UPPSALA UNIVERSITET

Charmonium production in B-decays with Soft Color Interactions

David Eriksson
Theoretical High Energy Physics, Uppsala University

13/5 2005

B-physics

B-physics is an important field in todays particle physics. It is a place

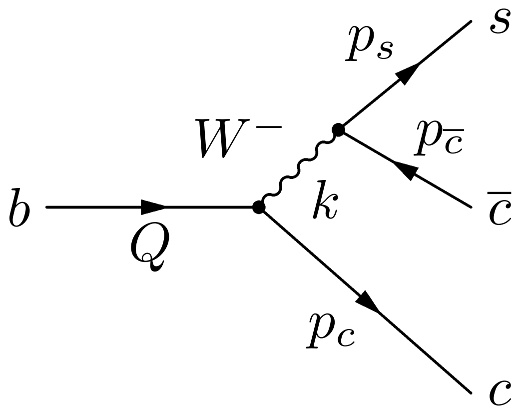
- to study CP-violation, e.g. in the golden mode $B \to J/\Psi K$
- to search for new physics, in loop corrections
- that offers the possibility for detailed studies of QCD-effects

Large b mass $\Rightarrow$ Perturbative calculations possible as starting point

Low total energy $\Rightarrow$ Soft QCD effects are big

The B-meson decay model

- ACCMM model for the B-meson
  - One b-quark and one spectator quark
  - Spectator quark: Fixed mass
  - Momentum from Gaussian distribution
- Hard decay
  - tree-level b-quark decay
- Only $b \to c\bar{c}s$.
  - $B \to D_s D$, $B \to DDX$, ...
  - $B \to \eta_c X$, $B \to J/\Psi X$, ...
- Hadronisation
  - modified Pythia
- Normalization
  - K-factors, semi-leptonic and total width



Soft Color Interaction

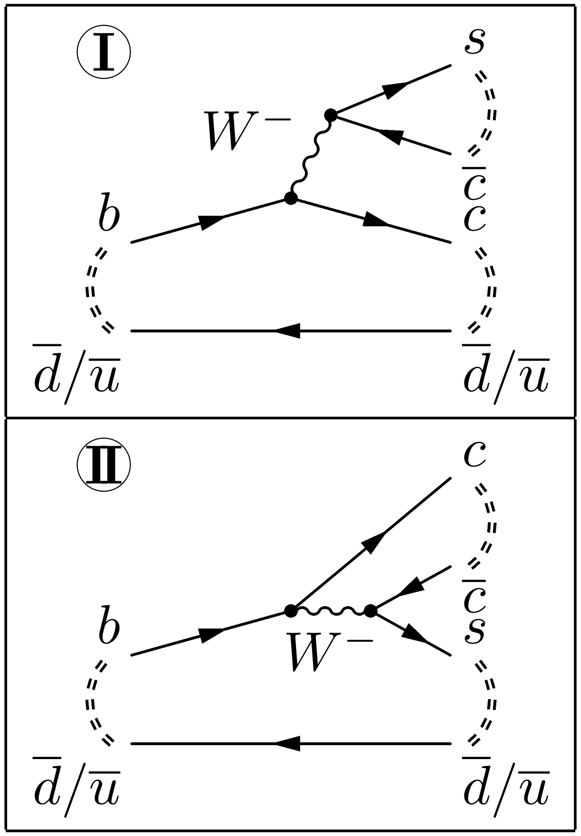
Charmonium states are color suppressed at tree level

Soft Color Interaction

- Soft gluon exchange
  - Carry only color
  - Exchanged between partons
- Only one parameter, the probability
- Rapidity gaps, both Hera and Tevatron
- J/Ψ production at hadron collitions

I shows the normal color connection.

II shows the color connection after a soft color interaction.



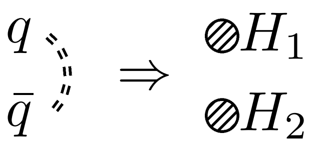
Small mass systems

For a system, string, with

Large invariant mass Pythia, Lund string hadronisation, works well

Low invariant mass Other method needed

1. Two hadrons, with $m_{H_1} + m_{H_2} + m_E < m_{q\bar{q}}$



2. One hadron, with $m_H < m_{q\bar{q}} + m_g$

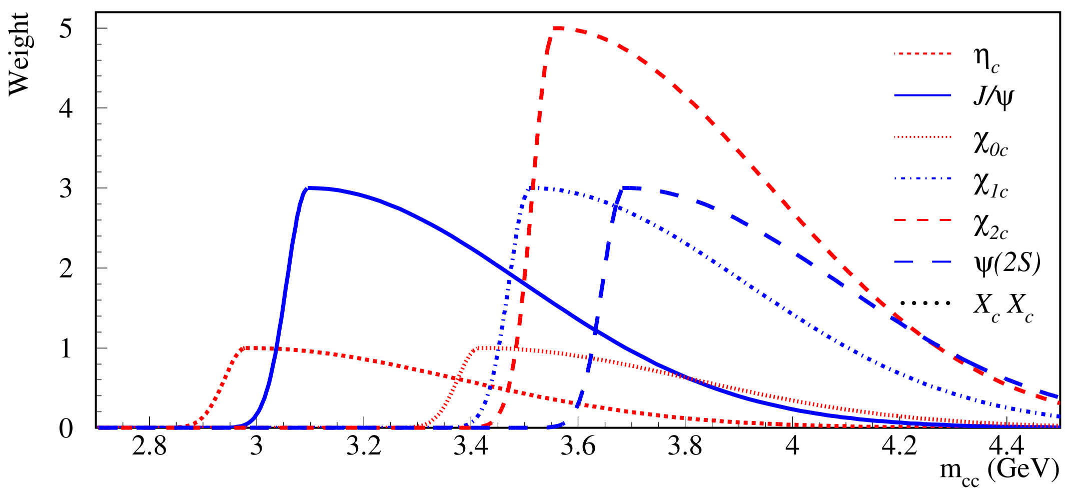
   Need to give or take energy and momentum (the gluon)
   No big system available

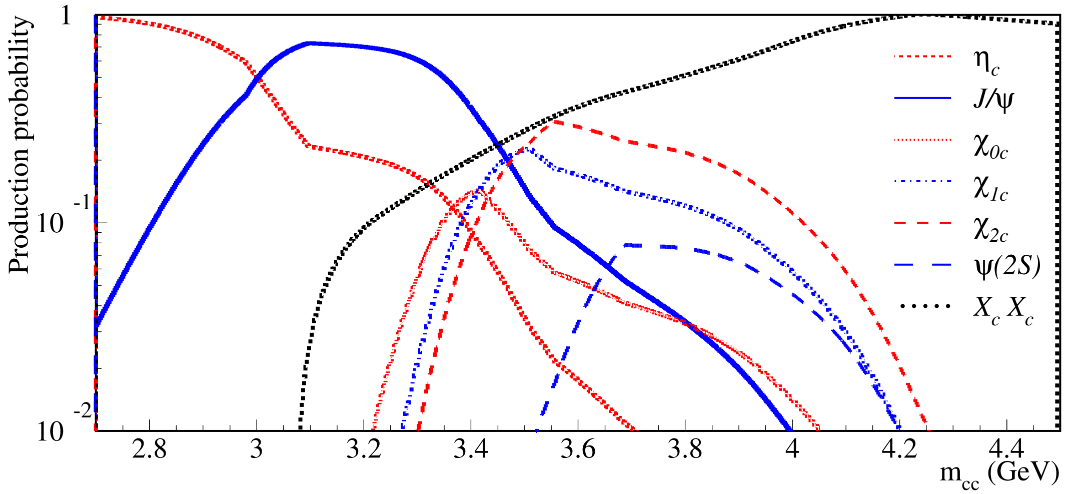
Pythia Four vector of system scaled

Our model Effective gluon has zero invariant mass

Treatment of charmonium

- Included states
  - η_c
  - J/Ψ
  - χ_{0c}
  - χ_{1c}
  - χ_{2c}
  - $\Psi(2S)$.
- Probability for specific state is calculated with weights
  - Spin statistics weight $2J+1$
  - Overlap in mass weight $\exp\left(-\frac{(m_{c\bar{c}}-m)^2}{2\sigma_{sme}^2}\right)$
  - Suppression of heavy mesons

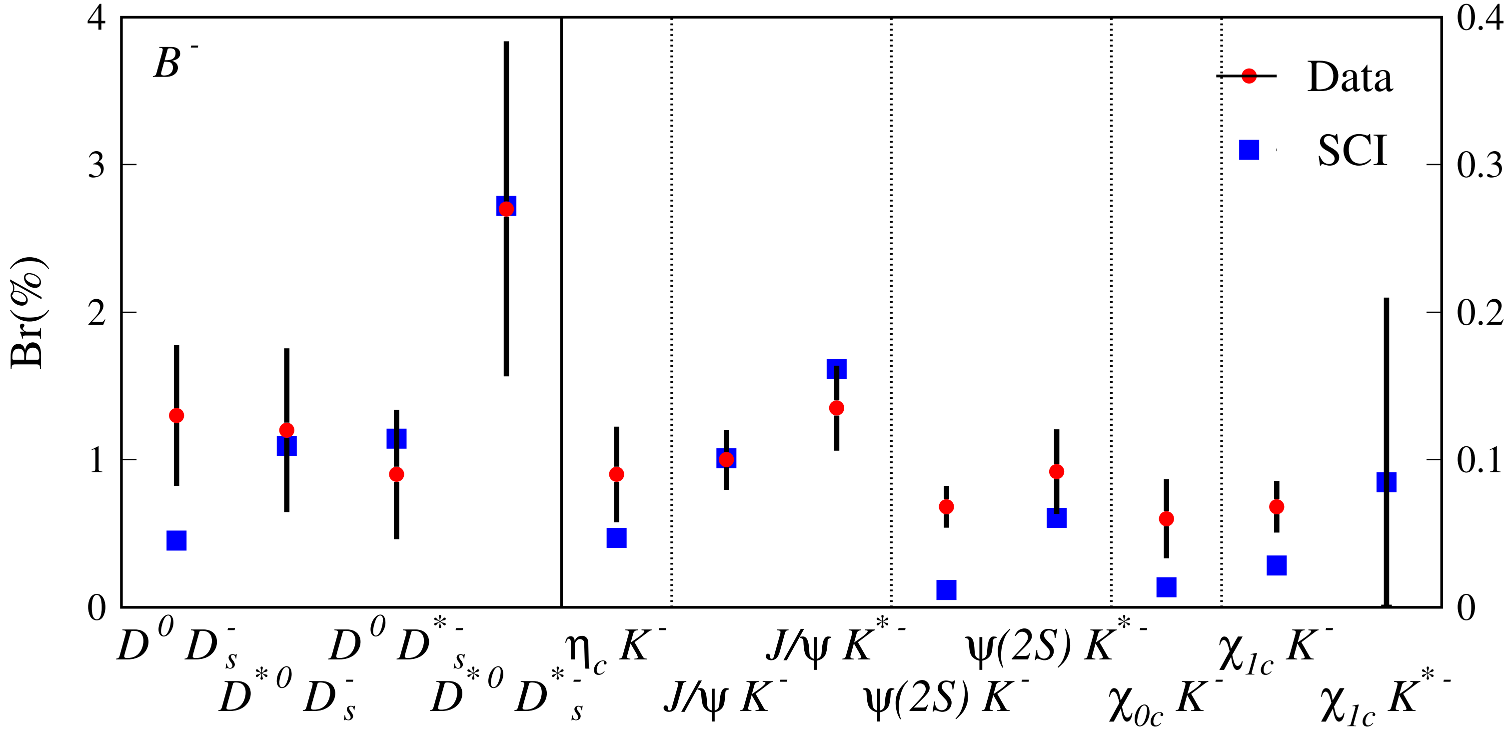




Parameters

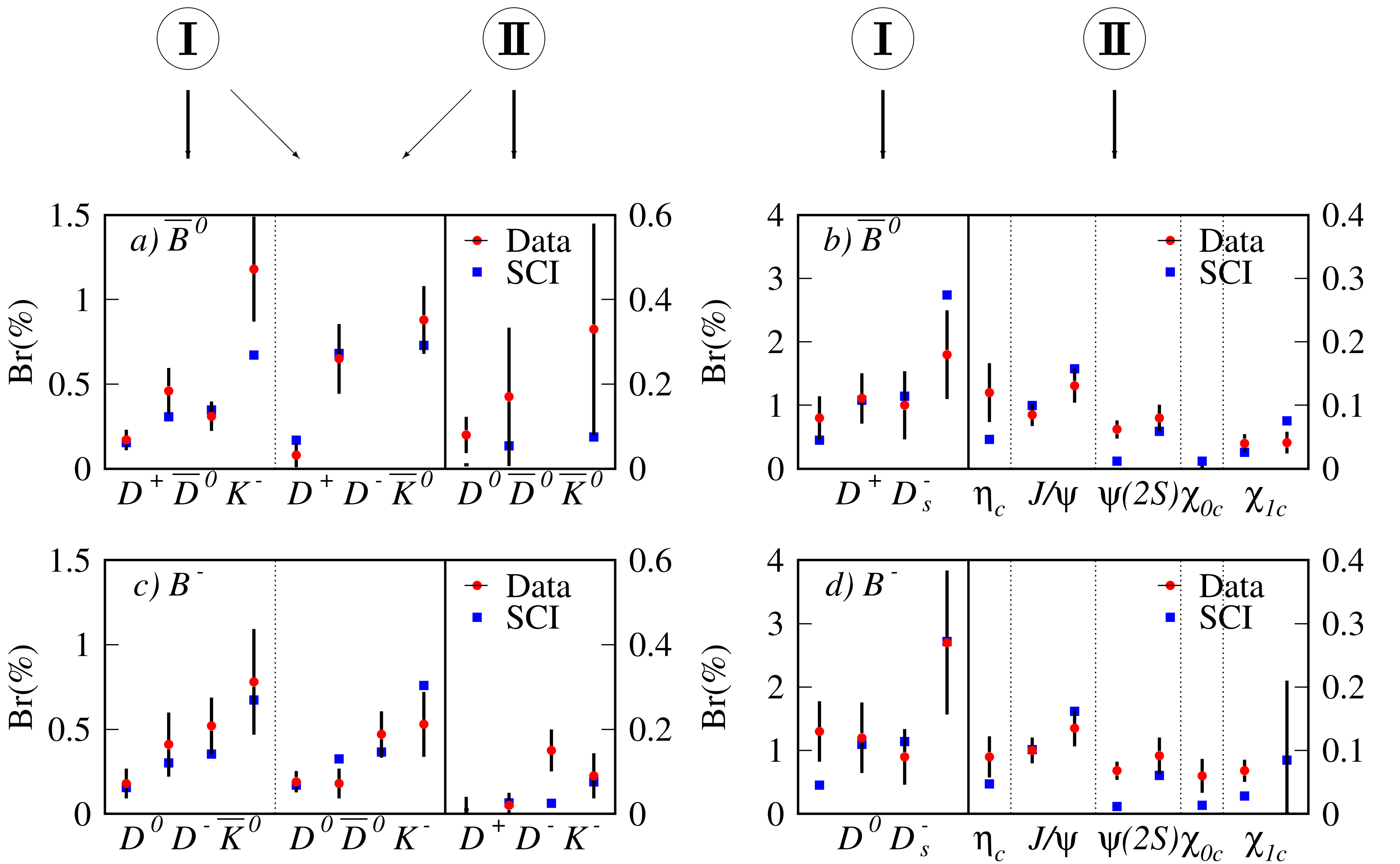
- ACCMM parameters
  - p_f, width of the momentum distribution for the initial quarks
  - m_{sp}, mass of the spectator quark
- SCI parameter
  - P_0, soft colour prob. parameter, fitted
- Modified hadronisation
  - n_{try}, # of attempts used in one and two hadron formation
  - m_g, excess mass needed in one hadron formation
  - m_E, excess mass needed in two hadron formation, fitted
  - P_{hom}, probability for higher order mesons, $L = 1,\ S = 0$, fitted ($K(1270)$, $D(2420)$, . . .)

Results for Branching ratios



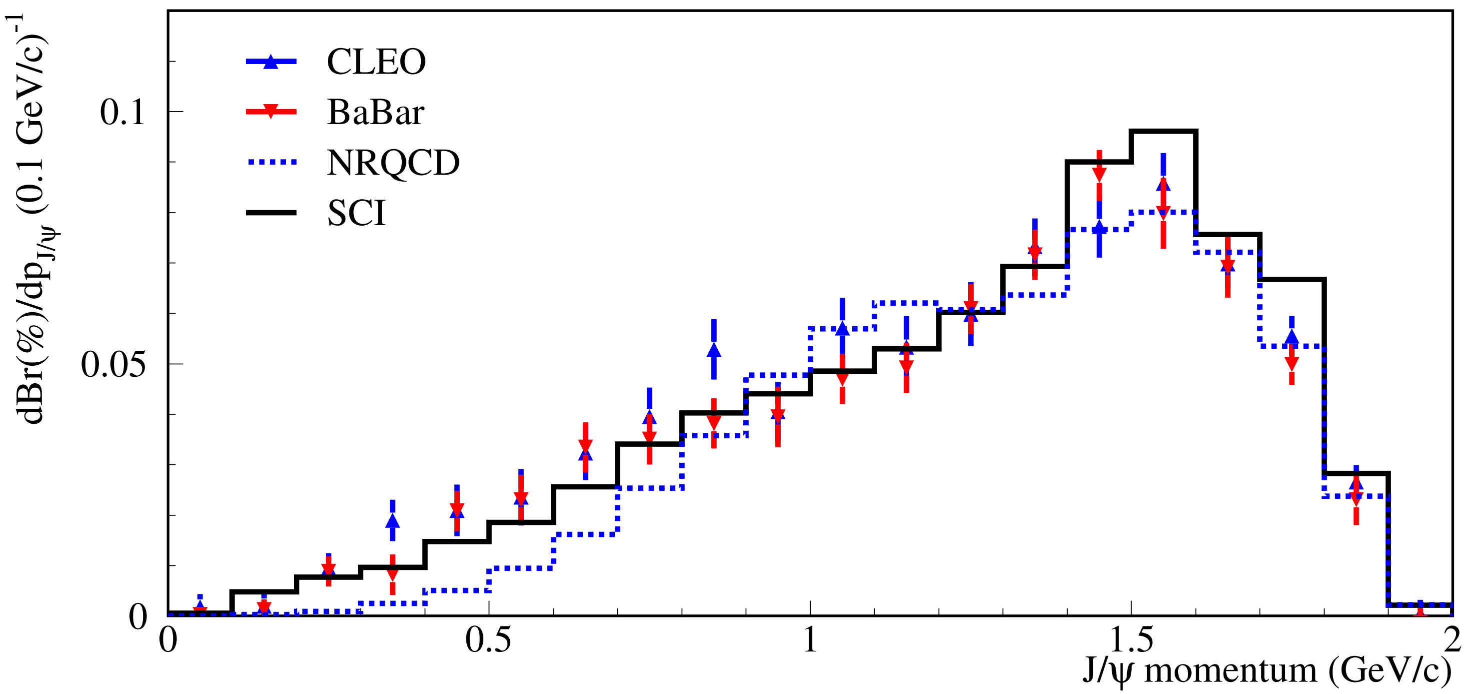
4 hand tuned parameters, 3 fitted parameters, 56 channels, theory error 20%, $\chi^2 = 90$

More results for Branching ratios



Results for J/Ψ momentum distribution

Measured in the rest frame of $\Upsilon(4S)$



NRQCD Problem in the soft part, also shape only

– Hybrids, exotics states

Our model Good in the soft part, normalization from other data

Conclusions

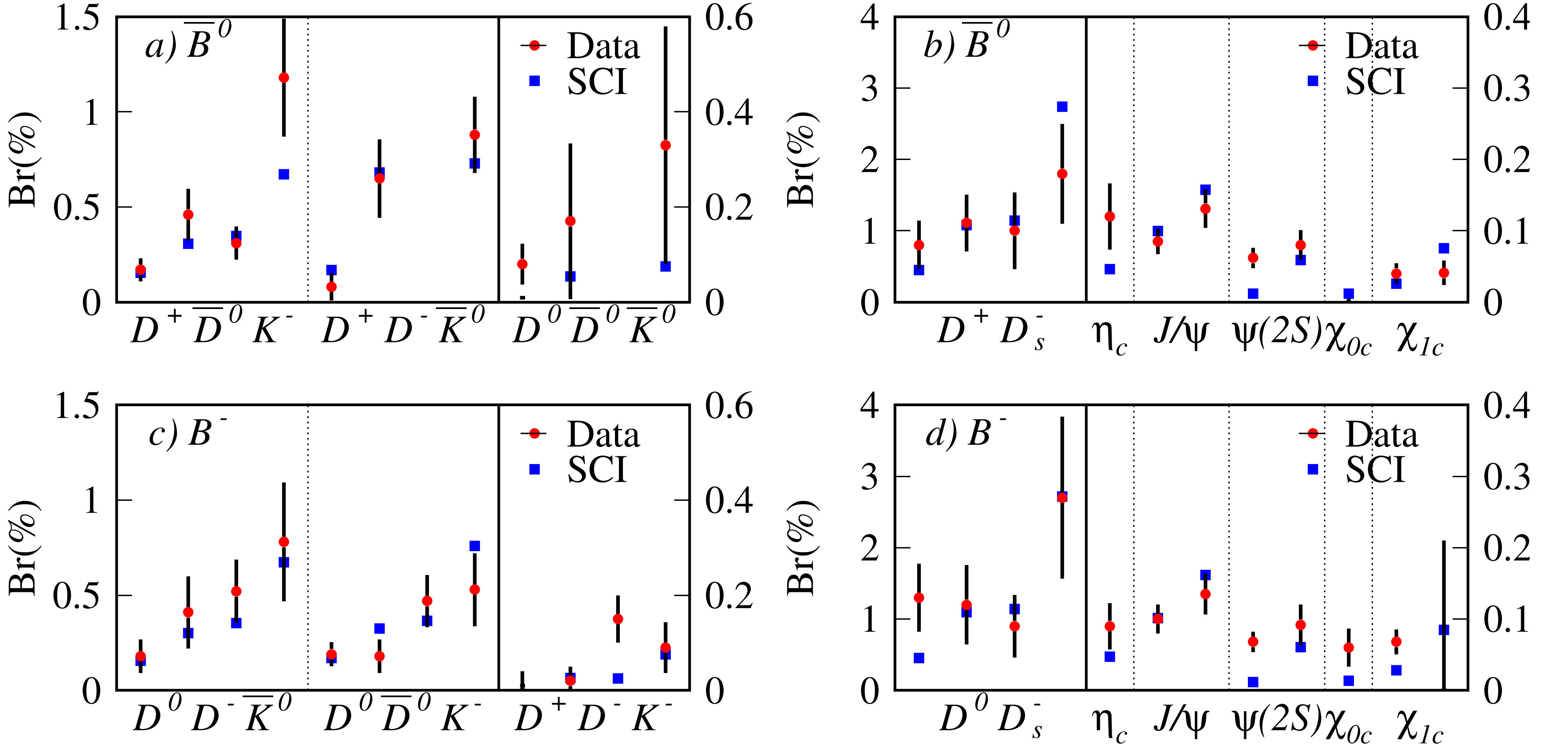
- A phenomenological model for B-meson decay
- Based on
  - Tree level b-decay
  - Soft Color Interactions
  - Modified Pythia hadronisation
- Describes a wide range of measured branching ratios
  - Color allowed
  - Color suppressed
- Describes the J/Ψ measured momentum distribution
  - Even the softest part

Normalization

Two K-factors, one for semi-leptonic and one for hadronic decays, $K_{sl}/K_h = 0.54$.

decay channel	CKM-factors	Simulated decay width (10^{-15} GeV)	Branching ratio without K-factors	Branching ratio with two K-factors
$b \to c\, e^-\, \overline{\nu}_e$	V_{cb}	*57.52*	*15.98%*	*10.39%*
$b \to u\, e^-\, \overline{\nu}_e$	V_{ub}	*0.74*	*0.21%*	*0.13%*
$b \to c\, \mu^-\, \overline{\nu}_\mu$	V_{cb}	*57.24*	*15.90%*	*10.34%*
$b \to u\, \mu^-\, \overline{\nu}_\mu$	V_{ub}	*0.74*	*0.21%*	*0.13%*
$b \to c\, \tau^-\, \overline{\nu}_\tau$	V_{cb}	14.95	4.15%	2.70%
$b \to u\, \tau^-\, \overline{\nu}_\tau$	V_{ub}	0.28	0.08%	0.05%
$b \to c\, s\, \overline{c}$	$V_{cb}V_{cs}$	**66.52**	**18.48%**	**22.20%**
$b \to c\, s\, \overline{u}$	$V_{cb}V_{us}$	7.07	1.96%	2.36%
$b \to c\, d\, \overline{u}$	$V_{cb}V_{ud}$	148	41.11%	49.38%
$b \to c\, d\, \overline{c}$	$V_{cb}V_{cd}$	3.71	1.03%	1.24%
$b \to u\, s\, \overline{c}$	$V_{ub}V_{cs}$	1.11	0.31%	0.37%
$b \to u\, s\, \overline{u}$	$V_{ub}V_{us}$	0.09	0.03%	0.03%
$b \to u\, d\, \overline{u}$	$V_{ub}V_{ud}$	1.96	0.54%	0.65%
$b \to u\, d\, \overline{c}$	$V_{ub}V_{cd}$	0.06	0.02%	0.02%
All channels		360	100%	100%
Total fraction of c			118%	122%

Results for Branching ratios, with theory errors



Results for inclusive branching ratios