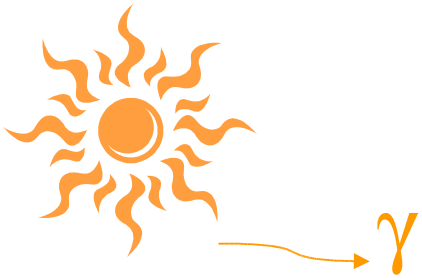

The RHIC Photon ~~Feast~~ BBQ

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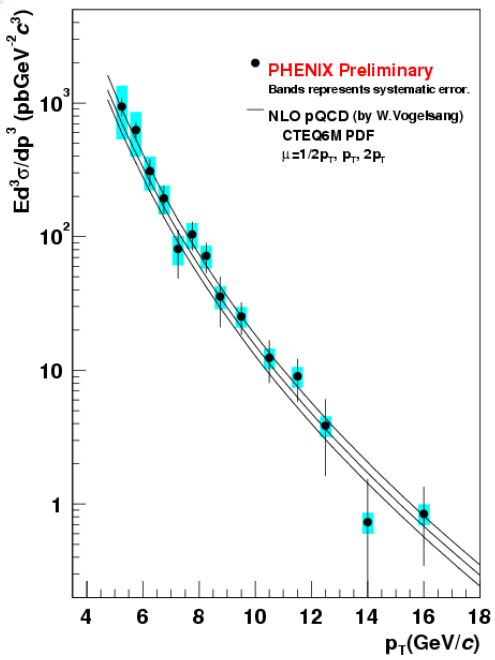
RHIC/AGS Users Meeting Photon Workshop June 21, 2005

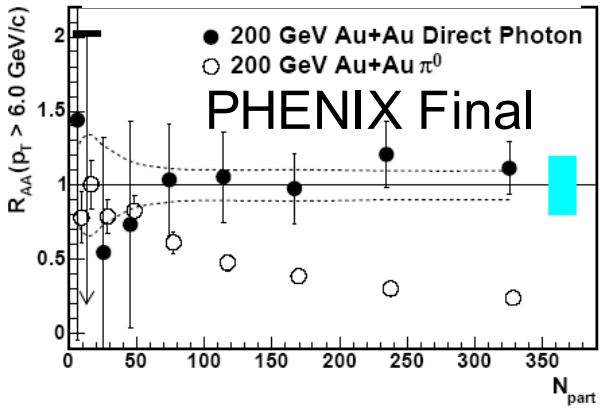
A Succesful BBQ Starts With Flavors and Ingredients…

- **Properly Aged:** Theoretical techniques well established and have perhaps reached a milestone of maturity ?
- **Healthy:** A lot of activity by many different groups, theoretical community actively pursuing many new avenues (e.g. HBT)
- **Organically Grown:** Some tuning on SPS data possible
- **Fresh:** Medium Induced γ sources generating fresh excitement

Ingredients: Hard Scattering Rates

- Perturbative QCD NLO predictions solid for years (*Phox*)
- At RHIC high p_T π^0 and γ works well…
- However predicted rates still have scale, FF (π^0) uncertainties unconstrained by the data
- Quantitative ~50%? getting larger as we go down
- NNLL/O gluon resummation not quite yet (see hep-ph/0504115), but maybe not *too* important @ RHIC





Ingredients: Thermal Rates

- QGP: perturbative Thermal QCD
  - Hard Thermal Loop (HTL) calculations "complete"? Resummation of all order loops with LPM performed by A.M.Y. Reliable fit in "the large E/T range" (Aurenche hep-ph/0410282) "Full result to LO in α_s".
  - Factor of 2 enhancement to previous
  - What systematic should we assign? 50%?

rate has been used as an educated guess. Moreover, one has to keep in mind that these rates have been derived under the unrealistic assumption of $g \ll 1$, which renders their applicability even more dubious. Since non-perturbative methods such as lattice QCD do not allow the calculation of

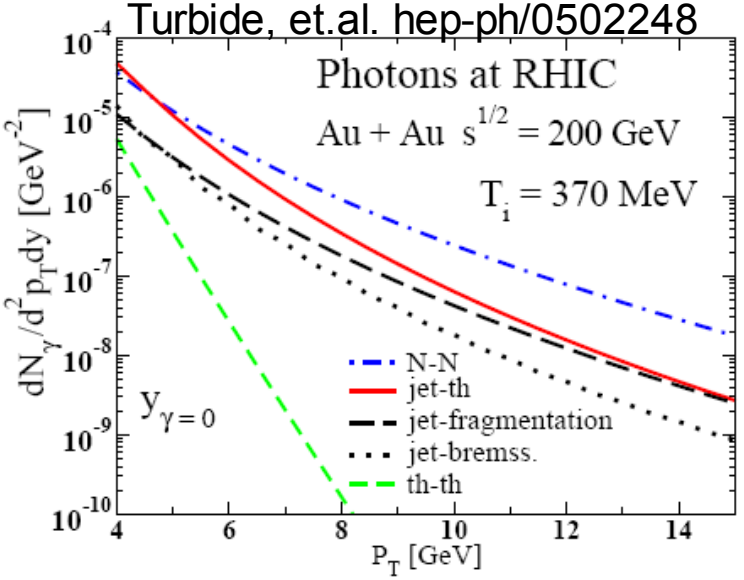
T. Peitzmann, M.H. Thoma / Physics Reports 364 (2002) 175–246

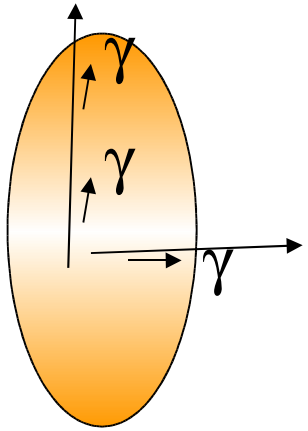
- Hadron Gas (HHG): pQuantum Hadro-Dynamics
  - Also mature calculations
  - However, including process X? ($\pi^{\pm}\rho \rightarrow \pi^{\pm}\gamma$ via $a_1 \rightarrow \pi\gamma$ etc…)
  - New processes usually can potentially change rates by factor of ~2 but often turn out to be less. "stable?" +/- 50-100%

The New Ingredient: Jet-Medium Induced Photons

- Specific p_T region ~3-7 GeV, just where the hard rates become truly hard
- Assumes QG degrees of freedom, equilibrium, different dependence than thermal rates
- Two possible components: multiple scattering, Bremmstrahlung
- Non-zero flow pattern!

Turbide, et.al. hep-ph/0502248





Spices, Marinates, Prepwork

- Putting it all together! Rates folded against:
- Realistic Phase Space Distributions and Evolutions
  - Initial State or other state points
- Hydrodynamics, uRQMD, Parton Cascade Models
- Mixed phase, pre-equilibrium effects:
- Hydro-based “Complete” Evolution Models:
  - Renk, et.al. fireball: flow / HHG important
  - Turbide, Gale, Rapp fireball, but HHG not important.
  - d’Enterria & Peresseunko: 2+1D Expansion, includes peripheral prediction
    - Previous include no Jet-Medium, [< 4 GeV]
  - Turbide, Gale, Jeon, Moore Jet Medium
  - Bass, et.al. PCM + Bjorken Expansion

Differences?

Must have the proper BBQ Utensils

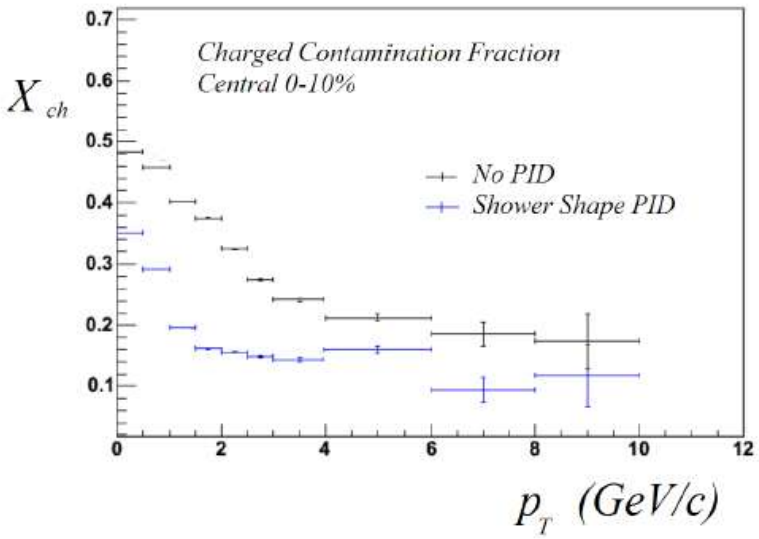
- The Grill: RHIC

AGS

RHIC

Single γRate Measurements

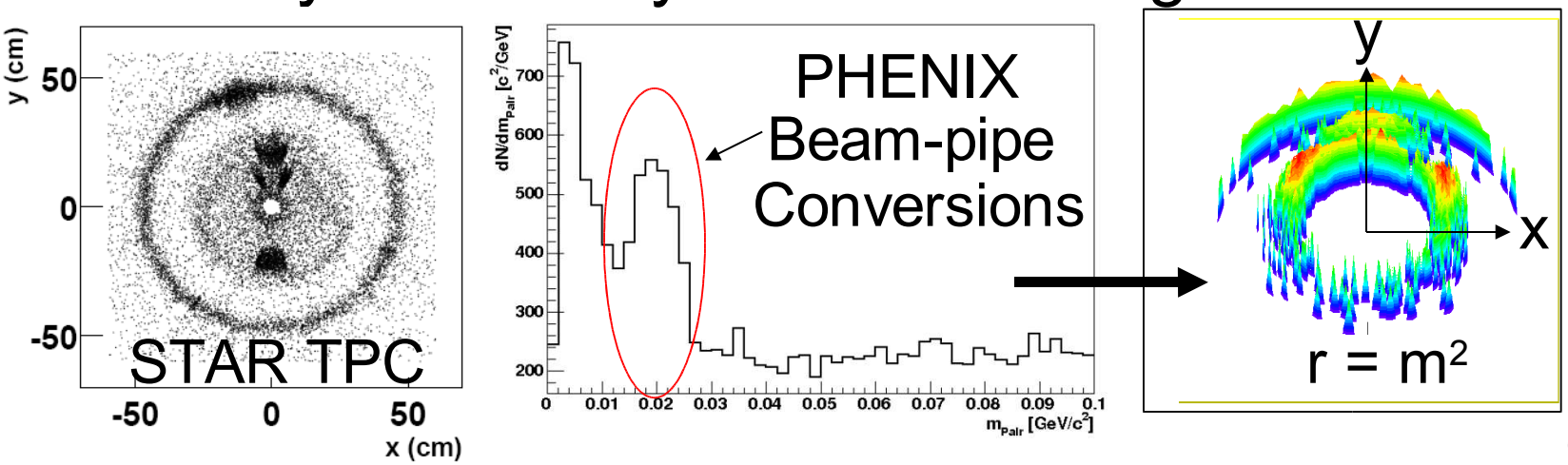
- EM Calorimeter "Base Method": Count Cal Hits
  - PHENIX Calorimeters (seg. $\Delta\phi\Delta\theta \sim 0.01^2$) PbSc/Gl MidRap
  - STAR Calorimeters (BC seg. $\Delta\phi\Delta\theta \sim 0.05^2$ MidRap, ECC ForwardRap seg smaller)
- Limitations at low pT
  - Hadronic showers (50% @ pt < 1GeV)
  - Resolution ($\sigma_E/E = A/\sqrt{E}+B$)
  - Cluster splitting effects
  - acceptance for π^0



- Systematic errors for photon 10-15%, π^0 14-18%
  - Dominated by Energy Scale and Efficiency at high p_T
  - At very low p_T by large hadron contamination

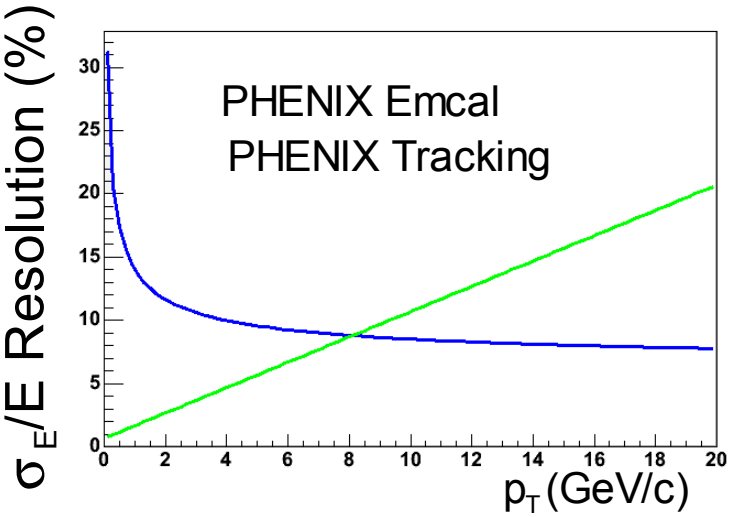
Singles Rate, Conversion Method

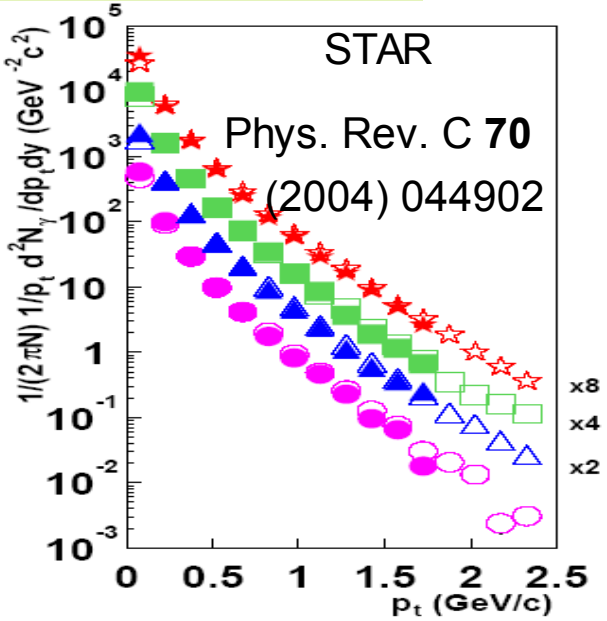
- Both PHENIX and STAR can measure photons via $\gamma \rightarrow e^+e^-$ conversion
- Slightly different methods
- Opening angle cuts, Dalitz removal, Electron ID
- Totally different systematics: charge tracks



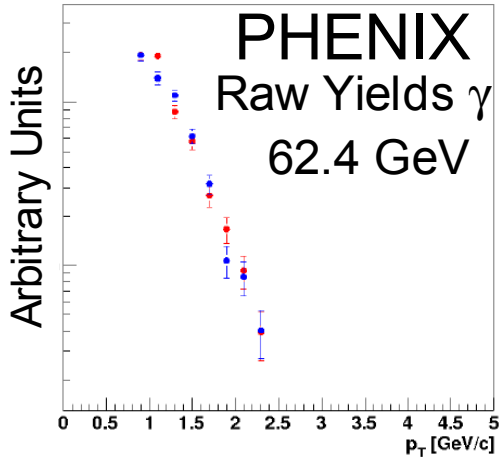
Singles Rate, Conversion Method

- Energy Resolution has opposite behavior



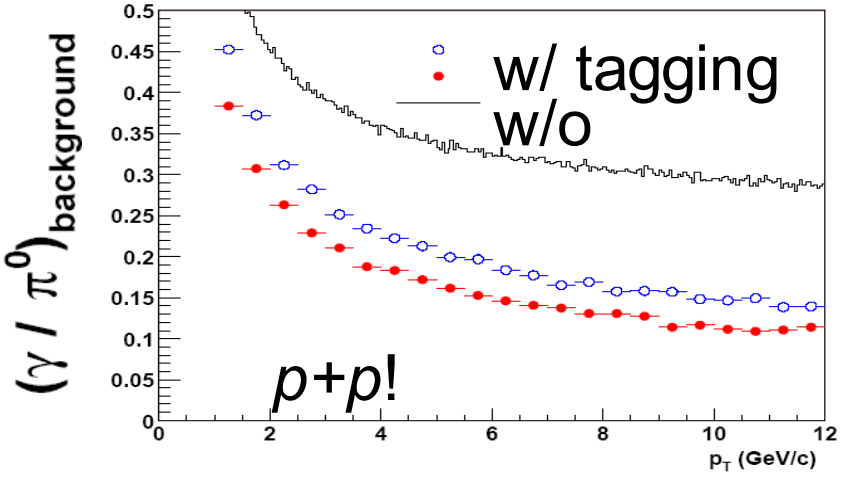


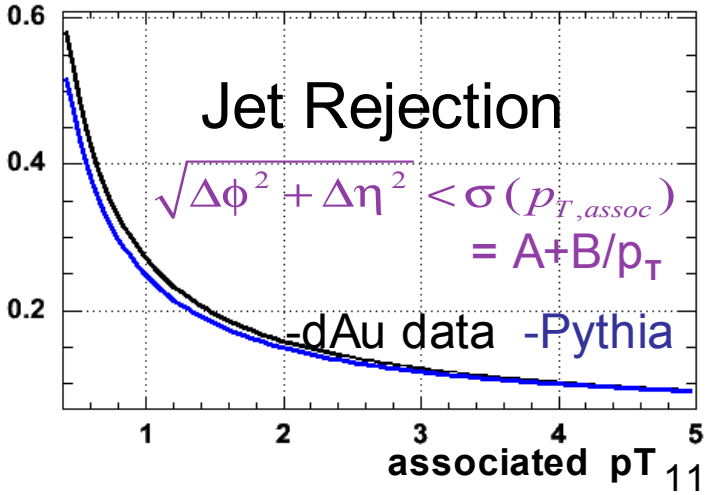
- Scale uncertainty slightly smaller, combine with Cal to reduce
- Electron ID runs out (e.g @ 5 Gev/c)
- Total systematics 13% (STAR)



The Statistical Method. Tagging & Isolation Cuts:

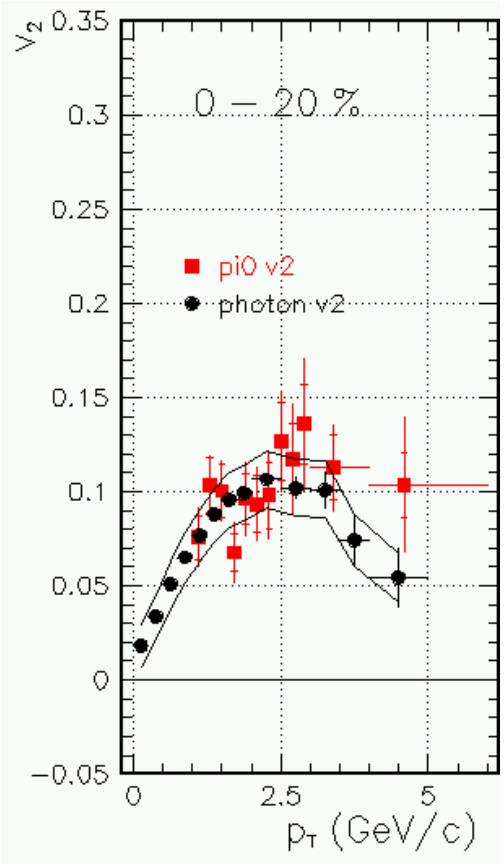
- Extract Direct γ from inclusive γ: Subtract decay γ (cocktail) contribution
- Cocktail based on measured meson (π^0) rates
- Double Ratio $R_{\gamma/\pi 0}$: Stat==syst error gets smaller in Run4
- Anti-Tagging π^0 increases S/B
- As does isolation cut*
- In Au+Au apply isolation cut in peripheral bins

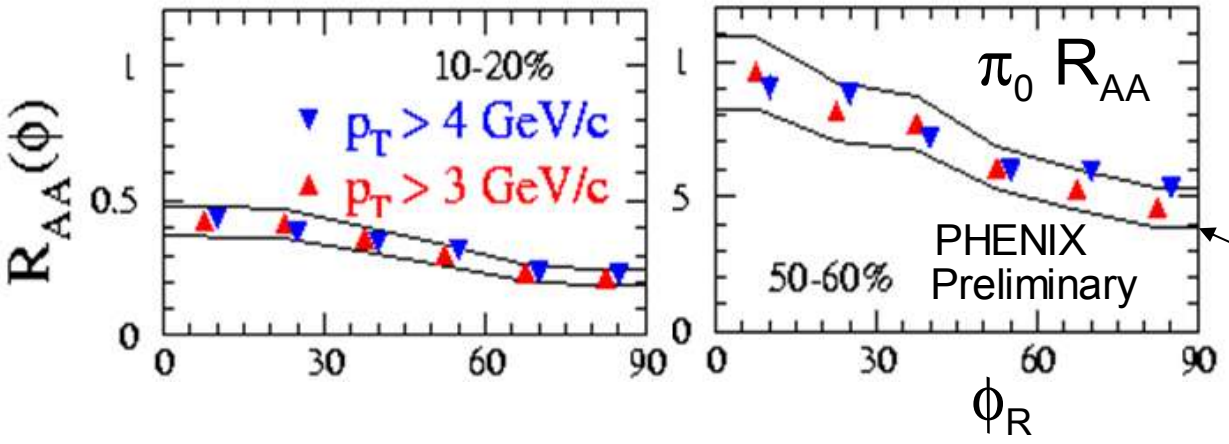




Photon (Non?) Flow

- Measure reaction plane (PHENIX new MVD measurement)
- Indications of direct photon in inclusive (decay + direct) γ flow?
- Repeat direct γ Stat. Method vs. ϕ_R





Suppression of π^0 background like in central events

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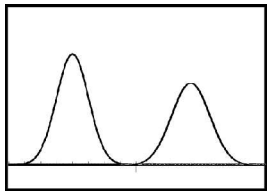
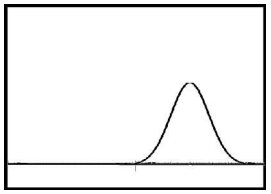
Photon-Jet Correlations

- Motivation: Direct Photon (e.g. Energy) Cleanliness: **high p_T**
- Convenient for triggering
- Subtract $\pi 0$ decay photon trigger distribution - use charge pions
- Azimuthal correlations: separate (jet-medium) Brems and Compton direct on the near side:

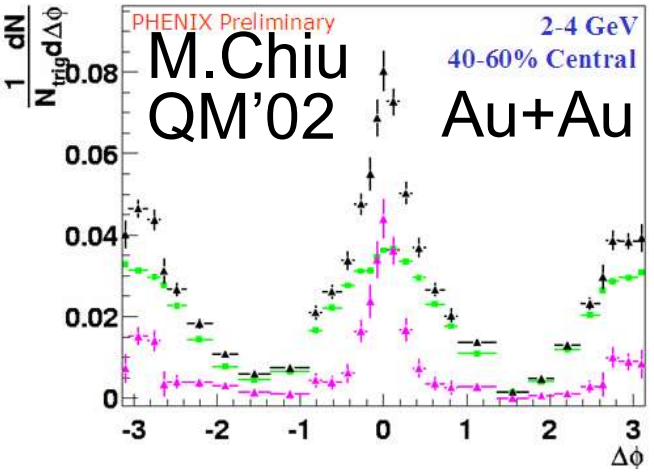


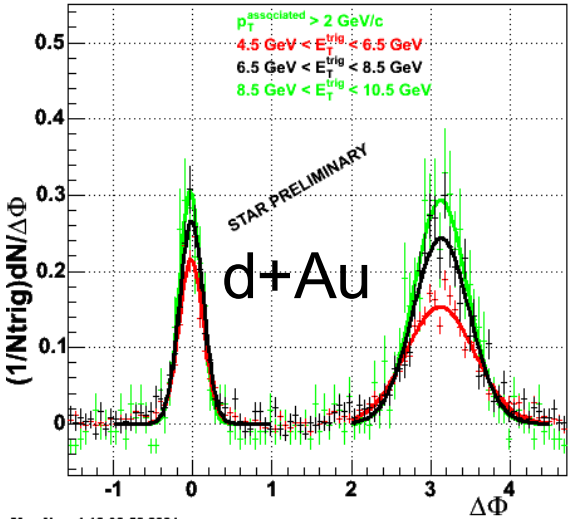
π^0/Brems



Compton γ

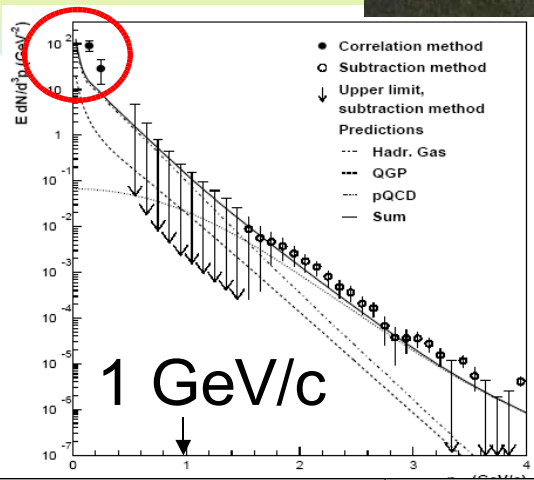
- Fragmentation Function dN/dz using clean E_γ

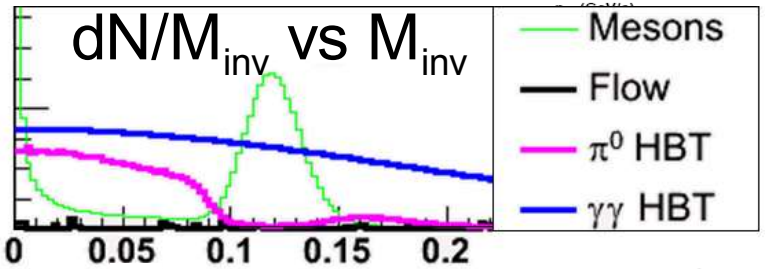


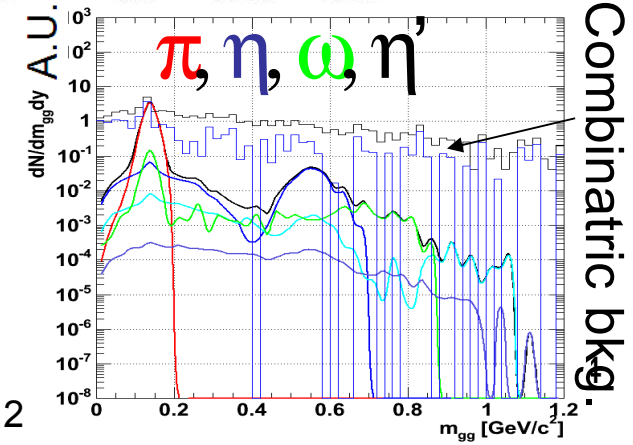


γγ Interferometry / HBT

- HBT real correlation at very low pT. Tie down total **rate** with 1D Q_{inv}
- Shape for γ–γ vs Minv different from π^0–π^0, other contributions (e.g.detector)
- Could be performed with conversions too
- Au+Au 3D spacetime geo. $Q_{out,side,etc}$…Info? Large combinatorics!





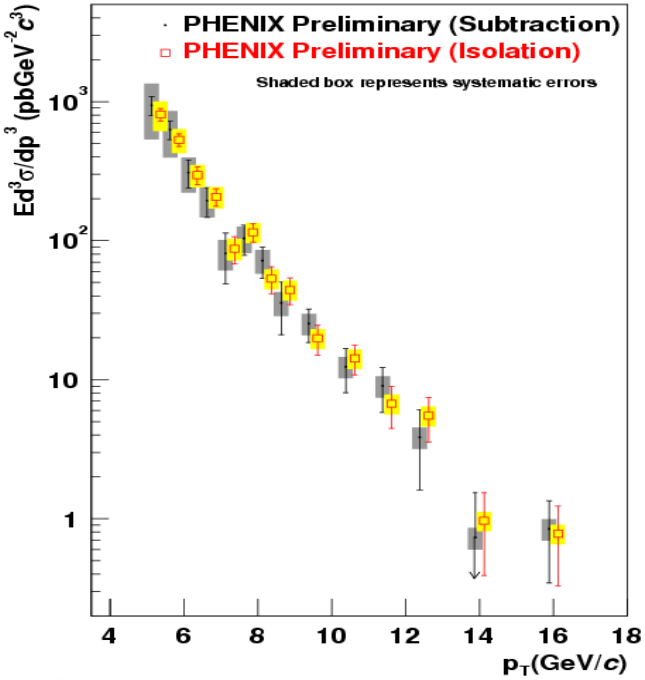


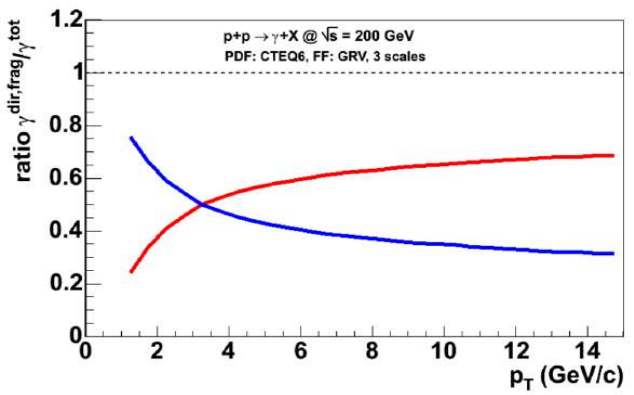
Follow the Recipes to Make Meals!

- A few of my own personal receipes:…

Recipes: @ high p_T more precision

- *p+p* Preliminary Comparison between isolation/non-iso method: negative Brems?
- pQCD Brems ~ 30%
- Plenty of room in those systematics
- Make real R_{AA} (with p+p γ–it's a there!) More precise also look for nuclear effects (k_T, Cronin)?





Recipe: Use Conversion Measurements, too

- Use the conversion measurement:
- At low p_T < ~3 GeV systematics probably smaller
- Factor of $10^{2\text{-}4}$ loss in statistics won't hurt in Run4
- In the region of overlap with the Calorimeter measurements, reduce γ energy scale uncertainty by "combining" rate normalization
- extend *p*+*p* γ measurement to lower p_T ?
- **Meal:** Constrain thermal model rates below 4 GeV **and** confirm or deny jet-medium enhancement

Recipe: Focus on Reaction Plane for Jet-Medium p_T

- Perform Reaction Plane dependent direct photon statistical analysis (under way @ PHENIX)
- Also with conversions where possible
- Measure direct γ flow directly (may be 0)
- Meal: Combine with HBT and other measurements to constrain space time geometry, path dependencies

Other Recipes:

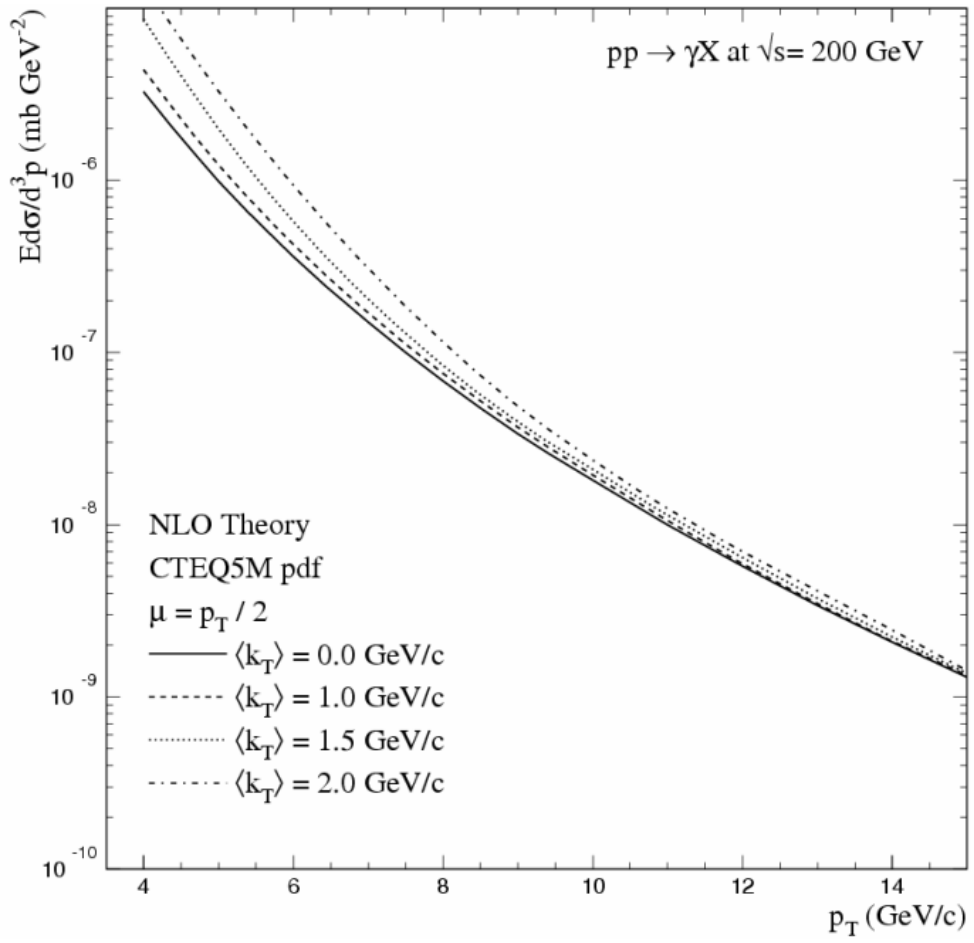
- **Study γ-h correlations:** separate angular jet shape differences btw Brems., Compton π^0 bkg
- Also difference in flow portion of γ-h angular correlation shape

- Any of your “family favorites”?

Conclusions

- No BBQ is complete without some good libations!
- Exciting time in the RHIC photon world!
- Not quite time yet: More time needed in front of the grill.
- But as our meals are slowly served, there will certainly be much to celebrate!

Back-up possible k_T effects (e.g. nuclear?)



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