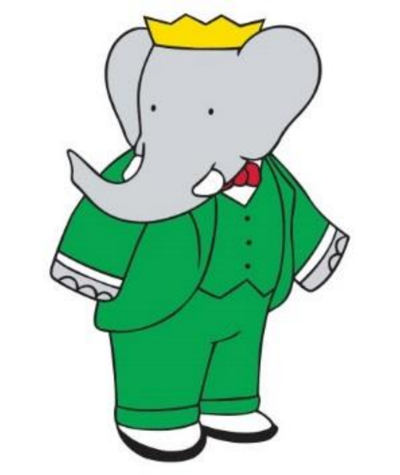
Study of $B \to K\pi\pi\gamma$ decays



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on behalf of the BaBar Collaboration

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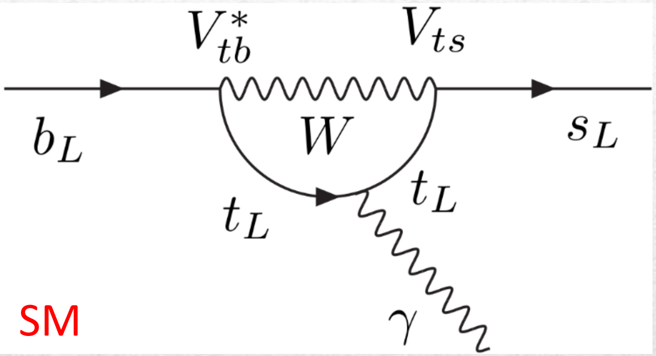
Outline

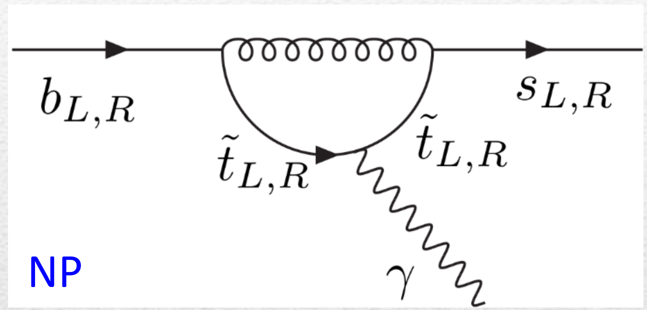
- Analysis Overview
- $B^+ \to K^+\pi^+\pi^-\gamma$ analysis
- Time-dependent $B^0 \to K_S\pi^+\pi^-\gamma$ analysis
- Conclusions

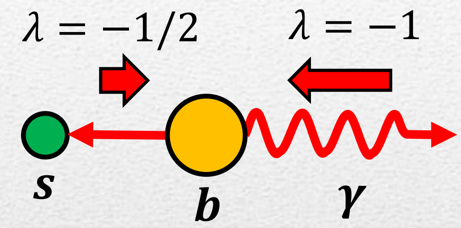
$B \to K\,\pi\pi\,\gamma$: the photon polarization

Radiative decays $b \to s\,\gamma$ (FCNC):

In SM interaction between left-handed (LH) quarks or right-handed (RH) antiquarks







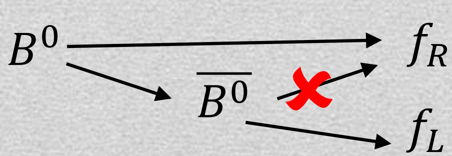
λ = helicity

Predominance of LH photons

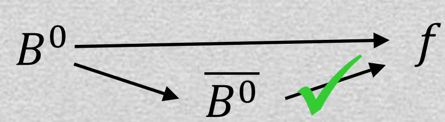
Enhancement of RH photons

Measurement of photon polarization via *CP* asymmetry

$b \to s_L \gamma_L$ or $\bar{b} \to \bar{s}_R \gamma_R$:
No interference, $CPV \sim 0$



$b \to s_{L,R} \gamma_{L,R}$ or $\bar{b} \to \bar{s}_{L,R} \gamma_{L,R}$:
Interference, $CPV \neq 0$

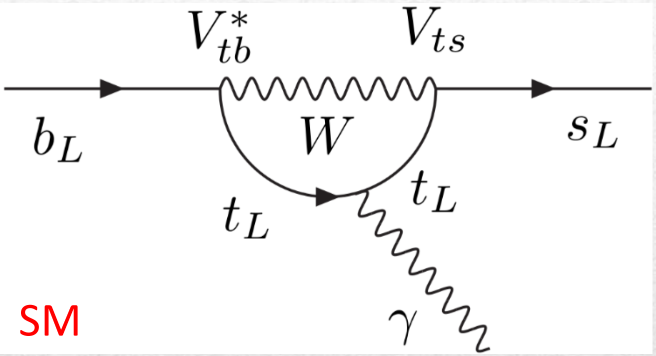


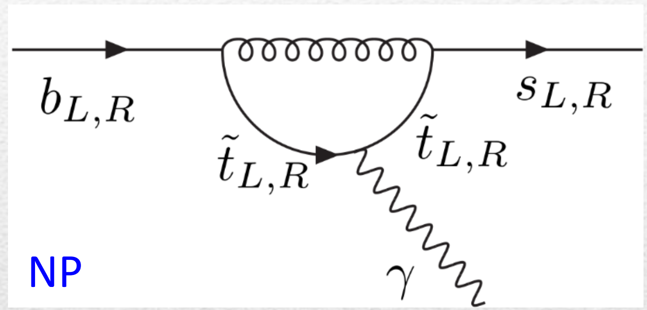
$f = CP$ eigenstate
$B^0 \to K_S\,\rho^0\,\gamma$

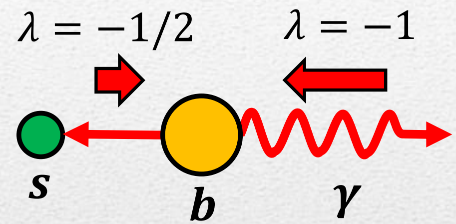
$B \to K\pi\pi\gamma$: the photon polarization

Radiative decays $b \to s\gamma$ (FCNC):

In SM interaction between left-handed (LH) quarks or right-handed (RH) antiquarks







λ = helicity

Predominance of LH photons

Enhancement of RH photons

Measurement of photon polarization via *CP* asymmetry

$$A_{CP}(\Delta t) = \frac{\Gamma(B^0(\Delta t) \to f) - \Gamma(\overline{B^0}(\Delta t) \to f)}{\Gamma(B^0(\Delta t) \to f) + \Gamma(\overline{B^0}(\Delta t) \to f)}$$

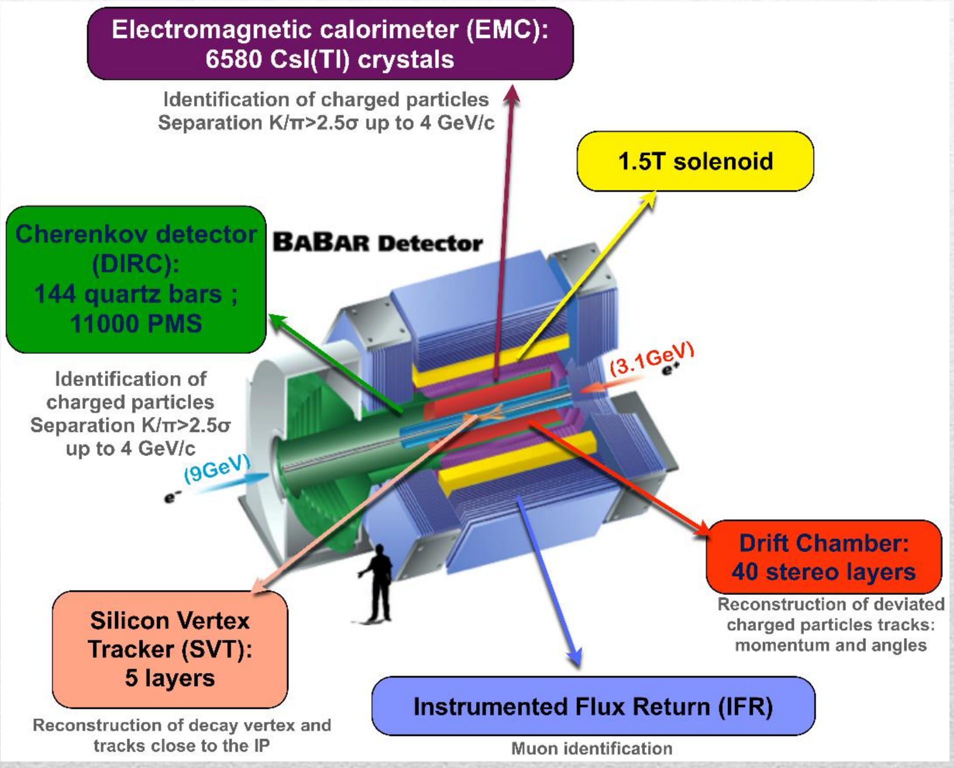
$$= S_{K_S\rho^0\gamma} \sin \Delta m\, \Delta t - C_{K_S\rho^0\gamma} \cos \Delta m\, \Delta t$$

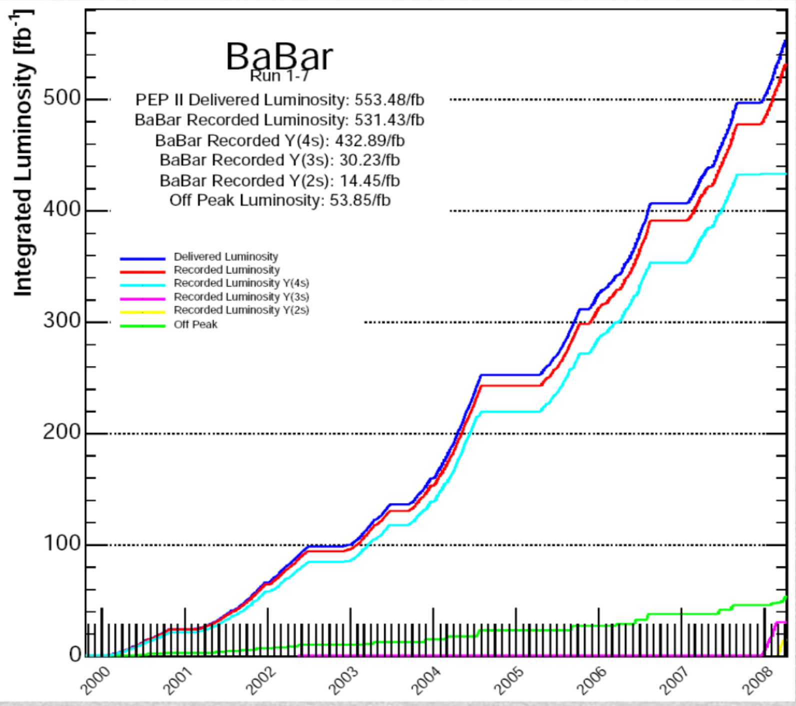
In SM, $S_{K_S\rho^0\gamma} \sim \frac{m_s}{m_b} \sim 0.02$

The BaBar experiment

The Babar detector was located at the interaction point of PEP II at SLAC

Asymmetric e^+e^- collider, mostly at $\sqrt{s} \sim 10.58$ GeV

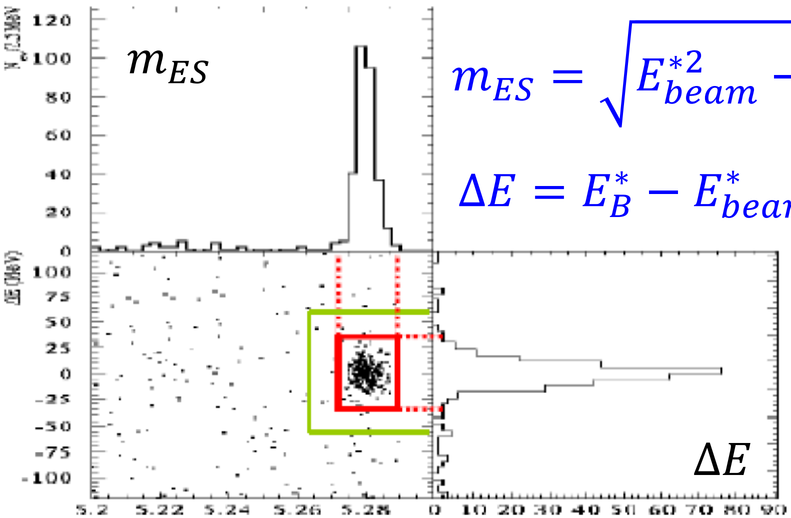




$\int L\,dt \sim 430\ \text{fb}^{-1}$ at the $\Upsilon(4S)$ peak, $470 \times 10^6\ B\bar{B}$ coherent pairs

Common analysis techniques

Kinematics of fully reconstructed B

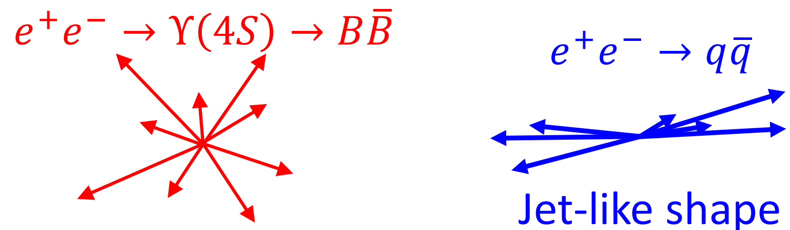


$$m_{ES} = \sqrt{E_{beam}^{*2} - p_B^{*2}}$$

$$\Delta E = E_B^* - E_{beam}^*$$

Background discrimination

Suppression by multi-variable classifiers based on event-shape variables

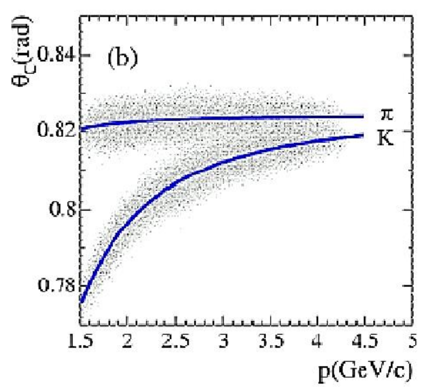


Strongly discriminate continuum events $e^+e^- \to q\bar{q}$ with $q = u, d, s, c$

K/π separation

Very good particle ID

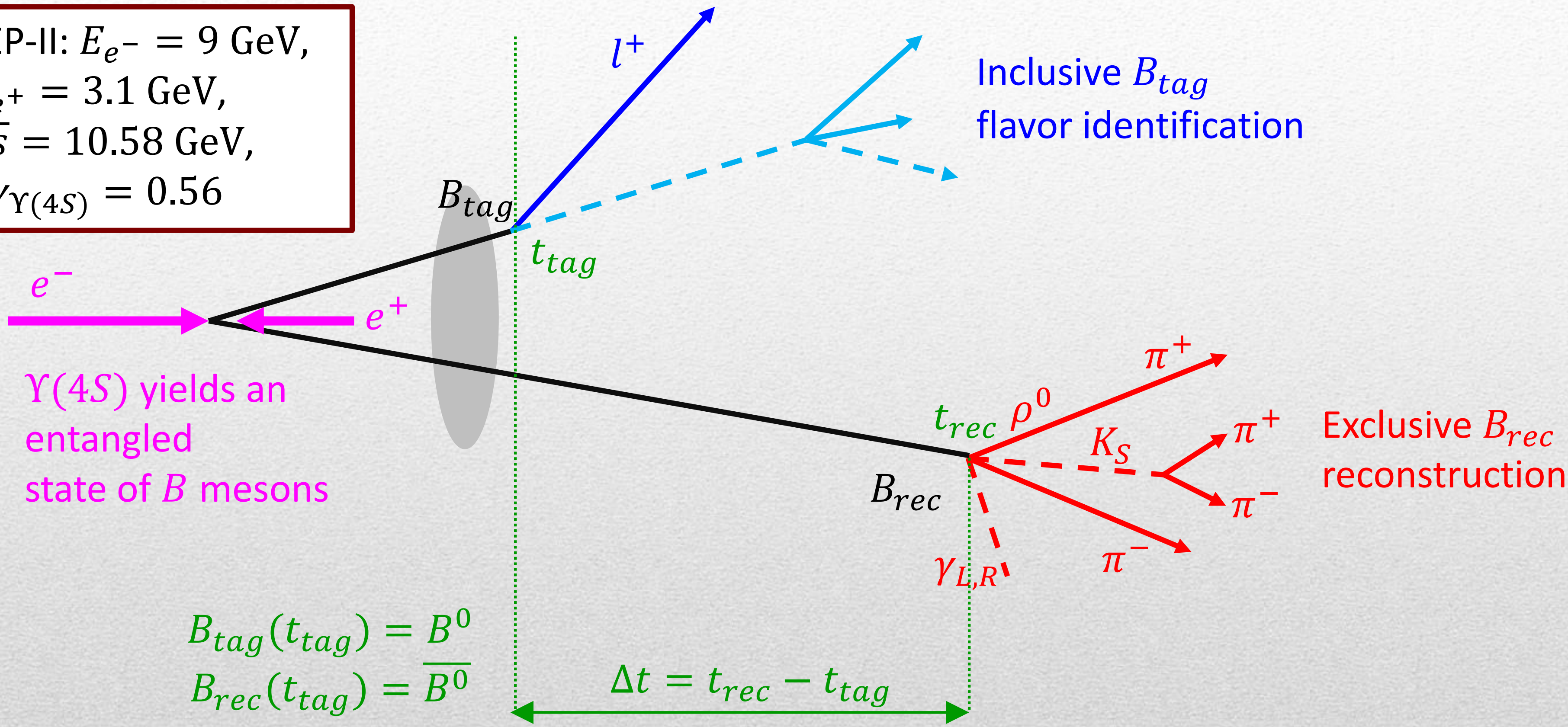
$p \in [1.5, 4]\text{GeV}/c$



Variables are often combined in a likelihood function, used in a maximum likelihood fit for signal/background separation and to measure parameters of interest

Flavor tagging and time-dependent analyses

PEP-II: $E_{e^-} = 9$ GeV,
$E_{e^+} = 3.1$ GeV,
$\sqrt{s} = 10.58$ GeV,
$\beta\gamma_{\Upsilon(4S)} = 0.56$



$$\Delta t = \frac{\Delta z}{\beta\gamma c}, \langle \Delta z \rangle = 257\ \mu\text{m}$$

Good vertexing required for time difference determination

Analysis strategy

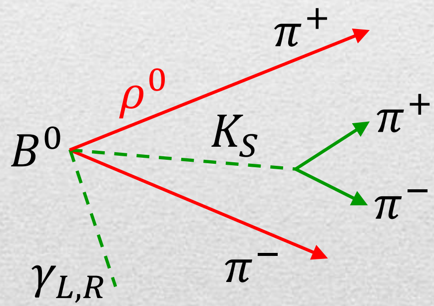
Goal :

- Extract the parameter $S_{K_s\rho\gamma}$ from time-dependent analysis of $B^0 \to K_S\pi^+\pi^-\gamma$ decays

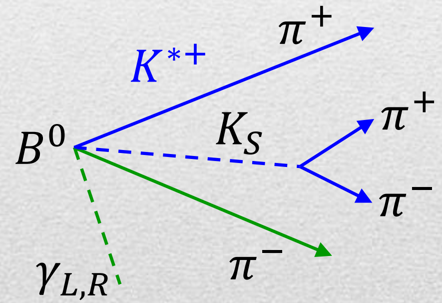
Difficulties :

- rare decay, $BR(B^0 \to K_S\pi^+\pi^-\gamma) = (9.8 \pm 1.1) \times 10^{-6}$
- irreducible contribution from non-*CP* eigenstates diluting the value of $S_{K_s\rho\gamma}$

$$B^0 \to K_S\rho^0(\to \pi^+\pi^-)\gamma$$



$$B^0 \to K^{*+}(\to \pi^+K_S)\pi^-\gamma$$



…

Strategy :

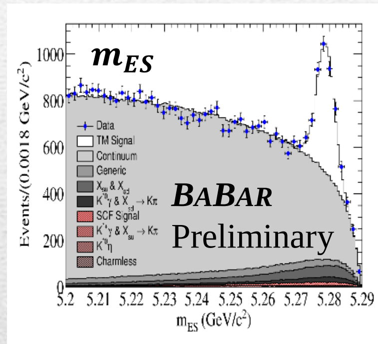
- not enough statistic to measure directly $S_{K_s\rho\gamma}$ via amplitude analysis
- we need to estimate the dilution factor $D_{K_S\rho\gamma} = S_{K_s\pi\pi\gamma}/S_{K_s\rho\gamma}$
- $D_{K_S\rho\gamma}$ is extracted from an amplitude analysis of $B^+ \to K^+\pi^+\pi^-\gamma$ decay using the hypothesis of isospin symmetry

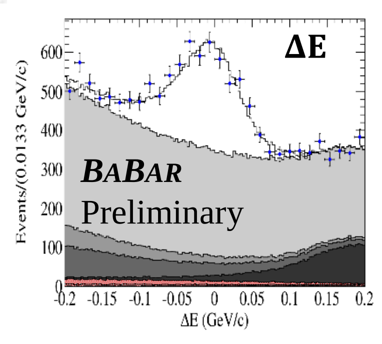
$B^+ \to K^+\pi^+\pi^-\gamma$: strategy

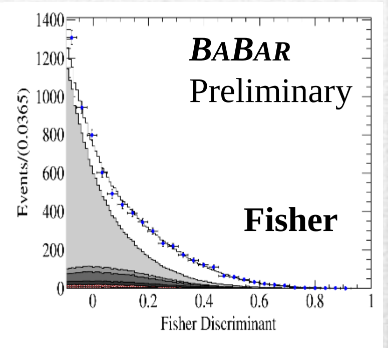
Apply a set of selection criteria to enhance S/B :

- High energy photon: $1.5 < E_\gamma < 3.5$ GeV (select radiative B decays)
- $\pi^0 \to \gamma\gamma$ and $\eta \to \gamma\gamma$ veto
- Event shape variables: different kinematics in $B\bar{B}$ and $q\bar{q}$ events

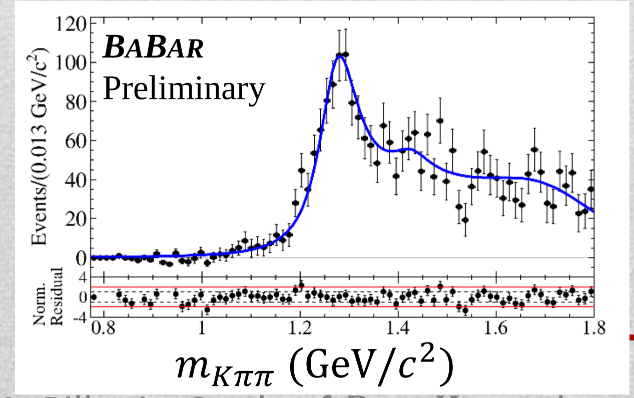
1) 3D ML fit to extract $m_{K\pi\pi}$ and $m_{K\pi}$ signal spectra with $_sPlot$ technique







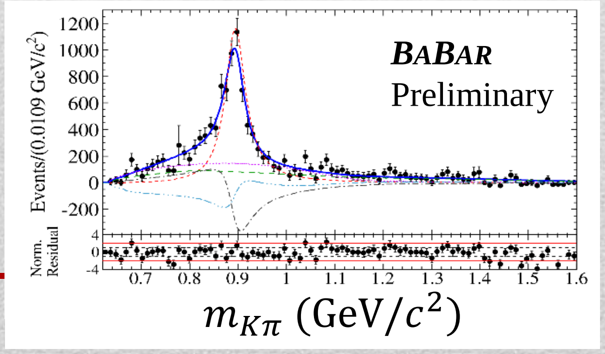
2) Fit to $m_{K\pi\pi}$ spectrum to determine $\mathrm{B} \to K_{res}\,\gamma$ amplitudes and BFs



K_{res} BFs used as input

3) Fit to $m_{K\pi\pi}$ spectrum to determine amplitudes of $K^*(892)$, $\rho^0(770)$,...

4) dilution factor calculation



2) Fit to $m_{K\pi\pi}$

- Five resonances modeled by BW (means and some widths fixed to PDG values)

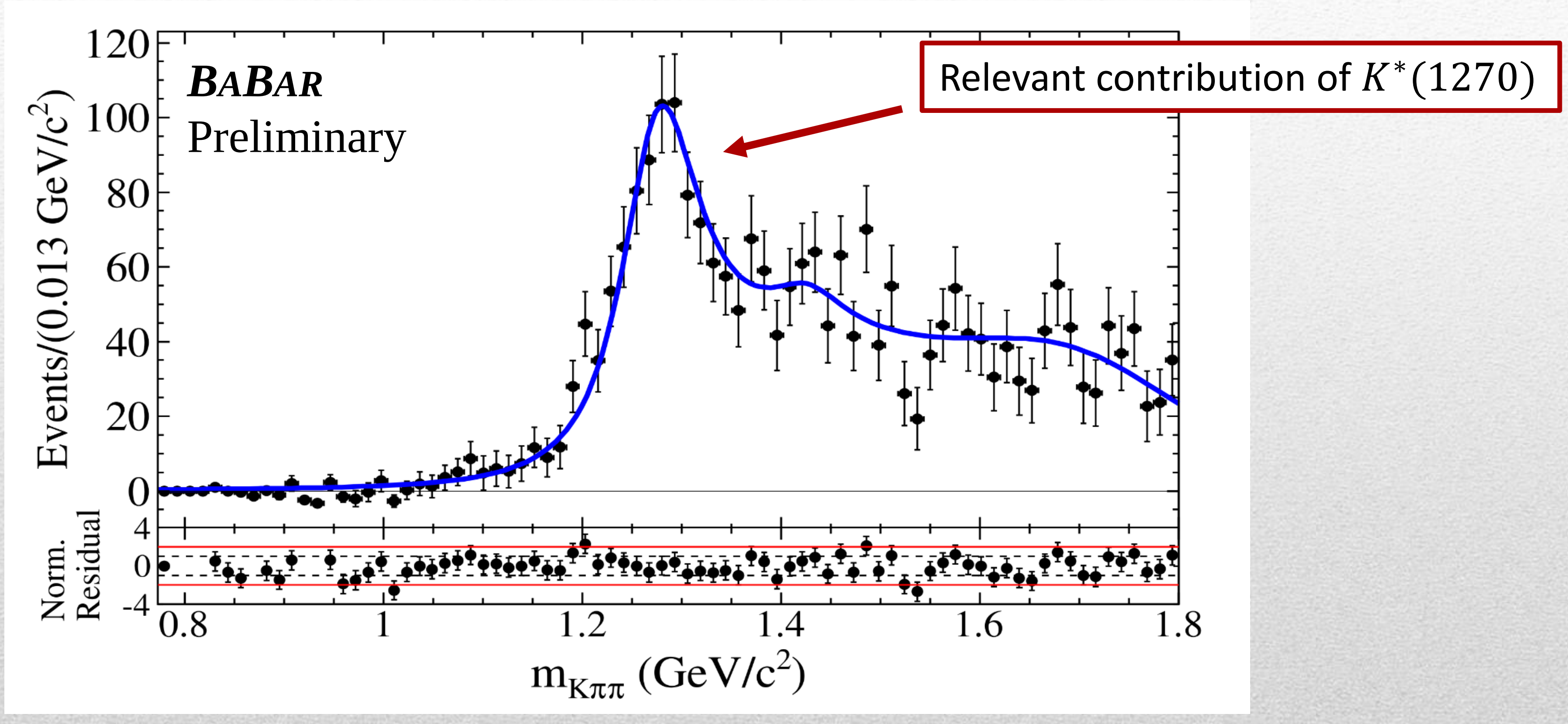
J^P	K_{res}	Mass m^0 (MeV/c^2)	Width Γ^0 (MeV/c^2)
1^+	$K_1(1270)$	1272 ± 7	90 ± 20
	$K_1(1400)$	1403 ± 7	174 ± 13
1^-	$K^*(1410)$	1414 ± 15	232 ± 21
	$K^*(1680)$	1717 ± 27	322 ± 110
2^+	$K_2^*(1430)$	1425.6 ± 1.5	98.5 ± 2.7

$$BW_J(m) = \frac{1}{m_0^2 - m^2 - i\, m_0\, \Gamma_J(m)}$$

$$A(m) = \sum_J \left| \sum_k \alpha_k\, e^{i\phi_k} BW_J(m;k) \right|^2$$

- Fit to $K\pi\pi$ invariant mass ${}_sPlot$ distribution
- 8 fitted parameters:
  - 4 magnitudes, 2 relative phases
  - 2 widths ($K_1(1270)$ and $K^*(1680)$, the lightest and heaviest resonances)
- Due to the integration over the angular variables, only resonances with same J^P interfere
- Randomized initial parameter values
- Fit fractions computed from magnitudes and phases

2) Fit to $m_{K\pi\pi}/2$



$_s Plot$ distribution of $m_{K\pi\pi}$, studied in the region $m_{K\pi\pi} < 1.8$ GeV

2) BF from $m_{K\pi\pi}$

Several of these measurements are the world best (or done for the first time)

Mode	$\mathcal{B}(B^+ \to \text{Mode})\times$ $\mathcal{B}(K_{\text{res}} \to K^+\pi^+\pi^-) \times 10^{-6}$	$\mathcal{B}(B^+ \to \text{Mode}) \times 10^{-6}$	PDG values ($\times 10^{-6}$)
Inclusive $B^+ \to K^+\pi^+\pi^-\gamma$	$\cdots$	$27.2 \pm 1.0^{+1.1}_{-1.3}$	27.6 ± 2.2
$K_1(1270)^+\gamma$	$14.5^{+2.0+1.1}_{-1.3-1.2}$	$44.0^{+6.0+3.5}_{-4.0-3.7} \pm 4.6$	43 ± 13
$K_1(1400)^+\gamma$	$4.1^{+1.9+1.3}_{-1.2-0.8}$	$9.7^{+4.6+3.1}_{-2.9-1.8} \pm 0.6$	< 15 CL$=90\%$
$K^*(1410)^+\gamma$	$9.7^{+2.1+2.4}_{-1.9-0.7}$	$23.8^{+5.2+5.9}_{-4.6-1.4} \pm 2.4$	$\emptyset$
$K_2^*(1430)^+\gamma$	$1.5^{+1.2+0.9}_{-1.0-1.4}$	$10.4^{+8.7+6.3}_{-7.0-9.9} \pm 0.5$	14 ± 4
$K^*(1680)^+\gamma$	$17.0^{+1.7+3.5}_{-1.4-3.0}$	$71.7^{+7.2+15}_{-5.7-13} \pm 5.8$	< 1900 CL$=90\%$

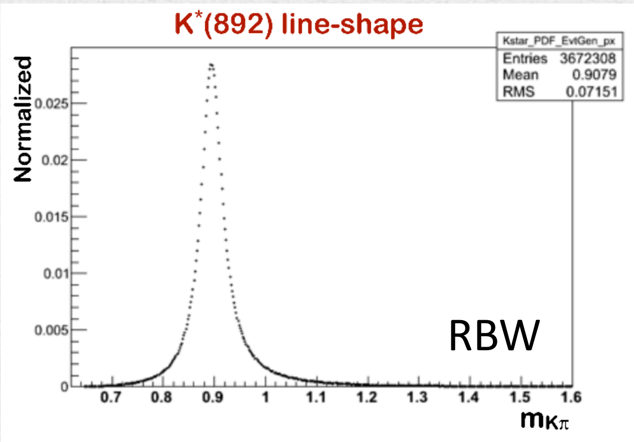
BaBar Preliminary

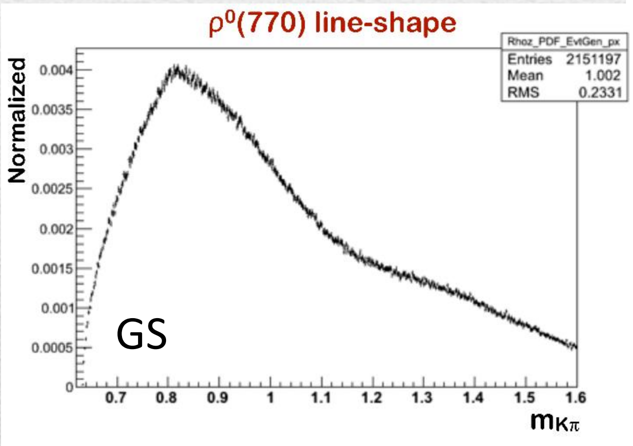
The Fit Fractions enter the S-wave component in $m_{K\pi}$ fit

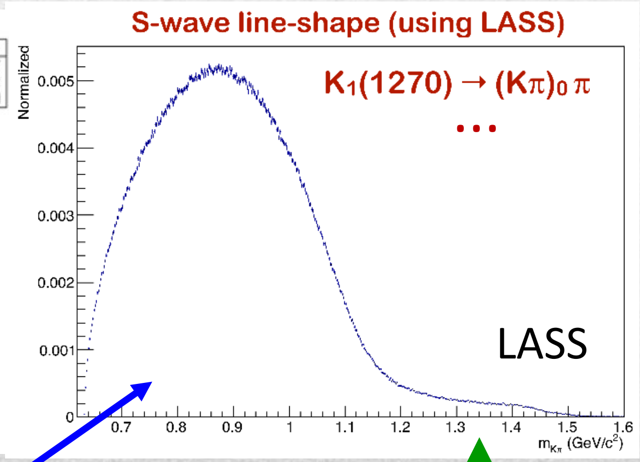
3) Fit to $m_{K\pi}$

Ideally, extraction of the dilution factor with a full amplitude analysis in $m_{K\pi} - m_{\pi\pi}$, but the sample is too small!

Instead: perform a one-dimensional fit to signal $m_{K\pi}$ ${}_sPlot$ corrected for efficiency:
(efficiency maps built in $m_{K\pi} - m_{\pi\pi}$ plane)
A unique PDF: coherent sum of $K^*(892), \rho^0(770)$ and $K\pi$ S-wave
All projected on the $m_{K\pi}$ dimension







Line-shapes significantly distorted due to phase-space effects
Take 2D histograms $H_k(m_{K\pi}, m_{\pi\pi})$ from MC (EvtGen)
at generator level, take phase-space corrections into account

$m_{K\pi\pi}$ Fit Fractions enter here

3) Fit to $m_{K\pi}/2$

Coherent sum of $K^*(892)$, $\rho^0(770)$ and $K\pi$ S-wave component

$$|A(m_{K\pi};c_k)|^2 = \left|\int_{m_{\pi\pi}^{min}}^{m_{\pi\pi}^{max}} \left(\sum_k c_k \sqrt{H_k(m_{K\pi},m_{\pi\pi})}e^{i\Phi_k(m)}\right) dm_{\pi\pi}\right|^2, \qquad c_k = \alpha_k e^{i\phi_k}$$

$$= |c_{K^*}|^2 h_{K^*} + \left|c_\rho\right|^2 h_\rho + \left|c_{(K\pi)}\right|^2 h_{(K\pi)} + interference$$

Invariant-mass-dependent magnitude defined as the projection 2D histograms:

$$h_k(m_{K\pi}) = \int_{m_{\pi\pi}^{min}}^{m_{\pi\pi}^{max}} H_k(m_{K\pi},m_{\pi\pi})\, dm_{\pi\pi}$$

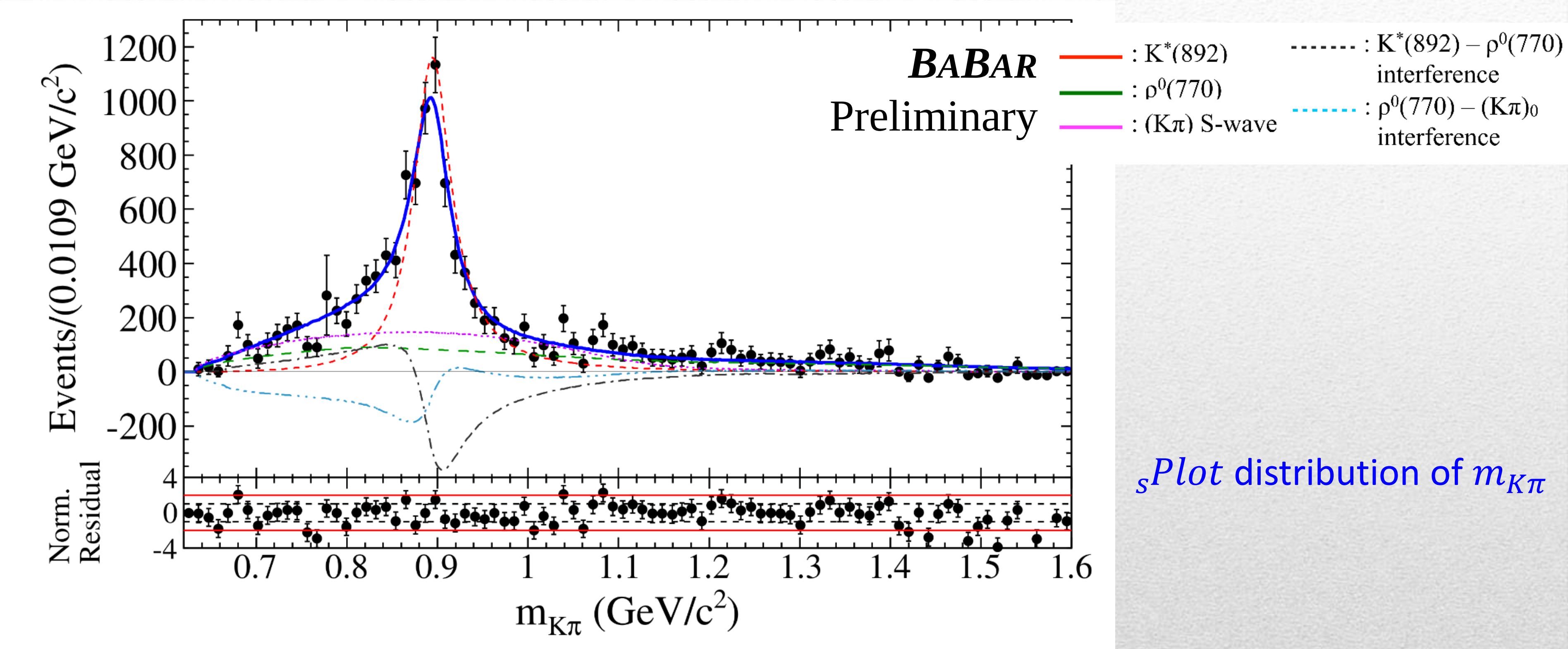
The invariant-mass-dependent phase is taken from the analytical expression of the corresponding lineshape:

$$\Phi_k(m) = \arccos\left(\frac{\mathrm{Re}\, R_k(m)}{|R_k(m)|}\right)$$

$m = m_{\pi\pi}$ for $\rho^0(770)$,
$m = m_{K\pi}$ otherwise

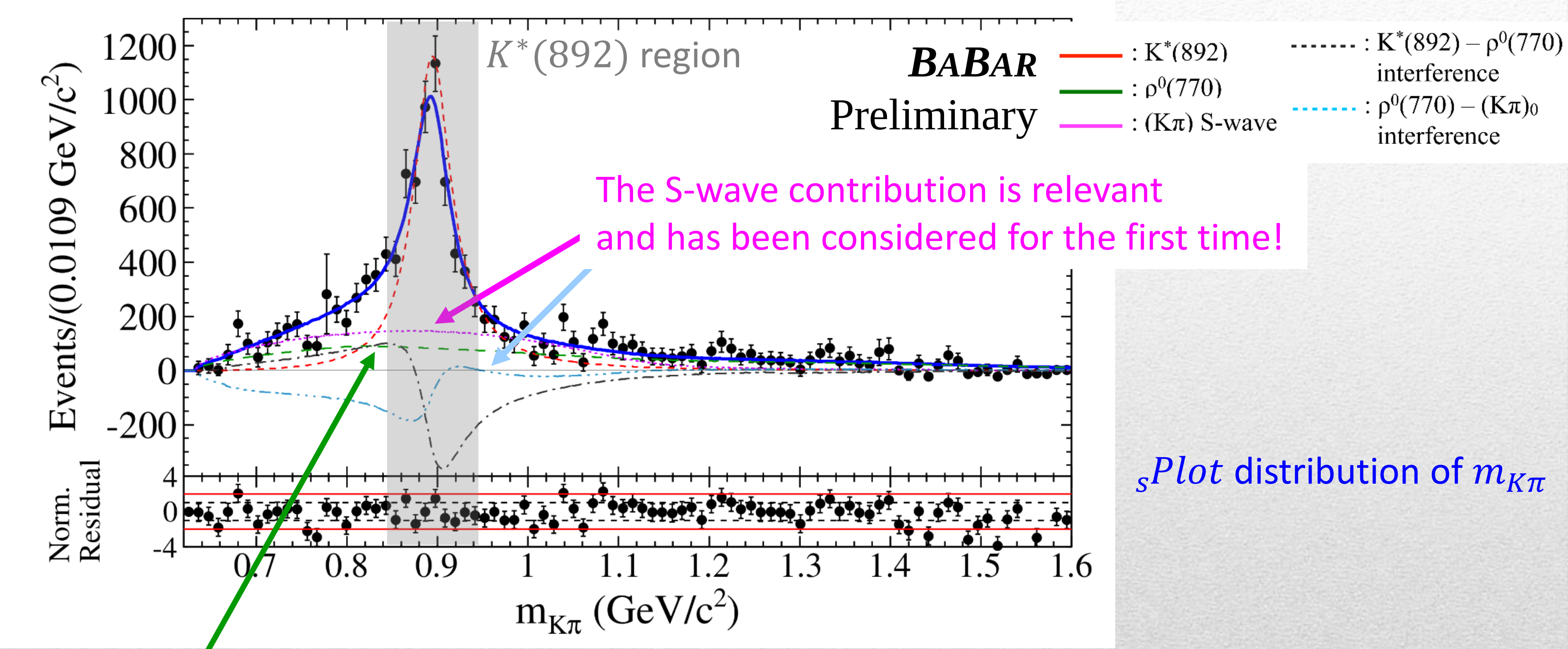
The interference between the $K^*(892)$ and $K\pi$ S-wave amplitudes vanishes because of the integration over $m_{\pi\pi}$

3) Fit to $m_{K\pi}$/3



$_{s}Plot$ distribution of $m_{K\pi}$

3) Fit to $m_{K\pi}/3$



The S-wave contribution is relevant and has been considered for the first time!

${}_sPlot$ distribution of $m_{K\pi}$

Basically, we are interested in these events only!

3) BF from $m_{K\pi}$

Mode	$\mathcal{B}(B^+ \to \text{Mode})\times$ $\mathcal{B}(R \to hh) \times 10^{-6}$	$\mathcal{B}(B^+ \to \text{Mode}) \times 10^{-6}$	PDG values ($\times 10^{-6}$)
Inclusive $B^+ \to K^+\pi^+\pi^-\gamma$	$\cdots$	$27.2 \pm 1.0^{+1.1}_{-1.3}$	27.6 ± 2.2
$K^{*0}(892)\pi^+\gamma$	$17.3 \pm 0.9^{+1.2}_{-1.1}$	$26.0^{+1.4}_{-1.3}\pm 1.8$	20^{+7}_{-6}
$K^+\rho(770)^0\gamma$	$9.1^{+0.8}_{-0.7}\pm 1.3$	$9.2^{+0.8}_{-0.7}\pm 1.3 \pm 0.02$	< 20 CL$=90\%$
$(K\pi)^{*0}_0\pi^+\gamma$	$11.3 \pm 1.5^{+2.0}_{-2.6}$	$\cdots$	$\emptyset$
$(K\pi)^0_0\pi^+\gamma$ (NR)	$\cdots$	$10.8^{+1.4+1.9}_{-1.5-2.5}$	< 9.2 CL$=90\%$
$K^*_0(1430)^0\pi^+\gamma$	$0.51 \pm 0.07^{+0.09}_{-0.12}$	$0.82 \pm 0.11^{+0.15}_{-0.19} \pm 0.08$	$\emptyset$

BaBar Preliminary

The Fit Fractions (FF) extracted can be used to calculate the dilution factor

4) The dilution factor

"overlap" between $(K\pi)^+$ and $(K\pi)^-$ $\propto \mathrm{FF}_{(K\pi)_0}$

"overlap" between K^{*+} and K^{*-} $\propto \mathrm{FF}_{K^*}$

$$\mathcal{D}_{K^0_S\rho\gamma} = \frac{\int \left[|A_\rho|^2 + \Re(A^*_\rho A_{K^{*+}}) + \Re(A^*_\rho A_{K^{*-}}) + \Re(A^*_{K^{*+}} A_{K^{*-}}) + \Re(A^*_{(K\pi)^+} A_{(K\pi)^-}) \right]}{\int \left[|A_\rho|^2 + \Re(A^*_\rho A_{K^{*+}}) + \Re(A^*_\rho A_{K^{*-}}) + \frac{|A_{K^{*+}}|^2 + |A_{K^{*-}}|^2}{2} + \frac{|A_{(K\pi)^+}|^2 + |A_{(K\pi)^-}|^2}{2} \right]}$$

$\propto \mathrm{FF}_\rho$ $\quad \propto \mathrm{FF}^{\mathrm{interf.}}_{K^*-\rho}$ $\quad \propto \mathrm{FF}_{K^*}$ $\quad \propto \mathrm{FF}_{(K\pi)_0}$

Need to have D as large as possible, applied a posteriori cuts on $m_{\pi\pi}$ and $m_{K\pi}$ to enhance the proportion of ρ and improve precision of final result

$$m_{\pi\pi} \in [600,900] \mathrm{MeV}/c^2, m_{K\pi} \notin [845,945]\ \mathrm{MeV}/c^2$$

$$D_{K_S\rho\gamma} = 0.549^{+0.096}_{-0.094}$$

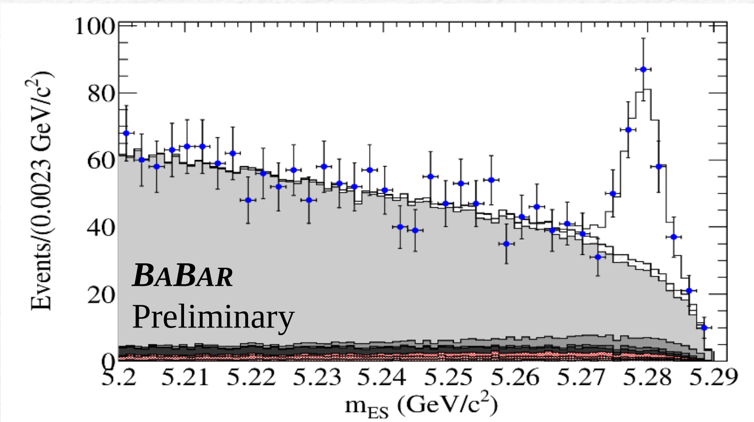
(systematics are summed in quadrature with statistical errors)

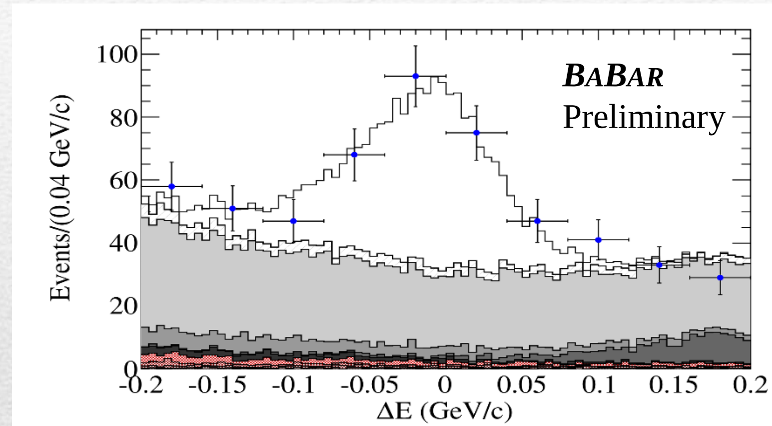
The dominant source of errors for D comes from the weights of K_{res}

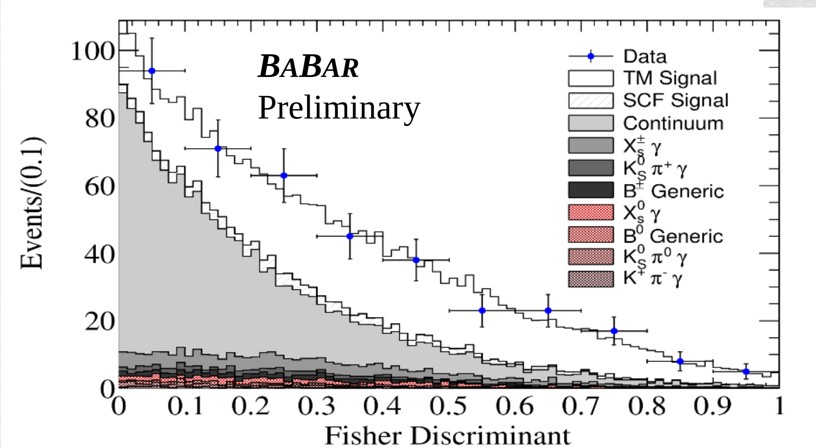
A better knowledge of the BFs will improve the error on D and hence the sensitivity on $S_{K_S\rho\gamma}$

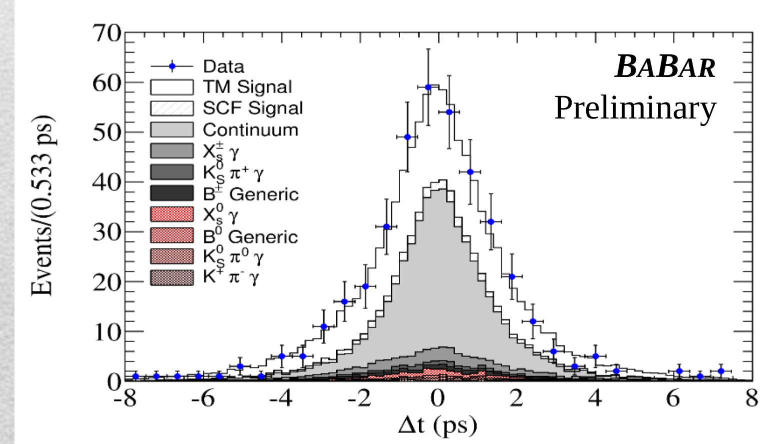
$B^0 \to K_S\pi^+\pi^-\gamma$: fit

A similar analysis can be performed on the neutral channel
4D ML fit to four discriminating variables, added Δt dependence
Same cuts as for $D_{K_S\rho\gamma}$: $m_{\pi\pi} \in [600,900]\mathrm{MeV}/c^2, m_{K\pi} \notin [845,945]\ \mathrm{MeV}/c^2$









$B^0 \to K_S\pi^+\pi^-\gamma$: result

$$\mathcal{P}(\Delta t, \sigma_{\Delta t}) \equiv \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}} \times \left[1 + q_{\rm tag}\frac{\Delta D^c}{2} - q_{\rm tag}\langle D\rangle^c \mathcal{C}\cos(\Delta m_d \Delta t) + q_{\rm tag}\langle D\rangle^c \mathcal{S}\sin(\Delta m_d \Delta t)\right] \otimes \mathcal{R}^c(\Delta t, \sigma_{\Delta t})$$

Mistag related

CP observables

Resolution

$$S_{K_S\pi\pi\gamma} = 0.137 \pm 0.249^{+0.042}_{-0.033}$$
$$C_{K_S\pi\pi\gamma} = -0.390 \pm 0.204^{+0.045}_{-0.050}$$

+

$$D_{K_S\rho\gamma} = 0.549^{+0.096}_{-0.094}$$

$$S_{K_S\rho\gamma} = \frac{S_{K_S\pi\pi\gamma}}{D_{K_S\rho\gamma}} = 0.249 \pm 0.455^{+0.076}_{-0.060}$$

***BaBar* Preliminary**

to compare with:

$$S_{K_S\rho\gamma}(\text{Belle}) = 0.11 \pm 0.33^{+0.05}_{-0.09}$$
$$S_{K_S\rho\gamma}(\text{SM}) \simeq 0.02$$

Systematic uncertainties

Different systematics are taken into account, in general:

- Possible biases arising from fixed parameters and fixed lineshapes in the fits
- Procedure of the signal ${}_sPlot$ extraction

- In the $m_{K\pi\pi}$ fit the dominant effect is due to the fixed lineshape parameters of the resonances
- In the $m_{K\pi}$ fit the dominant effect is due to the weights of the K_{res} extracted from the $m_{K\pi\pi}$ fit
- For the Branching Fractions, we account for errors in BB counting, input branching fractions, photon reconstruction, tracking and selection efficiencies, PID (K_S, K^+,π^+)
- The error on $S_{K_S\rho\gamma}$ is dominated by the error on the dilution factor, and therefore to the weights of K_{res}. A better knowledge of the BFs will improve the sensitivity on $S_{K_S\rho\gamma}$

Conclusions

Even at 6 years from the shutdown,
BaBar still produces competitive physics results, adding more information and establishing new sophisticated analysis techniques to improve the precision of measurements in radiative-penguin B decays

Our result on *CP* violation agree with the standard model predictions, larger samples are needed to tell whether or not there could be indications for NP.

The measurements of hadronic branching fractions are interesting *per se* and improve PDG values

This analysis has interesting prospects with more data (Belle II and LHCb)

The paper is in preparation and should appear soon

Thank you!

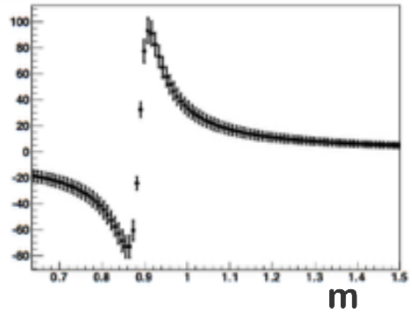
BACKUP

3) Fit to $m_{K\pi}/3$

Interference:

Illustration:

RBW+GS interf. ($\phi_{\rho^0}=\pi/2$)



- **Interference terms:**

$$
\begin{aligned}
I(m_{K\pi}; c_{\rho^0}, c_{(K\pi)_0}) \quad = \quad & 2\alpha_{\rho^0}\left[\cos(\phi_{\rho^0} - \Phi_{\rm RBW})\int_{m_{\pi\pi}^{min}}^{m_{\pi\pi}^{max}} \sqrt{{\rm H}_{\rho^0}{\rm H}_{K^*}}\cos(\Phi_{\rm GS})\, dm_{\pi\pi}\right. \\
& \left. - \sin(\phi_{\rho^0} - \Phi_{\rm RBW})\int_{m_{\pi\pi}^{min}}^{m_{\pi\pi}^{max}} \sqrt{{\rm H}_{\rho^0}{\rm H}_{K^*}}\sin(\Phi_{\rm GS})\, dm_{\pi\pi}\right] \\
& +2\alpha_{\rho^0}\alpha_{(K\pi)_0}\left[\cos(\phi_{\rho^0} - \phi_{(K\pi)_0} - \Phi_{\rm LASS})\int_{m_{\pi\pi}^{min}}^{m_{\pi\pi}^{max}} \sqrt{{\rm H}_{\rho^0}{\rm H}_{(K\pi)_0}}\cos(\Phi_{\rm GS})\, dm_{\pi\pi}\right. \\
& \left. - \sin(\phi_{\rho^0} - \phi_{(K\pi)_0} - \Phi_{\rm LASS})\int_{m_{\pi\pi}^{min}}^{m_{\pi\pi}^{max}} \sqrt{{\rm H}_{\rho^0}{\rm H}_{(K\pi)_0}}\sin(\Phi_{\rm GS})\, dm_{\pi\pi}\right] .
\end{aligned}
$$

Term describing the interference between $K^*(892)$ and $\rho^0(770)$ amplitudes

Term describing the interference between $\rho^0(770)$ and $K\pi$ S-wave amplitudes

The interference between the $K^*(892)$ and $K\pi$ S-wave amplitudes vanishes because of the integration over $m_{\pi\pi}$

4) The dilution factor

- **In terms of amplitudes:**

$$B^0(t) \to H_{\rm res} P_{\rm scal} \gamma \qquad H_{\rm res} = \rho^0,\ K^{*\pm} \text{ or } (K\pi)^\pm \text{ S-wave}\ ; \quad P_{\rm scal} = K^0_S \text{ or } \pi^\pm$$

$$\begin{aligned}
A_R^{H_{\rm res}}(B^0 \to H_{\rm res} P_{\rm scal} \gamma_L) &= \xi_1 A_{H_{\rm res}} \sin\psi e^{-i\phi_R^{H_{\rm res}}} e^{i\delta^{H_{\rm res}}} \\
A_L^{H_{\rm res}}(B^0 \to H_{\rm res} P_{\rm scal} \gamma_R) &= \xi_2 A_{H_{\rm res}} \cos\psi e^{-i\phi_L^{H_{\rm res}}} e^{i\delta^{H_{\rm res}}} \\
\overline{A}_L^{H_{\rm res}}(\overline{B}^0 \to H_{\rm res} P_{\rm scal} \gamma_L) &= \xi_3 A_{H_{\rm res}} \cos\psi e^{i\phi_L^{H_{\rm res}}} e^{i\delta^{H_{\rm res}}} \\
\overline{A}_R^{H_{\rm res}}(\overline{B}^0 \to H_{\rm res} P_{\rm scal} \gamma_R) &= \xi_4 A_{H_{\rm res}} \sin\psi e^{i\phi_R^{H_{\rm res}}} e^{i\delta^{H_{\rm res}}}
\end{aligned}$$

$$\begin{aligned}
\tan\psi &= C'_{7_\gamma}/C_{7_\gamma} \\
\phi_{L/R}^{H_{\rm res}} &\Rightarrow CP\text{-odd weak phases} \\
\delta^{H_{\rm res}} &\Rightarrow CP\text{-even strong phases} \\
\xi_i &\equiv CP(H_{\rm res} P_{\rm scal}) = \pm 1 \\
(\xi_1, \xi_2, \xi_3, \xi_4) &= (+,-,+,-) \text{ for } \rho \text{ and } K^{*\pm} \\
(\xi_1, \xi_2, \xi_3, \xi_4) &= (+,+,+,+) \text{ for } (K\pi)^\pm \text{ S-wave}
\end{aligned}$$

$$\mathcal{A}_{CP}(t) = \frac{\Gamma_{\overline{B}^0}(t) - \Gamma_{B^0}(t)}{\Gamma_{\overline{B}^0}(t) + \Gamma_{B^0}(t)} \equiv \mathcal{C}\cos(\Delta {\rm M} t) + \mathcal{S}\sin(\Delta {\rm M} t)$$

$$\begin{aligned}
\Gamma_{B^0}(t) &= |\mathcal{M}_L(t)|^2 + |\mathcal{M}_R(t)|^2 \\
\Gamma_{\overline{B}^0}(t) &= |\overline{\mathcal{M}}_L(t)|^2 + |\overline{\mathcal{M}}_R(t)|^2
\end{aligned}$$

$$\begin{aligned}
\mathcal{M}_L(t) &= \sum_{H_{\rm res}} \left(A_L^{H_{\rm res}} {\rm f}_+(t) + \overline{A}_L^{H_{\rm res}} \frac{q}{p} {\rm f}_-(t) \right) ; \quad \overline{\mathcal{M}}_L(t) = \sum_{H_{\rm res}} \left(\overline{A}_L^{H_{\rm res}} {\rm f}_+(t) + A_L^{H_{\rm res}} \frac{q}{p} {\rm f}_-(t) \right) \\
\mathcal{M}_R(t) &= \sum_{H_{\rm res}} \left(A_R^{H_{\rm res}} {\rm f}_+(t) + \overline{A}_R^{H_{\rm res}} \frac{q}{p} {\rm f}_-(t) \right) ; \quad \overline{\mathcal{M}}_R(t) = \sum_{H_{\rm res}} \left(\overline{A}_R^{H_{\rm res}} {\rm f}_+(t) + A_R^{H_{\rm res}} \frac{q}{p} {\rm f}_-(t) \right)
\end{aligned}$$

$${\rm f}_\pm(t) \equiv \frac{1}{2} \left(e^{-i{\rm M}_L t} e^{-\frac{1}{2}\Gamma_L t} \pm e^{-i{\rm M}_H t} e^{-\frac{1}{2}\Gamma_H t} \right) \qquad \frac{q}{p} = e^{-i2\beta}$$

CPV results

$$S_{K_S\rho\gamma}^{BaBar} = 0.249 \pm 0.455^{+0.076}_{-0.060}$$

BABAR Preliminary

Compared with other *CPV* measurements in radiative decays:

$S_{K_S\rho\gamma}^{Belle} = 0.11 \pm 0.33^{+0.05}_{-0.09}$	PRL 101, 251601
$S_{K_S\pi^0\gamma}^{BaBar} = -0.78 \pm 0.59 \pm 0.09$	PRD 78, 071102
$S_{K_S\pi^0\gamma}^{Belle} = -0.10 \pm 0.31 \pm 0.07$	PRD 74, 111104