Study of $B^0 \to K^+ K^- \pi^0$

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Fudan University

BHadronic

Contents

- Belle II result
  - Add photonMVA cut
  - CS cut
  - Linearity Test
  - Control channel
- Next to do

Event Selection

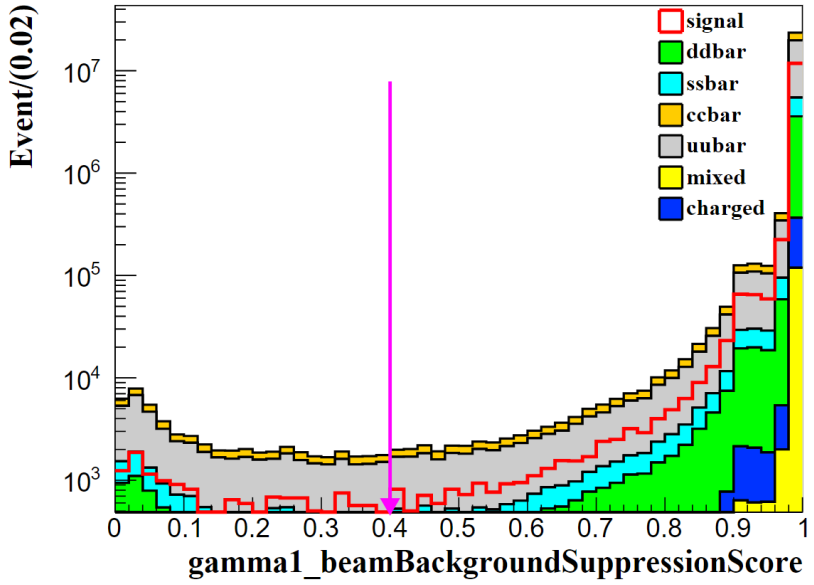
- $B^0 \to K^+K^-\pi^0$
  - **Tracks**
    - dr $<$ 0.2 cm & |dz| $<$ 5 cm
    - thetaInCDCAcceptance
    - nTracks $>$ 2
  - B^0
    - 5.25 $< M_{bc} <$ 5.289 GeV/c^2
    - -0.3 GeV $< \Delta E <$ 0.15 GeV
    - treefit
  - $K^{\pm}$
    - $\mathcal{L}(K/\pi) > 0.52$
  - **Charm Veto**
    - 1.846 $< M_{K^{\pm}\pi^{\mp}} <$ 1.884 GeV/c^2
  - $\pi^0 \to \gamma\gamma$
    - StdPi0 (eff50_May2020)
      - 0.105 $<$ InvM $<$0.150 GeV/c^2
    - kFit
    - pi0_MassChi2 $<$ 6
    - pi0_daughterAngle $<$ 0.4
    - |pi0_cosHelicityAngleMomentum| $<$ 0.93
  - γ
    - StdPhoton (eff50_May2020)
      - ClusterNHits $>$ 1.5
      - 0.2967 $<$ ClusterTheta $<$ 2.6180
      - Cluster E in different area:
        - E_γ in forward endcap $>$ 0.025 GeV
        - E_γ in barrel $>$ 0.025 GeV
        - E_γ in backforward endcap $>$ 0.04 GeV
    - |ClusterTiming| $<$ 200 ns

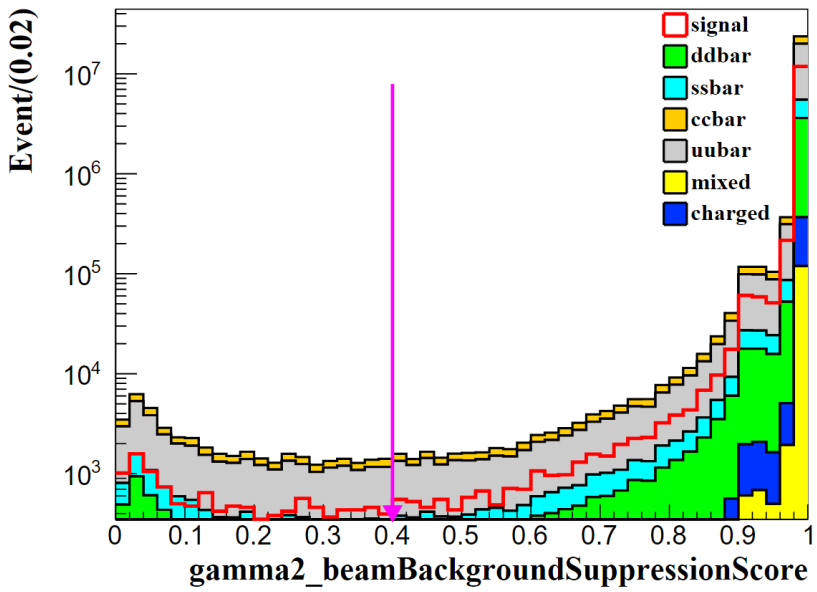
PhotonMVA

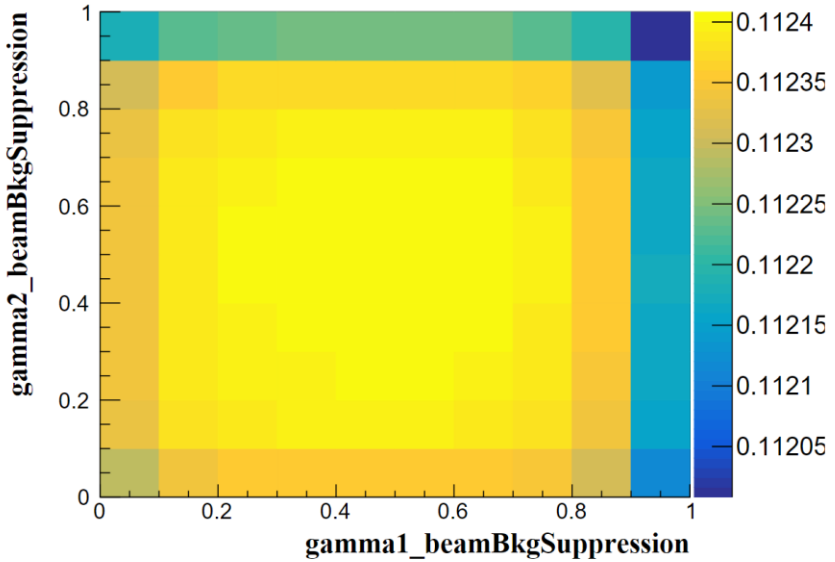
- $B^0 \to K^+K^-\pi^0\ (\pi^0 \to \gamma\gamma)$
  - beamBackgroundSuppressionScore > 0.4
  - fakePhotonSuppressionScore

- Figuer of Merit (FOM) $= \frac{N_S}{\sqrt{N_S+B}}$

- N_S : signal events estimated by assuming the branching ratio to be $\mathcal{B}(B^0 \to K^+K^-\pi^0) = 2.17 \times 10^{-6}$





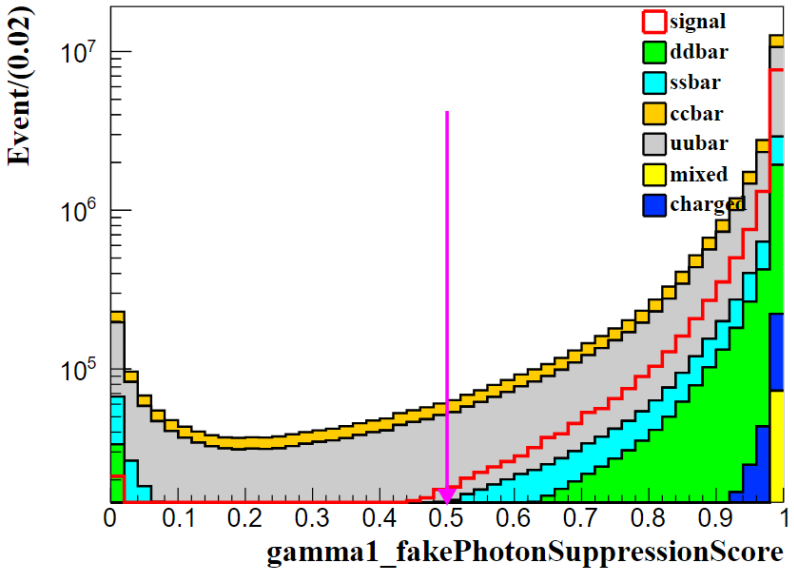


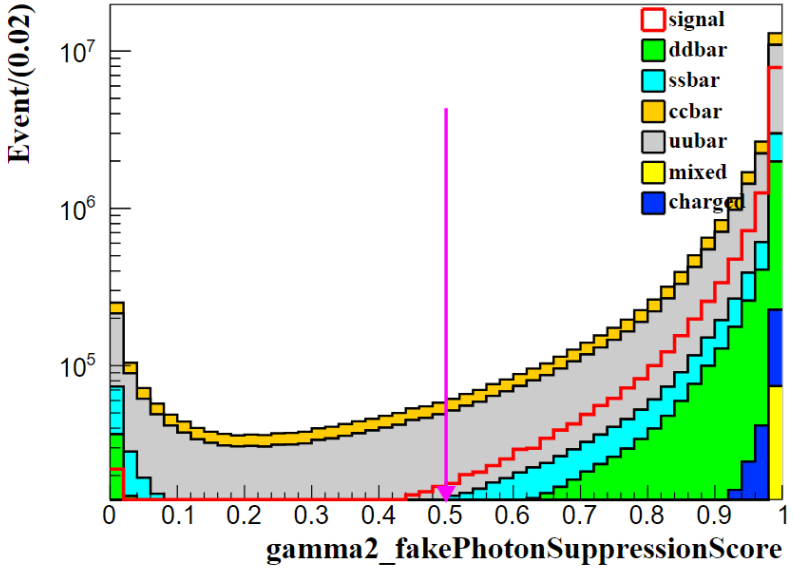
PhotonMVA

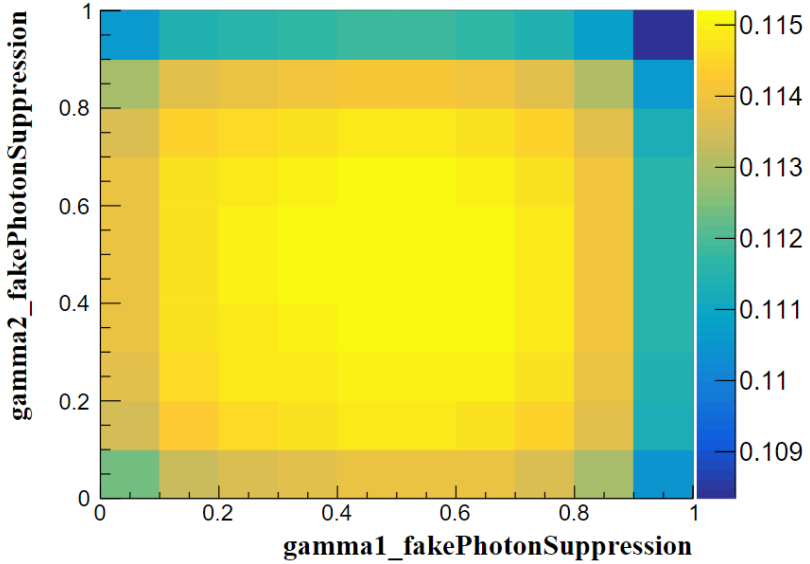
- $B^0 \to K^+K^-\pi^0\ (\pi^0 \to \gamma\gamma)$
  - beamBackgroundSuppressionScore
  - fakePhotonSuppressionScore > 0.5

- Figuer of Merit (FOM) $= \frac{N_S}{\sqrt{N_S+B}}$

- N_S : signal events estimated by assuming the branching ratio to be $\mathcal{B}(B^0 \to K^+K^-\pi^0) = 2.17 \times 10^{-6}$







Event Selection

- $B^0 \to K^+K^-\pi^0$
  - **Tracks**
    - dr $<$ 0.2 cm & |dz| $<$ 5 cm
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    - nTracks $>$ 2
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  - $K^{\pm}$
    - $\mathcal{L}(K/\pi) > 0.52$
  - **Charm Veto**
    - 1.846 $< M_{K^{\pm}\pi^{\mp}} <$ 1.884 GeV/c^2
  - $\varepsilon = 29.34\%$ SCF = 4.32%
- $\pi^0 \to \gamma\gamma$
  - StdPi0 (eff50_May2020)
    - 0.105 $<$ InvM $<$0.150 GeV/c^2
  - kFit
  - pi0_MassChi2 < 6
  - pi0_daughterAngle < 0.4
  - |pi0_cosHelicityAngleMomentum| < 0.93
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  - StdPhoton (eff50_May2020)
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    - Cluster E in different area:
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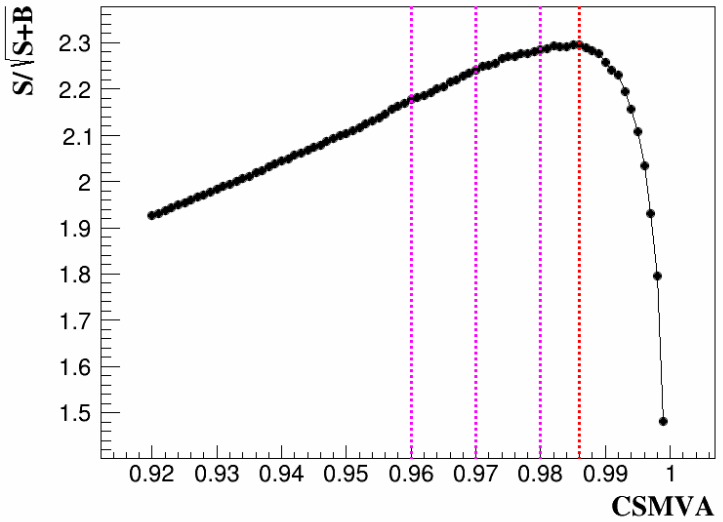
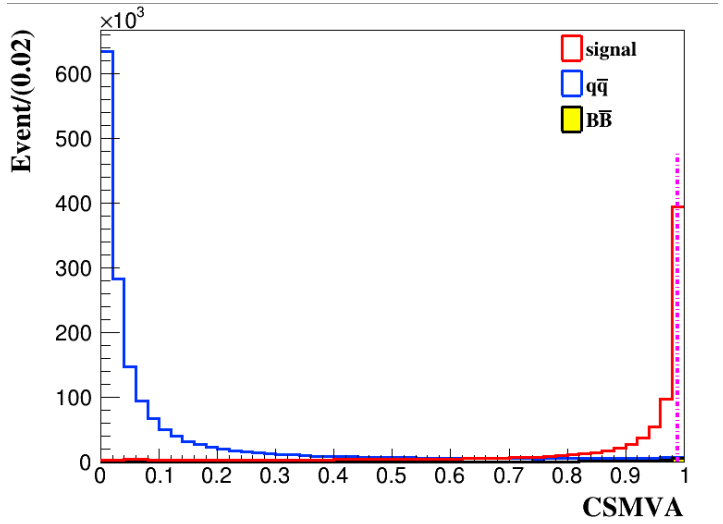
      - E_γ in barrel > 0.025 GeV
      - E_γ in backforward endcap > 0.04 GeV
  - |ClusterTiming| $<$ 200 ns
  - beamBackgroundSuppressionScore > 0.4
  - fakePhotonSuppressionScore > 0.5

Search for optimal CS cut

- Analysis Strategy
  - tight requirement on M_{bc}
  - 2D Fit on ΔE & transformed CS output C'





- Last Talk
  - Try CS cut and perform 2D Fit

  (CS = 0.96, 0.97, 0.98, 0.986)

- This Talk
  - Try CS cut and perform 2D Fit

  (From 0.60 to 0.99 with a step of 0.01)

After applying basic selection cut

$\varepsilon = 29.34\ \%\ , SCF = 4.34\ \%$

After continuum suppression (C > 0.6) (FBDT)

$\varepsilon = 26.51\%\ ,\qquad SCF = 3.84\%$

reject 94.73% continuum background
preserve 90.35% signal events

Correlation in different CS cut

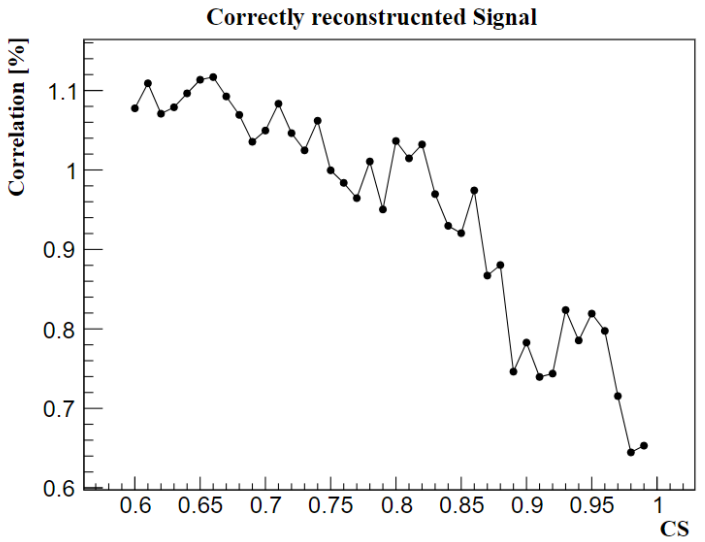
PDF used to model each event category

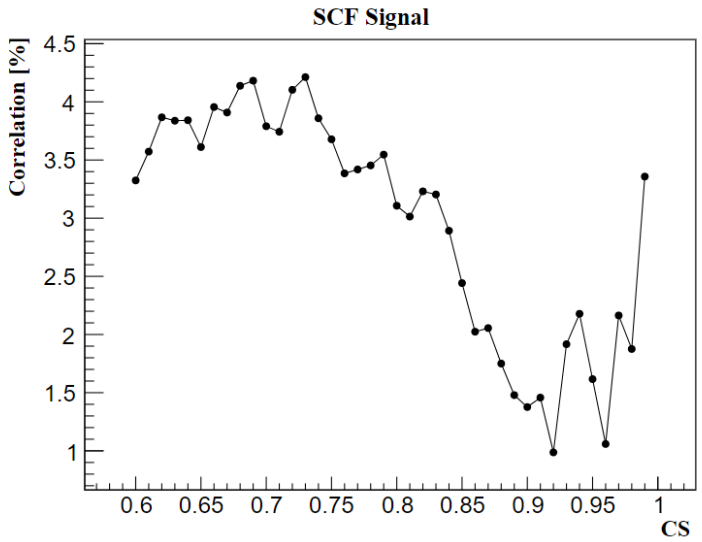
Event category	ΔE	C'
CR signal	CB + G	Double G
SCF signal	2D histogram	
Continuum Background	Poly1	CB
Generic $B\overline{B}$ Background	Double G	BG
Peaking Background	2D histogram	

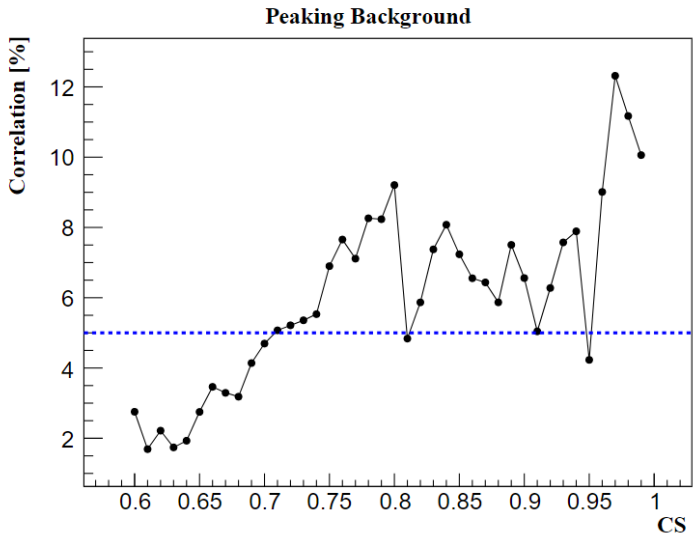
$$\mathcal{P} = \mathcal{P}(\Delta E)\,\mathcal{P}(C')$$

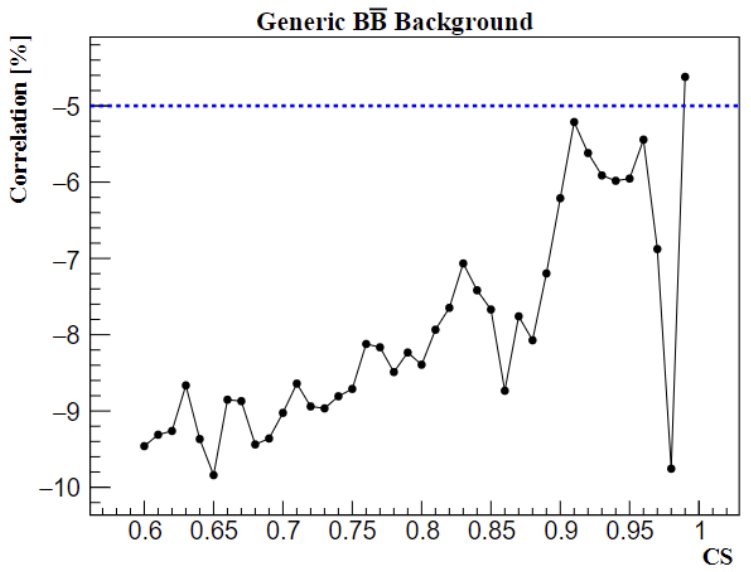
$$C' = \log\left(\frac{CS - CS_{min}}{1 - CS}\right)$$

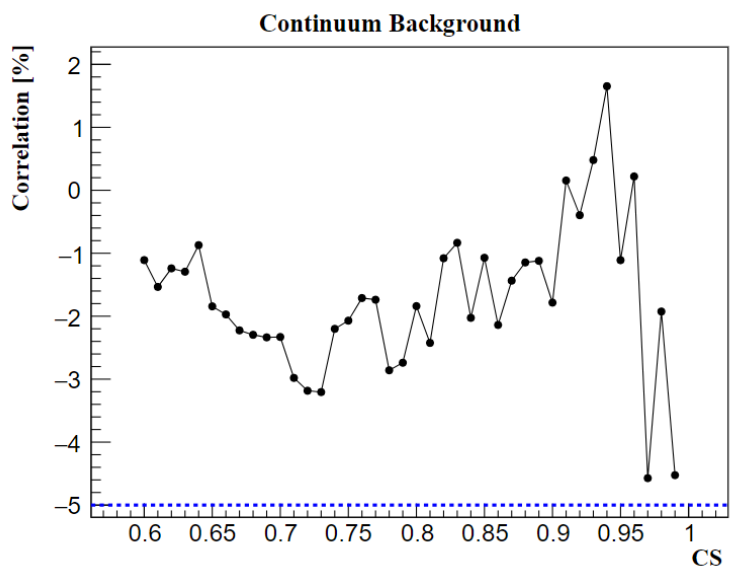
(Peaking Background : $B \rightarrow K\pi\pi$)







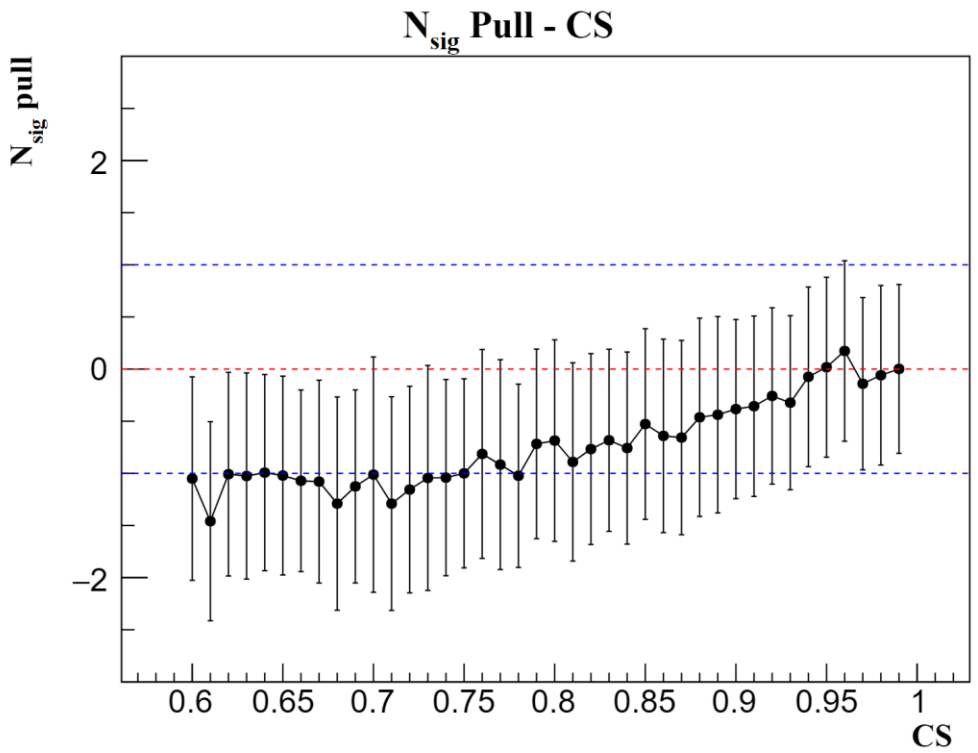


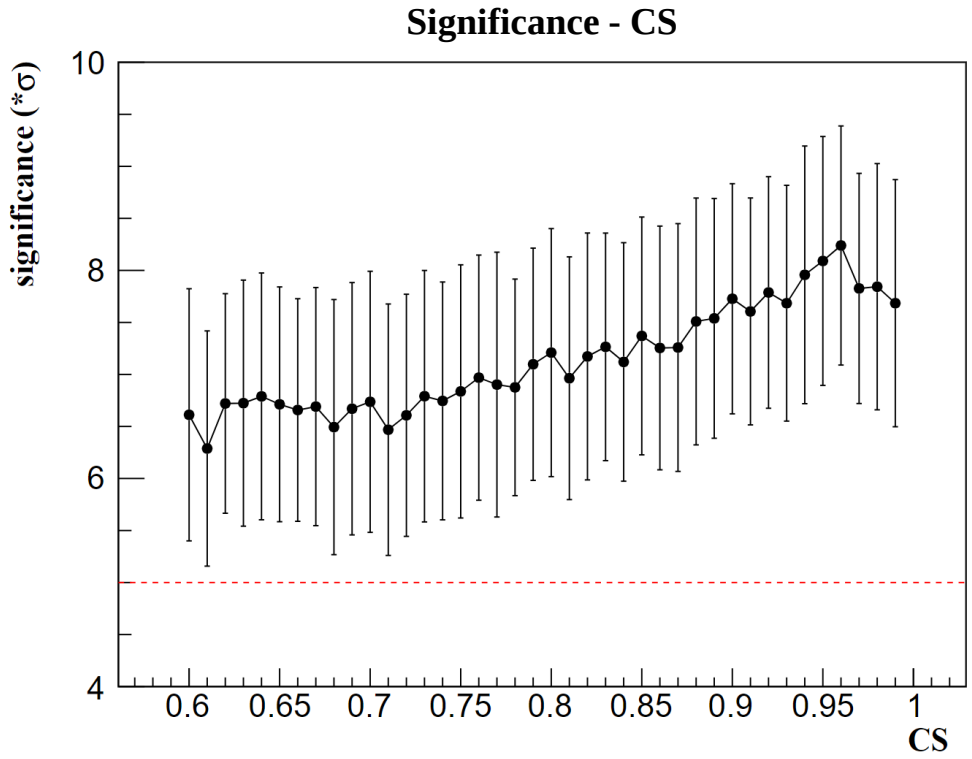


Search for optimal CS cut

Bootstrap (500 samples for each CS requirement)

Floated Parameters : Yields of each component





Error bars : statistical standard deviation of the datasets

Significance : $\sqrt{2 * (NLL - NLL_{min})}$

CS > 0.95

$\varepsilon = 18.68\%$, $SCF = 3.03\%$

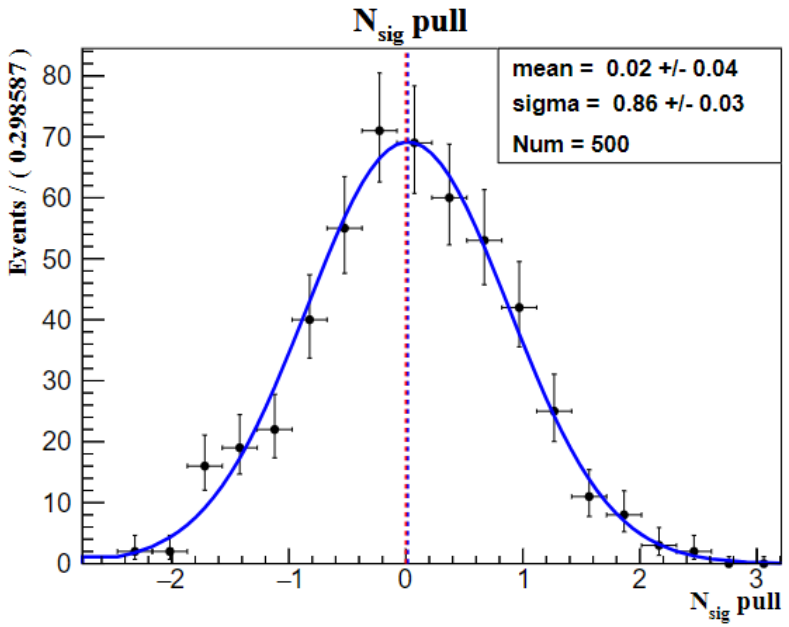
reject 99.62% continuum background

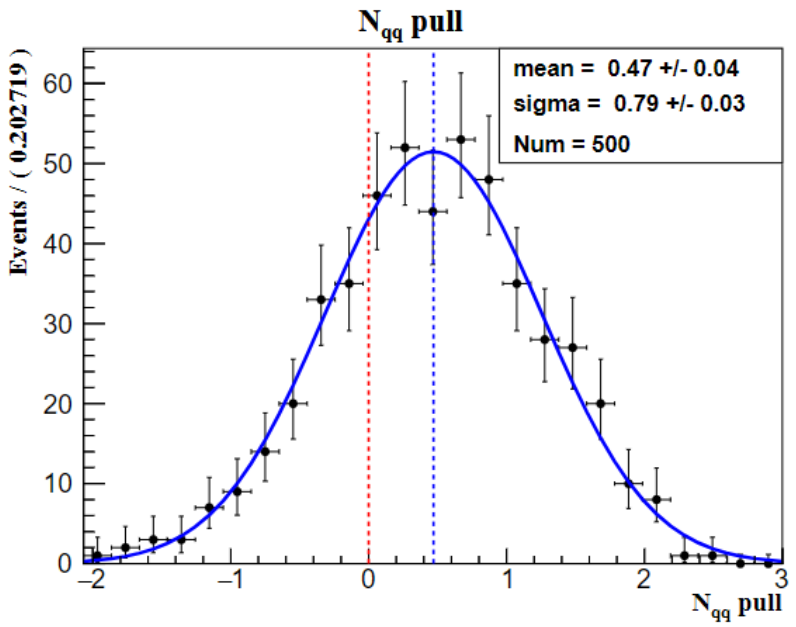
preserve 63.67% signal events

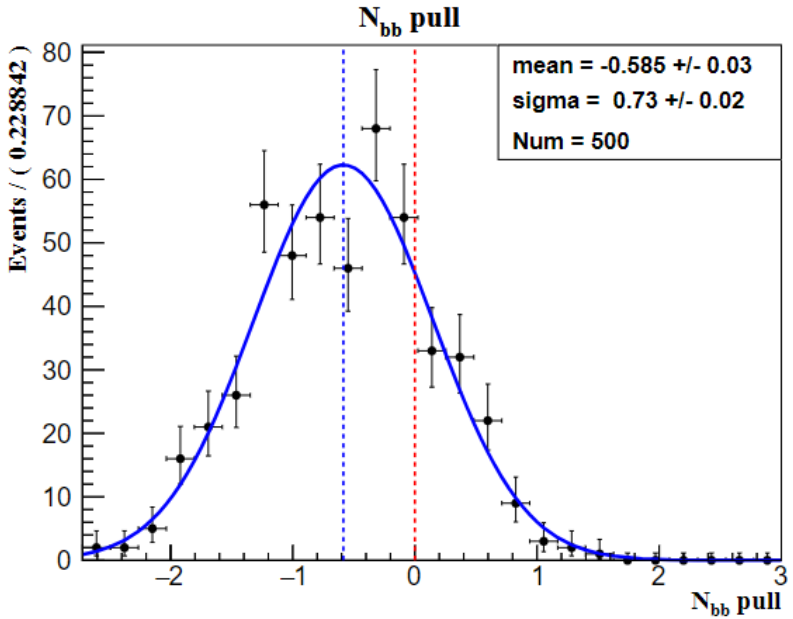
Fitter Validation based on bootstrap

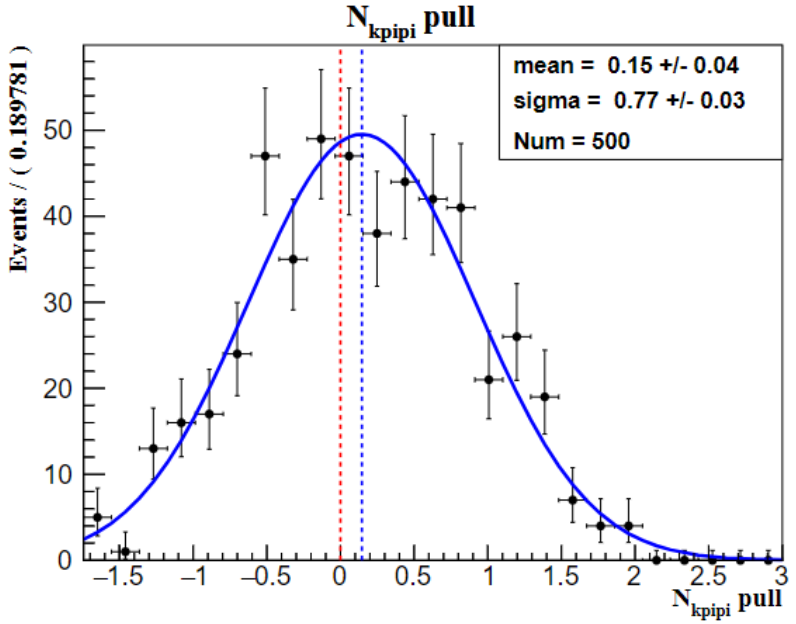
Bootstrap (500 samples)

CS > 0.95







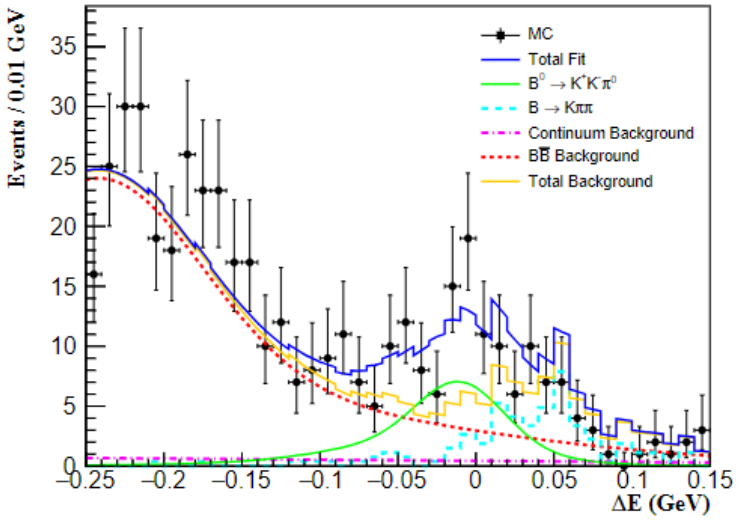


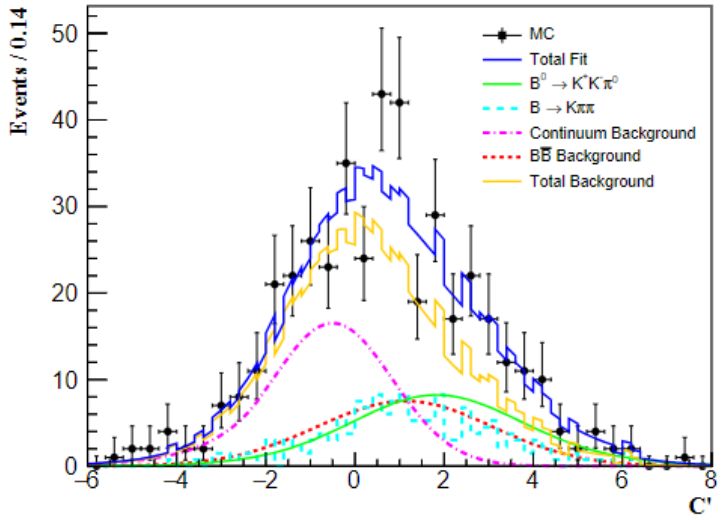
Fitter Validation based on bootstrap

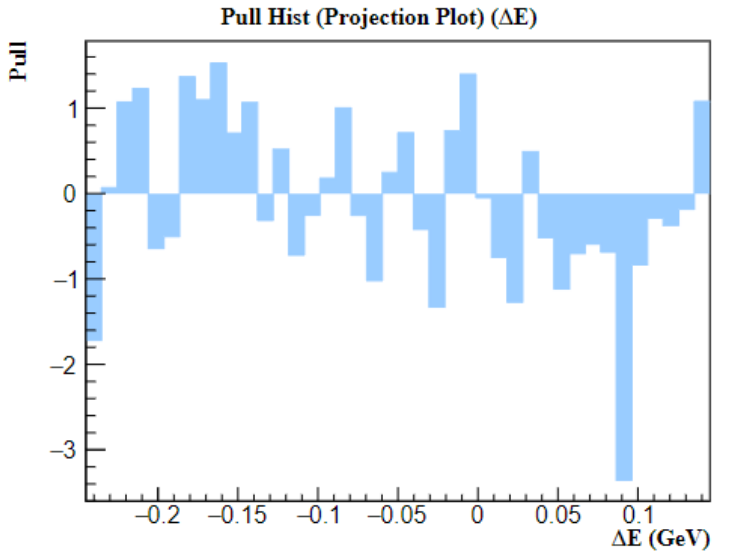
CS > 0.95

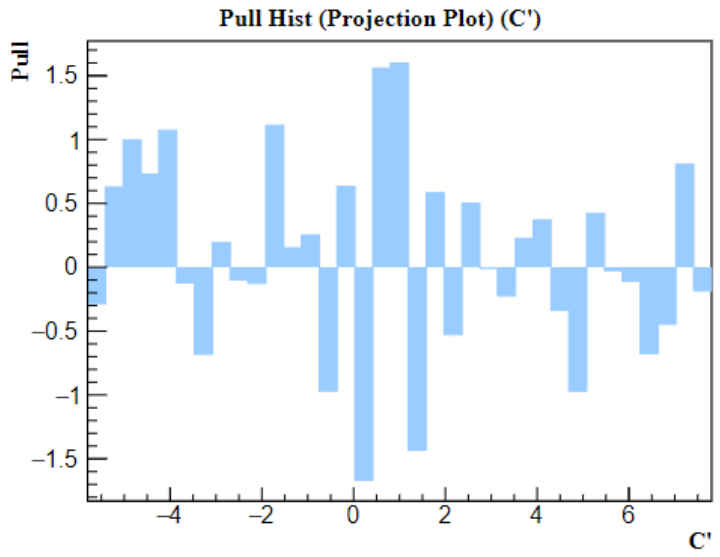
- Fit Range
  - ΔE [-0.25,0.15] GeV
  - C’ [-6, 8]
- Projection Plot
  - $|\Delta E| < 0.05$ GeV, and
  - C’ > 2

Projection plots of 2D fit obtained using one of the bootstrap samples





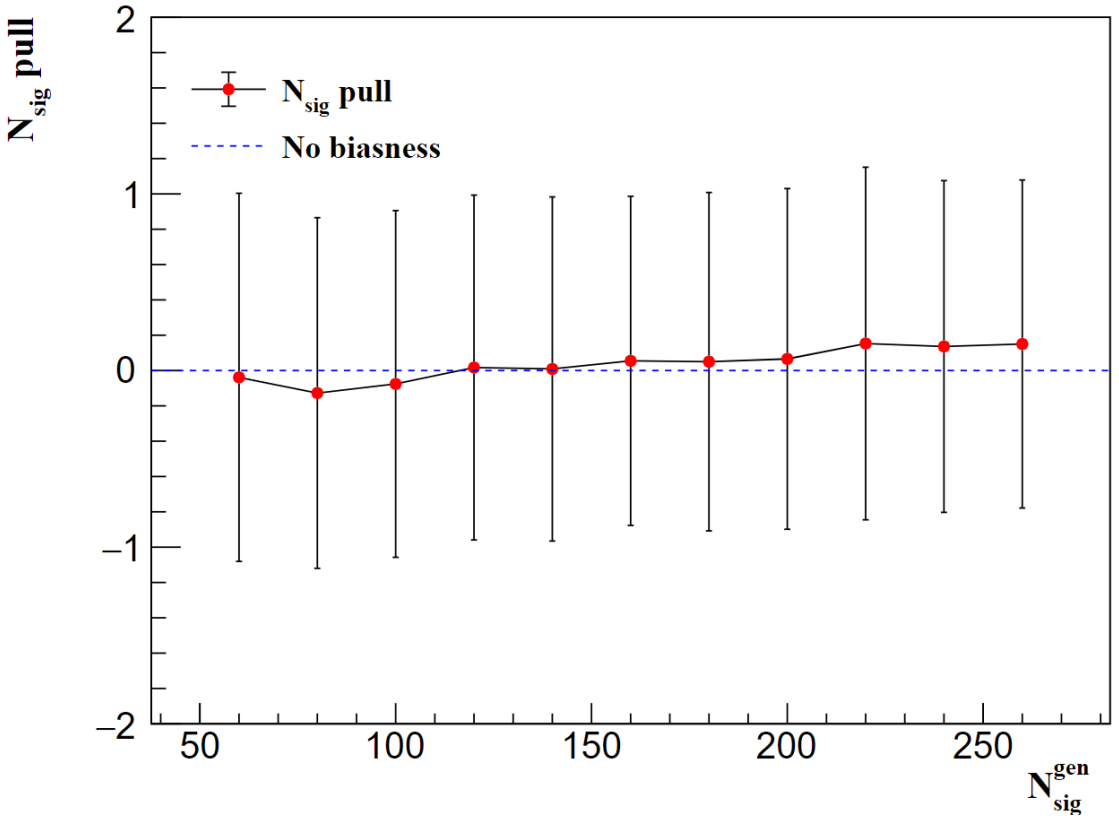


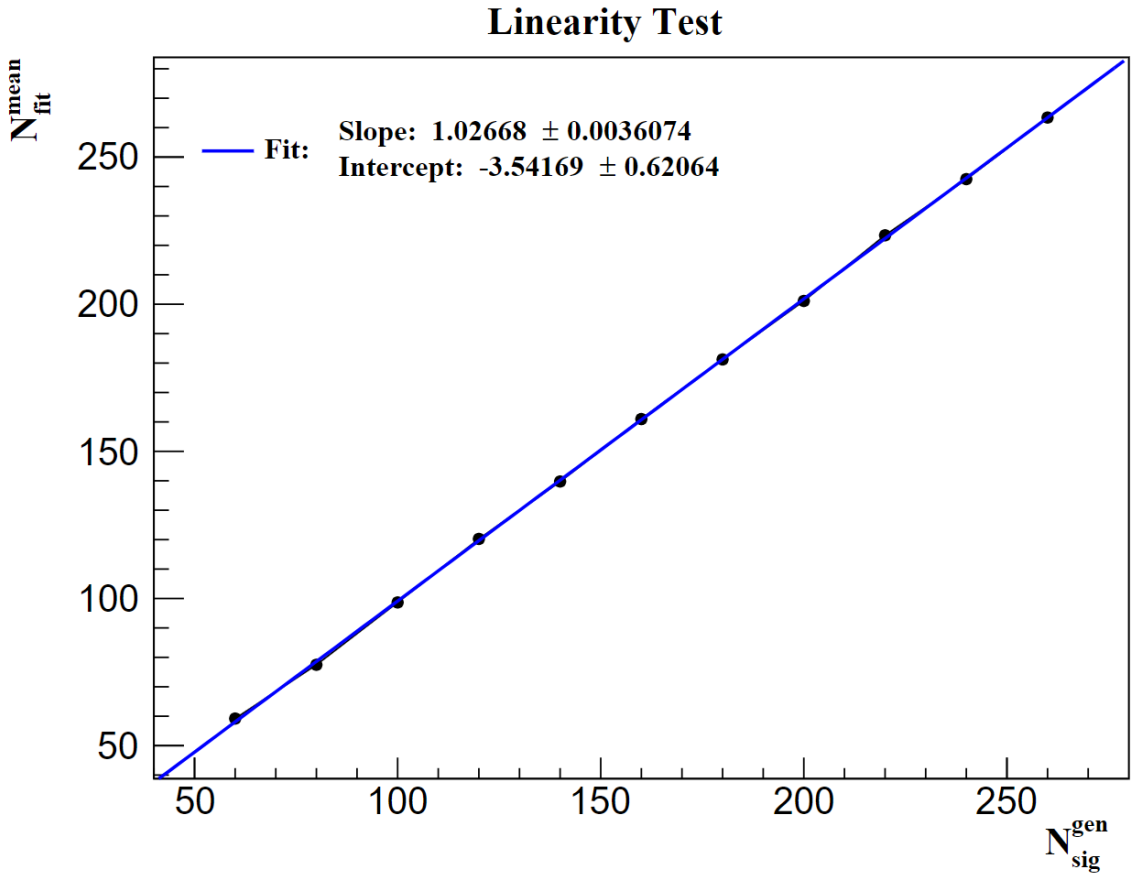


Linearity Test

CS > 0.95 Expected signal yield : 153

(From 60 to 260, with a step of 20)



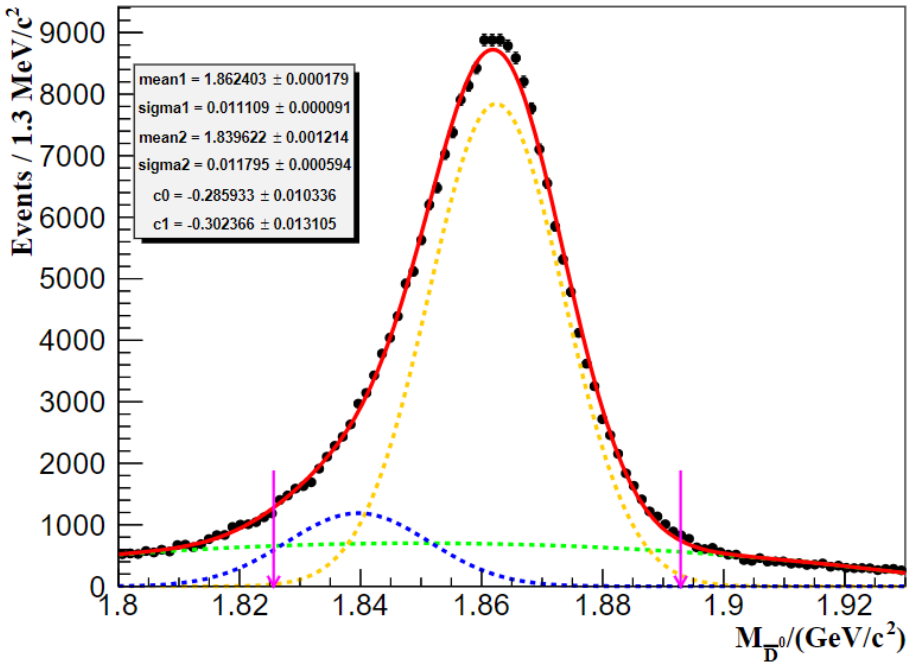


Error bars : statistical standard deviation of the datasets

Control Channel

$$B^+ \to \bar{D}^0(\to K^+\pi^-\pi^0)\pi^+$$

- To extract calibration parameter (shift and scale factor)
- To assess possible differences in the CS efficiency between data and MC



The selection criteria for $B^+ \to \bar{D}^0(\to K^+\pi^-\pi^0)\pi^+$

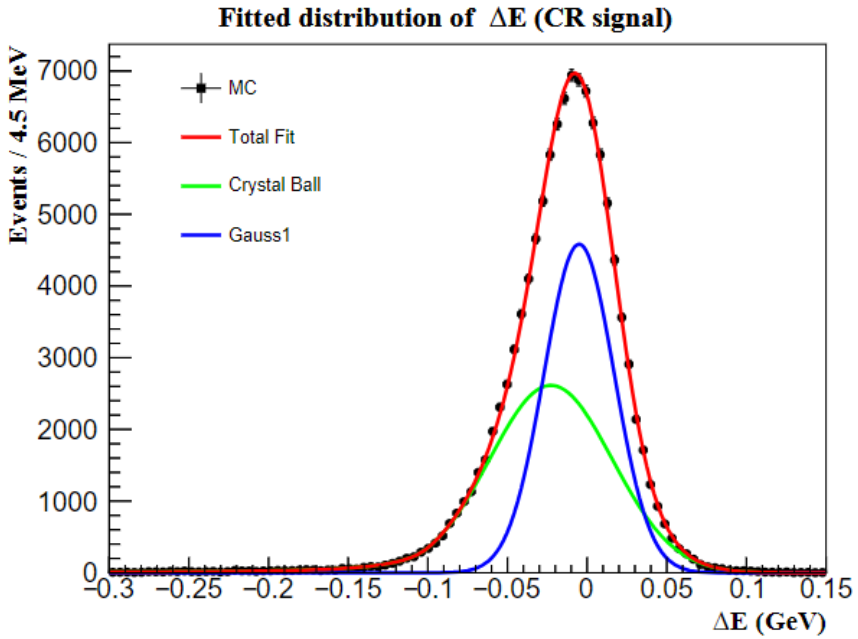
Target	Selection
charged tracks	$\lvert dz\rvert < 5$ cm $dr < 0.2$ cm theta in CDC acceptance
γ	$0.2976 < \theta < 2.6180$ rad clusterNHits > 1.5 $\lvert$clusterTiming$\rvert < 200$ ns forward > 25 MeV, barrel > 25 MeV, backward > 40 MeV beamBackgroundSuppressionScore > 0.4 fakePhotonSuppressionScore > 0.5
π^0	$105 < M_{\gamma\gamma} < 150$ MeV/c^2 $\chi^2_{\pi^0} < 6$ daughterAngle < 0.4 $\lvert$cosHelicityAngleMomentum$\rvert < 0.93$
K/π	$\mathcal{L}_{K/\pi} > 0.52$ for selecting kaons, rest considered pions
$\bar{D}^0$	$1.826 < M_{\bar{D}^0} < 1.893$ GeV/c^2
B^+	$5.27 < M_{bc} < 5.289$ GeV/c^2 $-0.25 < \Delta E < 0.15$ GeV
CSMVA	CSMVA > 0.95

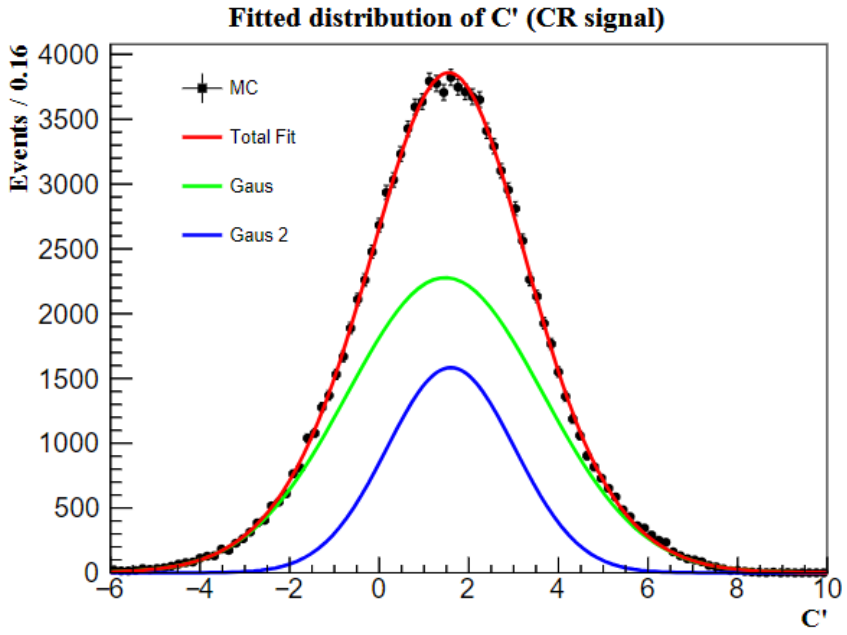
Control Channel

$B^+ \to \bar{D}^0(\to K^+\pi^-\pi^0)\pi^+$

PDF used to model each event category

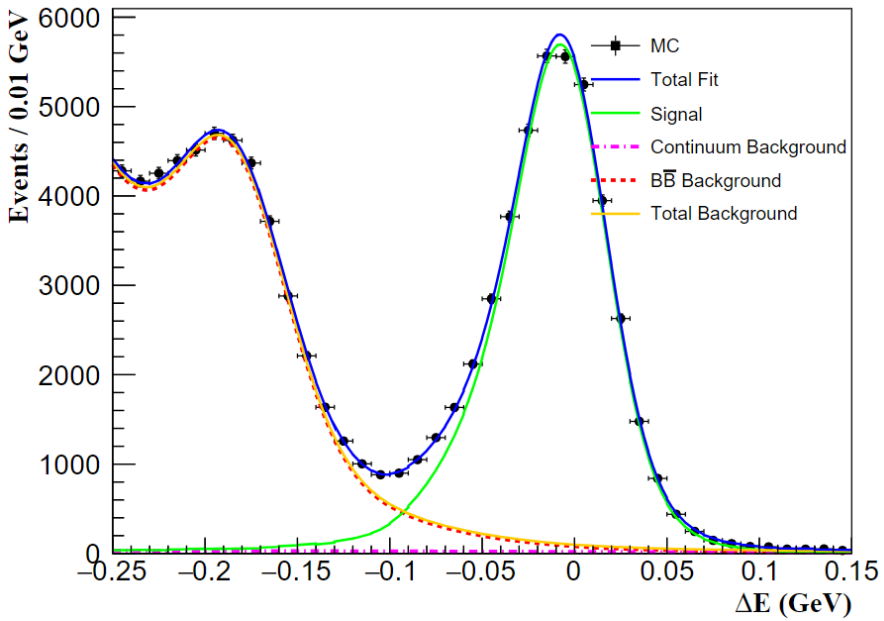
Event category	ΔE	C'
CR signal	CB + G	Double G
SCF signal	2D histogram	
Continuum Background	Poly1	CB
Generic $B\bar{B}$ Background	Double G + Poly2	BG

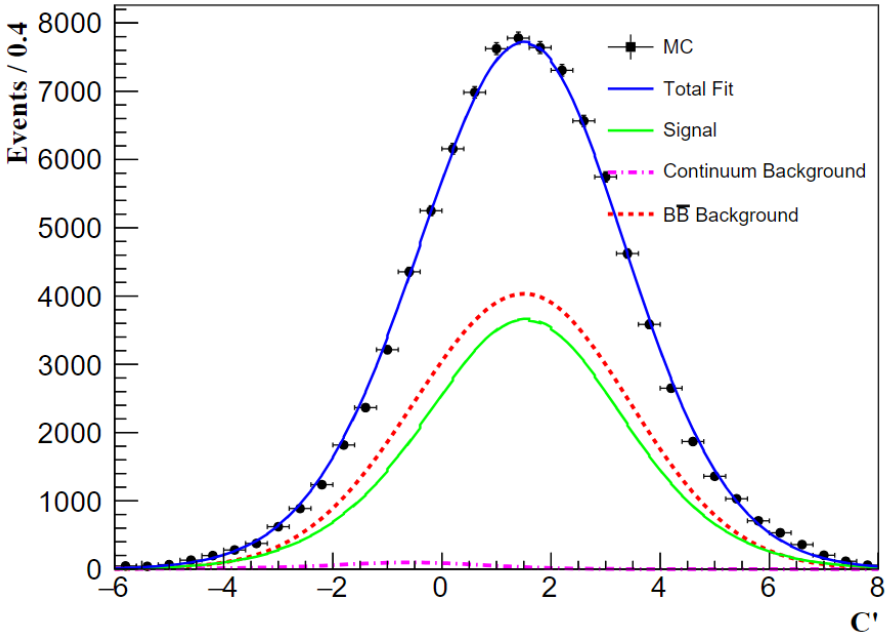




Control Channel

$B^+ \to \bar{D}^0(\to K^+\pi^-\pi^0)\pi^+$





Fitting result of generic MC sample

Next to do

- Extract calibartion parameters
- CS efficiency correction
- Systematic uncertainties
- ……

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Thanks for your attention!

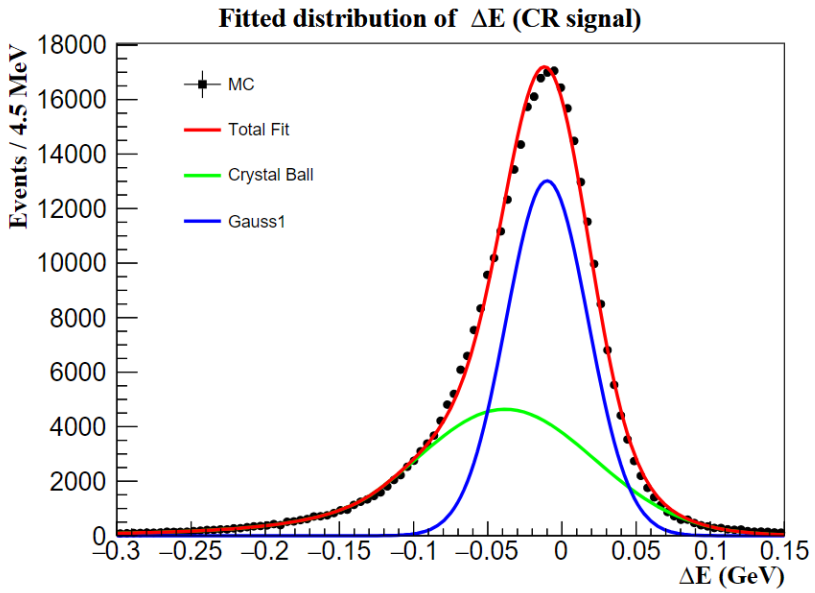
Back up

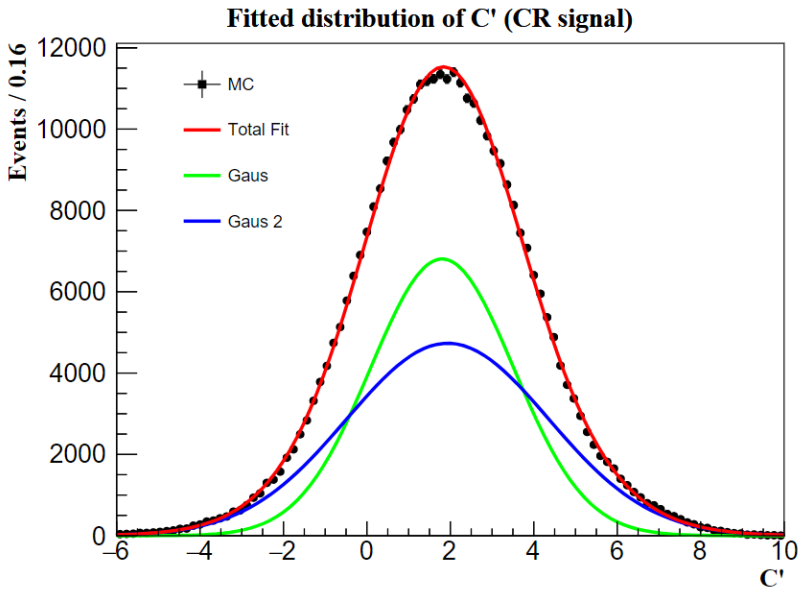
photonMVA

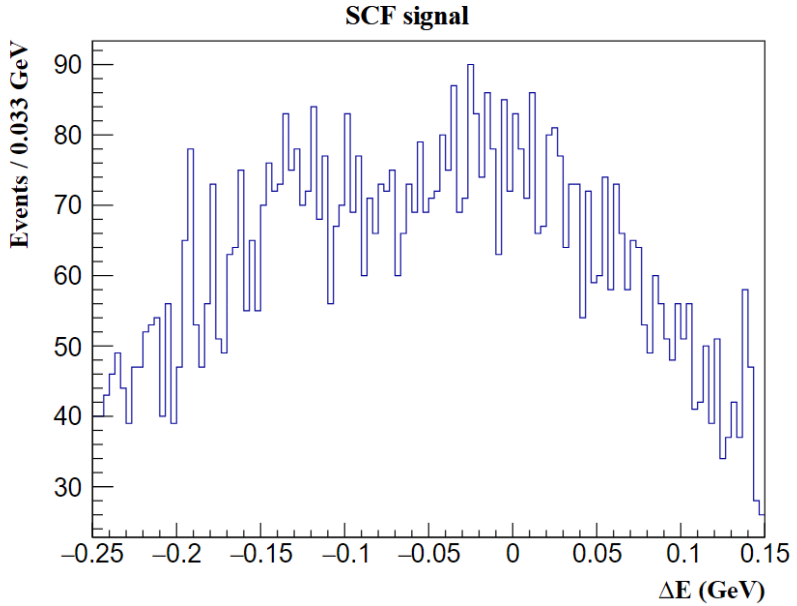
γ relevant variable	
beamBackgroundSuppressionScore	The output of an MVA classifier that uses shower-related variables to distinguish true photon clusters from beam background clusters
fakePhotonSuppressionScore	The output of an MVA classifier that uses shower-related variables to distinguish true photon clusters from fake photon clusters

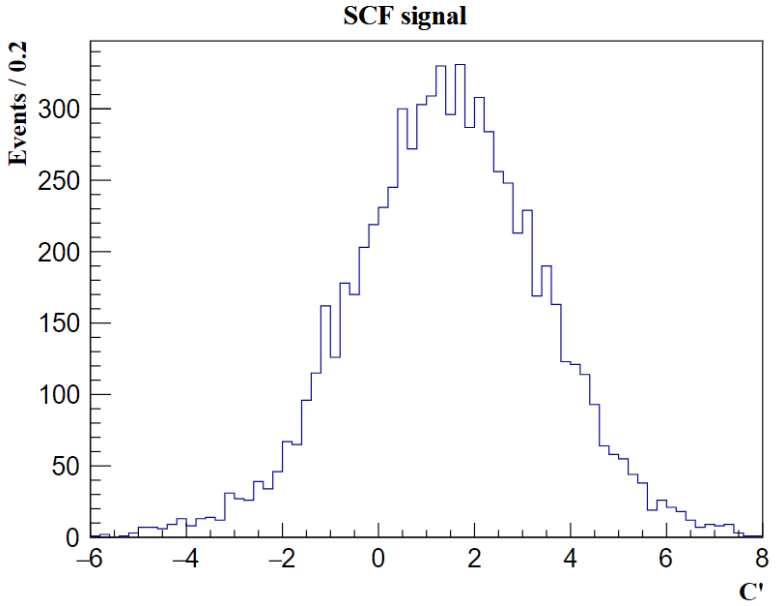
https://confluence.desy.de/display/BI/Neutrals+Performance

PDFs

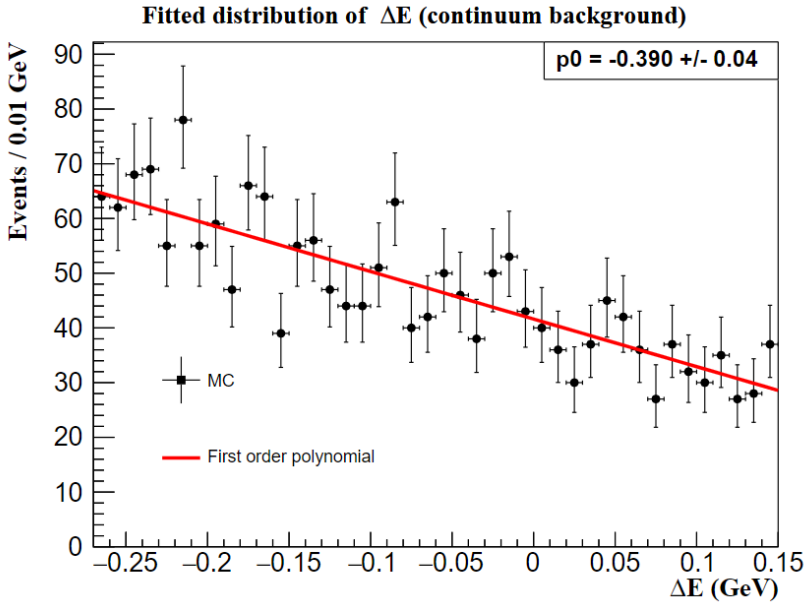

Fitted distribution of ΔE (CR signal)
Events / 4.5 MeV
MC
Total Fit
Crystal Ball
Gauss1
ΔE (GeV)

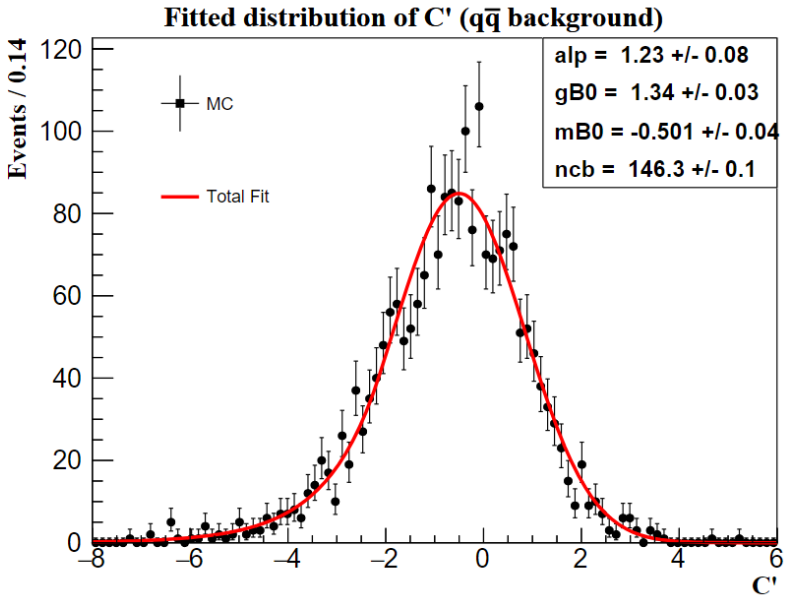

Fitted distribution of C' (CR signal)
Events / 0.16
MC
Total Fit
Gaus
Gaus 2
C'

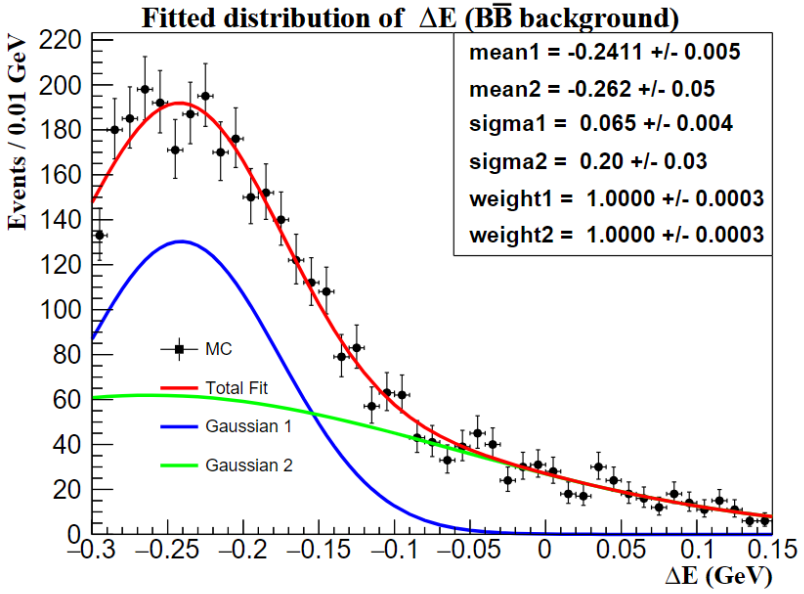

SCF signal
Events / 0.033 GeV
ΔE (GeV)

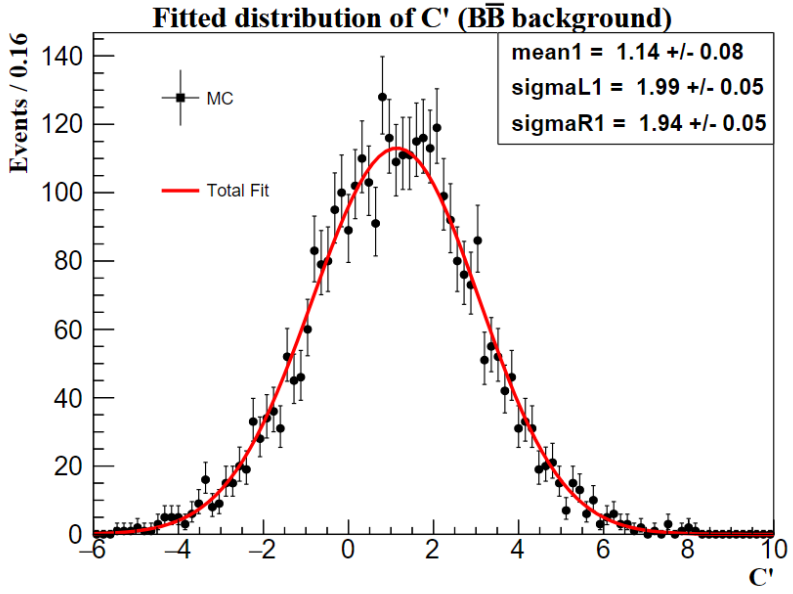

SCF signal
Events / 0.2
C'

PDFs

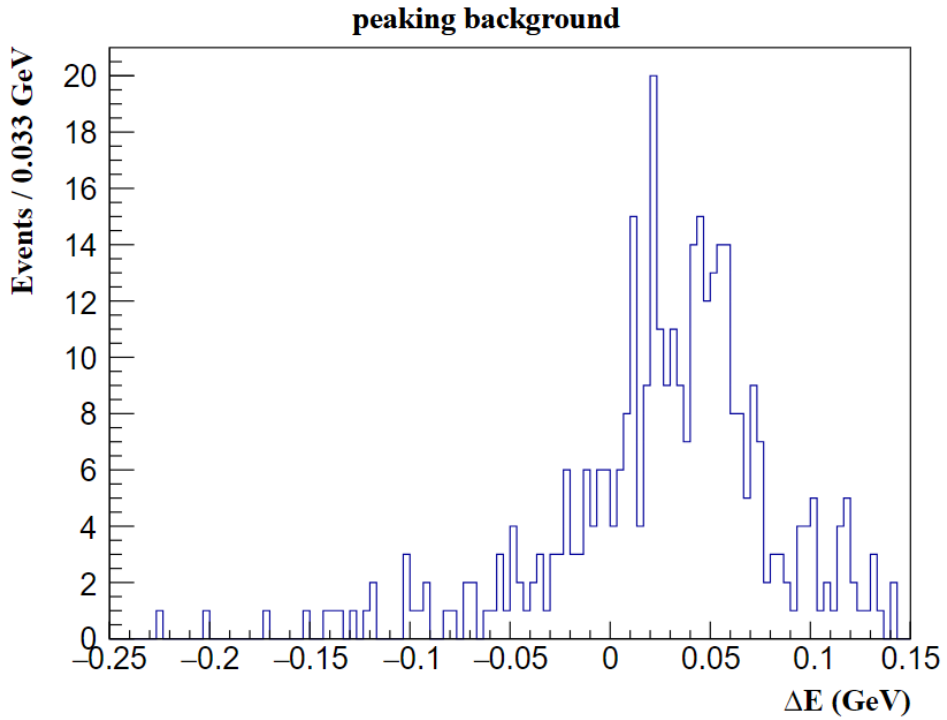

Fitted distribution of ΔE (continuum background)
p0 = -0.390 +/- 0.04
MC
First order polynomial
Events / 0.01 GeV
ΔE (GeV)

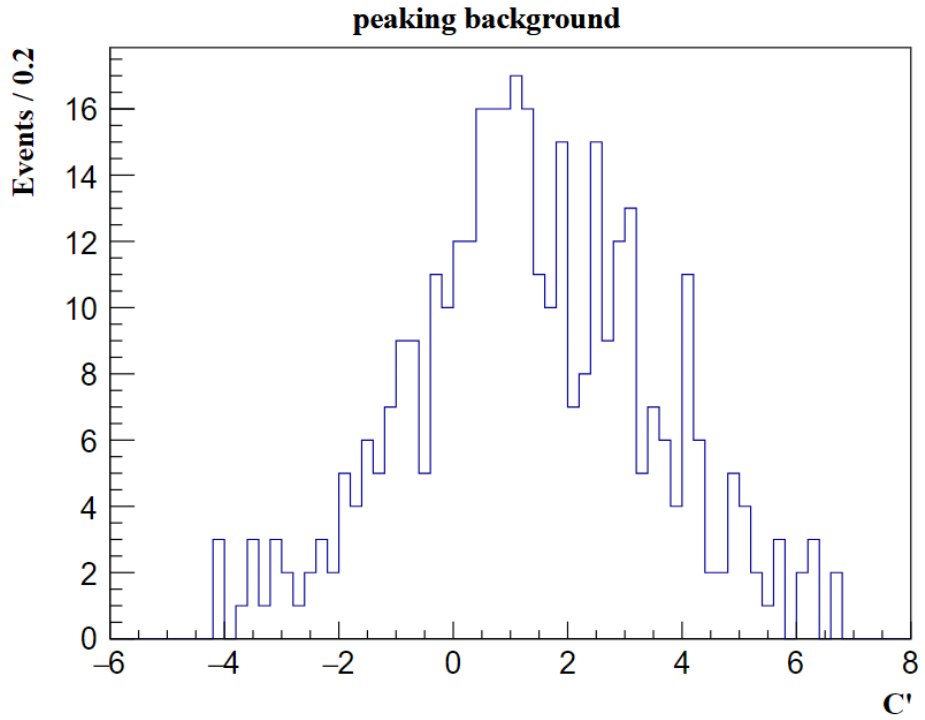

Fitted distribution of C' (qq̄ background)
alp = 1.23 +/- 0.08
gB0 = 1.34 +/- 0.03
mB0 = -0.501 +/- 0.04
ncb = 146.3 +/- 0.1
MC
Total Fit
Events / 0.14
C'


Fitted distribution of ΔE (BB̄ background)
mean1 = -0.2411 +/- 0.005
mean2 = -0.262 +/- 0.05
sigma1 = 0.065 +/- 0.004
sigma2 = 0.20 +/- 0.03
weight1 = 1.0000 +/- 0.0003
weight2 = 1.0000 +/- 0.0003
MC
Total Fit
Gaussian 1
Gaussian 2
Events / 0.01 GeV
ΔE (GeV)

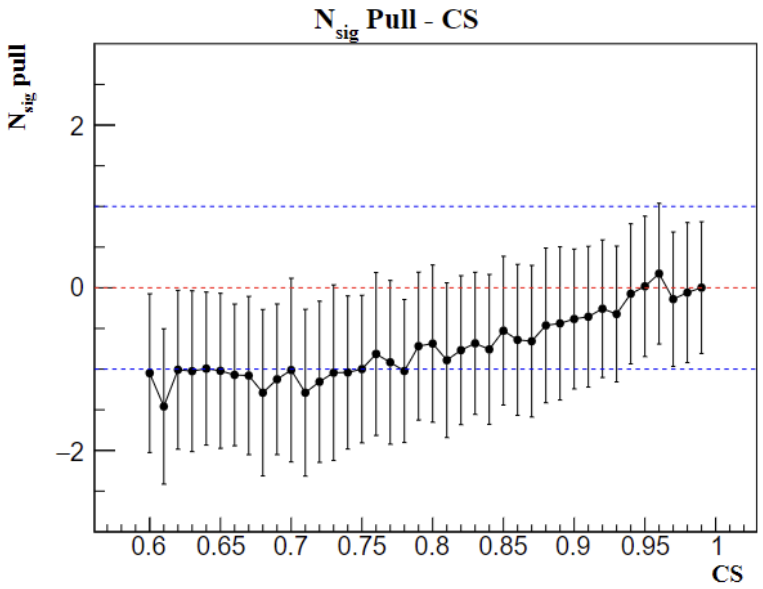

Fitted distribution of C' (BB̄ background)
mean1 = 1.14 +/- 0.08
sigmaL1 = 1.99 +/- 0.05
sigmaR1 = 1.94 +/- 0.05
MC
Total Fit
Events / 0.16
C'

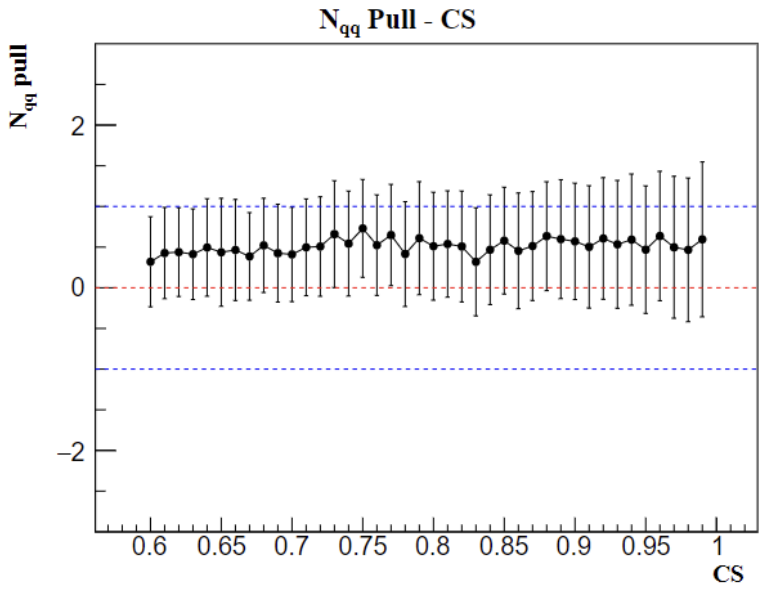
PDFs

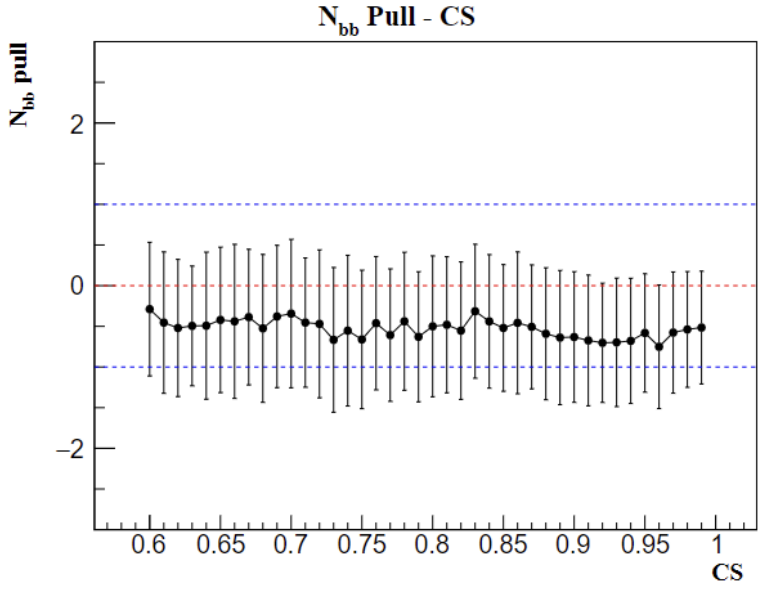

peaking background
Events / 0.033 GeV
20
18
16
14
12
10
8
6
4
2
0
−0.25
−0.2
−0.15
−0.1
−0.05
0
0.05
0.1
0.15
ΔE (GeV)

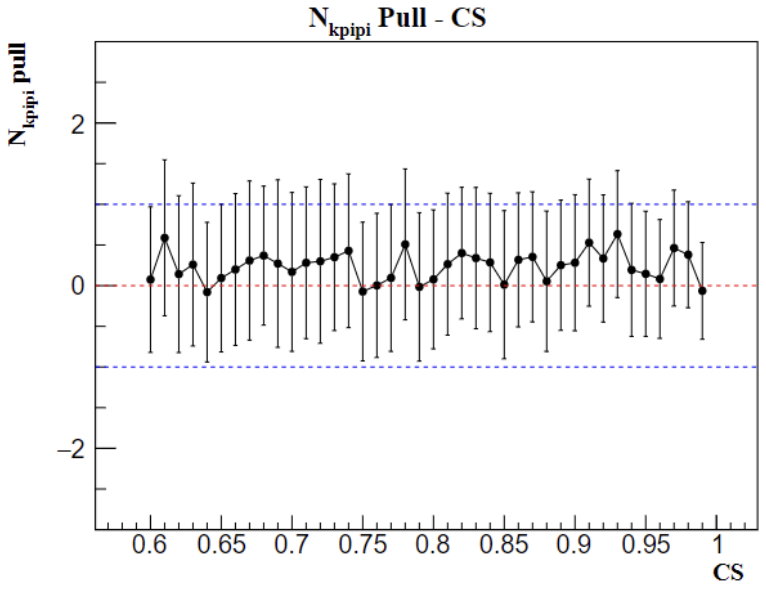

peaking background
Events / 0.2
16
14
12
10
8
6
4
2
0
−6
−4
−2
0
2
4
6
8
C'

Different CS cut

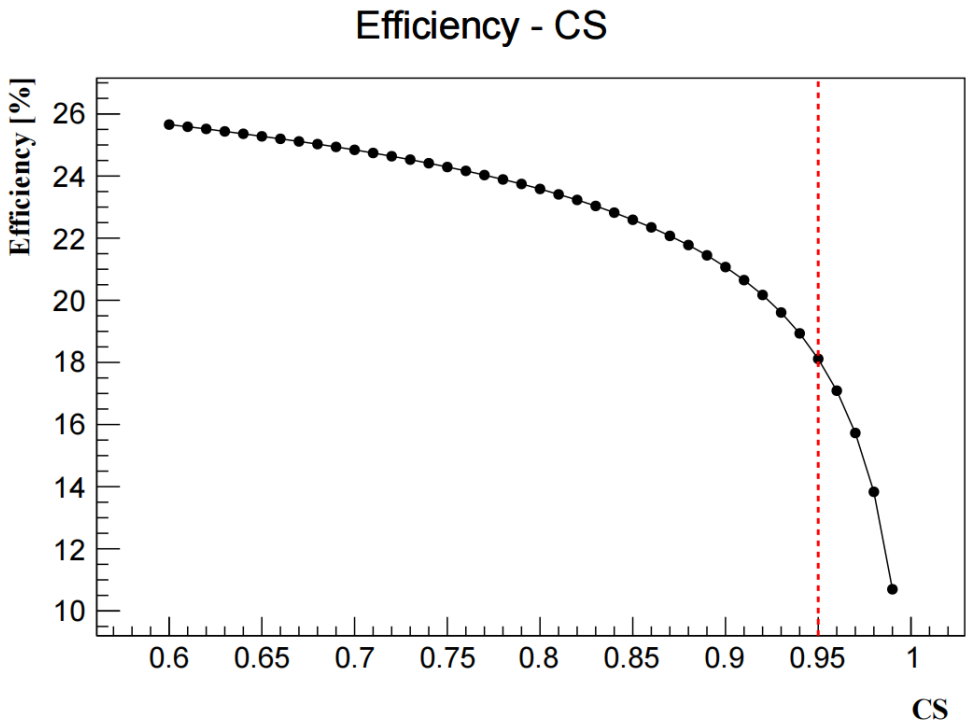


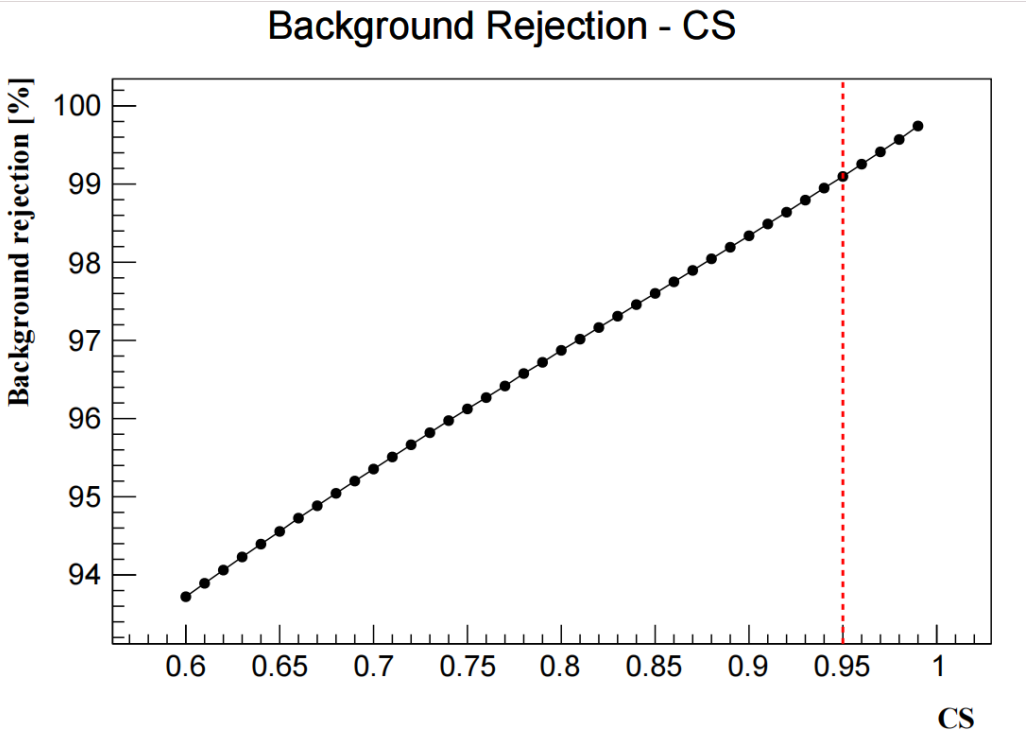




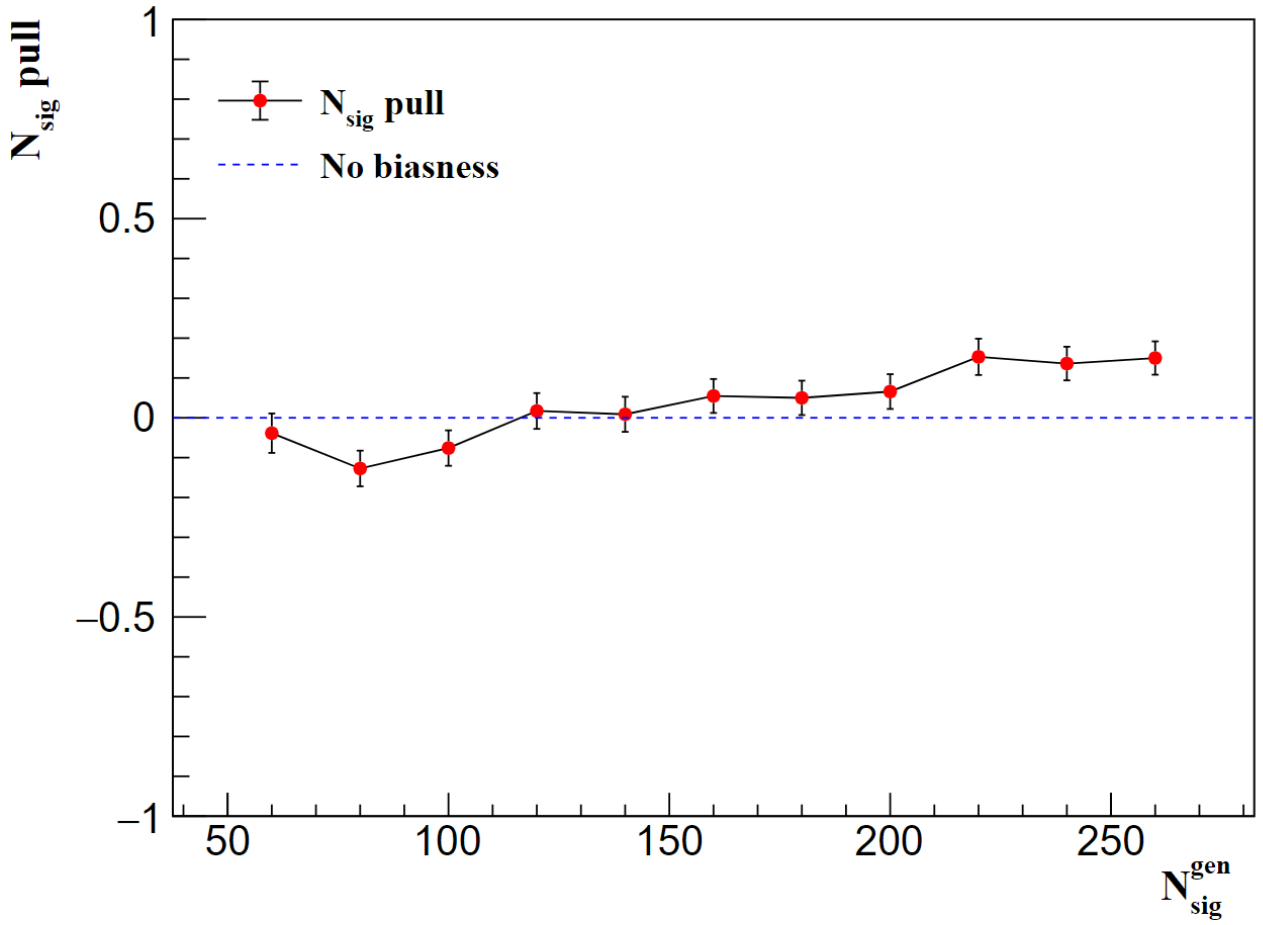


Different CS cut



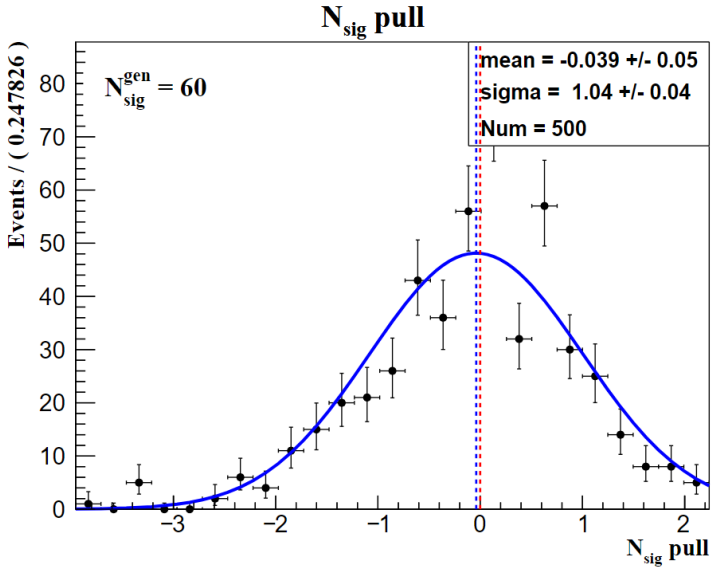


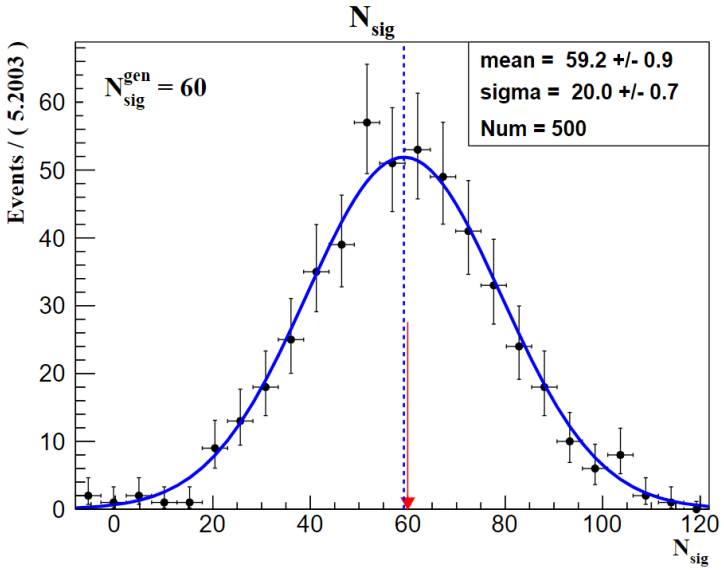
Linearity Test

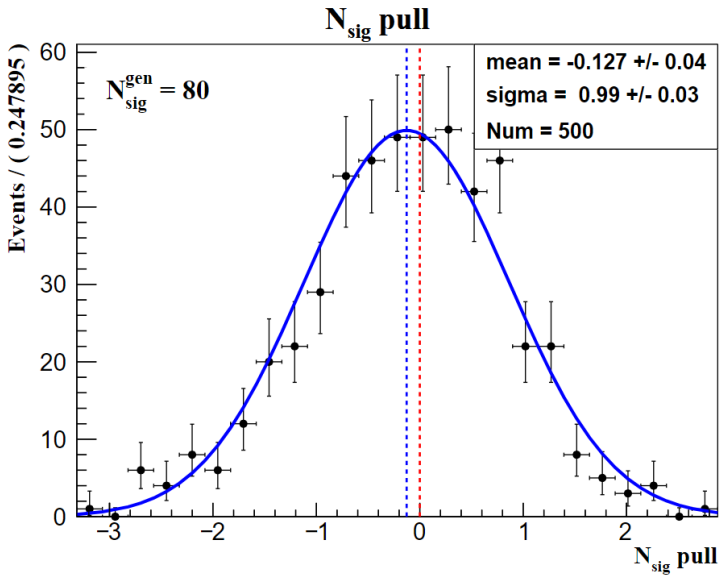


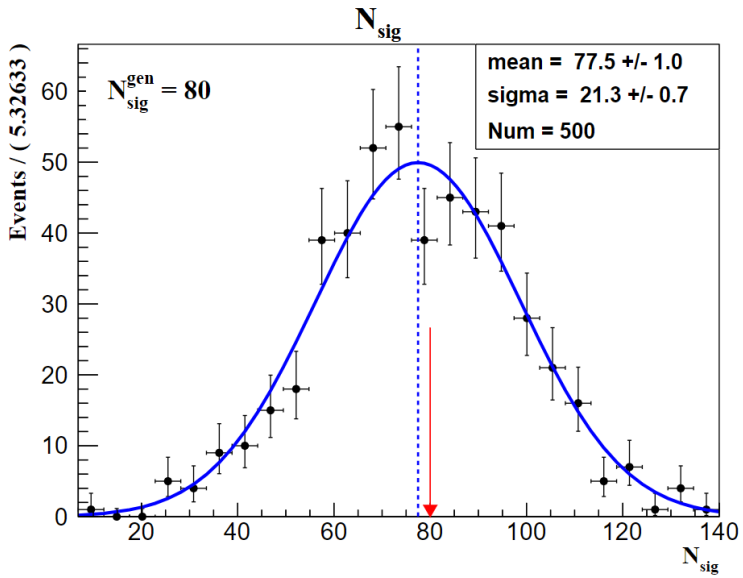
Error bars : Uncertainty on the pull mean

Linearity Test

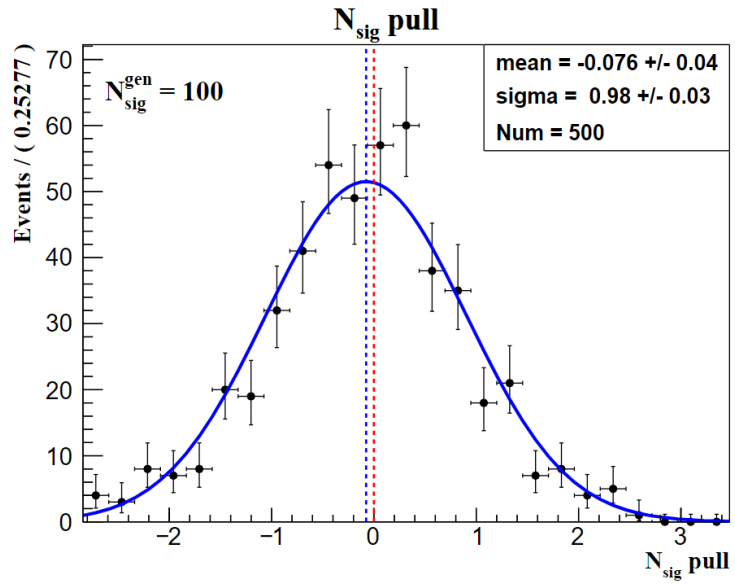


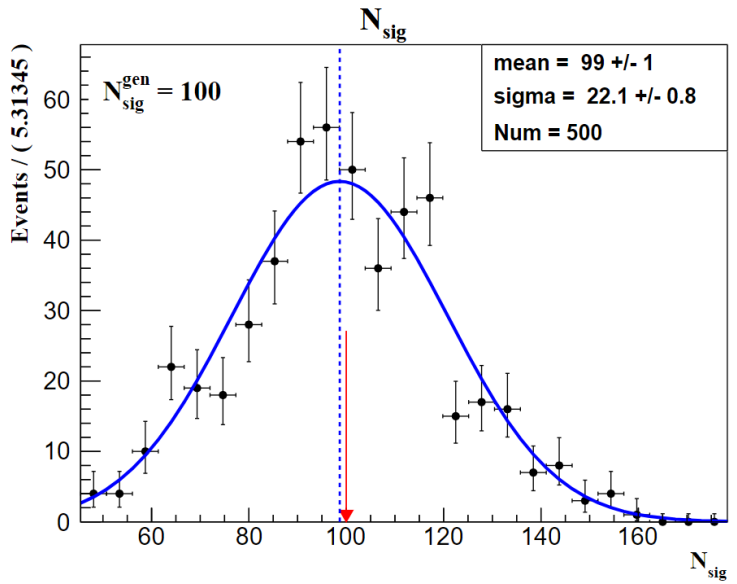


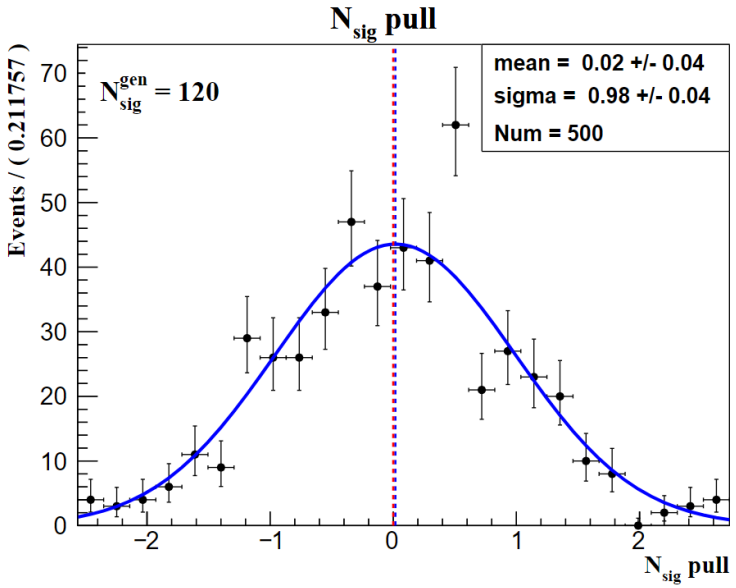


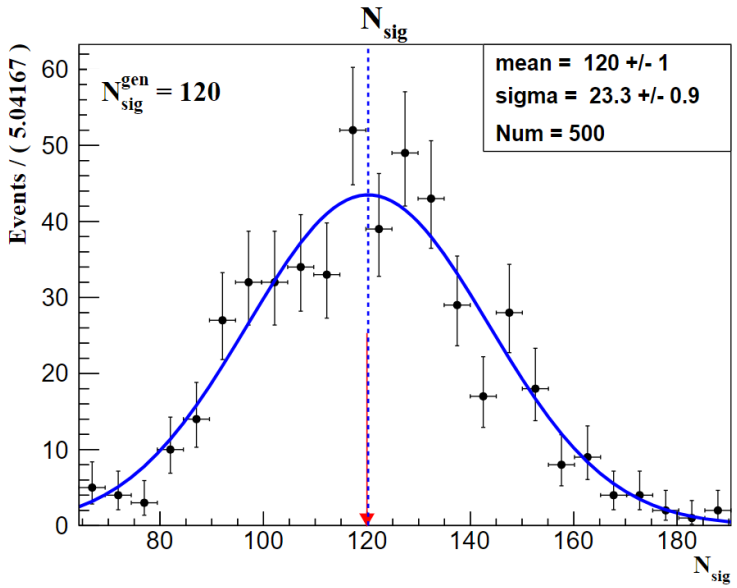


Linearity Test

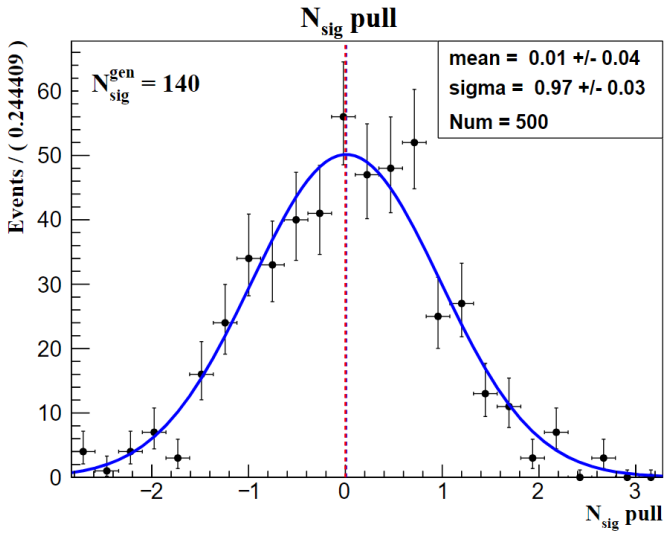


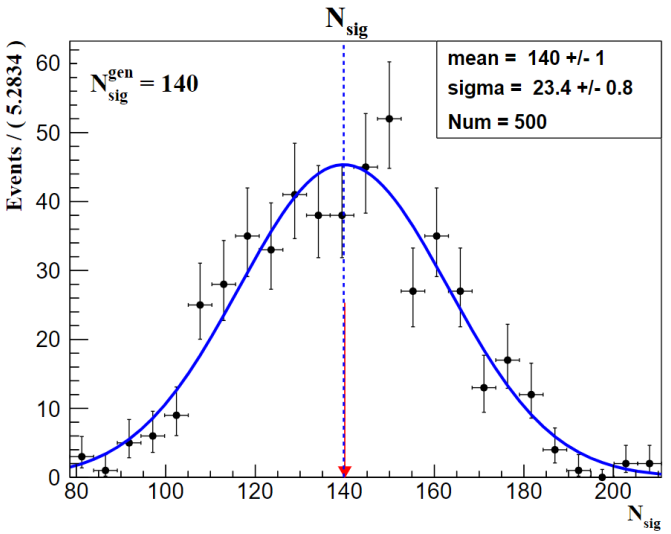


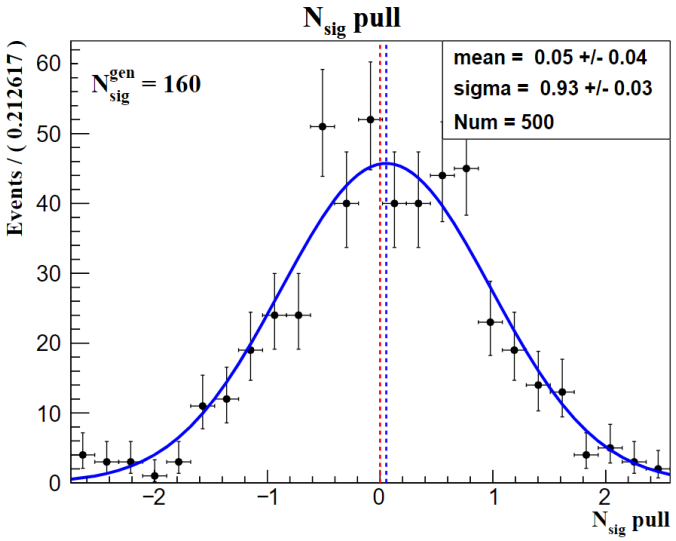


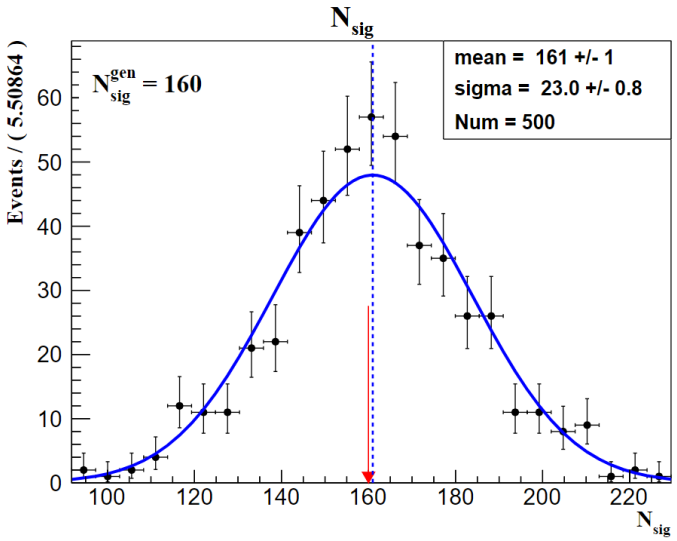


Linearity Test

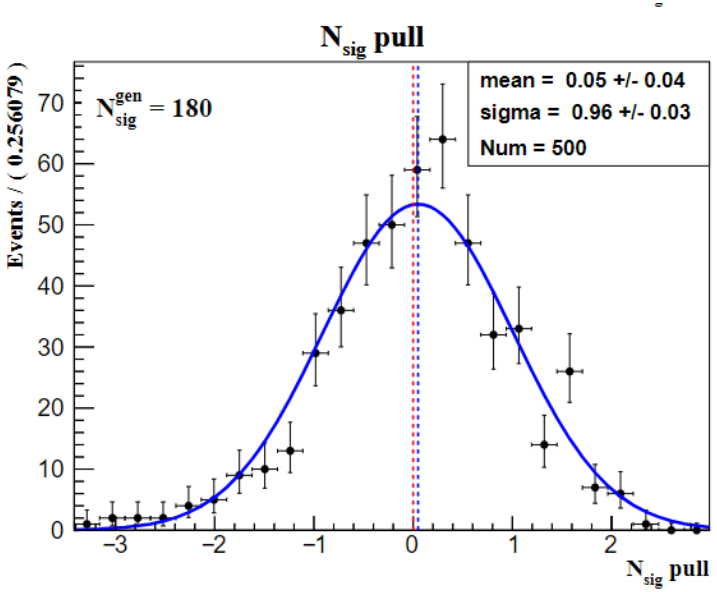


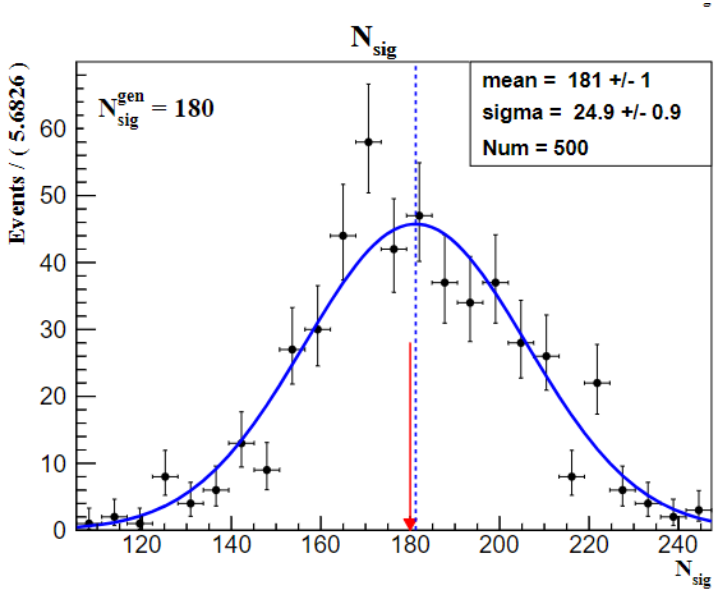


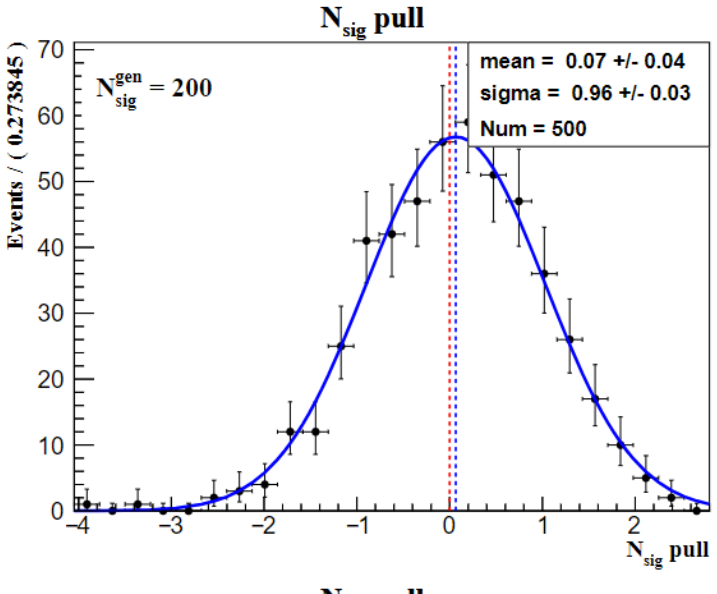


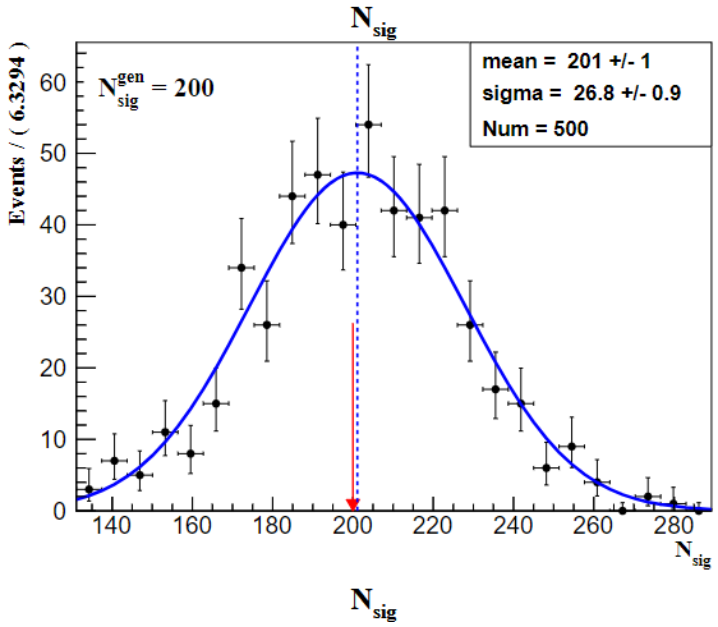


Linearity Test

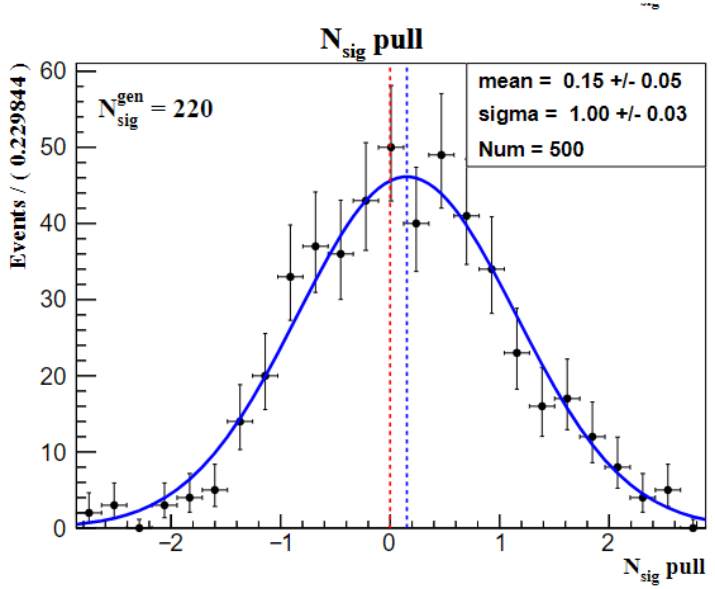


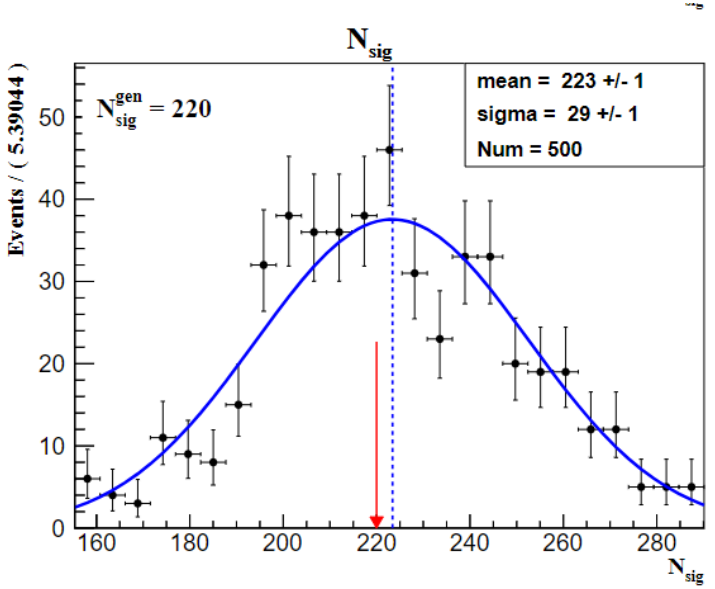


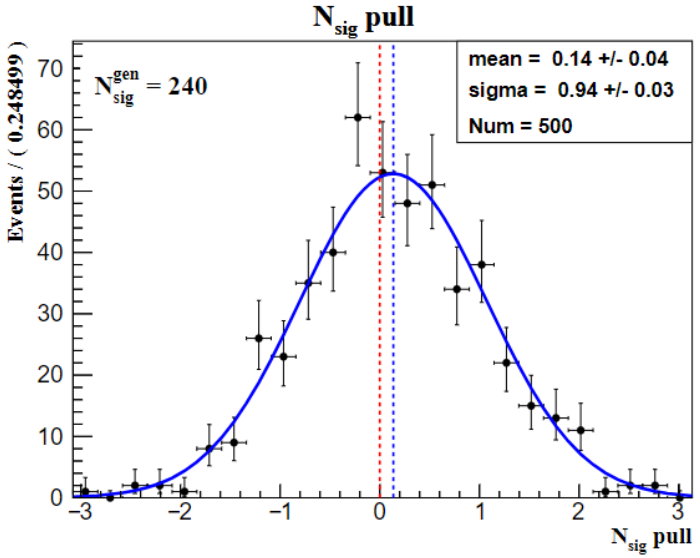


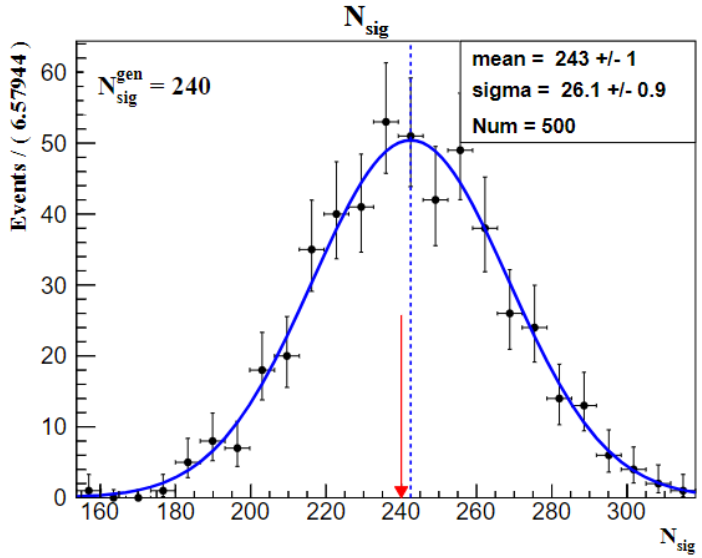


Linearity Test









Linearity Test