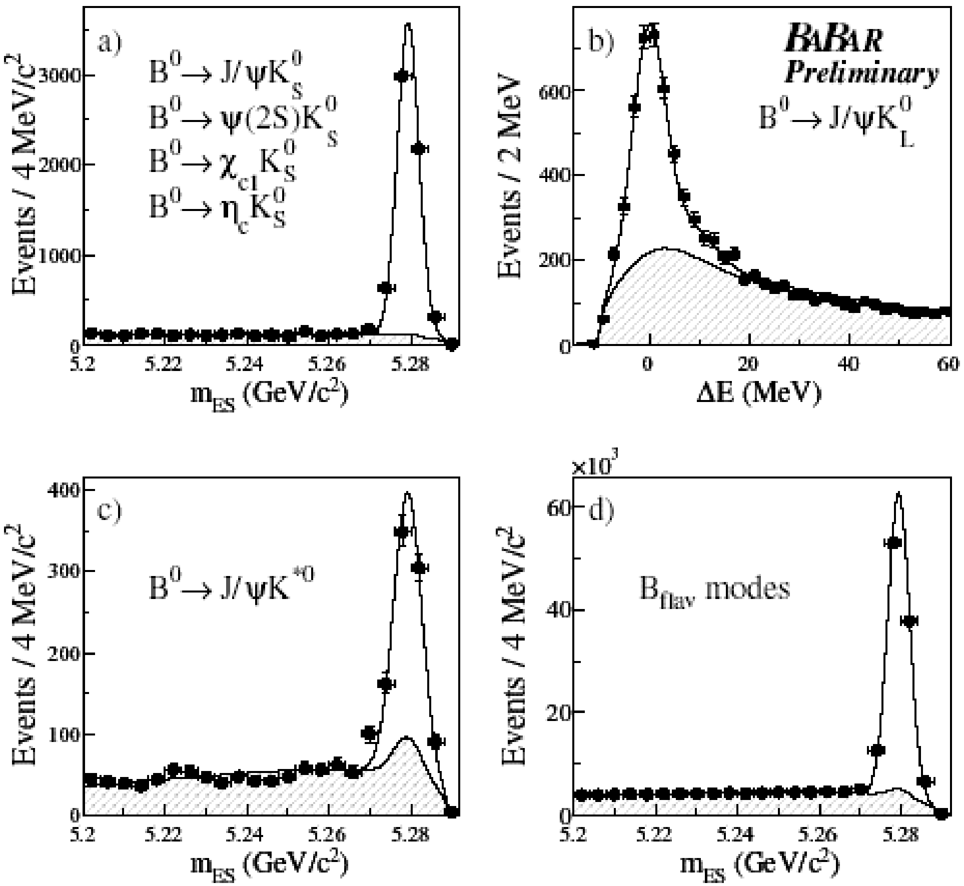
$K_S^0K_S^0K_S^0, \eta' K^0, K_S^0\pi^0,$

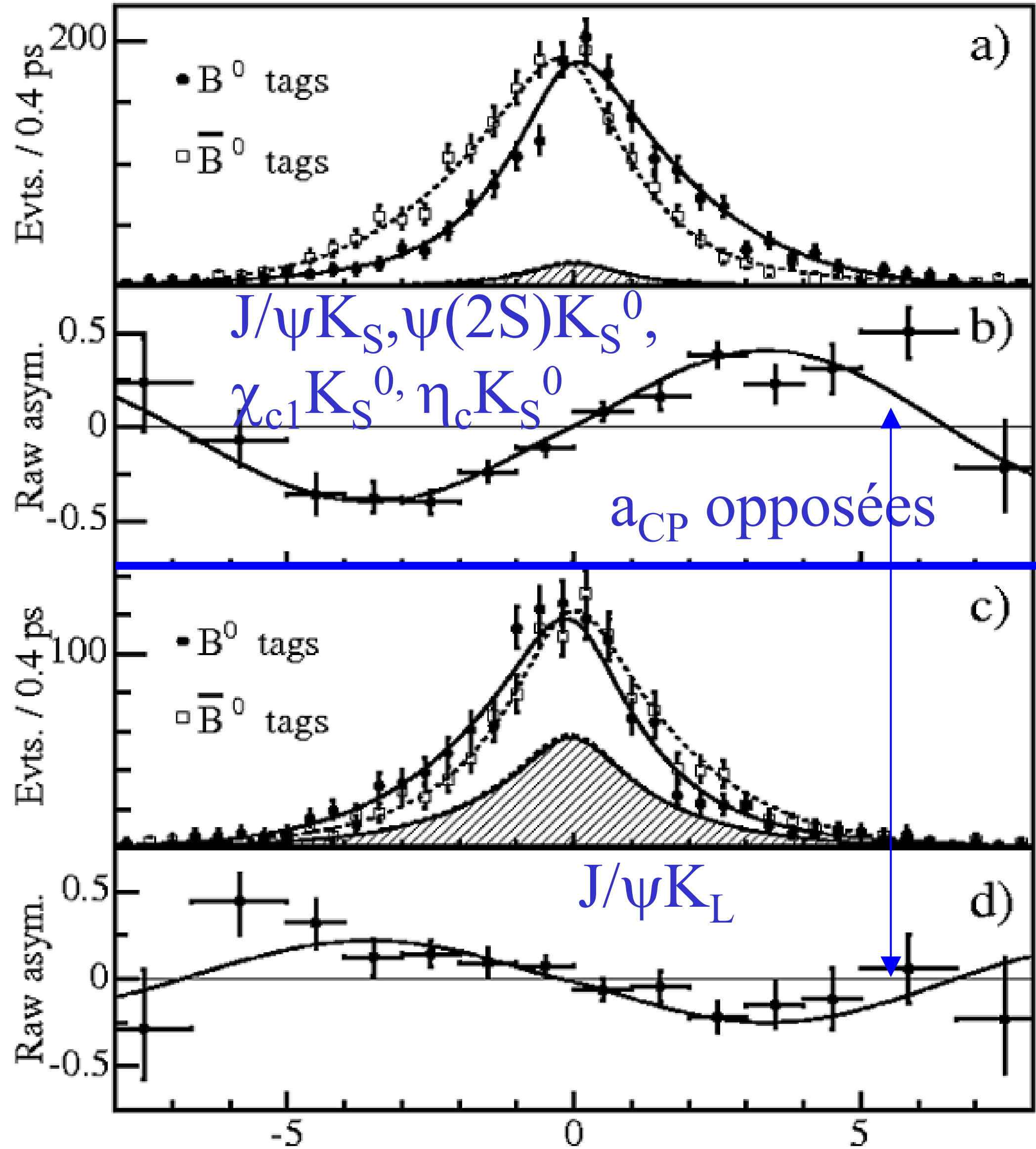
ωK_S^0, $f_0(980)K_S^0$,

$K_S^0K_S^0, \rho K_S^0$

nouveau: $B^0 \to \rho^0(770)K_S^0$

347×10^6 BB hep-ex/0607107





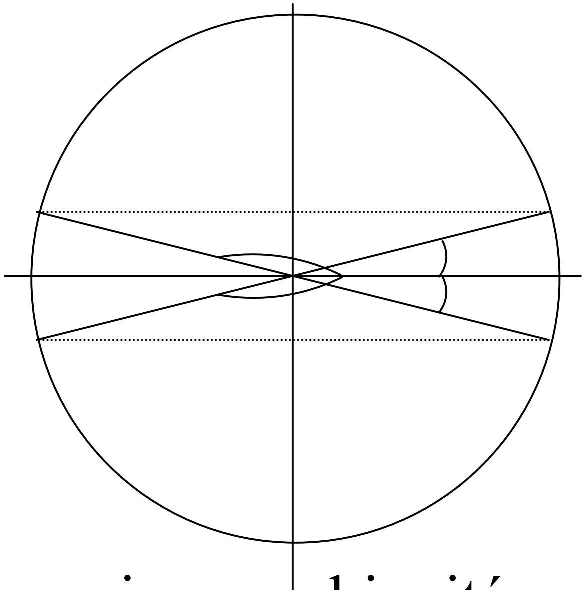
très propre expérimentalement,
BR importants (10^{-3}-10^{-4})

$$\sin 2\beta = 0.710 \pm 0.034 \pm 0.019$$

$$|\lambda| = 0.932 \pm 0.026 \pm 0.017$$

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

Ambiguités d'angle



soit ϕ un angle (α, β, γ)

Soit une mesure $|\sin 2\phi| = x$

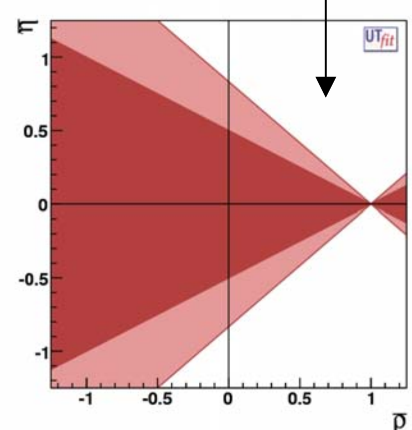
4 solutions: $\phi = z$, $\phi = z + \pi$, $\phi = \pi/2 - z$, $\phi = 3\pi/2 - z$

$\alpha + \beta + \gamma = \pi \rightarrow$ 16 solutions à γ sachant (α, β)

supprimer ambiguités:

- signe($\cos 2\phi$) $\rightarrow$ supprime ambiguité $\pi/2 - \phi$
- signe($\sin \phi$) $\rightarrow$ supprime ambiguité $\pi + \phi$

exclu



- analyse f(t) $B \rightarrow J/\psi\, K^{*0}$ ($K^{*0} \rightarrow K_s \pi^0$)
- $B^0 \rightarrow D^0 \pi^0$

$\rightarrow$ $\beta = (21.2 \pm 1.0)^\circ$ or $\cancel{(68.8 \pm 1.0)^\circ}$

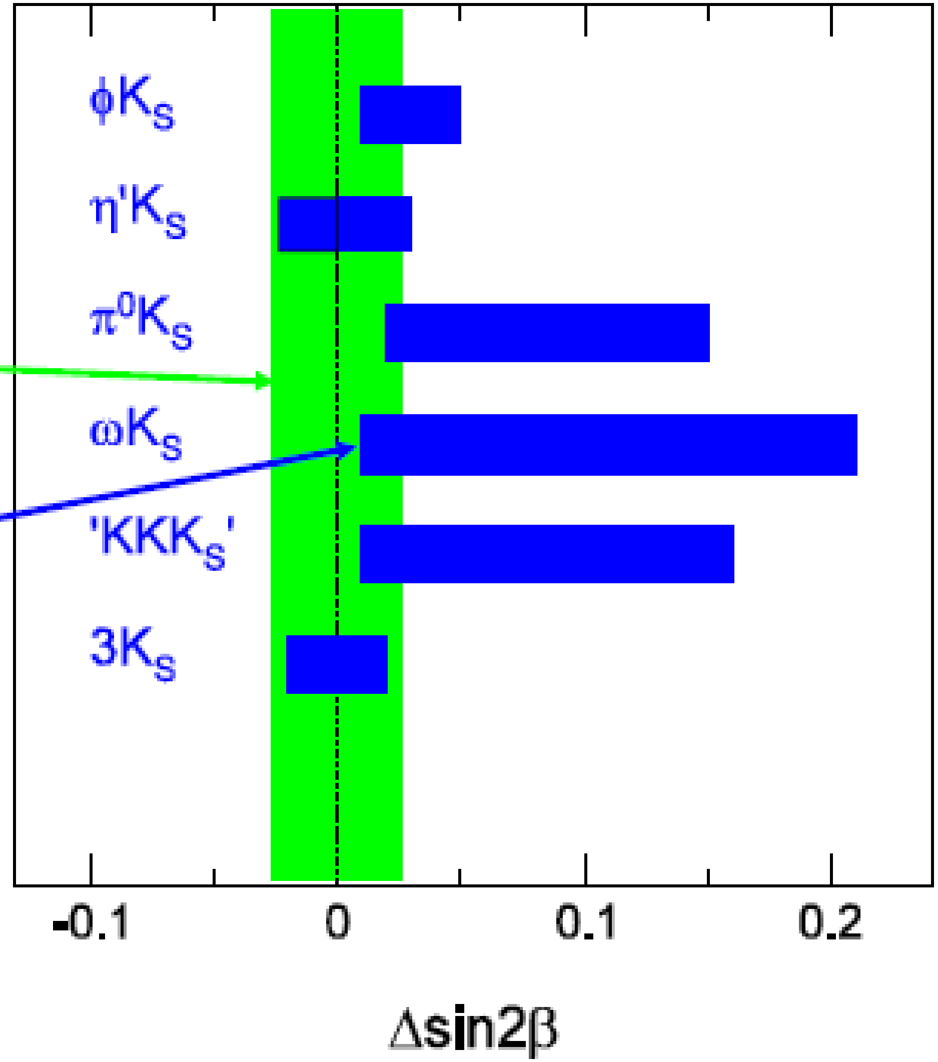
95% CL

sin2β from charmless B decays

Compare sin2β measured in penguin modes to sin2β from $(c\bar{c})K$

sin2β experimental uncertainty from $(c\bar{c})K$

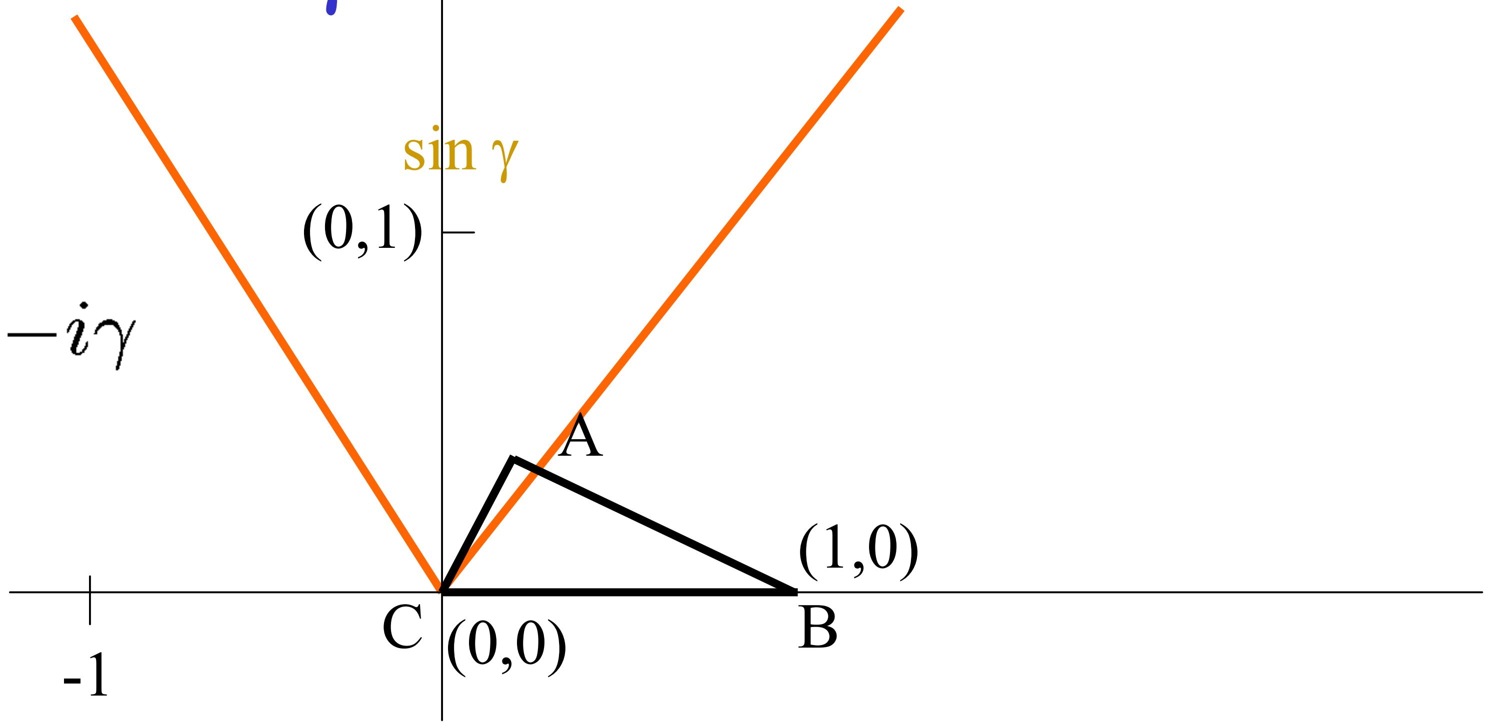
b→s penguin theory uncertainty



Beneke PLB 620 143 (2005)
Mishima, Sanda PRD 72 114005 (2005)
Williamson, Zupan PRD 74 014003 (2006)
Cheng, Chua, Soni PRD 014006 (2005)

Sin γ

$$V_{ub} = |V_{ub}| e^{-i\gamma}$$



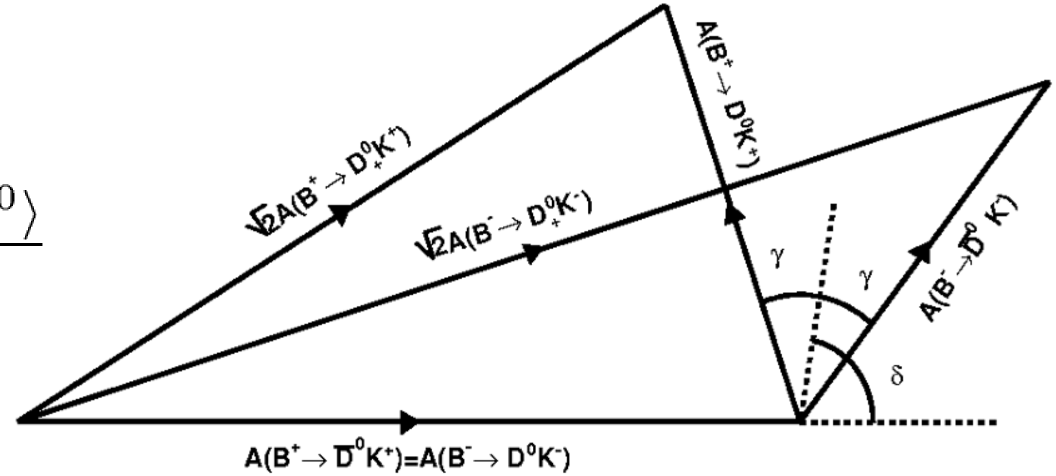
- Gronau, London, Wyler (GLW), 1991: $(D^0/\bar{D}^0)_{CP}\, K^{+-}$
- Aleksan, Dunietz, Kayser (ADK), 1992
- Atwood, Dunietz, Soni (ADS), 1997: $K^+K^-\pi^{+-}$
- GGSZ (Giri, Grossman, Soffer, Zupan), «Dalitz»: $(K_S{}^0\pi^+\pi^-)K^{+-}$
- sin (2β+γ) (analyse en temps de $B \rightarrow D^{(*)}\pi$)

GLW, ADS: comparer désintégrations $B \rightarrow D^{(*)}K$ avec V_{cb} et V_{ub}

GLW

États propres CP $|D^0_\pm\rangle = \frac{|D^0\rangle \pm |\bar{D}^0\rangle}{\sqrt{2}}$

deux quantités mesurant γ



- Asymétrie de CP

$$A_{CP\pm} = \frac{Br(B^- \to D^0_{CP\pm}K^-) - Br(B^+ \to D^0_{CP\pm}K^+)}{Br(B^- \to D^0_{CP\pm}K^-) + Br(B^+ \to D^0_{CP\pm}K^+)}$$

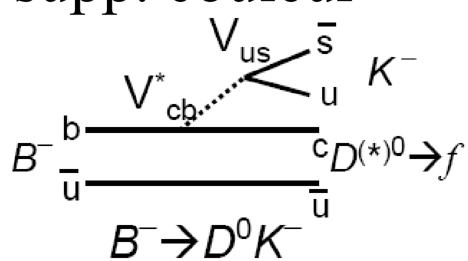
- $R_{CP\pm}$

$$R_{CP\pm} = \frac{Br(B^- \to D^0_{CP\pm}K^-) + Br(B^+ \to D^0_{CP\pm}K^+)}{[Br(B^- \to D^0K^-) + Br(B^+ \to \bar{D}^0K^+)]/2}$$

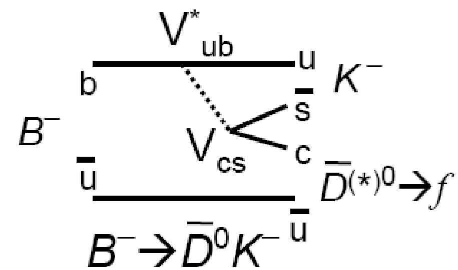
$=f(\gamma)$

r_B: rapport sup/fav

supp. couleur



fav. couleur



Propre théoriquement (pas de pingouin), pas d'incertitudes hadroniques. r_B faible→faible sensibilité à γ. Br faibles: stat limitée. Ambiguité d'ordre 8 sur γ

ADS

Atwood, Dunietz, Soni hep-ph/9612433, hep-ph/0008090

Inconvénient de GLW: r_B faible

$r_B = |A(B^- \rightarrow \bar{D}^0 K^-)/A(B^- \rightarrow D^0 K^-)|$

Idée: rendre ces rapports plus proches:

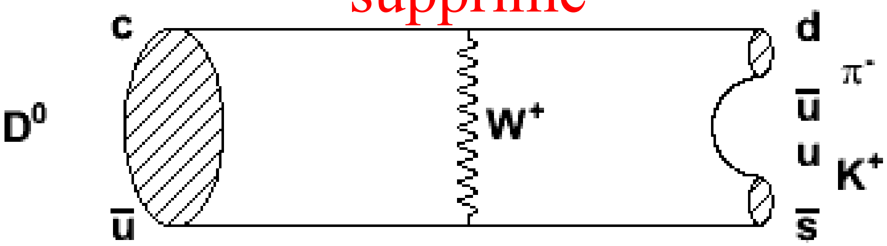
$B^- \rightarrow D^0 K^-$ (favorisé) & $D^0 \rightarrow K^+\pi^-$ supprimé

$B^- \rightarrow \bar{D}^0 K^-$ (supprimé) & $\bar{D}^0 \rightarrow K^+\pi^-$ favorisé

$B^+ \rightarrow \bar{D}^0 K^+$ (favorisé) & $\bar{D}^0 \rightarrow K^-\pi^+$ supprimé

$B^+ \rightarrow D^0 K^+$ (supprimé) & $D^0 \rightarrow K^-\pi^+$ favorisé

supprimé



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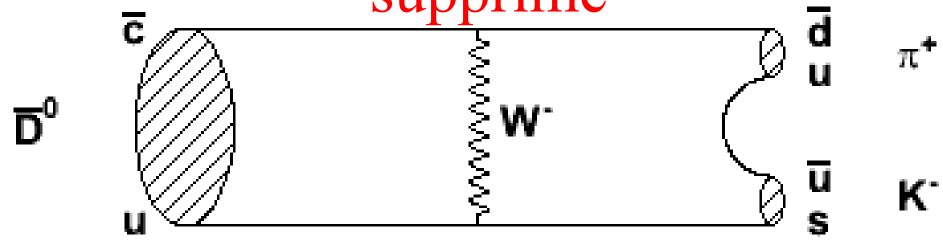
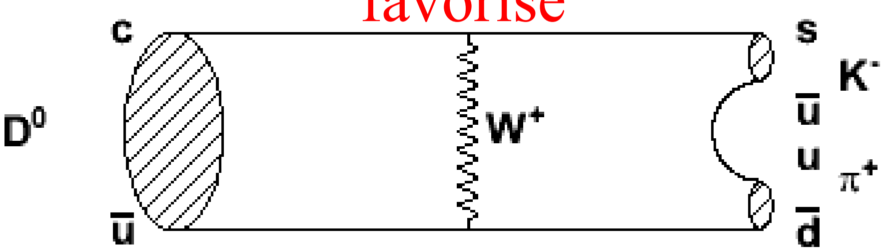
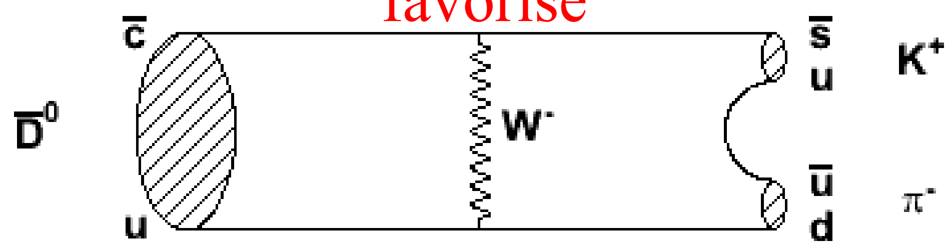


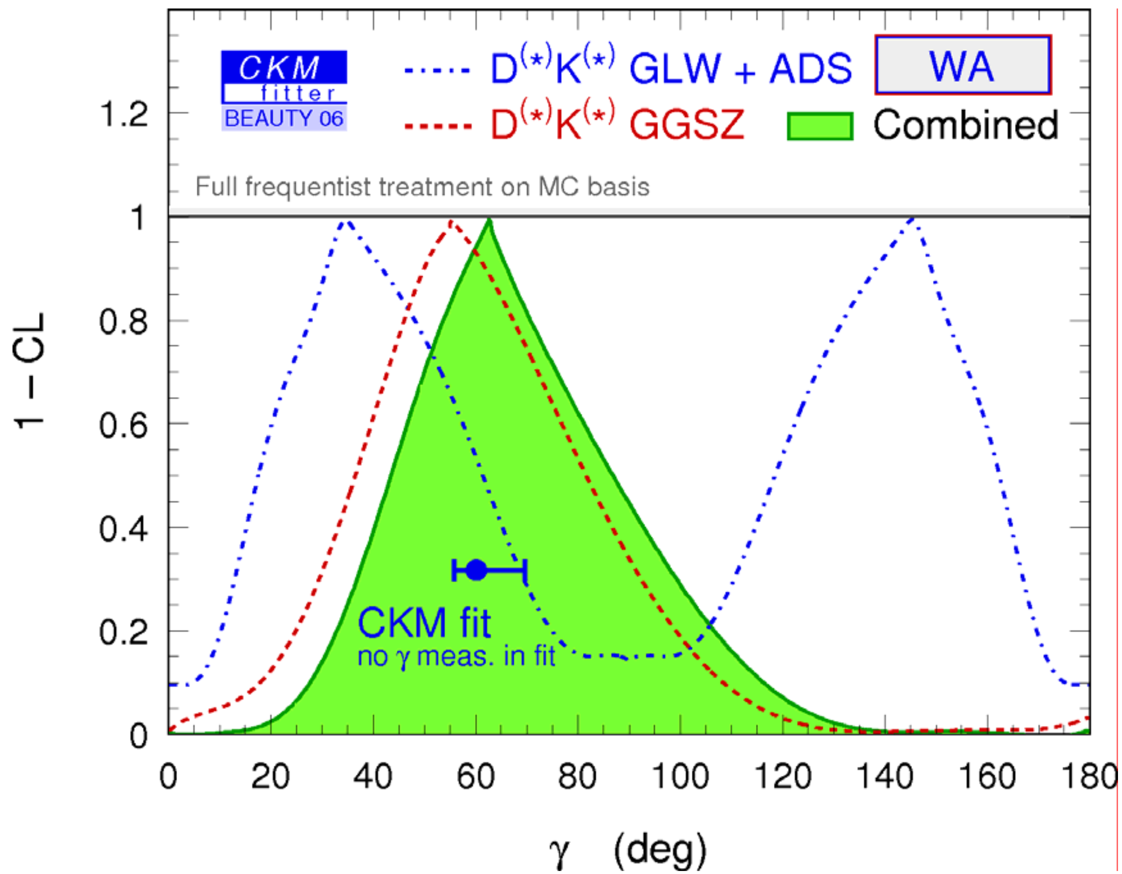
favorisé



favorisé



Résultats γ



62 +38/–24 deg

Extraction de α

$$\alpha = arg\left(-\frac{V_{td}V_{tb}^{*}}{V_{ud}V_{ub}^{*}}\right)$$

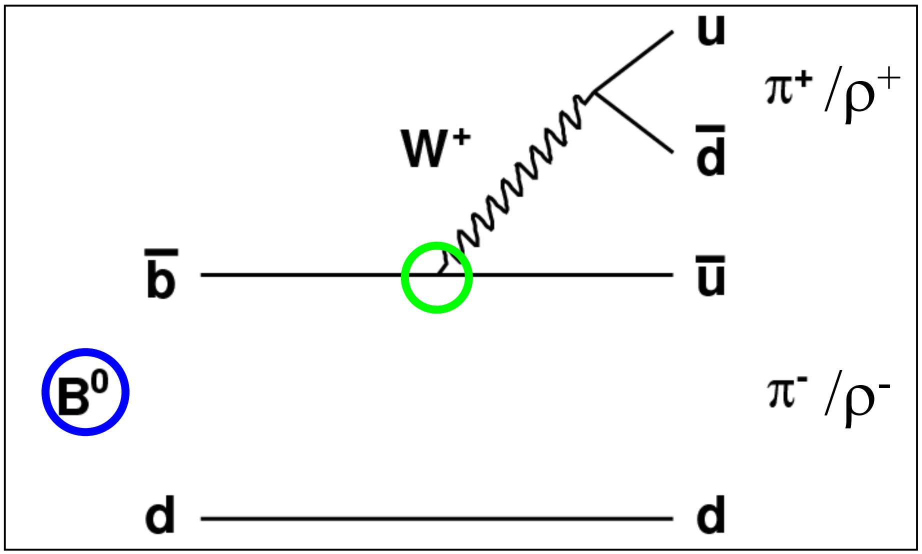
$$V_{td} = |V_{td}|e^{-i\beta}$$

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

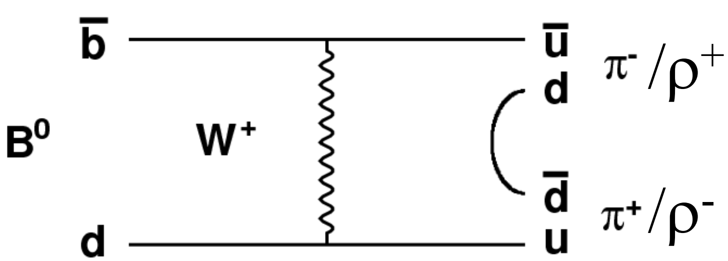
$B^0\bar{B}^0$ oscillation

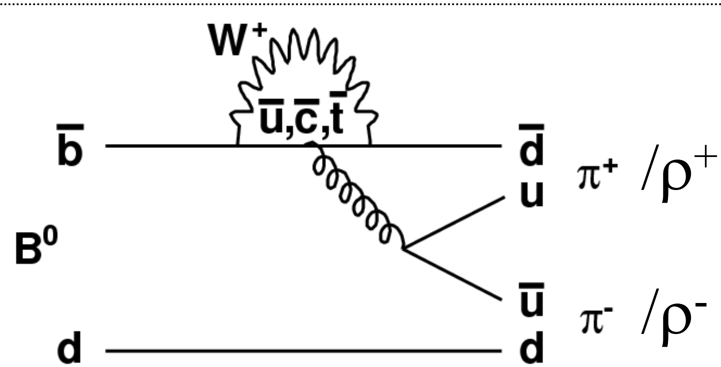
$$V_{ub} = |V_{ub}|e^{-i\gamma}$$

$\alpha \sim (\beta+\gamma)$



- $B^0/\bar{B}^0 \rightarrow \pi^+\pi^-$
- $B^0/\bar{B}^0 \rightarrow \rho^{\pm}\pi^{-+}$
- $B^0/\bar{B}^0 \rightarrow \rho^+\rho^-$

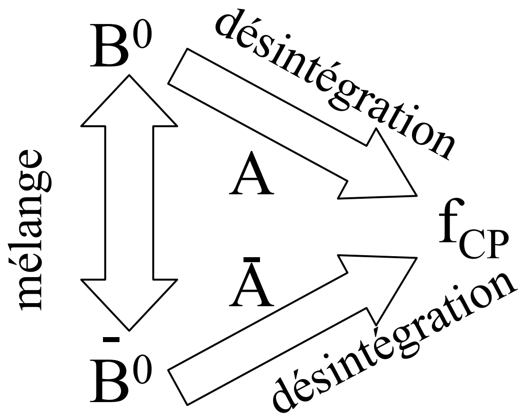
\+ 

\+ 

penguin

$\rightarrow \alpha_{eff}$

Violation de CP dans interférence entre désintég. avec & sans mélange



$$\lambda = \frac{q}{p}\frac{\langle f|H|\bar{M}^0\rangle}{\langle f|H|M^0\rangle}$$

≠ conventions

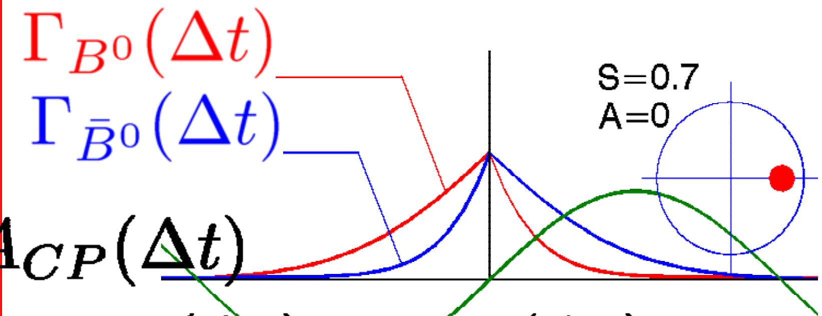
$$a_{CP}(t) = \frac{|\langle f|H|M^0_{phys}(t)\rangle|^2 - |\langle f|H|\bar{M}^0_{phys}(t)\rangle|^2}{|\langle f|H|M^0_{phys}(t)\rangle|^2 + |\langle f|H|\bar{M}^0_{phys}(t)\rangle|^2}$$

Si |q/p|~1 (vrai pour B, faux pour K)

$$a_{CP}(t) = -\boxed{C_f}\cos\Delta m t + \boxed{S_f}\sin\Delta m t$$

$$C_f = \frac{1-|\lambda|^2}{1+|\lambda|^2} \qquad S_f = \frac{-2Im\lambda}{1+|\lambda|^2}$$

$\cancel{C}$P directe $\qquad$ $\cancel{C}$P mélange

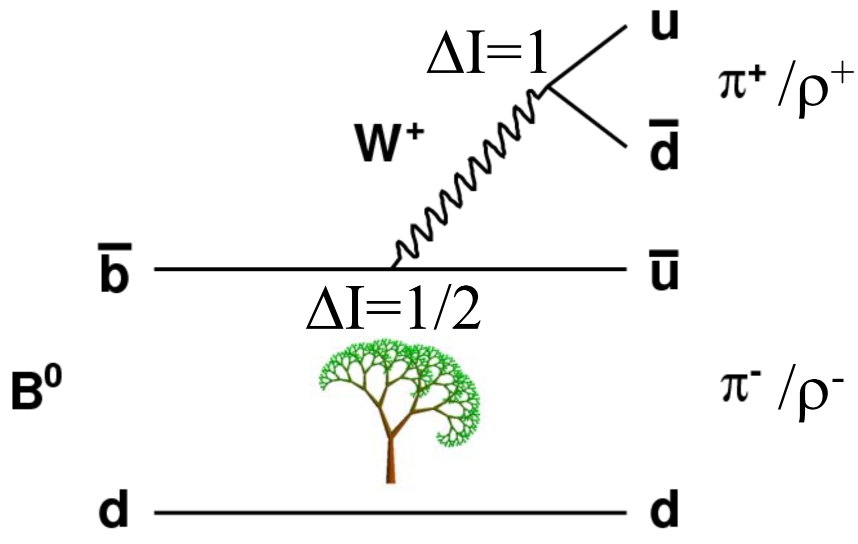


$$A_{CP}(\Delta t) \equiv \frac{\Gamma_{\bar{B}^0}(\Delta t) - \Gamma_{B^0}(\Delta t)}{\Gamma_{\bar{B}^0}(\Delta t) + \Gamma_{B^0}(\Delta t)} = \mathcal{S}\sin\Delta m\Delta t + \mathcal{A}\cos\Delta m\Delta$$

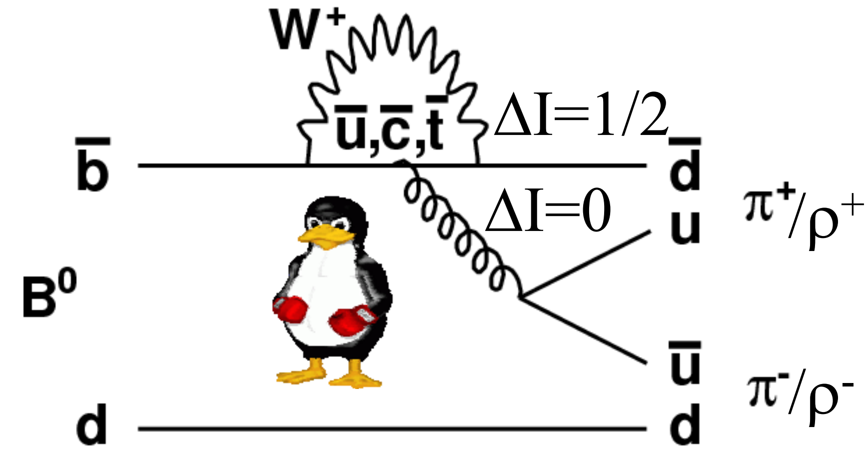
Babar/Belle: ≠ conventions $\qquad$ A=-C (Belle)

Isospin method

Gronau, London (1990)



tree: ΔI=1/2; 3/2



penguin: ΔI=1/2

strategy: use isospin relationship to remove penguin pollution

$$\langle\pi^+\pi^-|H_W|B^0\rangle = -\sqrt{\tfrac{1}{3}}A_{1/2,0} + \sqrt{\tfrac{1}{6}}A_{3/2,2} - \sqrt{\tfrac{1}{6}}A_{5/2,2}$$

$$\langle\pi^0\pi^0|H_W|B^0\rangle = \sqrt{\tfrac{1}{6}}A_{1/2,0} + \sqrt{\tfrac{1}{3}}A_{3/2,2} - \sqrt{\tfrac{1}{3}}A_{5/2,2}$$

$$\langle\pi^+\pi^0|H_W|B^+\rangle = \tfrac{\sqrt{3}}{2}A_{3/2,2} + \sqrt{\tfrac{1}{3}}A_{5/2,2}$$

$$\boxed{\frac{1}{\sqrt{2}}\langle\pi^+\pi^-|H_W|B^0\rangle + \langle\pi^0\pi^0|H_W|B^0\rangle = \langle\pi^+\pi^0|H_W|B^+\rangle}$$

Idem for ρρ

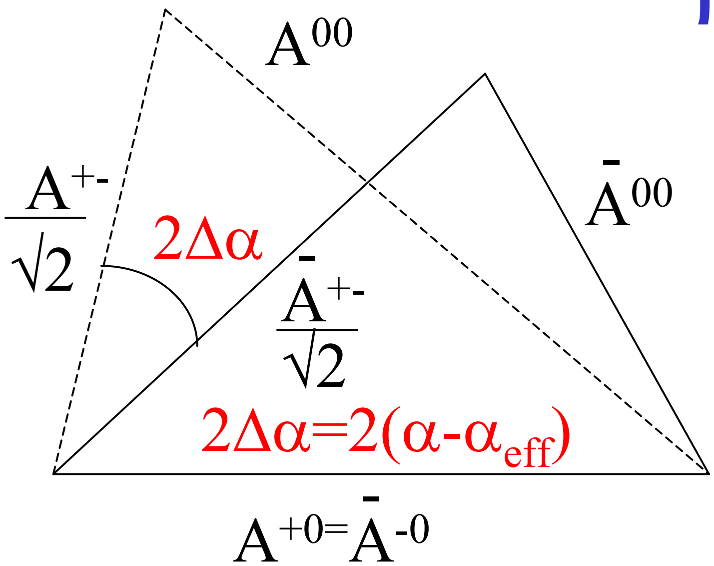
($A_{1/2}$=penguin)

($A_{5/2}$=NP)

→triangle **only** if $A_{5/2}=0$

$\rho\rho/\pi\pi$

similar approach to $B \to \pi\pi$: Gronau, London (1990)



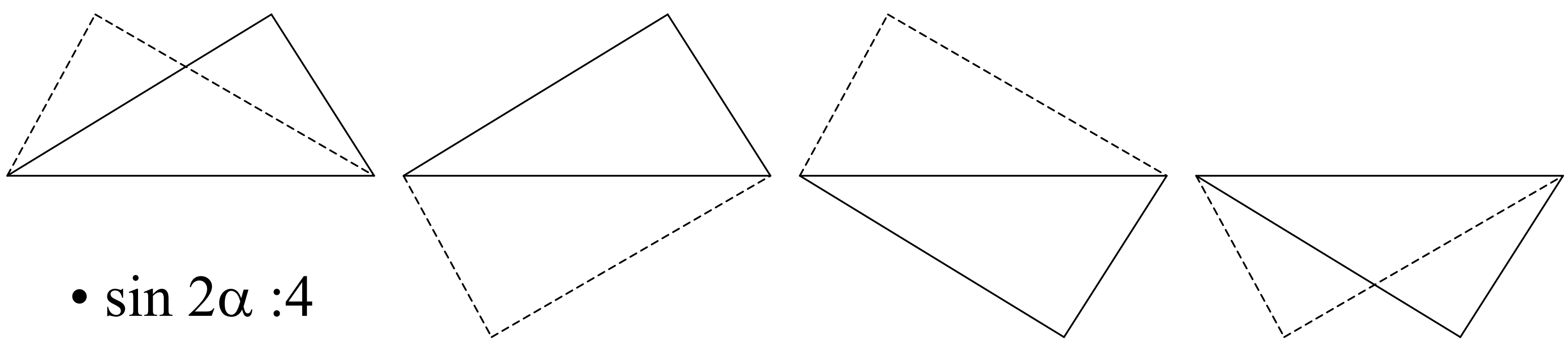
$A^{+-}=A(B^0 \to \rho^+\rho^-)$
$\bar{A}^{+-}=A(\bar{B}^0 \to \rho^+\rho^-)$
$A^{00}=A(B^0 \to \rho^0\rho^0)$
$\bar{A}^{00}=A(\bar{B}^0 \to \rho^0\rho^0)$
$\} \to \pi^+\pi^-\pi^+\pi^-$(vertex$\neq \pi^0\pi^0$) measure C^{00} & S^{00}

$A^{+0}=A(B^+ \to \rho^+\rho^0)$
$\bar{A}^{-0}=A(B^- \to \rho^-\rho^0)$
$\}$ = because tree (EW penguin<<1)

$$A_{Long}(B^+ \to \rho^+\rho^0) = 1/\sqrt{2} \cdot A_{Long}(B^0 \to \rho^-\rho^+) + A_{Long}(B^0 \to \rho^0\rho^0)$$

8-fold ambiguity

- triangles flip up/down:4

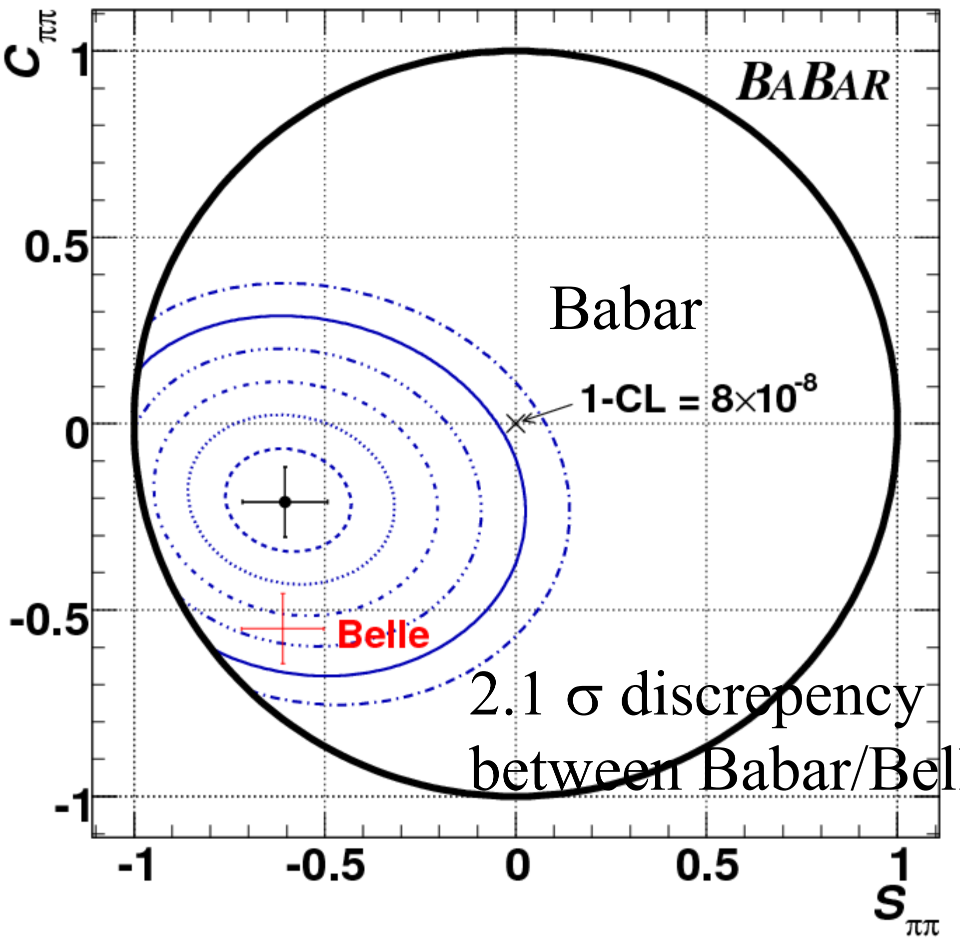


- sin 2α :4

$\phi=z$, $\phi=z+\pi$, $\phi=\pi/2-z$, $\phi=3\pi/2-z$

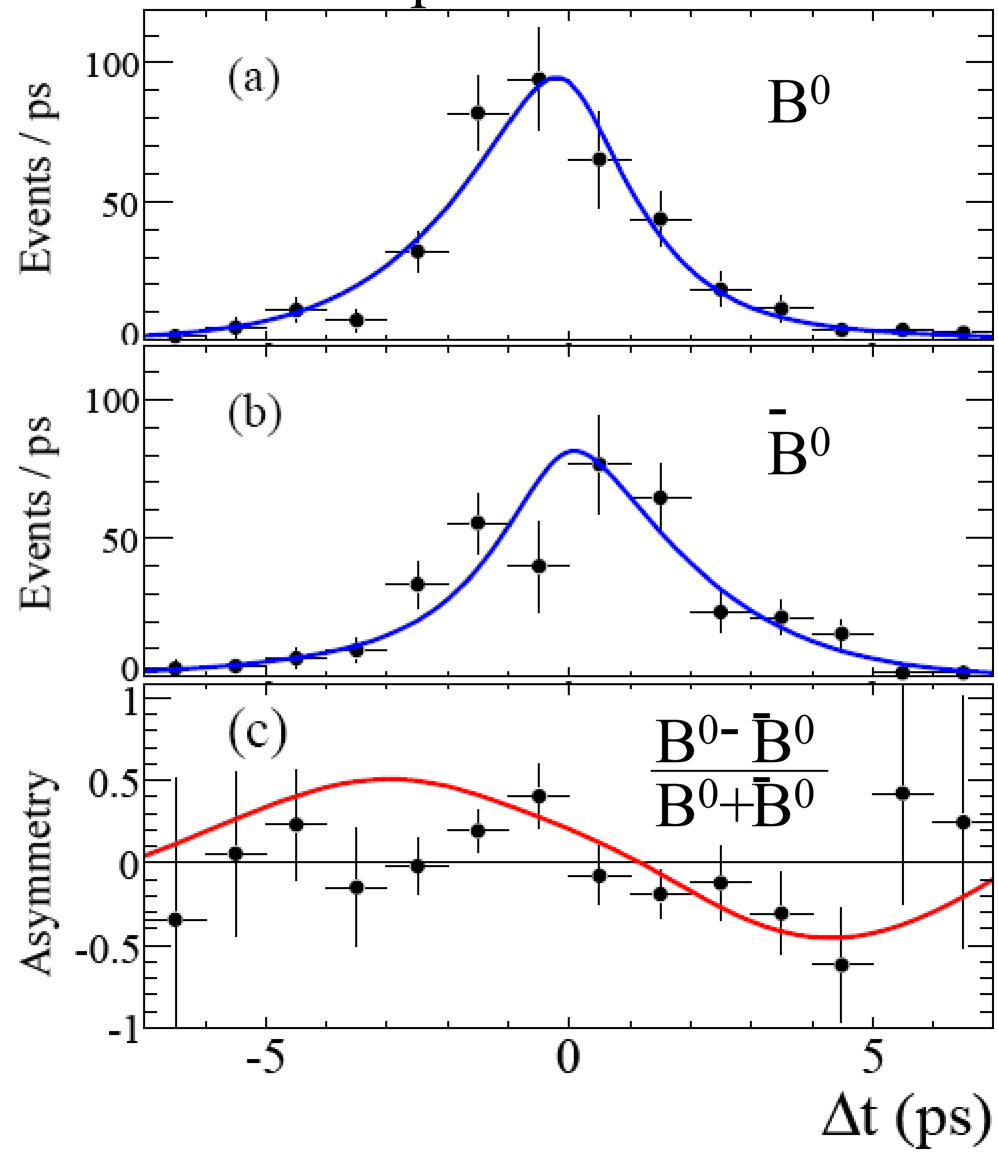
$B^0 \rightarrow \pi^+\pi^-$

383 Millions $B\bar{B}$



2.1 σ discrepency between Babar/Belle

hep-ex 0703016



$$\mathcal{A}_{K\pi} = -0.107 \pm 0.018\,(\mathrm{stat})^{+0.007}_{-0.004}\,(\mathrm{syst}),$$
$$S_{\pi\pi} = -0.60 \pm 0.11\,(\mathrm{stat}) \pm 0.03\,(\mathrm{syst}),$$
$$C_{\pi\pi} = -0.21 \pm 0.09\,(\mathrm{stat}) \pm 0.02\,(\mathrm{syst}).$$

S, C≠ 0 : 5,4 σ direct CP violation

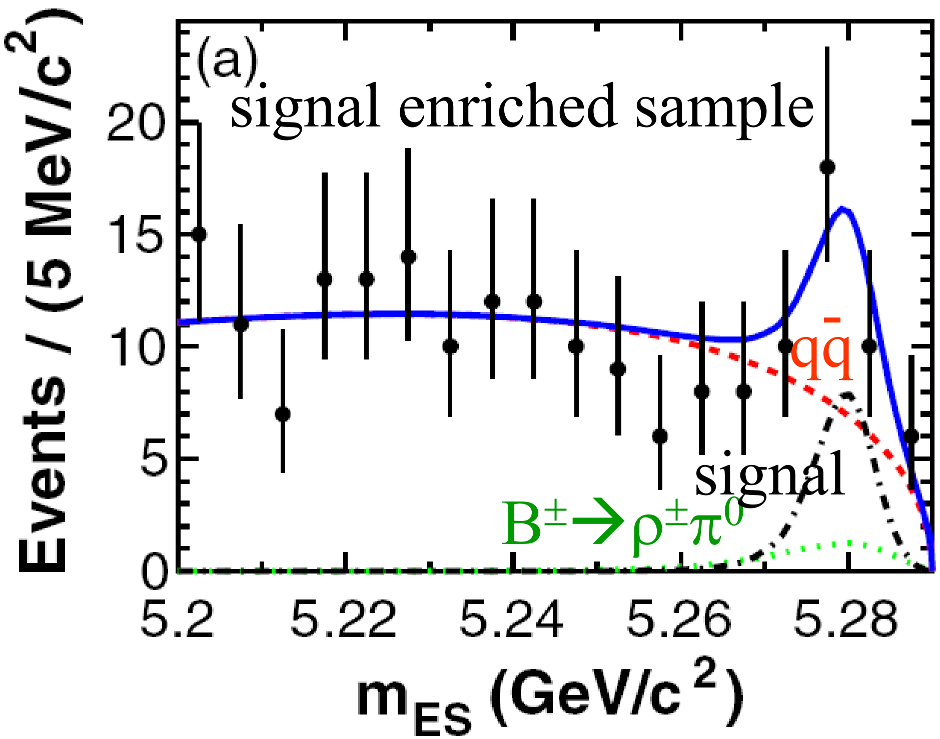
$B^0 \rightarrow \pi^0\pi^0$

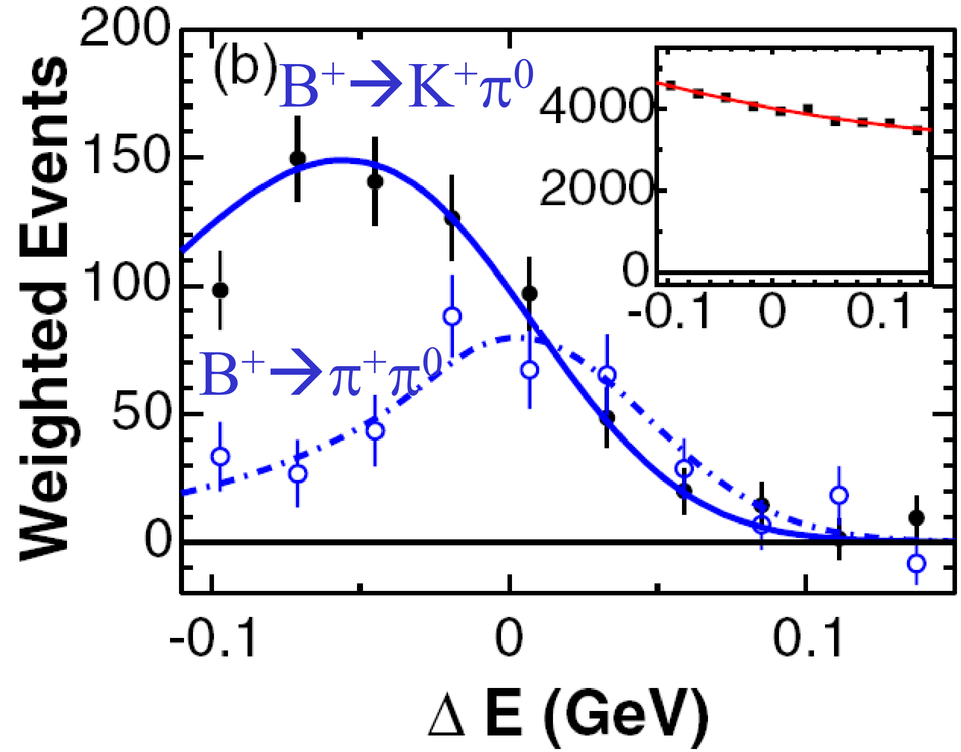
227 10^6 BB

$B^+ \rightarrow \pi^+\pi^0$

BR=$(1.17\pm0.32\pm0.10)10^{-6}$
C_{00}=$-0.12\pm0.56\pm0.06$
$61\pm17\pm5$ signal, 5.0 σ

BR=$(5.8\pm0.6\pm0.4)10^{-6}$
a_{CP}=$-0.01\pm0.10\pm0.02$
379 ± 41 signal





PRL 94, 181802 (2005)

B→ρρ

π: J=0 (S)
ρ: J=1 (V)

ρ: J=1→J=0, 1, 2

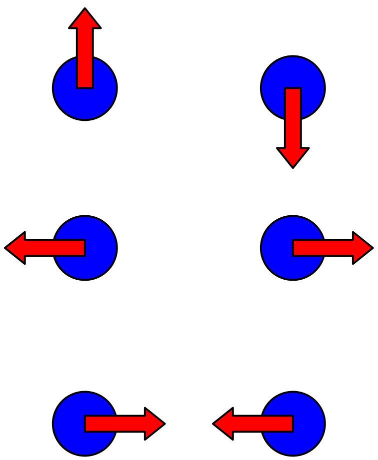
$\rho^+\rho^-$ more difficult:

- 2 π^0 in final state (→résolution vertex dégradé, + de SxF)
- wide ρ resonance→more background
- 3 polarization states w/ different CP eigenvalues

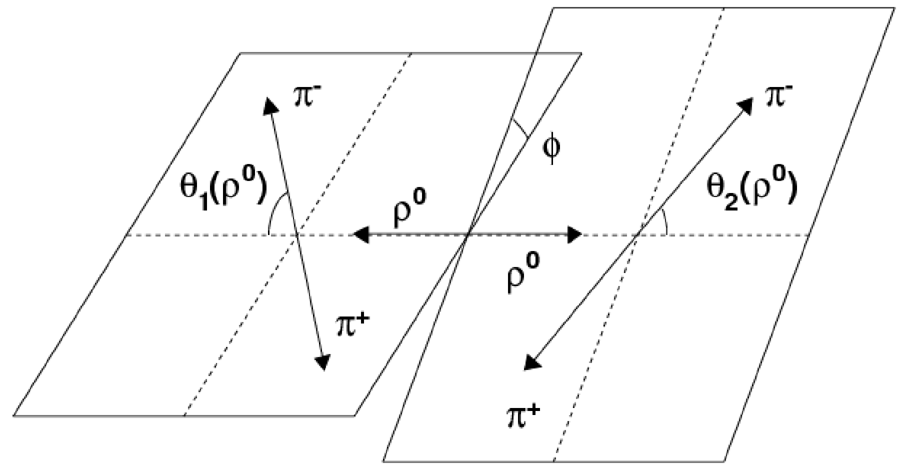
→separate contrib to avoid dillution

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{d\cos\theta_1\, d\cos\theta_2} = \frac{9}{4}\left[\cos^2\theta_1\cos^2\theta_2 f_L + \frac{1}{4}\sin^2\theta_1\sin^2\theta_2(1-f_L)\right]$$

ρ^+ ρ^-



$A_0=H_0$ (long)	CP=1
$A_\parallel=(H^++H^-)/\sqrt{2}$	CP=1
$A_\perp=(H^+-H^-)/\sqrt{2}$	CP=-1



eventually best mode:

- BR~6 x those from B→ππ
- Penguin pollution much small/B→ππ
- f_L~almost 100 % (pure CP-event state)

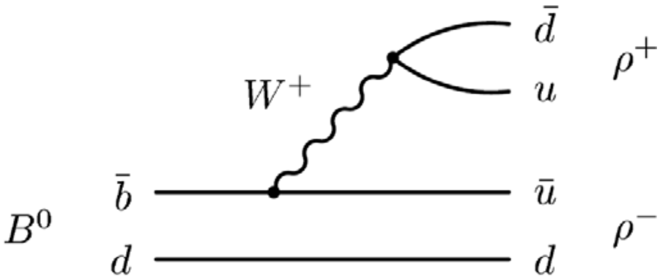
$B^0 \to \rho^+\rho^-$

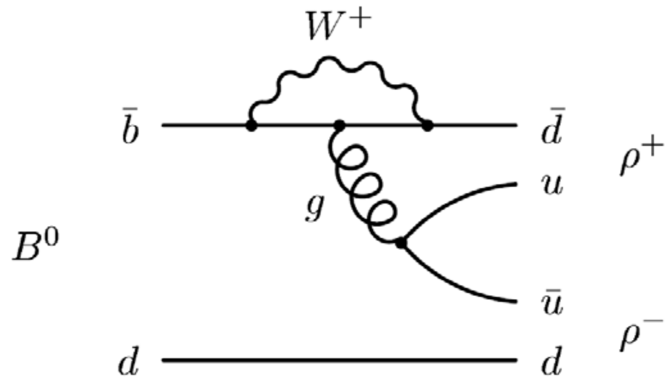
hep-ex/0607098

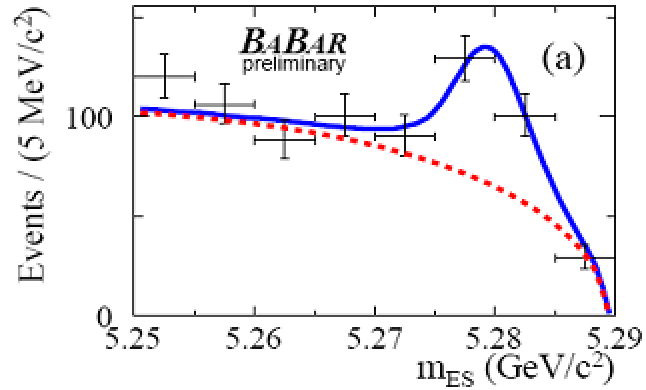
347 10^6 BB, 316 fb^{-1}

615±57 events

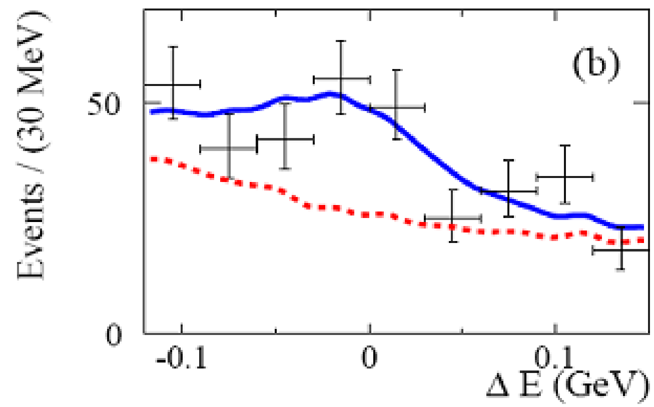
Bevan, George, Graham, Yèche

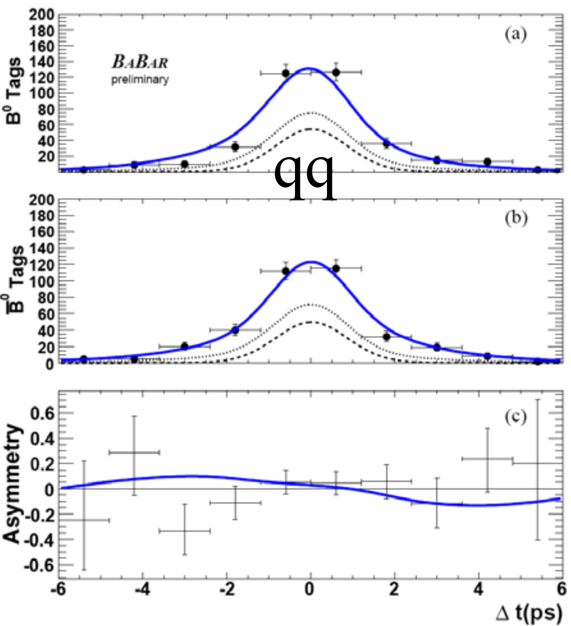






$$
\begin{aligned}
\mathcal{B}(B^0 \to \rho^+\rho^-) &= (23.5 \pm 2.2(\mathrm{stat}) \pm 4.1(\mathrm{syst}))\times 10^{-6}, \\
f_L &= 0.977 \pm 0.024(\mathrm{stat})^{+0.015}_{-0.013}(\mathrm{syst}), \\
S_{\mathrm{long}} &= -0.19 \pm 0.21(\mathrm{stat})^{+0.05}_{-0.07}(\mathrm{syst}), \\
C_{\mathrm{long}} &= -0.07 \pm 0.15(\mathrm{stat}) \pm 0.06(\mathrm{syst}).
\end{aligned}
$$





$\alpha = [74, 117]^\circ$ at 68% CL

Dominant systematic: SxF

no CP violation

1 ab^{-1} projection:

f_L±0.014±0.011 (statistically limited)

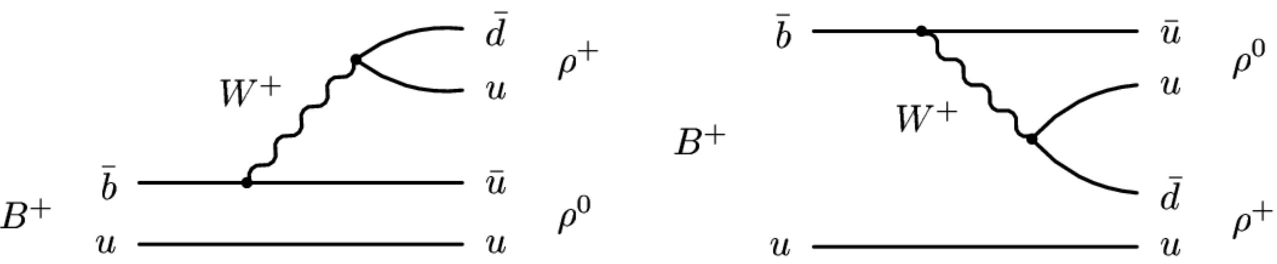
BF±1.3±3.8 (systematically limited)

232 M $B\bar{B}$

$B^{\pm} \rightarrow \rho^{\pm}\rho^{0}$

hep-ex/0607092

D. Hutchcroft, K. Schofield, G. Schott.



Observables	Fitted value
$B^{\pm} \to \rho^{\pm}\rho^{0}$ yield	390±49 events
Polarization f_L	0.897±0.042
Charge asymmetry A_{CP}	-0.12 ± 0.13
$B^{\pm} \to \rho^{\pm} f_0$ yield	51±30 events

$$\mathcal{B} = (16.8 \pm 2.2 \pm 2.3) \times 10^{-6}$$

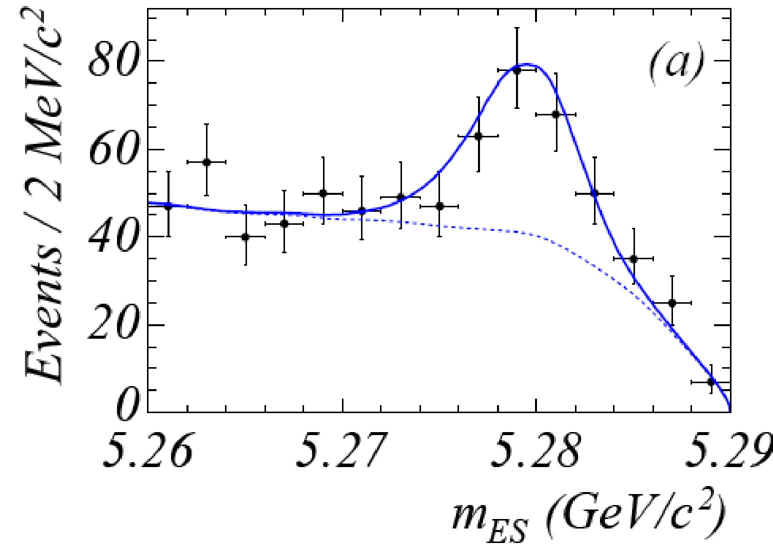
$$A_{CP} = -0.12 \pm 0.13 \pm 0.10$$

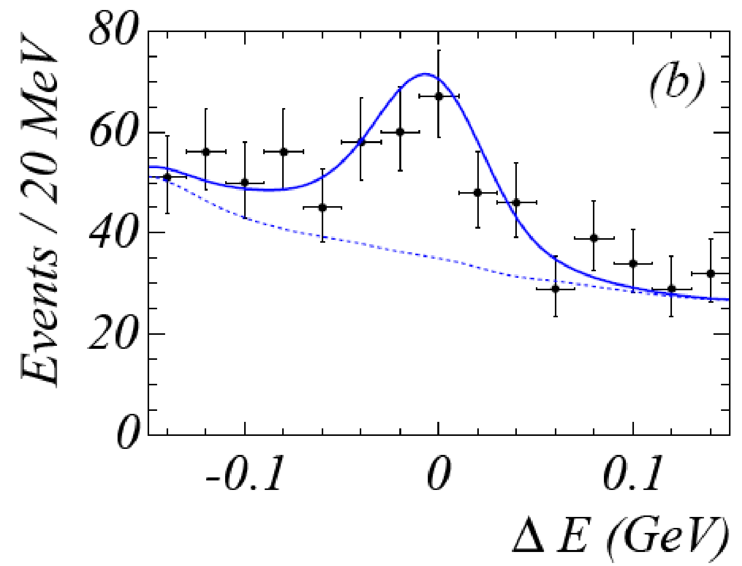
$$f_L = 0.905 \pm 0.042^{+0.023}_{-0.027}$$

$$C = -0.12 \pm 0.13 \pm 0.10$$

Dominant systematic: fit bias, SxF

1 ab^{-1} projection:
f_L ±0.002±0.018 (statistically limited)
BF±1.0±2.0 (systematically limited)

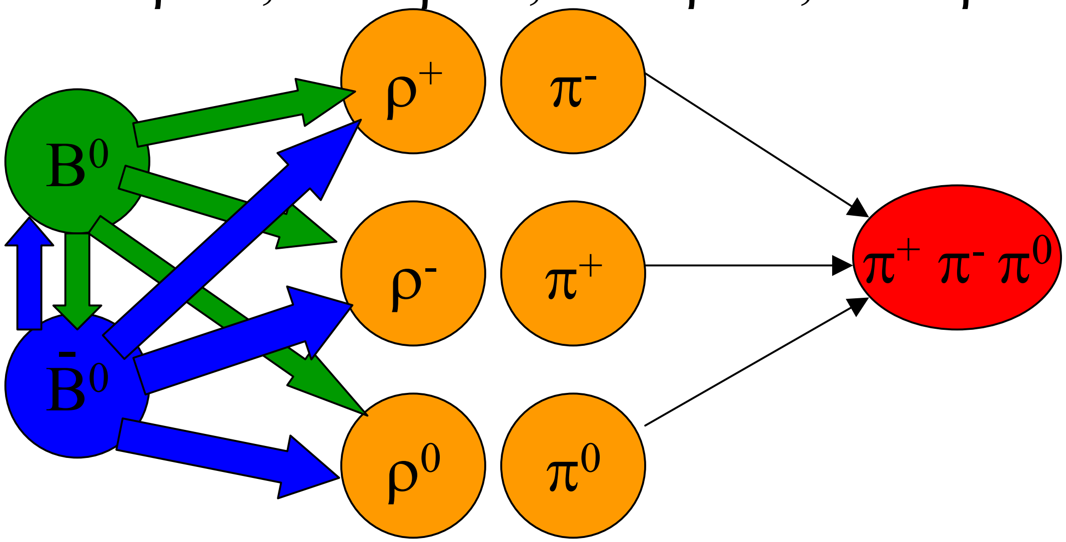




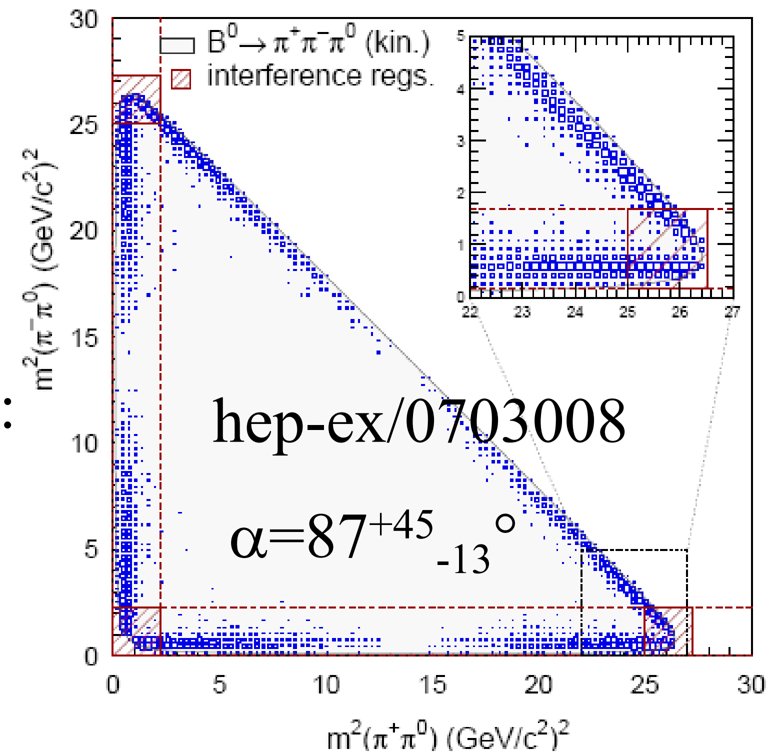
Dalitz analysis of $B^0 \to (\rho\pi)^0 \; \pi^+\pi^-\pi^0$

Snyder-Quinn, PRD 48, 2139 (1993)

dominant decay $B^0 \to \rho^+\pi^-$: not a CP eigenstate
isospin analysis not viable: too many amplitudes:
$B^0 \to \rho^+\pi^-$, $B^0 \to \rho^-\pi^+$, $B^0 \to \rho^0\pi^0$, $B^+ \to \rho^+\pi^0$, $B^+ \to \rho^0\pi^+$ and charge conjugates



375 M BB



better approach: Time-dependent Dalitz analysis:

- simultaneous fit of α, T, P amplitudes
- no ambiguity on α (unlike isospin analysis)

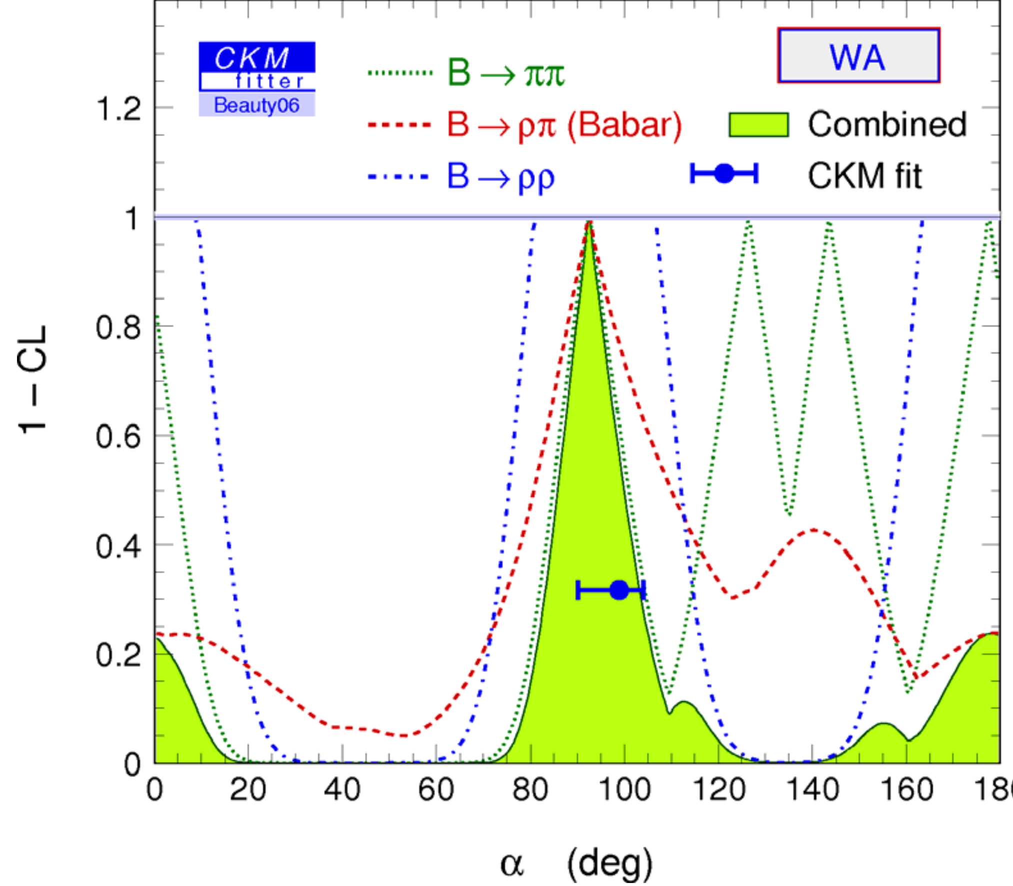
- $B^0/\bar{B}^0 \rightarrow \pi^+\pi^-$
- $B^0/\bar{B}^0 \rightarrow \rho^\pm\pi^{-+}$
- $B^0/\bar{B}^0 \rightarrow \rho^+\rho^-$

→ meilleure mesure simple

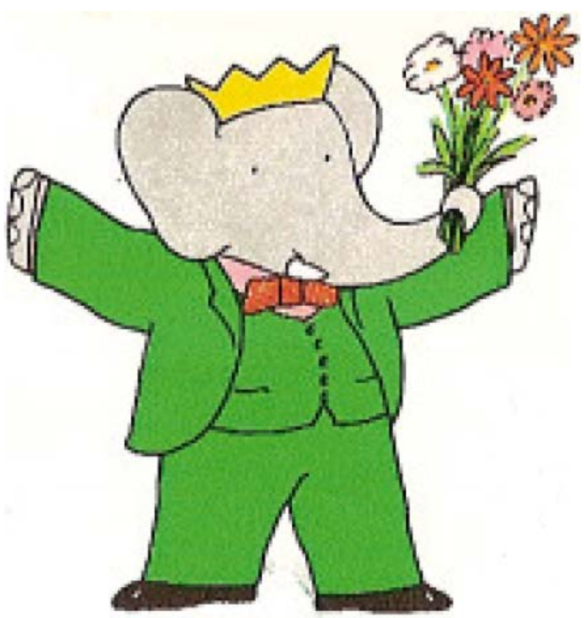
→ Élimine solutions miroirs

<u>Beauty 2006</u>

$\alpha = 92.6^{+10.7}_{-9.3}{}^\circ$



good agreement with global CKM fit



Babar is working fine

$\sim 400\ fb^{-1}$

2008: expected $\sim 1\ ab^{-1} = 1000\ fb^{-1}$

→many physics potential (rare modes)

I Recherche $B^0 \rightarrow K^{*0}\rho^0/f_0$, $B^+ \rightarrow K^{*0}\rho^+$

Travail dans Babar

run 1-4 $232\ 10^6\ B\bar{B}$

Saclay LBL South Carolina

Etude modes $\underline{K^*\rho}$: $\underbrace{K^{*0}\rho^+, K^{*0}\rho^0/f_0}_{\text{Saclay}}$, $\underbrace{K^{*+}\rho^0}_{\text{LBL}}$, $\underbrace{K^{*+}\rho^-}_{\text{South Carolina}}$

• modes désintégration dominants: $K^{*0} \rightarrow K^+\pi^-$

$\rho^+ \rightarrow \pi^0\pi^+$

$\rho^0/f_0 \rightarrow \pi^+\pi^-$

• modes rares: $BR=O(10^{-6})$

<u>Motivations:</u>

• test prédictions théoriques

• modes jamais observé ($K^{*0}\rho^0/f_0$)

• contrainte sur α, γ: plus lointain

Mesurer

• rapport d'embranchement

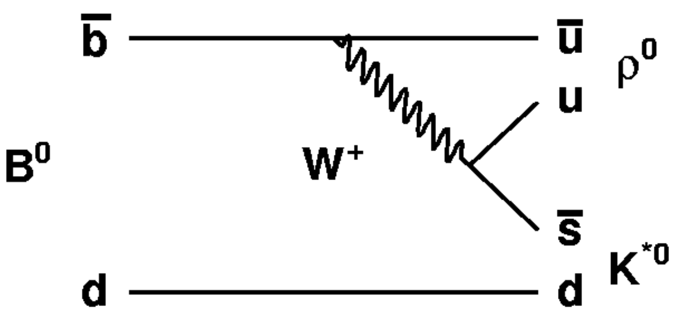
• fraction de polarisation longitudinale f_L

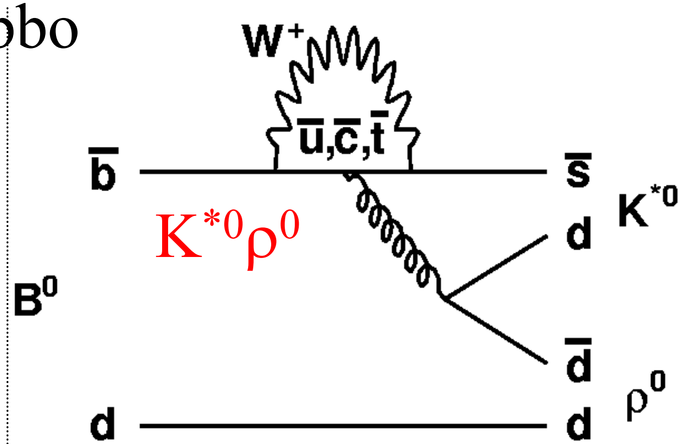
• asymmétrie directe de CP A_{CP}

Diagrammes de Feynman

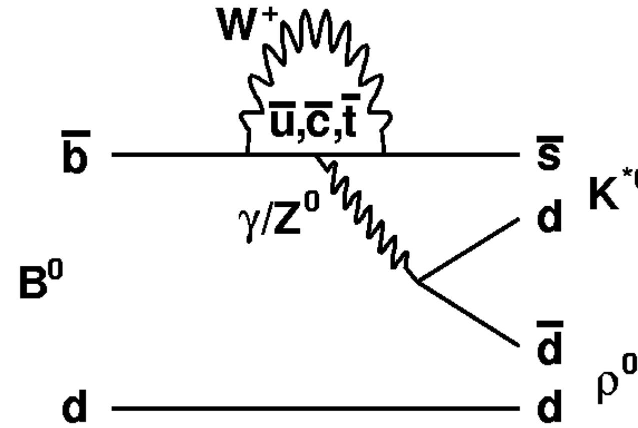
dominé par pingouin

suppr. de couleur & Cabibbo

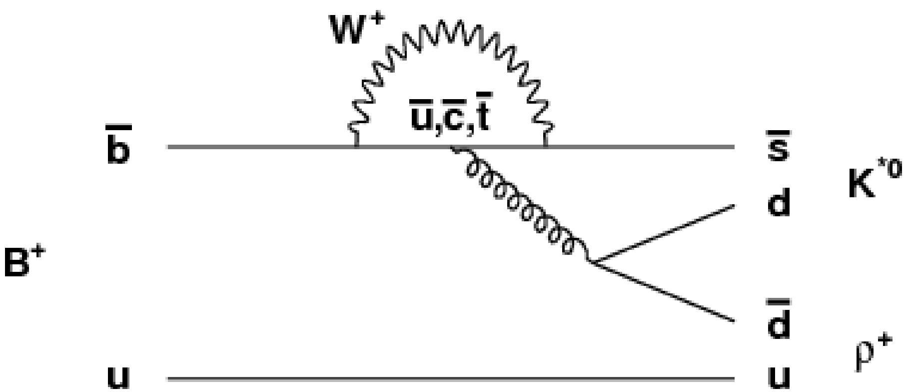


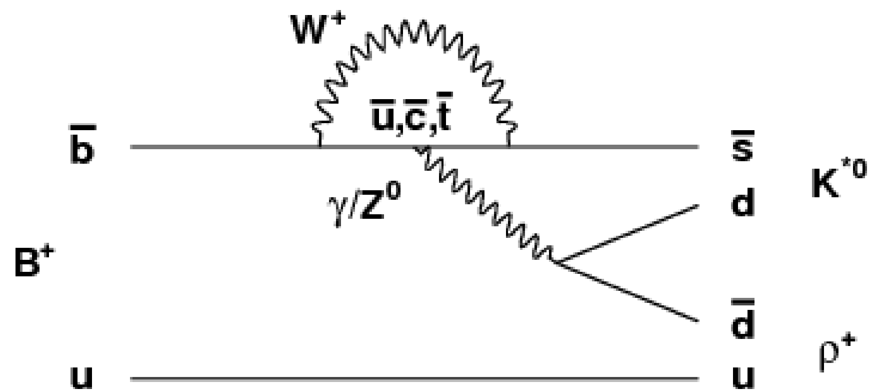


$K^{*0}\rho^0$



$K^{*0}\rho^+$

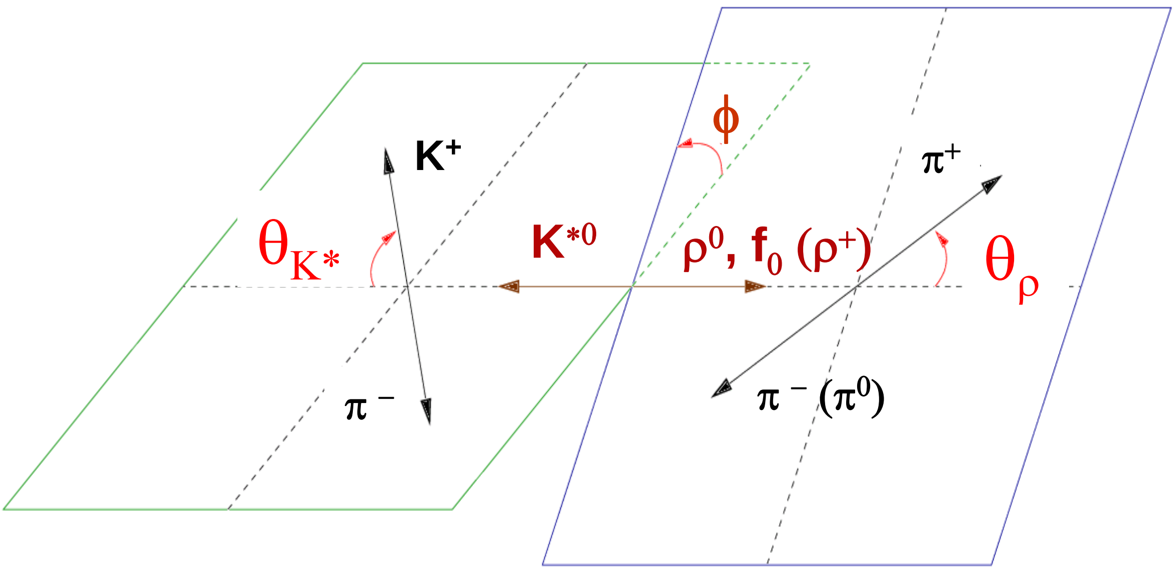


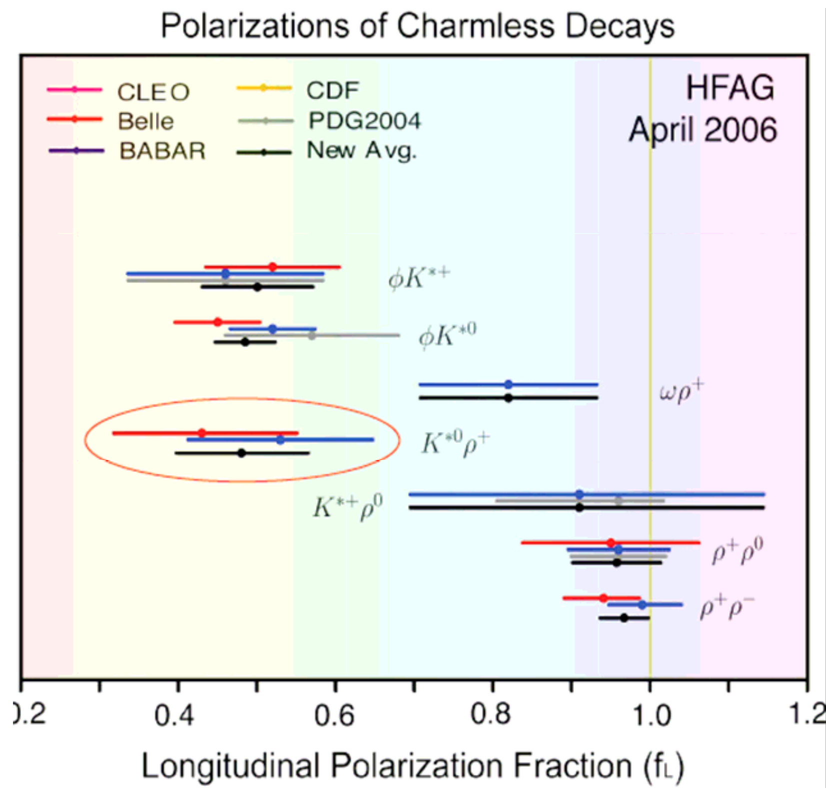


pingouin pur

Quelle polarisation pour modes VV ?

-distributions angulaires → polar. $\frac{dN}{d\cos\theta_1 d\cos\theta_2} \sim f_L \times (\cos\theta_1 \cos\theta_2)^2 + (1-f_L)\times \frac{1}{4}(\sin\theta_1 \sin\theta_2)^2$





Expérimentalement:

- dominé arbre : $f_L \sim 100$ %
- dominé pingouin: $f_L \sim 50$ %

Symétrie SU(3) → $m_u \sim m_d \sim m_s$

$\rho \sim (u\bar{u} - d\bar{d})$ $\phi = c_1(u\bar{u} + d\bar{d}) + c_2 s\bar{s}$

$K^{*0}\phi : f_L = 0.48 \pm 0.04$

Bruit de fond

Signal: $K^{*0}\rho^0/f^0(980)$
$(K^+\pi^-)$ $(\pi^+\pi^-)$

~200

- Continuum~40000
  ($e^-e^+ \to u, d, s, c$)

- B bruit de fond non résonant~600 bruit de fond réductible~7700

$$\left\{\begin{array}{ll}
\bullet K^+\pi^-\pi^+\pi^- & \\
\bullet K^{*0} & \pi^+\pi^- \\
\hookrightarrow K^+\pi^- & \\
\bullet K^+\pi^- & \rho^0 \\
 & \hookrightarrow \pi^+\pi^- \\
\bullet K^{**+} & \pi^- \\
\hookrightarrow K^+\pi^-\pi^+ & \\
\bullet K^{*0} & f_0(1370) \\
\hookrightarrow K^+\pi^- & \hookrightarrow \pi^+\pi^- \\
\bullet K^+\pi^- & f_0(980) \\
 & \hookrightarrow \pi^+\pi^- \\
\bullet K^+\pi^- & f_0(1370) \\
 & \hookrightarrow \pi^+\pi^-
\end{array}\right.$$

particules finales ≠
imitant certaines pdfs

charmé~7000
non charmé~700

S/B~0.4 %

Extraction du rapport d'embranchement

Signal (MC)

B (MC)

Continuum (offres)

Discrimination S/B

sélection: ε_{Lg}, ε_{Tr}

Échantillons réduits

Coupures lâches

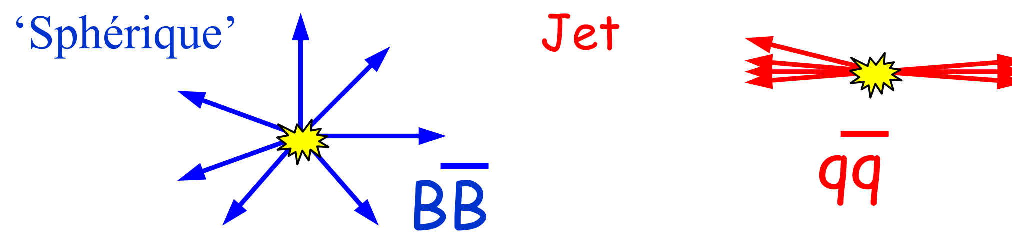
pdfs

Réj bruit de fond

$$m_{ES} = \sqrt{E^{*2}_{\text{beam}} - p^{*2}_{B}}$$

$$\Delta E = E^{*}_{B} - E^{*}_{\text{beam}}$$

+réseau neurones



+masses-helicités

---

données (on res)

pdfs

likelihood

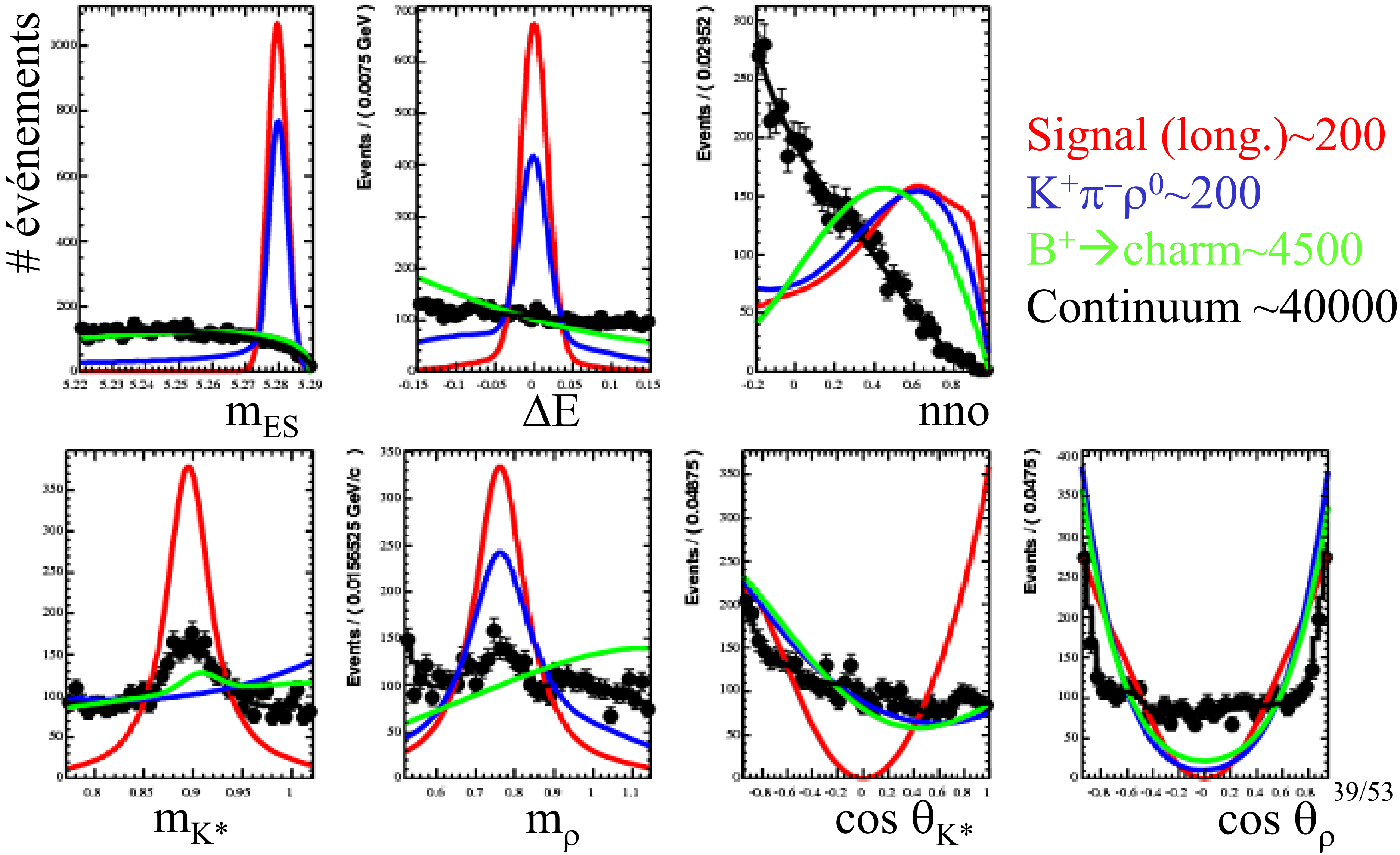
- $n_{signal}(K^{*0},\rho^{0/+}/f_0)$
- $f_L(K^{*0},\rho^{0/+})$

bck

S/B~0.4 % !!

variables discriminantes

- m_{ES}, ΔE: S/(B, continuum), variables forme (nno): (S, B)/continuum
- Mass-helicity(K^*,ρ): signal- B non-resonant B



efficacités

- $5.22<m_{ES}<5.29$ GeV
- $-0.15<\Delta E<0.15$
- $-0.2<nno<1$
- $0.7711 <m_V(K^{*}0)<1.0211$ GeV
- $0.52 <m_V(\rho^0)<1.1461$ GeV
- $-0.95<\cos\theta(K^*)<1$
- $-0.95<\cos\theta(\rho^0)<0.95$

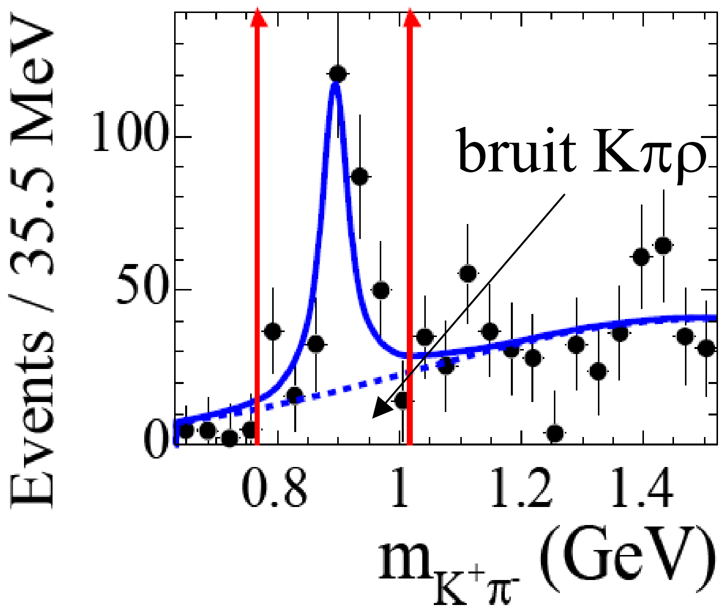
	$K^{*0}\rho^0$ analysis	**$K^{*0}\rho^+$ analysis**
Longitudinal Signal **Efficiency** (SxF included)	**17.3%**	10.6%
Transverse Signal **Efficiency** (SxF included)	**27.0%**	17.9%

longitudinal signal | **Transverse signal**

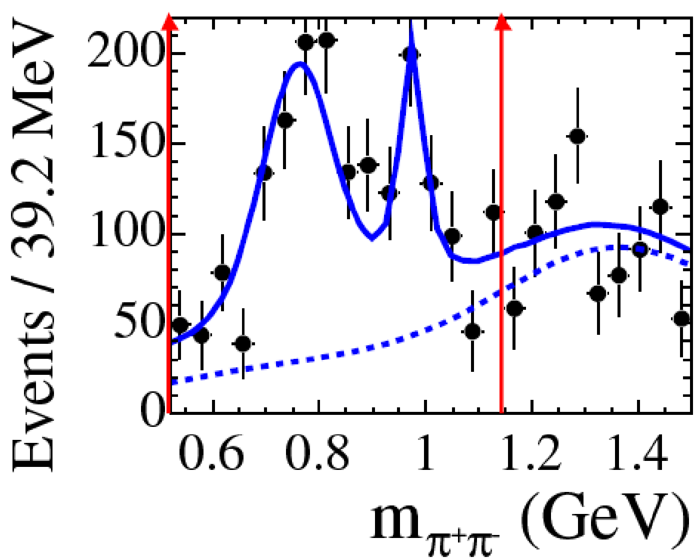
	Global Self-X-Feed rate (longitudinal)	**Fraction of true K^{*0}** (longitudinal)	**Fraction of true $\rho^{(0,+)}$** (longitudinal)	**Global Self-X-Feed rate** (transverse)	**Fraction of true K^{*0}** (transverse)	**Fraction of true $\rho^{(0,+)}$** (transverse)
$K^{*0}\rho^0$	**21.9%**	**93.6%**	**82.3%**	**6.6%**	**97.3%**	**95.3%**
$K^{*0}\rho^+$	**23.4 %**	**95.5 %**	**79.7 %**	**12.3 %**	**98.4 %**	**89.1 %**

Systématiques

dominantes: bck non résonants, forme pdfs



$K^{*0}\rho^+$



$K^{*0}\rho^0$

SYSTEMATICS for $K^{*0}\rho^+$

source	ΔBR
π^0 reco	3.0%
Track reco	3.9%
B counting	1.1%
Sum efficiency	5.0%

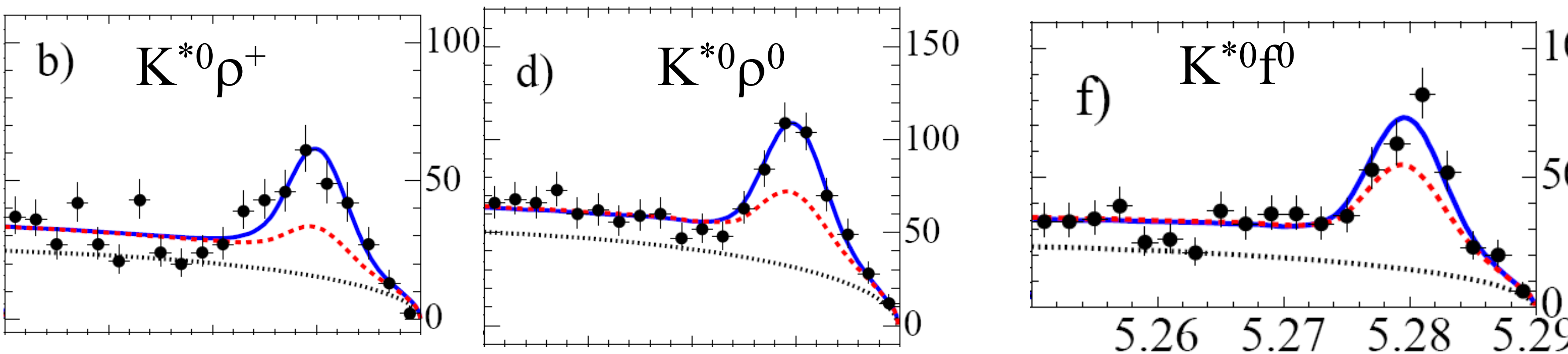
Source	ΔBR (10^{-6})	Δ fL
Efficiency	± 0.48	± 0.000
PID	± 0.10	± 0.002
εLg/εTr (±3.5%)	± 0.00	± 0.009
SXF rates	± 0.05	± 0.001
PDFs Shapes	± 0.71	± 0.029
Non resonant Backgrounds	+ 1.16 - 1.21	+ 0.027 - 0.030
Nb of B bckgs	± 0.17	± 0.008
TOTAL	**+1.46 -1.50**	**+0.041 -0.043**
Rounded up	**(± 1.5)**	**(± 0.04)**

Résultats

(Phys. Rev. Lett. **97**, 201801 (2006))

- $Br(K^{*0}\rho^0)=[5.6\pm0.9(stat)\pm1.3(syst)]\ 10^{-6}$
- $f_L(K^{*0}\rho^0)=0.57\pm0.09(stat)\pm0.08(syst)$ → 5.3 σ
- $Br(K^{*0}f_0)=[2.6\pm0.6(stat)\pm0.9(syst)]\ 10^{-6}$ → 3.5 σ
- $Br(K^{*0}\rho^+)=[9.6\pm1.7(stat)\pm1.5(syst)]\ 10^{-6}$ → 7.1 σ
- $f_L(K^{*0}\rho^+)=0.52\pm0.10(stat)\pm0.04(syst)$

$Br(H_{120}\rightarrow\gamma\gamma)$ au LHC: comparaison: $2\ 10^{-3}$



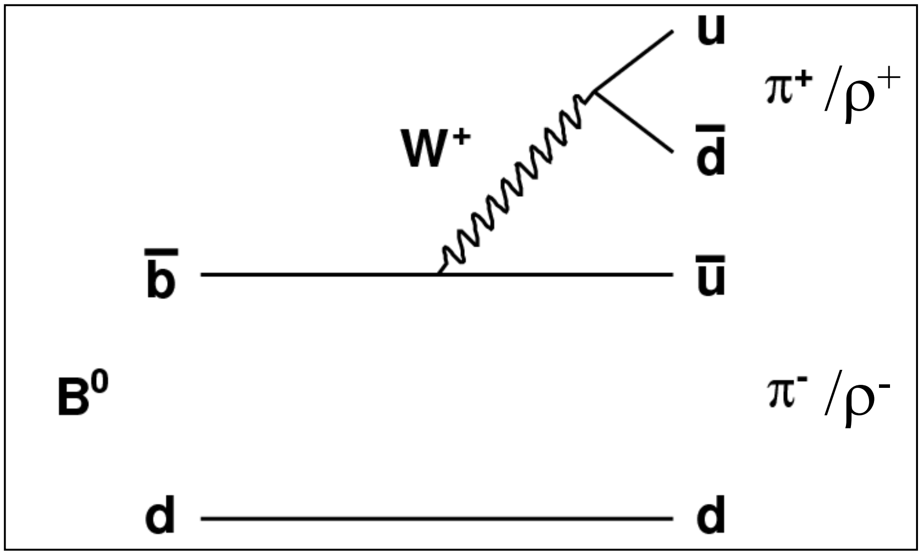
$$A_{CP} \equiv \frac{N(\bar{B}^0 \to K^{*0}\rho^0) - N(B^0 \to \overline{K}^{*0}\rho^0)}{N(\bar{B}^0 \to K^{*0}\rho^0) + N(B^0 \to \overline{K}^{*0}\rho^0)}$$

- $a_{CP}(K^{*0}\rho^0)=[0.09\pm0.19(stat)\pm0.02\ (syst)]$
- $a_{CP}(K^{*0}f_0)=[-0.17\pm0.28\ (stat)\pm0.02\ (syst)]$
- $a_{CP}(K^{*0}\rho^+)=[-0.01\pm0.16(stat)\pm0.02\ (syst)]$

- $K^{*0}\rho^0$ pour la 1ère fois, rapport $K^{*0}\rho^+/K^{*0}\rho^0$ compatible avec isospin
- f_L~compatible $K^{*0}\phi$
- Asymétries faibles

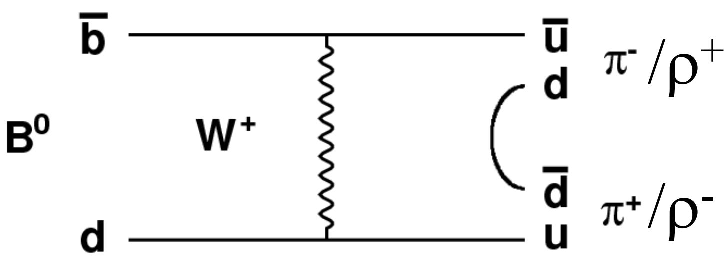
Extraction of α

$$\alpha = arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right)$$

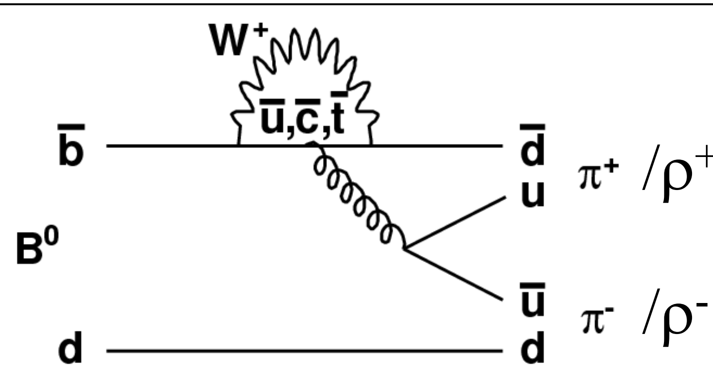


- $B^0/\bar{B}^0 \rightarrow \pi^+\pi^-$
- $B^0/\bar{B}^0 \rightarrow \rho^{\pm}\pi^{-+}$
- $B^0/\bar{B}^0 \rightarrow \rho^+\rho^-$

+



+



penguin

$\rightarrow \alpha_{eff}$

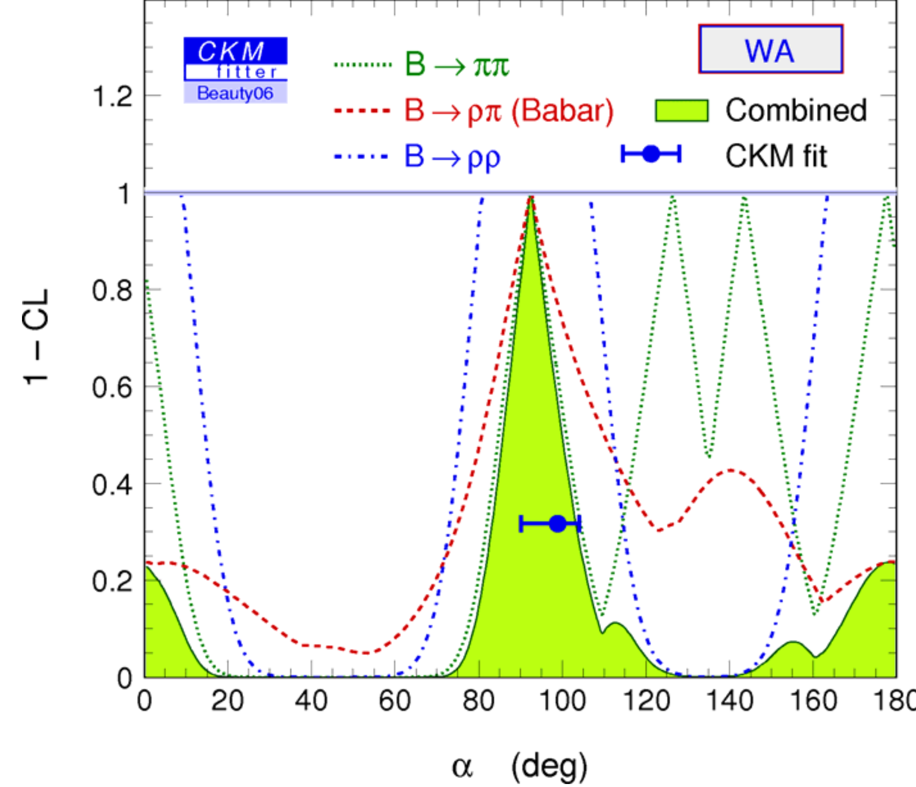
$B^0 \rightarrow \rho^+\rho^-$

Mesurer α :

- $B^0/\bar{B}^0 \rightarrow \pi^+\pi^-$
- $B^0/\bar{B}^0 \rightarrow \rho^\pm\pi^{-+}$
- $B^0/\bar{B}^0 \rightarrow \rho^+\rho^-$

Beauty 2006

$\alpha = 92.6^{+10.7}_{-9.3}{}^\circ$



$\rightarrow \rho^+\rho^-$

Mélange B^0-B^0

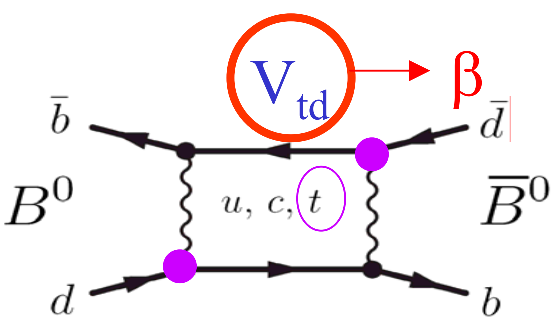


Diagramme arbre

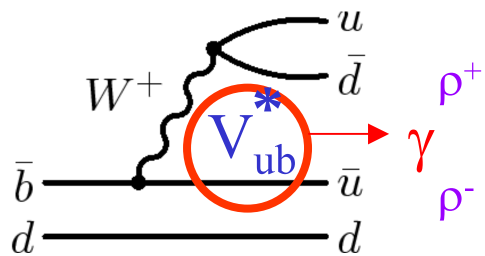
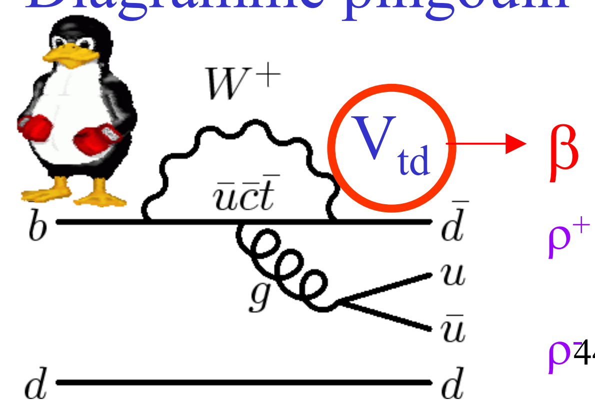


Diagramme pingouin

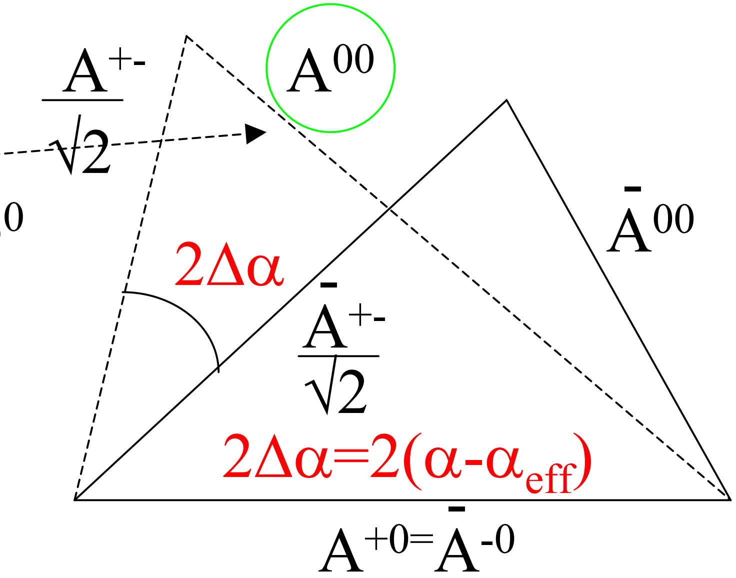


$B^0 \rightarrow \rho^0\rho^0$

pingouin important→α_{eff} mesuré

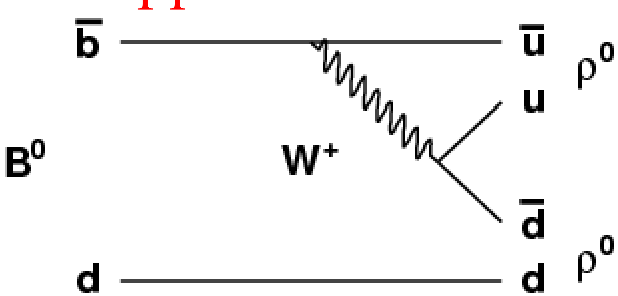
solution, analyse d'isospin, mesure C et S de $\rho^0\rho^0$

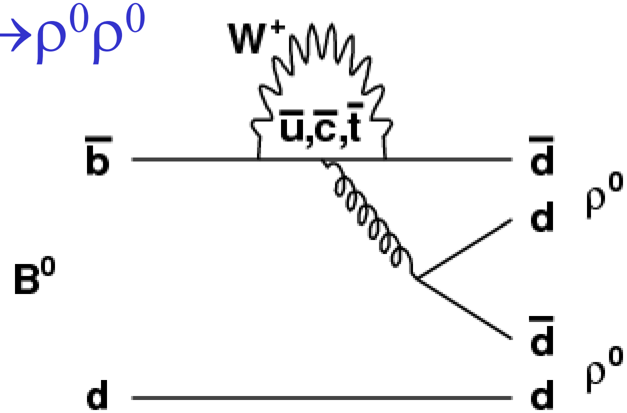
$$a_{CP}(t) = \boxed{C_f} \cos \Delta m t + \boxed{S_f} \sin \Delta m t$$

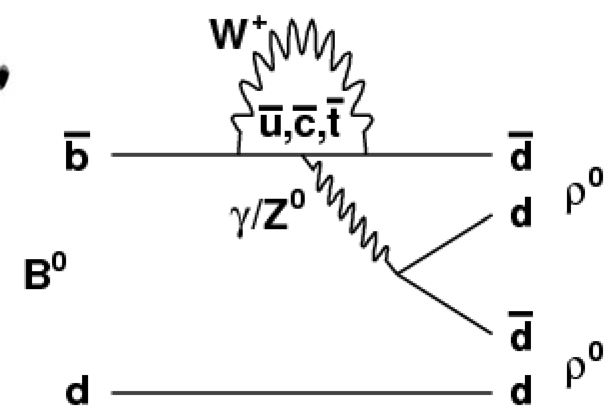


$B^0 \rightarrow \rho^0\rho^0$

suppr. de couleur







Background

S/B~0.15 %

Signal: $\rho^0\rho^0$
$(\pi^+\pi^-)$ $(\pi^+\pi^-)$

~100

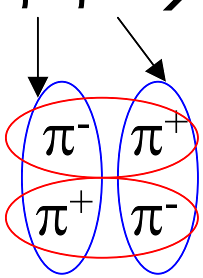
- Continuum~58000
($e^-e^+ \rightarrow$ u, d, s, c)

- B dominant background~220
  - $\rho^0 f_0$~20
  - $f_0 f_0$~0
  - $a_1\pi$~200

Reducible background~3200
- final particle≠
- mimic pdfs
- charm~3000
- charmless~200
  - •K*0f0
  - •K*0r0 long
  - •K*0r0 trans
  - • η'K
  - • $a_1^0\pi^+$
  - • $\rho^0\pi^+$
  - • $\rho^0\rho^+$ long

$\rightarrow$yield fixed

$B \rightarrow \rho^0\rho^0 \rightarrow$ symetrization for $B \rightarrow \rho^0\rho^0$, $a_1^{+/-}\pi^{-/+}$, $\rho^0 f_0$



bckg: C ans S fixed to 0, $a_1\pi$: C_{eff}, S_{eff} fixed to last result

The maximum likelihood fit

Unbinned extended maximum likelihood fit

$$-\ln L = \sum_{tag\ cat\ i} \left(N_{sig}\epsilon^{sig}_{tag_i} \prod_{obs_j} PDF_{sig_j} + N_{cont}\epsilon^{cont}_{tag_i} \prod_{obs_j} PDF_{cont_j} + \sum_{B\ bck_k} N^k_{B\ bck}\epsilon^{Bbck_k}_{tag_i} \prod_{obs_j} PDF^k_{B\ bck_j} \right)$$

$$PDF_{signal} = f_L \left[(1 - SxF_{Lg})PDF^{pur}_{Lg} + SxF_{Lg}PDF^{SxF}_{Lg} \right] + (1 - f_L)\left[(1 - SxF_{Tr})PDF^{pur}_{Tr} + SxF_{Tr}PDF^{SxF}_{Tr} \right]$$

Symmetrization for appropriate backgrounds

$$PDF_{sym} = \frac{PDF(\pi_1^+\pi_1^-, \pi_2^+\pi_2^-) + PDF(\pi_1^+\pi_2^-, \pi_1^-\pi_2^+)}{2}$$

Time decay distribution

μ ≠ tagging efficiciency

$$F^{\rho^0\rho^0}_{Q_{tag}}(\Delta t) \sim \frac{e^{-|\Delta t|/\tau}}{4\tau} \{1 - Q_{tag}\Delta w + Q_{tag}\mu(1-2\omega) + (Q_{tag}(1-2w) + \mu(1 - Q_{tag}\Delta\omega)) [S\sin(\Delta m_d \Delta t) - C\cos(\Delta m_d \Delta t)]\}$$

ω:mis-tagging frac: $(B^0+\bar{B}^0)/2$

+1: B^0, -1: $\bar{B}^0$

Δω ≠ of mis-tagging frac (B^0; $\bar{B}^0$)

$$(\omega, \Delta\omega) \longrightarrow \begin{cases} \text{mistagging fraction } \underline{B}^0 \\ \text{mistagging fraction } \bar{B}^0 \end{cases}$$

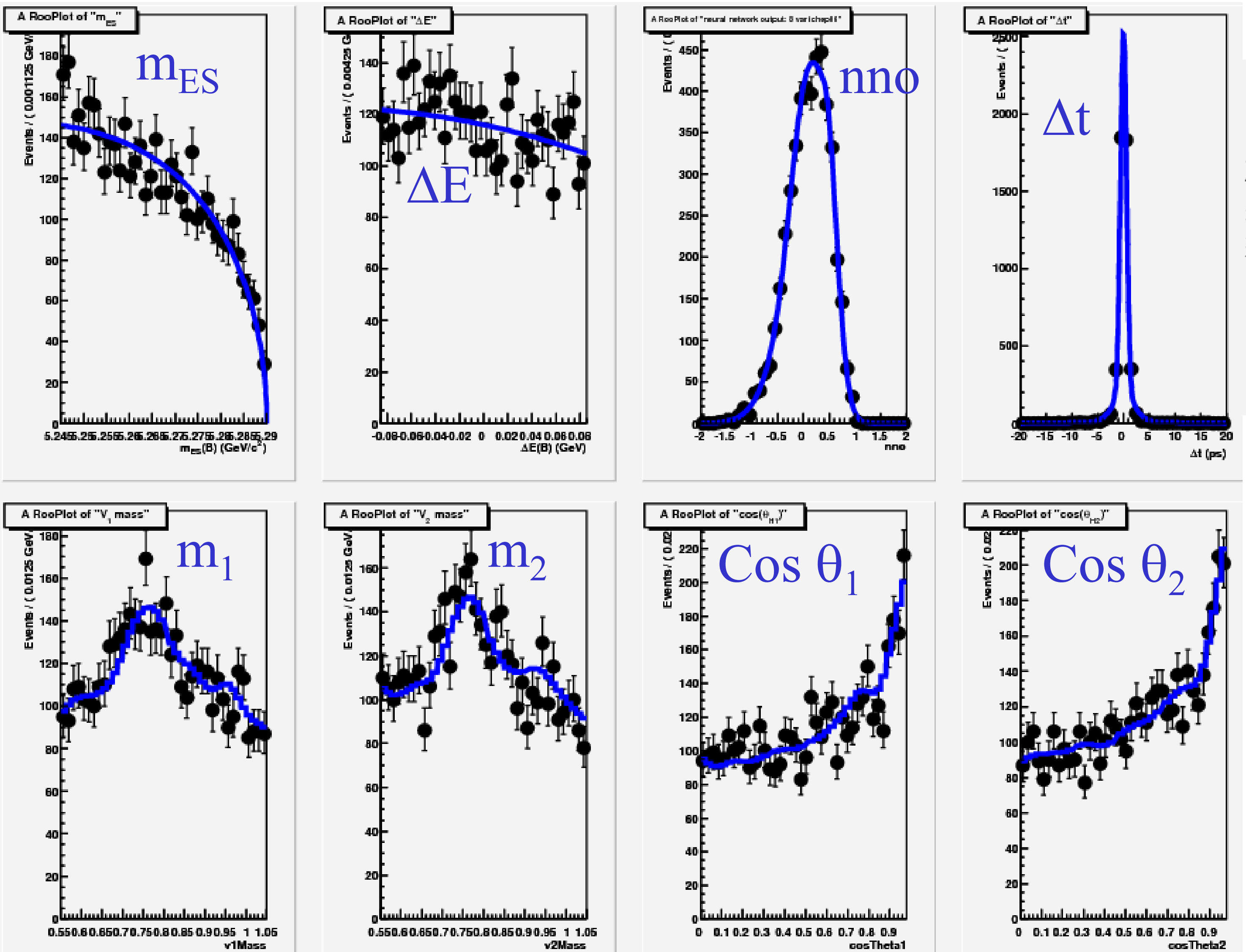
Efficacités et taux de mauvaise reconstruction

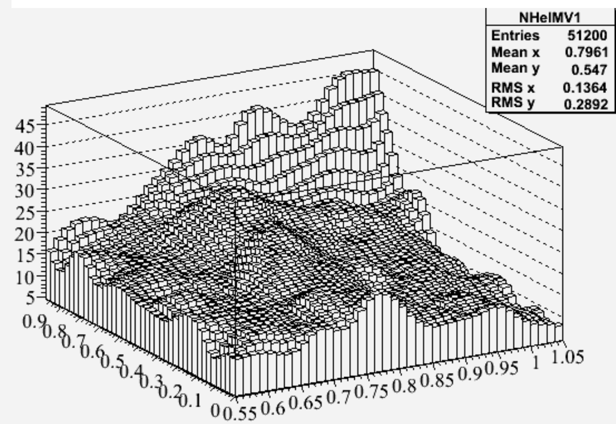
- $5.245<m_{ES}<5.29$ GeV
- -0.085 GeV$<\Delta E<0.085$ GeV
- $-2<nno<2$
- $0<|\cos\theta|<0.98$
- $0.55<m_V<1.05$ GeV

$\rho^0\rho^0$ Lg : Eff : 22.11±0.08 %
SxF:17.6±0.07 %
$\rho^0\rho^0$ Tr : Eff : 27.28±0.08 %
SxF:3.08±0.03 %
$\rho^0 f^0$:Eff:24.71±0.02%,SxF:12.78±0.09%
$f^0 f^0$:27.19±0.08%, SxF: 7.95±0.05%

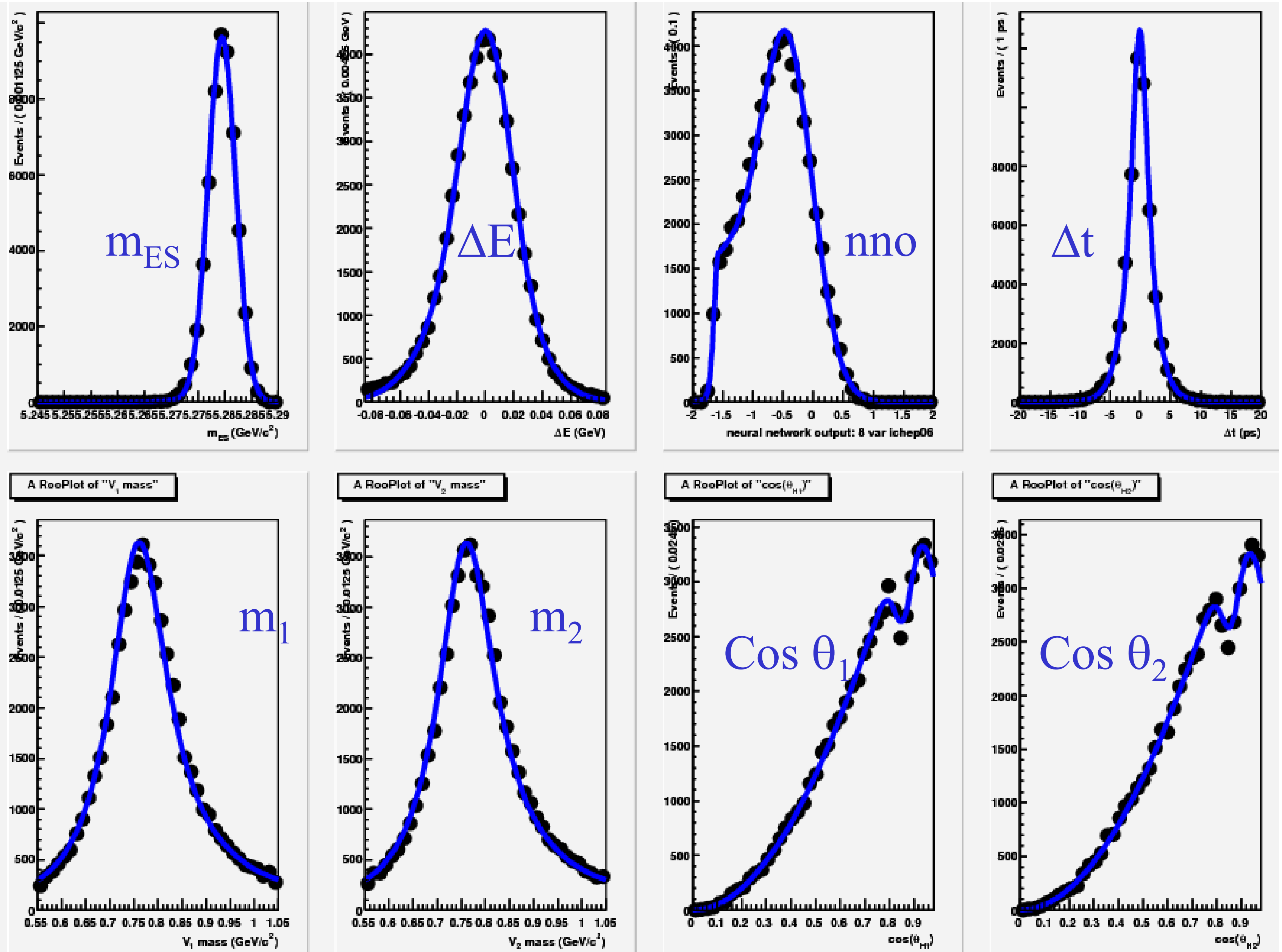
Pdfs for continuum

Mass-helicity:
- Use GSB from run1-5+offres
- Use a 2D parametrisation





Pdfs for pure signal Lg



Incertitudes

- B counting: (383.634±2.211) 10^6 BB→ **1.1%** uncertainty on BR
- tracks: 1.3 % per track→5.2 %

m_{ES}, ΔE (half)

variable	$\Delta N_{\rho^0\rho^0}$	Δf_L	ΔS_L	ΔC_L	$\Delta N_{\rho^0 f_0}$	$\Delta N_{f_0 f_0}$
m_{ES}	-3.40	-0.01	-0.07	0.01	1.45	-0.06

SxF rate

variable	$\Delta N_{\rho^0\rho^0}$	Δf_L	ΔS_L	ΔC_L	$\Delta N_{\rho^0 f_0}$	$\Delta N_{f_0 f_0}$
SxF	0.22	0.00	0.00	-0.00	-0.01	-0.00

+PDFs

+yields charmless

+efficacités tagging

+C et S dans $\rho^0 f^0$, $f^0 f^0$, a1π

+interférence a1pi (Loïc Estève, [nouveau thésard Saclay])

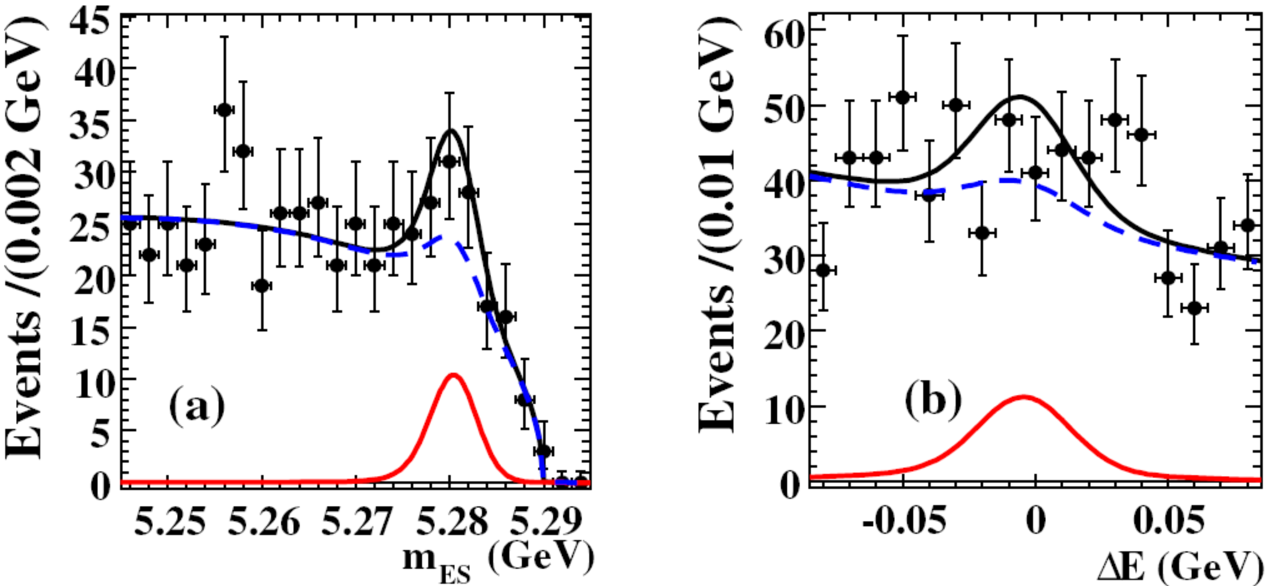
Résultats

$384\ 10^6\ B\bar{B}$ (Collaboration LBL, J. Hopkins, Saclay)

i) Analyse indépendante du temps

évidence (3,5 σ), pour la 1ère fois
$Br(\rho^0\rho^0)=(1{,}07\pm0{,}33\pm0{,}19)\ x10^{-6}$
$f_L=0{,}87\pm0{,}13\pm0{,}04$
$|\Delta\alpha|<18°$(68% CL)
$100\ \pm32\pm17\ \rho^0\rho^0$

PRL 98, 111801



dominant systematic:
Interference w/$a_1\pi$

Intérêt de mesurer C et S

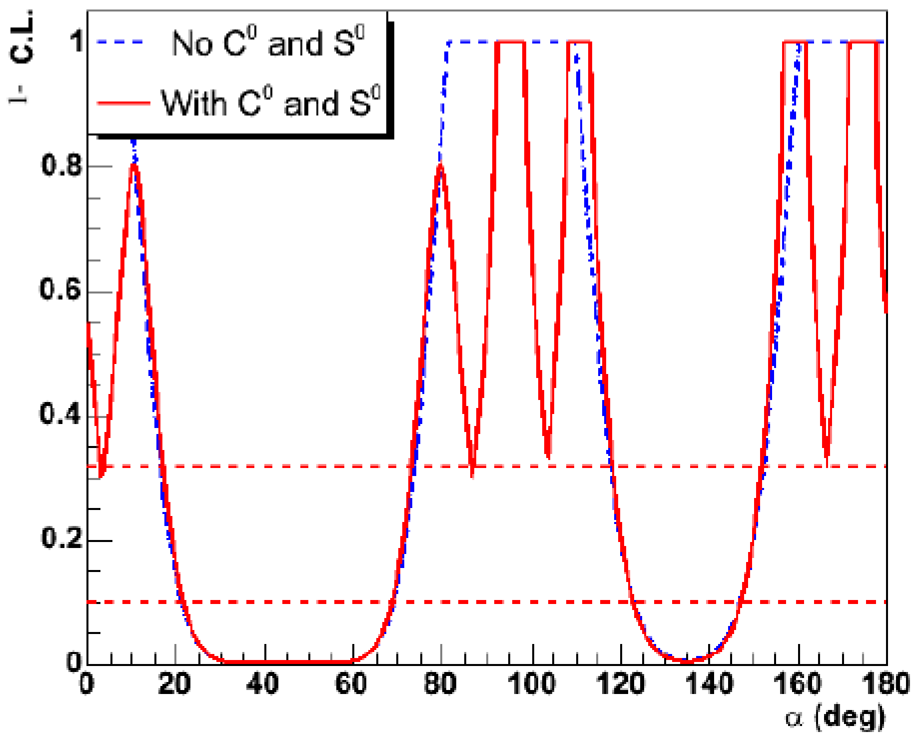
Analyse=f(t)

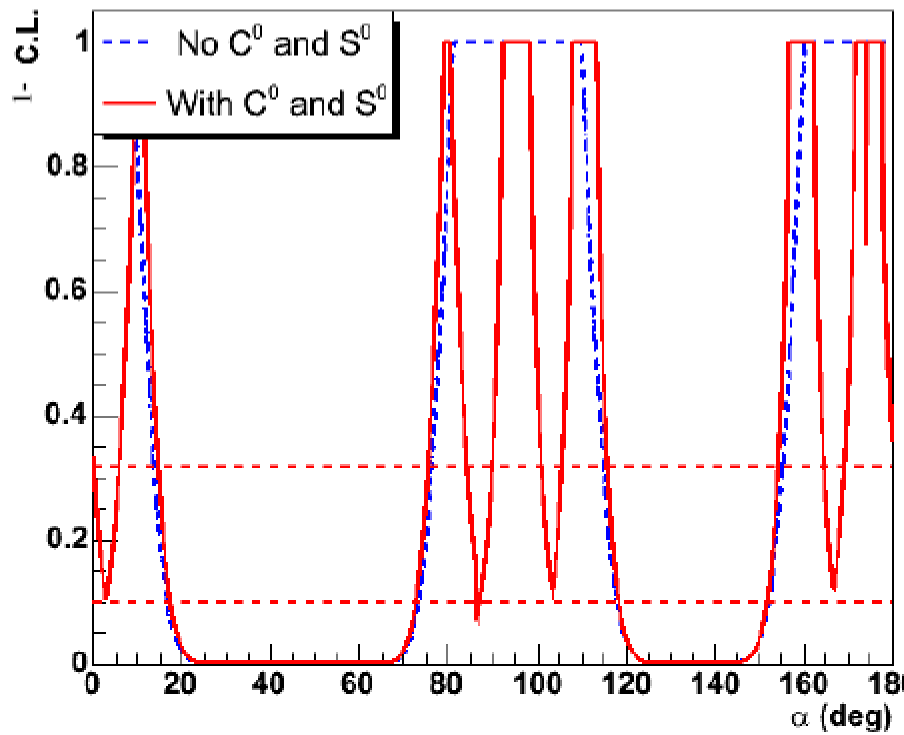
t: diff temps désint $B^0/\bar{B}^0$

en cours

S=(0,0)±0,7±0,06
C=(0,0)±0,6±0,06

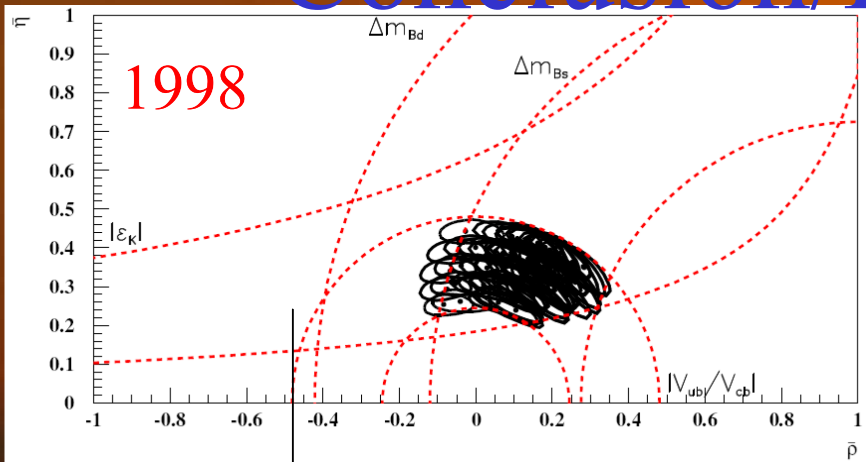
S=(0,0)±0,42±0,05
C=(0,0)±0,36±0,05
(limité statistique)

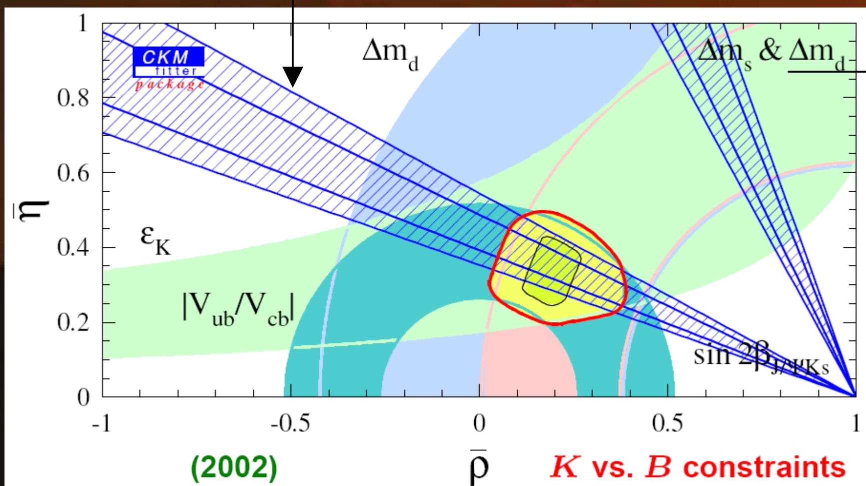


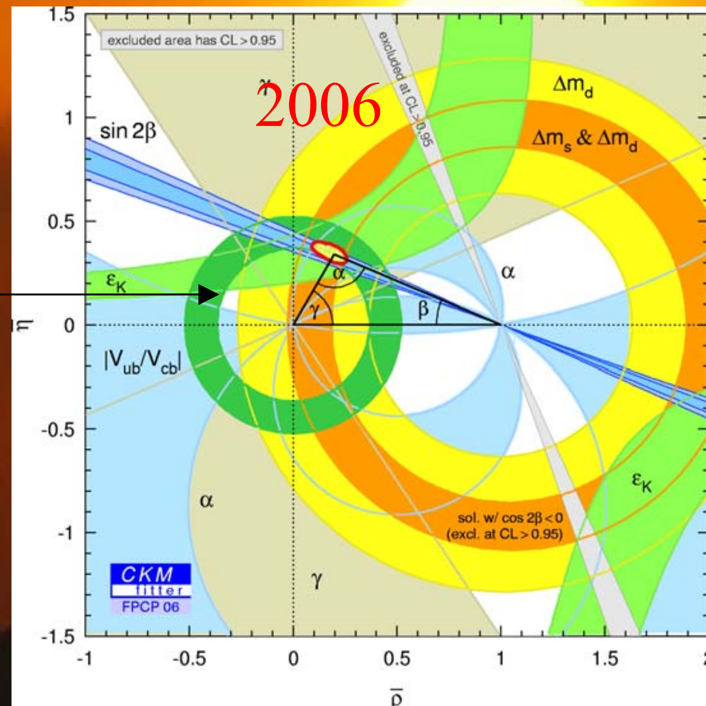


Plan: mesures pour conférences été 2007

Conclusion/Perspectives







- $B \rightarrow K^{*0}\rho^{0/+}$
- $B \rightarrow \rho^0\rho^0$

bcp de chemin parcouru depuis 1998

Davantage encore avec les futurs run6, …→2008 (Babar ~1 ab^{-1})

Dans le Modele Standard, la violation de CP est expliquee par la presence de termes complexes dans la matrice CKM. L'unitarite de cette matrice impose l'existence d'un triangle (dit d'unitarite) dont les cotes et angles sont mesurees par les experiences. Apres une breve revue des analyses pour la determination des angles, je presenterai mon travail d'etude des canaux B0->K*0 rho0 et B0->rho0 rho0, permettant pour ce dernier d'ameliorer la determination de l'angle alpha

appendice

$$A(B^- \to D^0(K^+\pi^-)K^-) = abr_D$$
$$A(B^- \to \bar{D}^0(K^+\pi^-)K^-) = abr_B e^{i(\delta_f+\delta_D)} e^{-i\gamma}$$
$$A(B^+ \to D^0(K^-\pi^+)K^+) = abr_B e^{i(\delta_f+\delta_D)} e^{i\gamma}$$
$$A(B^+ \to \bar{D}^0(K^-\pi^+)K^+) = abr_D$$

rapport suppr/ favor

$r_D = |A(D^0 \to K^+\pi^-)/A(D^0 \to K^-\pi^+)|$

$$Br(B^- \to D(K^+\pi^-)K^-) + Br(B^+ \to D(K^-\pi^+)K^+) = 2a^2b^2(r_D^2 + r_B^2 + 2r_B r_D \cos(\delta_D + \delta_f)\cos\gamma)$$
$$Br(B^- \to D(K^+\pi^-)K^-) - Br(B^+ \to D(K^-\pi^+)K^+) = 4a^2b^2 r_B r_D \sin(\delta_D + \delta_f)\sin\gamma$$

Deux quantités mesurant γ

- Asymétrie de CP

$$A_{ADS} = \frac{Br(B^- \to D(K^+\pi^-)K^-) - Br(B^+ \to D(K^-\pi^+)K^+)}{Br(B^- \to D(K^+\pi^-)K^-) + Br(B^+ \to D(K^-\pi^+)K^+)} = \frac{2r_B r_D \sin(\delta_D + \delta_f)\sin\gamma}{r_D^2 + r_B^2 + 2r_B r_D \cos(\delta_D + \delta_f)\cos\gamma}$$

- $R_{CP\pm}$

$$R_{ADS} = \frac{Br(B^- \to D(K^+\pi^-)K^-) + Br(B^+ \to D(K^-\pi^+)K^+)}{[Br(B^- \to D^0(K^-\pi^+)K^-) + Br(B^+ \to \bar{D}^0(K^+\pi^-)K^+)]} = r_B^2 + r_D^2 + 2r_B r_D \cos(\delta_B + \delta_D)\cos\gamma$$

Silva-Wolfenstein method (SU(3))

SU(3) symmetry: $B^0 \rightarrow K^+\pi^-$, $B^0 \rightarrow \pi^+\pi^-$

$$\Gamma(B^0 \to \pi^+\pi^-) = |T^{+-}|^2 + |P^{+-}|^2 + 2|T^{+-}||P^{+-}|\cos(\beta+\gamma-\delta)$$

$$\Gamma(B^0 \to K^+\pi^-) = |T'^{+-}|^2 + |P'^{+-}|^2 - 2|T'^{+-}||P'^{+-}|\cos(\gamma+\epsilon'-\epsilon-\delta')$$

$$\epsilon' = arg\left(-\frac{V_{us}V_{ud}^*}{V_{cs}V_{cd}^*}\right) \qquad \epsilon = arg\left(-\frac{V_{cb}V_{cs}^*}{V_{tb}V_{ts}^*}\right)$$

- $$R = \frac{\Gamma(B^0 \to K^+\pi^-) + \Gamma(\bar{B}^0 \to K^-\pi^+)}{\Gamma(B^0 \to \pi^+\pi^-) + \Gamma(\bar{B}^0 \to \pi^+\pi^-)}$$

$$= \frac{|T'^{+-}|^2}{|T^{+-}|^2}\frac{1 + r'^2 + 2r'\cos(\alpha+\beta+\epsilon-\epsilon')\cos\delta'}{1 + r^2 - 2r\cos\alpha\cos\delta}$$

from $J\psi/K_S$

small

- $$a_{CP}(\pi^+\pi^-) = -\sin 2(\alpha + \delta_\alpha)$$

$$\tan\delta_\alpha = \frac{r\sin\alpha}{1-r\cos\alpha}$$

$\rightarrow \alpha$ advantage: easy to measure

« Trajectographe » de vertex (Silicon Vertex Tracker)

- a_{CP} → Δt (désintégrations) → vertex 2 mésons, $\Delta z(B) \sim 260\ \mu m$
- P_T traces chargées P_T: 50-120 MeV (R^{-1} trop ↓ pour DCH)
- identification dE/dX (DCH)

Diffusion multiple : meilleure résolution couche internes

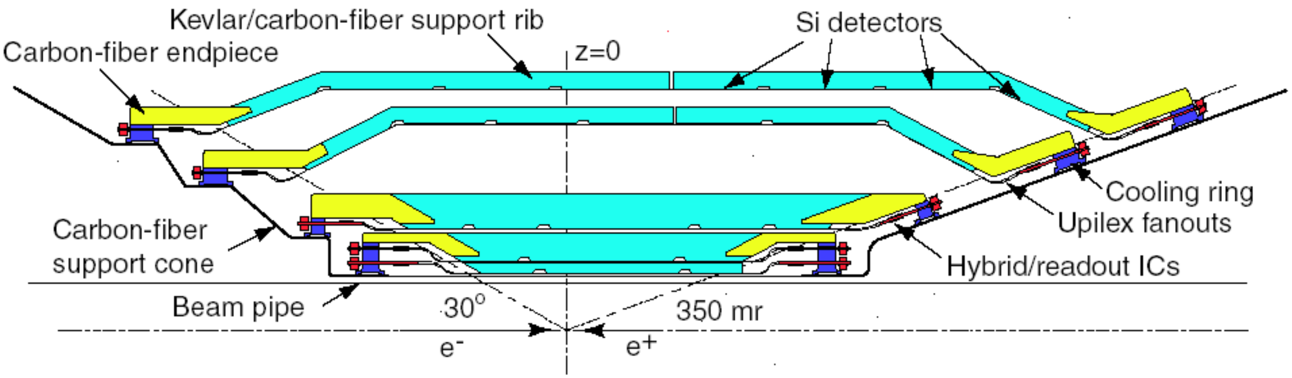
P_T<100 MeV: n'atteint pas DCH (ε↑ pour Pt>180 MeV) ➔ SV**Tracker**

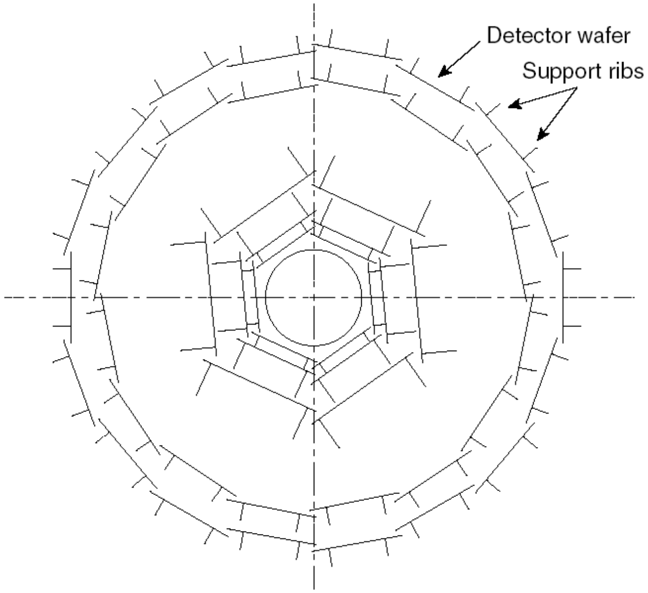
$\sigma_z \gg O(\Delta z/2)$ → $\sigma_z < 80\ \mu m$, silicium à micropistes

meilleure σ_z ➔ reconnaissance motifs, reconstruction vertex, rejet bruit

Limite par diffusion multiple → couches internes 10-15 μm, externes: 30-40 μm

5 couches cylindriques
2 externes: en arche (couverture angulaire, angles incidence↓)





3 couches internes: 6 modules: paramètre impact
Faces internes: pistes ⊥faisceaux→position longitudinale (z)
externes: pistes ‖ faisceaux→angle azimutal (ϕ)
340 détecteurs silicium, 150000 canaux lecture, 90 % angle solide

Chambre à dérive (DCH)

particules chargées (impulsion et angles) acceptance: 17.2°-152.6°

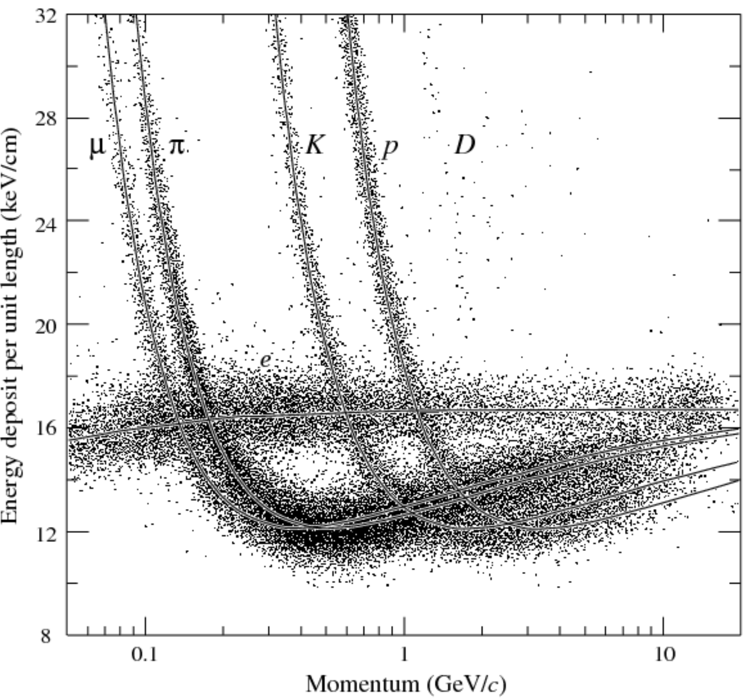
40 points de mesure par trace, σ<140 μm

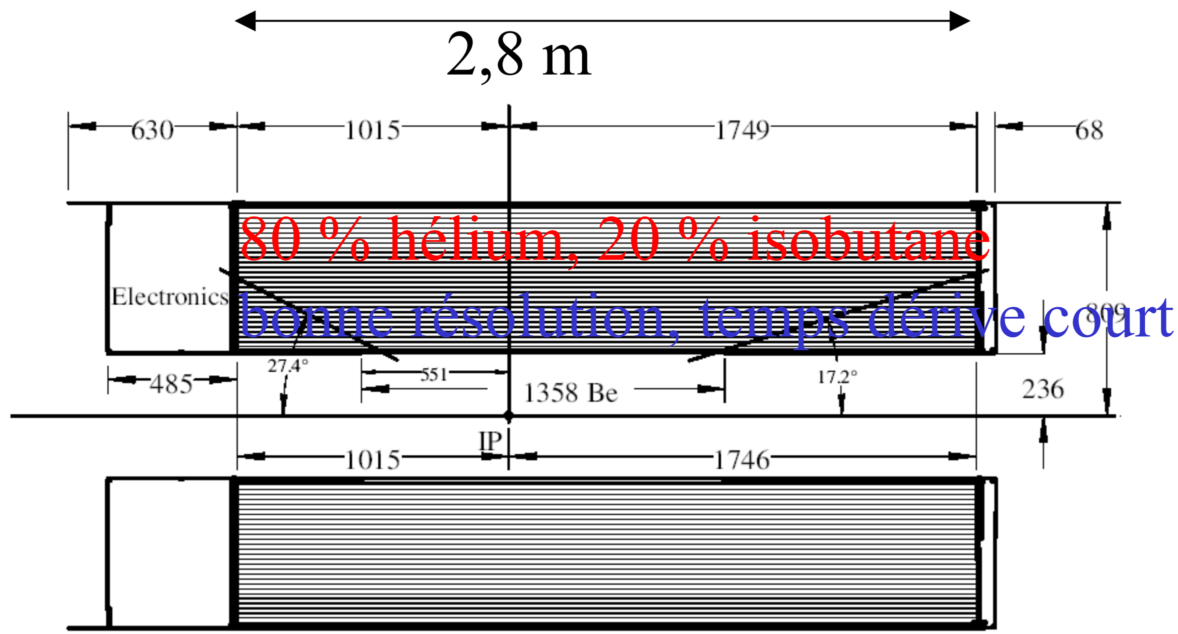
Avec SVT, reconstruction traces P_T>100 MeV

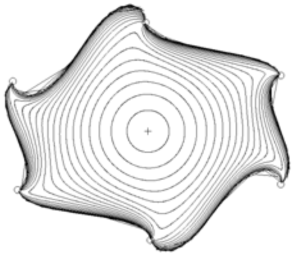
reconstruire vertex déplacé (non dans SVT)→bonne résolution longitudinale

Identification particules (dE/dx) sépare π/K jusqu'à 700 MeV

↓P_T: σ:7 %, ↑P_T>1 GeV: σ~0,3 %



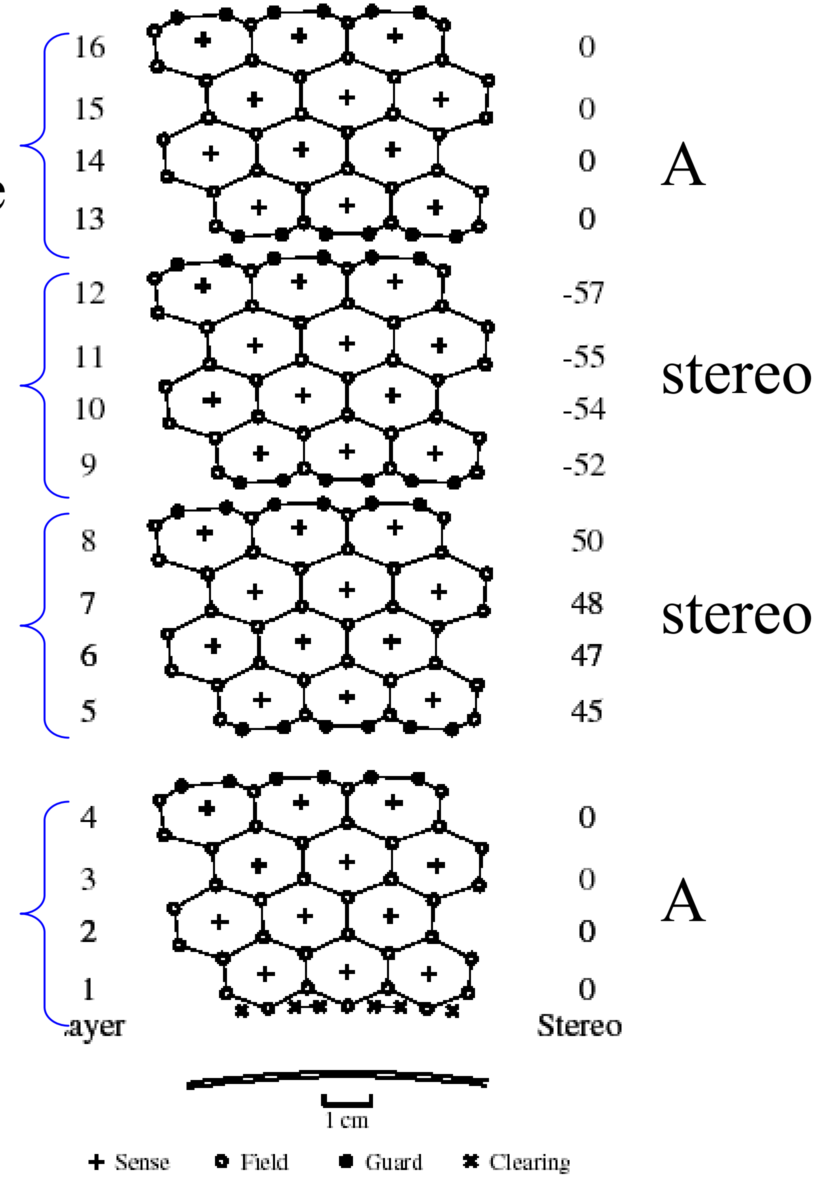




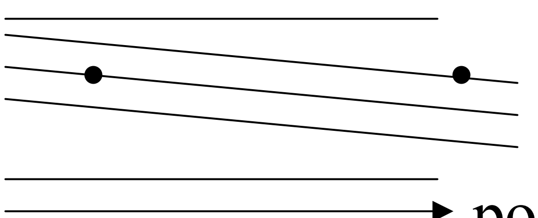
- 1 fil capteur

20 µm, alliage tungstène-rhénium
Résistivité ↓, résistance mécanique
ionisation gaz, avalanche
seuil détection: 2 e^- (1 trace~22 e^-)

- 6 fils de champ



7104 cellules hexagonales, 11,9 x19,0 mm
10 super-couches (chacune 4 couches)
→jusqu'à 40 points de mesures
Mesure 3D: angle stereo super-couches:
alterne axiale, stereo (U-V)
θ~ [±45 mrad;±76 mrad]
Axiales : angle courbure traces (impulsion)
Stereo: en plus: position longitudinale



position longitudinale

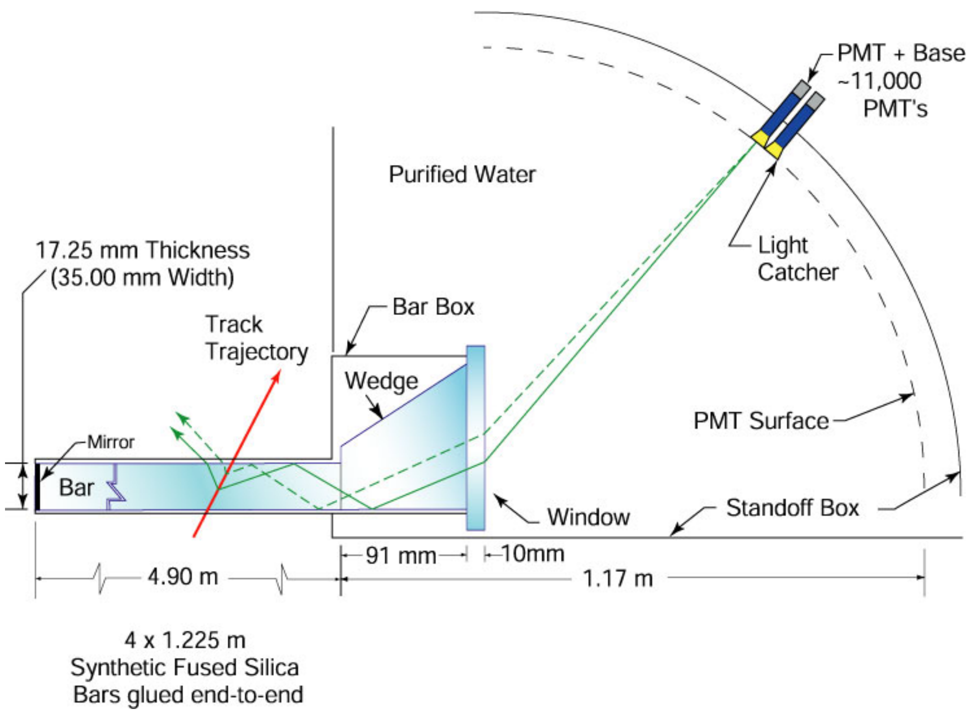
Résolution temporelle: 1 ns → 140 µm

DIRC: (detection of Internally Reflected Cerenkov light)

Identification particules chargées, distingue $\pi^{+/-}$/K
(P_T:[0,7 GeV;4 GeV]), p (P>1.3 GeV)
K→étiquetage saveur B (b→c→s)
Rayonnement Cerenkov particule chargée $\beta>1/n$
SVT+DCH: p→identification particule

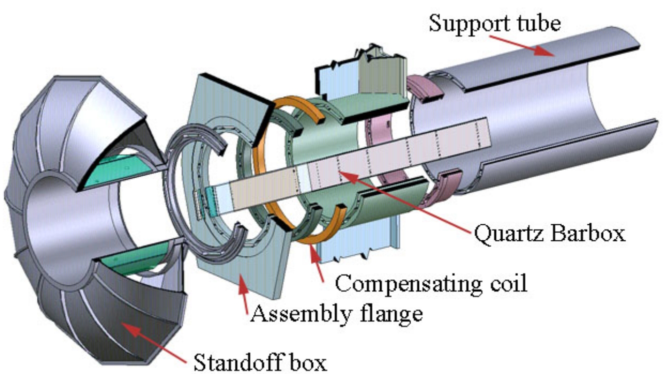
$$\cos\theta_C = \frac{1}{\beta n}$$

$$m^2c^4 = \frac{1-\beta^2}{\beta^2}p^2$$



radiateur 144 barres quartz (résistant radiations, longueur atténuation ↑, n↑,dispersion chromatique faible)
lumière→arrière détecteur
Prisme: rabat photons trop grand angle (réduit PMT), angle 6 mrad prisme
Ambiguïté parité réflexion

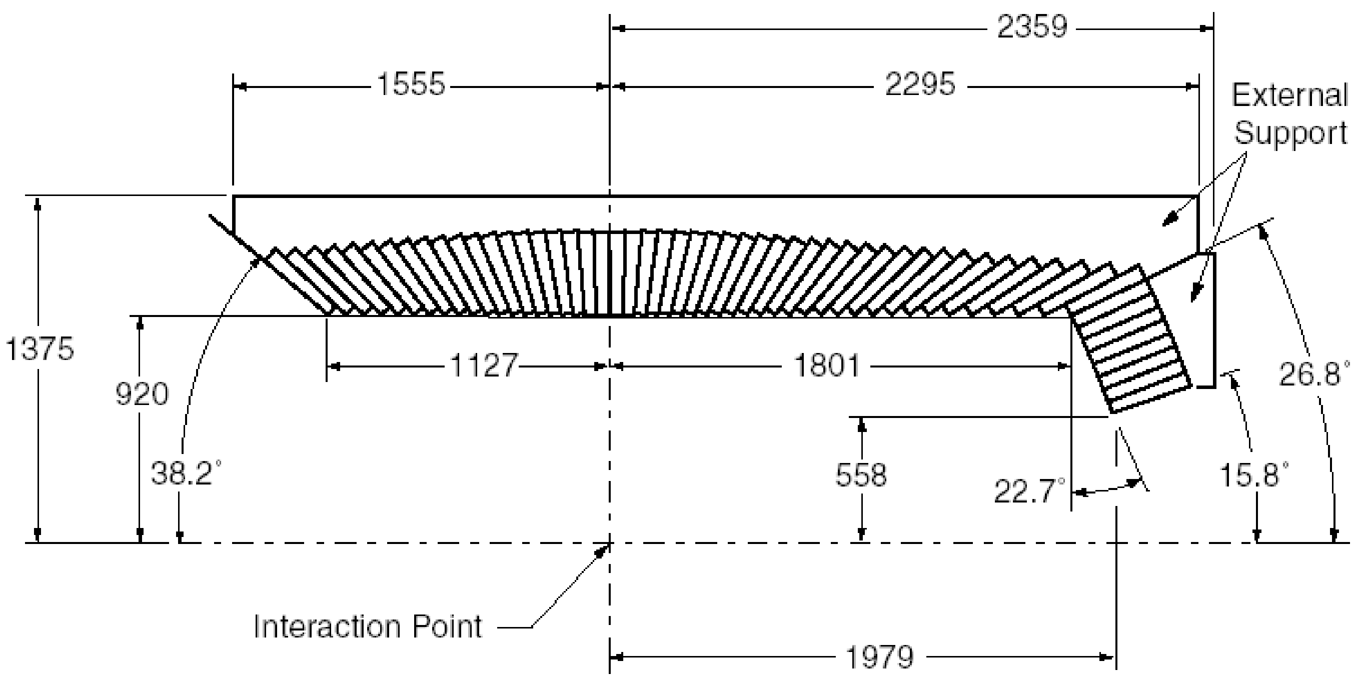
Cuve à eau (Stand Off Box)
Eau: indice proche quark, minimise perte réflexions quartz/eau
photons→11000 PMT



Calorimètre électromagnétique

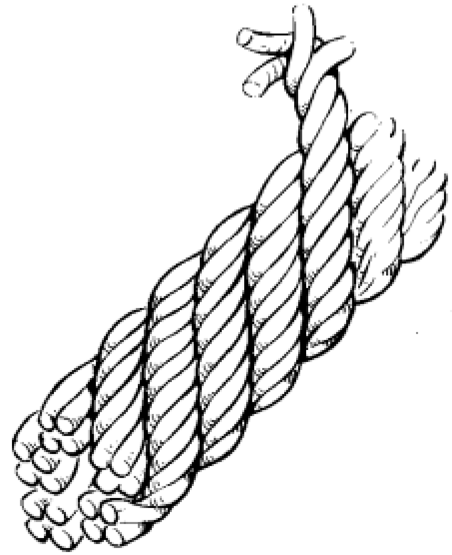
Gerbes électromagnétiques γ, π, η, position, énergie
20 MeV-9 GeV
Identification e^- par E/p, permet de tagger B par lepton

Tonneau cylindrique, bouchon conique avant
5760 cristaux scintillation (48 colonnes suivant angle polaire)
Cristaux CsI: bonne production lumière (50000 γ/MeV)
Lumière scintillation lue par photodiodes silicium



solénoïde

like the filaments in composite wires, cables
must be twisted to reduce coupling



1,5 T
Cable Rutherford 10 km
I=4600 A, hélium liquide 4.5 K
Retour de champ pour protéger aimants Q2, Q4, Q5

Retour de flux instrumenté
IFR(Instrumented Flux Return)

détecteur μ (étiquetage saveur B, désintégrations semi-leptoniques B)
P_T>GeV
Détection hadrons neutres (K_L^0, n)
RPC: Resistive Plate Chamber
RPC: détec tent particule ionisante dans gaz→étincelle entre deux plaques