

Study of the semi-leptonic decay of D- and B- mesons into muons with the PHENIX detector

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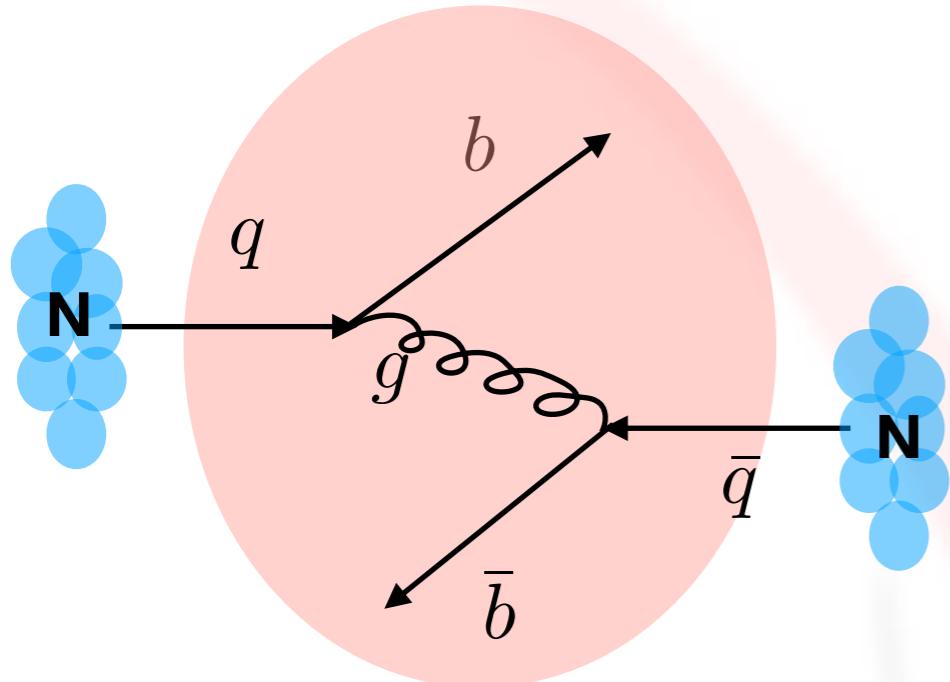
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09/09/2019-09/13/2019



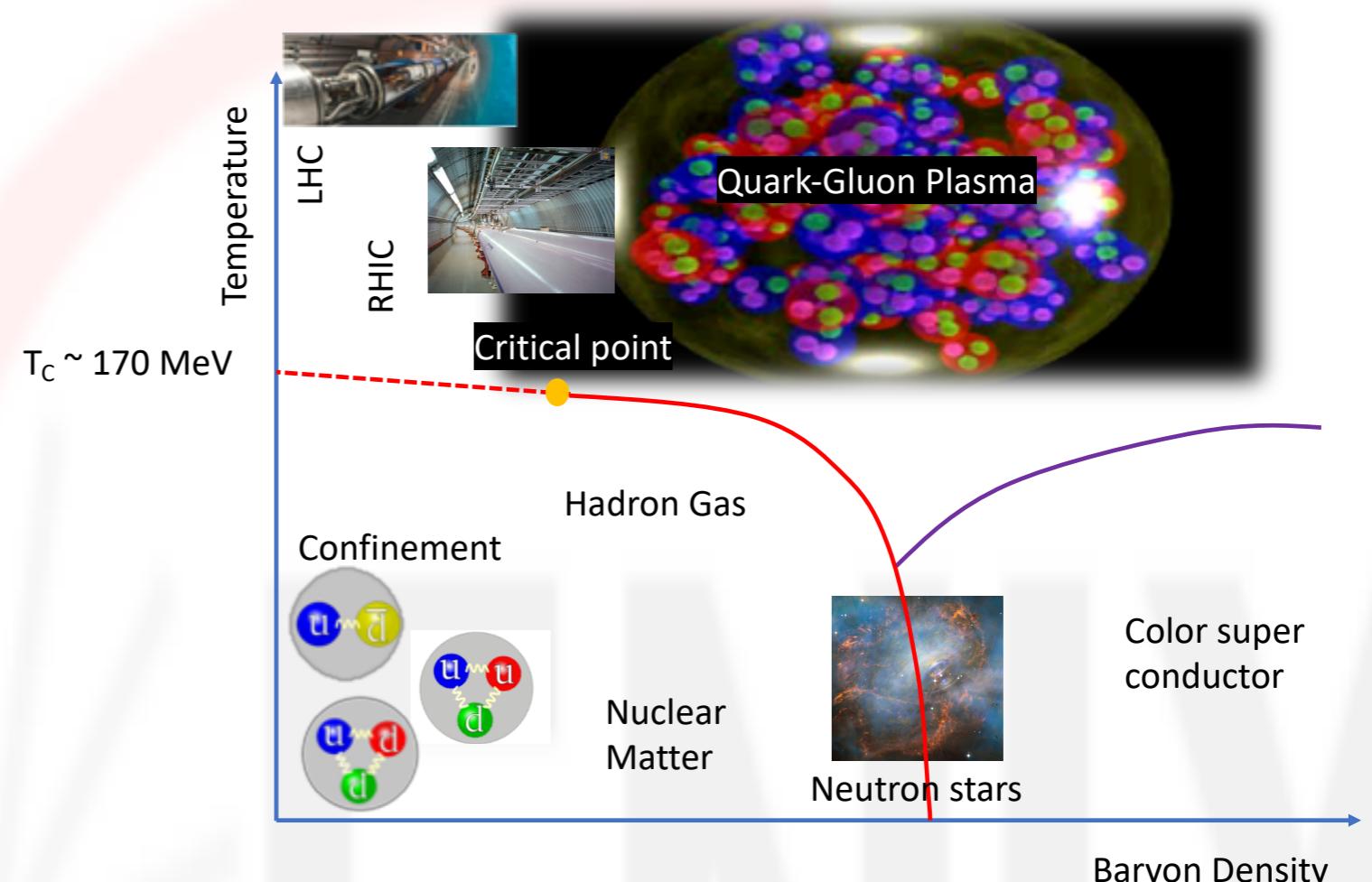
Heavy flavors as probes of QGP



Heavy flavor production at LO

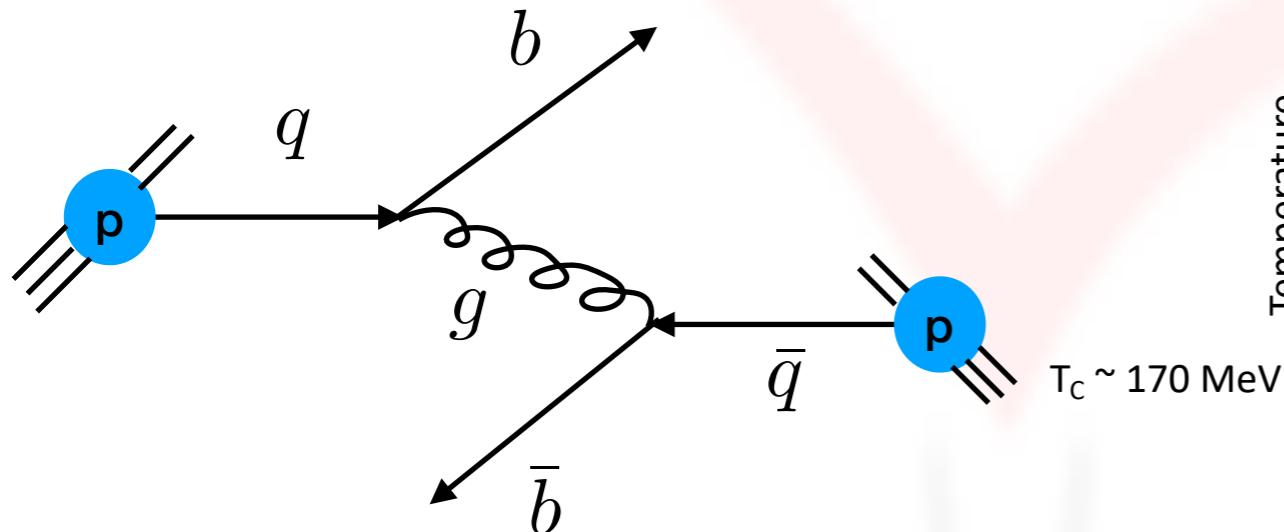
$$m_b > m_c > \Lambda_{QCD}, T_c$$

4.2 GeV 1.3 GeV 0.2 GeV



- Heavy quarks cannot be produced thermally at RHIC energies but interact with the QGP hot medium.
- Yields probe the QGP properties – parton energy loss and their mass dependence.
- Analogous measurements in p+p provide test of pQCD based cross section predictions and baseline.

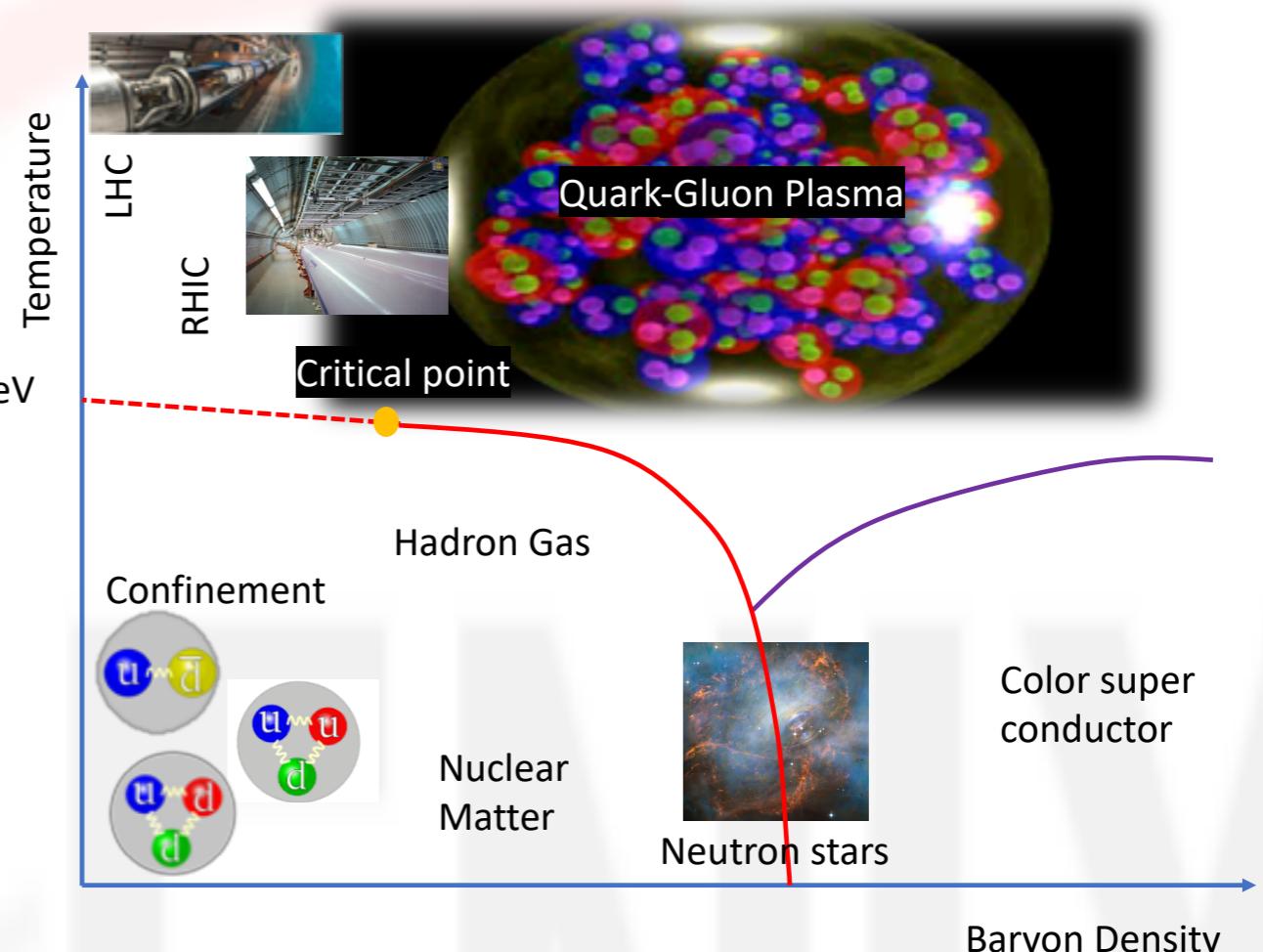
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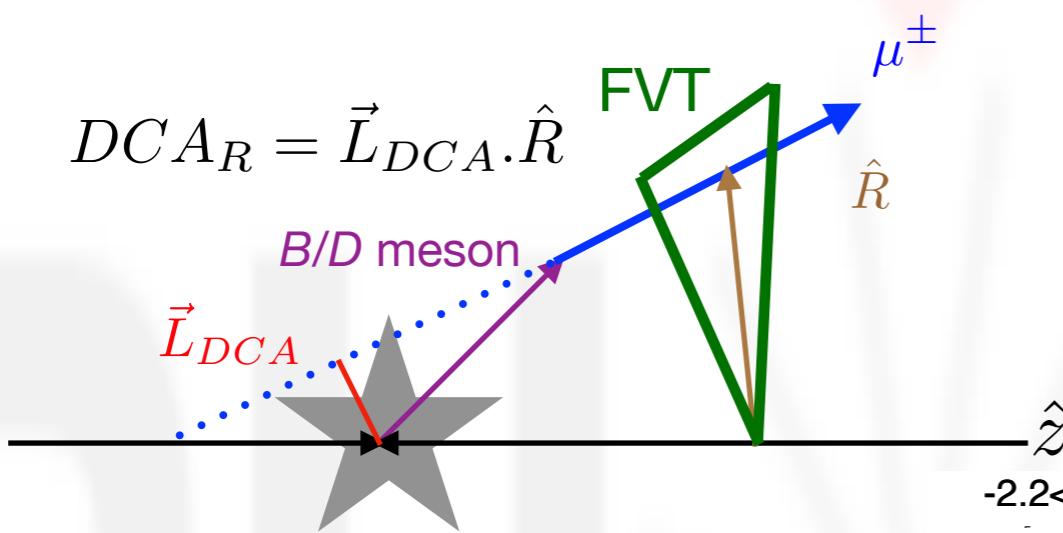
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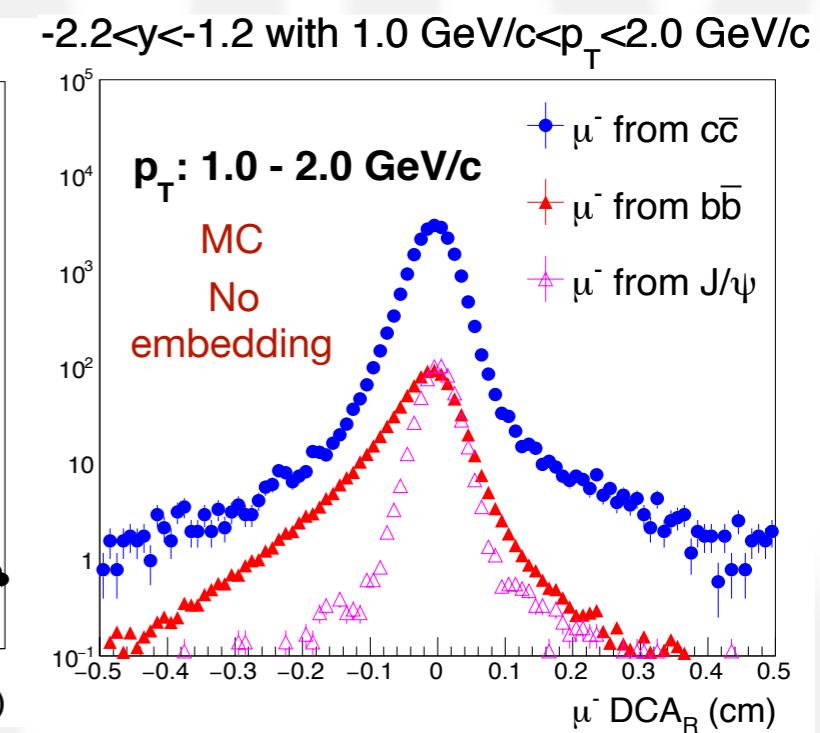
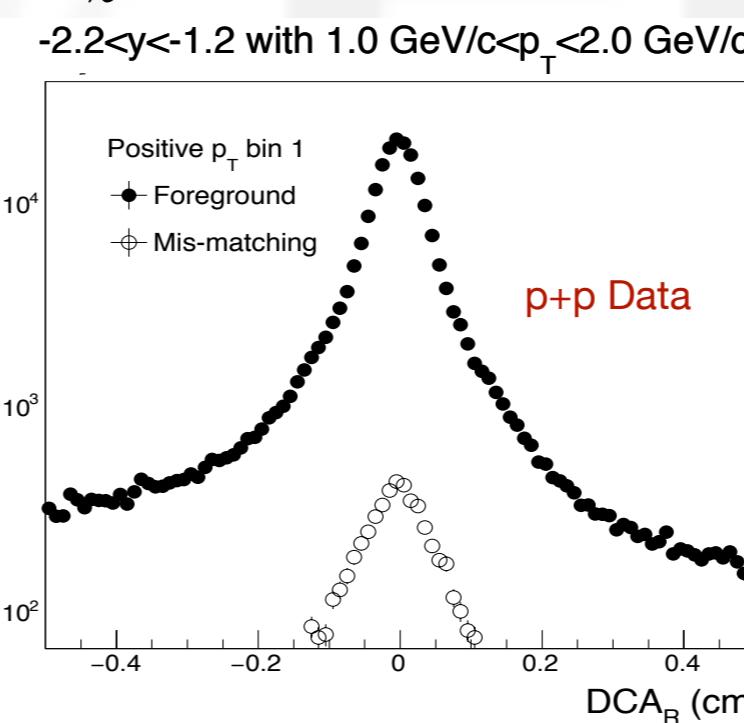
Semi-leptonic decay via single muon channel

- Single muons from semi-leptonic decay of D & B mesons can be reconstructed and identified with muon identification detectors.
- Due to the long lifetime of D & B they leave a signature of displaced vertex in the detector.



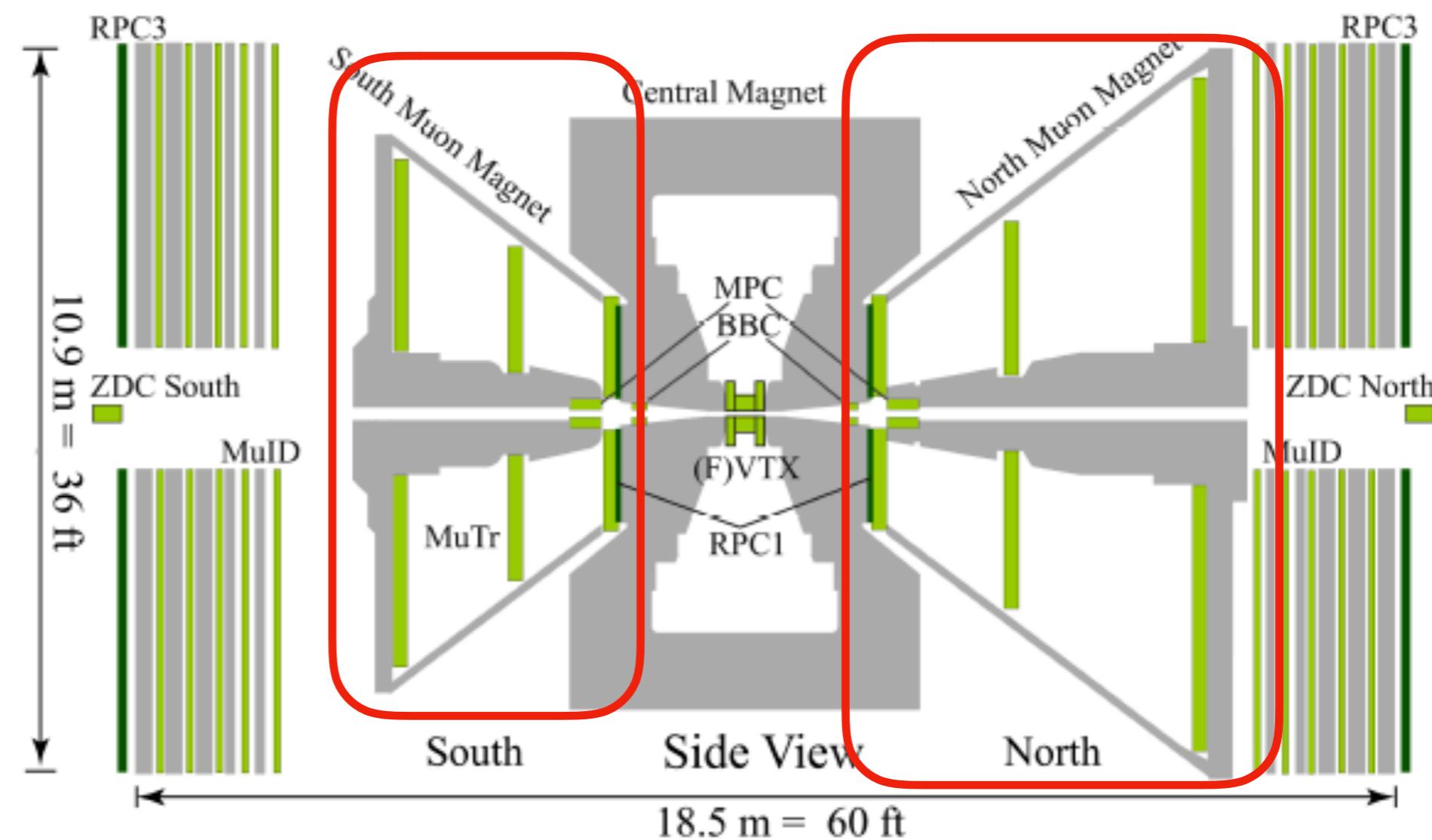
DCA_R (DCA along the radial projection of tracks) can be precisely determined with the FVTX+VTX.

Particle	Lifetime $c\tau_0$
D^0	129.9 μm
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Kinematics acceptance of heavy flavor decay products

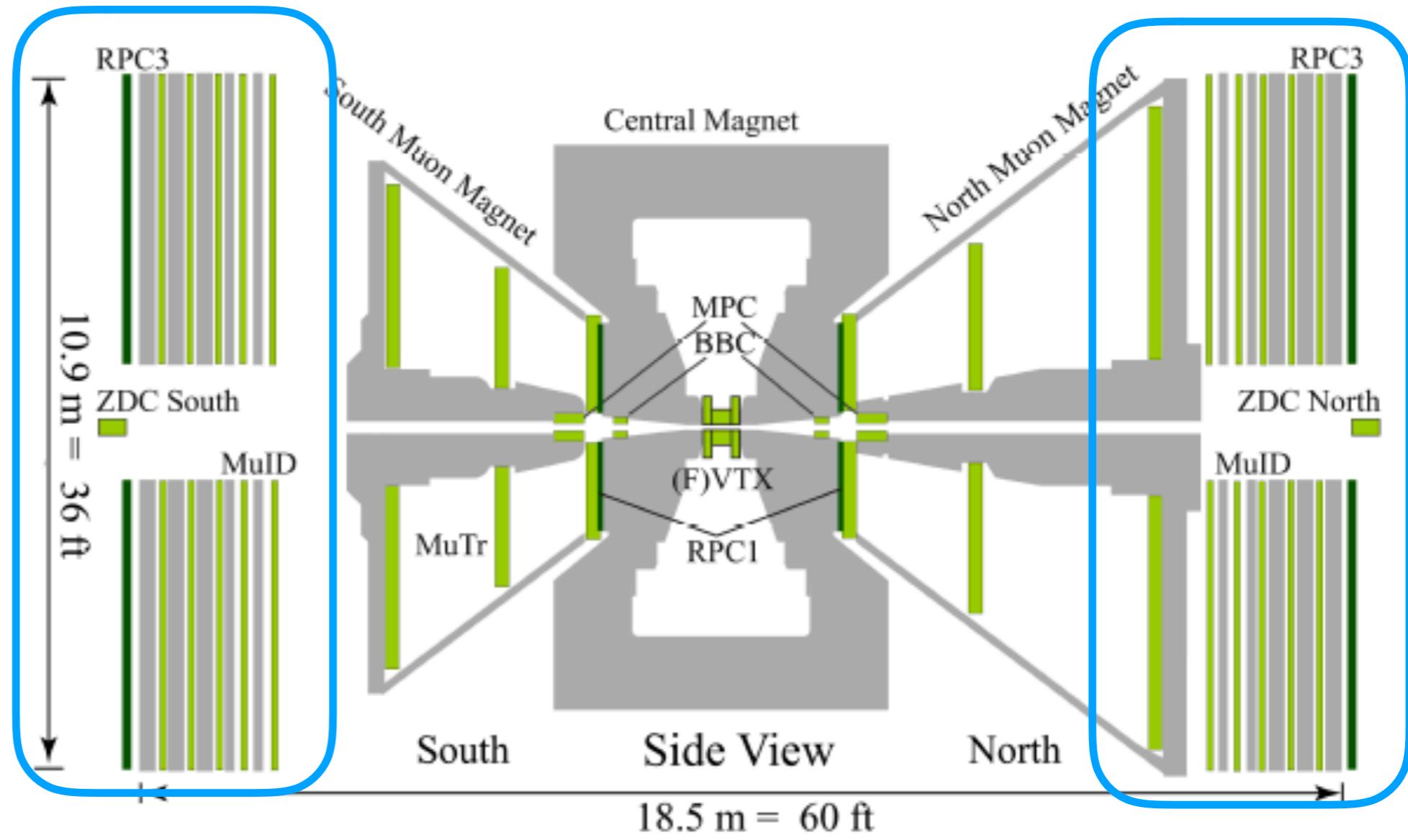
- 4000 ton detector with dozen sub-systems.
- Very high (5-7 kHz) DAQ rate for triggered events.
- **MuTr**, **MuID** and **FVTX** makes up the muon-arm.
- Pseudo-rapidity coverage: $1.2 < |\eta| < 2.2(2.4)$ for south(north) arm.



3 stations of cathode strip chambers for charged particle tracking

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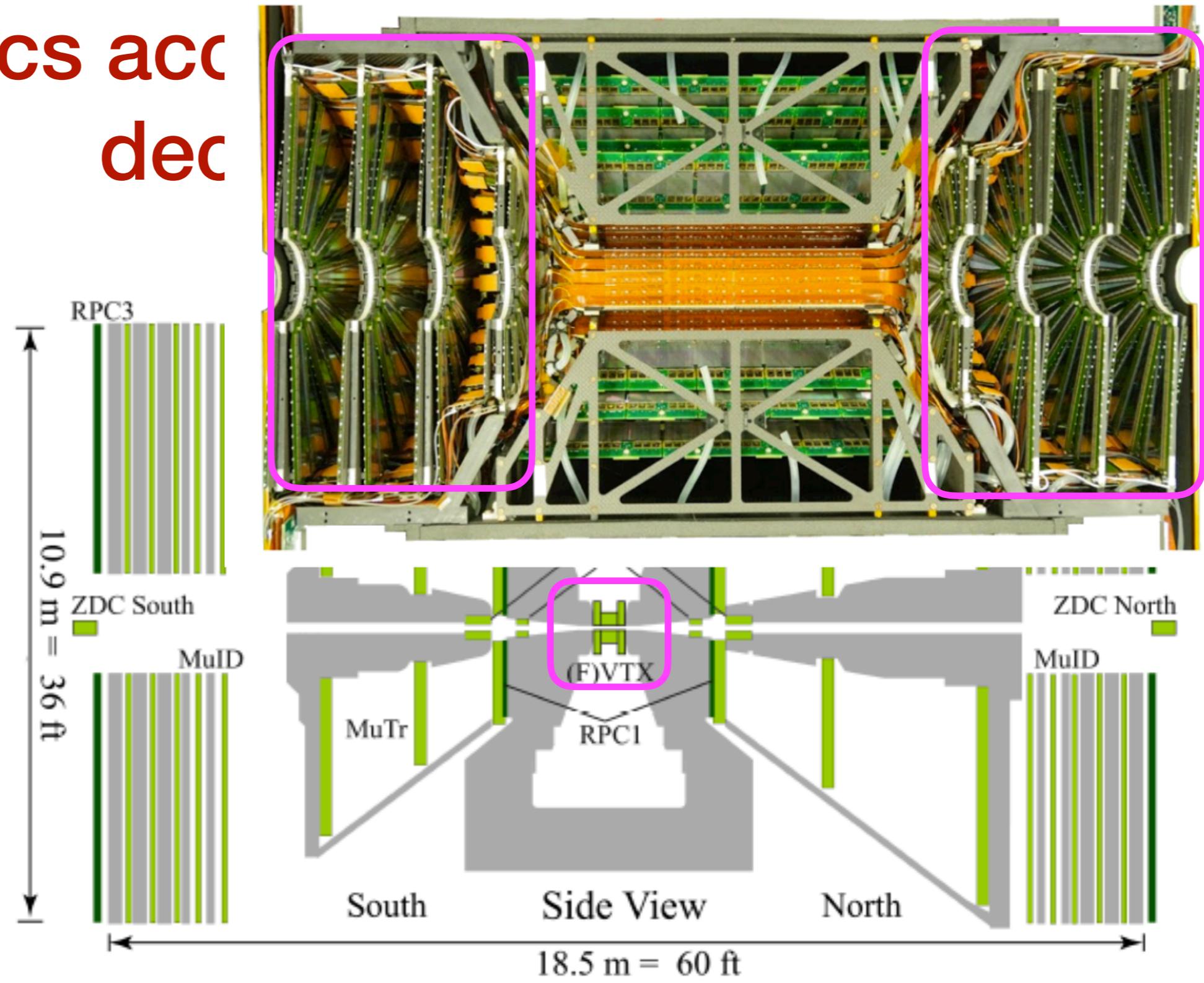
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Alternating layers of plastic proportional tubes for muon identification and steel absorbers

Kinematics acc dec

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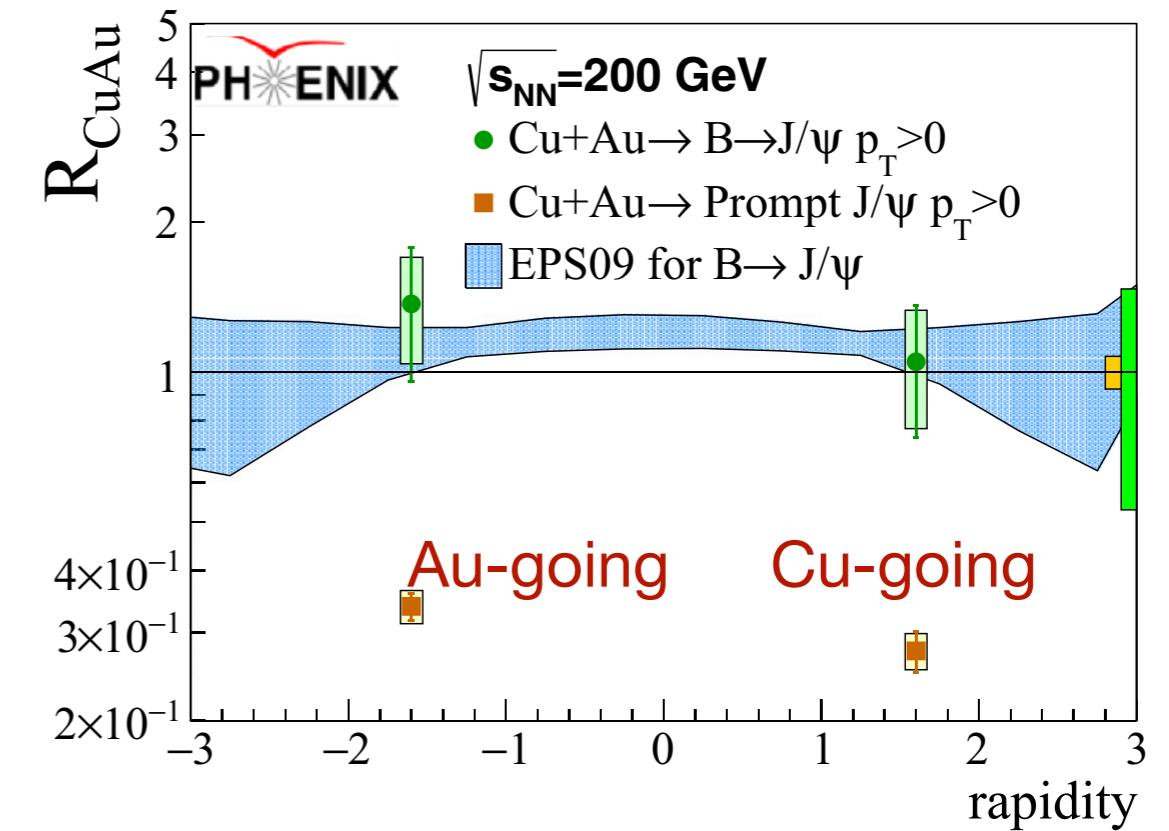
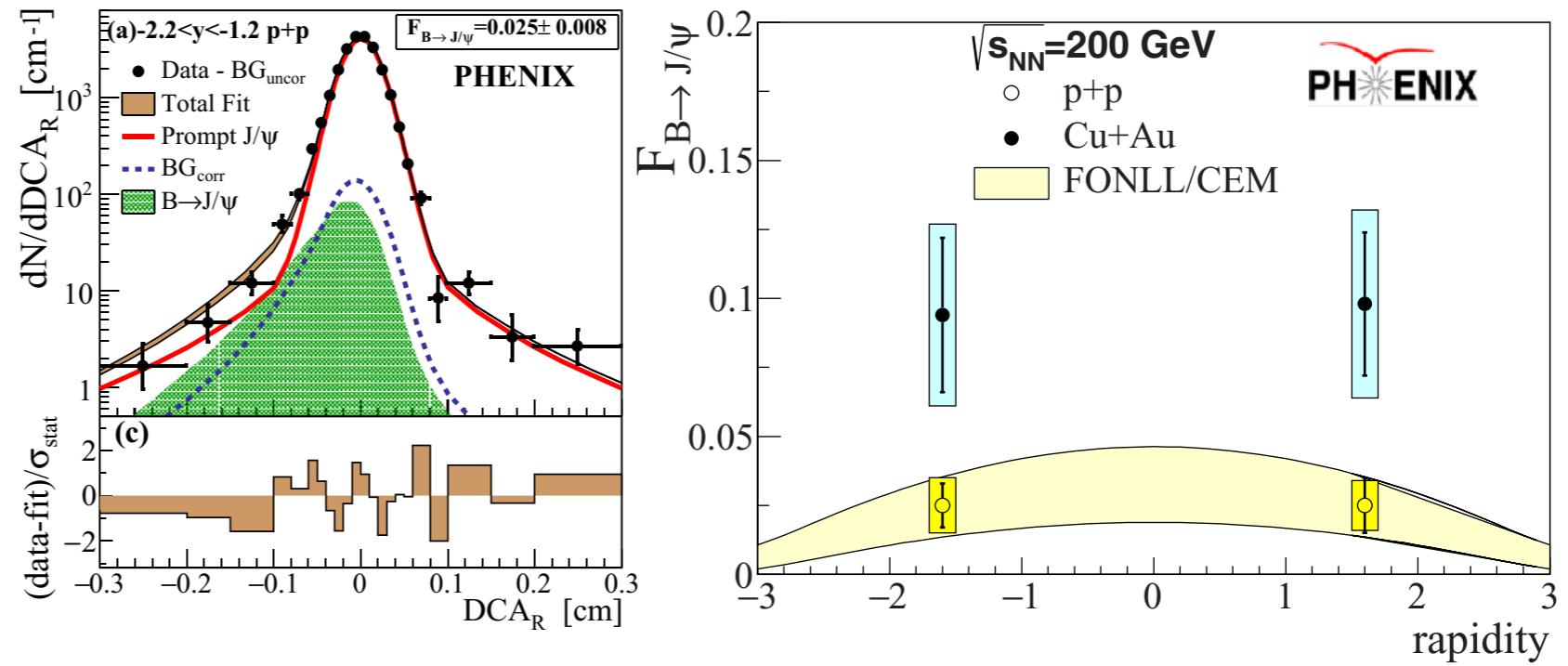


Vertex detector for precise tracking and vertex measurement

$B \rightarrow J/\psi$ in single muon, in 200 GeV p+p and Cu+Au

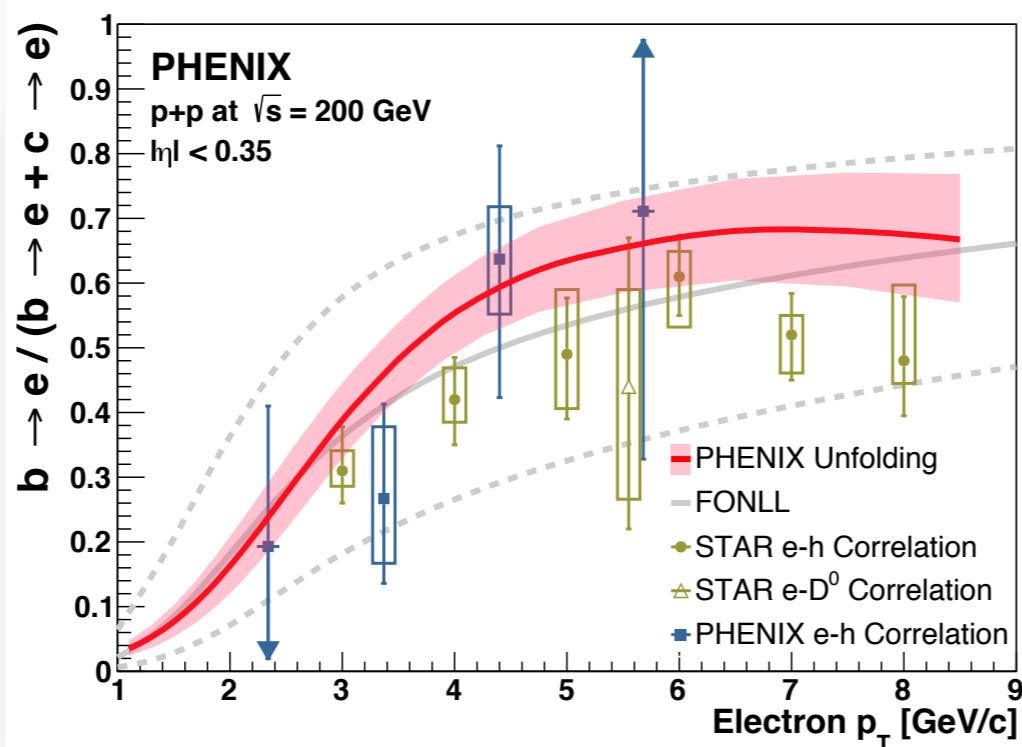
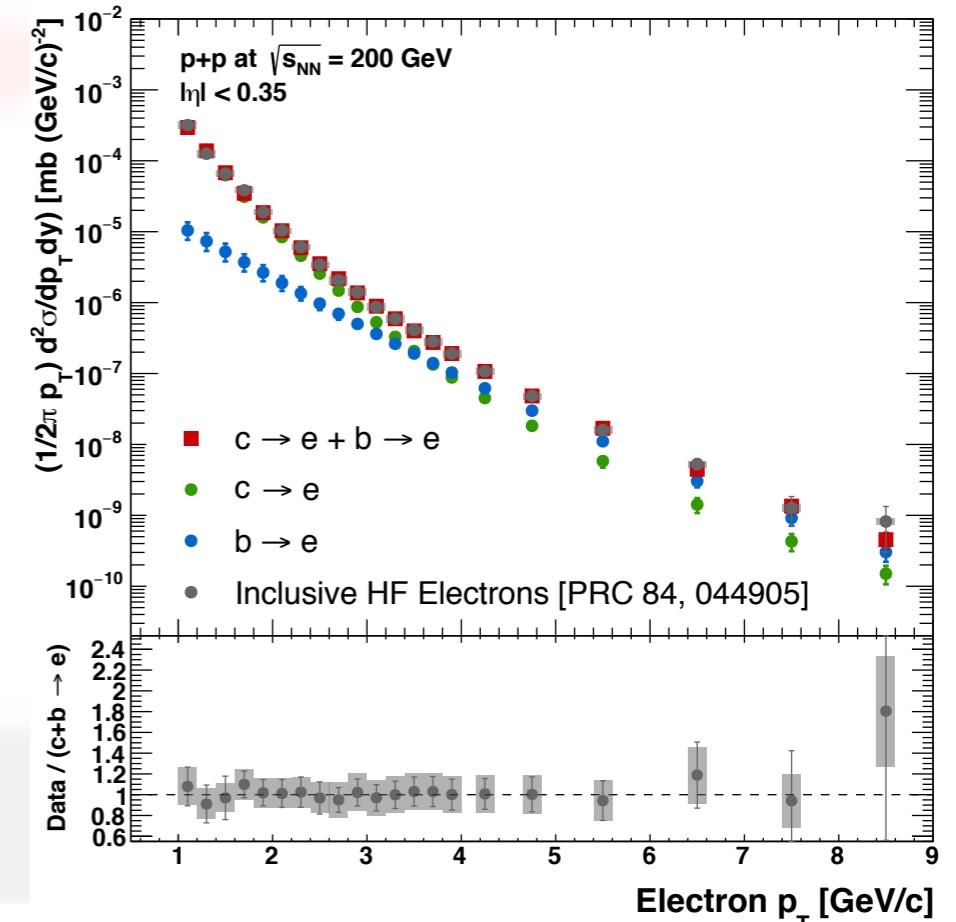
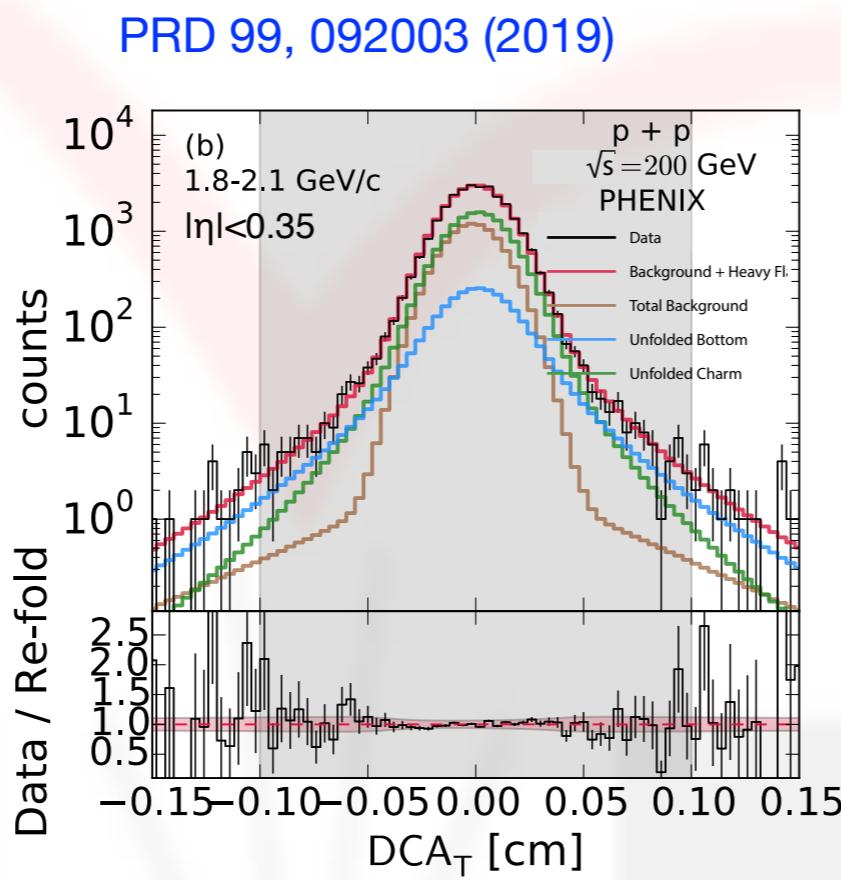
Phys. Rev. C 96, 064901

- Yields in p+p consistent with FONLL calculations.
- Smaller nuclear modification of B meson in Cu+Au collisions compared to prompt J/ψ (disassociation in QGP due to Debye color screening?).
- Small yield enhancement at backward rapidity (in agreement with cold-nuclear-matter effects).
- Integrated momentum result insufficiently sensitive to energy loss in QGP. Need to perform similar analysis but as a function of p_T to better understand energy loss phenomena.



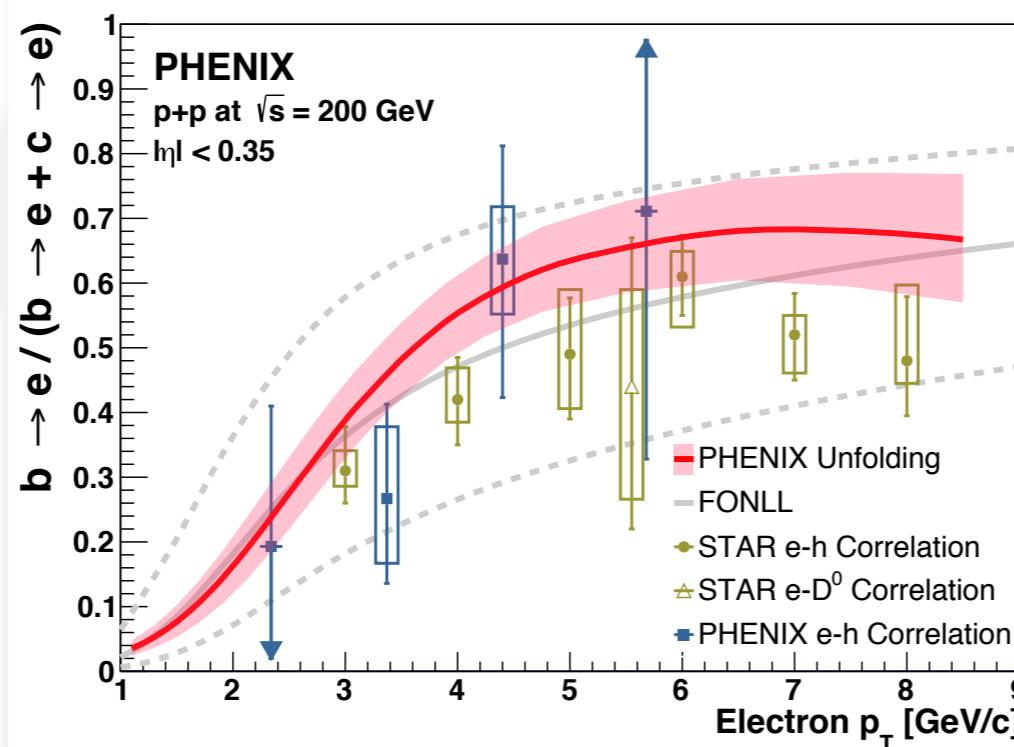
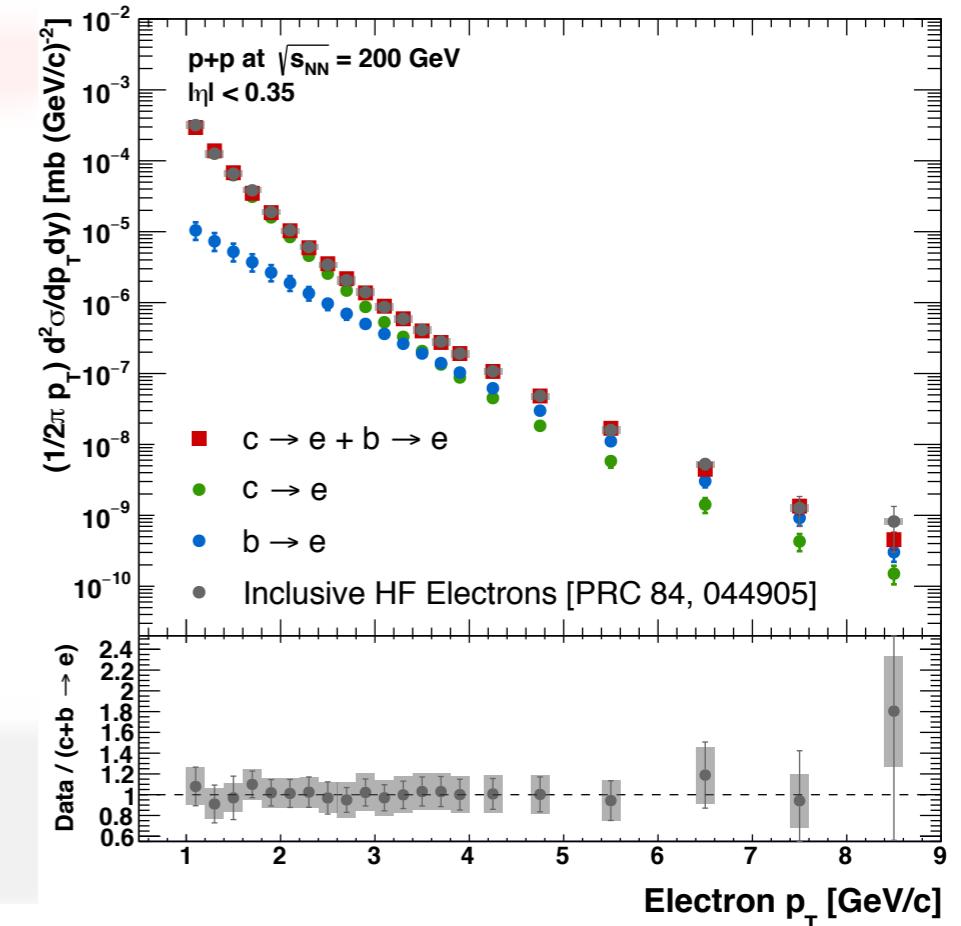
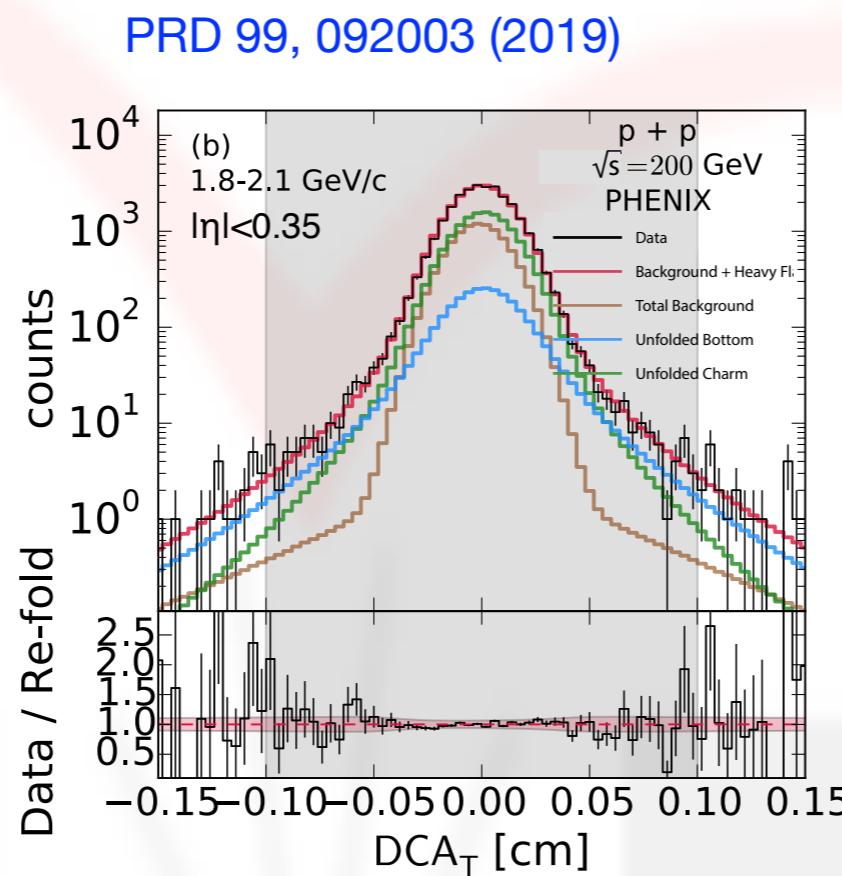
c/b decay in single electron, in 200 GeV p+p

- Fitting DCA_T (transverse component) to get HF yield.
- Unfolding procedure for c/b separation.



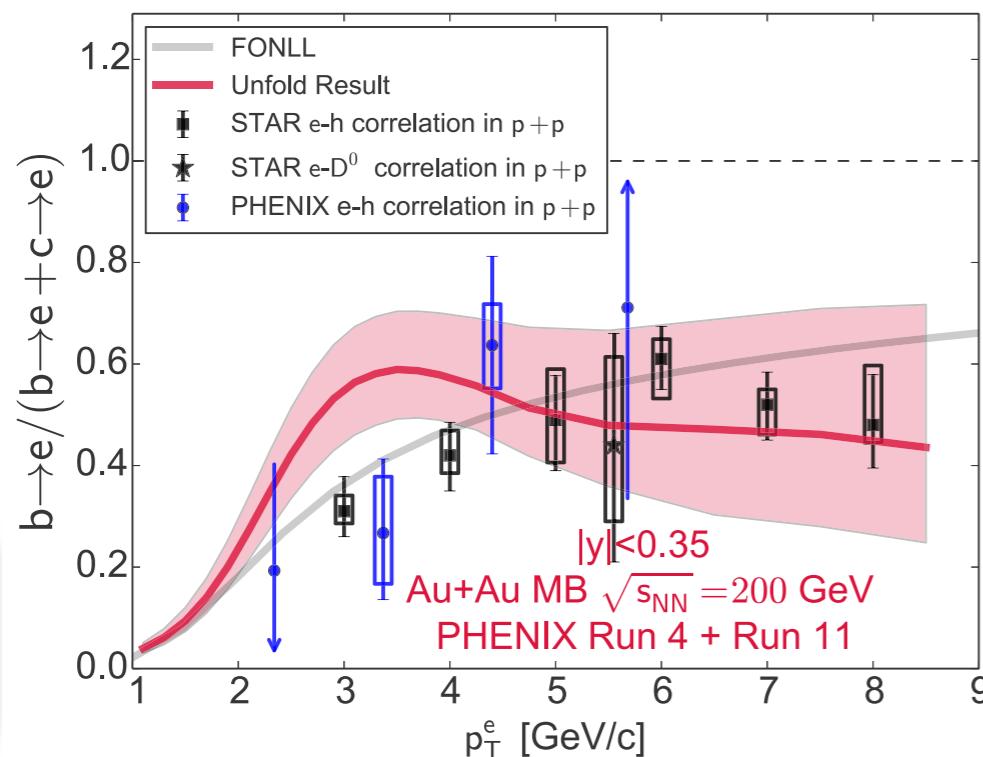
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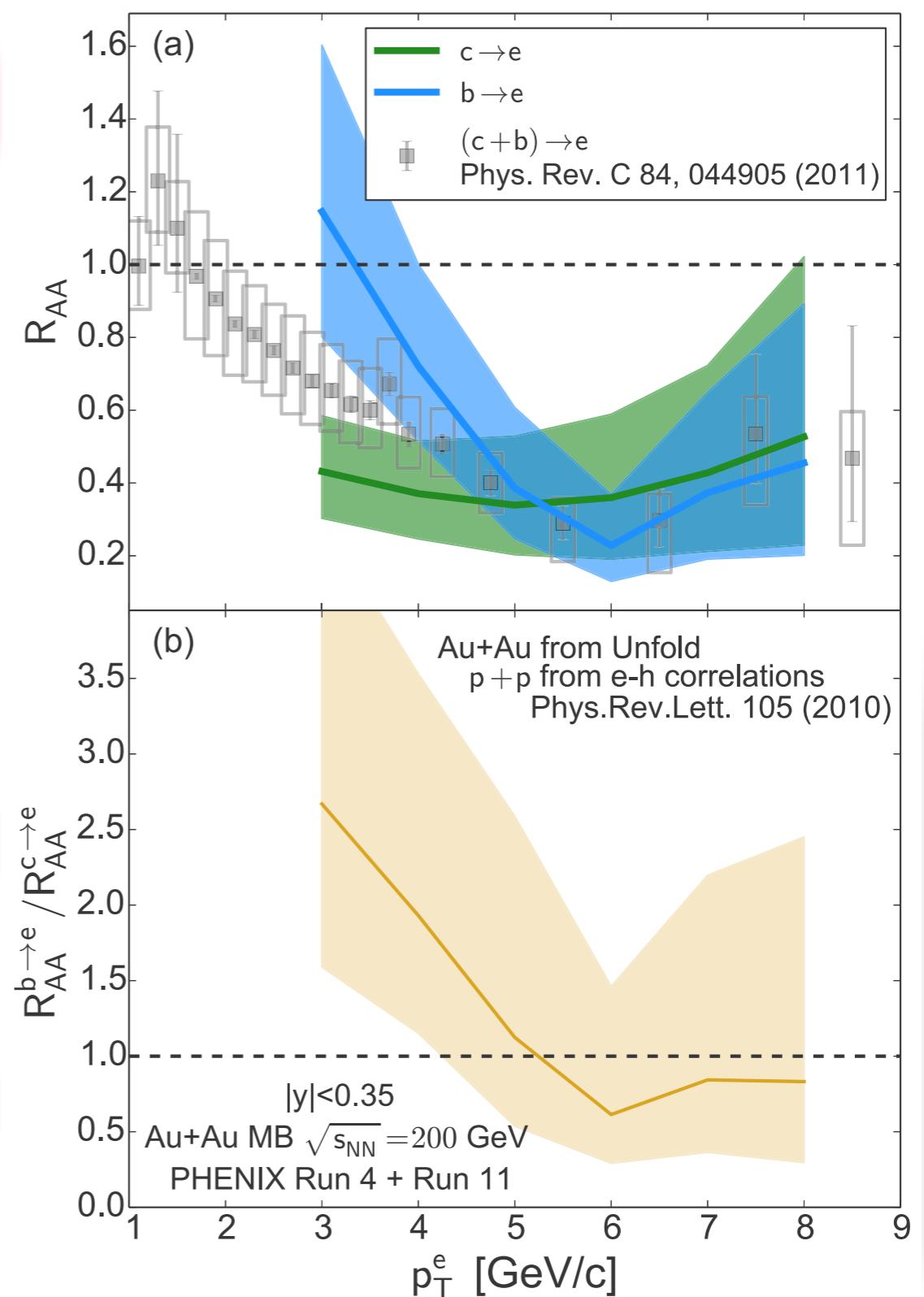
Inclusive HF yield from refolded distribution consistent with published measurements.

c/b decay in single electron, in 200 GeV Au+Au



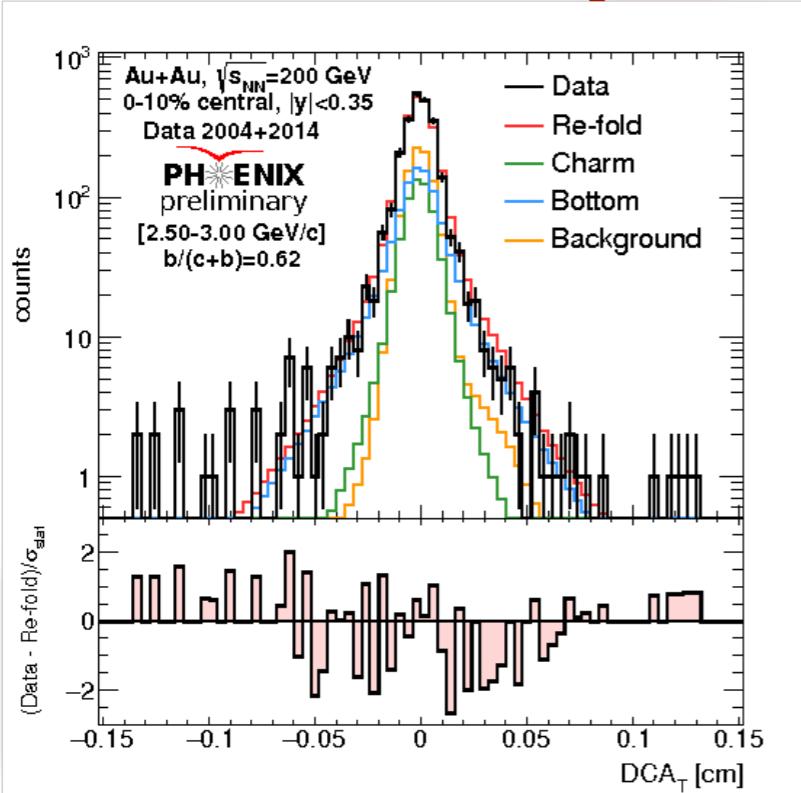
Expected energy loss in QGP:
 $E(u,d) > E(c) > E(b)$

- Unfolded b->e yield consistent with past e-hadron correlation results from PHENIX and STAR in p+p in $p_T > 4$ GeV (right).
- Higher c->e suppression than b->e at 1σ up to $p_T \sim 4$ GeV (right).

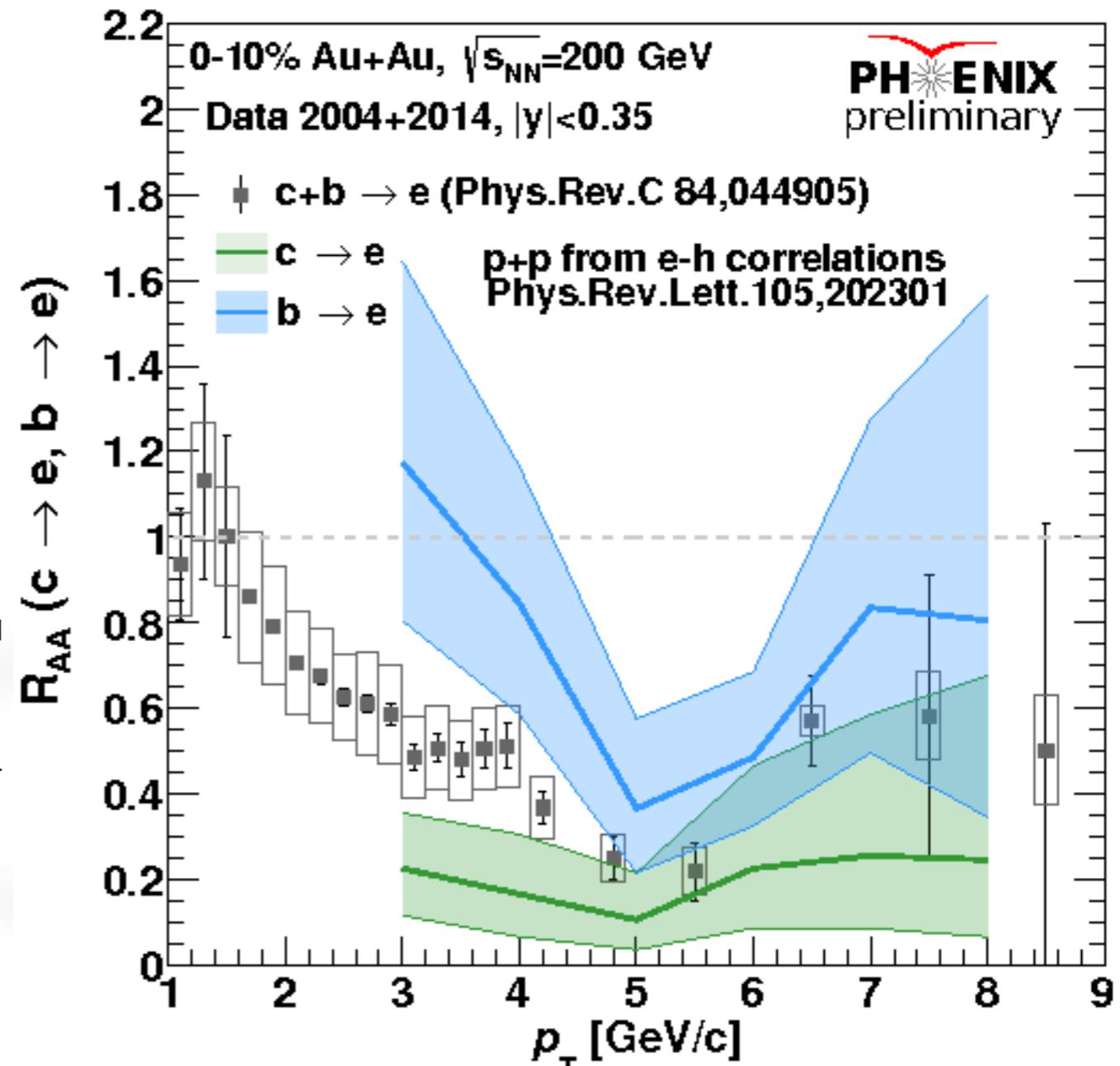


Phys. Rev. C 93, 034904 (2016)

c/b decay in single electron, in 200 GeV (0-10)% Au+Au



- Studied centrality dependence in the 200 GeV Au+Au data.
- Preliminary results show b->e suppression at large p_T for 0-10% centrality bins.
- Currently uses STAR's e-h correlation results for p+p baseline.
- More precise measurement at low p_T necessary to understand mass/flavor dependence to the energy loss.



Expected energy loss in QGP:
 $E(u,d) > E(c) > E(b)$

Summary of past analyses

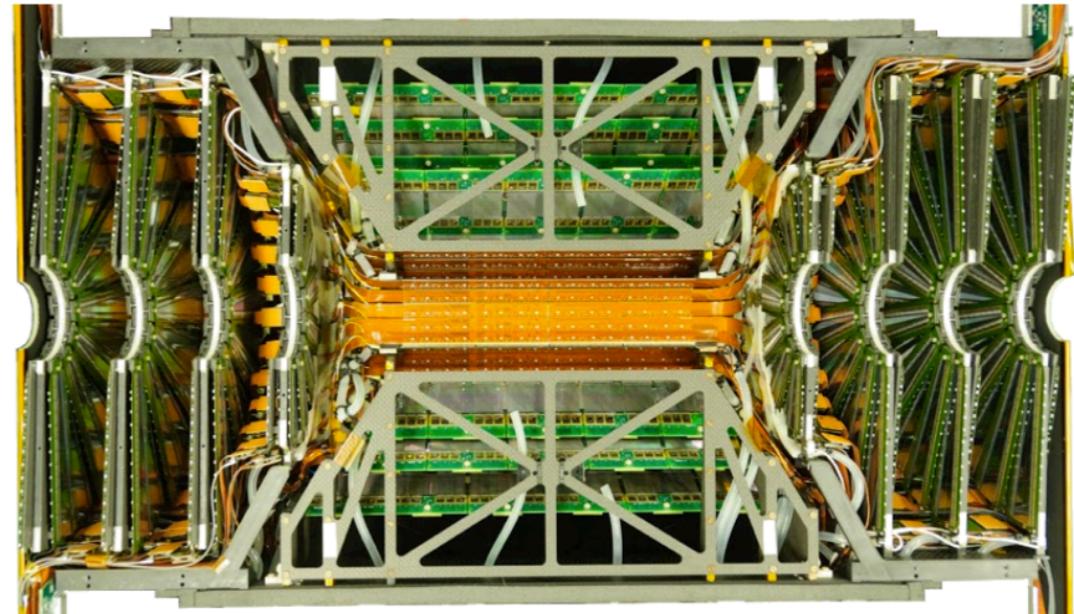
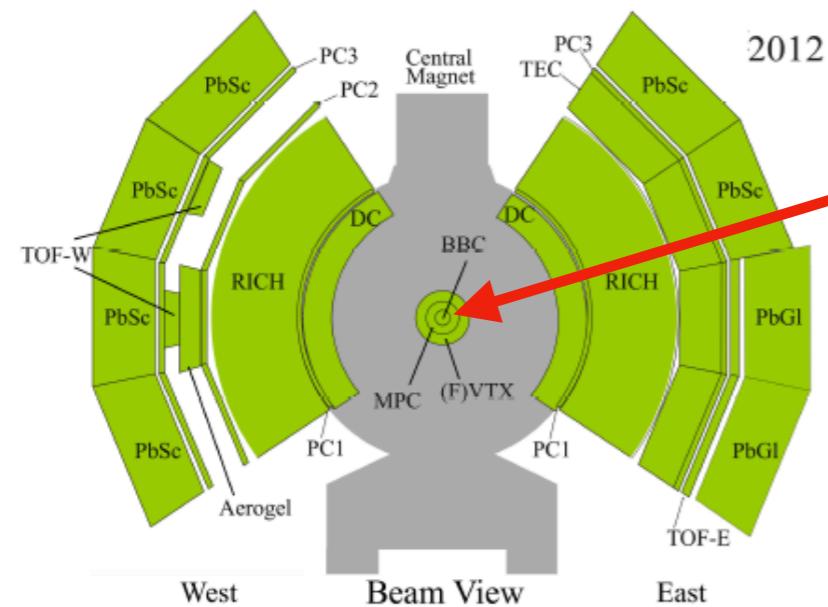
- Results in p+p collisions are consistent with HF fixed-order-plus-next-to-leading-log (FONLL) calculations.
- Total number of bottom quarks is unmodified as seen in the non-prompt J/ψ measured in Cu+Au collisions.
- Results in Au+Au consistent with quark mass hierarchy expected for HF in QGP medium.

Status of current analysis and future plans

- Data alignment, quality cuts, production of embedding simulation and tuning of the simulation has been completed.
- The following tasks are underway for single muon analysis using PHENIX Run 15 p+p data at 200 GeV:
 - Implementation of new machine learning based technique (Boosted Decision Tree classifier) to simultaneously use multiple discriminating variables (along with DCA_R) for more efficient signal/background classification.
 - Development of fitting procedure using output of the machine learning to extract heavy flavor muon decay from prompt hadrons, prompt muons, muons from light hadron decays and other sources of background.
 - Unfolding method to map the muon distributions to the parton level distributions corresponding to the parent hadron is being developed.

Backup

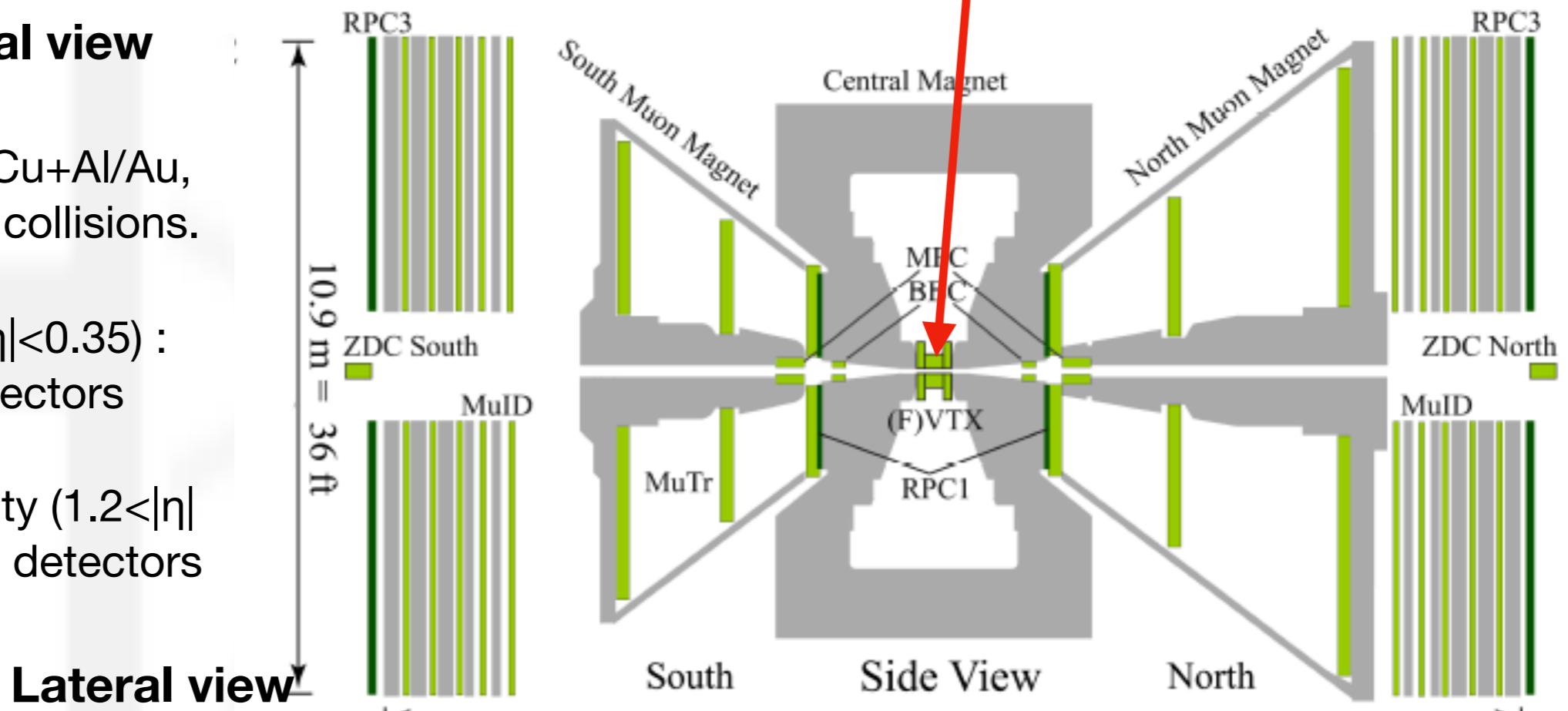
PHENIX



Silicon-Vertex Detectors

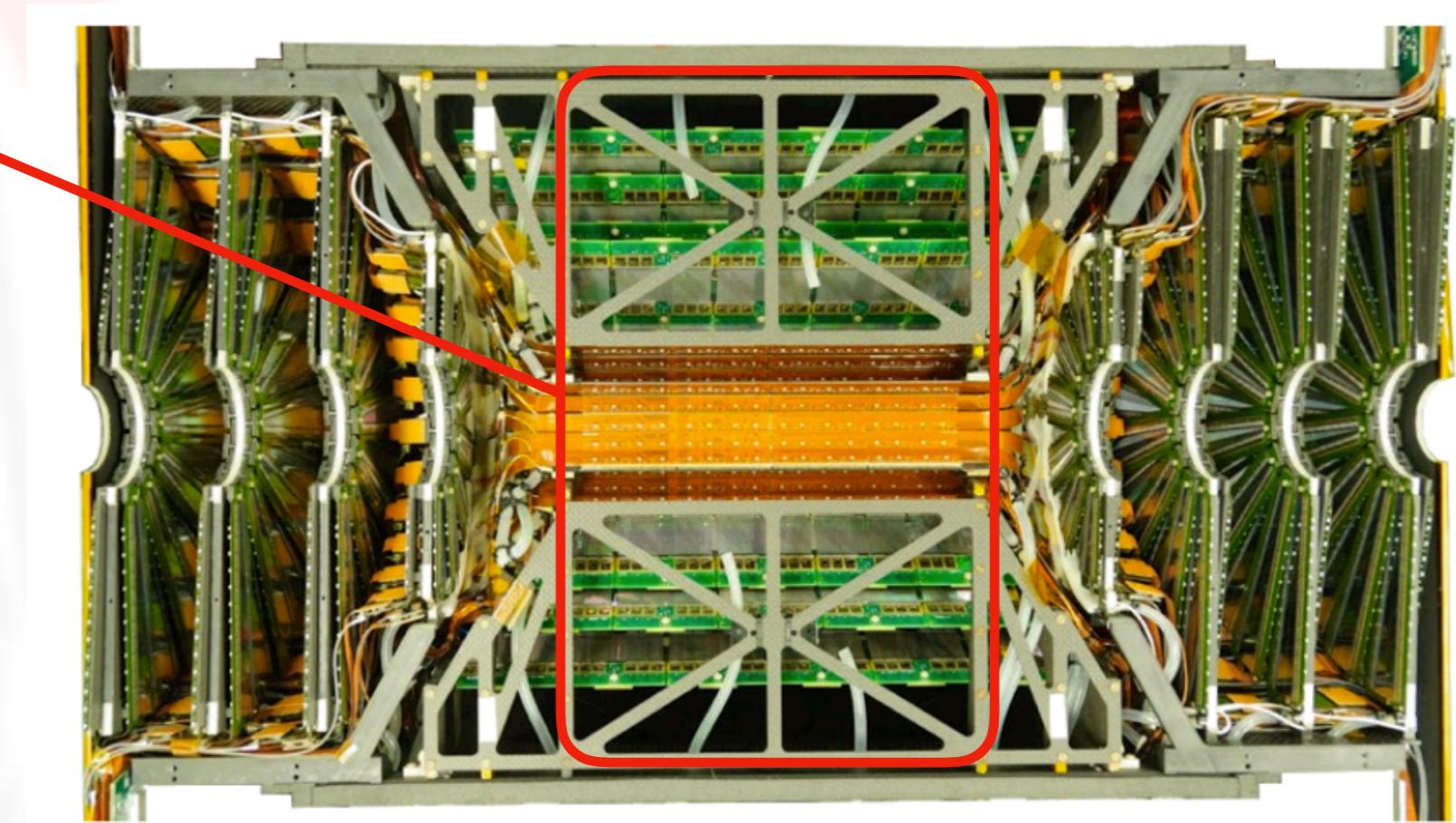
Cross sectional view

- p+p, p/d/ ^3He /Cu+Al/Au, and heavy ion collisions.
- Mid rapidity ($|\eta|<0.35$) : electron id detectors
- Forward rapidity ($1.2<|\eta|<2.2$): muon id detectors



Silicon Vertex Detectors

- The Silicon vertex detector (**VTX**) has 4 layers - 2 inner pixel layers (14.4 μm resolution) and 2 outer strips (23 μm resolution)
- $|\eta|<1.2$, $\phi=0.8\pi$ in each arm coverage



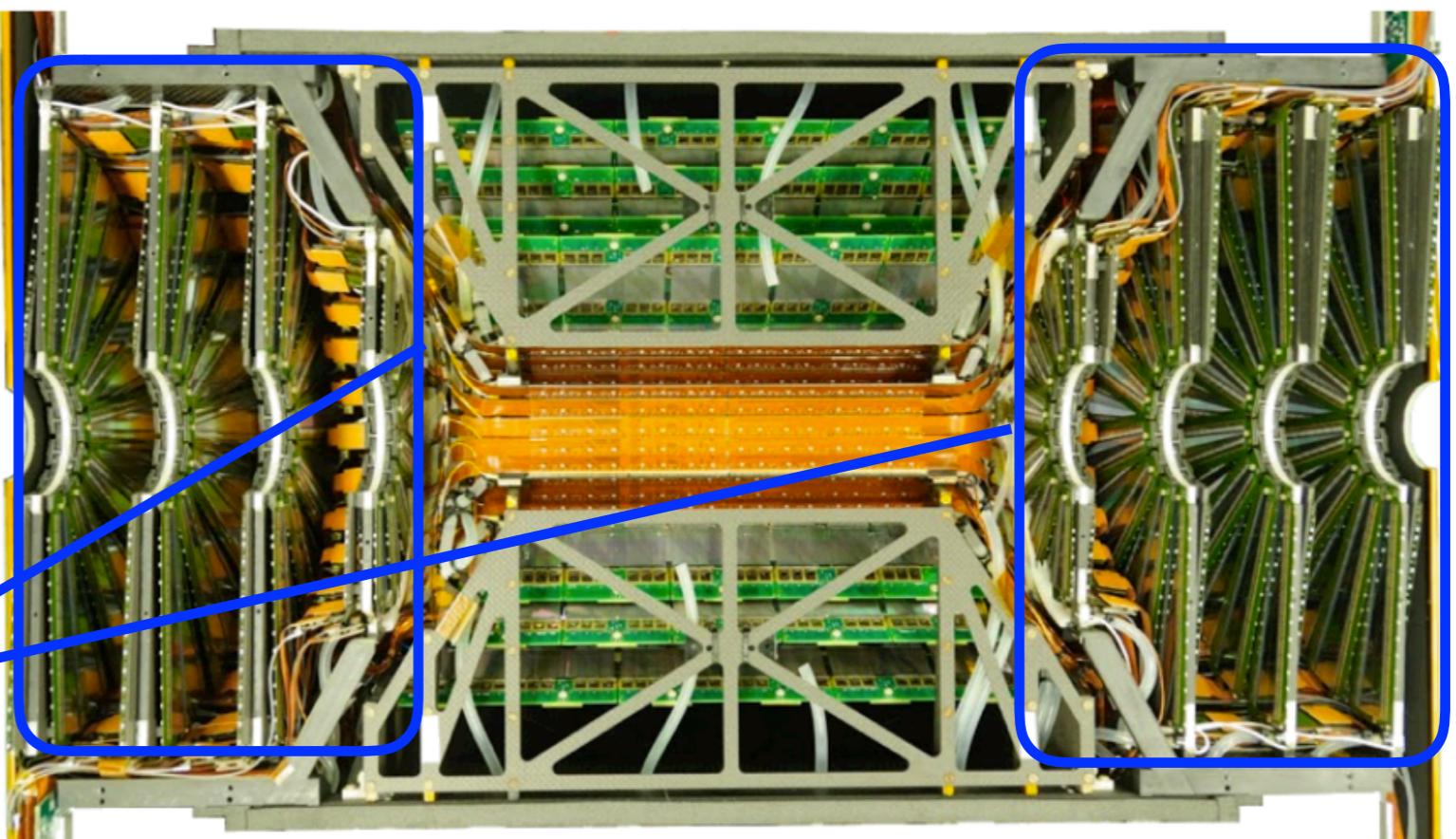
Silicon Vertex Detectors

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- $|\eta| < 1.2$, $\phi = 0.8\pi$ in each arm coverage

- The Forward Silicon vertex detector (**FVTX**) has 4 strip layers each in the north and south arms from $z=20 \text{ cm}$ to $z=38 \text{ cm}$.

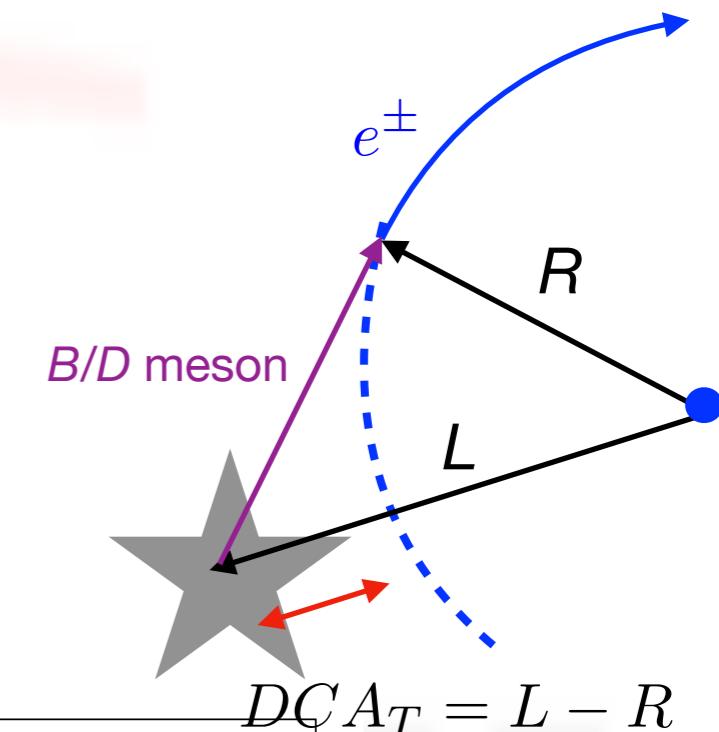
- $1.2 < |\eta| < 2.2$ and $\phi = 2\pi$



c/b decay in single electron, in 200 GeV p+p

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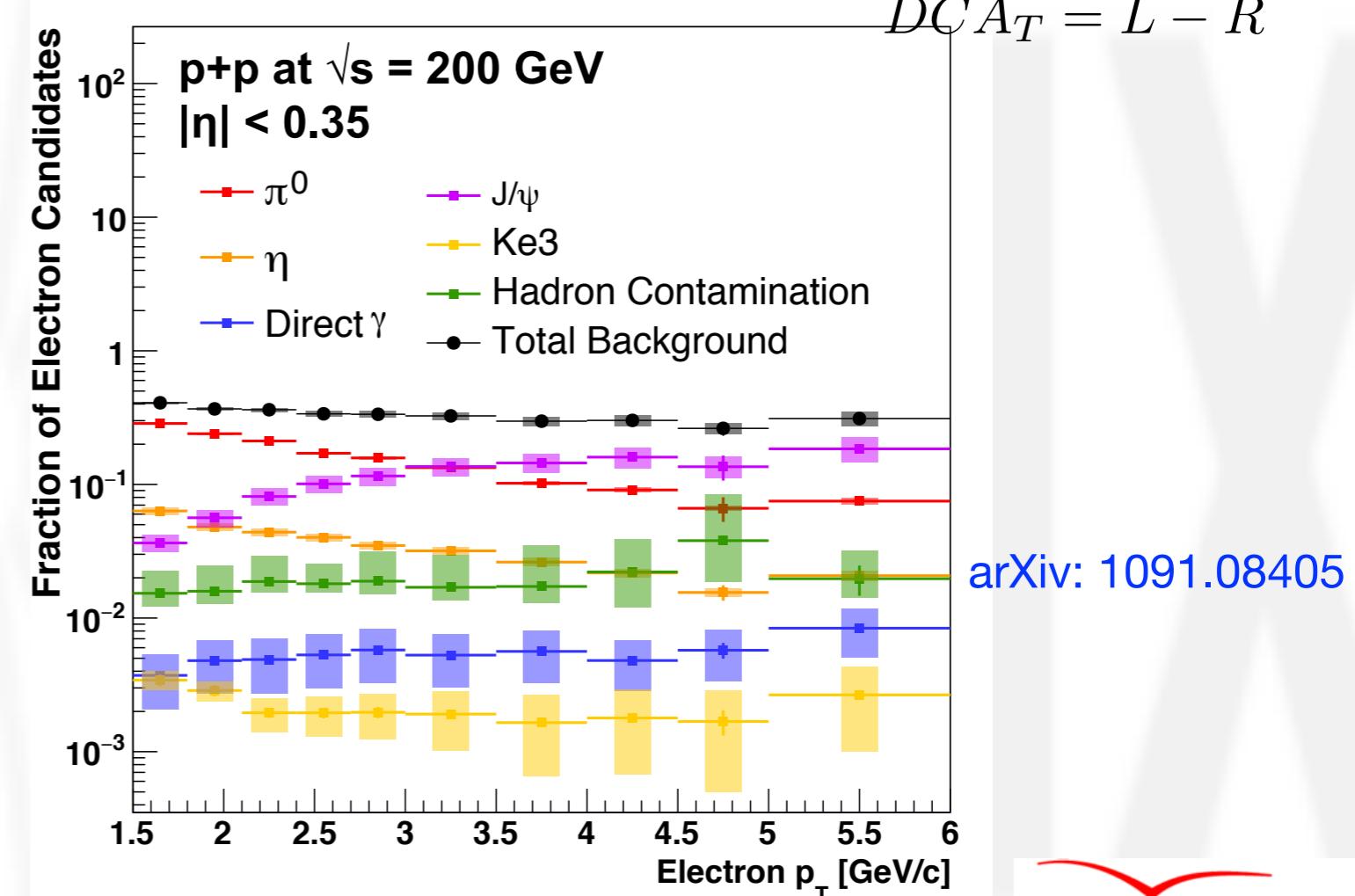
DCA_T is proportional to decay length and is precisely measured by the VTX.



Methodology:

- Measure the photonic background contribution.
- Determine background contributions from photonic, non-photonic and hadronic contaminations (bottom right).

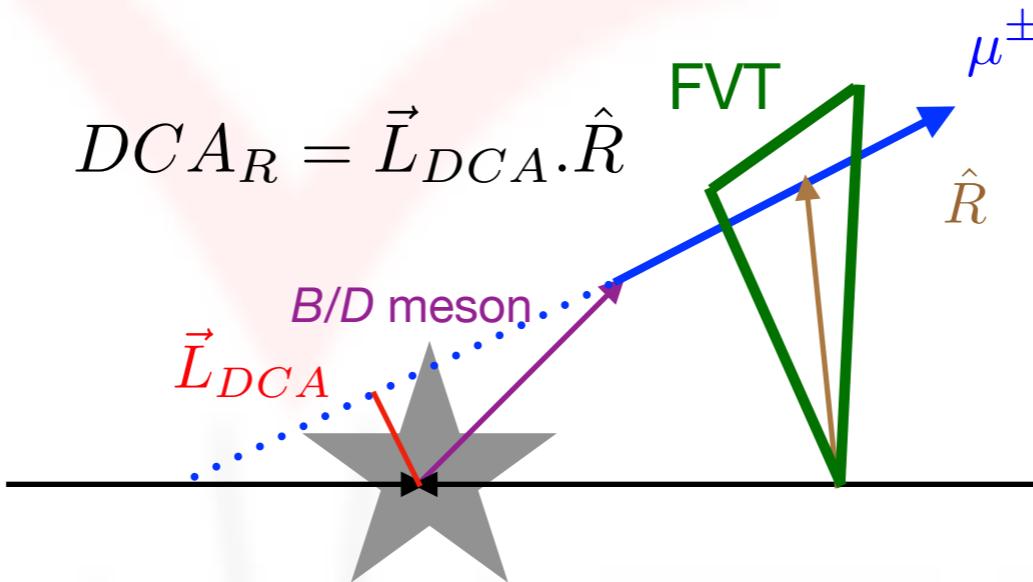
Large π^0 background in electron channel.



B->J/ ψ in single muon, in 200 GeV p+p and Cu+Au

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DCA_R (DCA along the radial projection of tracks) can be precisely determined with FVTX+VTX.



- Single muon tracks of μ from J/ψ decay using FVTX associated tracks.
- DCA_R distribution from semi-leptonic decay of J/ψ to muons.
- Large di-muon combinatorics and mismatches between MuTr and FVTX are removed using mixed event techniques.
- Uncorrelated backgrounds (tracks from light hadron decays) dominate large DCA_R.

