Extracting bottom quark production cross section from p+p collisions at RHIC

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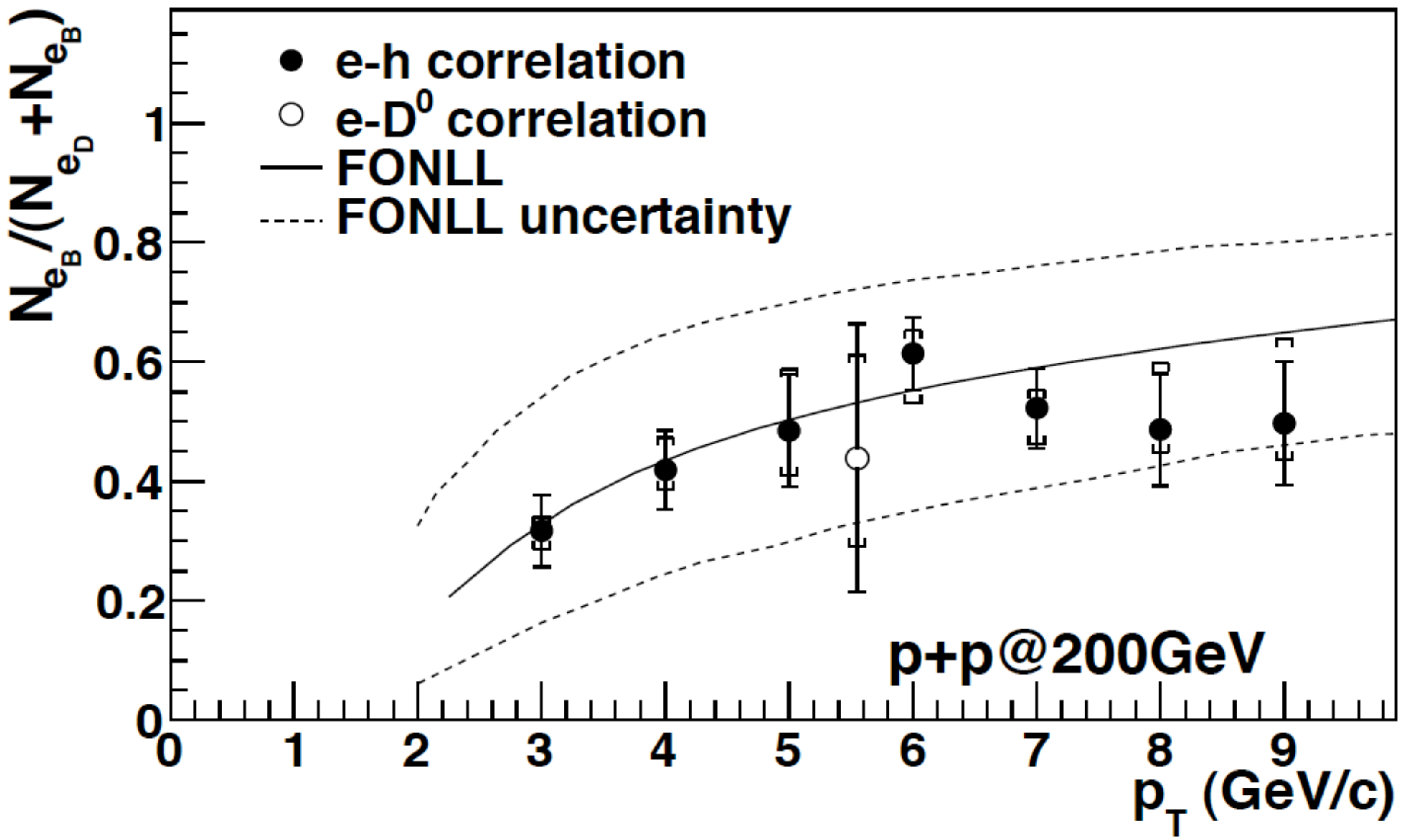
Contents

- Calculate B->e, D->e spectra from measured Non-Photonic Electron (NPE) spectrum and $N_{e\_B}/(N_{e\_B}+N_{e\_D})$
- Model calculations and total cross section extrapolations

DNP 2010, Sante Fe

the $N_{e\_B}/(N_{e\_B}+N_{e\_D})$ ratio



STAR arXiv:1007.1200

A study on the azimuthal correlations between the non-photonic electrons and hadrons in pp collisions at $\sqrt{s} = 200$ GeV.

Compared against PYTHIA calculations to obtain the ratios.

Formulas to get B->e and D->e

$$N_{e_B} = (N_{e_B} + N_{e_D}) \cdot \frac{N_{e_B}}{N_{e_B} + N_{e_D}}$$

$$E\frac{d^3\sigma}{d\vec{p}^3}\bigg|_{e_B} = E\frac{d^3\sigma}{d\vec{p}^3}\bigg|_{e_B+e_D} \cdot \frac{N_{e_B}}{N_{e_B} + N_{e_D}}$$

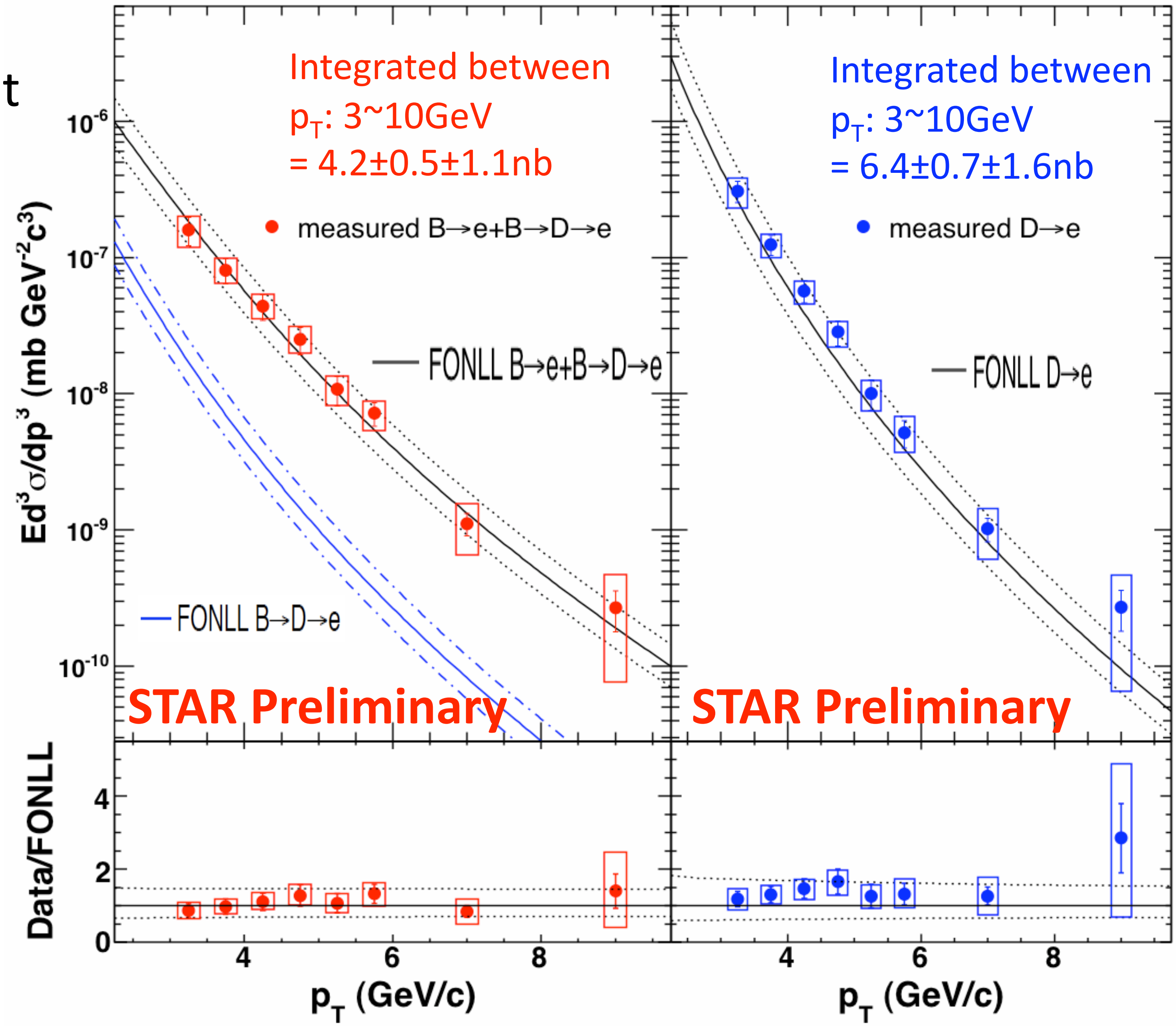
$$E\frac{d^3\sigma}{d\vec{p}^3}\bigg|_{e_B+e_D} = E\frac{d^3\sigma}{d\vec{p}^3}\bigg|_{e_{NPE}} - E\frac{d^3\sigma}{d\vec{p}^3}\bigg|_{e_{J/\psi}}$$

Measured J/Ψ by STAR and PHENIX, fed into PYTHIA and decay into electrons

p+p collisions at $\sqrt{s} = 200$ GeV
Run 2005: high material budget
Run 2008: low material budget
Consistent results.
See Xin Li's talk.

Invariant cross section of electrons from bottom and charm decays

pp collisions at $\sqrt{s} = 200$GeV



FONLL is from [1]

[1]:M. Cacciari, P. Nason and R. Vogt, Phys. Rev. Lett. **95, 20 122001 (2005);**
M. Cacciari, R. Vogt, private communications

Scale up the FONLL Prediction

- FONLL [1] predicts:

$$\sigma_{b\bar{b}} = 1.87^{+0.99}_{-0.67}\mu b$$

- Data/FONLL ratio is fit to be 1.1±0.1(stat.)±0.3(sys.)

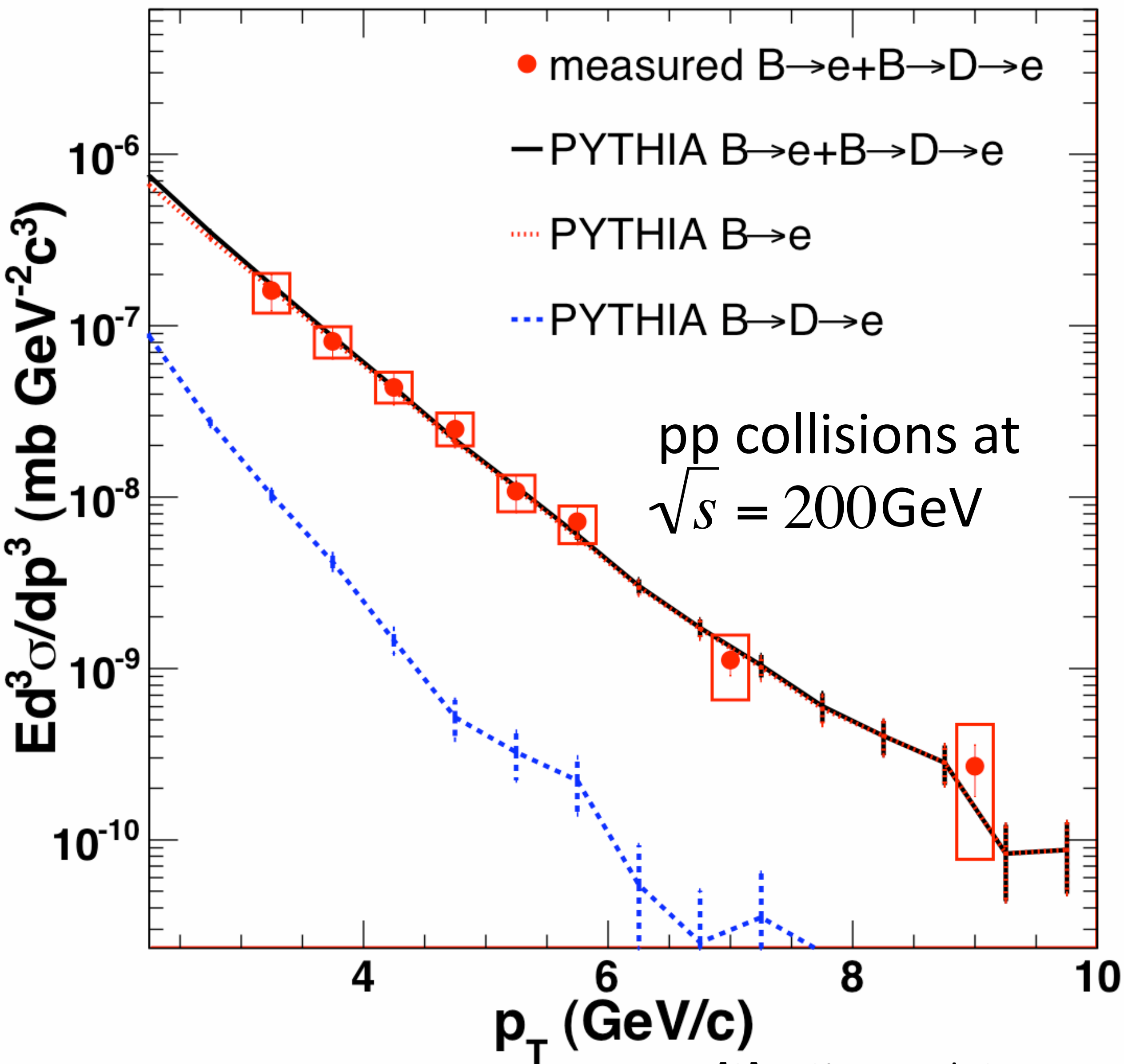
- Multiple it by 1.1:

$$\sigma_{b\bar{b}} = 1.87 \times 1.1 = 2.06\mu b$$

[1]:M. Cacciari, P. Nason and R. Vogt, Phys. Rev. Lett. **95, 20 122001 (2005);**
M. Cacciari, R. Vogt, private communications

MSEL=1

PYTHIA 6.409[2] calculations



All default set up, except:
p.d.f.= CTEQ5M1
Used in an earlier STAR paper:
Phys. Rev. Lett. 94, 062301 (2005).

The original PYTHIA calculation has been normalized to the data, i.e. the integrated cross section from 3GeV/c to 10GeV/c is fixed to be 4.2nb in PYTHIA

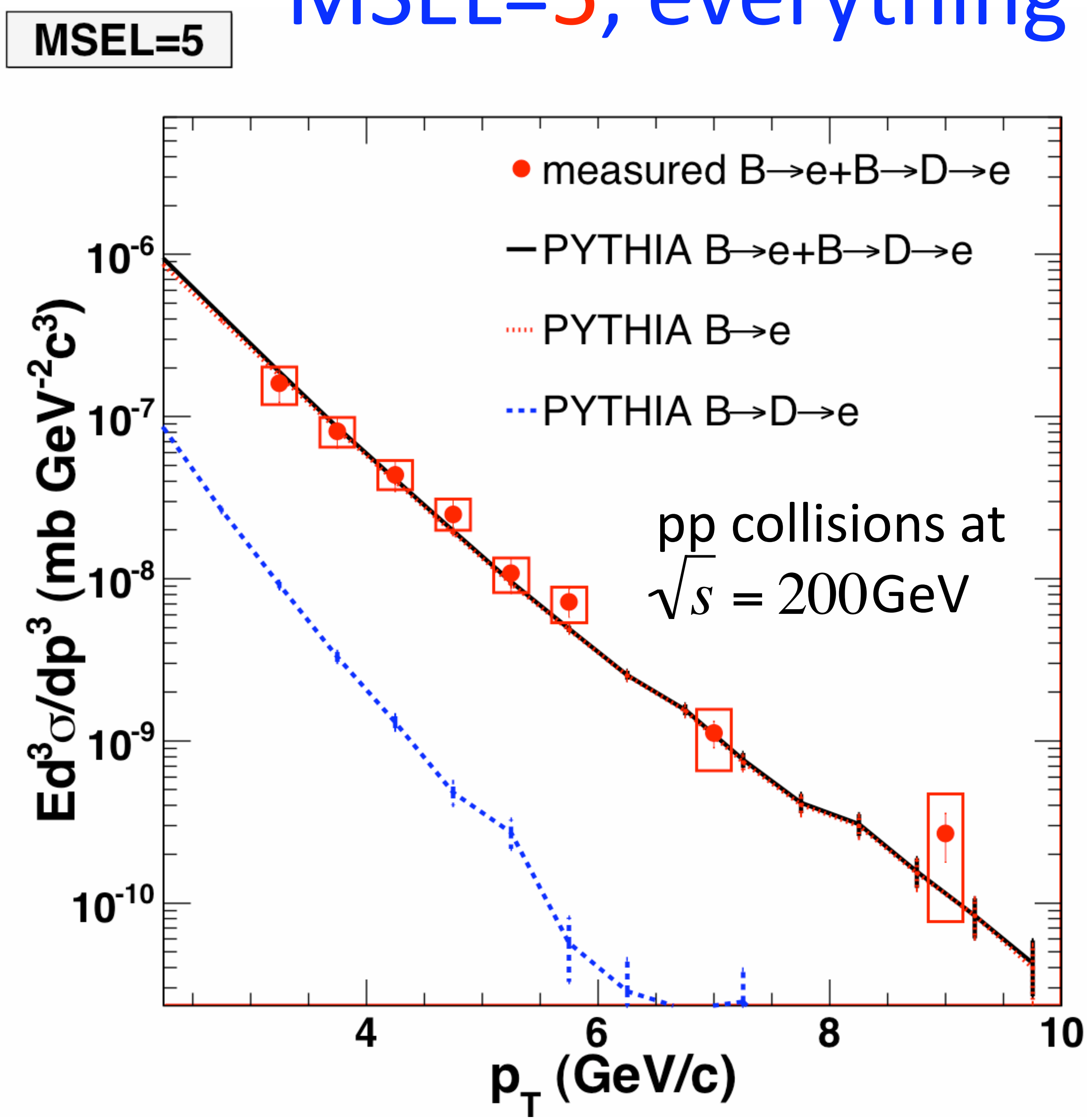
Use normalized PYTHIA calculation to extrapolate:

$$\left.\frac{d\sigma_{B->e}}{dy}\right|_{y=0} (0-10GeV/c) = 41.4nb$$

A factor of 10 extrapolation.

[2] T. Sjostrand, S. Mrenna and P. Skands, JHEP 0605, 026 (2006);
http://home.thep.lu.se/torbjorn/pythia/pythia6409.f

MSEL=5, everything else the same



In PYTHIA,
MSEL=1 is the Mini-bias processes mode, default
MSEL=5 is a heavy flavor (Bottom quark) processes mode

Use normalized PYTHIA calculation to extrapolate:

$$\left.\frac{d\sigma_{B->e}}{dy}\right|_{y=0} (0-10GeV/c) = 55.4nb$$

34% higher!

Mini-bias mode includes higher order diagrams, e.g. Flavor Excitation, etc
See [2] and also E. Norrbin, T.Sjostrand, Eur.Phys.J.C17:137-161,2000

Other PYTHIA calculations

PYTHIA parameters	$\sigma_{B\rightarrow e}(nb)$	deviation
$\langle k_T \rangle$*=2.0GeV(D); Max.k_T=5.0GeV(D); p.d.f=CTEQ5M1	41.4	0
$\langle k_T \rangle$=0.5GeV; Max.k_T=5.0GeV(D); p.d.f=CTEQ5M1	42.8	+3%
$\langle k_T \rangle$=1.5GeV; Max.k_T=10.0GeV; p.d.f=CTEQ5M1	39.6	-4%
$\langle k_T \rangle$=3.0GeV; Max.k_T=15.0GeV; p.d.f=CTEQ5M1	43.4	+5%
$\langle k_T \rangle$=4.5GeV; Max.k_T=20.0GeV; p.d.f=CTEQ5M1	37.1	-10%
$\langle k_T \rangle$=2.0GeV(D); Max.k_T=5.0GeV(D); p.d.f=CTEQ5L (D)	41.1	-1%
CDF tuneA [3]	47.1	+14%

PYTHIA default

All of them use the default MSEL=1 mode.

*The intrinsic k_T is a Gaussian distribution with the width set by parp(91) and the upper cut off set by parp(93).

[3] http://www.phys.ufl.edu/~rfield/cdf/tunes/py_tuneA.html

Branch ratio Correction

particle	Admixture in PDG	in PYTHIA	B.R. in PDG	in PYTHIA
B^0	$(40.1 \pm 1.3)\%$	39.5%	$(10.33 \pm 0.28)\%$	10.52%
B^+	$(40.1 \pm 1.3)\%$	39.7%	$(10.99 \pm 0.28)\%$	10.47%
B_s^0	$(11.3 \pm 1.3)\ \%$	11.6%	$(7.9 \pm 2.4)\%$	10.53%
$b - baryon$	$(8.5 \pm 2.2)\%$	9.1%	$(\sim 9.3)\%$	9.24%
Admixture Average	-	-	$(10.86 \pm 0.35)\%$	10.4%

- The $B^{\pm}$,B^0,B^s,B-baryons admixture and branch ratios in PYTHIA are close to PDG [4] values, based on measurements at LEP, Tevatron, $Sp\bar{p}S$, etc.
- $B^{\pm}$,B^0,B^s and B-baryons have similar semi-leptonic branch ratios and masses. So the result is not sensitive to the admixture.
- Estimated overall B.R.~ 10.4%

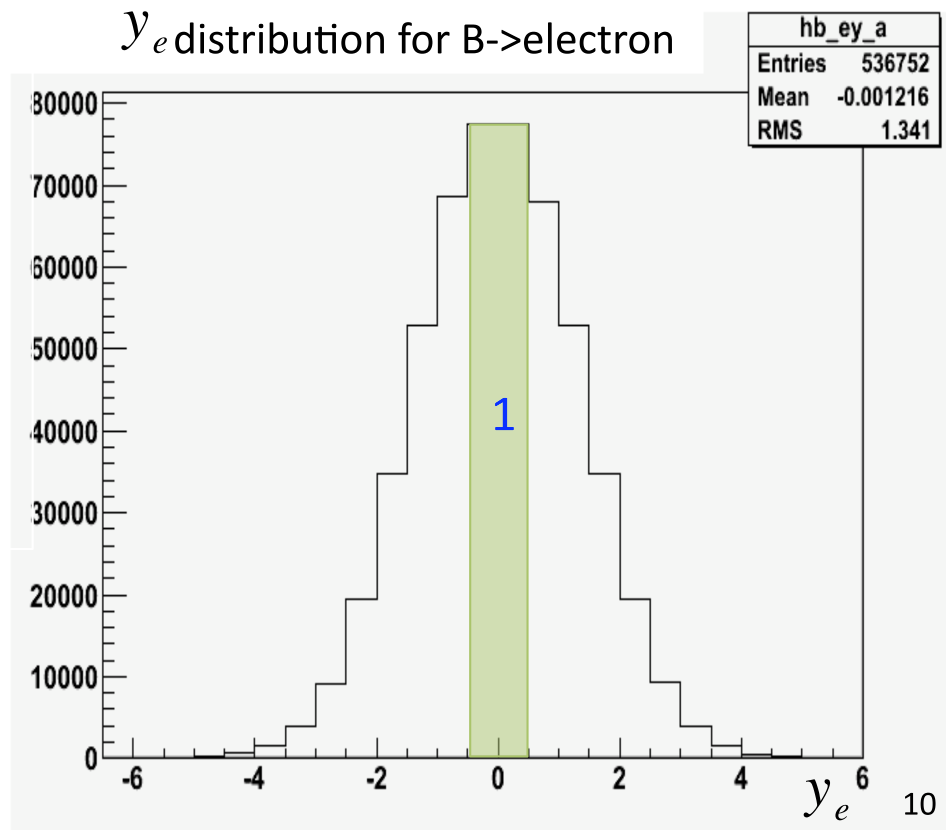
[4]:K. Nakamura *et al. (Particle Data Group), JPG* ***37, 075021 (2010)***

Rapidity distribution correction

$$\sigma_{b\bar{b}} = \frac{\sigma_{B->e}}{B.R.} = \left(\frac{\int \frac{d\sigma_{B->e}}{dy_e} dy_e}{\int_{-0.5}^{0.5} \frac{d\sigma_{B->e}}{dy_e} dy_e}\right) \cdot \frac{\left.\frac{d\sigma_{B->e}}{dy_e}\right|_{y_e=0}}{B.R.}$$

Need a correction to extrapolate from $|y_e| < 0.5$ to the full rapidity:

$$\frac{\int \frac{d\sigma_{B->e}}{dy_e} dy_e}{\int_{-0.5}^{0.5} \frac{d\sigma_{B->e}}{dy_e} dy_e} = \frac{\text{The whole Area under the histogram}}{1} = 3.5$$



The total $b\bar{b}$ production cross sections

Based on model calculations scaled to match STAR NPE measurements in p+p collisions at $\sqrt{s} = 200$ GeV:

PYTHIA, Mini-bias Mode: $\sigma_{b\bar{b}} = 1.38 \mu b$

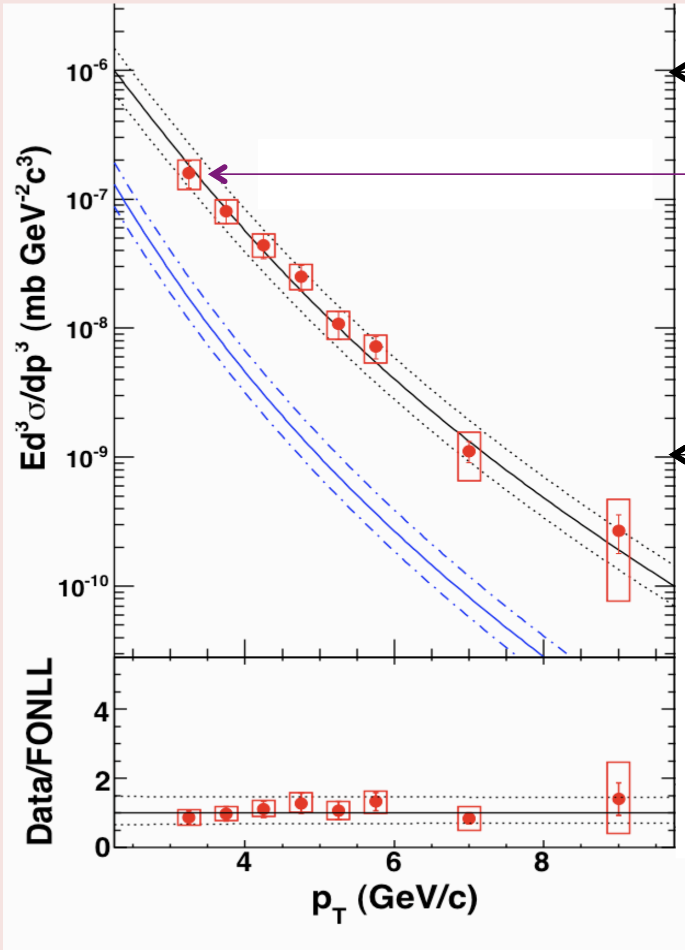
PYTHIA, MSEL=5 Mode: $\sigma_{b\bar{b}} = 1.88 \mu b$

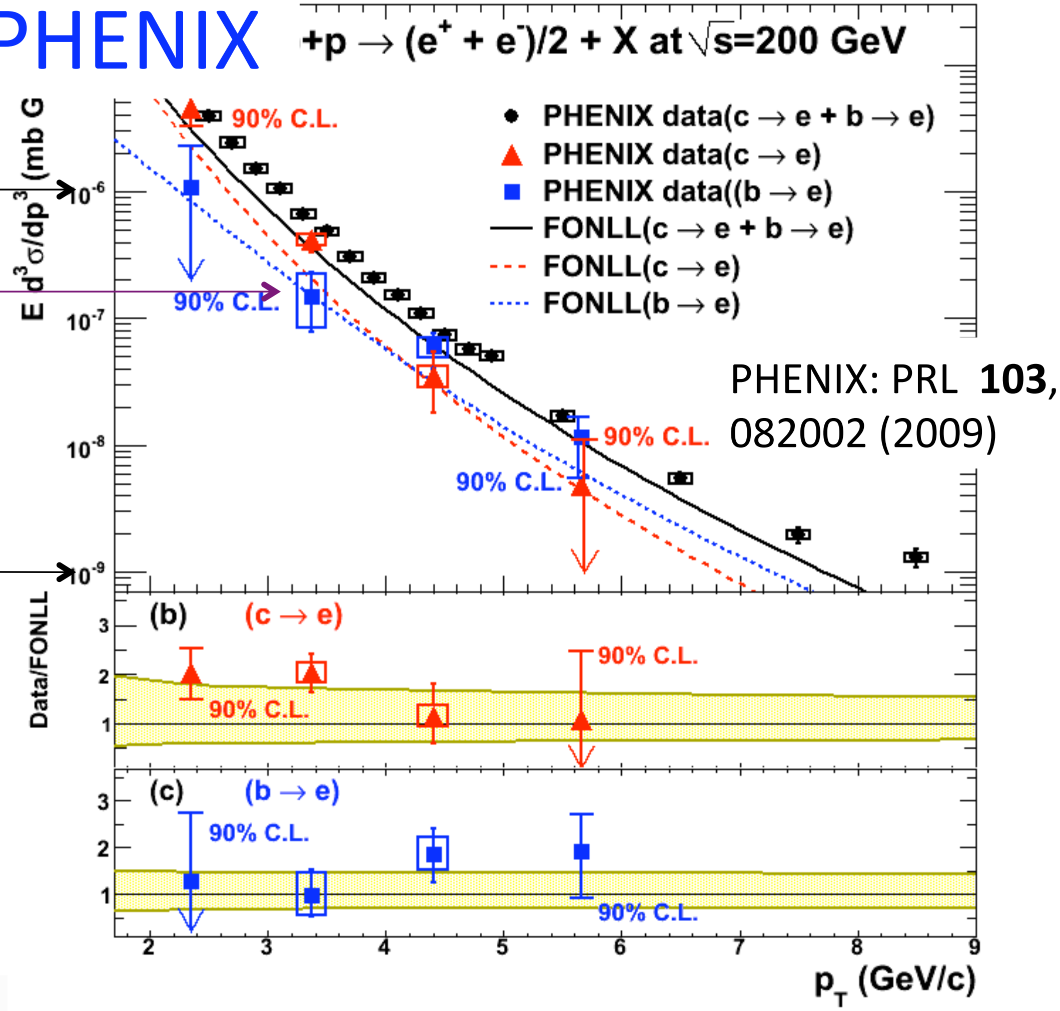
FONLL×1.1: $\sigma_{b\bar{b}} = 2.06 \mu b$

With 12% (stat.) and 26% (sys.) experimental uncertainty.

backup

Compare this result with PHENIX





PHENIX: PRL **103**, 082002 (2009)

Integrated p_T: 3~10GeV= 4.2±0.5(stat)±1.1(sys)nb

The electron spectrum from bottom shown in Fig. 3 is integrated from $p_T = 3$ to 5 GeV/c and gives $4.8^{+1.8}_{-1.6}$(stat)$^{+1.9}_{-1.8}$(syst) nb. This spectrum is then extrapo-

PYTHIA Mini-bias	PYTHIA MSEL=5
$\sigma_{b\bar{b}} = 1.38\mu b$	$\sigma_{b\bar{b}} = 1.88\mu b$

rapidity, the total bottom cross section is determined to $\sigma_{b\bar{b}} = 3.2^{+1.2}_{-1.1}$(stat)$^{+1.4}_{-1.3}$(syst)$\mu b$. Various PDF's and b

PHENIX: PRL **103**, 082002 (2009)

Exp. uncertainty: 12% (stat.) and 26% (sys.)

J/Ψ contribution

PHENIX:A. Adare *et al. [PHENIX Collaboration], Phys. Rev.* ***D*** 59 **82, 012001 (2010).**
STAR:B. I. Abelev *et al. [STAR Collaboration], Phys. Rev.* ***C*** 61 **80, 041902 (2009).**