PHENIX Opportunities with Direct Photons and Heavy Flavor

RHIC/AGS Users' Meeting WS

June 18, 2007

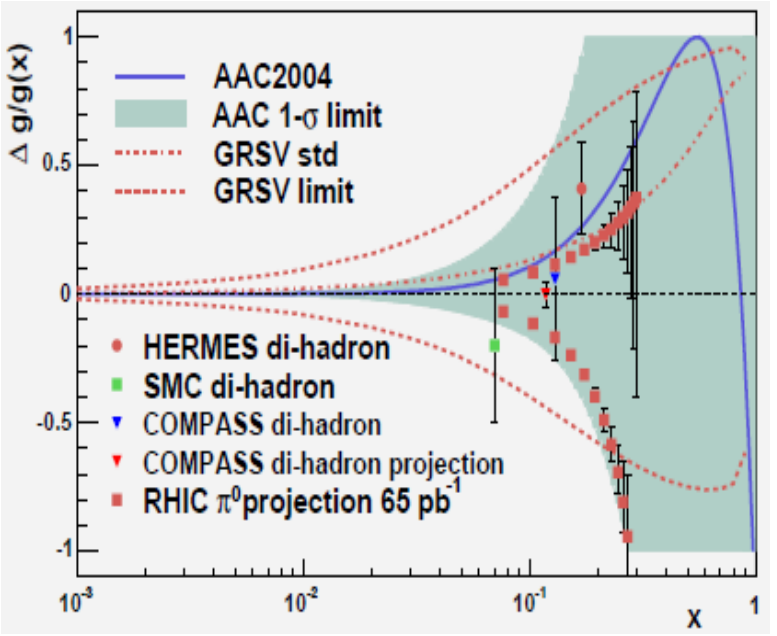
Yuji Goto (RIKEN/RBRC)

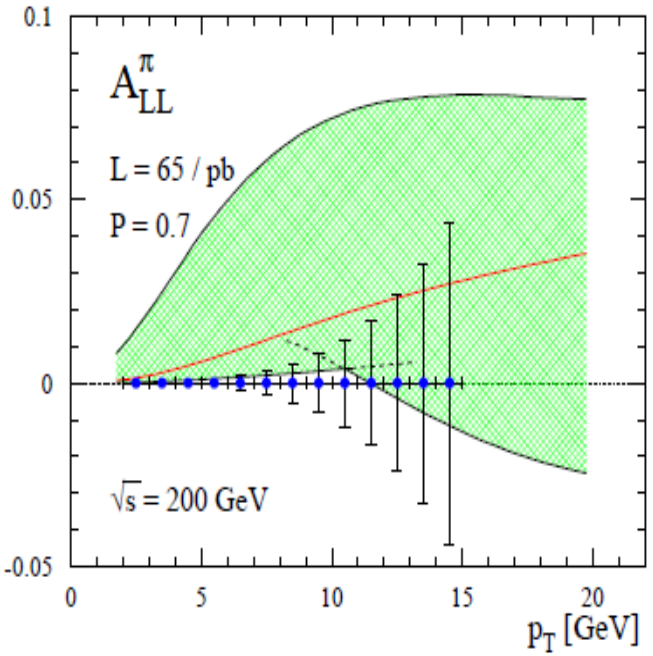
Direct photon, heavy flavor, …

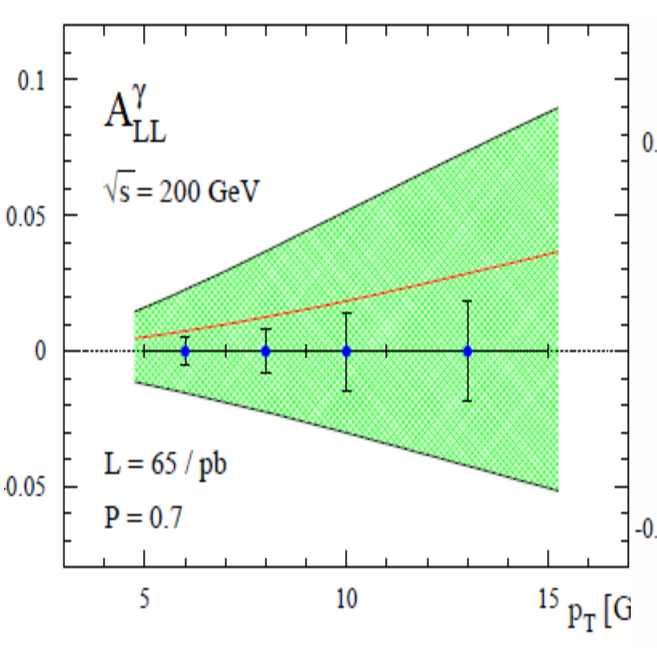
- For precision physics, measurements of multi-channels (and by multi-experiments) with different kinematic coverage (with overlap region) and systematic uncertainty are important
- Direct photon and heavy flavor production channels are golden channels for ΔG measurement
- All these data must be consistently understood on the basis of common physics framework
  - global QCD analysis
  - test of experimental data
  - test of QCD

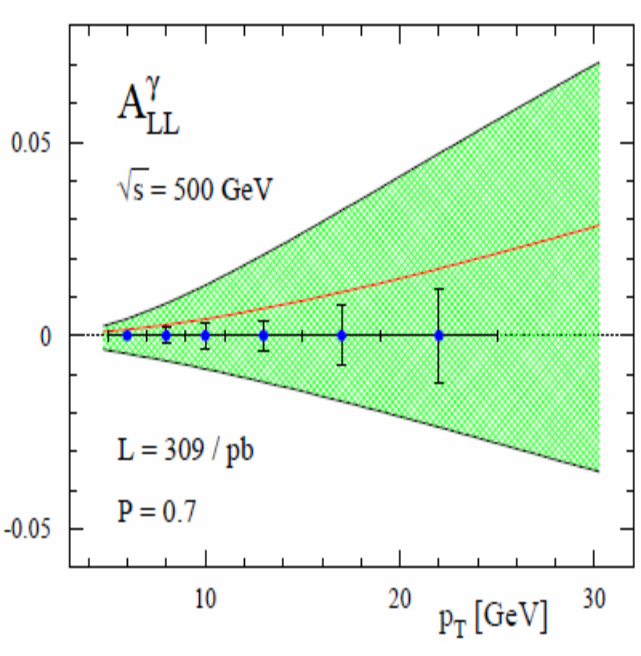
Direct photon

- $A_{LL}(\gamma)$ provides ΔG with sensitivity to its sign
  - $A_{LL}(\pi^0)$ can give us two solutions on ΔG
- Smaller statistics than π^0
  - but significant at high-x







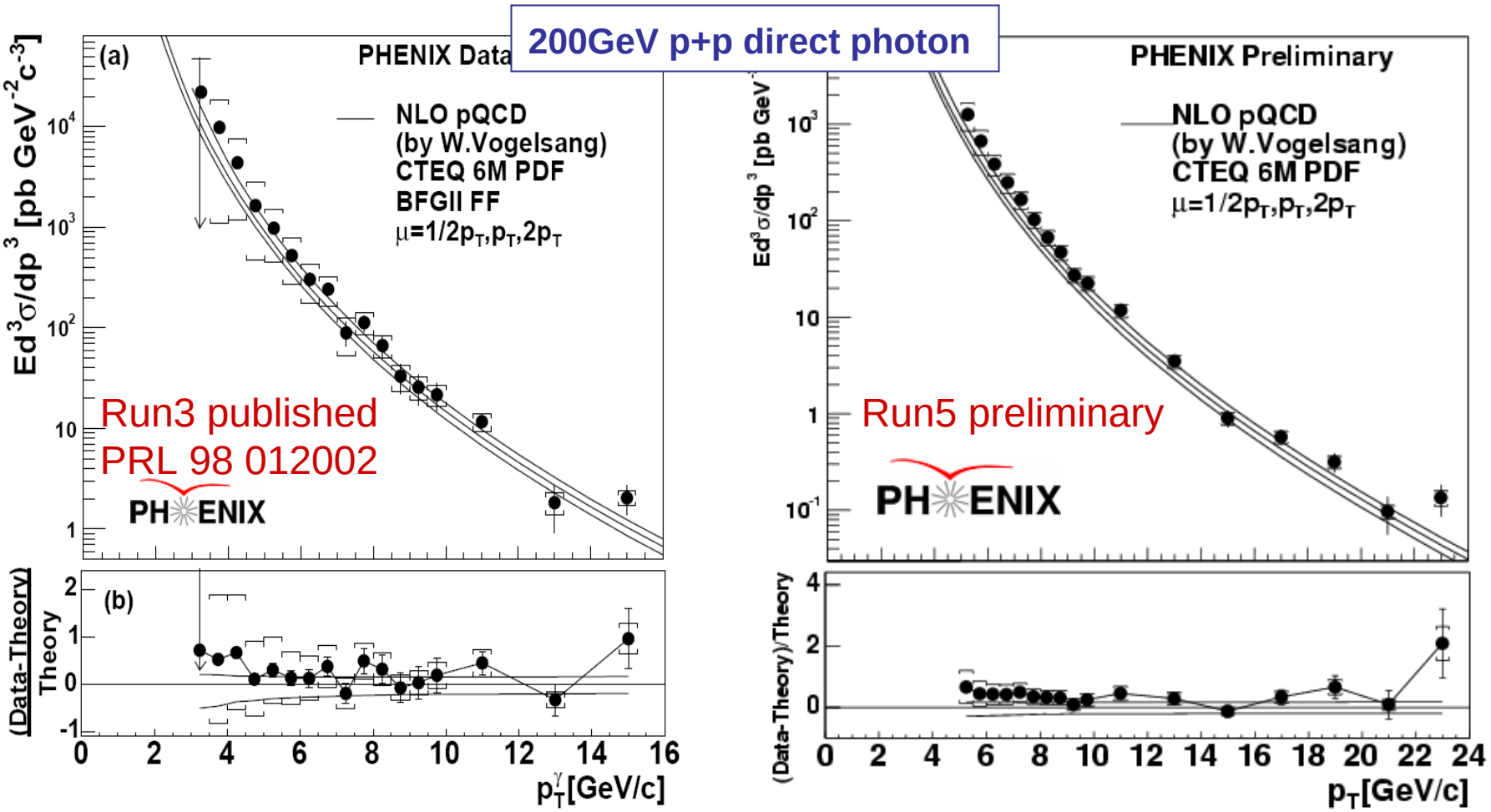


Direct photon

- Status and issues – background
  - experimentally subtracted and evaluated
    - large background from π^0 and η
  - theoretically evaluated
    - gluon Compton and annihilation
    - higher order – bremsstrahlung and fragmentation
- Cross section measurement
  - better understood than π^0?
  - scale and fragmentation function
- For A_{LL} measurement, the isolation cut is essential
  - to increase the signal purity
  - fragmentation issue to be investigated

Direct photon

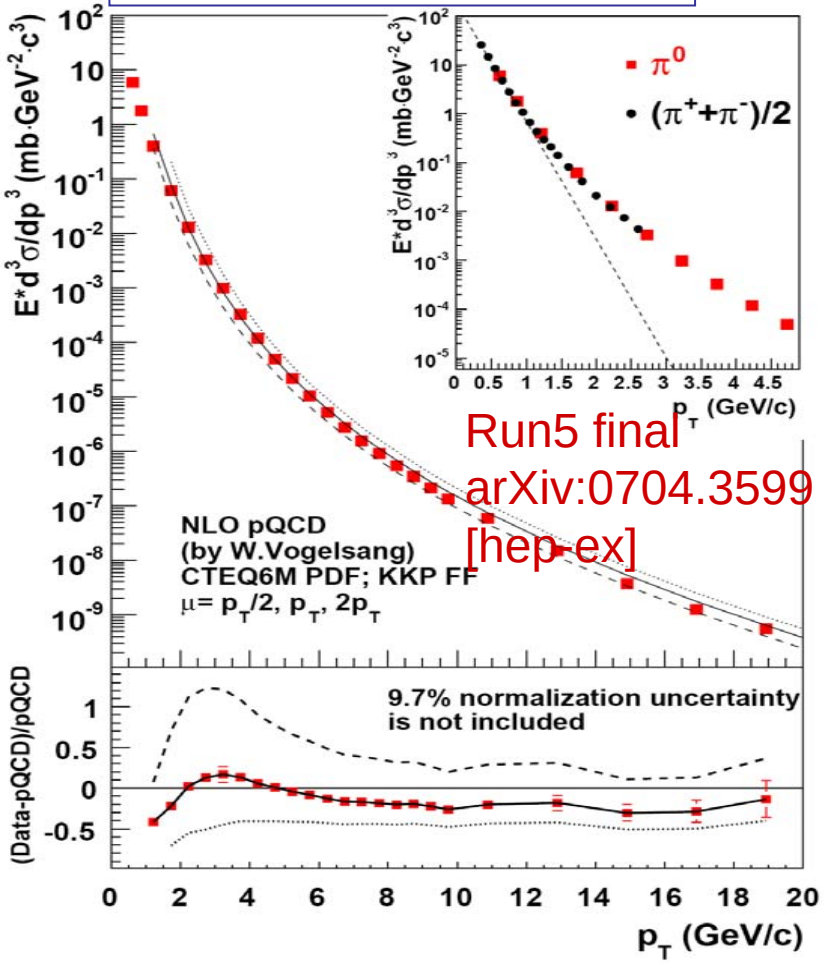
- Cocktail method and π^0-tagging method
  - evaluate or subtract known background sources
  - the NLO pQCD calculation describes our result well.



Direct photon

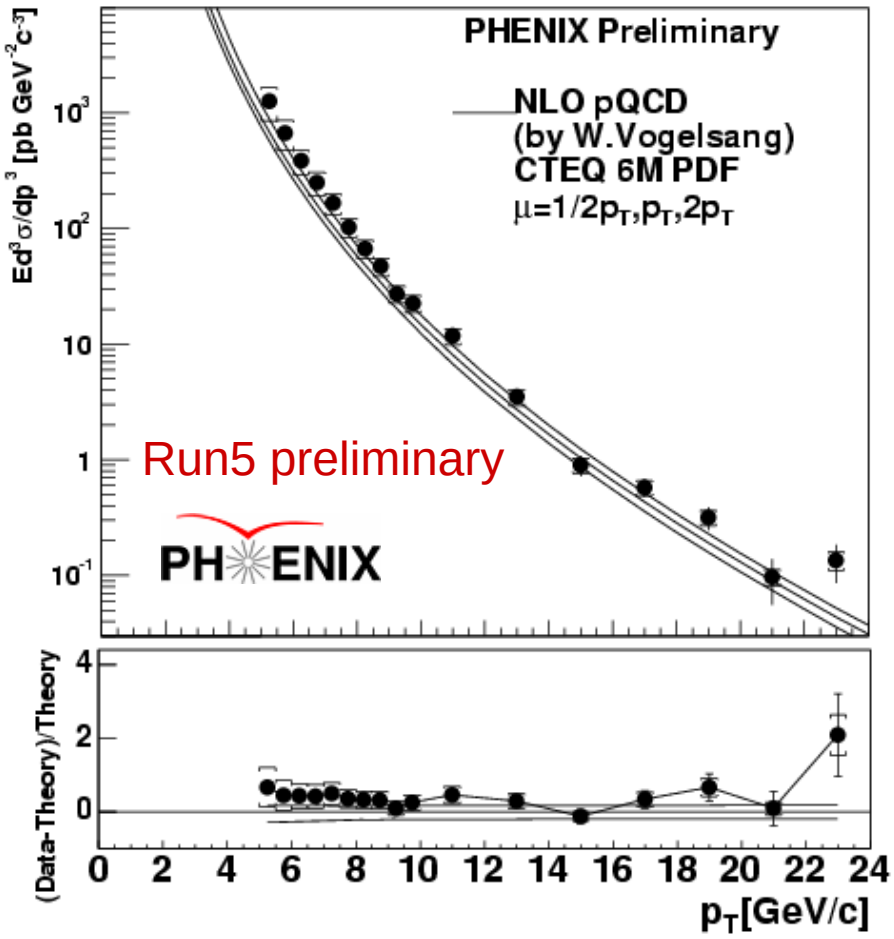
- π^0 vs direct photon
  - high statistics at high pT
  - better scale uncertainty?

200GeV p+p π^0 production



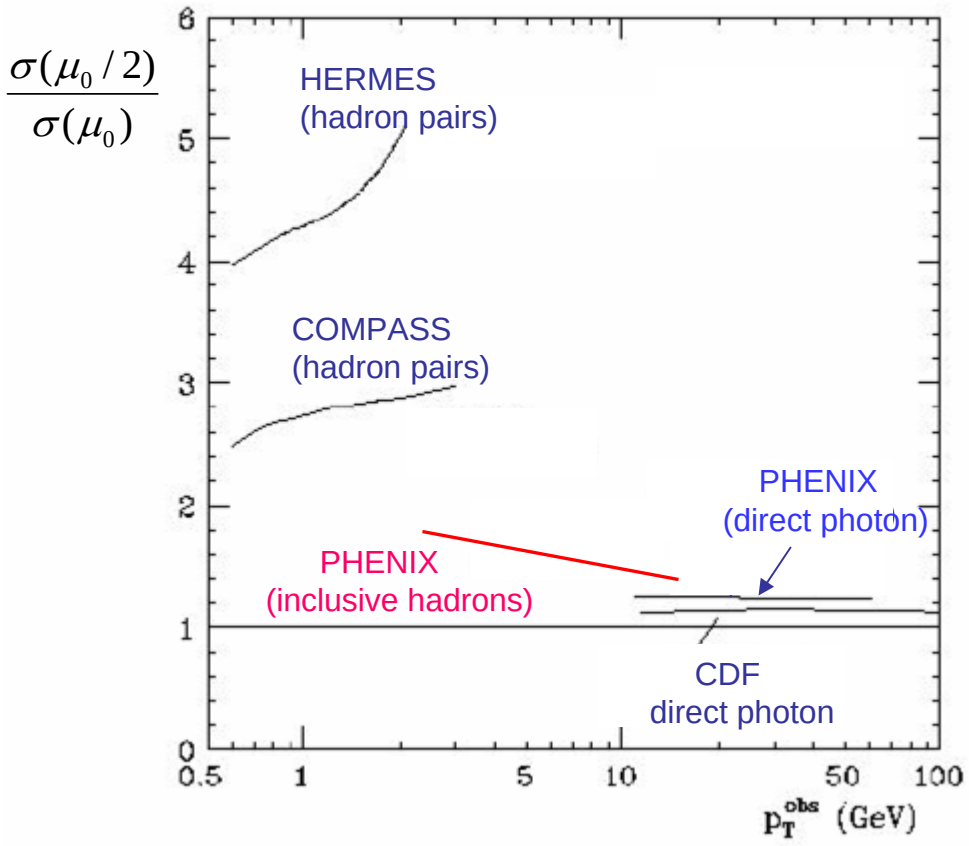
Run5 final
arXiv:0704.3599
[hep-ex]

200GeV p+p direct photon



Direct photon

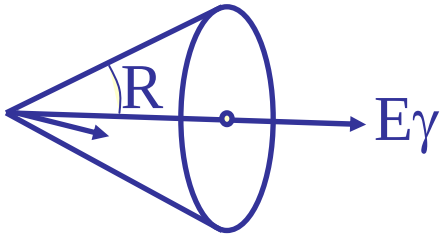
- Scale uncertainty of NLO pQCD calculation
  - better for photon…



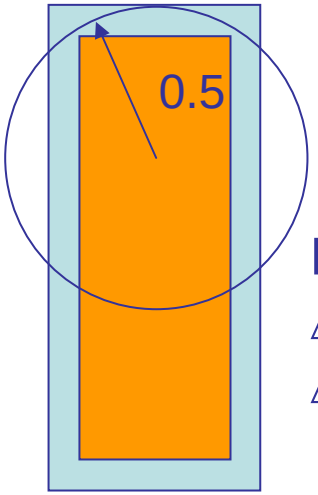
Direct photon

- Isolated photon
  - for asymmetry measurement, it is important to reduce background event-by-event, otherwise the asymmetry is diluted by that of the background
  - though our detectors aren't large enough, an isolation cut is applied

$0.1E\gamma > E_{cone}$ (R=0.5rad)



E_{cone} : photon energy
+ charged particle momentum

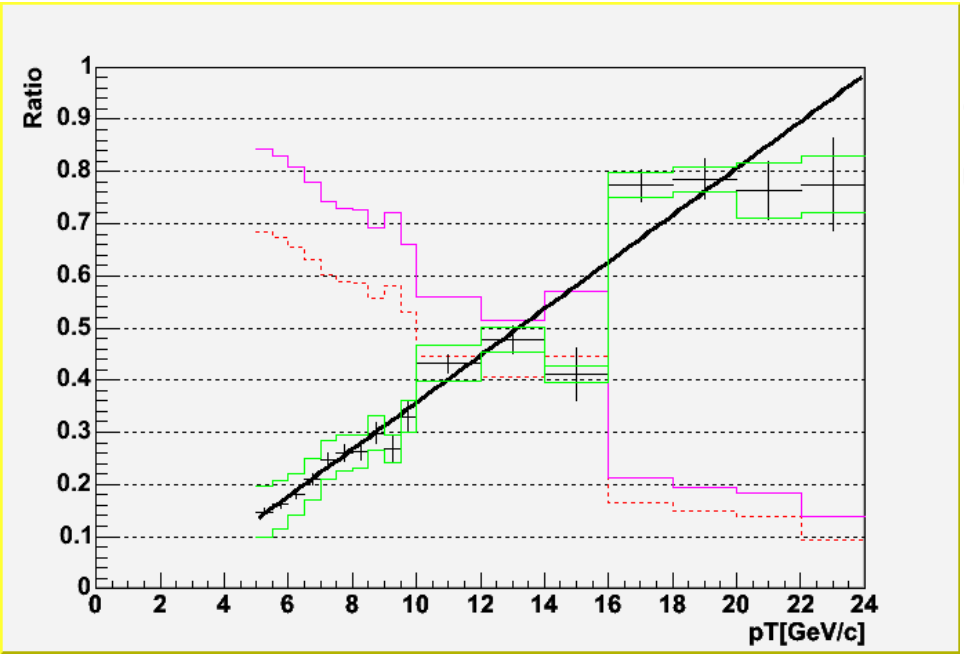


PHENIX arm
$\Delta\eta$=0.7
$\Delta\phi$=π/2

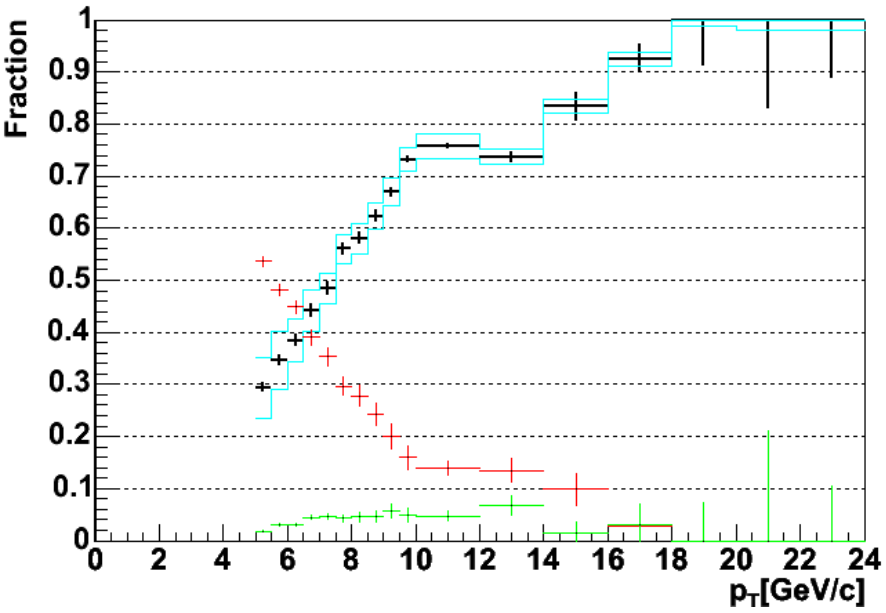
  - also important to know the asymmetry of the background $\rightarrow$ isolated π^0 measurement

Direct photon

- Isolated photon
  - background reduction
  - significant



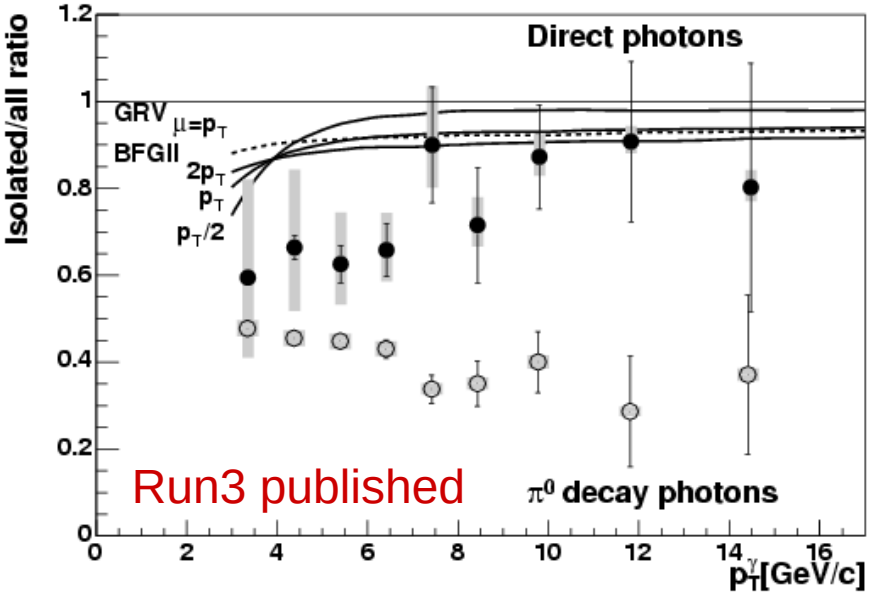
before isolation cut



after isolation cut

Direct photon

- Isolated photon

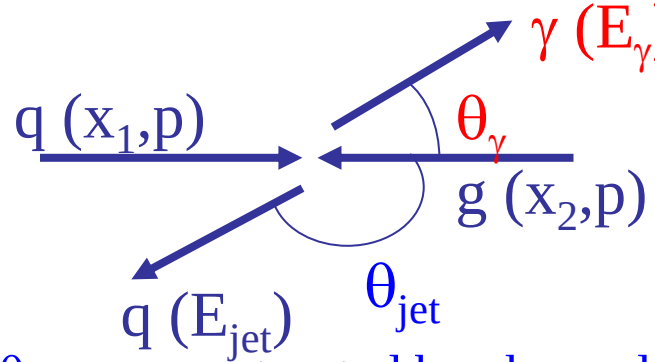


  - in contrast to π^0 decay photons, direct photons are mostly isolated
  - theory calculations agree well to the measurement at high p_T region (p_T > ~7GeV/c)
    - to be studied by higher statistics
    - effect of underlying event larger at lower p_T
    - larger fragmentation component at lower p_T
  - isolated π^0 asymmetry to be used for background asymmetry

Direct photon

- photon + jet with VTX
  - jet axis obtained with VTX

obtained by EMCal



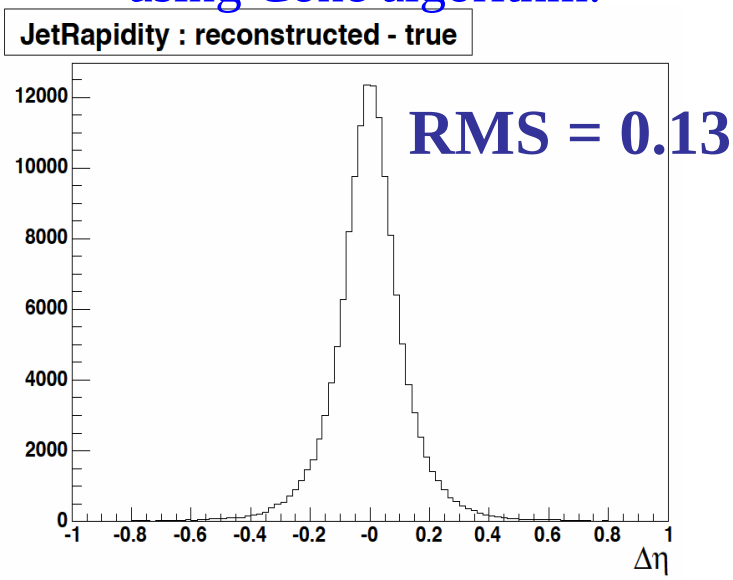
θ_{jet} : reconstructed by charged particles using Cone algorithm.

***Assuming that the p_T of the prompt photon and recoil jet are balanced.**

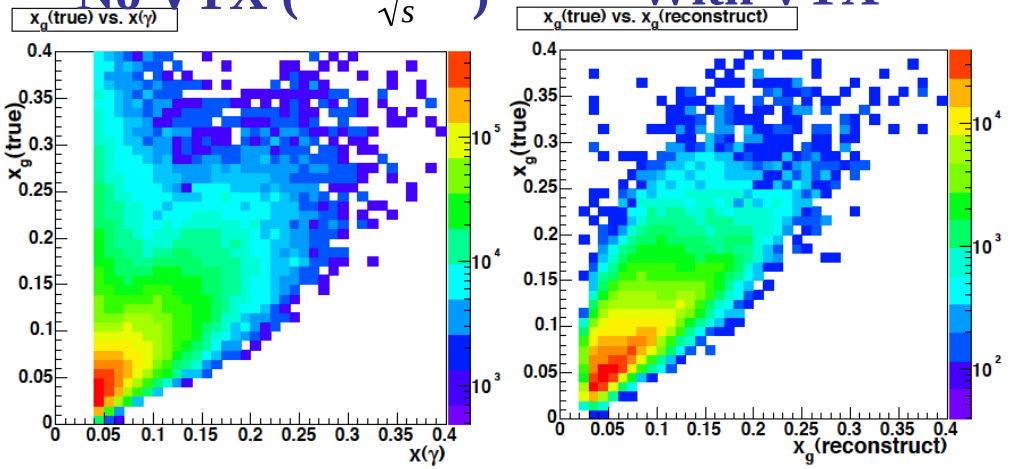
$$x_1 = \frac{p_T}{\sqrt{s}}\left(e^{\eta_{jet}} + e^{\eta_\gamma}\right) \quad x_2 = \frac{p_T}{\sqrt{s}}\left(e^{-\eta_{jet}} + e^{-\eta_\gamma}\right)$$

***Assuming that $x_g < x_q$**

$$x_g = min(x_1, x_2) \quad x_q = \max(x_1, x_2)$$



No VTX ($\langle x \rangle = \frac{2p_T}{\sqrt{s}}$) **With VTX**

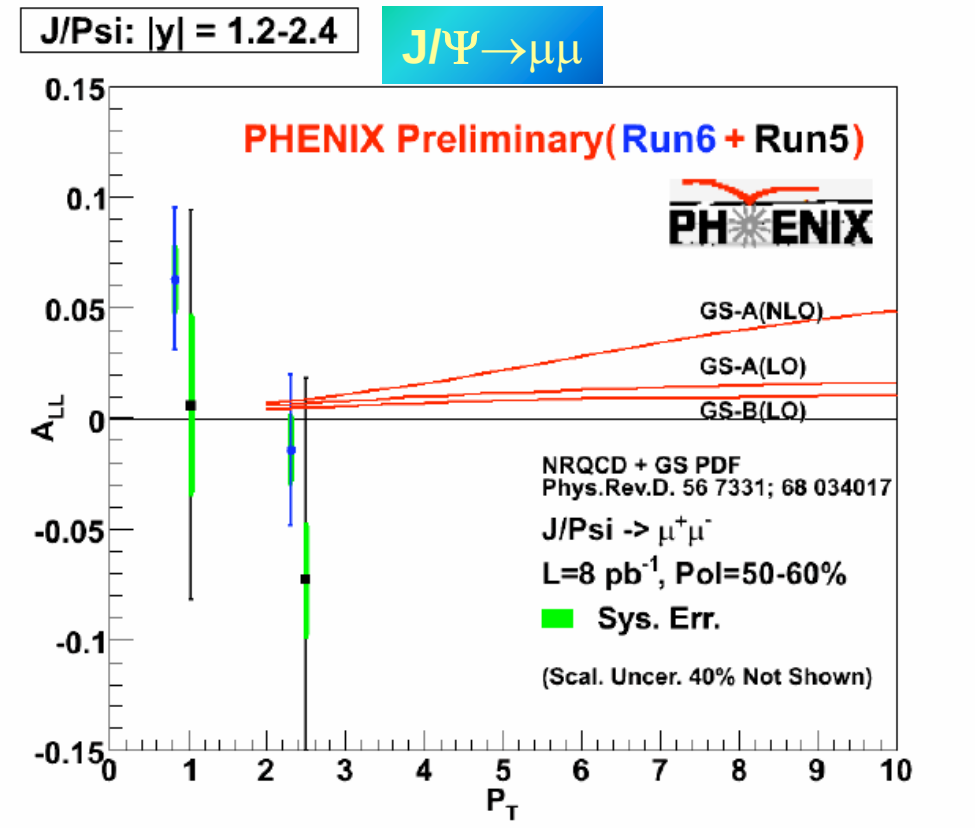


x_g(true) vs. x_g(reconstruct)

pp $\sqrt{s} = 200GeV$

Heavy flavor

- J/Ψ
  - preliminary A_{LL} result
  - more (and more) statistics necessary as an input for ΔG



Heavy flavor

c quark

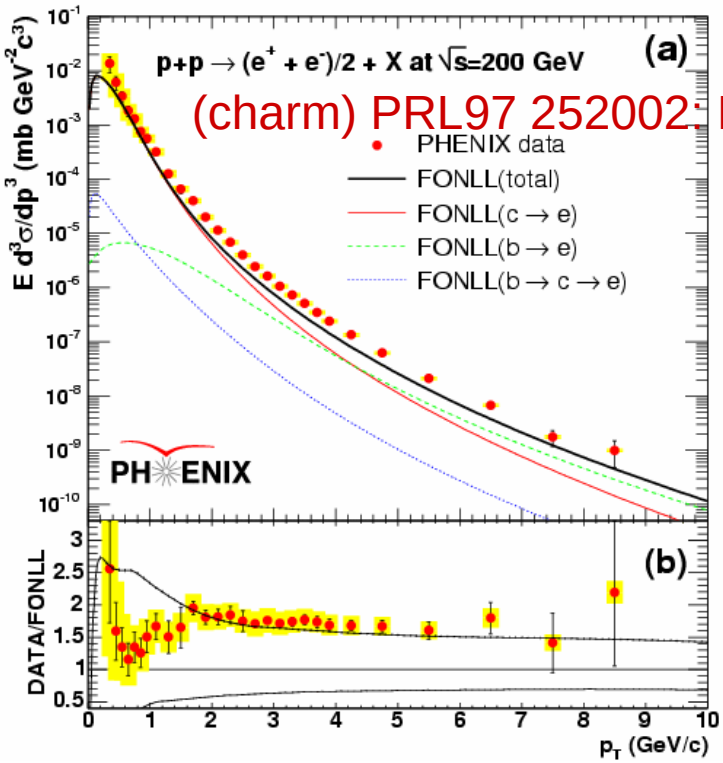
$D \rightarrow e$ (+anything), πK

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

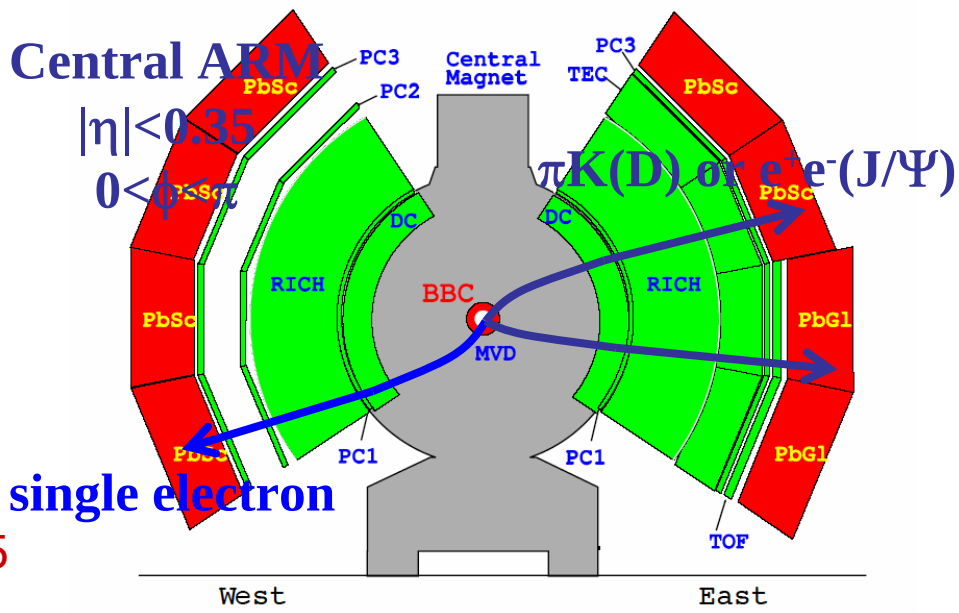
b quark

$B \rightarrow e$ (+anything)

$B \rightarrow J/\Psi + X$



(charm) PRL97 252002: Run5

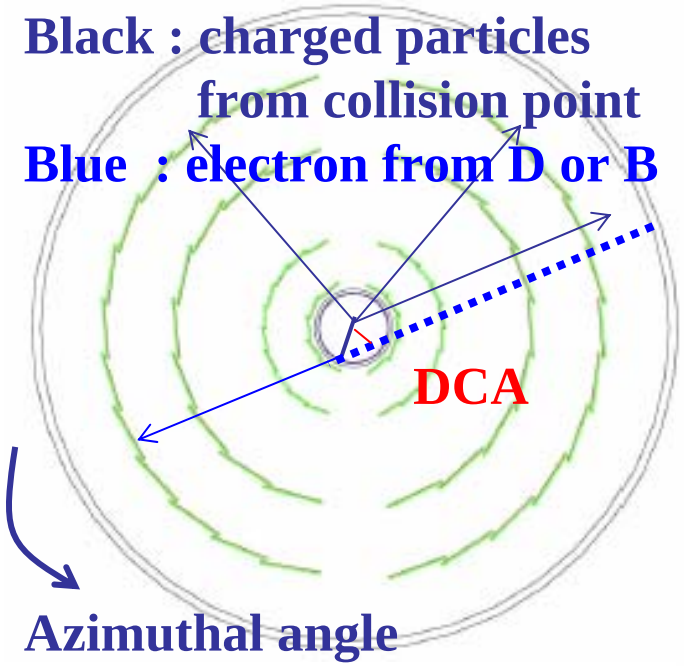


In single electron analysis

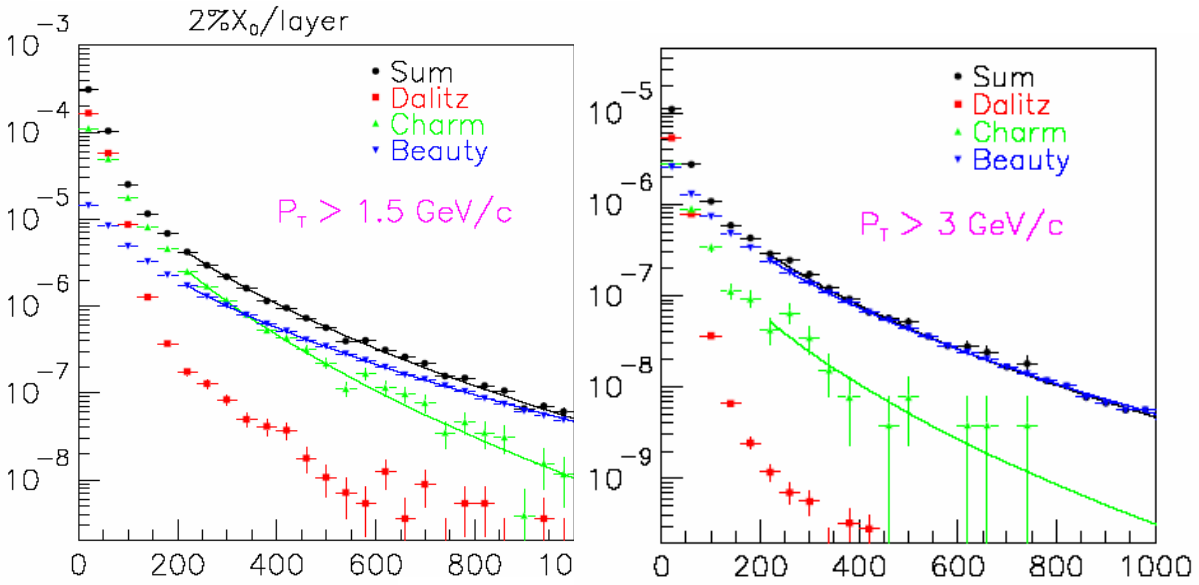
- background.
  - π^0, η Dalitz decay
  - γ conversion ($\gamma \rightarrow e^+e^-$)
- can not distinguish electron from D and B (and J/Ψ)

Heavy flavor

- single electron with VTX



- DCA (**D**istance of **C**losest **A**pproach) of D and B meson are different.
  - **can distinguish each other, and from background**

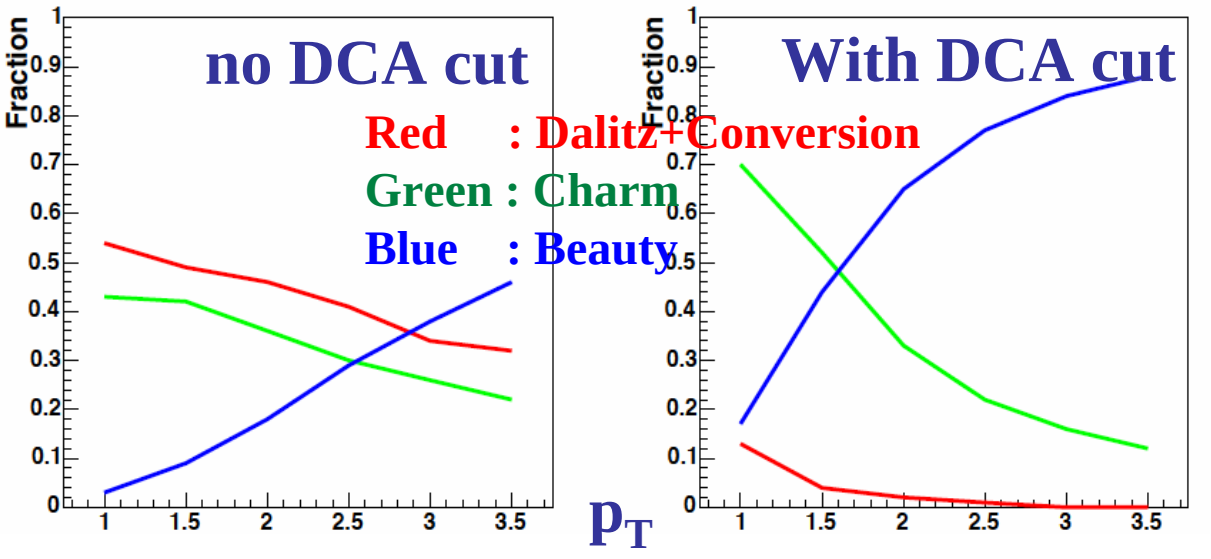


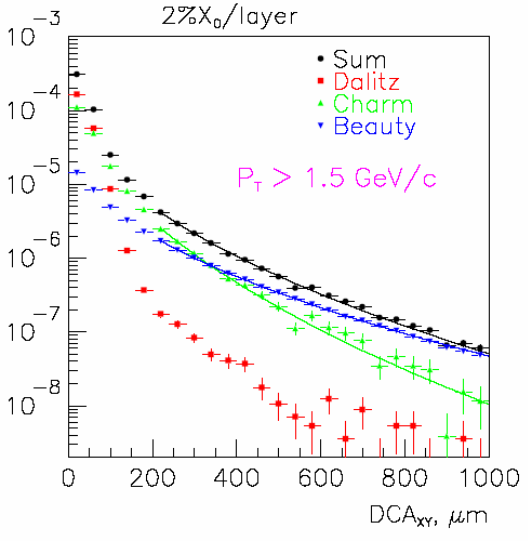
meson	Life-time(μm)
$D^{\pm}$	315
D^{0}	124
$B^{\pm}$	496
B^{0}	464

studied by Vladimir L. Rykov with tuned PYTHIA

Heavy flavor

Fraction of electron source





No DCA cut

e_{all}(no DCA cut) = $e_{Dalitz} + e_D + e_B$

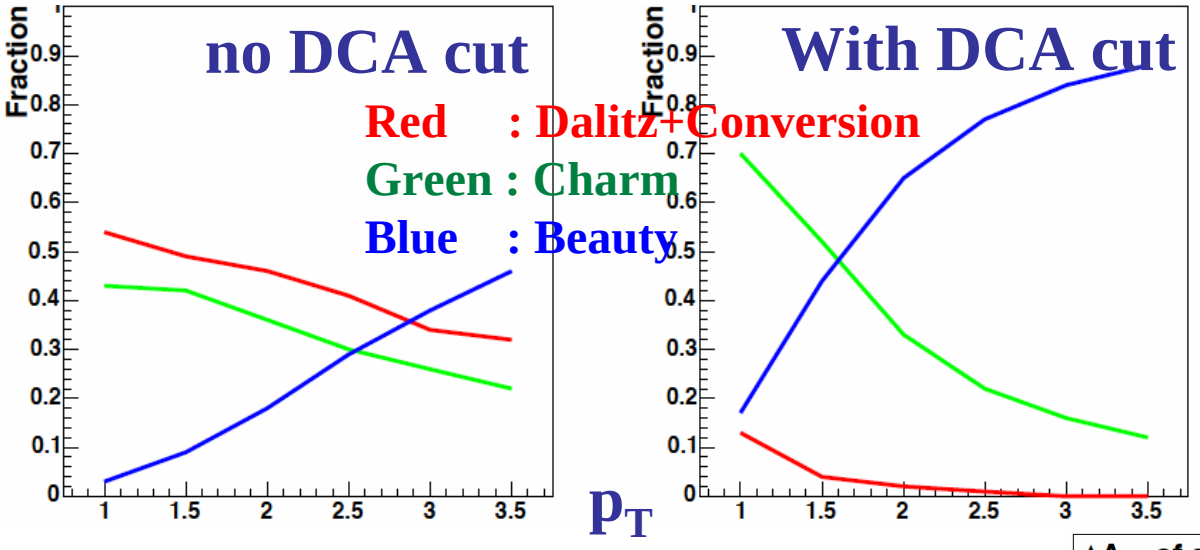
With DCA cut

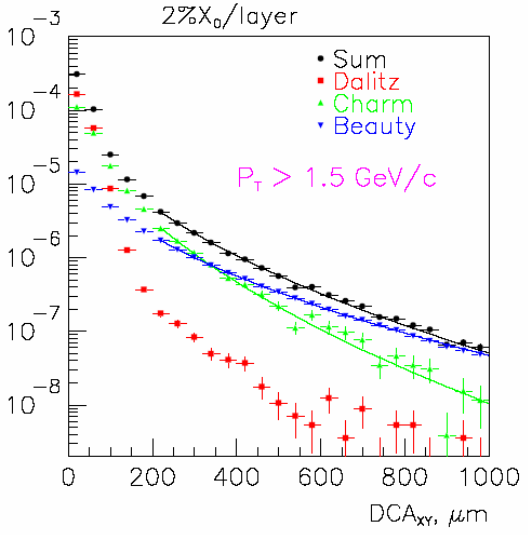
e_{all}(DCA cut) = $R_{dalitz}(p_T)\, e_{Dalitz} + R_D(p_T)\, e_D + R_B(p_T)\, e_B$

R_{XXX} is electron ratio of "no DCA cut" to "DCA cut" for xxx. (can be estimated by simulation)

Heavy flavor

Fraction of electron source



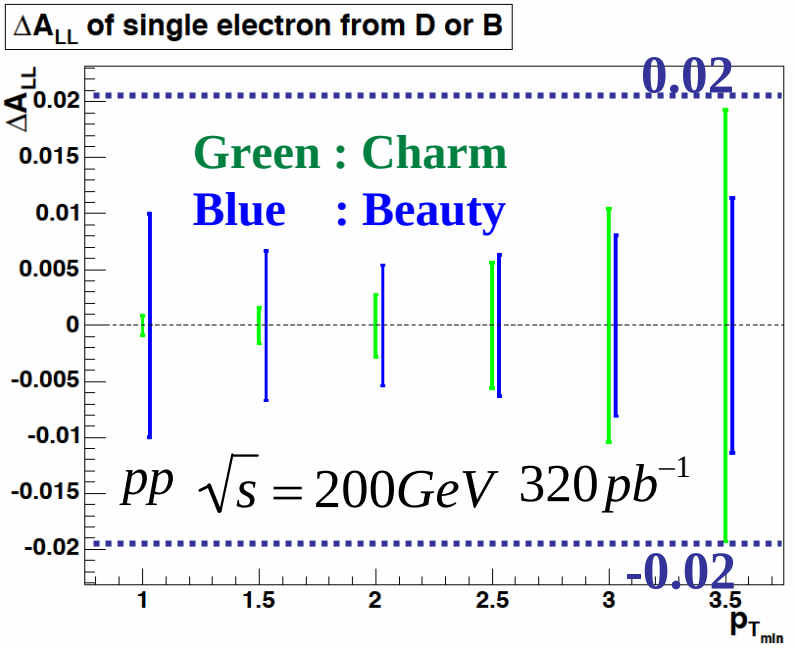


Low p_T : Determine c first

High p_T : Determine b first

$$\sigma_{A_{LL}^{c(b)}} = \frac{\sqrt{\sigma^2_{A_{LL}^{c(b)+BG}} + r^2\sigma^2_{A_{LL}^{BG}}}}{1-r}$$

error estimation



A_{LL}^{Dalitz} can be evaluated by π^0

Summary

- Direct photon and heavy flavor production channels are golden channels for ΔG measurement
- VTX will extend PHENIX capability for both measurements significantly
- VTX will be installed at PHENIX in 2008 and will be available from 2008-2009 run (Run-9)
- All these data must be consistently understood on the basis of common physics framework by global QCD analysis, finally