Invariant mass line shape

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Problem that we are posed on

- The shape of the line of the subsystem of the heavy mesons decays into two mesons.

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$$H_b \; -> \; h^{+} h^{-} \; (\gamma)$$

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Aim of the presentation

Since we have decays with the same final products we have to find out how to distinguish them:

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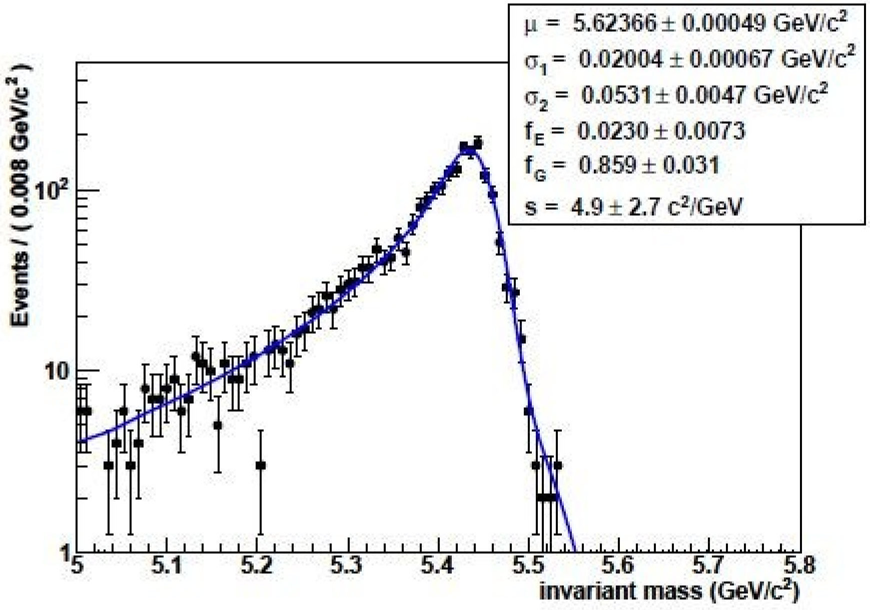
- $B^0 \to \pi^+ \pi^-$
- $B^0_s \to \pi^+ \pi^-$
- $B^0 \to K^+ K^-$
- $B^0_s \to K^+ K^-$

Problem with the heavy mesons radiation

The decay products radiate photons due to QED final state radiation processes, hence leading to missing momentum that distorts the shape of the charged pair invariant mass.



Monte Carlo problems

- Point-like hadrons approximation

- Well motivated extent of point-like hadrons approximation to heavy hadrons decays gives good results but the time of the computation is too long (it would dominate the likelihood function computation)

- Since we need hight statistics for MC simulation, we can't do it in this way…

How to parametrized p.d.f?

- P.d.f (parton density function):

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$$f(m) = f_E \theta(m_B - m) \frac{1}{s}\, e^{-s(m_B - m)} + (1 - f_E)\delta(m_B - m)$$

photon emission no proton emission

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P.d.f under resolution effects of the detector

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$$g(m) = f_E E_d(m - m_B; f_1, \sigma_1, \sigma_2, s) +$$
$$+ (1 - f_E) C G_d(m - m_B; f_1, \sigma_1, \sigma_2)$$

+

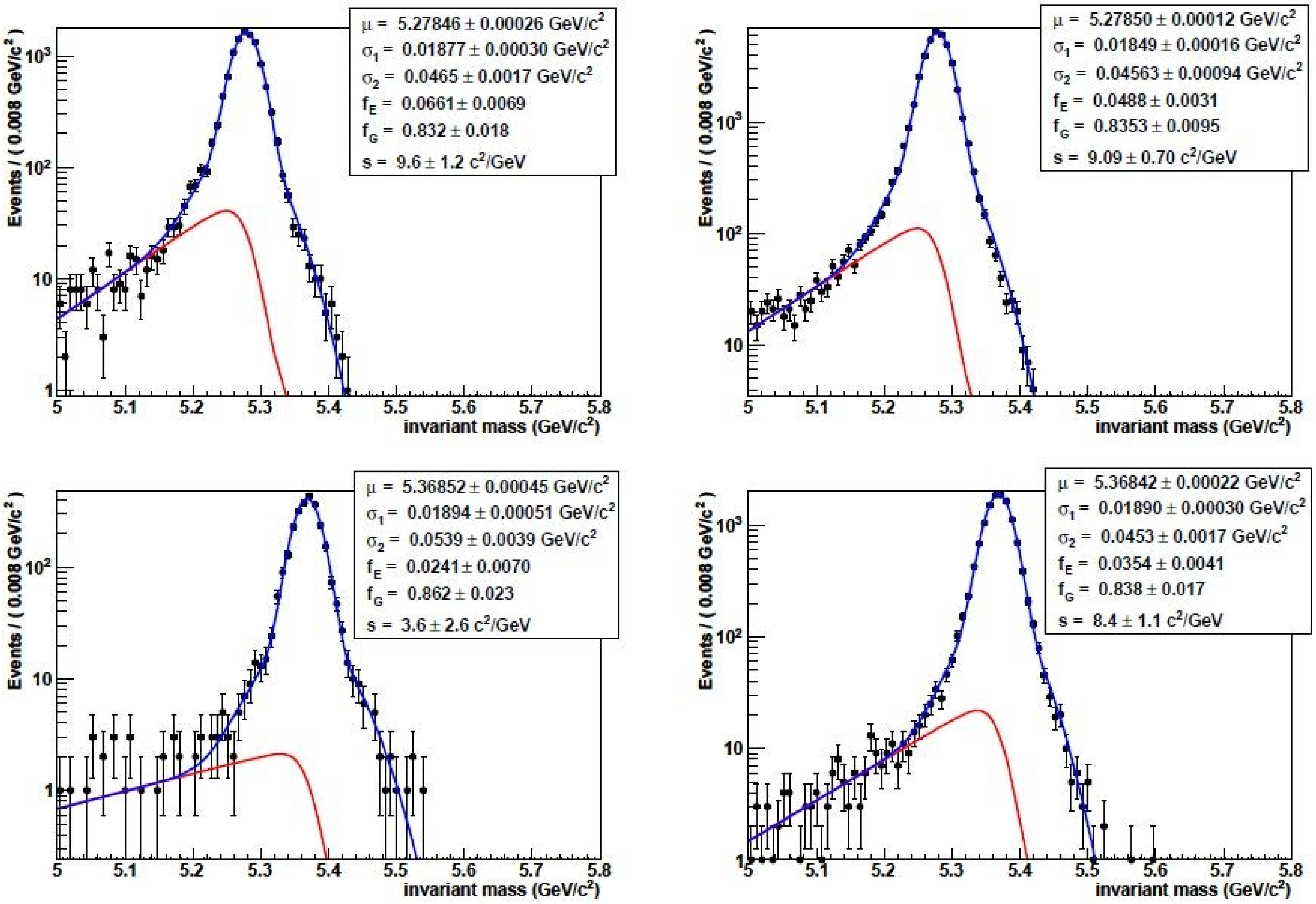
Incredible happines

- $g(m) = f_E E_d(m - m_B; f_1, \sigma_1, \sigma_2, s) + (1 - f_E) C G_d(m - m_B; f_1, \sigma_1, \sigma_2)$

$$E_d(m - m_B; f_1, \sigma_1, \sigma_2, s) = f_1 K_1^{-1} e^{s(m-m_B)} \left[1 - Erf\left(\frac{m - m_B + s\sigma_1^2}{\sqrt{2}\,\sigma_1}\right)\right] + (1 - f_1) K_2^{-1} e^{s(m-m_B)} \left[1 - Erf\left(\frac{m - m_B + s\sigma_2^2}{\sqrt{2}\sigma_2}\right)\right]$$

$$K_{1(2)} = \int_{m_{min}}^{m_{max}} e^{s(m-m_B)} \left[1 - Erf\left(\frac{m - m_B + s\sigma_{1(2)}^2}{\sqrt{2}\sigma_{1(2)}}\right)\right]$$

Effects of equation applications



Results of equation applications

Channel	μ [MeV/c^2]	f_G	σ_1 [MeV/c^2]	σ_2 [MeV/c^2]	f_E	s [c^2/GeV]	μ_{MC} [MeV/c^2]
$B^0 \to \pi^+\pi^-$	5278.5 ± 0.3	0.832 ± 0.018	18.8 ± 0.3	47 ± 2	0.066 ± 0.007	9.6 ± 1.2	5279.4
$B^0 \to K^+\pi^-$	5278.5 ± 0.1	0.835 ± 0.010	18.5 ± 0.2	46 ± 1	0.049 ± 0.003	9.1 ± 0.7	5279.4
$B_s^0 \to \pi^+K^-$	5368.5 ± 0.5	0.86 ± 0.02	18.9 ± 0.5	54 ± 4	0.024 ± 0.007	3.6 ± 2.6	5369.6
$B_s^0 \to K^+K^-$	5368.4 ± 0.2	0.838 ± 0.017	18.9 ± 0.3	45 ± 2	0.035 ± 0.004	8.4 ± 1.1	5369.6
$\Lambda_b \to p\pi^-$	5623.5 ± 0.6	0.90 ± 0.03	19.1 ± 0.7	53 ± 7	0.053 ± 0.014	9.9 ± 2.0	5624.0
$\Lambda_b \to pK^-$	5623.7 ± 0.5	0.83 ± 0.03	18.7 ± 0.7	47 ± 4	0.029 ± 0.006	5.7 ± 1.3	5624.0

Second approach with only $\pi^+\pi^-$ assumption

- Let's assume that particles that we observe are only pions.

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- Then we define a new parameter that underline differences between plus and minus mesons momenta:

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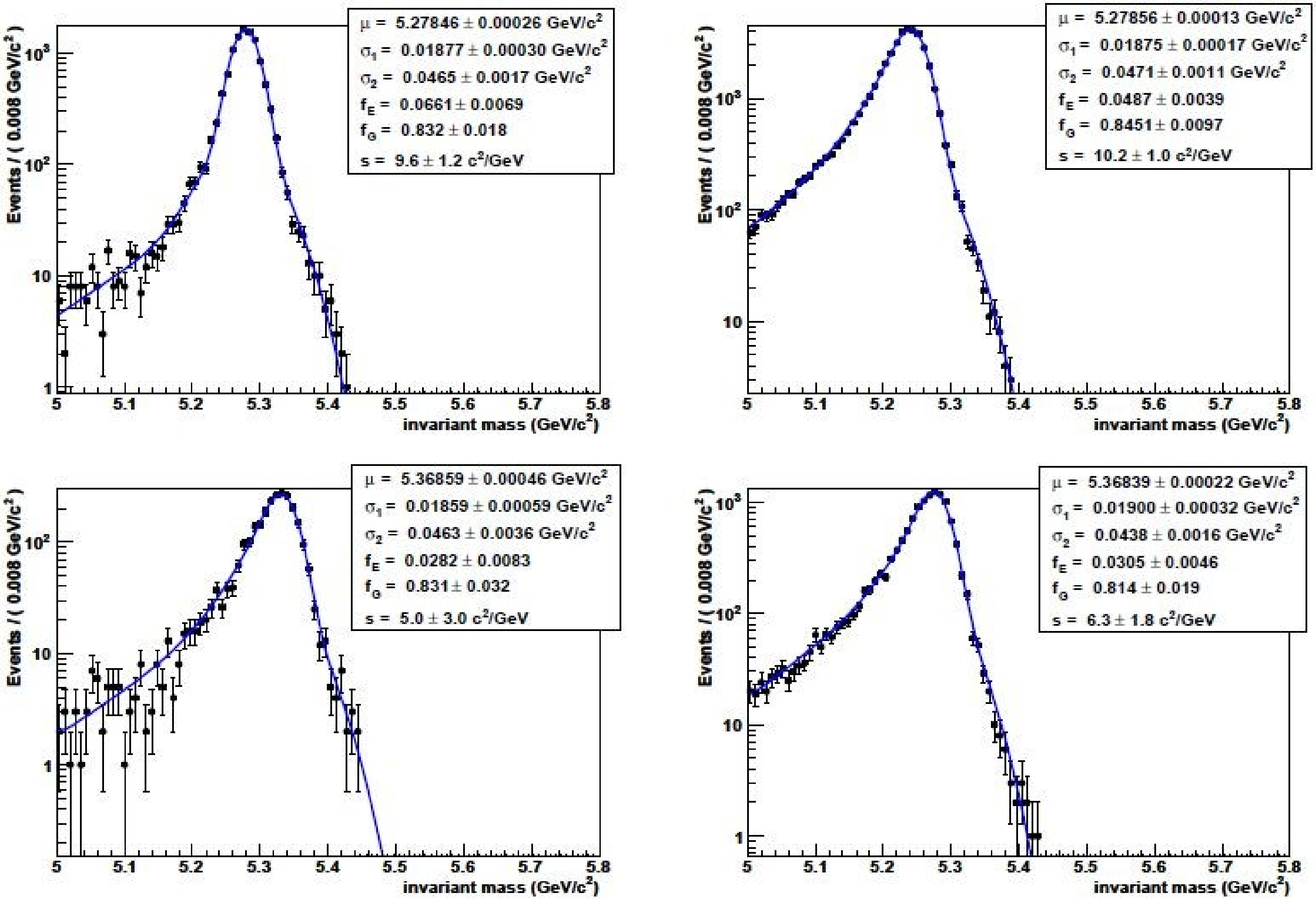
$$\beta = \frac{p_+ - p_-}{p_+ + p_-}$$

Full p.d.f description

- $\bar{f}(m_{\pi\pi},\beta) = [f_E E_d(m-\mu(\beta); f_1,\sigma_1,\sigma_2,s)\ +$
  $(1-f_E) C G_d(m-\mu(\beta); f_1,\sigma_1,\sigma_2)] \cdot \bar{h}(\beta)$
- $\mu(\beta) = \sqrt{m_B^2 - F_{h^+h'^-}(\beta)}$
- $F_{h^+h'^-}(\beta) = \left(m_{h^+}^2 - m_\pi^2\right)\left(1 + \frac{1-\beta}{1+\beta}\right) +$
  $\left(m_{h^-}^2 - m_\pi^2\right)\left(1 + \frac{1+\beta}{1-\beta}\right)$

Effects of second approach



Results of second aproach

Channel	μ [MeV/c^2]	f_G	σ_1 [MeV/c^2]	σ_2 [MeV/c^2]	f_E	s [c^2/GeV]	μ_{MC} [MeV/c^2]
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$B^0 \to K^+\pi^-$	5278.6 ± 0.1	0.835 ± 0.010	18.8 ± 0.2	47 ± 1	0.049 ± 0.004	10.2 ± 1.0	5279.4
$B_s^0 \to \pi^+K^-$	5368.6 ± 0.5	0.83 ± 0.03	18.6 ± 0.6	46 ± 4	0.028 ± 0.008	5.0 ± 3.0	5369.6
$B_s^0 \to K^+K^-$	5368.4 ± 0.2	0.814 ± 0.019	19.0 ± 0.3	44 ± 2	0.031 ± 0.005	6.3 ± 1.8	5369.6
$\Lambda_b \to p\pi^-$	5623.4 ± 0.7	0.85 ± 0.06	19.2 ± 0.9	43 ± 5	0.058 ± 0.016	10.6 ± 2.4	5624.0
$\Lambda_b \to pK^-$	5623.7 ± 0.5	0.86 ± 0.03	20.0 ± 0.7	53 ± 5	0.023 ± 0.007	4.9 ± 2.7	5624.0

Summary

Two different aproaches lead us to proper p.d.f. description in the case of photon radiation in heavy mesons decays.

EVERYTHING IS GOOD WHEN IT WORKS –