Status report on the

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

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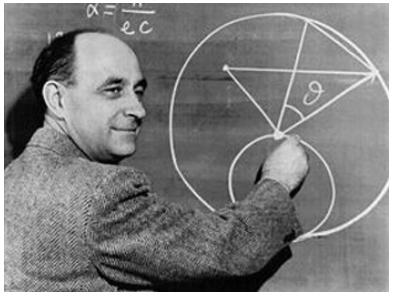
29 9 2008



Reminder

Conclusions from PONZA

$\eta \to \pi^+\pi^-e^+e^-$ analysis in advanced status

evaluation of systematics

investigation of unknown background

Possible solutions: - Bhabha MC production

- off-peak data reprocessing

Reminder

Data-MC comparison

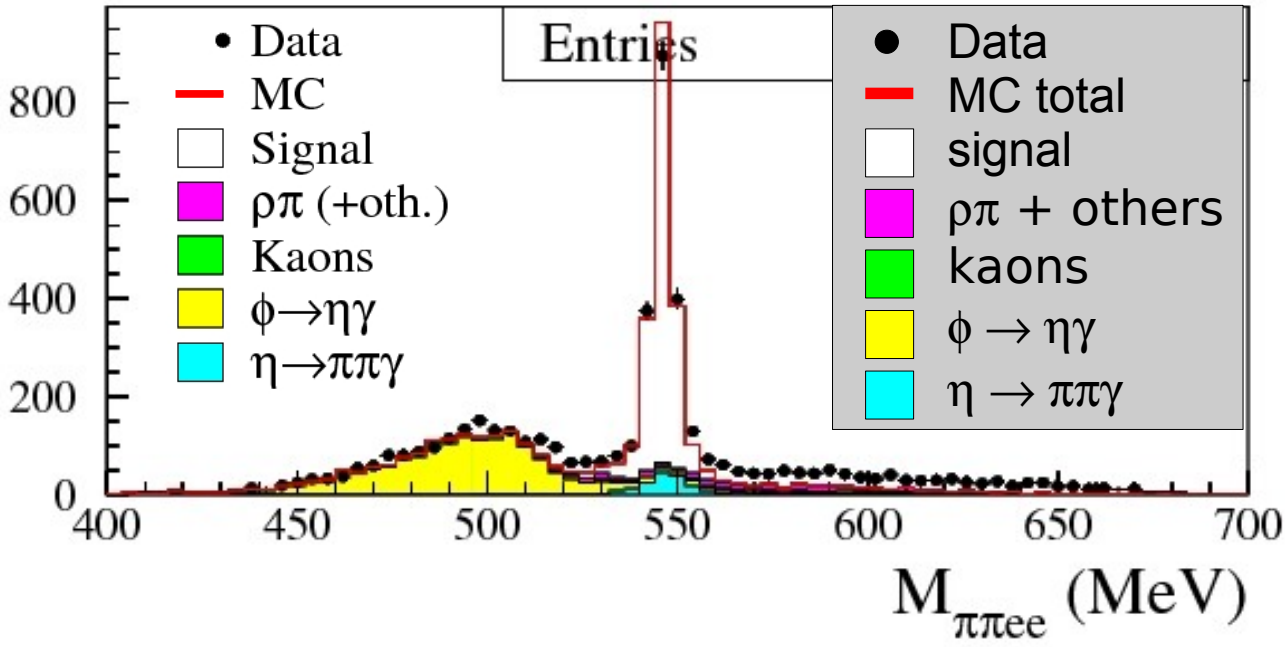
Not applying the cut

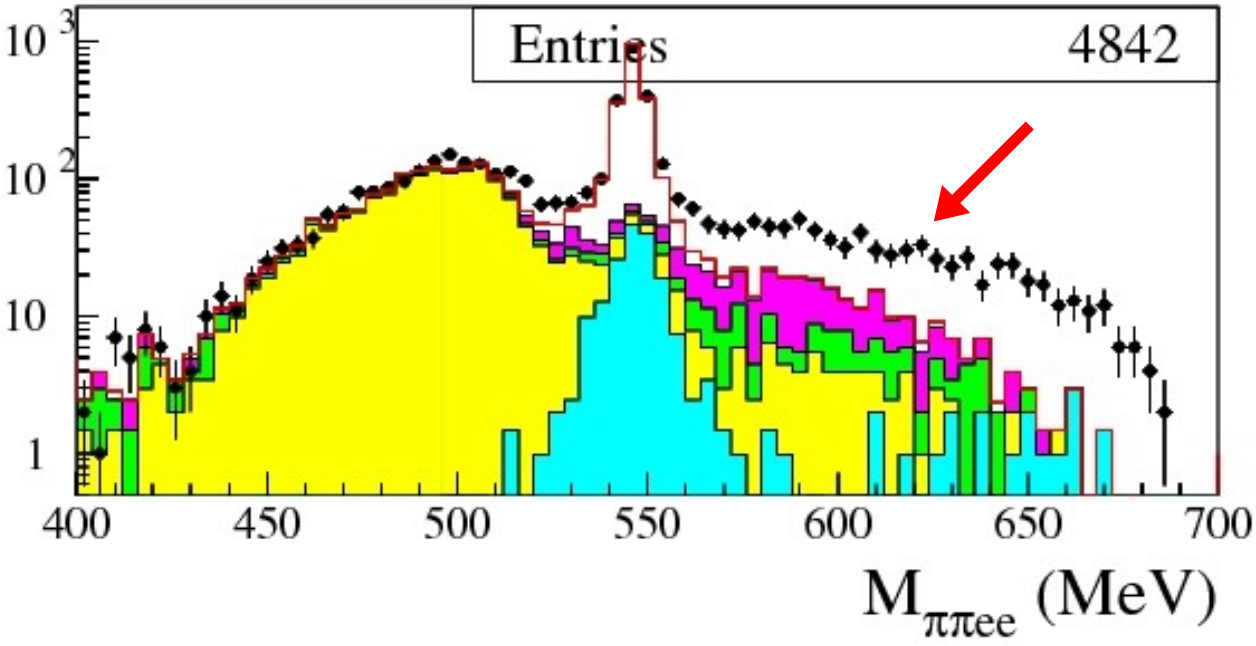
$535 < M_{\pi\pi ee} < 555$ MeV

Something is rotten in the state of ~~Denmark~~ etappee

Data-MC disagreement for $M_{\pi\pi ee} > M_{\eta}$

Could come from continuum processes, not in `all_phys` MC





Data sample

Using drc/mrc streams
with ETA4C tag

79 pb^{-1} data 2002 → As of now, not used

1733 pb^{-1} data 2004/05

50517 pb^{-1} MC signal only → New: Run by run background simulation

3479 pb^{-1} MC all_phys(2/3) 2004/05

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

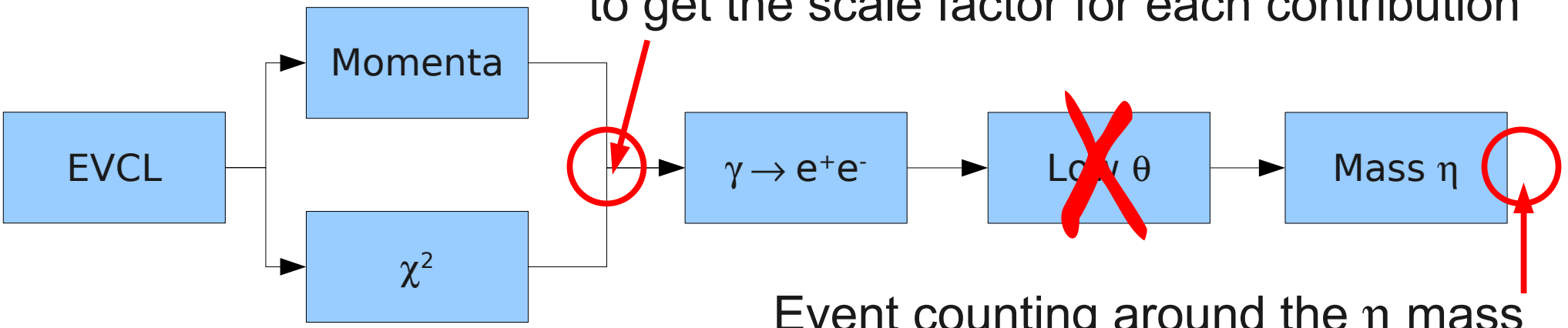
↓

New

Procedure review

1. **EVCL** ETA4CTAG
2. **Momenta** 450 < S4p < 600 MeV `.and.` 270 < S2p < 460 MeV
3. **χ^2** $\chi^2 < 4000$
4. **Conversions** Mee > 15 MeV `.or.` Dee > 2.5 cm (@BP)
5. **$M_{\pi\pi ee}$** $535 < M_{\pi\pi ee} < 555$ MeV

We fit the data with the “MC” shapes
to get the scale factor for each contribution



Event counting around the η mass
after background subtraction

Fit description

- Stand alone program using HBOOK and MINUIT
  (we have dropped midnight)
- Components that can be used:
  MC signal, MC all_phys, Data offpeak
- Possible to fit both whole spectrum and sidebands
- Possible to fix scale factors using luminosity

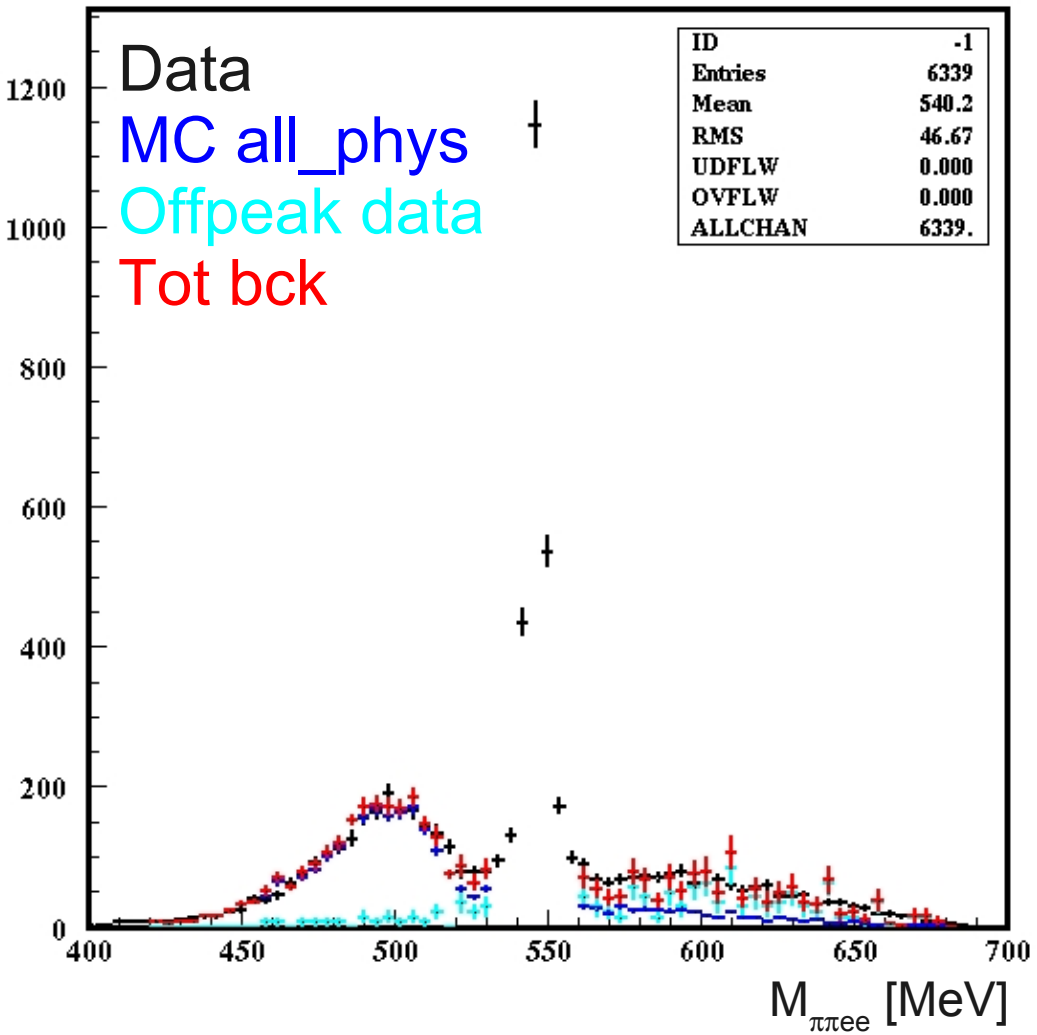
Fit description

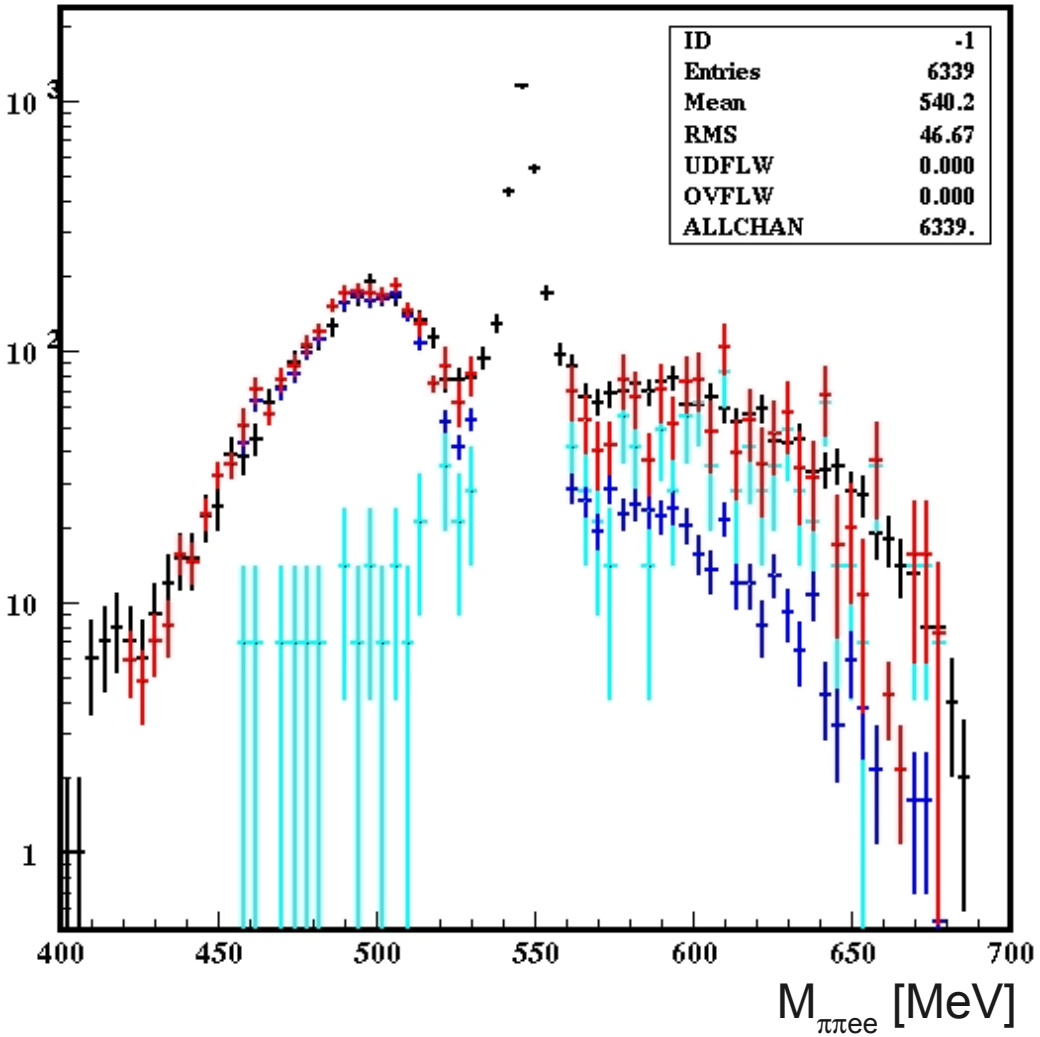
As default we have chosen to:

- fit on sidebands using offpeak data and all_phys MC
  [420.,530.] MeV U [560.,680.] MeV

- fix offpeak using luminosity, because of its small statistics
  $SF_{offpeak} = L_{data} / L_{offpeak} = 6.93$
  scaling with $\sqrt{s}$ has been accounted for

Fit results


Data
MC all_phys
Offpeak data
Tot bck
ID -1
Entries 6339
Mean 540.2
RMS 46.67
UDFLW 0.000
OVFLW 0.000
ALLCHAN 6339.
1200
1000
800
600
400
200
0
400
450
500
550
600
650
700
$M_{\pi\pi ee}$ [MeV]


ID -1
Entries 6339
Mean 540.2
RMS 46.67
UDFLW 0.000
OVFLW 0.000
ALLCHAN 6339.
10^3
10^2
10
1
400
450
500
550
600
650
700
$M_{\pi\pi ee}$ [MeV]

Fit results

FCN=159.9 dof=56 $P(\chi^2)=0.62\cdot10^{-11}$

SF all_phys 0.5368 ± 0.0035 frac. unc. 0.0064

N_{Data} = 1979 N_{signal} = 1559.1 N_{bckg} = 419.9

N_{ap} = 281.3 N_{op} = 138.6

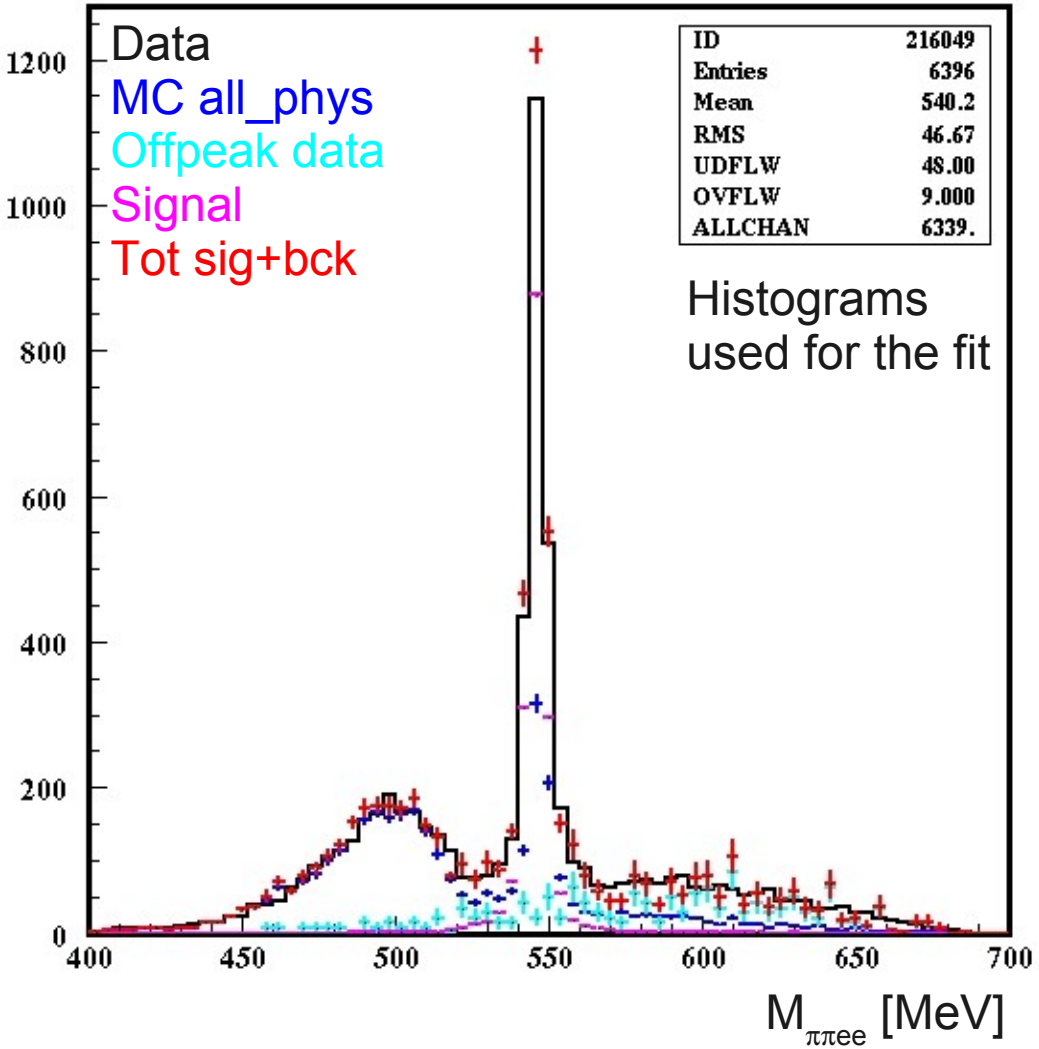
$\Delta N_{signal}/N_{signal}$ = 0.0537

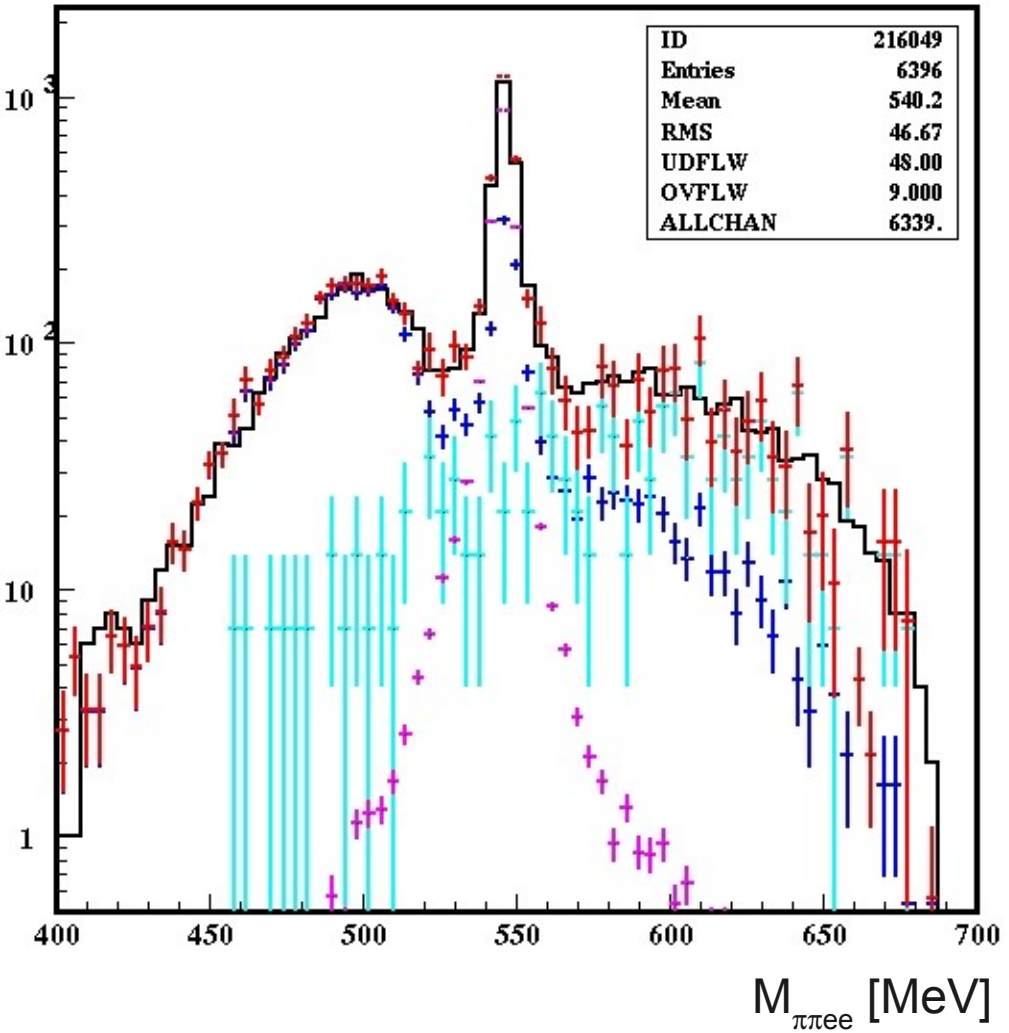
N_η = (717 ± 11)·10^5 $\Delta N_\eta/N_\eta$ = 0.0156 from $N_\eta = L\sigma$

ε = 0.0835 ± 0.0003 $\Delta\varepsilon/\varepsilon$ = 0.0036 from MC signal

$BR = N_{signal} / N_\eta / \varepsilon = (26.05 \pm 1.47)\cdot10^{-5}$ $\Delta BR/BR = 0.056$

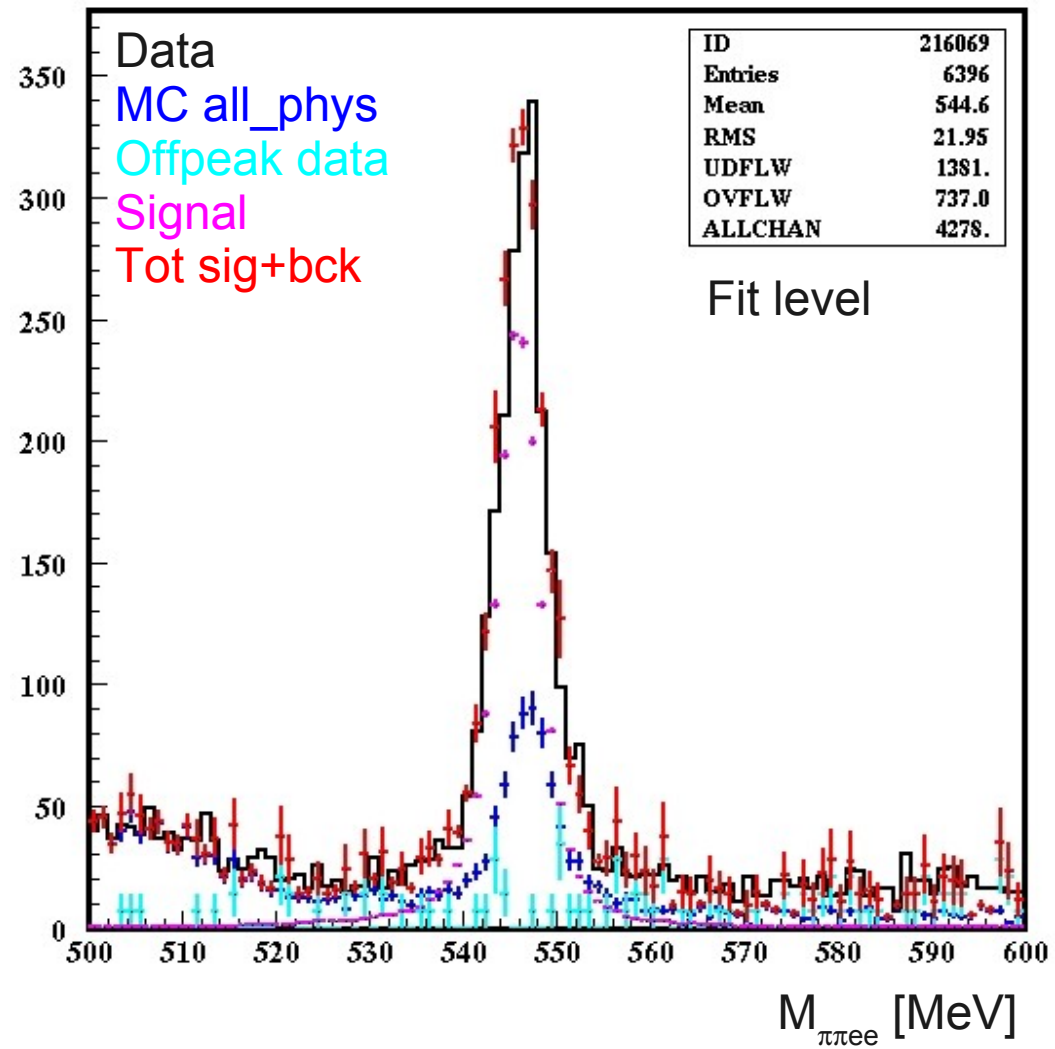
Applying scale factors from the fit

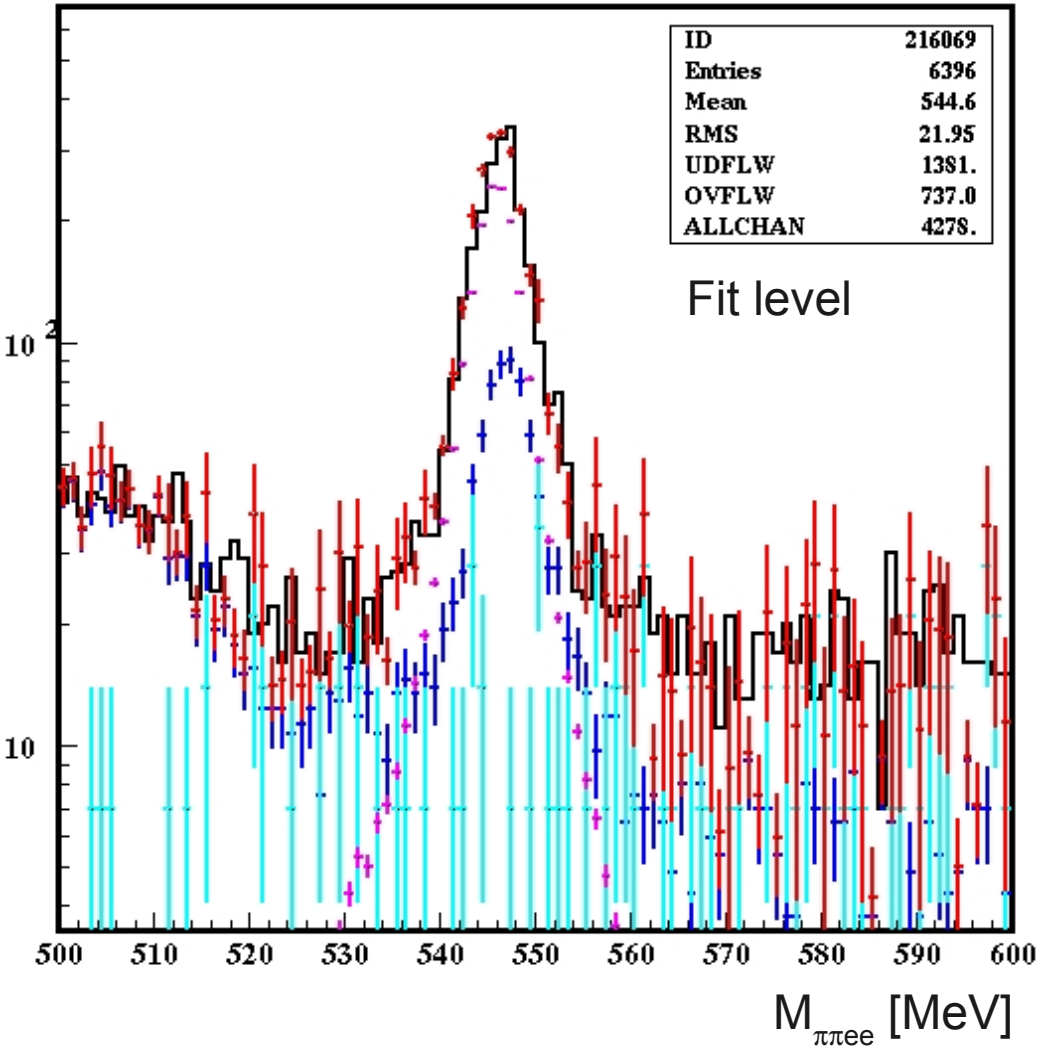




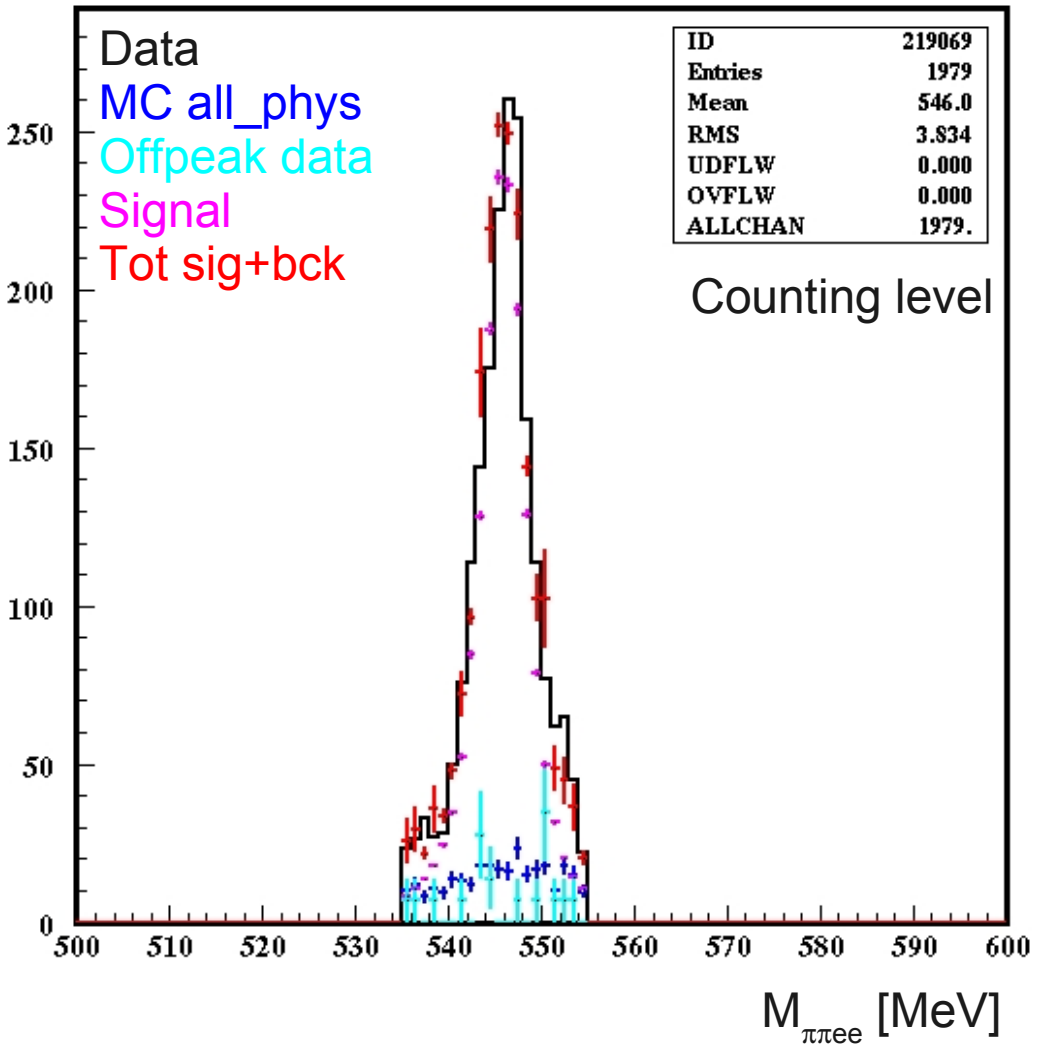
Signal SF = N_{ev} (data-bck) / N_{ev} (signal MC)

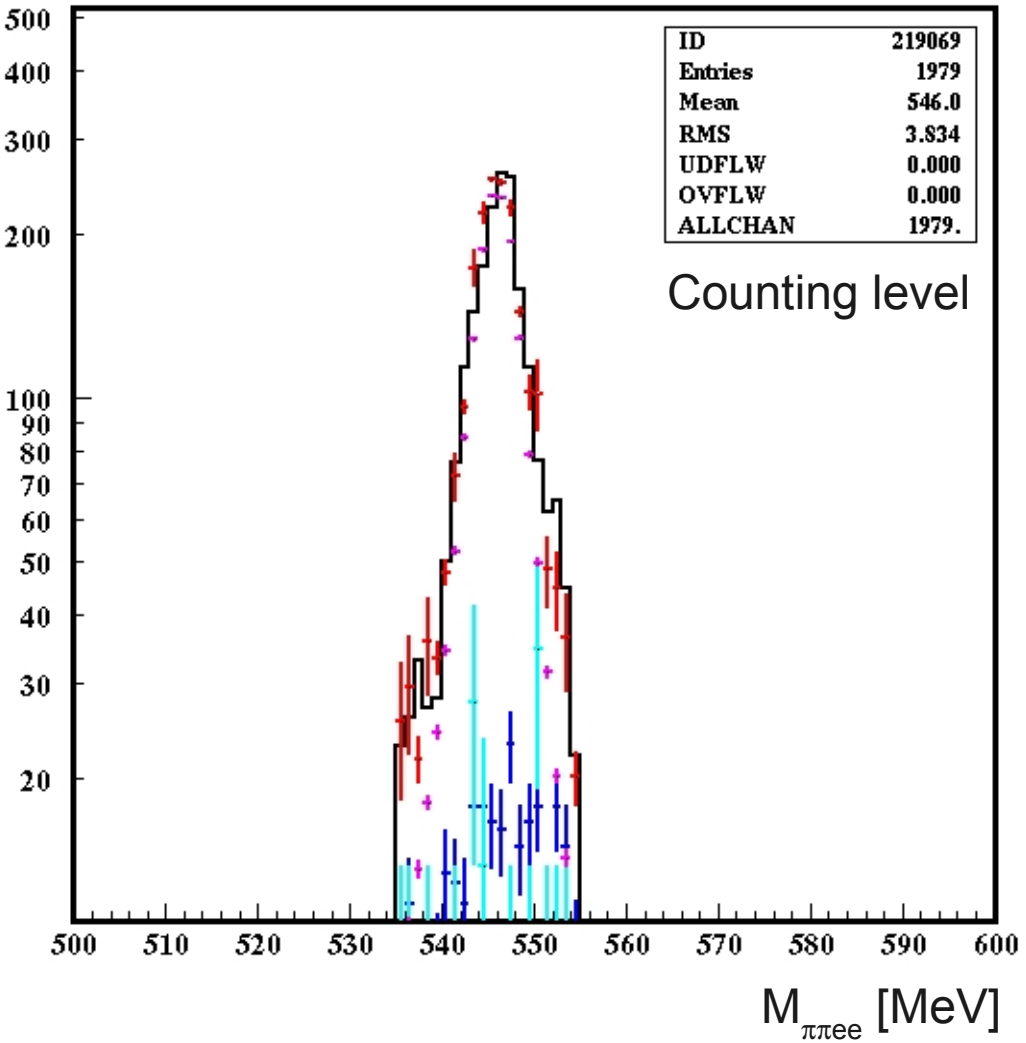
Applying scale factors from the fit





Applying scale factors from the fit





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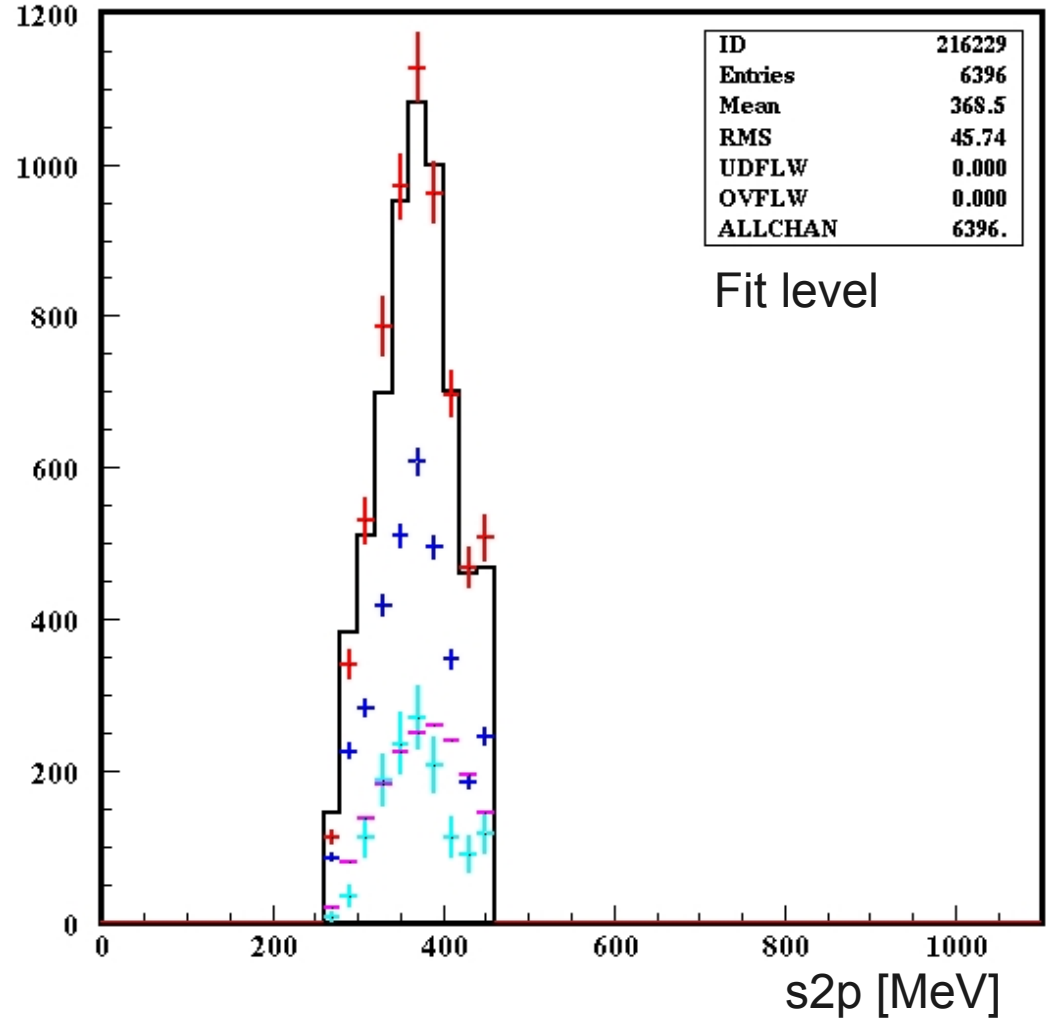

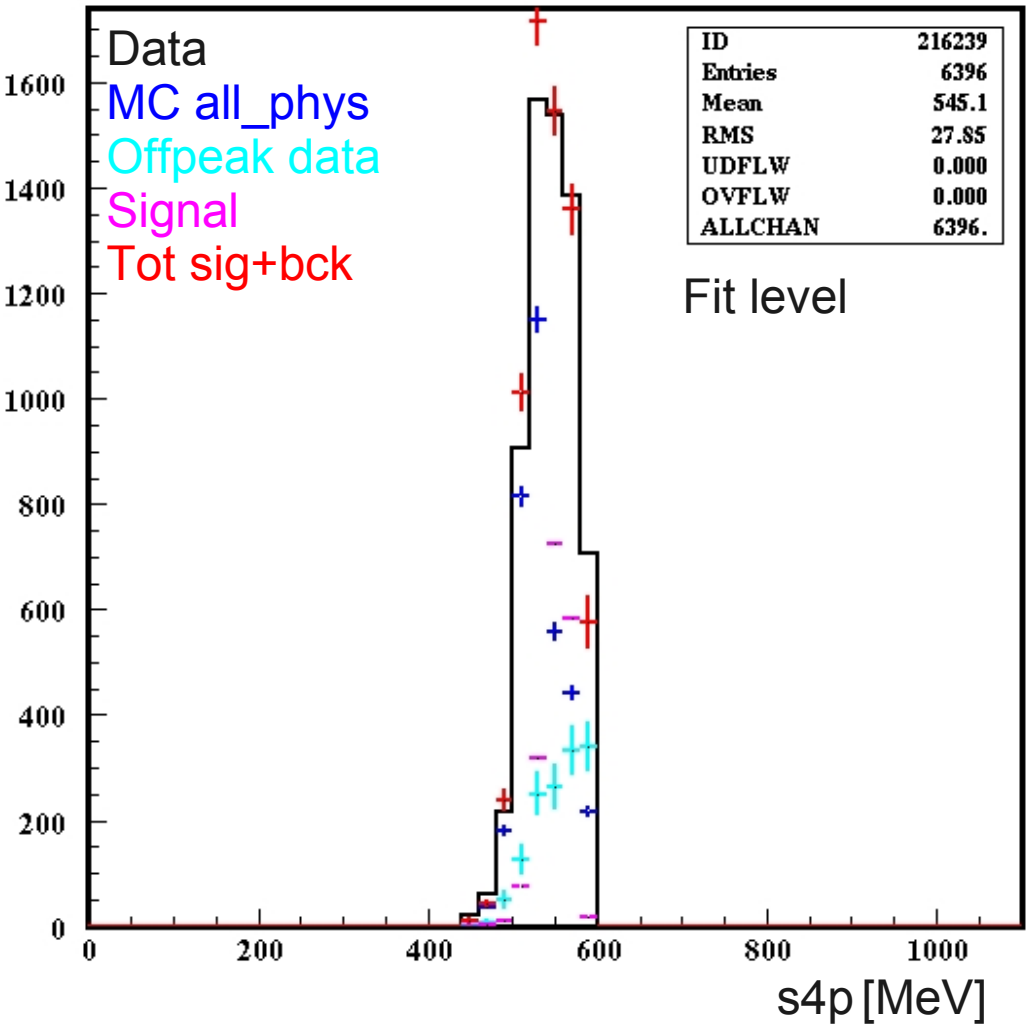

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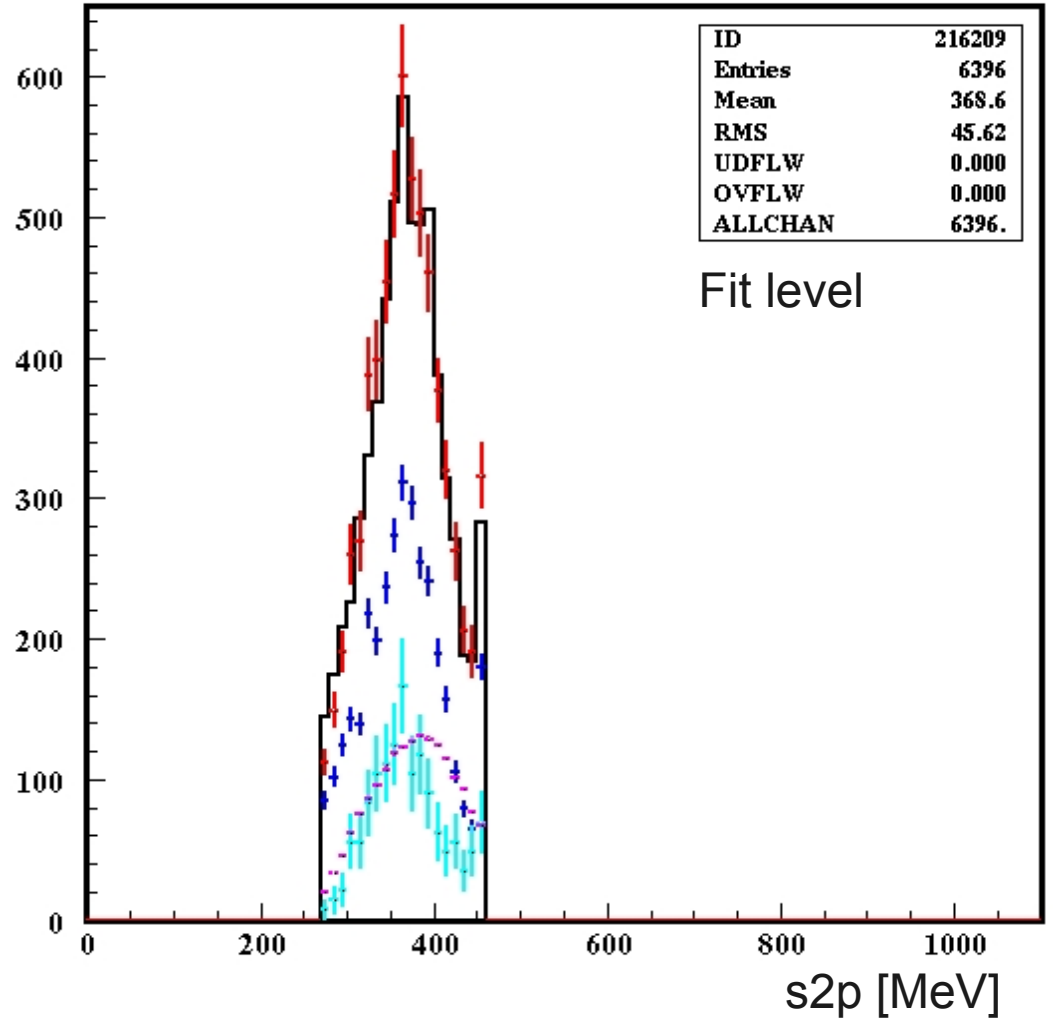
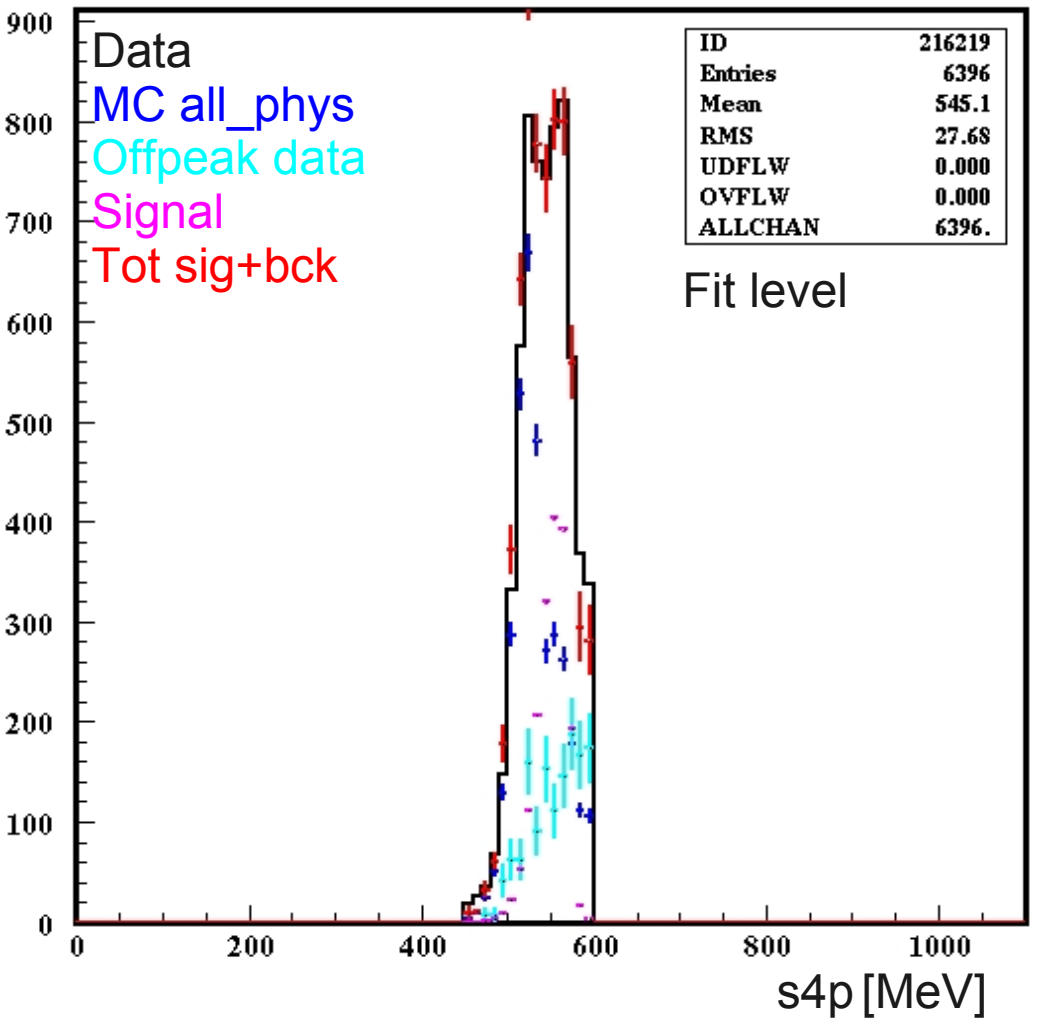
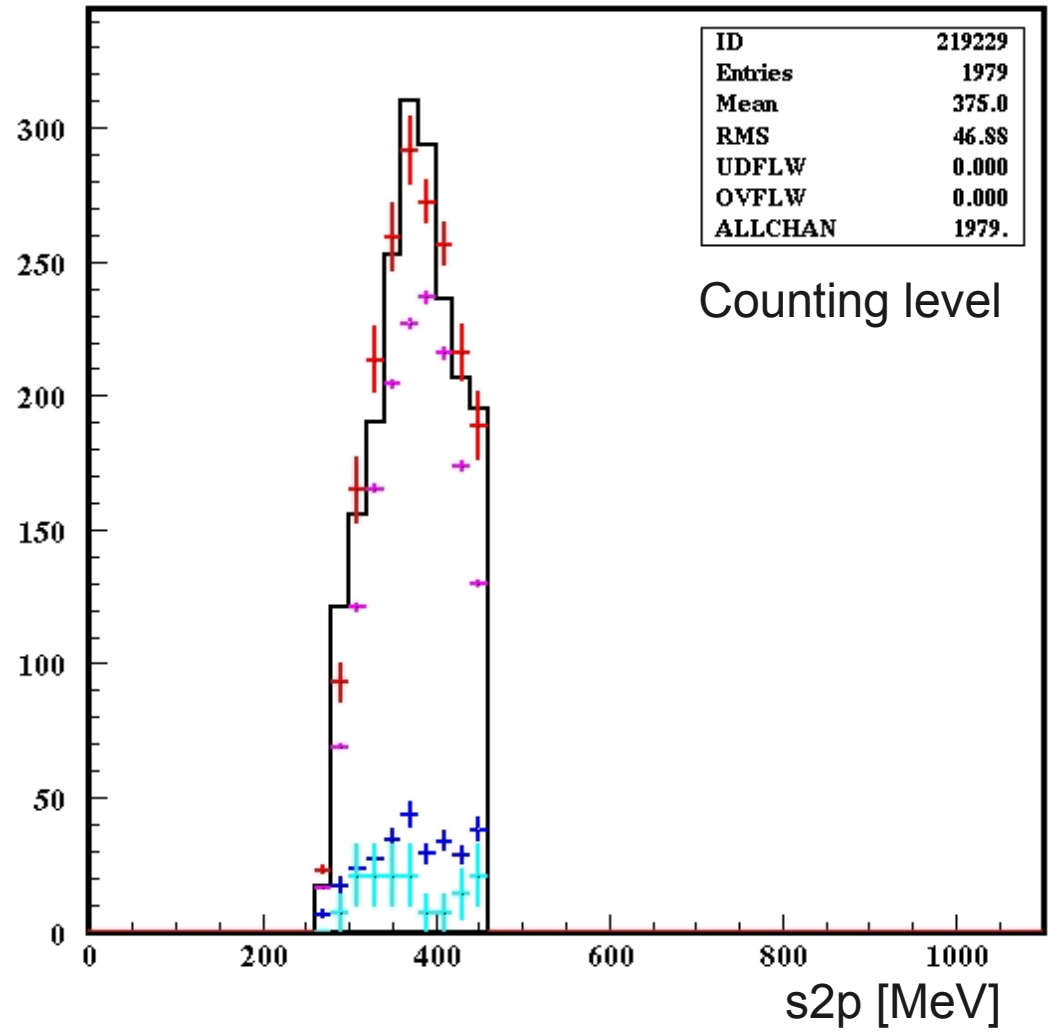
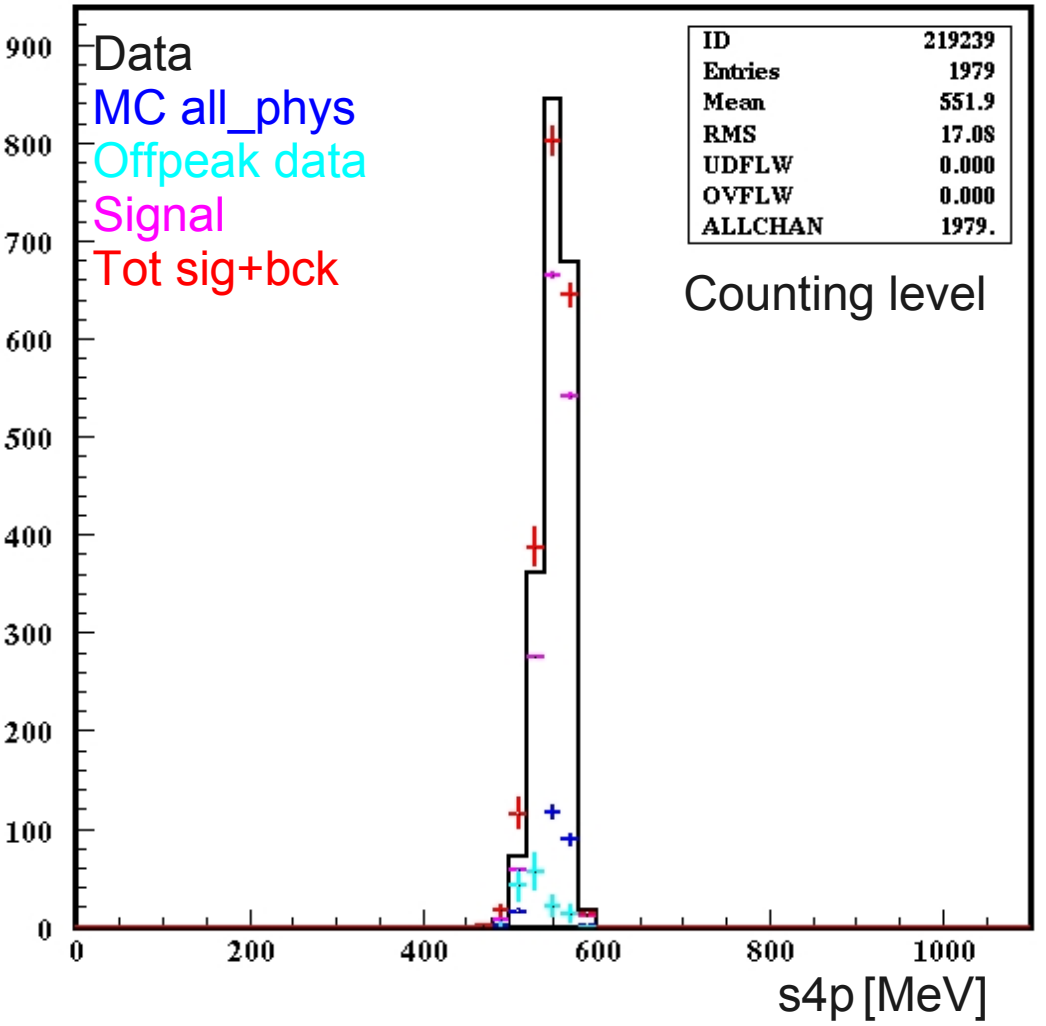




Applying scale factors from the fit





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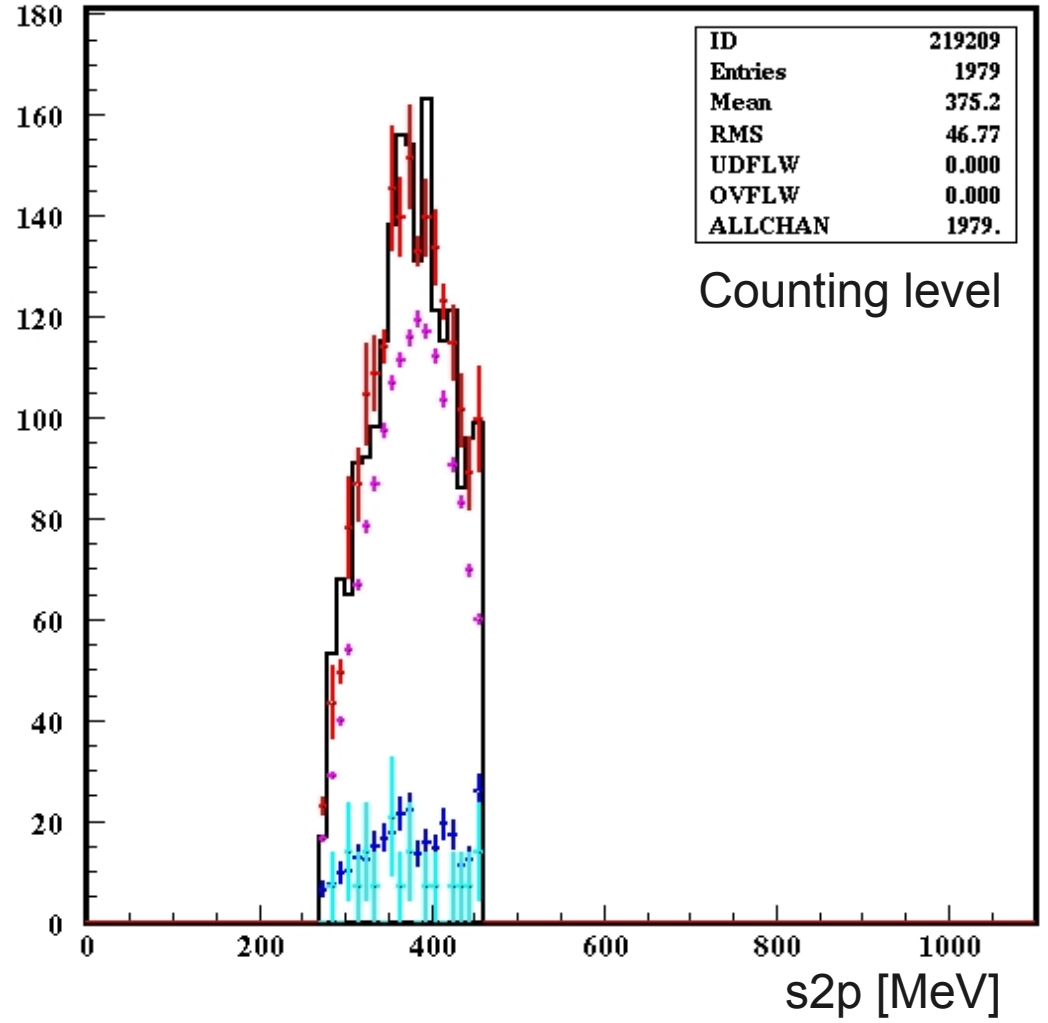

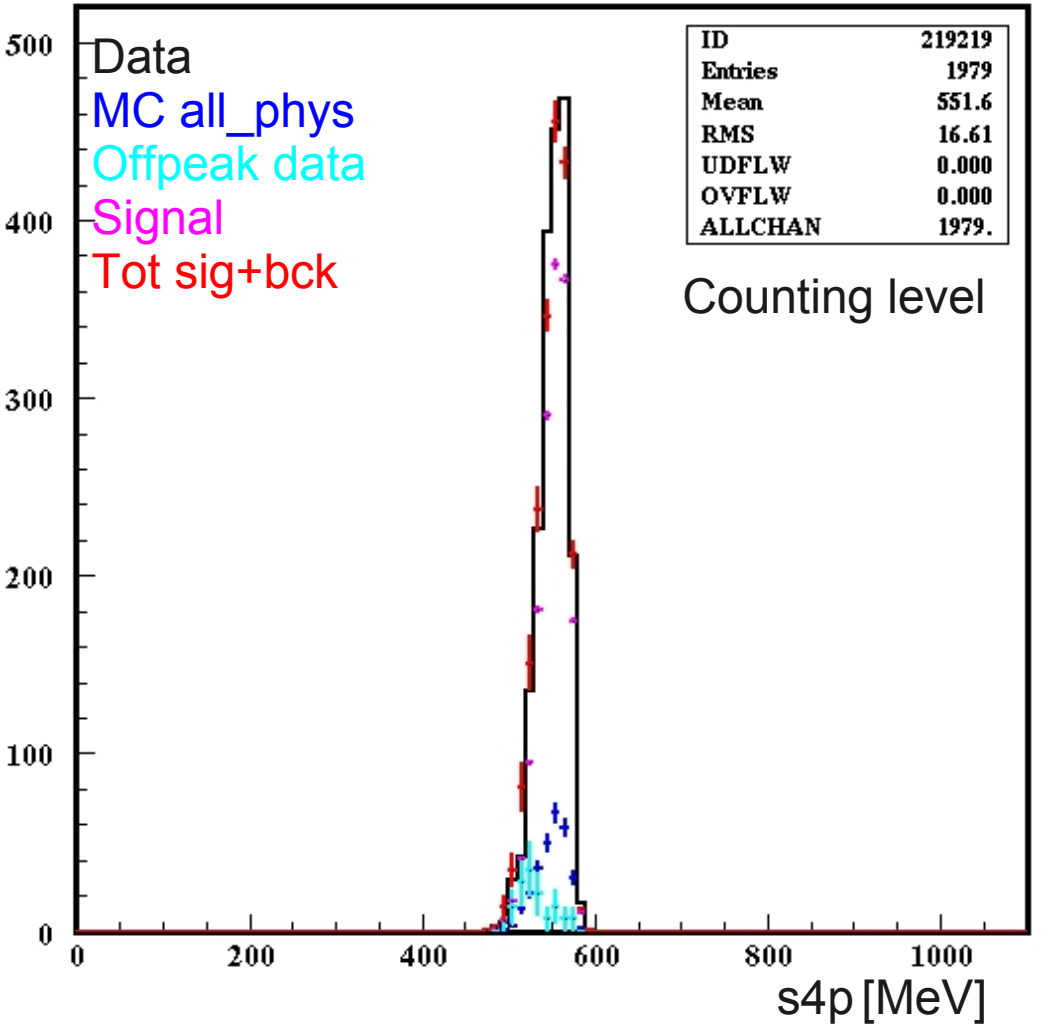

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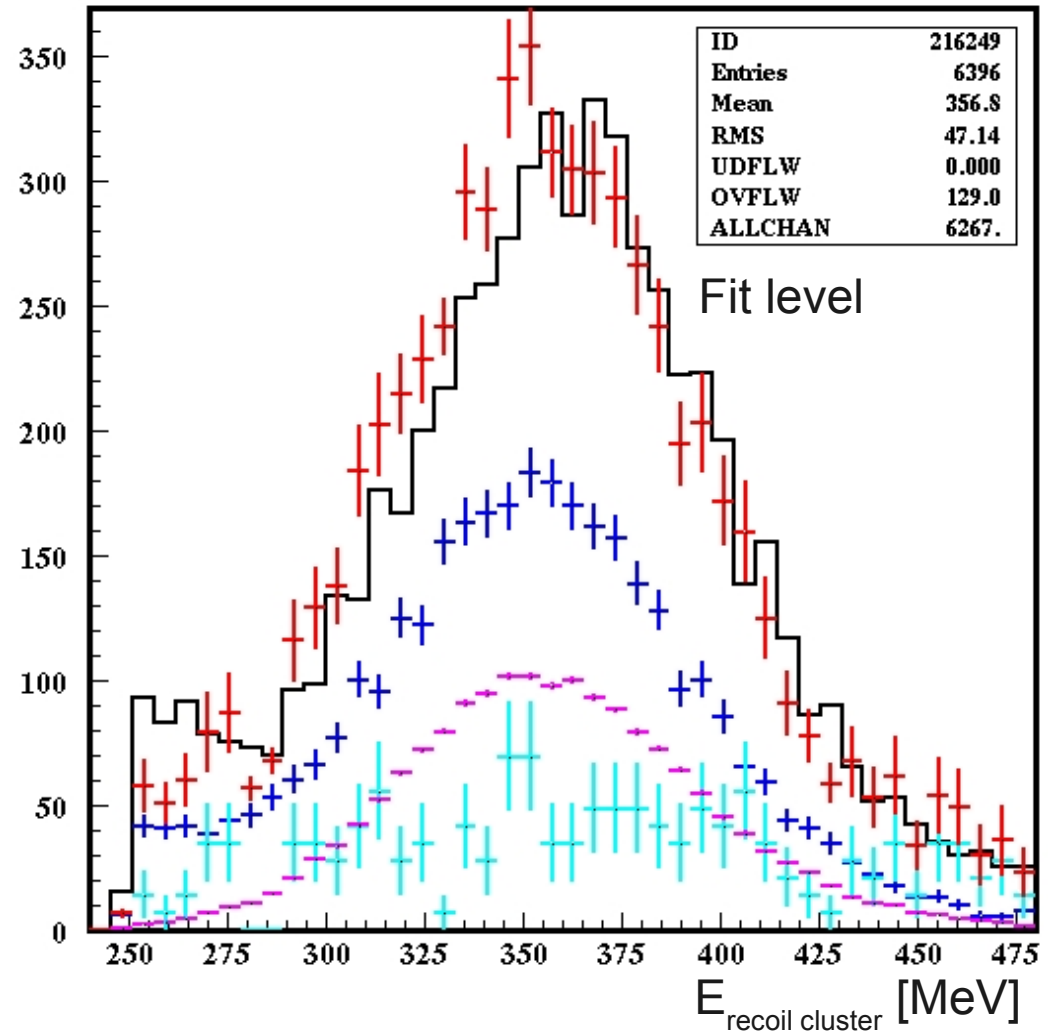
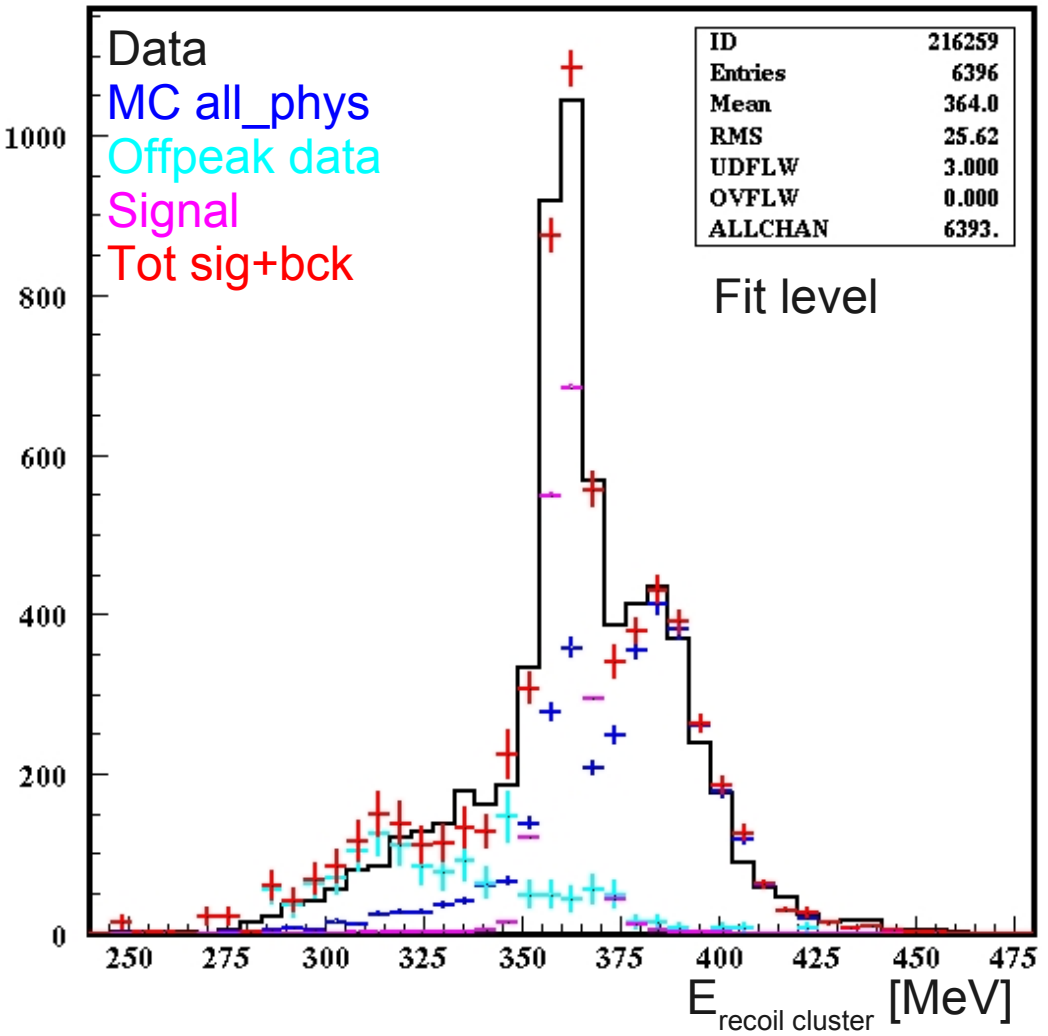
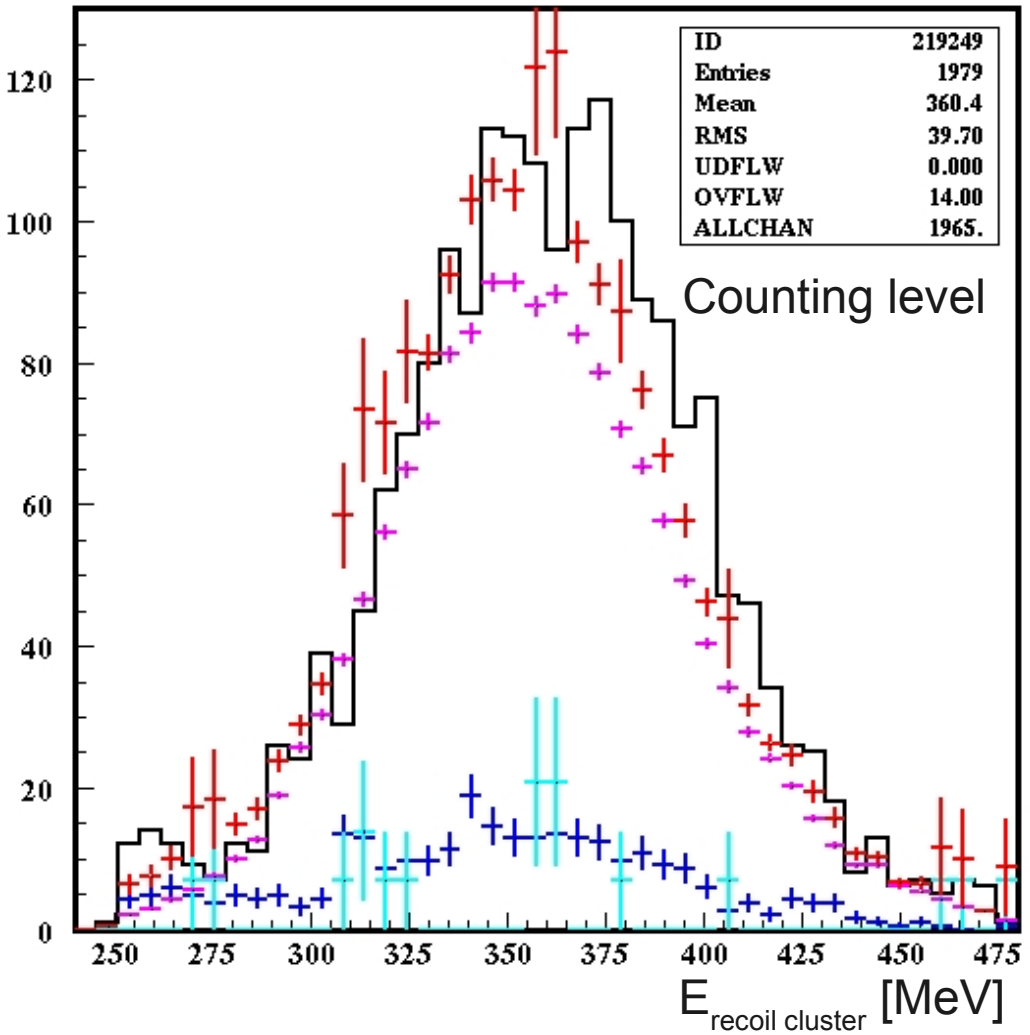


w/o kinematic fit

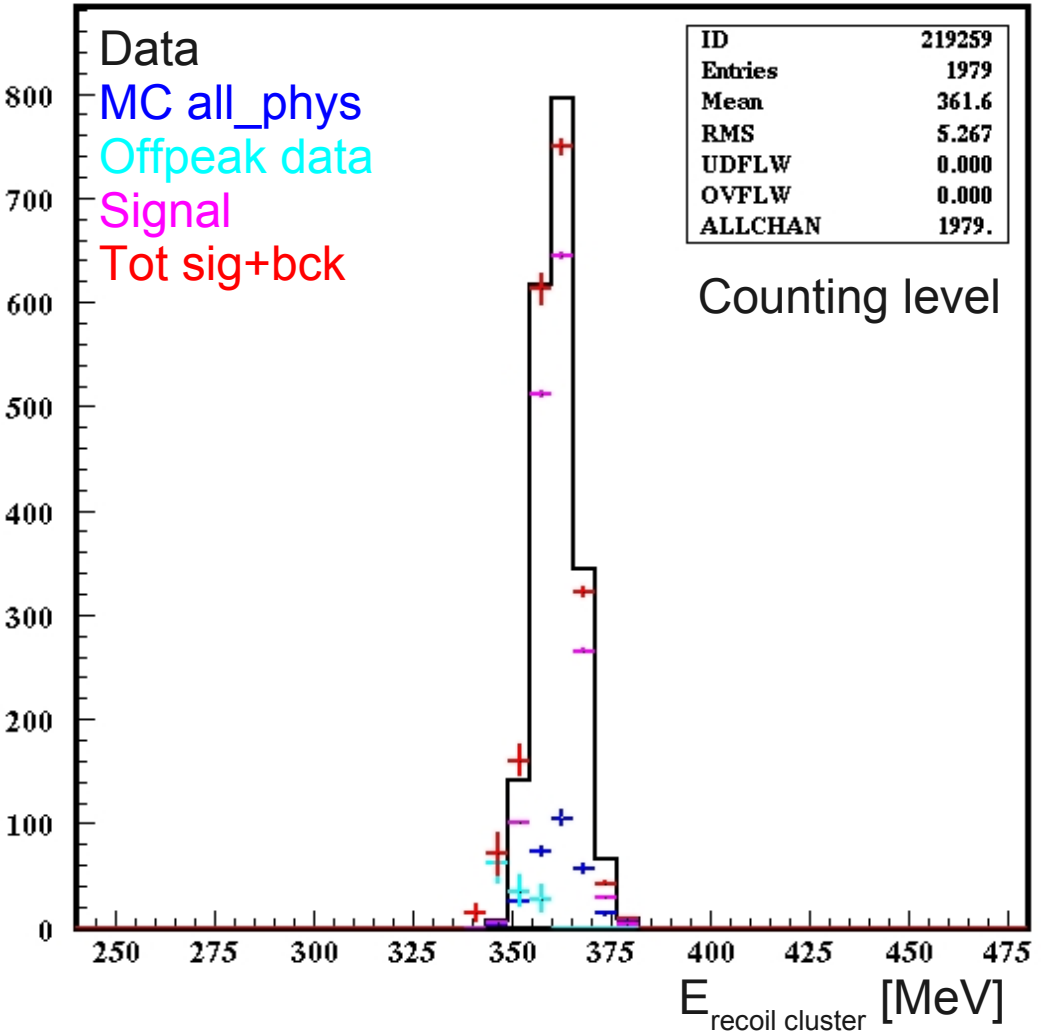


w/ kinematic fit

Applying scale factors from the fit

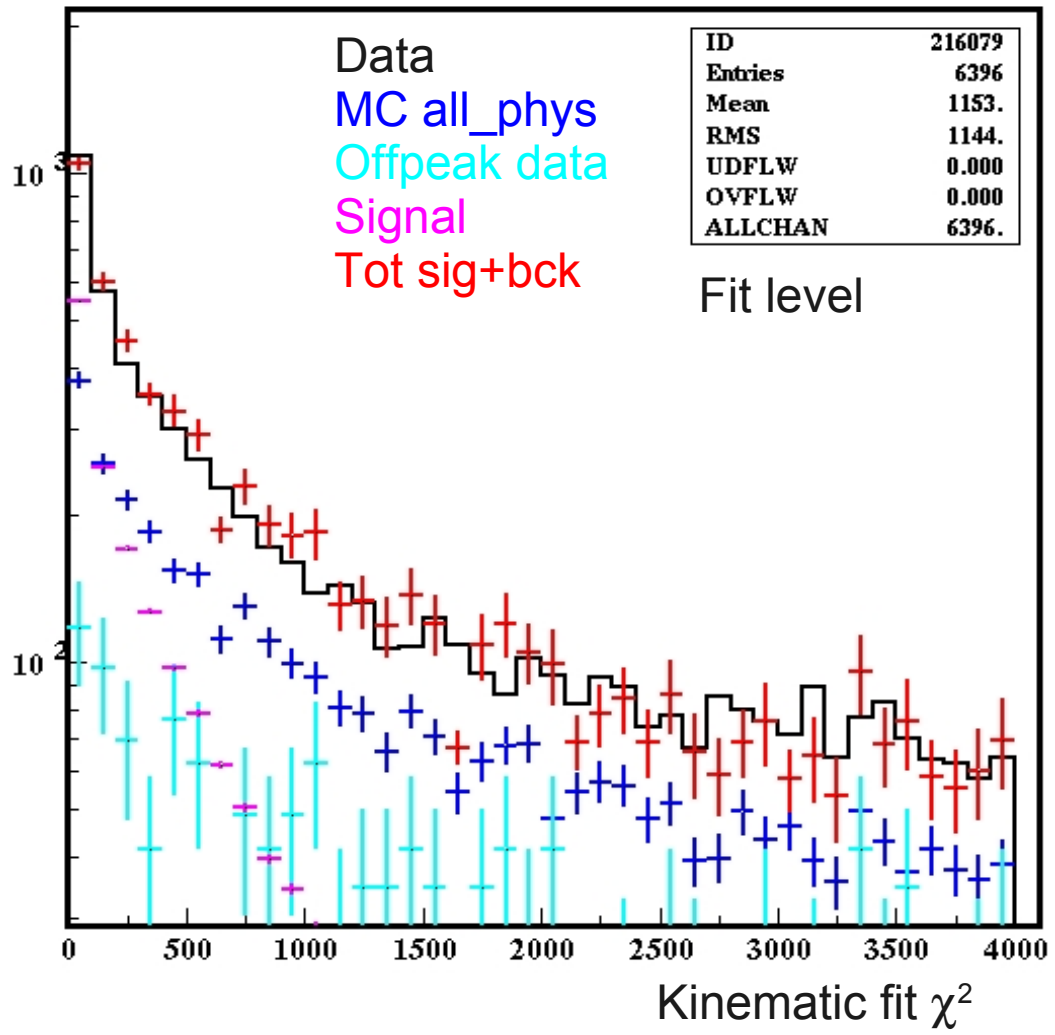


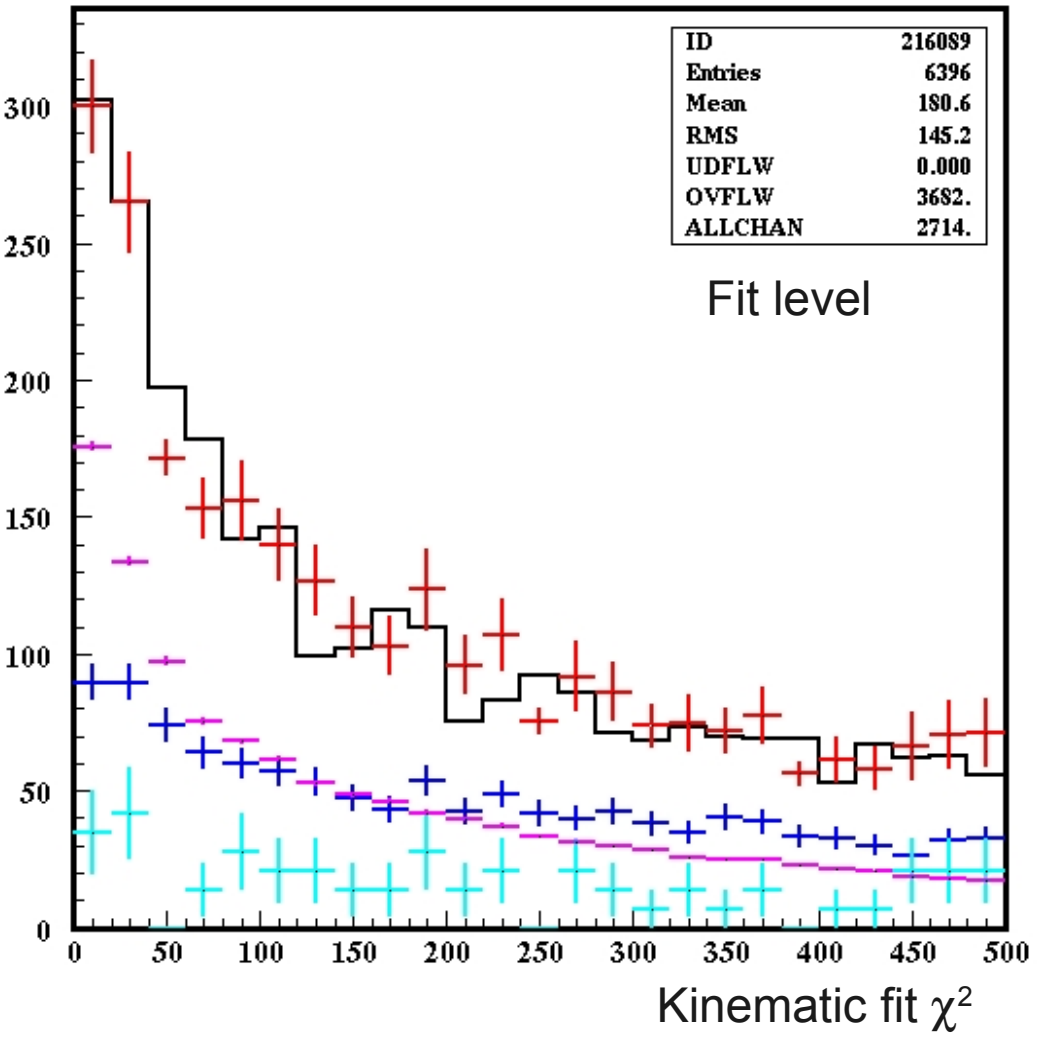
w/o kinematic fit



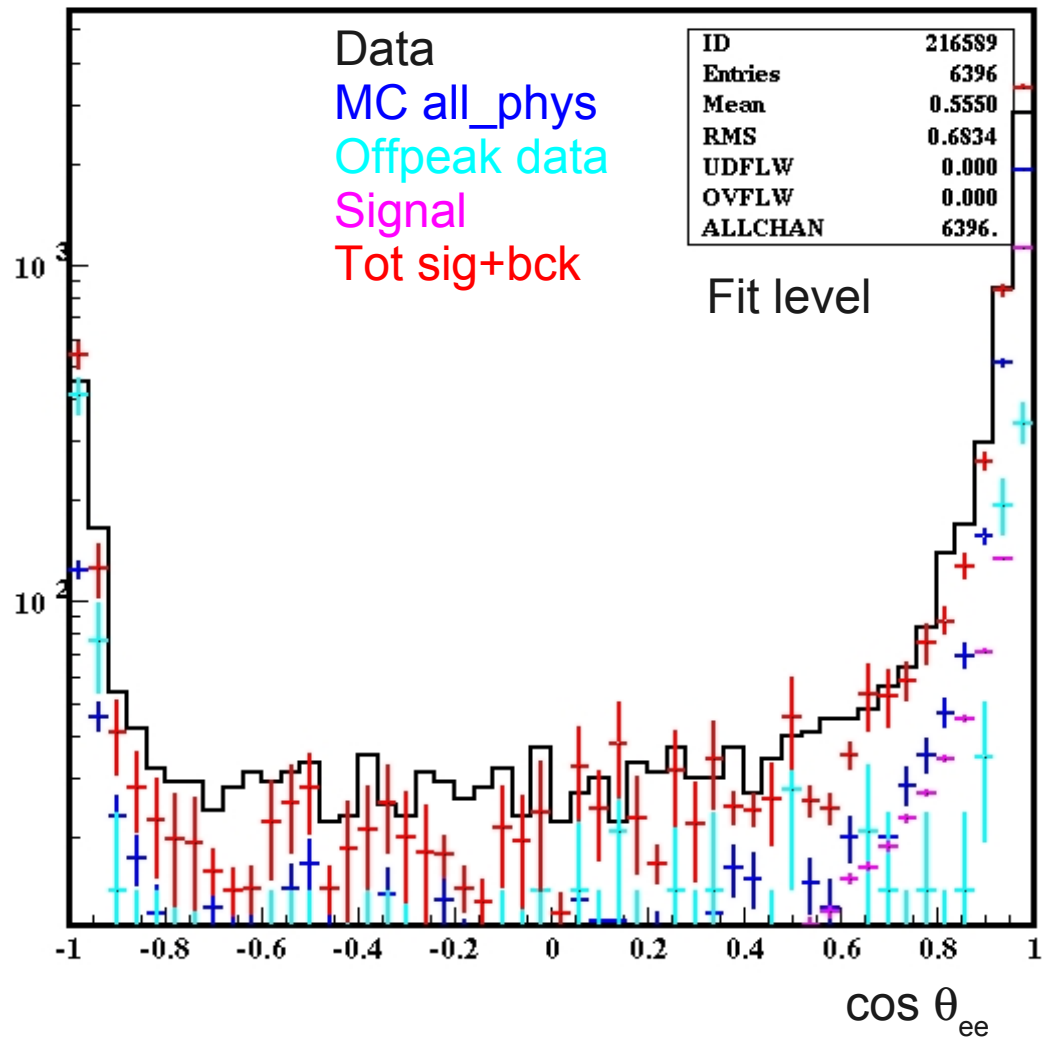
w/ kinematic fit

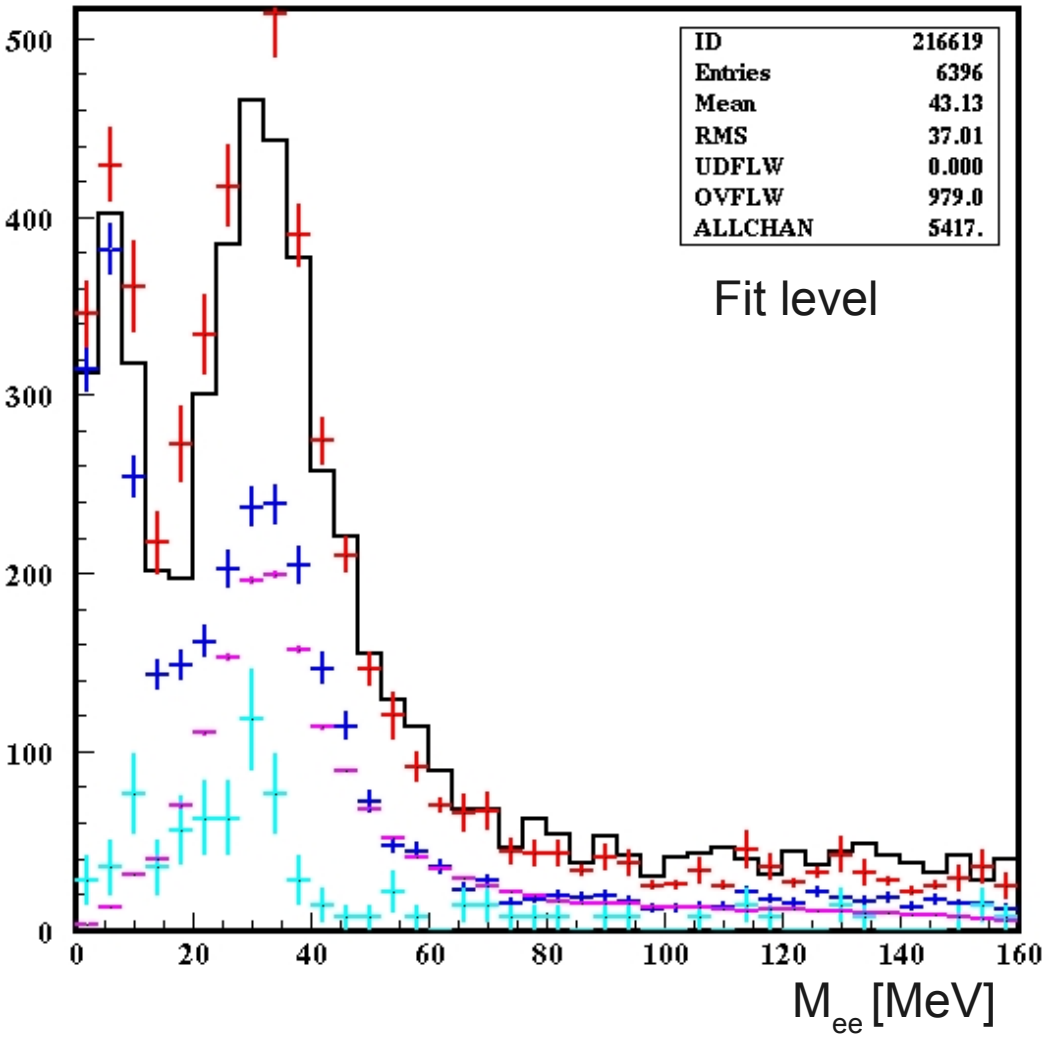
Applying scale factors from the fit





Applying scale factors from the fit





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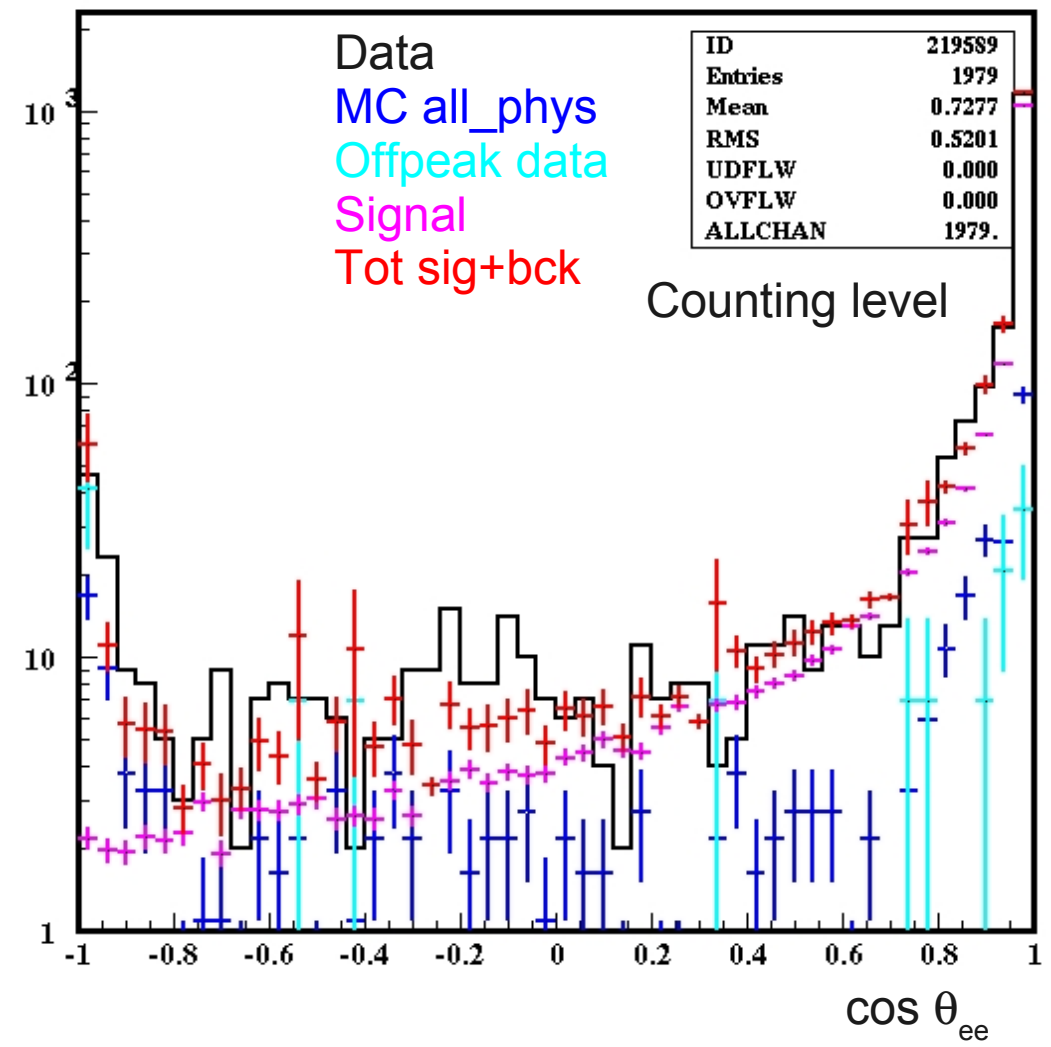

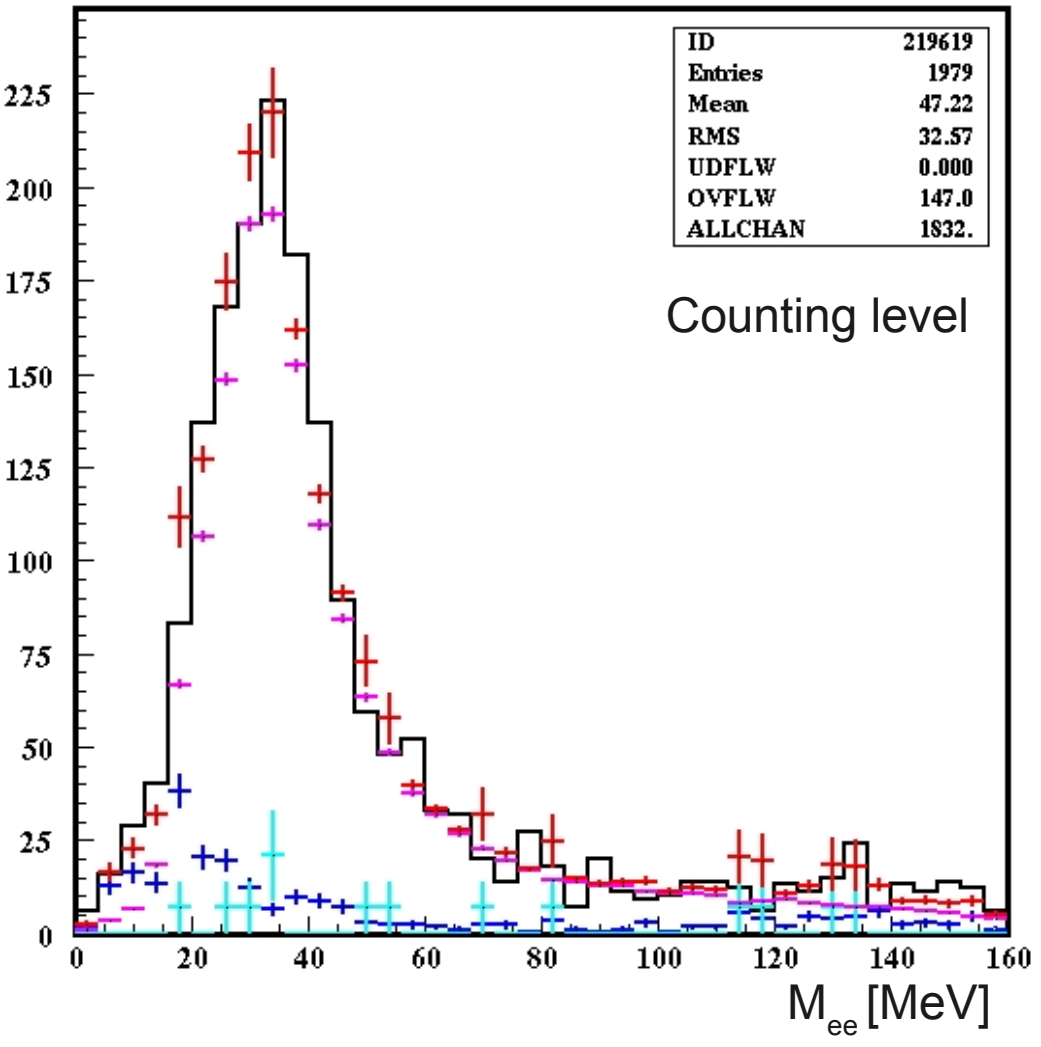

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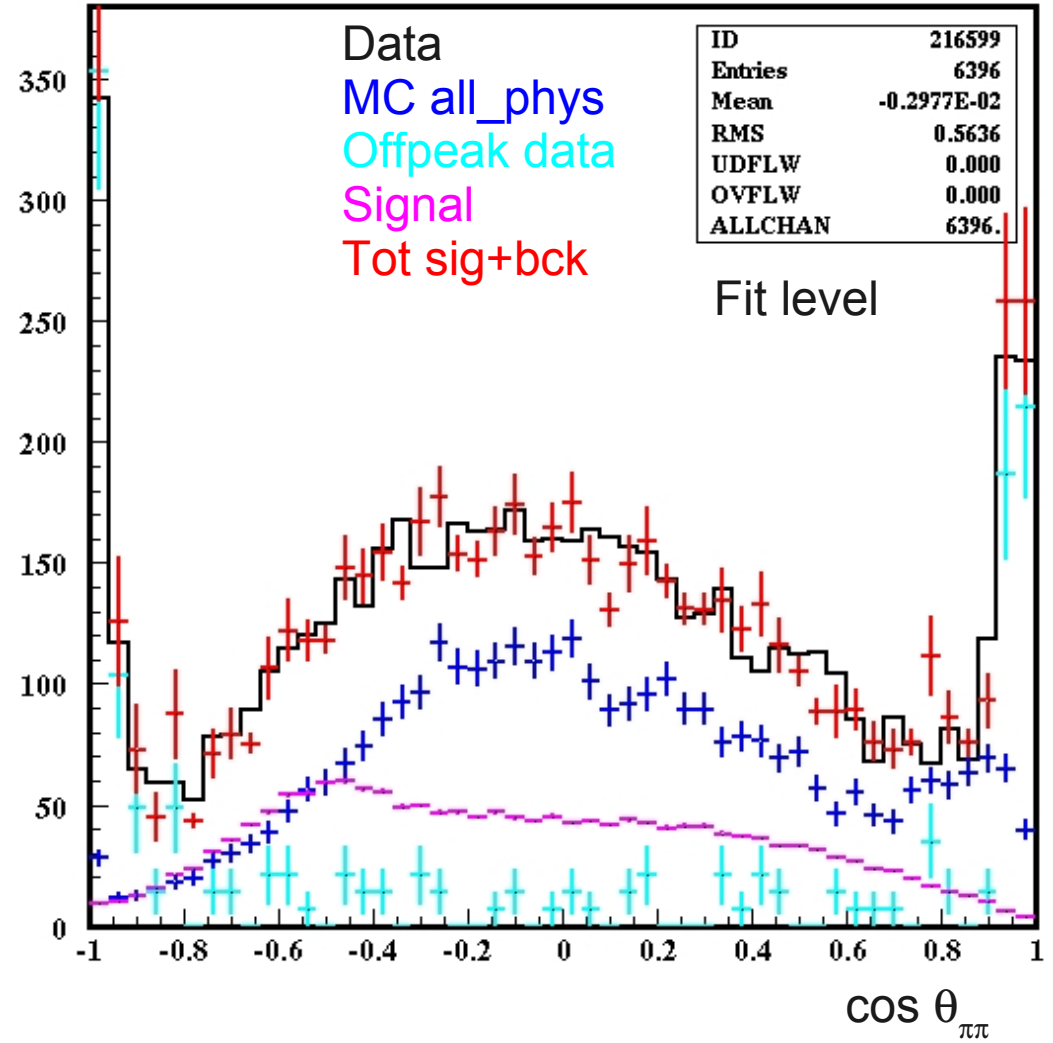

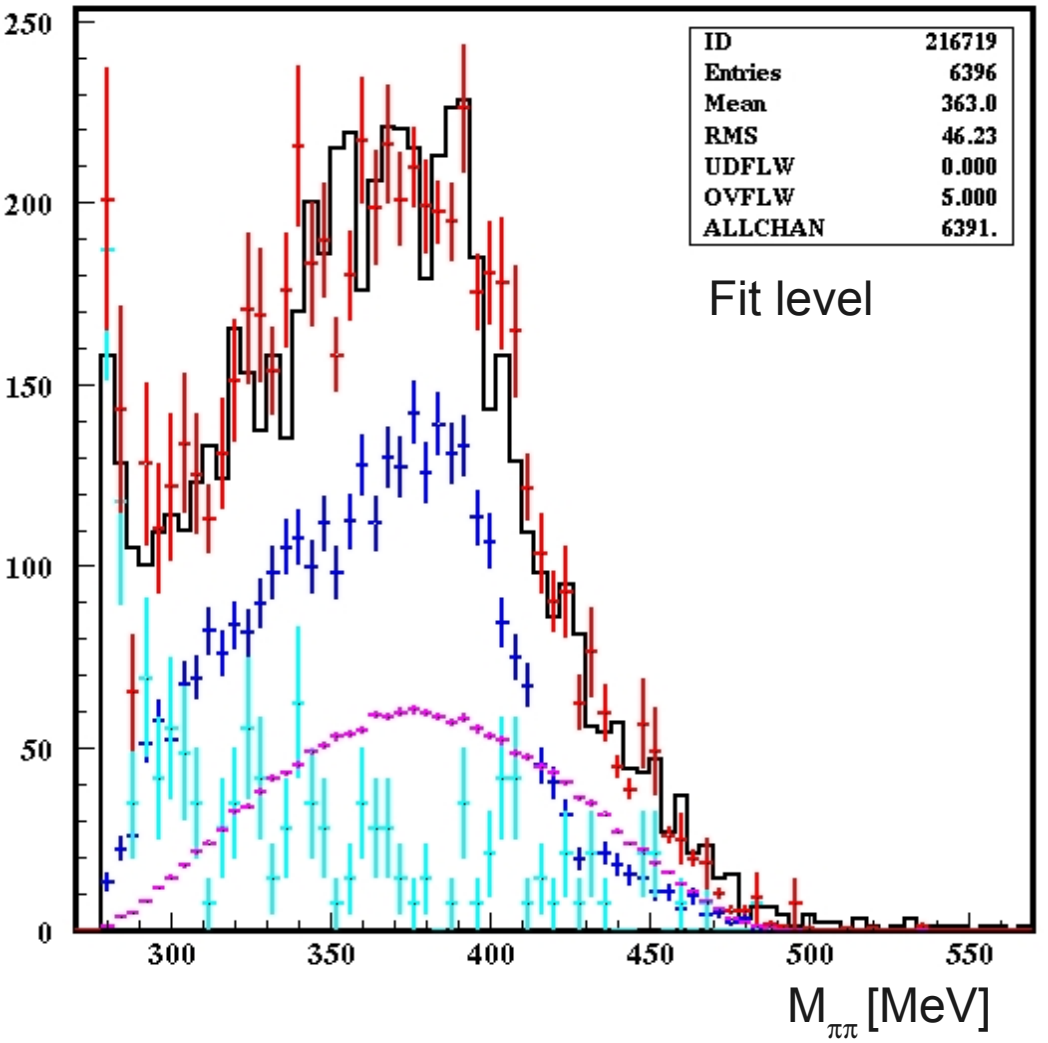

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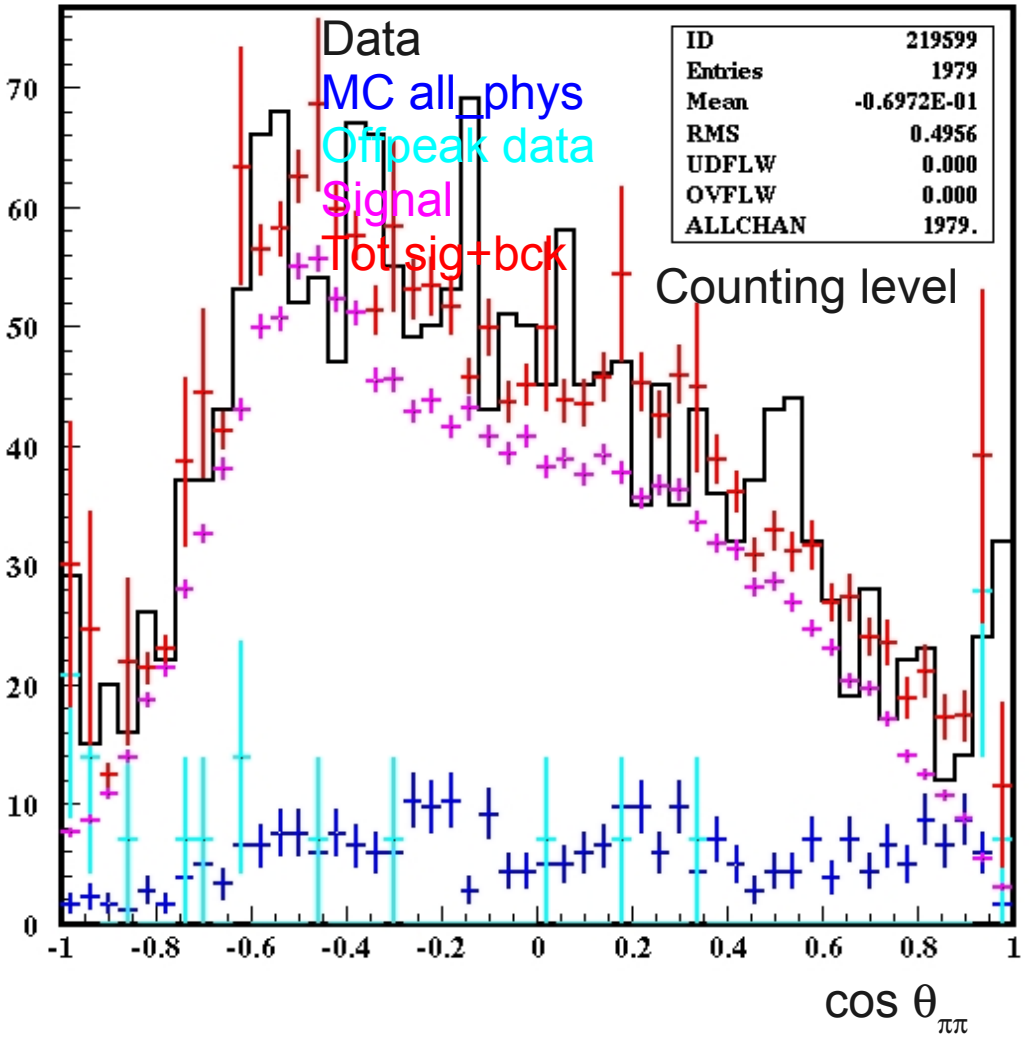
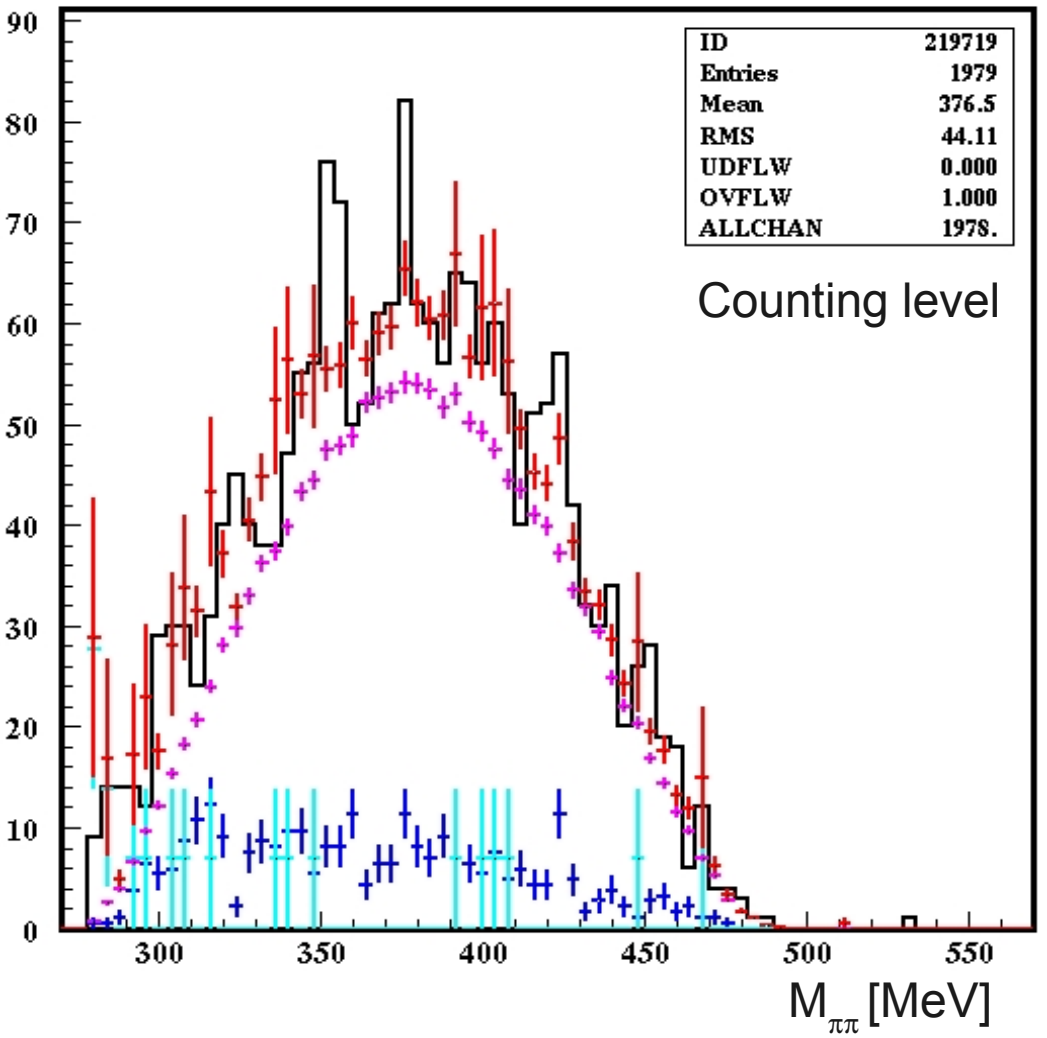




Systematics

- Changing each cut separately

  Two ways:

  1) maximum difference between BR values

  2) RMS of BR distributions
- Changing the counting level
- Changing the binning
- Changing the fit range
- Changing scale factors “freedom”

  (free or fixed with luminosity)

Changing cuts

Systematics

	RMS		Max ΔBR	
χ^2	100-10000	0.30	3000-5000	0.20
d_{ee}	1.5-3.5 cm	0.02	2.0-3.0 cm	0.05
M_{ee}	5-25 MeV	0.45	13-17 MeV	0.23
$M_{\pi\pi ee}$ min	525-540 MeV	0.15	530-540 MeV	0.39
$M_{\pi\pi ee}$ max	550-565 MeV	0.13	550-560 MeV	0.16
s2p min	240-300 MeV	0.19	260-280 MeV	0.23
s2p max	430-490 MeV	0.11	450-470 MeV	0.13
s4p min	420-480 MeV	0.09	440-460 MeV	0.07
s4p max	570-630 MeV	0.01	590-610 MeV	0.01
		$\sqrt{\Sigma x^2} = 0.62$		$\sqrt{\Sigma x^2} = 0.59$

Huge variations!

Systematics

Default reminder:
fit after χ^2 and momenta cuts
counting after cut on $M_{\pi\pi ee}$

Counting after χ^2 and momenta cuts

$N_{Data} = 6396$ $N_{signal} = 1671.0$ $N_{bckg} = 4725.0$

$N_{ap} = 3373.7$ $N_{op} = 1351.3$

$\Delta N_{signal}/N_{signal} = 0.0192$

$\varepsilon = 0.0928 \pm 0.0003$ $\Delta\varepsilon/\varepsilon = 0.0034$ from MC signal

$BR = N_{signal} / N_{\eta} / \varepsilon = (25.13 \pm 0.65)\cdot 10^{-5}$ $\Delta BR/BR = 0.026$

Counting after cut on conversions

$N_{Data} = 5467$ $N_{signal} = 1747.3$ $N_{bckg} = 3719.7$

$N_{ap} = 2458.5$ $N_{op} = 1261.3$

$\Delta N_{signal}/N_{signal} = 0.0213$

$\varepsilon = 0.0899 \pm 0.0003$ $\Delta\varepsilon/\varepsilon = 0.0035$ from MC signal

$BR = N_{signal} / N_{\eta} / \varepsilon = (27.12 \pm 0.74)\cdot 10^{-5}$ $\Delta BR/BR = 0.027$

Both within 1σ

Changing fit range

Systematics

[420.,530.] MeV U [560.,680.] MeV BR = (26.05 ± 1.47) ·10^{-5}

[420.,525.] MeV U [565.,680.] MeV BR = (26.07 ± 1.70) ·10^{-5}

[420.,520.] MeV U [570.,680.] MeV BR = (26.11 ± 1.69) ·10^{-5}

[420.,515.] MeV U [575.,680.] MeV BR = (26.20 ± 1.58) ·10^{-5}

[450.,530.] MeV U [560.,650.] MeV BR = (26.08 ± 1.75) ·10^{-5}

[450.,520.] MeV U [570.,650.] MeV BR = (26.15 ± 1.67) ·10^{-5}

[500.,530.] MeV U [560.,600.] MeV BR = (25.96 ± 1.85) ·10^{-5}

RMS = 0.07

Changing binning

Systematics

1 MeV/bin	BR = (26.12 ± 1.47) $\cdot 10^{-5}$
2 MeV/bin	BR = (26.09 ± 1.47) $\cdot 10^{-5}$
3 MeV/bin	BR = (26.05 ± 1.65) $\cdot 10^{-5}$
4 MeV/bin	BR = (26.05 ± 1.47) $\cdot 10^{-5}$
5 MeV/bin	BR = (25.99 ± 1.61) $\cdot 10^{-5}$

RMS = 0.04

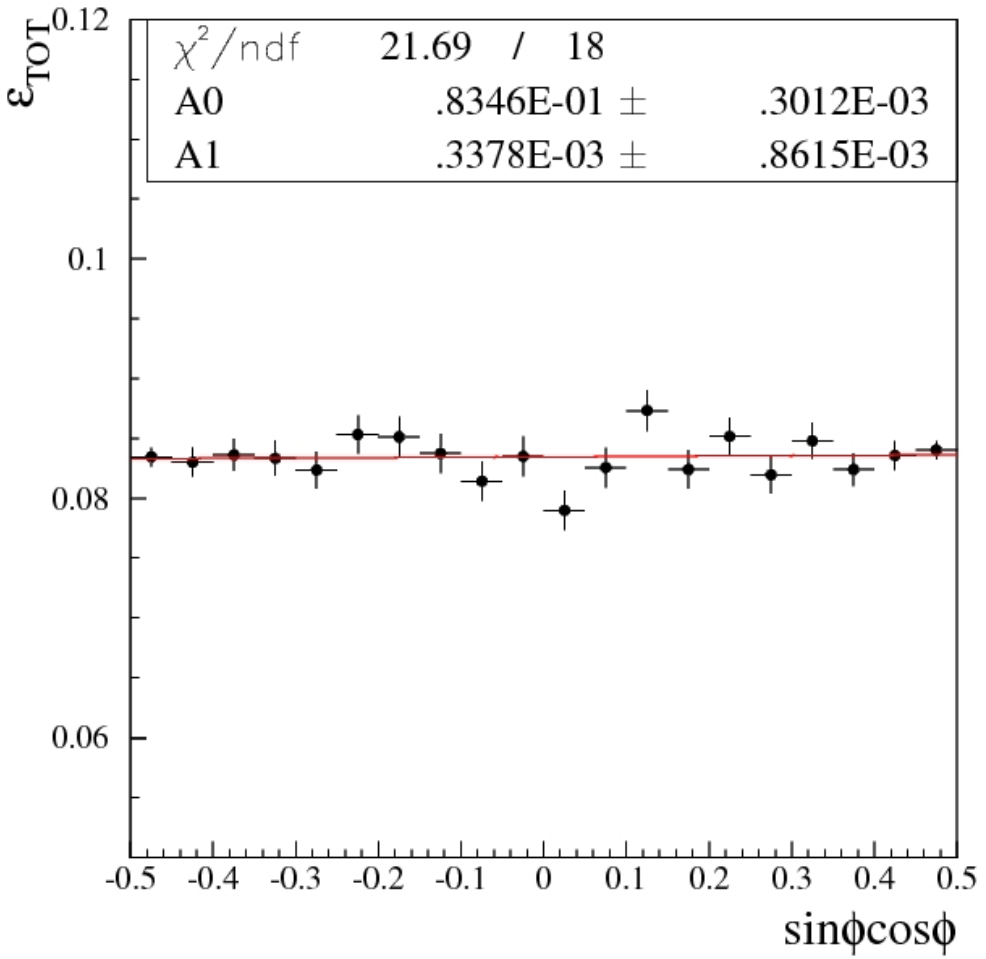
Changing SF freedom

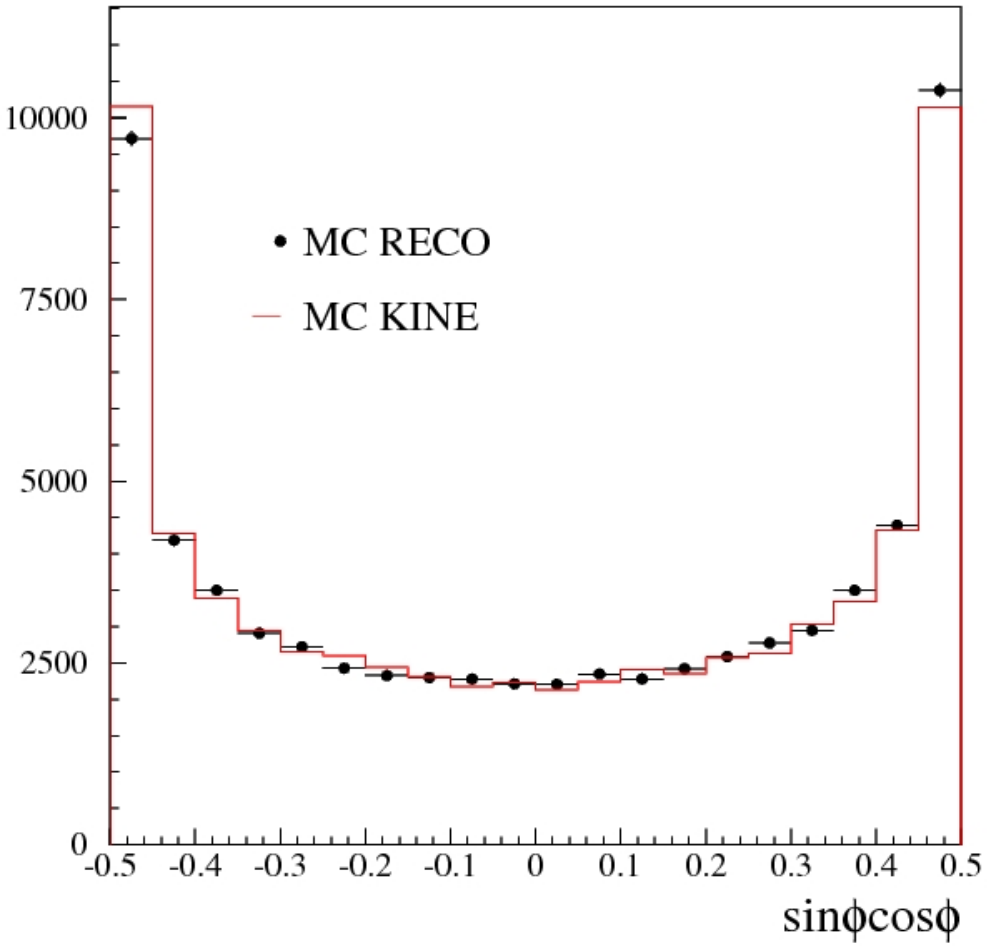
Systematics

all_phys free – offpeak w/ lumi	BR = (26.05 ± 1.47) $\cdot 10^{-5}$
Both all_phys and offpeak with lumi	BR = (26.43 ± 1.79) $\cdot 10^{-5}$
all_phys w/ lumi – offpeak free	BR = (26.69 ± 1.82) $\cdot 10^{-5}$
Both all_phys and offpeak free	BR = (26.22 ± 1.98) $\cdot 10^{-5}$

RMS = 0.24

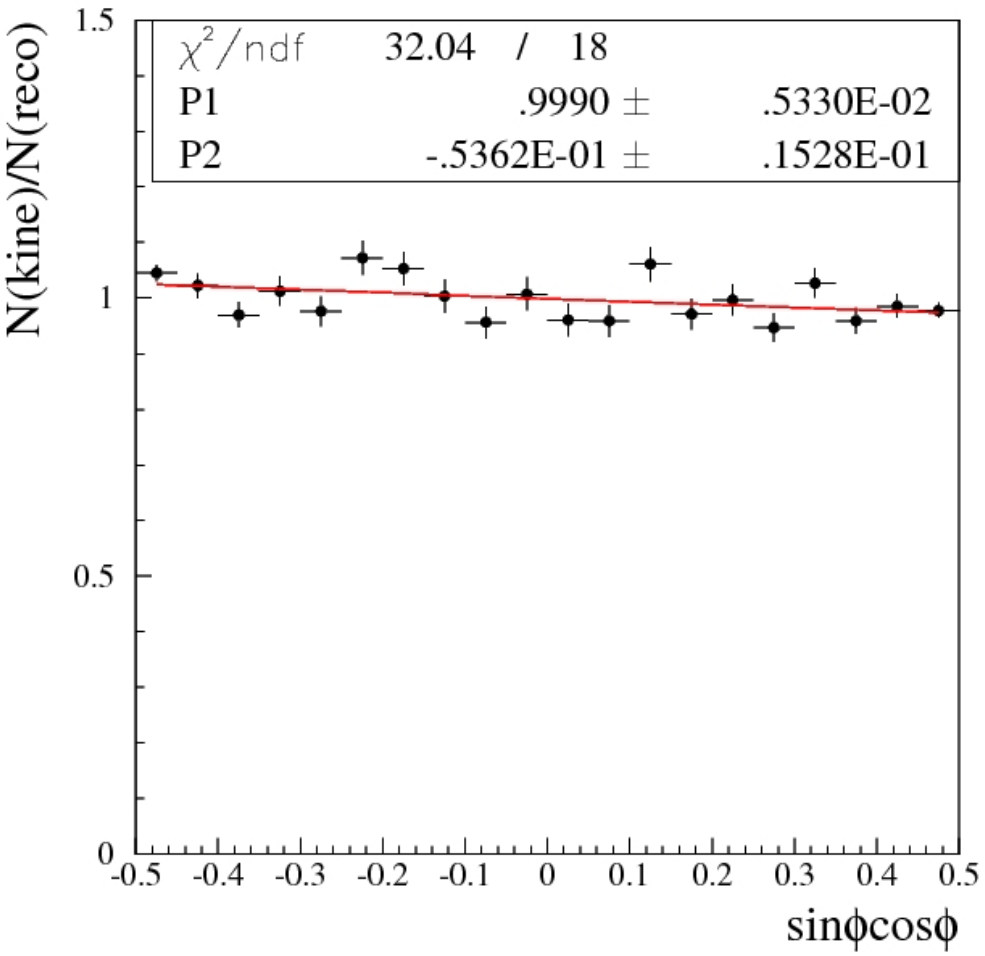
Asymmetry

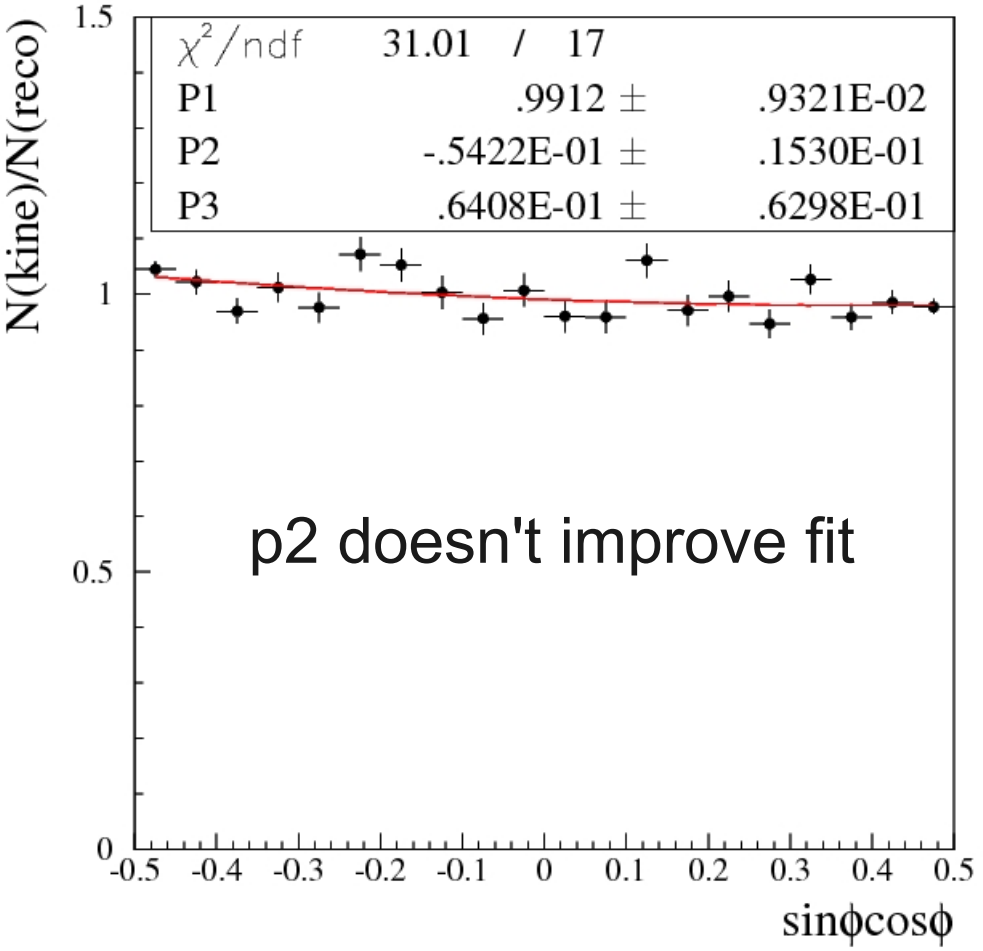




Asymmetry is slightly distorted by the analysis

Asymmetry



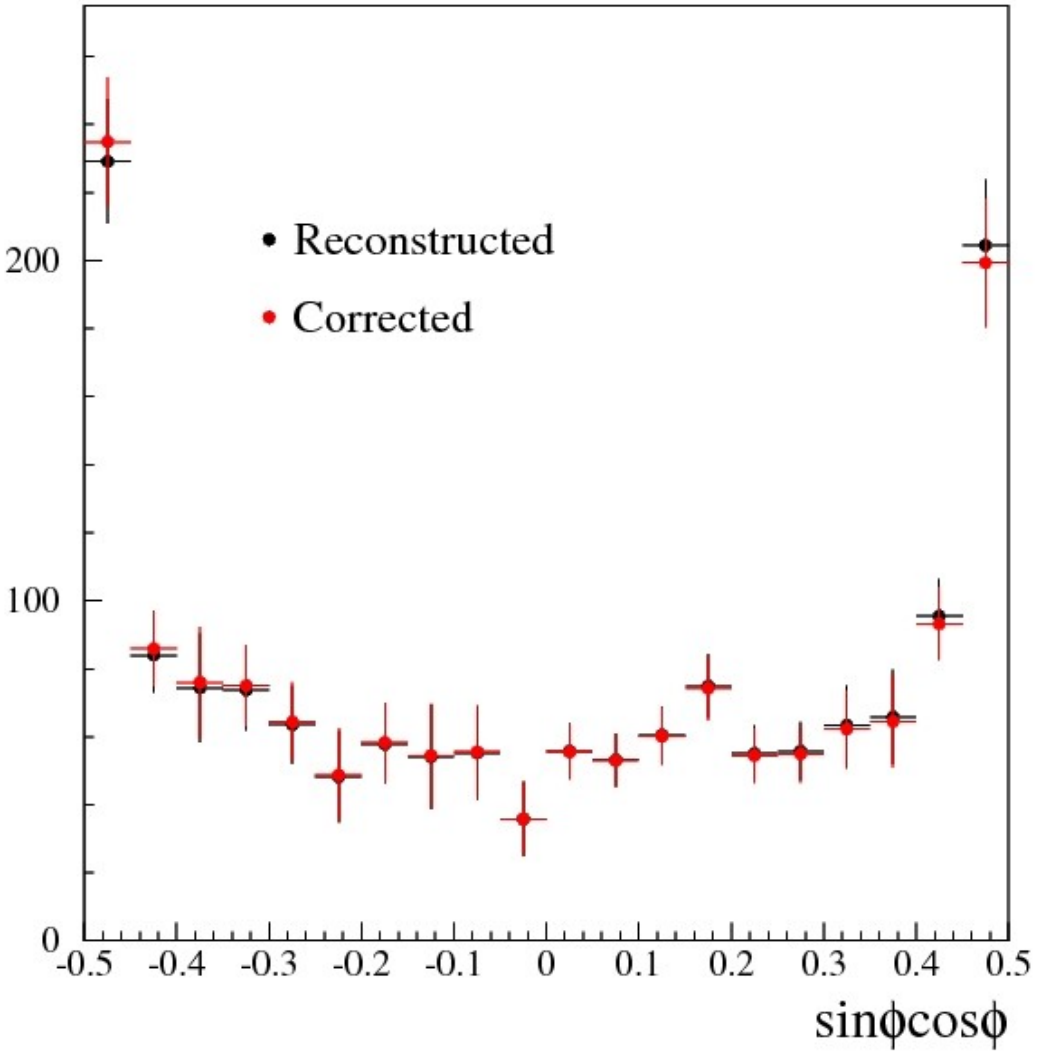


A correction can be applied

We have used a p1 correction

with a ±1σ variation for systematics evaluation

Asymmetry



$A_\phi = -1.13 \pm 2.53_{stat.} \pm 0.47_{syst.} \pm X_{syst.}$

The first systematic uncertainty accounts for different corrections

The second systematic uncertainty, accounting for changes of the analysis cuts, has still to be evaluated

Conclusion

Branching ratio ready for collaboration review

meeting with referee already scheduled

last checks to be performed

$$\mathbf{BR = (26.05 \pm 1.47_{stat.} \pm 0.67_{syst.}) \cdot 10^{-5}}$$

Asymmetry very close to the end

$$\mathbf{A_{\phi} = -1.13 \pm 2.53_{stat.} \pm 0.47_{syst.} \pm X_{syst.}}$$

Backup slides

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