RooRarFit Tutorial

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What is RooRarFit

- A general ML fitter based on ROOT/RooFit

Why use RooRarFit?

- A question asked by many people: Why so many people write their own fitters with ROOT/RooFit? What's wrong?
- ROOT/RooFit are toolkits, engines, so one needs to build a fitter, an application, to make use of them. So nothing wrong!
- RooRarFit is one of such fitters, applications, but as a **general** fitter, it can be used by many different analyses, with benefits:
- Access to the full power of RooFit
- Coding free to final users (no C++ experience needed)
- Driven by readable text configuration files
- Flexible design, 'programmable' config files
- Lots of fitting, plotting functions implemented
- Fully documented, lots of working examples from many analyses already

RooRarFit implementation

- Wrappers of RooRealVar, RooDataSet, RooPDFs, etc. implemented, so can be defined through ascii configs
  - Dataset classes
  - PDF classes
- Fitting actions implemented as functions driven by ascii configs
- Auxiliary classes, main program, scripts
  - String parser class
  - NLL class to deal with NLL curve
  - Minuit class derived from RooMinuit for contour plot
  - Version control header file
  - Main program
  - submitToy (toy study batch processor for slac, cu-boulder, ed, ral)
- Assume users have experience with ROOT/RooFit, so no ROOT/RooFit details in this tutorial

Get and run RooRarFit

- With Babar SRT release version >= 16.0.3-physics-1

```
addpkg RooRarFit V00-01-21
gmake RooRarFit.all
```

- In workdir, run the application (**rarFit**) without any args to get short help page:

```
rarFit [-options] <RooRarFit_Config_file>
        -h this help page
        -D <data input section> (default "Dataset Input")
        -C <mlFitter config section> (default "mlFitter Config")
        -A <fitter action section> (default "Fitter Action")
        -t <toy job id> (default 0)
        -n <toyNexp> (default 0, use config)
        -d <toy dir> (default .toyData)
e.g.
        To run rarFit from config file demo.config
rarFit demo.config
        and with mlfitter config from section [myMLFitter]
rarFit -C myMLFitter demo.config
        and with mlfitter action from section [my Fit Action]
rarFit -C myMLFitter -A "my Fit Action" demo.config
```

RooRarFit config file

- Dataset definition section

  Define dataset structures

- Dataset input section

  Define, read in datasets

- PDF configuration section
  - PDFs are created from top to bottom with PDF config sections.
  - Simple, composite PDF

- Fit action section

  - pdfFit
  - mlFit
  - projPlot
  - sPlot
  - toyStudy
  - scanPlot
  - contourPlot

Dataset Definition & Input

Define the structure of dataset entry

&

Read in datasets

Dataset definition section

- Define dataset entry structure with dsd section
  - "Fields" declares dataset columns
  - Define all declared columns in this section
  - Observable definition syntax

columnName = <columnType> "<title>" <specifications>

Obs/Param types: **RooRealVar**, **RooCategory**, **RooStringVar**, **RooConstVar**, **RooUnblindPrecision**, **RooMappedCategory**, **RooThresholdCategory**, **RooFormulaVar**

```
[Dataset Definition]
Fields = runNum mes de fisher
runNum = RooRealVar "runNum" 0 1e10
mes = RooRealVar "M_{es}" 5.19 5.29 B(50) "GeV"
de = RooRealVar "#Delta E" -.2 .2 B(45) "GeV"
fisher = RooRealVar "Fisher"  -4 5  B(45)
```

Latex in RooFit

RRV unit

columnType | Title | RRV range | Plot bins

Dataset definition section (Cont.)

- "AddOns" declares derived columns
- Define all declared 'add-on' columns in this section as well
- columnType can be:

  RooMappedCategory, RooThresholdCategory, RooFormulaVar

```
[Dataset Definition]
Fields = runNum mes de fisher
runNum = RooRealVar "runNum" 0 1e10
mes = RooRealVar "M_{es}" 5.19 5.29 B(50) "GeV"
de = RooRealVar "#Delta E" -.2 .2 B(45) "GeV"
fisher = RooRealVar "Fisher"  -4 5  B(45)
AddOns = runBlock
runBlock = RooMappedCategory "Run Block" noIdx runRange \\
           Run1   "*Run1" "Run1"  "*Run2" "Run2"  \\
                  "*Run3" "Run3"  "*Run4" "Run4"
runRange = RooThresholdCategory "Run Range" noIdx runNum  \\
           "mcRun2" 18000  "daRun1"  30000 "daRun2"  \\
                    40000  "daRun3" 200000 "daRun4"  \\
                    770000 "mcRun1"
```

Dataset input section

- Input datasets with dsi section
  - "Datasets" declares all datasets to be input
  - Define all declared datasets in this section
  - Dataset definition syntax

datasetName = <inputType> "<title>" <specifications>

Dataset input types: **ascii, root, reduce, add**

```
[Dataset Input]
Datasets = onData sigMC bbMC gsbData desbData
onData = ascii "on peak data" "mydats/on.text" Q
sigMC = ascii "sig MC" "mydats/sigMC.txt" Q
bbMC = ascii "peaking BB MC" "mydats/bbMC.txt" Q   // Q for quiet mode
gsbData = reduce "gsb Data" onData "mes<5.27"
desbData = reduce "de sb Data" onData "(de<-.1)||(de>.1)"
```

Dataset file name

inputType | title | source dataset | reduce cuts

Dataset input section (Cont.)

- Other (optional) configs for dsi section
  - dsdSec = <dataset definition section name>

    Default: **`Dataset Definition`**
  - setWeightVar = <obs used as weightVar>

    Default: no weightVar for datasets
  - tabulateDatasets = yes

    Tabulate datasets for each RooCategory observable.

    Default: no tabulation
  - computeCorrelations = <yes|no|dataSetName1 ...>

    Compute correlation matrices for (given) datasets.

    Default: yes

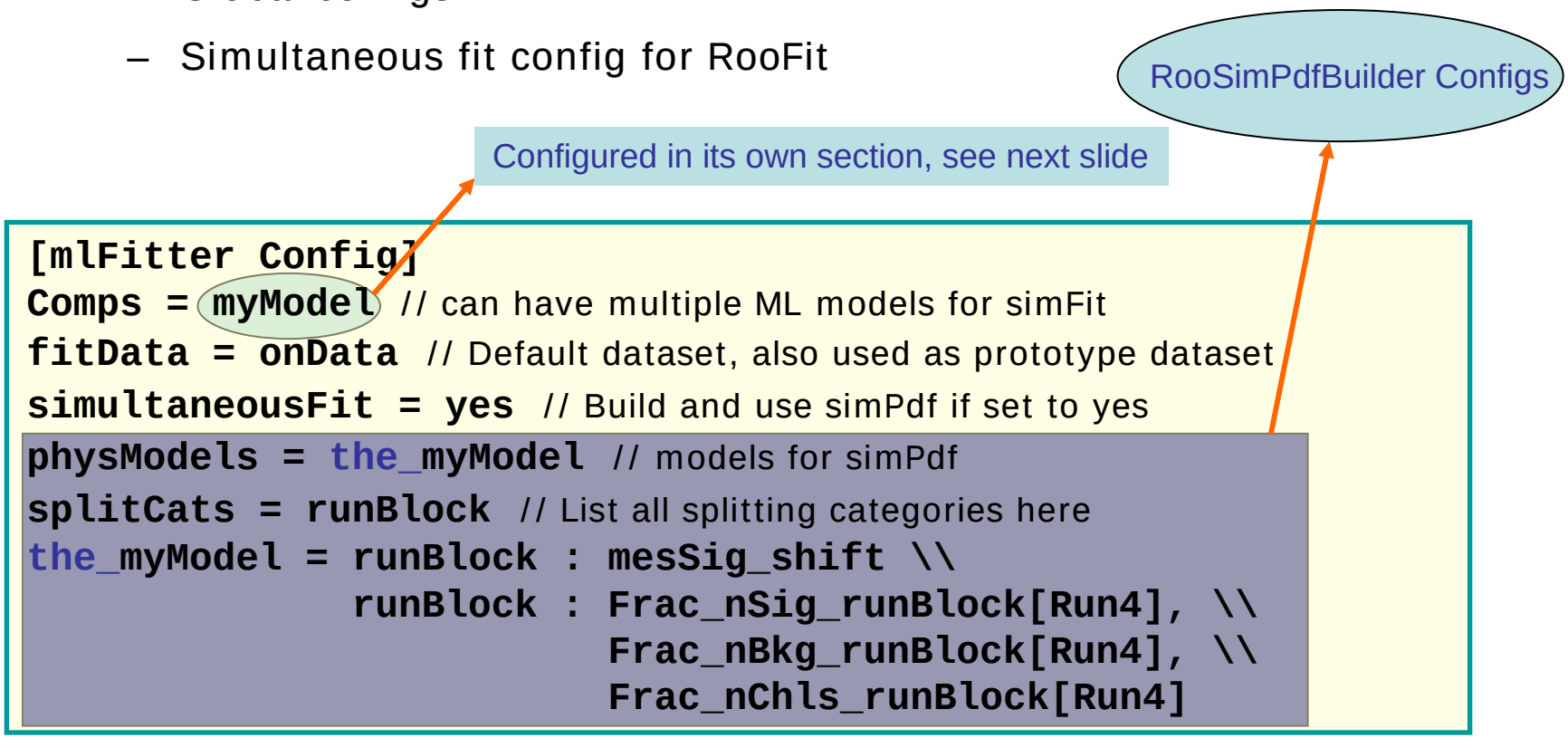
PDF Configuration Sections

Define PDFs from top to bottom

with config sections

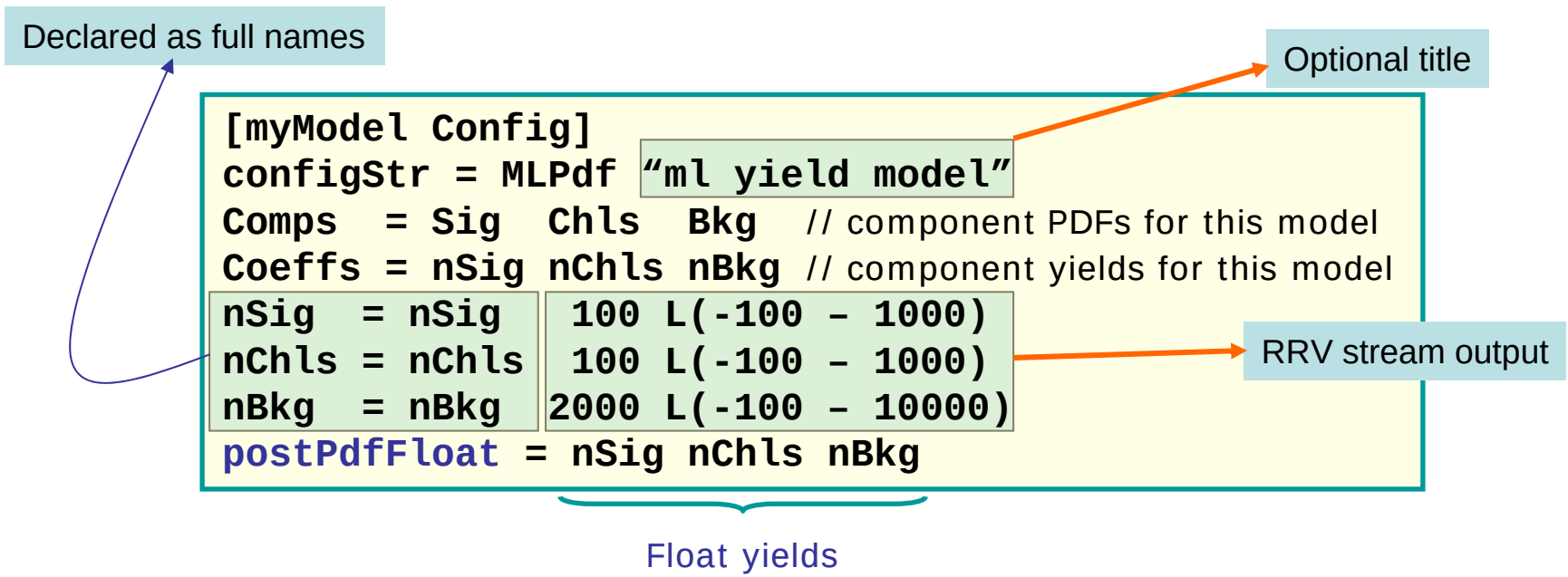
PDF config sections

- Master fitter config section
  - Starting point for all PDFs, also include:
  - Global configs
  - Simultaneous fit config for RooFit



PDF config sections

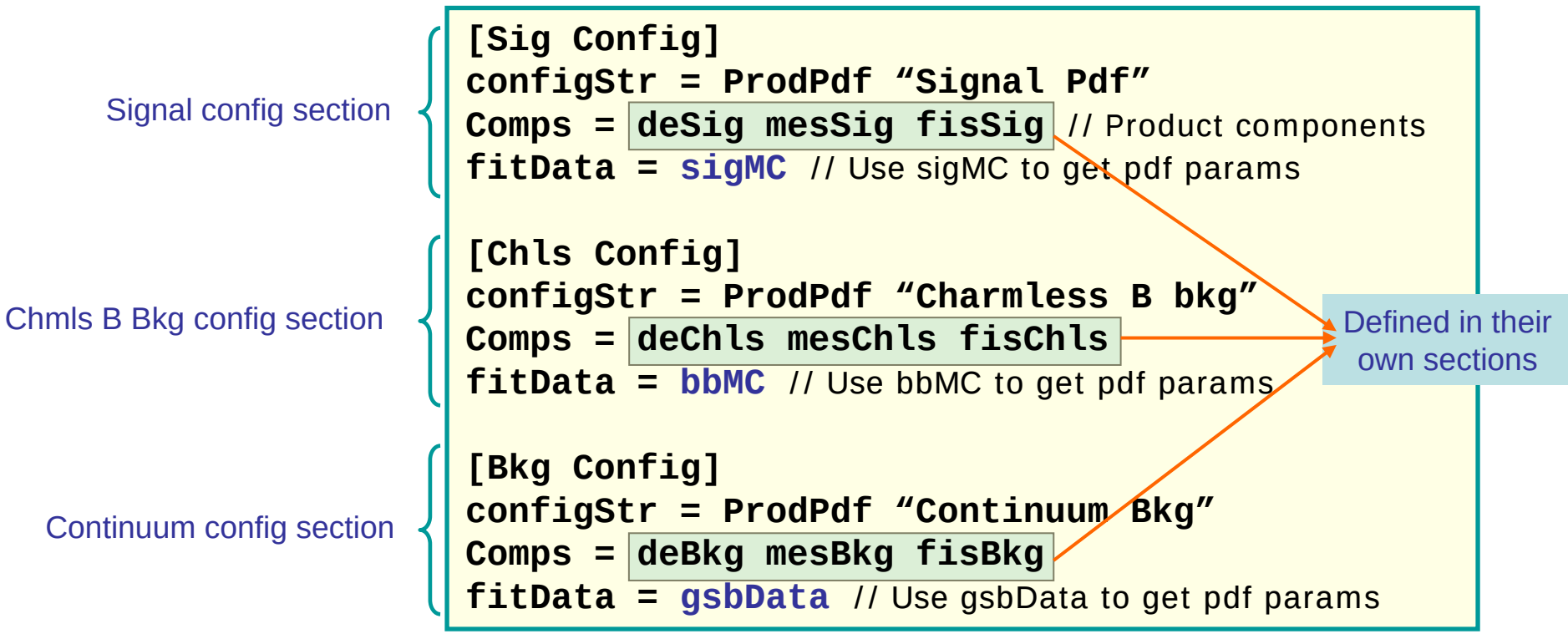
- ML model config section
  - Each model declared in ML fitter section has its own config section
  - **`configStr`** set to **`MLPdf`**' for ML models
  - Declare as many species as wanted with config **`Comps`**'
  - Each component has its own config section (see next slide)
  - Corresponding yields listed with config **`Coeffs`**'
  - Declared yields defined within the section



PDF config sections

- Species config sections
  - Each species in ML model has its own config section
  - **configStr** can be set to any valid PDF type in RooRarFit,

    but usually `**ProdPdf**' for composite PDF as product of PDFs for observables included in the model



PDF config sections

- Signal PDF config sections

```
[deSig Config]
configStr = TwoGauss
x = de
meanC =  0.    L(-.1 - .1)
meanT = -0.04  L(-.1 - .1)
sigmaC = 0.025 L(0.0 - .15)
sigmaT = 0.09  L(0.0 – 0.3)
fracC =  0.75  L(0.5 – 1.0)

[mesSig Config]
configStr = TwoGauss
x = mes
meanC = 5.28    L(5.25 – 5.29)
meanT = 5.27    L(5.25 – 5.29)
sigmaC = 0.0028 L(0.0 – 0.01)
sigmaT = 0.008  L(0.0 – 0.10)
fracC = 0.95    L(0.5 – 1.0)
shift = 0.0   C L(-.1 - 0.1)
```

```
[fisSig Config]
configStr = BGGauss
x = fisher
mean = -0.5 L(-2 - 2)
rms  =  0.6 L(0.0 – 1)
asym =  0.1 L(-.5 – 0.5)
```

If full name is not specified for params, RRV name will be prefixed with PDF name, for example, **fisSig_mean**, **fisSig_rms**, and **fisSig_asym**.
In RooRarFit, params belong to RooRarFit PDF objects, so full names are needed to distinguish same param names from different PDFs.

PDF config sections

- Charmless B background PDF config sections

```
[deChls Config]
configStr = TwoGauss
x = de
meanC =  0.13  L(-.2 - .2)
meanT = -0.20  L(-.3 - .2)
sigmaC = 0.06  L(0.0 - .3)
sigmaT = 0.14  L(0.0 – 0.3)
fracC =  0.35  L(0.0 – 1.0)

[mesChls Config]
configStr = AddPdf
Comps = mesChlsG mesChlsA
Coeffs = fracG
fracG = T “f_{G}” 0.08 L(0 -1)
[mesChlsG Config]
configStr = Gaussian
x = mes
mean = 5.28    L(5.25 – 5.29)
sigma = 0.004 L(0.0 – 0.1)
```

```
[mesChlsA Config]
configStr = ArgusBG
x = mes
max = 5.29 C
c = -30 L(-80 - -.1)

[fisChls Config]
configStr = BGGauss
x = fisher
mean = -0.4 L(-2 - 2)
rms  =  0.6 L(0.0 – 1)
asym =  0.1 L(-.5 – 0.5)
```

PDF config sections

- Continuum background PDF config sections

```
[deBkg Config]
configStr = Polynomial
x = de
nOrder =  2
P01 = -1.5  L(-100 - 100)
P02 =  2.0  L(-100 - 100)
postPdfFloat = P01

[mesBkg Config]
fitData = desbData
configStr = ArgusBG
x = mes
max = 5.29 C
c = -15 L(-80 - -.1)
postPdfFloat = c
```

```
[fisBkg Config]
configStr = AddPdf
Comps = fisBkgC fisBkgT
Coeffs = fracC
fracC = T "f_{C}" 0.97 L(0 -1)
[fisBkgC Config]
configStr = BGGauss
x = fisher
mean = T "#mu_{C}"  -0.4 L(-2 - 2)
rms = T "#sigma_{C}" 0.6 L(0.0 – 1)
asym = T "A_{C}"   0.1 L(-.5 – 0.5)
[fisBkgT Config]
configStr = Gaussian
x = fisher
mean = T "#mu_{T}" 0.8 L(-1 – 2)
Sigma = T "#sigma_{T}" 2.0 L(0 – 5)
```

PDF config sections

- RooFit PDFs implemented:
  - RooProdPdf
  - RooAddPdf
  - RooAddModel
  - RooSimPdfBuilder
  - RooArgusBG
  - RooBDecay
  - RooDecay
  - RooBifurGauss
  - RooCBShape
  - RooExponential
  - RooGaussian
  - RooBreitWigner
  - RooLandau
  - RooGaussModel
  - RooGenericPdf
  - RooKeysPdf
  - Roo2DKeysPdf
  - RooPolynomial
  - RooChebychev
  - RooParametricStepFunction
  - Triple Gaussian
  - Triple Guassian Model
  - Gexp
  - Double Gaussian (w/ scale and shift)

Fit Action Sections

Guide fitter to finish its jobs

- pdfFit
- mlFit
- projPlot
- sPlot
- toyStudy
- scanPlot
- contourPlot

Fit action - pdfFit

- Get PDF params from fits of individual PDFs to datasets
  - Input: init values in PDF config sections
  - Output: fitted params in intermediate file; PDF plots in ROOT file

```
// Action section name, command line option –A PdfAct
[PdfAct]
// pdfFit options
pdfFit = yes // enable pdfFit action
postPdfMakePlot = yes // To output PDF plots into root file
postPdfWriteParams = yes // To output params to text file
```

Other configs for pdfFit action

- pdfToFit = <pdf1> ...

  Only those listed PDFs will be fitted if this config exists.

- postPdfReadSecParams = <no|yes|secName>

  Override params from PDF fits with values listed in action section (and section if specified here).

Fit action - toyStudy

- toyStudy action is to validate the fitter
  - Input: param values from pdfFit action
  - Output: toyStudy results (pulls, etc) in ROOT file

```
// Action section name, command line option –A ToyAct
[ToyAct]
// toyStudy options
toyStudy = yes  // enable toyStudy action
preToyReadParams = yes
preToyReadSecParams = yes
nSig   =  93 +/- 10 L(-10 – 3000)
nChls = 200 +/- 50 L(-10 – 3000)
protDatasets = onData
toyNexp = 100
toyNevt = 0 floated // 0: nEvt from protDataset; and fluctuation.
toySrc_nSig = sigMC “@0 nSig”
toySrc_nChls = bbMC “@0 nChls”
toySrc_nBkg = gsbData 1 pdf “@0-1 nBkg”
```

Override params from pdfFit or init values

If not specified, `pure toy'.
a variety of `embd toys' if specified

Fit action - toyStudy advanced features

- Param scanning

  Validate the fitter on all possible values for some params,

  for example, signal yields.

```
[ToyAct]
toyStudy = yes // enable toyStudy action
nSig  =  93 +/- 10 L(-10 – 3000)
protDatasets = onData
toyNexp = 100
preToyRandParams = nSig “@0+@1 nSig nSigGen” \\
                   nBkg “@0-@1 nBkg nSigGen”
preToyRandGenerators = nSigGenPdf

// PDF config section for param randomizer
[nSigGenPdf Config]
configStr = Generic
formula = "1" nSigGen
nSigGen = nSigGen 0 L(-43 - 57) // nSig scan range (50, 150)
```

Fit action - toyStudy advanced features

- Prototype datasets
  - Default RooFit prototype dataset facilities supported, and
  - Can have prototype dataset for each species
  - Can have prototype obs generated from specified PDFs
- toyEmbdUnCorrelate = <obsGroup1>...

  Uncorrelate obs among groups for embedded events, for example

```
toyEmbdUnCorrelate = de mes "fisher resMass"
```

- postEmbdRandObs

  Re-generate obs for embedded event, for example

```
postEmbdRandObs = sigMC tagFlav trueDtModel
```

Fit action - mlFit

- Fit full ML fitter on dataset to get yields, etc.
  - Input: param values from pdfFit action
  - Output: final params in intermediate file, mlFit results, including:
    - Yields, floating params
    - Significance of any floating param wrt any particular value
    - Systematic errors of floating params due to the uncertainty of fixed params

```
// Action section name, command line option -A MLAct
[MLAct]
// mlFit options
mlFit = yes // enable mlFit action
mlFitData = onData
postMLSignf = nSig // signal yield signf. (wrt 0 by default)
postMLSysVars = nSig // calculate syst. error for nSig by varying fixed params
postMLSysParams = deSig_meanC  deSig_meanT \\
                  deSig_sigmaC deSig_sigmaT \\
                  deSig_fracC
```

List all fixed params to vary for syst. errors

Fit action - scanPlot

- Scan NLL within interested param spaces
  - Input: params from mlFit action
  - Output: NLL points within param spaces, NLL plot (for 1D scanning), in ROOT file

```
// Action section name, command line option –A ScanAct
[ScanAct]
// scanPlot options
scanPlot = yes  // enable scanPlot action
scanPlotData = onData
nScanPoints = 100 // Number of NLL values
scanVars = nSig 0 100
scanUnCorrErr = 5.1 // nll plot with uncorrelated error included
scanCorrErr = 2.2 // nll plot with correlated error (and uncorrelated
                  // if any) included
```

  - UL, signf., calculation based on NLL plot is provided as static functions within RooRarFit class, rarMLFitter
  - NLL curve operations: combine, shift, etc.

Fit action - projPlot

- Get projection plots for given species
  - Input: params from mlFit action
  - Output: projection plots, LLR histograms, asym plots, in ROOT file

```
// Action section name, command line option –A ProjAct
[ProjAct]
// projPlot options
projPlot = yes // enable projPlot action
projPlotData = onData
projComps = Sig // signal PDF to be projected
projLLRPlots = yes // create LLR histograms
projVars = mes de fisher // obs to get projection plots
projLRatioCut = .810
projLRatioCut_mes = .835
projLRatioCut_de = .920
projLRatioCut_fisher = .890
projFindOptimCut = yes
projOptimRange_mes = "abs(mes-5.28)<0.006"
projOptimRange_de = "abs(de)<0.07"
projOptimRange_fisher = "fisher<0.0"
projPlotCat = runBlock // get projection plot for each cat type
```

Likelihood ratio cuts

Find optimal cuts

Fit action - contourPlot

- Get contour plots for two floating params
  - Input: params from mlFit action
  - Output: contour plots in ROOT file

```
// Action section name, command line option –A ContourAct
[ContourAct]
// contourPlot options
contourPlot = yes  // enable contourPlot action
contourPlotData = onData
nContours = 3 // Number of contours
contourVars = nSig 0 100 fL .3 1.4
```

Fit action - sPlot

- Get sPlots
  - Input: params from mlFit action
  - Output: sPlots in ROOT file

```
// Action section name, command line option –A SPlotAct
[ProjAct]
// sPlot options
sPlot = yes // enable sPlot action
sPlotData = onData
sPlotComps = all // sPlots for all species
sPlotVars = mes de fisher // obs to get sPlots
sPlotPdfOverlay = direct // direct PDF used for PDF overlay
sPlotIgnoredVars_heli = resMass
sPlotNormIgnoredObs = tagFlav dtErr
```

correlated obs should be removed

removed from PDF normalization due to PDF inconsistency across species

- Extended sPlot with fixed species
  - To be implemented soon

Documentation
&
Current Status

Documentation

- HTML reference manual comes with the package

  RooRarFit/doc/RooRarFit.html

  Preface
  1. RooRarFit Implementation
  2. RooRarFit Configuration
  3. Questions and Answers
  Index

- Lots of working examples from many analyses

  RooRarFit/doc/Sample_configs

- Sample scripts to deal with RooRarFit ROOT output

  RooRarFit/doc/Sample_scripts

- Source code documented using doxygen

  http://www.slac.stanford.edu/~zhanglei/RooRarFit/html

Current users and modes (known to me as of 11/11/05)

Analysis	Who
eta'K S, C, Acp, BR	Jim Smith
omegaKs "	Keith Ulmer
omegah Acp, BR	"
omegaK*/rho BR, Acp, Pol	Arik Kreisel
eta'K*/rho	Paul Bloom, Phil Clark
$K^{*+}rho^{0}$ BR, Acp, Pol	Lluisa-Maria Mir
eta*K	Gena Kukartsev
$rho^{+}rho^{-}$	Yuriy Groysman
a1pi	Dan Walker
omegaomega, omegaphi	Justin Albert, David Doll
K*Ks	Steve Foulkes
KsKsKl	Lei Zhang

and more ...

Future plan/to-do list

- More RooFit PDFs will be `wrapped' (added) as needed
- More functionalities, like Dalitz analysis, might be added
- Independent of Babar SRT
- Any comments, contributions, are welcome

Get RooRarFit! Reclaim Your Fitter!