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

Wenqin Xu
University of California, Los Angeles
For the STAR collaboration

Lake Louise Winter Institute

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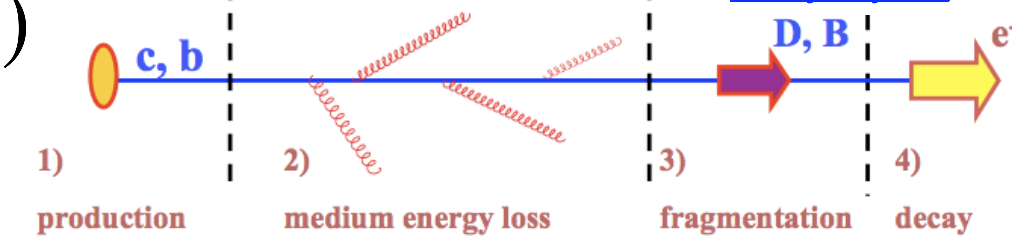
Introduction

- Heavy quarks are good probes to study the QCD matter
- NPE: semi-leptonic decays of open heavy quark hadrons

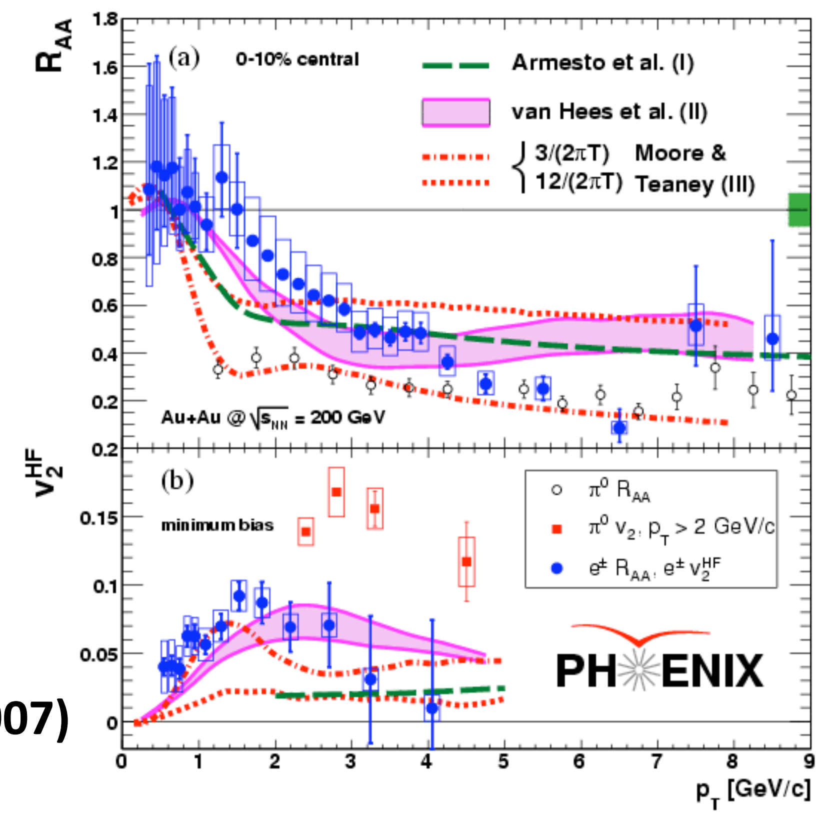
$$e.g.: c \rightarrow e^{+} + anything(9.6\%)$$

$$D^{0} \rightarrow k^{-} + e^{+} + \nu_{e}(3.5\%)$$

M. Djordjevic, 06



- ➢NPE yield at high p_T largely suppressed
- ➢Models under predicted this suppression
- ➢Need to disentangle bottom and charm contributions



PHENIX PRL **98,** 172301 **(2007)**

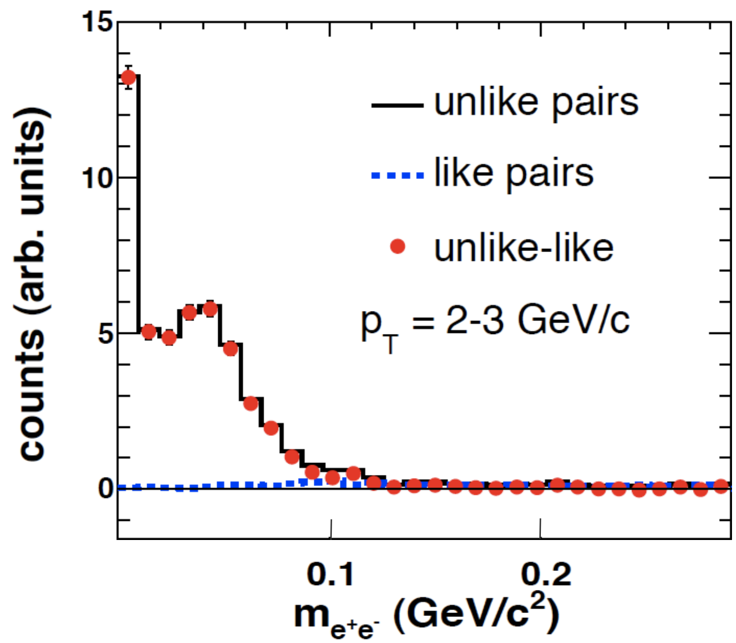
The background in NPE analysis

The main background is photonic electrons:

Photon conversions in material $\gamma \rightarrow e^{+} + e^{-}$

Dalitz decays of pseudoscalar mesons $\pi^{0},\eta \rightarrow \gamma + e^{+} + e^{-}$

Reconstruct the invariant masses of electron pairs
+ apply opening angles cuts =>
Statistically obtain the yield of photonic electrons



STAR **arXiv:1102.2611** (2011)

Other background:

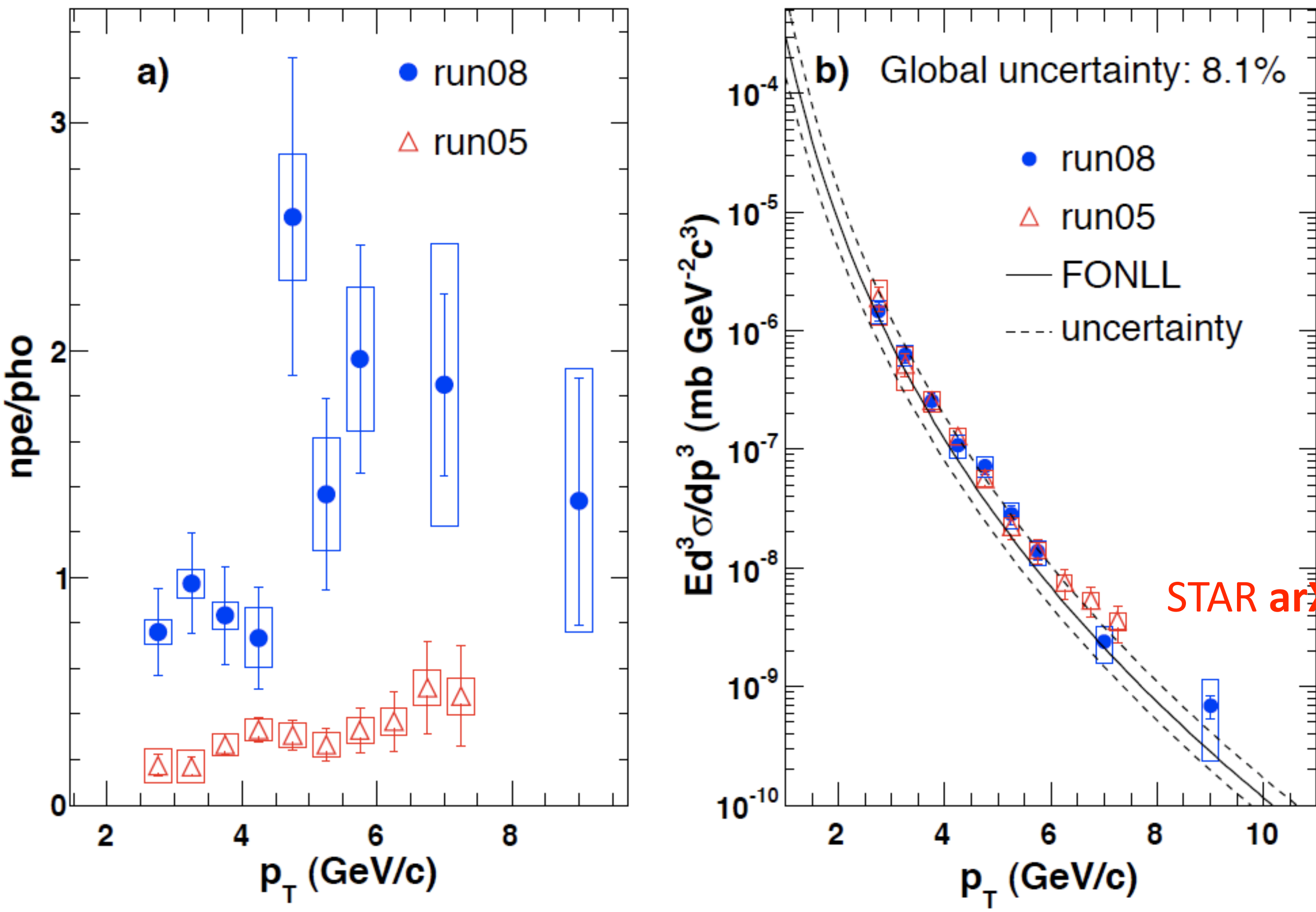
vector meson decays $\omega,\rho,\phi,J/\Psi \rightarrow e^{+}e^{-}$

The contributions can be estimated through decay simulations with PYTHIA.
ω,ρ,ϕ contribute very little at high p_T;

Hadron Contaminations

Controlled by particle ionization energy loss difference in STAR TPC gas.

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



STAR **arXiv:1102.2611** (2011)

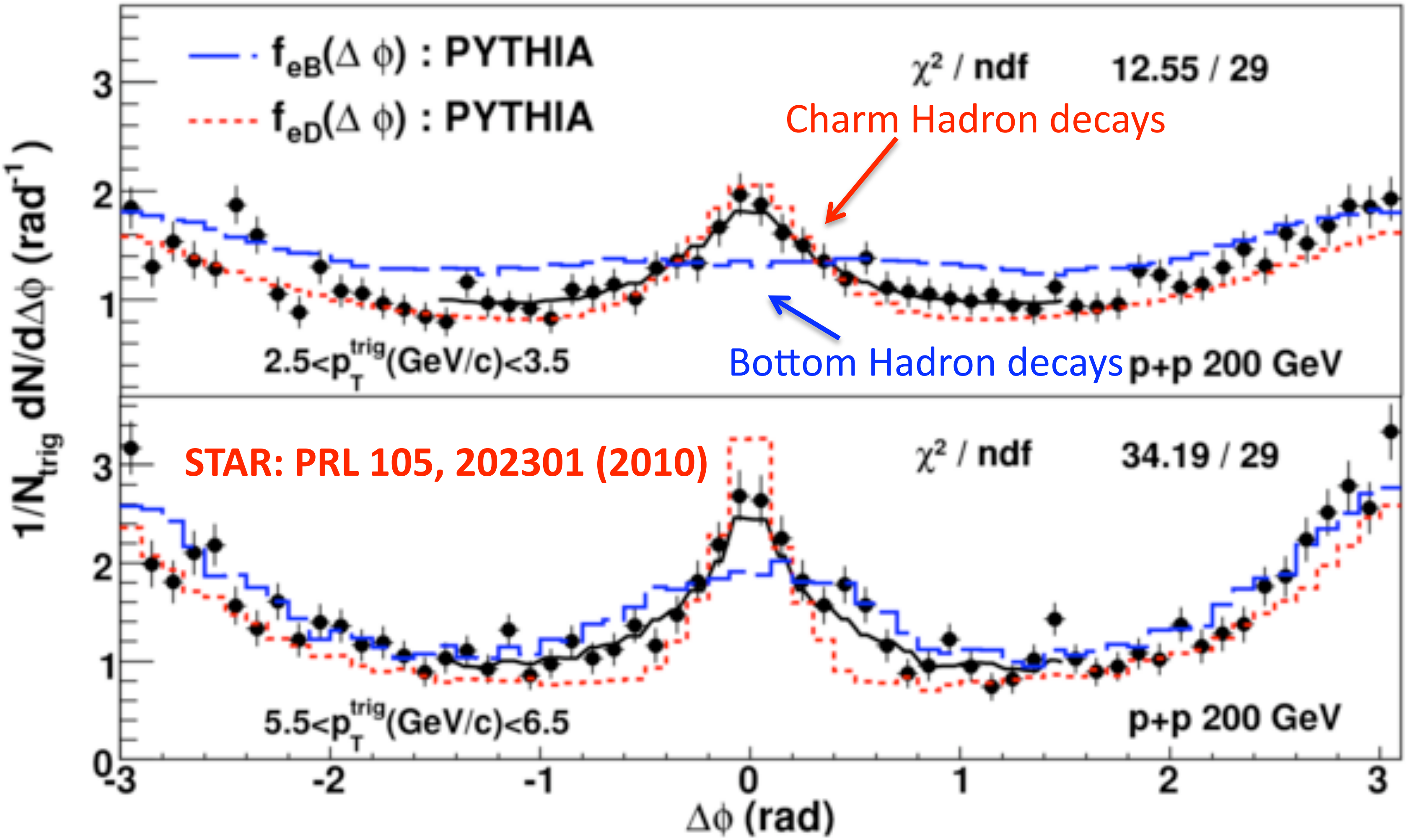
J/Ψ, upsilon and Drell-Yan contributions are kept in this plot

Measurement done with TPC+EMC for run08 and run05.

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

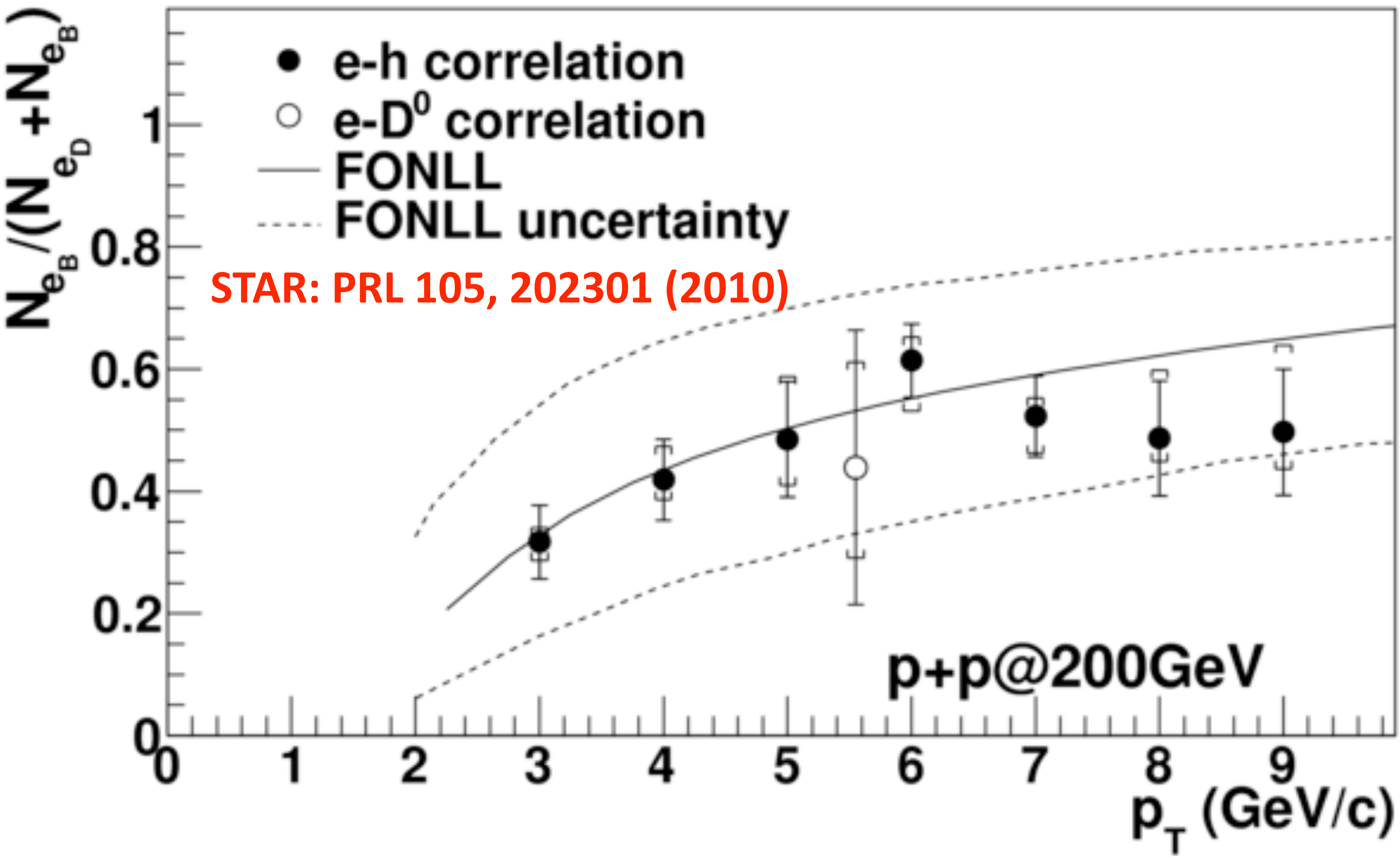
p_T>2.5GeV/c NPE measurement with dramatically different photonic electron background agree with each very well

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



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

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

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

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

p+p collisions at $\sqrt{s} = 200$GeV
Run8 and Run5 combined

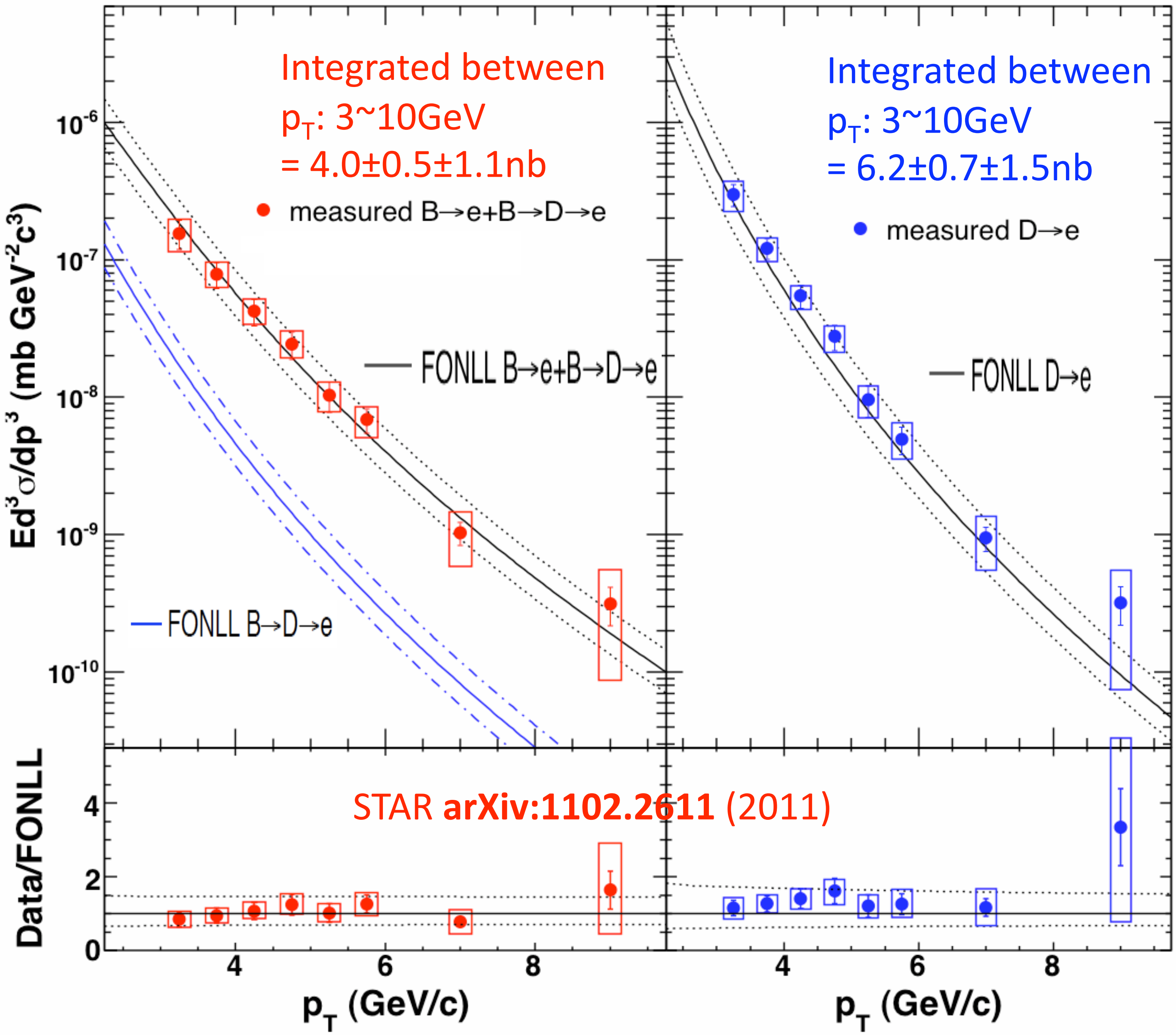
STAR **arXiv:1102.2611** (2011)

J/Ψ from STAR and PHENIX,
Υ and Drall-Yan from pQCD,
fed into PYTHIA
and decay into electrons

Invariant cross section of electrons from charm and bottom

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

|η|<0.5



For bottom electrons, FONLL [1] is consistent With data!

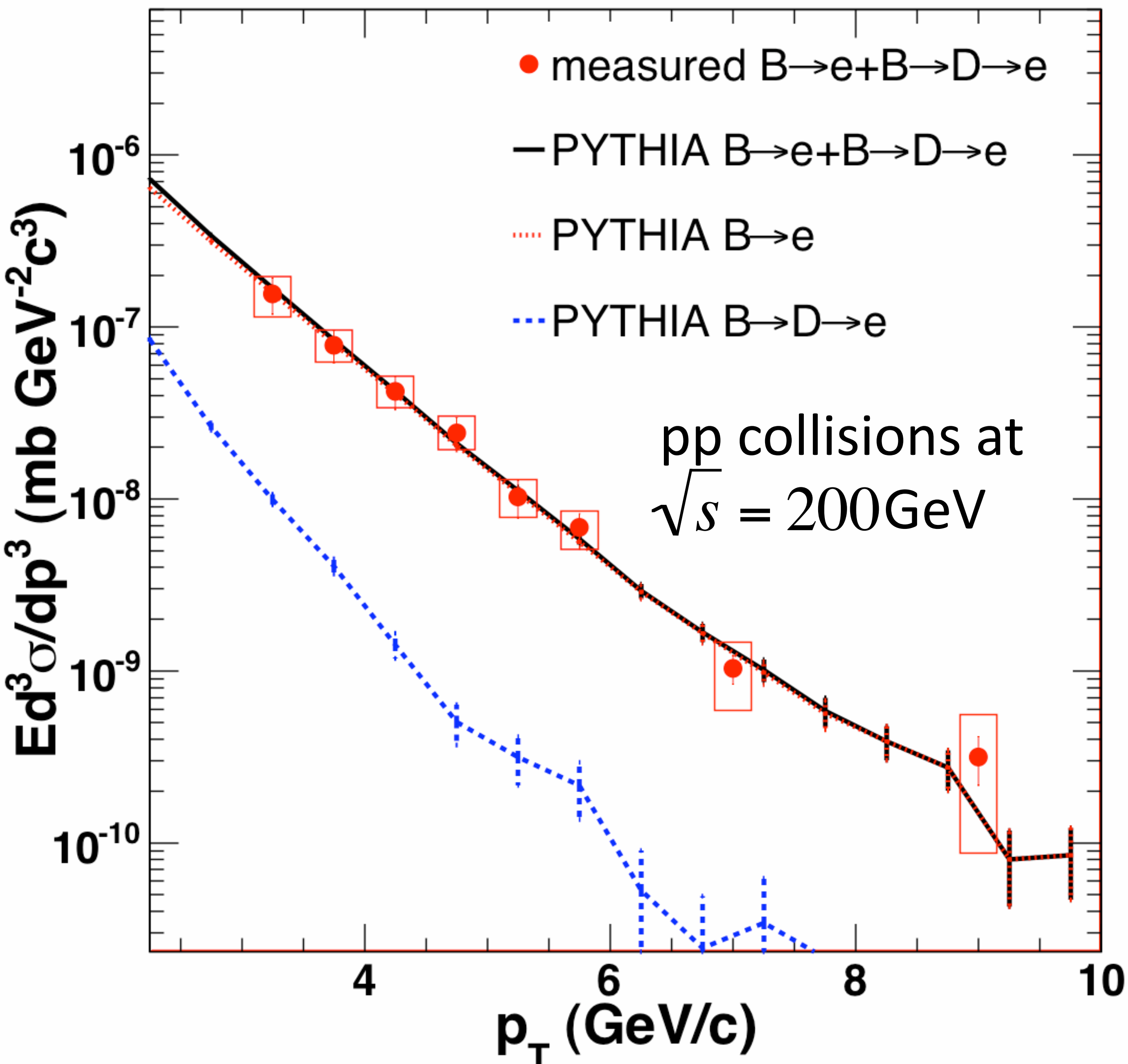
FONLL prediction:

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

[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 4.0nb in PYTHIA

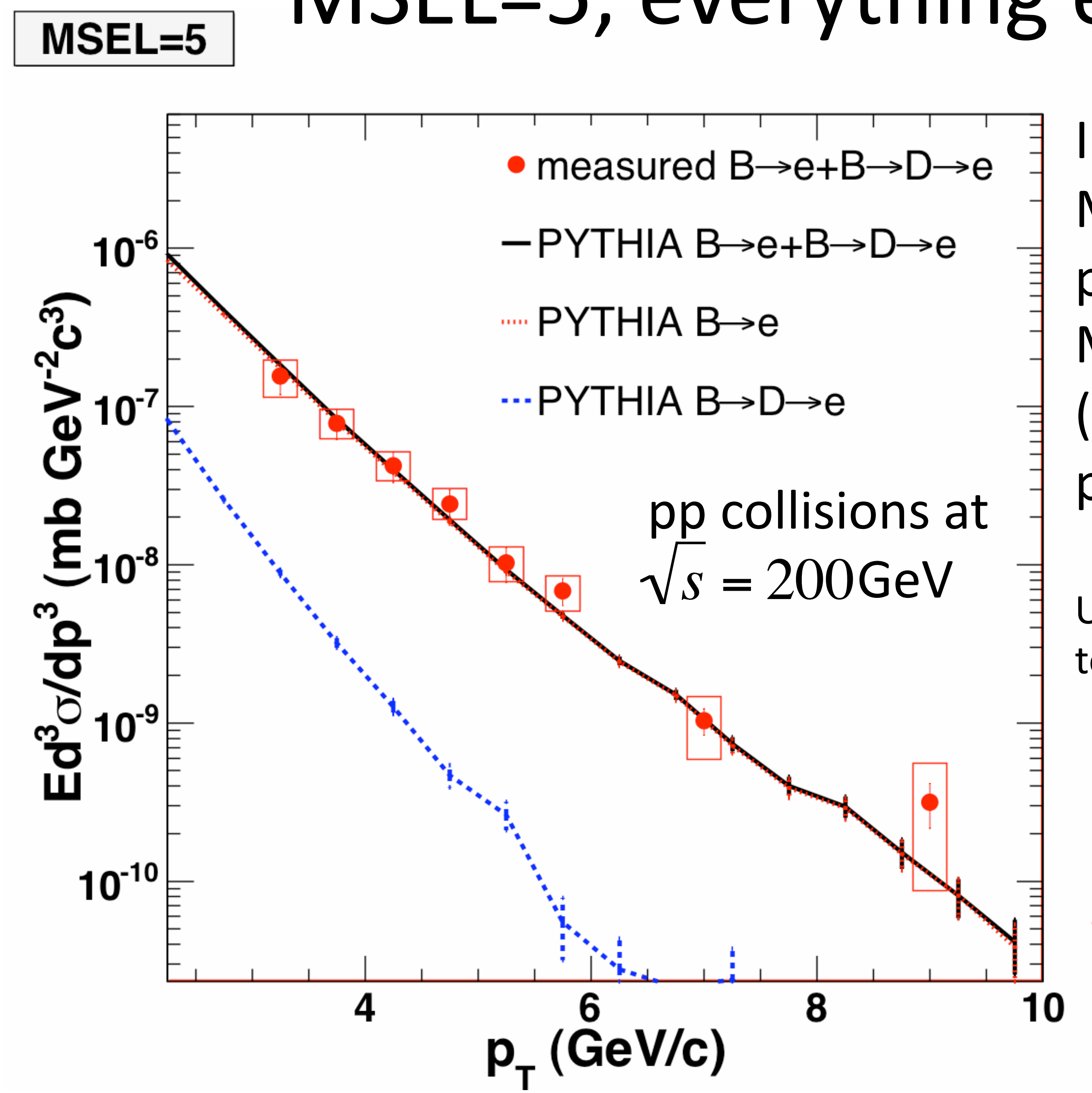
Use normalized PYTHIA calculation to extrapolate:

$$\left.\frac{d\sigma_{B->e}}{dy}\right|_{y=0} (0-10GeV/c) = 40.2nb$$

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

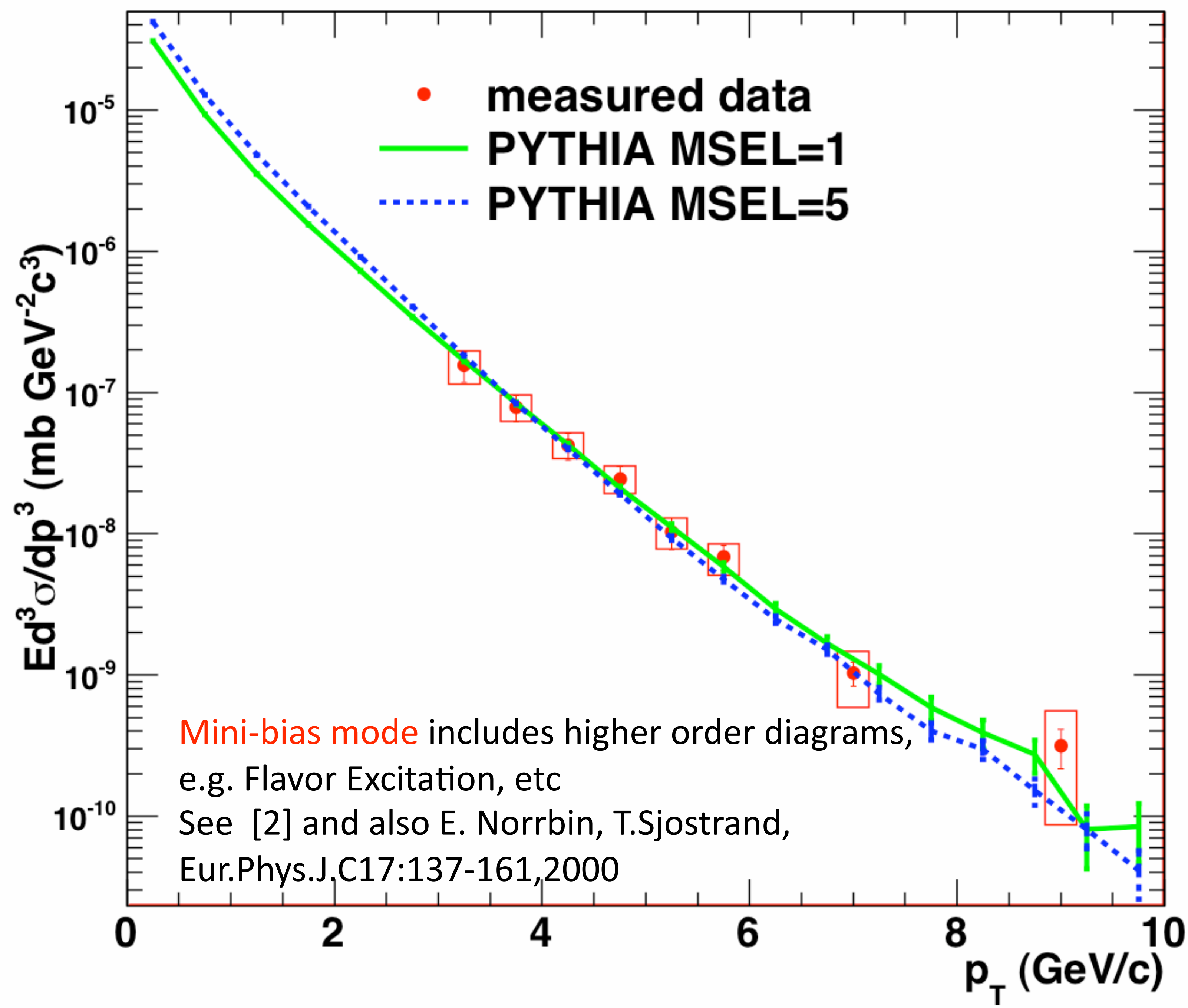
Use normalized PYTHIA calculation to extrapolate:

$$\left.\frac{d\sigma_{B->e}}{dy}\right|_{y=0} (0-10GeV/c) = 53.8nb$$

34% higher!

B→e+B→D→e

MSEL=5 vs MSEL=1



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	40.2	0
$\langle k_T \rangle$=0.5GeV; Max.k_T=5.0GeV(D); p.d.f=CTEQ5M1	41.6	+3.5%
$\langle k_T \rangle$=1.5GeV; Max.k_T=10.0GeV; p.d.f=CTEQ5M1	38.5	-4.3%
$\langle k_T \rangle$=3.0GeV; Max.k_T=15.0GeV; p.d.f=CTEQ5M1	42.2	+5%
$\langle k_T \rangle$=4.5GeV; Max.k_T=20.0GeV; p.d.f=CTEQ5M1	36.0	-10.5%
$\langle k_T \rangle$=2.0GeV(D); Max.k_T=5.0GeV(D); p.d.f=CTEQ5L (D)	38.8	-3.5%
CDF tuneA	45.7	+14%

PYTHIA default

All of them use the default MSEL=1 mode.

[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)***

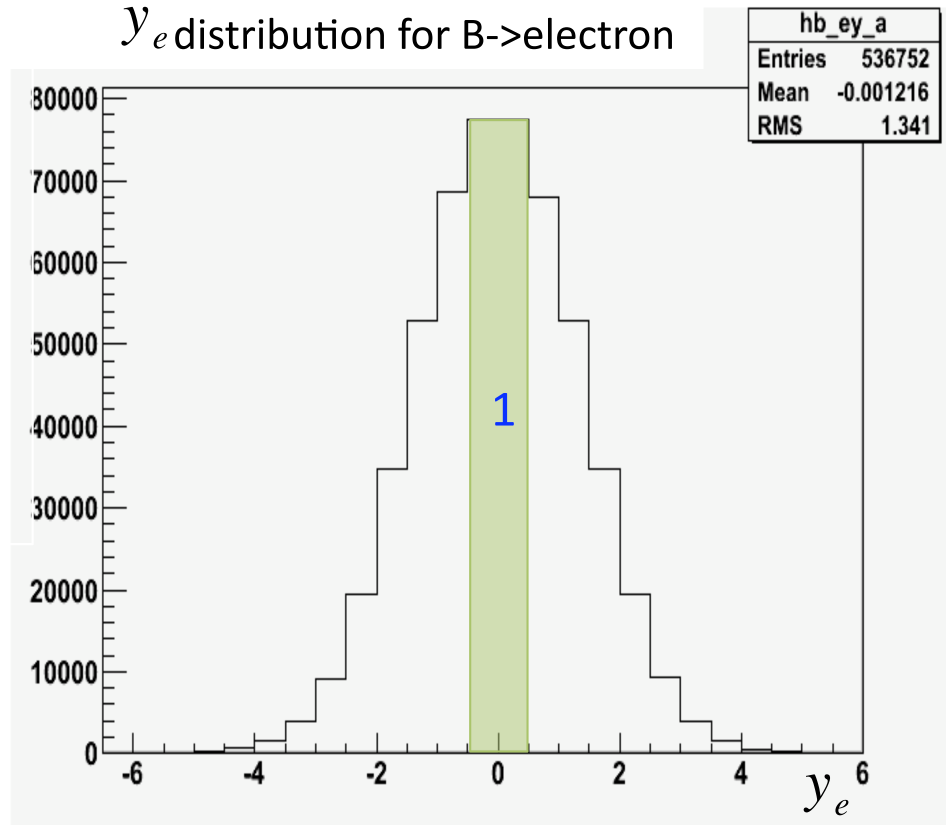
Rapidity distribution correction

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

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

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

y_e distribution for B->electron



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

In p+p collisions at $\sqrt{s} = 200$ GeV, extrapolated

based on STAR NPE measurements at high p_T,

$\sigma_{b\bar{b}} = 1.34 \mu b$ with PYTHIA, MSEL=1 Mode.

$\sigma_{b\bar{b}} = 1.83 \mu b$ with PYTHIA, MSEL=5 Mode.

PYTHIA results bear12.5% (stat.) and 27.5% (sys.) experimental uncertainties.

FONLL[1] calculation: $\sigma_{b\bar{b}} = 1.87^{+0.99}_{-0.67} \mu b$

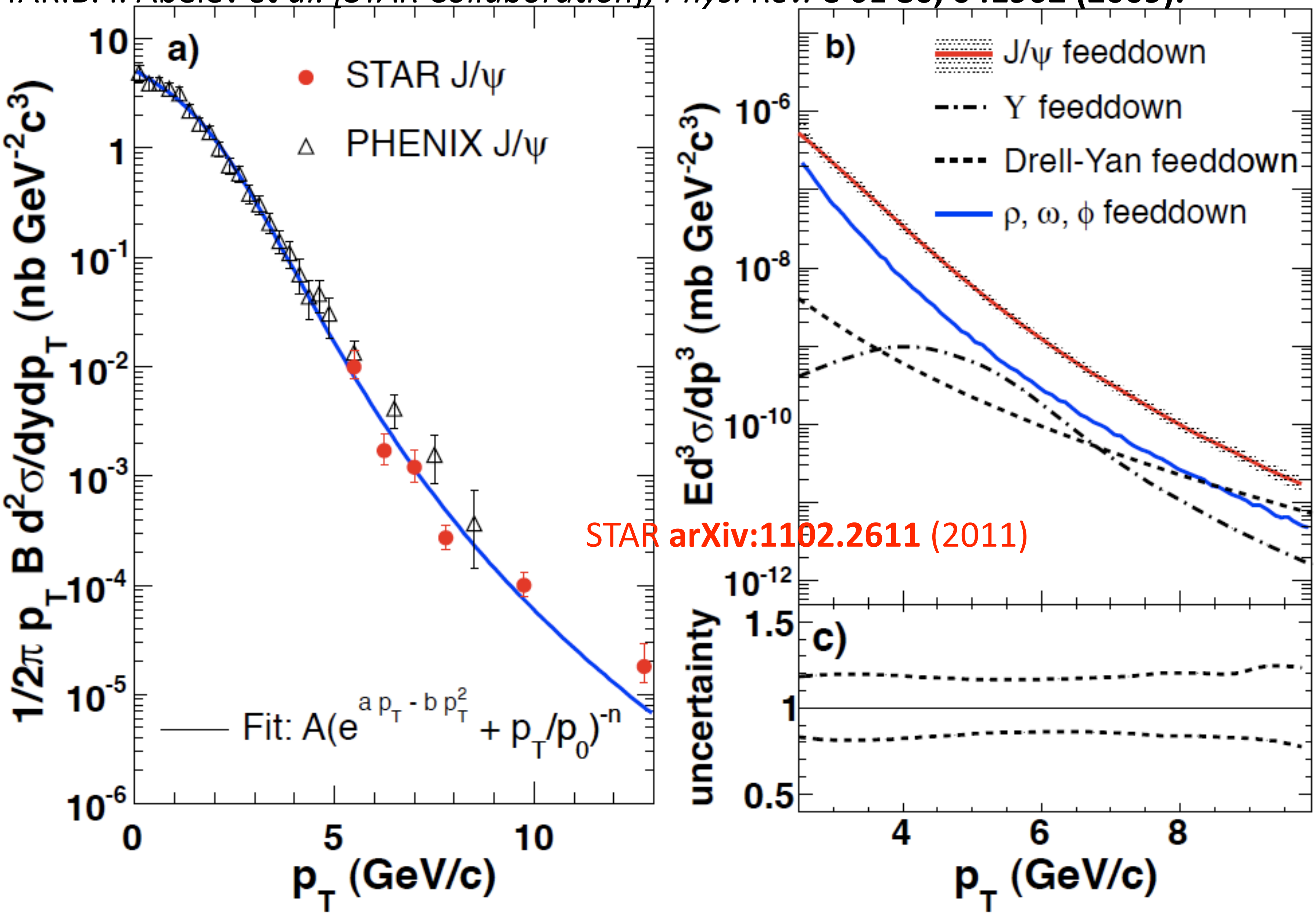
[1]:M. Cacciari, P. Nason and R. Vogt, Phys. Rev. Lett. **95, 20 122001 (2005);**
M. Cacciari, R. Vogt, private communications

backup

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).**



STAR **arXiv:1102.2611** (2011)