# Neutral pion production in d-Au collisions at $\sqrt{s_{NN}}$=200 GeV

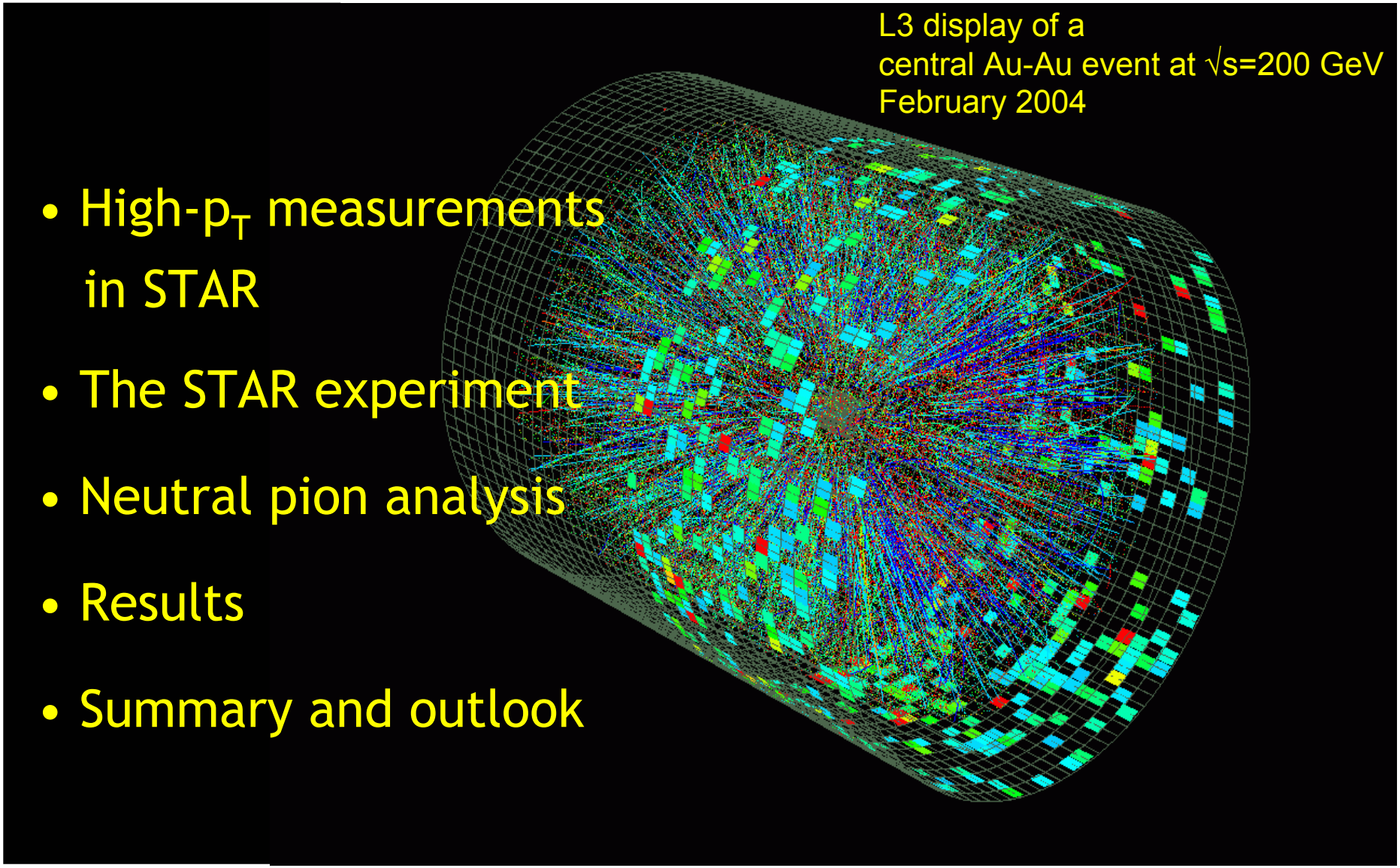
André Mischke

Universiteit Utrecht


for the STAR Collaboration


Hard Probes conference
Ericeira, Portugal, November 4-10, 2004

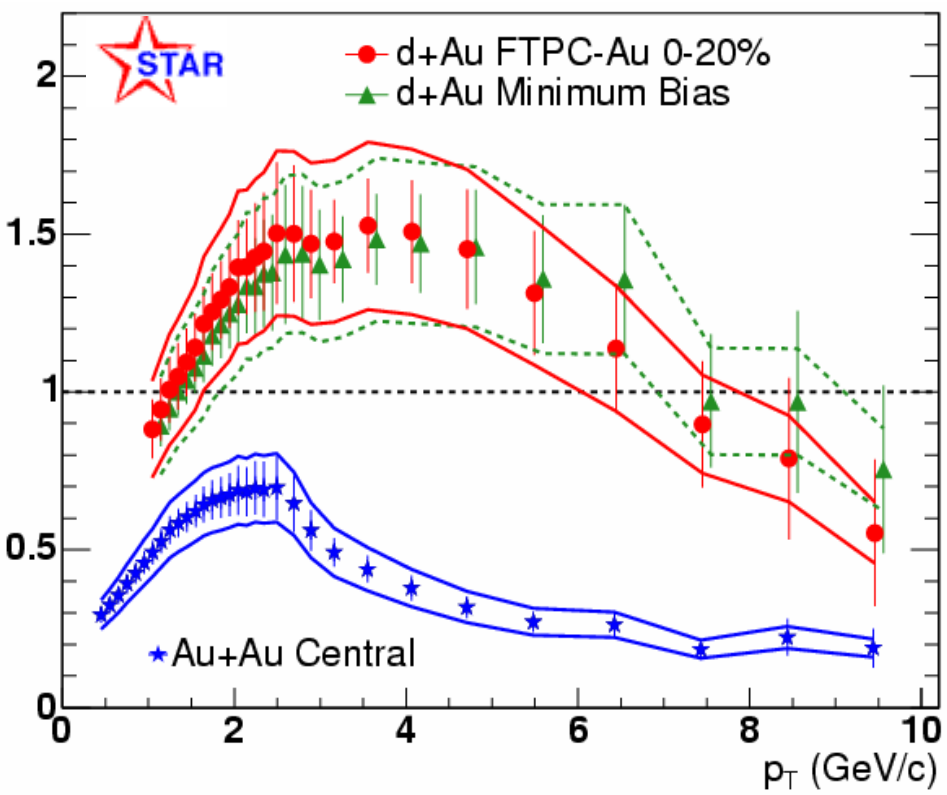
# Outline




- High-$p_T$ measurements in STAR
- The STAR experiment
- Neutral pion analysis
- Results
- Summary and outlook

# High-$p_T$ hadron suppression

$R_{AB}$



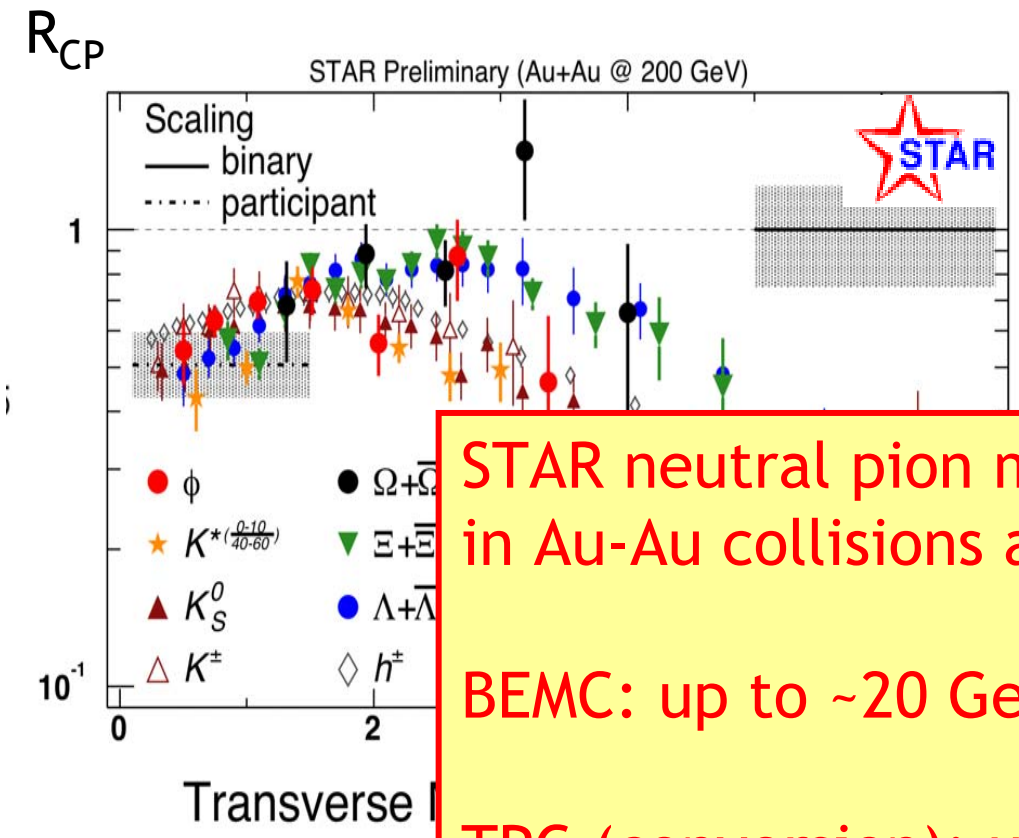

- Central Au-Au collisions:
  - Strong high-$p_T$ particle suppression

→ Medium induced parton energy loss

- d-Au collisions (cold nuclear matter):
  - No particle suppression
  - Cronin effect instead

→ Suppression is a final state effect

# $R_{CP}$: Particle species dependence




At intermediate $p_T$:

- Different behavior for mesons and baryons
- Dependence on number of
- d by jets
- on production
- alescence

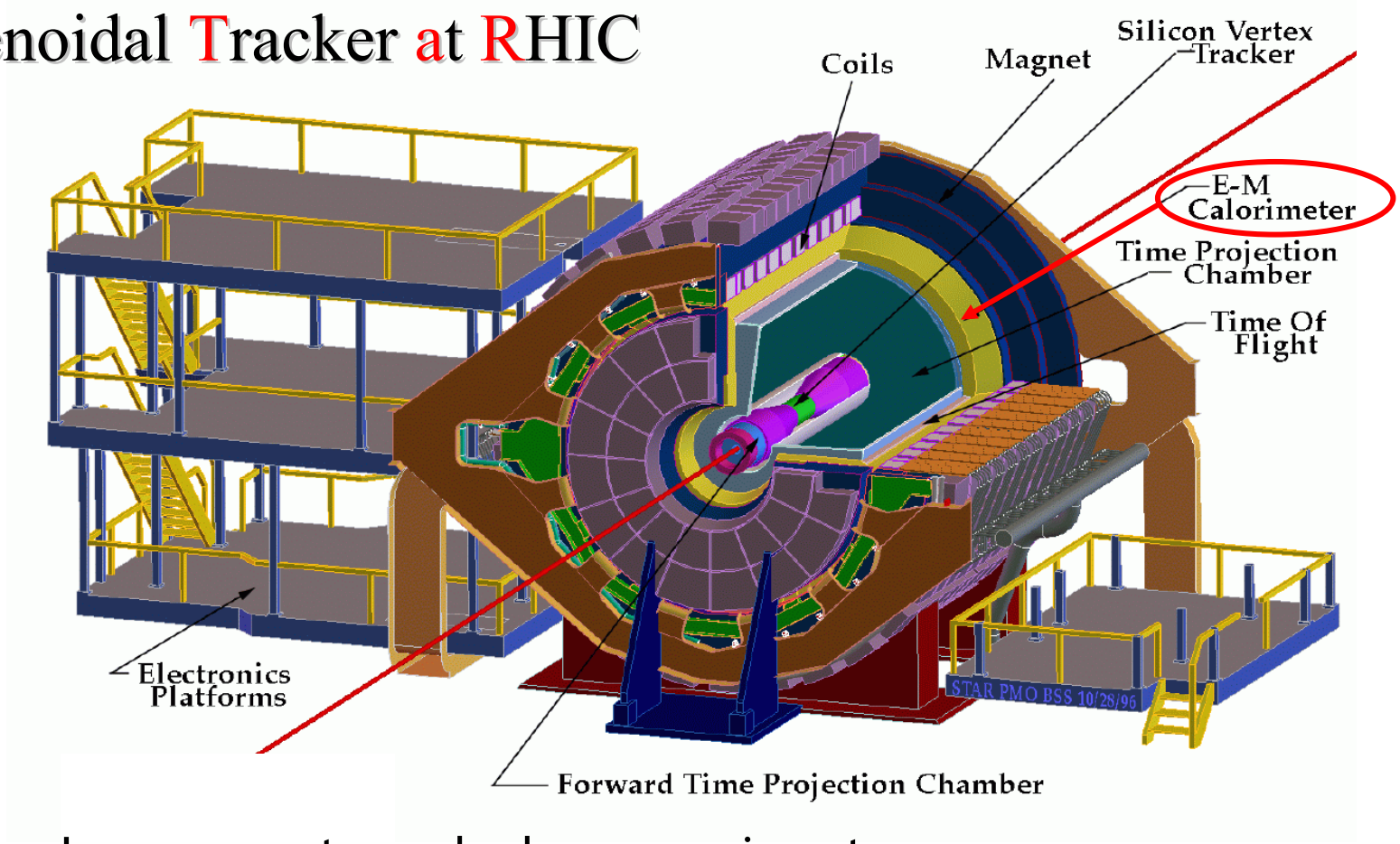
STAR neutral pion measurements in Au-Au collisions at $\sqrt{s}$ = 200 GeV:

BEMC: up to ~20 GeV/c

TPC (conversion): up to ~6 GeV/c

# The STAR detector

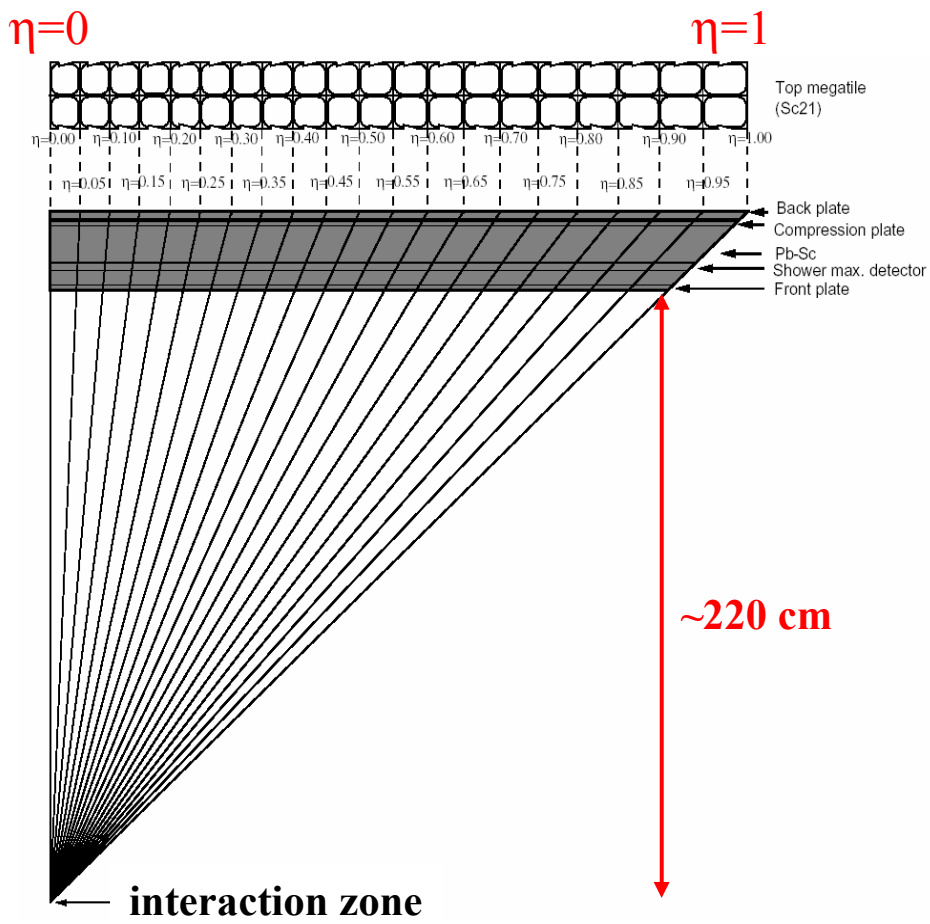
## Solenoidal Tracker at RHIC




- Large acceptance hadron experiment
- Solenoidal field (0.5 T)
- TPC's, ToF, SVT, PMD, and EMC's

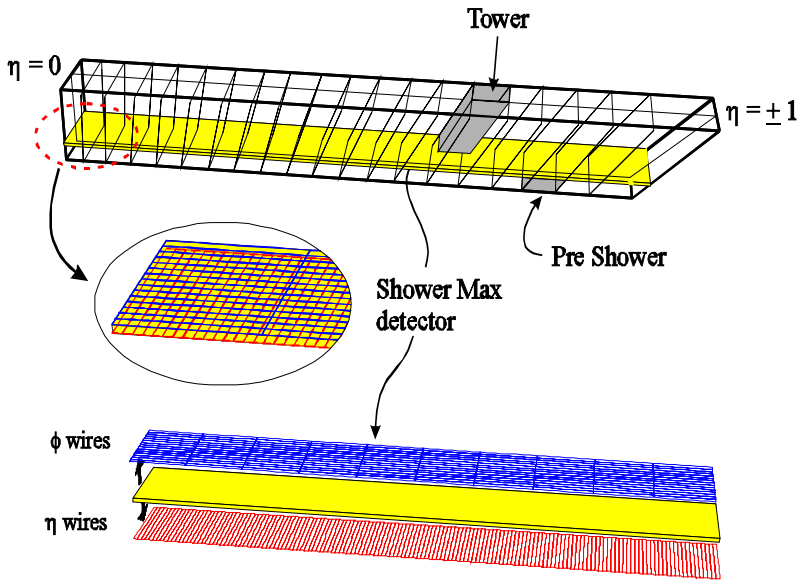
# Barrel Electromagnetic Calorimeter

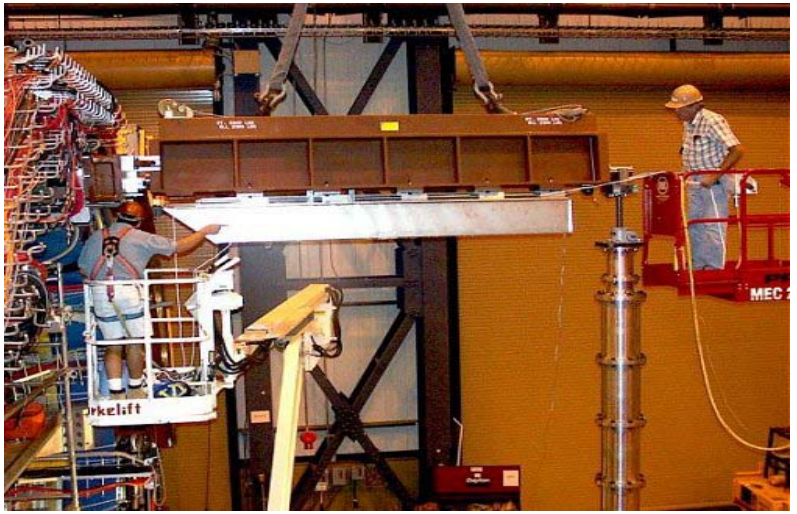
- One of the short-term upgrades
- Lead-scintillator sampling calorimeter
- 120 modules with 4800 towers
- $|\eta| \leq 1$ and full azimuthal coverage
- For the 2003 run: 50% installed and operational
- Tower
  - 21 radiation length ($X_0$)
  - $(\Delta\eta, \Delta\phi)_{tower}$ ~ (0.05, 0.05)
  - dE/E ~16%/$\sqrt{E}$



# BEMC (cont'd)

- Shower maximum detector (SMD)
  - located after 5 $X_0$
  - wire proportional counter with strip read-out
  - 150 x 150 strips per module
  - large spatial resolution $(\Delta\eta, \Delta\phi)_{SMD} \sim (0.007, 0.007)$
- Pre-shower detector (PSD)
  - $\pi^0/\gamma$ and e/h discrimination
  - separate read-out of the first two layers
- 45,600 channels in total

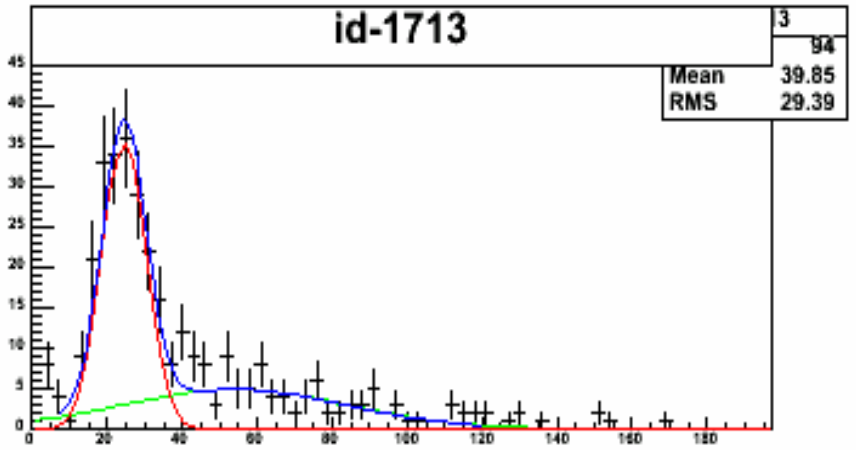


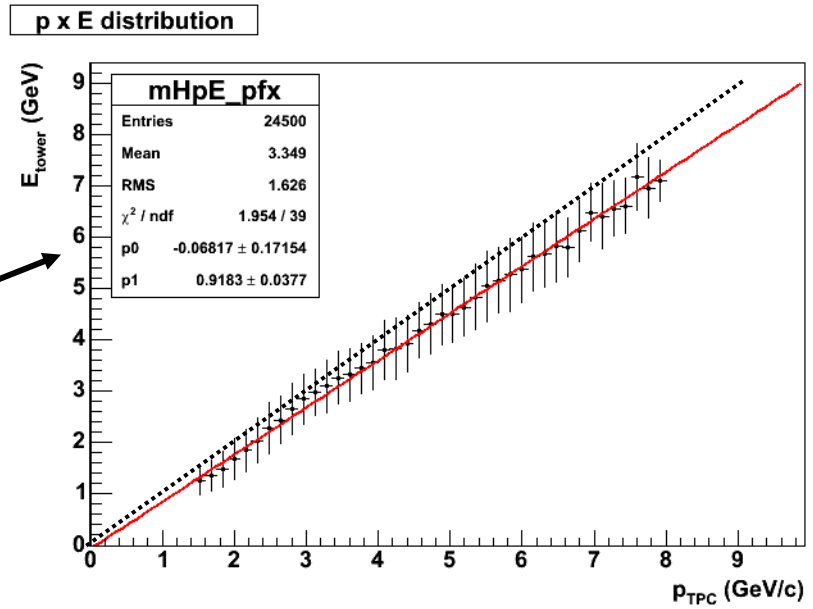



# BEMC calibration

- Absolute energy calibration
  - $\pi^-$ beam with 0.3-8 GeV/c
  - Average tower gain

    ~16 MeV/ADC counts
- Relative gain
  - Single tower MIP calibration
    - ♦ Project high-p tracks into EMC
    - ♦ p > 1.2 GeV/c
    - ♦ 3x3 towers isolation
  - Electron calibration
  - $\pi^0$ peak position

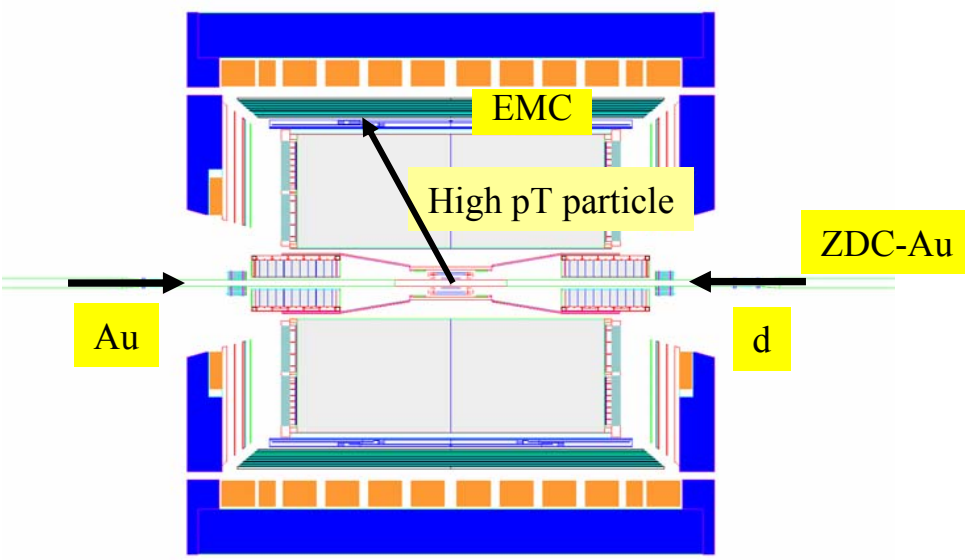


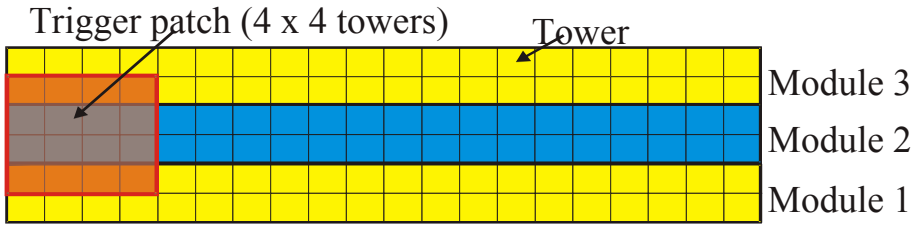



# Event selection

- Minimum bias trigger: ZDC-Au (95±3% of $\sigma_{hadronic}$)
- High tower trigger:
  - Enhance high-$p_T$ range
  - Photons, electrons and $\pi^0$
  - Trigger patches
    - 4 x 4 towers
    - $(\Delta\eta, \Delta\phi) \sim (0.2, 0.2)$
    - Highest tower in patch

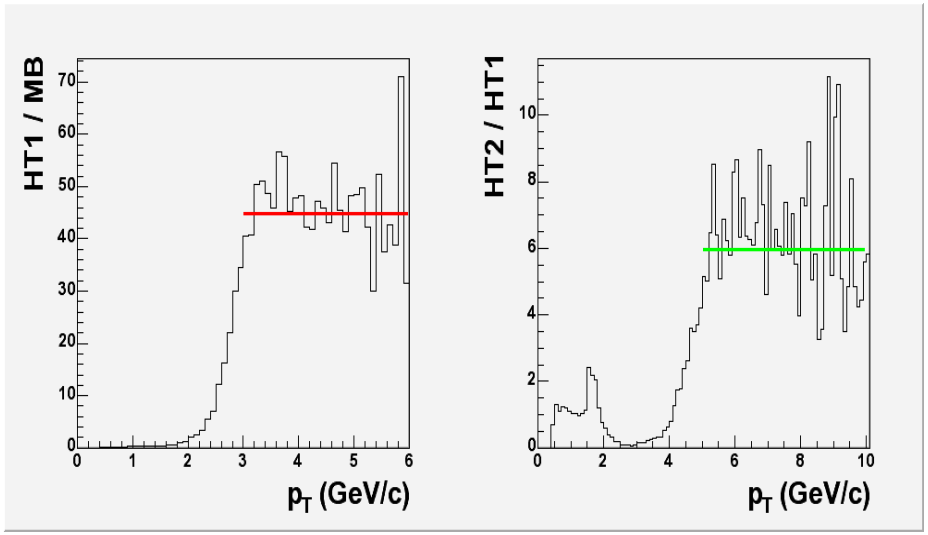
      0.5 GeV energy resolution

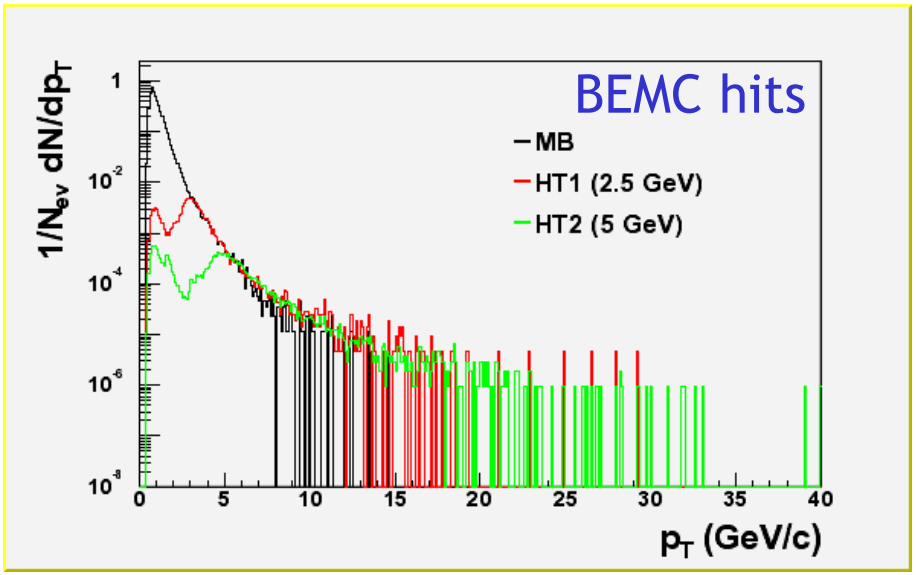



- Trigger classes
  - Minimum bias
  - High tower 1: energy threshold >2.5 GeV
  - High tower 2: energy threshold >5.0 GeV

# Pre-scale factors

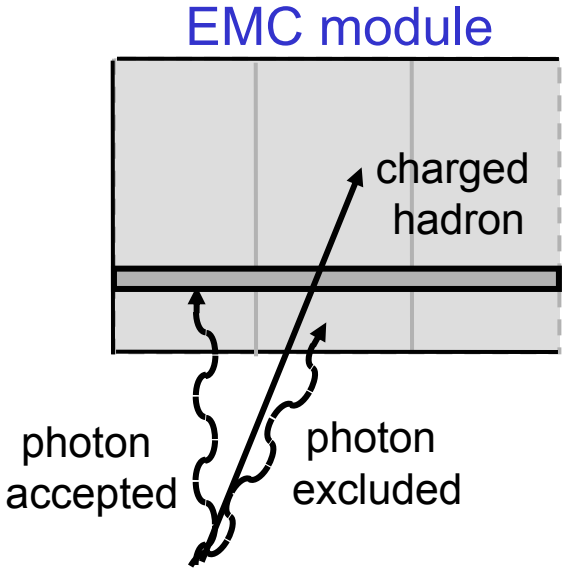



- For high tower trigger spectra normalization
- BEMC cluster with the highest transverse energy
- Enhancement of about 50 at 4 GeV/c (HT1/MB) and 6 at 6 GeV/c (HT2/HT1)

# Neutral pion analysis

- Event cuts
  - Number of Bemc hits
  - Main z-vertex




- $\pi^0$ reconstruction
  - $\pi^0 \rightarrow \gamma\gamma$ (branching ratio: 98.8%)
  - $m_{inv} = \sqrt{2E_1E_2(1-\cos\theta)}$

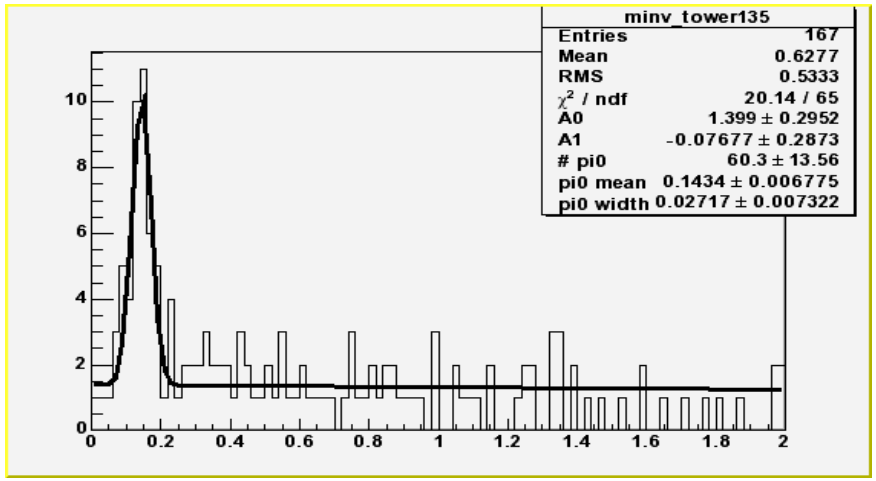
- Photon quality cuts
  - Charged particle veto using TPC
  - Asymmetry of photon pair:

$$\alpha = \left|\frac{E1-E2}{E1+E2}\right| < 0.5$$

- Combinatorial background of random pairs described by
  - Event-mixing method
  - Polynomial fit (2nd order)

# $\pi^0$ analysis: Tower sub-sample

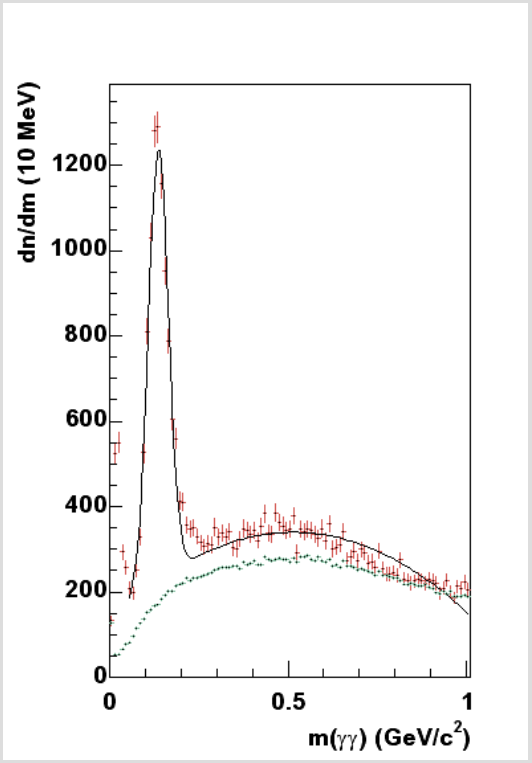
- Tower/SMD Quality Assurance (status tables) are underway
- QA: Single tower invariant mass spectra

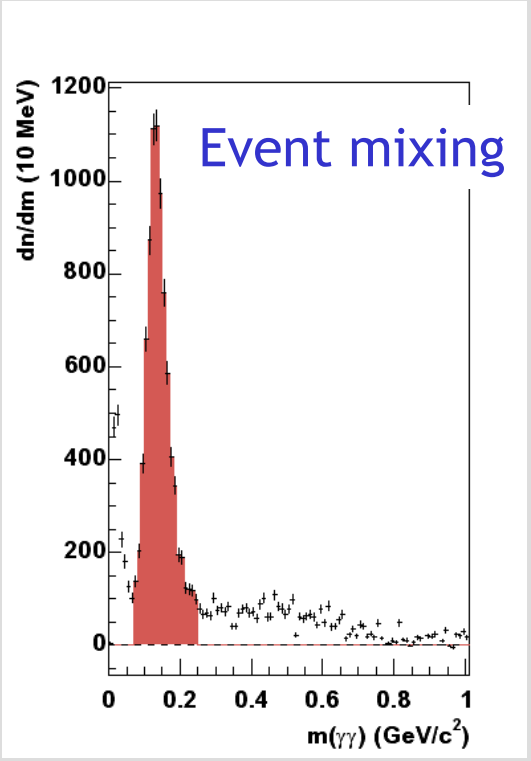


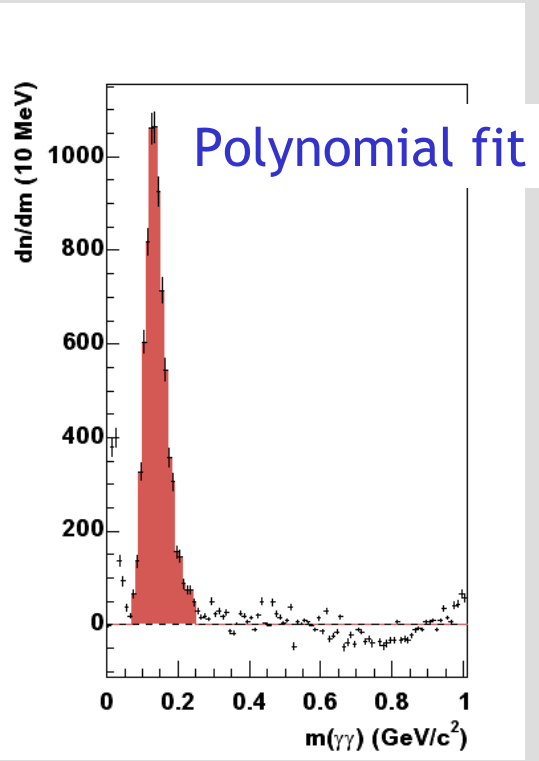

  - Use $\pi^0$ peak position for additional tower gain correction (mean correction 7%)
  - Sub-sample of good towers

- pi0 analysis

# $\pi^0$ invariant mass distribution



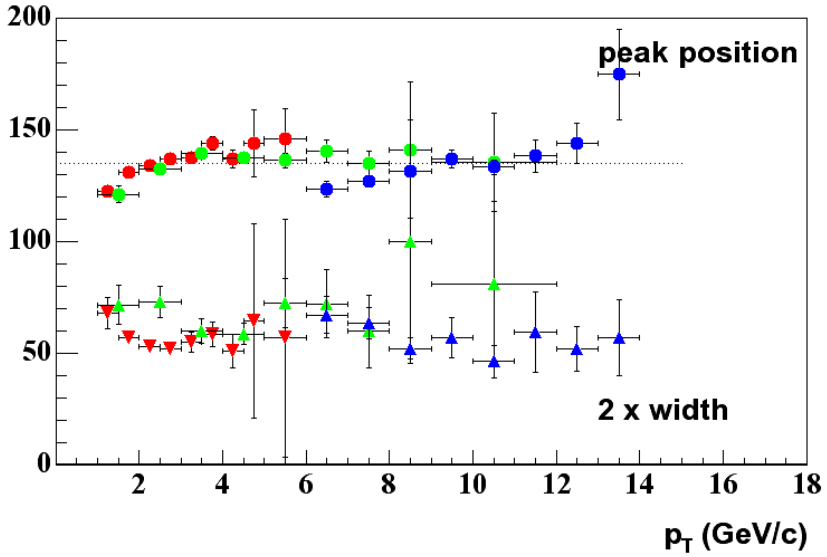



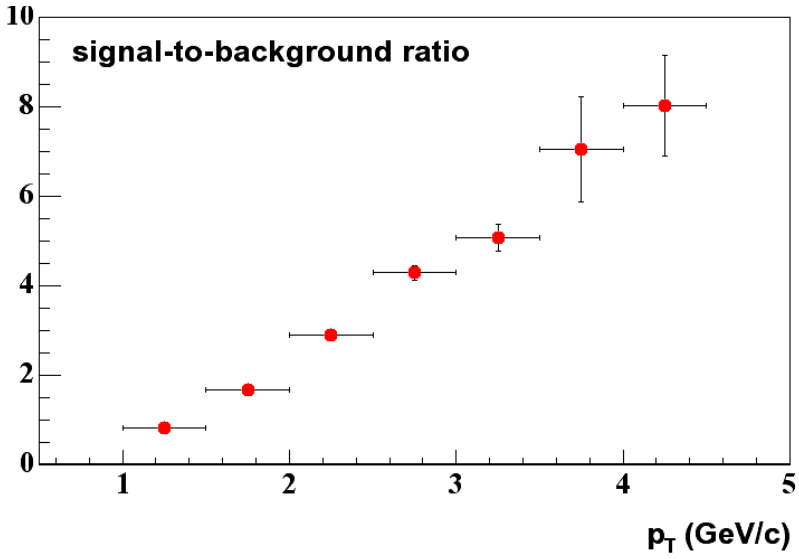




- MinBias, $p_T$ integrated
- Mass = 135±1 MeV
- Width = 28±0.6 MeV
- S/B ratio ~2.5
- 9k raw $\pi^0$

# Signal extraction and corrections

- 0.5 (1) GeV bins for MB (HT1,2)
- Yield extracted by integration of the background subtracted distribution ±3σ around signal
- Corrections
  - Detector efficiency
  - Acceptance
    - MC simulation
    - Cluster density effects not yet included
  - Losses due to weak decays, e.g. $K^0$, not included yet

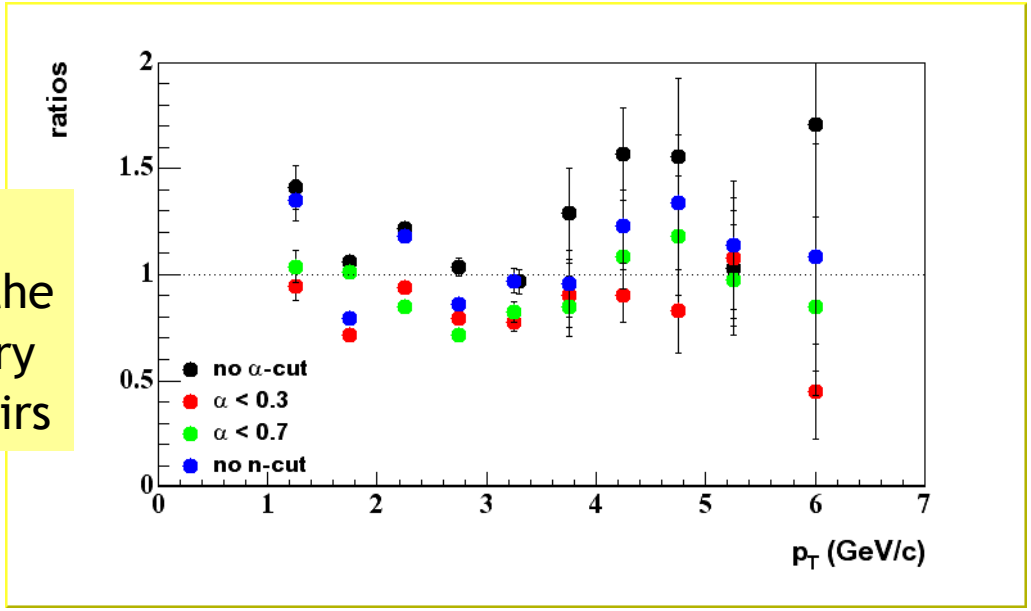


# Systematic errors

- Yield extraction: 10-15%
- Pre-scale factor: 6% (HT1), 10% (HT2)
- Quality cuts (acceptance + efficiency included): 20-30%

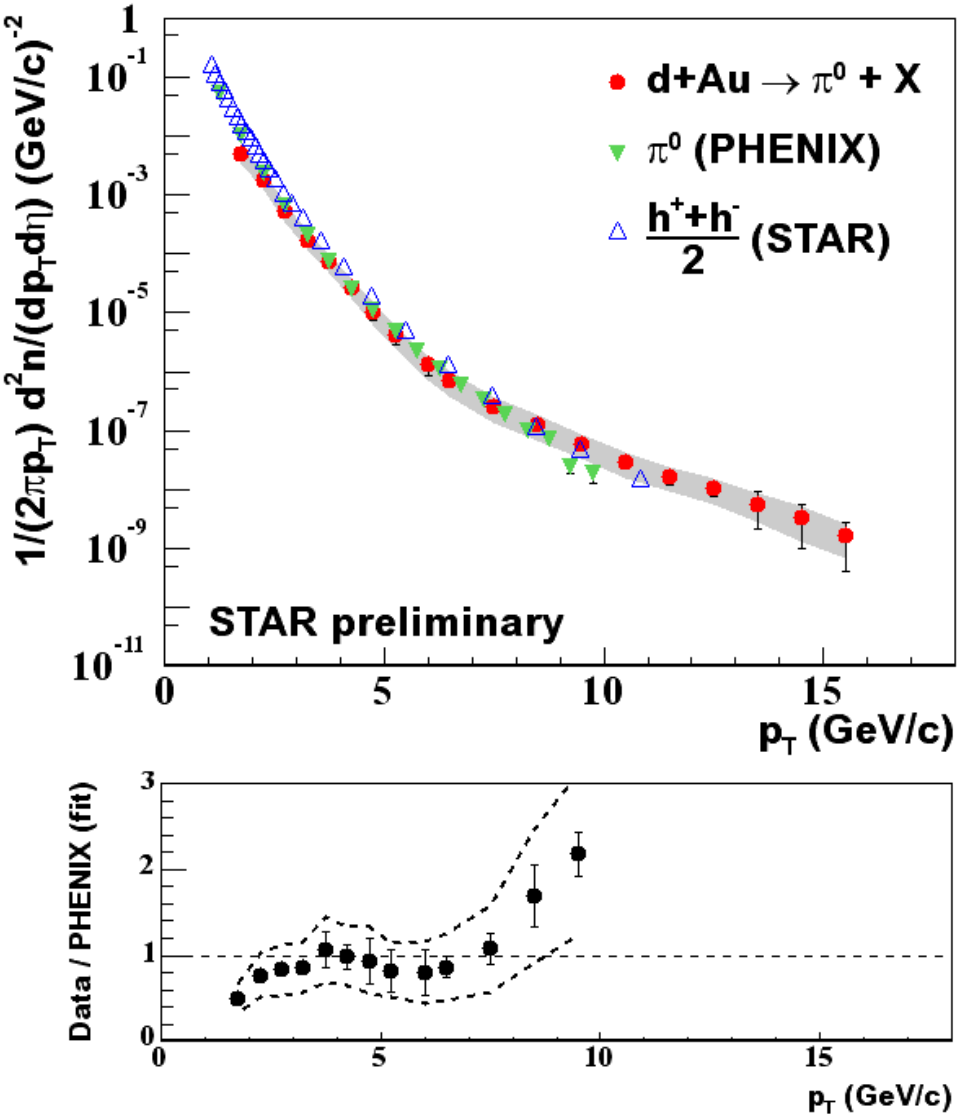
Ratio of the $p_T$ spectra varying the energy asymmetry of the photon pairs




- Energy calibration uncertainty: low-pT (<6 GeV/c): 5-10%
  high-pT (>6 GeV/c): 30%

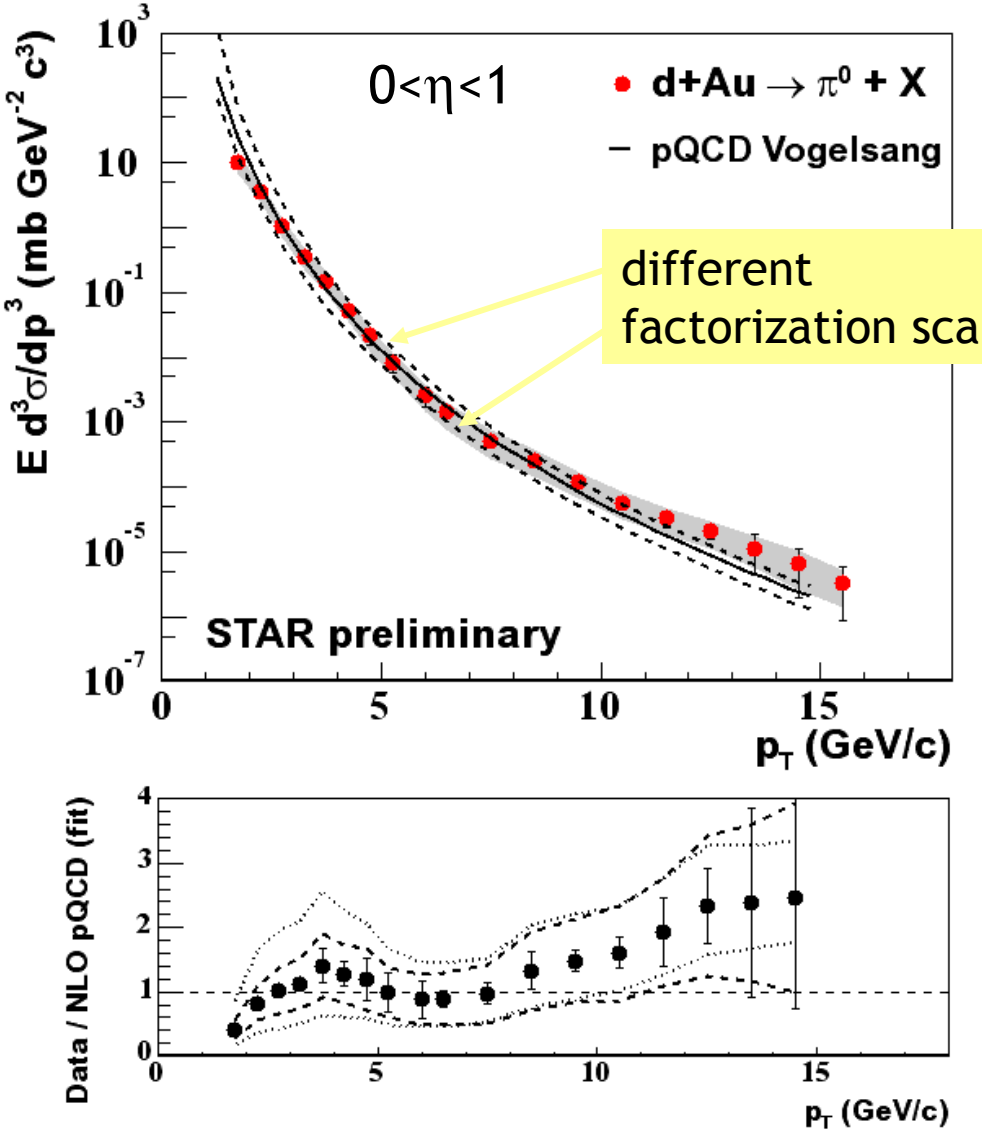
# $\pi^0$ transverse mass spectrum

PHENIX data: PRL 91, 072303 (2003)



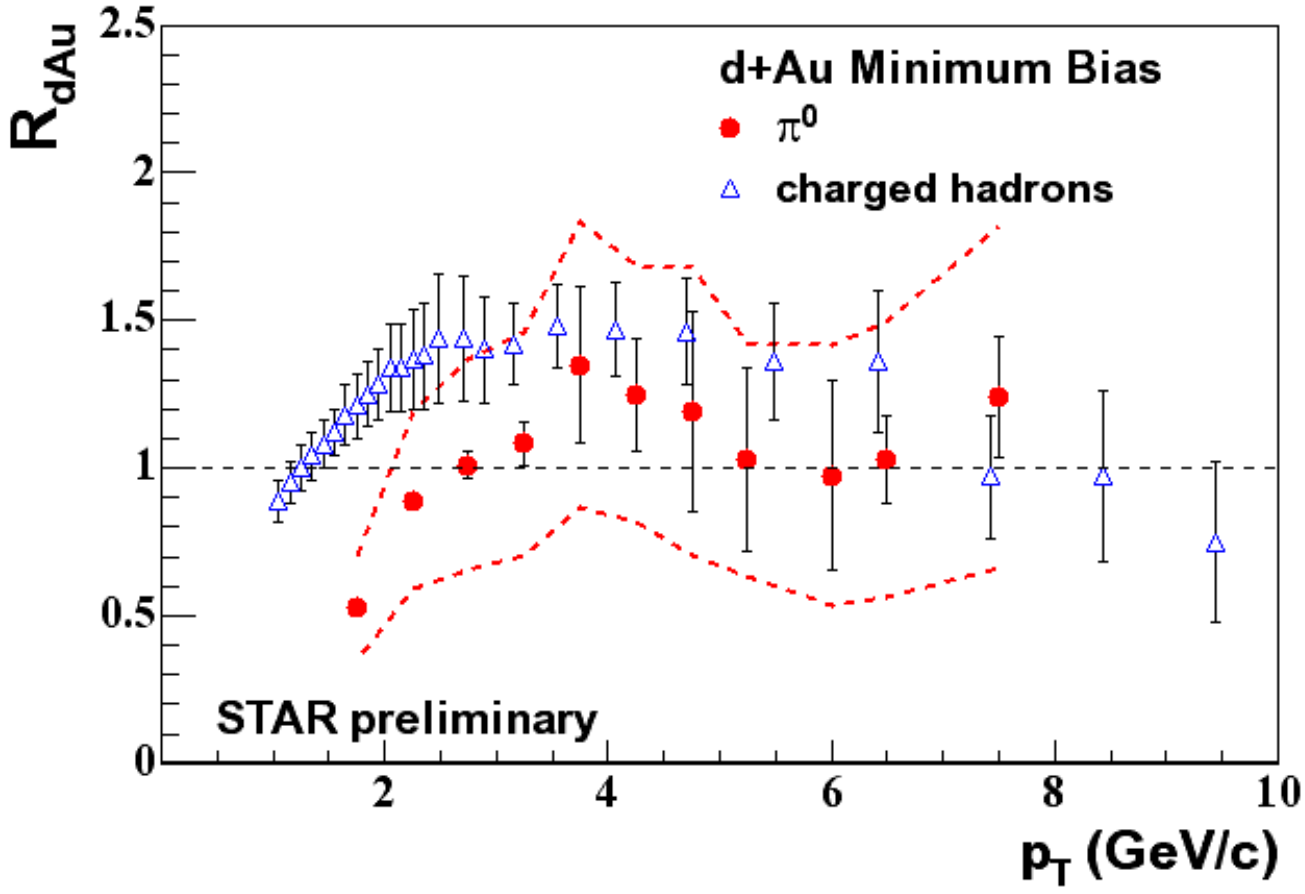

- Neutral pion $p_T$ measurement up to 13-16 GeV/c
- Agreement with PHENIX measurement within 10%

# Comparison with NLO pQCD calculations




- Werner Vogelsang
  - Nuclear effects included
  - PDFs: Frankfurt et al. (CTEQ6M)
  - Fragmentation fct.: Kniehl et al.
  - no Cronin effect included
- 10% normalization uncertainty
- Reasonable agreement within errors
- Energy calibration at high $p_T$ under investigation

# $R_{dAu}$ for neutral pion



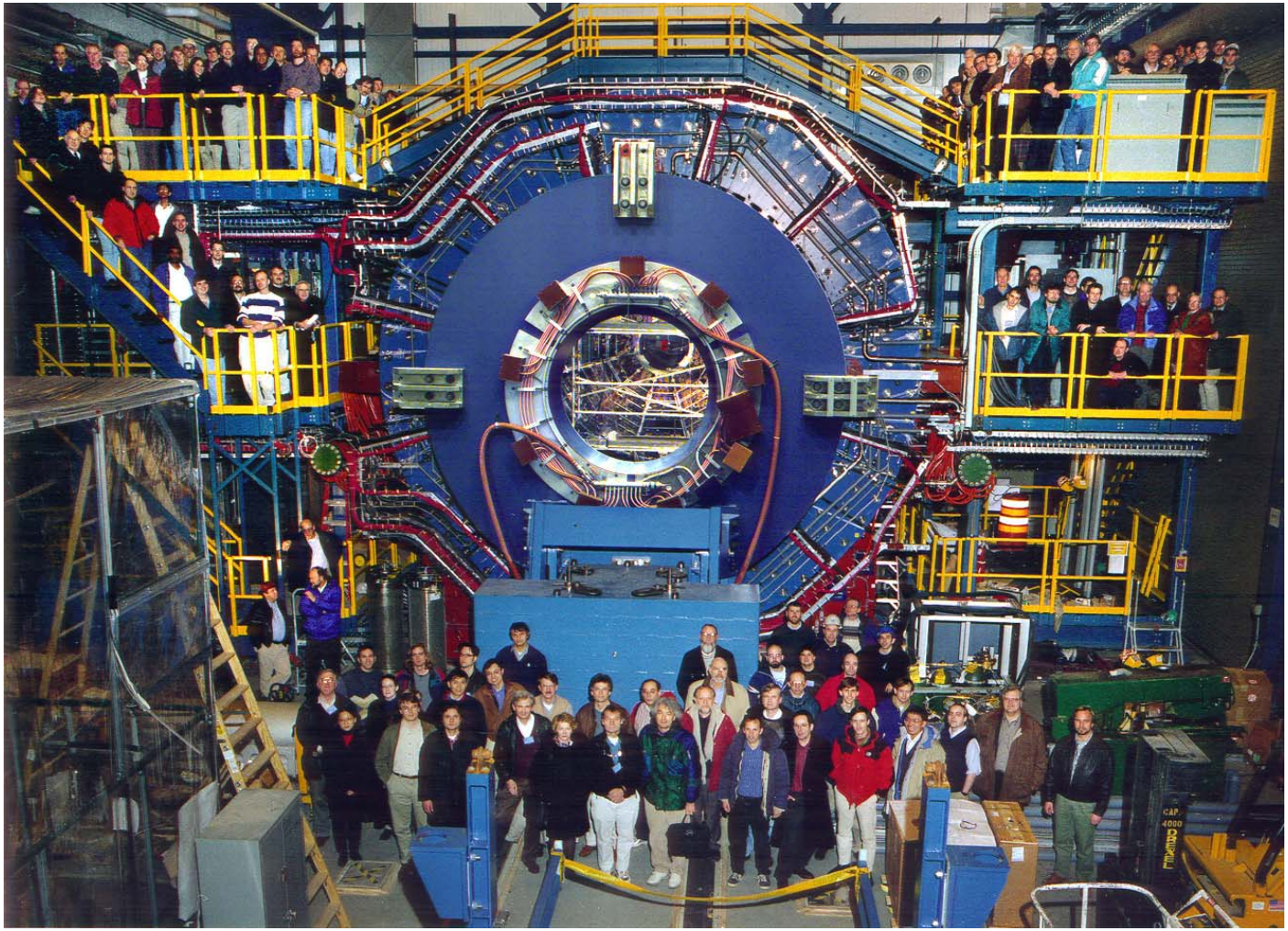

p-p reference for neutral pions:
power law fit to PHENIX data, PRL 91 (2003) 241803

# Summary and Outlook

- Preliminary neutral pion $p_T$ spectrum from d-Au collisions at $\sqrt{s}$ = 200 GeV
- Good agreement with earlier PHENIX $\pi^0$ and STAR charged hadron measurement
- Reasonable agreement with NLO pQCD calculations
- Next
  - $\pi^0$ spectra in Au-Au ($\sqrt{s}$ = 62.4 and 200 GeV)
  - Heavy mesons: $\rho^{\pm}(770)$ and $\omega(782)$
  - Direct photons

# The STAR collaboration

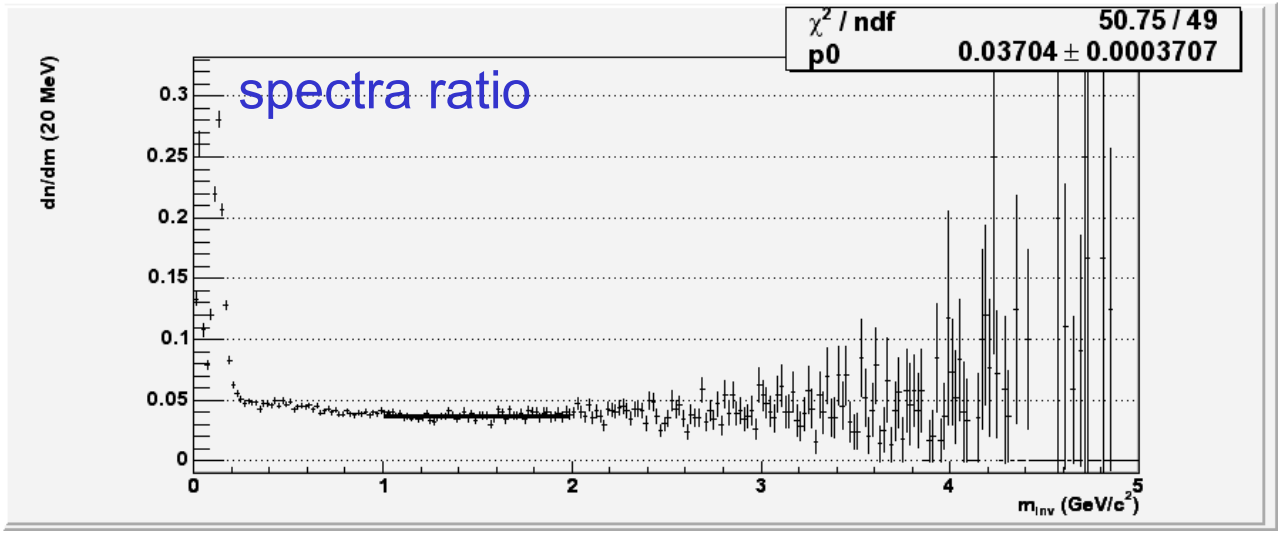
49 institutes from 13 countries, 522 participants



# Additional slides

# Normalization of the Combinatorial Background

- Checked with "integral" normalization




- Well described up to 5 GeV/c