UNIVERSITY
OF TRIESTE

INFN

Toward $\mathcal{B}(B \to D^0 \rho)$

TS analysis meeting
june 2022

Mirco Dorigo
Riccardo Manfredi
Olga Werbycka

Overview

- Changes in the preselection cuts
- Previous selection results
- New selection + results of 3D optimization
- BB-bar background composition
- Summary

Preselection

Made on MC14 (200 fb^{-1})

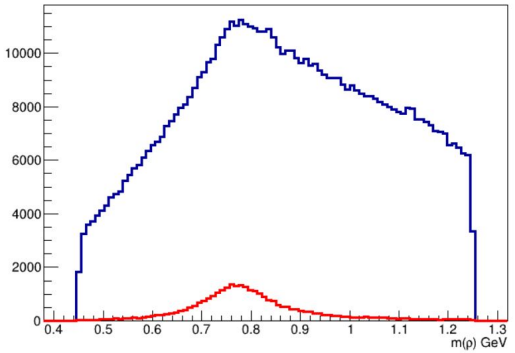
General cuts:

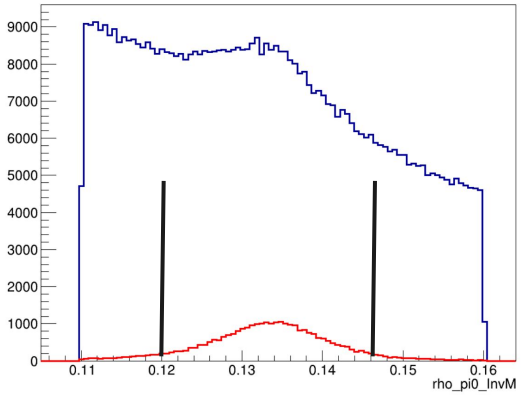
- ➔ Mbc > 5.27 GeV
- ➔ 1.85 < m(Kπ) < 1.88 (~3 σ) GeV
- ➔ binary kaon PID from D^0 > 0.2
- ➔ binary pion PID from D^0 < 0.8
- ➔ binary pion PID from ρ < 0.8
- ➔ **-0.15 < ΔE < 0.15 GeV**
- ➔ **0.12 < m(π^0) > 0.145 (2σ) GeV**
- ➔ **0.45 < m(ρ) > 1.25 GeV**
- ➔ **photon0E >0.04**
- ➔ **photon1E>0.05**

new or modified

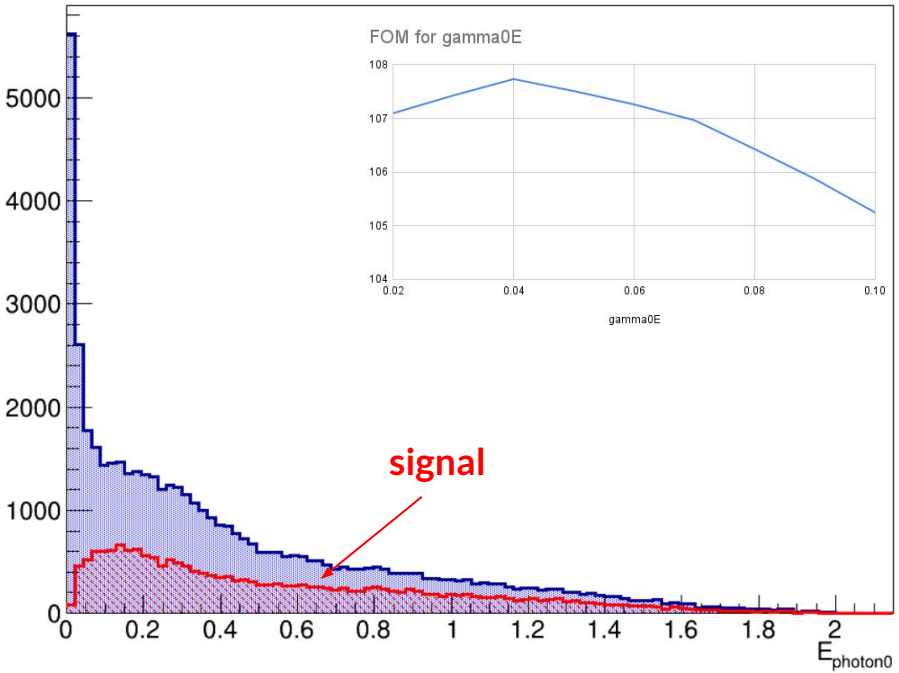
π^0 candidates are taken from *stdPi0s_winter2020* list

The vertex of the signal *B* candidate was reconstructed using *tree fitter*

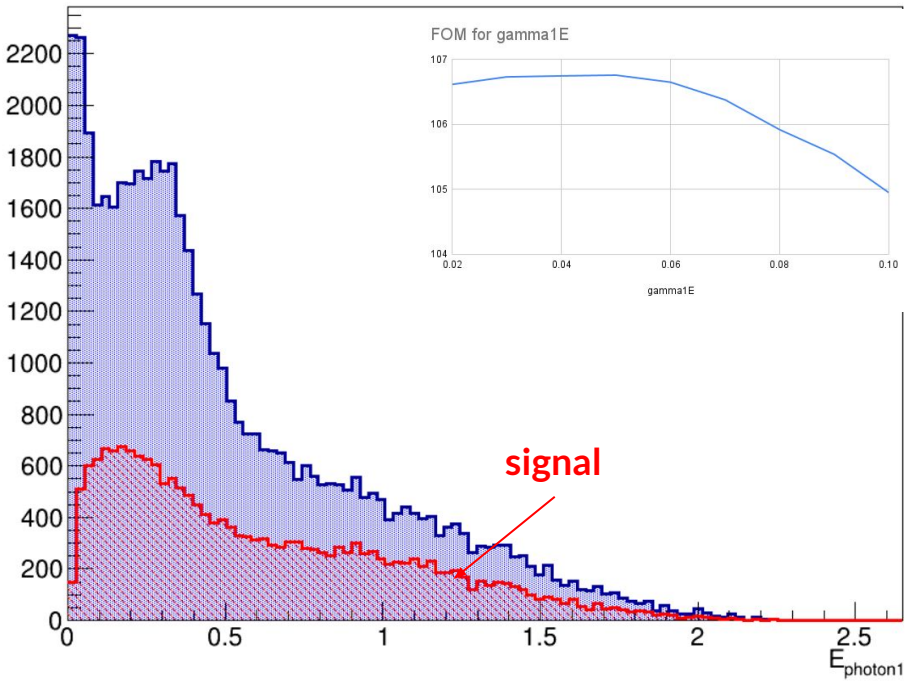




Photon energy optimization

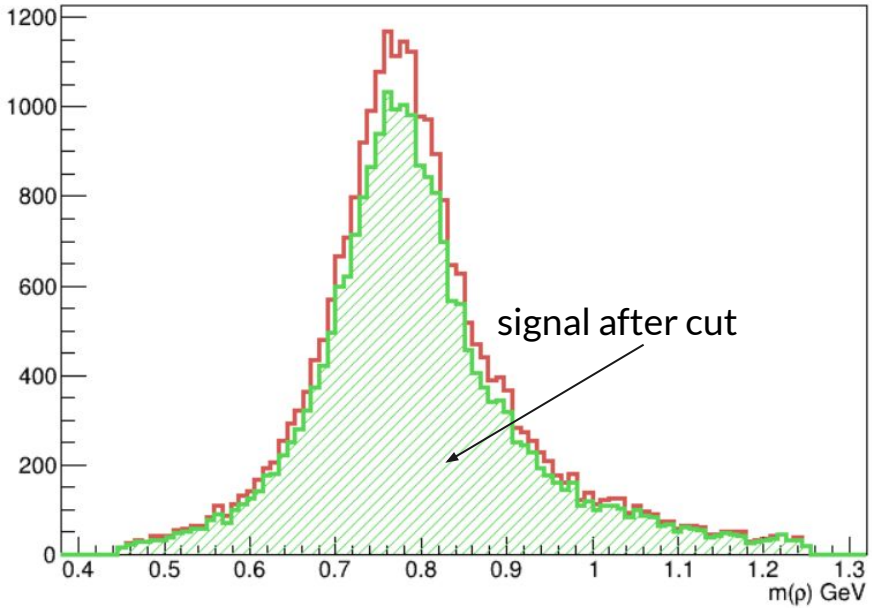


Ephoton0 > 0.04

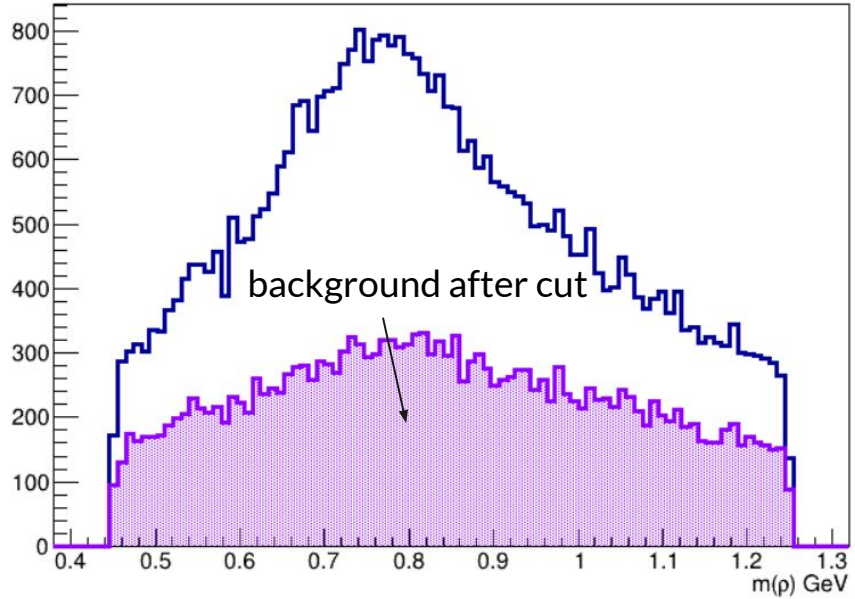


Ephoton1 > 0.05

m(ρ) signal and background after applying photon/pi⁰ cuts



88% of signal remains



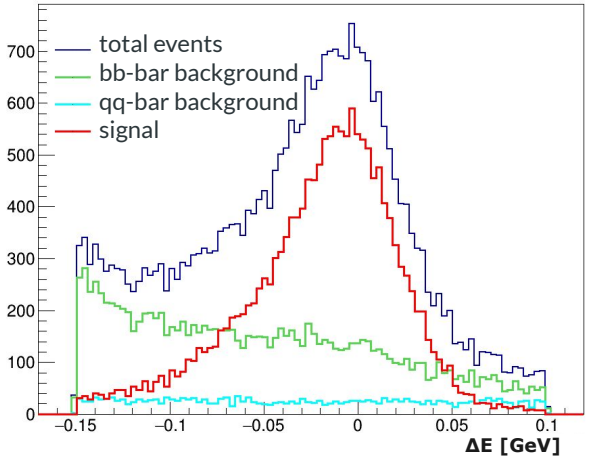
53% of background is rejected

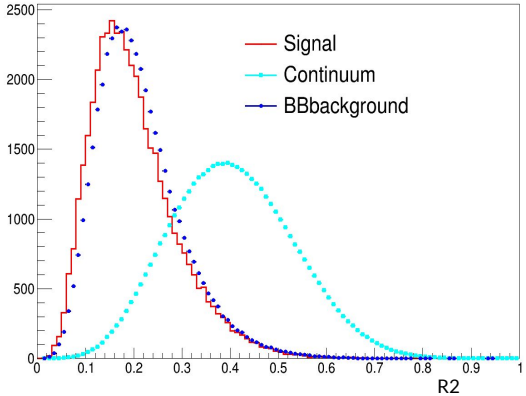
Old Selection criteria

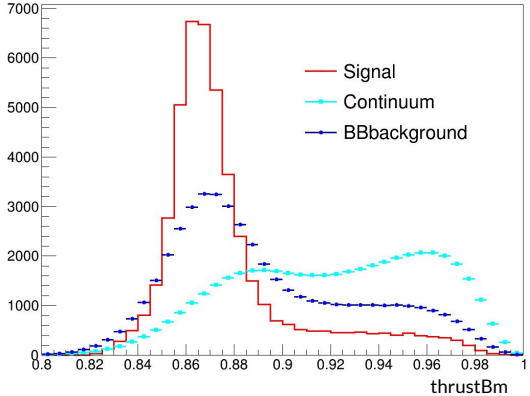
- ➔ R2 < 0.28
- ➔ thrustBm > 0.83
- ➔ thrustBm < 0.9

➔ $\cos\Theta_{\pi\pi 0} < 0.62$

- 1D FOM based optimisation of $\cos\Theta_{\pi\pi 0}$,
- cuts of R2 and thrustBm based on the shape only

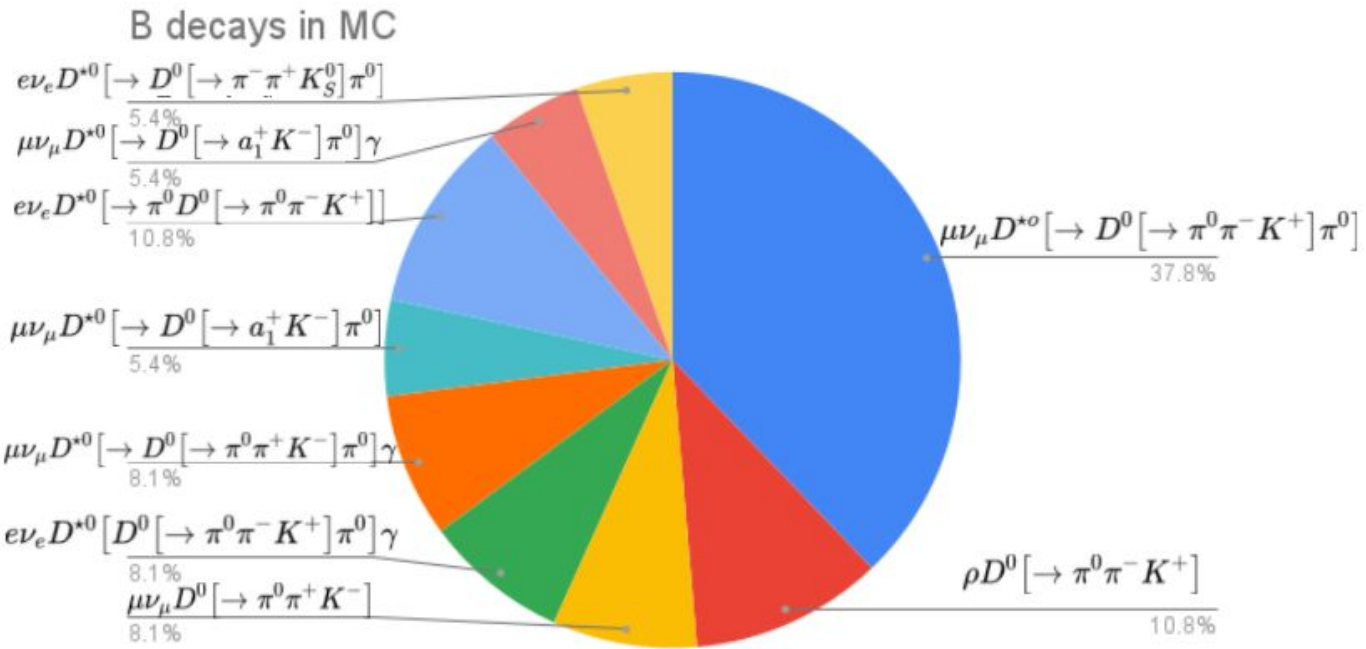






Composition	Fraction
Signal	0.59
Continuum	0.13
BB-bar bkg	0.28

Result of the topology analysis



The most frequent B- decays go through $D^{*0} \to D^0 pi^0$

Selection variables

Focus on three variables for background suppression: $\cos\Theta_{\pi\pi^0}$, R2 and D^0_{mom}:

$\cos\Theta_{\pi\pi^0}$

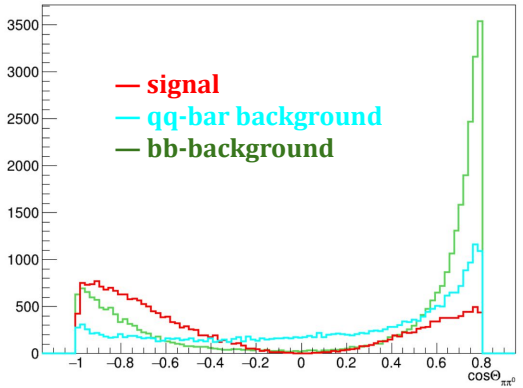
Cosine helicity angle between B momentum and pion momentum in the ρ reference frame

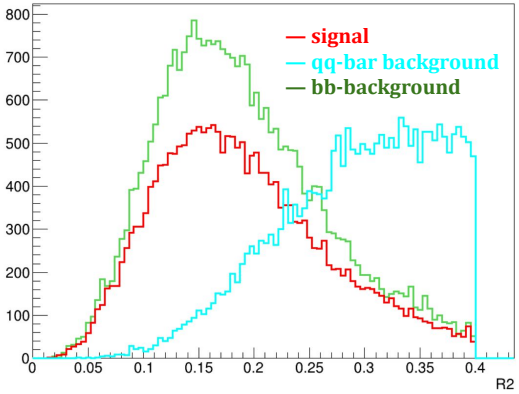
R2

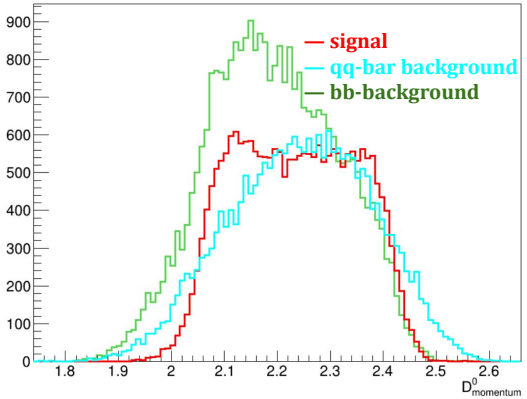
$\mathcal{R}2 = \mathcal{H}_2/\mathcal{H}_0$

D^0_{mom}

D^0 momentum in CMS



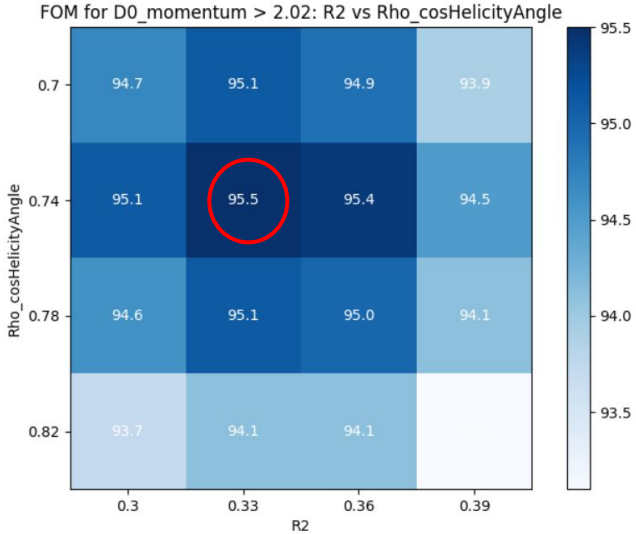


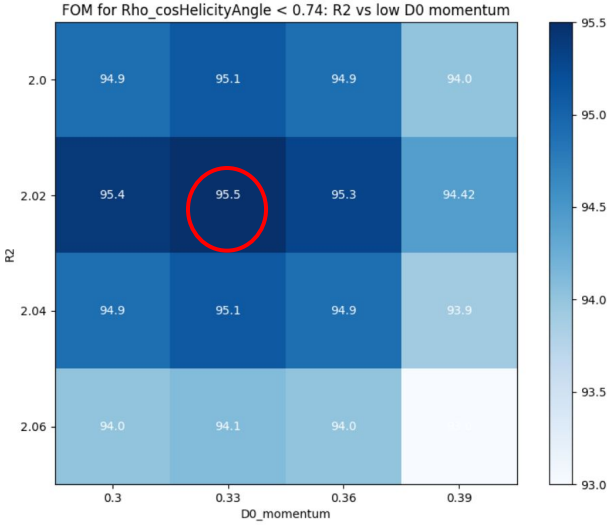


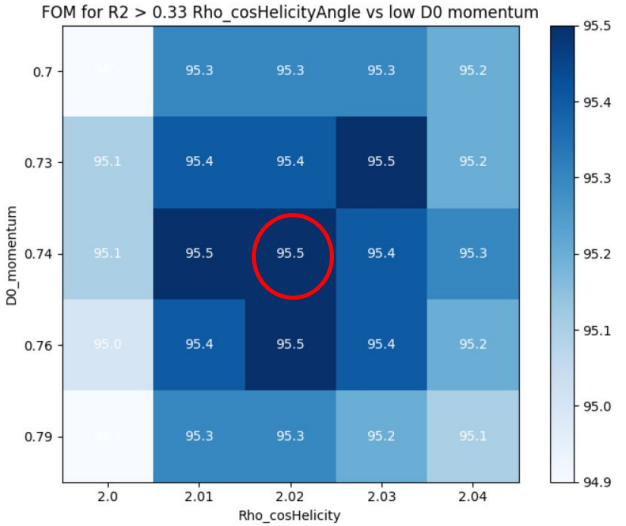
New selection

Results of 3D optimisation of $\cos\Theta_{\pi\pi 0}$ vs R2 vs D^0_{mom};

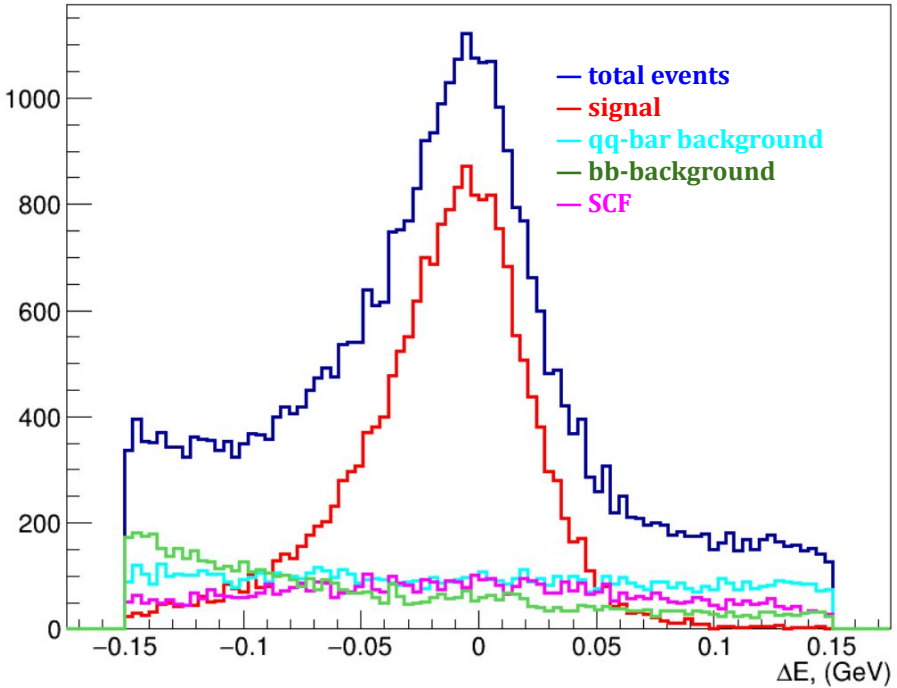
- ➔ R2 < 0.33
- ➔ $\cos\Theta_{\pi\pi}$ < 0.74
- ➔ D^0_{mom} > 2.02





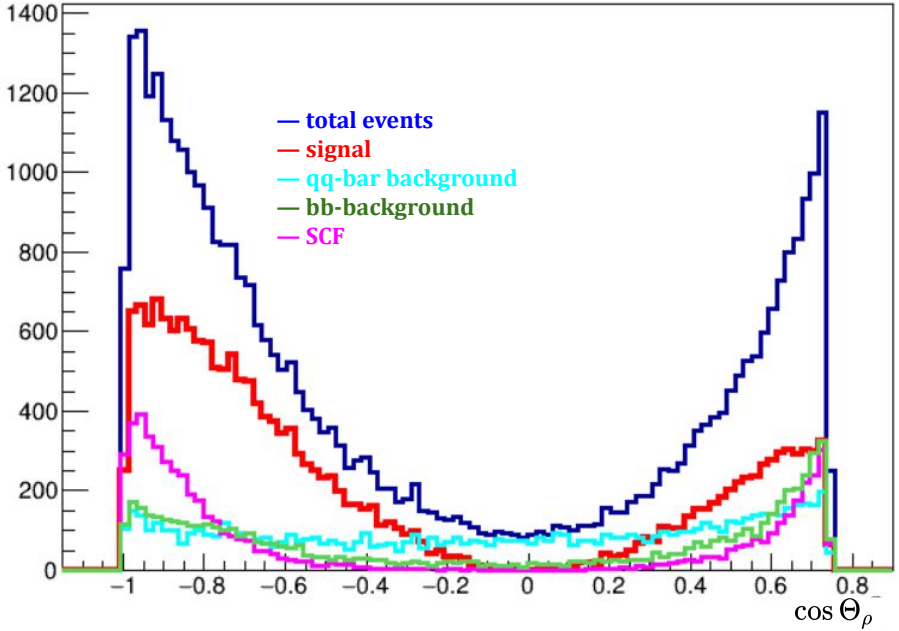


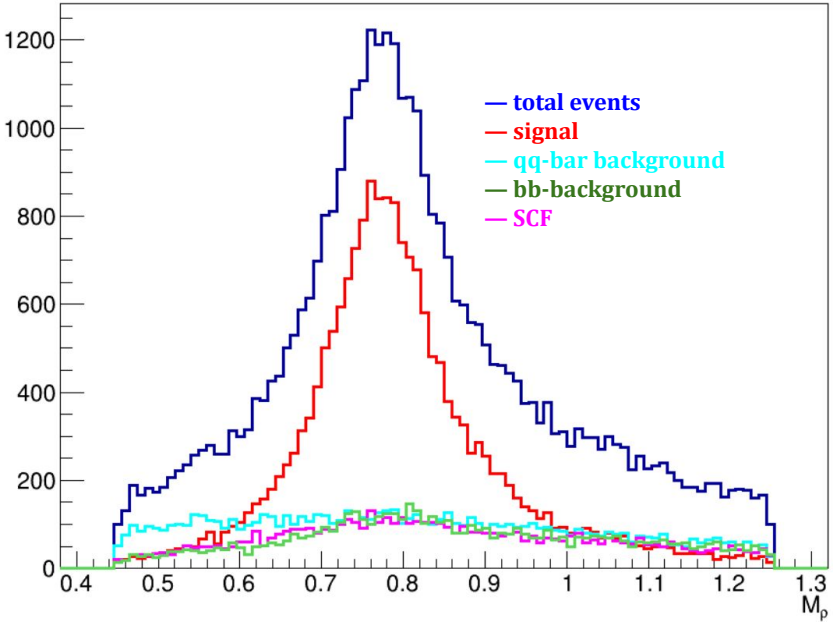
Result



Composition	Fraction
Signal	0.48
Continuum	0.21
SCF	0.16
BB-bar bkg	0.15

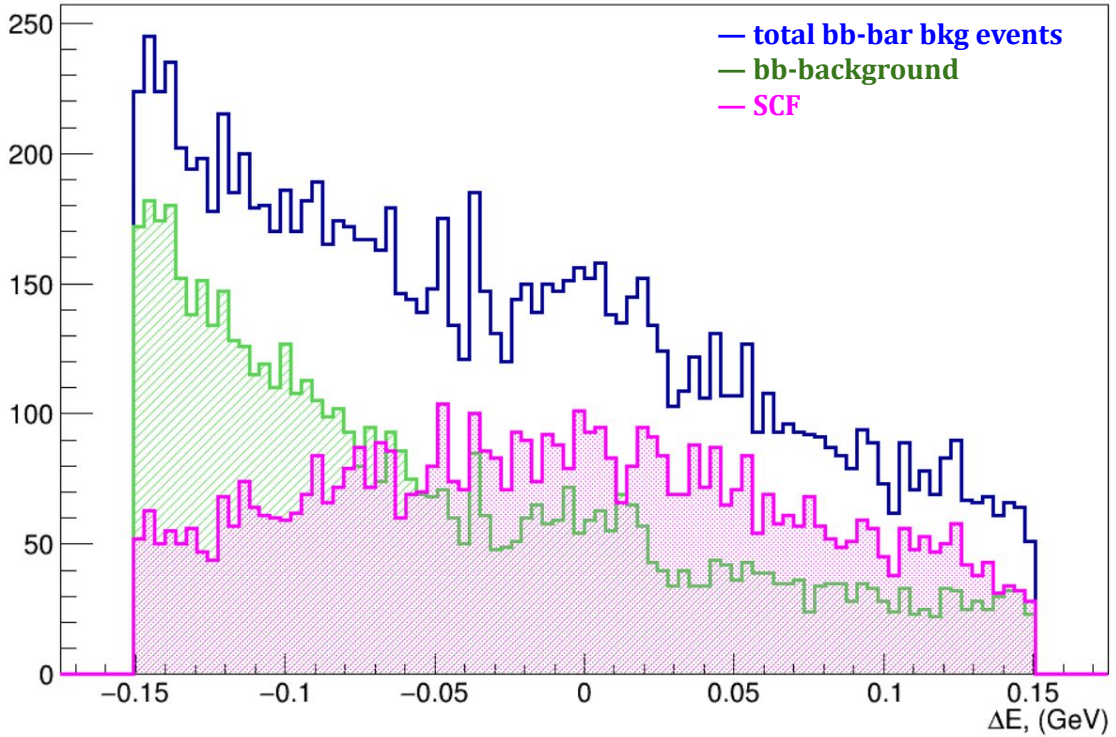
Result (2)



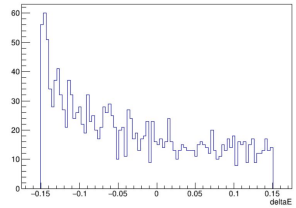


shapes between the 4 components look different in cosTheta_rho. We can use it's discrimination power in a 3D fit to (deltaE, m(rho), cosHel).

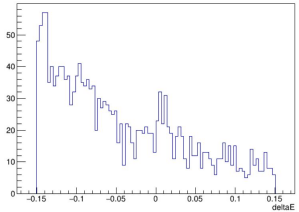
BB-bar background composition



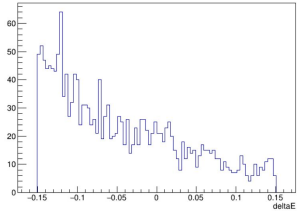
BB-bar background and SCF compositions



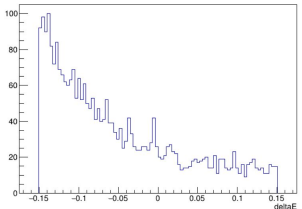
Rest (B0B0-bar)
13.1%



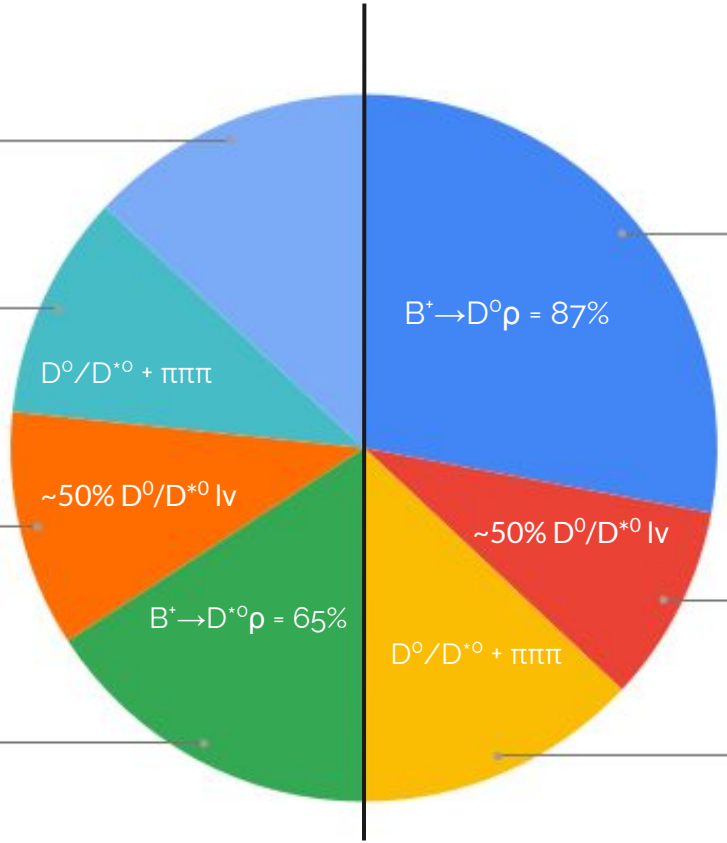
Rest(>3-body
10.3%

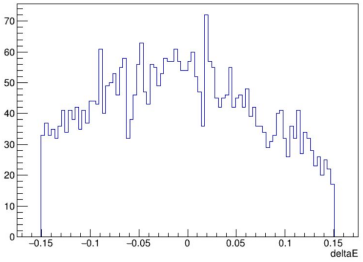


Rest(3-body
10.8%

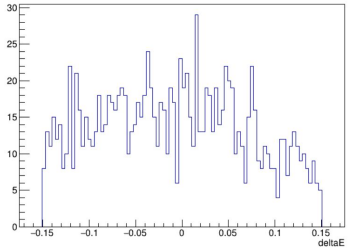


Rest(2-body
15.8%

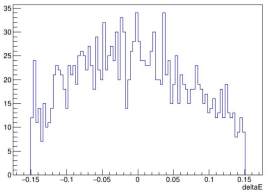




SCF(2-body
27.9%



SCF(3-body
9.0%



SCF(>3 body
13.0%

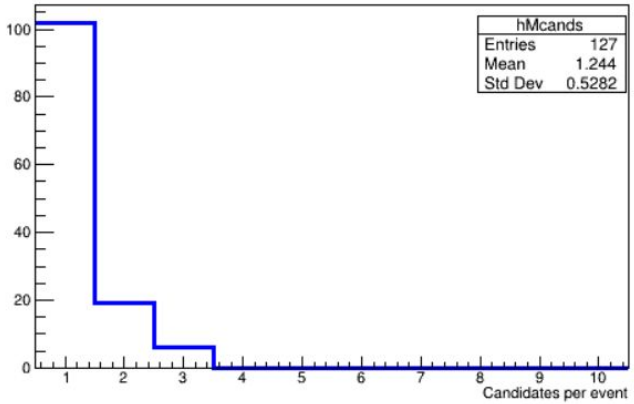
Summarizing table for MC 200 fb^{-1}

	Before preselection	After preselection	After preselection + selection
Signal eff (ε)	~41%	~24%	~17%
Background rejection	–/–	99.56%	99.94%

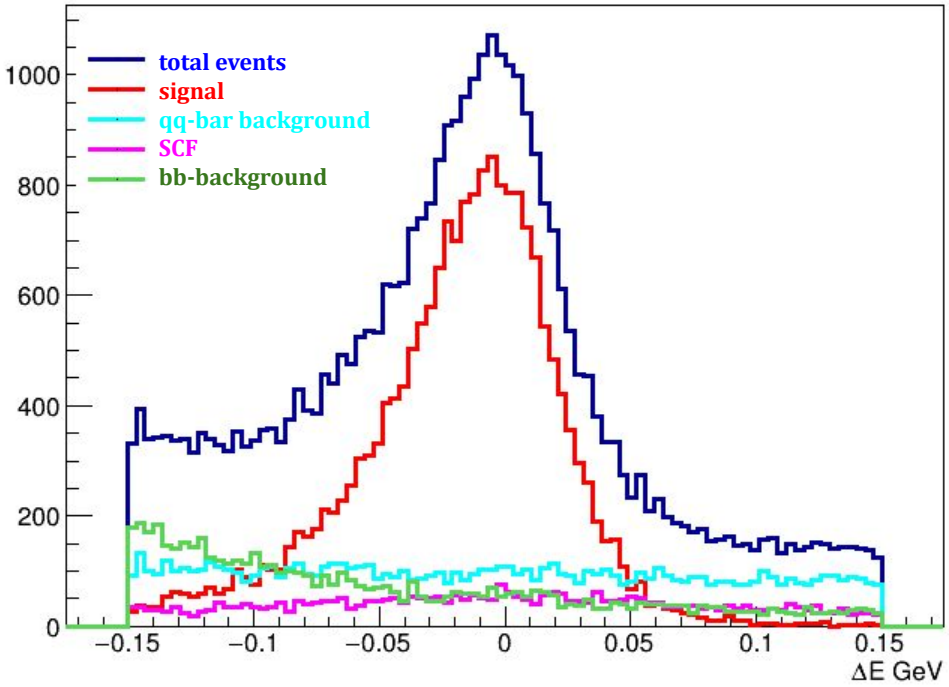
We expect to see in data (200 fb^{-1}) (events):

$$N_{signal} = L \times \epsilon = 19700$$

Candidate multiplicity was studied on a small generic MC dataset after applications of all selection criteria



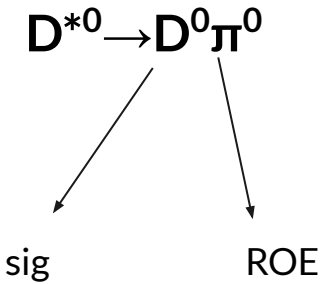
ΔE after one candidate selection

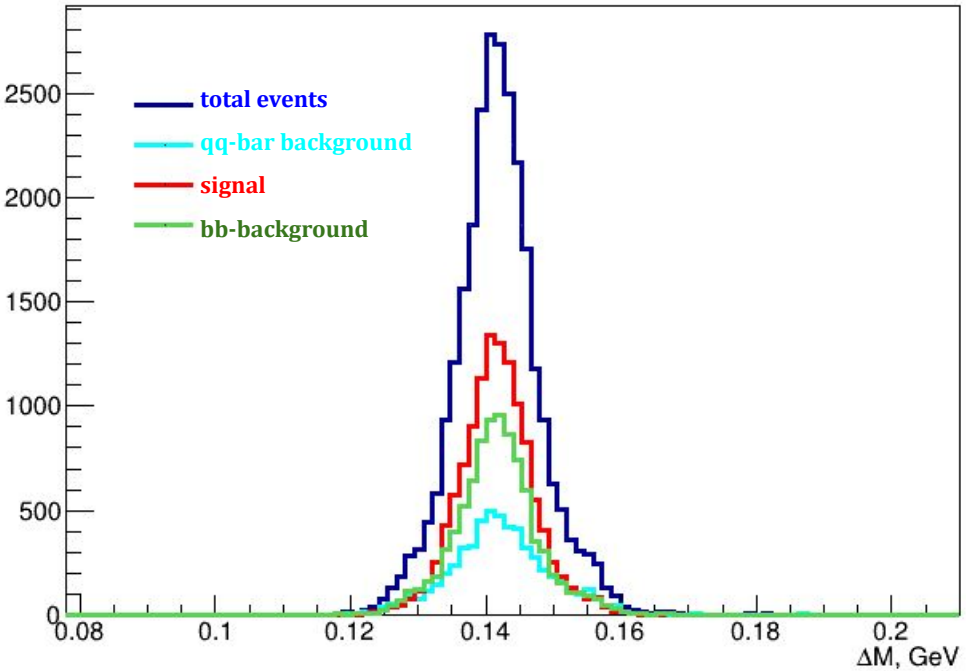


Composition	Fraction
Signal	0.52
Continuum	0.22
SCF	0.10
BB-bar bkg	0.16

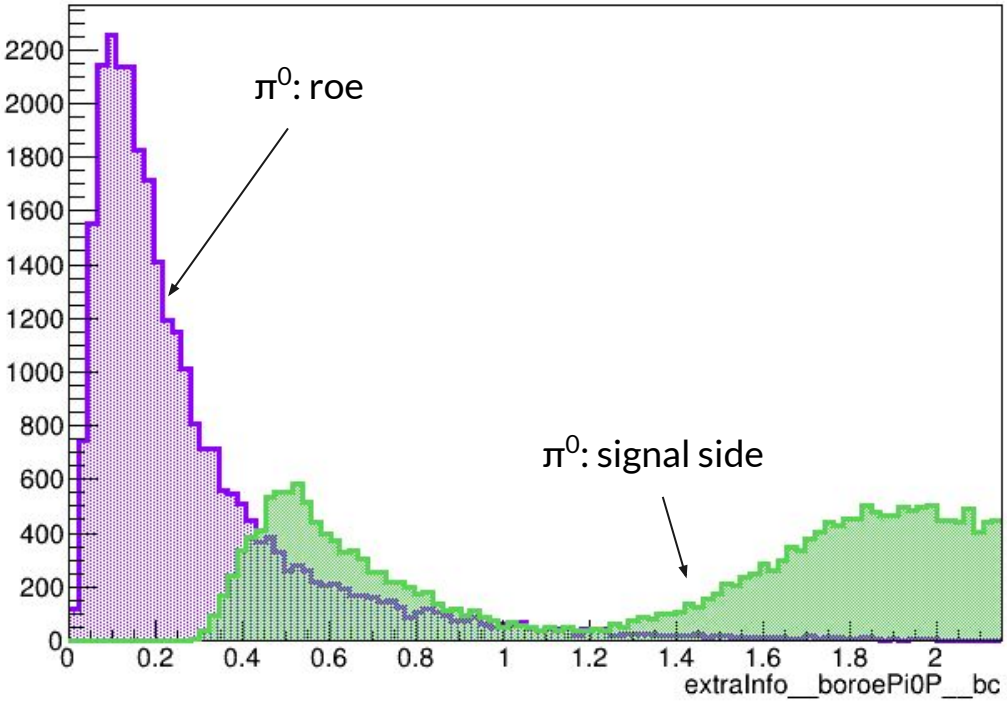
D*⁰ veto

$$\Delta M = m_{D^{*0}} - m_{D^0} = 0.142\,MeV$$

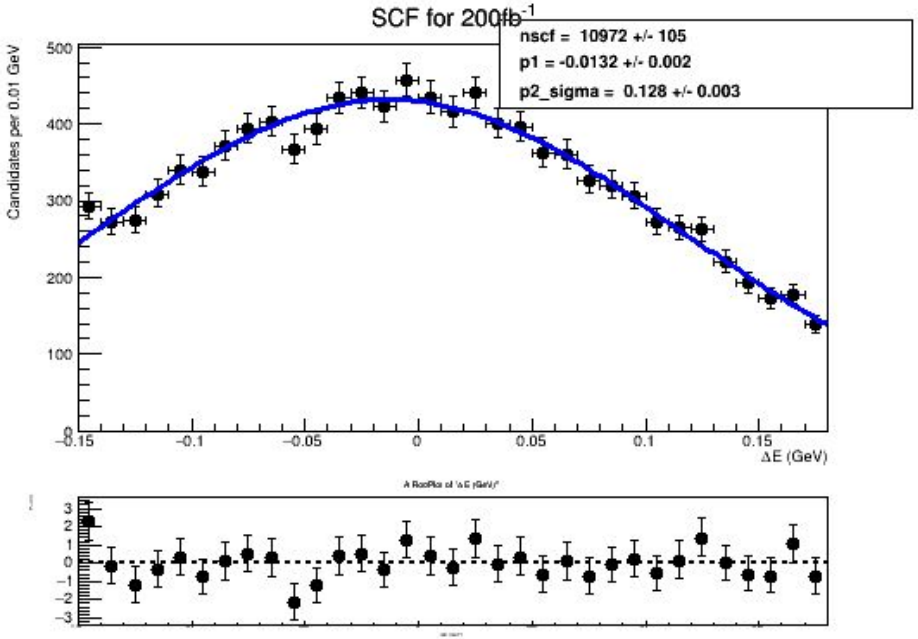




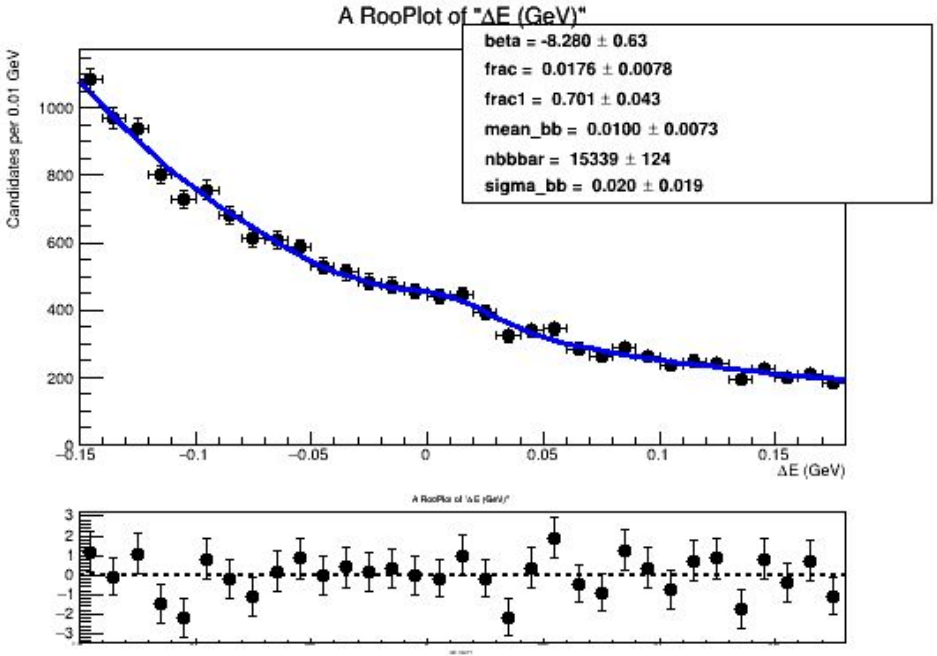
D*⁰ veto: π⁰ momenta



Fits for SCF and BBbar of deltaE (200 fb-1)

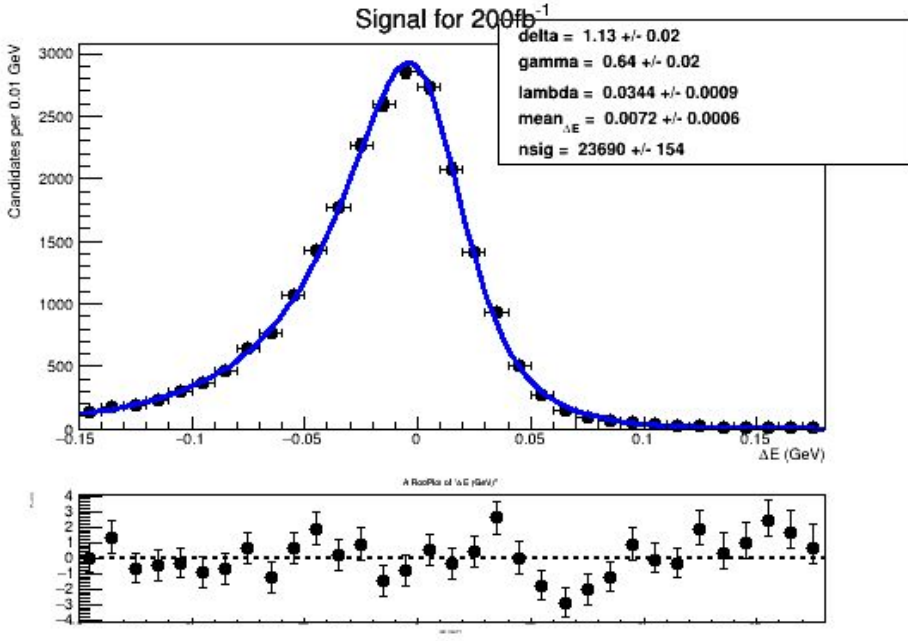


rooGaussian

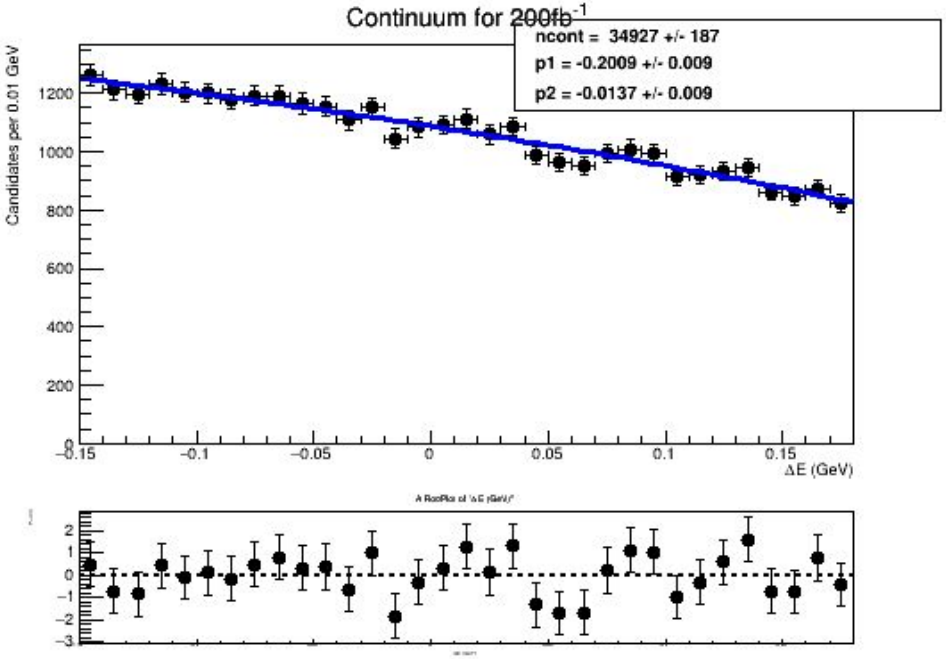


rooExponetial x rooChebyshev(0) x rooGaussian

Fits for signal and continuum of deltaE (200 fb-1)

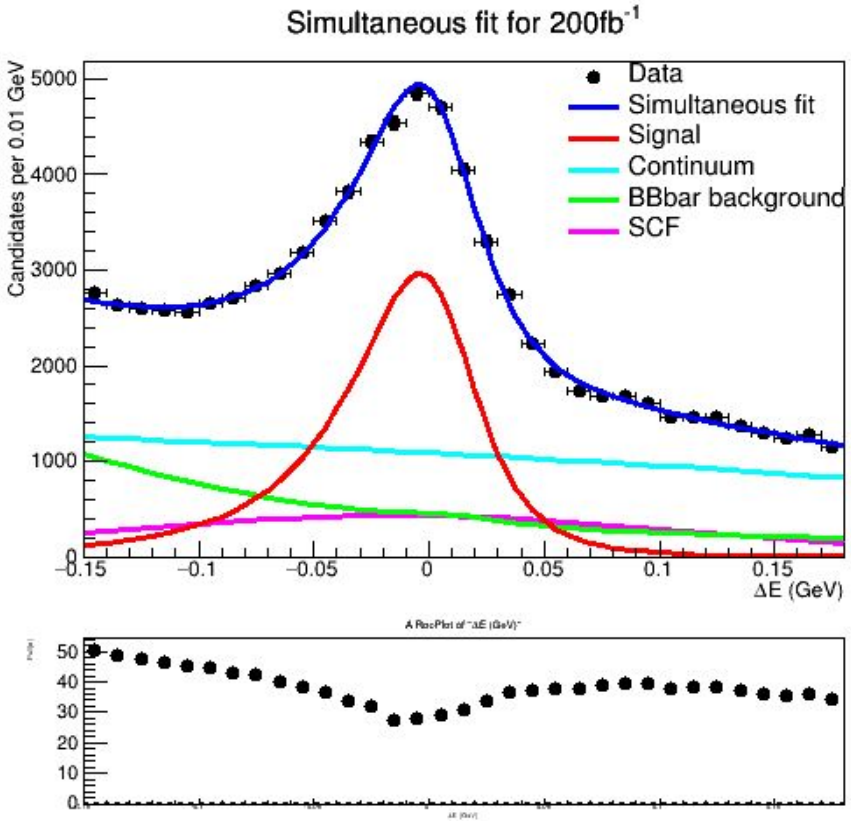


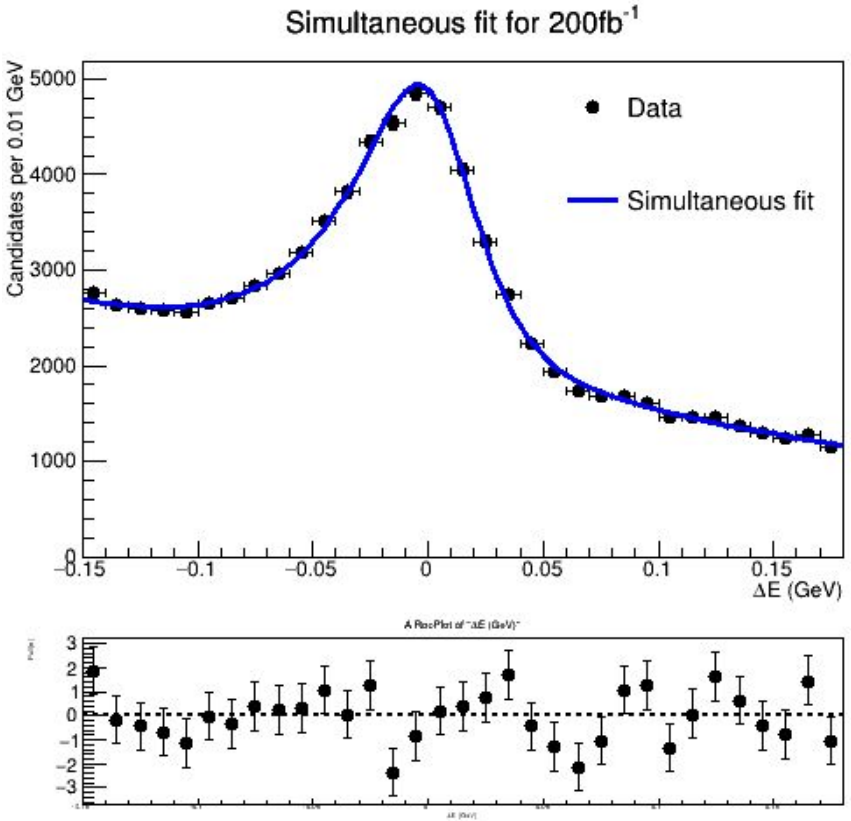
rooJohnson



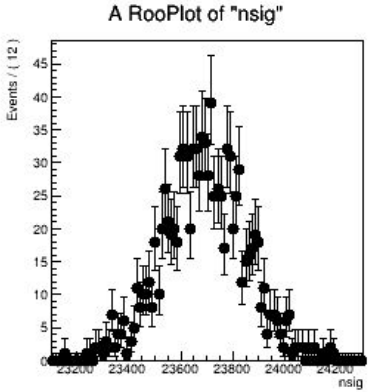
rooChebyshev (2)

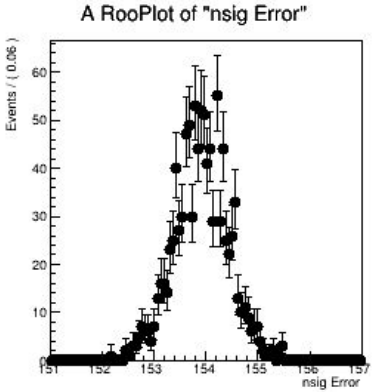
Simultaneous fit of deltaE

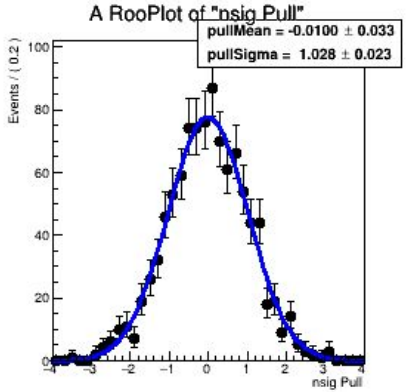


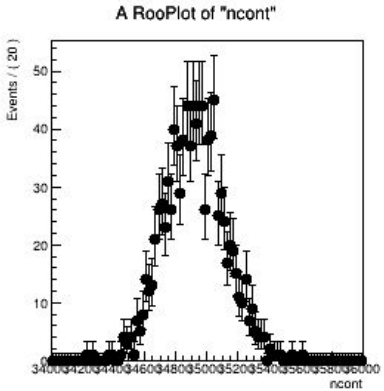


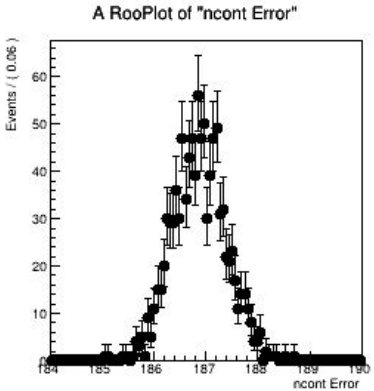
TOYs for Simultaneous fit (Signal and Continuum)

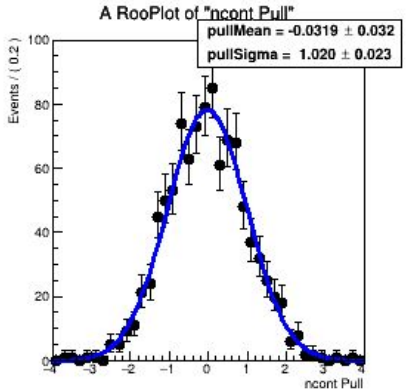




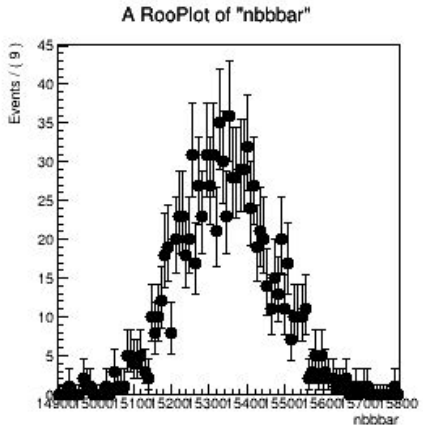


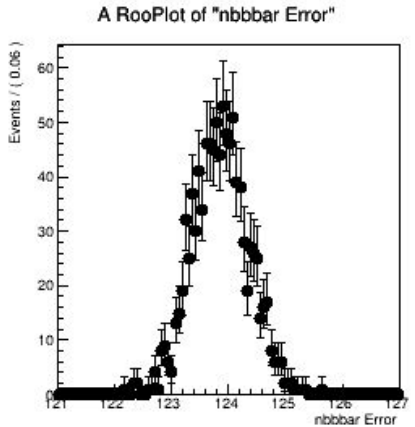


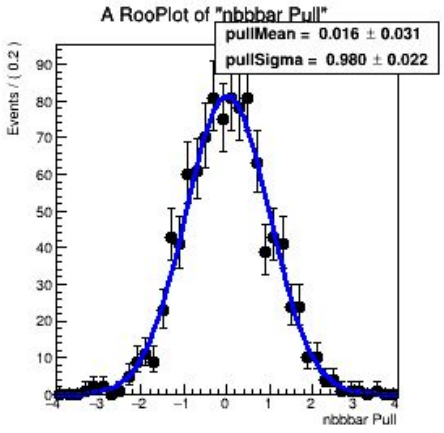


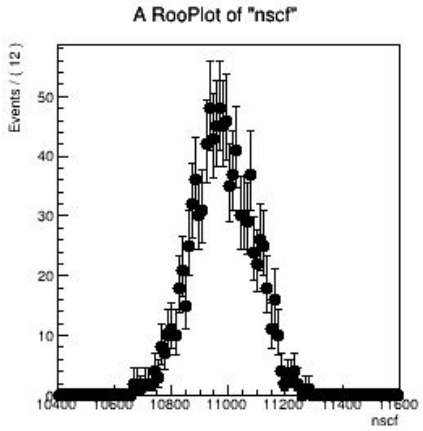


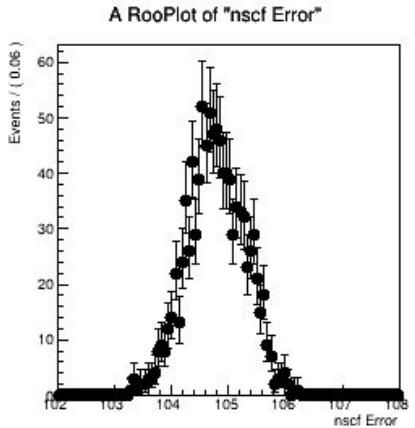
TOYs for Simultaneous fit (BBbar and SCF)

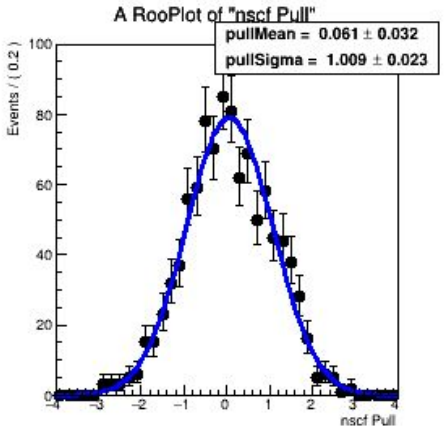






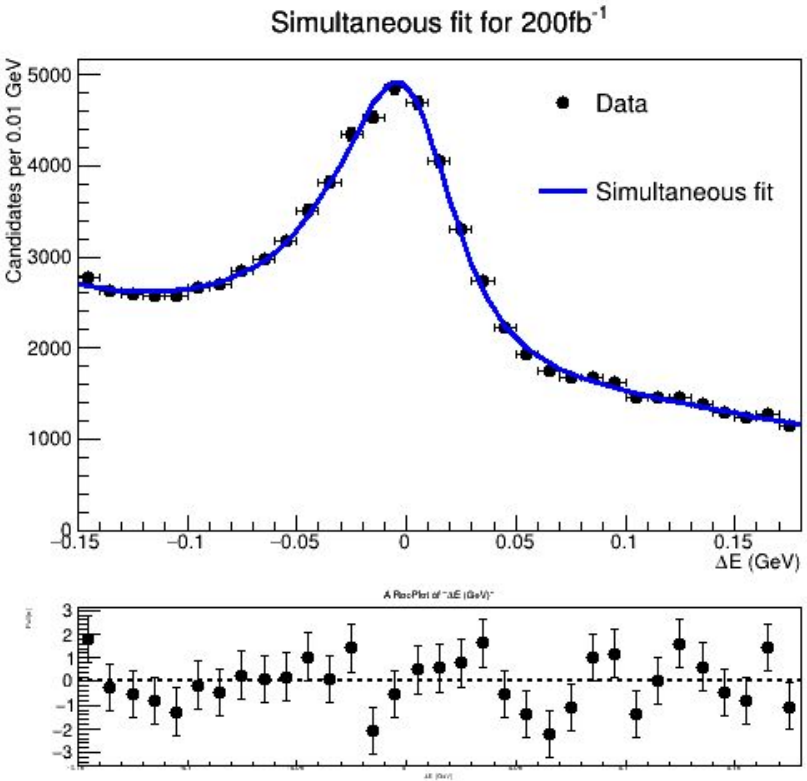


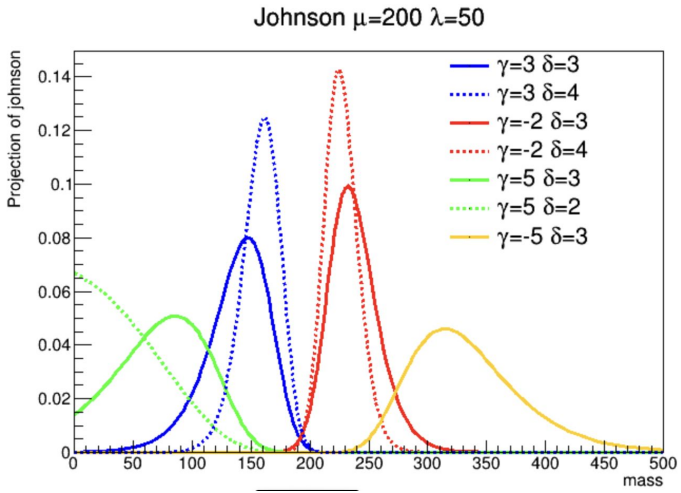


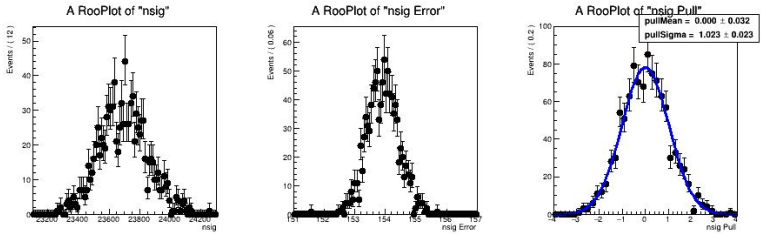


Update 03/06/2022

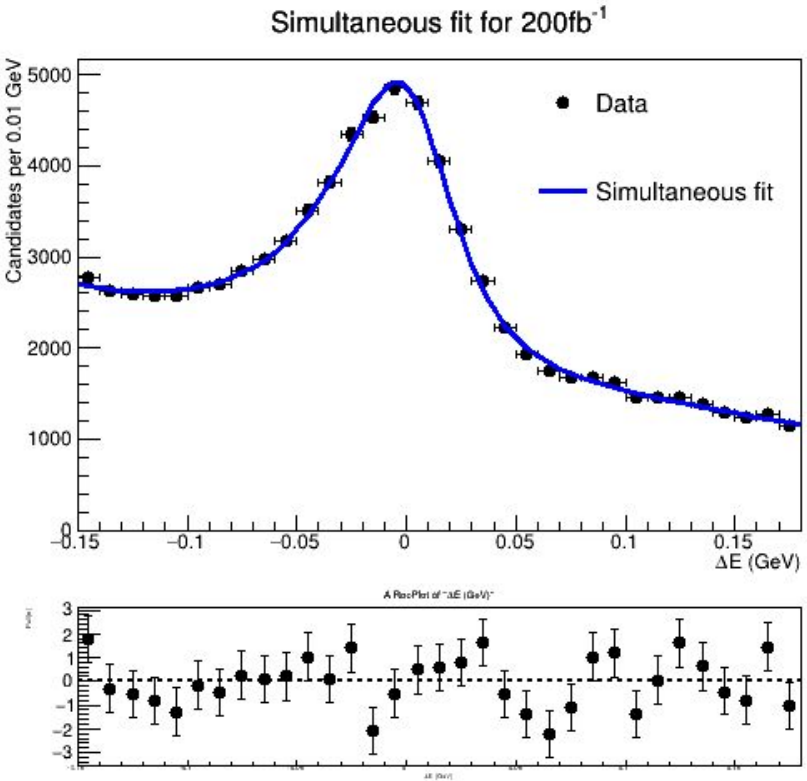
Simultaneous fit with 2 float parameters

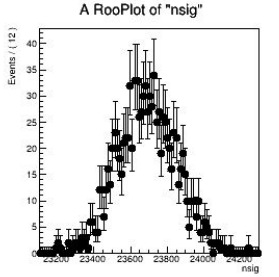


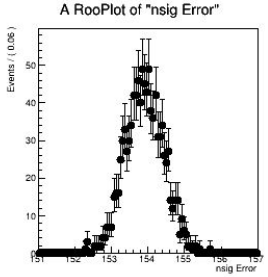


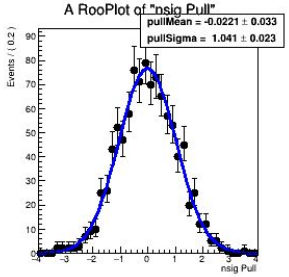


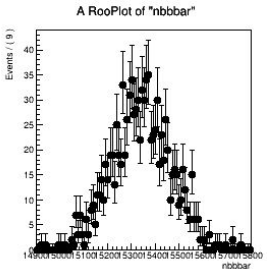
Simultaneous fit with 3 float parameters

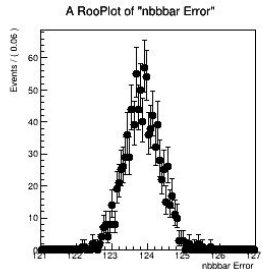


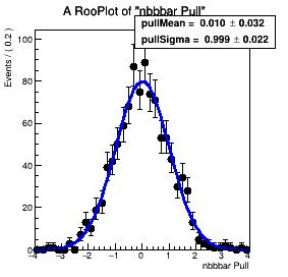




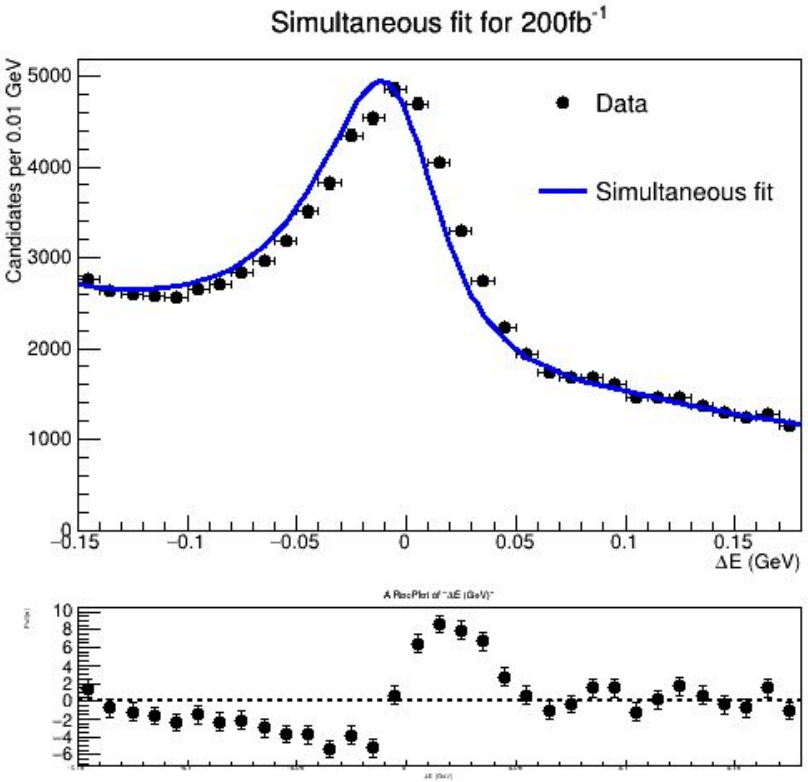


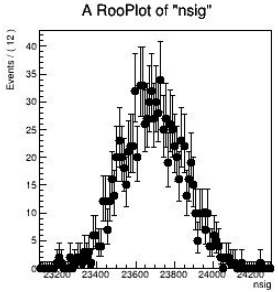


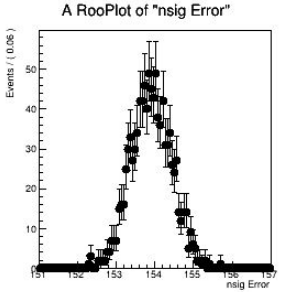


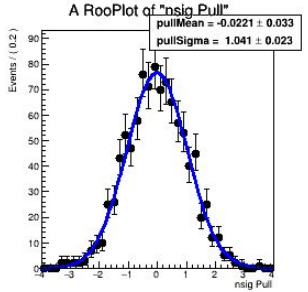


Simultaneous fit with 3 float parameters in Sig PDF



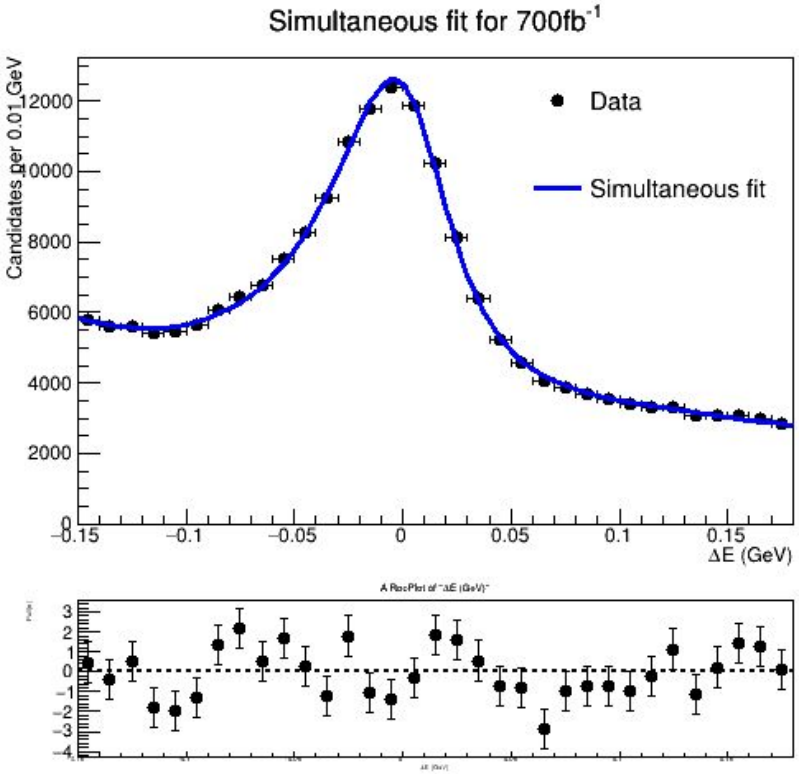


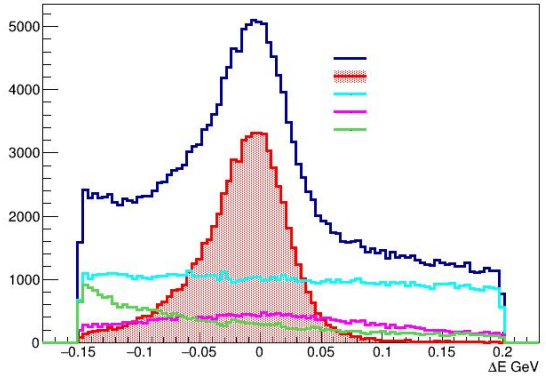




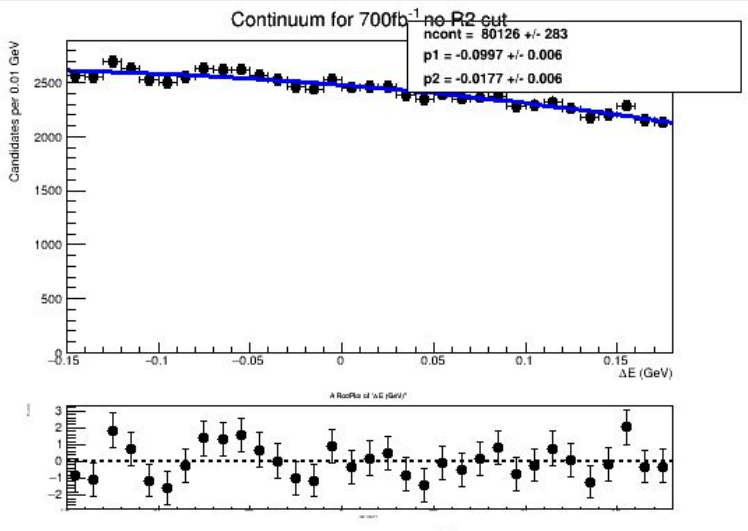
float parameters: delta, gamma, mean

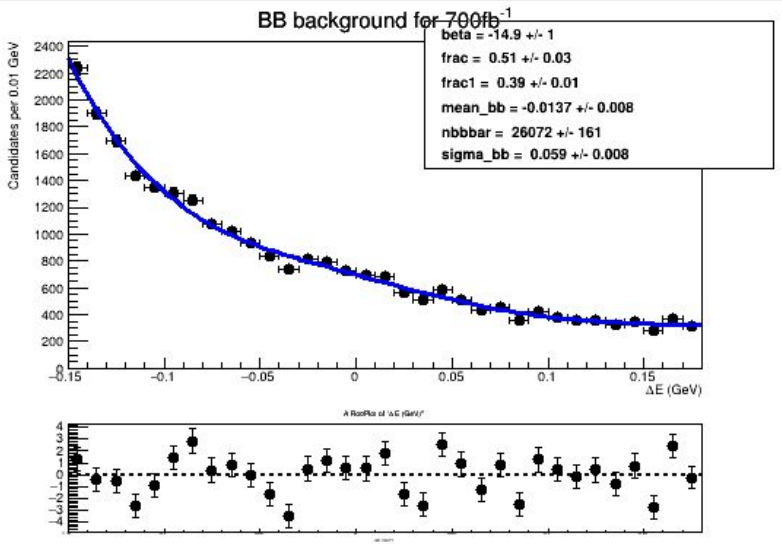
Simultaneous fit of deltaE for 700 fb-1 without R2 cut

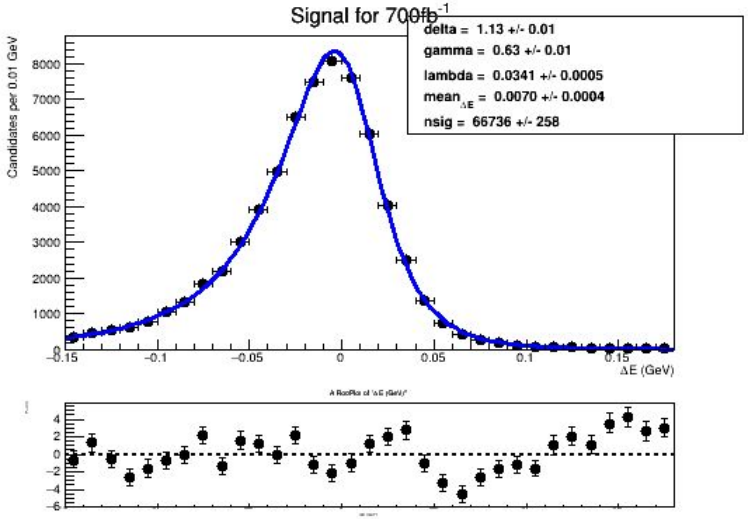


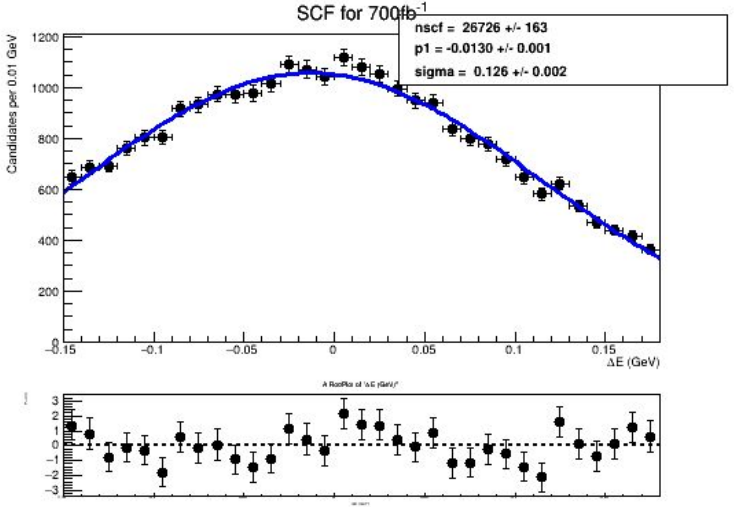


Composition	Fraction before fit	Fraction after fit
Signal	0.32	0.33
Continuum	0.41	0.4
SCF	0.13	0.13
BB-bar bkg	0.13	0.13


Continuum for 700fb^{-1} no R2 cut
ncont = 80126 +/- 283
p1 = -0.0997 +/- 0.006
p2 = -0.0177 +/- 0.006
Candidates per 0.01 GeV
ΔE (GeV)

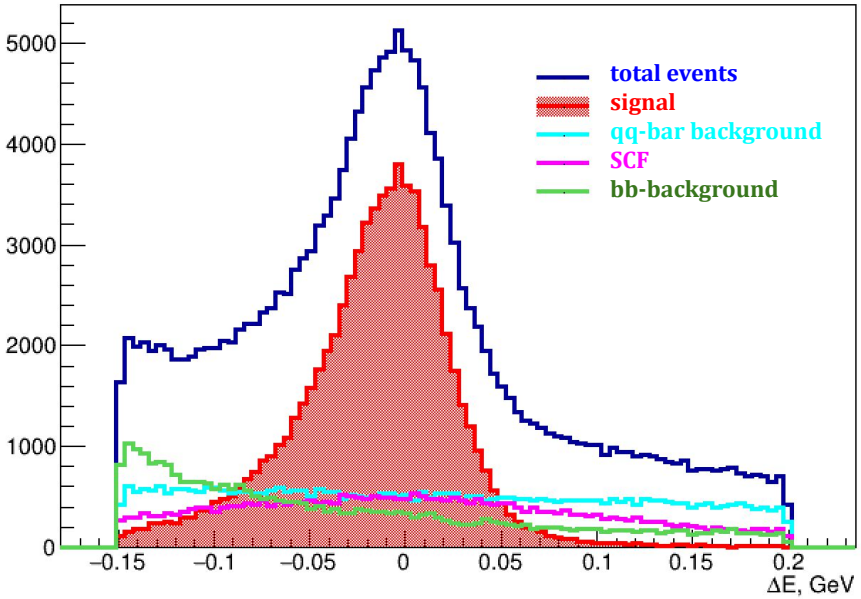

BB background for 700fb^{-1}
beta = -14.9 +/- 1
frac = 0.51 +/- 0.03
frac1 = 0.39 +/- 0.01
mean_bb = -0.0137 +/- 0.008
nbbbar = 26072 +/- 161
sigma_bb = 0.059 +/- 0.008
Candidates per 0.01 GeV
ΔE (GeV)

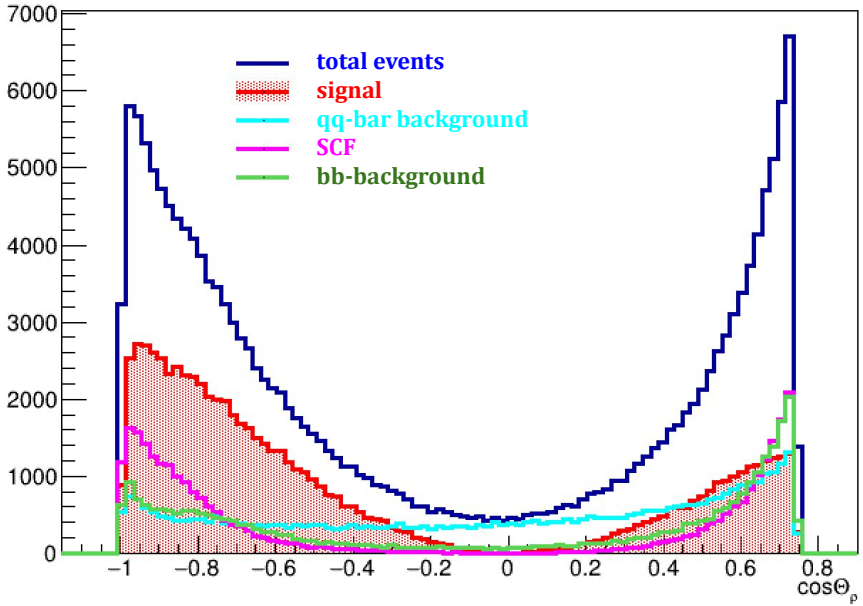

Signal for 700fb^{-1}
delta = 1.13 +/- 0.01
gamma = 0.63 +/- 0.01
lambda = 0.0341 +/- 0.0005
mean$_{\Delta E}$ = 0.0070 +/- 0.0004
nsig = 66736 +/- 258
Candidates per 0.01 GeV
ΔE (GeV)

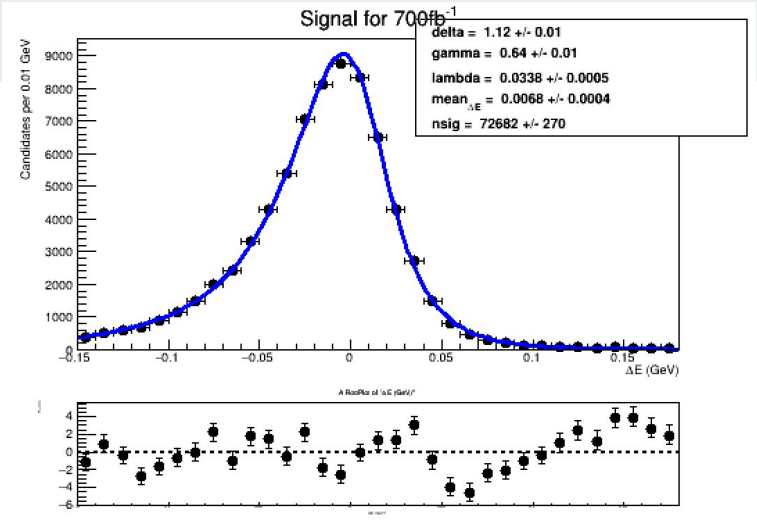

SCF for 700fb^{-1}
nscf = 26726 +/- 163
p1 = -0.0130 +/- 0.001
sigma = 0.126 +/- 0.002
Candidates per 0.01 GeV
ΔE (GeV)

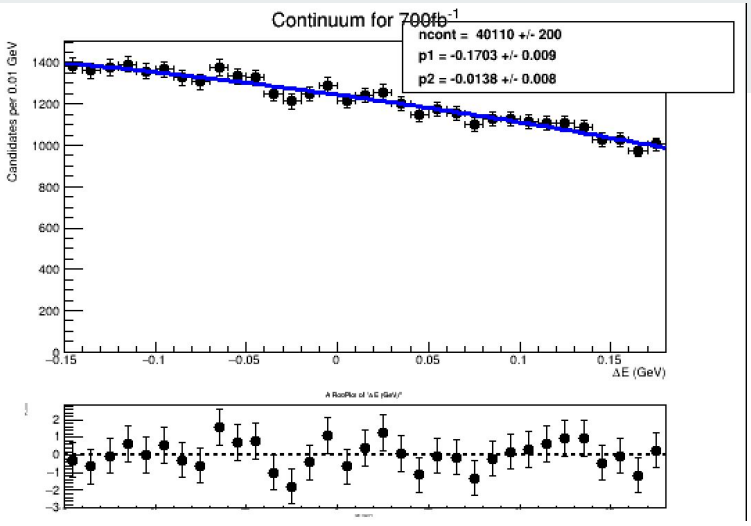
17/06/2022

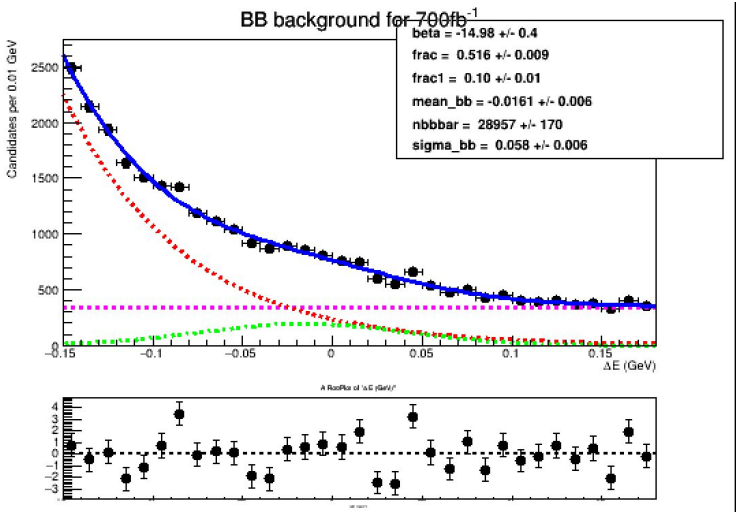
700 fb^{-1} dataset

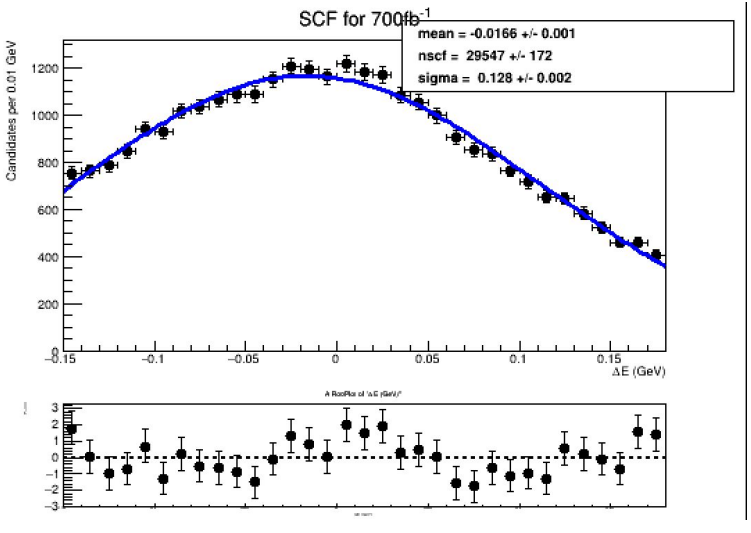





Signal for 700fb-1
delta = 1.12 +/- 0.01
gamma = 0.64 +/- 0.01
lambda = 0.0338 +/- 0.0005
mean_ΔE = 0.0068 +/- 0.0004
nsig = 72682 +/- 270
Candidates per 0.01 GeV
ΔE (GeV)

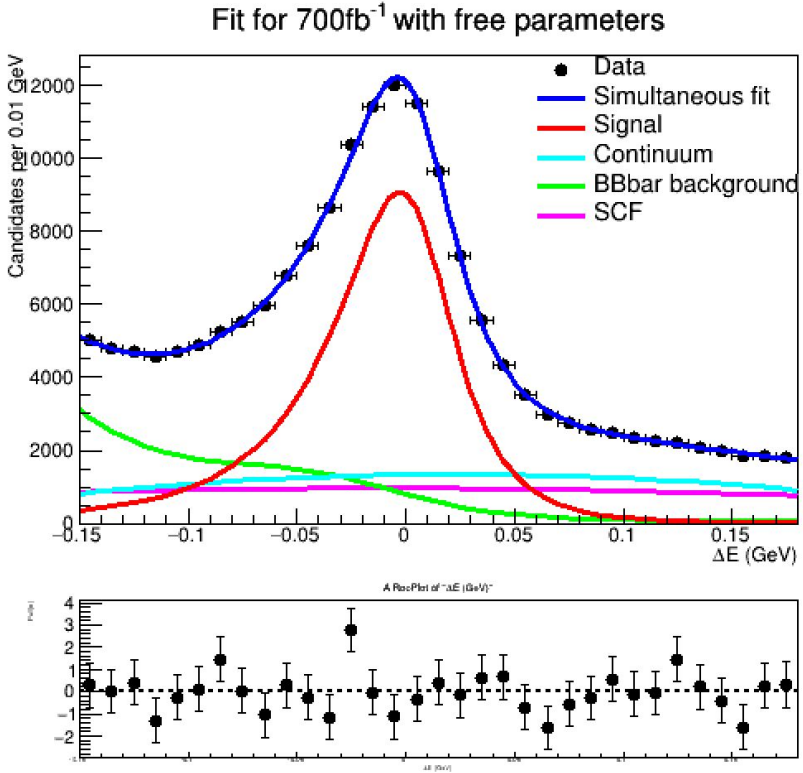

Continuum for 700fb-1
ncont = 40110 +/- 200
p1 = -0.1703 +/- 0.009
p2 = -0.0138 +/- 0.008
Candidates per 0.01 GeV
ΔE (GeV)


BB background for 700fb-1
beta = -14.98 +/- 0.4
frac = 0.516 +/- 0.009
frac1 = 0.10 +/- 0.01
mean_bb = -0.0161 +/- 0.006
nbbbar = 28957 +/- 170
sigma_bb = 0.058 +/- 0.006
Candidates per 0.01 GeV
ΔE (GeV)


SCF for 700fb-1
mean = -0.0166 +/- 0.001
nscf = 29547 +/- 172
sigma = 0.128 +/- 0.002
Candidates per 0.01 GeV
ΔE (GeV)

Update 24/06/2022

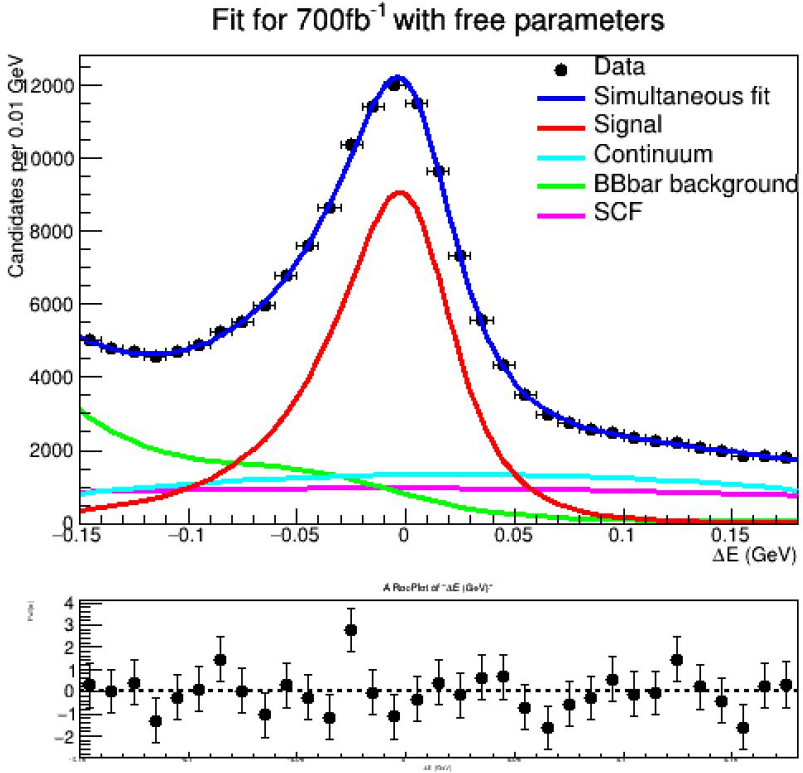
Free parameters fit (700 fb-1)



Composition	Nevents	Fraction after fit
Signal	72680	72973 ± 391
Continuum	40110	39007 ± 115
SCF	29548	29987 ± 1976
BB-bar bkg	28962	29496 ± 266

$$PDF_{sig} + PDF_{cont} + PDF_{SCF} + PDF_{BBbkg}$$

Free parameters fit (700 fb-1)



Sig PDF	cont PDF	SCF PDF	BBbar PDF
Sig Yield	Cont Yield	SCF Yield	BB Yield
Γ_factor	Cheb1	mean_scf	beta
Δ_factor	Cheb2	sigma_factor	fraction1
mean			fraction2
			mean_bb
			sigma_bb

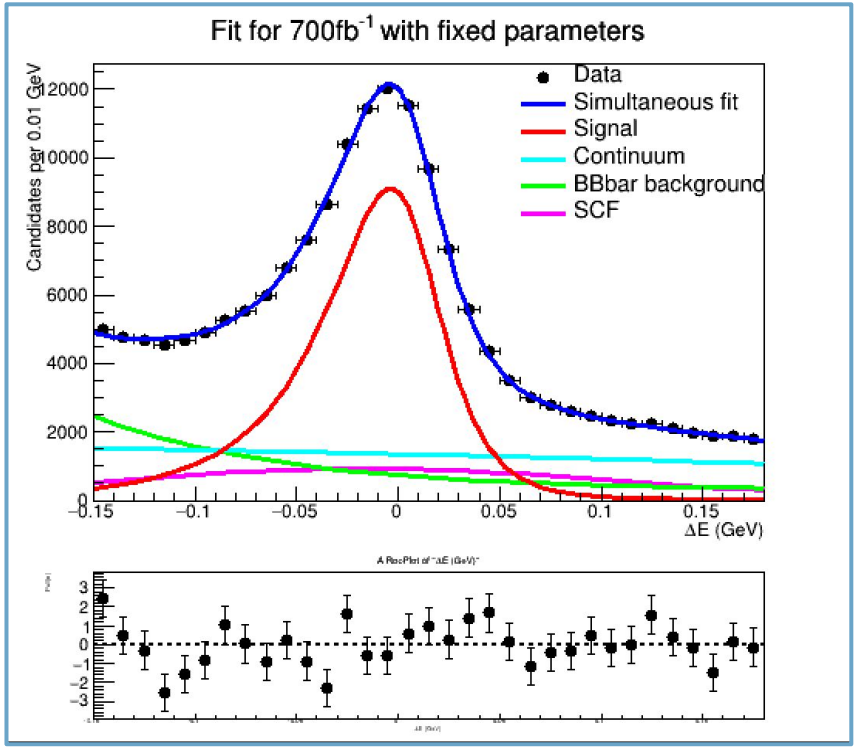
Fit output

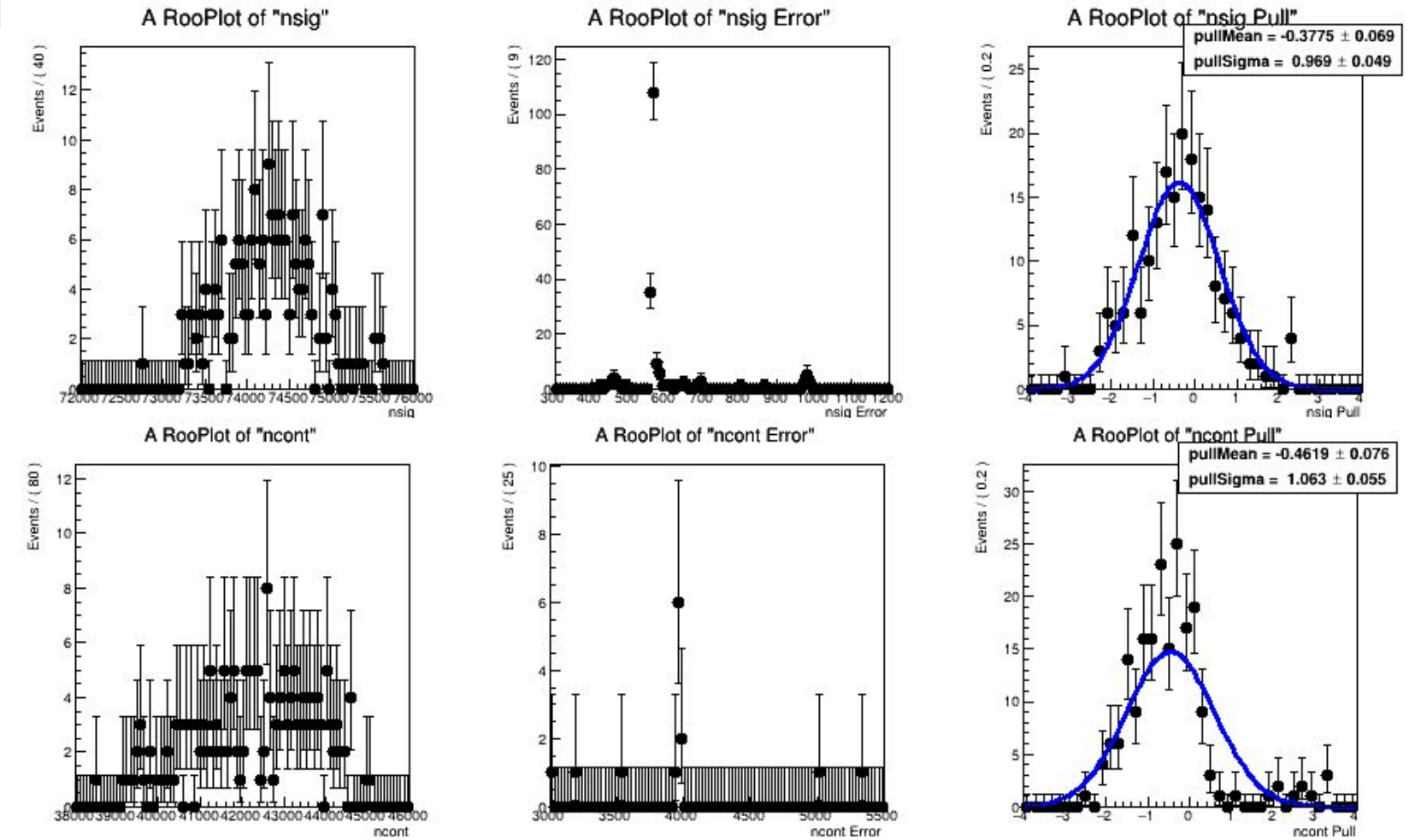
```
============== MATRIX FORCED POS-DEF BY ADDING 0.123468 TO DIAGONAL.
FCN=-2.11114e+06 FROM HESSE     STATUS=NOT POSDEF    211 CALLS        2914 TOTAL
                     EDM=0.423433    STRATEGY= 1      ERR MATRIX NOT POS-DEF
  EXT PARAMETER                 APPROXIMATE     INTERNAL      INTERNAL
  NO.   NAME      VALUE            ERROR       STEP SIZE       VALUE
   1  beta        -1.49998e+01   3.84079e-01   4.28880e-01  -1.55902e+00
   2  f_johns      9.81894e-01   9.12448e-03   2.00037e-03  -9.33355e-01
   3  f_johns1     8.90654e-01   2.96194e-02   3.62293e-03  -9.64684e-01
   4  frac         6.82301e-01   3.77738e-02   2.09064e-02   3.73205e-01
   5  frac1        3.13786e-02   7.80284e-02   6.32502e-02  -1.21464e+00
   6  frac_scf     2.18519e+00   1.09548e+00   4.46460e-02  -5.97966e-01
   7  mean_bb     -4.48516e-02   5.82851e-03   1.16895e-01  -1.02152e+00
   8  mean_scf    -1.21563e-02   8.69515e-02   3.05380e-02  -9.97807e-01
   9  mean_{#DeltaE}   7.10454e-03   3.42200e-04   4.14403e-02   4.34447e-01
  10  nbbbar       2.94959e+04   2.65631e+02   5.00000e-01   1.48013e+00
  11  ncont        3.90067e+04   1.14739e+02   5.00000e-01  -1.70482e+00
  12  nscf         2.99866e+04   1.97569e+03   5.00000e-01   1.43698e+00
  13  nsig         7.29731e+04   3.91342e+02   5.00000e-01   1.80333e+00
  14  p1           4.03993e-02   8.31949e-02   1.48390e-02   4.04103e-02
  15  p2          -2.15499e-01   7.32064e-02   1.69932e-02  -2.17203e-01
  16  sigma_bb     4.24333e-02   3.01740e-03   1.04336e-02  -1.11132e+00
                               ERR DEF= 0.5
```

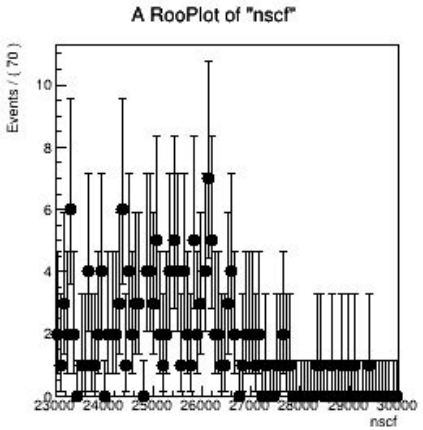
```
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-2.11113e+06 FROM HESSE     STATUS=OK          31 CALLS         220 TOTAL
                     EDM=0.00107776    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   INTERNAL      INTERNAL
 NO.   NAME      VALUE            ERROR          STEP SIZE       VALUE
  1  nbbbar       2.96604e+04   6.56375e+02   3.43423e-02  -3.39673e-02
  2  ncont        4.36704e+04   4.44901e+03   4.93023e-02   1.56694e-01
  3  nscf         2.34789e+04   5.14434e+03   5.08913e-02  -7.10359e-01
  4  nsig         7.44949e+04   1.05720e+03   4.91144e-02   2.69222e-01
                               ERR DEF= 0.5
EXTERNAL ERROR MATRIX.    NDIM=  25    NPAR=  4    ERR DEF=0.5
 4.314e+05 -2.045e+05 -2.079e+05  1.327e+04
-2.045e+05  2.277e+07 -2.668e+07  4.539e+06
-2.079e+05 -2.668e+07  3.197e+07 -5.524e+06
 1.327e+04  4.539e+06 -5.524e+06  1.126e+06
PARAMETER  CORRELATION COEFFICIENTS
       NO.  GLOBAL      1      2      3      4
        1  0.85368   1.000 -0.065 -0.056  0.019
        2  0.99709  -0.065  1.000 -0.989  0.896
        3  0.99768  -0.056 -0.989  1.000 -0.921
        4  0.94273   0.019  0.896 -0.921  1.000
```

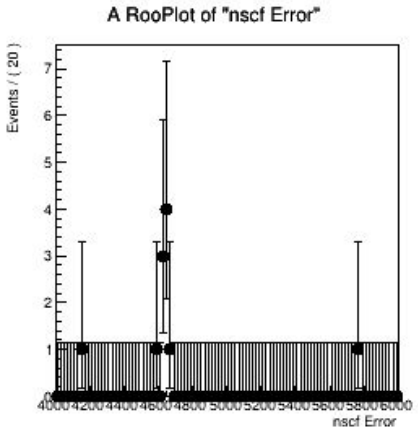
fit result for Signal = Johnson

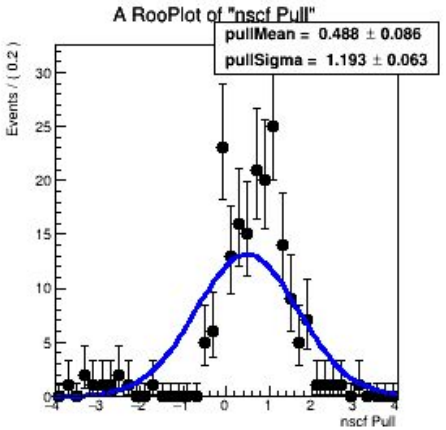
Composition	Nevents	Fraction after fit	χ2
Signal	72680	74495± 1057	1.7
Continuum	40110	43670 ± 4449	0.8
SCF	29548	23479 ± 5144	1.2
BB-bar bkg	28962	29660 ± 656	1.1

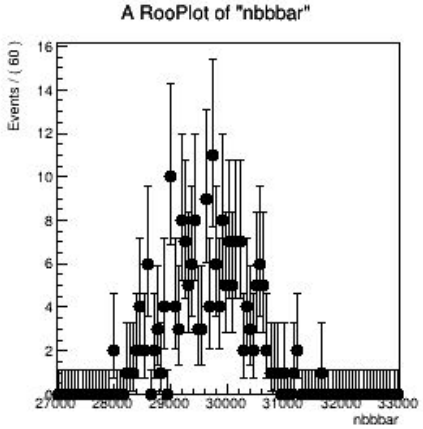


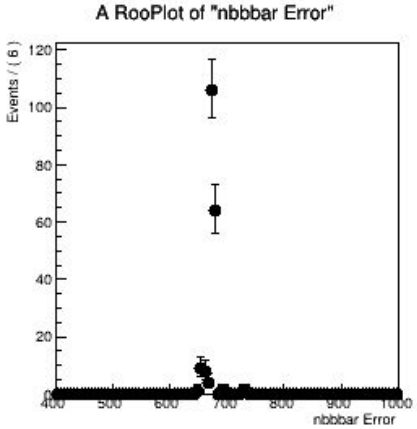

A RooPlot of "nsig"
Events / (40)
nsig
A RooPlot of "nsig Error"
Events / (9)
nsig Error
A RooPlot of "nsig Pull"
pullMean = -0.3775 ± 0.069
pullSigma = 0.969 ± 0.049
Events / (0.2)
nsig Pull
A RooPlot of "ncont"
Events / (80)
ncont
A RooPlot of "ncont Error"
Events / (25)
ncont Error
A RooPlot of "ncont Pull"
pullMean = -0.4619 ± 0.076
pullSigma = 1.063 ± 0.055
Events / (0.2)
ncont Pull

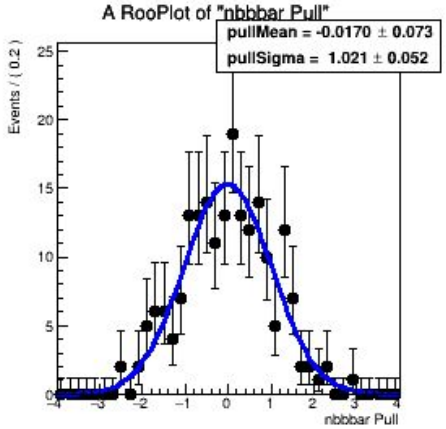

A RooPlot of "nscf"
Events / (70)
nscf

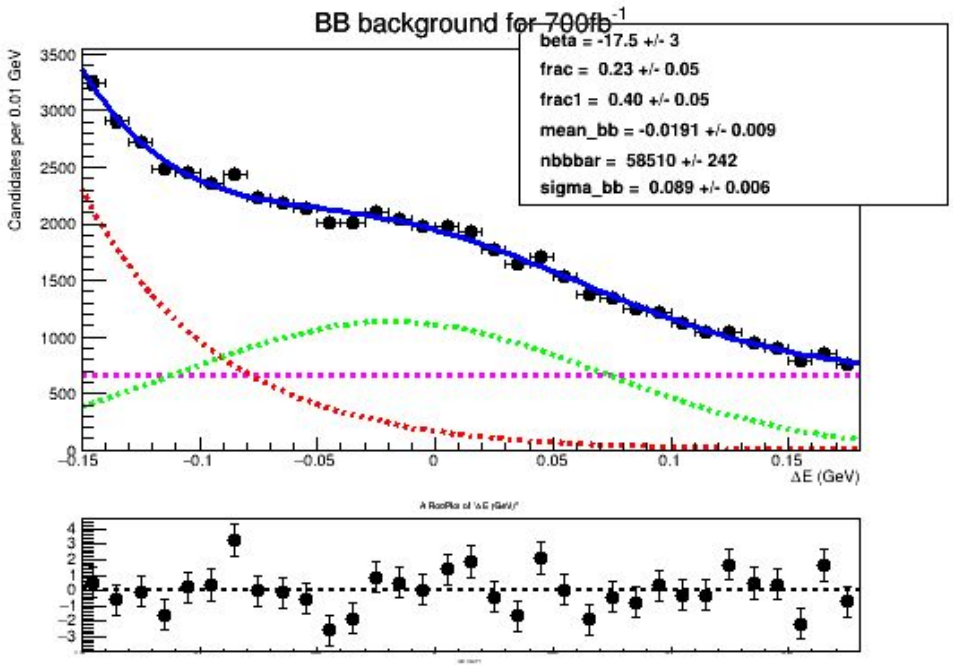

A RooPlot of "nscf Error"
Events / (20)
nscf Error


A RooPlot of "nscf Pull"
pullMean = 0.488 ± 0.086
pullSigma = 1.193 ± 0.063
Events / (0.2)
nscf Pull


A RooPlot of "nbbbar"
Events / (60)
nbbbar

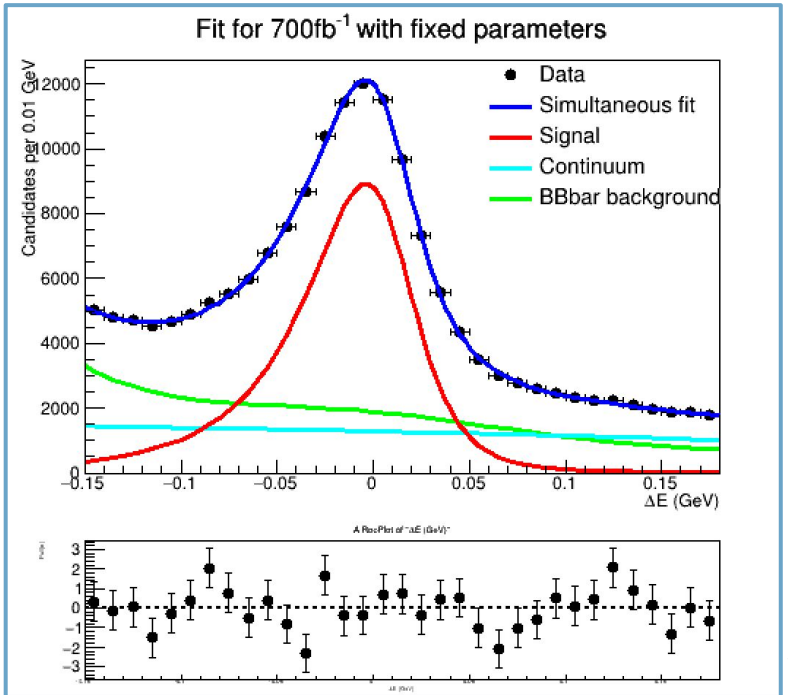

A RooPlot of "nbbbar Error"
Events / (6)
nbbbar Error

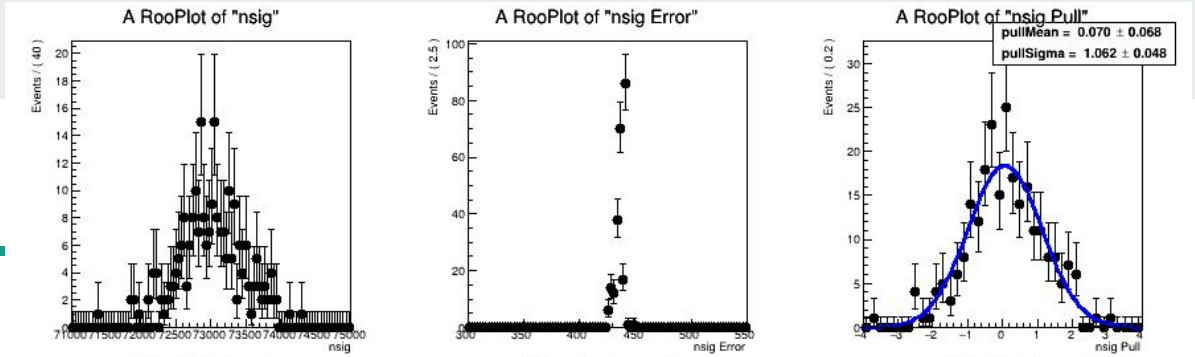

A RooPlot of "nbbbar Pull"
pullMean = -0.0170 ± 0.073
pullSigma = 1.021 ± 0.052
Events / (0.2)
nbbbar Pull

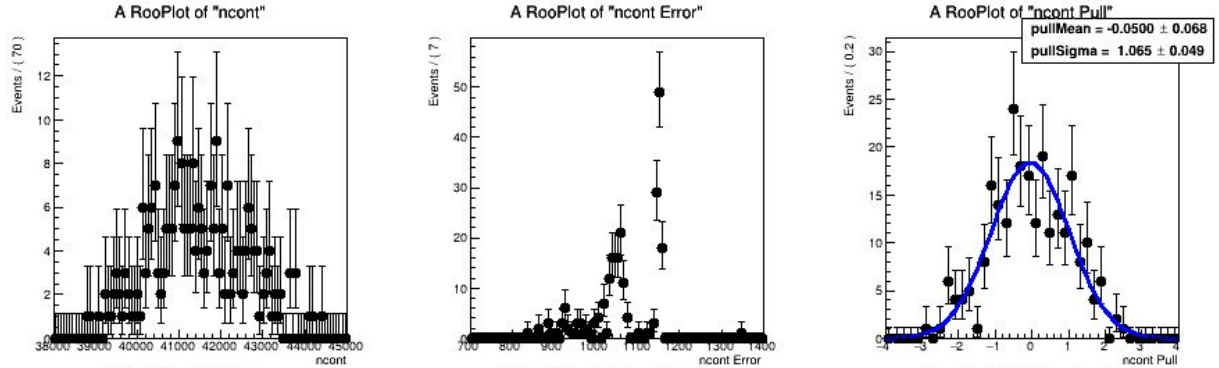

BB background for 700fb-1
beta = -17.5 +/- 3
frac = 0.23 +/- 0.05
frac1 = 0.40 +/- 0.05
mean_bb = -0.0191 +/- 0.009
nbbbar = 58510 +/- 242
sigma_bb = 0.089 +/- 0.006
Candidates per 0.01 GeV
ΔE (GeV)

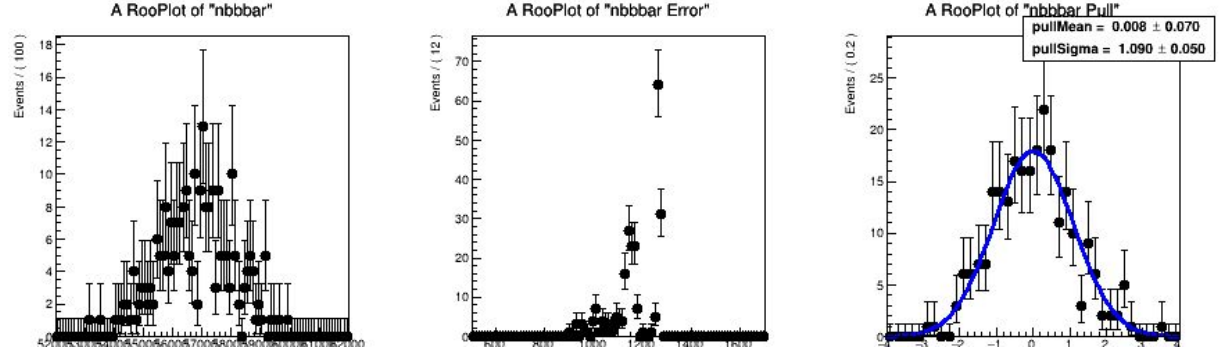
```
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-2.11113e+06 FROM HESSE     STATUS=OK             16 CALLS         281 TOTAL
                     EDM=0.00188849    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   INTERNAL      INTERNAL
 NO.   NAME      VALUE            ERROR          STEP SIZE       VALUE
  1  nbbbar       5.68471e+04   1.28955e+03   1.39739e-03   2.13995e+00
  2  ncont        4.14672e+04   1.17086e+03   1.96422e-03   3.27974e+00
  3  nsig         7.29759e+04   4.41899e+02   1.89717e-03   3.07809e+00
                               ERR DEF= 0.5
EXTERNAL ERROR MATRIX.    NDIM=  25    NPAR=  3    ERR DEF=0.5
 1.671e+06 -1.416e+06 -1.989e+05
-1.416e+06  1.382e+06  7.652e+04
-1.989e+05  7.652e+04  1.955e+05
PARAMETER  CORRELATION COEFFICIENTS
       NO.  GLOBAL      1      2      3
        1  0.95603   1.000 -0.932 -0.348
        2  0.95093  -0.932  1.000  0.147
        3  0.59999  -0.348  0.147  1.000
```

Composition	Nevents	Fraction after fit	χ^2
Signal	72680	72976 ± 442	0.67
Continuum	40110	41467 ± 1171	1.2
BB-bar bkg	58510	56847 ± 1290	1.3

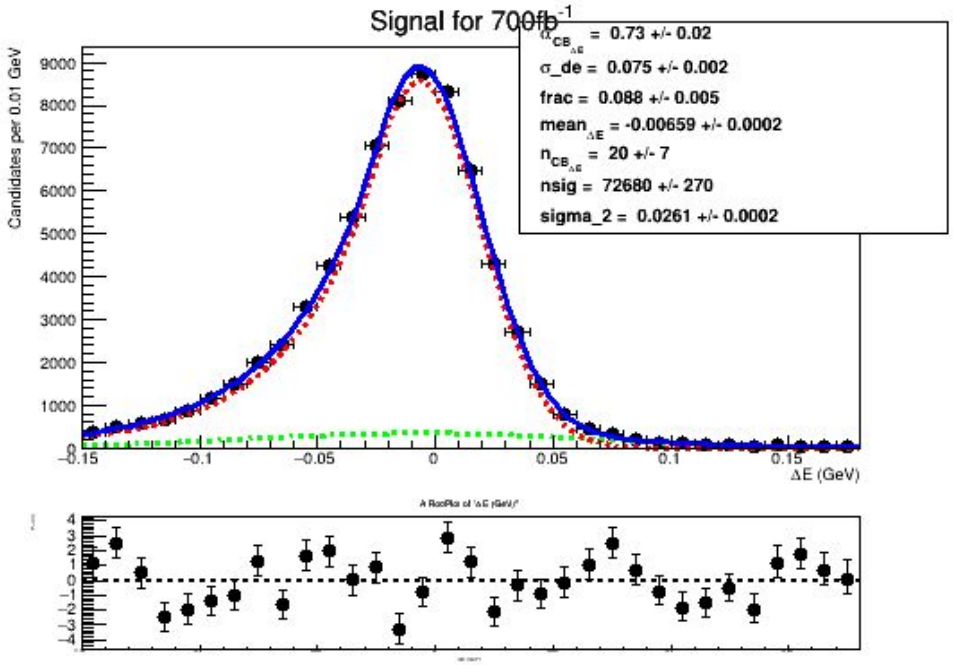



A RooPlot of "nsig"
Events / (40)
nsig
A RooPlot of "nsig Error"
Events / (2.5)
nsig Error
A RooPlot of "nsig Pull"
pullMean = 0.070 ± 0.068
pullSigma = 1.062 ± 0.048
Events / (0.2)
nsig Pull


A RooPlot of "ncont"
Events / (70)
ncont
A RooPlot of "ncont Error"
Events / (7)
ncont Error
A RooPlot of "ncont Pull"
pullMean = -0.0500 ± 0.068
pullSigma = 1.065 ± 0.049
Events / (0.2)
ncont Pull


A RooPlot of "nbbbar"
Events / (100)
A RooPlot of "nbbbar Error"
Events / (12)
A RooPlot of "nbbbar Pull"
pullMean = 0.008 ± 0.070
pullSigma = 1.090 ± 0.050
Events / (0.2)

New signal parametrization

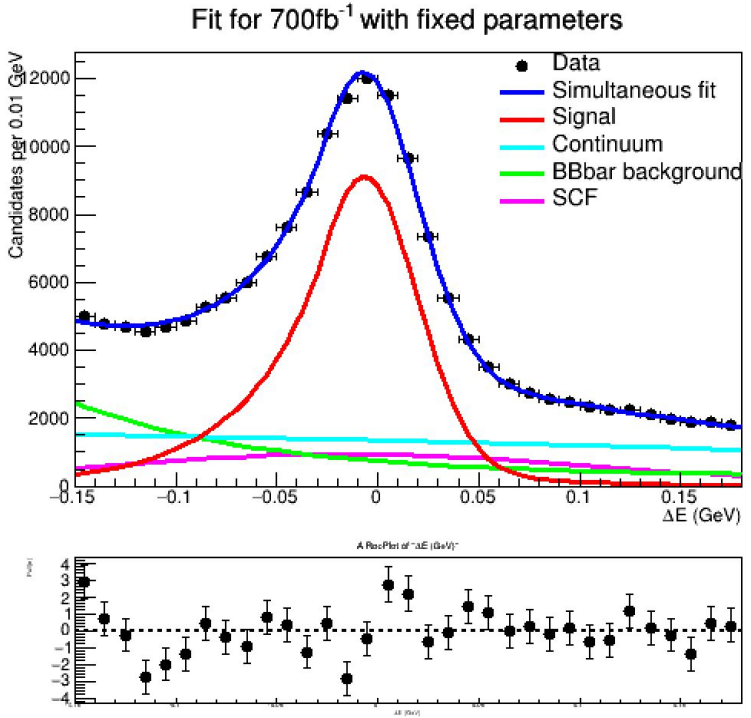


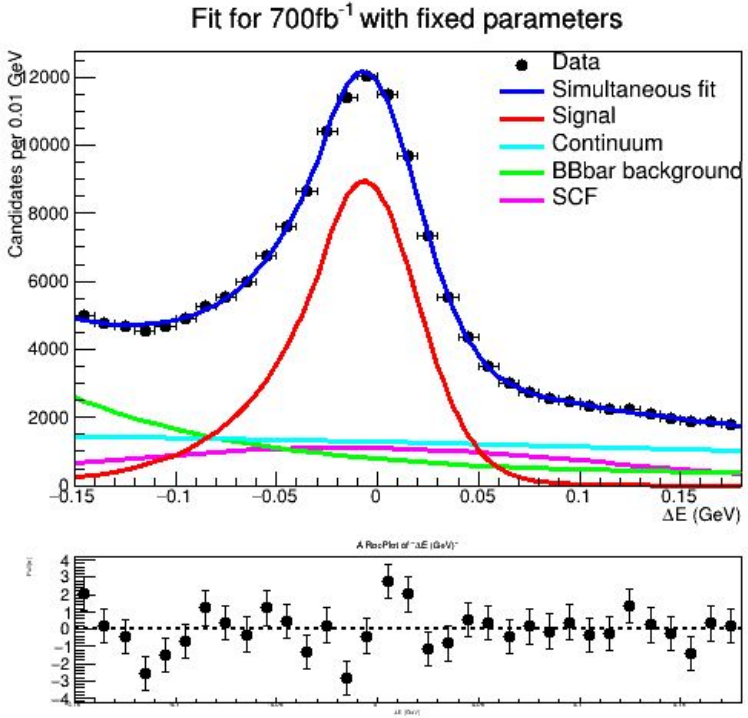
CristalBall + Gauss

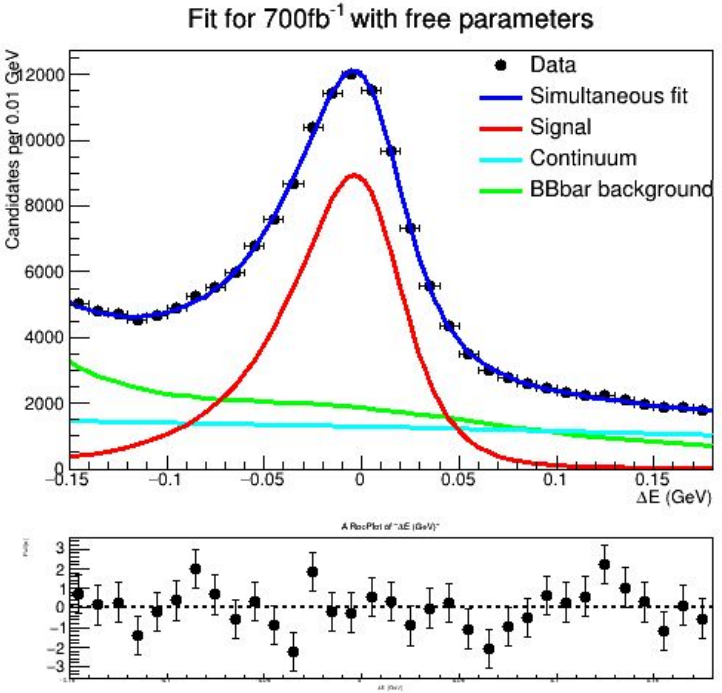
```
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-2.11112e+06 FROM HESSE     STATUS=OK             23 CALLS         231 TOTAL
                     EDM=5.89109e-05    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   INTERNAL      INTERNAL
 NO.   NAME      VALUE            ERROR          STEP SIZE       VALUE
  1  nbbbar      2.95213e+04   6.74513e+02   8.05829e-04  -5.51466e-01
  2  ncont       4.34743e+04   2.06351e+03   1.96306e-03   1.30269e-01
  3  nscf        2.38876e+04   2.24668e+03   1.93928e-03  -6.57623e-01
  4  nsig        7.44212e+04   5.61428e+02   1.95807e-03   2.59043e-01
                               ERR DEF= 0.5
EXTERNAL ERROR MATRIX.    NDIM=  25    NPAR=  4    ERR DEF=0.5
 4.552e+05 -5.334e+05  1.538e+05 -4.622e+04
-5.334e+05  4.372e+06 -4.460e+06  6.671e+05
 1.538e+05 -4.460e+06  5.189e+06 -8.618e+05
-4.622e+04  6.671e+05 -8.618e+05  3.158e+05
PARAMETER  CORRELATION COEFFICIENTS
       NO.  GLOBAL      1      2      3      4
        1  0.86208   1.000 -0.378  0.100 -0.122
        2  0.98474  -0.378  1.000 -0.936  0.568
        3  0.98565   0.100 -0.936  1.000 -0.673
        4  0.77704  -0.122  0.568 -0.673  1.000
```

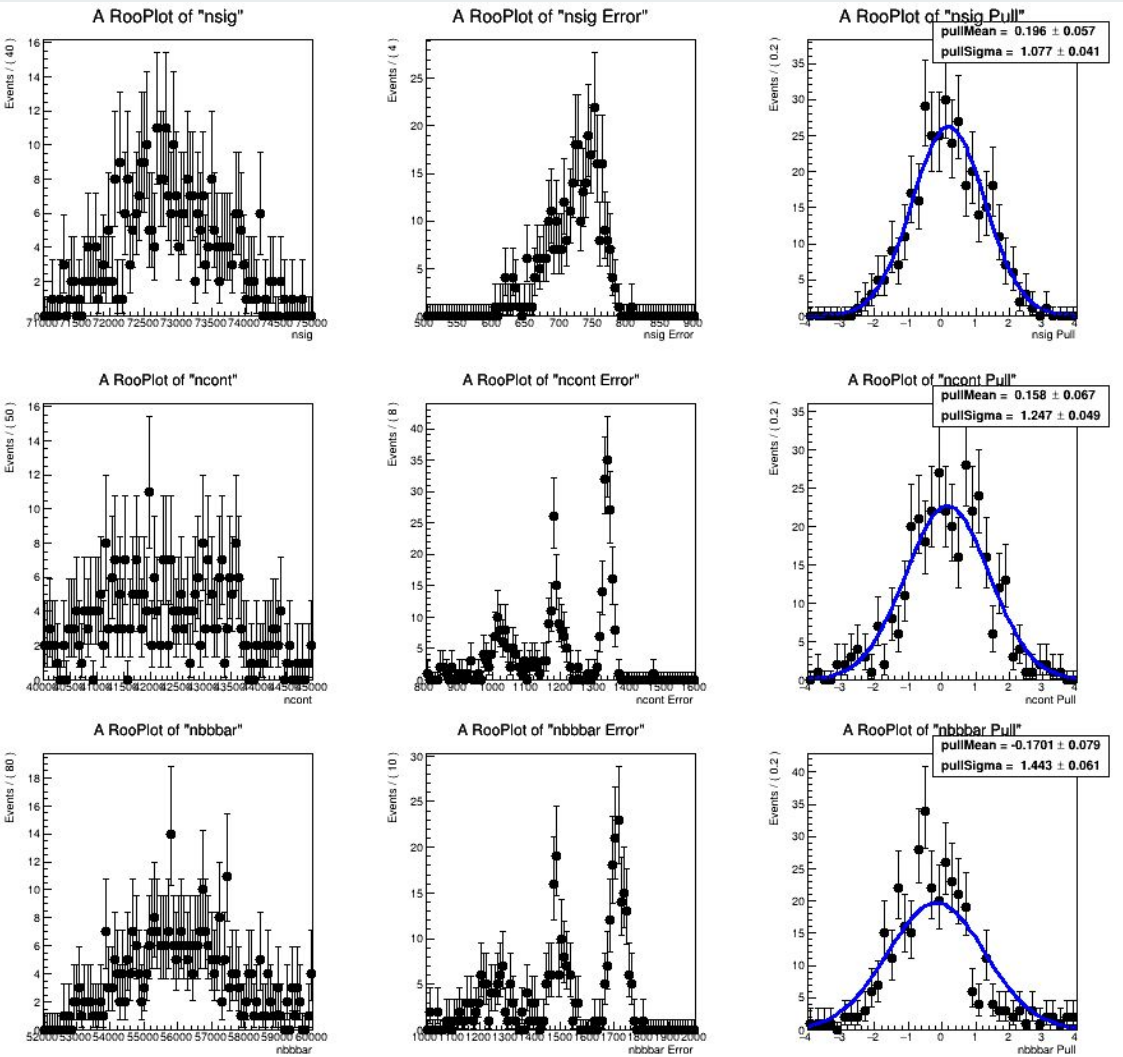
fit result for Signal = CB + Gauss

Composition	Nevents	Fraction after fit	χ2
Signal	72680	74421± 561	3.1
Continuum	40110	43474 ± 2064	1.6
SCF	29548	23888 ± 2247	2.5
BB-bar bkg	28962	29521 ± 675	0.8



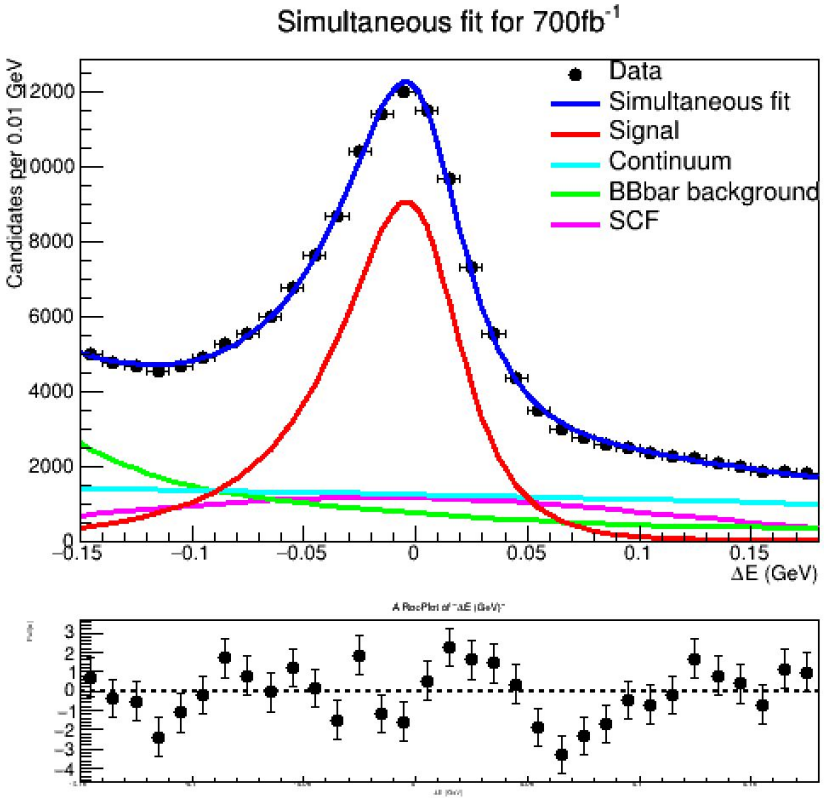

Fit for 700fb^{-1} with fixed parameters
Data
Simultaneous fit
Signal
Continuum
BBbar background
SCF
Candidates per 0.01 GeV
ΔE (GeV)


Fit for 700fb^{-1} with free parameters
Data
Simultaneous fit
Signal
Continuum
BBbar background
Candidates per 0.01 GeV
ΔE (GeV)


A RooPlot of "nsig"
Events / (40)
nsig
A RooPlot of "nsig Error"
Events / (4)
nsig Error
A RooPlot of "nsig Pull"
pullMean = 0.196 ± 0.057
pullSigma = 1.077 ± 0.041
Events / (0.2)
nsig Pull
A RooPlot of "ncont"
Events / (50)
ncont
A RooPlot of "ncont Error"
Events / (8)
ncont Error
A RooPlot of "ncont Pull"
pullMean = 0.158 ± 0.067
pullSigma = 1.247 ± 0.049
Events / (0.2)
ncont Pull
A RooPlot of "nbbbar"
Events / (80)
nbbbar
A RooPlot of "nbbbar Error"
Events / (10)
nbbbar Error
A RooPlot of "nbbbar Pull"
pullMean = -0.1701 ± 0.079
pullSigma = 1.443 ± 0.061
Events / (0.2)
nbbbar Pull

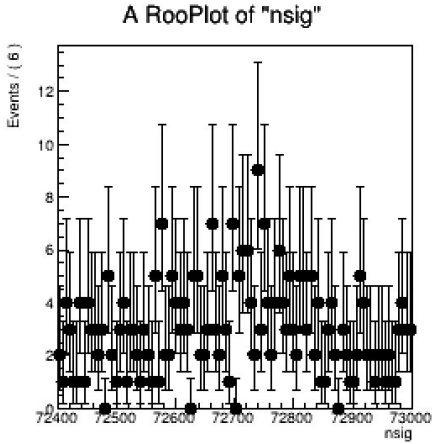
Backup

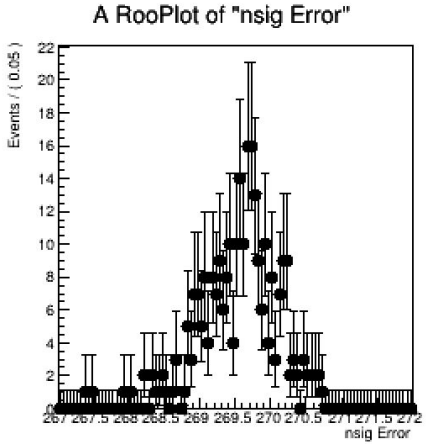
Free parameters simultaneous fit (700 fb-1)

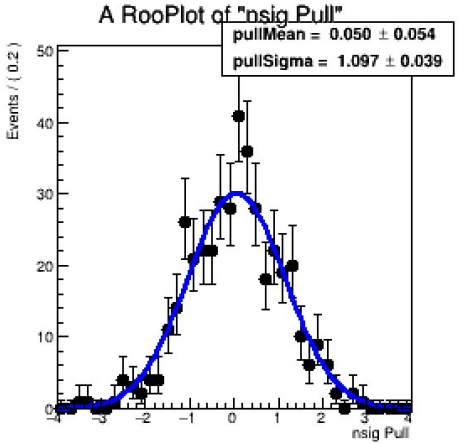


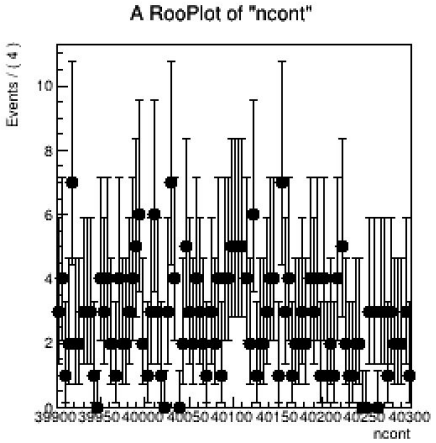
Composition	Nevents	Fraction after fit
Signal	72680	72692 ± 270
Continuum	40110	40109 ± 200
SCF	29548	29548 ± 172
BB-bar bkg	28962	28967 ± 170

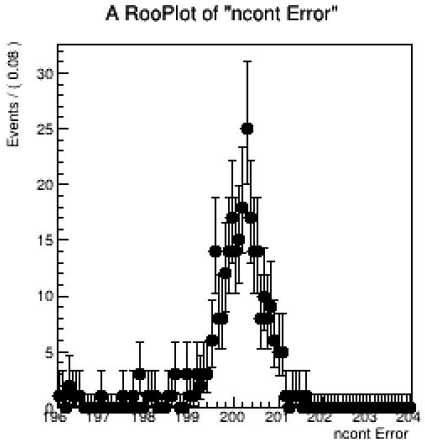
Toy MC result for fit with 16 free parameters

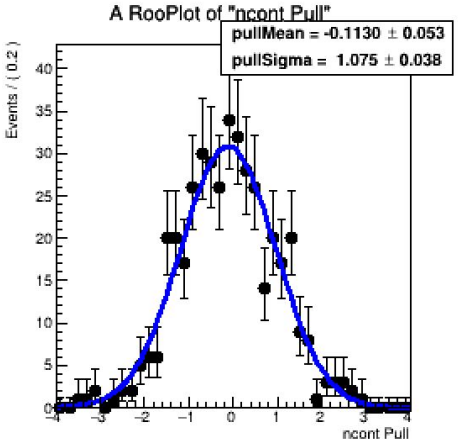




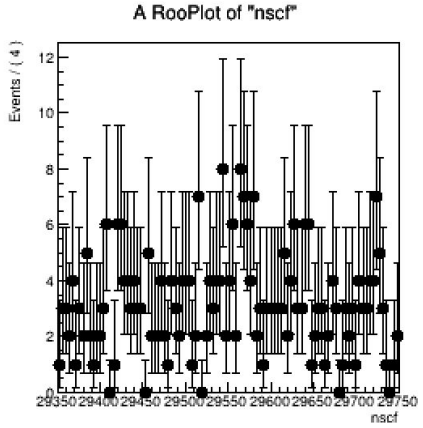


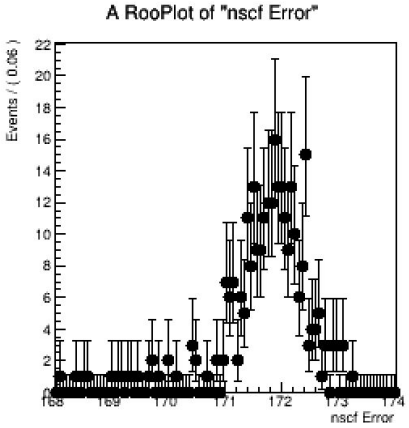


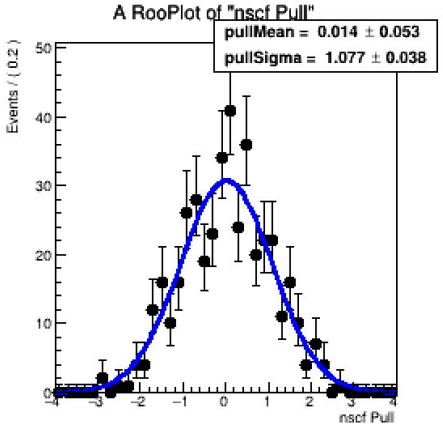


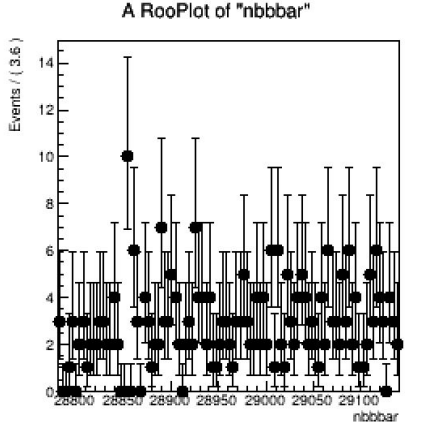


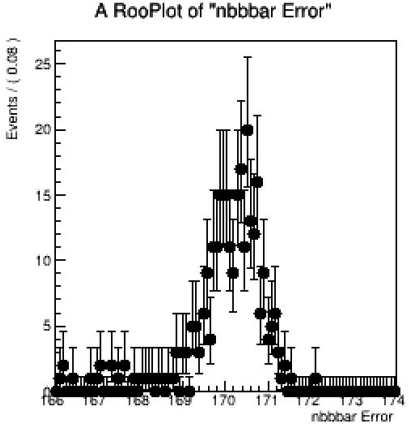
Toy MC result for fit with 16 free parameters (2)

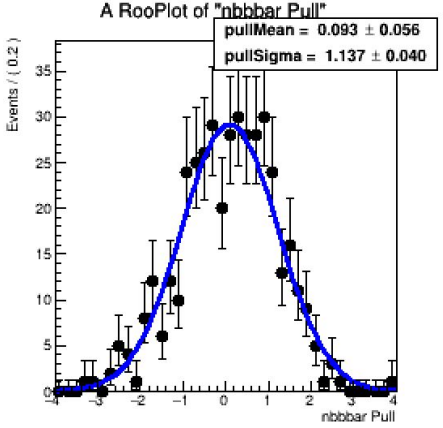




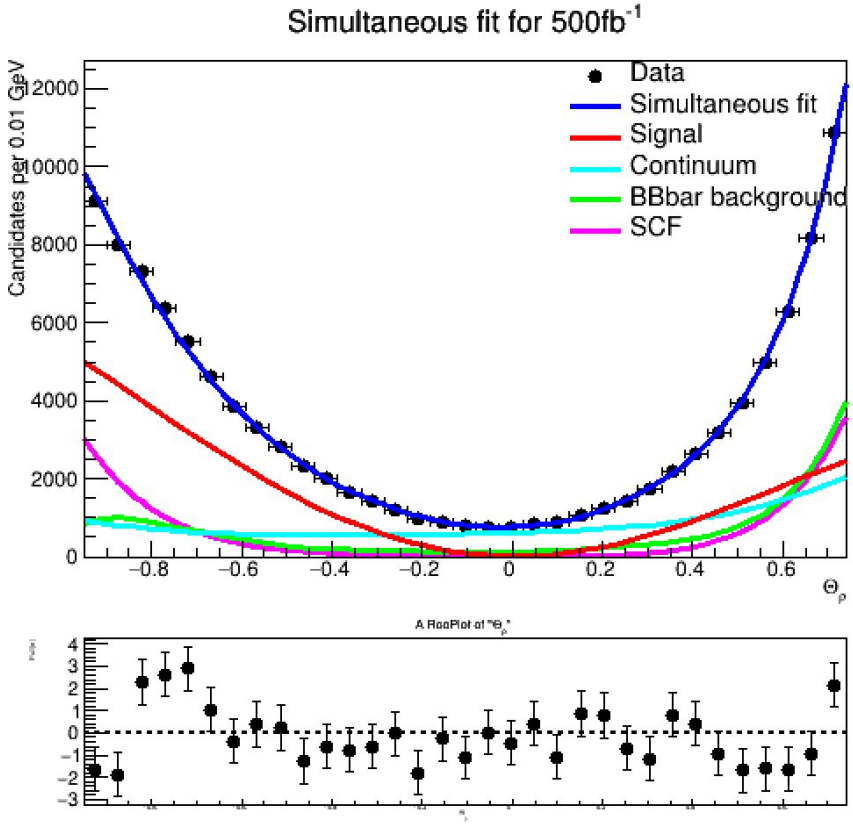








Simultaneous fit of cosΘp with fixed parameters



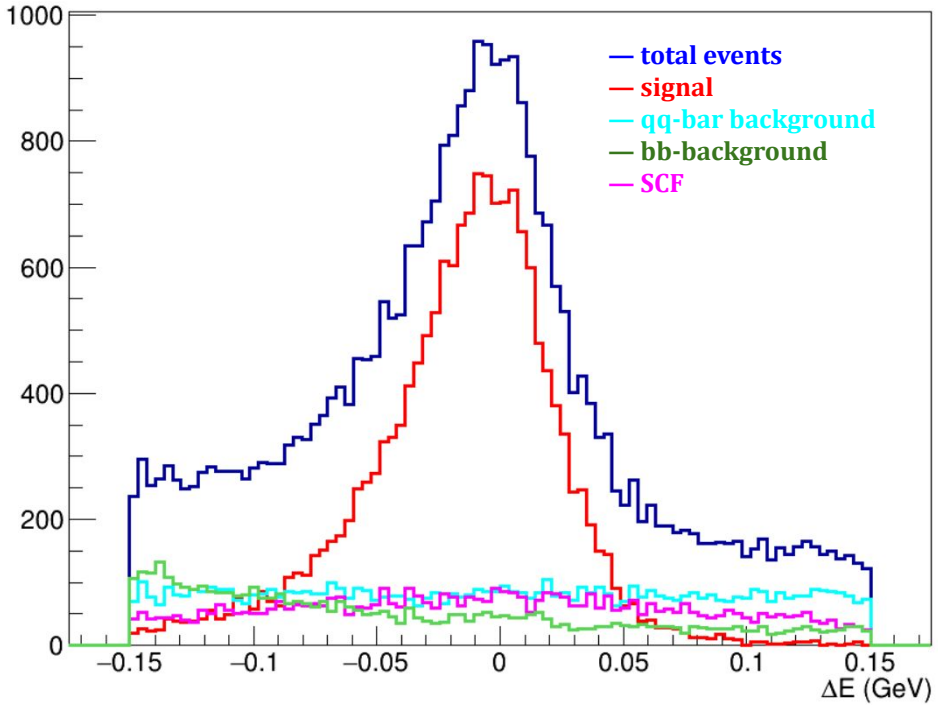
Conclusions

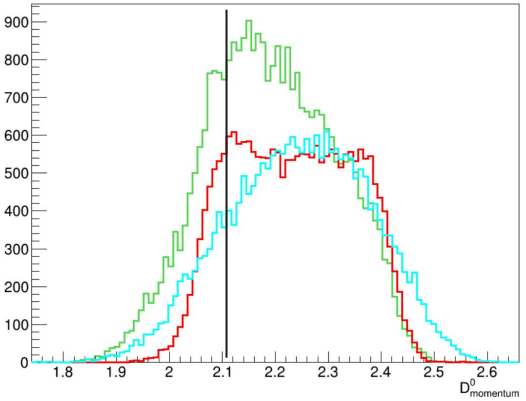
- Additional pre-selection cuts were taken into account
- New optimized selection criteria were applied
- Analysis of the BB-bar background composition was performed
- With new cuts we are able to keep higher reconstruction efficiency (~20%) with smaller background fraction

To do:

- Determine the $B \to D\pi\pi^0$ signal yield by fitting the deltaE distribution.
- Will inspect $m(\pi\pi^0)$ mass to separate ρ and non-ρ contribution to the signal
- Will consider if using also $\cos\theta_{\pi\pi}$ in the fit.

Delta E with harder cut on p(D⁰)>2.1





Composition	Share
Signal	0.49
Continuum	0.22
SCF	0.16
BB-bar bkg	0.13

Possible cut on the angle difference between 2 photons