KLOE study on the

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

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on behalf of the KLOE collaboration

Outline

Motivations

Reminders

Data sample

Event and track selection

Background rejection

Particle ID

Data - MC comparison

Conclusions

Motivations

η structure, using virtual photon

Model comparison (VMD, χPT)

Test of CP violation [D.N.Gao, Mod.Phys.Lett.A17 (2002)1583-1588]

Angular asymmetry between ee and $\pi\pi$ planes, A_{CP},

can be due to unconventional CPV mechanism

described by a T×V 4 quarks operator with Ds=0.

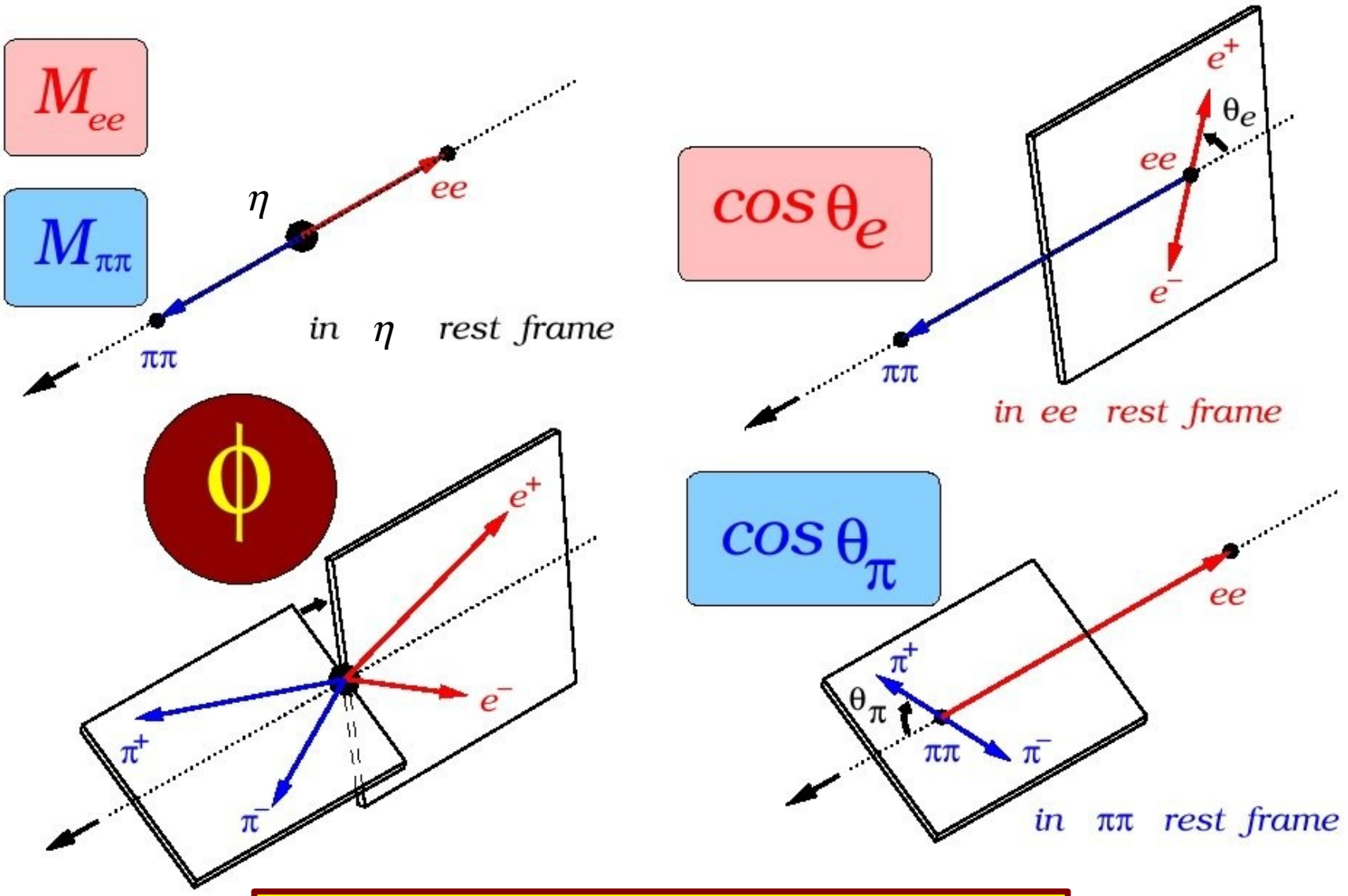
Within SM constrained by BR($\eta \to \pi\pi$),

using the experimental upper limit: $A_{CP} < 10^{-4}$

using theoretical prediction: $A_{CP} \sim 10^{-15}$

CPV model predicts an upper bound of 10^{-2}

Asymmetry



$$\sin\phi\cos\phi = (\hat{n}_{ee}\times\hat{n}_{\pi\pi})\hat{z}(\hat{n}_{ee}\cdot\hat{n}_{\pi\pi})$$

BR: theory & experiment

Jarlskog, Pilkuhn 1967	$0.0065 \times BR(\eta \to \pi^+\pi^-\gamma)$
Using PDG06	Using CLEO '07
$(30.5 \pm 0.7) \times 10^{-5}$	$(25.7 \pm 1.3) \times 10^{-5}$
Picciotto, Richardson 1993	$(32 \pm 3) \times 10^{-5}$
Faessler et al. 2000	36×10^{-5}
Borasoy, Nissler 2007	$(29.9^{+0.6}_{-0.9}) \times 10^{-5}$

CMD-2 (4 events)	$(37\ ^{+25}_{-18\ stat} \pm 3_{syst}) \times 10^{-5}$
CELSIUS-WASA-2006 (16 events)	$(43 \pm 13_{stat} \pm 4_{syst}) \times 10^{-5}$
CELSIUS-WASA-2007 (16 events)	$(43\ ^{+20}_{-16\ stat} \pm 4_{syst}) \times 10^{-5}$

Reminder

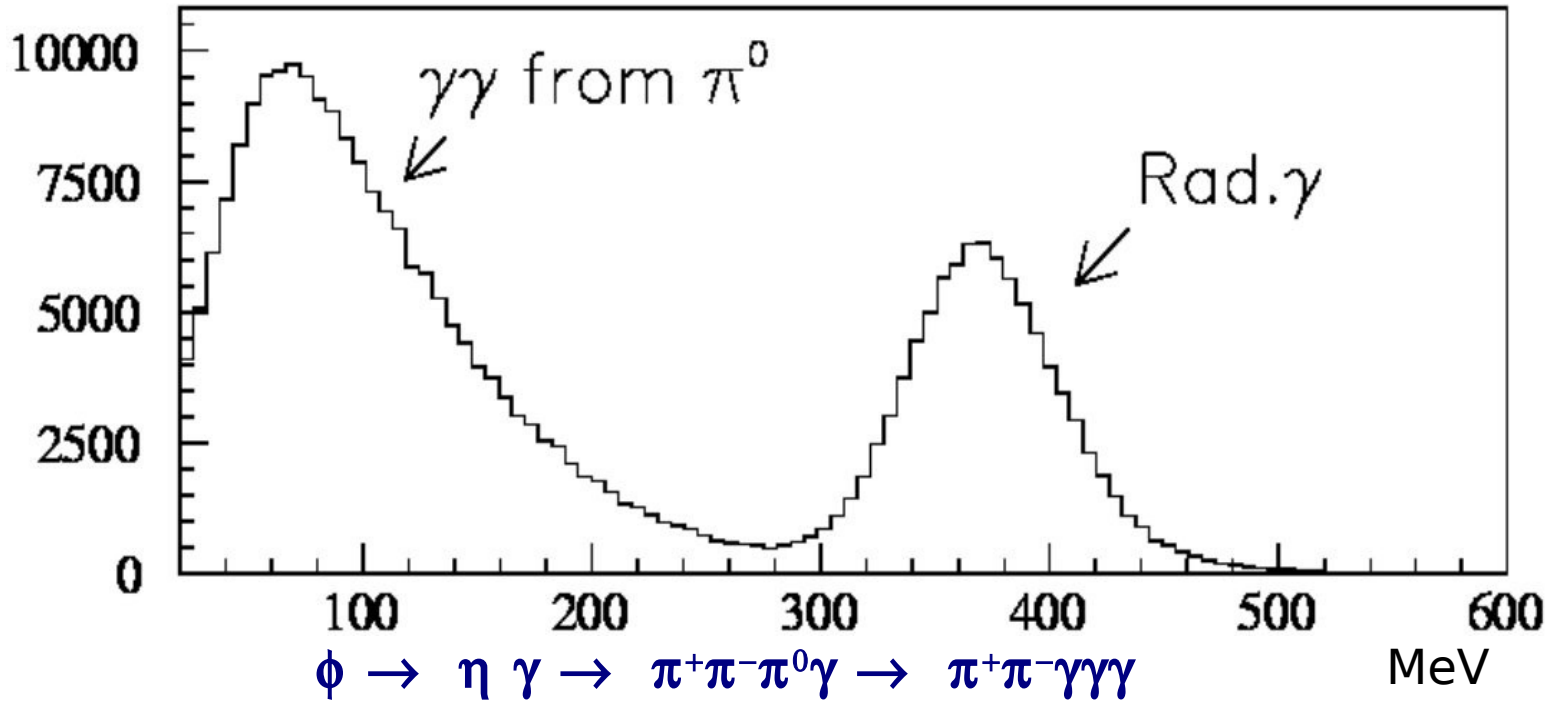
η production at KLOE

DAΦNE is an e^+e^- collider running at $\sqrt{s} = M_\phi$

η produced through transition $\phi \rightarrow \eta\gamma$ (BR=0.013)

Monochromatic recoil photon (363 MeV)

very powerful for event ID



Preliminary BR evaluation

1/3 of KLOE 2004-05 data set

Fit to $M_{\pi\pi ee}$ spectrum

with 3 MC components

Signal $\eta \to \pi^+\pi^- e^+e^-$

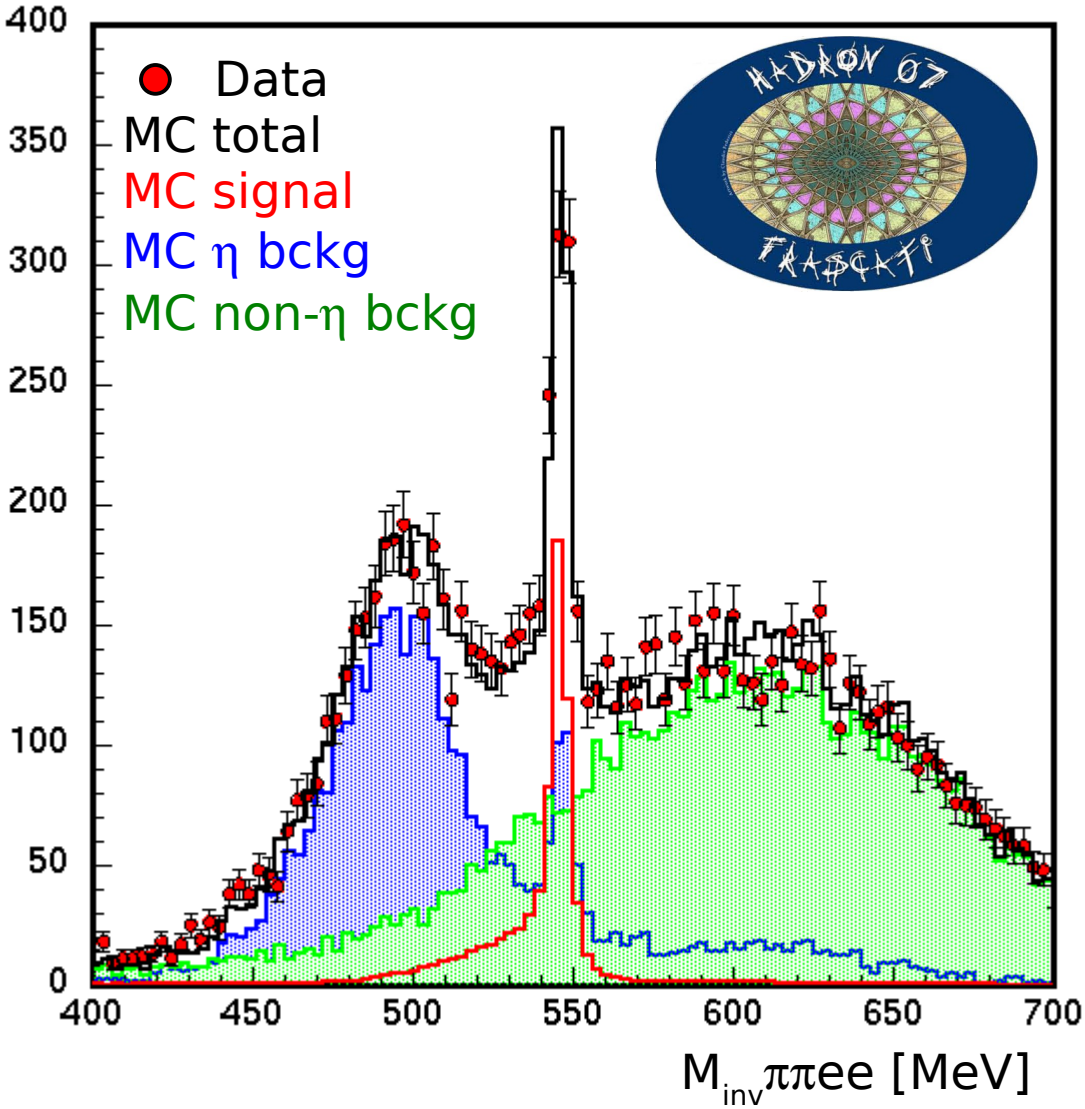
Other η decays

Non η backgrounds

 # events = 733(62)

$\chi^2 = 92/97$

$P(\chi^2) = 0.61$



$$BR(\eta \to \pi^+\pi^- e^+e^-) = (2.4 \pm 0.2_{Stat.} \pm 0.4_{Syst.}) \times 10^{-4}$$

Data sample

Today	1719 pb^{-1} data 2004/05	
	3479 pb^{-1} MC	
Preliminary result October 2007	622 pb^{-1} data 2004/05	3 times more
	1723 pb^{-1} MC	2 times more

Event and Track selection

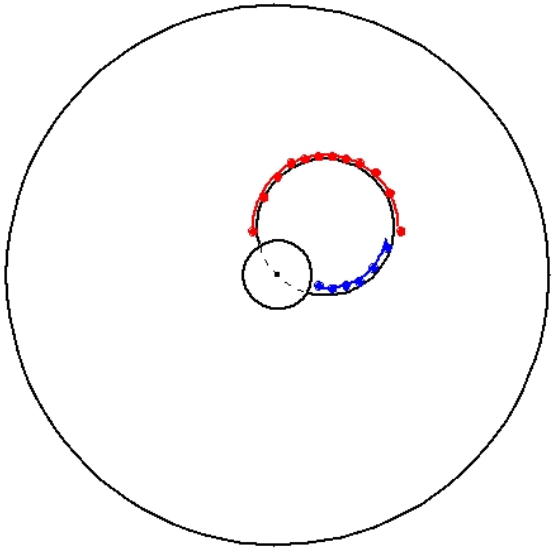
Event selection

- ≥ 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: higher momentum pions

lower momentum electrons

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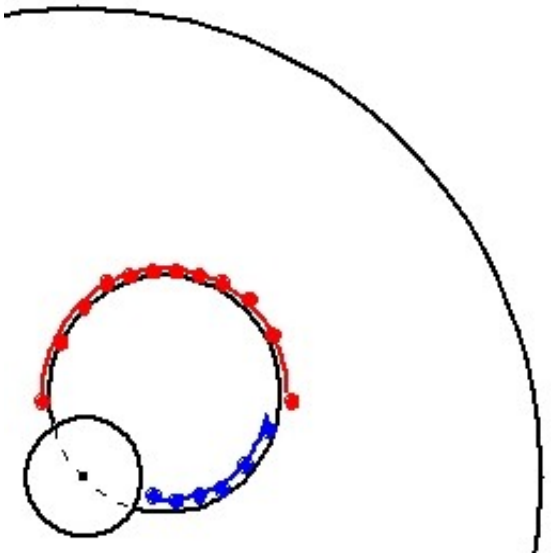

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Kinematic fit

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 ϕ momentum

The 5 constraints are:

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

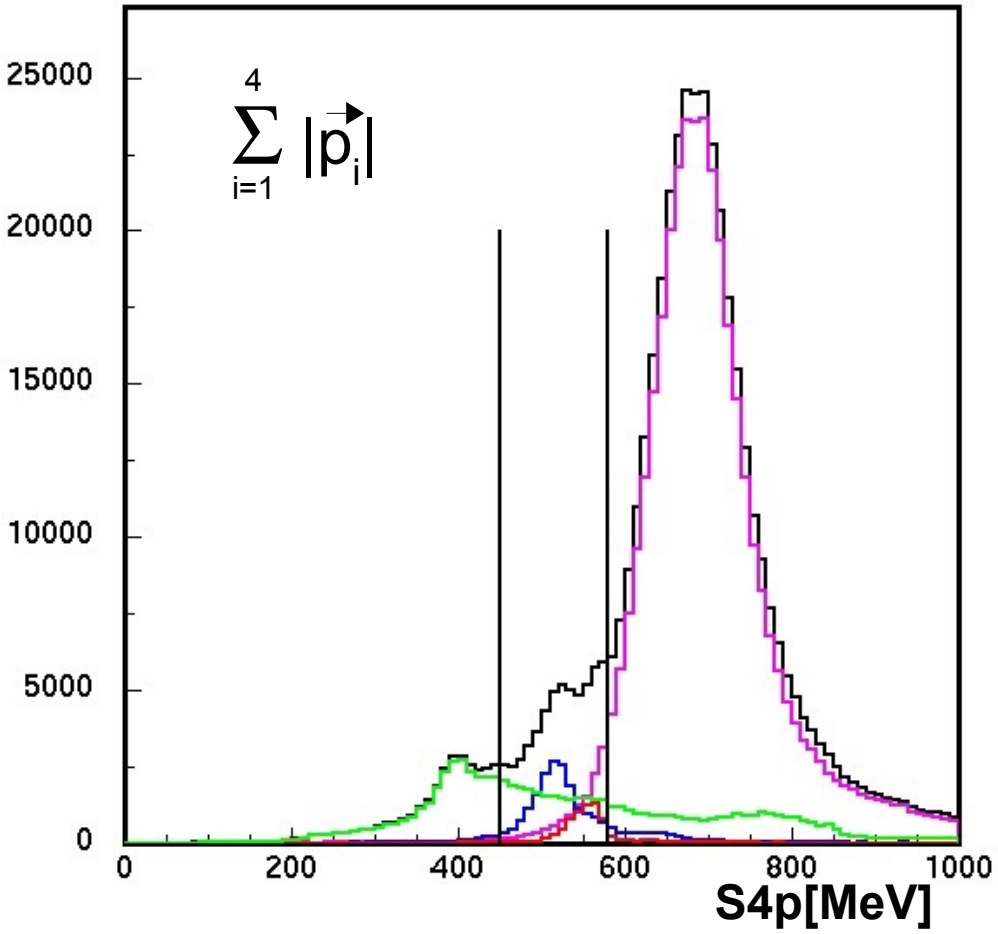
Background rejection in 5 steps

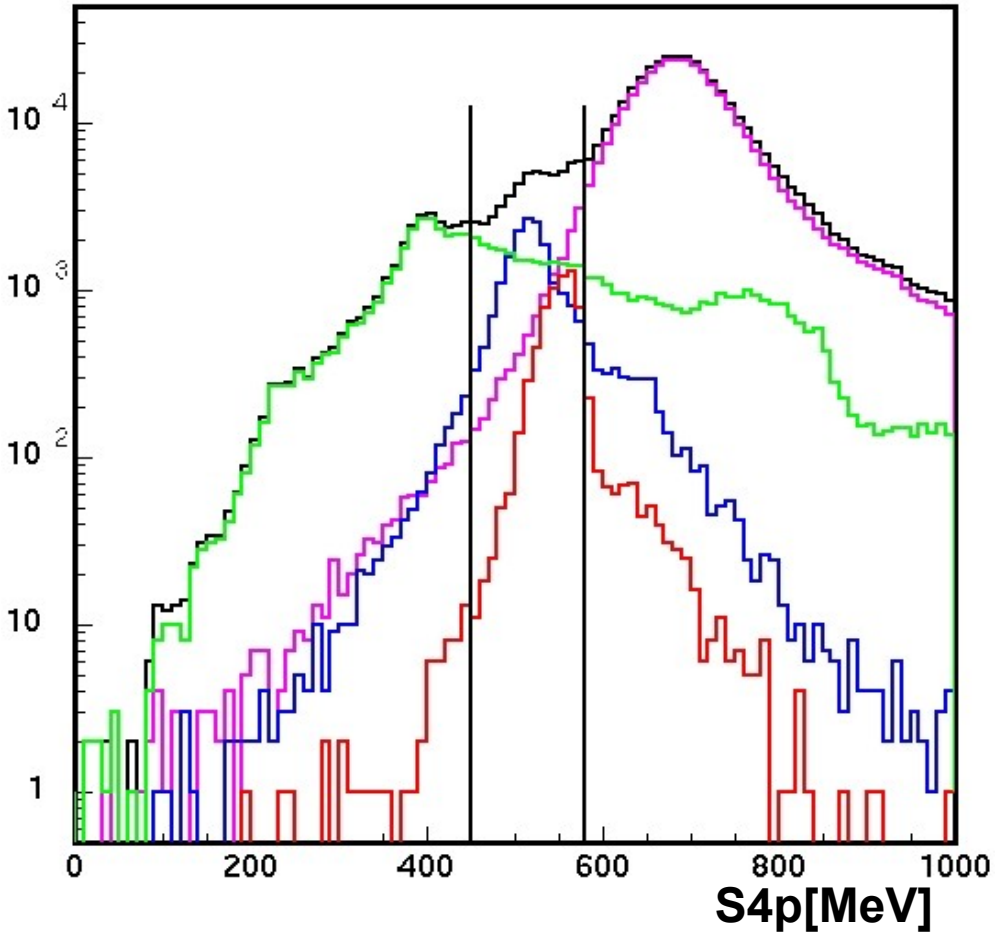
Background rejection - step 1

$$450\ \text{MeV} < \sum_{i=1}^{4} |\vec{p}_i| = S4p < 580\ \text{MeV}$$

Total $\phi \to \eta\gamma$ $\phi \to \rho\pi + \pi^+\pi^-\pi^0$

Signal $\eta \to \pi^+\pi^-e^+e^-$ Other backgrounds



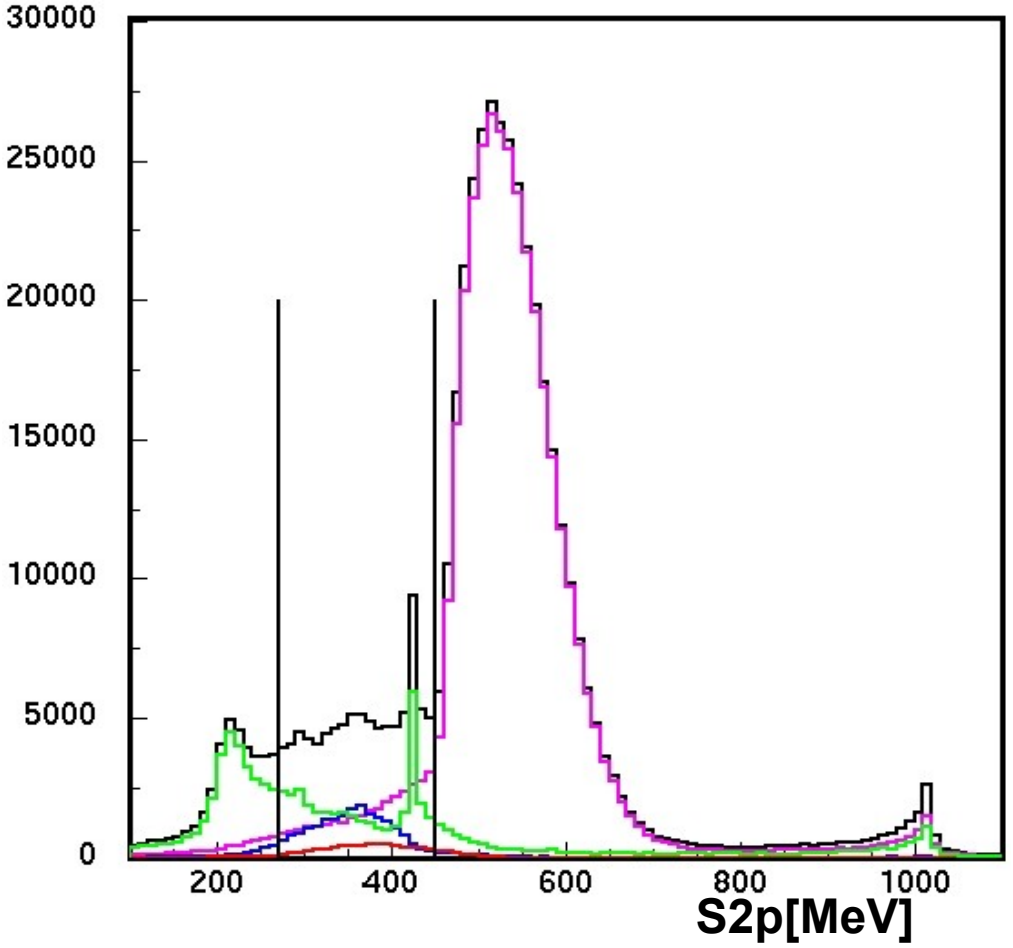


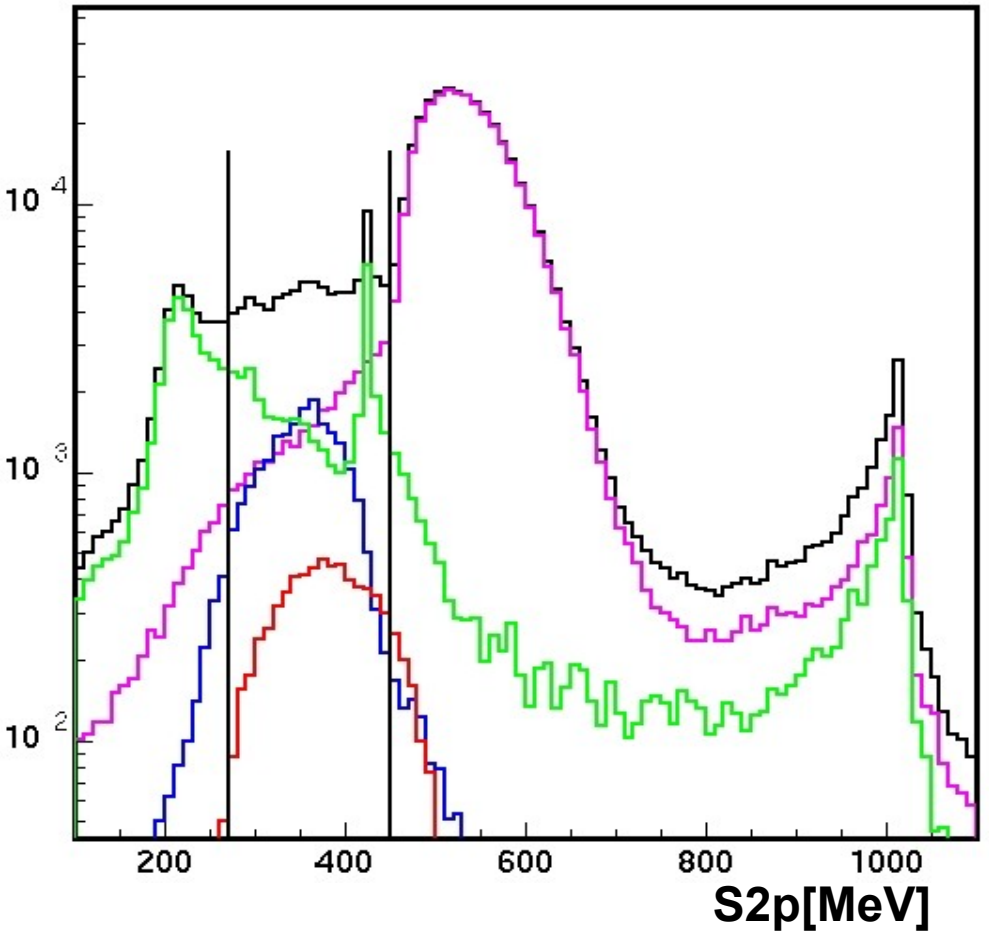
Background rejection - step 2

$270 < |P(p^+1)| + |P(p^-1)| = s2p < 450$ MeV

Total $\phi \to \eta\gamma$ $\phi \to \rho\pi + \pi^+\pi^-\pi^0$

Signal $\eta \to \pi^+\pi^-e^+e^-$ Other backgrounds





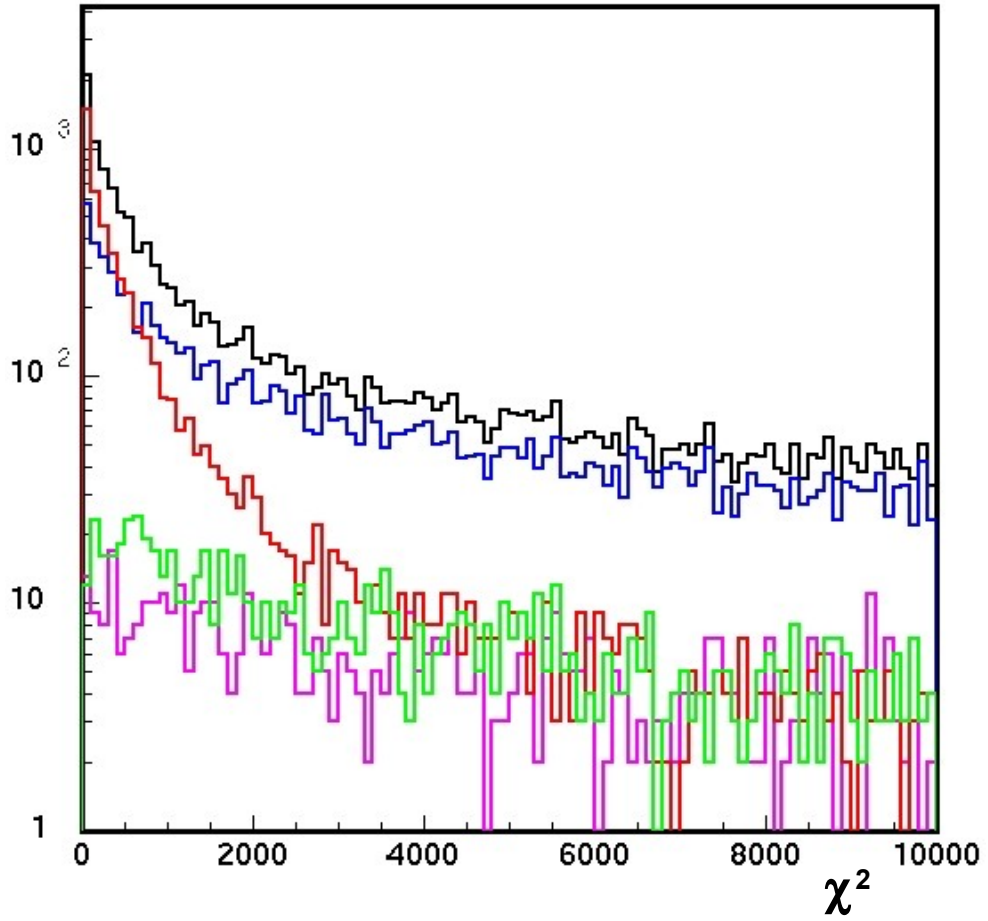
Background rejection - step 3

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

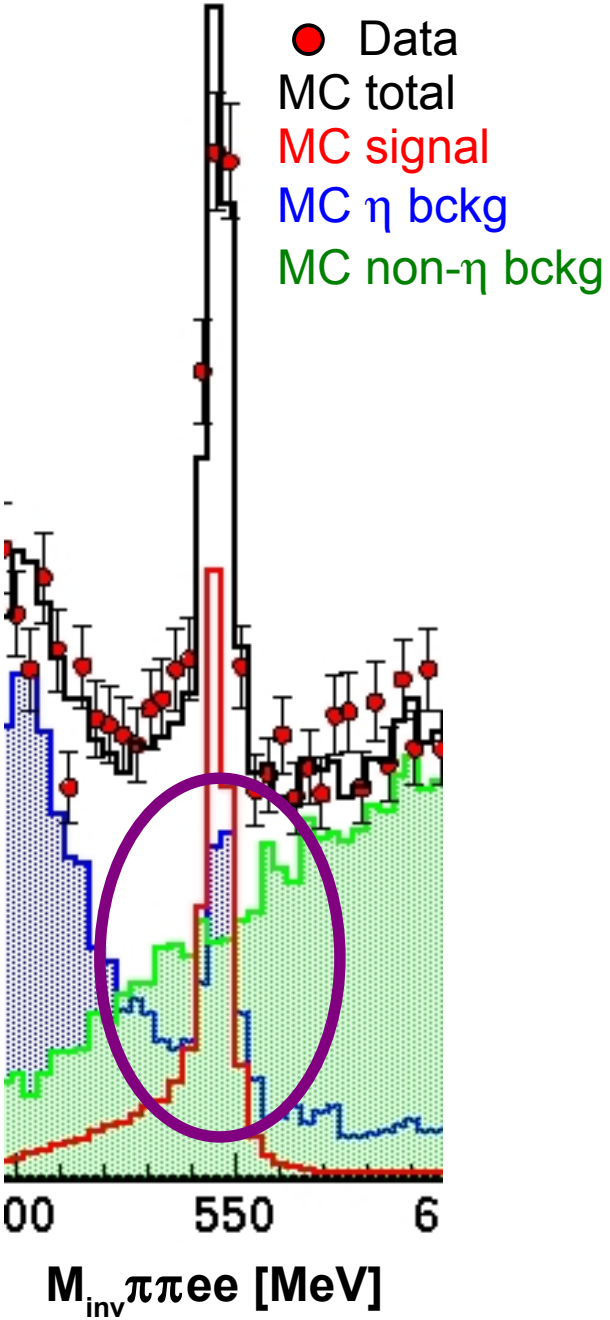
New

Total $\phi \to \eta\gamma$ $\phi \to \rho\pi + \pi^+\pi^-\pi^0$

Signal $\eta \to \pi^+\pi^-e^+e^-$ Other backgrounds

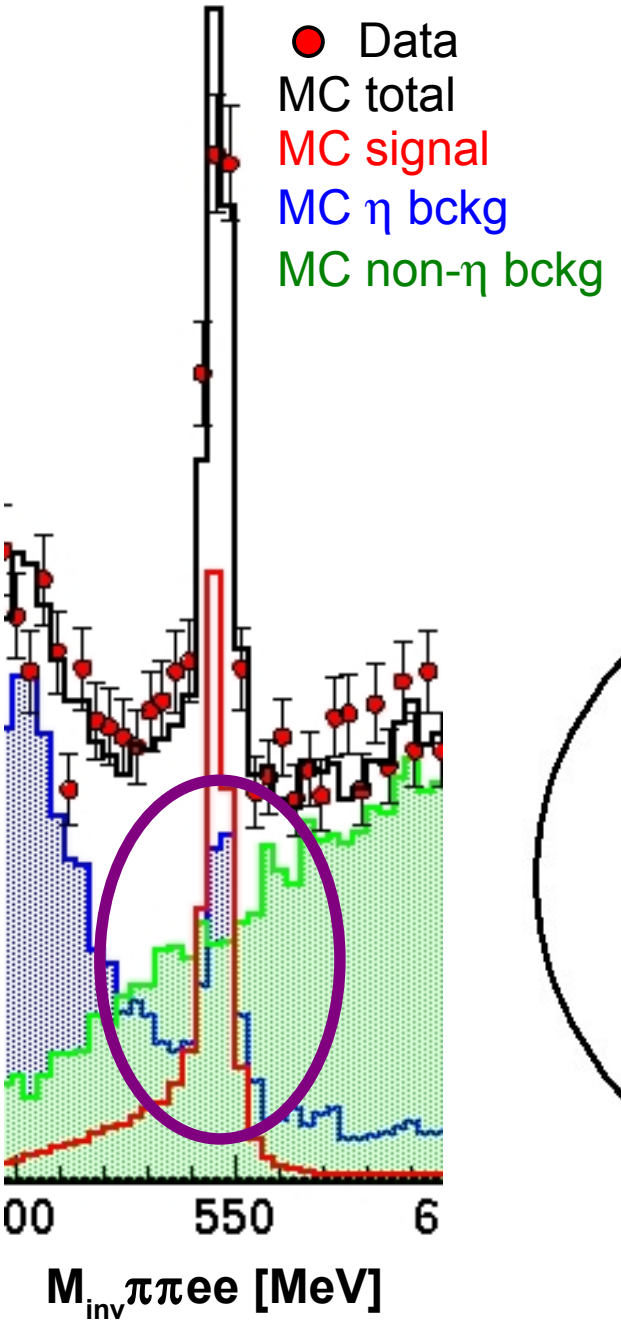


Background rejection - step 4



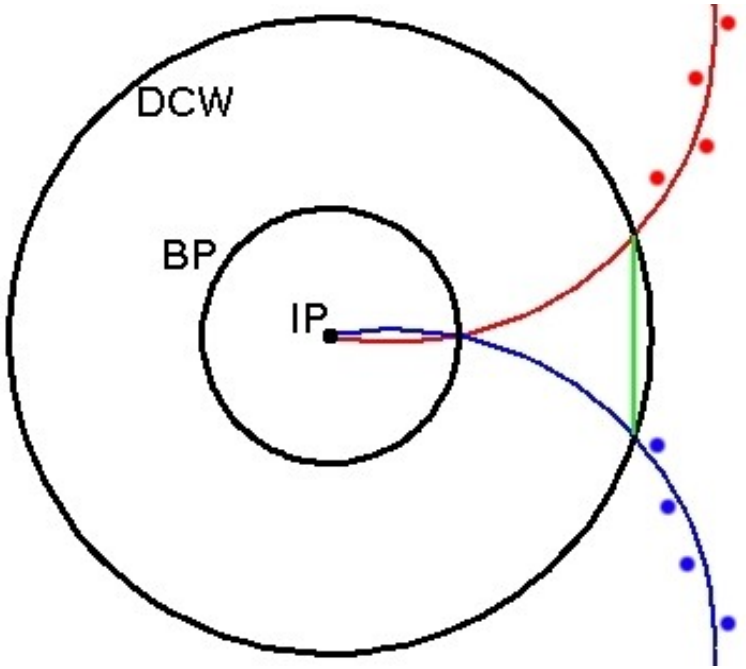
There is a background having the same signature of $\eta \rightarrow \pi\pi ee$

Background rejection - step 4



There is a background having the same signature of $\eta \to \pi\pi ee$

It is mainly due to photon conversion on the BP in $\eta \to \pi\pi\gamma$ events

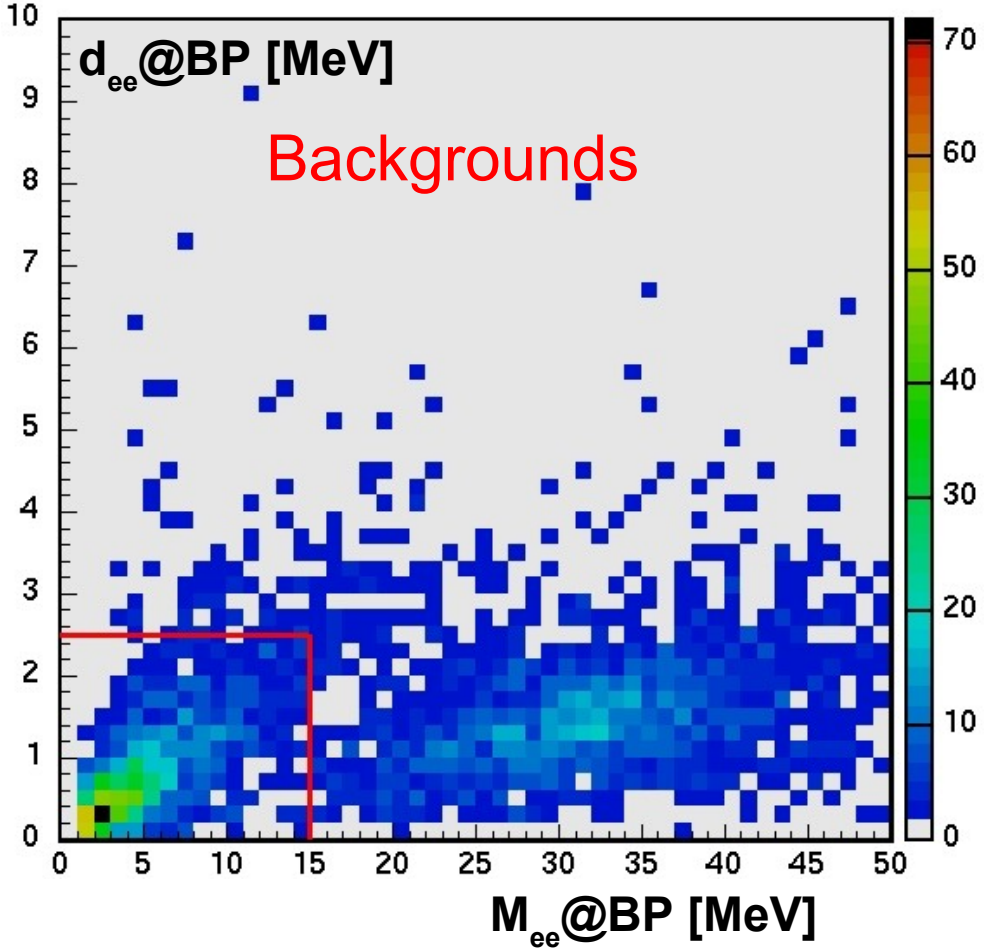


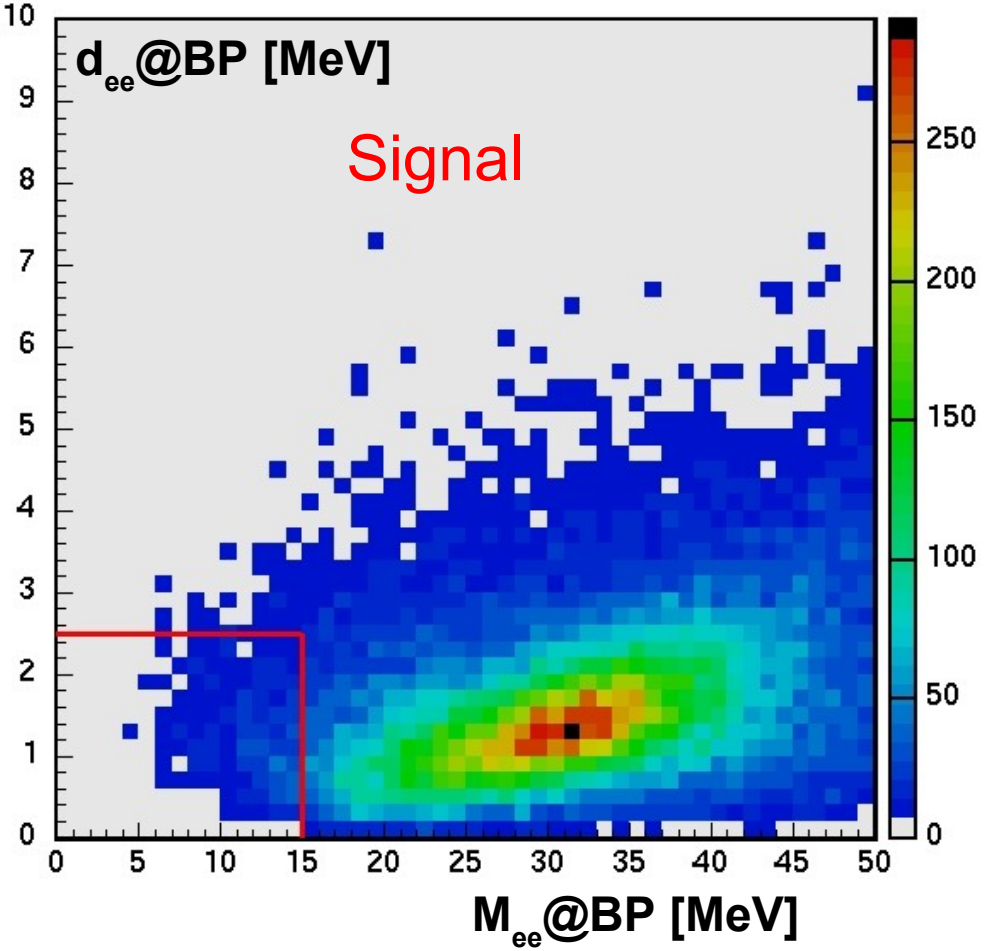
Disentangle using $M_{inv}(e^+e^-)$ and $Dist(e^+e^-)$ Should be zero at the conversion

Background rejection - step 4

M_{ee}@BP > 15 MeV .or. d_{ee}@BP > 2.5 cm

New

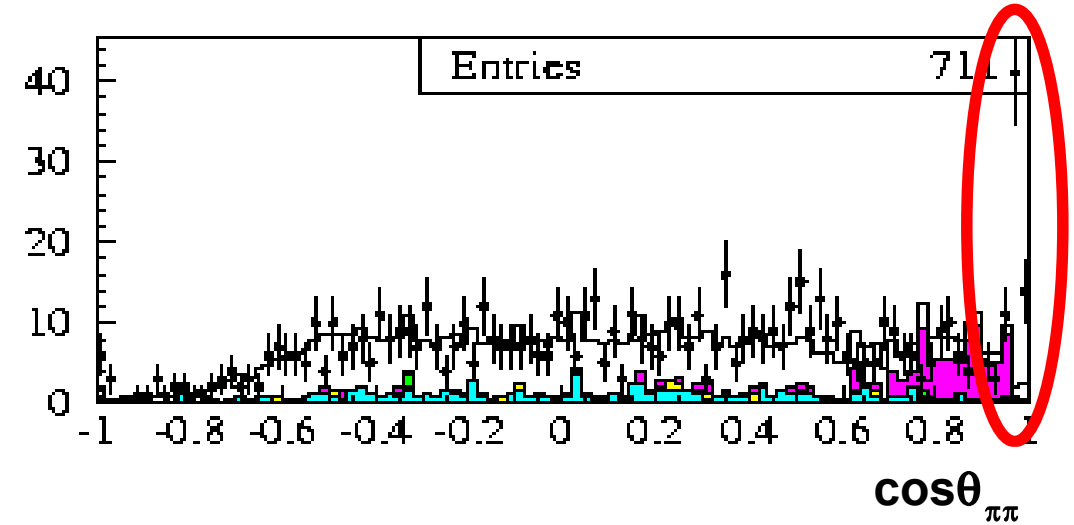


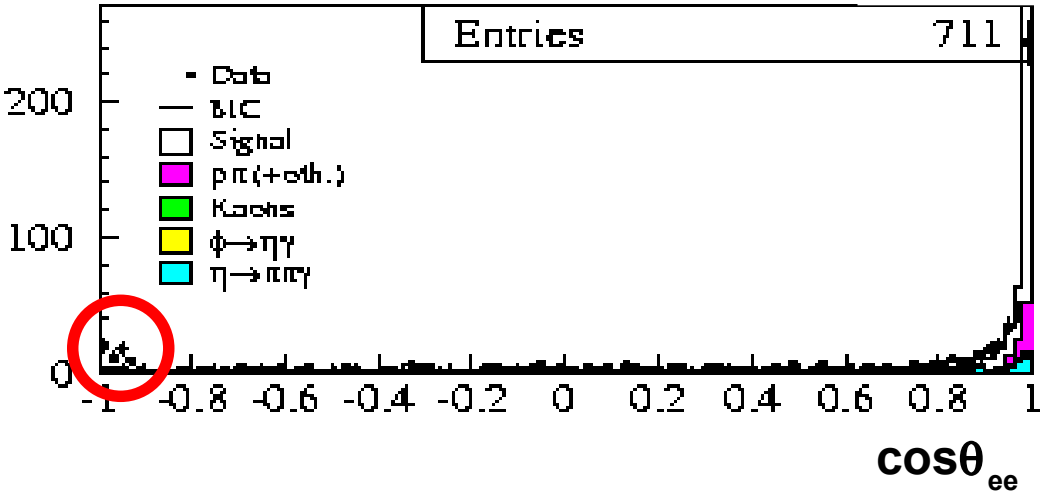


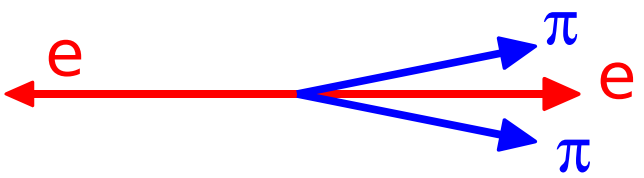
Background rejection - step 5

Low-θ background

We see on data events not simulated in MC







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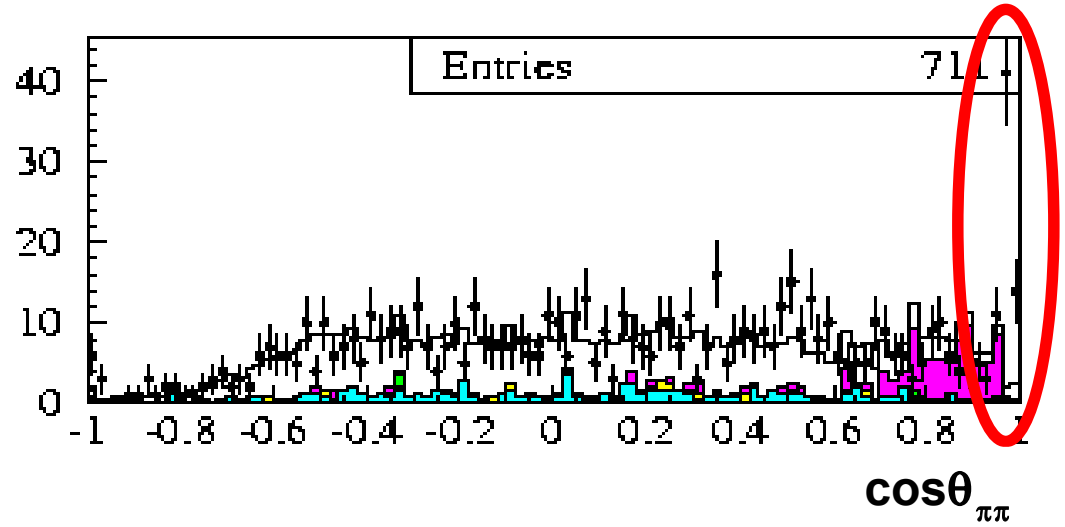
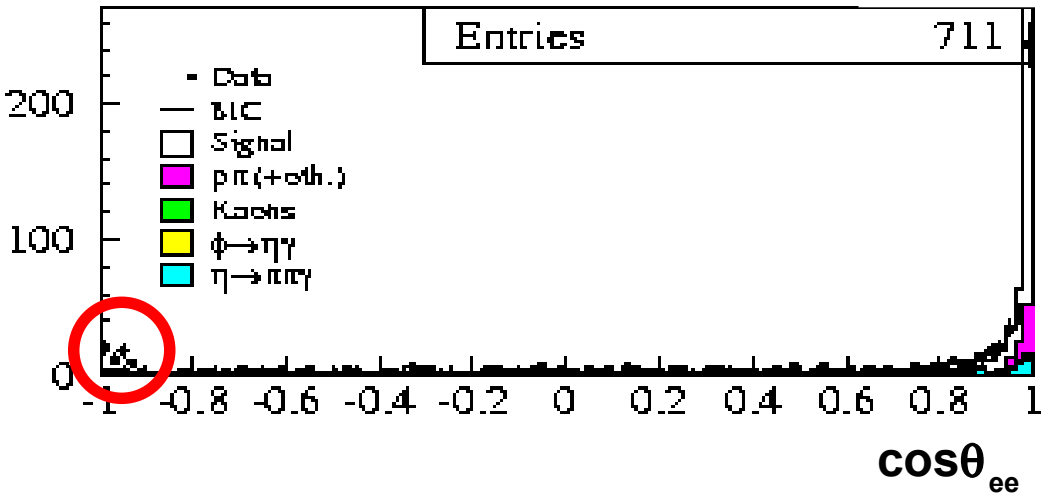
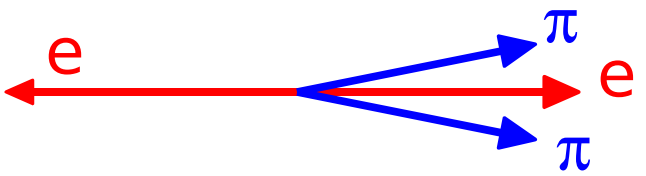
TOF of “pions” (i.e. particles with higher momenta), compatible with electrons TOF







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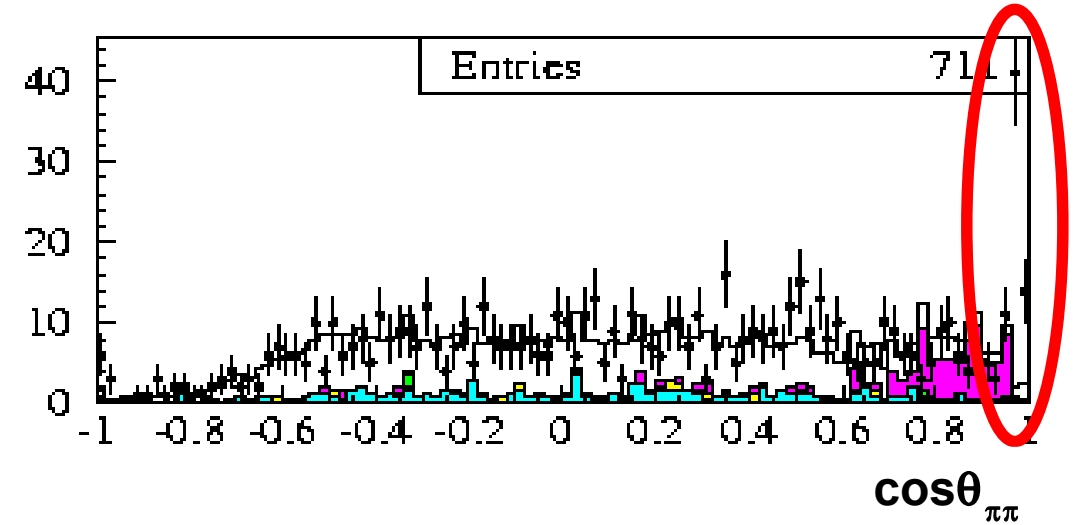
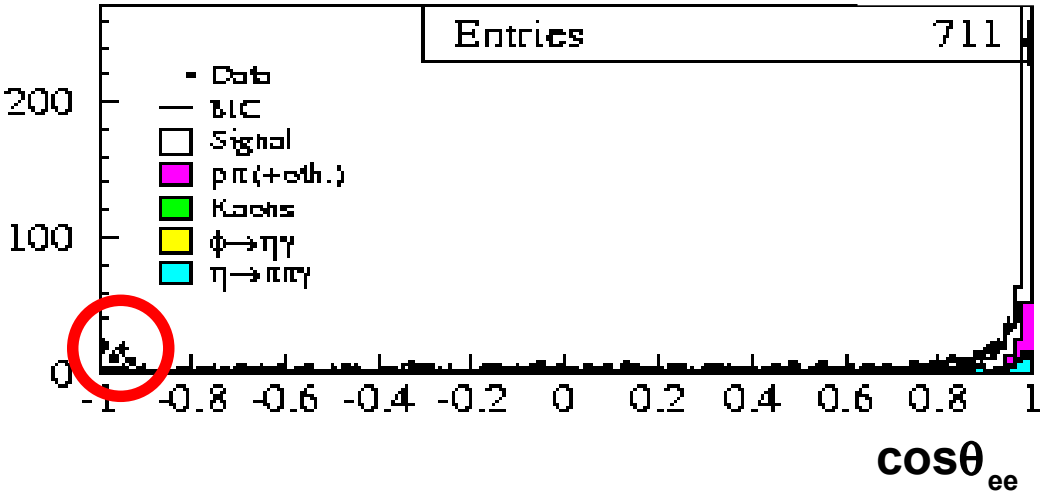
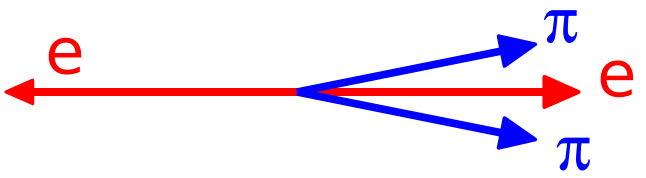
Studied with event display



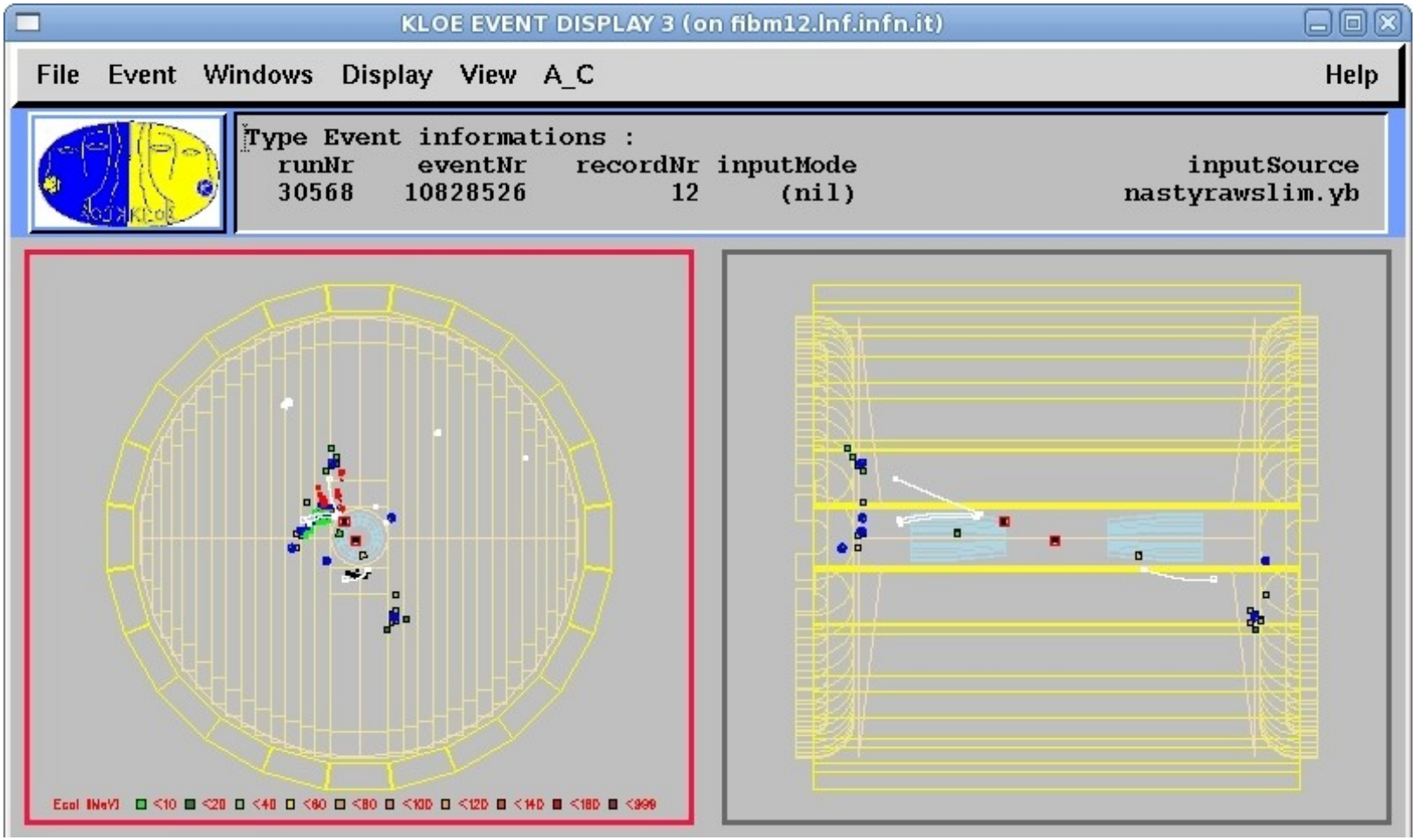




Background rejection - step 5

$\langle \cos\theta_+ \rangle < 0.85$ .and. $\langle \cos\theta_- \rangle > -0.85$

New



Small angle tracks

A particle hits something before DC producing two more particles

Improving particle ID using Time Of Flight

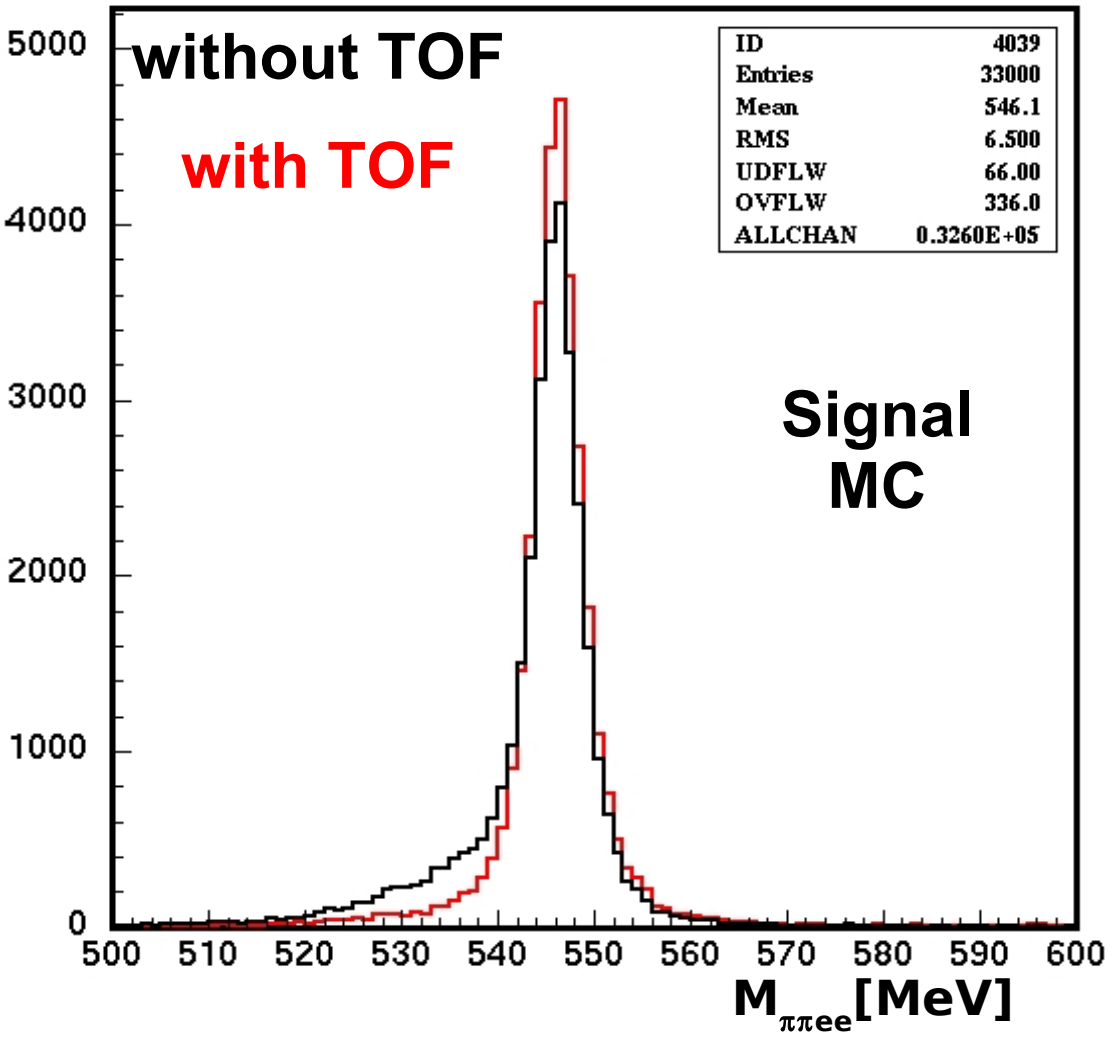
PID using TOF

Asymmetry in Mππee spectrum due to *wrong mass assignment*

Can be improved using TOF

We evaluate $\Delta t = t_{track} - t_{cluster}$ in both electron (Δt_e) and pion (Δt_π) hypotheses

Also look for kink (i.e. decay)

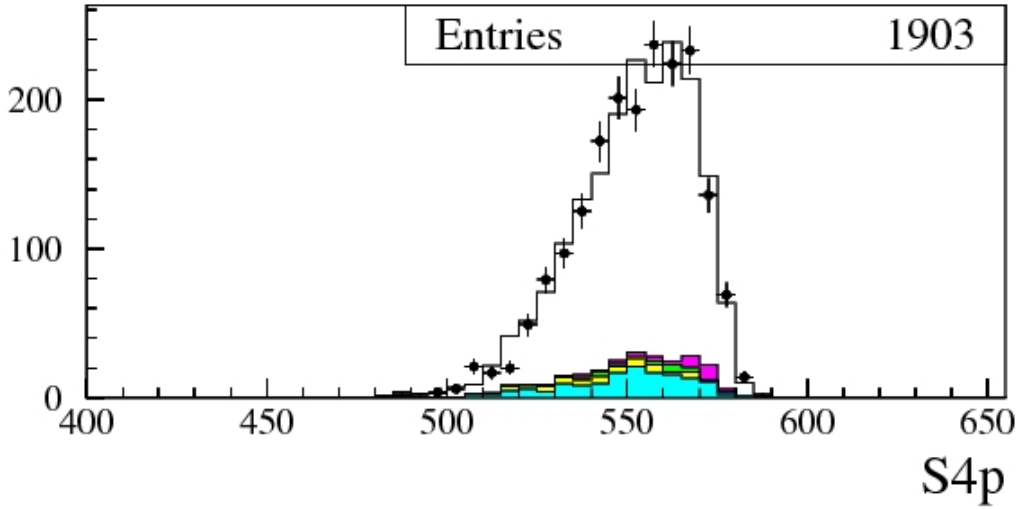


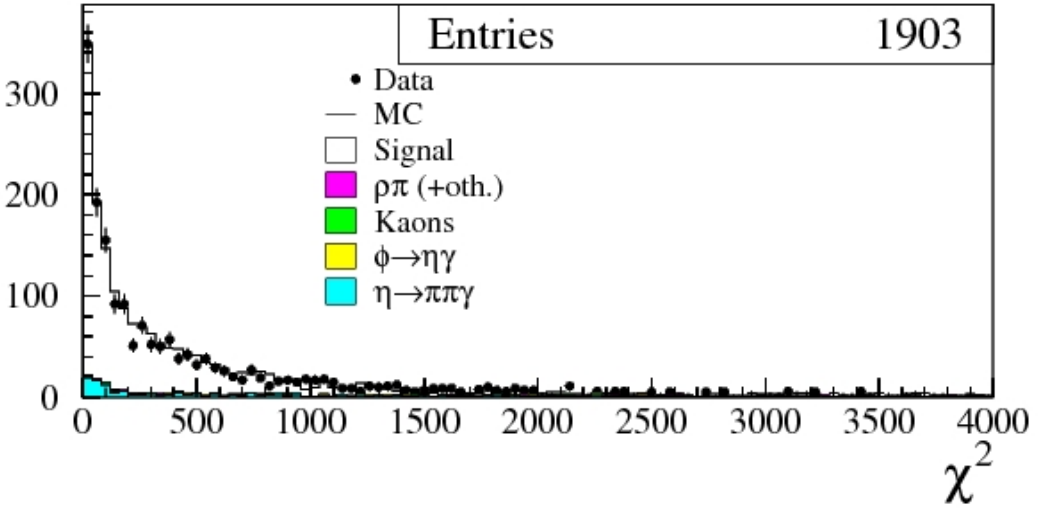
Data-MC comparison

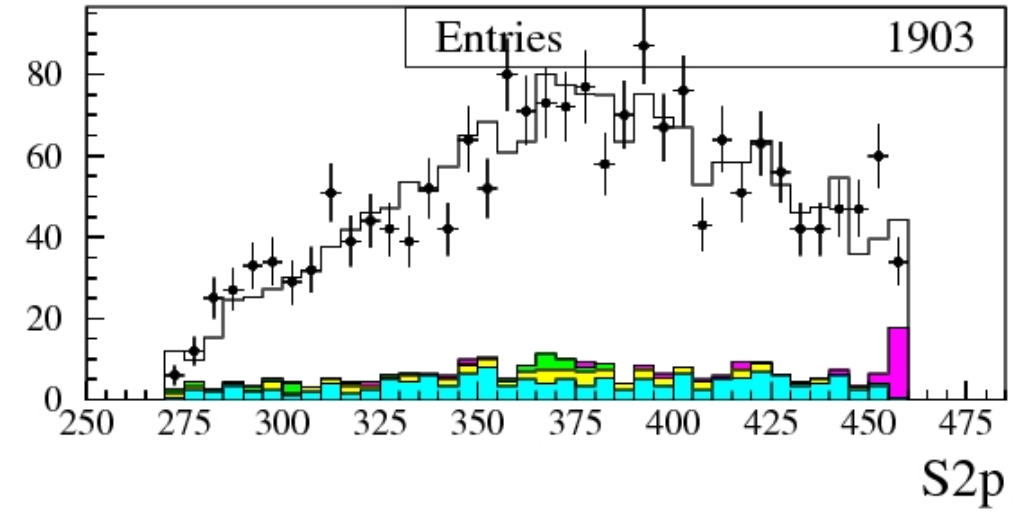
Data-MC comparison

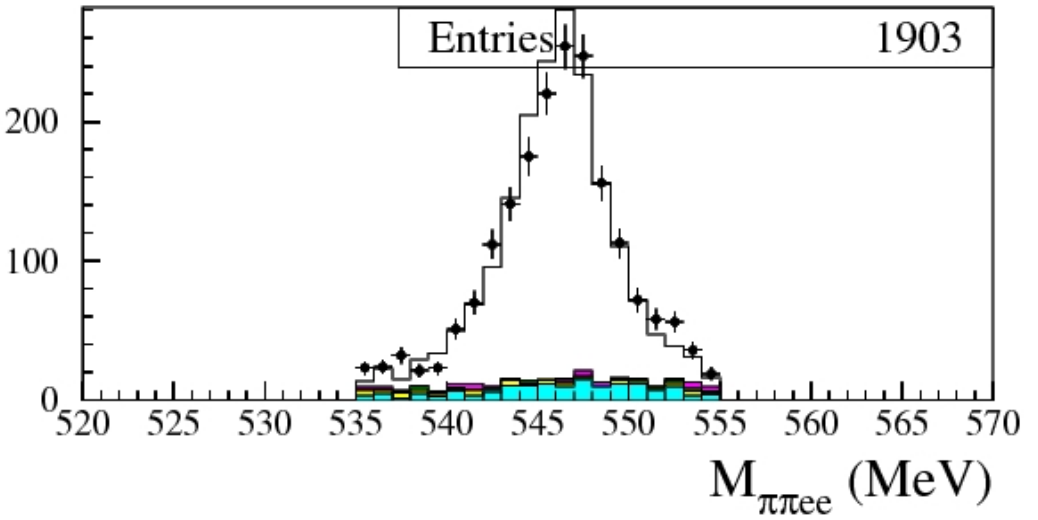
Data
MC total
signal
$\rho\pi$ + others
kaons
$\phi \to \eta\gamma$
$\eta \to \pi\pi\gamma$

$535 < M_{\pi\pi ee} < 555$ MeV









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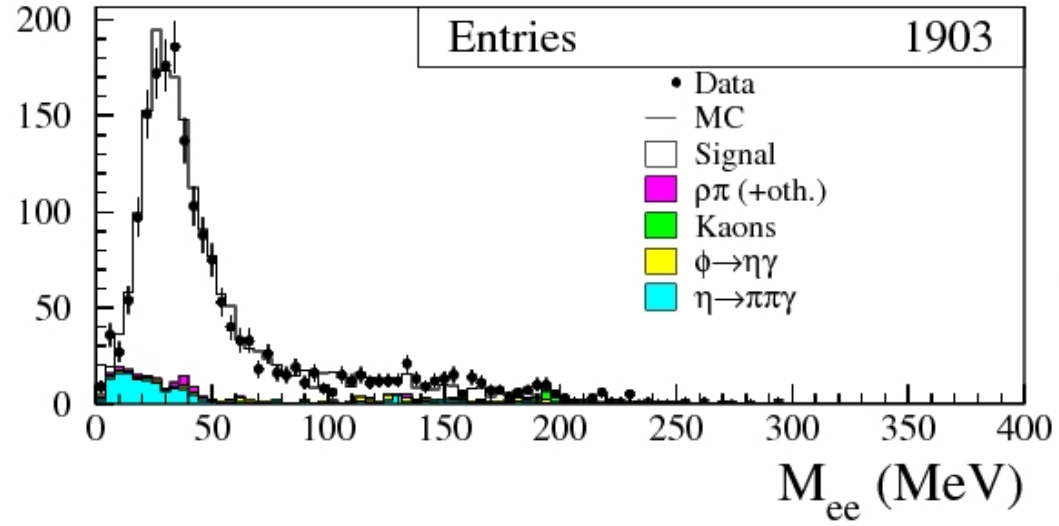

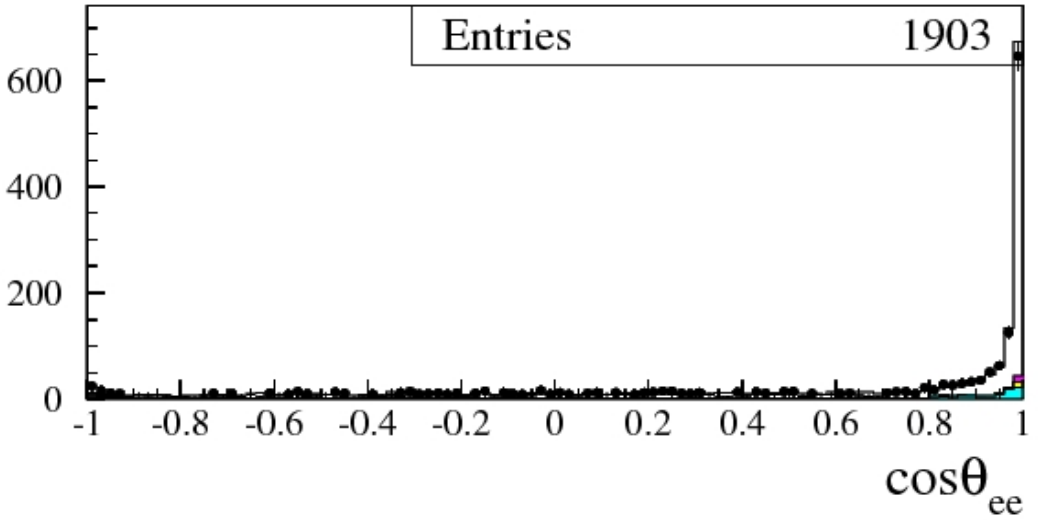

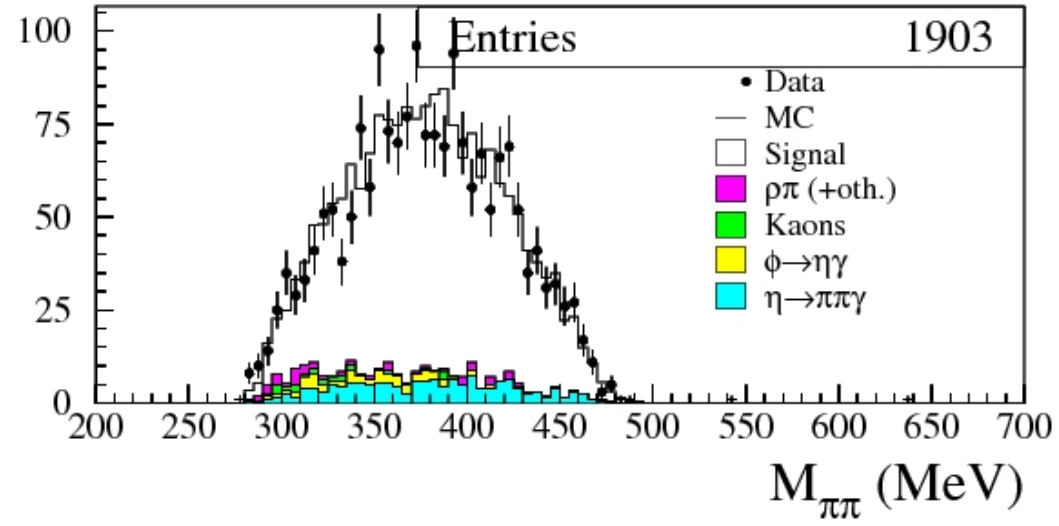

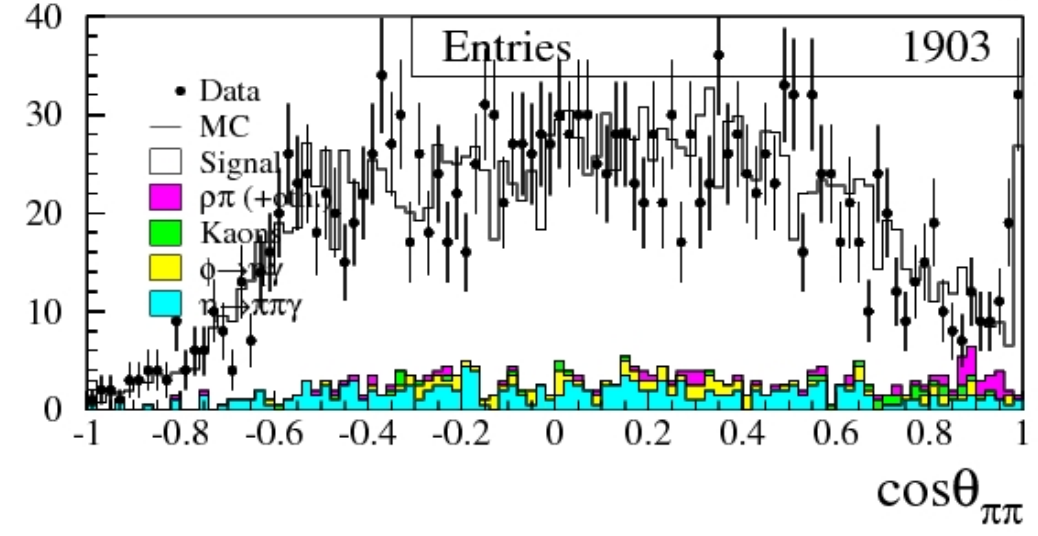

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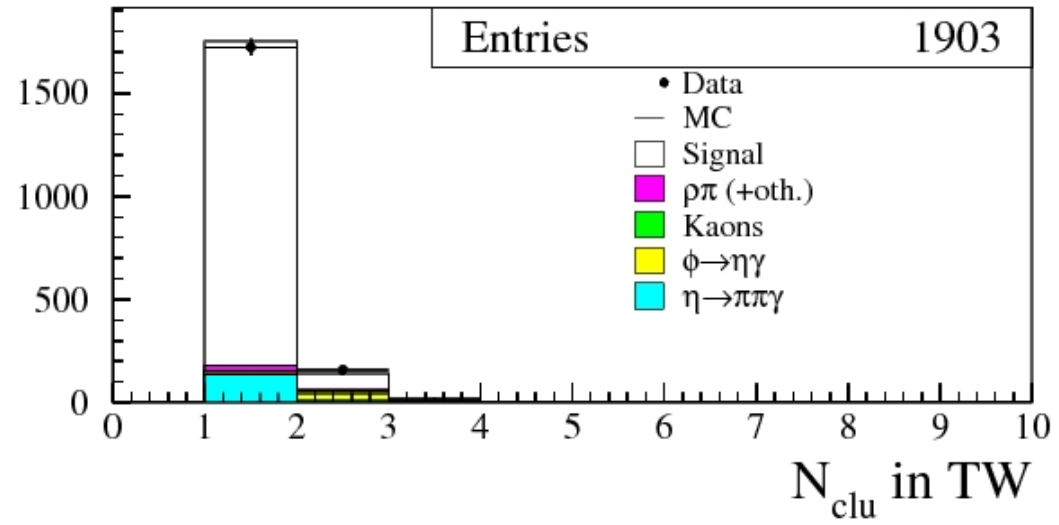

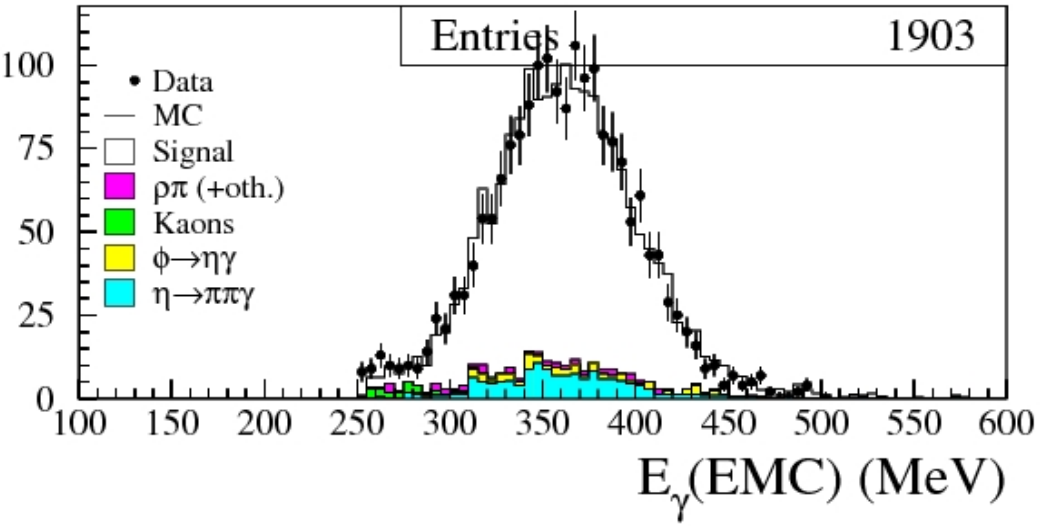

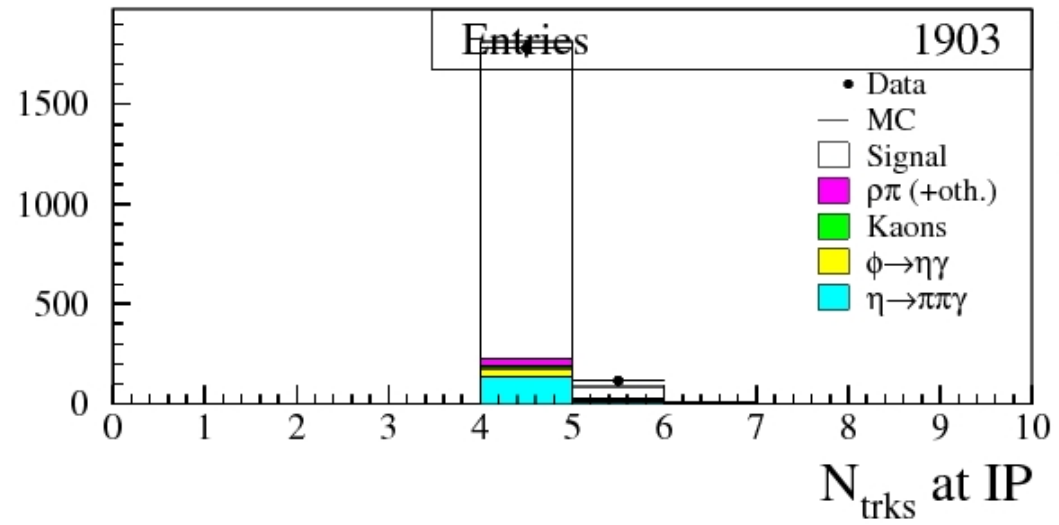

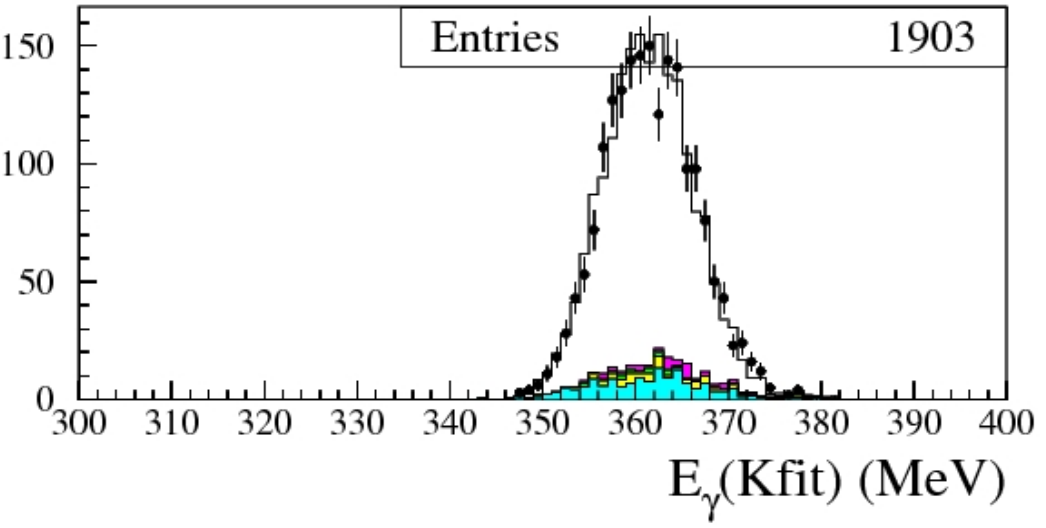

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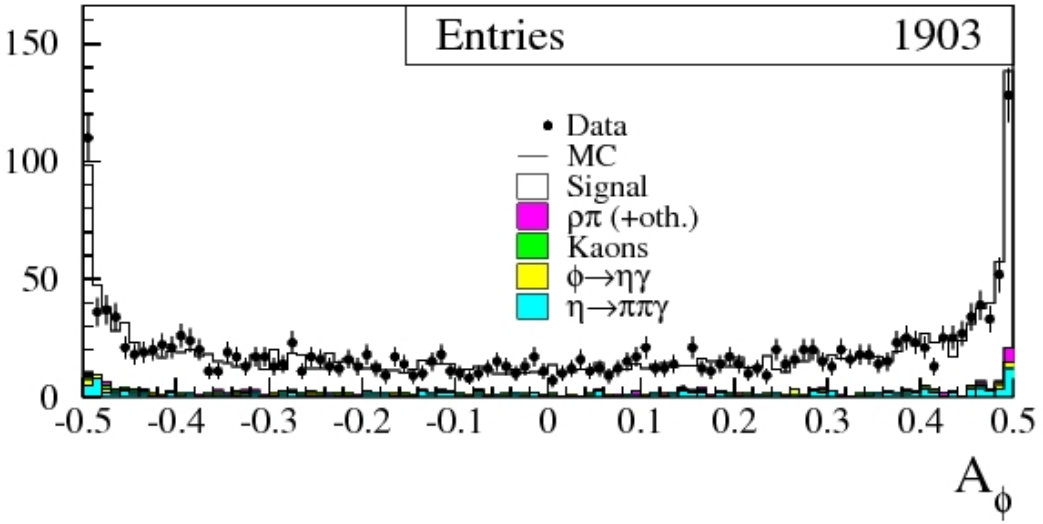

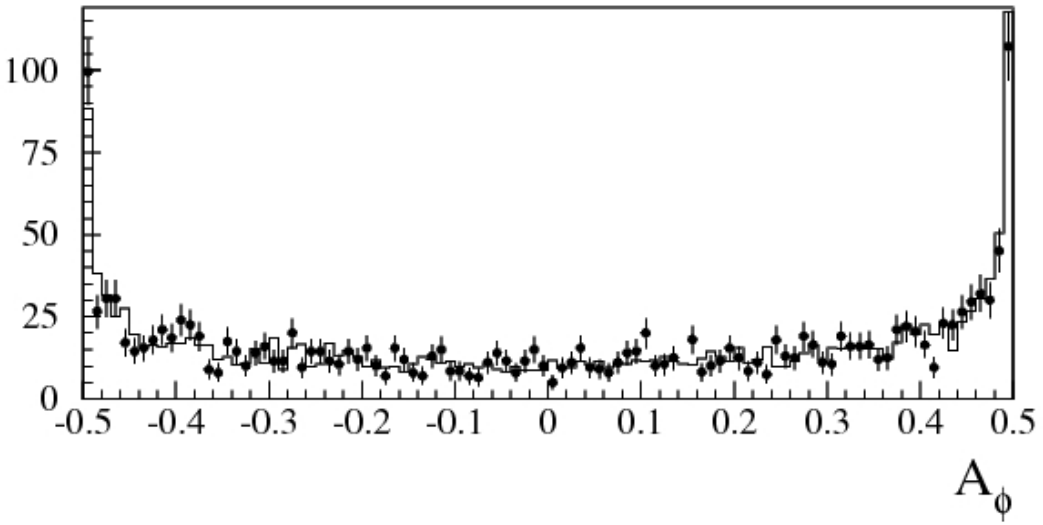

After background subtraction

Conclusions

The analysis is in an advanced status

About 1800 events observed

Evaluation of systematics in progress

Asymmetry measurement next in line

Study of $\eta \rightarrow l^+ l^- l^+ l^-$ just started