Production, spectroscopy and decays of orbitally excited B mesons at LEP

Presented by Pauline Gagnon

Indiana University - OPAL collaboration

Outline

- Motivation for B_J^* studies (aka B^{**})
- Exclusive sample selection from Aleph
- Inclusive sample selection from L3 and OPAL
- Model-independent $\mathrm{BR}(\mathrm{B}_\mathrm{J}^* \to \mathrm{B}^* \pi(X))$ from OPAL
- Mass fits from ALEPH, L3 and OPAL
- Conclusions

For more details, see:

ALEPH: Phys. Lett. B 425, 1-2 (1998) 215

L3 : Phys. Lett. B 465, 1-4 (1999) 323

OPAL : To be sub. to EPJC. See http://opal.web.cern.ch/Opal/pubs/pr/

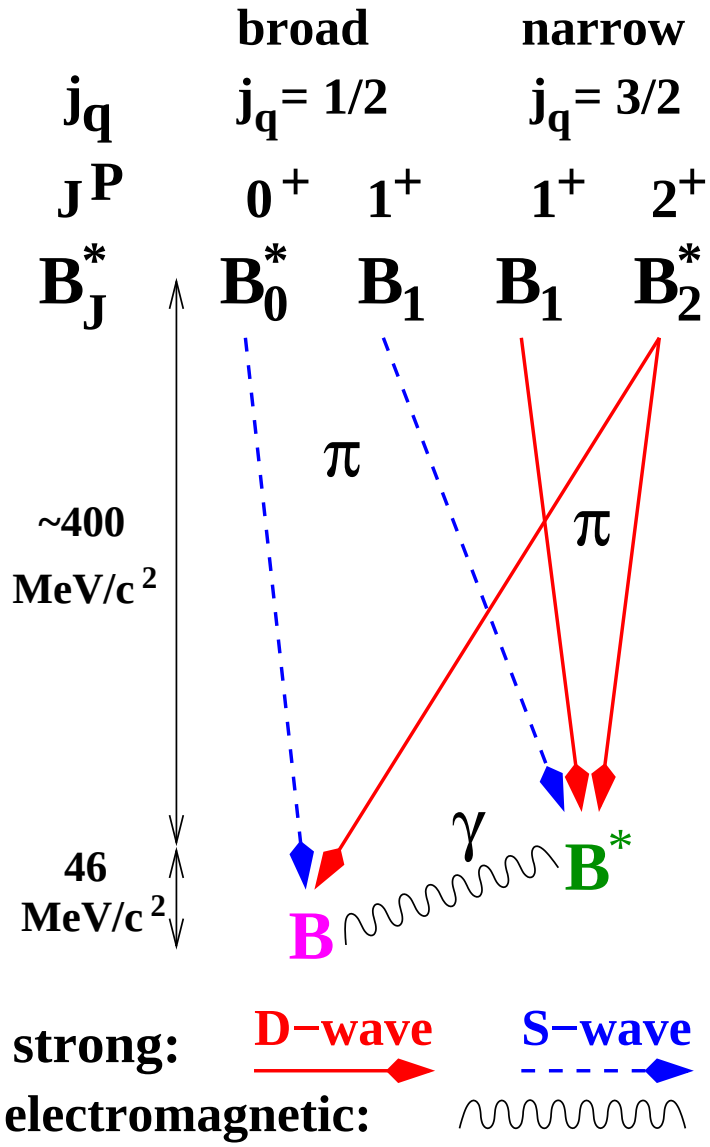
Theoretical background

- Heavy Quark Symmetry predicts four $\mathrm{B}_{\mathrm{J}}^{*}$ states

  $$J^P = 0^+,\ 1^+,\ 1^+,\ 2^+$$

- Parity and angular momentum impose $\mathrm{B}_{\mathrm{J}}^{*} \to \mathrm{B}^{*}\pi$ or $\mathrm{B}\pi$
- All $\mathrm{B}_{\mathrm{J}}^{*}$ states are expected to overlap in mass
- $\mathrm{B}_{\mathrm{J}}^{*} \to \mathrm{B}^{(*)}\pi\pi$ is phase-space suppressed

  $\hookrightarrow$ would add five more transitions below



Purpose of these analyses

First observation reported by OPAL in 1994

	OPAL (94)	DELPHI (94)	ALEPH (95)
$b \to \mathrm{B}^*_\mathrm{J}$	$> 0.27 \pm 0.06$	0.26 ± 0.16	0.28 ± 0.07
$M_{\mathrm{B}^*_\mathrm{J}}$	$5600 - 5850$	5734 ± 18	5703 ± 11

- Measure the production fraction

  $\hookrightarrow \frac{\mathrm{BR}(b \to \mathrm{B}^*_\mathrm{J})}{\mathrm{BR}(b \to \mathrm{B}_{\mathrm{u,d}})}$

- Unknown B^*_J composition

  $\hookrightarrow$ separate $\mathrm{B}^*_\mathrm{J} \to \mathrm{B}^*\pi$ from $\mathrm{B}^*_\mathrm{J} \to \mathrm{B}\pi$

- Masses and widths still largely unmeasured

  $\hookrightarrow$ measure M and Γ for dominant states

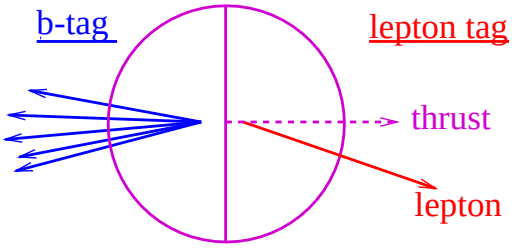
- Exclusive samples can be used to tag the B meson flavour

  $\hookrightarrow$ important for B oscillations studies

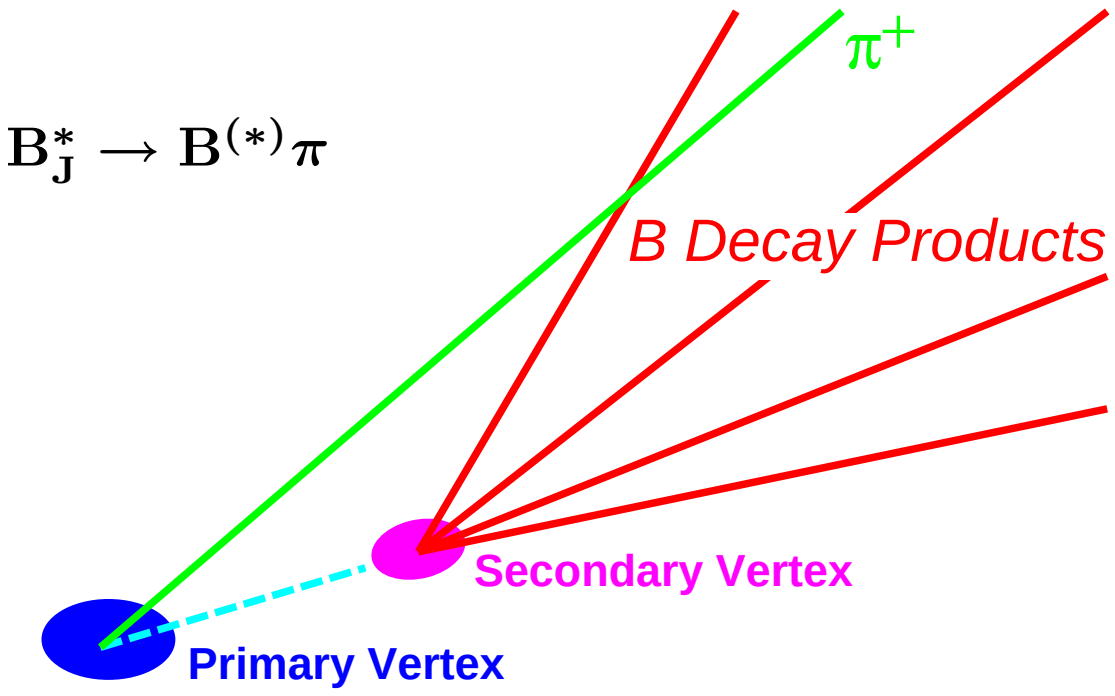
General technique for B_J^* reconstruction

- Separate event in two using thrust axis

  $\hookrightarrow e^+e^- \rightarrow \mathrm{Z}^0 \rightarrow \mathrm{b\bar{b}}$



- Apply a b-tag to enhance b content
- Reconstruct B mesons from tracks
  belonging to a secondary vertex or via exclusive modes
- Associate B meson with a pion coming from primary vertex
- Try to disentangle the underlying four B_J^* states



Aleph: exclusive B meson sample

- Exclusive sample of 404 fully reconstructed B mesons

  $\hookrightarrow$ 80% from $\mathrm{B} \to D^* X, \;\; X = \pi^{\pm}, \rho^{\pm}, a_1^{\pm}$

  $D^* \to D^0\gamma$ or $D^0\pi^0 \Rightarrow$ satellite peak

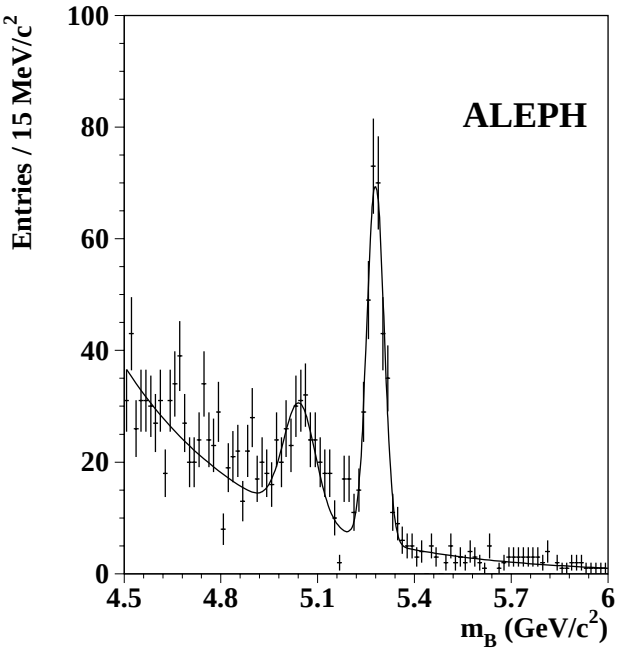
  $\hookrightarrow$ 20% from $\mathrm{B} \to J/\psi(\psi^{'})X, \;\; X = K^{\pm}, K^*$

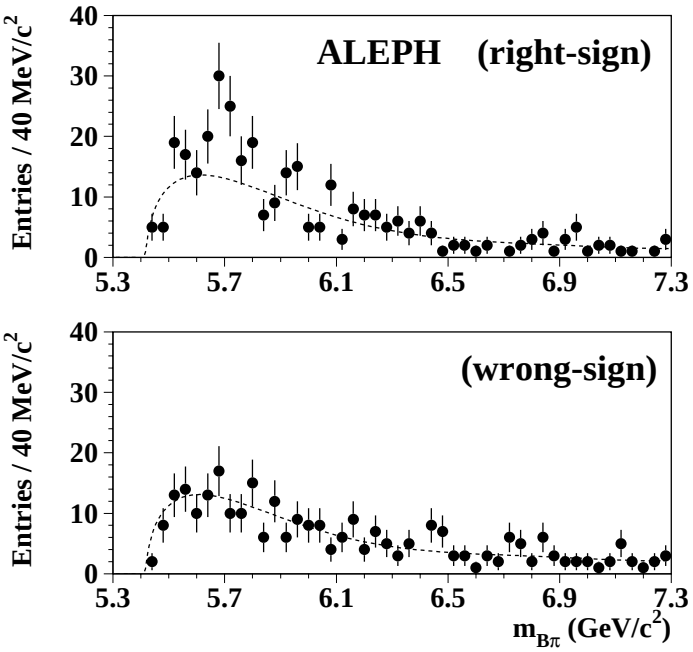
- Associate a pion with these B mesons to form B_J^*

  $\hookrightarrow$ Charge-correlations: right/wrong-sign samples

  $\hookrightarrow$ Background normalisation from wrong-sign sample

ALEPH B_J^* signal: 41 ± 6 events





$$\frac{\mathrm{BR}(b \to \mathrm{B}_\mathrm{J}^*)}{\mathrm{BR}(b \to \mathrm{B}_{\mathrm{u,d}})} = (30^{+12}_{-10} \pm 3\,(\mathrm{syst}))\%$$

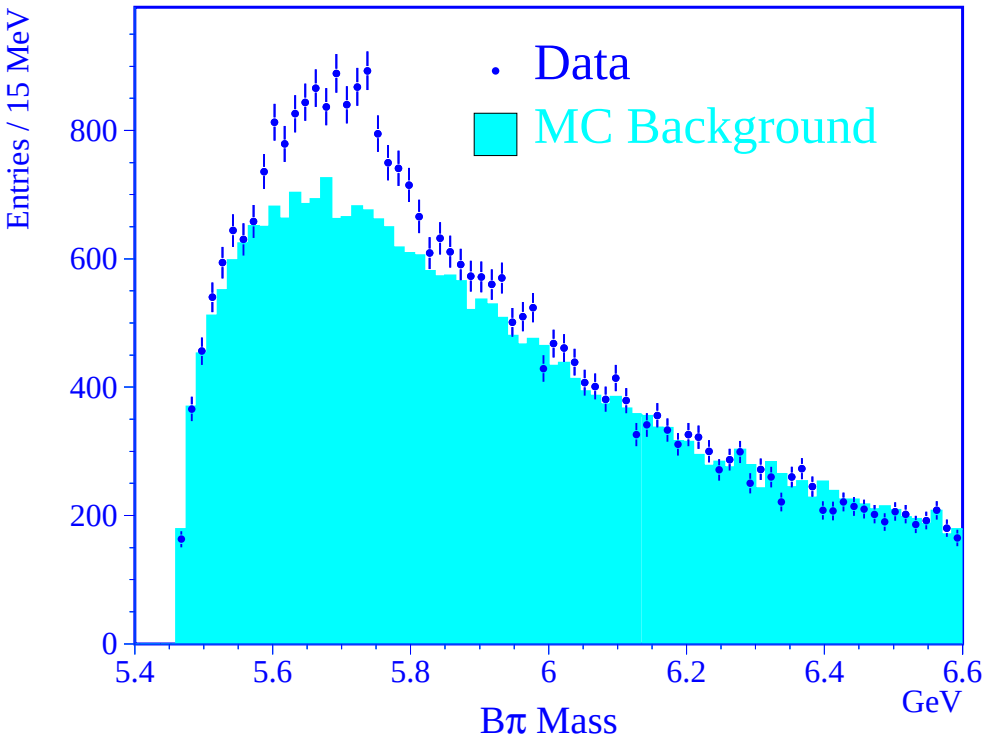
B_J^* reconstruction from inclusive B mesons

- Use an inclusive sample of partially reconstructed B mesons
- Associate a pion with these B mesons to form B_J^*
- Background normalisation from $B\pi$ mass dist. side-band

L3 result

B_J^* signal: 2784 ± 274 events

$$\frac{BR(b \to B_J^*)}{BR(b \to B_{u,d})} = (32 \pm 3 \pm 6\ (syst))\%$$



Background shape taken from Monte Carlo

Separating $\mathrm{B}_\mathrm{J}^* \to \mathrm{B}^*\pi$ from $\mathrm{B}\pi$ at OPAL

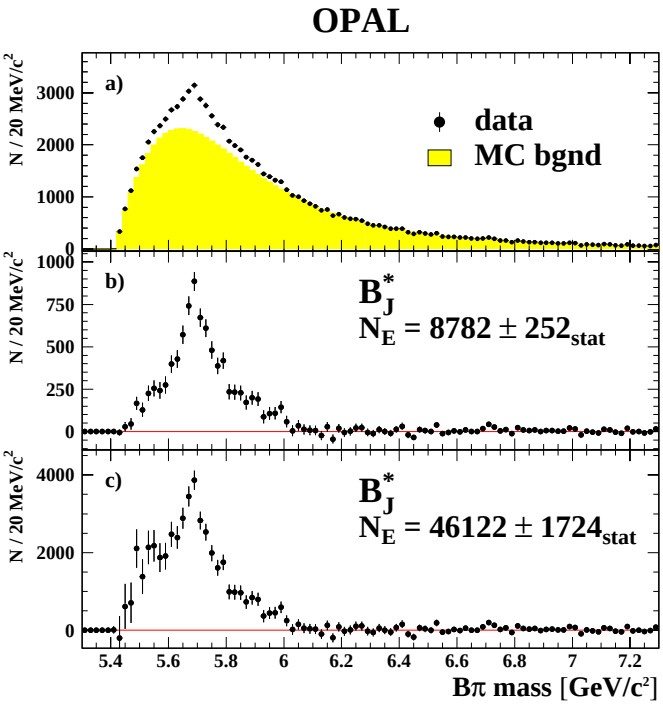
No attempt to reconstruct $\mathrm{B}_\mathrm{J}^* \to \mathrm{B}^*\pi \to \mathrm{B}\pi\gamma$

- Form inclusive B_J^* sample from $\mathrm{B}\pi$ combinations
- Assign a probability $\mathcal{W}_{\mathrm{B}^*}$ that B came from $\mathrm{B}^* \to \mathrm{B}\gamma$

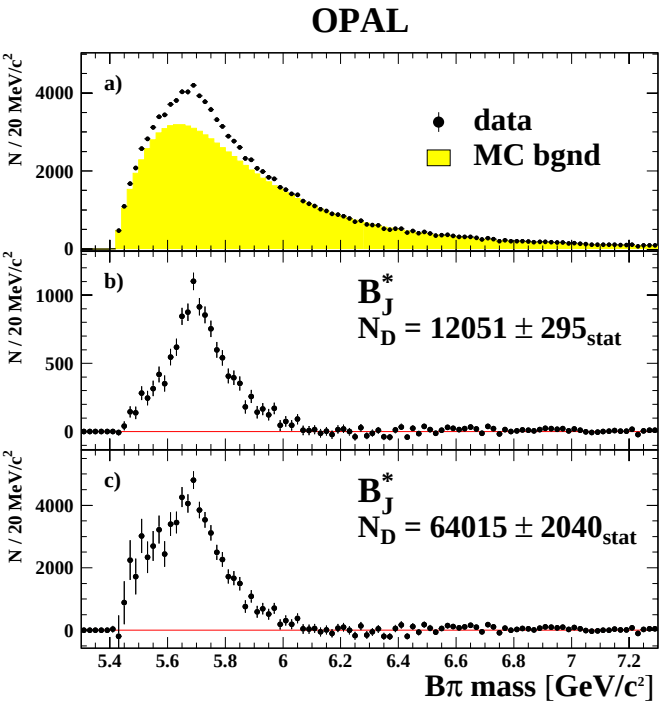
  $\hookrightarrow$ look for $\mathrm{B}^* \to \mathrm{B}\gamma$ by searching for γ in the hemis.

  $\hookrightarrow$ form B^* enriched and depleted samples with $\mathcal{W}_{\mathrm{B}^*}$
- #'s of B_J^* in each sample yield $\mathrm{BR}(\mathrm{B}_\mathrm{J}^* \to \mathrm{B}^*\pi(X))$

$\mathrm{B}^*\pi$ enriched



$\mathrm{B}^*\pi$ depleted



(Middle) background subtracted (Bottom) efficiency corrected

$$\mathrm{BR}(\mathrm{B}_\mathrm{J}^* \to \mathrm{B}^*\pi(X)) = 0.85 \pm 0.27 \pm 0.12\,(\mathrm{syst})$$

Mass fits

	ALEPH	L3	OPAL
# events	41 ± 6	2770 ± 394	20840 ± 388
$\sigma(M_{\mathrm{B}\pi})$	$2-5$ MeV	45 MeV	40 MeV

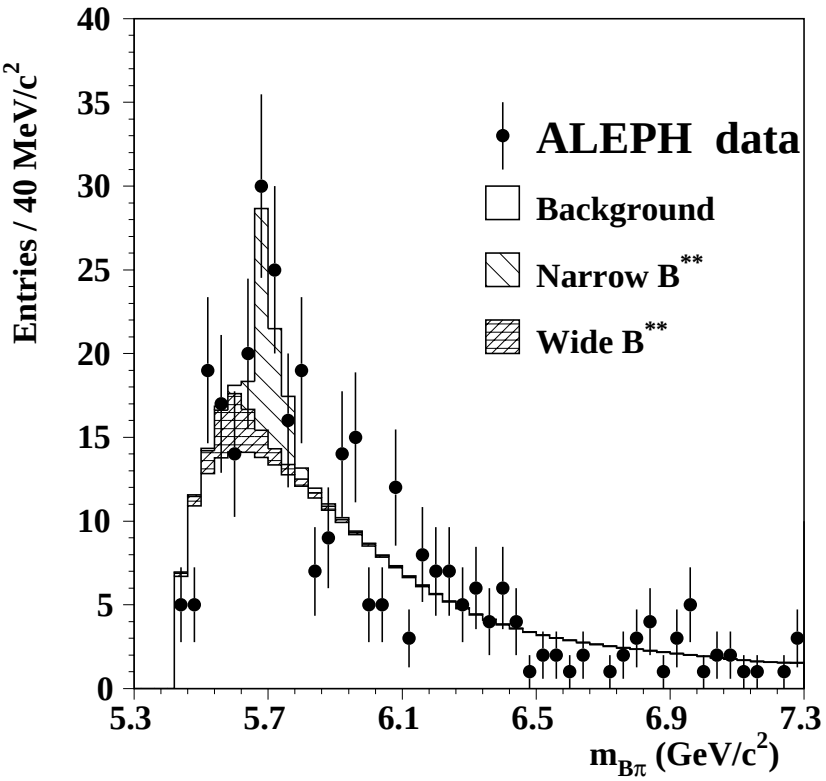
Fit parameters : free in red or purple (less robust)

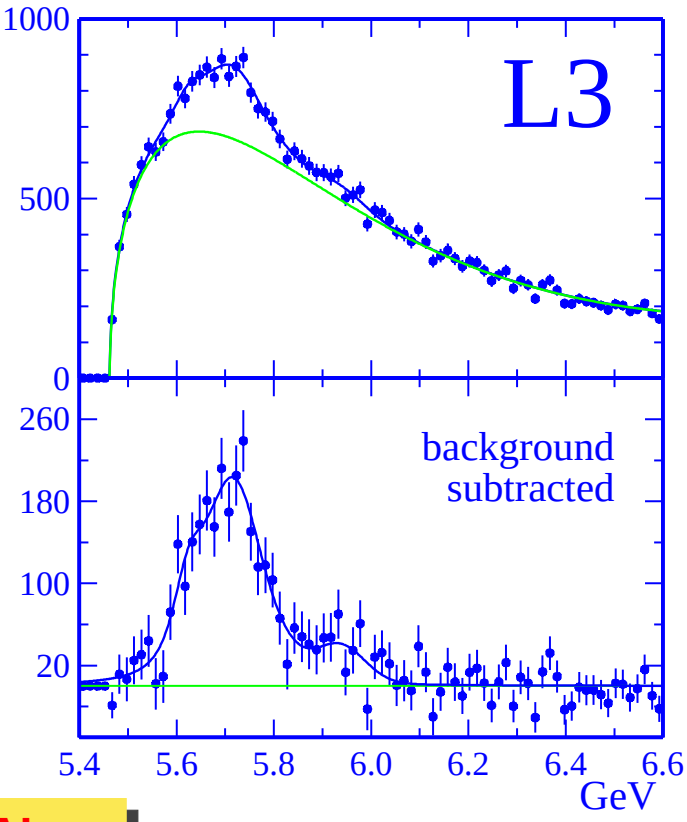
All in MeV $\pm$ total errors. Fixed assumptions in black.

Assumptions for B_J^* states production fractions not shown

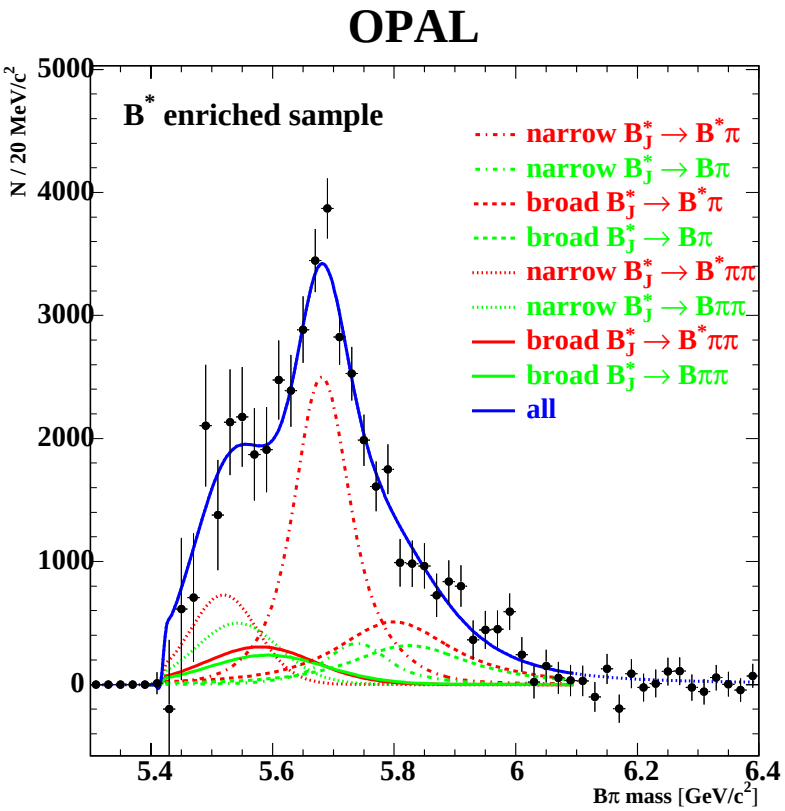
	ALEPH	L3	OPAL
$\Delta(M)_{\mathrm{narrow}}$	12	12	20
$\Delta(M)_{\mathrm{broad}}$	12	12	12
Γ_{narrow}	21, 25	24 ± 31	18 ± 30
Γ_{broad}	150	70 ± 33	129 ± 68
M_{narrow}	5727^{+10}_{-12}	5756 ± 8	5738 ± 8
M_{broad}	$M_{\mathrm{narrow}} - 100$	5658 ± 16	5839 ± 40
$b \to \mathrm{B}_\mathrm{J}^*$	0.31 ± 0.11	0.32 ± 0.06	-
$\mathrm{B}_\mathrm{J}^* \to \mathrm{B}^*\pi$	-	-	0.74 ± 0.21
$\mathrm{B}_\mathrm{J}^* \to \mathrm{B}^*\pi\pi$	-	-	0.33 ± 0.15
$M_{\mathrm{B}'}$	-	5937 ± 21	none
$\sigma(M_{\mathrm{B}'})$	-	50 ± 22	-
$b \to \mathrm{B}'$	-	0.034 ± 0.014	-

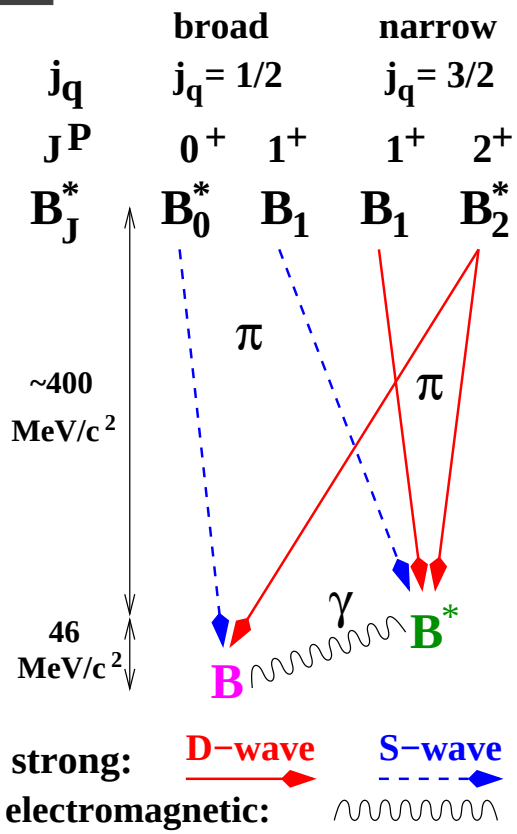
Mass fit results from Aleph, L3 and OPAL





...and OPAL





Discussion

(Some) agreement between OPAL and ALEPH:

1) Both see a broad peak below a narrow peak

2) ALEPH assumed $M_{\rm broad} = M_{\rm narrow} - 100$ for the fit

3) OPAL fit assigned this peak to $\mathrm{B}^{(*)}\pi\pi$ with one missing π

A few disagreements:

1) $M_{\rm narrow}$ - $M_{\rm broad}$ (OPAL versus ALEPH, L3)

2) Evidence for B' from L3 not observed by OPAL

3) $M_{\rm narrow}$: (OPAL, ALEPH versus L3)

Core issue: fit robustness

Fit stability needs clear understanding of bgnd and efficiencies

- L3 uses same MC simulation as OPAL

  $\hookrightarrow$ OPAL saw that efficiency depends on $M(\mathrm{B}\pi)$

  $\hookrightarrow$ only OPAL corrects shape of $M_{\mathrm{B}\pi}$ distribution

- OPAL and ALEPH check background shape with data

  $\hookrightarrow$ shape taken from MC for L3

- $\mathrm{BR}(\mathrm{B}_{\mathrm{J}}^{*} \to \mathrm{B}^{*}\pi(X)) = 0.85 \pm 0.27 \pm 0.12\ (\mathrm{syst})$

  $\hookrightarrow$ first measurement, model-independent result

- Evidence for $\mathrm{B}^{(*)}\pi\pi$ by OPAL needs cross-check