

Particle Physics II

Winter Semester 2011/2012

Albert-Ludwigs-Universität Freiburg



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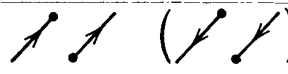


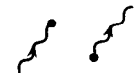
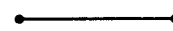
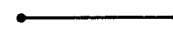


<http://terascale.physik.uni-freiburg.de/lehre/>

Kapitel 2

Die elektromagnetische Wechselwirkung QED - Quantenelektrodynamik

Feynmanregeln der QED

TABLE 6.2
Feynman Rules for $-i\mathcal{M}$

		Multiplicative Factor
● External Lines	Spin 0 boson (or antiboson)	 1
	Spin $\frac{1}{2}$ fermion (in, out)	 u, \bar{u}
	antifermion (in, out)	 \bar{v}, v
	Spin 1 photon (in, out)	 $\epsilon_\mu, \epsilon_\mu^*$
● Internal Lines—Propagators (need $+i\epsilon$ prescription)	Spin 0 boson	 $\frac{i}{p^2 - m^2}$
	Spin $\frac{1}{2}$ fermion	 $\frac{i(\not{p} + m)}{p^2 - m^2}$
	Massive spin 1 boson	 $\frac{-i(g_{\mu\nu} - p_\mu p_\nu / M^2)}{p^2 - M^2}$
	Massless spin 1 photon (Feynman gauge)	 $\frac{-ig_{\mu\nu}}{p^2}$
	● Vertex Factors	Photon—spin 0 (charge $-e$)
Photon—spin $\frac{1}{2}$ (charge $-e$)		

Loops: $\int d^4k / (2\pi)^4$ over loop momentum; include -1 if fermion loop and take the trace of associated γ -matrices

Identical Fermions: -1 between diagrams which differ only in $e^- \leftrightarrow e^-$ or initial $e^- \leftrightarrow$ final e^+

Differentieller WQ für $e^-e^- \rightarrow e^-e^-$

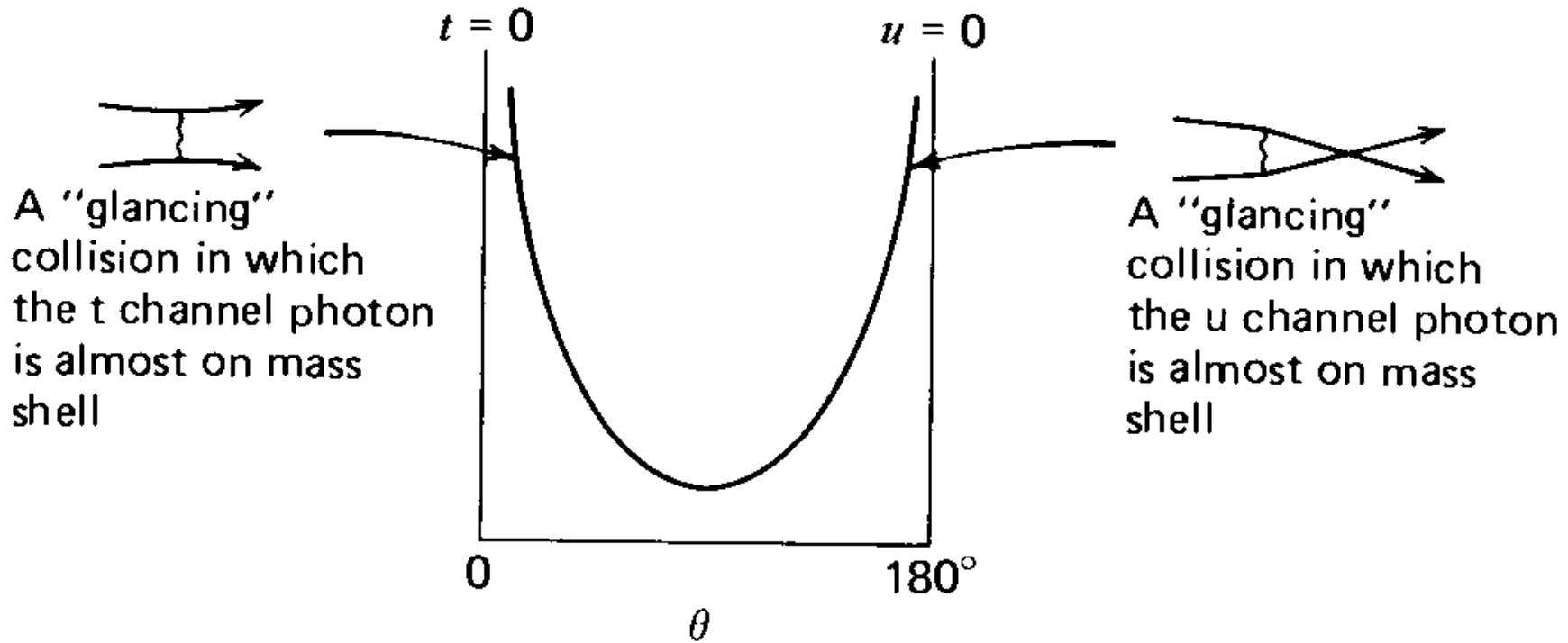
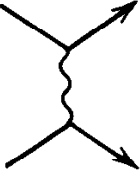
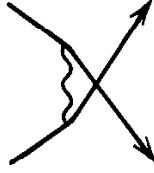
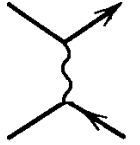
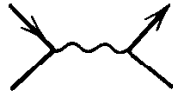
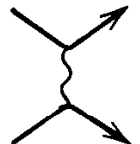
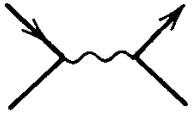


Fig. 4.8 The differential cross section, $d\sigma/d\Omega$, for electron-electron scattering.

Übersicht über Matrixelemente

TABLE 6.1
Leading Order Contributions to Representative QED Processes

	Feynman Diagrams		$ \overline{\mathcal{M}} ^2/2e^4$		
	Forward peak	Backward peak	Forward	Interference	Backward
Møller scattering $e^-e^- \rightarrow e^-e^-$ ↓ (Crossing $s \leftrightarrow u$) ↓			$\frac{s^2 + u^2}{t^2} + \frac{2s^2}{tu} + \frac{s^2 + t^2}{u^2}$		
			($u \leftrightarrow t$ symmetric)		
Bhabha scattering $e^-e^+ \rightarrow e^-e^+$ ↓ (Crossing $s \leftrightarrow t$) ↓			$\frac{s^2 + u^2}{t^2} + \frac{2u^2}{ts} + \frac{u^2 + t^2}{s^2}$	Forward Interference	Time-like
$e^-e^+ \rightarrow \mu^-\mu^+$			$\frac{s^2 + u^2}{t^2}$		$\frac{u^2 + t^2}{s^2}$

Positron Elektron Tandem Ring-Anlage

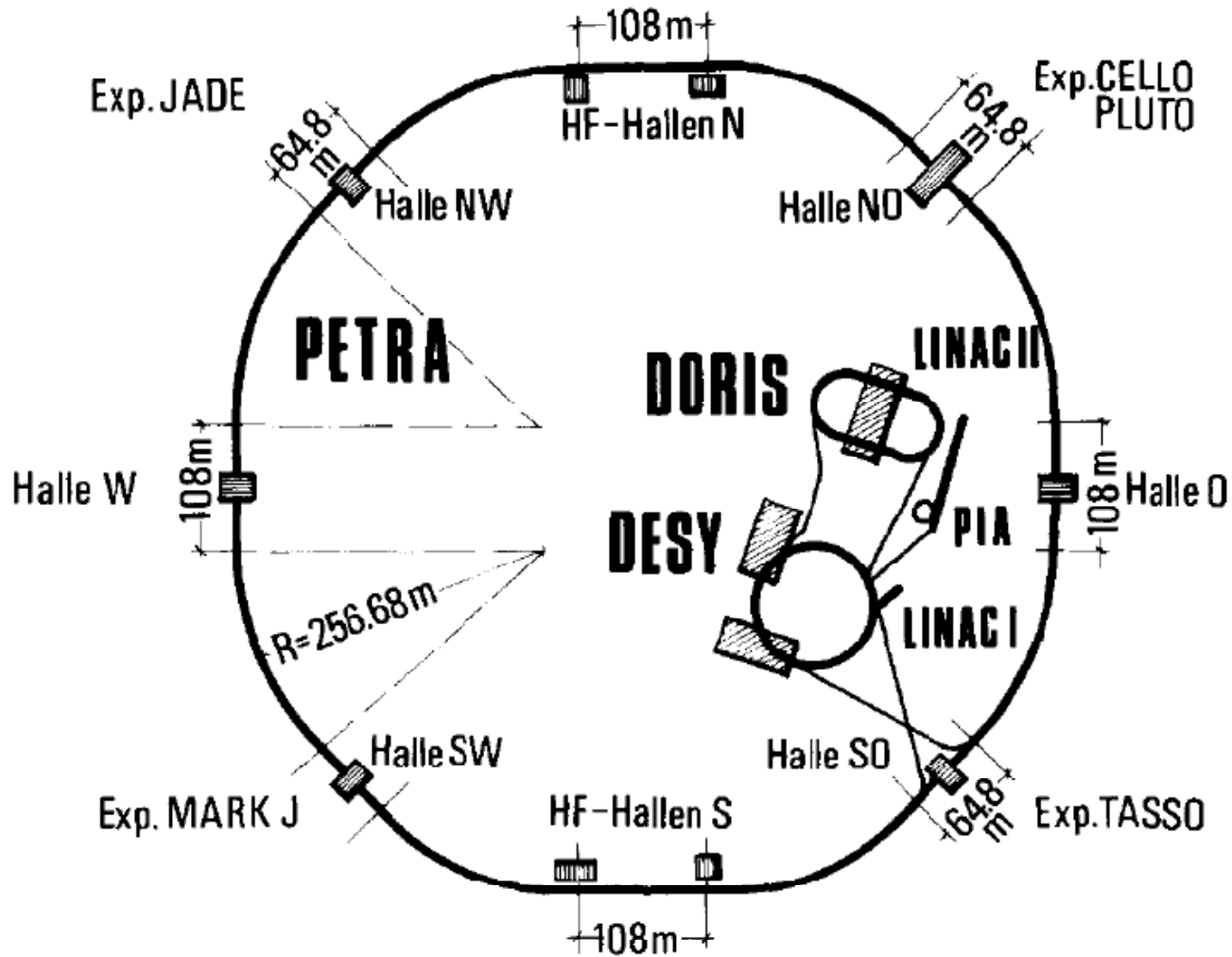
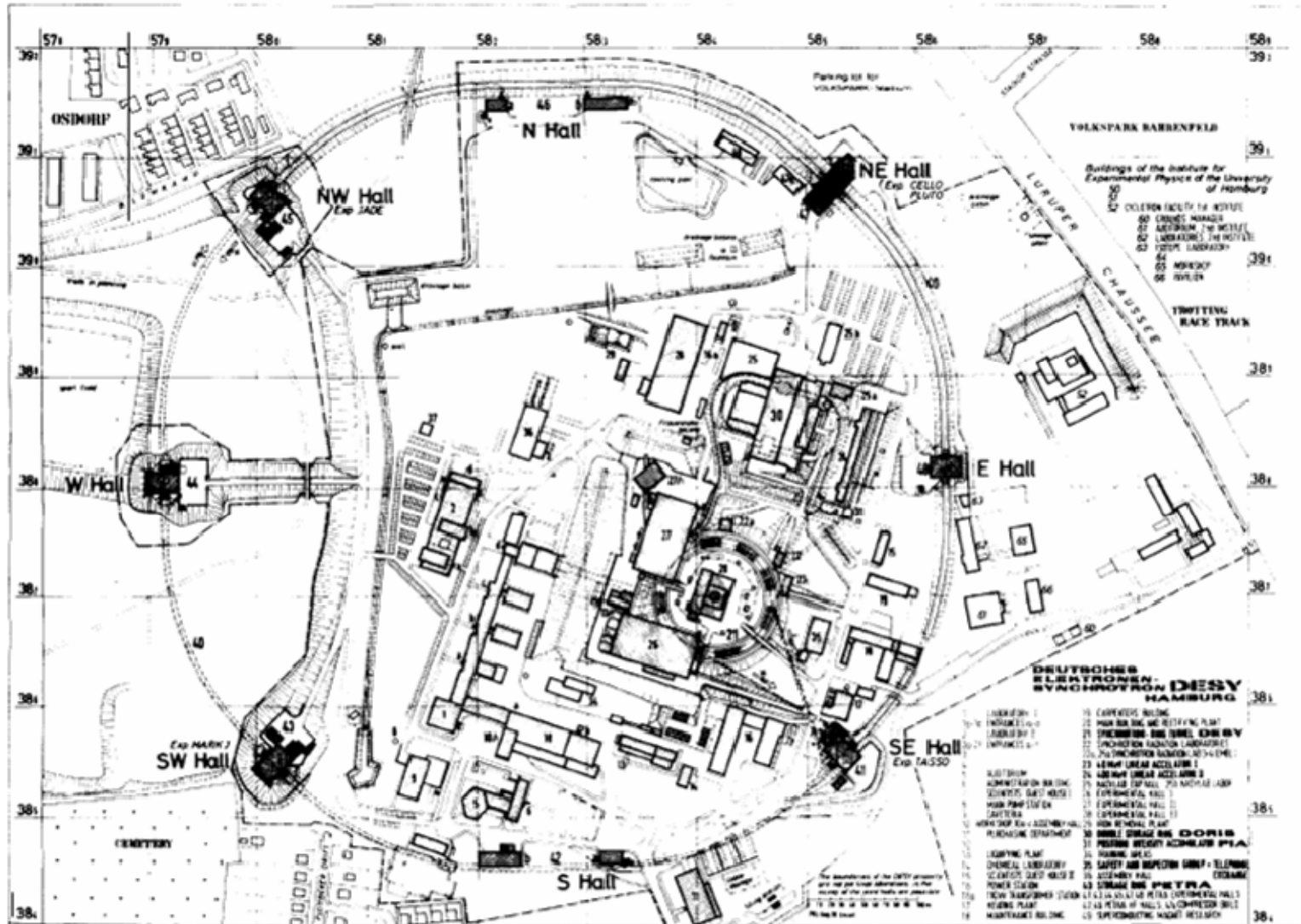


Fig. 1.1a. PETRA (Positron-Electron Tandem Ring Accelerator).

PETRA

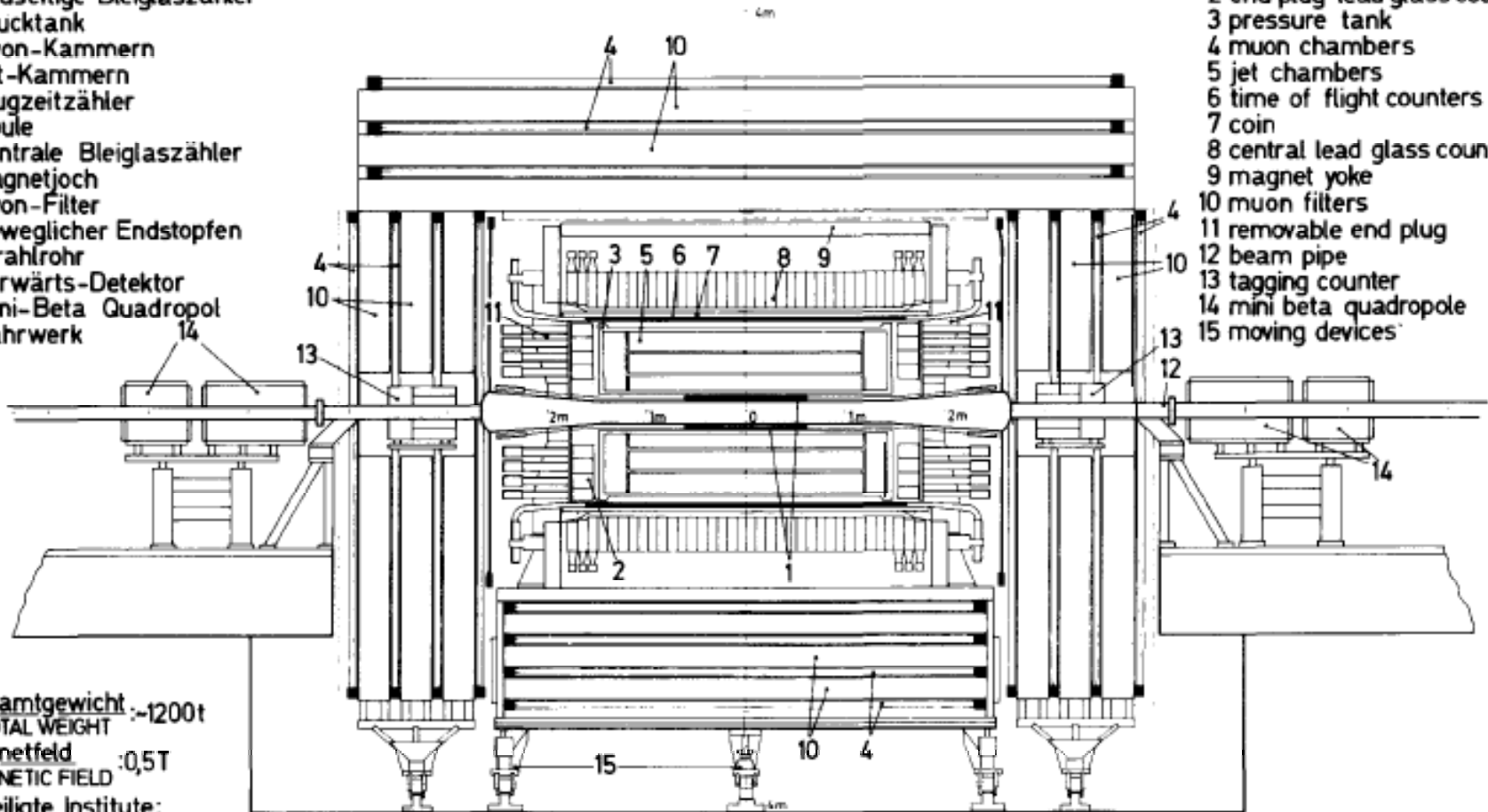


JADE-Detektor

MAGNETDETEKTOR MAGNET DETECTOR **JADE**

- 1 Strahlrohrzähler
- 2 Endseitige Bleiglaszähler
- 3 Drucktank
- 4 Myon-Kammern
- 5 Jet-Kammern
- 6 Flugzeitzähler
- 7 Spule
- 8 Zentrale Bleiglaszähler
- 9 Magnetjoch
- 10 Myon-Filter
- 11 Beweglicher Endstopfen
- 12 Strahlrohr
- 13 Vorwärts-Detektor
- 14 Mini-Beta Quadropol
- 15 Fahrwerk

- 1 beampipe counters
- 2 end plug lead glass counters
- 3 pressure tank
- 4 muon chambers
- 5 jet chambers
- 6 time of flight counters
- 7 coil
- 8 central lead glass counters
- 9 magnet yoke
- 10 muon filters
- 11 removable end plug
- 12 beam pipe
- 13 tagging counter
- 14 mini beta quadropole
- 15 moving devices



Gesamtgewicht :~1200t
TOTAL WEIGHT

Magnetfeld :0,5T
MAGNETIC FIELD

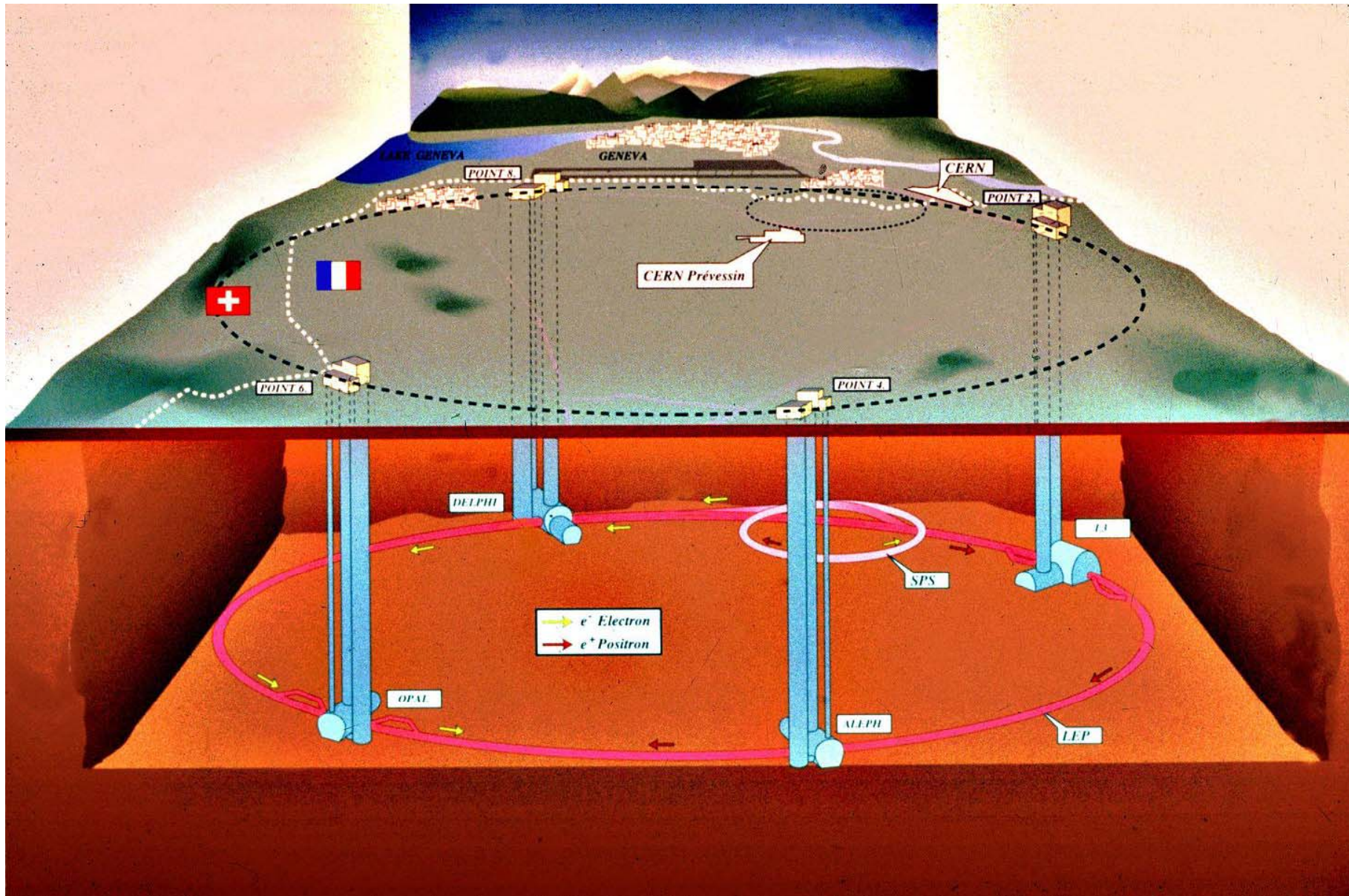
Beteiligte Institute:
PARTICIPANTS

DESY, Hamburg, Heidelberg,
Lancaster, Manchester,
Rutherford Lab, Tokio

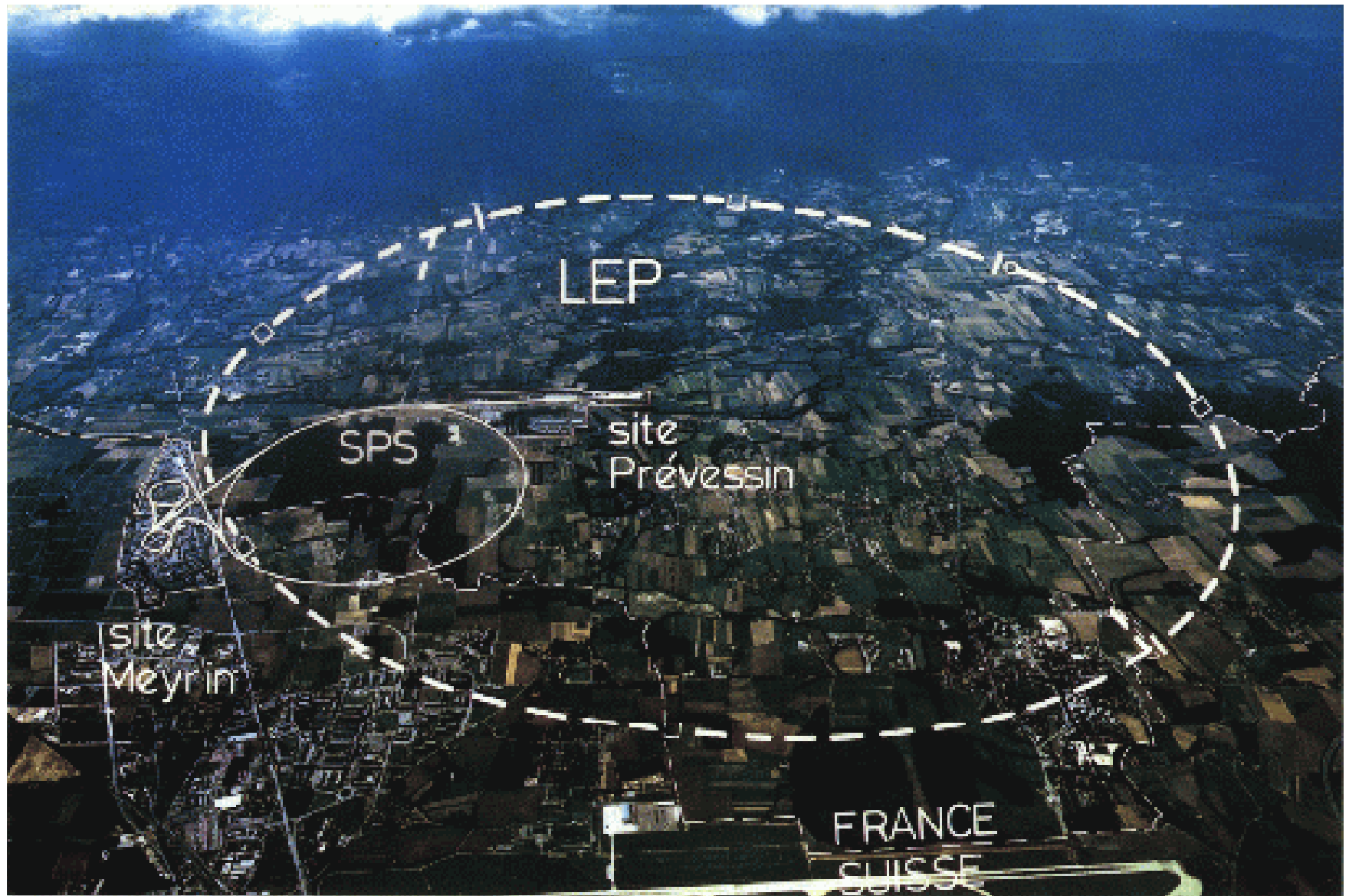
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Fig. 1.10. Cross section through the JADE detector.

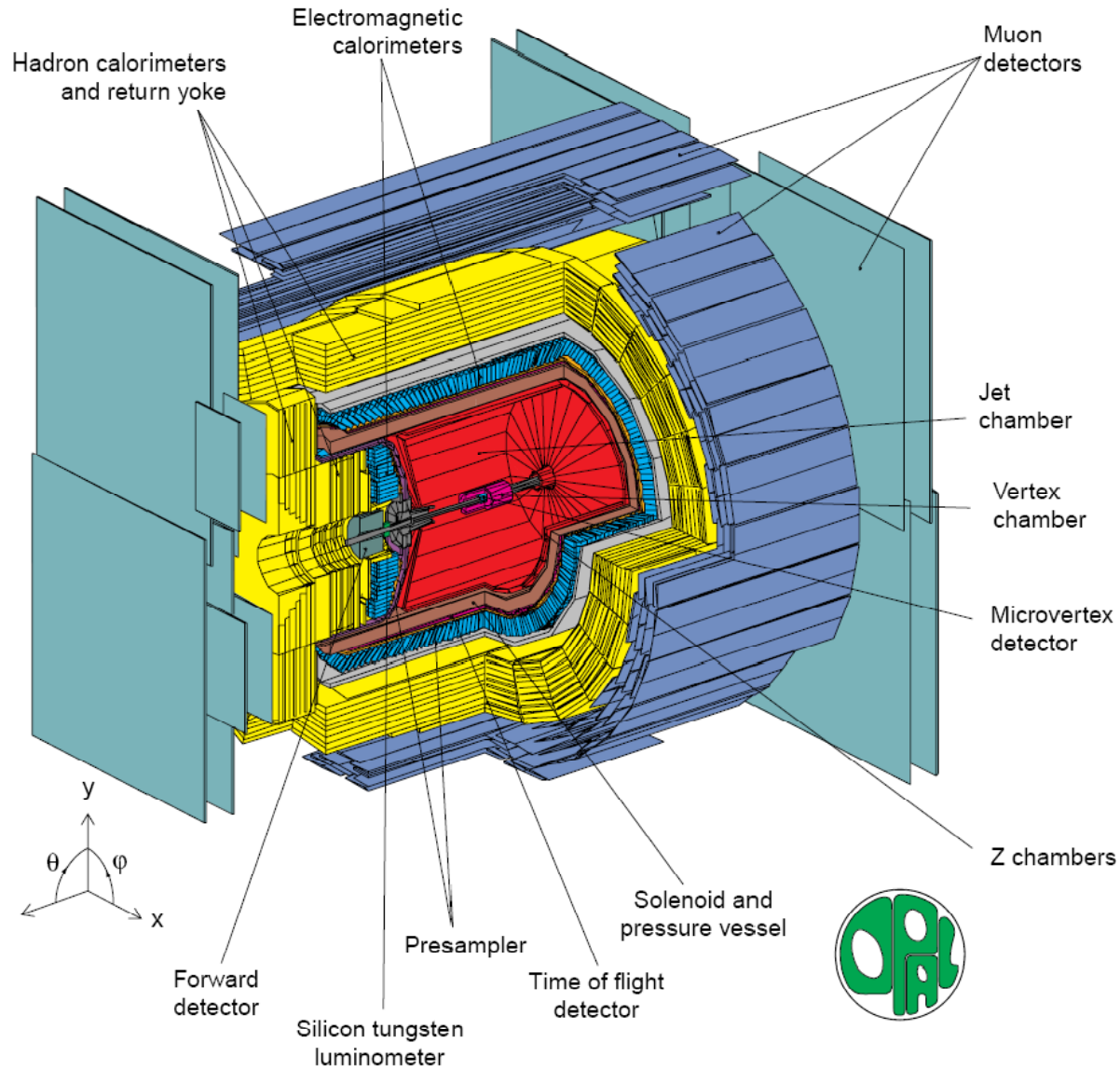
LEP: Large Electron Positron Collider



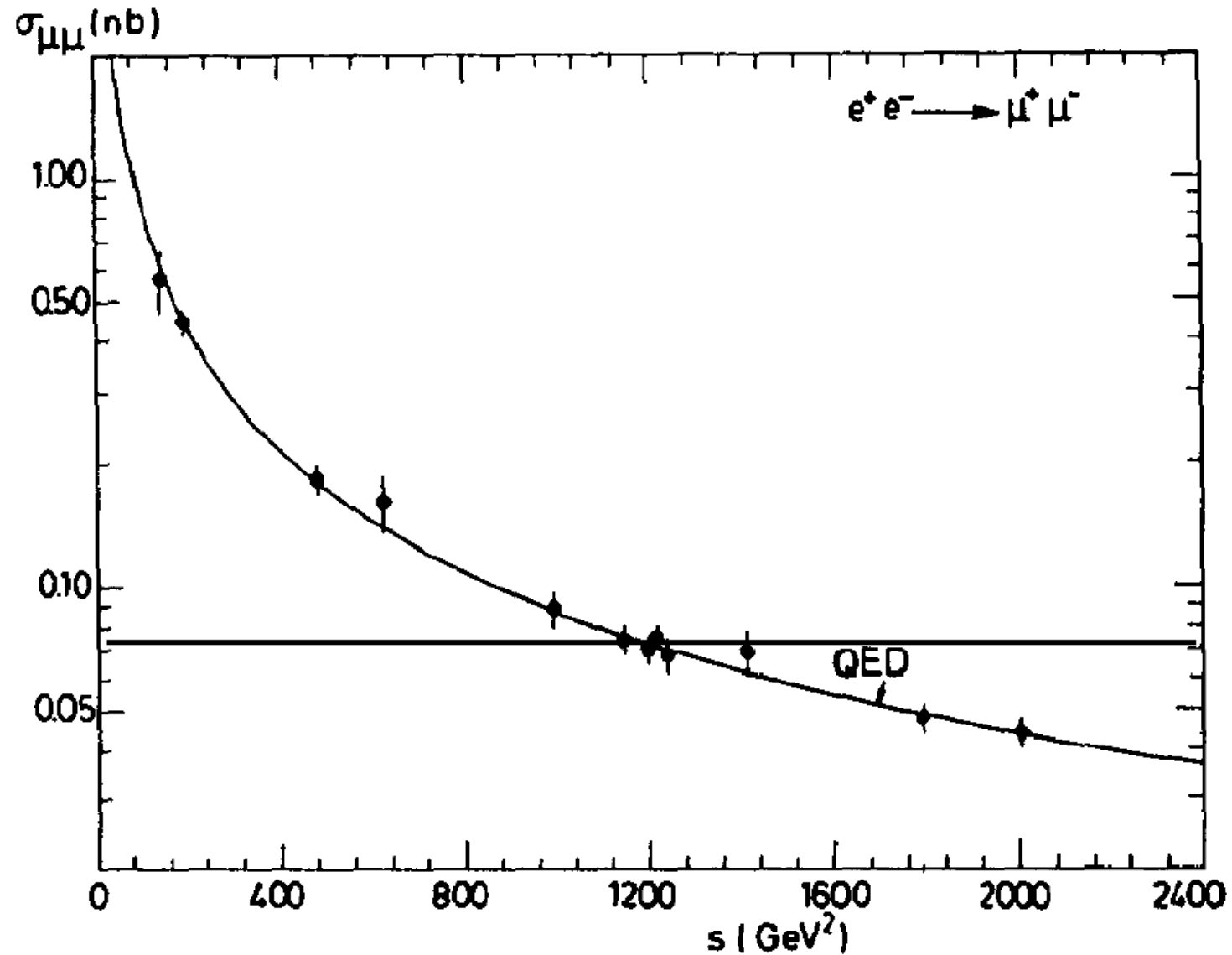
LEP Large Electron Positron Collider



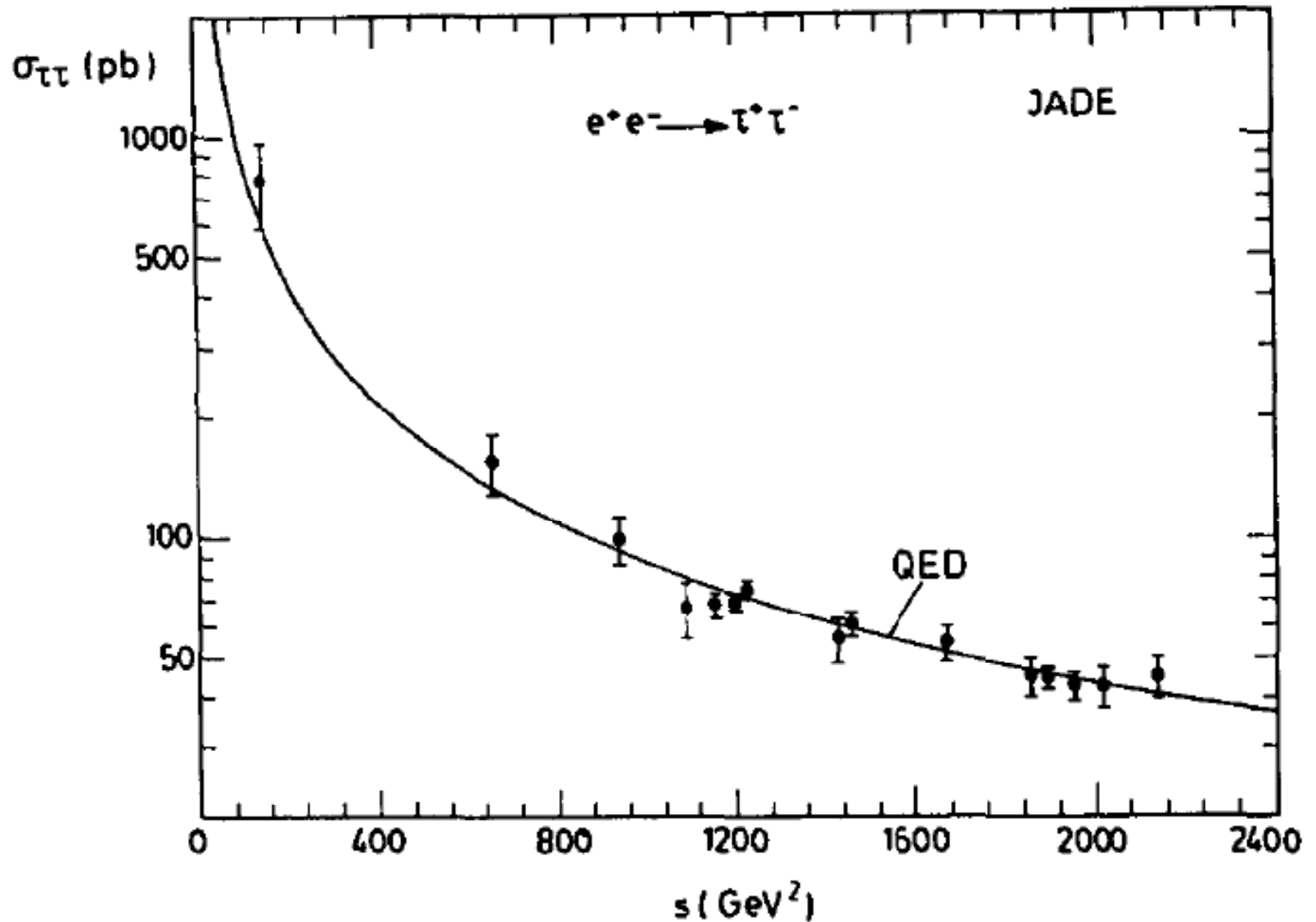
OPAL-Detektor



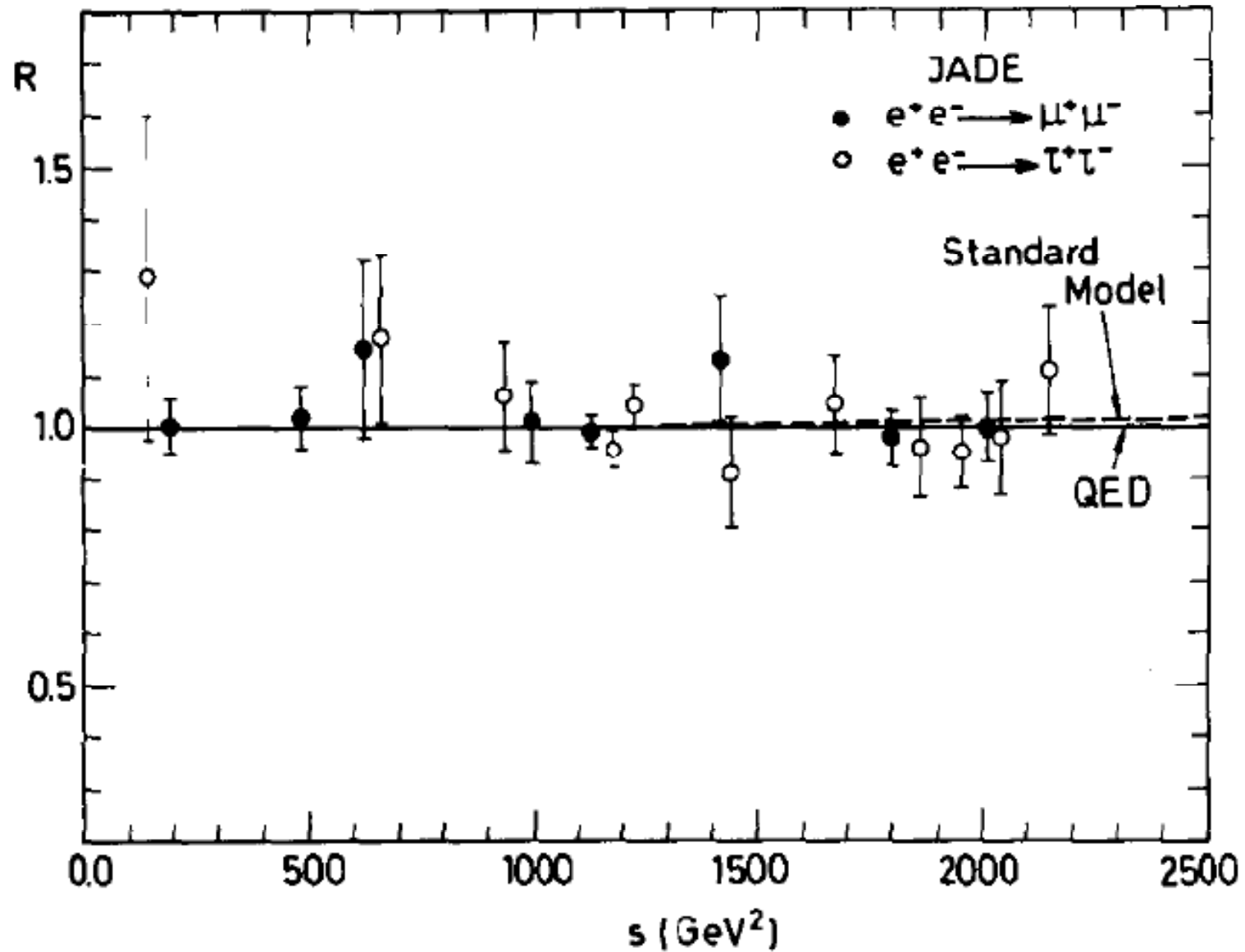
Totaler WQ für $e^+e^- \rightarrow \mu^+\mu^-$



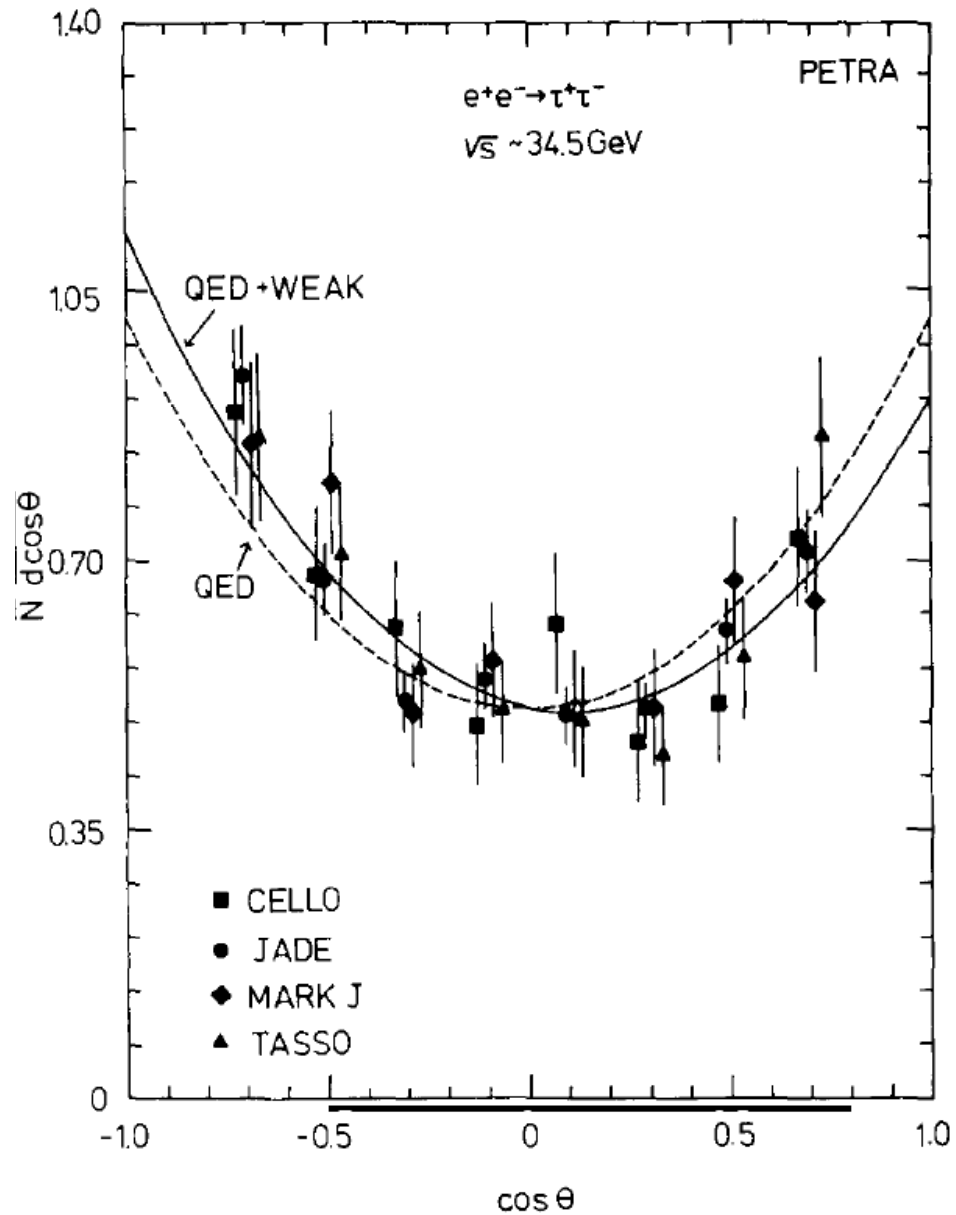
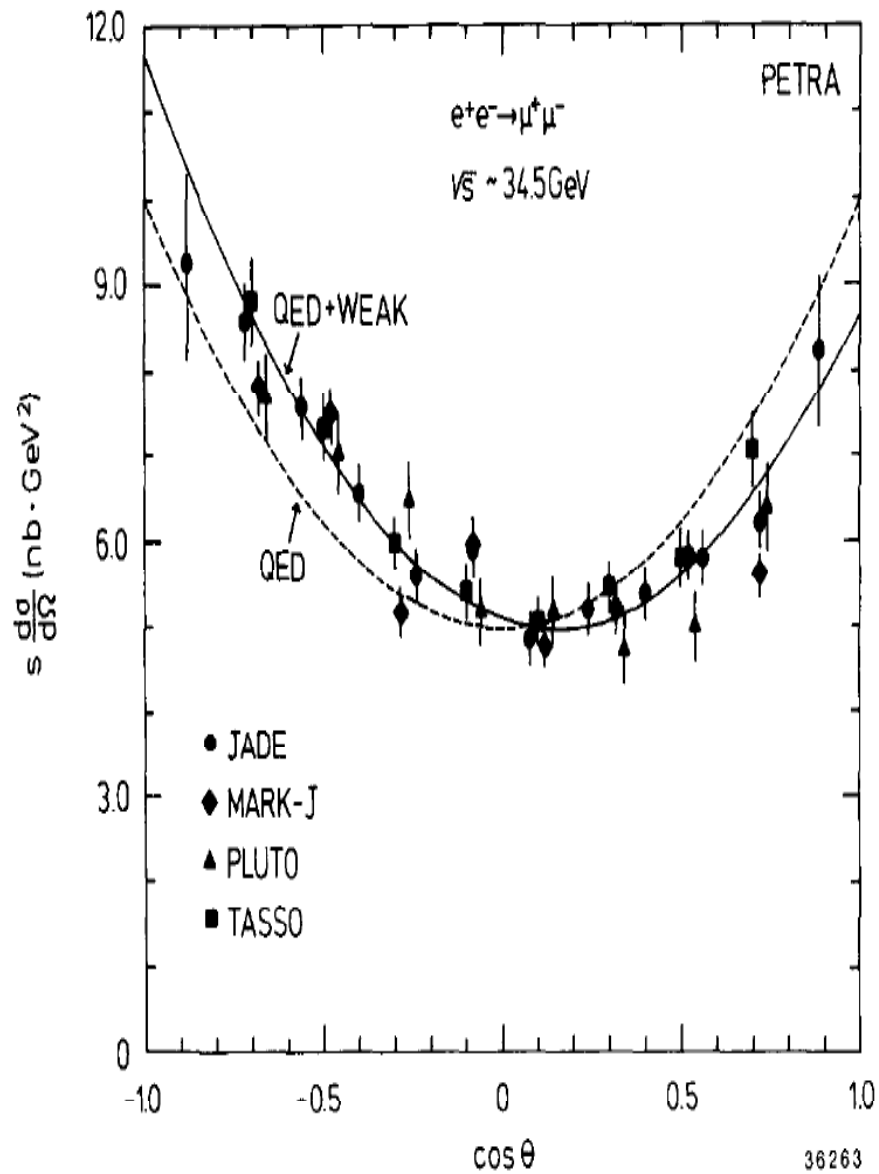
Totaler WQ für $e^+e^- \rightarrow \tau^+\tau^-$



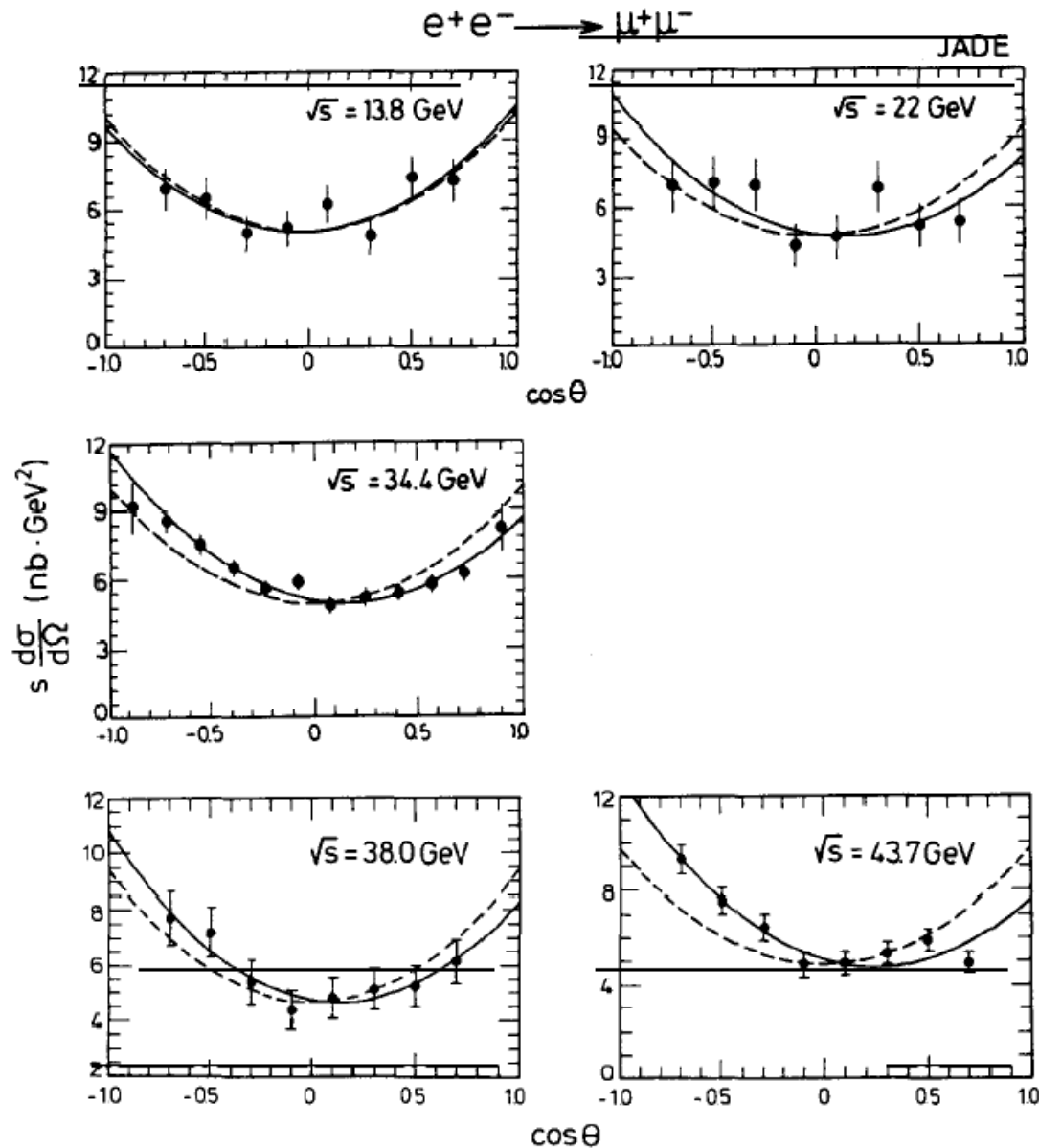
Test der QED und Leptonuniversalität



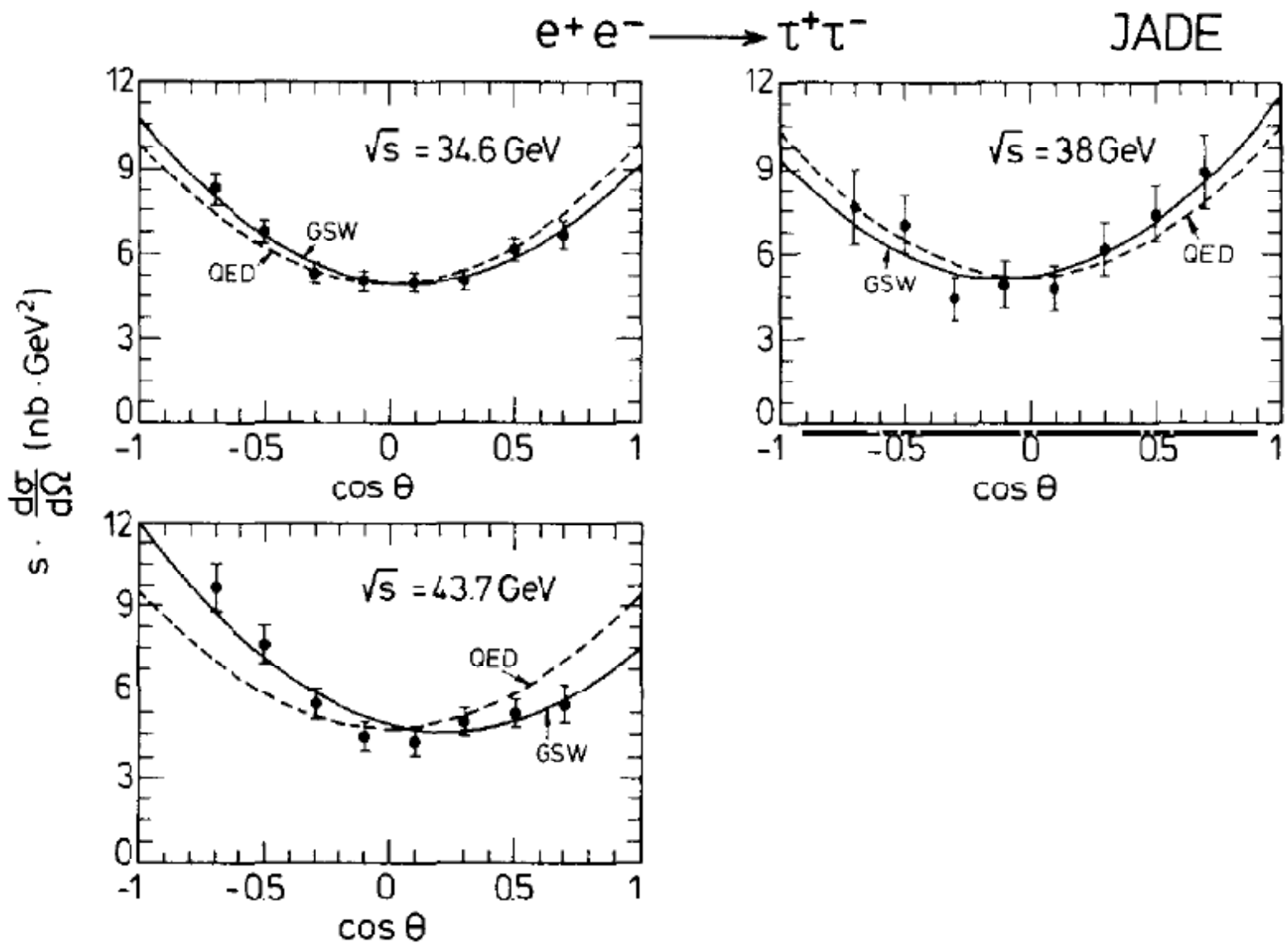
Differentieller WQ für $e^+e^- \rightarrow \mu^+\mu^-$ und $\tau^+\tau^-$



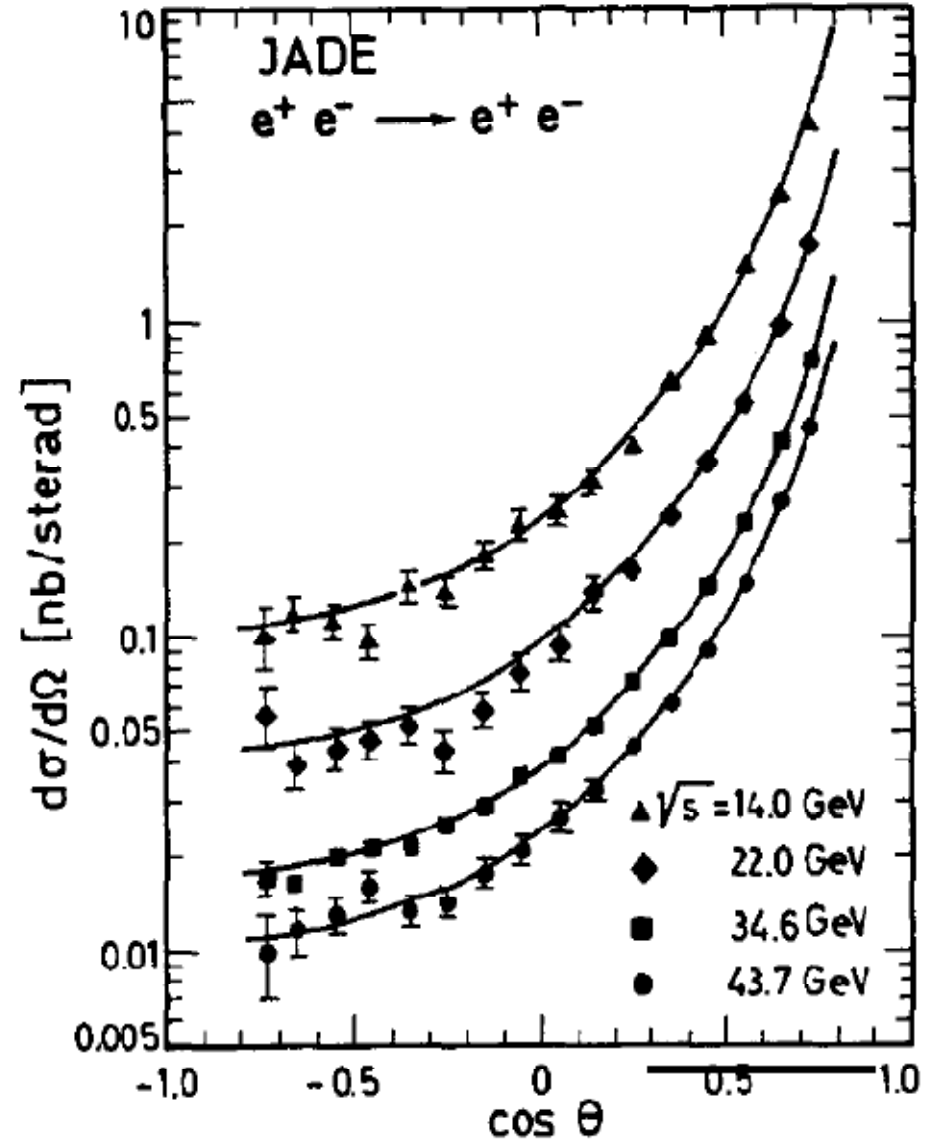
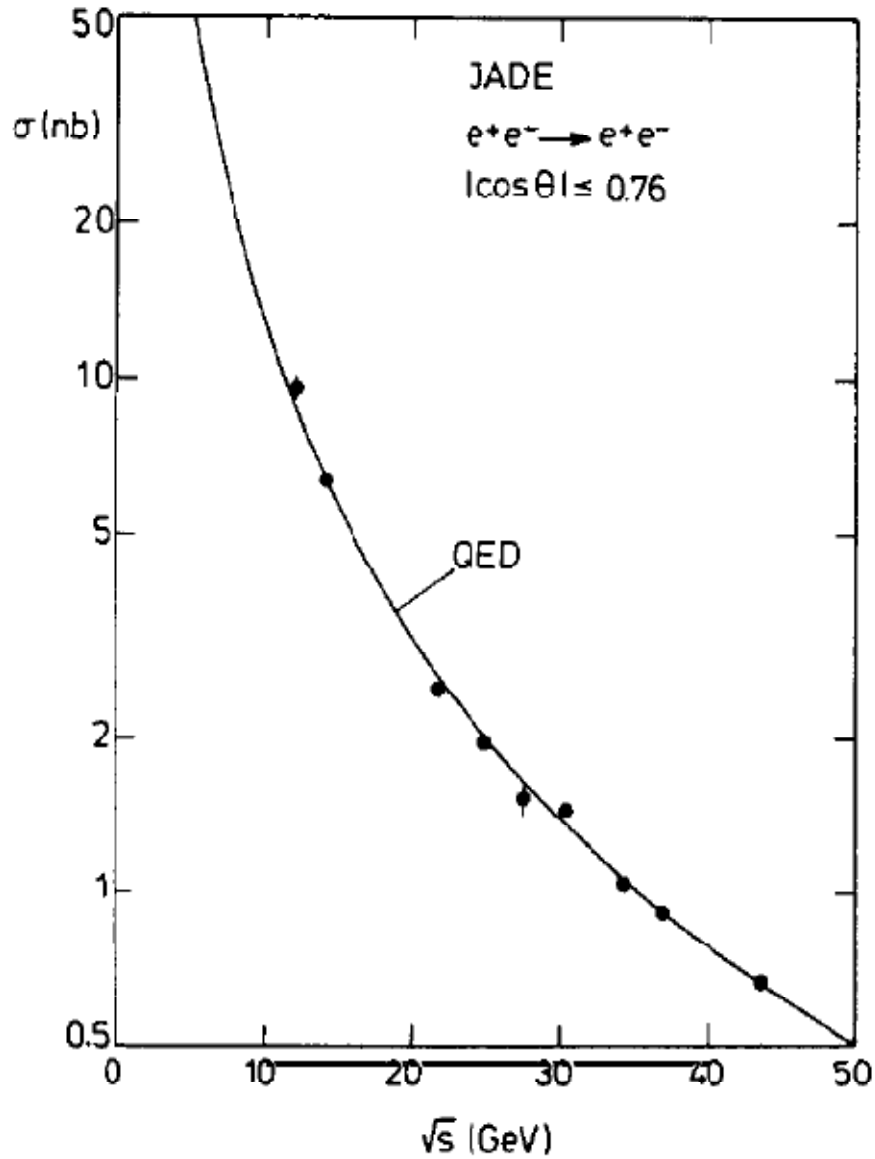
Differentieller WQ für $e^+e^- \rightarrow \mu^+\mu^-$ als Fkt. von s



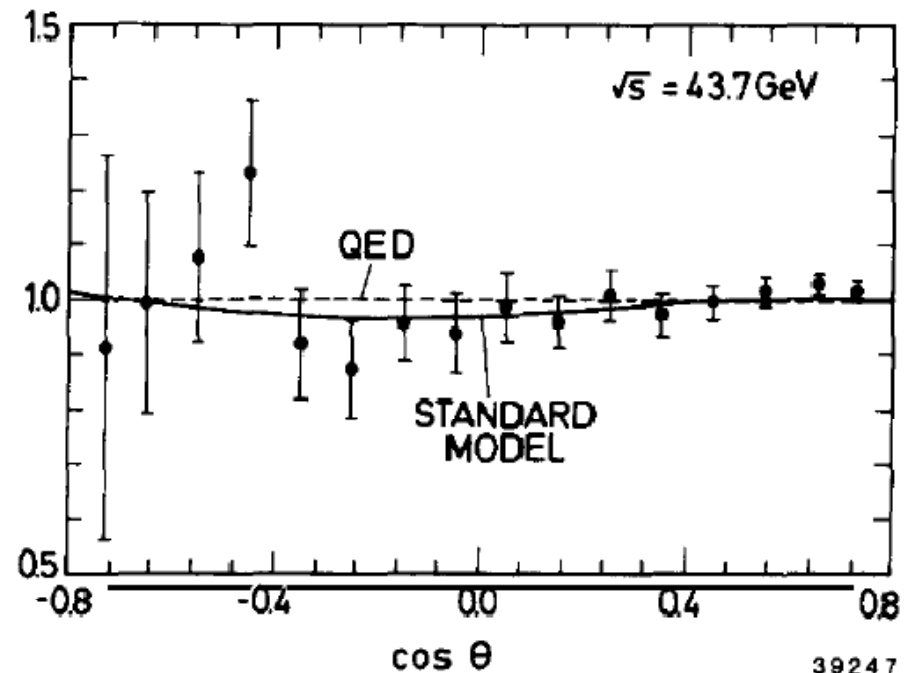
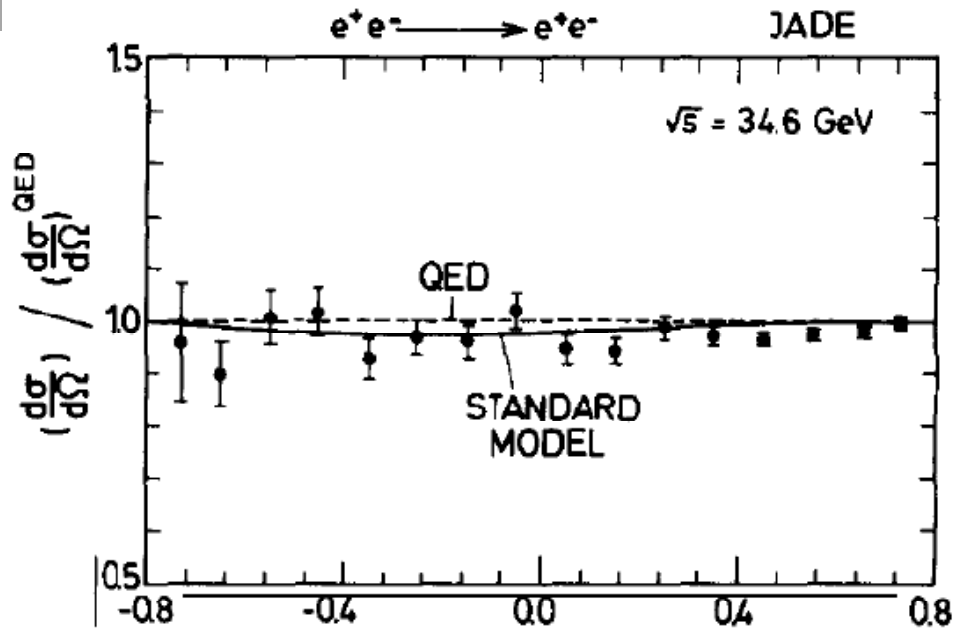
Differentieller WQ für $e^+e^- \rightarrow \tau^+\tau^-$ als Fkt. von s



Totaler und differentieller WQ für $e^+e^- \rightarrow e^+e^-$

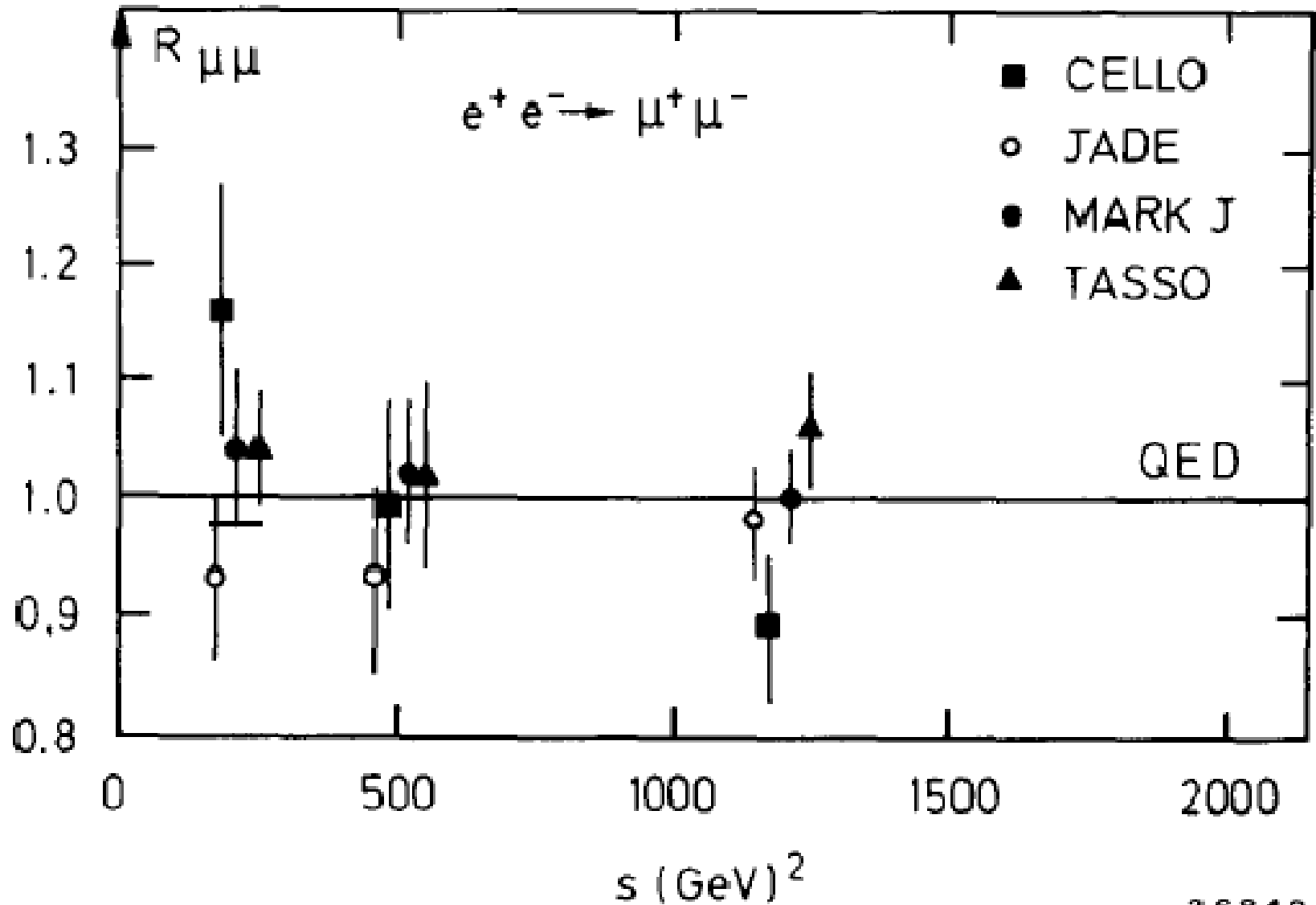


Differentieller WQ für $e^+e^- \rightarrow e^+e^-$: VGL zu QED



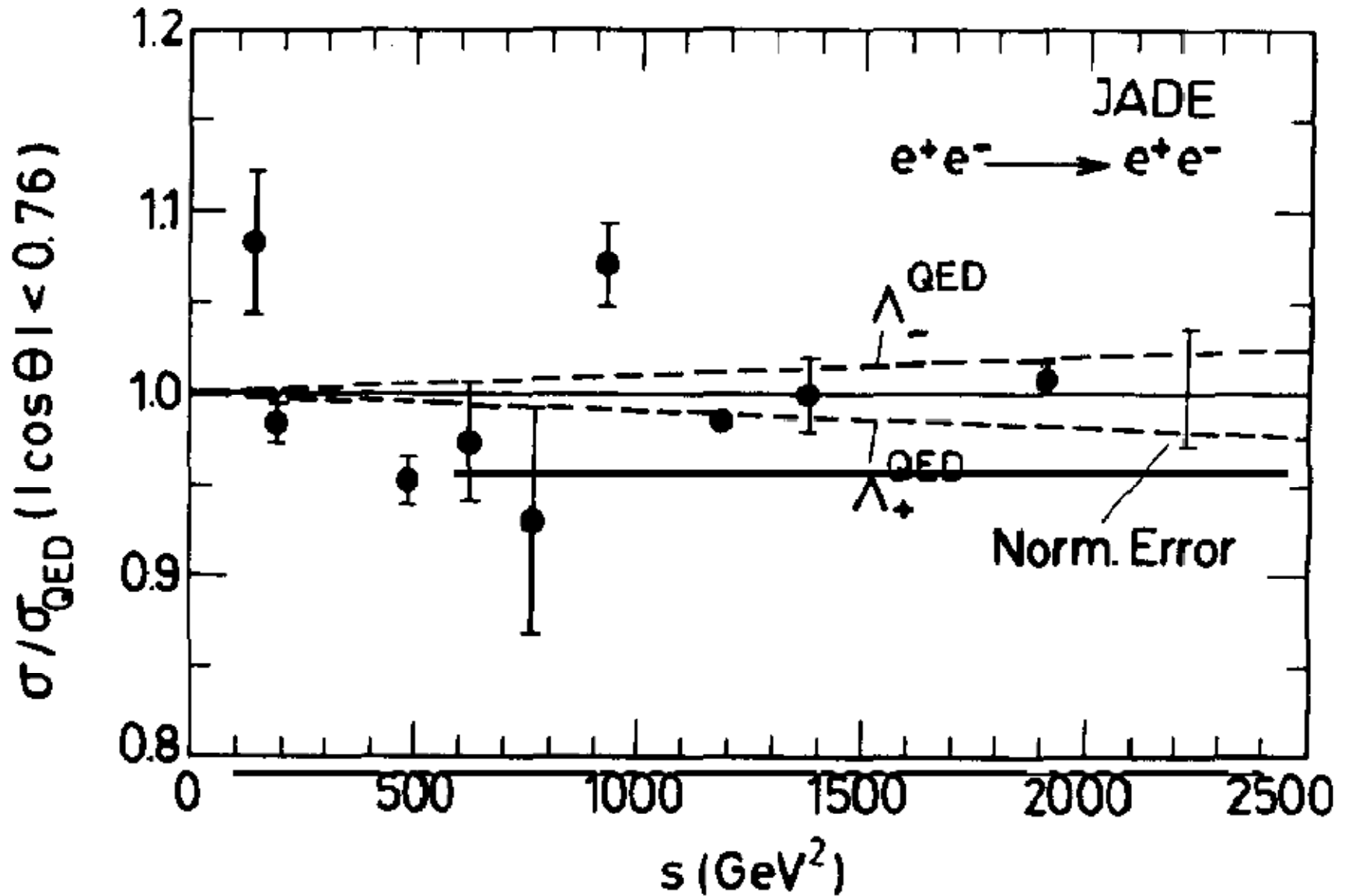
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Totaler WQ für $e^+e^- \rightarrow \mu^+\mu^-$: Test der QED

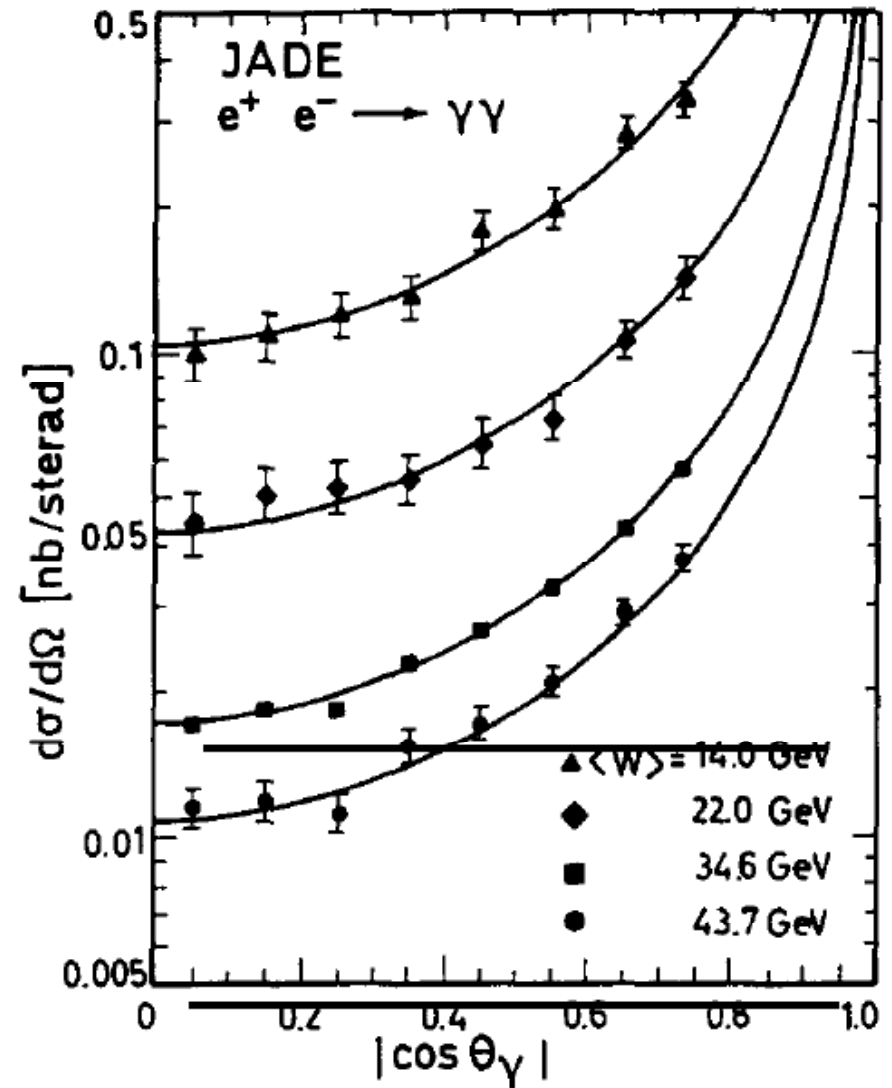
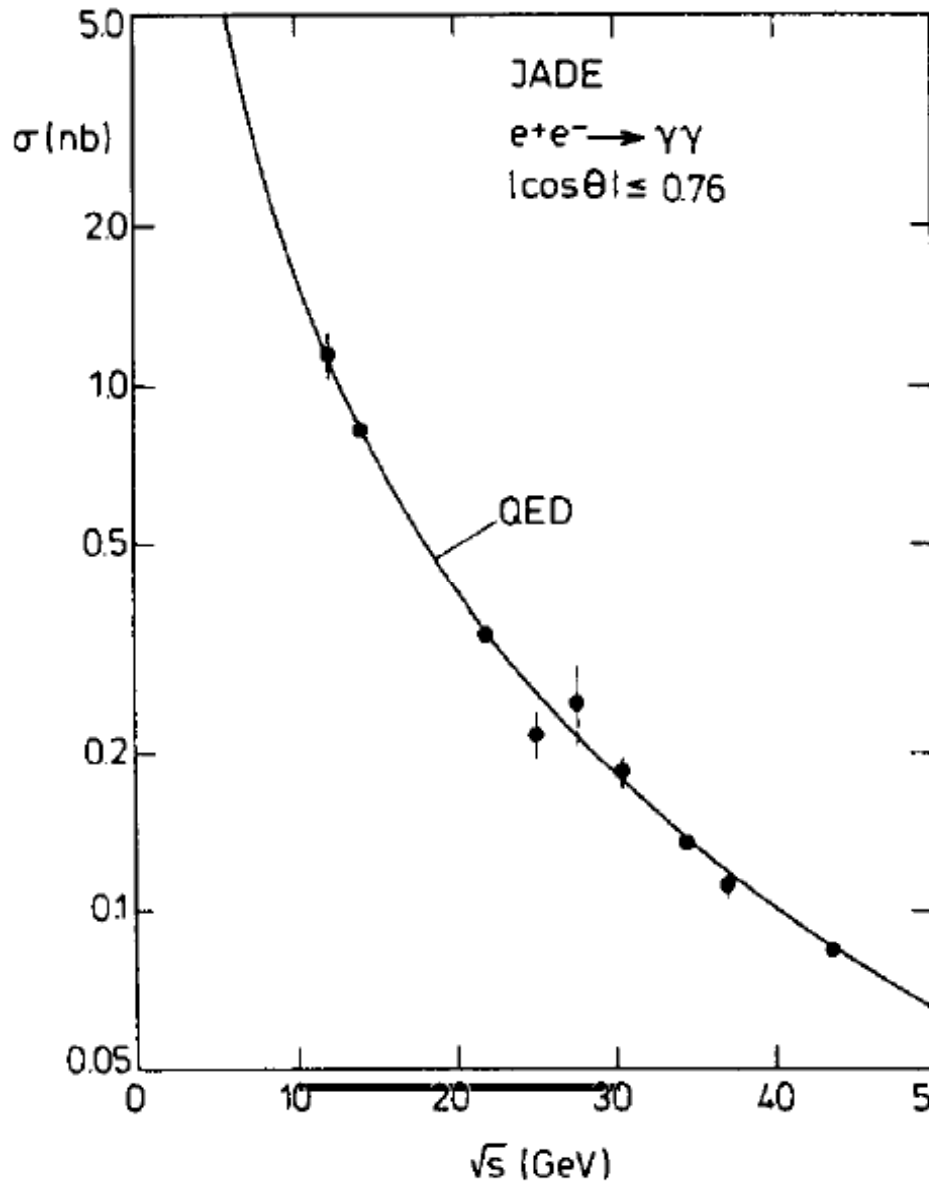


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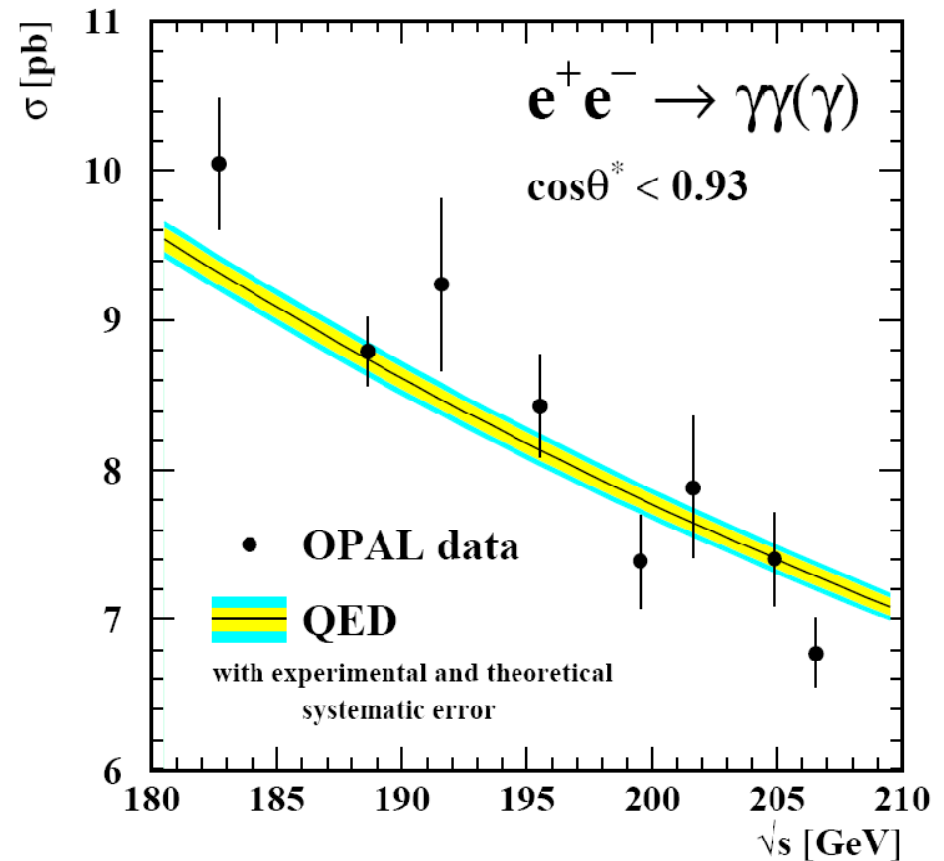
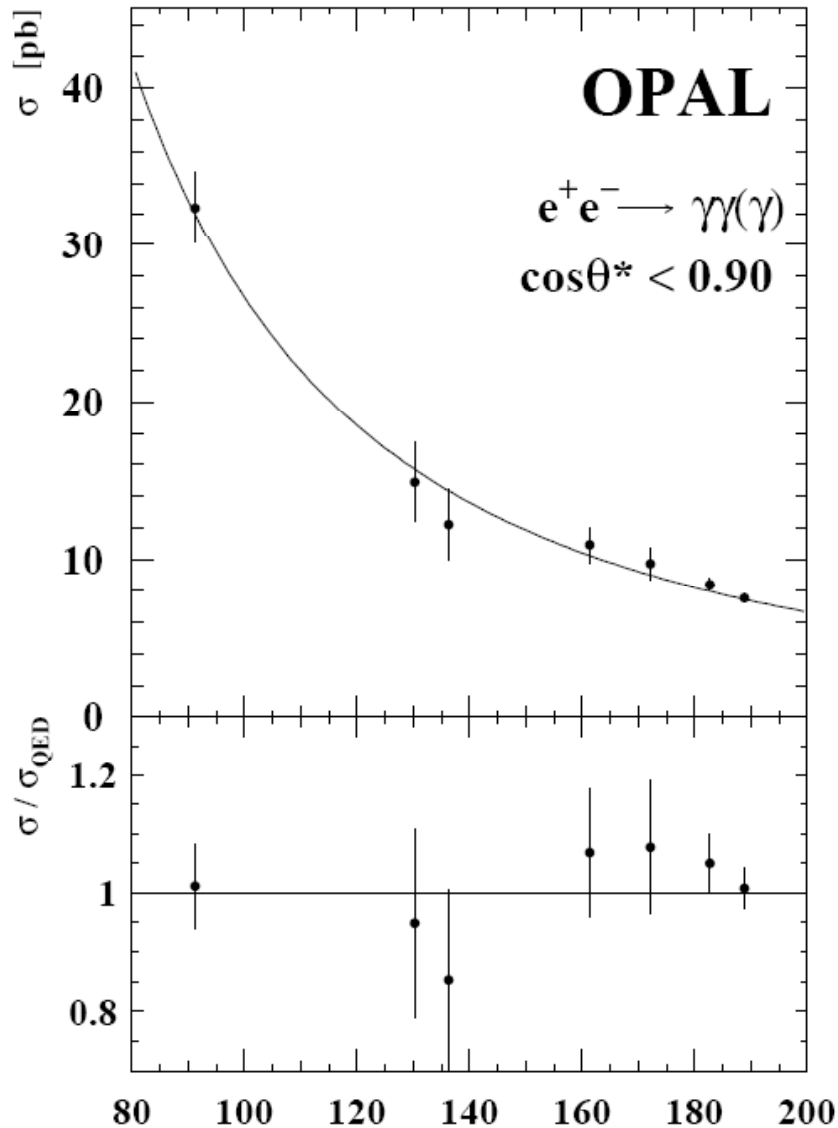
Grenzen auf neue Physik



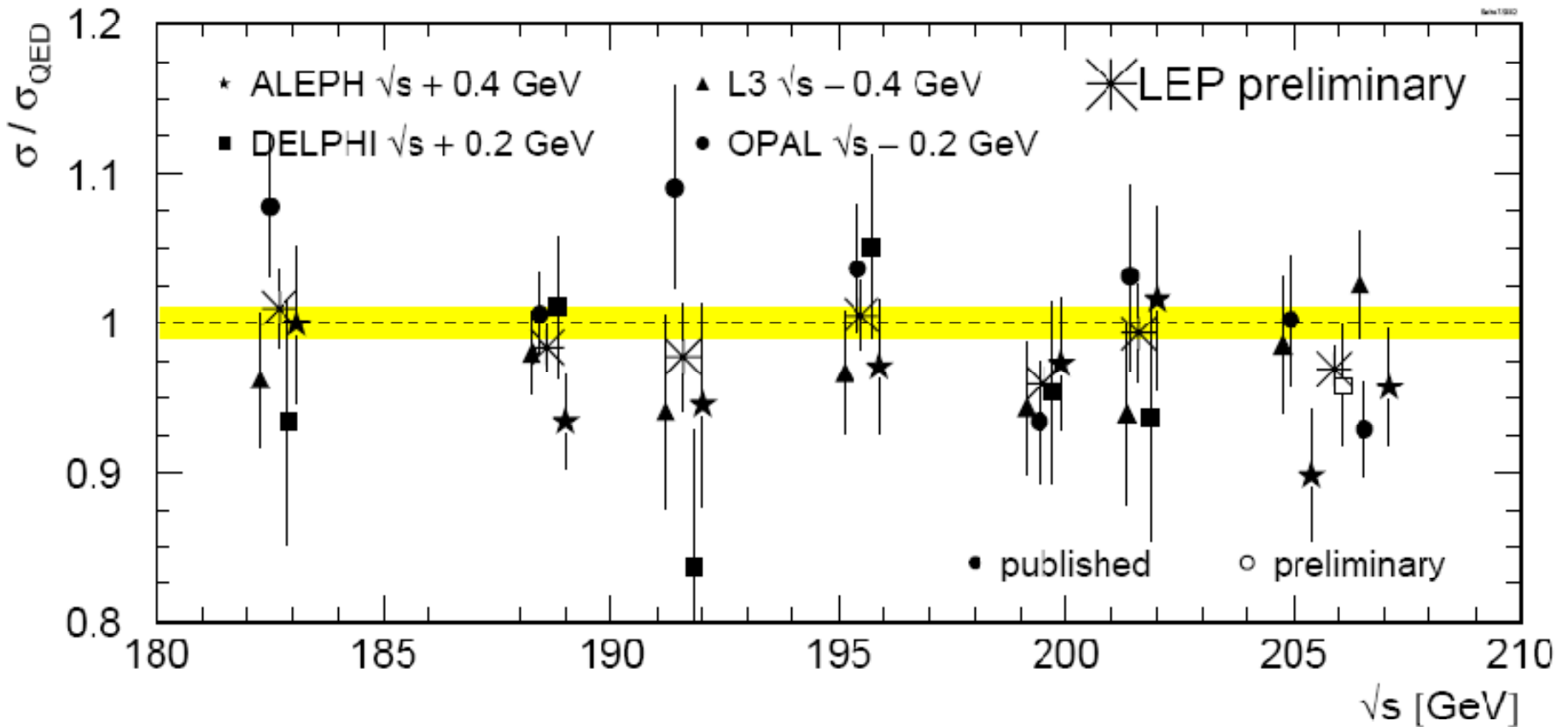
PETRA Test der QED in $e^+e^- \rightarrow \gamma\gamma$



LEP: Test der QED in $e^+e^- \rightarrow \gamma\gamma$

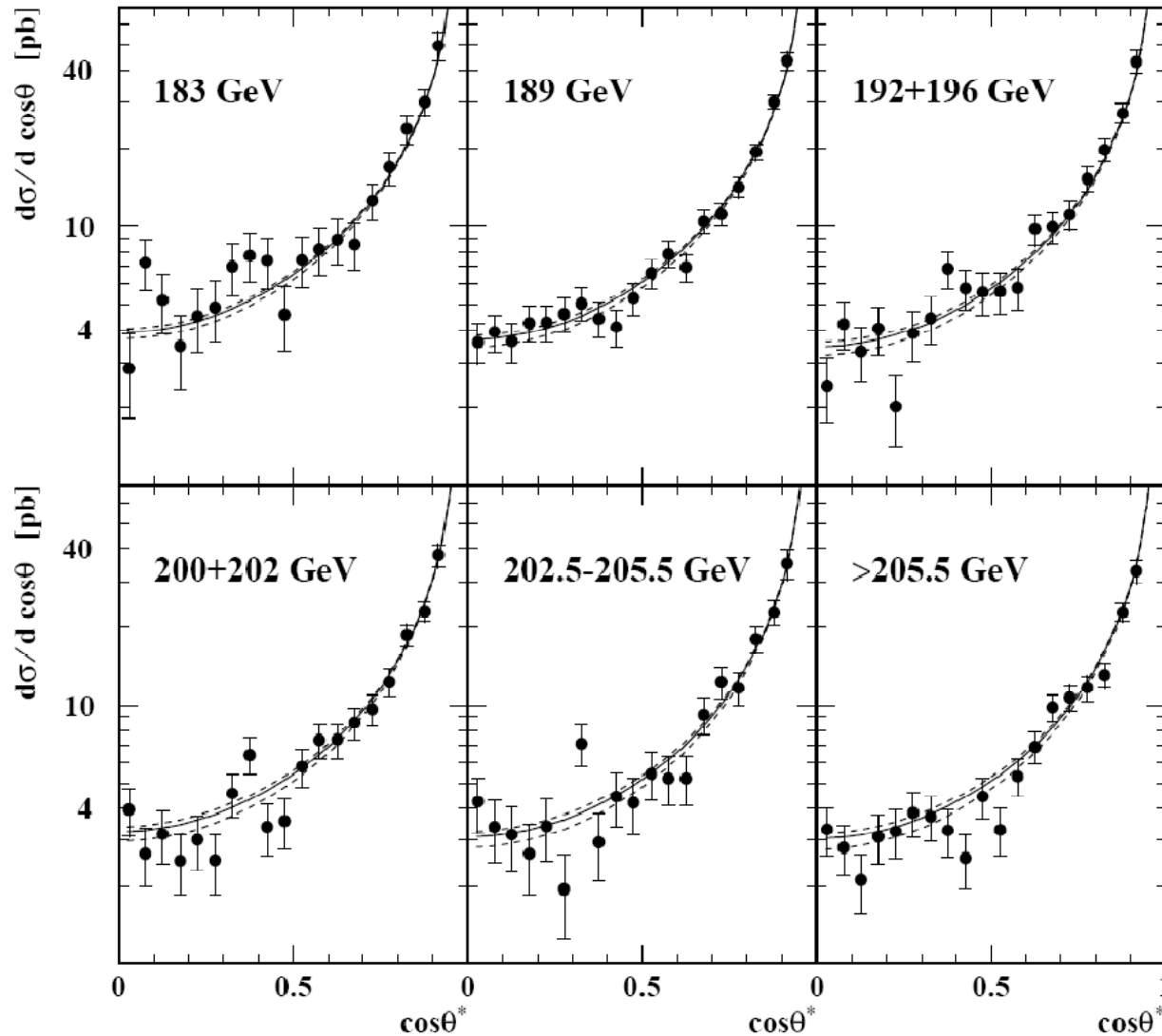


LEP: Test der QED in $e^+e^- \rightarrow \gamma\gamma$

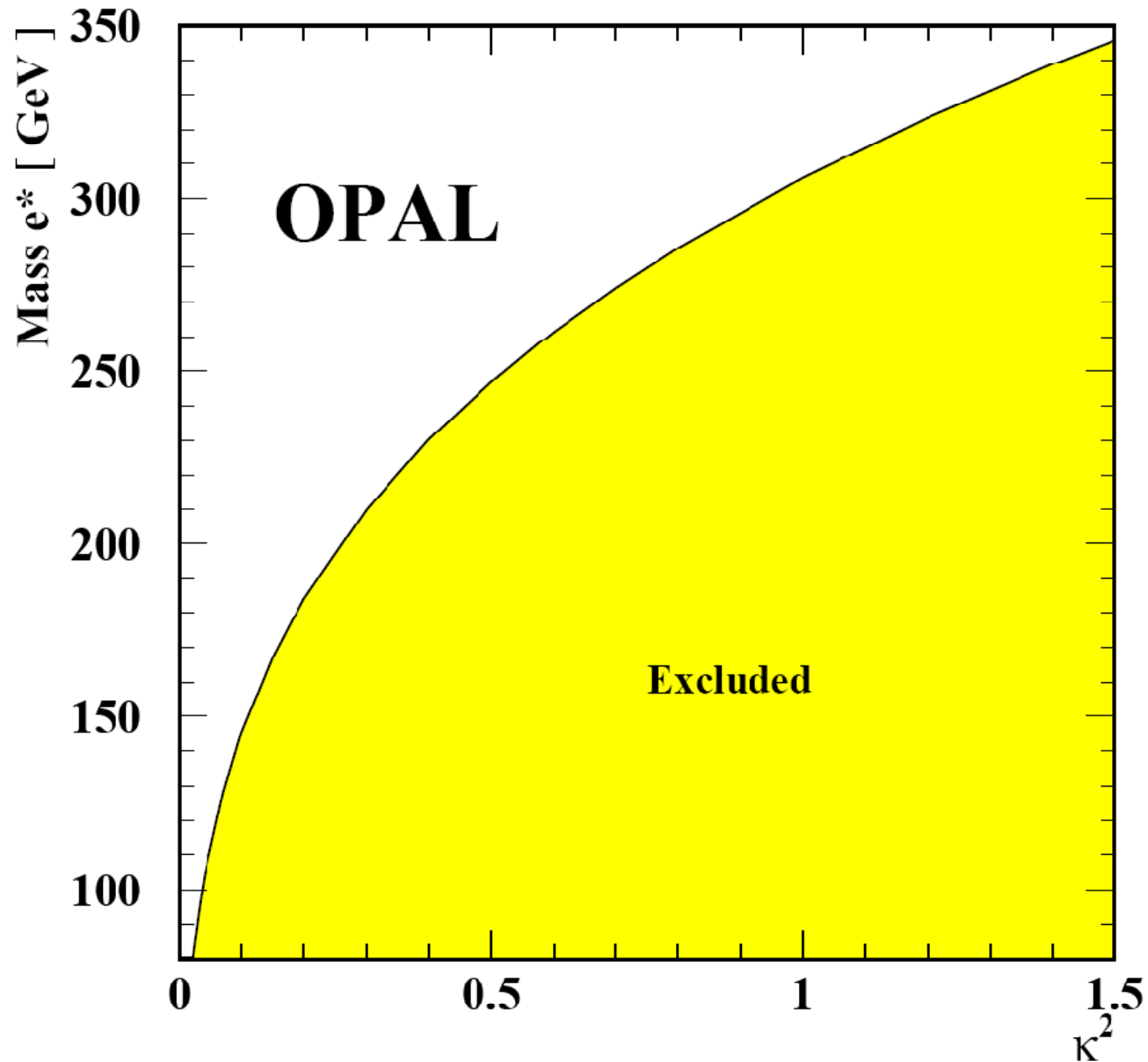


LEP: Test der QED in $e^+e^- \rightarrow \gamma\gamma$

$e^+e^- \rightarrow \gamma\gamma(\gamma)$ OPAL



Grenzen auf die Masse eines schweren Elektrons



Messung der laufenden Kopplung der QED

