Exercise/Lesson #7

Scientific Data Analysis Lab course

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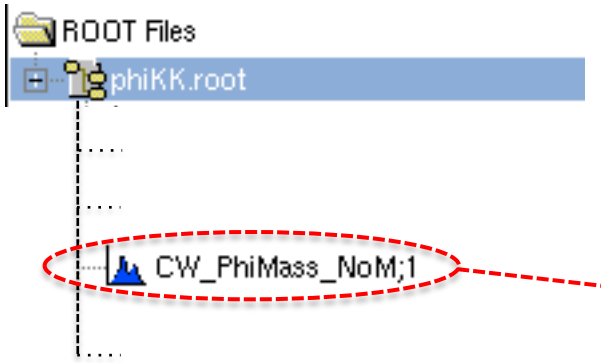
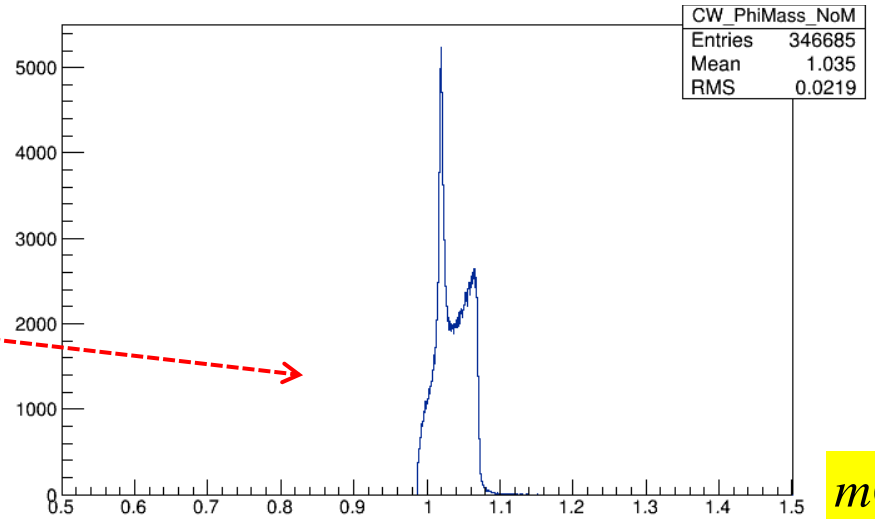
Fit of the invariant mass distribution when the mass resolution is lower than the natural width of the resonance/particle

Preliminarily let us visualize the distribution that should be fitted :



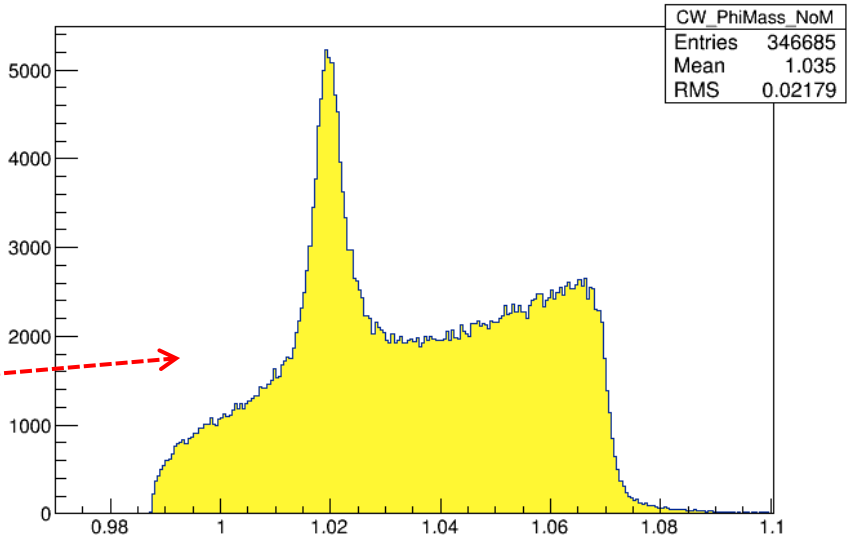


$m(K^+K^-)$

This histogram represents the **invariant mass of a couple of tracks to which the Kaon mass is assigned** [these data are from CMS]. **The ϕ signal is sitting on a mainly combinatorial background.**

It can be better seen with few settings given sequentially at the prompt:

```
-bash-3.2$ root -l phiKK.root
root [0]
Attaching file phiKK.root as _file0...
root [1] CW_PhiMass_NoM->SetAxisRange(0.97,1.1)
root [2] CW_PhiMass_NoM->SetTitle("")
root [3] CW_PhiMass_NoM->SetFillColor(5)
root [4] CW_PhiMass_NoM->Draw()
Info in <TCanvas::MakeDefCanvas>:  created default TCanvas with name c1
root [5]
```



Exercise: Try by yourself to write a macro to execute the fit like previously done for the …

… signal $\psi' \to \mu^+\mu^-$

For reference here is some useful code to accomplish the task:

```
////////////////////////////////////
// run with root: .x phiKK_fit.C
////////////////////////////////////
#include <vector>

gROOT->Reset();
gROOT->Clear();

using namespace RooFit;

void phiKK_fit() {
  //
  gROOT->ForceStyle();
  gStyle->SetTitleOffset(1.4, "Y");
  gStyle->SetOptFit(1);
  //
  TFile* f1 = TFile::Open("./phiKK.root","read");
  //
  ////////////////////////// PREPARE HISTO
  //
  TH1F* hPhiKK;
  hPhiKK = (TH1F*) f1->Get("CW_PhiMass_NoM");
  //
  TCanvas *myC = new TCanvas("myC","PhiMassPlot", 1100, 800);
  //
  Double_t xMin = hPhiKK->GetXaxis()->GetXmin();
  Double_t xMax = hPhiKK->GetXaxis()->GetXmax();
  Int_t nBins = hPhiKK->GetNbinsX();
  //
  //RooRealVar xVar("xVar", "m(K^{+}K^{-}) [GeV/c^{2}]", xMin, xMax);
  RooRealVar xVar("xVar", "m(K^{+}K^{-}) [GeV/c^{2}]", 0.987, 1.0645);
  xVar.setBins((nBins/10)*0.2);
  //
  RooDataHist* KKHist = new RooDataHist("KK_hist", hPhiKK->GetTitle(), RooArgSet(xVar), Import(*hPhiKK,kFALSE));
  //
  ////////////////////////// CONFIGURE and MAKE FIT
  //
```

```
//////////////////////// CONFIGURE and MAKE FIT
//
// --- SIG
RooRealVar mean("mean","mean of voigtian", 1.0197, 1.019, 1.0205);
RooRealVar gamma("gamma","width of BW", 0.0045, 0.001, 0.01);
RooRealVar sigma("#sigma", "mass resolution", 0.0013); // to set at the MC value of 1.3MeV
RooVoigtian sigPDF("sigPDF","sigPDF", xVar, mean, gamma, sigma);
//
// --- BKG
RooRealVar c0("c_{0}", "c0", 0.001 ,-15, 15);
RooRealVar c1("c_{1}", "c1", -0.1 ,-15, 15);
RooRealVar c2("c_{2}", "c2", -0.1 ,-15, 15);
RooRealVar c3("c_{3}", "c3", 0.1 ,-10, 10);
RooRealVar c4("c_{4}", "c4", 0.1 ,-10, 10);
RooRealVar c5("c_{5}", "c5", 0.05 ,-10, 10);
RooRealVar c6("c_{6}", "c6", 0.0 ,-1, 1);
//
RooChebychev bkgPDF("bkgPDF", "bkgPDF", xVar, RooArgSet(c0,c1,c2,c3,c4,c5) );
//
RooRealVar nSig("nSig", "Number of signal candidates ", 5e+5, 1000., 5e+6);
RooRealVar nBkg("nBkg", "Bkg component", 2e+6, 1000., 5e+7);
//
RooAddPdf* totalPDF = new RooAddPdf("totalPDF", "totalPDF", RooArgList(sigPDF, bkgPDF), RooArgList(nSig, nBkg));
//
totalPDF->fitTo(*KKHist, Extended(kFALSE));
//

//////////////////////// PLOT RESULTS
```

Set the mass resolution to the value found in CMS Monte Carlo !

(*)

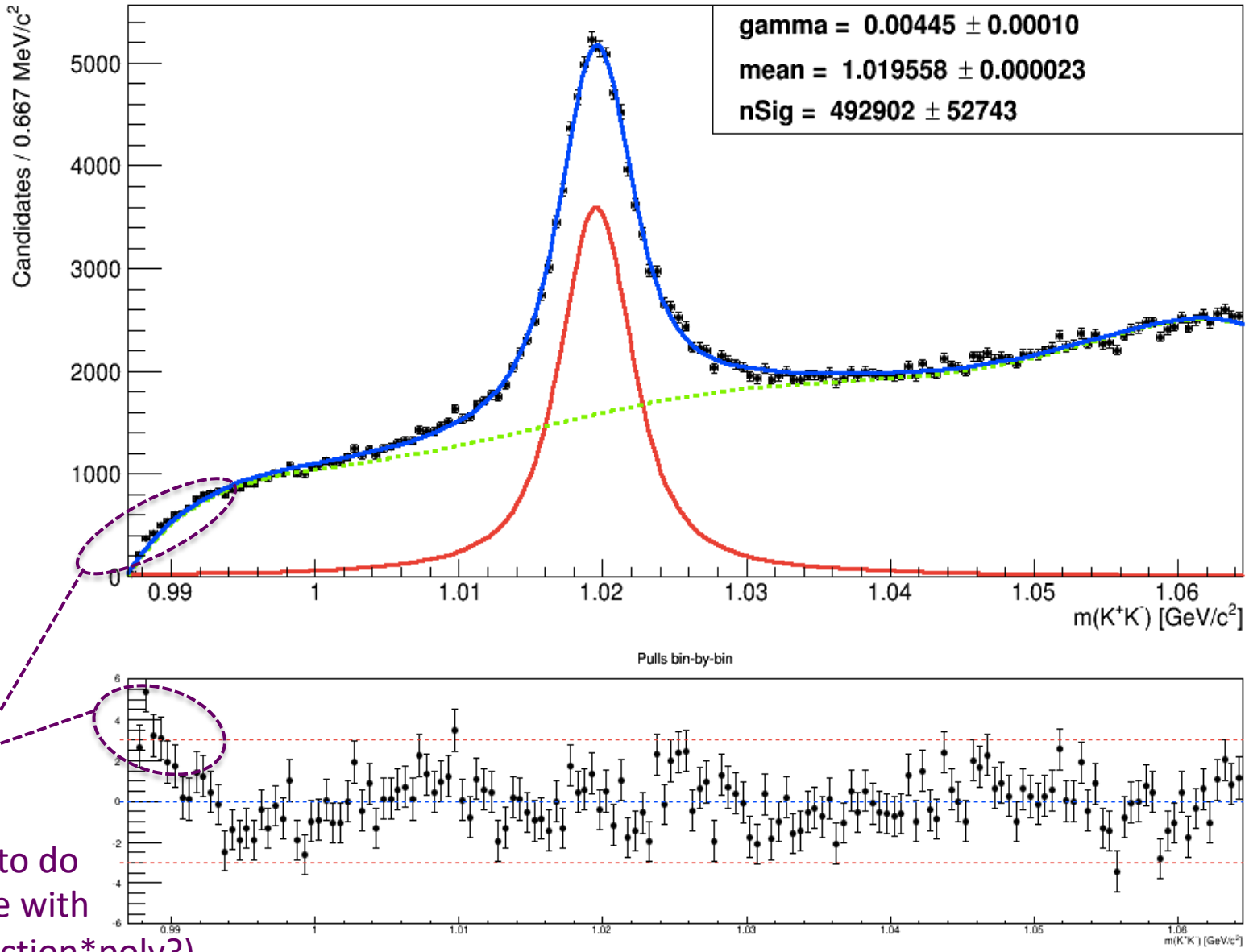
Chebyshev poly of enough high order

(*) Voigtian (=BW⊗G) — `Voigtian::v(x,mean,gamma,sigma)`

→ **non-relativistic !**

```
  ////////////////////////// PLOT RESULTS
  //
  RooPlot* xframe = xVar.frame();
  //xframe->SetTitle( hPhiKK->GetTitle() );
  xframe->SetTitle("");
  xframe->SetYTitle("Candidates / 0.667 MeV/c^{2}");
  //xframe->SetTitleOffset(1.45,"Y");
  //
  gStyle->SetMarkerSize(0.65);
  gStyle->SetMarkerStyle(20);
  KKHist->plotOn(xframe);
  totalPDF->plotOn(xframe);
  //
  totalPDF->plotOn(xframe, Components(RooArgSet(sigPDF)), LineColor(kRed));
  totalPDF->plotOn(xframe, Components(RooArgSet(bkgPDF)), LineColor(kGreen), LineStyle(kDashed) );
  totalPDF->paramOn(xframe, Parameters(RooArgSet(mean,sigma,gamma,nSig)), Layout(0.52,0.9,0.9));
  //
  totalPDF->plotOn(xframe);
  //
  //myC->cd();
  //xframe->Draw();
  //
  // add the pulls bin-by-bin instead:
  //
  RooPlot* framePull = xVar.frame();
  framePull->SetTitle("Pulls bin-by-bin");
  framePull->addObject( (TObject*)xframe->pullHist(), "p" );
  framePull->SetMinimum(-6);
  framePull->SetMaximum(6);
  //
  myC->Divide(0,2);
  myC->cd(2);
  gPad->SetPad(0.,0.,1.,0.3);
  framePull->Draw();
  TLine *line = new TLine(0.9865, 0., 1.0645, 0.);
  line->SetLineColor(kBlue);
  line->SetLineStyle(kDashed);
  line->Draw("same");
  TLine *lineup = new TLine(0.9865, 3., 1.0645, 3.);
  lineup->SetLineColor(2);
  lineup->SetLineStyle(kDashed);
  lineup->Draw("same");
  TLine *linedown = new TLine(0.9865, -3., 1.0645, -3.);
  linedown->SetLineColor(2);
  linedown->SetLineStyle(kDashed);
  linedown->Draw("same");
  //
  myC->cd(1);
  gPad->SetPad(0.,0.3,1.,1.);
  //
  xframe->Draw();
  //
////////////////////////// SAVE IN OUTPUT PLOT
  //
  myC->SaveAs("./Plots/PhiKK-Voigtian.png");
  //
//////////////////////////////////////////////////////////////////////
}
```

This code provides the following plot:



We could try to do better (maybe with threshold function*poly?)

Check that the fit result is compatible with PDG world average :

Citation: C. Patrignani *et al.* (Particle Data Group), Chin. Phys. C, **40**, 100001 (2016) and 2017 update

$\phi(1020)$ $I^G(J^{PC}) = 0^-(1^{--})$

$\phi(1020)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1019.460±0.016 OUR AVERAGE				

$\phi(1020)$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
4.247±0.016 OUR AVERAGE				Error includes scale factor of 1.2.

The fit result is: $m(\phi) \cong [1019.558 \pm 0.023] MeV$ (within 3σ)

$\Gamma(\phi) \cong [4.45 \pm 0.10] MeV$ (within 2σ)

NOT BAD !

Note : some enhancement can be obtained using a relativistic BW convoluted with a gaussian resolution function