2016手征有效场论研讨会

X(5568): $B_s\pi$和$B\bar{K}$道的相互作用

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报告内容

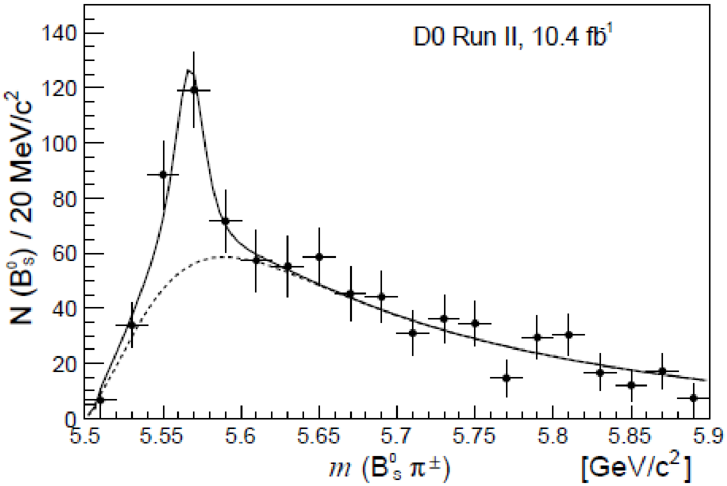
- 实验背景
- 理论框架
- 计算过程
- 结论分析

X(5568)：D0组实验发现

- PRL, 117, 022003, (2016)
- D0实验组：质子反质子碰撞：$\sqrt{s} = 1.96 TeV$
- $10.4 fb^{-1}$, 5.1σ,

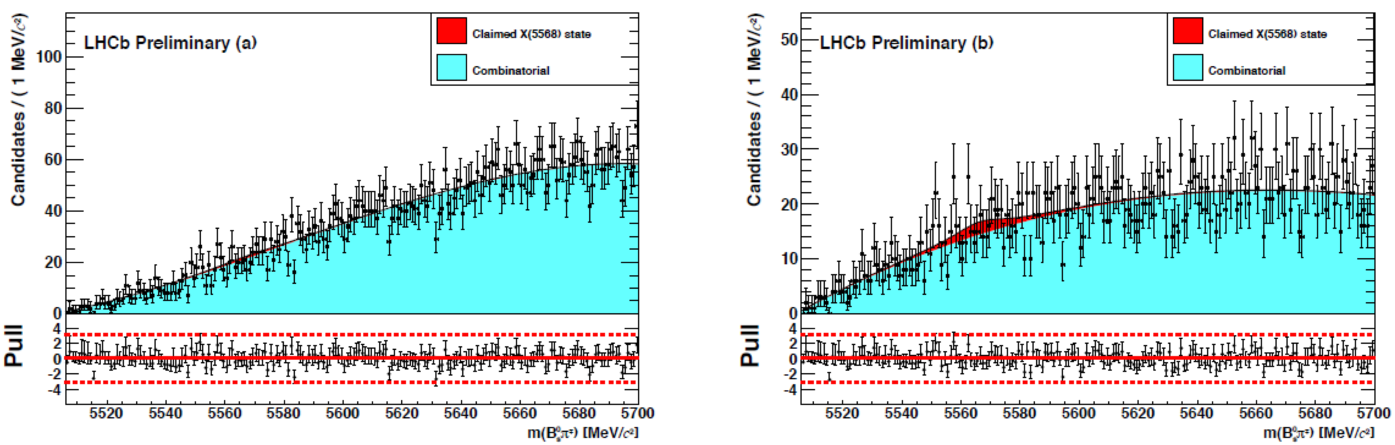
$$M = 5567.8 \pm 2.9^{+0.9}_{-1.9}\ MeV$$

$$\Gamma = 21.9 \pm 6.4^{+5.0}_{-2.5} MeV$$



LHCb实验结果

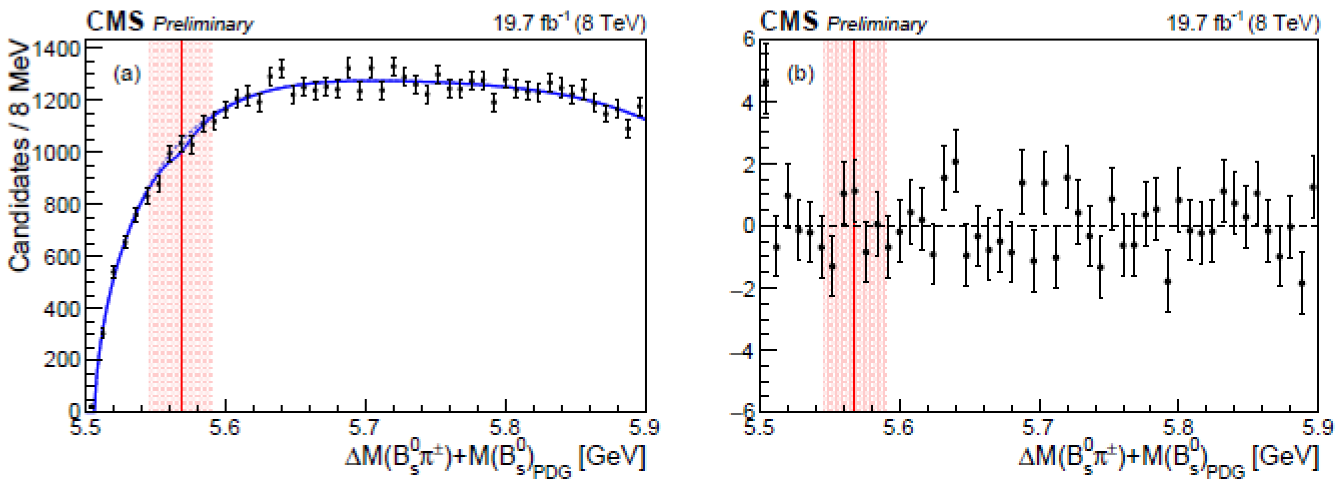
- LHCb实验组：质子质子碰撞 $\sqrt{s} = 7 \sim 8TeV$
- 3fb^{-1}，没有发现X(5568) 粒子。



CMS实验结果

质子质子碰撞 $\sqrt{s} = 8TeV$

- 17.9fb^{-1}，没有发现X(5568) 粒子



B介子和赝标量介子的相互作用

领头阶拉氏量

$$\mathcal{L}^{(1)} = \langle \mathcal{D}_\mu P \mathcal{D}^\mu P^\dagger \rangle - m_P^2 \langle P P^\dagger \rangle - \langle \mathcal{D}_\mu P^{*\nu} \mathcal{D}^\mu P_\nu^{*\dagger} \rangle + m_{P^*}^2 \langle P^{*\nu} P_\nu^{*\dagger} \rangle,$$

次领头阶拉氏量：

$$\begin{aligned}
\mathcal{L}^{(2)} = & -2[c_0 \langle P P^\dagger \rangle \langle \chi_+ \rangle - c_1 \langle P \chi_+ P^\dagger \rangle - c_2 \langle P P^\dagger \rangle \langle u^\mu u_\mu \rangle - c_3 \langle P u^\mu u_\mu P^\dagger \rangle \\
& + \frac{c_4}{m_P^2} \langle \mathcal{D}_\mu P \mathcal{D}_\nu P^\dagger \rangle \langle \{u^\mu, u^\nu\} \rangle + \frac{c_5}{m_P^2} \langle \mathcal{D}_\mu P \{u^\mu, u^\nu\} \mathcal{D}_\nu P^\dagger \rangle + \frac{c_6}{m_P^2} \langle \mathcal{D}_\mu P [u^\mu, u^\nu] \mathcal{D}_\nu P^\dagger \rangle] \\
& + 2[\tilde{c}_0 \langle P_\mu^* P^{*\mu\dagger} \rangle \langle \chi_+ \rangle - \tilde{c}_1 \langle P_\mu^* \chi_+ P^{*\mu\dagger} \rangle - \tilde{c}_2 \langle P_\nu^* P^{*\nu\dagger} \rangle \langle u^\mu u_\mu \rangle - \tilde{c}_3 \langle P_\nu^* u^\mu u_\mu P^{*\nu\dagger} \rangle \\
& + \frac{\tilde{c}_4}{m_{P^*}^2} \langle \mathcal{D}_\mu P_\alpha^* \mathcal{D}_\nu P^{*\alpha\dagger} \rangle \langle \{u^\mu, u^\nu\} \rangle + \frac{\tilde{c}_5}{m_{P^*}^2} \langle \mathcal{D}_\mu P_\alpha^* \{u^\mu, u^\nu\} \mathcal{D}_\nu P^{*\alpha\dagger} \rangle \\
& + \frac{\tilde{c}_6}{m_{P^*}^2} \langle \mathcal{D}_\mu P_\alpha^* [u^\mu, u^\nu] \mathcal{D}_\nu P^{*\alpha\dagger} \rangle]
\end{aligned}$$

B介子和赝标量介子的相互作用

其中 $P = (B^-, \bar{B}^0, \bar{B}^0_s)$ $P^\dagger = (B^+, B^0, B^0_s)$,

$$P^*_\mu = (B^{*-}, \bar{B}^{*0}, \bar{B}^{*0}_s)_\mu \qquad P^{*\dagger}_\mu = (B^{*+}, B^{*0}, B^{*0}_s)_\mu .$$

赝标量介子为

$$\Phi = \sqrt{2}\begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & -\frac{2}{\sqrt{6}}\eta \end{pmatrix} .$$

B介子和赝标量介子的相互作用

- 协变微商为

$$\mathcal{D}_\mu P_a = \partial_\mu P_a - \Gamma_\mu^{ba} P_b, \quad \mathcal{D}^\mu P_a^\dagger = \partial^\mu P_a^\dagger - \Gamma_{ab}^\mu P_b^\dagger,$$

- 其中

$$\Gamma_\mu = \frac{1}{2}(\xi^\dagger \partial_\mu \xi + \xi \partial_\mu \xi^\dagger) \qquad \xi^2 = \exp(i\Phi/f_0)$$

$$u_\mu = i(\xi^\dagger \partial_\mu \xi - \xi \partial_\mu \xi^\dagger) \qquad \chi_+ = \xi^\dagger \mathcal{M} \xi^\dagger + \xi \mathcal{M} \xi$$

$$\mathcal{M} = \mathrm{diag}(m_\pi^2, m_\pi^2, 2m_K^2 - m_\pi^2)$$

B介子和赝标量介子的相互作用

- 领头阶相互作用势

$$V_{LO} = \frac{m_B}{4f_0^2} C_{LO} \left(E + E' \right)$$

- 次领头阶相互作用势

$$V_{NLO} = -\frac{2}{f_0^2} c_0 C_0 + \frac{1}{2f_0^2} c_1 C_1 - \frac{4}{f_0^2} c_{24} C_2 E E' - \frac{2}{f_0^2} c_{35} C_3 E E',$$

- 其中

	C_{LO}	C_0	C_1	C_2	C_3
$B\bar{K} \to B\bar{K}$	0	$4m_K^2$	0	-2	0
$B\bar{K} \to B_s^0\pi^0$	-2	0	$4(m_K^2 + m_\pi^2)$	0	2
$B_s^0\pi^0 \to B_s^0\pi^0$	0	$4m_\pi^2$	0	-2	0

B介子和赝标量介子的相互作用

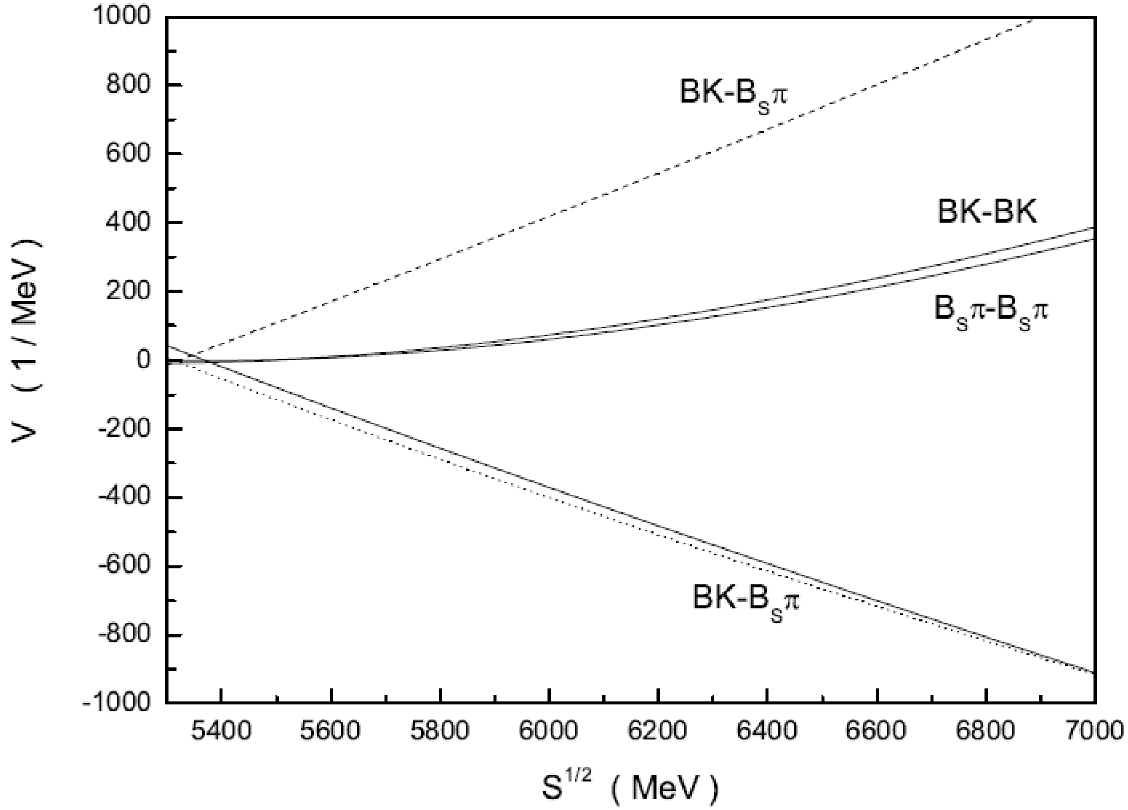
- 相互作用参数
- M.Altenbuchinger et al., PRD,89,014026(2014)

$$c_{i,B}/m_B = c_{i,D}/m_D,$$

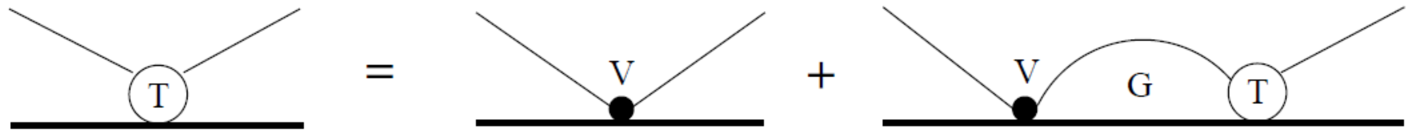
	c_0	c_1	c_{24}	c_{35}
HQS UChPT	0.015	−0.214	−0.068	−0.011

$$m_B = 53331.9MeV \qquad m_D = 1972.1MeV$$

B介子和赝标量介子的相互作用



耦合道近似下的Bethe-Salpeter方程

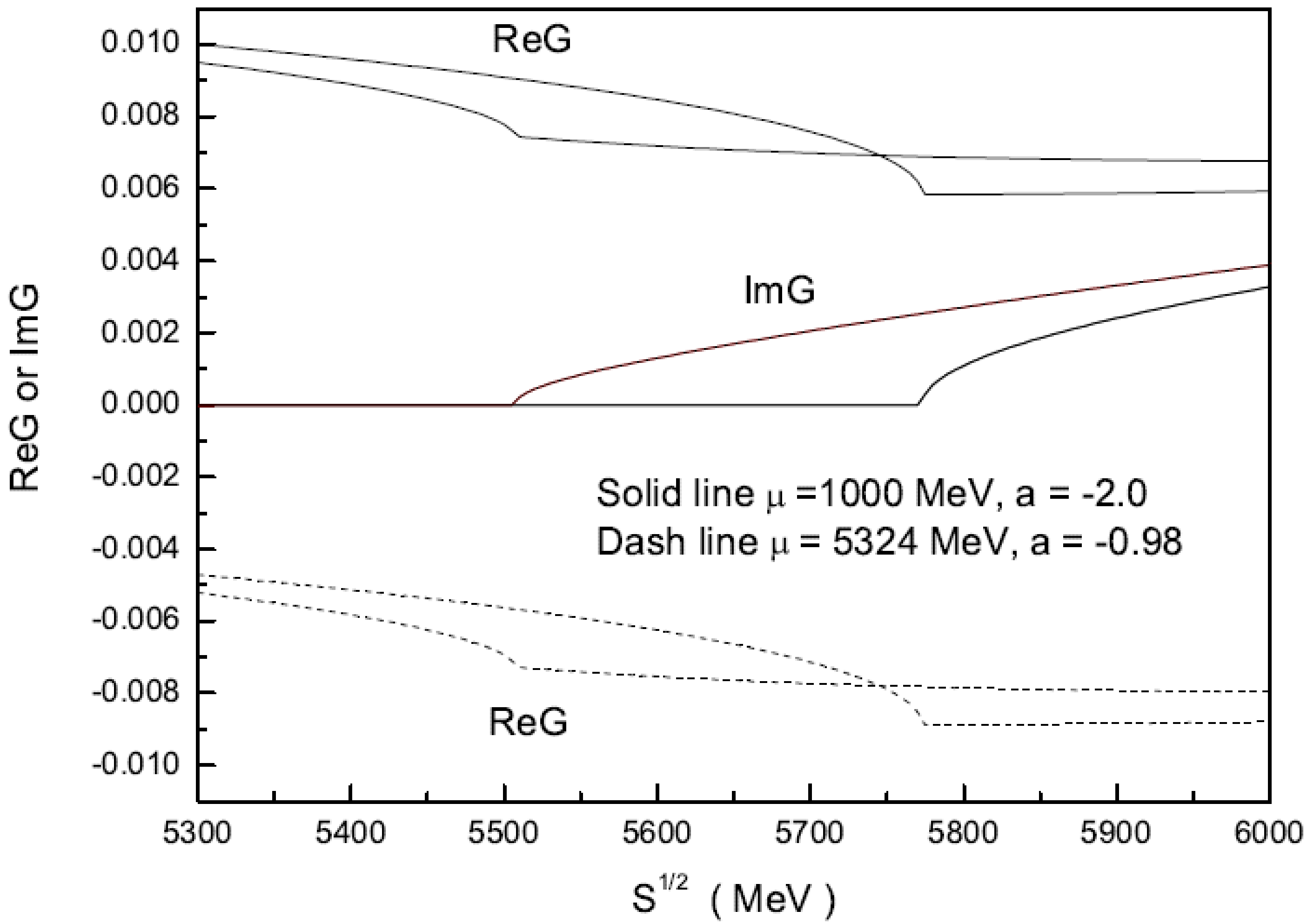


- 保持散射振幅的幺正性： $T(\sqrt{s}) = [1 - V_S(\sqrt{s})\, G(s)]^{-1}\, V_S(\sqrt{s}),$
- 维数正规化的传播子形式：

$$
\begin{aligned}
G_l(s) &= i \int \frac{d^4 q}{(2\pi)^4} \frac{1}{(P-q)^2 - M_l^2 + i\epsilon} \frac{1}{q^2 - m_l^2 + i\epsilon} \\
&= \frac{1}{16\pi^2} \Big\{ a_l(\mu) + \ln \frac{M_l^2}{\mu^2} + \frac{m_l^2 - M_l^2 + s}{2s} \ln \frac{m_l^2}{M_l^2} + \\
&\quad + \frac{\bar{q}_l}{\sqrt{s}} \big[\ln(s - (M_l^2 - m_l^2) + 2\bar{q}_l \sqrt{s}) + \ln(s + (M_l^2 - m_l^2) + 2\bar{q}_l \sqrt{s}) \\
&\quad - \ln(-s + (M_l^2 - m_l^2) + 2\bar{q}_l \sqrt{s}) - \ln(-s - (M_l^2 - m_l^2) + 2\bar{q}_l \sqrt{s}) \big] \Big\}
\end{aligned}
$$

- 其中 $$\bar{q}_l = \frac{\lambda^{1/2}(s, m_l^2, M_l^2)}{2\sqrt{s}} = \frac{\sqrt{s - (M_l + m_l)^2}\sqrt{s - (M_l - m_l)^2}}{2\sqrt{s}},$$

传播子G函数



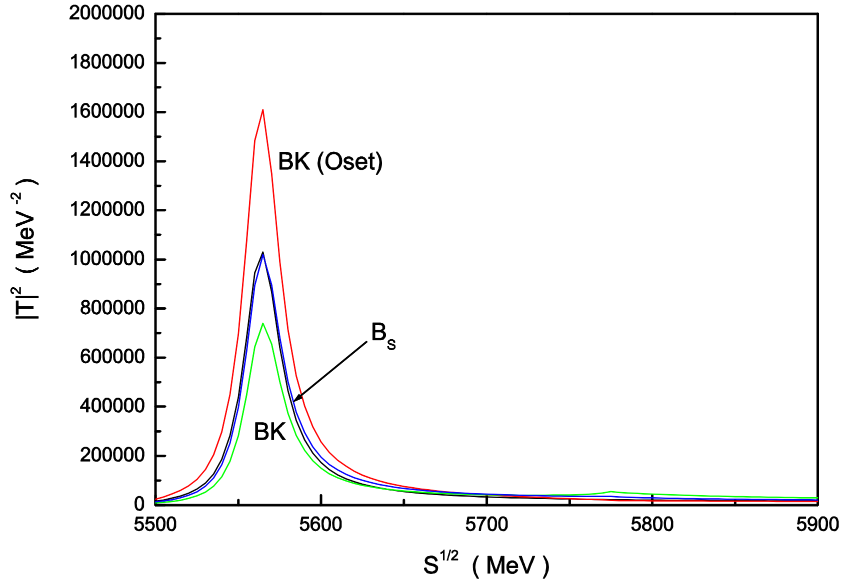
ReG
ImG
ReG
Solid line μ =1000 MeV, a = -2.0
Dash line μ = 5324 MeV, a = -0.98
ReG or ImG
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
5300
5400
5500
5600
5700
5800
5900
6000
S1/2 (MeV)

共振态

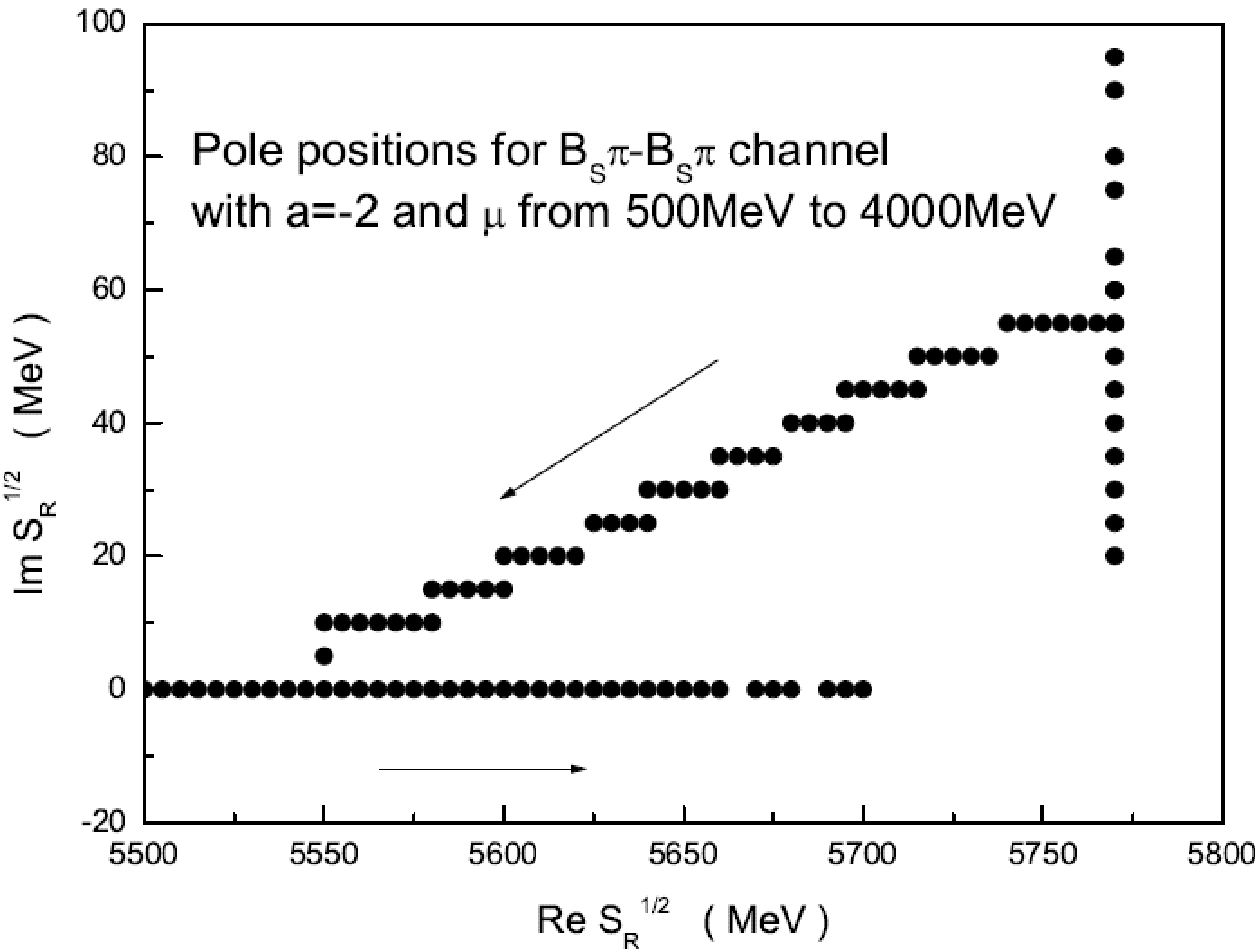
$$\mu = 1000 MeV, a = -2.0$$

$$\mu = 5568 MeV,$$

$$\Gamma = 0 MeV$$



共振态位置随μ 的变化



Pole positions for $B_s\pi$-$B_s\pi$ channel
with a=-2 and μ from 500MeV to 4000MeV
Im $S_R^{1/2}$ (MeV)
Re $S_R^{1/2}$ (MeV)
100
80
60
40
20
0
-20
5500
5550
5600
5650
5700
5750
5800

M. Albaladejo et al., PLB, 757, 515(2016)

$$V_{11}(s) = 0, \quad V_{22}(s) = 0,$$
$$V_{12}(s) = \frac{1}{8f_0^2}\left(3s - (M_1^2 + M_2^2 + m_1^2 + m_2^2) - \frac{\Delta_1\Delta_2}{s}\right),$$

$$\begin{aligned} & det|1 - VG| \\ = & \begin{vmatrix} 1 - V_{11}(s)G_1(s) & -V_{12}(s)G_2(s) \\ -V_{21}(s)G_1(s) & 1 - V_{22}(s)G_2(s) \end{vmatrix} \\ = & \ 0, \end{aligned}$$

$$1 - V_{12}^2(s)G_1(s)G_2(s) = 0.$$

谢谢