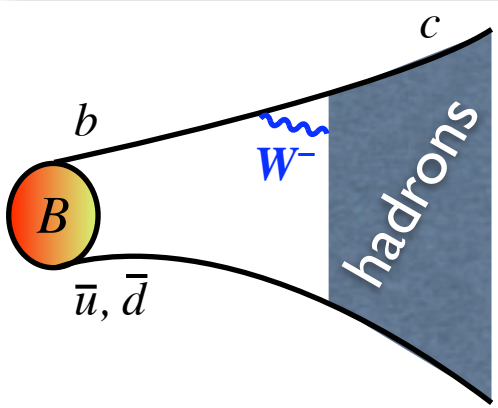


Hadronic $b \to c$ decays at BABAR

Tae Min Hong

University of California, Santa Barbara

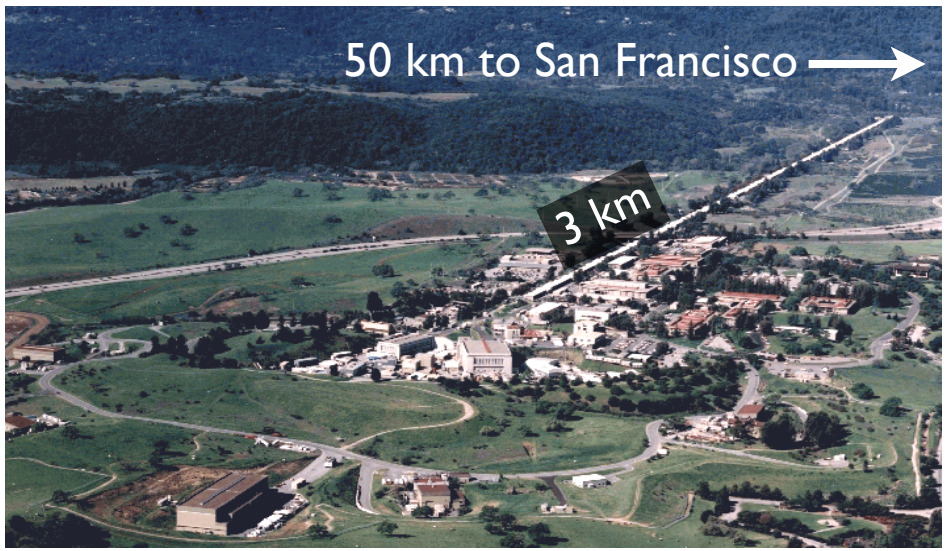
Representing the BABAR Collaboration

- Study of $B \to D^{(*)} p\bar{p}$, $D^{(*)} p\bar{p}\pi$, $D^{(*)} p\bar{p}\pi\pi$
- Study of $B^- \to D^+ \pi^- \pi^-$ and D_0^{*0}, D_2^{*0}

The 2009 Europhysics Conference on High Energy Physics

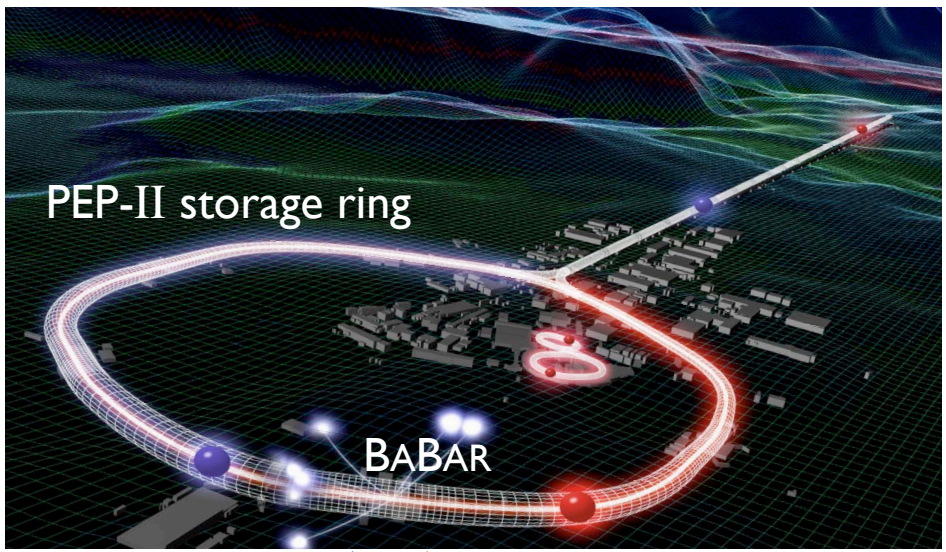
Krakow, Poland

PEP-II and BABAR

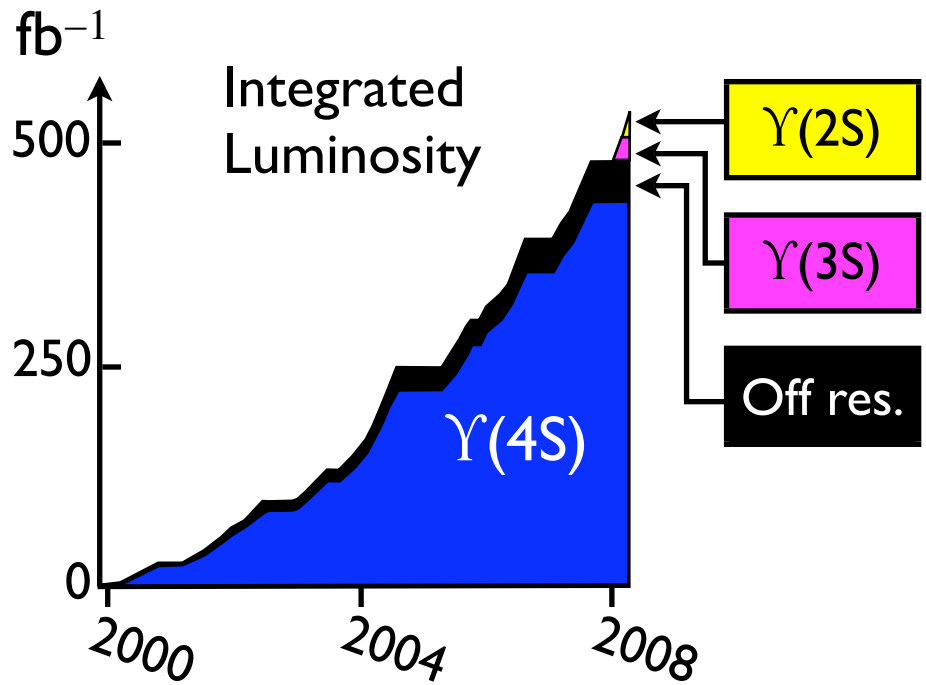


SLAC National Accelerator Laboratory

$\sqrt{s}$	fb^{-1}	Events
$\Upsilon(4S)$	433	475 M $B\bar{B}$
Off res.	54	
$\Upsilon(3S)$	30	122 M
$\Upsilon(2S)$	14	110 M
Total	531	



$\sqrt{s} = 10.58$ GeV



BABAR has good **p**, E resolution, and particle id.

EM calorimeter 6580 CsI (Tl) crystals

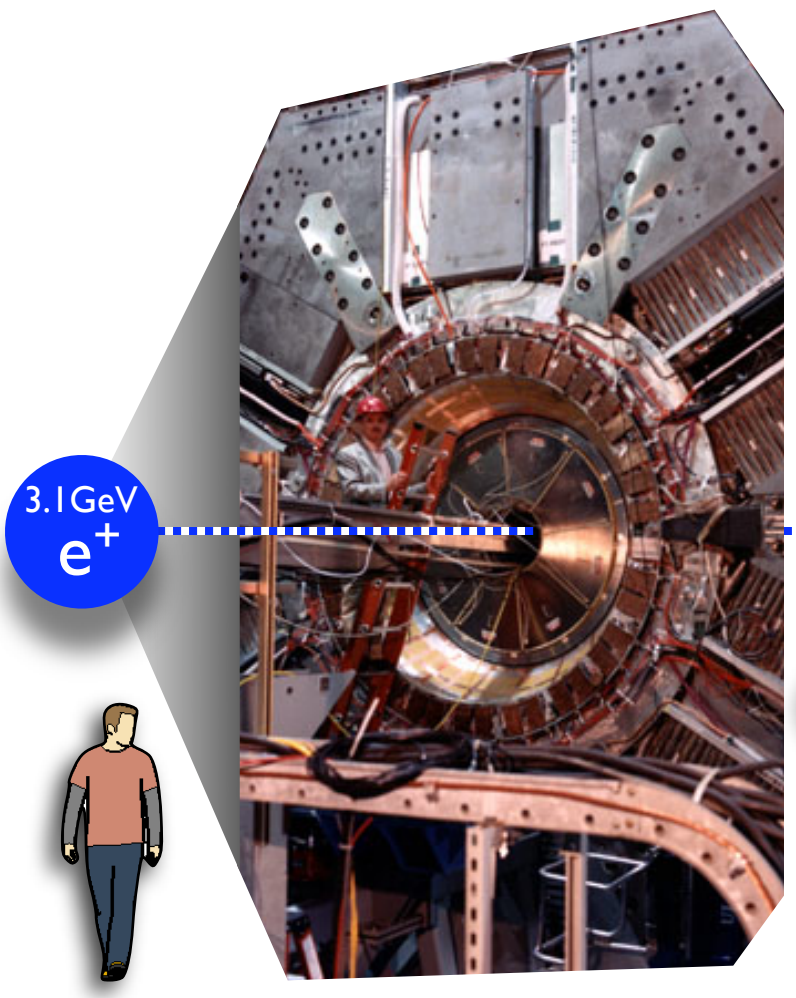
RPC / LST flux return (μ, K_L)

Cherenkov light detector 144 quartz bars, 11000 PMTs

Solenoid 1.5 T magnetic field

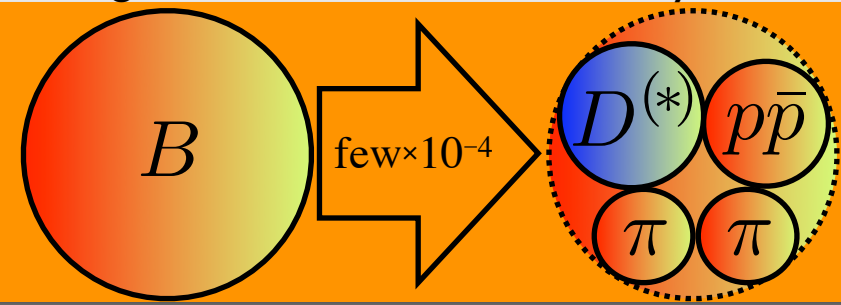
Drift chamber 40 layers

Silicon vertex tracker 5 layers, 2-sided strips

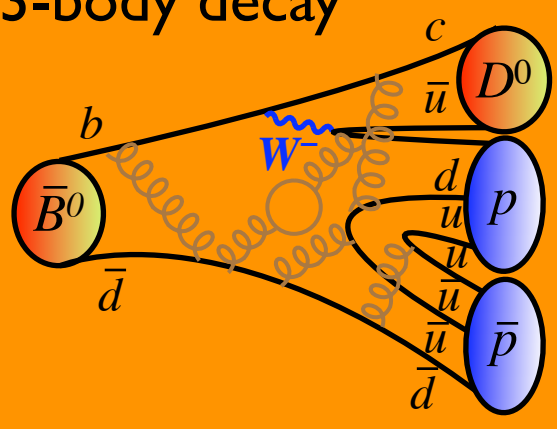


Study of baryonic B decays

$$B \to D^{(*)} p\bar{p},\ D^{(*)} p\bar{p}\pi,\ D^{(*)} p\bar{p}\pi\pi$$



3-body decay



Using 455M $B\bar{B}$ pairs

PRL **86** 2732 (01)
PRL **89** 151802 (02)
PRD **74** 051101 (06)

Decays to D^*	Body	BF (10^{-4})
$\bar{B}^0 \to D^0 p\bar{p}$	3	1.1 ± 0.1
$\bar{B}^0 \to D^{*0} p\bar{p}$		1.0 ± 0.1
$\bar{B}^0 \to D^+ p\bar{p}\pi^-$	4	3.4 ± 0.3
$\bar{B}^0 \to D^{*+} p\bar{p}\pi^-$		4.8 ± 0.5
$B^- \to D^0 p\bar{p}\pi^-$		No prev. meast.
$B^- \to D^{*0} p\bar{p}\pi^-$		No prev. meast.
$\bar{B}^0 \to D^0 p\bar{p}\pi^-\pi^+$	5	No prev. meast.
$\bar{B}^0 \to D^{*0} p\bar{p}\pi^-\pi^+$		No prev. meast.
$B^- \to D^+ p\bar{p}\pi^-\pi^+$		No prev. meast.
$B^- \to D^{*+} p\bar{p}\pi^-\pi^+$		No prev. meast.

- Do these br. fractions follow a pattern?
- Do these show interesting decay dynamics?

Theory references

BF is large!	Dunietz.....	PRD **58** 0556	(98)
Curr. model	Chua, Hou, Tsai..	PRD **65** 034003	(02)
Pole model	Cheng, Yang.....	PRD **66** 094009	(02)
Fragment.	Rosner.....	PRD **68** 014004	(03)
5-quark	Jaffe, Wilczek.....	PRL **91** 232003	(03)
4-quark	Rosner.....	PRD **69** 094014	(04)
Pole model	Cheng.....	JMP-A **21** 4209	(06)
Pole model	Cheng, et al.....	PRD **78** 054016	(08)

Four modes: $\overline{B}^0 \to D^{(*)} p\bar{p}, D^{(*)} p\bar{p}\pi$

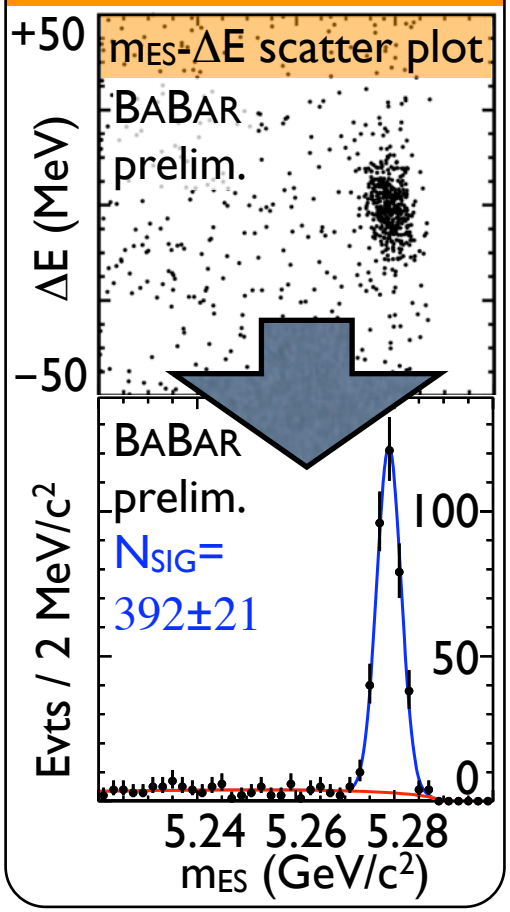
Instead of m = $\sqrt{E_B^2 - \mathbf{p}_B^2}$, utilize beam energy

$\Delta E = E_B - \sqrt{\frac{s}{4}}$ & $m_{ES} = \sqrt{\frac{s}{4} - \mathbf{p}_B^2}$

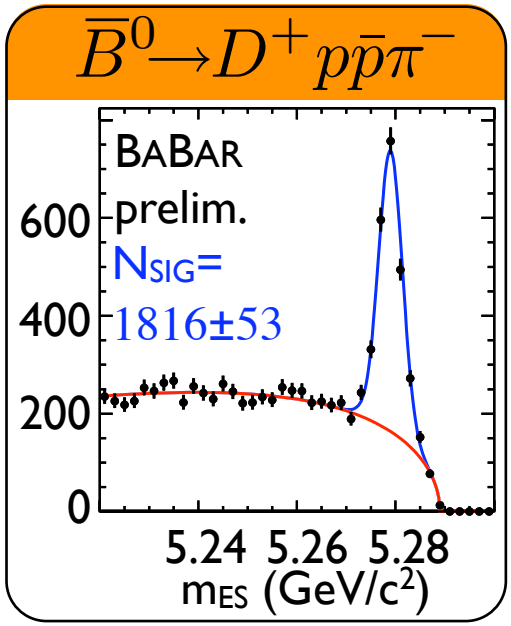
B candidate and beam energy difference

Beam-energy-substituted mass

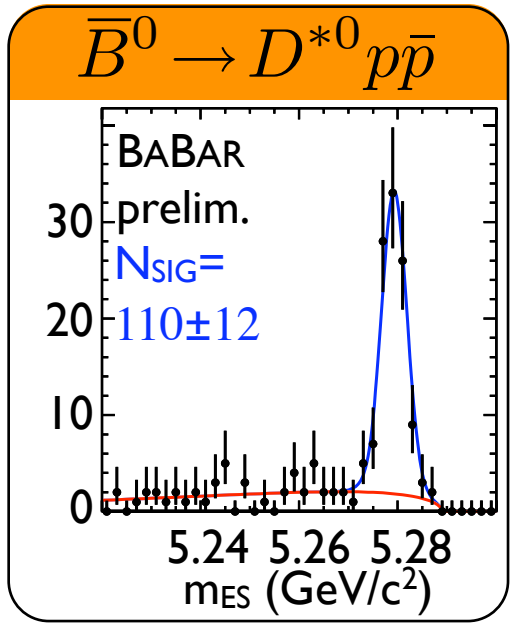
$\overline{B}^0 \to D^{*+} p\bar{p}\pi^-$



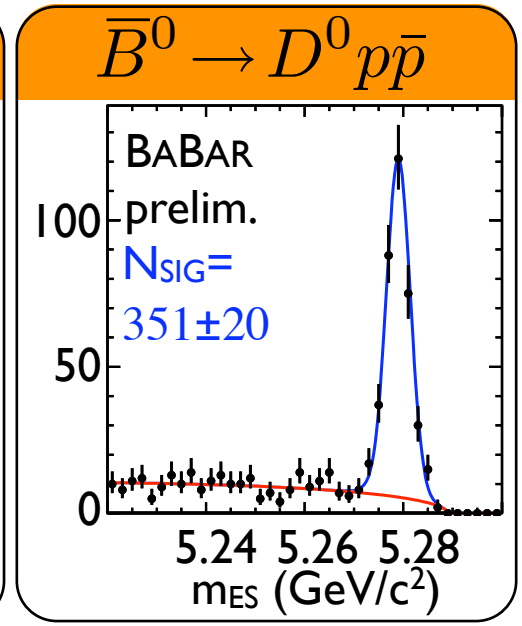
$\overline{B}^0 \to D^{+} p\bar{p}\pi^-$



$\overline{B}^0 \to D^{*0} p\bar{p}$



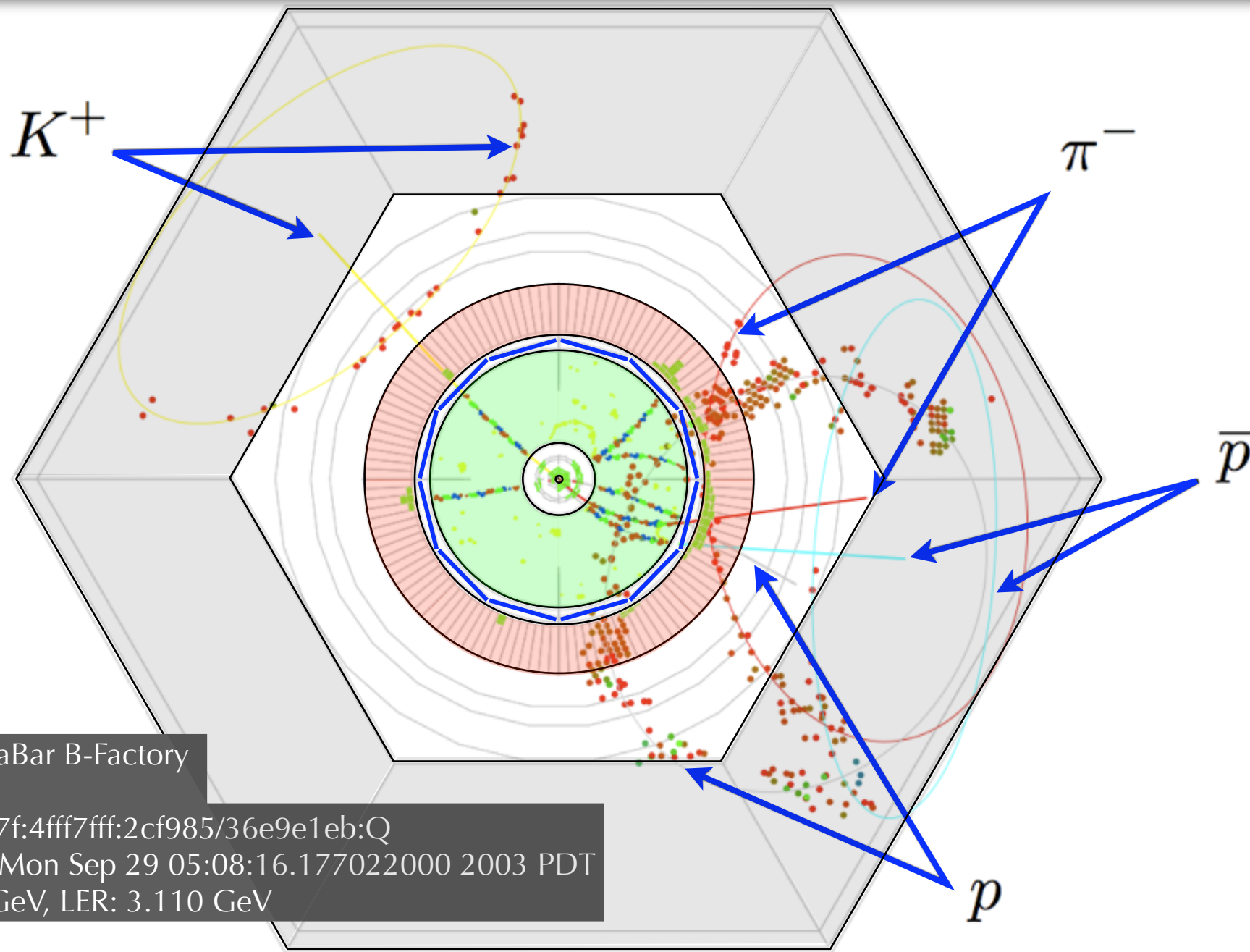
$\overline{B}^0 \to D^{0} p\bar{p}$



Show $D^{*0} \to D^0\pi^0$ $D^{*+} \to D^0\pi^+$ $D^0 \to K^-\pi^+$ $D^+ \to K^-\pi^+\pi^+$

For the study, also reconstruct $K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+$

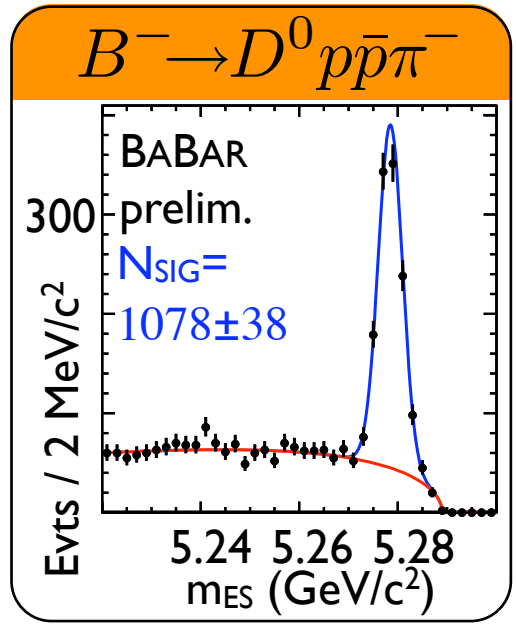
BABAR event display of $B^0 \to \overline{D}^0 p\bar{p}$, $\overline{D}^0 \to K^+\pi^-$

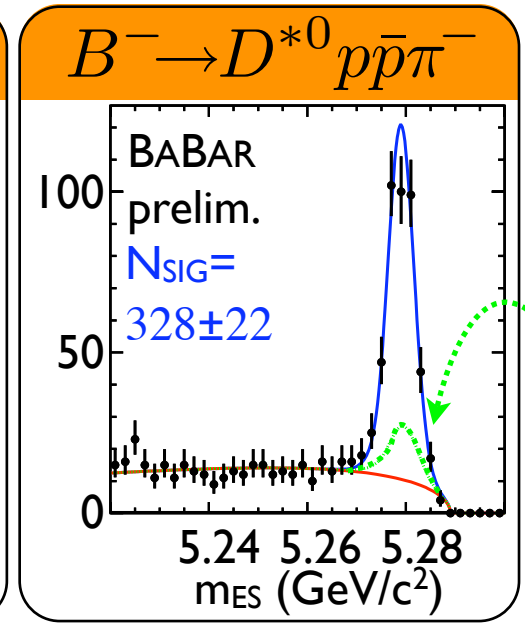


Six NEW modes: $B \to D^{(*)} p\bar{p}\pi, D^{(*)} p\bar{p}\pi\pi$

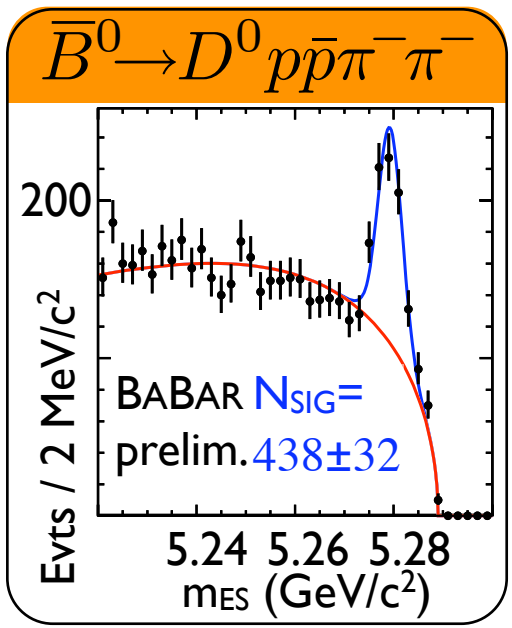
4 body

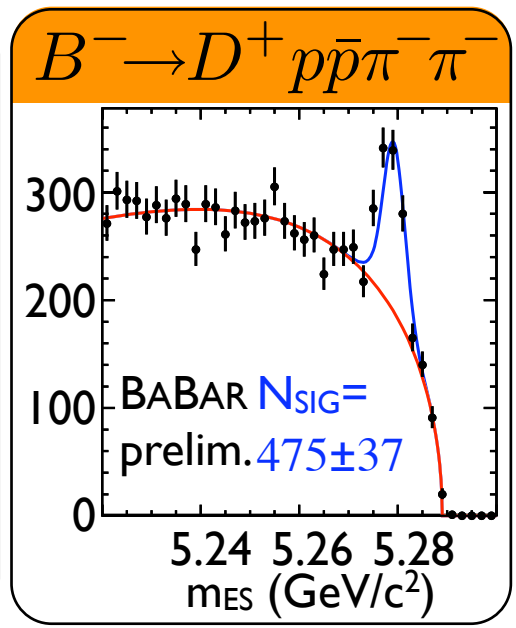
5 body

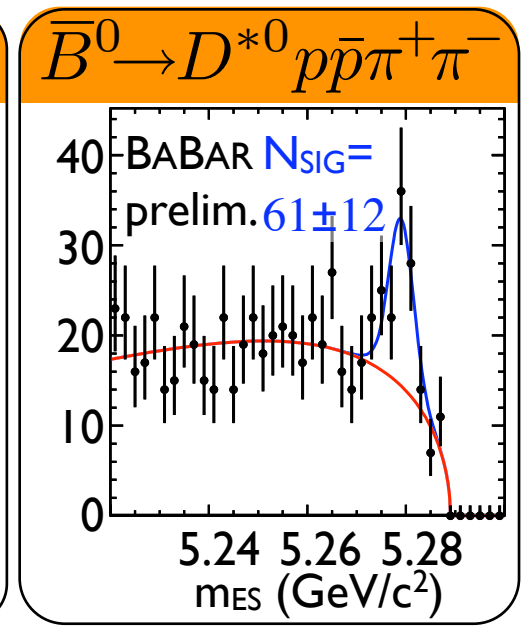


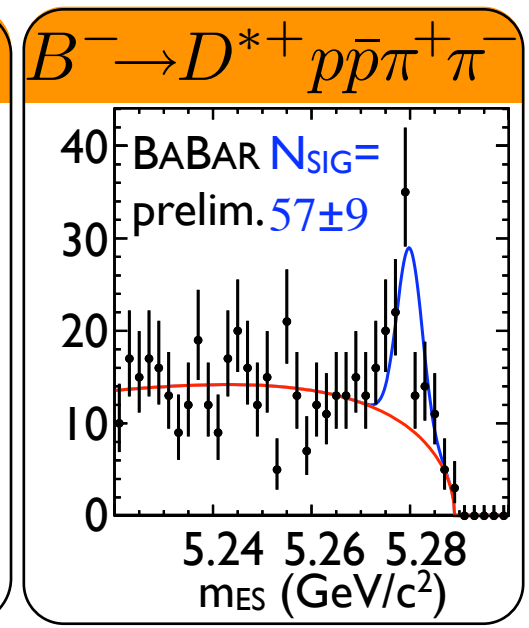


Peaking background from $\bar{B}^0 \to D^{*+} p\bar{p}\pi^-$ unique to this mode



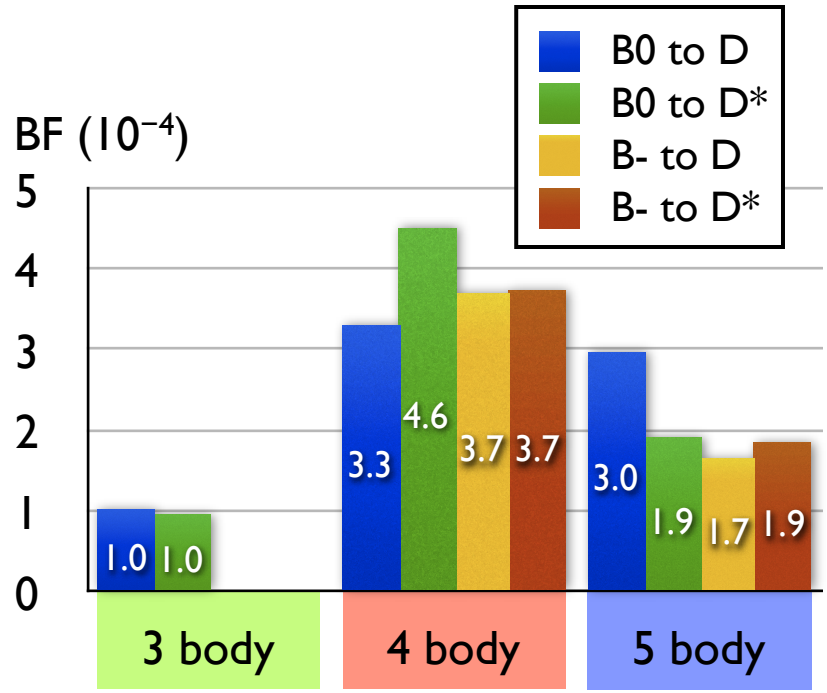






Branching fractions

N-body	Decay	BF±stat±syst (10^{-4})	N_{sig}
3	$\bar{B}^0 \to D^0 p\bar{p}$	1.02 ± 0.04 ± 0.05	1230
	$\bar{B}^0 \to D^{*0} p\bar{p}$	0.97 ± 0.07 ± 0.08	353
4	$\bar{B}^0 \to D^+ p\bar{p}\pi^-$	3.32 ± 0.10 ± 0.27	1816
	$\bar{B}^0 \to D^{*+} p\bar{p}\pi^-$	4.55 ± 0.16 ± 0.37	1371
	$B^- \to D^0 p\bar{p}\pi^-$	3.72 ± 0.11 ± 0.23	1871
	$B^- \to D^{*0} p\bar{p}\pi^-$	3.73 ± 0.17 ± 0.40	366
5	$\bar{B}^0 \to D^0 p\bar{p}\pi^-\pi^+$	2.99 ± 0.21 ± 0.44	3550
	$\bar{B}^0 \to D^{*0} p\bar{p}\pi^-\pi^+$	1.91 ± 0.36 ± 0.30	1153
	$B^- \to D^+ p\bar{p}\pi^-\pi^-$	1.66 ± 0.13 ± 0.27	475
	$B^- \to D^{*+} p\bar{p}\pi^-\pi^-$	1.86 ± 0.16 ± 0.19	217



In red are new observations

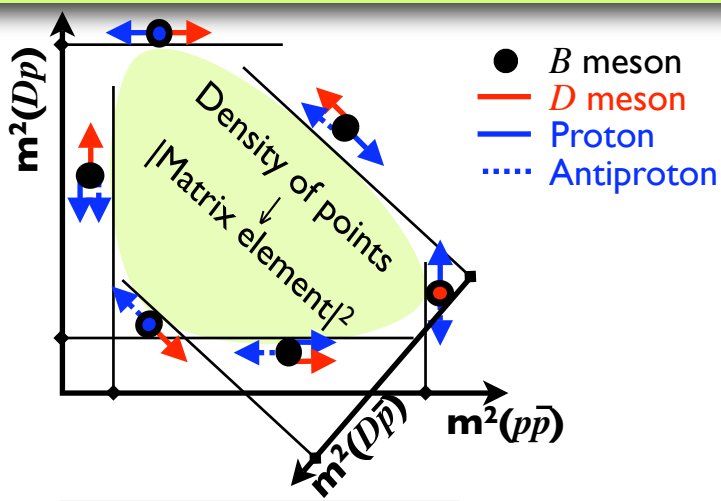
This column gives the signal sample size

Why is 4-body BF so large?

Let's look at kinematic distributions.

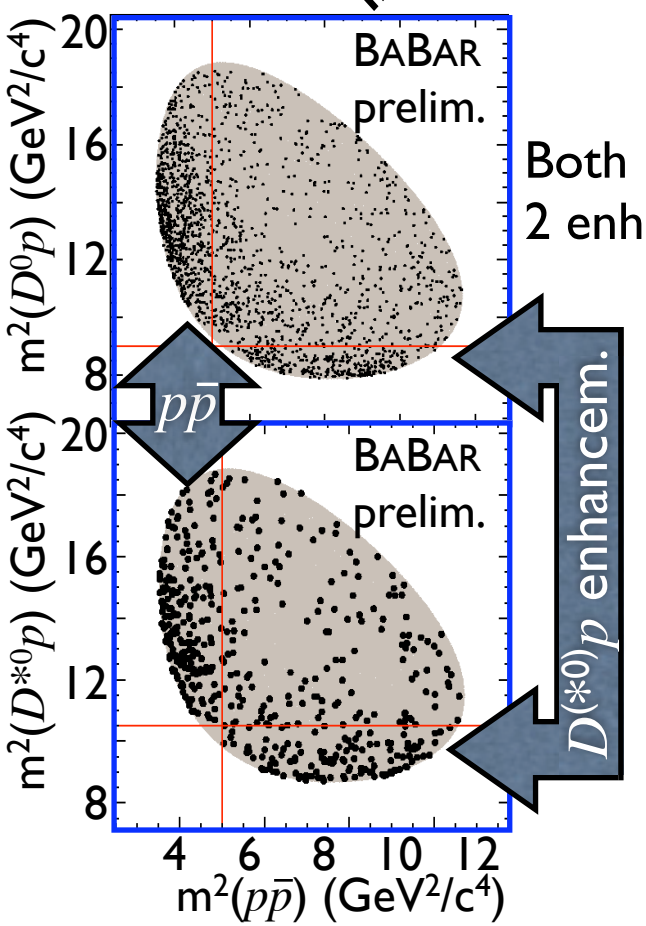
3-body decays

Dalitz plot meaning



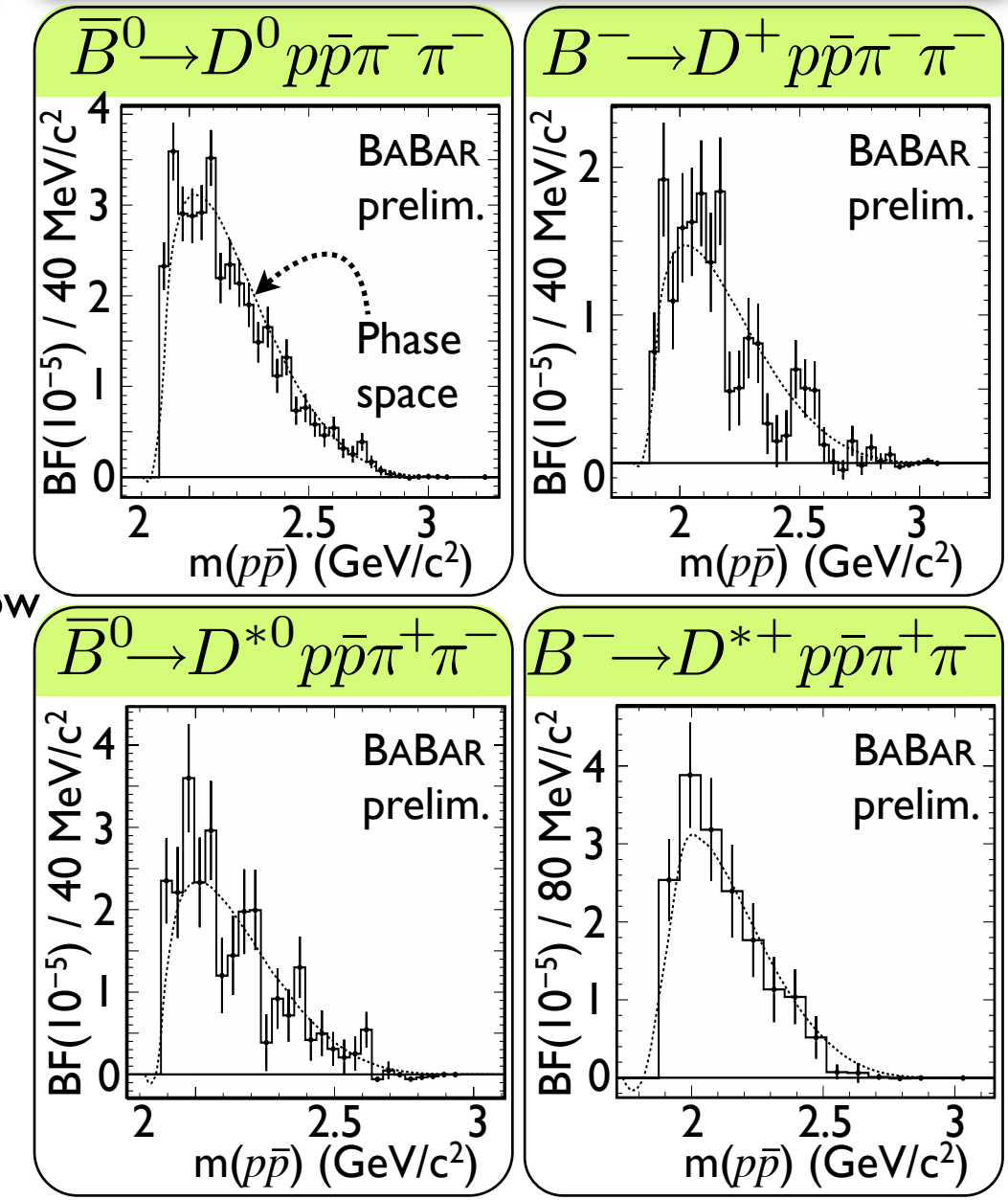
$\overline{B}^0 \to D^0 p\bar{p}$

$\overline{B}^0 \to D^{*0} p\bar{p}$



Both 3-body show 2 enhancements

5-body decays



This and other 5-body distributions are similar to phase space expectations.

4-body decay $\overline{B}^0 \to D^+ p \bar{p} \pi^-$

Like-sign

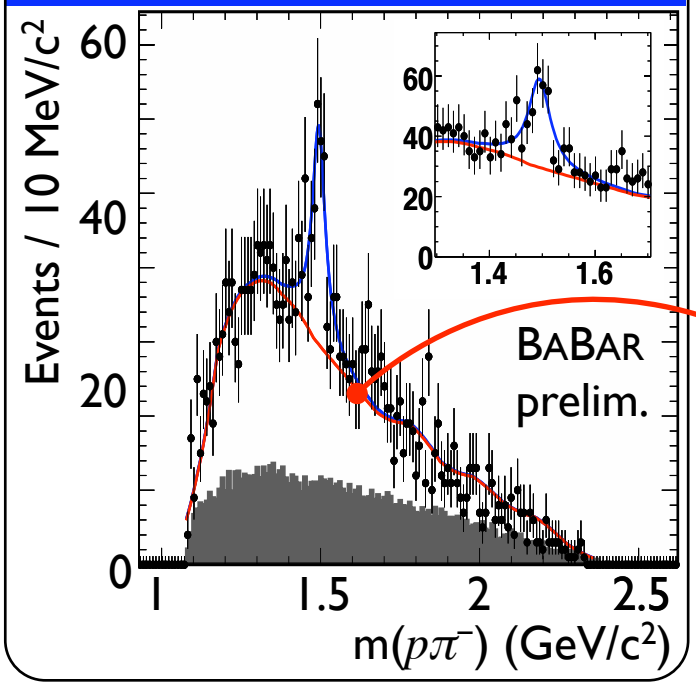
Opposite-sign

Fit opposite-sign sample with Background pdf + floating B-W

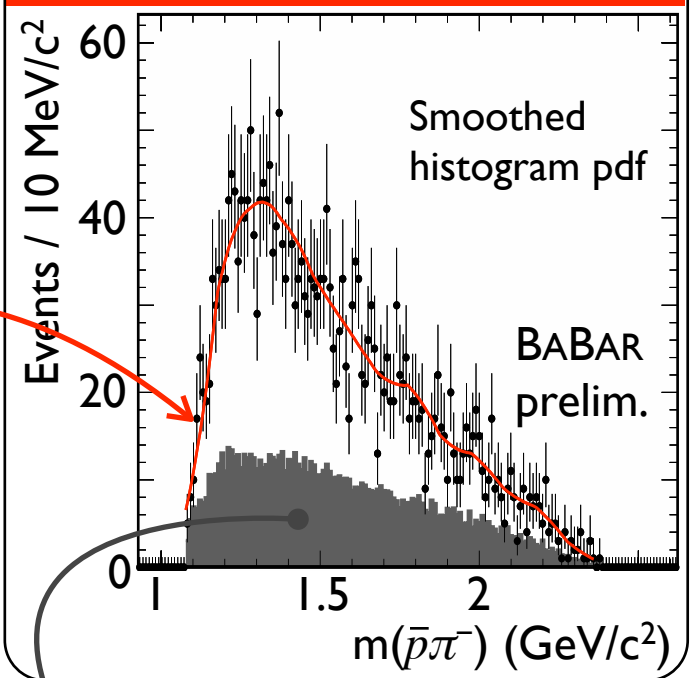
Use like-sign sample to get Background pdf only

Fit opposite-sign sample with Background pdf + 4 known N^*

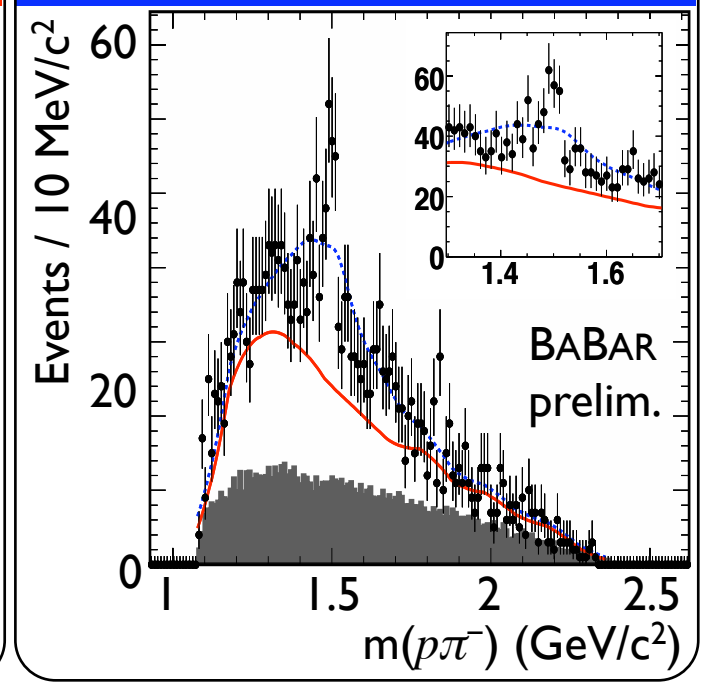
Opposite-sign fit



Like-sign distribution



OS alternate fit



Scaled M_{ES}-ΔE sideband

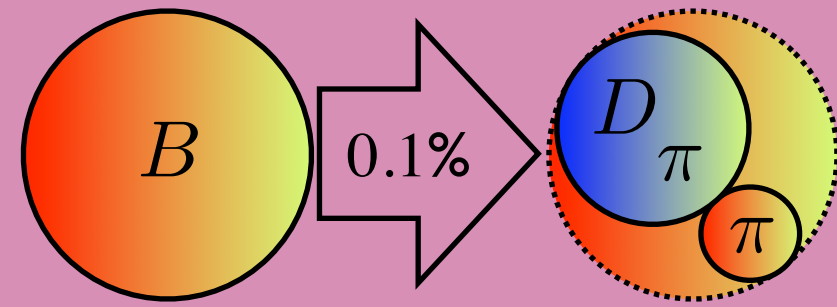
Stat. signif.	$\sqrt{2\Delta L} = 8.6$
Mass	$1494 \pm 4 \pm 2$
Width	$51 \pm 18 \pm 12$

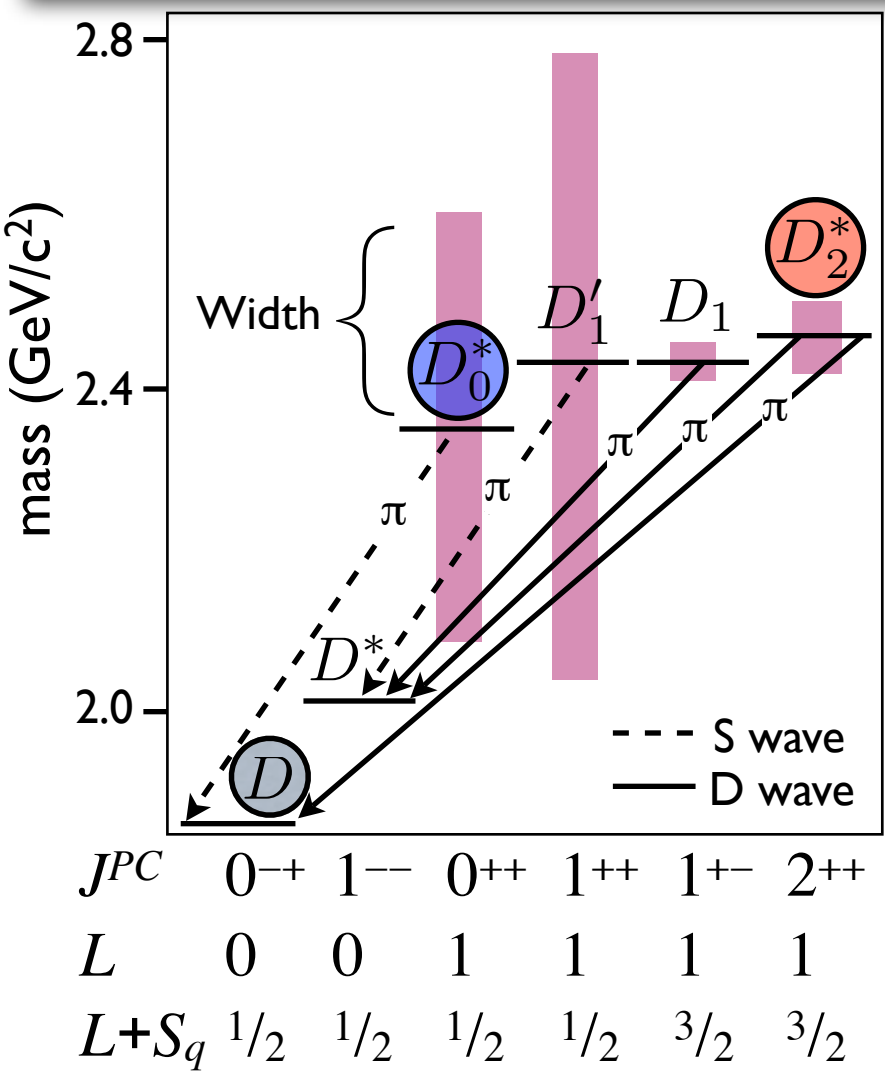
MeV/c² stat syst

Much wider than resol'n.

Detector resolution < 4 MeV/c²

BF & Dalitz plot study of $B^- \to D^+\pi^-\pi^-$ $\hookrightarrow K^-\pi^+\pi^+$





PDG: PL-B **667** 1 (08)

D_J states test HQET predictions

Isgur, Wise..PL-B **232** 113 (89)
Neubert..... PR **245** 259 (94)

J^P allows $D^*_{0,2} \to D\pi$, not D_1, D_1'

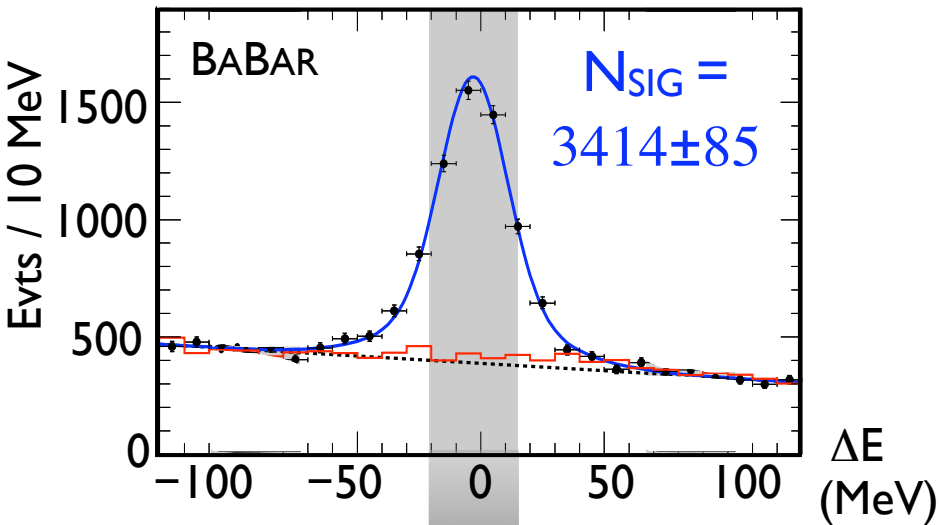
chg
L
D_0^{*0} not yet confirmed in PDG
J

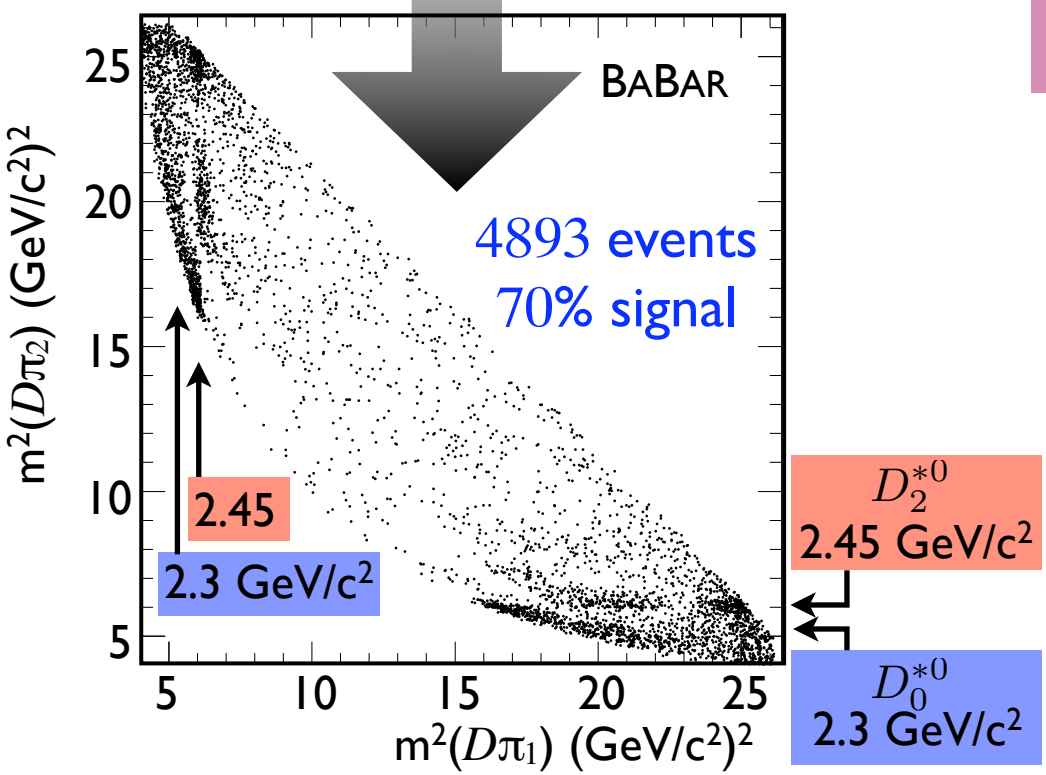
Expt.	m(D_0^{*0})
FOCUS, γA	2407±21±35
Belle, 60 fb^{-1}	2308±17±32
This, 343 fb^{-1}	2297± 8±20

PL-B **586** 11 (04)
PRD **69** 112002 (04)
PRD **79** 112004 (09)

MeV/c² stat syst

$B^- \to D^+\pi^-\pi^-$ BF & Dalitz plot analysis





Branching fraction analysis

	BF (10^{-3})
This 343 fb^{-1}	1.08±0.03±0.05
Belle 60 fb^{-1}	1.02±0.04±0.15
	stat syst

Dalitz plot analysis

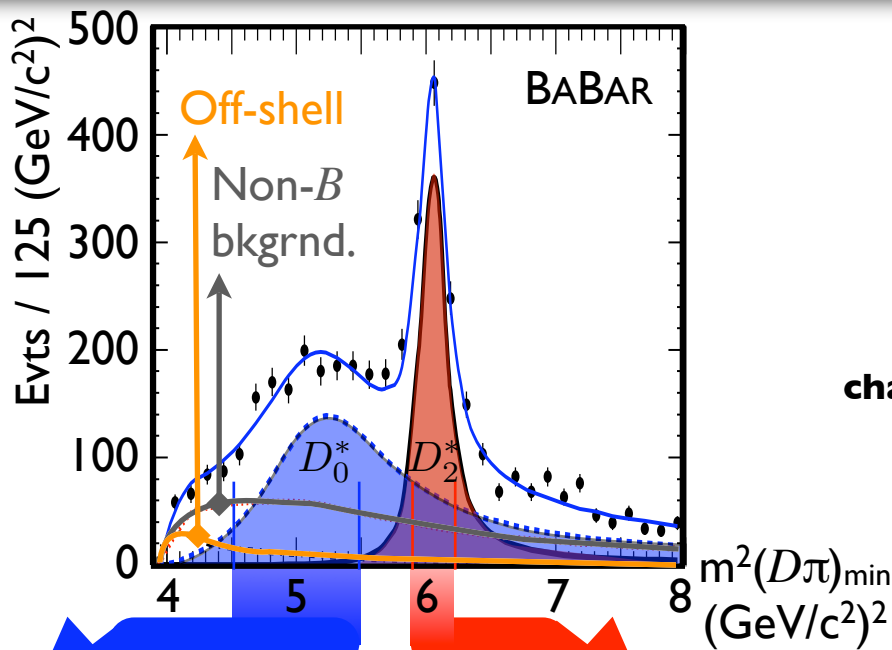
Use 2-D isobar model for signal B

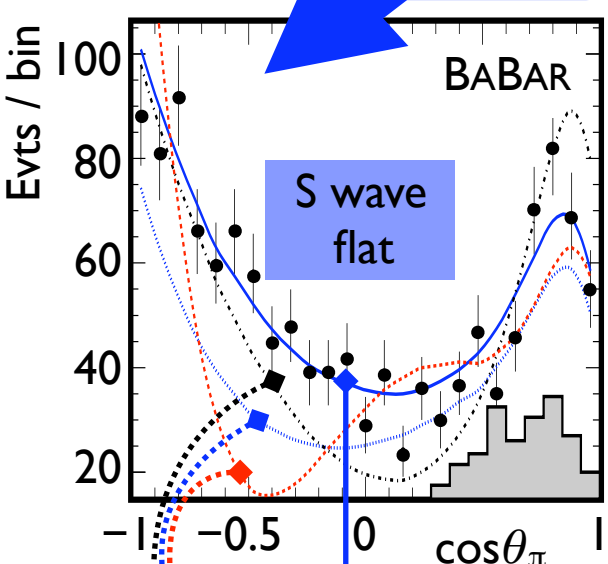
$$\mathfrak{M} = \sum_{\text{Res}} e^{i\phi} R + \sum_{\text{Nonres}} e^{i\varphi} N$$

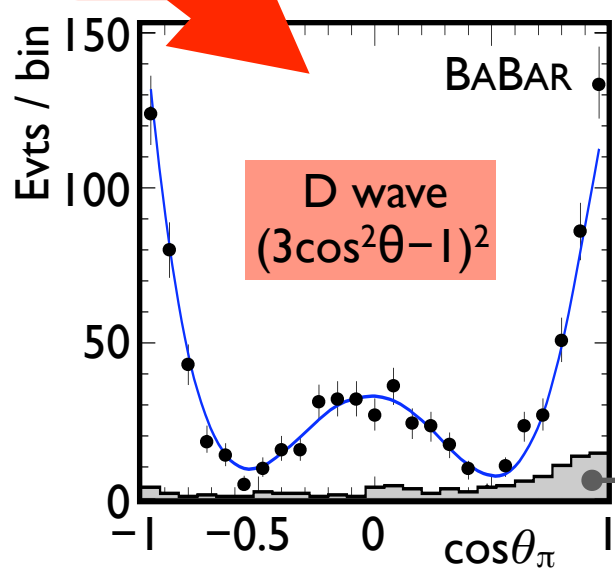
Breit-Wigner × angular for D_J & Off-shell $D^*(2007)$ $B^*(5325)$

Nonresonant B signal

D_J resonances in $B^- \to D^+\pi^-\pi^-$







Dark blue line includes s-wave D_0^{*0}.

Dotted lines do not include D_0^{*0}.

Non-B background

Mass and width

D_0^{*0}: m = 2297± 8± 5±19 MeV/c²
Γ = 273±12±17±45 MeV
stat syst model

charge
L
J

D_2^{*0}: m = 2460.4±1.2±1.2±1.9 ″
Γ = 41.8±2.5±2.1±2.0 ″
stat syst model

Product branching fractions

D_0^{*0}: $\mathcal{B}(B\to D_0^*\pi)\times\mathcal{B}(D_0^*\to D\pi)$
$= (6.8\pm0.3\pm0.4\pm2.0)\times10^{-4}$
stat syst model

D_2^{*0}: $\mathcal{B}(B\to D_2^*\pi)\times\mathcal{B}(D_2^*\to D\pi)$
$= (3.5\pm0.2\pm0.2\pm0.4)\times10^{-4}$
stat syst model

Summary

- Study of $B \to D^{(*)} p\bar{p}$, $D^{(*)} p\bar{p}\pi$, $D^{(*)} p\bar{p}\pi\pi$

BF of ten decays (six are new observations)
BF pattern shows 3-body < 5-body < 4-body

3-body: Threshold enhancement $D^{(*)}p$, $p\bar{p}$
5-body: Similar to phase space expectations
4-body: Narrow $p\pi^-$ peak near 1.5 GeV/c²

PRD in preparation

- Study of $B^- \to D^+ \pi^- \pi^-$ and D_0^{*0}, D_2^{*0}

BF is 3x improvement of prev. result
Measure D_0^{*0}, D_2^{*0} mass, width, & spin
Confirmation of the D_0^{*0} state

PRD **79** 112004 (09)