SOFT PHOTONS & $B_s^0 \to \mu^+\mu^-$

KRISTOPHER J. HEALEY
ALEXEY A. PETROV
Y.G. ADITYA

WAYNE STATE UNIVERSITY

PHENOMENOLOGY SYMPOSIUM 2012
UNIVERSITY OF PITTSBURGH

THE DECAY $B_s^0 \to \mu^+\mu^-$

- Helicity Suppressed
  - Pseudoscalar – Lepton pair spin flip
  - Standard Model amplitude is small

$$\mathcal{A}(B_s^0 \to \mu^+\mu^-) \propto \left(\frac{m_\ell}{m_{B_s^0}}\right)$$

THE DECAY $B_s^0 \to \mu^+\mu^-$

- Helicity Suppressed
  - Pseudoscalar – Lepton pair spin flip
  - Standard Model amplitude is small

$$\mathcal{A}(B_s^0 \to \mu^+\mu^-) \propto \left(\frac{m_\ell}{m_{B_s^0}}\right)$$

- The SM prediction is very clean

$$\mathrm{Br}(\ B_s^0 \to \mu^+\mu^-)_{SM} \quad = \quad (3.2 \pm 0.2) \times 10^{-9}$$

  - A. J. Buras, **Phys. Lett. B566(2003) 115**

$$\mathrm{Br}(\ B_s^0 \to \mu^+\mu^-)_{SM} \quad = \quad (3.33 \pm 0.21) \times 10^{-9}$$

  - Golowich, Hewett, Pakvasa, Petrov, Yeghiyan, **Phys.Rev.D83(2011):114017**

THE DECAY $B_s^0 \to \mu^+\mu^-$

- Helicity Suppressed
  - Pseudoscalar – Lepton pair spin flip
  - Standard Model amplitude is small

$$\mathcal{A}(B_s^0 \to \mu^+\mu^-) \propto \left(\frac{m_\ell}{m_{B_s^0}}\right)$$

- The SM prediction is very clean

$$\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{SM} = (3.2 \pm 0.2) \times 10^{-9}$$

  - A. J. Buras, **Phys. Lett. B566(2003) 115**

$$\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{SM} = (3.33 \pm 0.21) \times 10^{-9}$$

  - Golowich, Hewett, Pakvasa, Petrov, Yeghiyan, **Phys.Rev.D83(2011):114017**

- Current Experimental Upper Limits $(95\% C.L.)$

$$\begin{aligned}
\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{D0} &< 5.1 \times 10^{-8} \\
\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{ATLAS} &< 2.2 \times 10^{-8} \\
\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{CDFII} &< 4.0 \times 10^{-8} \\
\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{CMS} &< 7.7 \times 10^{-9} \\
\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{LHCb} &< 4.5 \times 10^{-9}
\end{aligned}$$

THE DECAY $B_s^0 \to \mu^+\mu^-$

- Suppressed SM = Excellent probe of New Physics
  - Additional final state particle lifts the suppression.
    - Can carry away angular momentum

- SM contributions from soft photons may be a large source of systematic uncertainty

$$\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{exp} = \mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{SM}\,(1 + R_{\gamma_s})$$

THE DECAY $B_s^0 \to \mu^+\mu^-$

- Suppressed SM = Excellent probe of New Physics
  - Additional final state particle lifts the suppression.
    - Can carry away angular momentum
- SM contributions from soft photons may be a large source of systematic uncertainty

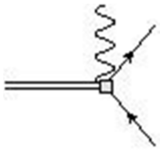
$$\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{exp} = \mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{SM}\,(1 + R_{\gamma_s})$$

- Previous work on $B_s^0 \to \mu^+\mu^-\gamma$
  - Model dependent form factors
  - Photon Energy Cuts
    - Near our region of interest
- Our calculation:
  - Focus on soft region
  - Model independent (where we can)
  - Expand in powers of 1/M + Chiral

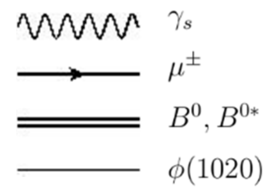
Final Di-Muon Signal Windows

$$\mathrm{D0}: \ (5.0(\mathrm{GeV}) < m_{\mu\mu} < 5.8(\mathrm{GeV})) \to E_{\gamma_{cut}} \approx 350\ (\mathrm{MeV})$$
$$\mathrm{ATLAS}: \ (5.1(\mathrm{GeV}) < m_{\mu\mu} < 5.7(\mathrm{GeV})) \to E_{\gamma_{cut}} \approx 300\ (\mathrm{MeV})$$
$$\mathrm{CDF}: \ (5.3(\mathrm{GeV}) < m_{\mu\mu} < 5.4(\mathrm{GeV})) \to E_{\gamma_{cut}} \approx 60\ (\mathrm{MeV})$$
$$\mathrm{CMS}: \ (5.3(\mathrm{GeV}) < m_{\mu\mu} < 5.4(\mathrm{GeV})) \to E_{\gamma_{cut}} \approx 60\ (\mathrm{MeV})$$
$$\mathrm{LHCb}: \ (5.3(\mathrm{GeV}) < m_{\mu\mu} < 5.4(\mathrm{GeV})) \to E_{\gamma_{cut}} \approx 60\ (\mathrm{MeV})$$

CHIRAL + 1/M EXPANSION



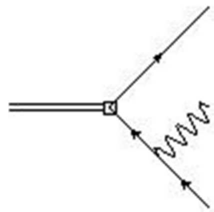
$=$

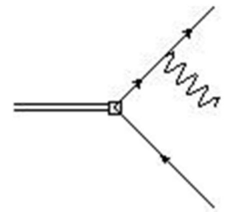


Chiral L.O.

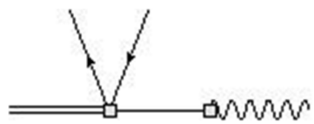
$$\left(\frac{1}{M_{B_s^0}}\right)^0$$

Bremsstrahlung

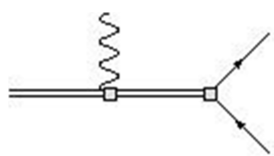




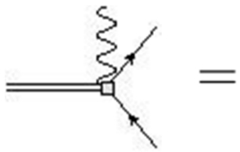
Vector Resonance
$\phi(1020)$

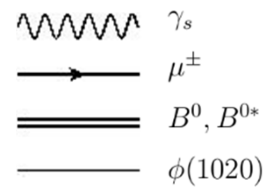


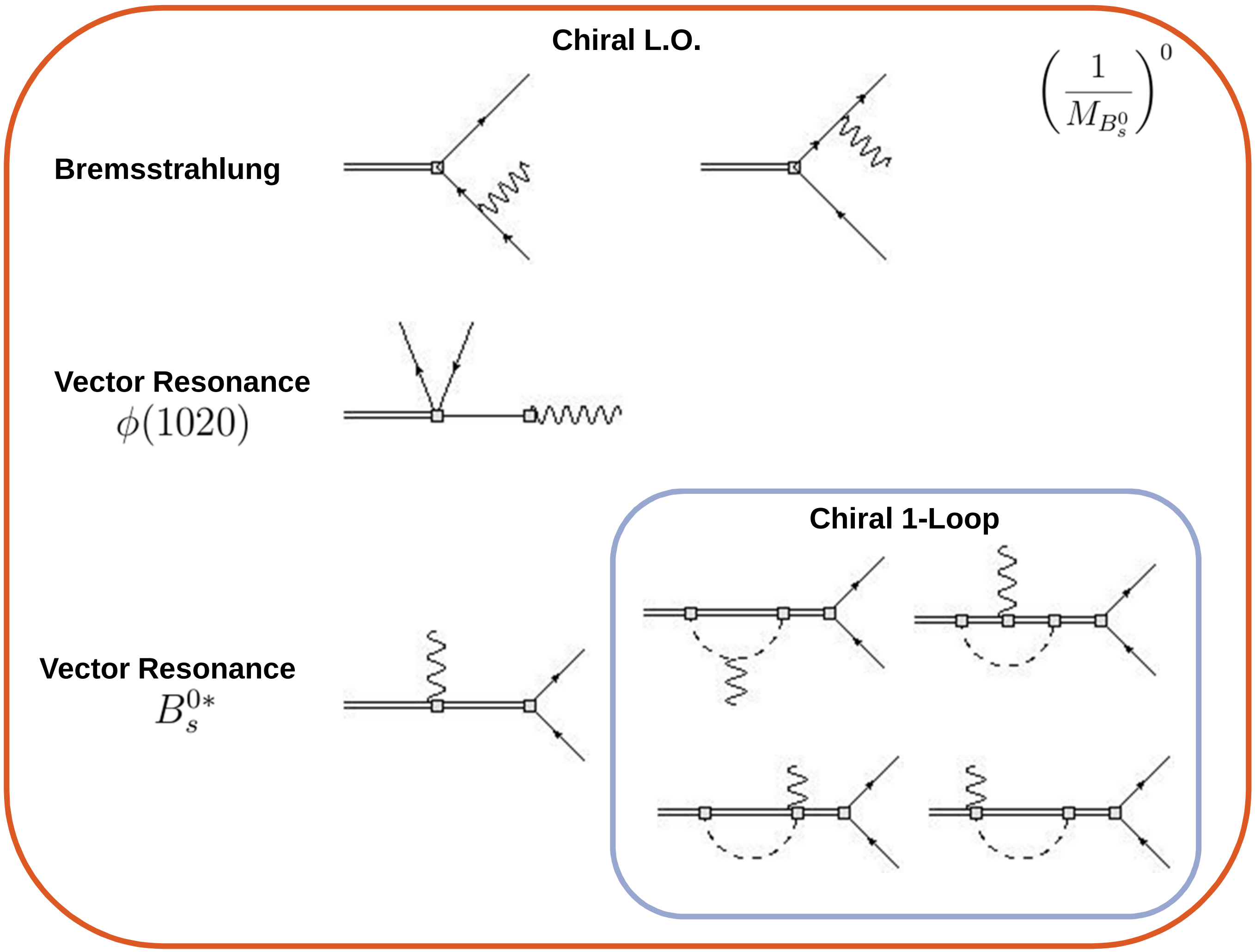
Vector Resonance
B_s^{0*}



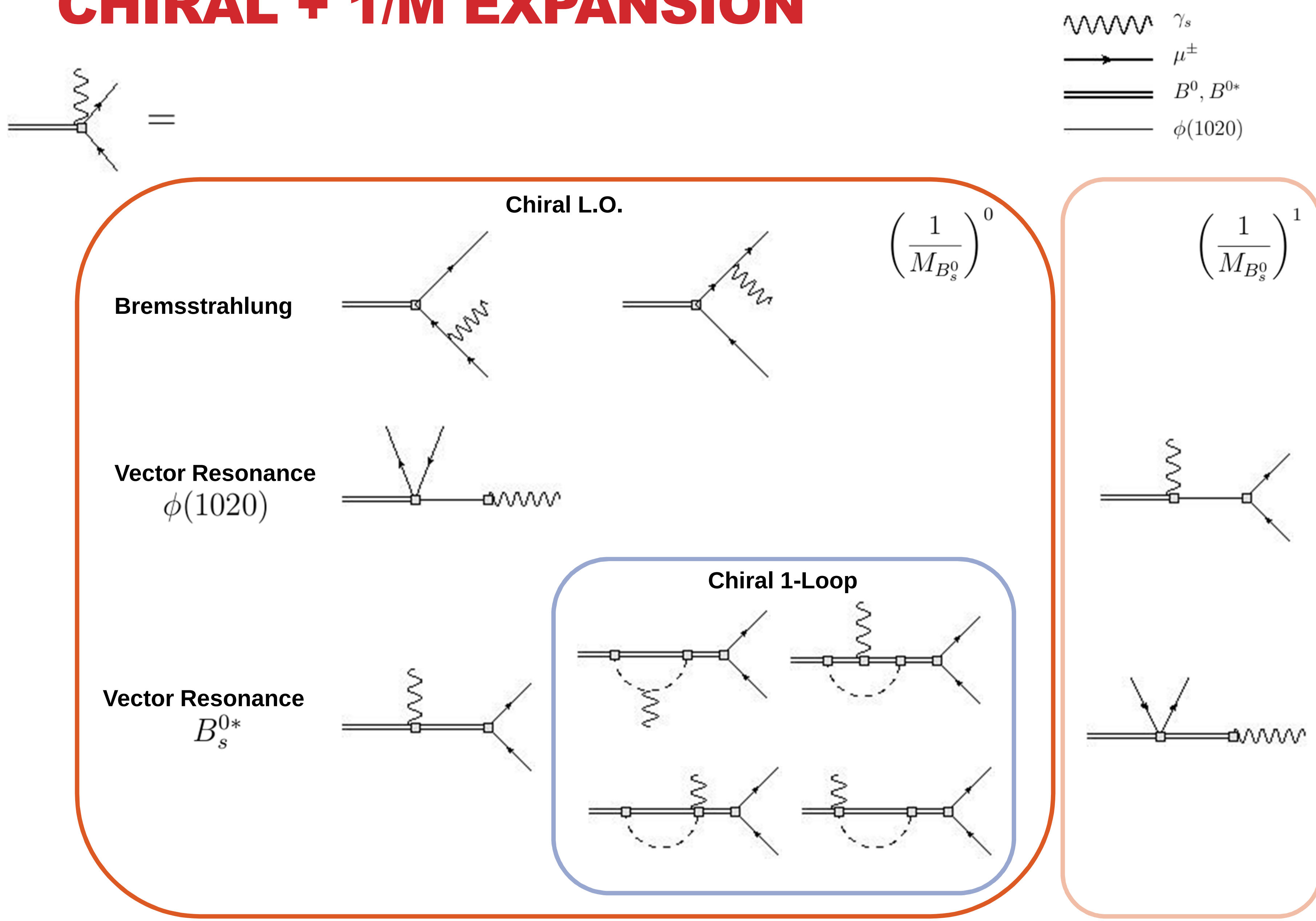
CHIRAL + 1/M EXPANSION







CHIRAL + 1/M EXPANSION

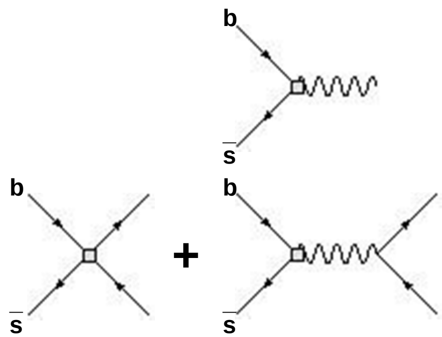


EFFECTIVE WEAK B-S TRANSITION

The (bs) FCNC is at 1-loop in SM (penguin + box)

- **Weak transition can be expanded in terms of effective operators:**

$$\mathcal{H}_{eff}^{b\to s} = \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum C_i(\mu) O_i(\mu)$$



$$\mathcal{H}_{b\to s\gamma} = \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e}{8\pi^2} m_b C_{7\gamma}(\mu^2) \cdot \bar{s}\sigma^{\mu\nu}(1+\gamma_5) b \cdot F_{\mu\nu}$$

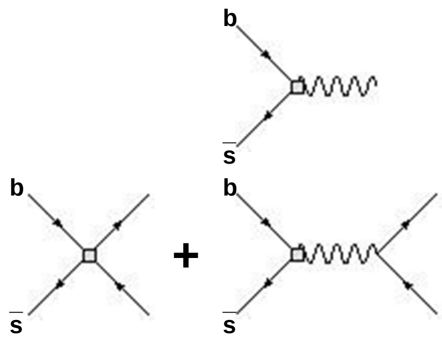
$$\mathcal{H}_{b\to s\bar{\ell}\ell} = \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{8\pi^2} \Big[\bar{s}\gamma^\mu(1-\gamma_5)\, b \cdot \bar{\ell} \left[C_{9V}^{eff}(\mu, q^2)\gamma_\mu + C_{10A}(\mu^2)\gamma_\mu\gamma_5 \right] \ell - 2im_b \frac{C_{7\gamma}(\mu^2)}{q^2} q_\nu \cdot \bar{s}\sigma^{\mu\nu}(1+\gamma_5) b \cdot \bar{\ell}\gamma_\mu \ell \Big]$$

EFFECTIVE WEAK B-S TRANSITION

The (bs) FCNC is at 1-loop in SM (penguin + box)

- **Weak transition can be expanded in terms of effective operators:**

$$\mathcal{H}_{eff}^{b\to s} = \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum C_i(\mu) O_i(\mu)$$



$$\mathcal{H}_{b\to s\gamma} = \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e}{8\pi^2} m_b C_{7\gamma}(\mu^2) \cdot \bar{s}\sigma^{\mu\nu}(1+\gamma_5) b \cdot F_{\mu\nu}$$

$$\mathcal{H}_{b\to s\bar{\ell}\ell} = \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{8\pi^2} \left[\bar{s}\gamma^\mu (1-\gamma_5)\, b \cdot \bar{\ell} \left[C_{9V}^{eff}(\mu, q^2)\gamma_\mu + C_{10A}(\mu^2)\gamma_\mu\gamma_5 \right] \ell - 2im_b \frac{C_{7\gamma}(\mu^2)}{q^2} q_\nu \cdot \bar{s}\sigma^{\mu\nu}(1+\gamma_5) b \cdot \bar{\ell}\gamma_\mu \ell \right]$$

Heavy Meson Chiral Perturbation Theory to parameterize the (bs) quark bilinears:

$$\langle 0 | (\bar{s}_L \gamma^\mu b_L) | B_s^* \rangle = \frac{i}{2} M_{B_s} f_{B_s} \eta^\mu$$

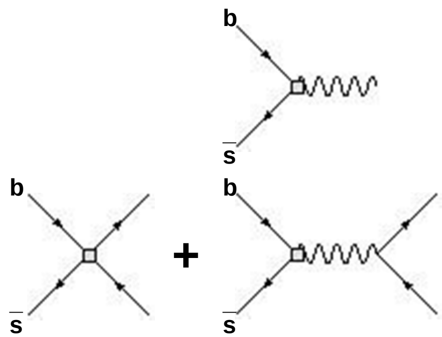
$$\langle 0 | (\bar{s}\sigma^{\mu\nu}(1+\gamma_5) b) | B_s^* \rangle = M_B f_{B_s} [i\epsilon^{\mu\nu\alpha\beta} v_\alpha \eta_\beta + v^\mu \eta^\nu - v^\nu \eta^\mu]$$

EFFECTIVE WEAK B-S TRANSITION

The (bs) FCNC is at 1-loop in SM (penguin + box)

- **Weak transition can be expanded in terms of effective operators:**

$$\mathcal{H}_{eff}^{b\to s} = \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum C_i(\mu) O_i(\mu)$$



$$\mathcal{H}_{b\to s\gamma} = \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e}{8\pi^2} m_b C_{7\gamma}(\mu^2) \cdot \bar{s}\sigma^{\mu\nu}(1+\gamma_5) b \cdot F_{\mu\nu}$$

$$\mathcal{H}_{b\to s\bar{\ell}\ell} = \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{8\pi^2} \Big[\bar{s}\gamma^\mu (1-\gamma_5) b \cdot \bar{\ell} \left[C_{9V}^{eff}(\mu, q^2)\gamma_\mu + C_{10A}(\mu^2)\gamma_\mu\gamma_5 \right] \ell$$
$$- 2 i m_b \frac{C_{7\gamma}(\mu^2)}{q^2} q_\nu \cdot \bar{s}\sigma^{\mu\nu}(1+\gamma_5) b \cdot \bar{\ell}\gamma_\mu \ell \Big]$$

Heavy Meson Chiral Perturbation Theory to parameterize the (bs) quark bilinears:

$$\langle 0 | (\bar{s}_L \gamma^\mu b_L) | B_s^* \rangle = \frac{i}{2} M_{B_s} f_{B_s} \eta^\mu$$

$$\langle 0 | (\bar{s}\sigma^{\mu\nu}(1+\gamma_5) b) | B_s^* \rangle = M_B f_{B_s} [i\epsilon^{\mu\nu\alpha\beta} v_\alpha \eta_\beta + v^\mu \eta^\nu - v^\nu \eta^\mu]$$

HMXpT

Heavy Mesons

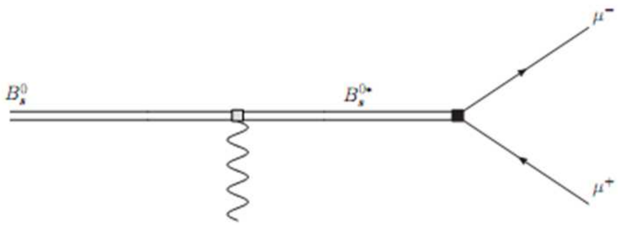
$$H_a = \frac{1+\not{v}}{2} (B_{a\mu}^* \gamma^\mu - B_a \gamma_5)$$

Light Pseudoscalar Mesons

$$\xi = \exp(i\Pi/f) \qquad \Pi = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & -\sqrt{\frac{2}{3}}\eta \end{pmatrix}$$

HEAVY VECTOR RESONANCE

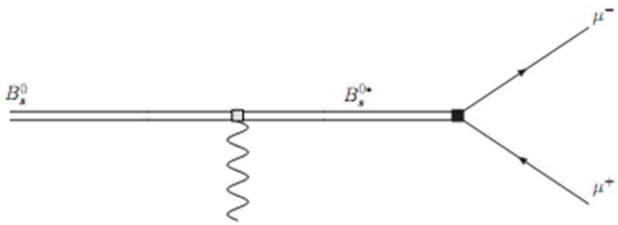
Expansion (Leading Order): $\left\{ \begin{array}{l} \left(\frac{1}{M_{B_s^0}}\right)^0 \\ \frac{p_\pi}{\Lambda_\chi} \end{array} \right.$



$$= \mathcal{M}_{B_s \to B_s^* \gamma} \left(\frac{-ig^{\mu\alpha}}{2(v \cdot k + \Delta)} \right) \mathcal{M}_{B_s^* \to \mu^+ \mu^-}$$

HEAVY VECTOR RESONANCE

Expansion (Leading Order): $\begin{cases} \left(\frac{1}{M_{B_s^0}}\right)^0 \\ \frac{p_\pi}{\Lambda_\chi} \end{cases}$



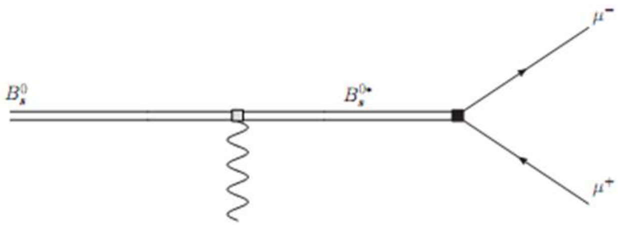
$$= \mathcal{M}_{B_s \to B_s^* \gamma} \left(\frac{-ig^{\mu\alpha}}{2(v \cdot k + \Delta)} \right) \mathcal{M}_{B_s^* \to \mu^+ \mu^-}$$

$$\mathcal{M}_{B_s \to B_s^* \gamma} = -ie\mu\eta_\alpha^* v_\beta k_\mu \epsilon_\nu^* \epsilon^{\mu\nu\alpha\beta}$$

Matrix Element : Transition Magnetic Moment

HEAVY VECTOR RESONANCE

Expansion (Leading Order): $\left\{ \begin{array}{l} \left(\frac{1}{M_{B_s^0}}\right)^0 \\ \frac{p_\pi}{\Lambda_\chi} \end{array} \right.$



$$= \mathcal{M}_{B_s \to B_s^* \gamma} \left(\frac{-i g^{\mu\alpha}}{2(v \cdot k + \Delta)} \right) \mathcal{M}_{B_s^* \to \mu^+ \mu^-}$$

$$\mathcal{M}_{B_s \to B_s^* \gamma} = -ie\mu \eta_\alpha^* v_\beta k_\mu \epsilon_\nu^* \epsilon^{\mu\nu\alpha\beta}$$

Matrix Element : Transition Magnetic Moment

Described by the effective b-s Weak Transition: $\mathcal{H}_{eff}^{b \to s} = \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum C_i(\mu) O_i(\mu)$

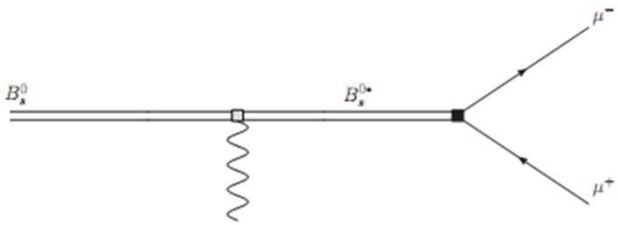
$$\mathcal{M}_{B_s^* \to \mu^+ \mu^-} = i \frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{8\pi^2} f_{B_s} m_{B_s} [\eta_\mu^* \bar{u}(p_{\mu^+}) [C_9 \gamma^\mu + C_{10} \gamma^\mu \gamma_5] v(p_{\mu^-}) - 2 m_b \frac{C_7}{q^2} (\bar{u}(p_{\mu^+}) \gamma_\mu v(p_{\mu^-})) q_\nu (i \epsilon^{\mu\nu\alpha\beta} v_\alpha \eta_\beta + v^\mu \eta^\nu - v^\nu \eta^\mu)]$$

Parameterized in terms of the decay constant

HEAVY VECTOR RESONANCE

Expansion (Leading Order):

$$\begin{cases} \left(\frac{1}{M_{B_s^0}}\right)^0 \\ \frac{p_\pi}{\Lambda_\chi} \end{cases}$$

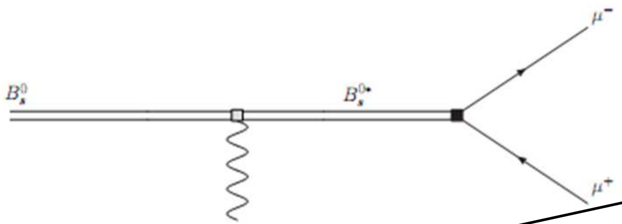


$$= i\, e\, \mu_{eff}\, \epsilon_{\mu\nu\alpha\beta} k^\mu \epsilon^{*\nu} p^\alpha (C_V(q^2) L_V^\beta + C_A(q^2) L_A^\beta)$$

$$L_V^\beta = \bar{\ell}\gamma^\beta \ell \qquad L_A^\beta = \bar{\ell}\gamma^\beta \gamma_5 \ell$$

HEAVY VECTOR RESONANCE

Heavy quark contribution: $\left\{ \begin{array}{l} \left(\frac{1}{M_{B_s^0}}\right)^0 \\ \frac{p_\pi}{\Lambda_\chi} \end{array} \right.$



$$= i\, e\, \mu_{eff}\, \epsilon_{\mu\nu\alpha\beta} k^\mu \epsilon^{*\nu} p^\alpha (C_V(q^2) L_V^\beta + C_A(q^2) L_A^\beta)$$

$$L_V^\beta = \bar{\ell}\gamma^\beta \ell \qquad L_A^\beta = \bar{\ell}\gamma^\beta\gamma_5 \ell$$

$$\mu_{eff} = -\frac{1}{3m_b}$$

- Note on 1/M
  - Don't know the 1/M behavior of μ_{eff}

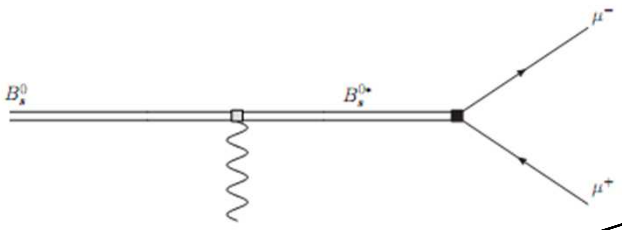
Coupling to the Heavy Quark

$$\mathcal{L}_h = \frac{Q_Q}{2m_Q} \bar{h}_v \sigma_{\mu\nu} h_v F^{\mu\nu}.$$

HEAVY VECTOR RESONANCE

Light DOF Contribution :

$$\begin{cases} \left(\frac{1}{M_{B_s^0}}\right)^0 \\ \frac{p_\pi}{\Lambda_\chi} \end{cases}$$



$$= i\, e\, \mu_{eff}\, \epsilon_{\mu\nu\alpha\beta} k^\mu \epsilon^{*\nu} p^\alpha (C_V(q^2) L_V^\beta + C_A(q^2) L_A^\beta)$$

$$L_V^\beta = \bar{\ell}\gamma^\beta \ell \qquad L_A^\beta = \bar{\ell}\gamma^\beta\gamma_5 \ell$$

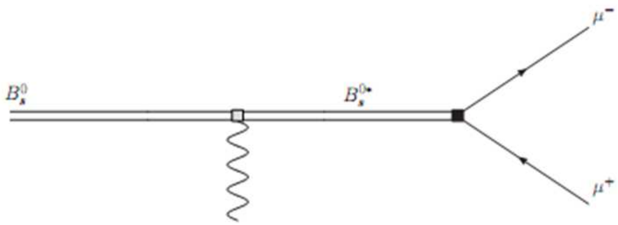
$$\mu_{eff} = -\frac{1}{3m_b} - \frac{1}{3}\beta$$

Coupling to the Light Quark

$$\mathcal{L}_\beta = \frac{\beta e}{4} Tr(\bar{H}_a H_b \sigma^{\mu\nu} F_{\mu\nu} Q_{ba}^\xi)$$

HEAVY VECTOR RESONANCE

Light DOF : Chiral 1- Loop: $\left\{ \begin{array}{l} \left(\frac{1}{M_{B_s^0}}\right)^0 \\ \frac{p_\pi}{\Lambda_\chi} \end{array} \right.$

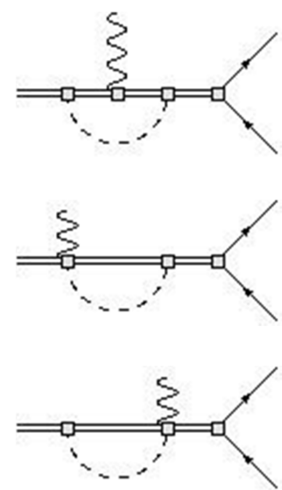


$$= i\, e\, \mu_{eff}\, \epsilon_{\mu\nu\alpha\beta} k^\mu \epsilon^{*\nu} p^\alpha (C_V(q^2) L_V^\beta + C_A(q^2) L_A^\beta)$$

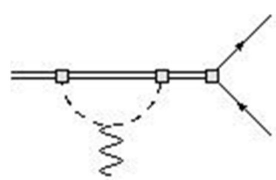
$$L_V^\beta = \bar{\ell}\gamma^\beta \ell \qquad L_A^\beta = \bar{\ell}\gamma^\beta\gamma_5 \ell$$

$$\mu_{eff} = -\frac{1}{3m_b} - \frac{1}{3}\beta + g^2 \frac{m_K}{4\pi f_K^2}$$

Chiral Loop Contributions



Leading Contribution :



HEAVY VECTOR RESONANCE

HMxPT coupling constants:

$$\mu_{eff} = -\frac{1}{3m_b} - \frac{1}{3}\beta + g^2\frac{m_K}{4\pi f_K^2}$$

- **Use experimental D decays.**

$$\Gamma(D_q^* \to D_q\gamma) = \frac{\alpha}{3}\frac{M_{D_q^*}}{M_{D_q}}|\mu_{eff}|^2|\vec{k}|^3$$

$$\mu_{eff}[D^{\pm *} \to D^{\pm}\gamma] = \frac{2}{3\Lambda_c} - \frac{1}{3}\beta + g^2\frac{m_\pi}{4\pi f_\pi^2}$$

$$\mu_{eff}[D^{0*} \to D^{0}\gamma] = \frac{2}{3\Lambda_c} + \frac{2}{3}\beta - g^2\frac{m_K}{4\pi f_K^2} - g^2\frac{m_\pi}{4\pi f_\pi^2}$$

$$\Gamma(D^{*+} \to D^0\pi^+) = \frac{g^2}{6\pi f_\pi^2}|p_\pi|^3$$

$$\Gamma(D^{*0} \to D^0\pi^0) = \frac{g^2}{12\pi f_\pi^2}|p_\pi|^3$$

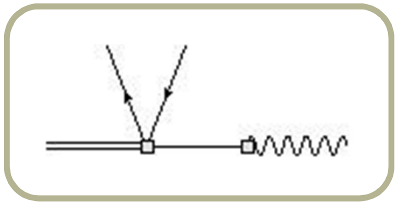
$$0.52 < g < 0.66$$

$$2.0\,GeV^{-1} < \beta < 4.1\,GeV^{-1}$$

$$0.19\,GeV^{-1} < \mu_{eff}(B_s^* \to B_s\gamma) < 0.53\,GeV^{-1}$$

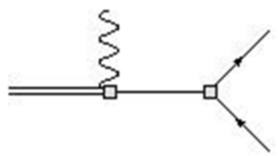
LIGHT VECTOR RESONANCE

Light Vector Resonance Pole Diagrams : ϕ(1020)



Leading Contribution

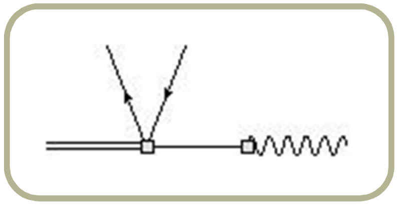
$$\mathcal{A}(B_s^0 \to \mu\bar{\mu}\phi \to \mu\bar{\mu}\gamma_s) = \mathcal{A}(B_s^0 \to \mu\bar{\mu}\phi) \times \frac{g_{\mu\nu}}{m_\phi^2} \times \mathcal{A}(\phi \to \gamma_s)$$



Subleading Contribution (1/M)

LIGHT VECTOR RESONANCE

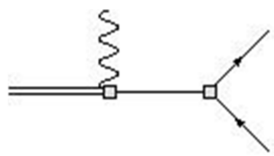
Light Vector Resonance Pole Diagrams : ϕ(1020)



Leading Contribution

$$\mathcal{A}(B_s^0 \to \mu\bar{\mu}\phi \to \mu\bar{\mu}\gamma_s) = \mathcal{A}(B_s^0 \to \mu\bar{\mu}\phi) \times \frac{g_{\mu\nu}}{m_\phi^2} \times \mathcal{A}(\phi \to \gamma_s)$$

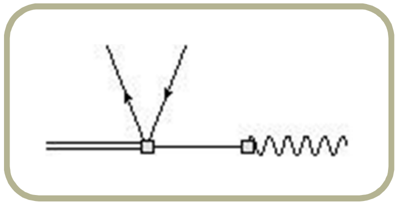
$$\mathcal{A}^\mu(\phi \to \gamma_s) = \frac{1}{3}\, e\, f_\phi\, m_\phi\, \epsilon_\mu^*$$



Subleading Contribution (1/M)

LIGHT VECTOR RESONANCE

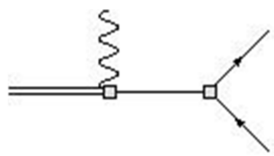
Light Vector Resonance Pole Diagrams : ϕ(1020)



Leading Contribution

$$\mathcal{A}(B_s^0 \to \mu\bar{\mu}\phi \to \mu\bar{\mu}\gamma_s) = \mathcal{A}(B_s^0 \to \mu\bar{\mu}\phi) \times \frac{g_{\mu\nu}}{m_\phi^2} \times \mathcal{A}(\phi \to \gamma_s)$$

Couple HMxPT to Light Vector Resonances



Subleading Contribution (1/M)

$$\rho_\mu \equiv i\frac{g_V}{\sqrt{2}} \begin{pmatrix} \frac{\rho^0}{\sqrt{2}} + \frac{\omega}{\sqrt{2}} & \rho^+ & K^{*+} \\ \rho^- & -\frac{\rho^0}{\sqrt{2}} + \frac{\omega}{\sqrt{2}} & K^{*0} \\ K^{*-} & \bar{K}^{*0} & \phi \end{pmatrix}$$

$$L_{1a}^{\mu\nu} = i\alpha_1 \left\{ g^{\mu\alpha} g^{\nu\beta} - \frac{i}{2}\epsilon^{\mu\nu\alpha\beta} \right\} \langle \gamma_5 H_b \left[\gamma_\alpha (\rho_\beta - \mathcal{V}_\beta)_{bc} - \gamma_\beta (\rho_\alpha - \mathcal{V}_\alpha)_{bc} \right] \xi_{ca}^\dagger \rangle$$

$$L_{1a}^{\mu} = \alpha_1 \langle \gamma_5 H_b (\rho^\mu - \mathcal{V}^\mu)_{bc} \xi_{ca}^\dagger \rangle$$

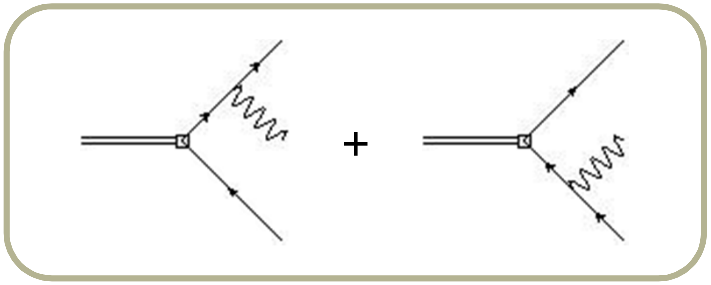
First order in 1/M and derivitaves.

Next Step : Bremsstrahlung

BREMSSTRAHLUNG

Bremsstrahlung

- **Photon is emitted from final state leptons**
  - Creates an IR divergence
  - Interferes with our region of interest

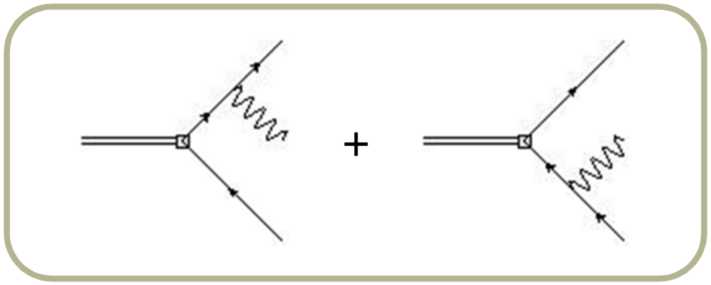


  - IR divergence cancelled by 1-Loop QED Corrections to $B_s^0 \to \mu^+\mu^-$

BREMSSTRAHLUNG

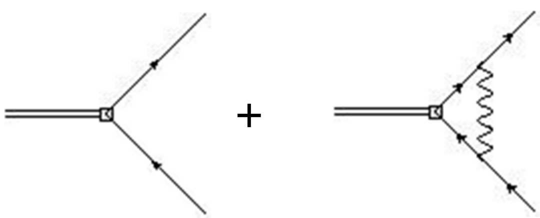
Bremsstrahlung

- **Photon is emitted from final state leptons**
  - Creates an IR divergence
  - Interferes with our region of interest



  - IR divergence cancelled by 1-Loop QED Corrections to $B_s^0 \to \mu^+\mu^-$

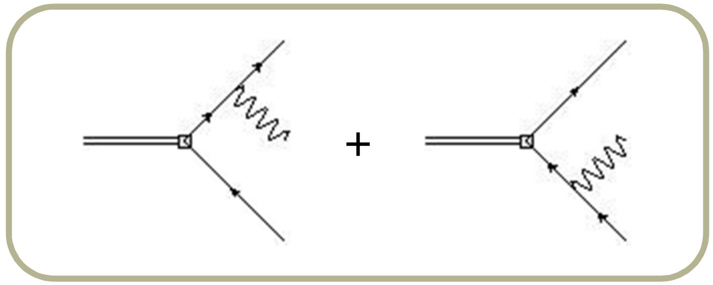
TREE



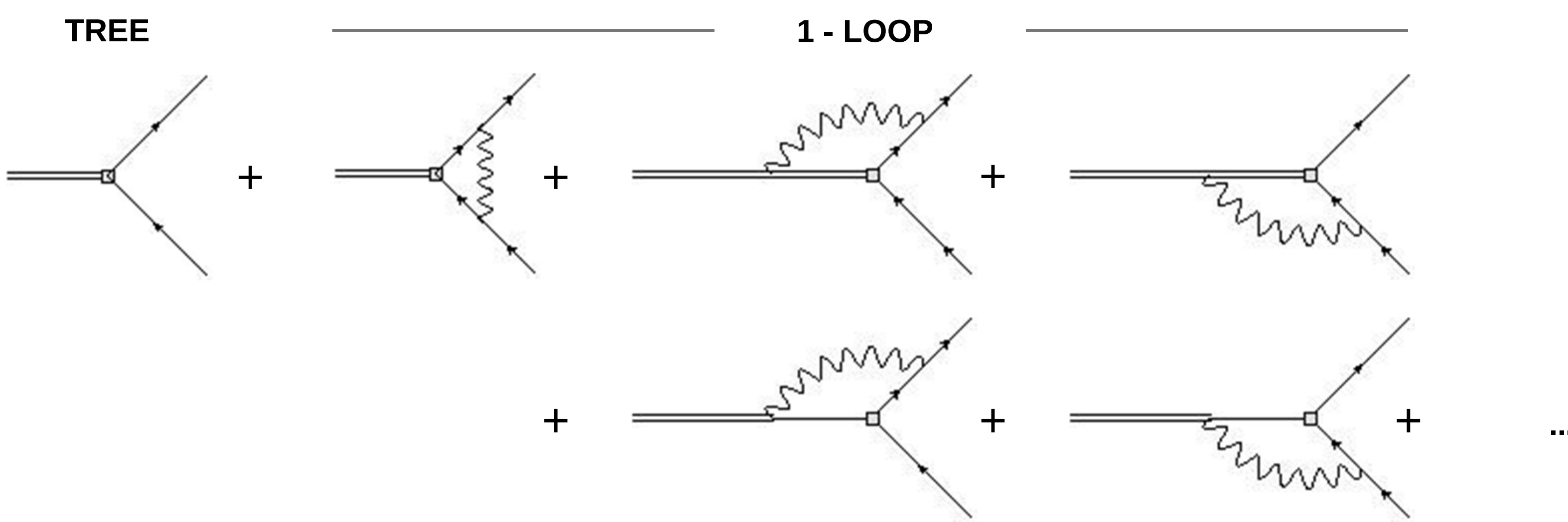
BREMSSTRAHLUNG

Bremsstrahlung

- **Photon is emitted from final state leptons**
  - Creates an IR divergence
  - Interferes with our region of interest



  - IR divergence cancelled by 1-Loop QED Corrections to $B_s^0 \to \mu^+\mu^-$

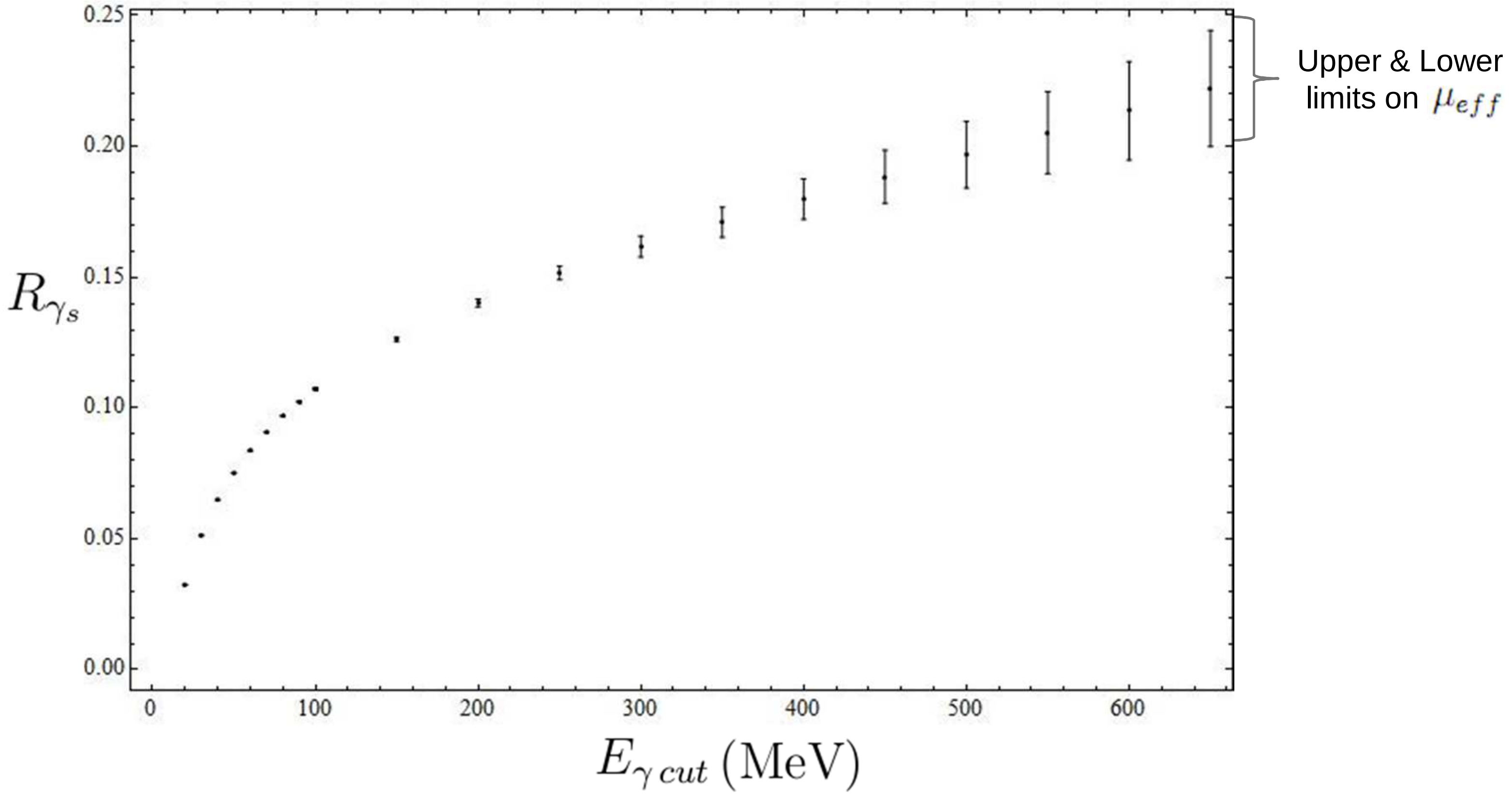


RESULTS

Preliminary Results (Without 1-Loop QED Corrections)

- Use Lower Energy cut of 10 MeV

$$\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{exp} = \mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{SM}\,(1 + R_{\gamma_s})$$

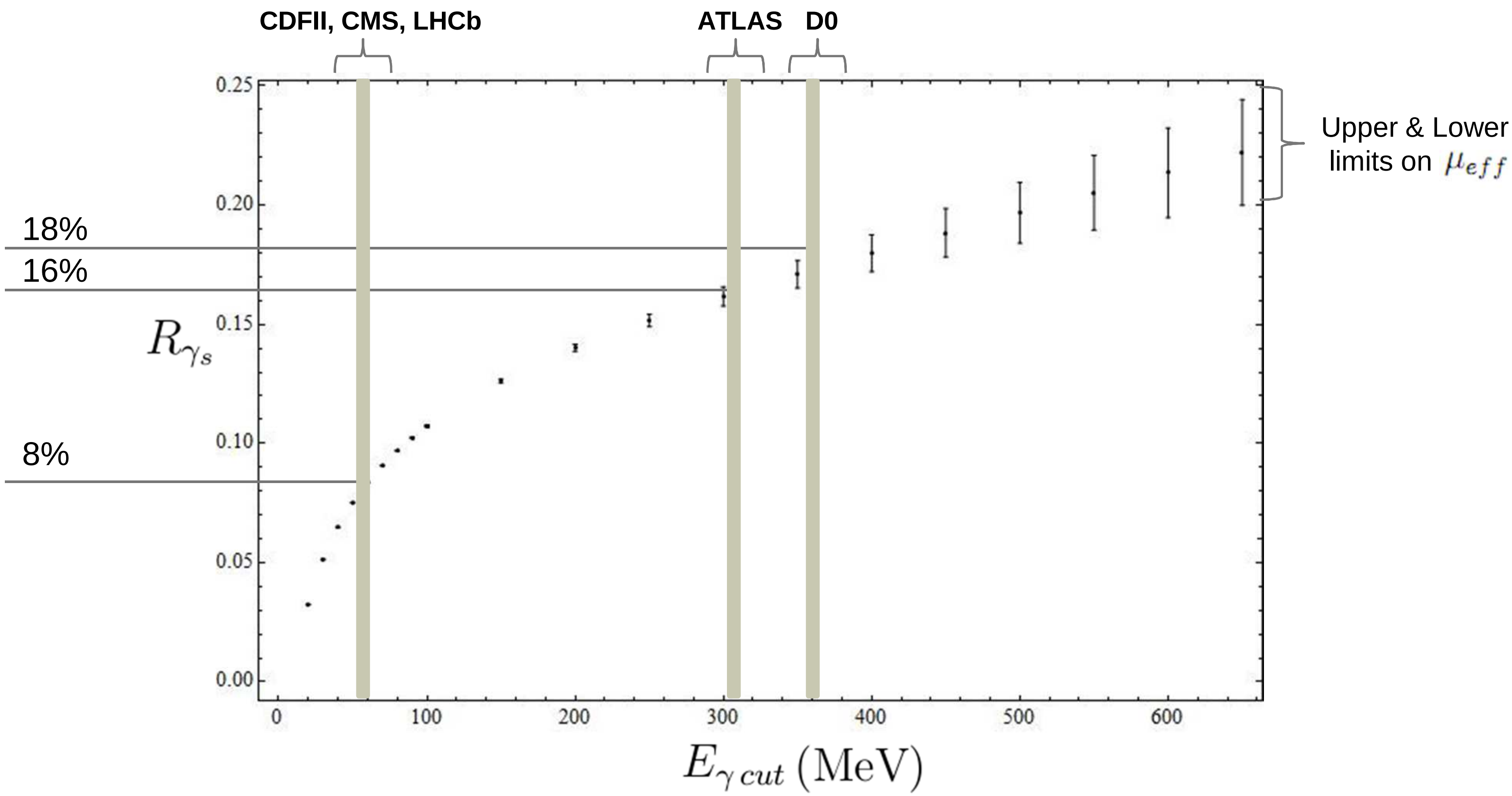


RESULTS

Preliminary Results (Without 1-Loop QED Corrections)

- Use Lower Energy cut of 10 MeV

$$\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{exp} = \mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{SM}\,(1 + R_{\gamma_s})$$



CONCLUSIONS

$$\mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{exp} = \mathrm{Br}(B_s^0 \to \mu^+\mu^-)_{SM}\,(1 + R_{\gamma_s})$$

- **Soft photons that are not discernable by detectors can amplify SM contributions to the $B_s^0 \to \mu^+\mu^-$ decay width**
  - Depending on experimental photon cuts the contribution R_{γ_s} can be large.
  - CDFII, CMS, LHCb ~ 8%
  - ATLAS, D0 > 15%

Thank You.