Further studies on IPCHI2 fit

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Ω_c^0 *lifetime measurement meeting*

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$\log \chi^2_{IP}$ modelling

- Bukin function, a modified Novosibirsk function with extended tail parameters

$$\mathcal{P}(x;\mu,\sigma,\xi,\rho_1,\rho_2) = \begin{cases} \exp\left\{ \dfrac{(x-x_1)\xi\sqrt{\xi^2+1}\sqrt{2\ln 2}}{\sigma\left(\sqrt{\xi^2+1}-\xi\right)^2 \ln\left(\sqrt{\xi^2+1}+\xi\right)} + \rho_1\left(\dfrac{x-x_1}{\mu-x_1}\right)^2 - \ln 2 \right\} & x \le x_1, \\ \exp\left\{ -\left[\dfrac{\ln\left(1+2\xi\sqrt{\xi^2+1}\dfrac{x-\mu}{\sigma\sqrt{2\ln 2}}\right)}{\ln\left(1+2\xi^2-2\xi\sqrt{\xi^2+1}\right)} \right]^2 \times \ln 2 \right\} & x_1 < x < x_2, \\ \exp\left\{ \dfrac{(x-x_2)\xi\sqrt{\xi^2+1}\sqrt{2\ln 2}}{\sigma\left(\sqrt{\xi^2+1}-\xi\right)^2 \ln\left(\sqrt{\xi^2+1}+\xi\right)} + \rho_2\left(\dfrac{x-x_2}{\mu-x_2}\right)^2 - \ln 2 \right\} & x \ge x_2. \end{cases}$$

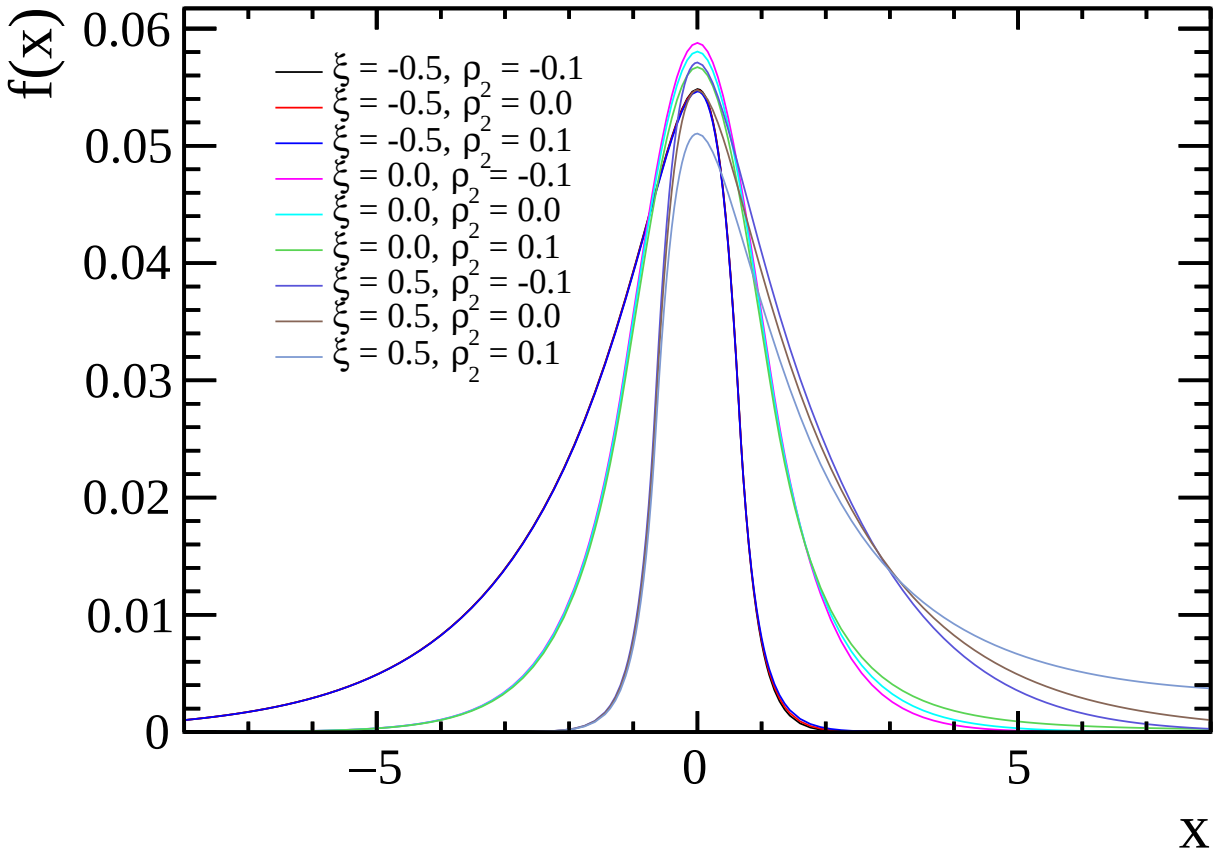
where

$$x_1 = \mu + \sigma\sqrt{2\ln 2}\left(\frac{\xi}{\sqrt{\xi^2+1}} - 1\right)$$

$$x_2 = \mu + \sigma\sqrt{2\ln 2}\left(\frac{\xi}{\sqrt{\xi^2+1}} + 1\right)$$

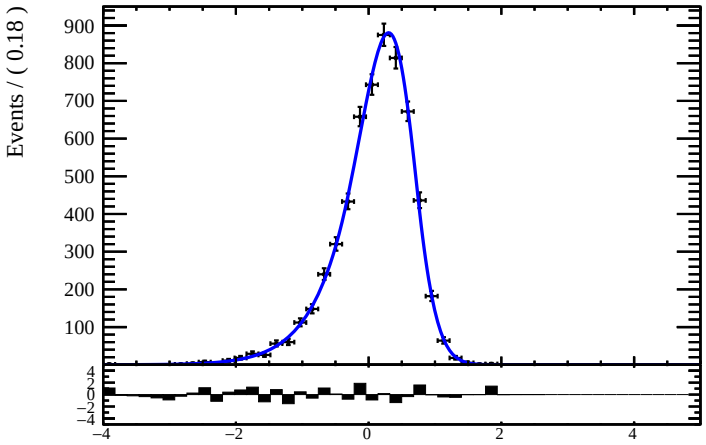
Illustration of Bukin functions

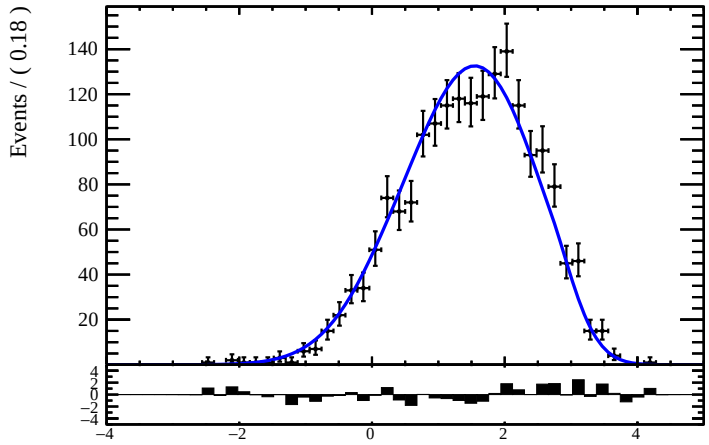
- Influence of asymetry and tail parameters with $\mu = 0, \sigma = 1, \rho_1 = 0$



Fit to MC sample of $D^0 \to K^-K^+\pi^-\pi^+$

- Fit with all parameters free
- Prompt component (left) and secondary component (right)



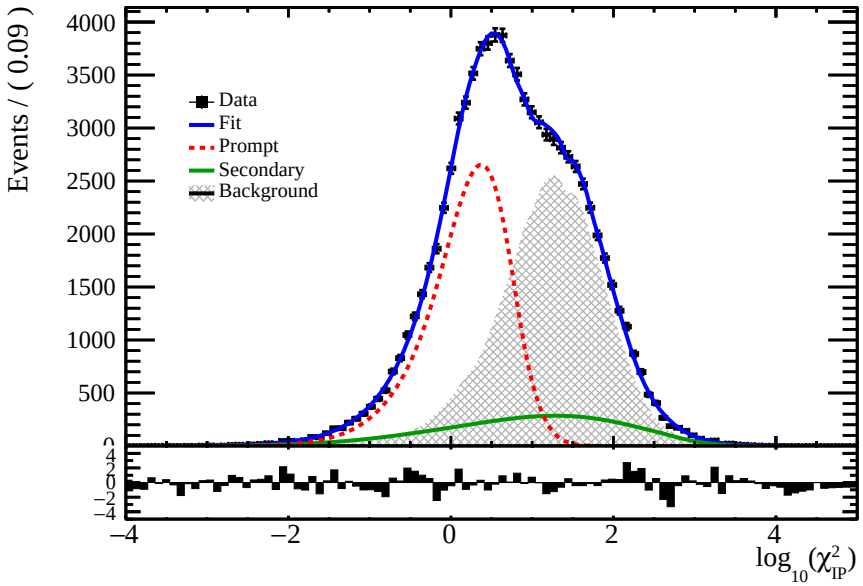



```
**********
**   18 **HESSE        3000
**********
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-40934.9 FROM HESSE     STATUS=OK              40 CALLS         312 TOTAL
                    EDM=0.000105749    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   INTERNAL      INTERNAL
 NO.   NAME      VALUE            ERROR          STEP SIZE       VALUE
  1  ap           3.01116e-01   1.58813e-02   3.84446e-04  -4.09083e-01
  2  nsig         5.93789e+03   7.70554e+01   3.16406e-04  -1.35336e-01
  3  rho1        -5.16211e-02   2.41066e-02   2.28282e-05  -1.72079e-02
  4  rho2        -6.17691e-01   1.66544e-01   1.49960e-04  -2.07380e-01
  5  sigp         4.53218e-01   8.45137e-03   2.46165e-05  -7.72398e-01
  6  xi          -1.67549e-01   2.38002e-02   1.78737e-04  -1.68343e-01
```

```
**********
**   18 **HESSE        3000
**********
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-7992.68 FROM HESSE     STATUS=OK              40 CALLS         324 TOTAL
                    EDM=0.00036862    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   INTERNAL      INTERNAL
 NO.   NAME      VALUE            ERROR          STEP SIZE       VALUE
  1  ap           1.54812e+00   8.62113e-02   3.17448e-04  -4.68873e-01
  2  nsig         1.59698e+03   3.99616e+01   1.12107e-04  -8.74681e-01
  3  rho1        -8.33808e-01   3.10118e-01   1.11682e-04  -2.81645e-01
  4  rho2        -2.61826e+00   9.49960e-01   6.93521e-04  -1.06082e+00
  5  sigp         1.03763e+00   3.39189e-02   1.43360e-04  -3.13348e-01
  6  xi          -5.05356e-02   6.64170e-02   1.46991e-04  -5.05571e-02
```

Fit to data sample in decay time bin $[1, 2]\,\mathrm{ps}$

- Step 1
  - Fixed parameters: all parameters free
  - Gaussian constrains: Total number of D^0 from mass fit
  - Error matrix not positive-definite

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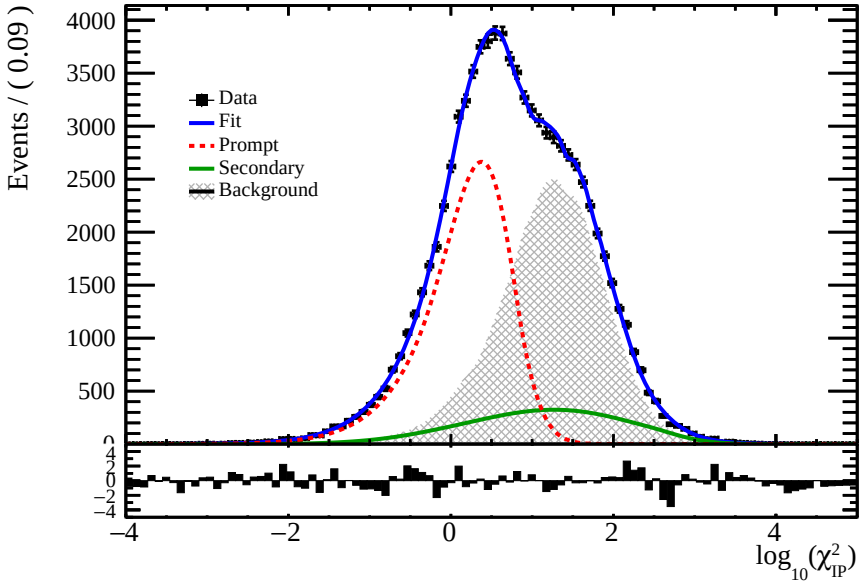
MINUIT WARNING IN HESSE
============== MATRIX FORCED POS-DEF BY ADDING 0.889651 TO DIAGONAL.
FCN=-808721 FROM HESSE     STATUS=NOT POSDEF    145 CALLS         753 TOTAL
                     EDM=26481.8    STRATEGY= 1      ERR MATRIX NOT POS-DEF
 EXT PARAMETER                APPROXIMATE     INTERNAL      INTERNAL
 NO.   NAME      VALUE            ERROR       STEP SIZE       VALUE
  1  ap_b         1.28961e+00   1.69681e-02   9.17332e-03  -5.30165e-01
  2  ap_p         3.73158e-01   9.88766e-03   6.00398e-04  -2.89325e-01
  3  nbkg         4.43614e+04   2.88535e+02   9.37748e-03   8.31072e-01
  4  nprompt      3.50182e+04   2.77066e+02   5.77522e-03   2.73259e-01
  5  nsig         4.40661e+04   2.50451e+02   1.75504e-02  -9.51595e-02
  6  rho1_b      -7.33821e-01   2.60970e-02   5.00000e-01   1.58666e+00
  7  rho1_p      -1.10116e-01   1.71383e-03   2.68051e-02  -6.24819e-01
  8  rho2_b      -2.53326e+00   3.13664e-02   5.00000e-01  -1.78335e+01
  9  rho2_p      -7.15697e-01   1.48266e-02   5.00000e-01  -8.05406e+00
 10  sigp_b       1.16975e+00   1.29872e-02   1.76992e-02   2.67407e-01
 11  sigp_p       4.50238e-01   7.41328e-03   1.26991e-03  -5.95949e-03
 12  xi_b        -1.33725e-01   7.29018e-03   1.78332e-02  -2.80980e-01
 13  xi_p        -1.62241e-01   1.13689e-02   3.27339e-03   1.76943e-02
                              ERR DEF= 0.5
```

Fit to data sample in decay time bin $[1, 2]\,\mathrm{ps}$

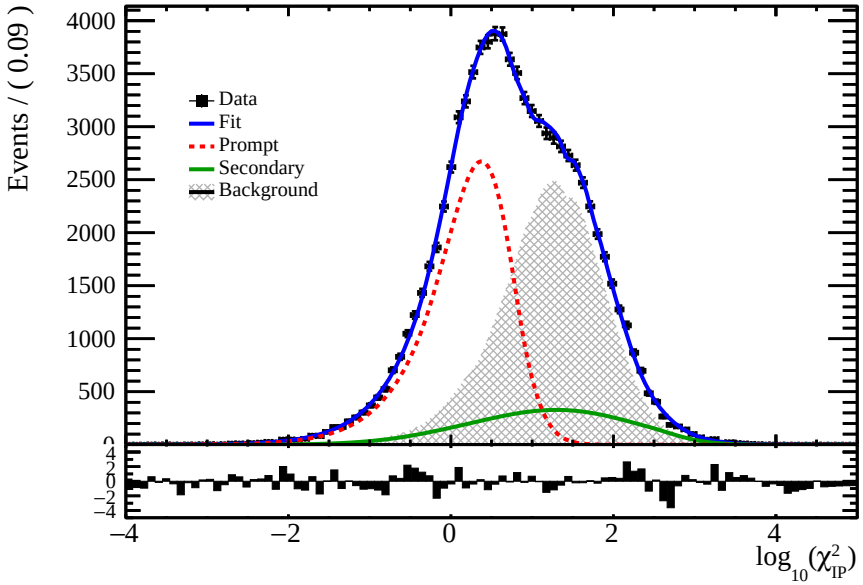
- Step 2
  - Fixed parameters:
    - Prompt: ρ_2
    - Secondary: ρ_1, ρ_2, ξ
  - Gaussian constrains: Total number of D^0 from mass fit
  - MIGRAD error matrix not positive-definite HESSE error matrix accurate




```
**********
**   18 **HESSE        4500
**********
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-808720 FROM HESSE     STATUS=OK             79 CALLS        1815 TOTAL
                     EDM=0.124075    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   INTERNAL      INTERNAL
 NO.   NAME      VALUE            ERROR          STEP SIZE       VALUE
  1  ap_b         1.26829e+00   1.62453e-01   3.62944e-04  -5.46717e-01
  2  ap_p         3.77096e-01   8.91766e-03   4.62289e-02  -2.86587e-01
  3  nbkg         4.35669e+04   1.37478e+03   3.52632e-04   7.85977e-01
  4  nprompt      3.57575e+04   1.35305e+03   1.12004e-03   3.01212e-01
  5  nsig         4.49187e+04   1.37276e+03   7.09443e-04  -1.12690e-04
  6  rho1_p      -6.45614e-02   1.23944e-02   1.56322e-03  -1.29767e-01
  7  sigp_b       1.05304e+00   6.83498e-02   7.03822e-04   3.08271e-02
  8  sigp_p       4.52061e-01   8.46827e-03   6.69668e-04  -2.31250e-03
  9  xi_p        -1.74311e-01   1.14560e-02   3.27010e-04  -2.25417e-02
```

Fit to data sample in decay time bin $[1, 2]\,\mathrm{ps}$

- Step 3
  - Fixed parameters:
    - Prompt: $\rho_2, \rho_1, \xi, \sigma$
    - Secondary: ρ_1, ρ_2, ξ
  - Gaussian constrains: Total number of D^0 from mass fit
  - Both MIGRAD and HESSE error matrix accurate




```
**********
**    18 **HESSE        3000
**********
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-808719 FROM HESSE     STATUS=OK             50 CALLS         368 TOTAL
                     EDM=0.000175427    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   INTERNAL      INTERNAL
 NO.   NAME      VALUE            ERROR          STEP SIZE       VALUE
  1  ap_b         1.29731e+00   4.78273e-02   8.71199e-03  -5.24222e-01
  2  ap_p         3.74397e-01   2.08353e-03   1.63552e-03  -2.88463e-01
  3  nbkg         4.33422e+04   9.46978e+02   8.70464e-03   7.73590e-01
  4  nprompt      3.60387e+04   4.78695e+02   5.49126e-03   3.11907e-01
  5  nsig         4.51421e+04   9.51056e+02   1.75577e-02   2.47612e-02
  6  sigp_b       1.03335e+00   2.33958e-02   1.73618e-02  -8.56377e-03
                               ERR DEF= 0.5
```

Next to-do

- Cross check fit projections
  - Check whether the combined prompt and secondary log(IPCHI2) pdf is a good description of the overall yields of D^0 as a function of log(IPCHI2)
  - Split sample into bins of log(IPCHI2) and perform the mass fit
- Test the statistical precision and probe possible biases
  - Generate samples according to the fitted mass and log(IPCHI2) shapes for prompt, secondary and combinatorial components

Backup

IPCHI2 in different decay time bins

- Binning: [-0.005, 0., 0.001, 0.002, 0.003, 0.005, 0.01] ns
- Signal IPCHI2 distribution