Updates for Background study of Drell-Yan process ($\mu^+\mu^-$ case)

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(V.A. Matveev, R.M. Muradian, A.N Tavkhelidze, JINR-P2-4543, JINR, Dubna, 1969; SLAC-TRANS-0098)

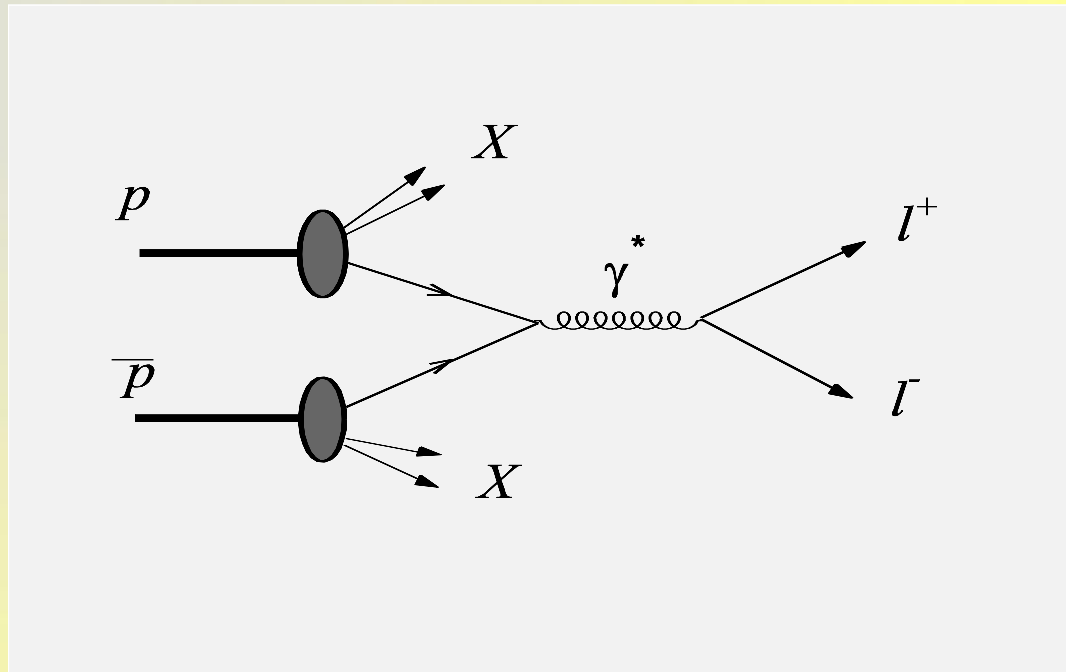
process, called also as Drell-Yan

(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 $\ell^+\ell^-$ production is the perturbative QED/QCD partonic 2 → 2 process

$\bar{q}_i q_i \to \gamma^* / Z^\circ \to \ell^+\ell^-$

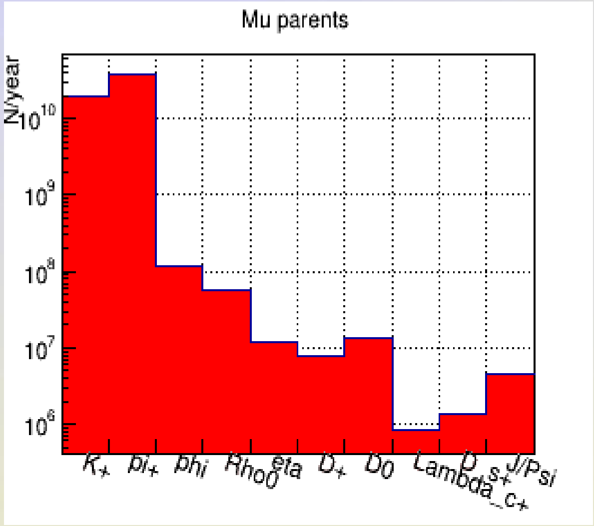
$\sigma = 4.6 * 10^3$ *pb*



PYTHIA 6.4 simulation for the P_{beam} = 15 GeV (E_{cms} = 5.474 GeV)

For the Luminosity L = 2×10^{32} cm^{-2} s^{-1} with assumption of the 10^7 sec/year beam operation we expect up to 9.2 x 10^7 Drell-Yan events/year

Background muons



Information from PYTHIA

The most probable <u>parents</u> of bkg <u>muons</u> - are <u>charged</u> π and K

The most probable <u>grandparents</u> of bkg <u>muons</u> - are «string» (Lund model),

$$\rho^0, \rho^+, K^0_S, K^{*0}, K^+, \eta'$$

Background cross sections : PYTHIA =~ 37.4 mb

DPM =~ 44.23 mb → initial S/B = 1.04 * 10^{-7}

Thus for reduction of backgrouns the preselection cuts (filters) were chosen as:

<u>Presence of at least 1</u> (**K+** or **π+**) & (**K-** or **π-**) **with** ***PT > 0.3 GeV*** **and** ***P > 1.5 GeV***

Now for Background calculations we have used DPM generator with PandaRoot *version* ***PandaRoot oct19, FairRoot v18.2, FairSoft june19p1***

Muon identification

Initial number of background generated in DPM events – 1026444289
after precut – 90.000.000 (9*10^7)

Used PID algorithm "PidAlgoMvd; PidAlgoStt; PidAlgoDrc; PidAlgoEmcBayes; PidAlgoDisc; PidAlgoMdtHardCuts "
(It was checked with BOX generator that these 6 algorithms allow to detect muons betteer in backward direction compared to stand alone PidAlgoMdtHardCuts)

Initial assumption of even **Tight muons (P ≥ 0.5)** for signal DY events (200 000) give significant loss of muons/event:
0μ= 12,46% 1μ= 46.37% **2μ= 35.31%** 3μ= 5.19% 4μ=0.59% 5μ=0.06% 6μ<0.01%

Finally were taken in consideration Muons **VeryTight** – required **(probability) P ≥ 0.9**
And for DY events we have:
0μ= 18.92% 1μ= 51.46% **2μ= 27.32%** 3μ= 2.12% 4μ=0.15% 5μ<0.01%

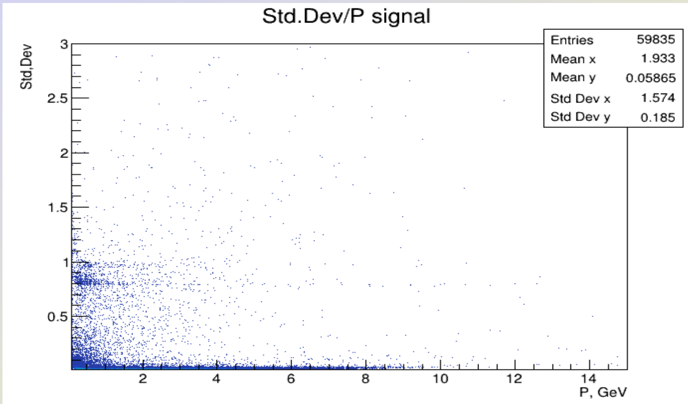
There were considered 2 cases :

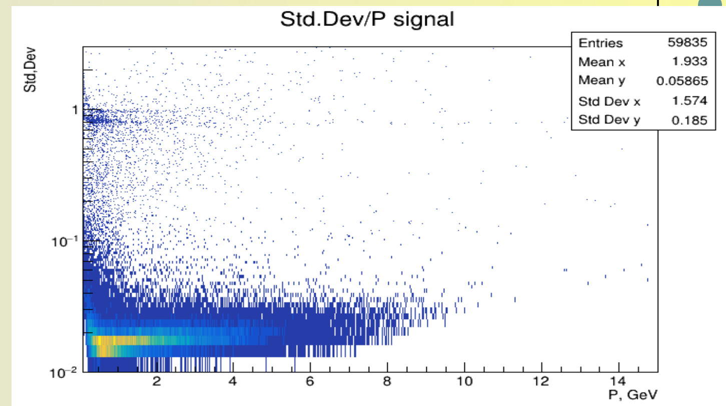
1. All obtained data (without momenta selection*) /all following plots are made for this case/*
2. Only events with "well" measured momenta (ΔP/P < 3%)

Deviations in muons momenta resolution

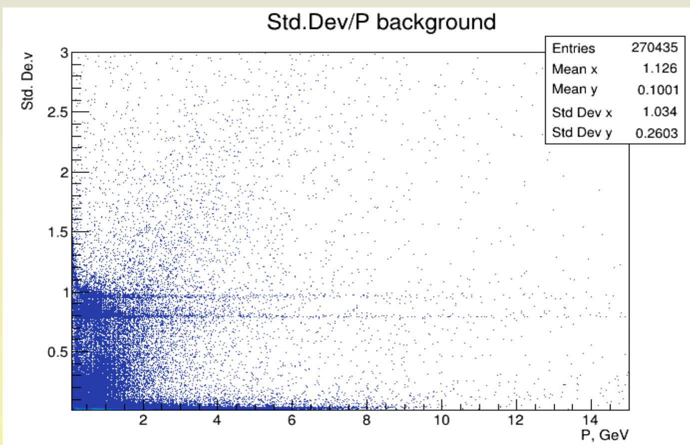
Sig & BKG in log scale

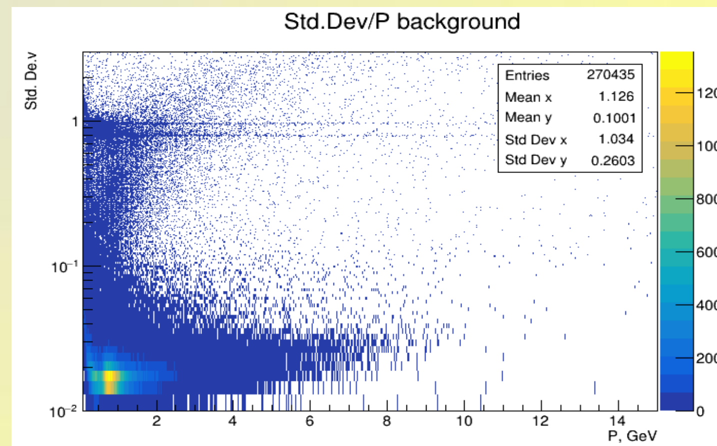
SIG





BKG

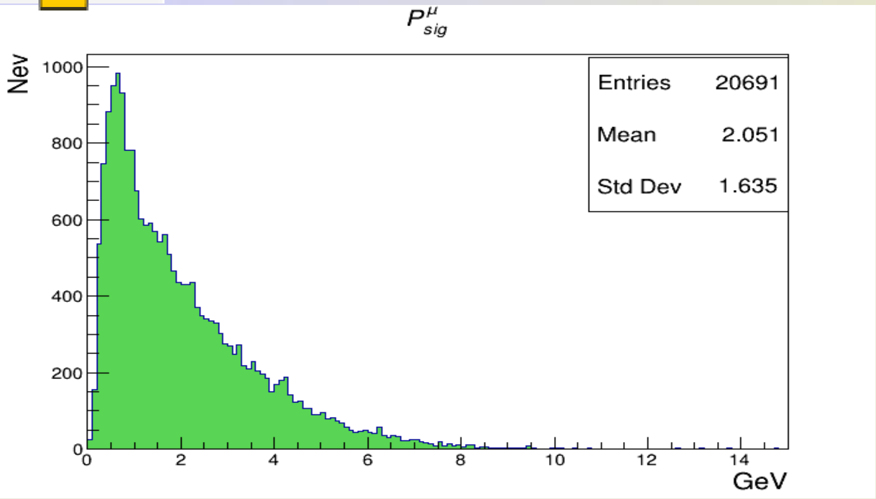


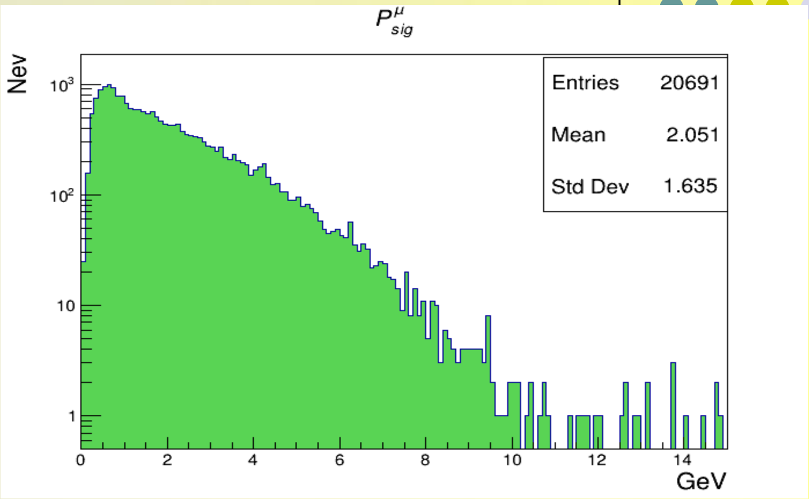


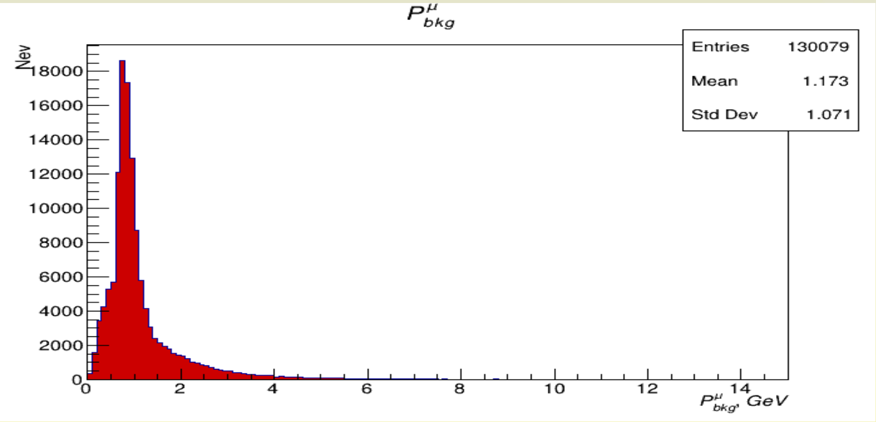
To safe the most part of statistics we have chosen ΔP/P < 3% GeV

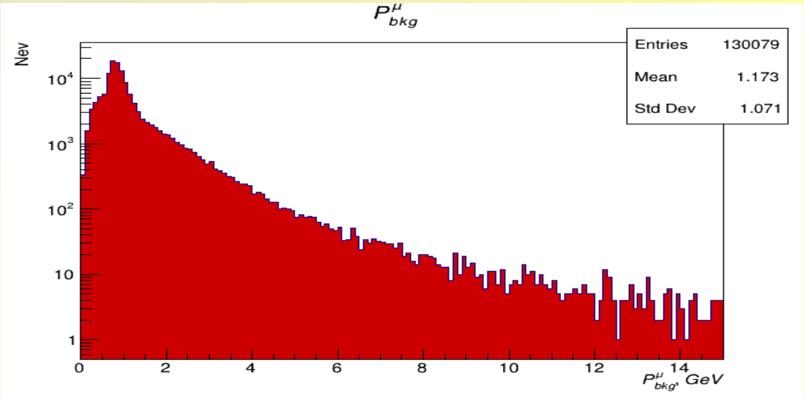
(Where ΔP is a square root of the sum of diagonal elements of 3x3 covariance matrix of momentum vector described in P3Cov() method of RhoCandidate)

First cuts — on E(P)$^{\mu}$



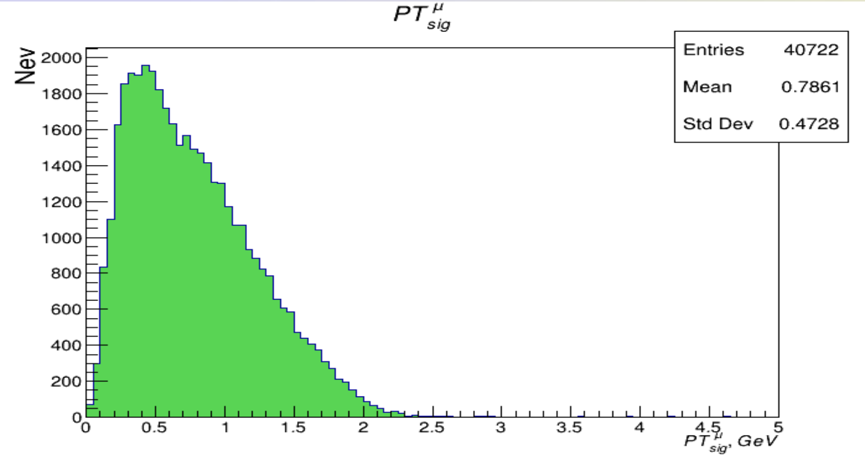


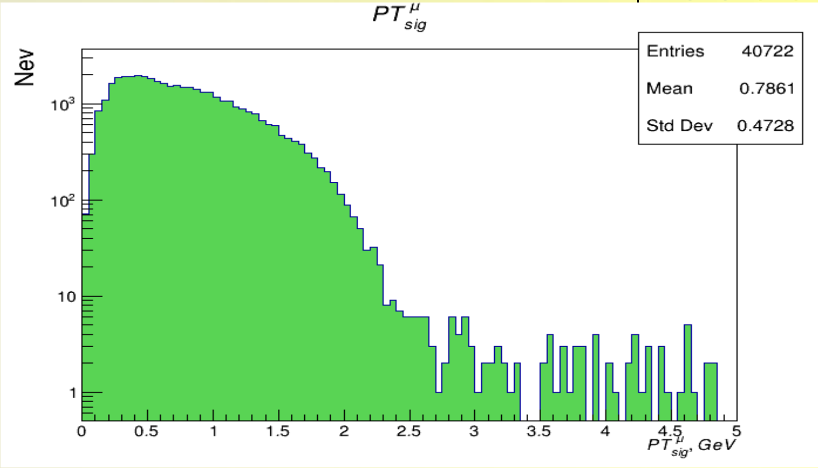


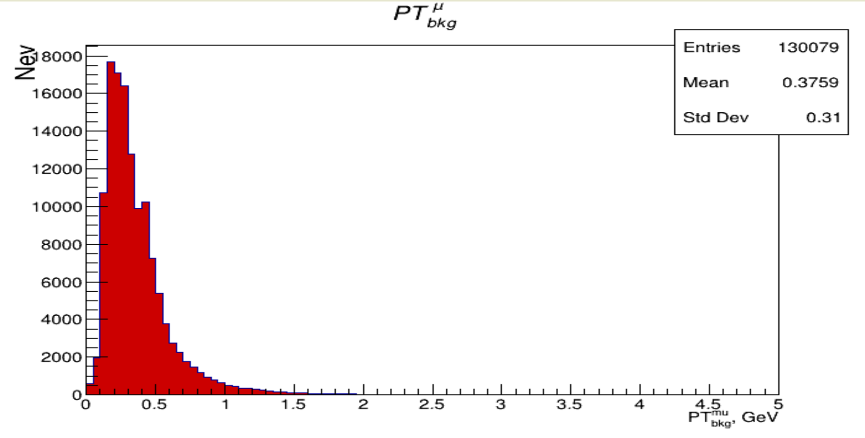


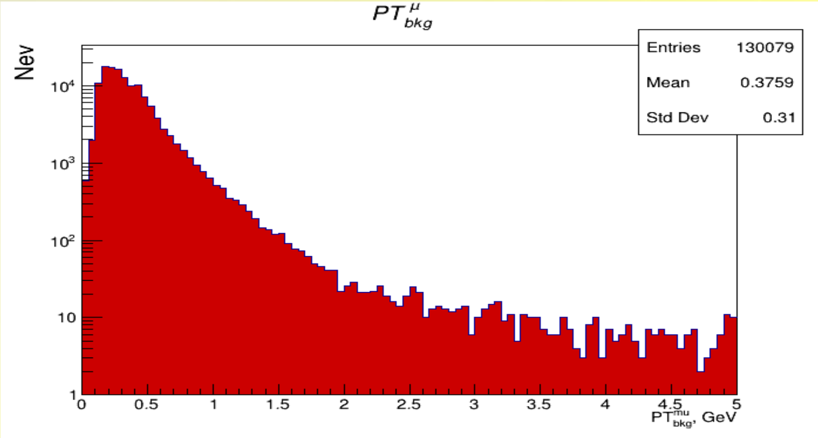
Effective cut off is **P^{μ} > 1.0 GeV** *(before > 1.5 GeV)*

First cuts — on PT^{μ}



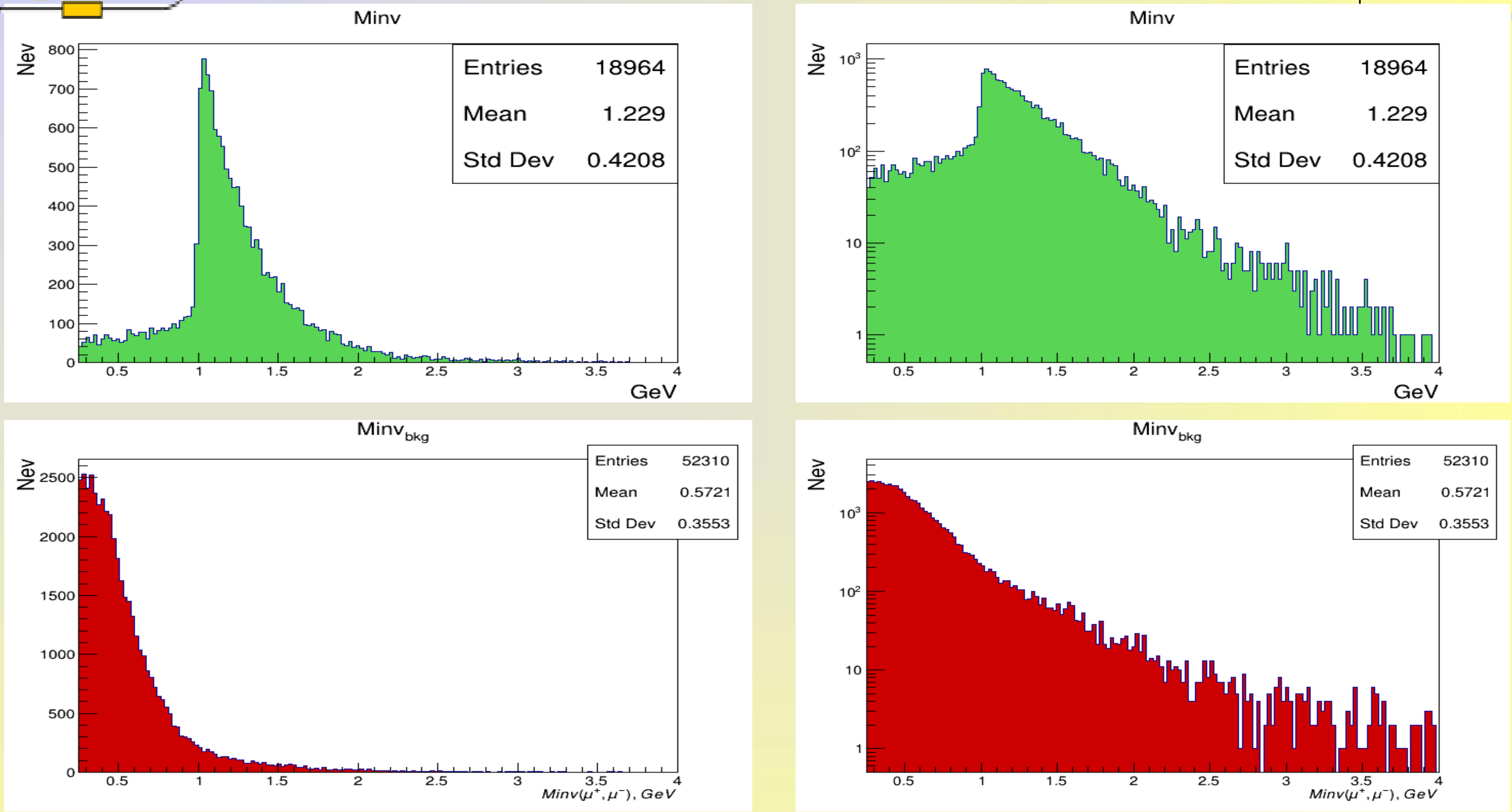






Effective cut off is **PT^{μ} ~ 0.5 GeV**

Invariant mass (μ+μ-) cut

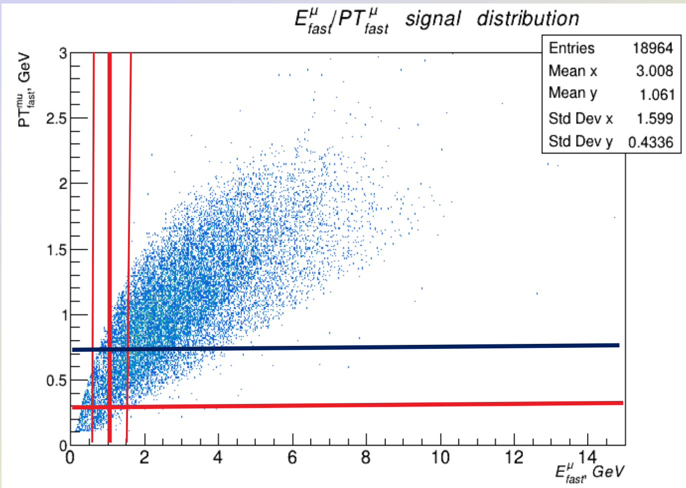


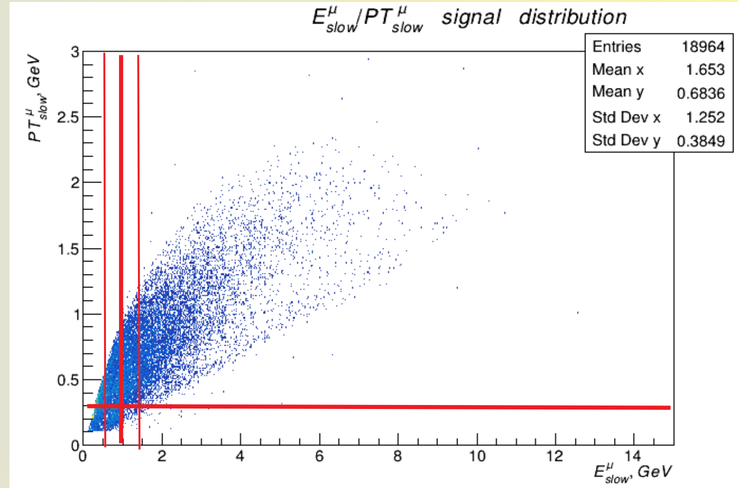
The most effective cut is in the region **Minv >1 GeV.**

The peak at 1 GeV for DY is caused by some internal PYTHIA restrictions.

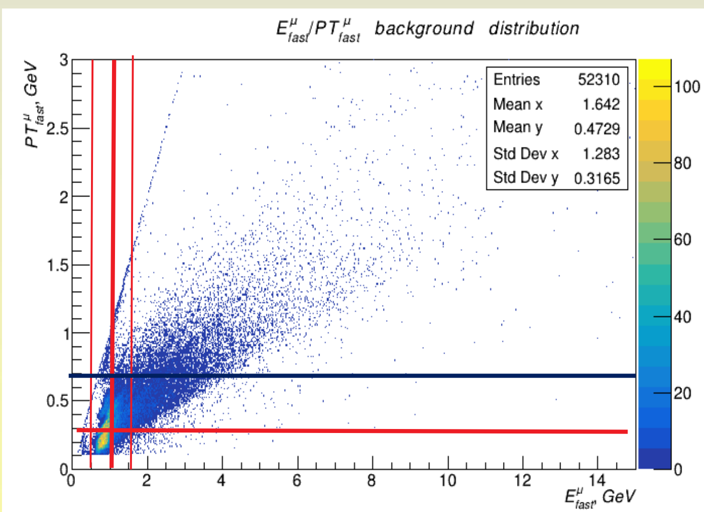
E^{μ}/PT^{μ} correlations for muons with max(fast)/min(slow) E_{μ} in the pair

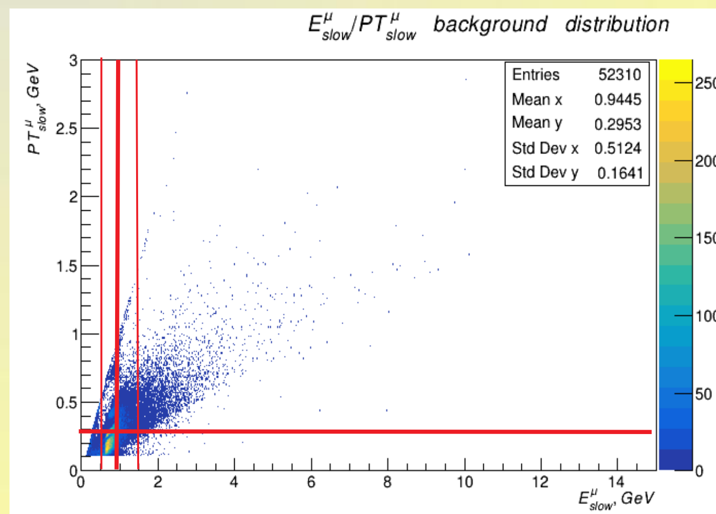
SIG





BKG





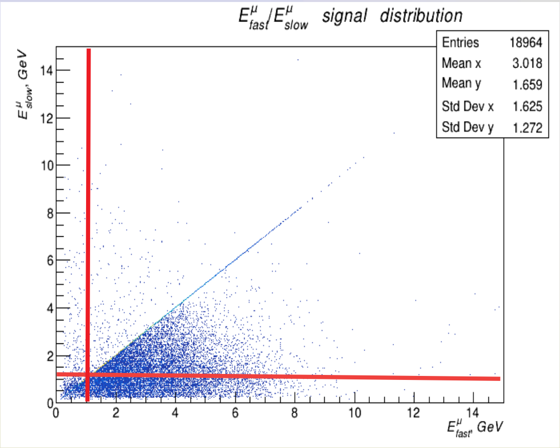
$PT^{\mu}_{Emax} > 0.7$ GeV

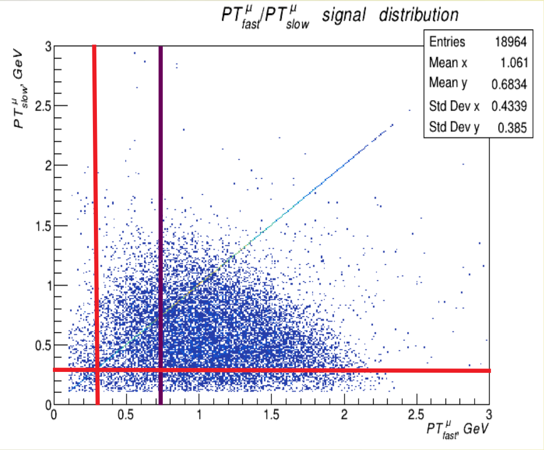
additionally will be more efficient

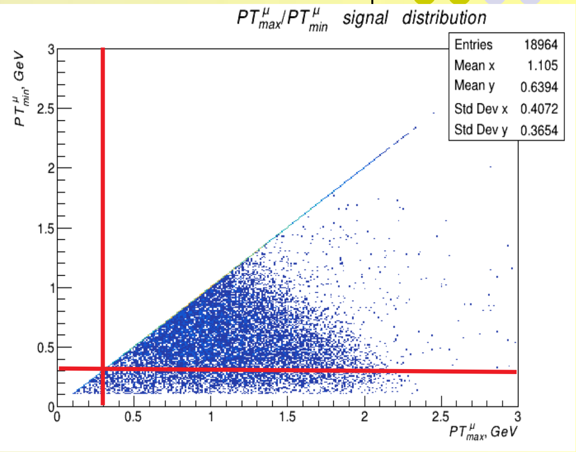
Cut on PTμ > 0.3 GeV and E(P)μ > 1.0 (0.5, 1.5) GeV

E^μ(fast) / E^μ(slow), PT^μ(fast)/PT^μ(slow), PT^μ max/PT^μ min distributions

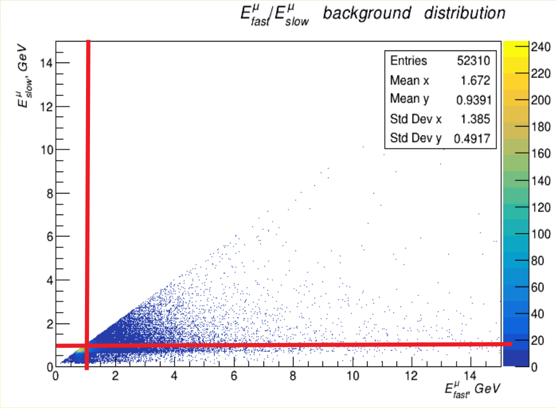
S I G

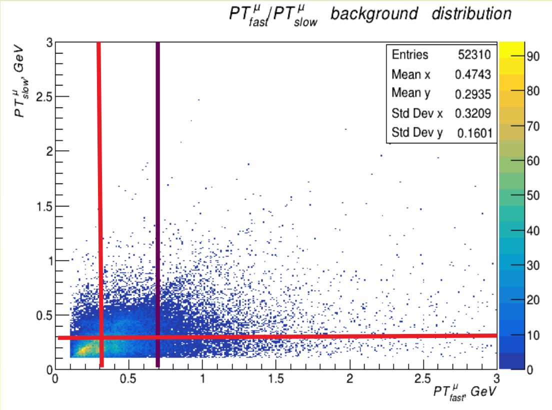


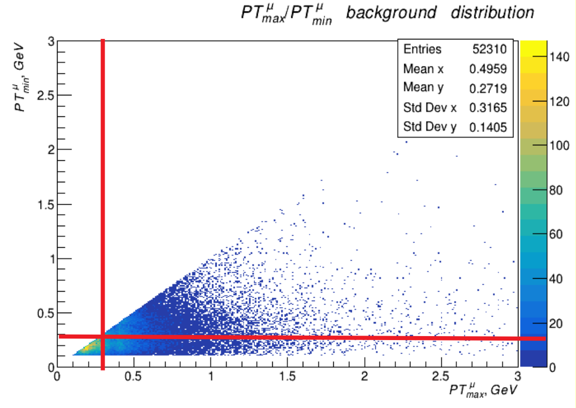




B K G







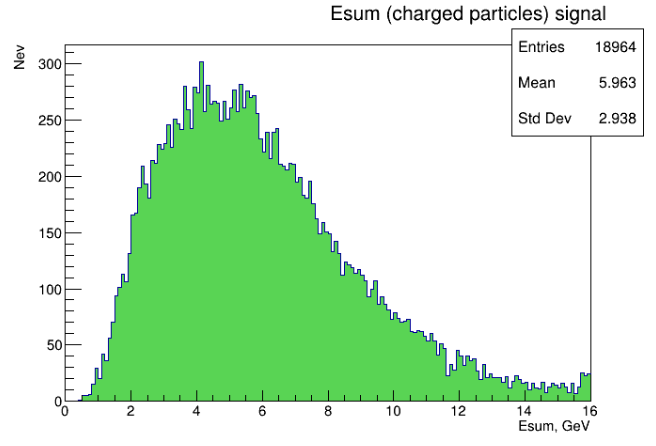
E(P) > 1.0 GeV

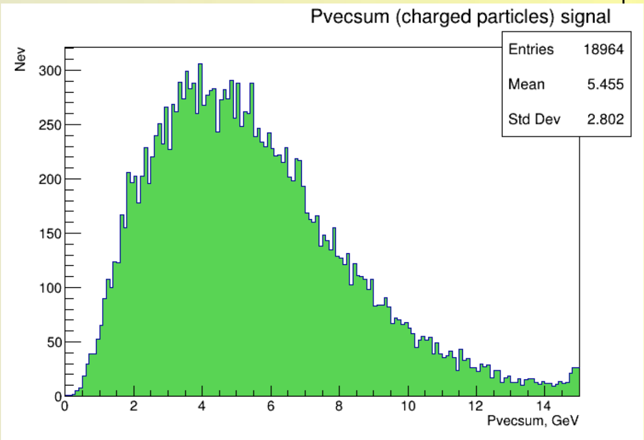
PT > 0.3 GeV,
PT_{fast} > 0.7 GeV

PT > 0.3 GeV

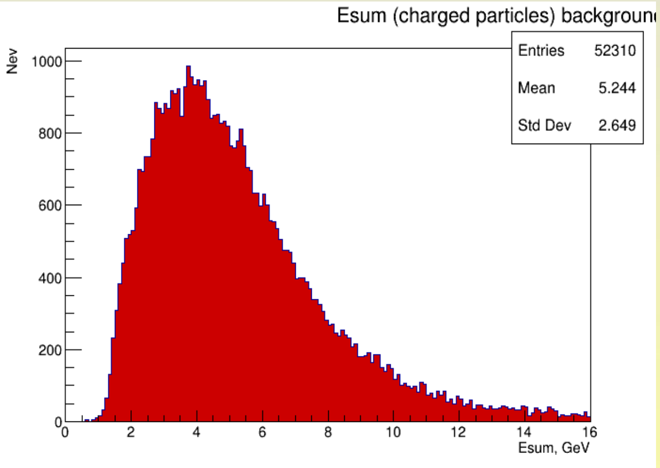
Cut on Esum - summarized energy of all charged particles in event and their vector sum of PT

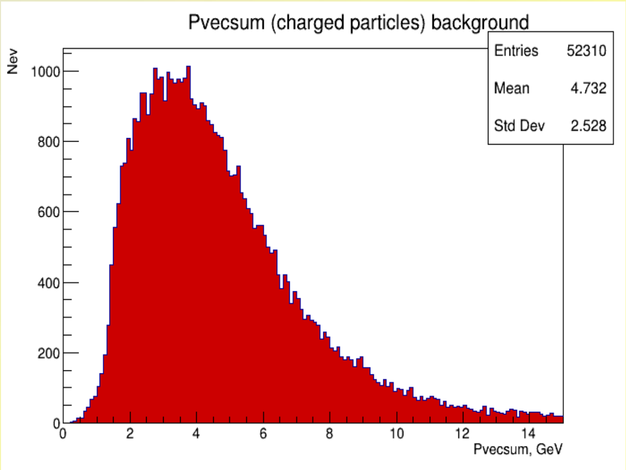
S
I
G





B
K
G

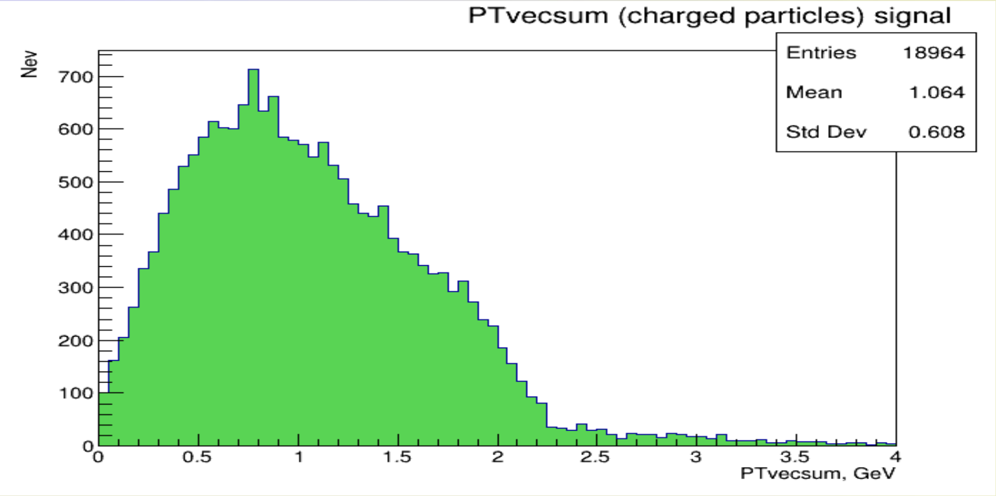




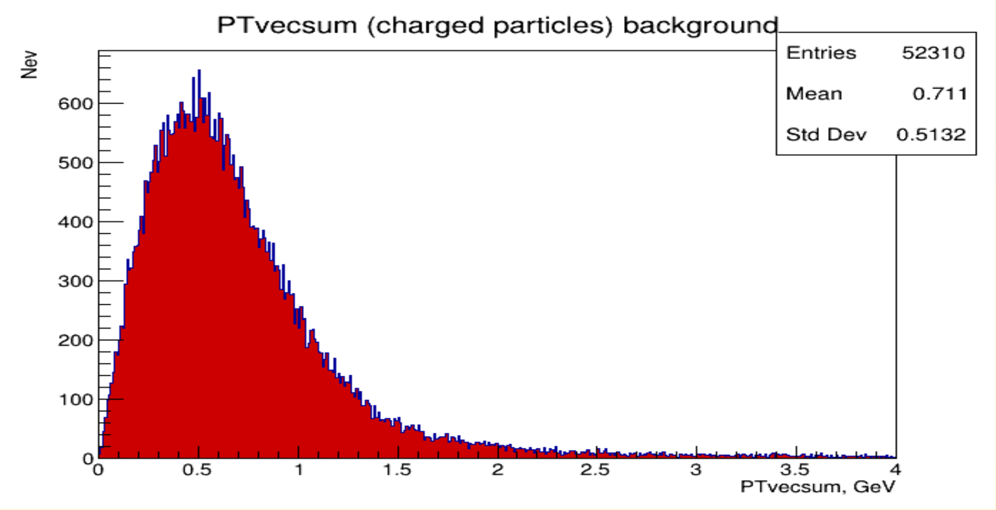
For only charged particles these variables obviously do not work

Cut on PT- vector summa of all charged particles transverse momenta in event

S
I
G

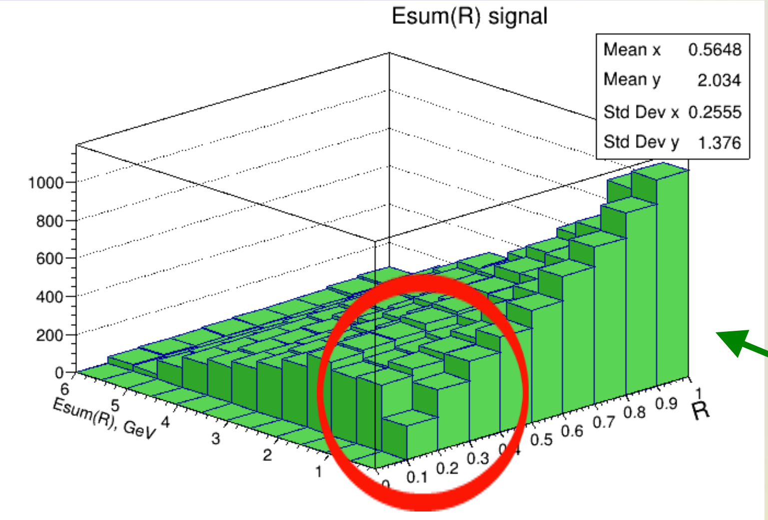


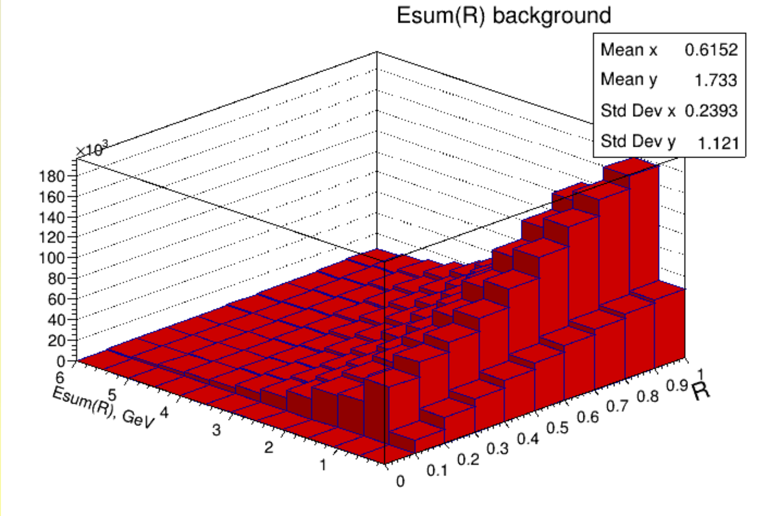
B
K
G



PT_{vecsum} > 0.7 GeV can help to improve S/B ratio

Lepton (μ) isolation criterion





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

(**η** – *pseudorapidity*, **φ** — ***azimuthal angle***)

upper plot **signal events**

bottom plot **background**

Isolation criteria **($R_{isolation}$ = 0.2)**

E (of particles) < 0.5 GeV

"Isolation criterion" in PandaRoot shows visibly worse results than in "pure" generators

Proposed cuts

1. *Events with only 2 muons with*

$PT_{\ell} > 0.3$ GeV, $E(P)_{\ell} > 1.0$ GeV

2. *Muons are of the opposite sign*

3. *$M_{inv}(l^{+}, l^{-}) > 1.0$ GeV*

4. $PT^{\mu}_{fast} > 0.7$ GeV

5. Vector sum of charged particles PTsum > 0.7 GeV

6. *Isolation criterion $E^{sum}_{(R\ isolation\ =\ 0.2)} < 0.5$ GeV*

Cuts separate and summarized & their efficiencies for DPM background events (all)

Efficiency Eff (K,N) = Nev(cutN) / Nev(cutK)

N of cuts	S/B ratio	*Efficiency for BKG*	Rest of BKG	*Efficiency for SIG*	Rest of SIG
1 *Exactly 2μ* with $PT_l > 0.3$ GeV, $P_l > 1.0$ GeV	$2.13 * 10^{-5}$	Eff (1,init) = 4907.2	2.03×10^{-2} %	24.2	4.14 %
2^{+1} *2μ are of the opposite sign*	$3.11 * 10^{-5}$	Eff (2,1) = 1.69	1.20×10^{-2} %	1.15	3.59 %
3^{+2+1} $M_{inv}(\mu^+,\mu^-) > 1.0$ GeV	$1.92 * 10^{-4}$	Eff (3,2) = 6.69	1.80×10^{-3} %	1.07	3.33 %
4^{+3+2+1} $PT^{\mu}_{all} > 0.7$ GeV	$2.41 * 10^{-4}$	Eff (4,3) = 1.42	1.27×10^{-3} %	1.13	2.94 %
5^{+3+2+1} $PT^{Emax}_{vecsum} > 0.7$ GeV	$3.01 * 10^{-4}$	Eff (5,3) = 2.09	$8,61 \times 10^{-4}$ %	1.33	2.49%
6^{+3+2+1} *Isolation criterion*	<u>$7.48 * 10^{-4}$</u>	Eff (6,3) =1.29	1.39×10^{-3} %	1.11	**3.00 %**
$5^{+4+3+2+1}$ $PT^{all}_{vecsum} > 0.7$ GeV	$4.00 * 10^{-4}$	Eff (5,4) = 1.29	6.63×10^{-4} %	1.11	2.55 %
$6^{+4+3+2+1}$ Isolation criterion	$2.84 * 10^{-4}$	Eff (6,4) =1.31	9.68×10^{-4} %	1.12	**2.65 %**
$6^{+5+4+3+2+1}$ Isolation criterion	$3.84 * 10^{-4}$	Eff (6,5) =1.86	4.61×10^{-4} %	1,24	**2.01 %**

Cuts separate and summarized & their efficiencies for DPM background events

("Good" P)

N of cuts	S/B ratio	*Efficiency for BKG*	Rest of BKG	*Efficiency for SIG*	Rest of SIG
1 *Exactly 2μ* with **PT_l > 0.3 GeV, P_l > 1.0 GeV**	**$3.90 * 10^{-5}$**	Eff (1,init) =12011.8	8.32×10^{-3} %	**32.05**	**3.12 %**
2^{+1} *2μ are of the **opposite sign***	**$5.11 * 10^{-5}$**	Eff (2,1) = 1.45	5.74×10^{-3} %	1.10	2.82 %
3^{+2+1} ***$M_{inv}(\mu^+,\mu^-)$ > 1.0 GeV***	**$8.91 * 10^{-5}$**	Eff (3,2) = 7.45	7.70×10^{-4} %	1.06	2.66 %
4^{+3+2+1} ***PT_{μ}^{Emax} > 0.7 GeV***	**$4.56 * 10^{-4}$**	Eff (4,3) = 1.44	5.36×10^{-4} %	1.13	2.35 %
5^{+3+2+1} ***PT_{all}^{vecsum} > 0.7 GeV***	**$8.47 * 10^{-4}$**	Eff (5,3) = 3.11	2.48×10^{-4} %	1.32	2.02 %
6^{+3+2+1} ***Isolation criterion***	**$3.65 * 10^{-4}$**	Eff (6,3) =1.09	7.03×10^{-4} %	1.08	2.47 %
$5^{+4+3+2+1}$ ***PT_{all}^{vecsum} > 0.7 GeV***	**$1.03 * 10^{-3}$**	Eff (5,4) = 1.33	1.85×10^{-4} %	1.10	**1.82 %**
$6^{+4+3+2+1}$ **Isolation criterion**	**$4.62 * 10^{-4}$**	Eff (6,4) =1.09	4.90×10^{-4} %	1.08	2.18 %
$6^{+5+4+3+2+1}$ **Isolation criterion**	**$1.01 * 10^{-3}$**	Eff (6,5) =1.44	1.72×10^{-4} %	1.20	**1.68 %**

So, finaly, "Isolation criterion" doesn't bring *additional* background suppression

Conclusion

So final Full generation of Signal (PYTHIA6) and Background (DPM) have shown ~4 orders of magnitude worse S/B separation results that were predicted by Fast generation.

The best achieved ***S/B ratio = 1/1000***

That can be caused by:

1. *Not good enough current particle identification (only ~30% of signal is fully determined) {could give factor x3}.*
2. *Errors in momenta determination (even within Std.Dev. account) {could be factor x3, in comparison with Fast simulation}*

/finally ~10 times less signal events after the1st cut/

3 . Not yet calculated contribution of cuts on variables of Esum (P, PT vector sum) of ***all particles*** *{that all together could at most give a factor x~50}*

That all together with some adjustments of kinematical parameters (using neural networks) in the very best case could give total a factor ~x500.

But!!! That will not allow to improve S/B to any acceptable level.

Conclusion

Drell-Yan process study at PANDA should be considered as a <u>hopeless</u>

and <u>excluded from the PANDA physics program</u>