

CDF au LPNHE depuis la dernière biennale

Deux lignes de recherche centrées sur la recherche de BSM:

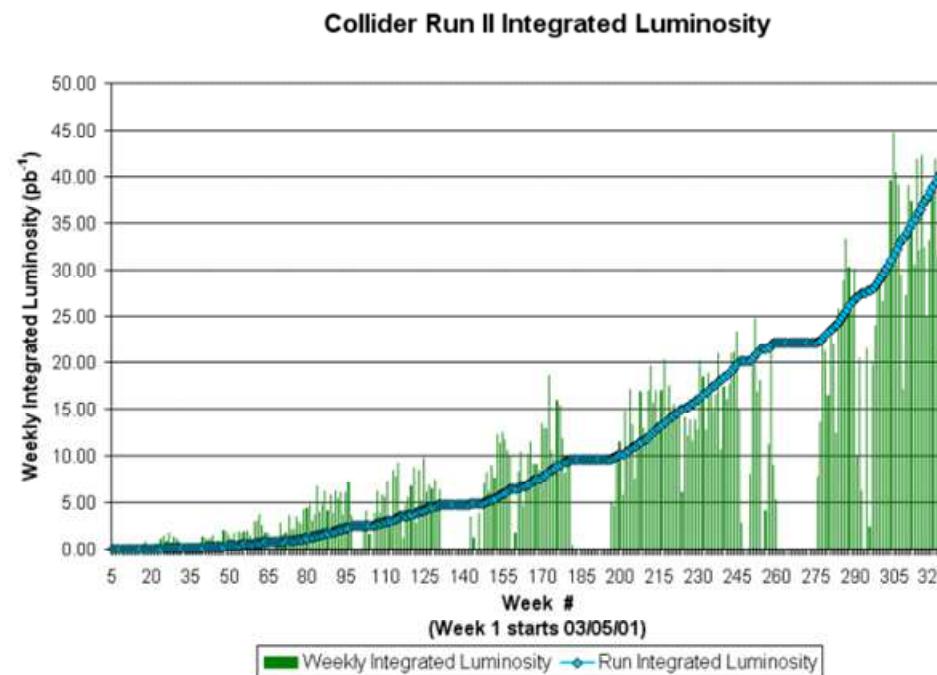
- La physique du B => le secteur du Bs (oscillations et violation CP)
- La physique du lepton τ => le top en tau et perspectives

Ces deux lignes de recherche sont en prolongement de la participation à la phase finale de la construction de CDF II et de sa mise en route dès 1998, et au travail d'analyse entrepris à partir de 2002.

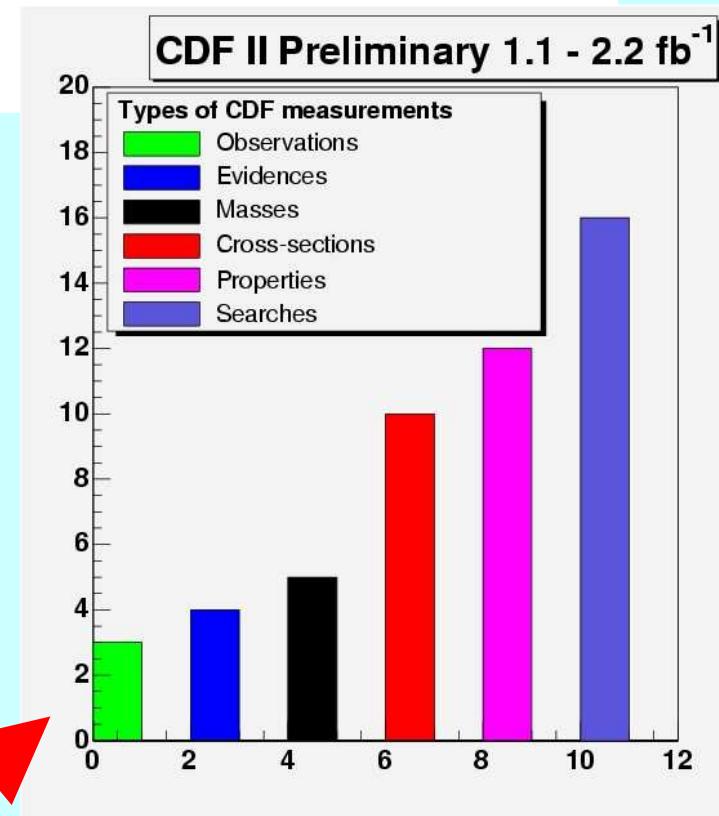
Contribution du CCIN2P3 pour CDF-GRID depuis 2005

Biennale 2007 du LPNHE
12 au 14 Septembre 2007

Villa Clythia - Fréjus

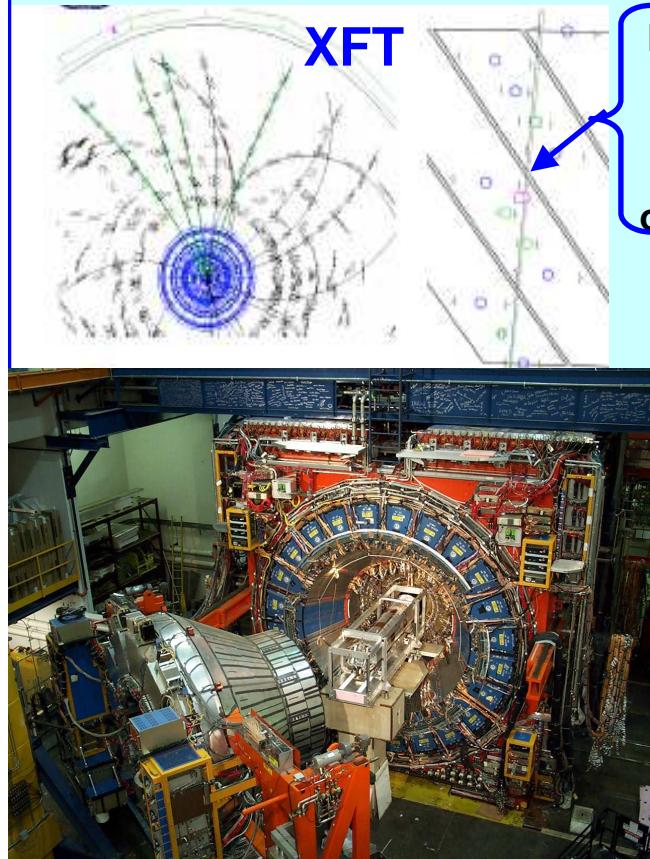


**3.2 fb⁻¹ délivrés, plus de 2.7 fb⁻¹ enregistrés,
~40pb⁻¹ délivrés/sem, L_{max}:2.85x10³² cm⁻²s⁻¹**

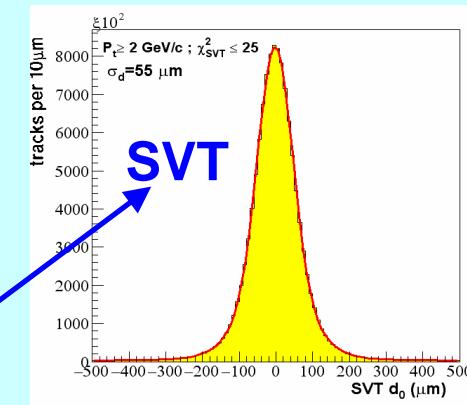


The CDF scorecard is an impressive one. Fifty-one new results will be shown, thirty-one of them utilizing the newest data collected through April of this year. The scope of these results is vast: from precise measurements of the copious particles produced by the strong force to searches for the scant signals of new particles produced by unknown forces. In many cases, these results demonstrate pioneering work and present "first" or "world's best" measurements.

High Precision Drift + Si Tracking & L1xL2 Track Triggering

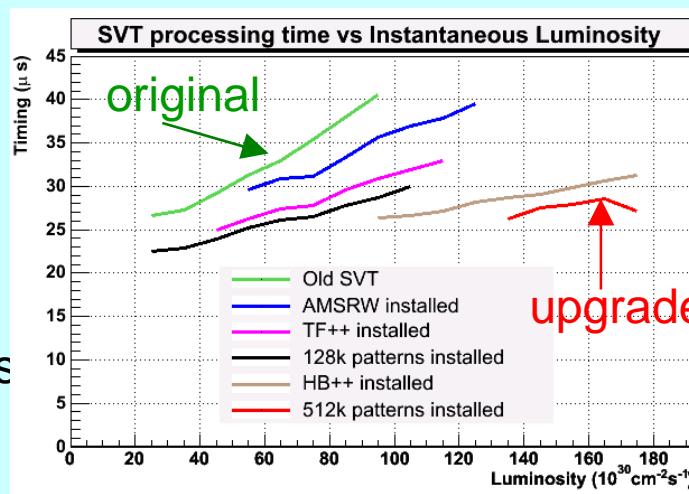
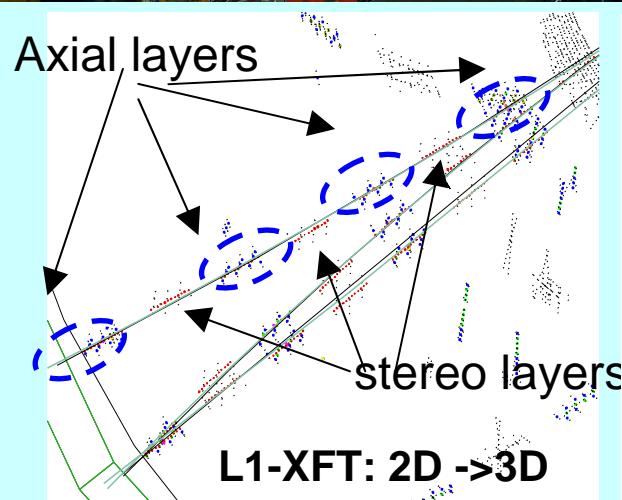
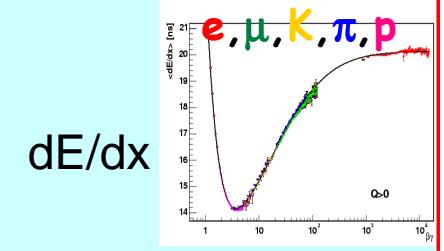
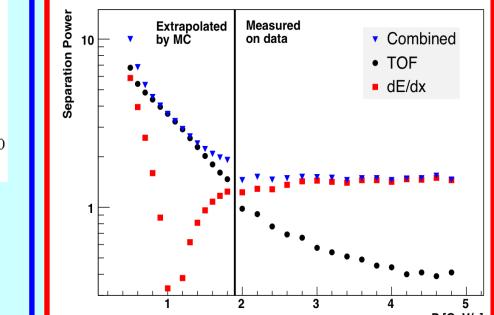
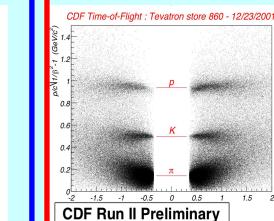


Finds $P_t > 1.5 \text{ GeV}$
tracks in $1.9 \mu\text{s}$
For every bunch
Crossing
 $\sigma(1/P_t) = 1.7\%/\text{GeV}$
 $35 \mu\text{m} \oplus 33 \mu\text{m}$
resol \oplus beam
 $\Rightarrow \sigma = 48 \mu\text{m}$



Particle ID

ToF



Luminosity increase

Upgrade =>

- good data @ High L

- more data @ Low L

L2-SVT: faster devices
& new AM 32K → 512K
patterns

RECHERCHE DU TOP EN TAUS A L'LDL

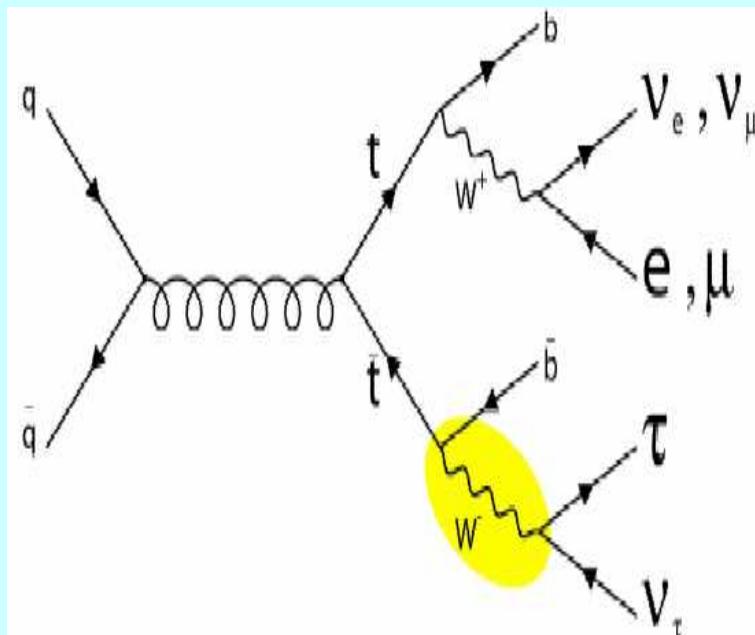
(S. Tourneur, A. Savoy-Navarro)

Suite au travail sur déclenchement Lepton + Track =>
multileptons de bas Pt y inclus les leptons tau → unique pour
recherche SUSY et BSM Higgs

Objectifs de la recherche :

- 1) 1^{ère} mise en évidence du top dans ce canal de désintégration
- 2) Signature similaire à plusieurs canaux BSM (SUSY& $H^0 \rightarrow \tau^+ \tau^-$)
- 3) Tester le modèle standard

$BR(t \rightarrow \tau v b) \stackrel{?}{=} BR(t \rightarrow e v b) = BR(t \rightarrow \mu v b)$:

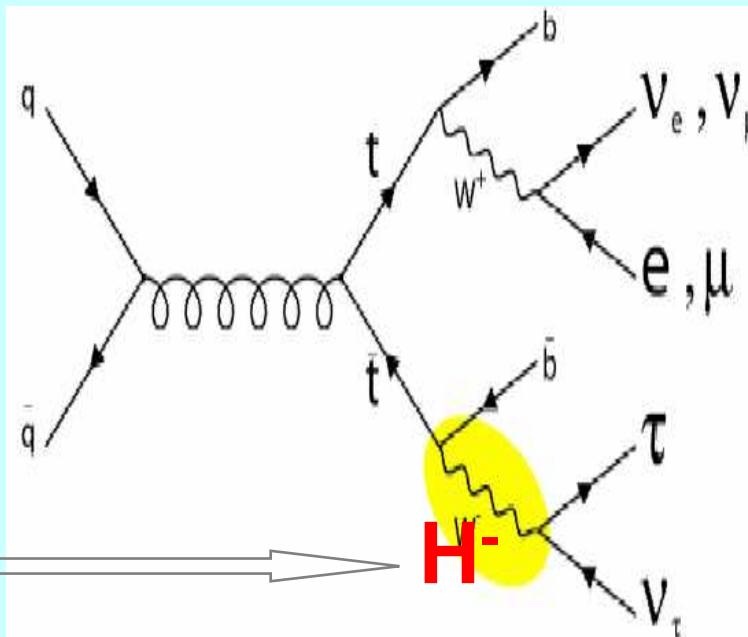


Recherche de top en taus à CDF

Objectifs de la recherche :

- 1) 1^{ère} mise en évidence du top dans ce canal de désintégration
- 2) Signature similaire à plusieurs canaux BSM (SUSY& $H^0 \rightarrow \tau^+\tau^-$)
- 3) Tester le modèle standard

$BR(t \rightarrow \tau\nu b) \stackrel{?}{=} BR(t \rightarrow e\nu b) = BR(t \rightarrow \mu\nu b)$:

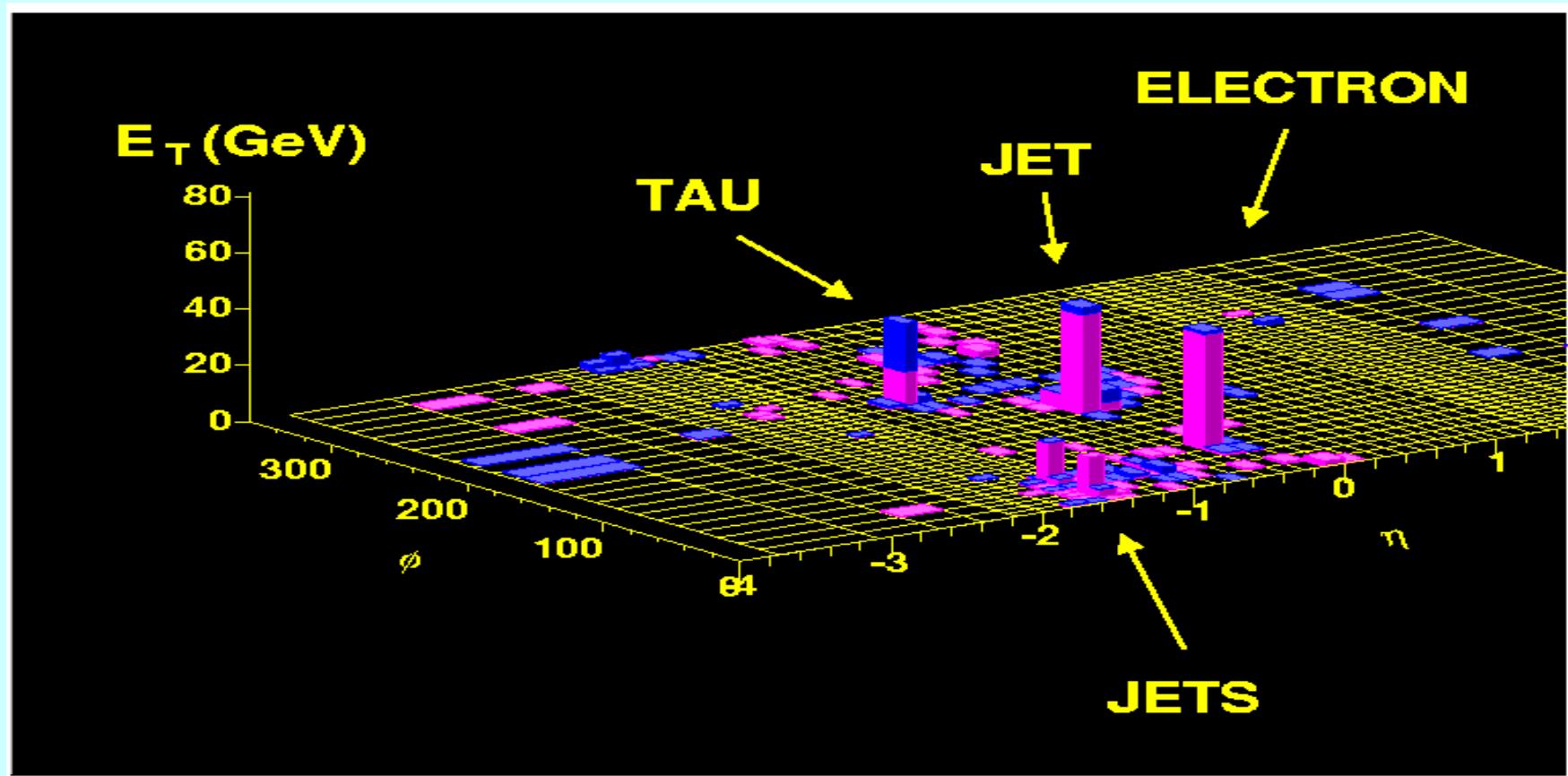


- \exists Higgs chargé ?

Le canal $t \rightarrow \tau v q$

Difficile en collisions hadroniques

Identification de τ , e, μ , jets, énergie transverse manquante :



Recherche de top en tau ($t \rightarrow \tau\nu q$)

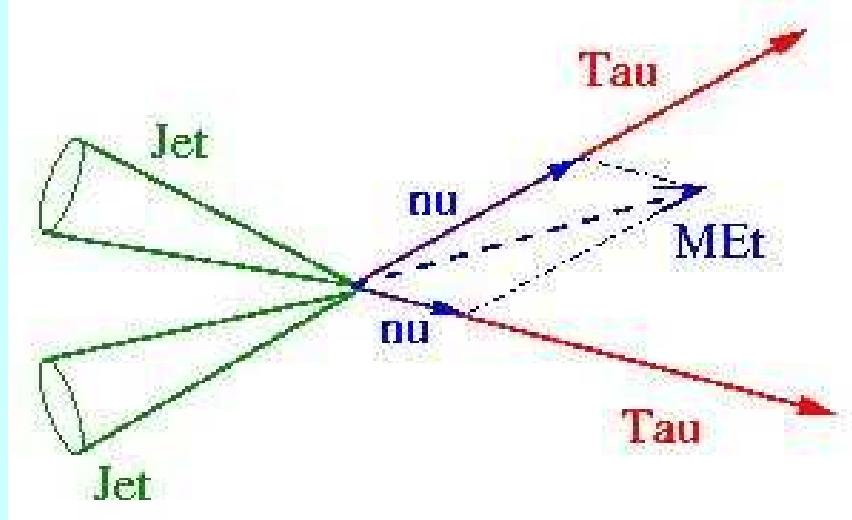
⇒ Priorités pour l'observation de ce signal :

- Estimation et réduction du bruit de fond :
 - fond de $Z \rightarrow \tau\tau$: utilise simulations et données réelles
 - fonds $W+jets$ et QCD : utilise les données réelles seules

Recherche de top en tau ($\text{top} \rightarrow \tau\nu q$)

⇒ Priorités pour l'observation de ce signal :

- Estimation et réduction du bruit de fond
 - fond de $Z \rightarrow \tau\tau$: utilise simulations et données réelles
 - Développement d'une méthode originale utilisant la direction d'émission des neutrinos pour la réduction du fond $Z \rightarrow \tau\tau + 2 \text{ jets}$
 - Réduction du fond de 70% contre 8% de perte du signal

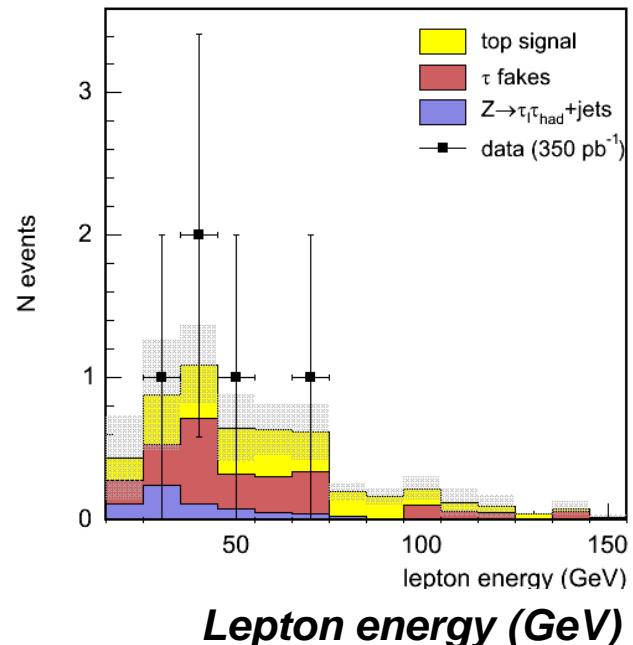


Recherche de top en tau ($\text{top} \rightarrow \tau\nu q$)

- Estimation et réduction du fort bruit de fond (suite) :
 - Fonds $W+\text{jets}$ et QCD :
 - Nouvelle méthode pour estimer dans les données la probabilité qu'un jet soit mal identifié comme un tau :
 - Analyse des différences de **forme des jets** issus de quarks vs. gluons, événements QCD à 2 jets vs. $W + 3$ jets
 - « fake rate » fonction de :
$$p(jetE_T, \sum E_T) \times f(N_{\text{jets}})$$
 - Valeur \sim de 0.5 à 1% avec une incertitude de 6%
 - Incertitude **améliorée d'un facteur 5** pour les événements à un jet
 - Optimisation de la sélection pour l'extraction du signal :
 - Coupures séquentielles maximisant la signification

Résultats officialisés par CDF (mi 2006)

CDF Run II preliminary

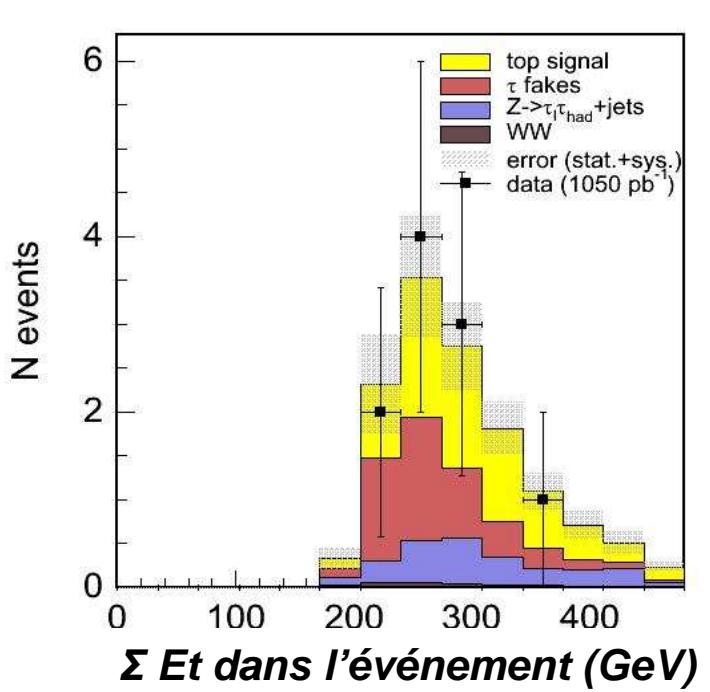


Lepton energy (GeV)

CDF Run II preliminary	Lepton(e, μ) + tau (350 pb ⁻¹)
Total fond	2.7 ± 0.4
SIGNAL (ttbar → l+τ)	2.2 ± 0.4
Total modèle standard	5.0 ± 0.6
OBSERVATION	5

- Résultat publié avec les données de 2002-2004 : **15%** de probabilité pour le fond seul (2.7 ± 0.4) d'avoir fluctué jusqu'aux 5 événements observés ou plus (p-valeur)
- Analyse présentée par S. Tourneur aux conférences APS et Ecole d'été de Corfou (proceedings dans Journal of Physics : Conference Series 53 (2006) 227-233)
- Présentée par collaborateurs de CDF aux conférences TAU06 et HCP06
- Attente de la collaboration de publication: actuellement en cours de préparation

- Poursuite de l'analyse sur CDF avec les données 2005-06 :
 - Utilisation d'une méthode statistique de maximum de vraisemblance
 - Amélioration de $+1\sigma$ de la sensibilité pour l'observation du signal
 - **Préparation d'un papier dont nous sommes éditeurs (fin 07)**
- Résultats avec 1 fb^{-1} :
 - P-valeur de 8%
 - $\Gamma(t \rightarrow \tau\nu q)/\Gamma_{\text{SM}}(t \rightarrow \tau\nu q) < 1.5 \text{ à } 95\% \text{ CL}$ (**résultat 2005 : } < 5.2)**

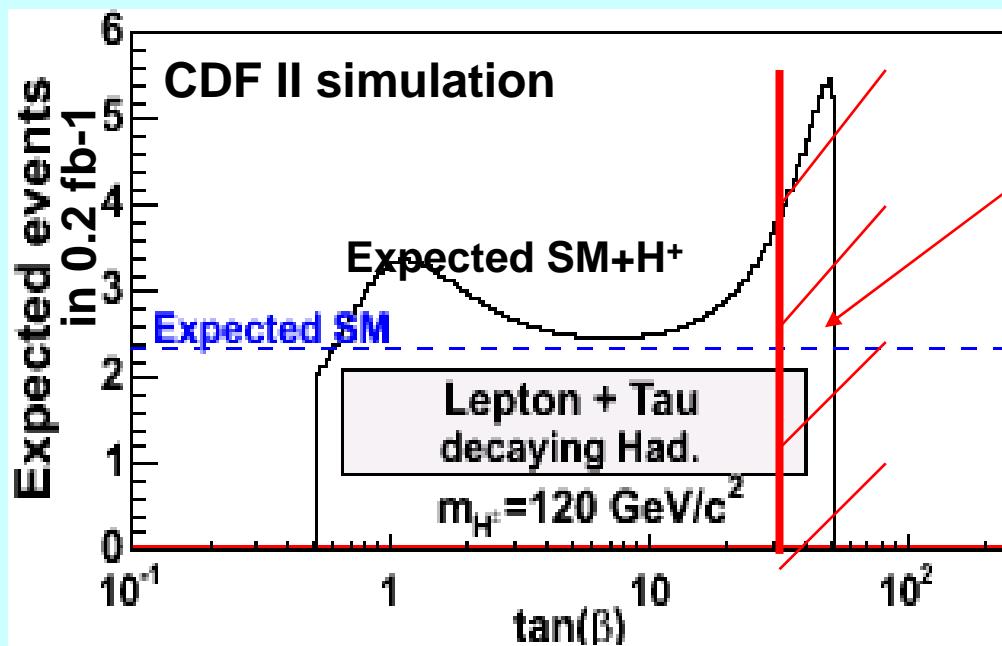


Résultats finaux	Lepton(e, μ) + tau (1 fb ⁻¹)
Total fond	7.7 ± 1.7
SIGNAL (ttbar → l+τ)	6.4 ± 0.7
Total modèle standard	14.1 ± 1.8
OBSERVATION	11

➡ Thèse de S. Tourneur, soutenue 17/11/ 2006

Perspectives sur le Higgs chargé

- Existence prédictive par SUSY
- Recherches du H^+ :
 - LEP, Tevatron : $H^+ \rightarrow \tau\nu, cs, t^*b$
- $t \rightarrow bH^+ \rightarrow b\tau^+\nu$ peut être le canal d'observation privilégié au Tevatron



Impact de notre résultat :

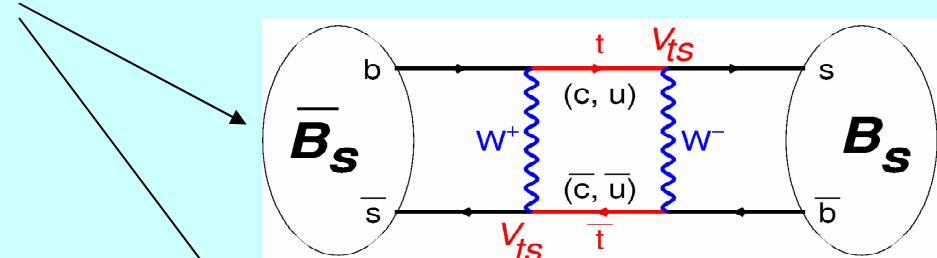
$\tan \beta < 30$
(avec MSSM:
 $m_{H^+} = 120 \text{ GeV}/c^2$
 $\mu = -500 \text{ GeV}/c^2$
 $A_t = A_b = 2000 \text{ GeV}/c^2$)

Neutral B_s system

B_s meson is special: contrary to any other system it has very high frequency of transition

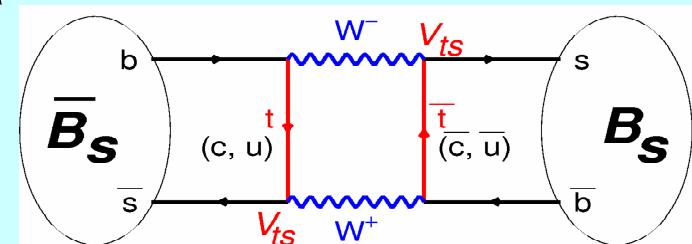
Flavor eigenstates:

$$|B_s\rangle = (\bar{b}s); \quad |\bar{B}_s\rangle = (b\bar{s})$$



At production two states are pure \bar{B}_s and B_s :

$$i \frac{\partial}{\partial t} \begin{pmatrix} |B_s^0(t)\rangle \\ |\bar{B}_s^0(t)\rangle \end{pmatrix} = \left(M - i \frac{\Gamma}{2} \right) \begin{pmatrix} |B_s^0(t)\rangle \\ |\bar{B}_s^0(t)\rangle \end{pmatrix}$$



Mass eigenstates are such as ($|p|^2 + |q|^2 = 1$):

$$|B_H(t)\rangle = p|B_s(t)\rangle + q|\bar{B}_s(t)\rangle = |B_H(t=0)\rangle e^{-iM_H t - \frac{1}{2}\Gamma_H t}$$

2 Masses & Lifetimes:

$$|B_L(t)\rangle = p|B_s(t)\rangle - q|\bar{B}_s(t)\rangle = |B_L(t=0)\rangle e^{-iM_L t - \frac{1}{2}\Gamma_L t}$$

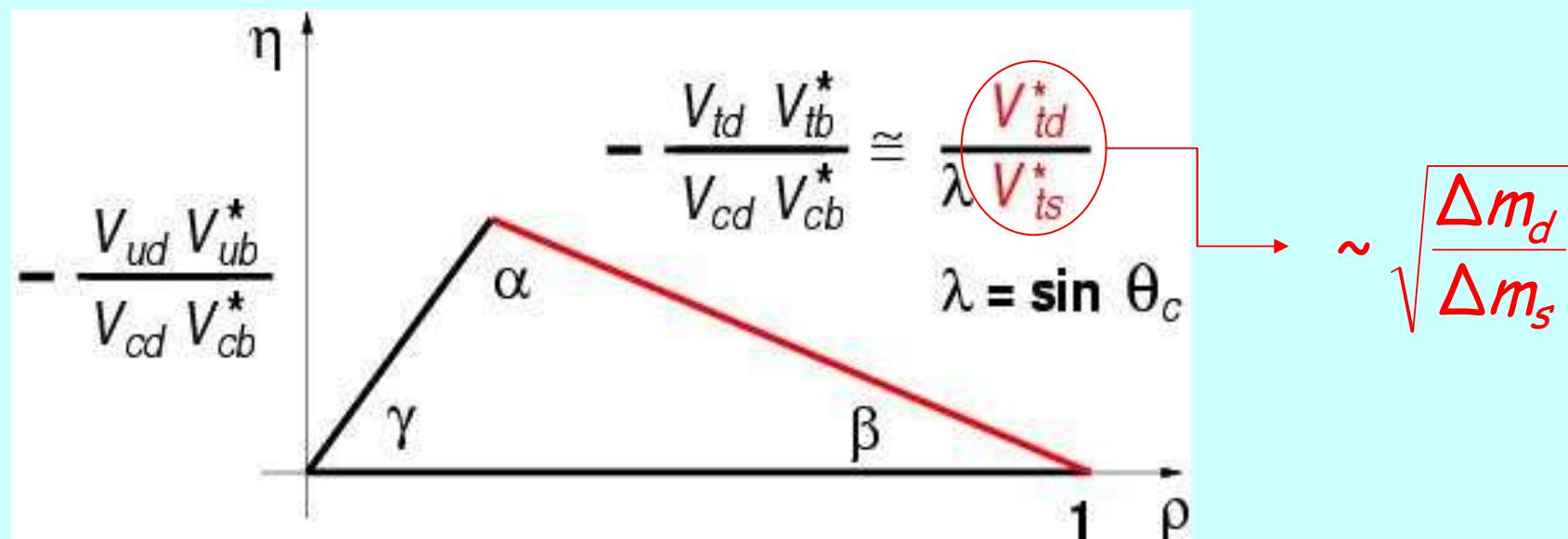
$$\Delta m_s = M_H - M_L$$

$$\Delta \Gamma_s = \Gamma_H - \Gamma_L$$

Unitarity Triangle

CKM Matrix Unitarity Conditions

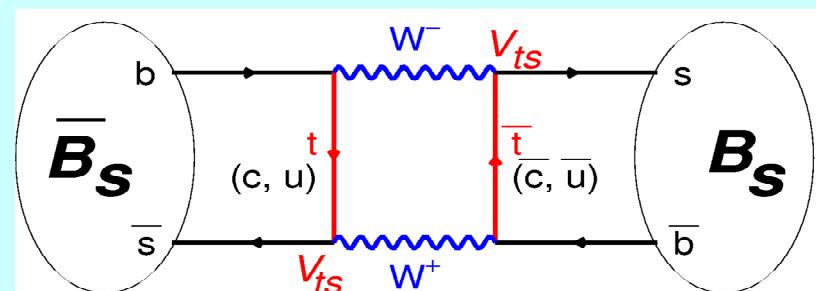
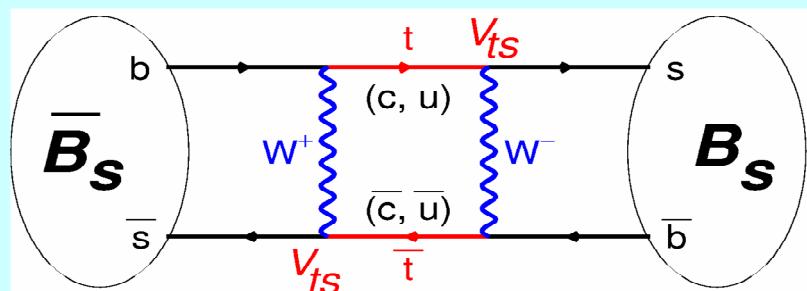
$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$



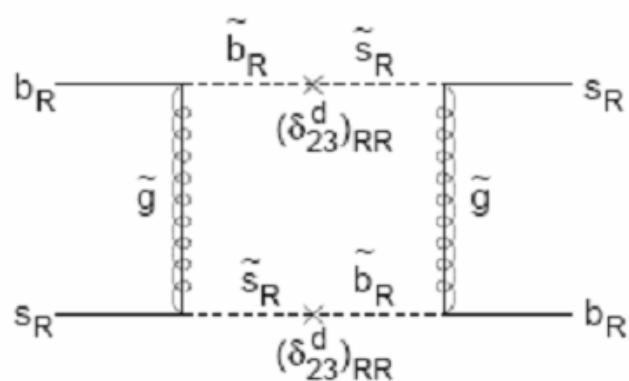
Standard Model does not predict values

Experimental input is crucial

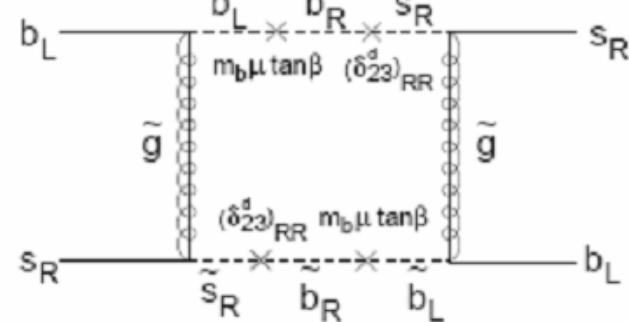
$\Delta m_s^{\text{BSM}} \neq \Delta m_s^{\text{SM}} ?$



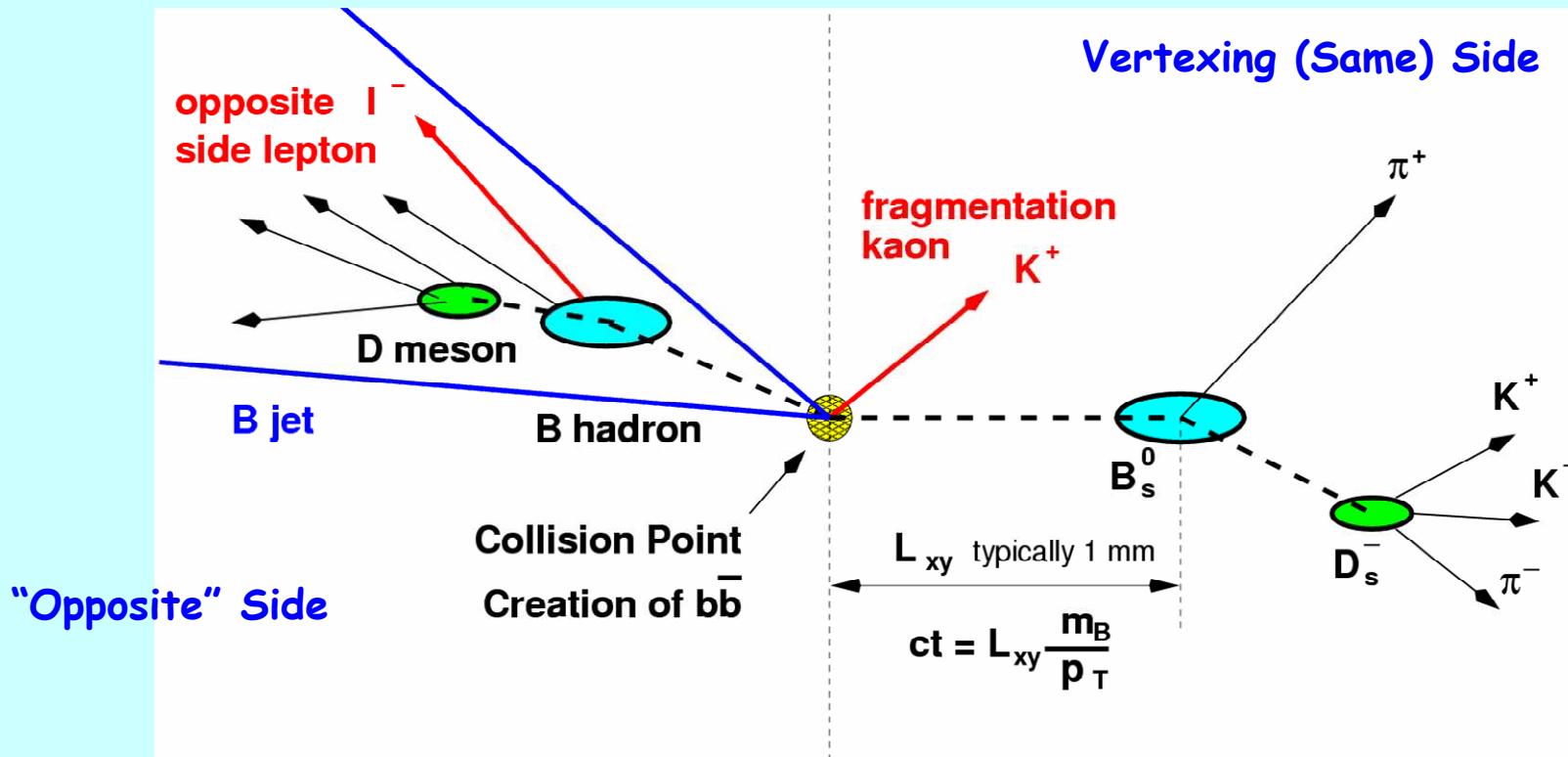
New Physics in Loops?



from Murayama et al. hep-ph/0212180



The Big Picture



Analyze B properties:

- Reconstruct B_s decays \rightarrow decay flavor from decay products
- Measure proper time of the decay
- Infer B_s production flavor (flavor tagging)

Golden Hadronic Sample

Fully reconstructed peak:

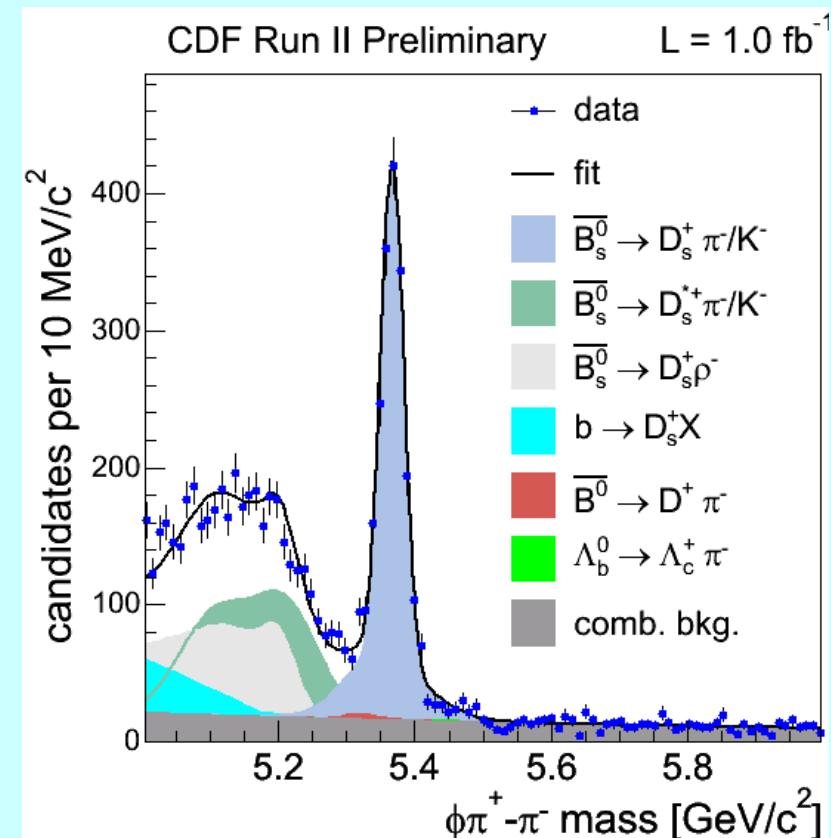
- 2000 $B_s \rightarrow D_s^-\pi^+, D_s^- \rightarrow \Phi\pi^-$ candidates

Partially reconstructed signals:

- \approx double signal yield
- soft γ or π^0 lost, fraction of p_T reconstructed $\sim 96\%$
- nearly fully reconstructed, critical attribute for σ_{ct}

Why "golden mode"?

- Few tracks (4), narrow Φ
- Low comb. Bkg; Great $S/\sqrt{S+B}$

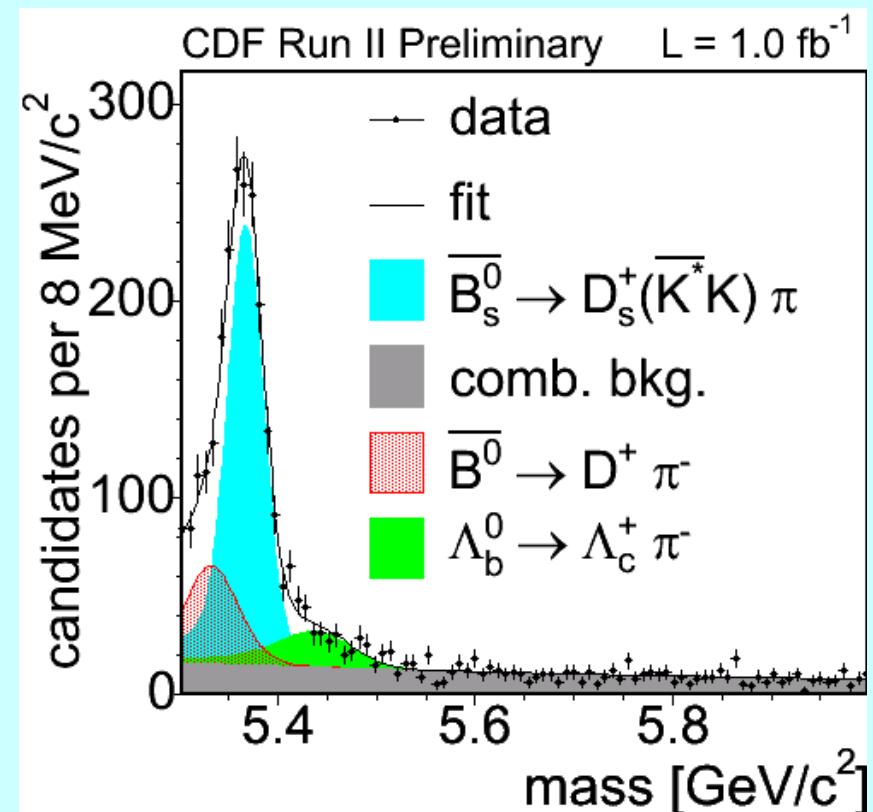


Other Fully Hadronic Samples

B_s Decay	Yield
$D_s(\Phi\pi)\pi$	2000
Partially Reco'd	3100
$D_s(K^*K)\pi$	1400
$D_s(3\pi)\pi$	700
$D_s(\Phi\pi)3\pi$	700
$D_s(K^*K)\pi$	600
$D_s(3\pi)3\pi$	200
Total	8700

Neural Network Selection:

- Improved bkg rejection
- PID used for B^0 suppression in $B_s \rightarrow D_s(K^*K)(3)\pi$



Semileptonic Decays

Sample composition:

- ID_s contains B^0 , B^+ and B_s
- Fraction fitted in data

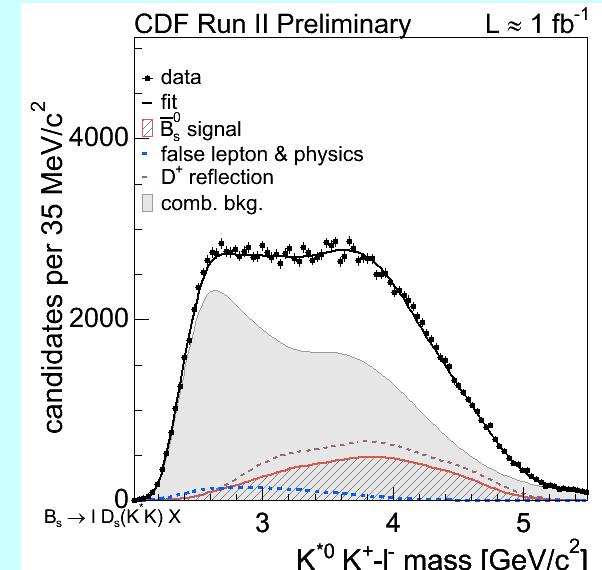
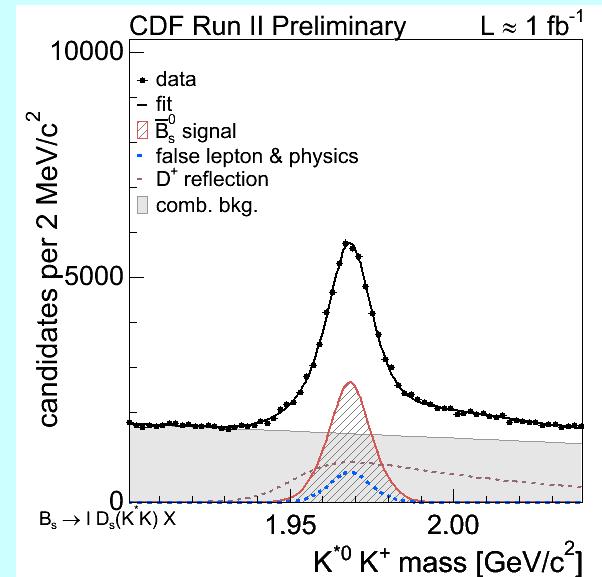
Introduced particle-id into selection

- Standard practice at B factories
- Reduce D^+ reflection in $K^* K$
- Combinatorial background dominated by pions

Signal yield 61,500 (April 2006: ~ 53 K)

Sensitivity driven by high ID_s mass candidates

- Exploited as fit input



Proper Time Resolution

$$\sigma_{ct} = \sqrt{\sigma_{ct}^0 + ct \cdot \frac{\sigma_p}{p}}$$

Fully reco'd $B_s \rightarrow D_s(3)\pi$:

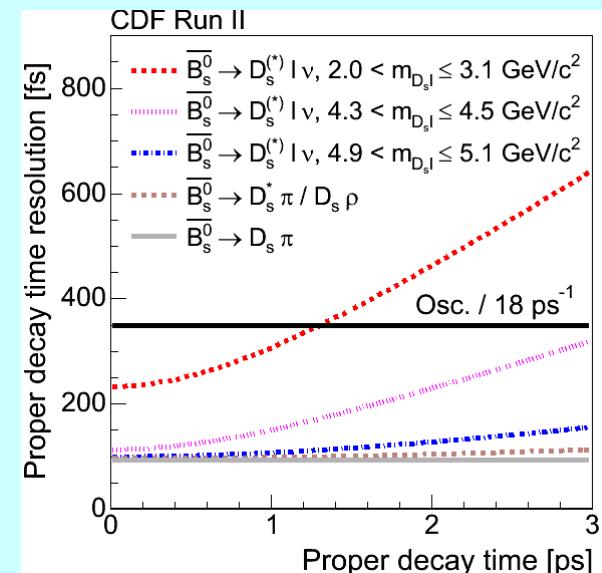
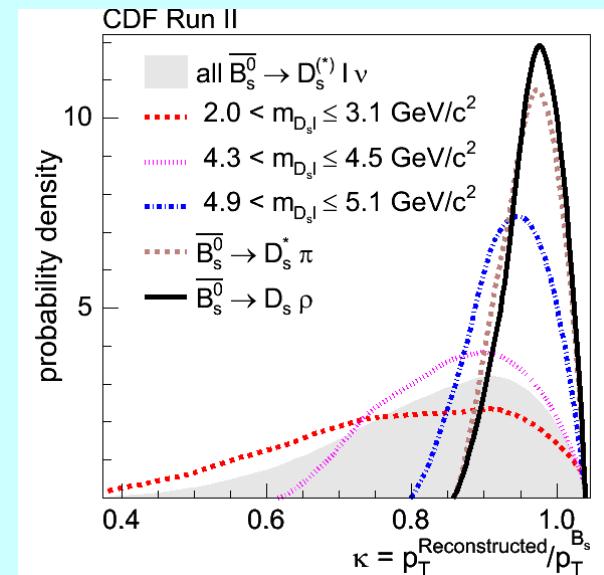
- $\sigma_{ct}^0 \sim 26 \mu\text{m}$ (87 fs)
- $\sigma_p/p < 1\%$

Partially reco'd $B_s \rightarrow D_s^*\pi, D_s^*\rho$:

- $\sigma_{ct}^0 \sim 29 \mu\text{m}$ (97 fs)
- $\sigma_p/p < 2\%$

Semileptonic $B_s \rightarrow D_s l X$:

- $\sigma_{ct}^0 \sim 30\text{-}70 \mu\text{m}$ (100-230 fs)
- $\sigma_p/p < 3\text{-}20\%$



Opposite Side Tagging

Soft Lepton Tagger

- Look for $B \rightarrow l X$ decays on OS
- Lepton charge indicates b-flavor

Jet Charge Tagger

- Look for jet or secondary vertex on OS
- Jet charge indicates the b-flavor

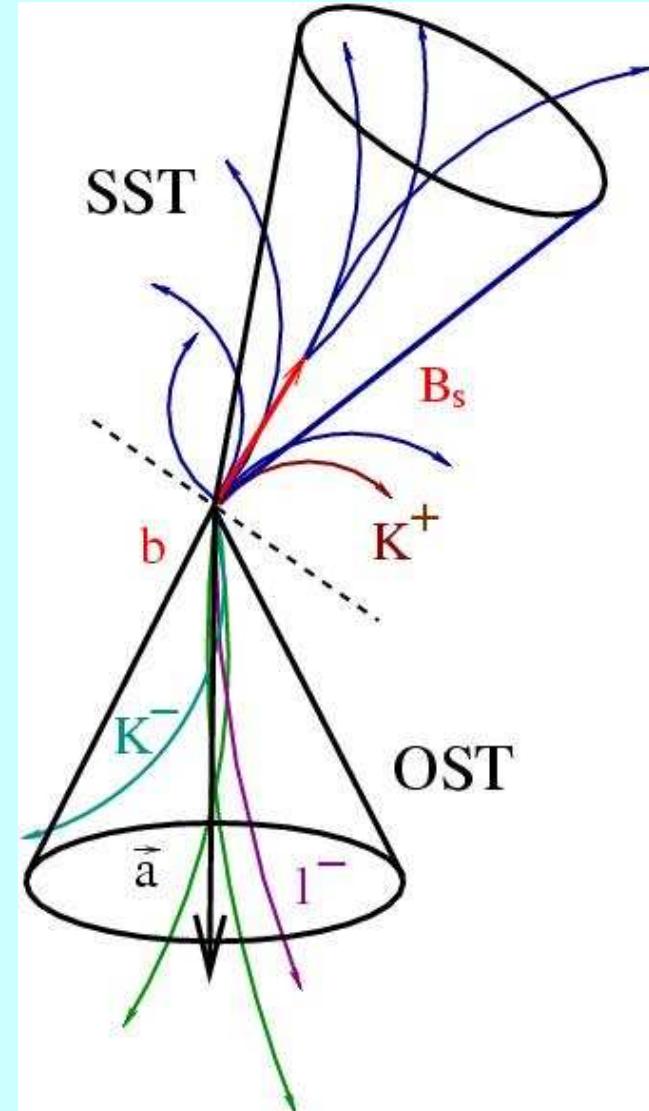
Opposite Side Kaon Tagger

- Look for strange decays on OS
- Kaon charge indicates b-flavor

Neural Network combines taggers

OST's perform identically in $B_{u,d,s}$:
Calibrated in high statistics B^+ / B^0 data

$$\epsilon D^2 = 1.8\%$$



Same Side Tagging

Most powerful tagger available

- 2-3 times more effective than combined OST

Exploit charge correlation between b and fragmentation tracks

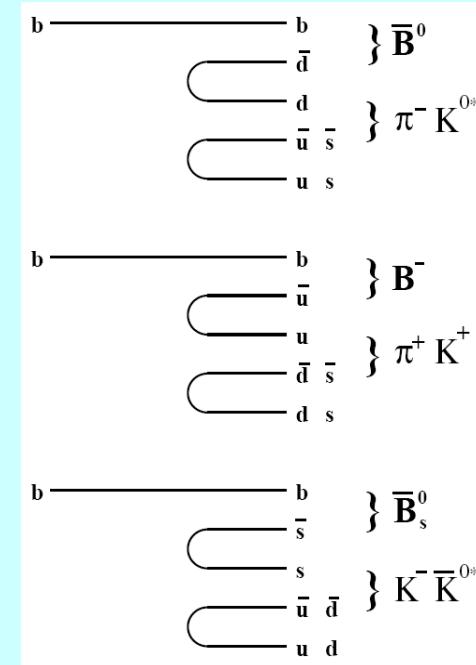
- B^+, B^0 likely to have a π^-, π^+ nearby
- B_s likely to have K^+

Neural Network separates kaons and pions

- TOF and COT dE/dx crucially important
- Kinematic of candidate provide additional separating power

Unlike OST, SSKT is different for B^0, B^+ and B_s

- SST needs to rely on MC simulation
- Data and MC thoroughly compared



Measured performance

- Hadronic
 $\epsilon D^2 = 3.5\%$
- Semileptonic
 $\epsilon D^2 = 4.8\%$

B_s Discovery at CDF

E. BenHaim, **G.P. di Giovanni**, J. Piedra, ASN

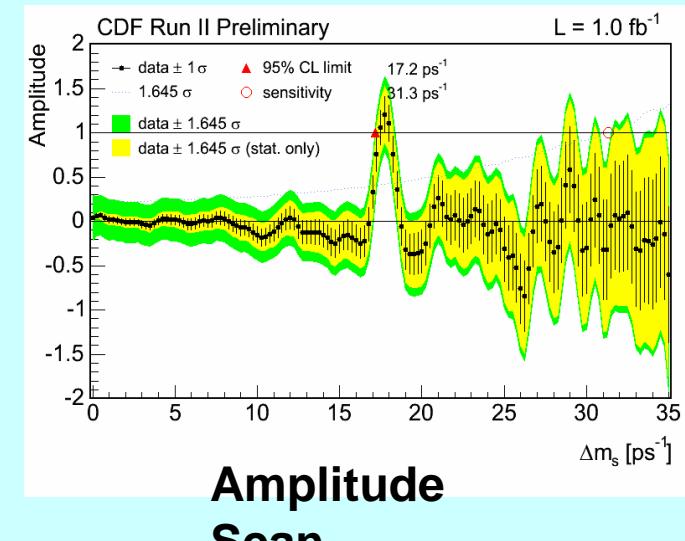
Observation of $B_0(s)$ - anti- $B_0(s)$ Oscillations in
Phys.Rev.Lett.97:242003,2006

$$\Delta m_s = 17.77 \pm 0.10(stat) \pm 0.07(sys)$$

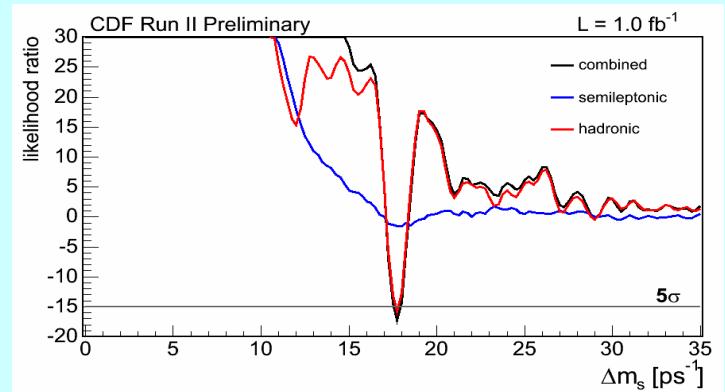
$$\frac{|V_{td}|}{|V_{ts}|} = 0.2060 \pm 0.0007 \text{ exp}^{+0.0081}_{-0.0060} theor$$

LPNHE–Paris VI Activities Mainly Focused on
the Fully Reconstructed Decays:

- Same Side (Kaon) Tagging Development
- Opposite Side Tagging Calibration
- Background Studies on the Amplitude Scan
- Systematics Evaluation



Amplitude
Scan



Likelihood

$$\Delta M_s = M_H - M_L \approx 2|M_{12}|$$

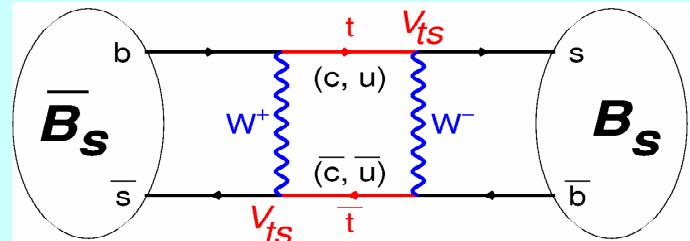
$$\Delta \Gamma_s = \Gamma_L - \Gamma_H \approx 2|\Gamma_{12}| \cos \phi_s$$

$$\phi_s = \arg\left(-\frac{M_{12}}{\Gamma_{12}}\right)$$

$$\bar{\tau}_s = \frac{2}{\Gamma_L + \Gamma_H}; M_s = \frac{M_L + M_H}{2}$$

THE Bs SECTOR: 5 PARAMETERS

Neutral B_s system

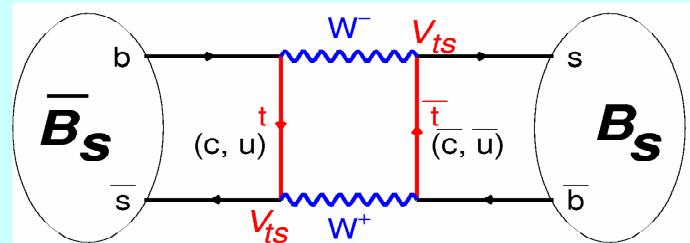


Flavor eigenstates:

$$|B_s\rangle = (\bar{b}s); |\bar{B}_s\rangle = (b\bar{s})$$

At production two states are pure \bar{B}_s and B_s :

$$i \frac{\partial}{\partial t} \begin{pmatrix} |B_s^0(t)\rangle \\ |\bar{B}_s^0(t)\rangle \end{pmatrix} = \left(M - i \frac{\Gamma}{2} \right) \begin{pmatrix} |B_s^0(t)\rangle \\ |\bar{B}_s^0(t)\rangle \end{pmatrix}$$



Mass eigenstates are such as ($|p|^2 + |q|^2 = 1$):

$$|B_H(t)\rangle = p|B_s(t)\rangle + q|\bar{B}_s(t)\rangle = |B_H(t=0)\rangle e^{-iM_H t - \frac{1}{2}\Gamma_H t}$$

$$|B_L(t)\rangle = p|B_s(t)\rangle - q|\bar{B}_s(t)\rangle = |B_L(t=0)\rangle e^{-iM_L t - \frac{1}{2}\Gamma_L t}$$

2 Masses & Lifetimes:

$$\Delta m_s = M_H - M_L$$

$$\Delta \Gamma_s = \Gamma_H - \Gamma_L$$

mass eigenstates

SM value

$\phi_s \sim 0.04$ in SM, NP increases ϕ thus decreasing width-difference

$$\Delta \Gamma = \Gamma_L - \Gamma_H \approx \Delta \Gamma_{CP,SM} \cos(\phi)$$

Window into new physics (I)

- CP Violating Phase in mixing Φ_s

$$\frac{q}{p} \sim e^{-\Phi M} \left(1 - \frac{1}{2} \left| \frac{\Gamma_{12}}{M_{12}} \right| \right) \sin \Phi_s \quad \Delta \Gamma = 2 |\Gamma_{12}| \cos \Phi_s$$

- If $\Phi_s = 0 \Rightarrow$ no CP violation in mixing
- Φ_s is expected to be of order $\sim 1\%$ in Standard Model

$$CP |B_{L,H}\rangle \cong \pm |B_{L,H}\rangle \quad \Rightarrow \text{Mass and CP states are very close}$$

- New physics doesn't take much to modify it
- Search for manifestation beyond the Standard Model

Fitter Framework

1. Reconstruct decays from exclusive final states with charged particles :

$$B_s^0 \rightarrow J/\psi \Phi \rightarrow \mu^+ \mu^- K^+ K^-$$

J/ ψ Φ is C-odd \Rightarrow Different Parity = different angular distribution
 \Rightarrow Separate CP States

Control Sample \Rightarrow Similar angular decay

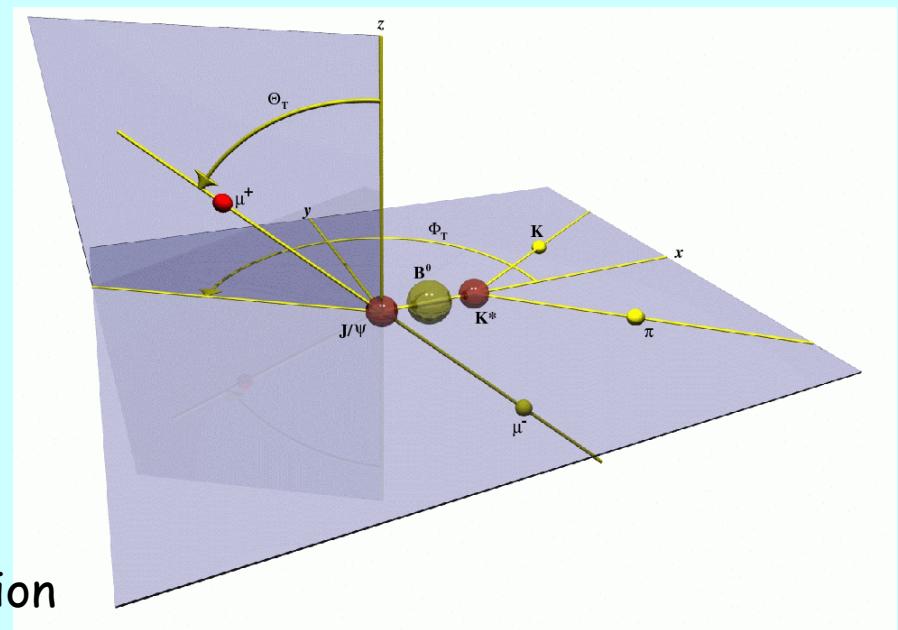
$$B_d^0 \rightarrow J/\psi K^{*0} \rightarrow \mu^+ \mu^- K^+ \pi^-$$

2. Calculate Event Variables:

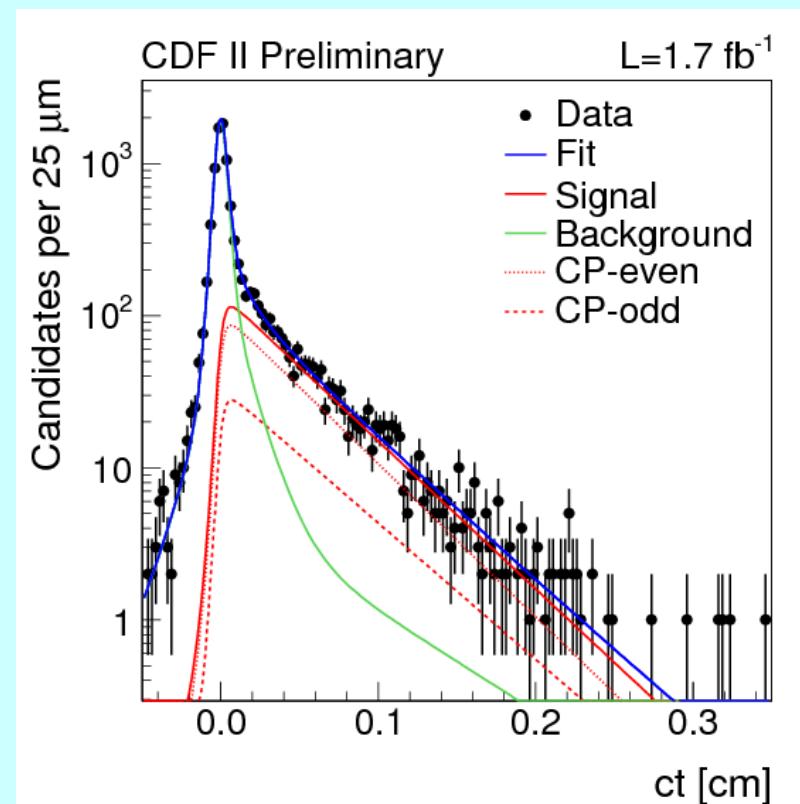
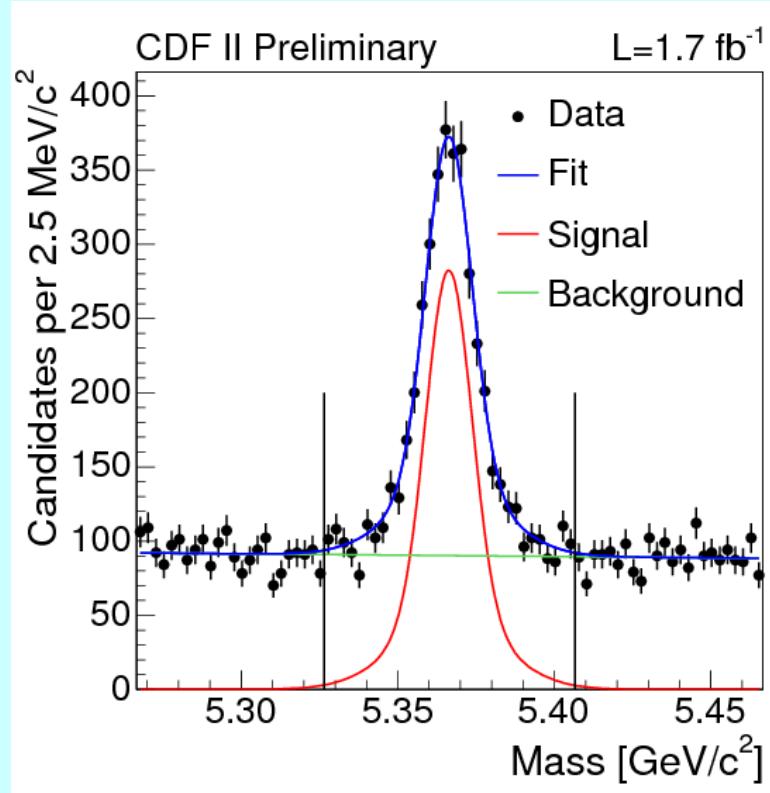
- Invariant Mass
- Lifetime
- $\vec{w} \equiv \Theta_T, \Phi_T, \Psi_T$

3. Perform Maximum Likelihood Fit:

- Likelihood in $M, c\tau, \vec{w}$
- Assume rate(B) = rate(\bar{B}) at production
- Untagged Analysis



B_s Lifetime Difference (I)



Mesure directe du temps de vie du B_s : $c\tau_s$

B_s Lifetime Difference (II)

Différence du temps de vie $\Delta\Gamma$, exprimé dans région de confiance dans plan $(\Delta\Gamma_s, \Phi_s)$

Assuming no CP violation:

$$\Delta\Gamma_s = 0.076^{+0.059}_{-0.063} (\text{stat}) \pm 0.006 (\text{syst}) \text{ ps}^{-1}$$

$$cT_s = 456 \pm 13 (\text{stat}) \pm 7 (\text{syst}) \mu\text{m}$$

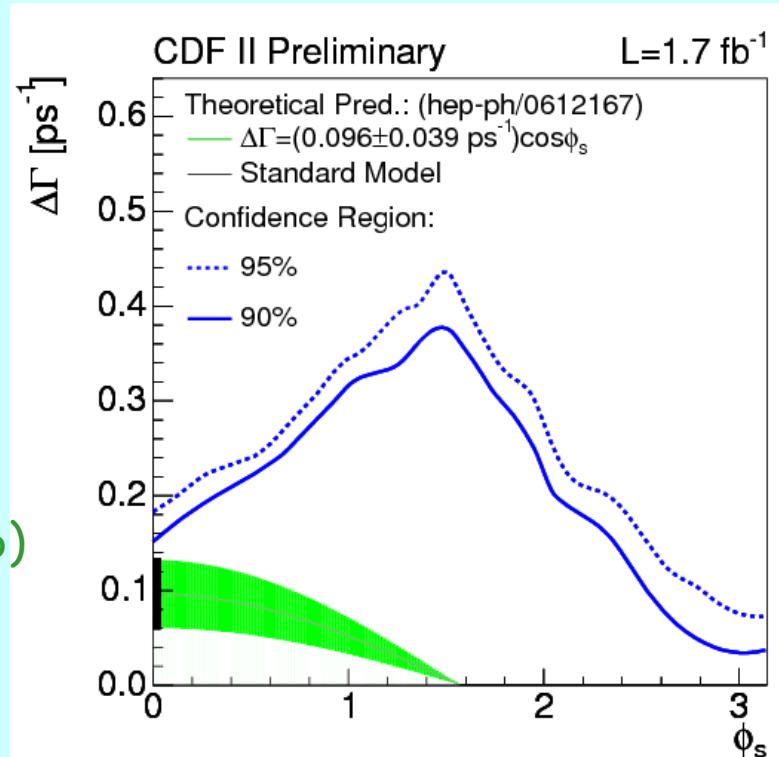
$$|\mathcal{A}_0|^2 = 0.530 \pm 0.021 (\text{stat}) \pm 0.007 (\text{syst})$$

$$|\mathcal{A}_1|^2 = 0.230 \pm 0.027 (\text{stat}) \pm 0.009 (\text{syst})$$

$\Delta\Gamma_s$ measurement agrees well with SM (0.096)

Allowing for CP violation:

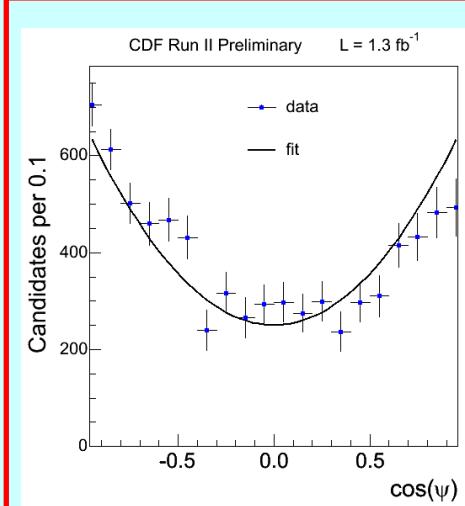
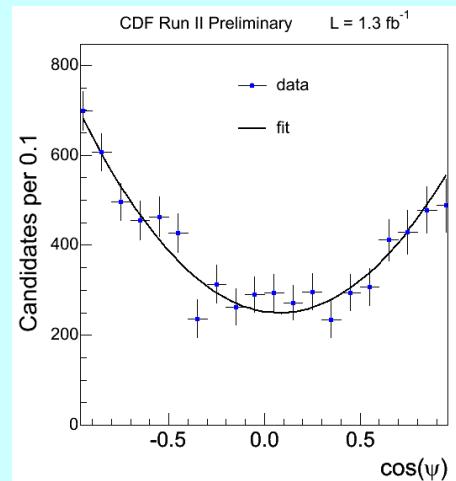
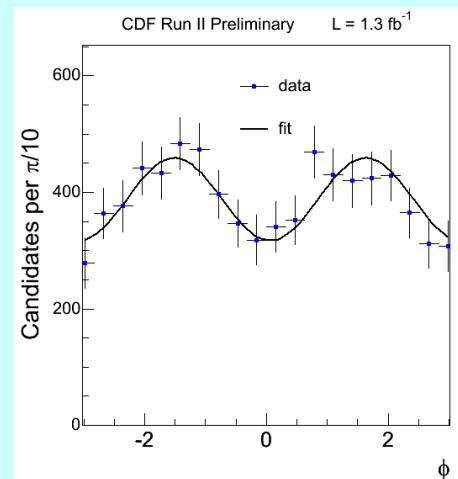
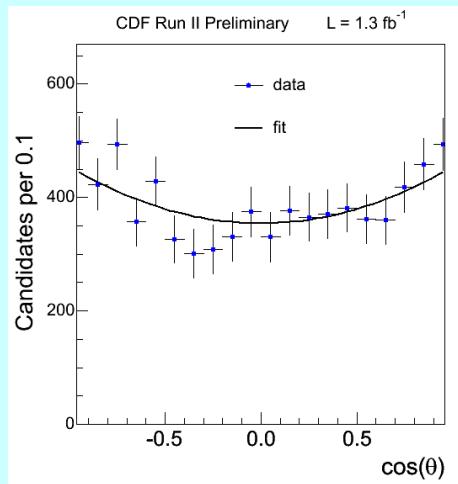
- Bias for low $\Delta\Gamma_s$ and Φ_s observed in toy MC
- Quote p-value and confidence region instead of point estimate



The p-value for $\Delta\Gamma_s = 0.1 \text{ ps}^{-1}$ and $\Phi_s = 0$ is 22%.

B_d Angular Analysis

Introducing the *S*-wave interference for the $K\pi$ in the likelihood
the angular projections agree better with data



With only
the P-wave
contribution

B_d Final Results

CDF is (unexpectedly!) competitive with B factories

<u>Parameter</u>	CDF	BaBar hepex07040522	Belle hepex0504030
$ A_0 ^2$	0.569 ± 0.009 ± 0.009	0.556 ± 0.009 ± 0.010	0.574 ± 0.012 ± 0.009
$ A_{ } ^2$	0.211 ± 0.012 ± 0.006	0.211 ± 0.010 ± 0.006	0.231 ± 0.012 ± 0.008
$\delta_{ } - \delta_0$	-2.956 ± 0.08 ± 0.03	-2.93 ± 0.08 ± 0.04	-2.887 ± 0.090 ± 0.008
$\delta_{\perp} - \delta_0$	2.971 ± 0.06 ± 0.01	2.91 ± 0.05 ± 0.03	2.938 ± 0.064 ± 0.010

Résultats depuis Septembre 2005

- Publications: ~20 + 45 + ~75 = 140 (environ 12 où nous avons contribués et encore au moins 3 d'ici fin 2007)
- Elementary particle physics. Proceedings, Corfu Summer Institute, CORFU2005, Corfu, Greece, September 4-26, 2005.
K. Anagnostopoulos, (ed.), I. Antoniadis, (ed.), G. Fanourakis, (ed.), A. Kehagias, (ed.), A. Savoy-Navarro, (ed.), J. Wess, (ed.), G. Zoupanos, (ed.)
Prepared for 8th Hellenic School on Elementary Particle Physics (CORFU2005), Corfu, Greece, 4-26 Sep 2005. Published in J. Phys. Conf. Ser. 53 (2006) 899 p
(Présentations: J. Piedra (Bs oscillation search) S. Tourneur: (Top into tau)
APS 2006: S. Tourneur and GP di Giovanni
FPCP-2006 (J. Piedra first results on Bs oscillations)
Beauty 2006 (E. BenHaim)
EPS July 2007: ASN
Résultats présentés à IHEP-Moscow 2006 et TAU2006
- 3 postdocs E.U.: Subir Sarkar, Antonio Sidoti et Jonatan Piedra
- 2 PhDs ont été en partie sur fonds E.U (E. BenHaim et GP di Giovanni)
- LIA avec Corée pour CDF-Grid (au CCIN2P3)
- MEC-IN2P3 avec ICFA
- Une thèse soutenue: S. Tourneur Nov 2006 une autre en cours (GPdi G.) et UNE DECOUVERTE où le LPNHE a pris une part active

Objectifs: poursuivre sur ces deux secteurs porteurs



Spokewpersons

J. Konigsberg

R. Roser

Local Committee

I. Cossin

G.P. Di Giovanni

A. Savoy-Navarro

D. Terront

Invited talks

- I. Antoniadis: Physics & signatures of extradimensions
- D. Boutigny: French computing center and perspectives
- C. Grojean: Electroweak theory beyond SM
- S. Heinemeyer: Higgs & SUSY at CDFII before LHC takes over
- M. Mangano: Workshop summary and further thoughts
- L. Rolandi: Perspective of an outsider on Higgs hunting at CDF
- G. Salam: Jets, higher order & interplay between them



UNIVERSITÉ
PIERRE ET MARIE CURIE
Sorbonne Paris Cité



CNRS
CENTRE NATIONAL DE LA RECHERCHE
SCIENTIFIQUE



INSTITUT NATIONAL DE PHYSIQUE NUCLÉAIRE
ET DE PHYSIQUE DES PARTICULES

<http://lpnhe-cdf.in2p3.fr/>