Final result of the

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

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Frascati 11 -04 - 2011

BR: theory & experiment

CMD-2 $< 6.9 \times 10^{-5}$ @90%C.L.

WASA $(2.7\ ^{+2.1}_{-2.7\ \text{stat.}} \pm 0.1_{\ \text{syst.}}) \times 10^{-5}$

Theoretical predictions : $(2.41 - 2.67) \times 10^{-5}$

In $\eta \to \pi\pi ee$ analysis we have observed 1555 events,

assuming as lower bound the same efficiency,

we expect at least 155.5 events

Data sample

Using drc/mrc streams
with ETA4C tag

1733 pb^{-1} data 2004/05

167531 pb^{-1} MC signal only

3447 pb^{-1} MC all_phys(2/3) 2004/05

1751 pb^{-1} MC allrad 2004/05

242 pb^{-1} data offpeak ($\sqrt{s}$ = 1000 MeV)

MC signal accounts for FSR and run by run conditions

Event selection

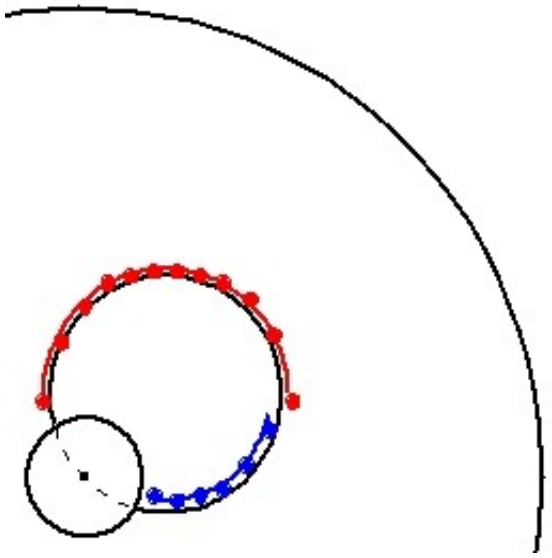
EVCL algorithm ETA4CTAG:

- ≥ 4 tracks from the Interaction Point
- 1 high energy neutral cluster ($E_{cl} \geq 250$ MeV)
- 0 medium energy neutral cluster ($50 \leq E_{cl} \leq 250$ MeV)

Track selection

Tracks are required to came from a cylinder around the IP:

$R \leq 4$ cm $h/2 = 10$ cm



Check on broken tracks is applied:

$\Delta P_T < 4.5$ MeV $\Delta P_Z < 3$ MeV

≥ 2 positive and ≥ 2 negative tracks are requested

Tracks are ordered by momentum

Kinematic fit

A kinematic fit to the ϕ meson is performed for all the events having # good tracks ≥ 4

The 22 inputs are:

- 4 tracks x 3 momenta
- x,y,z,E,t of the neutral cluster
- x,y,z of the IP
- $\sqrt{s}$ and f momentum

The 5 constraints are:

- Four momentum conservation
- Photon time of flight ($cT_\gamma = R_\gamma$)

Background rejection - step 1

$$600\ \text{MeV} < \sum_{i=1}^{4} |\vec{p}_i| = s4p < 700\ \text{MeV}$$

Data

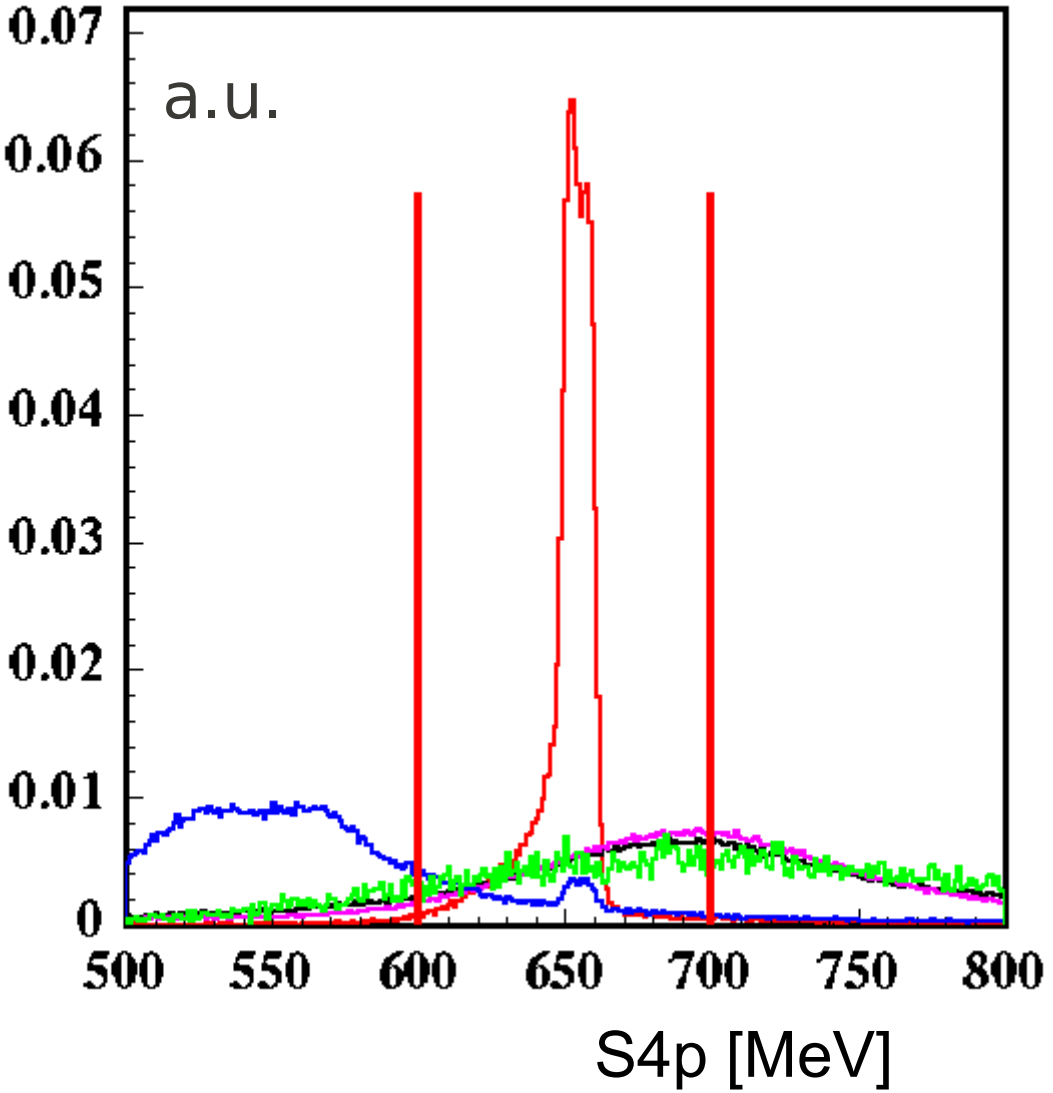
Continuum

allrad

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

all_phys (kaons + 3pions)

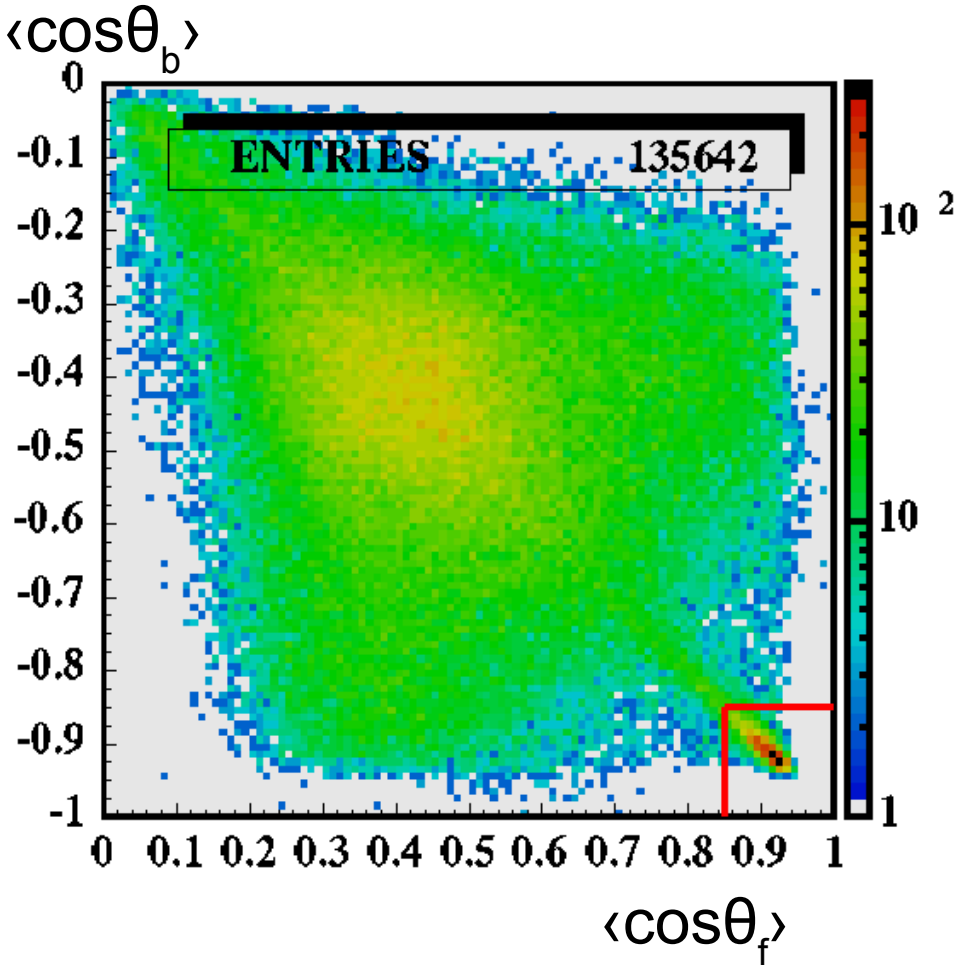
Histograms not scaled for luminosity



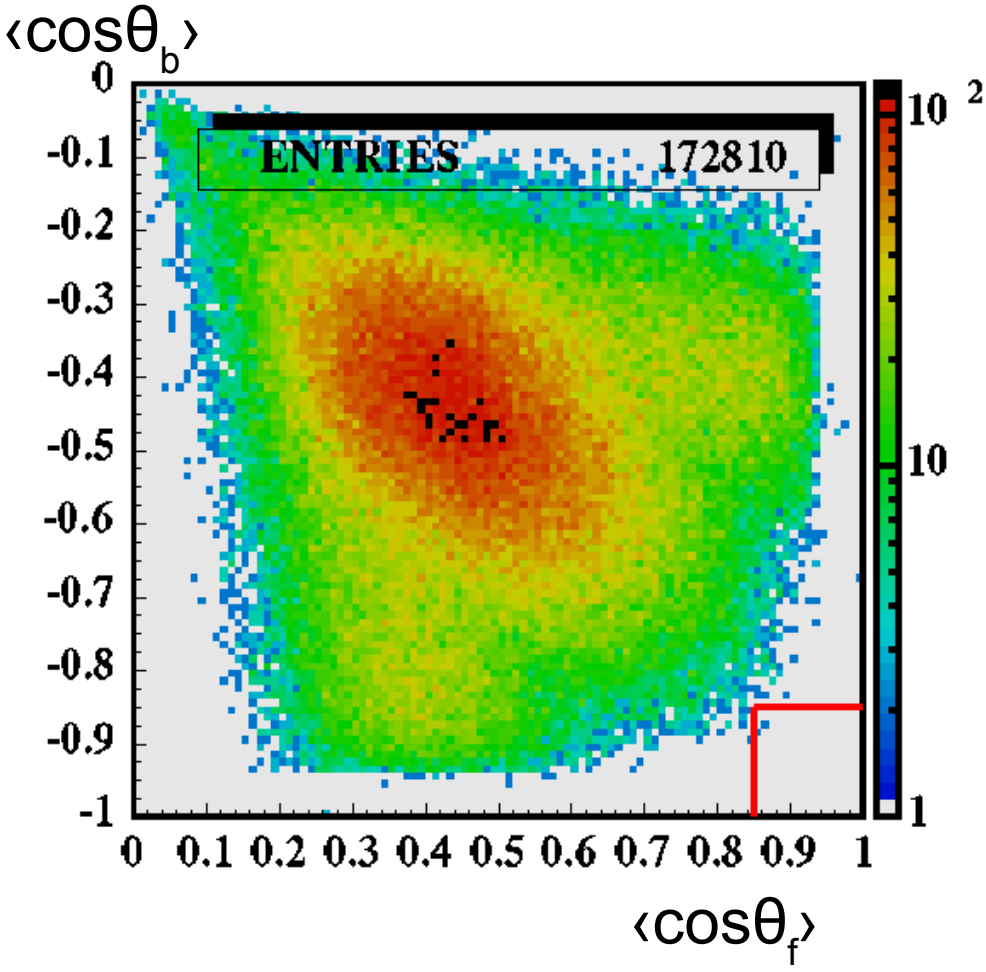
Background rejection - step 2

$\langle\cos\theta_f\rangle < 0.85$ .and. $\langle\cos\theta_b\rangle > -0.85$

Data



MC all_phys



Background rejection - step 3

$\chi^2_{KF} < 4000$

Data

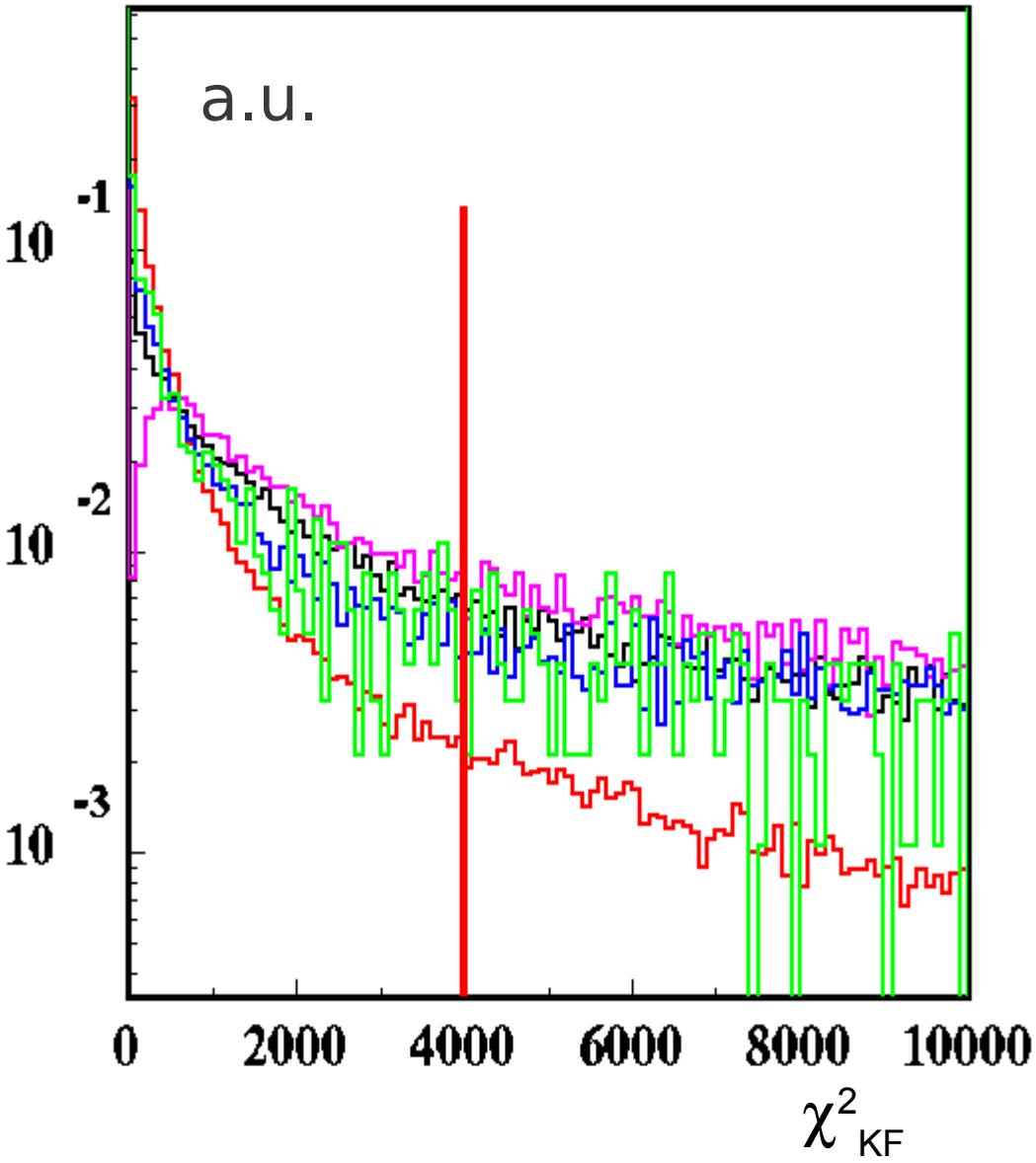
Continuum

allrad

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

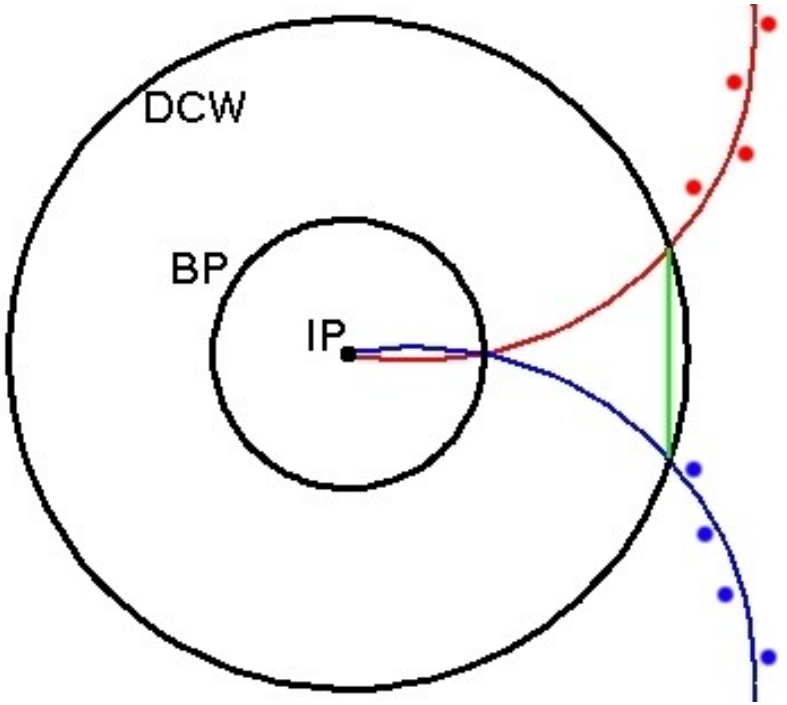
all_phys (kaons + 3pions)

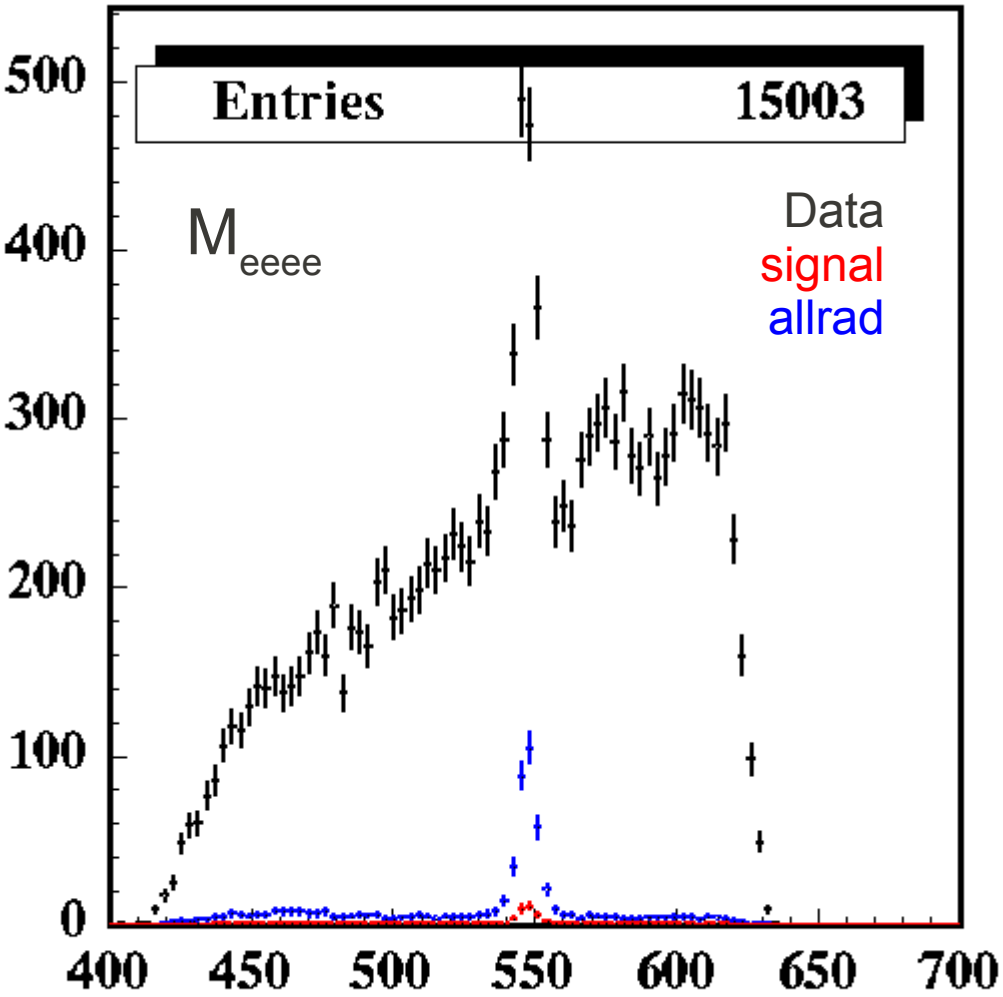
Histograms not scaled for luminosity



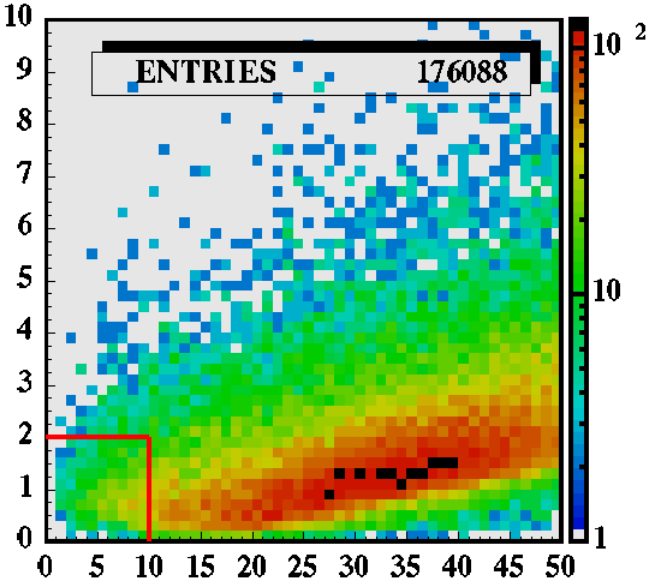
Background rejection - step 4

$\eta \rightarrow e^+e^- \gamma$ with photon conversion mimics the signal

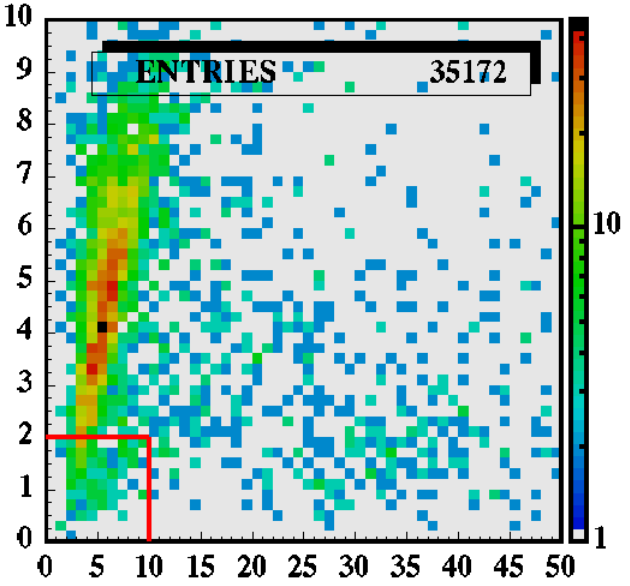




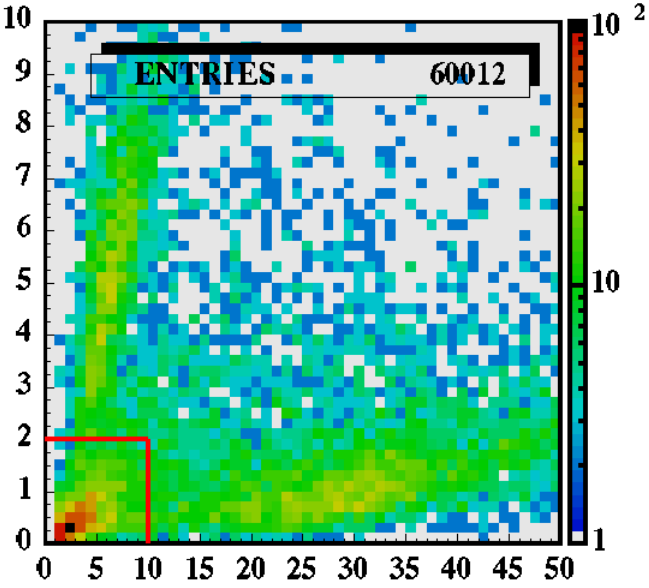
Background rejection - step 4



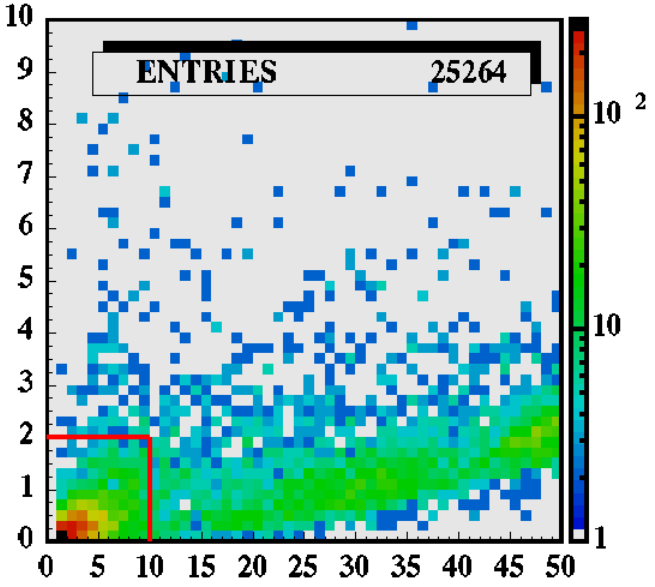
Signal



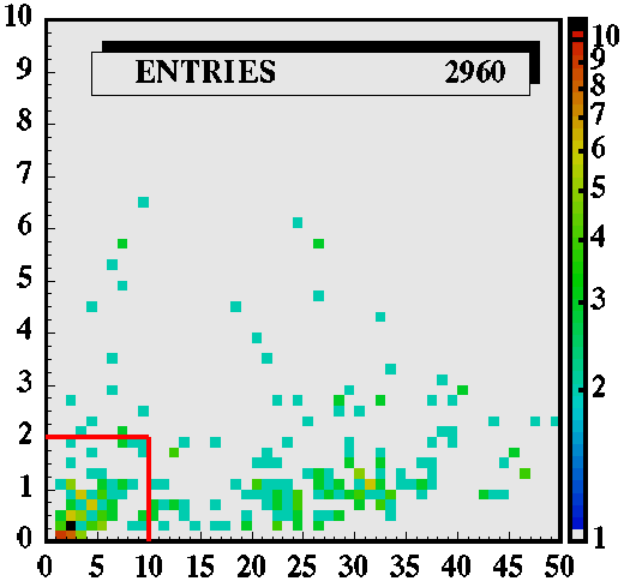
all_phys Kaons+ρπ



Data



allrad



offpeak

γ conversion cut

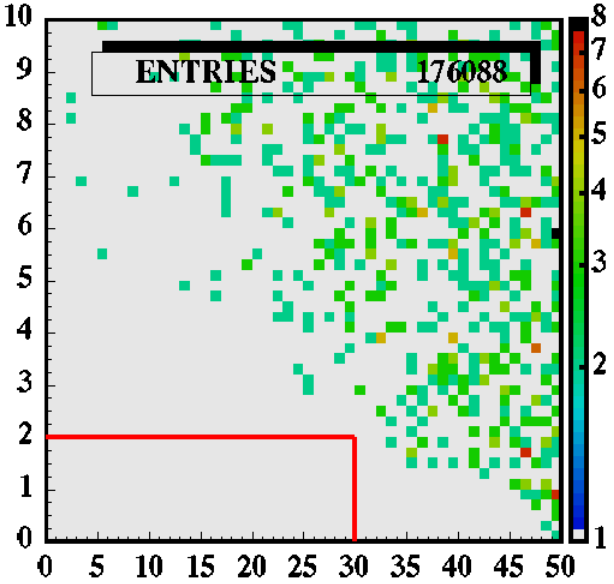
Dee@BP > 2 cm

.or.

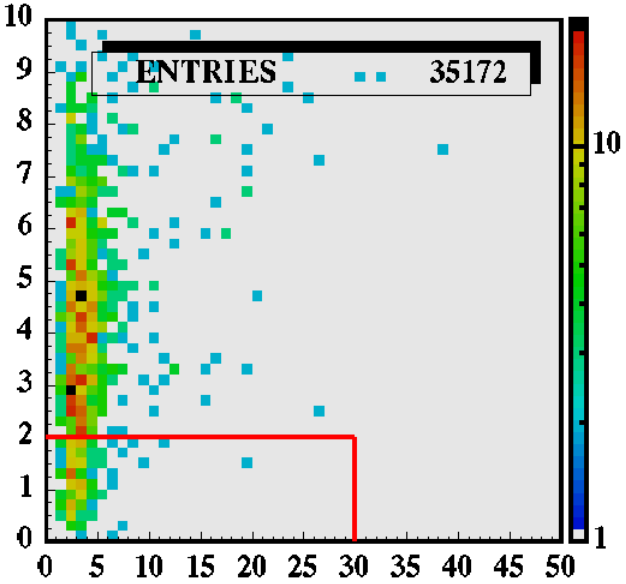
Mee@BP > 10 MeV

D_{ee} [cm] vs M_{ee}[MeV]

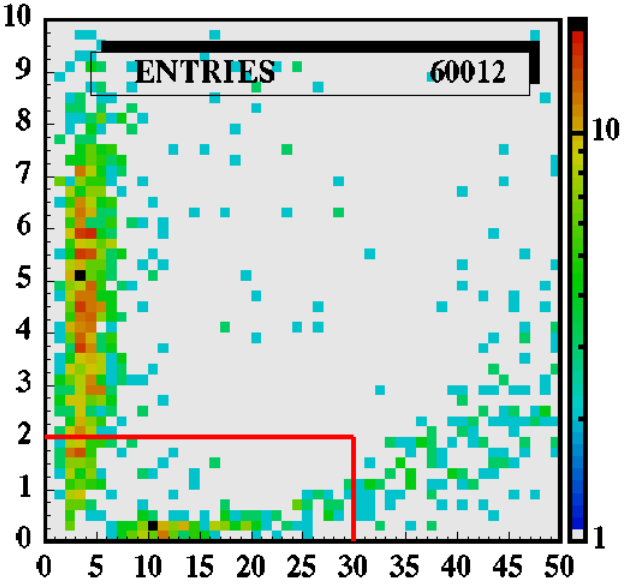
Background rejection - step 4



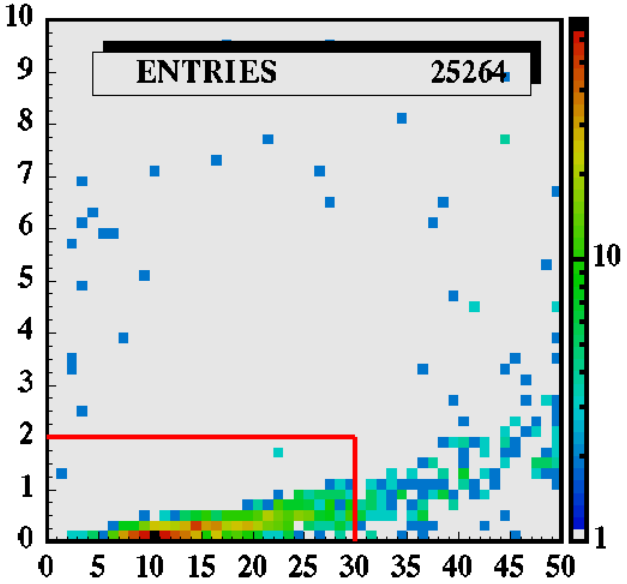
Signal



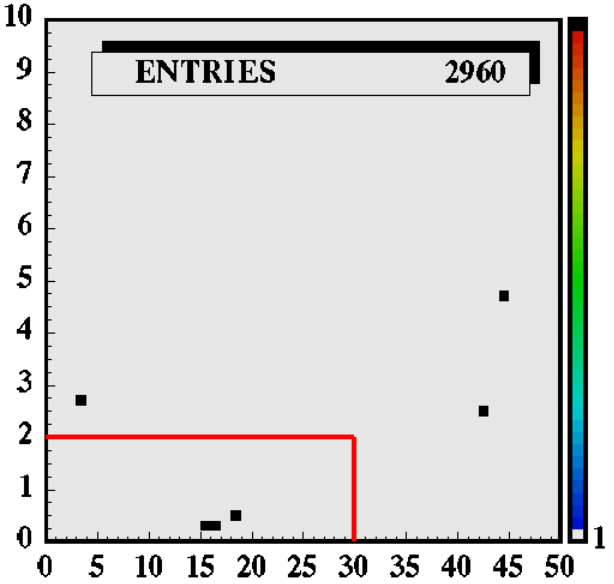
all_phys Kaons+ρπ



Data



allrad



offpeak

γ conversion cut

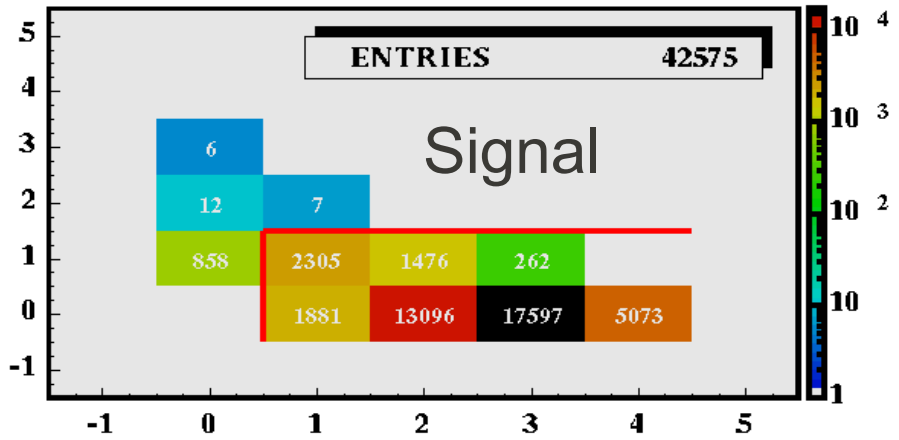
Dee@DCW > 2 cm

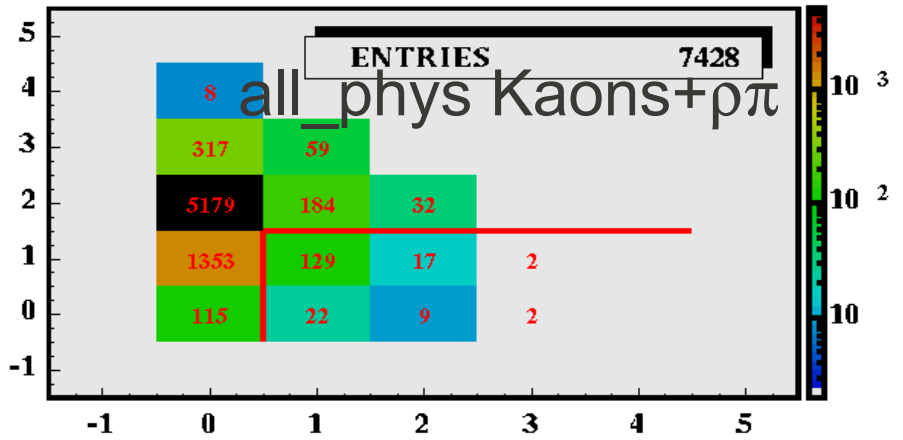
.or.

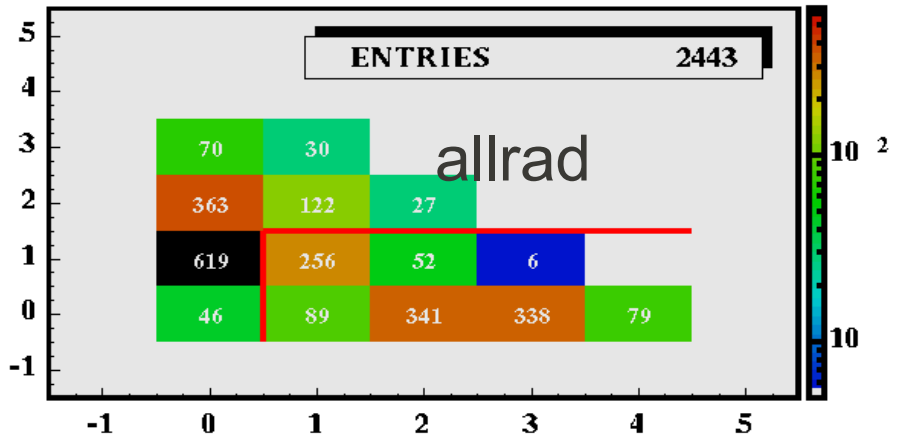
Mee@DCW > 30 MeV

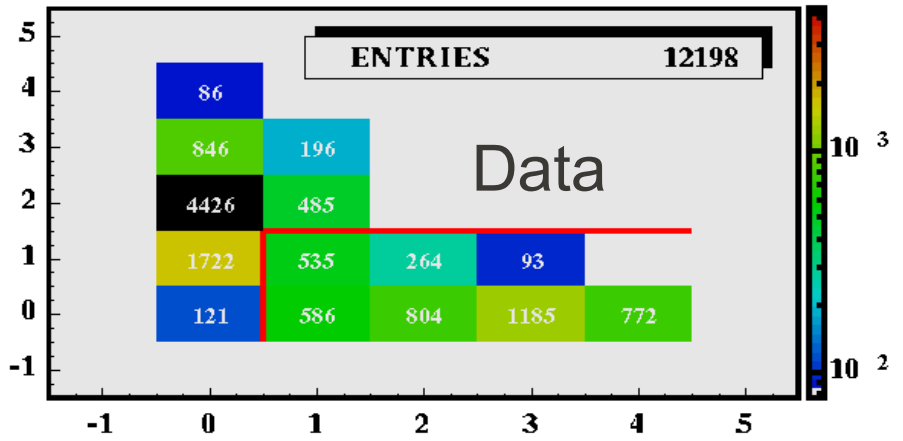
D_{ee} [cm] vs M_{ee}[MeV]

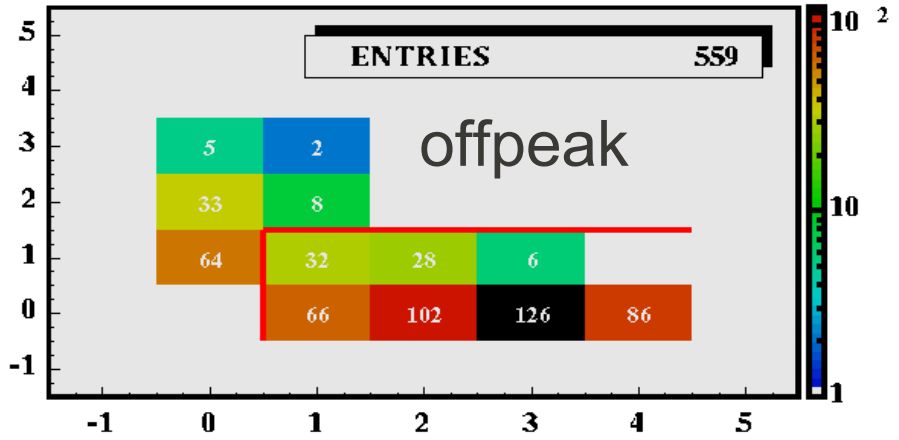
Background rejection - step 5









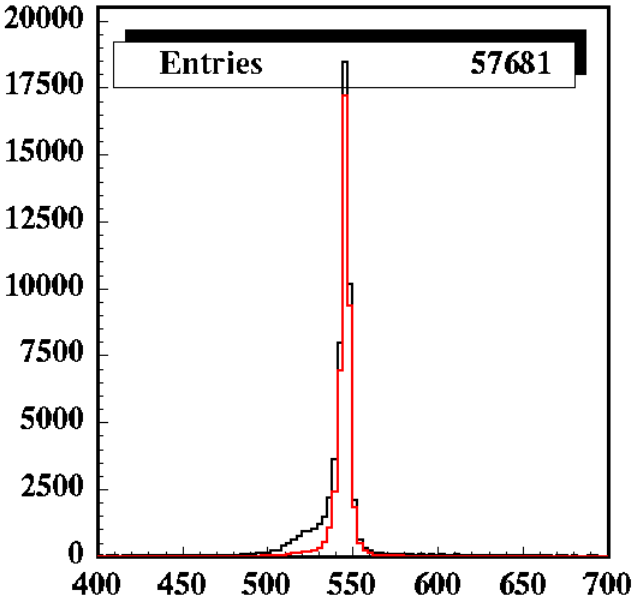


Cut on the PID

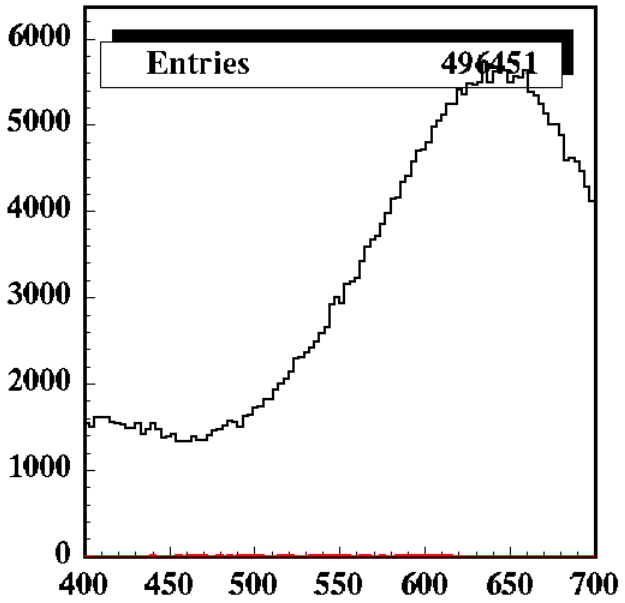
#electrons > 0 .and. #pions < 2

#pions vs #electrons

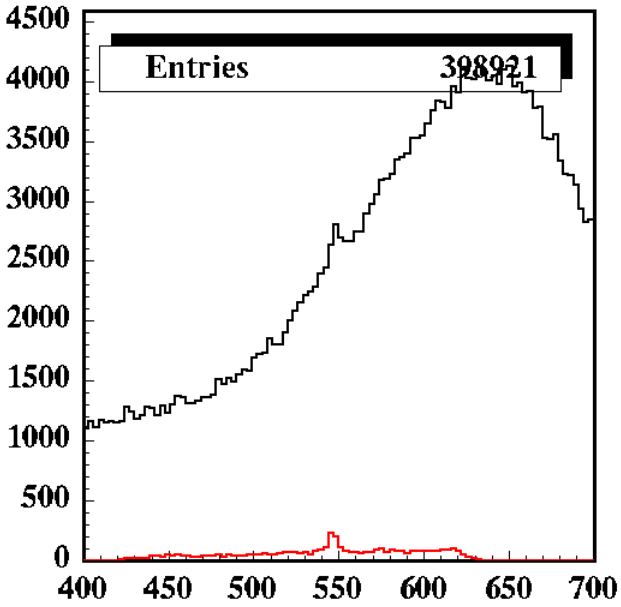
Meeee after background rejection cuts



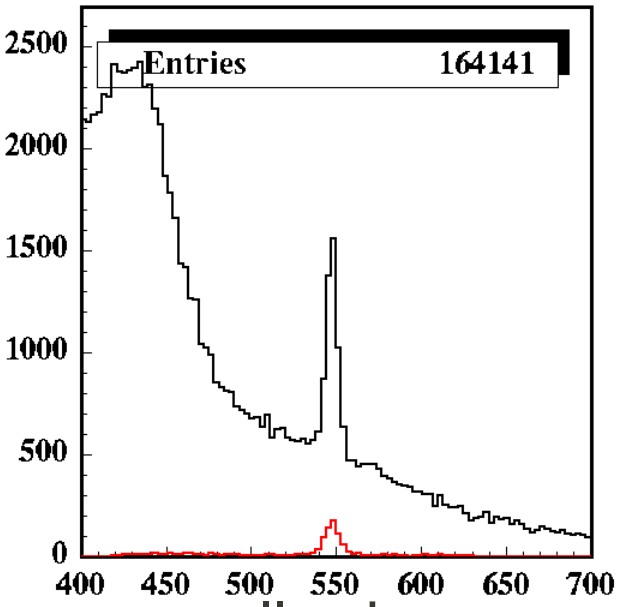
Signal



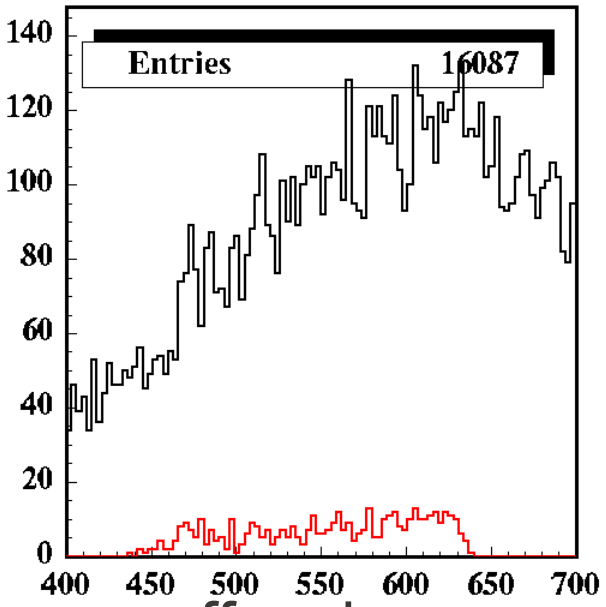
all_phys Kaons+ρπ



Data



allrad



offpeak

After EVCL

After bckg cuts

Background rejection summary table

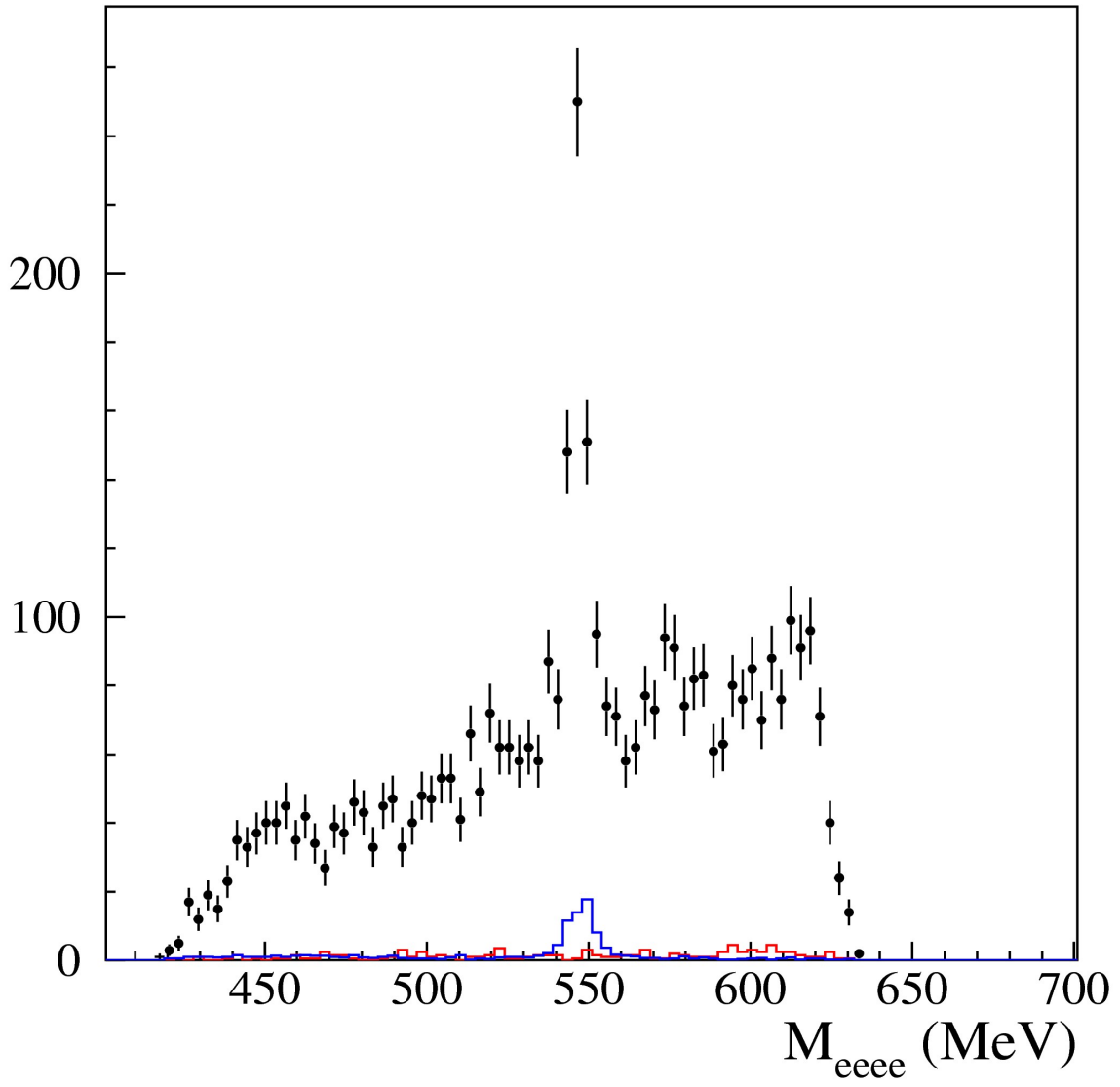
	offpeak	allphys	allrad	signal	data
LSF	-	2	10	100	-
EVCL	16087	464640	164141	57681	398921
s4p	4417	172810	26103	55516	135642
Low θ	3981	172791	26097	55506	132096
Kinematic fit	740	8793	6316	44022	15003
γ conversion	559	7428	2443	42575	12198
PID	446	181	1161	41690	4239

ϕ background subtraction

ϕ background subtracted
using the MC shapes
scaled with the luminosity

The aim is to remove
$\eta \rightarrow ee\gamma$ background

Data
allphys
allrad

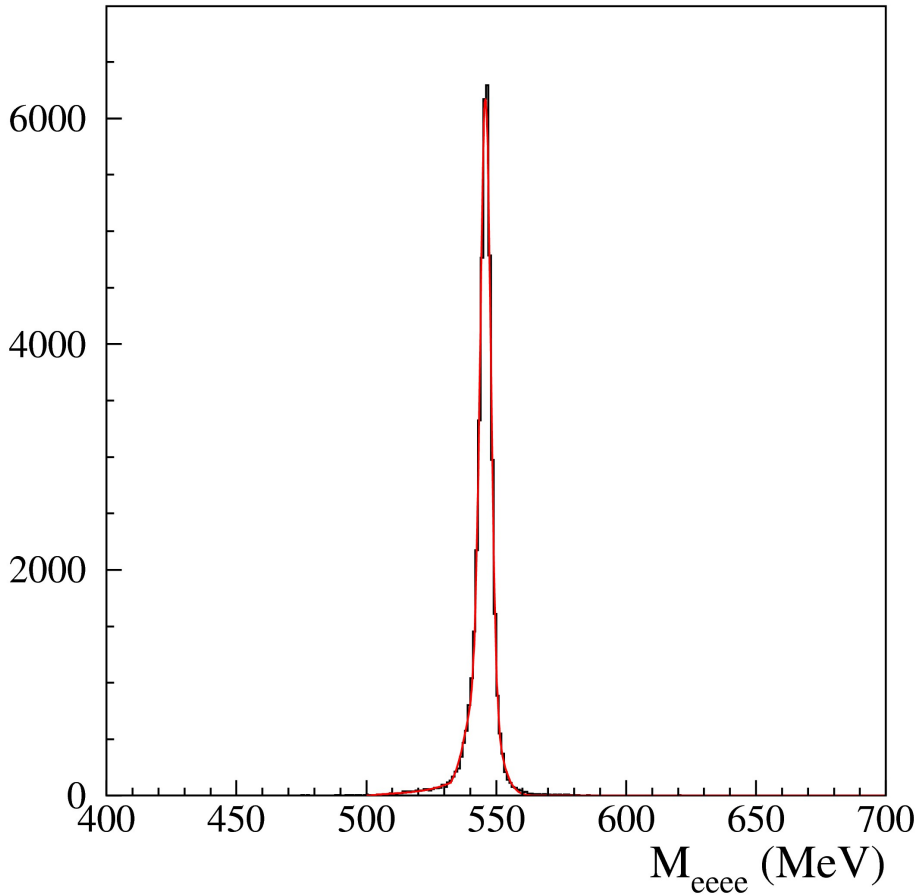


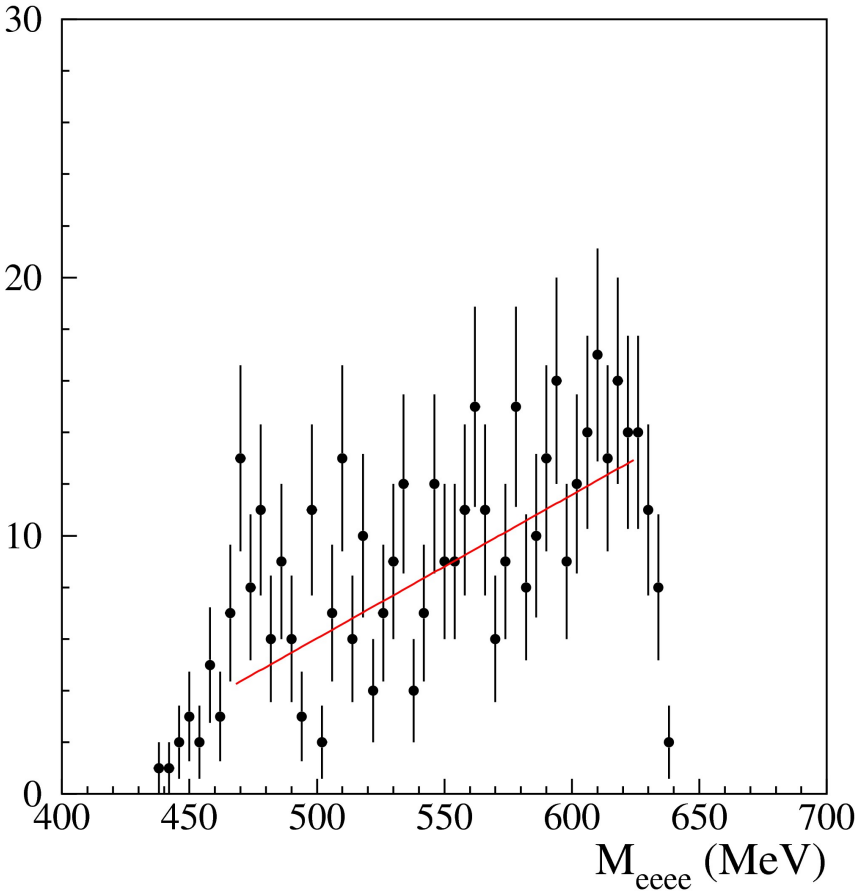
Fit to data components

Fit to data using two components

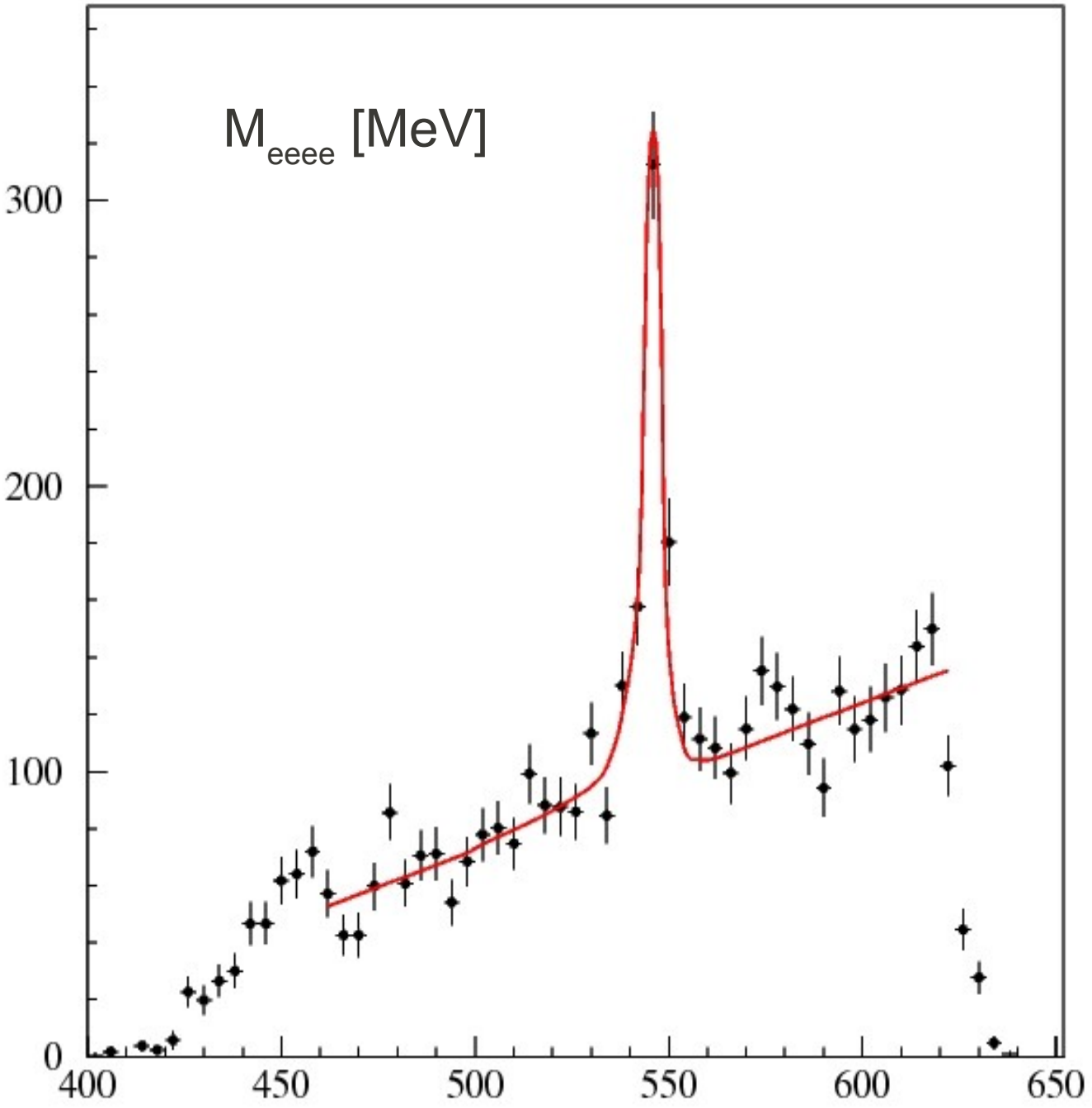
1) signal MC shape (2 gaussians + p3)

2) p1 to account for the offpeak





Fit to data



Two components:

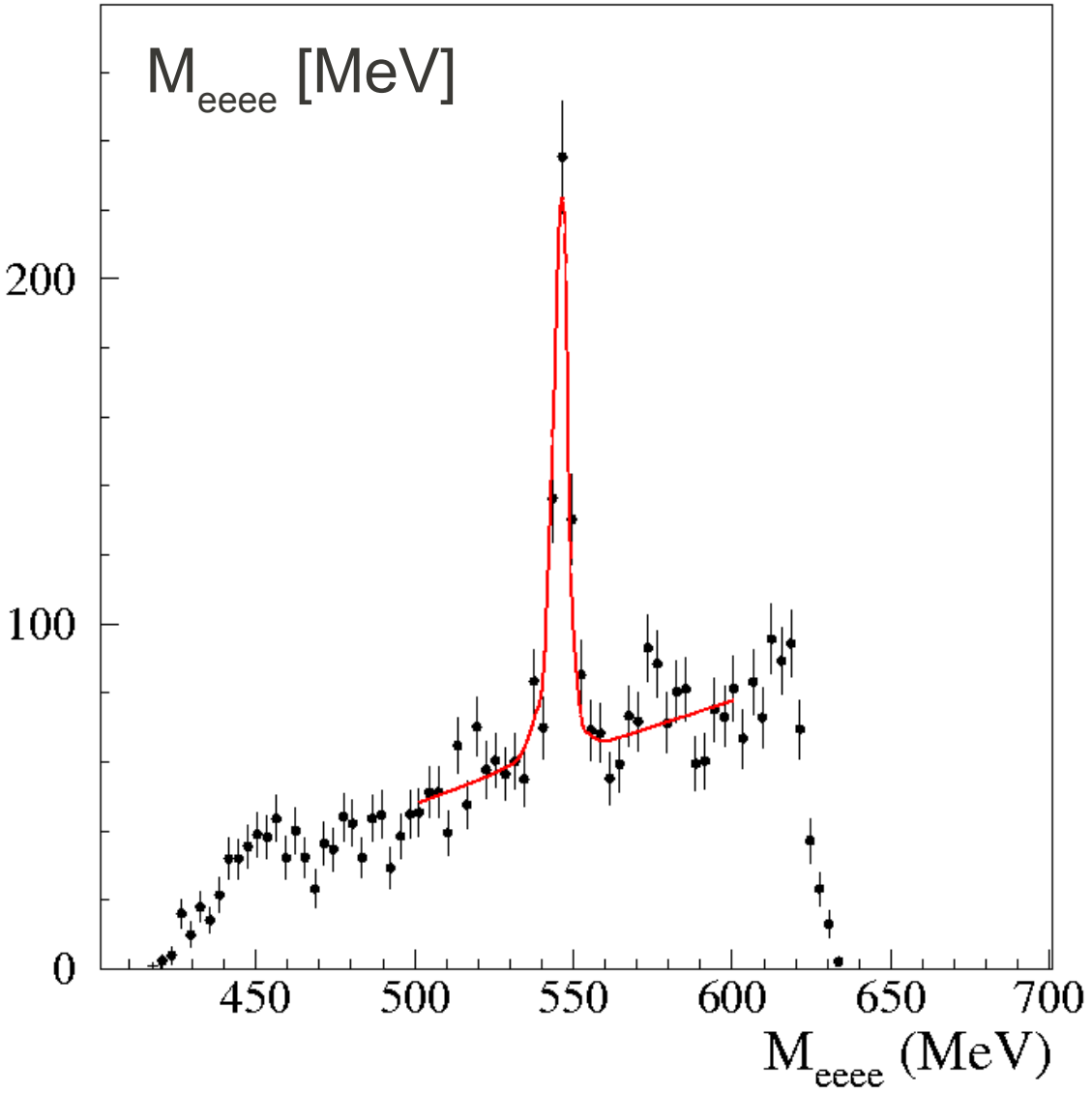
1) MC signal shape
2) p1

χ^2/dof = 43.9/34

P(χ^2) = 0.12

#events = 362 ± 29

Fit to data



Two components:

1) MC signal shape
2) p1

χ^2/dof = 43.9/34

P(χ^2) = 0.12

#events = 362 ± 29

Fit to data result

$$BR = \#events / \#\eta\gamma / \varepsilon$$

#events = 362 ± 29

$\#\eta\gamma = L\ \sigma(\phi \rightarrow \eta\gamma)$

$L = (1733 \pm 10)\ pb^{-1}$

$\sigma = (41.7 \pm 0.6)\ nb$

Efficiency $\varepsilon = 0.2046(9)$ (from MC)

$$BR = (2.44 \pm 0.19_{stat.} \pm 0.04_{norm.}) \times 10^{-5}$$

Systematics evaluation

ANALYSIS CUTS

Evaluated separtely applying 1σ variation on each cut

χ^2 evaluated moving the cut ± 500

PID evaluated changing the pion/electron separation by 10%

FIT

M_{eeee} histogram binning changed from 3MeV/bin to 2 and 4 MeV/bin

Fit range ± 10MeV on each side

P1 fixed to the offpeak fit slope

Systematics evaluation

Source	Relative error (%)	
s4p	-	0.11
Low θ	-0.04	0.47
Kinematic fit	-0.51	2.62
γ conversion(BP)	-0.64	2.42
γ conversion (DCW)	-0.38	0.24
PID	-	1.84
Binning	-3.21	0.19
Fit range	-0.38	1.13
Background slope	-	0.38
Total	**-3.35**	**4.22**

Final result

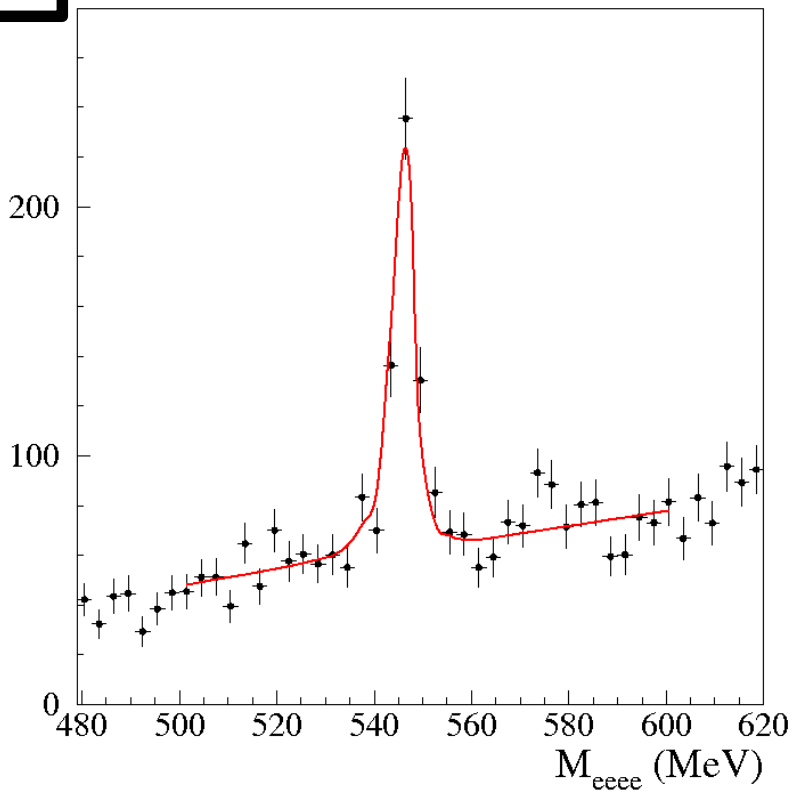
BR = #events / #ηγ / ε

#events = 362 ± 29

#ηγ = L σ(ϕ–>ηγ)

L = (1733 ± 10) pb^{-1}

σ = (41.7± 0.6) nb



Efficiency ε = 0.2046(9) (from MC)

BR = (2.44 ± 0.19$_{stat.}$ ± 0.04$_{norm.}$ $^{+0.10}_{-0.08\ syst.}$) × 10^{-5}

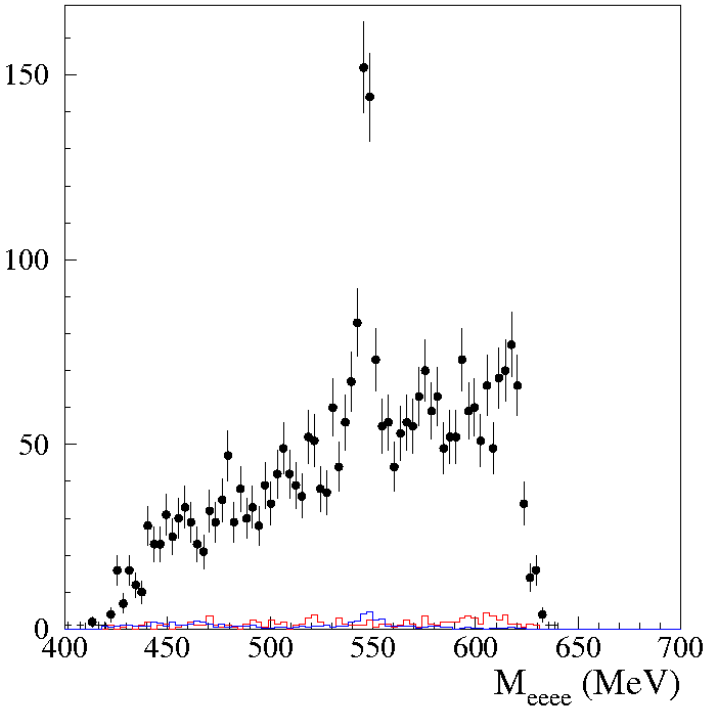
Further checks

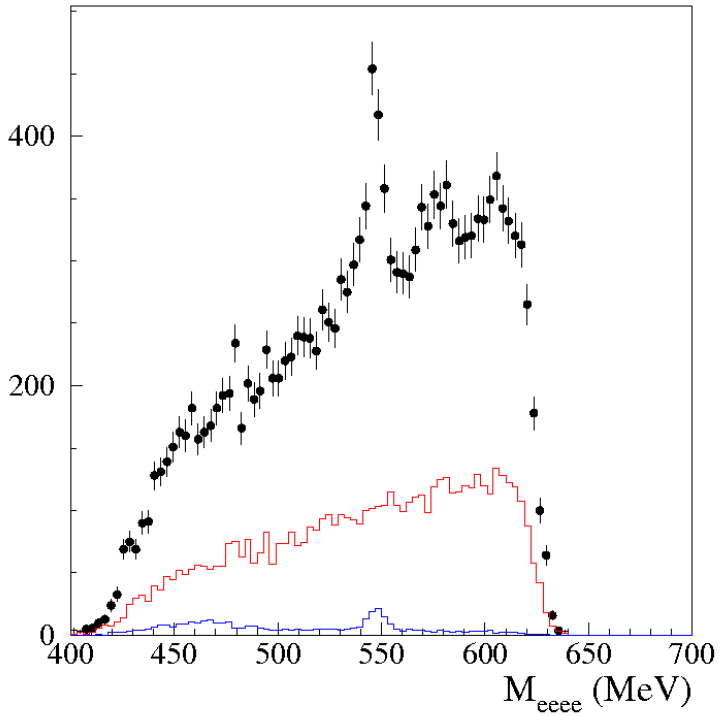
Hardened the cut on conversion

DeeDC < 10 cm and MeeDC < 80 MeV

#events = 271 ± 25

$$BR = (2.52 \pm 0.23_{stat.}) \times 10^{-5}$$





Removing cut on PID

#events = 421 ± 50

$$BR = (2.57 \pm 0.31_{stat.}) \times 10^{-5}$$