Two Particle Correlations at Forward Rapidity in STAR

Ermes Braidot

for the STAR Collaboration

Utrecht University & Nikhef

RBRC Glasma workshop 2010

Outline

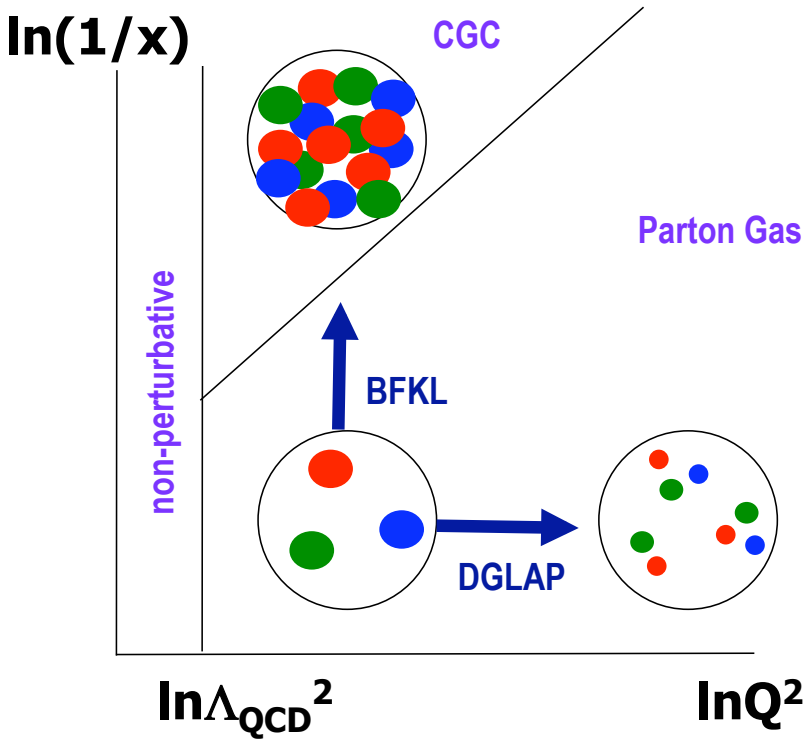
- Introduction: two particle correlation
- Low-x physics at STAR
- FMS results:
  - π^0+$h^{\pm}$ forward-mid rapidity azimuthal correlation
  - π^0+π^0 forward-mid rapidity azimuthal correlation
  - π^0+π^0 forward-forward rapidity azimuthal correlation
- Outlook and Conclusions

Low-x and Color Glass Condensate

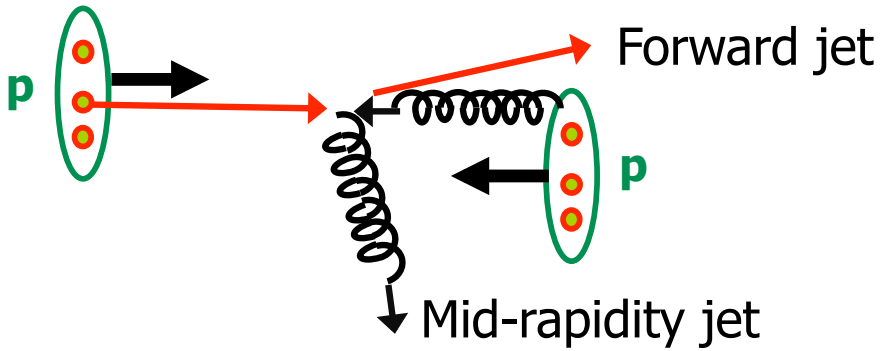
- **Color Glass Condensate**: semi-classical effective field theory for computing low-x gluons in nuclei
  - High occupation numbers (**condensate**)
  - Weak coupling methods
  - Collective behaviour of gluons
  - Different time scale evolution (**glass**)

from: incoherent sum of partons (A*proton)

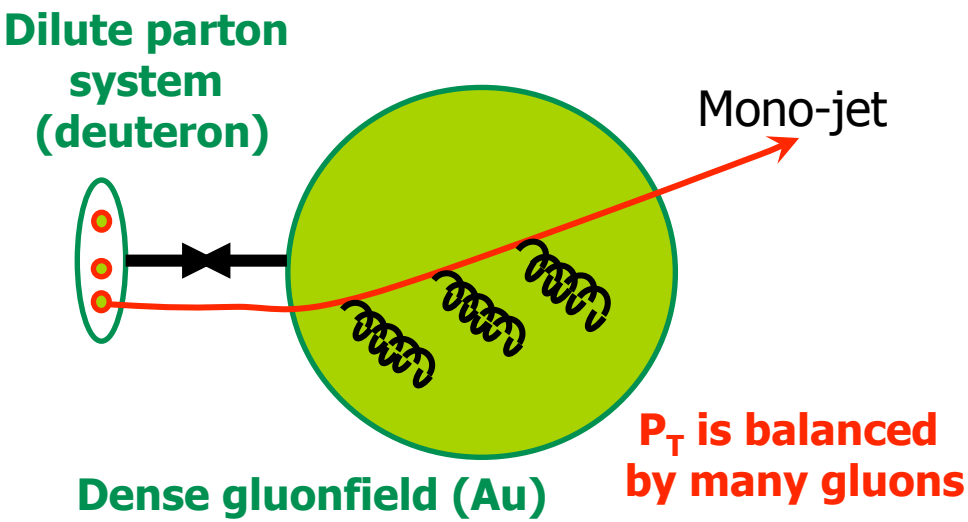
to: thin wall of coherent gluons randomly distributed



Probing the medium:
diluted vs. saturated

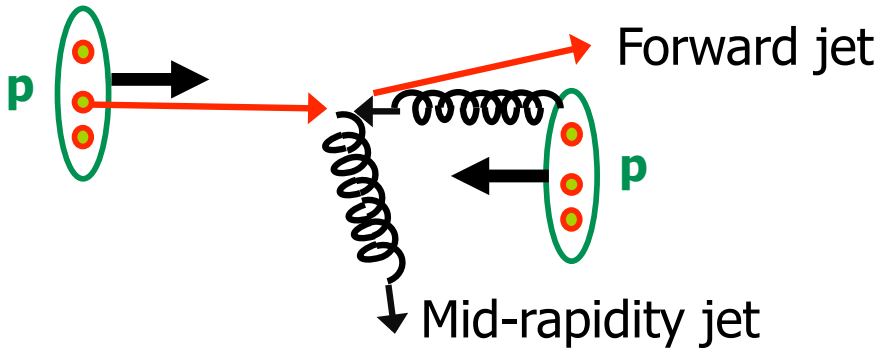


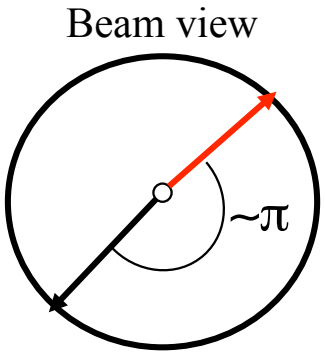
- **Scattering off dilute system**:
  - low gluon density (p+p like)
  - 2->2 process (**back-to-back**) expected from pQCD

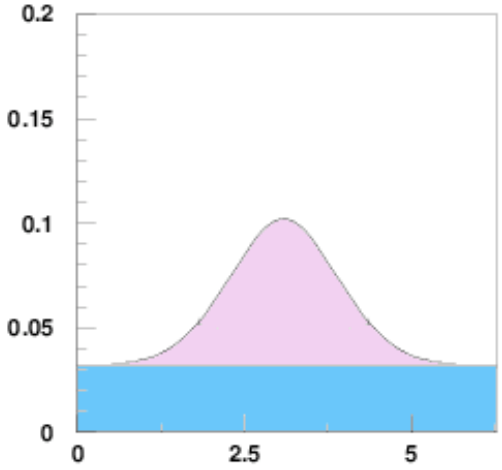


- **Scattering off saturated system**:
  - high gluon density (CGC)
  - collective behaviour
  - recoil balanced by many gluons
  - 2->1 (or 2->many) process (**mono-jet**)

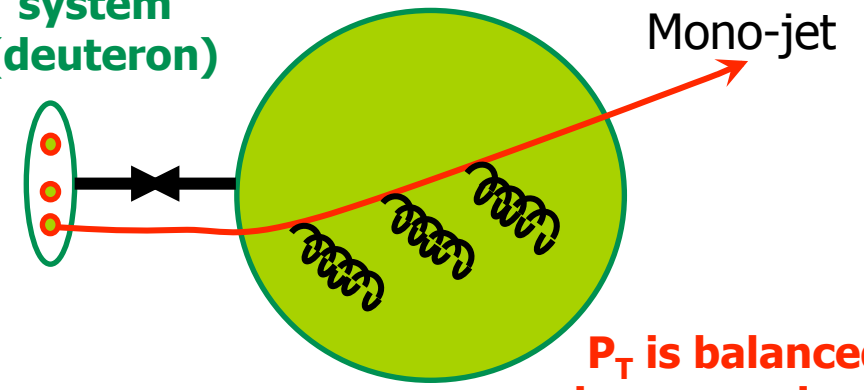
Probing the medium:
azimuthal correlations





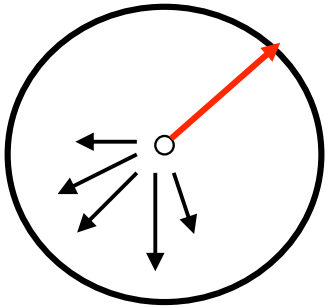


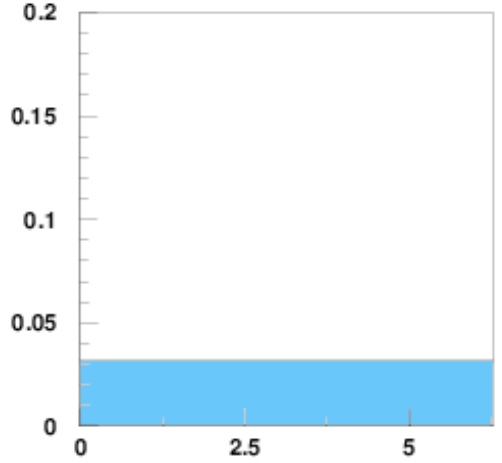
Dilute parton system (deuteron)



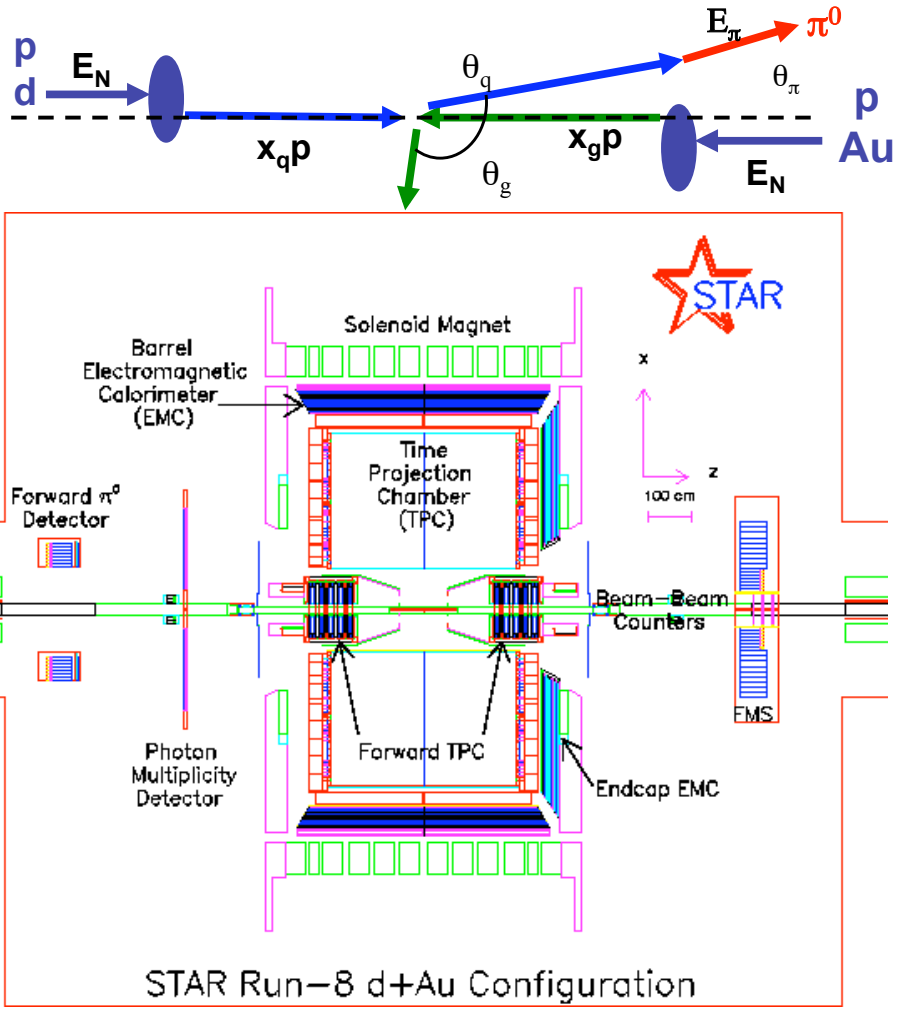
Dense gluonfield (Au)

P_T is balanced by many gluons

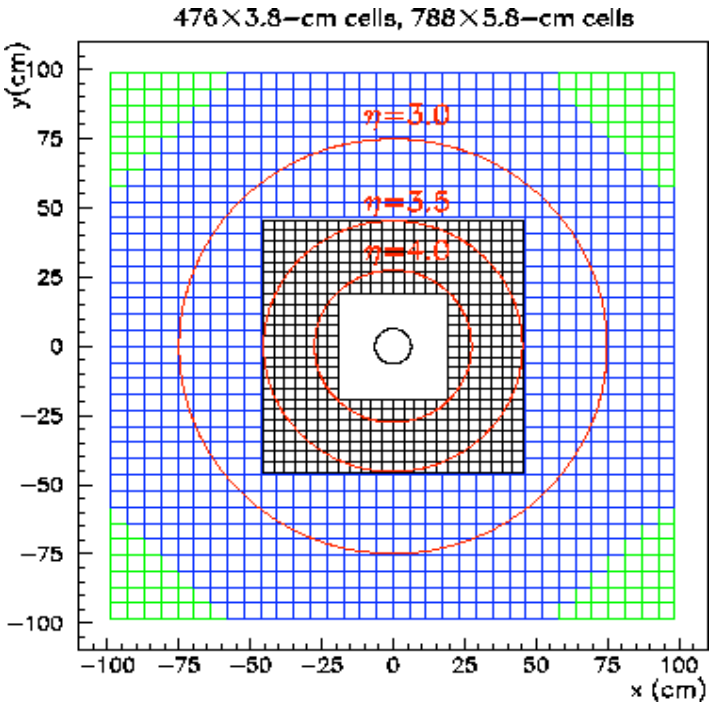




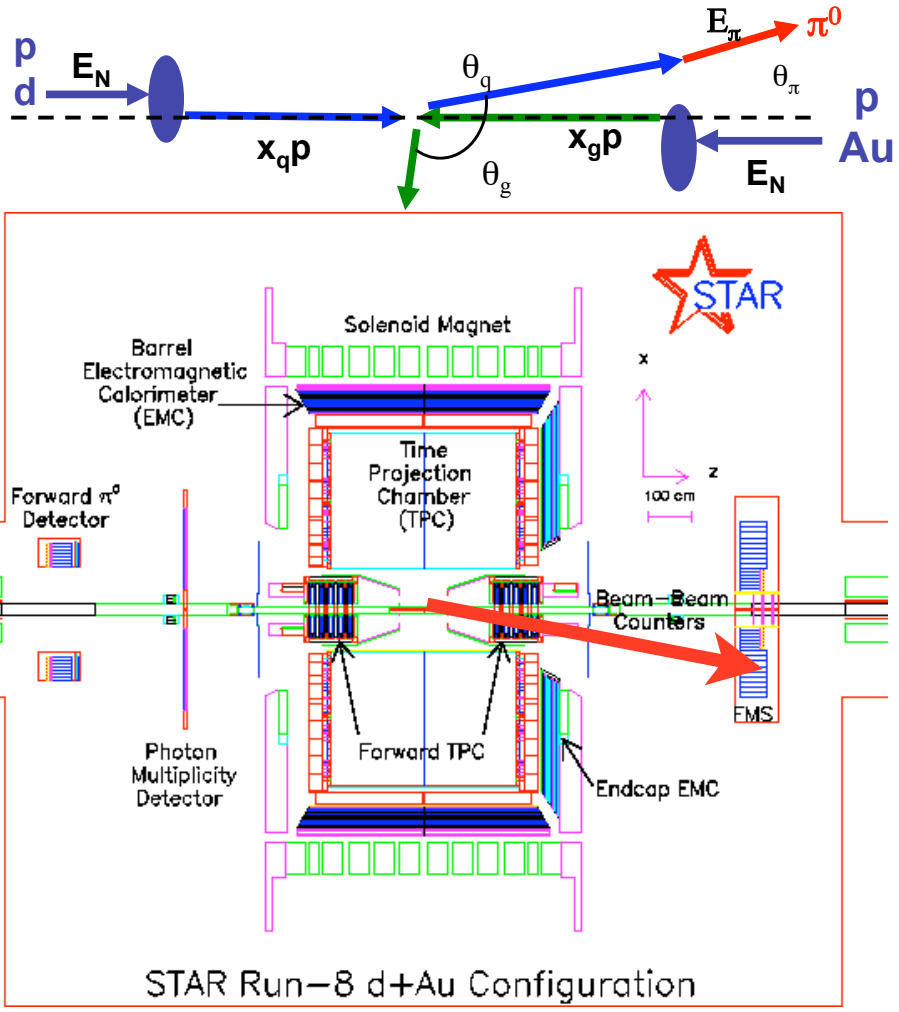
Looking forward at STAR



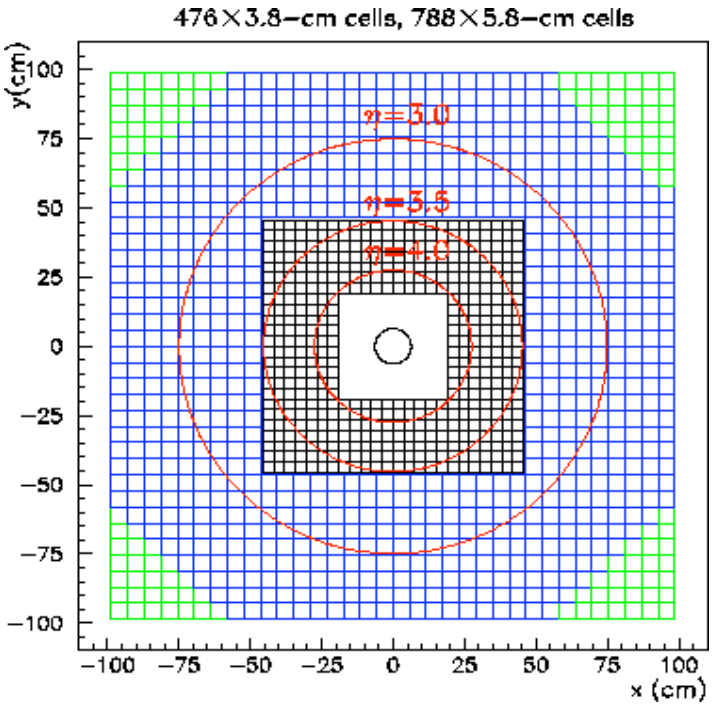
- **Forward Meson Spectrometer** (FMS)
  - trigger π^0
  - 2m*2m forward calorimeter
  - 788+476 lead glass cells



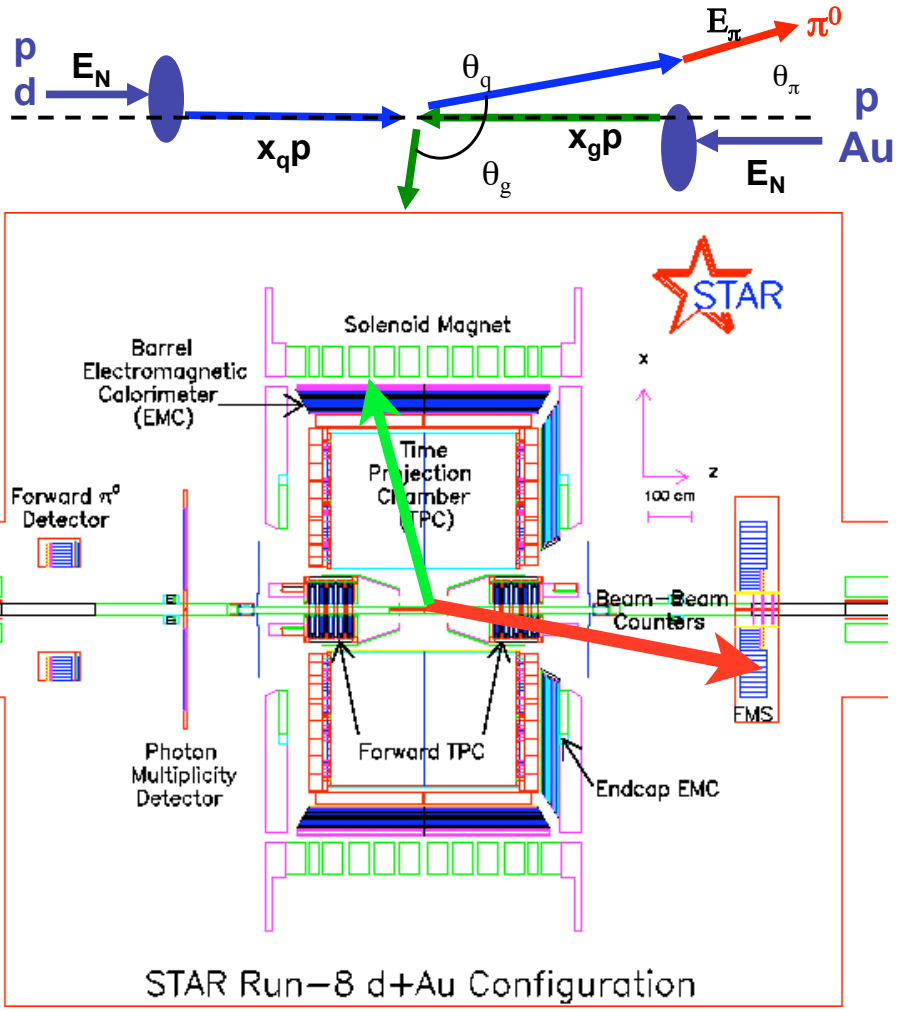
Looking forward at STAR



- **Forward Meson Spectrometer** (FMS)
  - trigger π^0
  - 2m*2m forward calorimeter
  - 788+476 lead glass cells

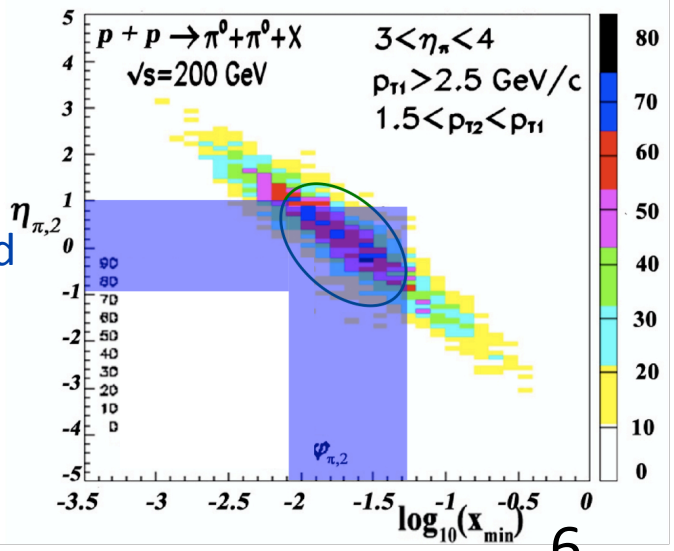


Looking forward at STAR

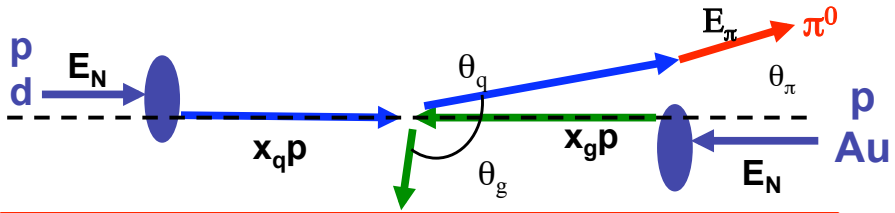


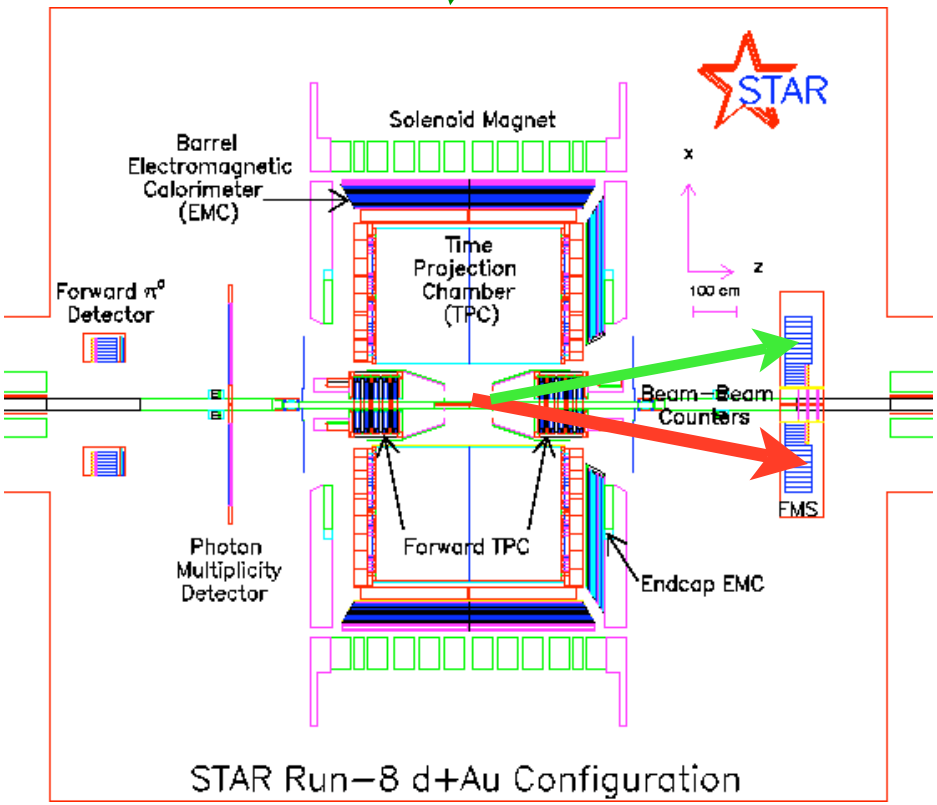
- **Forward Meson Spectrometer** (FMS)
  - trigger π^0
- **Time Projection Chamber** (TPC)
  - associated $h^{\pm}$
- **Barrel EM Calorimeter** (EMC)
  - associated π^0

Fwd-Mid

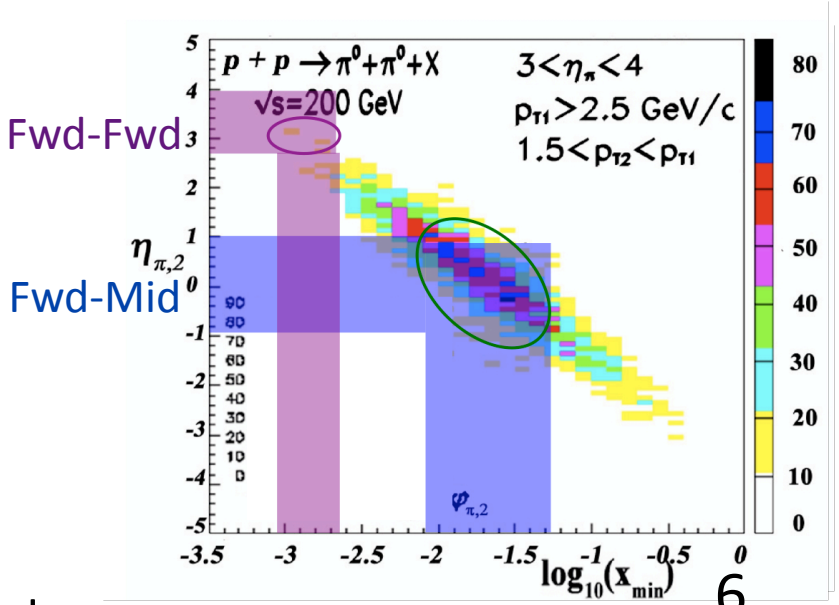


Looking forward at STAR

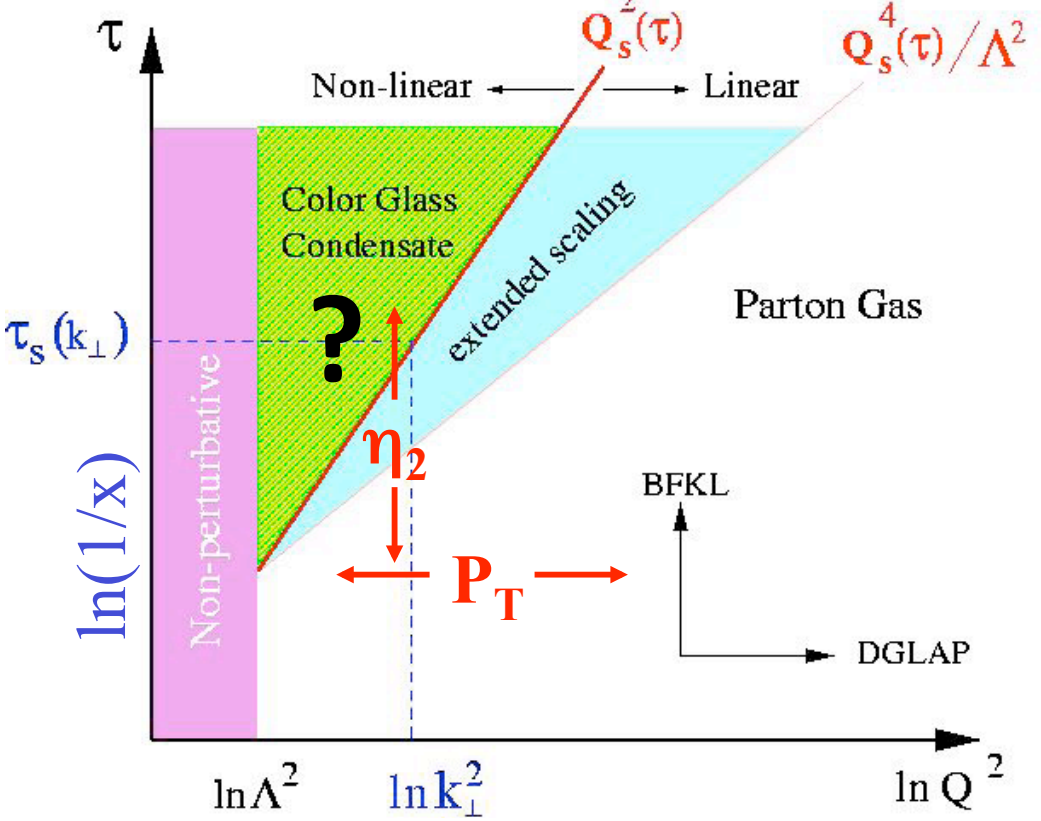




- **Forward Meson Spectrometer** (FMS)
  - trigger π^0
- **Time Projection Chamber** (TPC)
  - associated $h^{\pm}$
- **Barrel EM Calorimeter** (EMC)
  - associated π^0
- **Forward Meson Spectrometer** (FMS)
  - associated π^0



Looking forward at STAR



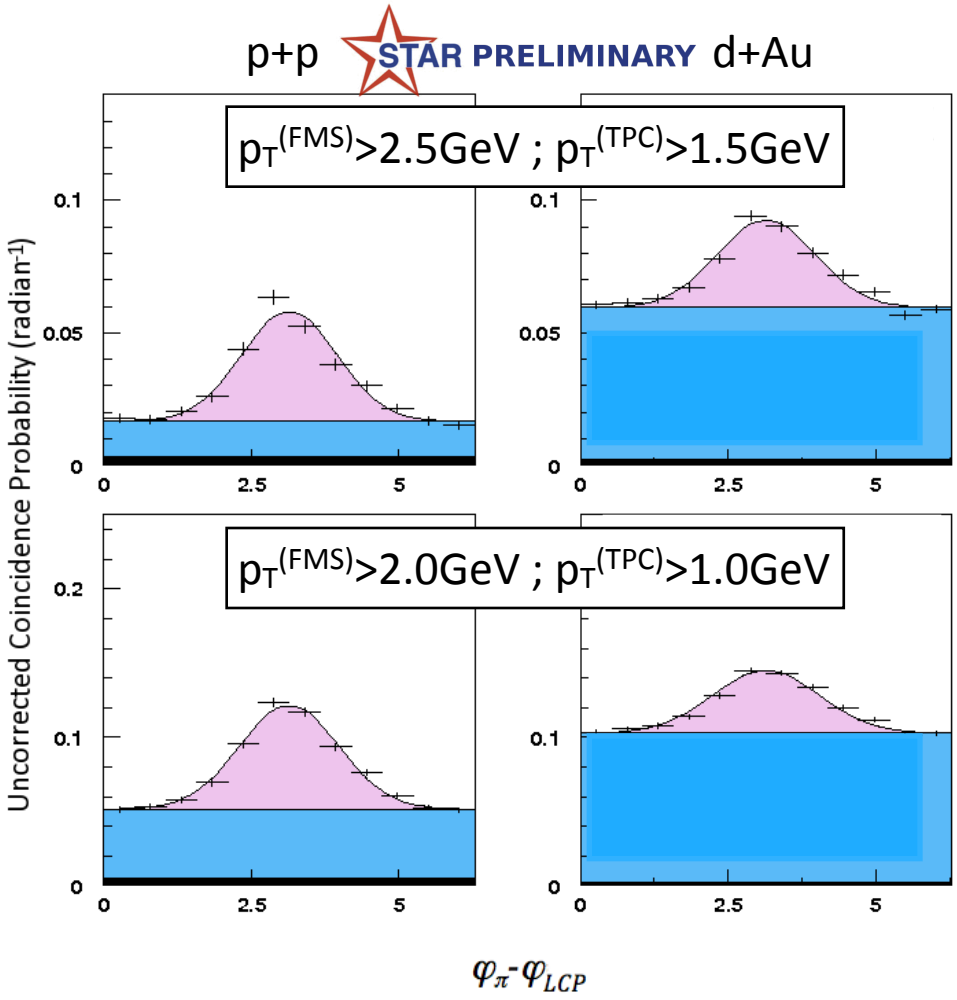
Edmond Iancu and Raju Venugopalan, hep-ph/0303204

- **Forward Meson Spectrometer** (FMS)
  - trigger and associated π^0
  - acceptance: $2.5<\eta<4.0$
- **Time Projection Chamber** (TPC)
  - associated $h^{\pm}$ $(-0.9<\eta<0.9)$
- **Barrel EM Calorimeter** (EMC)
  - associated π^0 $(-0.9<\eta<0.9)$

- **Higher p_T cut** (GSV)
  - (Guzey, Strikman and Vogelsang, hep-ph/0407201)
  - $p_T^{(LEAD)}>2.5$GeV ; $p_T^{(ASSC)}>1.5$GeV
- **Lower p_T cut** (Low)
  - $p_T^{(LEAD)}>2.0$GeV ; $p_T^{(ASSC)}>1.0$GeV

FMS-TPC (π^0+$h^{\pm}$) correlations

- Forward (FMS) π^0 as trigger particle
- Mid-rapidity (TPC) $h^{\pm}$ as associated
- Data not yet efficiency corrected



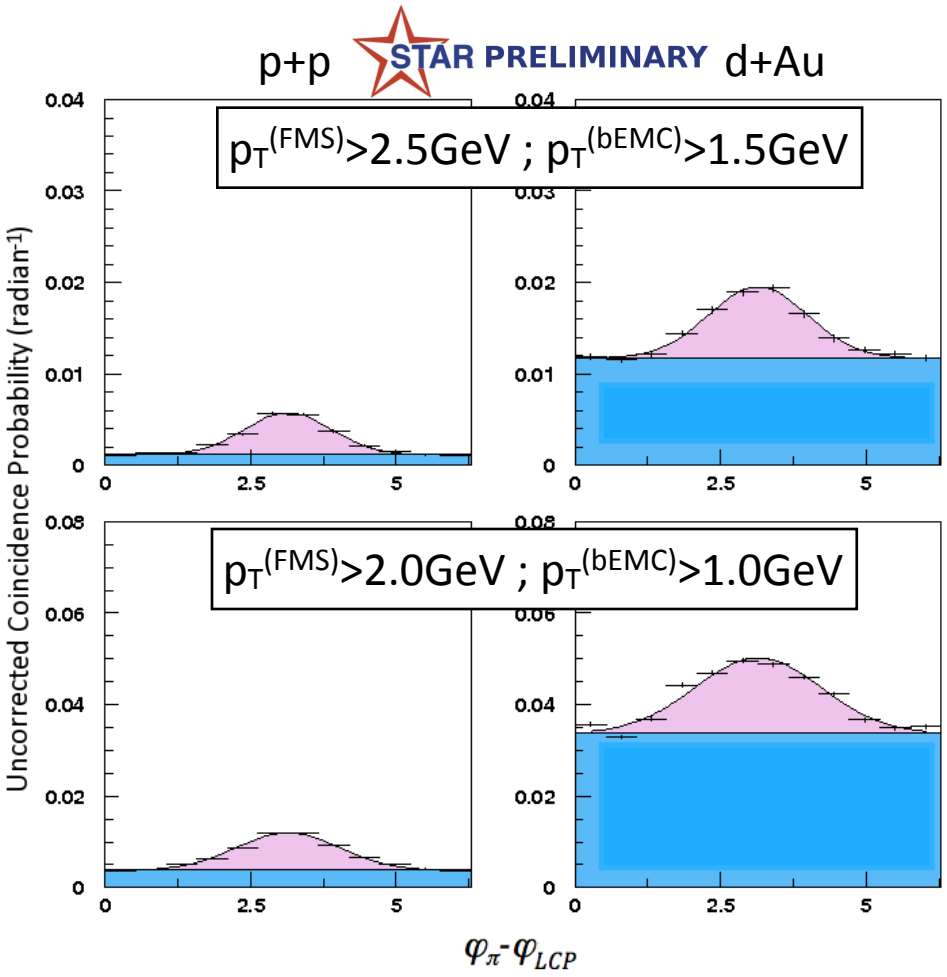
- Indication of signal broadening from p+p to d+Au
- Azimuthal broadening p_T dependent:
  - above: σ_{dAu}-σ_{pp}= 0.03±0.05 (stat)
  - below: σ_{dAu}-σ_{pp}= 0.06±0.04 (stat)
- Back-to-back peaks clearly evident

E. Braidot, Quark Matter 2009 proceedings, arXiv:0907.3473

FMS-BEMC (π^0+π^0) correlations

- Forward (FMS) π^0 as trigger particle
- Mid-rapidity (BEMC) π^0 as associated
- Data need to be efficiency corrected
- Larger combinatorial background contribution (correction ongoing)

- Consistency with TPC measurements (comparable width amplitude)
- Azimuthal broadening from p+p to d+Au is p_T dependent:
  - above: σ_{dAu}-σ_{pp}= 0.11±0.04 (stat)
  - below: σ_{dAu}-σ_{pp}= 0.20±0.03 (stat)
- No hints of away-side peak disappearance (as above)

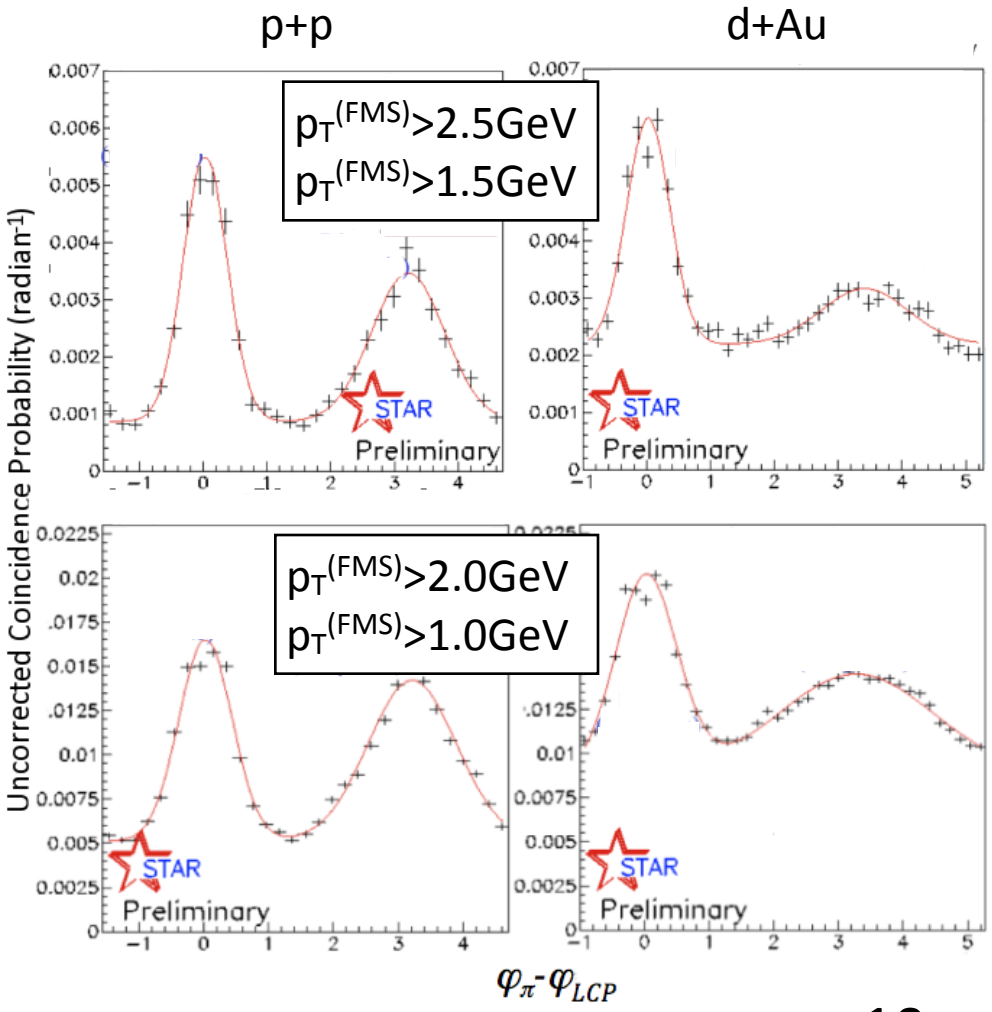


E. Braidot, Quark Matter 2009 proceedings, arXiv:0907.3473

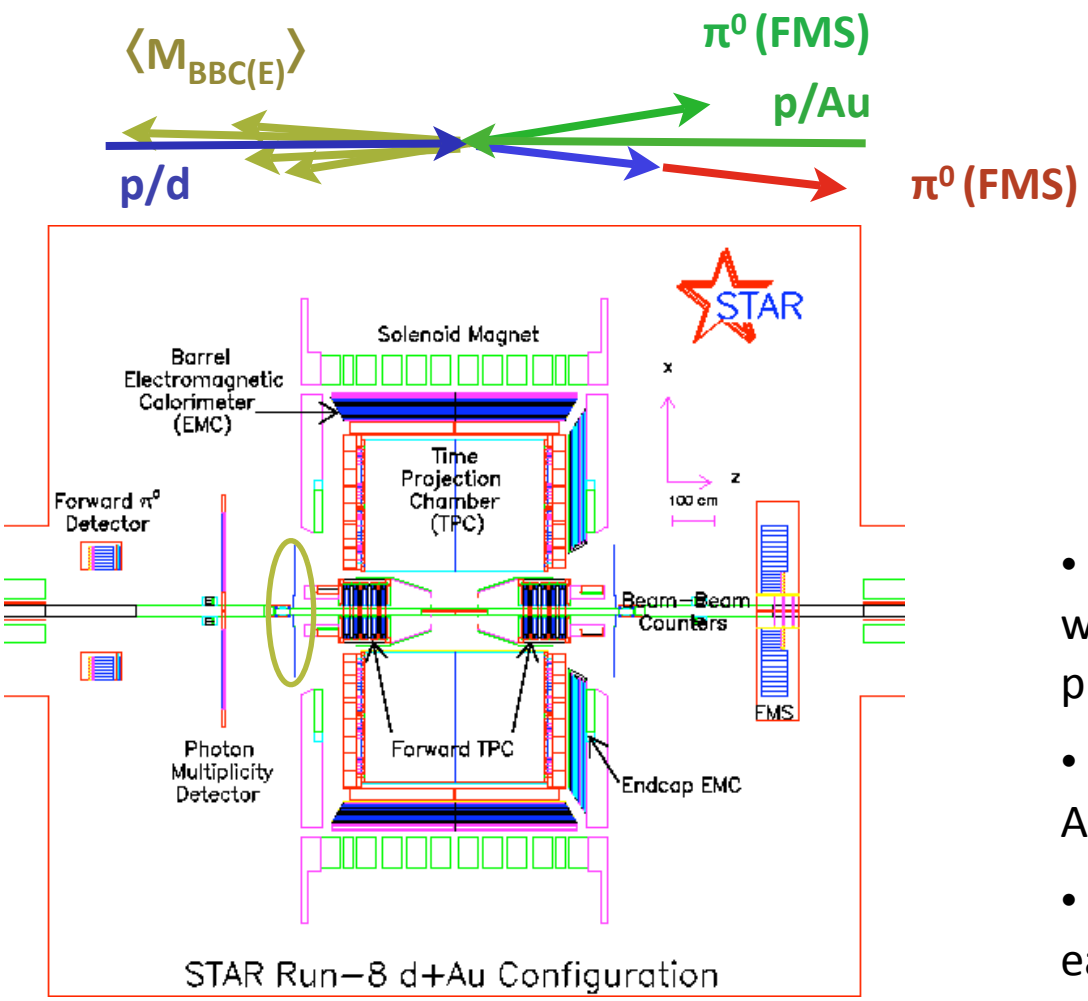
FMS-FMS ($\pi^0+\pi^0$) correlations

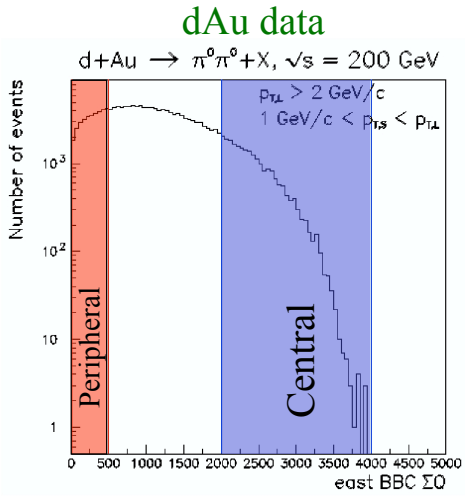
- Forward (FMS) π^0 as trigger particle
- Forward (FMS) π^0 as associated

- Centrality averaged
- Near-side peak visible ($\Delta\eta\sim0$)
- Near-side peak similar p+p vs. d-Au
- Away-side signal suppression from p+p to d+Au
- Strong azimuthal broadening
- Azimuthal broadening p_T dependent:
  - above: $\sigma_{dAu}-\sigma_{pp}= 0.11\pm0.06$
  - below: $\sigma_{dAu}-\sigma_{pp}= 0.52\pm0.05$



Centrality dependence

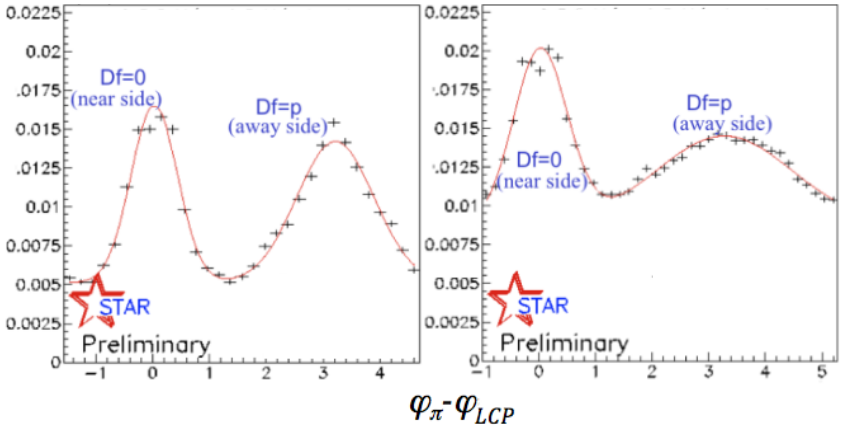




- Saturation expected more when thick part of the nucleus is probed
- Centrality selection through Au-side multiplicity
- Selection: charge sum from east (Au side: $-5.0 < \eta_{BBC} < -3.4$) BBC phototubes

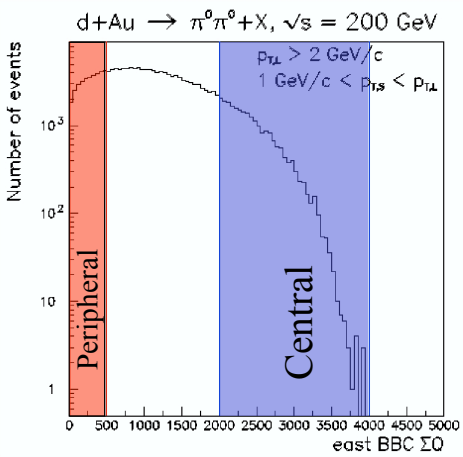
Centrality dependence

p+p d+Au



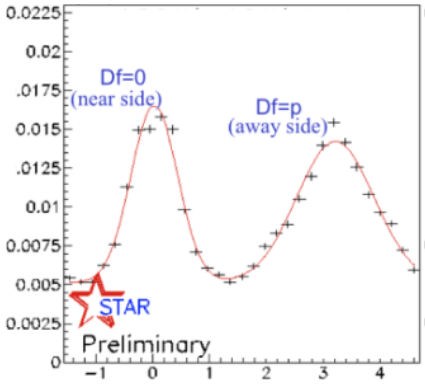
$p_T^{(FMS)}$>2.0GeV
$p_T^{(FMS)}$>1.0GeV

dAu data

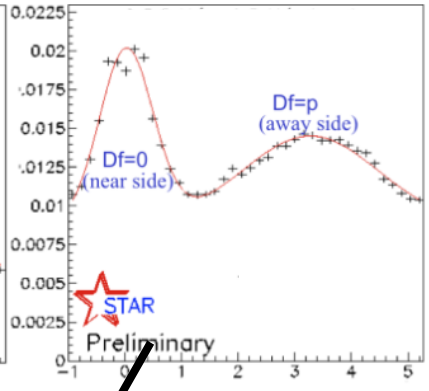


Centrality dependence

p+p

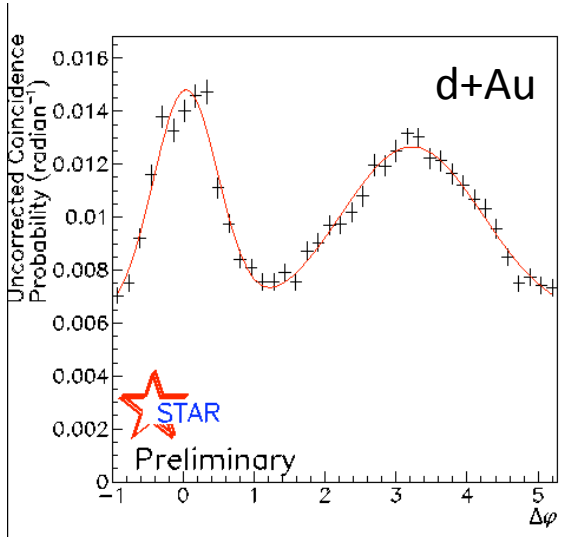


d+Au



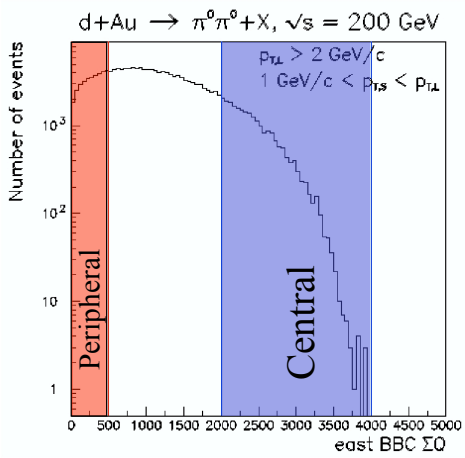
φ_π-φ_{LCP}

peripheral



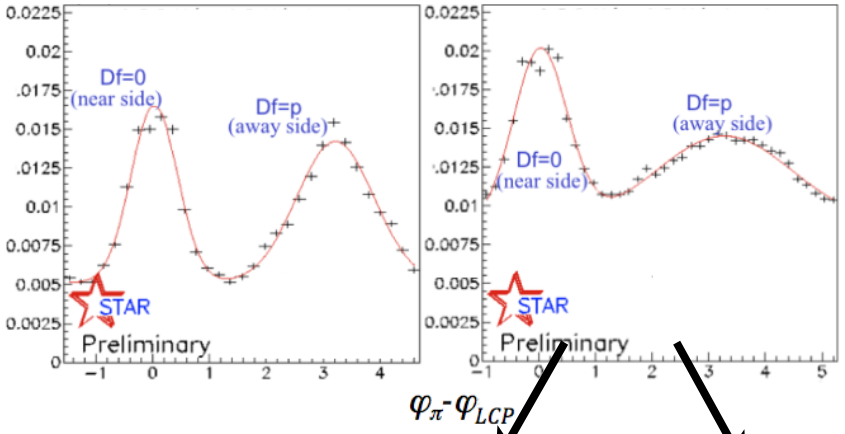
$p_T^{(FMS)}$>2.0GeV
$p_T^{(FMS)}$>1.0GeV

dAu data



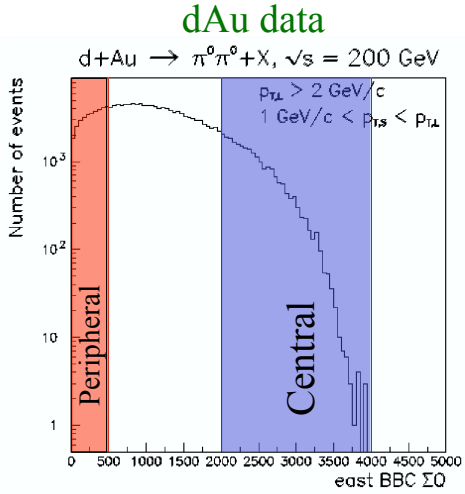
Centrality dependence

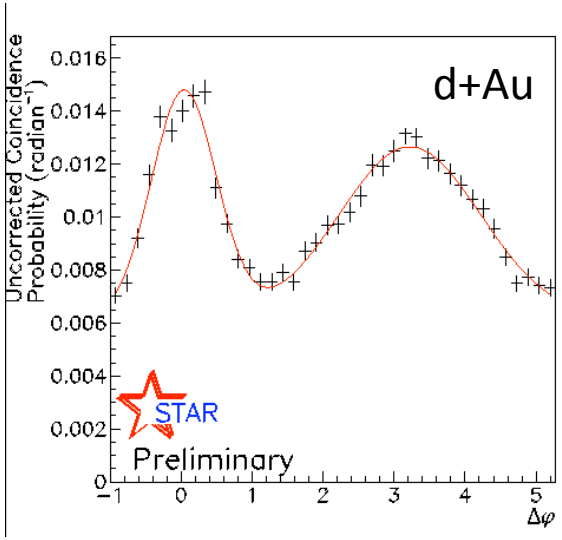
p+p d+Au

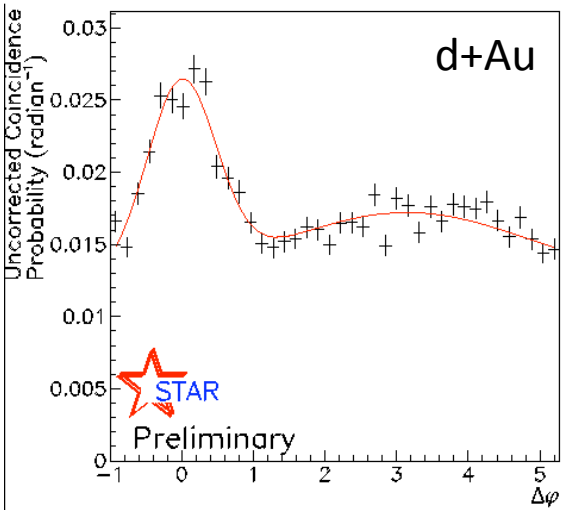


$p_T^{(FMS)}$>2.0GeV
$p_T^{(FMS)}$>1.0GeV

peripheral central





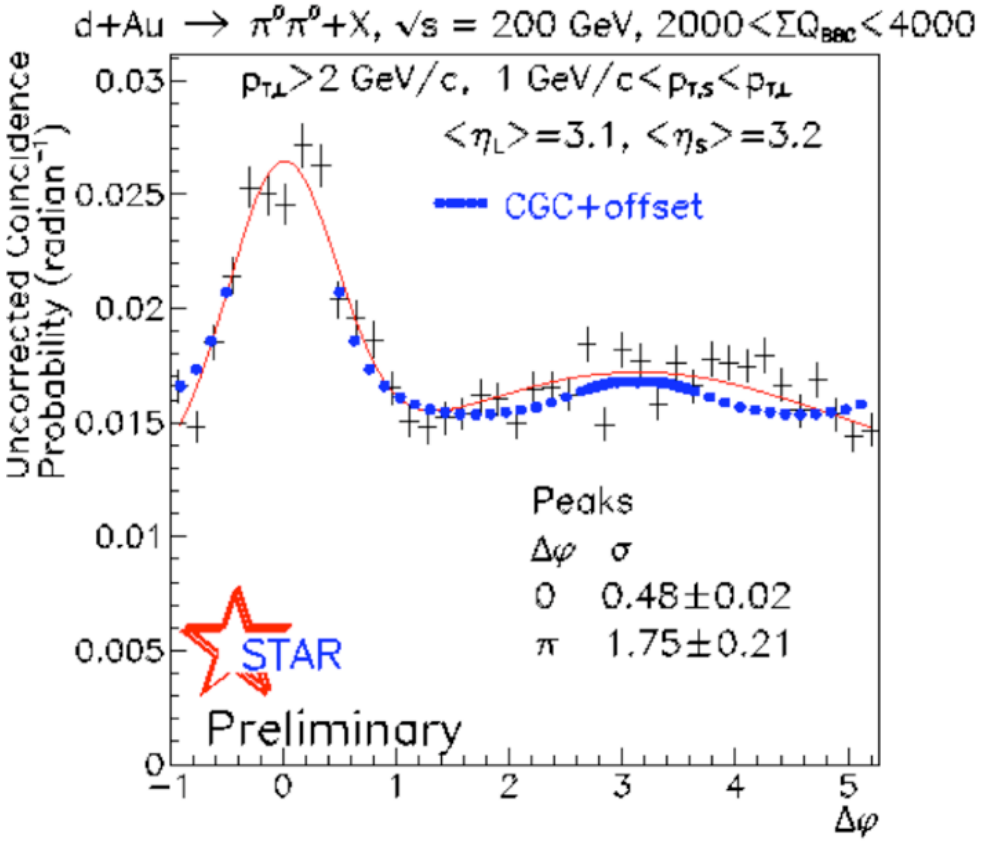


- Near-side peak similar p+p vs. d-Au
- Away-side signal changing with centrality:
- Peripheral d+Au collisions similar to p+p
- Central d+Au collision show strong suppression

Theory comparison: CGC

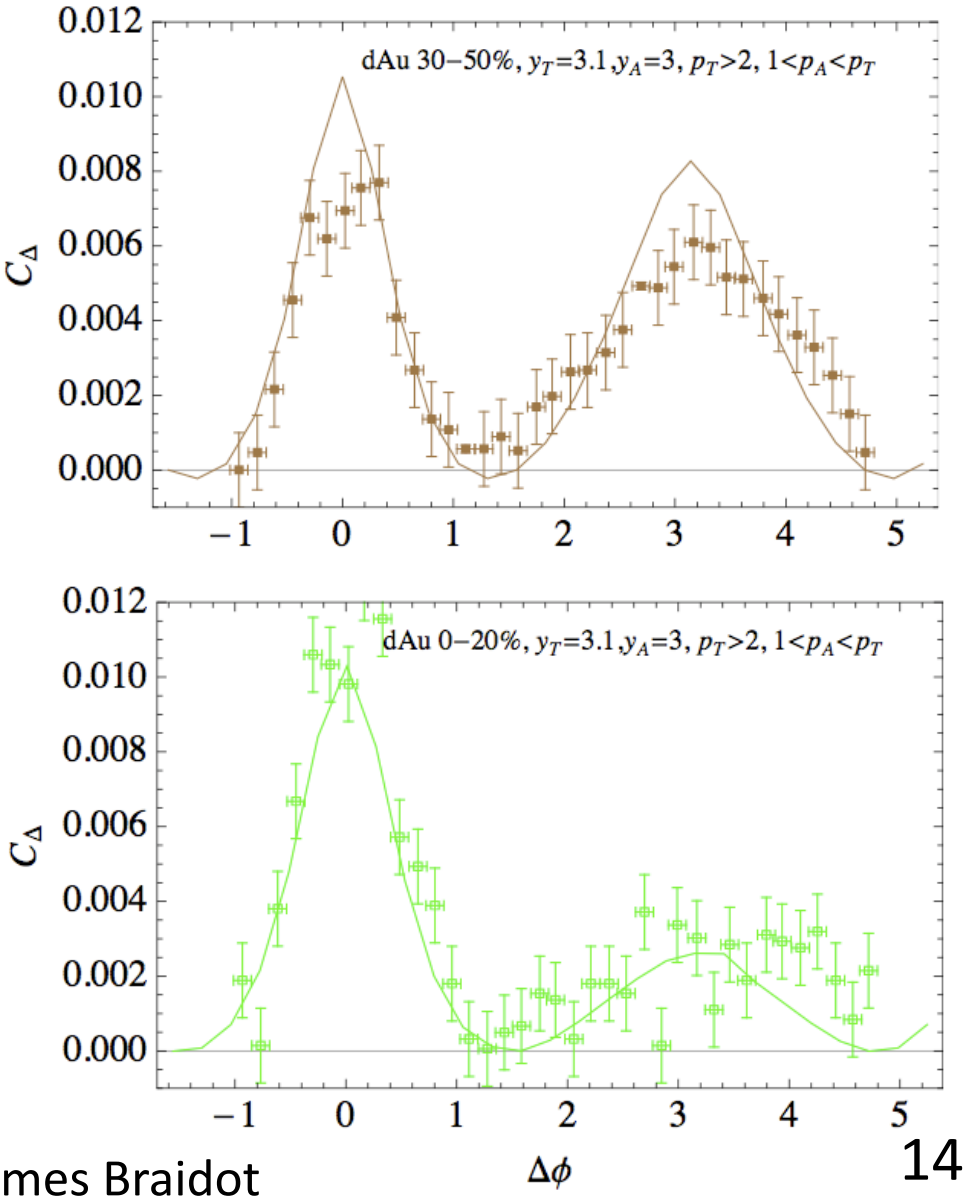
- Cyrille Marquet: **arXiv:0708.0231**
  - calculation: central collisions b=0
  - data: central collision <b>=2.7fm
  - η_{trg} = 3.0 ; η_{asso} = 3.0
  - x_g~0.002
  - uncorrelated background offset
  - normalization fixed from inclusive

- More CGC calculations show:
  - away-side peak disappearance for central d+Au collisions
  - de-correlations are p_T dependent
  - de-correlations are centrality dependent
  - near-side peak unchanged in d+Au



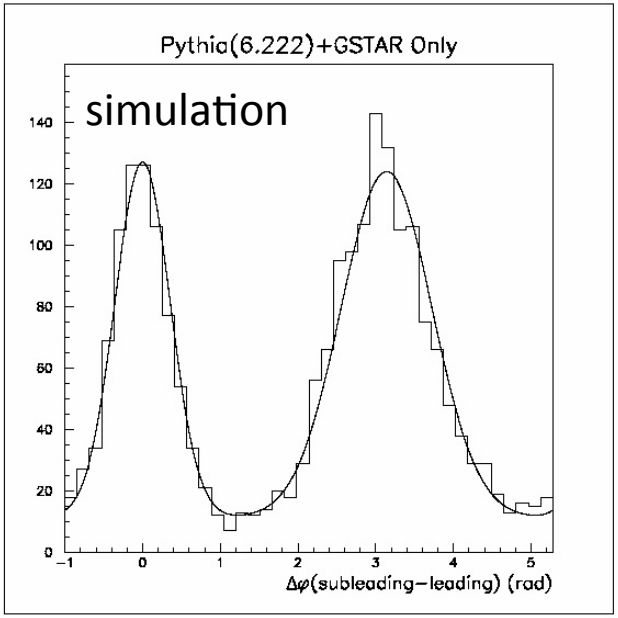
Theory comparison: CGC

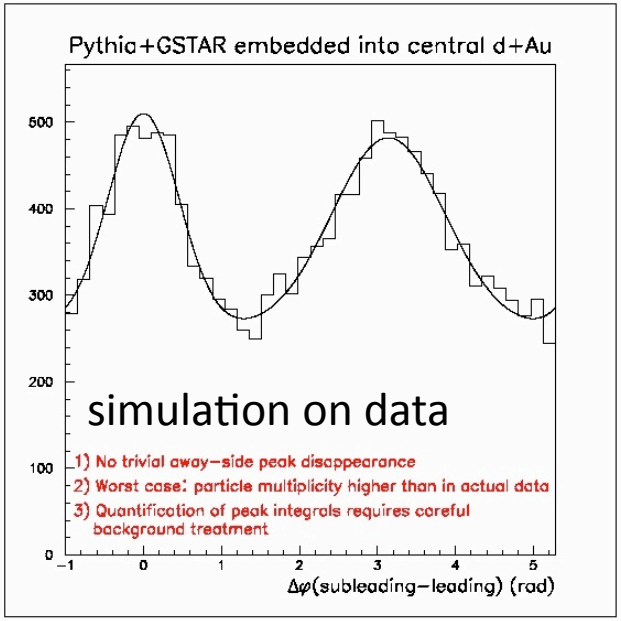
- Kirill Tuchin: **arXiv:0912.5479v1**
  - central collisions
  - other calculations available:
    - peak present at mid-rapidity
  - peak present in peripheral d+Au
  - parton level (no fragmentation)
  - gluon-gluon initiating (no valence quarks contribution)
  - normalization to fit peak heights
  - better agreement with signal widths



Outlook

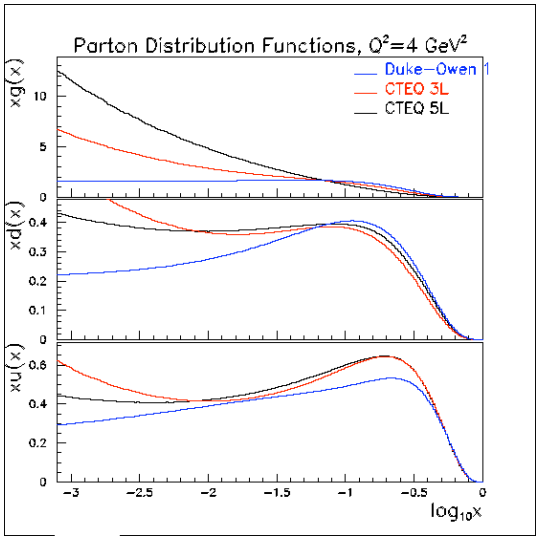
- Away-side peak disappearance not caused by additional multiplicity (embedded simulation into min-bias d+Au data)
- Efficiency and background correction ongoing

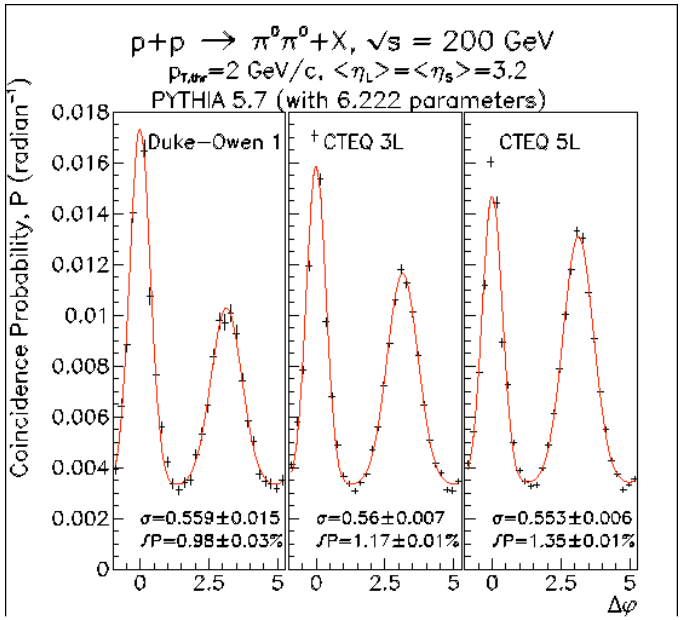




Outlook

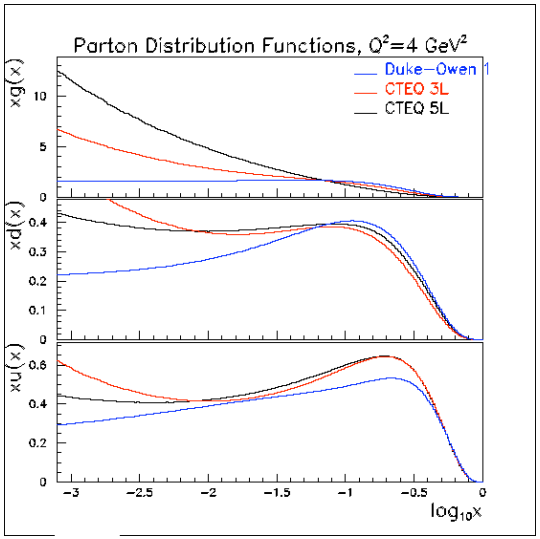
- Away-side peak disappearance not caused by additional multiplicity (embedded simulation into min-bias d+Au data)
- Efficiency and background correction ongoing
- Systematic Pythia studies on gluon pdf
  - p+p away-side peak area sensitive to gluon density at low x
  - data consistent with pdf that include a rapid rise of the gluon density

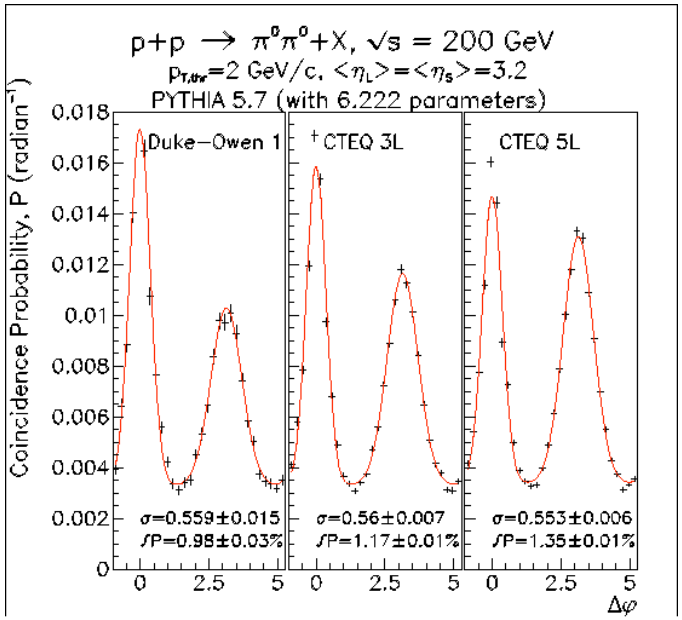




Outlook

- Away-side peak disappearance not caused by additional multiplicity (embedded simulation into min-bias d+Au data)
- Efficiency and background correction ongoing
- Systematic Pythia studies on gluon pdf
  - p+p away-side peak area sensitive to gluon density at low x
  - data consistent with pdf that include a rapid rise of the gluon density
- Quantitative theory comparison
- Extending analysis at $1<\eta_{asso}<2$ (EEMC)





Conclusions

- RHIC run-8 provided large d+Au data set
- **Strong suppression of away-side peak in central d+Au collisions compared to p+p (FMS-FMS)**
- CGC expectations of away-side peak suppression for central d+Au collisions are qualitatively consistent with data
- Is the CGC a unique explanation?

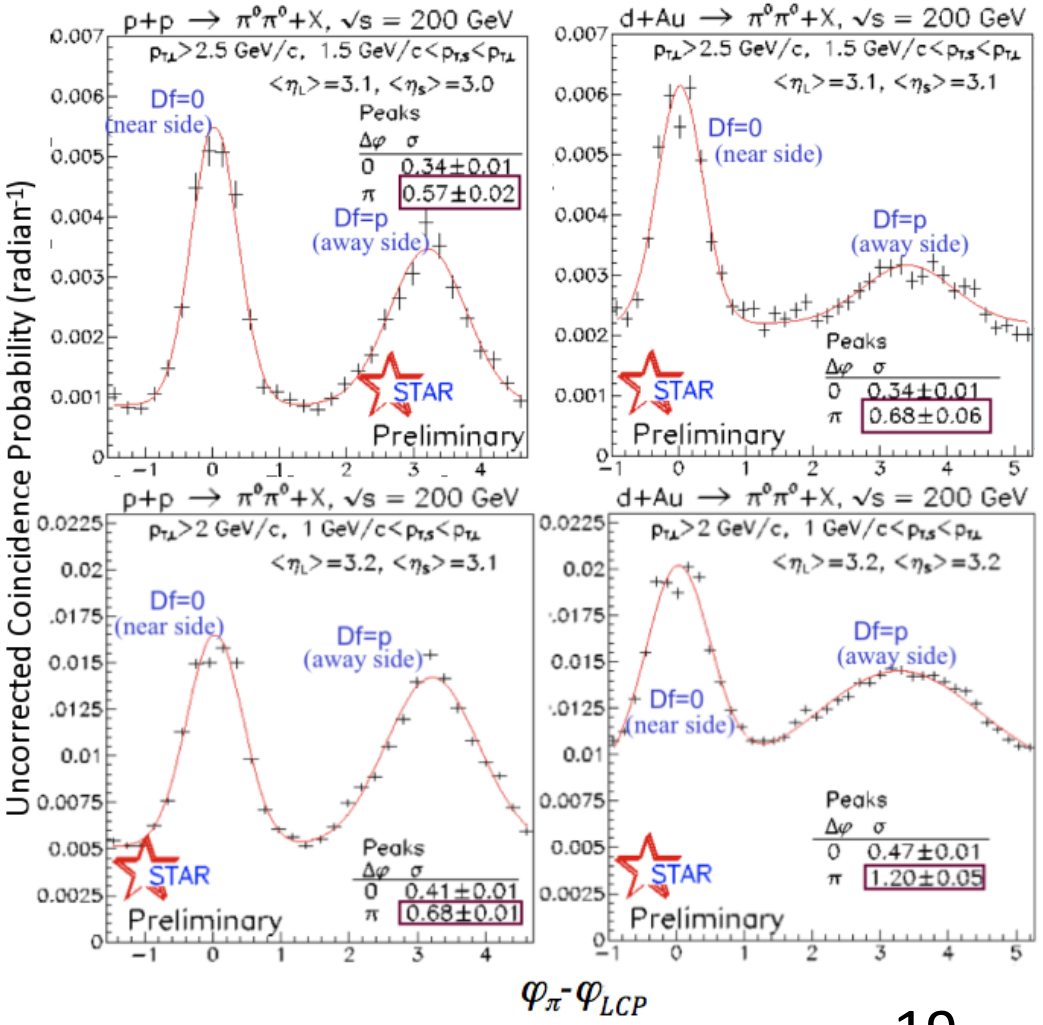
back-up

FMS-FMS ($\pi^0+\pi^0$) correlations

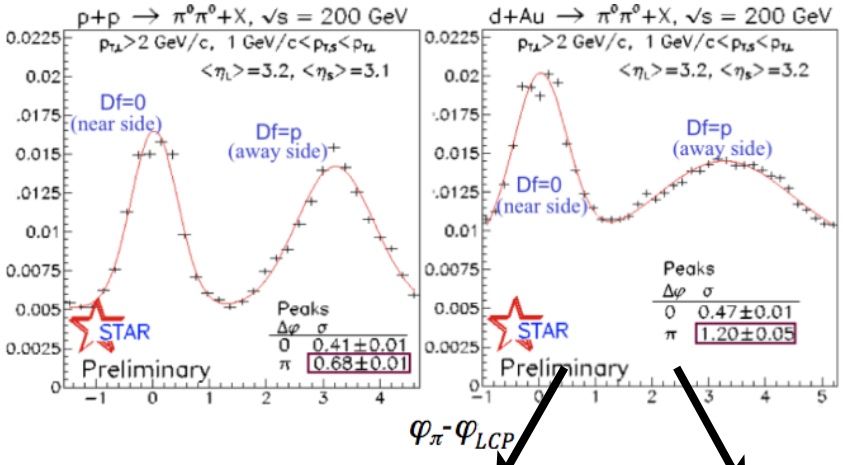
- Forward (FMS) π^0 as trigger particle
- Forward (FMS) π^0 as associated

- Above: $p_T^{(FMS)}$>2.5GeV ; $p_T^{(FMS)}$>1.5GeV
- Below: $p_T^{(FMS)}$>2.0GeV ; $p_T^{(FMS)}$>1.0GeV

- Near-side peak evident
- Near-side peak similar p+p vs. d-Au
- Signal broadening from p+p to d+Au
- Strong azimuthal broadening
- Azimuthal broadening p_T dependent:
  - above: $\sigma_{dAu}-\sigma_{pp}= 0.11\pm0.06$
  - below: $\sigma_{dAu}-\sigma_{pp}= 0.52\pm0.05$



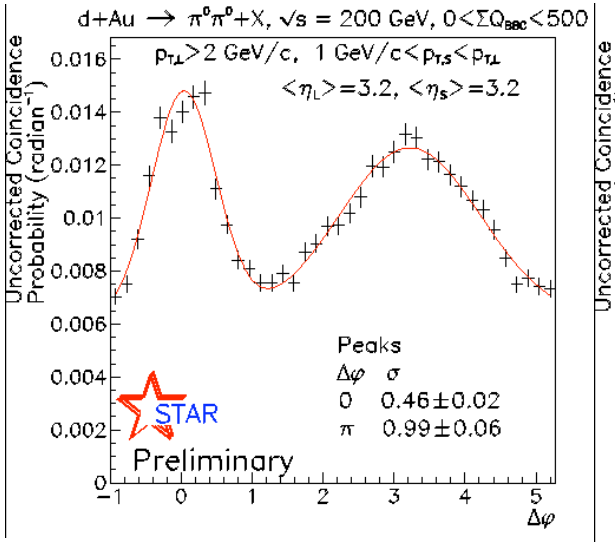
Centrality dependence

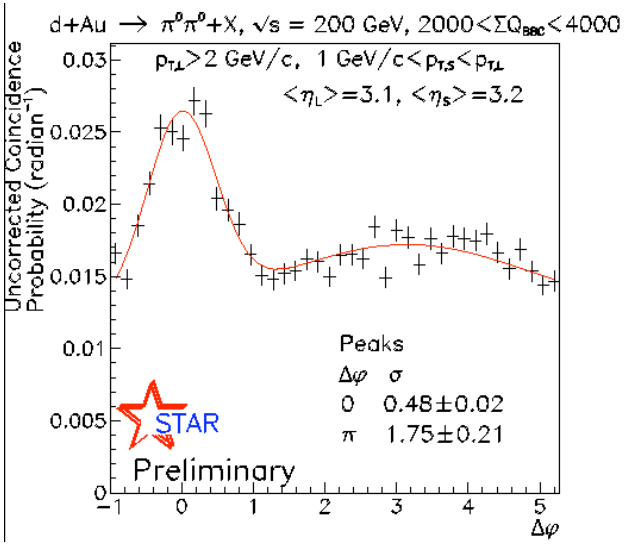


φ_π-φ_{LCP}

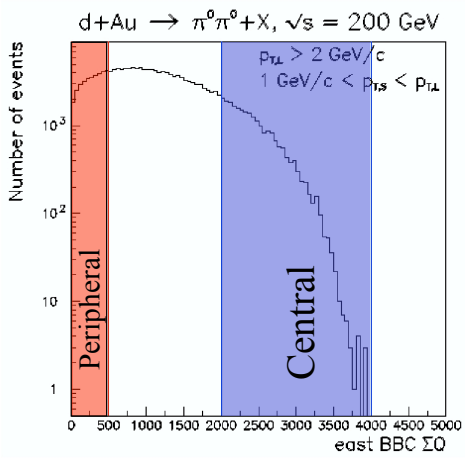
peripheral

central





dAu data

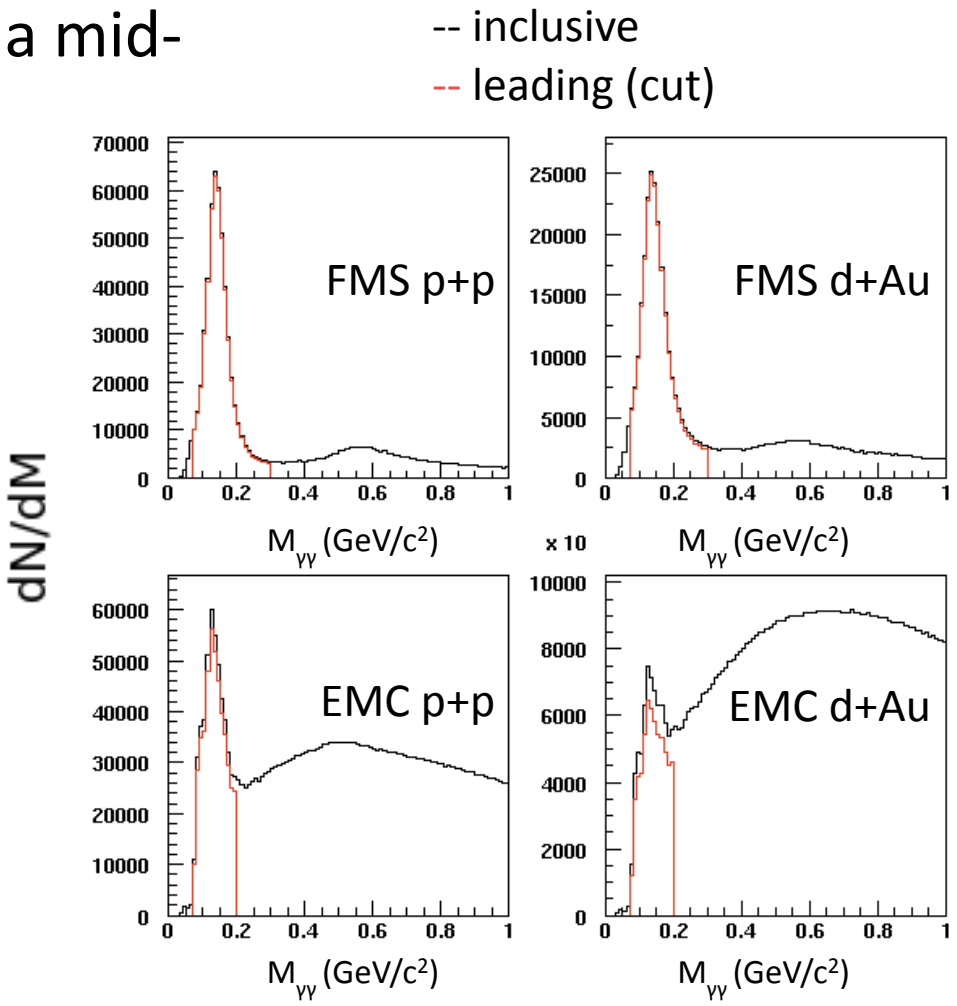


- Near-side peak similar p+p vs. d-Au
- Away-side signal changing with centrality:
- Peripheral d+Au collisions similar to p+p
- Central d+Au collision show strong suppression

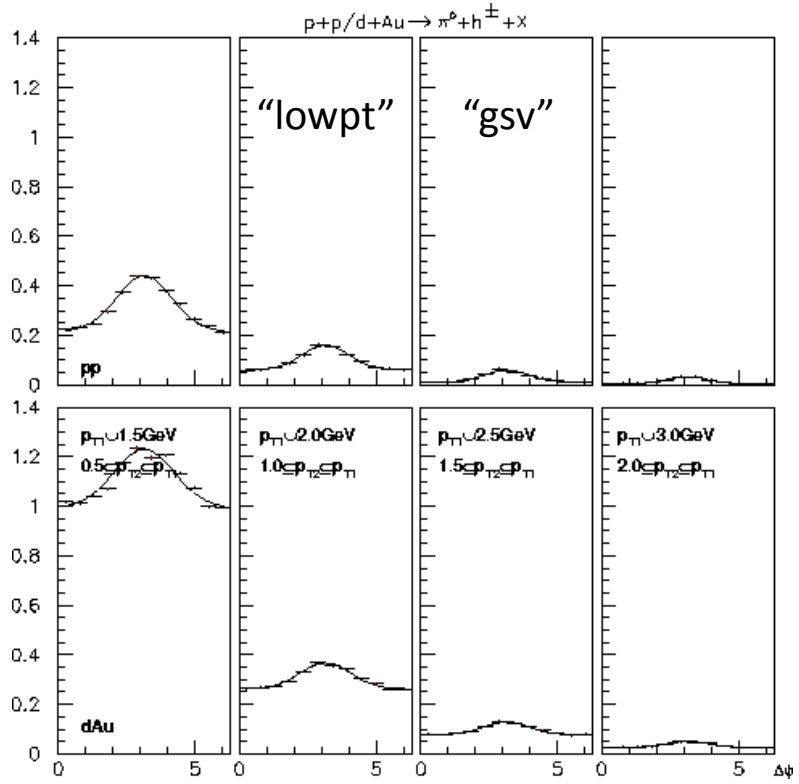
FMS results: $\pi^0+\pi^0$ correlations

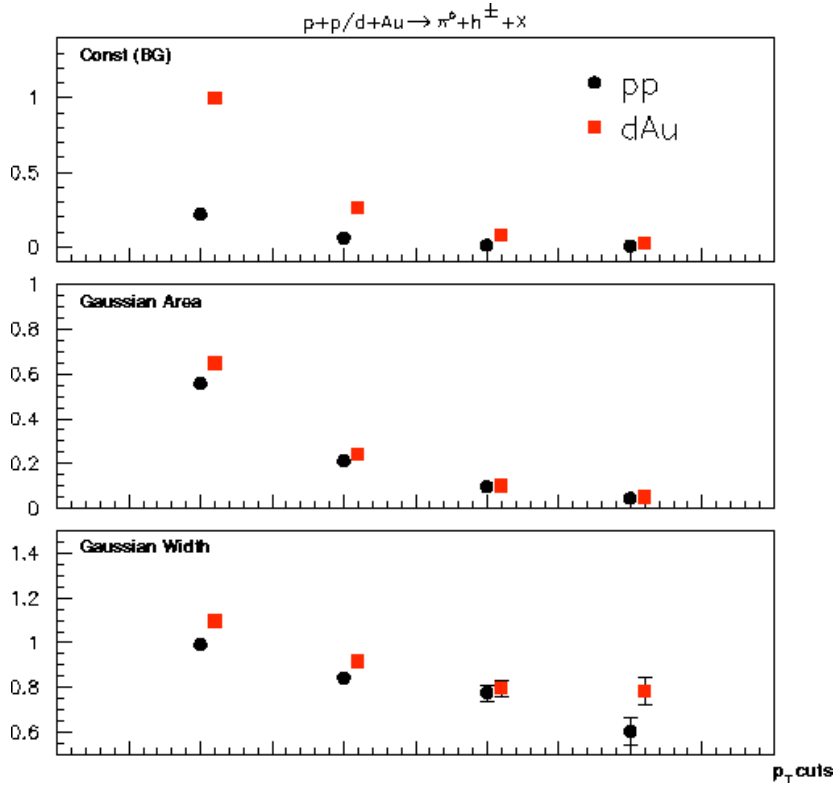
- Correlate forward π^0 with a mid-rapidity π^0 (bEMC)

- $|\eta_{EMC}| < 0.9$;
- $2.8 < \eta_{EMC} < 3.8$;
- $2.5\text{GeV} < p_T^{(FMS)}$;
- $1.5\text{GeV} < p_T^{(EMC)} < p_T^{(FMS)}$;
- $|\alpha_{FMS/EMC}|<0.7$;
- $0.07 < M_{\gamma\gamma}^{(FMS)} < 0.30$ GeV
- $0.07 < M_{\gamma\gamma}^{(EMC)} < 0.20$ GeV
- Only EMC towers used (no SMD)
- only leading particles considered



pT scan (inclusive)



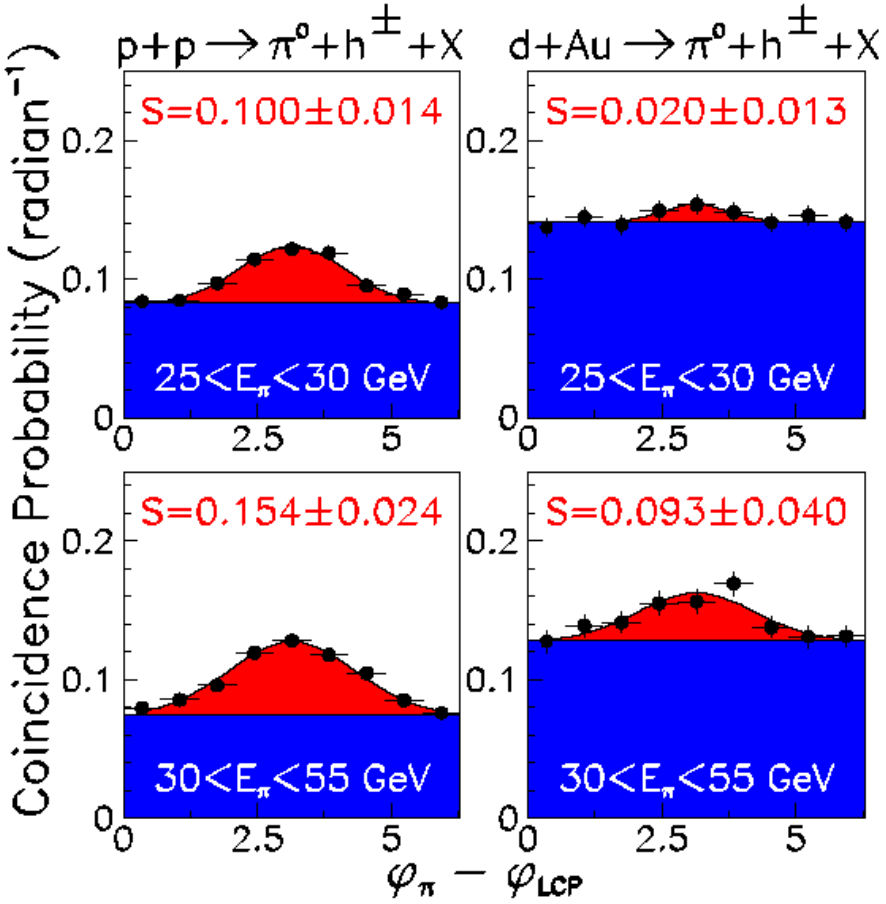


- dAu width larger than pp (consistent with FMS-BEMC results)
- dAu back-to-back peak area larger than pp at lower pT

FPD results

published run-3 results

- Di-jet studies with azimuthal correlations (FPD early results)
- Disappearance or broadening of jet-like correlation as expected in saturation models
- Mono-jet picture arising?

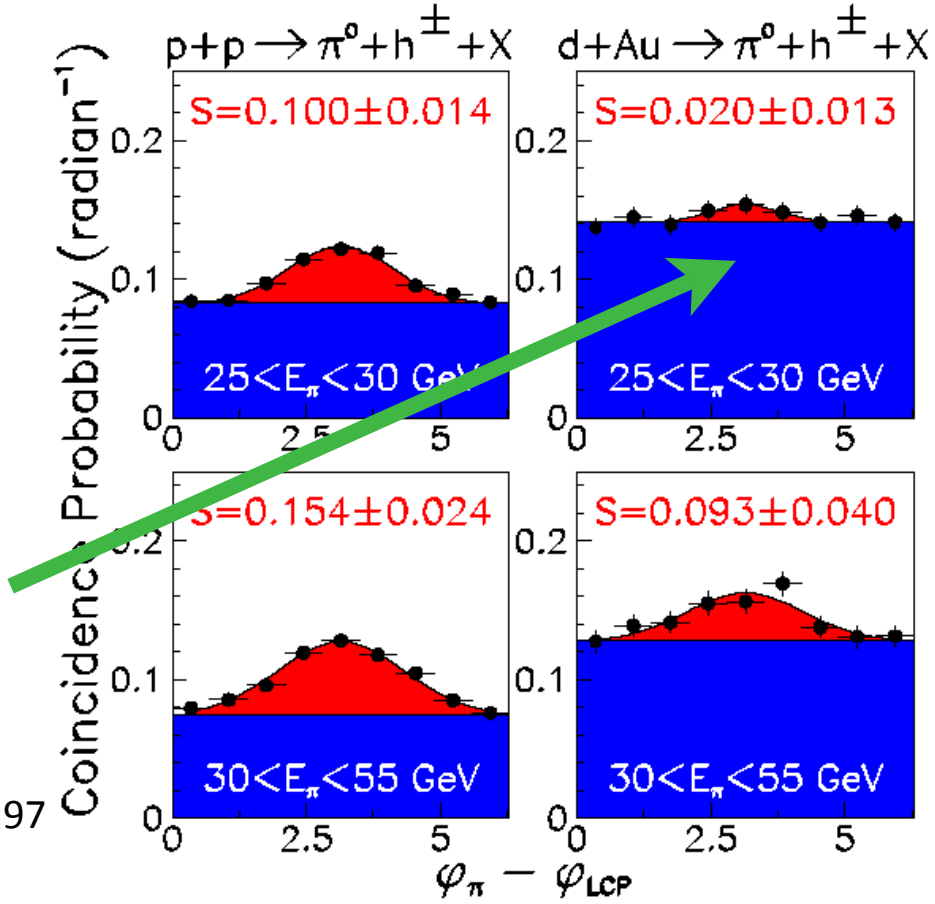


Phys. Rev. Lett. 97 (2006) 152302

FPD results

published run-3 results

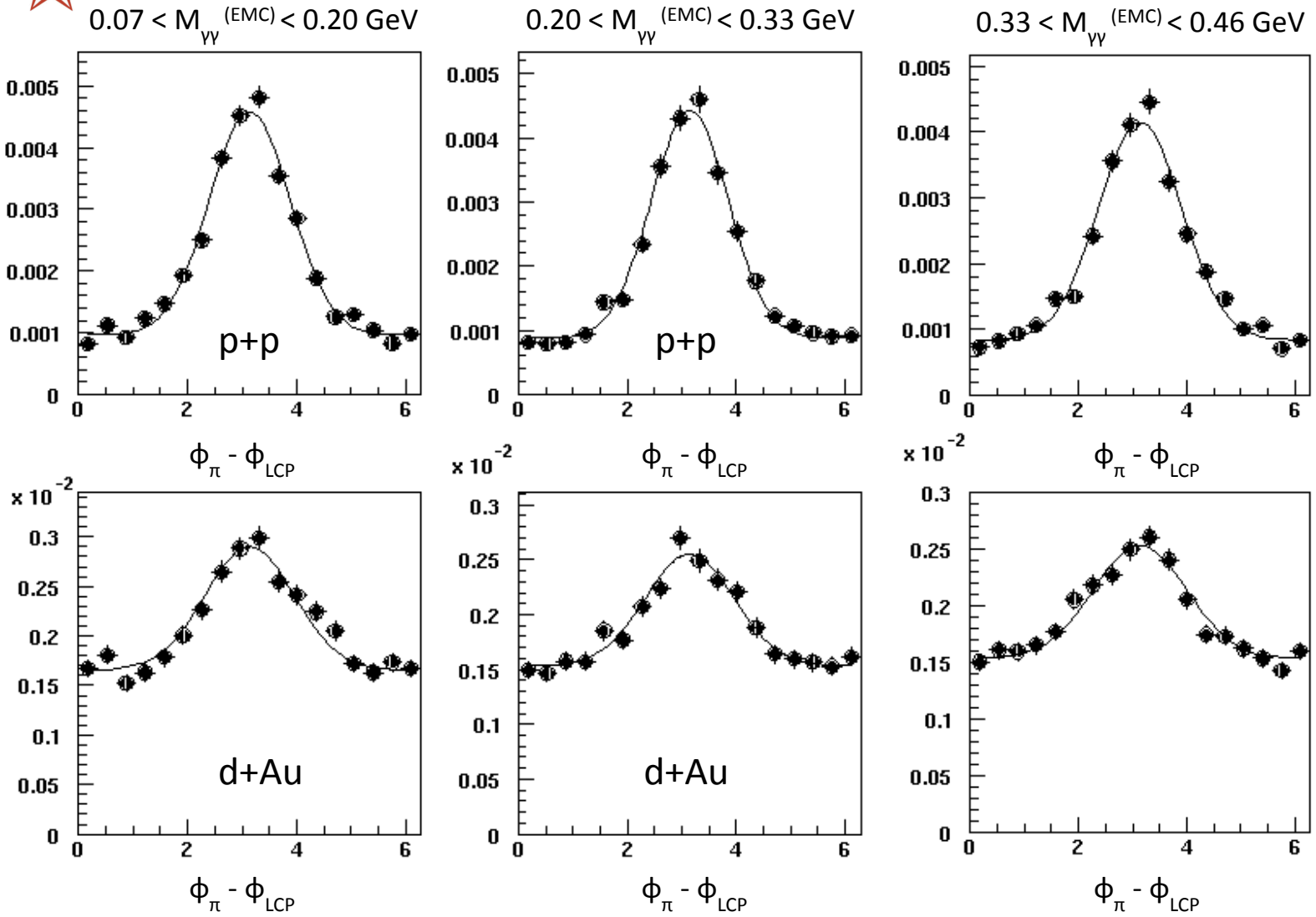
- Di-jet studies with azimuthal correlations (FPD early results)
- Disappearance or broadening of jet-like correlation as expected in saturation models
- Mono-jet picture arising?



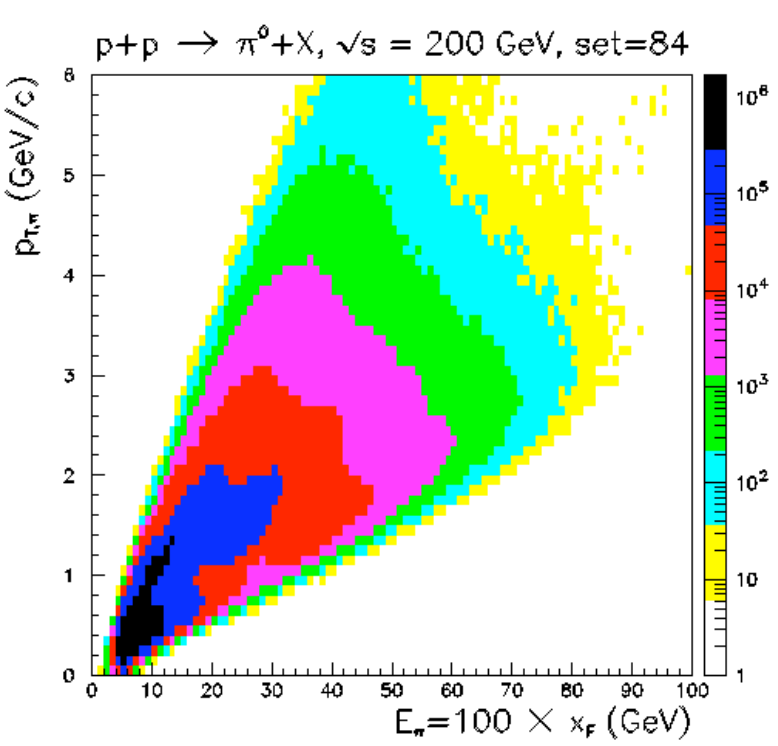
Phys. Rev. Lett. 97 (2006) 152302

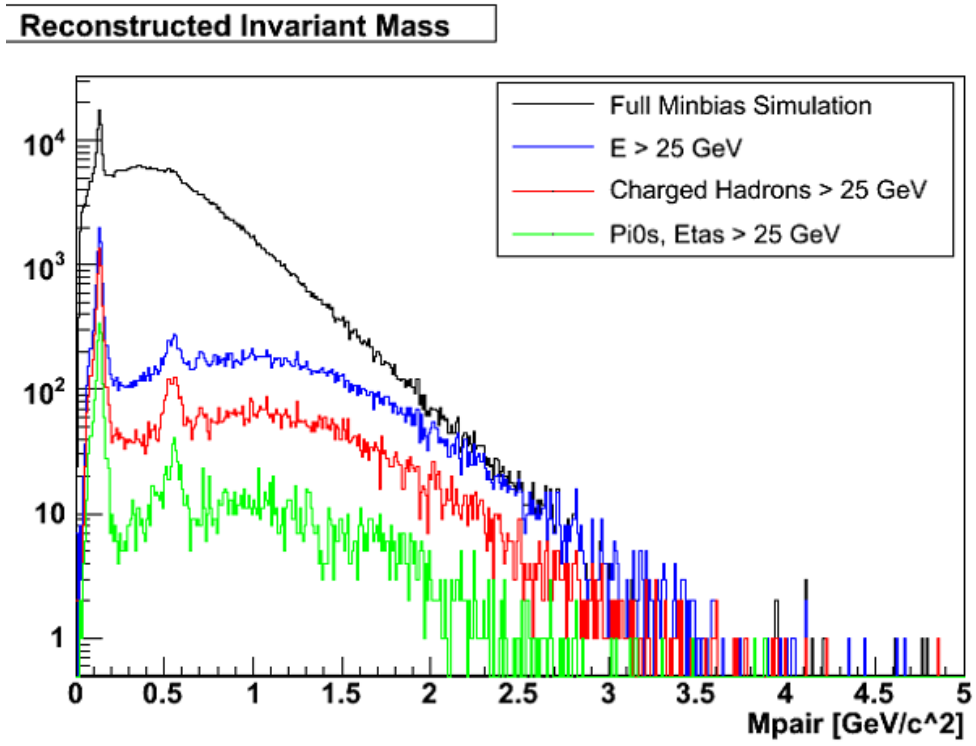
Off-peak analysis

STAR PRELIMINARY



FMS run8


p+p → π⁰+X, √s = 200 GeV, set=84
p_T,π (GeV/c)
E_π=100 × x_F (GeV)


Reconstructed Invariant Mass
Full Minbias Simulation
E > 25 GeV
Charged Hadrons > 25 GeV
Pi0s, Etas > 25 GeV
Mpair [GeV/c^2]