Leptonic Structure Functions Measured with the L3 Detector

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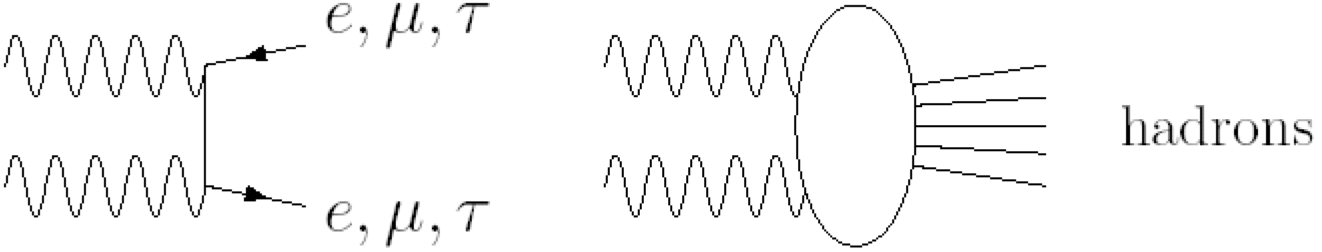
May 12, 2009

Photon 2009 11-15 May 2009 DESY, Hamburg

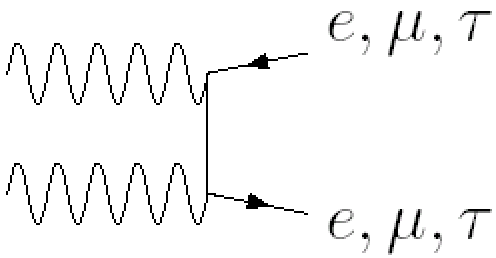
"Structure of the Photon"

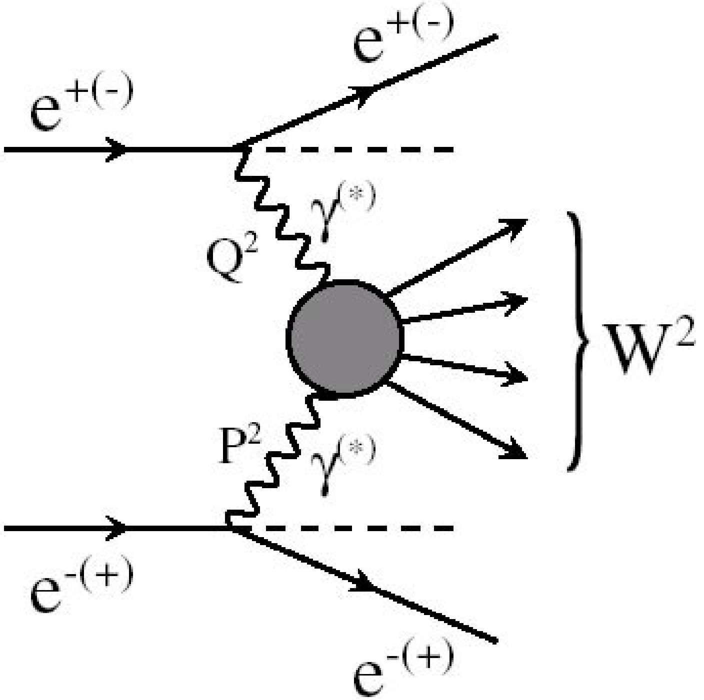
- Dual nature of photons: uncertainty principle allows photon to fluctuate into various states (leptons, quarks, …)
- Photon is ideal tool for probing structure of objects



Dilepton Formalism

$$e^+e^- \rightarrow e^+e^-\gamma^*\gamma^* \rightarrow e^+e^-\mu^+\mu^-$$

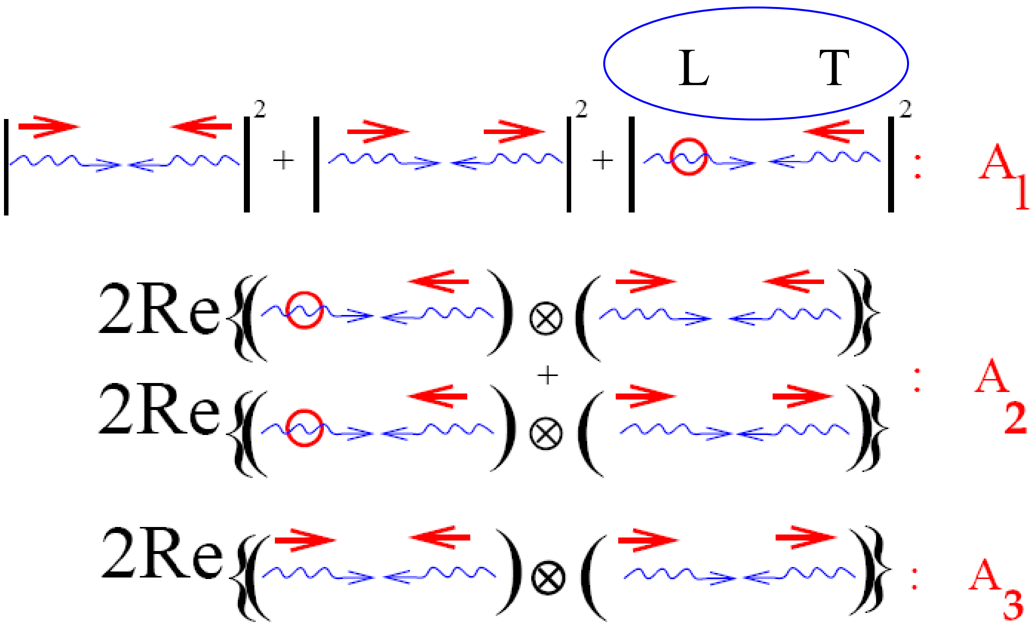




Dilepton Formalism

$$d\sigma = K(4\rho_1^{++}\rho_2^{++}\sigma_{TT} + 2\rho_1^{00}\rho_2^{++}\sigma_{LT} + 2\rho_1^{++}\rho_2^{00}\sigma_{TL} + \rho_1^{00}\rho_2^{00}\sigma_{LL}$$

$$+2|\rho_1^{+-}\rho_2^{+-}|\tau_{TT}\cos 2\tilde{\phi} - 8|\rho_1^{+0}\rho_2^{+0}|\tau_{TL}\cos\tilde{\phi})\frac{d^3p_1' d^3p_2'}{E_1 E_2}$$



$$K = \frac{\alpha^2}{16\pi^4 q_1^2 q_2^2}\sqrt{\frac{\nu^2 - q_1^2 q_2^2}{(p_1 p_2)^2 - m^4}}$$

ρ_i^{MN} : density matrix

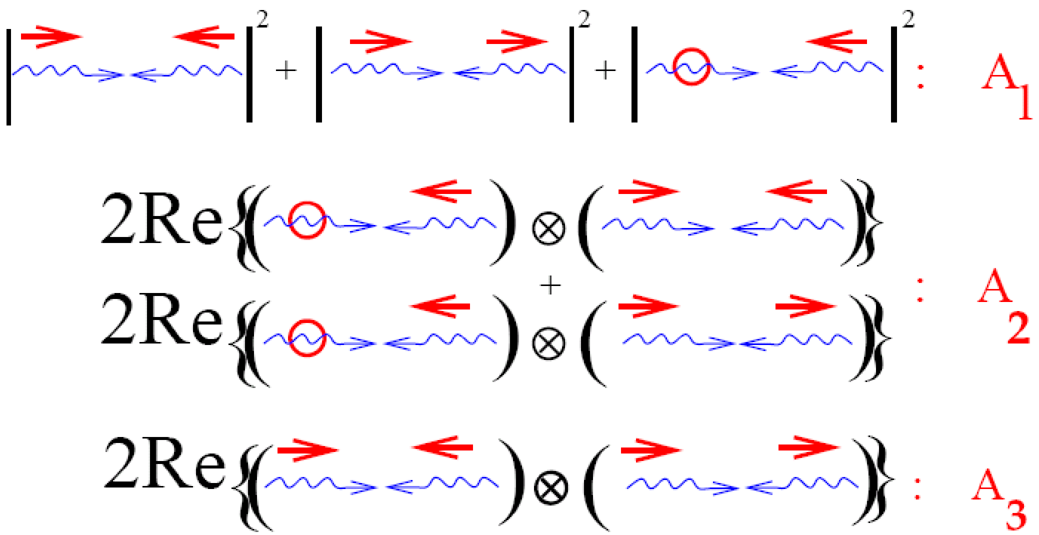
σ_{PQ}, τ_{PQ} : cross-sections

for different helicity states of the photon

Dilepton Formalism

$$F_1 = \frac{\sqrt{\nu^2 - q_1^2 q_2^2}}{4\pi^2\alpha}\left(\sigma_{TT} - \frac{1}{2}\sigma_{TL}\right)$$

$$F_2 = \frac{\nu |q_1^2|}{4\pi^2\alpha\sqrt{\nu^2 - q_1^2 q_2^2}}\left(\sigma_{TT} + \sigma_{LT} - \frac{1}{2}(\sigma_{LL} + \sigma_{TL})\right)$$



ρ_i^{MN} : density matrix

σ_{PQ}, τ_{PQ} : cross-sections

for different helicity states of the photon

Single Tag Formalism

→ One electron detected

→ One electron escapes undetected

$\Rightarrow$ $\boxed{q_2^2 \rightarrow 0}$

→ Photon with $-q_1{}^2 = Q^2$: probe photon

→ Photon with $-q_2{}^2 = P^2$: target photon

Structure Function

Extraction of $F^{\gamma}_{2,QED}$

Express $d\sigma$ in terms of Structure Functions

$$
\begin{aligned}
d\sigma \;=\; & K\Big(2|\rho_1^{+-}\rho_2^{+-}|\tau_{TT}\cos 2\tilde{\phi} - 8|\rho_1^{+0}\rho_2^{+0}|\tau_{TL}\cos\tilde{\phi} \\
& +2\rho_1^{++}\rho_2^{00}\{F_2(W,q_1^2,q_2^2)/D - F_1(W,q_1^2,q_2^2)/C\} \\
& +4\rho_1^{++}\rho_2^{++}F_1(W,q_1^2,q_2^2)/C\Big)\frac{d^3p_1' d^3p_2'}{E_1E_2}
\end{aligned}
$$

Structure Function

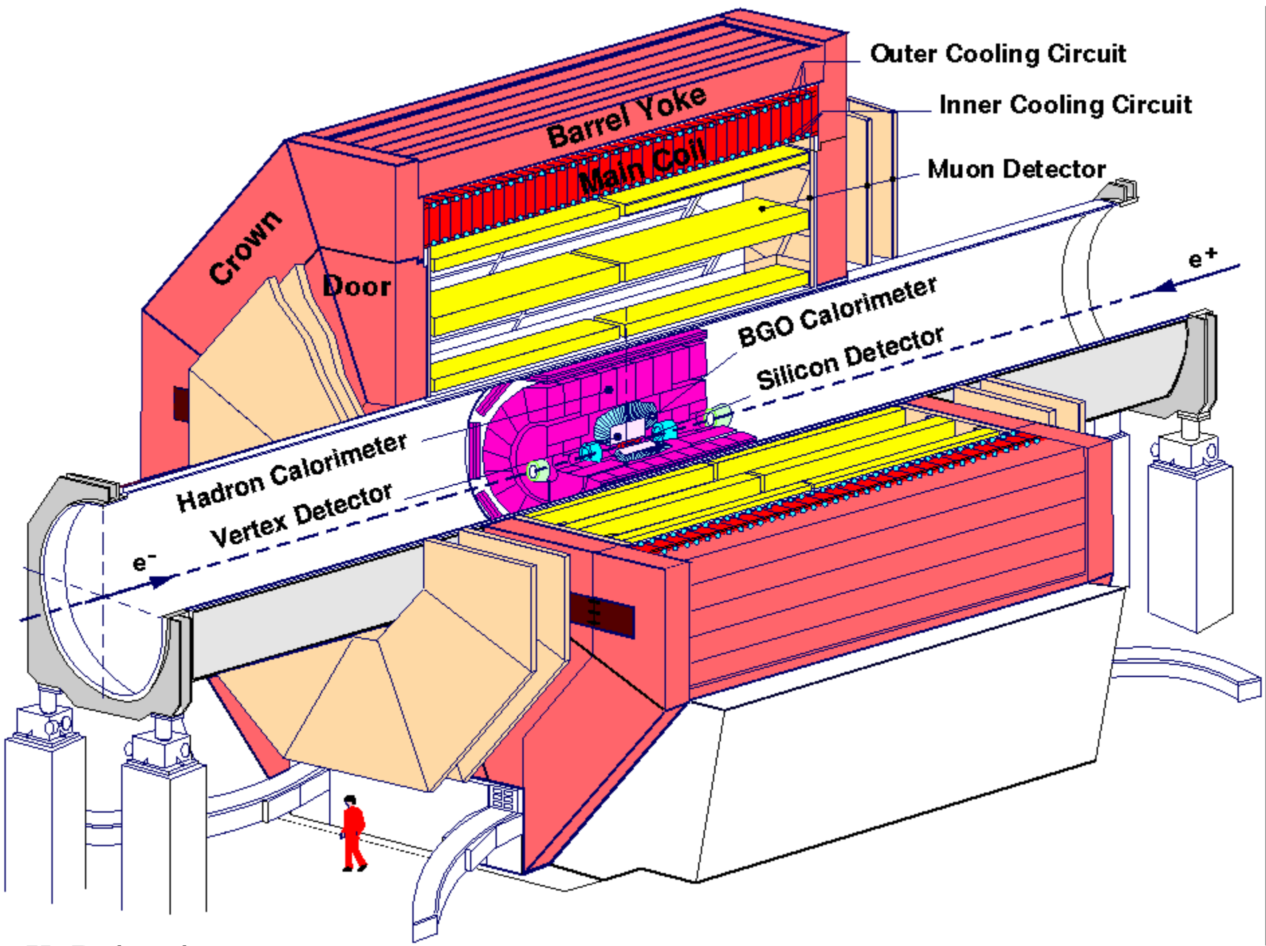
Extraction of $F_{2,QED}^{\gamma}$

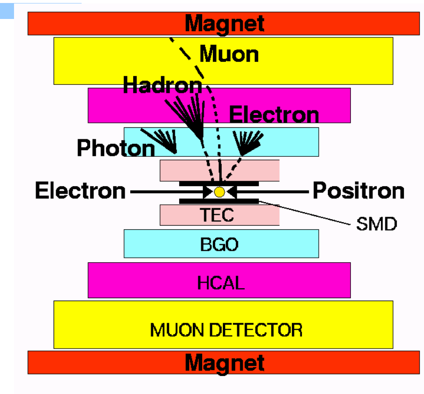
Normalize the portion of $F_{2,QED}^{\gamma}$

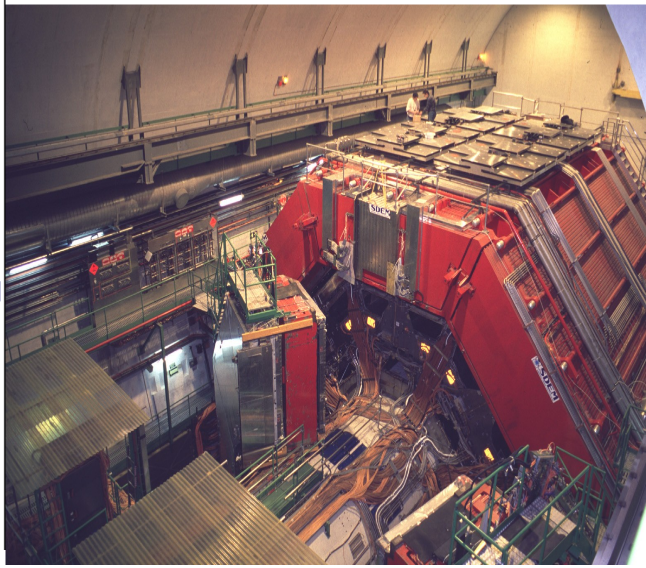
$$F_2(W, q_1^2, q_2^2) \equiv 1$$

$$F_2^{\gamma}/\alpha = \frac{d\sigma_{measured}}{d\sigma_{Galuga,F_2=1}}$$

L3 – The Detector



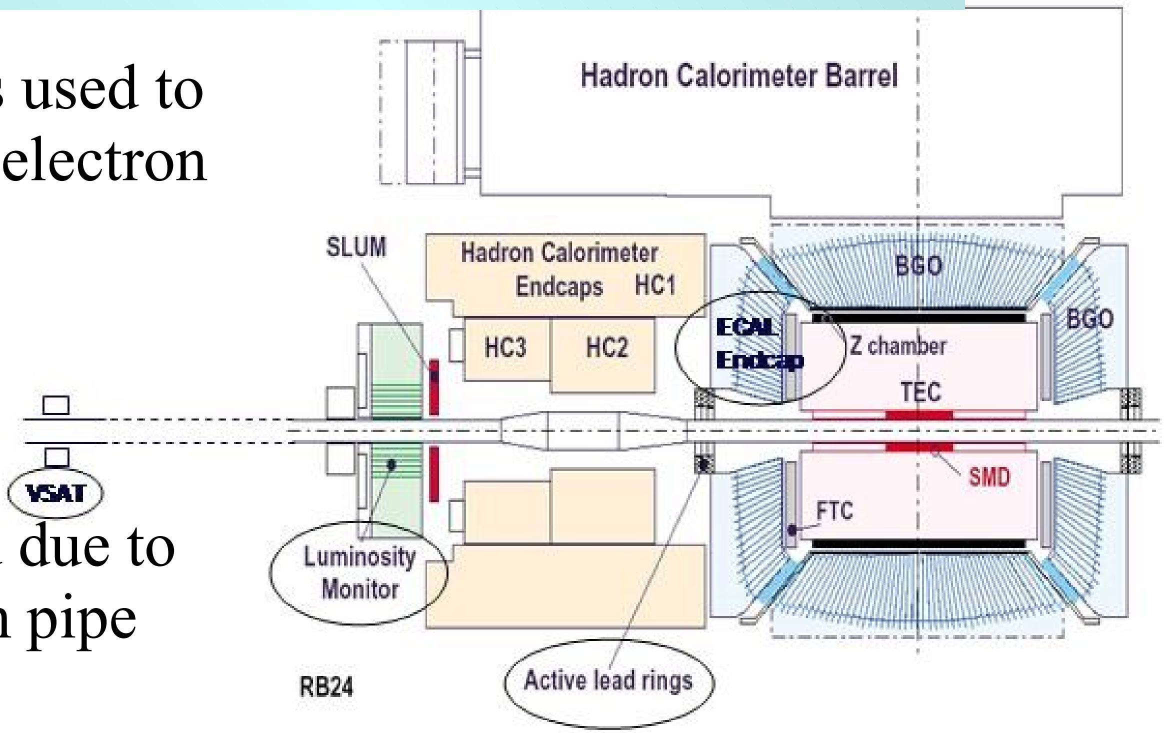




L3 Tagging Detectors

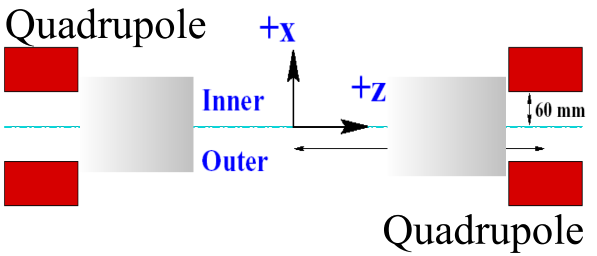
Very Small Angle Tagger – VSAT
Luminosity Monitor – LUMI
Active Lead Ring – ALR
Electromagnetic Calorimeter Endcaps – BGO Endcaps

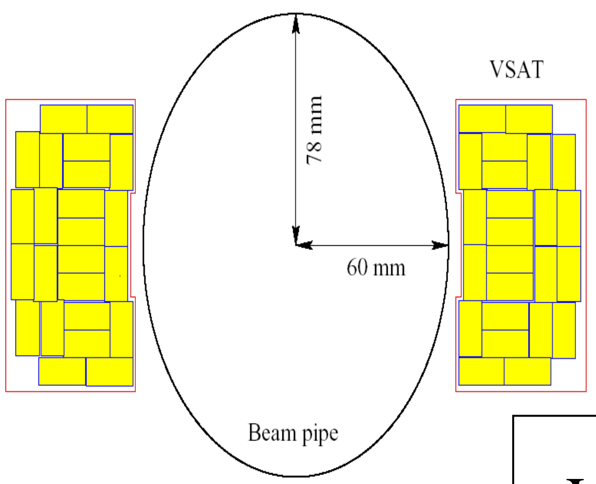
Tagging detectors used to identify scattered electron

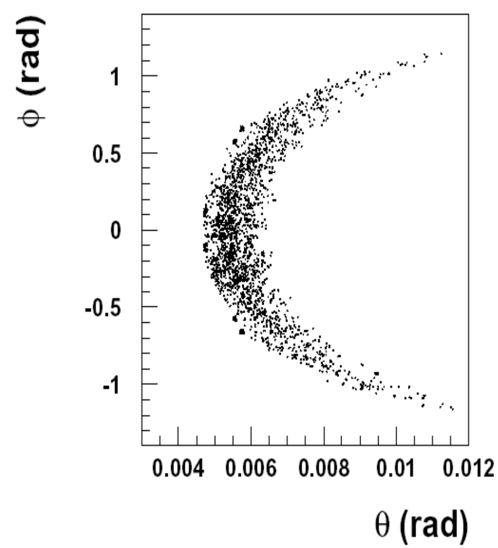


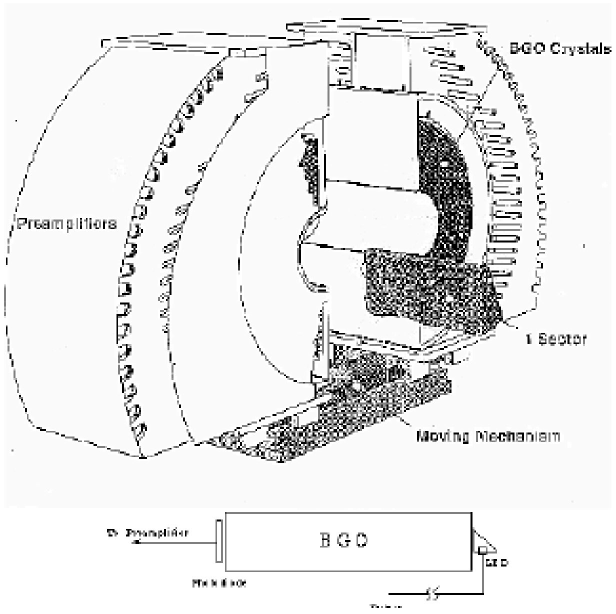
VSAT: background due to proximity to beam pipe

L3 Tagging Detectors: VSAT / LUMI







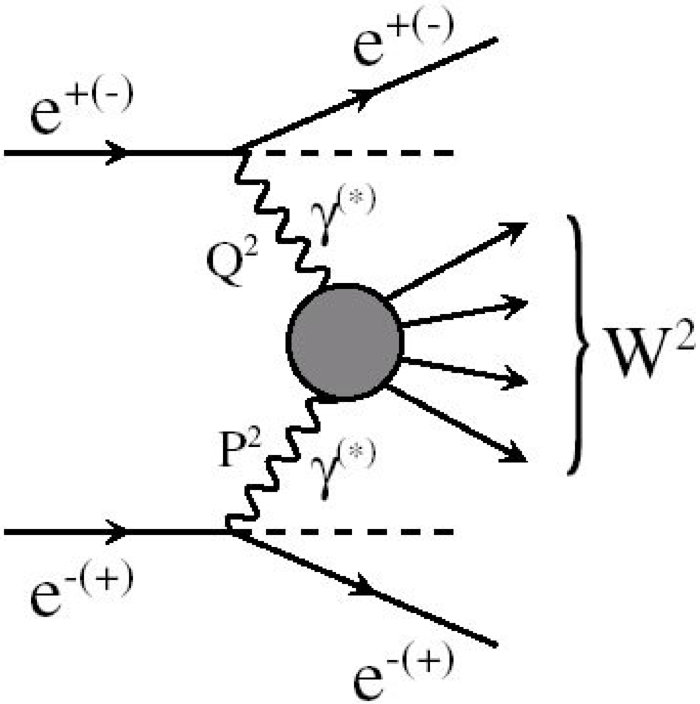


VSAT

LUMI

Two-Photon Interactions with Dimuon Events

$$e^+e^- \rightarrow e^+e^-\gamma^*\gamma^* \rightarrow e^+e^-\mu^+\mu^-$$



Data sample:

$E_{cms} = 189 \ldots 206\, GeV$

$\mathcal{L}_{int} = 600\, pb^{-1}$

- Single Tagged Electron, High Energy Deposition in Electromagnetic Calorimeters
- Two tracks, at least one to be identified as a lepton ($\mu^{\pm}$)
- VERMASEREN Monte Carlo generator for large statistics

Selection Criteria VSAT

- Single tag: $\mathbf{0.5\ \boldsymbol{x}\ E_{beam} \leq E_{VSAT}}$

  and only one

- Two well-measured tracks with $\mathbf{\Sigma \boldsymbol{Q_i} = 0}$

- At least one track to be identified as μ

- Squared four-momentum transfer:

$$\mathbf{0.2\ GeV^2 \leq Q^2 \leq 0.85\ GeV^2}$$

with track information: $\mathbf{Q^2 = (\vec{p}_{T,1} + \vec{p}_{T,2})^2}$

Selection Criteria LUMI

- Single tag: $\mathbf{0.7}\ \boldsymbol{x}\ \mathbf{E_{beam} \leq E_{LUMI}}$

  and only one

- Two well-measured tracks with $\mathbf{\Sigma} \boldsymbol{Q_i}\mathbf{=0}$

- At least one track to be identified as μ

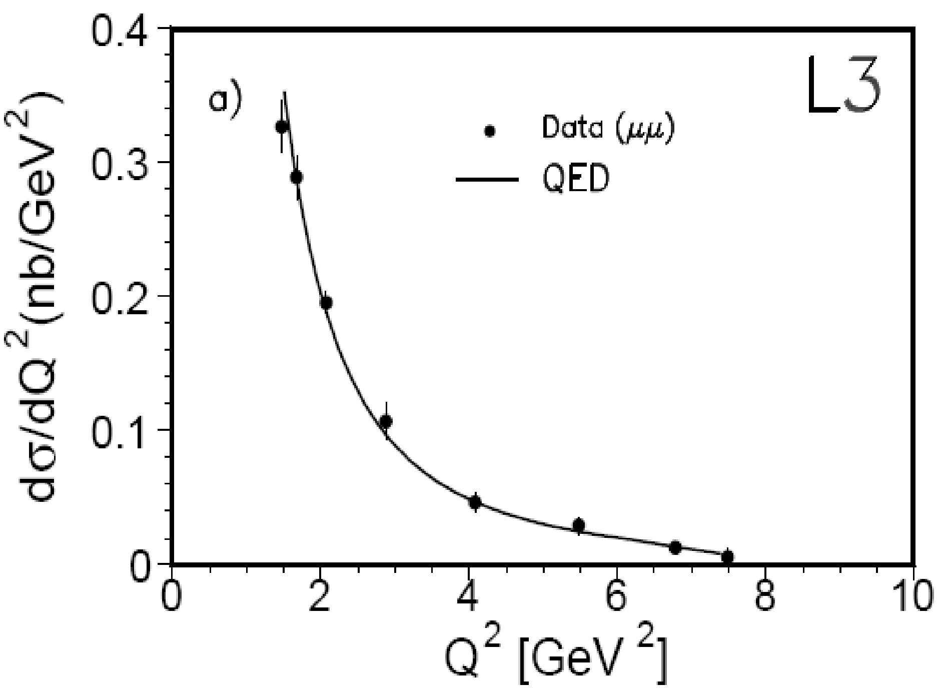
- Squared four-momentum transfer:

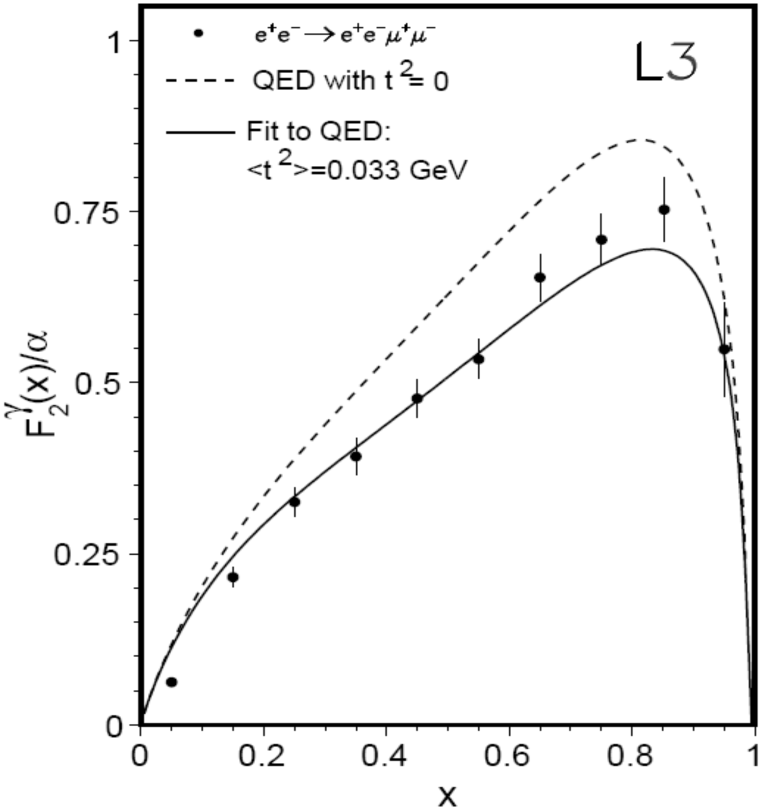
$$\mathbf{11\ eV^2 \leq Q^2 \leq 34\ GeV^2}$$

with track information: $\mathbf{Q^2 = (\vec{p}_{T,1}+\vec{p}_{T,2})^2}$

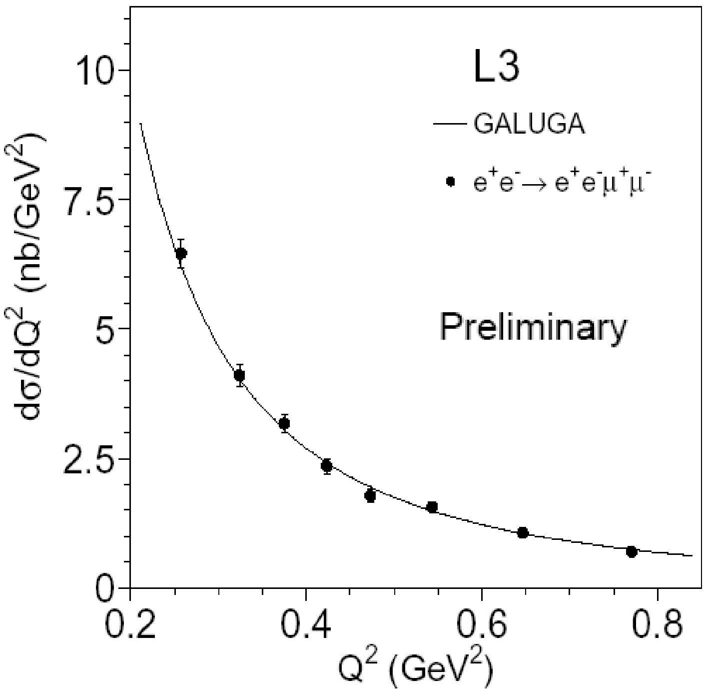
Cross-Section & Structure-Function

Physics Letters B 438 (1998) 363–378



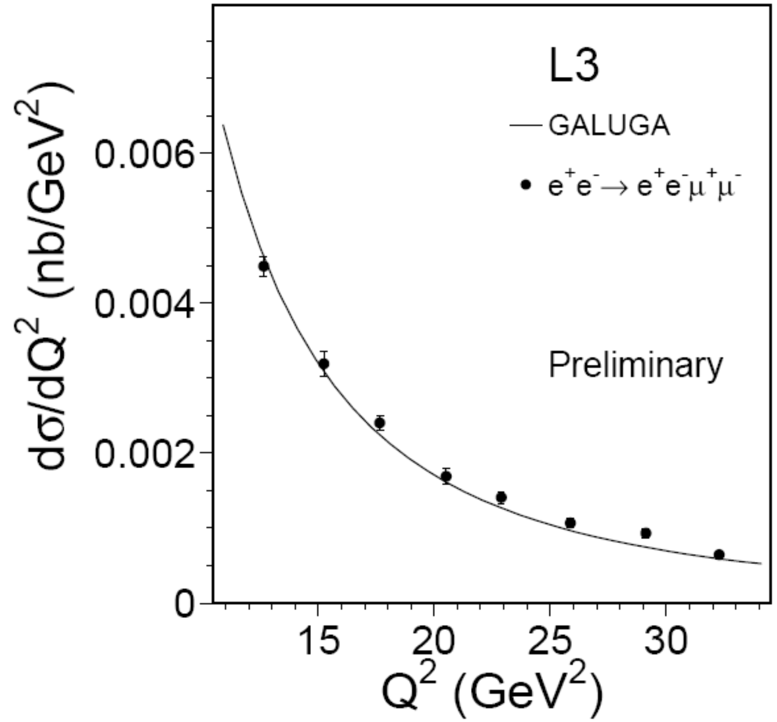


Cross-Section & Structure-Function



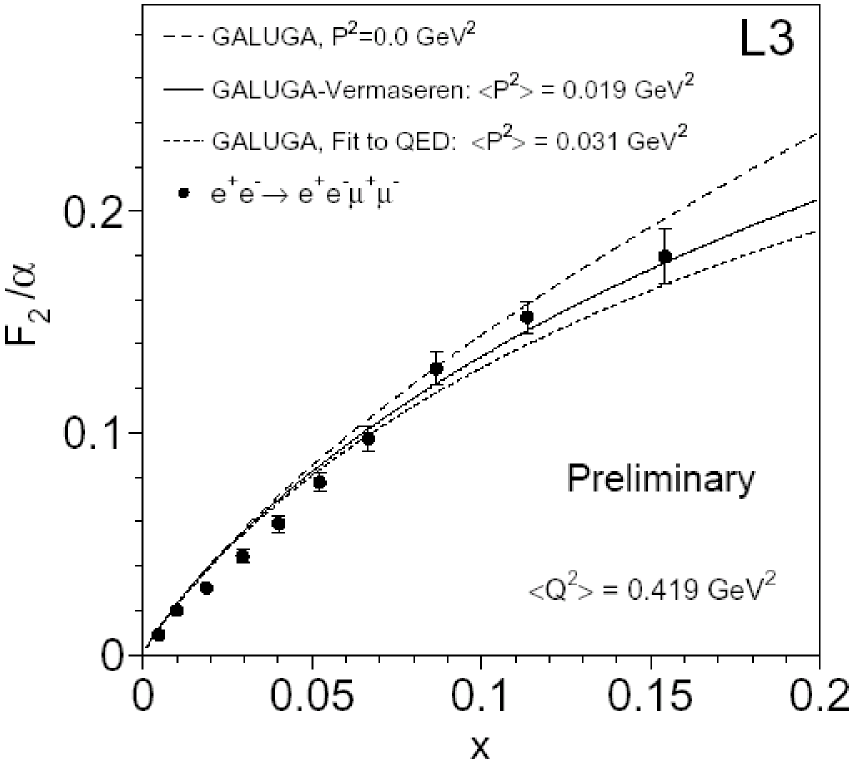
VSAT

$$\frac{d\sigma}{dQ^2} = \frac{N_{data}}{\Delta Q^2 \cdot \mathcal{A} \cdot \varepsilon \cdot \mathcal{L}}$$



LUMI

Cross-Section & Structure-Function



Leptonic Structure-Function

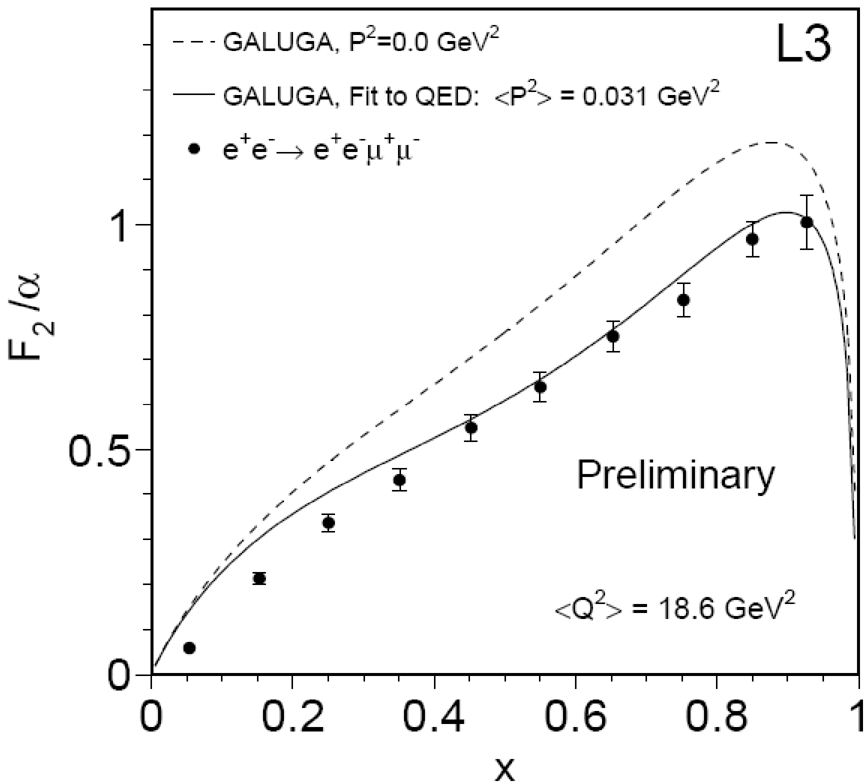
F_2 (VSAT)

Limited x-range

due to small Q^2

Leptonic Structure-Function

F_2 (LUMI)



Summary

- ✓ Measurement of
  - differential cross-section $\frac{d\sigma}{dQ^2}$
  - structure-function $F_{2,QED}^{\gamma}$

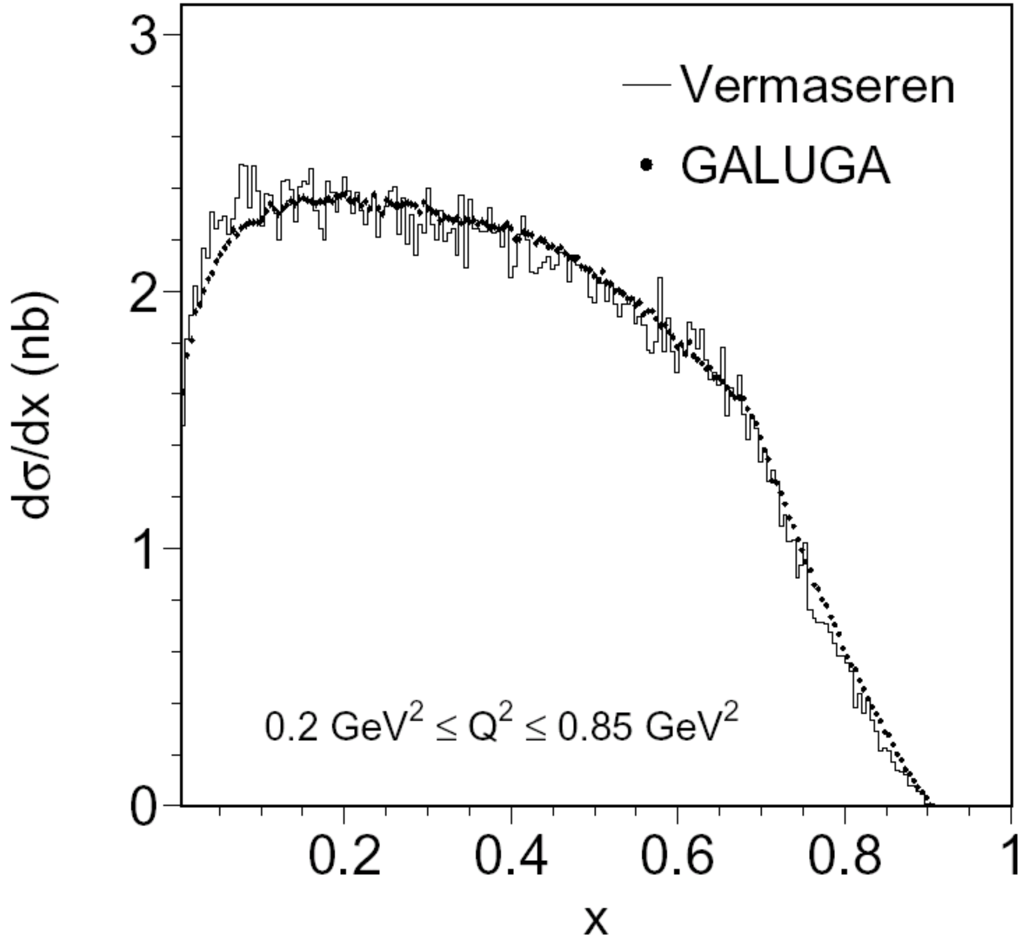
in the kinematical range **$0.2\ \mathrm{GeV}^2 \leq Q^2 \leq 0.85\ \mathrm{GeV}^2$**
$11\ \mathrm{GeV}^2 \leq Q^2 \leq 34\ \mathrm{GeV}^2$
$189\ \mathrm{GeV} \leq \sqrt{s} \leq 206\ \mathrm{GeV}$

- ✓ Data suggest $P^2 > 0$

Backup Slides

Cross-Section & Structure-Function VERMASEREN - GALUGA

Adaptation of parameters
GALUGA - VERMASEREN



Systematic Error Estimation

Error source	Error contribution (in %)
Luminosity Data	0.06
Luminosity MC	0.90
Background	0.09
Radiative events	0.60
Trigger efficiency	0.12
Selection criteria	2.36
GALUGA	2.16
Total	3.38

Background sources

$e^- e^+ \rightarrow e^- e^+ l^- l^+ \ (l = e, \mu)$ → Non Multiperipheral