Strong and electromagnetic relative phase via J/ψ resonance scan

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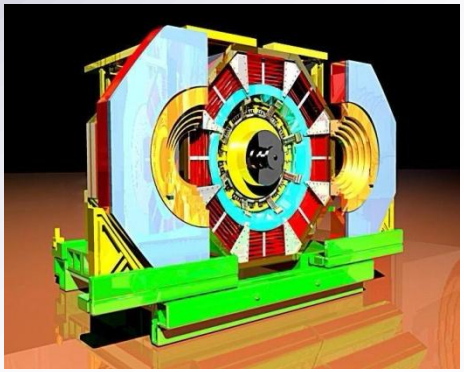


Meeting GDR PH-QCD Groupe 2: Scattering and annihilation electromagnetic processes
Paris (France)
October 4, 2011

Overview

- Motivation
- Studied processes
- Choice of the energy points
- Luminosity hypothesis
- Summary

J/ψ Strong and Electromagnetic Decay Amplitudes

Resonant contributions

$\Phi_p(G^M{}_p) \sim \Phi_\gamma \quad \Phi_{3g} = 0$

Φ_γ: relative A_{3g} - A_p

$J/\psi \rightarrow N\bar{N}$ $\Phi_p = 89° \pm 15°$ [1,2]

$J/\psi \rightarrow VP\ (1^-0^-)$ $\Phi_p = 106° \pm 10°$ [3]

$J/\psi \rightarrow PP\ (0^-0^-)$ $\Phi_p = 89.6° \pm 9.9°$ [4]

$J/\psi \rightarrow VV\ (1^-1^-)$ $\Phi_p = 138° \pm 37°$ [4]

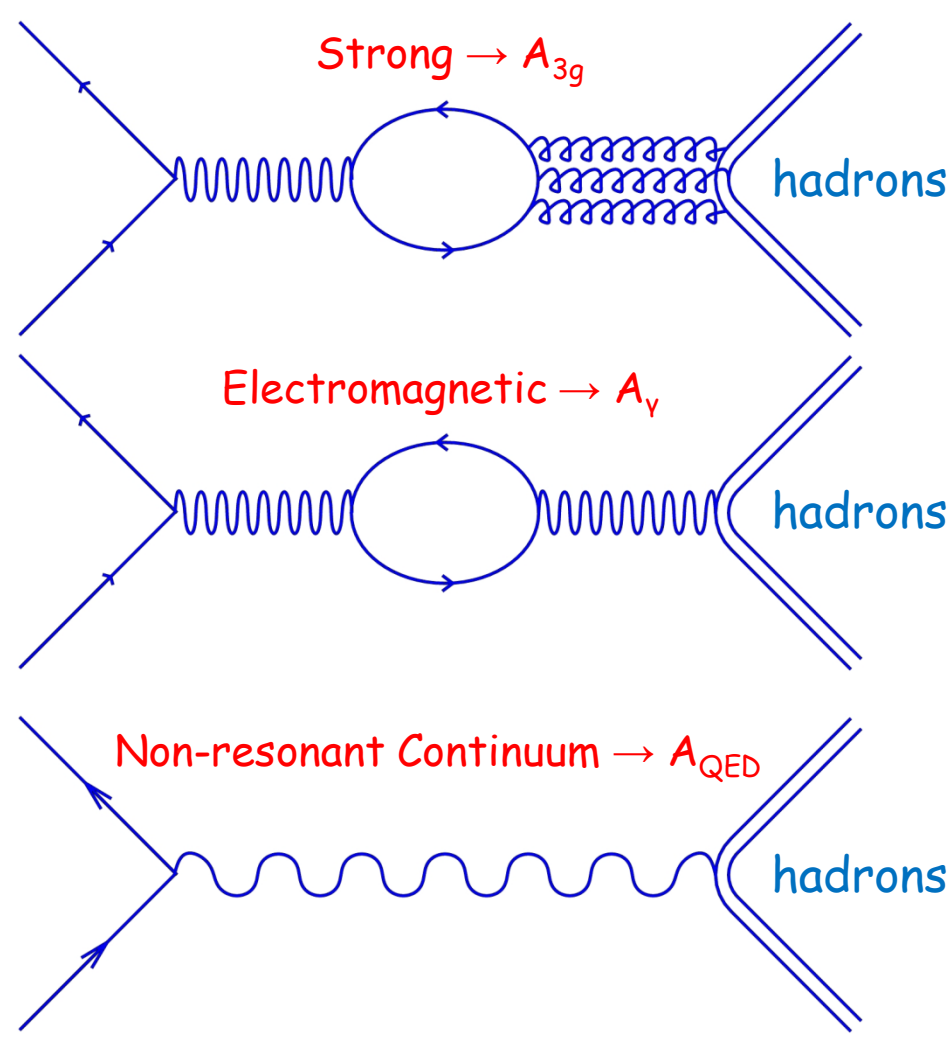
NO INTERFERENCE!

Non-resonant continuum

affects the measured BR [5]

affects Φ_p [5]

INTERFERENCE WITH A_{3g}!



[1] R. Baldini, C. Bini, E. Luppi, Phys. Lett. B404, 362 (1997); R. Baldini et al., Phys. Lett. B444, 111 (1998)
[2] J.M. Bian, J/ψ -> ppbar and J/ψ -> nnbar measurement by BESIII, approved draft
[3] L. Kopke and N. Wermes, Phys. Rep. 174, 67 (1989); J. Jousset et al., Phys. Rev. D41,1389 (1990).
[4] M. Suzuki et al., Phys. Rev. D60, 051501 (1999).
[5] P. Wang, arXiv:hep-ph/0410028v2 and references therein.

J/ψ Strong and Electromagnetic Decay Amplitudes

$J/\psi \rightarrow N\bar{N}$

Favoured channel

3g match $3q\bar{q}$ pairs

Without EM contribution p = n, due to isospin

With EM contribution amplitude has opposite sign, due to magnetic moments

$BR_{n\bar{n}}$ should be $\frac{1}{2}$ $BR_{p\bar{p}}$

But the BR are almost equal according to BESIII[1]:

$$BR(J/\psi \rightarrow p\bar{p}) = (2.112 \pm 0.004 \pm 0.027)\cdot 10^{-3}\%$$

$$BR(J/\psi \rightarrow n\bar{n}) = (2.07 \pm 0.01 \pm 0.14)\cdot 10^{-3}\%$$

- Proof of 90° phase

[1] J.M. Bian, J/ψ -> ppbar and J/ψ -> nnbar measurement by BESIII, approved draft

J/ψ Strong and Electromagnetic Decay Amplitudes

IMAGINARY AMPLITUDES HARD TO BE EXPLAINED!

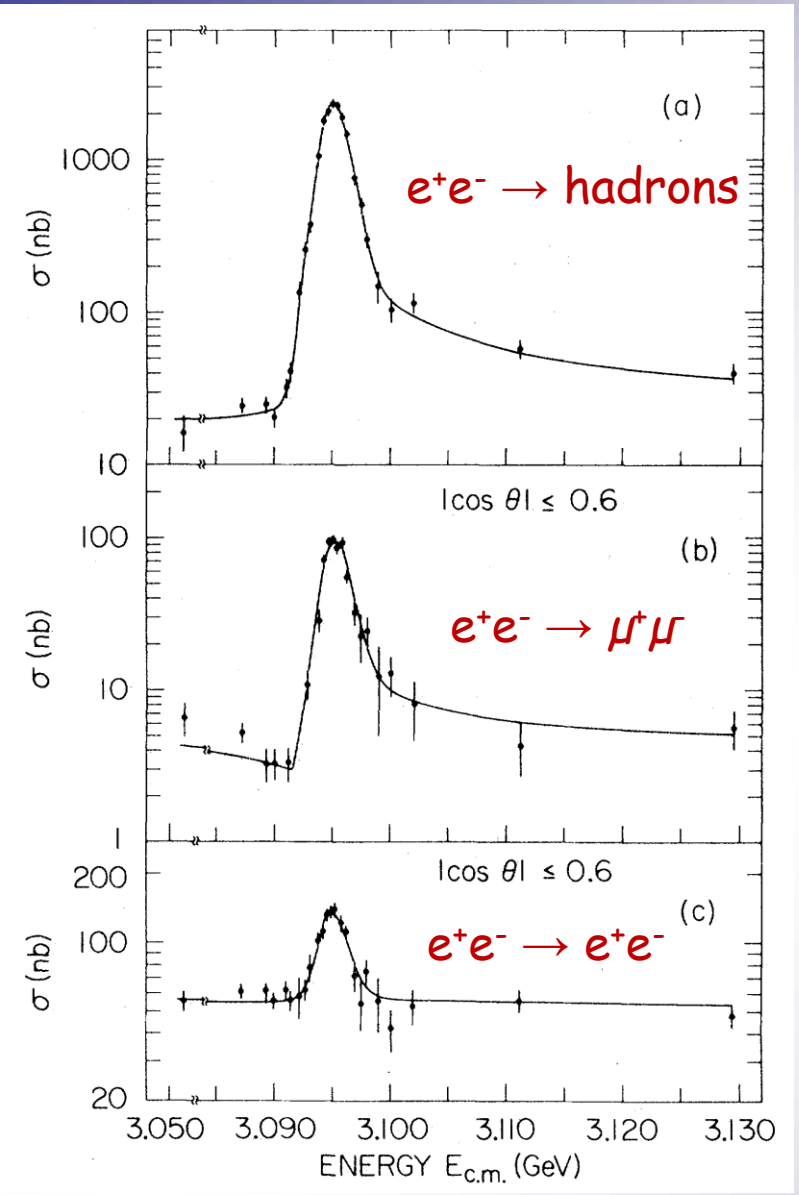
- J/ψ perturbative regime (← $\Gamma_{J/\psi}$ ~ 93KeV)
- pQCD → real A_γ, A_{3g}
- QCD does not provide sizeable imaginary amplitudes (Φ_p 10° at most [1])
- a J/ψ - V glueball mixing [2] may explain imaginary amplitudes; and ψ'?
- determination of phases Φ_p rely on theoretical hypotheses

EXPERIMENTAL DATA

- no interference term in the inclusive J/ψ and ψ' production
- expected evidence of an interf. term in $e^+e^- \to J/\psi \to \mu^+\mu^-$ @ BESII [3]
- no clear evidence of interf. or glueball in $e^+e^- \to J/\psi \to \rho\pi$ @ BESII [4]

[1] J. Bolz and P. Kroll, WU B 95-35.
[2] S.J. Brodsky, G.P. Lepage, S.F. Tuan, Phys. Rev. Lett. 59, 621 (1987).
[3] J.Z. Bai et al., Phys. Lett. D 355, 374-380 (1995).
[4] J.Z. Bai et al., Phys. Rev. D 54, 1221 (1996).

Was an Interference Already Seen?



Historically
J/ψ production
at SPEAR (SLAC)

Phys. Rev. Lett. 34, 1357 (1975)

Choice of the Processes

- Inclusive scenario: does not see anything

The phase is there, but the mean goes to 0

Interference $\propto \langle f | 3g \rangle^* \langle f | \gamma \rangle$

Sum over all the final states $\sum \langle 3g | f \rangle \langle f | \gamma \rangle$

Closure approximation $\sum | f \rangle \langle f | \approx 1$

But $\langle 3g | \gamma \rangle \cong 0$ orthogonal states

If we sum over all the channels, the interference ≈ 0

Choice of the Processes

- Esclusive scenario: could see interference effects

- $e^+e^+ \to J/\psi \to p\bar{p}, n\bar{n}$ $\quad N\bar{N}$

  BR ~ $2.17\times10^{-3}\%$ $\quad \sigma_{cont}$~ 11 pb

- $e^+e^- \to J/\psi \to \rho\pi$ $\quad VP$

  BR ~ 1.69% $\quad \sigma_{cont}$~ 20 pb

- $e^+e^- \to J/\psi \to 2(\pi^+\pi^-)\pi^0$

  BR ~ 3.37% $\quad \sigma_{cont}$~ 500 pb

All the other channel for free

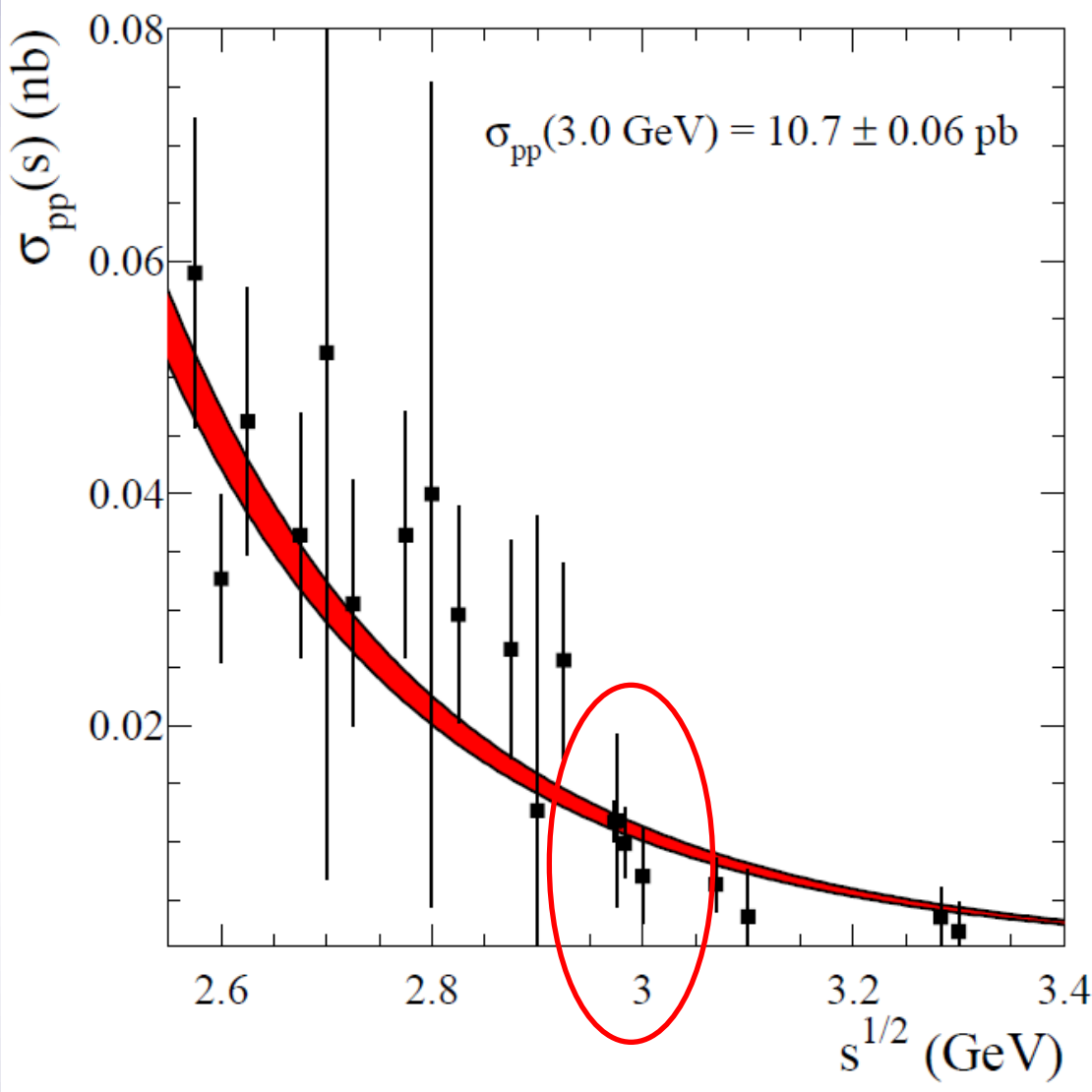
Continuum Cross Section ($p\bar{p}$)

$$\sigma \propto \frac{1}{S} FF^2$$

$$S = W^2 \qquad FF \propto \frac{1}{W^4}$$

$$\sigma \propto \frac{1}{W^{10}}$$

$\sigma_{cont} \sim 11$ pb

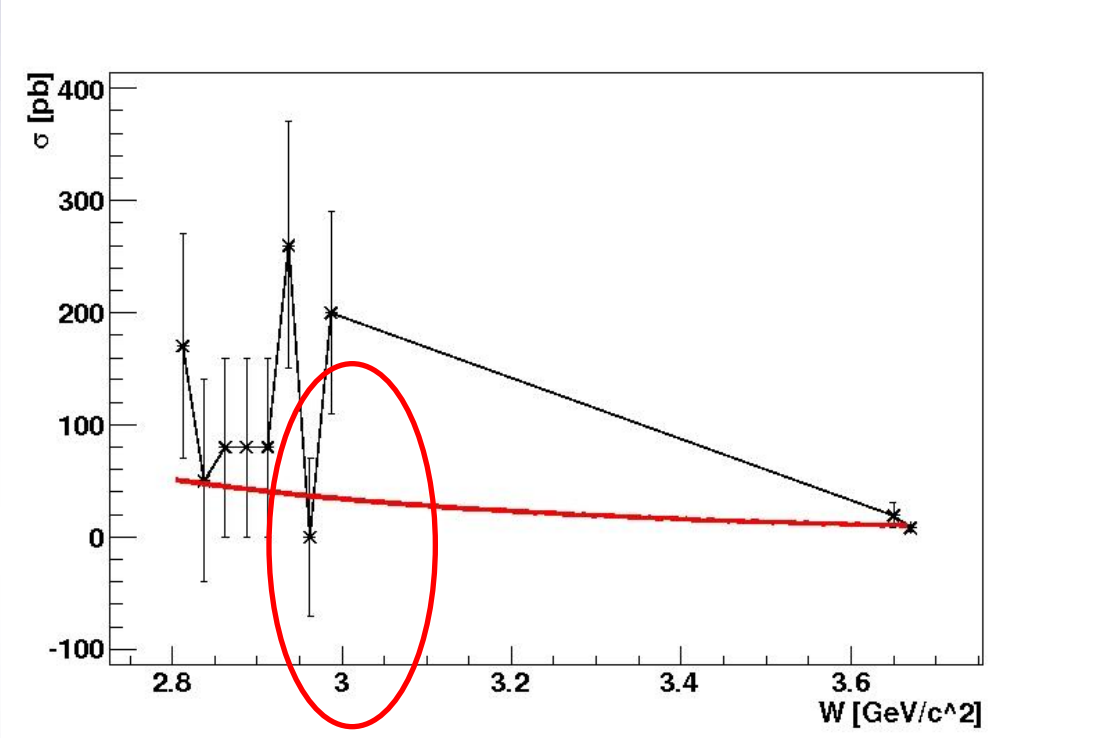


Continuum Cross Section (ρπ)

$$\sigma \propto \frac{1}{S} FF^2$$

$$S = W^2 \qquad FF \propto \frac{1}{W^2}$$

$$\sigma \propto \frac{1}{W^6}$$



σ_{cont}~ 20 pb

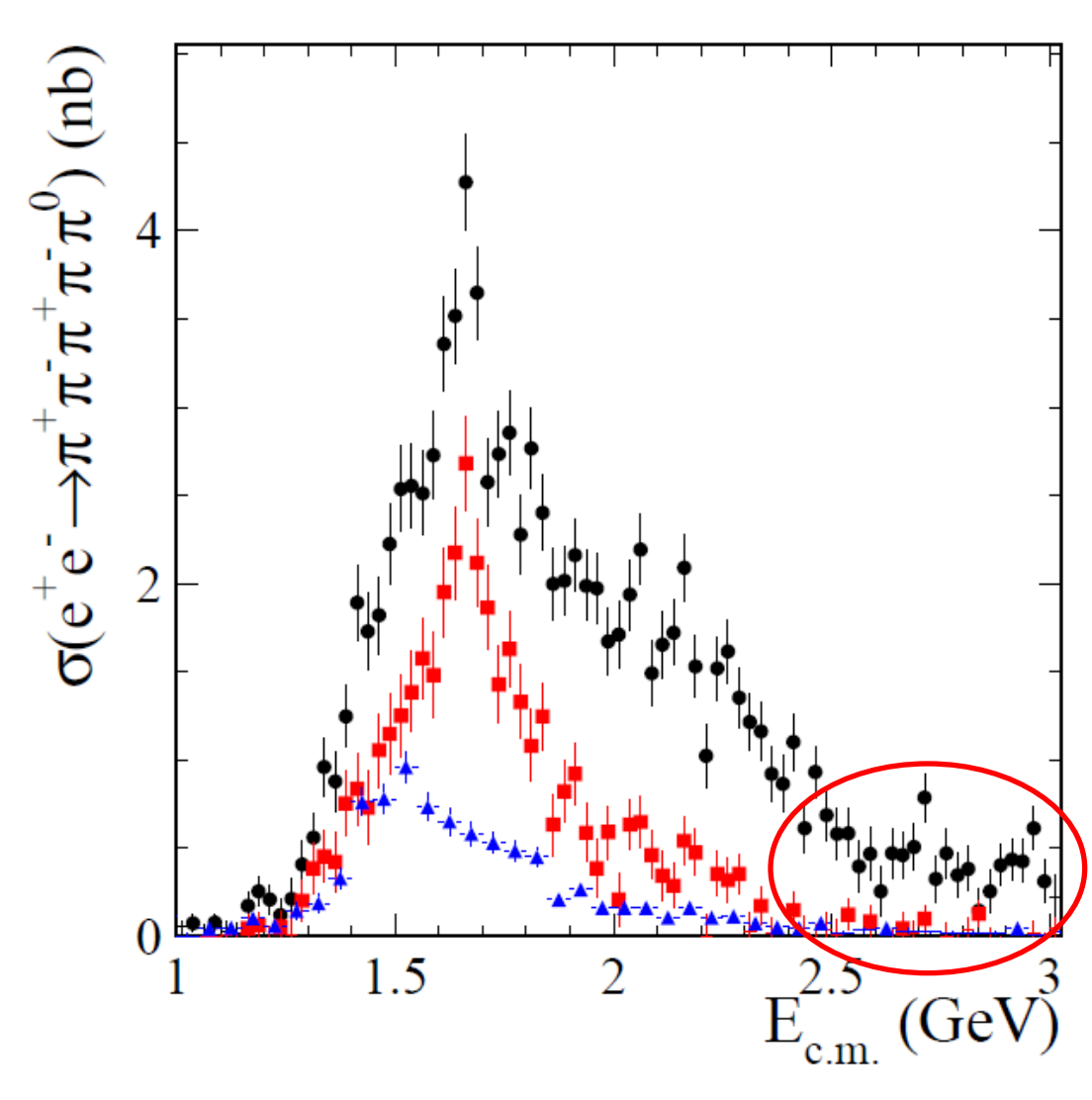
Continuum Cross Section (5π)

$$\sigma \propto \frac{1}{S} FF^2$$

Flat behavior

$$\sigma \propto \frac{1}{W^0}$$

σ_{cont}~ 500 pb



arXiv:1105.4975v2 [hep-ex], BABAR Collaboration (2011).

Phase Generator

- Event generator
- Monte-Carlo method (100000 iterations)
- Cross section evaluation at each point
- Beam spread gaussian (0.93)
- Radiative correction (simple model to be optimized)
- Max radiation 300 MeV (~20% E_{CM})
- Cross section:

$$\sigma[nb] = 12\pi B_{in} B_{out} \left[\frac{\hbar c}{W}\right]^2 \cdot 10^7 \cdot \left| -\frac{C_1 + C_2 e^{i\varphi}}{W - W_{ris} + i\Gamma_{ris}/2} + C_3 e^{i\varphi} \right|^2$$

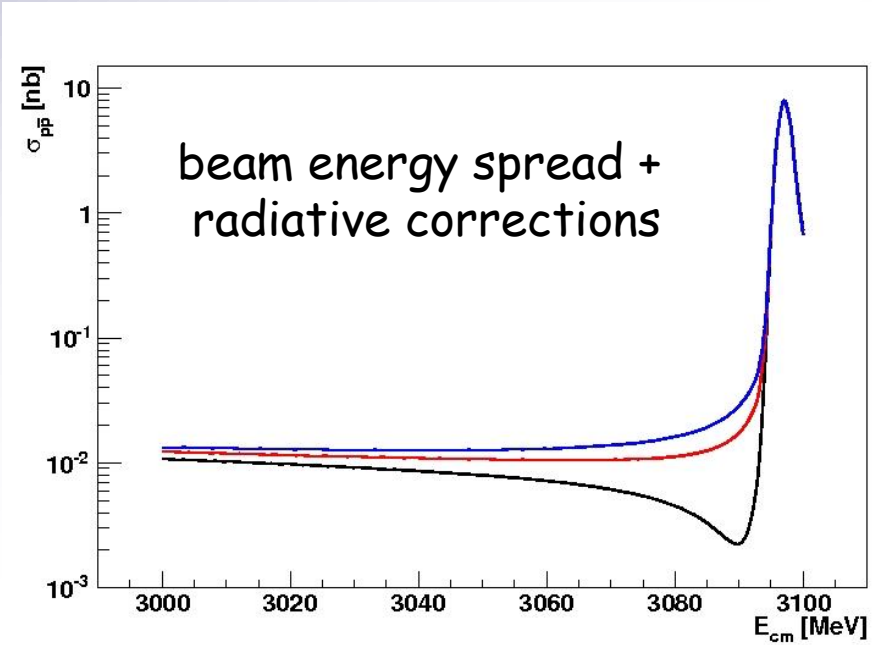
Simulated Yields for $e^+e^- \to \bar{p}p$

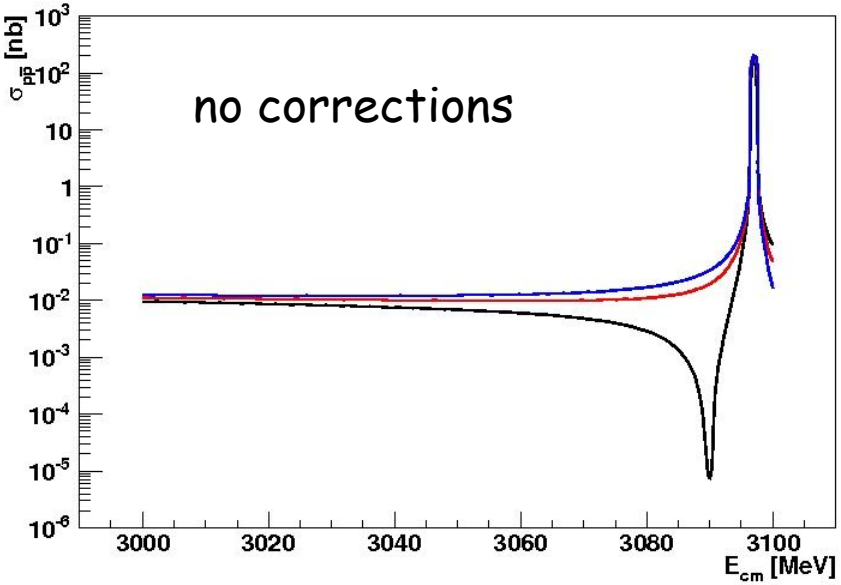
— $\Delta\varphi = 0^\circ$

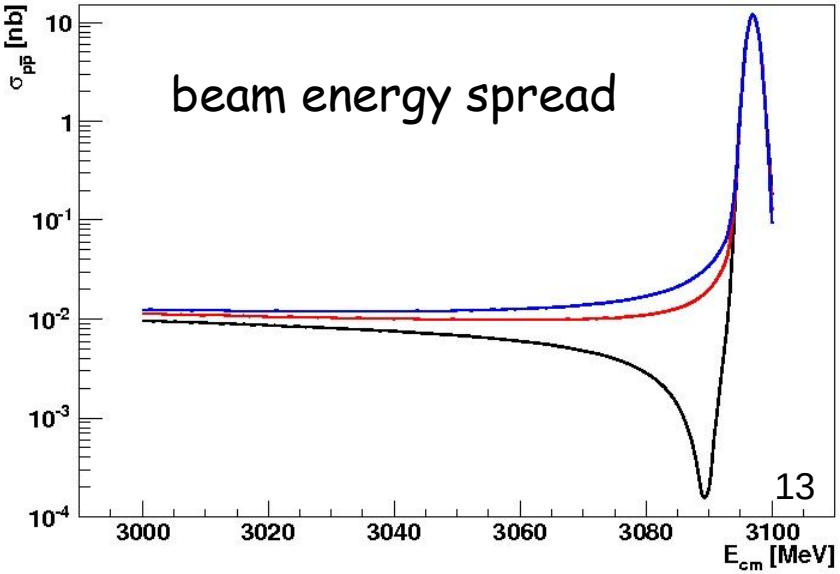
— $\Delta\varphi = 90^\circ$

— $\Delta\varphi = 180^\circ$

continuum reference
$\sigma \sim 11$ pb

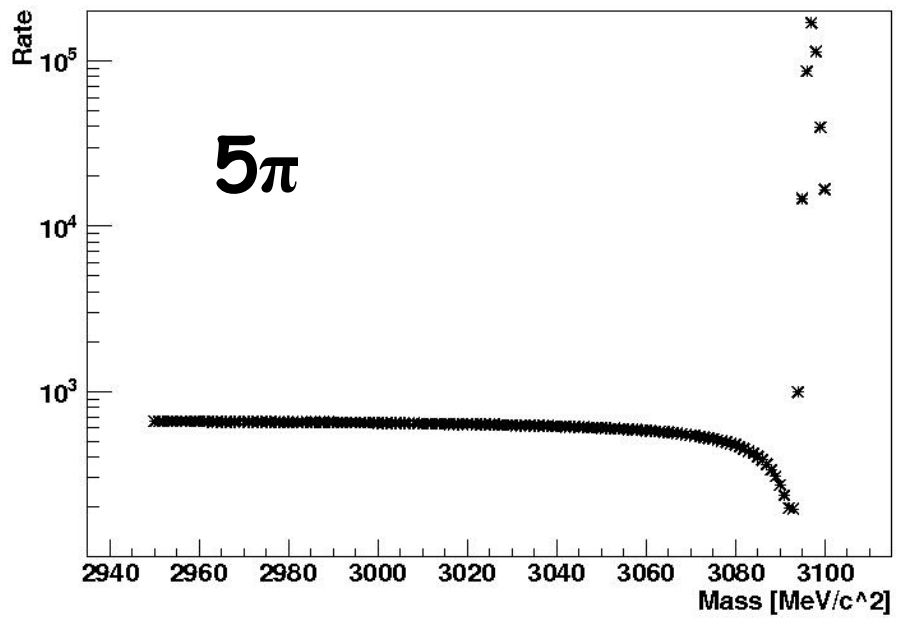


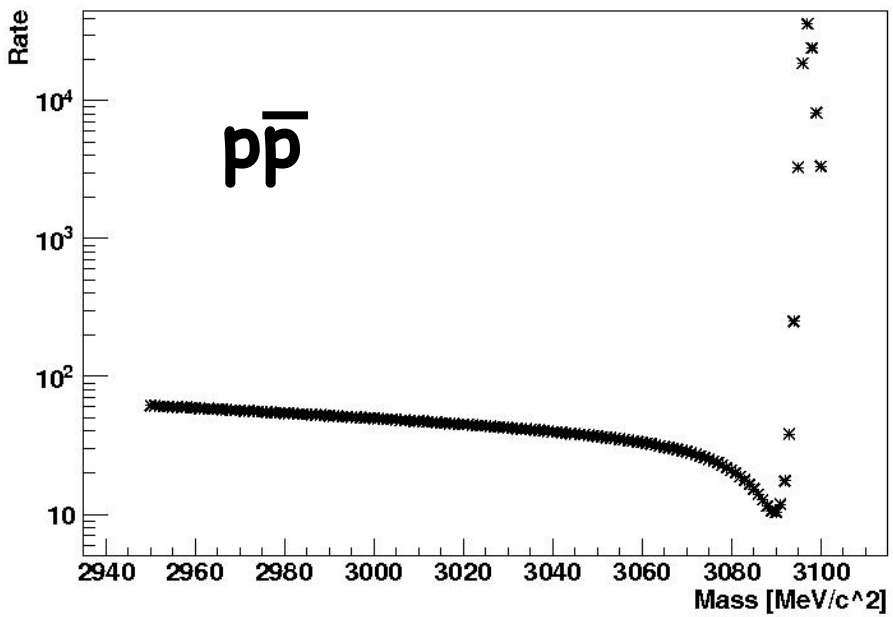


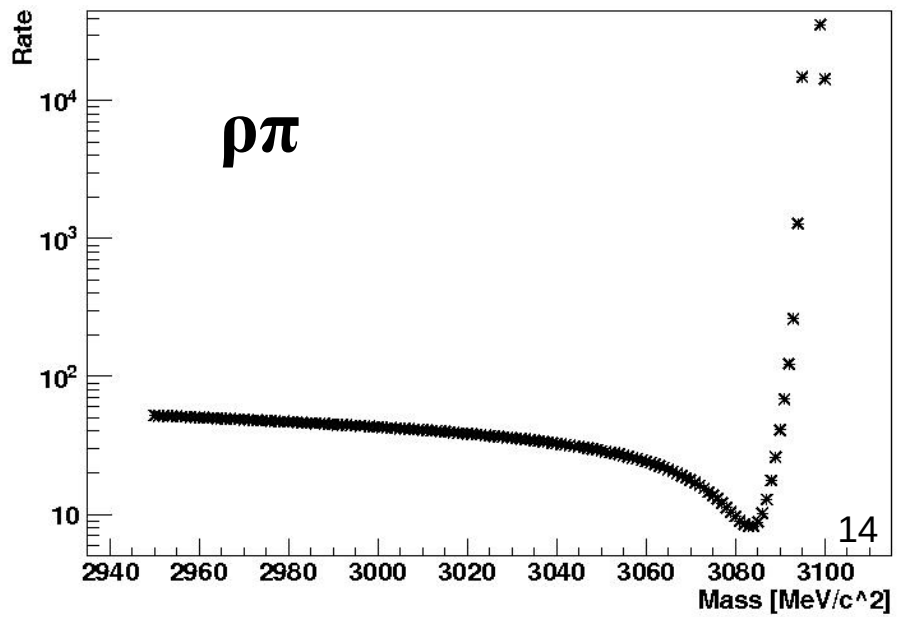


Energy Points Choice

Depends on the continuum reference



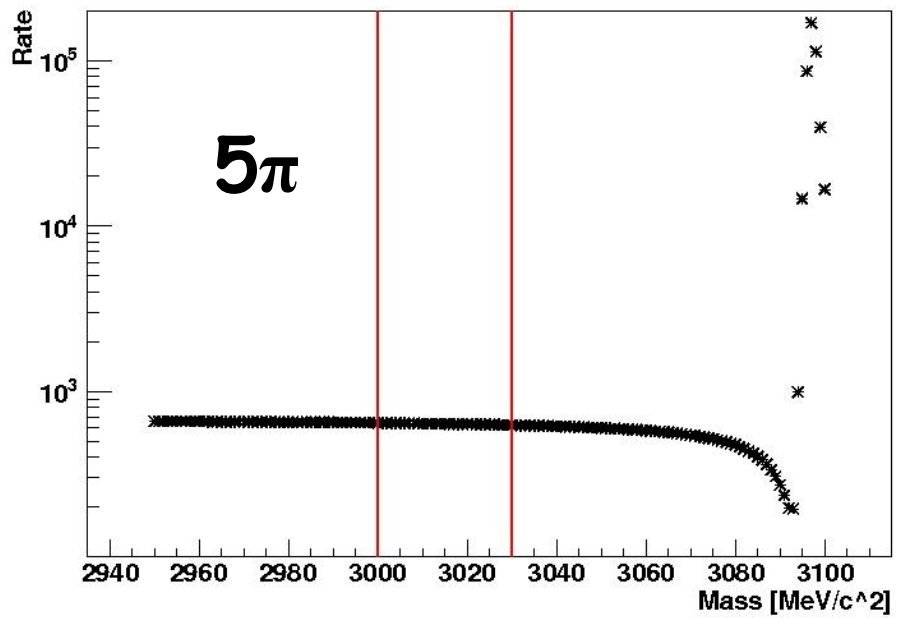


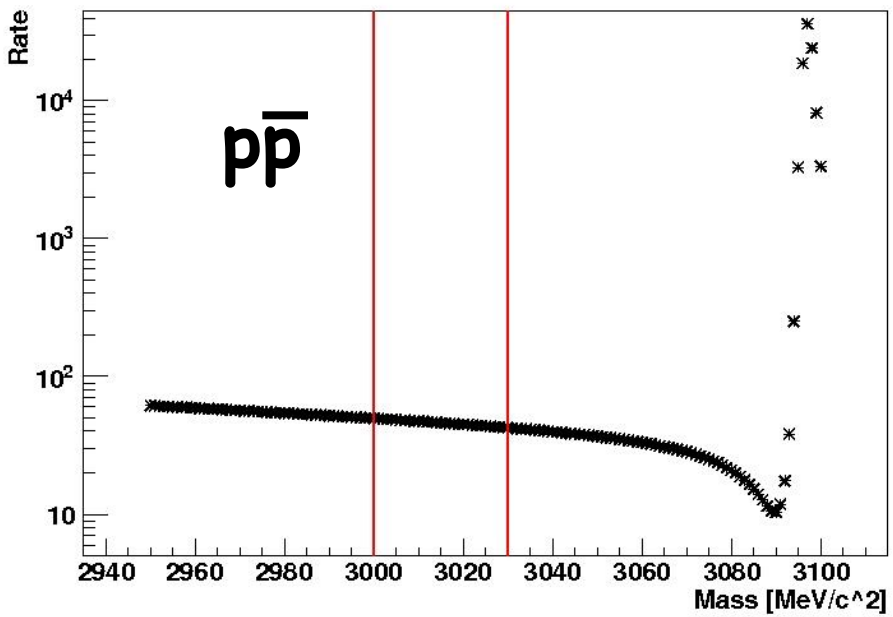


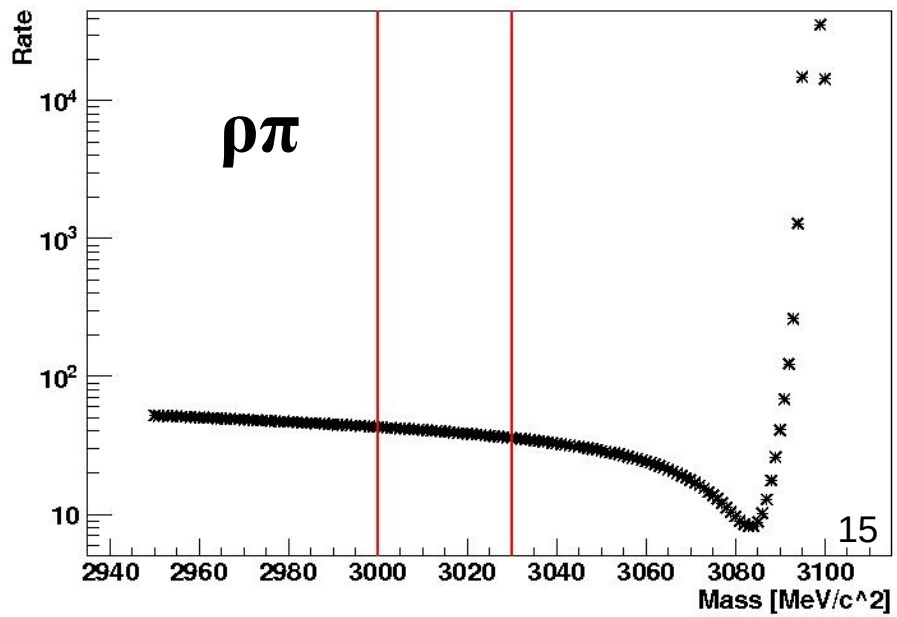
Energy Points Choice

Maximum interference: 0°

- 2 points at low W
  - fit the continuum
  - Student test
  - slope



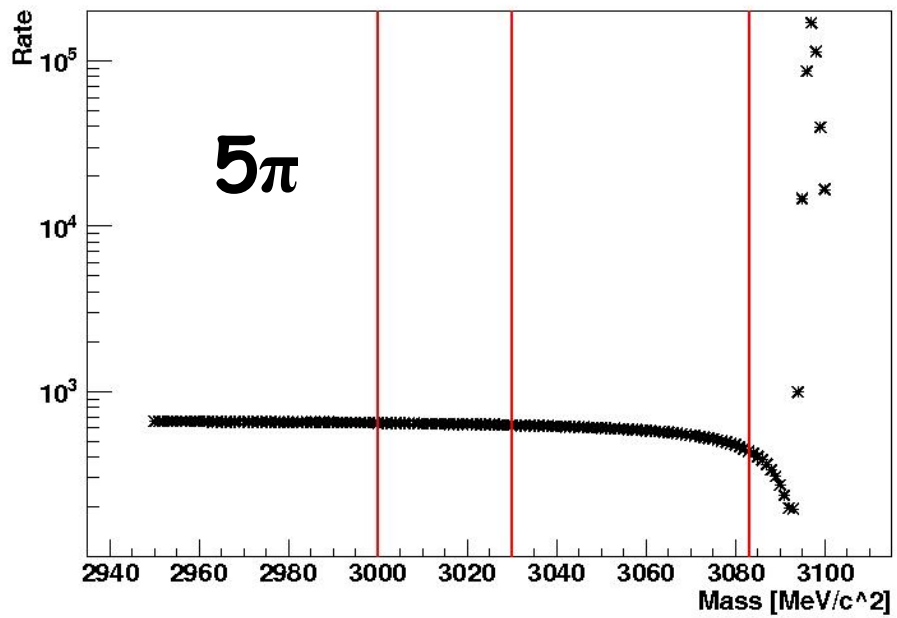


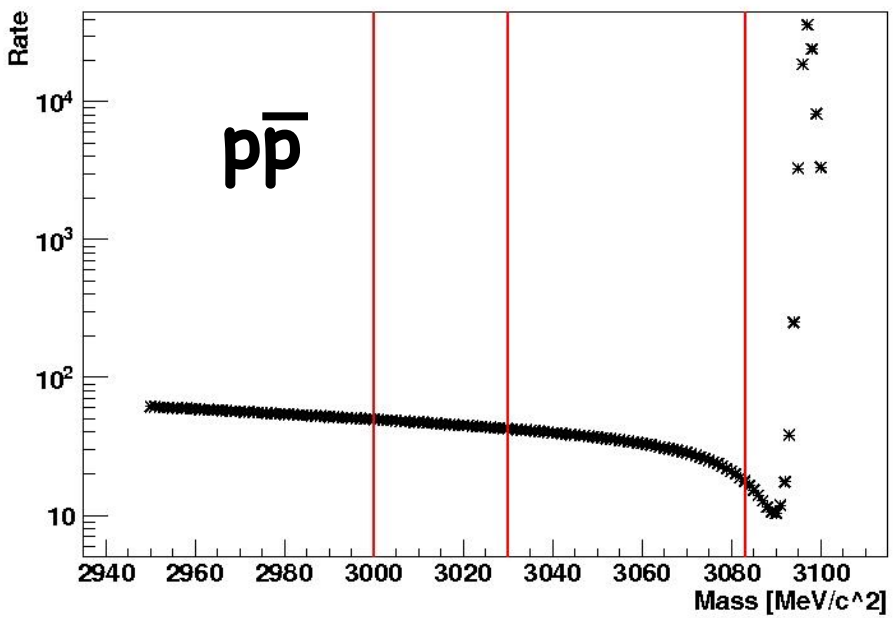


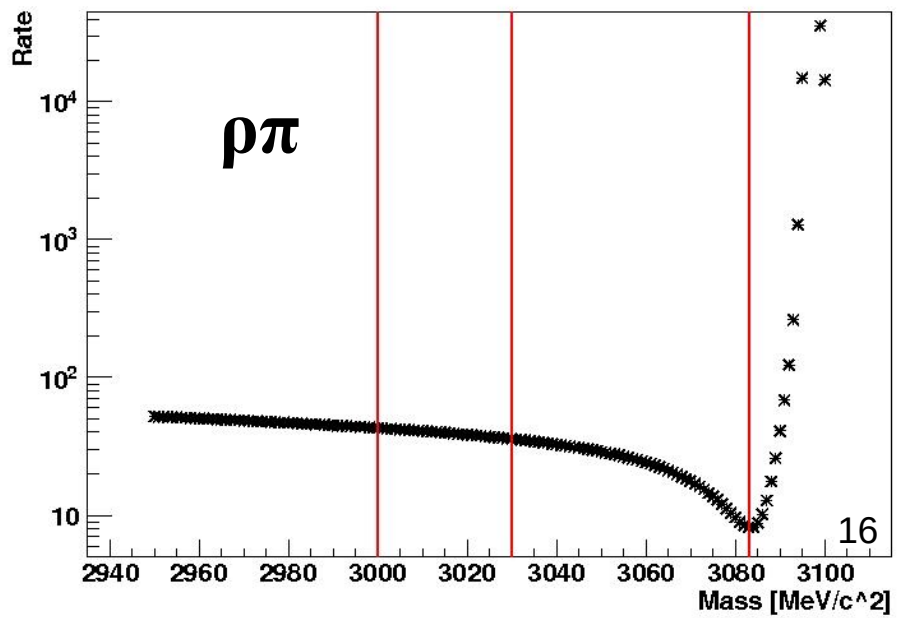
Energy Points Choice

Maximum interference: 0°

- 2 points at low W
  - fit the continuum
  - Student test
  - slope
- Deep position



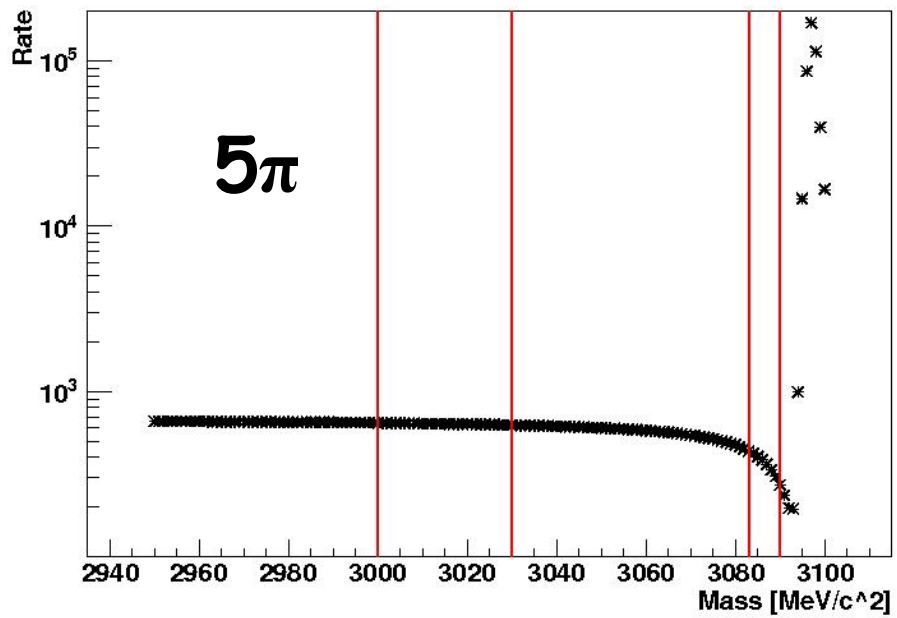


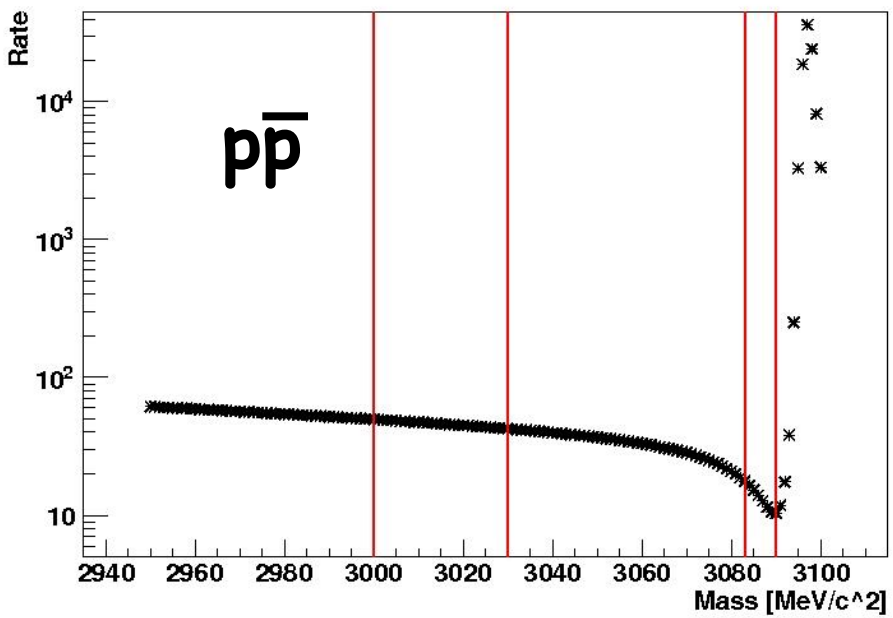


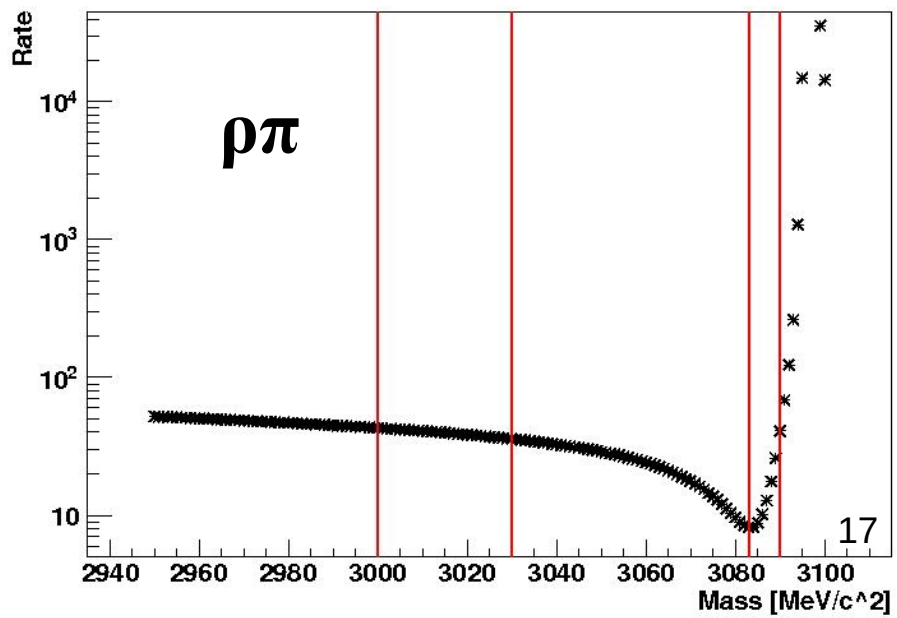
Energy Points Choice

Maximum interference: 0°

- 2 points at low W
  - fit the continuum
  - Student test
  - slope
- Deep position



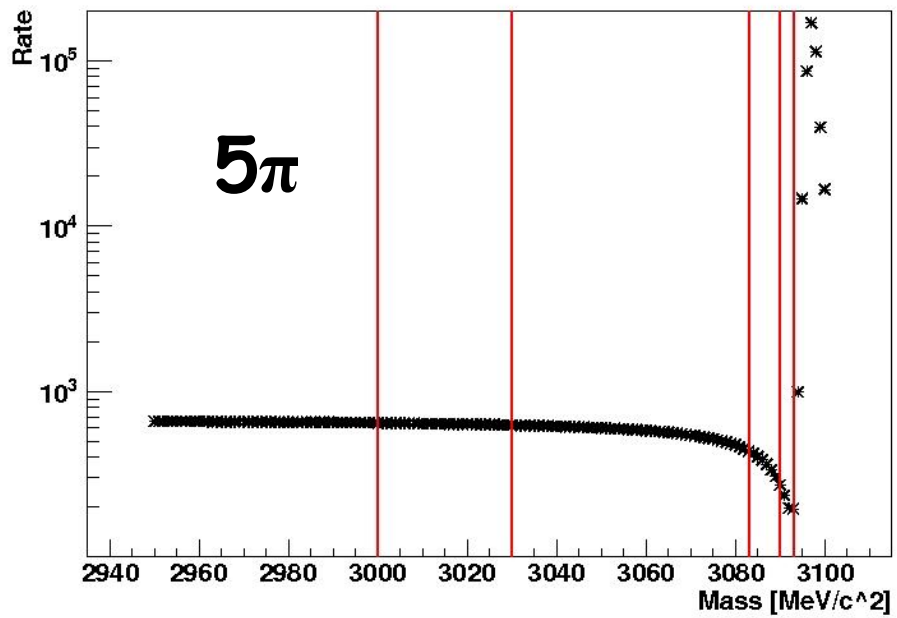


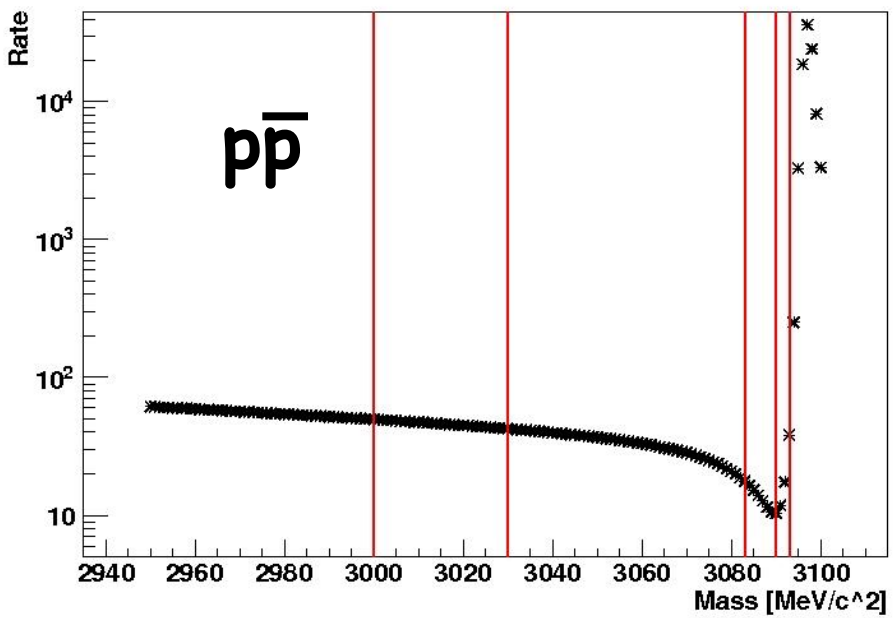


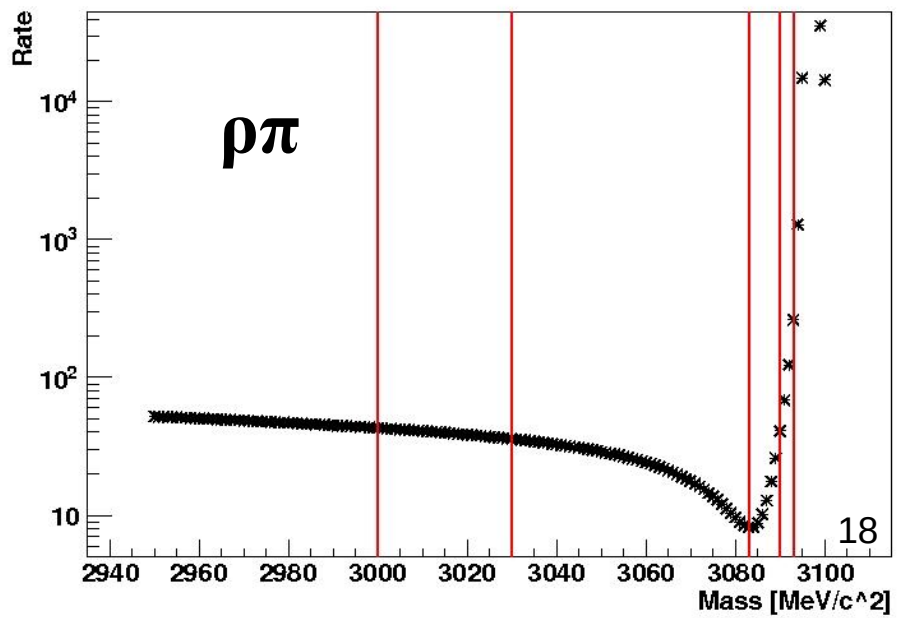
Energy Points Choice

Maximum interference: 0°

- 2 points at low W
  - fit the continuum
  - Student test
  - slope
- Deep position
- Beginning of Breit-Wigner







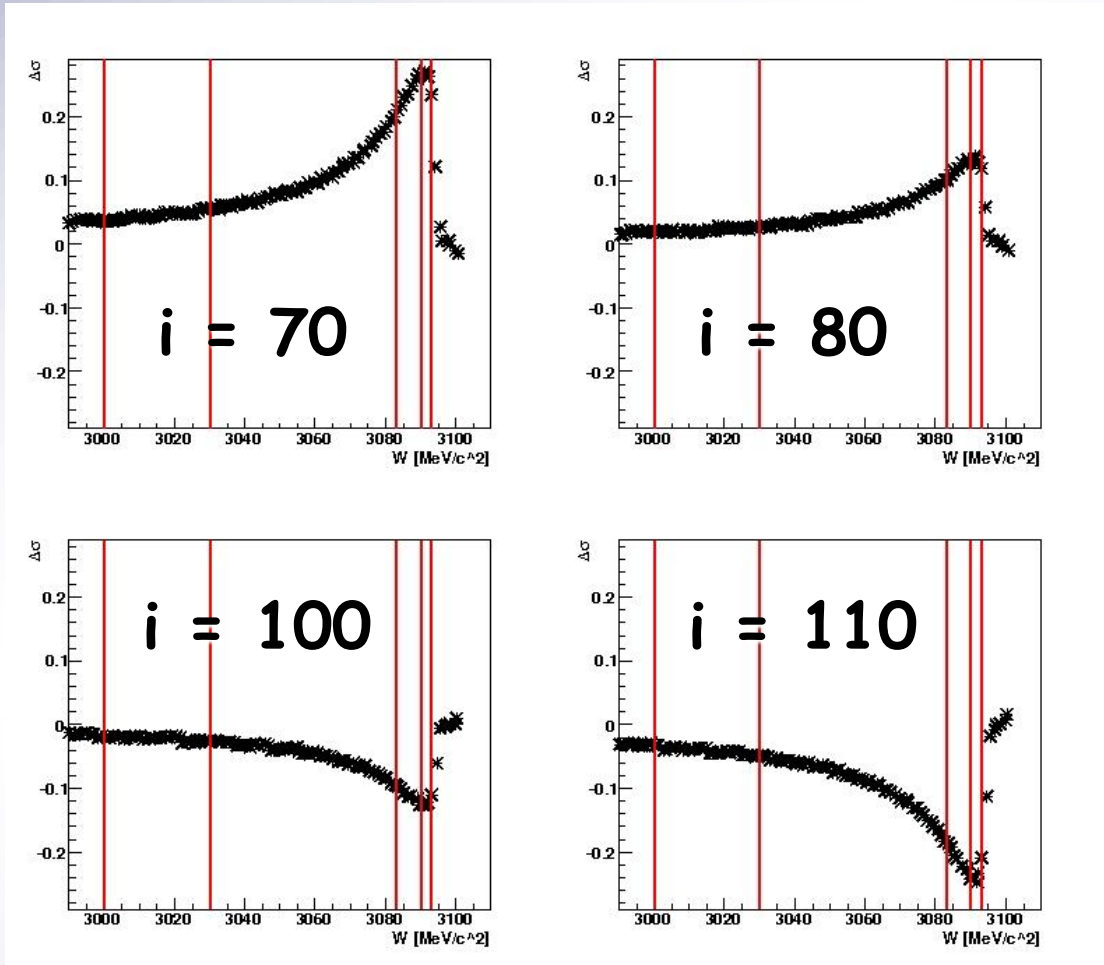
Energy Points Choice

$p\bar{p}$

- What happens at 90°

Cross section simulated at 70°, 80°, 90°, 100°, 110°

Gradient calculation $(\sigma_{90}-\sigma_i)/\sigma_{90}$



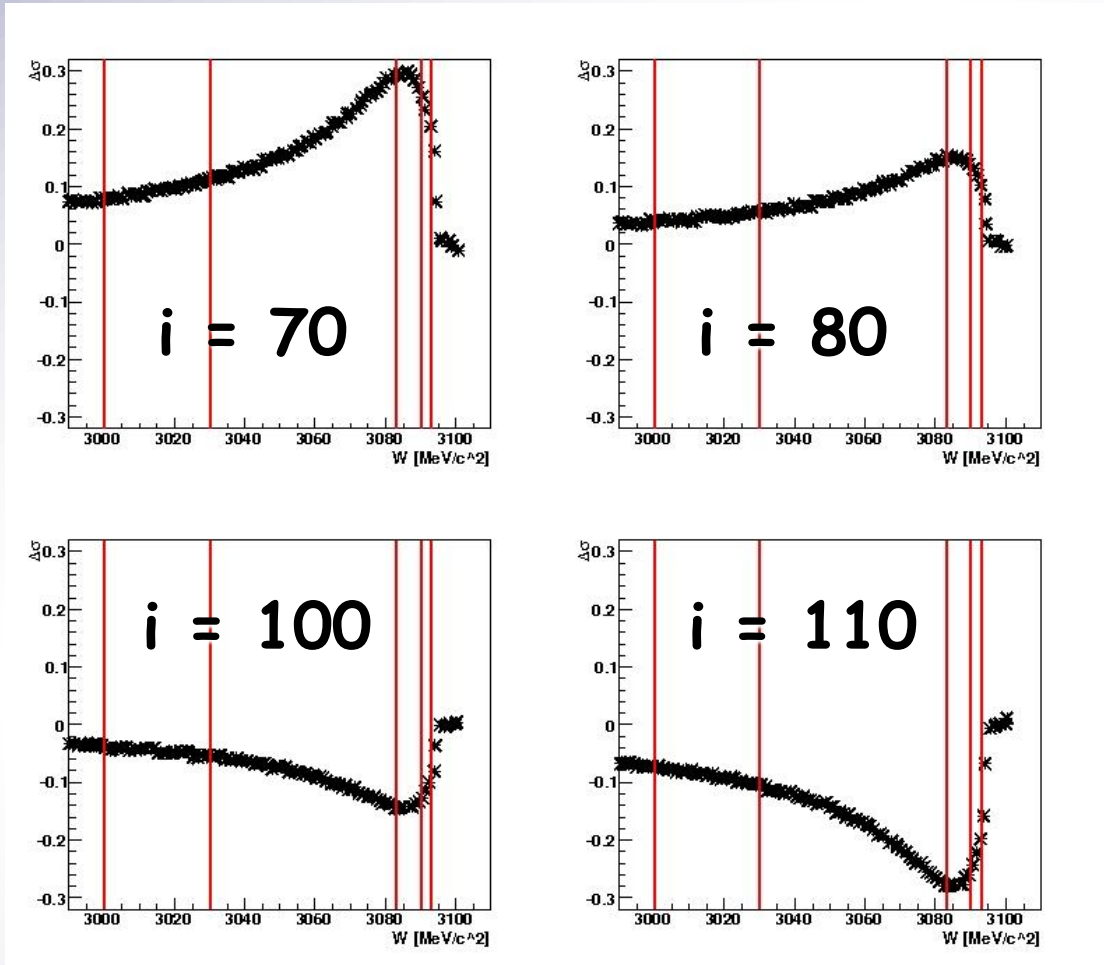
Energy Points Choice

$\rho\pi$

- What happens at 90°

Cross section simulated at 70°, 80°, 90°, 100°, 110°

Gradient calculation $(\sigma_{90}-\sigma_i)/\sigma_{90}$



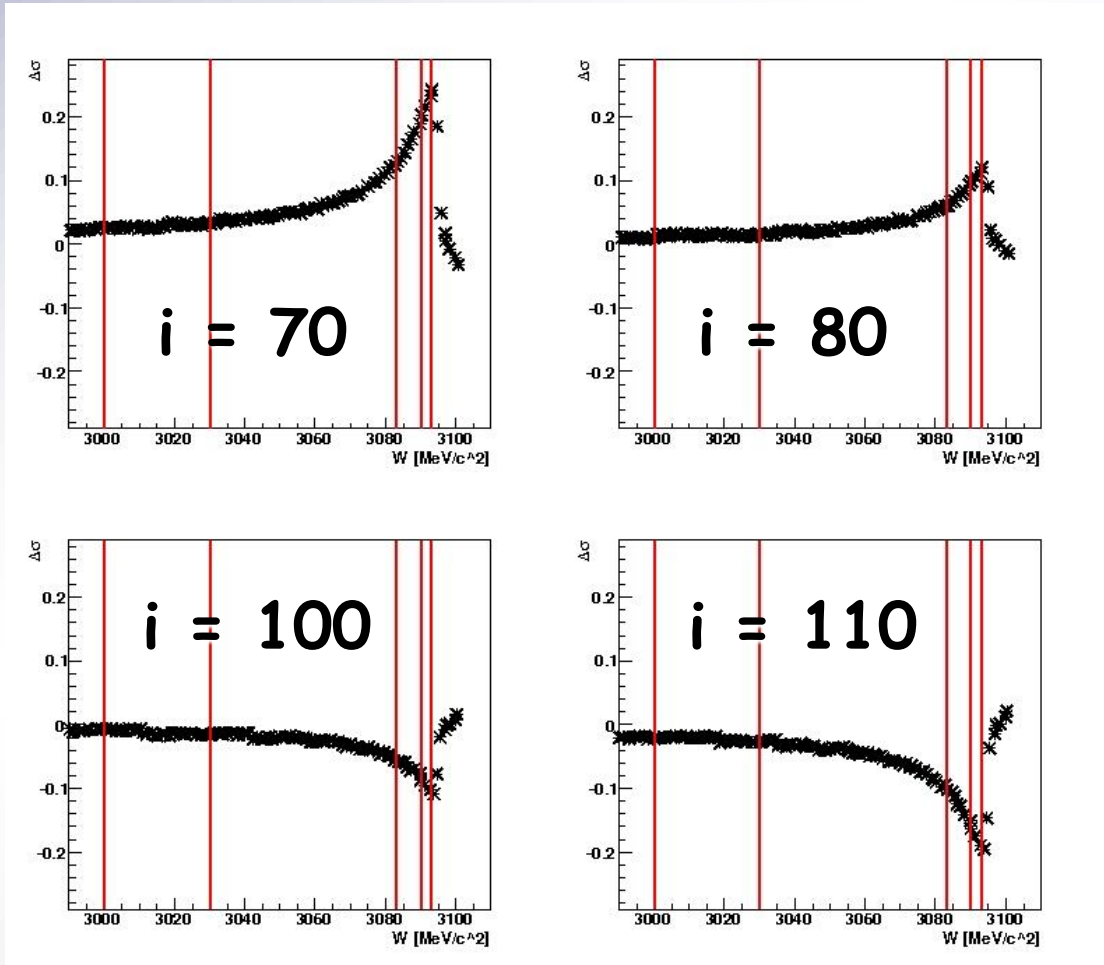
Energy Points Choice

5π

- What happens at 90°

Cross section simulated at 70°, 80°, 90°, 100°, 110°

Gradient calculation $(\sigma_{90}-\sigma_i)/\sigma_{90}$



Energy Points Choice

3000 MeV

3030 MeV

3083 MeV

3090 MeV

3093 MeV

Luminosity Hypothesis

- 6 values of Luminosity:
  10^{31}, $8.64 \cdot 10^{31}$, 10^{32},
  $2 \cdot 10^{32}$, $5 \cdot 10^{32}$, 10^{33}
- Time: 1 day = 86400 s
- Injection efficiency = 0.8
- Reconstruction efficiency
  $p\bar{p}$ = 0.67
  $\rho\pi$ = 0.38
  5π = 0.20
- Rate = $L \cdot \sigma$

Integrated Luminosity

$6.91 \cdot 10^{35}$, $5.97 \cdot 10^{36}$,
$6.91 \cdot 10^{36}$, $1.38 \cdot 10^{37}$,
$3.46 \cdot 10^{37}$, $6.91 \cdot 10^{37}$

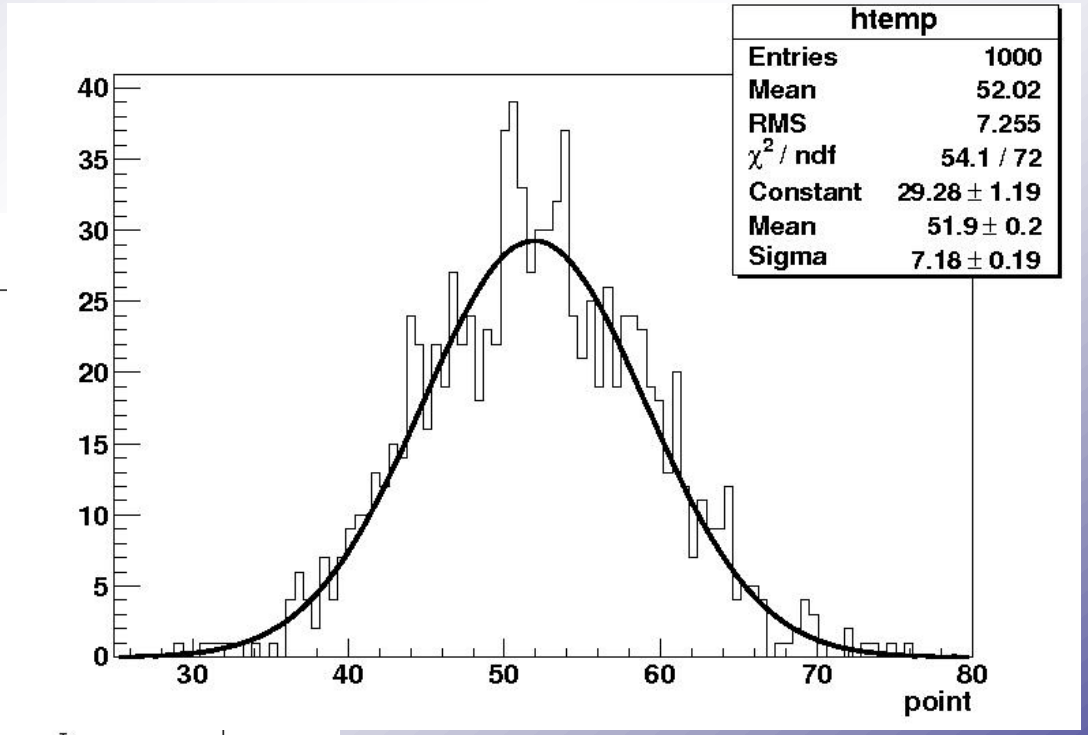
Fit procedure

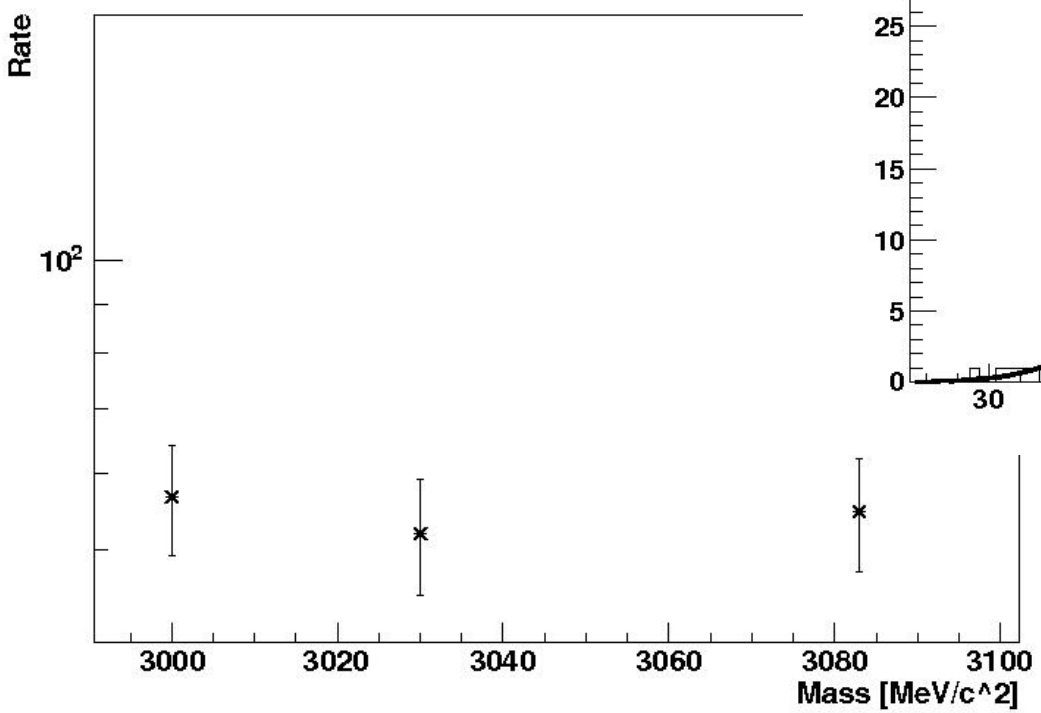
$p\bar{p}$

90° case $L = 10^{32}$

Smear each point 100 times

Error bars: $\sqrt{nev}$





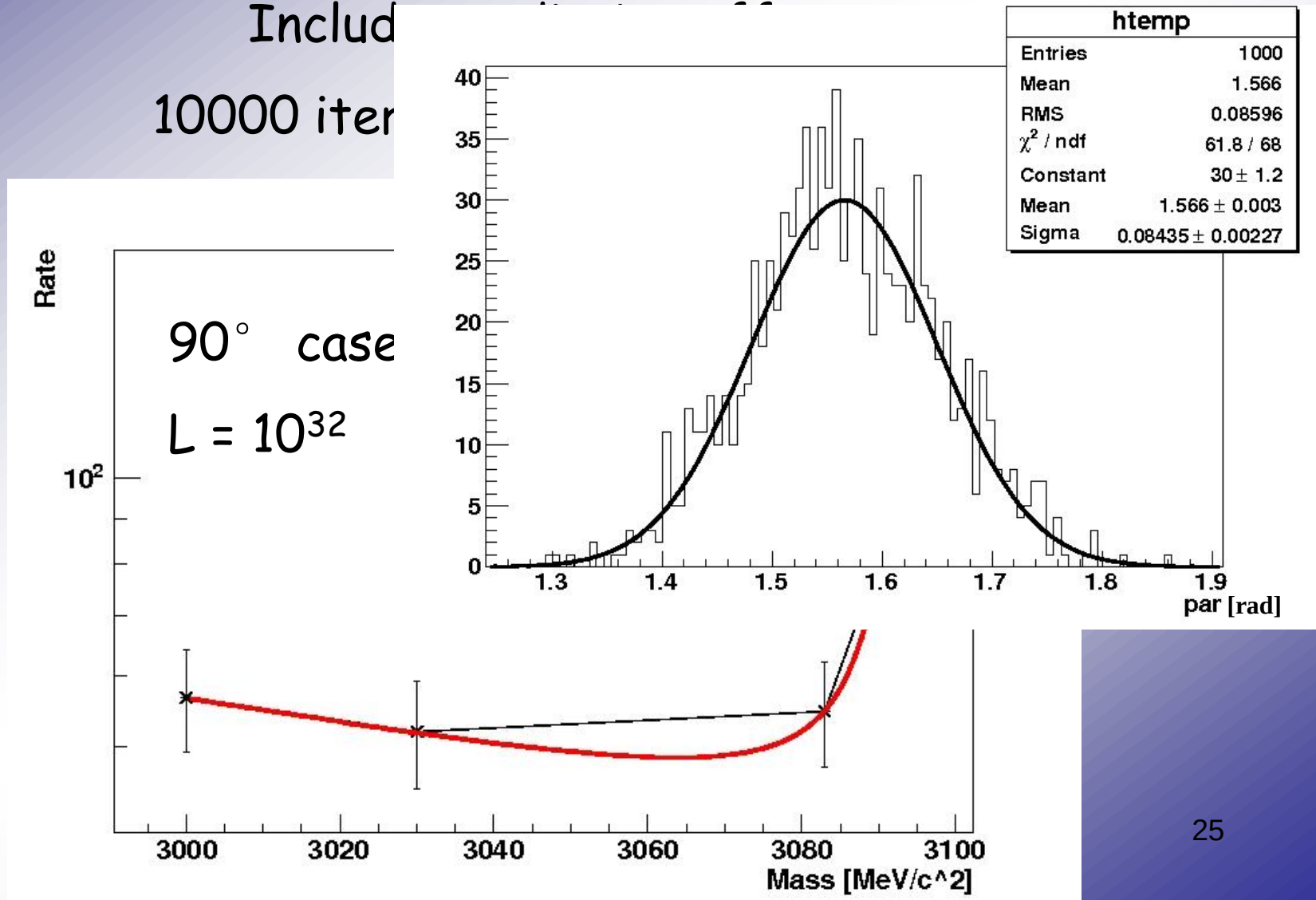
Fit procedure

$p\bar{p}$

Fit done with Monte-Carlo method

Includ

10000 iter



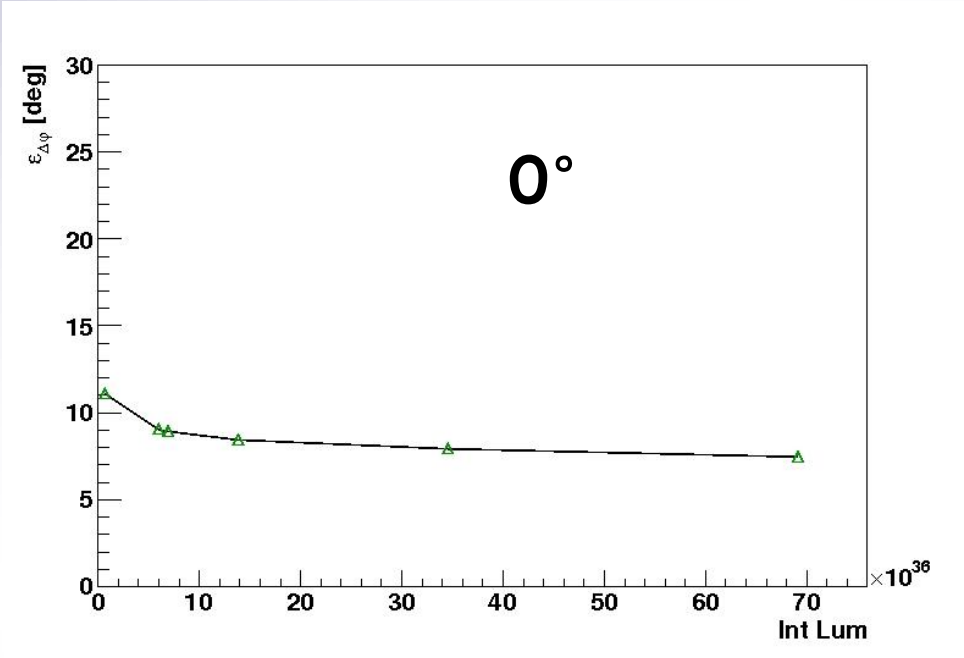
Precision of the Fit ($p\bar{p}$)

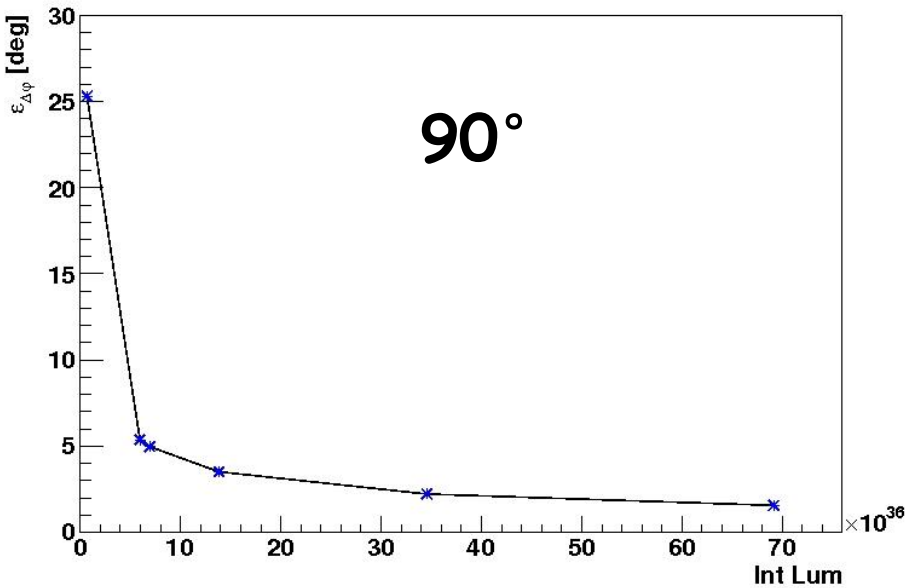
Statistical error for:

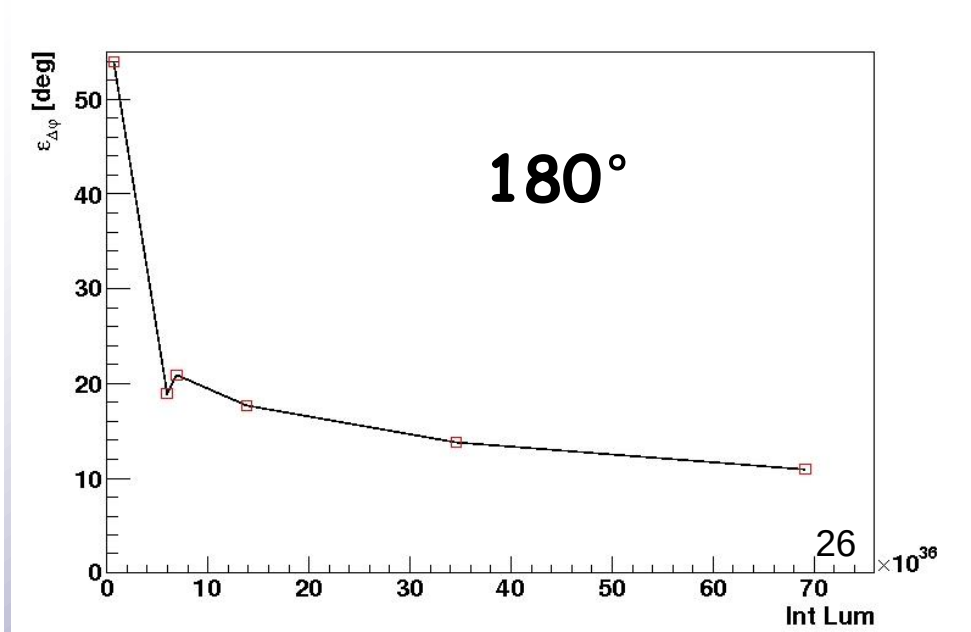
0° triangle

90° asterisk

180° square







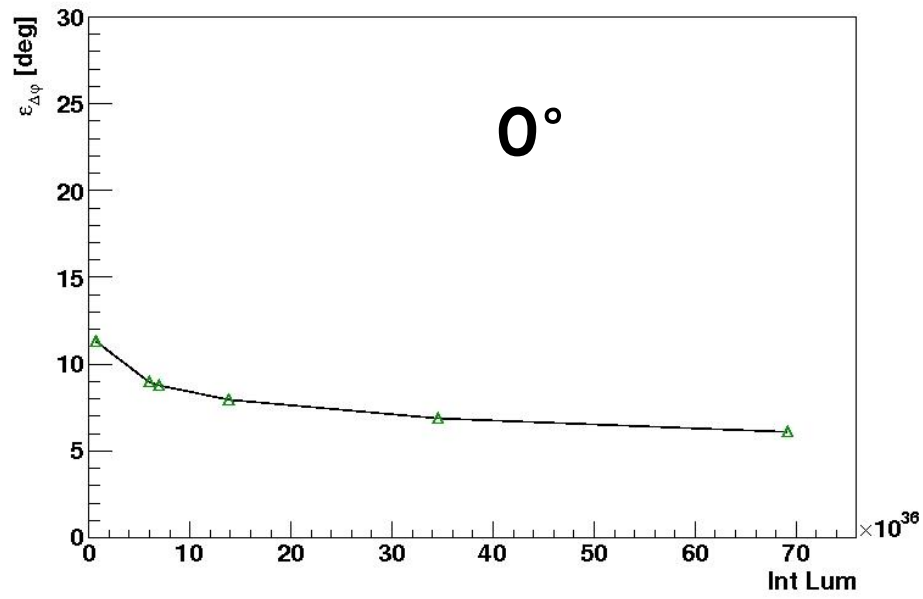
Precision of the Fit (ρπ)

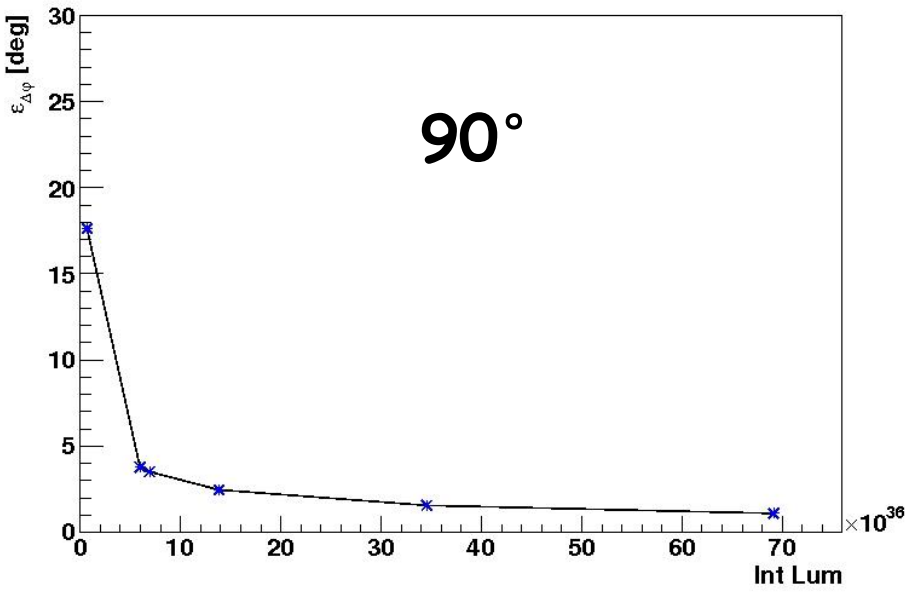
Statistical error for:

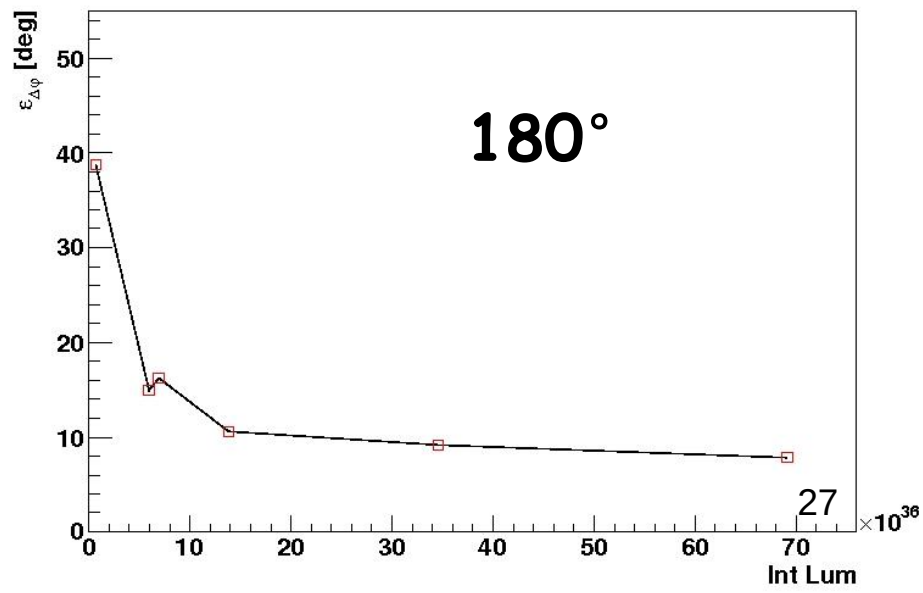
0° triangle

90° asterisk

180° square







Results

Assuming 5 days of data taking 90° case

Luminosity	J/ψ → ppbar	J/ψ → ρπ
10^{31}	25.3°	17.6°
$8.64 \cdot 10^{31}$	5.4°	3.8°
10^{32}	5.0°	3.5°
$2 \cdot 10^{32}$	3.5°	2.5°
$5 \cdot 10^{32}$	2.2°	1.6°
10^{33}	1.6°	1.1°

Summary

- Interest on J/ψ decay amplitudes
- Choice of processes
- Continuum cross section
- Simulation of different phases
- Reasonable energy point choice
  - deep position at 0°
  - higher gradient region at 90°
- Fit routine
- Estimation of statistical error
- Precision of fit → Luminosity dependence

Next Steps

- Investigation of 5π reaction
- Optimization of the procedure