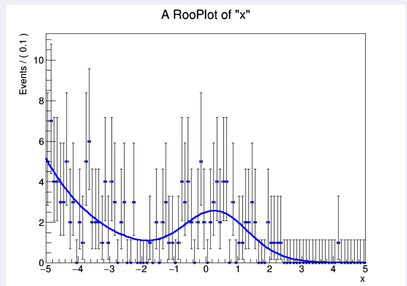
RooFit, RooStats & HistFactory

a python data science *Cheat Sheet*

A Simple Example

```
import ROOT
w = ROOT.RooWorkspace()
w.factory('Gaussian::g(x[-5,5],mu[-3,3],sigma[1])')
w.factory('Exponential::e(x,tau[-.5,-3,0])')
w.factory('SUM::model(s[50,0,100]*g,b[100,0,1000]*e)')
x = w.var('x')
pdf = w.pdf('model')
frame = x.frame()
data = pdf.generate(ROOT.RooArgSet(x))
data.plotOn(frame)
fitResult = pdf.fitTo(data,ROOT.RooFit.Save())
pdf.plotOn(frame)
frame.Draw()
```



Models and Fitting

For a set of PDFs e.g. signalpdf and backgroundpdf and a fractional normalization fsig:

```
fsig = ROOT.RooRealVar("fsig","signal fraction",0.5,0.,1.)
model = ROOT.RooAddPdf("model","model",
        RooArgList(signalpdf,backgroundpdf),RooArgList(fsig))
```

We can create a negative log-likelihood (nll) function and from this and profile log-likelohood (pll) function. These relate estimators for the parameters in a model to some data.

```
nll = pdf.createNLL(data)
pll = nll.createProfile(paramOfInterest)
```

Various minimizers are available through the minuit package, these can act on all parameters or just those specified.

```
m = ROOT.RooMinimizer(nll)
m.migrad()                          efficient and fast, struggles with nonlinearities
m.hesse()                           calculates the full error matrix from second derivatives
m.minos(ParametersOfInterest)       correct even non-parabolic, but slow
```

Using Data

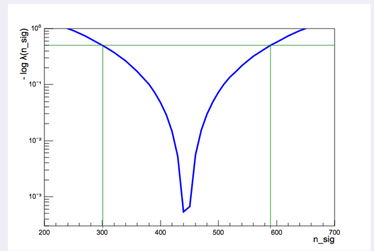
Data can be imported from histograms or generated from a model.

```
hh = ROOT.TH1F("hh","some histogram",21,-10,10)
x = ROOT.RooRealVar("x","x",-10,10)
real_data = ROOT.RooDataHist("data","dataset with x",x,hh)
pseudo_data = model.generate(ROOT.RooArgSet(x),10000)
```

Statistical Tests with RooStats

Profile Likelihood

```
pl = ROOT.RooStats.ProfileLikelihoodCalculator(data,ModelConfig)
pl.SetConfidenceLevel(0.683)                    set desired interval
interval = pl.GetInterval()                     perform calculation
firstPOI = mc.GetParametersOfInterest().first()     only one POI
lowerLimit = interval.LowerLimit(firstPOI)          extract limits
upperLimit = interval.UpperLimit(firstPOI)          this is a number
plot = ROOT.RooStats.LikelihoodIntervalPlot(interval)
plot.Draw()     Custom plot object but regular frame->plotOn also works.
```

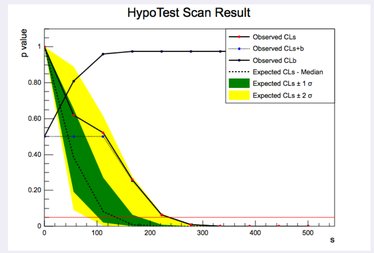


Hypothesis Test (asymptotic formula)

```
ac = ROOT.RooStats.AsymptoticCalculator(data, sbModel, bModel)
asResult = ac.GetHypoTest()     where sbModel is signal+background
asResult.Print()  bModel = background only.  Gives p-value & Z_0
```

Limits using Hypothesis Test Inversion (CLs Limits)

```
ac = ROOT.RooStats.AsymptoticCalculator(data, sbModel, bModel)
calc = ROOT.RooStats.HypoTestInverter(ac)                   as above
calc.SetConfidenceLevel(0.95)                               desired limit
calc.UseCLs(True)                                scan CLs+b or CLs values
toymcs = calc.GetHypoTestCalculator().GetTestStatSampler()
profll = ROOT.RooStats.ProfileLikelihoodTestStat(sbModel.GetPdf())
toymcs.SetTestStatistic(profll)          Profile likelihood test statistics
calc.SetFixedScan(npoints,poi.getMin(),poi.getMax())        set range
r = calc.GetInterval()       or scan until reaching the desired precision
upperLimit = r.UpperLimit()                  the result for this confidence level.
plot = ROOT.RooStats.HypoTestInverterPlot("HTI_Result_Plot",
                                          "HypoTest Scan Result",r)
plot.Draw("CLb 2CL")
```



Workspaces and Histfactory

```
w = ROOT.RooWorkspace("w")                          Make a workspace
getattr(w,'import')(pdf1)                           Move a pdf into the workspace
w.factory('SUM::model(n_sig[5,0,10]*pdf1,n_bkg[10,0,100]*pdf2)')
w.var("n_sig").setVal(2)                            Factory can be used to create models
model = w.pdf("model")                              objects (e.g PDFs) are extracted by name
data = model.generate(ROOT.RooArgSet(x))            data to be used
getattr(w,'import')(data)                           most WS's need a PDF and data
mc = ROOT.RooStats.ModelConfig("ModelConfig",w)     configure model
mc.SetPdf(model)                                    target subset of variables
mc.SetParametersOfInterest(ROOT.RooArgSet(w.var("n_sig")))   POI
mc.SetSnapshot(ROOT.RooArgSet(w.var("n_sig")))      preserve values
mc.SetObservables(ROOT.RooArgSet(w.var("x")))       target range
w.defineSet("nuisParams","n_bkg")                   there can be hundreds of NPs
nuis = getattr(w,'set')("nuisParams")               added to WS as normal
mc.SetNuisanceParameters(nuis)                      NPs distingushed from POIs in model
getattr(w,'import')(mc)                             import ModelConfig to WS
w.writeToFile("outputdir/name.root",True)           save the workspace to file
```

```
meas = ROOT.RooStats.HistFactory.Measurement("meas", "meas")
meas.SetPOI( "SigXsecOverSM" )
chan = ROOT.RooStats.HistFactory.Channel( "SignalRegion" )
chan.SetStatErrorConfig(0.05, "Poisson")
chan.SetData( data_hist )
signal = ROOT.RooStats.HistFactory.Sample( "signal" )
signal.SetHisto( signal_hist )
signal.AddNormFactor( "SigXsecOverSM", 1, 0, 3)
signal.AddOverallSys( "flat_uncertainty", low_val, high_val )
signal_shape = ROOT.RooStats.HistFactory.HistoSys("shape_uncert")
signal_shape.SetHistoHigh( sig_up_hist )
signal_shape.SetHistoLow( sig_down_hist )
signal.AddHistoSys( signal_shape )
chan.AddSample( signal )
hist2workspace =
        ROOT.RooStats.HistFactory.HistoToWorkspaceFactoryFast(meas)
workspace = hist2workspace.MakeSingleChannelModel(meas, chan)
```

RooVariables, RooPdfs, and Data

Variables and P.D.Fs

```
observable = ROOT.RooRealVar("x","x",-10,10)
mean = ROOT.RooRealVar("mean","Mean",-10,10)
sigma = ROOT.RooRealVar("sigma","Width",3,-10,10)
gauss = ROOT.RooGaussian("gauss","pdf title",x,mean,sigma)
```

Common P.D.Fs

```
ROOT.RooBifurGauss("name", "title", x, μ, σ_L, σ_R)
ROOT.RooExponential("name", "title", x, c)
ROOT.RooPolynomial("name", "title", x, RooArgList(c_1,c_2)
ROOT.RooPoisson("name", "title", x, η)
```

Bifurcated Gaussian	$f(x;\mu,\sigma) = \frac{1}{N} \cdot \exp(-(x-\mu)^2/(2\sigma(x-\mu)^2)$
Exponential	$f(x;c) = \frac{1}{N}\exp(cx)$
Polynomial	$f(x;c_0,...,c_n) = \frac{1}{N} \cdot \left(1+\sum_{k=1}^{n} c_k x^k\right)$
Poisson	$f(x;\eta) = \frac{1}{x!} \cdot \eta^x \exp(-\eta)$

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ROOT Data Analysis Framework