Background study for MMT-DY process at SPD

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(V.A. Matveev, R.M. Muradian, A.N Tavkhelidze, JINR-P2-4543, JINR, Dubna, 1969; SLAC-TRANS-0098, JINR P2-4543, Jun 1969; 27p.)

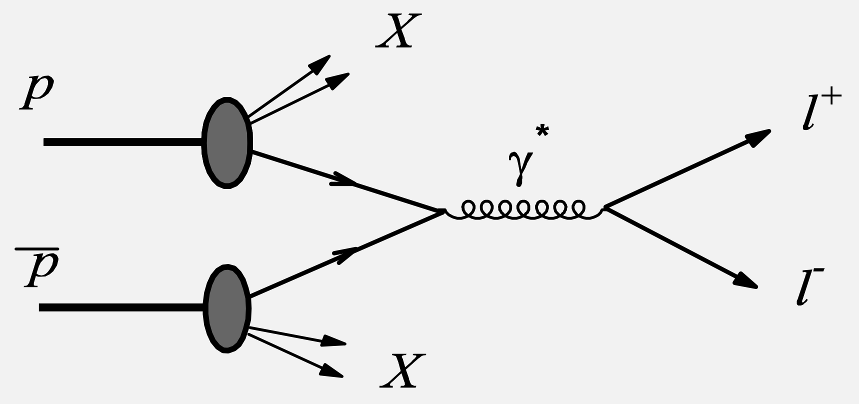
process, called also as Drell-Yan

(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 l^+l^- production is the perturbative QED/QCD partonic 2 -> 2 process

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

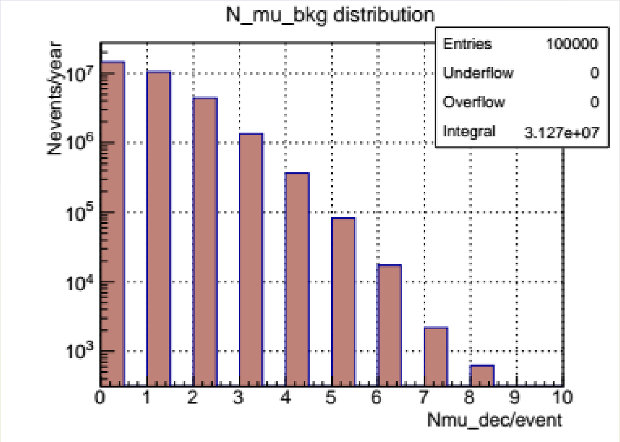
$\sigma = 9.9 * 10^3$ *pb*



PYTHIA 6.4 simulation for the E_{cms} = 27 GeV

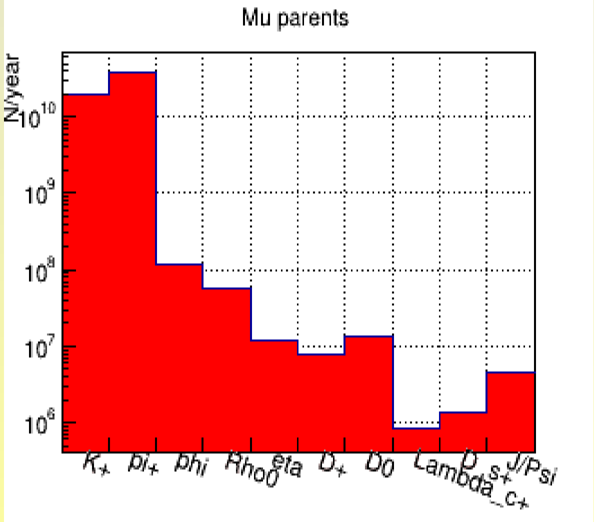
For the Luminosity L = 1×10^{32} $cm^{-2}s^{-1}$ with assumption of the full year beam operation we expect up to 3.1 x 10^7 Drell-Yan events/year

Background muons in signal events



53.5 % of signal events contais >2 muons - up to 8μ/event

We allow particles decay (and produce muons) in the volume before Muon (Range) System :
cylindr radius **R = 2 400 mm**,
size from the centre along Z axis **L = 4 000 mm**
and search for muons in the angle region **9º< Θ < 171º**

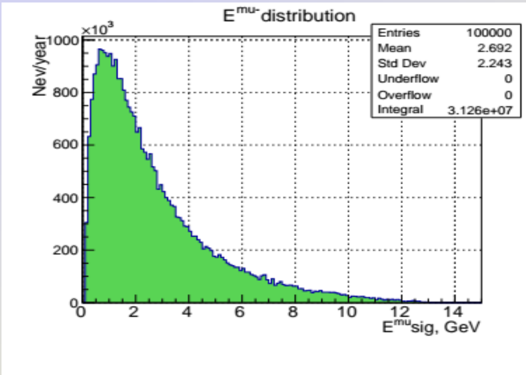


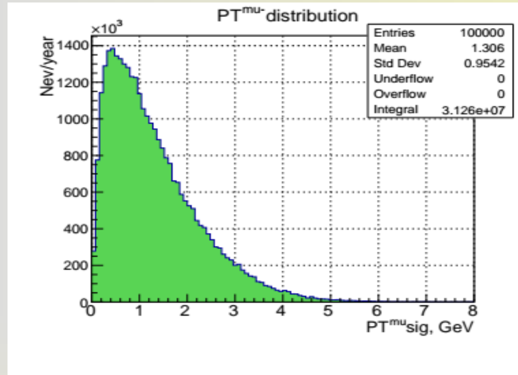
The most probable parents of bkg muons - are charged π and K

The most probable grandparents of bkg muons - are «string» (Lund model),
ρ^0, ρ^+, K^0_s, K^{*0}, K^+, η'

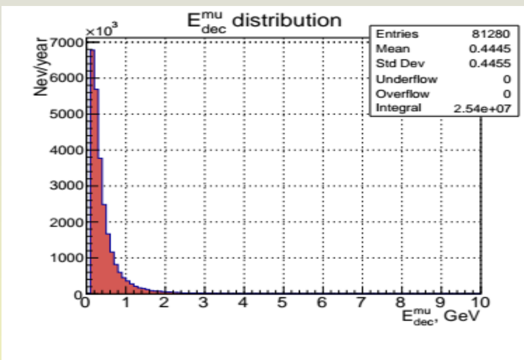
Decay muons in signal events

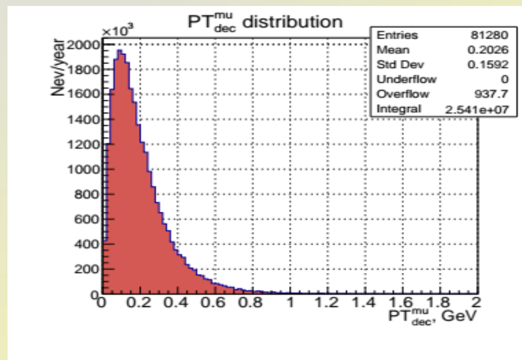
SIG



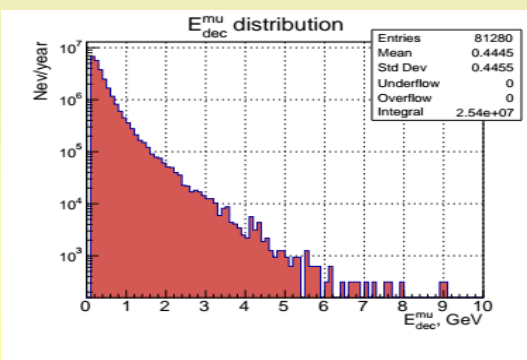


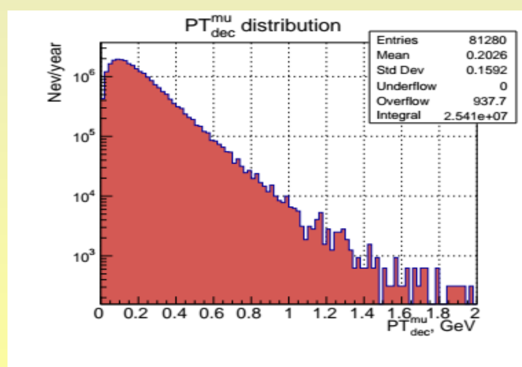
DEC





DEC (log)





Cuts : **exactly 2 muons**	**E > 0.8 GeV PT > 0.4 GeV**	**E > 1.0 GeV PT > 1.0 GeV**
Reminder of signal events	54.1%	23.5%
Fraction of initial signal events with additional muons	2.1%	0.08%
Fraction of remaining signal events with additional muons	3.9 %	0.3%

Another situation when we have exactly 2 μ —
first signal, the second — survived fake one.

We have 2 situations -

1. Muons are of the same sign — easy to cut off
2. Muons are of different signes

After cutting off the events with additional (>2) muons we have

Cuts: **exactly 2 muons with opposite signes**	E > 0.8 GeV PT > 0.4 GeV	E > 1.0 GeV PT > 1.0 GeV
Reminder of signal events	51.9%	23.4%
Fraction of initial signal events with fake muons of the same sign	0.9%	0.09%
Fraction of remaining signal events with muons of the same sign	1.7 %	0.4%
Reminder of signal events after cut off the events with the muons of the same sign	51.0%	23.4%
Fraction of initial signal events with fake muons of different sign	0.9%	0.1%
Fraction of remaining signal events with muons of different sign	1.8 %	0.4%

Here we consider 2 kinds of backgrounds: QCD and Minimun-bias events

The generation was done with the use of more than 20 QCD subprocesses existed in PYTHIA

The main contributions come from the following partonic subprocesses:

- *q + g --> q + g* (gives 2.8**%** of events with the **σ = 4.83** mb);
- *g + g --> g + g* (gives 2.5**%** of events with the **σ = 4.31** mb);
- ***q + q' --> q + q'*** (gives 0.7**%** of events with the **σ = 1.17** mb);

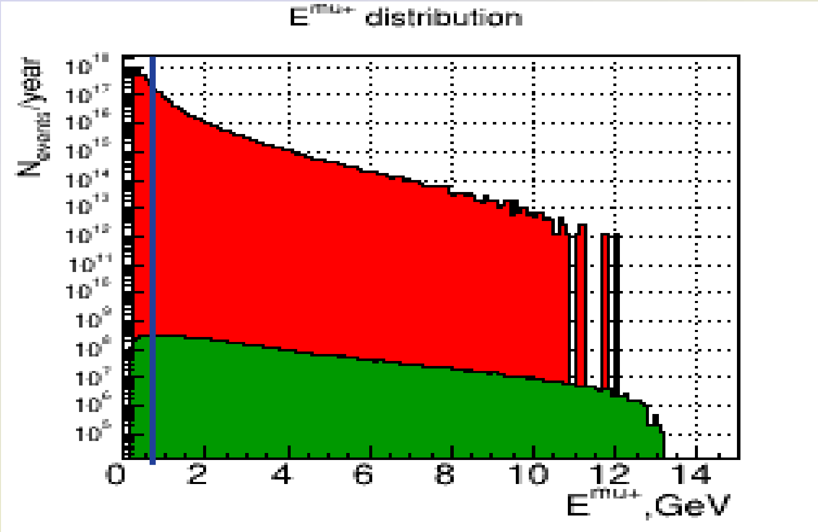
For QCD background **S/B ≃ 10^{-6}**

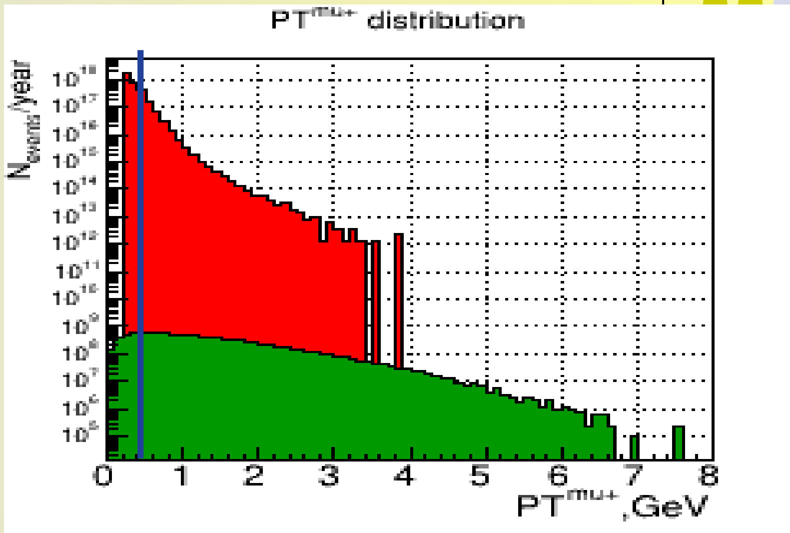
The main source of background for the $\bar{q}\,q \rightarrow \gamma^* \rightarrow \mu^+\mu^-$ are the Minimum-Bias processes:

- *Low - PT scattering* (gives 65**%** of events with the **σ** = **13.0** mb);
- ***Single diffractive*** (gives 22.3**%** of events with the **σ** = **7.35** mb);
- *Double diffractive* (gives 6.4**%** of events with the **σ** = **2.12** mb);
- $\bar{q} + q \rightarrow l^+ + l^-$ (has **0.000028%** of events with the **σ = 9.9 x 10^{-6}** mb);

For Mini-bias background **S/B ≃ 3 x 10^{-7}**

First cuts — on E and PT

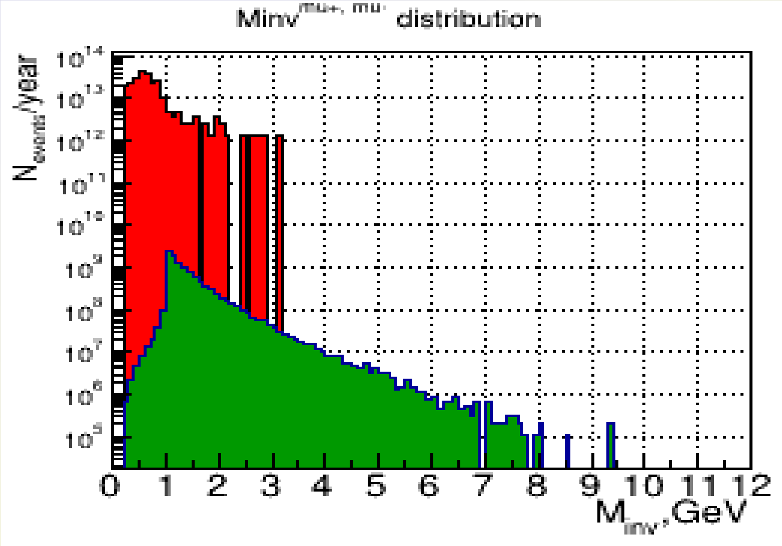




Effective cut off on E(P) only in the region **E^{μ}_{bkg} < 1.5 GeV** ***(E^{μ}_{bkg} = 0.8 GeV)*** where is the maximum gradient in E^{μ}_{bkg} distribution

The most effective cuts off are in the region **PT^{μ}_{bkg} < 1.5 GeV** **(PT^{μ}_{bkg} = 0.4 GeV)**

Invariant mass cut



The most effective cut is in the region **< 0,9 — 1 GeV.**

Further increase of Minv cut has no sense for Minimum-bias background events (it leads to significant loss of signal events without real improvement of S/B ratio) except backgrounds in the regions of J/Ψ and other resonances production.

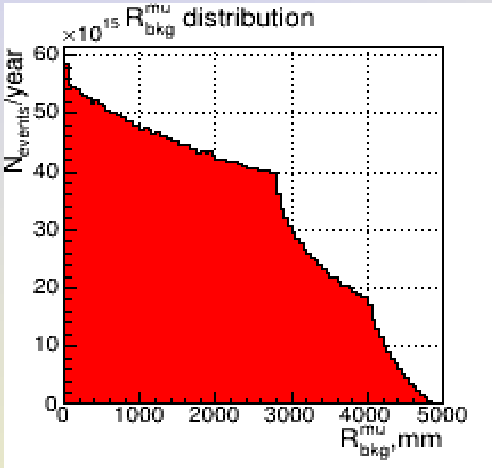
Efficiency of M_{inv} (μ^+,μ^-) cut

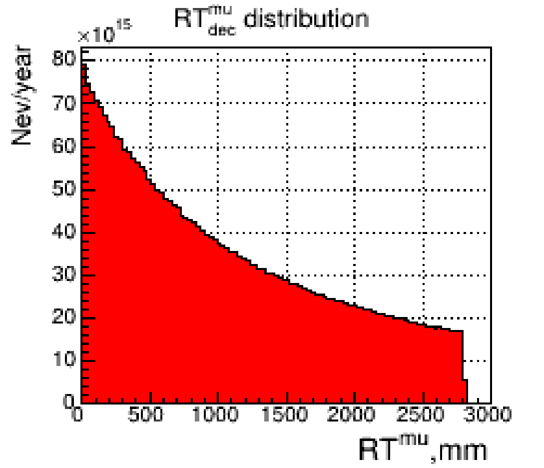
Together with the cut E, PT > 1 GeV

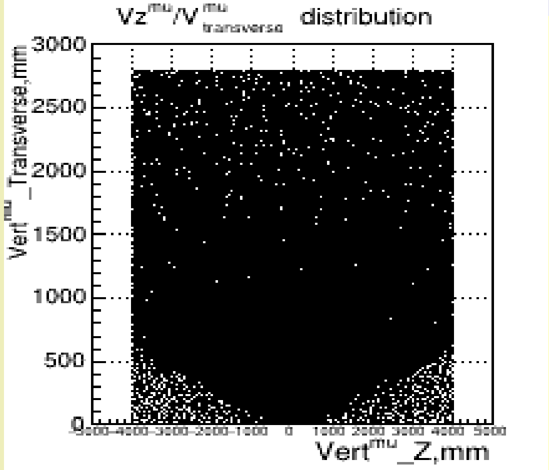
Supposing 100 % - without Minv cut

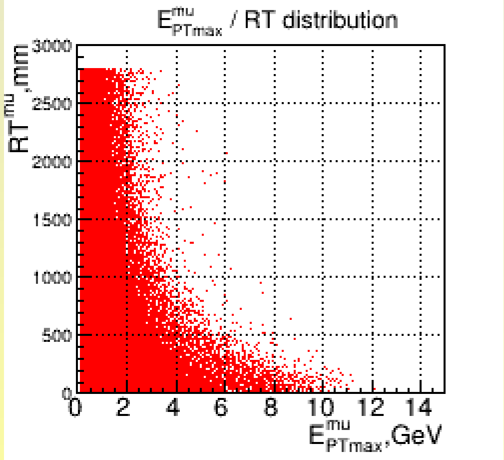
M_{inv} cut	Rest of BKG	Cut efficiency	Rest of sig	Cut efficiency	S/B
$M^{\mu\mu}_{inv}$ > 0.9 GeV	76.7 %	1.3	100 %	1	0.038
$M^{\mu\mu}_{inv}$ > 1.0 GeV	73.8 %	1.35	99.4 %	1.006	0.039
$M^{\mu\mu}_{inv}$ > 1.5 GeV	64.4 %	1.55	39.2 %	2.55	0.021
$M^{\mu\mu}_{inv}$ > 2.0 GeV	55.8 %	1.79	21.1 %	4.73	0.013
$M^{\mu\mu}_{inv}$ > 2.5 GeV	35.9 %	2.78	12.6 %	7.9	0.010
$M^{\mu\mu}_{inv}$ > 3.0 GeV	19.7 %	5.06	7.6 %	13.1	0.014
$M^{\mu\mu}_{inv}$ > 3.5 GeV	9.7 %	10.3	4.5 %	21.9	0.019
$M^{\mu\mu}_{inv}$ > 4.0 GeV	5.2 %	19.1	2.7 %	36.7	0.018
$M^{\mu\mu}_{inv}$ > 4.5 GeV	3.1 %	31.6	1.6 %	61.6	0.030
$M^{\mu\mu}_{inv}$ > 5.0 GeV	2.0 %	48.5	1.0 %	101.5	0.046

Vertex distributions









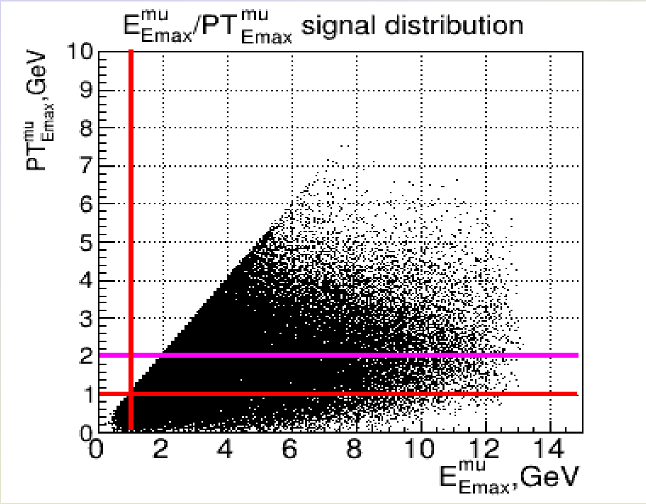
$R = \sqrt{(x^2+y^2+z^2)}$

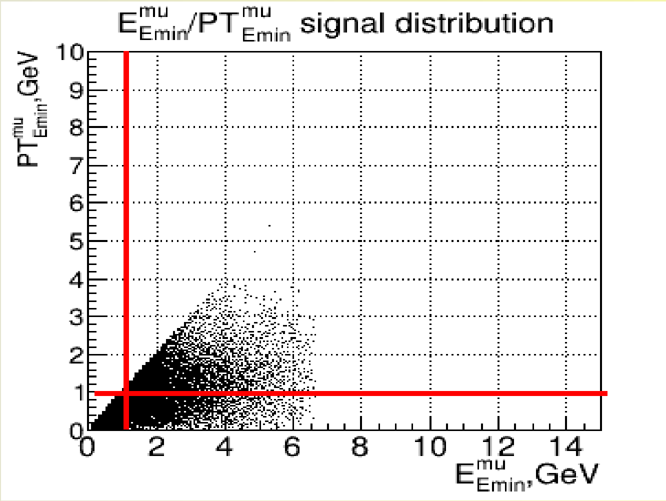
$RT = \sqrt{(x^2+y^2)}$

E^{mu}_{PTmax} - energy of leading μ with max PT

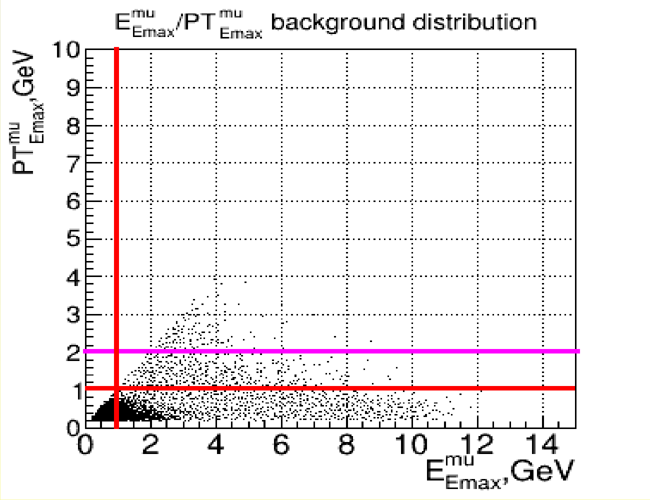
E^{μ}/PT^{μ} correlations for muons with max(fast)/min(slow) E^{μ} in the pair

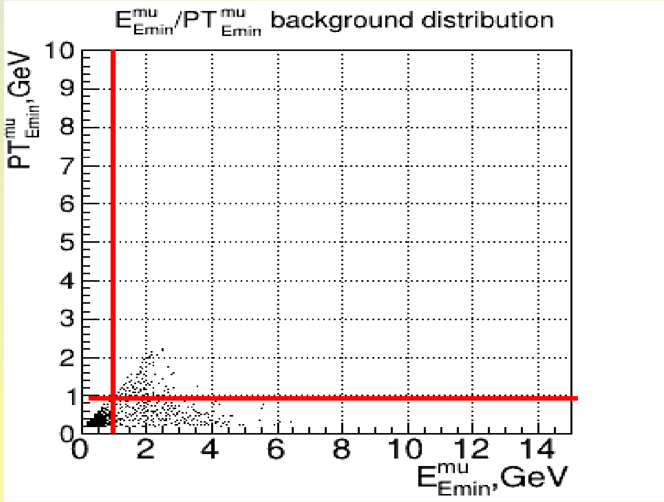
S
I
G





B
K
G



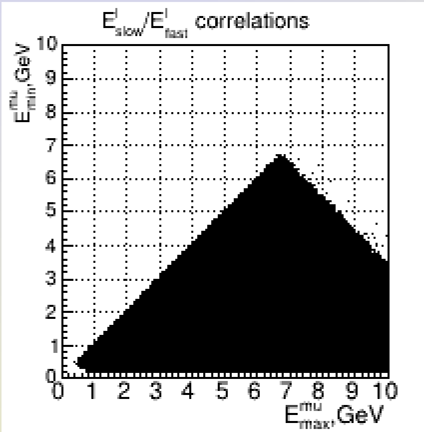


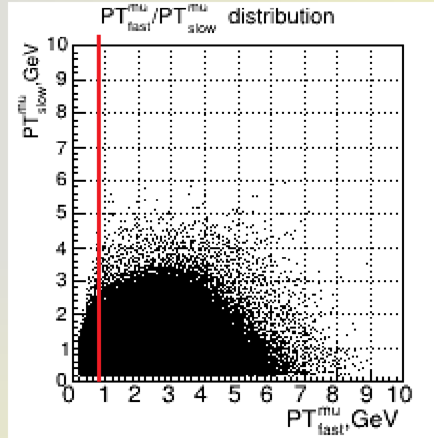
PT^{μ}_{Emax} > 2.0 GeV can also be considered

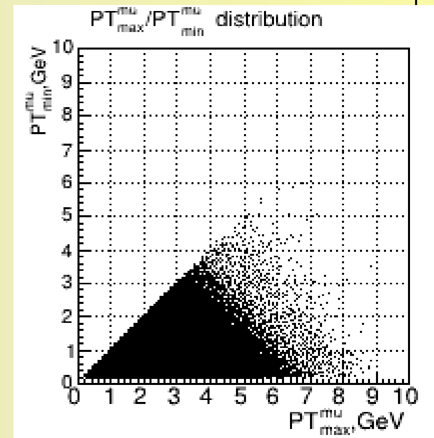
Cut on PT_l > 1.0 GeV and Eμ > 1.0 GeV

E_{max}(fast) /E_{min}(slow), PT_{fast}/PT_{slow}, PT_{max}/PT_{min} distributions

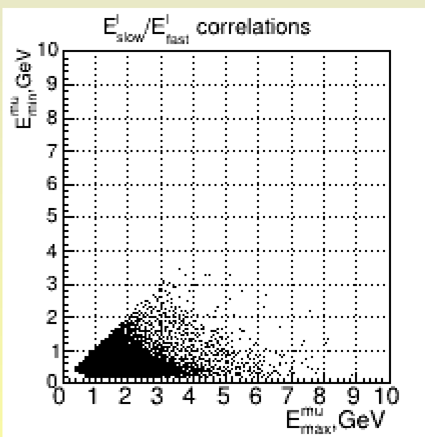
S I G

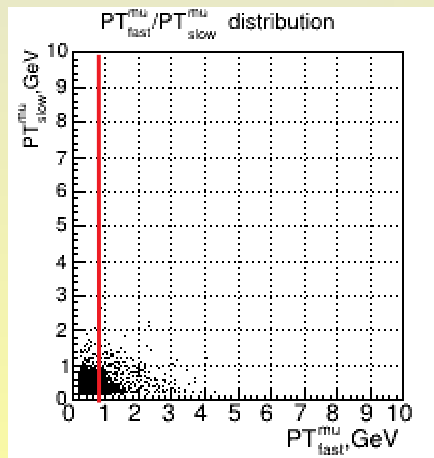


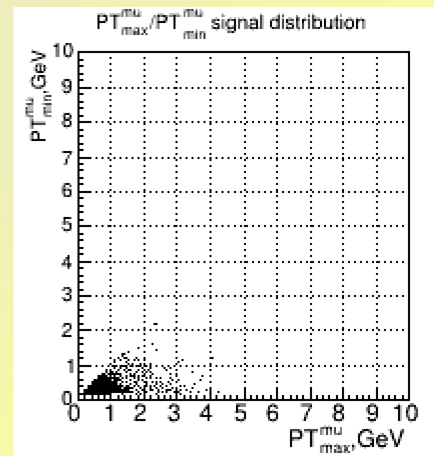




B K G



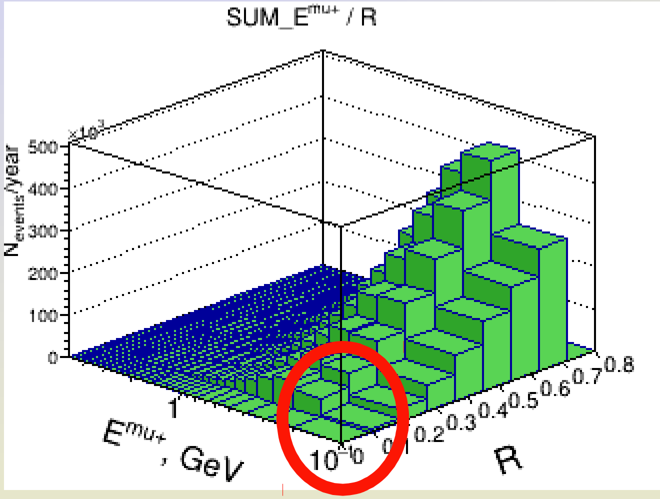


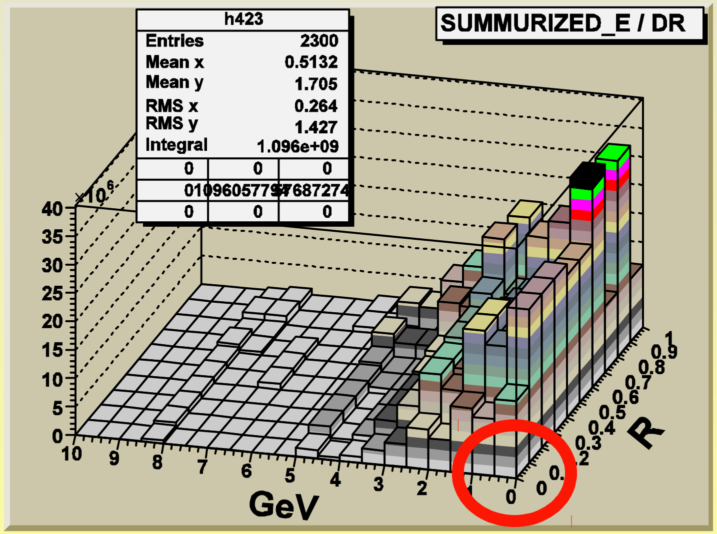


Proposed cuts

1. *Events with only 2 muons with* $PT_l > 1.0$ GeV, $E_l > 1.0$ GeV ($PT_l > 0.4$ GeV, $E_l > 0.8$ GeV & $PT^{\mu}_{Emax} > 1.0$ *GeV*)
2. *Muons are of the opposite sign*
3. *Minv* $(l^+, l^-) > 0.9$ *GeV*
4. *The vertex of origin lies within the distance from the interaction point* < 1 *mm*
5. *Isolation criteria* $E^{sum}_{(R\ isolation = 0.2)} > 0.5$ *GeV*

Lepton (μ) isolation criteria





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 **Mini-bias background**

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

$E_{(of\ particles)}$ > 0.5 GeV

allows to separate most part
of Mini-bias & QCD bkg muons
with the loss of **0.7 %** of signal events

after applied 4 cuts discussed above

Cuts *separate* efficiency for mini-bias and QCD background events (10^9)

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- 3.1 x 10^7 /year
1 *Exactly 2μ* with **PT$_l$ > 1.0 GeV, E$_l$ > 1.0 GeV**	**$1.7 * 10^{-2}$**	Eff (1,init) = **286041**	3.5×10^{-4} %	4.8	20.9 %
2^{+1} *2μ are of the opposite sign*	**$2.9 * 10^{-2}$**	Eff (2,1) = **1.67**	2.1×10^{-4} %	1	20.9 %
3^{+2+1} ***$M_{inv}(\mu_1,\mu_2)$ > 0.9 GeV***	**$3.8 * 10^{-2}$**	Eff (3,2) = **1.3**	1.6×10^{-4} %	1	20.9 %
4^{+3+2+1} *The vertex is in R < 1 mm*	**2.8**	Eff (4,3) = **72.8**	2.2×10^{-6} %	1	20.9 %
5^{+3+2+1} ***PT^{μ}_{Emax} > 2.0 GeV***	**0.415**	Eff (5,3) = **30.2**	5.3×10^{-6} %	2.8	7.5 %
6^{+3+2+1} *Isolation criterium*	**> 59**	Eff (6,3) **>1602**	< 8.6×10^{-8} %	1.03	**20.2 %**

Cuts *separate* efficiency for mini-bias and QCD background events (10^9 - not enough)

$M^{\mu+\mu-}$ inv > 4.3 GeV *S/B = 1.7×10^{-9} !*

N of cuts	S/B ratio	*Efficiency for BKG*	Rest of BKG	*Efficiency for SIG*	Rest of SIG — 1.4 x 10^5 /year
1 *Exactly 2μ* with **PT$_l$ > 1.0 GeV, E$_l$ > 1.0 GeV**	**$3.9 * 10^{-4}$**	Eff (1,init) = **293599**	3.4×10^{-4} %	1.26	79.4 %
2^{+1} *2μ are of the opposite sign*	**$6.6 * 10^{-4}$**	Eff (2,1) = **1.7**	2.0×10^{-4} %	1	79.3 %
3^{+2+1} ***$M_{inv}(\mu_1,\mu_2)$ > 4.3 GeV***	**$1.2 * 10^{-2}$**	Eff (3,2) = **18**	1.2×10^{-5} %	~1	79.3 %
4^{+3+2+1} *The vertex is in R < 1 mm*	**> 1.3**	Eff (4,3) **> 113**	< 10^{-7} %	1	79.3 %
5^{+3+2+1} ***PT^{μ}_{Emax} > 2.0 GeV***	**$5.0 * 10^{-2}$**	Eff (5,3) = **6.6**	1.7×10^{-6} %	1.58	50.1 %
6^{+3+2+1} *Isolation criterium*	**> 0.8**	Eff (6,3) **> 113**	< 10^{-7} %	1.63	**48.6 %**

Processes with charmonium production – S/B ~7,6*10^{-3}

86) $g\,g \to J/\Psi + g \to \mu^+\mu^- + X$ R.Baier and R.Rücke, Z.Phys. **C19** (1983) 251

106) $g\,g \to J/\Psi + \gamma \to \mu^+\mu^- + X$ M.Drees and C.S.Kim, Z.Phys. **C53** (1991) 673

421) $g\,g \to c\bar{c}\ [{}^3S_1{}^{(1)}]\ g \to \mu^+\mu^- + X$

422) $g\,g \to c\bar{c}\ [{}^3S_1{}^{(8)}]\ g \to \mu^+\mu^- + X$

423) $g\,g \to c\bar{c}\ [{}^3S_0{}^{(8)}]\ g \to \mu^+\mu^- + X$

424) $g\,g \to c\bar{c}\ [{}^3P_J{}^{(8)}]\ g \to \mu^+\mu^- + X$

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

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

427) $g\,g \to c\bar{c}\ [{}^3S_1{}^{(1)}]\ q \to \mu^+\mu^- + X$

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

429) $q\,\bar{q} \to c\bar{c}\ [{}^1S_0{}^{(8)}]\ g \to \mu^+\mu^- + X$

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

431) $g\,g \to c\bar{c}\ [{}^3P_0\,({}^1)]\ g \to \mu^+\mu^- + X$

432) $g\,g \to c\bar{c}\ [{}^3P_1\,({}^1)]\ g \to \mu^+\mu^- + X$

433) $g\,g \to c\bar{c}\ [{}^3P_2\,({}^1)]\ g \to \mu^+\mu^- + X$

434) $g\,q \to c\bar{c}\ [{}^3P_0\,({}^1)]\ q \to \mu^+\mu^- + X$

435) $g\,q \to c\bar{c}\ [{}^3P_1\,({}^1)]\ q \to \mu^+\mu^- + X$

436) $g\,q \to c\bar{c}\ [{}^3P_2\,({}^1)]\ q \to \mu^+\mu^- + X$

437) $q\,q \to c\bar{c}\ [{}^3P_0\,({}^1)]\ g \to \mu^+\mu^- + X$

438) $q\,\bar{q} \to c\bar{c}\ [{}^3P_1\,({}^1)]\ g \to \mu^+\mu^- + X$

439) $q\,\bar{q} \to c\bar{c}\ [{}^3P_2\,({}^1)]\ g \to \mu^+\mu^- + X$

431, 433, 434, 436 – maximum contribution

G.T.Badwin, E.Braten and G.P.Lepage, Phys.Rev. **D51** (1995) 1125 [Erratum: *ibid* **D55** (1997) 5883];

M.Beneke, MKrämer and M.Vänttinen, Phys.Rev.**D57** (1998) 4258;

B.A.Kniehl and J.Lee, Phys.Rev. **D62** (2000) 114027

Cuts separate efficiency for charmonium background events (10^8)

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 > 1.0 GeV, E_l > 1.0 GeV**	**0.306**	Eff (1,init) = **170.8**	5.8 x 10^{-1} %	4.27	23.4 %
2^{+1} *2μ are of the opposite sign*	**0.307**	Eff (2,1) = **1.005**	5.8 x 10^{-1} %	1.003	23.3 %
3^{+2+1} ***$M_{inv}(\mu_1,\mu_2)$ > 0.9 GeV***	**0.307**	Eff (3,2) = **1.001**	5.8 x 10^{-1} %	1.003	23.2 %
4^{+3+2+1} *The vertex is in R < 1 mm*	**0.302**	Eff (4,3) = **1.007**	5.7 x 10^{-1} %	1.02	22.7 %
5^{+3+2+1} ***PT^{μ}_{Emax} > 2.0 GeV***	**0.348**	Eff (5,3) = **2.19**	2.6 x 10^{-1} %	1.93	12.0 %
6^{+3+2+1} *Isolation criterium*	**> 175138**	Eff (6,3) > **577184**	< 1.01 x 10^{-6} %	1.01	**23.0 %**

Cuts separate efficiency for charmonium background events (10^8)

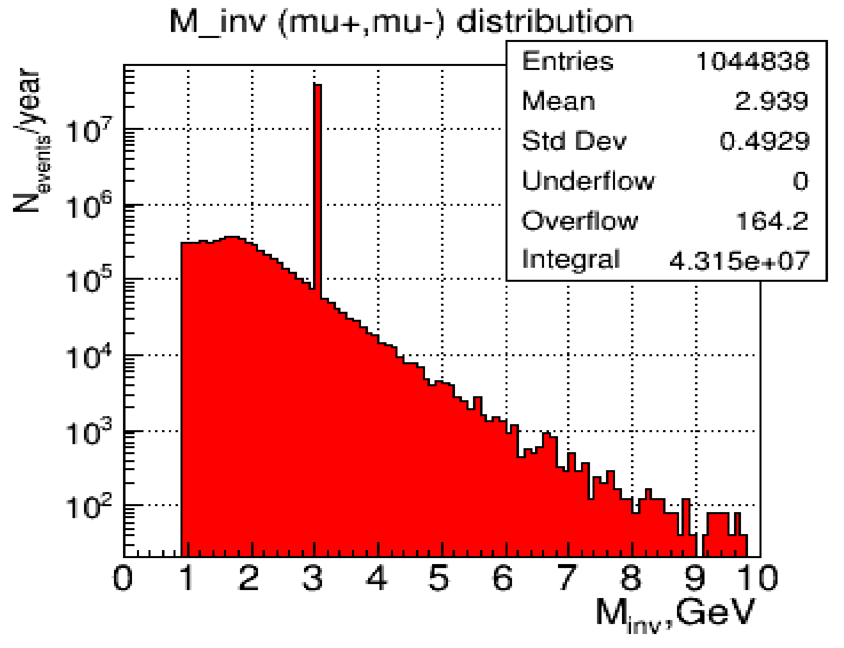
N of cuts	S/B ratio	*Efficiency for BKG*	Rest of BKG	*Efficiency for SIG*	Rest of SIG
1 *Exactly 2μ* with **PT_l > 0.4 GeV, E_l > 0.8 GeV**	**0.32**	Eff (1,init) = **79.9**	1.2 %	1.92	52.1 %
2^{+1} *2 μ are of the opposite sign*	**0.36**	Eff (2,1) = **1.14**	1.1 %	1,01	51.3 %
3^{+2+1} ***$M_{inv}(l_1,l_2)$ > 0.9 GeV***	**0.37**	Eff (3,2) = **1.004**	1.05 %	1,00	51.0 %
4^{+3+2+1} *The vertex is in R < 1 mm*	**0.27**	Eff (4,3) = **1.16**	0.9 %	1,60	31.8 %
5^{+3+2+1} ***PT^{μ}_{Emax} > 1.0 GeV***	**0.39**	Eff (5,3) = **1.22**	0.86 %	1.16	44.0 %
6^{+3+2+1} *Isolation criteria*	**> 377979**	Eff (6,3) > **1044838**	< 1.01 x 10^{-6} %	1.03	**49.6 %**

For charmoniums background Vertex information doesn“t work.

Cut on PT of leading muon weakly helps.

The best criterium - the isolation criterium.

Additional S/B reduction can be achieved by excluding the resonance Minv peaks.



Cuts separate efficiency for mini-bias and QCD background events (10^9)

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 2 μ* with **PT$_l$ > 0.4 GeV, E$_l$ > 0.8 GeV**	**2.1 * 10 $^{-4}$**	Eff (1,init) = **1606**	6.2 x 10^{-2} %	2.17	46 %
2^{+1} *2 μ are of the opposite sign*	**3.7 * 10 $^{-4}$**	Eff (2,1) = **1.76**	3.5 x 10^{-2} %	1.02	45 %
3^{+2+1} ***$M_{inv}(\mu_1,\mu_2)$ > 0.9 GeV***	**4.7 * 10 $^{-4}$**	Eff (3,2) = **1.28**	2.7 x 10^{-2} %	1.01	44.7%
4^{+3+2+1} ***PT^{μ}_{Emax} > 1.0 GeV***	**6.9 * 10 $^{-3}$**	Eff (4,3) = **19.7**	1.4 x 10^{-3} %	1.34	33.3 %
5^{+3+2+1} *The vertex is in R < 1 mm*	**0.158**	Eff (5,3) = **334**	8.2 x 10^{-5} %	1	44.7%
6^{+3+2+1} *Isolation criterium*	**3.5**	Eff (6,3) = **7656**	3.6 x 10^{-6} %	1.03	**43.3 %**

Cuts summarized efficiency for mini-bias and QCD background events (10^9)

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 2 μ* with **PT$_l$ > 0.4 GeV, E$_l$ > 0.8 GeV**	$2.1 * 10^{-4}$	Eff (1,init) = **1606**	6.2×10^{-2} %	2.17	46 %
2^{+1} *2μ are of the opposite sign*	$3.7 * 10^{-4}$	Eff (2,1) = **1.76**	3.5×10^{-2} %	1.02	45 %
3^{+2+1} $M_{inv}(\mu_1,\mu_2)$ **> 0.9 GeV**	$4.7 * 10^{-4}$	Eff (3,2) = **1.28**	2.7×10^{-2} %	1.01	44%
4^{+3+2+1} PT^{μ}_{Emax} > **1.0 GeV**	$6.1 * 10^{-3}$	Eff (4,3) = **19.7**	1.4×10^{-3} %	1.5	29 %
5$^{+4+3+2+1}$ *The vertex is in R < 1 mm*	**1.75**	Eff (5,4) = **5625**	4.9×10^{-6} %	1.5	29%
6$^{+5+4+3+2+1}$ *Isolation criterium*	**> 86**	Eff (6,5) > **275635**	< 1×10^{-7} %	1.5	**29 %**

Conclusion

The proposed cuts:

1. *Events with only 2 leptons of the opposite sign*

   and E_l > 0.8 GeV, PT_l > 0.4 GeV (& PT^{μ}_{Emax} > 1.0 GeV)

2. *The vertex of origin lies within the distance from the interaction point < 1 mm*

3. *Minv* $(l^+, l^-) > 0.9$ *GeV*

4. Isolation criteria $E_{(R\ isolation\ =\ 0.2)} > 0.5$ GeV

*Allow to suppress **for muons** QCD & Mini-bias bkgd up to **S/B > 80** with the **loss of signal ~ 70%***

Further study with SPDRoot is needed