Electron Measurement at PHENIX

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Electron measurement

+ "penetrating probe" carrying early stage of the nuclear collision

- small cross section, huge background (mainly from π^0 Dalitz decay

Proposed signatures

- J/Ψ suppression
- Charm (thermometer)
- dilepton continuum
- vector mesons (phi/omega/rho)
  - change in mass, width
  - "secondary peak"
  - rho as "clock"
  - phi ehancement
  - etc,etc

Experimental constraint

small acceptance
large background (π^0 Dalitz,etc)
small event rate (L = 2×10^{26})

Acceptance (new proposal)
$33.75 < \phi < 123.75$
$-0.35 < \eta < 0.35$

dYdϕ ~ $0.35\times2\pi$ for single paricle
3-4%*dσ/dy for pair

Electron ID
p < 5 GeV/c for RICH(C_2H_6)

I want to evaluate how well we can address proposed "signatures" of QGP in our experiment

I. J/Ψ suppression

Event Rate for J/Ψ,Ψ(2S)

L = 2 x 10^{26} (Au + Au)
1 year = 1.08 x 10^{7} sec
Ldt = 2.16 nb^{-1} per year

Bdσ(pp->J/Ψ)/dy ~ 50 nb ($s^{1/2}$=200GeV)
BdN(AuAu->J/Ψ)/dy = ?

If we assume σ(AA) = $A^{2\alpha}$,α = 0.92
dσ/dy(Au+Au-->J/Ψ-->ee)(min. bias)
~ 0.83 mb

dN/dy(per year) ~ 1.8 million

Acceptance ~ 4% of dN/dy

N(J/Ψ accepted)~ 70K/year (min.bias)
~ 14K/year (central)

N(Ψ(2s) accepted)~ 1.4K/year
~ 300/year

If we have "J/Y suppression" as expected in QGP, there will be almost no cevents for central collisions.

Pt distribution

It is pointed out that J/Ψ cross section should be measured for wide range of pt to clarify "J/Ψ suppression" mechanism.

There are a few measurement of J/Ψ at high transverse momentum.

$s^{1/2}$= 63 GeV B$d\sigma/dy$ ~ 5pb (Pt>5GeV/c)
$s^{1/2}$= 630 GeV B$d\sigma/dy$ ~ 1.7nb(pt>5GeV/c)
$s^{1/2}$= 1.8 TeV B$d\sigma/dy$ ~ 6.9nb(pt>6GeV/c)

From those values, I estimate that
Bds/dy ~ 200pb for pt>5GeV at s = 200GeV

Acceptance ~ 2% of $d\sigma/dy$

If we assume that α=1 at high pt, we expect ~300 (~60) events above pt>5GeV/c for min. bias (central) events.

Although the statistics is limited, we can probably cover pt distribution of J/Ψ up to 6-7 GeV/c.
For Ψ(2S),higher luminosity is needed to measure high pt cross section.

II. Charm production

Enhanced production of charm quark is proposed as a "signature" of QGP, as well as a sensitive "thermometer" of early stage of H. I. collisions.

Charm is also a major background source for di-lepton measurement.

It is important to understand the charm production at RHIC in pp, pA and AA collisions.

Charm Production cross section

Measurements at low energy

$s^{1/2}$ = 28GeV	$\sigma_{c\bar{c}}$ =15 +- 2μb	(NA27)
$s^{1/2}$ = 40GeV	$\sigma_{c\bar{c}}$ =24 +- 5μb	(E743)
	$\sigma_{c\bar{c}}$ =18 +- 4μb	(E789)
	$\sigma_{c\bar{c}}$ =38 +-13μb	(E653)

QCD calculation predicts that charm cross section will increase by factor ~10 from $s^{1/2}$=40 to 200 GeV.
--> Charm cross section σ(pp->cc) is 150-250μb at RHIC energy ($s^{1/2}$=200GeV)

The nuclear dependence α ($\sigma(pA) = A^{\alpha}$) of charm cross section is found as α ~ 1.0 near mid rapidity (y~0 or x_F~0).
α = 1.02+-0.03+-0.02 $\langle x_F \rangle$=0.03 (E789)
This is consistent with QCD gluon fusion model.

If we assume that $\sigma(pp\to c\bar{c})$ is 160μb at RHIC, ~4.8 charm pairs are expected in a central Au+Au collision. (X.N.Wang pointed out this number is reduced by ~50% by nuclear shadowing)

Charm detection by single electron measurement

Leptonic decay of Charm

D^+ --> e X (B.R. = 17.2 +- 1.9%)

D^0 --> e X (B.R. = 7.7 +- 1.2%)

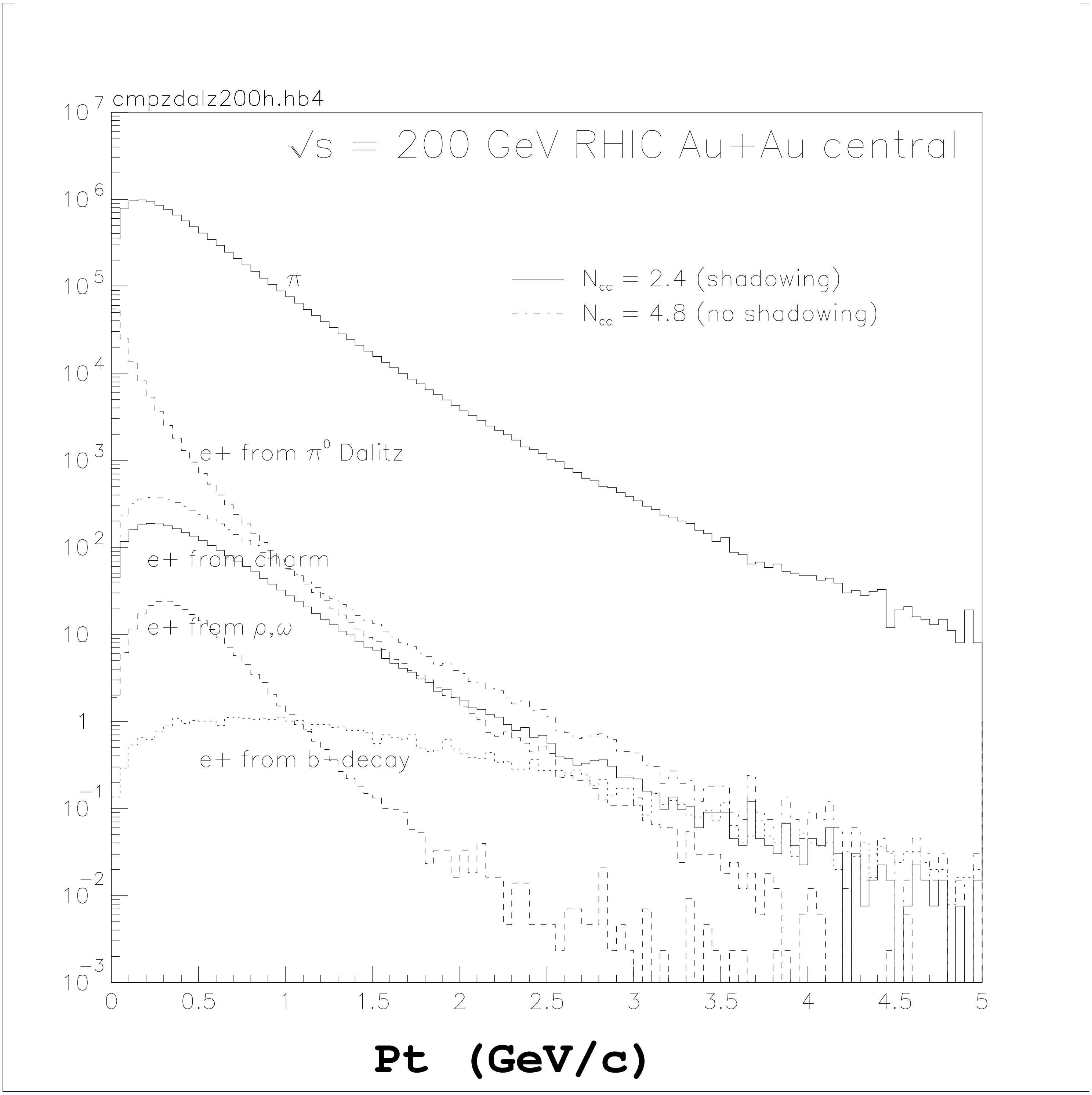
In average, 12% of charm decays into electron(positron).

The daughter electron can be observed as "single electron" at high pt.

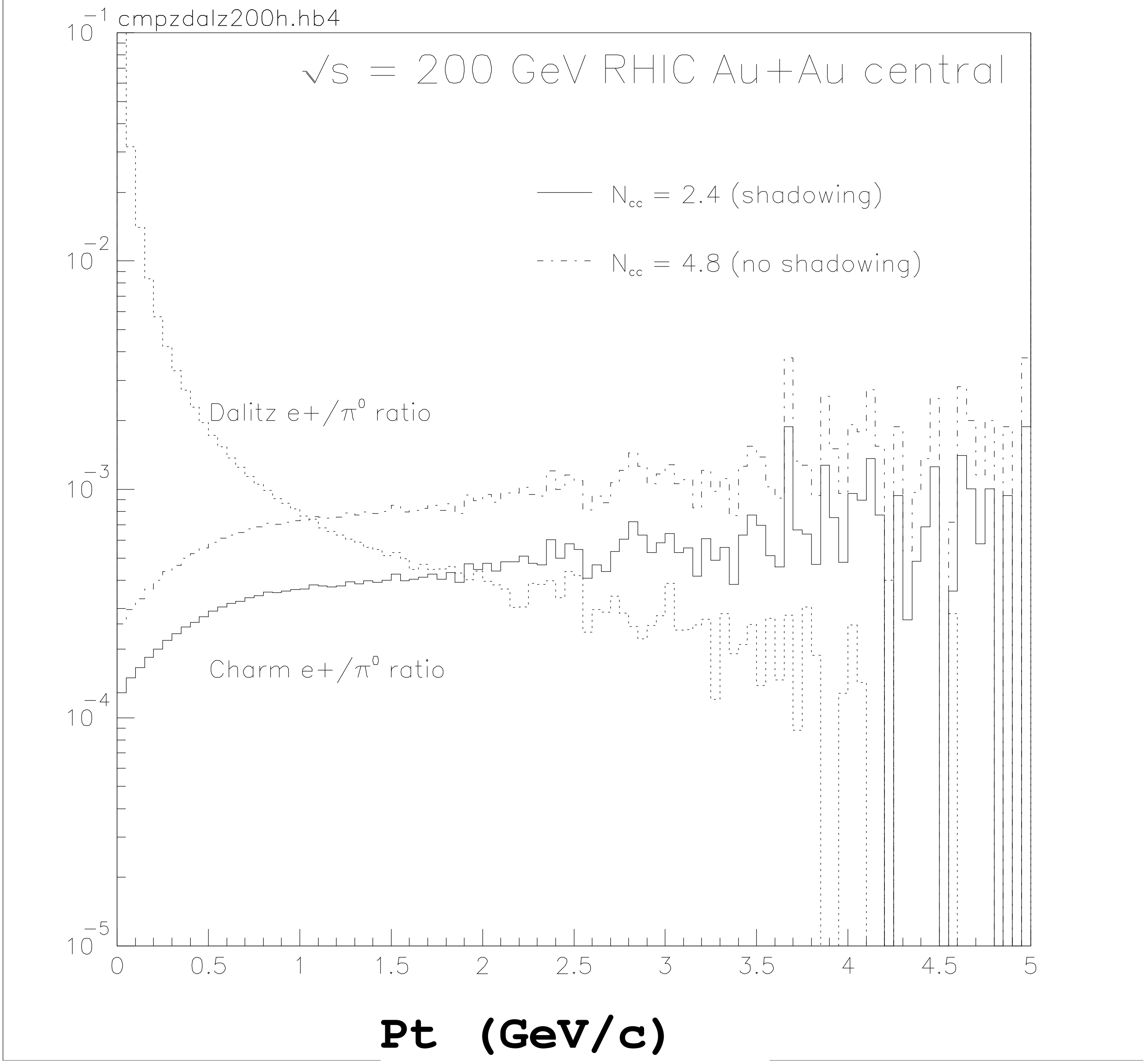
I estimated the yield of charm decay electrons in Au+Au central collision, and compare it with electron yield from π^0 Dalitz decay

As a check of the calculation, I also calculated the electron spectrum from charm decay at $s^{1/2}$=53 GeV, and compare it with "single electron measurement" at ISR.

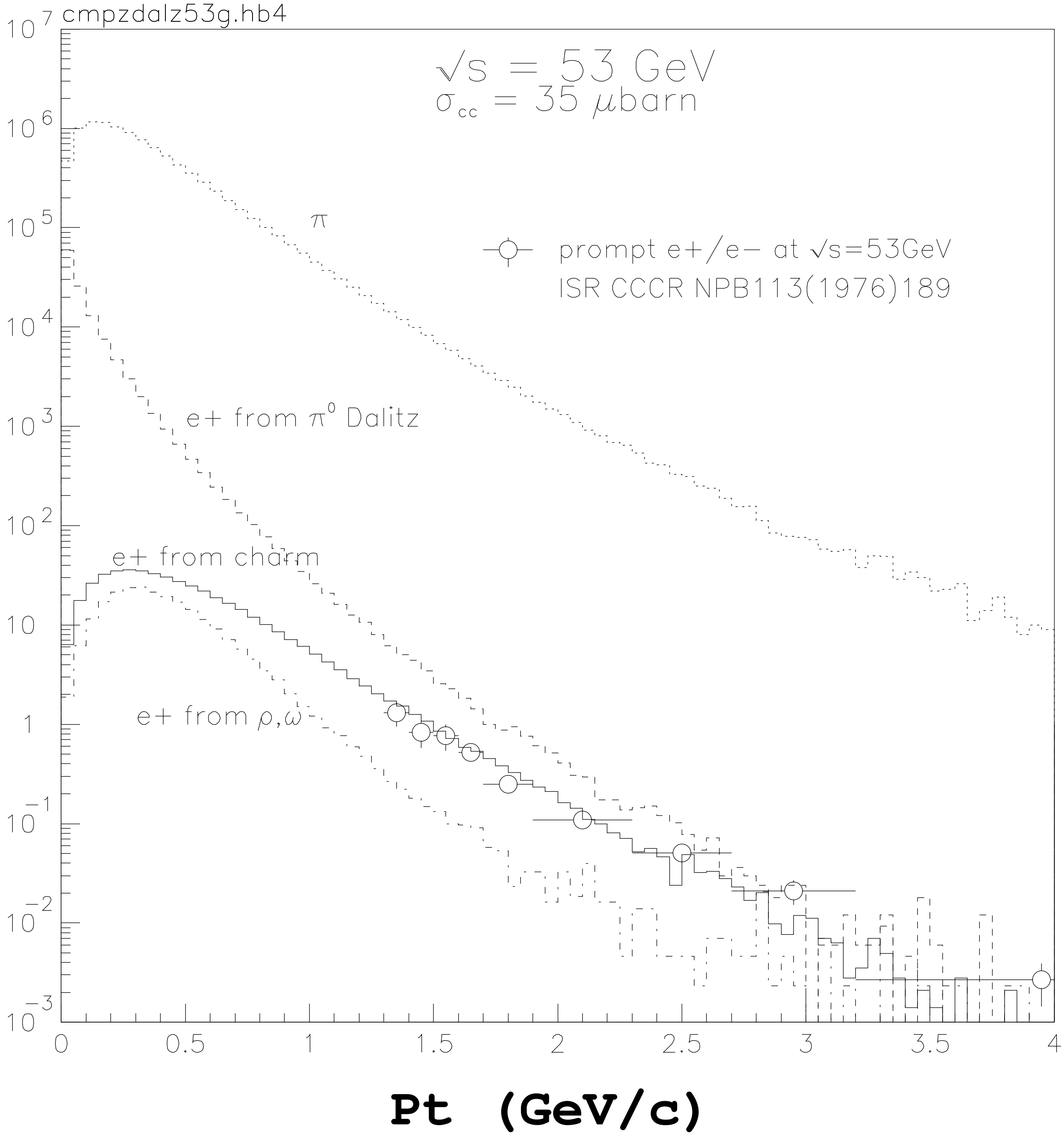
"single electron" spectrum in Rhic Au+Au central collisions



e/π ratio at Rhic Au+Au



Comparison of "charm electron" calculation with experiment ($s^{1/2}$=53GeV)



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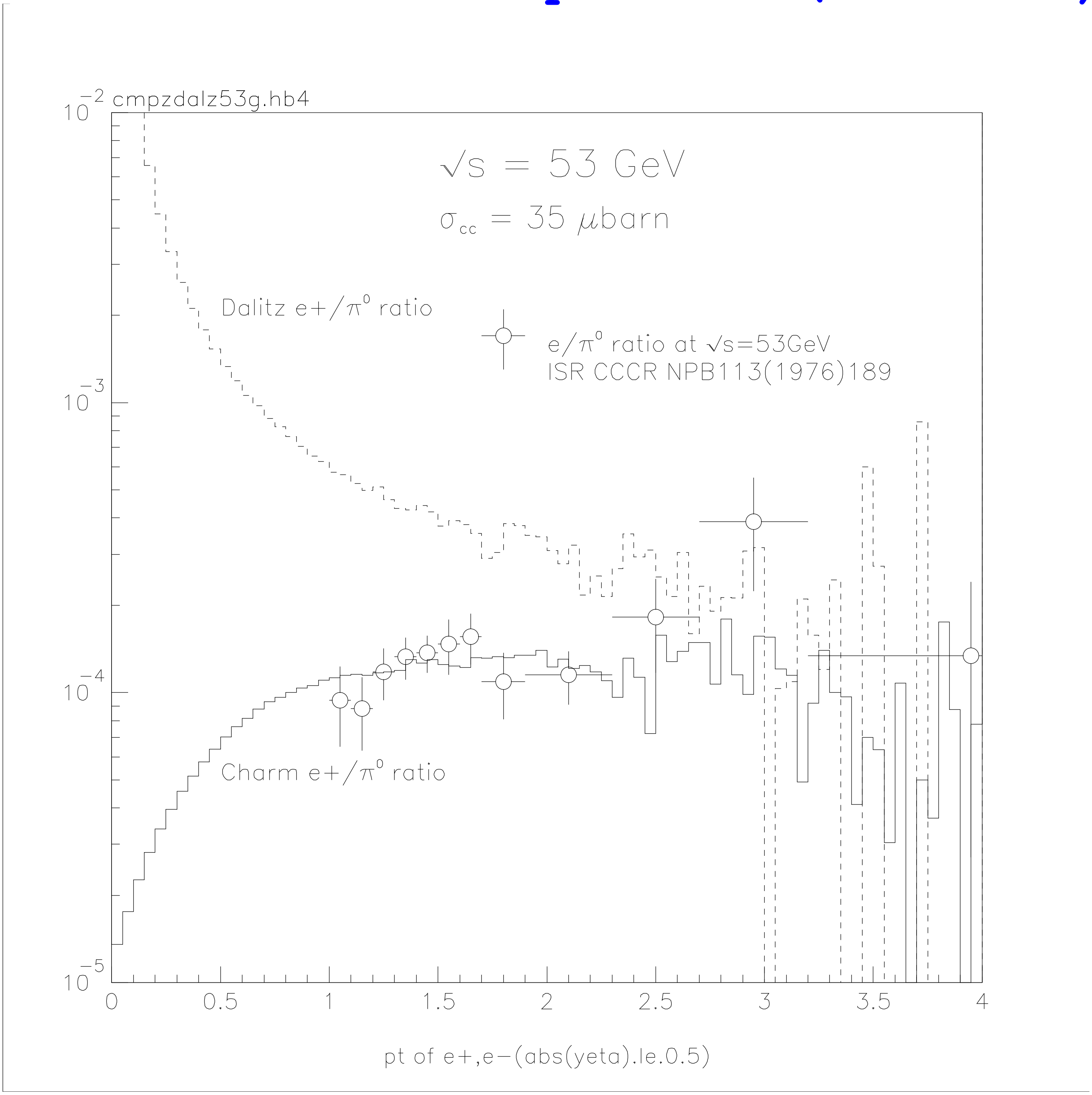


Inputs for the calculation:

π^0 pt distribution

UA1 parameterization at $s^{1/2}$=200GeV

D/D* pt distribution

calculated by ISAJET7.6

D* decays to

$D+\pi$ (82%)

$D+\gamma$ (18%)

D decays to

$Ke\nu$	(42%)
$K^*(892)e\nu$	(27%)
$\pi e\nu$	(3%)
$K(1270)e\nu$	(28%)

(The first 3 is the combined B.R.of D^+ and D^0. The last one is to account for "other" leptonic branches)

The $s^{1/2}$=53GeV calculation uses the pion pt distribution measured by British-Scandinavia collaboration. D/D* pt distribution is calculated by ISAJET7.6

The charm decay electron yield is expected as large as that from π^0 Dalitz decay above pt~1.5GeV/c.

e/p ratio is ~4-5x10^{-3},compared with ~10^{-4} at ISR pp collisions. This is due to larger $c\bar{c}$ production as well as nuclear effect. (α(cc)~1, α(π)~0.7)

If there is no nuclear shadowing (or there is "pre-equilibrium production" as predicted by X.N.Wang), charm electron dominates above pt~1.0 GeV/c

Yield of electrons from vector meson decays are less than 10% of that from charm decay.

At very high pt (pt>4GeV/c), electron from b decay can be as important as that from charm. This point depends on b production cross section. Here I assume σ(pp-> $b\bar{b}$)=2.5μb and α=1.0. (UA1 reports that s($p\bar{p}$-> $b\bar{b}$)~20μb at $s^{1/2}$=630GeV)

Charm electron yield is very large.

dN(c)/dy ~ 0.6 (w. shadowing)
dN(c->e)/dy ~ 0.07

Acceptance:
 0.35*dN/dy
 10% of e from c have pt(e)>1GeV/c

N(c->e,pt>1GeV/c,accepted)
 ~ 0.0025 per central collision
 ~ 2.5M per year

Highest Pt covered is limited by e-ID capability (pt<5GeV/c) if C2H6 radiator is used for RICH

How low in pt we can measure charm electron depends on how well we can control systematic uncertainties. Pt limit as low as ~0.5GeV/c might be possible.

- accurate π^0, η measurement from EMCAL to subtract background
- low filed runs to reduce Dalitz background (only a few day will be sufficient)

III continuum

There are many predictions on di-lepton continuum from QGP.

It is difficult to compare those predictions with our di-lepton measurement capability because:

-- those predictions are "very soft"

-- Theorists use different K factors to calculate di-lepton yield. Even the rate for "Drell-Yan" are different from paper to paper.

In the following, I compare some of recent theoretical predicitons with backgrounds from charm di-lepton and from π^0 Dalitz decays.

di-lepton from charm

We expect large production of charm quarks at RHIC. They produce a large background for di-lepton continuum.

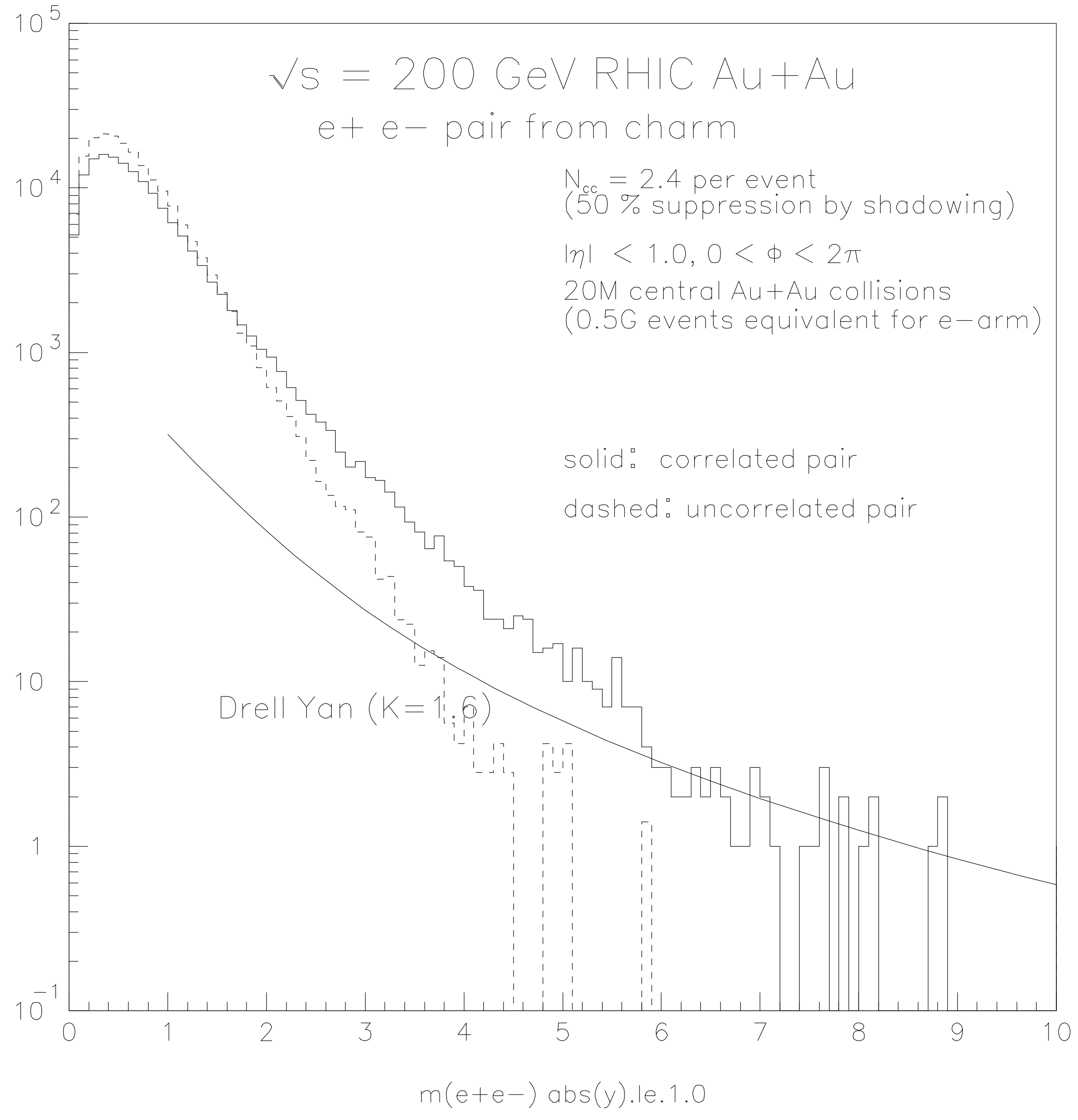
There are two kind of di-lepton pairs from charm:
(1) Correlated pair:
(2) Un-correlated pair:

Uncorrelated pair increased as N2, where N is the multiplicity of charm pair produced. They can be subtracted by unlike sign pair. Correlated pair increased as N, but can not be subtract by unlike sign pair.**

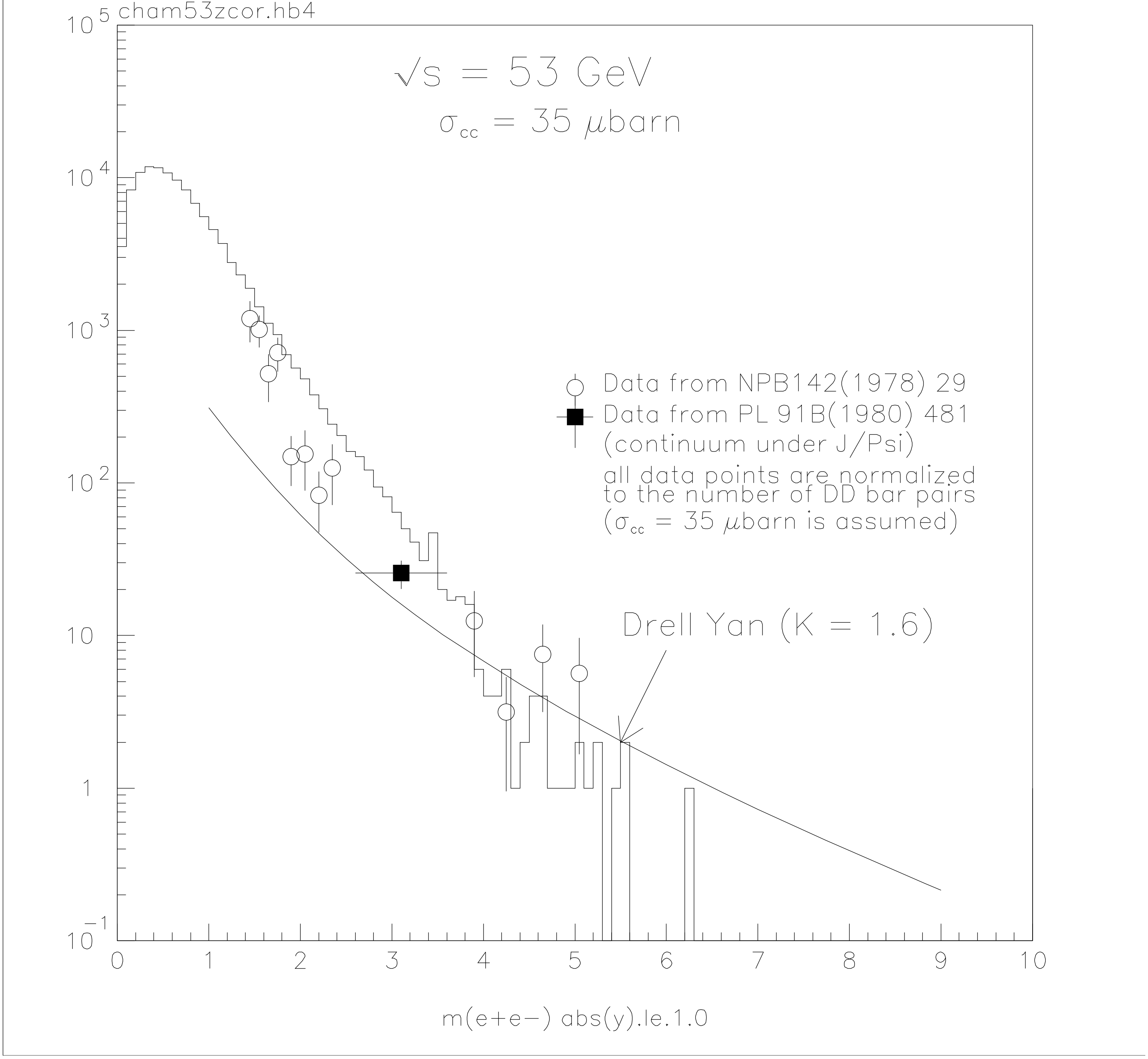
I calculated the yield of di-leptons from charm. Correlated charm pairs are produced by ISAJET7.6. Its leptonic decays are simulated in the same way as in single electron rate calculation.

Un-correlated pairs are produced by random combination of e+ and e- from un-related charm decay.

di-lepton from charm pair



Comparison of charm B.G. with experiment ($s^{1/2}$=53GeV)



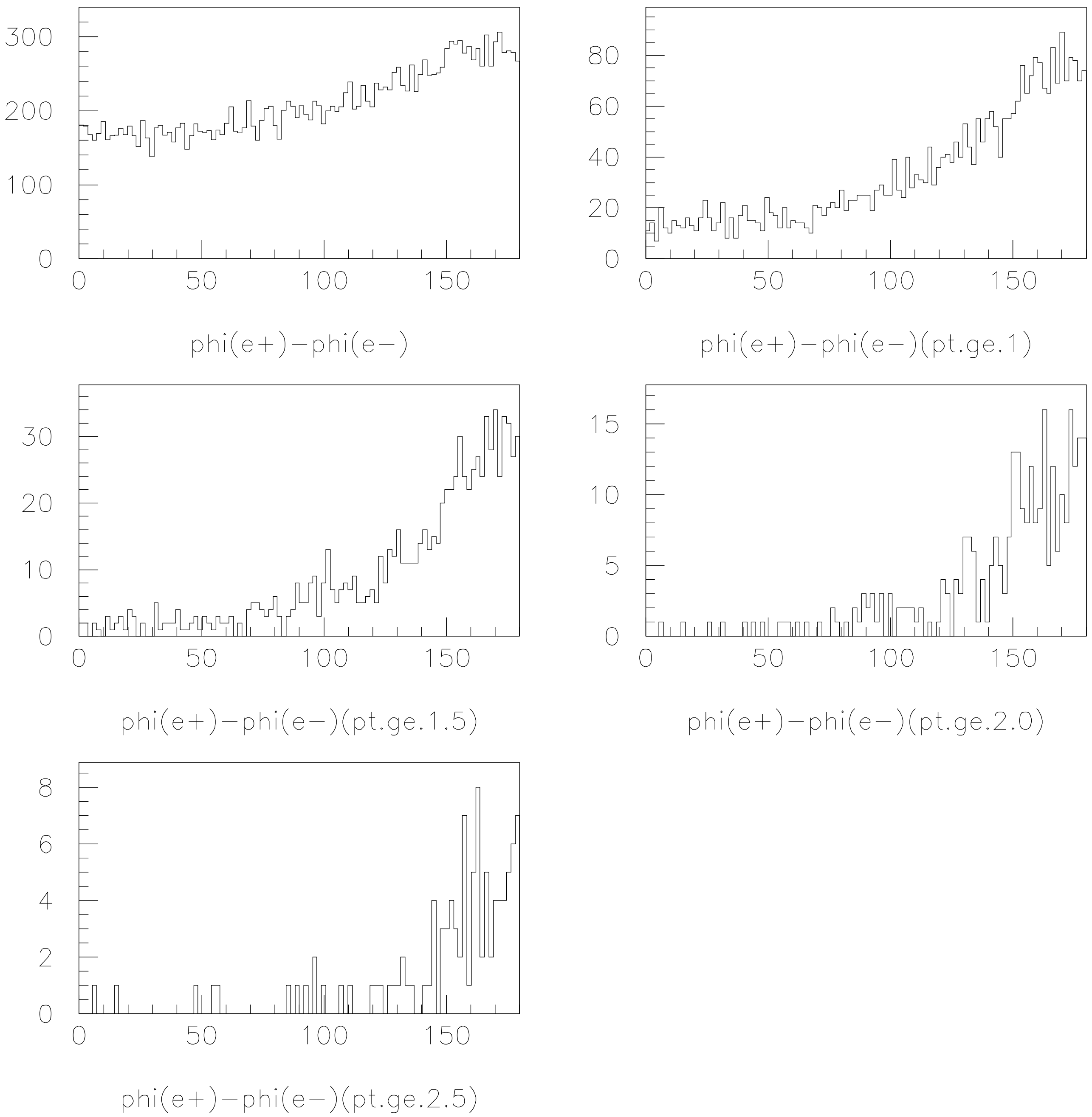
Yield of Lepton pairs from charm decay is several times larger than that of Drell Yan below M<6-7 GeV.

The yield of un-correlated pairs is smaller than that of correlated pairs above M~3GeV. This is because correlated pair have strong back-to-back correlation, and tends to produce higher mass
.

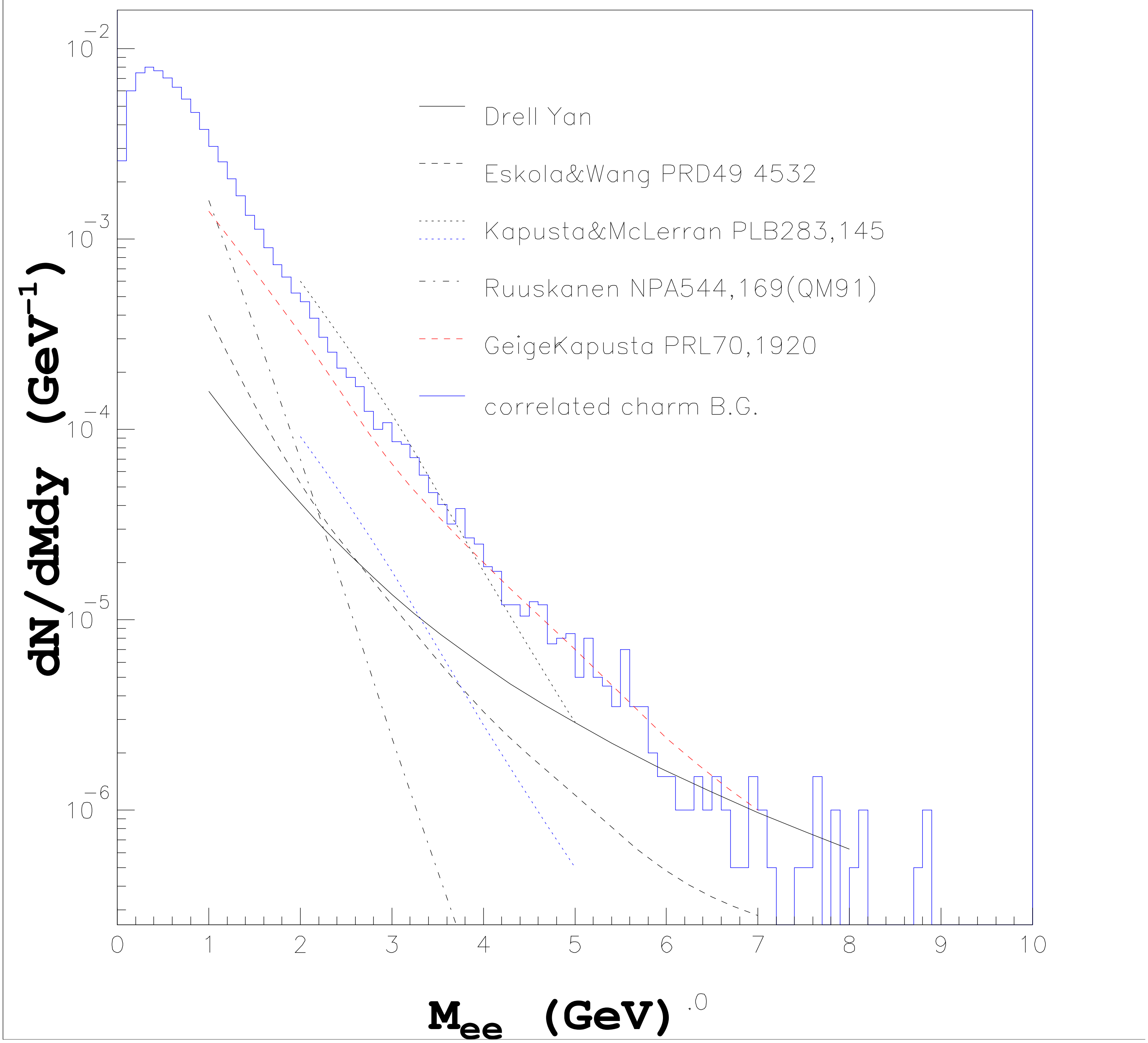
It is possible that ISAJET overestimate the momentum correlation between cc pair. In addition, the correlation can be destroyed in real H.I. collisions as c quarks traverse in dense nuclear matter. In this case, the mass spectrum from correlated charm becomes softer than this simulation, and becomes similar to that of un-correlated pairs.

The charm B.G.(correlated) is larger than most of theoretical predictions of "di-lepton continuum from QGP".

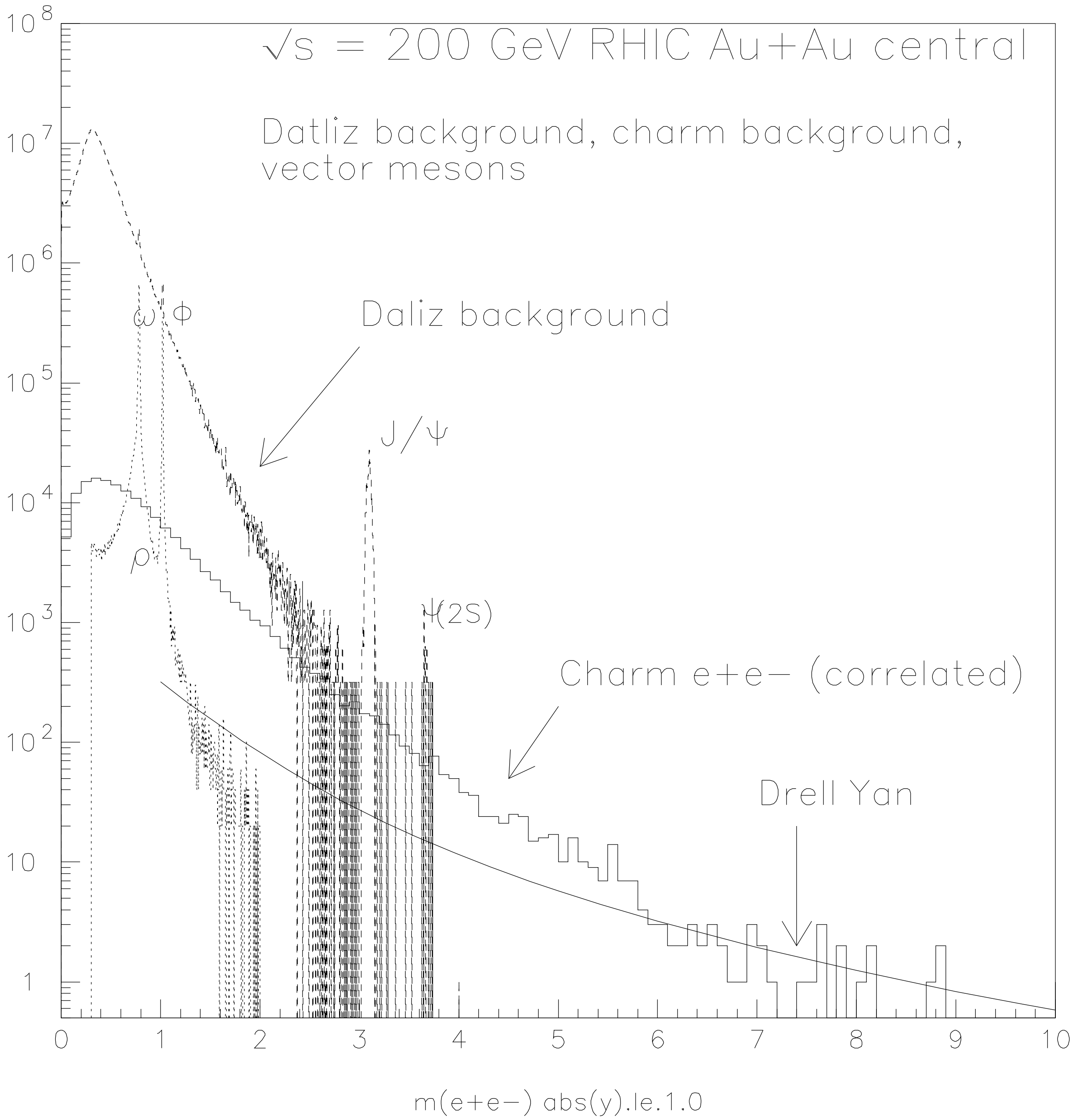
e+ e− angular (Φ) correlation from $\bar{c}c$ pair (ISAJET)



Dilepton continuum and Charm background



Drell Yan, Charm dileptons, vector mesons, and π^0 Datliz background



Accepted Rate (/year) of charm dilepton

Mee(GeV)	yield/GeV/Yr	B.G.	S/N
1	100K	8M	1/80
2	18K	100K	1/5
3	4K	2K	2
4	1K	--	large
5	300	--	large
6	70	--	large

If "dilepton continuum" is as copious as charm dilepton, we are able to measure it. In any case, we need to understanding charm dileptons very well to measure is needed "thermal dilepton".

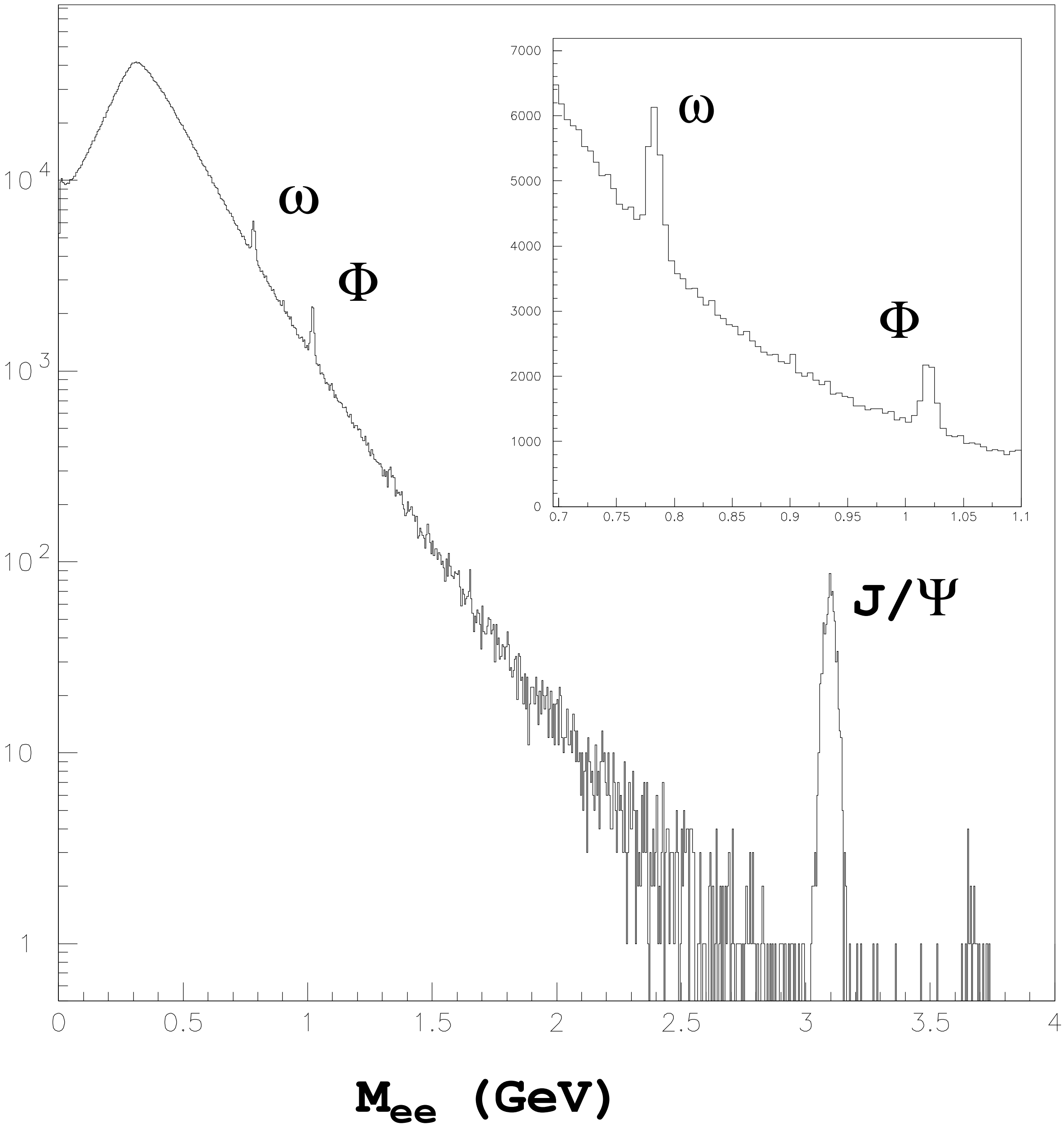
IV. Light vector mesons

There are many theoretical predictions how the property of light vector meson might be changed in high density/high temperature state created in H.I. collisions.

-- mass shift of ρ,ω,Φ
-- change in width ρ,ω,Φ
-- "melt down" of ρ
-- ρ "enchancement" by re-generation
-- secondary peak of Φ
etc,etc

Problem in searching for those exotic phenomena is a large background from π^0 Dalitz decay

Vector mesons and Dalitz B.G.



Yield(per year) and S/N ratio

$L=2x10^{26}$,1 year=$1.08x10^{8}$ sec
Ldt = 2.16 nb^{-1}
10% central --> 1G event/year

Here I assume that
- ρ/π ratio = 20%
- ρ/ω ratio = 1
- Φ/π ratio = 2%

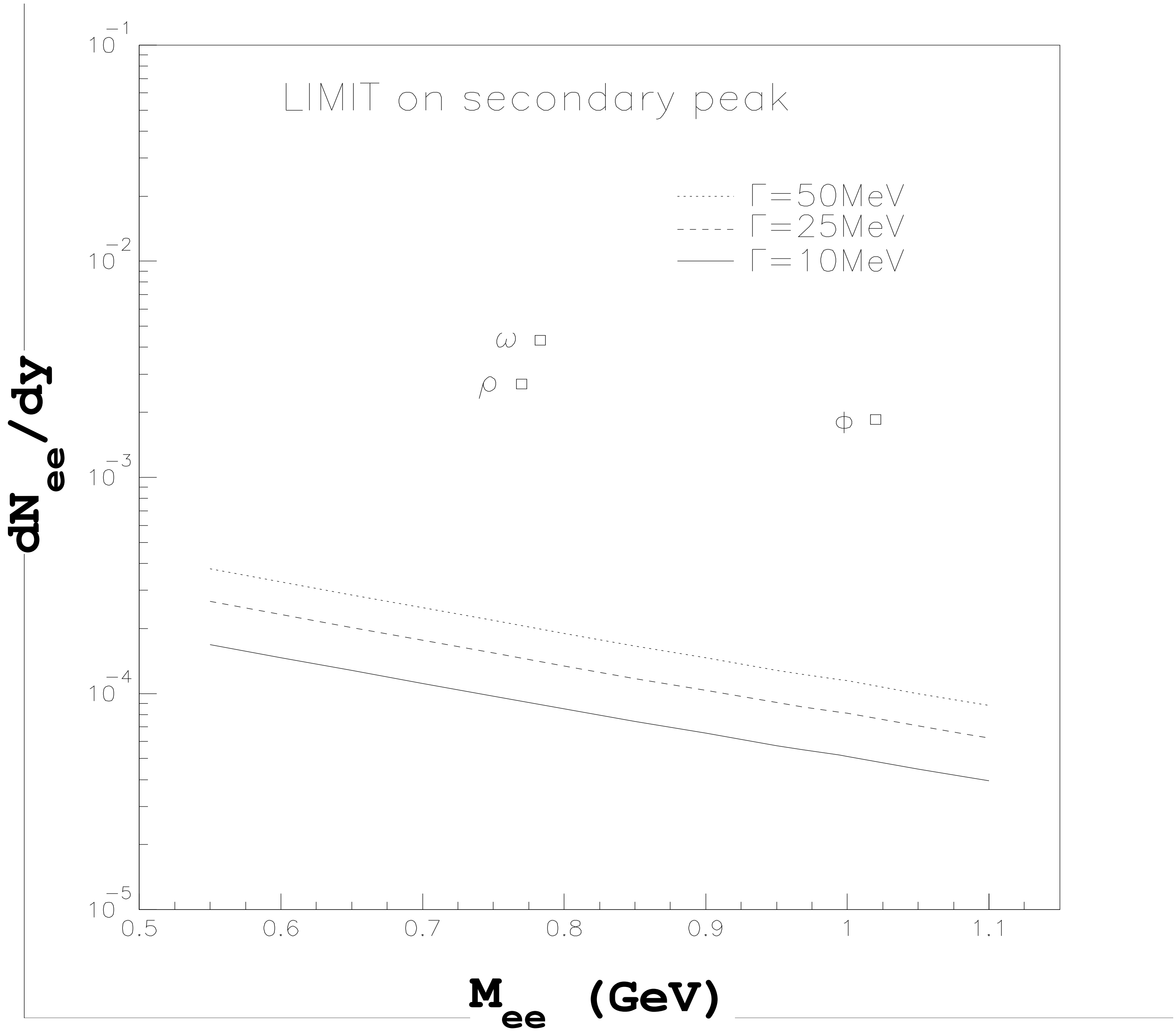
Acceptance ~ 4% of dN/dy

	Yield	B.G	S/N	$(B.G)^{1/2}$
ρ	110K	3.9M	1/35	2 K
ω	170K	500K	1/3	0.7K
Φ	75K	150K	1/2	0.4K

Statistically it is possible to measure ρ under the huge B.G, but we need to understand the B.G. shape very well.

Asakawa et al predicted "secondary Φ" will appear if QGP phase transition is 1st order or very close to 1st order

Here I calcuated the sensitivity of our experiemnt to detect for such narrow peak over Dalitz background. (5σ effect over [m−Γ,m+Γ]in one year)



Summary

J/Ψ

can measure pt up to 6 GeV/c

Charm

large "single electron" yield is expected from charm decay.

continuum

- difficut unless the yield is large
- charm di-lepton continuum can be measured

light vector mesons

ω,Φ 75K-170K /year
good S/N ratio

ρ poor S/N(1/35)
measurable if B.G.shape is well understood, or yield is enhanced by "regeneration"

"exotics"

sensitivity limit dN/dy~10^{-4}