

Status report on

$$\eta \rightarrow \pi^+ \pi^- e^+ e^-$$

Phi-decays WG meeting 12-12-2006

Study on the event selection using

800000 signal events private production

~400 runs mc2006 ~50 pb⁻¹

~600 runs rhopi2002 ~42 pb⁻¹

Event selection

Sample	Sigmc	$\rho\pi$ 2002	MC2006
total events	800000	756964816	4484993
nt \geq 3	718935	5698858	1502308
nt \geq 4	155423	14266	4350
ETA4CTAG=1	215826	N.A.	8005
scratch TAG .and. nt \geq 4	155423	14266	4350
Efficiency			
(nt \geq 3 / TE)	0.2162(6)	0.00250(2)	0.00290(4)
(sTAG/nt \geq 3)	0.898(1)	0.007529(3)	0.3349(3)

Event selection

Sample	Sigmc	$\rho\pi$ 2002	MC2006
Efficiency			
(nt \geq 3 / TE)	0.2162(6)	0.00250(2)	0.00290(4)
(sTAG/nt \geq 3)	0.898(1)	0.007529(3)	0.3349(3)
	$\sim 1.94 \cdot 10^{-1}$	$\sim 1.88 \cdot 10^{-5}$	$\sim 0.97 \cdot 10^{-4}$
$\phi \rightarrow \eta \gamma \rightarrow \pi \pi e e \gamma$	$\sim 5.2 \cdot 10^{-6}$		
$\phi \rightarrow \rho \pi + \pi^+ \pi^- \pi^0$	$\sim 15.3 \cdot 10^{-2}$		

Event selection

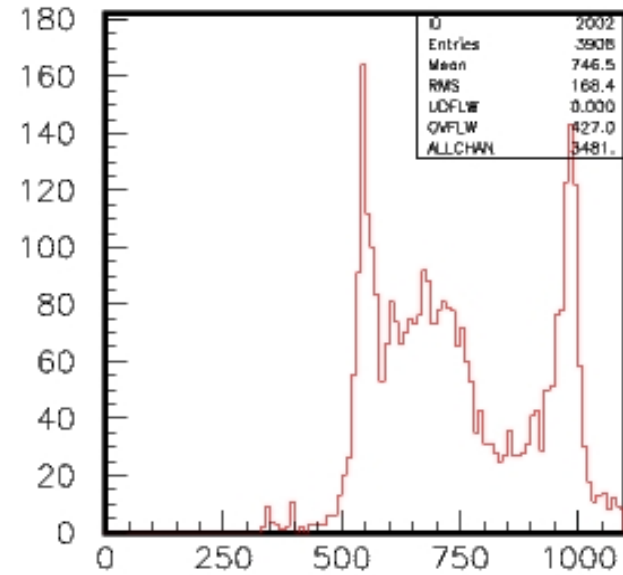
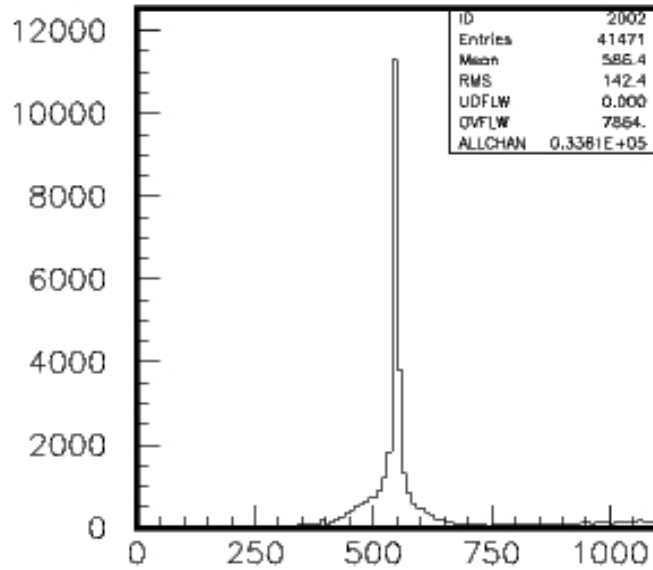
Four different strategies:

- VTXPLUS routine, 4 tracks vertex
- Two 2 tracks vertexes
- Angle between the $\gamma - \Sigma_{\text{trk}}$
- Kinematic fit



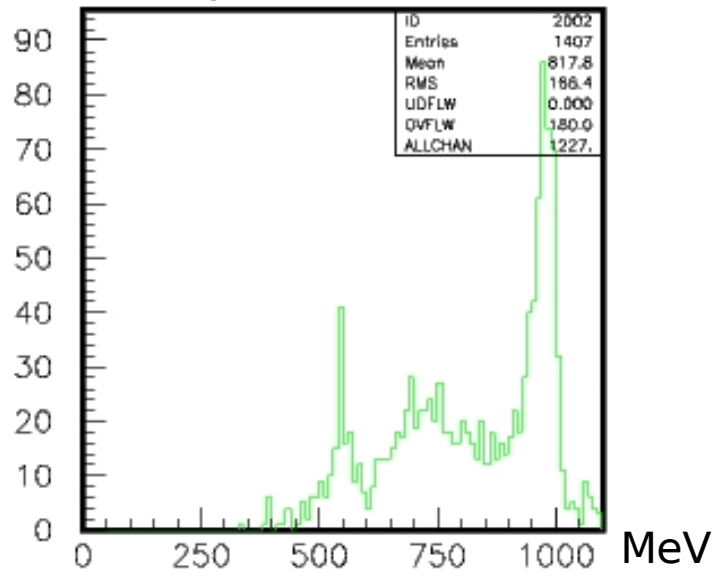
Momenutm conservation
four tracks, radiative photon, ϕ

VTXPLUS



vtxplus etamass1

vtxplus etamass1



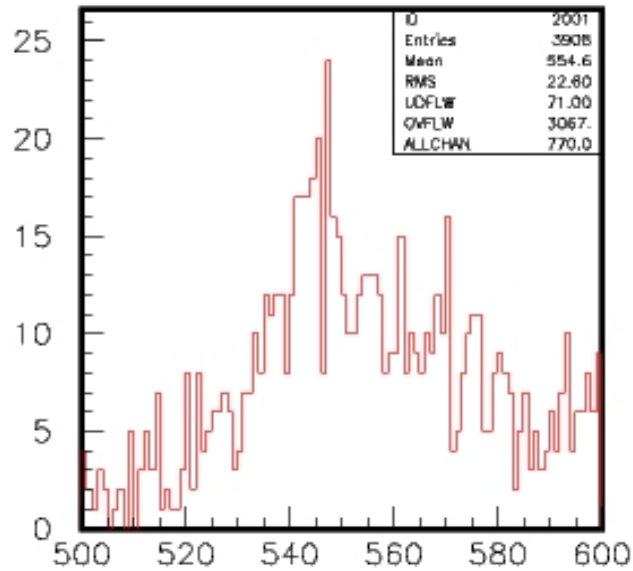
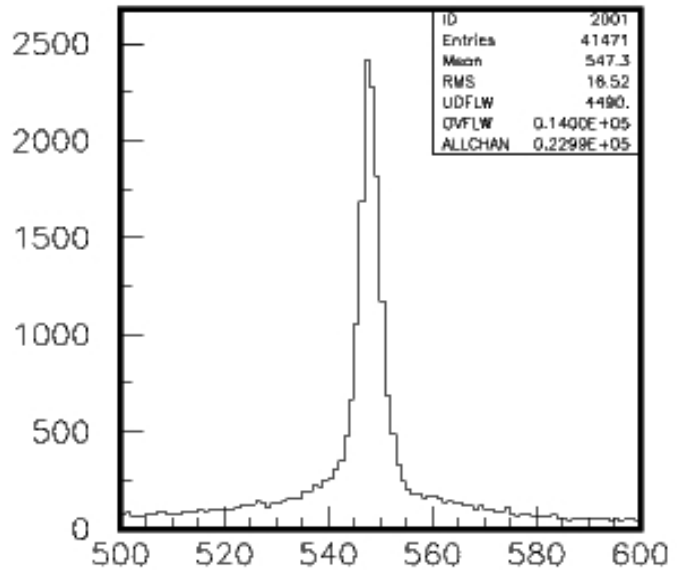
vtxplus etamass1

sigmc

$\rho\pi$ 2002

mc2006

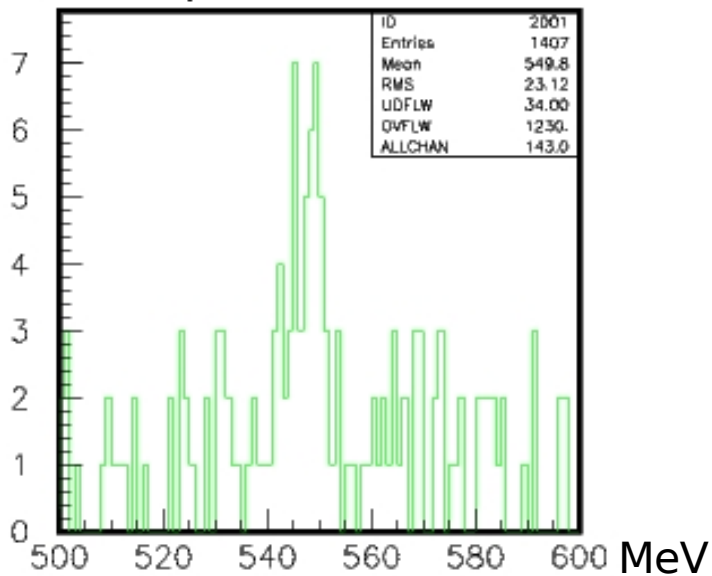
VTXPLUS



sigmc
 $\rho\pi$ 2002
 mc2006

vtxplus etamass1

vtxplus etamass1



vtxplus etamass1

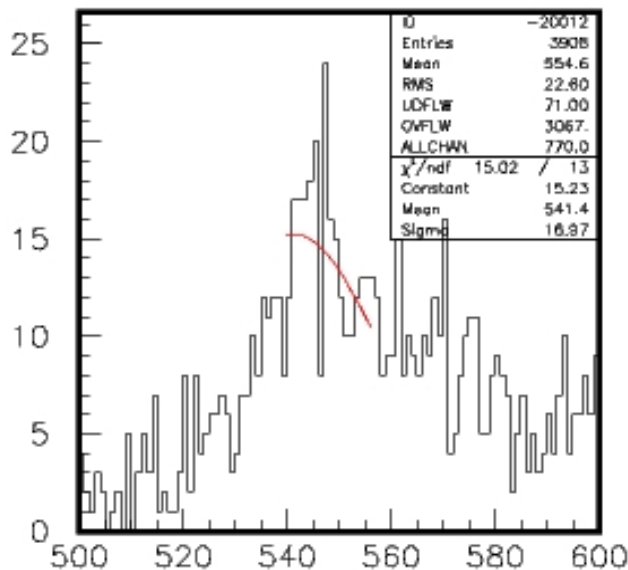
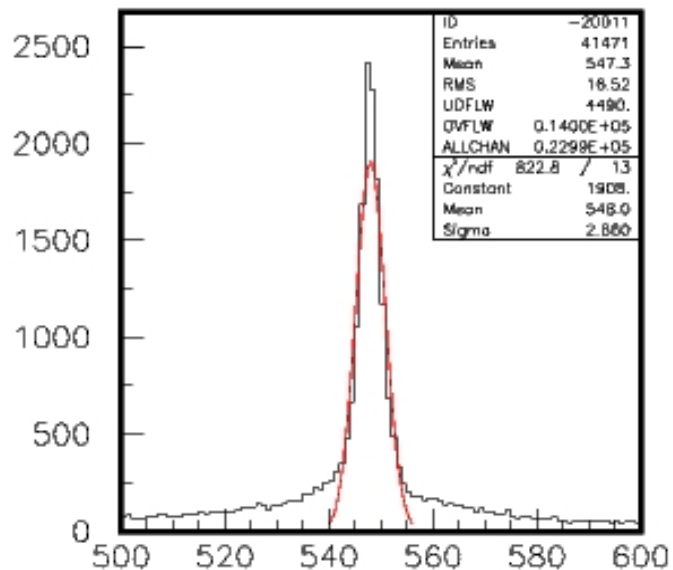
$$540 \leq m(\eta) \leq 555 \text{ MeV}$$

$$\varepsilon = 0.0915 \pm 0.0008$$

$$\varepsilon = 0.0151 \pm 0.0010$$

$$\varepsilon = 0.0070 \pm 0.0010$$

VTXPLUS

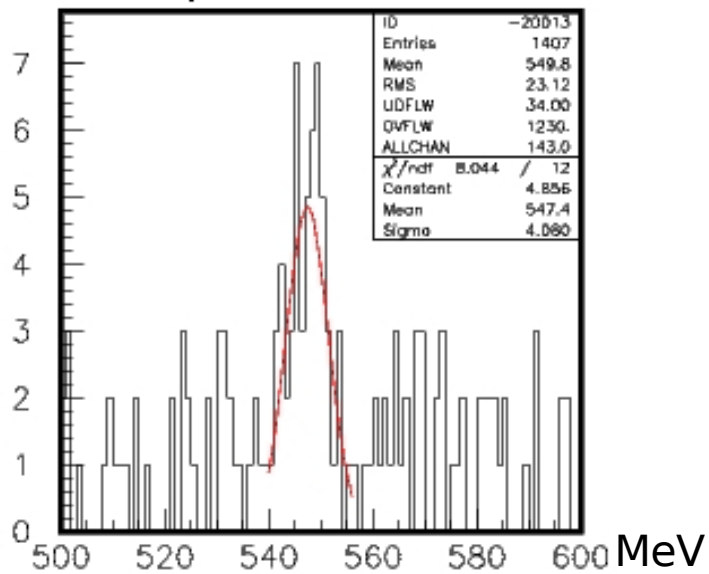


$$\chi^2/\text{dof} = 822/13$$

$$\chi^2/\text{dof} = 15/13$$

$$\chi^2/\text{dof} = 8/12$$

vtxplus etamass1



vtxplus etamass1

$$m(\eta) = 548.04 \pm 0.01 \quad \sigma = 2.86 \pm 0.03$$

$$m(\eta) = 541.39 \pm 4.18 \quad \sigma = 17.0 \pm 5.8$$

$$m(\eta) = 548.04 \pm 0.01 \quad \sigma = 4.08 \pm 0.85$$

vtxplus etamass1

Fit range 540-555 MeV



Session Edit View Bookmarks Settings Help

```
=====
VTXPLUS histo 2001 range 540-555 MeV
=====
```

```
FCN= 822.7830 FROM MIGRAD STATUS=FAILED 98 CALLS 99 TOTAL
EDM= 0.33E+00 STRATEGY=1 ERROR MATRIX UNCERTAINTY= 9.5%
```

EXT	PARAMETER		APPROXIMATE	STEP	FIRST
NO.	NAME	VALUE	ERROR	SIZE	DERIVATIVE
1	Constant	1907.8	24.757	0.0000	0.12843E-02
2	Mean	548.04	0.13681E-01	0.0000	39.907
3	Sigma	2.8595	0.29801E-01	0.0000	0.81122

```
CHISQUARE = 0.6329E+02 NPFIT = 16
```

```
=====
FCN= 15.02199 FROM MIGRAD STATUS=CONVERGED 189 CALLS 190 TOTAL
EDM= 0.53E-03 STRATEGY= 1 ERROR MATRIX ACCURATE
```

EXT	PARAMETER			STEP	FIRST
NO.	NAME	VALUE	ERROR	SIZE	DERIVATIVE
1	Constant	15.229	1.7495	0.14654	-0.25231E-02
2	Mean	541.39	4.1812	1.3696	0.26230E-02
3	Sigma	16.966	5.7692	0.56781	-0.48754E-02

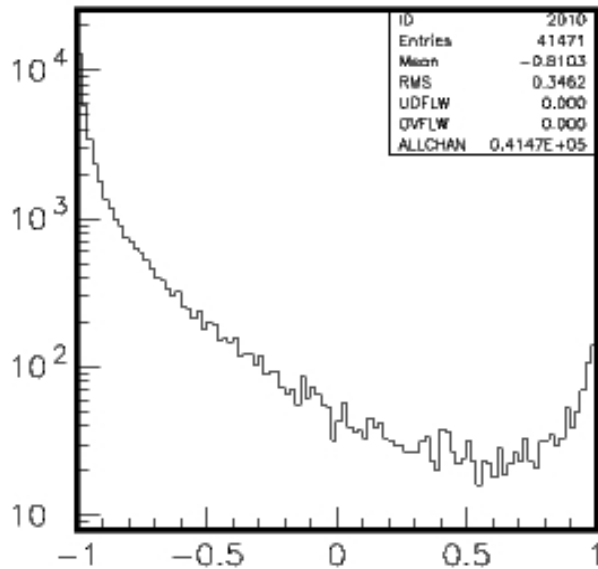
```
CHISQUARE = 0.1156E+01 NPFIT = 16
```

```
=====
FCN= 8.043923 FROM MIGRAD STATUS=CONVERGED 69 CALLS 70 TOTAL
EDM= 0.85E-03 STRATEGY= 1 ERROR MATRIX ACCURATE
```

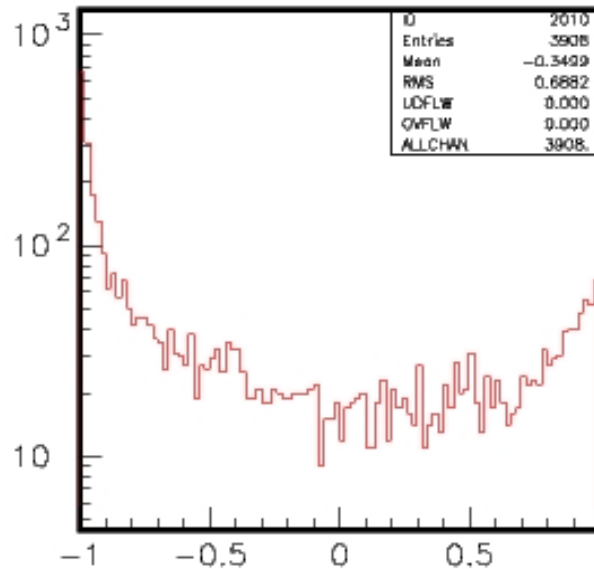
EXT	PARAMETER			STEP	FIRST
NO.	NAME	VALUE	ERROR	SIZE	DERIVATIVE
1	Constant	4.8558	1.0571	0.76756E-01	0.24203E-01
2	Mean	547.43	0.75842	1.3849	-0.21764E-01
3	Sigma	4.0796	0.85093	0.62721E-01	-0.11920E-01

```
CHISQUARE = 0.6703E+00 NPFIT = 15
```

VTXPLUS

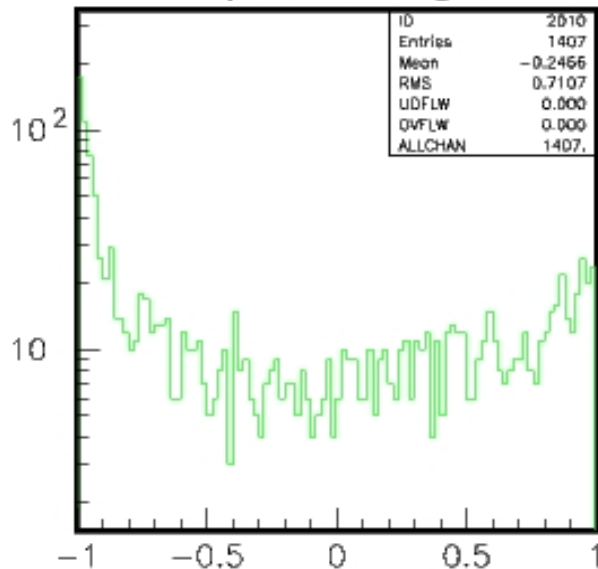


vtxplus cos grk



vtxplus cos grk

sigmc
 $\rho\pi$ 2002
 mc2006



vtxplus cos grk

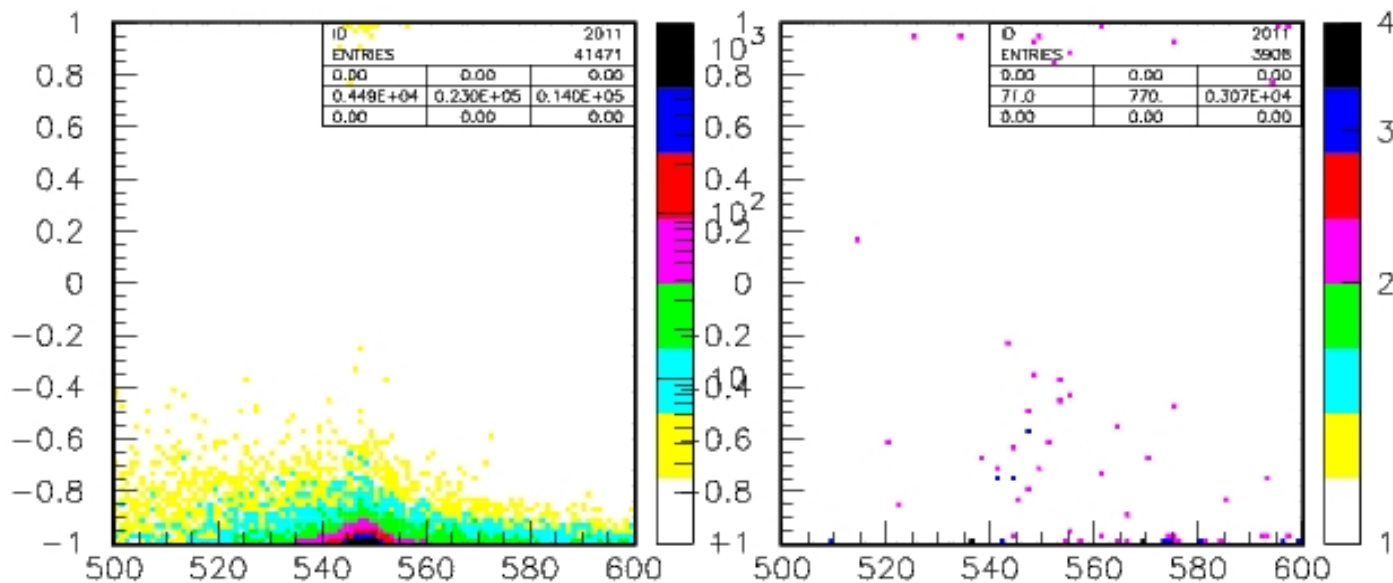
$$\cos(\gamma\text{-trk}) \leq -0.9$$

$$\varepsilon = 0.1686 \pm 0.0011$$

$$\varepsilon = 0.0932 \pm 0.0026$$

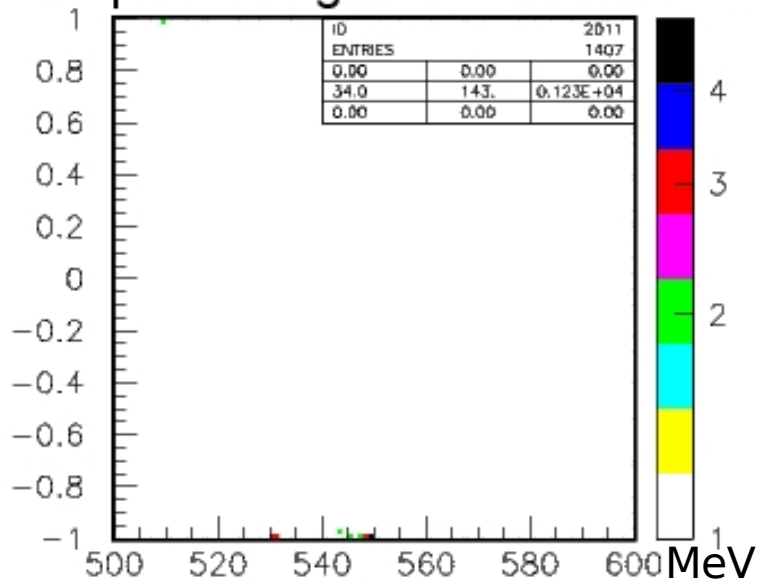
$$\varepsilon = 0.0583 \pm 0.0029$$

VTXPLUS



sigmc
 $\rho\pi$ 2002
 mc2006

vtxplus cos gtrk vs etamass1 vtxplus cos gtrk vs etamass1



$540 \leq m(\eta) \leq 555$ MeV .and.
 $\cos(\gamma\text{-trk}) \leq -0.9$

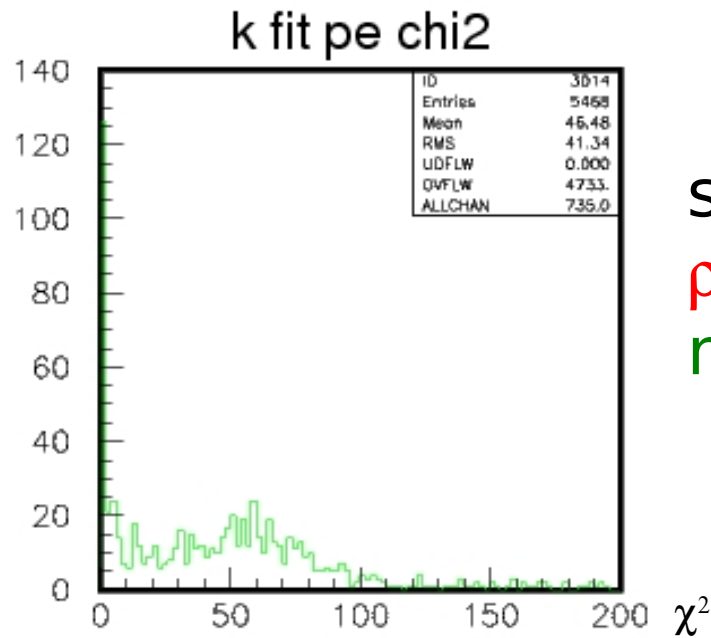
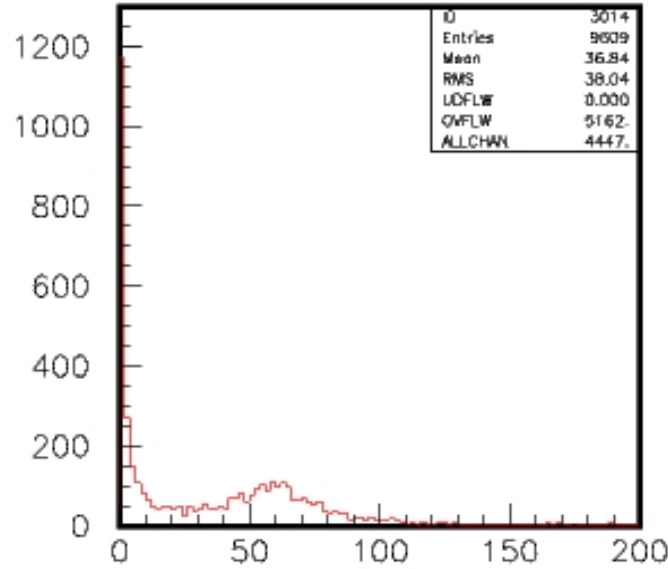
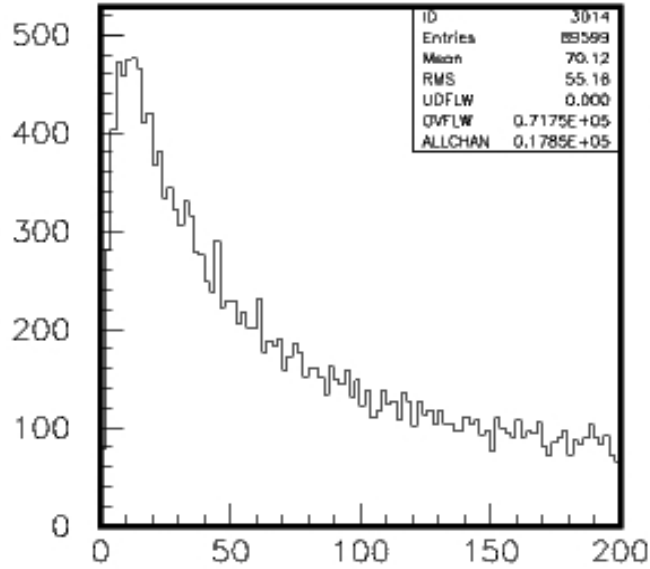
$$\varepsilon = 0.0802 \pm 0.0007$$

$$\varepsilon = 0.0018 \pm 0.0003$$

$$\varepsilon = 0.0041 \pm 0.0007$$

vtxplus cos gtrk vs etamass1

KINEMATIC FIT



sigmc
 $\rho\pi$ 2002
 mc2006

k fit pe chi2

$$\chi^2/\text{dof} \leq 5$$

$$\varepsilon = 0.0863 \pm 0.0008$$

$$\varepsilon = 0.2922 \pm 0.0051$$

$$\varepsilon = 0.0911 \pm 0.0036$$

$$\chi^2/\text{dof} \leq 2$$

$$\varepsilon = 0.0494 \pm 0.0006$$

$$\varepsilon = 0.1760 \pm 0.0038$$

$$\varepsilon = 0.0490 \pm 0.0026$$

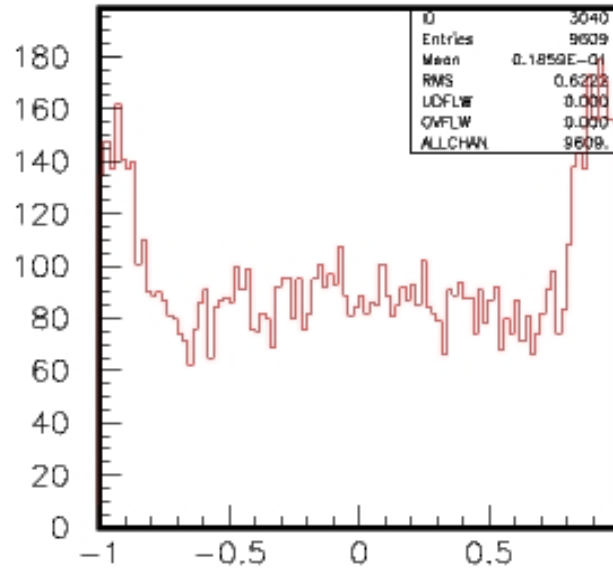
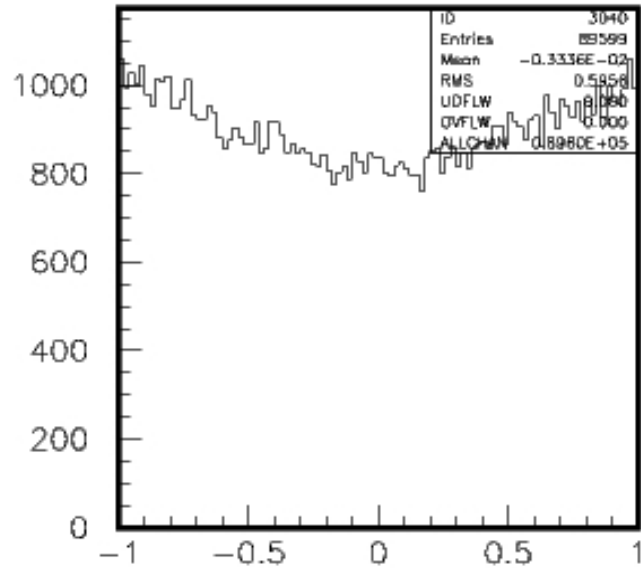
$$\chi^2/\text{dof} \leq 1$$

$$\varepsilon = 0.0277 \pm 0.0004$$

$$\varepsilon = 0.1415 \pm 0.0033$$

$$\varepsilon = 0.0340 \pm 0.0021$$

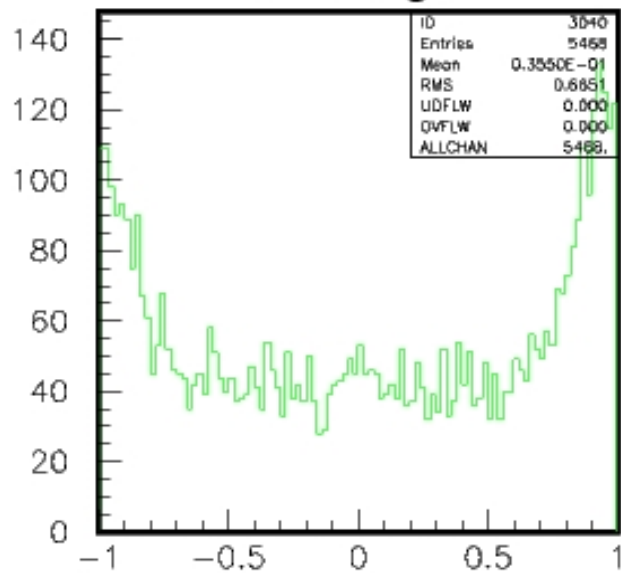
KINEMATIC FIT



sigmc
 $\rho\pi$ 2002
mc2006

kfit cos grk

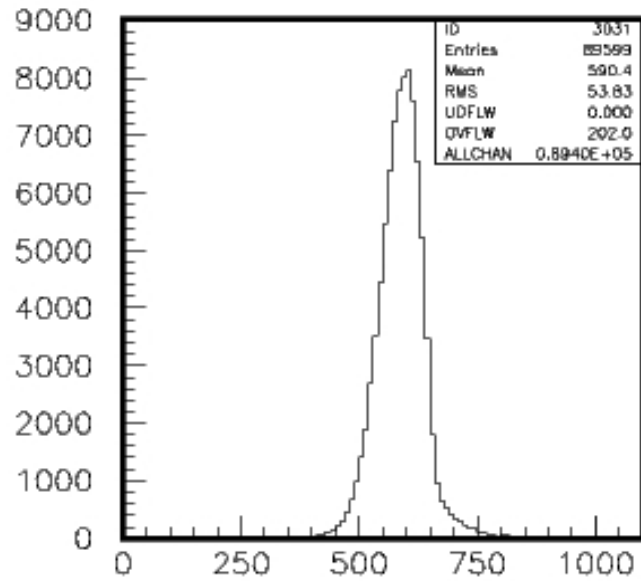
kfit cos grk



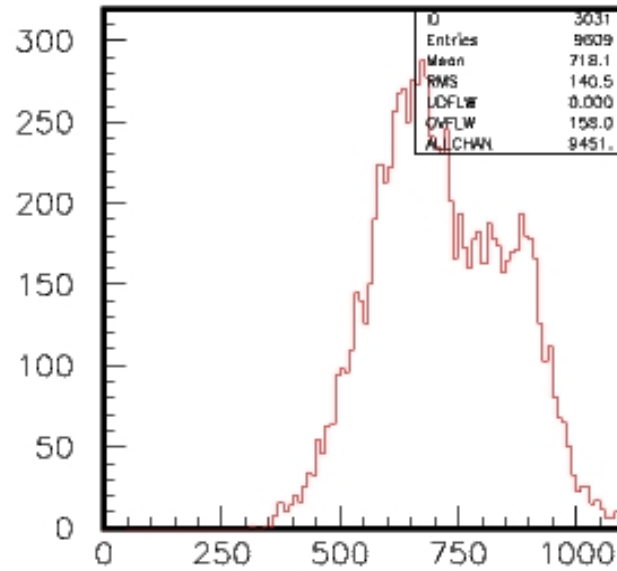
kfit cos grk

Wrong sign of track momenta
under investigation

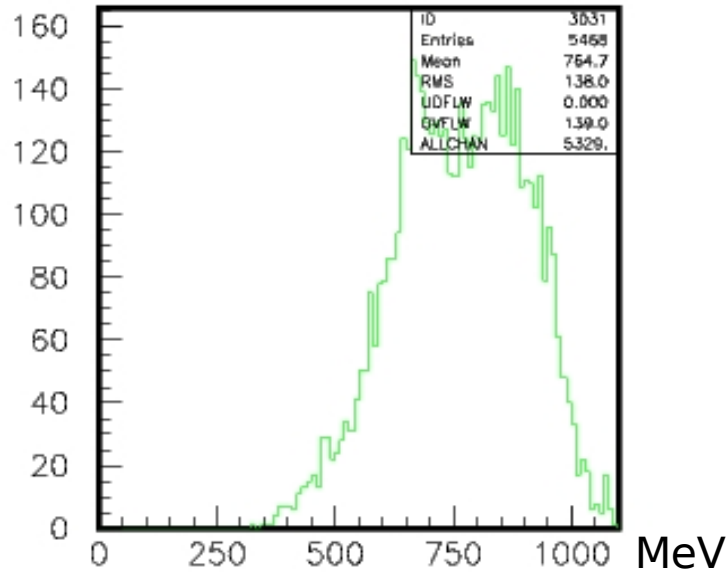
KINEMATIC FIT



kfit etamass



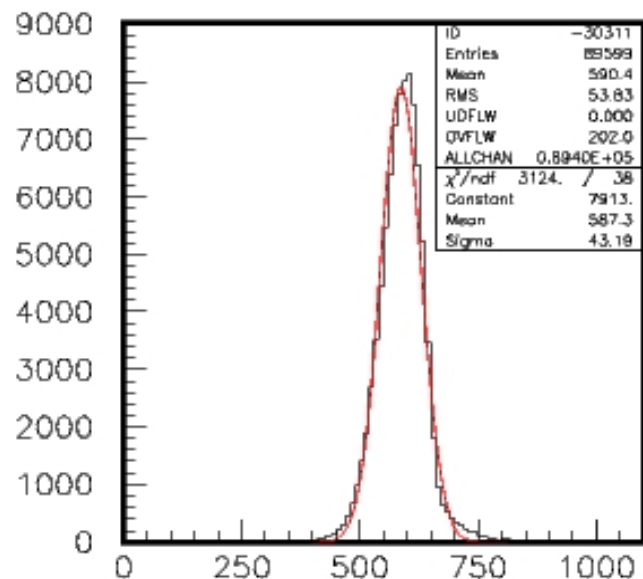
kfit etamass



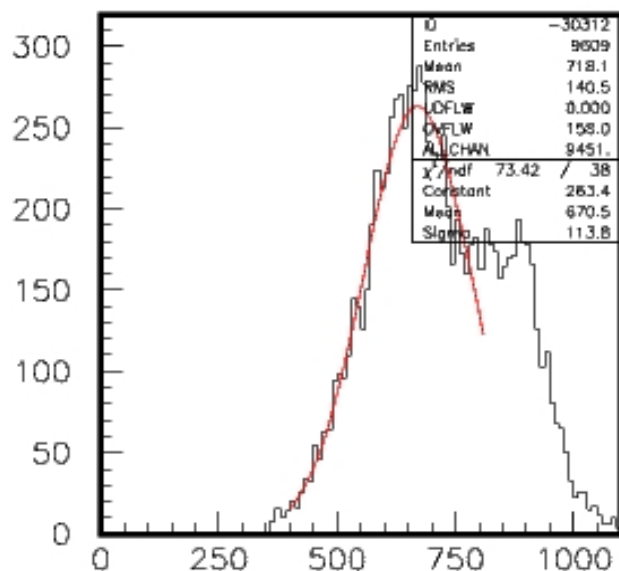
kfit etamass

sigmc
 $\rho\pi$ 2002
mc2006

KFIT



kfit etamass

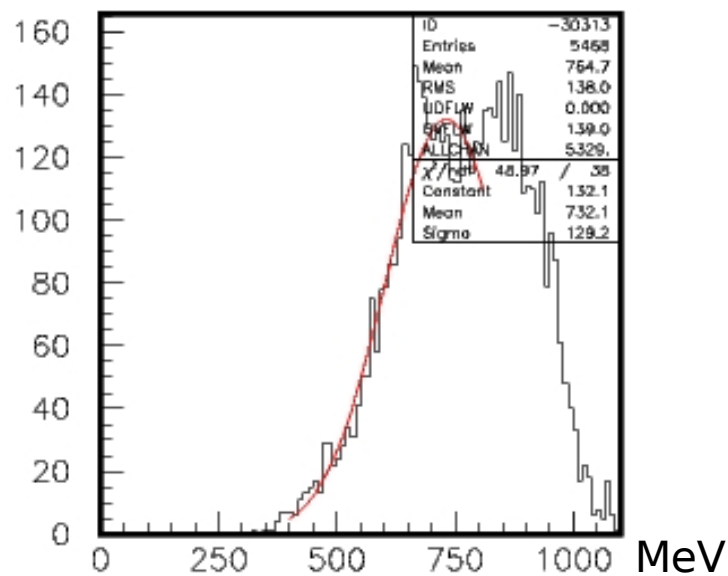


kfit etamass

$$\chi^2/\text{dof} = 3124/38$$

$$\chi^2/\text{dof} = 73/38$$

$$\chi^2/\text{dof} = 48/38$$



kfit etamass

$$m(\eta) = 587.28 \pm 0.10 \quad \sigma = 43.1 \pm 0.13$$

$$m(\eta) = 670.46 \pm 2.23 \quad \sigma = 113.8 \pm 2.0$$

$$m(\eta) = 732.10 \pm 6.54 \quad \sigma = 129.2 \pm 4.5$$

Fit range 400-800 MeV

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```
=====
=====
===== KFIT histo 3031 fit range 400-800 MeV
=====
```

```
FCN= 3124.155 FROM MIGRAD STATUS=CONVERGED 77 CALLS 78 TOTAL
EDM= 0.13E-02 STRATEGY=1 ERROR MATRIX UNCERTAINTY= 0.6%
```

EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	Constant	7913.4	36.925	0.0000	-0.66147E-04
2	Mean	587.28	0.98738E-01	0.0000	0.48052
3	Sigma	43.192	0.13150	0.0000	0.10992E-01

```
CHISQUARE = 0.8221E+02 NPFIT = 41
```

```
=====
=====
FCN= 73.41729 FROM MIGRAD STATUS=CONVERGED 81 CALLS 82 TOTAL
EDM= 0.57E-04 STRATEGY= 1 ERROR MATRIX ACCURATE
```

EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	Constant	263.44	4.1957	0.99250	-0.79442E-05
2	Mean	670.46	2.2389	1.6962	0.47618E-02
3	Sigma	113.77	2.0017	0.38115	-0.58561E-05

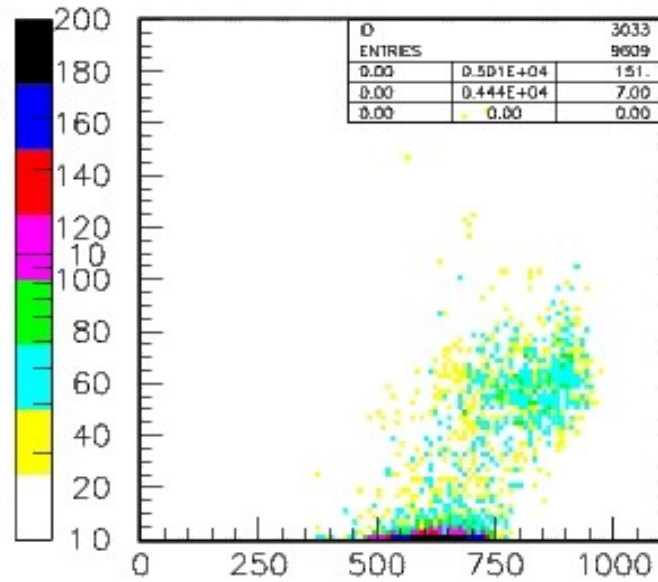
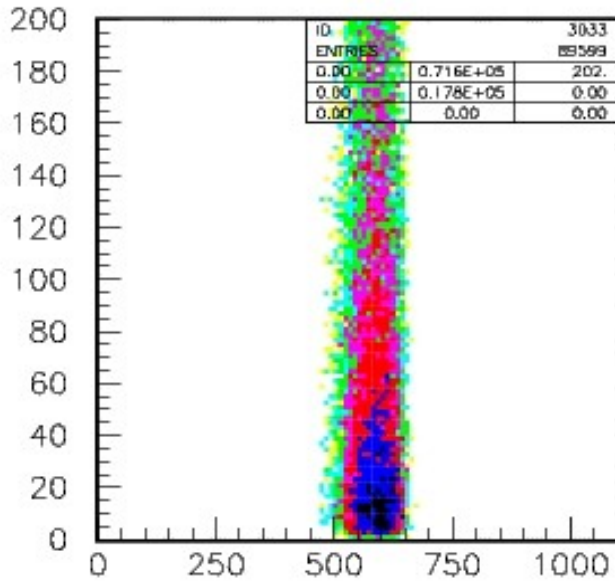
```
CHISQUARE = 0.1932E+01 NPFIT = 41
```

```
=====
=====
FCN= 48.97064 FROM MIGRAD STATUS=CONVERGED 83 CALLS 84 TOTAL
EDM= 0.76E-04 STRATEGY= 1 ERROR MATRIX ACCURATE
```

EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	Constant	132.10	2.8811	0.59704	-0.79624E-03
2	Mean	732.10	6.5389	1.8521	0.15863E-02
3	Sigma	129.23	4.5412	0.48484	0.45895E-03

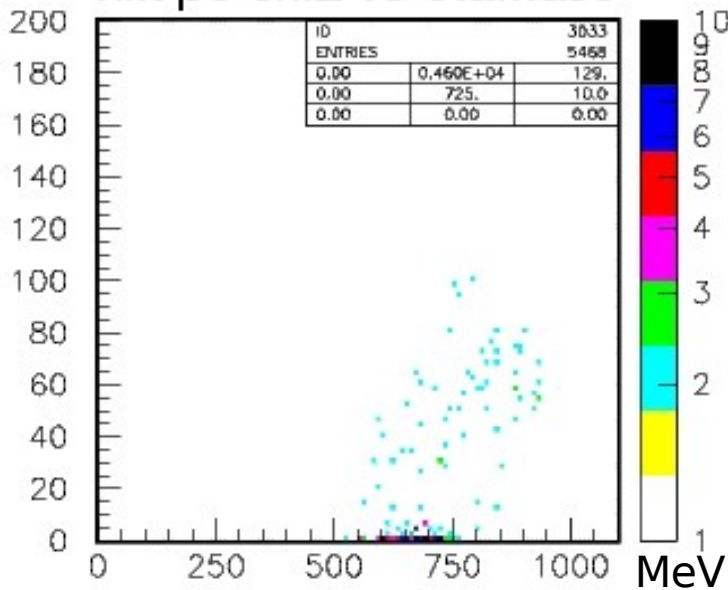
```
CHISQUARE = 0.1289E+01 NPFIT = 41
```


KINEMATIC FIT



sigmc
 $\rho\pi$ 2002
 mc2006

χ^2 kfit pe chi2 vs etamass

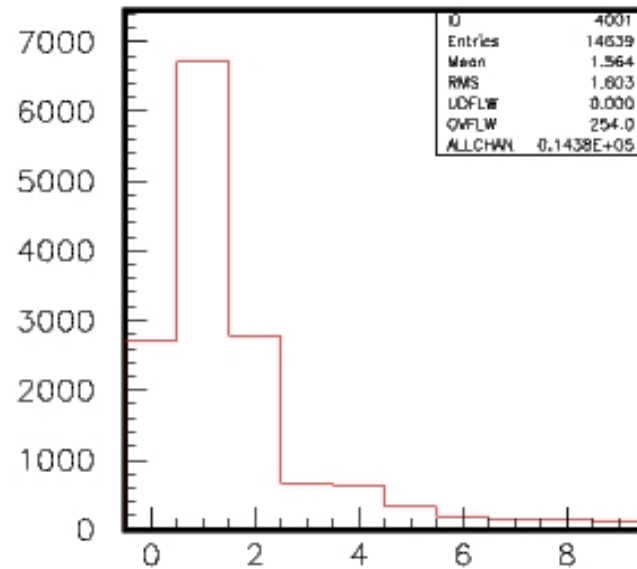
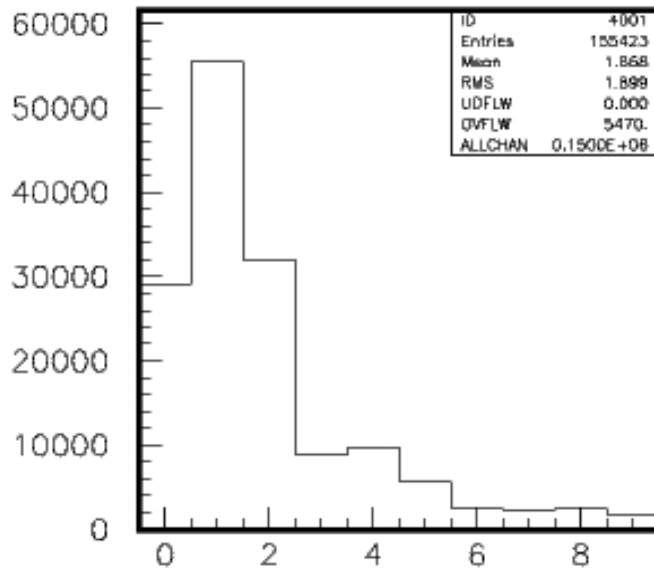


kfit pe chi2 vs etamass

kfit pe chi2 vs etamass

MeV

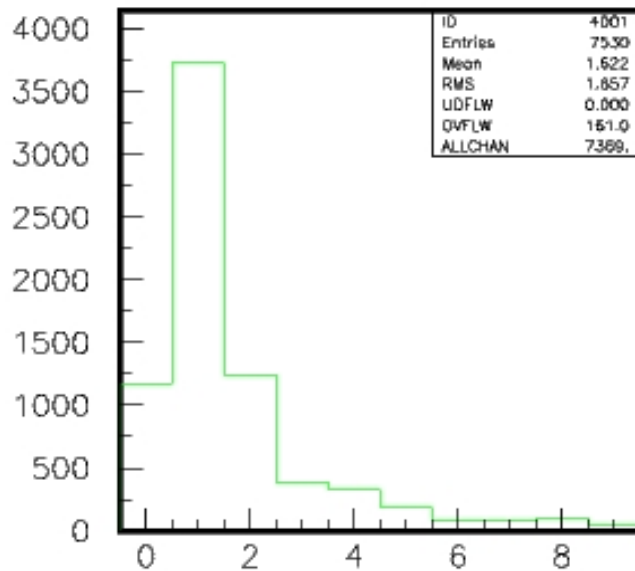
DOUBLE VERTEX



sigmc
 $\rho\pi 2002$
mc2006

n double vertex

n double vertex



n double vertex

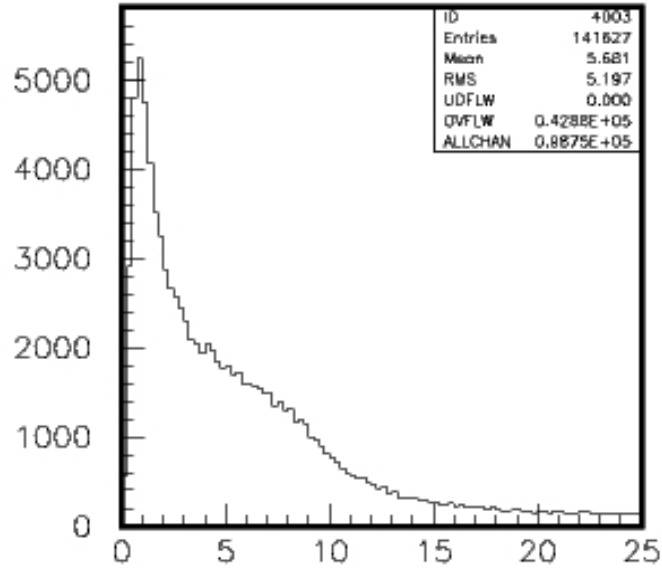
$N_{DV} > 0$

$$\varepsilon = 0.8126 \pm 0.0030$$

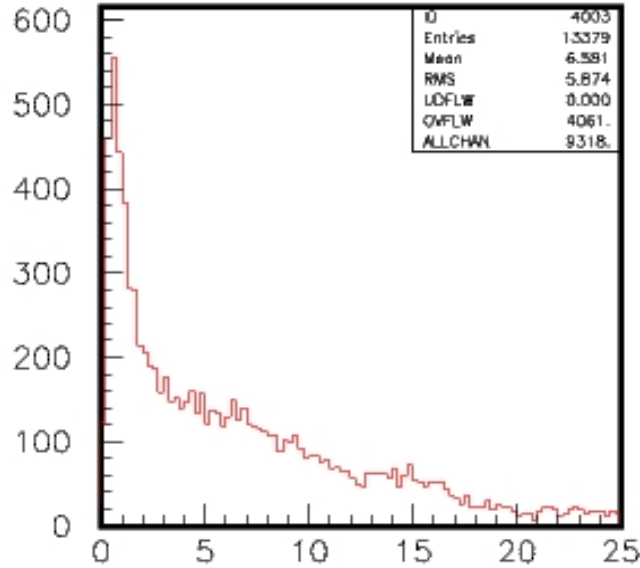
$$\varepsilon = 0.8156 \pm 0.0100$$

$$\varepsilon = 0.8437 \pm 0.0144$$

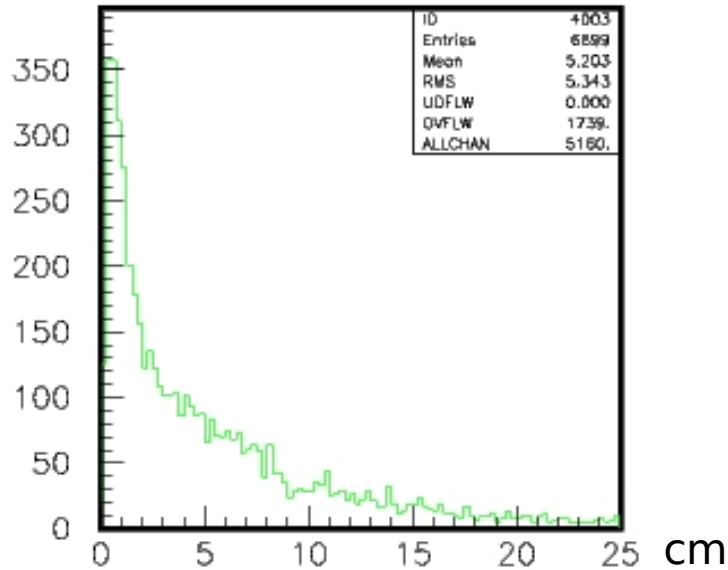
DOUBLE VERTEX



Dmin vertexes



Dmin vertexes



Dmin vertexes

$$d_{\min} \leq 5$$

$$\varepsilon = 0.3580 \pm 0.0018$$

$$\varepsilon = 0.3207 \pm 0.0054$$

$$\varepsilon = 0.4264 \pm 0.0090$$

$$d_{\min} \leq 2.5$$

$$\varepsilon = 0.2230 \pm 0.0013$$

$$\varepsilon = 0.2141 \pm 0.0042$$

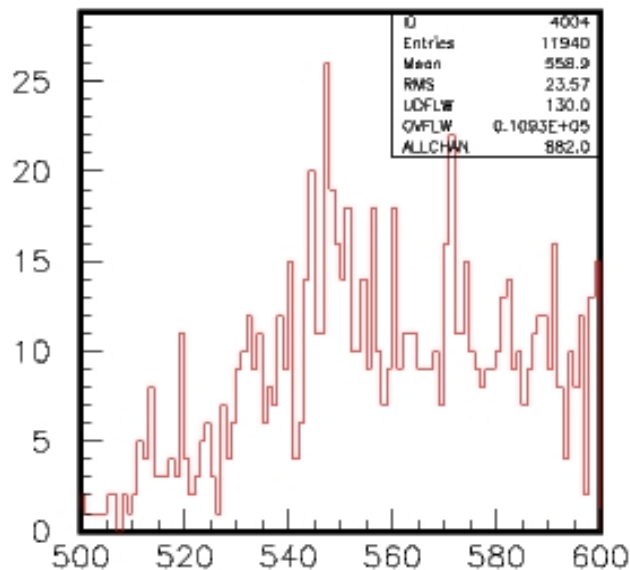
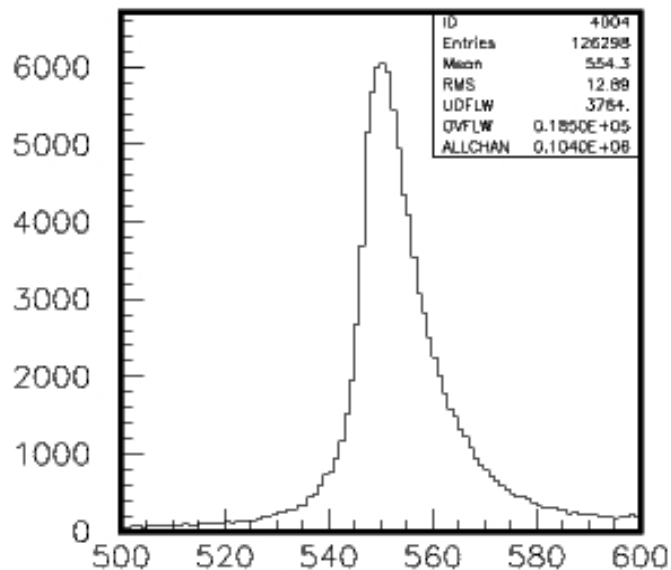
$$\varepsilon = 0.2947 \pm 0.0071$$

sigmc

$\rho\pi$ 2002

mc2006

DOUBLE VERTEX



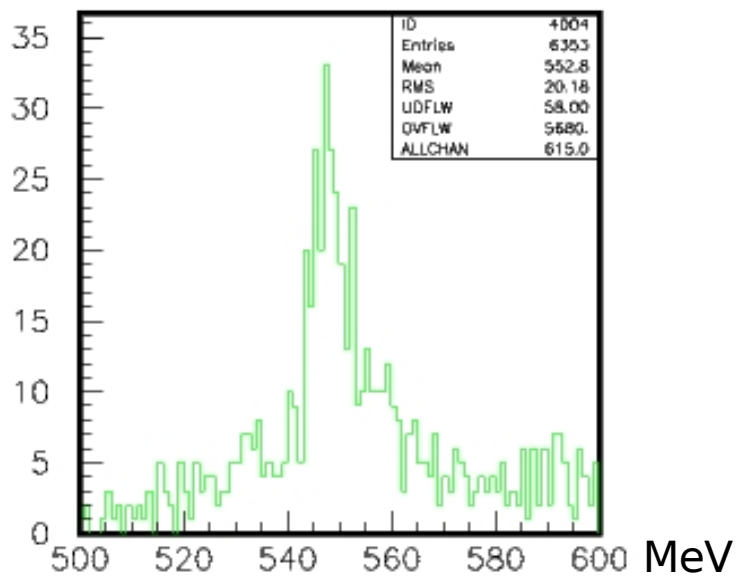
$$540 \leq m(\eta) \leq 555 \text{ MeV}$$

$$\epsilon = 0.3622 \pm 0.0018$$

$$\epsilon = 0.0142 \pm 0.0009$$

$$\epsilon = 0.0351 \pm 0.0022$$

DV etamass



DV etamass

sigmc

$\rho\pi$ 2002

mc2006

$$500 \leq m(\eta) \leq 600 \text{ MeV}$$

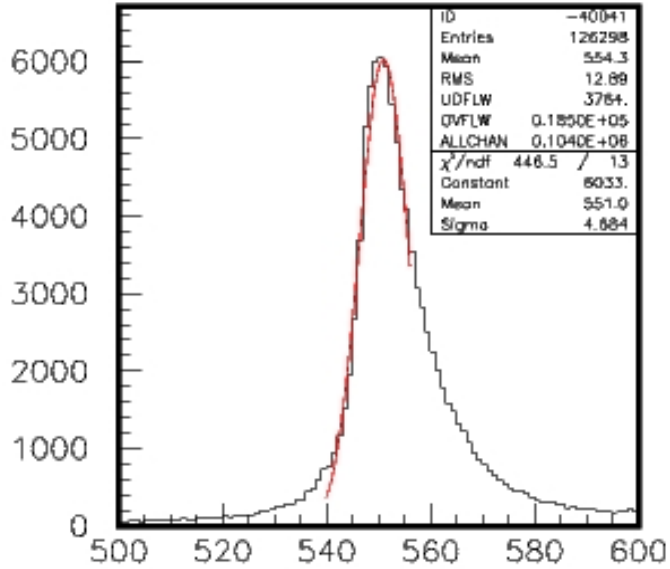
$$\epsilon = 0.6693 \pm 0.0027$$

$$\epsilon = 0.0602 \pm 0.0021$$

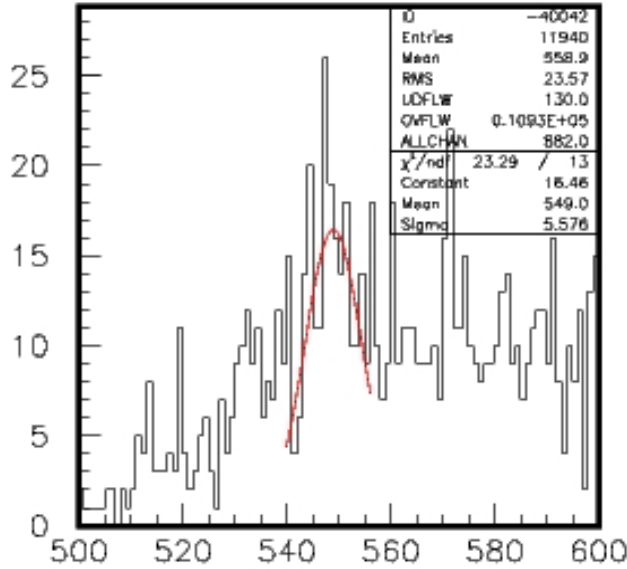
$$\epsilon = 0.0817 \pm 0.0034$$

DV etamass

DOUBLE VERTEX



DV etamass

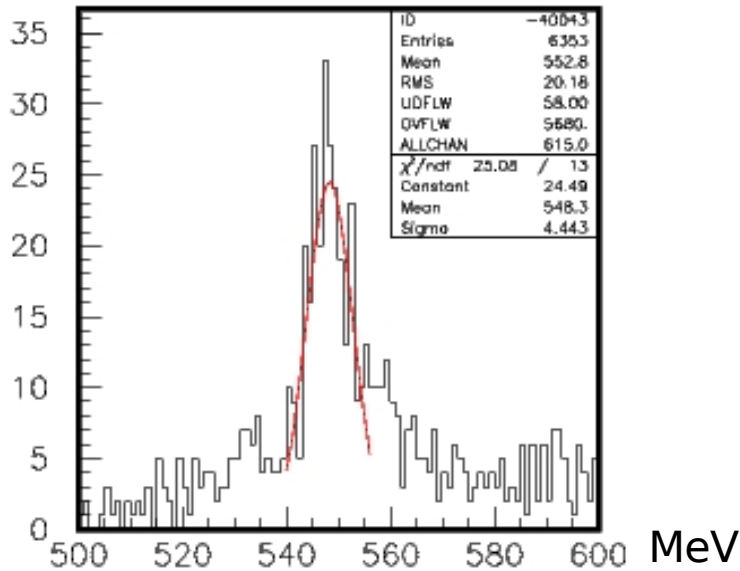


DV etamass

$$\chi^2/\text{dof} = 446/13$$

$$\chi^2/\text{dof} = 23/13$$

$$\chi^2/\text{dof} = 25/13$$



DV etamass

$$m(\eta) = 550.99 \pm 0.03 \quad \sigma = 4.68 \pm 0.03$$

$$m(\eta) = 548.99 \pm 0.82 \quad \sigma = 5.57 \pm 1.12$$

$$m(\eta) = 548.30 \pm 0.43 \quad \sigma = 4.44 \pm 0.53$$

Fit range 540-555 MeV

=====
DOUBLE VERTEX histo 3003 fit range 540-555 MeV
=====

FCN= 446.4962 FROM MIGRAD STATUS=FAILED 86 CALLS 87 TOTAL
EDM= 0.21E+02 STRATEGY=1 ERROR MATRIX UNCERTAINTY= 3.1%

Table with 6 columns: EXT PARAMETER NO., NAME, VALUE, APPROXIMATE ERROR, STEP SIZE, FIRST DERIVATIVE. Rows include Constant, Mean, and Sigma parameters.

CHISQUARE = 0.3435E+02 NPFIT = 16

FCN= 23.28513 FROM MIGRAD STATUS=CONVERGED 121 CALLS 122 TOTAL
EDM= 0.65E-03 STRATEGY= 1 ERROR MATRIX ACCURATE

Table with 6 columns: EXT PARAMETER NO., NAME, VALUE, ERROR, STEP SIZE, FIRST DERIVATIVE. Rows include Constant, Mean, and Sigma parameters.

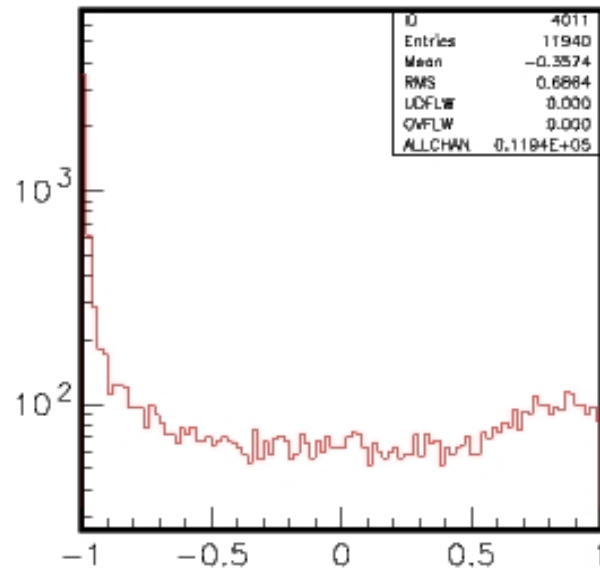
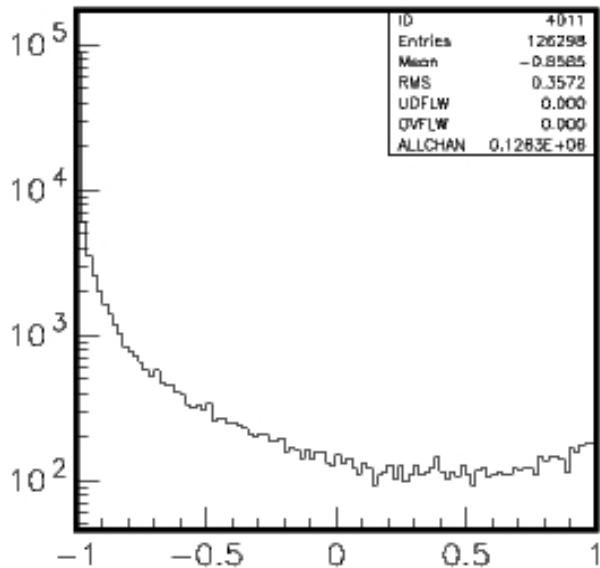
CHISQUARE = 0.1791E+01 NPFIT = 16

FCN= 25.07972 FROM MIGRAD STATUS=FAILED 116 CALLS 117 TOTAL
EDM= 0.21E-02 STRATEGY= 1 ERR MATRIX APPROXIMATE

Table with 6 columns: EXT PARAMETER NO., NAME, VALUE, APPROXIMATE ERROR, STEP SIZE, FIRST DERIVATIVE. Rows include Constant, Mean, and Sigma parameters.

CHISQUARE = 0.1929E+01 NPFIT = 16

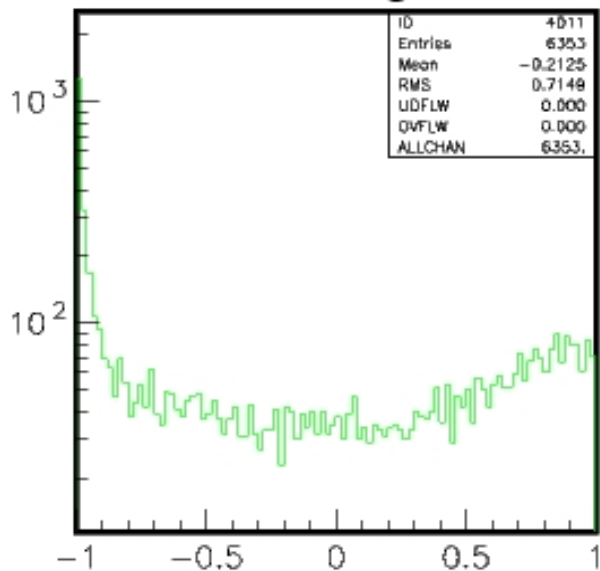
DOUBLE VERTEX



sigmc
 ρπ2002
 mc2006

DV cos gtrk

DV cos gtrk



DV cos gtrk

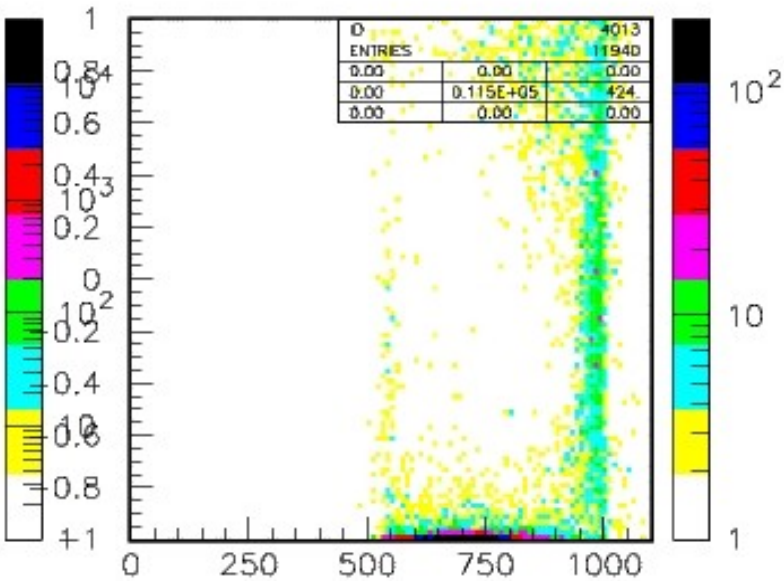
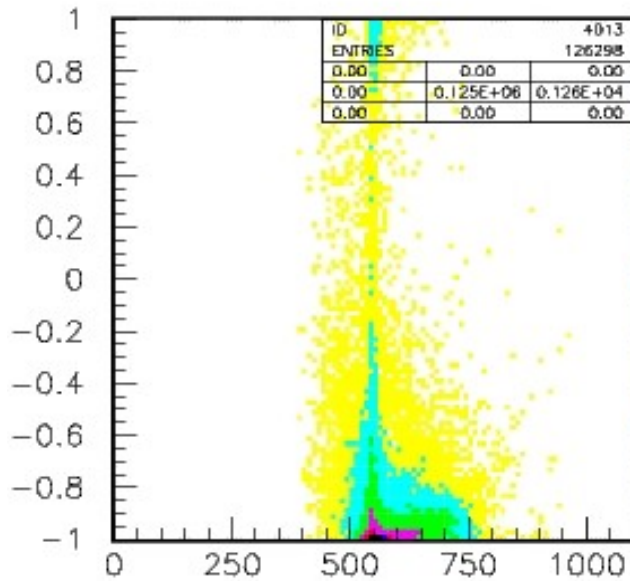
$$\cos(\gamma\text{-trk}) \leq -0.9$$

$$\epsilon = 0.6546 \pm 0.0026$$

$$\epsilon = 0.3269 \pm 0.0054$$

$$\epsilon = 0.2609 \pm 0.0066$$

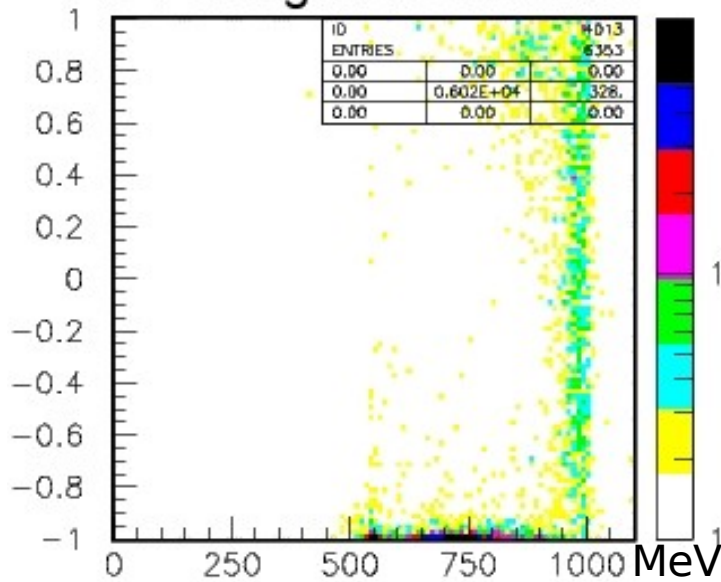
DOUBLE VERTEX



sigmc
 $\rho\pi$ 2002
 mc2006

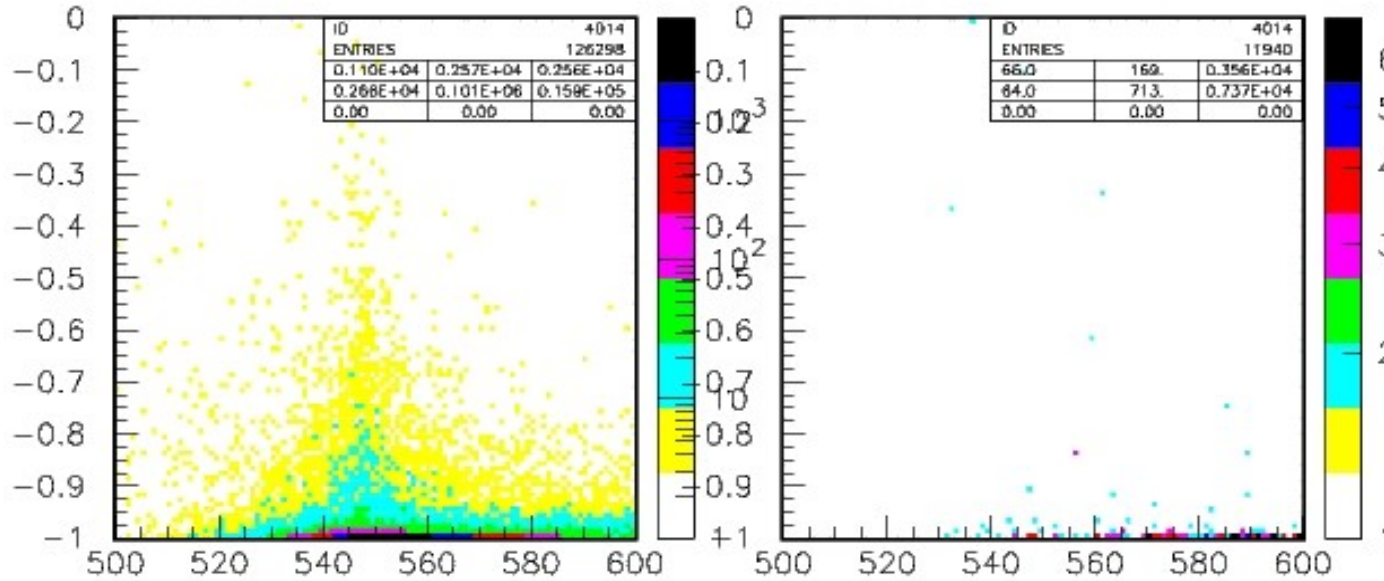
DV cos gtrk vs etamass

DV cos gtrk vs etamass

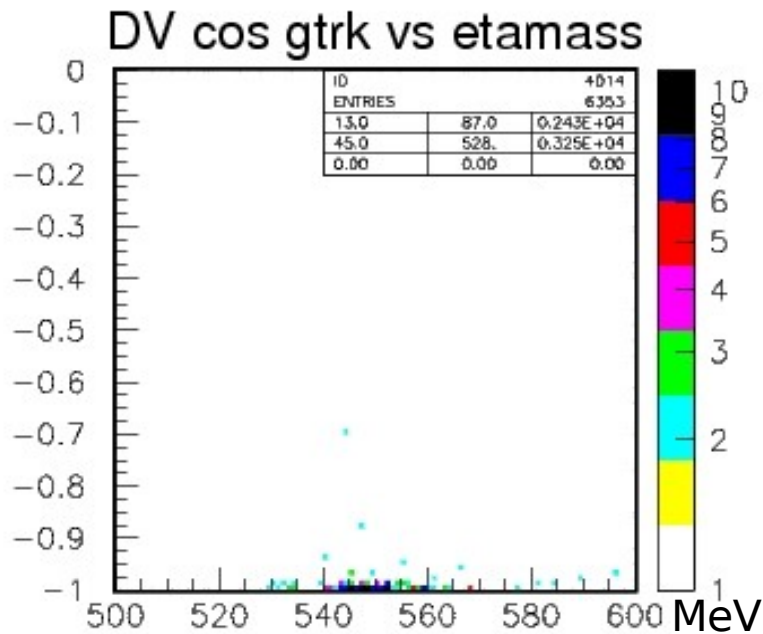


DV cos gtrk vs etamass

DOUBLE VERTEX



sigmc
 $\rho\pi$ 2002
 mc2006



DV cos gtrk vs etamass

$540 \leq m(\eta) \leq 555$ MeV .and.

$\cos(\gamma\text{-trk}) \leq -0.9$

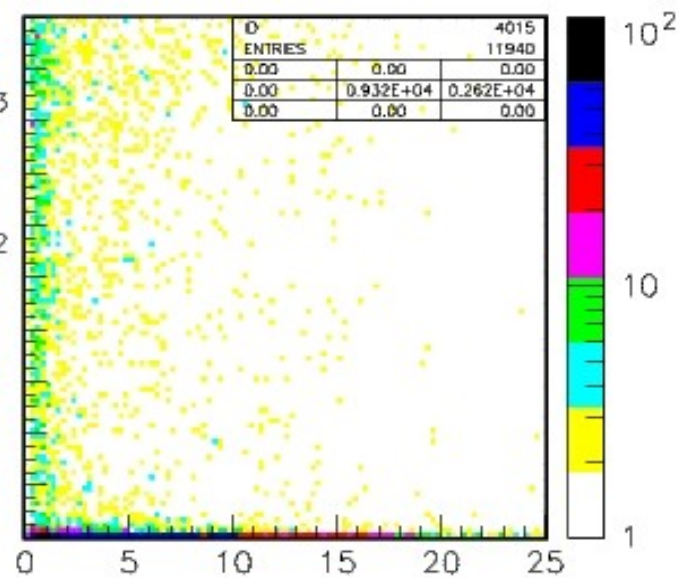
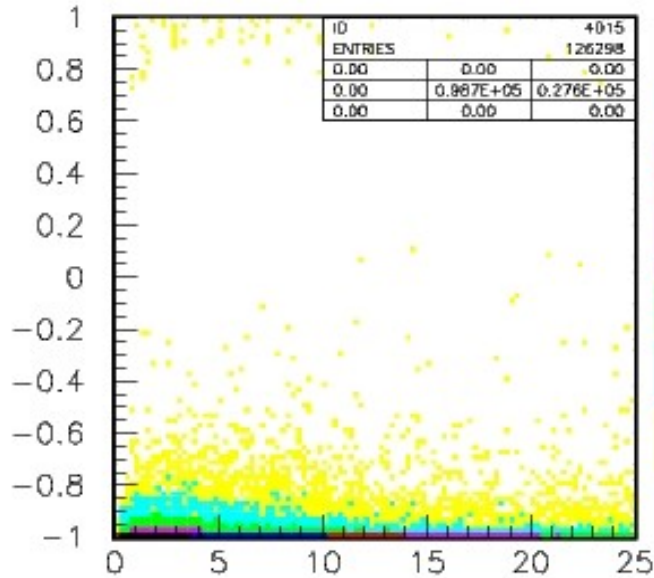
$\epsilon = 0.3364 \pm 0.0017$

$\epsilon = 0.0046 \pm 0.0006$

$\epsilon = 0.0230 \pm 0.0018$

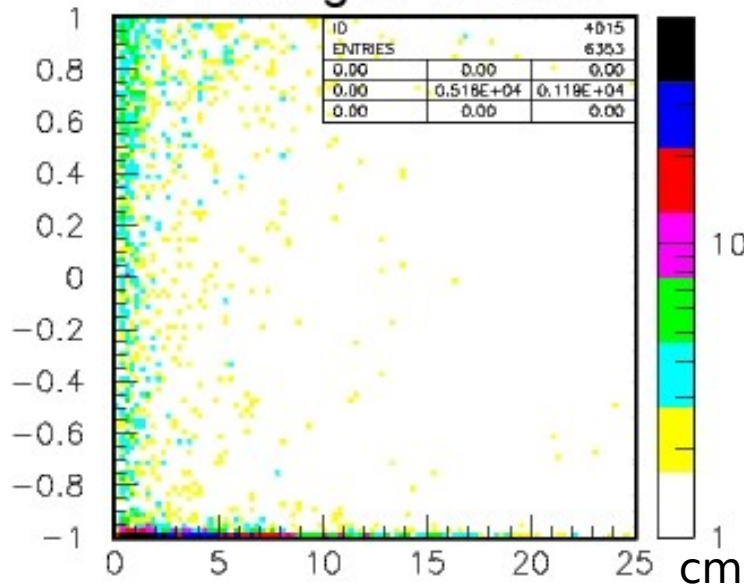
DV cos gtrk vs etamass

DOUBLE VERTEX



sigmc
 $\rho\pi$ 2002
 mc2006

DV cos gtrk vs Dmin



DV cos gtrk vs Dmin

$$d_{\min} \leq 5 \text{ cm .and.}$$

$$\cos(\gamma\text{-trk}) \leq -0.9$$

$$\varepsilon = 0.3427 \pm 0.0017$$

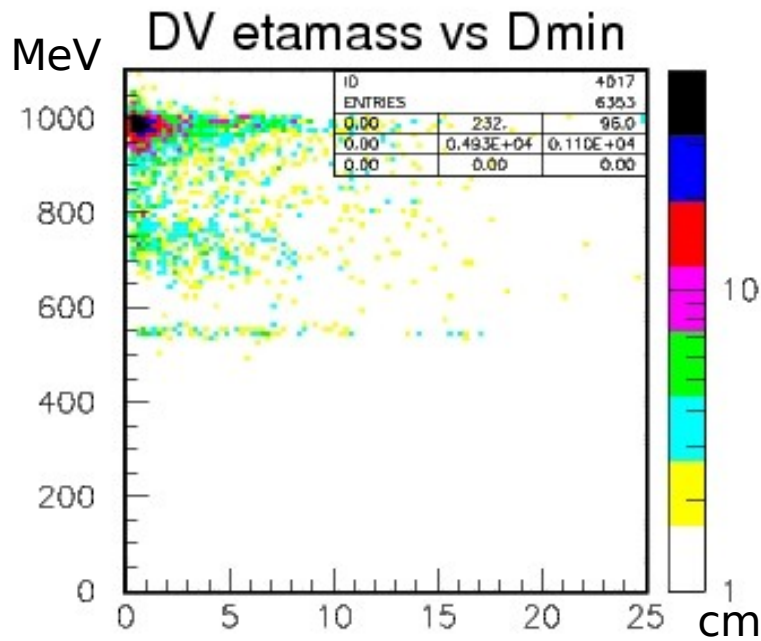
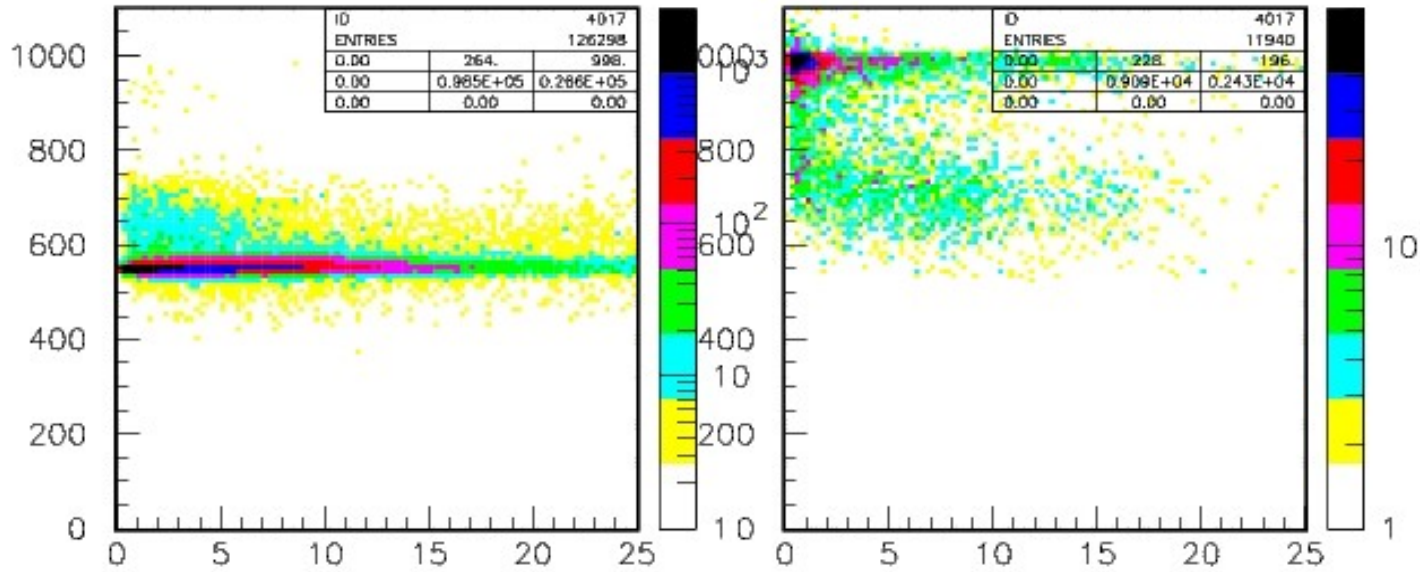
$$\varepsilon = 0.1116 \pm 0.0029$$

$$\varepsilon = 0.1297 \pm 0.0044$$

DV cos gtrk vs Dmin

DOUBLE VERTEX

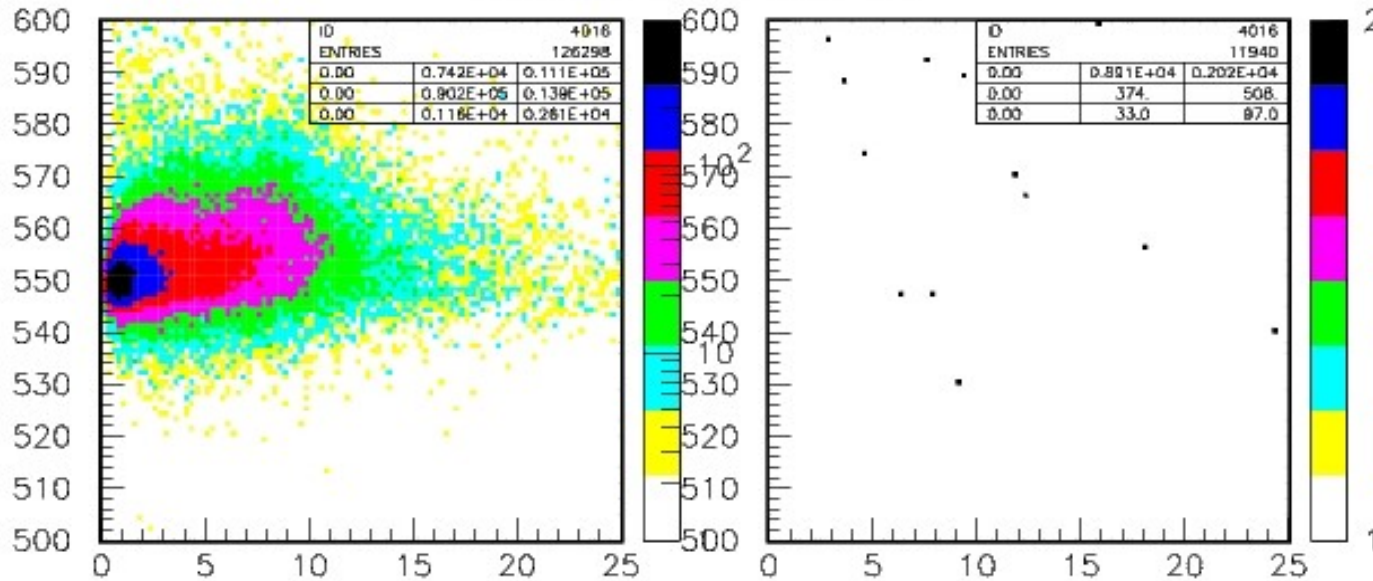
sigmc
 $\rho\pi$ 2002
 mc2006



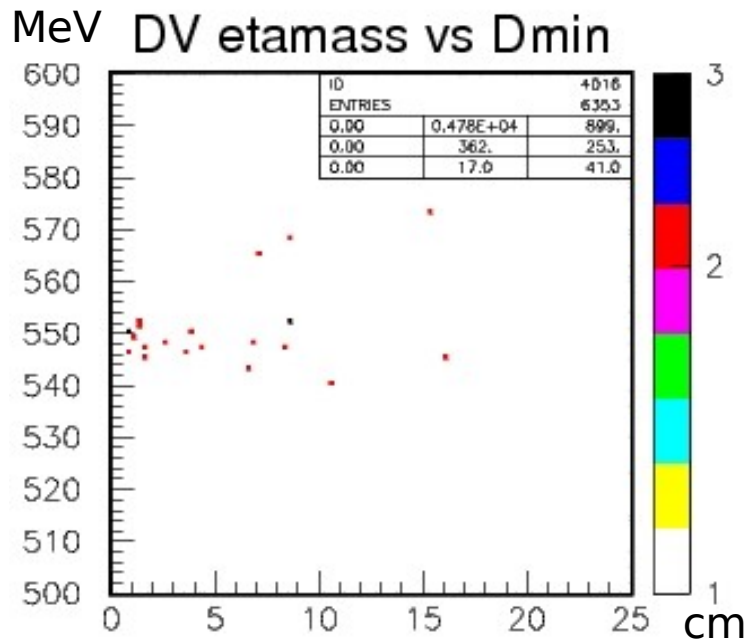
DV etamass vs Dmin

DV etamass vs Dmin

DOUBLE VERTEX



sigmc
 $\rho\pi$ 2002
 mc2006



DV etamass vs Dmin

$540 \leq m(\eta) \leq 555$ MeV .and.

$d_{\min} \leq 5$ cm

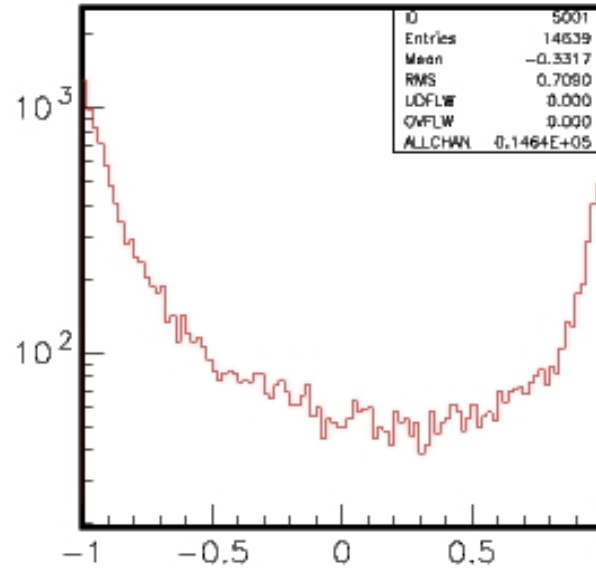
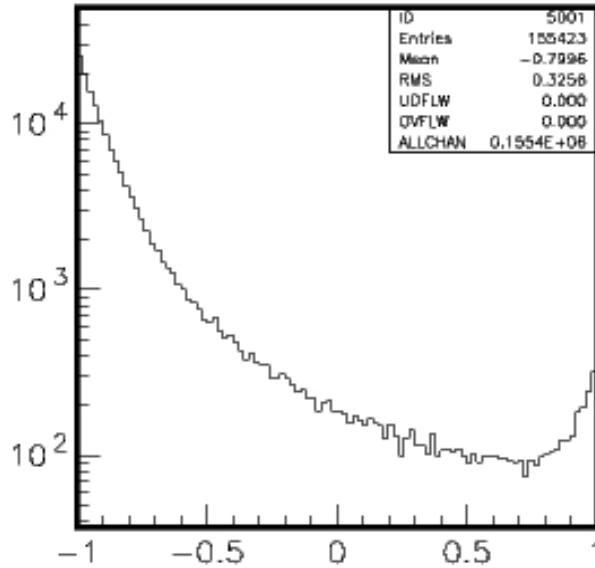
$\epsilon = 0.2297 \pm 0.0013$

$\epsilon = 0.0009 \pm 0.0002$

$\epsilon = 0.0089 \pm 0.0011$

DV etamass vs Dmin

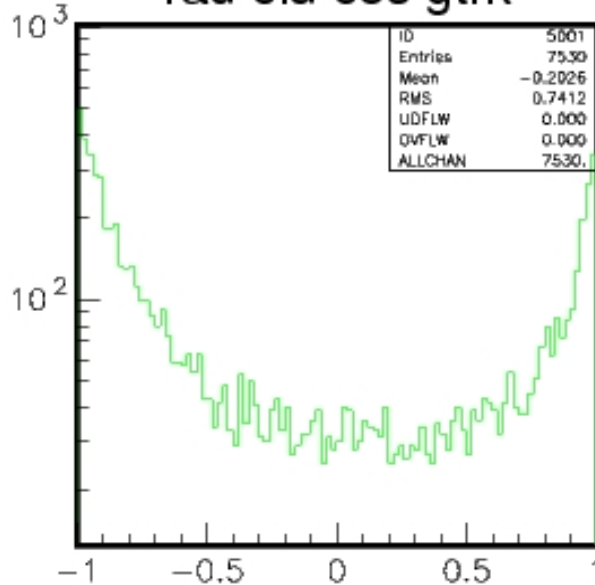
RADIATIVE CLUSTER



sigmc
 $\rho\pi 2002$
 mc2006

rad clu cos grk

rad clu cos grk



rad clu cos grk

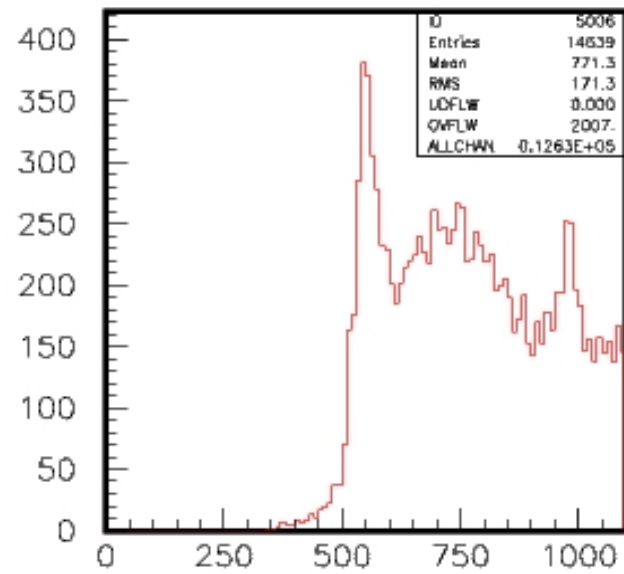
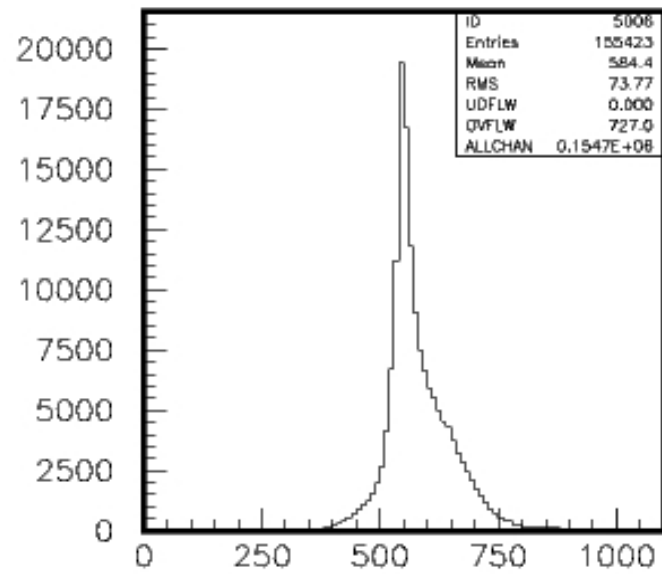
$$\cos(\gamma\text{-trk}) \leq -0.9$$

$$\epsilon = 0.5443 \pm 0.0023$$

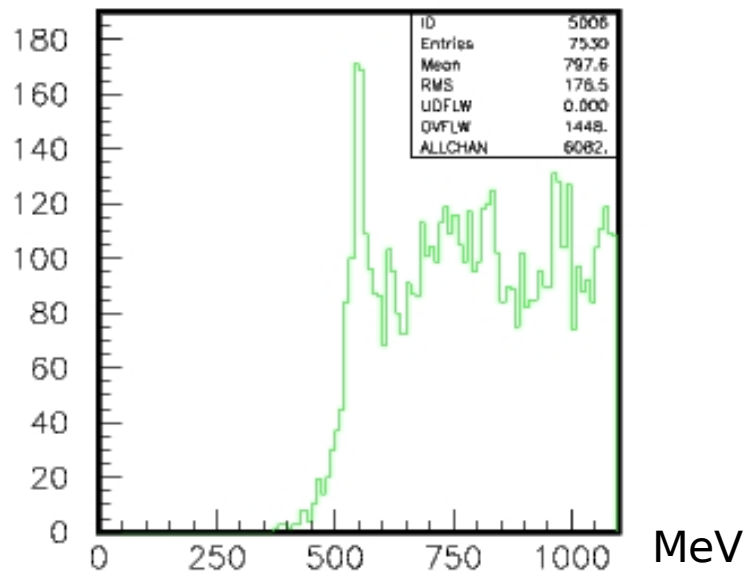
$$\epsilon = 0.3010 \pm 0.0052$$

$$\epsilon = 0.2398 \pm 0.0063$$

RADIATIVE CLUSTER

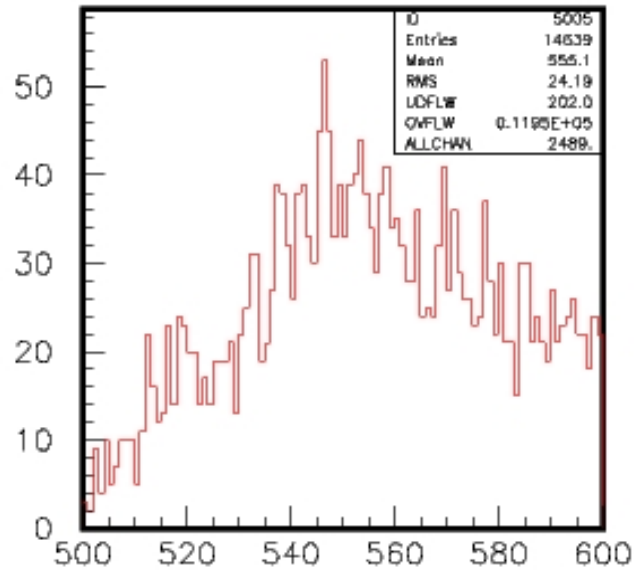
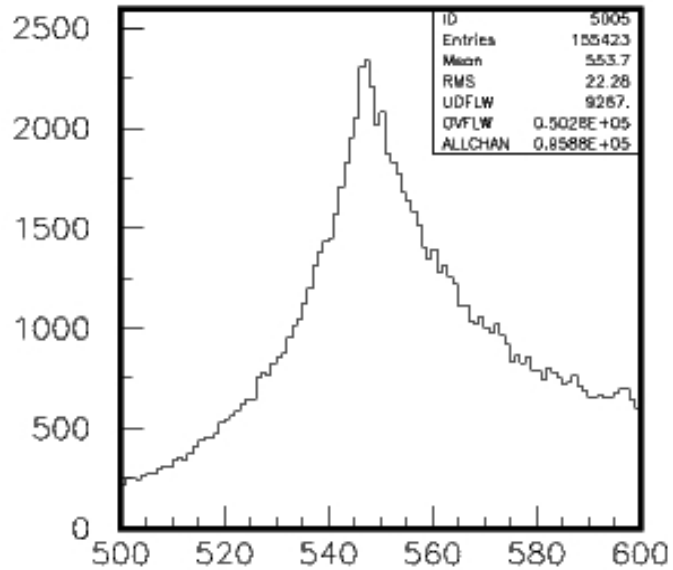


sigmc
 $\rho\pi 2002$
mc2006



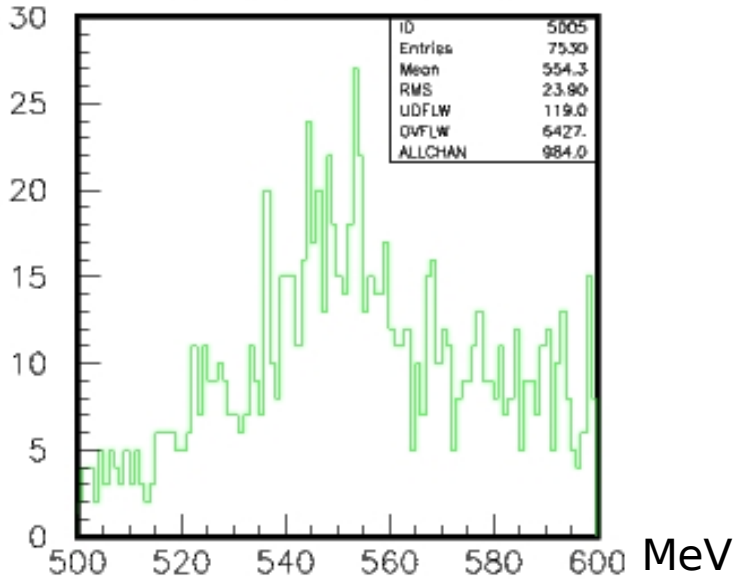
rad clu etamass

RADIATIVE CLUSTER



sigmc
 $\rho\pi 2002$
 mc2006

rad clu etamass



rad clu etamass

$$540 \leq m(\eta) \leq 555 \text{ MeV}$$

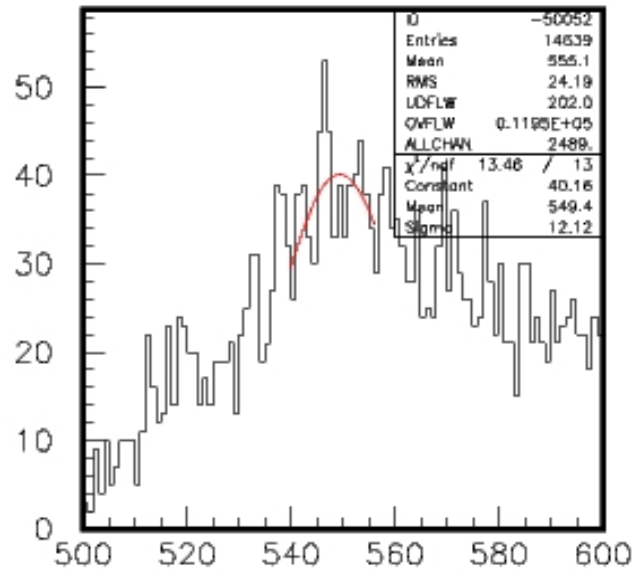
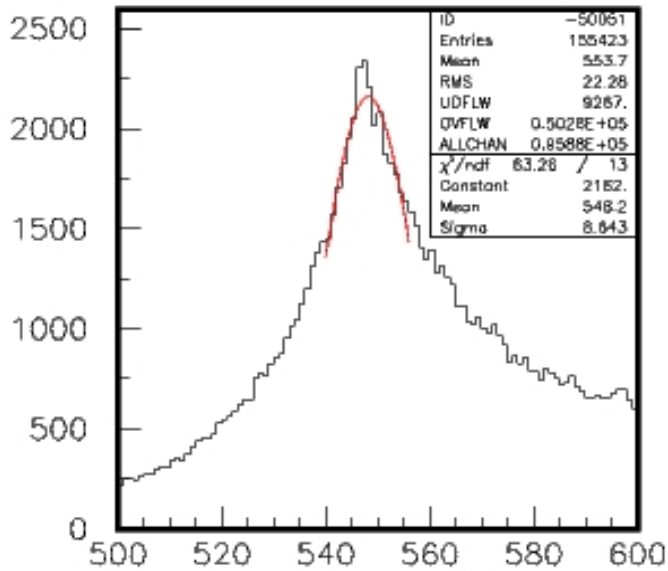
$$\varepsilon = 0.1844 \pm 0.0012$$

$$\varepsilon = 0.0393 \pm 0.0017$$

$$\varepsilon = 0.0354 \pm 0.0022$$

rad clu etamass

RADIATIVE CLUSTER

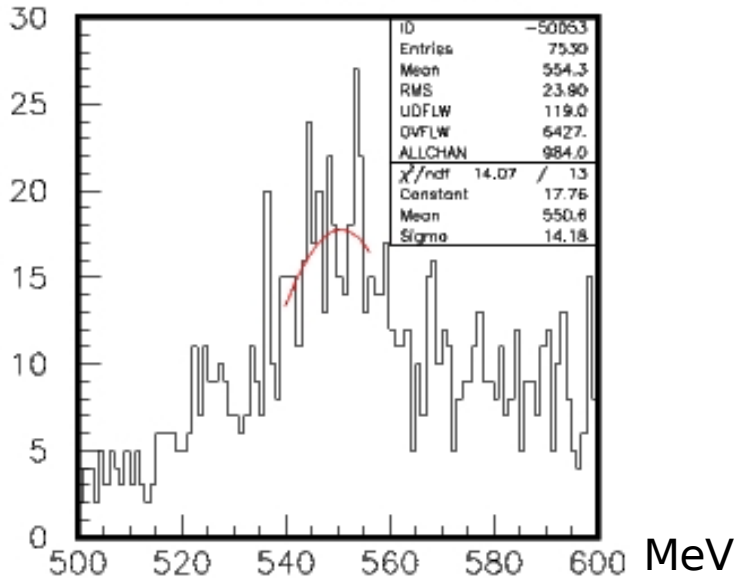


$$\chi^2/\text{dof} = 63/13$$

$$\chi^2/\text{dof} = 13/13$$

$$\chi^2/\text{dof} = 14/13$$

rad clu etamass



rad clu etamass

$$m(\eta) = 548.22 \pm 0.13 \quad \sigma = 8.64 \pm 0.29$$

$$m(\eta) = 549.39 \pm 1.00 \quad \sigma = 12.1 \pm 3.61$$

$$m(\eta) = 550.57 \pm 1.00 \quad \sigma = 14.2 \pm 5.85$$

rad clu etamass

Fit range 540-555 MeV

=====
=====
===== RADIATIVE CLUSTER histo 5005 fit range 540-555 MeV
=====
=====

FCN= 63.26404 FROM MIGRAD STATUS=CONVERGED 104 CALLS 105 TOTAL
EDM= 0.76E-05 STRATEGY= 1 ERROR MATRIX ACCURATE

Table with 6 columns: EXT PARAMETER NO., NAME, VALUE, ERROR, STEP SIZE, FIRST DERIVATIVE. Rows include Constant, Mean, and Sigma parameters.

CHISQUARE = 0.4866E+01 NPFIT = 16

FCN= 13.45995 FROM MIGRAD STATUS=FAILED 121 CALLS 122 TOTAL
EDM= 0.70E-01 STRATEGY= 1 ERR MATRIX NOT POS-DEF

Table with 6 columns: EXT PARAMETER NO., NAME, VALUE, APPROXIMATE ERROR, STEP SIZE, FIRST DERIVATIVE. Rows include Constant, Mean, and Sigma parameters.

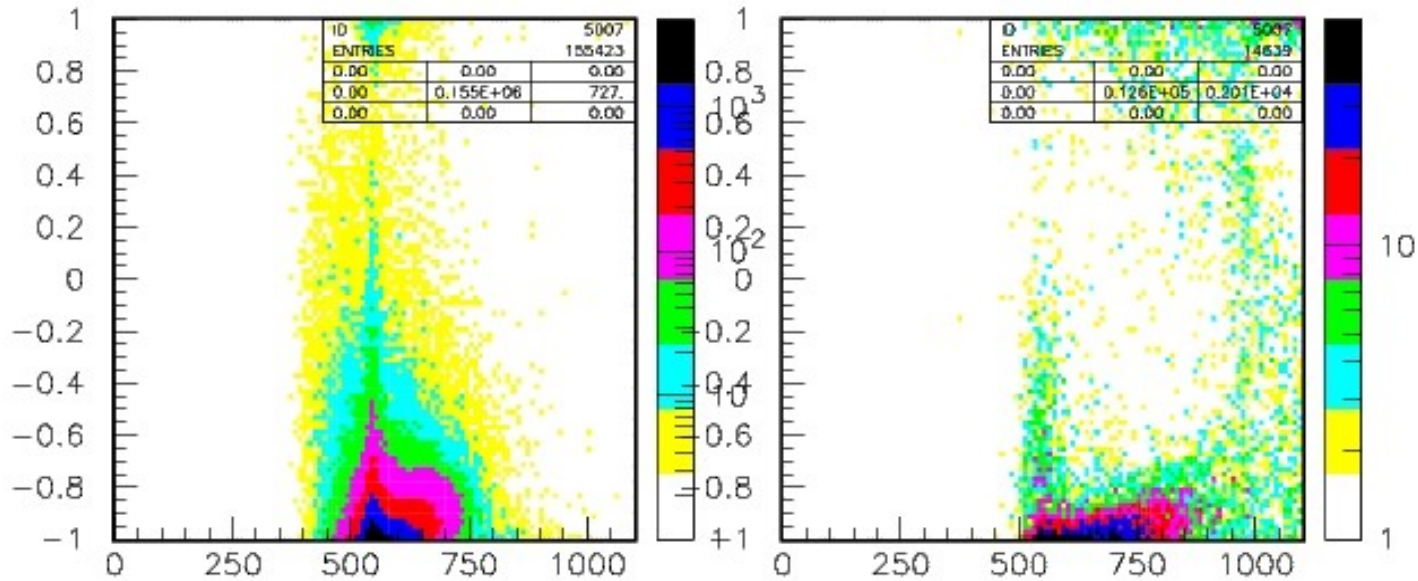
CHISQUARE = 0.1035E+01 NPFIT = 16

FCN= 14.06764 FROM MIGRAD STATUS=FAILED 137 CALLS 138 TOTAL
EDM= 0.90E-01 STRATEGY= 1 ERR MATRIX NOT POS-DEF

Table with 6 columns: EXT PARAMETER NO., NAME, VALUE, APPROXIMATE ERROR, STEP SIZE, FIRST DERIVATIVE. Rows include Constant, Mean, and Sigma parameters.

CHISQUARE = 0.1082E+01 NPFIT = 16

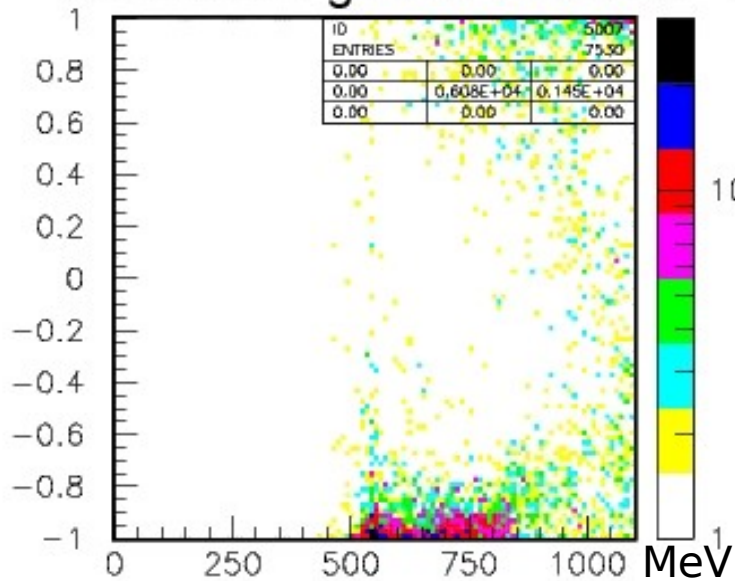
RADIATIVE CLUSTER



sigmc
 $\rho\pi$ 2002
 mc2006

rad clu cos gtrk vs etamass

rad clu cos gtrk vs etamass



$540 \leq m(\eta) \leq 555$ MeV .and.

$\cos(\gamma\text{-trk}) \leq -0.9$

$\varepsilon = 0.1158 \pm 0.0009$

$\varepsilon = 0.0149 \pm 0.0010$

$\varepsilon = 0.0159 \pm 0.0015$

rad clu cos gtrk vs etamass

Summary

We are left with very few events $O(10^{-2})$
in any selection

Understand the problem with track direction (KFIT)

Identify other sources of background

($\eta \rightarrow \pi^+ \pi^- \pi^0$, $\eta \rightarrow \pi^+ \pi^- \gamma$...)

Big problem: lack of disk space

