What's New in Hyperons?

New SELEX data on $\sigma_{tot}(\Sigma p)$

New PDG parametrization of σ_{tot} - Three Terms

New data on Λ polarization from DIS and Z decays

What do these tell us about

How does QCD make hadrons out of quarks and gluons?

How does SU(3) breaking in hyperon decays affect
analyses of proton spin structure?

What is the spin structure of the Λ?

How does a polarized quark produced by photon or Z
fragment into a polarized Λ?

What is this third term in σ_{tot}?

Do we understand it? - No; Is it interesting - Yes!

Thanks to

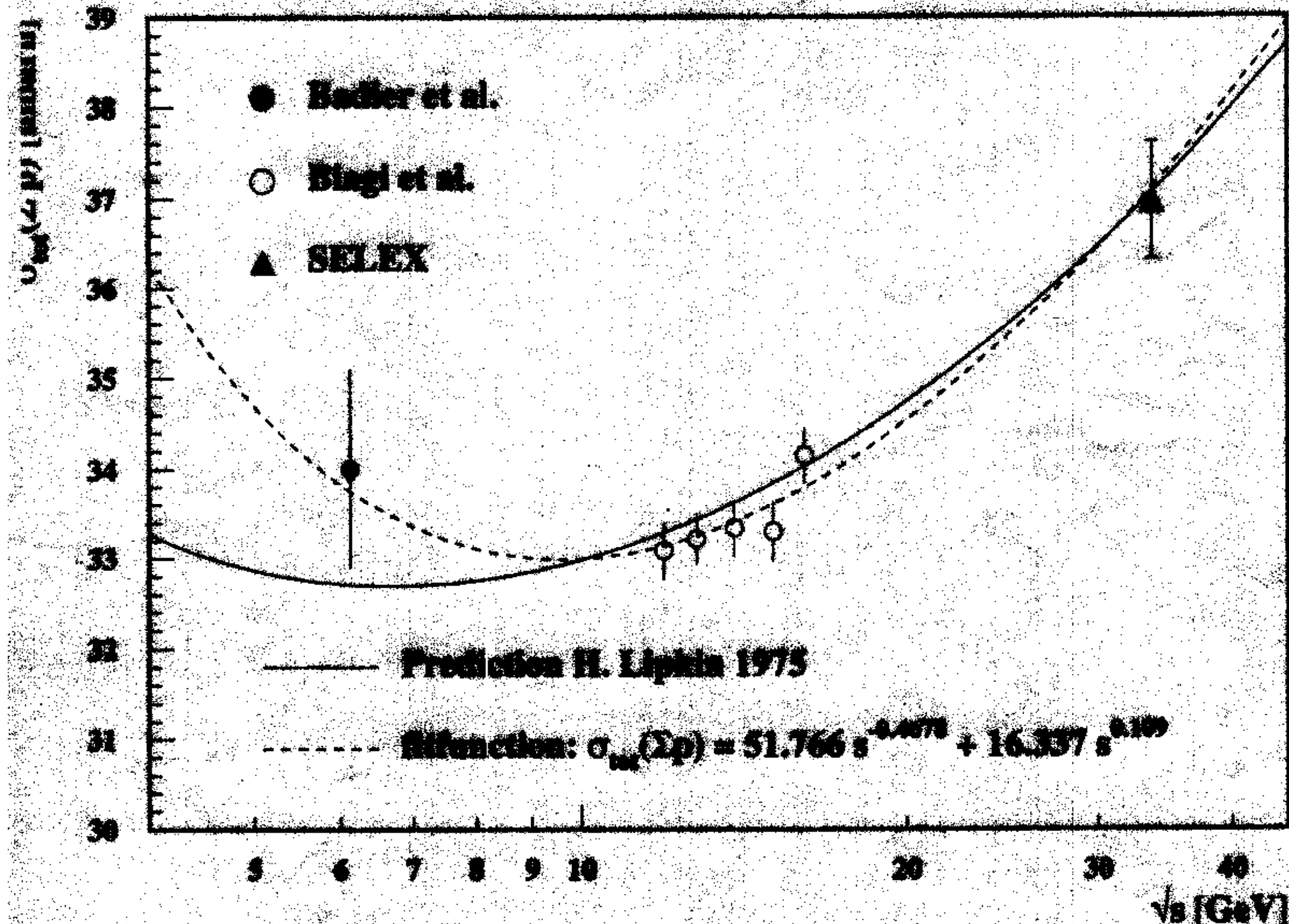
Joe Lach, Murray Moinester, Uwe Dersch and SELEX
for σ_{tot}

Danny Ashery for Λ polarization

Marek Karliner for proton spin and SU(3) breaking

The SELEX average for $\sigma_{tot}(\Sigma^- p)$:

$$\sigma_{\rm tot}(\Sigma^- \rm p) = 36.96 \text{ mbarn} \pm 0.65 \text{ mbarn}$$
$$\text{(at 609 GeV/c)}$$



The SELEX message:

→ $\sigma_{tot}(\Sigma^- p)$ shows a definite rise with increasing center of mass energy, which is in good agreement with the TCP model of H. Lipkin.

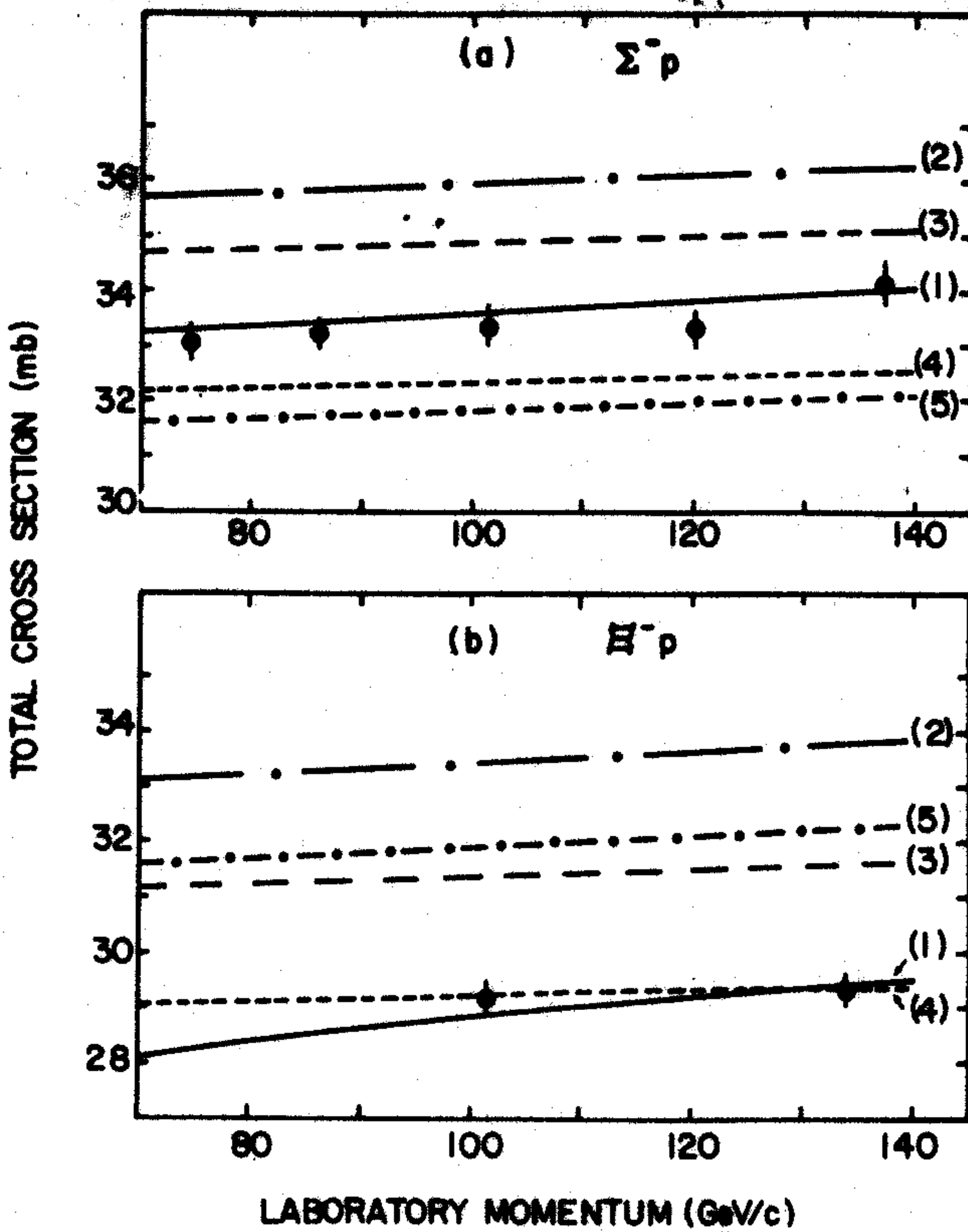


Fig. 3 Comparison of various model predictions with a) Σ^-p, b) Ξ^-p total cross sections. The curves represent the following models: (1) Lipkin[6]; (2) Joynson and Nicolescu[7]; (3) Additive Quark Model[16]; (4) Carlitz, Green and Zee[9]; (5) Yoshida[8].

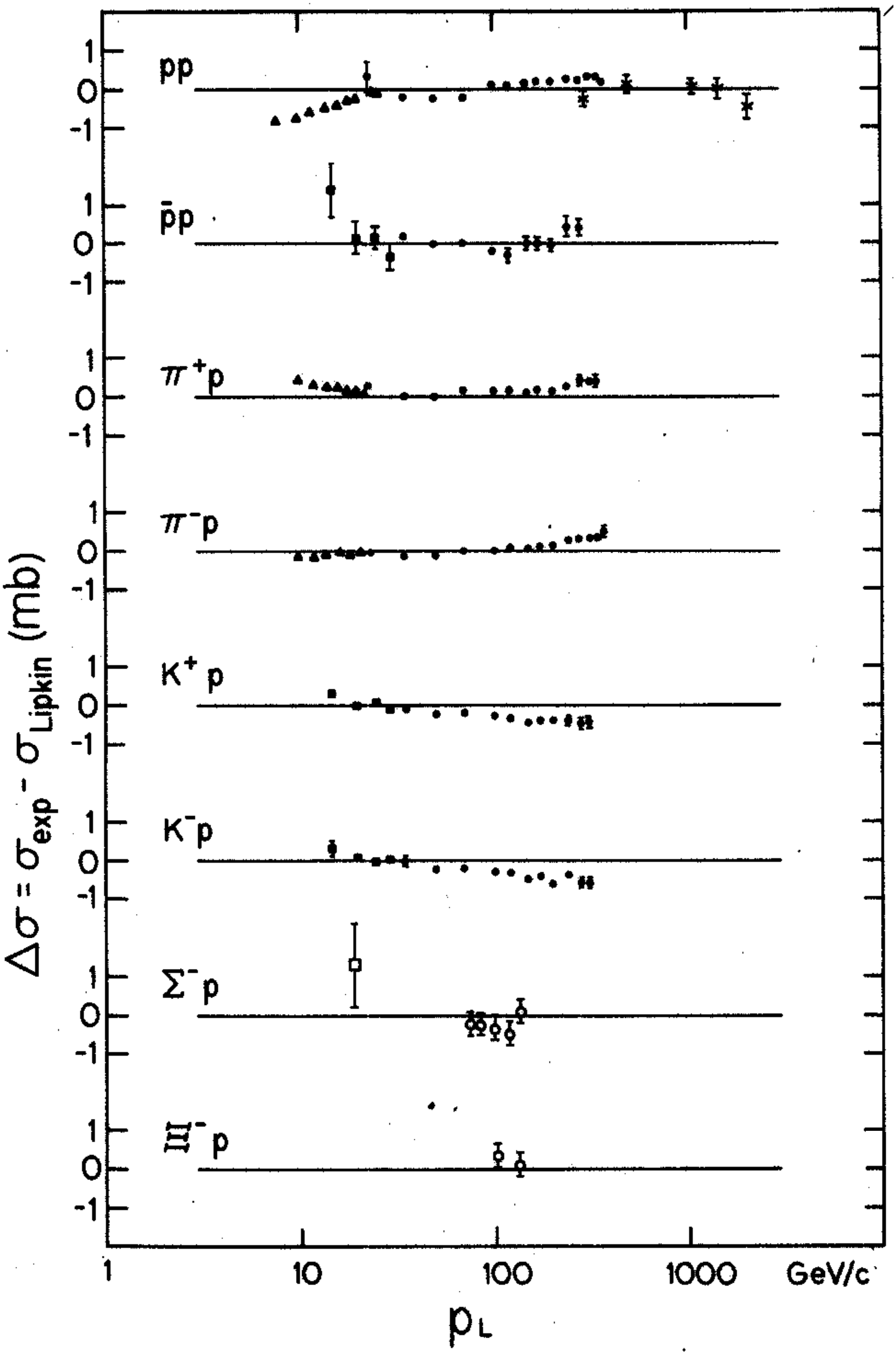


Fig. 4 Differences between experimental hadron-proton total cross sections and Lipkin's predictions. ▲Ref. 17; ● Ref. 4; × Ref. 18; ■Ref. 19; □ Ref. 15; ○ This experiment.

1998 PDG Fit to σ_{total}

$$\sigma(Ap) = X_{Ap} s^{\epsilon} + Y_{1Ap} s^{-\eta_1} + Y_{2Ap} s^{-\eta_2}$$

Pomeron ↗ (X_{Ap})

↕ (Y_{1Ap}) ?

Leading Reggeons ↖ (Y_{2Ap})

What is this third component?

Dirt or interesting Physics

Proposed in 1975 by HJL

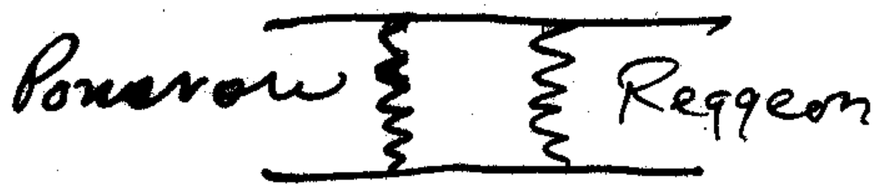
as interesting physics

Worthy of future investigation

Simple Model

only first approximation

Try higher order term - Double

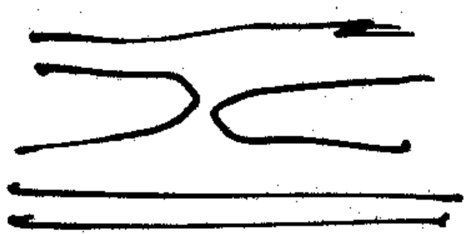


Simple ansatz gives remarkable agreement for flavor dependence

Pomeron counts quarks

Reggeon counts Harari-Rosner

Duality diagrams



Pomeron-f cut counts $N_q \cdot N_n$

Wrong energy dependence.

1998 Particle-Data-Group Regge σ_{total} analysis

Now includes three terms, confirming 1975 TCP model

New SELEX data confirm TCP prediction for $\sigma_{tot}(\Sigma p)$

.2. WHERE IS THE PHYSICS? WHAT CAN WE LEARN?

1975 - Regge poles can't be whole story

Subtract naive pole terms from σ_{tot}. What else is there?

Found universal contribution scaling like Pomeron-f cut

Scaling factors of 9:4:2 like for protons, pions and kaons.

Extrapolated to 6 and 3 for Σp and Ξp - predict data!

$\sigma_{tot}(\pi^- p) - \sigma_{tot}(K^- p) = (2/3)\{\sigma_{tot}(pp) - \sigma_{tot}(\Sigma p)\}$

But energy dependence not given by any model

Haim Harari (1974)

"I don't believe a word of this crazy model.

Numbers are impressive. Find better explanation".

Still looking (1999)

Pomeron-f scaling and fit to s^ϵ works.

We still don't understand why

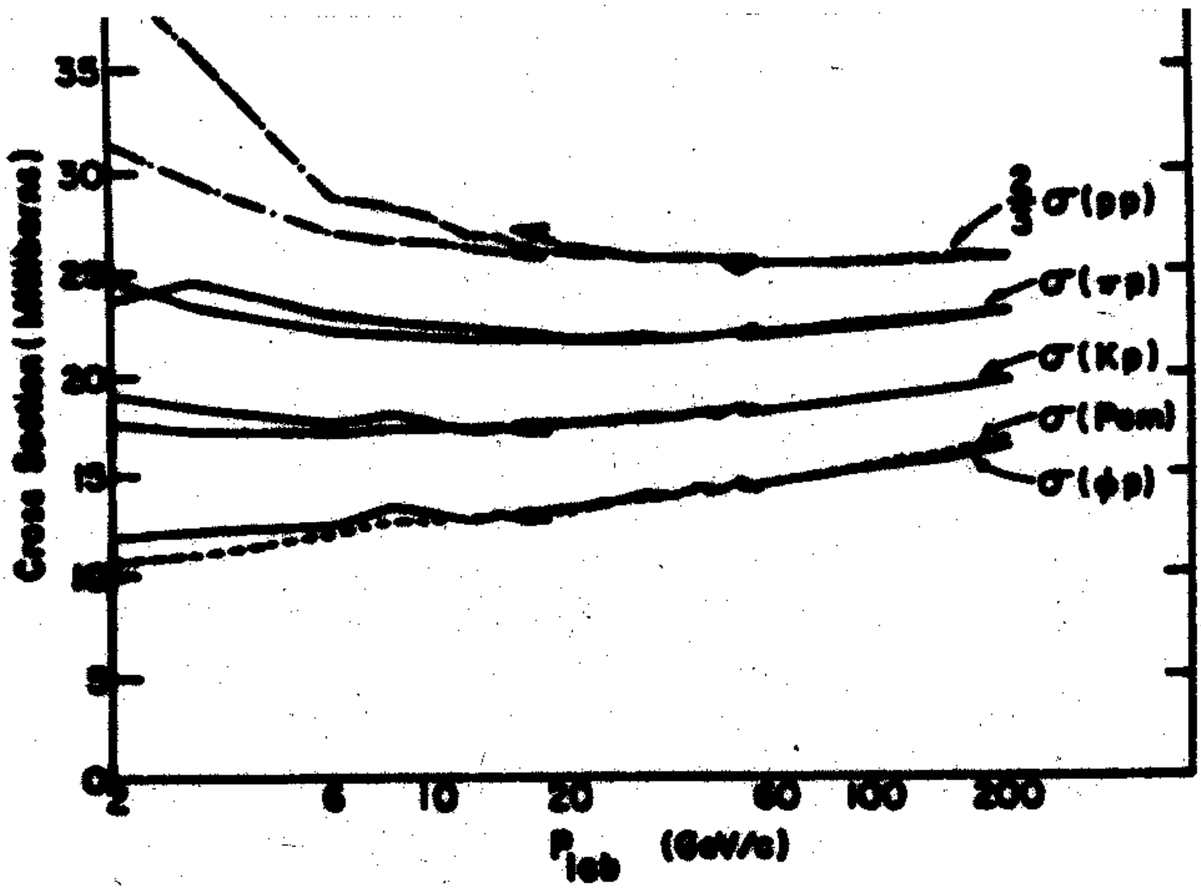
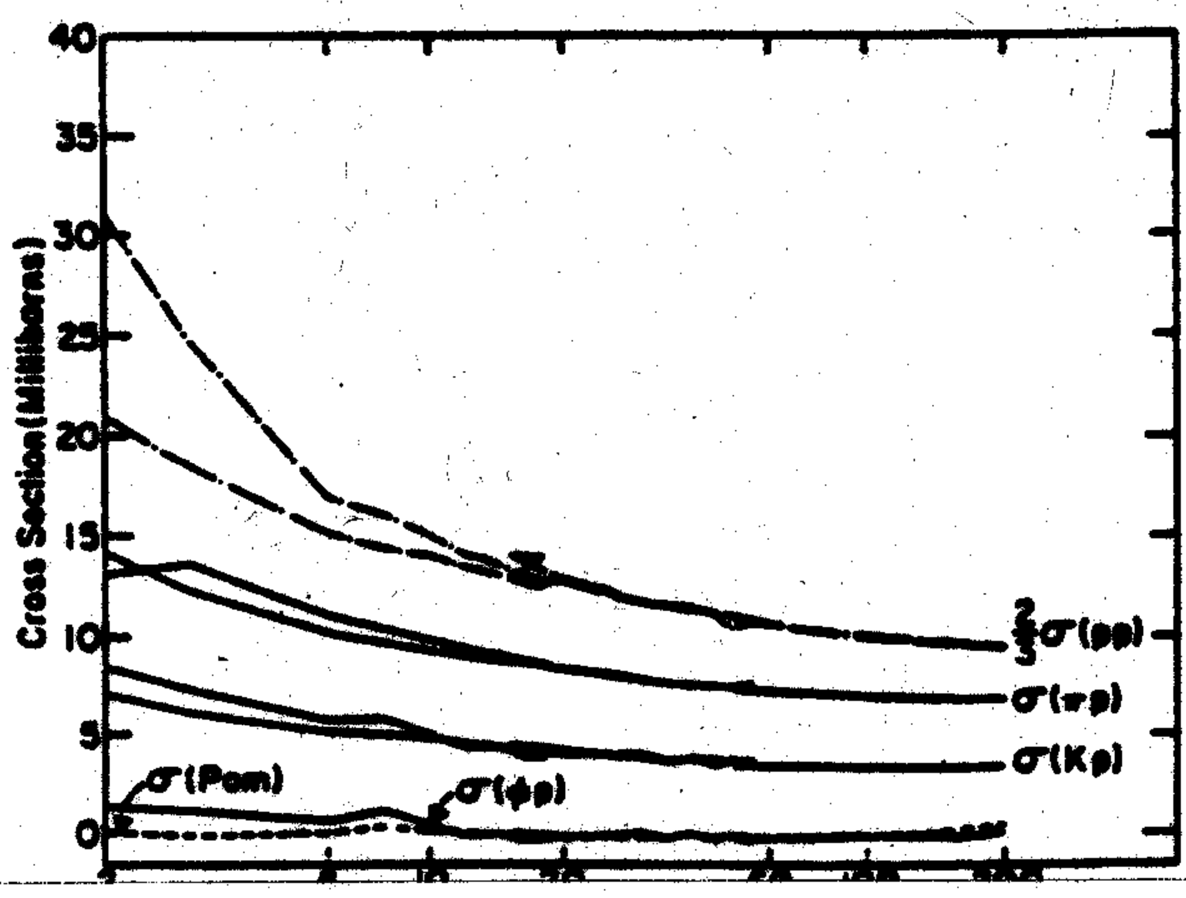


FIG. 2. The differences $\sigma_{tot} - \sigma_{R}$.



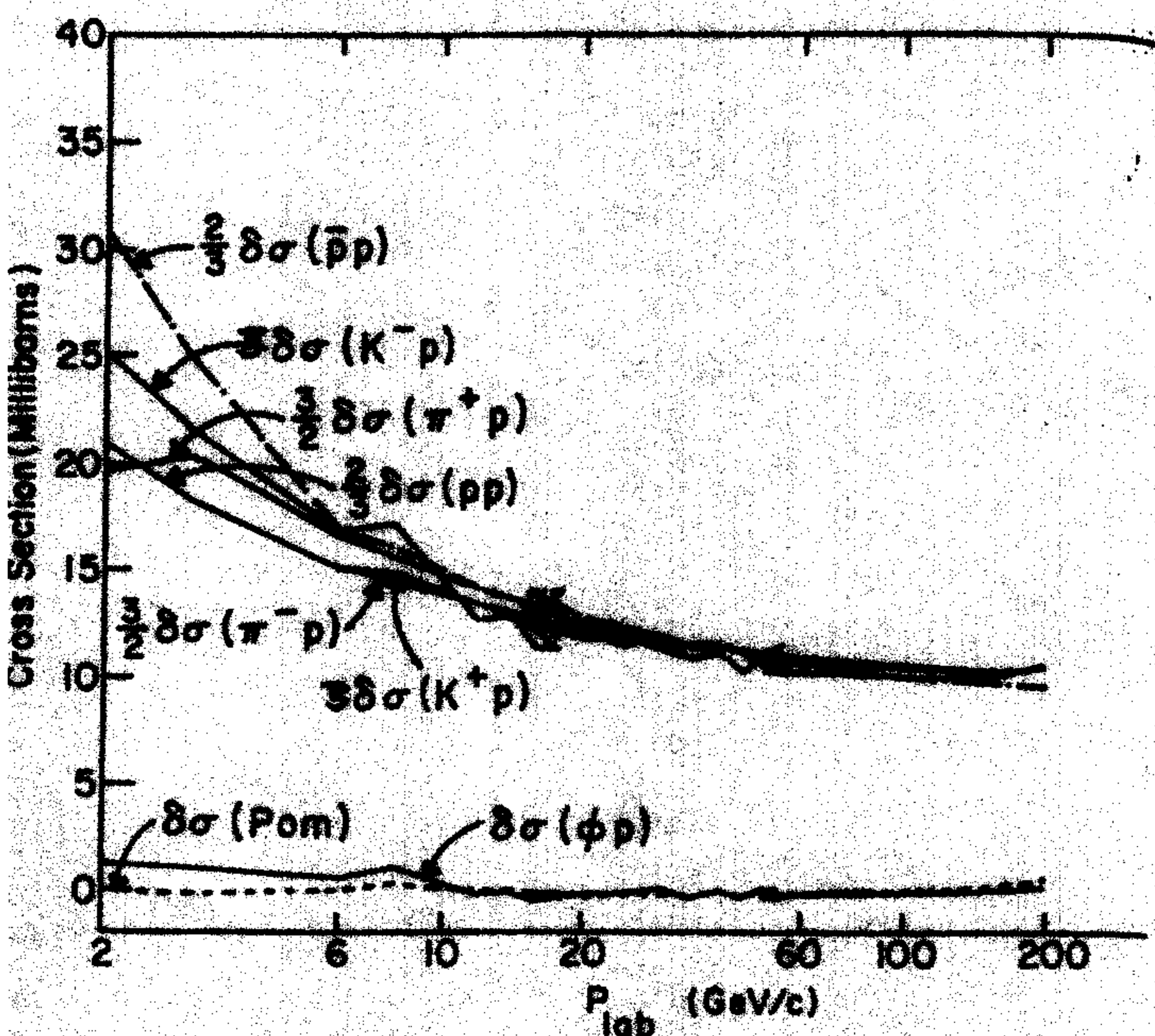
1975 - Regge poles can't be whole story

Subtract naive pole terms from σ_{tot}. What else is there?

VERY NAIVE POLE ASSUMPTIONS

Leading Regge is $s^{-(1/2)}$, counts Duality Diagrams

Pomeron simply counts quarks and fit by s^{ϵ}



$\sigma(Pom) \equiv (3/2)\sigma_{tot}(K^+p) - (1/3)\sigma_{tot}(pp)$

$\sigma_{tot}(\text{"}\phi\text{"}p) = \sigma_{tot}(K^+p) + \sigma_{tot}(K^-p) - \sigma_{tot}(\pi^-p) \approx$

Lipkin (see [37]), which is given by:

$$\sigma_{tot}(\Sigma^- p, p_{lab}) = 19.5 \left(\frac{p_{lab}}{20}\right)^{0.13} + 13.2 \left(\frac{p_{lab}}{20}\right)^{-0.2} \tag{45}$$

for $p_{lab} > 10\,\mathrm{GeV/c}$, σ_{tot} in mbarn, p_{lab} in GeV/c .

The corresponding curve in figure 18 shows that the agreement between our measurement and this prediction is perfect.

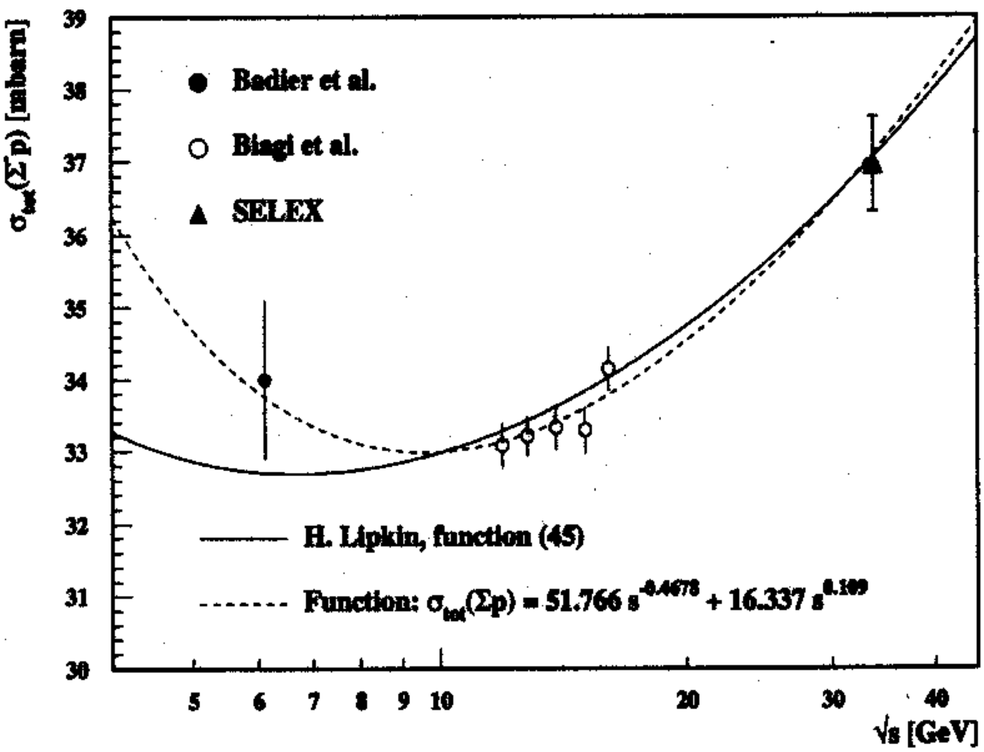


Fig. 18. Existing data for $\sigma_{tot}(\Sigma^- p)$ in comparison with our results and predictions.

To get a feeling for the growth of $\sigma_{tot}(\Sigma^- p)$ at high energy, we estimated the corresponding effective soft Pomeron intercept ε, which is a frequently used parameter to describe the increase of total cross sections. Therefore, we fitted the function:

$$\sigma_{tot}(\Sigma^- p, s) = \underbrace{Y s^{-\eta}}_{\text{Reggeon term}} + \underbrace{X s^{+\varepsilon}}_{\text{Pomeron term}} \tag{46}$$

to all data on $\sigma_{tot}(\Sigma^- p)$ and kept the effective Reggeon intercept η fixed to its average value as presented in [39]: $\eta = 0.4678$. The fit resulted in parameters presented in table 10 with $\chi^2/dof = 0.83$. The obtained fit-function (46) is shown in figure 18.

1975 TCP Third Component Model Confirmed by PDG

Both PDG and TCP models write

$$\sigma Ap = X_{Ap}s^{\epsilon} + Y_{1Ap}s^{-\eta_1} + Y_{2Ap}s^{-\eta_2}$$

PDG sets

$$X_{\bar{A}p}^{PDG} = X_{Ap}; \quad Y_{1\bar{A}p}^{PDG} = Y_{1Ap}; \quad Y_{2\bar{A}p}^{PDG} = -Y_{2Ap}$$

X_{AB}, Y_{1AB}, Y_{2AB}, ϵ, η_1, η_2 determined by fitting data
Independent of one another, except for isospin relations.

TCP sets

$$X_{Ap}^{TCP} = X \cdot N_q(A); \quad Y_{1Ap}^{TCP} = Y_1 \cdot N_q(A) \cdot N_n(A)$$

$$Y_{2Ap}^{TCP} = Y_2 \cdot [2N_{\bar{u}}(A) + N_{\bar{d}}(A)]; \quad \eta_2 = -0.5$$

Coefficients X, Y_1 and Y_2 universal for all hadrons,

$N_q(A)$ total number of valence q and $\bar{q}$ in A,

$N_n(A)$ number of nonstrange valence q and $\bar{q}$ in A,

$N_{\bar{u}}(A)$ and $N_{\bar{d}}(A)$ number of valence $\bar{u}$ and $\bar{d}$ in A.

Both PDG and TCP fix parameters by fitting data

Many fewer free parameters in TCP

Particle-antiparticle relations in Y_2 very different

Y_2 has only odd signature ρ, ω in PDG; no f, $A2$

ρ, ω, f, $A2$ exchange degenerate in TCP

$Y_2 = 0$ in exotic channels

Original TCP notation

$$\sigma_{Ap}^{TCP} = \frac{N_q(A)}{2} \cdot \sigma_1 (P_{lab}/20)^{\epsilon} + \frac{N_q(A) \cdot N_n(A)}{2} \cdot \sigma_2 (P_{lab}/20)^{-\delta} +$$

$$+ [2N_{\bar{u}}(A) + N_{\bar{d}}(A)] \cdot \sigma_R (P_{lab}/20)^{-0.5}$$

Values determined in 1975 - not changed since

$\sigma_1 = 13$ mb, $\epsilon = 0.13$, $\sigma_2 = 4.4$ mb, $\delta = 0.2$

$\sigma_R = 1.75$ mb.

[redacted]

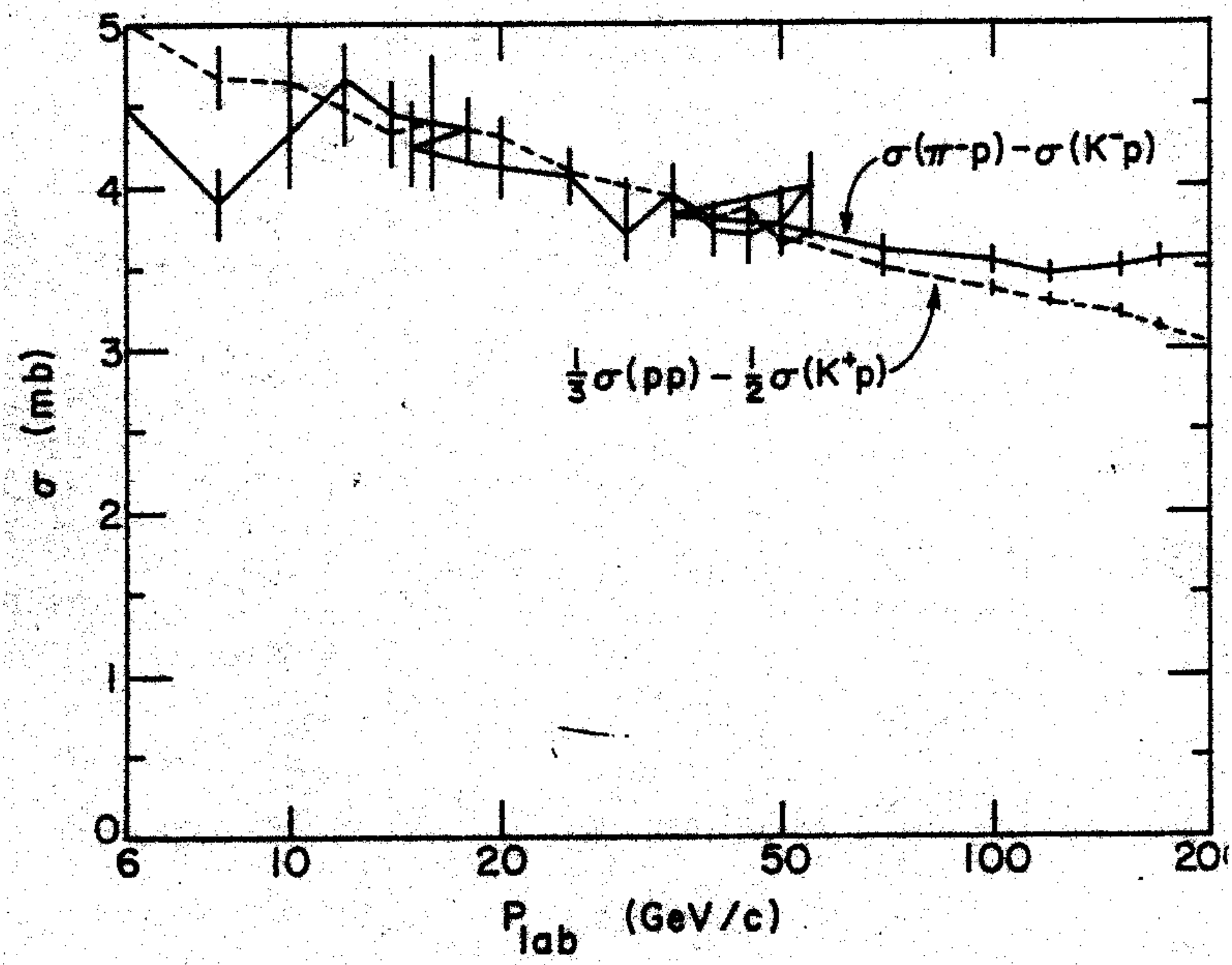


Fig. 7.3. Plots of Δ(πK) and Δ(MB) on an expanded scale

QCD Motivated Corrected Additive Quark Model

$$\sigma_{\infty}(Hp) \equiv (N_q/2)\{\sigma_{tot}(K^+p) + \sigma_{tot}(K^-p) - \sigma_{tot}(\pi^-p)\} \approx$$

$$\approx (N_q/3) \cdot 19.5 \cdot (P_{lab}/20)^{0.13}$$

$$\sigma(Pom) \equiv (3/2)\sigma_{tot}(K^+p) - (1/3)\sigma_{tot}(pp) =$$

$$= \sigma_{tot}(\text{``}\phi\text{''}p) = \sigma_{tot}(K^+p) + \sigma_{tot}(K^-p) - \sigma_{tot}(\pi^-p) \approx$$

$$\approx 13.0 \cdot (P_{lab}/20)^{0.13}$$

$$\sigma_2(Hp) = (N_q N_n) \cdot 2.2 \cdot (P_{lab}/20)^{-0.2}$$

No data on proton targets available above $P_{lab} = 310$ GeV/c

[illegible] GeV/c

$$\sigma_{tot}([illegible]) = [illegible]\,\sigma_{tot}(\pi^+ p) - ([illegible])\,\sigma_{tot}(K^- p)$$

[illegible] ± [illegible] mb = [illegible] ± [illegible] mb

$$\sigma_{tot}([illegible]) = ([illegible])\{\sigma_{tot}(K^+ p) + \sigma_{tot}(\pi^- p) - \sigma_{tot}(K^- p)\}$$

[illegible] ± [illegible] mb = [illegible] ± [illegible] mb

$$\sigma_{tot}([illegible]) = ([illegible])\,\sigma_{tot}(K^+ p)$$

[illegible] ± [illegible] mb = [illegible] ± [illegible] mb

$$\frac{1}{[illegible]}\{\sigma([illegible]) + \sigma([illegible])\} - \frac{1}{[illegible]}\{\sigma(K^+ p) + \sigma(K^+ n)\} = [illegible] \pm [illegible]\ \text{mb}$$

$$\frac{1}{[illegible]}\{\sigma(\pi^- p) - \sigma(K^- p) + \sigma(\pi^+ p) - \sigma(K^- n)\} = [illegible] \pm [illegible]\ \text{mb}$$

[illegible] GeV/c

03 WHERE IS THE PHYSICS? WHAT CAN WE LEARN?

1. **Odd signature universality**

   ρ universality (Sakurai) - conserved isospin current

   ω universality - related to ρ by U(2)

   Energy dependence - like $s^{-1/2}$

2. Exchange degeneracy - No exotic contributions

   Only planar quark diagrams contribute

3. Universal Pomeron - Counts quarks

   Given by amplitude with no quark exchanges

   "Gedanken" $\sigma_{tot}(\phi p) = \sigma_{tot}(K^+p)+\sigma_{tot}(K^-p)-\sigma_{tot}(\pi^-p)$

4. What's left?

   Universal contribution scaling like Pomeron-f cut

   Scaling factors of 9:4:2 like for protons, pions and kaons.

   Extrapolated to 6 and 3 for Σp and Ξp - predict data!

   But what is it?

TCP pinpoints open questions and puzzles

Relation between masses and baryon structure

Link between Regge phenomenology and QCD,

QCD and remarkable success of constituent QM

interesting analogy? EM form factors and charges?

Form factors complicated, total charge simple

Total charge given by charges of constituent quarks

Rutherford scattering measures total charge

Does universality of contributions to $\sigma_{tot}(Np)$

Suggest measurements of some kinds of total charge?