High-mass dimuon and secondary charmonium spectra in heavy ion collisions at the LHC

I.P. Lokhtin, A.M. Snigirev,
(SINP MSU, Moscow, Russia)

- PYQUEN - model of jet quenching in heavy ion collisions
- Mechanisms of heavy quark production
- Medium-induced energy loss of b-quarks and dimuon spectra
- Summary

Monte-Carlo models to simulate jet quenching and flow effects in HIC

- PYQUEN - fast code to simulate jet quenching (modify PYTHIA6.4 jet event), http://cern.ch/lokhtin/pyquen

- HYDJET - merging soft part (with including flow effects) and multijets generated with PYQUEN http://cern.ch/lokhtin/hydro/hydjet.html

HydjetRHIC and PyquenRHIC are also available by web

The codes are included in LHC generator database GENSER

(HYDJET1_1 and PYQUEN 1_1 are latest versions)

I. Lokhtin, A. Snigirev, Eur. Phys. J. C 46 (2006) 211

Medium-induced partonic energy loss

General kinetic integral equation:

$$\Delta E(L,E)=\int_0^L dx\,\frac{dP}{dx}(x)\,\lambda(x)\,\frac{dE}{dx}(x,E),\quad \frac{dP}{dx}(x)=\frac{1}{\lambda(x)}\exp(-x/\lambda(x))$$

1. Collisional loss and elastic scattering cross section:

$$\frac{dE}{dx}=\frac{1}{4T\lambda\sigma}\int_{\mu_D^2}^{t_{max}} dt\,\frac{d\sigma}{dt}t,\quad \frac{d\sigma}{dt}\simeq C\frac{2\pi\alpha_s^2(t)}{t^2},\quad \alpha_S=\frac{12\pi}{(33-2N_f)\ln(t/\Lambda_{QCD}^2)},\quad C=9/4\ (gg),\ 1\ (gq),\ 4/9(qq)$$

2. Radiative loss (BDMS):

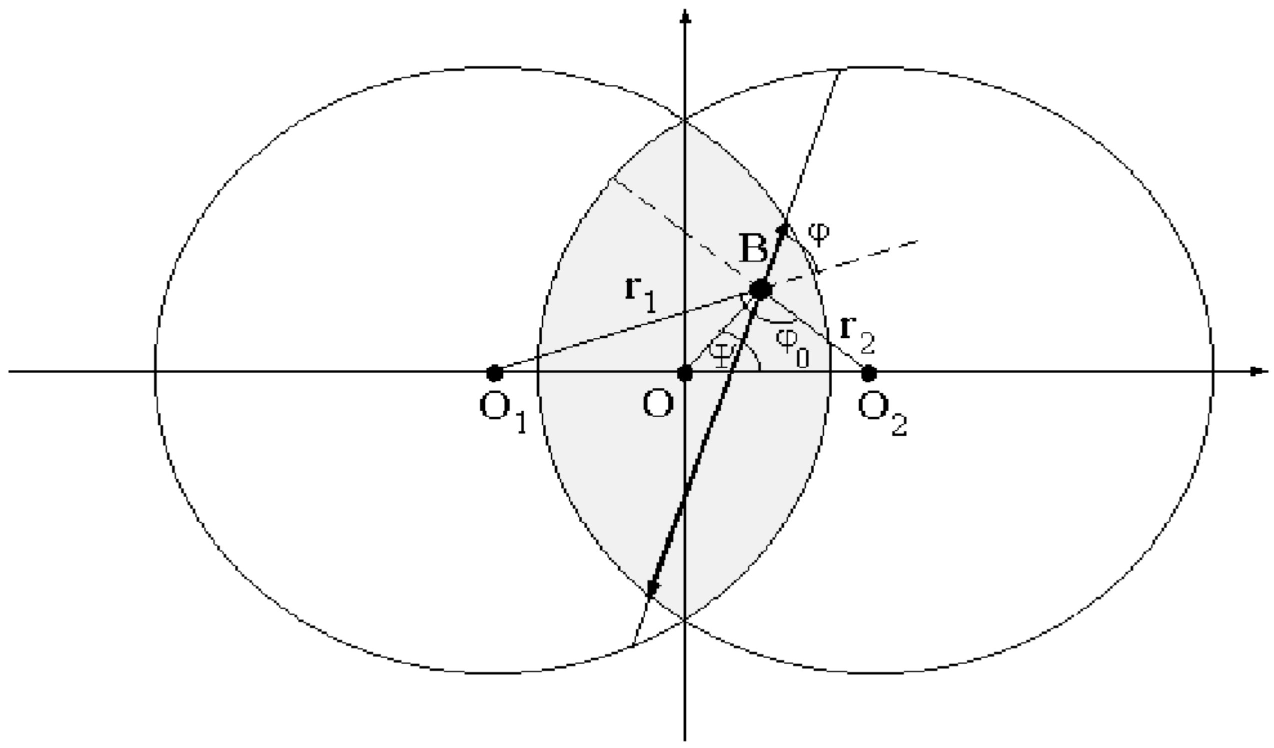
$$\frac{dE}{dx}(m_q=0)=\frac{2\alpha_s C_F}{\pi\tau_L}\int_{E_{LPM}\sim\lambda_g\mu_D^2}^{E} d\omega\left[1-y+\frac{y^2}{2}\right]\ln\left|\cos(\omega_1\tau_1)\right|,\quad \omega_1=\sqrt{i\left(1-y+\frac{C_F}{3}y^2\right)\bar{k}\ln\frac{16}{\bar{k}}},\quad \bar{k}=\frac{\mu_D^2\lambda_g}{\omega(1-y)},\quad \tau_1=\frac{\tau_L}{2\lambda_g},\quad y=\frac{\omega}{E},\quad C_F=\frac{4}{3}$$

"dead cone" approximation for massive quarks:

$$\frac{dE}{dx}(m_q\neq0)=\frac{1}{\left(1+(l\omega)^{3/2}\right)^2}\frac{dE}{dx}(m_q=0),\qquad l=\left(\frac{\lambda}{\mu_D^2}\right)^{1/3}\left(\frac{m_q}{E}\right)^{4/3}$$

Nuclear geometry and QGP evolution

impact parameter b≡ |O_1O_2| - transverse distance between nucleus centers



Space-time evolution of QGP, created in region of initial overlaping of colliding nuclei, is descibed by Lorenz-invariant Bjorken's hydrodynamics J.D. Bjorken, PRD 27 (1983) 140

Monte-Carlo simulation of parton rescattering and energy loss in QGP

- Distribution over jet production vertex $V(r\cos\psi, r\sin\psi)$ at im.p. b

$$\frac{dN}{d\psi\,dr}(b)=\frac{T_A(r_1)T_A(r_2)}{\int_0^{2\pi} d\psi \int_0^{r_{max}} rdrT_A(r_1)T_A(r_2)}$$

- Transverse distance between parton scatterings $l_i=(\tau_{i+1}-\tau_i)\,E/p_T$

$$\frac{dP}{dl_i}=\lambda^{-1}(\tau_{i+1})\exp\left(-\int_0^{l_i}\lambda^{-1}(\tau_i+s)ds\right),\quad \lambda^{-1}=\sigma\rho$$

- Radiative and collisional energy loss per scattering

$$\Delta E_{tot,i}=\Delta E_{rad,i}+\Delta E_{col,i}$$

- Transverse momentum kick per scattering

$$\Delta k_{t,i}^2=\left(E-\frac{t_i}{2m_{0i}}\right)^2-\left(p-\frac{E}{p}\frac{t_i}{2m_{0i}}-\frac{t_i}{2p}\right)^2-m_q^2$$

Angular spectrum of gluon radiation

Medium-modified jet fragmentation depends on fraction of partonic energy loss falling outside the jet cone

But full treatment of angular spectrum of emitted gluons is sophisticated and model-dependent

---

Two simple parameterizations of gluon angular distribution:

Small-angular radiation: $$\frac{dN^g}{d\theta} \propto \sin\theta \exp\left(\frac{-(\theta-\theta_0)^2}{2\theta_0^2}\right), \quad \theta_0 \sim 5^o$$

Broad-angular radiation: $$\frac{dN^g}{d\theta} \propto \frac{1}{\theta}$$

PYQUEN (PYthia QUENched)

Initial parton configuration

PYTHIA6.4 w/o hadronization: mstp(111)=0

↓

Hard parton rescattering and energy loss + emitted gluons

PYQUEN rearranges partons to update ns strings: ns call PYJOIN

↓

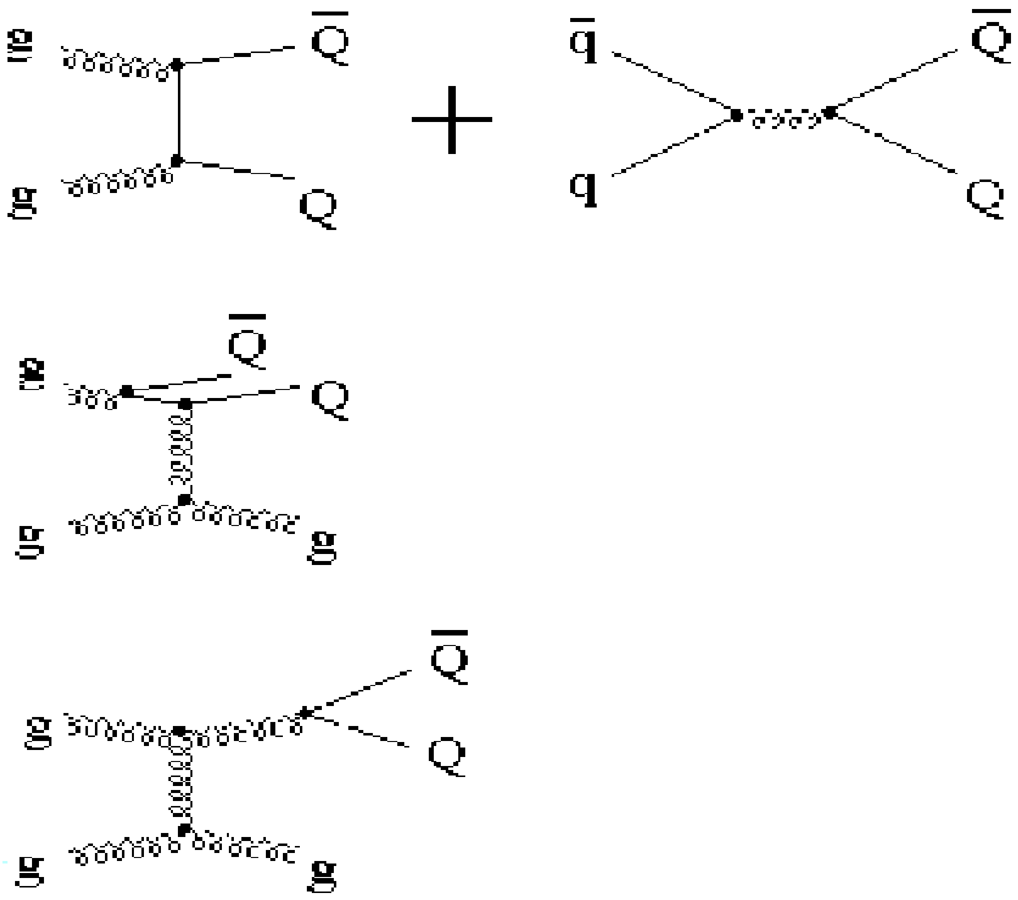
Parton hadronization and final particle formation

PYTHIA6.4 with hadronization: mstp(111)=1, call PYEXEC

More details on PYQUEN physics can be found in:

I.Lokhtin, A.Snigirev, EPJ C45 (2006) 211; ; and references therein.

Mechanisms of heavy quark production at high energy



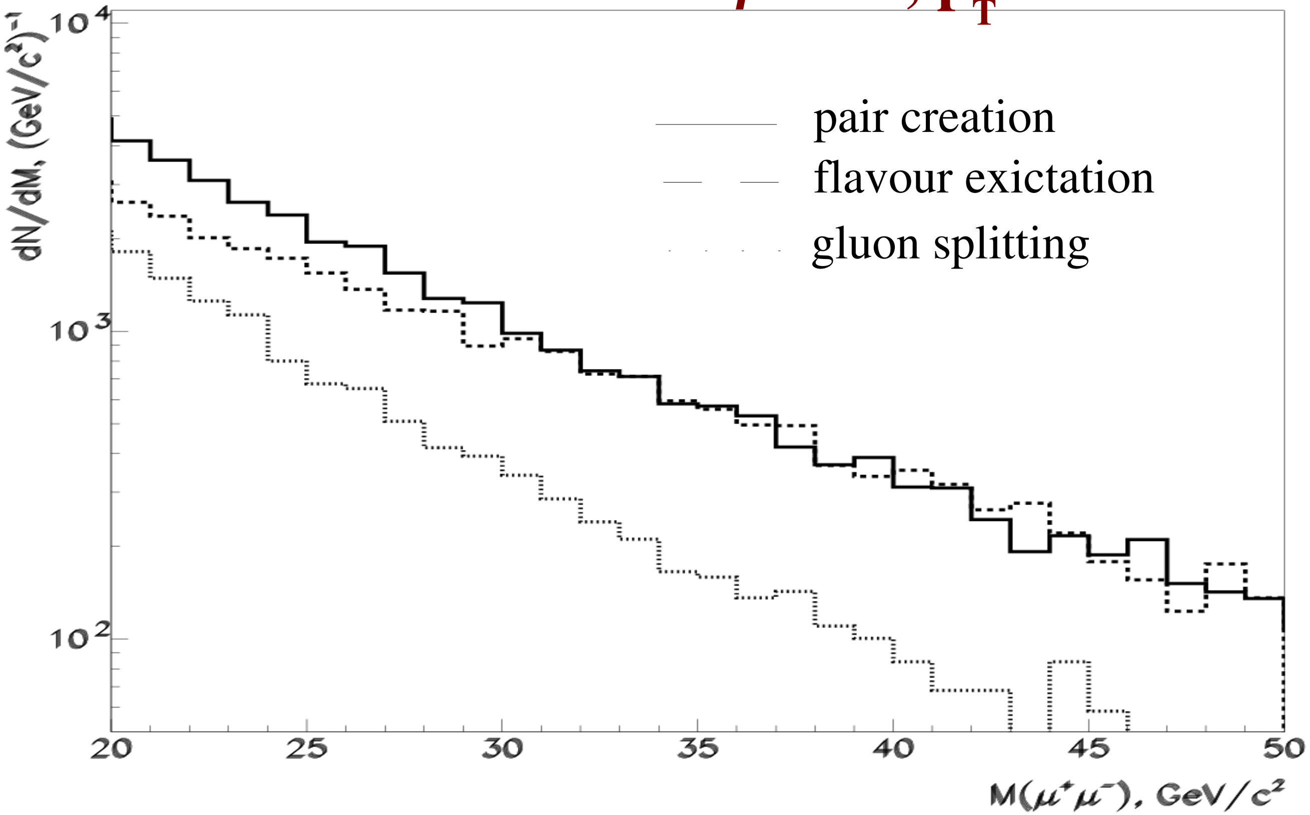
Pair creation

Flavour excitation

Gluon splitting

Spectrum of $\mu^+\mu^-$ - pairs of high invariant mass from BB decays

$|\eta|^{\mu}<2.5$, $p_T^{\mu}>5$ GeV/c

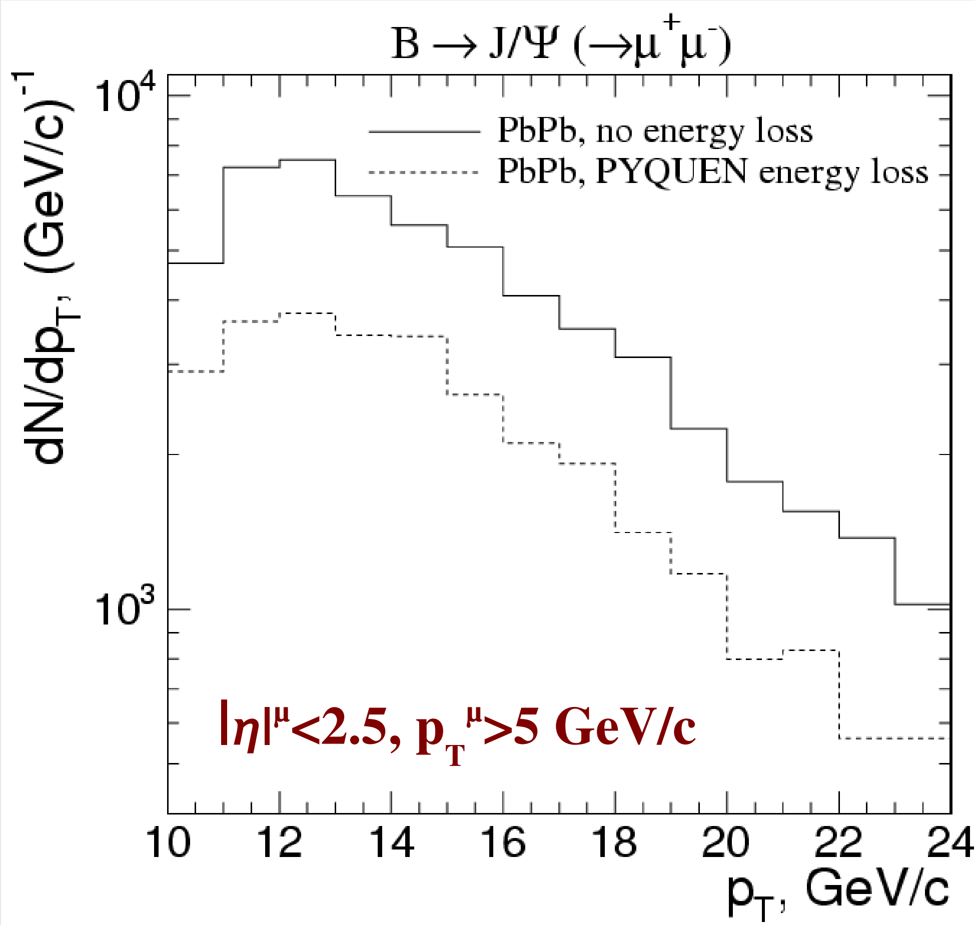


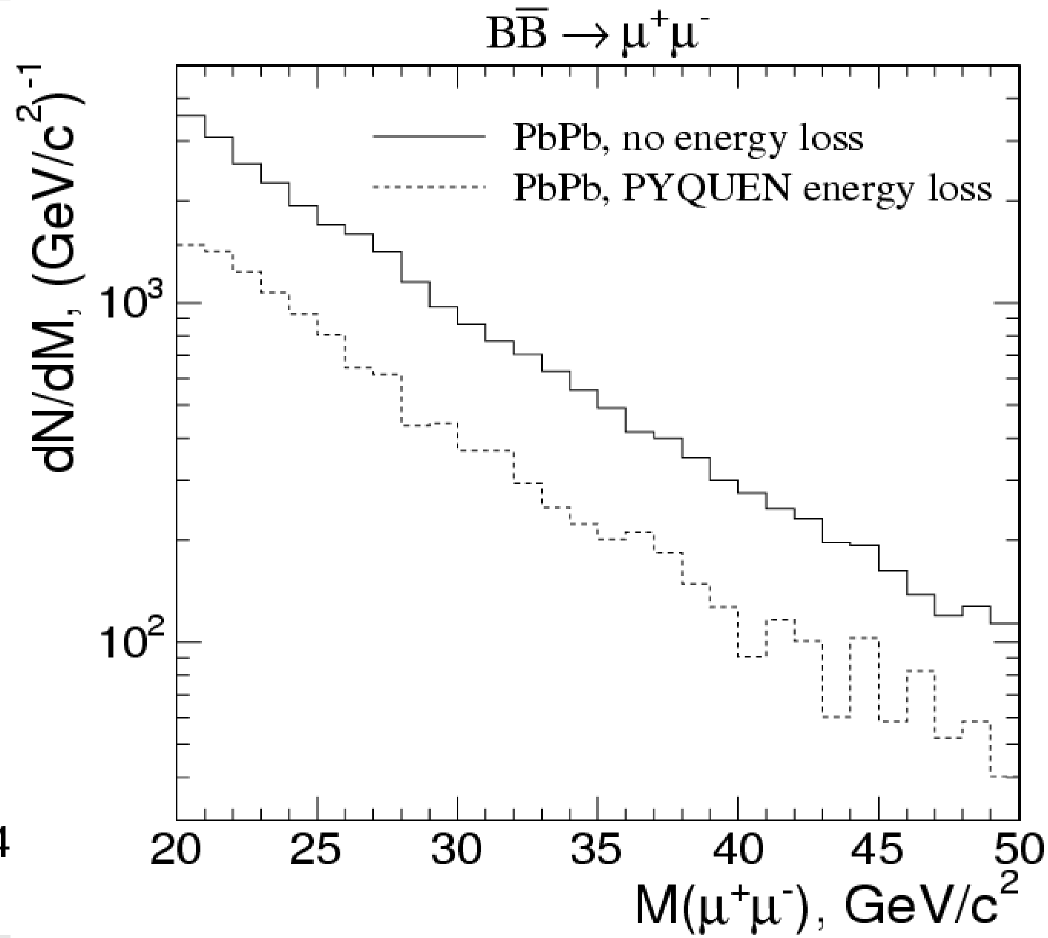
Contribution of showering b-quarks in BB→$\mu^+\mu^-$ is comparable with pair creation

Contribution of showering b-quarks in B→J/ψ→$\mu^+\mu^-$ is dominant (~80%)

Medium-modified high-mass dimuons and secondary J/ψ spectra

~5×10[4] events for each unquenched channels is expected for 1 month LHC run (with showering b-bbar production)

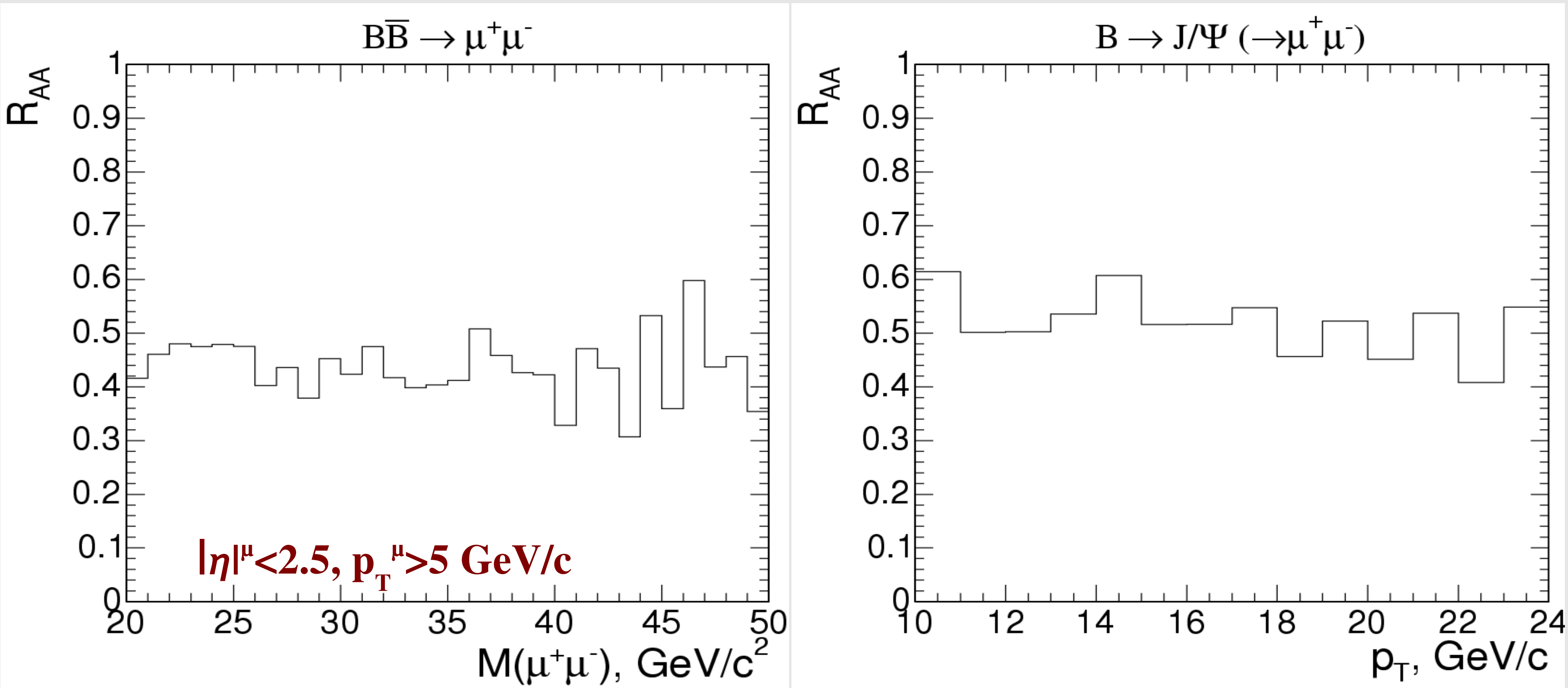




In-medium energy loss of b-quark (collisional+radiative) affects significantly the dimuon spectra

Nuclear modification factors for high-mass dimuons and secondary J/ψ

~5×10^4 events for each unquenched channels is expected for 1 month LHC run (with showering b-bbar production)



Nuclear modifications factors are slightly dependent on kinematics and above EKS shadowing (~15%)

Summary on PYQUEN predictions for dimuons in PbPb events at the LHC

Medium-induced rescattering and energy loss of b-quark (collisional+radiative) will affect the dimuon spectra, and can result in significant suppression of rates of high-mass dimuons (by a factor ~2.5) and secondary charmonia (by a factor ~2) above nuclear shadowing effect.

Showering mechanism of heavy quark production for dimuon spectra will be important.