BROOKHAVEN NATIONAL LABORATORY

STAR High Pt Capabilities in the RHIC II Era

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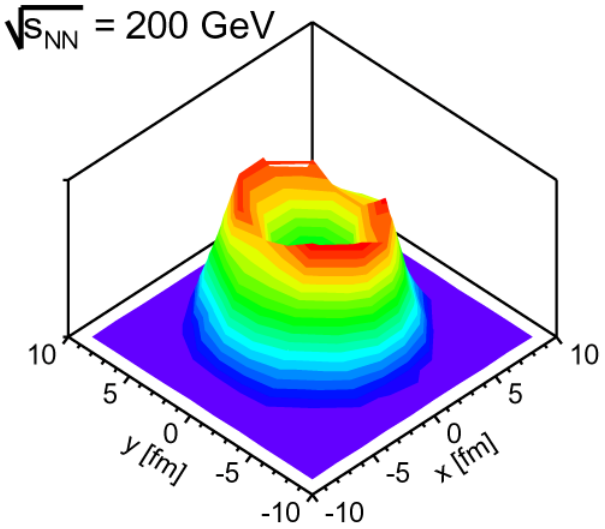
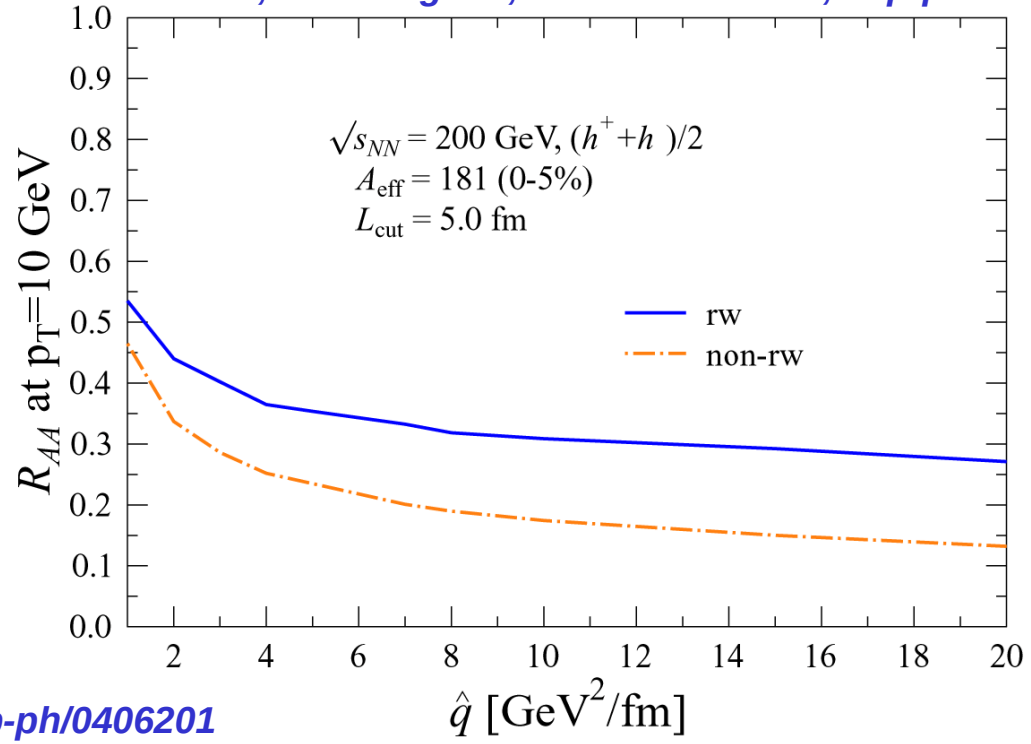
Geometry, Correlations, and "Fragile" R_{AA}

K.J. Eskola, H. Honkanken, C.A. Salgado, U.A. Wiedemann, hep-ph/0406319





A. Dainese, C. Loizides, G. Paic, hep-ph/0406201

- Quenching so strong that R_{AA} loses sensitivity to the density of the medium: dominated by unquenched "halo"
- Increased sensitivity only through detailed angular correlations and/or decreasing coupling strength

New idea: need an UPPER bound

- Muller, Rajogopal hep-ph/0502174
- LOWER bound on entropy density (at early stage) from late stage properties at freezeout
  - Compute entropy density at chemical freezeout, assuming that there is no entropy creation between early thermalization and chemical freezeout:
  - $s(t_0)>33$ +/- 3 fm^{-3} at t=1 fm/c (transverse box with R=7 fm)
  - Likely this will need a more sophisticated treatment
- UPPER bound on energy density combined with LOWER bound on entropy density translates to a LOWER bound on effective number of degrees of freedom

  $\nu(T) = 0.96\ s^4/\varepsilon^3$:3 for pion gas, 47.5 for massless 3-flavor uncoupled quarks and gluons
  - For $\varepsilon<5, 7, 9$ GeV/fm^3 gives $\nu > 71, 26, 12$
- Related issue: how quantitative can the determination of the energy density be?
  - Coupling between probe and medium even uncertain, never mind uncertainties introduced by medium evolution
  - Backward argument with assumed $\varepsilon<100$ GeV/fm^3 at 0.2 fm:
    - qhat = c $\varepsilon^{3/4}$ gives c=8-19, greater than 4 times perturbative c=2 (Eskola, Honkanen, Salgado, Wiedemann hep-ph/0406319, Baier hep-ph/0209038).
  - Large cross-sections? Evolution? Is the theory not under control?

Heavy Quark Energy Loss

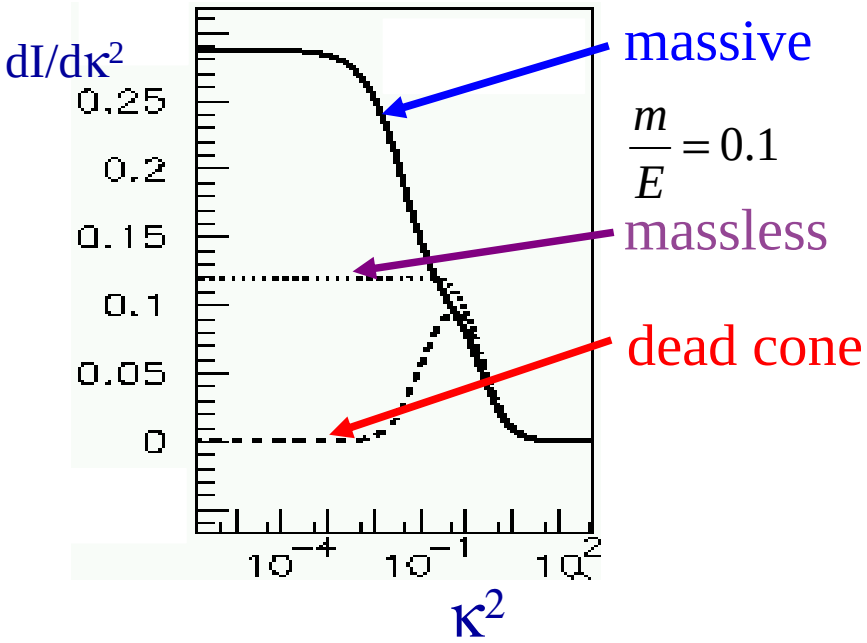
- vacuum radiation suppressed in the dead-cone $\theta < m/E$

Dokshitzer, Kharzeev, PLB 519 (2001) 199

Flavor dependence of coupling: Less radiation, and so less suppression, for massive objects

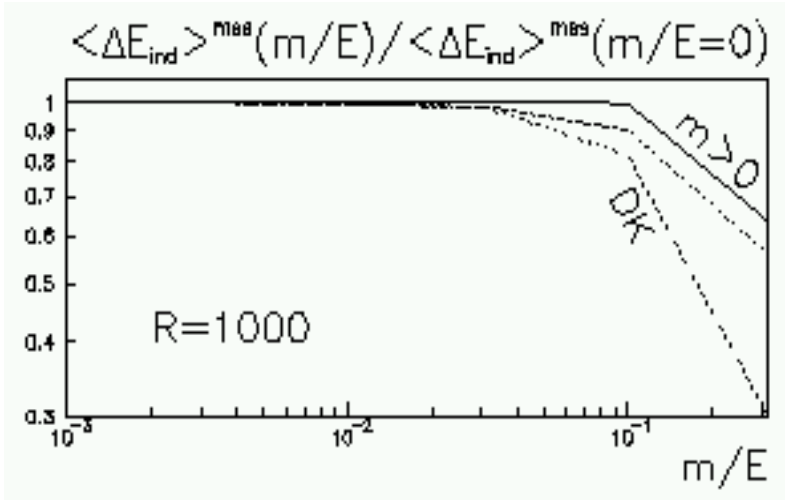
- medium-induced radiation fills the dead-cone

Armesto, Salgado, Wiedemann, PRD69 (2004) 114003



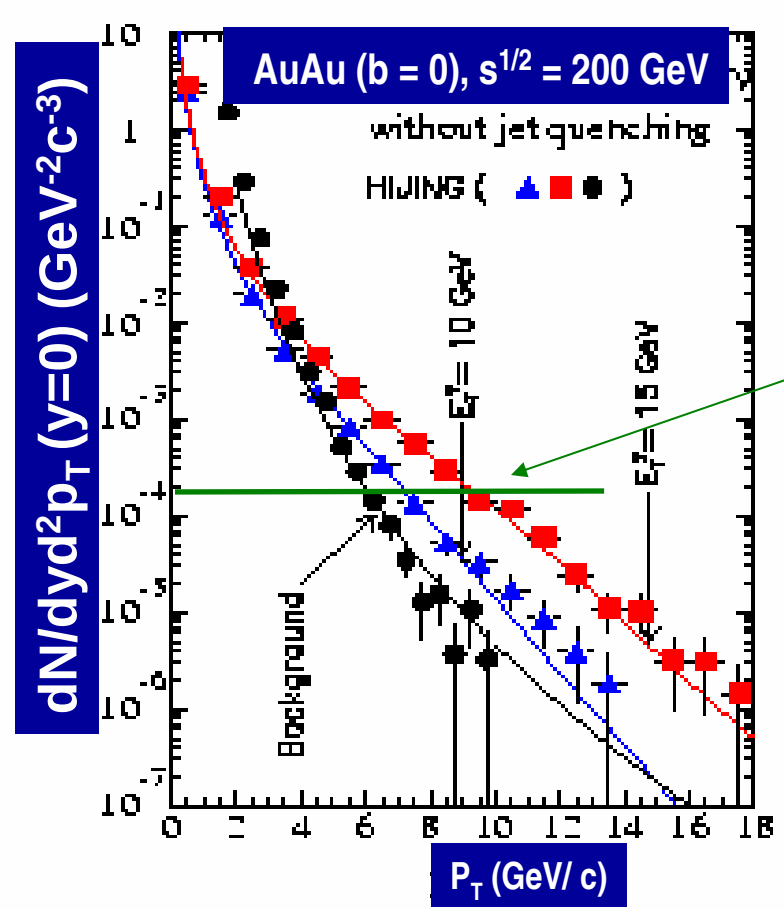
- total energy loss comparable but smaller than in the massless case

Armesto, Salgado, Wiedemann, PRD69 (2004) 114003
B.W. Zhang, E. Wang, X.N. Wang, PRL93 (2004) 072301
Djordjevic, Gyulassy, NPA733 (2004) 265



γ + Leading Particle

Quantitative measurement of partonic energy loss

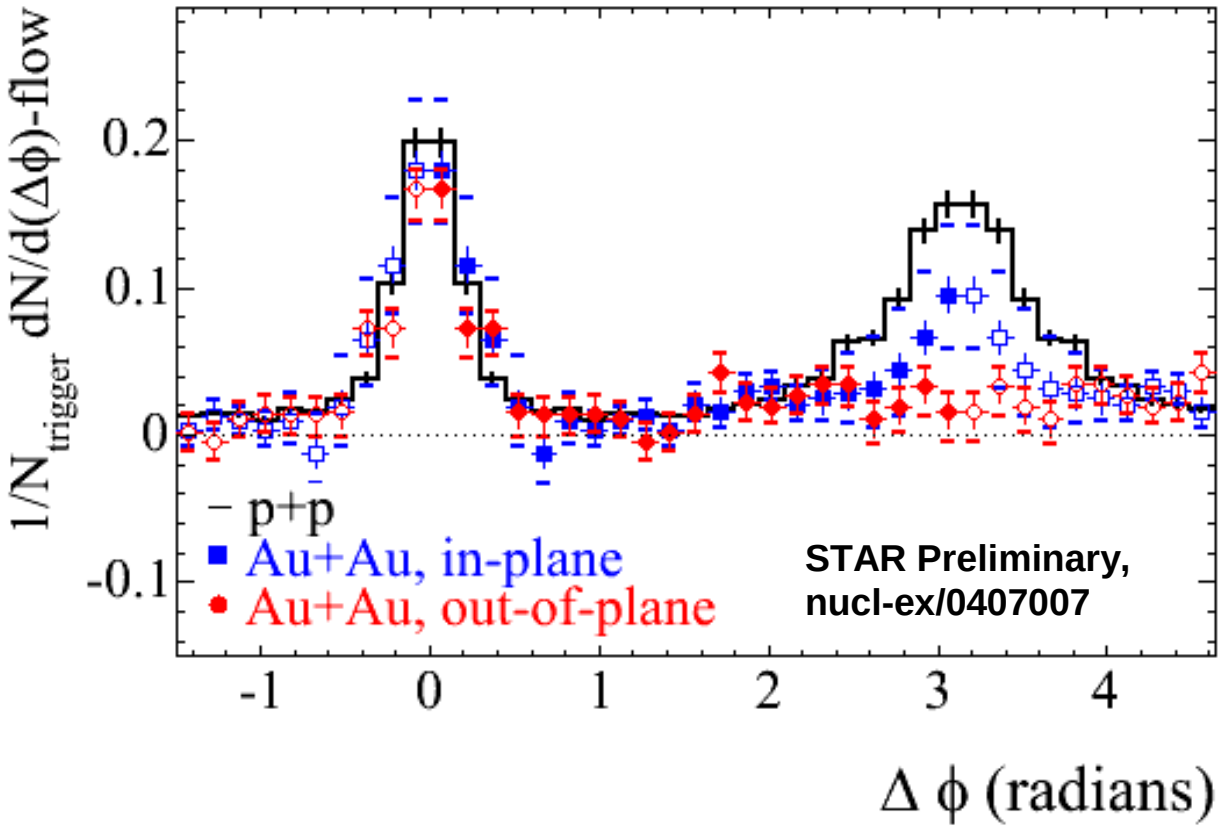


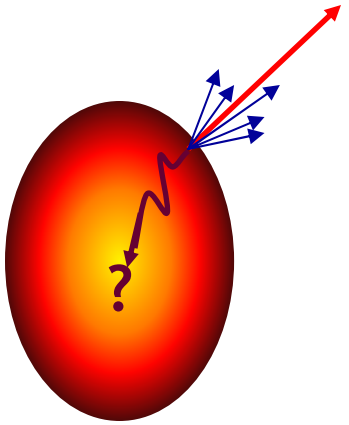
Measurement of the gluon density via direct γ + jet and flavor-tagged jets to study the quark mass dependence of energy loss

- **Leading hadrons are very rare: only ~0.1% of jets fragment hard enough that hadrons are above incoherent background**
- **cross section for γ + jet coincidences (central Au+Au):**
  - **E_γ=10 GeV: 6 nb/GeV**
  - **E_γ=15 GeV: 0.6 nb/GeV**
- **50 weeks of Au+Au @ RHIC I design: 10 nb^{-1} !! → luminosity upgrade needed to access this physics!**

Remaining question: fragmentation γ

Towards real tomography

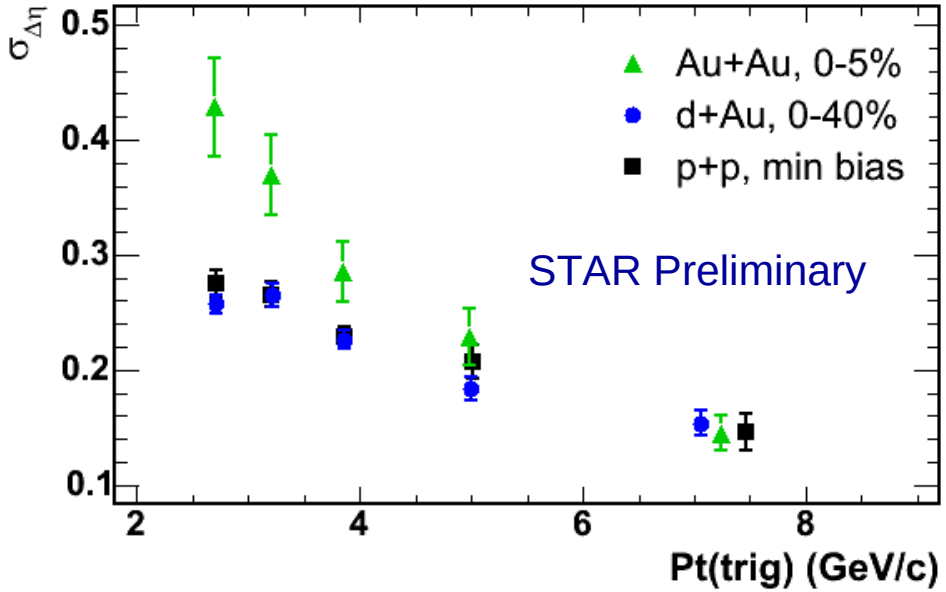




- **Au+Au: Away-side suppression is larger in the out-of-plane direction compared to in-plane**
- **Geometry of dense medium imprints itself on correlations**

Asymmetry in near-side correlations

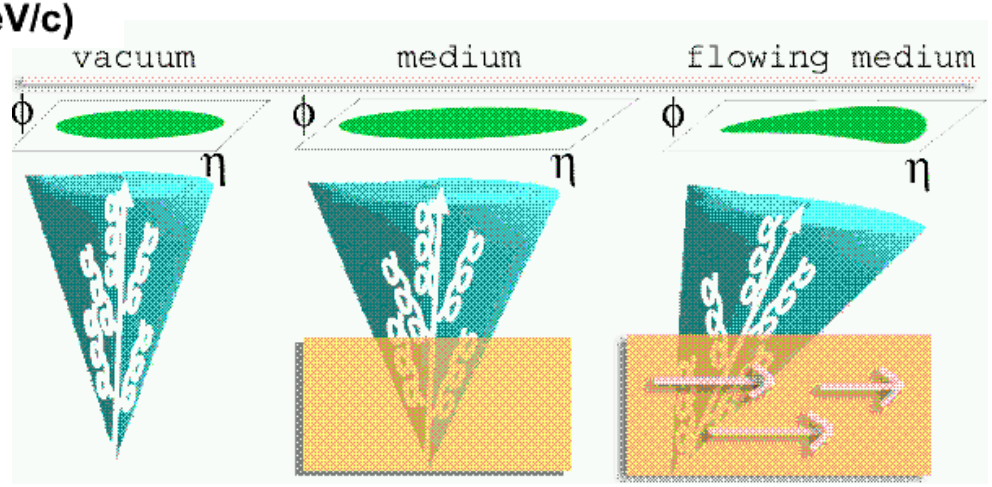
D. Magestro, Hard Probes 2004



At intermediate p_T, significant increase in width in η of near-side cone

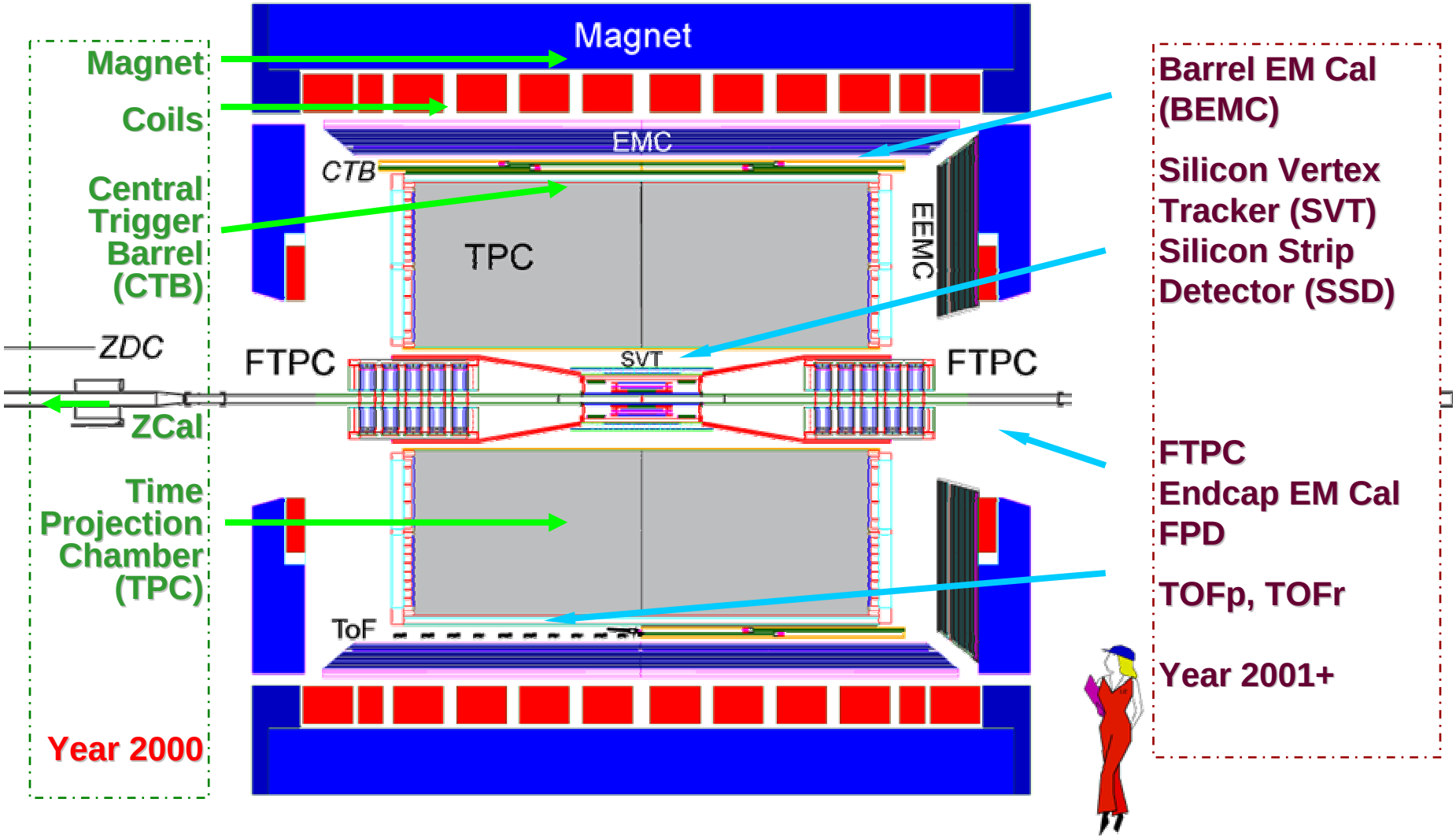
Is this due to energy loss in a flowing medium? Or recombination effects (PID)? Or does it not at all matter for HIGH pt?

What beyond density can be learned from strong coupling to the medium?

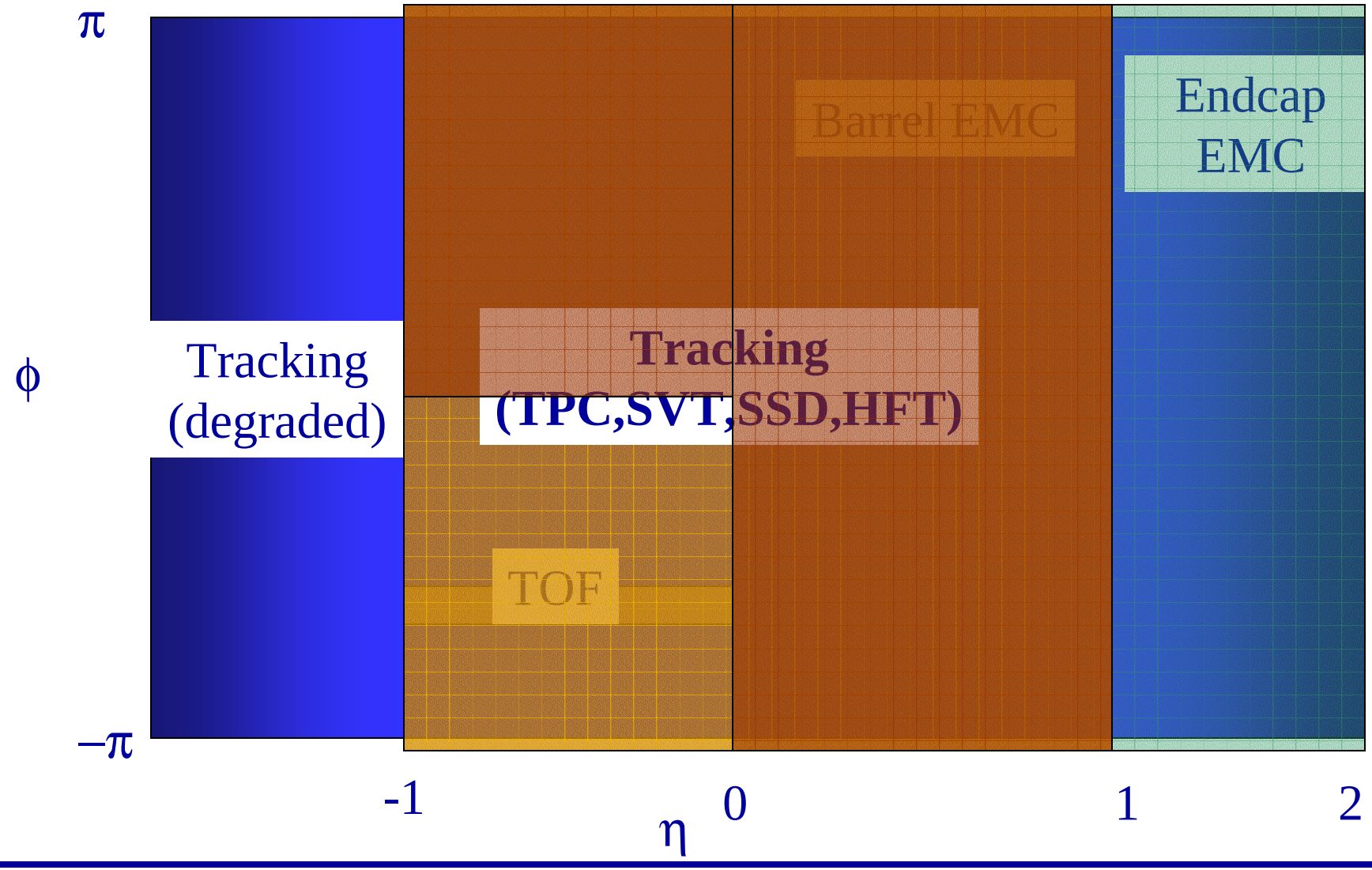


Armesto, Salgado, Wiedemann, hep-ph/0405301, Phys. Rev. Lett. in press

The STAR Detector



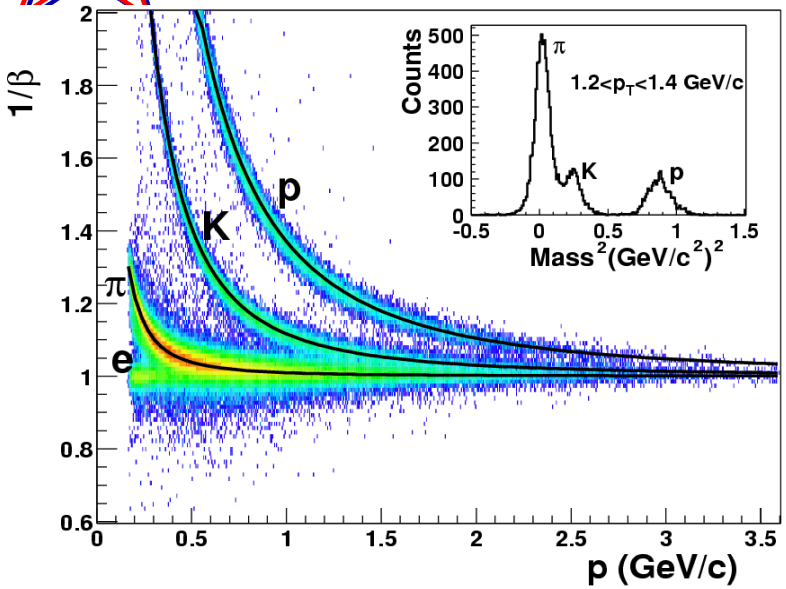
STAR (Central) Coverage



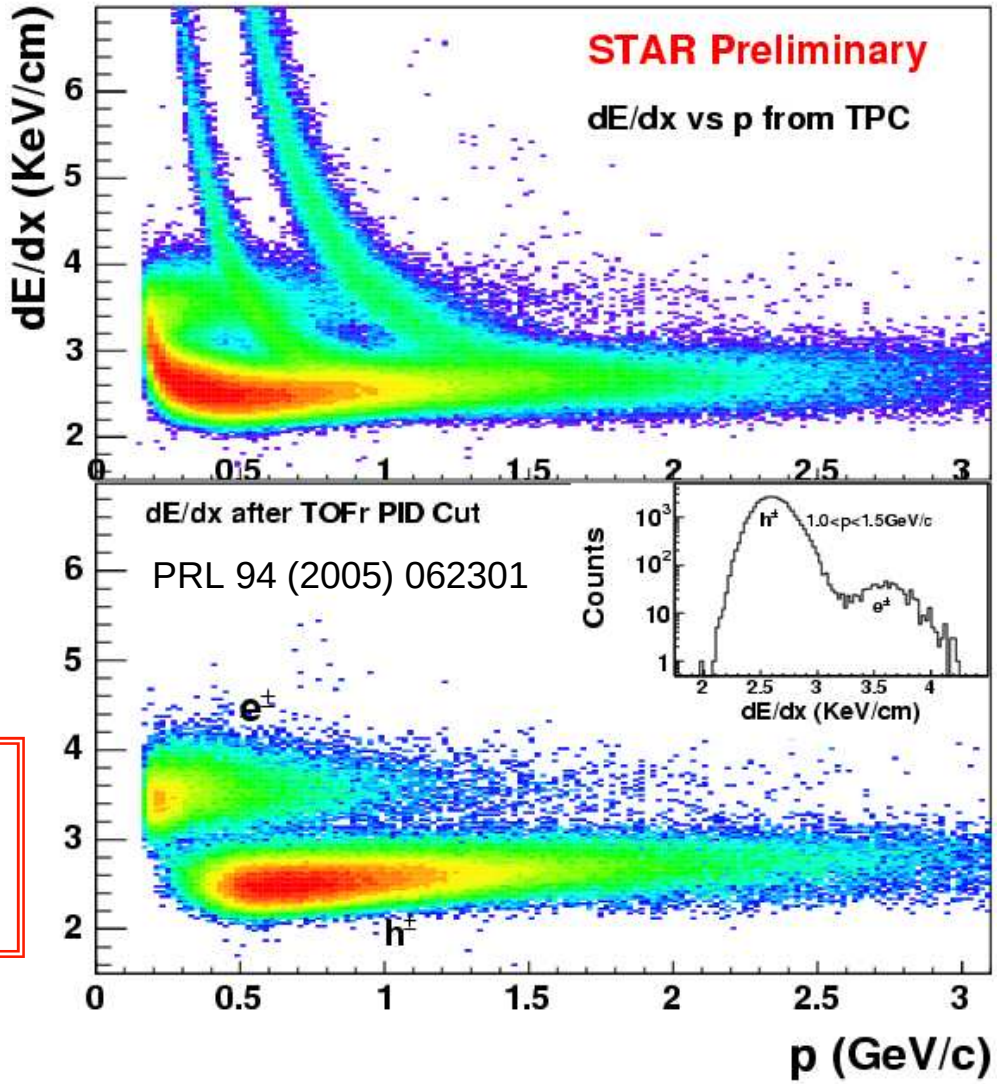
“Upgrades” relevant to high pt

- Barrel Electromagnetic Calorimeter (EMC)
  - Current ¾ barrel will be instrumented to full azimuthal coverage, $-1 < \eta < 1$, for next RHIC run
- Barrel Time of Flight (TOF)
  - Current prototype patches to be upgraded to full azimuth, $-1 < \eta < 1$.
  - Project is in President’s budget.
- Forward Meson Spectrometer (FMS)
  - Full azimuthal EM Calorimetry $2.5 < \eta < 4.0$
  - Possibility of charm measurements in this region
  - Proposal submitted to NSF
- Data acquisition upgrade (DAQ1000)
  - Upgrade TPC readout an order of magnitude, ~double effective Luminosity
- Heavy Flavor Tracker (HFT)
  - High precision (<10 um) measurements for displaced vertices

PID Capabilities I: TOF and TPC



Hadron identification:
STAR Collaboration, *nucl-ex/0309012*

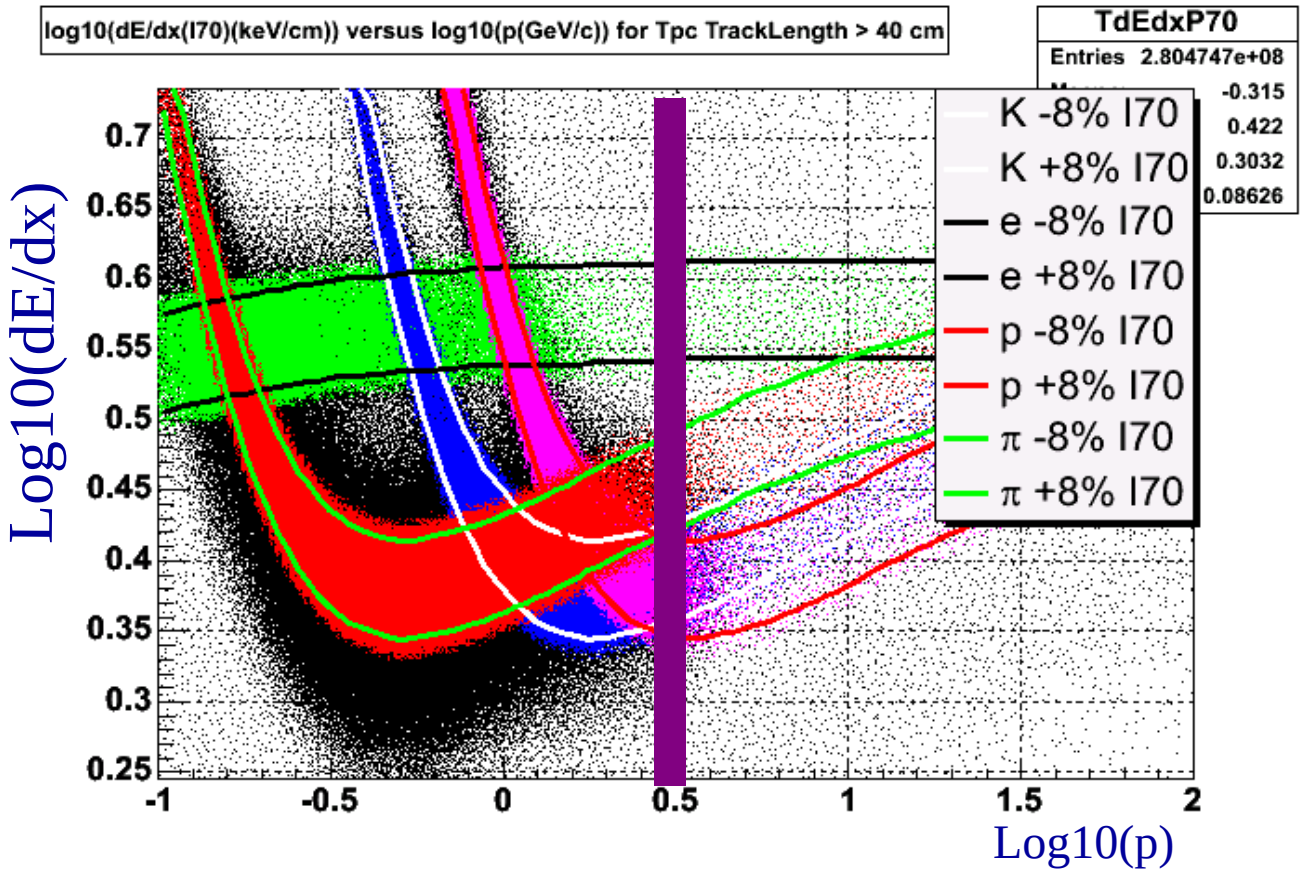


Electron identification:

TOFr |1/ß-1| < 0.03

TPC dE/dx electrons!!!

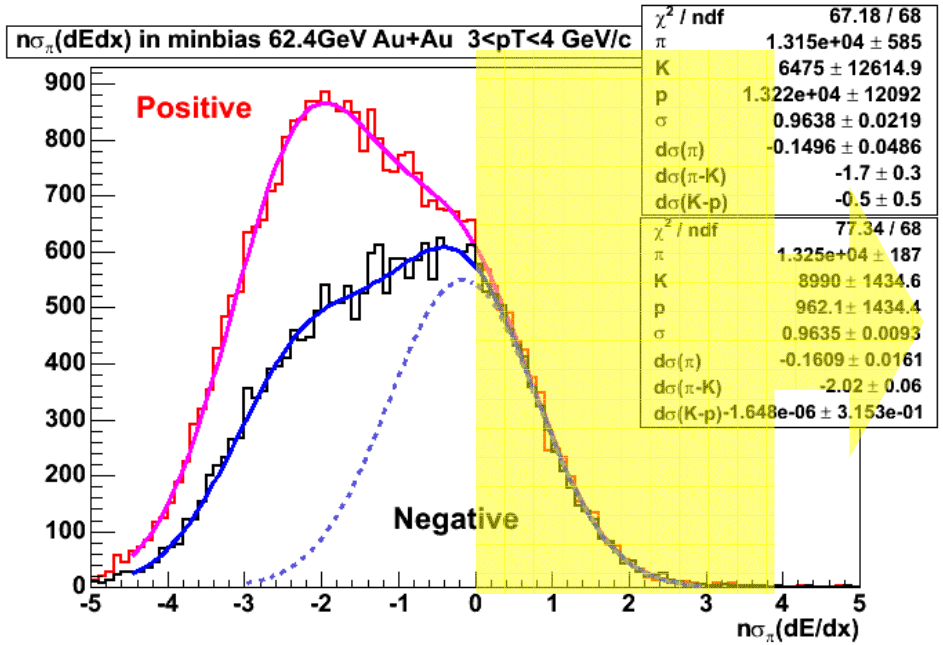
dE/dx at higher pt

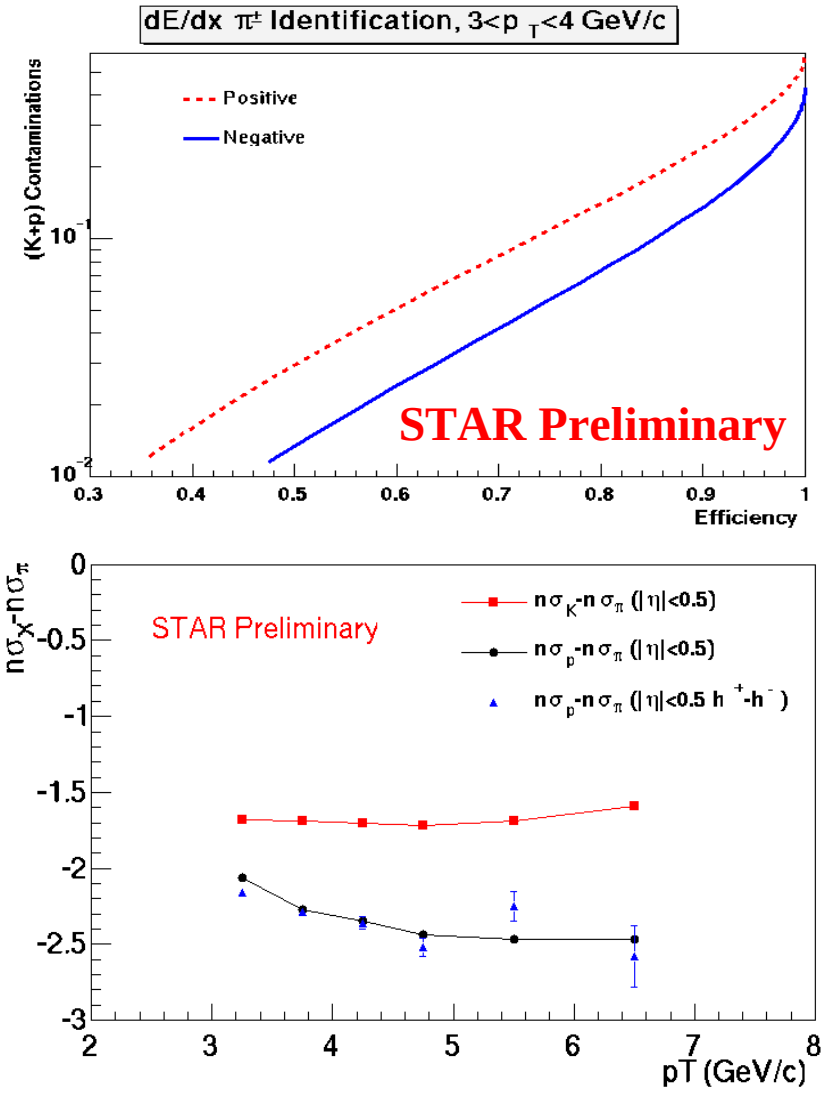


Momentum: $3 < p \lesssim 10$ GeV/c

dE/dx of π (K,p) separation: 2σ

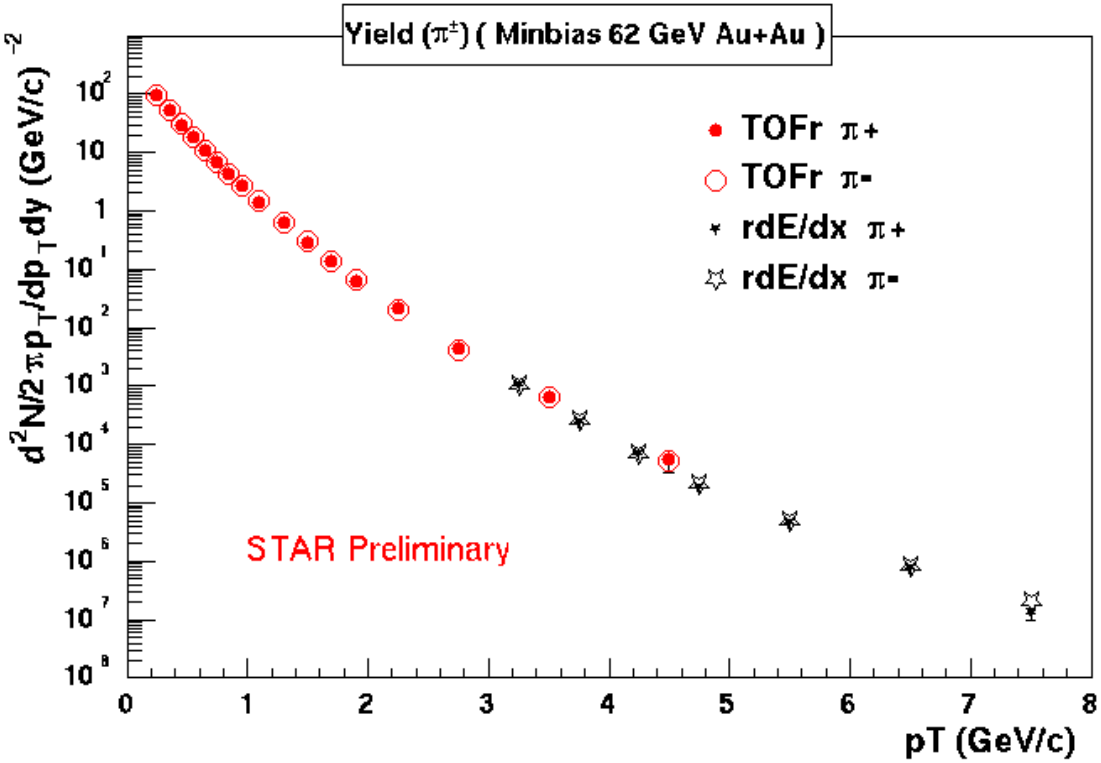
π-(K+p) Separation





- 3 Gauss fits: dE/dx(π)>1.3*dE/dx(K)
  dE/dx(π) as normal Gauss: σ=1, mean=0
- π-(K+p) Separation: ~1.5-2σ
- Worst Contamination:
  1-3% at 50% Eff , 10% at 70-90% Eff

Pion Spectra

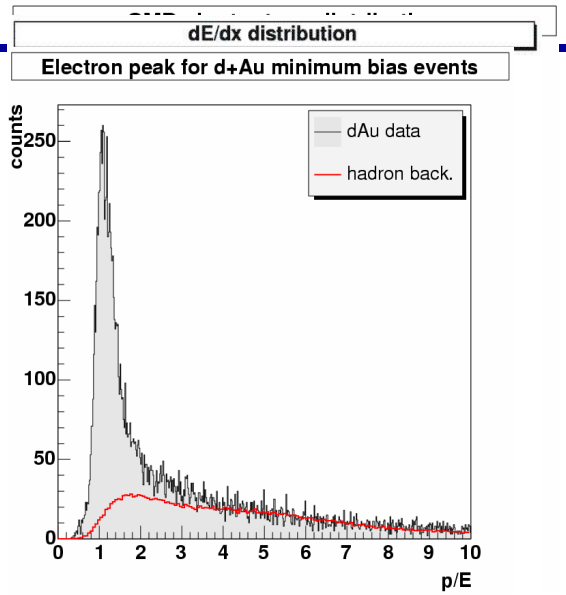


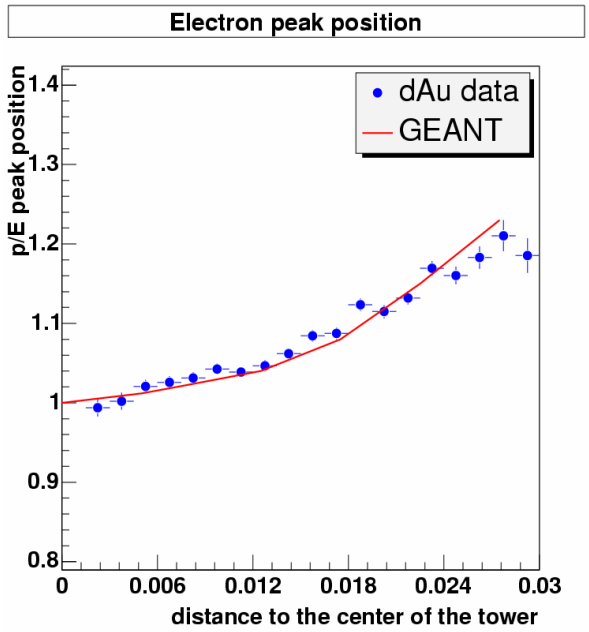
π+/ π- ratio is about 1
pbar/p ~=0.5

- TPC:
  - Pion: 0-~0.6GeV/c
  - Kaon: 0.2-~0.6GeV/c
  - Proton: 0.2-~1 GeV/c
- TOF:
  - Pion: 0.2-~1.6GeV/c
  - Kaon: 0.2-~1.6GeV/c
  - Proton: 0.2-~3 GeV/c
- TPC+TOF:
  - Pion: 0.-~10 GeV/c
  - Kaon: 0.2-~3GeV/c
  - Proton: 0.2-~? GeV/c

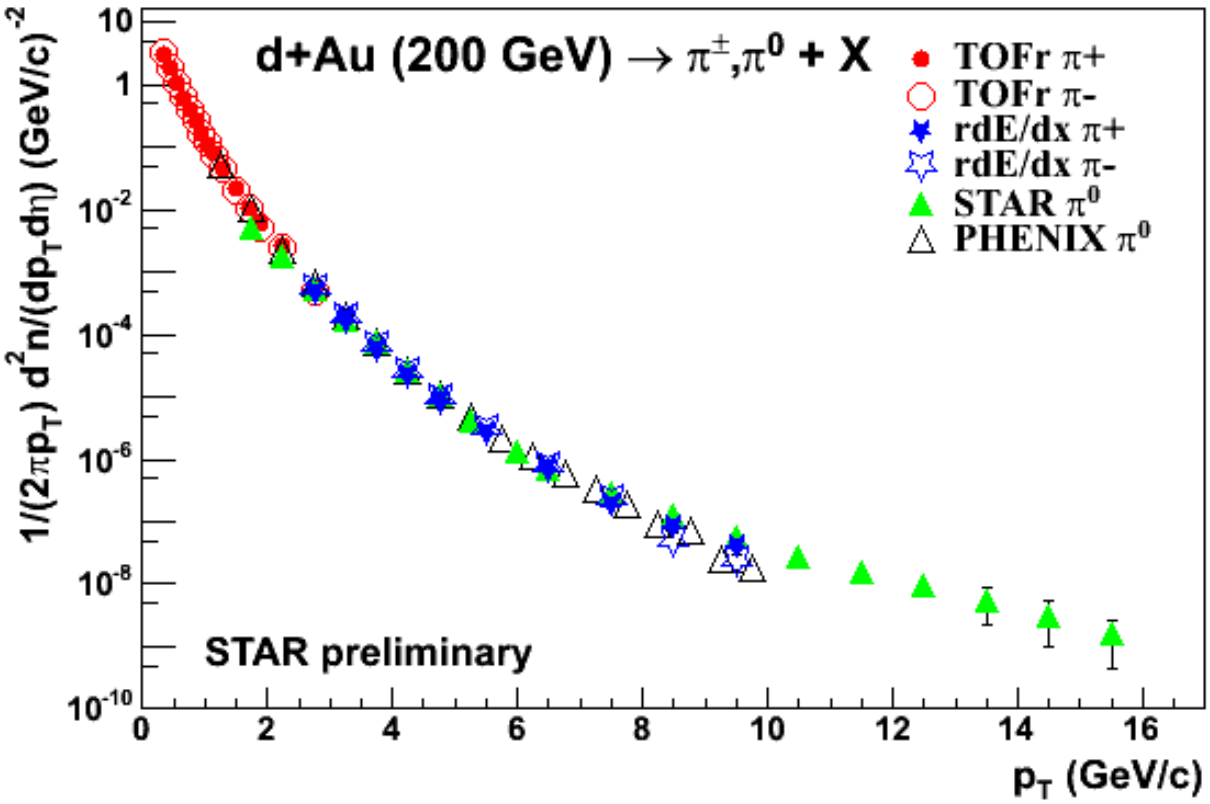
PID Capabilities II: EMC

- TPC as a candidate selector
  - dE/dX for p > 1.5 GeV/c
    - Electrons can be discriminated from hadrons up to >8 GeV/c
- EMC
  - Towers
    - **p/E for electron and hadron candidates**
      - p is the track momentum
      - E is the tower energy
      - Peak position depends on the distance to the center of the tower
  - SMD (Shower Max Detector)
    - **Shower cluster type**
      - **Type 3 = both SMD planes**
    - **Track-SMD cluster distance**
      - Hadrons have a wider distribution
- e/h discrimination power ~ 10^5
  - **TPC ~ 500**
  - **EMC ~ 250**





Extending pion identification: EMC

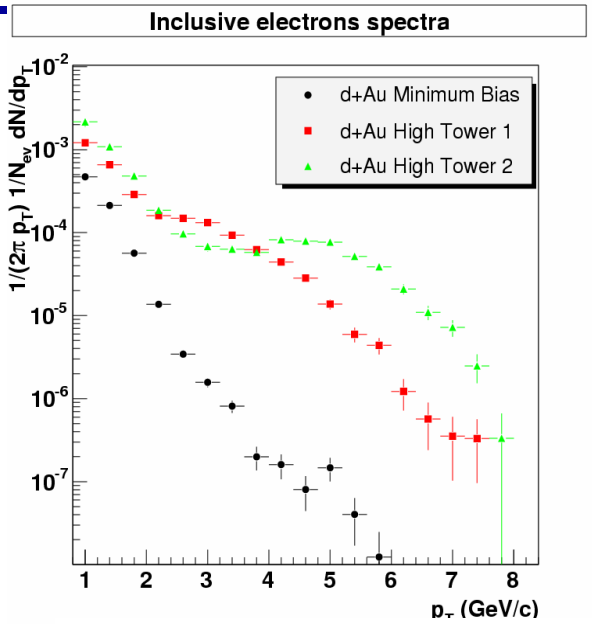


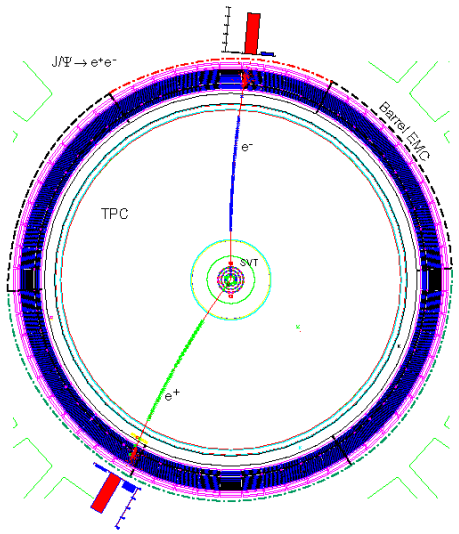
Neutral pions: triggered in EMC (A. Mischke (STAR) nucl-ex/0412045)
Triggered and reconstructed from daughter γ

Triggering Capabilities from the EMC

- EMC provides a Level 0 high-p_T electron/photon trigger
  - Runs for every RHIC crossing (10 MHz)
  - Multiple E_T thresholds in prescale ladder
    - For this plot, 2.5 and 5 GeV
  - Enhancement proven to be >1000 for p_T > 5 GeV/c
  - Can be dialed up to match whatever luminosity available

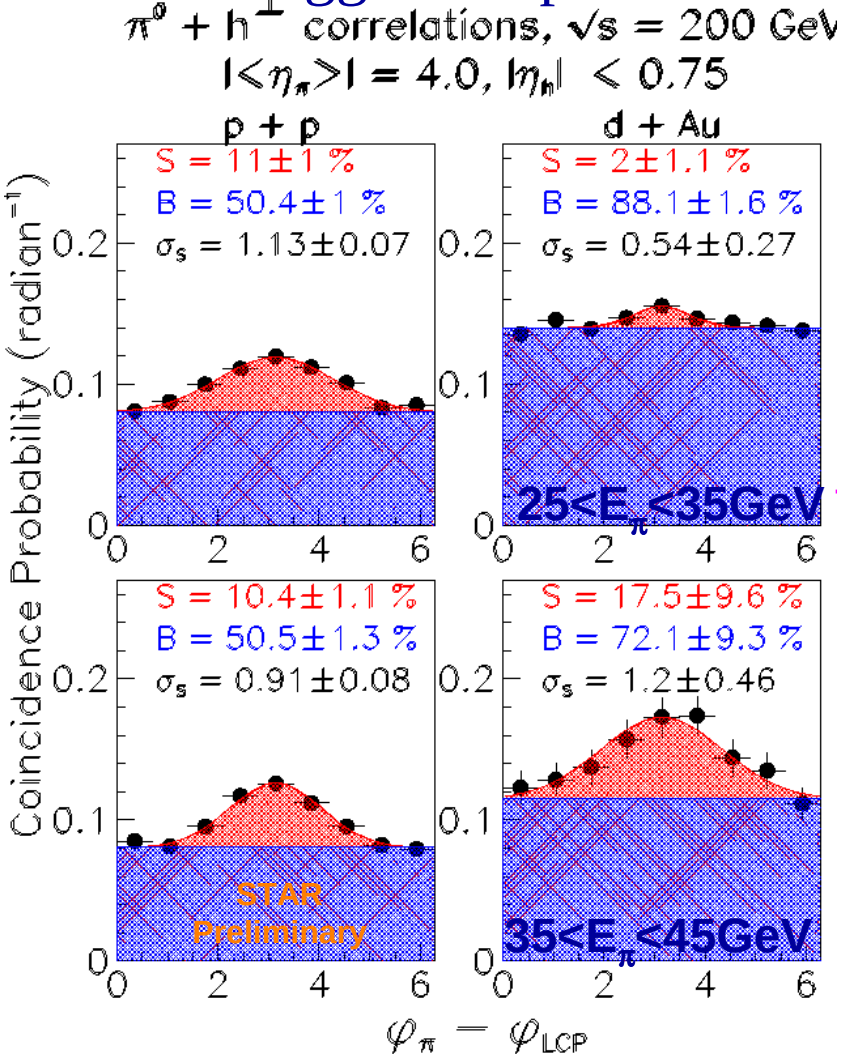
- More sophisticated triggers:
  - Upsilon
    - Limited only by luminosity
    - ~15K Upsilon in 30 nb^{-1}
  - J/Psi
    - Needs TOF for discrimination in Au+Au

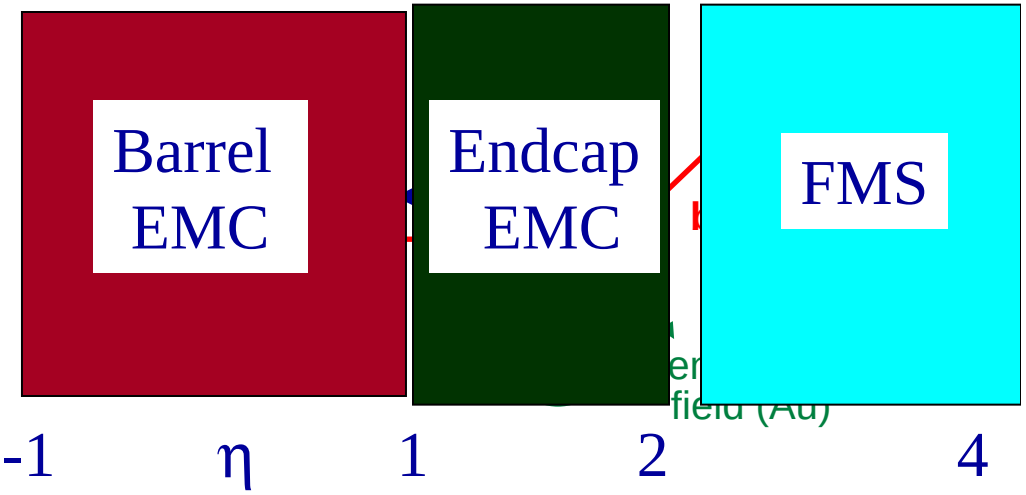


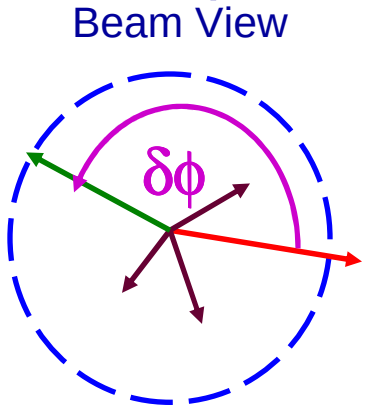


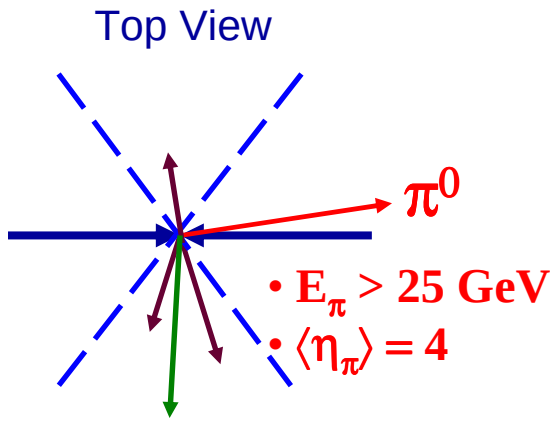
Full Calorimetric Coverage

Triggerable photons in full azimuth from -1 < η < 4







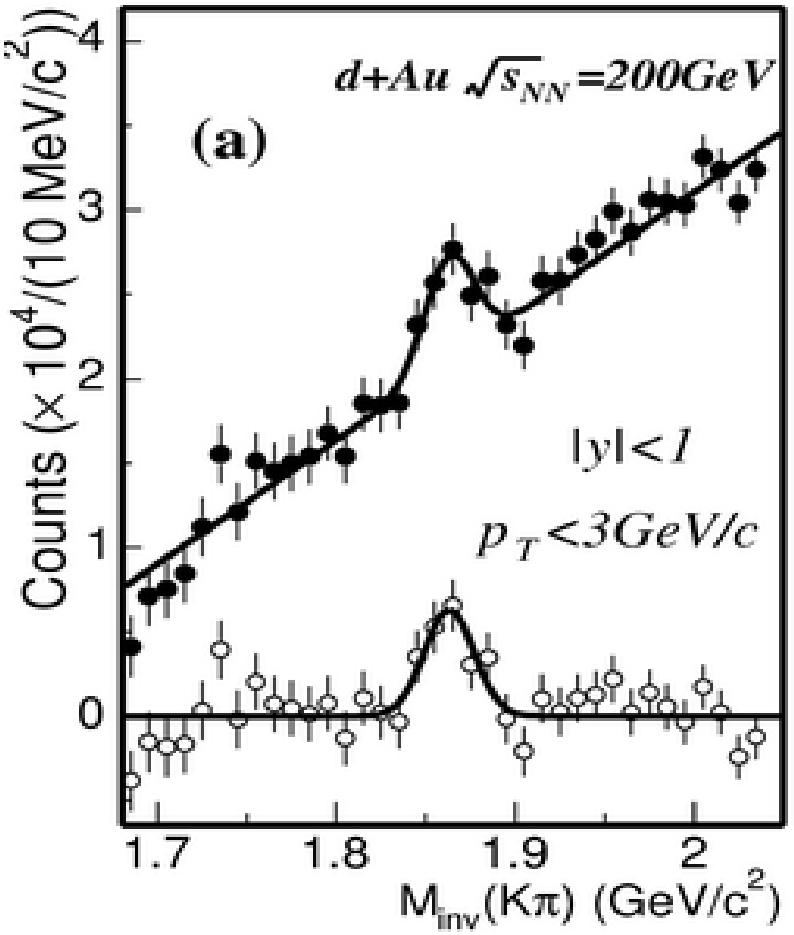


Statistical errors only

PID Capabilities III: Direct Reconstruction

PRL 94 (2005) 062301

- Direct reconstruction using M_{inv}
  - Uncertainty limitation is combinatoric background
    - TOF: cleanly identify daughters
    - HFT: identify displaced vertices



Number of Au+Au events required for 3σ signal.
FOM=reduction in N_{events} from TOF

N_{Events} for 3σ D0→Kπ Signal

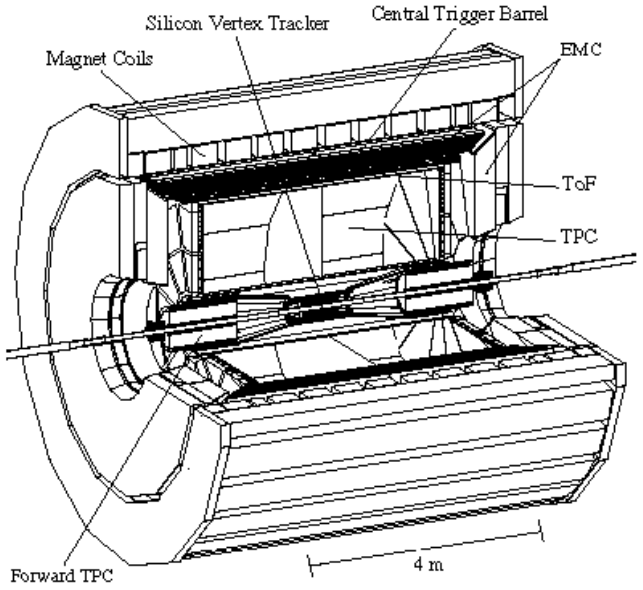
p_T range	TPC PID	TPC + TOF	FOM
All	12M	2.6M	4.6
2-4 GeV/c	59M	23M	2.6
4-6 GeV/c	85M	42M	2.0
>6 GeV/c	115M	115M	1.0

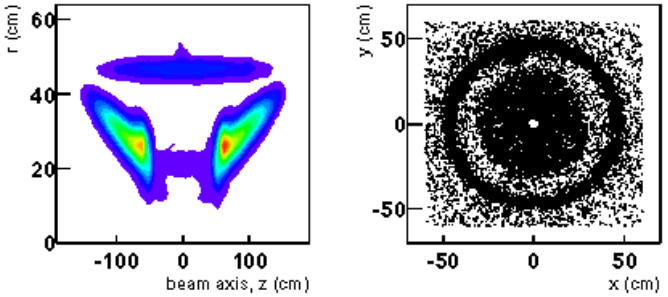
DAQ Limitations (and their removal)

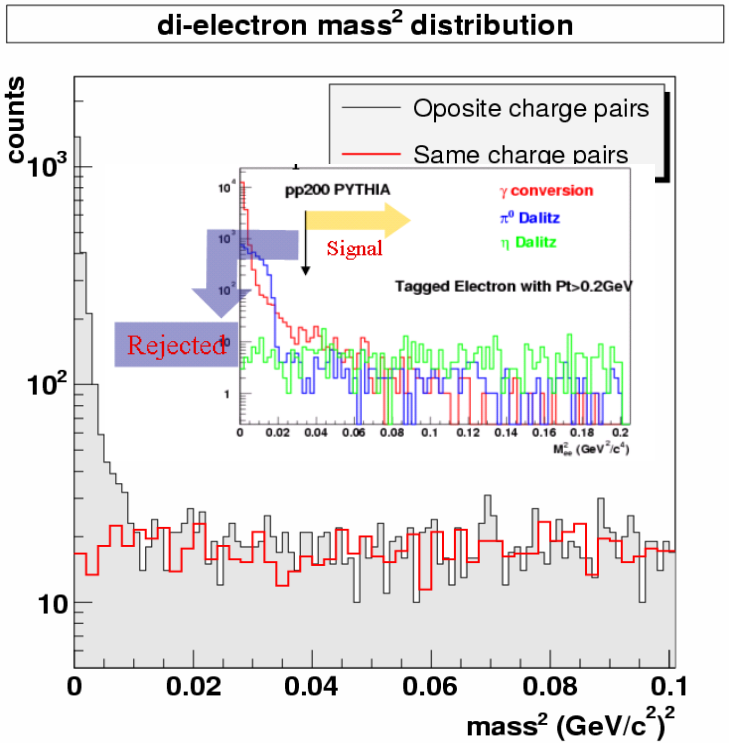
- Current limit from TPC front-end electronics is 100 Hz
  - Limits size of datasets
    - ~100M events/nominal RHIC run
    - Most problematic for untriggered samples in lighter systems (10 MHz pp rate to 100 Hz is loss of 10^5)
  - Affects available luminosity
    - Deadtime scales linearly with rate
    - 50 Hz = 50% dead, i.e. 50% drop in luminosity available to rare triggers: usual compromise
- Proposal to replace TPC electronics with ALICE chips to increase maximum rate by order of magnitude
  - Rate of events to disk increased (though timely processing of events on disk is an issue)
  - Removes deadtime: effective doubling of RHIC luminosity

Conversion measurements

PRC 70 (2004) 044902



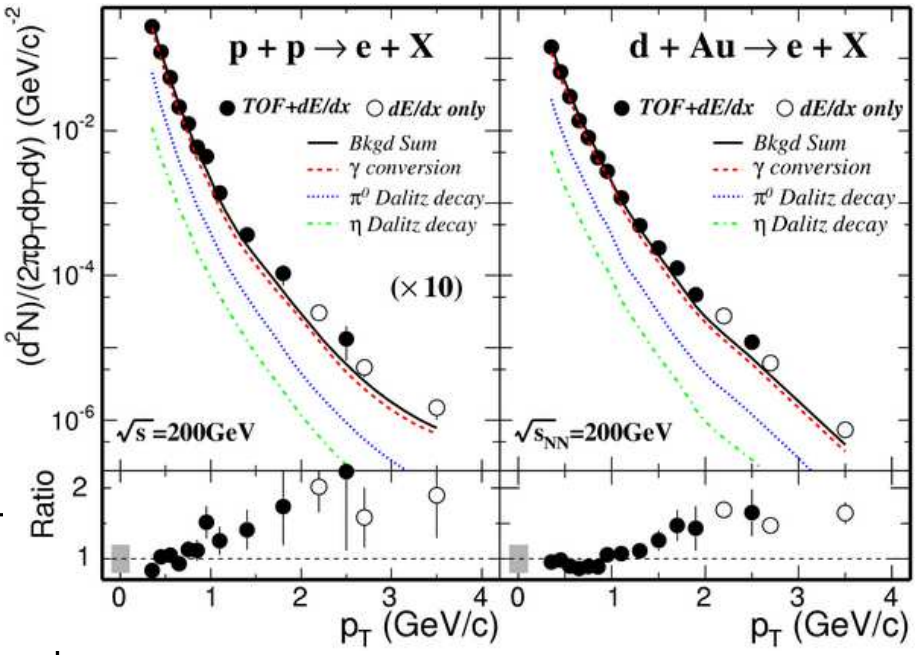


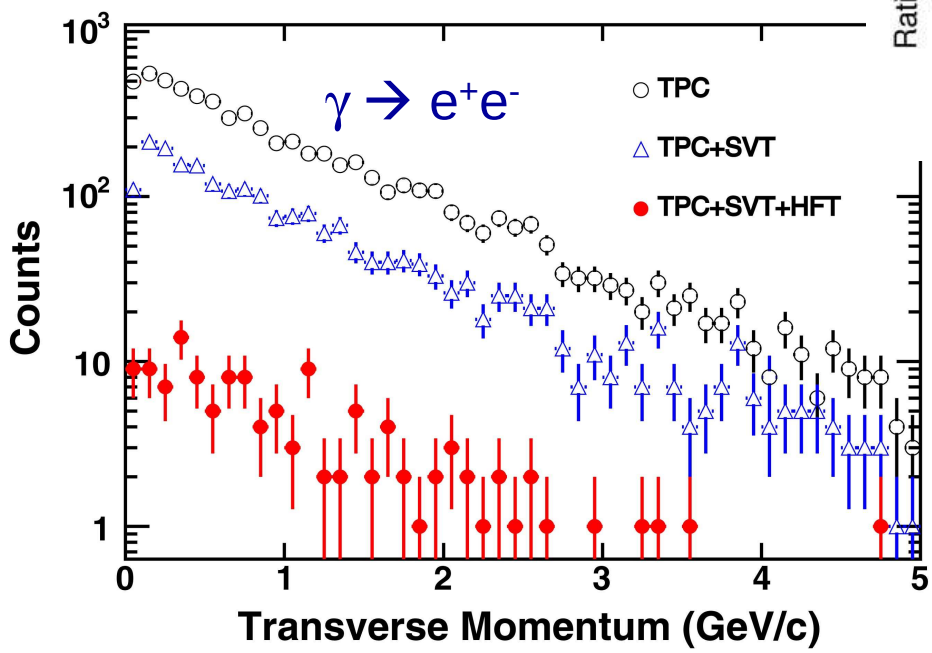


- STAR reconstructs π^0, γ from conversions in material inside the TPC
- Crucial cross-check of material budget:
  - Sweet spot: ~6% radiation length from vertex to TPC
- Removal efficiency from low M_{inv} cut ~60%

Photonic Background II

- Current methods
  - Photonic electrons dominate below ~1 GeV/c
  - Clear nonphotonic signals above





Future capabilities:
Large suppression by HFT

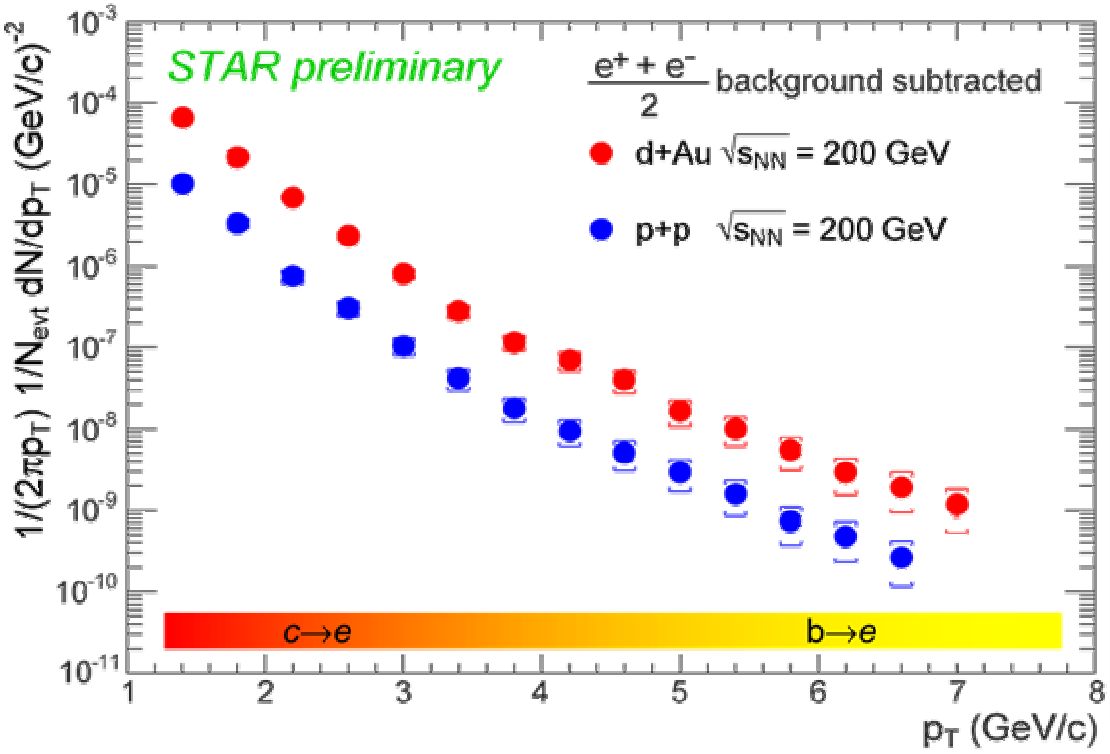
Enabling technology for low-mass dilepton measurements

b quark measurements

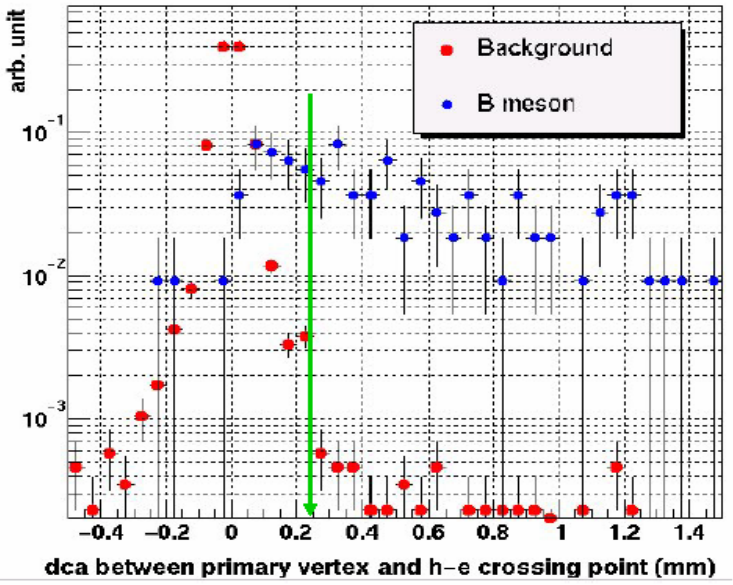
- B mesons accessible using semileptonic decay electrons
- Issue: nonphotonic electrons will be measured, but what is the real fraction of these from B? Highly model dependent
- Using displaced vertex tag may be the ONLY reliable method

p_T ~ 15 GeV/c: σ (Au+Au) ~ 20μb/Gev →30 nb^{-1} yields 600K b-bar pairs

Non-photonic electrons in d+Au



Tagging in Au+Au (w/ HFT)



Summary

- STAR has proven capabilities for high pt measurements at RHIC
  - Electron identification using three detector systems (TPC, TOF, EMC) from 1 to >10 GeV/c
  - H
  - PID with π/K/p using dE/dx out to ~10 GeV + topological id
  - Triggering capabilities to utilize full luminosity for rare probes
  - Direct reconstruction of charmed mesons
- STAR has a clear path for improving its capabilities
  - Completion and extension of calorimetric coverage
  - Extension of TOF coverage to full azimuth for electrons and combinatoric background rejection in direct reconstruction
  - Upgrade of Data Acquisition to increase effective luminosity and untriggered data samples
  - Installation of the heavy flavor tracker for displaced vertices