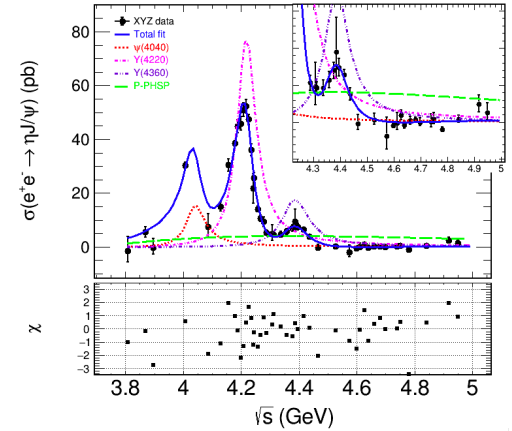
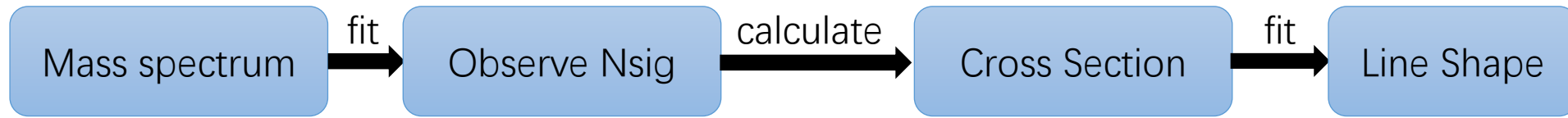


Global Fitting of the Lineshape

Outline

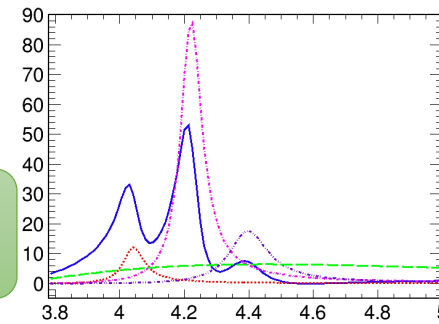
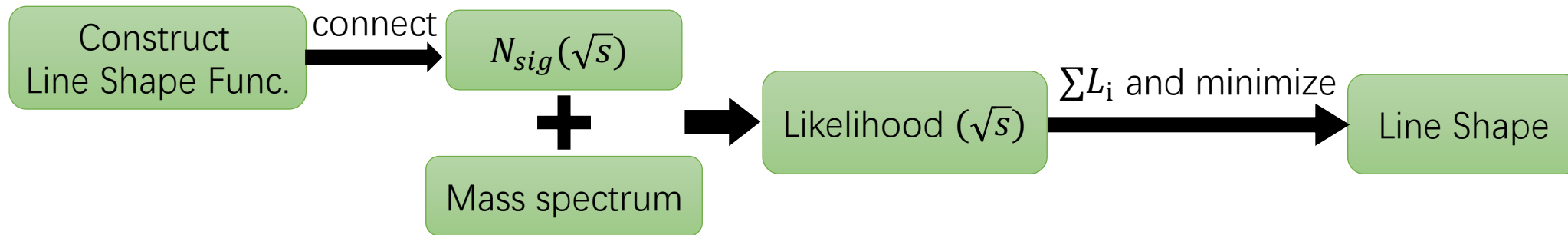
Traditional



For traditional method, we may only obtain the upper limit of some datasets with little statistics.

But by this global fit, these datasets can be also put into the line shape fitting.

Global Fit



A Simultaneous Fit:

The parameters of the line shape are shared between the datasets in different C.M. energy.

Strategy

Construct my Line Shape Func.

$$\sigma^B(\sqrt{s}) = \left| C_0 \sqrt{\Psi(\sqrt{s})} + BW_1(\sqrt{s})e^{i\phi_1} + BW_2(\sqrt{s})e^{i\phi_2} + BW_3(\sqrt{s})e^{i\phi_3} \right|^2$$

- Establish the connection between the fitting variable of individual mass spectrum ([RooAbsReal](#) Nsig) and the function of line shape.

$$N_{obs}(\sqrt{s}) = \sigma^B(\sqrt{s}) \cdot \mathcal{L}_{int} \cdot (1 + \delta^{ISR}) \cdot (1 + \delta^{VP}) \cdot \epsilon \cdot Br \quad (1)$$

Use [RooArgSet](#) to package the parameters of the lineshape

```
RooArgSet *roo_pars[nums];
roo_pars[i] = new RooArgSet(Mass1, Width1, GamEE1, Phi1, Mass2, Width2, GamEE2, Phi2, Mass3);
roo_pars[i]->add(Width3);
roo_pars[i]->add(GamEE3);
roo_pars[i]->add(Phi3);
roo_pars[i]->add(c0);
roo_pars[i]->add(*LINT[i]);
roo_pars[i]->add(*DEL[i]);
roo_pars[i]->add(*Eff_2ee[i]);
roo_pars[i]->add(*Eff_2mu[i]);
roo_pars[i]->add(*Eff_3ee[i]);
roo_pars[i]->add(*Eff_3mu[i]);
```

```
RooRealVar Mass1("Mass4040", "Mass4040", vstart[0]);
RooRealVar Width1("Wid4040", "Wid4040", vstart[1]);
RooRealVar GamEE1("GamEe4040", "GamEe4040", iniPar[2], 0.0, 100);
RooRealVar Phi1("Phi4040", "Phi4040", iniPar[3], 0.0, 6.284);

RooRealVar Mass2("Mass4220", "Mass4220", iniPar[4], 4.190, 4.25);
RooRealVar Width2("Wid4220", "Wid4220", iniPar[5], 0.0, 0.10);
RooRealVar GamEE2("GamEe4220", "GamEe4220", iniPar[6], 0.0, 100);
RooRealVar Phi2("Phi4220", "Phi4220", iniPar[7], 0.001, 6.284);

RooRealVar Mass3("Mass4360", "Mass4360", iniPar[8], 4.30, 4.5);
RooRealVar Width3("Wid4360", "Wid4360", iniPar[9], 0.0, 0.3);
RooRealVar GamEE3("GamEe4360", "GamEe4360", iniPar[10], 0.0, 20);
RooRealVar Phi3("Phi4360", "Phi4360", iniPar[11], 0.00, 6.284);

RooRealVar c0("c0", "c0", iniPar[12], 6e+03, 1e+05);
RooRealVar N("N", "N", iniPar[13], 0.0, 10);
```

Use [bindFunction](#) to build the connection

```
F1 *n1_func = new TF1("n1_func", N_SIG1, 3.78, 5.0, 19);
TF1 *n2_func = new TF1("n2_func", N_SIG2, 3.78, 5.0, 19);
TF1 *n3_func = new TF1("n3_func", N_SIG3, 3.78, 5.0, 19);
TF1 *n4_func = new TF1("n4_func", N_SIG4, 3.78, 5.0, 19);
RooAbsReal *nsig1[nums];
RooAbsReal *nsig2[nums];
RooAbsReal *nsig3[nums];
RooAbsReal *nsig4[nums];
nsig1[i] = bindFunction(n1_func, *ecms[i], *roo_pars[i]);
nsig2[i] = bindFunction(n2_func, *ecms[i], *roo_pars[i]);
nsig3[i] = bindFunction(n3_func, *ecms[i], *roo_pars[i]);
nsig4[i] = bindFunction(n4_func, *ecms[i], *roo_pars[i]);
```

- The N_SIG* is the function written in C++ symbolize Func.(1)
- The *ecms[i] is a [RooRealVar](#) with fixed value symbolize C.M. energy.

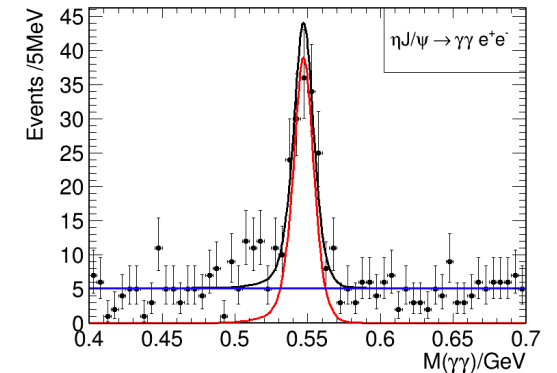
Strategy

- Construct PDF of Signal and Background of mass spectrum normally

Get the likelihood of individual mass spectrum by `createNLL`

(by some tests, we find the likelihood obtained by `createNLL()` is same as results from RooFit as following.)

$$-\log L(p) = - \sum_{data} \log M(x_i) - \log \text{Poisson}(N_{expected}, N_{observed})$$



```
RooDataSet *data1[nums];
RooAbsReal *lk11[nums];
RooAddPdf *sum1[nums];

data1[i] = new RooDataSet("data1_"+DataSet[i],"data1_"+DataSet[i], t_data_2gee[i], x);
sum1[i]=new RooAddPdf("sum1_"+DataSet[i],"sum1_"+DataSet[i],RooArgList(*sig1_pdf[i],*bg1_pdf[i]),RooArgSet(*nsig1[i],*nbkg1[i]));
lk11[i] = sum1[i]->createNLL(*data1[i]);
```

Use `RooAddition` to add the likelihood together

```
RooAddition* ll_ttl[nums];
ll_ttl[i] = new RooAddition("ll_ttl_"+DataSet[i],"ll_ttl_"+DataSet[i], RooArgSet(*lk11[i],*lk12[i],*lk13[i],*lk14[i]));
```

Add the total likelihood and use `RooMinuit` to make a fit

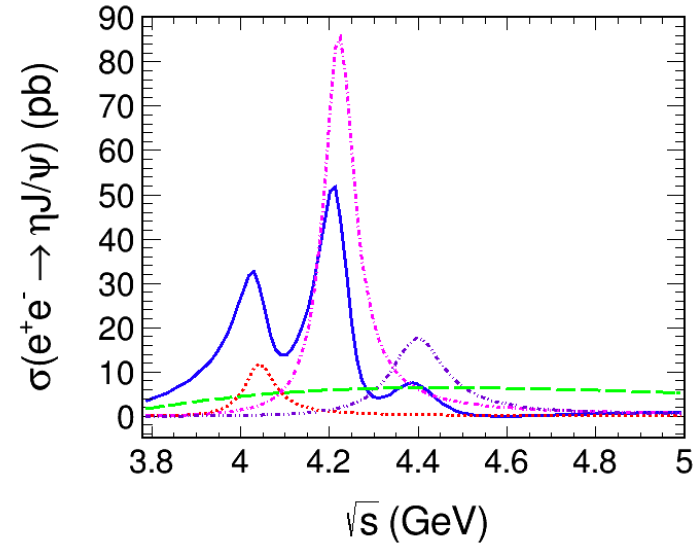
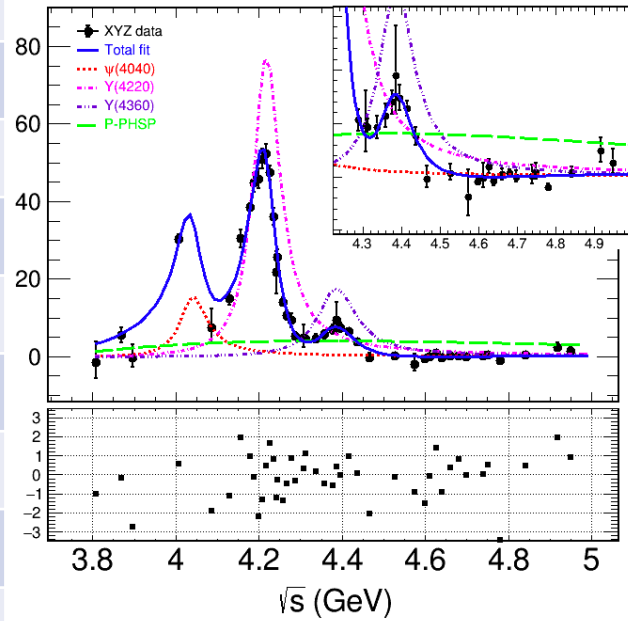
```
RooMinuit m(*likelihood);
m.migrad();
m.hesse();
```

*likelihood is the addition of the total likelihood

Comparison

$$\sigma_{fit} = \left| C_0 \sqrt{\Psi(\sqrt{s})} + BW_1(\sqrt{s})e^{i\phi_1} + BW_2(\sqrt{s})e^{i\phi_2} + BW_3(\sqrt{s})e^{i\phi_3} \right|^2 \quad \Psi(\sqrt{s}) = \frac{q^3}{s^n}$$

	Old_45	new
$\Gamma_{4040}^{e^+e^-} Br_{4040} (eV)$	1.36 ± 0.22	1.07 ± 0.16
$\phi_{4040} (rad)$	3.02 ± 0.20	3.24 ± 0.11
$M_{4220} (MeV/c^2)$	4215.6 ± 2.17	4218.8 ± 1.19
$\Gamma_{4220} (MeV)$	79.45 ± 4.44	80.24 ± 1.84
$\Gamma_{4220}^{e^+e^-} Br_{4220} (eV)$	7.44 ± 1.00	8.56 ± 0.29
$\phi_{4220} (rad)$	4.12 ± 0.13	4.21 ± 0.06
$M_{4360} (MeV/c^2)$	4383.3 ± 12.41	4392.5 ± 4.37
$\Gamma_{4360} (MeV)$	112.44 ± 26.92	144.95 ± 7.60
$\Gamma_{4360}^{e^+e^-} Br_{4360} (eV)$	2.58 ± 0.96	3.36 ± 0.31
$\phi_{4360} (rad)$	2.47 ± 0.16	2.72 ± 0.11
C_0	$9.29 \times 10^3 \pm 1.66 \times 10^4$	$6.36 \times 10^3 \pm 2.41 \times 10^2$
n	5.70 ± 1.20	5.29 ± 0.04



Back up

Back up

Comparison of results from a simultaneous fit by RooFit and RooMinuit.

```
** 9 **HESSE 2500
*****
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-27703.4 FROM HESSE STATUS=OK 31 CALLS 259 TOTAL
EDM=7.67701e-05 STRATEGY= 1 ERROR MATRIX ACCURATE

EXT PARAMETER
NO. NAME VALUE ERROR INTERNAL STEP SIZE INTERNAL VALUE
1 Bpeta_new_4180 3.75313e+01 1.09624e+00 1.34365e-04 -1.19115e+00
2 co1_f00 -1.24128e-01 5.12772e-01 3.15373e-05 -3.41593e-01
3 co3_f00 -4.71969e-01 1.52654e-01 9.81962e-06 -3.46520e-01
4 nbkg1_f00 4.06359e+02 2.22372e+01 7.43846e-05 -9.92612e-01
5 nbkg2_f00 1.81674e+03 4.52465e+01 8.58065e-05 -2.76828e-01
ERR DEF= 0.5
EXTERNAL ERROR MATRIX. NDIM= 25 NPAR= 5 ERR DEF=0.5
1.202e+00 7.969e-03 1.242e-03 -2.637e+00 -6.321e+00
7.969e-03 2.629e-01 8.238e-06 -2.664e-01 -4.192e-02
1.242e-03 8.238e-06 2.330e-02 -2.726e-03 -4.534e-02
-2.637e+00 -2.664e-01 -2.726e-03 4.945e+02 1.387e+01
-6.321e+00 -4.192e-02 -4.534e-02 1.387e+01 2.047e+03
PARAMETER CORRELATION COEFFICIENTS
NO. GLOBAL 1 2 3 4 5
1 0.16655 1.000 0.014 0.007 -0.108 -0.127
2 0.02614 0.014 1.000 0.000 -0.023 -0.002
3 0.00934 0.007 0.000 1.000 -0.001 -0.007
4 0.11035 -0.108 -0.023 -0.001 1.000 0.014
5 0.12756 -0.127 -0.002 -0.007 0.014 1.000
[#1] INFO:Minization -- RooMinimizer::optimizeConst: deactivating const optimization
[#1] INFO:Caching -- RooAbsCachedPdf::getCache(sig1_f4180) creating new cache 0x54dac00 with pdf mcPdf2_4180_CONV_gauss1_CACHE_Obs[m2g] for nset (m2g) with code 0 from preexisting content.
LIKELIHOOD1=-2748.3
LIKELIHOOD2=-3365.2
### xsec = 37.5313 +- 1.09624
it.log [+]
```

```
*****
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-30250.7 FROM HESSE STATUS=OK 31 CALLS 260 TOTAL
EDM=1.48127e-05 STRATEGY= 1 ERROR MATRIX ACCURATE

EXT PARAMETER
NO. NAME VALUE ERROR INTERNAL STEP SIZE INTERNAL VALUE
1 Bpeta_new_4180 3.75335e+01 1.09627e+00 1.40406e-04 -1.19114e+00
2 co1_f00 -1.26370e-01 5.10723e-01 3.50954e-05 -3.41625e-01
3 co3_f00 -4.70817e-01 1.53052e-01 1.03753e-05 -3.46503e-01
4 nbkg1_f00 4.06319e+02 2.22356e+01 7.77199e-05 -9.92641e-01
5 nbkg2_f00 1.81667e+03 4.52451e+01 8.96534e-05 -2.76856e-01
ERR DEF= 0.5
EXTERNAL ERROR MATRIX. NDIM= 30 NPAR= 5 ERR DEF=0.5
1.202e+00 7.923e-03 1.247e-03 -2.637e+00 -6.321e+00
7.923e-03 2.608e-01 8.208e-06 -2.649e-01 -4.167e-02
1.247e-03 8.208e-06 2.342e-02 -2.736e-03 -4.550e-02
-2.637e+00 -2.649e-01 -2.736e-03 4.945e+02 1.387e+01
-6.321e+00 -4.167e-02 -4.550e-02 1.387e+01 2.047e+03
PARAMETER CORRELATION COEFFICIENTS
NO. GLOBAL 1 2 3 4 5
1 0.16654 1.000 0.014 0.007 -0.108 -0.127
2 0.02609 0.014 1.000 0.000 -0.023 -0.002
3 0.00935 0.007 0.000 1.000 -0.001 -0.007
4 0.11033 -0.108 -0.023 -0.001 1.000 0.014
5 0.12755 -0.127 -0.002 -0.007 0.014 1.000
[#1] INFO:Caching -- RooAbsCachedPdf::getCache(sig1_f4180) creating new cache 0xc31b0 with pdf mcPdf2_4180_CONV_gauss1_CACHE_Obs[m2g] for nset (m2g) with code 0 from preexisting content.
[#1] INFO:Caching -- RooAbsCachedPdf::getCache(sig2_f00) creating new cache 0x35860 with pdf mcPdf1_4180_CONV_gauss2_CACHE_Obs[m2g] for nset (m2g) with code 0 from preexisting content.
LIKELIHOOD1=-2748.29
LIKELIHOOD2=-3365.2
### xsec = 37.5335 +- 1.09627
ituit.log
```

```
** 18 **HESSE 2500
*****
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-30250.7 FROM HESSE STATUS=OK 31 CALLS 260 TOTAL
EDM=1.48127e-05 STRATEGY= 1 ERROR MATRIX ACCURATE

EXT PARAMETER
NO. NAME VALUE ERROR INTERNAL STEP SIZE INTERNAL VALUE
1 Bpeta_new_4180 3.75335e+01 1.09627e+00 1.40406e-04 -1.19114e+00
2 co1_f00 -1.26370e-01 5.10723e-01 3.50954e-05 -3.41625e-01
3 co3_f00 -4.70817e-01 1.53052e-01 1.03753e-05 -3.46503e-01
4 nbkg1_f00 4.06319e+02 2.22356e+01 7.77199e-05 -9.92641e-01
5 nbkg2_f00 1.81667e+03 4.52451e+01 8.96534e-05 -2.76856e-01
ERR DEF= 0.5
EXTERNAL ERROR MATRIX. NDIM= 30 NPAR= 5 ERR DEF=0.5
1.202e+00 7.923e-03 1.247e-03 -2.637e+00 -6.321e+00
7.923e-03 2.608e-01 8.208e-06 -2.649e-01 -4.167e-02
1.247e-03 8.208e-06 2.342e-02 -2.736e-03 -4.550e-02
-2.637e+00 -2.649e-01 -2.736e-03 4.945e+02 1.387e+01
-6.321e+00 -4.167e-02 -4.550e-02 1.387e+01 2.047e+03
PARAMETER CORRELATION COEFFICIENTS
NO. GLOBAL 1 2 3 4 5
1 0.16654 1.000 0.014 0.007 -0.108 -0.127
2 0.02609 0.014 1.000 0.000 -0.023 -0.002
3 0.00935 0.007 0.000 1.000 -0.001 -0.007
4 0.11033 -0.108 -0.023 -0.001 1.000 0.014
5 0.12755 -0.127 -0.002 -0.007 0.014 1.000
[#1] INFO:Caching -- RooAbsCachedPdf::getCache(sig1_f4180) creating new cache 0xfb450 with pdf mcPdf2_4180_CONV_gauss1_CACHE_Obs[m2g] for nset (m2g) with code 0 from preexisting content.
[#1] INFO:Caching -- RooAbsCachedPdf::getCache(sig2_f00) creating new cache 0xda0 with pdf mcPdf1_4180_CONV_gauss2_CACHE_Obs[m2g] for nset (m2g) with code 0 from preexisting content.
LIKELIHOOD1=-2748.29
LIKELIHOOD2=-3365.2
### xsec = 37.5335 +- 1.09627
ituit.log
```