Studying the relative bottom contribution via electron-tagged jets in STAR

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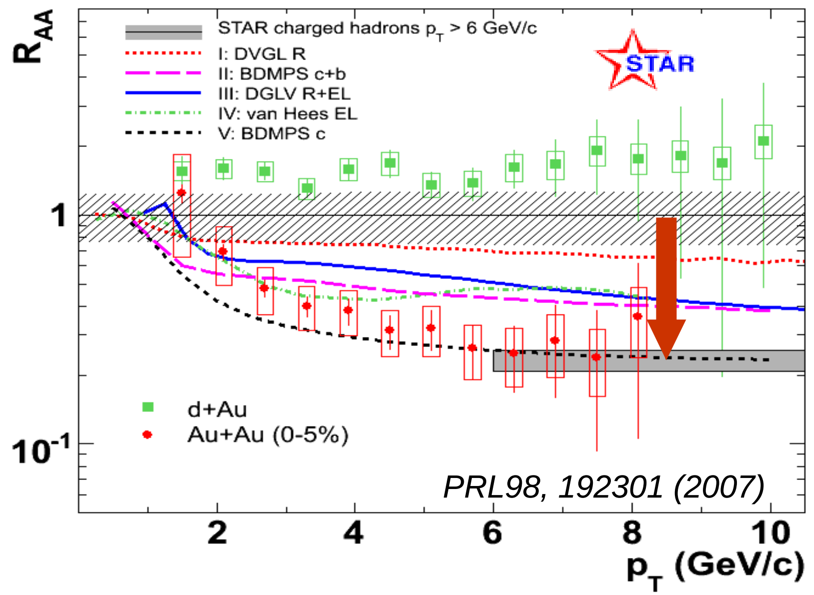
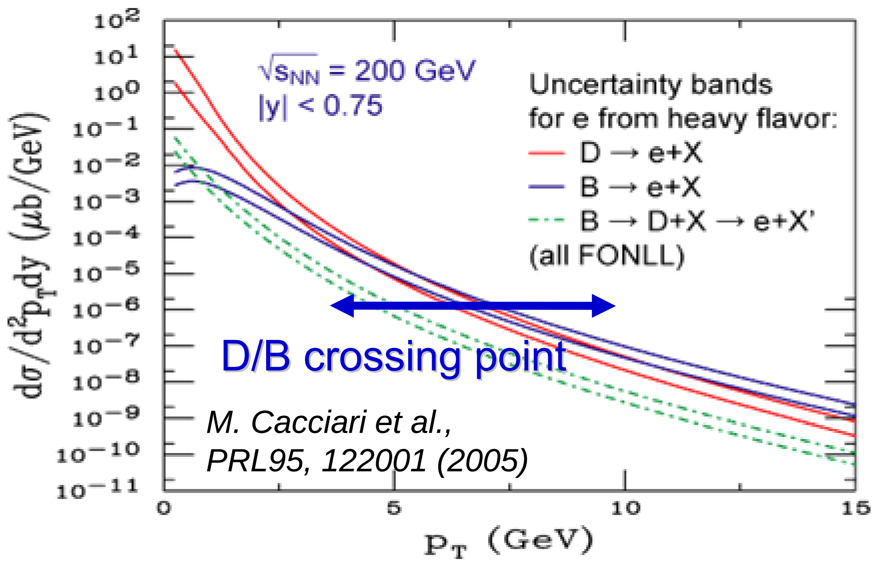
Outline

- Motivation
- Correlation method
- Gluon splitting rate at RHIC
  - D* in jets
  - comparison to MC@NLO simulations
- Data analysis in p+p collisions
  - e-D^0 azimuthal correlations
  - relative bottom contribution
- Summary and conclusions

Motivation

- Study dynamical properties of QGP: initial gluon density, drag coefficient
- Heavy quarks
  - well calibrated probes
  - lose less energy due to dead-cone effect
- Surprise in central Au+Au: Heavy-flavor decay electrons are strongly suppressed
- Models implying D and B energy loss are inconclusive yet
- pQCD: Large uncertainty on D/B crossing point
- Goals
  - access to underlying production mechanisms
  - separate D and B contribution experimentally



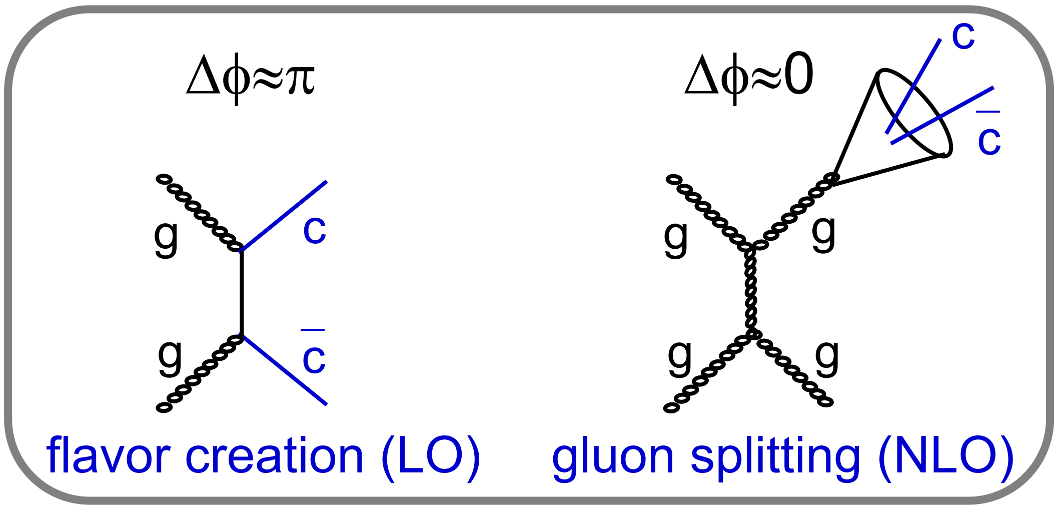


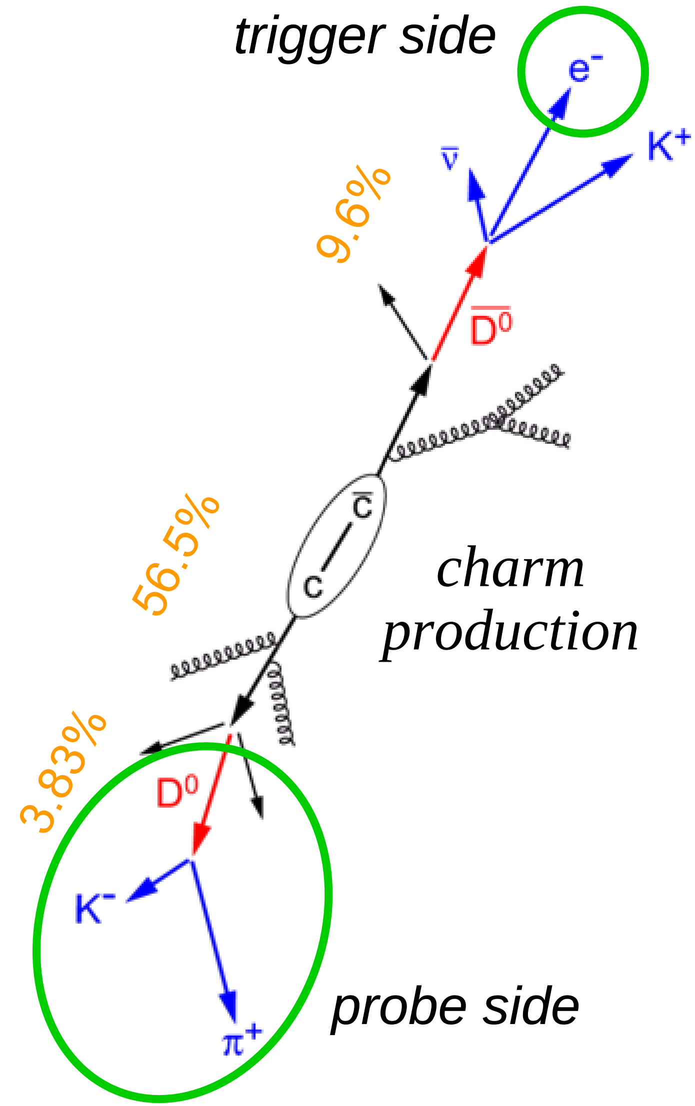
Correlation method

Identification and separation of charm and bottom production processes using their decay topology and azimuthal angular correlation of their decay products

- electrons from D/B decays are used to trigger on charm/bottom quark pairs

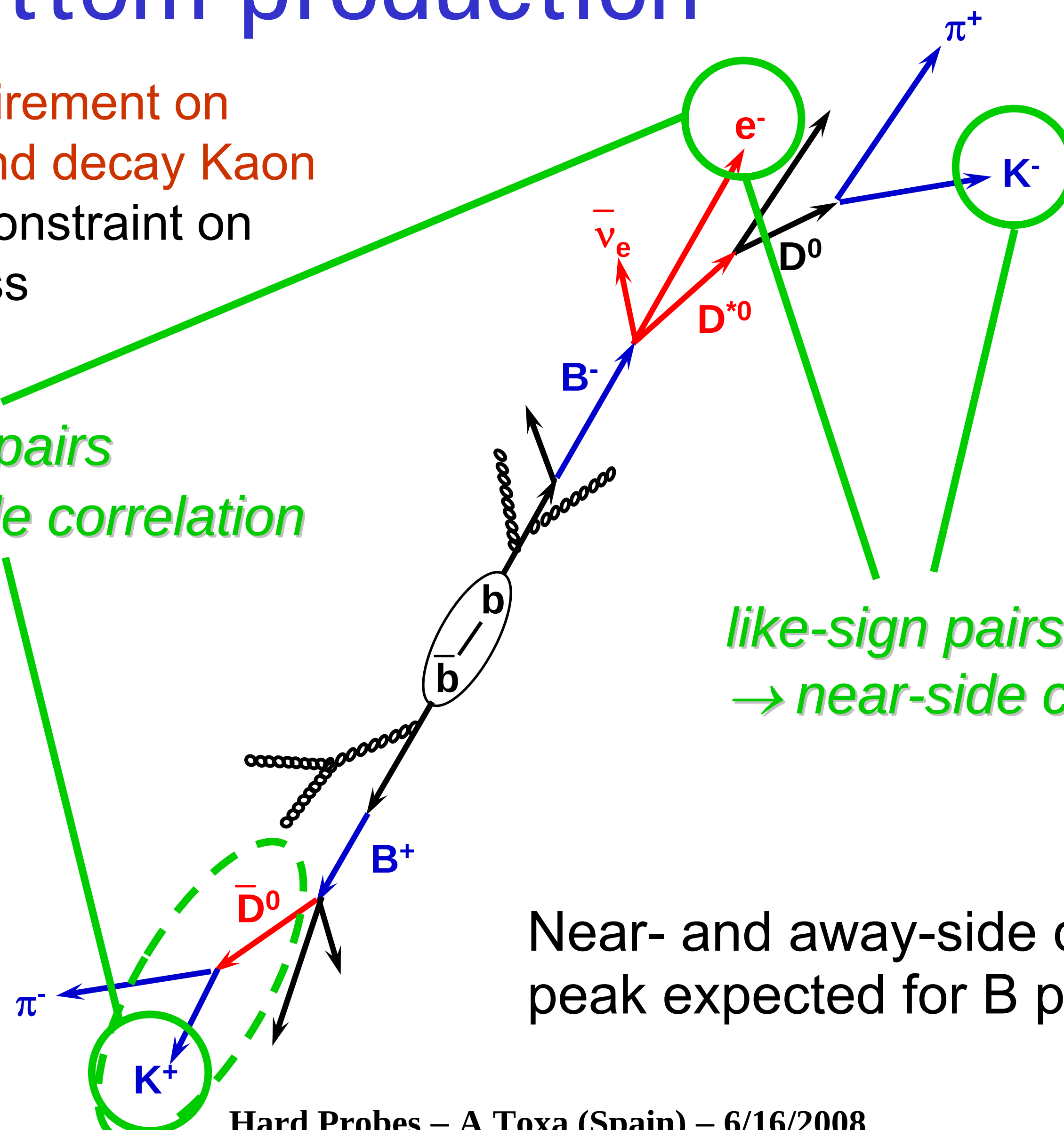
- associate D^0 mesons are reconstructed via their hadronic decay channel (probe)





Electron tagged correlations: bottom production

Charge-sign requirement on trigger electron and decay Kaon gives additional constraint on production process



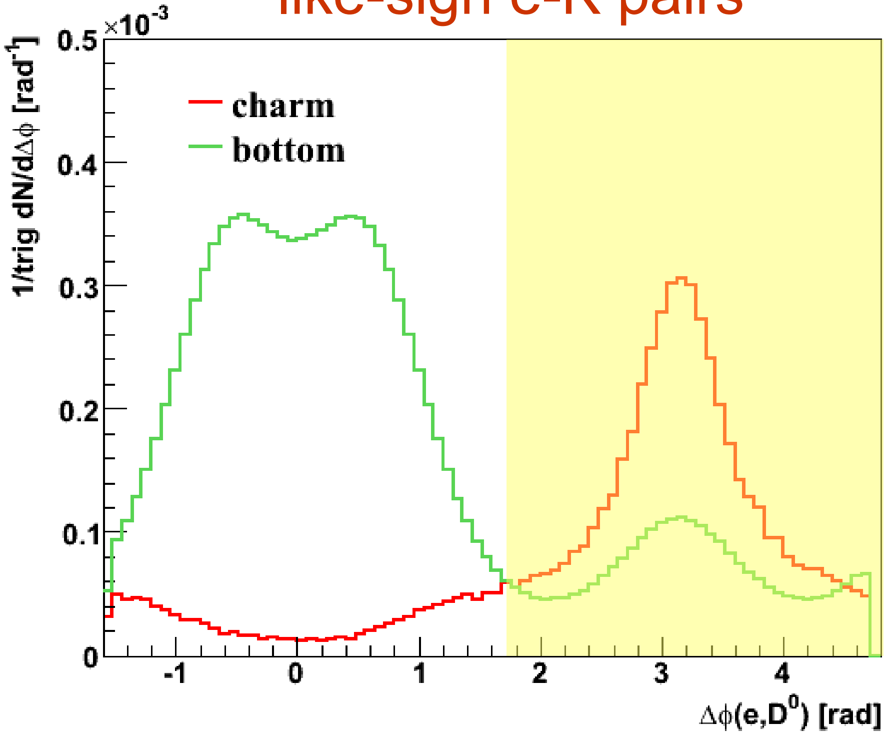
unlike-sign pairs
→ away-side correlation

like-sign pairs
→ near-side correlation

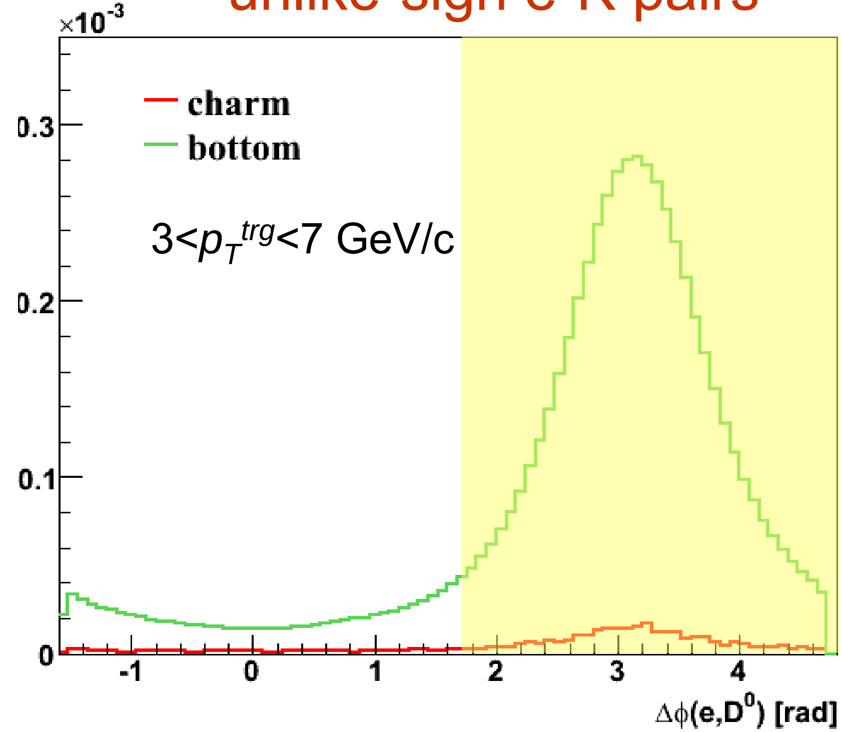
Near- and away-side correlation peak expected for B production

Leading order PYTHIA simulations

like-sign e-K pairs



unlike-sign e-K pairs

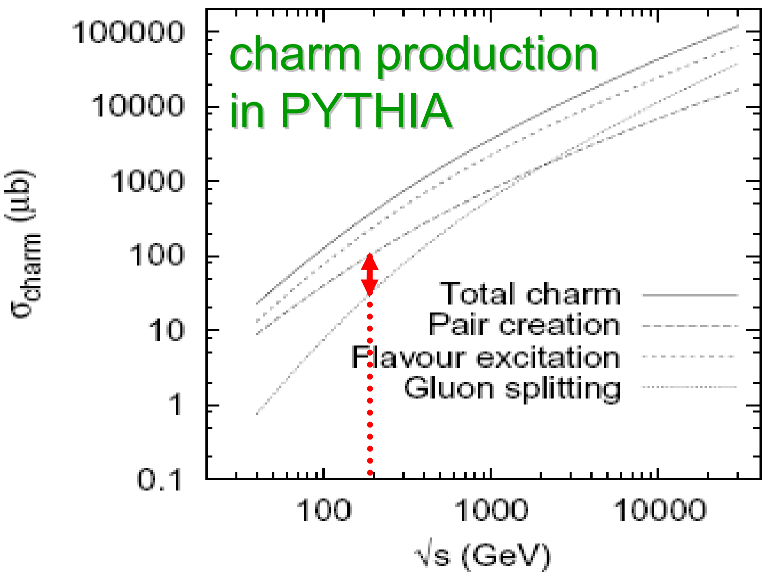


- Near-side
  - B decays
- Away-side
  - charm flavor creation (dominant)
  - small bottom contribution

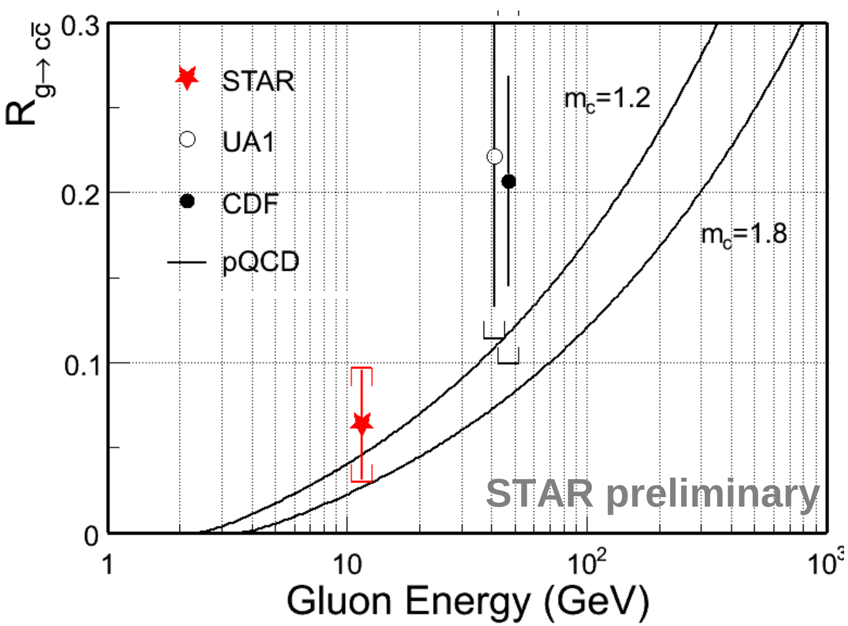
- Away-side
  - charm flavor creation (dominant)
  - small charm contribution

NLO process: Gluon splitting

E. Norrbin & T. Sjostrand, Eur. Phys. J. C17, 137 (2000)



Mueller & Nason PLB 157, 226 (1985)

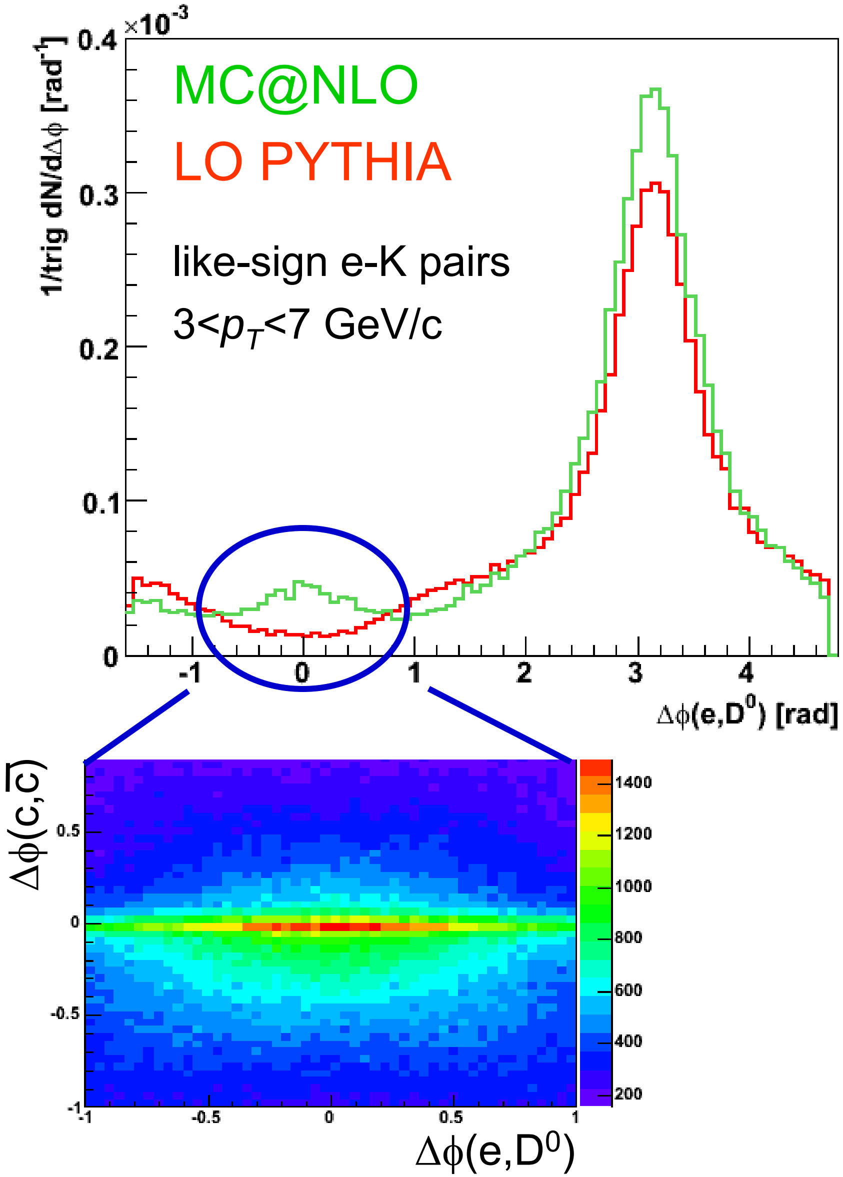


- FONLL/NLO calculations only give single inclusive distribution → no correlations
- PYTHIA is not really adequate for NLO predictions

- STAR measurement of D* in jets → access to charm content in jets
- Gluon splitting rate consistent with pQCD calculation

→ Gluon splitting contribution to total charm production ~6%

Charm production in MC@NLO



- NLO QCD computations with a realistic parton shower model
- Remarkable agreement of away-side peak shape between the two models
- Near-side: GS/FC = (6.5±0.5)%

→ small gluon splitting contribution

→ in agreement with STAR measurement

MC@NLO computation

- S. Frixione, B.R. Webber, JHEP 0206 (2002) 029

- S. Frixione, P. Nason, and B.R. Webber, JHEP 0308 (2003) 007

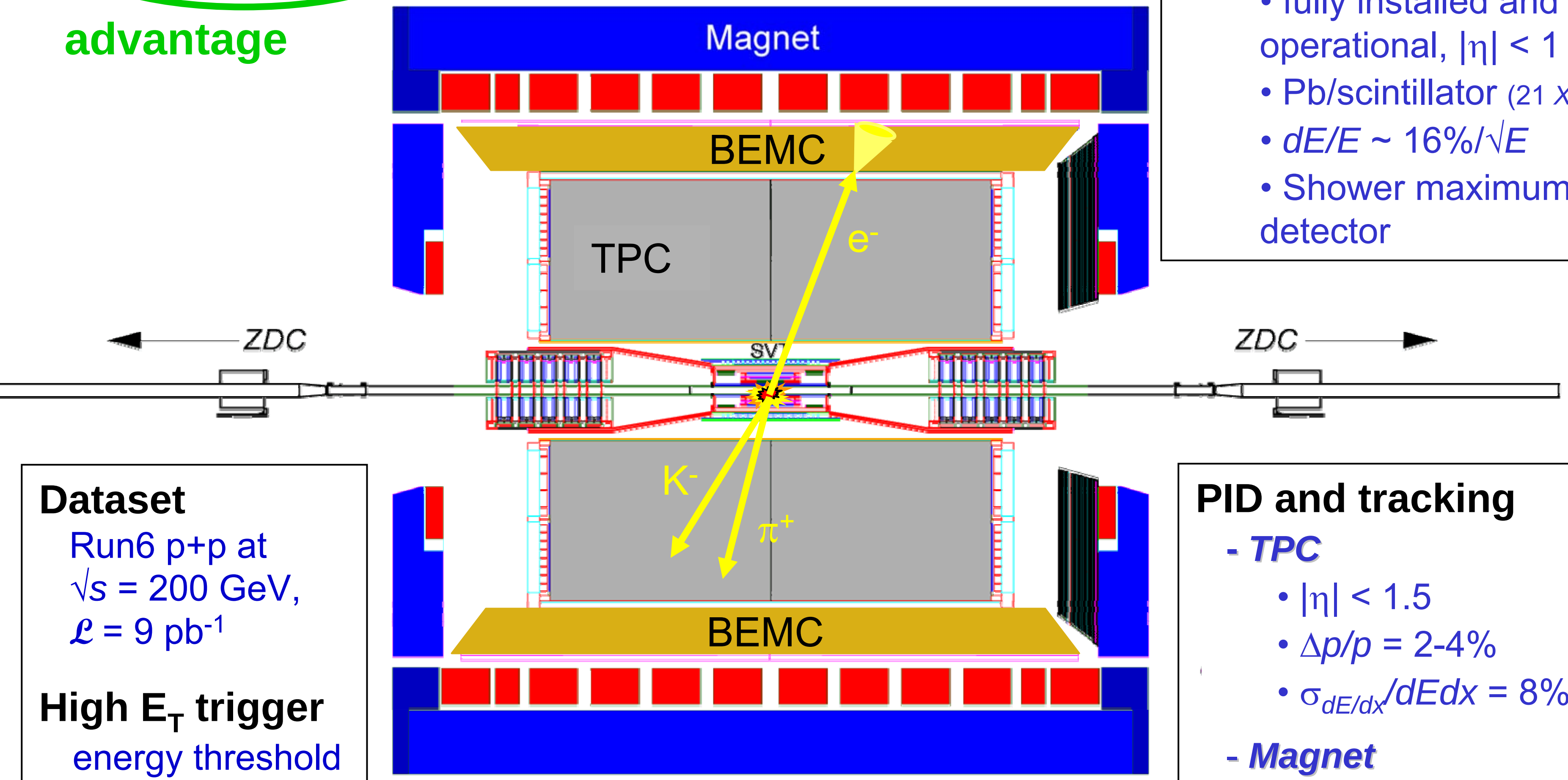
e-D^0 correlation analysis

STAR experiment

Solenoidal Tracker at RHIC

Large acceptance magnetic spectrometer

advantage



Energy measurement

- ***Barrel EMC***
  - fully installed and operational, $|\eta| < 1$
  - Pb/scintillator (21 X_0)
  - $dE/E \sim 16\%/\sqrt{E}$
  - Shower maximum detector

Dataset

Run6 p+p at $\sqrt{s}$ = 200 GeV, $\mathcal{L}$ = 9 pb^{-1}

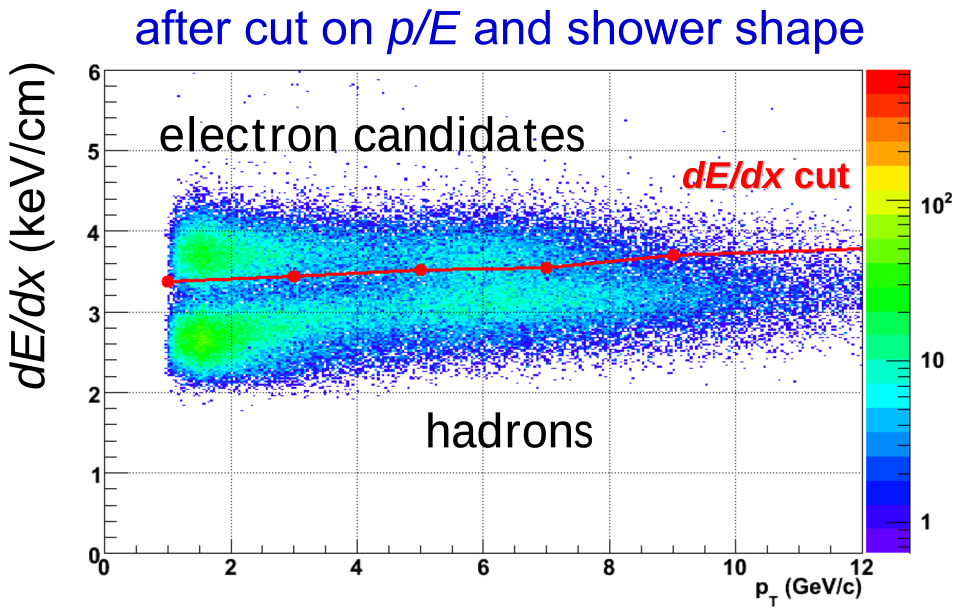
High E_T trigger

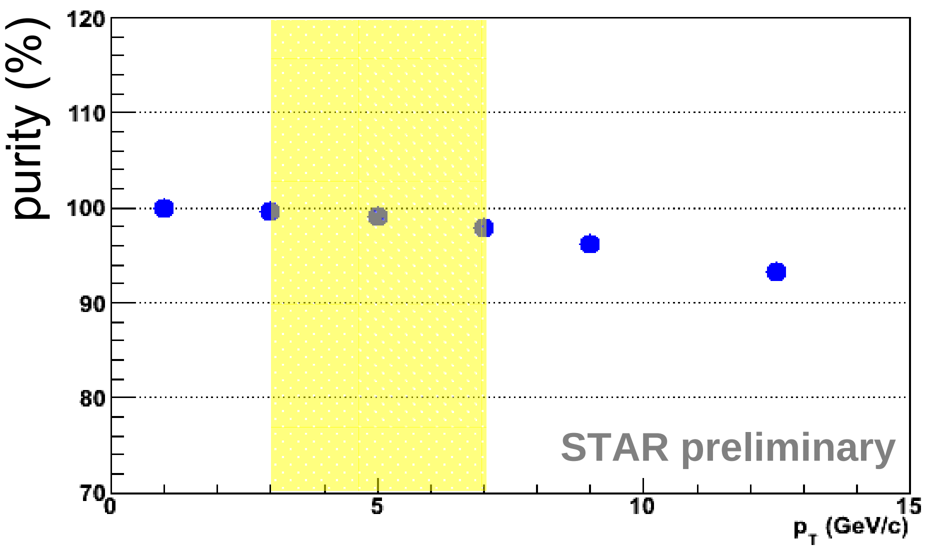
energy threshold 5.4 GeV

PID and tracking

- ***TPC***
  - $|\eta| < 1.5$
  - $\Delta p/p$ = 2-4%
  - $\sigma_{dE/dx}/dEdx$ = 8%
- ***Magnet***
  - 0.5 Tesla

Electron identification





- Quality cuts on EMC point and TPC track of particles
  - ➢ well developed shower
  - ➢ $0. < p/E_{tower} < 2.$
  - ➢ $3.5 < dE/dx < 5.0$ keV/cm (p_T dependent)

- High electron purity up to high p_T

→ Clean electron sample

Photonic electron background

• Most of the electrons in the final state are originating from other sources than heavy-flavor decays

• Dominant photonic contribution

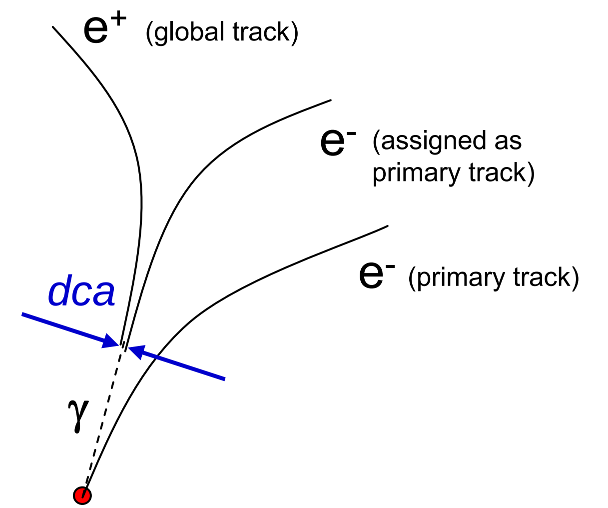
- γ conversions

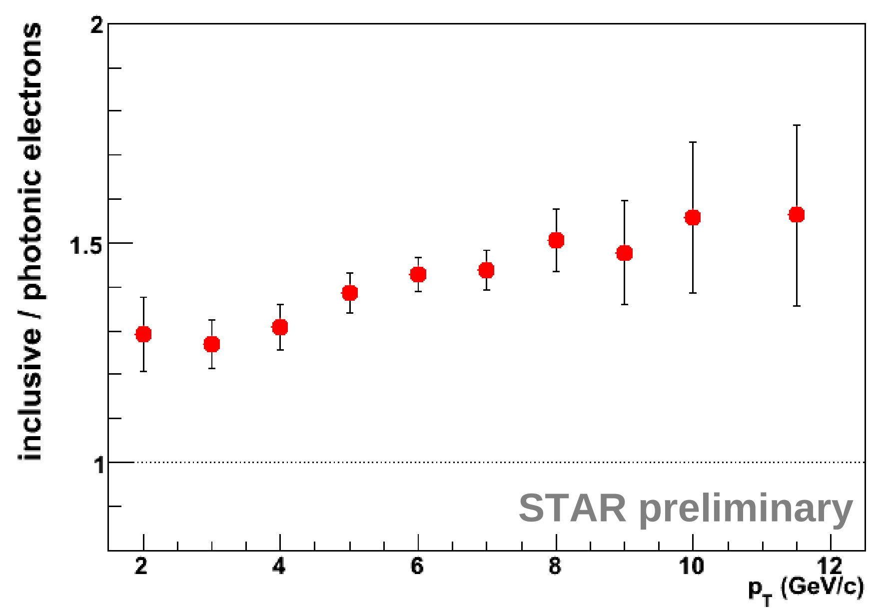
- π^0 and η Dalitz decays

• Exclude electrons with low invariant mass $m_{inv} < 150$ MeV/c^2

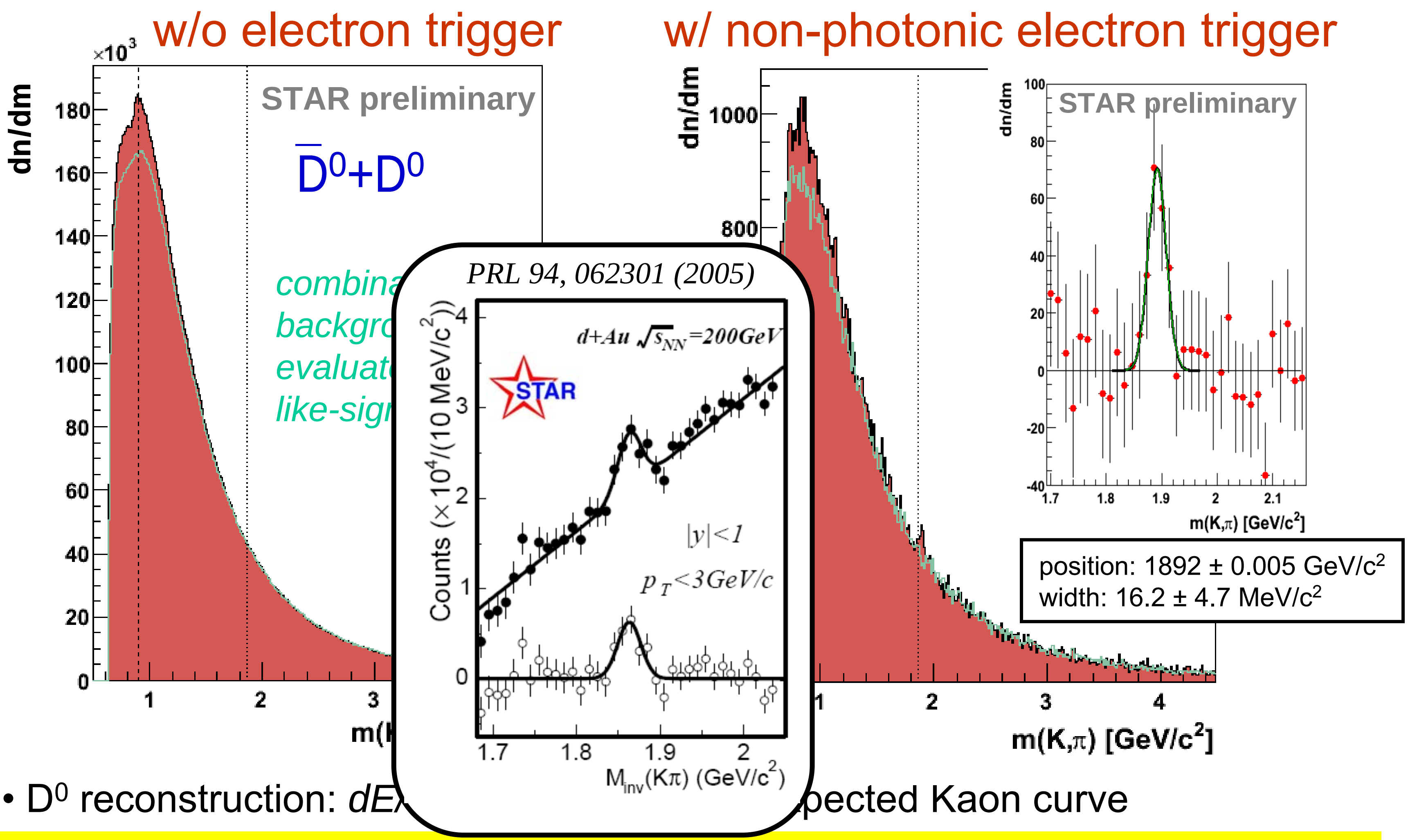
$\rightarrow$ Non-photonic electron excess at high p_T

• Photonic background rejection efficiency is ~70%





K-π invariant mass distribution

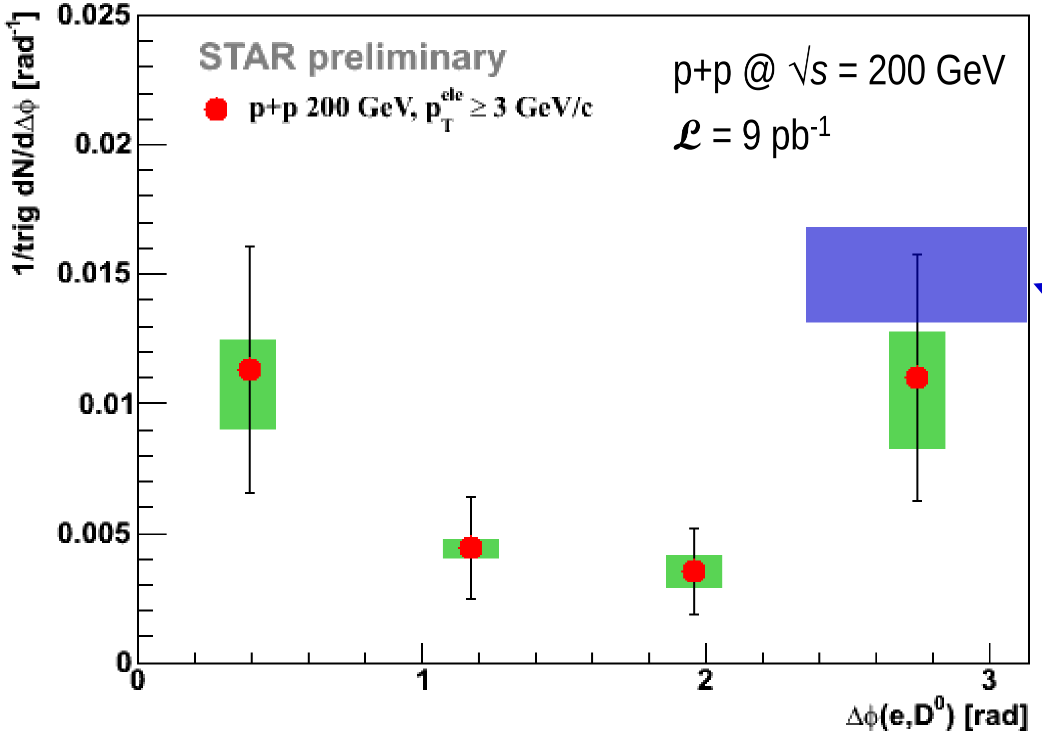


• D^0 reconstruction: *dE*... ...pected Kaon curve

• Significant suppression of combinatorial background (by a factor of ~200)

• S/B = 14% and signal significance = 3.7

Azimuthal correlation of non-photonic electrons and D^0 mesons



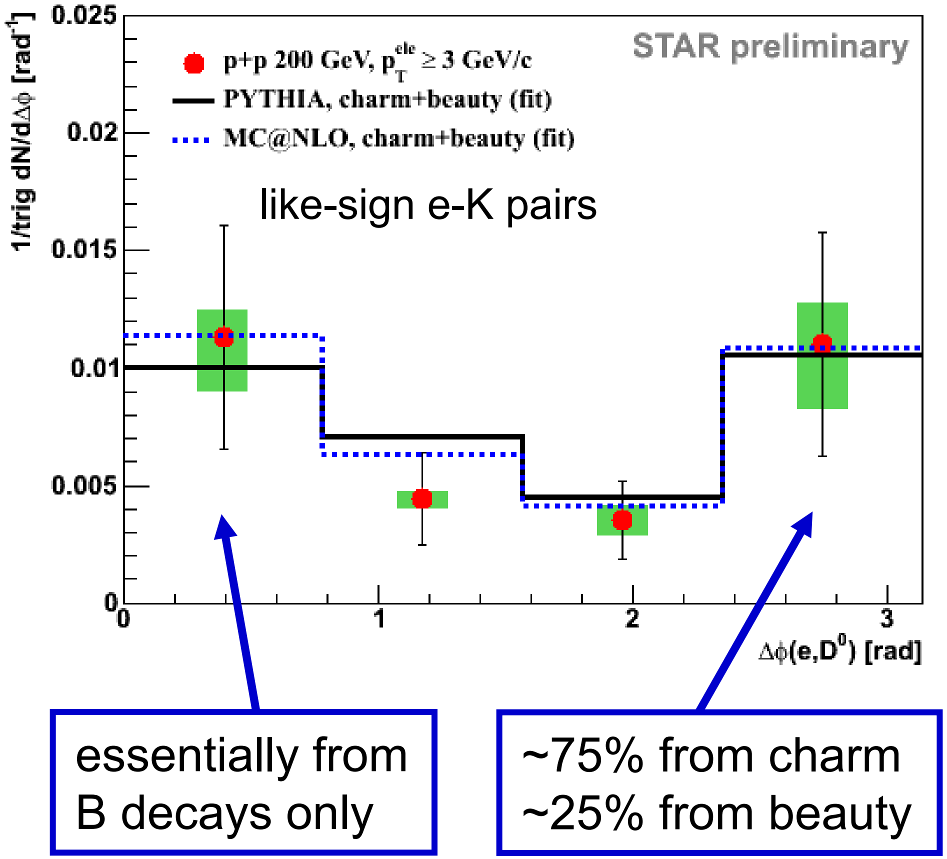
like-sign e-K pairs:
$(e^- - D^0) + (e^+ - \bar{D}^0)$

expected D^0/e ratio for charm flavor creation assuming a D^0 reconstruction efficiency of 70%

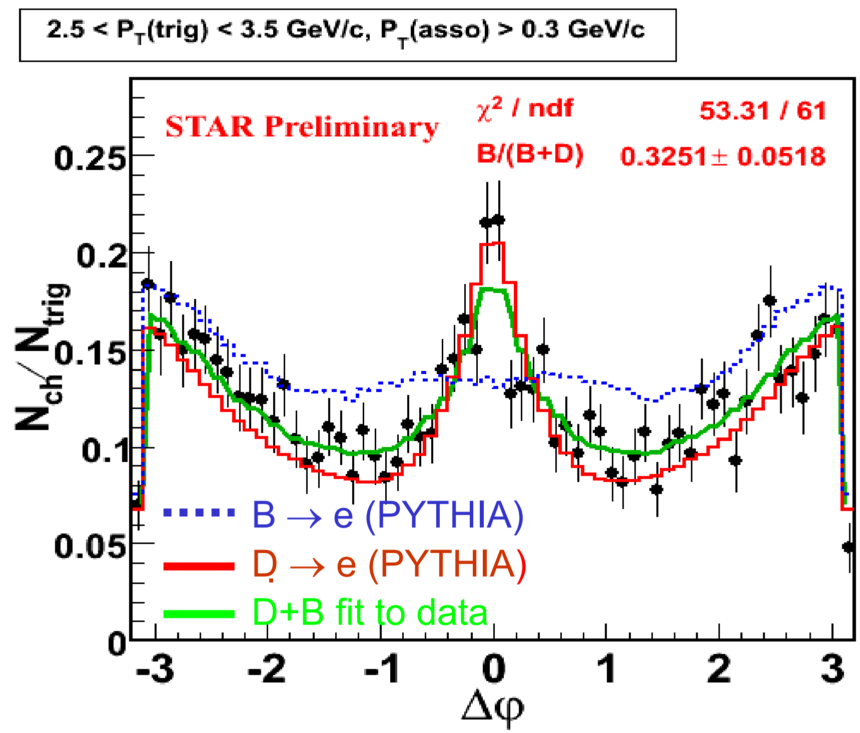
- First two heavy-flavor particle correlation measurement at RHIC
- Near- and away-side correlation peak – yields are about the same

Heavy-flavor particle correlations

e-D^0 correlations

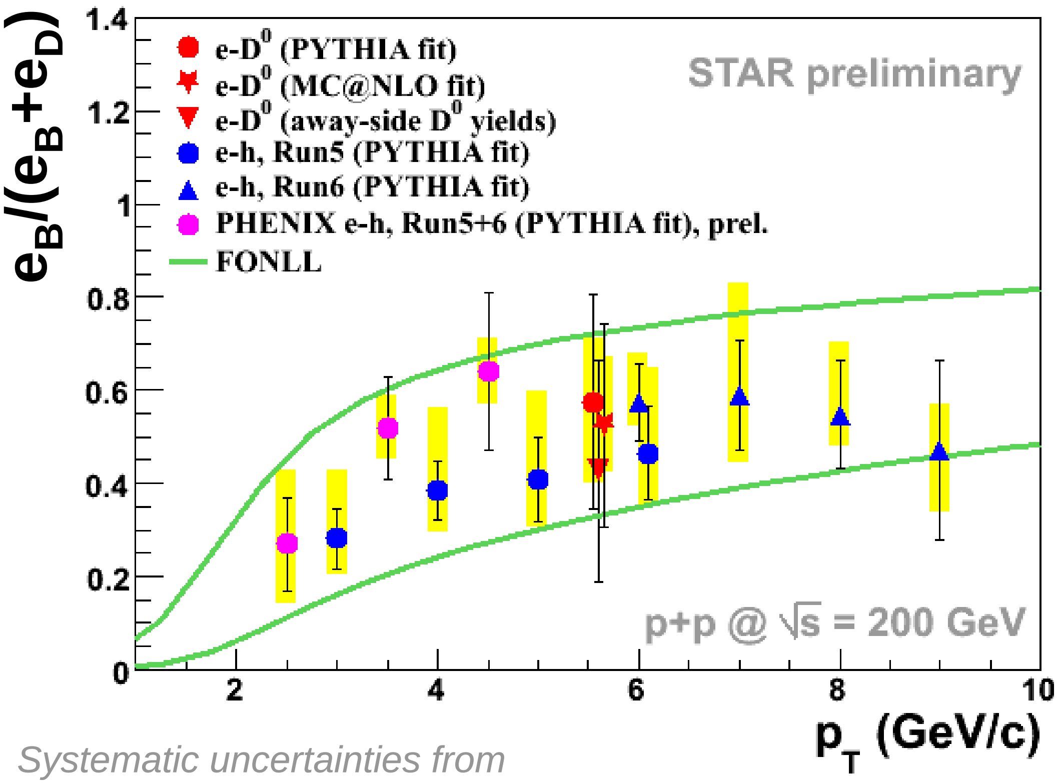


e-h correlations



- Different kinematics for D and B decays
- Exploit different fragmentation of associated jets

Relative B→e contribution



Systematic uncertainties from MC@NLO not included yet

- Good agreement between different analyses
- Data consistent with FONLL calculations within errors
- Comparable D and B contributions to non-photonic electrons at high p_T

Together with Au+Au measurement: Hint for significant suppression of electrons from bottom decays in the medium?

Summary and conclusions

• First two heavy-flavor particle correlation measurement in p+p collisions at RHIC

• "D* in jets" measurement + MC@NLO simulations: Small gluon-splitting contribution

• Azimuthal correlation of non-photonic electrons and D^0 mesons

- access to production mechanisms

$\rightarrow$ allows separation of charm and bottom production processes

- efficient trigger on heavy-quark production events

- significant suppression of the combinatorial background in D^0 reconstruction

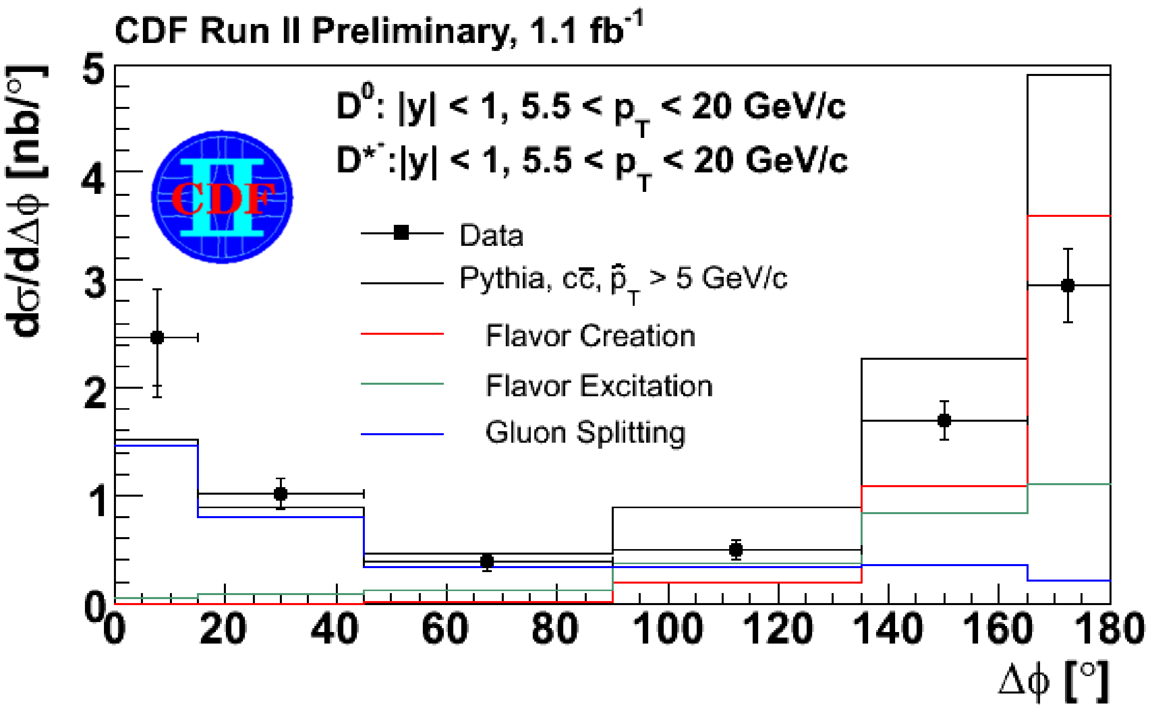
• Bottom contribution to non-photonic electrons is significant at p_T > 5 GeV/c (~50%)

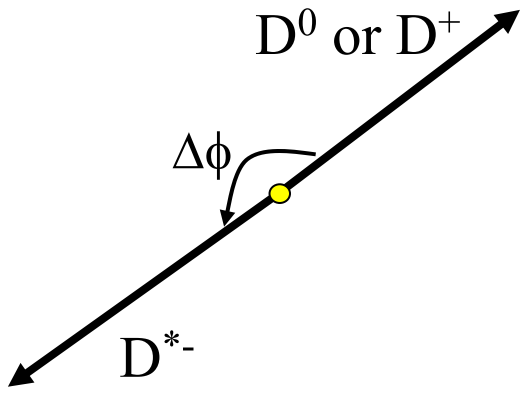
• Correlation method is a powerful tool for comprehensive energy-loss measurements of heavy quarks in heavy-ion collisions (e.g. I_{AA})

The STAR collaboration

Backup slides

D^0D^{*-} cross section measurement at the Tevatron





B. Reisert et al., Beauty 2006, Nucl. Phys. B (Proc. Suppl.) 170, 243 (2007)

- Within errors near- and away-side yields are the same
$\rightarrow$ gluon splitting as important as flavor creation

- Near-side yield: PYTHIA underestimates gluon splitting

PYTHIA event generator

Parameter settings

• version: 6.222 (Jan. 2004)	
• MSEL = 4 or 5	charm or bottom
• PMAS(4,1) = 1.3 or 4.5	m_c or m_b
• PARP(91) = 1.5	$\langle k_T \rangle$
• PARP(31) = 3.5	k factor
• MSTP(33) = 1	common k factor
• MSTP (32) = 4	Q^2 scale
• MSTP(51) = 7	CTEQ5L PDF
• PARJ(13) = 0.594	D/D* spin factor
• CKIN(3) = 1	
• PARP(67) = 4	ISR+FSR
• MSUB(81)= MSUB(82)= MSUB(84)= 1	sub-processes

- k_t ordering in shower
- String hadronization
- default FF (Peterson)
- B mixing included

$$\sigma_{c\bar{c}}^{PYTHIA} = 232\,\mu b$$
$$\sigma_{b\bar{b}}^{PYTHIA} = 2.13\,\mu b$$

MC@NLO event generator

- Version 3.3 (Dec. 2006)
- CTEQ6M PDF
- HERWIG event generator (version 6.510, Oct. 2005)
  - parton showering
  - hadronization
  - particle decays
- Parameter settings
  - $m_c = 1.55$ GeV/c^2
  - $m_b = 4.95$ GeV/c^2

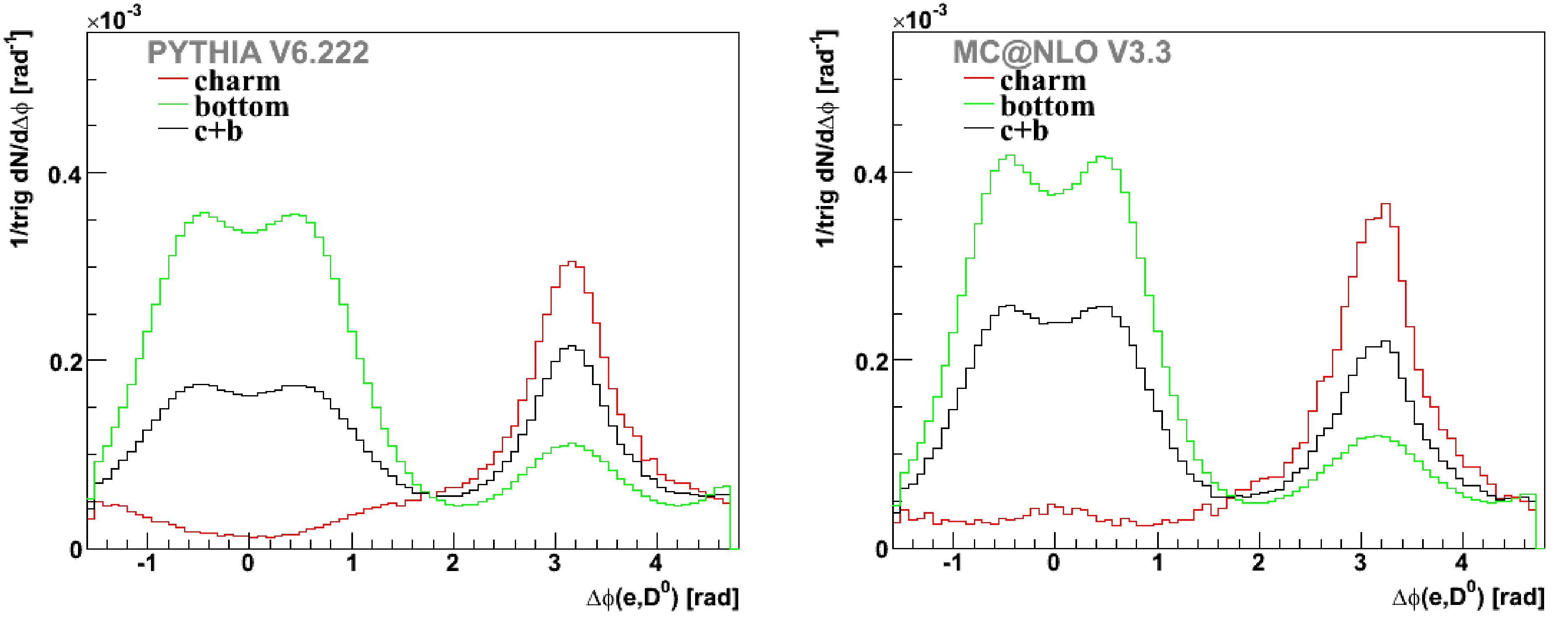
HERWIG

- Angular-ordered shower
- Cluster hadronization

$$\sigma_{c\bar{c}}^{MC@NLO} = 184 \mu b$$

$$\sigma_{b\bar{b}}^{MC@NLO} = 1.60 \mu b$$

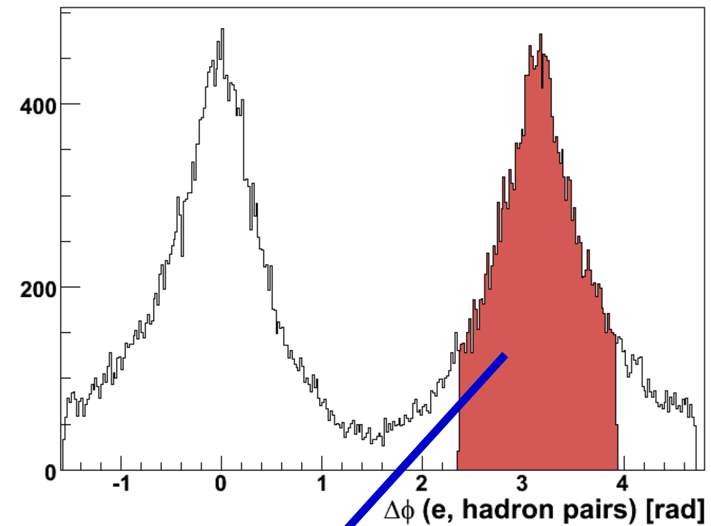
Model comparison

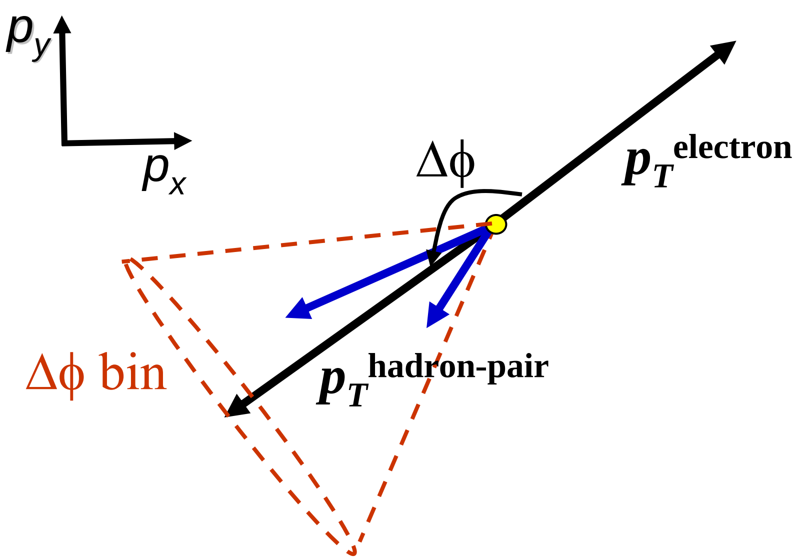


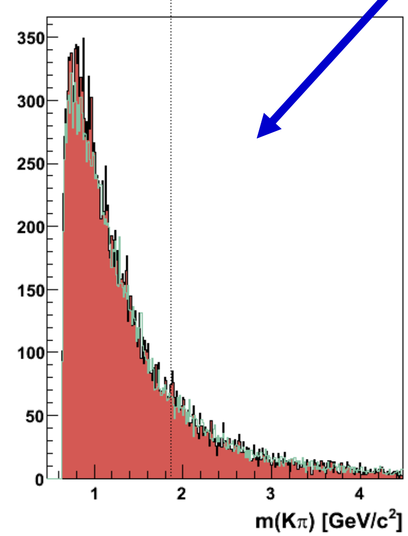
$$Sum = \frac{\sigma^{MB}_{c\bar{c}} D^{0}_{c\bar{c}} + \sigma^{MB}_{b\bar{b}} D^{0}_{b\bar{b}}}{\sigma^{MB}_{c\bar{c}} e^{-}_{c\bar{c}} + \sigma^{MB}_{b\bar{b}} e^{-}_{b\bar{b}}}$$

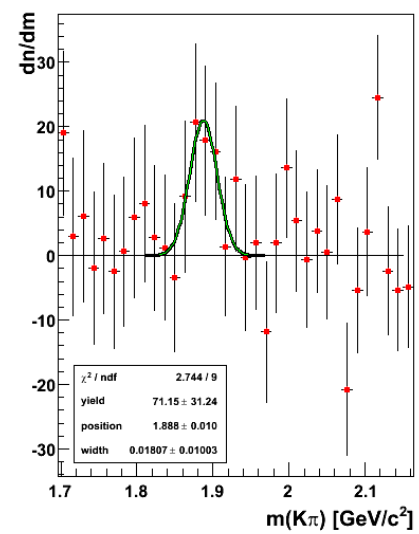
D^0 yield versus $\Delta\phi$(e, hadron pair)

- Calculate $\Delta\phi$ between non-photonic electron trigger and hadron pair p_T
- Extract D^0 yield from invariant mass distribution for different $\Delta\phi$ bins

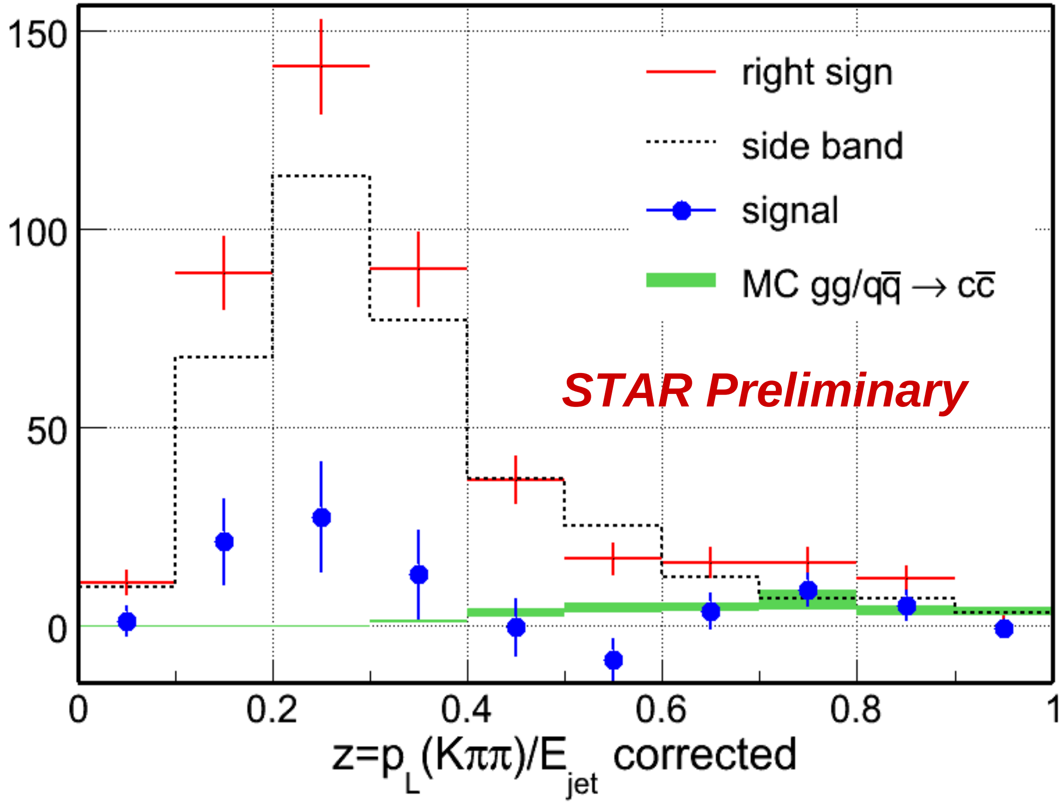








D* in jet measurement



Run V p+p, jet patch triggered data:
1.7 M jets > 8 GeV/c

- Magnitude at high z region is suppressed due to trigger, and it is consistent with MC simulation for only direct flavor creation process
- Excess at low z region is expected to be from gluon splitting process