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

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Contents

- STAR measurement of Non-Photonic Electron (NPE) spectrum
- Disentangle the Bottom contribution to NPE and get $N_{e\_B}/(N_{e\_B}+N_{e\_D})$
- Calculate B->e, D->e spectra
- Model calculations and total cross section extrapolations

How to Measure Non-Photonic Electron (NPE) spectrum

- Non-photonic electron yield is calculated according to:

$$N(non-photonic\ electron) = N(inclusive\ electron)\cdot purity - N(photonic\ electron)/\varepsilon$$

Photonic electron (PHE) background is mainly from γ conversion and π^0, η Dalitz decays.

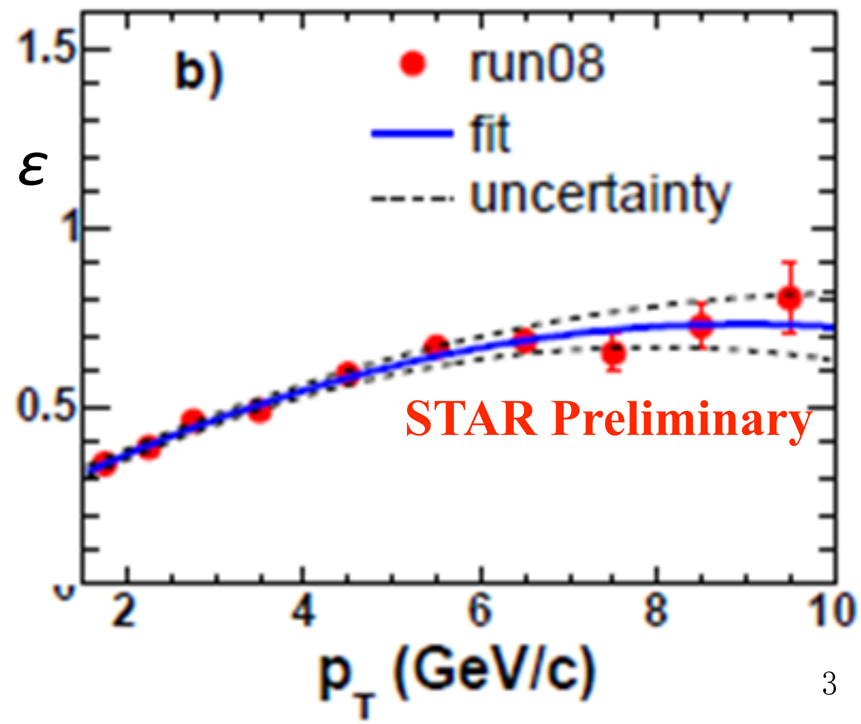
•Identify the photonic electron via mass reconstruction and small mass cut, get its statistics using unlike-like method.

•Does not depend on the accurate knowledge of the material budget.

•There is an in-efficiency due to detector acceptance, etc.

ε: photonic electron reconstruction efficiency

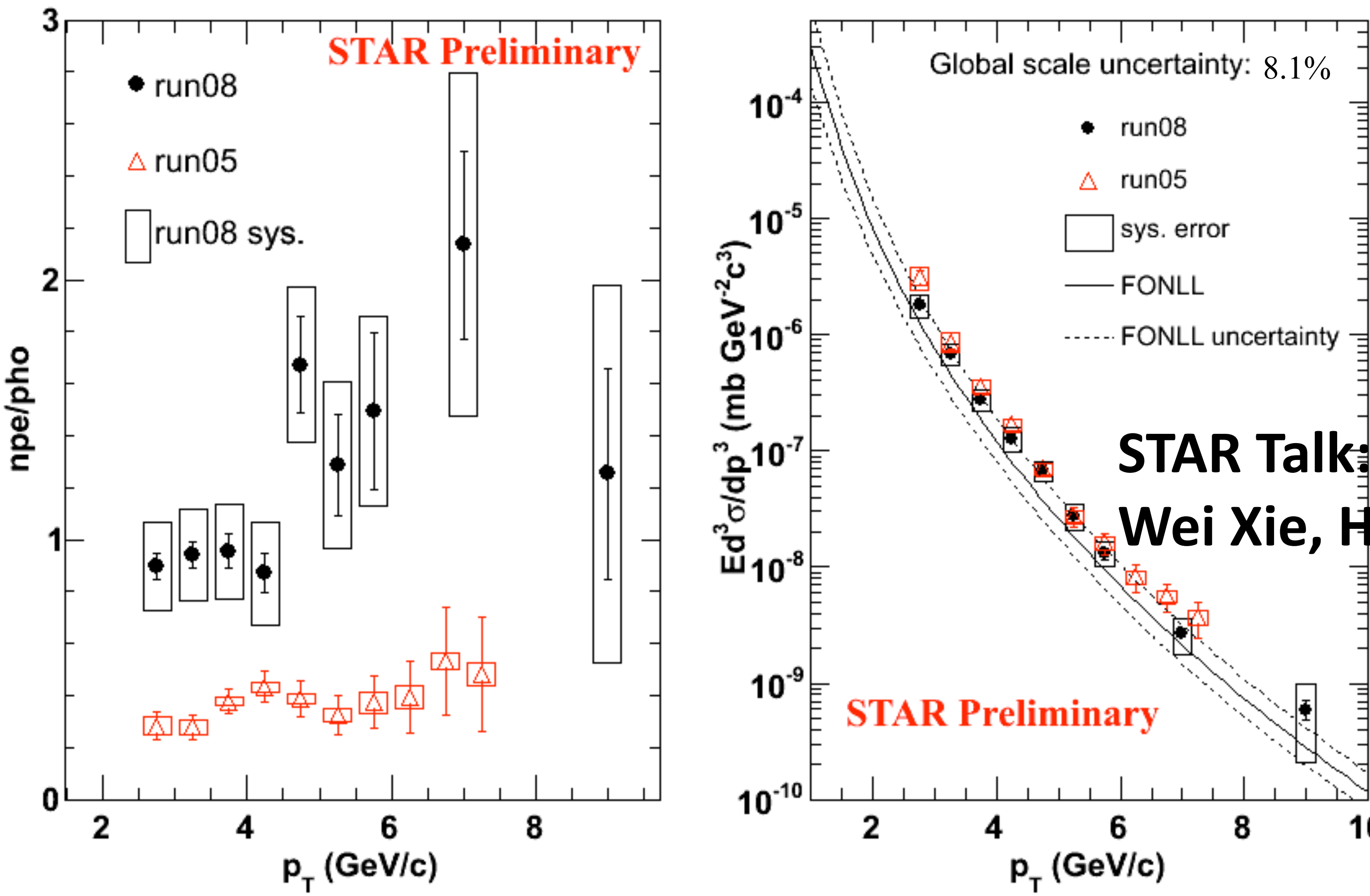
STAR Talk: Xin Li, DNP 2010



- NPE cross section:

$$E\frac{d^3\sigma}{dp^3} = \frac{1}{\mathcal{L}}\frac{1}{2\pi\, p_T\, \Delta p_T\, \Delta y}\frac{N_{npe}}{\epsilon_{rec}\,\epsilon_{trig}\,\epsilon_{eid}\,\epsilon_{BBC}}$$

STAR high pT NPE Measurements in 200GeV p+p collisions



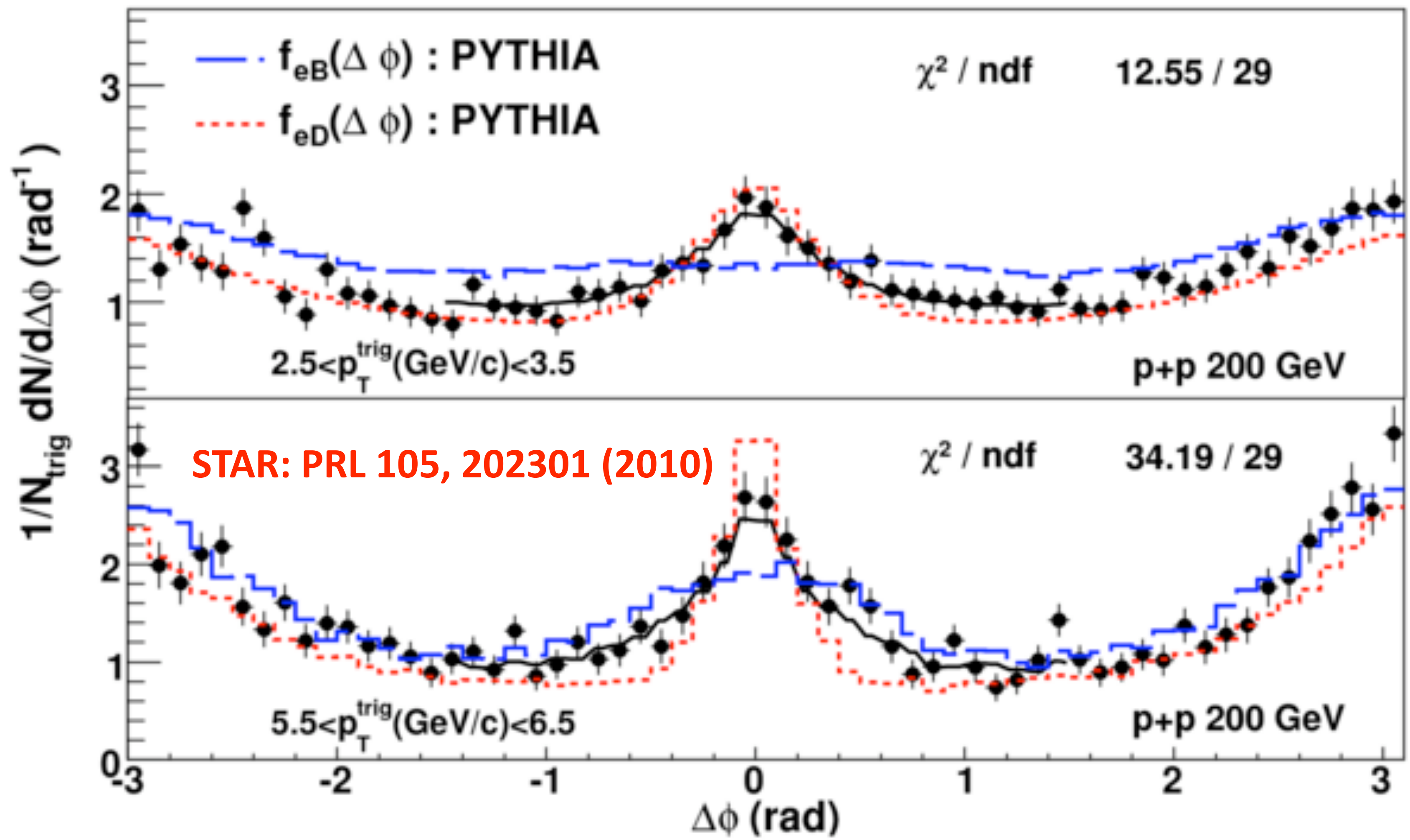
STAR Talk:
Wei Xie, Hard Probe 2010

Measurement done using TPC+EMC using run08 and run05 data.

Run 2005: high material budget v.s. Run 2008: low material budget

✓pT>2.5GeV/c NPE measurement with dramatically different background agree with each very well

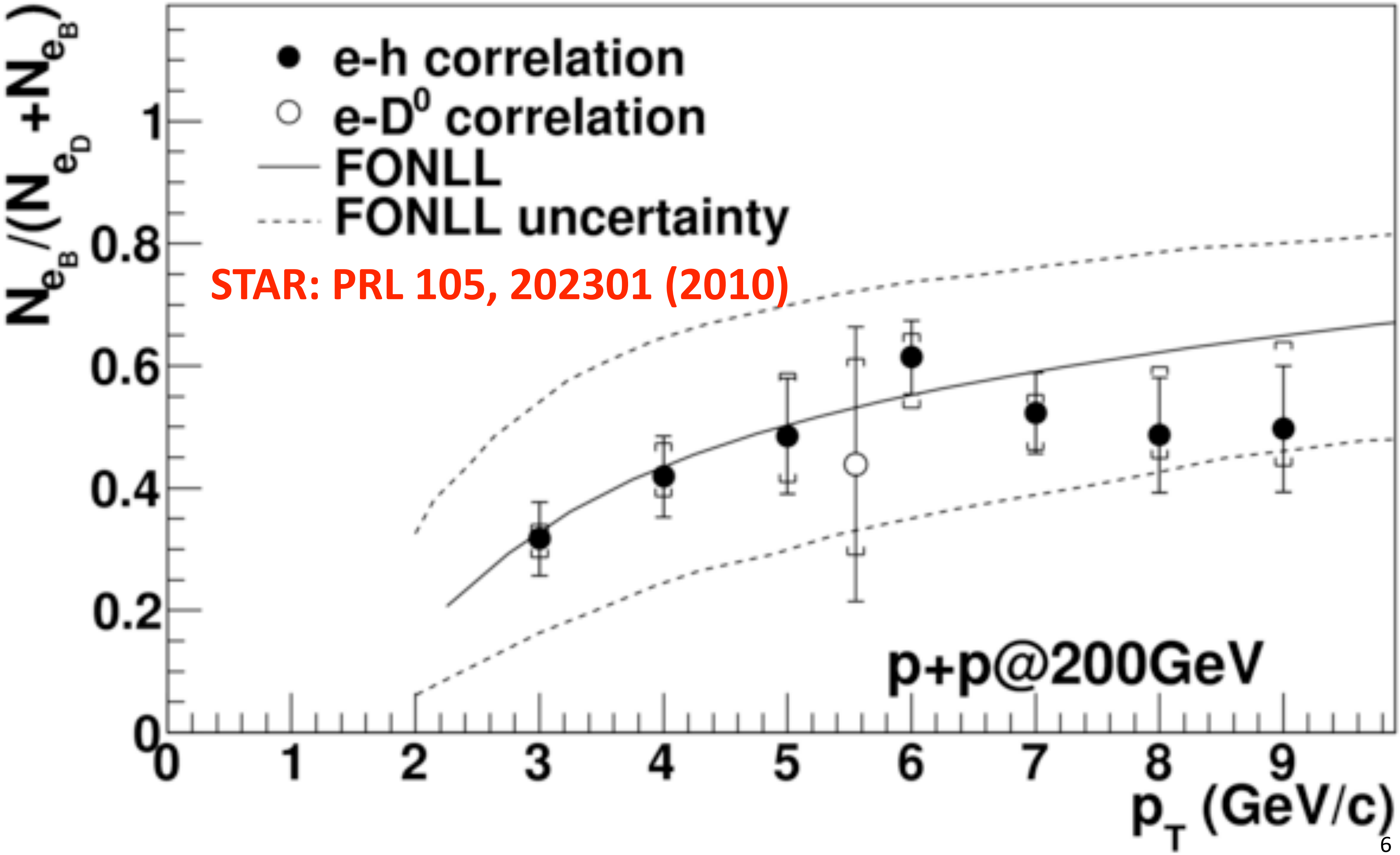
the Bottom Quark Contribution to NPE



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 relative contributions of Bottom and Charm mesons.

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



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

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

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

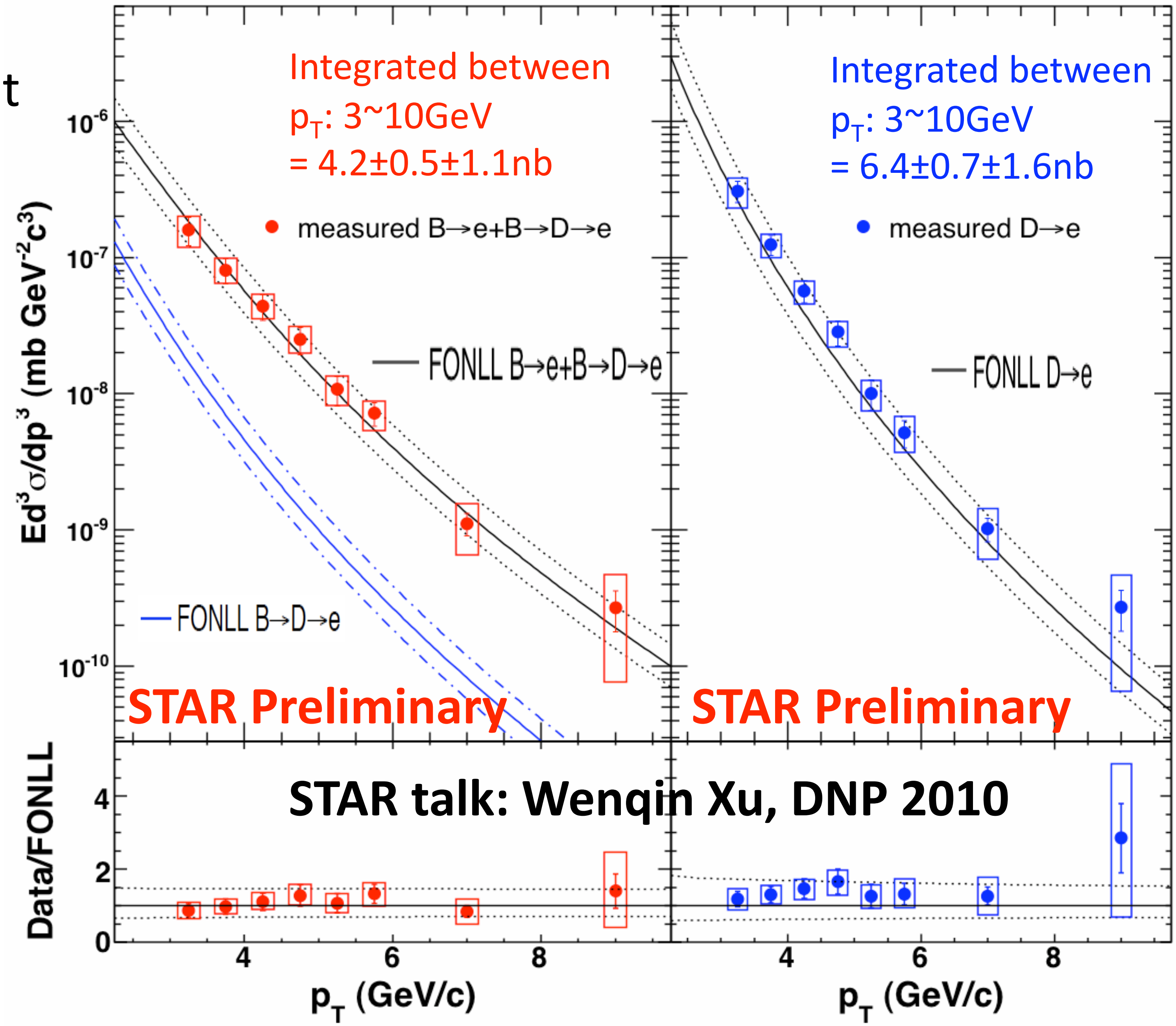
$$E\frac{d^3\sigma}{d\vec{p}^3}\bigg|_{e_B+e_D} = E\frac{d^3\sigma}{d\vec{p}^3}\bigg|_{e_{NPE}} - E\frac{d^3\sigma}{d\vec{p}^3}\bigg|_{e_{J/\psi}}$$

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

p+p collisions at $\sqrt{s} = 200$ GeV
Run8 and Run5 combined result
See Wei Xie's talk at HP10.

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.)

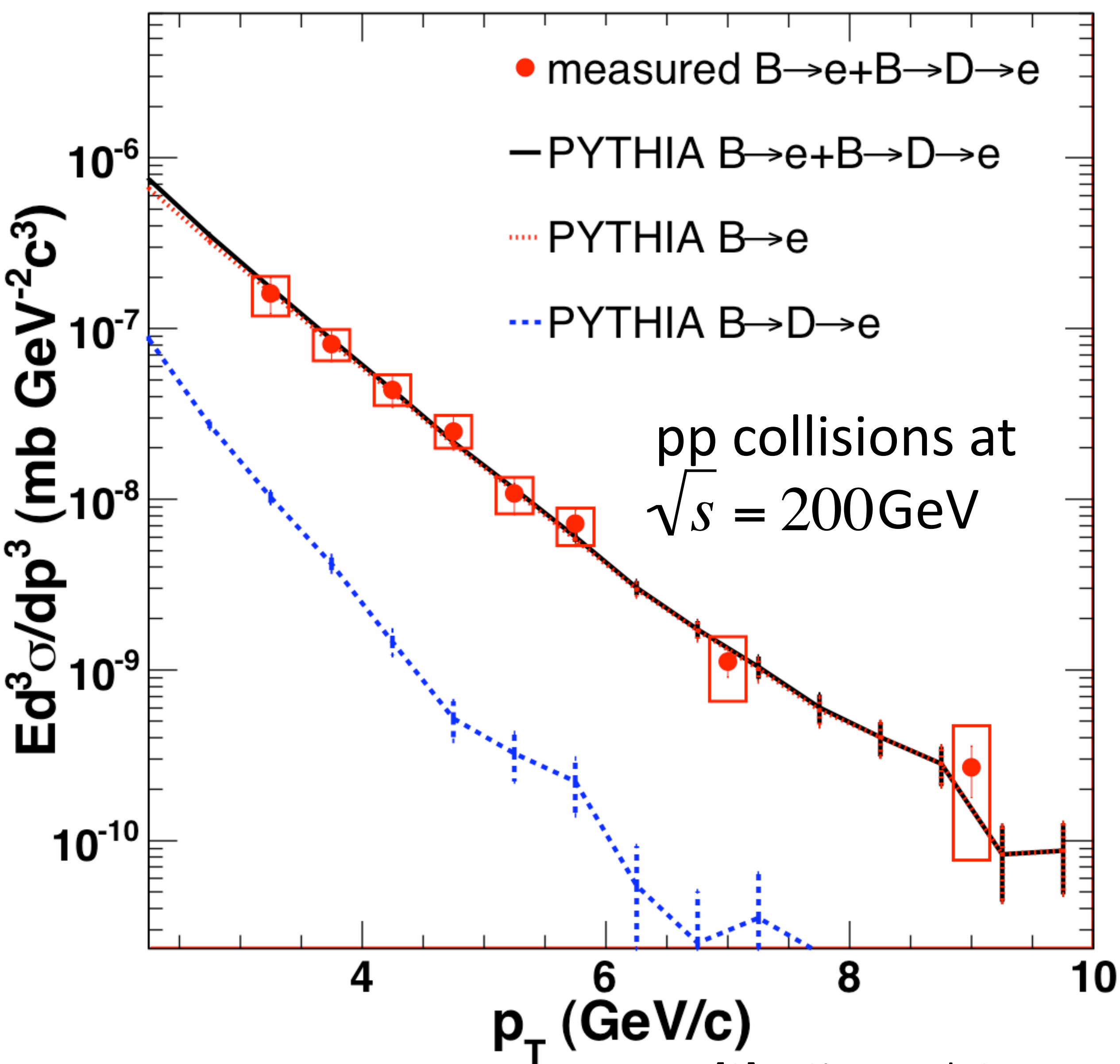
- Multiple it by 1.1:

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

[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

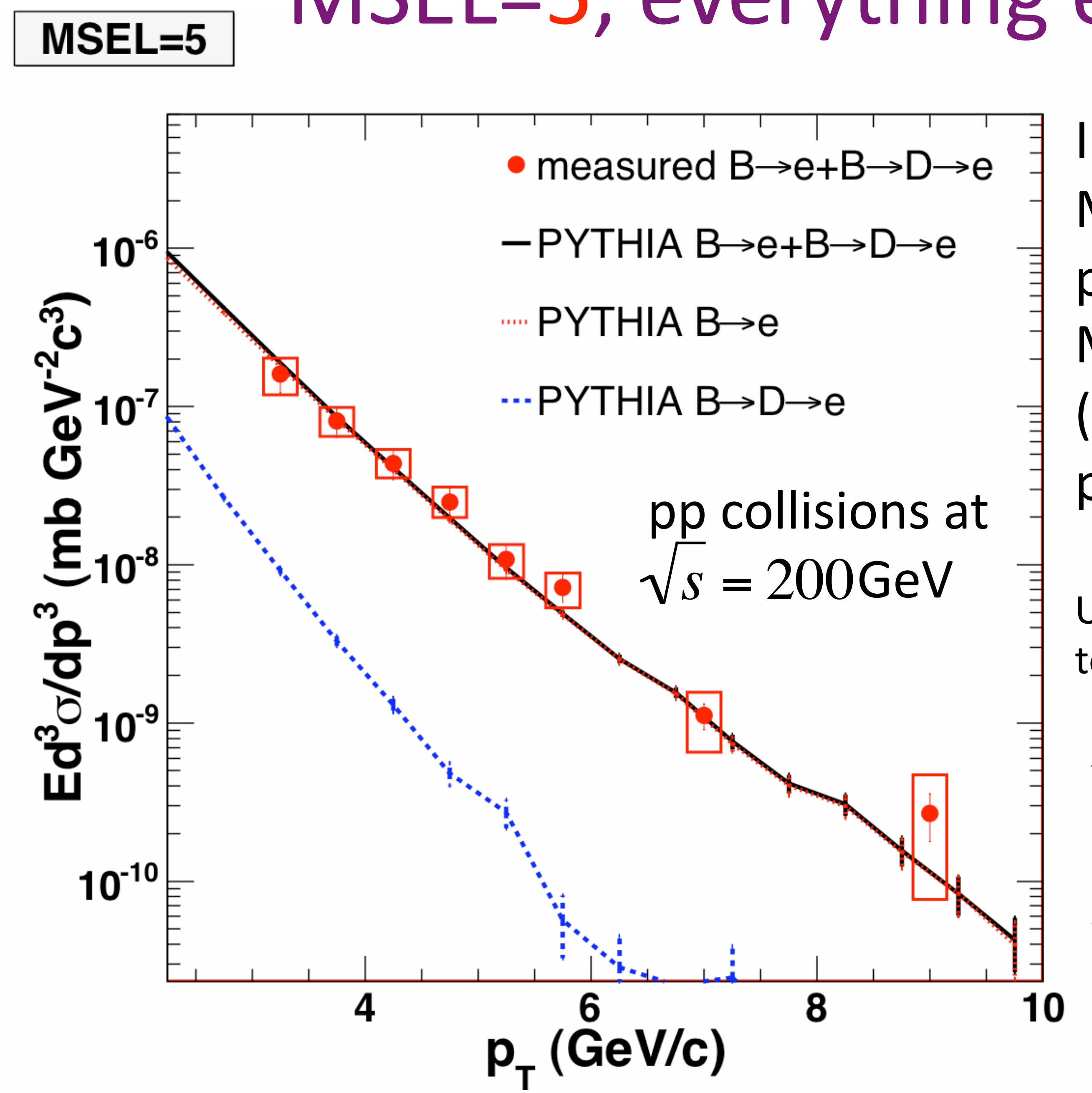
Use normalized PYTHIA calculation to extrapolate:

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

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	$\sigma_{B\to e}(nb)$	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%

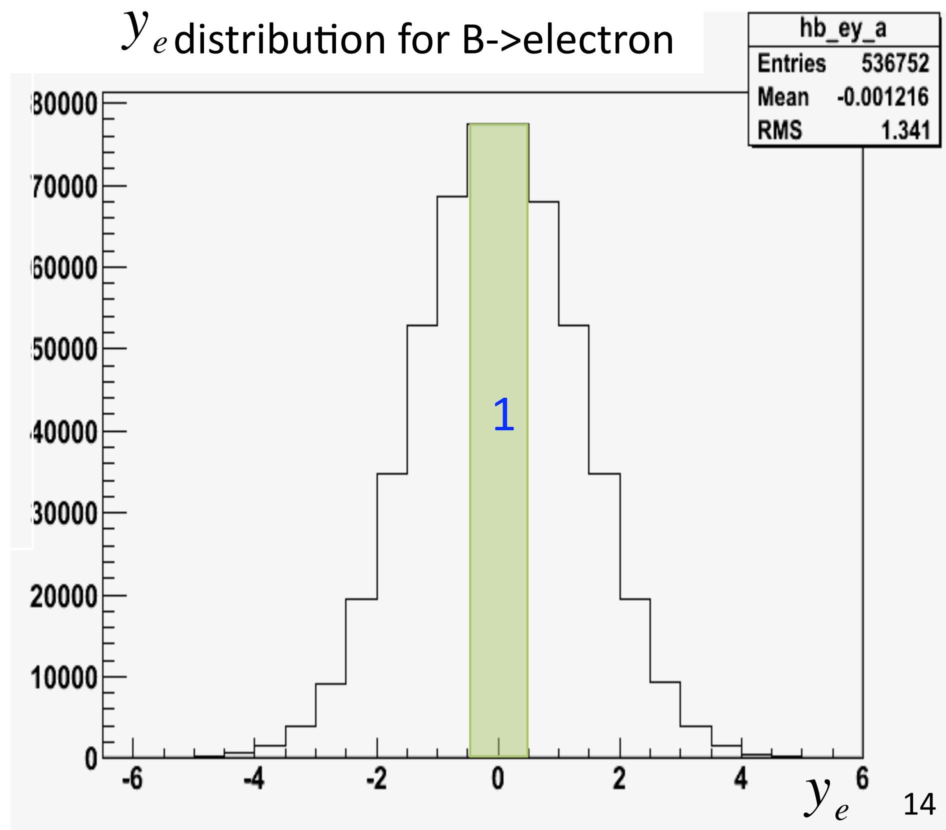
[4]:K. Nakamura *et al. (Particle Data Group), JPG* ***37, 075021 (2010)***

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:

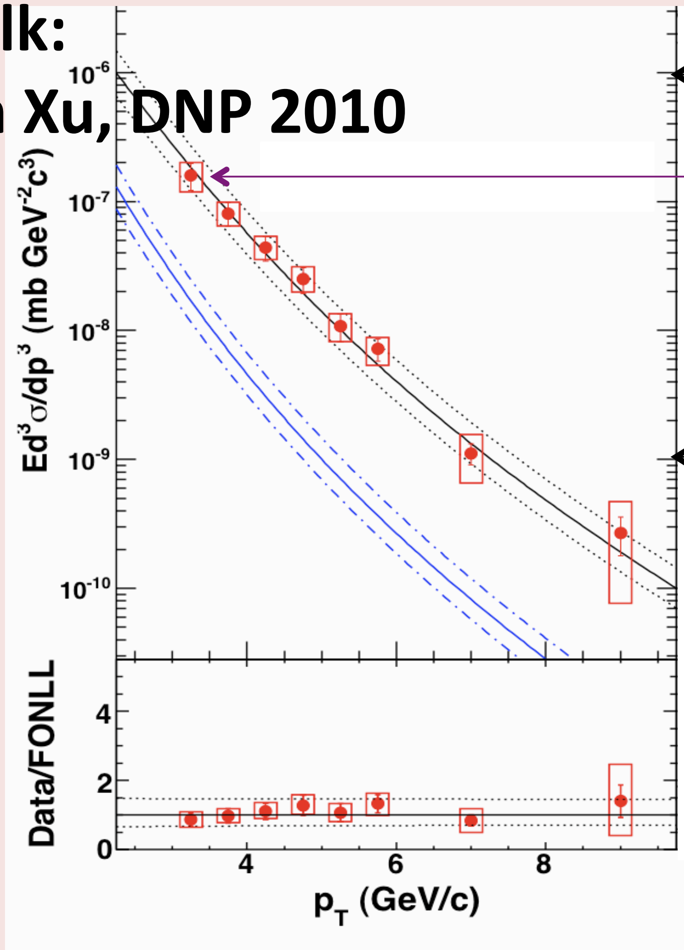
PYTHIA, Mini-bias Mode:	$\sigma_{b\bar{b}} = 1.38\mu b$
PYTHIA, MSEL=5 Mode:	$\sigma_{b\bar{b}} = 1.88\mu b$
FONLL×1.1:	$\sigma_{b\bar{b}} = 2.06\mu b$

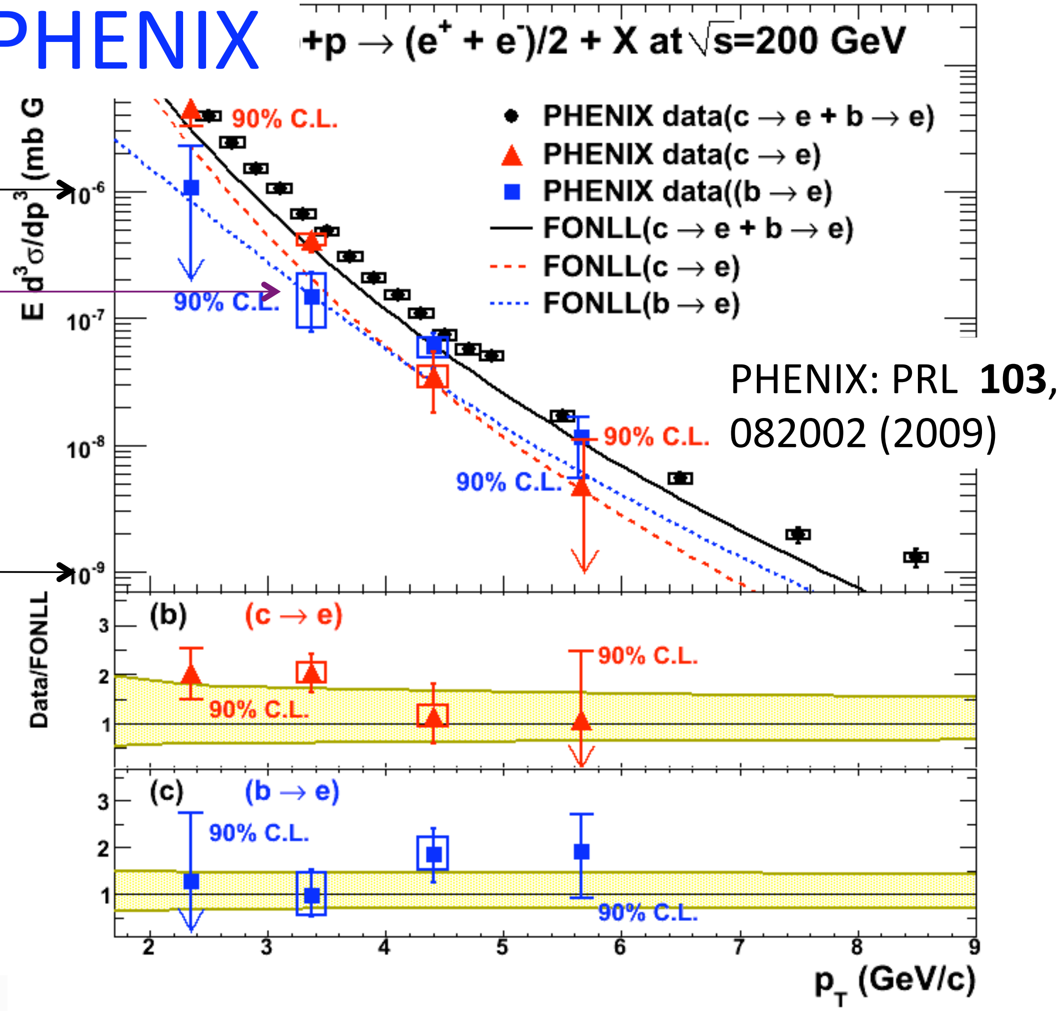
With 12% (stat.) and 26% (sys.) experimental uncertainty.

backup

Compare this result with PHENIX

STAR talk:
Wenqin Xu, DNP 2010





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 $\sigma_{b\bar{b}} = 3.2^{+1.2}_{-1.1}(\mathrm{stat})^{+1.4}_{-1.3}(\mathrm{syst})\,\mu b$. Various PDF's and b

12%&8% systematic uncertainty for the extrapolations

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

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

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).**