On lepton pair production in proton-antiproton collisions at intermediate energies and the main backgrounds.

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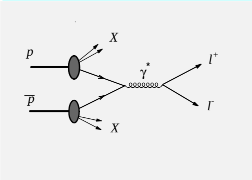
This intermediate energy experiment (**E_{beam} < 15 GeV**) may play an important role, because it allows to study the energy range, where the perturbative methods of QCD (pQCD) come into interplay with a rich physics of bound states and resonances. The physics of hadron resonances formation and decay is strongly connected with the confinement problem, i.e. with the *parton dynamics* at large distances [1]. A detailed and high-precision experimental study at PANDA may allow to discriminate between a large variety of existing nonperturbative approaches and models that already exist or are under development now.

Dilepton events may serve as a powerful tool to get out the *information about the parton distribution functions (PDFs)* in hadrons [2]. The plans to study this process are included into the LoI and TPR of PANDA experiment at HESR. This study may provide an interesting *information about quark dynamics inside the nucleon.*

The results of study of leptons angle and energy spectra distributions, based on this Monte-Carlo simulation, was used for a proper "geometrical" design of PANDA muon system.

In the following we consider the case of antiproton beam energy Ebeam = 14 GeV which corresponds to the center-of-mass energy of the $\bar{p}p$ system Ecm = 5.3 GeV.

MMT-DY process



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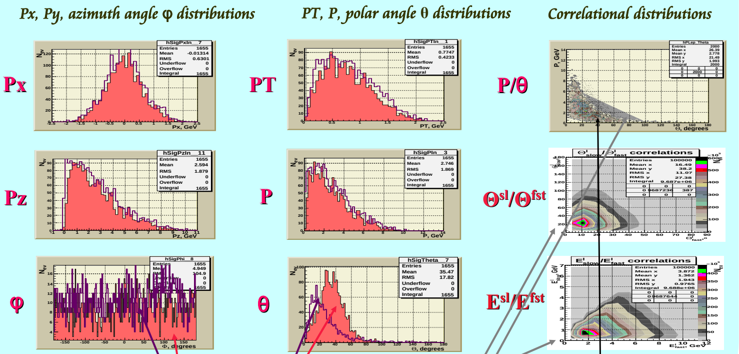
(V.A. Matveev, R.M. Muradian, A.N Tavkhelidze, JINR P2-4543, JINR, Dubna, 1969; SLAC-TRANS-0098, JINR R2-4543, Jun 1969; 27p.)
process, called also as "Drell-Yan process"
(S.D. Drell, T.M. Yan, SLAC-PUB-0755, Jun 1970,12p.; Phys.Rev.Lett. 25(1970)316-320, 1970)

The dominant mechanism of the l^+l^- production is the perturbative QED/QCD partonic 2 → 2 subprocess

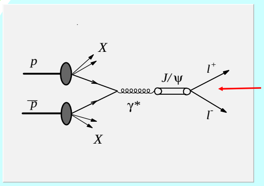
$\bar{q}q \to \gamma^*/Z^* \to l^+l^-$

$\sigma = 5.6 \cdot 10^3$ pb (about 7×10^6 events per 1 year for $L = 2\cdot10^{32} cm^{-2} s^{-1}$)



- PYTHIA 6.4 simulation
- PANDARoot & GEANT 3 simulation
- PYTHIA 6.4 simulation
- PANDARoot & GEANT 3 simulation

J/Ψ production (benchmark process)



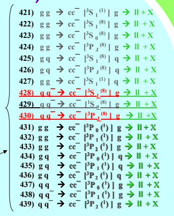
The main contributions to the cross section give the following processes:

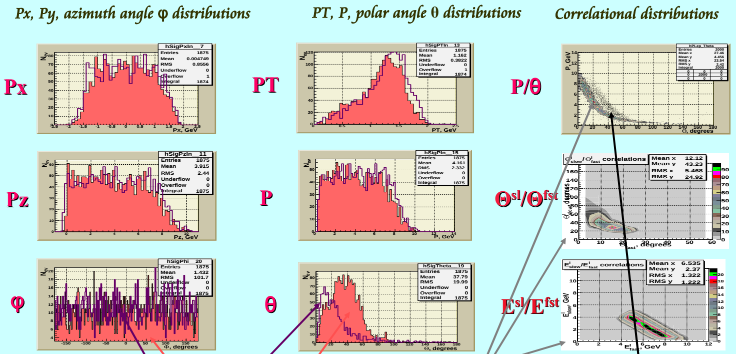
$q\bar{q} \to \gamma^* \to c\bar{c} \to J/\Psi \to l^+l^- + X$

$q\bar{q} \to c\bar{c}\ [^3S_1{}^{(8)}]\ g \to l^+l^- + X$

$q\bar{q} \to c\bar{c}\ [^3P_J{}^{(8)}]\ g \to l^+l^- + X$

Another considered subprocesses are :





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Backgrounds to the $\bar{q}q \to \gamma^* \to l^+l^-$ process

The simulation wad done at the level of PYTHIA6.4 (without account of magnetic field and detector effects) in approximation that particles are allowed to decay in cylinder volume R=2500 x L=8000 mm

1-st source – leptons from hadronic decays in the same p pbar → l^+l^- process

2-nd source - Background QCD processes

The generation was done with the use of more than 20 QCD subprocesses existed in PYTHIA6.4 (including the signal one $\bar{q}q \to \gamma^* \to l^+l^-$).

The main contributions come from the following partonic subprocesses:

- $q + g \to q + g$ (gives 50% of events with the σ = 4.88 mb);
- $g + g \to g + g$ (gives 30% of events with the σ = 2.96 mb);
- $q + q' \to q + q'$ (gives 18% of events with the σ = 1,75 mb);
- $q + \bar{q} \to g + g$ (gives 0.6% of events with the σ = $5.89 \cdot 10^{-2}$ mb);
- $q + \bar{q} \to l^+ + l^-$ (signal process gives 0.00005% of bkgd events, due to σ = $5.02 \cdot 10^{-6}$ mb);

So, initially there is 1 signal event among 2.000.000 of QCD background i.e., initially → S/B = $5.5 \cdot 10^{-6}$

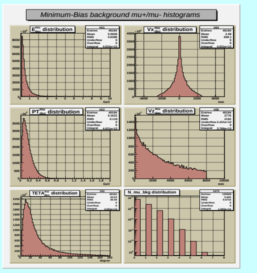
3-d source (the most difficult) - Minimum-Bias processes:

Some examples:

- *Low - PT scattering* (gives 68% of events with the σ = **34.25** mb);
- *Single diffractive* (gives 6% of events with the σ = **3.32** mb);
- $\bar{q} + q \to l^+ + l^-$ (gives 0.000012% of events, σ = $5.9 \cdot 10^{-6}$ mb);

So, we have 1 signal event against 8.333.333 of Mini-bias bkgd → S/B = 10^{-7}

Mini-bias background is 5 times harder than QCD background



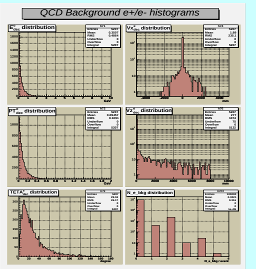
The shape of **muon** distributions, produced in ***background events*** do not differ from those of fake "decay" muons, produced in ***the signal process***

→ Up to 7 fake muons in the final state.

→ a rather high probability of appearing Of the muon pair with the different signs of their charges in background events

→ fake pretty well the signal events

Fake muons production vertices are distributed within detector volume → ***Vertex position*** information can be useful for Signal / Background separation



The shape of **background electron's** distributions are identical to the ones, appearing in the signal events

The most of electron pairs do appear as Dalitz pairs ($\pi^0 \to e^+e^-\gamma$) produced in decays of ***neutral mesons***, which may also appear from **η, ω** or more ***heavy mesons*** or ***barions***, produced n their turn as the resonance states according to the LUND fragmentation model.

The life time of these resonance states is rather short → the electron pairs are produced close to the nteraction point → the **vertex position** information will not be efficient for the Signal / Background separation.

Cuts for separation of background events

1. selection of events with the only 2 leptons, having $E_l > 0.2$ GeV, $PT_l > 0.2$ GeV;
2. these 2 leptons have charges of the opposite charge;
3. the vertex of lepton origin lies within the R< 15mm from the interaction point;
4. $M_{inv}(l^+l^-) \geq 0.9$ GeV;
5. leptons have to satisfy the isolation criteria: the summed energy of particles E_{sum} **< 0.5 GeV** within the **cone** of $R_{isolation} = \sqrt{\Delta_\eta^2+\Delta_\varphi^2} = 0.2$.

The first 3 cuts, being applied to the sample of signal events, can allow one to select a subsample which include a strongly reduced fraction (fr) of events, containing fake leptons (fr_e = 0.008% for the case of e^+e^- production and fr_μ = 0.001% for the $\mu^+\mu^-$ production). The loss of the signal events due to application of cuts 1) – 3) is about ≈ 17 % for $\mu^+\mu^-$ and ≈ 14% for e^+e^- production.

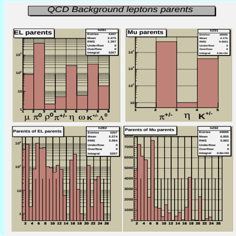
Efficiency of cuts in the presence of mini-bias and QCD background & S/B ratio

N of cuts	S/B for $\mu^+\mu^-$ production	Efficiency	S/B for e^+e^- production	Efficiency
1	$1.41\cdot10^{-5}$	0.007	$5.34\cdot10^{-4}$	$1.78\cdot10^{-4}$
2	$2.12\cdot10^{-5}$	0.665	$5.41\cdot10^{-4}$	0.98
3	$9.94\cdot10^{-5}$	0.002	$5.47\cdot10^{-4}$	0.99
4	0.123	0.08	$9.27\cdot10^{-2}$	0.006
5	Background = 0	–	3.8	0.024

The total loss of signal events after application of all five cuts is expected to be about 25%.

So, we can expect to gain a huge sample of about 7×10^6 signal dilepton events per 1 year (10^7 sec.)

Parents of background leptons

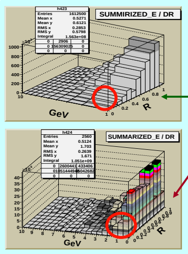


*The most probable parents of fake **electrons** → are neutral pions ($\pi^0 \to e^+e^-\gamma$)*
***muons** → are charged pions*

*The most probable grandparents of fake **electrons** → are strings (Lund model), ρ^+, η, ω, Δ^0, Δ^+*

***muons** → are strings (Lund model), ρ^0, ρ^+, ω*

Lepton (e) isolation criteria



The plots show the distributions over the ***summarized energy*** of the final state particles in the cones of radius $R_{isolation} = \sqrt{\eta^2+\varphi^2}$ respect to the (η – *pseudorapidity*)

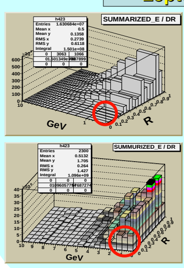
upper plot → **signal events**

bottom plot → **background events**

Isolation criteria ($R_{isolation}$ = **0.2**)
$E_{(of\ particles)}$ = 0.5 GeV
allows to separate **100%** of QCD leptons with loss of **8%** of signal events

Final ***S/B ratio = 3.6!*** $M_{inv}(l^+,l^-) > 0.9$
S/B ratio = 9! For $M_{inv}(l^+,l^-) > 1.0$

Lepton (μ) isolation criteria



The plots show the distributions over the ***summarized energy*** of the final state particles in the cones of radius $R_{isolation} = \sqrt{\eta^2+\varphi^2}$ respect to the

upper plot → **signal events**

bottom plot → **background events**

Isolation criteria ($R_{isolation}$ = **0.2**)
$E_{(of\ particles)}$ = 0.5 GeV

allows to separate 100% of Mini-bias bkg leptons with the loss of **8%** of signal events

*(after first 3 cuts applied (see the table) + cut **M inv** (l^+,l^-) **> 0.9**)*

REFERENCES

[1]. Phys.Part.Nucl.Lett, 2009, V.6, N.4(153), P.504-518
[2]. arXiv: hep-ph/0506139v2

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"Hadron 2011". XIV International Conference on Hadron Spectroscopy. June13-17, Munich, Germany.