The photon polarisation in radiative B decays

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LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

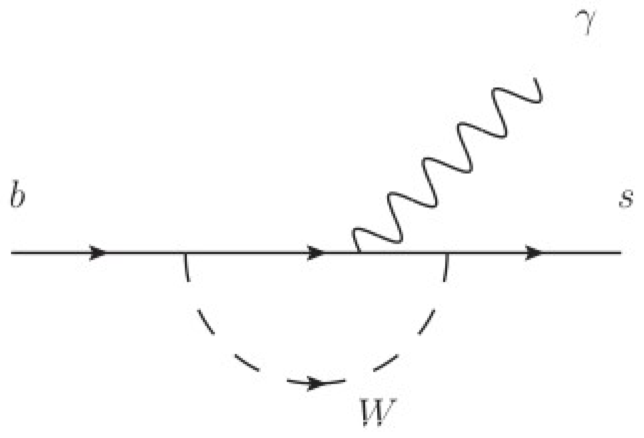
cnrs IN2P3 Les deux infinis

Introduction

- Radiative B meson decays
- How to extract the photon polarisation
- Experimental results

Why b→sϒ ?

- Since this is a Flavour Changing Neutral Current (FCNC), this process only occurs through at loop level.



- May be sensitive to New Physics.

- We can test the standard model for such decays by confronting theoretical predictions against experimental measurements.

Which observable to use ?

- Exlusive decay rate : $\Gamma(B \to M\gamma)$

  Experimentaly accessible but difficulty to predict accurately.

- Inclusive decay rate : $\Gamma(b \to X_s\gamma)$

  Experimentaly difficult but small theoretical uncertaincies.

- Photon Polarisation : $\frac{\Gamma_R - \Gamma_L}{\Gamma_R + \Gamma_L} = \lambda_\gamma$

  In accelerator experiment, the polarisation cannot be directly measured but the theoretical uncertaincies are of the order of 10%.

- CP asymmetry : $\frac{\overline{\Gamma} - \Gamma}{\overline{\Gamma} + \Gamma}$

  Experimentaly difficult but small theoretical uncertaincies.

Photon polarisation in the SM

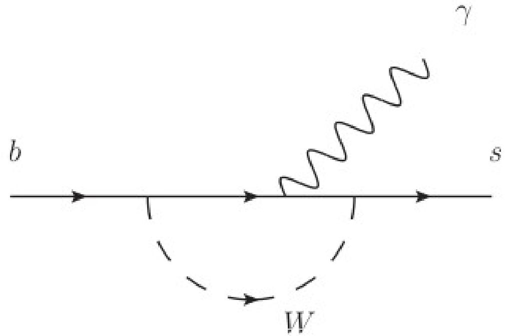
- Decay rate :

$$\bar{s}\Gamma(b \to s\gamma)_\mu b \propto \bar{s}\sigma_{\mu\nu}q^\nu(m_b\frac{1+\gamma^5}{2} + m_s\frac{1-\gamma^5}{2})b$$

$m_s \approx 95 Mev$

$\frac{m_s}{m_b} \approx 0.02$

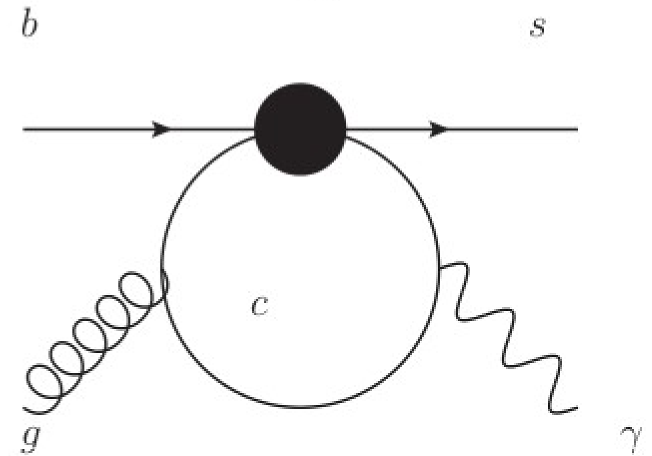
$m_b \approx 4.18 Gev$



O_2

According to the SM :
The photon will be mostly left-handed for $b \to s\gamma$ and right-handed for $\bar{b} \to \bar{s}\gamma$.

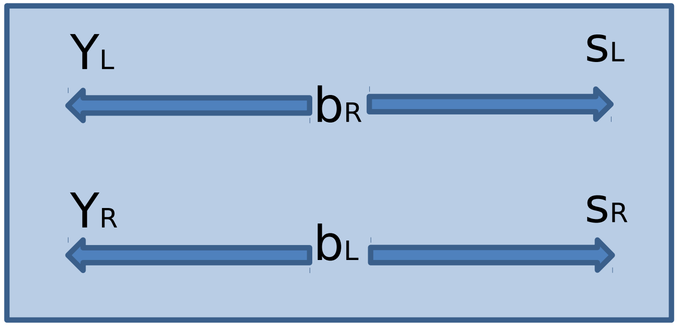
We expect $\lambda_\gamma \approx -1$



- Charm loop contribution : 10 %

Extracting the photon polarisation

We can relate the polarisation of the s quark and the photon :



<u>How to measure the polarisation of the s quark :</u>

We need an observable which changes sign under parity.

Angular analysis can provide such observables given that we have 2 amplitudes with a relative phase.

If the photon decays, we can as well measure the interferences of left and right handed amplitude :

Virtual photon contribution. $b \rightarrow s(e^+e^-)$

Nuclear conversion to a lepton pair.

Extracting the photon polarisation

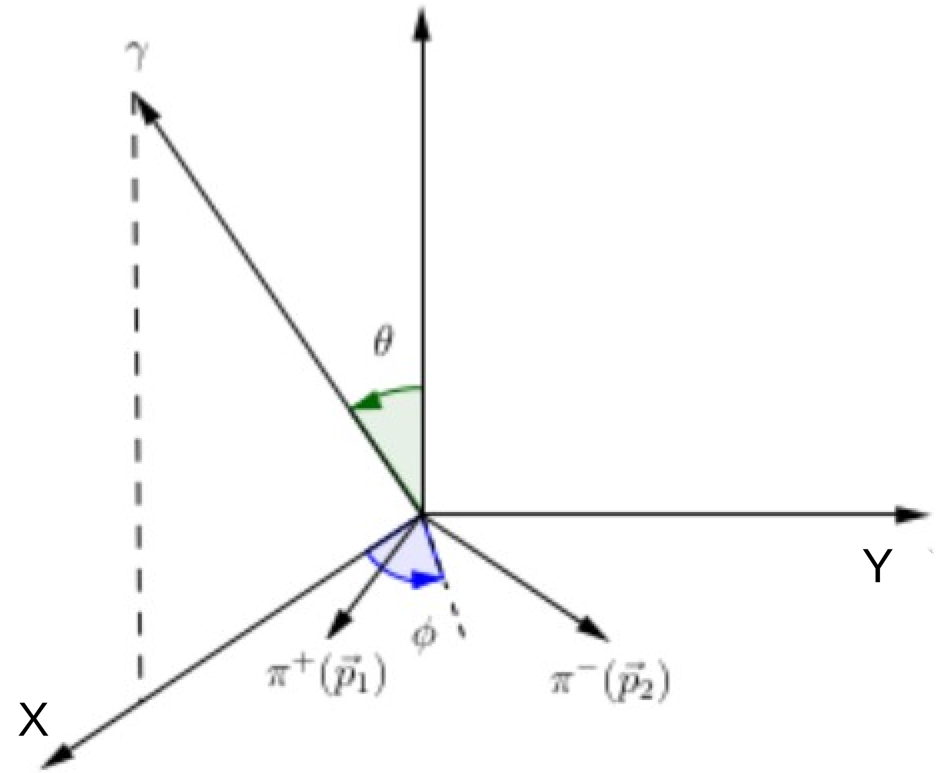
$$\vec{n} = \frac{\vec{p}_1 \times \vec{p}_2}{|\vec{p}_1 \times \vec{p}_2|}$$

- Why and which 3-body decay?

$$B^+ \to K_1^+\gamma \to (K^+\pi^-\pi^+)\gamma$$

- The Kππ decay can be used as a reference plane

- We count how many times ϒ is going above and under this plane.



$$|M(K_1 \to K\pi\pi)|^2 \propto |\vec{\epsilon}_{K_1} \cdot \vec{J}|^2$$

$$|M(K_{1R/L} \to K\pi\pi)|^2 \propto \frac{1}{4}(1+\cos^2\theta)(|J_x|^2+|J_y|^2) \pm \cos\theta Im[J_x J_y^*]$$

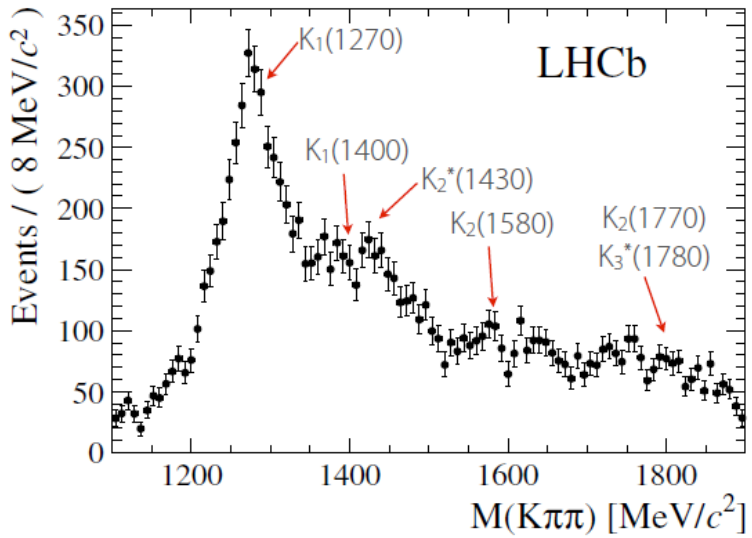
$$\mathscr{A}_{up-down} = \frac{\int_0^1 d\cos\theta \frac{d\Gamma}{d\cos\theta} - \int_{-1}^0 d\cos\theta \frac{d\Gamma}{d\cos\theta}}{\int_{-1}^1 d\cos\theta \frac{d\Gamma}{d\cos\theta}} = \lambda_\gamma \frac{3}{2} \frac{\int ds_{23} ds_{13} Im[J_x J_y^*]}{\int ds_{23} ds_{13} (|J_x|^2 + |J_y|^2)}$$

Modeling the hadronic decay

Considering only K1(1270), we have 3 decay channels leading to Kππ :

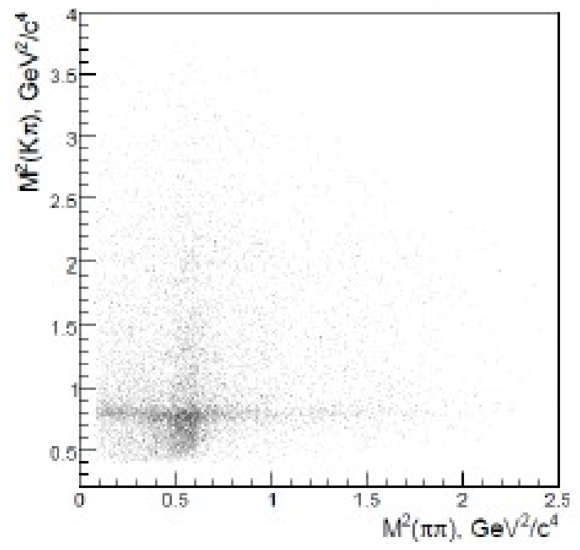
$$K^*\pi \qquad \rho K \qquad \kappa\pi$$

Large uncertainties originating from the kappa channel contribution and limited knowledge on the relative branching ratios of other kaonic resonances.

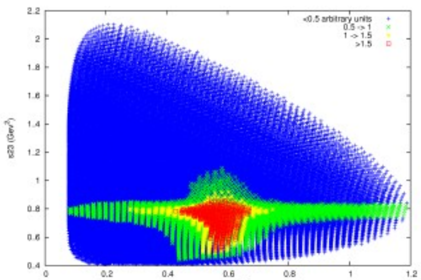


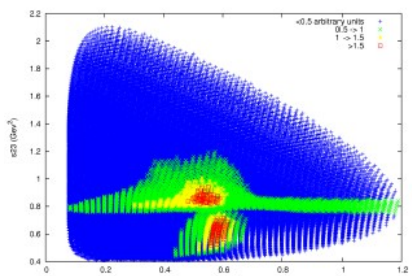
$$\mathscr{A}_{up-down} = \lambda_\gamma \frac{3}{2} \frac{\int ds_{23} ds_{13} Im[J_x J_y^*]}{\int ds_{23} ds_{13} (|J_x|^2 + |J_y|^2)}$$

Babar results for the $B^+ \to J/\psi K^+\pi^+\pi^-$



My results :



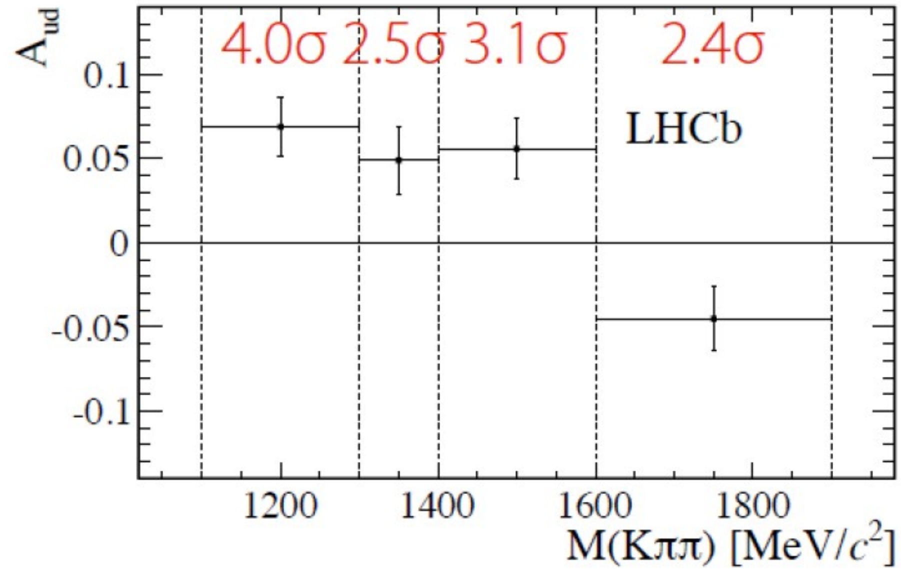


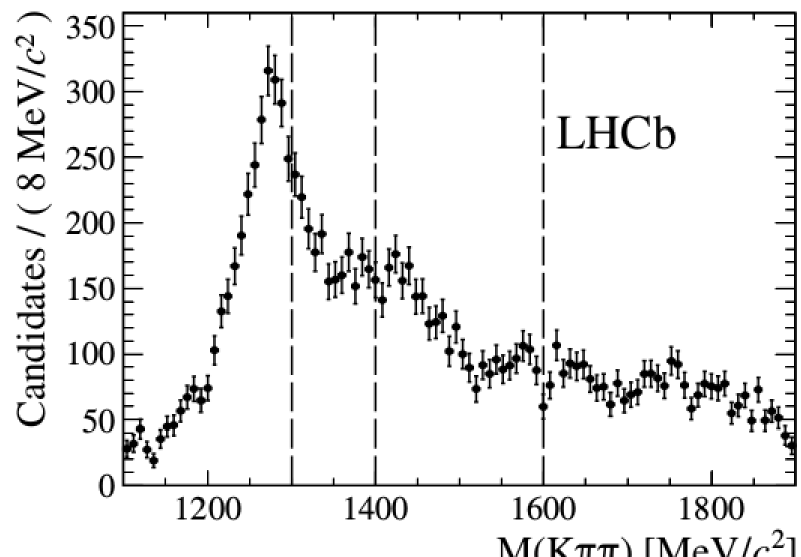
Experimental results

$$B^+ \to K_1^+ \gamma \to (K^+ \pi^- \pi^+)\gamma$$

LHCb recently collected a sample of about 14000 events leading to a measurements of the Up-Down asymmetry 4 σ away from zero in the K1(1270) region.

Belle has smaller sample but we can expect results from Belle II in the future.



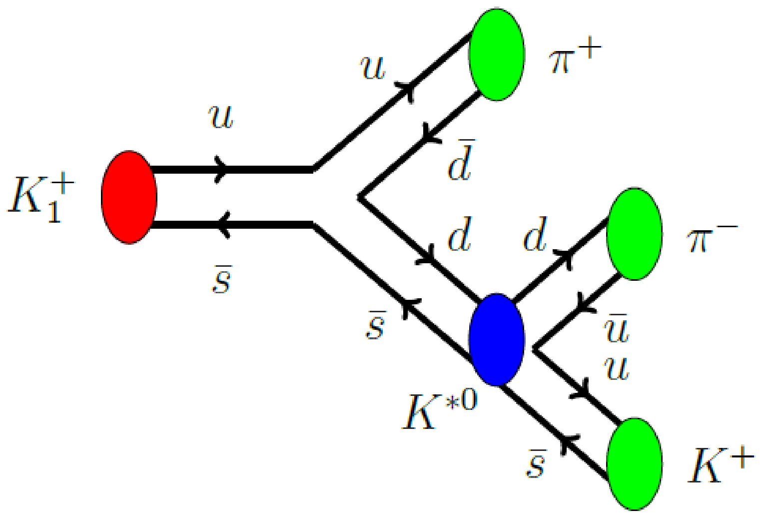


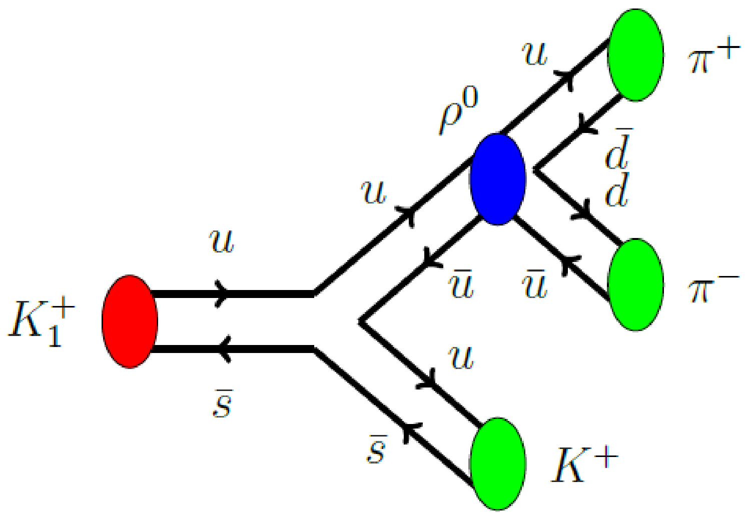
Conclusions

- We can test the SM with the B→K1ϒ decay.
- Experimental results show a 4 σ deviation from zero for the measurements of the Up- Down asymmetry.
- More work is needed on the modelisation of K1 decay in order to extract the photon polarisation.

Back up slides

$$B^+ \to K_1^+\gamma \to K^+\pi^+\pi^-$$





Input parameters

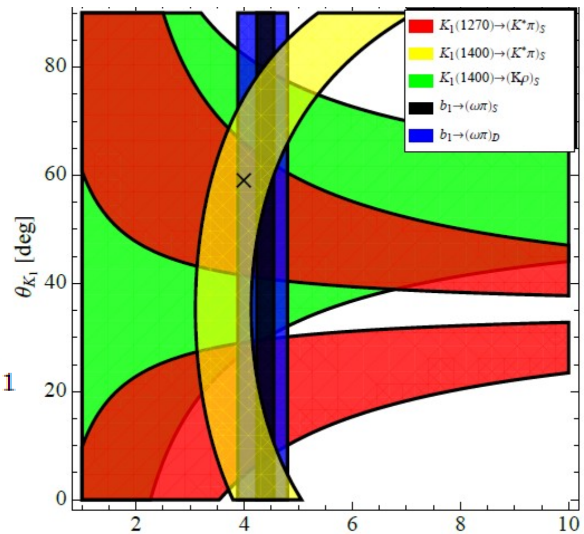
$K_{1(1270)}$ and $K_{1(1400)}$ are a mixture of 1^1P_1 and 1^3P_1 states

$$|K_1(1270)\rangle = |K_{1A}\rangle \sin\theta_{K_1} + |K_{1B}\rangle \cos\theta_{K_1}$$
$$|K_1(1400)\rangle = |K_{1A}\rangle \cos\theta_{K_1} - |K_{1B}\rangle \sin\theta_{K_1}$$

$$A^S_{K_1(1270)\to K^*\pi/K\rho} = S_{K^*/\rho}(\sqrt{2}\sin\theta_{K_1} \mp \cos\theta_{K_1})$$
$$A^D_{K_1(1270)\to K^*\pi/K\rho} = D_{K^*/\rho}(-\sin\theta_{K_1} \mp \sqrt{2}\cos\theta_{K_1})$$
$$A^S_{K_1(1400)\to K^*\pi/K\rho} = S_{K^*/\rho}(\sqrt{2}\cos\theta_{K_1} \pm \sin\theta_{K_1})$$
$$A^D_{K_1(1400)\to K^*\pi/K\rho} = D_{K^*/\rho}(-\cos\theta_{K_1} \pm \sqrt{2}\sin\theta_{K_1})$$

$$S^{(ABC)} = \gamma\sqrt{\frac{3}{2}\frac{2I_1^{(ABC)} - I_0^{(ABC)}}{18}}, \quad D^{(ABC)} = \gamma\sqrt{\frac{3}{2}\frac{I_1^{(ABC)} + I_0^{(ABC)}}{18}}$$

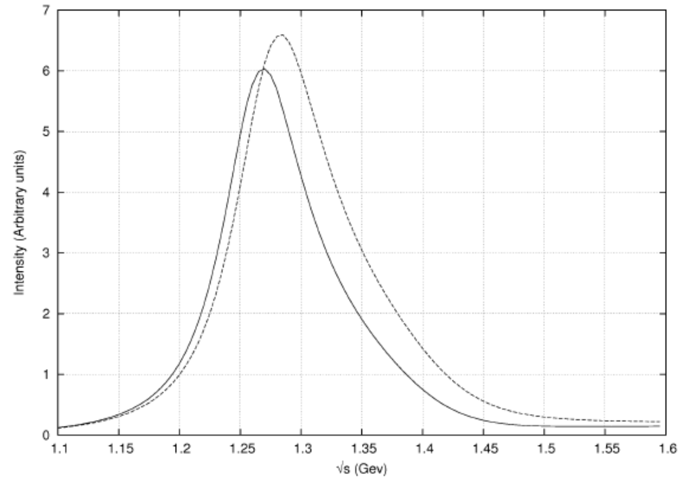
In this model, $\mathscr{I}$ can be computed in term of γ and θ_{K_1}



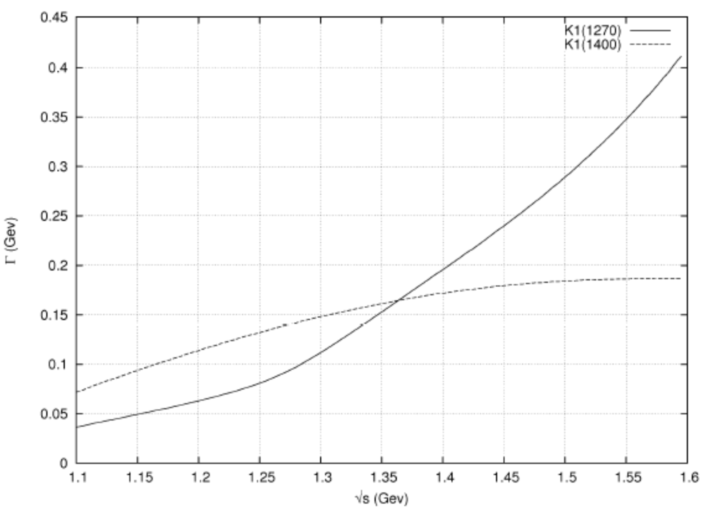
$$I_m^{(ABC)} = \frac{1}{8}\int d^3\vec{k}\,\mathcal{Y}_1^m(\vec{k}_B - \vec{k})\psi^{(A)}(\vec{k}_B + \vec{k})\psi^{(B)}(-\vec{k})\psi^{(C)}(\vec{k})$$

Results s-depedant with

$$\left|\frac{\vec{\mathscr{J}}_{K_1(1270),pol.}}{(s-m^2_{K_1(1270)})-im_{K_1(1270)}\Gamma_{K_1(1270)}(s)}+\frac{f_p\vec{\mathscr{J}}_{K_1(1400),pol.}}{(s-m^2_{K_1(1400)})-im_{K_1(1400)}\Gamma_{K_1(1400)}(s)}\right|^2$$



$$\Gamma_{K_1,pol.}(s)=\int_{s13,s23}\frac{1}{128(2\pi)^3}\frac{1}{s^{3/2}}\frac{3}{2}\left|\mathscr{M}_{K_1,pol.}\right|^2 ds_{13}ds_{23}$$



$$\Gamma_{K_{1(1270)}}\approx 90Mev$$

$$\Gamma_{K_{1(1400)}}\approx 174Mev$$