Production of $l = 1$ B mesons

in Z Decays at LEP

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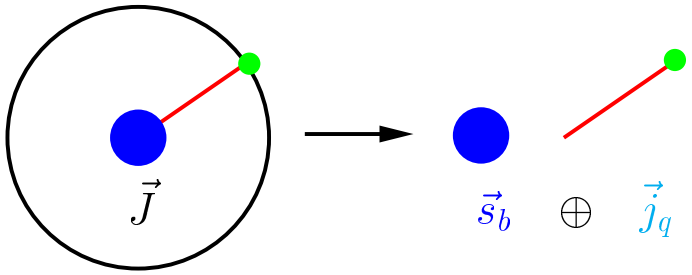
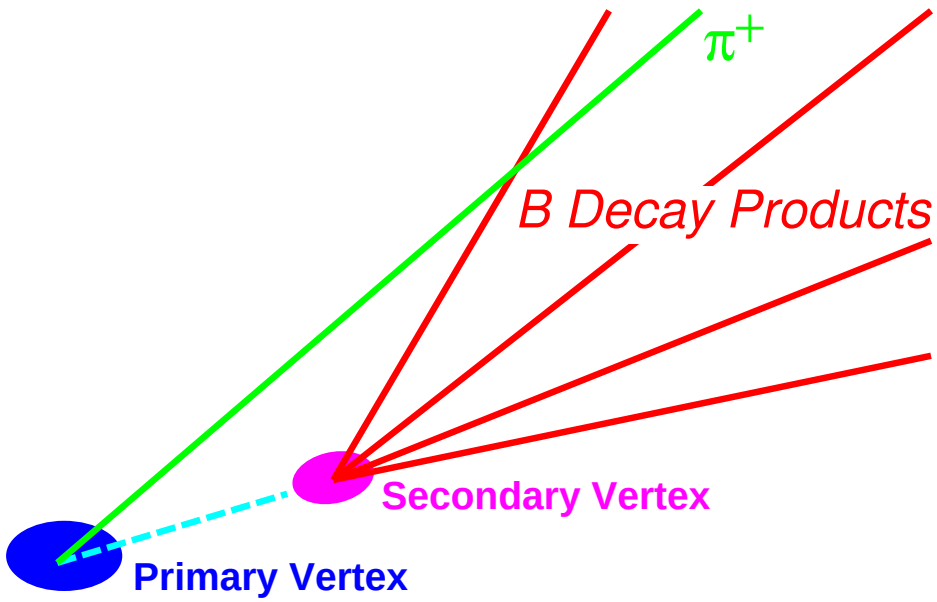


International Conference on High Energy Physics

Vancouver BC, Canada – 24 July 1998

Selection of $B^{**} \to B\pi$ Decays



Selection of $Z \to b\bar{b}$

- Lifetime-Based Event Tag

Selection of B

- Two Most Energetic Jets
- Reconstructed Decay Vertex: DL $> 3\sigma$

Selection of π

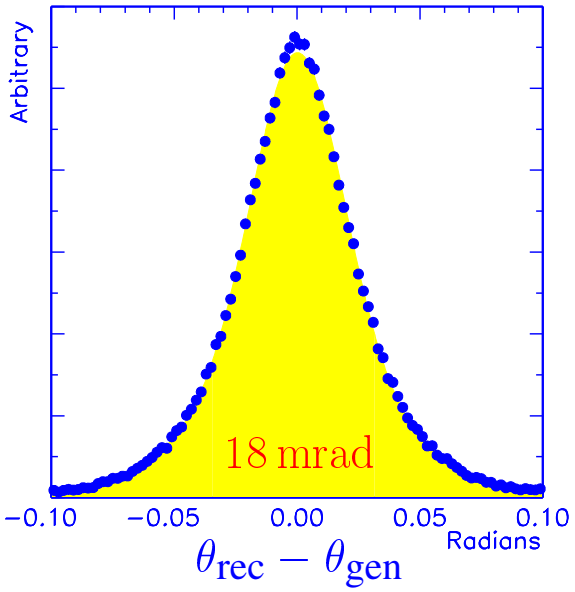
- Maximum p_l^B Event Vertex Track

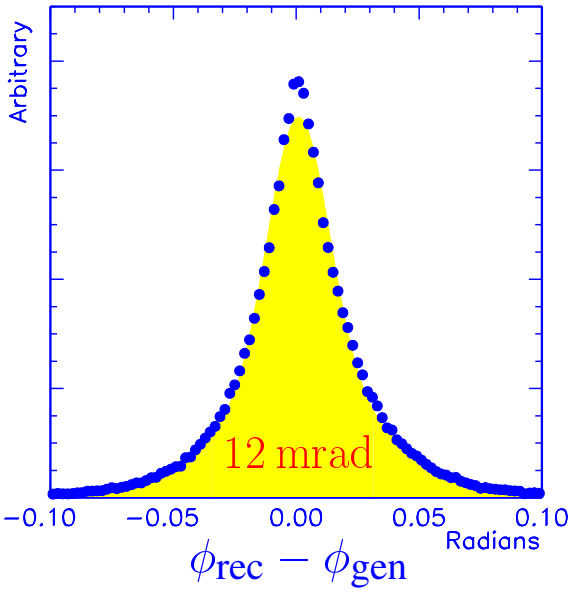
$48,022$ Bπ candidates

$(\pi_B = 0.942)$

Inclusive B Reconstruction

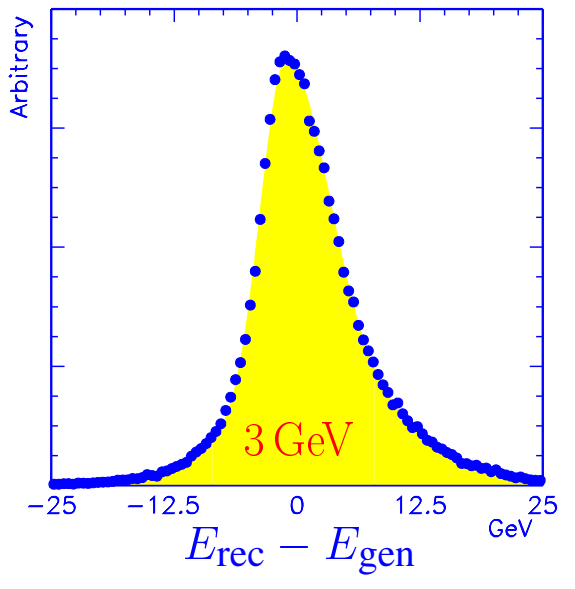
Direction: *Error-Weighted Average*

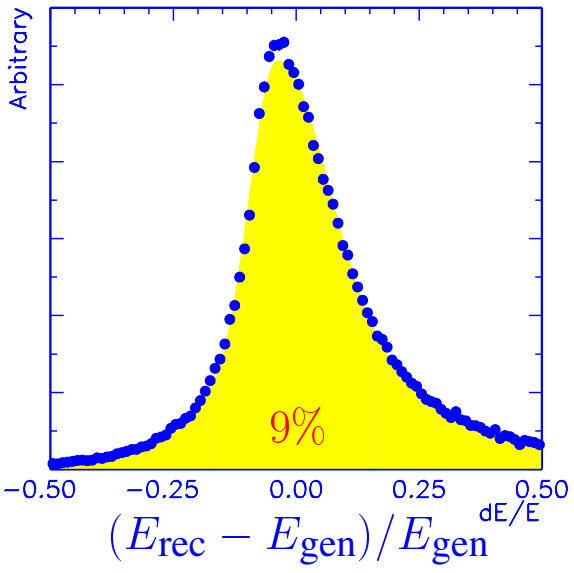




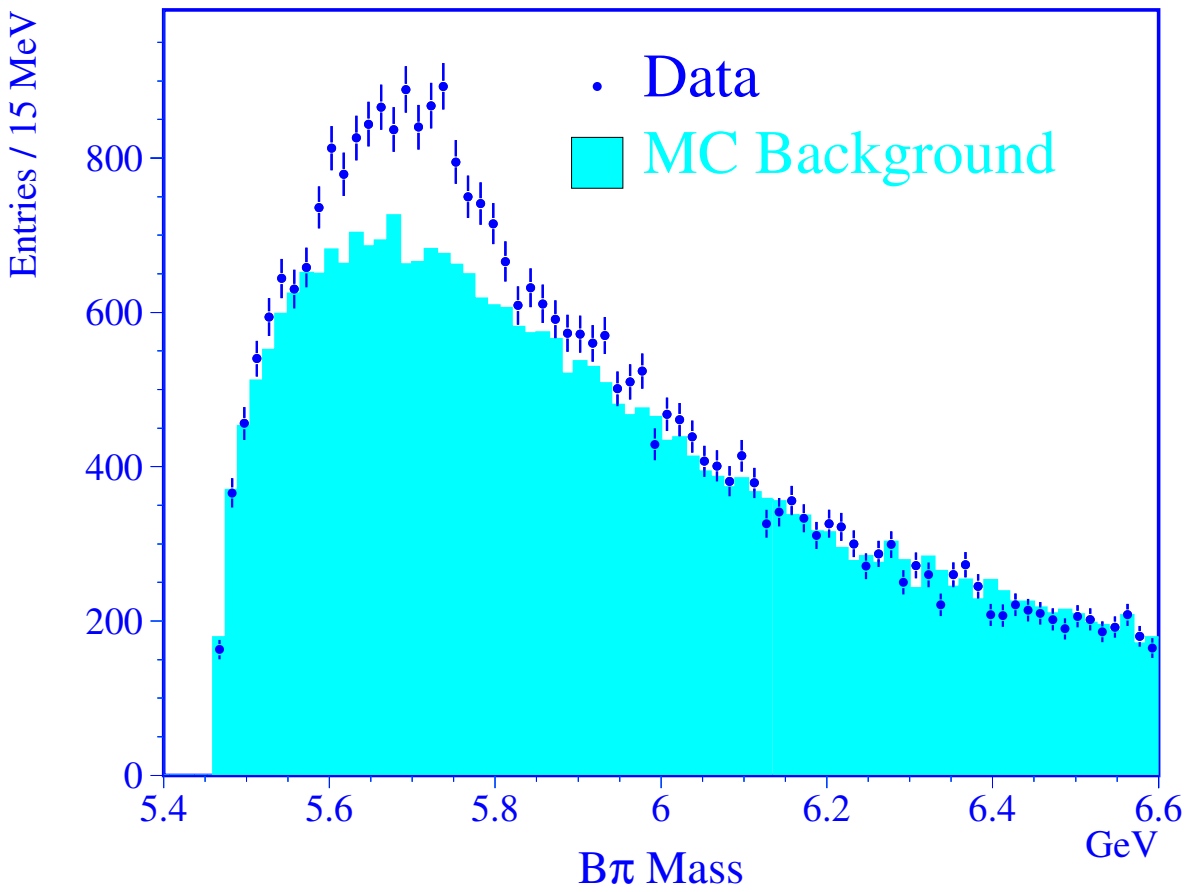
Energy: *Constrained by* E_{CM}

$$E_B = \frac{M_Z^2 - M_B^2 + M_{\rm recoil}^2}{2M_Z}$$





Reconstructed Bπ Mass Spectrum



$$M_{B\pi} = \sqrt{M_B^2 + m_\pi^2 + 2E_B E_\pi - 2p_B p_\pi cos\alpha}$$

Predictions and Fit Constraints

HQET Predictions *(Eichten,Hill,Quigg - 1994)*

j_q	J^P	Name	Mass	Width	Decay
$3/2$	2^+	B_2^*	$5771\,\mathrm{MeV}$	$25\,\mathrm{MeV}$	$l=2$ (d-wave) $\rightarrow \mathrm{B}\pi, \mathrm{B}^*\pi$
$3/2$	1^+	B_1	$5759\,\mathrm{MeV}$	$21\,\mathrm{MeV}$	$l=2$ (d-wave) $\rightarrow \mathrm{B}^*\pi$
$1/2$	1^+	B_1^*	$M_{\mathrm{B}_2^*} - 100\,\mathrm{MeV}$ $(5671\,\mathrm{MeV})$	$\sim 150\,\mathrm{MeV}$	$l=0$ (s-wave) $\rightarrow \mathrm{B}^*\pi$
$1/2$	0^+	B_0^*	$M_{\mathrm{B}_1^*} - 12\,\mathrm{MeV}$ $(5659\,\mathrm{MeV})$	$\sim 150\,\mathrm{MeV}$	$l=0$ (s-wave) $\rightarrow \mathrm{B}\pi$

Constrained Fit to Signal

- *Five Breit-Wigners Convoluted by Resolution*

  $\sigma(M)$ *unfolded from Monte Carlo*

- *Parameters Constrained to HQET:*

  spin counting (5:3:3:1)

  $M_{\mathrm{B}_2^*} - M_{\mathrm{B}_1} = 12\,\mathrm{MeV}$

  $M_{\mathrm{B}_1^*} - M_{\mathrm{B}_0^*} = 12\,\mathrm{MeV}$

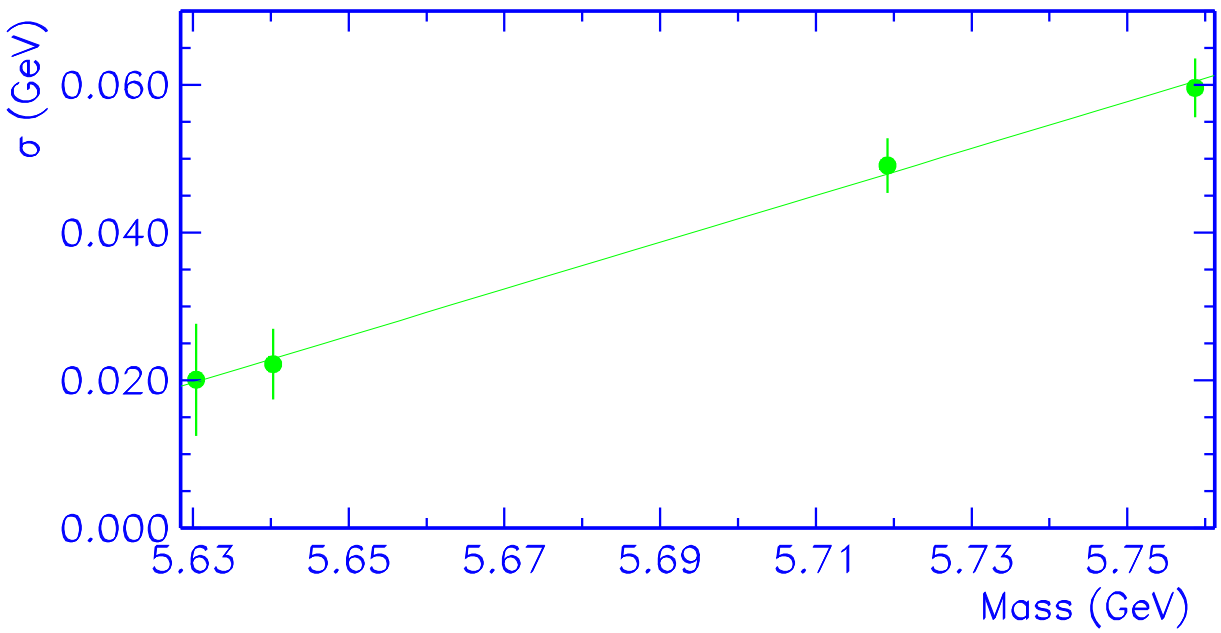
  $\Gamma_{\mathrm{B}_1} = (21/25) \times \Gamma_{\mathrm{B}_2^*}$

  $\Gamma_{\mathrm{B}_0^*} = \Gamma_{\mathrm{B}_1^*}$

$\Rightarrow$ $\boxed{f^{**}, M_{\mathrm{B}_2^*}, \Gamma_{\mathrm{B}_2^*}, M_{\mathrm{B}_1^*}, \Gamma_{\mathrm{B}_1^*}}$

Resolution and Efficiency Functions

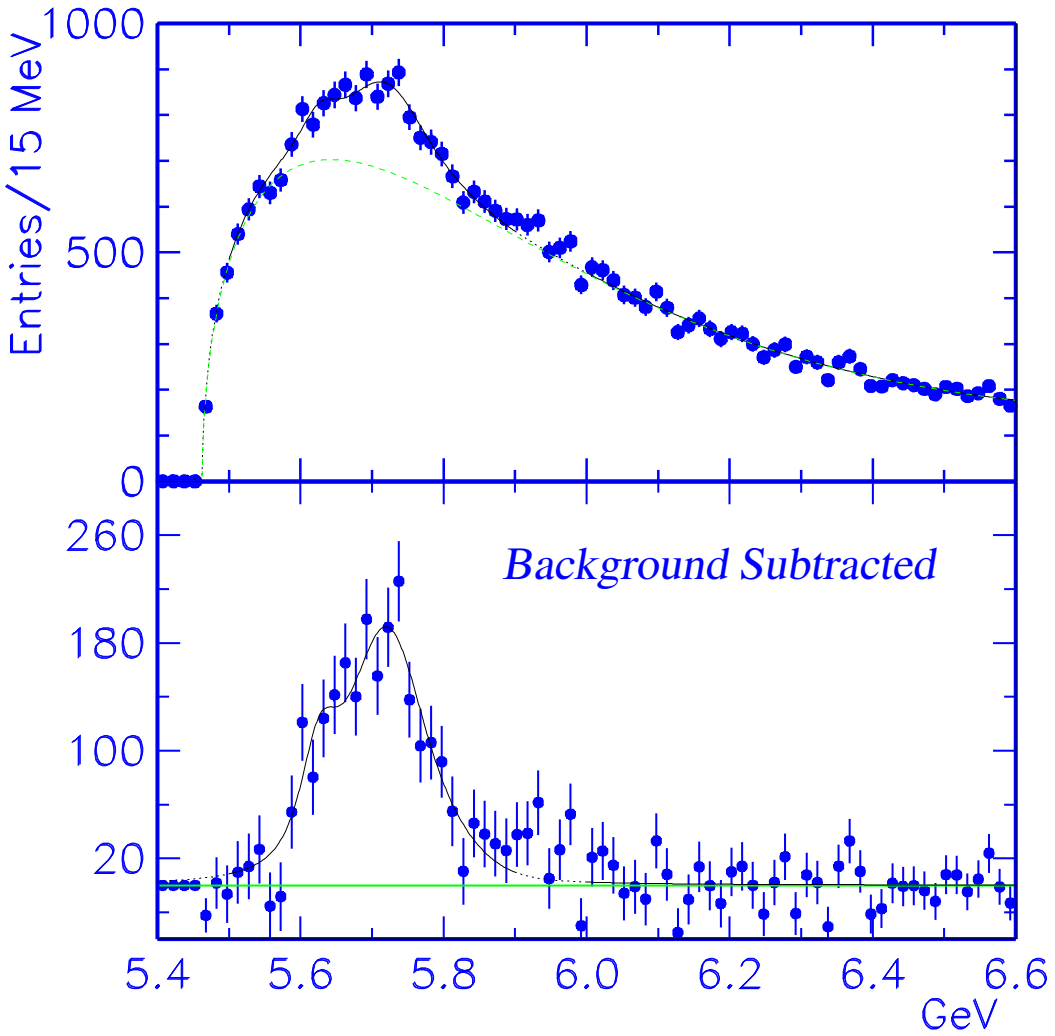
- Fit Several Simulated Decay Spectra
  - *Breit-Wigner* $\otimes$ *Gaussian*
  - *Fix* Γ *to* Γ_{gen}
  - *Extract* $\sigma(M)$ *and* $\epsilon(M)$



$$\sigma(M) = 0.448M - 2.496\,\text{GeV}$$
$$\epsilon(M) = 0.925M(\,\text{GeV}) - 4.307$$

$B\pi$ Mass Fit

Background + Signal a la HQET



$M_{B_2^*}$	$= (5770 \pm 5)$ MeV
$\Gamma_{B_2^*}$	$= (26 \pm 22)$ MeV
$M_{B_1^*}$	$= (5674 \pm 12)$ MeV
$\Gamma_{B_1^*}$	$= (79 \pm 19)$ MeV
$N_{B^{**}}$	$= 2637 \pm 232$
$f_{B^{**}}$	$= 0.42 \pm 0.04$
$\chi^2/\mathrm{DoF} = 57/60$	$(\mathrm{prob} = 0.57)$

Uncertainty Estimates

Sources of Uncertainty	$\delta M_{\mathrm{B}_2^*}$	$\delta\Gamma_{\mathrm{B}_2^*}$	$\delta M_{\mathrm{B}_1^*}$	$\delta\Gamma_{\mathrm{B}_1^*}$	δf^{**}
b purity: $0.91 - 0.96$	—	—	—	—	± 0.02
$\mathrm{B}_{u,d}$ fraction: $0.74 - 0.83$	—	—	—	—	± 0.03
background modeling	± 2	± 9	± 2	± 9	± 0.04
resolution function	± 6	± 13	± 8	± 13	± 0.02
efficiency function	< 1	± 2	< 1	± 2	± 0.02
mass constraints: $6 - 18\,\mathrm{MeV}$	± 3	± 5	± 3	± 5	< 0.01
width constraints: $0.8 - 1$	< 1	± 4	< 1	± 4	± 0.01
state counting: $(1:1:1:1)$	$+13$	-26	$+3$	$+7$	-0.01
Total	± 7	± 17	± 9	± 17	± 0.06

Results of This Measurement

$$
\begin{aligned}
M_{\mathrm{B}_2^*} &= (5770 \pm 5(\text{stat}) \pm 7(\text{syst}))\ \text{MeV} \\
\Gamma_{\mathrm{B}_2^*} &= (26 \pm 22(\text{stat}) \pm 17(\text{syst}))\ \text{MeV} \\
M_{\mathrm{B}_1^*} &= (5674 \pm 12(\text{stat}) \pm 9(\text{syst}))\ \text{MeV} \\
\Gamma_{\mathrm{B}_1^*} &= (79 \pm 19(\text{stat}) \pm 17(\text{syst}))\ \text{MeV} \\
f_{\mathrm{B}^{**}} &= 0.42 \pm 0.04(\text{stat}) \pm 0.06(\text{syst})
\end{aligned}
$$

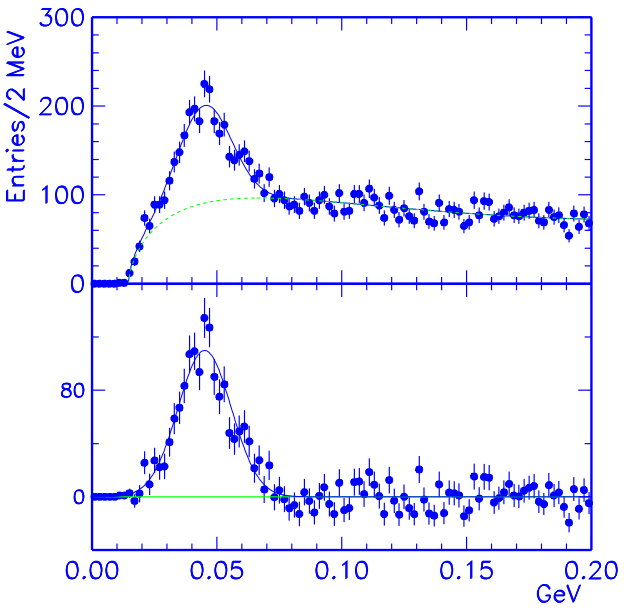
Other B^{**} Measurements from LEP

Analysis	Measurement
OPAL Inclusive *(Vertex Charge)*	$M(\mathrm{B}^{**}_{u,d}) = (5.60 - 5.85)\ \text{GeV}$ $\text{Br}(\bar{b} \to \mathrm{B}^{**0} \to \mathrm{B}^{(*)+}\pi^-)/\text{Br}(\bar{b} \to \mathrm{B}^+)$ $= 0.18 \pm 0.01(\text{stat}) \pm 0.04(\text{syst})$ $\Rightarrow f^{**} = 0.27 \pm 0.06\ (\text{isospin})$
DELPHI Inclusive *(Rapidity)*	$M(\mathrm{B}^{**}_{u,d}) = (5734 \pm 5(\text{stat}) \pm 17(\text{syst}))\ \text{MeV}$ $\sigma(\Delta M) = (72 \pm 5(\text{stat}) \pm 8(\text{syst}))\ \text{MeV}$ $\sigma_{\mathrm{B}^{**}_{u,d}}/\sigma_{b-\text{jet}} = 0.26 \pm 0.015(\text{stat}) \pm 0.05(\text{syst})$ $\Rightarrow f^{**} = 0.32 \pm 0.018(\text{stat}) \pm 0.06(\text{syst})$
ALEPH Inclusive *(Rapidity)*	$M_{\mathrm{B}\pi} - M_{\mathrm{B}} = (424 \pm 4(\text{stat}) \pm 10(\text{syst}))\ \text{MeV}$ $\Rightarrow M(\mathrm{B}^{**}_{u,d}) = (5703 \pm 4(\text{stat}) \pm 10(\text{syst}))\ \text{MeV}$ $\sigma(\Delta M) = (53 \pm 3(\text{stat}) \pm 9(\text{syst}))\ \text{MeV}$ $f^{**} = 0.279 \pm 0.016(\text{stat}) \pm 0.059(\text{syst})\ ^{+3.9}_{-5.6}(\text{model})$
ALEPH Reconstructed	$M_{\mathrm{B}_2^*} = (5739\ ^{+8}_{-11}(\text{stat})\ ^{+6}_{-4}(\text{syst}))\ \text{MeV}$ $f^{**} = 0.31 \pm 9(\text{stat})\ ^{+6}_{-5}(\text{syst})$

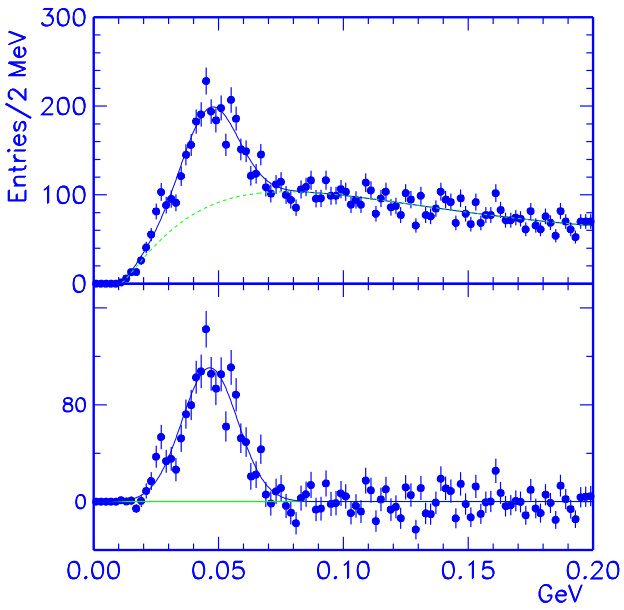
Mass Resolution

Confidence in Data/MC Agreement

- Largest Component Due to B Reconstruction
- Same as for B^* Uncertainty



$M_{\mathrm{B}\gamma} - M_{\mathrm{B}}$ (Data)

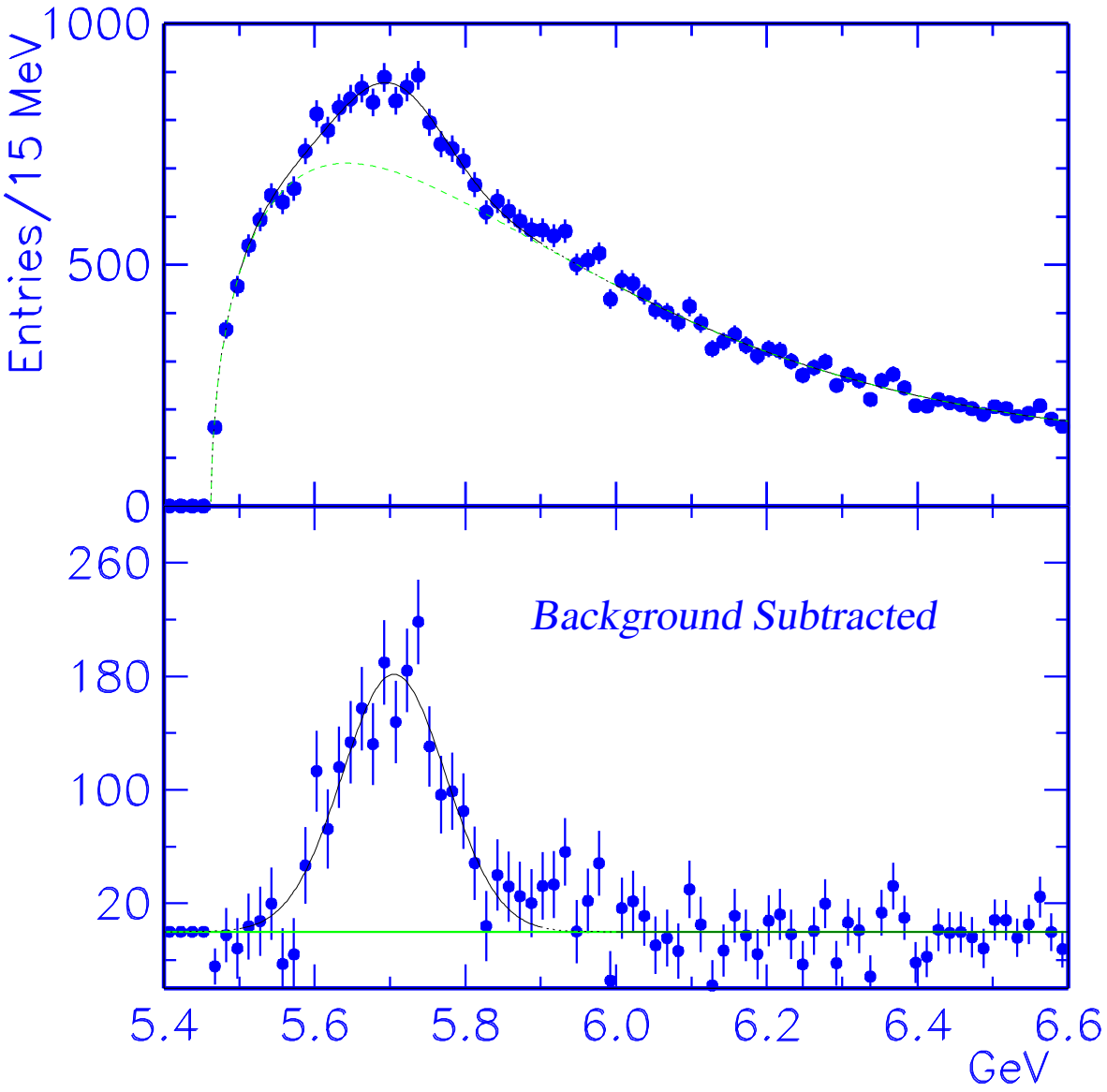


$M_{\mathrm{B}\gamma} - M_{\mathrm{B}}$ (MC)

Quantity	Monte Carlo	Data
$M_{\mathrm{B}^*} - M_{\mathrm{B}}$	(46.5 ± 0.6) MeV	(45.1 ± 0.6) MeV
$\sigma(\mathrm{B}^*)$	(11.1 ± 0.7) MeV	(10.7 ± 0.6) MeV

$B\pi$ Mass Fit

Gaussian + Background



$\hat{M}_{B^{**}}$	$= (5705 \pm 5)$ MeV
$\hat{\sigma}_{B^{**}}$	$= (69 \pm 7)$ MeV
$N_{B^{**}}$	$= 2083 \pm 259$
$f_{B^{**}}$	$= 0.36 \pm 0.04$
$\chi^2/\text{DoF} = 56/61$	$(\text{prob} = 0.66)$