Measuring Hard Processes at STAR

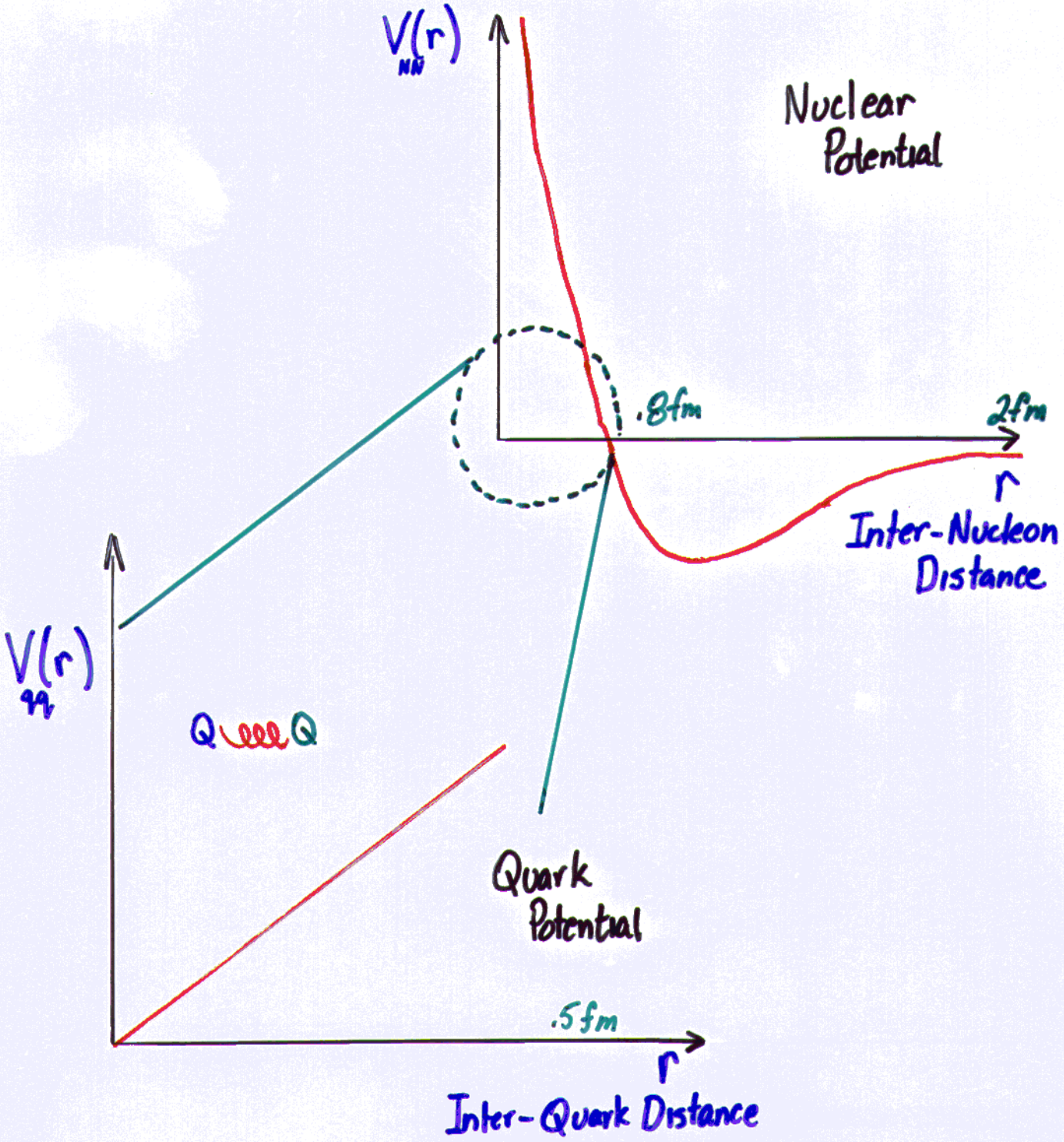
Brian Lasiuk

Yale University

Department Of Physics

- **Heavy Ion Physics**
  - Before RHIC
  - ...at RHIC (What RHIC gives us...)
- **Capabilities of STAR**
- **High P_T Observables**
- **Importance**

The Nuclear/QCD Potential



Hadronic Evolution

=> Heavy Ion Collisions encompass all aspects of hadronic processes

- Free (Asymtotic Limit) [Note: Initial State]
- Short Range Effects and Parton Production

- Parton Equilibrium (pQCD → phenom.)
- Hadronization (fragmentation function)
- Hadronic Interactions (in medium)

universal phenomenon

↑ effective theory!!

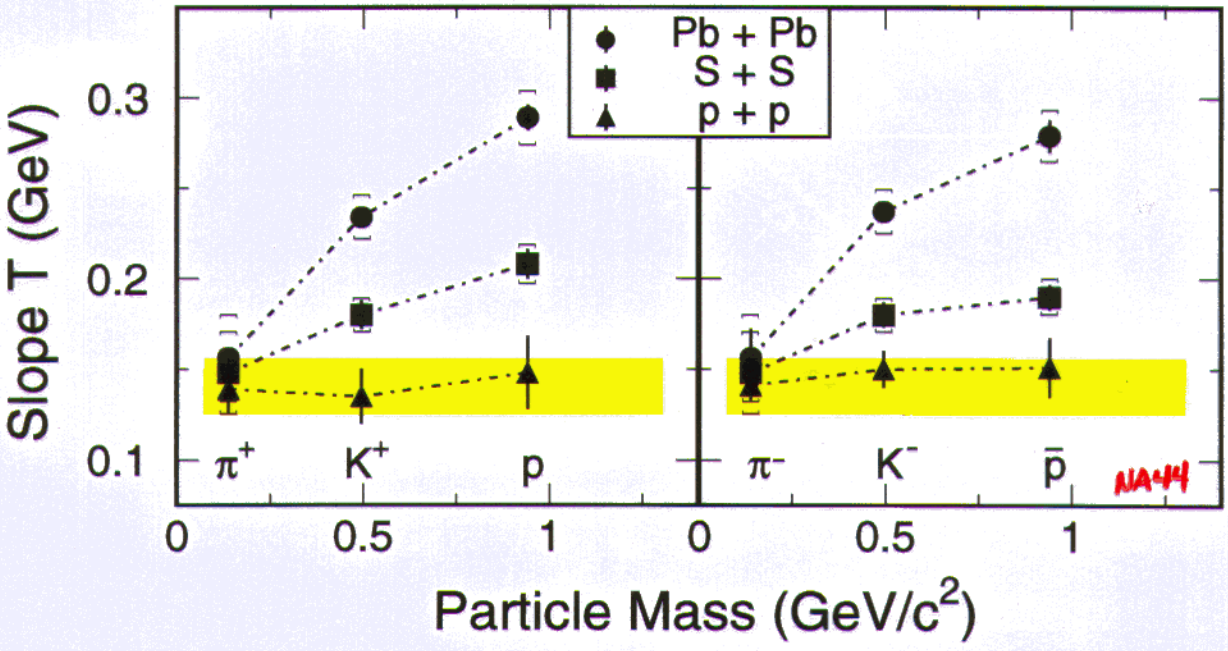
Transitional Region is Most Difficult to Describe

- laminar → turbulent flow
- static → dynamic
- ...

...Non-Equilibrium Physics

Soft Physics

Hadronization is universal => e^+e^-, pp, AA



CONDITIONS & ENVIRONMENT SHAPE THE FINAL STATE IN DIFFERENT WAYS. EVEN AT CERN-SPS ENERGIES, PARTICLE SPECTRA ARE DECIDEDLY SOFT IN NATURE

... STILL DESCRIBED IN PHENOMENOLOGY

IT WORKS... WELL... BUT...

Partition Function

$$Z \sim \int d\psi d\bar{\psi}\, e^{\int d^4x \mathcal{L}}$$

$$\mathcal{E} \sim \frac{T^2}{V} \frac{\partial \ln Z}{\partial T} \qquad S \sim \frac{1}{V} \frac{\partial T \ln Z}{\partial T}\Big|_{V_n}$$

We have access only to statistical properties assuming EQUILIBRIUM !!!!

AT RHIC we have hope to map calculations from 1st principles to extended HADRONIC SYSTEMS

Make use of well tested & trusted weak coupling METHODS !!!

Energy Evolution

HARD PROCESSES

- CERN-SPS $\sqrt{s} \sim 17$ GeV — Fluctuations
- RHIC $\sqrt{s} \sim 200$ GeV — ~ 50% of energy transfer
- Tevatron $\sqrt{s} \sim 2000$ GeV — Dominant

AT RHIC, ESTIMATES SUGGEST ~ 50% OF ENERGY IS TRANSFERRED VIA PROCESSES QUANTIFIABLE WITH WEAK COUPLING TECHNIQUES

- Not as easy as "simple" system => MUCH SOFT EXISTS!

Processes of Interest

How to see Partons and effects at RHIC?

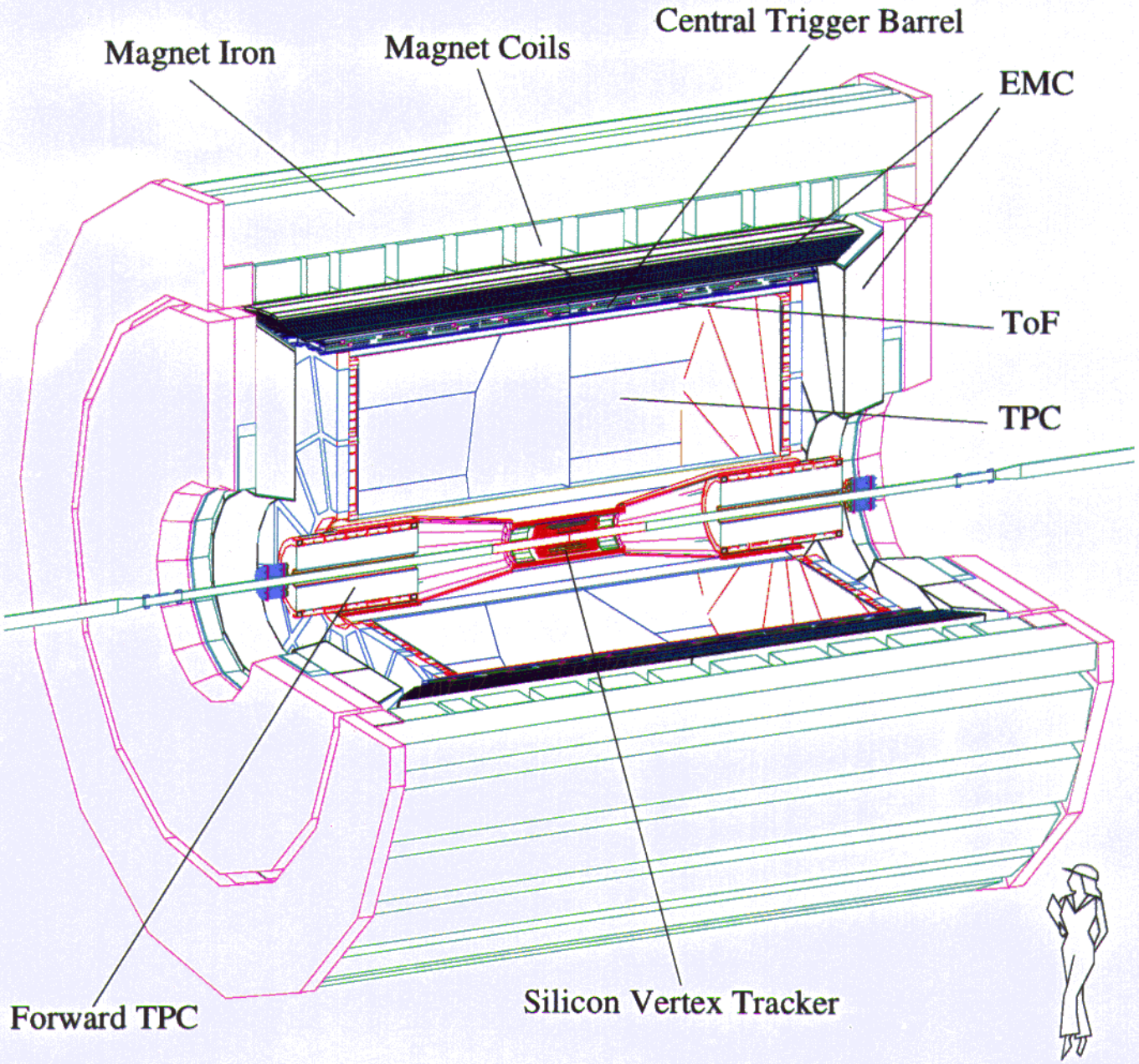
- **Jets and Mini-Jets** → Smoking Gun Experiments
  - qq interaction
  - asymtotically free

Rates calculated and experimentally tested in e^+e^- Collisions...

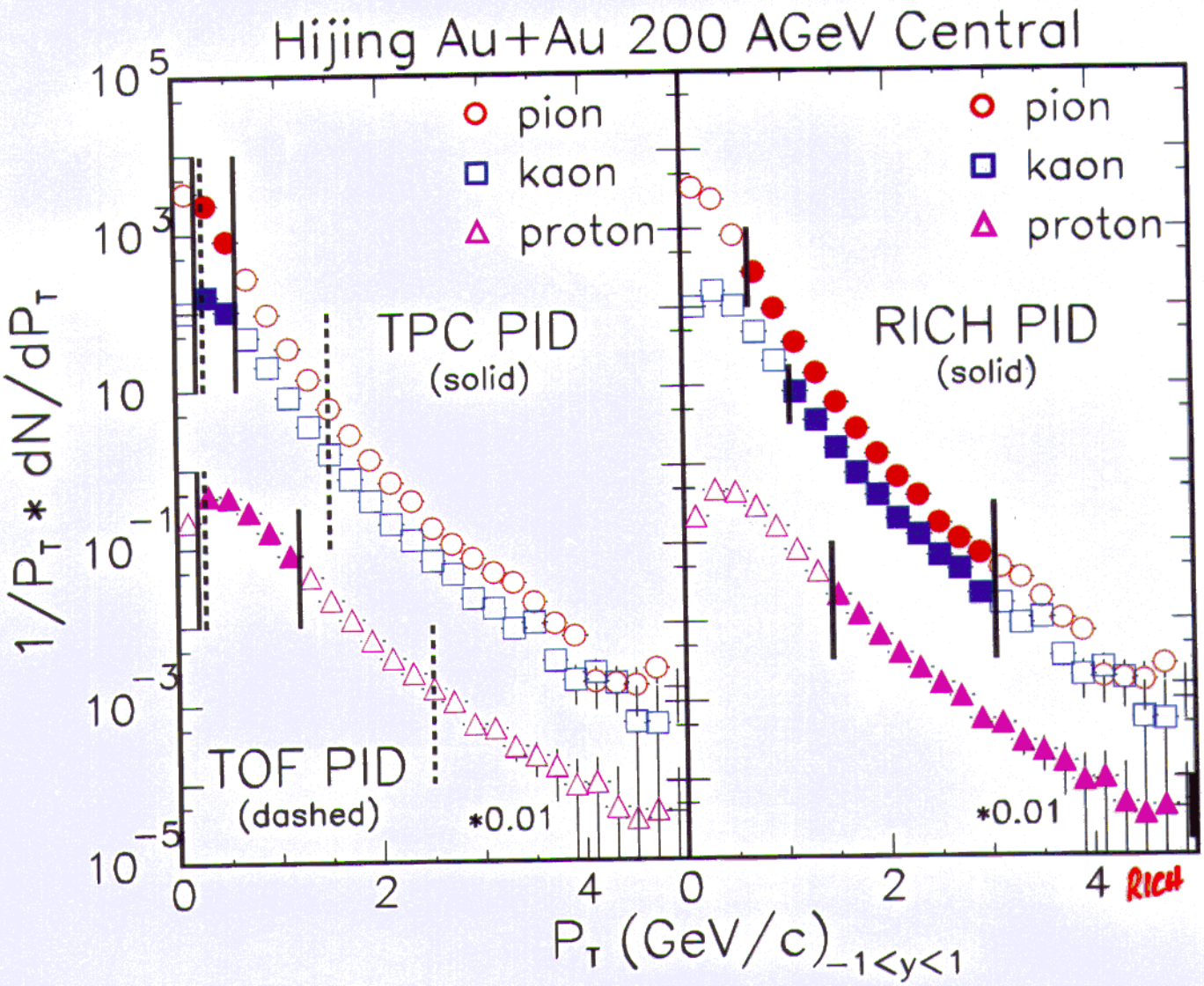
- **Quarkonia** → Not Rescattering
  - Heavy System
  - Radiative Corrections Small
  - gg fusion

How does this relate to study of matter and search for collective (transitional behavior) effects?

STAR


Magnet Iron
Magnet Coils
Central Trigger Barrel
EMC
ToF
TPC
Forward TPC
Silicon Vertex Tracker

RICH – PID



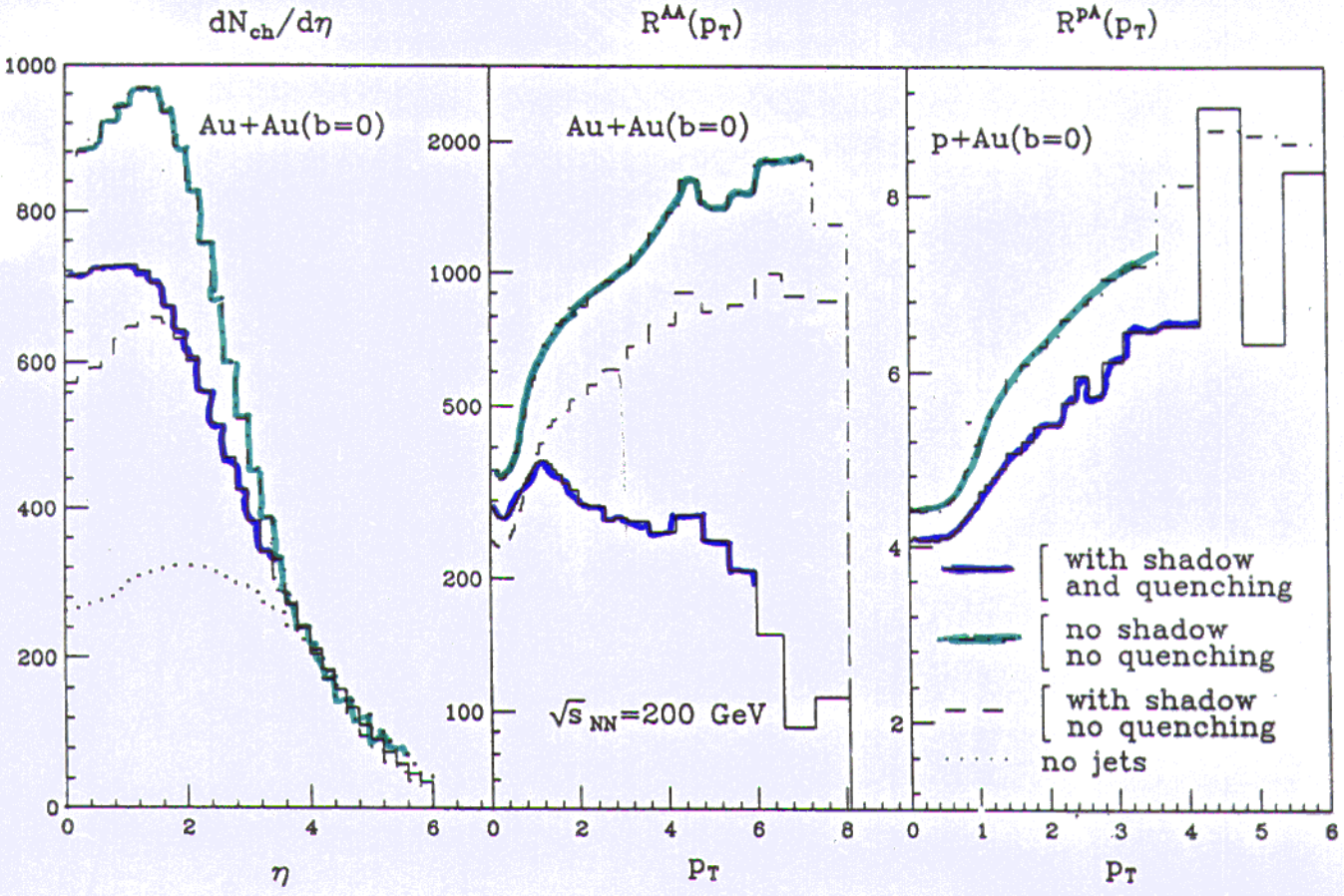
π/K separation 1<p< 3 (GeV/c)

p ID 1.5<p< 5 (GeV/c)

Effects of Hard Processes

The Picture that started it all...

CAN WE UNDERSTAND INTERACTION OF A PARTON IN MEDIA?.....



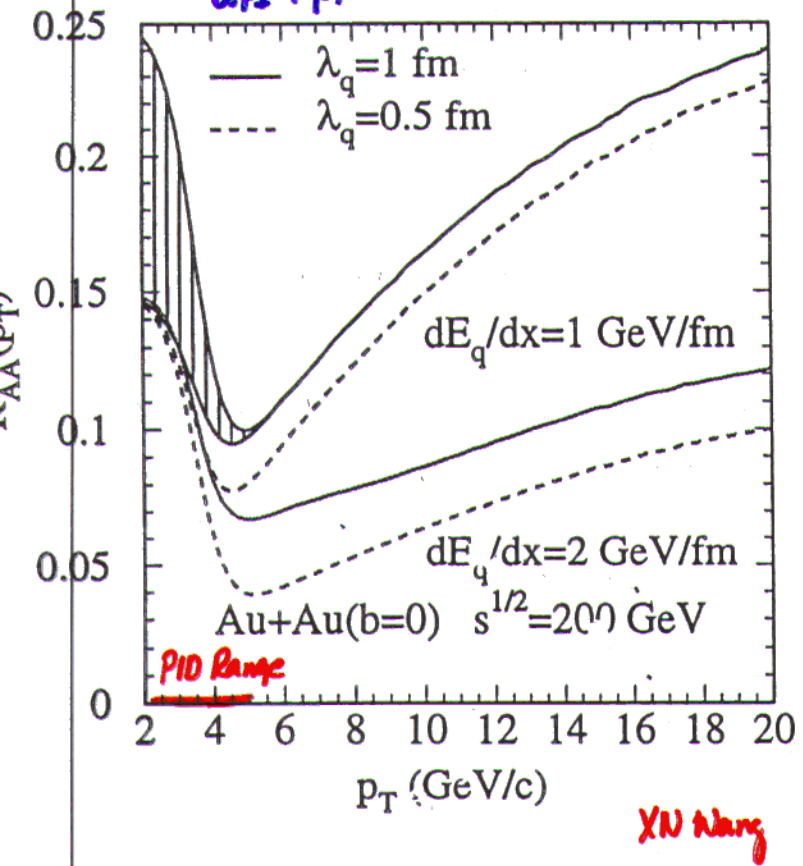
XN Wang
M Gyulassy
PRL 68 (1992) 1480

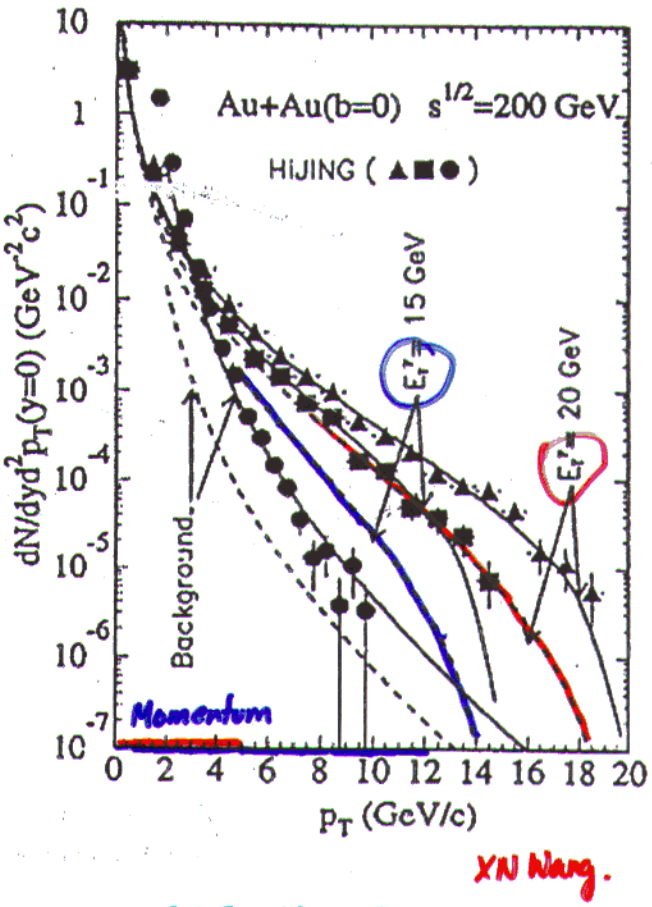
Jet Quenching (Energy Loss)

THE SPECTRUM SOFTENS...

- Medium Effects
- QGP → Debye screening
- Hadronic Gas → weak interaction

$R \sim \frac{\frac{dN}{dp_\perp}\Big|_{AuAu}}{\frac{dN}{dp_\perp}\Big|_{pp}}$



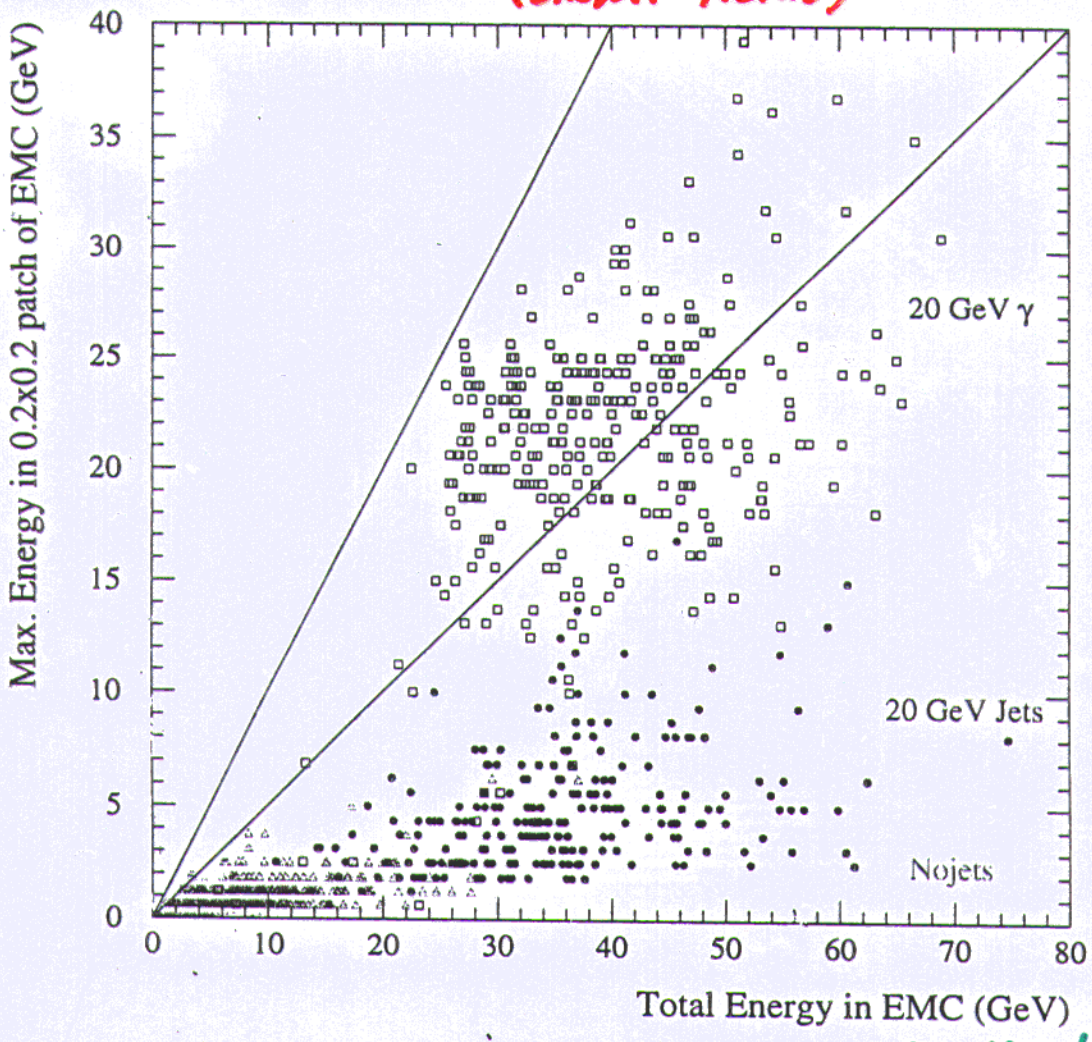


$p_\perp$ BRINGS IN HADRONIZATION EFFECTS...

Jet Finding

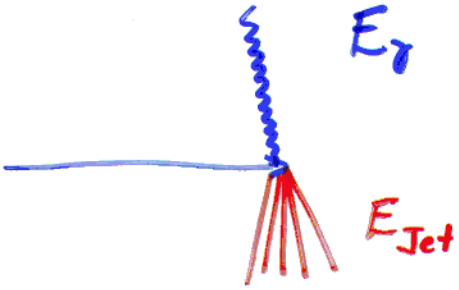
STAR is actively studying jet finding algorithms

$\mathcal{E}$ ... Discrimination Between γ, jets
(Shower Profile)



G. Westfall et al. SN.

γ - Jet Events



$E_\gamma \approx E_{Jet}$

The Jet is a remnant of a high energy parton

It Interacted with the matter... (γ weakly couples)

1. DOES ENERGY BALANCE HOLD?
2. DOES PLANARITY HOLD?

} Interaction of Parton

3. IS THERE A DIFFERENCE IN FLAVOR COMPOSITION OF THE JET?

- What does this tell us???
- Can We experimentally do this?

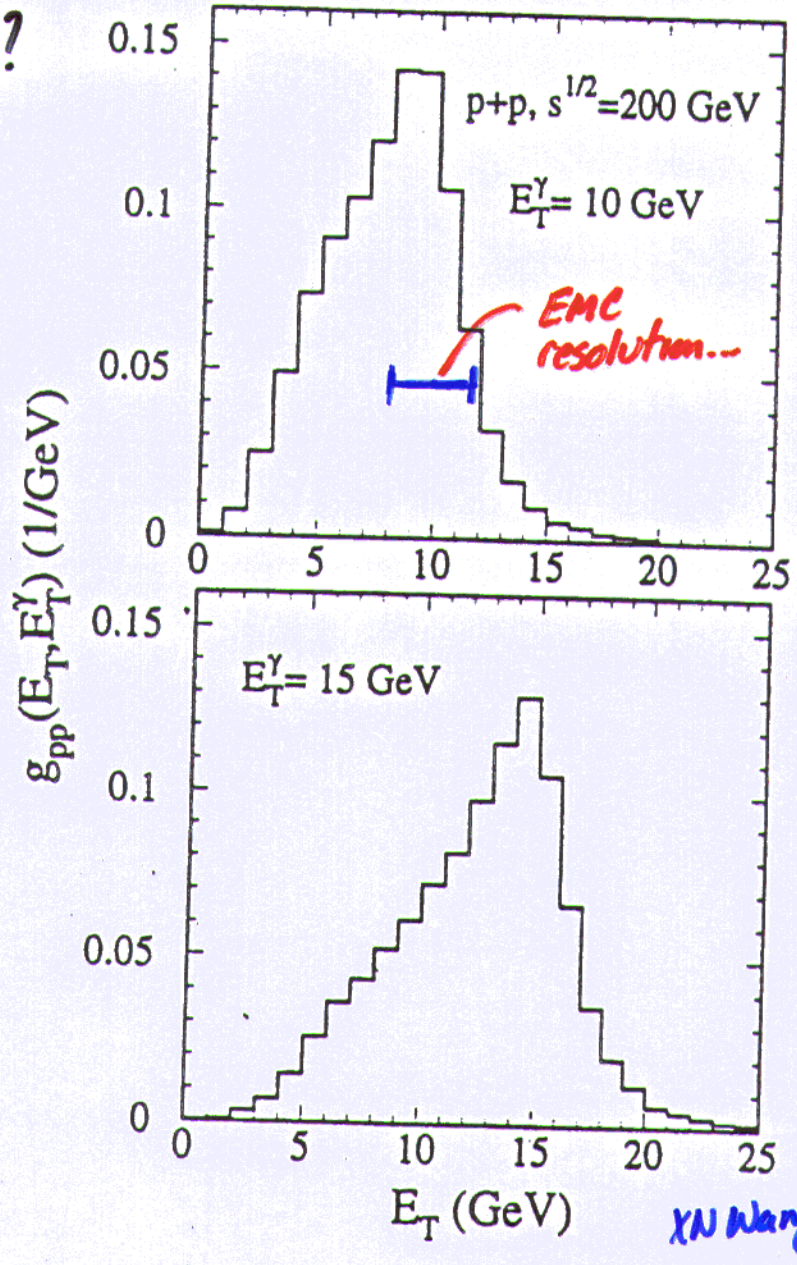
Jet-Correlations

Oops... Initial k_T DEPENDENCE.

AT NLO $E_{JET} \neq E_j$ => model arguments

$d\sigma/d\ell \sim \Delta k$

γ-γ Events ??



Rate Estimate

At STAR in pp:

$\mathcal{L} \sim 10^{31}\ cm^{-2}/s$

6000 - 7000 γ-jet events / year $E_0 > 10 GeV$

For AuAu

X-section scales by:

- at least $A \sim 200$
- moreso $A^{4/3} \sim 1200$

but

$\mathcal{L}_{AuAu} \sim 10^{26}\ cm^{-2}/s$

$$\frac{[6000 - 7000]}{10^5} \times [200 - 1200]$$

$\sim 10 - 1000$ per year....

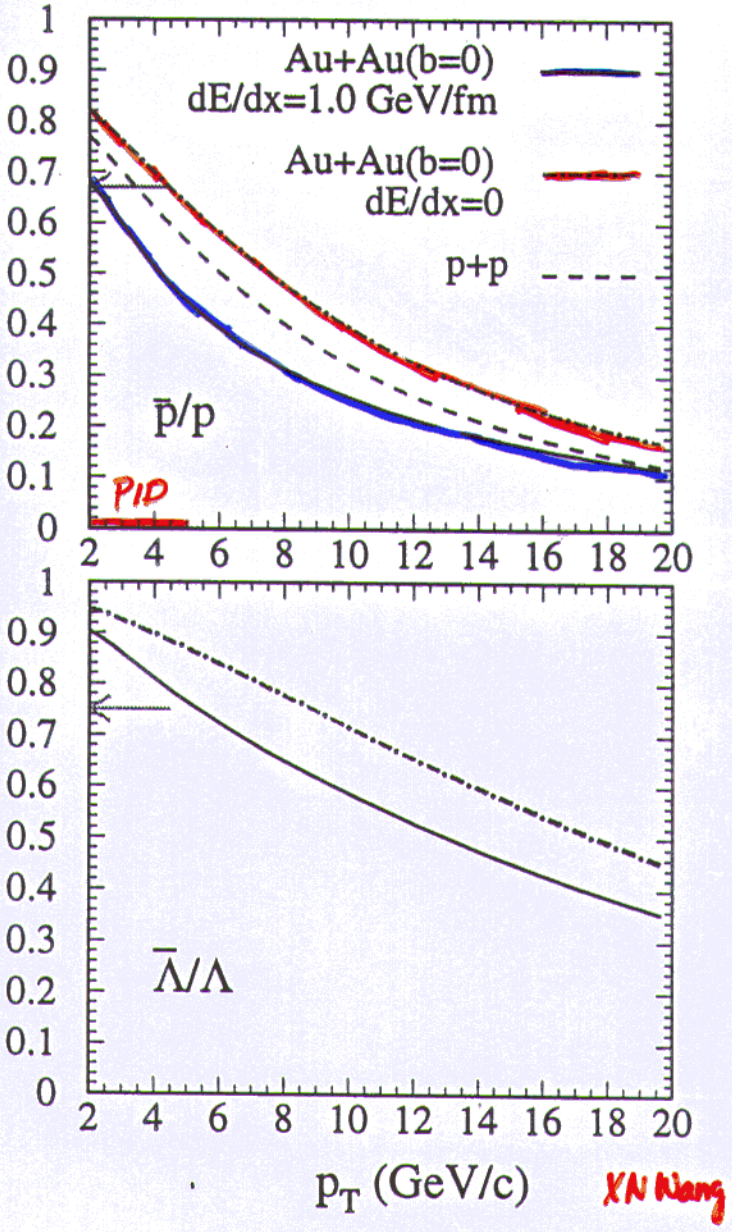
Di-photons are even rarer....

Why so difficult?

Flavor Tagging

We can see a difference in fragmentation

HADRONIZATION IN: VACUUM <=> MATTER



Quarkonia

- Production Rates are Calculable via pQCD

  $t\bar{t}$ $b\bar{b}$ $c\bar{c}$ Gluon Fusion Processes

- Extremely Sensitive to type of environment

- Decay EM

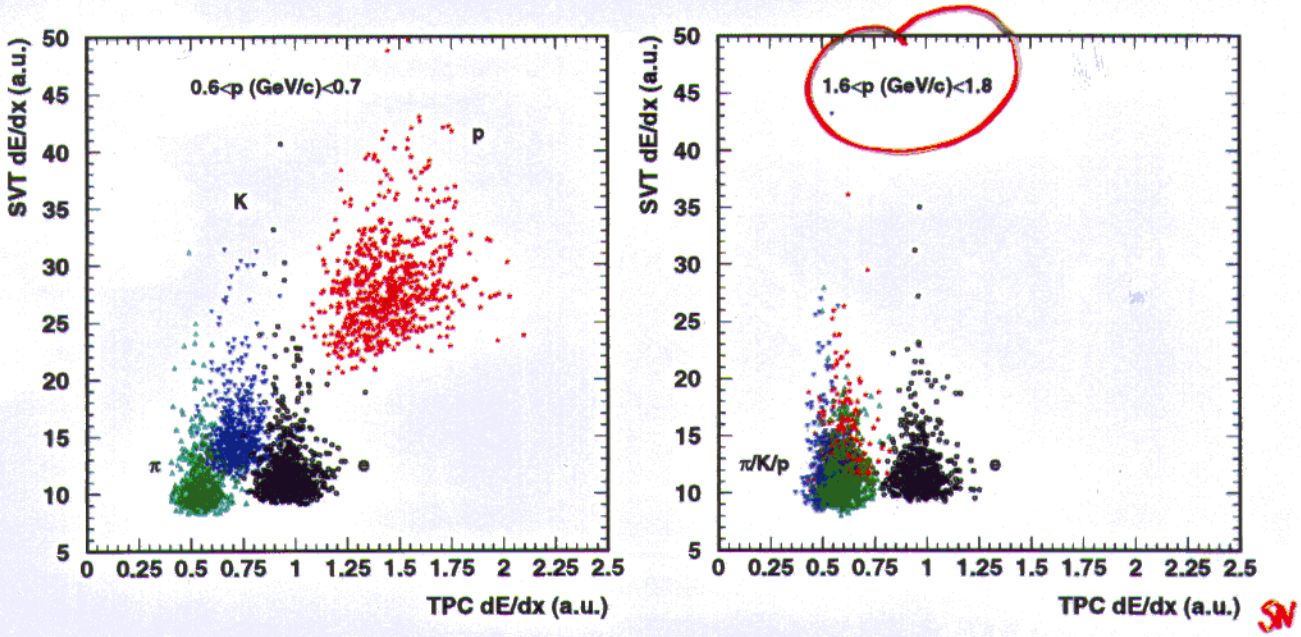
  $J/\psi \rightarrow e^+e^-$

- Small X-section

- STAR Rate ...

- but acceptance large and $\bar{e}/h$ rejection ???

TPC – PID



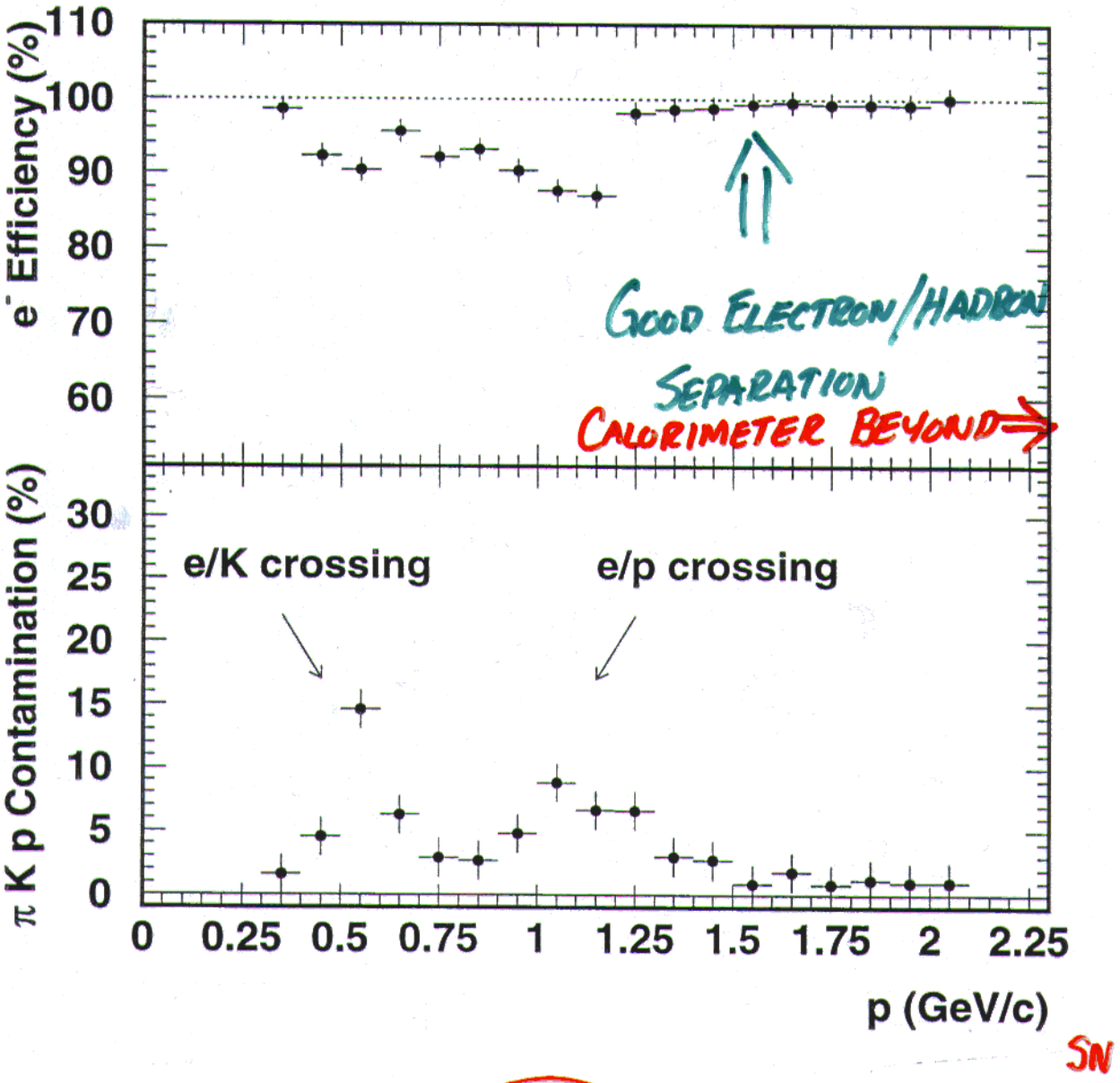
MOST DIFFICULT REGION FOR e/h separation IS below CALORIMETER THRESHOLD

$1 < p\ (GeV/c) < 2$

TPC + SVT are powerful !!!

ACCESS TO LOW p_t J/ψ

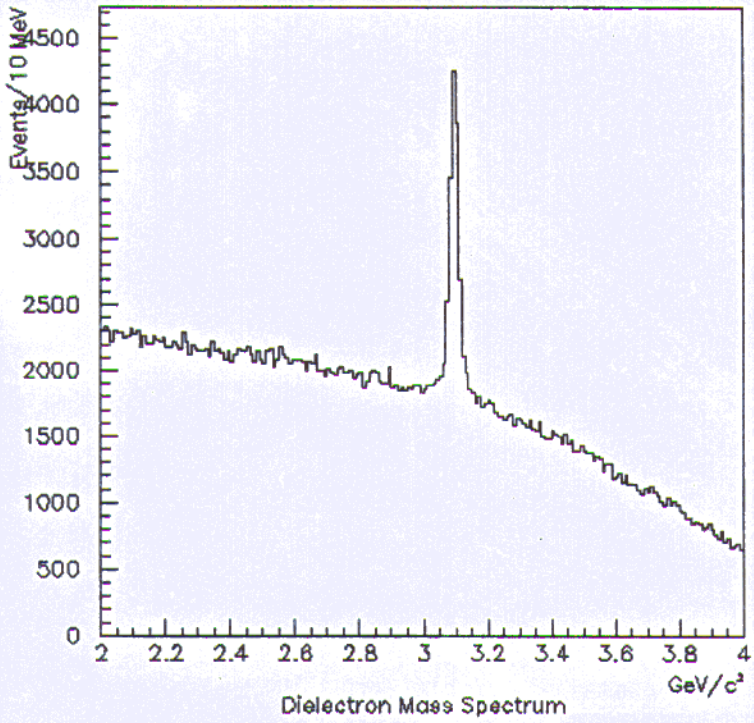
- Triggering
- Rate



– PID via dE/dx usable up to 2.5 GeV/c

– hadron rejection factor $\gtrsim 10$

J/Ψ



T. Lelonke SN

Work In Progress ....

- TPC reconstruction
- PID: - calorimeter
  - ionisation