Photon-jet coincidence measurements in polarized pp collisions at $\sqrt{s}$ = 200 GeV with the STAR Endcap Calorimeter

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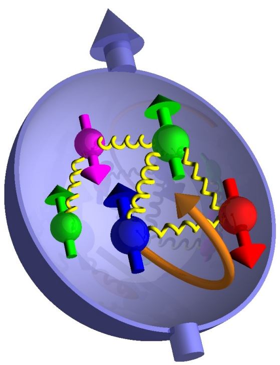
STAR

Proton spin puzzle

ΔΣ: spins from quarks

Accounts only ~33% of the proton spin
(from polarized DIS experiments)



$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

ΔG: gluon spin contribution

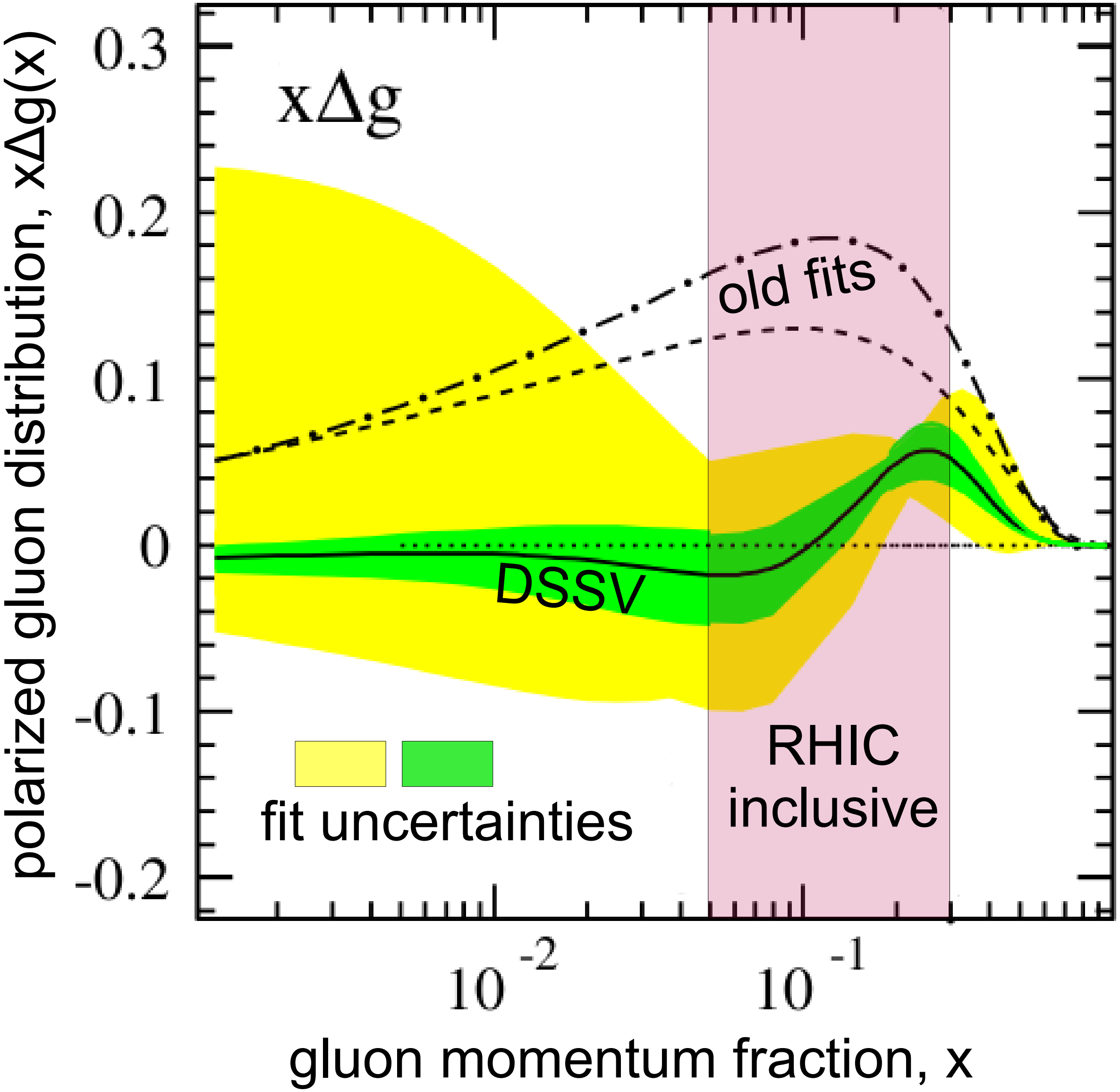
RHIC spin program with
longitudinally polarized proton beams

Parton's orbital momentum

RHIC spin program with
transversely polarized proton beams

Competing experiments: COMPAS, HERMES, JLAB

Latest global analysis of ΔG with RHIC data



DSSV: Florian, Sassot, Stratmann, Vogelsang
PRL 101 (2008) 072001

DSSV analysis includes:
NLO pQCD calculations with fits to polarized (semi)-inclusive DIS and inclusive RHIC data

Integral ΔG is uncertain

Needs to constrain:

- shape of Δg(x): initial parton kinematics via coincidence measurements
- Behavior at small gluon x: forward rapidity or higher energy

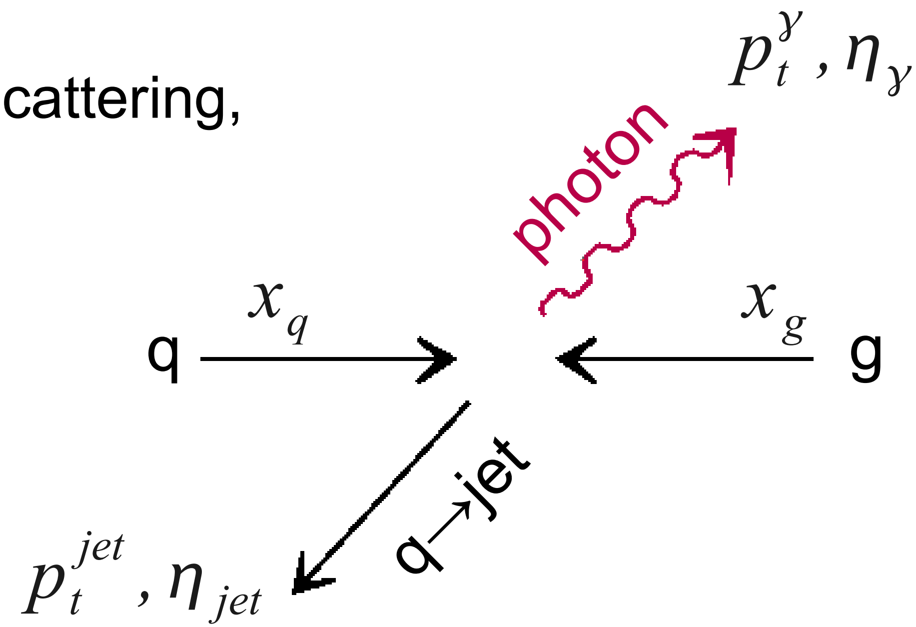
Why study photon-jet coincidences?

- Allows reconstruction of parton kinematics, thus to determine the shape of Δg(x)

  $$x_{q,g} = \frac{1}{\sqrt{s}}\left[p_t^{\gamma} e^{\pm\eta_\gamma} + p_t^{jet} e^{\pm\eta_{jet}} \right]$$

  Better kinematic reconstruction compared to more often di-jets

- Dominated by quark-gluon Compton scattering, while di-jets contain contributions from many partonic sub-processes



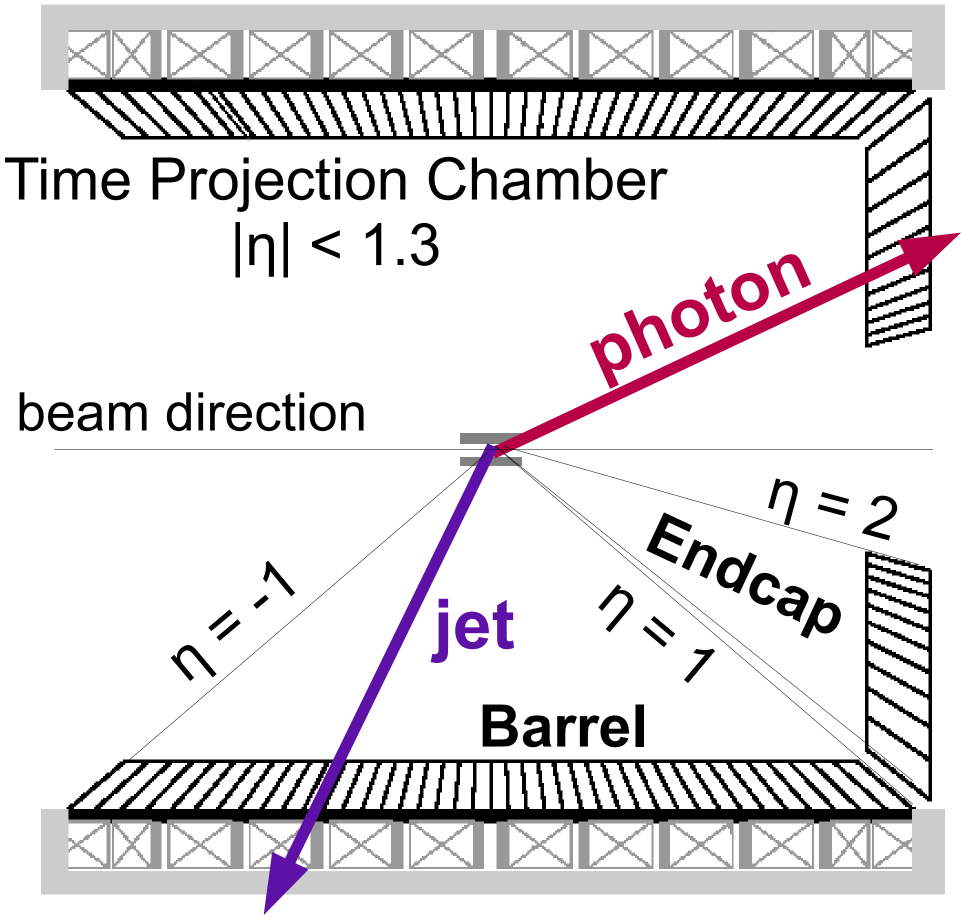
- Probes Δg(x) over wide range of x, what removes uncertainties in integral ΔG determination

  Sensitivity to Δg(x) at small x with forward rapidity photon

Rare process → measurement is statistics hungry
Large background (mostly photons from neutral pion decay)

Exciting, but very challenging problem to analyze

Photon-jet reconstruction



mid-point cone jet-finding algorithm

photon: $1.08 < \eta_\gamma < 2$ $p_t^\gamma > 7\mathrm{GeV}$

jet: $|\eta_{jet}| < 0.8$ $p_t^{jet} > 5\mathrm{GeV}$

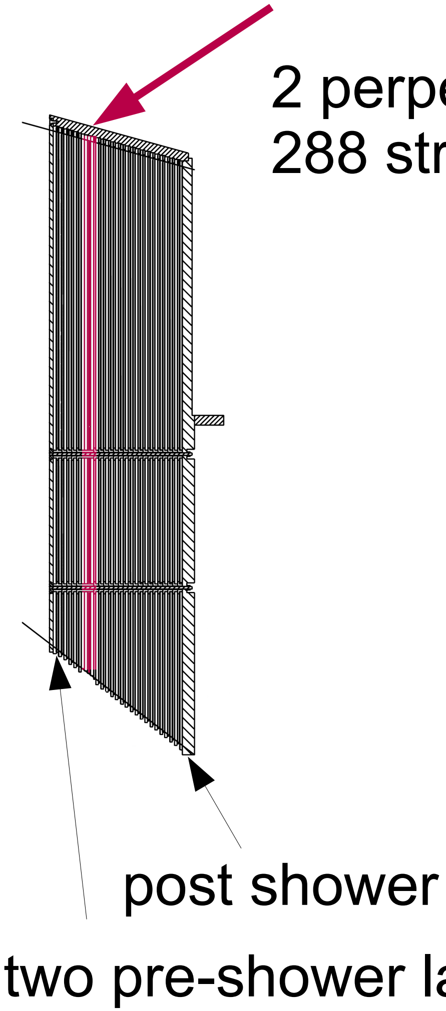
photon and jet are back-to-back

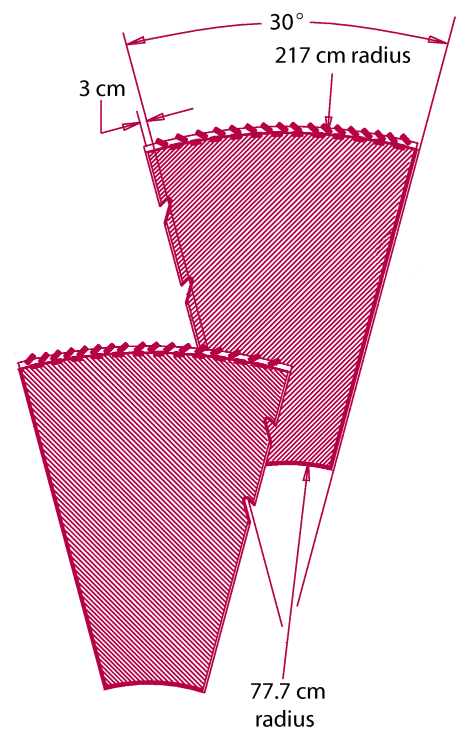
Endcap EMC
(Electro-Magnetic Calorimeter)

1.08 < η < 2, full azimuth
720 projective towers, 12 sectors

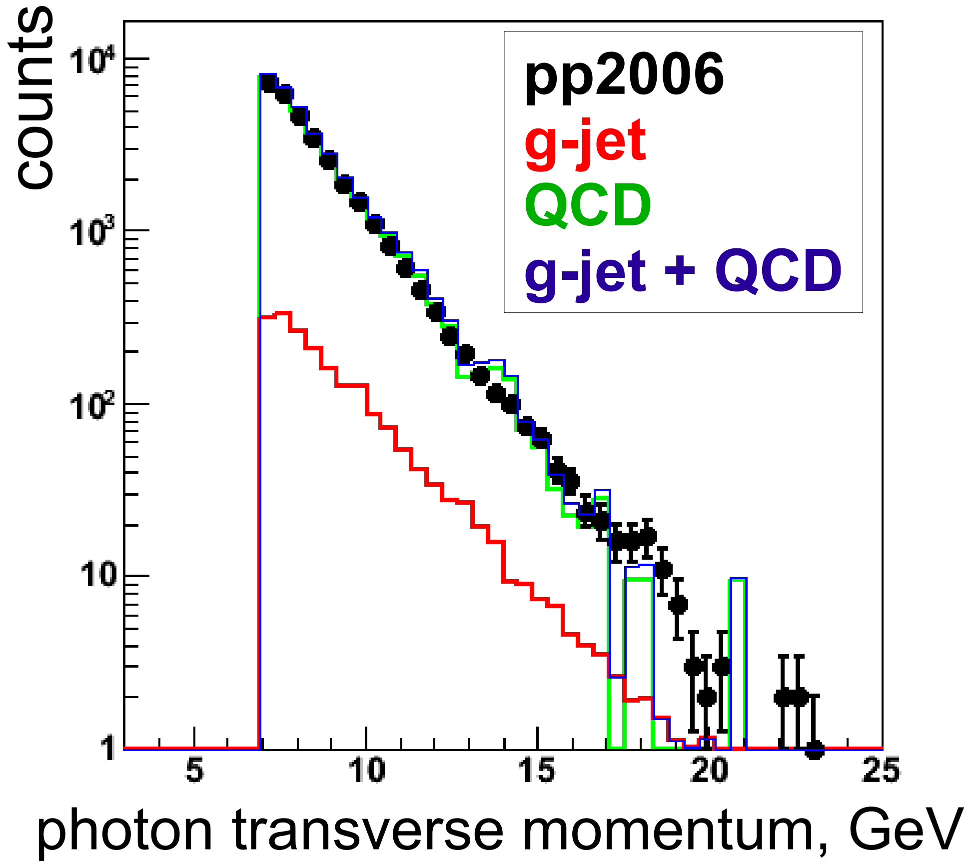
Shower Maximum Detector (SMD)

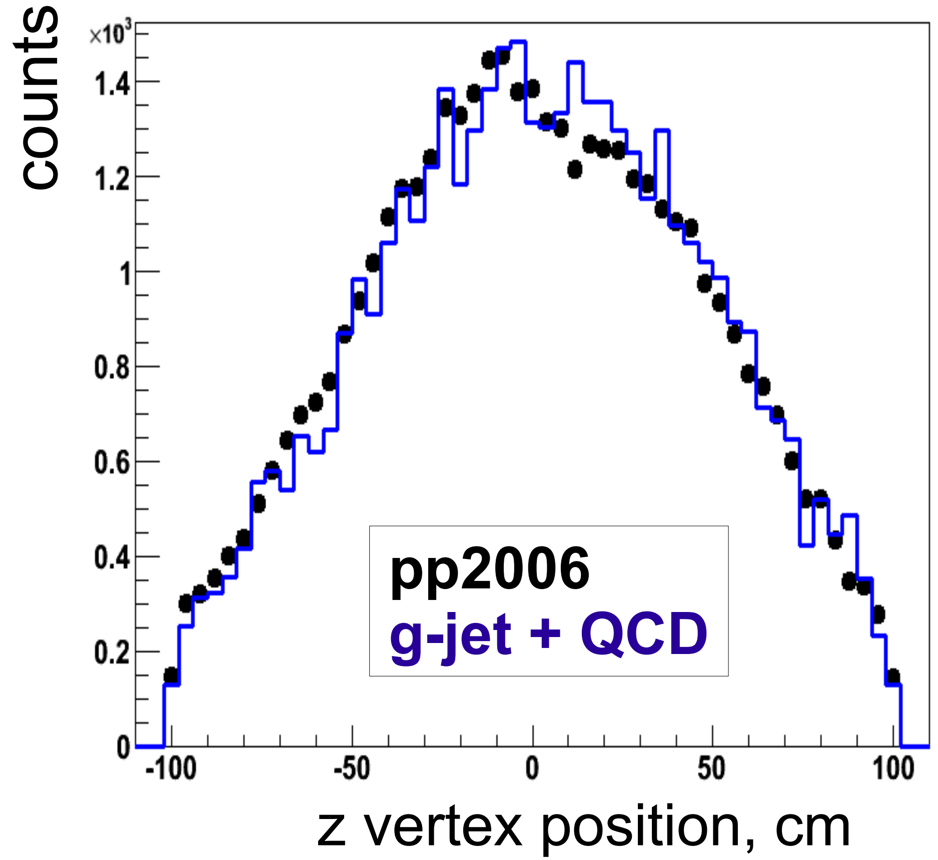
2 perpendicular planes
288 strips per plane/sector





Yields before background suppression





pp2006 (3.1 pb^{-1}) STAR y2006 data
proton-proton collisions at $\sqrt{s}$ = 200 GeV

g-jet (7 pb^{-1}) prompt photon simulations

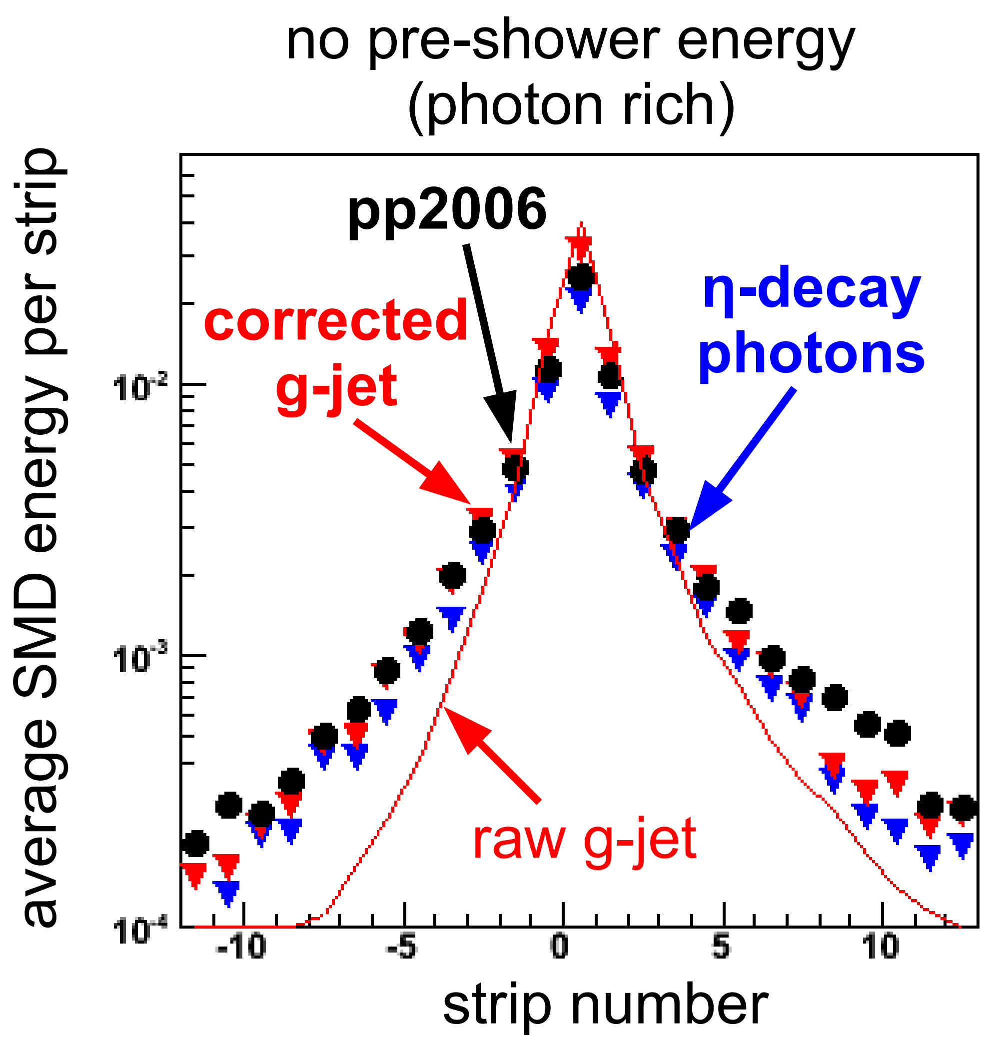
QCD (1 pb^{-1}) hard QCD simulations

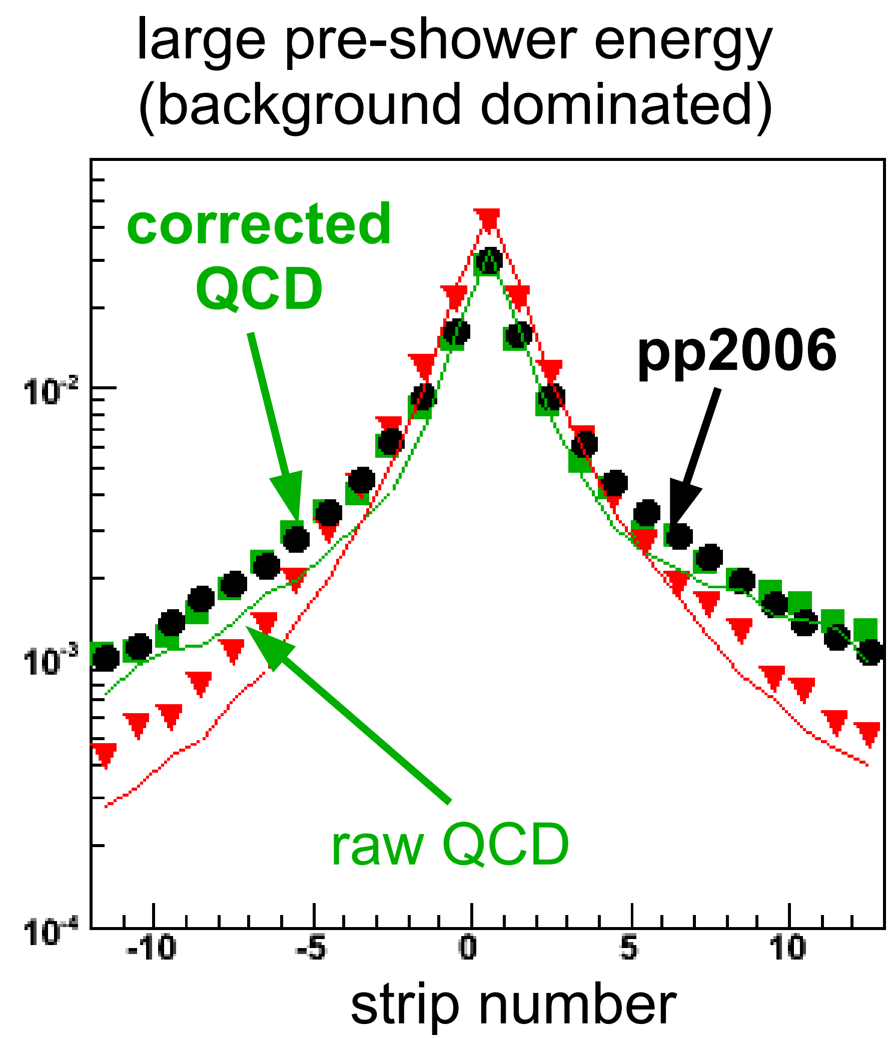
Monte-Carlo:

PYTHIA v6.4 (CDF tune A)
GEANT+Trigger emulation
Partonic p_t range: 2-25 GeV

Normalization: PYTHIA luminosity plus 25% overall correction

Transverse shower shapes

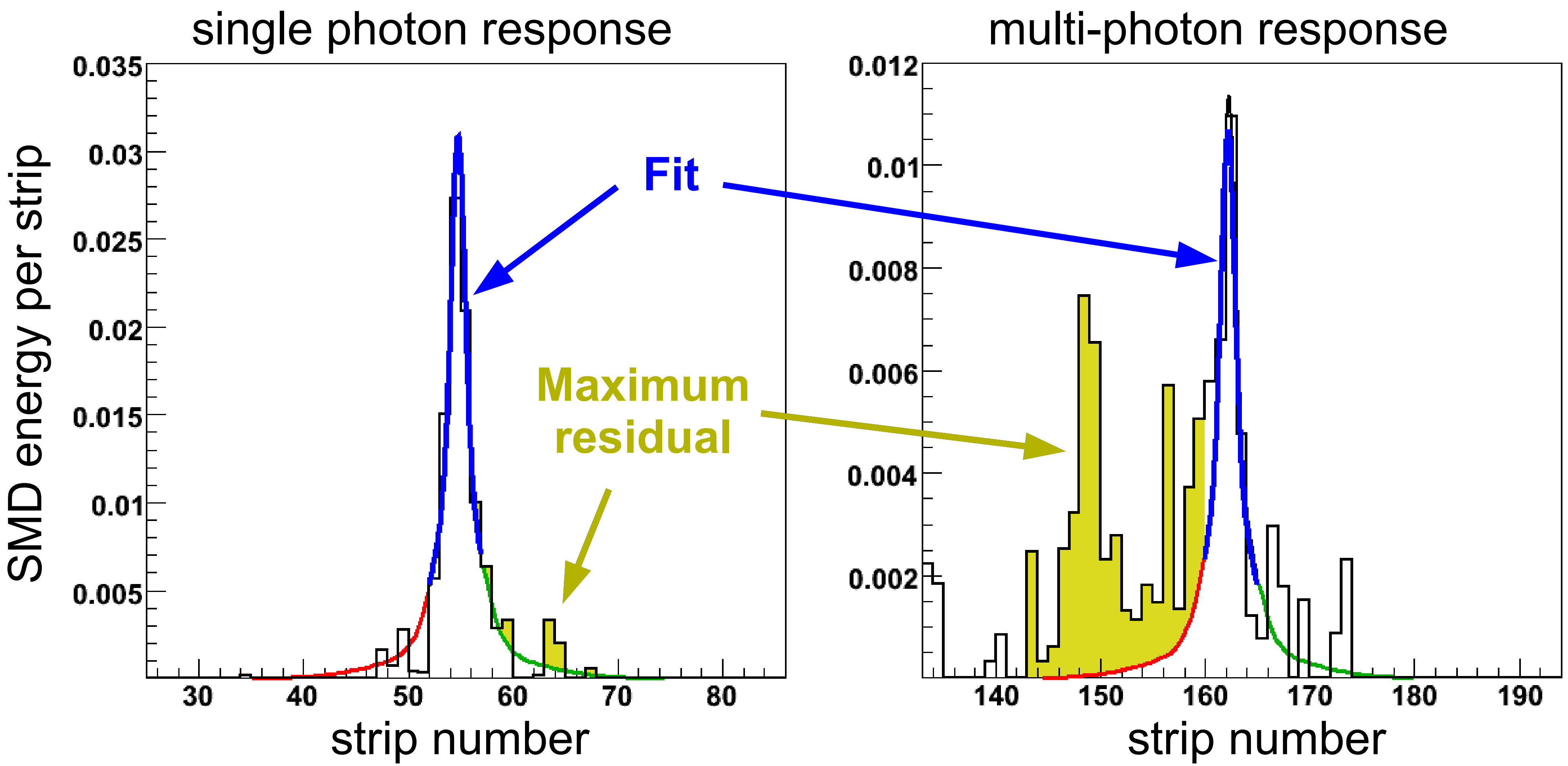




data-driven Monte-Carlo:
substituting SMD response with that of real photons from eta-meson analysis

Good agreement between shower shapes from real data and data-driven Monte-Carlo

Shower shape analysis



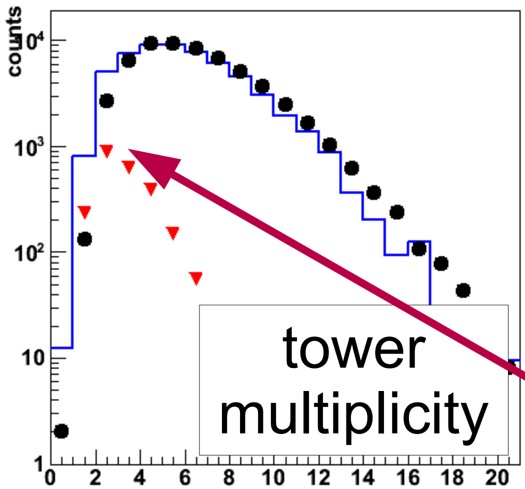
Procedure:
Fit central strips with parametrized shape

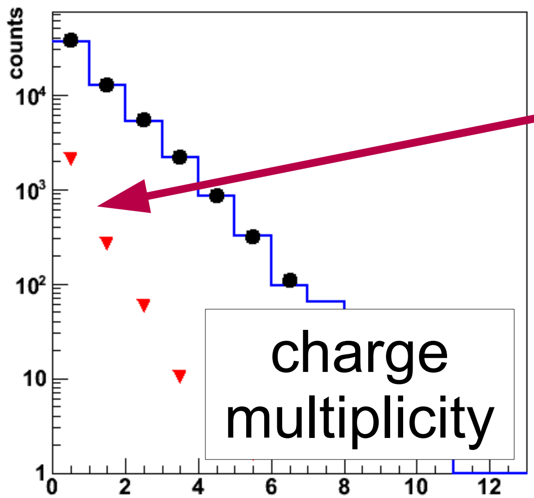
Find maximum residual
(actual energy deposition minus fit)
and use it for background discrimination

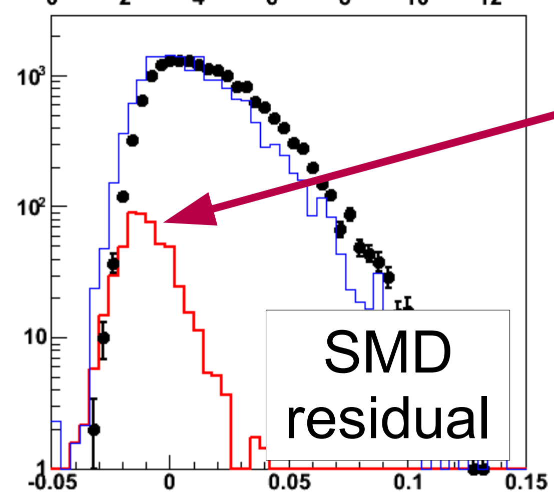
Discriminate between direct photon and multi-photon (background) events by searching for an extra energy on a side of the peak

Main photon-jet signatures

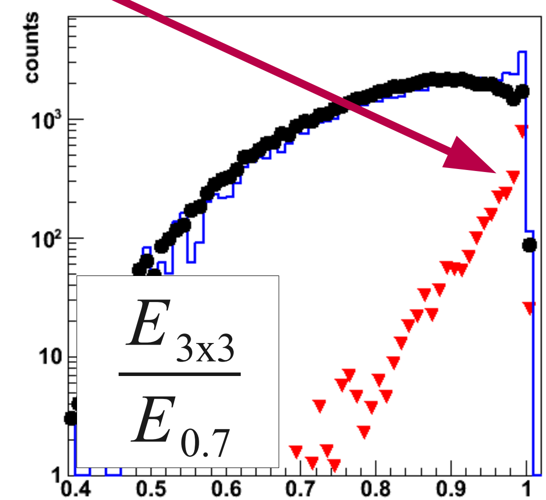
pp2006 g-jet
g-jet + QCD
raw yields before background suppression

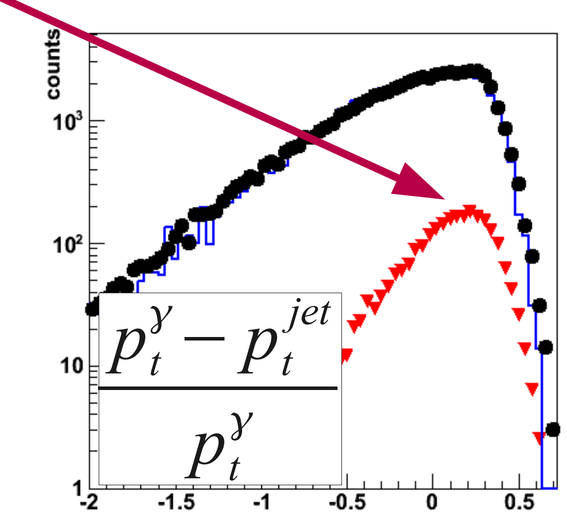






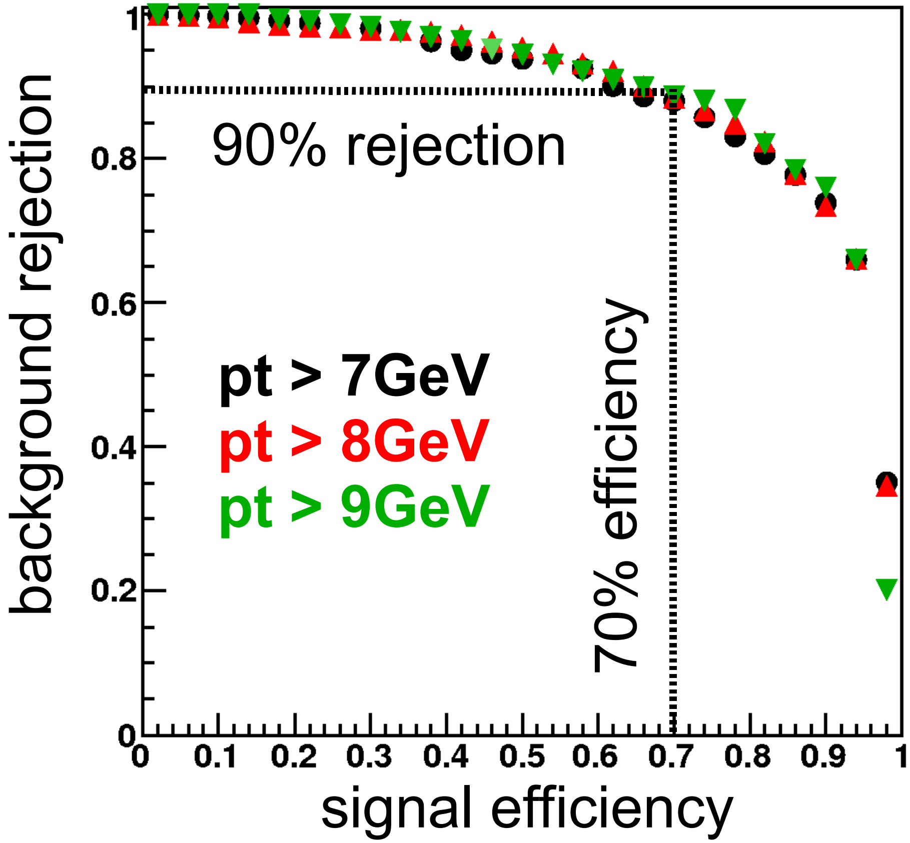
- > 95% of energy deposition localized in small Δη-Δφ radius
- photon deposits all energy in small (<4) number of towers
- (almost) no charge particles accompanying photon
- good matching between photon momentum and that of the away side jet
- Small residual: photon shower is narrow and symmetric

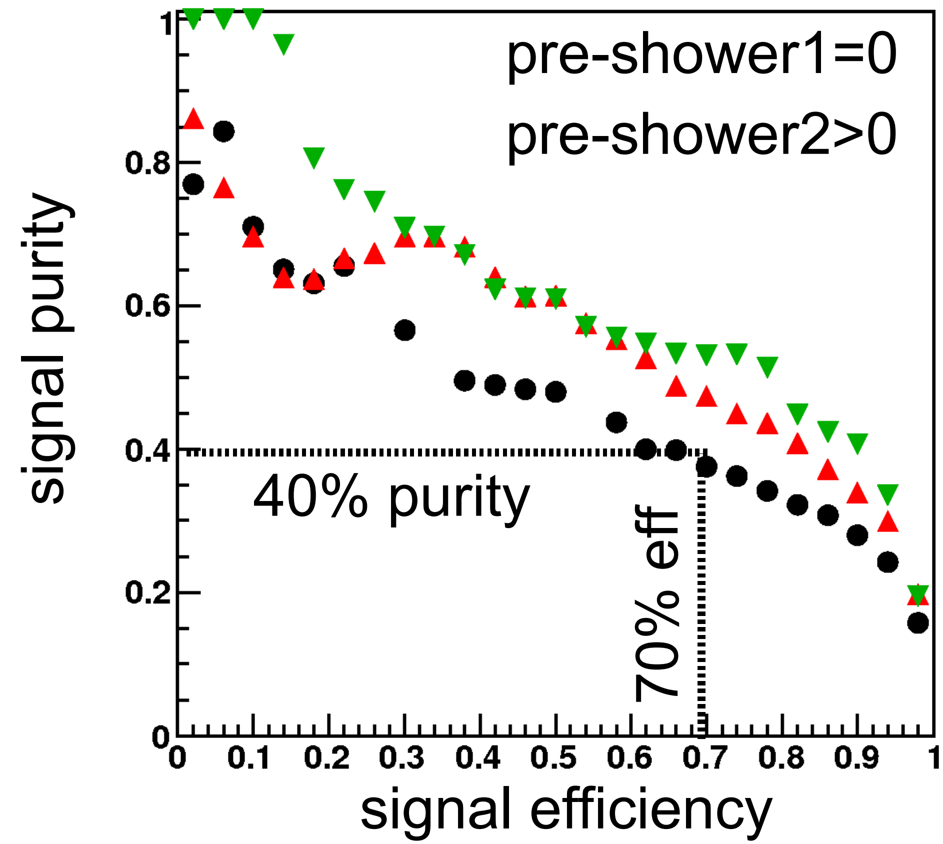




data and Monte-Carlo match within 5-10%

Background discrimination and cut optimization





Combine all variables with weights and construct a single discriminant:

$$D=\sum_i weight(i)\times variable(i)$$

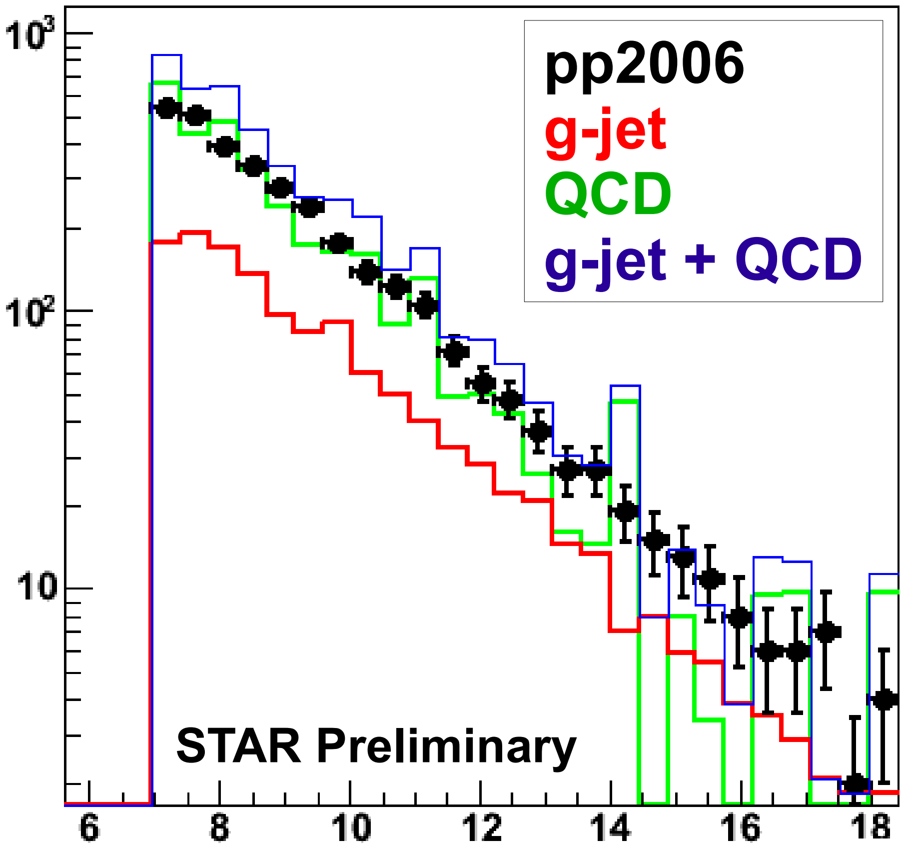
Maximize signal/background separation by optimizing weights with ROOT LDA (Linear Discriminant Analysis)

Purity/efficiency/rejection correlations strongly depend on photon energy and pre-shower condition

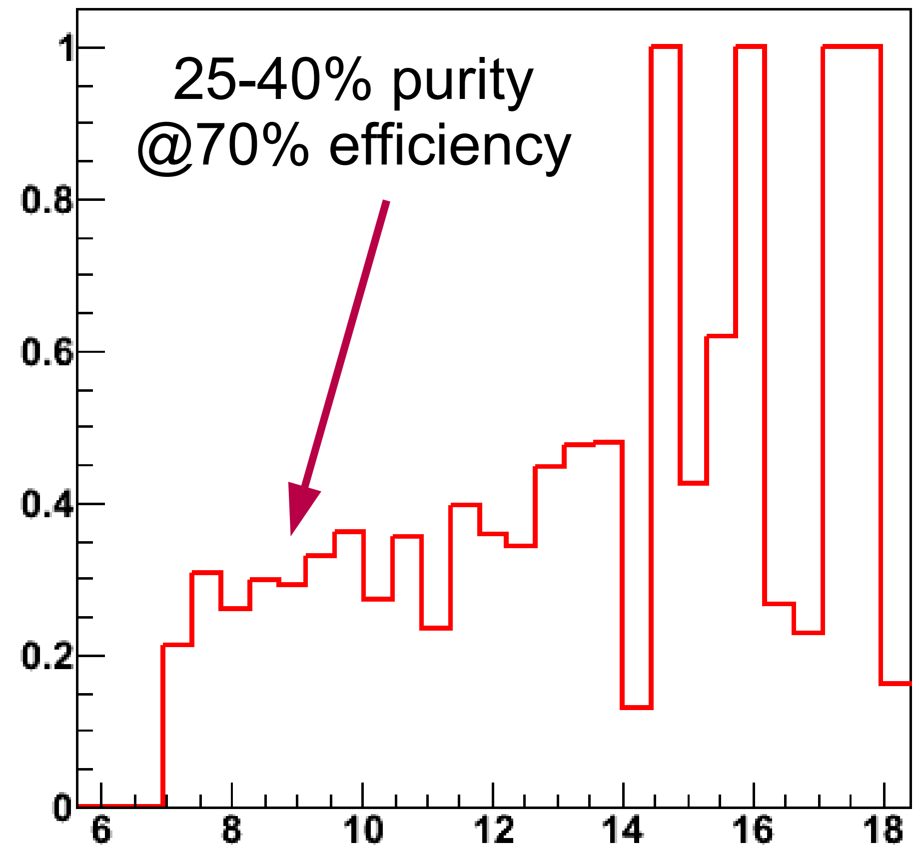
For a given efficiency, the signal purity improves with increase in photon pt

Photon-jet yield after background suppression with 70% efficiency (pre-shower average)

uncorrected yield



photon-jet purity



photon transverse momentum, GeV

Depends on photon momentum, we can reach 25-40% purity with 70% efficiency

Summary

Agreement between data and Monte-Carlo within 5-10%

- Still working on issues with some of the variables for detailed data to MC comparison

Transverse shower shape analysis

- Reproducing real shower shapes with data-driven Monte-Carlo
- Multi-photon background discrimination with maximum sided residual analysis

Isolation cuts and purity/efficiency optimization

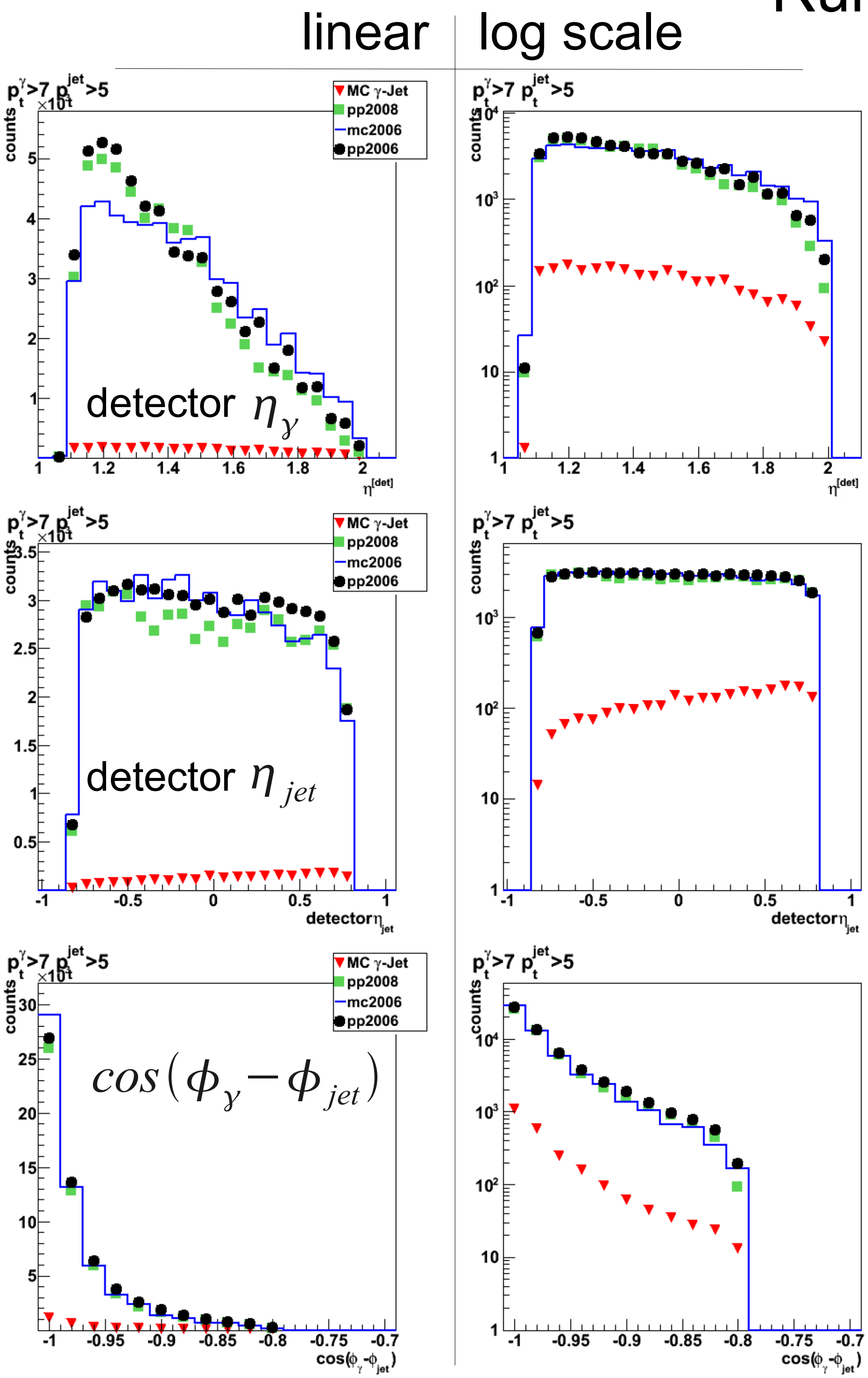
- Maximum signal/background separation with cuts optimized by LDA (Linear Discriminant Analysis)
- With current cuts can reach 25-40% purity with 70% efficiency

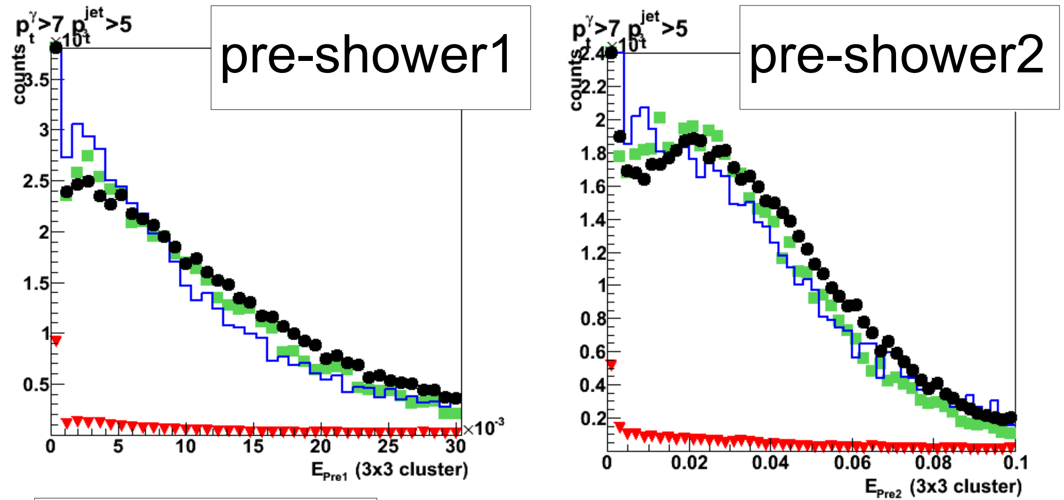
Future plans

- Improving purity and efficiency
- Extract photon-jet cross section
- STAR/RHIC is currently accumulating statistics for ΔG sensitivity via photon-jet channel

Backup slides

Run 6 vs. Run 8





pp2006
pp2008
QCD+g-Jet
g-jet

pp2008 data normalized to match pp2006 yield

Pre-shower energy deposition in MC don't match well real data with same geometry

MC with y2006 geometry looks more like data from Run 8 which has less material in front of EEMC (SVT structure removed)

Propagate into normalization difference when sorting by pre-shower conditions.