Introduction to Dalitz Plot Analysis

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479.WE-Heraeus-Seminar
Physics at LHCb
26 April 2011

What Is a Dalitz Plot?

- Visual representation of
  - the phase-space of a three-body decay
    - involving only spin-0 particles
    - (term often abused to refer to phase-space of any multibody decay)
  - Named after it's inventor, Richard Dalitz (1925–2006):
  - "On the analysis of tau-meson data and the nature of the tau-meson."
    - R.H. Dalitz, Phil. Mag. 44 (1953) 1068
    - (historical reminder: tau meson = charged kaon)
  - For scientific obituary, see
    - I.J.R. Aitchison, F.E. Close, A. Gal, D.J. Millener,
    - Nucl.Phys.A771:8-25,2006

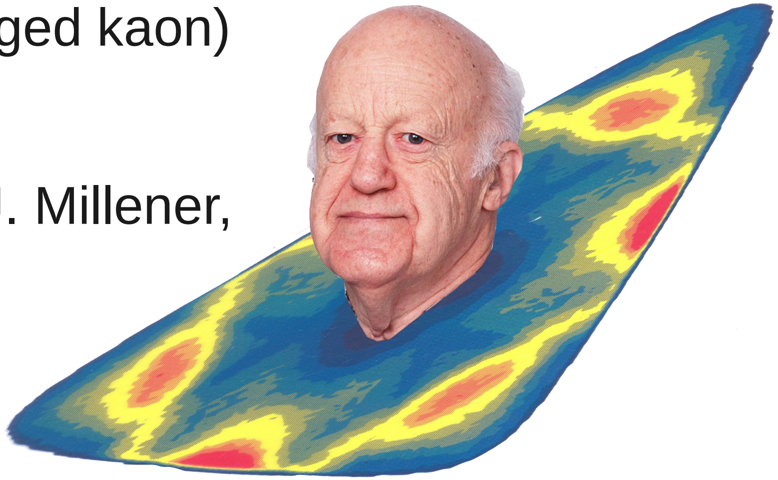


Image credit: Mike Pennington

“Equilateral representation”

Connection between scattering and decay processes provides a solid theoretical ground for describing some hadronic effects – “Watson's theorem”

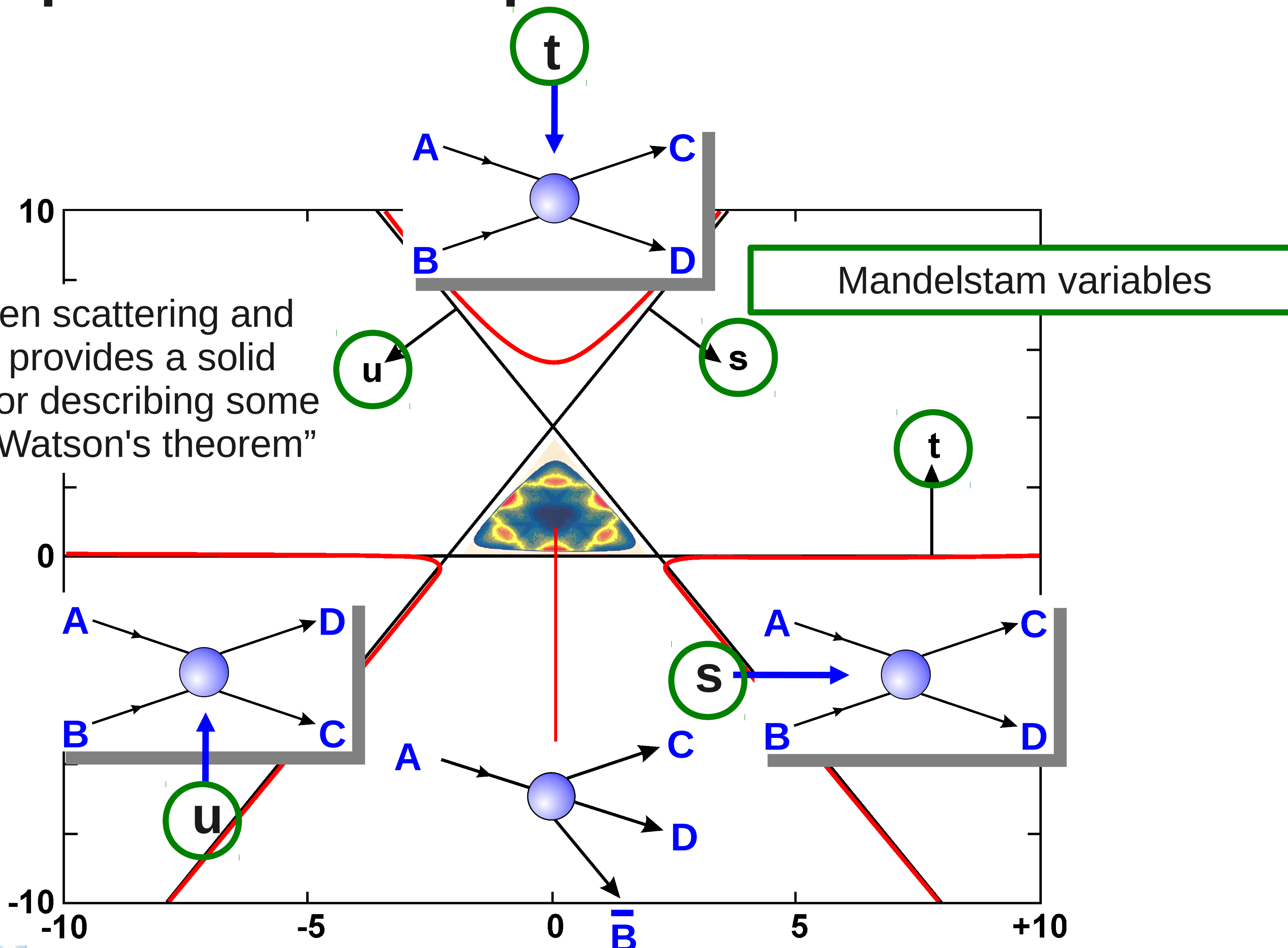
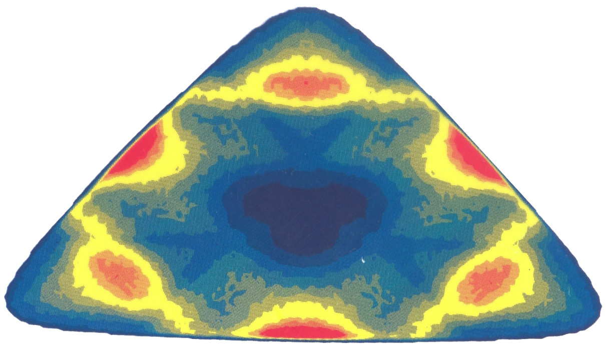
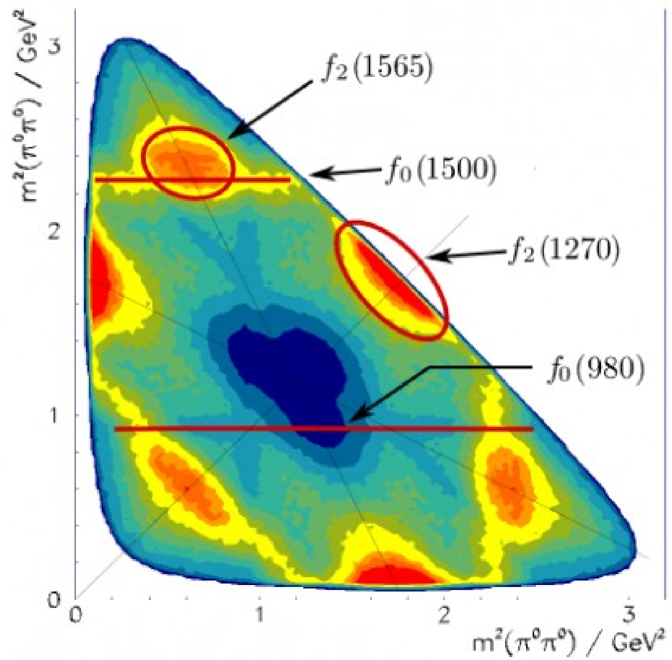


Image credit: Mike Pennington

In case anyone is wondering ...

- Previous plot shows $p\bar{p} \rightarrow \pi^0\pi^0\pi^0$ from Crystal Barrel experiment (LEAR)
  - C.Amsler et al., EPJC 23 (2002) 29
- Highly symmetrized because 3 identical bosons in the final state
  - symmetric under interchange of any 2 π^0



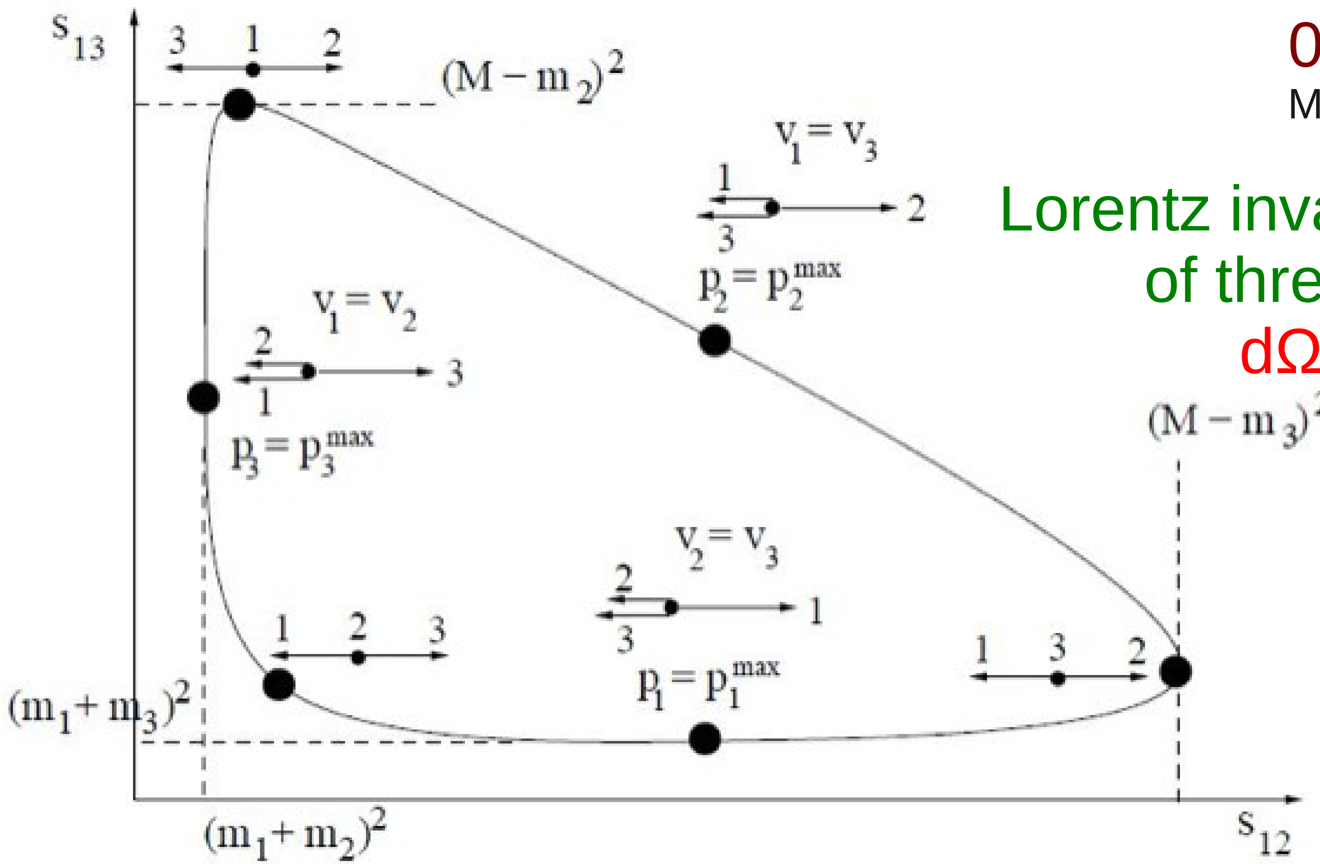


"Right-angled representation"

Removes some of the symmetry … but easier for most software to handle

(Most decays that we are interested in are not so symmetric anyway)

Retains & heightens intuitive connection between visualisation and kinematics



$0 \rightarrow 1\ 2\ 3$

$M \quad m_1\ m_2\ m_3$

Lorentz invariant phase-space of three-body decay

$d\Omega \sim ds_{12} ds_{13}$

Dalitz plots as visualiser of kinematics

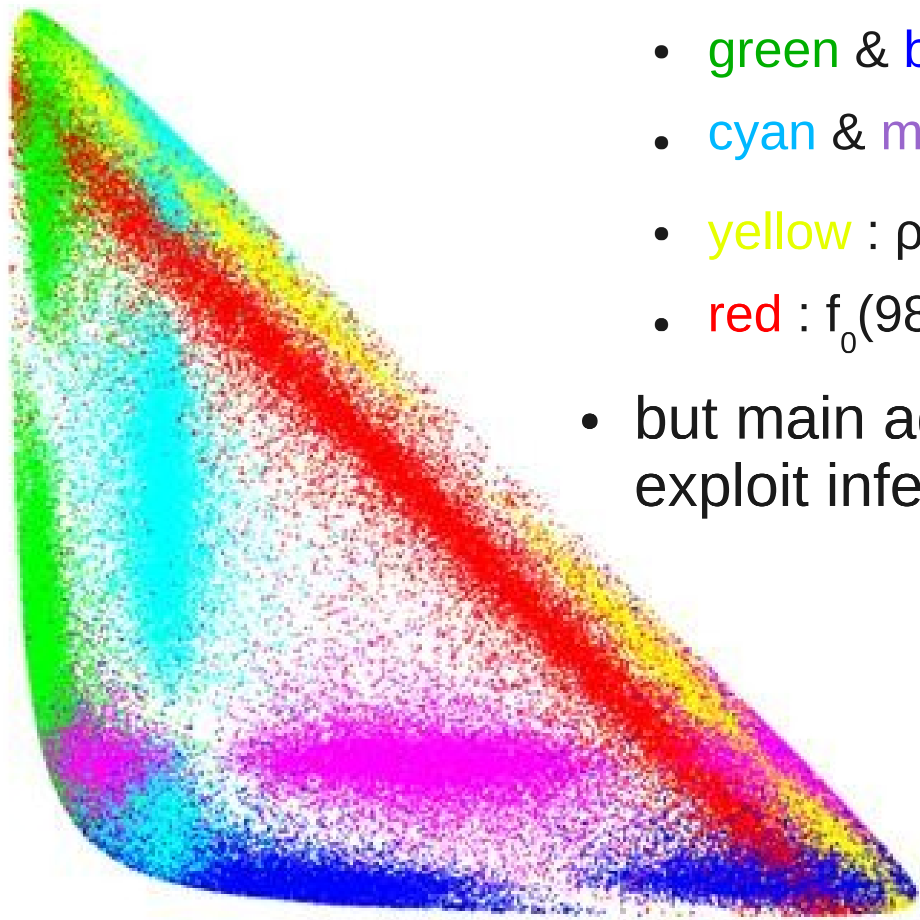
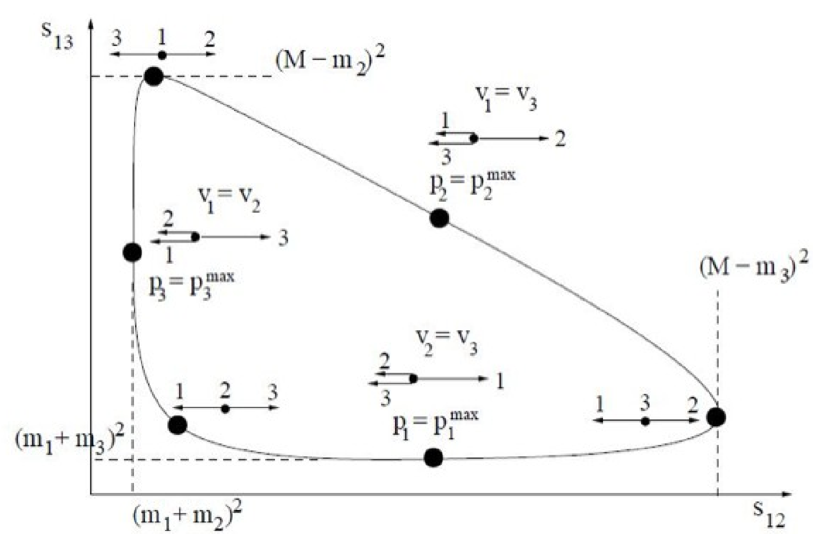


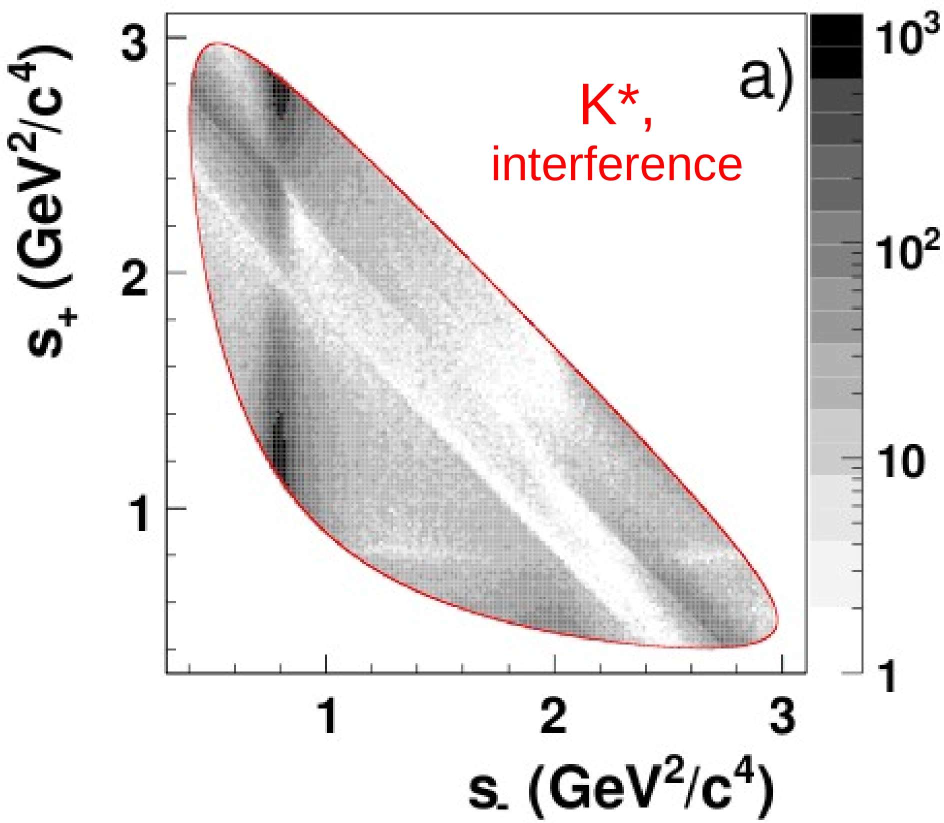
Image credit: Tom Latham

- Illustration for $D \to K_S \pi^+ \pi^-$
  - green & blue: K*(892) (vector)
  - cyan & magenta : K_2*(1430) (tensor)
  - yellow : ρ(770) (vector)
  - red : f_0(980) (scalar)
- but main advantage of Dalitz plots is ability to exploit inference between different resonances

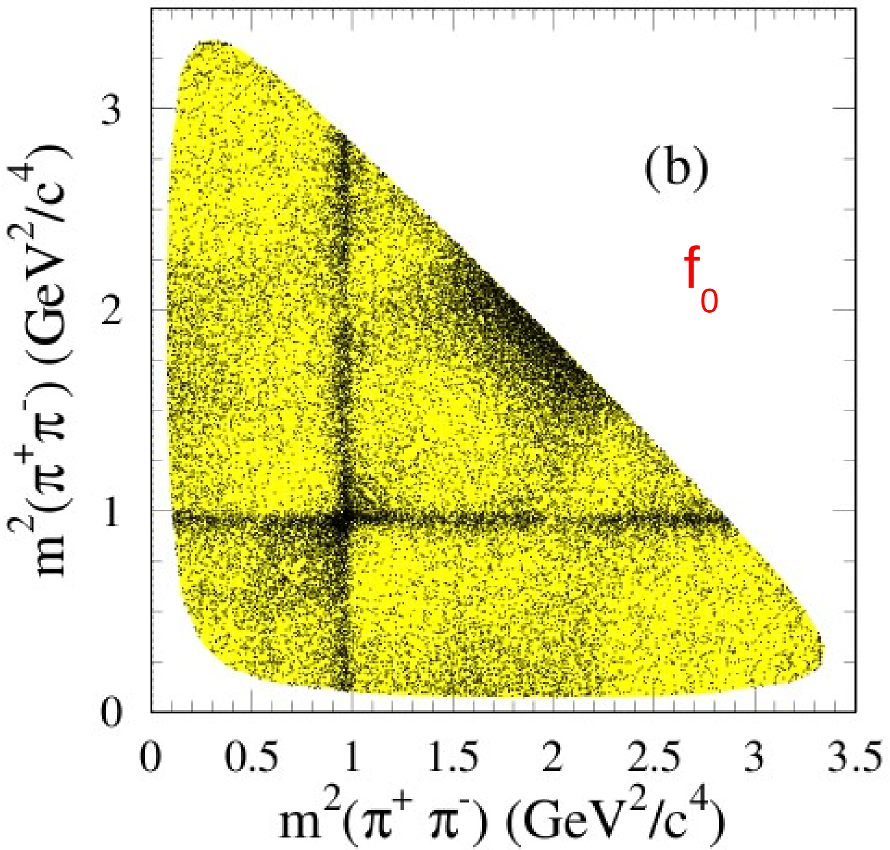


Some examples of Dalitz plots

$D^0 \rightarrow K_s\pi^+\pi^-$
BaBar PRL 105 (2010) 081803



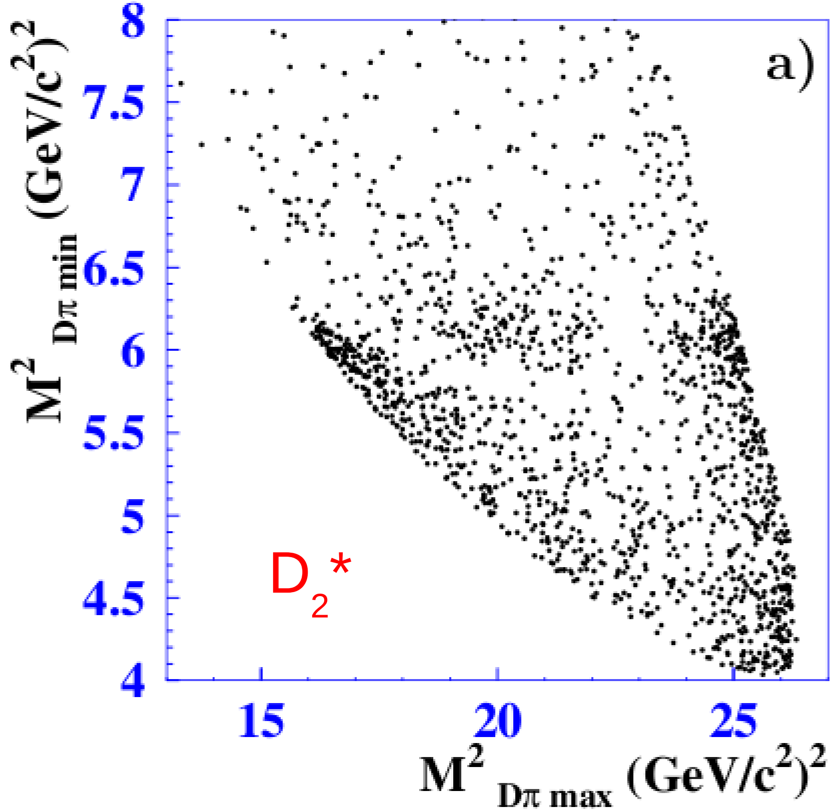
$D_s^+ \rightarrow \pi^+\pi^-\pi^+$
BaBar PRD 79 (2009) 032003



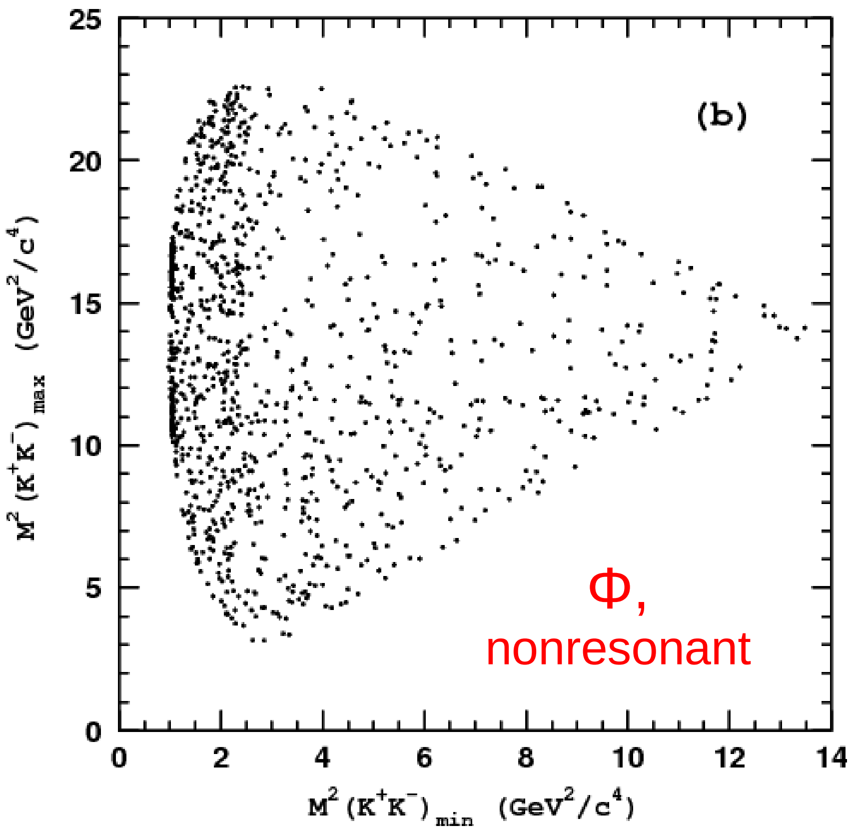
Note symmetries

Some examples of Dalitz plots

$B^+ \to D^- \pi^+ \pi^+$
Belle PRD 69 (2004) 112002



$B^+ \to K^+ K^+ K^-$
Belle PRD 71 (2005) 092003



Note symmetries

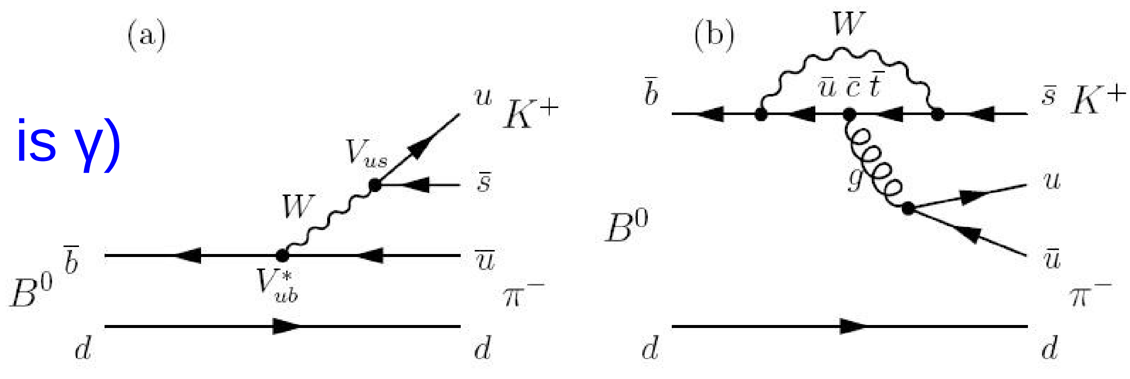
Why are we so interested in Dalitz plots?

- Condition for DCPV: $|\bar{A}/A| \neq 1$
- Need $\bar{A}$ and A to consist of (at least) two parts
  - with different weak (φ) and strong (δ) phases
- Often realised by “tree” and “penguin” diagrams

$$A = |T| e^{i(\delta_T - \phi_T)} + |P| e^{i(\delta_P - \phi_P)} \qquad \bar{A} = |T| e^{i(\delta_T + \phi_T)} + |P| e^{i(\delta_P + \phi_P)}$$

$$A_{CP} = \frac{|\bar{A}|^2 - |A|^2}{|\bar{A}|^2 + |A|^2} = \frac{2\,|T||P| \sin(\delta_T - \delta_P) \sin(\phi_T - \phi_P)}{|T|^2 + |P|^2 + 2\,|T||P| \cos(\delta_T - \delta_P) \cos(\phi_T - \phi_P)}$$

Example: B→Kπ
(weak phase difference is γ)



Feynman tree (a) and penguin (b) diagrams for the $B_d^0 \to K^+\pi^-$ decay

Why are we so interested in Dalitz plots?

- Condition for DCPV: $|\bar{A}/A| \neq 1$

Problem with two-body decays:

- 2 observables (B, A_{CP})
- 4 unknowns ($|T|$, $|P|$, $\delta_T - \delta_P$, $\varphi_T - \varphi_P$)

$$A_{CP} = \frac{|\bar{A}|^2 - |A|^2}{|\bar{A}|^2 + |A|^2} = \frac{2\,|T||P|\sin(\delta_T - \delta_P)\sin(\phi_T - \phi_P)}{|T|^2 + |P|^2 + 2\,|T||P|\cos(\delta_T - \delta_P)\cos(\phi_T - \phi_P)}$$

Example: B→Kπ
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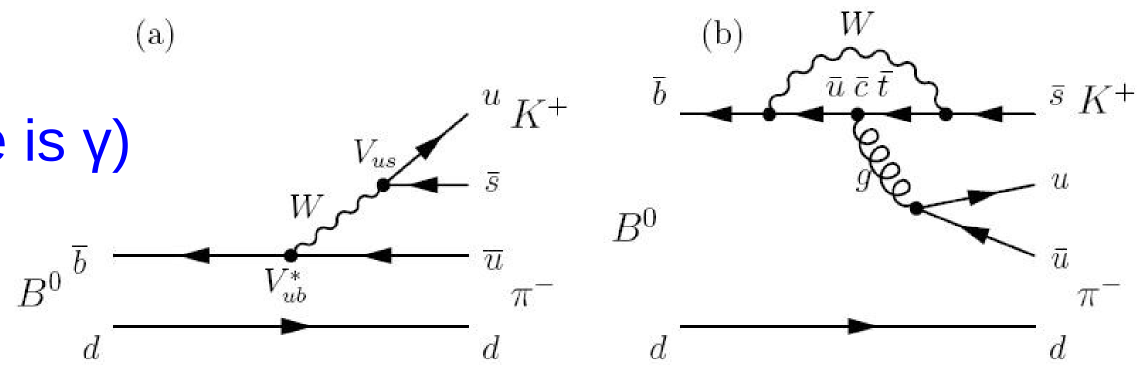


Feynman tree (a) and penguin (b) diagrams for the $B_d^0 \to K^+\pi^-$ decay

Direct CP violation in B→Kπ

- Direct CP violation in B→Kπ sensitive to γ

too many hadronic parameters ⇒ need theory input

NB. interesting deviation from naïve expectation

"Kπ puzzle"

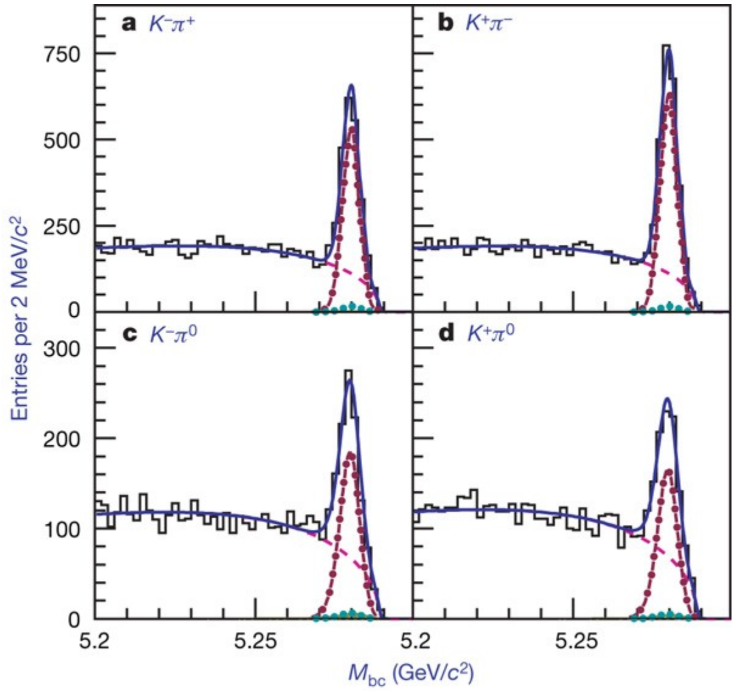
$$A_{CP}(K^-\pi^+)=(-9.8^{+1.2}_{-1.1})\% \quad A_{CP}(K^-\pi^0)=(5.0\pm2.5)\%$$
$$\Delta(A_{CP})=(-14.8\pm2.8)\%$$

HFAG averages
BABAR PRD 76 (2007) 091102 & arXiv:0807.4226; also CDF

and now LHCb!
(results not in average yet)

Could be a sign of new physics …
… but need to rule out possibility of larger than expected QCD corrections

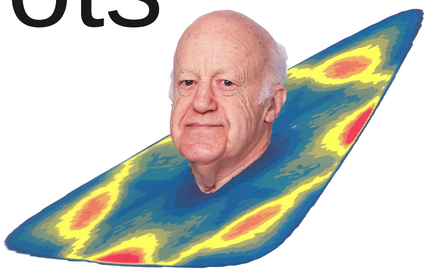
Belle Nature 452 (2008) 332



Dalitz plot analysis

- Amplitude analysis to extract directly information related to the phase at each Dalitz plot position
- Most commonly performed in the “isobar model”
  - sum of interfering resonances
  - each described by Breit-Wigner (or similar) lineshapes, spin terms, etc.
  - fit can be unbinned, but has inherent model dependence
- Alternative approaches aiming to avoid model dependence usually involve binning
  - partial wave analysis

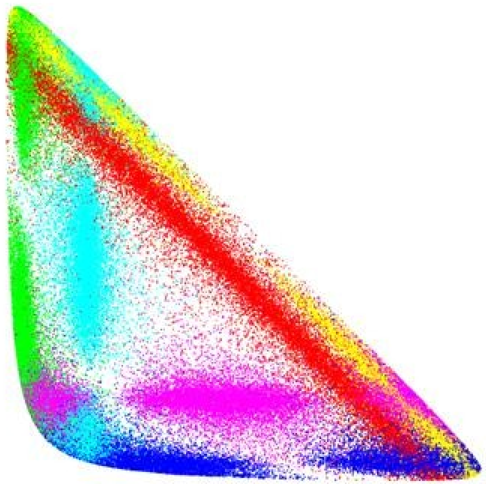
Pros and cons of Dalitz plots



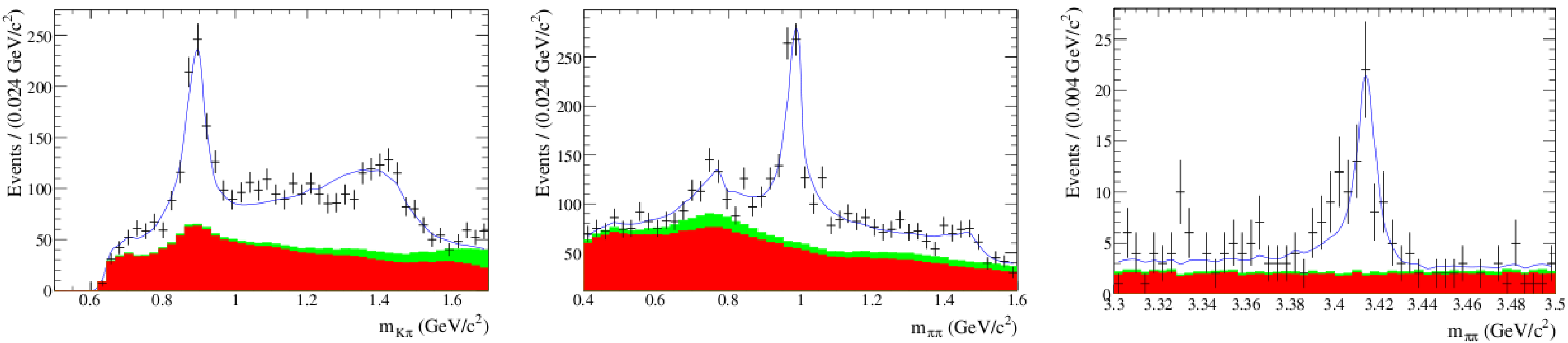
- Pros
  - More observables (B & A_{CP} at each Dalitz plot point)
  - Using isobar formalism, can express total amplitude as coherent sum of quasi-two-body contributions

$$A(m_{12}^2, m_{23}^2) = \sum_r c_r F_r(m_{12}^2, m_{23}^2)$$

    - where c_r & F_r contain the weak and strong physics, respectively
    - n.b. each c_r is itself a sum of contributions from tree, penguin, etc.
  - Interference provides additional sensitivity to CP violation
- Cons
  - Need to understand hadronic (F_r) factors
    - lineshapes, angular terms, barrier factors, ...
  - Isobar formalism only an approximation
  - Model dependence



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



BaBar PRD 78 (2008) 012004
See also Belle PRL 96 (2006) 251803

Model includes:

- $K^{*0}(892)\pi+$, $K_2^{*0}(1430)\pi^+$
- $(K\pi)_0{}^*\pi^+$ (LASS lineshape)
- $\rho^0(770)K^+$, $\omega(782)K^+$, $f_0(980)K^+$, $f_2(1270)K^+$, $\chi_{c0}K^+$
- $f_X(1300)K^+$, phase-space nonresonant

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

TABLE II: Summary of measurements of branching fractions (averaged over charge conjugate states) and CP asymmetries. Note that these results are not corrected for secondary branching fractions. The first uncertainty is statistical, the second is systematic, and the third represents the model dependence. The final column is the statistical significance of direct CP violation determined as described in the text.

Mode	Fit fraction (%)	$\mathcal{B}(B^+ \to \text{Mode})(10^{-6})$	A_{CP} (%)	DCPV sig.
$K^+\pi^-\pi^+$ total		$54.4 \pm 1.1 \pm 4.5 \pm 0.7$	$2.8 \pm 2.0 \pm 2.0 \pm 1.2$	
$K^{*0}(892)\pi^+$; $K^{*0}(892) \to K^+\pi^-$	$13.3 \pm 0.7 \pm 0.7\,^{+0.4}_{-0.9}$	$7.2 \pm 0.4 \pm 0.7\,^{+0.3}_{-0.5}$	$+3.2 \pm 5.2 \pm 1.1\,^{+1.2}_{-0.7}$	0.9σ
$(K\pi)^{*0}_0\pi^+$; $(K\pi)^{*0}_0 \to K^+\pi^-$	$45.0 \pm 1.4 \pm 1.2\,^{+12.9}_{-0.2}$	$24.5 \pm 0.9 \pm 2.1\,^{+7.0}_{-1.1}$	$+3.2 \pm 3.5 \pm 2.0\,^{+2.7}_{-1.9}$	1.2σ
$\rho^0(770)K^+$; $\rho^0(770) \to \pi^+\pi^-$	$6.54 \pm 0.81 \pm 0.58\,^{+0.69}_{-0.26}$	$3.56 \pm 0.45 \pm 0.43\,^{+0.38}_{-0.15}$	$+44 \pm 10 \pm 4\,^{+5}_{-13}$	3.7σ
$f_0(980)K^+$; $f_0(980) \to \pi^+\pi^-$	$18.9 \pm 0.9 \pm 1.7\,^{+2.8}_{-0.6}$	$10.3 \pm 0.5 \pm 1.3\,^{+1.5}_{-0.4}$	$-10.6 \pm 5.0 \pm 1.1\,^{+3.4}_{-1.0}$	1.8σ
$\chi_{c0}K^+$; $\chi_{c0} \to \pi^+\pi^-$	$1.29 \pm 0.19 \pm 0.15\,^{+0.12}_{-0.03}$	$0.70 \pm 0.10 \pm 0.10\,^{+0.06}_{-0.02}$	$-14 \pm 15 \pm 3\,^{+1}_{-5}$	0.5σ
$K^+\pi^-\pi^+$ nonresonant	$4.5 \pm 0.9 \pm 2.4\,^{+0.6}_{-1.5}$	$2.4 \pm 0.5 \pm 1.3\,^{+0.3}_{-0.8}$	—	—
$K_2^{*0}(1430)\pi^+$; $K_2^{*0}(1430) \to K^+\pi^-$	$3.40 \pm 0.75 \pm 0.42\,^{+0.99}_{-0.13}$	$1.85 \pm 0.41 \pm 0.28\,^{+0.54}_{-0.08}$	$+5 \pm 23 \pm 4\,^{+18}_{-7}$	0.2σ
$\omega(782)K^+$; $\omega(782) \to \pi^+\pi^-$	$0.17 \pm 0.24 \pm 0.03\,^{+0.05}_{-0.08}$	$0.09 \pm 0.13 \pm 0.02\,^{+0.03}_{-0.04}$	—	—
$f_2(1270)K^+$; $f_2(1270) \to \pi^+\pi^-$	$0.91 \pm 0.27 \pm 0.11\,^{+0.24}_{-0.17}$	$0.50 \pm 0.15 \pm 0.07\,^{+0.13}_{-0.09}$	$-85 \pm 22 \pm 13\,^{+22}_{-2}$	3.5σ
$f_X(1300)K^+$; $f_X(1300) \to \pi^+\pi^-$	$1.33 \pm 0.38 \pm 0.86\,^{+0.04}_{-0.14}$	$0.73 \pm 0.21 \pm 0.47\,^{+0.02}_{-0.08}$	$+28 \pm 26 \pm 13\,^{+7}_{-5}$	0.6σ

- $f_X(1300)K^+$, phase-space nonresonant

BaBar PRD 78 (2008) 012004
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Evidence for direct CP violation
But significant model dependence

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

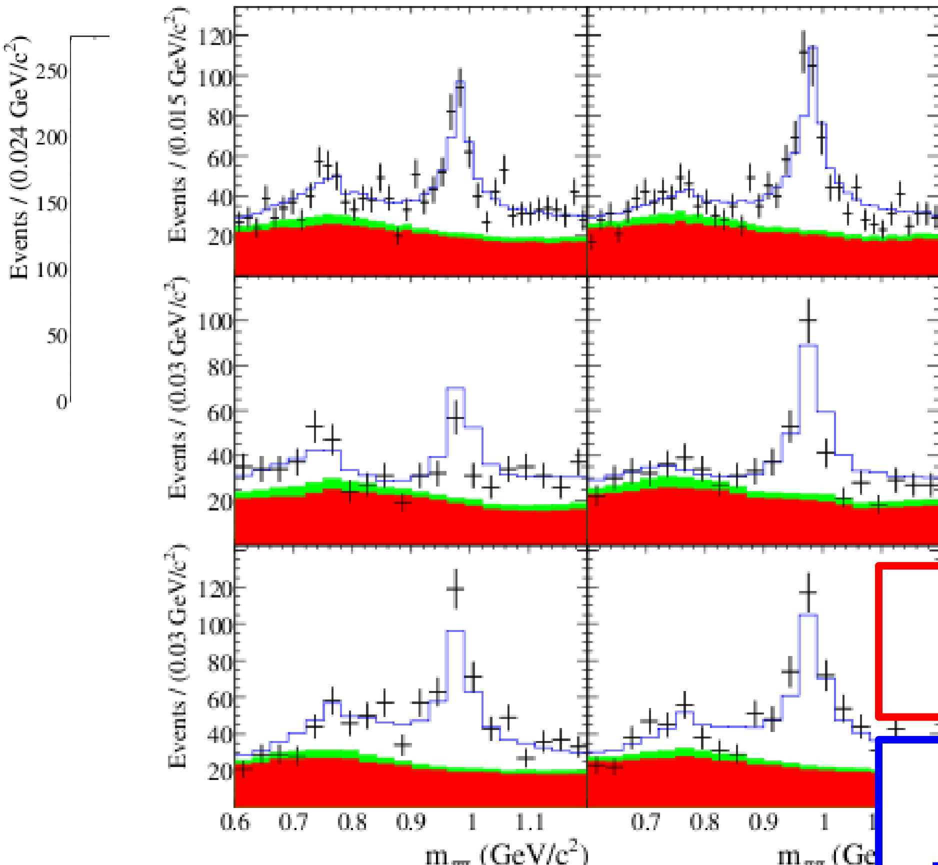

FIG. 4: Projection plots of the $\pi^+\pi^-$ invariant mass in the region of the $\rho^0(770)$ and $f_0(980)$ resonances. The left (right) plots are for B^- (B^+) candidates. The top row shows all candidates, the middle row shows those where $\cos\theta_H > 0$, and the bottom row shows those where $\cos\theta_H < 0$. The data are the black points with statistical error bars, the lower solid (red/dark) histogram is the $q\overline{q}$ component, the middle solid (green/light) histogram is the $B\overline{B}$ background contribution, while the blue open histogram shows the total fit result.

veraged over charge conjugate states) and CP asymmetries. ıg fractions. The first uncertainty is statistical, the second The final column is the statistical significance of direct CP

$\mathcal{B}(B^+ \rightarrow \text{Mode})(10^{-6})$	A_{CP} (%)	DCPV sig.
$54.4 \pm 1.1 \pm 4.5 \pm 0.7$	$2.8 \pm 2.0 \pm 2.0 \pm 1.2$	
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$24.5 \pm 0.9 \pm 2.1\,^{+7.0}_{-1.1}$	$+3.2 \pm 3.5 \pm 2.0\,^{+2.7}_{-1.9}$	1.2σ
$.56 \pm 0.45 \pm 0.43\,^{+0.38}_{-0.15}$	$+44 \pm 10 \pm 4\,^{+5}_{-13}$	3.7σ
$10.3 \pm 0.5 \pm 1.3\,^{+1.5}$	$-10.6 \pm 5.0 \pm 1.1\,^{+3.4}$	1.8σ
$.85 \pm 0.41 \pm 0.28$	$+5 \pm 23 \pm 4$	0.2σ
$.73 \pm 0.21 \pm 0.47\,^{+0.02}_{-0.08}$	$+28 \pm 26 \pm 13\,^{+7}_{-5}$	0.6σ

Evidence for direct CP violation
But significant model dependence

Huge potential for LHCb ...
… but need to reduce model dependence

onant

BaBar PRD 78 (2008) 012004
See also Belle PRL 96 (2006) 251803

Sources of model dependence

- Lineshapes
  - coupled channels, threshold effects, etc.
- Isobar formalism
  - "sum of Breit-Wigners" model violates unitarity
  - problem most severe for broad, overlapping resonances
    - even talking about "mass" and "width" for such states is not strictly correct (process dependent) – can only be defined by pole position
- Nonresonant contributions
  - such terms are small for D decays, but are found to be large for some B decays (not well understood why)
  - interference with other (S-wave) terms can lead to unphysical phase variations

Are methods used for D decay Dalitz plots also valid for B decays?

$D \to K^- \pi^+ \pi^0$

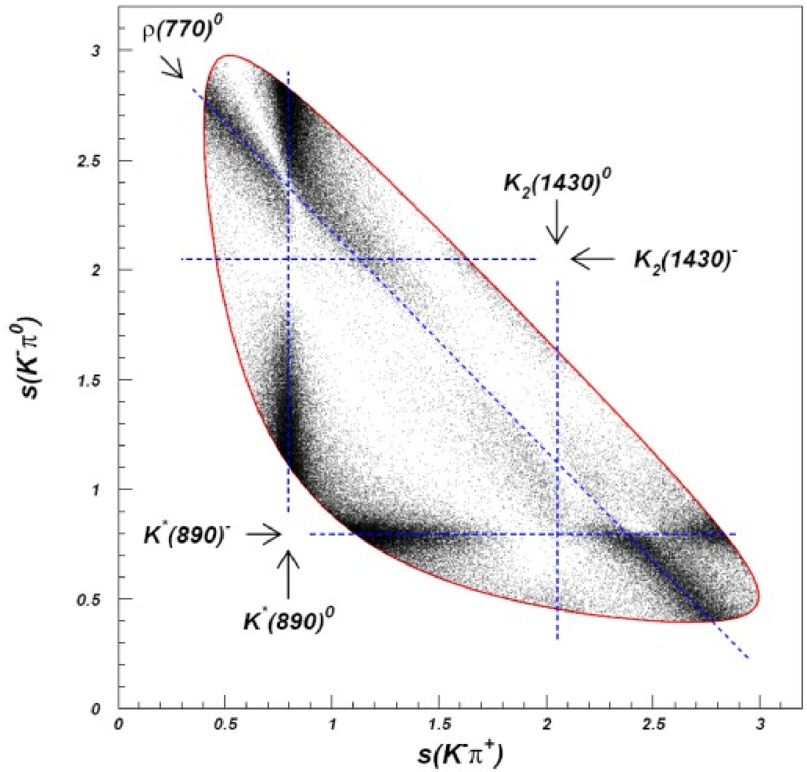
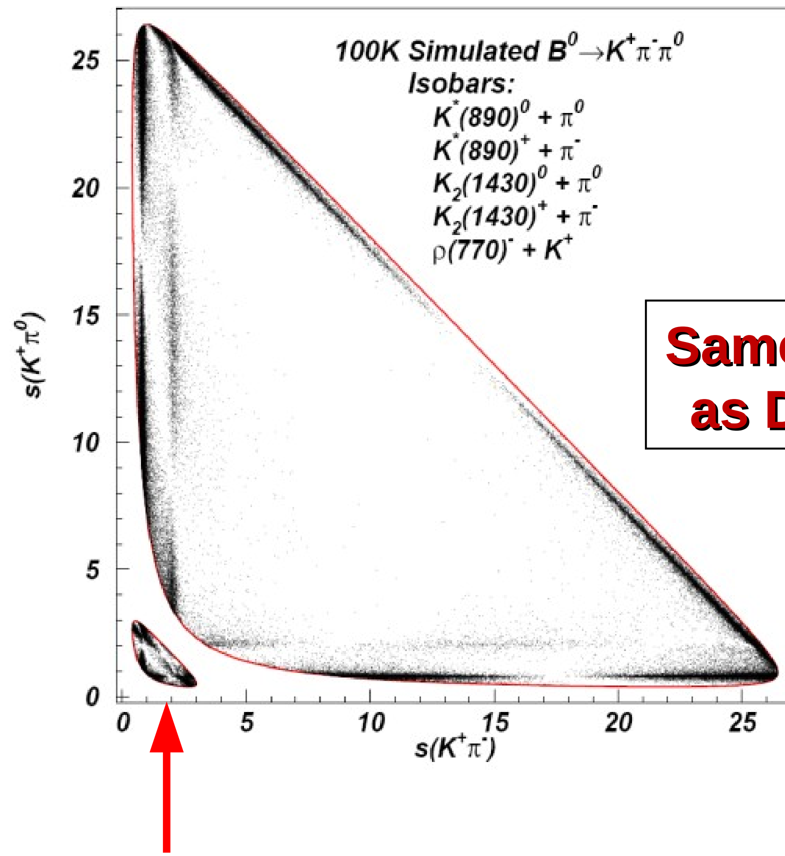


Image credit: Brian Meadows

$B \to K^- \pi^+ \pi^0$



Same model as D decay

D Dalitz plot on same scale

How to address model dependence?

- Model independent methods
  - Dalitz plot anisotropy (“Miranda” method)
  - binned D Dalitz plots for measurement of γ in B→DK (and charm mixing & CP violation)
  - partial wave analysis
- More robust (but still model dependent) methods
  - K-matrix approach
  - use of scattering data to constrain phase variation (Watson's theorem) – e.g. LASS shape for (Kπ) S-wave
  - input from theory (chiral symmetry, dispersion relations)

More details in talks of Christoph Hanhart and Leonard Lesniak in parallel session on Thursday

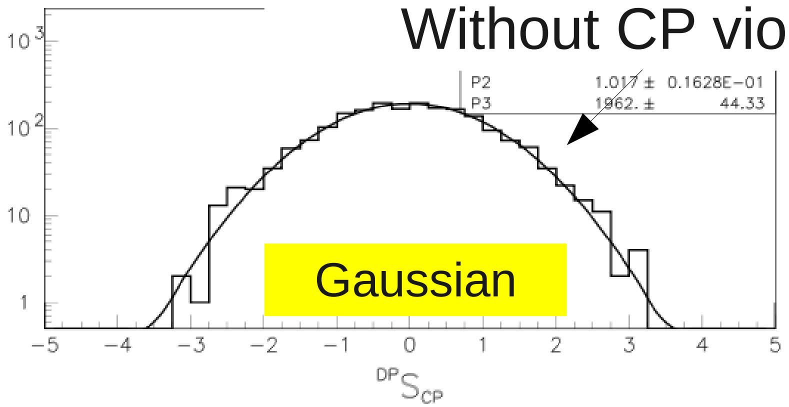
“Miranda” procedure
a.k.a. Dalitz plot anisotropy

PRD 80 (2009) 096006

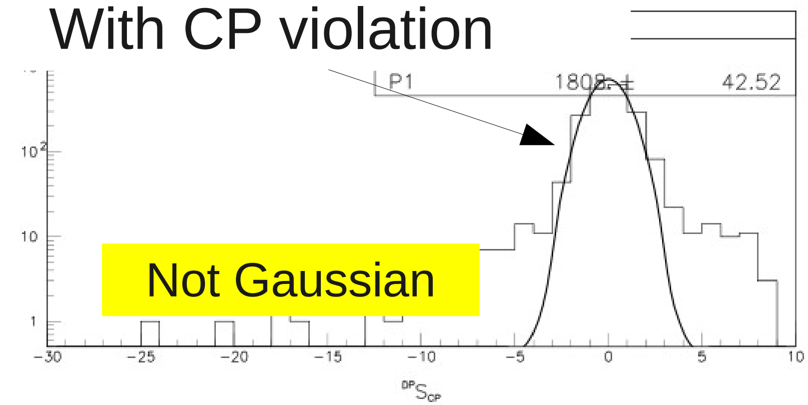
$$^{\mathrm{Dp}}S_{CP} \equiv \frac{N(i) - \bar{N}(i)}{\sqrt{N(i) + \bar{N}(i)}}$$

Toy model (using $B^+ \to K^+\pi^+\pi^-$)

Without CP violation



With CP violation



- Good model-independent way to identify CP violation
    - could be sufficient to identify non-SM physics in, e.g., charm decays
- Constant (DP independent) systematic asymmetries can be accounted for
- Can isolate region of the Dalitz plot where CP violation effects occur

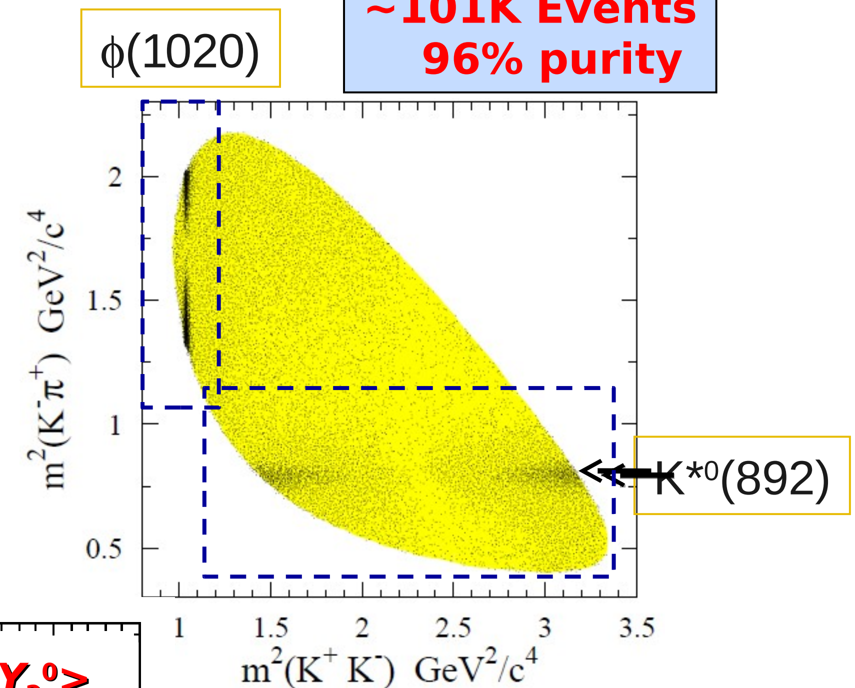
But does not provide quantitative measure of weak phase

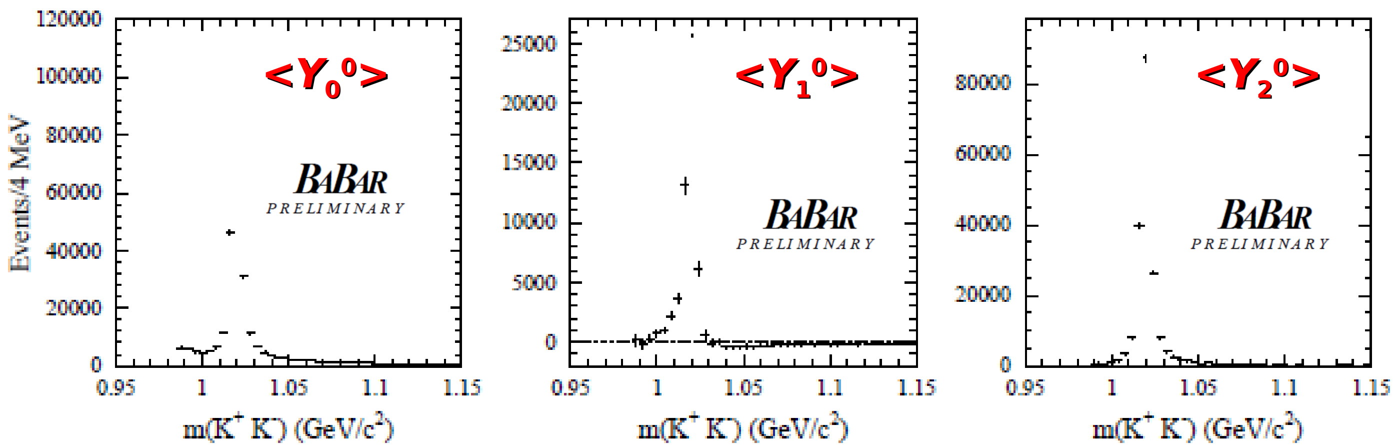
Example partial wave analysis: $D_s^+ \to K^+K^-\pi^+$ (BaBar)

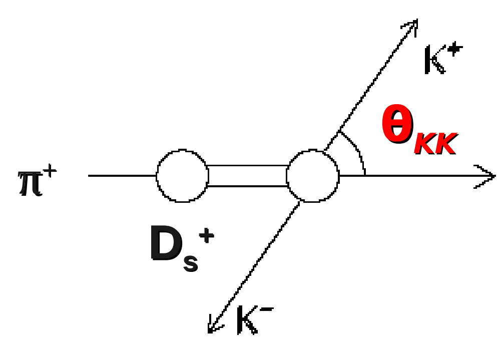
~101K Events
96% purity

Plot $m(K^+K^-)$, weighting events by factors $Y_L^0(\cos\theta_{KK})/\varepsilon$ to obtain "moments $\langle Y_L^0(m)\rangle$"

$$
\begin{aligned}
\sqrt{4\pi}\langle Y_0^0\rangle &= |S|^2 + |P|^2 \\
\sqrt{4\pi}\langle Y_2^0\rangle &= \frac{2}{\sqrt{5}}|P|^2, \\
\sqrt{4\pi}\langle Y_1^0\rangle &= 2|S||P|\cos\phi_{SP}
\end{aligned}
$$



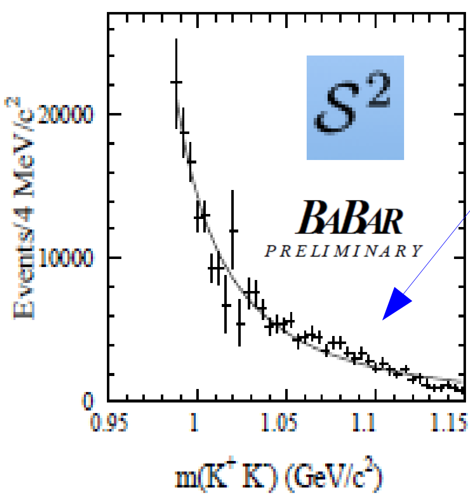


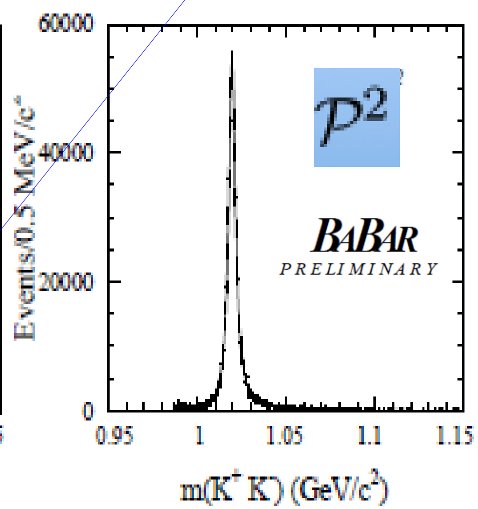


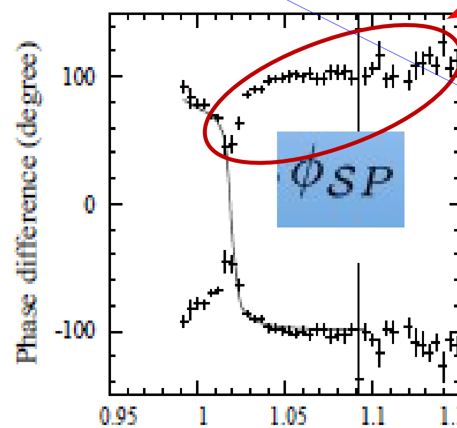
Example partial wave analysis: $D_s^+ \to K^+K^-\pi^+$ (BaBar)

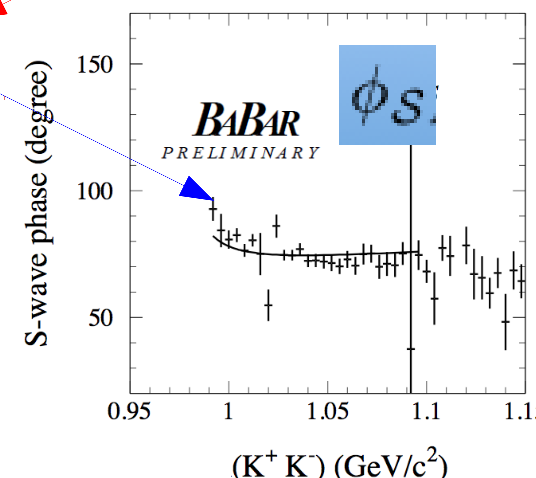
(Approximately) model-independent information on the KK S-wave magnitude and phase

Ambiguity in ϕ_{SP} resolved by knowledge of $\phi(1020)$ phase variation

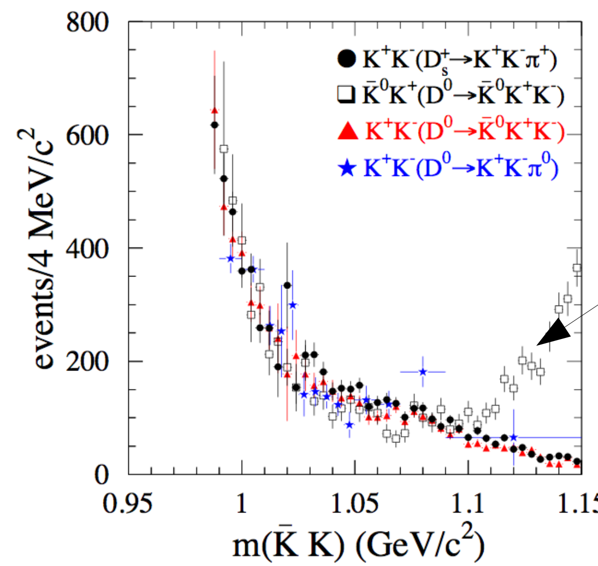








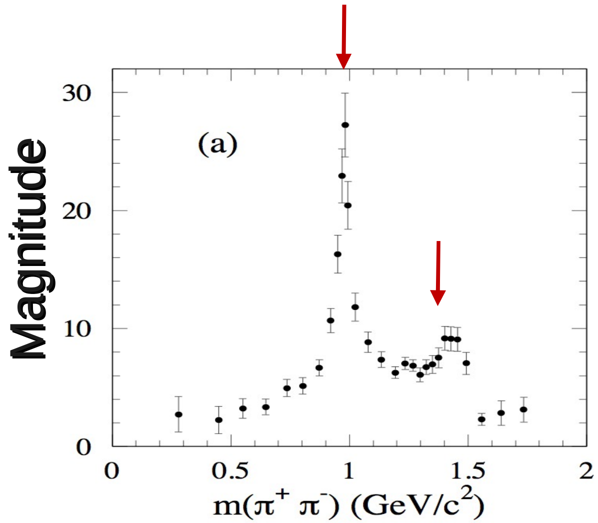
Seems process independent?

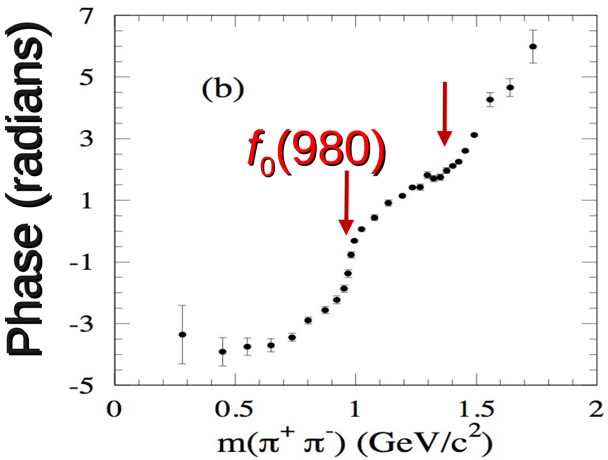


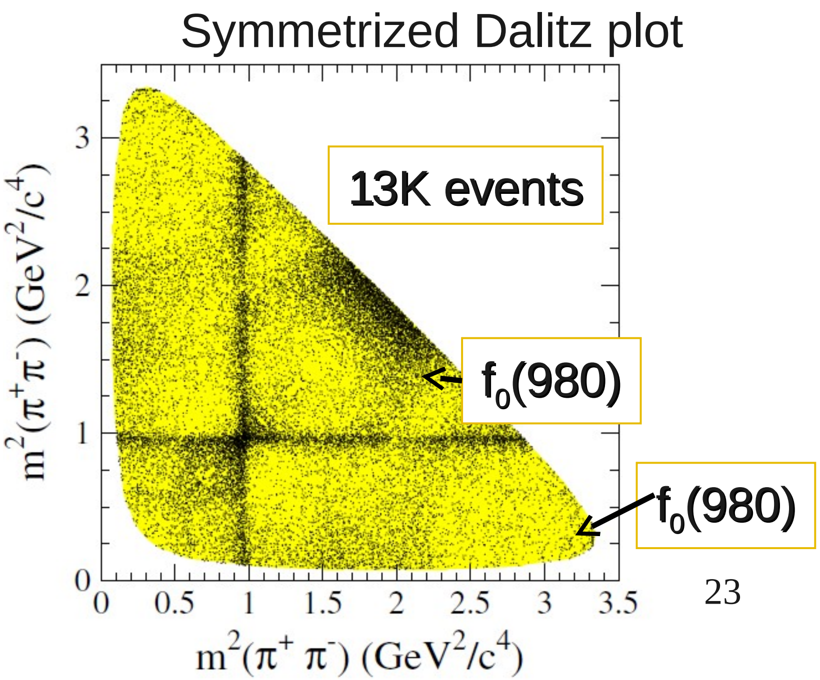
From K^+K^- cross channel

Quasi-model-independent partial wave analysis

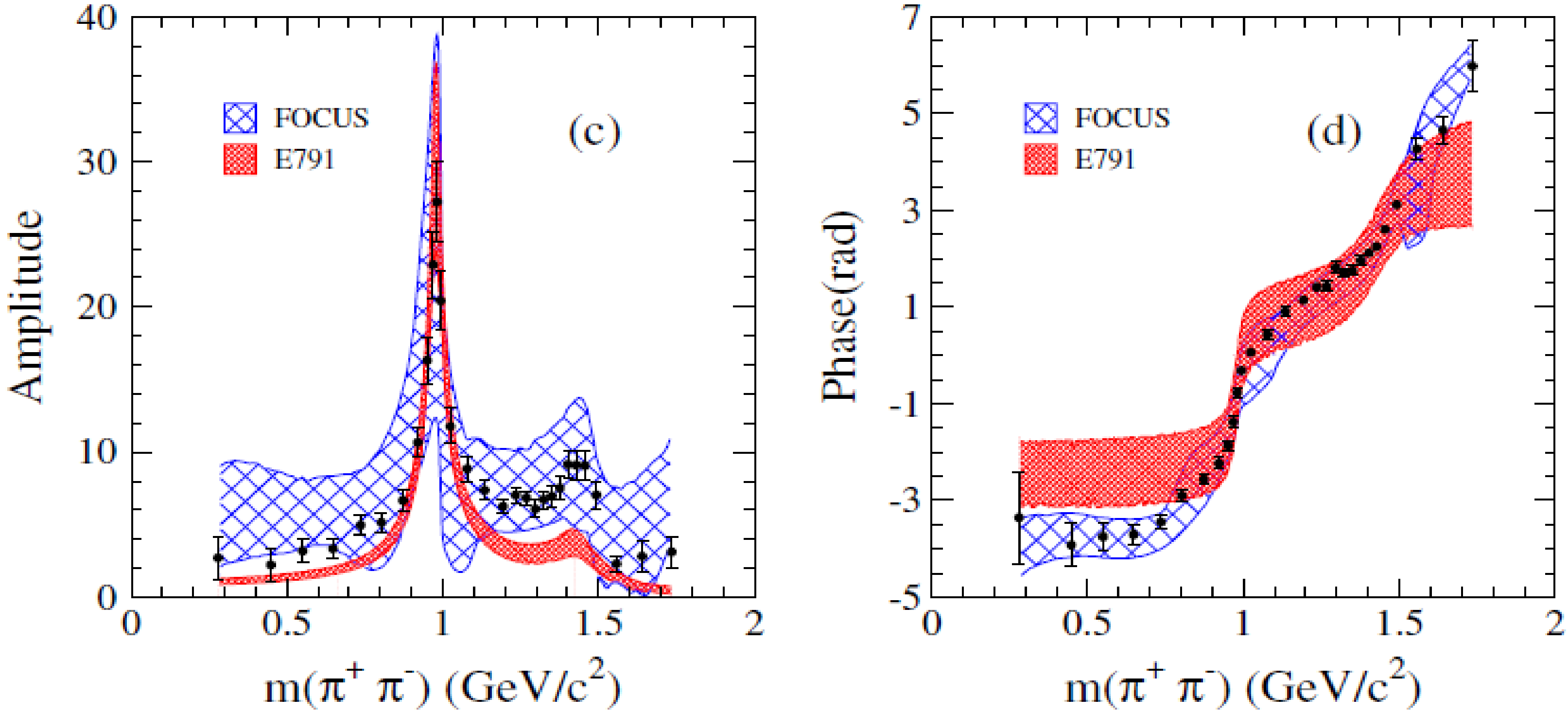
- Pioneered by E791 (B.Meadows) in $D^+ \rightarrow K^-\pi^+\pi^+$
- Describe S-wave by complex spline (many free parameters)
- Example: $D_s^+ \rightarrow \pi^-\pi^+\pi^+$ from BaBar





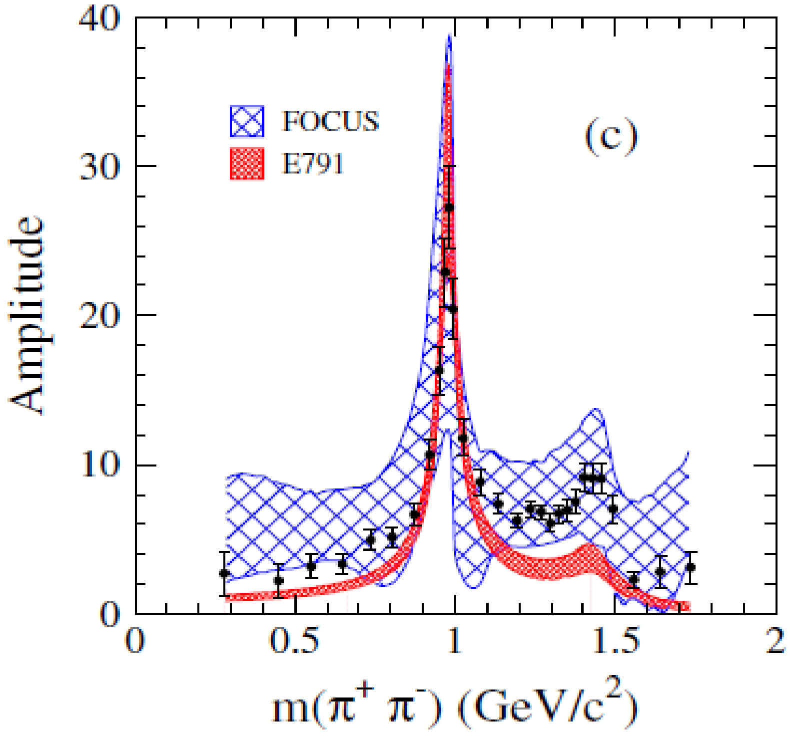


ππ S-wave comparison

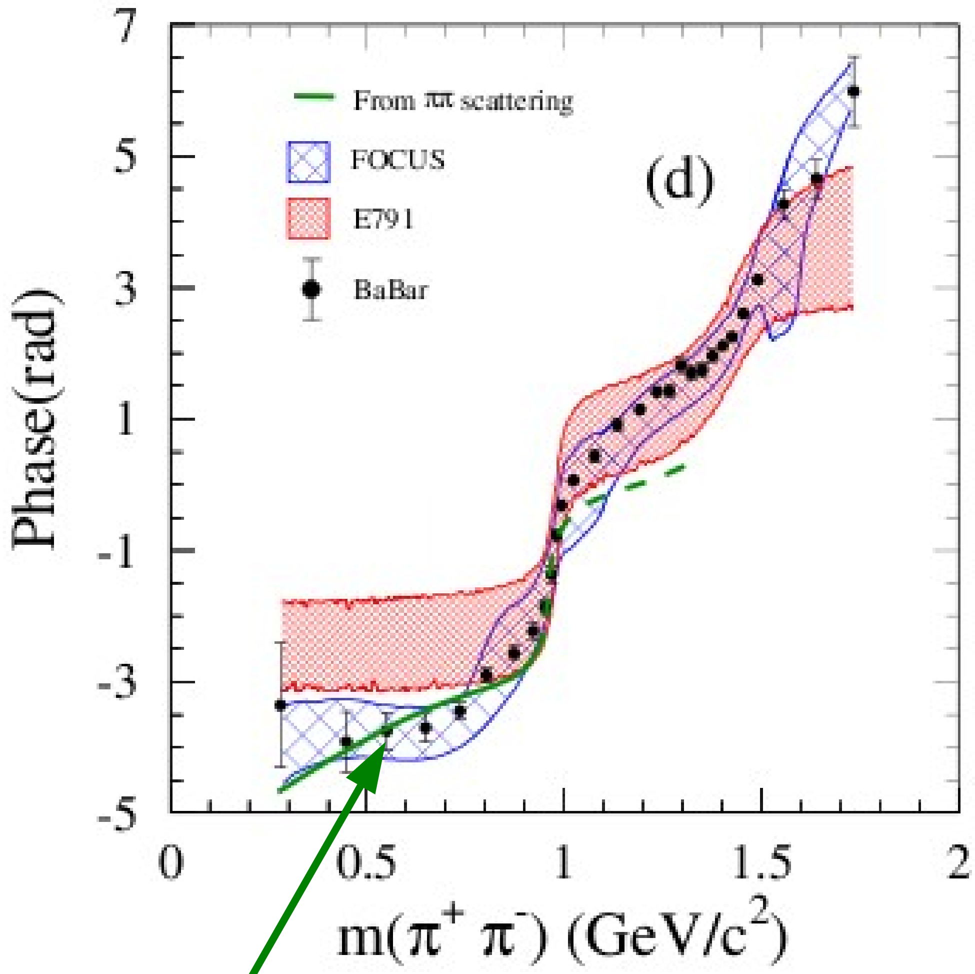


Data points from BaBar

ππ S-wave comparison



Data poin



Prediction from theory:
Kaminski et al. PRD77:054015,2008

Extracting weak phases from Dalitz plots

- Many methods exist in the literature
  - some have been used by the B factories
    - most results are statistically limited
    - in some cases model uncertainties are an issue
  - still plenty of room for good new ideas
- Examples (there are many more!)
  - Snyder-Quinn method to measure α from $B \to \pi^+\pi^-\pi^0$
  - GGSZ/BP method to measure γ from $B^\pm \to DK^\pm$ with $D \to K_S\pi^+\pi^-$
  - Measurement of charm oscillation parameters using $D \to K_S\pi^+\pi^-$
  - Various methods to measure γ from three-body charmless B decays ($B_{\{u,d,s\}} \to \pi\pi\pi, K\pi\pi, KK\pi, KKK$)
  - Penguin-free measurements of β & β_s from $D\pi^+\pi^-$ & DK^+K^-, respectively

$B \to \pi^+\pi^-\pi^0$ – B factory results

- Results from
  - Belle, 449 M BB pairs: PRL 98 (2007) 221602, PRD 77 (2008) 072001
  - BaBar, 375 M BB pairs: PRD 76 (2007) 012004

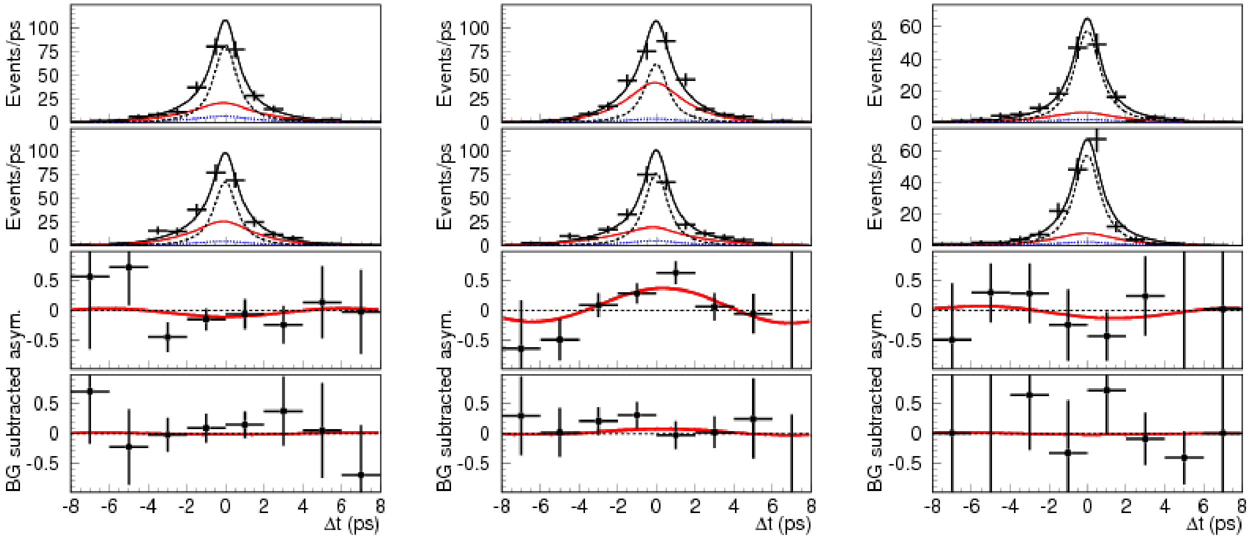
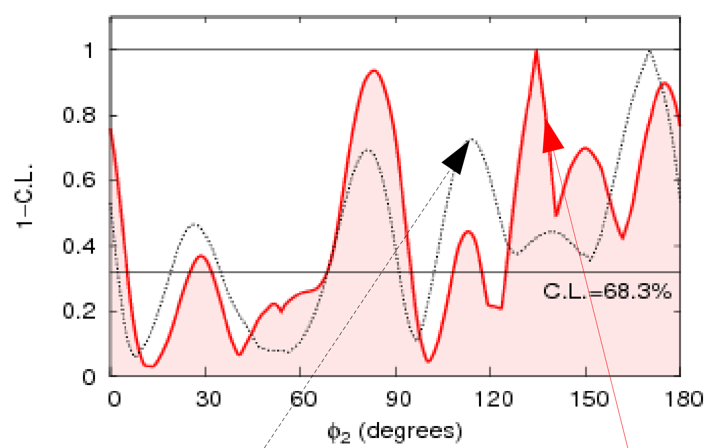


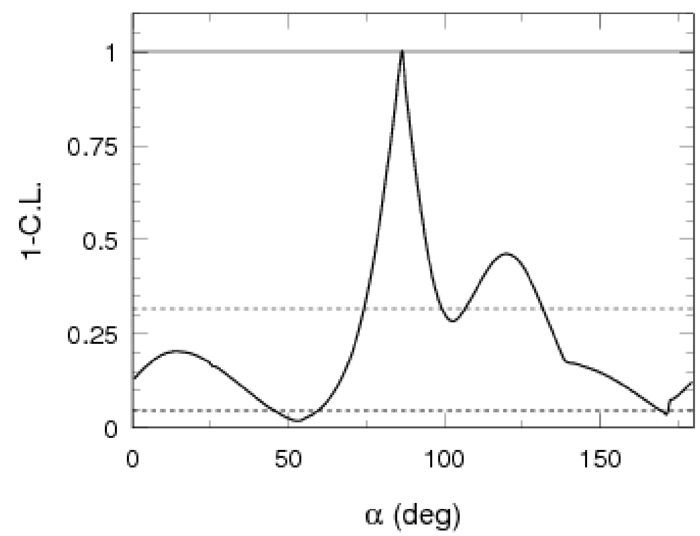
FIG. 10: Proper time distributions of good tag ($r > 0.5$) regions for $f_{\rm tag} = B^0$ (upper) and $f_{\rm tag} = \overline{B}^0$ (middle upper), in $\rho^+\pi^-$ (left), $\rho^-\pi^+$ (middle), $\rho^0\pi^0$ (right) enhanced regions, where solid (red), dotted, and dashed curves correspond to signal, continuum, and $B\overline{B}$ PDFs. The middle lower and lower plots show the background-subtracted asymmetries in the good tag ($r > 0.5$) and poor tag ($r < 0.5$) regions, respectively. The significant asymmetry in the $\rho^-\pi^+$ enhanced region (middle) corresponds to a non-zero value of U^-_-.

$\rho^+\pi^-$ $\rho^-\pi^+$ $\rho^0\pi^0$

$B \to \pi^+\pi^-\pi^0$ – B factory results

- Results from
  - Belle, 449 M BB pairs: PRL 98 (2007) 221602, PRD 77 (2008) 072001
  - BaBar, 375 M BB pairs: PRD 76 (2007) 012004





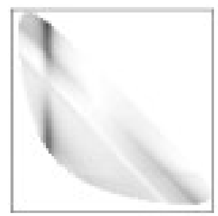
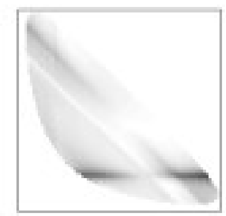
Contour from $B \to \pi^+\pi^-\pi^0$ only

Including also information on $B^+ \to \rho^+\pi^0$ and $B^+ \to \rho^0\pi^+$

$B^\pm \to DK^\pm$ with $D \to K_S\pi^+\pi^-$

Interference between $b \to u$ and $b \to c$ amplitudes when D is reconstructed in final state common to D^0 and $\bar{D}^0$ provides sensitivity to γ

$$|M_\pm(m_+^2, m_-^2)|^2 = |f_D(m_+^2, m_-^2) + re^{i\delta_B \pm i\phi_3} f_D(m_-^2, m_+^2)|^2$$

$$= \left| \quad \right.$$  $$+ re^{i\delta_B \pm i\phi_3}$$  $$\left. \quad \right|^2$$

Model ($f_D(m_+^2, m_-^2)$) taken from measurements of $|f_D|^2$ using flavour tagging D* decays – model dependence

BaBar obtain
$\gamma = (68\ ^{+15}_{-14} \pm 4 \pm 3)^\circ$
(from DK^-, D^*K^- & DK^{*-})

PRL 105 (2010) 121801

Belle obtain
$\phi_3 = (78\ ^{+11}_{-12} \pm 4 \pm 9)^\circ$
(from DK^- & D^*K^-)

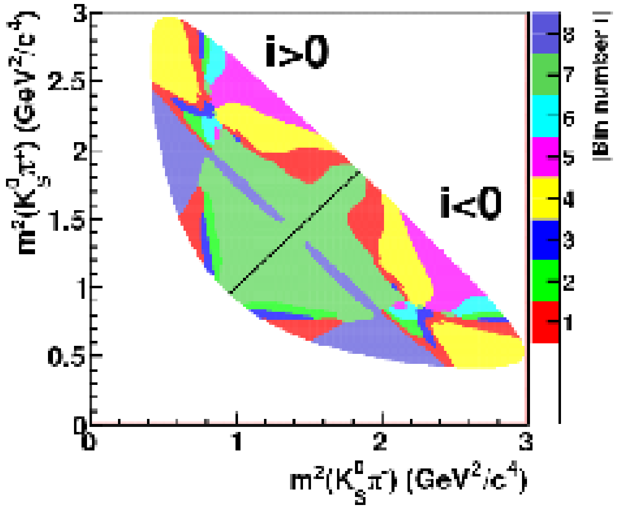
PRD 81 (2010) 112002

$B^{\pm} \to DK^{\pm}$ with $D \to K_S\pi^+\pi^-$

Solution – bin the Dalitz plot and use $\psi(3770) \to D\bar{D}$ events (CLEOc, BES) to measure per-bin phases

PRD 68, 054018 (2003), EPJ C 47, 347 (2006); EPJ C 55, 51 (2008)

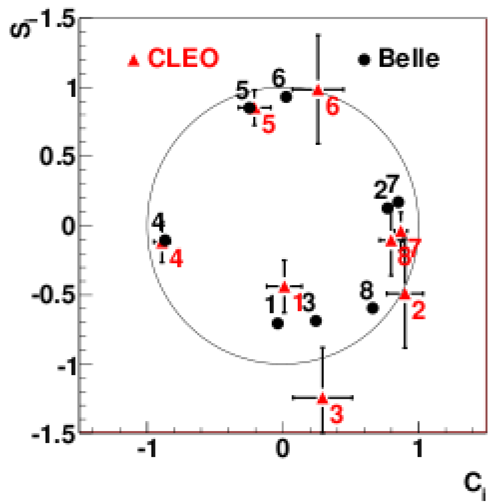
(unusual bin shapes to attempt to optimise sensitivity)



$$M_i^{\pm} = h\{K_i + r_B^2 K_{-i} + 2\sqrt{K_i K_{-i}}(x_{\pm}c_i + y_{\pm}s_i)\}$$

$$x_{\pm} = r_B\cos(\delta_B \pm \phi_3) \quad y_{\pm} = r_B\sin(\delta_B \pm \phi_3)$$

c_i, s_i measured by CLEO
PRD 82, 112006 (2010)



First model independent measurement of γ in this mode by Belle

Belle obtain

$\varphi_3 = (77.3\,^{+15.1}_{-14.9} \pm 4.2 \pm 4.3)°$

Looking ahead

- I hope I have already convinced you that there is great physics potential in Dalitz plot analysis
- But there are also considerable challenges
  - theoretical (hadronic effects, etc.)
  - experimental
    - Dalitz plot dependent effects:
    - Efficiency
    - Background
    - Mass resolution
    - Misreconstruction effects …
- I leave the details to the parallel session speakers, but ...

Motivation for “Les Nabis”

- From I. Bigi, “Hadronization — the Unsung Hero rather than the alleged Villain in the Tale of CP Violation”, proceedings of Hadron '05

- “We expect confidently that New Physics surfaces at the TeV scale. Yet we have to aim beyond ‘merely’ establishing the existence of New Physics – our goal has to be to identify its salient features. The discovery potential in B decays is essential, not a luxury. Yet due to the past ‘unlikely’ success of the CKM description one cannot count on massive manifestations of New Physics. Therefore we need high accuracy both on the experimental and theoretical side in heavy flavour studies. This requires a better quantitative understanding of hadronization to exhaust the discovery potential in B decays.”

- “The expertise required to attain an essential goal – namely to exhaust the discovery potential in heavy flavour transitions by harnessing low-energy hadronization – does exist or can be acquired with no need for a breakthrough. However it tends to reside in a community all too often disjoint from the heavy flavour community – this has to change!”

Erm, What is “Les Nabis”?

- A group of experimentalists and theorists, drawn from both particle/heavy flavour and nuclear/hadronic physics communities, set up to address issues in Dalitz plot analysis with the aim of obtaining both qualitative and quantitative information on weak phases and CP violation
- Theory:
  - I. Bigi, S. Gardner, C. Hanhart, B. Kubis, T. Mannel, U.-G. Meißner, J. Pelaez, M. Pennington
- Experiment:
  - I. Bediaga, A. Bondar, A. Denig, T. Gershon, W. Gradl, B. Meadows, K. Peters, U. Wiedner, G. Wilkinson
- (This is the list on the Nabis web page – apologies for any omissions)

OK, but why is it called “Les Nabis”?

- From the manifesto (yes, really):
  - “Les Nabis” means “the Prophets” in Hebrew, and this name had been adopted by a group of post-impressionist artists who set the pace for paintings and graphics in France in the 1890s. With some of us harbouring a similar sense of modesty as those artists, we found a re-incarnation of “Les Nabis” an appropriate motto for our group and its efforts. This is further strengthened by the fact that one work by a central member of the original “Les Nabis” seems to show a (somewhat artistically enhanced) image of a Dalitz plot – it is “The Talisman” by Paul Sérusier. We have chosen it as our logo.

“The Talisman”, Paul Sérusier

Summer school

- School on Amplitude Analysis in Modern Physics: from hadron spectroscopy to CP phases
- August 1-5, 2011 at Physikzentrum Bad Honnef, Germany
  - http://www2.fz-juelich.de/ikp/workshops/LesNabis/index.shtml

preliminary program August 1-5, 2011

	09:00 - 10:30	*11:00 - 12:30*	*14:00 - 15:30*	*16:00 - 17:30*
Mo	Introduction	Theory I	Experiment I	Discussion I
Tu	Theory II	Experiment II	Discussion II	Supplementary I
We	Theory I	Experiment I	Discussion III	Supplementary II
Th	Theory II	Experiment II	Discussion IV	Supplementary III
Fr	Experiment I	Theory I	Discussion V	

Introduction (NN)

Theory I (Jose Pelaez): **Dispersion Theory**

Theory II (Thomas Mannel): **CP violation in the Standard Model**

Experiment I (Klaus Peters): **Phenomenological Tools**

Experiment II (Timothy Gershon): **Precision Experiments / Data Analysis**

Supplementary I: Regge Theory

Supplementary II: Chiral Perturbation Theory

Supplementary III: Experimental Issues

Summary

- Dalitz plot analyses provide promising methods to measure weak phases and CP violation
- Many attractive features …
- … but significant complications due to model dependence
- Need progress on several fronts
  - Understand better (ππ), (Kπ), (KK), (Dπ), (DK) systems
  - "Nonresonant" contributions and 3-body unitarity
  - Methods to combat model-dependence
  - Nabis initiative set up to try to address this
- Many new possibilities opening up with LHCb

For more details, please come to the parallel session

Thursday 28 April 2011

Parallel Session: Dalitz Analysis *chairperson: Tim Gershon*			
14:00 - 14:35	Christoph Hanhart (Juelich)	Theoretical issues in Dalitz plot analysis	pdf
14:35 - 15:05	Marco Pappagallo (Bari)	Charm Dalitz plot analyses	pdf
15:05 - 15:30	Carla Gobel (Rio)	Model independent approaches to DP analysis	pdf
15:30 - 15:50	Hamish Gordon (Oxford)	Study of CP violation in D+ -> K+K-pi+ at LHCb	pdf
15:50 - 16:20	*Coffee*		
16:20 - 16:50	Jussara Miranda (Rio)	Dalitz plot analyses of charmless B decays	pdf
16:50 - 17:25	Leonard Lesniak (Krakow)	Model for charmless B decay Dalitz plots	pdf
17:25 - 17:50	Anton Poluektov (Warwick)	B->Dhh' Dalitz plot analyses	pdf
17:50 - 18:10	Daniel Johnson (Oxford)	Use of binned Dalitz plots to measure gamma at LHCb	pdf
18:10 - 18:30	Paras Naik (Bristol)	Four-body Amplitude Analyses at LHCb	pdf