PHENIX measurements of $b\bar{b}$ *production in p+p collisions*

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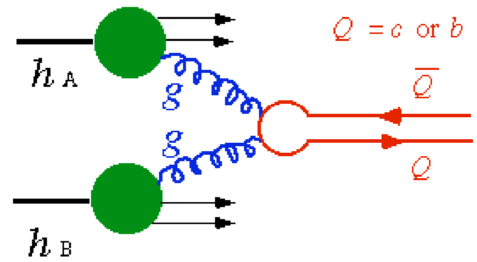
2015 KOBE JAPAN

PHENIX

Motivation

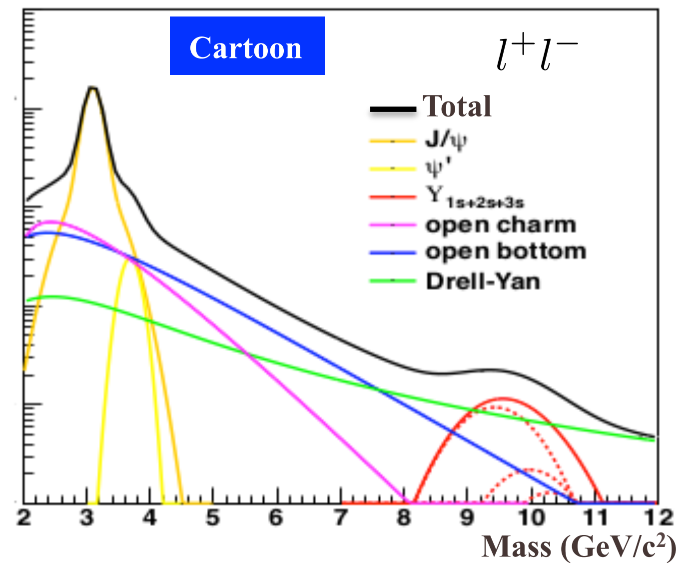
- Bottom quark production is very useful tool to test pQCD theories.

$$m_b \sim 5GeV \gg \Lambda_{QCD}$$

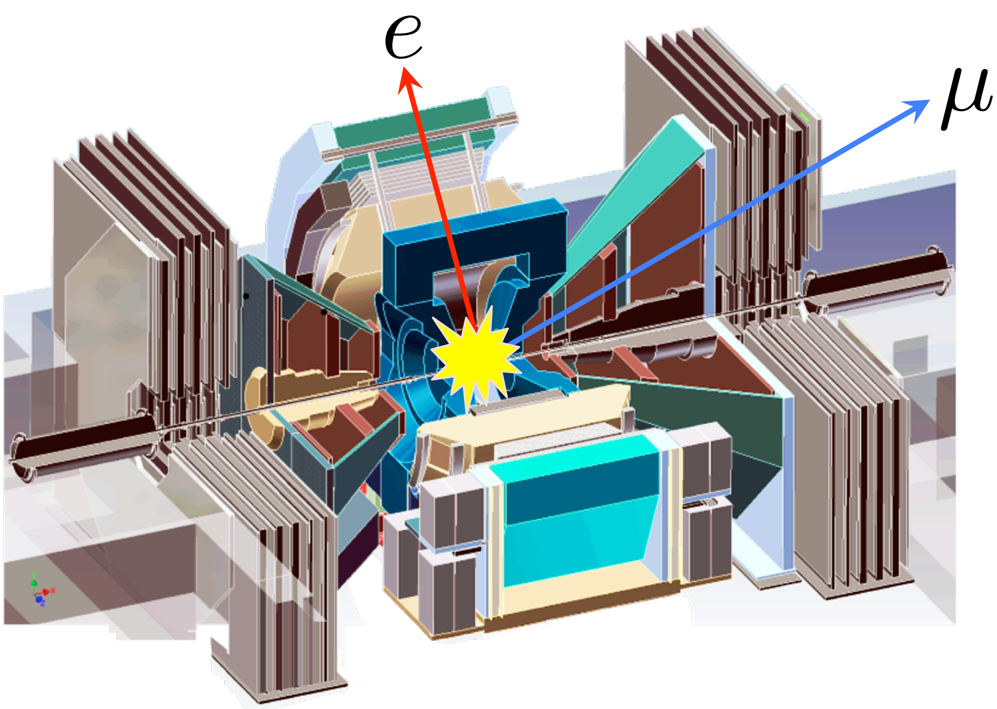


- Large semi-leptonic branching ratio $b \rightarrow e/\mu$, BR~10%.
- Focus on PHENIX open bottom measurements from di-leptons.
- Di-leptons are a unique probe
  - Allow access to diverse physics signal
  - Exploring the mass and p_T phase space

  simultaneously provides separation of charm and bottom.



The PHENIX detector



Electron acceptance:

- $|\eta|<0.35$
- $p_e > 0.2$ GeV/c
- $\Delta\varphi = \pi$(2 arms x $\pi/2$)

Muon acceptance:

- $1.2 <|\eta|<2.2$
- $p_\mu > 1$ GeV/c
- $\Delta\varphi = 2\pi$

Outline of this talk

$b\bar{b}$ **measurements in p+p collisions:**

- ❖ **At $\sqrt{s}$ = 200 GeV using unlike-sign e^+e^- pairs.**
- ❖ **At $\sqrt{s}$ = 500 GeV using like-sign $\mu^\pm\mu^\pm$ pairs from B oscillation.**

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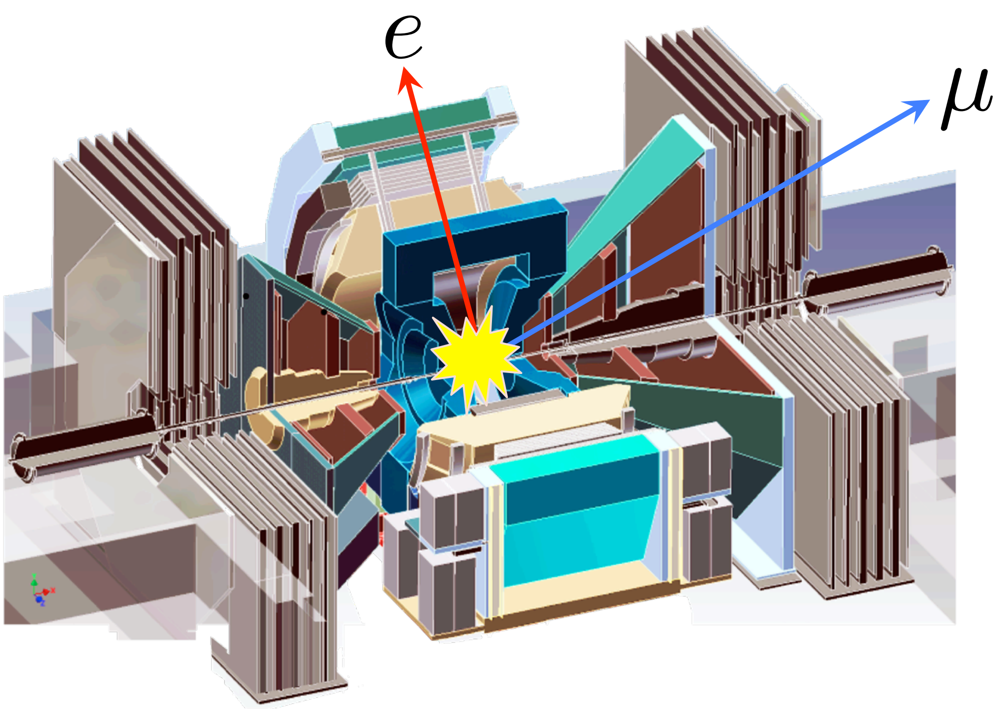

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Uniqueness:

- ❖ **No secondary vertex determination required.**
- ❖ **Results have smaller statistical uncertainties.**

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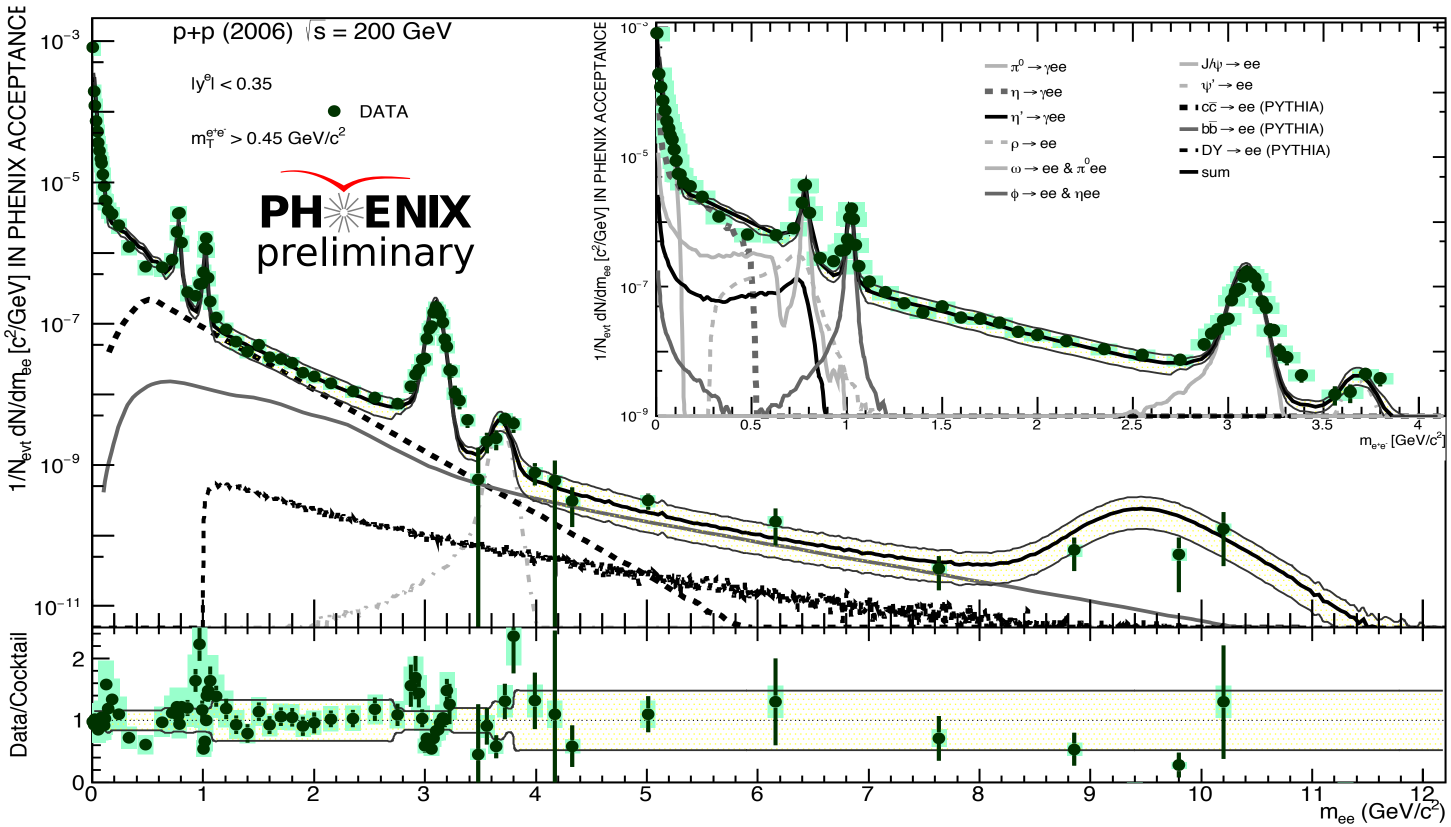
$b\bar{b}$ measurement using unlike-sign electron pairs

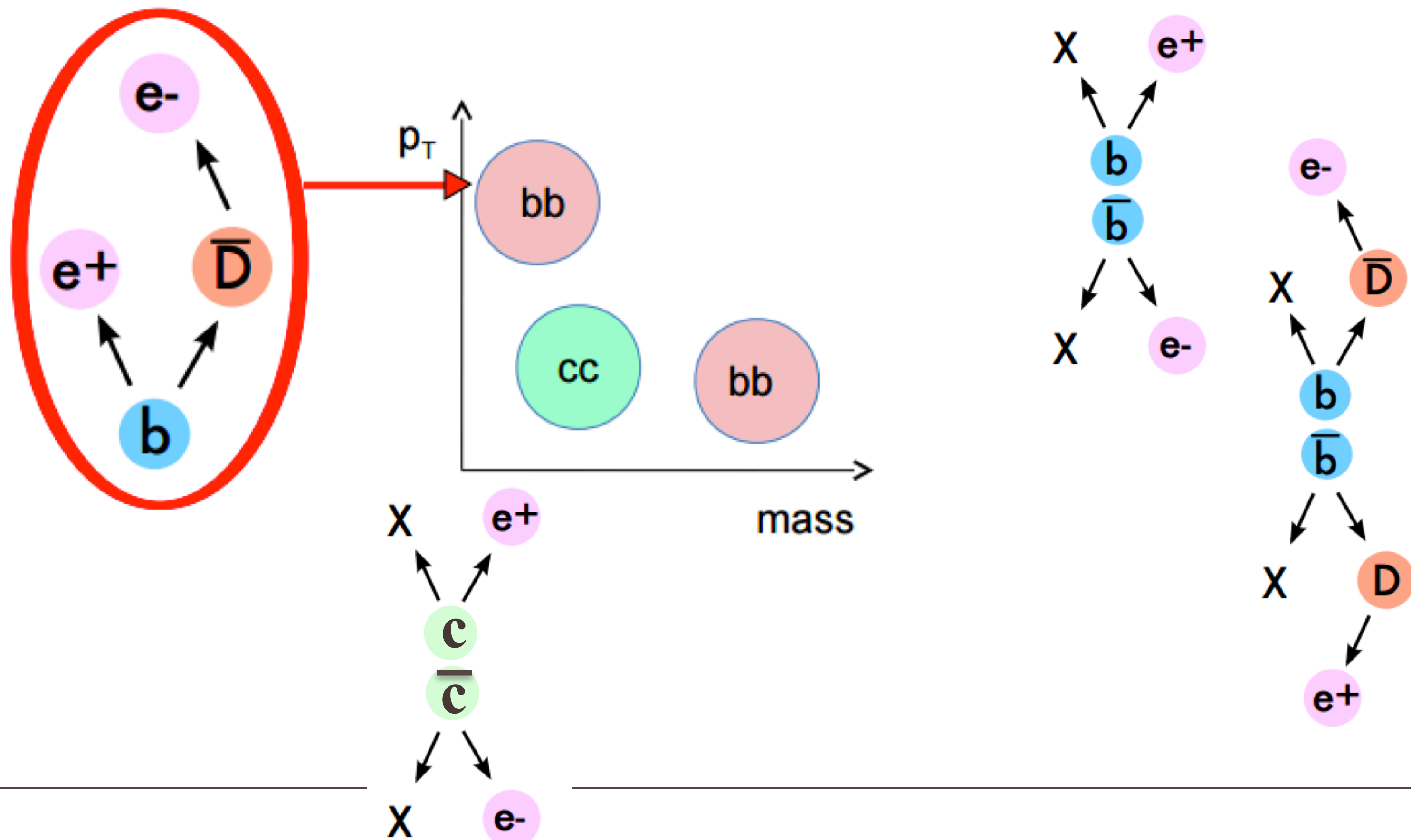
Unlike-sign di-electron spectra



- High quality, large mass range e^+e^- pair data from 2006.
- Very well understood in terms of
  - Hadronic cocktail at low masses
  - DY, charm and bottom at high masses
- Same technique as PRC 91, 2015, 014907 (d+Au)

Isolating charm and bottom contributions

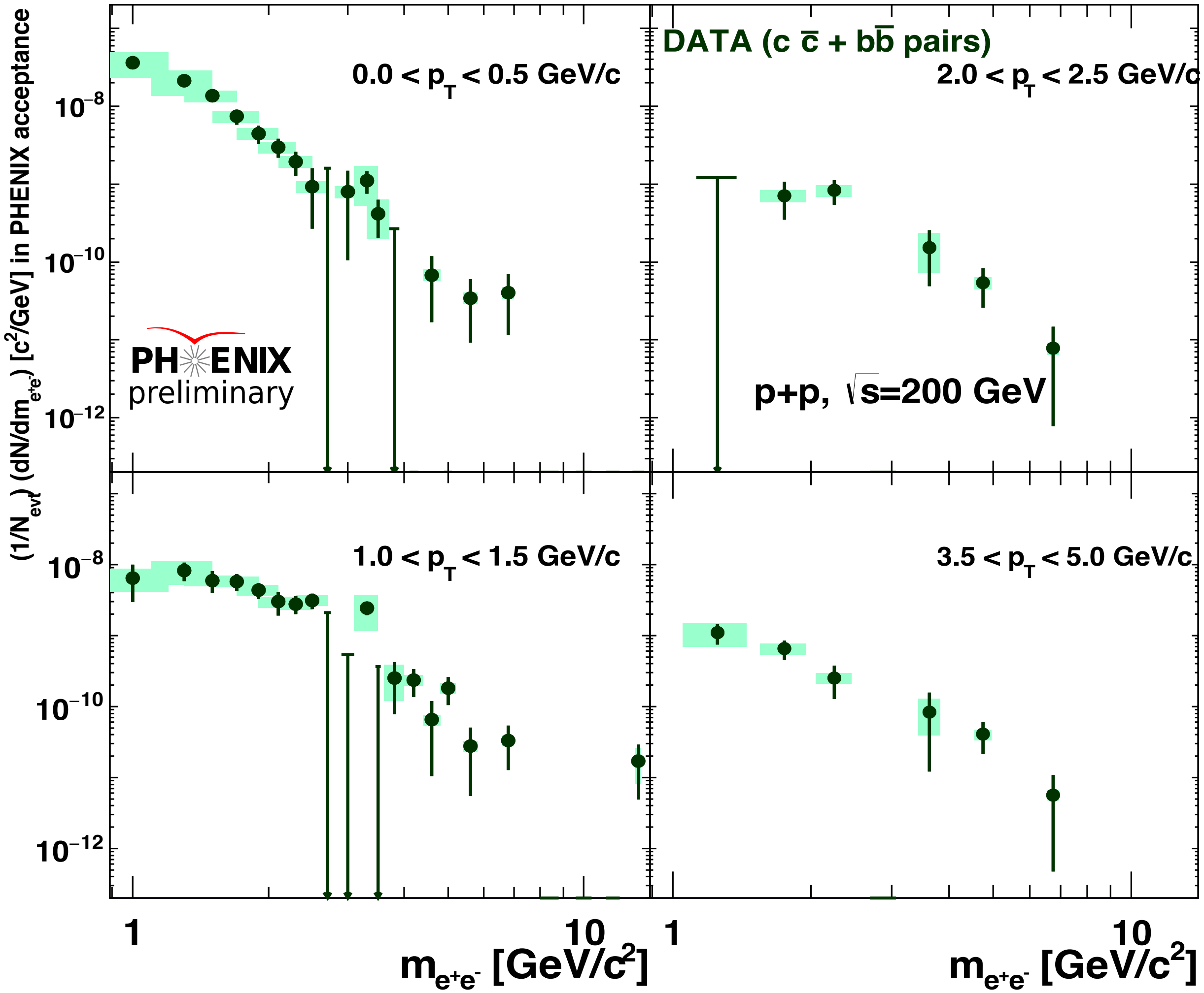
- ❖ Subtract the yield of
  - Vector and pseudo-scalar mesons
  - Drell-Yan
- ❖ Left with the electron pairs from charm and bottom.
- ❖ Separate charm and bottom by fitting mass and p_T simultaneously.



Heavy flavor mass spectra in p_T bins

Heavy flavor mass spectra

$$DATA - (\pi, \eta, \eta', \rho, \omega, \phi, J/\psi, \psi', \Upsilon, DY)$$



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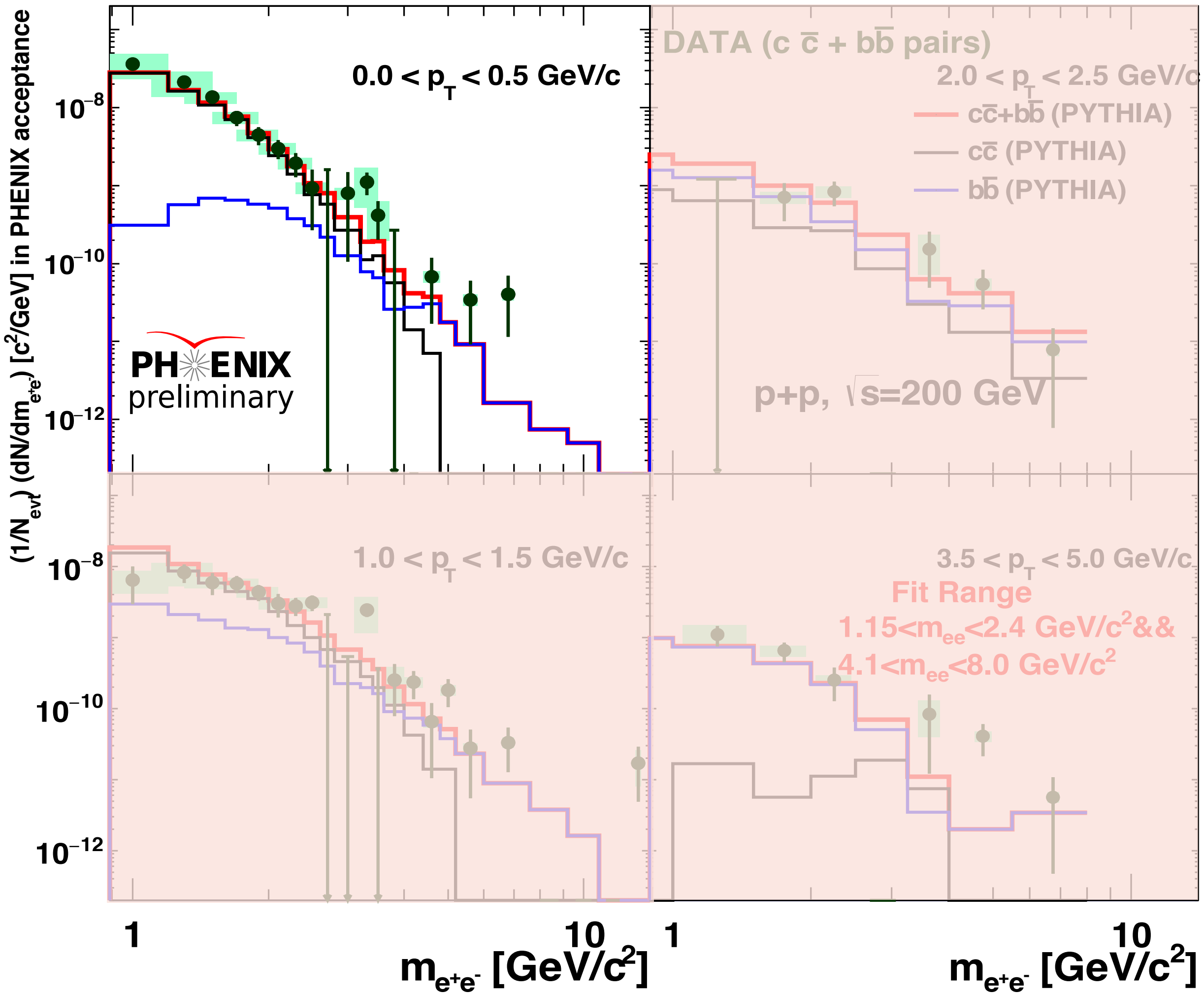
PYTHIA Shapes:

Charm

Bottom

Total



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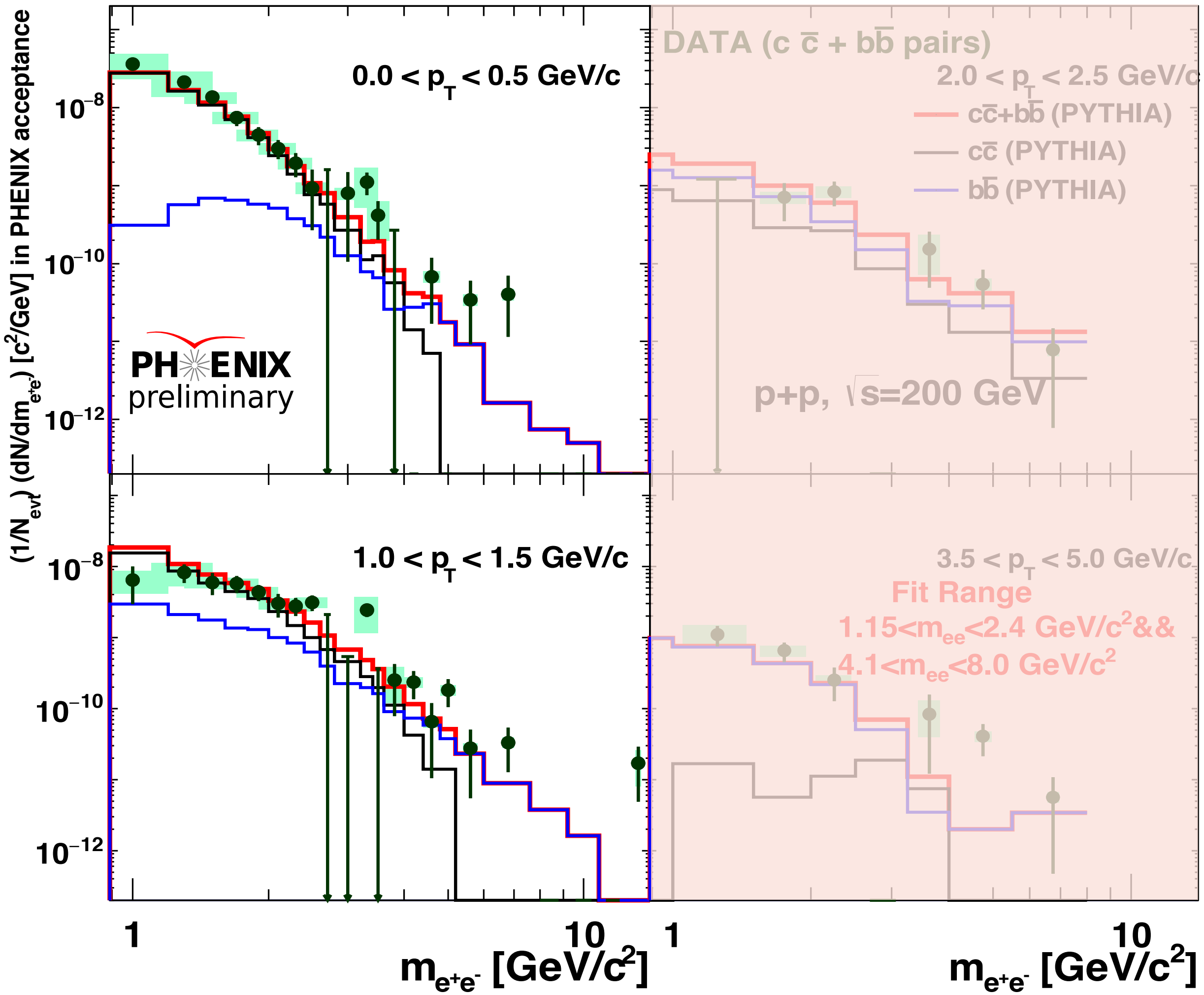

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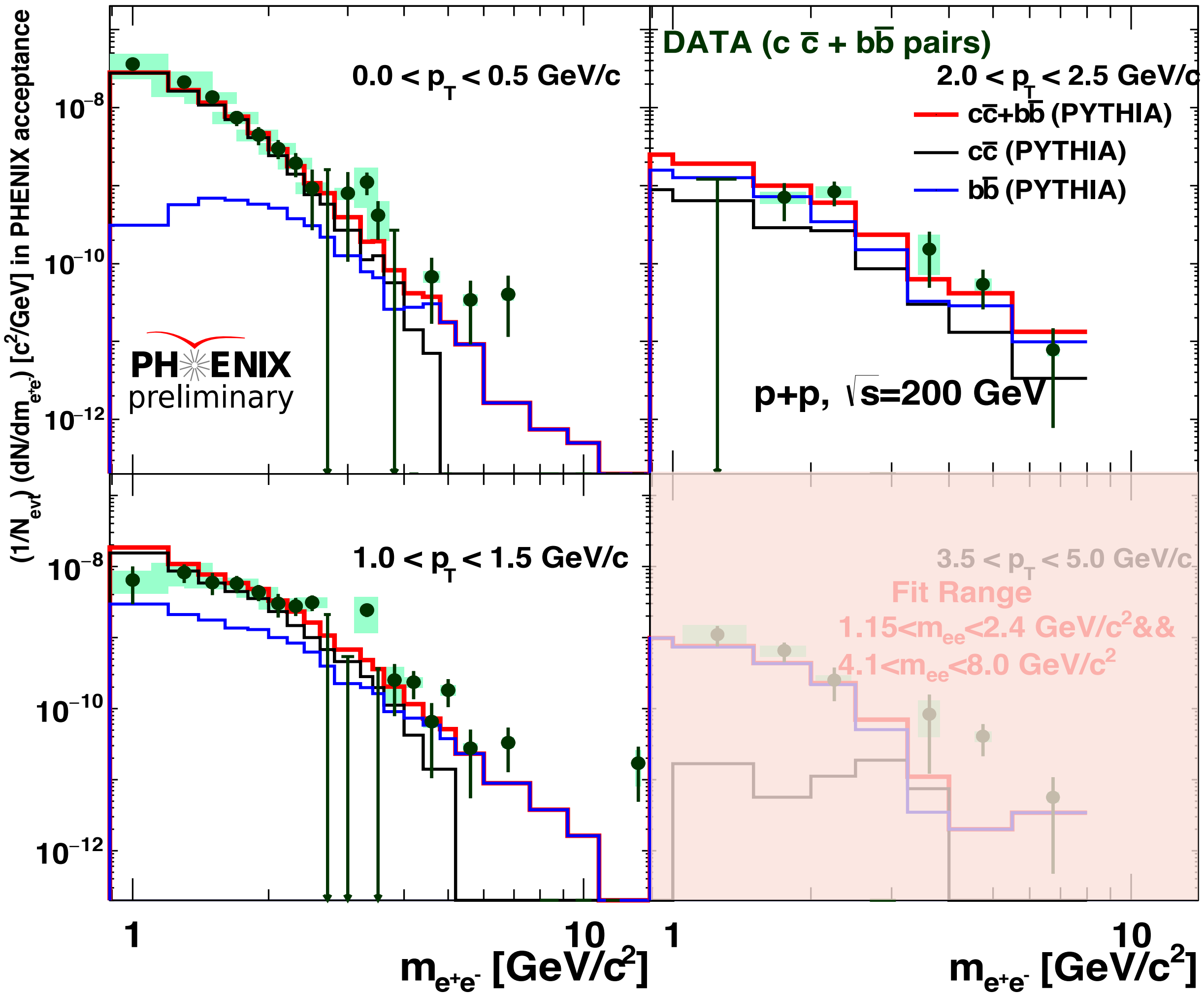

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Charm dominates

- Low p_T, low mass

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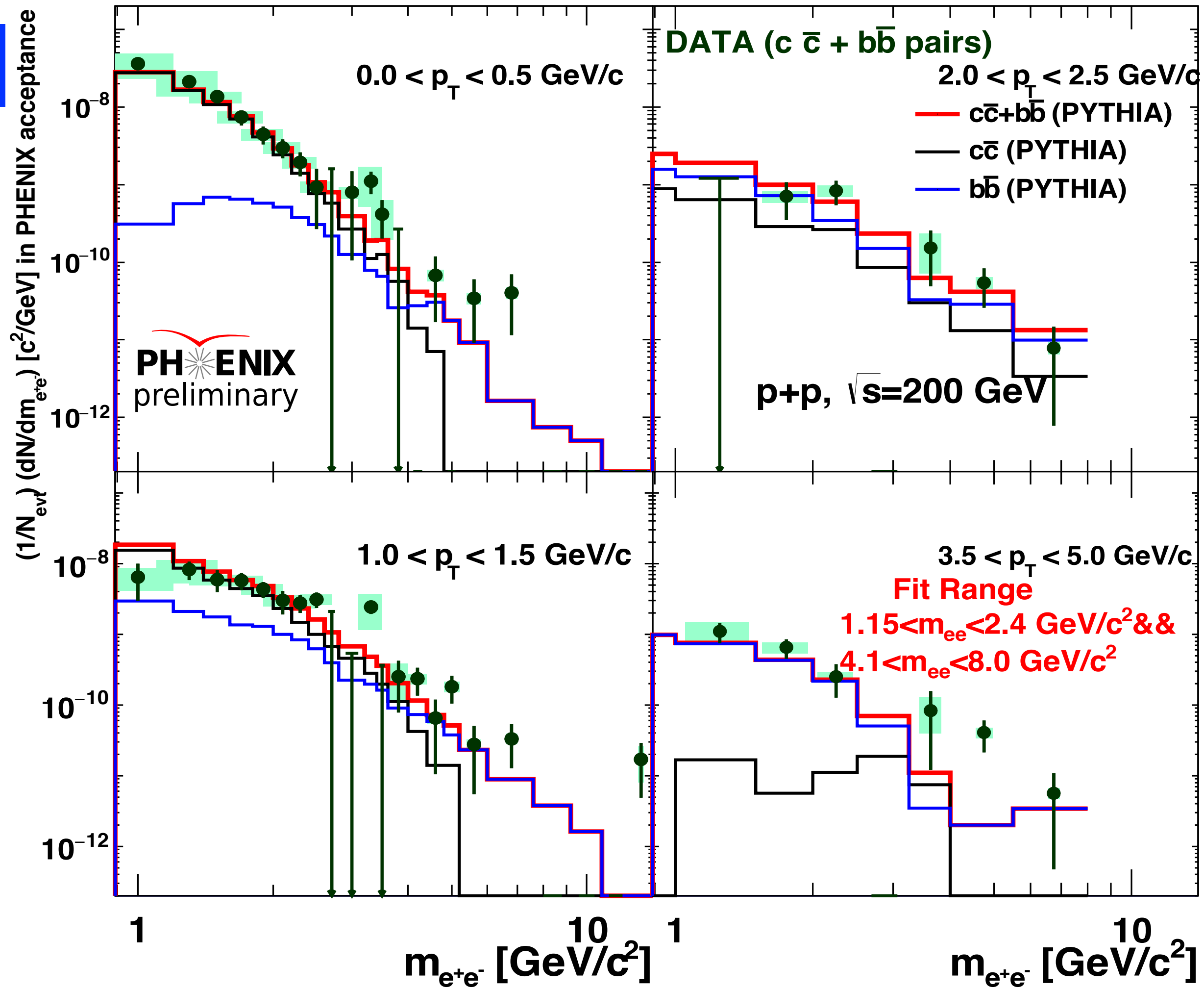
- Low p_T, high mass
- High p_T, low mass



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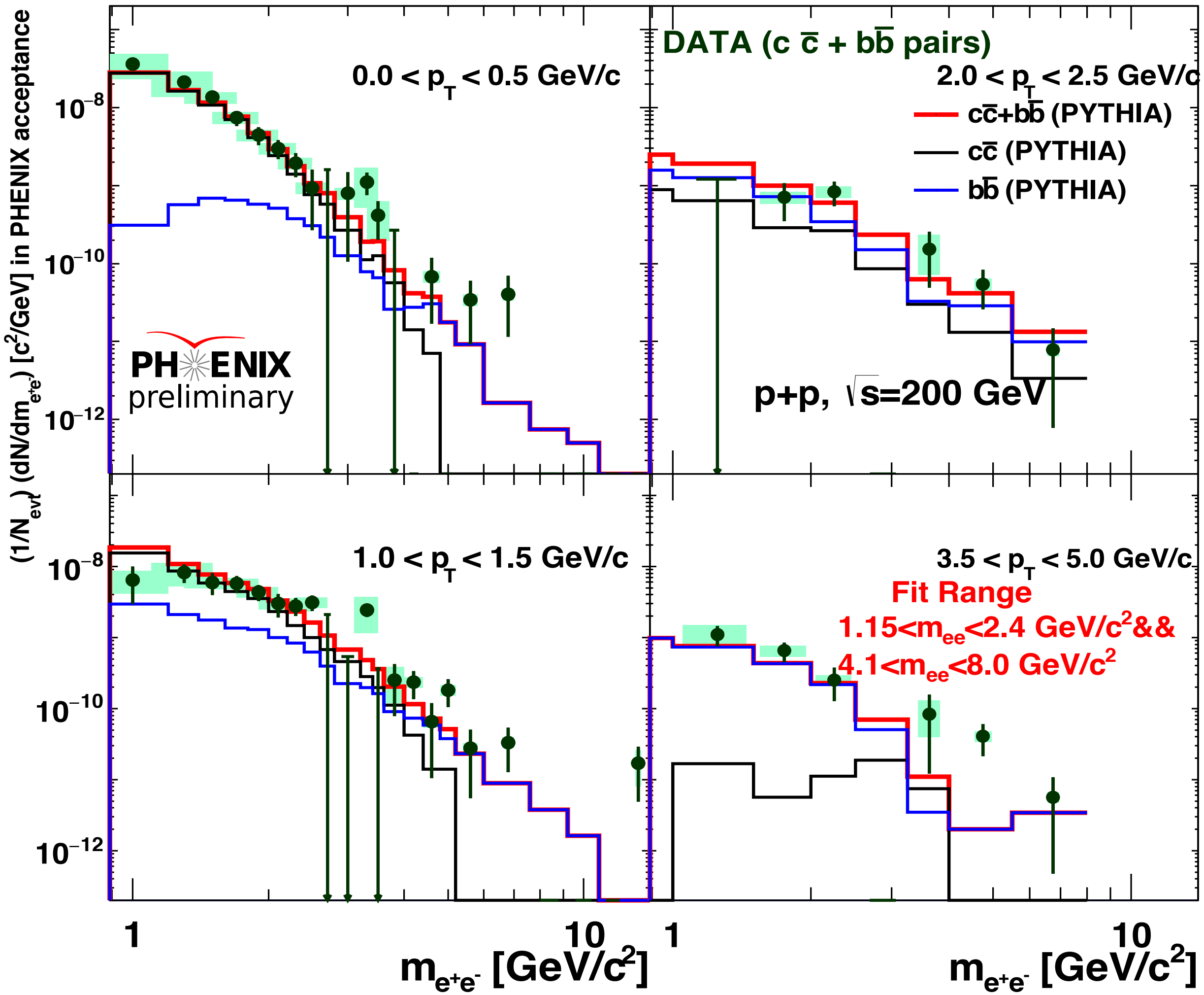


Charm dominates

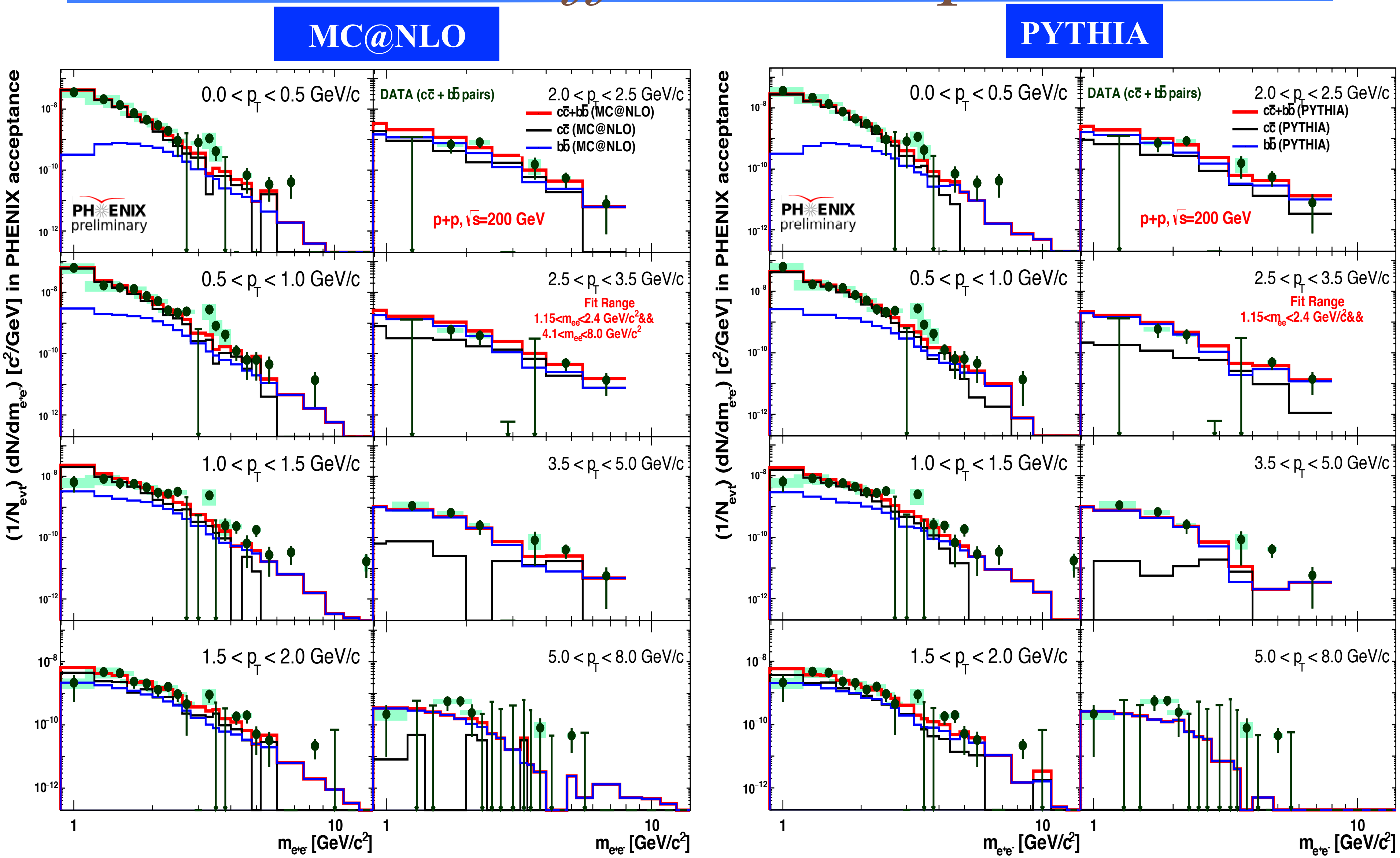
- Low p_T, low mass

Bottom dominates

- Low p_T, high mass
- High p_T, low mass

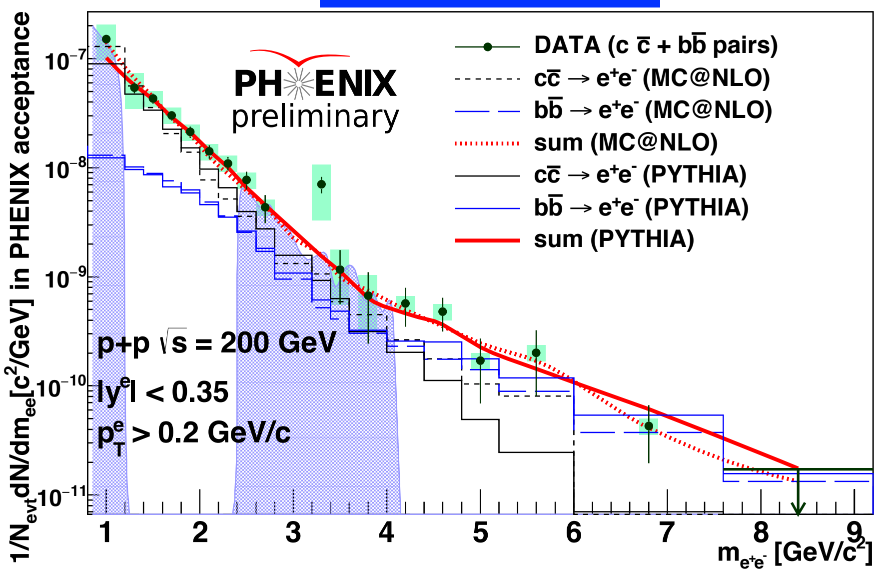
This behavior is model independent.

Double differential spectra

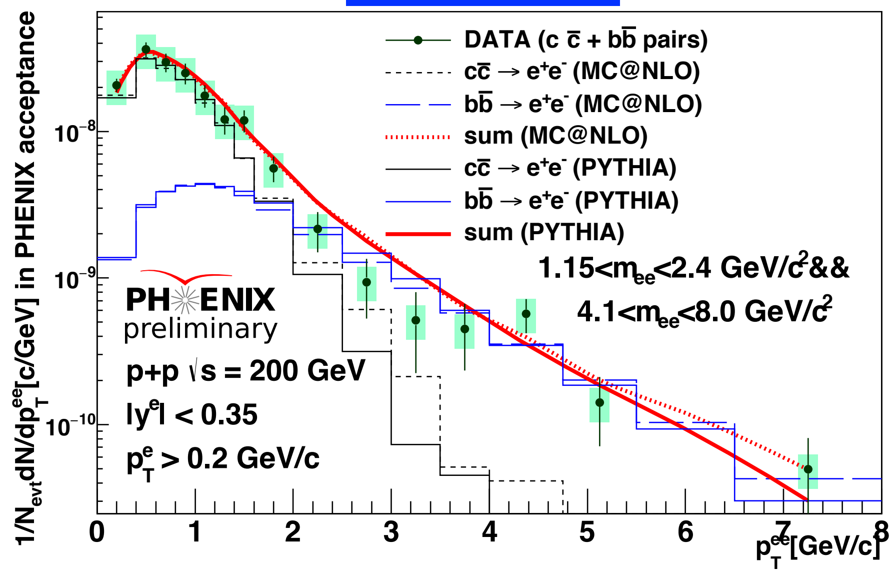


Integrated mass and p_T spectra

Mass spectra



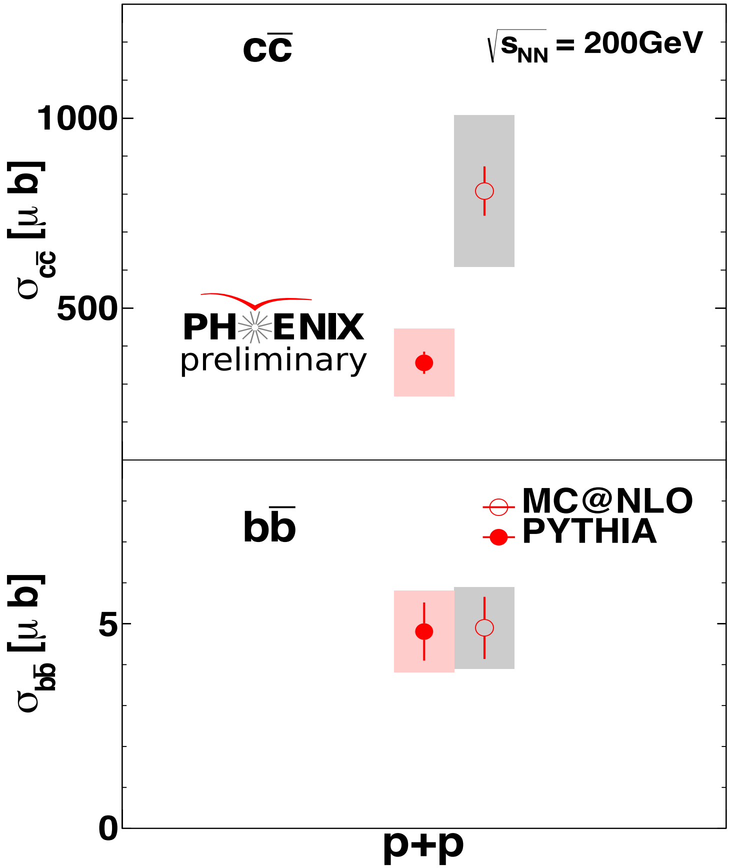
p_T spectra



$$\frac{1}{N_{\rm evt}^{\rm MB}} \frac{dN_{ee}^{hf}}{dmdp_T}\Big|_{PHENIX} = N_{c\bar{c}} \frac{dn_{ee}^{c\bar{c}}}{dmdp_T} + N_{b\bar{b}} \frac{dn_{ee}^{b\bar{b}}}{dmdp_T}$$

Both PYTHIA and MC@NLO describe the data equally well.
Shaded region in the mass region is excluded in the fits.

Extrapolation to total cross-section



Bottom cross-section is model independent.
Charm is not!

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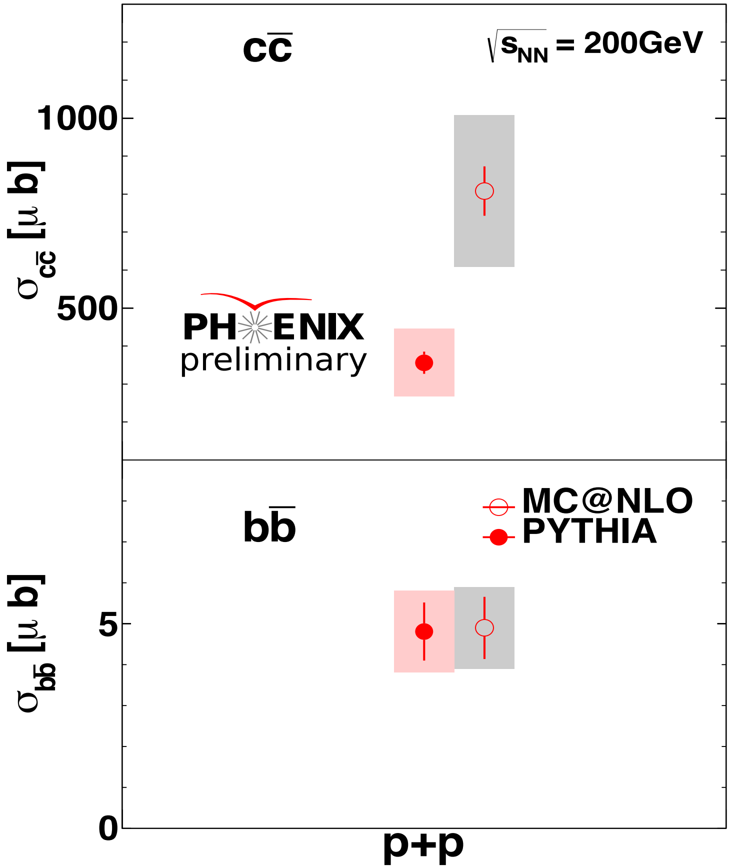

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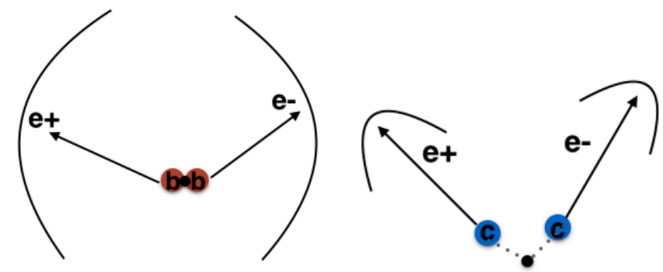
Model bias



- If m_q>>p, the e^+e^- decay randomizes the opening angle.
  - Otherwise, the opening angle between electrons depends on the opening angle between quark pair.
- The rapidity shapes between PYTHIA and MC@NLO are different for charm pairs.
- This implies a larger model dependence for $c\bar{c}$ than $b\bar{b}$ pairs.

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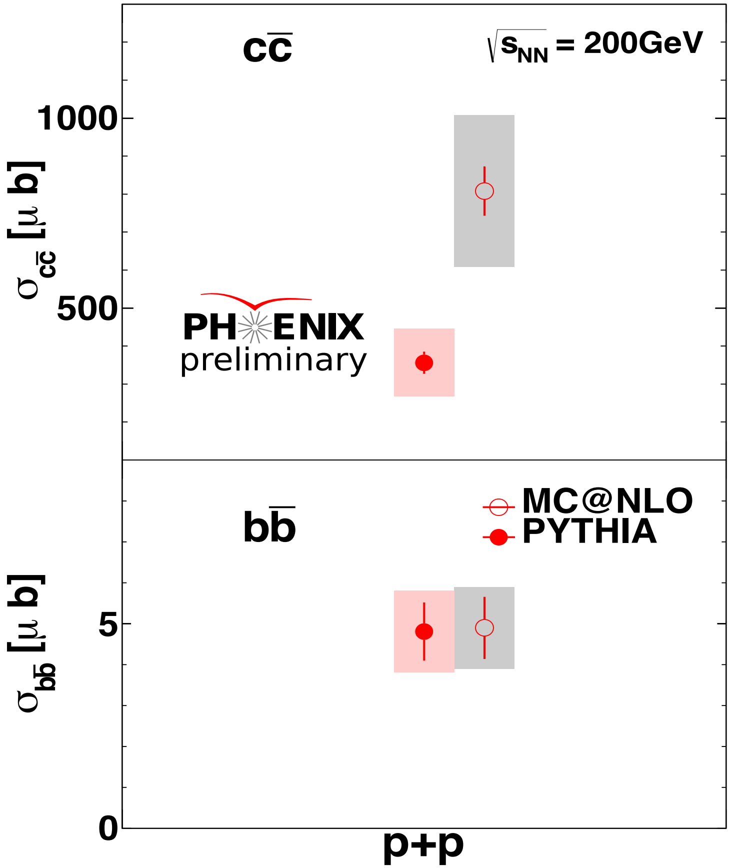

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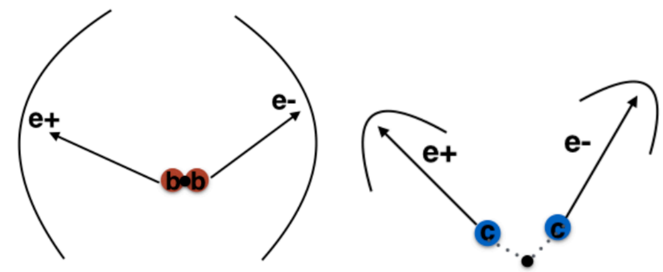

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See poster by Deepali Sharma (ID:256)

$b\bar{b}$ measurement using like-sign muon pairs from B oscillation

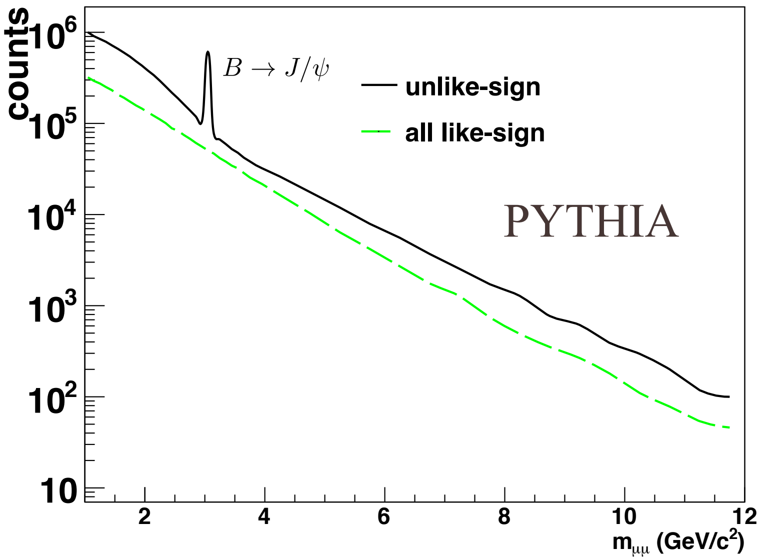
Advantages of like-sign pairs

Like-sign pairs: no contamination from Quarkonia, DY or vector mesons.

Like-sign pairs consists of

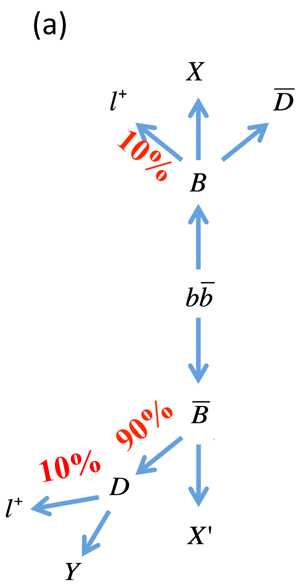
- ❖ Combinatorial pairs
  - Estimated from event mixing
- ❖ Correlated pairs
  - Charm pairs:
    - ✧ Negligible.
    - ✧ <1% in PHENIX acceptance
  - Bottom pairs.
  - Jet pairs.

Bottom decay



Nearly half of the total bottom yield is like-sign!

Closer look at b decay

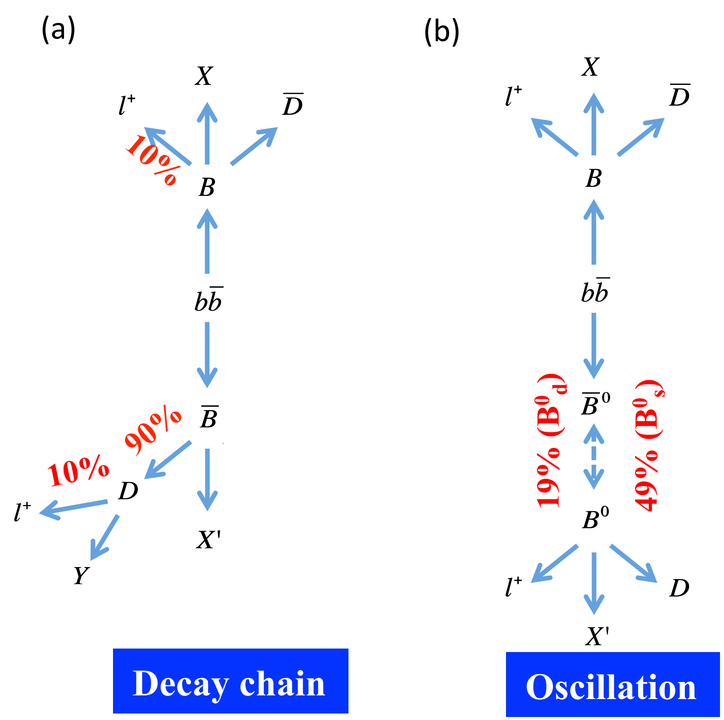


Decay chain

Primary: $B \to l^+ X$

Feed down: $B \to \bar{D} X \to l^- X$

Closer look at b decay

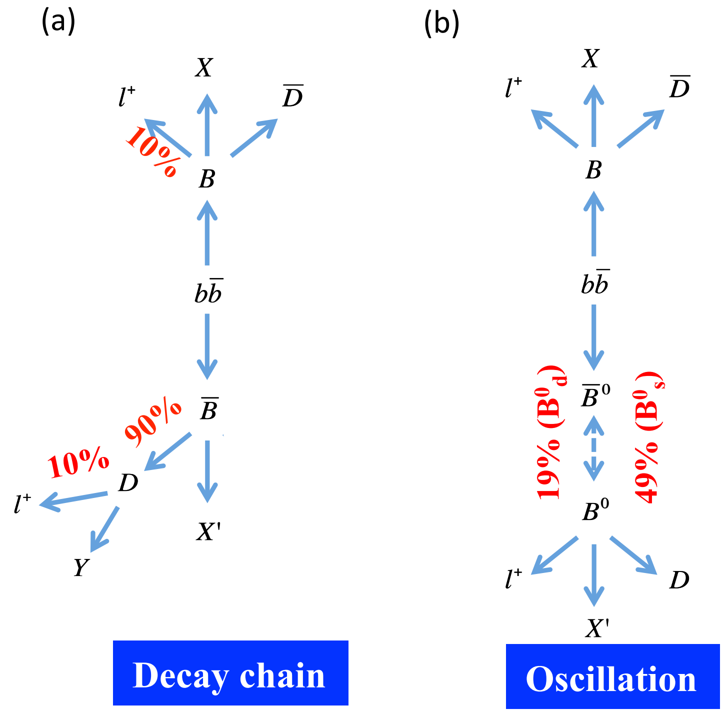


Primary: $B \to l^+ X$

Feed down: $B \to \bar{D}X \to l^- X$

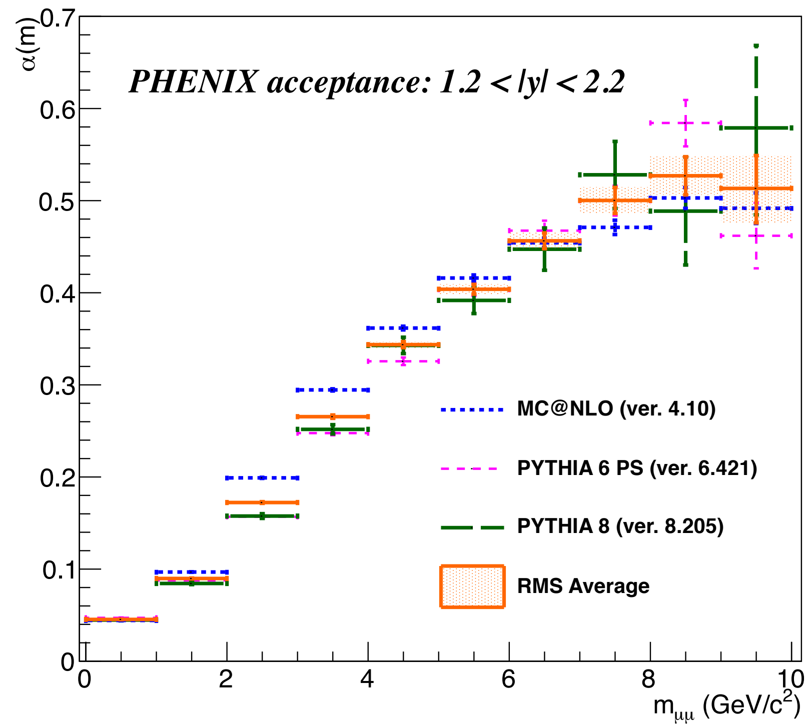
Primary-Primary decay only produces like-sign pairs via oscillation.

Closer look at b decay



Fraction of like-sign pairs comes from oscillations

$$\alpha(m) = \frac{b\bar{b} \to B\bar{B} \to \mu^{\pm}\mu^{\pm}\ (\mathrm{osc})}{b\bar{b} \to B\bar{B} \to \mu^{\pm}\mu^{\pm}}.$$



Primary: $B \to l^{+}X$

Feed down: $B \to \bar{D}X \to l^{-}X$

Primary-Primary decay only produces like-sign pairs via oscillation.

Total number of bottom pairs:

$$N_{b\bar{b}} = N_{primary-primary}/(BR(B \to \mu))^2$$

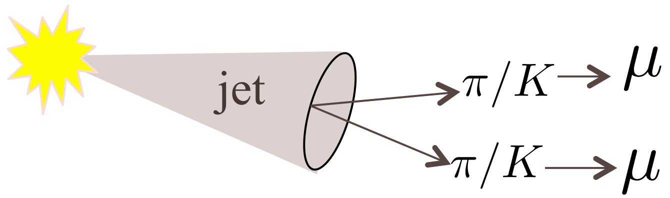
Dimuons at $\sqrt{s} = 500$ GeV

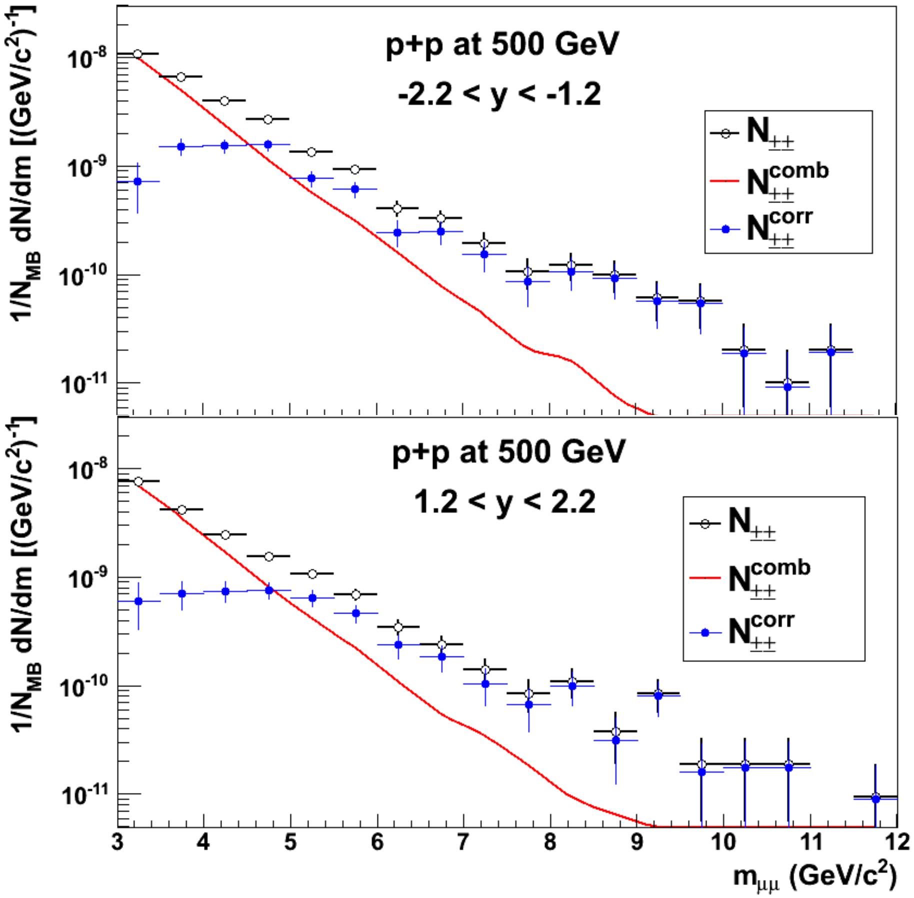
- Combinatorial background was subtracted out using event mixing method.

$$N_{\pm\pm}^{corr} = N_{\pm\pm}^{like} - N_{\pm\pm}^{mixed}$$

- In high mass region, correlated pairs contains:
  - Bottom pairs
  - Jet pairs

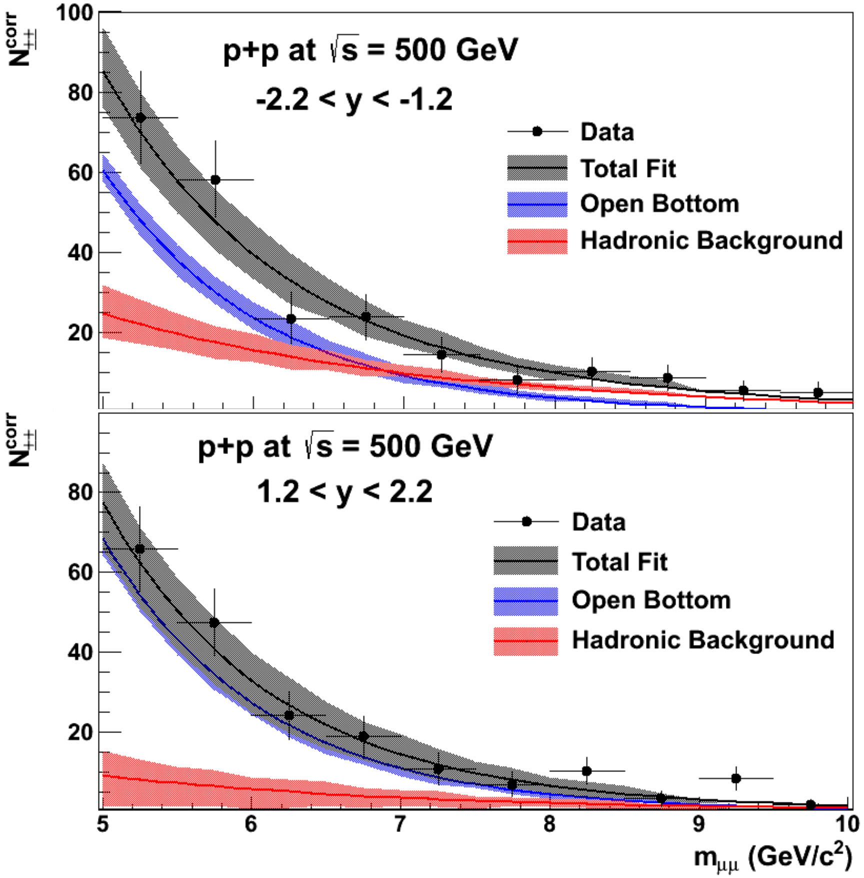
- Jet pair contribution is estimated from hadronic simulation



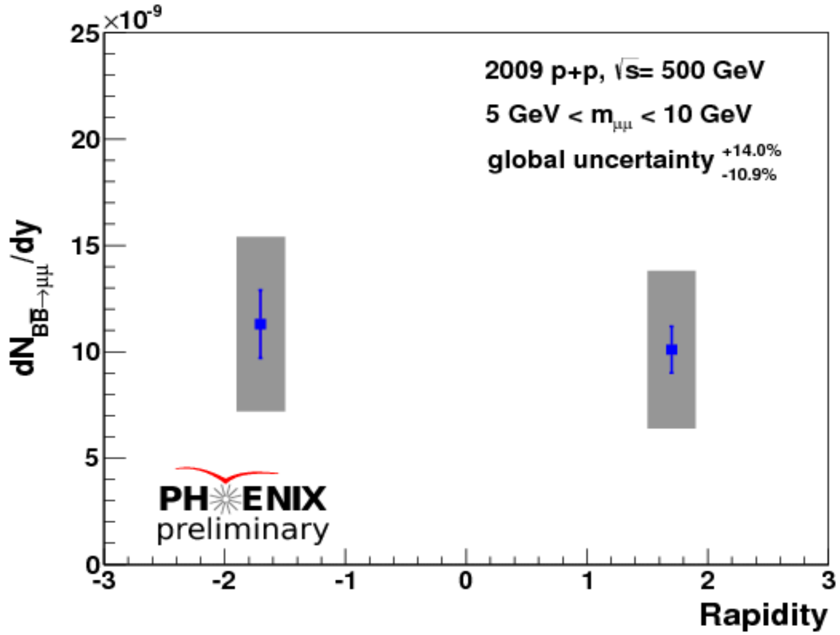


Extracting the bottom contribution

- Mass region between 5 and 10 GeV
  - B oscillation pairs dominate
- Slopes were fixed from simulation.
- Extracted hadronic and open bottom contribution.
- Forward/backward rapidity hadronic background differ due to different amount of absorber material.



Total cross-section



Bottom cross-section from primary-primary decay

$$N_{\pm\pm}^{osc} = \alpha(m) * N_{\pm\pm}^{B,corr}$$

$$N_{BB\to\mu\mu} = N_{\pm\pm}^{OSC} * \left(\frac{1}{\beta}\right)$$

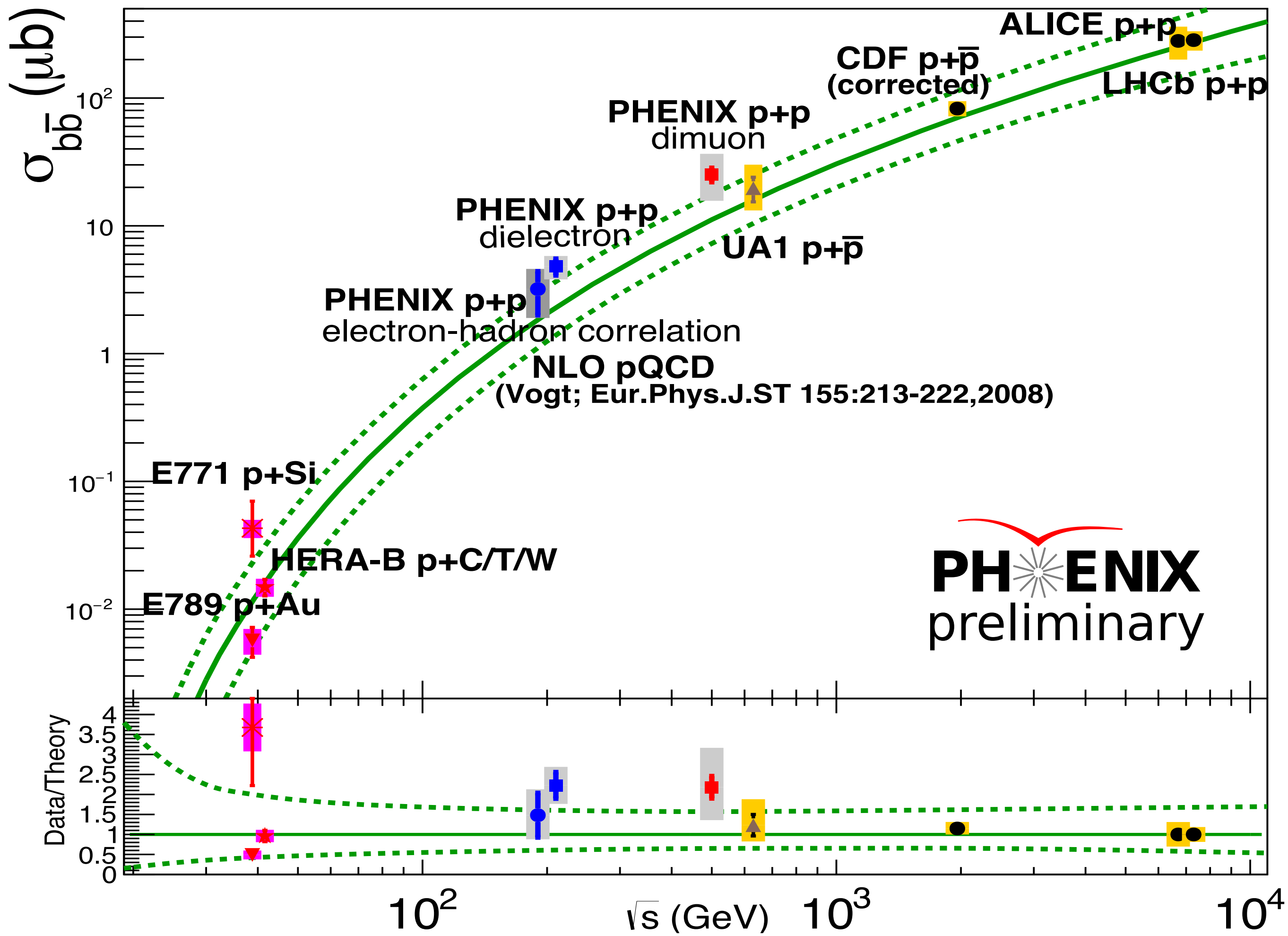
β is the fraction of primary-primary B decay from oscillation.

Total cross-section:

$$\sigma_{bb} = \frac{d\sigma_{bb\to\mu\mu}}{dy} * \frac{1}{scale} * \frac{1}{BR^2_{(B\to\mu)}}$$

Extrapolated using PYTHIA (scale~0.2%) to calculate the total cross-section.

Global perspective



Results are consistent with the NLO pQCD calculation within uncertainties.

Summary

- Dileptons provides a low background measurement of $b\bar{b}$.
- Measurements does not require secondary vertex determination.
- Both PYTHIA and MC@NLO describe the data nicely,
  - Precise measurement of bottom cross-section.
  - Large model uncertainty in charm cross-section.
- Measured bottom cross-section from like-sign dimuon pairs via oscillation.
  - Extrapolation of the bottom cross-section is higher than pQCD value but consistent within uncertainties.

See poster by Deepali Sharma (ID:256)

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Thank you

BACKUP

D oscillation

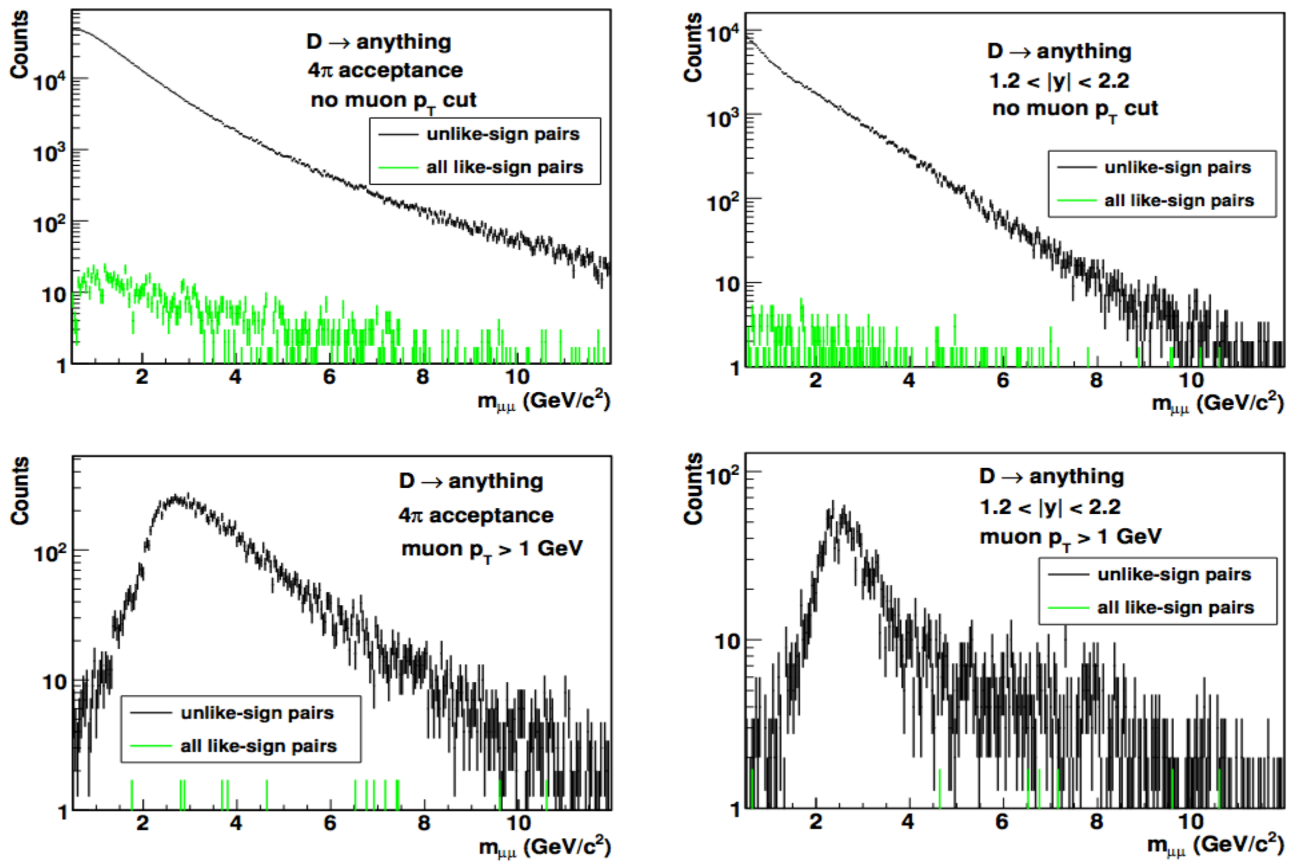
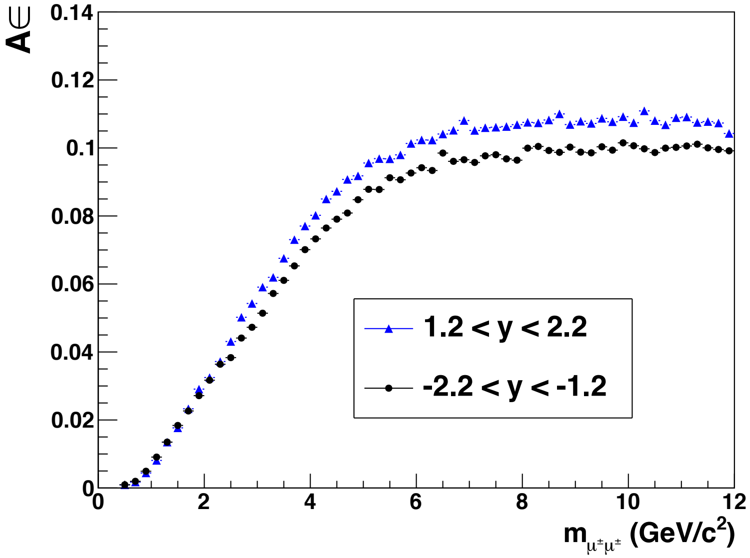
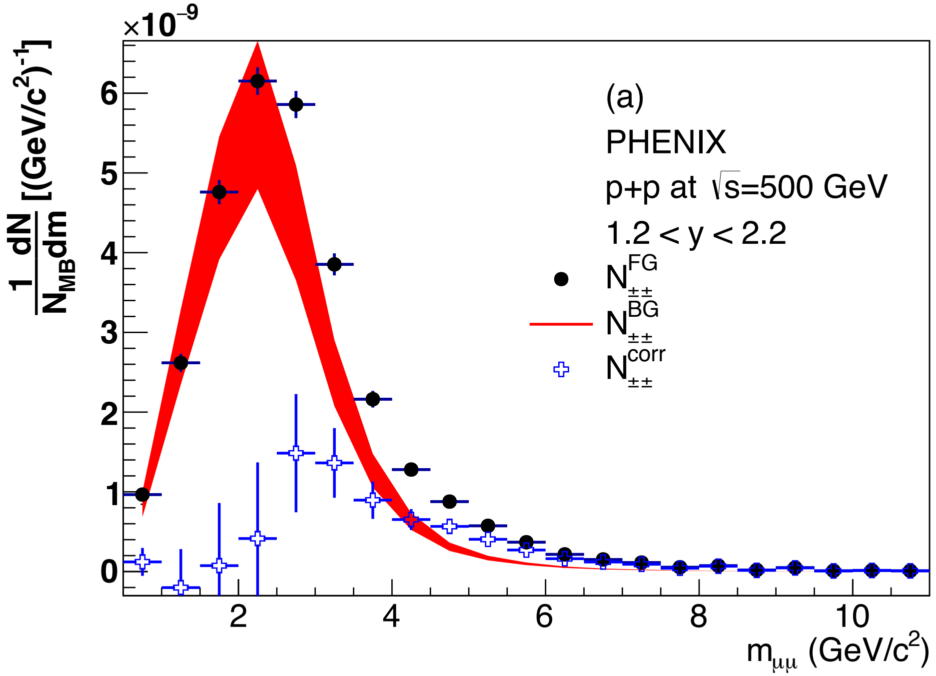


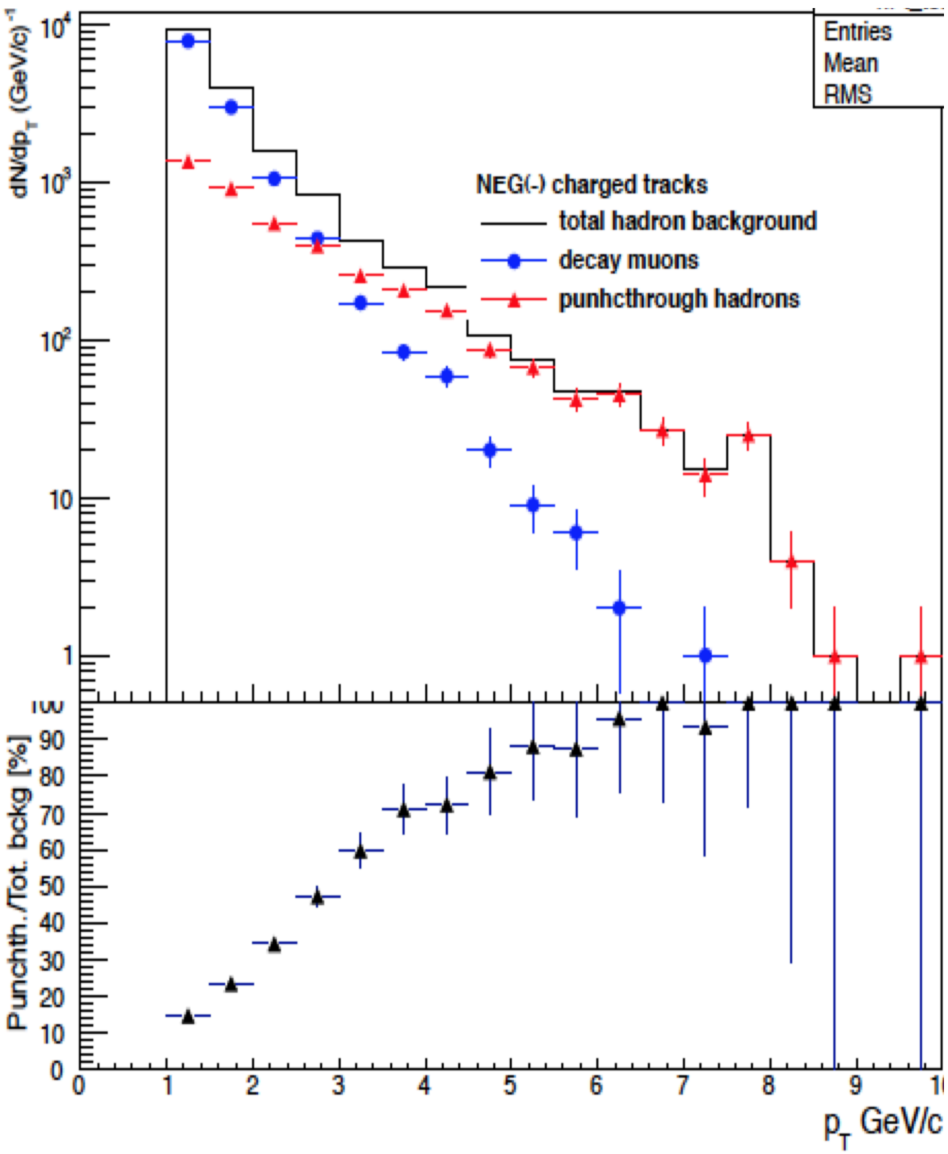
Figure 33: Invariant mass plots of the unlike-sign (black) and all like-sign (green) dimuons from open charm mesons generated in Pythia. The small number of counts in the high mass region are due to underlying events and are not correlated.

Normalization

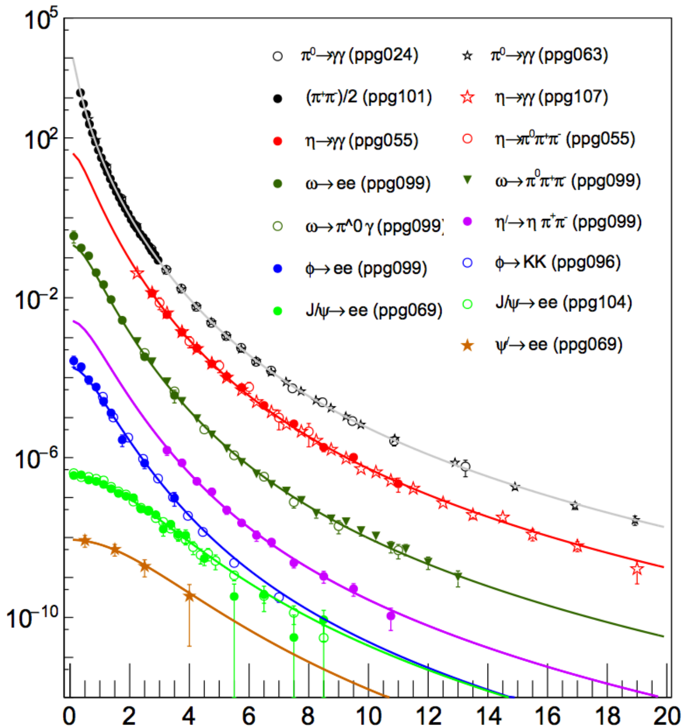




Hadron background



cocktail



Systematic source	Uncertainty (Mass $\leq$ 1.0 GeV/c^2)	Uncertainty (Mass > 1.0 GeV/c^2)
	Data systematics	
eID	15%	10%
ERT	10%	3%
Fiducials	8.6%	
$\alpha-$ correction	5%	
	Cocktail systematics	
Hadronic cocktail	20%	
$c\bar{c}$ cross-section	32%	
$b\bar{b}$ cross-section	36%	