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25th Oct 00'

σ^{tot} in e^+e^- : $(\sigma(e^+e^- \to e^+e^-\gamma\gamma \to e^+e^-$ hadrons$))$

1. Introduction $(\sigma_{\gamma\gamma}^{tot})$

2. Models of $\sigma_{\gamma\gamma}^{tot}(\gamma\gamma \to$ hadrons$)$ and comparison with data.

   What can linear colliders do to distinguish among models.

3. Folding with photon spectra from e^-/e^+ to calculate $\sigma^{tot}(e^+e^- \to e^+e^-$ hadrons$)$.

4. Outlook.

Calculation of $\sigma(e^+e^- \to e^+e^-\gamma\gamma \to e^+e^-\ \text{hadrons})$:

in good old Weizäcker Williams approximation.

(A) $\sigma(e^+e^- \to e^+e^-\gamma\gamma \to e^+e^-\ \text{hadrons})$

$$= \int dx_1 \int dx_2 \boxed{f_{\gamma_1/e}(x_1)\, f_{\gamma_2/e}(x_2)} \cdot \boxed{\sigma_{\gamma\gamma}^{tot}(\hat{s} = s\, x_1 x_2)}$$

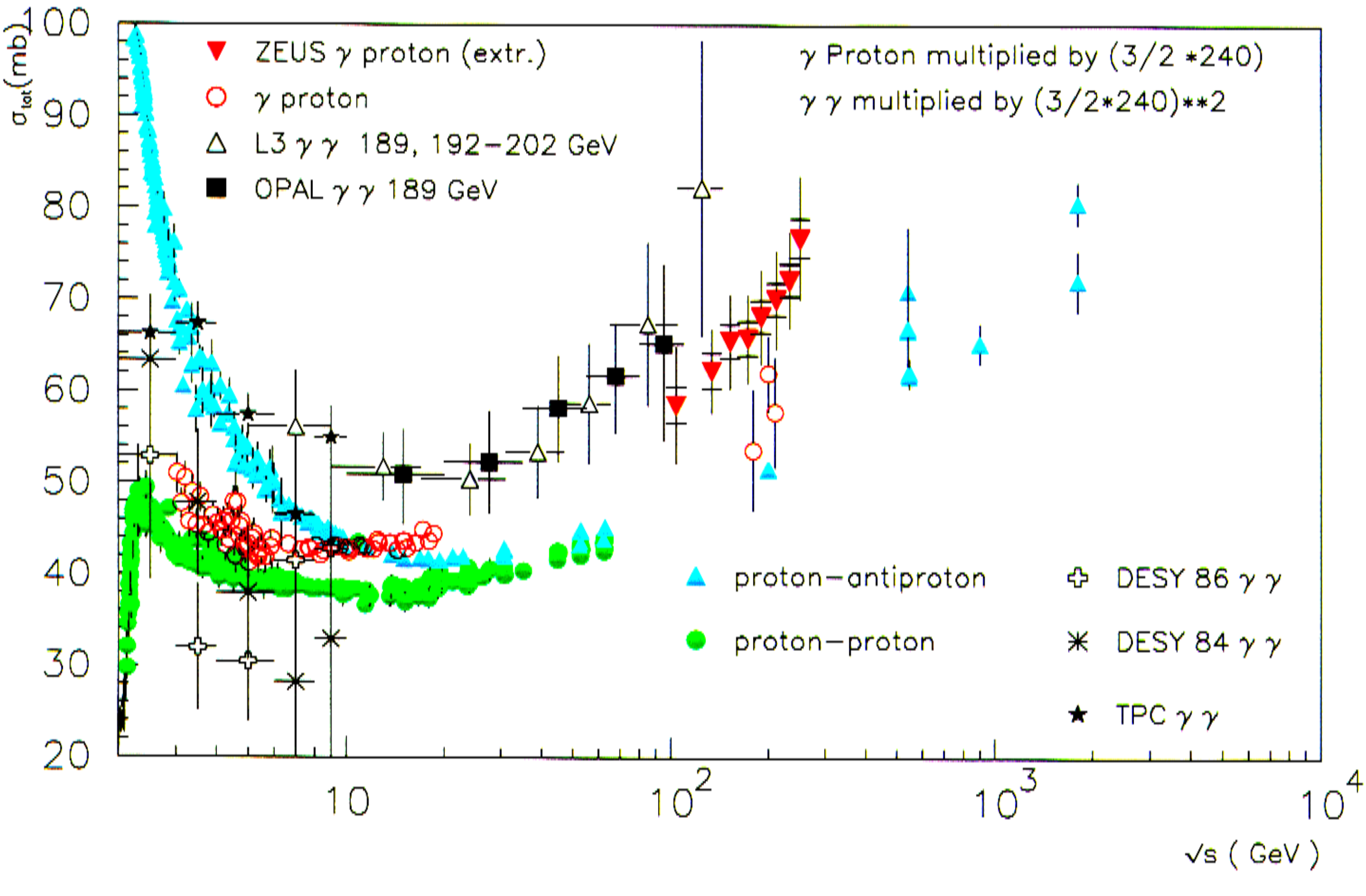
Begin with energy dependence of $\sigma_{\gamma\gamma}^{tot}(s)$.

* Theoretically very interesting. Hadronic cross-sections do rise with $\sqrt{s}$. A theoretical understanding in terms of basic physics is a challenging problem

* Pragmatically knowledge required to know (A)
  $\Rightarrow$ hadronic background caused by 2γ processes.
  Certainly needs to be estimated for machine like CLIC.

* $\gamma\gamma$ provides one more place to test theoretical models
* Increase our understanding of γ^s.
* The state of data improved dramatically with LEP.

(3)



* All cross-sections rise with $\sqrt{s}$.

* $\gamma\gamma$ seem to rise faster than $pp(\bar{p}p)/\gamma p$

Two types of Models

1. QCD based models:

(i) F_2^γ related to σ. Badelek, Kwiecinski, Stasto, Krawczyck. hep-ph/001161

(ii) Eikonalized Minijet Model (EMM) G. Pancheri, RG. Pythia, Phojet.

(iii) A version of EMM where overlap functions which control the rise calculated using QCD based ideas G. Pancheri, Grau, Srivastava

2. "Photon is like a proton"

(i) Regge/Pomeron : $\sigma^{tot} = Y_{ab}\, s^{-\eta} + X_{ab}\, s^{\epsilon}$

with $X_{\gamma\gamma} X_{pp} = X^2_{\gamma p}$ $\eta = 0.467$, $\epsilon = 0.079$

DL PLB, 296 (1992) 227. (Donnachie and Landshoff)

(ii) SAS : ZPC 73 (1997) 677. : similar to DL.

(iii) C. Bourrelly, J. Soffer, T.T. Wu : $\sigma_{\gamma\gamma} = A\, \sigma_{pp}$
MPLA 15 (2000) 9.

(iv) Aspen model : M.M. Block et al PRD 58 (1998) PRD 60 (1999)

It is like EMM; but with various parameters obtained from proton using Quark Model ideas

(v) GLMN model : EMM type model. Some inputs fixed using $pp/\bar{p}p$ case.

EMM :

$$\sigma_{\gamma p}^{tot} = 2 P_{had} \int d^2\vec{b} \left[1 - e^{-\chi_I} \cos \chi_R\right] \quad \text{--- (1)}$$

($\cos \chi_R \approx 0$)

$$\chi^I(s, b) = A(b) \left[\sigma^{soft}(s) + \frac{1}{P_{had}} \sigma^{jet}(s, p_T^{min})\right] \quad \text{--- (2)}$$

P_{had} : prob. that photon hadronizes

$$= \sum_{V=\rho,\omega,\phi} \frac{4\pi\alpha}{f_V^2} \simeq \frac{1}{240}$$

$\sigma^{soft}(s)$: non pert. parameter → fitted

A(b) : overlap of the partons in the two hadrons

$$\sigma^{jet} = \int_{p_T^{min}} \frac{d\sigma}{dp_T} \, dp_T$$

→ determined by QCD

* ↳ A(b) determined as F.T. of the distribution of partons in transverse space.

(f^n of k_T $dist^n$ of partons in photon) Transp.

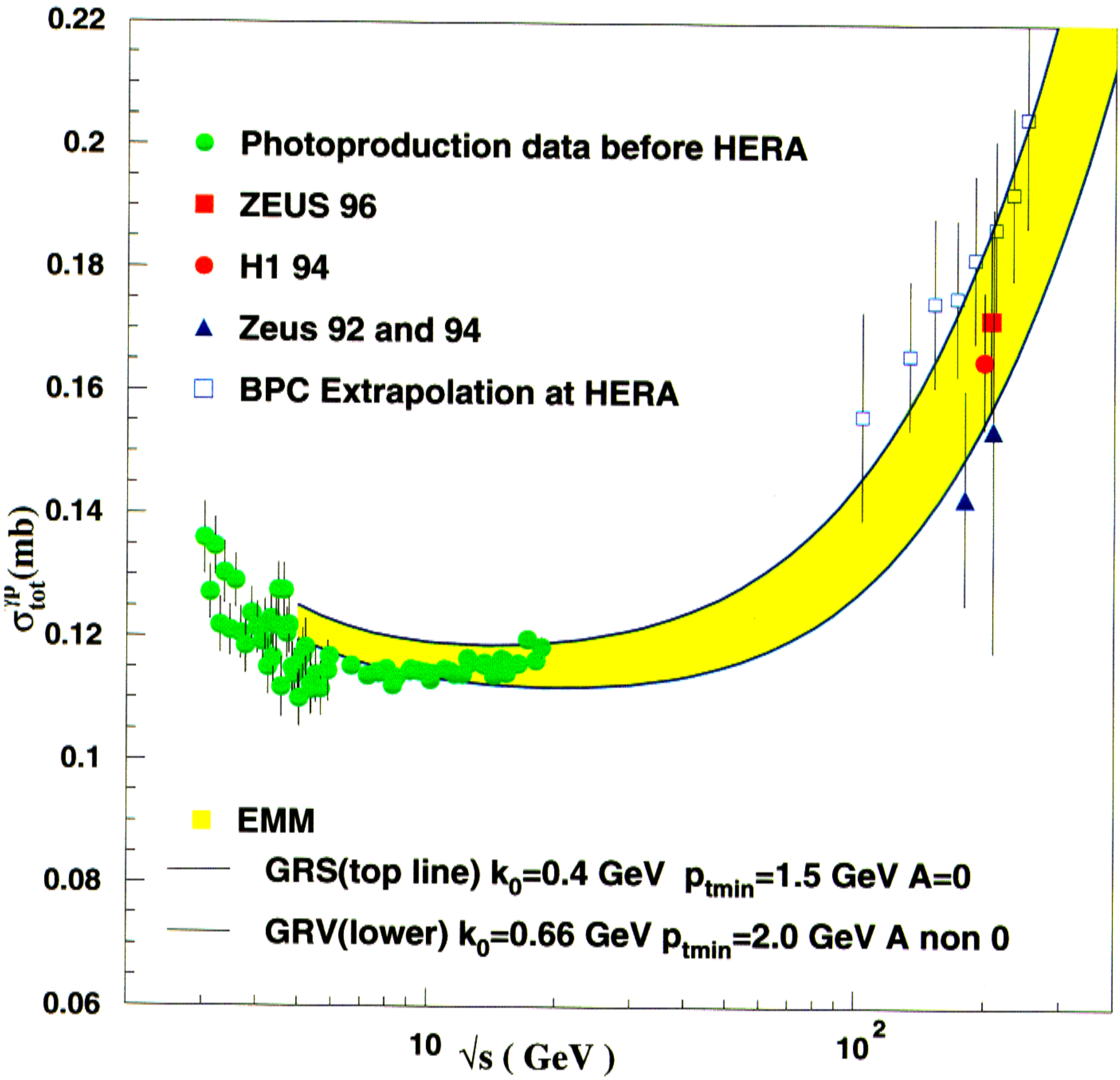
↳ σ^{jet}: This drives the rise of $\sigma_{\gamma p}^{tot}$ with $\sqrt{s}$.

But the $\int [1 - e^{-\chi_I}]$ factor tempers the rise to satisfy unitarity.

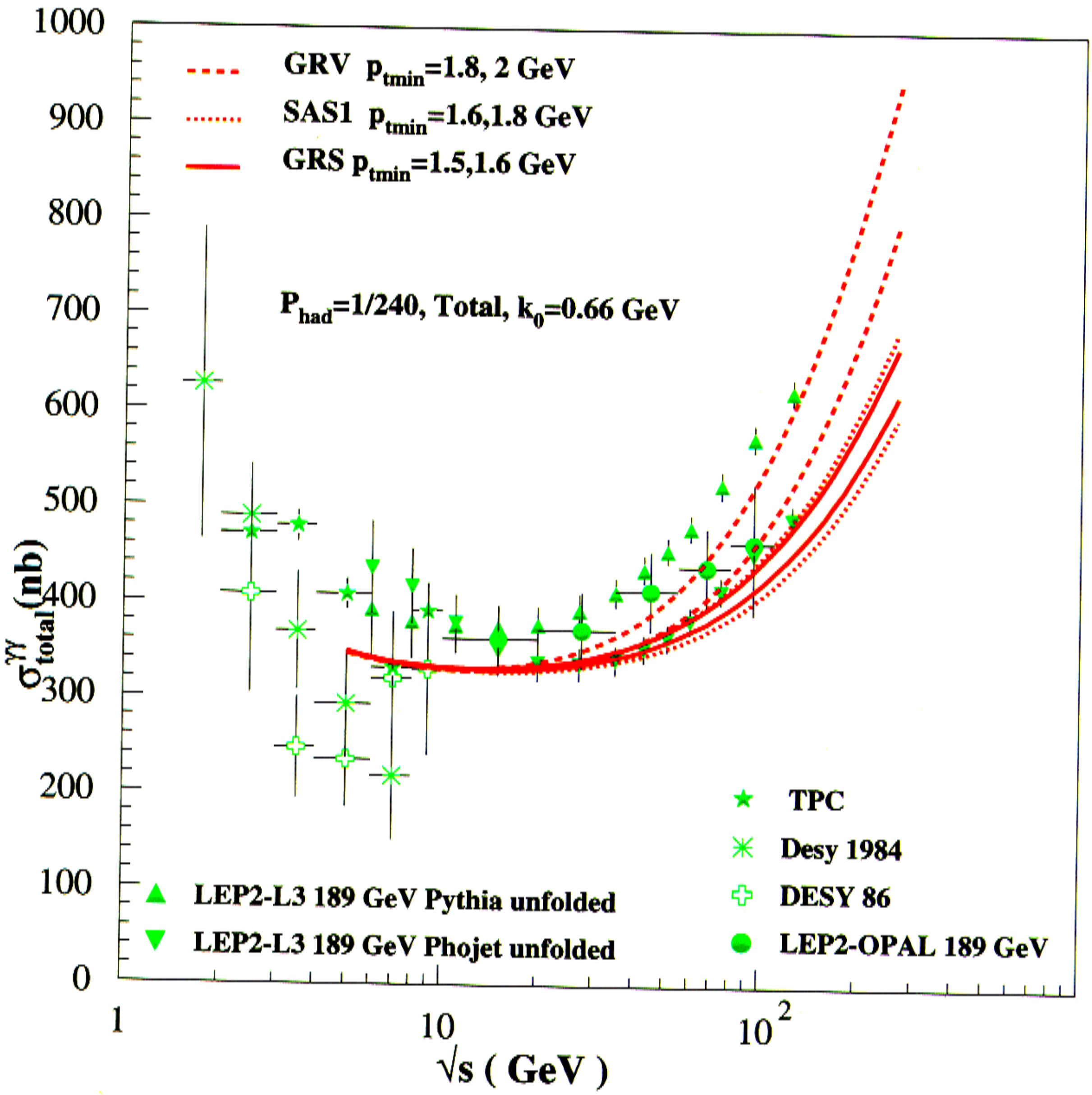
For $\gamma\gamma$

$$\sigma_{\gamma\gamma}^{soft} = \frac{2}{3} P_{had} \, \sigma_{\gamma p}^{soft}$$

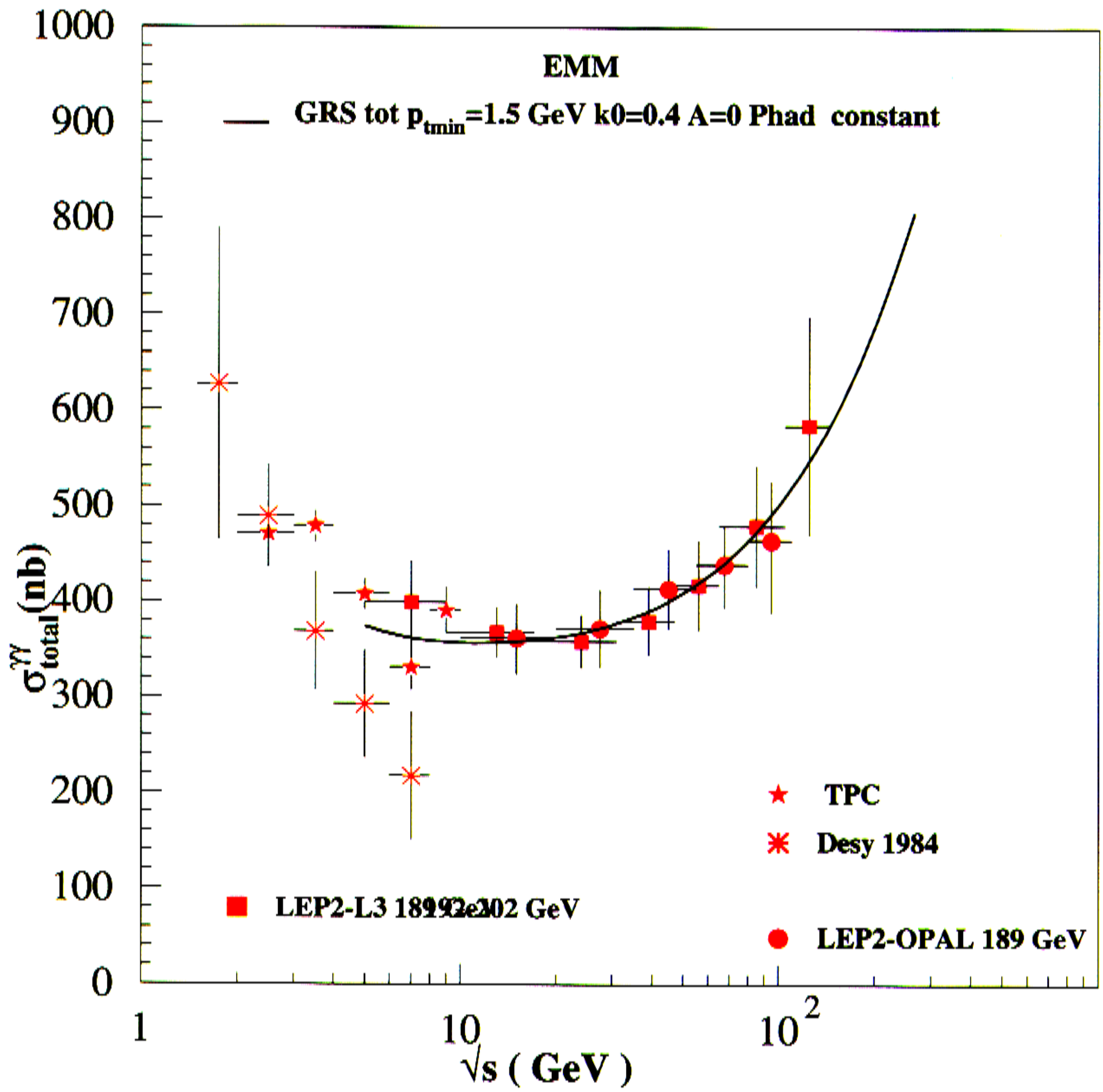
replaced $P_{had} \to (P_{had})^2$



exptally measured value of $K_0 = 0.66 \pm 0.22$ GeV



GRV p_{tmin}=1.8, 2 GeV
SAS1 p_{tmin}=1.6,1.8 GeV
GRS p_{tmin}=1.5,1.6 GeV
P_{had}=1/240, Total, k_0=0.66 GeV
TPC
Desy 1984
DESY 86
LEP2-OPAL 189 GeV
LEP2-L3 189 GeV Pythia unfolded
LEP2-L3 189 GeV Phojet unfolded
$\sigma^{\gamma\gamma}_{total}$ (nb)
$\sqrt{s}$ (GeV)
1000
900
800
700
600
500
400
300
200
100
0
1
10
10^2



This value of k_0 corresponds to topmost edge of the band for predictions in $\sigma_{\gamma p}$.

~ 10 % higher normalization

Aspen Model

Similar to EMM formulation.

Except: the σ_{jet}, $A(b)$ in EMM calculated in terms of parton densities in the two hadrons, QCD and form factors of hadron.

In Aspen model the parameters are fitted to $\bar{p}p$ data. Then factorization and Quark model is used

Bloch-Nordsieck model

$A(b)$ calculated from QCD resummation.

comparison of various model prediction with data

Data for $\gamma\gamma$ seem to rise faster than predictions of most 'photon is like a proton' models.

L3 data and the some of the mdoels

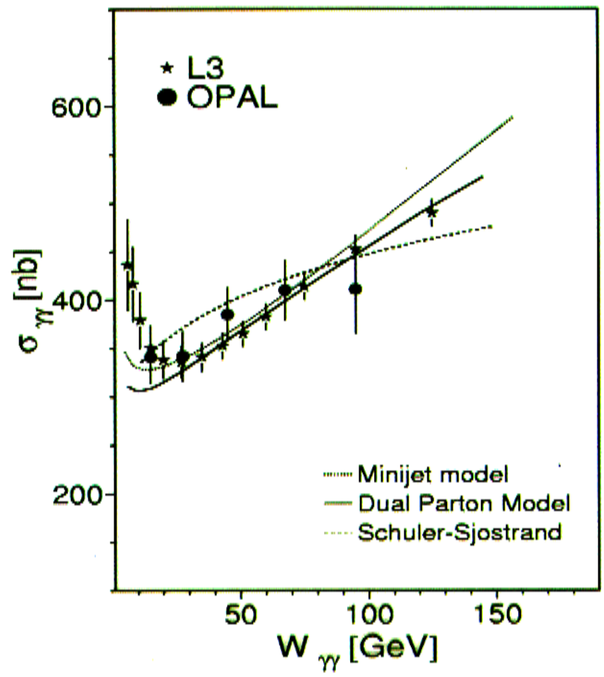
Comparison of the data with the predictions of these EMM type models and a representative Regge-Pomeron type model.

The Regge-Pomeron type models fit

$\sigma^{\gamma\gamma} = Y_{\gamma\gamma} s^{-\eta} + X_{\gamma\gamma} s^{\epsilon}$

Here the ϵ, η are assumed to be the same as that for the pp case.

However the data on $\gamma\gamma$ seem to indicate that the vlaue of ϵ for $\gamma\gamma$ case is higher than that for $pp(\bar{p}p)$.



This is not clear though. Recall the first slide on the data. This situation needs to be clarified.

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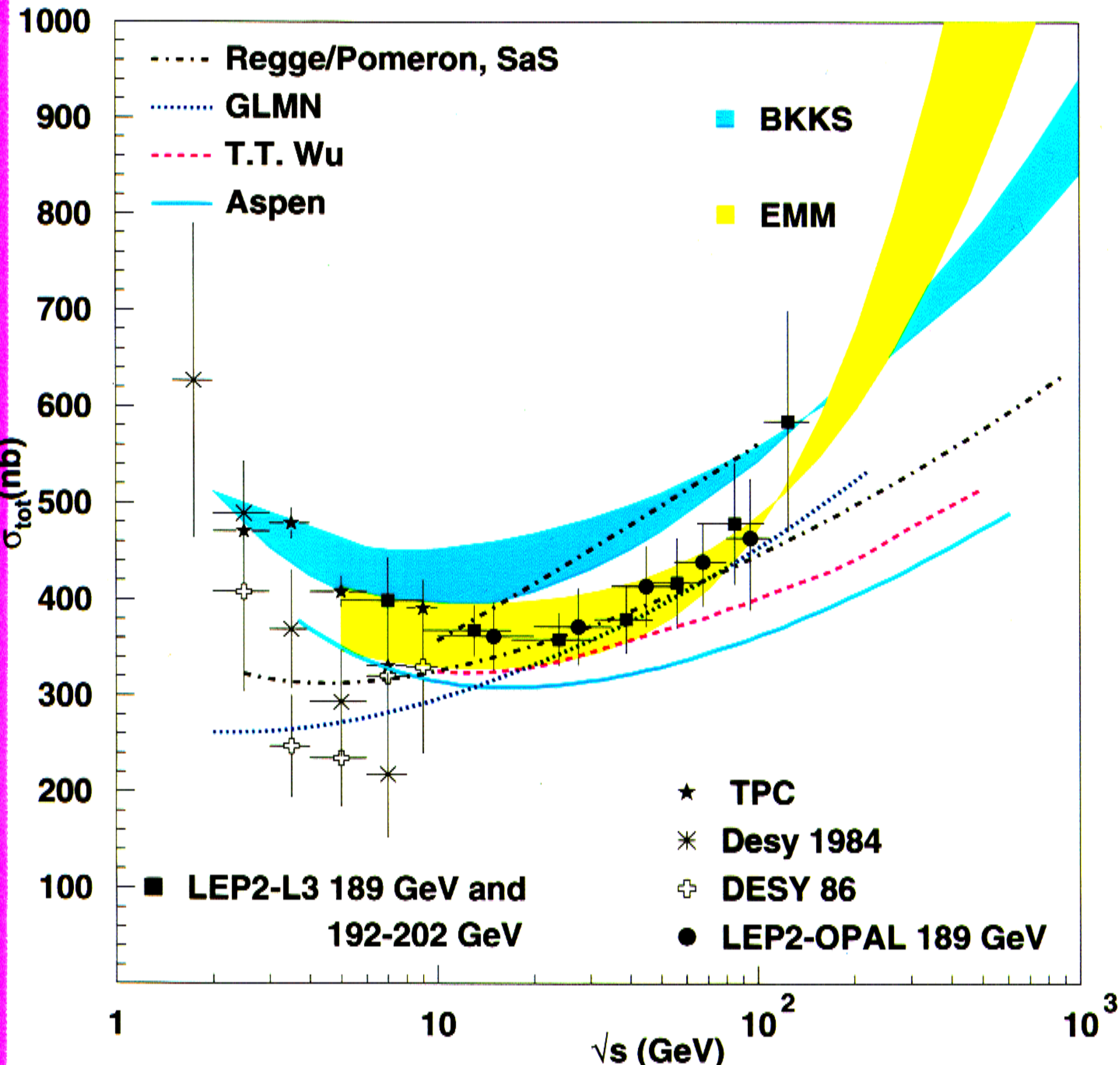
G. Pancheri, R.M.G.



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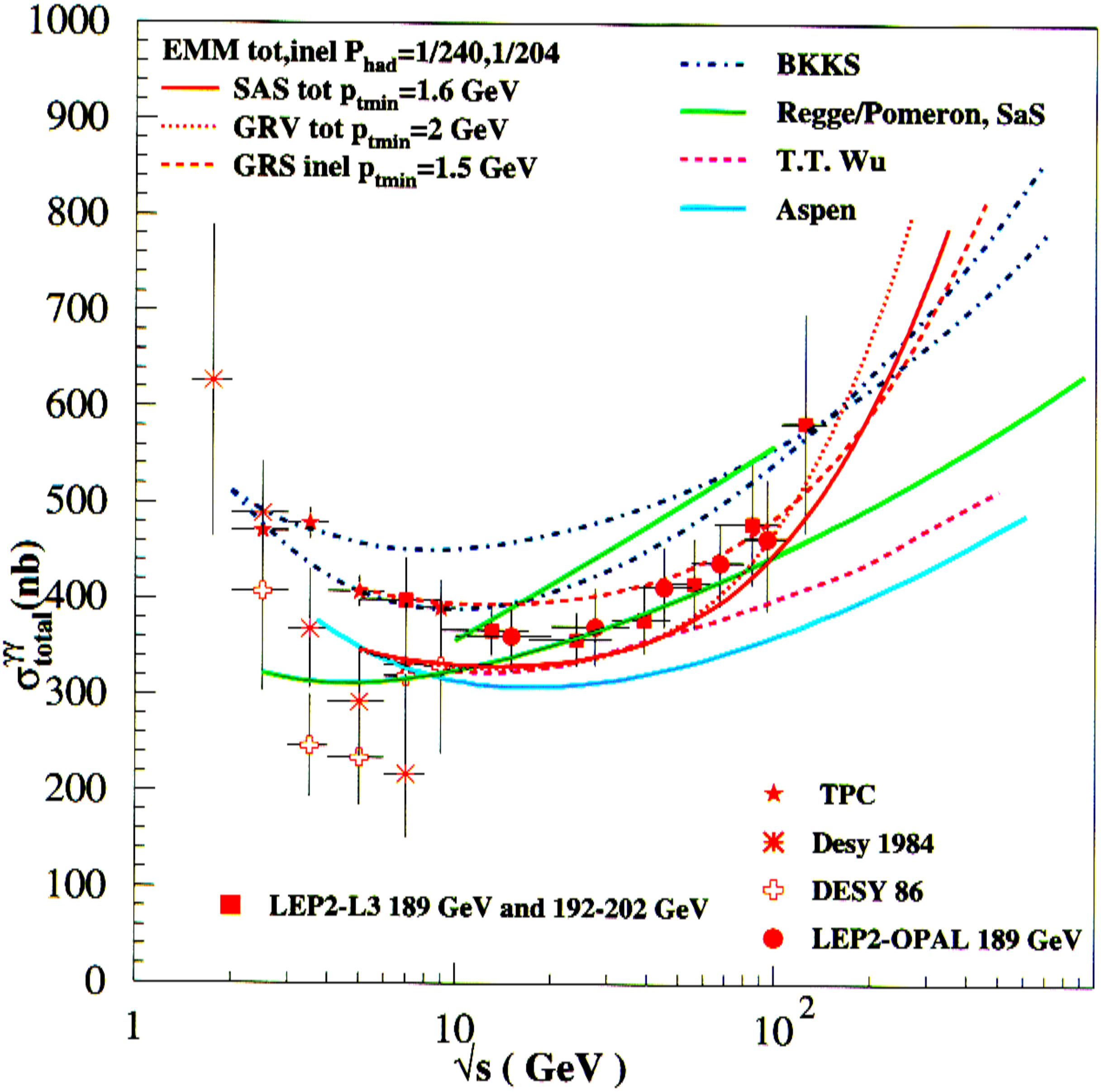

EMM tot,inel P_had=1/240,1/204
SAS tot p_tmin=1.6 GeV
GRV tot p_tmin=2 GeV
GRS inel p_tmin=1.5 GeV
BKKS
Regge/Pomeron, SaS
T.T. Wu
Aspen
TPC
Desy 1984
DESY 86
LEP2-OPAL 189 GeV
LEP2-L3 189 GeV and 192-202 GeV
σ^γγ_total(nb)
√s (GeV)
1000
900
800
700
600
500
400
300
200
100
0
1
10
10^2

Precision Required for a measurement of $\sigma_{\gamma\gamma}$ so as to distinguish between models?

Question asked by A. de Roeck.

1. ~ 8–10% (6–7%) to distinguish among the 'photon as a proton' models. (QCD models).

   ~ 20% between QCD based models and the 'photon is like a proton' models.

How well can a Compton Collider do?

Fig. with 'pseudo' data points

Precision for discrimination betwen models

Table 1: Total $\gamma\gamma$ cross-sections and required precision for models based on factorization

$\sqrt{s_{\gamma\gamma}}(GeV)$	Aspen	T.T. Wu	DL	1σ
20	309 nb	330 nb	379 nb	7%
50	330 nb	368 nb	430 nb	11%
100	362 nb	401 nb	477 nb	10%
200	404 nb	441 nb	531 nb	9%
500	474 nb	515 nb	612 nb	8%
700	503 nb	543 nb	645 nb	8%

Table 2: As in Table 1 for Eikonal Minijet Models

$\sqrt{s_{\gamma\gamma}}(GeV)$	BN GRV p_{tmin} 2 GeV	IPT GRS p_{tmin} 1.5 GeV	IPT GRV p_{tmin} 2 GeV	1σ
20	329 nb	312 nb	308 nb	0.3%
50	367 nb	357 nb	360 nb	1%
100	454 nb	435 nb	463 nb	4%
200	547 nb	581 nb	672 nb	8%
500	730 nb	928 nb	1171 nb	18%
700	873 nb	1105 nb	1420 nb	27%

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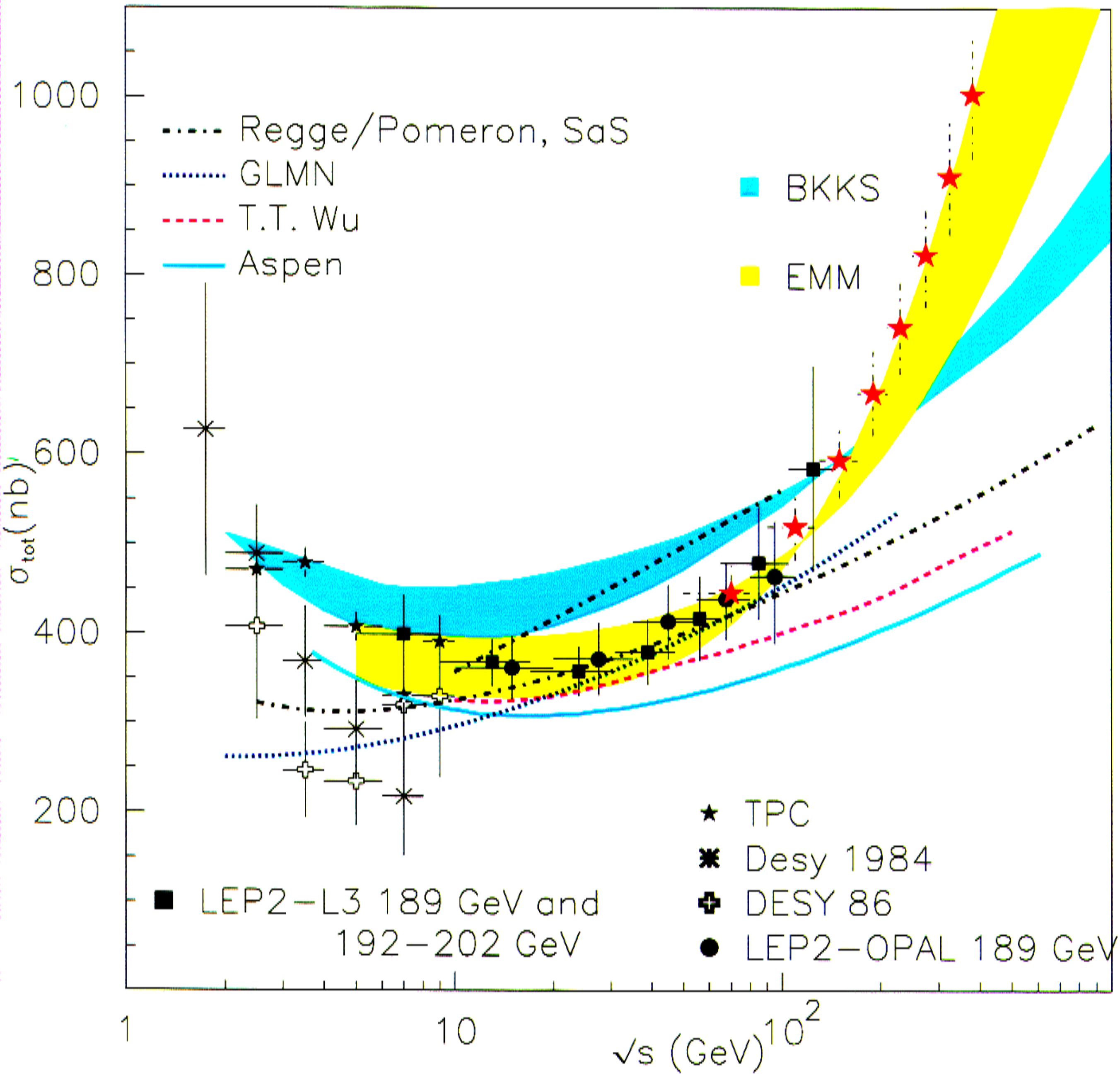

Calculating $\sigma^{had}_{e^+e^-}$ by folding $\sigma^{tot}_{\gamma\gamma}$ with photon spectra

$$\sigma^{had}_{e^+e^-} = \int dx_1 \int dx_2 \, f_{\gamma/e}(x_1) \, f_{\gamma/e}(x_2) \, \sigma^{tot}_{\gamma\gamma}(\gamma\gamma \to had) \quad [\hat{s} = s x_1 x_2]$$

Drawmp. Bremstrahlung, Beamstrahlung photons.

Right now have done the calculations for only

* bremstrahlung contribution.

* $$f_{\gamma/e}(z) = \frac{\alpha_{em}}{2\pi z} \left[(1 + (1-z)^2) \ln \frac{P^2_{max}}{P^2_{min}} - 2(1-z) \right]$$

$$P^2_{max} = \frac{s}{2} (1 - \cos\theta_{tag})(1-z)$$

$$P^2_{min} = \frac{m_e^2 z^2}{(1-z)}$$

* Further I add a suppression factor for cross-sections due to virtuality of γs.

For NLC have assumed

$\theta_{tag} = 0.025$ rad, $E_e^{min} = 0.20 \, E_{beam}$

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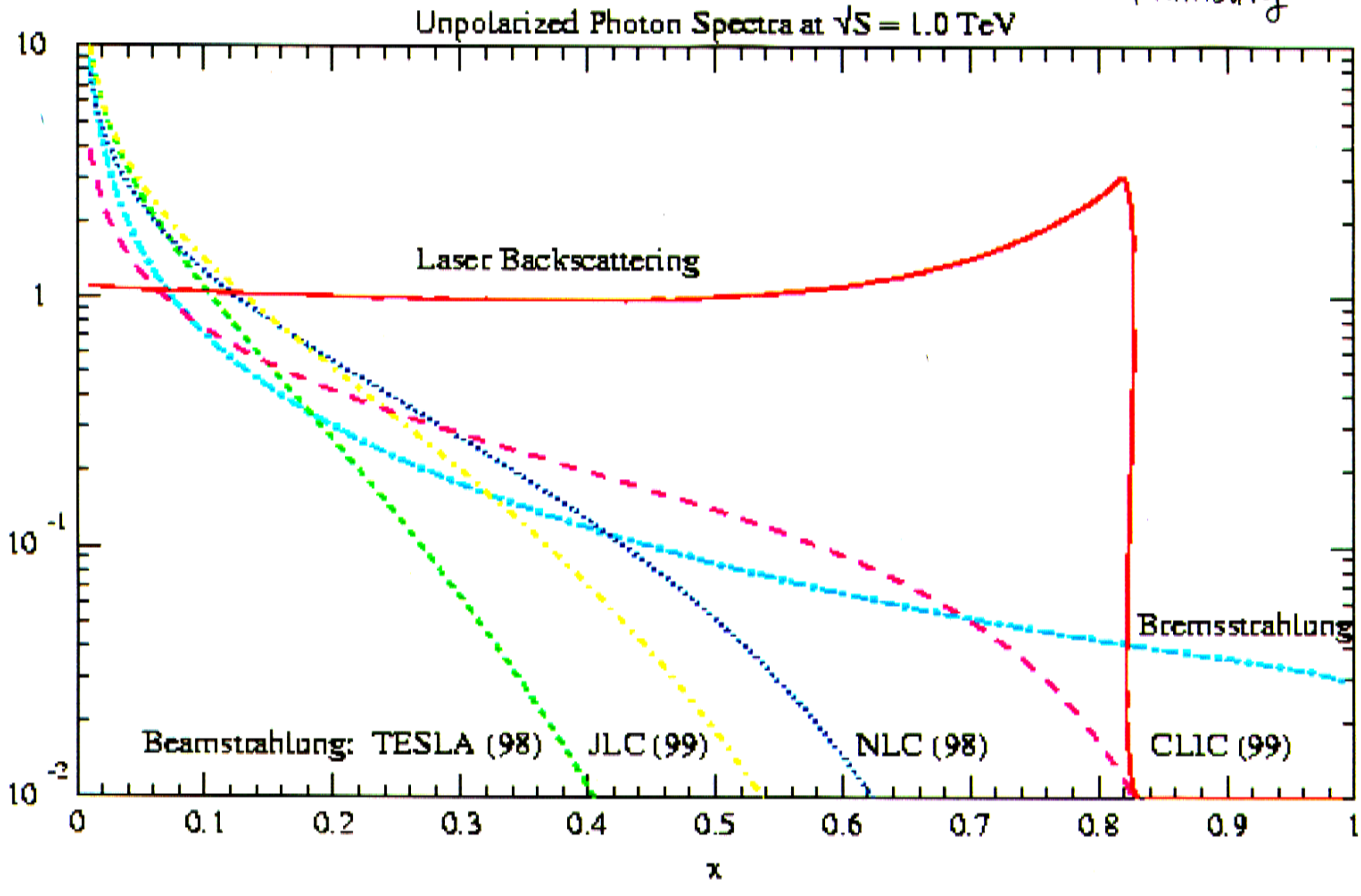

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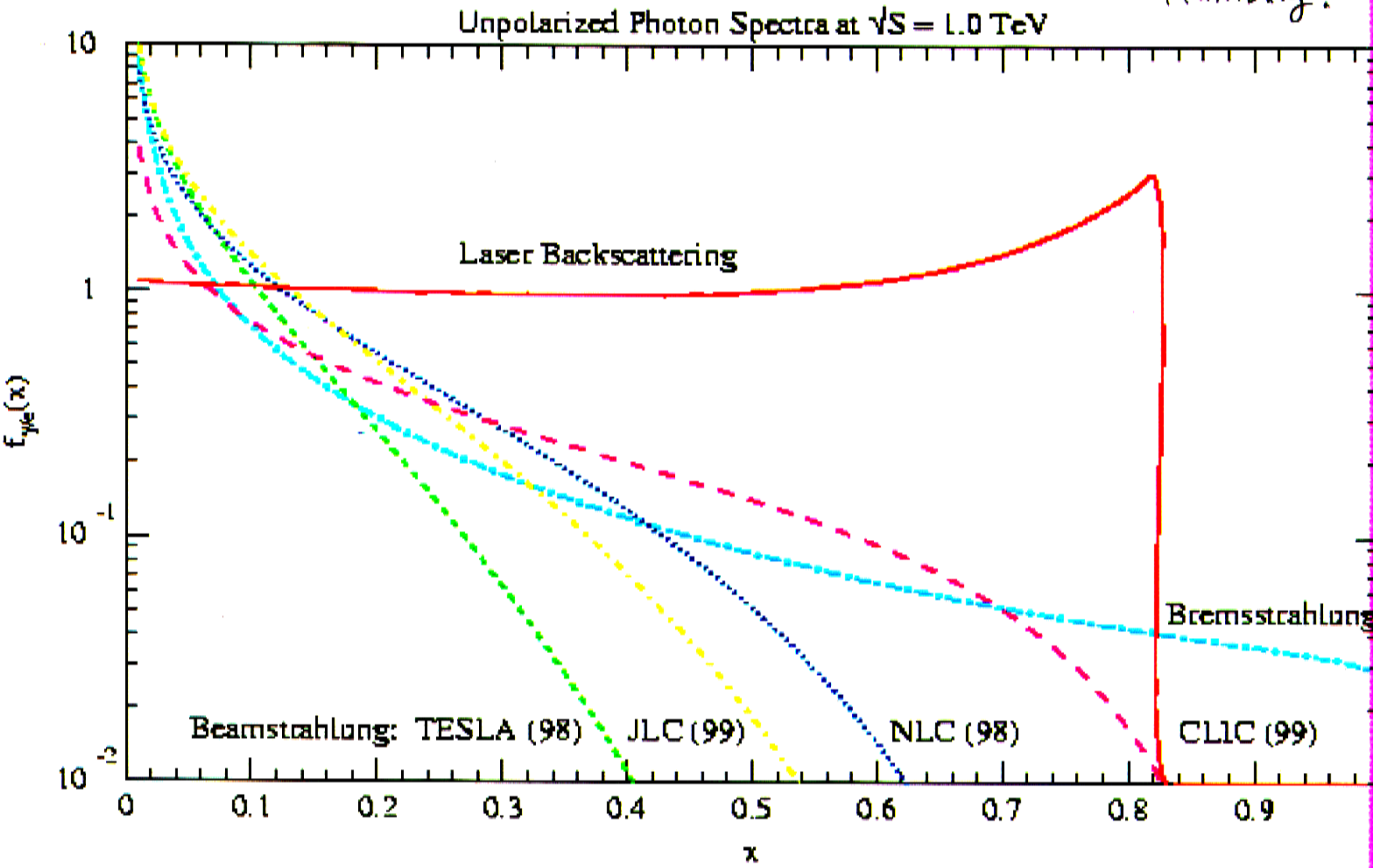
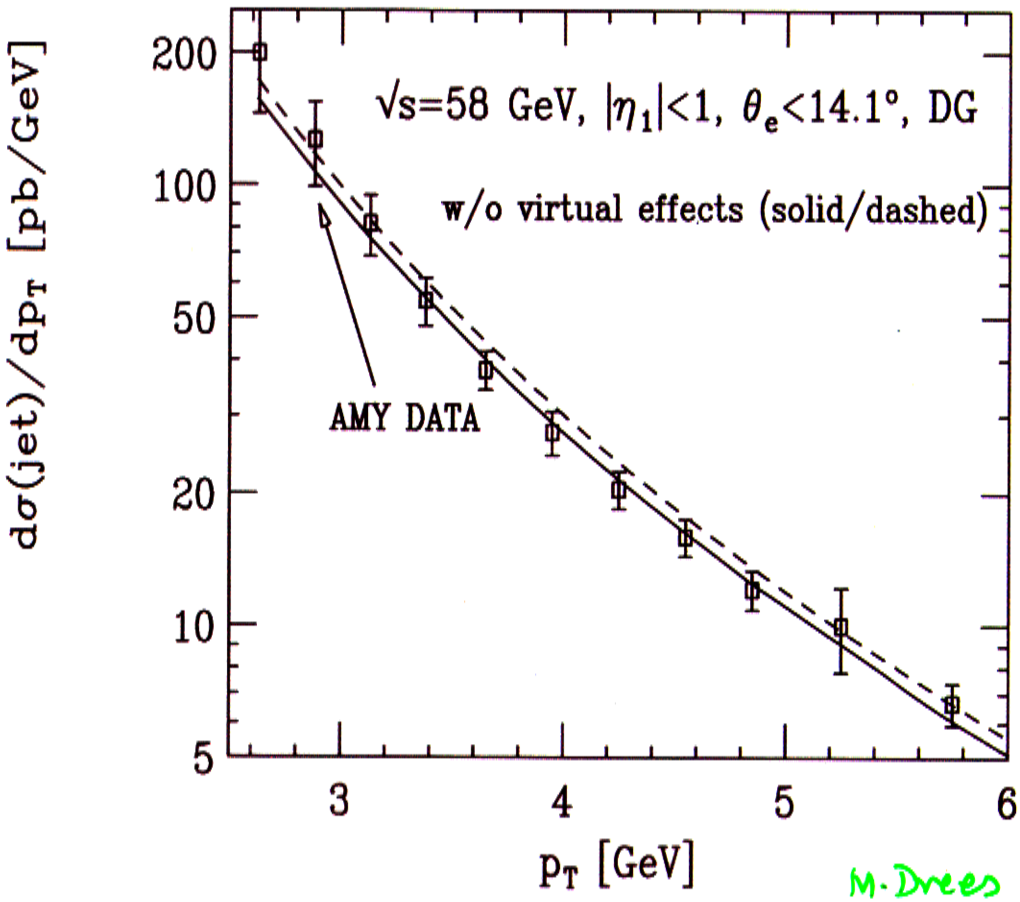
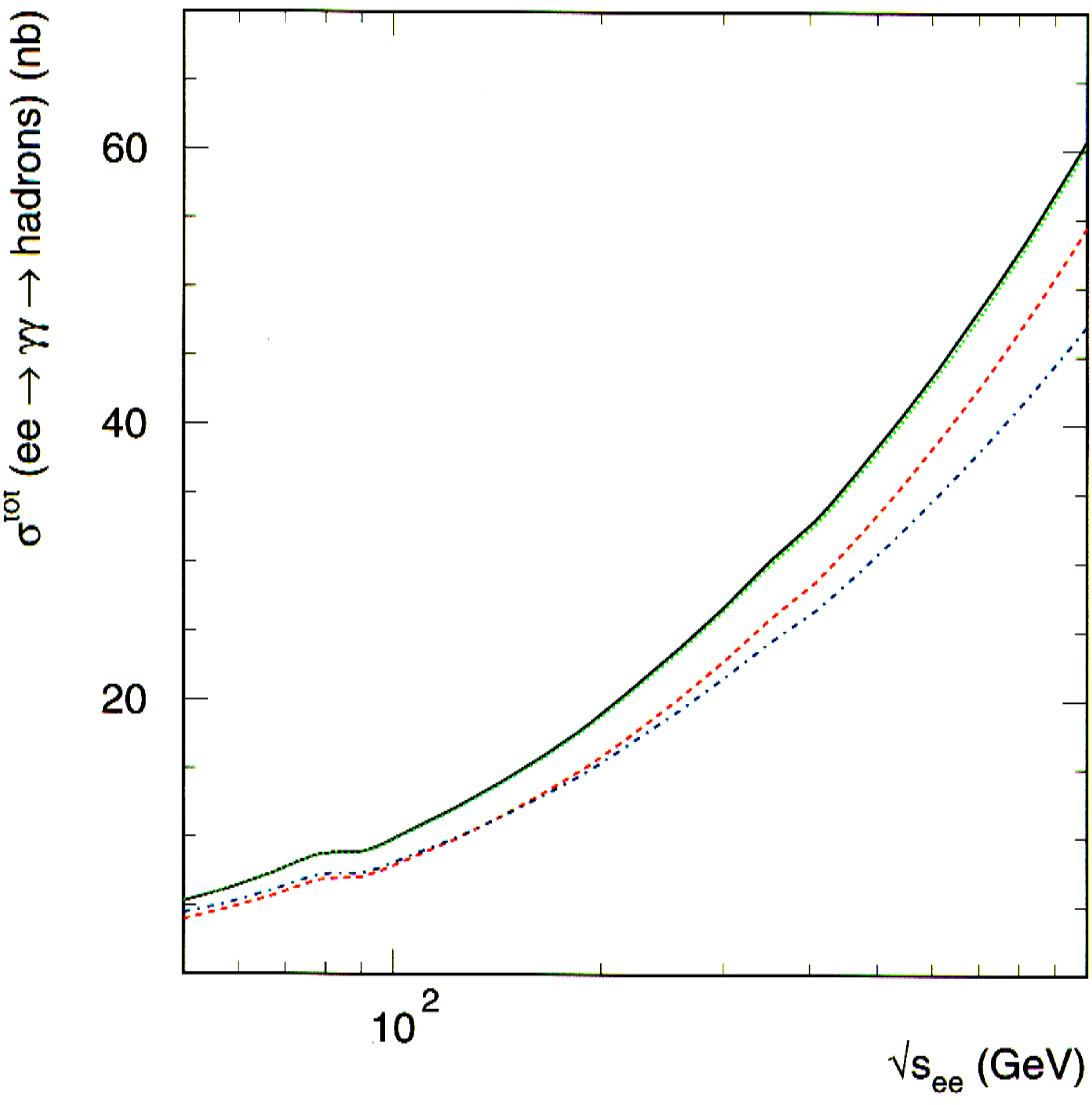
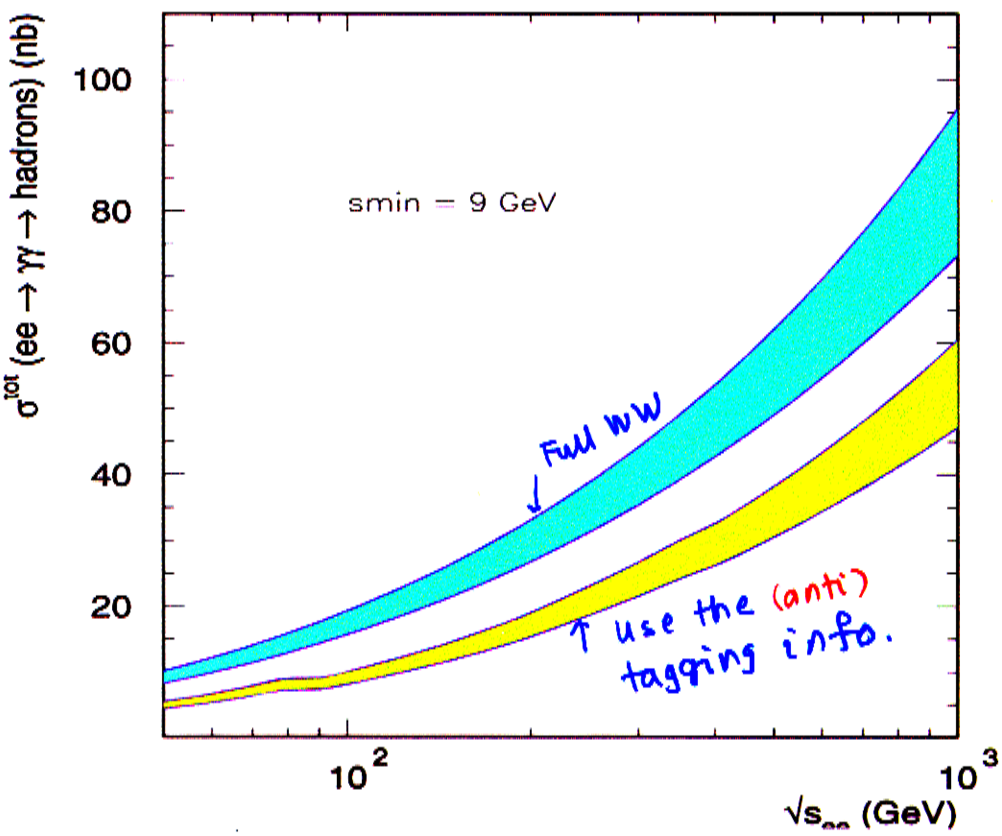




dσ(jet)/dp_T [pb/GeV]
200
100
50
20
10
5
√s=58 GeV, |η_1|<1, θ_e<14.1°, DG
w/o virtual effects (solid/dashed)
AMY DATA
3
4
5
6
p_T [GeV]

M. Drees
R.M.G.


σ^{TOT} (ee → γγ → hadrons) (nb)
60
40
20
10^2
$\sqrt{s_{ee}}$ (GeV)



$\sigma^{TOT}(ee \to \gamma\gamma \to hadrons)$ (nb)
100
80
60
40
20
smin = 9 GeV
Full WW
use the (anti) tagging info.
10^2
10^3
$\sqrt{s_{ee}}$ (GeV)

* When folded with photon spectra the differences in $\sigma_{\gamma\gamma}^{tot}$ of $\sim$ a factor 2-3 for different models $\Longrightarrow$ 30% difference for $\sigma_{e^+e^-}^{had}$

* situation might be difft. for machine with larger beamstrahlung.

* The reduction in brem. γ spectrum due to anti-tagging $\longrightarrow$ reduction of $\sim$ 40% at the highest end.

Conclusions and outlook:

1) Models which treat photon like a proton tend to predict a rise of c-sections $\sigma_{\gamma\gamma}^{tot}$ with energy slower than shown by the $\gamma\gamma$ data. QCD based models predict a faster rise.

2) γp data seems also to show tendency of needing a value of ϵ ($\sim s^{\epsilon}$) higher than that for $pp/\bar{p}p$

3) Extraction of $\sigma^{\gamma\gamma}$ ($\sigma^{\gamma p}$) from data is no mean task.

4) Accurate measurements of $\sigma^{\gamma\gamma}$ at a $\gamma\gamma$ collider will be capable of distinguishing between these different models. A precision $\sim 20\%$ is required for that.

5) When folded with bremsstrahlung spectra the diff. of 200–300% at high $\sqrt{s}$ in $\sigma_{\gamma\gamma}^{tot}$ in difft. models $\downarrow$ 30%

6) Needs to be investigated for higher energy $\sqrt{s}$ with beamstrahlung.