



Modeling of J/ψ Production and $\pi^+ \pi^- \rightarrow \mu^+ \mu^-$ Background for SPD at NICA

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PYTHIA8 Parameters for J/ψ ($pp, \sqrt{s} = 27 \text{ GeV}$)

Processes: “Charmonium:all =on” PDF: “MRST2004qed_proton” nEvents: 100 000 000

```

*----- PYTHIA Event and Cross Section Statistics -----*
Subprocess                                Code |           Number of events
                                           Tried  Selected  Accepted |           sigma +- delta
                                           |           |           |           |           (estimated) (mb)
-----|-----|-----|-----|-----|-----
g g -> ccbar(3S1)[3S1(1)] g                401 |    137281   57189   57186 |    4.887e-06  9.831e-09
g g -> ccbar(3S1)[3S1(8)] g                402 |    13531    4540   4539 |    3.891e-07  2.697e-09
q g -> ccbar(3S1)[3S1(8)] q                403 |    21711    7598   7598 |    6.447e-07  3.401e-09
q qbar -> ccbar(3S1)[3S1(8)] g            404 |     5010    1964   1964 |    1.679e-07  1.714e-09
g g -> ccbar(3S1)[1S0(8)] g                405 |    65403   22919   22919 |    1.964e-06  5.846e-09
q g -> ccbar(3S1)[1S0(8)] q                406 |    41899    8429   8429 |    7.032e-07  3.400e-09
q qbar -> ccbar(3S1)[1S0(8)] g            407 |       216     103     103 |    7.432e-09  3.449e-10
g g -> ccbar(3S1)[3PJ(8)] g                408 |   134283   42542   42541 |    3.647e-06  7.685e-09
q g -> ccbar(3S1)[3PJ(8)] q                409 |    87317   15617   15617 |    1.337e-06  4.806e-09
q qbar -> ccbar(3S1)[3PJ(8)] g            410 |       1990      858     858 |    6.961e-08  1.115e-09
g g -> ccbar(3PJ)[3PJ(1)] g                411 |   2628771  641253  641242 |    5.479e-05  3.013e-08
q g -> ccbar(3PJ)[3PJ(1)] q                412 |  1368649  182959  182956 |    1.563e-05  1.511e-08
q qbar -> ccbar(3PJ)[3PJ(1)] g            413 |    25486   10783   10783 |    9.155e-07  4.153e-09
g g -> ccbar(3PJ)[3S1(8)] g                414 |       892     289     289 |    2.502e-08  6.985e-10
q g -> ccbar(3PJ)[3S1(8)] q                415 |    1779     597     597 |    5.302e-08  9.926e-10
q qbar -> ccbar(3PJ)[3S1(8)] g            416 |       594     202     202 |    1.714e-08  5.473e-10
g g -> ccbar(3DJ)[3DJ(1)] g                417 |       789     160     160 |    1.383e-08  5.319e-10
g g -> ccbar(3S1)[3S1(1)] gamma            441 |     5004    1998    1998 |    1.702e-07  1.810e-09
sum                                         |  4540605  1000000  999981 |    8.543e-05  3.750e-08
*----- End PYTHIA Event and Cross Section Statistics -----*

```

- 1470431 dimuon events were selected
- After normalisation to $L_{\text{int}} = 1 \text{ fb}^{-1}$: 1255689 Events (At SPD CDR 12000000 is expected)
- $\sigma_{J/\psi \rightarrow \mu^+\mu^-} = 1.256 \text{ nb}$ (At SPD CDR $\sim 12 \text{ nb}$ is expected)

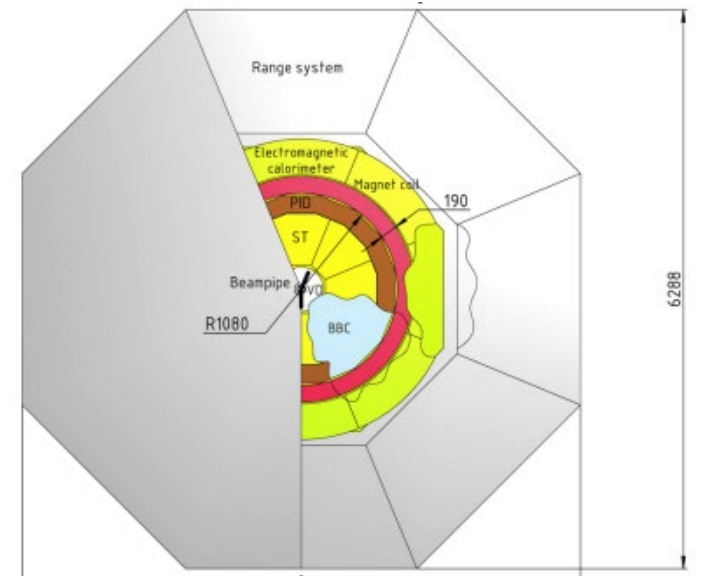
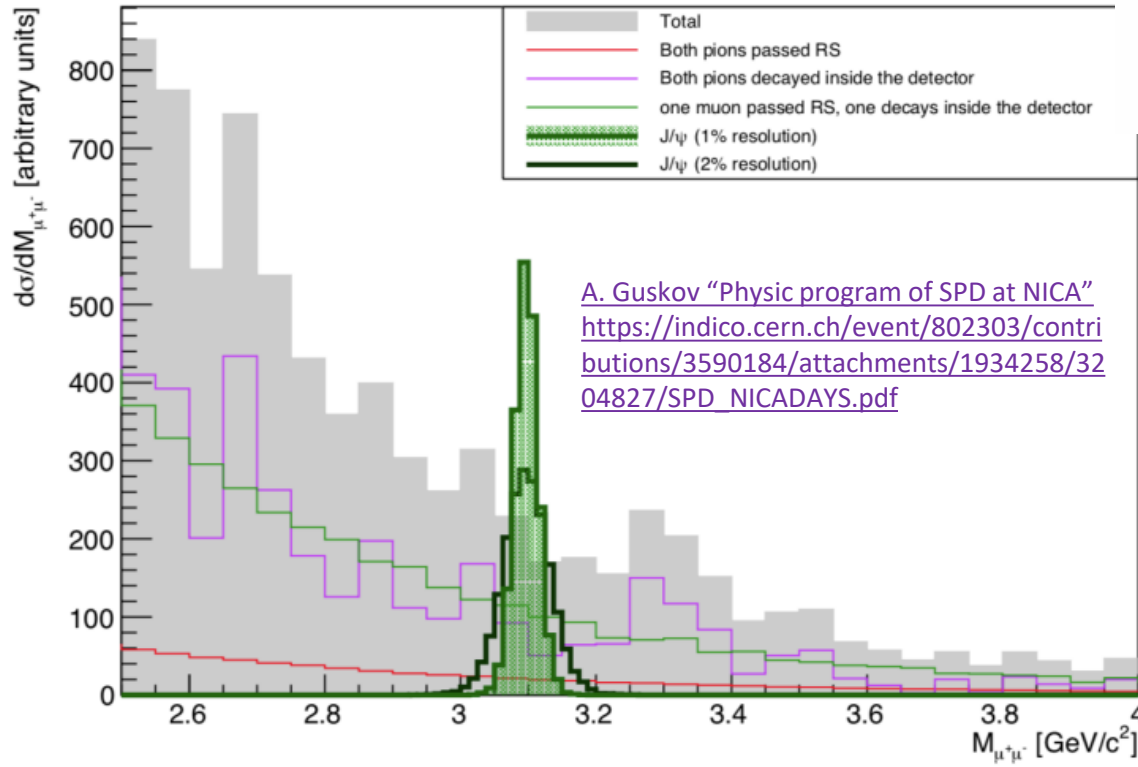
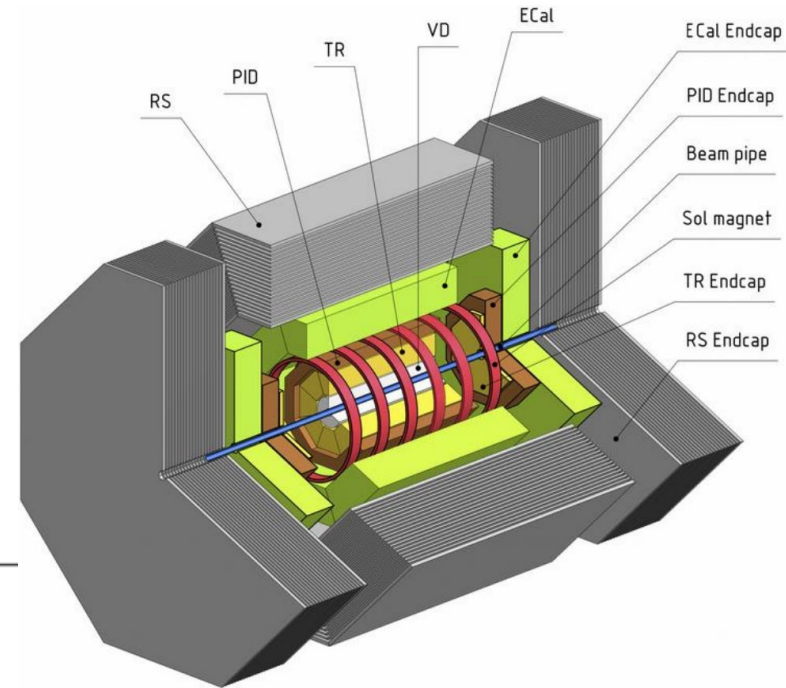
Why?



$\pi^+\pi^-\rightarrow\mu^+\mu^-$ Background

Types of Pions Background

1. Both of pions decayed inside the detector (before Range System)
2. The first pion decayed before RS. The second one was misidentified in RS as muon
3. Both of pions were misidentified in RS as muons





PYTHIA8 Parameters for Background (pp, $\sqrt{s} = 27$ GeV)

Processes: "HardQCD:all =on"

PDF: "MRST2004qed_proton"

nEvents: 10 000 000 000

```
*----- PYTHIA Event and Cross Section Statistics -----*
```

Subprocess	Code	Number of events			sigma +- delta (estimated) (mb)	
		Tried	Selected	Accepted		
g g -> g g	111	2101050	300917	300904	1.081e+00	1.070e-03
g g -> q qbar (uds)	112	22223	3802	3802	1.403e-02	1.253e-04
q g -> q g	113	4038530	504003	503985	1.813e+00	1.435e-03
q q(bar)' -> q q(bar)'	114	1730020	189152	189142	6.783e-01	8.219e-04
q qbar -> g g	115	6177	1090	1090	3.956e-03	6.544e-05
q qbar -> q' qbar' (uds)	116	2257	374	374	1.339e-03	3.856e-05
g g -> c cbar	121	3951	548	548	1.972e-03	4.912e-05
q qbar -> c cbar	122	942	114	114	4.153e-04	2.221e-05
g g -> b bbar	123	2	0	0	0.000e+00	0.000e+00
q qbar -> b bbar	124	0	0	0	0.000e+00	0.000e+00
sum		7905152	1000000	999959	3.594e+00	1.976e-03

```
*----- End PYTHIA Event and Cross Section Statistics -----*
```

Pions decay:

- Pions decay ON

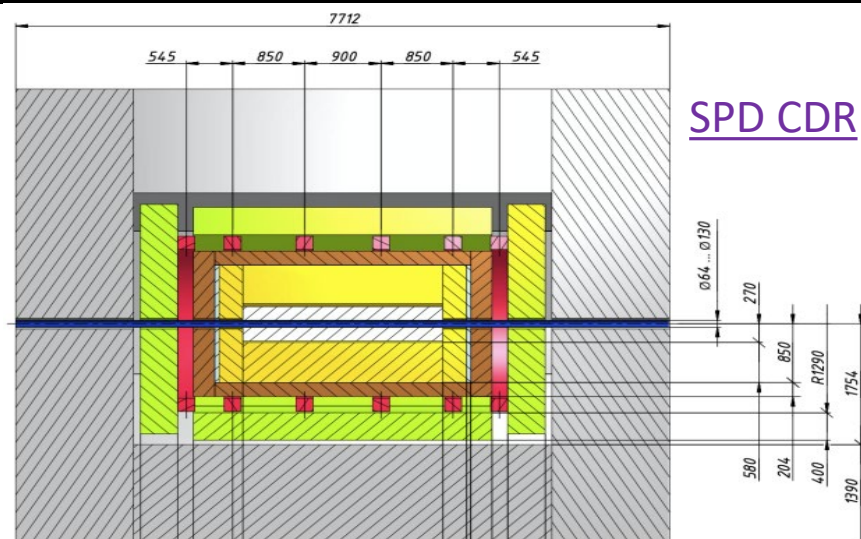
```
pythia.readString("211:mayDecay = true");
pythia.readString("-211:mayDecay = true");
```

- Cylindrical volume which pions can decay in

```
pythia.readString("ParticleDecays:limitCylinder = on ");
pythia.readString("ParticleDecays:xyMax = 4446.3 ");
pythia.readString("ParticleDecays:zMax = 3856. ");
```

flag ParticleDecays:limitCylinder (default = off)

When on, only particles with a decay within a volume limited by $\rho = \sqrt{x^2 + y^2} < xyMax$ and $|z| < zMax$ are decayed.





Dimuons Selection in Background

Selection conditions

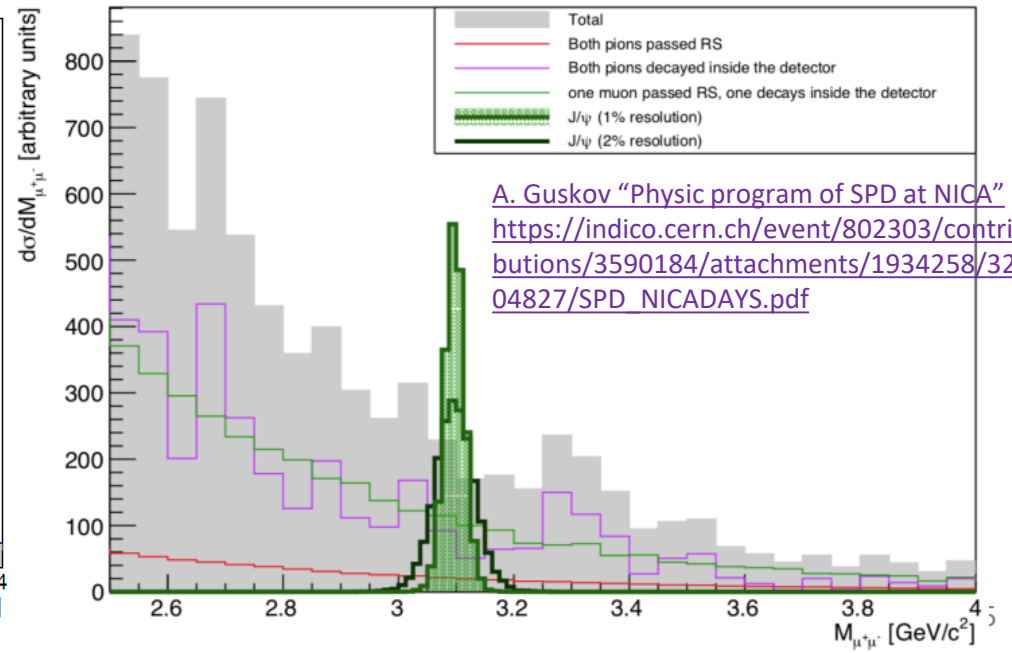
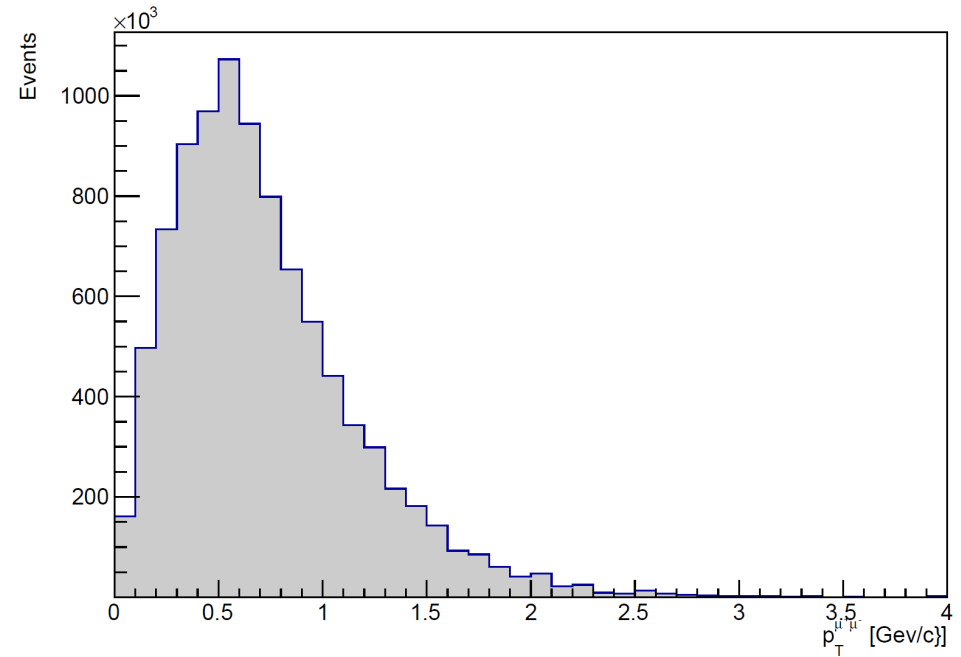
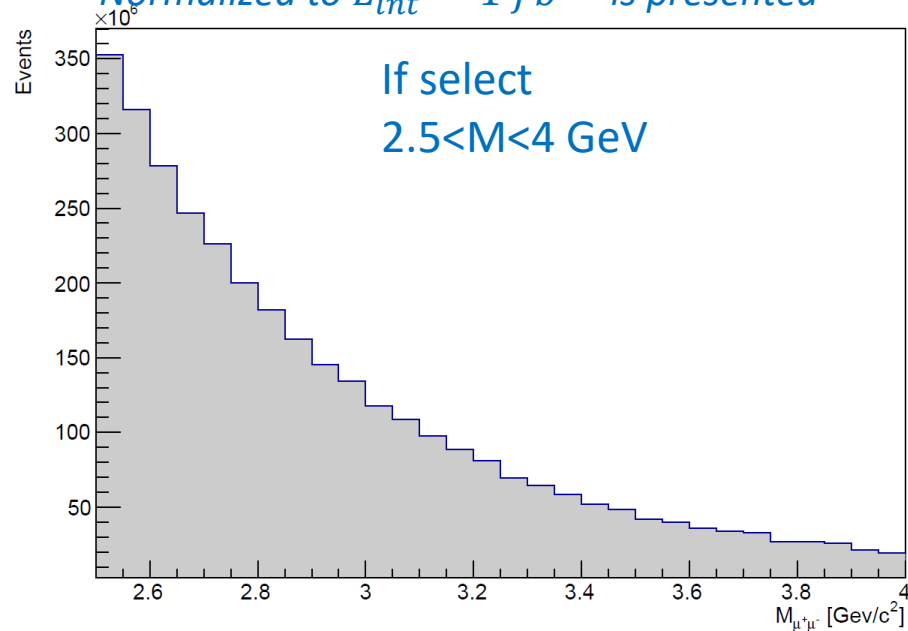
- Muon should be from pion decay
- Just one couple of opposite charged muons in one events was selected (but in one event could me more)
- Different combinations of muons were considered. Couple with $3.095 < M < 3.0995$ GeV was selected

Events selected: 25964 events

Cross Section: $\sigma = 9.34$ nb

Normalized to $L_{int} = 1 fb^{-1}$ is presented

If select
 $2.5 < M < 4$ GeV





First Signal/Background Comparison

Cross sections at $3.095 < M < 3.0995$ GeV

$$\sigma_{J/\psi \rightarrow \mu^+\mu^-} = 1.256 \text{ nb}$$

$$\sigma_{\pi^+\pi^- \rightarrow \mu^+\mu^-} = 9.34 \text{ nb}$$

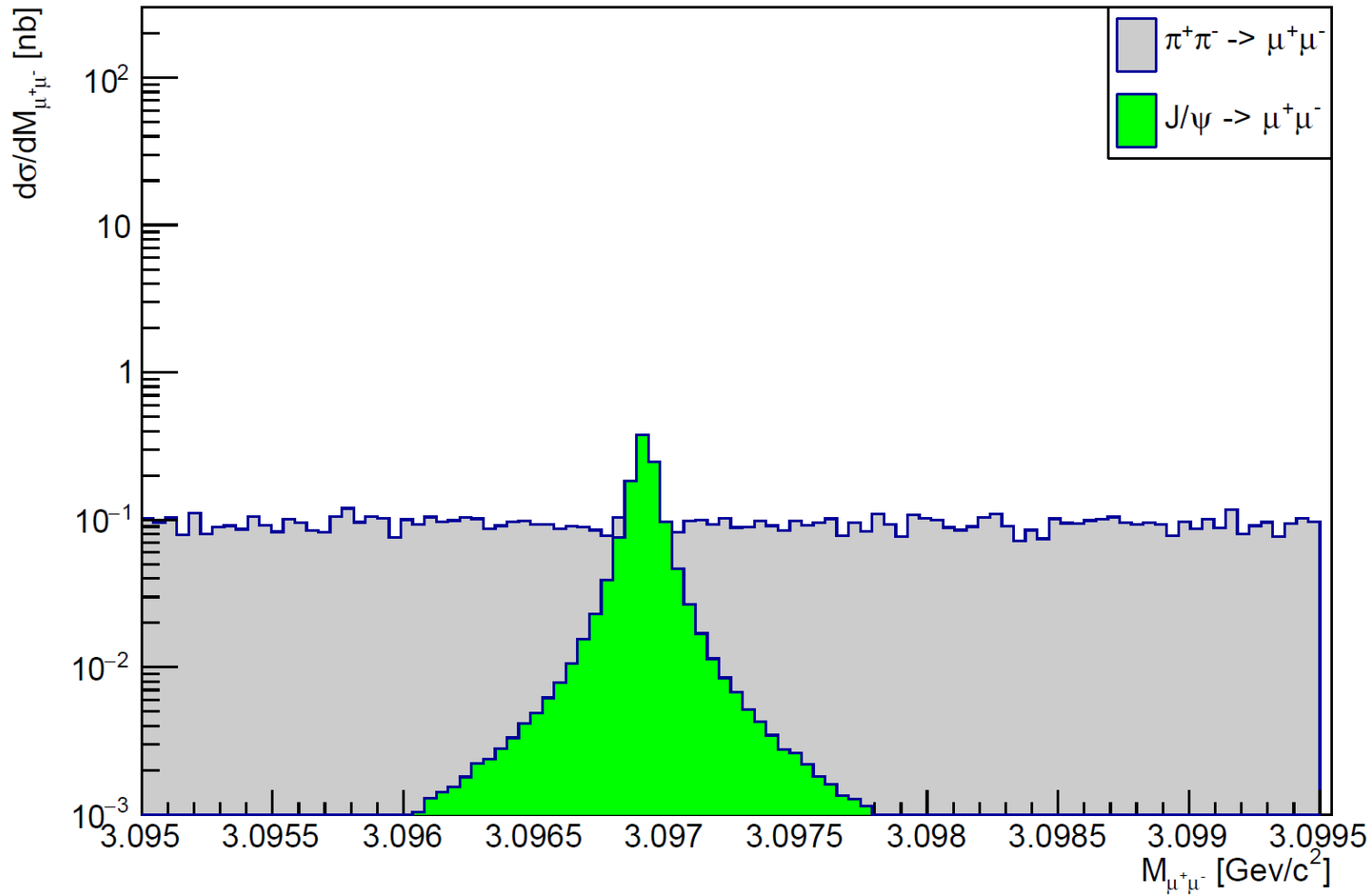
$$\frac{\sigma_S}{\sigma_B} \sim 0.14$$

Cross sections at $3.096 < M < 3.0978$ GeV

$$\sigma_{J/\psi \rightarrow \mu^+\mu^-} = 1.256 \text{ nb}$$

$$\sigma_{\pi^+\pi^- \rightarrow \mu^+\mu^-} = 1.9 \text{ nb}$$

$$\frac{\sigma_S}{\sigma_B} \sim 0.66$$





Dimuons Selection in Background

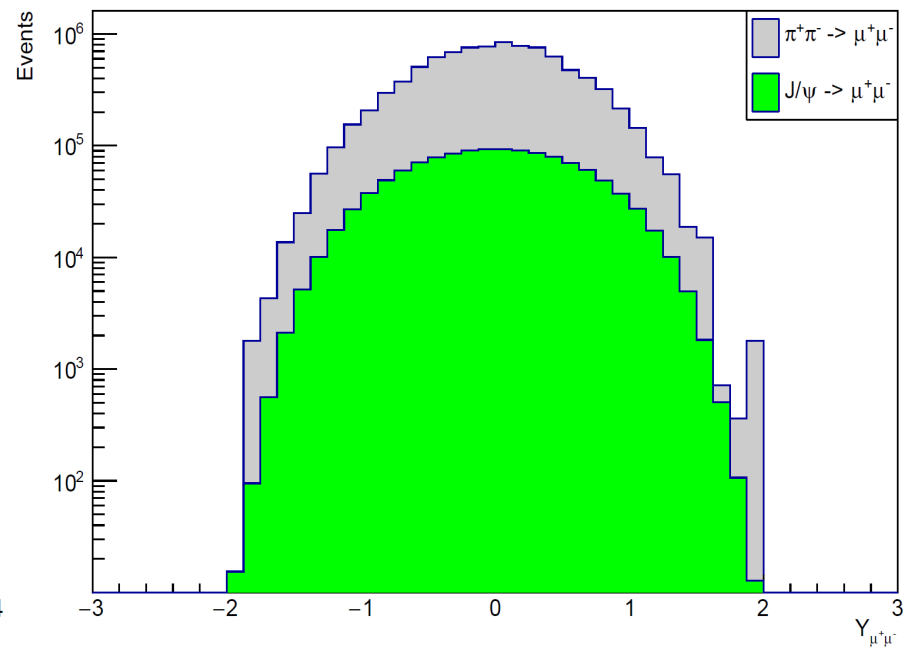
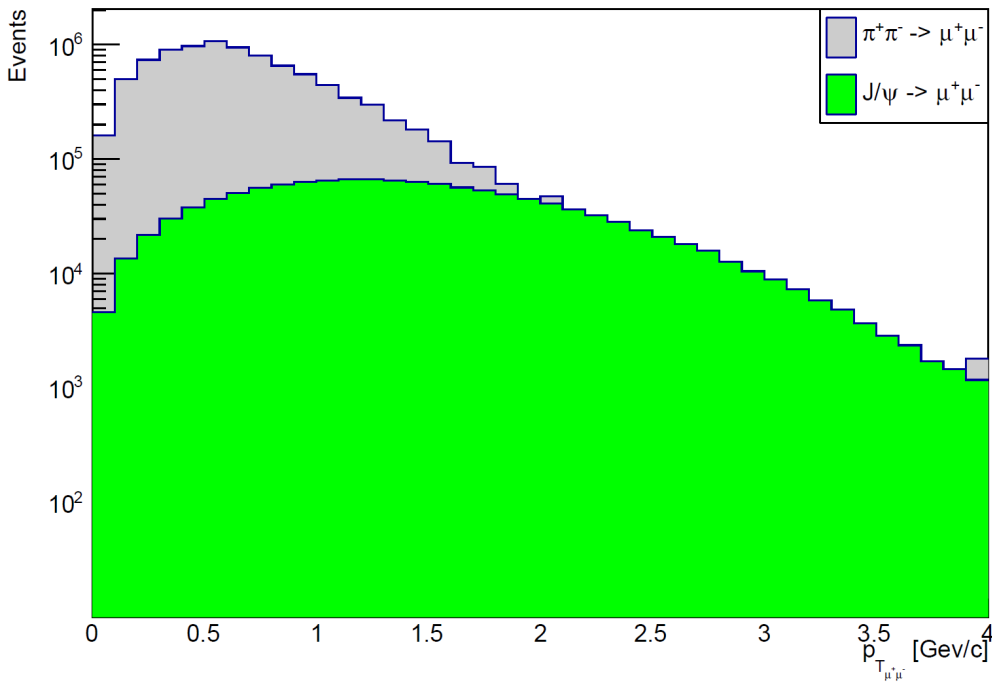
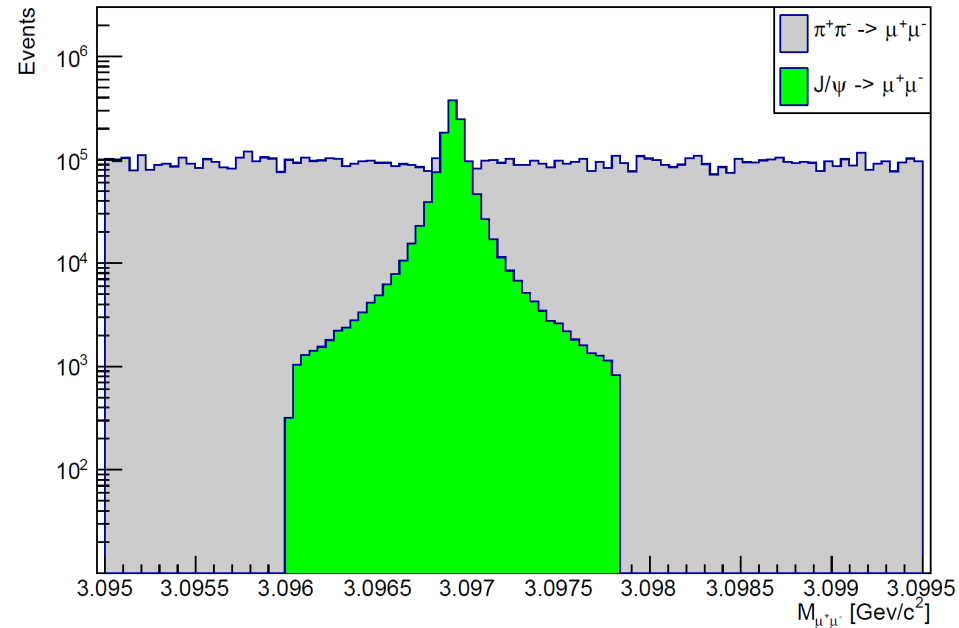
Cross sections at $3.095 < M < 3.0995$ GeV

$$\sigma_{J/\psi \rightarrow \mu^+\mu^-} = 1.256 \text{ nb} \quad \frac{\sigma_S}{\sigma_B} \sim 0.14$$
$$\sigma_{\pi^+\pi^- \rightarrow \mu^+\mu^-} = 9.34 \text{ nb}$$

Cross sections at $3.096 < M < 3.0978$ GeV

$$\sigma_{J/\psi \rightarrow \mu^+\mu^-} = 1.256 \text{ nb} \quad \frac{\sigma_S}{\sigma_B} \sim 0.66$$
$$\sigma_{\pi^+\pi^- \rightarrow \mu^+\mu^-} = 1.9 \text{ nb}$$

Normalized to $L_{int} = 1 \text{ fb}^{-1}$ is presented



J/ψ simulation using SPDRoot

Using processes:

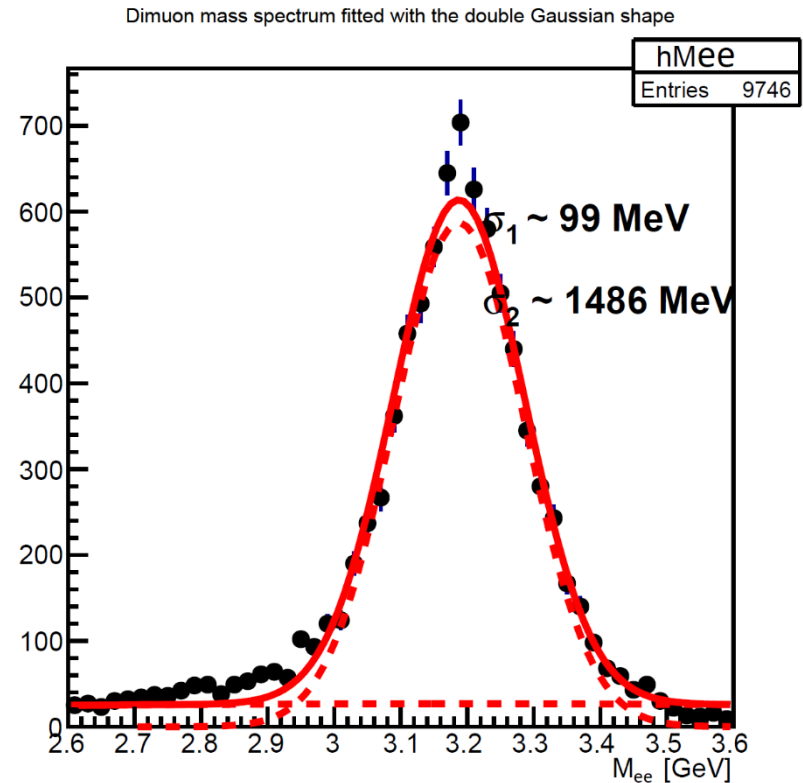
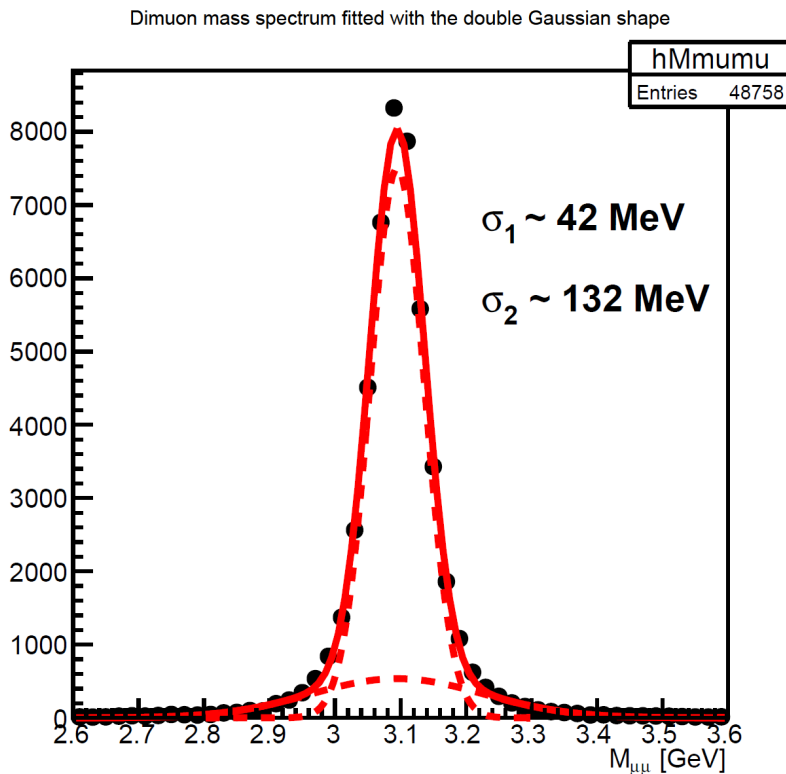
```
"Charmonium:gg2ccbar(3S1)[3S1(1)]g = on,off";  
"Charmonium:gg2ccbar(3S1)[3S1(8)]g = on,off";  
"Charmonium:qg2ccbar(3S1)[3S1(8)]q = on,off";  
"Charmonium:qqbar2ccbar(3S1)[3S1(8)]g = on,off";  
"Charmonium:gg2ccbar(3S1)[1S0(8)]g = on,off";  
"Charmonium:qg2ccbar(3S1)[1S0(8)]q = on,off";  
"Charmonium:qqbar2ccbar(3S1)[1S0(8)]g = on,off";
```

```
"Charmonium:gg2ccbar(3S1)[3PJ(8)]g = on,off";  
"Charmonium:qg2ccbar(3S1)[3PJ(8)]q = on,off";  
"Charmonium:qqbar2ccbar(3S1)[3PJ(8)]g = on,off";
```

Decay mode (always to mu+ mu-):

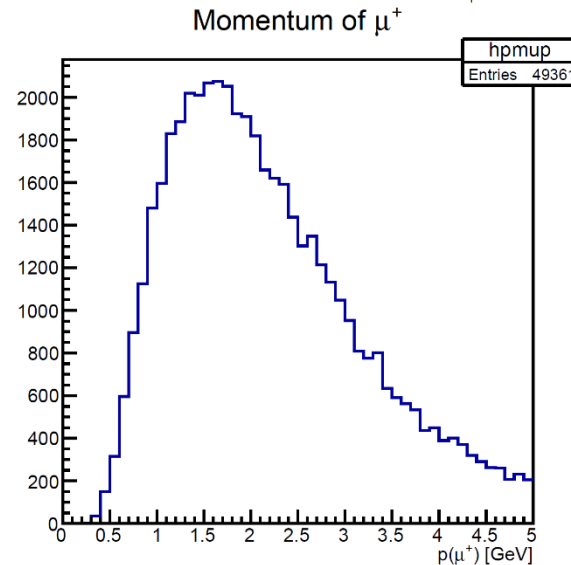
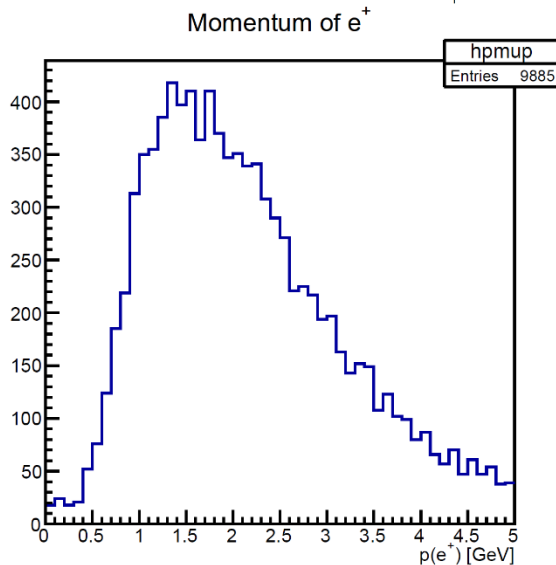
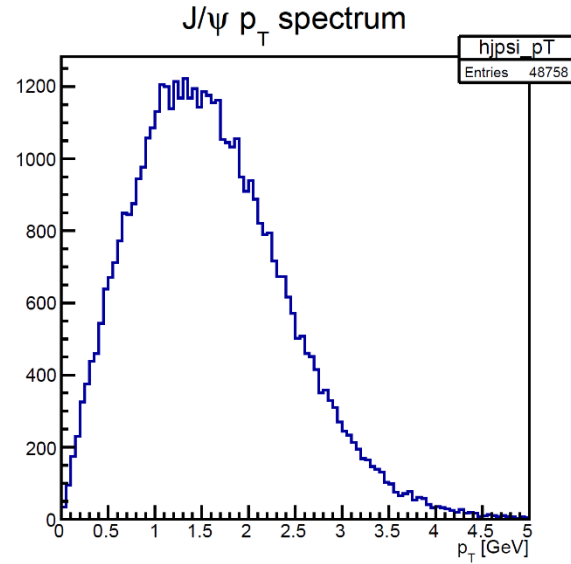
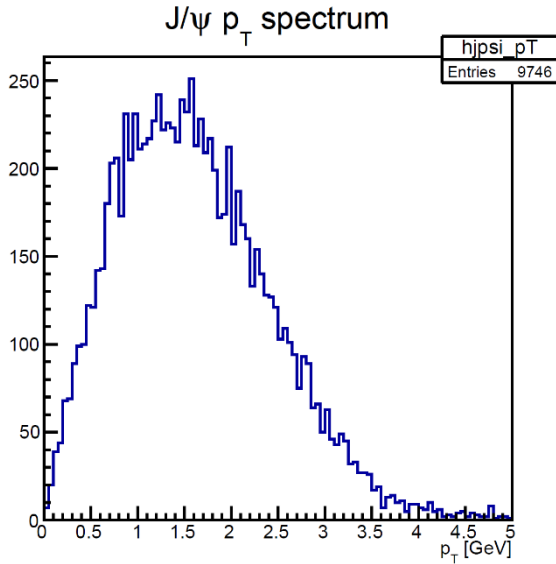
```
"443:onMode = off"  
"443:onIfAny = 13 -13"
```

Invariant mass distributions of muon (left) and electron (right) pairs of J/ψ decay.
Generated 50.000 and 10.000 of events, respectively.



J/ψ simulation using SPDRoot

Distributions of J/ψ p_T and e^+ (left) / μ^+ (right) p_T from corresponding channels of decay





Conclusions

J/ ψ production at NICA conditions was studied with PYTHIA8:

- ✓ 100 000 000 Charmonium:all events were generated
- ✓ 1470431 Events were selected
- ✓ After normalisation to $L_{\text{int}} = 1 \text{ fb}^{-1}$: 1255689 Events (At SPD CDR 12000000 is expected)
- ✓ $\sigma_{J/\psi \rightarrow \mu^+\mu^-} = 1.256 \text{ nb}$ (At SPD CDR $\sim 12 \text{ nb}$ is expected)

First steps in J/ ψ simulation using SPDRot were also done:

- ✓ First kinematic plots for $J/\psi \rightarrow \mu^+\mu^-$ and $J/\psi \rightarrow e^+e^-$ were obtained

An "upper estimate" of the background cross section for the observation of J/ ψ from pairs of charged pions was made using a MC generator PYTHIA8

- ✓ 10 000 000 000 QCD:all events were generated
- ✓ 25964 were selected
- ✓ Ratio $\frac{\sigma_{J/\psi \rightarrow \mu^+\mu^-}}{\sigma_{\pi^+\pi^- \rightarrow \mu^+\mu^-}} \sim 0.66$ (From results we have at this moment at $3.096 < M < 3.0978$ GeV)

- Continue work with SPDRot: Using batch systems to achieve more statistics
- Background Simulation with SPDRot
- Background separation to different categories