# Simulation and analyis of $\bar{p}p \to e^+e^-\pi^0$ using the TDA approach

## with the BaBar-like software

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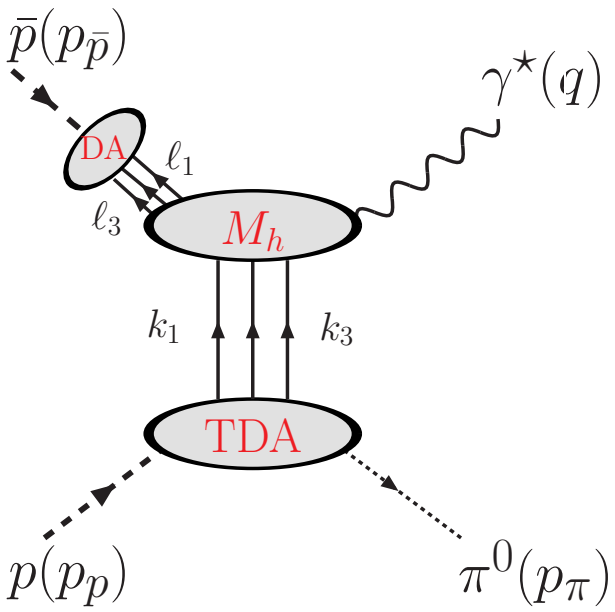
Computing Session

# Outline

# Physical processes

TDA'S APPROACH[1]:




- Study the validity of TDA's: Measuring the cross section of ($\bar{p}p \to e^+e^-\pi^0$) and comparing it with the theory.
- Approach valid at high energies.
- Event generator developed for Babar-like framework.
- Main background process is $\bar{p}p \to \pi^+\pi^-\pi^0$.

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

# Simulation characteristics

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

| $Q_{min}(Q^2_{min})$ | $Q_{max}(Q^2_{max})$ | $Q_{max_{possible}}$ $(Q^2_{max_{possible}})$ | $Q_{crit}(Q^2_{crit})$ | $W^2$ | fw/bw | p($\bar{p}$) | W=$\sqrt{s}$ |
|---|---|---|---|---|---|---|---|
| 1.9 (3.61) | 2.3 (5.29) | 2.10 (4.41) | 2.07 (4.28) | 5 | 1 | 1.45 | 2.23 |
| 1.9 (3.61) | 2.3 (5.29) | 2.10 (4.41) | 2.07 (4.28) | 5 | 0 | 1.45 | 2.23 |
| 2.4 (5.76) | 3.2 (10.24) | 3.03 (9.18) | 2.93 (8.58) | 10 | 1 | 4.29 | 3.16 |
| 2.4 (5.76) | 3.2 (10.24) | 3.03 (9.18) | 2.93 (4.28) | 10 | 0 | 4.29 | 3.16 |

- Background ($\bar{p}p \to \pi^+\pi^-\pi^0$):
  - $\pi^+\pi^-\pi^0$ in phasespace or with the same angular distribution as the signal.
  - We assume a background cross section $10^6$ times higher than signal
  - Cuts on kinematical region for simulation with phasespace assumption:
    - Limited $q^2$:
      - $q_{min}$=1.9 and $q_{max}$=2.3 for $W^2$=5 GeV
      - $q_{min}$=2.4 and $q_{max}$=3.2 for $W^2$=10 GeV
    - Limited $\Delta_{T_{\pi^0}}$: Transverse momentum $< 0.5$ GeV.

[2] Based on J.P. Lansberg Phys Rev D 76, 111502(R) (2007)

# Number of true events simulated

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

| $W^2$ (GeV$^2$) | 5 | 10 | | 5 | 10 |
|---|---|---|---|---|---|
| $\Delta_T = 0$ | | | $\Delta_T < 0.5$ GeV | | |
| $\pi^0$ forward | $\sim 10^6$ | $\sim 10^6$ | | No evtGen | No evtGen |
| $\pi^0$ backward | $\sim 10^6$ | $\sim 10^6$ | | No evtGen | No evtGen |

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

| $W^2$ (GeV$^2$) | 5 | 10 | | 5 | 10 |
|---|---|---|---|---|---|
| $\Delta_T = 0$ | | | $\Delta_T < 0.5$ GeV | | |
| Dist. as signal | | | Phasespace | | |
| $\pi^0$ forward | $\sim 10^8$ | $\sim 10^8$ | fw/bw | $\sim 10^8$ | $\sim 10^8$ |
| $\pi^0$ backward | $\sim 10^8$ | $\sim 10^8$ | | | |

Himster: New computing cluster in the Helmholz Institut Mainz

134 Nodes 8 cores pro socket 2000 cores

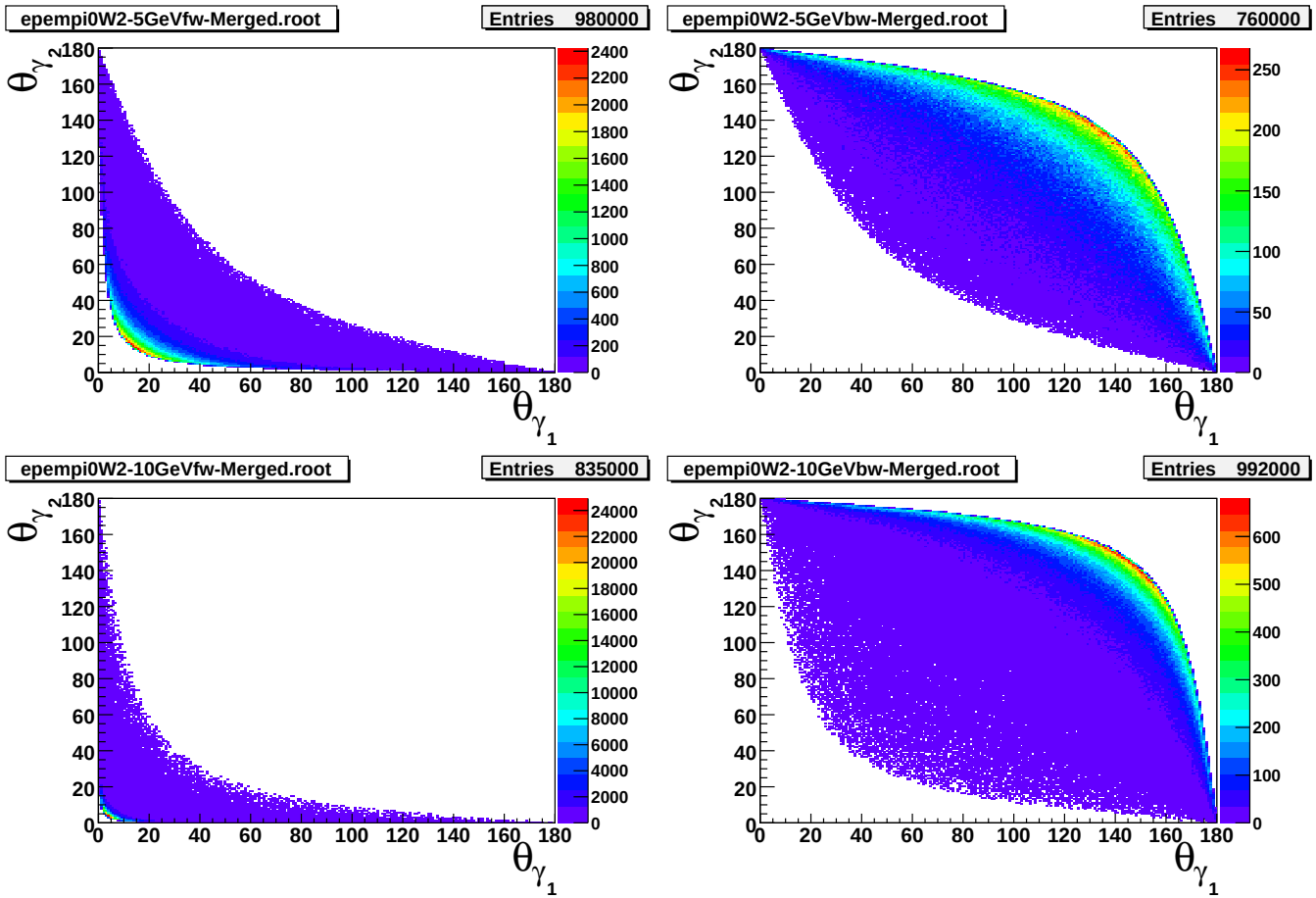
4.7 TByte of RAM 136 TByte Disk space

# Analysis process

- Event selection: Combinations of $\pi^0 + e^+ + e^-$ candidates per event
  - Particle identification cuts (PID):
    - Only 2 tracks (+ and -) and very loose electrons (+ and -) per event
    - Only 2 tracks (+ and -) and loose electrons (+ and -) per event
    - Only 2 tracks (+ and -) and tight electrons (+ and -) per event
    - Only 2 tracks (+ and -) and very tight electrons (+ and -) per event
  - Kinematical fit cuts - Confidence level (CL):
    - $\mathrm{CL}(e^{+/-}) > 0.001$ and $\mathrm{CL}(e^{+/-}) > 3 \cdot \mathrm{CL}(\pi^{+/-})$

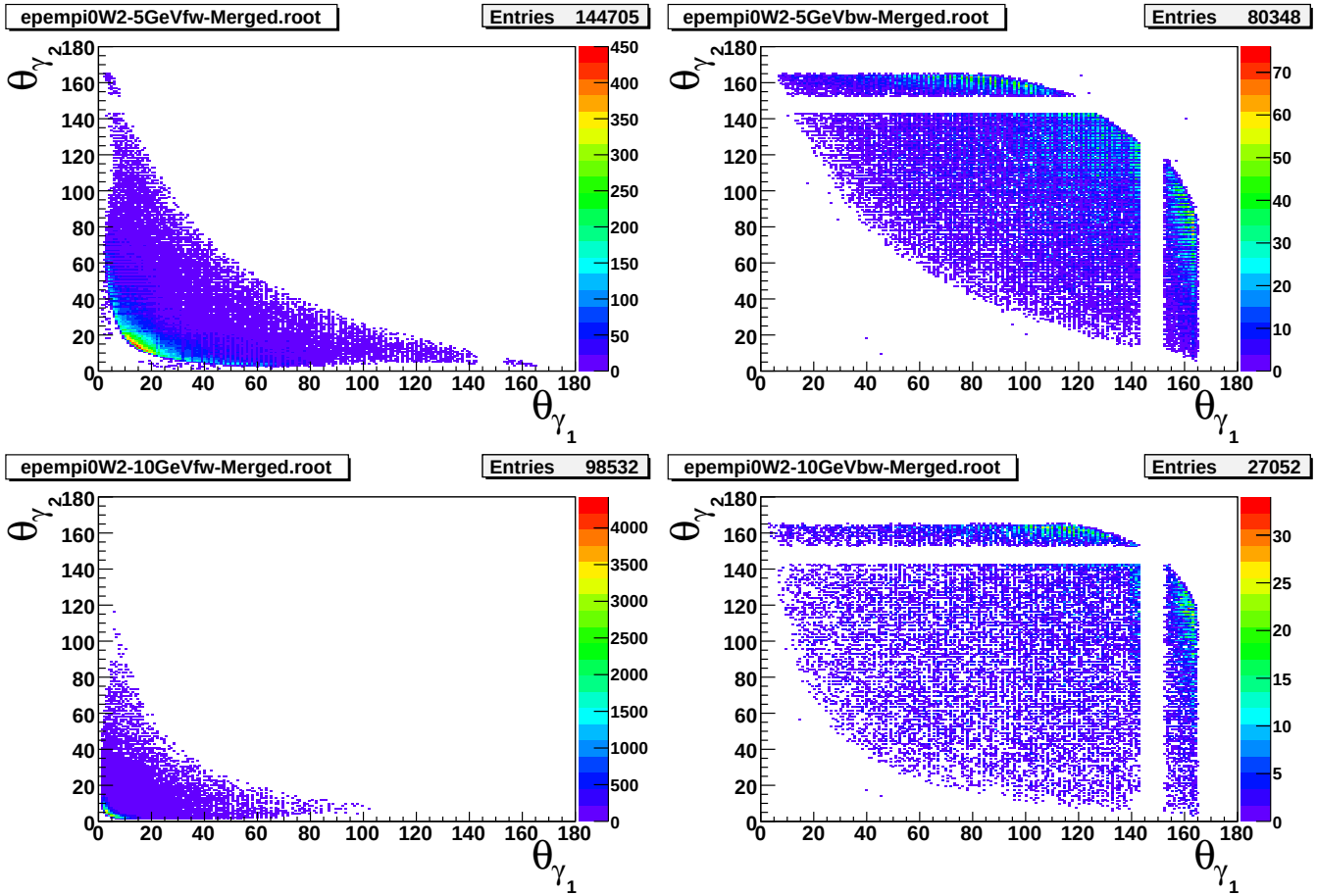
- Kinematical region selection:
  - $Q^2$ cuts in the region in which the cross section is integrated
  - $\Delta_{T_{\pi^0}} < 0.5\,\mathrm{GeV}$

# Signal ($\bar{p}p \rightarrow e^+e^-\pi^0$): Gammas angular distributions. True MonteCarlo.



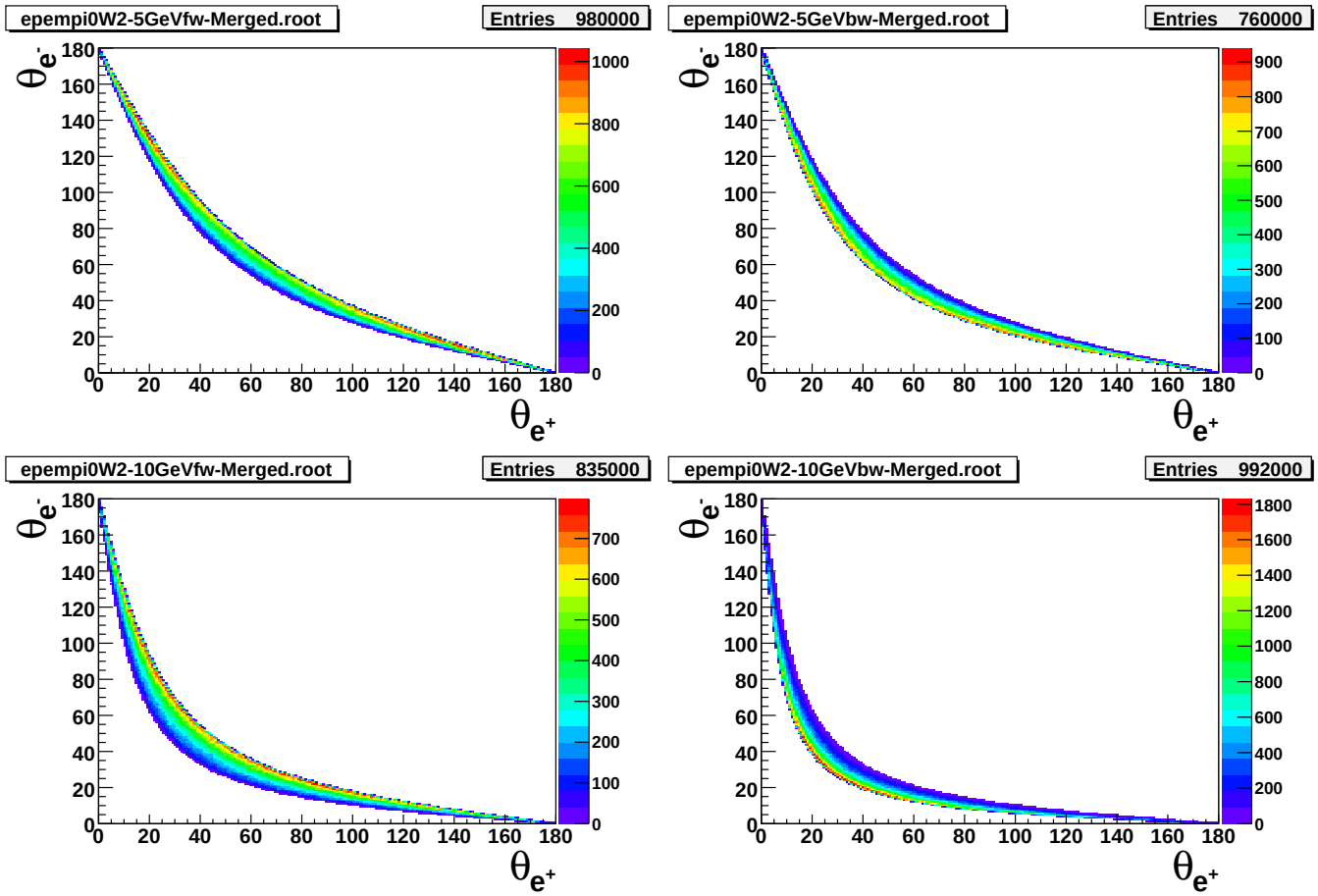
# Signal ($\bar{p}p \rightarrow e^+e^-\pi^0$): Gammas angular distributions. Reconstructed

CUT: PID+CL includes CL(electrons)>0.001 and CL(electrons)>3 CL(pions)




The Backward End Cap Calorimeter is very important to detect the $\pi^0$, specially at backward angles

# Signal ($\bar{p}p \rightarrow e^+e^-\pi^0$): Electrons angular distributions. True MonteCarlo.




The electrons, since they have mass, notice more the boost and go more forward

# Signal ($\bar{p}p \rightarrow e^+e^-\pi^0$): Electrons angular distributions. Reconstructed

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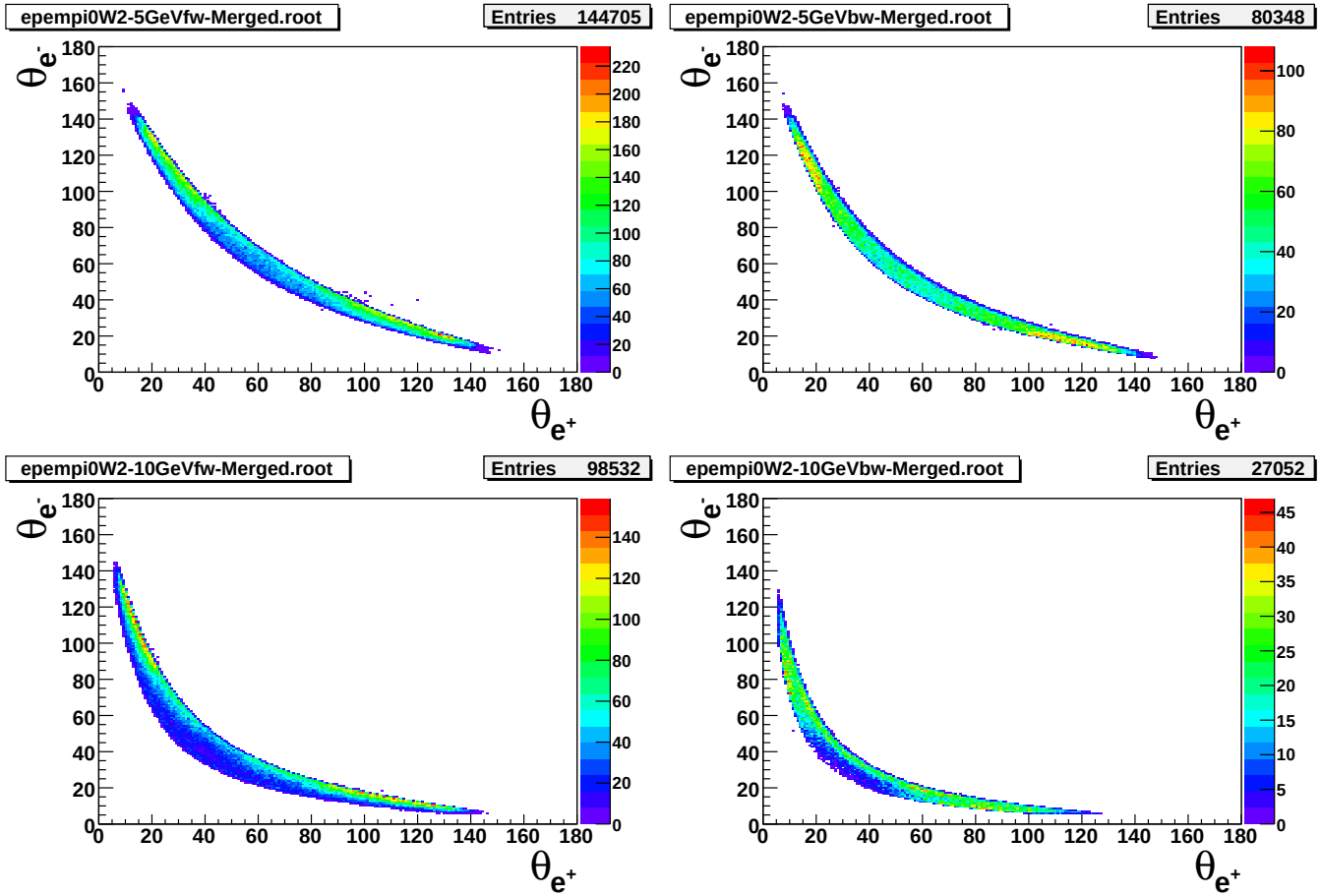
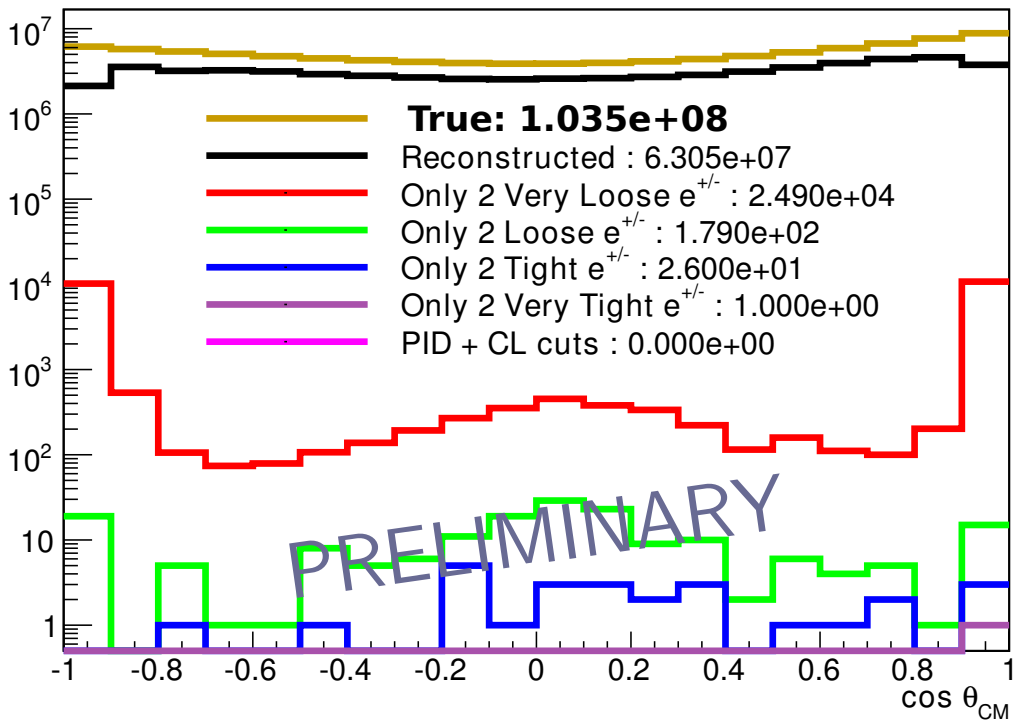



The electrons, since they have mass, notice more the boost and go more forward

# Background suppression with $\pi^0$ Backward ($\Delta_{T_{\pi^0}} = 0$ and $W^2 = 5\,\mathrm{GeV}^2$)

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




CUT: PID+CL includes CL(electrons)>0.001 and CL(electrons)>3 CL(pions)

$10^8$ events simulated in the HIMSTER (Mainz) in less than 24h (2000 cores)

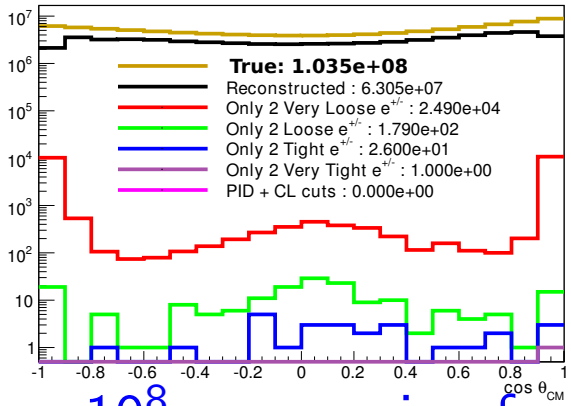
# Background suppression with $\pi^0$ Backward/Forward ($\Delta_{T_{\pi^0}} = 0$)

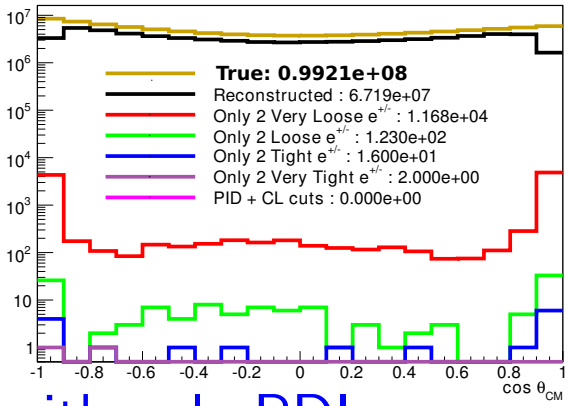
PRELIMINARY

$\bar{p}p \rightarrow \pi^+\pi^-\pi^0$

Backward Forward

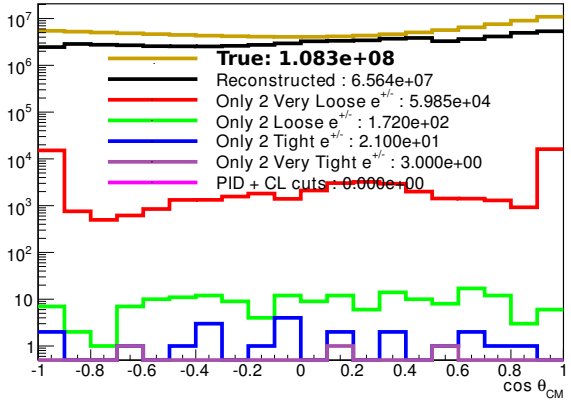
$W^2 = 5\,\mathrm{GeV}^2$:

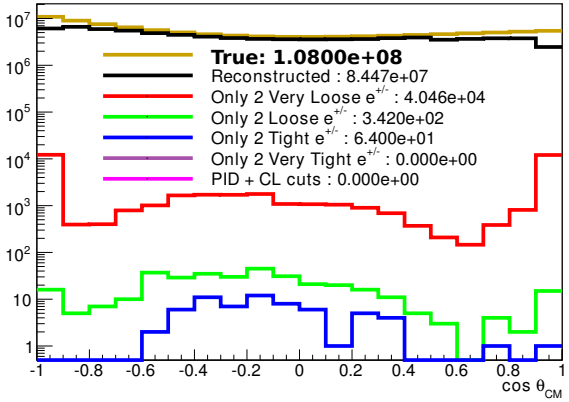



$\sim 10^8$ suppression factor with only PDI

$W^2 = 10\,\mathrm{GeV}^2$:



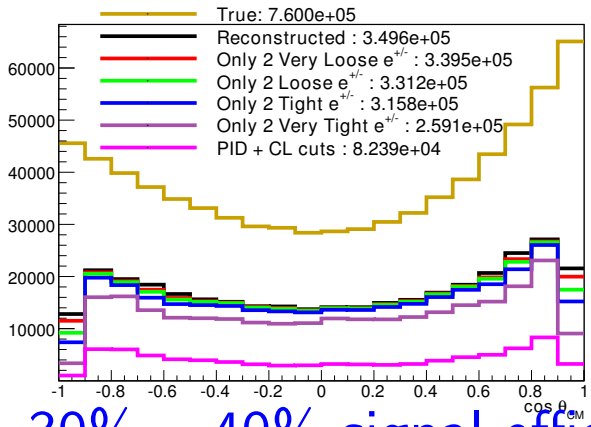

PID+CL includes CL(electrons)>0.001 and CL(electrons)>3 CL(pions)

# Signal efficiency with $\pi^0$ Backward/Forward ($\Delta_{T_{\pi^0}} = 0$)

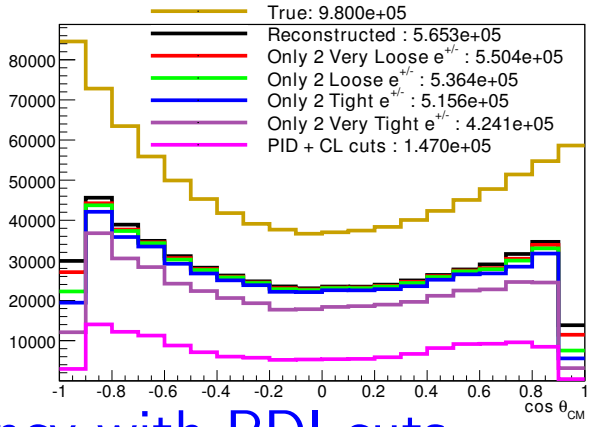
PRELIMINARY

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

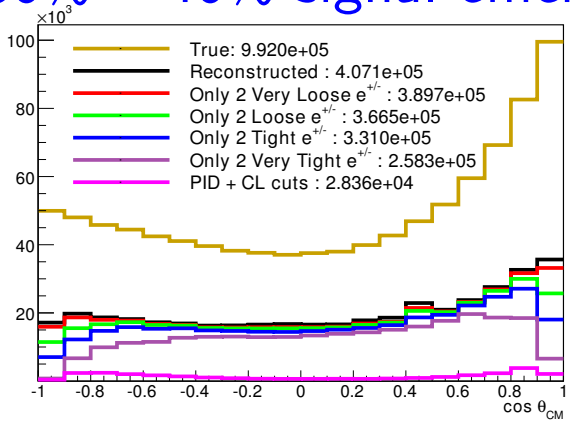
Backward

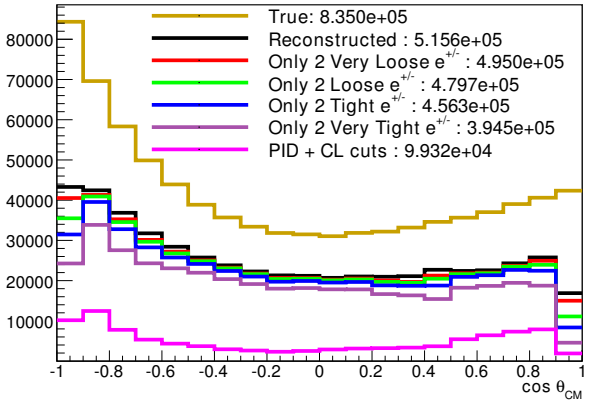



Forward




$W^2 = 5\,\mathrm{GeV}^2$: $\sim$ 30% – 40% signal efficiency with PDI cuts



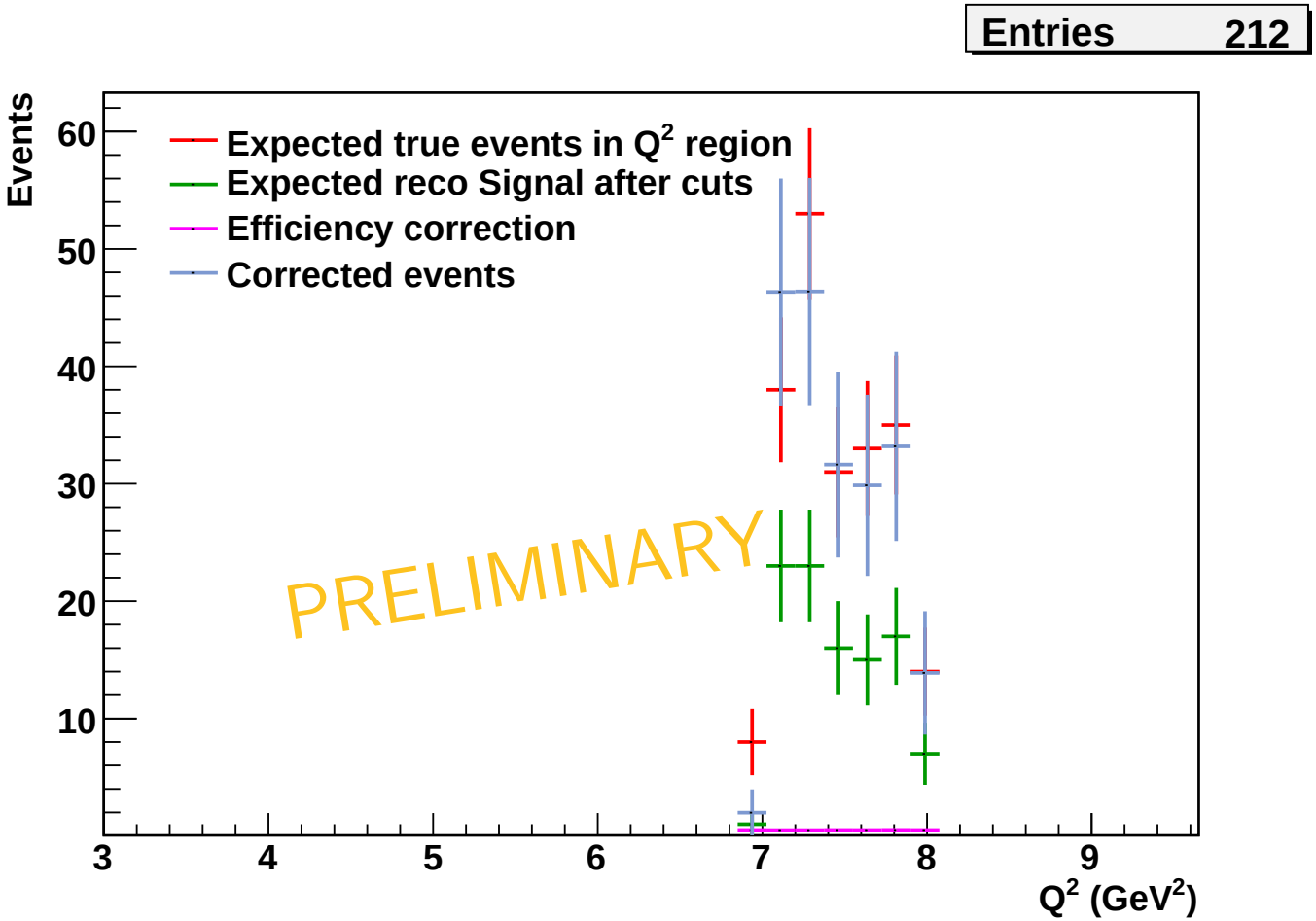

$W^2 = 10\,\mathrm{GeV}^2$:

PID+CL includes CL(electrons)>0.001 and CL(electrons)>3 CL(pions)

# First Analysis with expected statistics: $W^2 = 10\,\mathrm{GeV}^2$ and $\pi^0$ forward

CUTS: PID only and $Q^2$
According to the paper values: $\sim 200$ true events between $7\,\mathrm{GeV}^2 < Q^2 < 8\,\mathrm{GeV}^2$ with an integrated luminosity of $L = 2\,\mathrm{fb}^{-1}$ ($10^7$ s at design luminosity).

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



# Outlook and Conclusions

Immediate future:

- Calculate the integrated cross section of the signal in the region of our interest.
- Perform the analysis with realistic statistics and the best cuts.

Next steps:

- The event generator for signal for $\Delta_T < 0.5\,\text{GeV}$ has to be implemented.
- Study the actual angular distribution of the background.
- Implement a realistic event generator for the background.
- Repeat the analysis with a realistic cross section for the background.

CONCLUSIONS:

Under the assumptions that have been taken into account:

- A background suppression factor close to $10^8$ could be achieved with PID cuts keeping about 20% of signal.
- Preliminary results show that a first sight on the TDA's could be done with this channel using $\bar{\text{P}}$ANDA.