$B \rightarrow DK$ strategies in LHCb (part II)

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(on behalf of the LHCb Collaboration)

Introduction

- Decays of B to $D^0(\overline{D^0})K$ involve $b \rightarrow c$ and $b \rightarrow u$ transitions - sensitive to γ if a common final state is studied for both D^0 and $\overline{D^0}$
- LHCb will exploit a number of strategies to study such decays :
  - Gronau-London-Wyler-(Dunietz) ('GLW') $B^0$and $\overline{B^0}$ decays
  - Atwood-Dunietz-Soni ('ADS') $B^{\pm}$ decays

    (see M.Patel talk yesterday)
  - Dalitz B^0/B^0 and $B^{\pm}$ decays

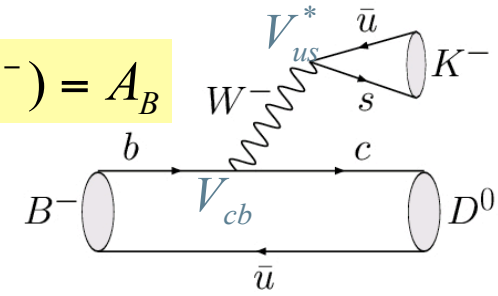
- In this talk will focus on Dalitz and GLW

- The Dalitz analysis is sensitive to the same parameters as ADS, two methods are complementary

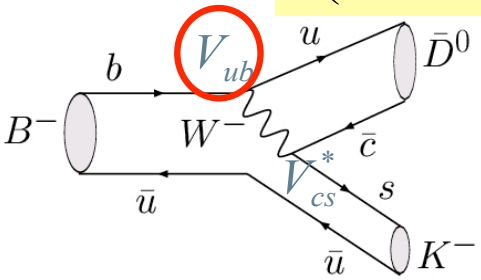
$B^+ \rightarrow D^0 K^+$

- γ is the weak phase between $b \rightarrow cus$ ($\propto V_{cb}$) and $b \rightarrow ucs$ ($\propto V_{ub}$)

$$A(B^- \rightarrow D^0 K^-) = A_B$$



$$A(B^- \rightarrow \overline{D}^0 K^-) = A_B r_B e^{i(\delta-\gamma)}$$



No need for a time-dependent analysis

- γ can be extracted from the interference of these two processes in charged $B \rightarrow D^0 K$ decays with $D^0/\overline{D^0}$ decaying to a common final state
  - r_B is the relative colour and CKM suppression between the two modes $O(0.1)$ – dilutes sensitivity to γ
  - δ is the strong phase difference - invariant under CP

Measuring γ : $B^+ \rightarrow D^0(K^0\pi^+\pi^-)K^+$

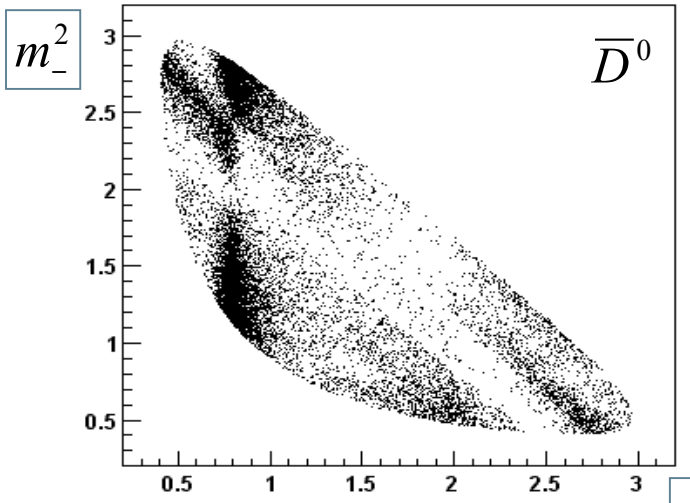
Giri, Grossman, Soffer, Zupan (PRD 68, 054018 (2003))

- Use three body Cabibbo allowed decays of the $D^0/\overline{D}^0$
  - $BR(D^0 \rightarrow K^0\pi^+\pi^-)=(5.97\pm0.35)\%$
  - $BR(D^0 \rightarrow K^* \pi)=(3.9\pm0.3)\%$, $BR(D^0 \rightarrow K_s \rho)=(1.55^{+0.12}_{-0.16})\%$…
- Large strong phases between the intermediate resonances allow the extraction of r_B, δ and γ by studying the Dalitz distribution of events

$$A^- = f(m_-^2, m_+^2) + r_B e^{i(-\gamma+\delta)} f(m_+^2, m_-^2)$$
$$A^+ = f(m_+^2, m_-^2) + r_B e^{i(\gamma+\delta)} f(m_-^2, m_+^2)$$

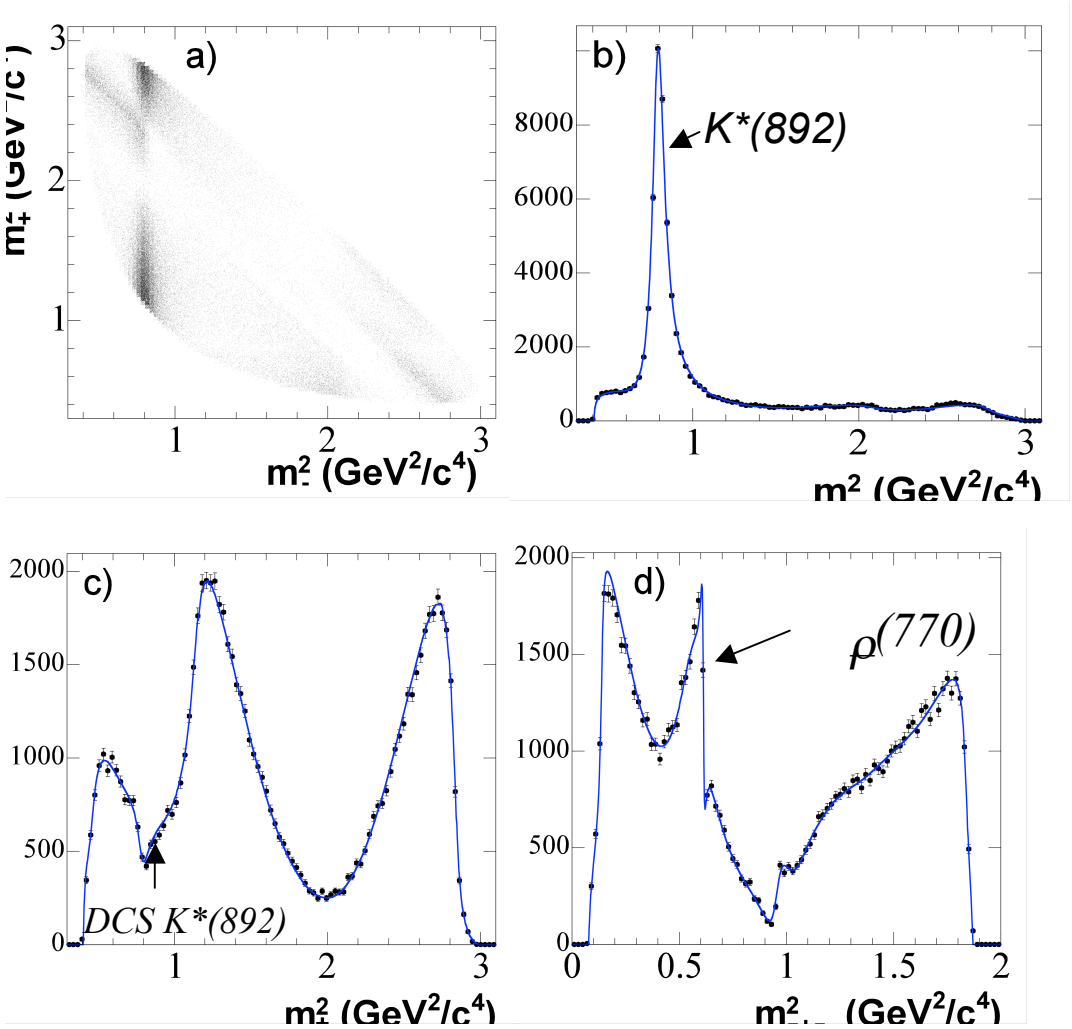
where $m_{\pm} = K_S^0\pi^{\pm}$ invariant mass

$f(m_{\pm}^2, m_m^2)$ Dalitz amplitudes



$$|A^-|^2 = |f(m_-^2, m_+^2)|^2 + r_B^2 |f(m_+^2, m_-^2)|^2 + 2r_B \Re(f(m_+^2, m_-^2) f^*(m_-^2, m_+^2) e^{i(-\gamma+\delta)})$$

Dalitz model

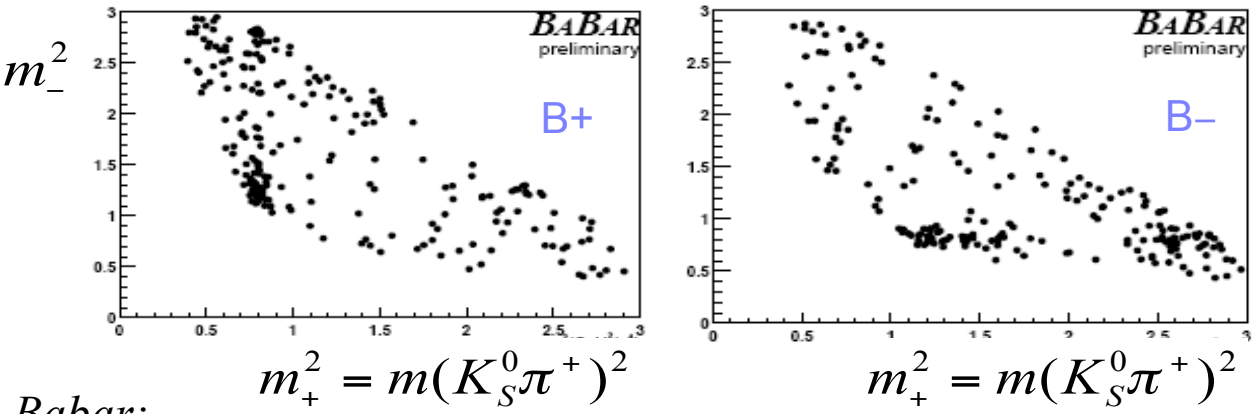


- B-factories use samples of O(100k) $D^{+}* \rightarrow D^{0}\pi^{+}$, $D^{0} \rightarrow K^{0}\pi^{+}\pi^{-}$ to measure amplitudes and phases - vary model to estimate systematics
- At present not negligible error from model

Dalitz model

- B factories consider 16 resonances + non resonant component
- At present dominant systematic error of 11° from model uncertainties
- Scope for improvement:
  - Alternative fit to Dalitz plane with full partial wave analysis of non-resonant component
  - CLEO-C and B factories will improve statistics to measure the Dalitz plot
  - Use model independent binned technique - loss of statistical power
    - CLEO-C correlated data could be used directly in a model independent binned treatment

Measuring γ from B-factories



hep-ex/0507101

D^* and D combined

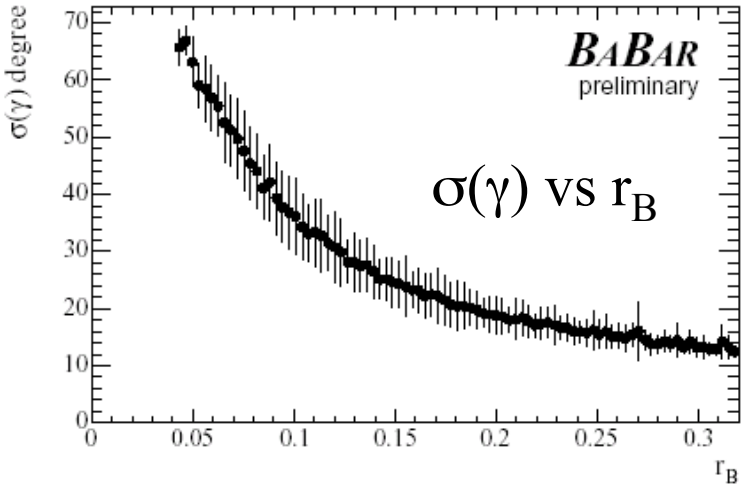
Babar:

$\gamma = 67° \pm 28° \pm 13° \pm 11°$

$r_B = 0.05 \pm 0.11$

Exp. systematic

Dalitz Model error



Belle:

PRD 70, 072003 (2004)

$\gamma = 68° \pm 14° \pm 13° \pm 11°$

$r_B = 0.21 \pm 0.08$

At present typical event yields / experiment ~ 300

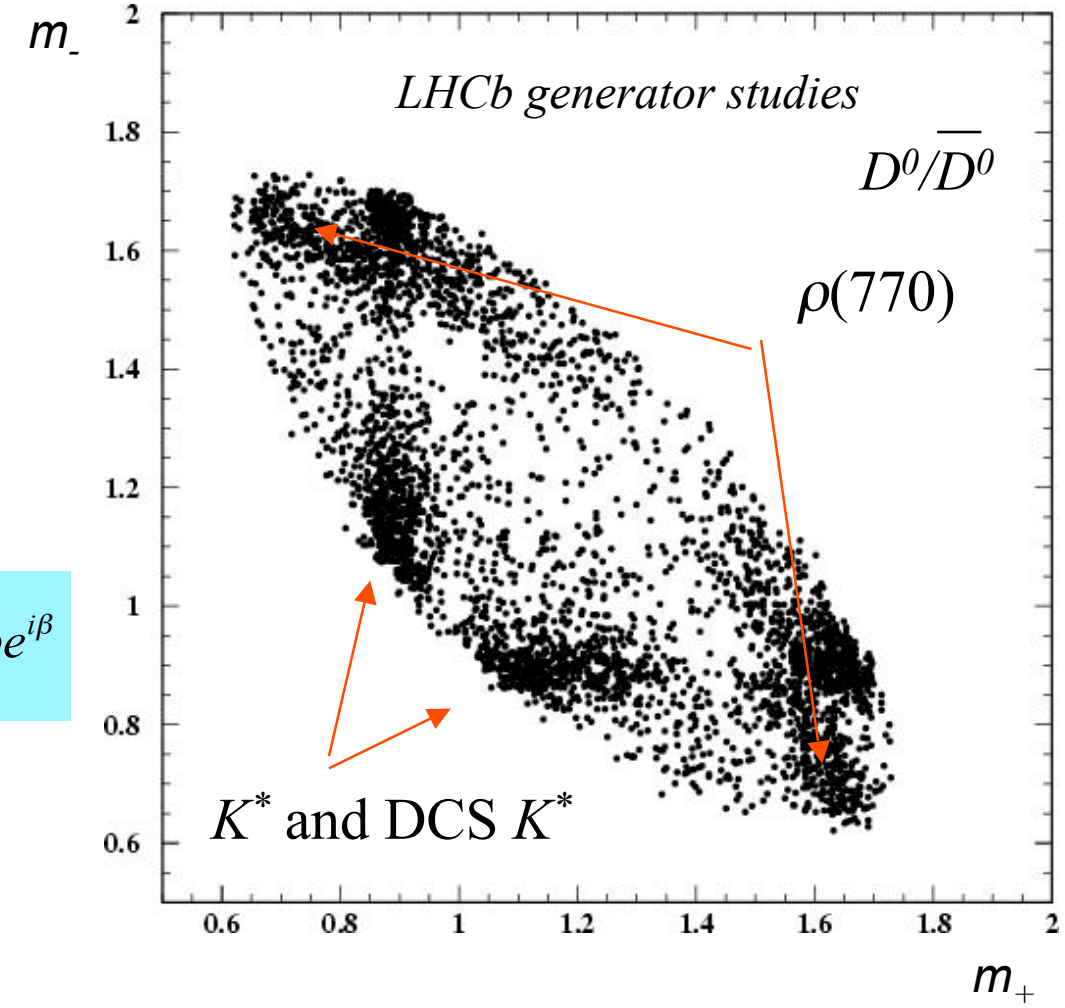
$B^+ \to D^0(K^0\pi^+\pi^-)K^+$: Dalitz plot

- Regions of the Dalitz plot with the largest interference are most sensitive to γ
- Need good understanding of Dalitz amplitudes
- Use isobar model from Belle/Babar with:

$$f(m_+^2, m_-^2) = \sum_{j=1}^{N} a_j e^{i\alpha_j} A_j(m_+^2, m_-^2) + b e^{i\beta}$$

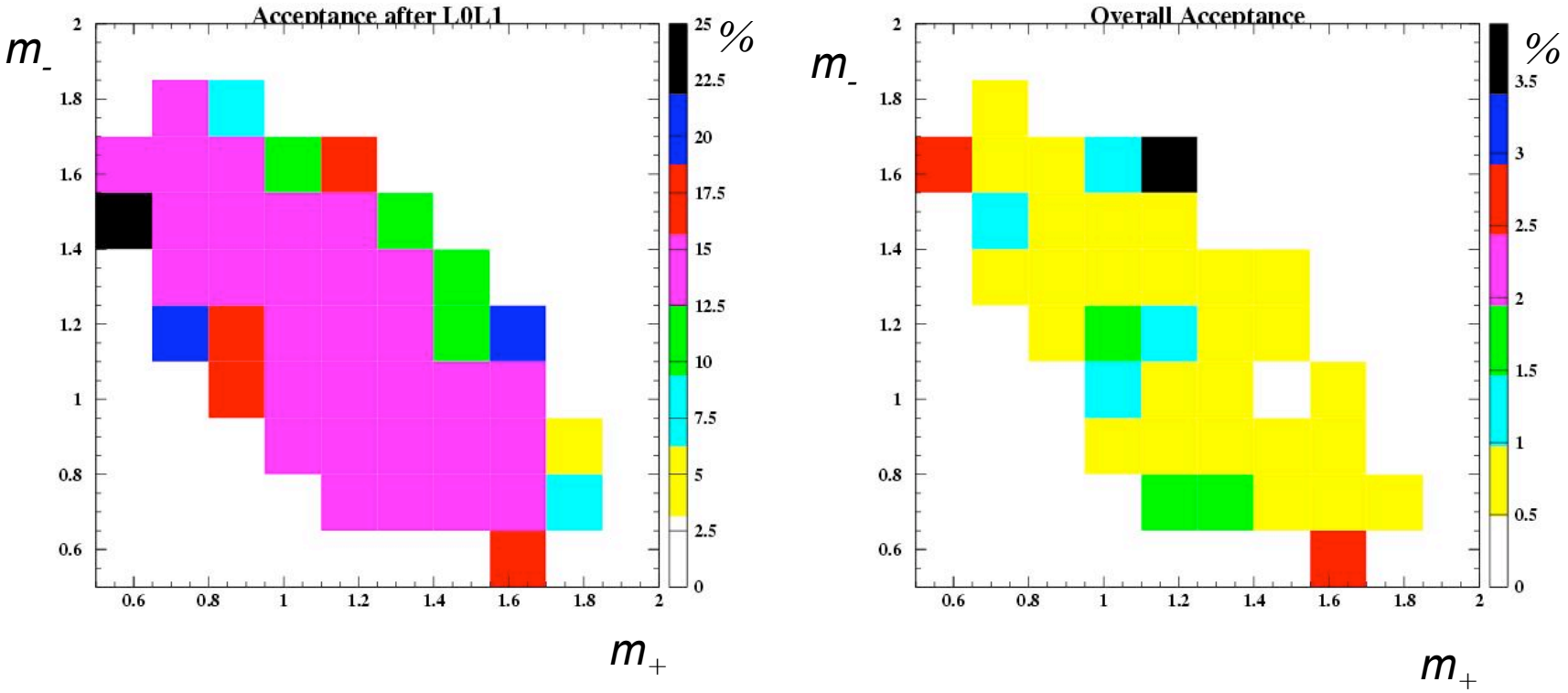
Breit-Wigner + non-resonant

• B simulated with γ=64.7°, δ=150°, r_b=0.16



Acceptance studies

- Selection tuned to maximise signal-to-background ratio
- Acceptance studied with phase space MC - flat within statistics



Acceptance evaluation with isobar model in progress - first indication suggests it is similar

Dalitz: High Level Trigger selection

- In the present preliminary High Level Trigger algorithm tracks decaying downstream of the VELO are not used
- 70% of the events in the present offline Dalitz selection would not be reconstructed
- Work is therefore needed to extend the trigger to include these tracks

Background studies

- At present no background found in 50 MeV mass window of equivalent 46 x 10^6 inclusive B and 80 x 10^6 minimum bias
- Still limited background statistics, equivalent to a few minutes of LHCb running
  - Use B mass sidebands 10 times larger than standard, to study possible sources of background
- In enlarged sidebands 4 bb events are found
  - 1 partially reconstructed b, 3 b-combinatorics - worth further investigation
- Contribution in low-mass sidebands from tails of $B^0 \rightarrow D^0(K^0\pi^+\pi^-)K^{*0}$ and from $B^+ \rightarrow D^{*0} K^+$ - under investigation

Annual yield: $B^+ \rightarrow D^0(K^0\pi^+\pi^-)K^+$

- Acceptance studied with phase space MC

  ε_{tot} = 0.10%

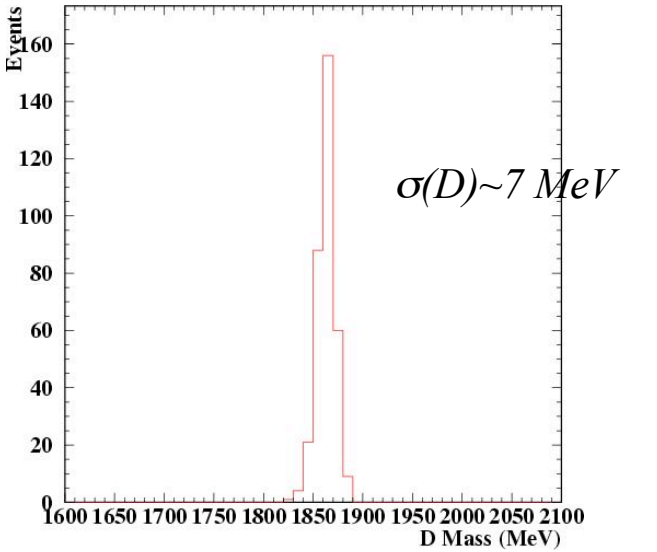
  (selection + L0L1 trigger = 5.8%)

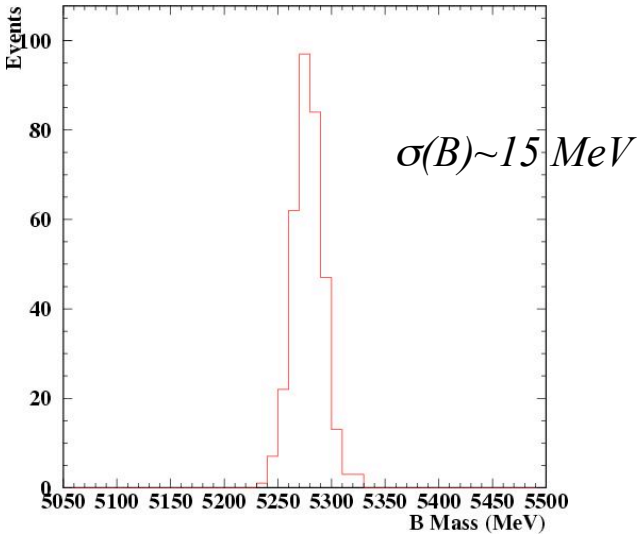
- Luminosity = 2 fb^{-1}

- BR($B^+ \rightarrow D^0(K_s\pi^+\pi^-)K^+$)= *7.5 x 10^{-6}*

- Expected ~6000 events/year not including High Level Trigger efficiency (or > 1300 including it)

  - 0.5< B/S < 3.2 @ 90%CL

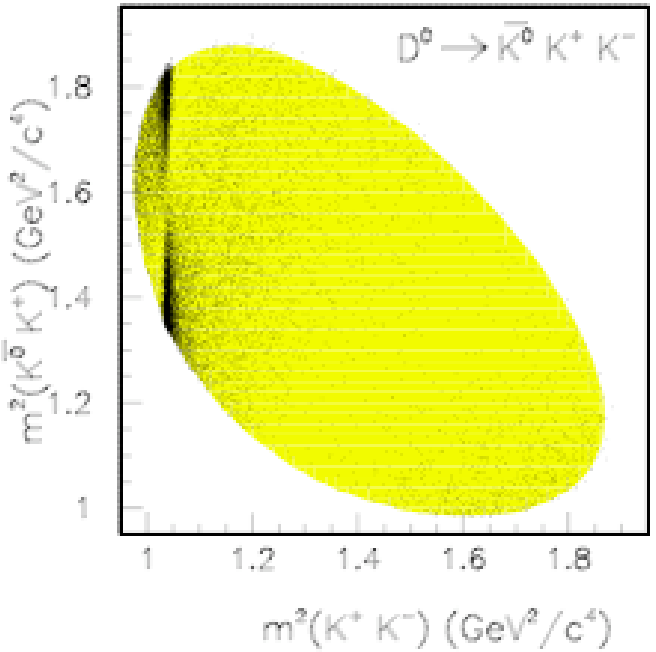




$B^+ \rightarrow D^0(K^0K^+K^-)K^+$

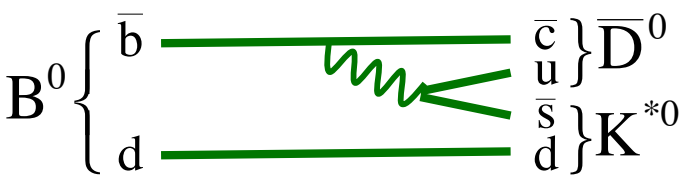
- Same method works for $D^0 \rightarrow K^0K^+K^-$ decay
  - Reduced BR:

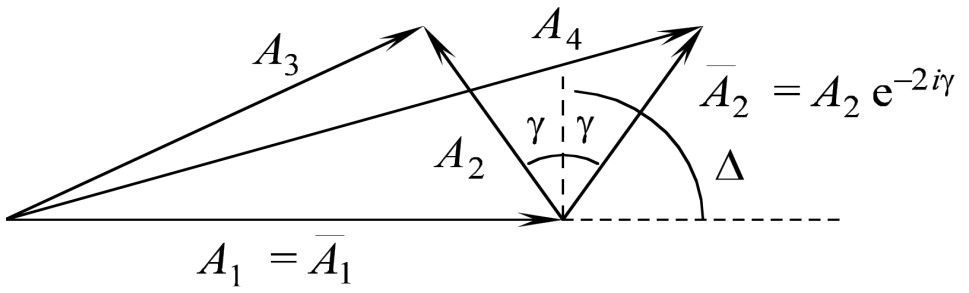
    $BR(D^0 \rightarrow K^0K^+K^-) = (1.03 \pm 0.10)\%$
  - But less background because two more particle identification constraints from RICH should substantially reduce background - also narrow phase space
- Acceptance evaluation in progress
- Dalitz model has fewer resonances (ϕ, a_0) but complex threshold effects (Babar hep-ex/0507026)
  - Separate study of sensitivity is necessary

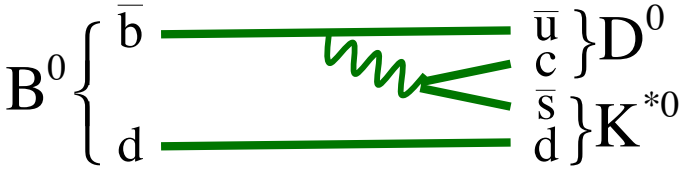


GLW method - γ from $B^0 \to D^0 K^{*0}$

- Dunietz variant of Gronau-Wyler method makes use of interference between two colour-suppressed diagrams interfering via D^0 mixing :







$A_1 = A(B^0 \to \bar{D}^0 K^{*0})$: b→c transition, phase 0

$A_2 = A(B^0 \to D^0 K^{*0})$: b→u transition, phase $\Delta+\gamma$

$A_3 = \sqrt{2}\, A(B^0 \to D_{CP} K^{*0}) = A_1 + A_2$, because $D_{CP} = (D^0 + \bar{D}^0)/\sqrt{2}$

- Measuring the 6 decay rates $B^0 \to D^0(K\pi,\pi K,KK)K^{*0}$ + CP conjugates allows γ to be extracted without flavour tagging or proper time determination

GLW method - γ from $B^0 \to D^0 K^{*0}$

- LHCb expectations for 2 fb^{-1} (γ=65°, Δ=0) :

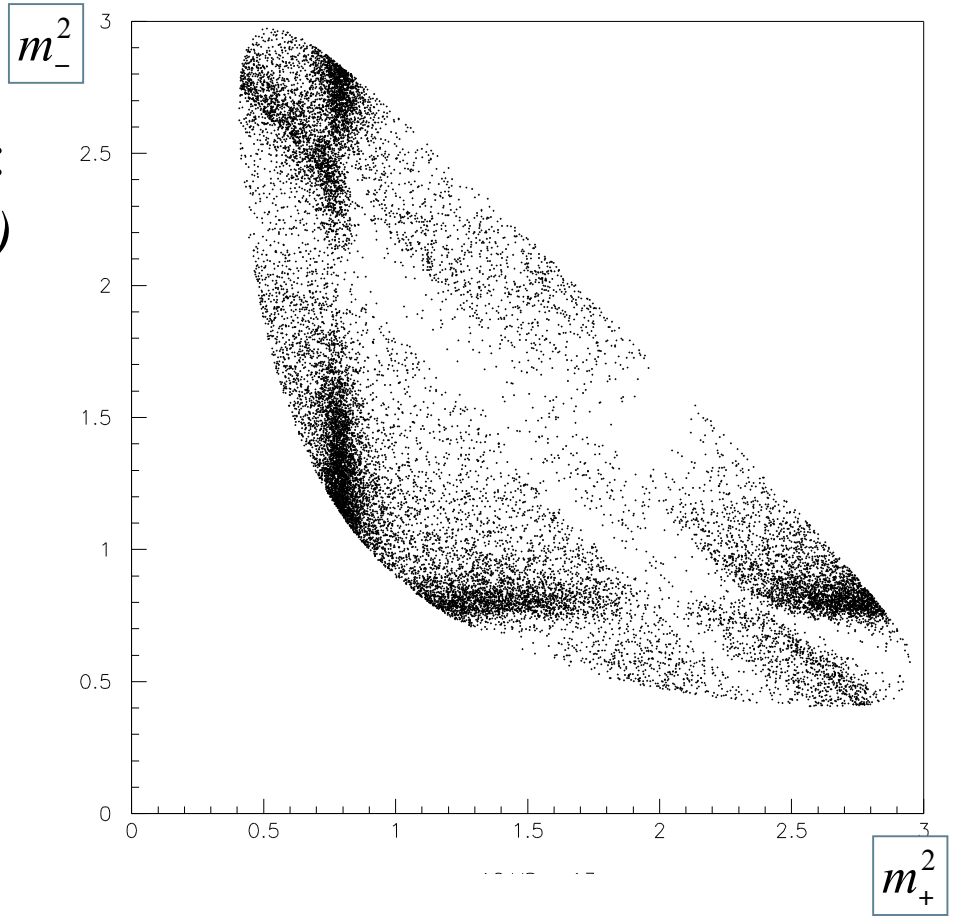
Mode (+ cc)	Yield	S/B_{bb} (90%CL)
$B^0 \to D^0\ (K^+\pi^-)\ K^{*0}$	3.4k	> 2
$B^0 \to D^0\ (K^-\pi^+)\ K^{*0}$	0.5k	> 0.3
$B^0 \to D^0_{CP}\ (K^+K^-)\ K^{*0}$	0.6k	> 0.3

$\to \sigma(\gamma) \sim 8°$ in one year

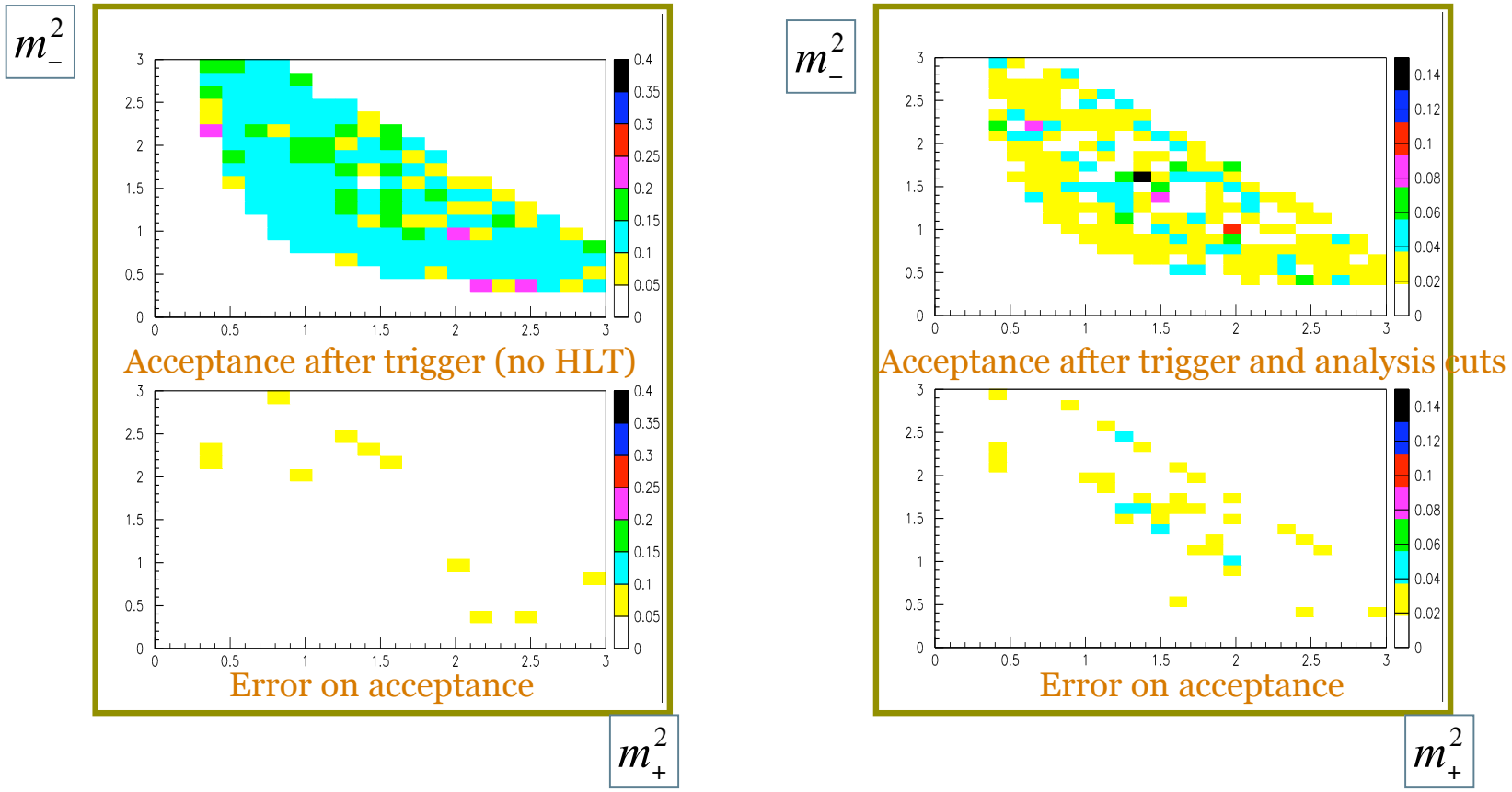
- Work ongoing to understand biases introduced by DCS amplitude in D->Kπ
- Properly including this will be equivalent to full ADS treatment of B^0 ->DK

Dalitz: $B^0 \rightarrow D^0(K^0 \pi^+\pi^-)\, K^{*0}\,(K^+ \pi^-)$

- Same method works as in charged B
  - BF Reduced by factor 10:
    $BF(B^0 \rightarrow D^0(K^0 \pi^+\pi^-)K^{*0})$
    with $K^{*0} \rightarrow K^+\pi^-$
    $= 6.4 \times 10^{-7}$
  - Higher interference ($r_b \sim 1$)
- Dalitz model imported from Belle; amplitudes and phases of resonances taken from CLEO (hep-ex/0207067)



Acceptance studies



- Large statistical error, more detailed study in progress
- Expected yield < 0.1 B^+ yield because of order of magnitude lower branching ratio and additional charged particle

$B^{\pm}$ Conclusions

- ADS method (from M.Patel talk):
  - Candidate for LHCb's most precise measurement of γ
  - Expected annual signal yields (Luminosity = 2 fb^{-1}) :
    - D(Kπ)K - favoured ~ 60k B/S ~ 0.5
      suppressed ~ 2k B/S ~ 0.5
    - D(KK)K …?
    - D(K$\pi\pi\pi$)K
  - With our present understanding of the background a precision on γ of ~5° looks feasible with 2fb^{-1} of data
- Dalitz method:
  - Expected annual signal yield ~6000 without High Level Trigger efficiency (to be compared to ~300 at B-factories)
  - $0.5 < B/S < 3.2$ @90% CL
  - Result on the sensitivity to γ will be available within the time scale of this workshop

B^0 Conclusions

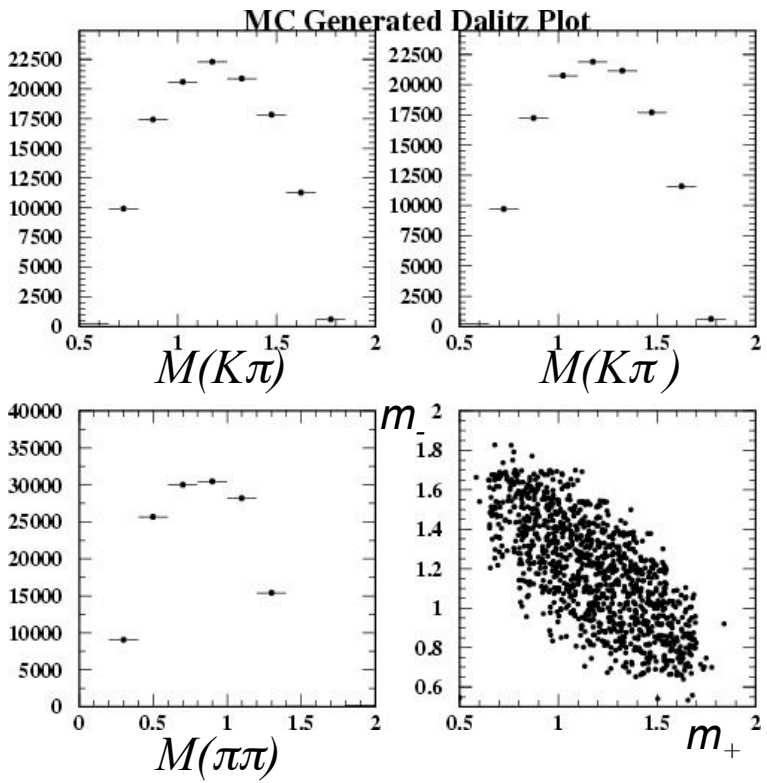
- GLW method:
  - Expected annual signal yields (Luminosity = 2 fb^{-1}) :
    - $D(K^+\pi^-)K^{*0}$ ~ 2.4k B/S >2
    - $D(K^-\pi^+)K^{*0}$ ~ 0.5k B/S>0.3
    - $D^0_{CP}(K^+K^-)K^{*0}$ ~0.6k B/S>0.3
  - $\sigma(\gamma)\sim 8^o$ in one year
  - Work ongoing to understand biases introduced by DCS amplitude in D->Kπ
- Dalitz method:
  - Expected annual signal yield < 600 due to BR 10 times lower than the charged one and the presence of one more final state particle
  - Background rejection under investigation
  - Sensitivity to γ in progress

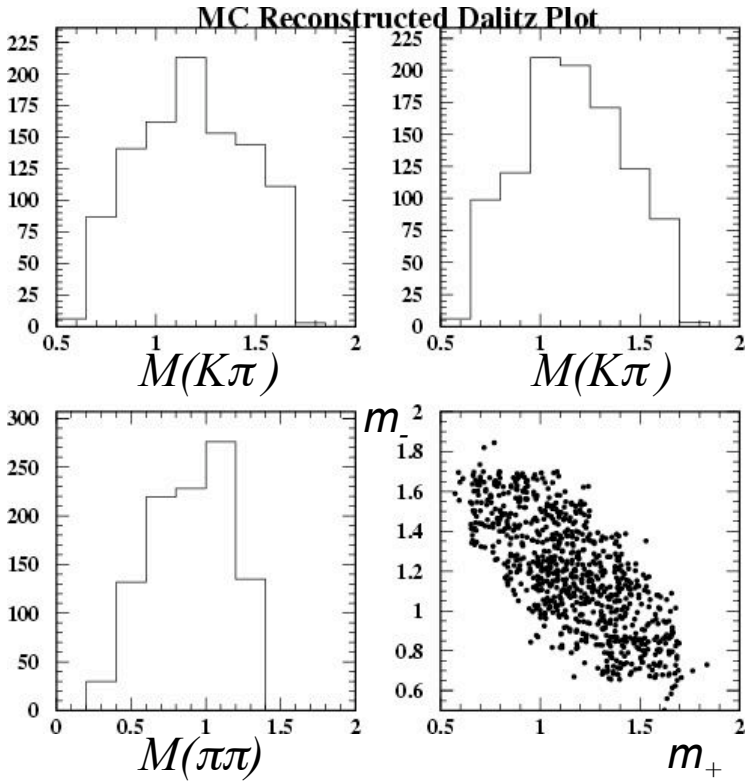
Outlook

- Possibility of including the K_S decaying outside the Vertex Detector in the High Level Trigger
- Dalitz model:
  - Refinement of the Dalitz model
  - Model-independent technique
  - Measure the resonance parameters ourselves
- Detailed studies of the acceptance over the Dalitz plot
- Further background investigation
- More results soon on the sensitivity to γ
- r_B and δ_B are the same for all charged (neutral) channels $\rightarrow$ global fit

LHCb has a great potential to measure γ in a wide variety of channels!

Spares


MC Generated Dalitz Plot
M(Kπ)
M(Kπ)
M(ππ)
m-2
m+


MC Reconstructed Dalitz Plot
M(Kπ)
M(Kπ)
M(ππ)
m-2
m+