

# POLARISATION AMPLITUDES IN $B \rightarrow VV$ DECAYS AT CDF

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## THEORETICAL MOTIVATION

We study polarisation structure of  $B \rightarrow VV$  decays, where  $V = \text{Vector Meson}$ .

Many such decays are dominated by tree diagrams. Good agreement with Standard Model is found.

E.g.  $B \rightarrow \rho^+ \rho^-$ , light meson decay, dominated by a single amplitude. Longitudinal polarisation  $\approx 100\%$ , as expected.

There are hints of anomalies in penguin diagram decays.

E.g.  $B \rightarrow \phi K^*$ , polarisation around 50%.

A challenge to theorists, merits detailed investigation.

An important preparation for  $B_s \rightarrow \phi\phi$  studies which can give  $\sin 2\beta_s$  determination.

### References:

- S Baek et al., PR D72 (2005) 094008
- X Li et al., PR D68 (2003) 11405
- M Beneke and M Neubert NP B675 (2003) 333

## CDF STUDIES

We use  $B^0 \rightarrow J/\psi K^{*0}$  as a control channel (good statistics) to confirm methodology.

This talk presents  $B \rightarrow \phi K^*$  results from  $362 \text{ pb}^{-1}$  integrated luminosity.

$J/\psi$  is detected in  $\mu^+ \mu^-$  decays

$K^{*0}$  is detected in  $K^+ \pi^-$  decays + c.c.

Two CDF triggers available:

- $J/\psi$  dimuon trigger
- Two-Track Trigger: Silicon array information, secondary vertex  
(For  $\phi$  channel and also extends  $J/\psi$  acceptance)

## EVENT SELECTIONS

Main selection criteria applied to  $B$  candidate and its tracks.

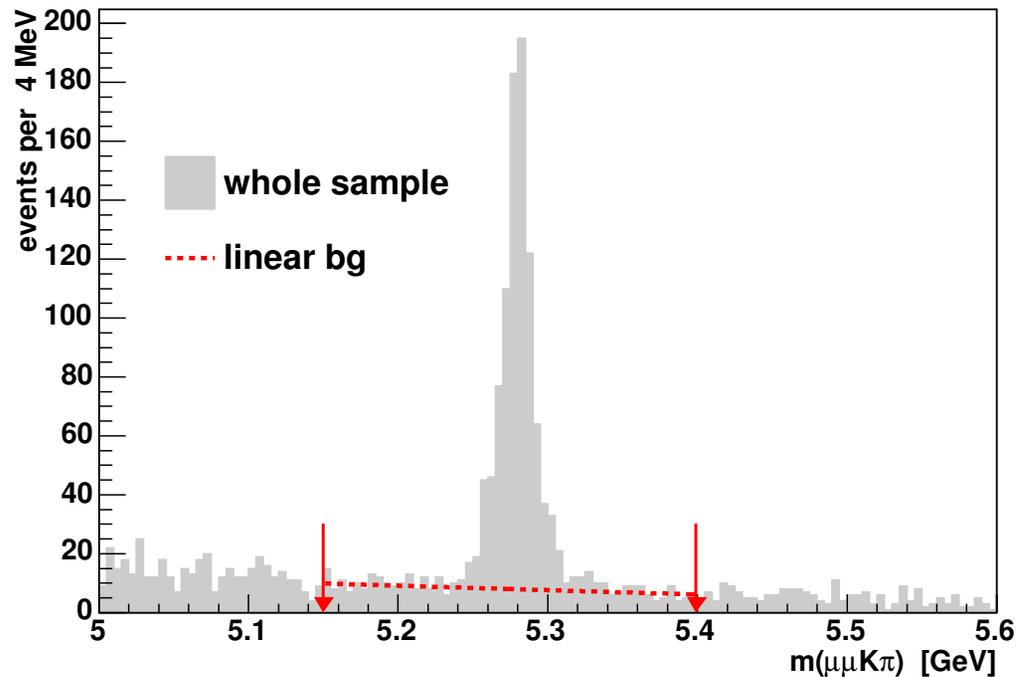
Preselections:

- Good track with momentum  $p_T > 0.4 \text{ GeV}/c$
- Good fit to 4-track vertex
- Vertex displacement  $> 100 \mu\text{m}$
- Sum of track  $p_T > 5.0 \text{ GeV}/c$
  
- $K^*$  candidate:  $K\pi$  mass =  $892 \pm 60 \text{ MeV}/c^2$
- $J/\psi$  candidate:  $\mu^+\mu^-$  mass imposed in fit
- $\phi$  candidate:  $K^+K^-$  mass =  $1020 \pm 7 \text{ MeV}/c^2$

The kinematic cuts were then tightened to optimise the final uncertainties.

# EVENT SELECTIONS

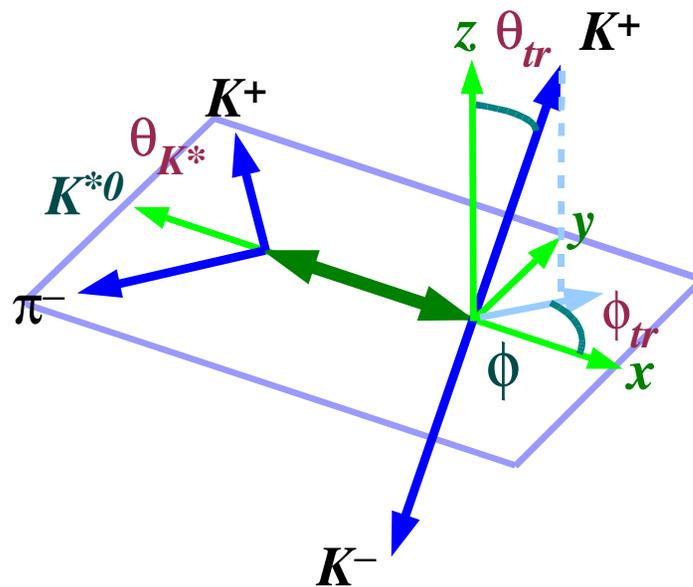
Resulting  $\mu\mu K\pi$  mass plot:



A good  $B^0 \rightarrow J/\psi K^{*0}$  peak is seen on low background, fitted linearly.

## TRANSVERSITY BASIS

The angles for the polarisation analysis illustrated for  $\phi \rightarrow K^+ K^-$  case:



Define  $x, y$  plane containing  $K^*$  decay products with  $x$  axis along  $\phi$ -meson or  $J/\psi$  direction.

$\theta_{K^*} = \psi = K$  angle wrt  $x$  axis;

$\theta_{tr} = \theta =$  polar angle of  $K^+$  or  $\mu^+$ ;

$\phi_{tr} = \phi =$  azimuthal angle of  $K^+$  or  $\mu^+$ ;

## POLARISATION ANALYSIS

The two channels have different structure since the  $J/\psi$  decay products are fermions,  $K^*$  products are scalars.

There are 3 complex amplitudes + interference terms:

$|A_0|^2$  longitudinal; CP even

$|A_{||}|^2 =$  transverse parallel; CP even

$|A_{\perp}|^2 =$  transverse perpendicular; CP odd

Six angular terms, of which:

$|A_{||}|^2$  multiplies a term in:

$$\begin{array}{l} \sin^2 \psi (1 - \sin^2 \theta \sin^2 \phi) \quad J/\psi \rightarrow \mu\mu + K^* \quad \text{or} \\ \sin^2 \psi \sin^2 \theta \sin^2 \phi \quad \phi \rightarrow K^+ K^- + K^* \end{array}$$

$|A_{\perp}|^2$  multiplies a term in:

$$\begin{array}{l} \sin^2 \psi \sin^2 \theta \quad J/\psi \rightarrow \mu\mu + K^* \quad \text{or} \\ \sin^2 \psi \cos 2\theta \quad \phi \rightarrow K^+ K^- + K^* \end{array}$$

**Extract these coefficients in a fit**

## POLARISATION ANALYSIS

Perform **log-likelihood fit of the data** to sum of all 6 terms.

Vary the complex amplitudes  $A_0, A_{||}, A_{\perp}$ , with  $A_0$  assigned zero phase.

**Allow for:**

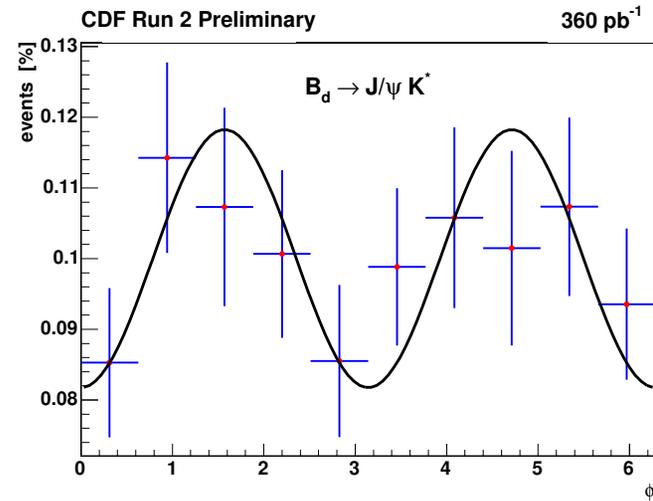
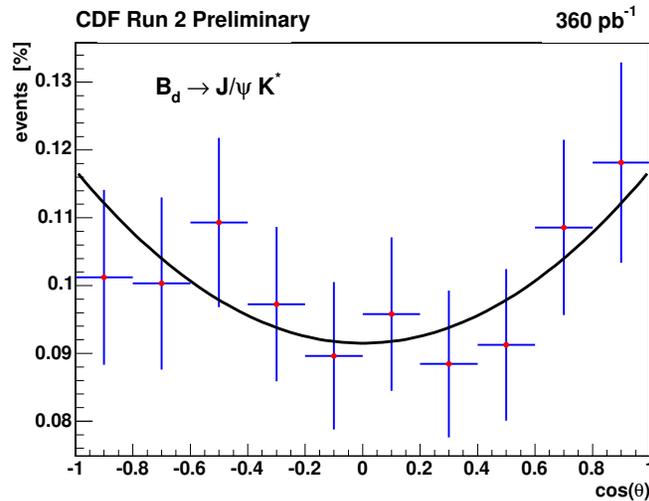
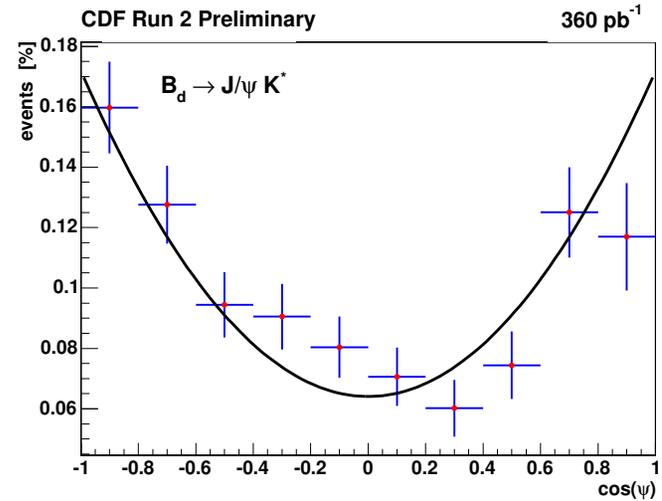
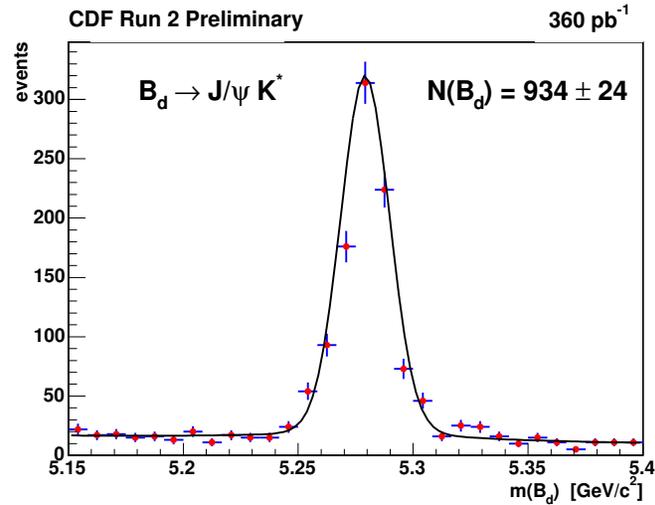
- angle-dependent experimental acceptances
- presence of background which has its own set of coefficients
- $K$ -  $\pi$  ambiguities

Reweight MC acceptance calculation to describe  $p_T(B^0)$  accurately.

**Systematics:** background description,  $p_T$  spectrum,  $K\pi$  ambiguities, resolution.

# RESULTS

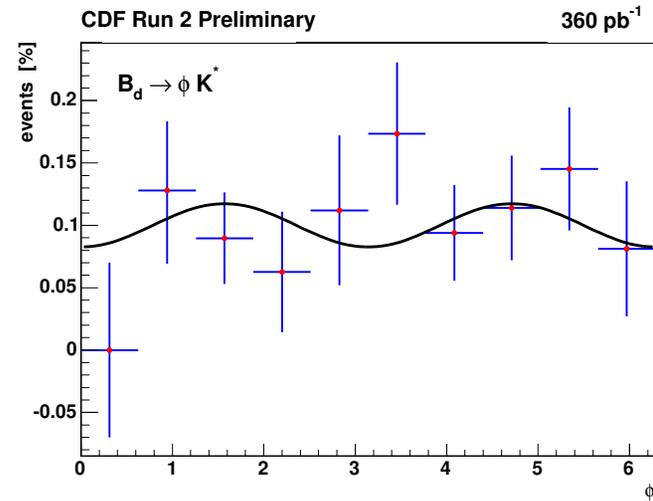
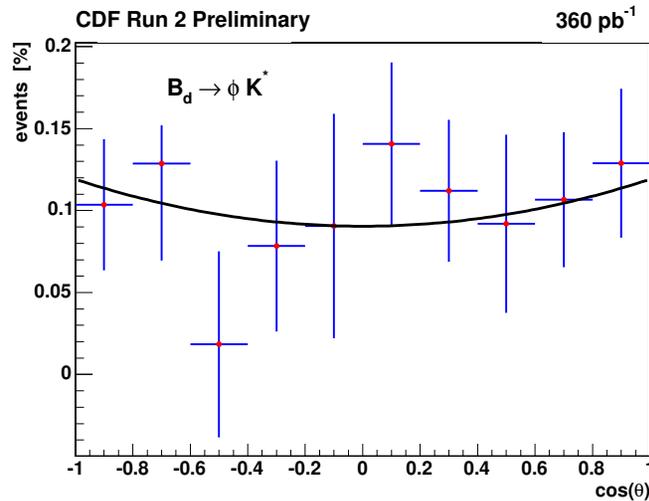
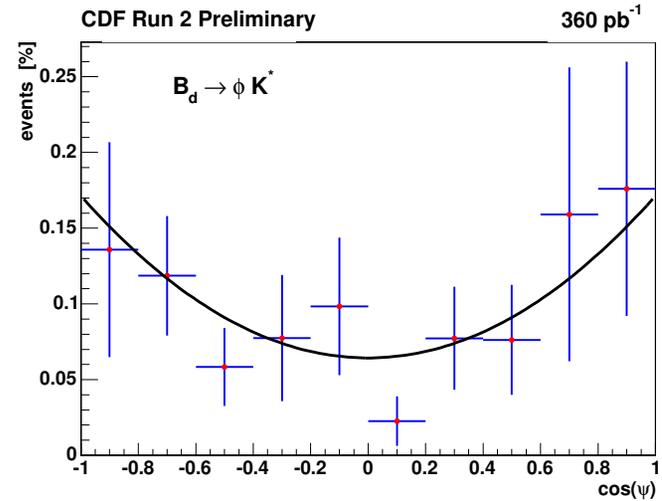
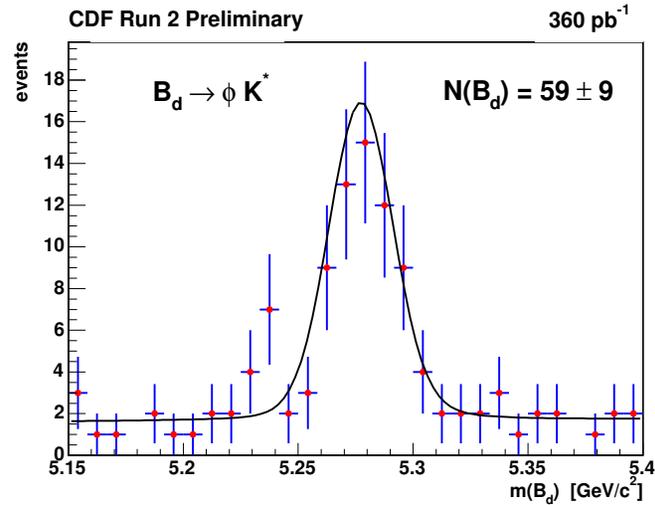
## $B \rightarrow J/\psi K^*$ results from fit.



Projections show clear angular structure.

# RESULTS

## $B \rightarrow \phi K^*$ results from fit.



Angular structure also present.

## RESULTS

**$B \rightarrow J/\psi K^*$  results from fit.**

	$ A_0 ^2$	$ A_{  } ^2$	$\delta(A_{  })$	$\delta(A_{\perp})$	Events
<b>CDF</b> 360 pb <sup>-1</sup>	<b>0.572</b> $\pm 0.026 \pm 0.018$	<b>0.207</b> $\pm 0.032 \pm 0.007$	<b>2.75</b> $\pm 0.23 \pm 0.06$	<b>2.99</b> $\pm 0.15 \pm 0.02$	<b>933</b> $\pm 24$
<b>BaBar</b> 82 fb <sup>-1</sup>	<b>0.566</b> $\pm 0.012 \pm 0.005$	<b>0.204</b> $\pm 0.015 \pm 0.005$	<b>-2.73</b> $\pm 0.10 \pm 0.05$	<b>2.96</b> $\pm 0.07 \pm 0.05$	<b>≈4000</b>

**$B \rightarrow \phi K^*$  results from fit.**

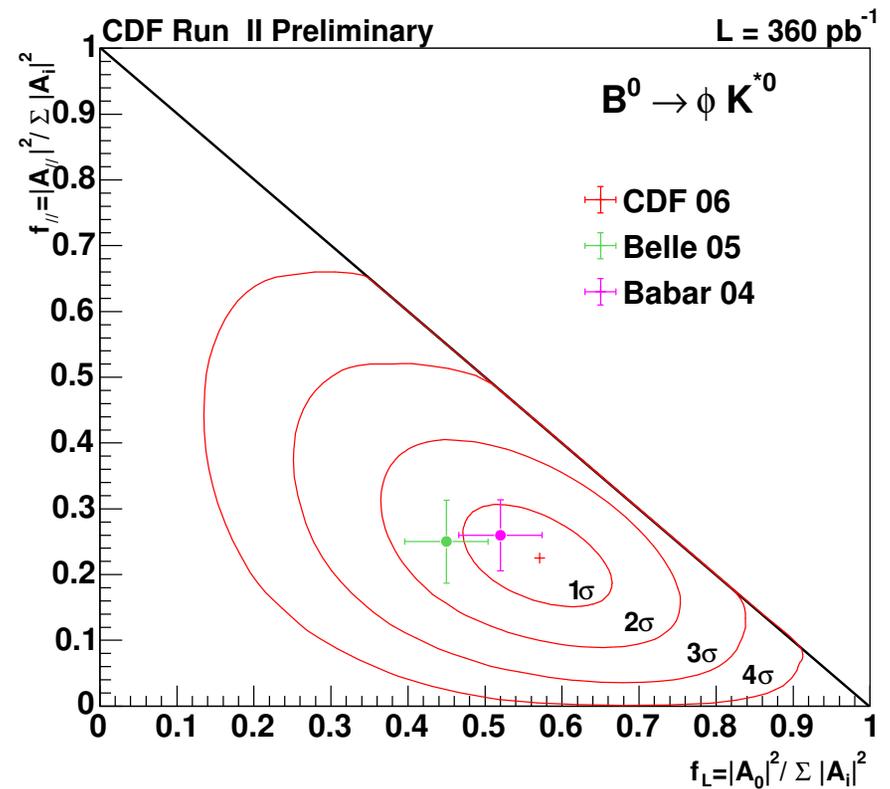
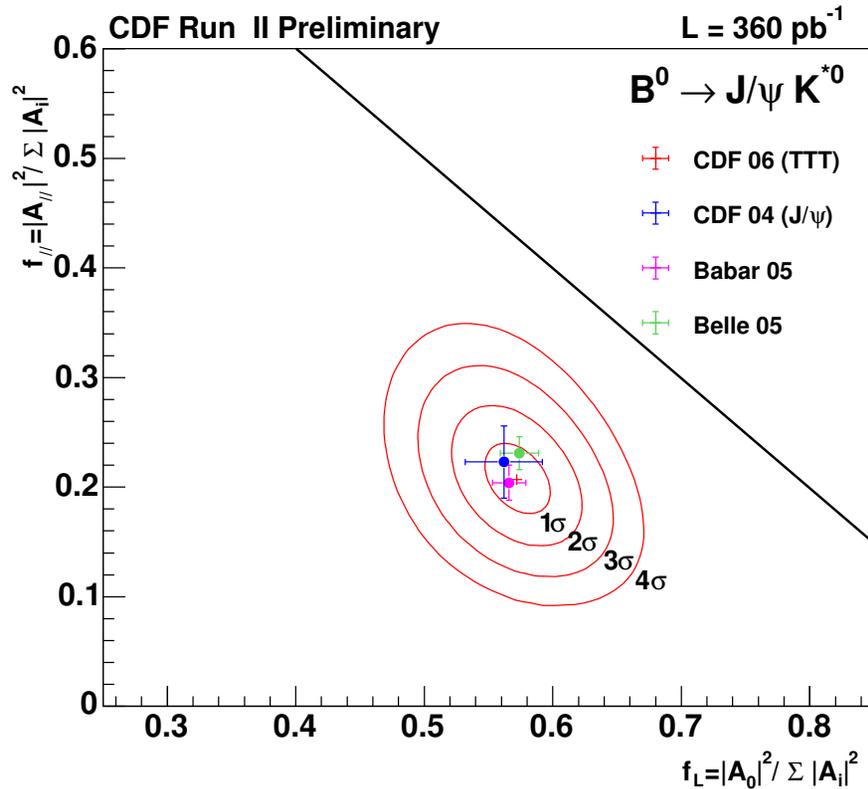
	$ A_0 ^2$	$ A_{  } ^2$	$\delta(A_{  })$	$\delta(A_0)$	Events
<b>CDF</b> 360 pb <sup>-1</sup>	<b>0.571</b> $\pm 0.097 \pm 0.050$	<b>0.223</b> $\pm 0.077 \pm 0.054$	<b>2.97</b> $\pm 0.52 \pm 0.26$	<b>2.77</b> $\pm 0.37 \pm 0.37$	<b>59</b> $\pm 9$
<b>BELLE</b> 250 fb <sup>-1</sup>	<b>0.45</b> $\pm 0.05 \pm 0.02$	<b>0.25</b> $\pm 0.06 \pm 0.02$	<b>2.39</b> $\pm 0.24 \pm 0.04$	<b>2.51</b> $\pm 0.23 \pm 0.04$	<b>≈170</b>
<b>BaBar</b> 200 fb <sup>-1</sup>	<b>0.52</b> $\pm 0.05 \pm 0.02$	<b>0.26</b> $\pm 0.05 \pm 0.02$	<b>2.34</b> $\pm 0.23 \pm 0.05$	<b>2.47</b> $\pm 0.25 \pm 0.05$	<b>≈200</b>

Uncertainties are  $\pm$ statistical  $\pm$ systematic.

$\delta$  = phase argument.

# RESULTS

Results for fit to  $A_{||}$  vs  $A_{\perp}$  as contour plots:

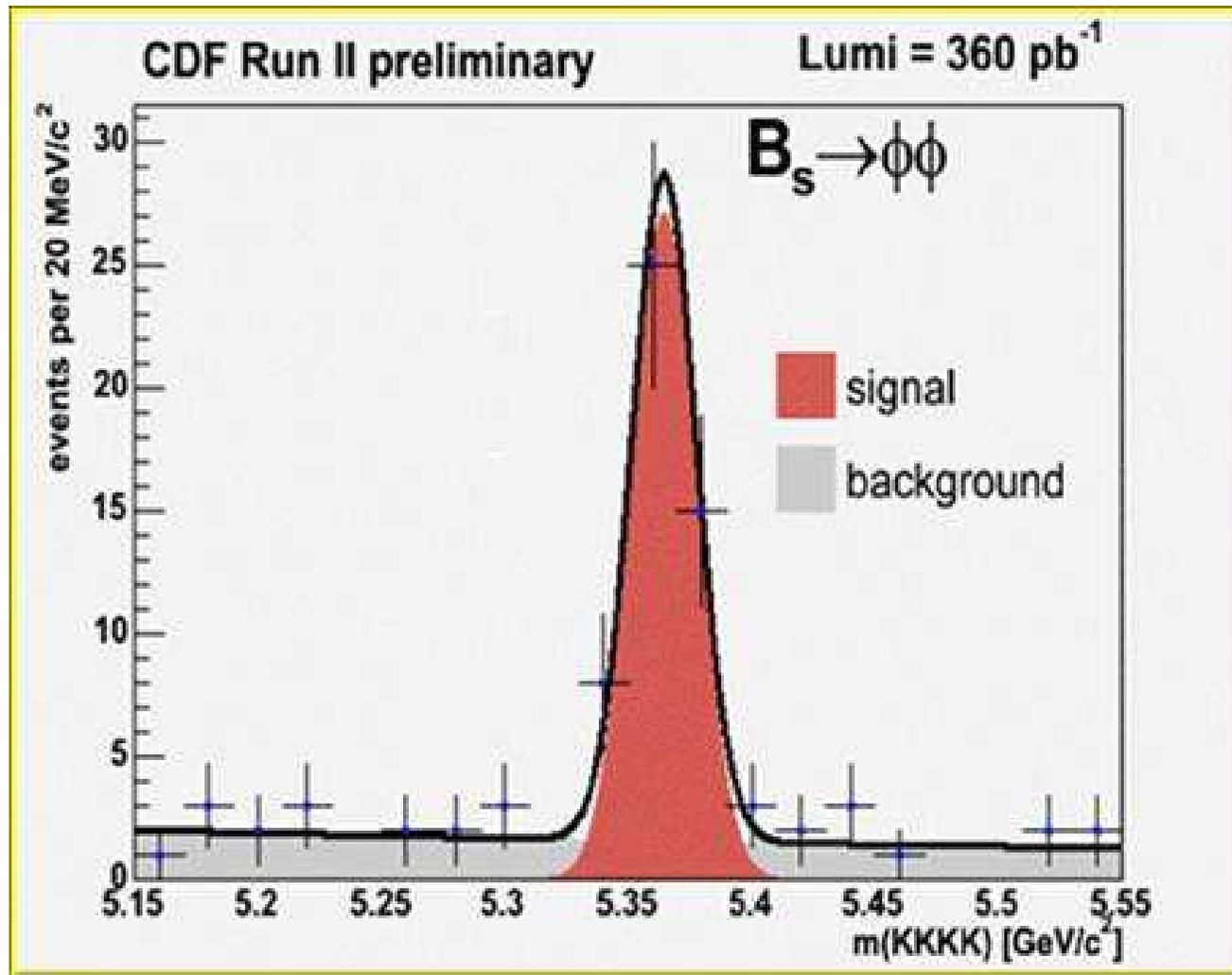


Good agreement with earlier CDF and BELLE and BaBar results.

## CONCLUSIONS

- First CDF measurement of the transverse polarisation amplitude in  $B \rightarrow \phi K^*$  decays.
- Results compare well to B factory experiments.
- More luminosity will add considerably to the precision. We can soon increase by factor of 3.
- Intend to progress to  $B_s \rightarrow \phi\phi$  decays and  $\sin 2\beta_s$  measurement.

# BACKUP: $B \rightarrow \phi\phi$



CDF signal (360 pb<sup>-1</sup>) for  $B_s \rightarrow \phi\phi$  decay.