electromagnetic radiation at rhic ii*

**dielectrons, dimuons, and photons*

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rhic ii worshop
bnl – april 28-29 2005

Outline

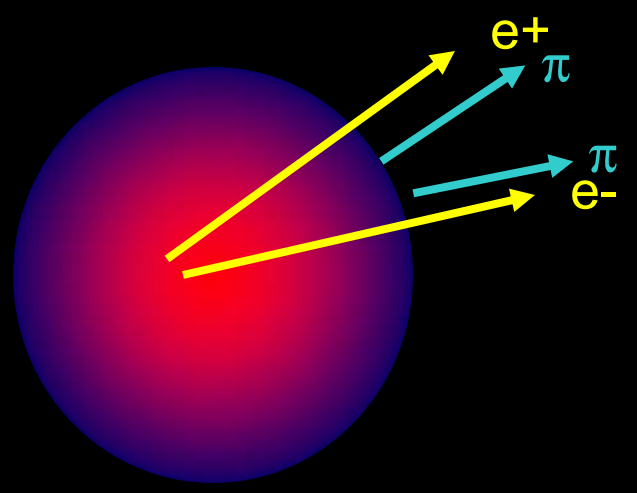
- Introduction
- Physics
  - Chiral Symmetry
  - Temperature
    - An example
- The Task
  - the challenge
  - What has been done
  - RHIC II suite of detectors
  - doing it
- Conclude

Two essential topics

- **MASS** in a **chirally symmetric phase of the vacuum**
  - low mass vector mesons decaying inside the fireball
- The **Temperature**
  - NOT INVERSE SLOPE – THE TEMPERATURE!

WHY electromagnetic radiation?

- it doesn't interact (strongly)
  - greatest strength – messenger from:
    - early stage
    - center



  - greatest weakness
    - rate is low compared to hadrons
    - huge backgrounds from decays far outside of the fireball (dalitz, charm…)

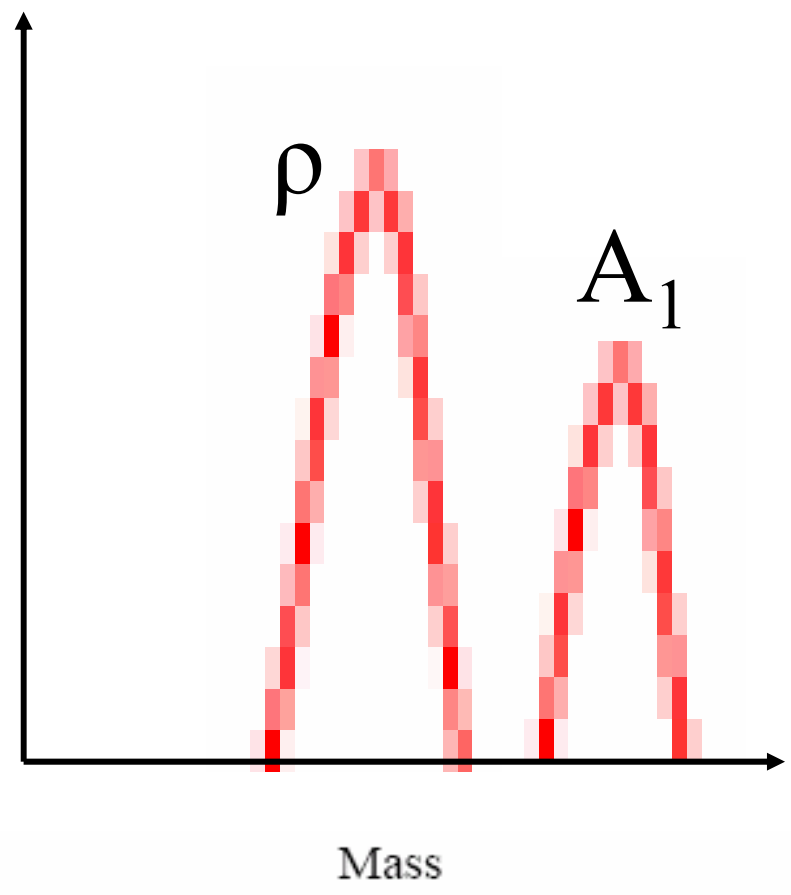
Why RHIC 2? (for this working group)

- Detector upgrades
  - Tracking dectors – charm
    - Si Vtx – phenix, new tracker (star)
  - HBD (phenix) [NEEDS CHARM MEASUREMENT]
  - calorimetery (PHENIX, STAR)
  - At least two detectors to cross check measurements
- Luminosity
  - Efficient Species and energy scans for systematic measurements
    - "Short" high luminosity runs for semi-rare probes at high statistics
      - high pt photons, dielectrons, dimuons
      - "high" mass dielectrons, dimuons (IMR – m~1-3 GeV)

Chiral Symmetry restoration- the low mass vector mesons

- "bare" mass of everything is ZERO
- QCD condensate → non-zero mass
- Condensate(T)

Question:
How ?
T?
eigenfunctions?



The Temperature

Hawking Radiation: General Relatativity and Quantum Mechanics

- Pairs created at the event horizon of a black hole
- One escapes, the other doesn't
- $T=g/2\pi$ g=accel of gravity at event horizon

The Temperature: Gravity=Acceleration

- General Relativity
  - Gravity = Accelerating Reference Frame
  - So accelerating things give off radiation with $T=a/2\pi$!!!!
    - e.g. from $g=9.8\ m/s^2$ we get $T=10^{-20}K$ …

Question: Where are the biggest accelerations we can ever get??? (think F=ma)

The Temperature : Kharzeev-Tuchin

ANSWER: Heavy Ion Collisions where the field is from the strong interaction

- Can these fields be calculated?
  - YUP – the CGC

$$T = \frac{Q_{sat}}{2\pi}$$

accel in field $gE \sim Q_s^2$
off shell mass $\sim Q_s$

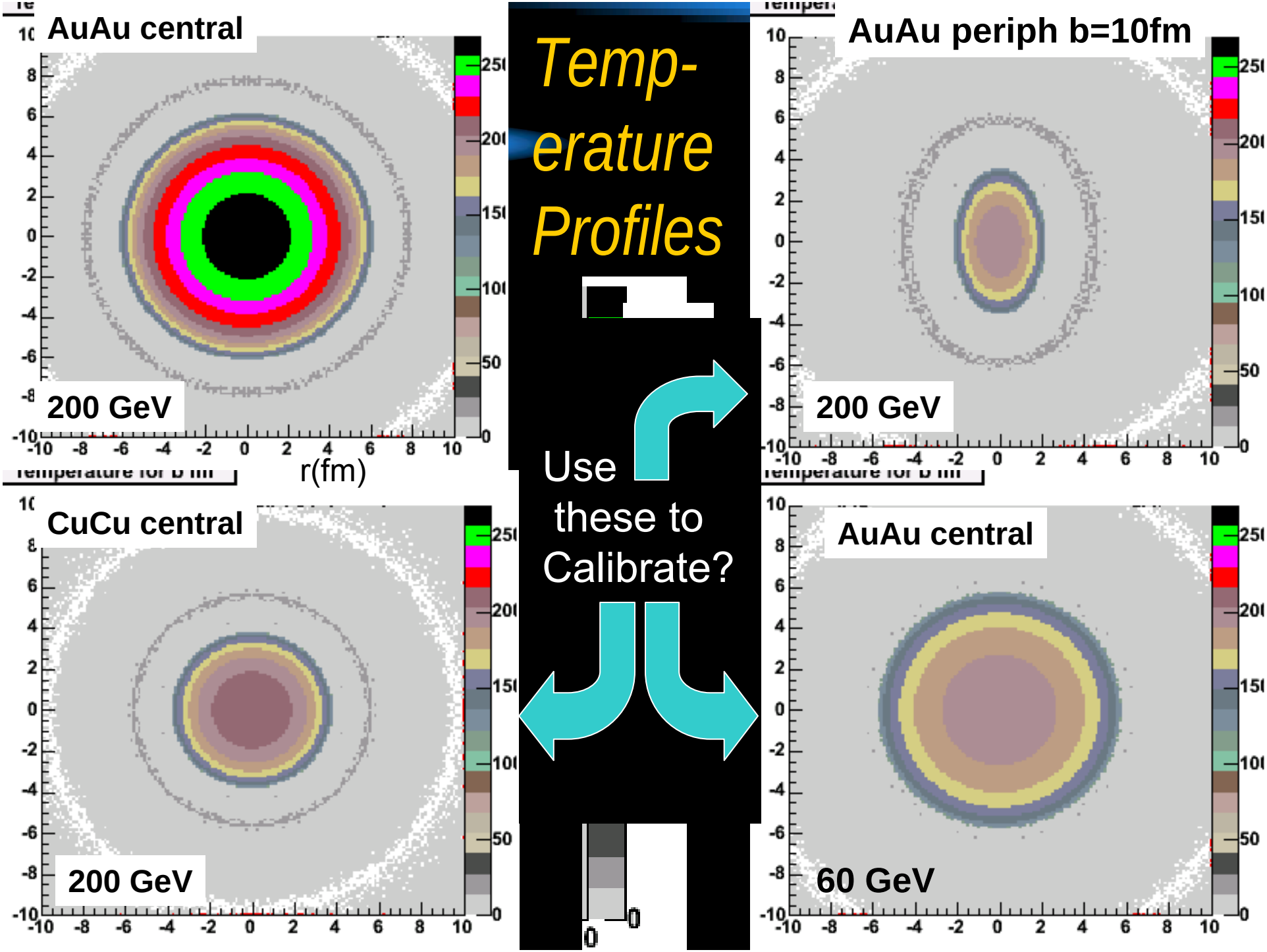
- So via "Hawking Radiation" a thermal bath is created when two heavy ions collide
  - Rapid Thermalization
  - A high temperature, deconfined, chirally symmetric phase born

- Q_{sat} (think Temperature) is a function of centrality and Beam Energy

$$Q_s^2 = \frac{8\pi N_C}{N_C^2 - 1}\alpha_s(Q_S^2)xG(x,Q_S^2)\frac{\rho_{part}}{2}$$

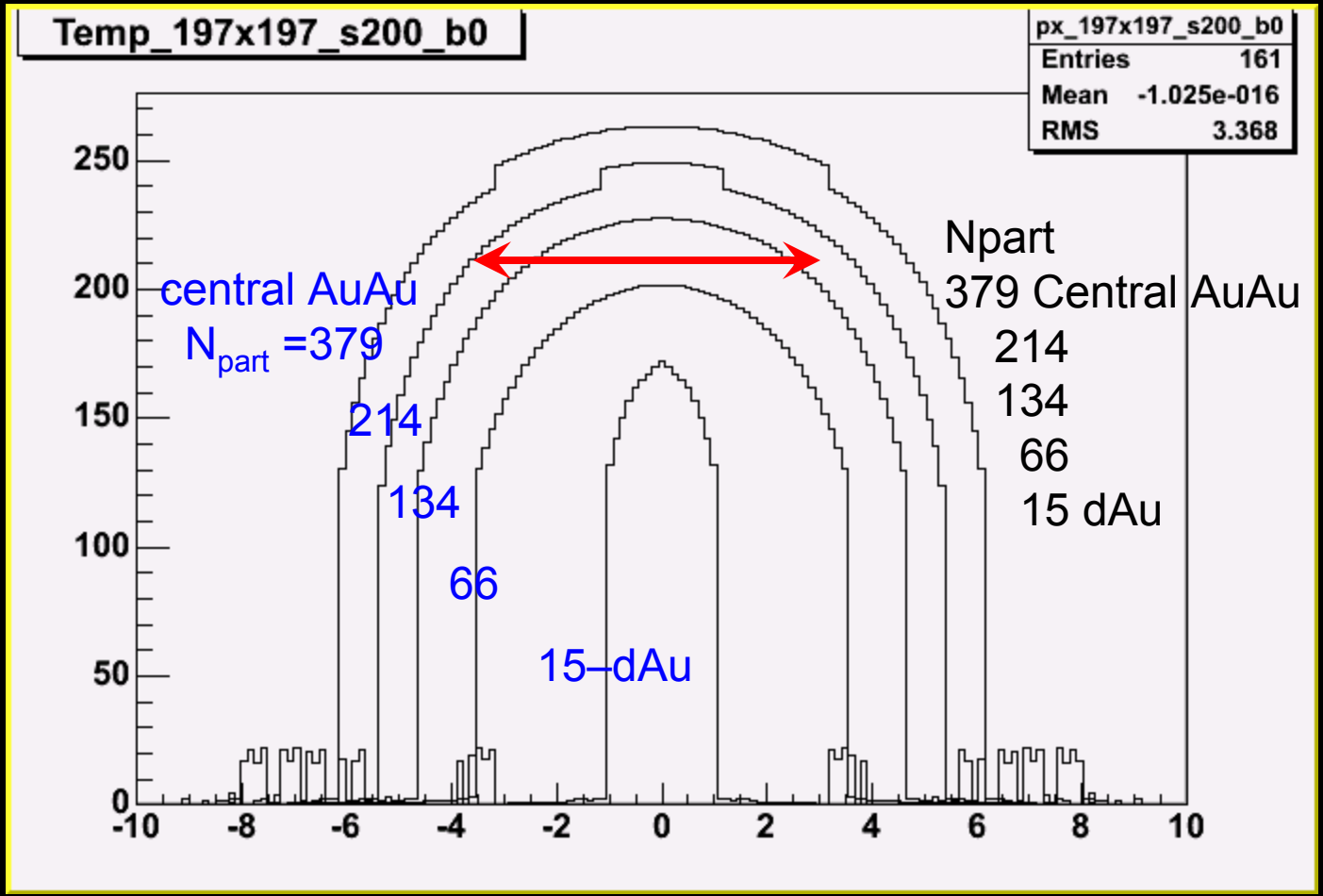
Beam energy dependence

centrality dependence

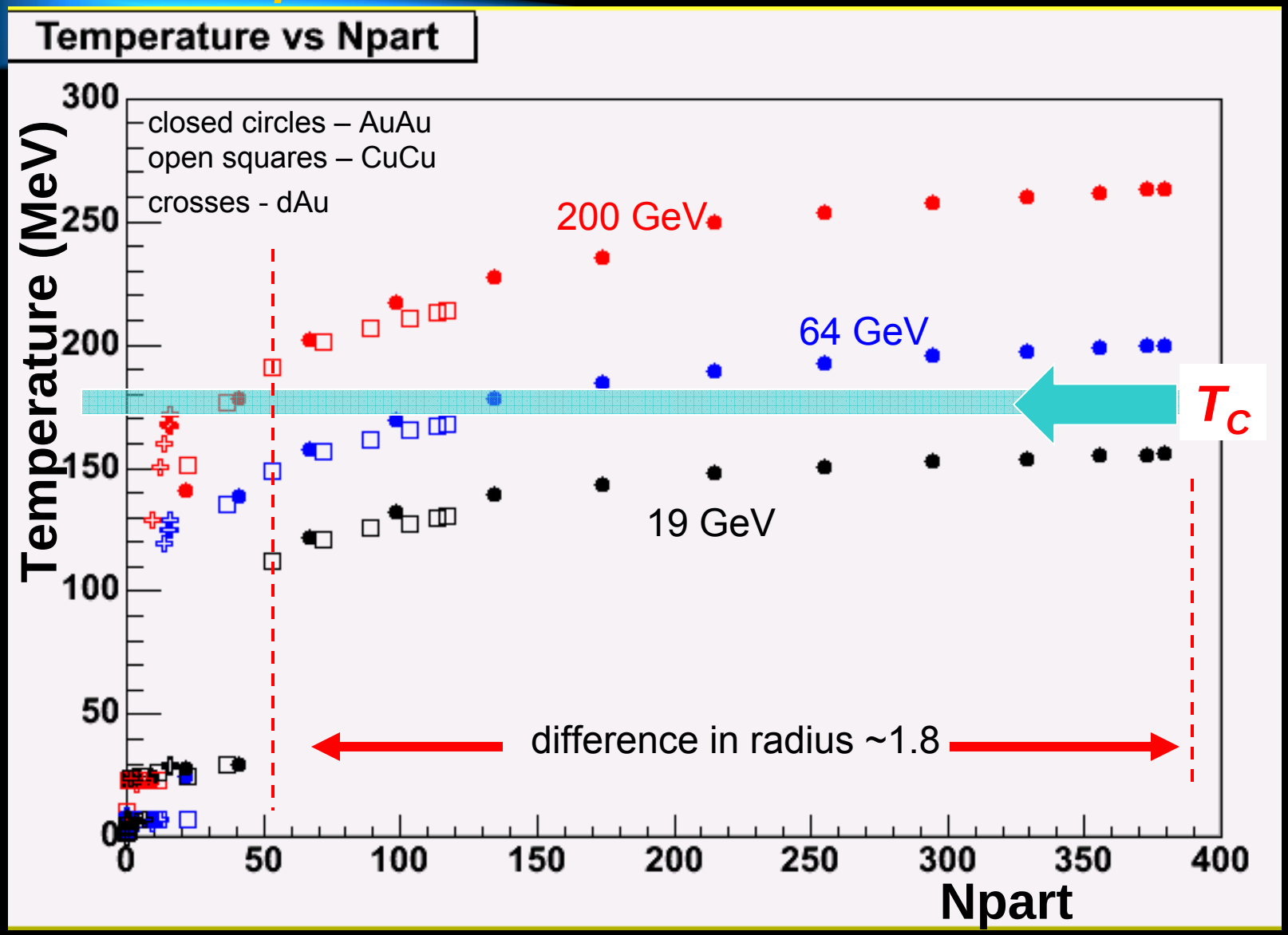

AuAu central
200 GeV
r(fm)
AuAu periph b=10fm
200 GeV
CuCu central
200 GeV
AuAu central
60 GeV
Temp-
erature
Profiles
Use
these to
Calibrate?

How uniform is the temperature?

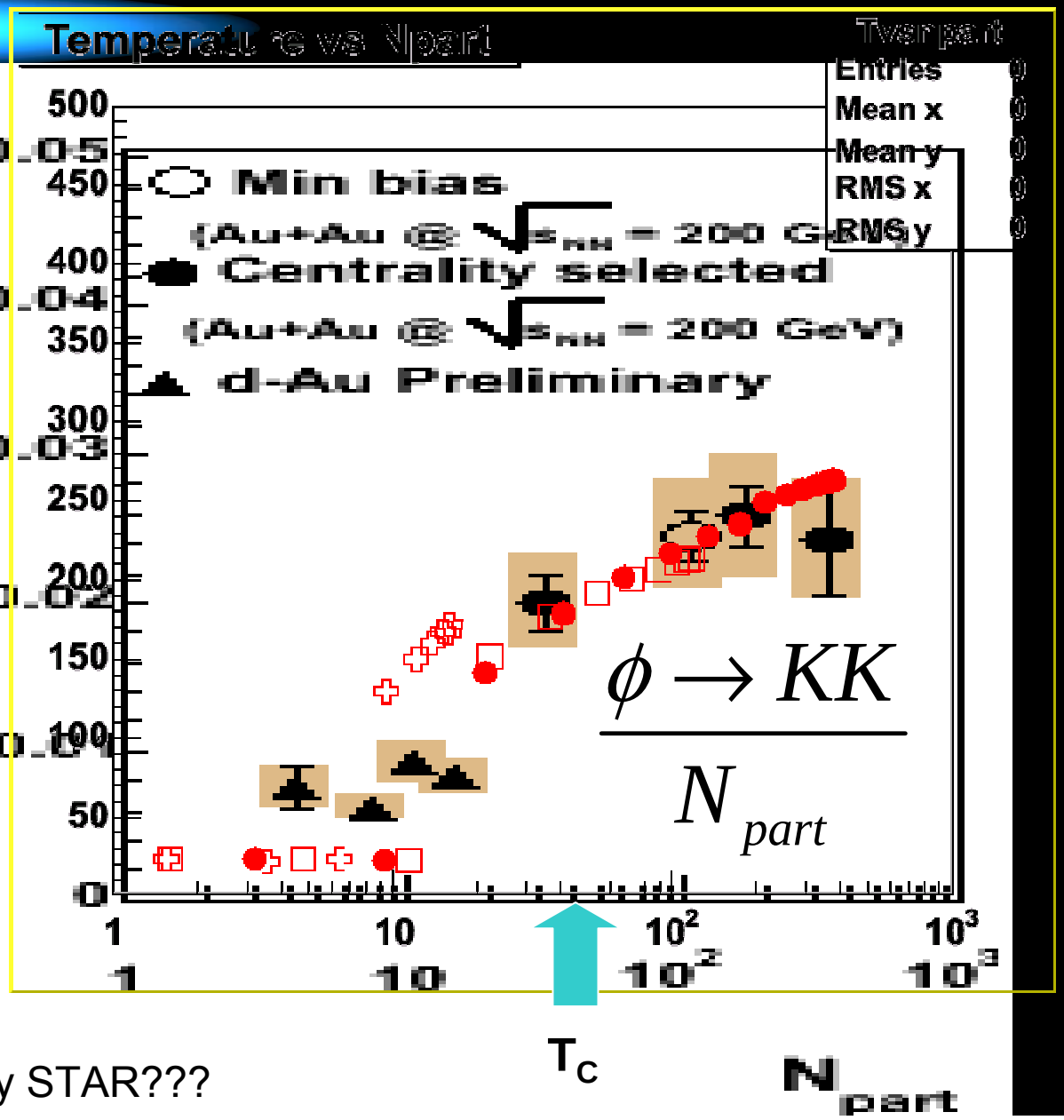
- < 20% over ~4 fm



Temperature???



$\phi \rightarrow KK$ vs T????



importance of
2 experiments

PHENIX
not seen by STAR???

if this is right

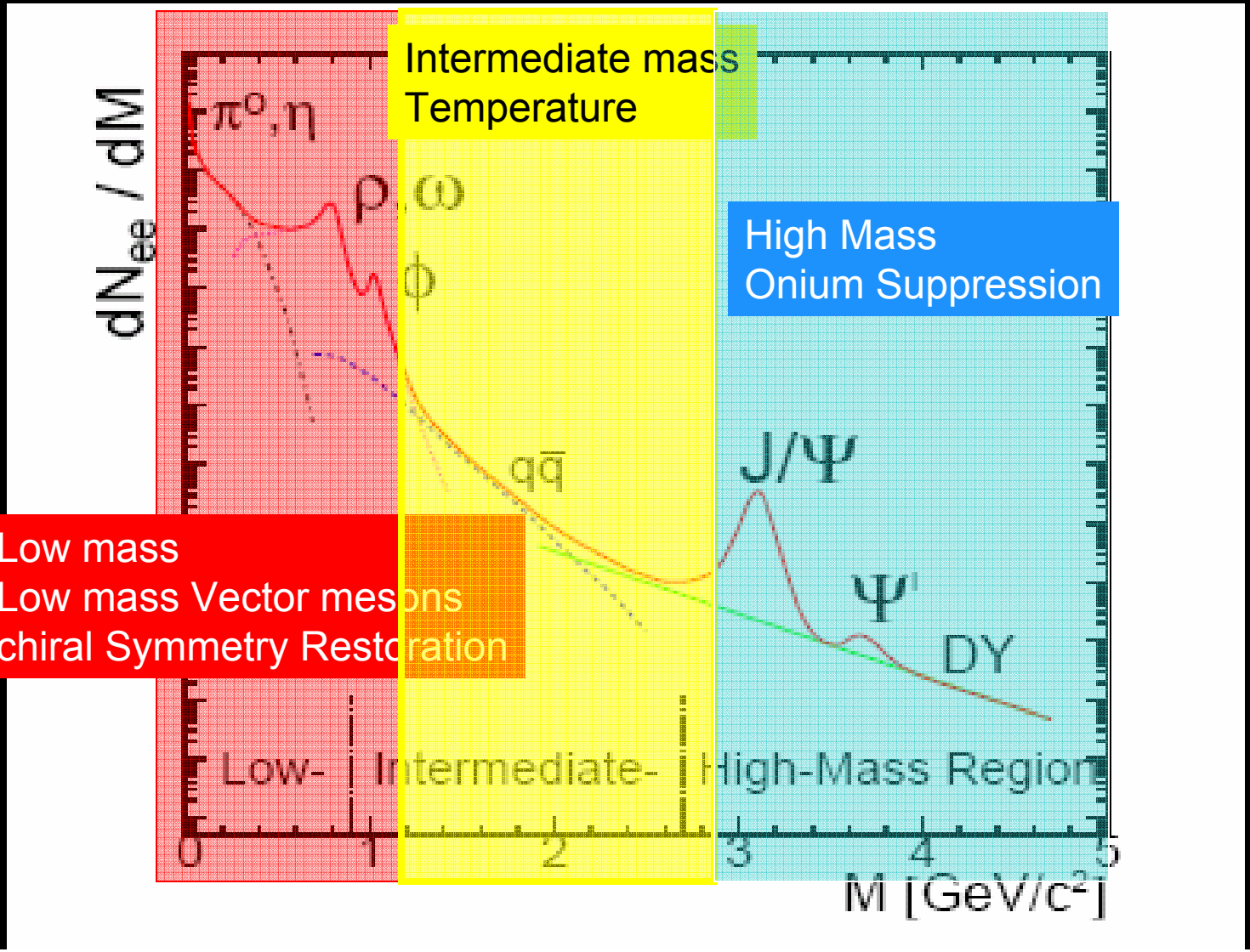
- We are dealing with a Temperature
- Temperature rises quickly early in Npart
  - to above ~T_C
- Equilibrium happens very fast
  - $\tau \sim 1/Q_S \sim 0.2$ fm

➔ We can "calibrate" the Temperature ~Npart

  - Thermal Dileptons, photons

  - Critical to do a thorough study vs E_{beam} and N_{part} (beam species) for "rare" electromagnetic probles

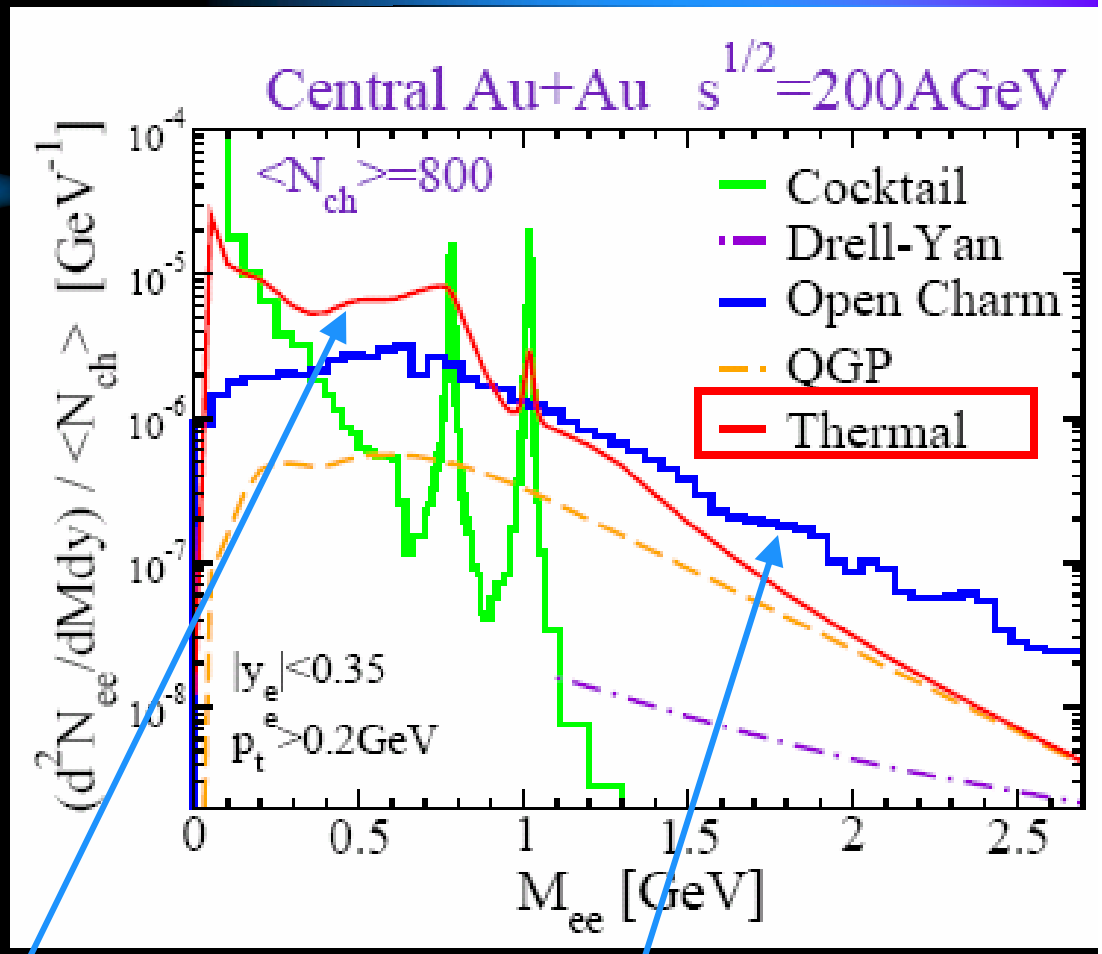
di-leptons mass - 3 General regions



The Challenge

its easy to say

- see Chiral Symmetry Restoration
  - measure low mass ee to find the mass(width) of low mass VM vs energy and centrality
- Measure the Temperature
  - Measure intermediate mass ee, μμ, and direct γ



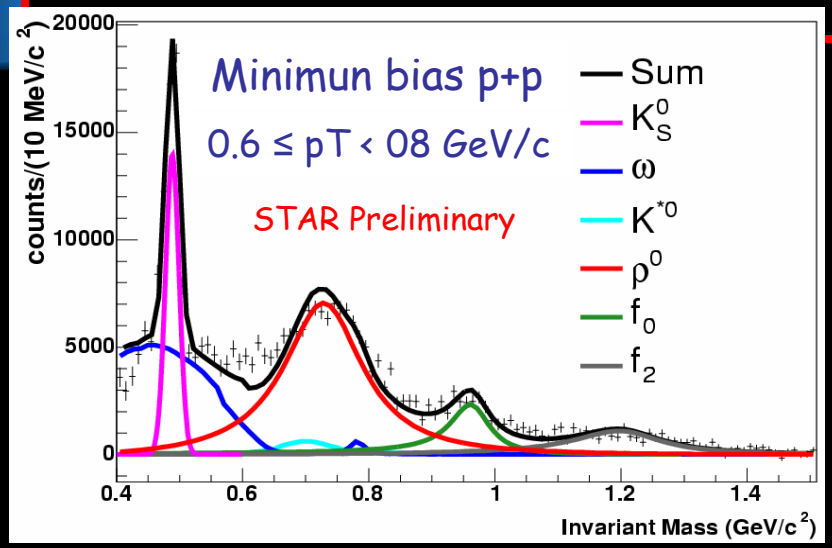
its hard to do!!!

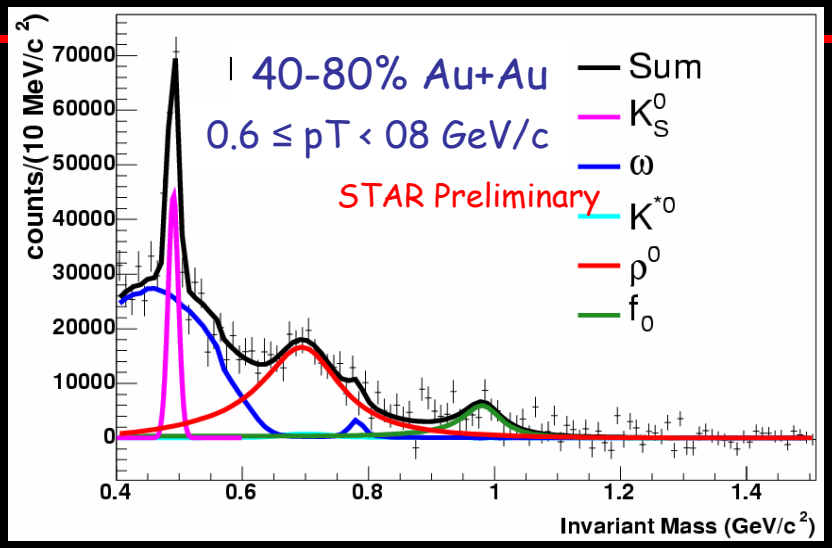
$\gamma \rightarrow e^+ e^-$

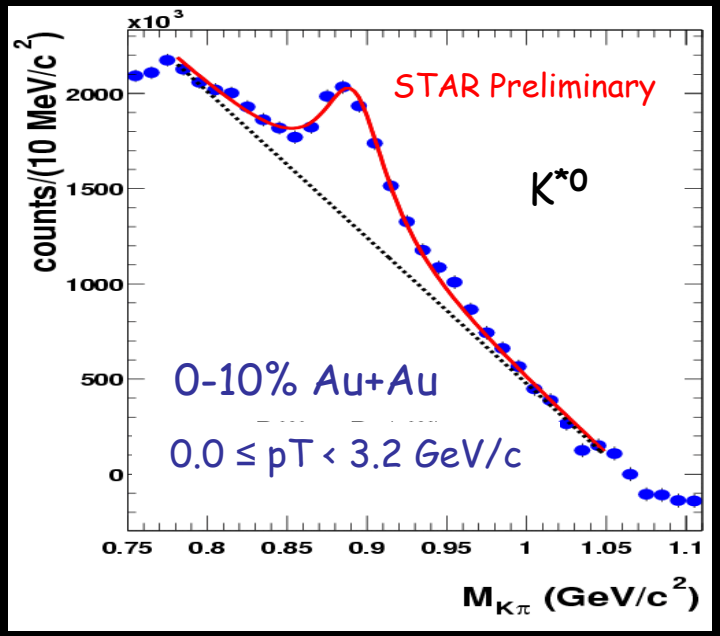
$\pi^o \rightarrow \gamma\ e^+ e^-$

- $M<m_\phi$
  - Dalitz suppression
  - charm under control
- $m_\phi<M<m_{J/\psi}$
  - accurate charm measurements to subtract

What has been done:
Low mass Vector mesons – hadronic final states

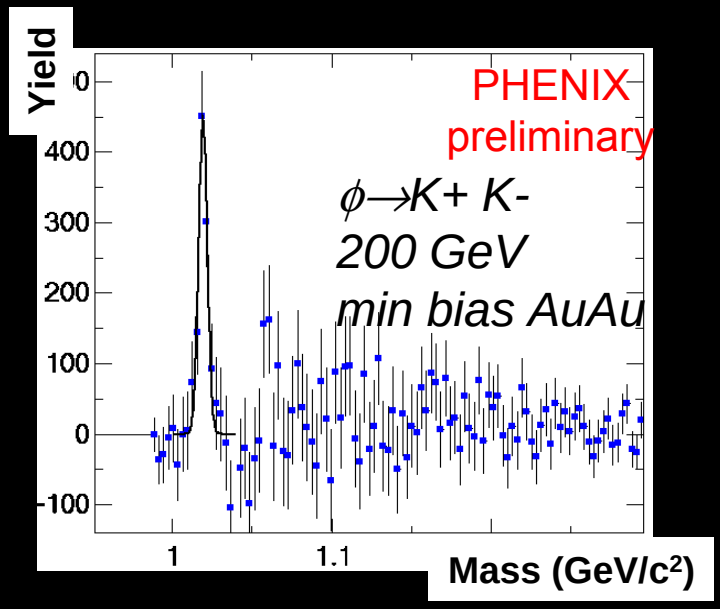






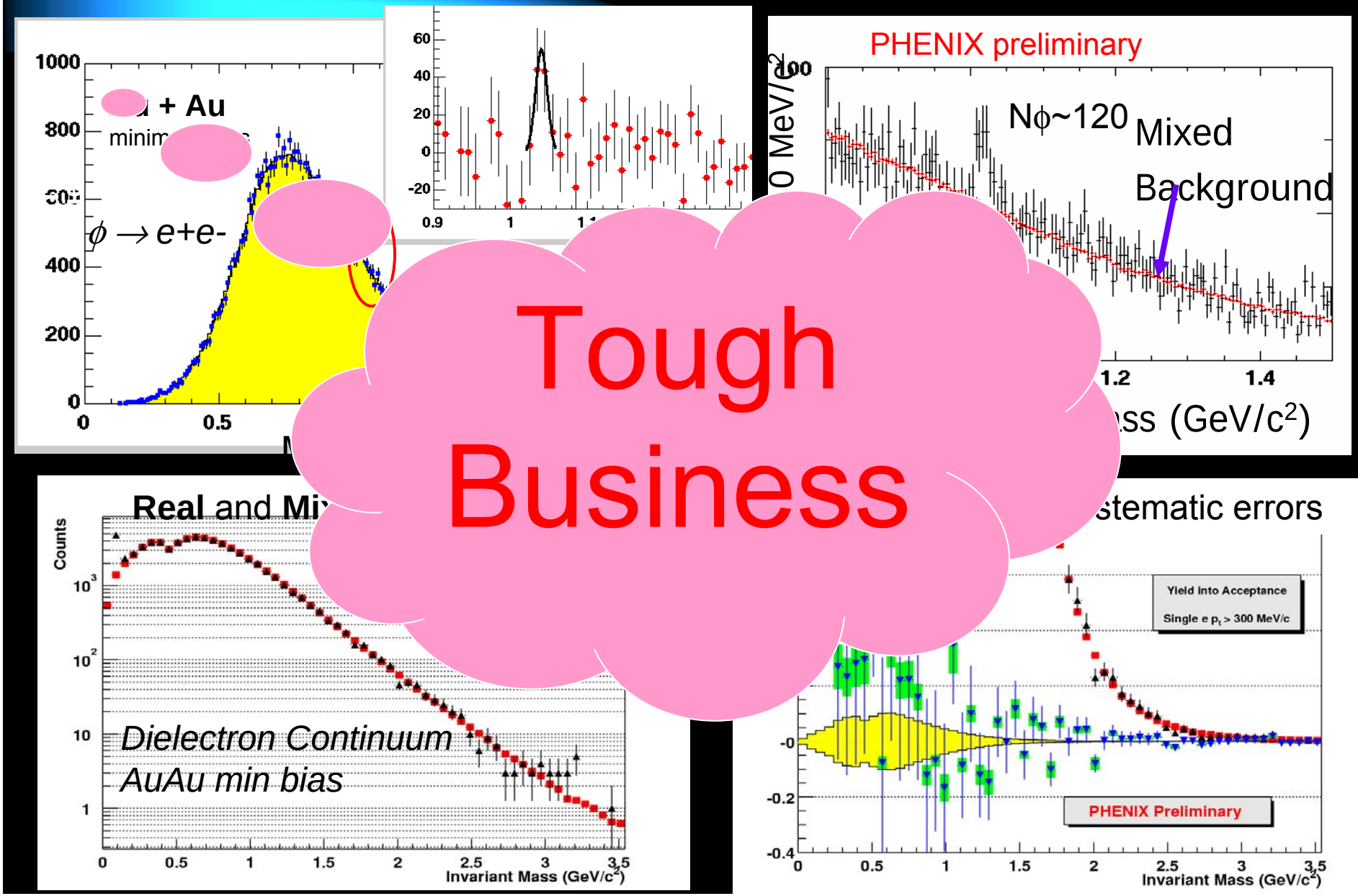
STAR:
√sNN = 200 GeV
|y|<0.5
Statistical error only

Very nice!!



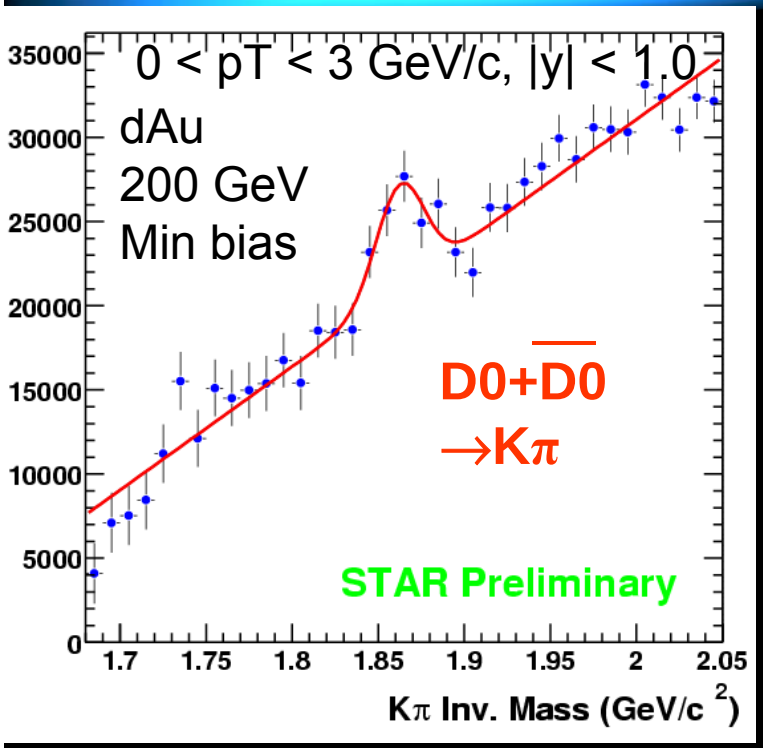
What has been done

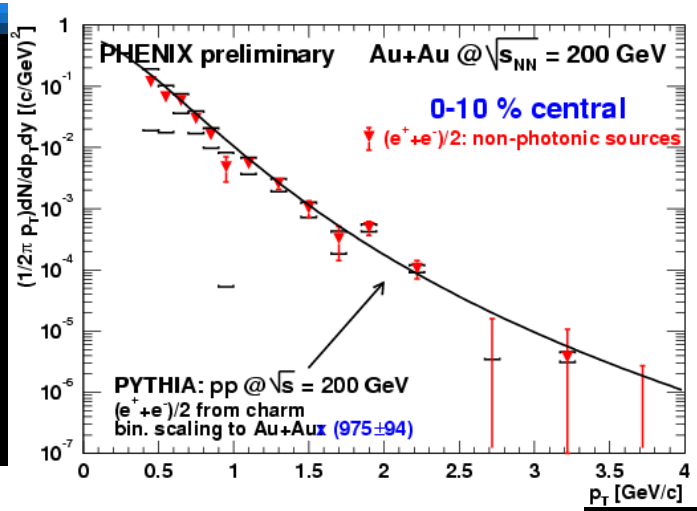
Dileptons: e^+e^- E_{cm}=200 GeV

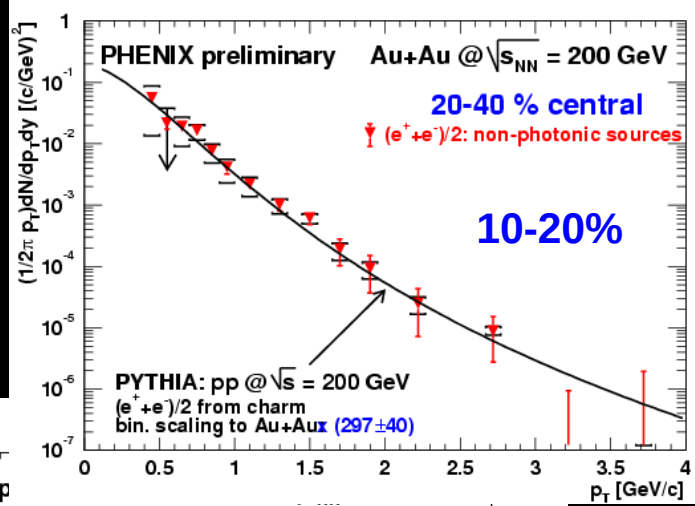


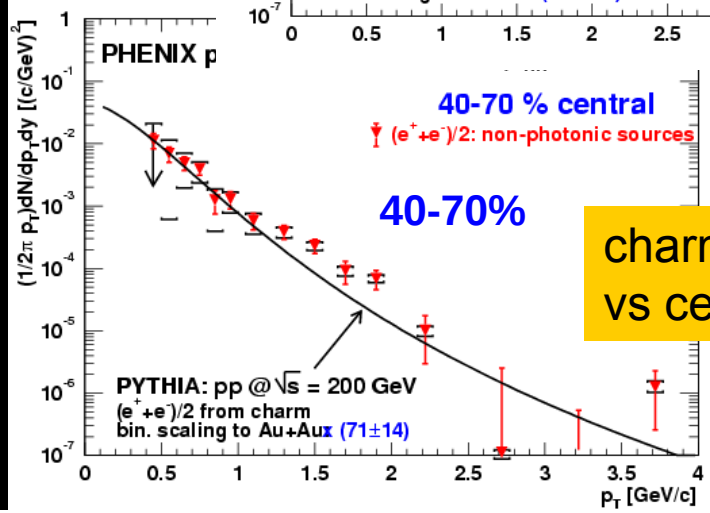
Tough Business

Measureing the Charm background









charm single electrons vs centrality

- $\sigma_{c\bar{c}}^{NN}$ **=1.12 ± 0.20 ± 0.37 mb**
- charm scales with binary collisions

RHIC II

- Suite of “new detectors” – full coverage tacking and calorimeter, large regions of TOF PID

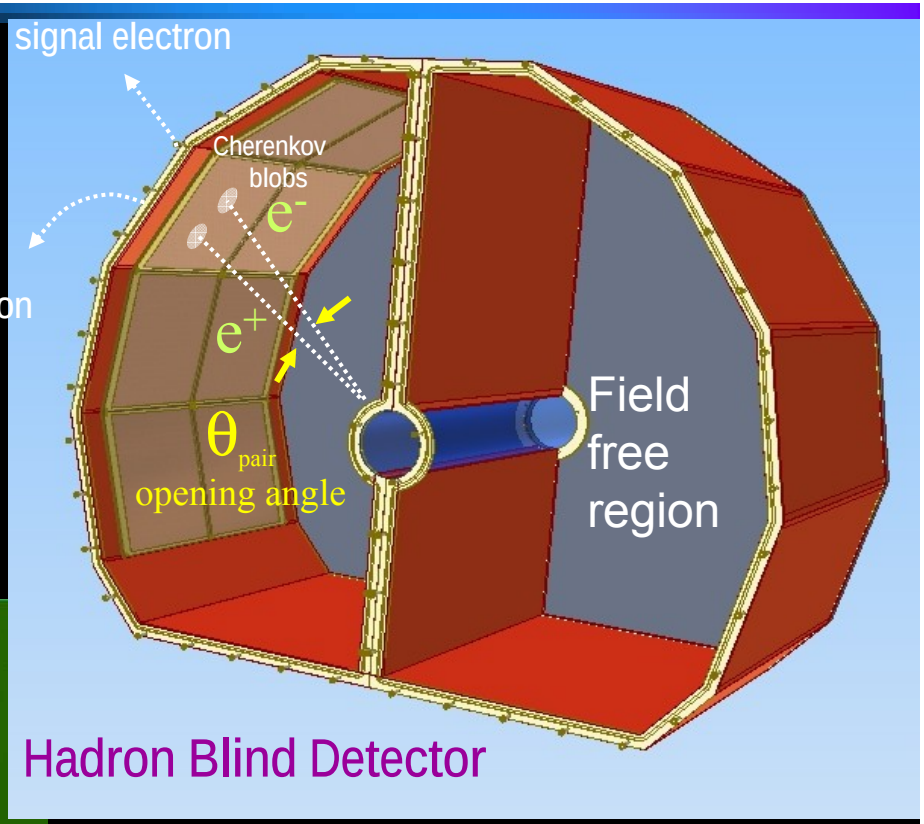
  +special detectors for lepton PID (PHENIX)

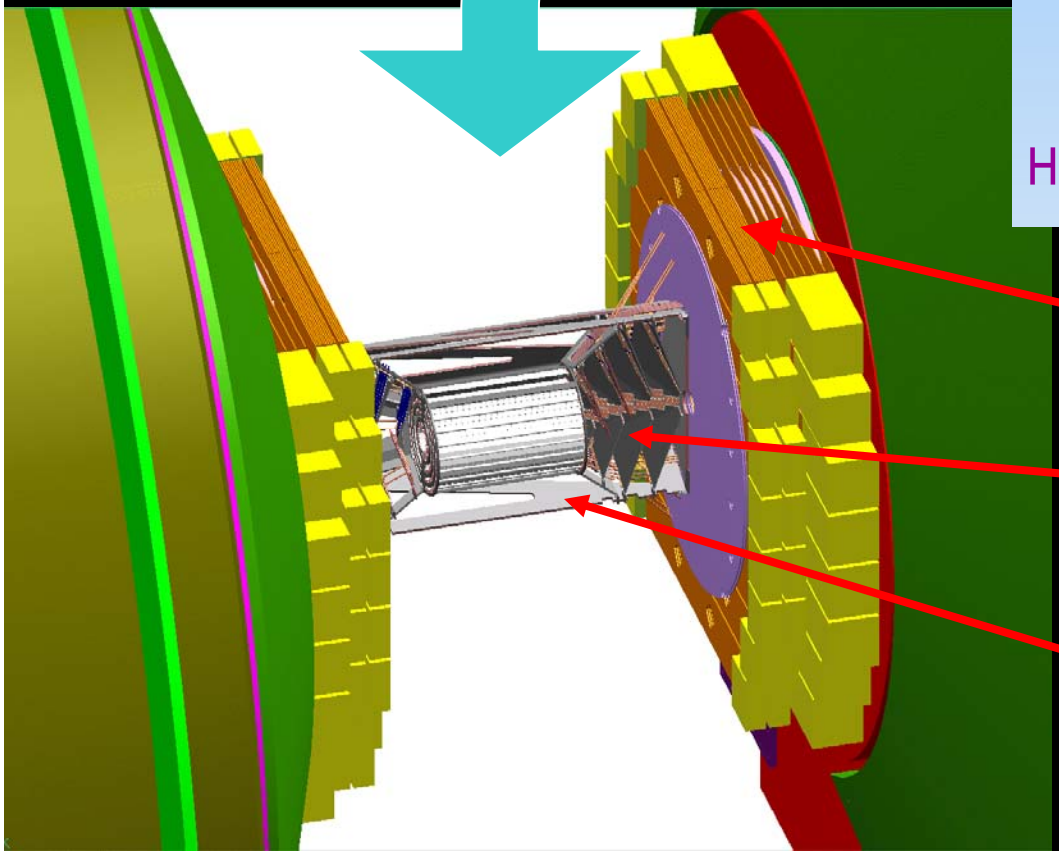
  - STAR
    - New Calorimeters everywhere
    - New tracking (including vertex)
    - New PID
  - PHENIX
    - New tracking (including vertex) = large solid angle
    - New Calorimeters (forward)
    - HBD
  - New detector proposal
    - large acceptance
    - fully instrumented

e.g. PHENIX

full coverage for tracking
and calorimetery +
special hadon
electron and muon PID

partner positron
needed for rejection





Nosecone Calorimeter
$1<\eta<3$

Forward Si Vertex Tracker

Central
Si Vertex tracker

Assumptions

Long runs (not possible if we want to run say 3 species/energies+spin)

RHIC 2 : 15 nb^{-1}

10^{11} MB events 10^{10} central

RHIC: 1.5 nb^{-1} (run 8)

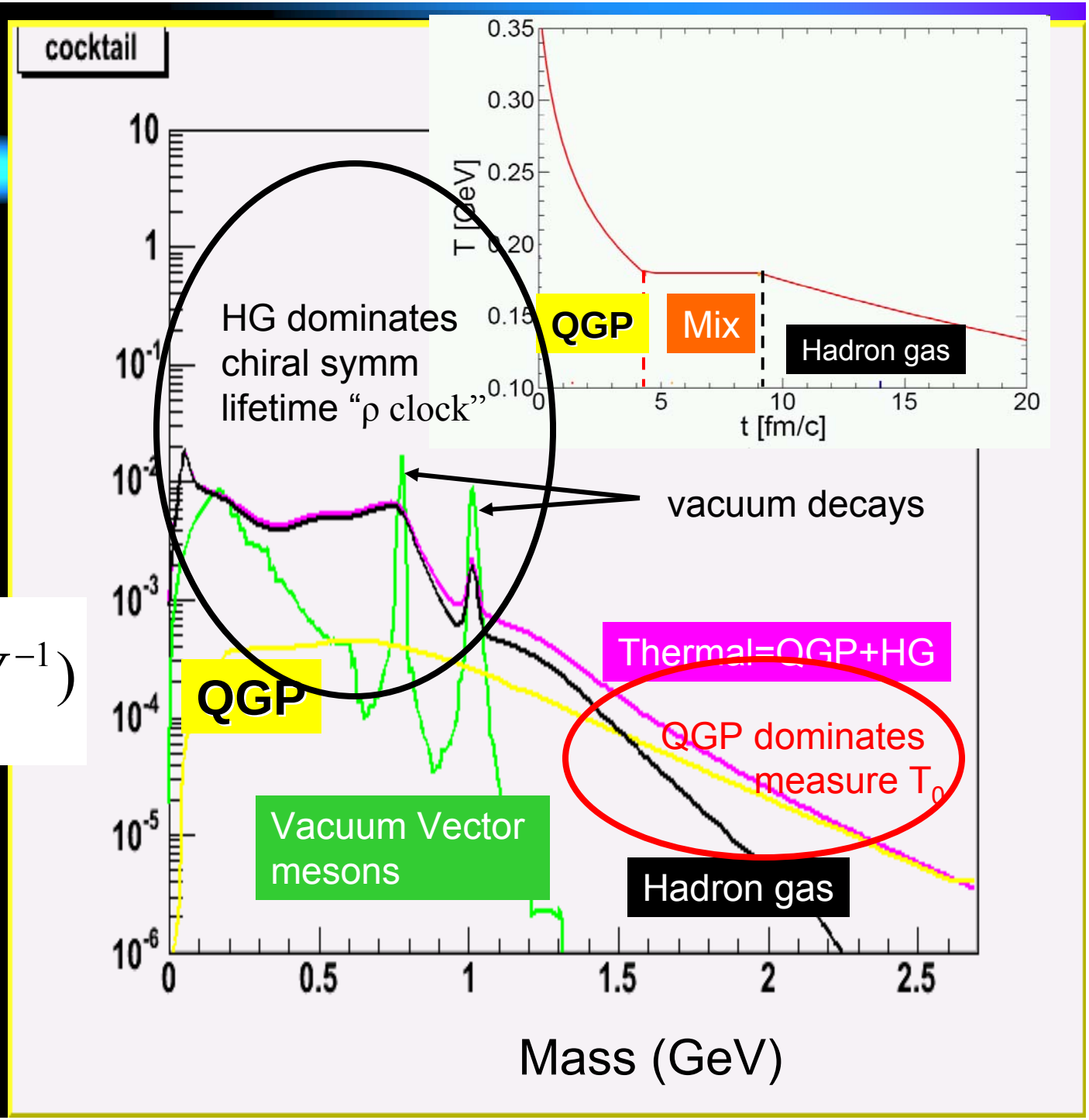
10^{10} MB events 10^{9} central

all plots dN/dMdy (GeV^{-1})

emission from the "QGP"

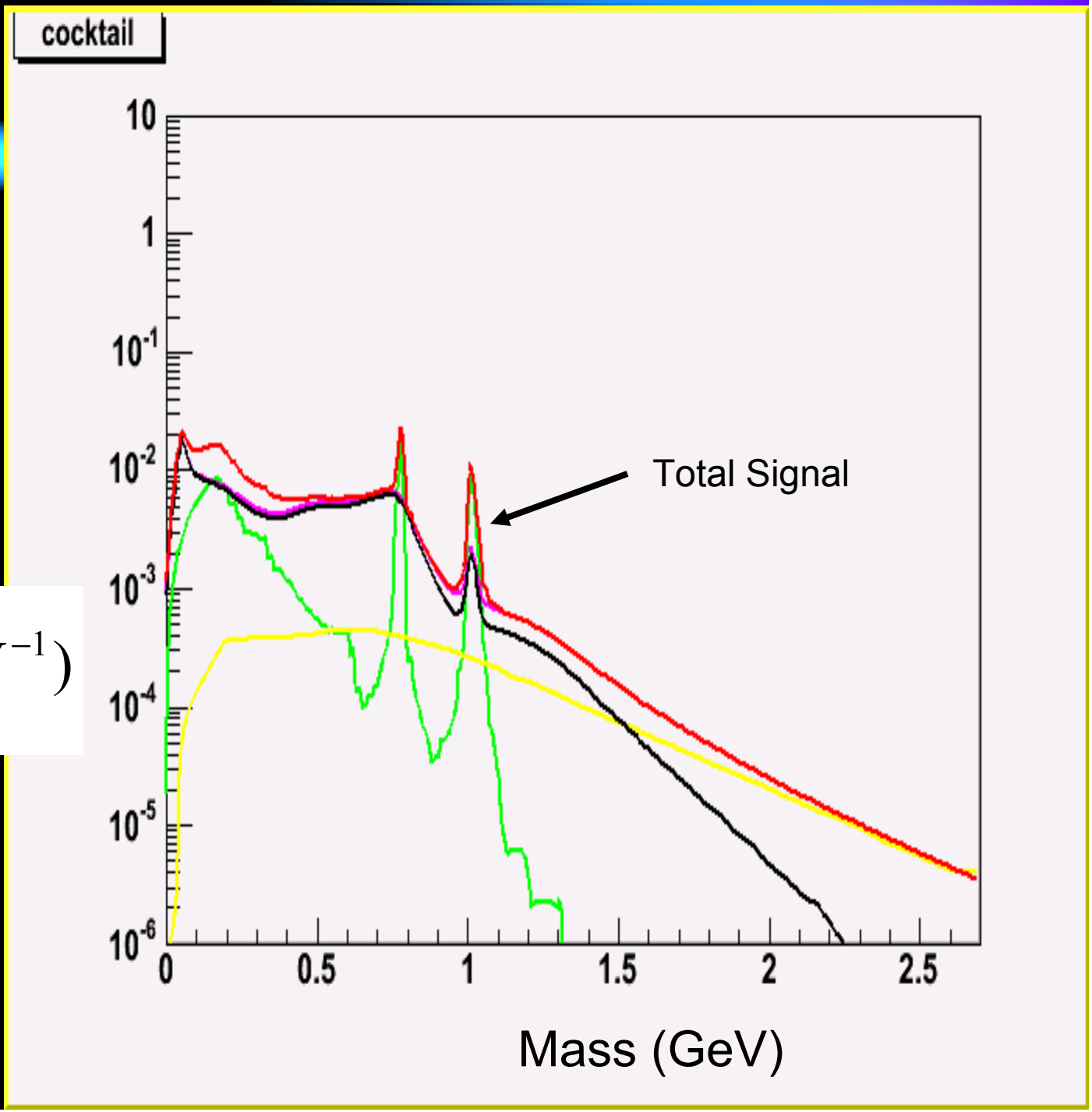
$$\frac{dN}{dMdy}(GeV^{-1})$$

R. Rapp
e.g. hep-ph
0010101



Total signal

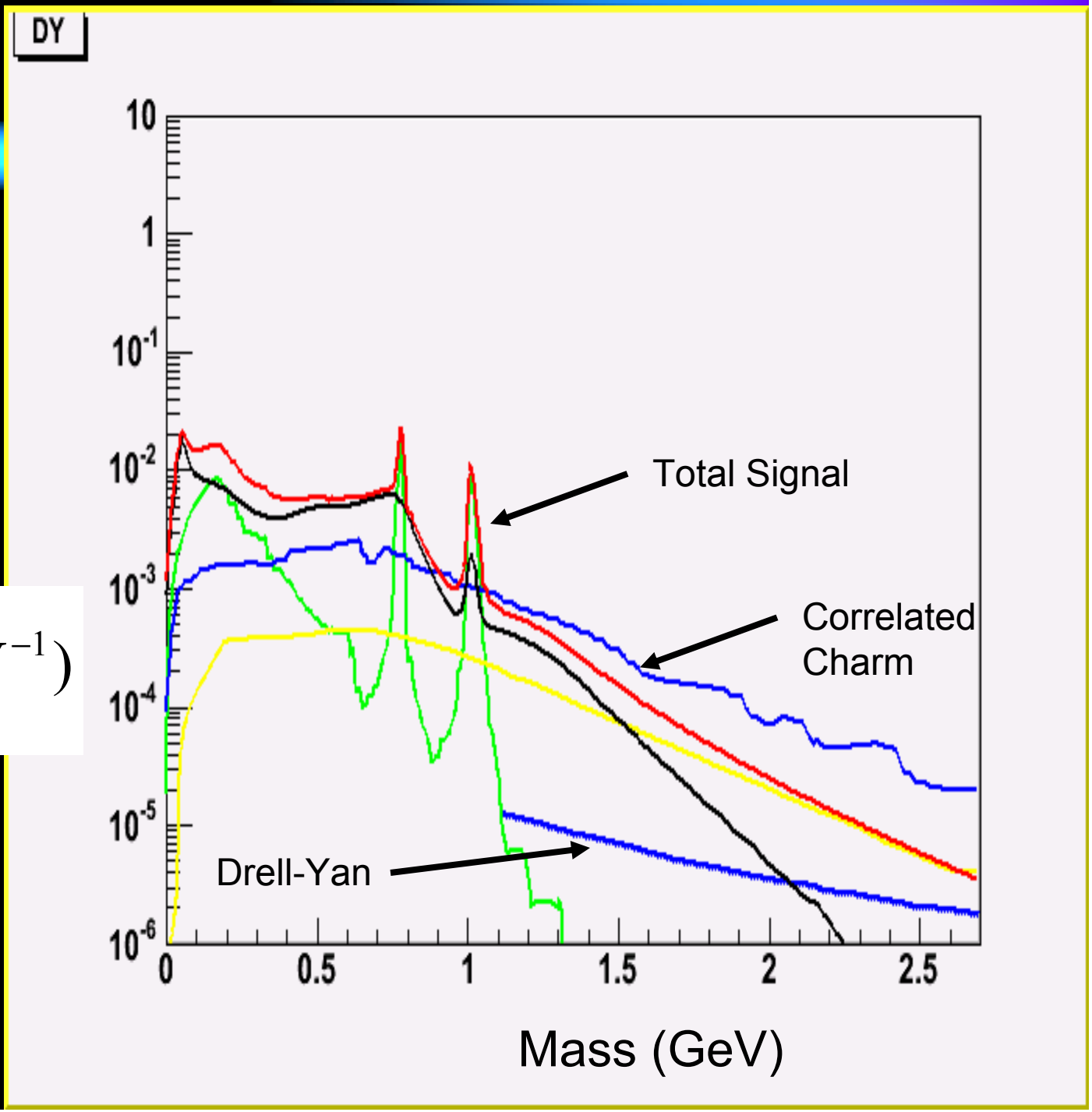
$$\frac{dN}{dMdy}(GeV^{-1})$$



Correlated background

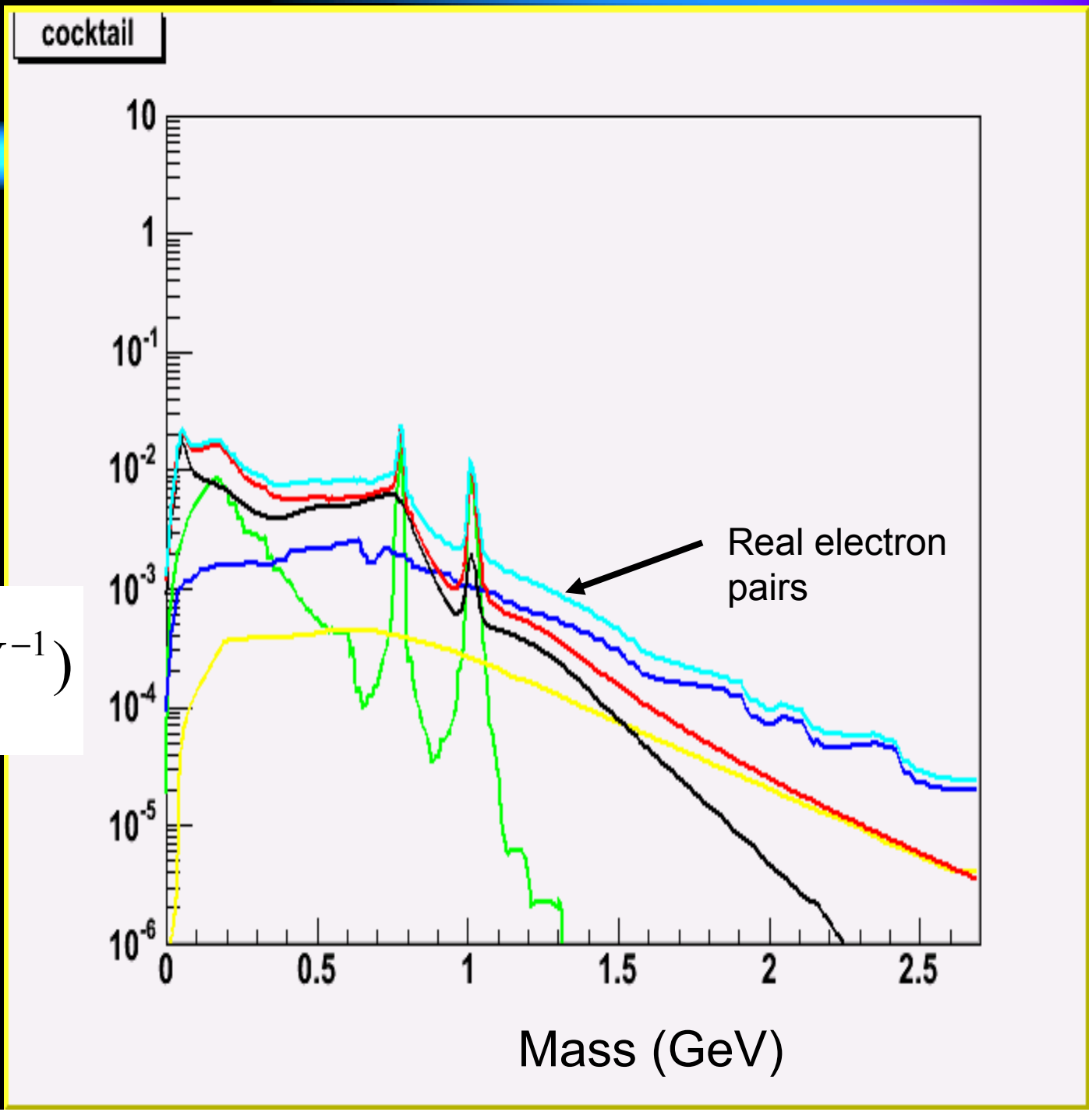
- DY not a problem
- Charm IS a problem
- Cannot use mixed event to subtract

$$\frac{dN}{dMdy}(GeV^{-1})$$



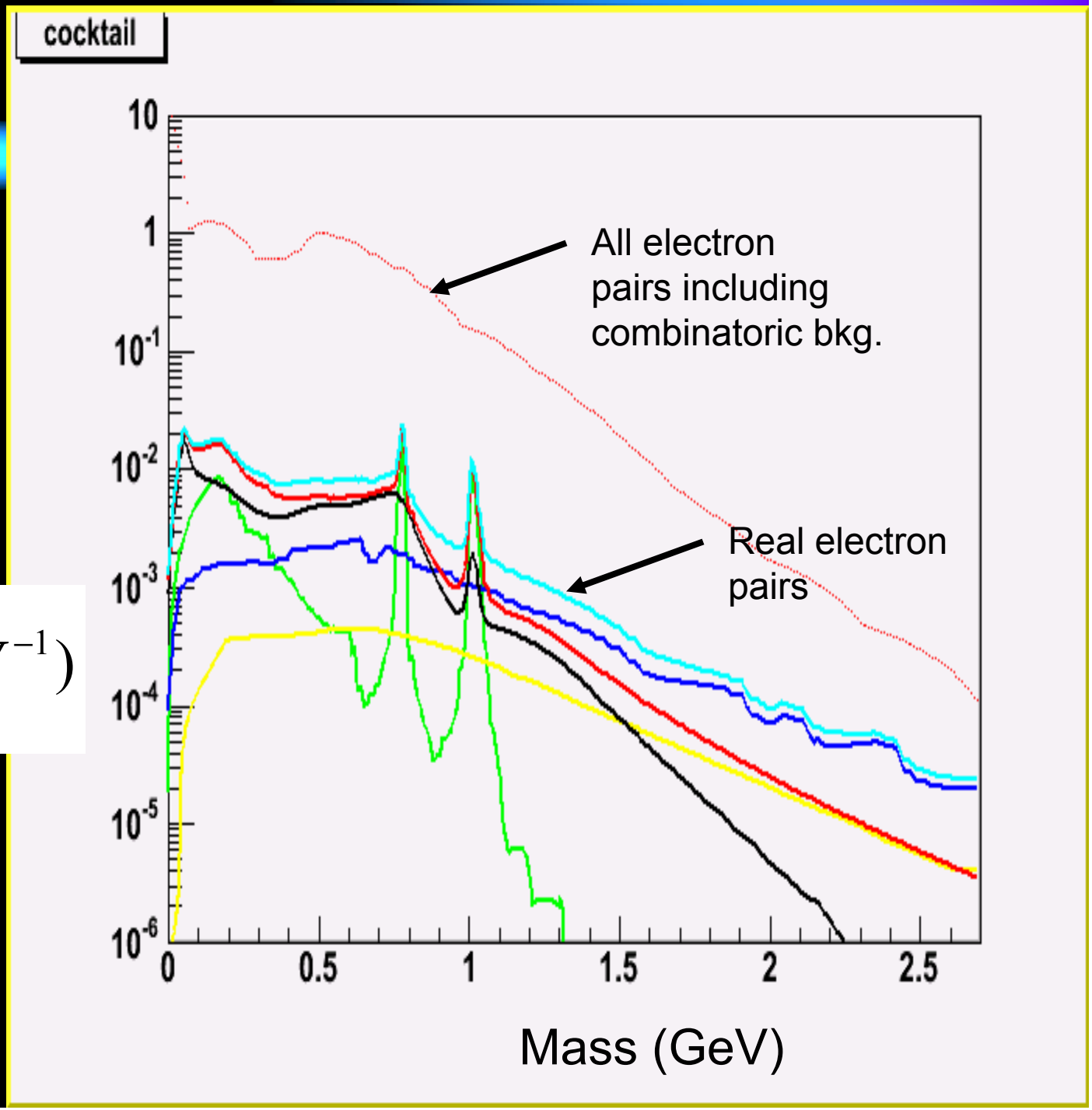
what you will see

$$\frac{dN}{dMdy}(GeV^{-1})$$



Start the analysis

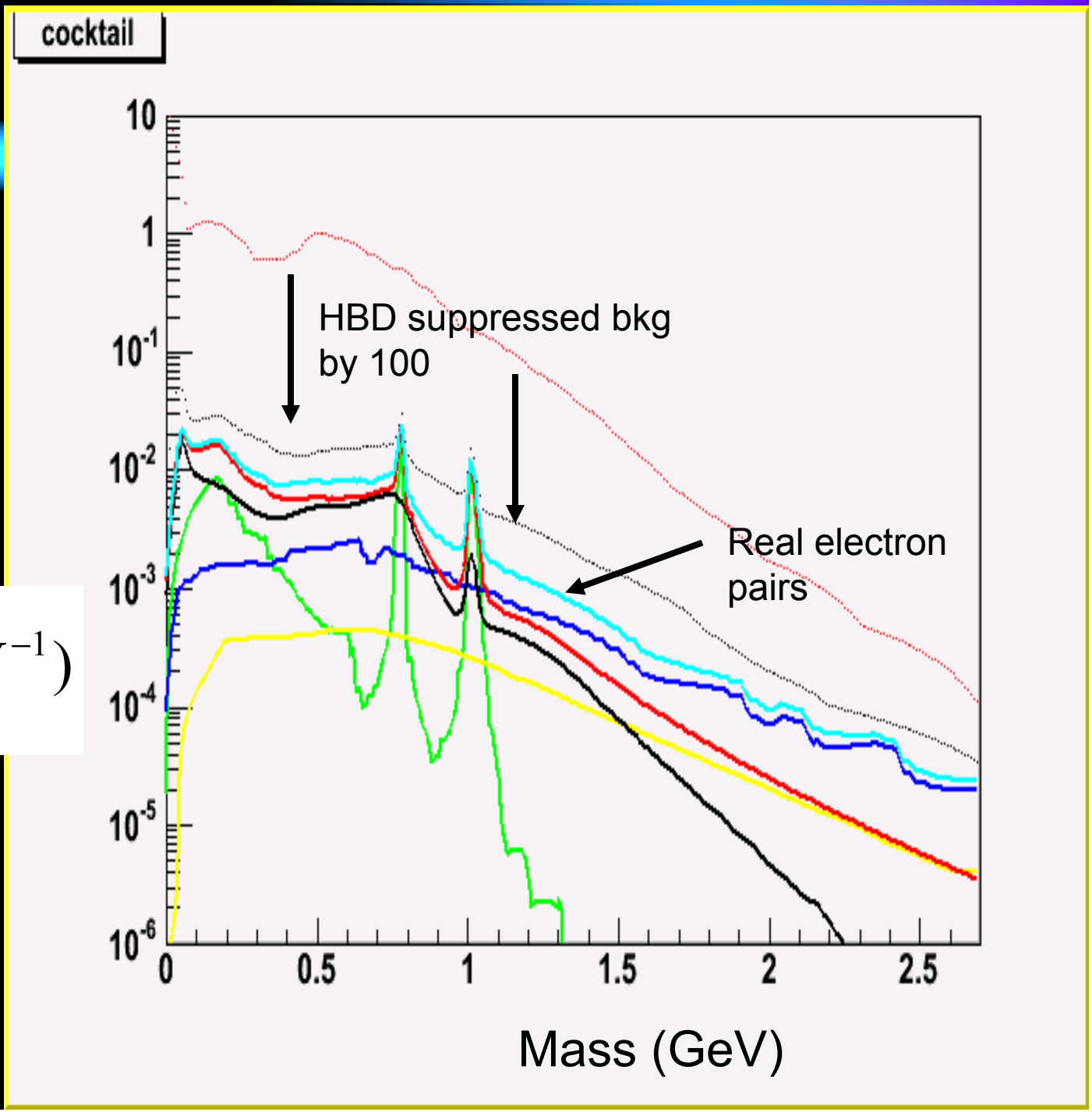
$$\frac{dN}{dMdy}(GeV^{-1})$$



hbd

- use hbd to kill small angle electron pairs
- suppress bkg by 100

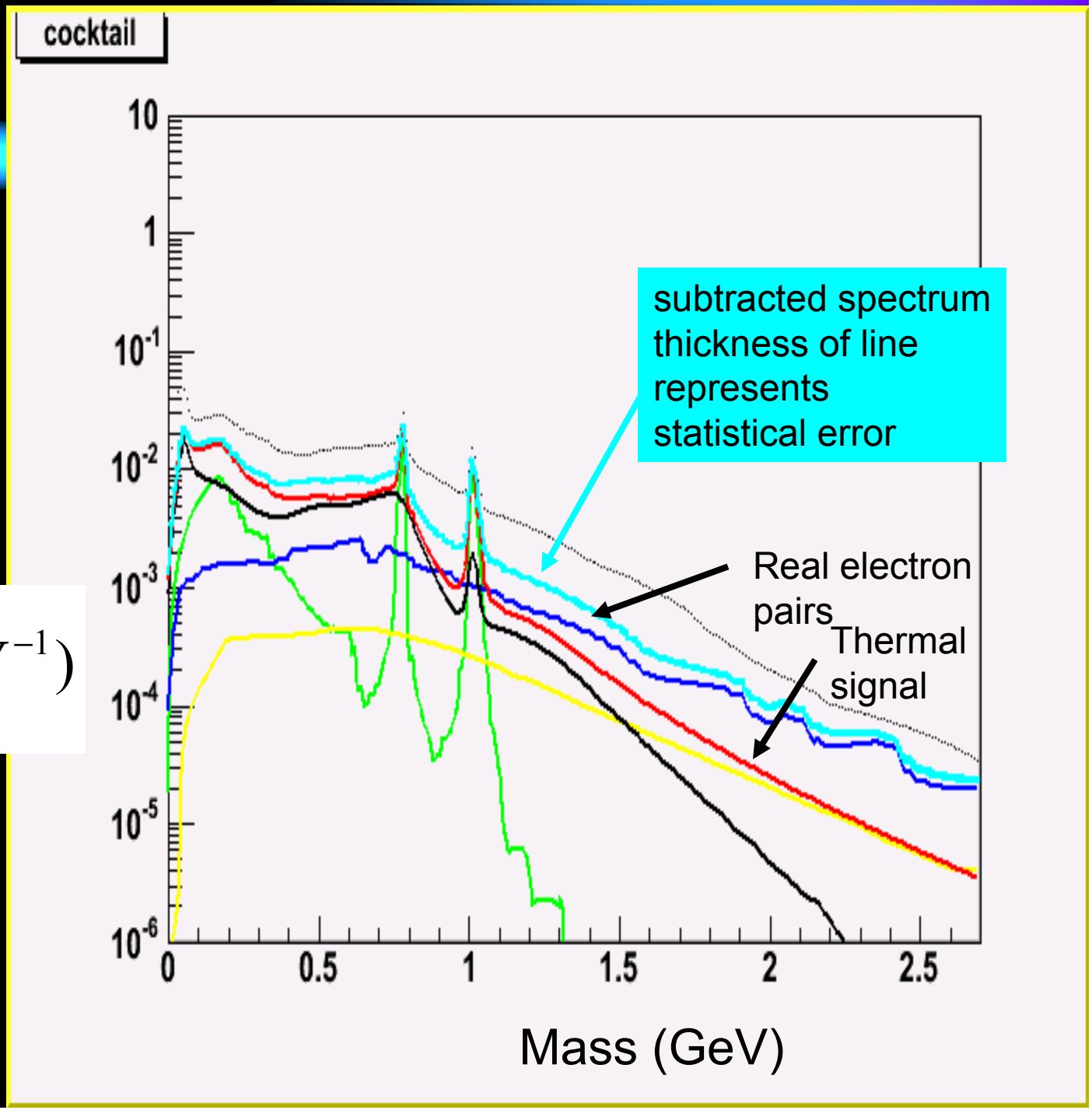
$$\frac{dN}{dMdy}(GeV^{-1})$$



mixed events

use mixed event bkg to subtract combinatorics

$$\frac{dN}{dMdy}(GeV^{-1})$$



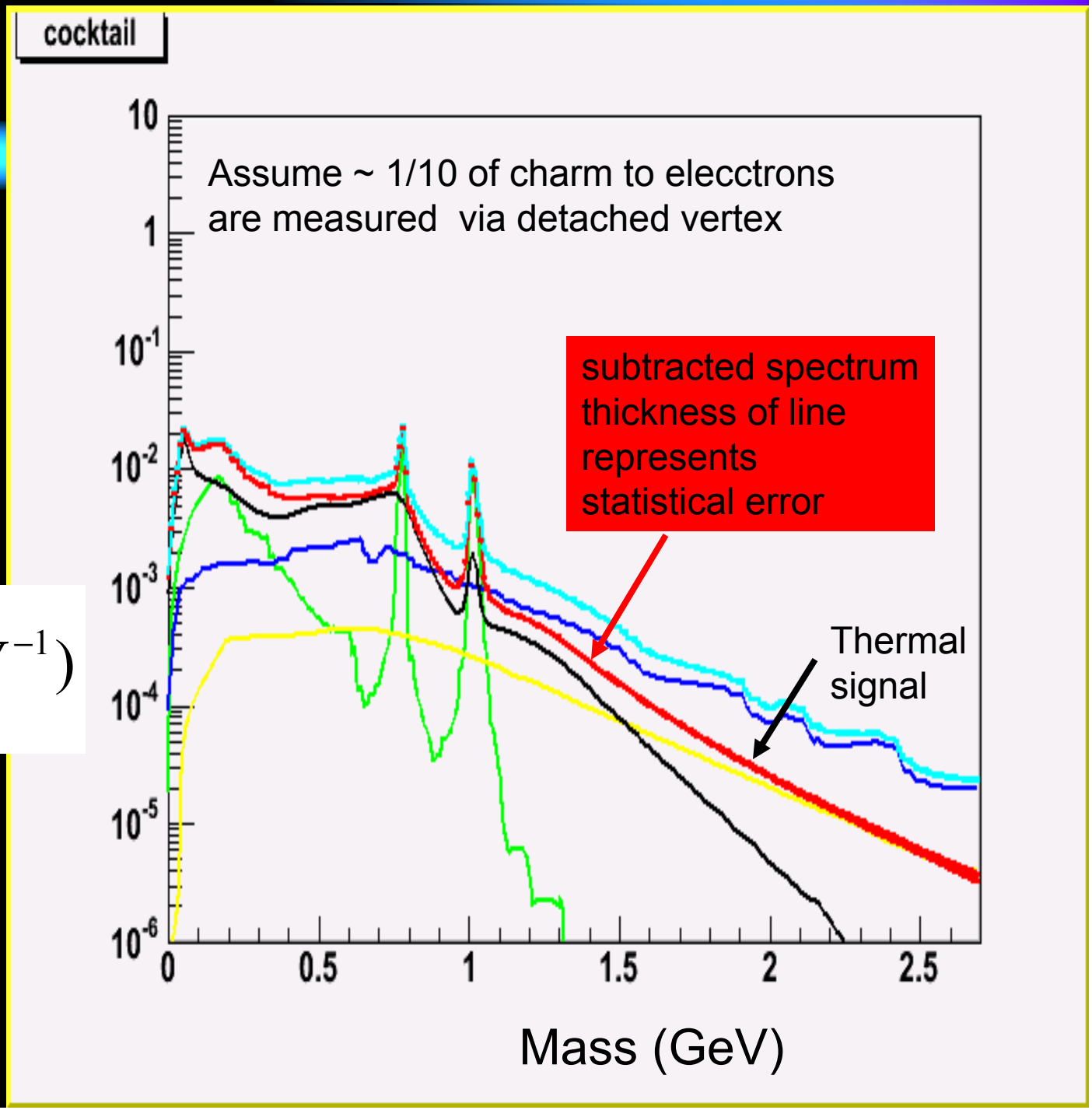
Now measure charm and subtract

RHIC II statistics

$$\frac{dN}{dMdy}(GeV^{-1})$$

- 2M charm
  - p_T>1 GeV +DCA

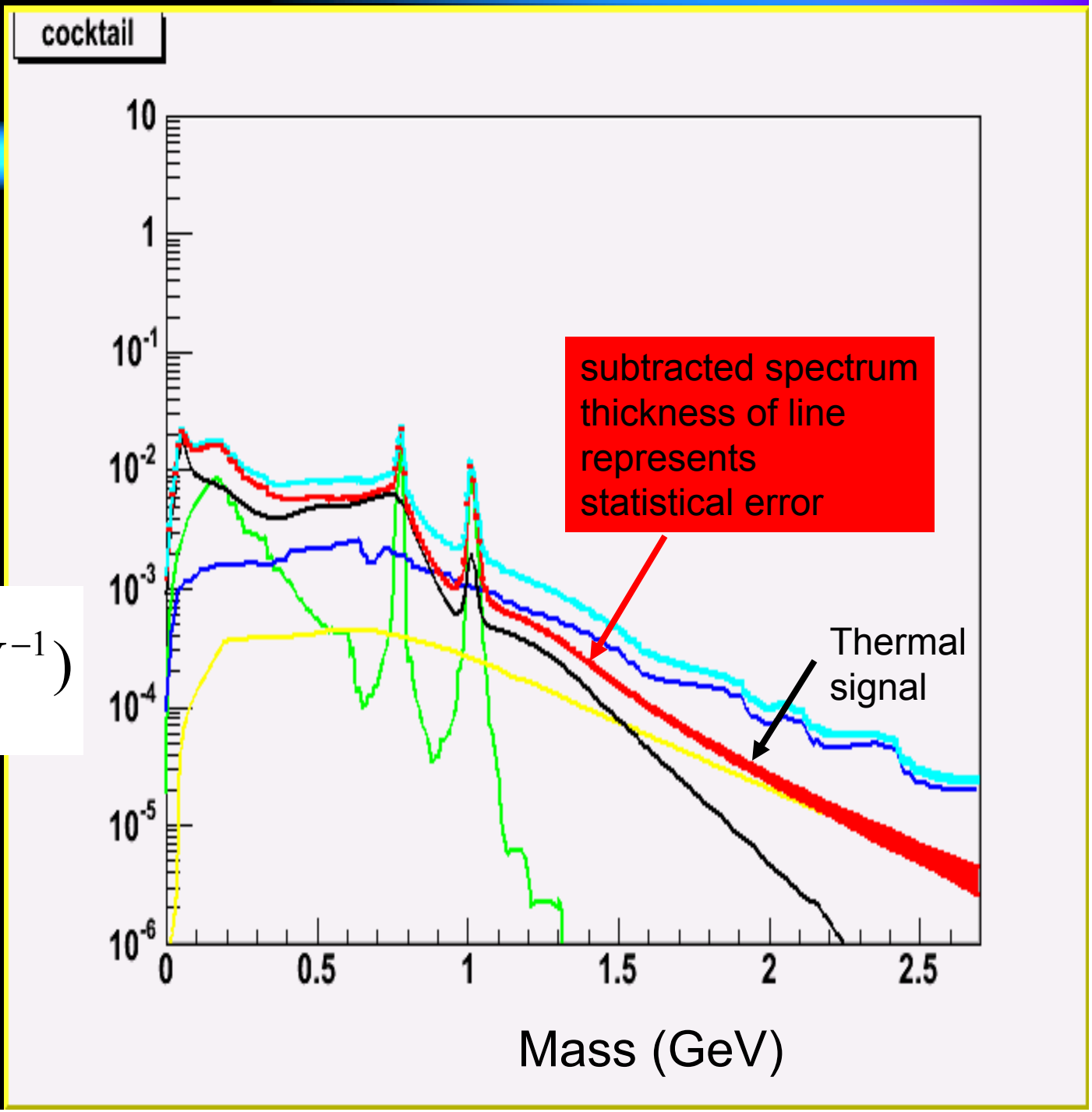
1.5% at m=2GeV



Now measure charm and subtract

RHIC I statistics

$$\frac{dN}{dMdy}(GeV^{-1})$$

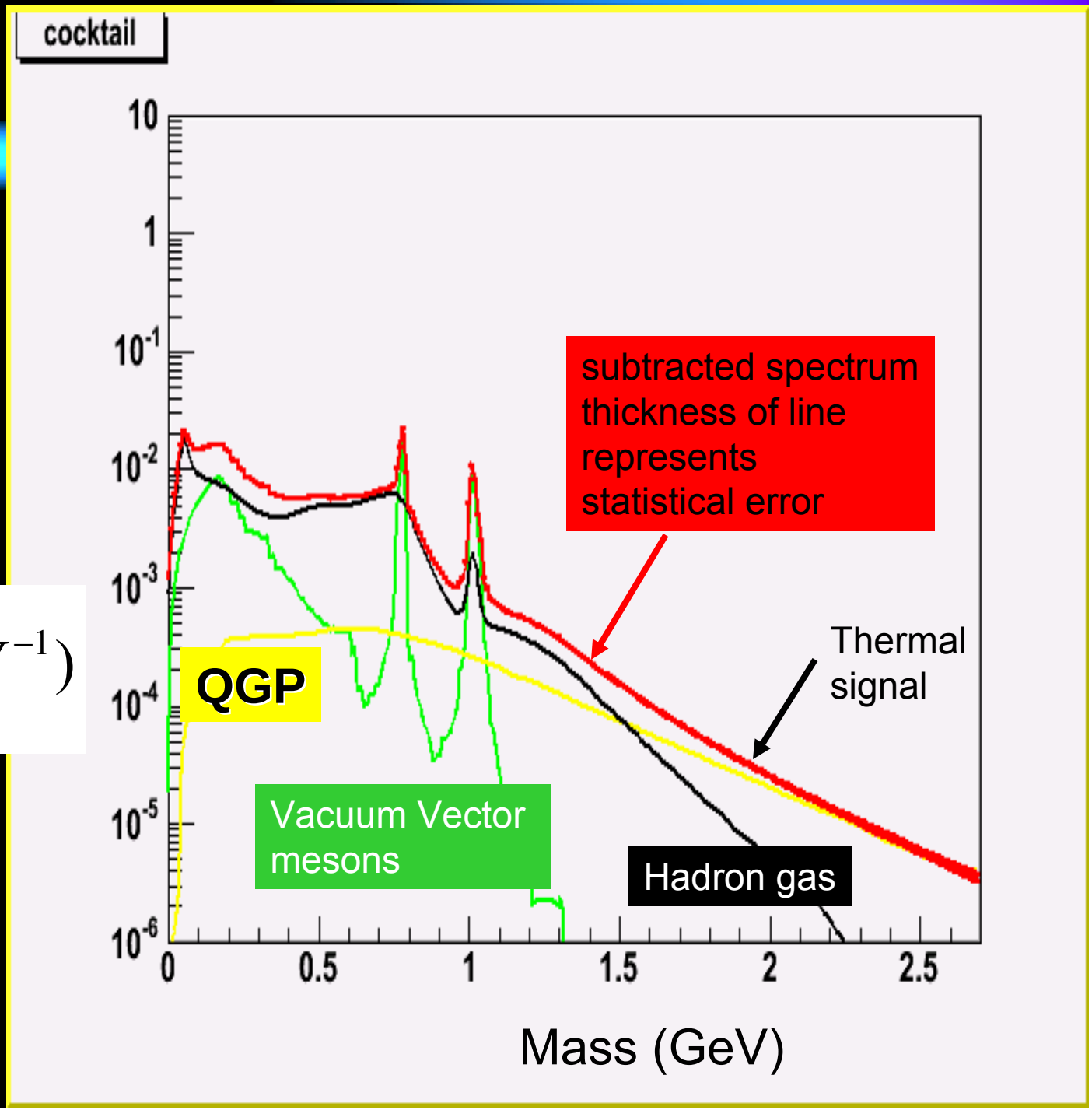


5% at m=2GeV

Use theory

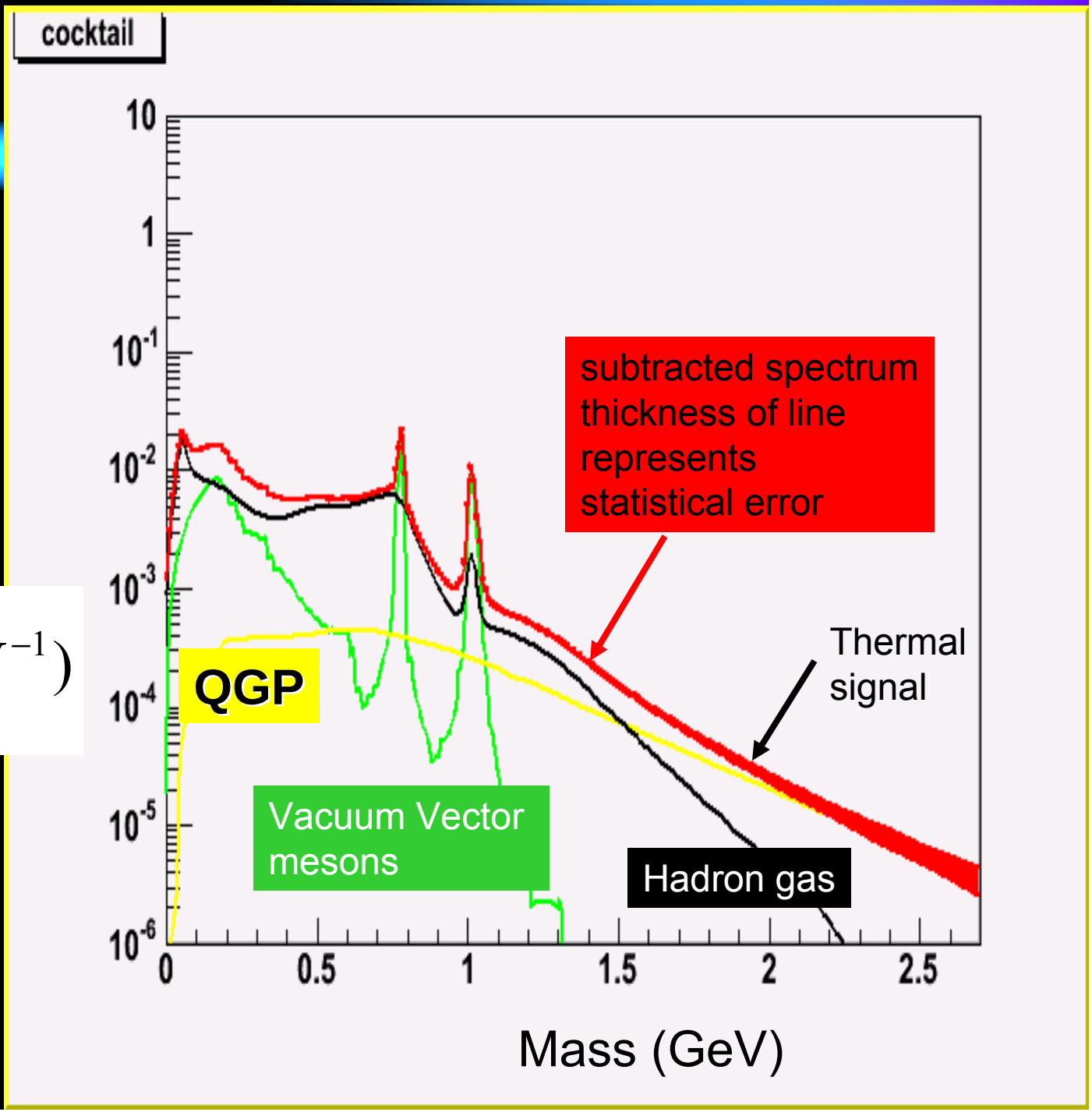
Find T and lifetime

$$\frac{dN}{dMdy}(GeV^{-1})$$



rhic 1

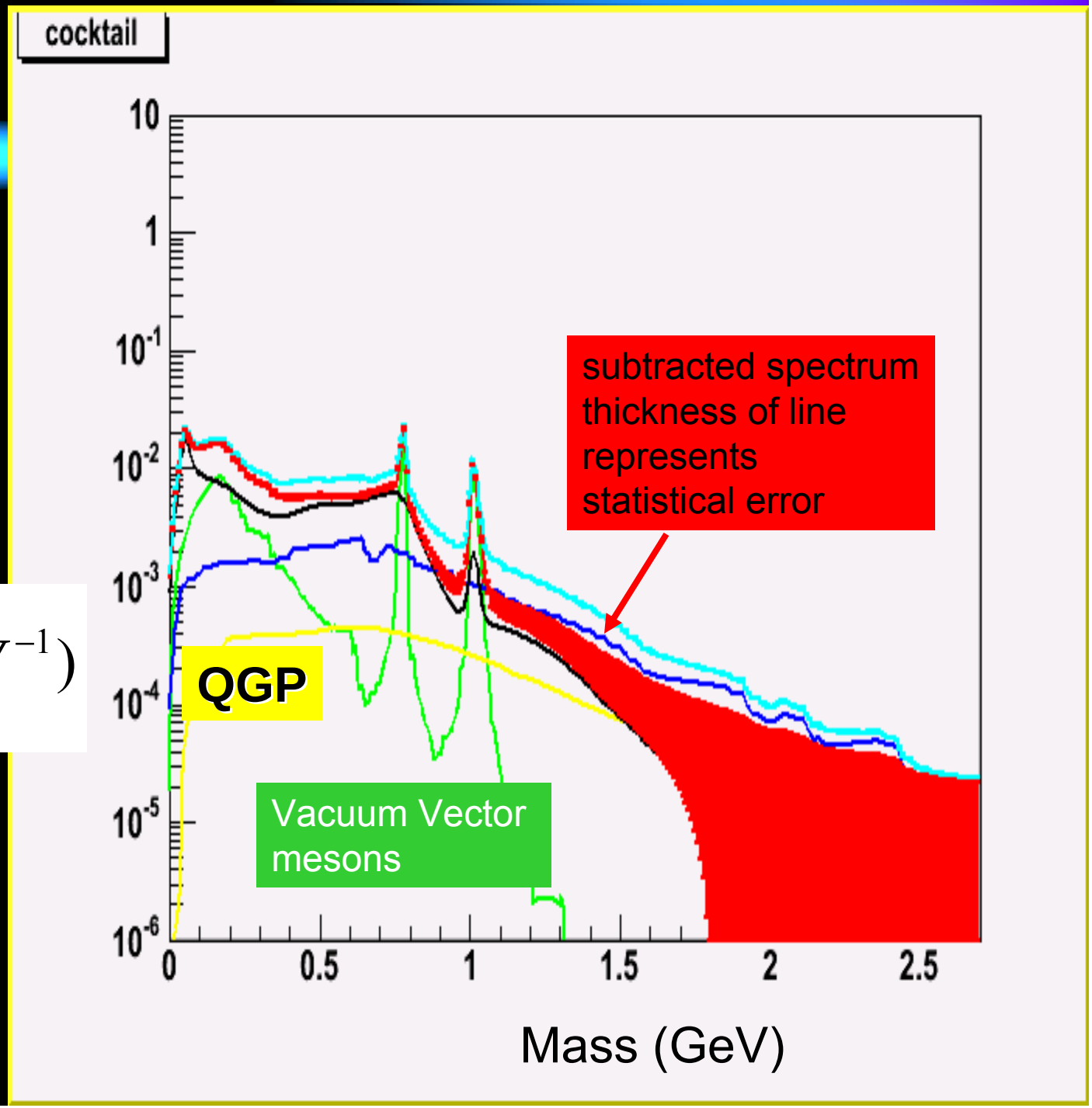
$$\frac{dN}{dMdy}(GeV^{-1})$$



crude charm rhic 2

15% at m=2GeV

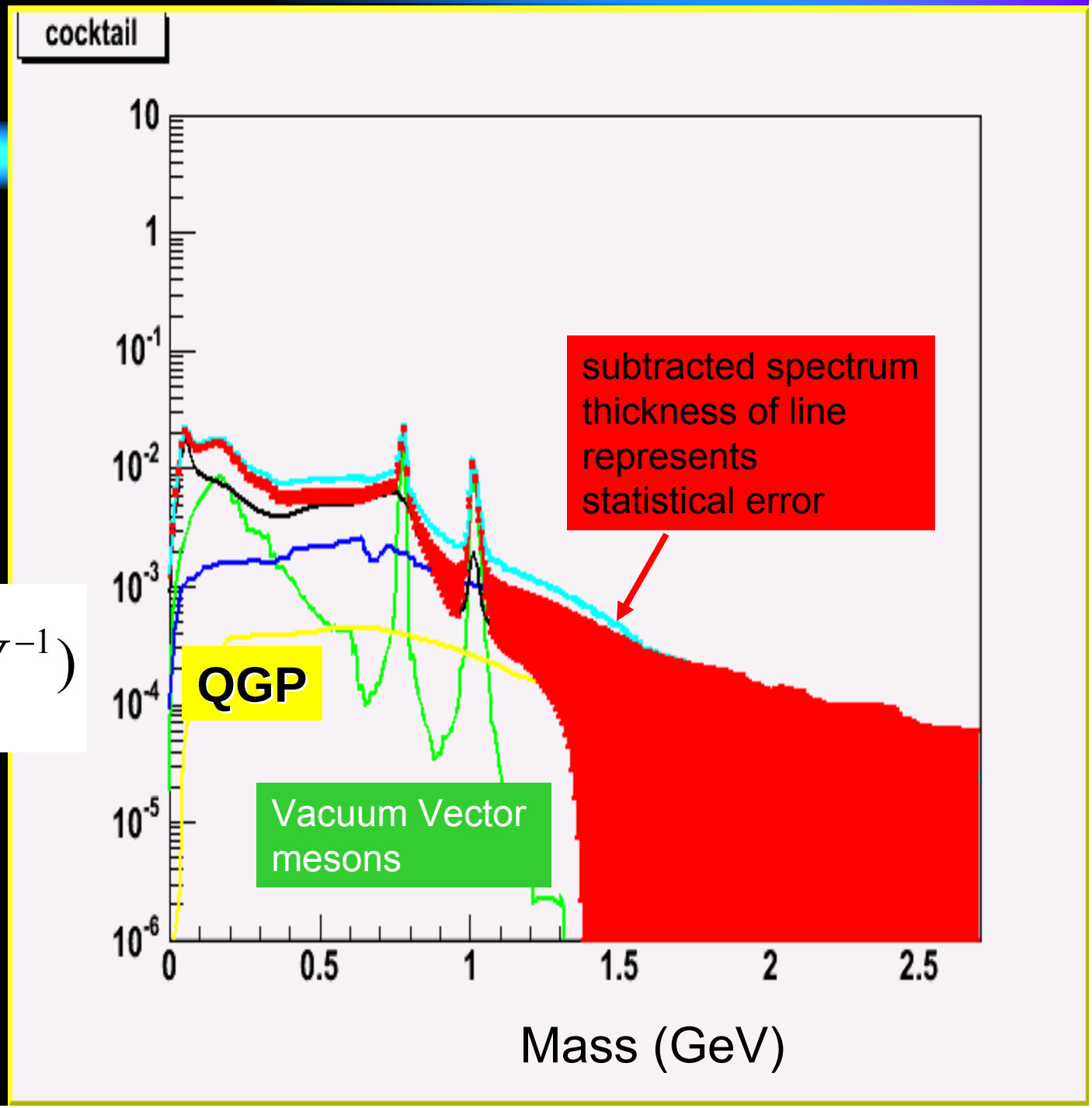
$$\frac{dN}{dMdy}(GeV^{-1})$$



crude charm rhic 1

45% at m=2GeV

$$\frac{dN}{dMdy}(GeV^{-1})$$



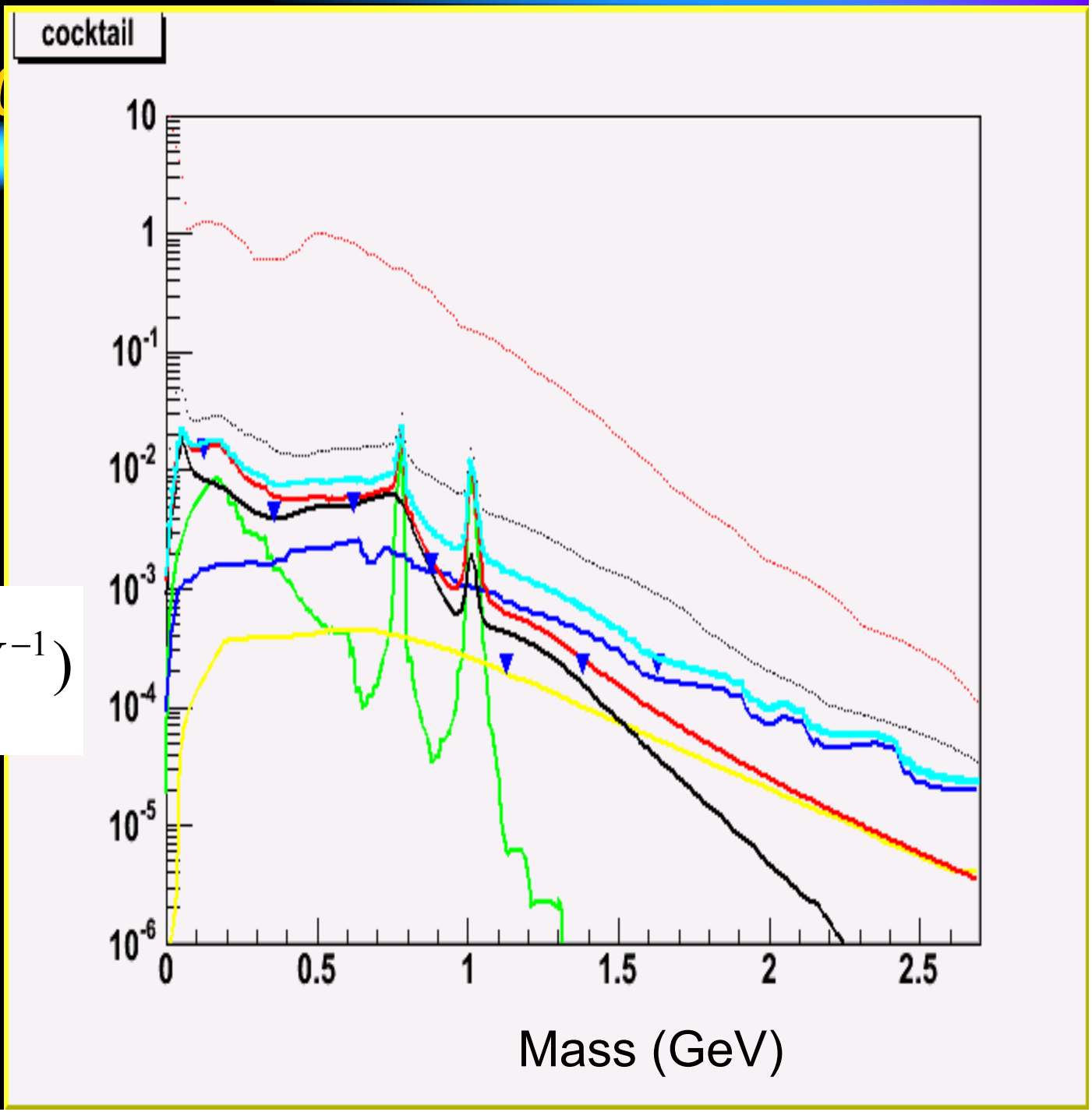
Conclusions

- Task of measuring di-electrons
  - Low mass regions
    - Dalitz suppression important
    - crude charm measurement probably good enough for low mass VM
  - IMR
    - Charm crucial for the measurement of T (IMR)
  - RHIC 2 needed in order to do a full exploration of energy/species

Questions

- Is the Kharzeev-Tuchin idea right?
  - How can we prove/disprove it
  - can we really "calibrate" $N_{part}(T)$
- Can we use the dilepton/direct photon spectrum to disentangle
  - T_0
  - $T_{Critical}$
  - Lifetime?
- Mass vs p_T ?? as additional handle to separate effects?
- Can we lay out a program to pin down the EOS using our new suite of detectors?
  - e.g. 3 energies (20,64,200)
  - 5 species (pp, dAu, OO, CuCu, AuAu)
  - 15 combinations at 5 combinations/year=3 years

a factory: the QCD "genome" project

backup slid

$$\frac{dN}{dMdy}(GeV^{-1})$$