Angular Distribution in the CM Frame of Direct Photons at CMS

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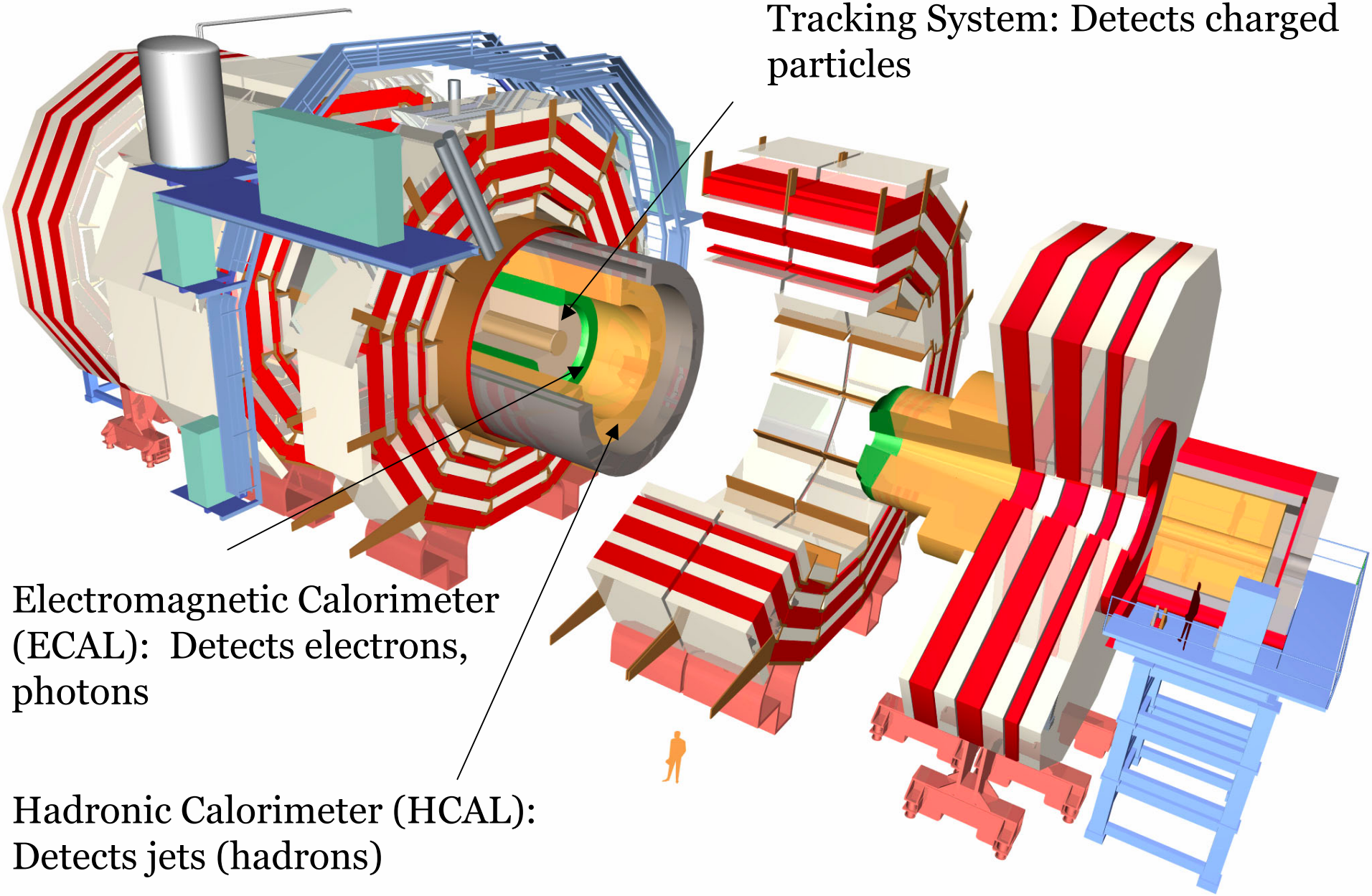
Tracking System: Detects charged particles

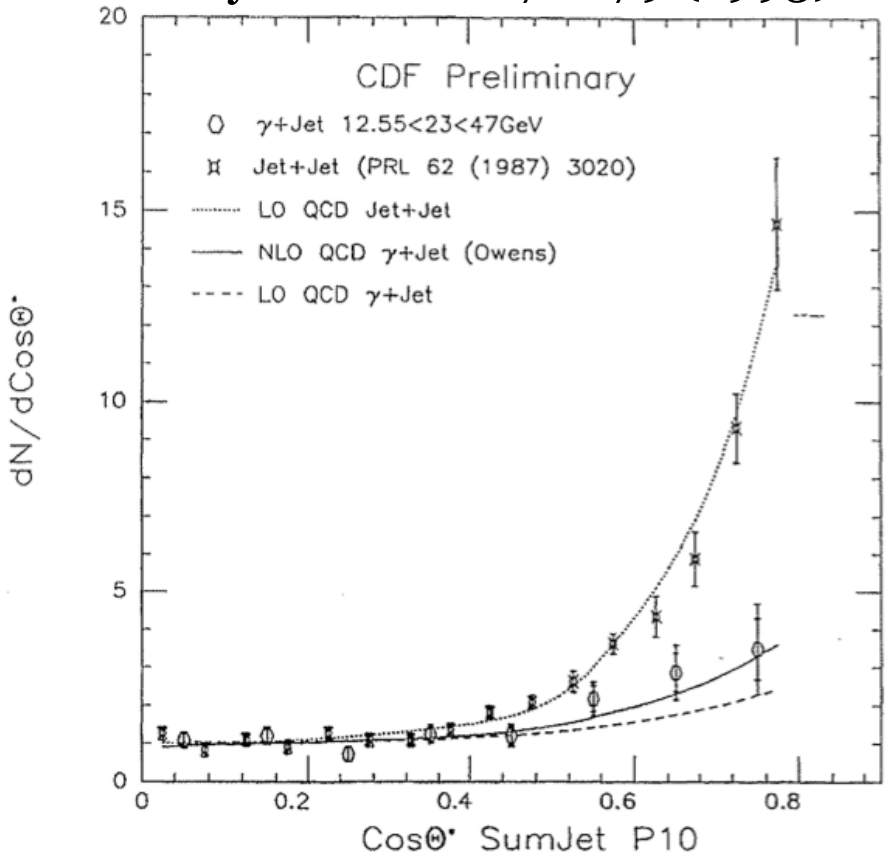


Electromagnetic Calorimeter (ECAL): Detects electrons, photons

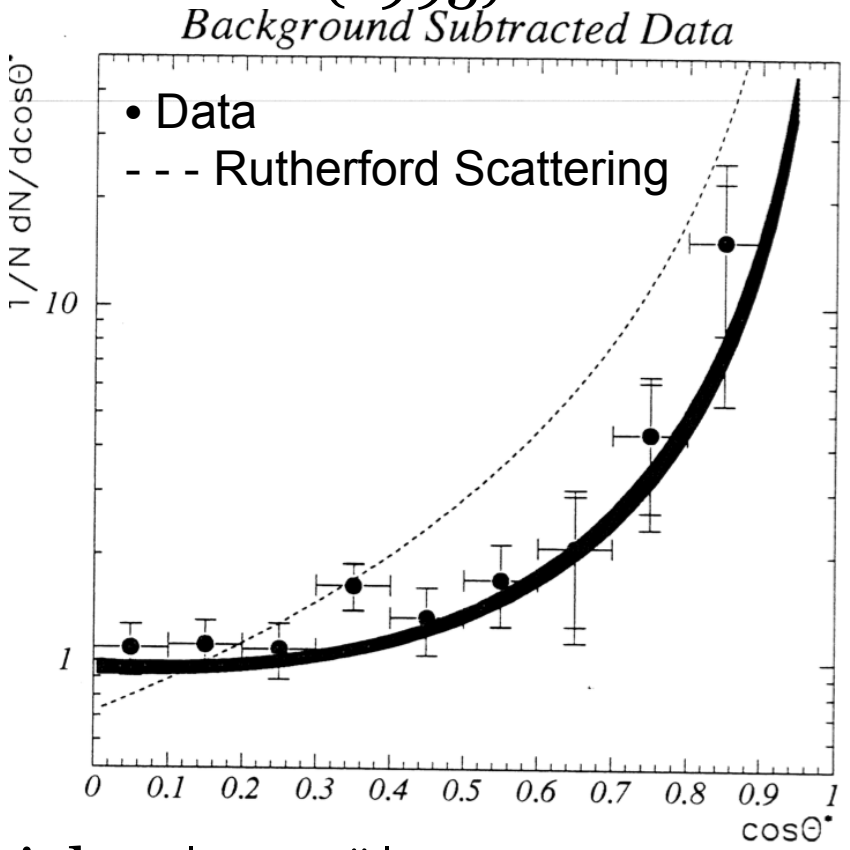
Hadronic Calorimeter (HCAL): Detects jets (hadrons)

Previous Measurements

CDF: Leslie Nakae, Thesis, Phys.Rev.Lett. 71 679 (1993)



DØ: Paul Rubinov, Thesis (1995)

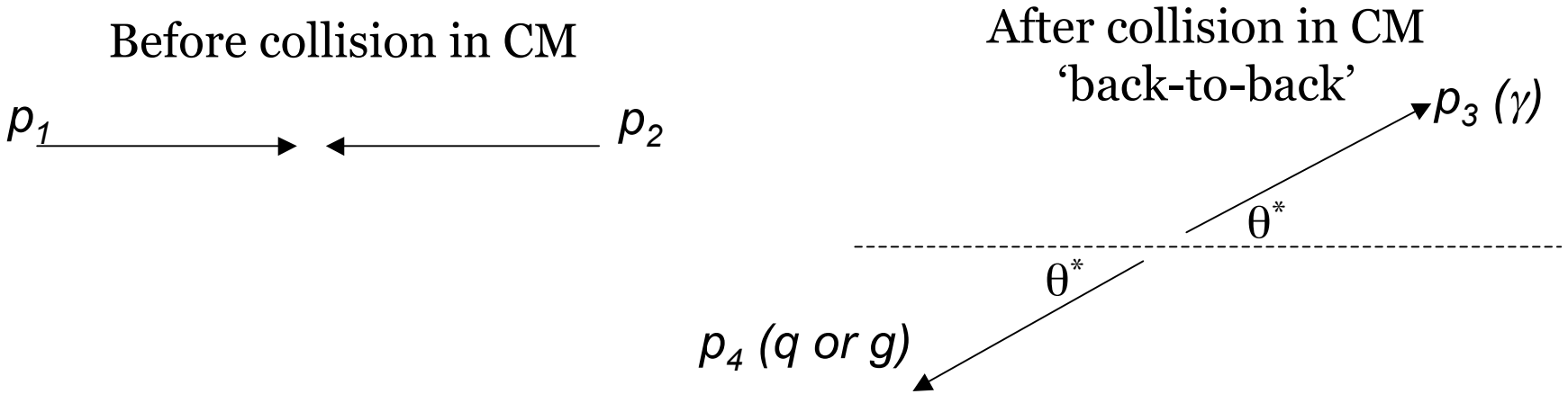


CMS may reach higher $|\cos\theta^*| \sim 0.9$

Customary in analysis to normalize points $|\cos\theta^*| < 0.3$ to 1

Introduction

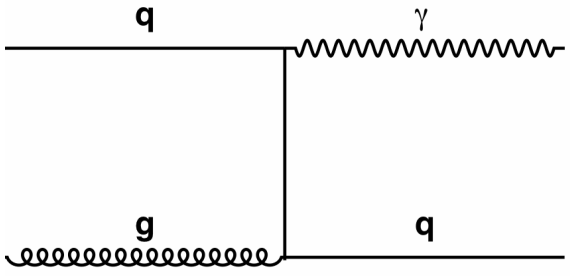
- 2→2 process, massless approximation
  - Outgoing particles are back-to-back in the CM frame



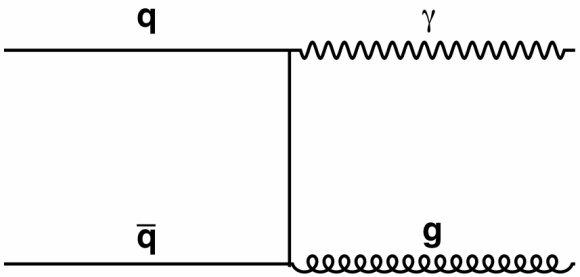
θ^* is the angle between the outgoing partons and the beam axis. The goal of this analysis is to measure cos θ^* and compare with NLO QCD

Direct Photons

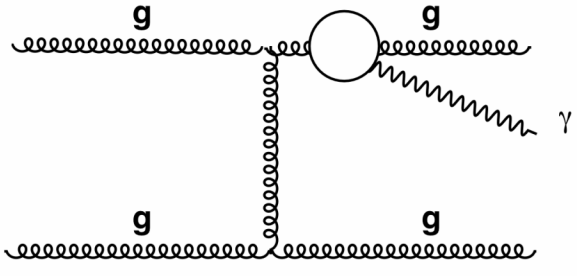
- Direct photons originate from the hard scatter in proton-proton collisions



QCD Compton



Quark Annihilation



Fragmentation

Process	$\lvert\mathcal{M}\rvert^2$
$q+\bar{q}\rightarrow\gamma+g$	$\frac{8}{9}e_q^2[\frac{\hat{u}}{\hat{t}}+\frac{\hat{t}}{\hat{u}}]$
$g+q\rightarrow\gamma+q$	$-\frac{1}{3}e_q^2[\frac{\hat{u}}{\hat{s}}+\frac{\hat{s}}{\hat{u}}]$
$g+g\rightarrow g+g$	$\frac{9}{2}[3-\frac{\hat{t}\hat{u}}{\hat{s}^2}-\frac{\hat{s}\hat{t}}{\hat{u}^2}-\frac{\hat{s}\hat{u}}{\hat{t}^2}]$

$$\hat{s} = 4\mathbf{p}^2$$

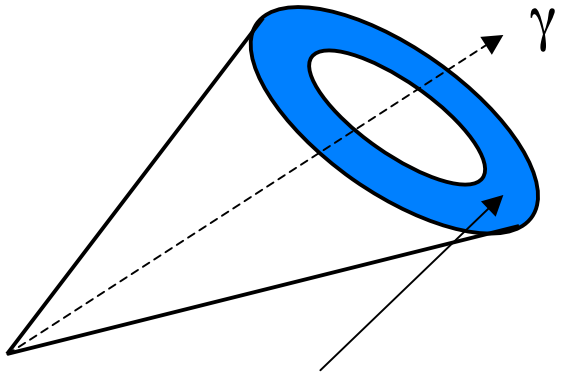
$$\hat{t} = -2\mathbf{p}^2(1-\cos\theta^*)$$

$$\hat{u} = -2\mathbf{p}^2(1+\cos\theta^*)$$

Angular distribution in CM frame directly linked to $|\mathcal{M}|^2$

Selection

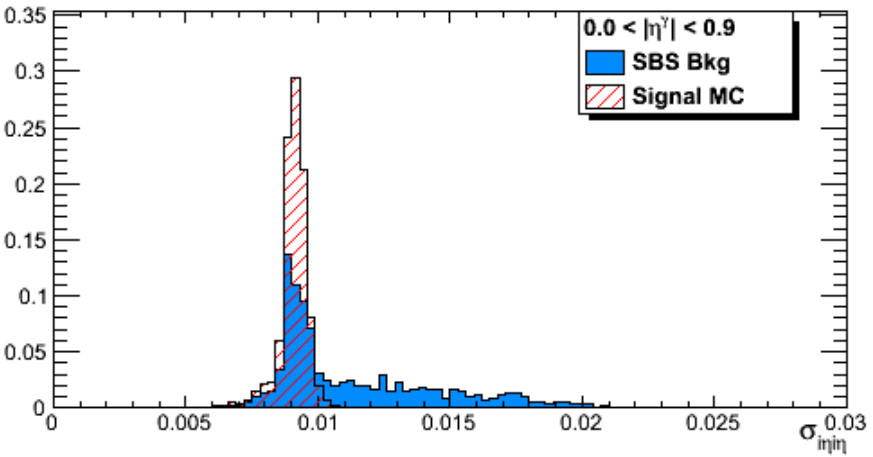
- Data taken During March-November 2010, 36 pb^{-1}
- Event Selection (1 γ + 1 jet)
  - Veto beam gas interactions, beam scraping
  - Require good quality primary vertex
- Photon ID
  - $p_T^{\gamma} > 25$ GeV
  - $|\eta^{\gamma}|<1.4442$
  - $Energy_{hadronic}/Energy_{EM} < 0.05$
  - Veto Tracker Pixel Match (electrons)
  - Isolation
    - Hollow Cone Track Isolation $< 2.0+0.001p_T^{\gamma}$
    - Electromagnetic Isolation $< 4.2+0.001p_T^{\gamma}$
    - Hadronic Isolation $< 2.2+0.003p_T^{\gamma}$
- Jet ID
  - $p_T^{jet} > 20$ GeV
  - $|\eta^{jet}| < 2.4$

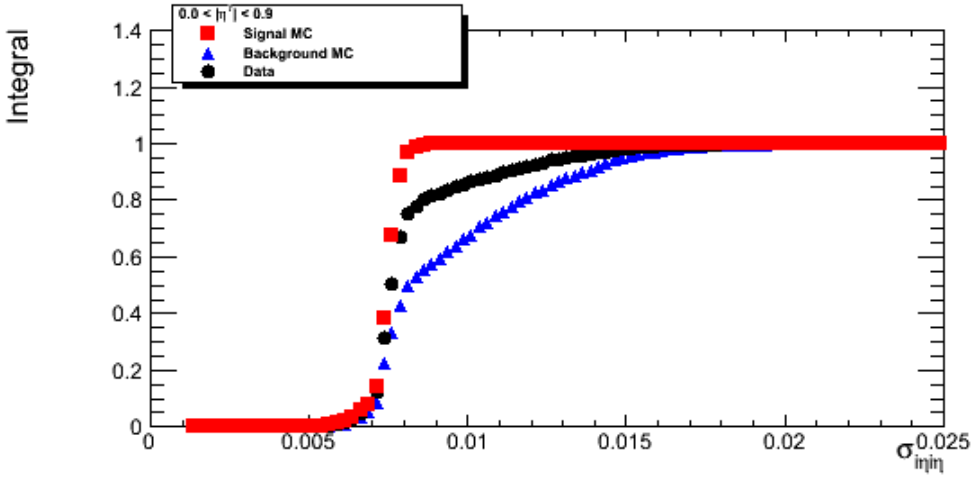


Sum E_T within annulus cone $\Delta R_i = 0.06$, $\Delta R_o = 0.4$

Photon Discriminant

- $\sigma_{i\eta i\eta}$ is the shower width of a photon candidate in η
  - Shows strong discriminating power for signal and background
  - Background template obtained through a data-driven technique
    - Use a variable normally cut to select signal and invert to select background
      - –Hollow Cone Track Isolation
- Plot Integral, take the difference at each point…point of largest difference is boundary location

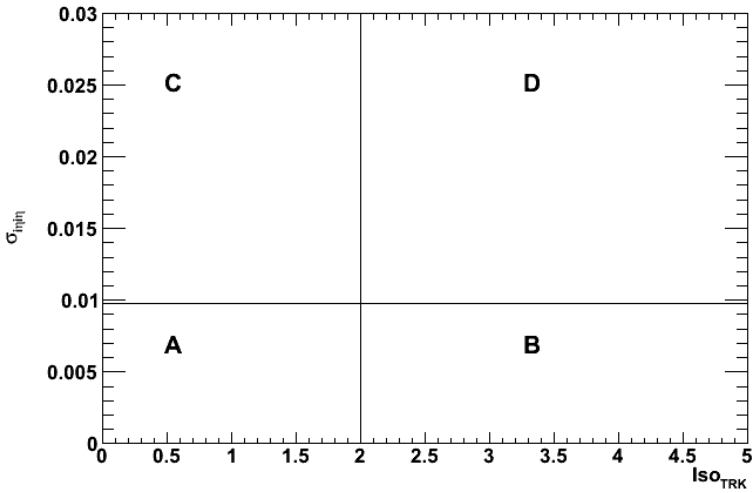




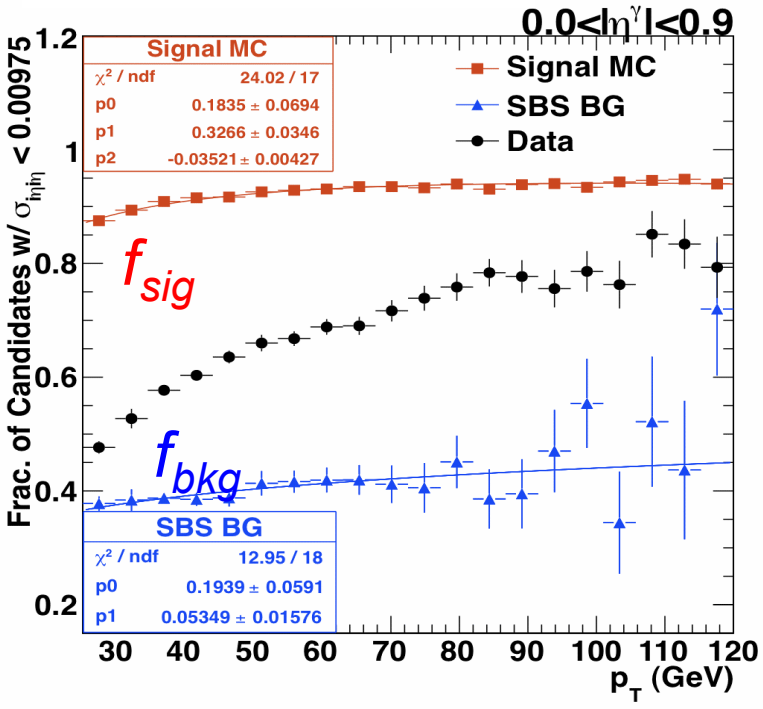
Background Estimation in Data

- Two-bin purity technique
- Similar to ABCD method:
  - Divide space into 4 regions
  - Assumes A/C = B/D and B/D can be determined from data

$$P = \frac{f_{data} - f_{bkg}}{f_{sig} - f_{bkg}}$$



Background Estimate



$$P = \frac{f_{data} - f_{bkg}}{f_{sig} - f_{bkg}}$$

We parameterize the dependence on p_T

Employ weighting on an event-by-event basis using equivalent expressions to P:

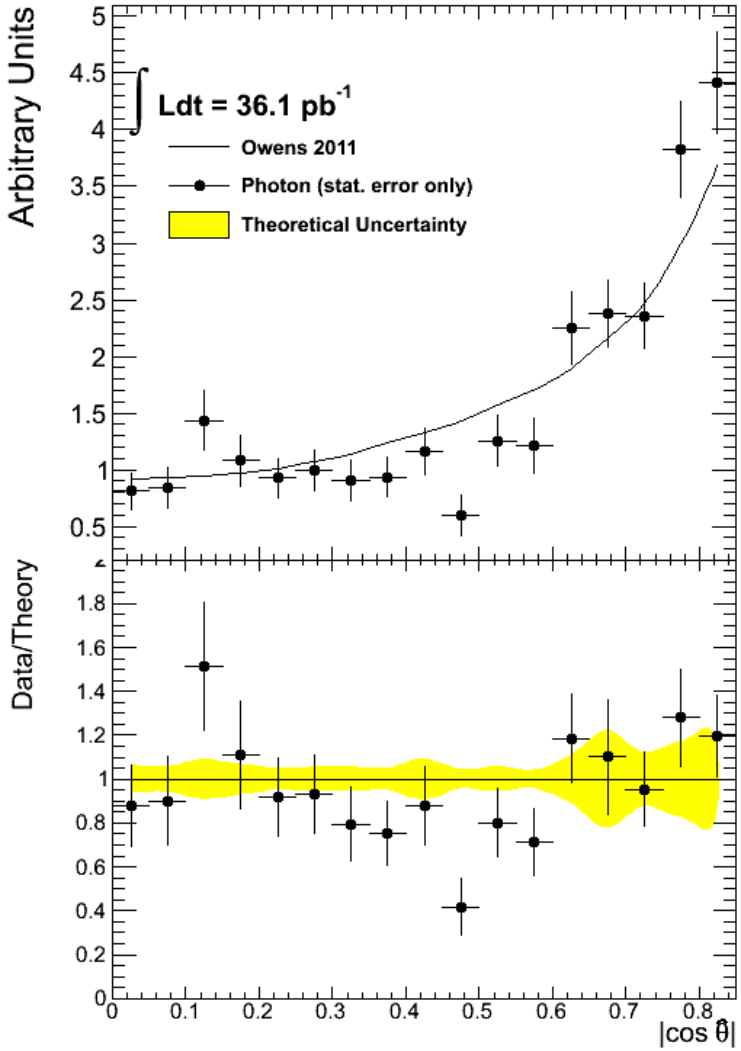
If candidate is below bin boundary

$$w_- = \frac{1 - f_{bkg}}{f_{sig} - f_{bkg}}$$

If candidate is above bin boundary

$$w_+ = \frac{-f_{bkg}}{f_{sig} - f_{bkg}}$$

Preliminary Results



- Systematic Uncertainties
  - Fit parameters < 10%
  - JES < 5%
  - background shape uncertainty (ongoing)
- Theory
  - J.F. Owens

  [Phys.Rev. D 42, 61–71 (1990)]
  - CT10 PDF and variations (band dominated by MC statistics)

Summary

- $\cos\theta^*$ is a direct probe into partonic cross section
  - Has not been measured since the early days of the Tevatron
  - Data shows good agreement with NLO QCD Theory
- Sensitivity to PDFs currently under study
  - y_{boost} may be affected
- Future 2011 analysis plans include studying fragmentation