Simulations for the measurement of $\bar{p}p \rightarrow e^+e^-\pi^0$ with $\overline{\text{P}}$ANDA in the TDA approach HK 8.9

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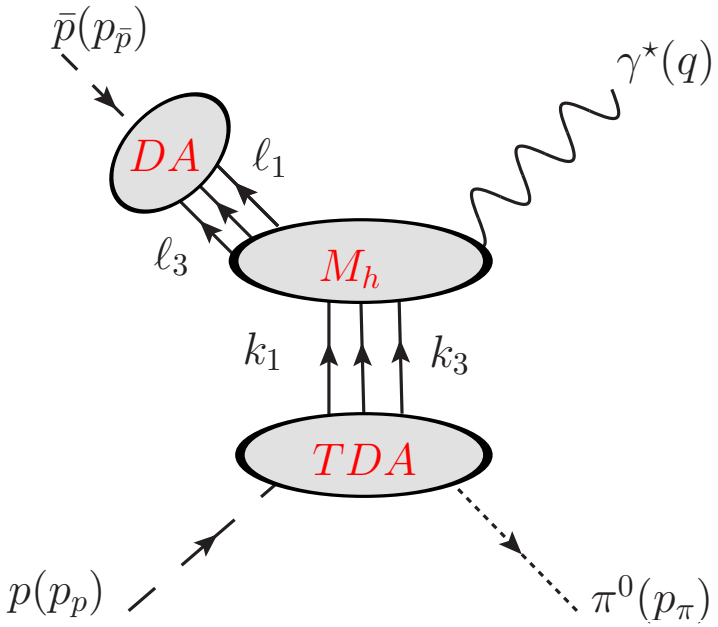
DPG 2012 - Johannes Gutenberg Universität, Mainz
March, 19th - 2012

Outline

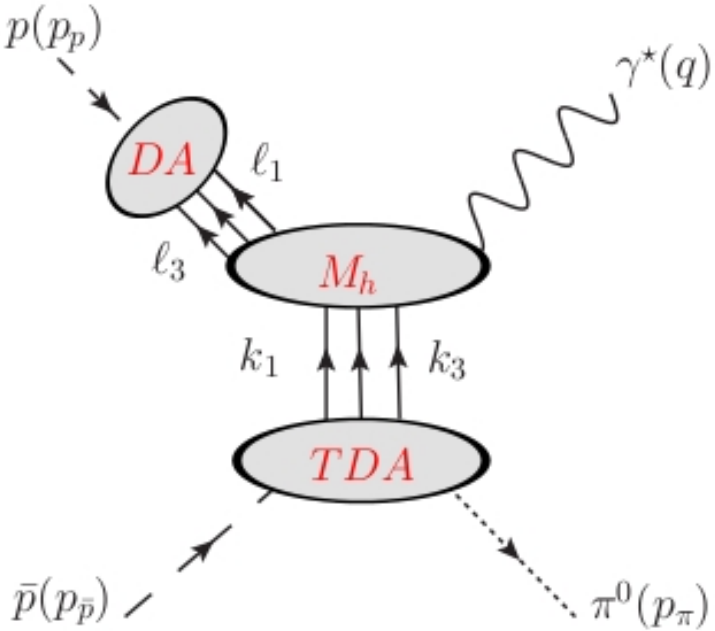
1. Introduction to Transition Distribution Amplitudes (TDA)
2. Simulation
3. Analysis
4. Results
5. Conclusions

Introduction to the TDA approach: reaction $\bar{p}p \to \gamma^\star \pi^0 \to e^+e^+\pi^0$

In CM π^0 backward $\to$ emmited by p



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

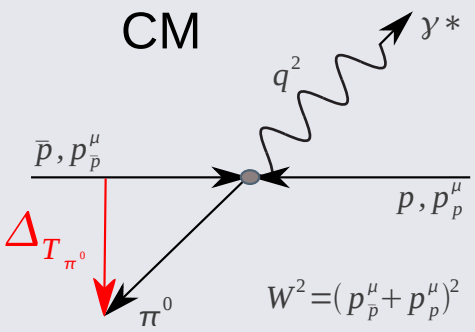


- Transition Distribution Amplitudes[1] are new non perturbative objects describing the transition between a proton and a pion.
- Approach valid at higher momentum transfer.
- Study the validity of TDA approach: Measuring the cross section of $\bar{p}p \to e^+e^-\pi^0$ and comparing it with the theory.

[1] J. P. Lansberg et al., Phys Rev D 76, 111502(R) (2007)

Signal and background simulation

- Signal ($\bar{p}p \rightarrow e^+e^-\pi^0$)[a]:
  - W^2=5 GeV^2 and 10 GeV^2 (W^2=s)
  - π^0 Forward and Backward
    $\rightarrow$ 4 simulations
  - Theoretical cross section calculated for $\Delta_{T_{\pi^0}} = 0$...
  - ... integrating over a $\Delta_{T_{\pi^0}} < 0.5$ GeV and $[q^2_{min},\ q^2_{max}]$[b]



[a] Based on J.P. Lansberg Phys Rev D 76, 111502(R) (2007)
[b] Values for q^2_{min} and q^2_{max} are shown later in slide 6

- Background ($\bar{p}p \rightarrow \pi^+\pi^-\pi^0$):
  - No data available in the region we want to measure.
  - We assume for $\pi^+\pi^-\pi^0$ the same angular distribution as the signal.
  - We assume a background cross section 10^6 times higher than signal

Simulations done in the old BaBar-like framework

Number of events simulated

	Reaction	W^2(GeV^2)	π^0	N_{events}
Background suppression	$\pi^+\pi^-\pi^0$	5	forward	$\approx 10^8$
	$\pi^+\pi^-\pi^0$	5	backward	$\approx 10^8$
	$\pi^+\pi^-\pi^0$	10	forward	$\approx 10^8$
	$\pi^+\pi^-\pi^0$	10	backward	$\approx 10^8$
Efficiency studies	$e^+e^-\pi^0$	5	forward	$\approx 10^6$
	$e^+e^-\pi^0$	5	backward	$\approx 10^6$
	$e^+e^-\pi^0$	10	forward	$\approx 10^6$
	$e^+e^-\pi^0$	10	backward	$\approx 10^6$
Expected statistics	$e^+e^-\pi^0$	5	forward	150 000
	$e^+e^-\pi^0$	5	backward	150 000
	$e^+e^-\pi^0$	10	forward	6 000
	$e^+e^-\pi^0$	10	backward	6 000

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

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

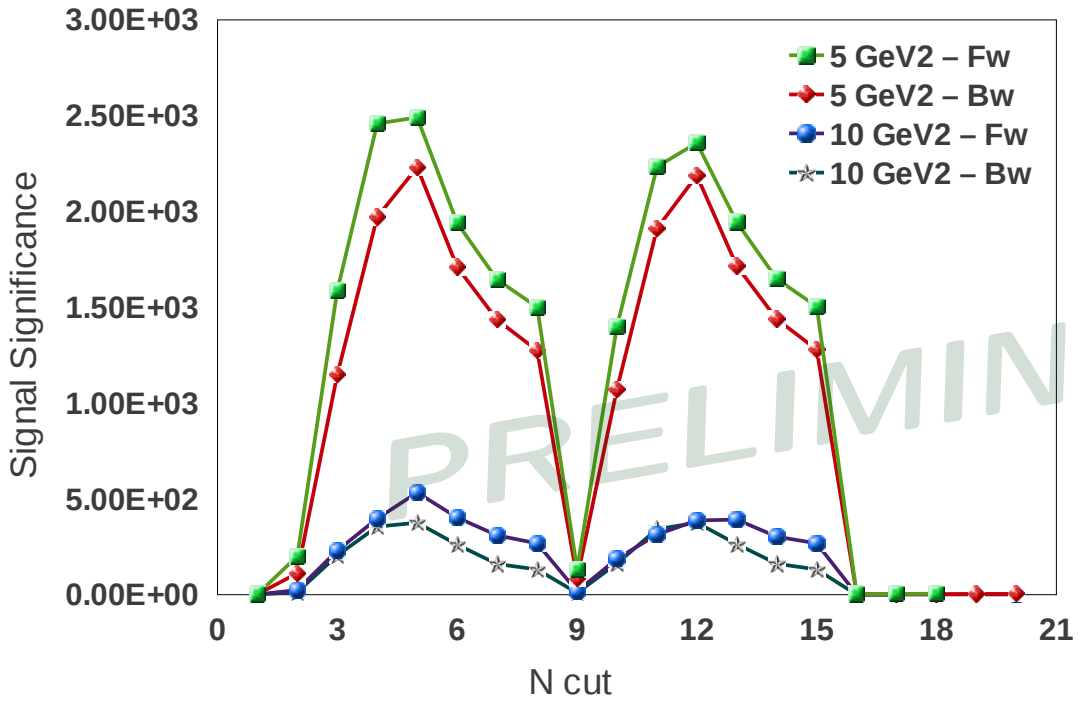
Kinematic region selection (Only for analysis)

- 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	$3.8 < q^2 < 4.2$	$7.00 < q^2 < 8.00$

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

Best Cut Selection



Best cut maximizes the Signal Significance

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

$$\mathrm{Eff}_{Bg} = \frac{N_{Cut}^{Bg}}{N_{True}^{Bg}}\,;\ \mathrm{Eff}_{Sg} = \frac{N_{Cut}^{Sg}}{N_{True}^{Sg}}\,;$$

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

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

Best cut: $N_{cut} = 5$

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

Background contamination fraction

Background contamination:

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

W^2	Forward		Backward	
	Signal	Background	Signal	Background
	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 [%]			
	$\mathrm{Cont}_{Bg,\,Fw}$		$\mathrm{Cont}_{Bg,\,Bw}$	
5	4.4 ± 3.7		2.8 ± 3.8	
10	1.9 ± 2.7		9.6 ± 5.8	

Results

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

Simulation	$N_{Sg+Bg}^{Reconstructed}$	N_{Sg}	$\text{Error}_{\text{relative}}[\%]$
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_{Sg}^{True}	$N_{Sg}^{Corrected}$	$\text{Error}_{\text{relative}}[\%]$
5fw	72263	72454 ± 2825	4
5bw	72405	73055 ± 2889	4
10fw	1336	1317 ± 62	5
10bw	1313	1289 ± 104	8

Errors are only statistical

Conclusions

- 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.

Related Presentations

Monday:

- HK 1.5, 15:15: Dmitry Khaneft, *"Feasibility studies of proton electromagnetic form factors with the PANDA detector"*
- HK 8.7, 18:15: Yue Ma, *"Proposal for a revisit of antiproton nucleus collision experiment with PANDA"*
- HK 8.8, 18:30: Bertalan Feher, *"Feasibility Study of a Transversely Polarized Target in Panda"*

Thursday:

- HK 45.3, 14:00: Iris Zimmermann *"Feasibility studies of proton FF measurements in $\bar{p}p$-collisions at PANDA"*

Friday:

- HK 54.7, 12:45: Manuel Zambrana, *"Monte Carlo event generators for Panda"*

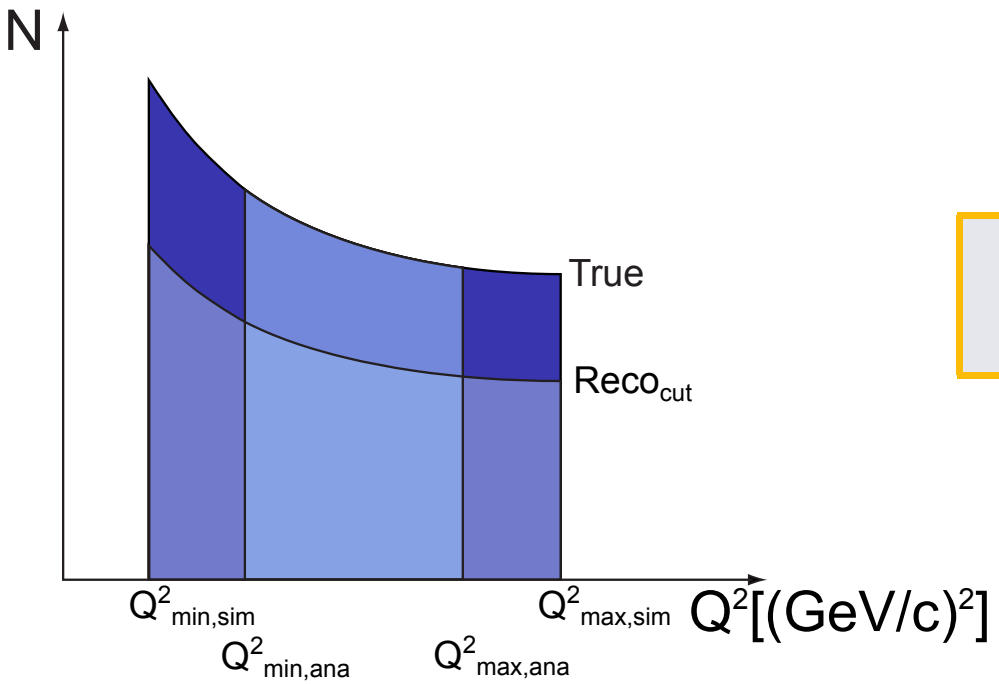
Cut number definitions

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



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

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	$N_{True\ w/o\ Bg}$	$N_{Reconstructed\ w/o\ Bg}$	$N_{Corrected\ w/o\ Bg}$	$\epsilon_{rel}[\%]$
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