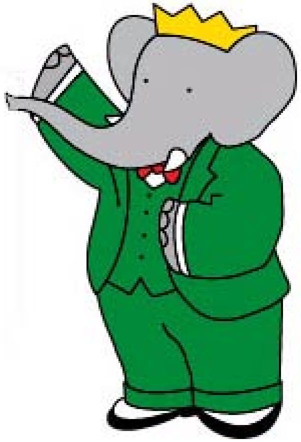
Charmless Hadronic *B* decays at *BaBar*

Gagan Mohanty

University of Warwick

Representing



XII. INTERNATIONAL CONFERENCE ON HADRON SPECTROSCOPY

8-13 OCTOBER 2007

Laboratori Nazionali di Frascati (Rome)

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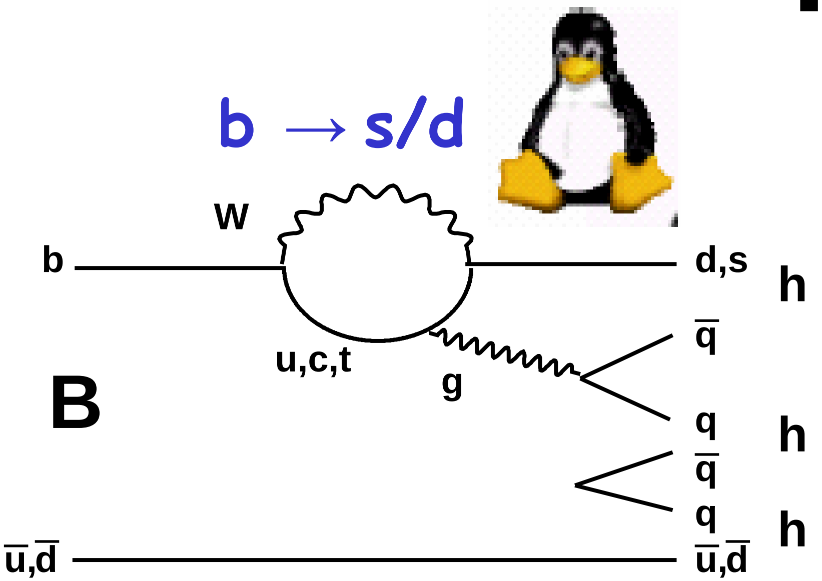
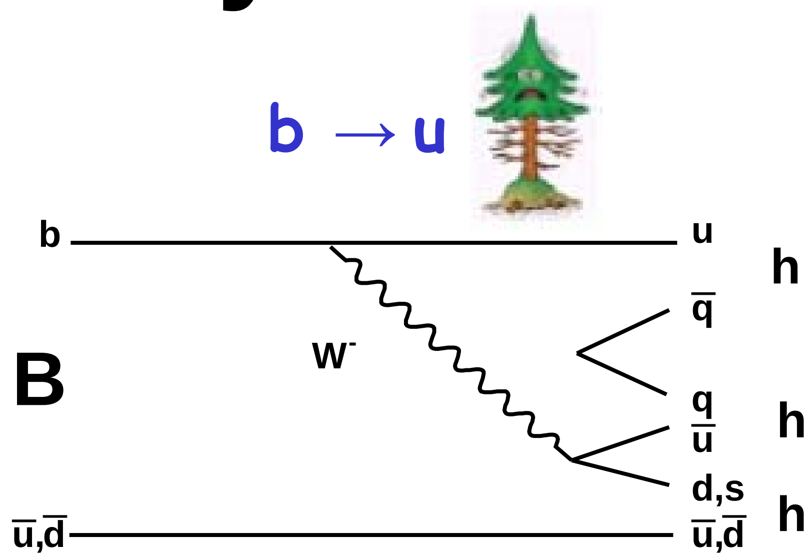
Outline of the talk

- Theory/Motivation
- Dataset and Detector
- Analysis Strategy
- Results
  - Three-body decay $K^+K^-\pi^+$
  - Vector-Vector mode $K^*\overline{K}^*$
  - Axialvector-Pseudoscalar modes (a_1h and b_1h, h=K/π)
- Conclusions and Outlook

♠ Results are preliminary unless journal reference given

Theory





- Diagrams for three-body processes shown for illustration purpose

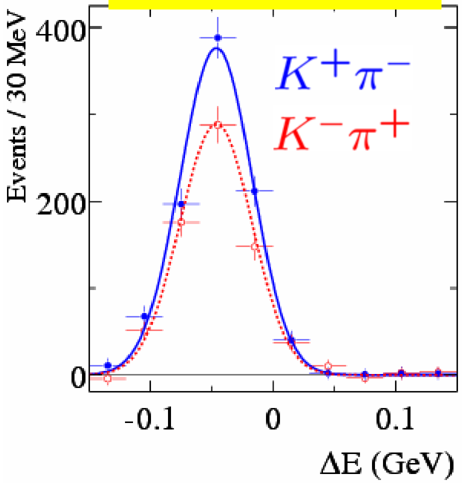
b → s loop (penguin) transition contributes only to the final states with odd number of kaons due to presence s quark *e.g. Kππ, KKK*

Final states with even number of kaons, such as *KKπ* get contributions from b → u tree and b → d penguin diagrams. Odd number kaon states are further Cabibbo suppressed [~ $\sin\theta_c$]

Motivation

- Interfering tree and penguin amplitudes ➡ good place to search for direct *CP* violation

PRL 93, 131801

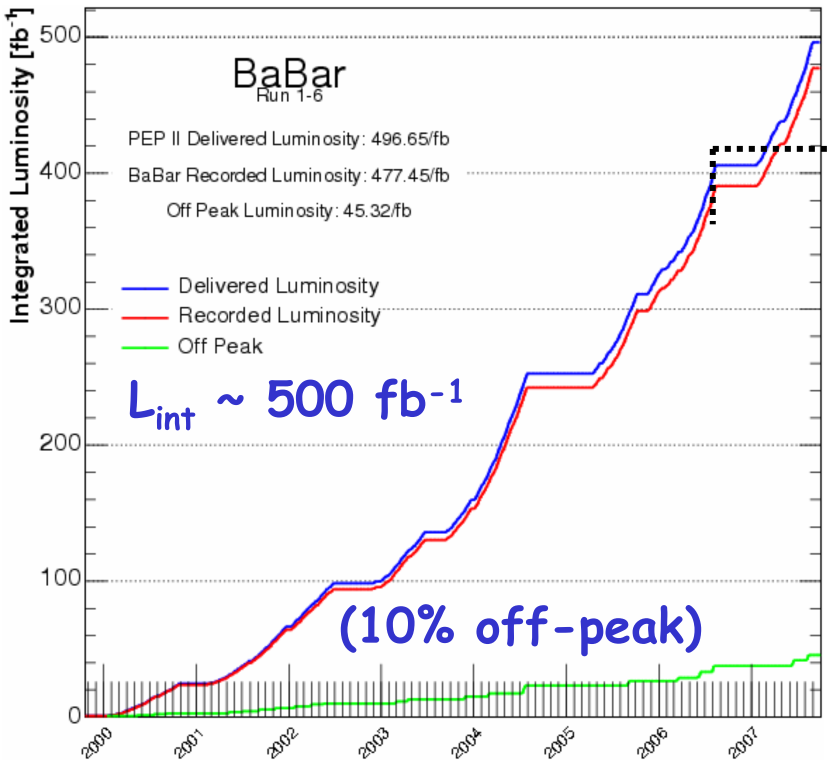


- Good place to search for new physics since NP particles can enter the loop
- Probes flavor sector, particularly by measuring
  - sin(2β) or just β in the $K_S h^+ h^-$ (K/π) Dalitz plot
  - α in the modes: ππ, ρπ, ρρ and $a_1 h$
  - γ using flavour symmetries (isospin, U-spin *etc.*)
- Low energy spectroscopy

Klempt et al., arXiv:0708.4016

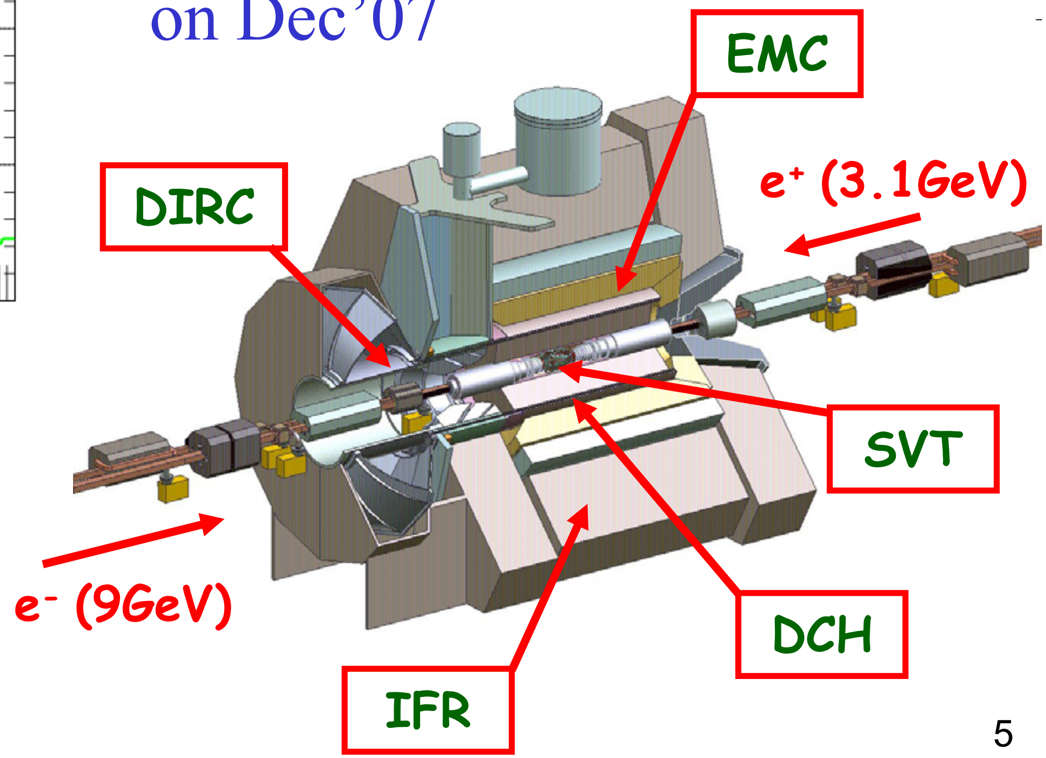
- Testing ground for pQCD, QCD factorization, SCET…

Dataset and Detector

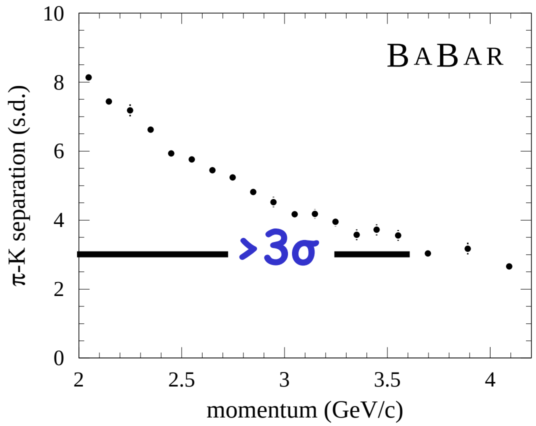


- ✓ Run 6 just ended last month
- Presented results mostly based on data from runs 1-5
- ✓ Final run 7 scheduled to start on Dec'07

- ➢ Main components to tag charmless *B* decays are tracking, DIRC (PID) and EMC (π^0, η)

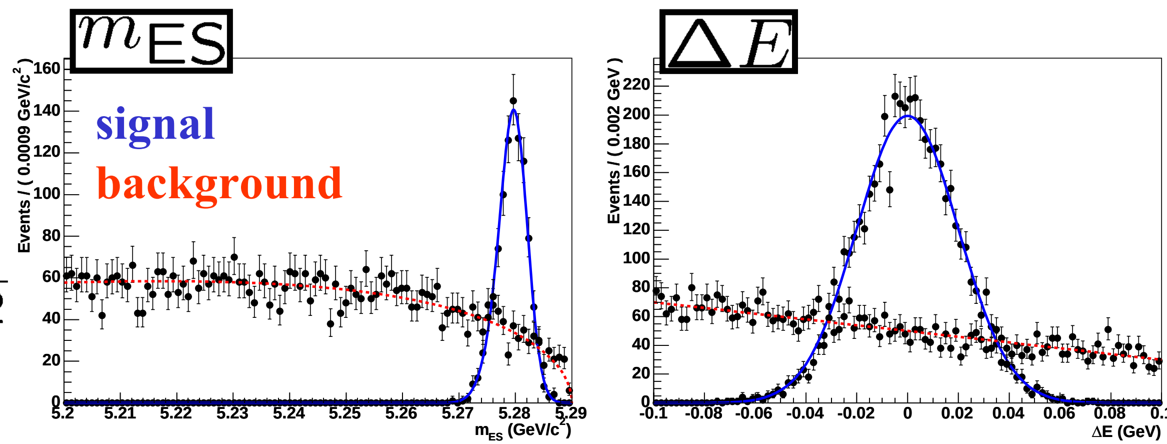


Analysis Strategy



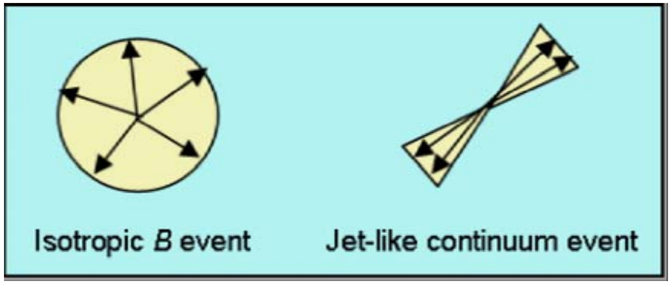
- PID is crucial for these analyses
  - Distinguish charged K *vs.* π
  - Veto the leptons

➢ Use beam-energy info and $(E,\mathbf{p})$ conservation



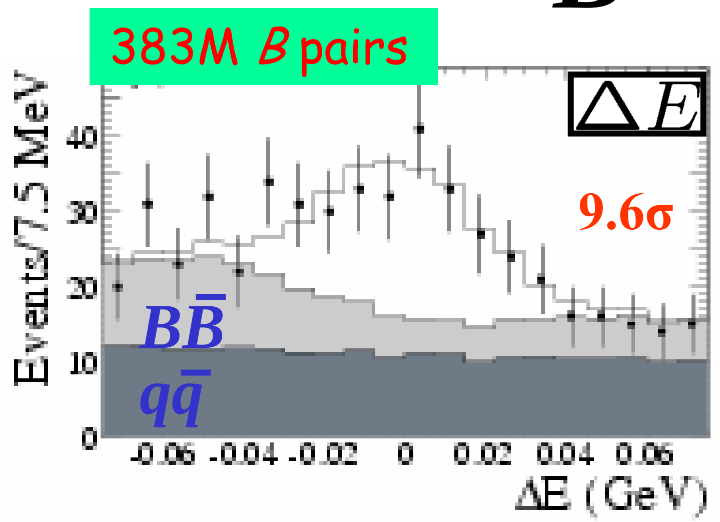
- $m_{\mathrm{ES}} = \sqrt{E^{\star 2}_{\mathrm{beam}} - \mathbf{p}^{\star 2}_{B}}$
- $\Delta E = (E^{\star}_{B} - E^{\star}_{\mathrm{beam}})$

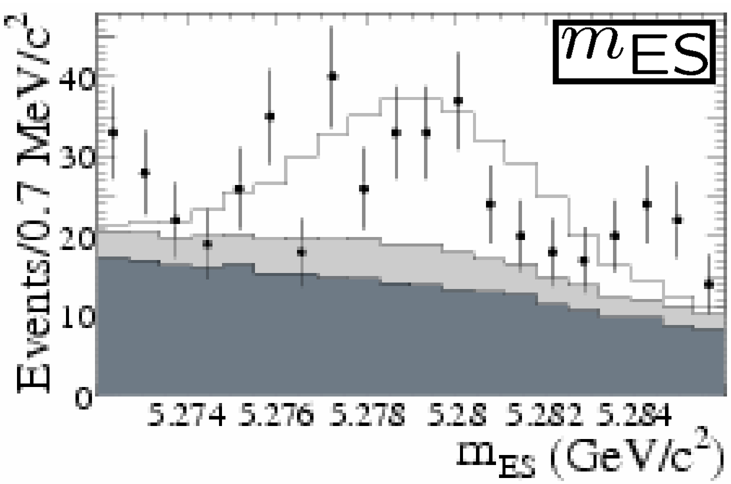
➢ Event topology to discriminate spherical signal events from jet-like $q\overline{q}$ continuum background



➢ Resonance mass and angular information wherever appropriate

$B^+ \to K^+K^-\pi^+$ inclusive





arXiv:0708.0376, accepted by PRL

- ✓ Possible contributions from b→d loop, b→u tree as well as other processes resulting $s\bar{s}$ production
- ✓ Q2B analyses have put stringent UL:

$\overline{K}^{*0}(892)K$	1.1×10^{-6}
$\overline{K}^{*0}_0(1430)K$	2.2×10^{-6}
$\phi(1020)\pi$	2.4×10^{-7}

arXiv:0708.2248, accepted by PRD(R)

PRD 74, 011102

- ❑ Inclusive analysis reveals a large signal yield of (429±43)

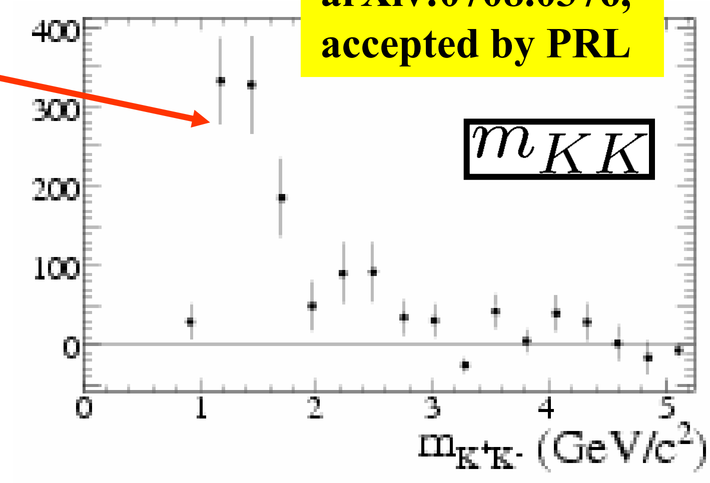
$$\boxed{\mathcal{B}(B^+ \to K^+K^-\pi^+) : (5.0 \pm 0.5 \pm 0.5) \times 10^{-6}}$$

$\boxed{\mathcal{A}_{CP} \text{ is consistent with zero}}$

$B^+ \rightarrow K^+K^-\pi^+$ inclusive

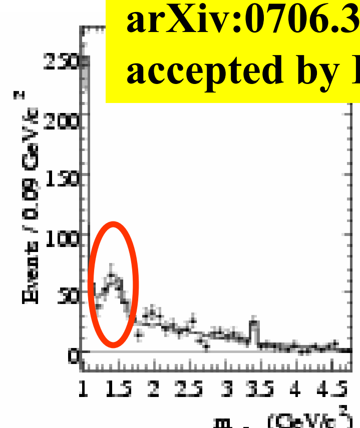
- ✓ Half of the events originates from
- ✓ Reminiscent of similar structures seen in $K_SK^+K^-$ and $K^+K^+K^-$
  - ➢ Nature of this state around 1.5GeV/c² is not very clear

arXiv:0708.0376, accepted by PRL

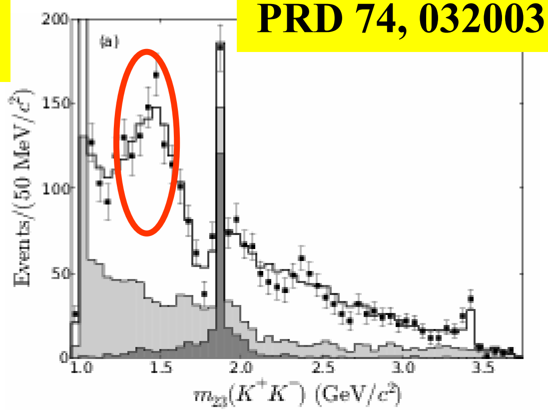


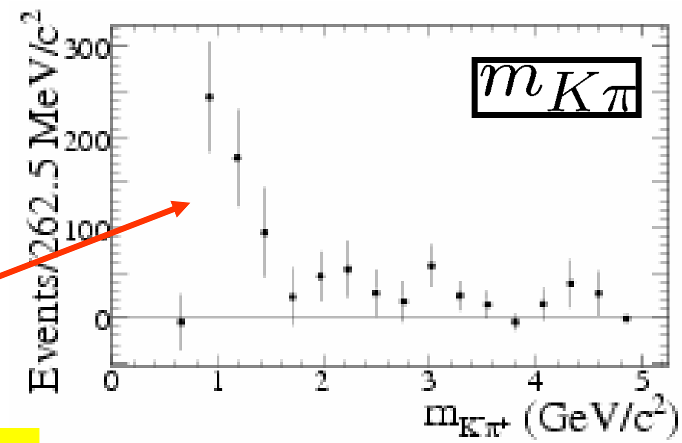
Efficiency-corrected distribution

arXiv:0706.3885, accepted by PRL



PRD 74, 032003





- ✓ Rate reasonably consistent with the Q2B results on $K^{*0}K$

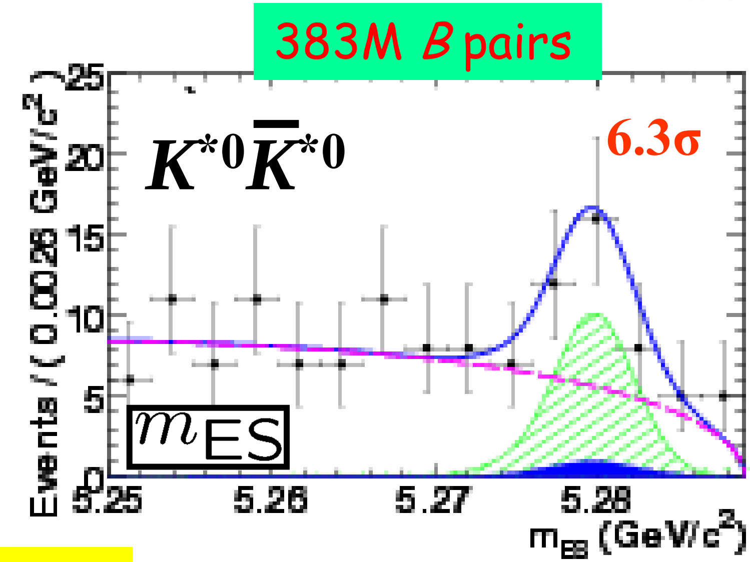
arXiv:0708.2248, accepted by PRD(R)

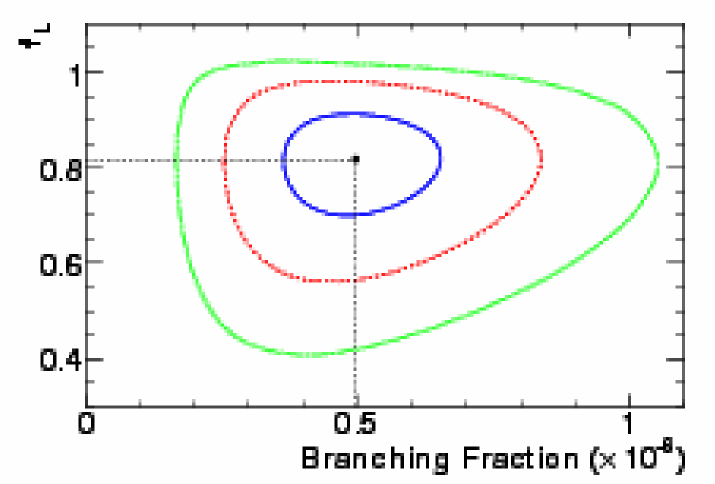
$B^0 \to K^{*0}\bar{K}^{*0}$ and $K^{*0}K^{*0}$

- ✓ First one proceeds through both gluonic and EW penguins; latter heavily suppressed (NP effect)
- ✓ Might provide insights into the polarization puzzle
  - ➢ $f_L \sim 0.5$ in $B \to \varphi K^*$
  - ➢ pQCD prediction 0.9

PRL 98, 051801, arXiv:0705.1798

Suzuki, PRD 66, 054018





arXiv:0708.2248

Channel	$K^{*0}\overline{K}^{*0}$	$K^{*0}K^{*0}$
n_{sig}	$28.8^{+9.1}_{-7.8}$	2.7 ± 3.3
$\mathcal{B}(10^{-6})$	$0.49^{+0.16}_{-0.13} \pm 0.06$	< 0.18¶
f_L	$0.81^{+0.10}_{-0.12} \pm 0.06$	–

¶ two orders of magnitude improvement

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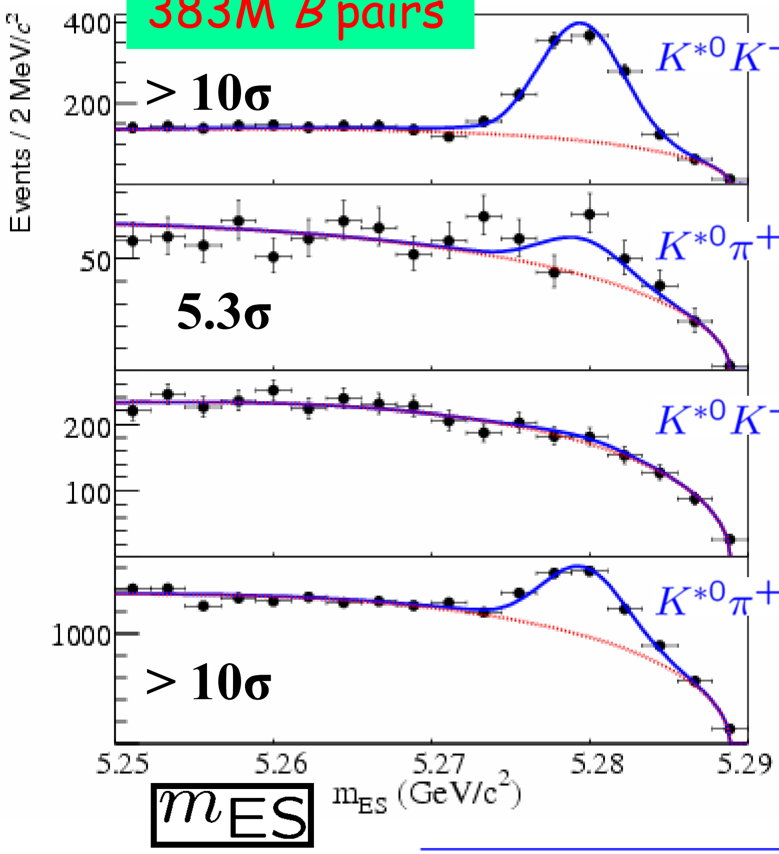
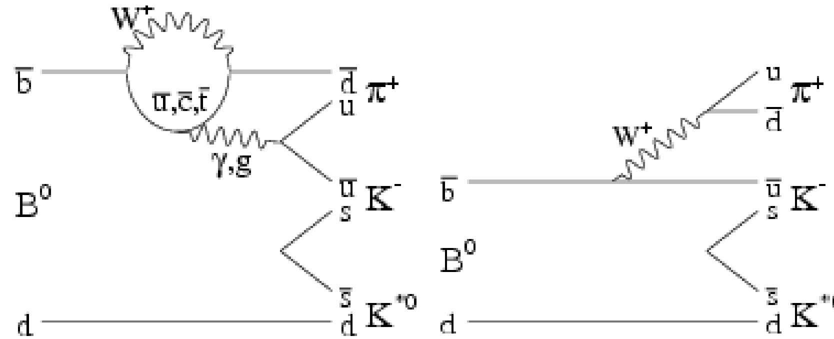
$B^0 \to K^{*0}(892)h^+h^-$ $(h=K/\pi)$





- Observation of SM suppressed decay mode $K^{*0}K^+\pi^-$ at par with $K^{*0}\pi^+K^-$ ➡ sign of new physics
  - Reconstruct K^{*0} via the self-tagging mode $K^+\pi^-$

$B^0 \to$ Mode	$n_{\rm sig}$	$\mathcal{B}(\times 10^{-6})$	$\mathcal{A}_{CP}$
$K^{*0}K^+K^-$	984 ± 46	$27.5 \pm 1.3 \pm 2.2$	$0.01 \pm 0.05 \pm 0.02$
$K^{*0}\pi^+K^-$	183 ± 42.4	$4.6 \pm 1.1 \pm 0.8$	$0.22 \pm 0.33 \pm 0.20$
$K^{*0}K^+\pi^-$	18.8 ± 29.4	< 2.2	$-$
$K^{*0}\pi^+\pi^-$	2019 ± 108	$54.5 \pm 2.9 \pm 4.3$	$0.07 \pm 0.04 \pm 0.03$

arXiv:0708.2543, accepted by PRD(R)

- All new measurements

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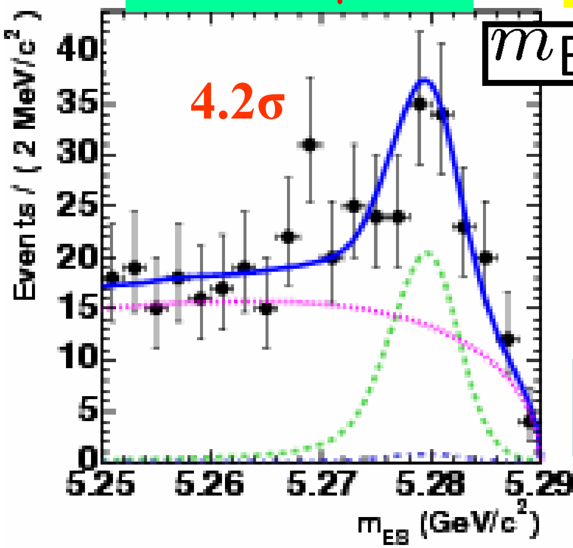
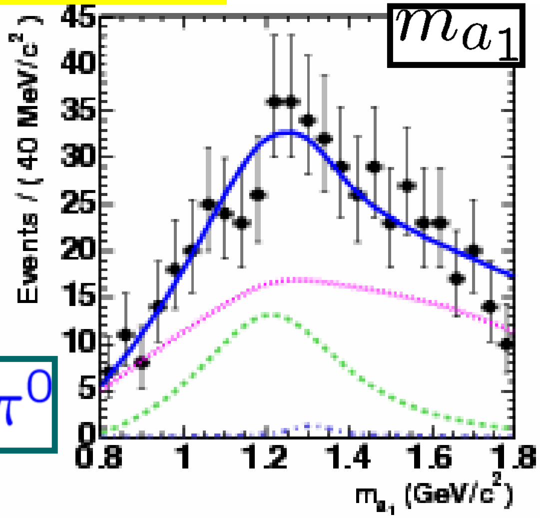
$B \to a_1(1260)\pi$

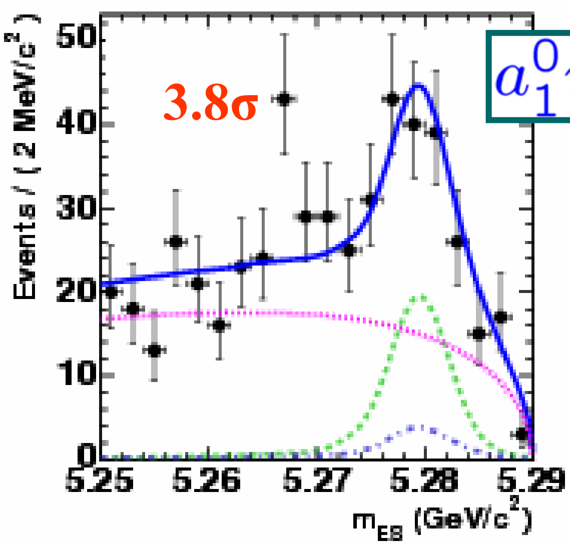
232M *B* pairs

arXiv:0708.0050





- Main contribution from b → u tree
  - $I^G=1^-$ member of $J^{PC}=1^{++}$ $^1P_1$ nonet
  - Reconstruct via the 3π decay mode



Mode	Yield	$\mathcal{B}(B \to a_1\pi) \times \mathcal{B}(a_1 \to \pi\pi\pi)$
$a_1^+\pi^0$	459 ± 78	$(13.2 \pm 2.7 \pm 2.1) \times 10^{-6}$
$a_1^0\pi^+$	382 ± 79	$(20.4 \pm 4.7 \pm 3.4) \times 10^{-6}$

✓ Agreement with the factorization model prediction

Laporta et al., PRD 74, 054035 hep-ph/0602243

✗ Search in the a_0 mode: arXiv:0708.0963

$$\mathcal{B}(B^+ \to a_0^+(980)\pi^0) \times \mathcal{B}(a_0^+ \to \eta\pi^+) < 1.4 \times 10^{-6}$$

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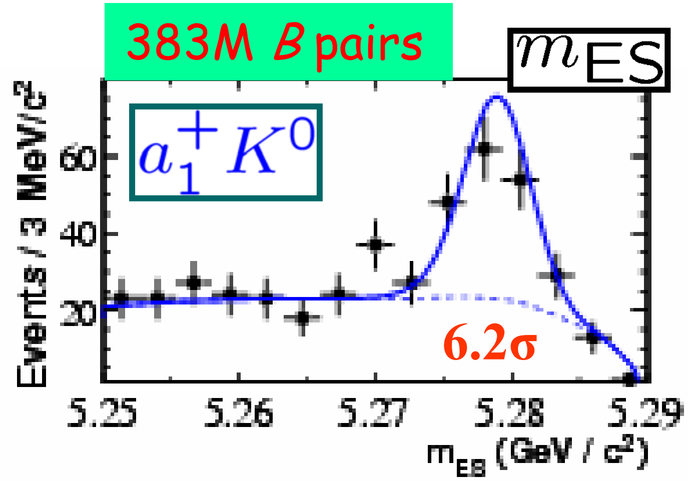
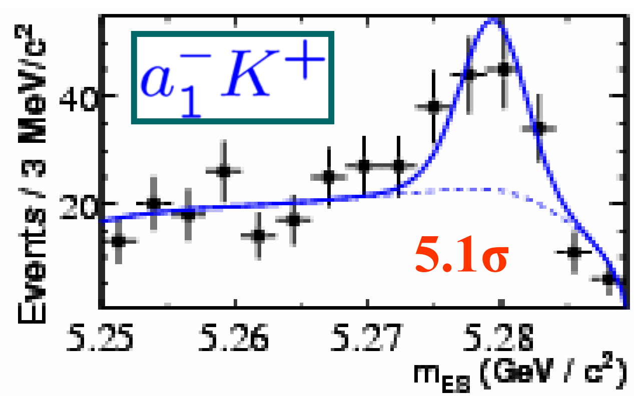
$B \to a_1(1260)K$



- ❑ CKM angle α using SU(3) flavour symmetry **Gronau et al., PRD 73, 057502**
- ❑ Test factorization model predictions **Laporta et al., PRD 74, 054035 hep-ph/0602243**
- ❑ No measurement exists to date

arXiv:0709.4165

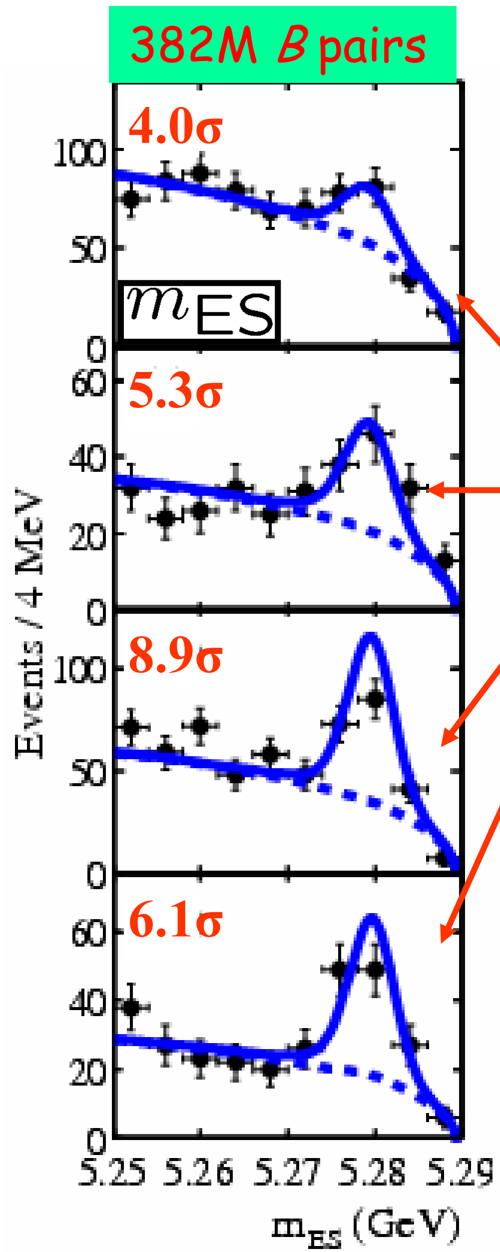
Value	$a_1^+(1260)K^0$	$a_1^-(1260)K^+$
n_{sig}	241 ± 32	272 ± 44
$\mathcal{B}(\times 10^{-6})$	$17.4 \pm 2.5 \pm 2.2$	$8.2 \pm 1.5 \pm 1.2$
$\mathcal{A}_{CP}$	$0.12 \pm 0.11 \pm 0.02$	$-0.16 \pm 0.12 \pm 0.01$



✓ Results in reasonable agreement with theoretical estimates

✖ No evidence for direct *CP* violation

$B \to b_1(1235)h$ (h=K/π)



- $I^G=1^+$ member of $J^{PC}=1^{+-}$ $^1P_1$ nonet
- Reconstruct via $b_1 \to \omega\{\to \pi^+\pi^-\pi^0\}\pi$

arXiv:0707.4561

Mode	Yield	$\mathcal{B}$ $(\times 10^{-6})$	$\mathcal{A}_{CP}$
$b_1^0\pi^+$	178^{+39}_{-37}	$6.7 \pm 1.7 \pm 1.0$	$0.05 \pm 0.16 \pm 0.02$
$b_1^0 K^+$	219^{+38}_{-36}	$9.1 \pm 1.7 \pm 1.0$	$-0.46 \pm 0.20 \pm 0.02$
$b_1^\mp\pi^\pm$	387^{+41}_{-39}	$10.9 \pm 1.2 \pm 0.9$	$-0.05 \pm 0.10 \pm 0.02$
$b_1^- K^+$	267^{+33}_{-32}	$7.4 \pm 1.0 \pm 1.0$	$-0.07 \pm 0.12 \pm 0.02$

✓ π modes consistent with naïve factorization

✖ b_1K values smaller than predicted ➡ need theoretical fine-tuning

Laporta et al., PRD 74, 054035 hep-ph/0602243

✓ $$\frac{\mathcal{B}(B^0 \to b^+\pi^-)}{\mathcal{B}(B^0 \to b^-\pi^+)} = -0.01 \pm 0.12$$ agrees with G-parity suppression

Weinberg, PR 112, 1375 (1958)

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Conclusions and outlook

- Plenty of new measurements in charmless hadronic *B* decays
  - $B^+ \rightarrow K^+K^-\pi^+$ (first observation a three-body final state with even number of kaons)
  - In axialvector (a_1,b_1) and pseudoscalar (K/π) sector, three new measurements and evidence for further three modes
  - Verification of G-parity suppression in a *B*-meson decay
  - Several results are updated with greater precision

- Probing Standard Model in two orthogonal directions
  - Weak interaction (CKM physics) by measuring angles β, α

    ♠ See the following talk by Sandrine Emery
  - Strong interaction (low energy spectroscopy) in the decays involving $f_x(1500)$ *etc.*

- Look forward to the last run that along with run 6 would double the dataset ➡ crucial for many rare decays