$J/\psi + \gamma$ simulation at SPD

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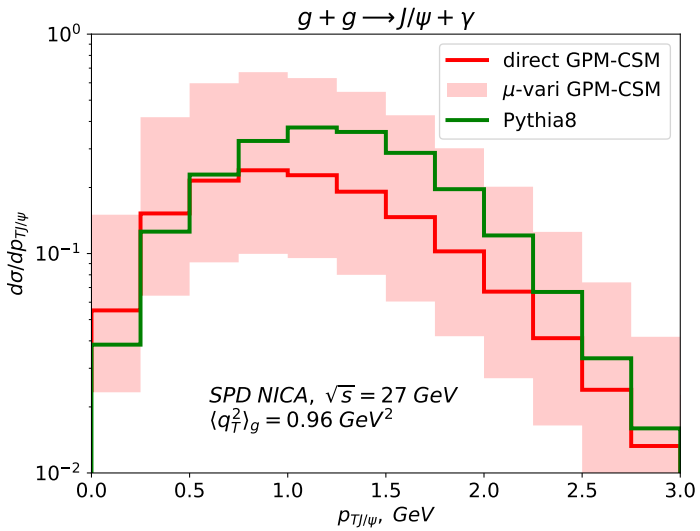
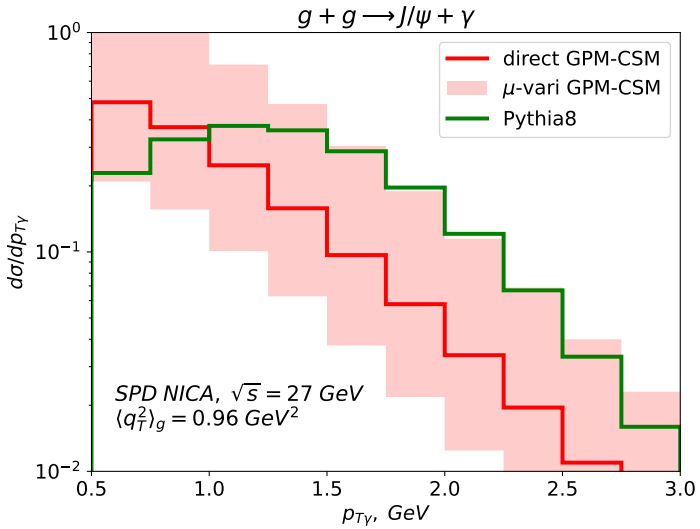
Introduction

Motivation:

- In leading order it can only be produced via gluon fusion $\rightarrow$ can serve as a very clean probe of the gluon densities inside the proton
- Sensitive to the intrinsic transverse momentum of partons $\rightarrow$ serve as a microscope on parton behaviour in the transverse plane
- (Daniël Boer, NICA SPD talk 2020) Clear probe TMD f-type Sivers gluon fuction

Estimation





- (left image) Calculating in gpm and pythia has good coincidence.
- Number of events per year estimation:

$$\sigma = 0.33\ nb$$
$$Br(J/\psi \to \mu^+\mu^-) = 0.06$$
$$L = 10^{32}\ s^{-1}cm^{-2} = 0.1\ s^{-1}nb^{-1}$$
$$N_{year} = \sigma * L * T * Br \sim 22200$$

Modeling I

Collinear model and leading order

$i = 1, 2;\ q_i^\mu = x_i P_i^\mu;\ P_i^{x,y} = 0 \ \Rightarrow$
$(q_{J/\psi} + q_\gamma)_T = 0;\ \Delta\phi = \phi_{J/\psi} - \phi_\gamma = \pi\ rad,\ |y_{J/\psi} - y_\gamma| = 0.$

Changing CPM correlations

- start particle $q_T \neq 0$
- $k > 1$, $n^k lo$ (we don't have)
- experimental error of the momentum ($\sim 1.5\%$).

In Pythia, distribution for last particles

$s = x,\ y;\ f(q_T^s) = \exp\left[-(q_T^s)^2/(2\sigma^2)\right]/(\sigma\sqrt{2\pi})$
σ — internal computated width

Not Back-To-Back

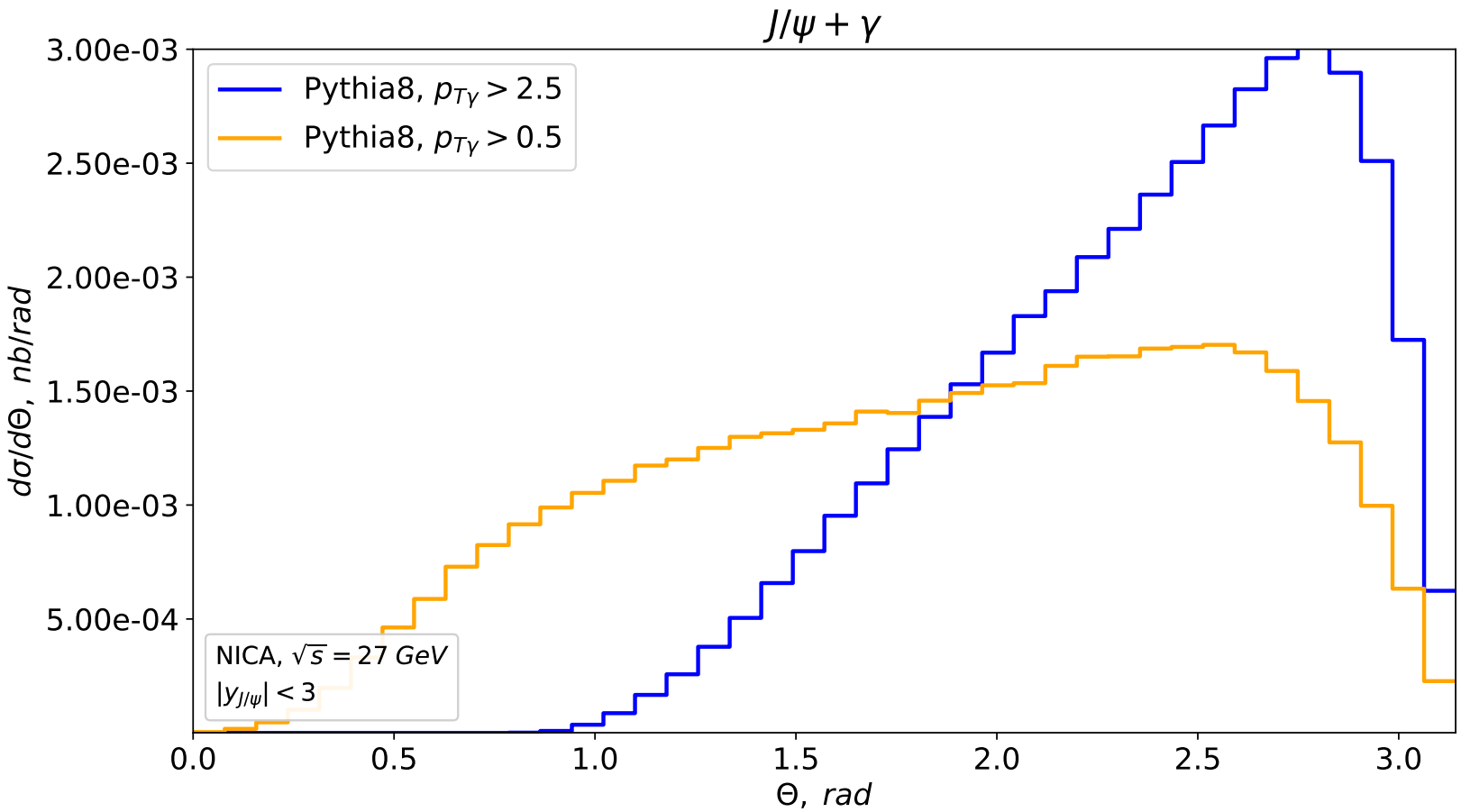


Рис.: Θ - the angle between the final particles

Modeling II

Signal: $g + g \to J/\psi(^3S_1^{(1)}) + \gamma$ AND combinatiorial background
Background 1: $h + \bar{h} \to J/\psi(^3S_1^{(1)}, {}^1S_0^{(8)}, {}^3P_J^{(8)}) + g$, $h = g, q$
Background 2: softQCD

Background: (100% of non-J/ψ's $\mu^{\pm}$) + (1% of $\pi^{\pm}$)

$$\begin{pmatrix} Weight & 0.01 & 1 & 1 & \dots \\ Particle & \pi^+ & \mu^+ & \mu^+ & \dots \end{pmatrix} \otimes \begin{pmatrix} Weight & 1 & 0.01 & 0.01 & \dots \\ Particle & \mu^- & \pi^- & \pi^- & \dots \end{pmatrix}$$

$$\Downarrow$$

$$\begin{pmatrix} Weight(product) & 0.01 & 1 & 1e-4 & \dots \\ Pair & (\pi^+, \mu^-) & (\mu^+, \mu^-) & (\pi^+, \pi^-) & \dots \end{pmatrix}$$

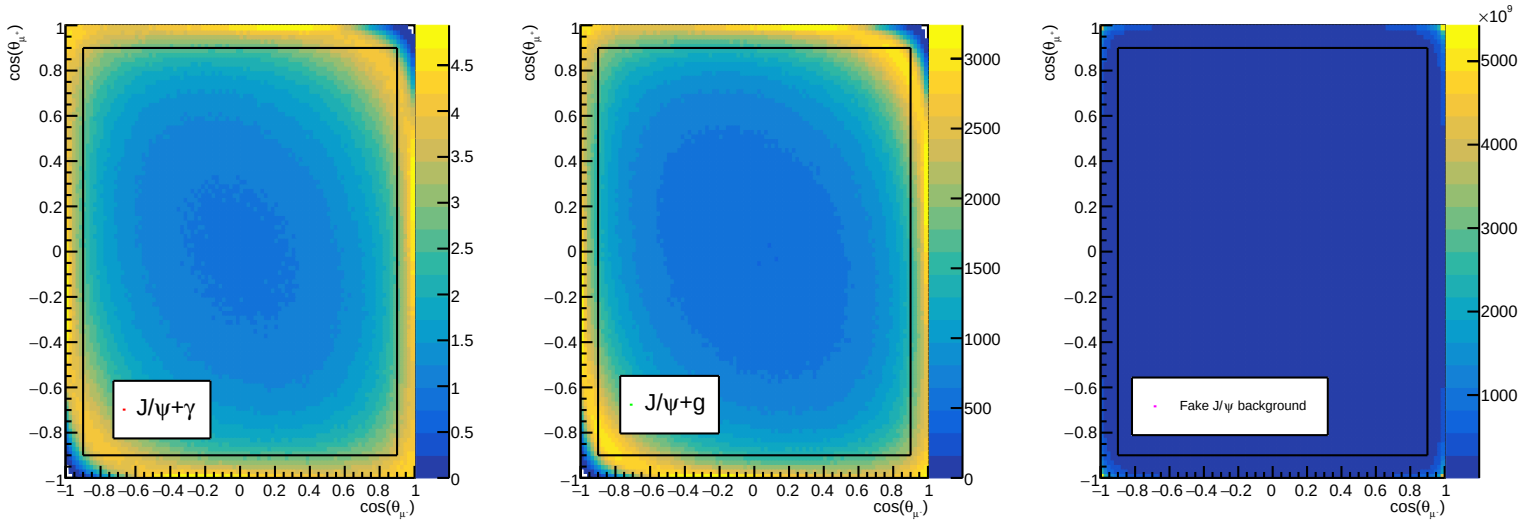
momentum error ($\sim 1.5\%$)

$\vec{p} = \vec{p} * \xi$, ξ - gaussian random variable ($\sigma = 0.015$, mean=1)

$|\cos(\theta_{\mu^+,\mu^-})| < 0.9$

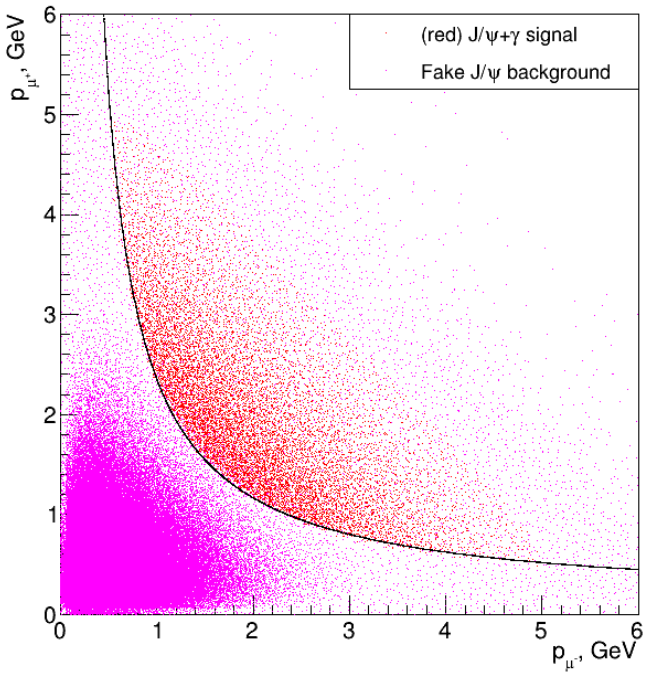
was generated	$J/\psi + \gamma$	$J/\psi + g$	Minimal bias
N_{event}	5×10^7	5×10^7	10^9

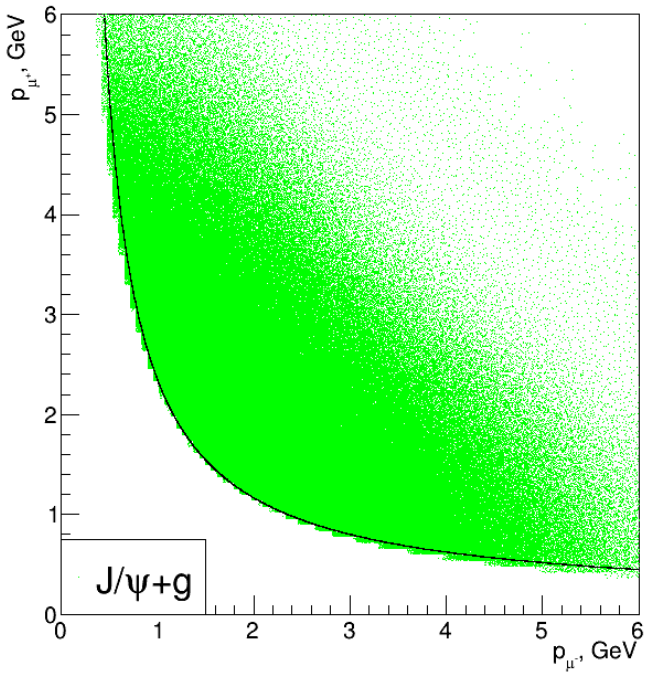
Further, all histograms are normalized by the number of events per year.



Standart cut for J/ψ reconstruction: $|\cos(\theta_{\mu^+})|$, $|\cos(\theta_{\mu^-})| < 0.9$

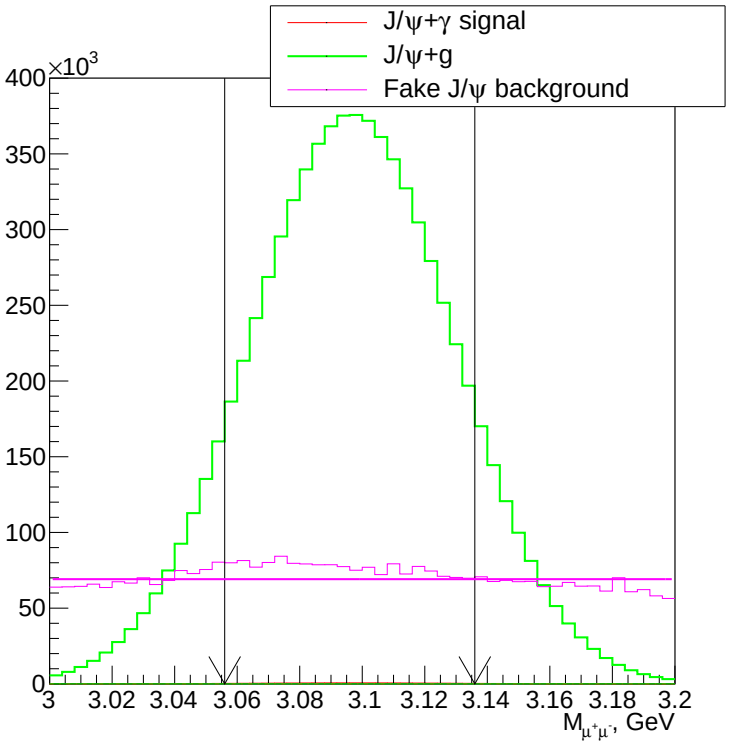
Pair (p_{μ^+}, p_{μ^-}) cut





Add non standart cut: $f(p_{\mu^-}) = 2/(p_{\mu^-} - a) + a$, $a = 0.11$

$M_{(\mu^+\mu^-)}$



- Inclusive J/ψ should be reconstructed well
- For $J/\psi + \gamma$ reconstruction we need to study correlations
- For $J/\psi + \gamma$ and $J/\psi + g$ separation, consider the γ transverse momentum
- Will add candidate invariant mass cut to estimate background: $|M_{(\mu^+\mu^-)} - m_{J/\psi}| < 40\ MeV$

$p_{T\gamma}$

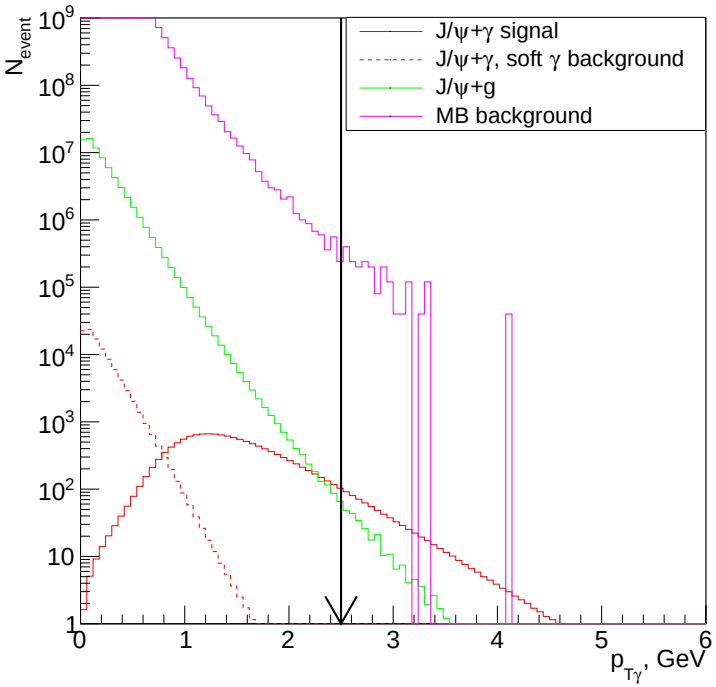


Рис.: Cuts at the moment $|\cos(\theta)| < 0.9$, $f(p_{\mu^-}) < p_{\mu^+}$, $|M_{(\mu^+\mu^-)} - m_{J/\psi}| < 40\ MeV$

- The $J/\psi + \gamma$ combinatorial background is completely removed
- unsatisfactory MB background statistics

γ-isolation

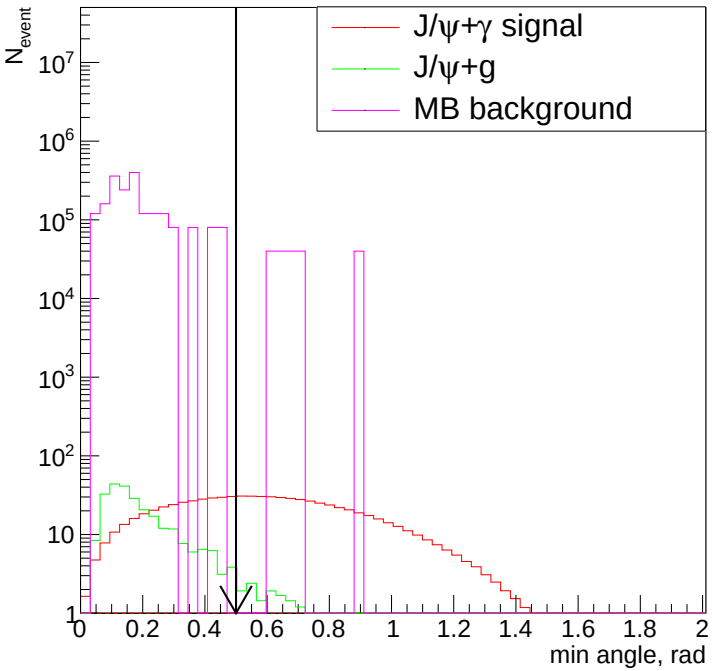


Рис.: After the requirement $p_{T\gamma} > 2.5\ GeV$

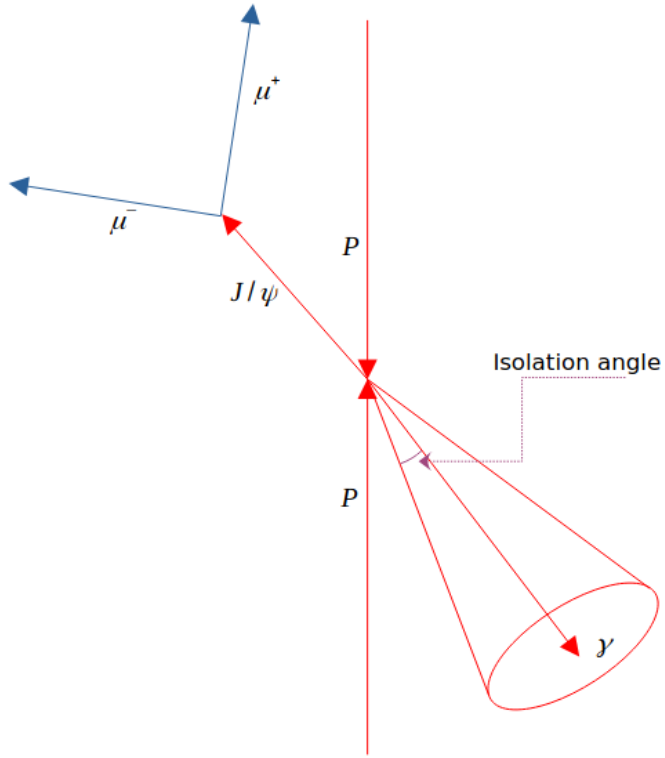
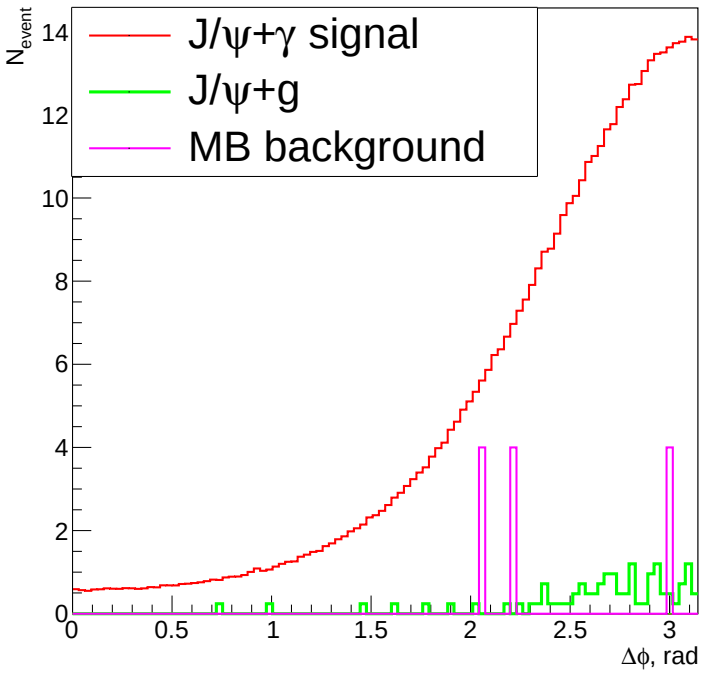


Рис.: There are no photons and tracks in some solid angle

Rates

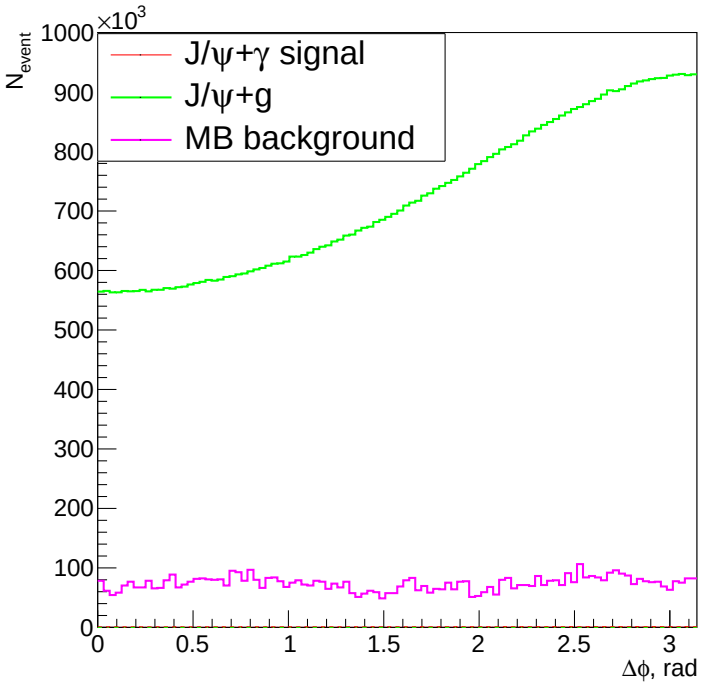
rate	$J/\psi + \gamma$	$J/\psi + g$	MB
$\lvert cos(\theta)\rvert < 0.9$	0.67	0.65	0.75
$f(p_{\mu^-}) < p_{\mu^+}$	0.986	0.987	0.07
$\lvert M_{(\mu^+\mu^-)} - m_{J/\psi}\rvert < 40\ MeV$	0.78	0.78	0.01
$p_{T\gamma} > 2.5 GeV$	0.06	4×10^{-5}	10^{-4}
Isolation cut	0.6	0.07	0.4
efficiency	1.8×10^{-2}	1.1×10^{-6}	2×10^{-8}

$\Delta\phi$-correlation



- $J/\psi + \gamma_{soft}$ (from $J/\psi + g$) and $J/\psi + \gamma$ signal are correlated
- It may be possible to delete jpsi+g remnants event like in prompt photon reconstruction algorithm.
- unsatisfactory background statistics

$\Delta\phi$-correlation



- actually MB background expects uncorrelated !!

- The number of events taking into account the efficiency of determining J/ψ ($\sim 40\%$): $N_{year} \sim 190$.
- Signal and $J/\psi + g$ background are correlated.
- There are potential problem: additional background from the fact that we can take π^0 for a high-energy photon.
- We could not conduct a realistic simulation in the spd nica package because there is not enough laptop capacity and there is no access to the supercomputer.