# Nuclear Modification of B-mesons in Cu+Au collisions at 200 GeV Measured Through B->J/ψ decay by the PHENIX Experiment

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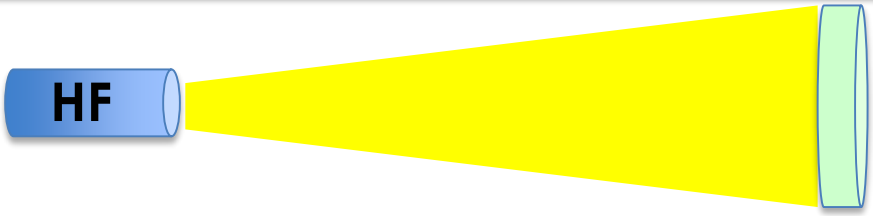
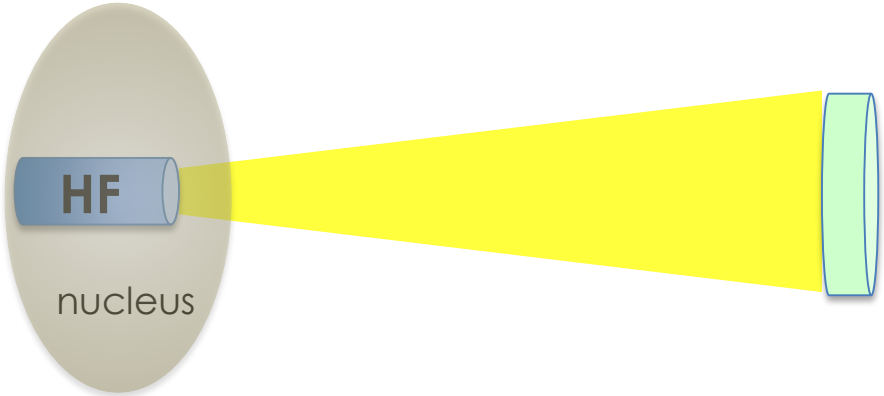
Quark Matter 2017, Chicago

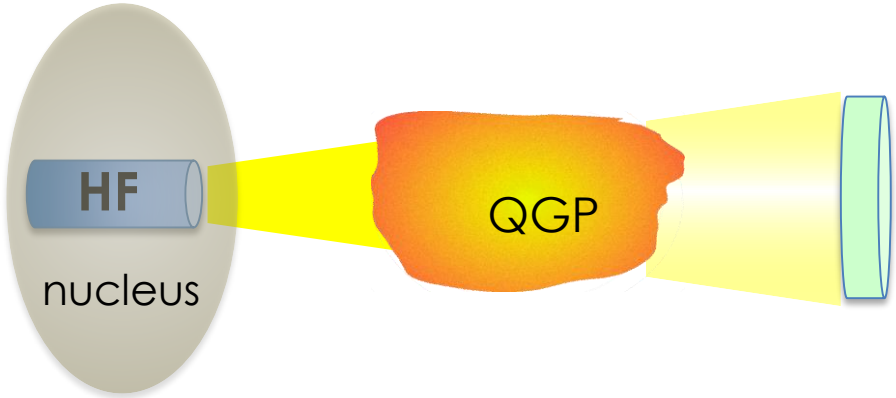
# What is needed to probe QGP property with b-quarks




**PRODUCTION**




**INITIAL STATE EFFECTS**

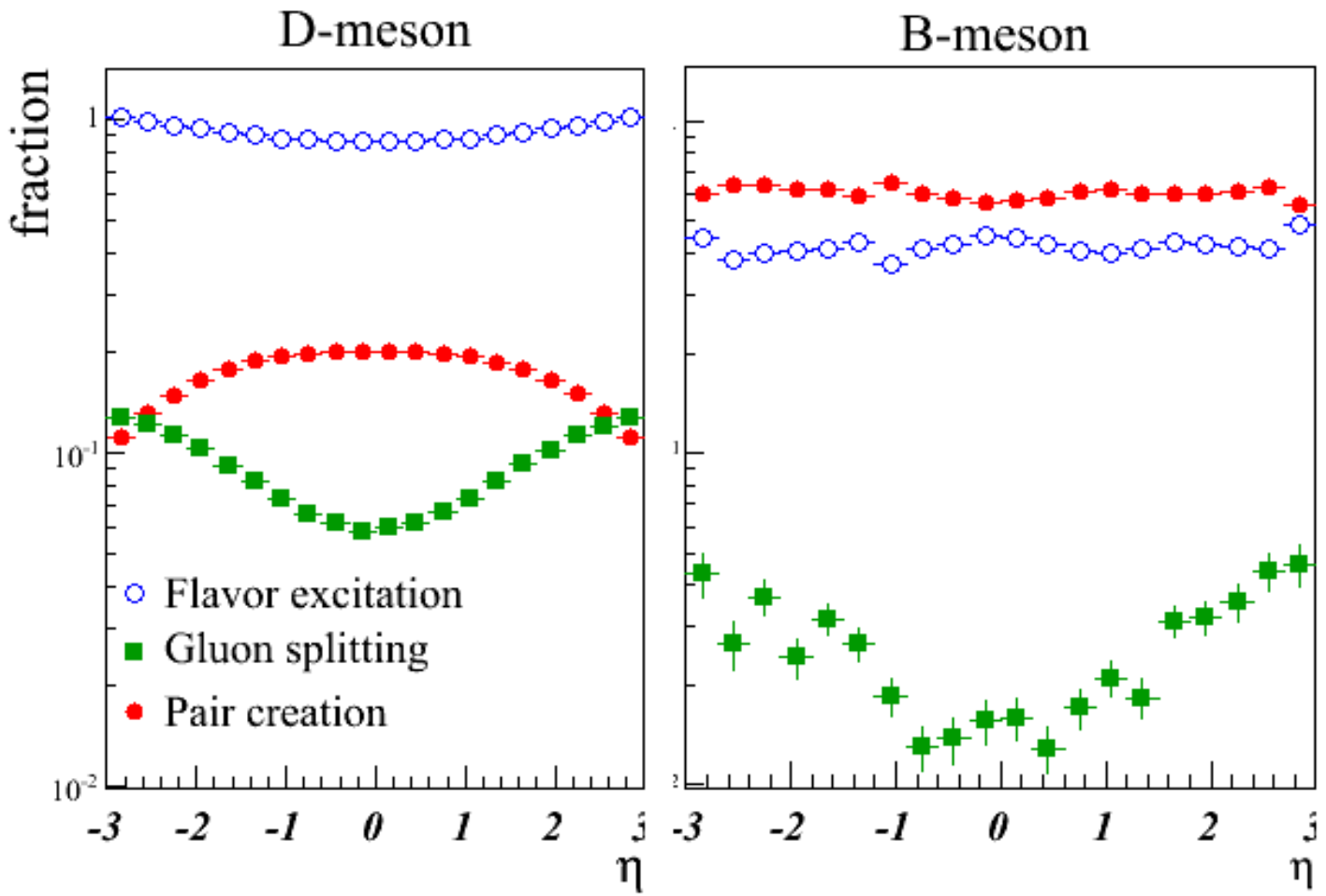



**FINAL STATE ENERGY LOSS, DIFFUSION …**

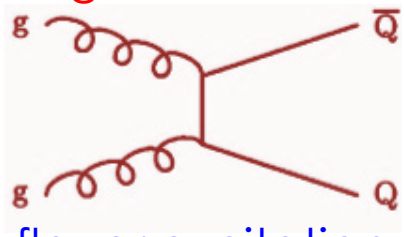
# Heavy Flavor production at RHIC

PHENIX

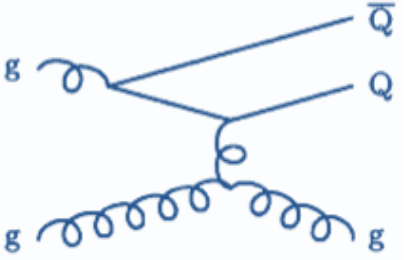
## PYTHIA6 hard scattering @ 200 GeV



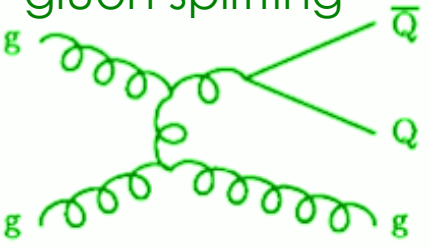

gluon fusion




flavor excitation

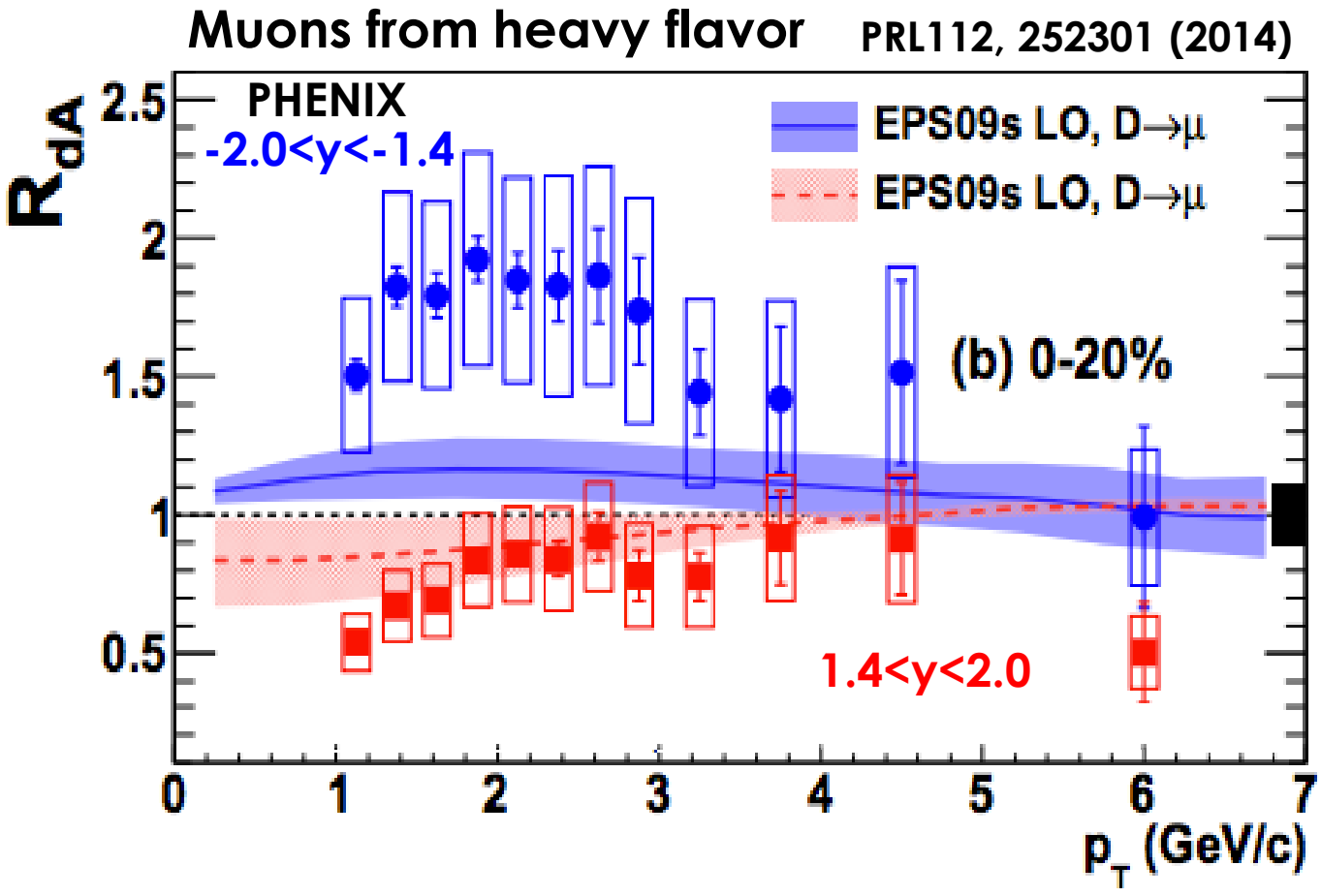



gluon splitting




**Contrast with LHC where gluon splitting dominates heavy flavor production.**

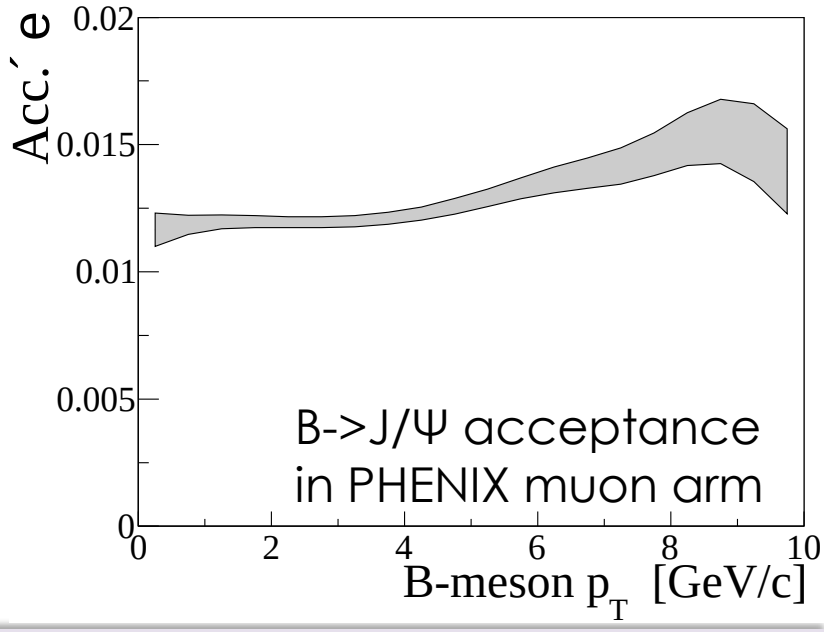
# Initial state effects on heavy flavor



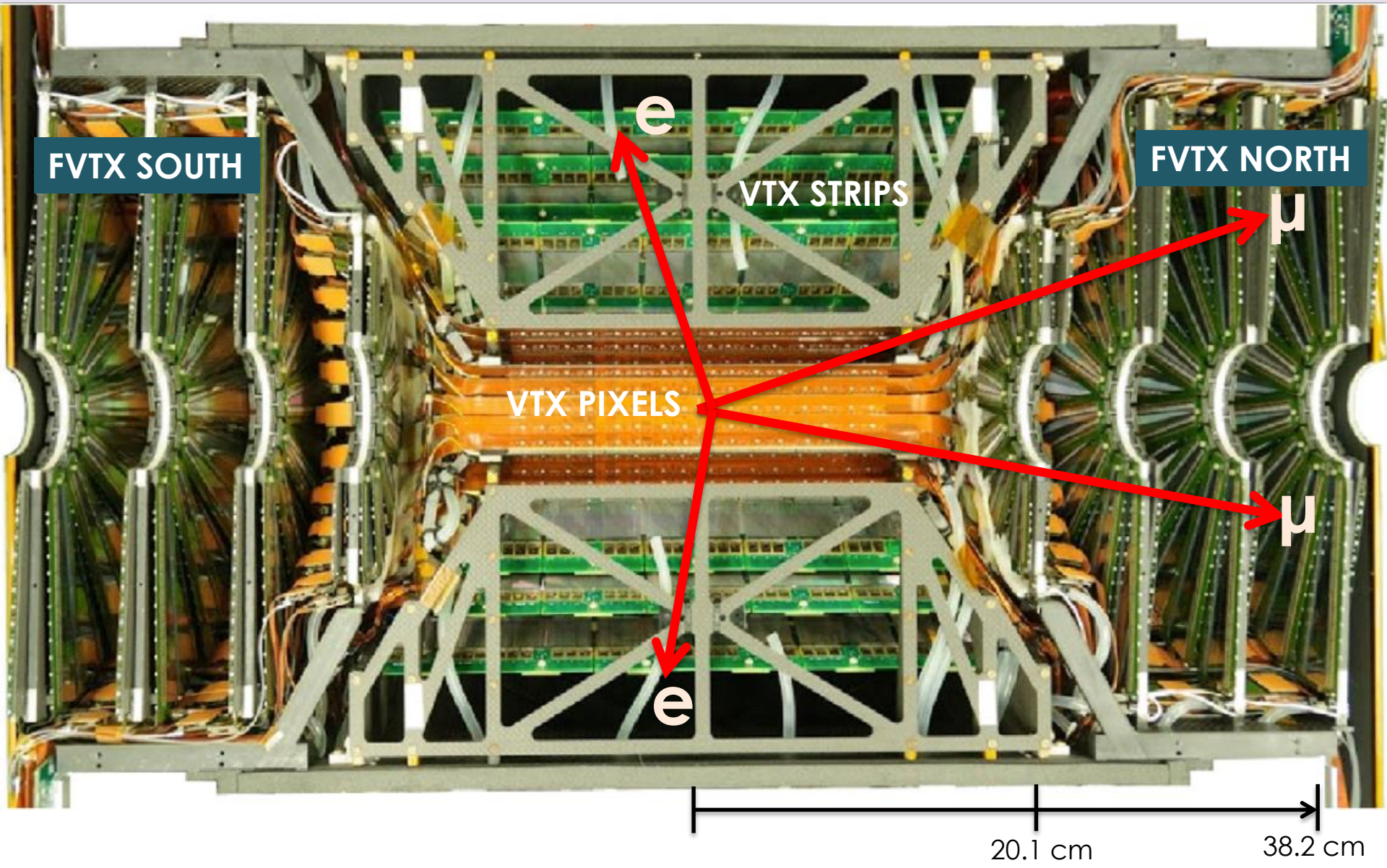

Initial state effects on gluons can suppress and enhance yields as observed in d+Au.

# Probing Initial State Effects in AB collisions

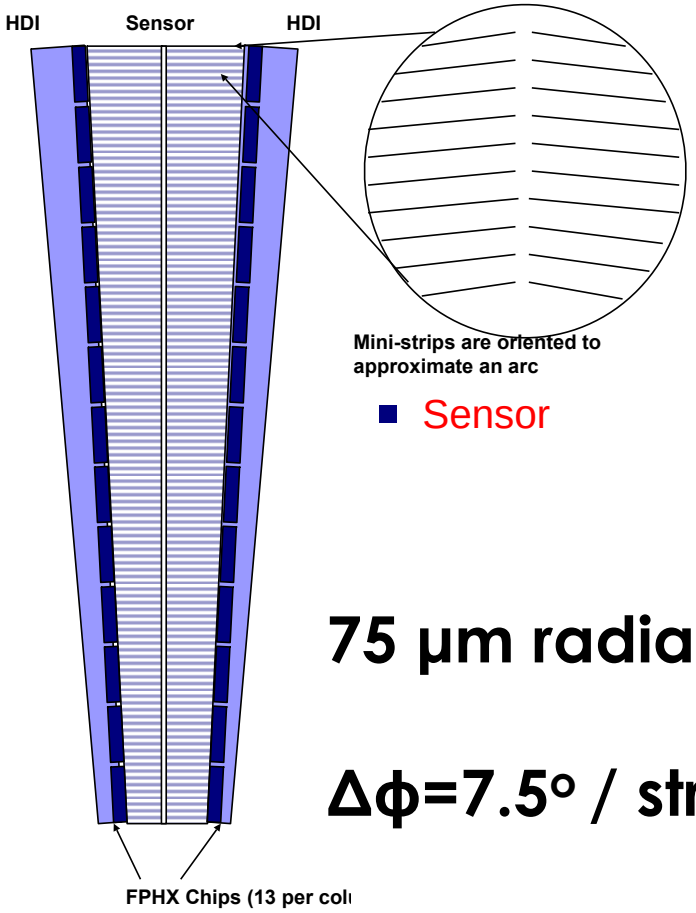
- Heavy quark number is preserved in strong interactions
- total heavy quark yield depends only on initial state effects on gluons
- Final state energy loss in the medium modifies only the heavy quark $p_T$ distribution
- B->J/Ψ channel in PHENIX muon arms(1.2<|y|<2.2)
  - Enough boost to distinguish non-prompt J/Ψ even at $p_T$=0
  - Almost flat $p_T$ acceptance



# Vertex Detectors in PHENIX



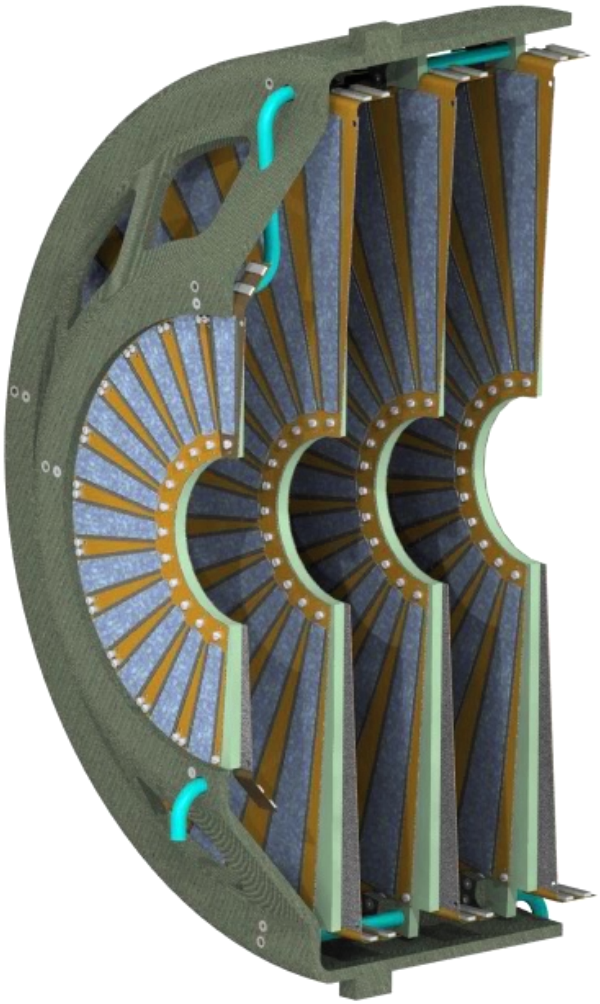
# The Forward Vertex Detector (FVTX)



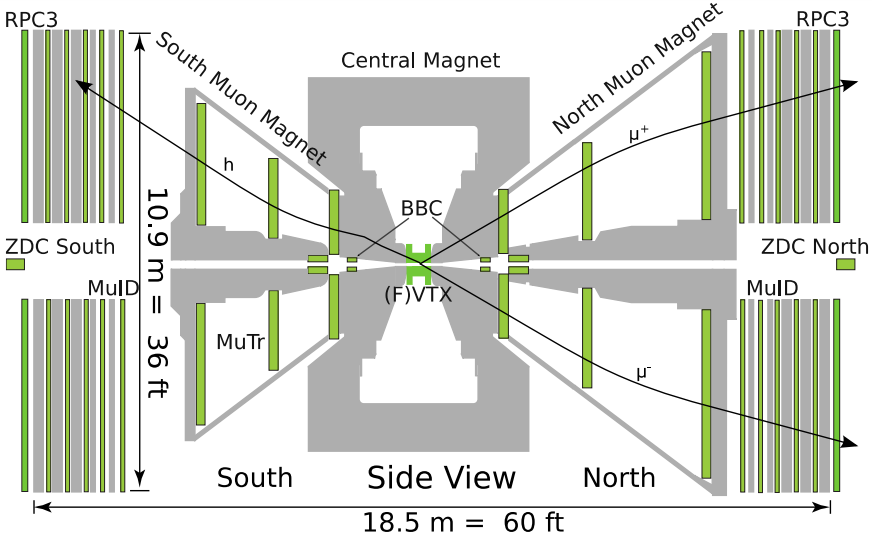

- Sensor

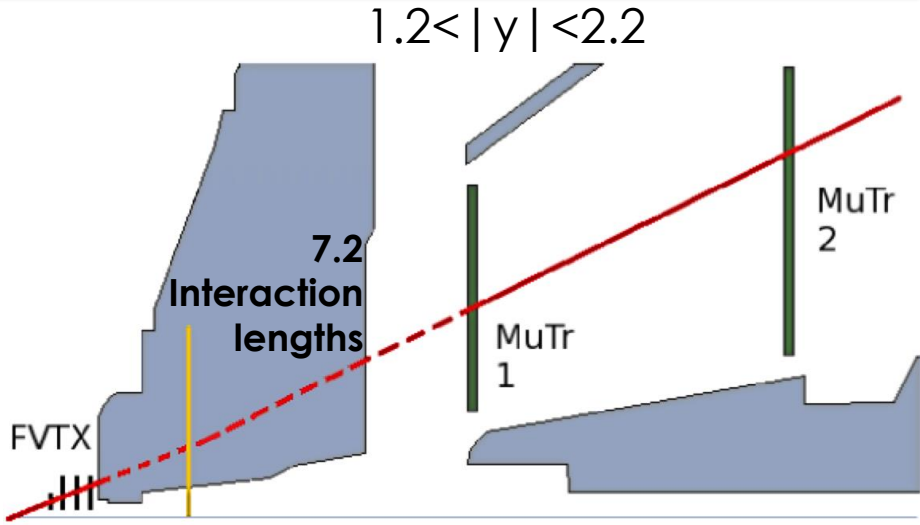
**75 μm radial segmentation**

**Δϕ=7.5° / strip**



# Muon Reconstruction



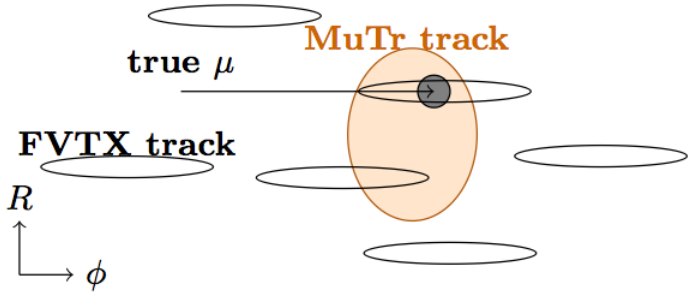




- Full muon track:
  - FVTX track + MuTr+MuID track

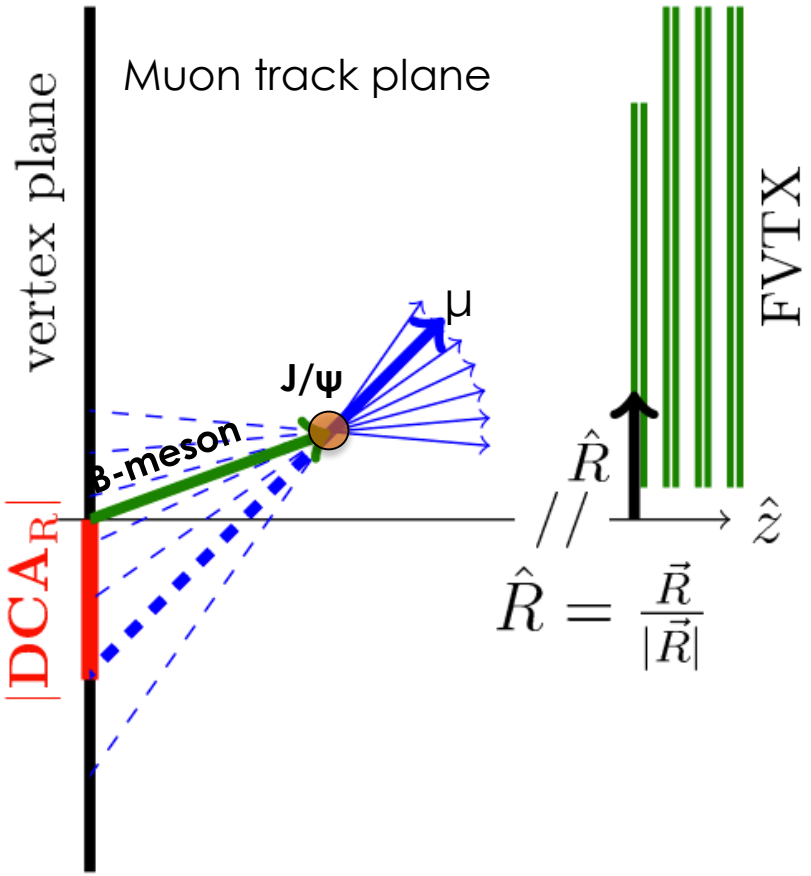
Large projection uncertainty of MuTr track on FVTX planes causing matching with >1 FVTX track

- Keeps all 3σ matchings
- subtract mismatches using event mixing technique

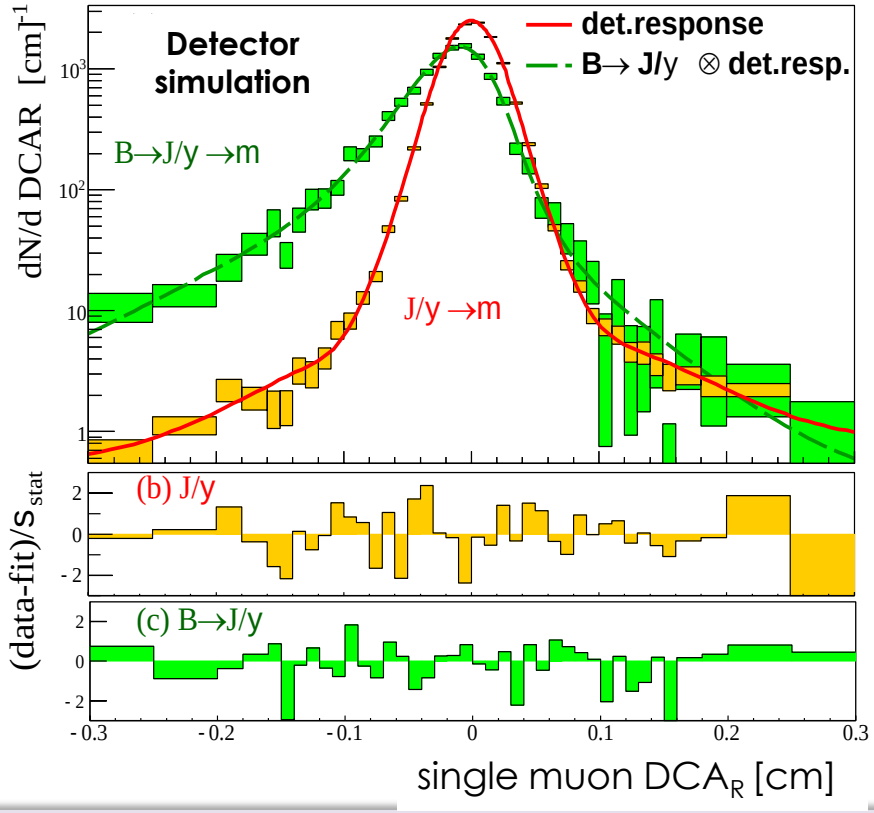
**Projections at one of the FVTX planes**



# Identifying B-meson decays

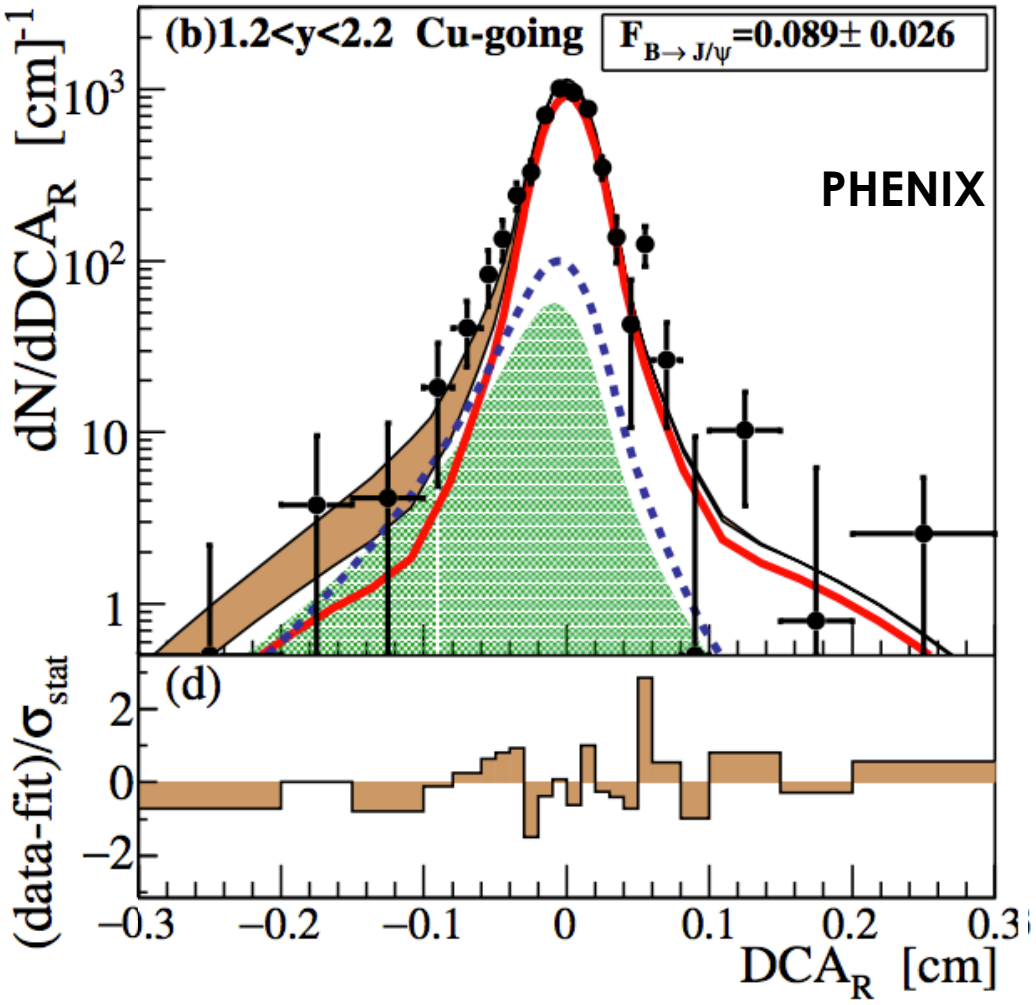



- Decays from long lived particles produce an asymmetric distribution.
- Detector simulation tuned with a large and clean sample of real data prompt pions and kaons reaching the MuID absorbers.




Look for non-prompt muons from dimuons in the J/Ψ mass region.

# $DCA_R$ Fits




**Integrated Centrality and $p_T$.**

BG from correlated $c\bar{c}$ and $b\bar{b}$ dimuons also produce non-prompt muons.

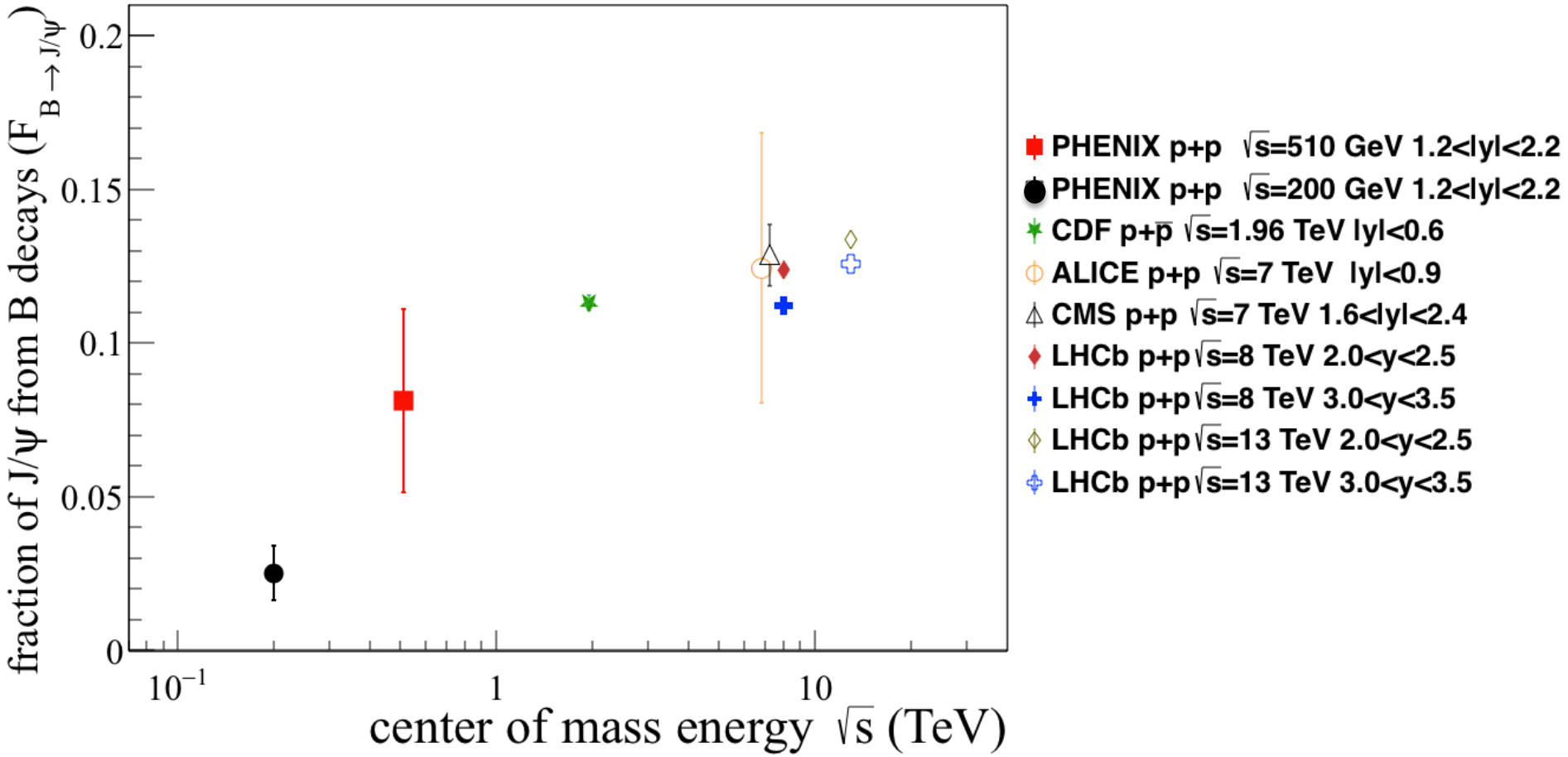
**Important systematic uncertainties:**

- $c\bar{c}$ and $b\bar{b}$ contribution
- Detector misalignments
- centrality and $p_T$ weighting for simulated DCAR profiles
- Background normalizations

Di-muon combinatorial and FVTX-MuTr mismatch backgrounds not shown for clarity, but considered in the likelihood fit.

# $F_{B\to J/\Psi}$ results in p+p

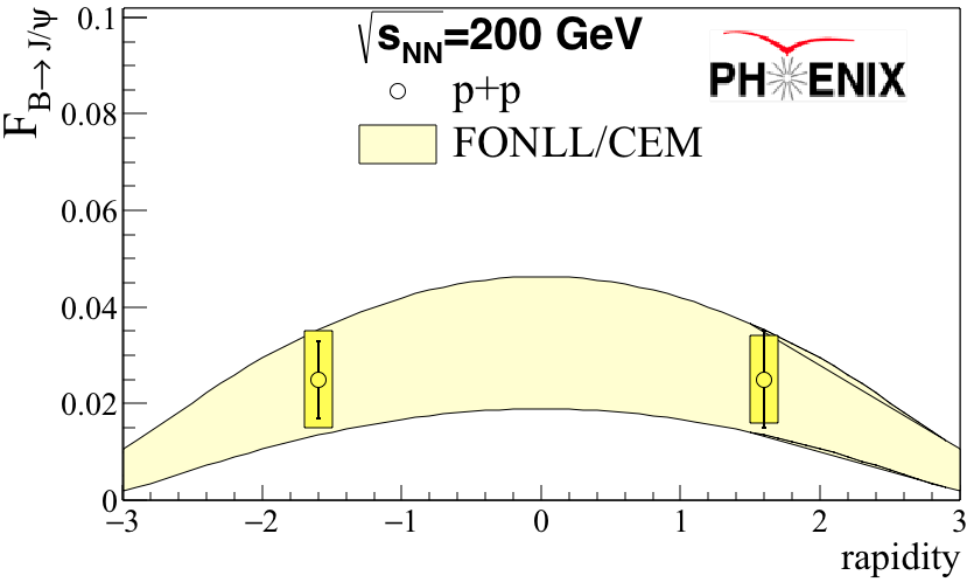
**510 GeV result:** arXiv 1701.01342
**200 GeV result**: arXiv 1702.01085

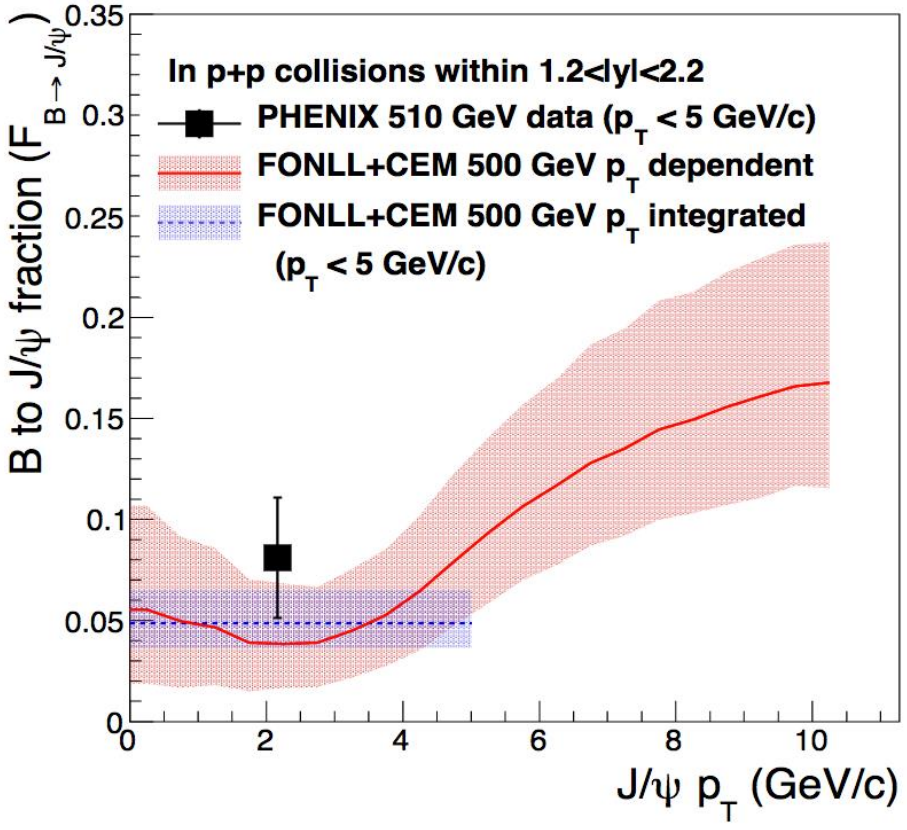



Clear transition from low energy to Tevatron, LHC.

# $F_{B\to J/\Psi}$ results in p+p

arXiv:1702.01085



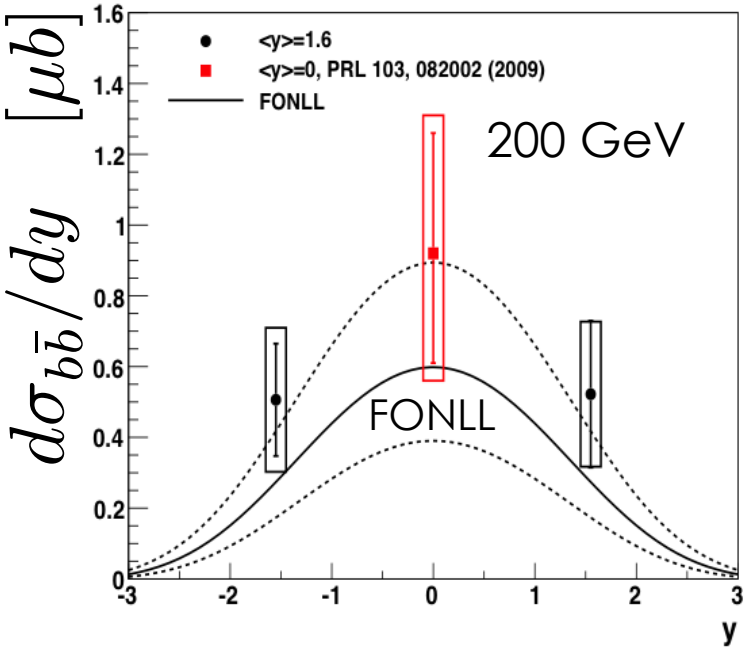




FONLL/(CEM+FONLL) agree with data.

Fixed-order Next to Leading Log (FONLL) [Cacciari, JHEP 05, 007 (1998)]

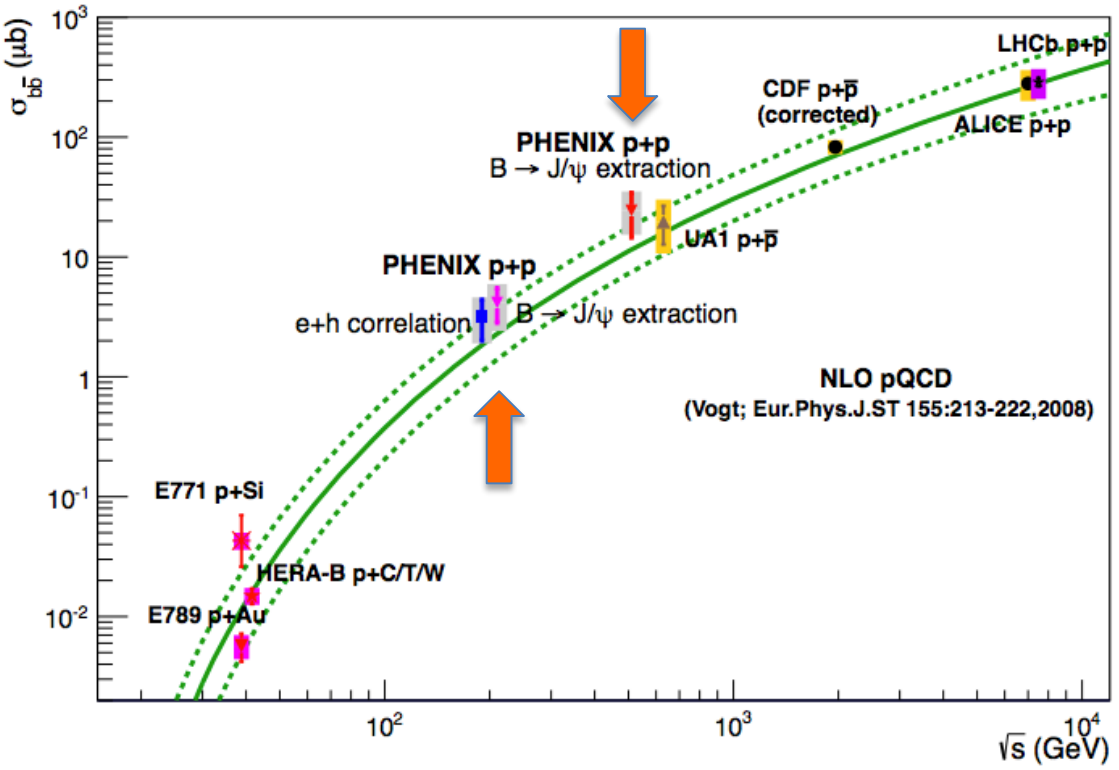
Color Evaporation Model (CEM) [R.Vogt *et. al*, Phys.Rep 462, 125 (2008)]

# $b\bar{b}$ cross sections




Using measured J/Ψ cross section and $F_{B->J/\Psi}$.

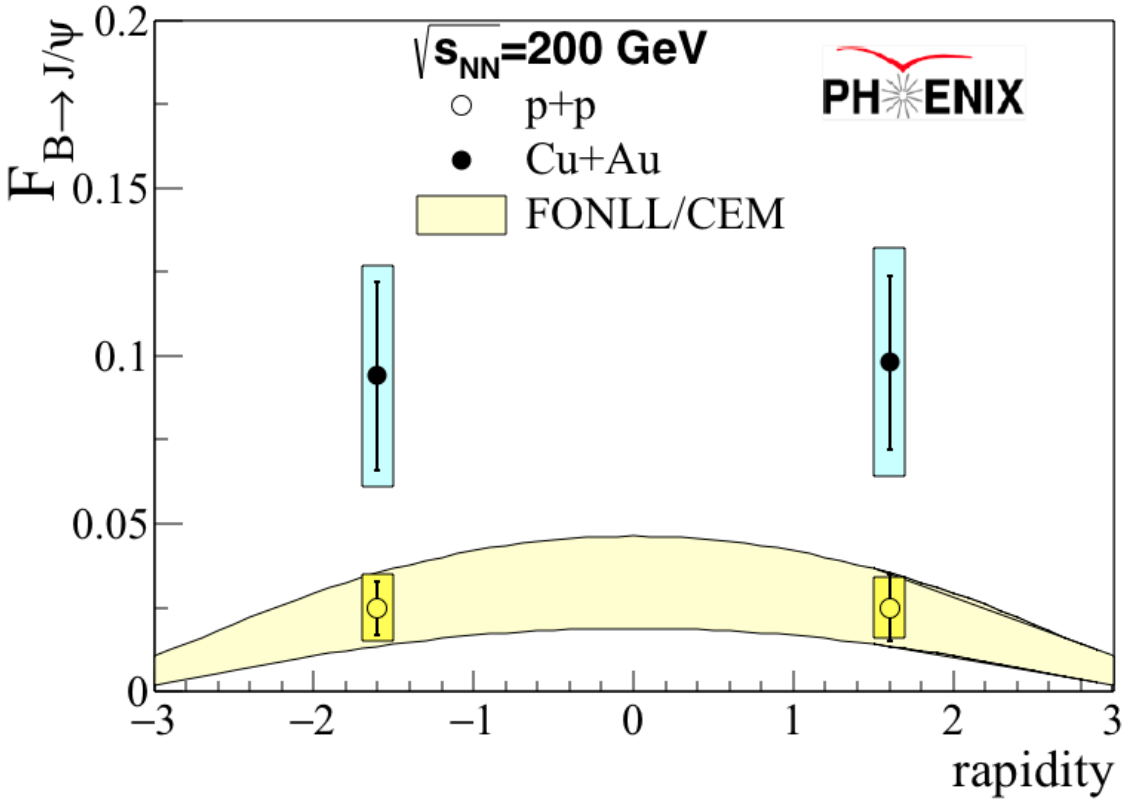
mid-rapidity from e-hadron correlation and PYTHIA extrapolation.




PHENIX measure most of the $b\bar{b}$ cross section.

**200 GeV result**: arXiv 1702.01085
**510 GeV result:** arXiv 1701.01342

# $F_{B\to J/\Psi}$ results in Cu+Au



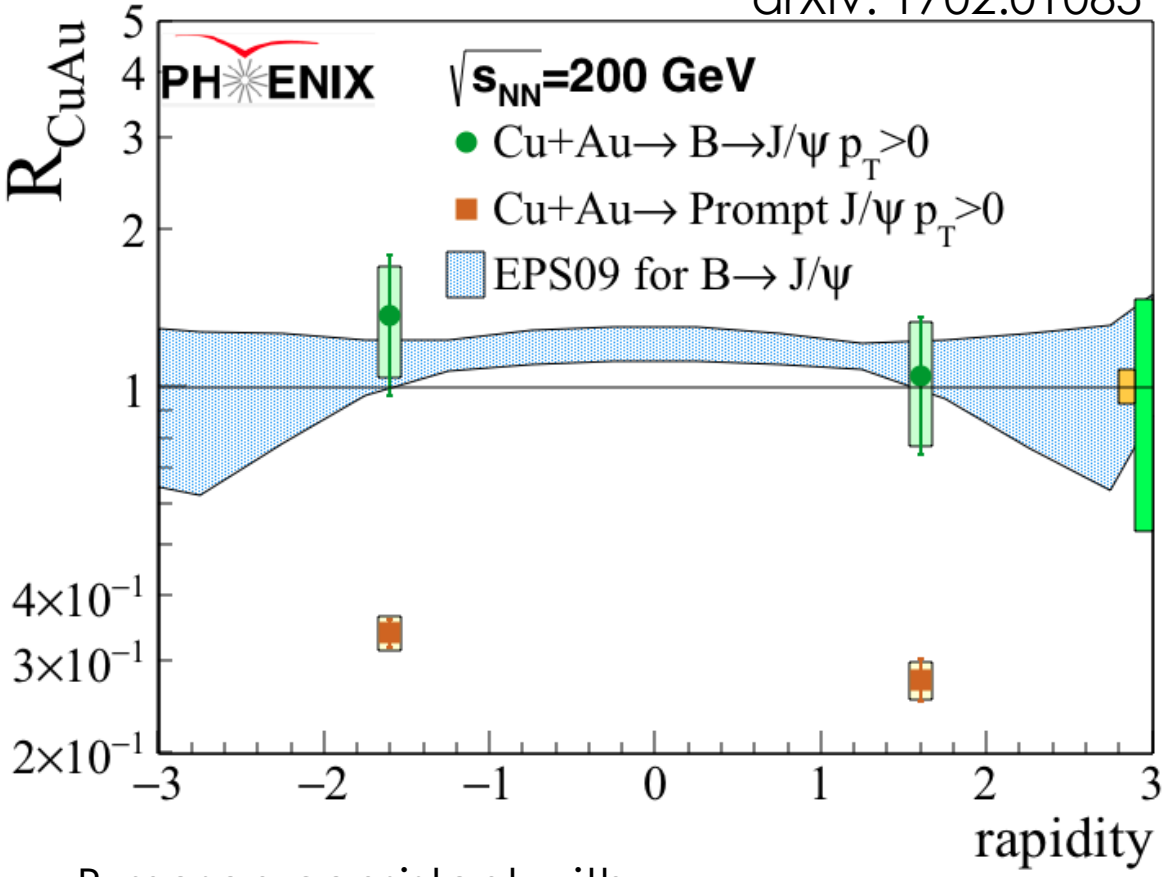

arXiv: 1702.01085

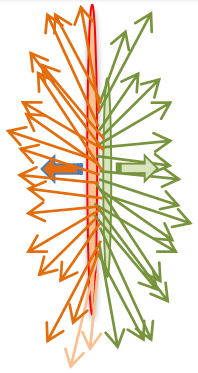
Non-prompt J/Ψ enhanced in Cu+Au collisions relative to p+p.

Reflects that B-mesons are less suppressed than prompt J/Ψ.

# B-meson $R_{CuAu}$

arXiv: 1702.01085



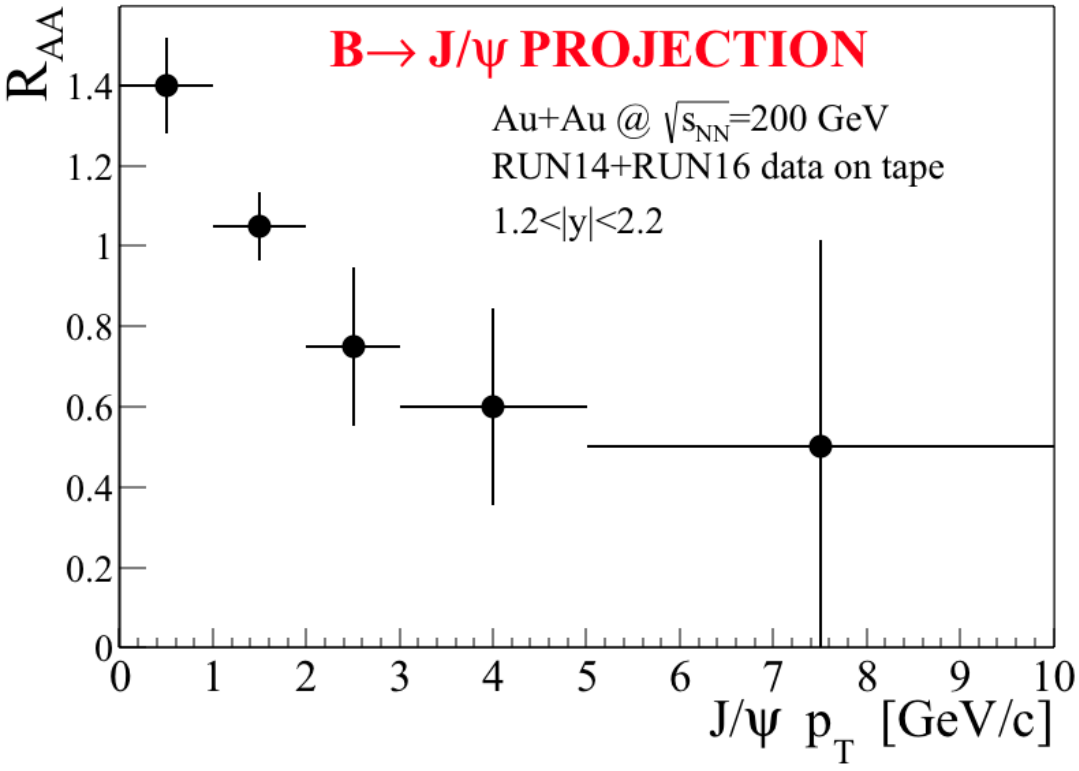

$$R^{B}_{CuAu} = \frac{F^{CuAu}_{B\to J/\psi}}{F^{pp}_{B\to J/\psi}} R^{incl.J/\psi}_{CuAu}$$

$$R^{J/\psi}_{CuAu} = \frac{(1 - F^{CuAu}_{B\to J/\psi})}{(1 - F^{pp}_{B\to J/\psi})} R^{incl.J/\psi}_{CuAu}$$

- B-meson consistent with
  - NO nuclear modification
  - enhancement suggested by EPS09
- Prompt J/Ψ number is not preserved in final interactions:
  - breaking/melting in medium

# What's Next

35B events on tape from 2014+2016 Au+Au runs
16x more B->J/Ψ statistics than in Cu+Au




Projection does not include:

- p+p reference uncertainties
- systematic uncertainties

Can use combined data+FONLL as p+p reference.

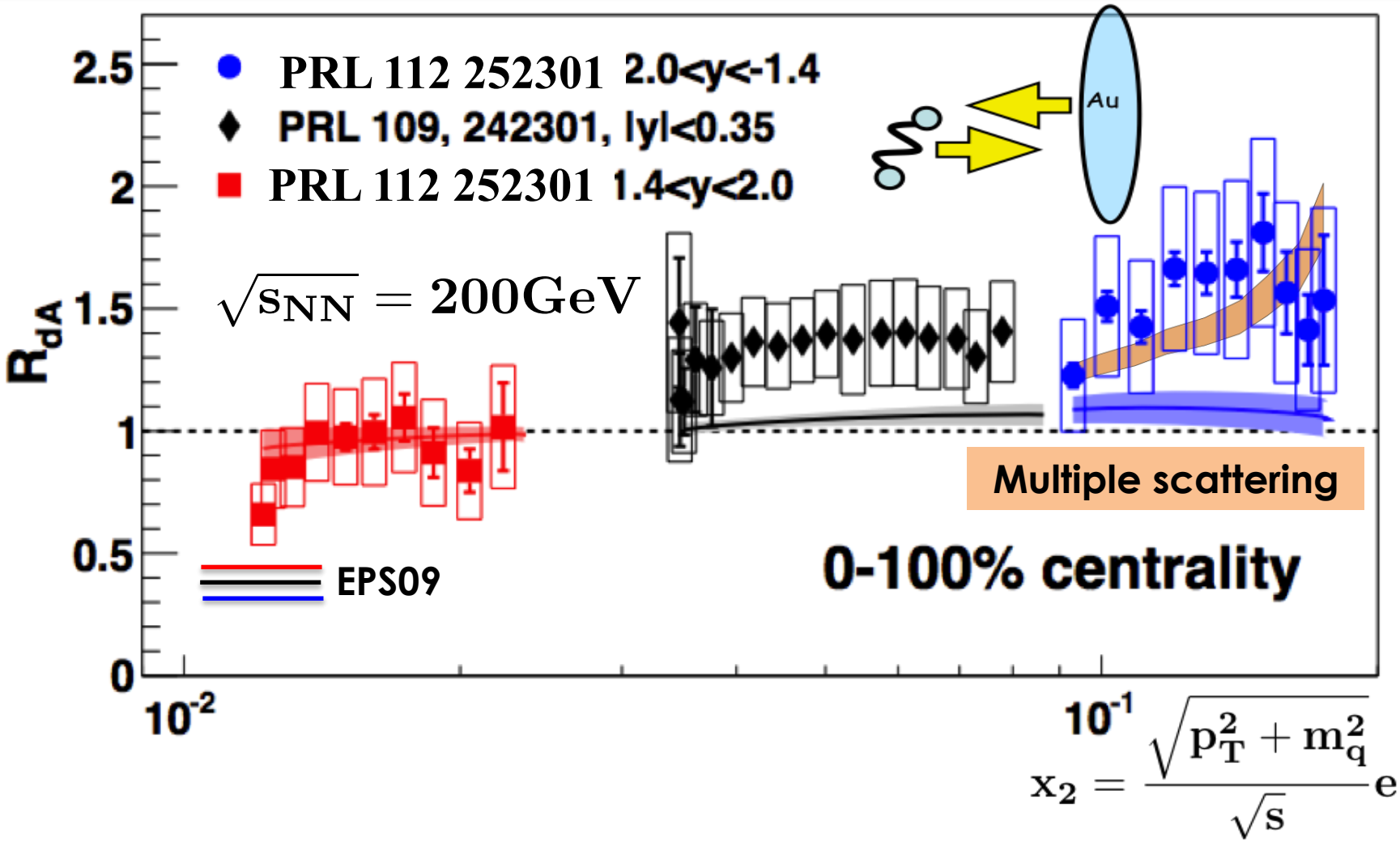
**Great opportunity to verify mass hierarchy in initial state effects and final state energy loss.**

# Summary

- B-meson cross section in p+p consistent with pQCD calculations (FONLL).
- Total B-meson yield in Cu+Au collisions is consistent with binary scaling of p+p yields and nPDF enhancement
- 16x more data to come from 2014 and 2016 Au+Au runs
  - Essential information to understand quark-mass hierarch in the energy loss in QGP

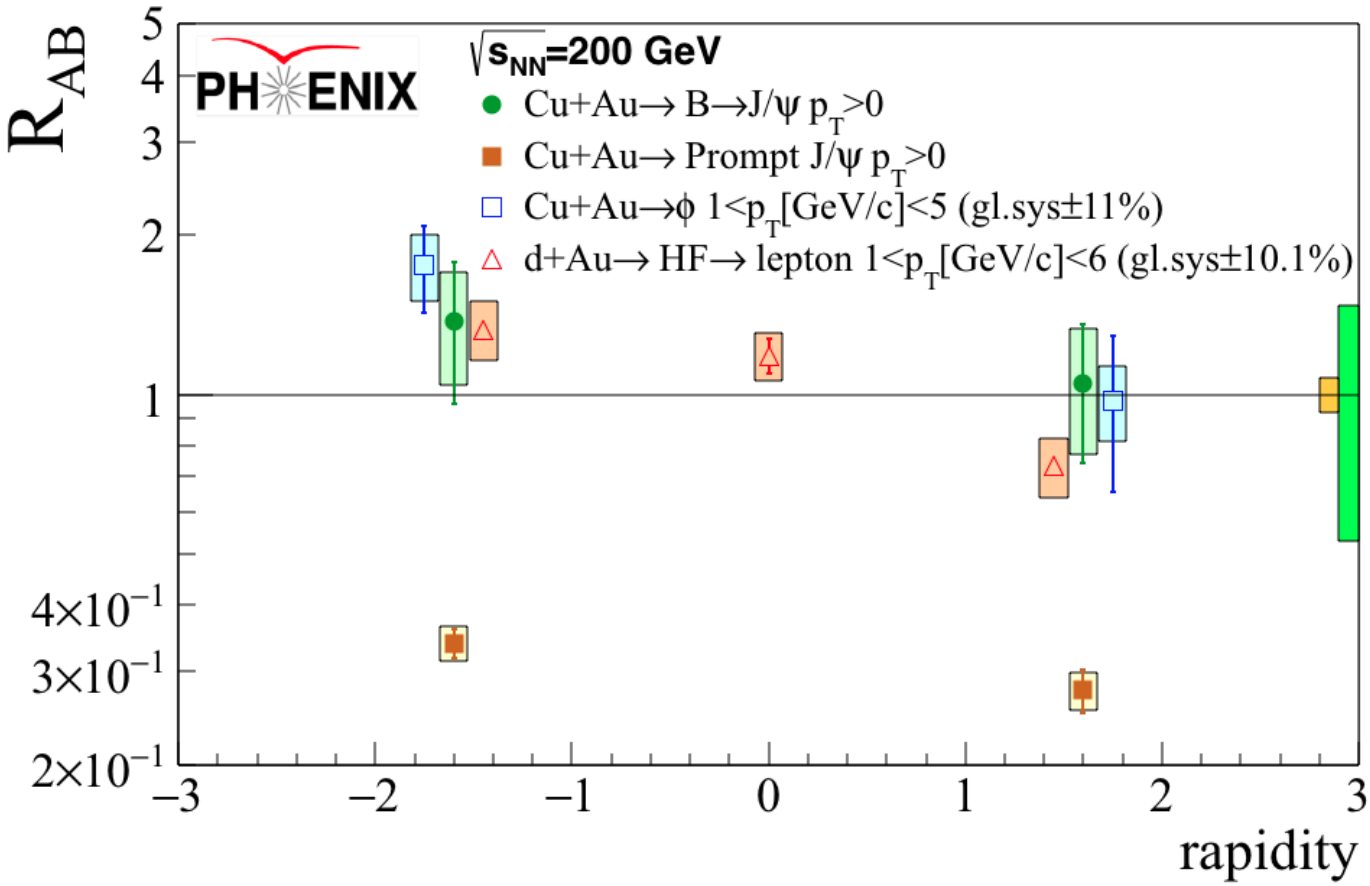
# EXTRA

# Initial state effects measured in d+Au



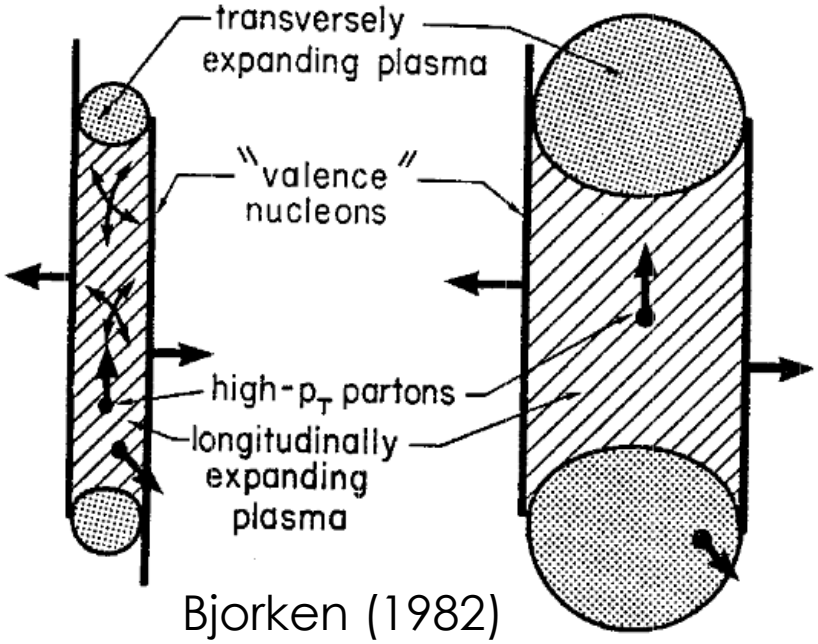

- Current nPDF cannot describe HF at **mid-** and **backward** rapidity (large-x)
- Better agreement with **multiple scattering model [Kang *et al.*, PLB 740, 23(2014)]**.

# B-meson $R_{CuAu}$




- Enhancement trend at negative rapidity also observed in
  - phi-meson in Cu+Au
  - inclusive heavy flavor in d+Au

# Partonic energy loss in QGP

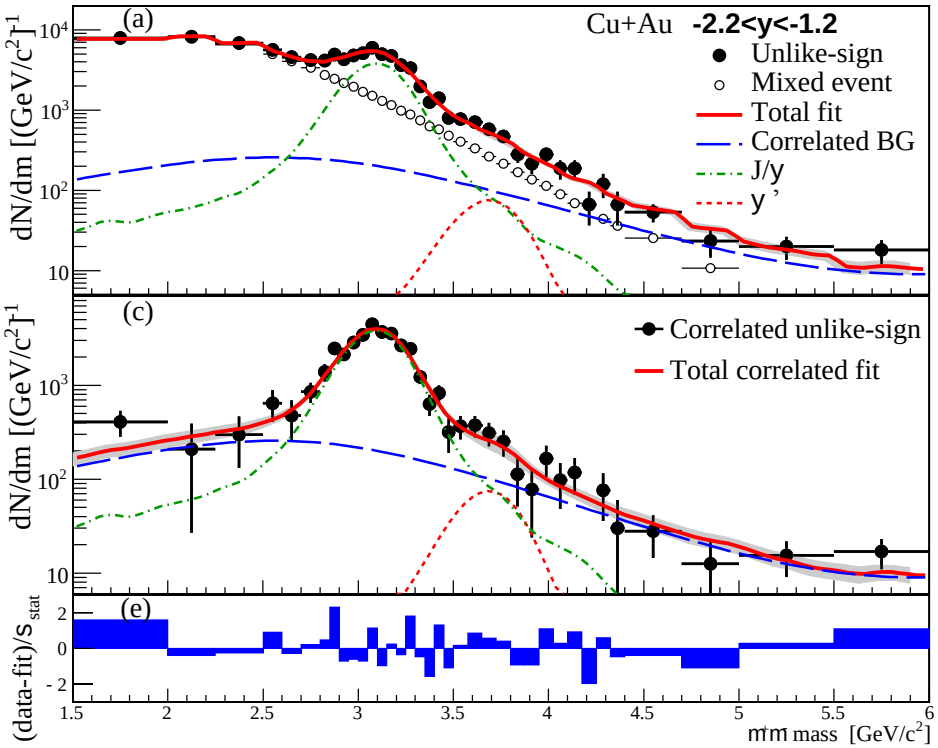


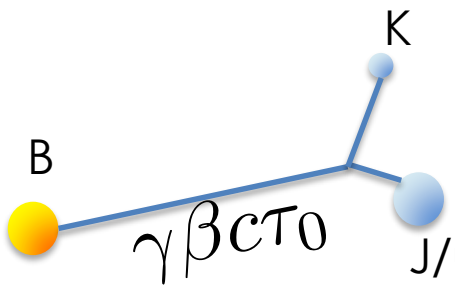

Bjorken (1982)

Energy loss:

- Gluon radiation, elastic collisions
- Gluon radiation suppressed for $\theta < M/E$ (dead cone effect)
- Low $p_T$ B-mesons:
  - $p_T << m_b$, where quark mass is relevant for energy loss

# B-mesons in the PHENIX muon arms

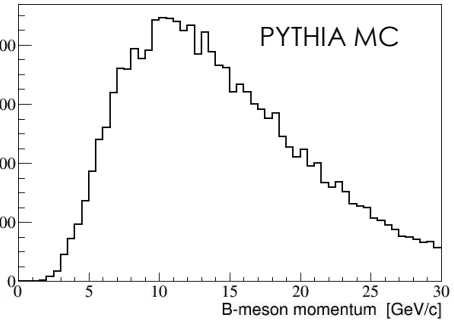


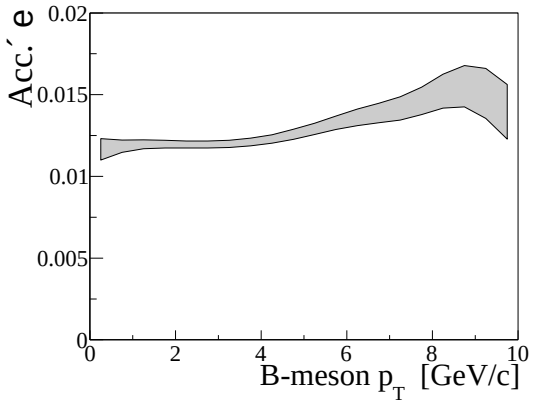




$$\gamma\beta c\tau_0$$

$$c\tau_0 \sim 450\mu m$$

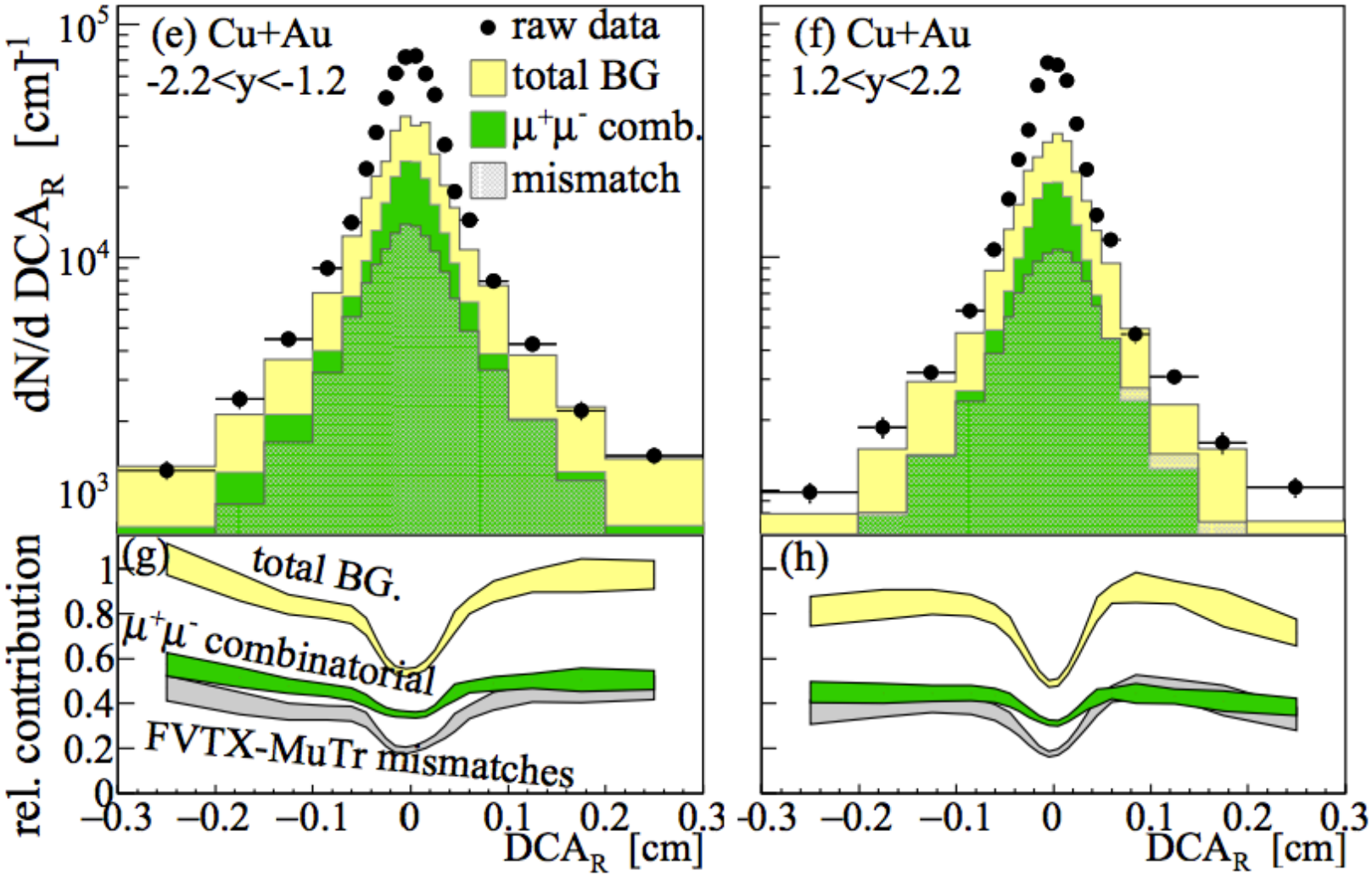
$$\gamma = \frac{\sqrt{p_z^2 + p_T^2 + M^2}}{M}$$




- Decay length is boosted at large rapidities ($p_Z$>>0) allowing to identify non-prompt particles down to $p_T$=0
- Flat $p_T$ acceptance for B->J/Ψ

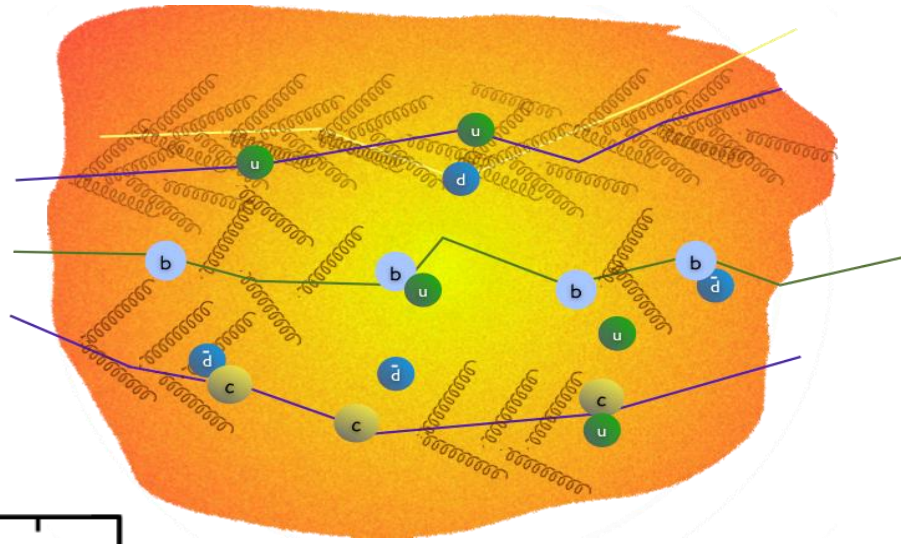
# Backgrounds

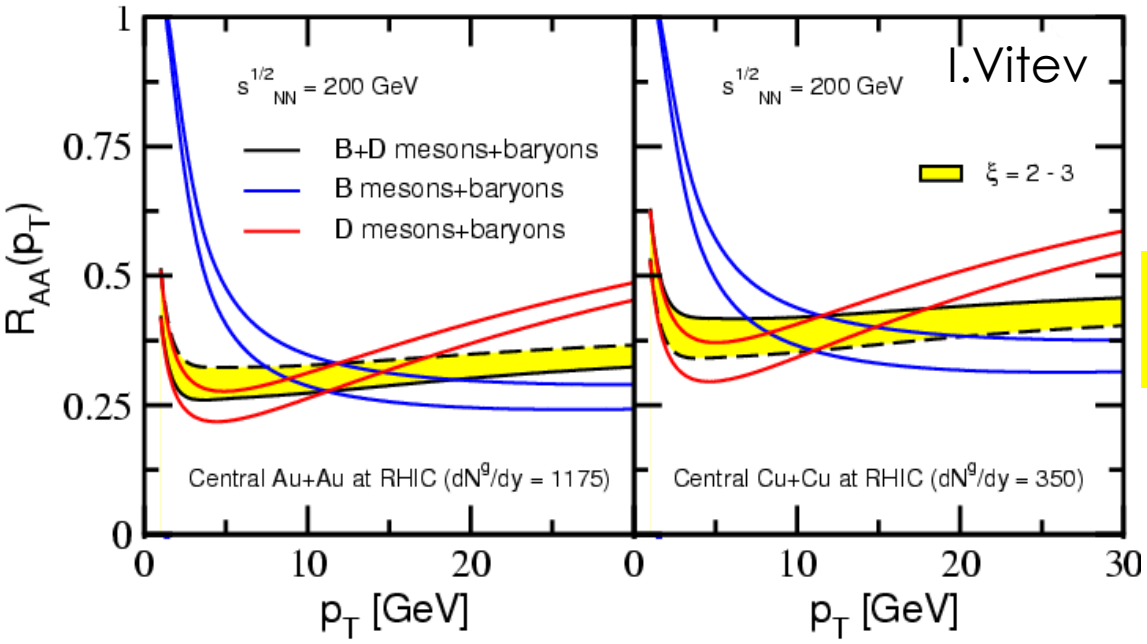


# Light, Charm and Bottom Quarks crossing QGP

Energy loss:

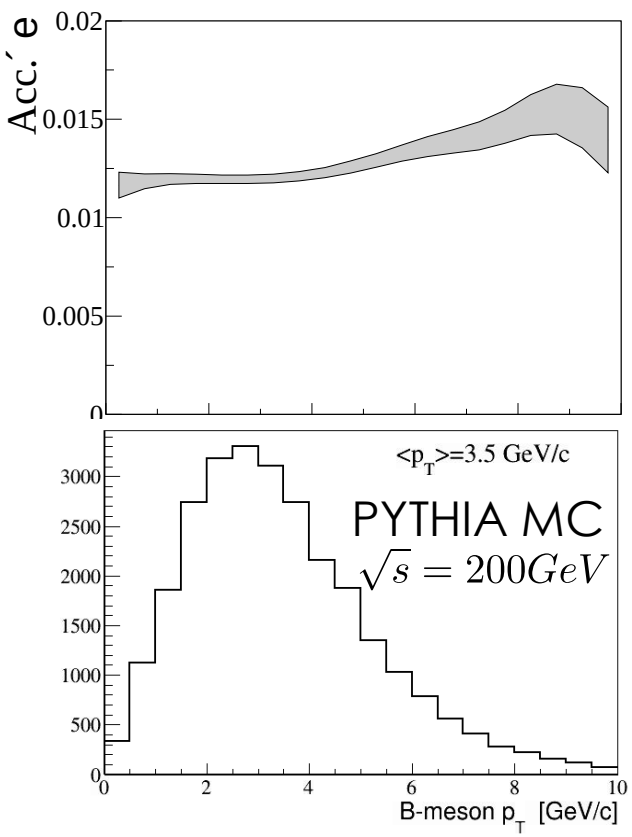
- Gluon radiation
- elastic collisions
- Gluon radiation suppressed for θ<M/E
- Heavy quarks hadronize quickly crossing the medium as mesons or dissociated quarks




**Quark mass dependency more pronounced at small $p_T$**

# B-mesons Acceptance




$$B \rightarrow J/\psi \rightarrow \mu$$

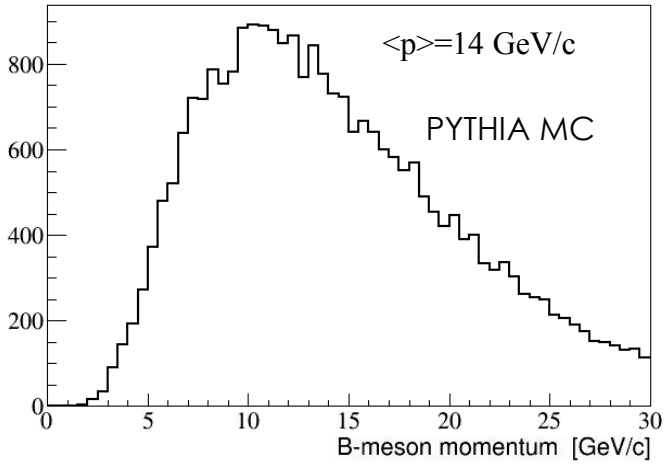
$$R^{\text{prompt}}_{\text{CuAu}} = \frac{1 - F^{CuAu}_{B\rightarrow J/\psi}}{1 - F^{pp}_{B\rightarrow J/\psi}} R^{\text{incl.}}_{\text{CuAu}}, \quad R^{B}_{\text{CuAu}} = \frac{F^{CuAu}_{B\rightarrow J/\psi}}{F^{pp}_{B\rightarrow J/\psi}} R^{\text{incl.}}_{\text{CuAu}}$$

Flat detector acceptance in small $p_T$ region.

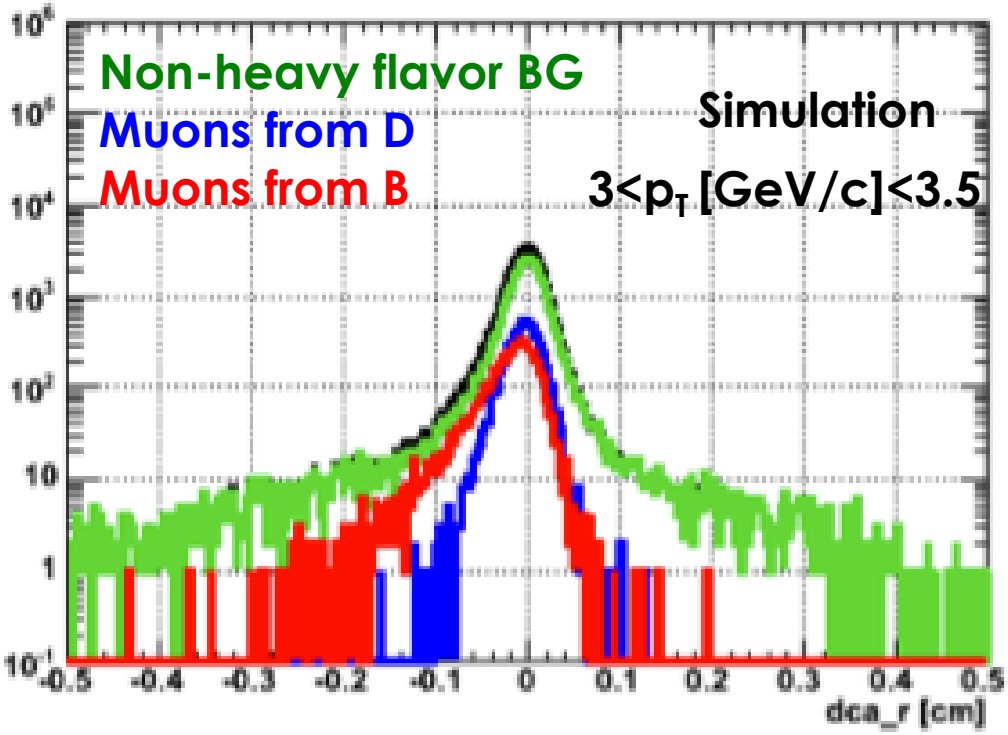
Clean access to small $p_T$ B-mesons.

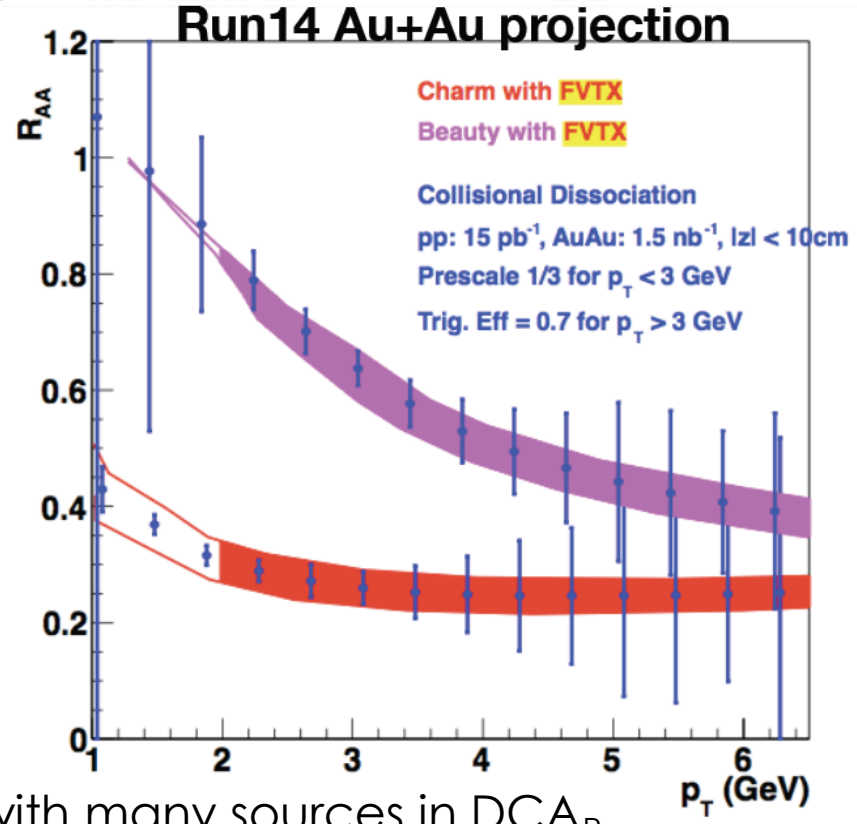
Boosted B-mesons :

- longer decay length
- may also have physics implications on path length until hadronization



# Charm and Bottom from inclusive single muons




- Provides high statistics but needs to deal with many sources in $DCA_R$ distribution.
- Very careful analysis underway with Cu+Au and p+p data sets to minimize systematics.

**Opportunity in many data samples for $R_{AA}$ and flow measurements.**