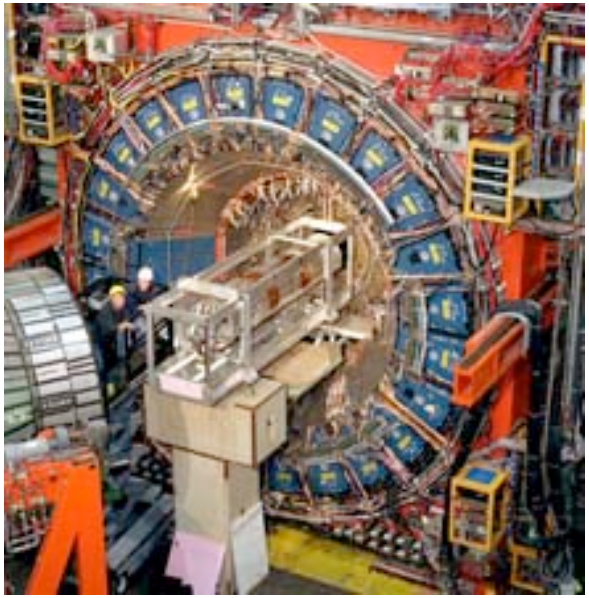


Measurement of $\gamma+b/c$+X production cross sections at CDF

Tingjun Yang/FNAL

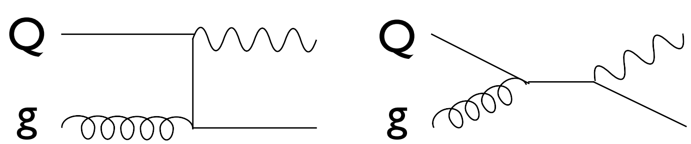
DPF 2011, Brown University

Outline

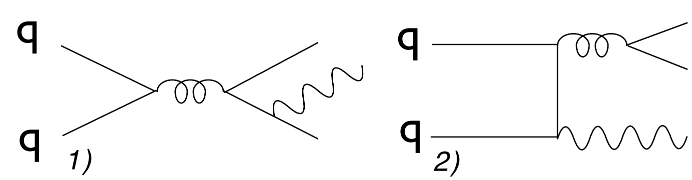
- Introduction: γ+*b*/*c*+X production
- Tevatron and CDF
- Analysis details
  - Photon fraction
  - Heavy-flavor jet fraction
  - Unfolding factors
- Preliminary results

γ+b/c+X production

- Photon produced in association with heavy quarks provides valuable information about PDFs of the initial state hadrons.
- LO contribution: Compton scattering (Qg->Qγ)– dominates at low photon p_T.
- NLO contribution: annihilation ($q\bar{q}$->$Q\bar{Q}\gamma$) – dominates at high photon p_T.
- Provide constraints on *b*, *c*, *g* PDFs.

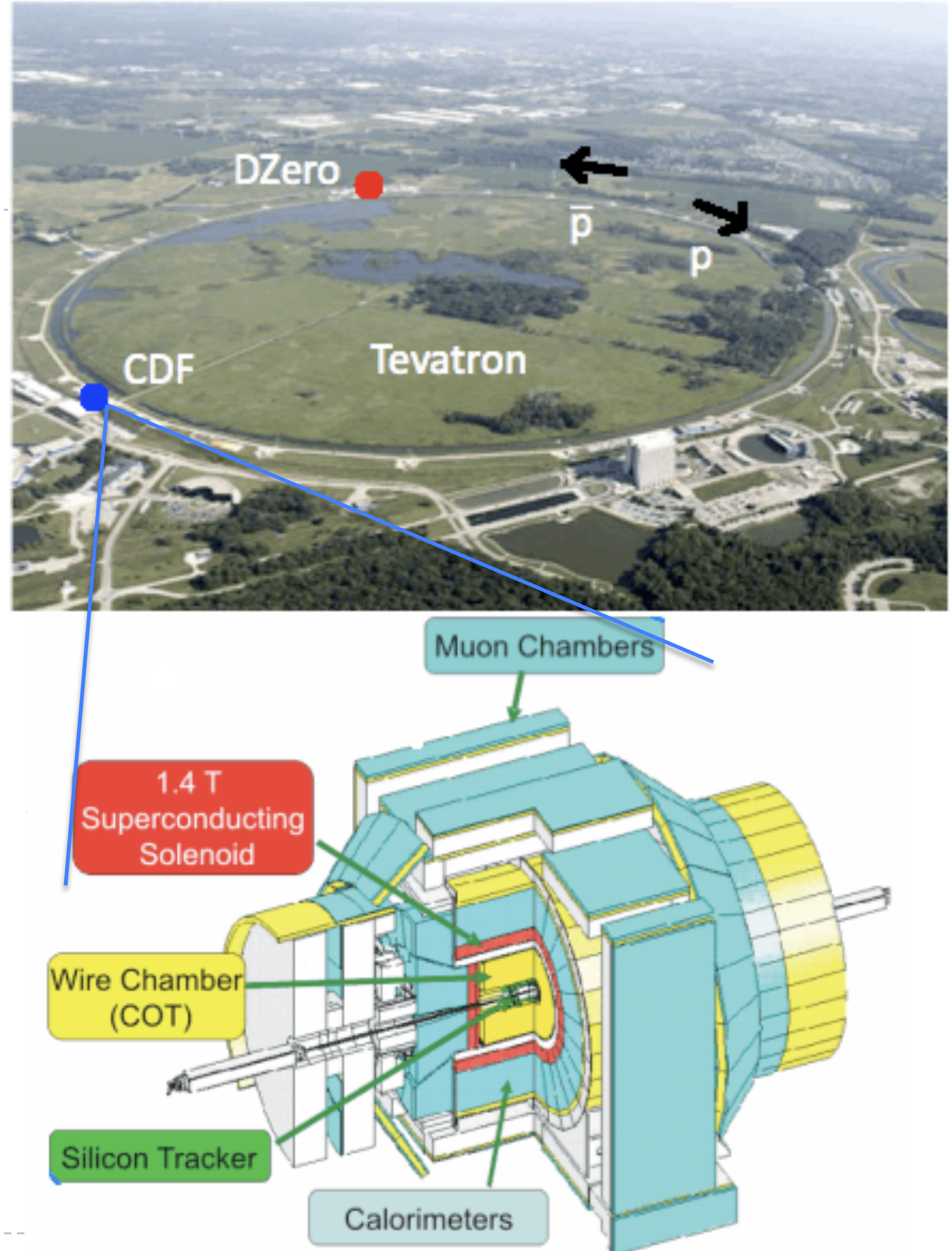


Compton scattering ~ $\alpha\alpha_S$



annihilation ~ $\alpha\alpha_S^2$

The Tevatron and CDF



<u>Tevatron</u>:

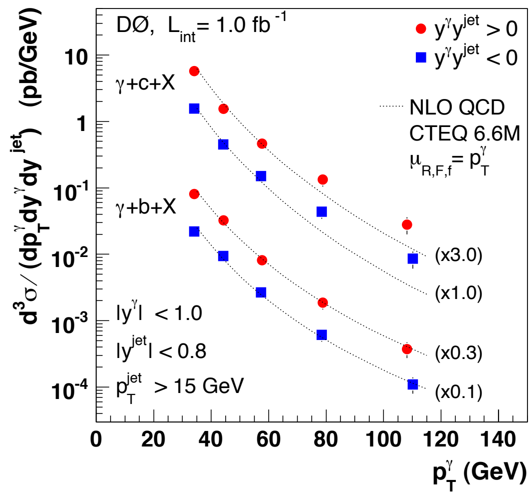
- Proton-antiproton accelerator
- $\sqrt{s}$ = 1.96 TeV
- Delivered 11.6 fb^{-1}
- Recorded 9.7 fb^{-1}

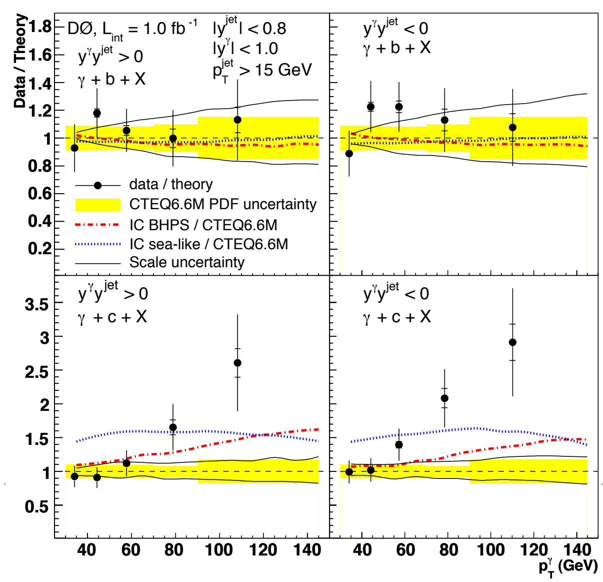
<u>CDF</u>

- Collider Detector at Fermilab
- Tracking (large *B* field):
  - Silicon tracking
  - Wire Chamber
- Calorimetry:
  - Electromagnetic (EM)
  - Hadronic
- Muon system

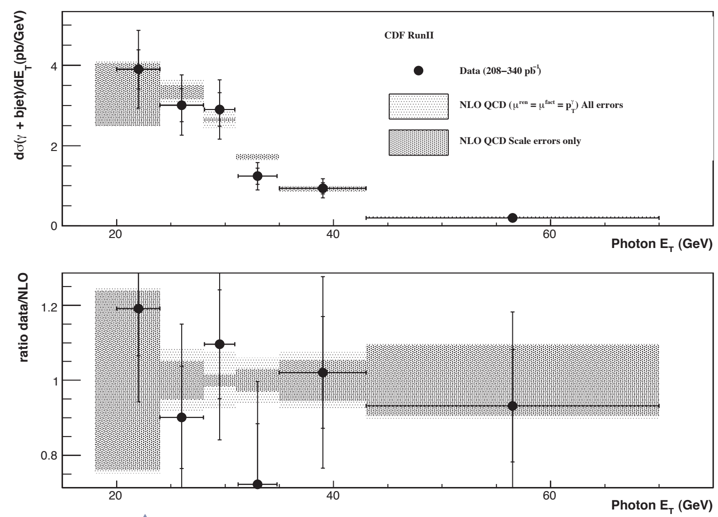
Previous results

D0: PRL 102, 192002 (2009) - 1 fb^{-1}





CDF: PRD 81, 052006 (2010) - 340 pb^{-1}



Measure low p_T σ using a special trigger

Good agreement for γ+b+X

Discrepancy for γ+c+X

Analysis overview

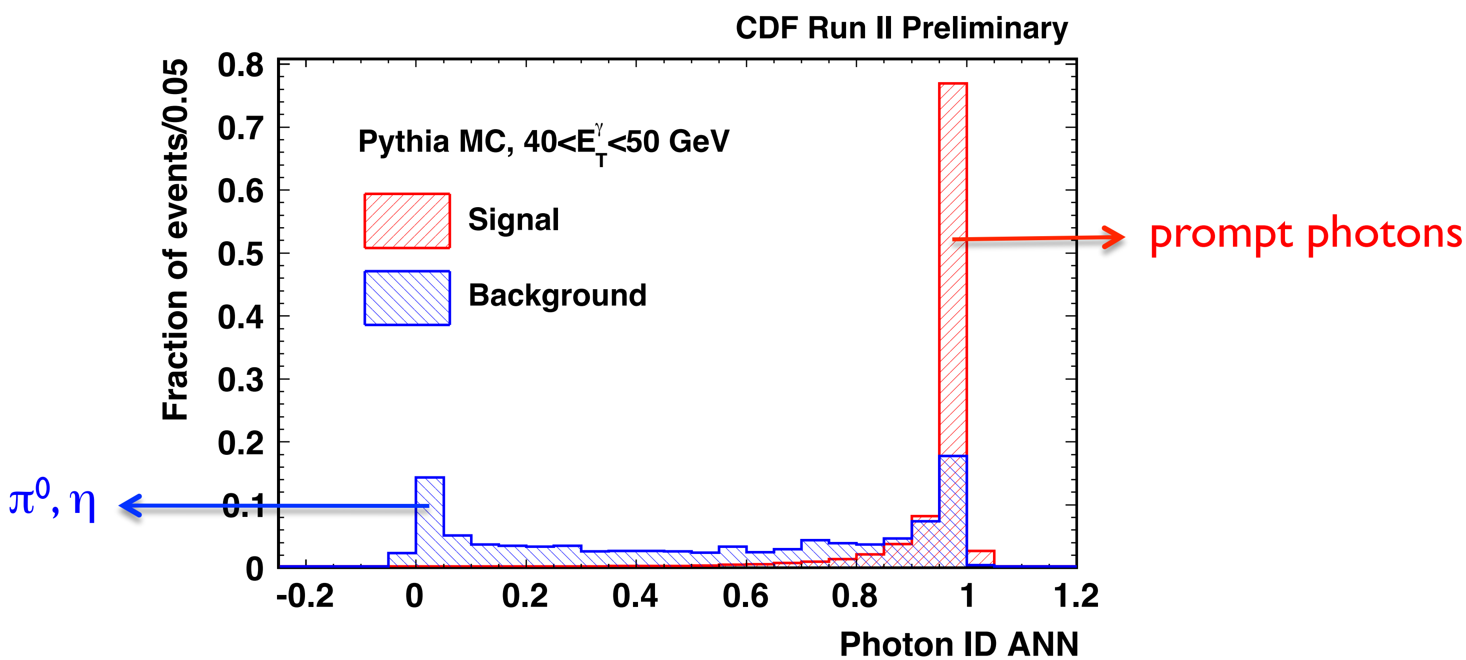
- Measure γ+*b*/*c*+X cross section using 6.6 fb^{-1} inclusive photon data collected with CDF II detector
- Use ANN (artificial neural network) to select photon candidates
  - Fit ANN distribution to signal/background templates to get photon fraction
- Use SecVtx b-tag to select heavy-flavor jets
  - Fit secondary vertex invariant mass to get light/c/b quark fractions
- Use MC to get unfolding factor
  - Photon ID efficiency, b-tagging efficiency, detector acceptance and smearing effects
- Cross section
  - $(N_{data}$-fake photon)*$f_{b/c}$/unfolding factor/lumi/binwidth

Event selection

- Use inclusive photon trigger to select photon events
  - Trigger efficiency is approximately 100% for γ E_T>30 GeV
- Interaction vertex in the fiducial region
- Photon candidate must pass a neural-net based photon ID
  - $|\eta|<1.05$, $30<E_T<120$ GeV, divided into 6 E_T bins
  - Working to expand to 300 GeV
- Jet is reconstructed with JetClu cone size 0.4 and must be positively tagged.
  - $|\eta|<1.5$, $E_T>20$ GeV
- $\Delta R(\gamma,\text{jet})>0.4$

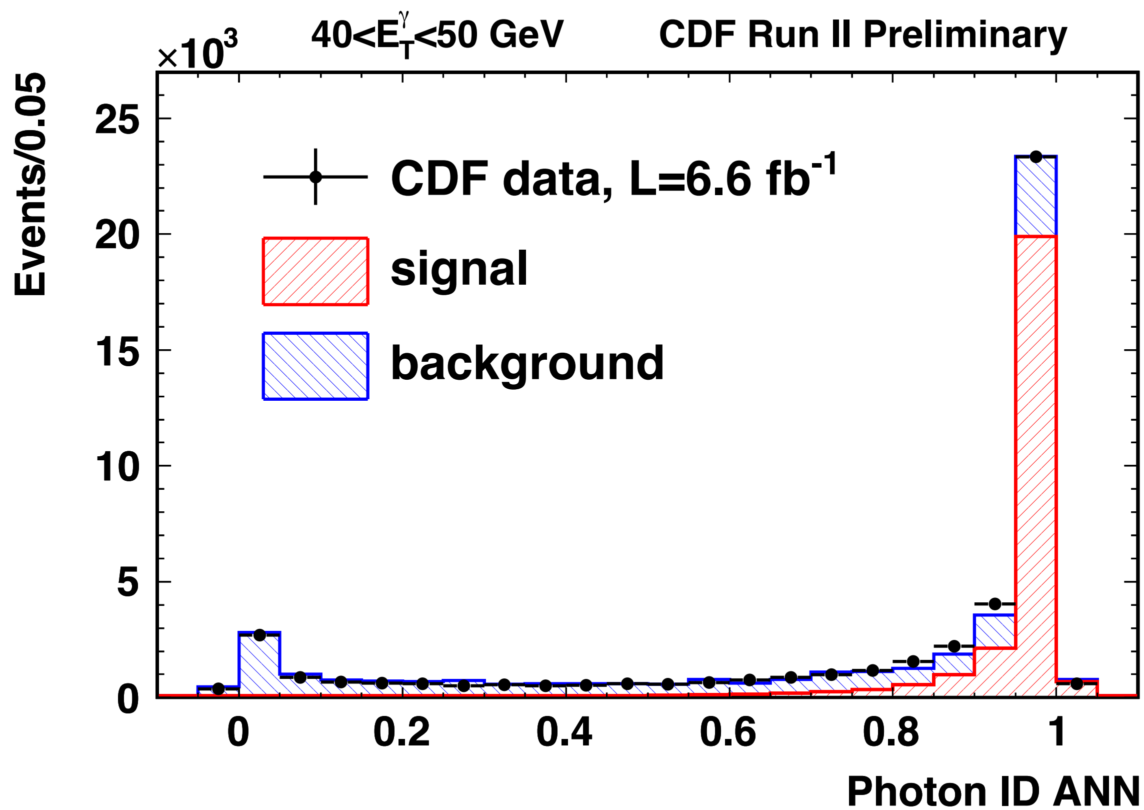
ANN photon ID

- Trained with TMVA (Toolkit for Multivariate Data Analysis with ROOT)
- 7 input variables to take into account difference between γ and π^0/η: isolation (2), lateral shower shape (3), Had/Em, CES/CEM
- Use Pythia MC with full detector simulation to get templates
  - Signal: prompt photons
  - Background: jets with prompt photons removed

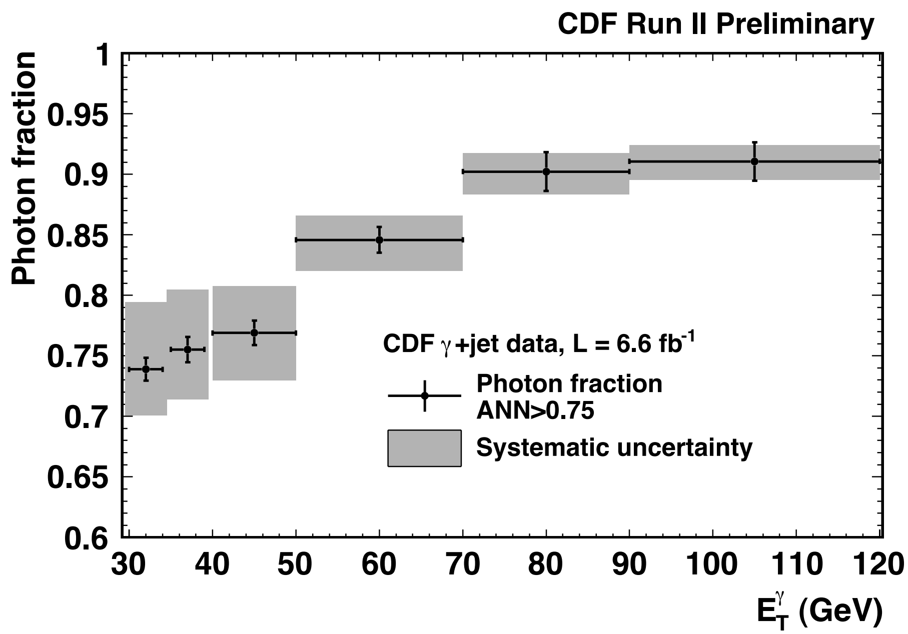


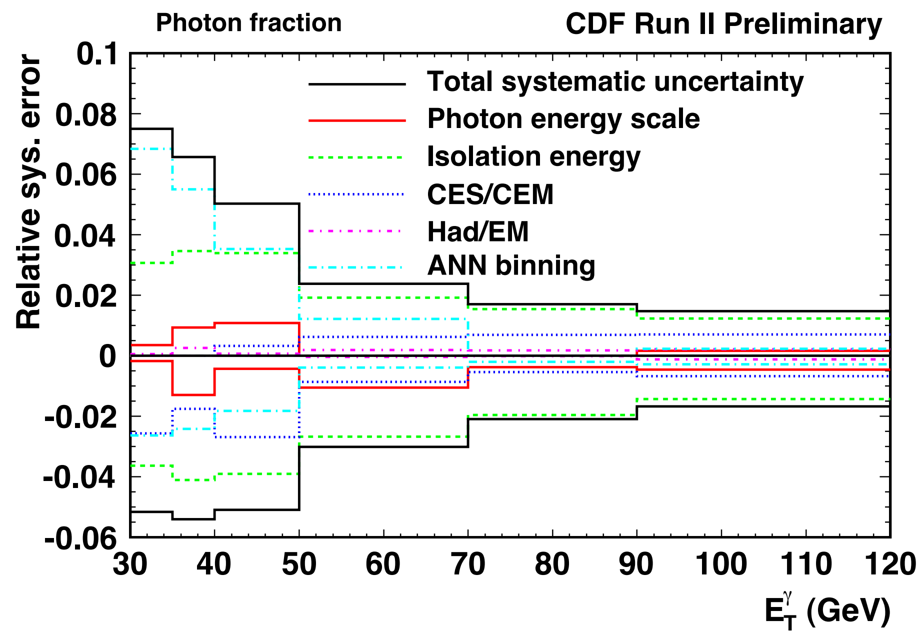
True photon fraction

- Fit data ANN distribution to signal and background templates using TMinuit to get true photon fraction



True photon fraction (continued)

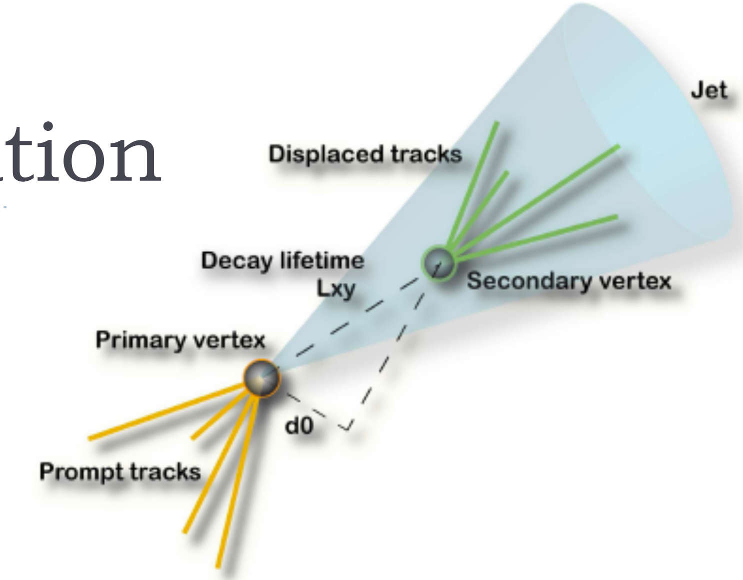


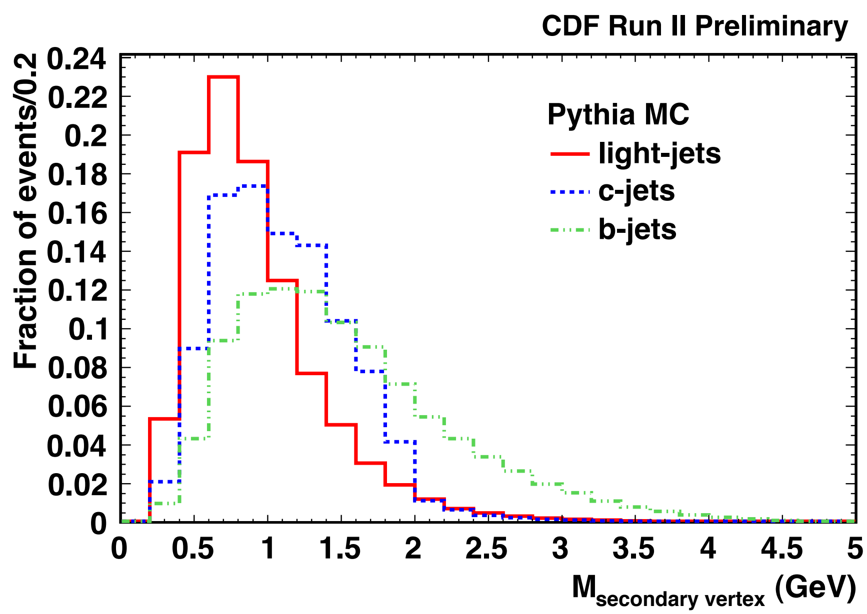


- Systematics
  - Photon energy scale
  - Vary inputs to photon ID ANN according to their uncertainties
  - Vary Photon ID ANN template binning to test sensitivity to shapes
  - 8% at low E_T, 2% at high E_T.

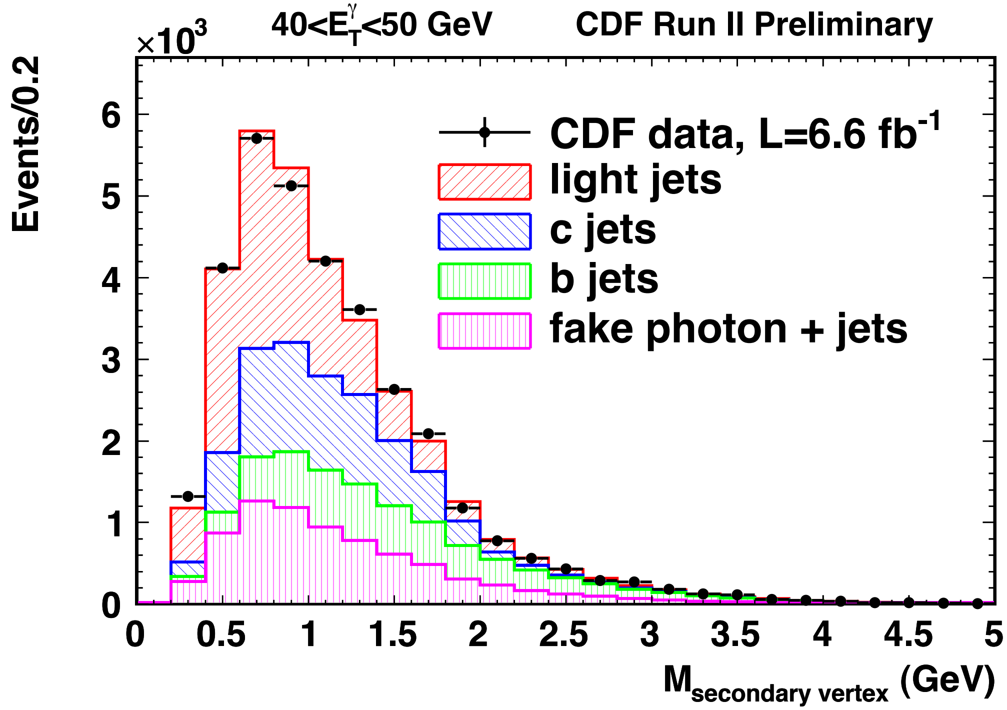
Standard b-jet identification

- B-hadrons are long-lived – search for displaced vertices
- Fit displaced tracks and cut on L_{xy} significance (σ ~ 200 μm)
- Charm hadrons have similar tag behavior but lower efficiency
- Can use "tag mass" to deduce the flavor composition of a sample of tagged jets
  - Mass of the tracks forming the secondary vertex
  - B-hadrons are heavy: will have higher m_{tag} spectrum than charm or light jet fakes



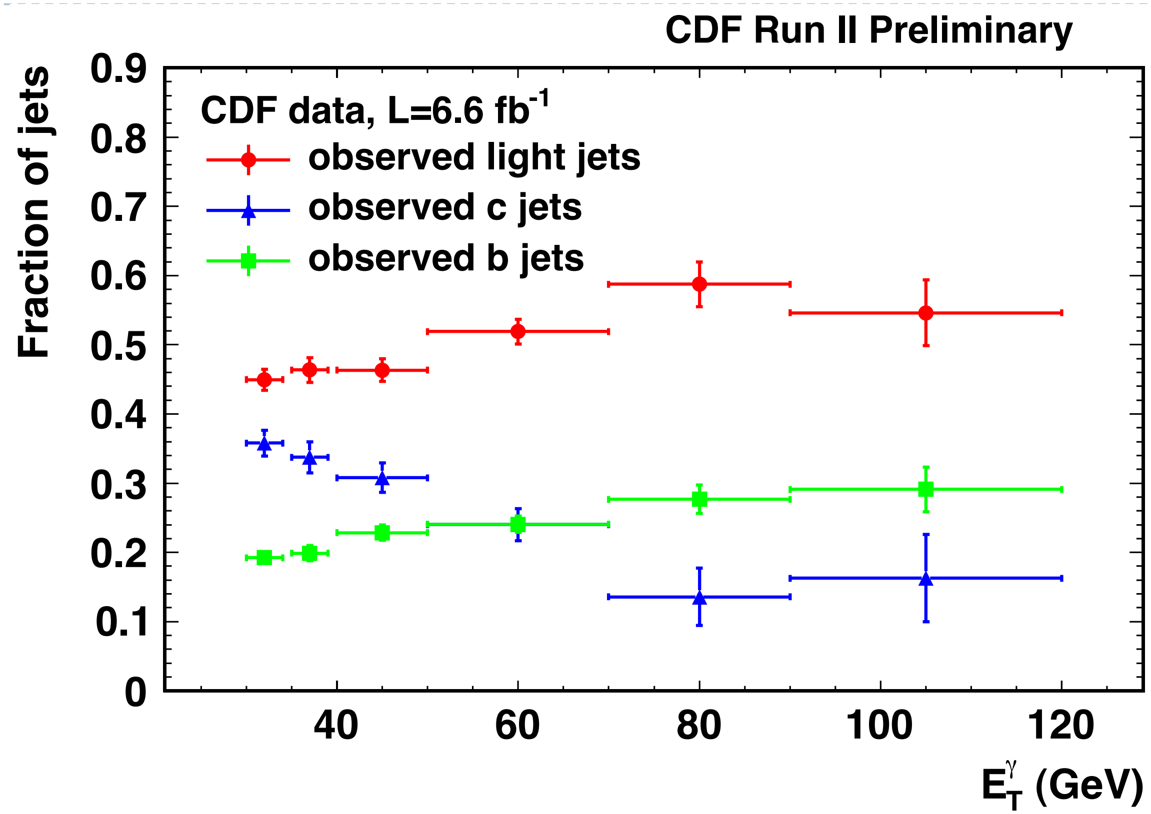


Light/ c/ b-jet fractions



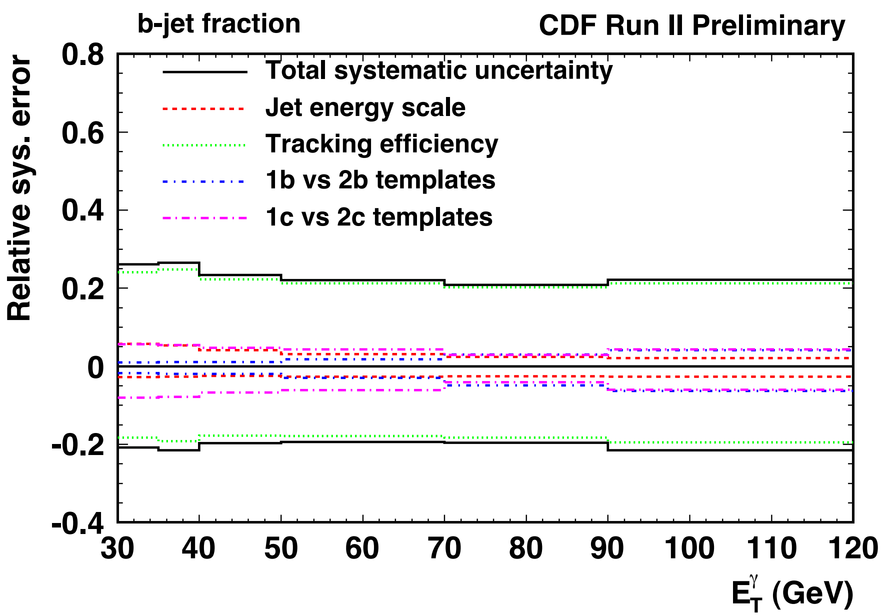
- Fit data secondary vertex mass to MC templates
- Shape of secondary vertex mass (light, *c* and *b*, including their ratios) for event with fake photon is taken from di-jet data, normalized to the fake photon rate obtained from ANN fit

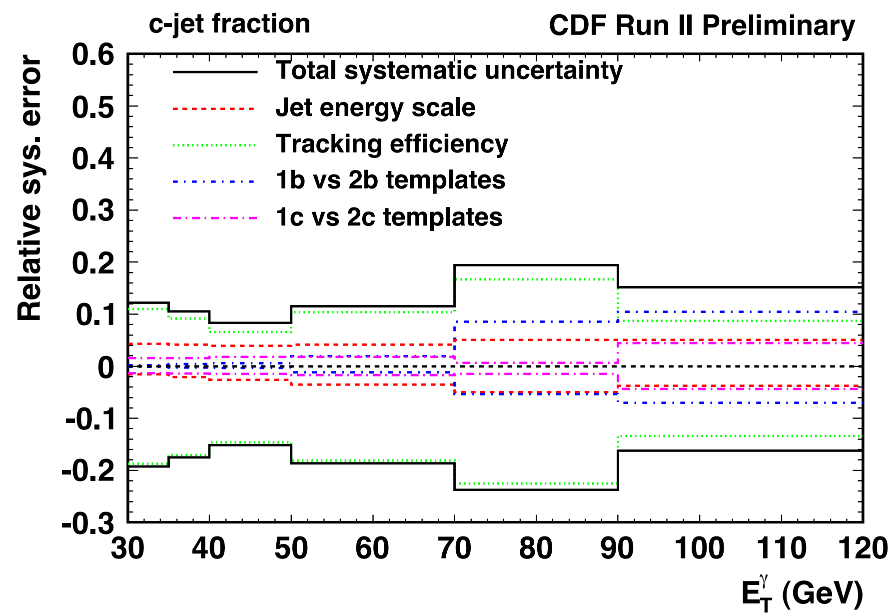
Light/c/b-jet fractions (continued)



- Error bars are statistical errors returned from fitter
- c-jet fraction is lower than b-jet fraction at high E_T because b-tagging efficiency is lower for charm mesons.

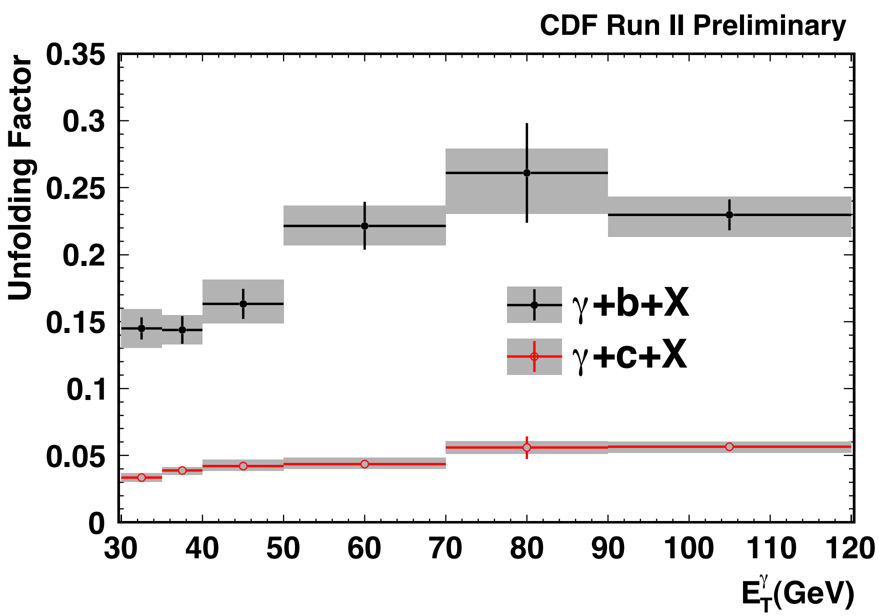
Systematics on b/c-jet fractions

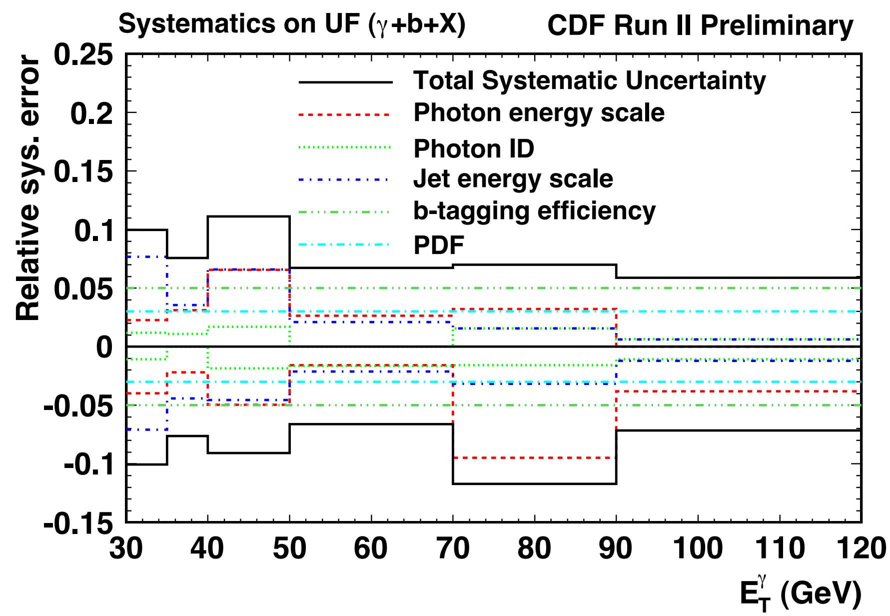




- Jet energy scale: affect acceptance
- Uncertainty in tracking efficiency: scale secondary vertex mass templates by ±3%
  - Dominant systematic effect
- Difference between single-quark and di-quark jets
- Total systematic error is ~20%

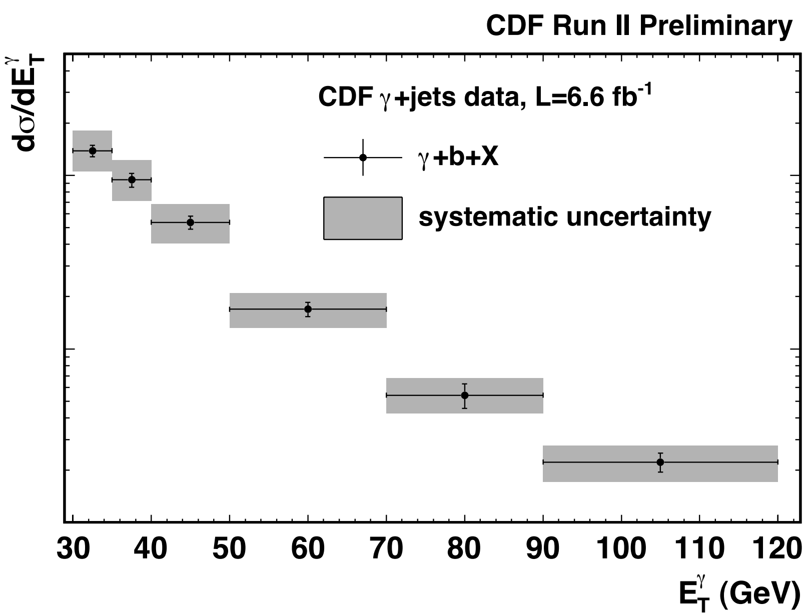
Unfolding factors

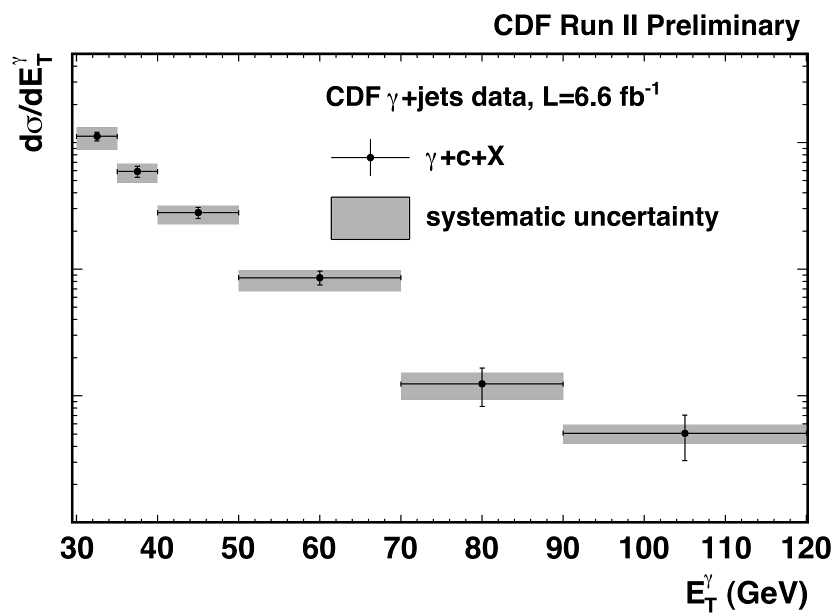




- Use Pythia MC to unfold photon ID efficiency, b-tagging efficiency, detector acceptance and smearing effects.
- Systematic effects evaluated: photon energy scale, photon ID, jet energy scale, b-tagging efficiency and PDF

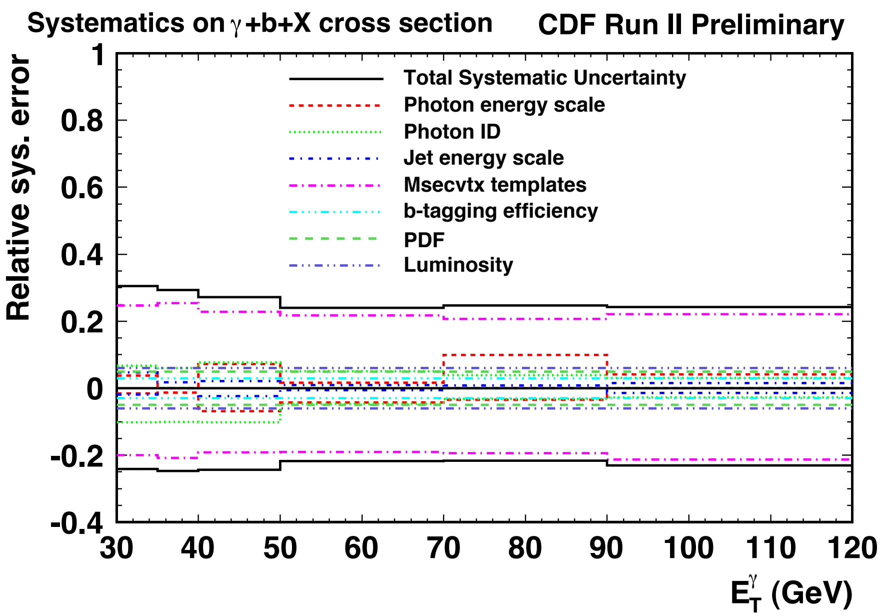
Preliminary cross section results

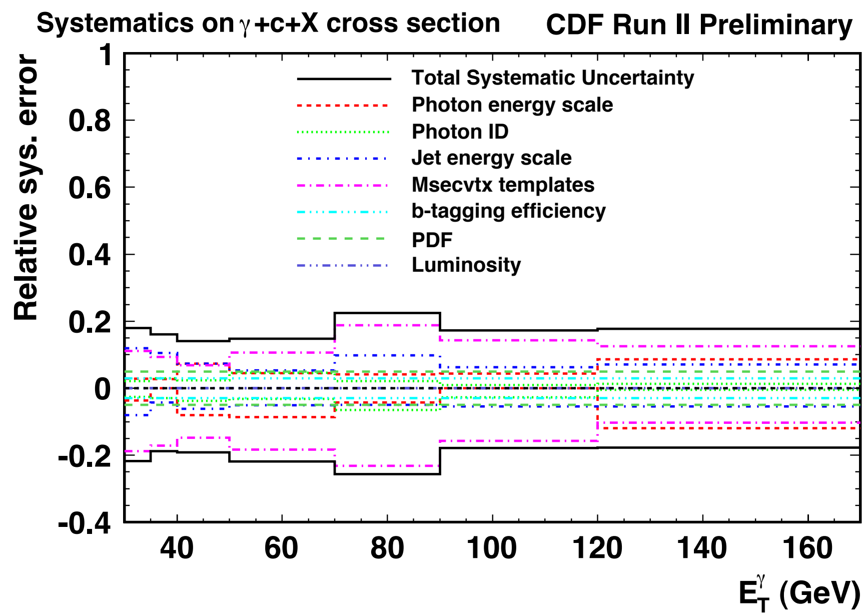




- Preliminary results
- Working to expand to 300 GeV
- Working on comparison with theory

Systematics





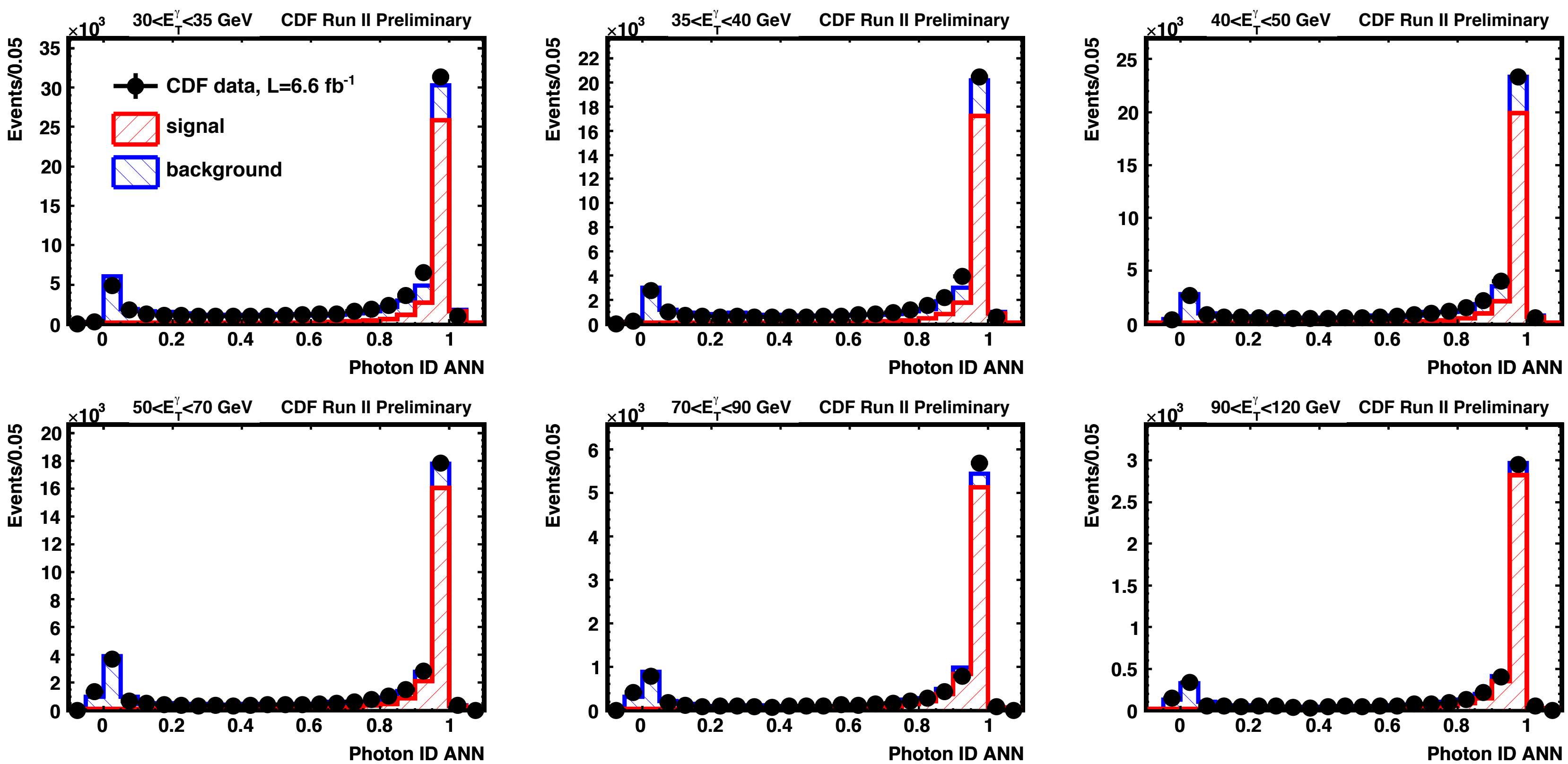
- The dominant systematic effect is the uncertainty in secondary vertex mass template shape
- 20% systematic error in total

Conclusions

- We have shown the details of the measurement of $\gamma+b/c+X$ production cross sections
  - Photon fraction
  - b/c fractions
  - Unfolding efficiencies and detector effects
- We have made good progress in this measurement and will release the final results soon – stay tuned!

Thank you for your attention!

Fit ANN



30<E$_T^\gamma$<35 GeV
CDF Run II Preliminary
35<E$_T^\gamma$<40 GeV
40<E$_T^\gamma$<50 GeV
50<E$_T^\gamma$<70 GeV
70<E$_T^\gamma$<90 GeV
90<E$_T^\gamma$<120 GeV
CDF data, L=6.6 fb^{-1}
signal
background
Events/0.05
×10^3
Photon ID ANN

Fit secondary vertex mass