Novelties for Beauty Country : Intrinsic Charm, Charmless Baryons, Strange Beauty

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September 18, 2001
SLAC E/T Seminar

- *Intrinsic* Charm in B and $\Upsilon(1S)$? — C.H.V. Chang, WSH, PRD'01
- Charmless Baryonic B Decays: $B \to \rho p \bar{n} \sim 10^{-5}$? — C.K. Chua, WSH, S.Y. Tsai to appear PRD & PLB
- Strange Beauty: . . . — A. Arhrib, C.K. Chua, WSH to appear PRD

Too Ambitious. Concentrate on *Intrinsic* Charm . . . and a little Baryons

Probing for Charm Content of B and $\Upsilon(nS)$: $B \to J/\psi D(\pi)$ and $\Upsilon(nS) \to J/\psi + X$, $D\bar{D} + X$

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September 14 & 18, 2001
Cornell LNS Journal Club & SLAC E/T Seminar

- Slow J/ψ from B and $\Upsilon(1S)$ Decays
- *Intrinsic* Charm in p, B and $\Upsilon(1S)$
- Semiquantitative Account of Rates ▷ C.H.V. Chang, WSH, PRD'01
- Impact on Experimental Search
- Conclusion: IC from B, $\Upsilon(nS)$!?

- Extra Spice: Charmless Baryonic B Decays? ▷ C.K. Chua, WSH, S.Y. Tsai to appear PRD & PLB

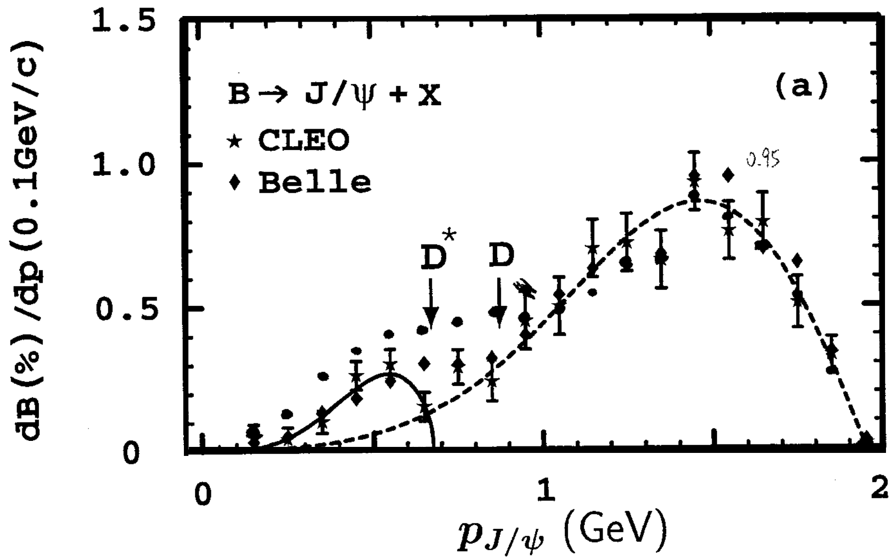
Slow J/ψ *from* B *Decays*

J/ψ historically a great harbinger for QCD.

Could it happen again? —— *Slow* J/ψ's from *Heavy* Mesons

★ CLEO (PRD'95) & Belle (ICHEP/DPF2000) $B \to J/\psi + X$

1.12 fb^{-1} 6.2 fb^{-1} [ψ', χ_c feed-down subtracted]



Simple modified 3-body phase space fit [Brodsky, Navarra, PLB'97]

$$f(p) = f_0 \frac{p}{p_{\max}} \left(1 - \frac{p}{p_{\max}}\right) e^{-(p-p_0)^2/\sigma_0^2},$$

$p_{\max}$, p_0, σ_0
1.95, 1.9, 0.8 GeV (dashed)
0.66, 1.4, 1.0 GeV (solid)

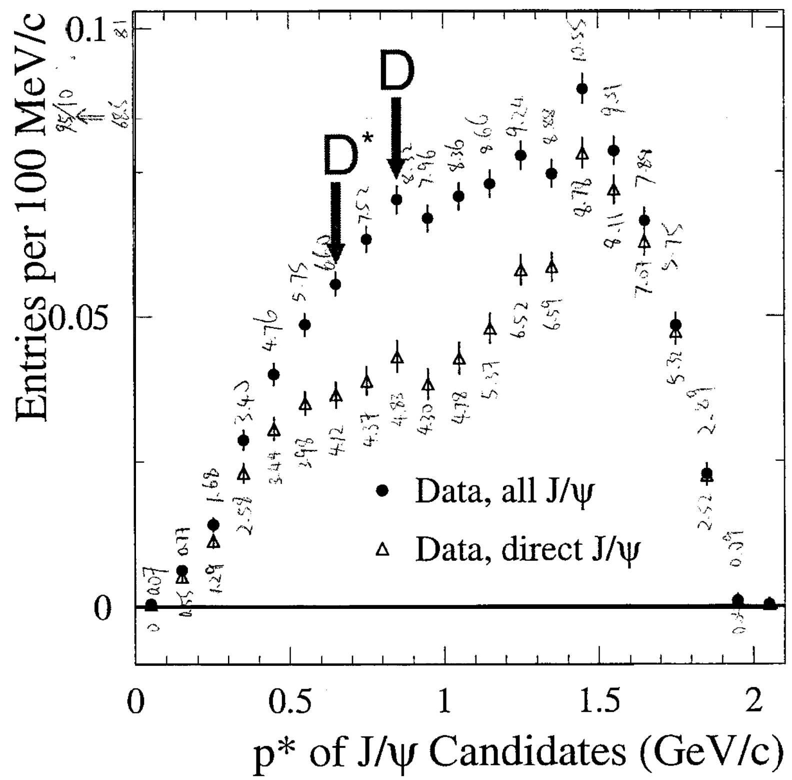
↪ D^* recoil threshold ($D\pi$ open up)

- BaBar result (PHENO2001) w/ 23.3 fb^{-1} seems (to me) *more prominent* (?) lump
- NRQCD/color octet based models(∗) similar to dash curve (softer at low $p_{J/\psi}$)

Could it be . . . $D\pi$ recoiling against J/ψ?

$B \to J/\psi\, X$ properties

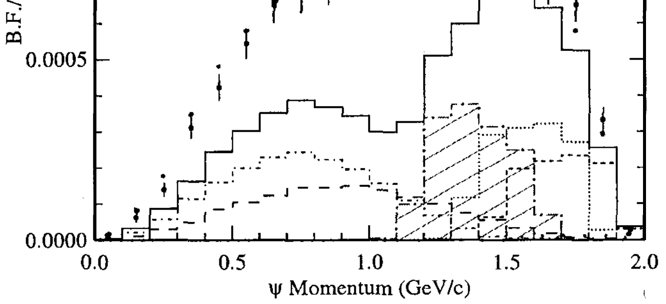
- Polarization
  - $p^* > 1.1$ (mainly 2-body): $A = -0.561 \pm 0.024$
  - $p^* < 1.1$ (mainly 3-body): $A = -0.174 \pm 0.040$
- Momentum distribution
  - Chang & Hou, 2001
    - Sizeable (>10^{-4}) $B \to J/\psi D(\pi)$ rate would offer evidence of intrinsic charm in B mesons.
    - Authors find that both CLEO (1.12 fb^{-1}) and Belle (6.2 fb^{-1}) data exhibit a low-p^* bump in the inclusive direct J/ψ spectrum
  - No such feature is present in 23.3 fb^{-1} of *BaBar* data



Summary (cont'd)

- Measured branching fractions of $B \to J/\psi\ K_1(1270)$:

$$\mathcal{B}(B^\circ \to J/\psi\ K_1^\circ(1270)) = (1.4 \pm 0.4 \pm 0.4) \times 10^{-3}$$
$$\mathcal{B}(B^+ \to J/\psi\ K_1^+(1270)) = (1.5 \pm 0.4 \pm 0.4) \times 10^{-3}$$



- Measured longitudinal and transverse (CP-odd) polarizations of $B \to J/\psi\ K^\star$:

$$\frac{\Gamma_L}{\Gamma} = 0.52 \pm 0.06 \pm 0.04$$
$$|A_\perp|^2 = 0.27 \pm 0.11 \pm 0.05$$

∗ e.g. Palmer, Paschos, Soldan, PRD'97

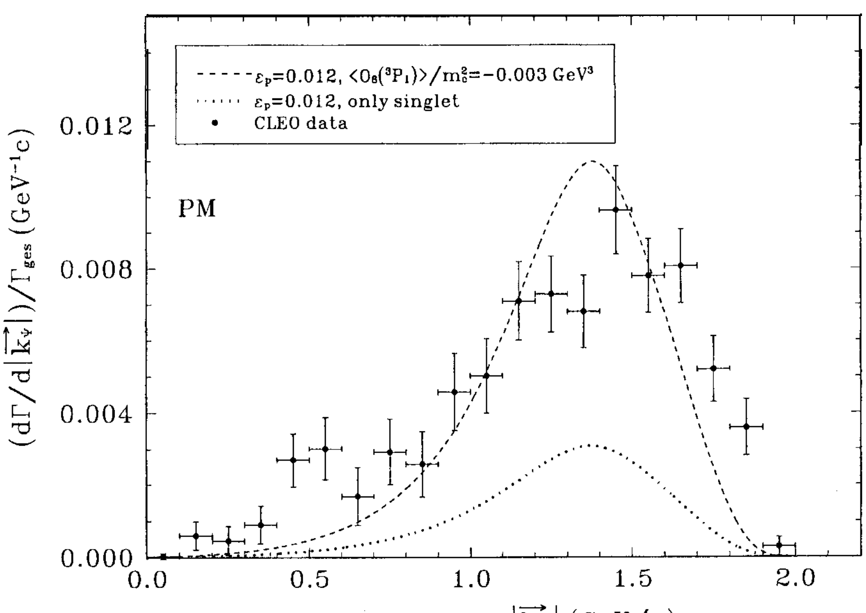


fig. 4

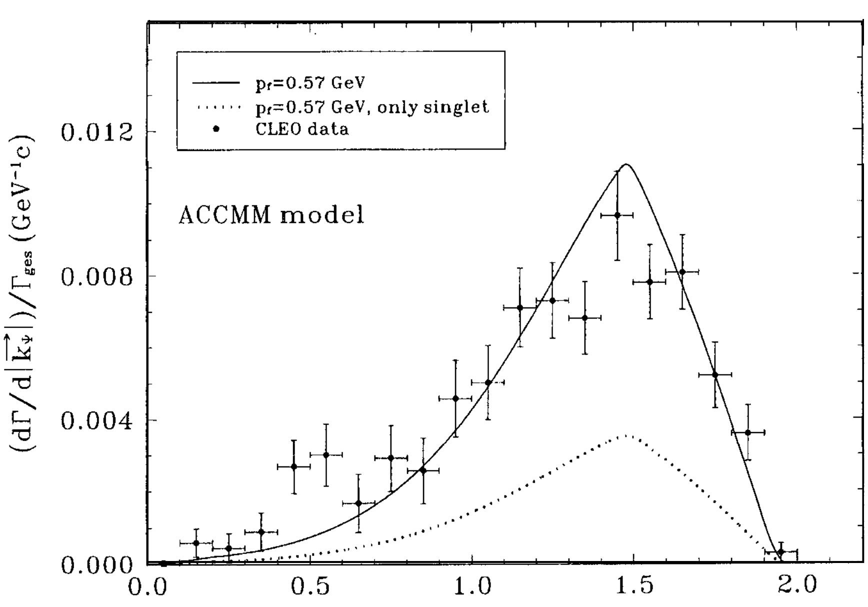


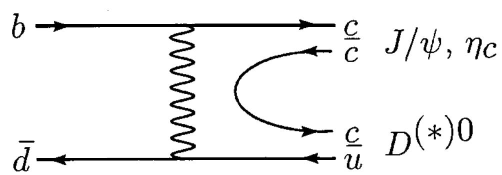
fig. 5

Slow J/ψ from B Decays

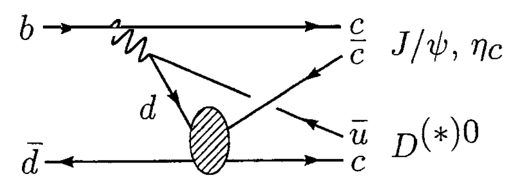
$B \to J/\psi D\pi \ \sim$ few $\times 10^{-4}$?

$c\bar{c}c$ in B Final State!!

Standard diagrams:



(a)



(b)

(a) Exchange: Annihilation $\oplus$ Hard Gluon (nonpert. expon. suppressed)

$\rightsquigarrow \quad (\frac{f_B}{m_B})^2 \ \times \ (\frac{\alpha_s}{\pi})^2 \ \times \ \underset{\mathcal{B}(\bar{B} \to DD_s^-)}{\overset{}{1\%}} \ \times \ \frac{1}{3} \quad \lesssim \quad 10^{-7}$ [confirmed by Eilam, Ladisa, Yang, hep-ph/0107043]

$\hookrightarrow \frac{p_{J/\psi}}{p_{D_s}}$ (Φ(2-body))

(b) Rescattering (blob): $d\bar{d} \to c\bar{c}$, i.e. $\underbrace{(c\bar{d}) \cdot (d\bar{u})} \xrightarrow{\mathcal{R}} \underbrace{(c\bar{c}) \cdot (c\bar{u})}$

$\rightsquigarrow \quad \zeta_{\bar{d}} \quad \times (\frac{\alpha_s}{\pi})^2 \ \times \ 1\% \ \times \ \frac{1}{3} \quad \ll \quad 10^{-5}$

$\ll 1$ since need energetic d and $\bar{d}$

$\Longrightarrow$ ***Cannot*** **account for few $\times 10^{-4}$ rate**

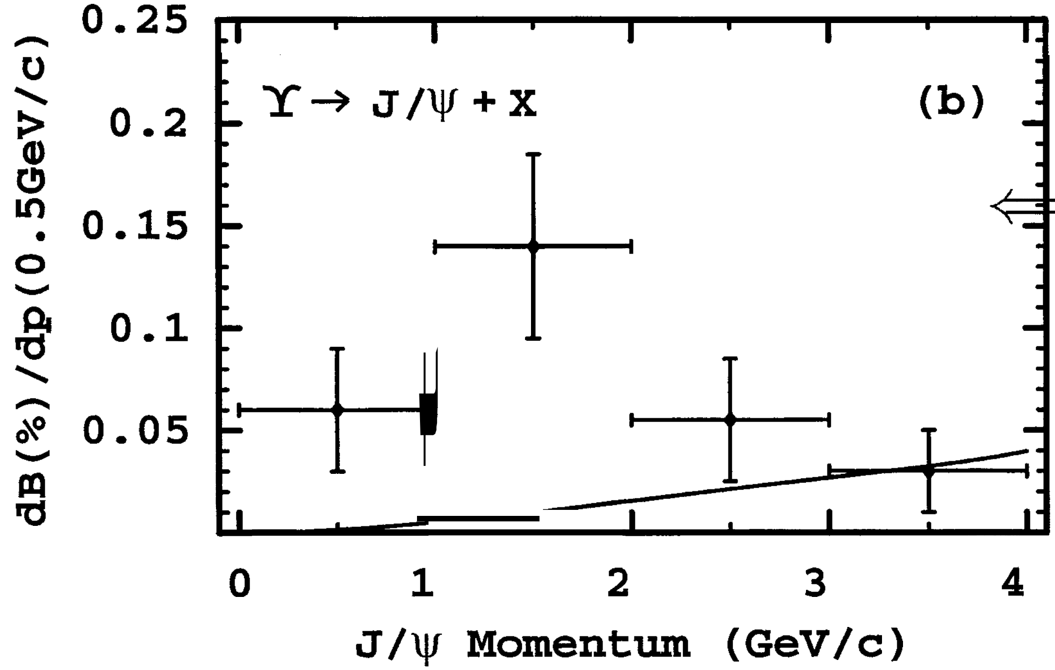
N.B. Rescattering Test: $(b\bar{d}) \xrightarrow{\mathcal{D}} \overbrace{(c\bar{d}) \cdot (d\bar{u})} \xrightarrow{\mathcal{R}} \overbrace{(c\bar{s}) \cdot (s\bar{u})}$

Expect $B \to J/\psi D\pi \ < \ \boxed{\bar{B} \to D_s K^- \ \lesssim \ 10^{-4}}$ (CLEO PLB'93) $\lhd$ **Improve !** Belle'01

Slow J/ψ from $\Upsilon(1S)$ Decays

★ CLEO PLB'89: $\Upsilon(1S) \to J/\psi + X \simeq 1 \times 10^{-3}$ Not Small

Old! ~ 0.037 fb^{-1}, Only (20 evts)



$\Leftarrow p_{J/\psi}$ peak at $\sim$ 1.5 GeV
Rather Soft

$\swarrow$ Color Octet Hard
(and too small)

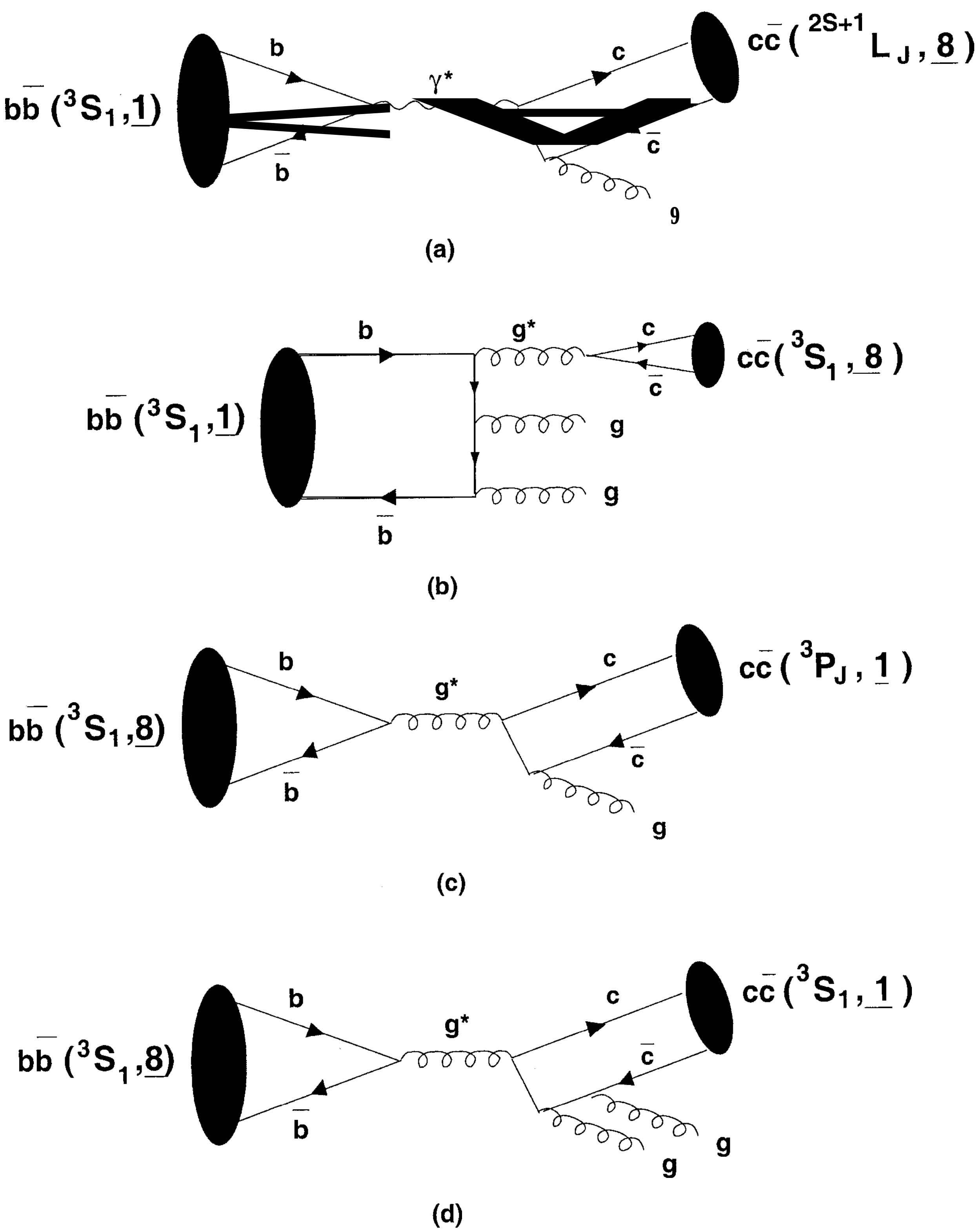
Why $\Upsilon(1S) \to J/\psi + X$ Spectrum so Soft?

Somehow it is *Produced "At Rest"* !!

▷ *Analogous to $B \to J/\psi|_{\rm soft} + X$ Excess* !?

Color Octet $\Upsilon \to J/\psi$ Production [Cheung, Keung, Yuan, PRD'96]

$p_{c\bar{c}} \sim m_{c\bar{c}}$ natural



Slow J/ψ from B and Υ Decays

Observation: *Both* $B \to J/\psi + X$ and $\Upsilon(1S) \to J/\psi + X$

▷ Lump at low $p_{J/\psi}$ ($\boxed{\text{few } \times 10^{-4}}$ and $\boxed{1 \times 10^{-3}}$ resp.).

▷ Too Much Final State $c\bar{c}$ vs Initial State?

Idea: *Intrinsic* Charm in B and $\Upsilon(1S)$ Mesons !?

"Pre-existing" (hence slow) $\bar{c}c$ Component in Meson before Decay !

i.e $b\bar{c}c\bar{d}\rangle$, $|b\bar{c}c\bar{b}\rangle$ Fock Components of

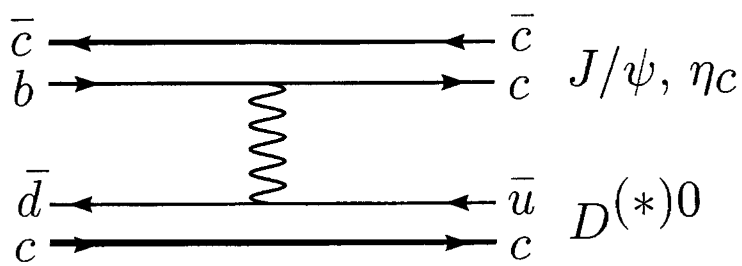
$$\bar{B}\rangle = \Psi_{b\bar{q}}\,|b\bar{q}\rangle + \Psi_{b\bar{c}c\bar{q}}\,|b\bar{c}c\bar{q}\rangle + \cdots \qquad \text{for } \bar{B}$$

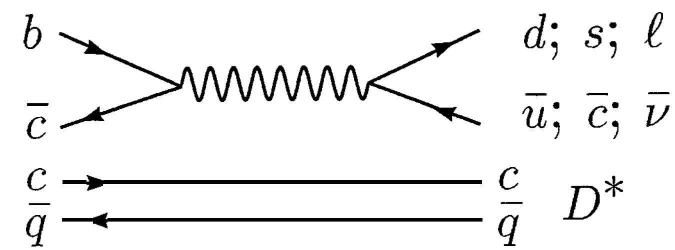
$$\Upsilon\rangle = \Psi_{b\bar{b}}\,|b\bar{b}\rangle + \Psi_{b\bar{c}c\bar{q}}\,|b\bar{c}c\bar{b}\rangle + \cdots \qquad \text{for } \Upsilon$$

In Principle Exist (QM) !

Slow J/ψ from B and Υ Decays

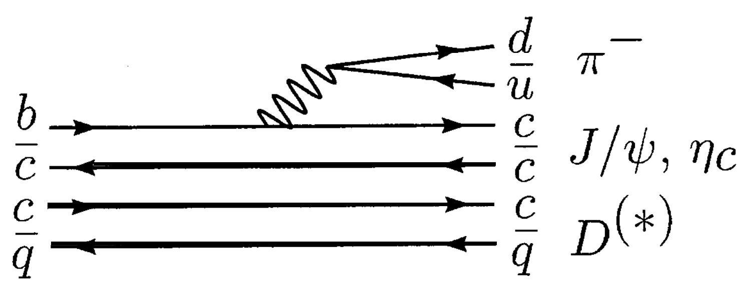
Decay Diagramatics from $|b\bar{c}c\bar{d}\rangle$, $|b\bar{c}c\bar{b}\rangle$ Configurations:

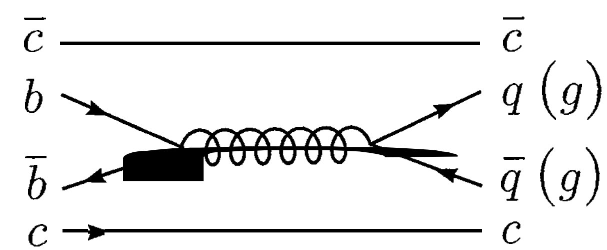




Exchange: Still Annihilation Suppressed

Annihilation: No Helicity Suppression in Vector Channel (later)





Spectator: $B \to J/\psi\, D\, \pi$ Just as Ordered!

$b\bar{b}$ Annihilation in Υ:

$\Upsilon(1S) \to (\bar{c}c)_{\rm soft} + 2$ jets

$\hookrightarrow J/\psi_{\rm soft}+g \quad [(D\bar{D})_{\rm soft}+g]$

Intrinsic Charm in p, B and $\Upsilon(1S)$

Brodsky et al.: *IC* from (Quantum) Energy Fluctuations $(gg \to c\bar{c})$

PLB'80, PRD'81 $\sim \alpha_s^2(m_c^2)/m_c^2$ vs Leading-twist "multiconnected"

w/ *large* x vs small x of (extrinsic) "sea" $q\bar{q}$ $(g \to q\bar{q})$

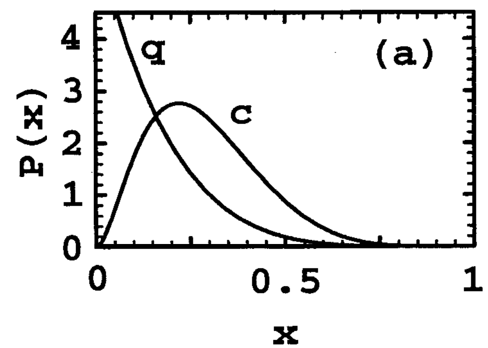
▷ $|u\bar{c}cud\rangle$ component of p: assume $\widehat{m}_c,\, \widehat{m}_{\bar{c}} \gg m_h,\, \widehat{m}_q$

$$\frac{dP_{IC}}{dx_1 \cdots dx_5} \propto \frac{\alpha_s^4(m_c^2)}{(\widehat{m}_c^2/x_c^2 + \widehat{m}_c^2/x_{\bar{c}}^2)^2}\,\delta(1-\sum_{i=1}^{5} x_i)$$

$q = u,\, d$ "valence" (peak near $x \sim 0$)
IC: x_c peak near ~ 0.25

Normalization Unknown (*Nonperturbative*)

IC in Proton $[\langle x_c \rangle = 0.28]$



▷ $|b\bar{c}c\bar{q}\rangle$ component of B: $\widehat{m}_c,\, \widehat{m}_{\bar{c}} < m_B,\, \widehat{m}_b$

$$\propto \frac{\alpha_s^4(m_c^2)}{(m_B^2 - \widehat{m}_b^2/x_b^2 - \widehat{m}_c^2/x_c^2 + \widehat{m}_c^2/x_{\bar{c}}^2)^2}\,\delta(1-\sum_{i=1}^{4} x_i)$$

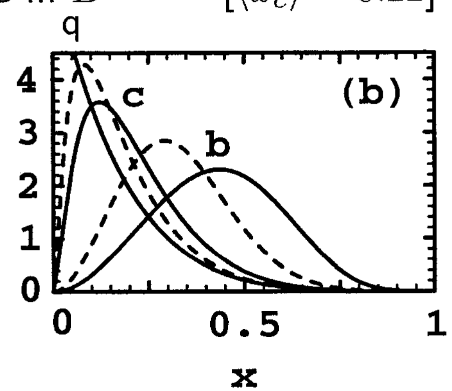
solid lines ⟶

▷ $|b\bar{c}c\bar{b}\rangle$ component of $\Upsilon(1S)$:

...

dashed lines ↗

IC in B $[\langle x_c \rangle = 0.22]$



Intrinsic Charm in p, B and $\Upsilon(1S)$

Strength ?: Guesstimates, from All-light-quarks to All-heavy-quarks

◊ *IC* ($|u\bar{c}cud\rangle$) in p:

- Some evidence from EMC Data [NPB'83]

  Fit finds —— $|\Psi^p_{u\bar{c}cud}|^2 \sim 0.86\%$! [Harris, Smith, Vogt NPB'96]

	$\bar{\nu} = 53$ GeV		$\bar{\nu} = 95$ GeV		$\bar{\nu} = 168$ GeV	
PDF	extrinsic	*IC*	extrinsic	*IC*	extrinsic	*IC*
CTEQ3	0.95 ± 0.64	0.36 ± 0.58	1.20 ± 0.13	0.39 ± 0.31	1.27 ± 0.06	0.92 ± 0.53
MRS(G)	1.02 ± 0.69	0.34 ± 0.58	1.38 ± 0.15	0.32 ± 0.32	1.47 ± 0.07	0.79 ± 0.53
GRV(94)	1.15 ± 0.77	0.33 ± 0.58	1.45 ± 0.16	0.34 ± 0.31	1.48 ± 0.08	0.88 ± 0.53

- Heavy quark mass expansion study : [Franz, Polyakov, Goeke PRD'00]

  ▷ *IC* Mom. Fraction estimate $\sim$ few 10^{-3}, consistent with HSV

  ▷ $\bar{c}c$ in color octet —— *IC* related to non-Abelian-ness of QCD

◊ *IC* ($|b\bar{c}c\bar{q}\rangle$) in B? Probably $\lesssim$ *IC* in p since Heavy-Light

[but B smaller than p (reduced mass)]

◊ *IC* ($|b\bar{c}c\bar{b}\rangle$) in $\Upsilon(1S)$? Probably *Lesser* since Heavy-Heavy (NR)

Low Frequencies

Table 2
Results of the least squares fit of EC and IC contributions to the EMC data according to (4.1). Uncertainties in the fit parameters are shown at the 95% confidence level

	$\bar{\nu}$ = 53 GeV		$\bar{\nu}$ = 95 GeV		$\bar{\nu}$ = 168 GeV	
PDF	α	β	α	β	α	β
CTEQ3	0.95 ± 0.64	0.36 ± 0.58	1.20 ± 0.13	0.39 ± 0.31	1.27 ± 0.06	0.92 ± 0.53
MRS(G)	1.02 ± 0.69	0.34 ± 0.58	1.38 ± 0.15	0.37 ± 0.32	1.47 ± 0.07	0.79 ± 0.53
GRV(94)	1.15 ± 0.77	0.33 ± 0.58	1.45 ± 0.16	0.34 ± 0.31	1.48 ± 0.08	[illegible] ± 0.53

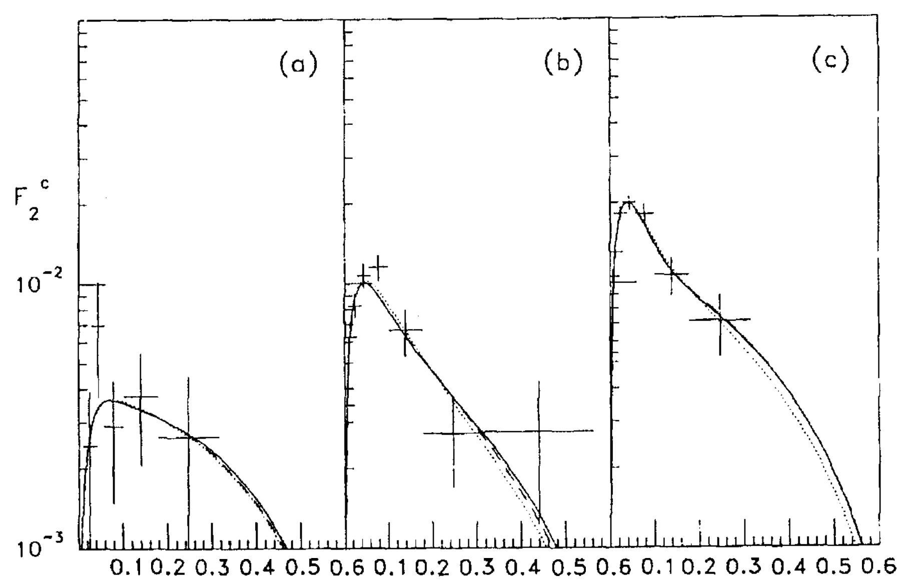


Fig. 7. (a) The EMC data for the structure function $F_2(x,Q^2,m_c^2)$ at $\bar{\nu}$ = 53 GeV plotted as a function of x together with the fitted results from (4.1). The solid line is for the CTEQ3 parton densities, the dotted line is for the MRS(G) parton densities and the dashed line is for the GRV94 parton densities. The parameters α and β are given in Table 1 (b) Same as (a) for $\bar{\nu}$ = 95 GeV. (c) Same as (a) for $\bar{\nu}$ = 168 GeV.

using the Levenberg–Marquardt algorithm [35]. The normalization of both the IC and EC components are taken as free parameters,

$$F_2^c(x,Q^2,m_c^2) = \alpha \cdot F_2^{c,\mathrm{EC}}(x,Q^2,m_c^2) + \beta \cdot F_2^{c,\mathrm{IC}}(x,Q^2,m_c^2)\,, \tag{4.1}$$

with the scale $\mu = \mu_0$. The shift in the normalization of the EC component may be considered as an estimate of the size of the NNLO contribution, which is equivalent to a shift in the scale μ. Since we have already assumed a 1% normalization of the IC component, the fitted β is the fraction of this normalization. The results are presented in Table 2. The errors quoted in the table correspond to a 95% confidence level on the central fit parameters. The final results for the combined model of Eq. (4.1) are shown in Fig. 7 for the CTEQ3, MRS (G) and GRV94 sets of parton densities. The table shows that given the quality of the data, no statement can be made about the intrinsic

Semiquantitative Account of $B \to J/\psi D\pi$ Rate

Question Now is: Can IC Account for Slow J/ψ Rates ?

$\star$ $B \to J/\psi D\pi$? 3-body Spectator Weak Decay $b \to c{+}d\bar{u}$

Rate $\propto \Delta E^5$ (Very Sensitive to Available Energy)

$\triangleright$ Simplest guesstimate: Since $\langle x_b \rangle \simeq 0.41$,
$x_b \simeq 0.41, 0.5, 0.55, 0.6, 0.65$ give (modulo $|\Psi_{b\bar{c}c\bar{q}}|^2$)

$$\frac{\Gamma_{b\bar{c}c\bar{q}}}{\Gamma_{b\bar{q}}} \sim \left(\frac{\Delta E_{b\bar{c}c\bar{q}}}{\Delta E_{b\bar{q}}}\right)^5 \sim \left(\frac{x_b m_B - m_c}{m_b - m_c}\right)^5 \sim 0.11\%,\ \underbrace{0.95\%,\ 2.3\%, 5\%},\ 9.7\%, \qquad \otimes$$

where $m_b - m_c \simeq 3.4$ GeV and $m_c \simeq 1.3$ GeV.

$\triangleright$ Color Pairings, Duality, and Hadronic Final State Phase Space suggest

$$\left|\boxed{b}\,\bar{c}c\bar{q}\right\rangle \longrightarrow \left|\boxed{d\bar{u}c}\,\bar{c}c\bar{q}\right\rangle \longrightarrow |d\bar{u}\rangle|c\bar{c}\rangle|c\bar{q}\rangle \longrightarrow \boxed{\pi^- J/\psi D \text{ Saturates Rate}}$$

Since $J/\psi D^+\pi^-$ Slow Moving, easily redress into $J/\psi D^0\pi^0$, even $J/\psi D^{*0}$ (D^0?)

$\triangleright$ Convoluting $\otimes$ with x_b Distribution and $|\Psi_{b\bar{c}c\bar{q}}|^2 \lesssim 1\%$,

$\Longrightarrow$ $B \to J/\psi D\pi \sim$ few $\times 10^{-4}$ Possible

But Very Handwaving...

... e.g., will not survive well if $|\Psi_{b\bar{c}c\bar{q}}|^2 \lesssim 0.1\%$

Semiquantitative Account of $\Upsilon(1S) \to J/\psi_{\rm soft} + X$ *Rate*

★ $\Upsilon(1S) \to J/\psi_{\rm soft} + X$? —— Inclusive! More Robust.

Since $\bar{c}c$ hence $b\bar{b}$ Color Octet $\Longrightarrow$ $\boxed{b\bar{b} \to q\bar{q},\, gg \text{ Annihilation}}$,

i.e. $\left|\bar{c}c\,\boxed{\bar{b}b}\right\rangle \longrightarrow \left|\bar{c}c\,\boxed{\bar{q}q, gg}\right\rangle \longrightarrow (c\bar{c})_{\rm soft} + 2$ jets

▷ We estimate

$$\frac{\Gamma_{(c\bar{c})_{\rm soft}jj}}{\Gamma_{ee}}\Gamma_{ee} \sim 6 \times 6 \times \left(\frac{\alpha_s}{\alpha}\right)^2 |\Psi_{b\bar{c}c\bar{b}}|^2 \times 1.3 \text{ keV}$$

where 6 from color vs (em) charge,
6 from $q = u, d, s$ plus $N_C \sim 3$ for gg

♠♠ $\boxed{36\frac{\alpha_S^2}{\alpha^2} \text{ factor Large} \Longrightarrow \text{Very Fast Decay}}$! ♠♠

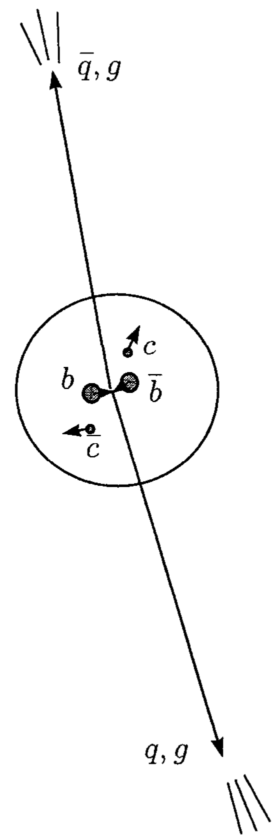
▷ To avoid overwhelming Γ_Υ, e.g. $\Gamma_{(c\bar{c})_{\rm soft}jj} < 0.5\,\Gamma_\Upsilon$

$\Longrightarrow$ $\boxed{|\Psi_{b\bar{c}c\bar{b}}|^2 \lesssim 10^{-3}}$! *Small*

▽

Conversely, even a small *IC* fraction *Sensitive Probe*

could easily give $\boxed{\Upsilon(1S) \to (c\bar{c})_{\rm soft} + 2 \text{ jets at } 10\% \text{ level}}$!?
(or $>$ 5 keV in rate)



N.B. $\Upsilon(1S)$ decay not well studied ! Await pre-CLEO-c !

In fact, $\Upsilon(1S) \to (c\bar{c})_{\text{soft}} + 2$ jets $\sim$ few % *ALLOWED* : [a]

- Strong α_S^3 dependence of $\Upsilon(1S) \to ggg$ rate
- Consistent with observed $\Upsilon(1S) \to J/\psi + X \sim 1.1 \times 10^{-3}$
  [$(c\bar{c})_{\text{soft}} \rightsquigarrow J/\psi\ (+X)$ only small fraction]
- Main part: $(c\bar{c})_{\text{soft}} \rightsquigarrow (D^{(*)}\bar{D}^{(*)})_{\text{slow}} + X$ radiating off soft gluons

Evades handily ARGUS ZPC'92 bound

$\Upsilon(1S) \to D^{*-}X < 1.9\%$ ($p_{D^*} > 0.86$ GeV cut)
D^* Efficiency (slow π^-)

i.e. $\Upsilon(1S) \to (D^{(*)}\bar{D}^{(*)})_{\text{slow}} + 2$ jets Could be Above ARGUS Bound

[a] $\Upsilon(2S)$ and $\Upsilon(3S)$ Could Exhibit *Similar* Behavior

Impact on Experimental Search —— B

Possibly
$$\begin{array}{lll} B & \to J/\psi D\pi & \sim \text{few } \times 10^{-4} \\ \Upsilon(1S) & \to J/\psi_{\text{(soft?)}} + X(= jj?) & \sim 1 \times 10^{-3} \quad \text{(PDG!} \\ \Upsilon(1S) & \to (D^{(*)}\bar{D}^{(*)})_{\text{slow}} + jj & \sim (1-10)\% \text{ !!} \end{array}$$

—— Fabulous Signals Could Indicate *Intrinsic* Charm ——

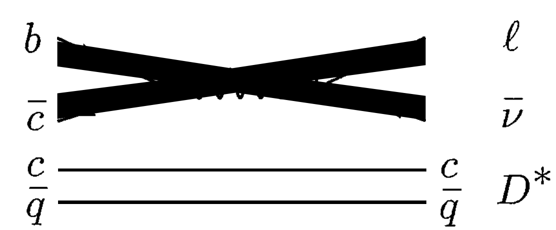
★ Search for $B \to J/\psi D\pi$ under Slow J/ψ "Bump"

- Belle/BaBar $\gtrsim$ 30 fb^{-1} Each! Clean; Vertex; π^0 Capability.
  but Slow, "non-D^*", $\pi^\pm$ a *Challenge*
- CDF Just Started Cross Section! Bigger Boost!
- "Scanning" Inclusive J/ψ_{slow} Event-by-Event ?
- Search for $\bar{B} \to D_s^{(*)} K^{(*)-}$ as *Control on Rescattering*
- How about $\bar{B} \to \phi D^{(*)}$? Intrinsic Strange?
  Much Harder to Disentangle *Rescattering*

★ $B \to D^*\ell\nu$: Impact on V_{cb} Extraction ?

For $b\bar{c}$ in *Vector* channel,

$$\left|\boxed{b\bar{c}}\, c\bar{q}\right\rangle \to \left|\boxed{\ell\nu}\, c\bar{q}\right\rangle \to \ell\nu + D^*_{\text{slow}}$$



No CKM, Helicity, or Phase Space Suppression
$\Longrightarrow$ Affect Endpoint hence Impact V_{cb} Systematics

Impact on Experimental Search —— Υ

⋆ Confirm/Spectrum for $\Upsilon(1S) \to J/\psi_{\rm slow} + X$ PROMISING !!

- ||CLEO/CESR Will Run on $\Upsilon(nS)$ starting Fall 2001 ("NOW")|| ! CLEO-c

  At least 1 fb^{-1} on $\Upsilon(1S)$; Should be Sufficient.

  Actually, Should Run till Sensitive to Color Octet Rate (Check)!

- Could find $\Upsilon(2S)$, $\Upsilon(3S) \to J/\psi_{\rm slow} + X$ as well

⋆ Search for $\Upsilon(1S) \to D^{(*)}(\bar{D}^{(*)})_{\rm slow} + X$ CLEO-c again

- But Slow $D^{(*)}$? [Remember ARGUS]

  Helpful with boost, so:

- Will Belle/BaBar Run on $\Upsilon(1S)$ to Compete ?

  Doubtful, But ... HOW ABOUT *RADIATIVE RETURN* ? $e^+e^- \to \gamma + \Upsilon(nS)$

Stress : $\Upsilon(nS) \to (c\bar{c})_{\rm slow} + 2$ "jets"

Rather Unusual Signal ! More Unequivocal.

Conclusion

Probing for Charm Content of B and $\Upsilon(nS)$

▷ Possibility of $B \to J/\psi\, D\pi$ at few $\times 10^{-4}$ $\Longleftarrow$ Search

Crosscheck Rescattering $(D_s K^-)$

▷ Old $\Upsilon(1S) \to J/\psi_{\text{soft}} + X \sim 10^{-3}$ $\Longleftarrow$ Confirm

$\Upsilon(2S)$ and $\Upsilon(2S)$, too?

▷ Possibility of $\Upsilon(1S) \to D^{(*)}_{\text{soft}} + X > 1\%$ $\Longleftarrow$ Search

▷▷ Evidence Soon for *Intrinsic* Charm in B/Υ Meson(s) ? ◁◁

Search at CLEO/BaBar/Belle, AND Tevatron !!

Charmless Baryonic B Decays: $B \to \rho p\bar{n} \sim 10^{-5}$?

- $B \to$ Mesons vs $B \to$ Baryons — Ratio Large!

  $B \to \pi\pi$, $K\pi$ etc. Emerge(ing) *en masse* since 1997 (CLEO II)

  But, *No Baryons*, e.g. $B \to p\bar{p}$, $\bar{\Lambda}p$: — Not a Single Soul*!*

  $< 7,\ 2.6\ [1.6,\ 2.1] \times 10^{-6}$ — CLEO (PRD'99) [Belle (LP'01)]

Reason: Weak Dynamics give 4-quark Operators

▷ Formation of $q_1\bar{q}_2$ Meson Structure Natural (even color matched)!

$$e.g. \quad (b\bar{q}) \to (s\bar{u})(u\bar{q}) \quad \rightsquigarrow \quad B \to K\pi$$

▷ For Baryon, $q_1q_2q_3$ Structure Harder to Form:

$$e.g. \quad (b\bar{u}) \to (su)(\bar{u}\bar{u}) \quad \rightsquigarrow \quad B \to \Lambda p$$

Need su Pairing and $d\bar{d}$ Popping: *Suppressed at* m_B *Scale* ?

$\Longrightarrow$ Enrich Baryons w/ Reduced Energy Release? [WSH and Soni PRL'01]

e.g. $\gamma\bar{\Lambda}p$, $\eta'\bar{\Lambda}p$? — Energetic γ, η'

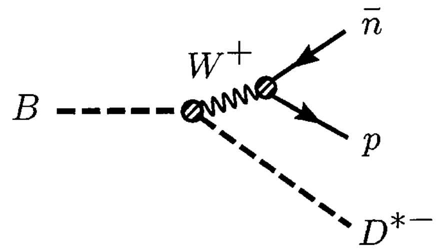
PRL Precipitated (?) by CLEO $B^0 \to D^{*-}p\bar{n}$ Observation [ICHEP2000; PRL'01]

Charmless Baryonic B Decays: $B \to \rho p\bar{n} \sim 10^{-5}$?

- *3-body* Baryonic: $\sim 1.4 \times 10^{-3}$ $\sim 6.8 \times 10^{-3}$

  Hint from CLEO PRL'01: $B \to D^{*-} p\bar{n} \sim \underline{\underline{\frac{1}{5}}} \times B^0 \to D^{*-}\rho^+$

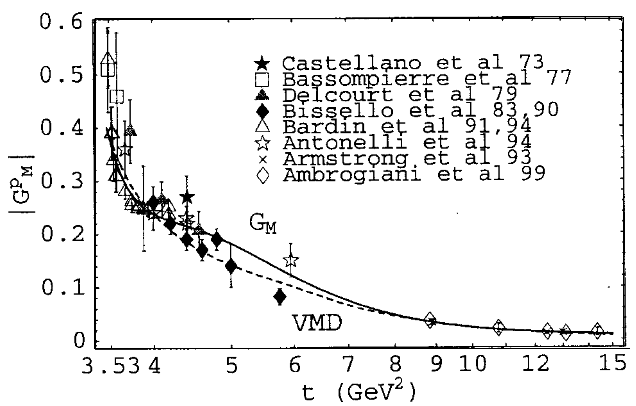
  Ansatz: Assume $B \to D^*$ and $p\bar{n}$ production *Factorized*

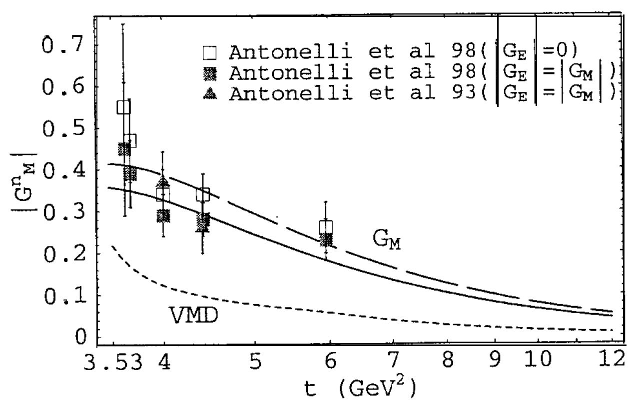


$\triangleleft$ V^+ *Current Produced* $p\bar{n}$

$\triangleleft$ V^- Current induce $B \to D^{*-}$ (usual)

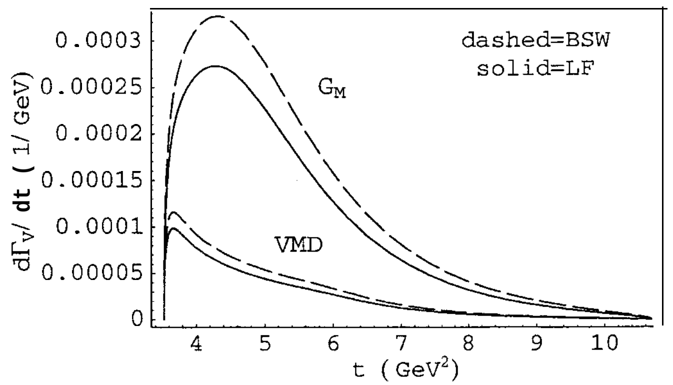
$\Longrightarrow$ Relate J^+ to $J^{\rm EM}$, hence Nucleon EM Form Factor Data !



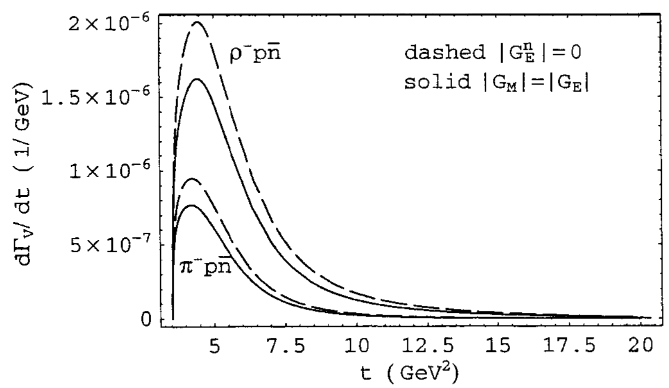


$\Longrightarrow$ Data-based "Prediction" of $t = m^2_{p\bar{n}}$ Spectrum ($V \cdot V$ part)

Charmless Baryonic B Decays: $B \to \rho p \bar{n} \sim 10^{-5}$?



▽



▷ Find 60% of $D^{*-} p \bar{n}$ Rate (still $A \cdot A$)

◁ Threshold Enhancement
Due to $1/m^4_{p\bar{n}}$ from PQCD Power Counting

★ ★ ★ Extend Idea by $D^{*-} \rightsquigarrow \rho^-$ Replacement !

↙

▷ $B^0 \to \rho^- p \bar{n} \simeq (3.6 - 4.5) \times 10^{-6}$ from $V \cdot V$

$\Longrightarrow$ With $A \cdot A$, become $\sim 7 \times 10^{-6} \sim \mathcal{O}(10^{-5})$

▷ More Prominent Threshold Enhancement

Three Body Greater Than Two Body *for* Rare Baryons !?