F2(γ) Measurements at a Future Linear Collider :

e+e- vs. γγ

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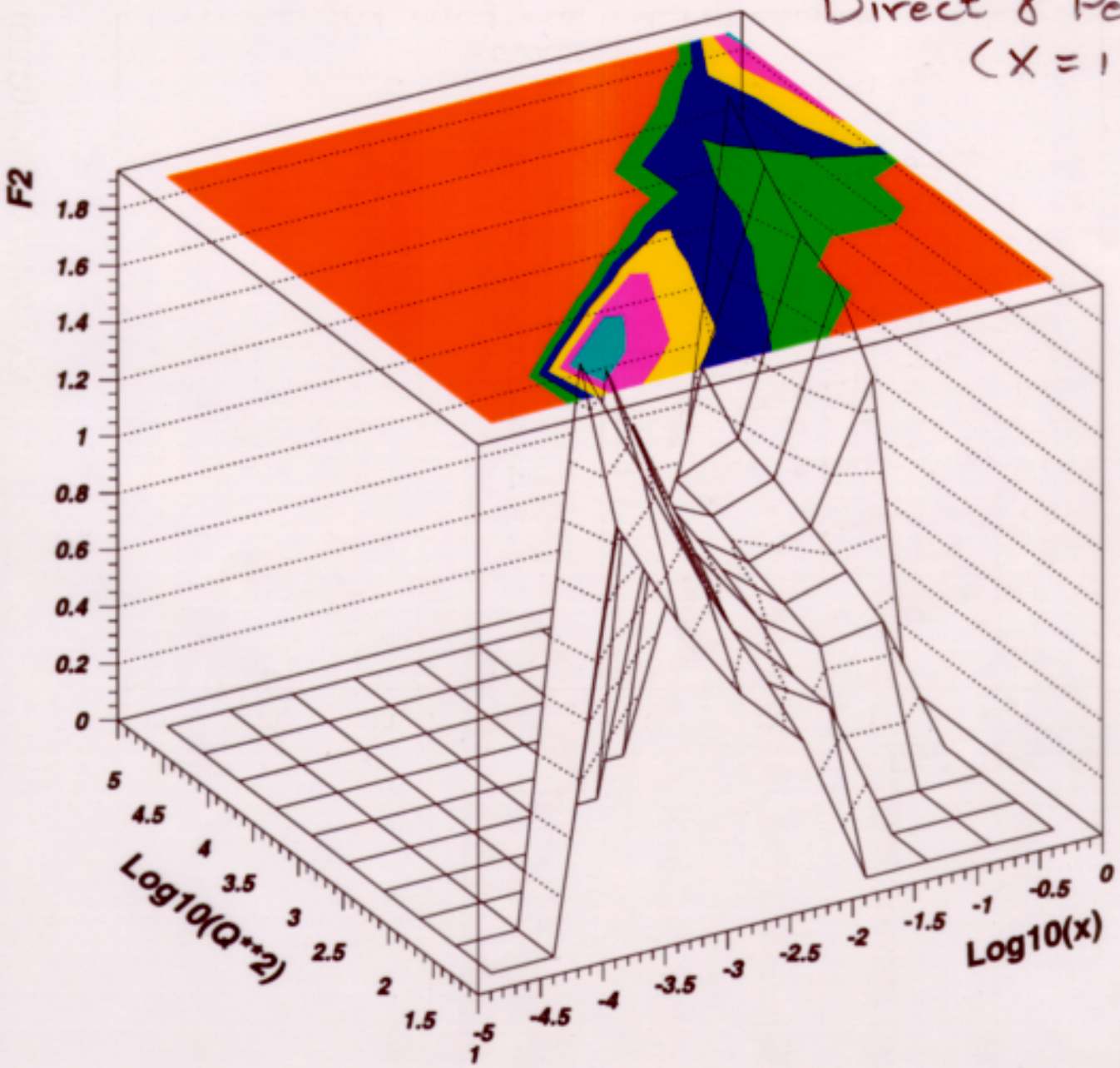
- F2(γ) (x,Q**2) Characteristics
- Detector Options in IR
- F2(γ) from eγ in e+e- mode
- F2(γ) from eγ in γγ mode
- Summary

Worldwide Study of the Physics and Detectors for Future Linear e^+e^- Colliders

F_2^{γ}

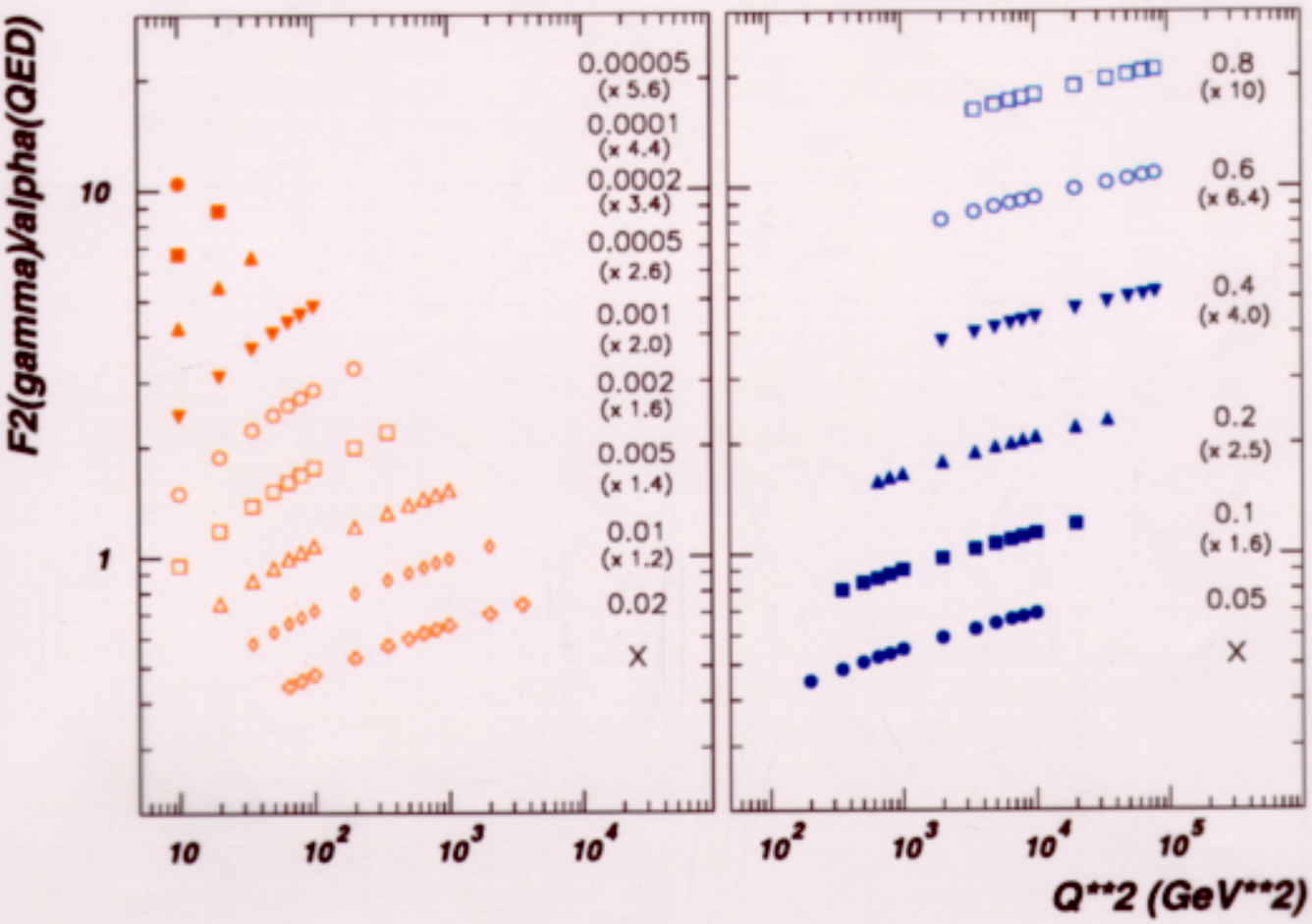
Direct γ Peak
($x = 1$)



Resolved γ ⟹ sea pdfs

– steep rise in F_2^{γ} at low x ?

$Q^2 > 10\ GeV^2$ $.01 < y < .85$ GRV-HO (PDFLIB)



F_2^γ region accessible at 500 GeV $e^+e^-/\gamma\gamma$ Collider

- positive scaling behavior everywhere

Detector Options in the IR

- **Aggressive Masking**

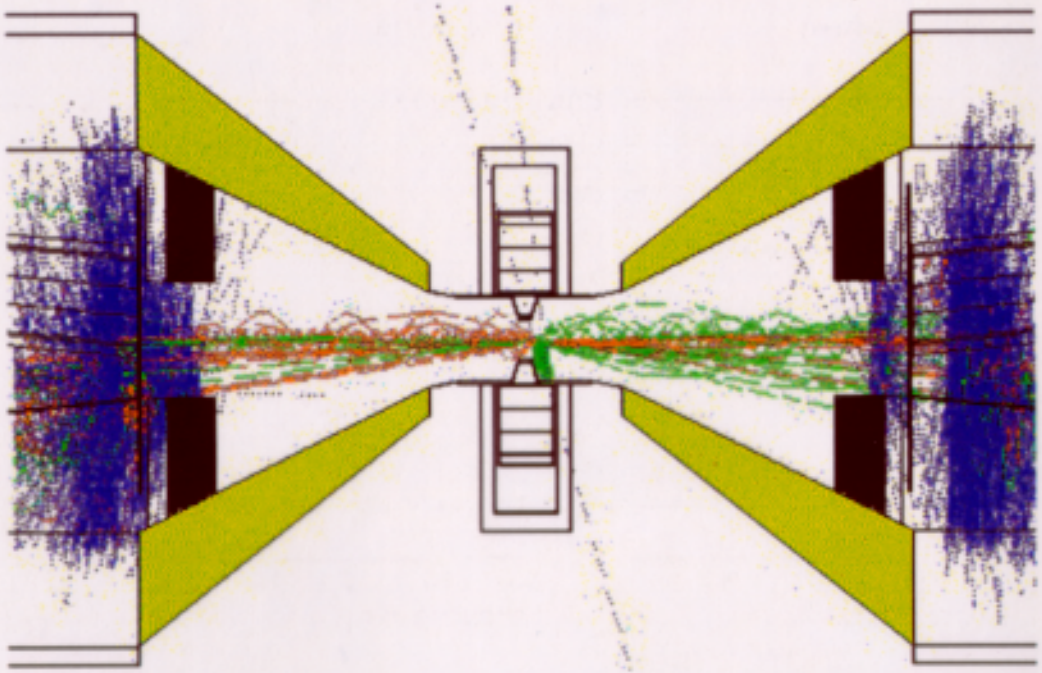
Outer Detector		*> 55 mr*
EMC	$15\%/\sqrt{E} \oplus 1\%$	
HAC	$50\%/\sqrt{E} \oplus 3\%$	
Mask		*30 -> 55 mr*
EMC	$25\%/\sqrt{E} \oplus 2\%$	
HAC	$100\%/\sqrt{E} \oplus 5\%$	

Aggressive approach
- *no inner detector*
- *instrumented mask*
- *outer detectors start at 55 mr*

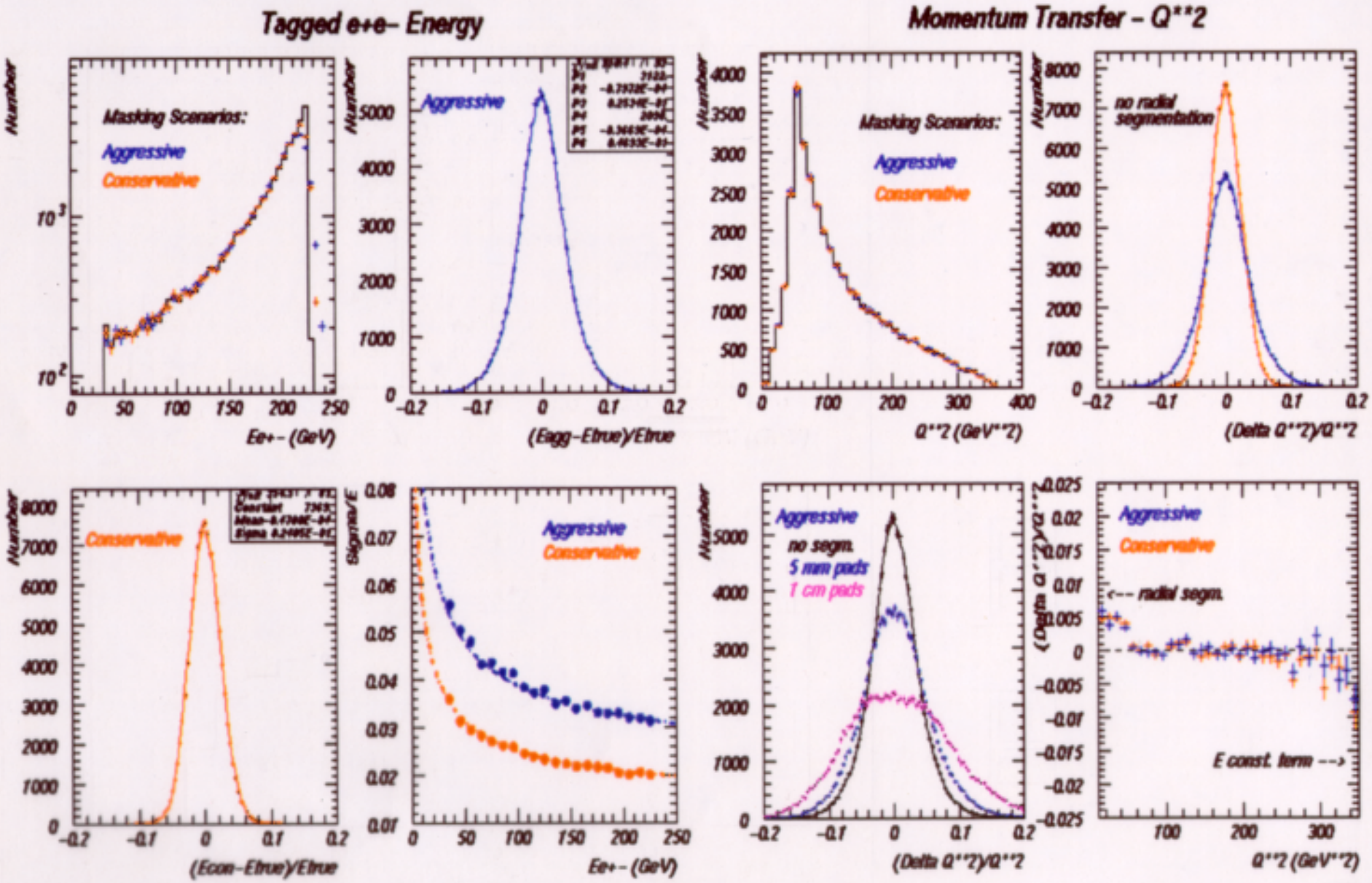
- **Conservative Masking**

Outer Detector		*> 110 mr*
EMC	$15\%/\sqrt{E} \oplus 1\%$	
HAC	$50\%/\sqrt{E} \oplus 3\%$	
Mask		*80 -> 110 mr*
EMC	$25\%/\sqrt{E} \oplus 2\%$	
HAC	$100\%/\sqrt{E} \oplus 5\%$	
Inner Detector		*30 -> 80 mr*
EMC	$15\%/\sqrt{E} \oplus 1\%$	

Conservative approach
- *inner EM calorimetry (30 -> 80 mr)*
- *instrumented mask*
- *outer detectors start at 110 mr*

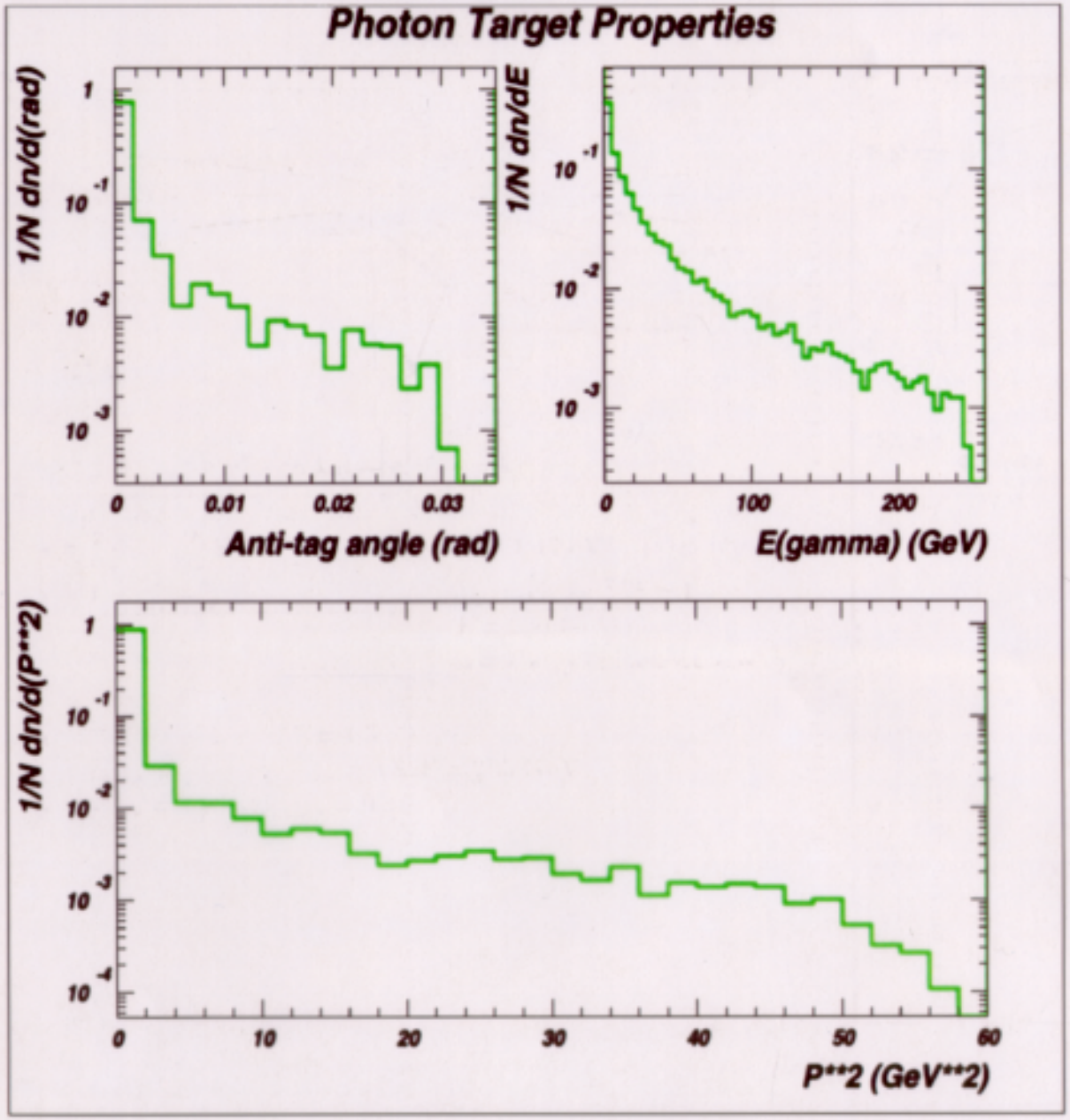


e+e- Method : Tag (γ^*) Properties



30 mr < θ_{tag} < 80 mr

e+e- Method : Target (γ) Properties



Anti-tag (θ_{tag} < 30 mr)

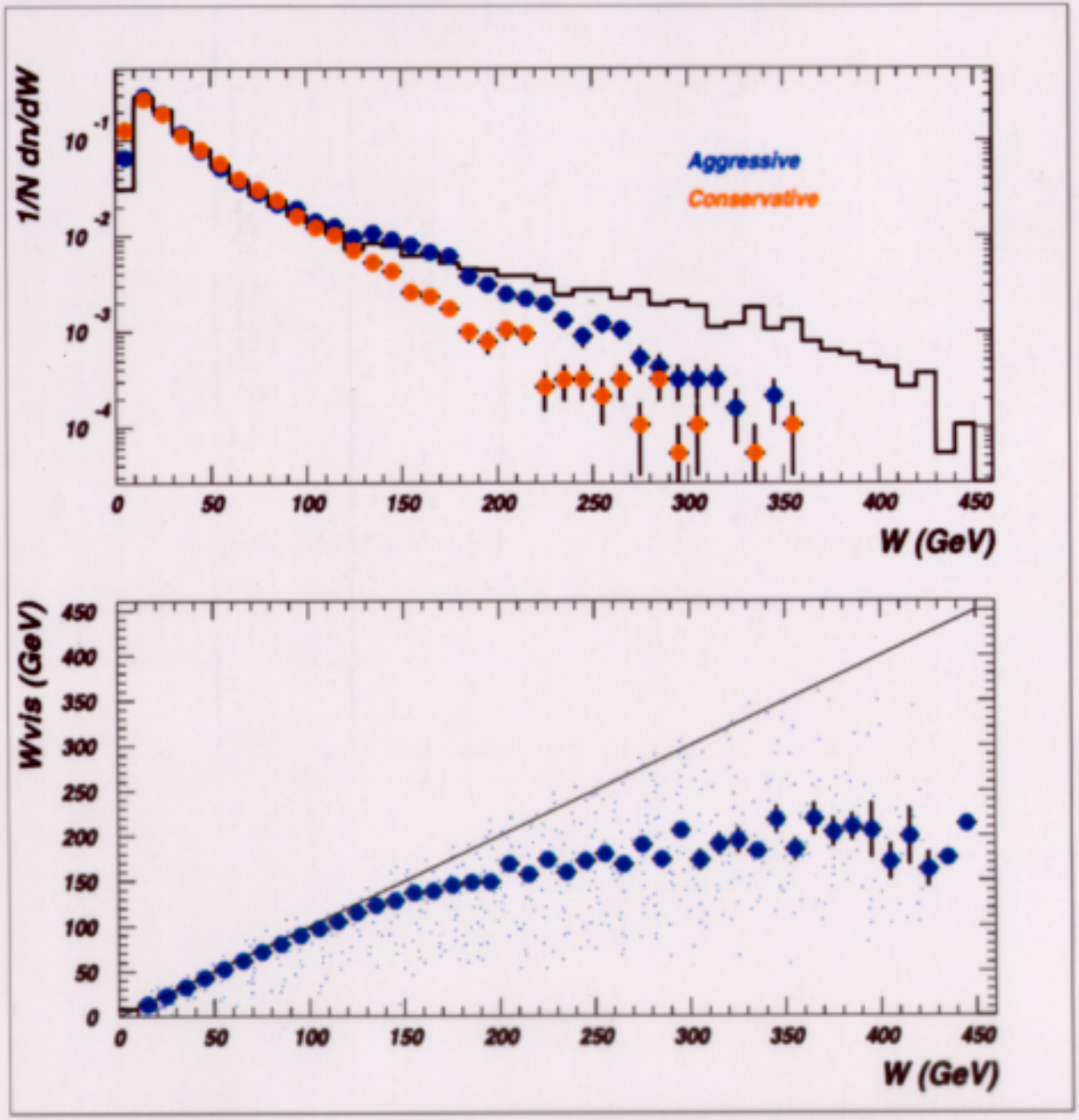
E_γ spectrum dominated by low energy photons

$\Rightarrow$ low $W_{\gamma^*\gamma}$

P^2 (Q^2 of target γ)

Average ~ 10^{-4} GeV^2 but have higher P^2 tail

e+e- Method : Wvis vs. W(γ*γ)



Aggressive Masking: hadron detection to 30 mr in instrumented mask

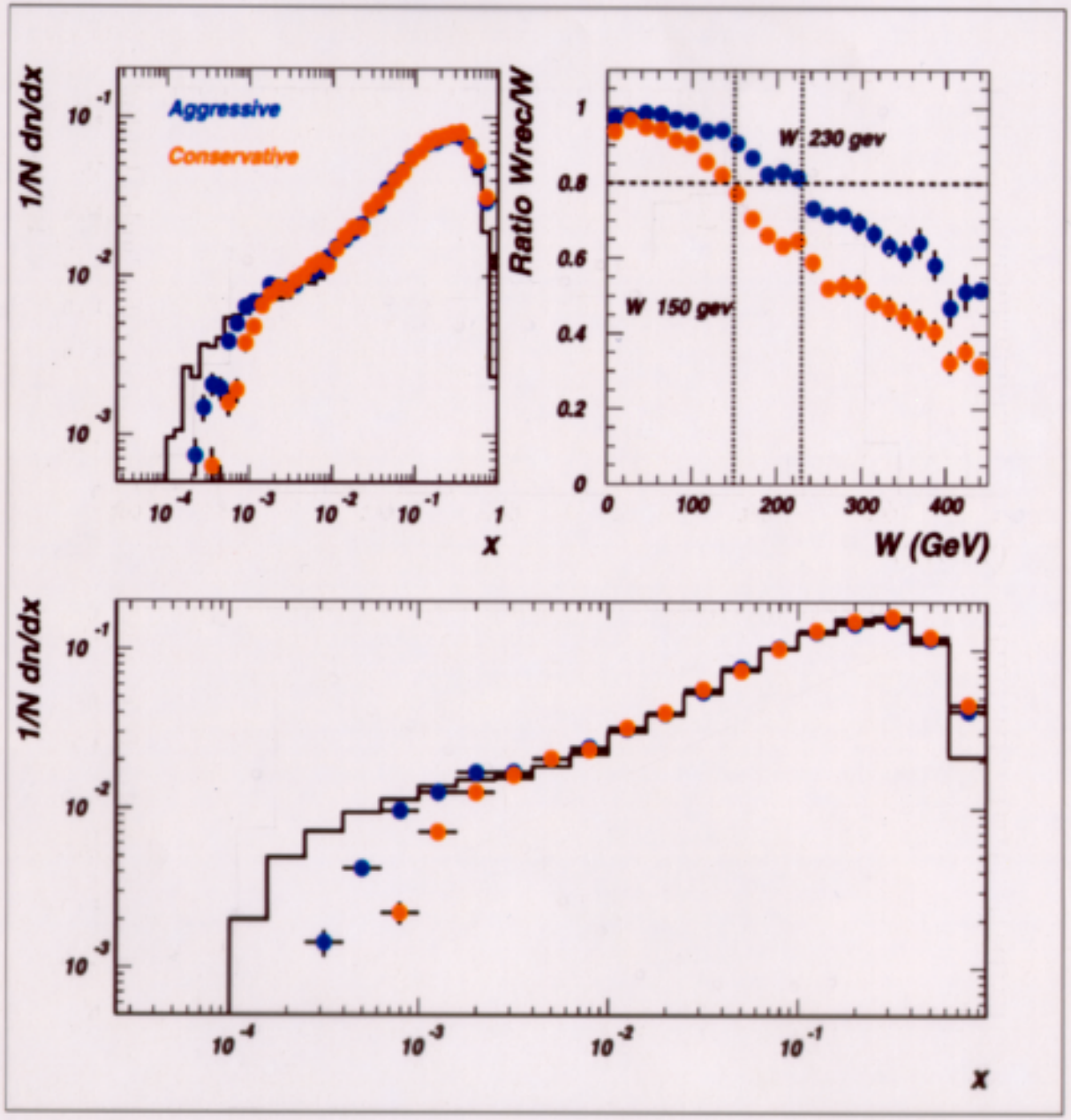
Conservative Masking: hadron detection > 80 mr

Correct W_{vis} with models

Some improvement using electron variables ⇒ W_{rec}

Conservation of E, p

e+e- Method : x Reconstruction



Require : ratio $W_{rec}/W > 0.8$

Aggressive : $W < 230$ GeV

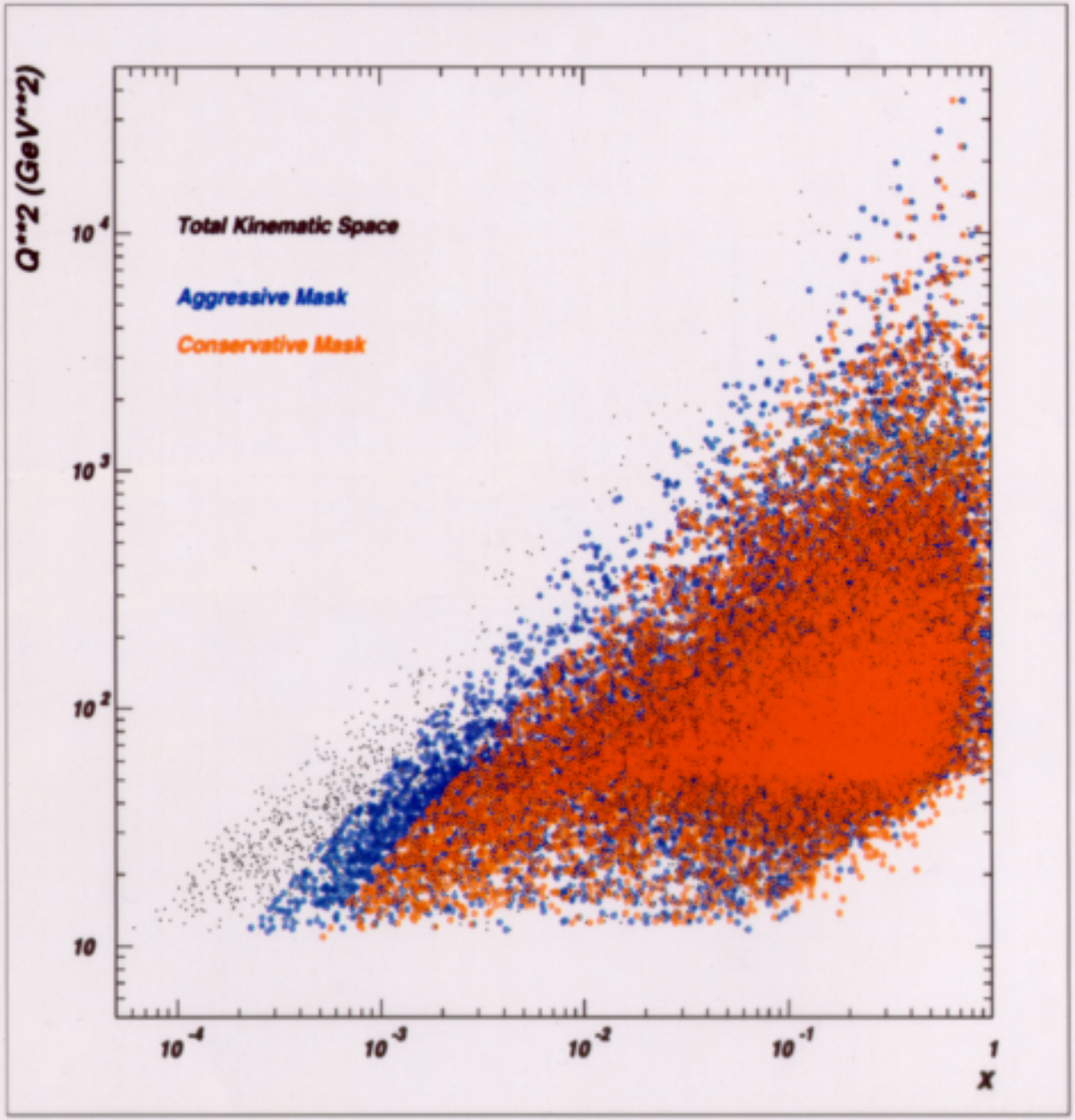
Conservative : $W < 150$ GeV

x_{rec} with W limits

$x \gtrsim 4 \times 10^{-4}$ for Aggressive

$x \gtrsim 10^{-3}$ for Conservative

e+e- Method : Kinematics



Black : Total x, Q^2 region

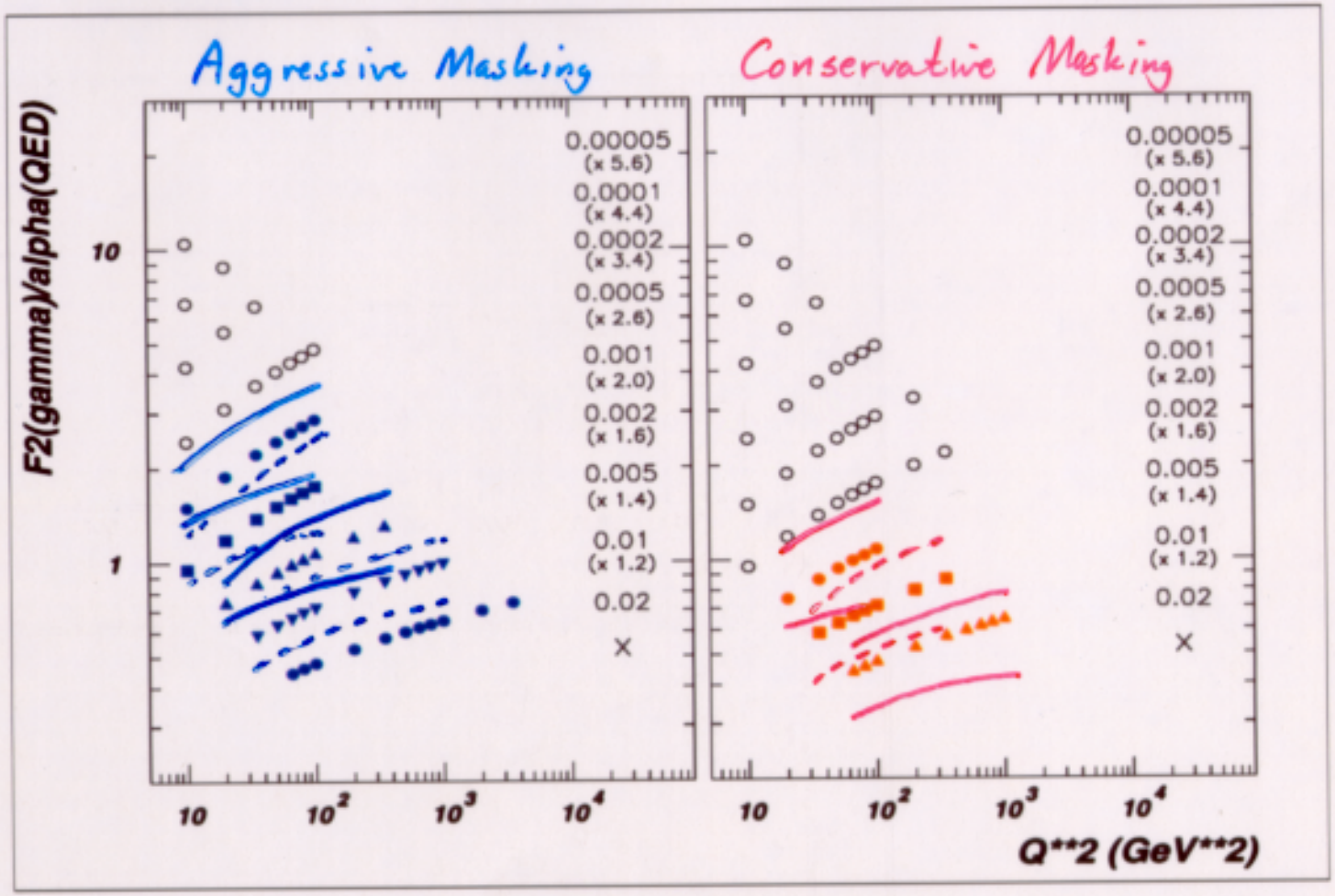
Blue : Aggressive masking approach with W limit $W < 230$ GeV

Red : Conservative masking approach with W limit $W < 150$ GeV

$E_e' > 50$ GeV

$y > 0.01$

e+e- Method : F2(γ)

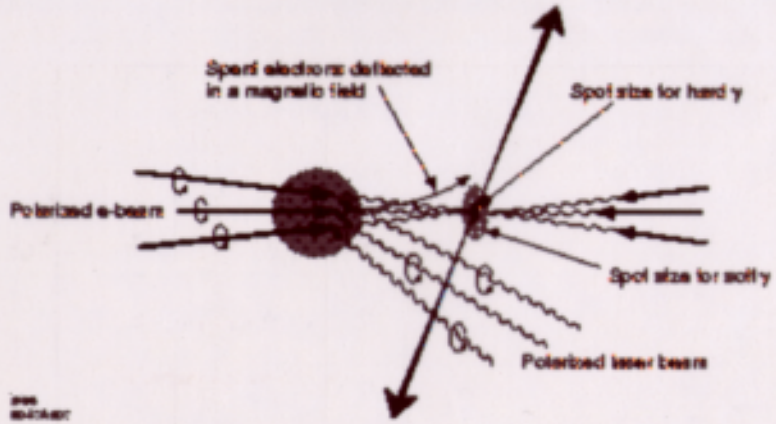


o = not accessible (W limit, large migrations)

● ■ = accessible

bands = migration systematic errors

$\gamma\gamma$ Method : Photons from Laser Backscattering



$$e(p) + \gamma_0(k_0) \to e(p') + \gamma(k)$$

$$x = \frac{2pk_0}{m_e^2c^2} = \frac{4E\omega_0}{m_e^2c^4}\cos^2\frac{\theta_0}{2}$$

$$y = 1 - \frac{pk}{pk_0} = \frac{\omega}{E}$$

$\omega_0 = 1.17$ eV

ω_0 small ; $\cos^2\frac{\theta_0}{2} \simeq 1$

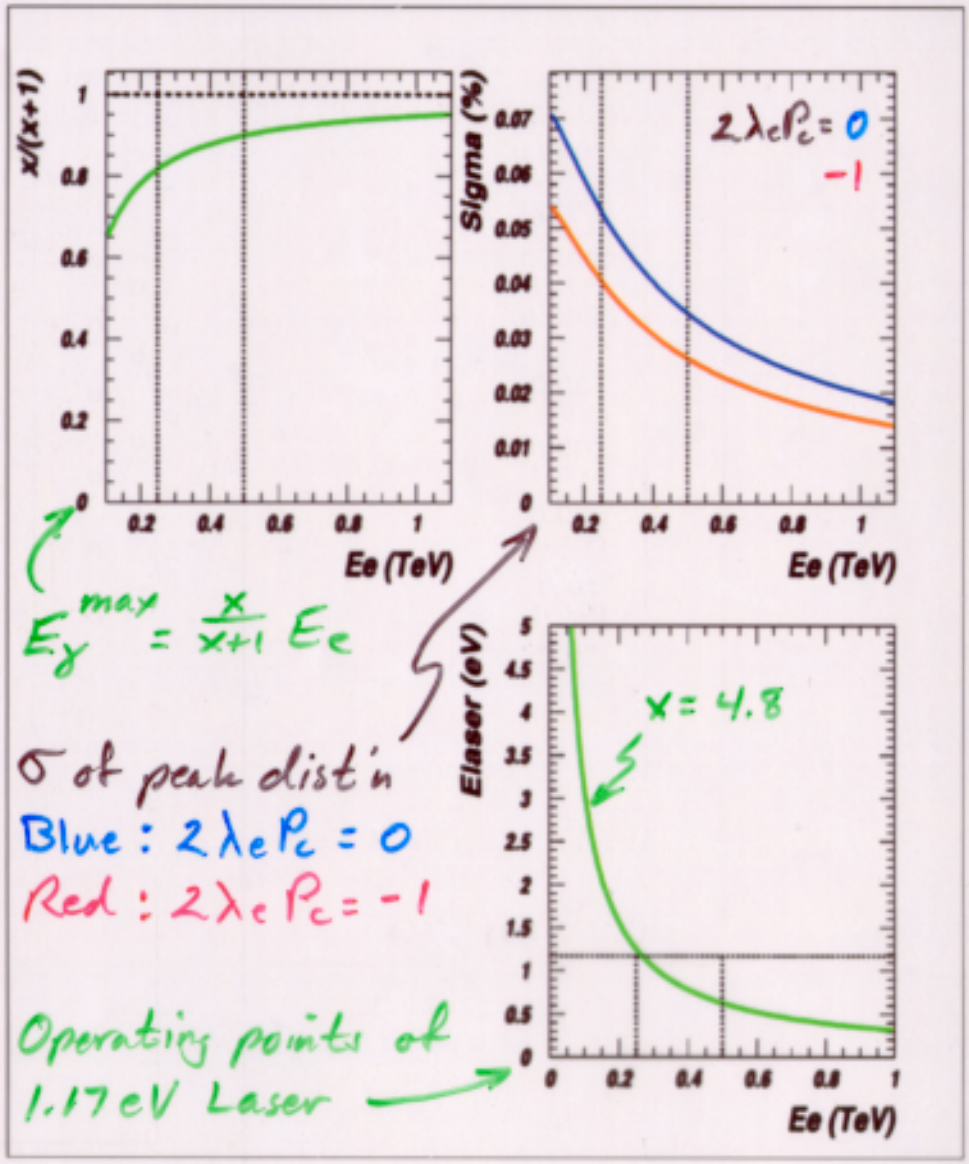
$E = 250$ GeV

ω = energy of backscattered γ

$$x = 15.3E(\text{TeV})\omega_0(\text{eV}) = 4.5$$

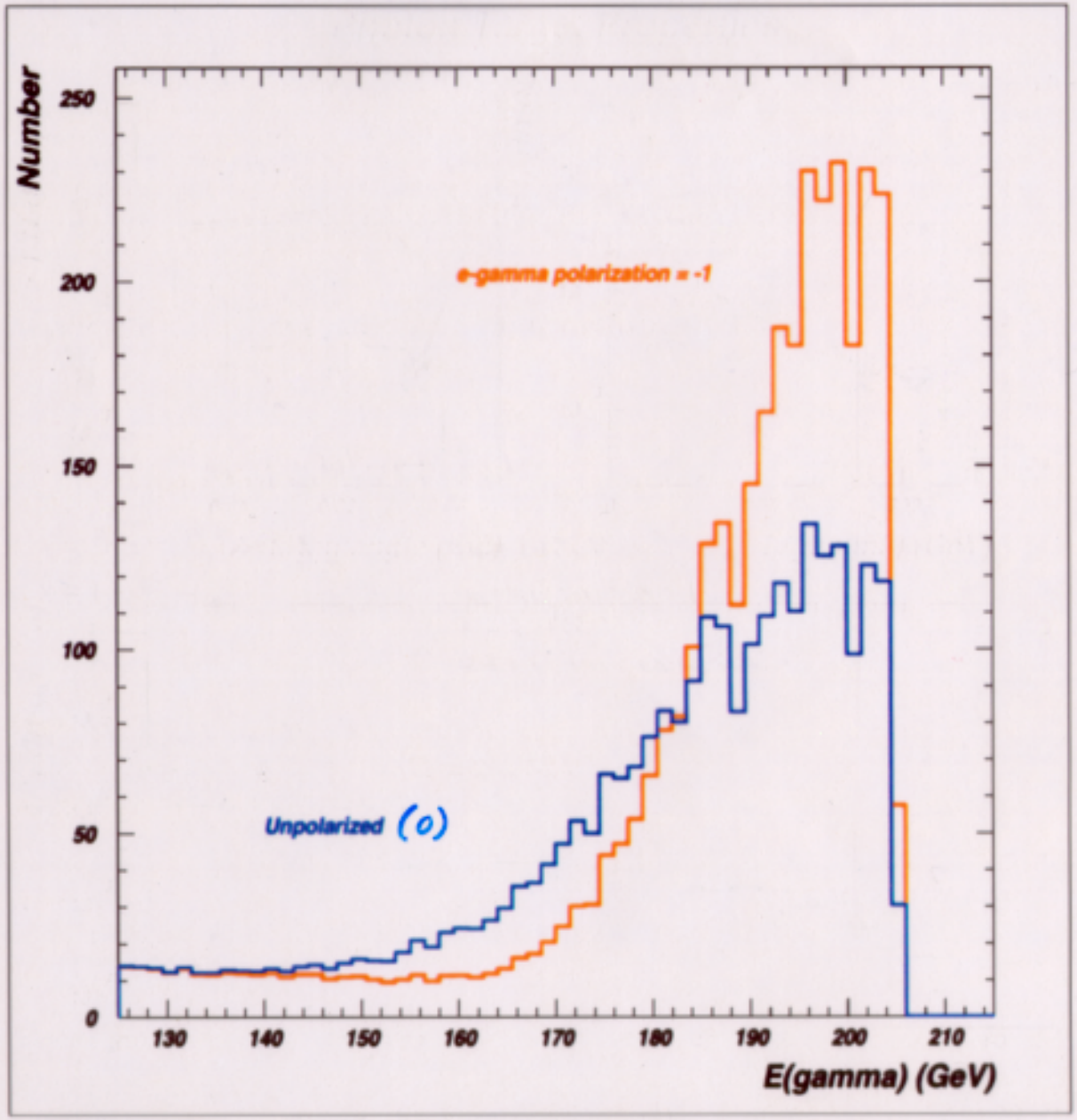
$$\omega \le \omega_{max} = \frac{x}{x+1}E \Rightarrow \omega_{max} = 0.82E = 205 \text{ GeV}$$

$$y \le y_{max} = \frac{x}{x+1} \Rightarrow y_{max} = 0.82$$



V. G. Serbo, "Compton effect as a basic process in the conversion region", International Workshop on High Energy Photon Colliders, June 14-17, 2000, DESYHamburg, Germany

$\gamma\gamma$ Method : Target (γ) Properties



"Toy" weighting function for E_γ

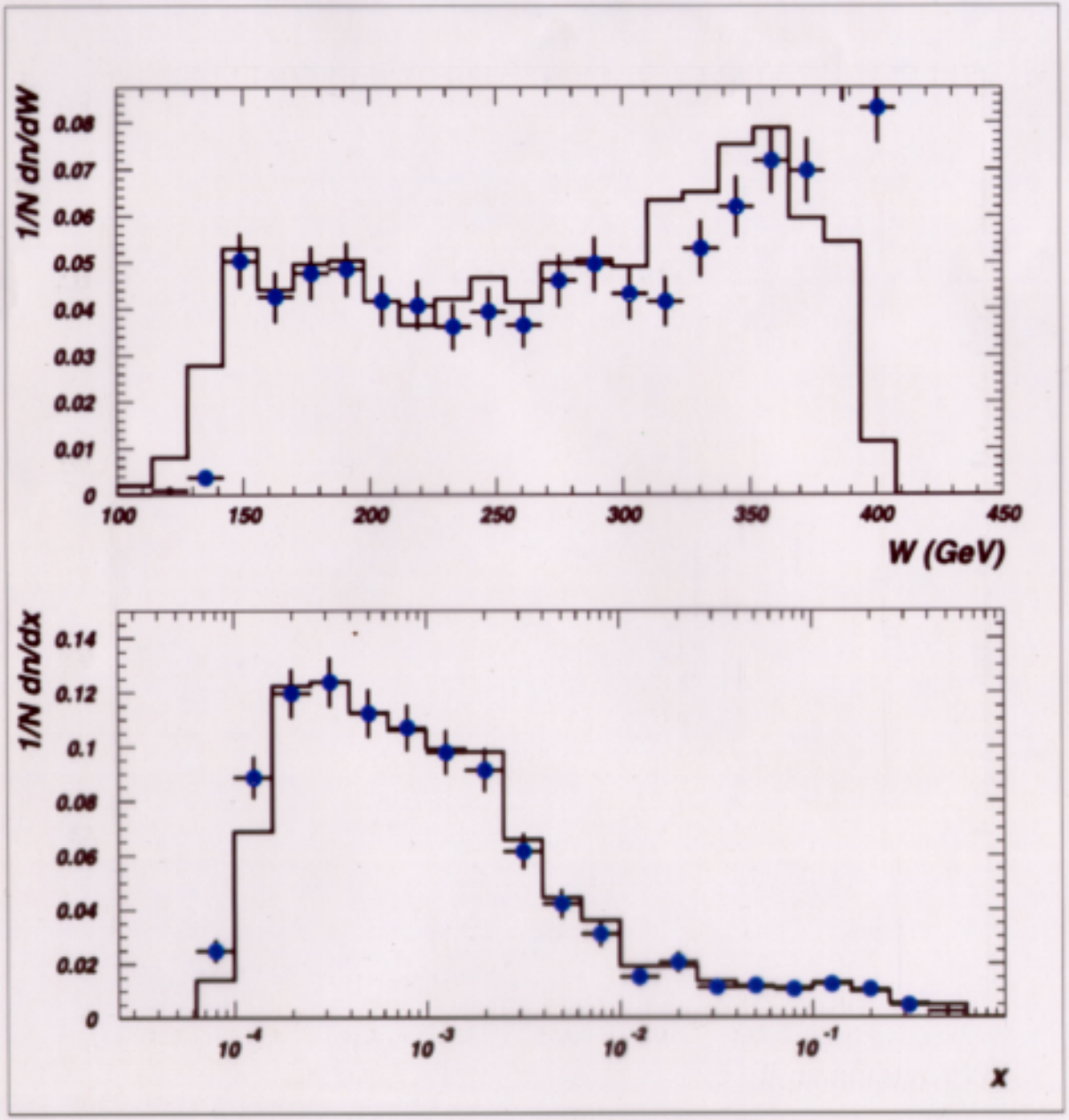
$$E_\gamma^{max} = .82\, E_e = 205\ \text{GeV}$$

$$\Delta E_{1/2} = \frac{E_\gamma^{max}}{x+2} \quad (2\lambda_e P_c = 0)$$

Peak of $E_\gamma^{max} \sim 2x$ for $2\lambda_e P_c = -1$

(no low E_γ tail)

$\gamma\gamma$ Method : $W(\gamma^*\gamma)$ and x Reconstruction



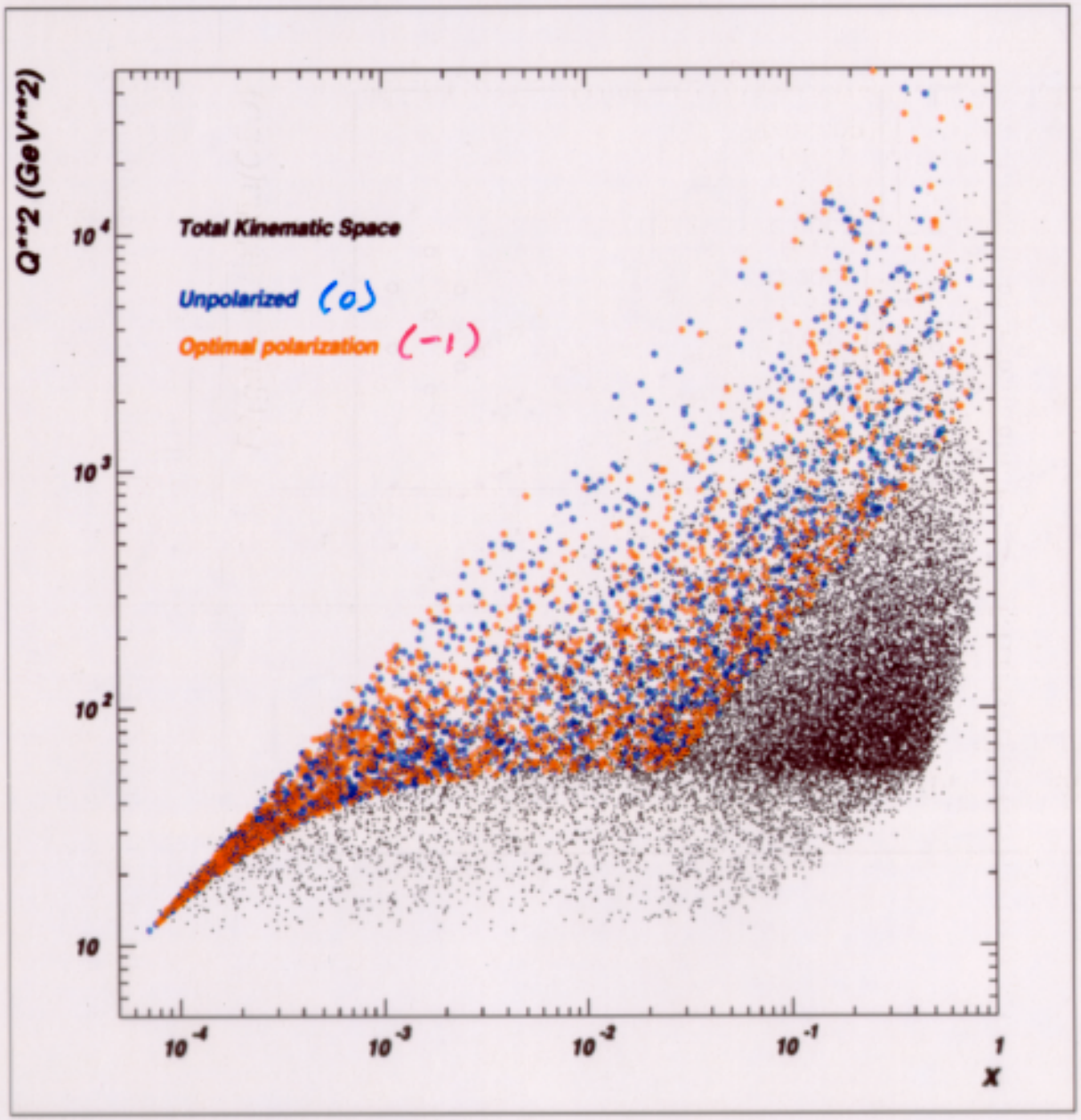
True $W_{\gamma^*\gamma}$ (histogram)

$W^{rec}_{\gamma^*\gamma}$ (for $2\lambda_e P_e = 0$) assuming E_γ fixed at 205 GeV

True x (histogram)

x_{rec} (points)

$\gamma\gamma$ Method : Kinematics



Black: Total x, Q^2 region

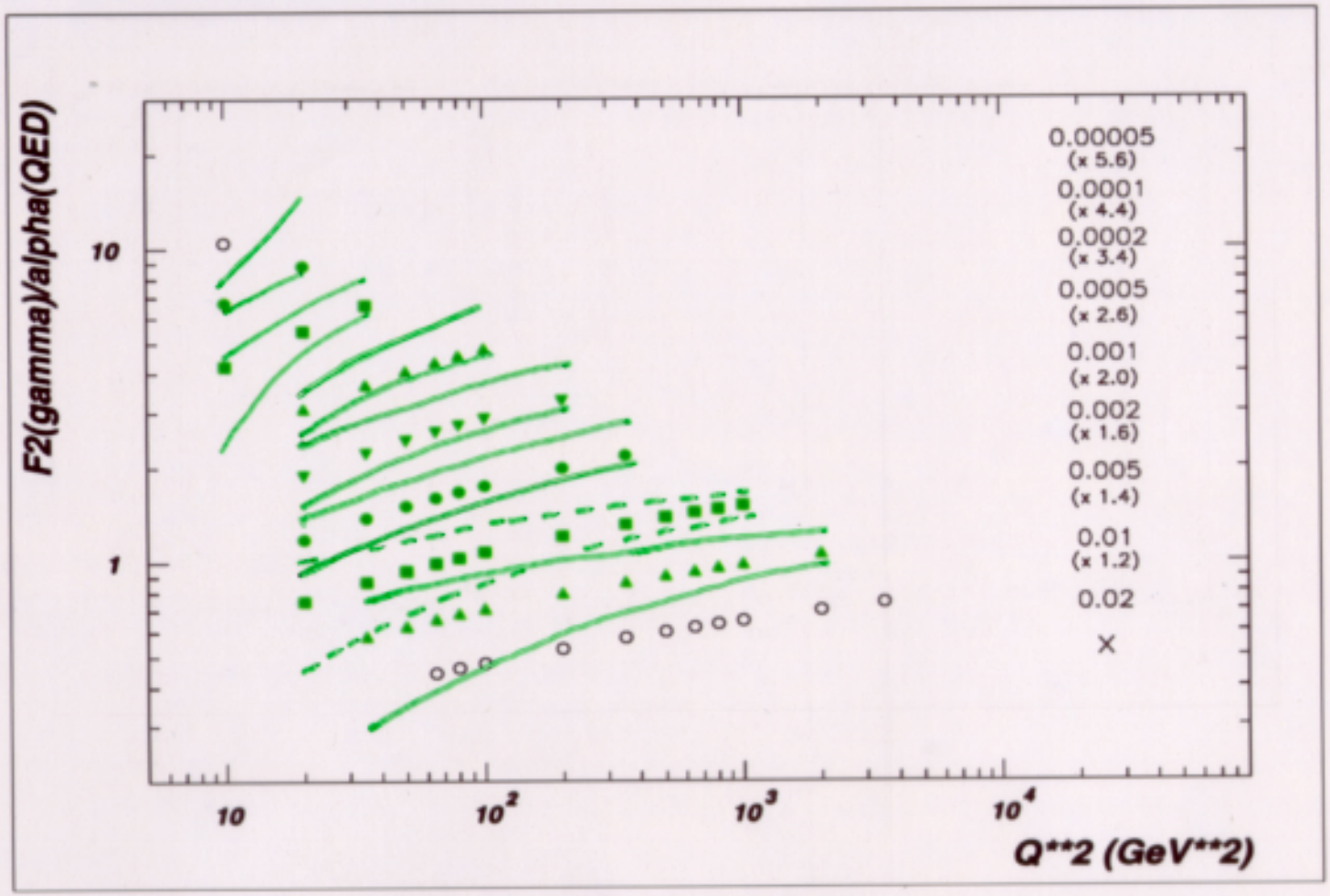
Red : $2\lambda_e P_e = -1$

Blue : $2\lambda_e P_e = 0$

$E_e' > 50$ GeV

$y > 0.01$

$\gamma\gamma$ Method : F2(γ)

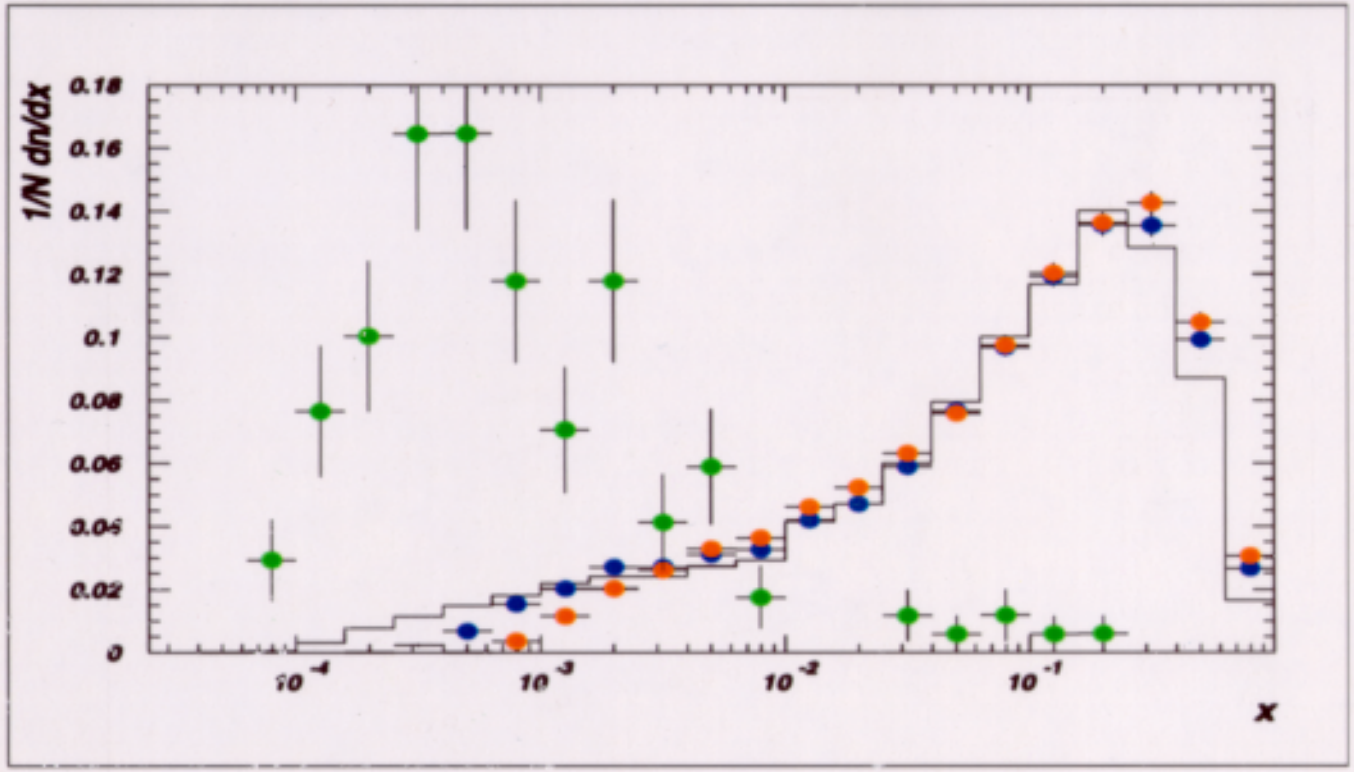


o = not accessible

● ■ = accessible

bands = migration systematic errors

Summary : Comparison of e+e- and γγ Methods



- Low x reach of eγ DIS in e^+e^- mode is limited by (required) reconstruction of $W_{\gamma^*\gamma}$
  hadron detection at small angles necessary to reduce model dependence
- Lowest x achieved in γγ mode by taking advantage of ~monochromaticity of laser-backscattered photons