Light Cone Sum Rules in B to Scalar meson Decays

Muhammad Jamil Aslam

Centre for Advanced Mathematics and Physics
National University of Science and Technology,
Rawalpindi,Pakistan

Plan of the Talk

- Scalar mesons
- A brief introduction about the non perturbative techniques used to calculate the form factors
- LCSR for the transition form factors involved in B to Scalar meson decays
- Discussion on Physical observables like decay rate and polarization asymmetries, etc.
- Summary

Scalar Mesons

The controversies about the inner structure of scalar mesons made them an alluring issue in contemporary particle physics.

They are divided in two nonets in terms of their spectrum:

- The flavor singlet, $f_0(600)$, $f_0(980)$, the isodoublet $K^*_0(800)$ and the isovector $a_0(980)$ constitutes the nonet below 1 GeV
- $f_0(1370)$, $f_0(1500)$/ $f_0(1710)$, $K^*_0(1430)$ and $a_0(1450)$ form the other one near 1.5 GeV.

Up to now, there is no general agreement on the nature of these states due to ambiguity existing in all available interpretations including conventional quark-antiquark states, glueball, hybrid states, molecular states as well as tetraquark states.

Now $K^*_0(1430)$ is predominantly viewed as $s\bar{u}$ or $s\bar{d}$.

So, $a_0(1450)$, $K^*_0(1430)$ and $f_0(1370)$ being in the same nonent can assumed to be: $u\bar{d}$, $u\bar{s}$ and $u\bar{u}+d\bar{d}$ resp.

Effective Hamiltonian

The effective Hamiltonian responsible for $b \to u$ transition is:

$$\mathcal{H}_{eff}(b \to u l \bar{\nu}_l) = \frac{G_F}{\sqrt{2}} V_{ub} \bar{u} \gamma_\mu (1-\gamma_5) b \, \bar{l} \gamma^\mu (1-\gamma_5) \nu_l + h.c.$$

and for $b \to s$ transition it is:

$$\mathcal{H}_{eff}(b \to s l \bar{l}) = \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* [C_9^{eff}(\mu) \bar{s} \gamma_\mu (1-\gamma_5) b \, \bar{l} \gamma^\mu (1-\gamma_5) l$$

$$+ C_{10} \bar{s} \gamma_\mu (1-\gamma_5) b \, \bar{l} \gamma^\mu \gamma_5) l$$

$$- \frac{2 m_b C_7(\mu)}{q^2} \sigma_{\mu\nu} (1-\gamma_5) q^\nu b \, \bar{l} \gamma^\mu l] + h.c.$$

with

$$C_9^{eff}(\mu) = C_9(\mu) + Y_{SD}(z, s') + Y_{LD}(z, s'), \qquad z = m_c/m_b, \; s' = q^2/m_b^2$$

Y_{SD} → Short distance

Y_{LD} → Long distance

$$Y_{SD}(z,s') = h(z,s')(3C_1(\mu) + C_2(\mu) + 3C_3(\mu) + C_4(\mu) + 3C_5(\mu) + C_6(\mu))$$

$$-\tfrac{1}{2}h(1,s')(4C_3(\mu) + 4C_4(\mu) + 3C_5(\mu) + C_6(\mu))$$

$$-\tfrac{1}{2}h(0,s')(C_3(\mu) + 3C_4(\mu)) + \tfrac{2}{9}(3C_3(\mu) + C_4(\mu) + 3C_5(\mu) + C_6(\mu))$$

$$h(z,s') = -\tfrac{8}{9}\ln z + \tfrac{8}{27} + \tfrac{4}{9}x - \tfrac{2}{9}(2+x)|1-x|^{1/2} \begin{cases} \ln\left|\frac{\sqrt{1-x}+1}{\sqrt{1-x}-1}\right| - i\pi & \text{for } x \equiv 4z^2/s' < 1 \\ 2\arctan\frac{1}{\sqrt{x-1}} & \text{for } x \equiv 4z^2/s' > 1 \end{cases}$$

$$h(0,s') = \tfrac{8}{27} - \tfrac{8}{9}\ln\frac{m_b}{\mu} - \tfrac{4}{9}\ln s' + \tfrac{4}{9}i\pi$$

Absorptive part of

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

$$C_7^{eff}(\mu) = C_7(\mu) + C'_{b\to s\gamma}(\mu)$$

$$C'_{b\to s\gamma}(\mu) = i\alpha_s[\tfrac{2}{9}\eta^{14/23}(G_1(x_t) - 0.1687) - 0.03C_2(\mu)]$$

$$\frac{x(x^2-5x-2)}{8(x-1)^3} + \frac{3x^2\ln^2 x}{4(x-1)^4}$$

$\alpha_s(m_W)/\alpha_s(\mu)$

Parameterization of Hadronic Matrix elements

For $B_{q'} \to S$ at hadronic level, the following two matrix elements need to be computed:

$$\langle S(p)|\bar{s}\gamma_\mu\gamma_5 b|B_{q'}(p+q)\rangle \quad , \langle S(p)|\bar{s}\sigma_{\mu\nu}\gamma_5 q^\nu b|B_{q'}(p+q)\rangle$$

Due to *Parity conservation*, the contribution from the vector and tensor current vanishes.

Generally, the above two matrix elements can be parameterized in terms of the form factors as:

$$\langle S(p)|\bar{s}\gamma_\mu\gamma_5 b|B_{q'}(p+q)\rangle = -i[f_+(q^2)p_\mu + f_-(q^2)q_\mu]$$

$$\langle S(p)|\bar{s}\sigma_{\mu\nu}\gamma_5 q^\nu b|B_{q'}(p+q)\rangle = -\frac{1}{m_B+m_S}\Big[(2p+q)_\mu q^2 - (m_B^2 - m_S^2)q_\mu\Big]f_T(q^2)$$

At large recoil,

$$f_+(q^2) = \frac{2\mathrm{m_B}}{\mathrm{m_B+m_S}} f_T(q^2), \qquad \boxed{f_-(q^2) = 0}$$

Non-perturbative methods for calculating the form factors

Quark Model:

The dynamics of the form factors is represented by the non-perturbative parameters in the hadronic wave function.

It is easy to use but its relation to QCD is unclear.

Lattice calculations:

Rigorous from the point of view of QCD, but they suffer from lattice artifacts and uncertainties connected with necessary extrapolations to the physical quark masses.

HQET:

Applicable to the restricted class of problems, like heavy to heavy transition, and sometimes require substantial corrections which can not be calculated with in same framework.

CHPT:

These are designed for the processes involving soft pions and Kaon.

pQCD:

The form factors are expressed as convolution of the hadronic wave functions with hard scattering kernals. These are dominated by the hard gluon exchange corresponding to the hard scattering mechanism.

But the soft contributions can not be estimated using the same meson distribution amplitudes resulting from the twist expansion.

QCD Sum rules:

QCD sum rules developed by Shifman, Vainstein and Zakharov (SVZ) has become widely used working tool for hadron spectroscopy.

The basic idea of QCD sum rules is the calculation of the correlations functions in the quark and hadron level respectively, and then matching them with the assumption of quark – hardon duality.

The QCD representation of the correlation function is calculated in the framework of operator product expansion (OPE), where the short - and long – distance quark – gluon interactions are separated.

The former can be computed using QCD perturbative theory, whereas the latter can be parameterized in terms of universal vacuum condensates or light cone distribution amplitudes (*Colangelo and Khodjamirian, hep-ph/0010175*).

Applications:

- Determination of light and heavy quark masses;
- Masses and decay constants of light and heavy meson and baryons
- Form factors of mesons and baryons
- Moments of distribution amplitudes of light mesons and baryons
- Strong couplings an moments
- Spectroscopy and properties of exotic hadrons (gluball, hybrids, etc)
- and many more ….

The accuracy of this method is limited, on one hand, by the approximations in the OPE of the correlation function and, on the other hand, by a very complicated and largely unknown structure of hadronic dispersion integrals. Consequently, the applicability of sum rules and uncertainties of their predictions must be carefully assessed case to case.

Problems with QCD sum rules:

The three point SVZ rules have some specific problems:

- OPE (short distance expansion in condensates) upsets power counting in the large momentum/mass.
- Contamination of the sum rules, at zero momentum transfer, by "non-diagonal" transitions of the ground state to excited states.

(V. M. Braun, hep-ph/9801222)

Light Cone Sum Rules

Light Cone Sum Rules (LCSR) were developed in late 80's of the last century just to make an attempt to solve or at least moderate the problems of the three point SVZ sum rules by making a partial resummation of the OPE to all orders and reorganizing the expansion in terms of twist of the relevant operators rather then their dimensions.

- The difference between LCSR and SVZSR is that the expansion at short distance is substituted by the expansion in the transverse distance between partons in the infinite momentum range.
- Technically the LCSR approach presents the marriage of QCD sum rules with the theory of hard exclusive processes.
- As a fruit, SVZ vacuum condensates are substituted by light-cone hadron distribution functions of increasing twist which have a direct physical significance.
- LCSR has been widely used in heavy to light decays of mesons and Baryons.

(P. Ball, 1998, 2005, A. Ali et al. 1994, A. Khodjamirian, 2000)

Distribution amplitudes of Scalar mesons

Up to leading fock states, the light-cone distributions of scalar mesons made up of quark-antiquark can be defined as:

$$\langle S(p)|\bar{q}_2(x)\gamma_\mu q_1(y)|0\rangle = p_u \int_0^1 du e^{i(up\cdot x+\bar{u}p.y)} \Phi_S(u,\mu)$$

Twist-2

$$\langle S(p)|\bar{q}_2(x)q_1(y)|0\rangle = m_S \int_0^1 du e^{i(up\cdot x+\bar{u}p.y)} \Phi_S^s(u,\mu)$$

Twist-3

$$\langle S(p)|\bar{q}_2(x)\sigma_{\mu\nu}q_1(y)|0\rangle = -m_S(p_\mu z_\nu - p_\nu z_\mu)\int_0^1 du e^{i(up\cdot x+\bar{u}p.y)} \Phi_S^\sigma(u,\mu)$$

$x-y$ $1-u$

Normalization:

$$\int_0^1 du\Phi_S(u,\mu) = f_S, \quad \int_0^1 du\Phi_S^s(u,\mu) = \int_0^1 du\Phi_S^\sigma(u,\mu) = \bar{f}_S$$

$$\langle S(p)|\bar{q}_2\gamma^\mu q_1|0\rangle = f_S p^\mu \qquad \langle S(p)|\bar{q}_2 q_1|0\rangle = m_S\bar{f}_S \rightarrow \mu_S f_S$$

$$\frac{m_S}{m_2(\mu)-m_1(\mu)}$$

μ_S^{-1}

$$\Phi_S(u,\mu) = \bar{f}_S(\mu) 6u\bar{u}\left[B_0(\mu) + \sum_{m=1}^{\infty} B_m(\mu) C_m^{3/2}(2u-1)\right],$$

$$\Phi_S^s(u,\mu) = \bar{f}_S(\mu)\left[1 + \sum_{m=1}^{\infty} a_m(\mu) C_m^{1/2}(2u-1)\right]$$

$$\Phi_S^\sigma(u,\mu) = \bar{f}_S(\mu) 6u\bar{u}\left[1 + \sum_{m=1}^{\infty} b_m(\mu) C_m^{3/2}(2u-1)\right]$$

The values of Gagenbaur moments both for twist 2 and twist 3 LCDAs can be found in Ref. [hep-ph/08042204]

LCSRs for form factors

With the light cone distribution amplitudes available, we are now in a position to derive the sum rules for the transition form factors which are responsible for the decay under consideration.

Just to recall, the basic object in LCSR approach is the correlation function in which one of the hadron is represented by the interpolating current with proper quantum number, <u>such as spin, isospin, charge, parity and so on</u>; and the other is described by its vector state manifestly. Information on the hadronic transition form factor can be extracted by matching the Green function calculated in two different representations, i.e., <u>phenomenological and theoretical forms, with the help of dispersion relation</u> under the assumption of quark-hadron duality.

For $f_{+}(q^2)$ ***and*** $f_{-}(q^2)$

The correlation function associated with the above form factors is determined by the matrix element

$$\Pi_{\mu}(p,q) = -\int d^4x e^{iqx} \langle S(p) | T\{ j_{2\mu}(x), j_1(0) \} | 0 \rangle$$

$$\langle B_{q_1} | \bar{b} i\gamma_5 q | 0 \rangle = \frac{m^2_{B_{q_1}}}{m_b + m_{q_1}} f_{B_{q_1}}$$

$$b(0) i\gamma_5 q_1(0)$$

$$\bar{q}_2(x)\gamma_{\mu}\gamma_5 b(x)$$

Inserting a complete set of states between the currents, we can arrive at the hadronic representation of correlator:

$$\Pi_{\mu}(p,q) = i\frac{\langle S(p)|\bar{q}_2(0)\gamma_{\mu}\gamma_5 b(0)|B_{q_1}(p+q)\rangle\langle B_{q_1}(p+q)|\bar{b}(0)i\gamma_5 q_1(0)|0\rangle}{m^2_{B_{q_1}} - (p+q)^2}$$

$$+\sum_h i\frac{\langle S(p)|\bar{q}_2(0)\gamma_{\mu}\gamma_5 b(0)|h(p+q)\rangle\langle h(p+q)|\bar{b}(0)i\gamma_5 q_1(0)|0\rangle}{m^2_h - (p+q)^2}$$

The phenomenological representations of correlation function can be derived as

$$\Pi_\mu(p,q) = \frac{m_{B_{q_1}}^2 f_{B_{q_1}}}{(m_b+m_{q_1})[m_{B_{q_1}}^2-(p+q)^2]}[f_+(q^2)p_\mu + f_-(q^2)q_\mu]$$

$$+\int_{s_0^{B_{q_1}}}^{\infty} ds \frac{\rho_+^h(s,q^2)p_\mu+\rho_-^h(s,q^2)q_\mu}{s-(p+q)^2}$$

Threshold parameter

On the theoretical side, the correlation function can also be computed in the perturbative theory with the help of OPE technique at the deep Euclidean region

$p^2,\ q^2 = -Q^2 \ll 0$

$$\Pi_\mu(p,q) = \Pi_+^{QCD}(q^2,(p+q)^2)p_\mu + \Pi_-^{QCD}(q^2,(p+q)^2)q_\mu$$

$$= \int_{(m_b+m_{q_1})^2}^{\infty} ds \frac{1}{\pi} \frac{\mathrm{Im}\Pi_+^{QCD}(s,q^2)}{s-(p+q)^2} p_\mu + \int_{(m_b+m_{q_1})^2}^{\infty} ds \frac{1}{\pi} \frac{\mathrm{Im}\Pi_-^{QCD}(s,q^2)}{s-(p+q)^2} q_\mu$$

Using quark hadron duality assumption

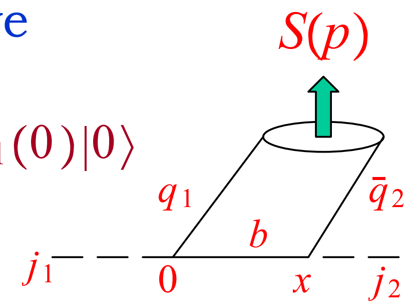
$$\rho_i^h(s,q^2) = \frac{1}{\pi}\mathrm{Im}\,\Pi_i^{QCD}(s,q^2)\Theta(s-s_0^h)$$

Performing Borel transformation with variable $(p+q)^2$, to both two representations of the correlation function, we can finally derive the sum rules for the form factors

$$f_i(q^2) = \frac{\mathrm{m_b+m_{q_1}}}{\pi\left(\mathrm{f_{B_{q_1}}m^2_{B_{q_1}}}\right)}\int_{(m_b+m_{q_1})^2}^{s_0^{B_{q_1}}} \mathrm{Im}\,\Pi_i^{QCD}(s,q^2)\exp\left(\frac{\mathrm{m^2_{B_{q_1}}-s}}{\mathrm{M^2}}\right)ds.$$

Now contracting the bottom quark in the correlator definition, and inserting the free b quark propagator, we have

$$\Pi_\mu(p,q) = i\int d^4x\int\frac{d^4k}{(2\pi)^4}\frac{e^{i(q-k)x}}{m_b^2-k^2}\langle S(p)|\bar{q}_2(x)\gamma_\mu\gamma_5(\not{k}+m_b)i\gamma_5 q_1(0)|0\rangle$$



Performing the integral in the coordinate space, we can achieve the correlation function in the momentum representation at the quark level as

$$\Pi_\mu(p,q) = p_\mu \int_0^1 du \frac{1}{m_b^2-(q+up)^2}\left\{-m_b\Phi_S(u) + um_S\Phi_S^s(u) + \frac{1}{6}m_S\Phi_S^\sigma(u)\left[2 + \frac{m_b^2-u^2p^2+q^2}{m_b^2-(q+up)^2}\right]\right\}$$

$$+q_\mu \int_0^1 du \frac{1}{m_b^2-(q+up)^2}\left\{m_S\Phi_S^s(u) + \frac{m_S}{6u}\Phi_S^\sigma(u)\left[1 - \frac{m_b^2+u^2p^2-q^2}{m_b^2-(q+up)^2}\right]\right\}$$

$$\equiv \Pi_+^{QCD}(q^2,(p+q)^2)p_\mu + \Pi_-^{QCD}(q^2,(p+q)^2)q_\mu$$

Finally, we have

$$f_+(q^2) = \frac{(m_b+m_{q_1})}{m_{B_{q_1}}^2 f_{B_{q_1}}} \exp\left(\frac{m_B^2}{M^2}\right) \times \left[\int_{u_0}^1 \frac{du}{u} \exp\left[-\frac{m_b^2+uup^2-\bar{u}q^2}{uM^2}\right] \times\right.$$

$$\left[\left(-m_b\Phi_S(u) + m_S\left(u\Phi_S^s(u) + \frac{1}{3}\Phi_S^\sigma(u)\right)\right) + \frac{1}{uM^2}\frac{m_S}{6}\Phi_S^\sigma(u)(m_b^2+u^2p^2+q^2)\right]$$

$$\left. + \frac{m_S}{6}\Phi_S^\sigma(u_0)\exp\left(-\frac{s_0}{M^2}\right)\frac{m_b^2-u_0p^2+q^2}{m_b^2+u_0^2p^2-q^2}\right]$$

$$f_-(q^2) = \frac{(m_b+m_{q_1})}{m^2_{B_{q_1}} f_{B_{q_1}}} \exp\left(\frac{m_B^2}{M^2}\right) \left[\int_{u_0}^{1} \frac{du}{u} \exp\left[-\frac{m_b^2+uup^2-\bar{u}q^2}{uM^2}\right] \times \right.$$

$$\left[\left(m_S\left(\Phi_S^s(u) + \frac{1}{6u}\Phi_S^\sigma(u)\right)\right) - \frac{1}{u^2M^2}\frac{m_S}{6}\Phi_S^\sigma(u)(m_b^2 + u^2p^2 - q^2)\right]$$

$$\left. - \frac{m_S}{6u_0}\Phi_S^\sigma(u_0)\exp\left(-\frac{s_0}{M^2}\right)\right]$$

Get contribution only from Twist -3 and hence is in agreement with larger recoil relation

$$u_0 = \frac{-(s_0-q^2-p^2)+\sqrt{(s_0-q^2-p^2)^2+4p^2(m_b^2-q^2)}}{2p^2}$$

LCSR for $f_T(q^2)$

The correlation function is

$$\tilde{\Pi}_\mu(p,q) = -\int d^4x e^{iqx} \langle S(p) | T\{\tilde{j}_{2\mu}(x), j_1(0)\} | 0 \rangle$$

$$\bar{q}_2(x)\sigma_{\mu\nu}a^\nu\gamma_5 b(x)$$

Repeating the same procedure as for the previous two form factors, the correlation function at hadronic level is

$$\tilde{\Pi}_\mu(p,q) = \frac{m^2_{B_{q_1}} f_{B_{q_1}}}{(m_b+m_{q_1})[m^2_{B_{q_1}}-(p+q)^2](m_B+m_S)}[(2p+q)_\mu q^2 - q_\mu(m_B^2 - m_S^2)]f_T(q^2)$$

$$+\int_{s_0^{B_{q_1}}}^{\infty} ds \frac{1}{s-(p+q)^2}[-p_\mu q^2 + q_\mu(p \cdot q)]\rho_T^h(s,q^2).$$

whereas at quark level it is

$$\tilde{\Pi}_\mu(p,q) = [-p_\mu q^2 + q_\mu(p\cdot q)] \int_0^1 du \frac{1}{m_b^2-(q+up)^2} \left\{ \Phi_S(u) - \frac{m_b m_S}{3} \frac{\Phi_S^\sigma(u)}{m_b^2-(q+up)^2} \right\}$$

Matching the two correlation functions and performing the Borel transformation, one has

$$f_T(q^2) = \frac{\left(m_b+m_{q_1}\right)(m_B+m_S)}{m_{B_{q_1}}^2 f_{B_{q_1}}} \exp\left(\frac{m_B^2}{M^2}\right)\left[-\frac{1}{2}\int_{u_0}^1 \frac{du}{u} \exp\left[-\frac{m_b^2+uup^2-\bar{u}q^2}{uT}\right] \times \right.$$

$$\left. \left[\Phi_S(u) - \frac{m_B m_S}{3uM^2}\Phi_S^\sigma(u)\right] + \frac{m_b m_S}{6}\Phi_S^\sigma(u_0)\exp\left(-\frac{s_0}{M^2}\right)\frac{1}{m_b^2+u_0^2p^2-q^2}\right]$$

Numerical Analysis of transition form factors

Thereshold Parameter: $s_0^{B_0} = (35 \pm 2)\mathrm{GeV}^2$, $s_0^{B_s} = (36 \pm 2)\mathrm{GeV}^2$

Borel platform: $M^2 \in [10, 15]\mathrm{GeV}^2$

$$\bar{B}_0 \to a_0(1450) l \nu_l$$

	$f_i(0)$	a_i	b_i
f_+	$1.04^{+0.20}_{-0.20}$	$0.98^{+0.08}_{-0.08}$	
	0.52 (LFQM)	1.57 (LFQM)	0.70 (LFQM)
f_-	$0.077^{+0.014}_{-0.014}$	$1.52^{+0.07}_{-0.12}$	
f_T	$0.66^{+0.13}_{-0.14}$	$0.88^{+0.10}_{-0.09}$	

$\bar{B}_0 \to K_0^*(1430)l\bar{l}$

	$f_i(0)$	a_i	b_i
f_+	$0.97^{+0.20}_{-0.20}$	$0.86^{+0.19}_{-0.18}$	
	0.52 (LFQM)	1.36 (LFQM)	0.86 (LFQM)
	0.62 ± 0.16 (QCDSR)	0.81(QCDSR)	-0.21 (QCDSR)
f_-	$0.073^{+0.02}_{-0.02}$	$2.50^{+0.44}_{-0.47}$	$1.82^{+0.69}_{-0.76}$
f_T	$0.60^{+0.14}_{-0.13}$	$0.69^{+0.26}_{-0.27}$	
	0.34 (LFQM)	1.64 (LFQM)	1.72 (LFQM)
	0.26 ± 0.07 (QCDSR)	0.41 (QCDSR)	-0.32 (QCDSR)

$B_s \to K_0^*(1430) l \nu_l$

	$f_i(0)$	a_i	b_i
f_+	$0.83^{+0.26}_{-0.13}$	$0.93^{+0.20}_{-0.06}$	
	0.48 ± 0.20 (QCDSR)	$1.25^{+0.07}_{-0.06}$ (QCDSR)	
f_-	$0.071^{+0.02}_{-0.02}$	$2.46^{+0.36}_{-0.39}$	$1.72^{+0.59}_{-0.64}$
f_T	$0.52^{+0.18}_{-0.08}$	$0.77^{+0.10}_{-0.07}$	

$B_s \to f_0(1500) l \bar{l}$

	$f_i(0)$	a_i	b_i
f_+	$0.86^{+0.15}_{-0.15}$	$1.17^{+0.06}_{-0.05}$	
f_-	$0.056^{+0.015}_{-0.015}$	$1.94^{+0.48}_{-0.85}$	$0.52^{+0.89}_{-1.6}$
f_T	$0.56^{+0.10}_{-0.11}$	$1.09^{+0.08}_{-0.07}$	

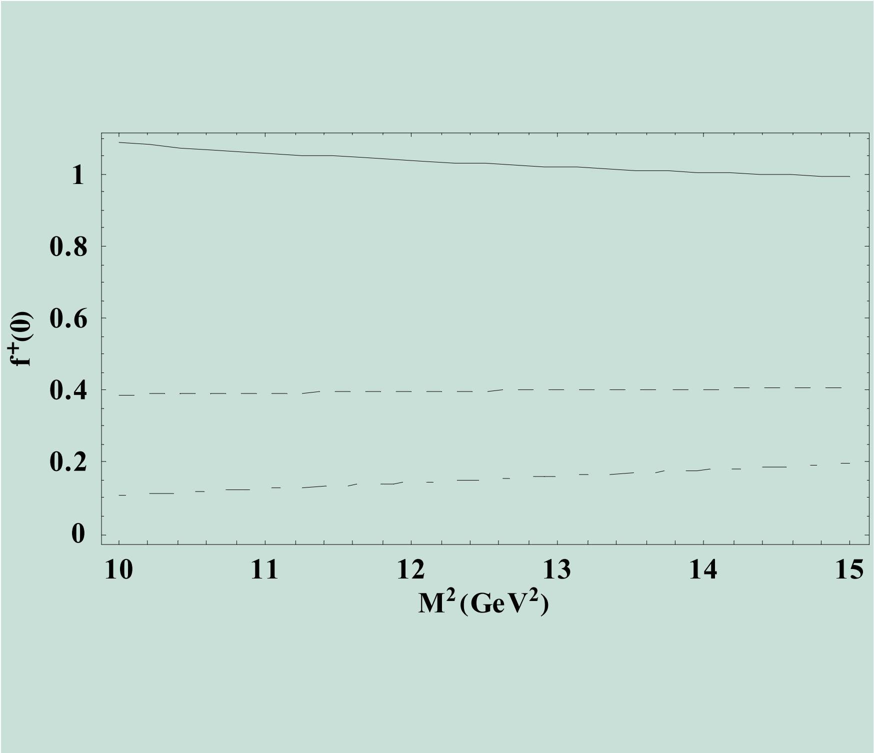
One can parameterize the form factors either by single pole or the double pole form as:

$$f_i(q^2) = \frac{f_i(0)}{1-a_i q^2/m^2_{B_{q1}}},$$

$$0 < q^2 < (m_{\Lambda_b} - m_{\Lambda})^2$$

$$f_i(q^2) = \frac{f_i(0)}{1-a_i q^2/m^2_{B_{q1}} + b_i q^4/m^4_{B_{q1}}}$$

$\bar{B}_0 \to a_0(1450) l \nu_l$



Decay Rate and Polarization Asymmetry

- Forward backward asymmetry for the decay modes $\bar{B}_0 \to K_0^*(1430) l\bar{l}$ and $B_s \to f_0(1500) l\bar{l}$ is zero in the SM due to the absence of the scalar type coupling between the lepton pair.
- The decay with of $\bar{B}_0 \to K_0^*(1430) l\bar{l}$ in the rest frame of B-meson can be written as:

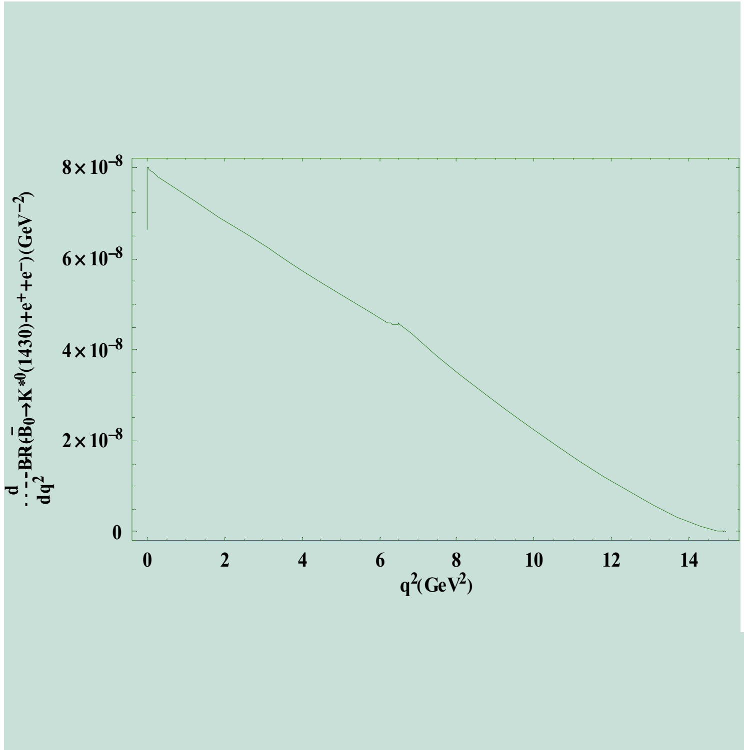
$$\frac{d\Gamma(\bar{B}_0 \to K_0^*(1430) l\bar{l})}{dq^2} = \frac{1}{(2\pi)^3} \frac{1}{32 m_{\bar{B}_0}} \int_{u_{min}}^{u_{max}} |\widetilde{M}_{\bar{B}_0 \to K_0^*(1430) l\bar{l}}|^2 du$$

$$u = (p_{K_0^*(1430)} + p_l)^2$$

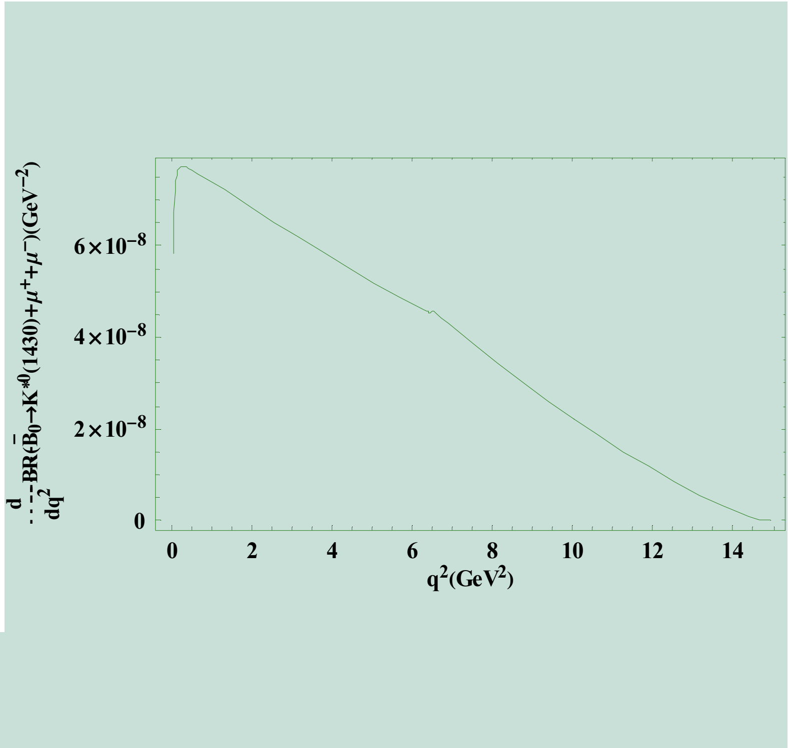
$$u_{max} = (E^*_{K_0^*(1430)} + E^*_l)^2 - \left(\sqrt{E^{*2}_{K_0^*(1430)} - m^2_{K_0^*(1430)}} - \sqrt{E^{*2}_l - m^2_l}\right)^2$$

$$u_{min} = (E^*_{K_0^*(1430)} + E^*_l)^2 - \left(\sqrt{E^{*2}_{K_0^*(1430)} - m^2_{K_0^*(1430)}} + \sqrt{E^{*2}_l - m^2_l}\right)^2$$

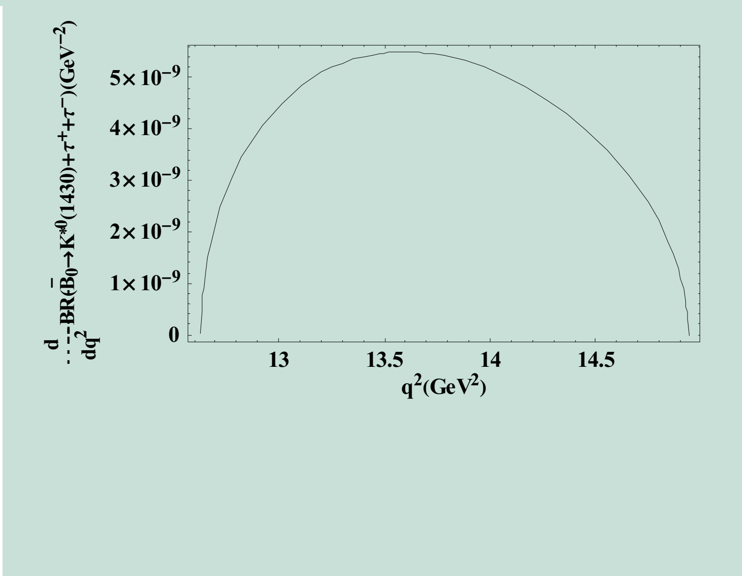
$$E^*_{K_0^*(1430)} = \frac{m^2_{B_0} - m^2_{K_0^*(1430)} - q^2}{2\sqrt{q^2}}, \qquad E^*_l = \frac{q^2}{2\sqrt{q^2}}$$



d/dq² BR(B̄0→K*0(1430)+e⁺+e⁻)(GeV⁻²)
8×10⁻⁸
6×10⁻⁸
4×10⁻⁸
2×10⁻⁸
0
0 2 4 6 8 10 12 14
q²(GeV²)



d/dq² BR(B̄0→K*0(1430)+μ⁺+μ⁻)(GeV⁻²)
6×10⁻⁸
4×10⁻⁸
2×10⁻⁸
0
0 2 4 6 8 10 12 14
q²(GeV²)



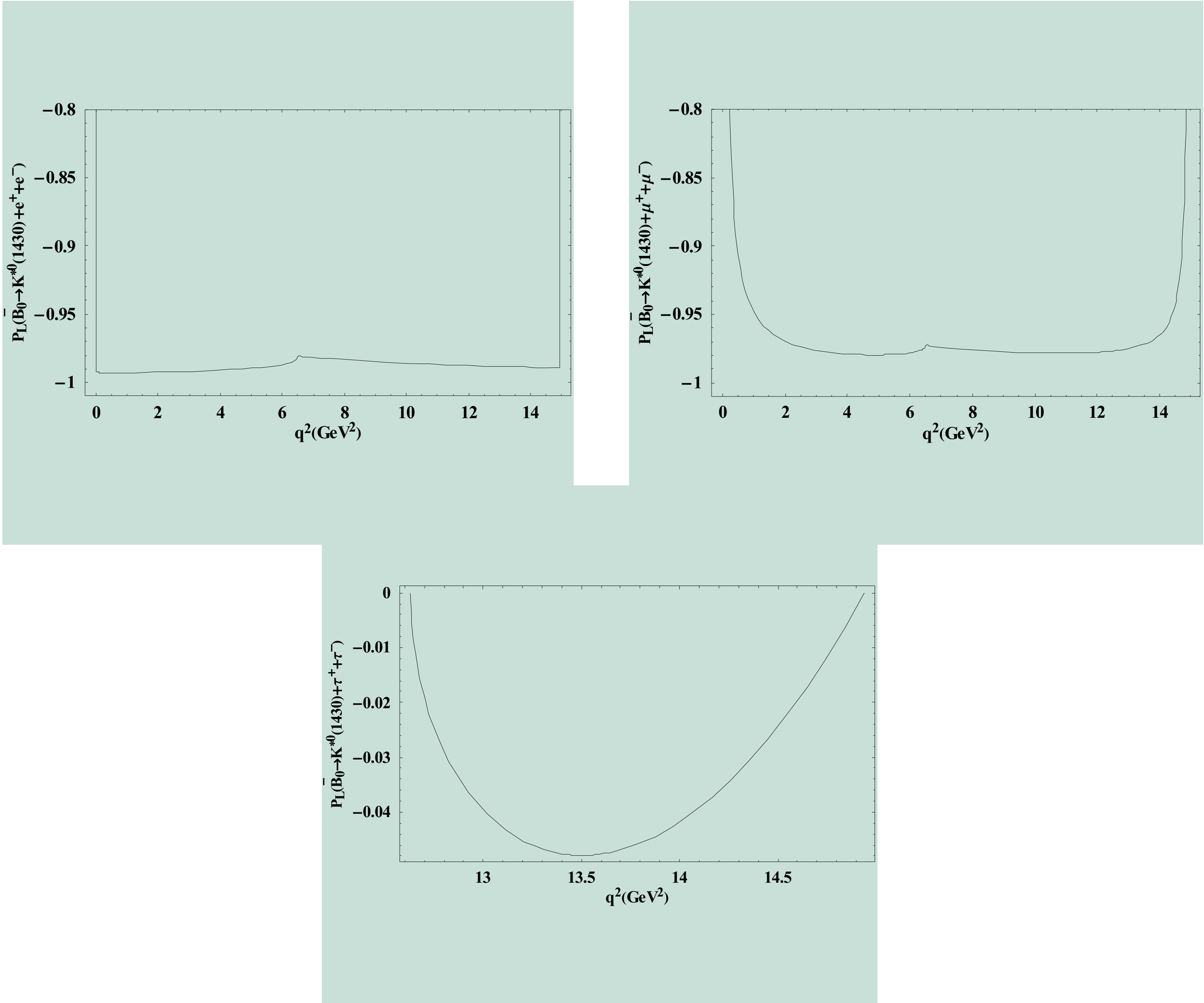
d/dq² BR(B̄0→K*0(1430)+τ⁺+τ⁻)(GeV⁻²)
5×10⁻⁹
4×10⁻⁹
3×10⁻⁹
2×10⁻⁹
1×10⁻⁹
0
13 13.5 14 14.5
q²(GeV²)

	$\bar{B}_0 \to a_0(1450) e \bar{\nu}_e$	$\bar{B}_0 \to K_0^*(1430) e^+ e^-$	$B_s \to K_0^*(1430) e \bar{\nu}_e$	$B_s \to f_0(1500) e^+ e^-$
LCSR	$1.8^{+0.9}_{-0.6} \times 10^{-4}$	$5.7^{+3.4}_{-2.4} \times 10^{-7}$	$1.3^{+1.3}_{-0.4} \times 10^{-4}$	$5.3^{+2.3}_{-1.8} \times 10^{-7}$
LFQM		1.63×10^{-7}		
QCDSR		$(2.09 \sim 2.68) \times 10^{-7}$	$3.6^{+3.8}_{-2.4} \times 10^{-5}$	
	$\bar{B}_0 \to a_0(1450) \mu \bar{\nu}_\mu$	$\bar{B}_0 \to K_0^*(1430) \mu^+ \mu^-$	$B_s \to K_0^*(1430) \mu \bar{\nu}_\mu$	$B_s \to f_0(1500) \mu^+ \mu^-$
LCSR	$1.8^{+0.9}_{-0.7} \times 10^{-4}$	$5.6^{+3.1}_{-2.3} \times 10^{-7}$	$1.3^{+1.2}_{-0.4} \times 10^{-4}$	$5.2^{+2.3}_{-1.7} \times 10^{-7}$
LFQM		1.62×10^{-7}		
QCDSR		$(2.07 \sim 2.66) \times 10^{-7}$		
	$\bar{B}_0 \to a_0(1450) \tau \bar{\nu}_\tau$	$\bar{B}_0 \to K_0^*(1430) \tau^+ \tau^-$	$B_s \to K_0^*(1430) \tau \bar{\nu}_\tau$	$B_s \to f_0(1500) \tau^+ \tau^-$
LCSR	$6.3^{+3.4}_{-2.5} \times 10^{-5}$	$9.8^{+12.4}_{-5.5} \times 10^{-9}$	$5.2^{+5.7}_{-1.8} \times 10^{-5}$	$1.2^{+0.8}_{-0.5} \times 10^{-8}$
LFQM		2.86×10^{-9}		
QCDSR		$(1.70 \sim 2.20) \times 10^{-9}$		

$$\langle A_{PL}\rangle = \int_{s'_{min}}^{s'_{max}} A_{PL}(s')ds'$$

$$s'_{min} = 4\mathrm{m}_l^2/\mathrm{m}_B^2 \qquad s'_{max} = (\mathrm{m}_B^2 - \mathrm{m}_S^2)/\mathrm{m}_B^2$$

	$\bar{B}_0 \to K_0^*(1430)e^+e^-$	$B_s \to f_0(1500)e^+e^-$
$\langle A_{PL}\rangle$	-0.99 ± 0.0	-0.99 ± 0.0
	-0.97 (LFQM)	
	$\bar{B}_0 \to K_0^*(1430)\mu^+\mu^-$	$B_s \to f_0(1500)\mu^+\mu^-$
$\langle A_{PL}\rangle$	-0.96 ± 0.0	-0.96 ± 0.0
	-0.95 (LFQM)	
	$\bar{B}_0 \to K_0^*(1430)\tau^+\tau^-$	$B_s \to f_0(1500)\tau^+\tau^-$
$\langle A_{PL}\rangle$	$-0.03^{+0.00}_{-0.01}$	-0.04 ± 0.0
	-0.03 (LFQM)	


−0.8
−0.85
−0.9
−0.95
−1
$P_L(\bar{B}_0 \to K^{*0}(1430)+e^+ +e^-)$
0
2
4
6
8
10
12
14
$q^2(GeV^2)$
−0.8
−0.85
−0.9
−0.95
−1
$P_L(\bar{B}_0 \to K^{*0}(1430)+\mu^+ +\mu^-)$
0
2
4
6
8
10
12
14
$q^2(GeV^2)$
0
−0.01
−0.02
−0.03
−0.04
$P_L(\bar{B}_0 \to K^{*0}(1430)+\tau^+ +\tau^-)$
13
13.5
14
14.5
$q^2(GeV^2)$

Summary

- Within the frame work of light cone sum rules the form factors responsible for semi-leptonic decays of $\bar{B}_0 \to a_0(1450) l \bar{\nu}_l$, $\bar{B}_0 \to K_0^*(1430) l \bar{l}$, $B_s \to K_0^*(1430) l \bar{\nu}_l$ and $B_s \to f_0(1500) l \bar{l}$ up to twist-3 distribution amplitudes of the leading Fock state.
- Owing to the strong coupling of scalar mesons to the scalar current, the form factors associate with B to scalar meson decays are approximately twice as large as that for the ones in B to psudoscalar case.
- The calculated form factors also verify the relations derived in the large recoil and heavy quark limit.
- Utilizing these form factors the decay rate and lepton Polarization asymmetries are studied. The average polarization asymmetries for the final state including electron and muon is approximately -1, where as for the tauons it is too small to be observed at future experiments.
- *The work presented here is not only helpful to clarify the inner structure of scalar meson but also for understanding of dynamics of Strong interactions.*

Thanks