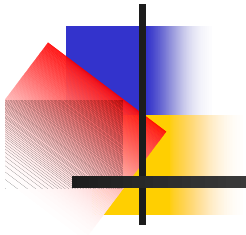


Dalitz Analysis Tools in BaBar



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Goal

- Charge of the DTF includes to provide a catalog of existing Dalitz tools
 - List of main features of each tool
 - Help new analysers to identify if an already existing piece of code accommodates to what he/she wants
- Particularly important now since traditional Dalitz techniques of light meson spectroscopy are taking new roles in measurements of CKM angles:
 - Time independent in 3-body D and B decays
 - Time dependent in 3-body B decays
- Catalog of tools and features based on AWG feed-back
 - Focus on currently used, public, and maintained tools
 - Each tool had a checklist to fill-out (next slide)
 - If any existing tool is missing in the list or you see any mistake, please let me know
- It is not the purpose of this report to give details on Dalitz analysis techniques but only identify, classify and list main features



Dalitz fit tools checklist

- Software basis (Fortran, ROOT, RooFit, EvtGenBase, etc.)
- B and/or D decays?
- Fit techniques: unbinned/binned maximum likelihood (UML/BML), chi2
- Goodness-of-fit (GOF): likelihood, chi2, adaptative binning
- Dalitz model(s):
 - Dynamics: isobar (BW's), K-matrix/P-vector, partial waves
 - Spin formalism: helicity, Zemach tensors (covariant, non-covariant), partial waves
- Normalization of amplitudes: toy MC, numerical, analytical
- Efficiency and mass resolution (for narrow resonances) treatment
- Background Dalitz shapes and characterization (m_{ES} , ΔE , Fisher, m_D , tag info)
- Fit support for masses and widths?
- How are fit fractions calculated?
- Visualization of results ALL
- Input: flat and/or ROOT file ALL
- Any other specific feature (CVS availability, documentation,...) ?



Overview of Dalitz tools

■ Charm AWG

- Bari (A. Palano)
- Cincinnati (B. Meadows)

■ Breco AWG

- $D^0(\text{Dalitz})K^-$
 - RooDKDalitz
 - RooBenDalitz
- $D^{*-}a_1^+$: DOOM
- $D^{(*)+}\pi^-\pi^-$ (D_J states): BToDjFittingTools

■ Charmless AWG

- $3\pi, K\pi\pi, 3K$: Laura++
- KKKs: custom
- $h^+h^+h^-$ ($h=\pi/K$): custom
- $K\pi\pi^0, \rho\pi$: RhoPiTools



Charm fitters

- Custom, Fortran based
- D decays
- UML
- Likelihood, chi2 and adaptive binning GOF
- Isobar model (BW's, Flatté, LASS), partial wave analysis
- Helicity and Zemach tensors (no covariant)
- Normalization: phase space MC weighted by the polynomial efficiency
- Efficiency correction: fitted 3rd order polynomial. No mass resolution
- Background: Gaussian to describe D
- Fractions computed as:
 - Errors on fit fractions from MC simulation
 - The fitted amplitudes and phases are randomly modified according to full covariance matrix

$$f_i = \frac{|c_i|^2 \int |A_i|^2 dm_x^2 dm_y^2}{\sum_{j,k} c_j c_k^* \int A_j A_k^* dm_x^2 dm_y^2}$$



RooDKDalitz

(D^0K^- , $D^0 \rightarrow 3\text{-body}$)

- General framework, RooFit and EvtGenBase based
 - EvtGenBase classes for 2- and 3-body kinematics, Dalitz plot boundaries, penetration factors, BWs, Flatté, d-functions, etc.
 - Optimized a general purpose fitter for γ from DK Dalitz
 - Model dependent and model independent methods
 - Flexibility for combining different B and D decays for γ
- D decays, can easily be adapted for B decays
- UML and BML
- Likelihood and binned chi2 GOF
 - Use independent (Fortran based) code for adaptive binning chi2 GOF
- Isobar model and K-matrix/P-vector
- Helicity and Zemach tensors (no covariant)
- Normalization: numerical and phase space MC
- Efficiency correction: fitted 3rd order polynomial. No mass resolution
- Background: 3rd order polynomial, on-reso SB+BB MC, m_{ES} , ΔE , Fisher
- Mass and width fitting
- Fit fractions: account for interference
- Available in CVS: `cvs co RooDKDalitz`

RooBenDalitz

($D^0 K^-$, $D^0 \rightarrow K_S \pi^+ \pi^-$)

- Custom, RooFit based
- Essentially, a custom version of RooDKDalitz optimized for $D^0 \rightarrow K_S \pi^+ \pi^-$ (3-body) studies and tuning
 - Simple
 - Fast
 - Addition of channels requires hard coding
 - Complementary to RooDKDalitz
- Available in CVS: `cvs co RooBenDalitz`

DOOM Dalitz Object Oriented Modeling ($D^* a_1^+$)

- General framework, ROOT and StatTools based
- Potentially for B and D decays
 - Now applied to study of 3 pion system in the $B \rightarrow D^* 3\pi$ decay
- UML
- Isobar model with covariant Zemach tensors
- Likelihood GOF
- Normalization: Phase space MC
- Efficiency correction: not yet available
- Background: SB m_{ES}
- Mass and width fitting: could be implemented if required
- Fit fractions: account for interference
- Visualization based on toy MC random extraction
- Available in CVS: `cvs co BToDstar3pi`
- Optimized for batch running rather than interactive analysis



BToDjFittingTools

$(D^{(*)+}\pi^-\pi^-, D_J \text{ states})$

- General framework, RooFit and EvtGenBase based
 - EvtGenBase classes for amplitude calculation (Pto3P classes)
- Potentially for B and D decays ($P \rightarrow PPP$ and $P \rightarrow VPP$)
 - Only B decay tested
- UML
- Isobar model
- Likelihood goodness-of-fit
- Normalization: Phase space MC and several numerical methods
 - Normalization calculated for each fit iteration, allowing mass and width fitting
- Efficiency correction: yes
- Fit fractions: account for interference
- Available in CVS: `cvs co BToDjFittingTools`



RhoPiTools

($K\pi\pi^0, \rho\pi$)

- General framework, RooFit based
- UML
- Likelihood and binned chi2 GOF
- Isobar model
- Normalization: phase space MC
- Efficiency correction: 2D histograms
- Mass resolution: reweighting of phase space MC
- Background: 2D histograms, on-reso SB+ BB MC
- No mass and width fitting
- Fit fractions: ignore interference
- Square Dalitz plot, time and tag dependence
- Available in CVS: `cvs co RooPiTools`
- Poorly documented: link from Charmless AWG page (simple recipe, but old)



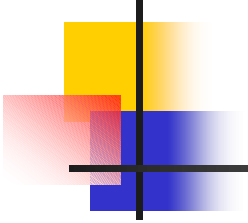
Laura++ (3π, Kππ, 3K)

- General framework, ROOT based
- 3-body B and D decays to π/K/π0/K0s
- UML
- Likelihood and chi2 GOF
- Isobar model (BW, Flatté, LASS) with Zemach tensors
- Normalization: MC and numerical Gauss-Legendre integration
- Efficiency correction: 2D histograms
- Mass resolution with MC reweighting technique (3K only)
- Background: 2D histograms, on-reso SB+ BB MC
- No mass and width fitting. Genetic
- Fit fractions: ignore interference
- Available in CVS:

$$\text{Fit Fraction} = \frac{\int |c_i e^{i\theta_i} F_i(m_{13}^2, m_{23}^2)|^2 dm_{13}^2 dm_{23}^2}{\int |\sum_i c_i e^{i\theta_i} F_i(m_{13}^2, m_{23}^2)|^2 dm_{13}^2 dm_{23}^2}$$

`cvs co NonCharmBDecayTools/ThreeBody/Laura++`

- Well documented: web page (link from Charmless Home page) and BAD# 806



$h^+ h^+ h^-$ ($h = \pi/K$) fitter

- Custom, ROOT based
- BML
- Binned χ^2 GOF
- Isobar model
- Normalization: numerical
- Efficiency correction: 2D histograms
- Mass resolution: interbin migration (convolution)
- Background: subtracted
- Mass and width fitting
- Fit fractions: ignore interference
- Poorly documented: pages 4-11 of BAD# 643



KKK_S fitter

- Custom, RooFit and EvtGenBase based
- UML
- Likelihood and chi2 GOF
- Isobar model
- Normalization: numerical
- Efficiency correction: 2D histograms
- No mass resolution (for now)
- Background: 2D histograms, on-reso SB+ BB MC
- Mass and width fitting
- Fit fractions: ignore interference
- Square Dalitz plot, time and tag dependence



Summary and comments

- Many DP packages (10 counted here)
 - optimal flexibility for each particular analysis (configuration, visualization, etc.)
 - ...but kernel of all these do the same thing:
 - 2- and 3-body kinematics, Dalitz plot boundaries, penetration factors, BWs, d-functions,...
- Having a minimal “standardization” (library of classes) would help
 - Too late?
 - Some already “standardized” using EvtGenBase classes (RooDKDalitz, BToDjFittingTools, KKK_S fitter)
- Starting to have available K-matrix/P-vector and time/tag dependence in some codes
 - Should this be standardized?

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