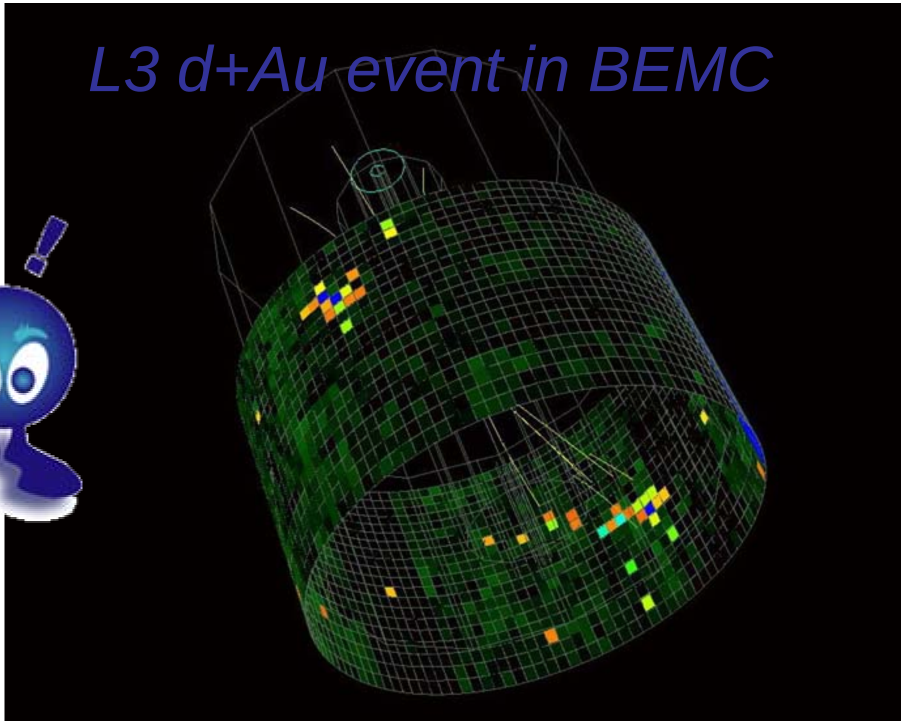
Direct photons with the STAR detector

outline:

- Motivation
- Experimental Setup
- Analysis strategy
- Correction / errors
- result in d+Au
- Outlook



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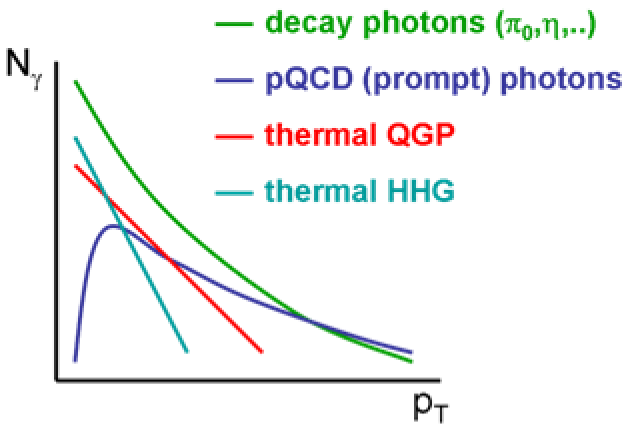
Why study photons in **A+A**?

in general:

- photons do not interact with medium
- carry information of various stages of the collision
- def: direct photons, not from hadronic decays. (for this analysis now fragmentation contribution not isolated)



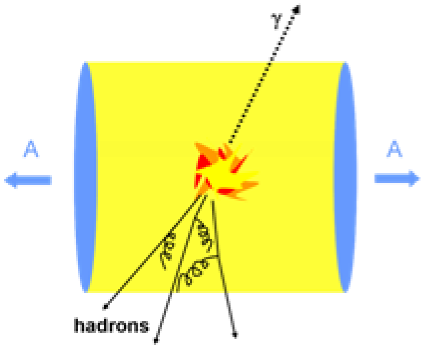
thermal photons:

- produced in QGP and hadron gas phase, carry information on temperature
- but large background from decays: $\pi^0 \rightarrow \gamma\gamma$

hard scattering (prompt):

- independent proof for jet-quenching as a final state effect

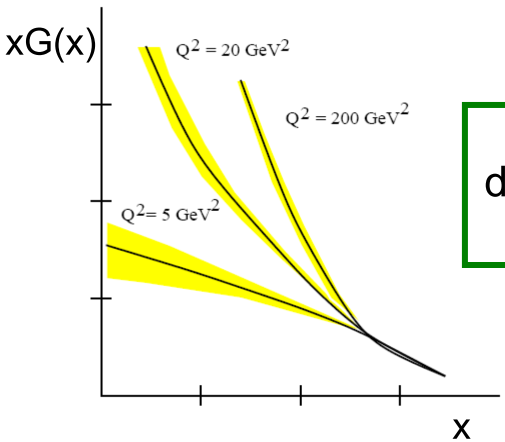
  $\rightarrow$ i.e. $R_{AA} \sim 1$ for photons.at high p_T
- gamma-jet: ultimate probe for energy-loss in A+A
- measurement of prompt photons needed to get thermal γs
- π^0 background in A+A suppressed at high p_T!



Why study photons in **d+A** and **p+p**?

p+p:

- sensitive to G(x) (and ΔG) without fragmentation uncertainty, intrinsic k_T, …



$$d\sigma \sim PDF \otimes pQCD \otimes FF$$

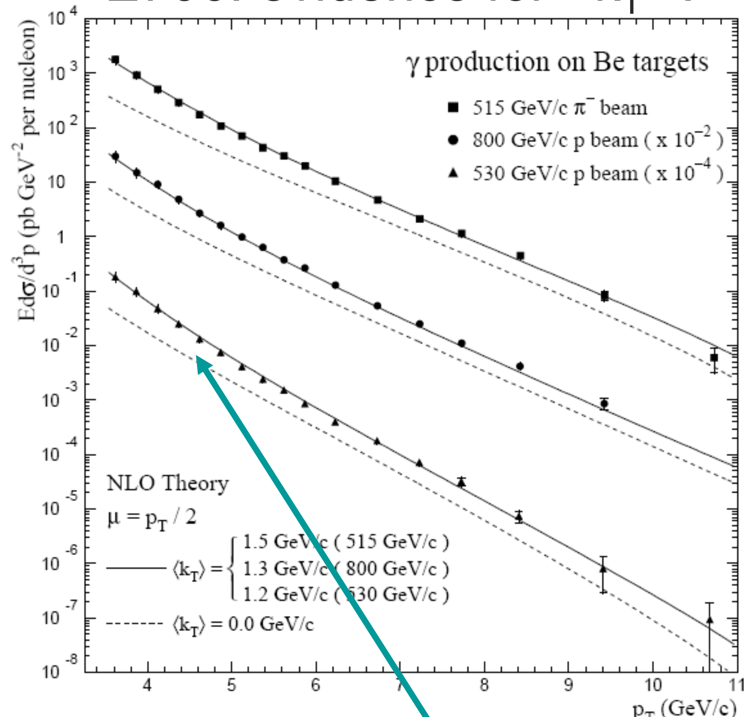
$= \delta(z)$

d+A:

- study initial state (gluon density, nuclear k_T, CGC, ….)

in general: precise knowledge of non-thermal photons needed for A+A

E706: evidence for $<k_T>$?



Phys. Rev. D70: 092009,2004

$<k_T>$ puts theory on data

Experimental Setup

BTOW:

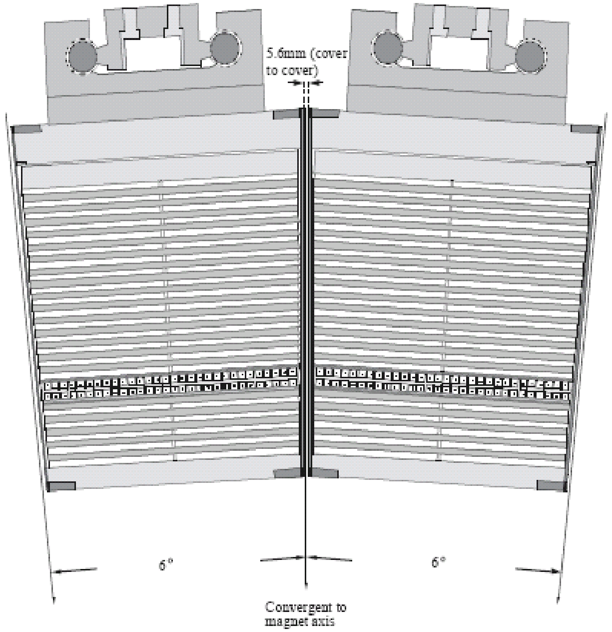
- 4800 PbSc towers with $-1<\eta<1$, $0<\phi<2\pi$, 0.05 x 0.05
- $dE/E \sim 16\%/\sqrt{E}$

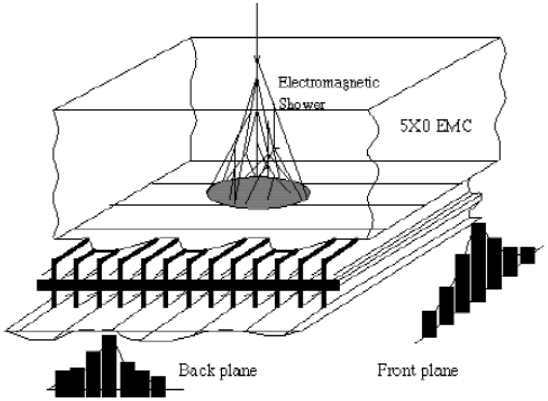
BSMD:

- wire-prop. counter at 5-7 X_o , 0.007 x 0.007
- $dE/E \sim 90\%/\sqrt{E}$

→ *to 1st order not an energy detector*

- necessary for γ/π^0 separation at high p_T





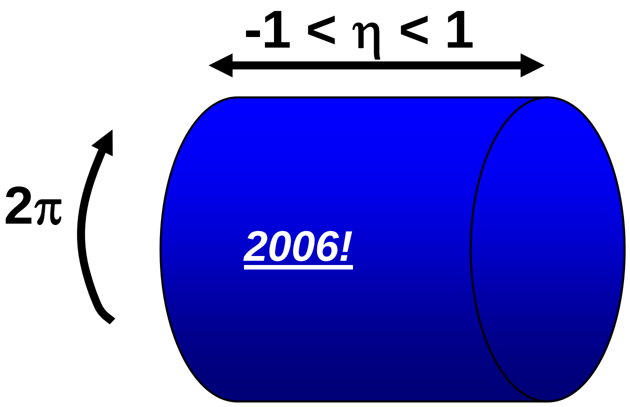
Calibration:

- MIP calibration
- electron p/E calibration
- BSMD calibration from bench..

Experimental Setup (2)

LØ trigger:

- BEMC trigger patches to enhance particle yield at high p_T (photons,electrons,jets)
- thresholds at 2.5 and 4.5 GeV, for pions 80% efficient at 6 and 10 GeV (***hightower-1***,***hightower-2***)
- and minbias condition from ZDC-Au > threshold

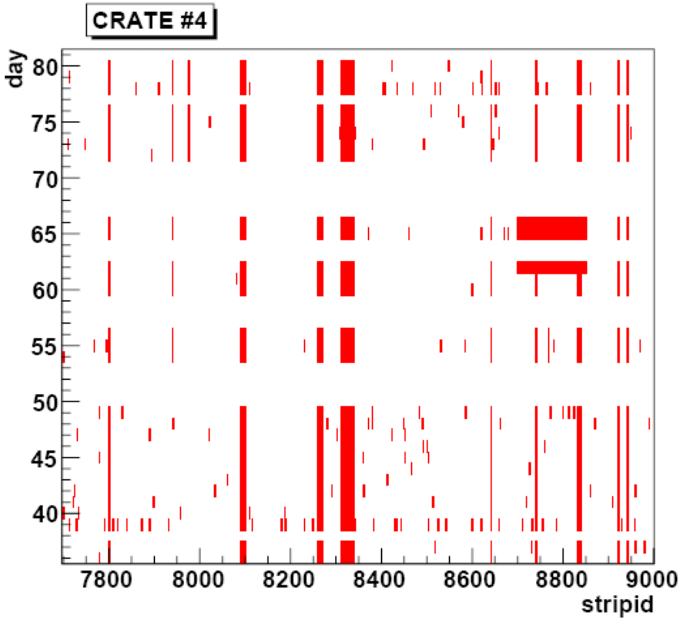


d+Au dataset:

- in d+Au 50% installed (commissioning status)

--- 2006 run EMCal+showermax fully operational! ---

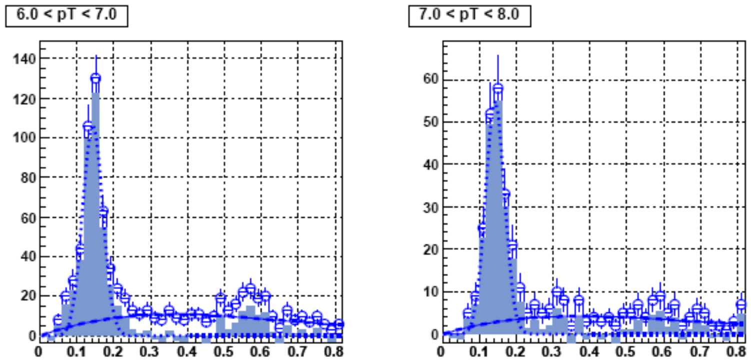
- 5% of towers and 10-15% of BSMD strips masked out for offline analysis
- uncertainty on gain of EMCal channels ~10% in 2003
- available statistics: 5M minbias, 200k dAuHighPt-1 and 120k dAuHighPt-2 triggered events after cuts

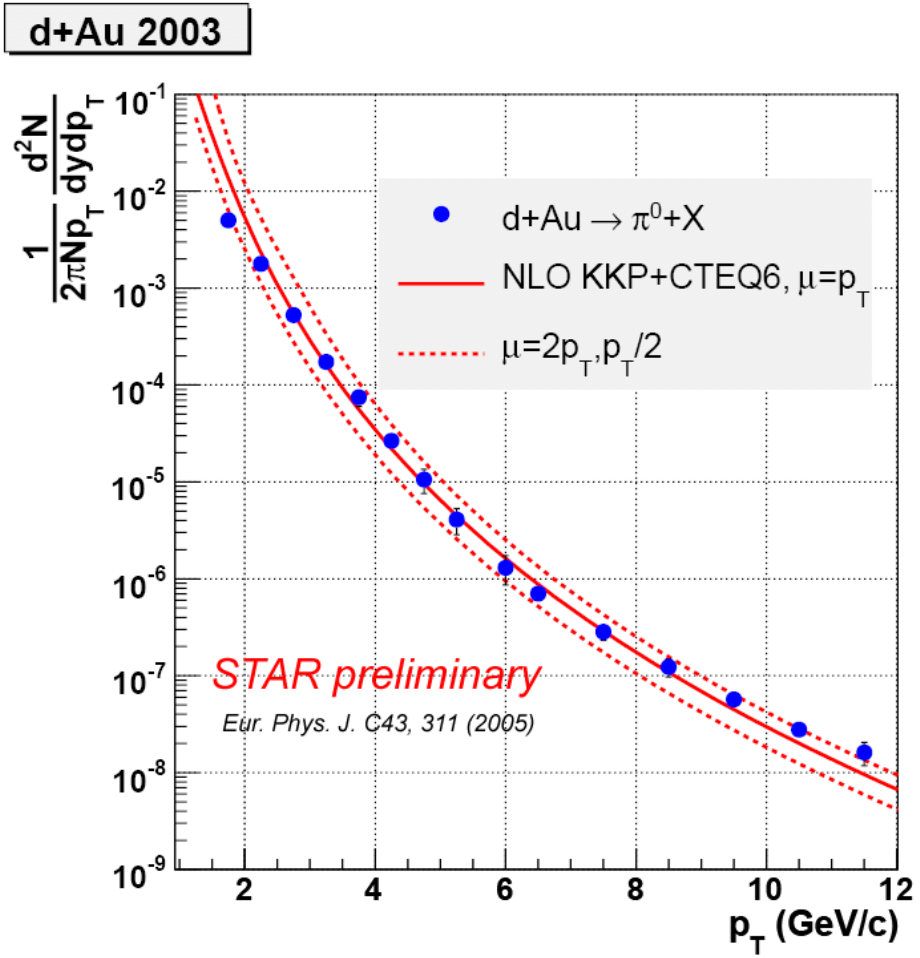


Analysis strategy

Statistical method:

- largest background is $\pi^0 \rightarrow \gamma\gamma$ (η,ω,…) + neutral hadrons
- pion spectrum main input, m_T scaling assumed for other mesons, η/π^0 taken as 0.45 +/- 0.05.
- pion spectrum through di-gamma invariant mass analysis and Charged Particle Veto from TPC

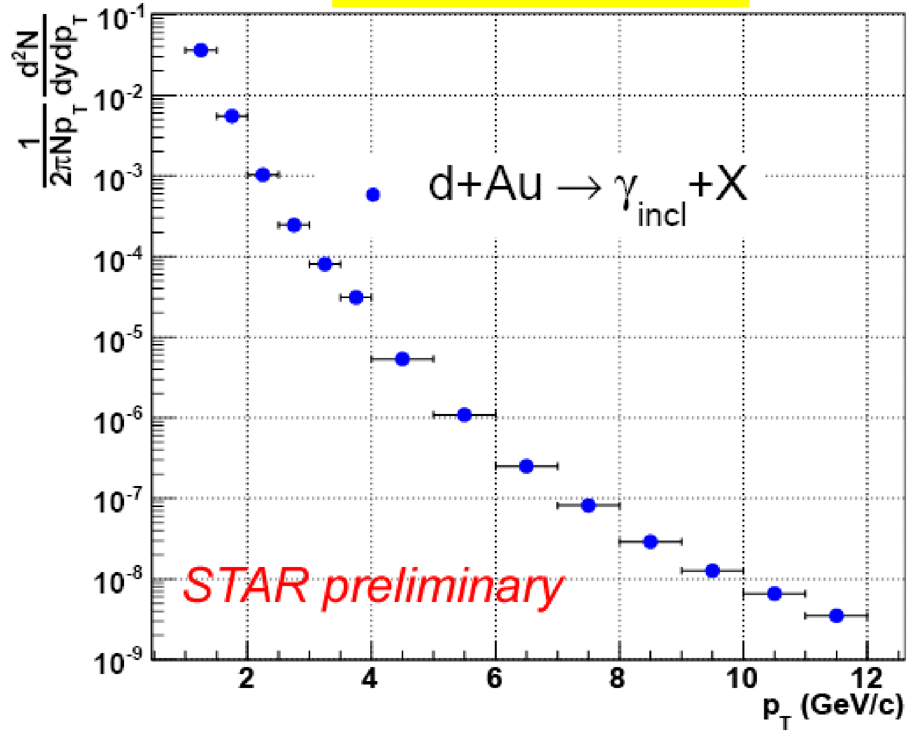




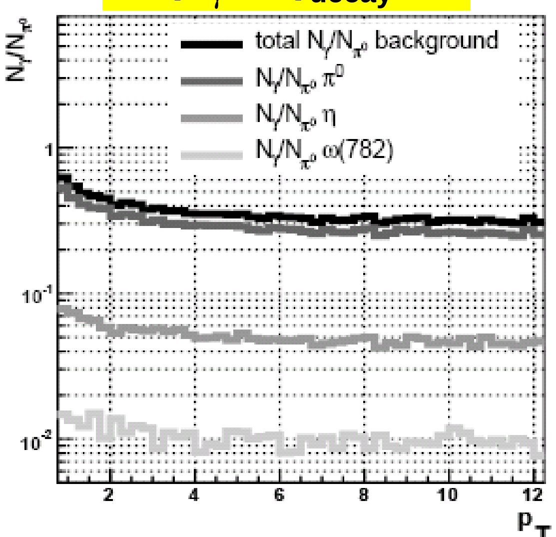
Analysis strategy

- Identify photons applying CPV and showershape criterium (BSMD) in same dataset
- subtract neutral hadrons
- efficiency and acceptance from GEANT pions, embedded in d+Au minimum bias events

inclusive photons:



$(N_\gamma / \pi^0)_{decay}$:



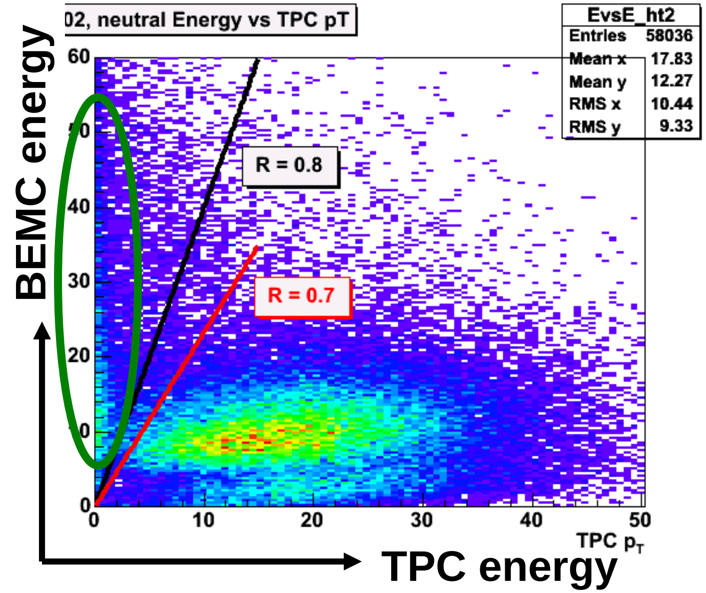
- R is point to point ratio of pions and photons divided by N_γ/N_π simulated:
- (partial) cancellation of many systematic errors

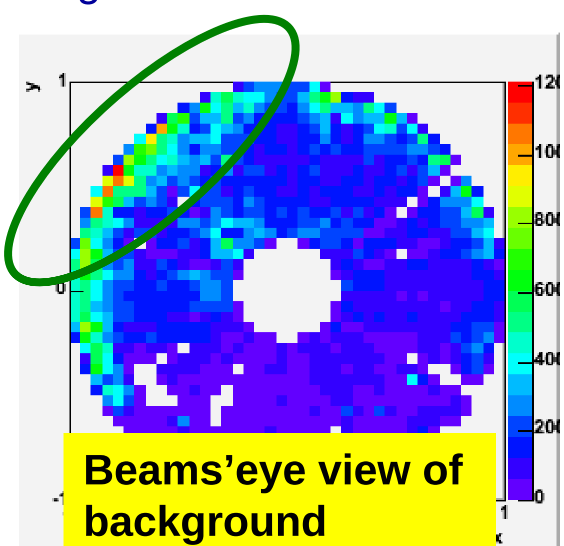
$$R = (\gamma_{incl}/\pi^0) / (\gamma_{decay}/\pi^0)$$
$$= 1 + \gamma_{dir} / \gamma_{decay}$$
$$> 1 \, ??$$

Corrections / Errors

Beam background:

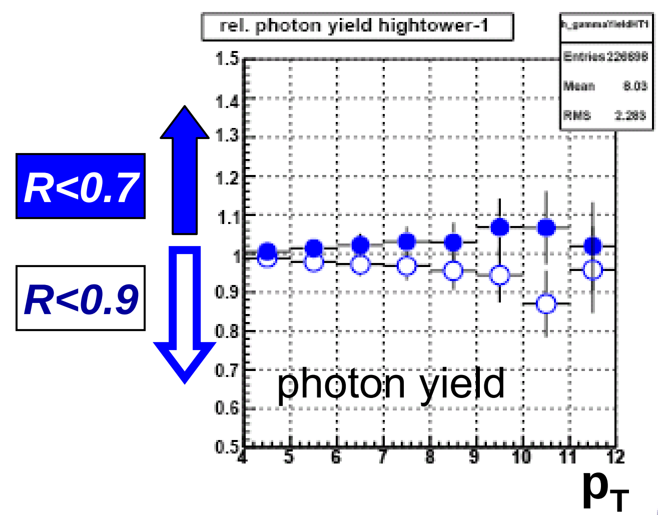
- upstream scattering of the beam-halo on magnet overlaps with minbias condition
- events with high energy deposit in calorimeter, but almost no signal in TPC, contaminating high p_T triggered event sample
- fiducial cut on detector volume and ratio R of neutral over total energy used to cut on background events:





Beams'eye view of background

- gives contribution to photon yield, but also pions via cluster splitting
- photon and pion yield sensitive to cut on R
- ultimately: EbyE rejection tool like straight-thru tracking
- now sys. error.



Corrections / Errors

Pion yield extraction / BSMD response:

- large systematic error (10%), that goes directly into the the double ratio
- background underneath the peak influenced by cluster splitting from showermax
- in general, better understanding of shower-maximum detector needed for significant direct photon measurement

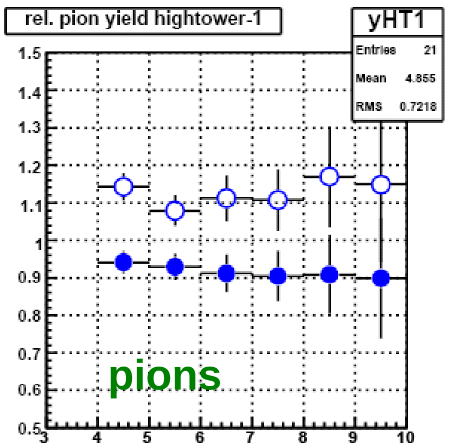
Energy scale:

- varying the overall gain in simulation by +/2% shows that absolute energy scale uncertainty of 5% leads to large error in both pion and photon spectra.
- causes a <3% uncertainty on ratio $\rightarrow$ **$R = (\gamma_{incl}/\pi^0) / (\gamma_{decay}/\pi^0)$**

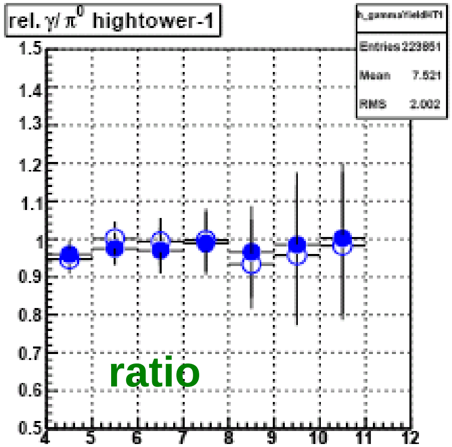
$N_\pi[+/-2\%] / N_\pi$

● = Escale -2%

○ = +2%



R[+/-2%] / R



Corrections / Errors

other systematics that have been checked are

- vertex dependence (<5%)
- Escale for photons (~25%)
- asymmetry cut (<5%)

future reduction of systematic errors:

- in situ calibration of showermax
- neutral pion calibration
- background event tagging
- more statistics for efficiency corrections

Main contributions to double ratio:

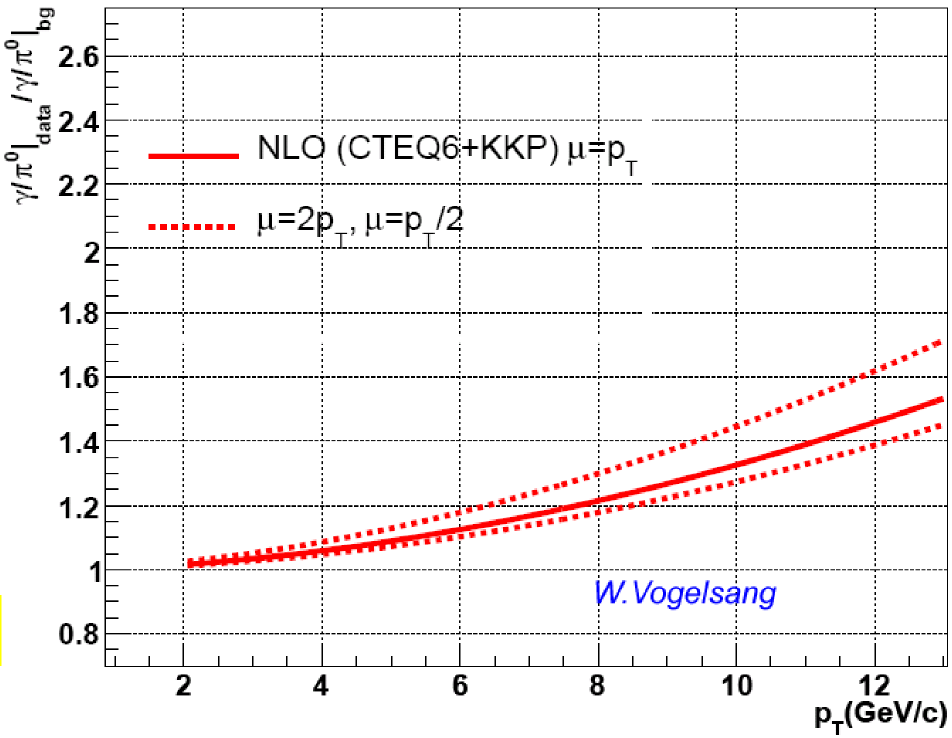
	3GeV	10GeV
yield extraction	5%	10%
energy scale	3%	3%
beam background	<1%	4%
eta/pion	2%	2%
fit to pions	3%	3%
Efficiency (stat.)	10%	4.5%
bsmd gain	5%	5%
stat. error	4%	7%

pQCD

pQCD:

- use Vogelsang pQCD for γ_{dir} and π^0 and calculate the ratio for the different scales
- excess over inclusive photons of ~0.3 at 10 GeV/c, approx. 3 times more pions:

pQCD @10 GeV $\gamma_{dir}/\pi^0 \approx 10\%$



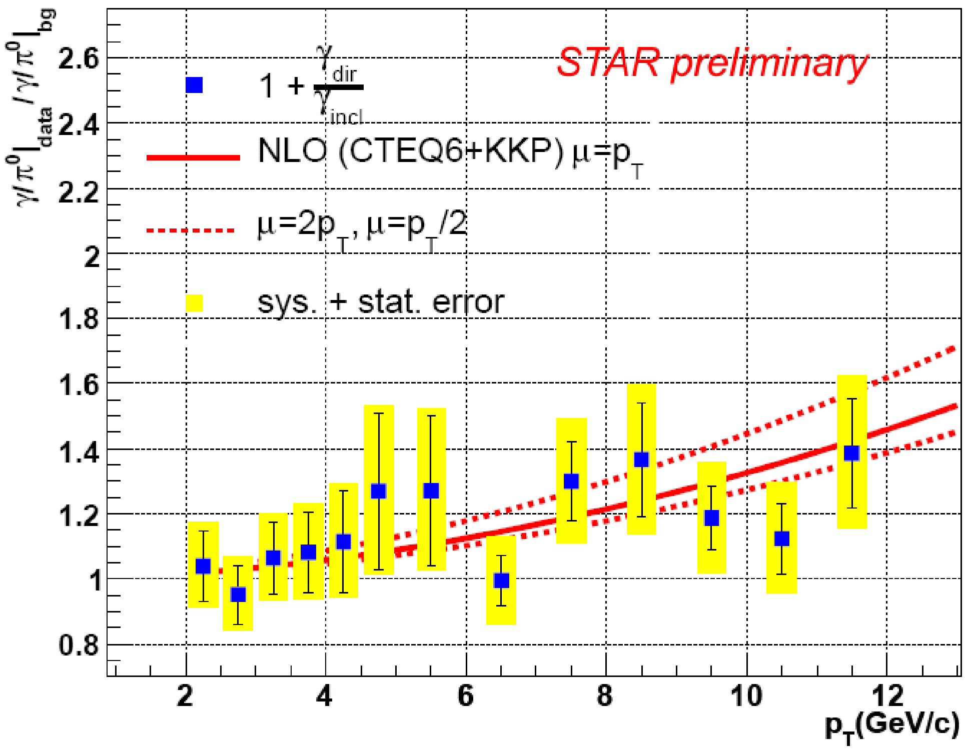
$$R = (\gamma_{incl}/\pi^0) / (\gamma_{decay}/\pi^0)$$

$$= 1 + \gamma_{dir}/\gamma_{decay}$$

Preliminary result in d+Au 2003

d+Au 2003 result:

- proof of principle measurement and setting a baseline for Au+Au
- consistent with pQCD
- reduction of systematic errors needed to extract spectrum



$$R = (\gamma_{incl}/\pi^0) / (\gamma_{decay}/\pi^0)$$

$$= 1 + \gamma_{dir}/\gamma_{decay}$$

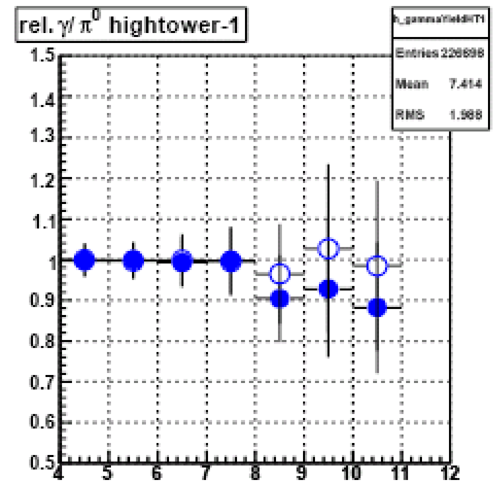
Summary/Outlook

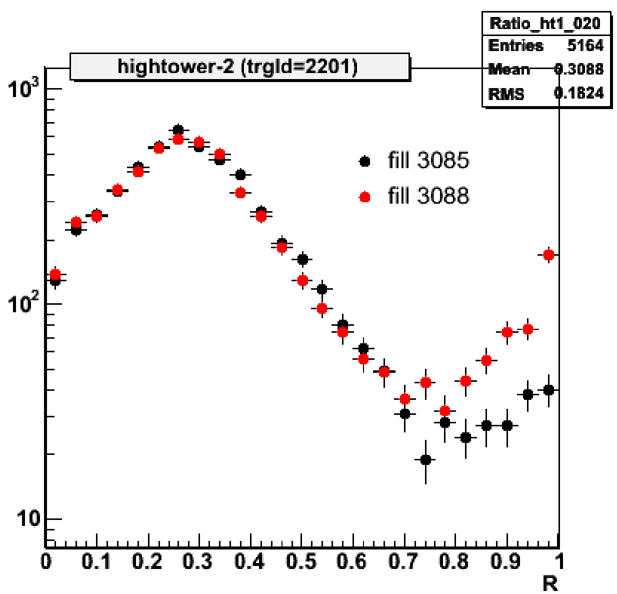
- first results in d+Au, double ratio consistent with pQCD
- working on reduction of systematic errors in order to extract a direct photon spectrum
- parallel analysis started in p+p 2005
- from there study nuclear effects (R_{dA})
- and analysis in Au+Au, when the lower multiplicity environments are under control

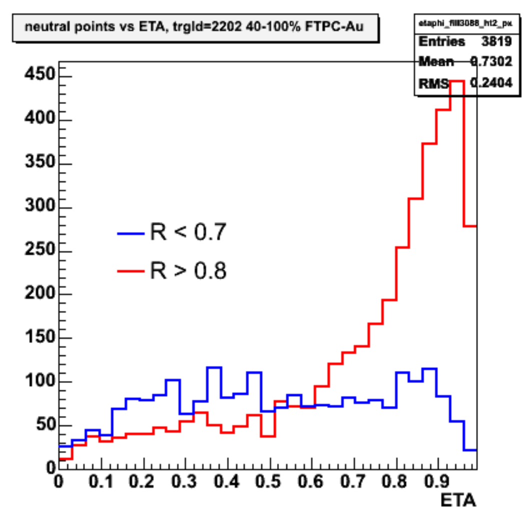
In general, the value of a direct photon measurement extends beyond Heavy Ion physics. In the near future, the spin program aims on using photon-jet events in polarized p+p to probe the gluon polarization.

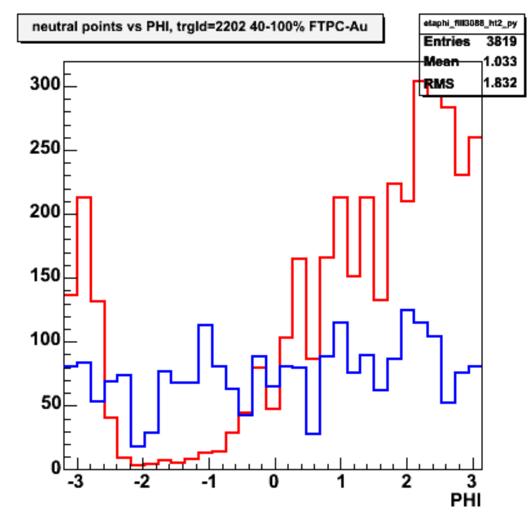
background

- fill to fill variation of background
- ratio has 2^{nd} order sensitivity to cut
- flat acceptance recovered after cut on R

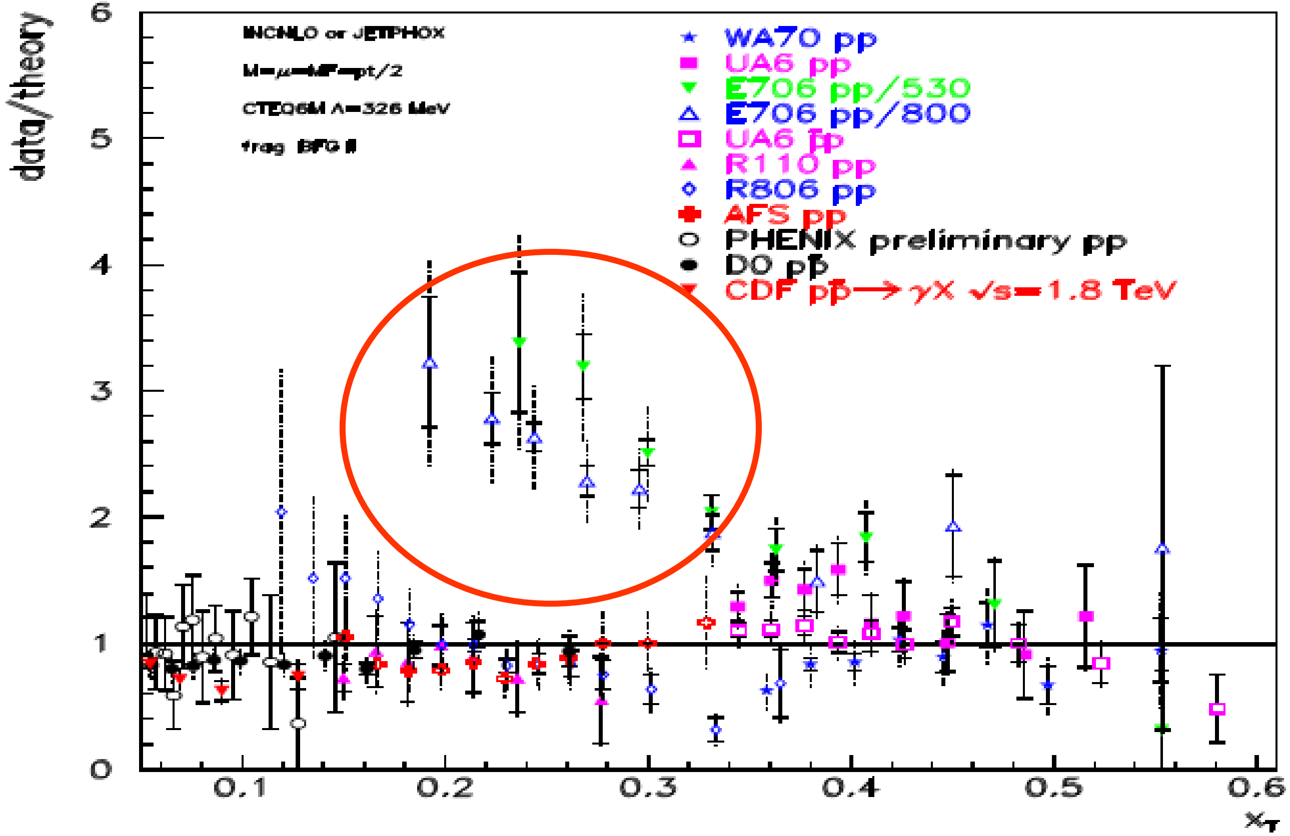








intrinsic k_T



Aurenche et al. **hep-ph/0602133**

eta to pion ratio:

PHENIX **hep-ph/0601037**

$\gamma_\eta / \gamma_\pi \approx 15\%$, so 0.45 +/- 0.05 means < +/-2% for simulated decay background

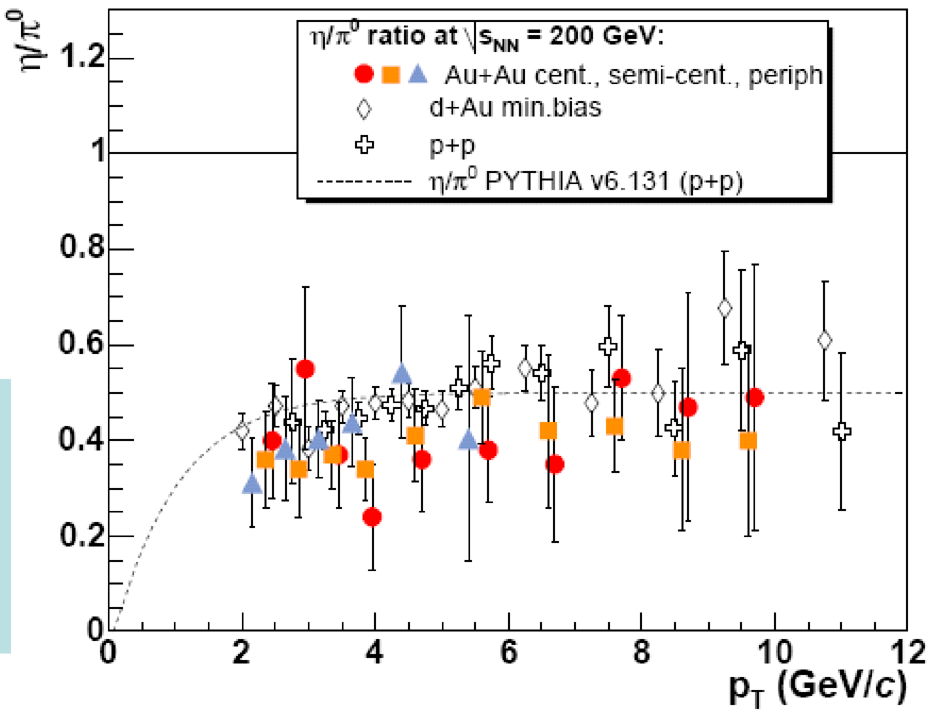
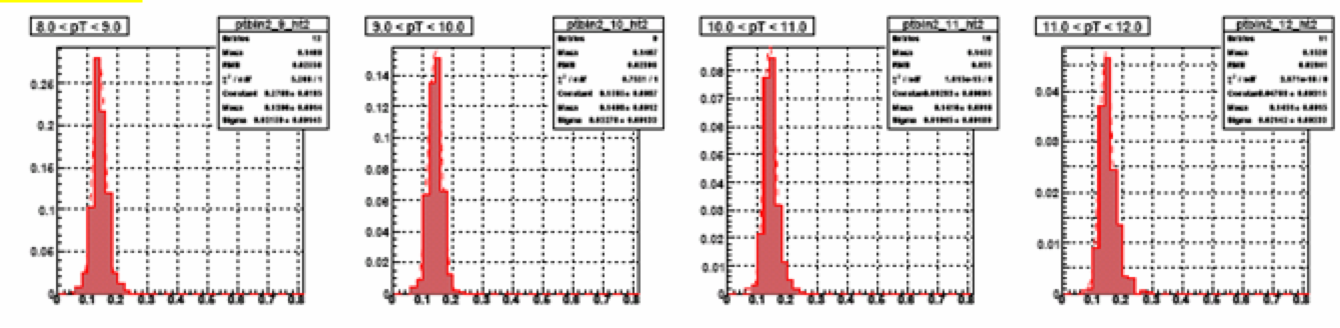


FIG. 4: η/π^0 ratio in Au+Au (centralities: 0-20%, 20-60%, 60-92%) compared to the ratio in p+p and d+Au [27] at $\sqrt{s_{NN}}$ = 200 GeV. The error bars include all point-to-point errors that do not cancel in the ratio of yields. The dashed curve is the PYTHIA [32] prediction for p+p at $\sqrt{s}$ = 200 GeV consistent with the asymptotic $R_{\eta/\pi^0} \approx 0.5$ measured in hadronic and e^+e^- collisions in a wide range of c.m. energies [27].

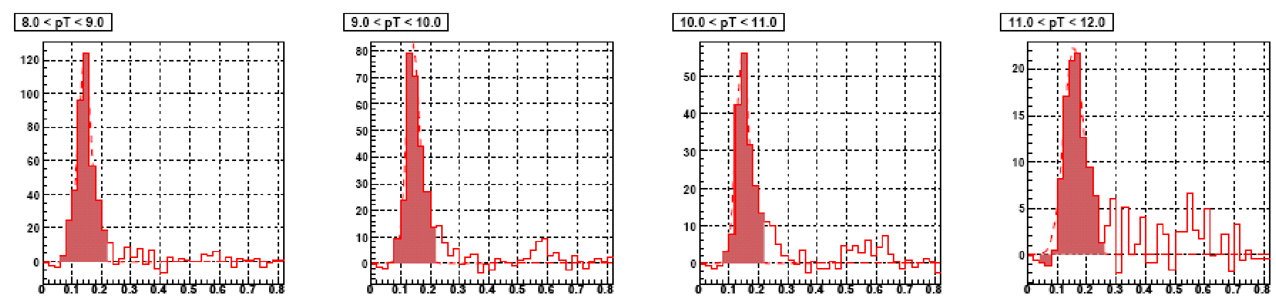
Data vs simulation

Tuning of the detector simulator needed to reproduce peak width and location

Geant:



Data:



Data vs simulation