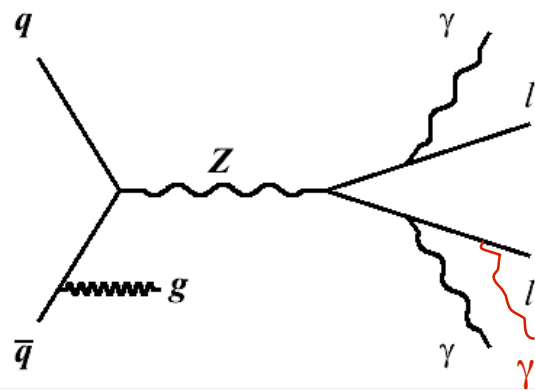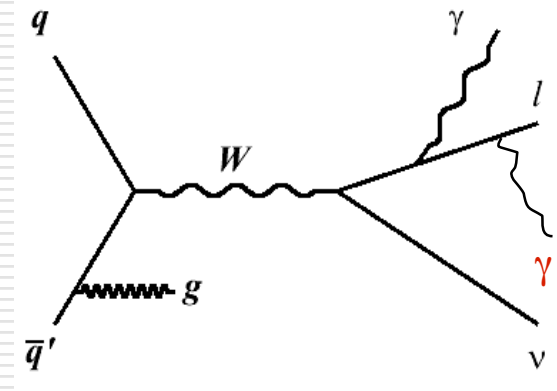# An Implementation of 2-Photon FSR

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for the CDF *W* mass group

QED and the *W* Mass Measurement

- ☐ Lepton momentum contains *W* mass information
  - ◼ *FSR systematically reduces measured lepton momentum*
    - ☐ O(150 MeV) reduction in measured *W* mass (without correction)
  - ◼ *ISR has mild effect on lepton momentum*
    - ☐ Swamped by QCD ISR
    - ☐ WGRAD study: ISR affects measured mass by ≤ 5 MeV

- ☐ Model for CDF Run II measurement (200 pb^{-1}):
  - ◼ *Simulate only FSR using parametrization of WGRAD*
  - ◼ *Apply correction to account for two-photon FSR*

FSR Parametrization

☐ Two-dimensional function:

  ■ *Fractional momentum $y = E_\gamma/E_l$*

  ■ *Photon-lepton separation $\Delta R(l,\gamma)$*

☐ Parametrize using 2-d histogram $y^{1/3}$ vs $\Delta R^{1/2}$
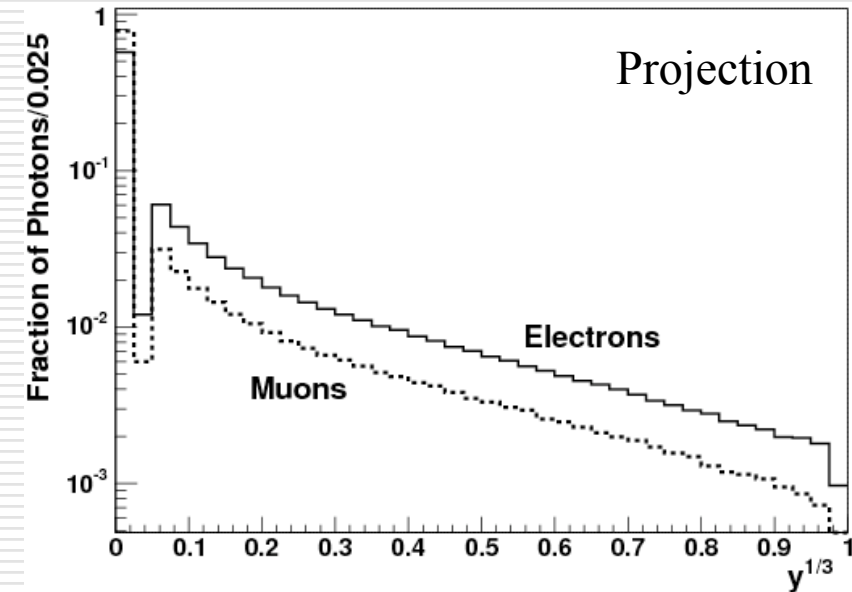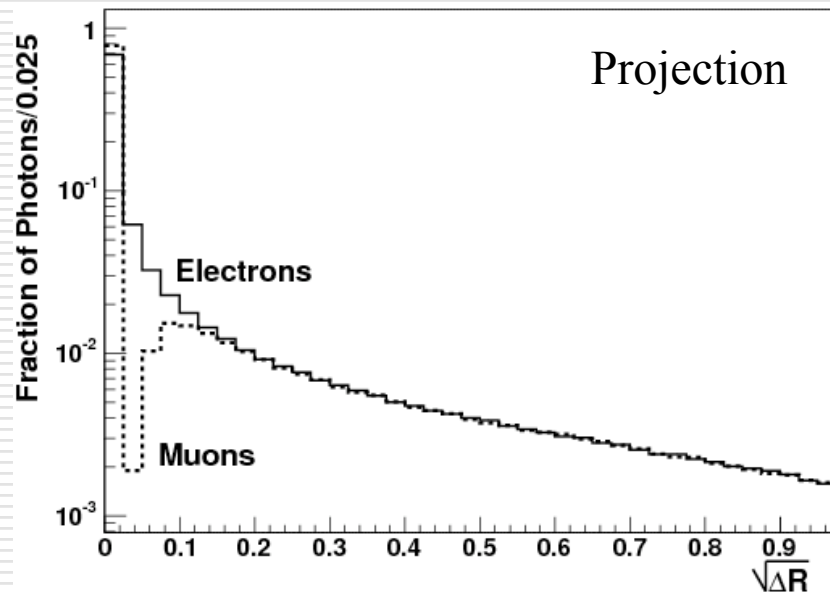
QED Model Validation

- **2-d histogram created using FSR-only mode of WGRAD**
  - *Parametrization consistent with FSR-only WGRAD*
    - Tested to statistical precision of 5 MeV
    - $\therefore$ any dependence on lepton p_T has small effect
  - *Histogram generated using lower bound of $y = 10^{-4}$*
    - Raising bound to 10^{-3} has ≤ 5 MeV effect on measured mass
  - *ISR-FSR interference has no noticable effect (≤ 5 MeV)*
    - Tested using interference-only mode of WGRAD
  - *No test of effect of QCD on histogram*
    - QCD-QED correlations?

Two-Photon FSR

- ☐ Expect second photon to reduce lepton momentum
  - ■ *Biases the measurement to a lower mass*

- ☐ Naive procedure to estimate effect:
  - ■ *Order the photons in y*
  - ■ *Assume y spectrum of first γ is same as for one-γ FSR*
    - ☐ Second photon y spectrum is necessarily softer
  - ■ *Use WGRAD y vs ΔR histogram twice*
    - ☐ Require second photon to have smaller y than first
    - ☐ Effectively hardens total radiation y spectrum
    - ☐ 200 pb^{-1} publication: one photon only, scale up y by 10%

Improving Two-Photon Model

☐ Significant assumption of the y spectra in the model

    ■ *Ideally obtain first and second photon spectra from theory*

    ■ *Need generator with multi-photon FSR-only option*

    ■ *Alternatively tune procedure to match effect of complete higher-order generator*

☐ Additional assumption in FSR model for Z events

    ■ *Uncorrelated between leptons*

    ■ *Take y vs ΔR spectrum from WGRAD with m_W set to m_Z*

Summary

- Implemented a two-photon FSR model
  - *Crucial assumptions may not be correct*
  - *Extrapolation of O(α) likely overestimates effect*

- Ideally want a multi-photon FSR-only generator in addition to a generator based on the full higher-order calculation

Backup

QED Uncertainties

Source	Uncertainty
ISR and interference	5 MeV
Infrared cutoff	5 MeV
FSR model	5 MeV
Higher-order corrections	7 MeV

Need a detailed list with individual uncertainties:
all-order 1-photon radiation, 2-photon radiation,
radiated photons that split into e+e-, electroweak
corrections...