Feasibility studies of a measurement of Transition Distribution Amplitudes with $\overline{\text{P}}$ANDA

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Electromagnetic Processes
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Outline

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2. Simulation Characteristics
3. Reconstruction and event selection
4. Results
5. Conclusion

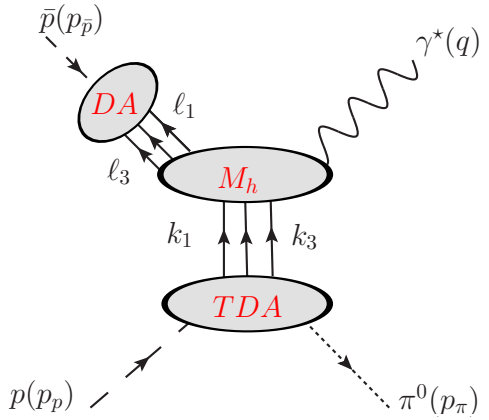
Transition Distribution Ampliltudes approach: reaction $\bar{p}p \to \gamma^\star \pi^0 \to e^+e^+\pi^0$

- New non perturbative objects
- Fourier transform of a Matrix Element of a three-quark light-cone local operator
- Transition between a proton and a pion
- Information about the π-cloud in the proton
- Hard scale higher momentum transfer

In CM of $\overline{\text{P}}$ANDA

π^0 backward $\to$ emmited by p

π^0 forward $\to$ emmited by $\bar{p}$



$\bar{p}p \to e^+e^-\pi^0$

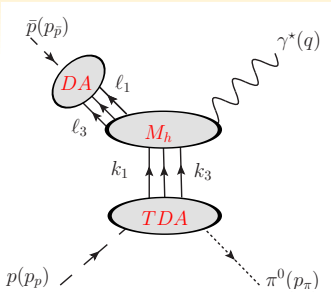
Validity?

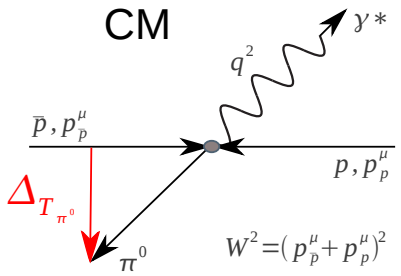
s-dependence of cross section $(\bar{p}p \to e^+e^-\pi^0)$ $\to$ $\overline{\text{P}}$ANDA

Studies based on: J. P. Lansberg et al., Phys Rev D 76, 111502(R) (2007)

Simulation of $\bar{p}p \to e^+e^-\pi^0$ and $\bar{p}p \to \pi^+\pi^-\pi^0$

Signal: $\bar{p}p \to e^+e^-\pi^0$



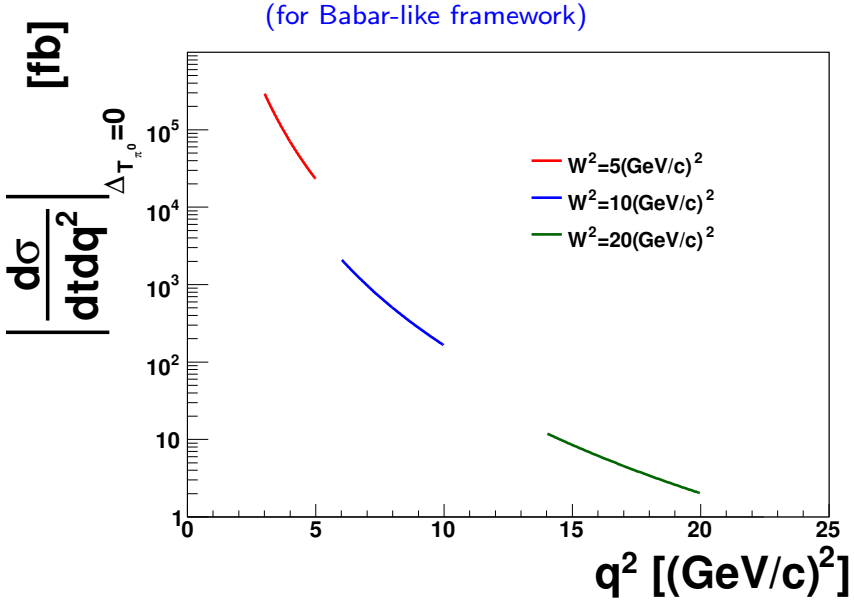


- W^2=5 GeV^2 and 10 GeV^2 (W^2=s)
- π^0 Forward and Backward
  $\to$ 4 simulations
- Calculated for π-transverse momentum $\Delta_{T_{\pi^0}} = 0$
- Extrapolated over a $\Delta_{T_{\pi^0}} < 0.5$ GeV and $[q^2_{min}, q^2_{max}]$[1]

[1] Values for q^2_{min} and q^2_{max} are shown later in slide 6

Input for the Event Generator

(for Babar-like framework)



Background: $\bar{p}p \to \pi^+\pi^-\pi^0$

- No data
- The same angular distribution as the signal
- 10^6 times higher

Number of events simulated

	Reaction	W^2(GeV^2)	π^0	N_{events}	q^2 region
Background suppression	$\pi^+\pi^-\pi^0$	5	forward	$\approx 10^8$	$3.61 < q^2 < 5.29$
	$\pi^+\pi^-\pi^0$	5	backward	$\approx 10^8$	$3.61 < q^2 < 5.29$
	$\pi^+\pi^-\pi^0$	10	forward	$\approx 10^8$	$5.76 < q^2 < 9.18$
	$\pi^+\pi^-\pi^0$	10	backward	$\approx 10^8$	$5.76 < q^2 < 9.18$
Acceptance studies	$e^+e^-\pi^0$	5	forward	$\approx 10^6$	$3.61 < q^2 < 5.29$
	$e^+e^-\pi^0$	5	backward	$\approx 10^6$	$3.61 < q^2 < 5.29$
	$e^+e^-\pi^0$	10	forward	$\approx 10^6$	$5.76 < q^2 < 9.18$
	$e^+e^-\pi^0$	10	backward	$\approx 10^6$	$5.76 < q^2 < 9.18$
Expected statistics	$e^+e^-\pi^0$	5	forward	150 000	$3.61 < q^2 < 5.29$
	$e^+e^-\pi^0$	5	backward	150 000	$3.61 < q^2 < 5.29$
	$e^+e^-\pi^0$	10	forward	6 000	$5.76 < q^2 < 9.18$
	$e^+e^-\pi^0$	10	backward	6 000	$5.76 < q^2 < 9.18$

For expected statistics: $\mathcal{L} = 2\,\text{fb}^{-1}$

Simulations done in the new cluster of the Helmoltz Institute Mainz

Reaction reconstruction

Event selection: Combinations of $\pi^0 + e^+ + e^-$ candidates per event

- Particle identification cuts (PID):
  - Different cuts on the particle identification probability
- Kinematic fit cuts - Confidence level (CL):
  - Different cuts on the quality of the fit for signal and background hypotheses

Kinematic region selection (Only for analysis)

- q^2 cuts in the region in which the cross section is integrated

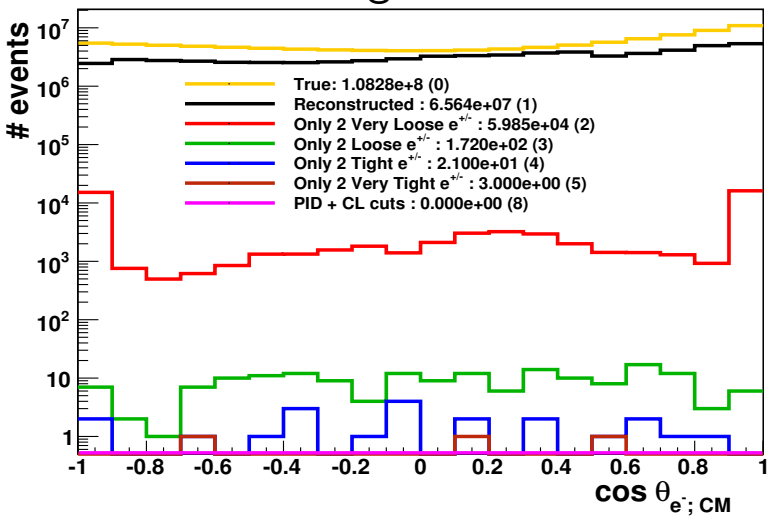
	$W^2 = 5\,\mathrm{GeV}^2$	$W^2 = 10\,\mathrm{GeV}^2$
Simulation limits	$3.61 < q^2 < 5.29$	$5.76 < q^2 < 9.18$
Analysis limits	$3.8 < q^2 < 4.2$	$7.00 < q^2 < 8.00$
Expected Statistics	$\sim 71\,000$	$\sim 1\,400$

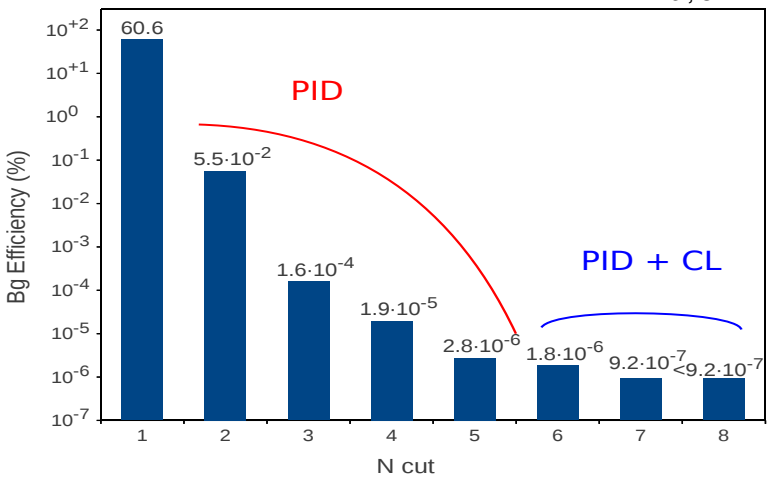
- $\Delta_{T_{\pi^0}} < 0.5\,\mathrm{GeV}$

Effect of the cuts on Background and Signal

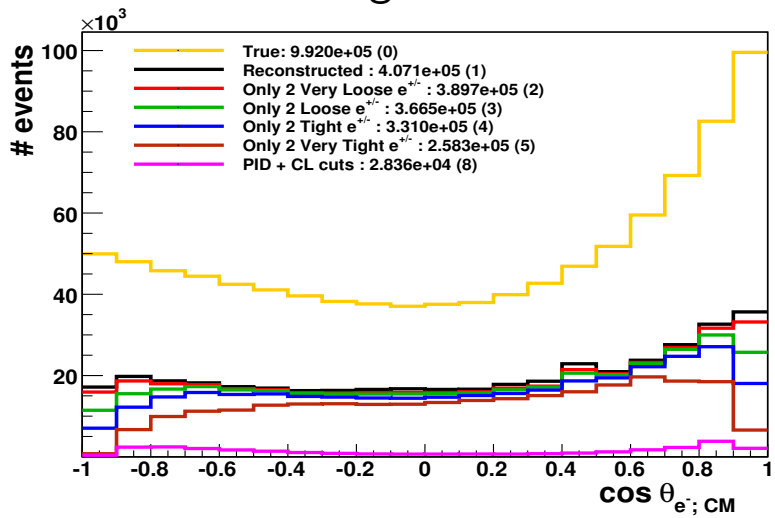
$W^2 = 10$ GeV/c^2, π^0 backward

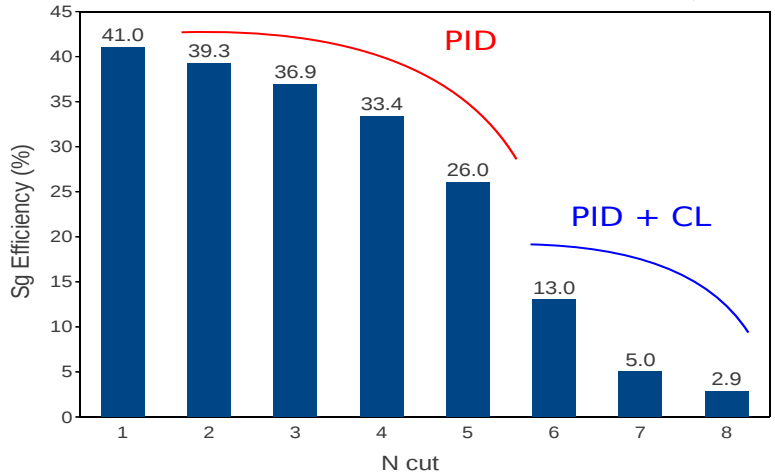
Background





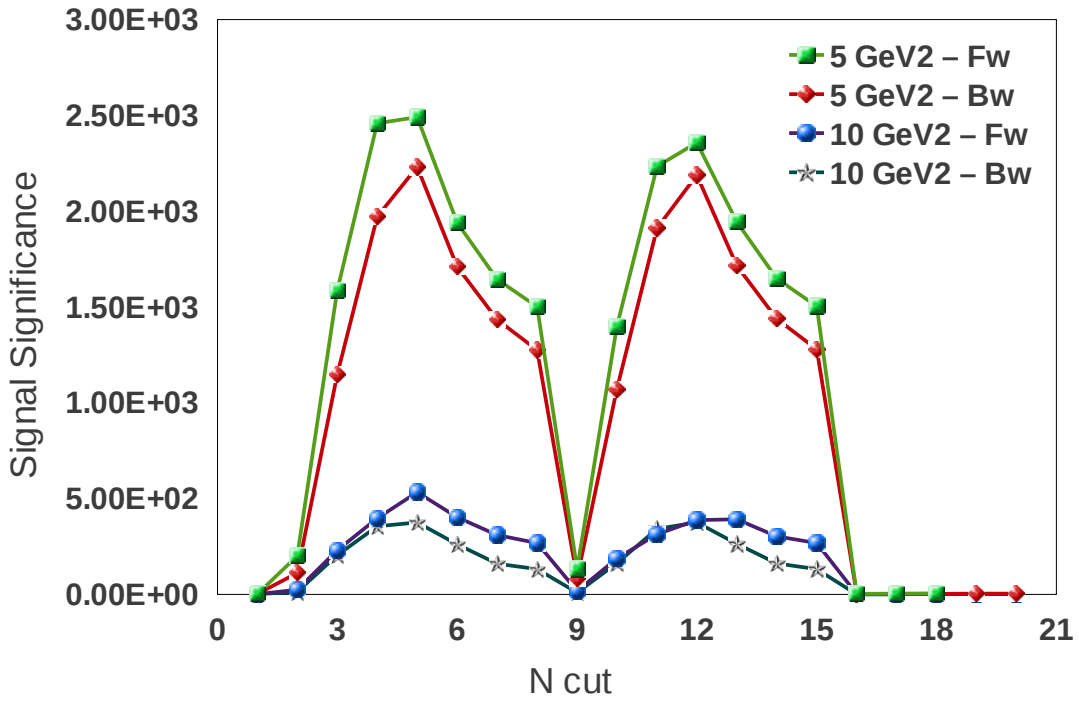
Signal





PID+CL: Only 2 Very Loose $e^{+/-} + CL(e) > 10^{-3} + CL(e) > 3 \cdot CL(\pi)$

Best Cut Selection



Definition of the cuts in the backup slides

Best cut maximizes the Signal Significance

$$S_{Sg} = \frac{N^{Sg}_{Cut}}{\sqrt{N^{Sg}_{Cut}+N^{Bg}_{Cut}}}$$

$$\mathrm{Eff}_{Bg} = \frac{N^{Bg}_{Cut}}{N^{Bg}_{True}}; \quad \mathrm{Eff}_{Sg} = \frac{N^{Sg}_{Cut}}{N^{Sg}_{True}};$$

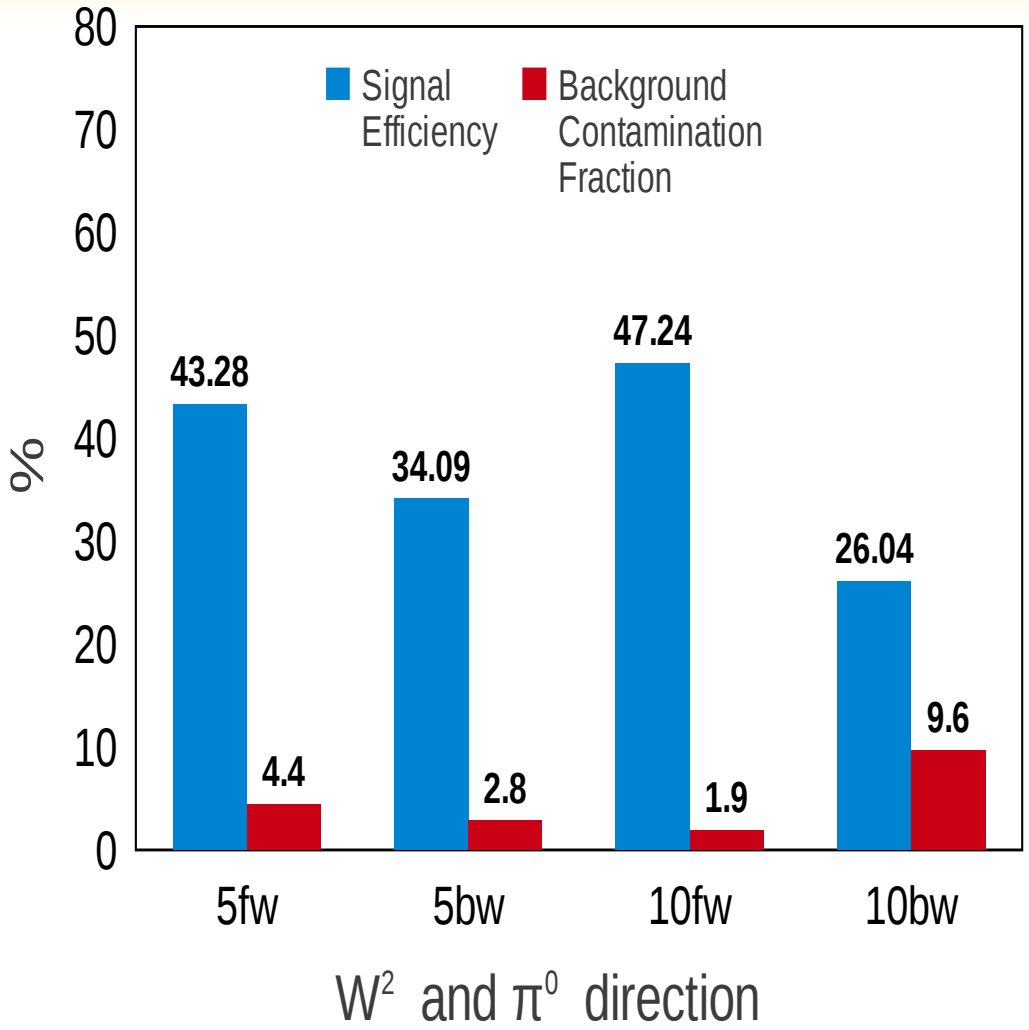
$$N^{Bg}_{True} = 10^6 \cdot N^{Sg}_{True}$$

$$S_{Sg} = \frac{\mathrm{Eff}_{Sg} \cdot N^{Sg}_{True}}{\sqrt{\mathrm{Eff}_{Sg} \cdot N^{Sg}_{True} + 10^6 \cdot \mathrm{Eff}_{Bg} \cdot N^{Sg}_{True}}}$$

Best cut: $N_{cut} = 5$

Only 2 tracks (+ and -) and very tight electrons (+ and -) per event

Background contamination fraction



Background contamination:

$$\mathrm{Cont}_{Bg} = \frac{N^{Bg}_{Reco}}{N^{Bg}_{Reco} + N^{Sg}_{Reco}}$$

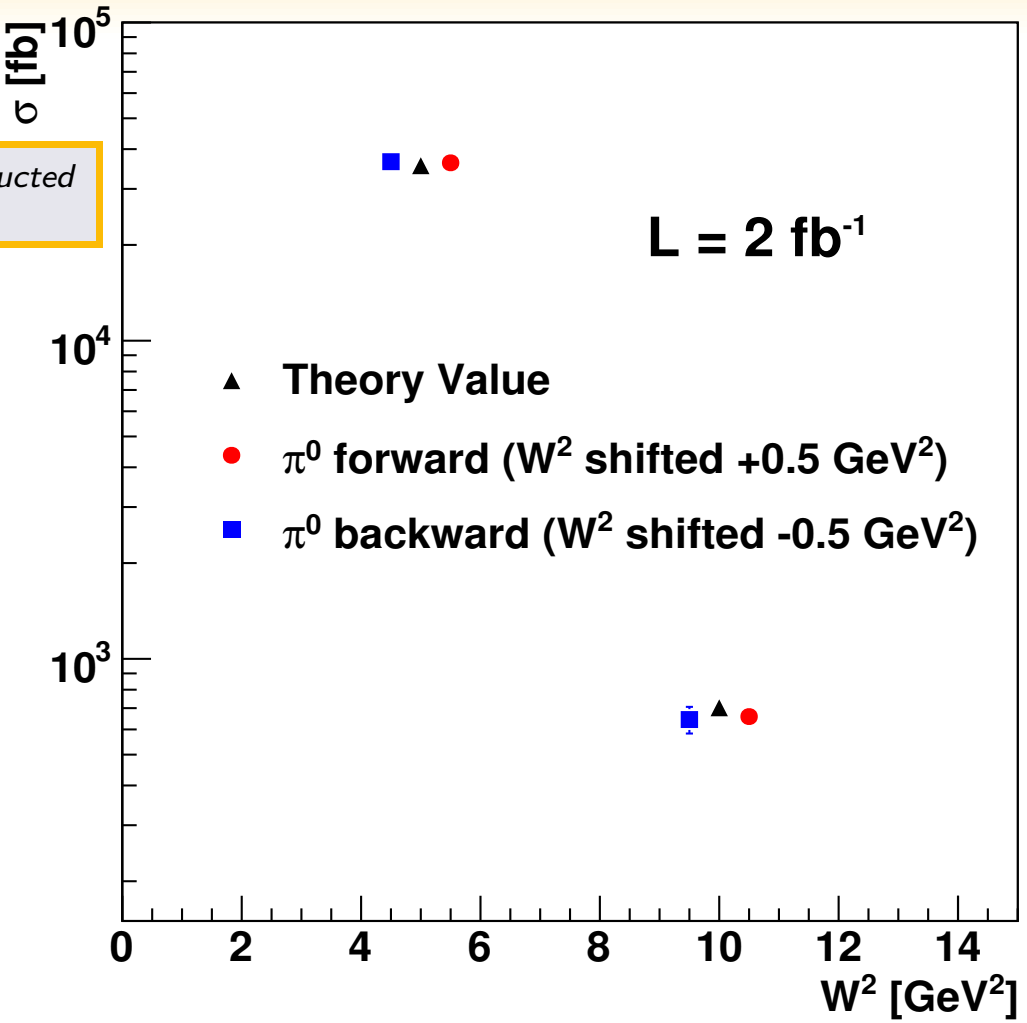
To keep a reasonable
Signal Efficiency
one has to accept a certain
Background Contamination
$\rightarrow$
$\sim$ 10% Still acceptable

Measurement of σ and comparison with the Theory

$$N_{Sg+Bg}^{Reconstructed} = N_{Bg}^{Calculated} + N_{sg}^{Reconstructed}$$

	N_{Sg}^{Corr}	$\frac{\Delta N_{Sg}^{Corr}}{N_{sg}^{Corr}}$ [%]
5fw	72454 ± 2825	4
5bw	73055 ± 2889	4
10fw	1317 ± 62	5
10bw	1289 ± 104	8

Errors are only statistical



s-dependence can be measured with $\overline{\text{P}}$ANDA

Conclusion

- First analysis for the measurement of $\bar{p}p \rightarrow e^+e^-\pi^0$ $\overline{\text{P}}$ANDA with in the TDA approach is done.
- A background rejection close to 10^8 is achievable
- The efficiency and acceptance of the detector are taken into account.
- A reasonable measurement of the cross section could be done in all cases with a relative error lower than 10%.
- A measurement of the TDA seems possible with $\overline{\text{P}}$ANDA.

Thank you

Backup Slides

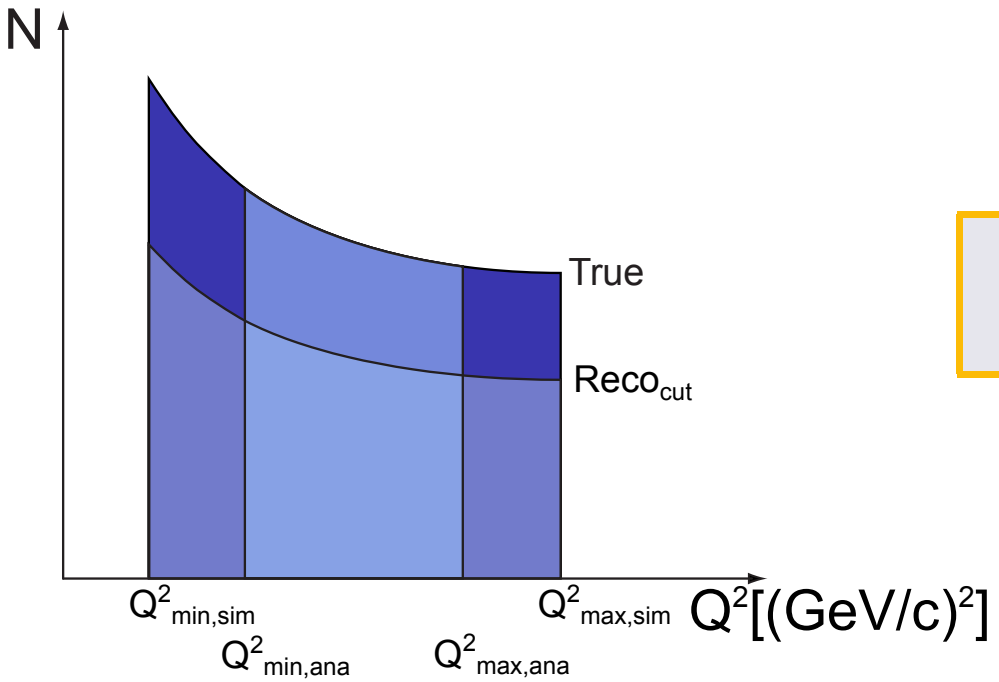
Cut number definitions

1 : No additional cuts, only event selection cuts involved
2 : Only one electron and one positron (2 tracks) with Very Loose probability.
3 : Only one electron and one positron (2 tracks) with Loose probability.
4 : Only one electron and one positron (2 tracks) with Tight probability.
5 : Only one electron and one positron (2 tracks) with Very Tight probability.
6 : Cut 5 and Cut 17
7 : Cut 5 and Cut 18
8 : Cut 5 and Cut 19
9 : At least one electron and one positron with Very Loose probability.
10 : At least one electron and one positron with Loose probability.
11 : At least one electron and one positron with Tight probability.
12 : At least one electron and one positron with Very Tight probability.
13 : Cut 12 and Cut 17
14 : Cut 12 and Cut 18
15 : Cut 12 and Cut 19
16 : Confidence level for the fit with $e^+e^-\pi^0$ hypothesis greater than 10^-3
17 : Cut 16 and Confidence level for the fit with $e^+e^-\pi^0$ hypothesis greater than the confidence level of the fit with $\pi^+\pi^-\pi^0$ hypothesis
18 : Cut 16 and Confidence level for the fit with $e^+e^-\pi^0$ hypothesis greater than two times the confidence level of the fit with $\pi^+\pi^-\pi^0$ hypothesis
19 : Cut 16 and Confidence level for the fit with $e^+e^-\pi^0$ hypothesis greater than three times the confidence level of the fit with $\pi^+\pi^-\pi^0$ hypothesis
20 : Cut 16 and Confidence level for the fit with $e^+e^-\pi^0$ hypothesis greater than four times the confidence level of the fit with $\pi^+\pi^-\pi^0$ hypothe

Kinematic region cuts

	$W^2 = 5\,\mathrm{GeV}^2$	$W^2 = 10\,\mathrm{GeV}^2$
Simulation limits	$3.61 < q^2 < 5.29$	$5.76 < q^2 < 9.18$
Analysis limits	$3.8 < q^2 < 4.2$	$7.00 < q^2 < 8.00$

In addition: $\Delta_{T_{\pi^0}} < 0.5\,\mathrm{GeV}$



$$\mathrm{Corr} = \frac{N_{\mathrm{Reco}}[q^2_{\mathrm{min,\,ana}}, q^2_{\mathrm{max,\,ana}}]}{N_{\mathrm{True}}[q^2_{\mathrm{min,\,ana}}, q^2_{\mathrm{max,\,ana}}]}$$

Background contamination fraction

W^2	Forward		Backward	
	Signal	Background	Signal	Background
	Expected number of true events (Calculated)			
	N^{Sg}_{True}	N^{Bg}_{True}	N^{Sg}_{True}	N^{Bg}_{True}
5	150000	$1.5 \cdot 10^{11}$	150000	$1.5 \cdot 10^{11}$
10	6000	$6 \cdot 10^{9}$	6000	$6 \cdot 10^{9}$
	Efficiencies [%] (From Simulations with high statistics)			
	Eff_{Sg}	Eff_{Bg}	Eff_{Sg}	Eff_{Bg}
5	43.28 ± 0.05	$(2.0 \pm 1.8) \cdot 10^{-6}$	34.09 ± 0.05	$(1.0 \pm 1.4) \cdot 10^{-6}$
10	47.24 ± 0.05	$(0.9 \pm 1.3) \cdot 10^{-6}$	26.04 ± 0.04	$(2.8 \pm 1.9) \cdot 10^{-6}$
	Reconstructed events after efficiencies (True·Efficiency)			
	N^{Sg}_{Reco}	N^{Bg}_{Reco}	N^{Sg}_{Reco}	N^{Bg}_{Reco}
5	64916	3023	51134	1449
10	2834	55	1562	166
	Background Contamination [%] ($\frac{N^{Bg}_{Reco}}{N^{Bg}_{Reco}+N^{Sg}_{Reco}}$) (Bg/Sg)			
	$\mathrm{Cont}_{Bg,\,Fw}$		$\mathrm{Cont}_{Bg,\,Bw}$	
5	4.4 ± 3.7 (~ 4.7)		2.8 ± 3.8 (~ 2.8)	
10	1.9 ± 2.7 (< 1.9)		9.6 ± 5.8 (~ 10.6)	

Results w/o Background

Selection cut

Only 2 tracks (+ and -) and very tight electrons (+ and -) per event

Kinematic region cut

$3.8 < q^2 < 4.2$ at $W^2 = 5\,\mathrm{GeV}^2$;
$7.00 < q^2 < 8.00$ at $W^2 = 10\,\mathrm{GeV}^2$;
$\Delta_{T_{\pi^0}} < 0.5\,\mathrm{GeV}$

Simulation	$N_{True\ \mathrm{w/o}\ Bg}$	$N_{Reconstructed\ \mathrm{w/o}\ Bg}$	$N_{Corrected\ \mathrm{w/o}\ Bg}$	$\epsilon_{rel}[\%]$
5 GeV - fw	72263 ±269	30661 ± 175	72732 ± 433	0.6
5 GeV - bw	72405 ±269	25386 ± 159	73164 ± 488	0.7
10 GeV - fw	1336 ±37	662 ± 26	1319 ± 51	3.9
10 GeV - bw	1313 ± 36	394 ± 20	1312 ± 66	5.0

Errors are only statistical

Analysis taking background contamination fraction into account

$$N_{Reconstructed} = N_{Background\ fraction} + N_{Reconstructed\ \text{w/o}\ Bg}$$

Simulation	$N_{Reconstructed}$	$N_{Signal\ fraction}$	$\epsilon_{rel}(N_{Signal\ fraction})[\%]$
5fw	31967 ± 179	30544 ± 1190	4
5bw	26067 ± 162	25348 ± 1601	4
10fw	674 ± 26	661 ± 31	5
10bw	429 ± 21	387 ± 31	8

	$N_{Corrected}$	$\epsilon_{rel}(N_{Corrected})[\%]$
5fw	72454 ± 2825	4
5bw	73055 ± 2889	4
10fw	1317 ± 62	5
10bw	1289 ± 104	8