MODELLING NN SCATTERING ABOVE 1 GeV

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OUTLINE

- $\lesssim 1$ GeV: MODELS & DATA REPRODUCTION
- > 1 GeV: PROBLEMS
- SPIN OBSERVABLES: MORE PROBLEMS
- CONCLUSIONS

$T_{lab}^{NN} \leq 1$ GeV:

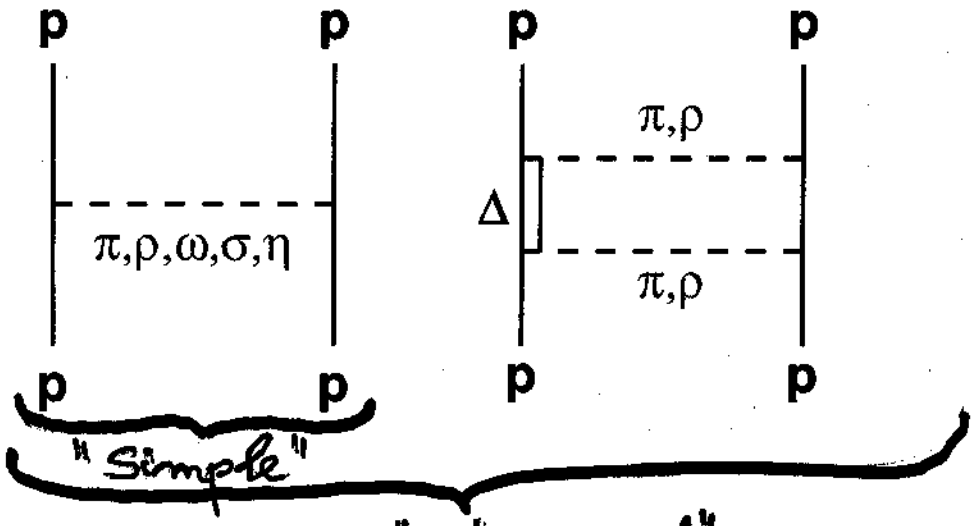
Models & Data

Reproduction

SIMPLE & ADVANCED MESON EXCHANGE MODELS

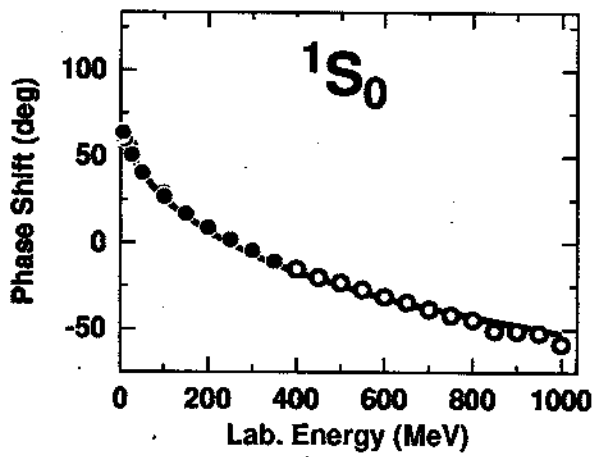
properties of the nuclear force

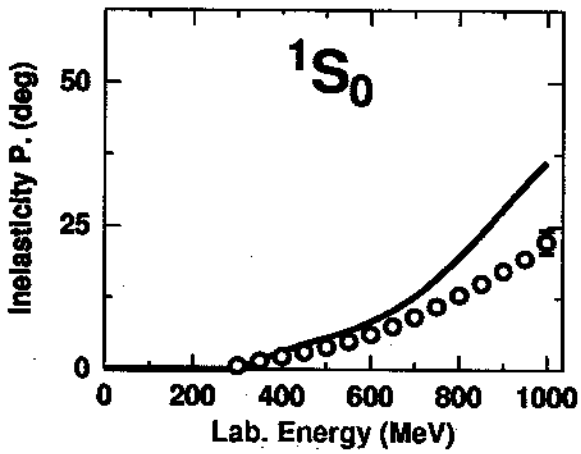
- short ranged
- attractive at medium distances
- repulsive core
- central force
- spin orbit force
- tensor force
- spin spin force

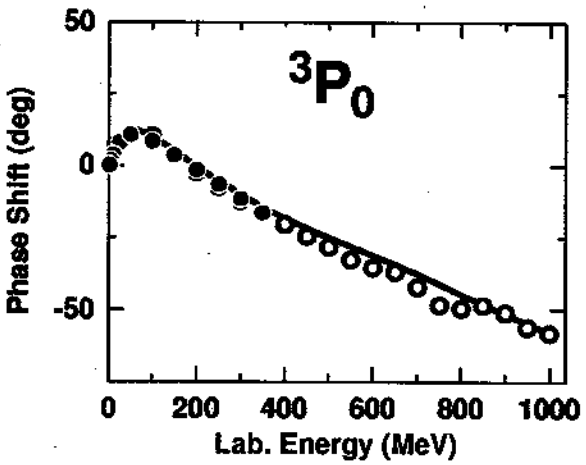


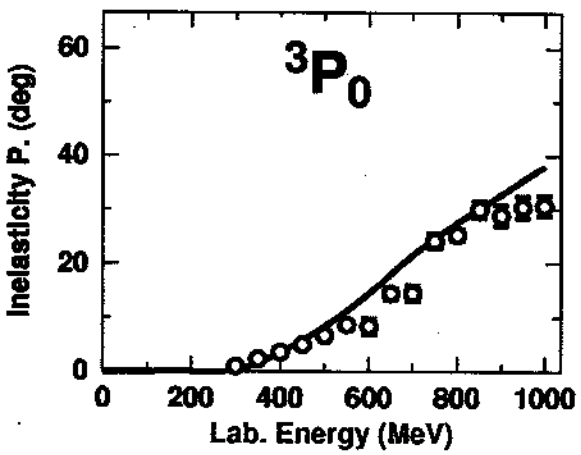
meson zoo

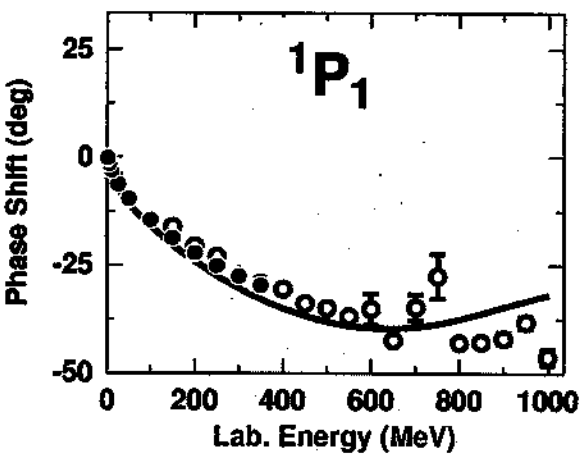
- $\pi \rightarrow$ *long* range & tensor force
- $\rho \rightarrow$ short range tensor force & *hard core*
- $\omega \rightarrow$ spin orbit force and *hard core*
- $\sigma \rightarrow$ intermediate range
- $\eta \rightarrow$ weak

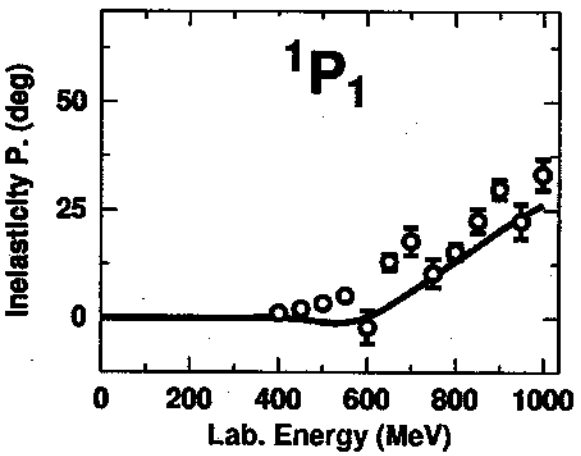

$^1S_0$
Phase Shift (deg)
100
50
0
-50
0
200
400
600
800
1000
Lab. Energy (MeV)

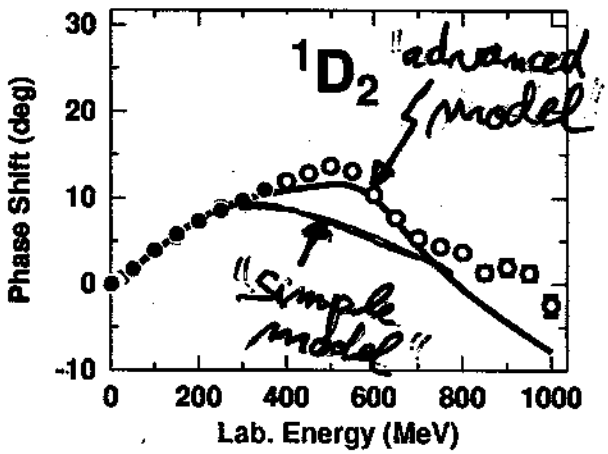

$^1S_0$
Inelasticity P. (deg)
50
25
0
0
200
400
600
800
1000
Lab. Energy (MeV)

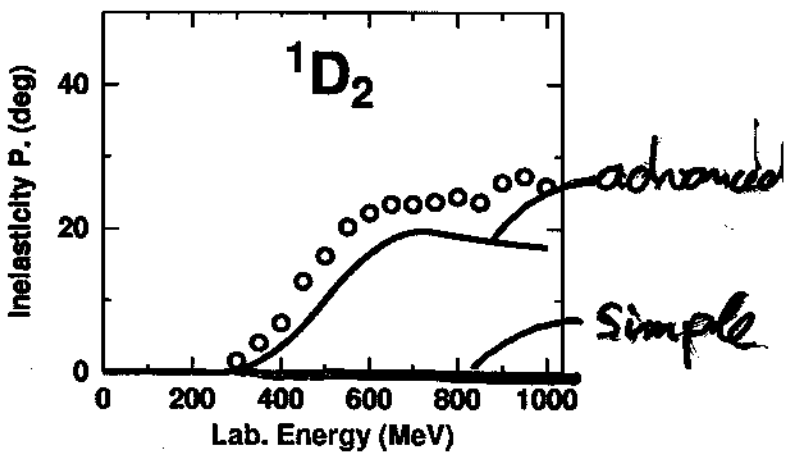

$^3P_0$
Phase Shift (deg)
50
0
-50
0
200
400
600
800
1000
Lab. Energy (MeV)

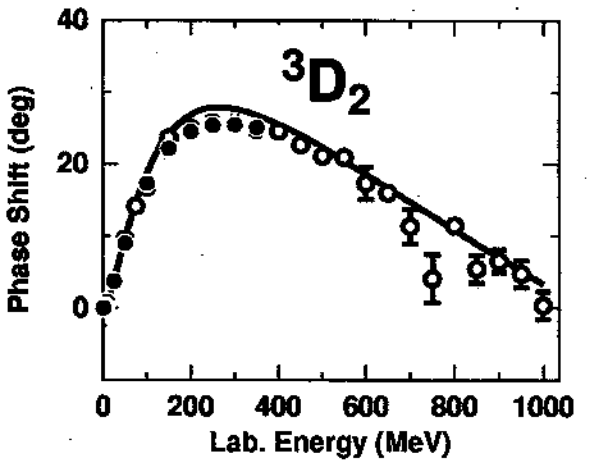

$^3P_0$
Inelasticity P. (deg)
60
40
20
0
0
200
400
600
800
1000
Lab. Energy (MeV)

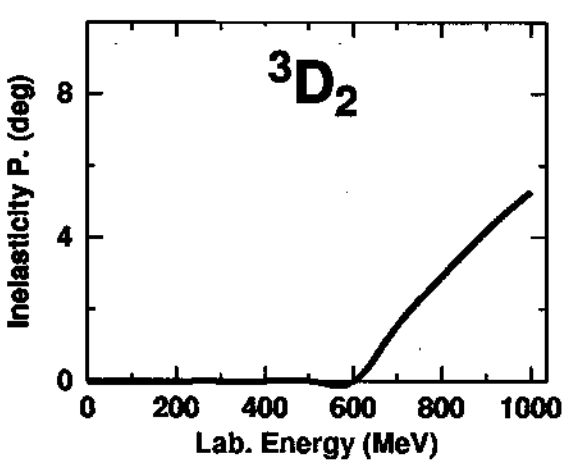

$^1P_1$
Phase Shift (deg)
25
0
-25
-50
0
200
400
600
800
1000
Lab. Energy (MeV)

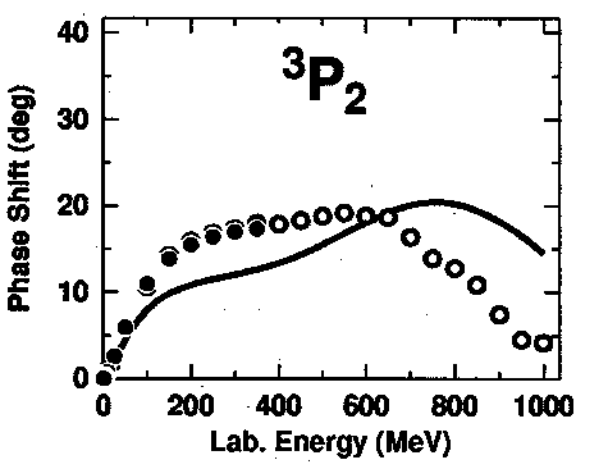

$^1P_1$
Inelasticity P. (deg)
50
25
0
0
200
400
600
800
1000
Lab. Energy (MeV)

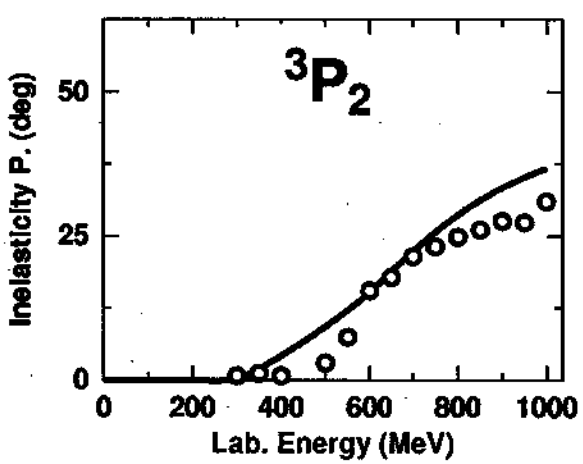

$^1D_2$
"advanced" model
"simple model"
Phase Shift (deg)
Lab. Energy (MeV)


$^1D_2$
advanced
Simple
Inelasticity P. (deg)
Lab. Energy (MeV)


$^3D_2$
Phase Shift (deg)
Lab. Energy (MeV)


$^3D_2$
Inelasticity P. (deg)
Lab. Energy (MeV)


$^3P_2$
Phase Shift (deg)
Lab. Energy (MeV)


$^3P_2$
Inelasticity P. (deg)
Lab. Energy (MeV)

MOVING UP:

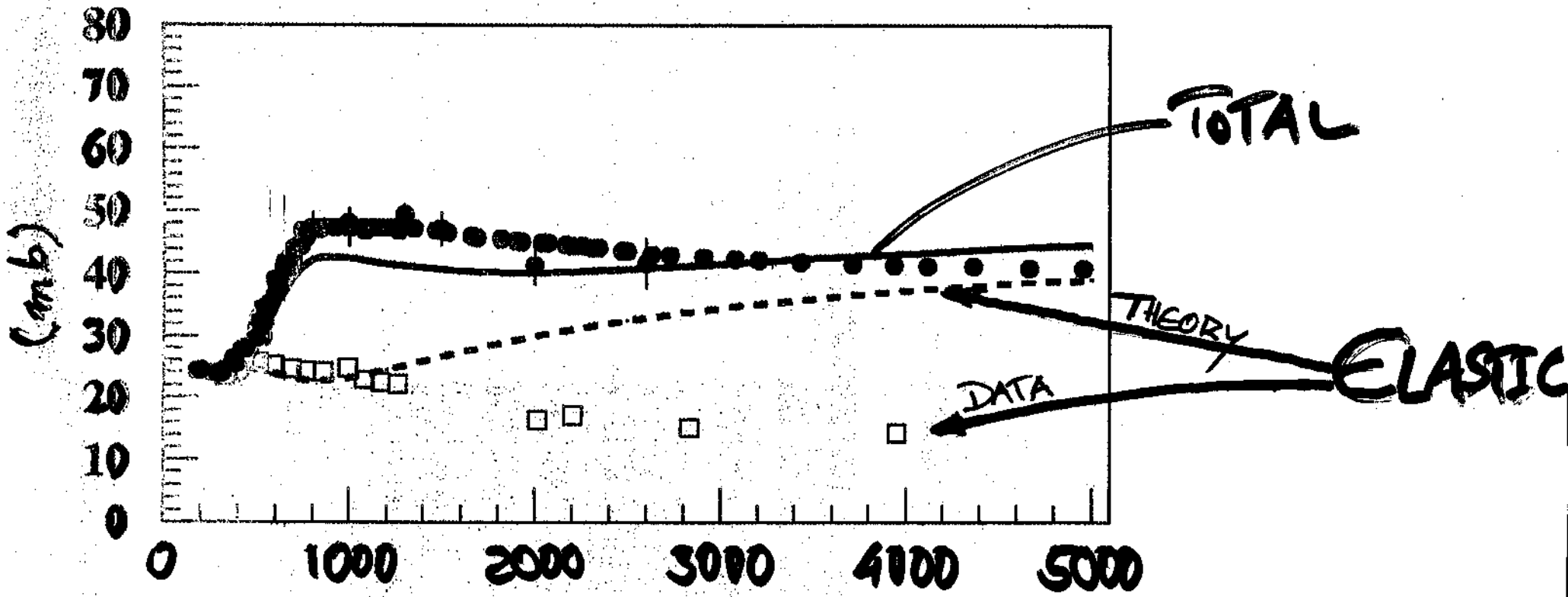
> 1 GeV

CONSIDER FIRST:

TOTAL CROSS SECTS.

CROSS SECTIONS

ORIGINAL MODEL



"THE" PROBLEM of Meson models at high energies:

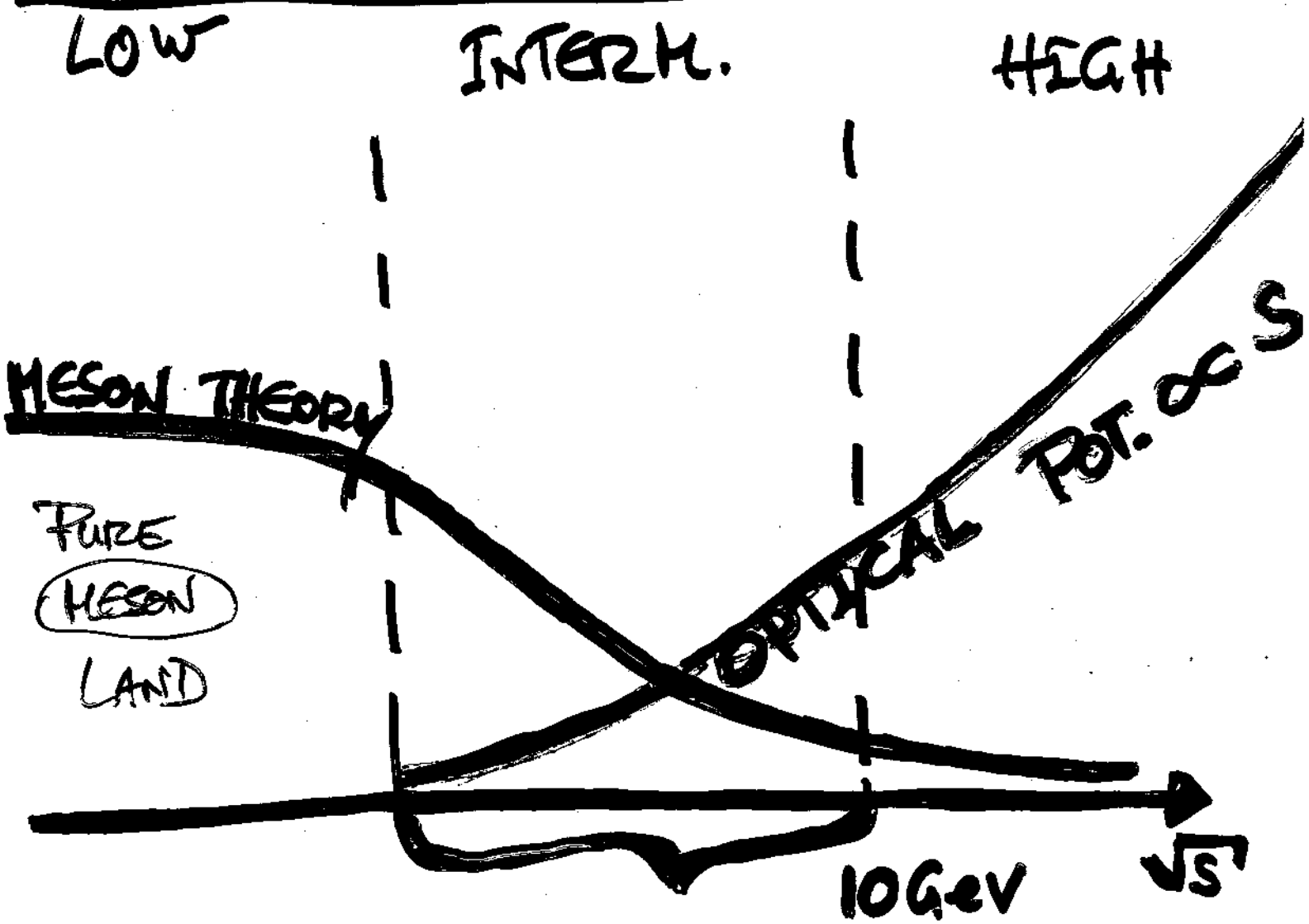
ω-exchange $\propto \frac{s}{t - m_\omega^2}$!

... and this is NOT what the elastic ϕ's do!

Historically, this was the reason why REGGE Theory was "invented".

→ DIVIDE it OUT! $\times \frac{1}{s}$

SUMMARY OF MODIFICATIONS :



- GRADUAL PHASING OUT MESONS

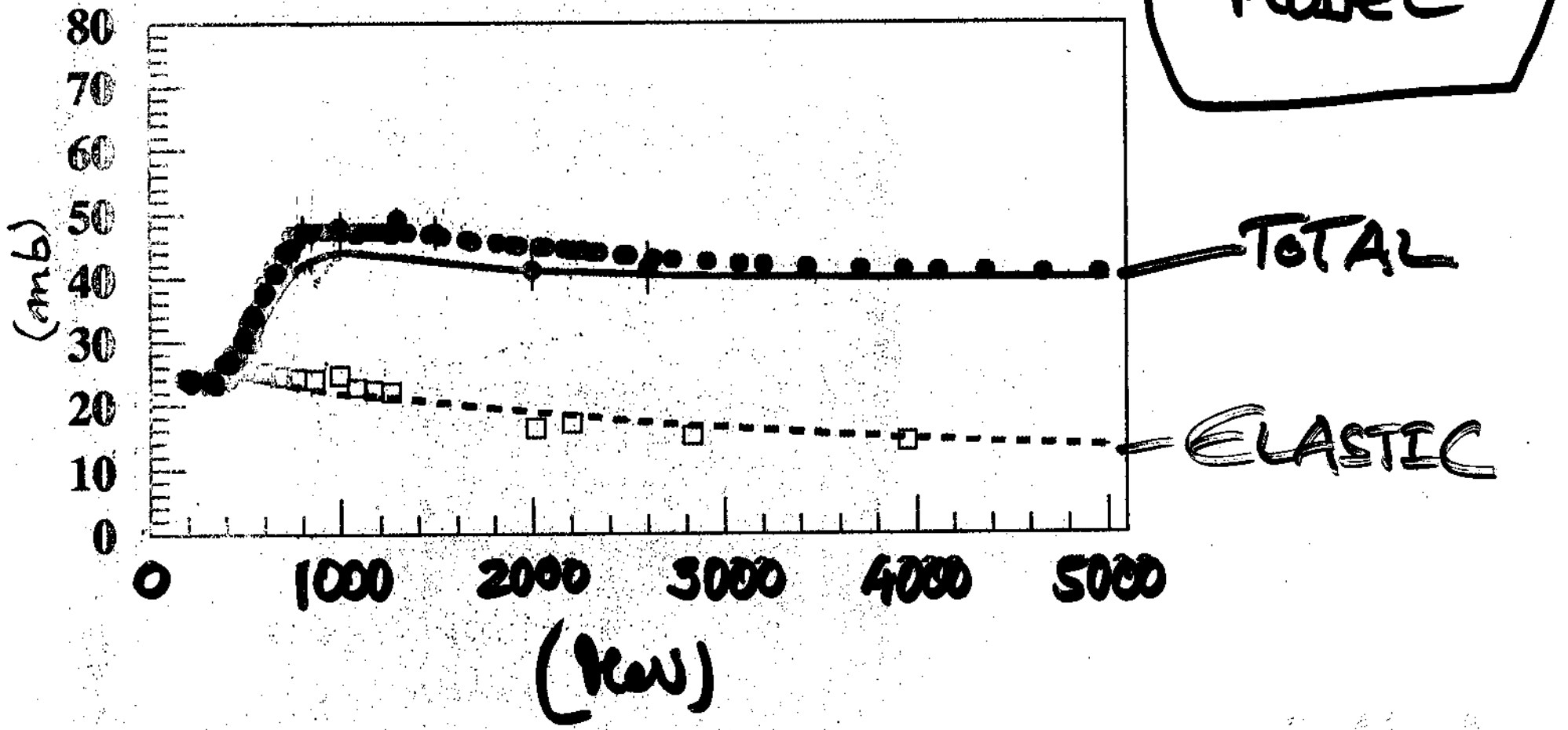
- GRADUAL PHASING IN of high-energy optical potential

OPTICAL POTENTIAL

$$V_{opt}(k,s) = (V_0 + i W_0) e^{-\frac{k^2 a^2}{4}\left[\frac{s-s_0}{4\pi^2}\right]}$$

2 PARAMETERS: V_0, W_0.

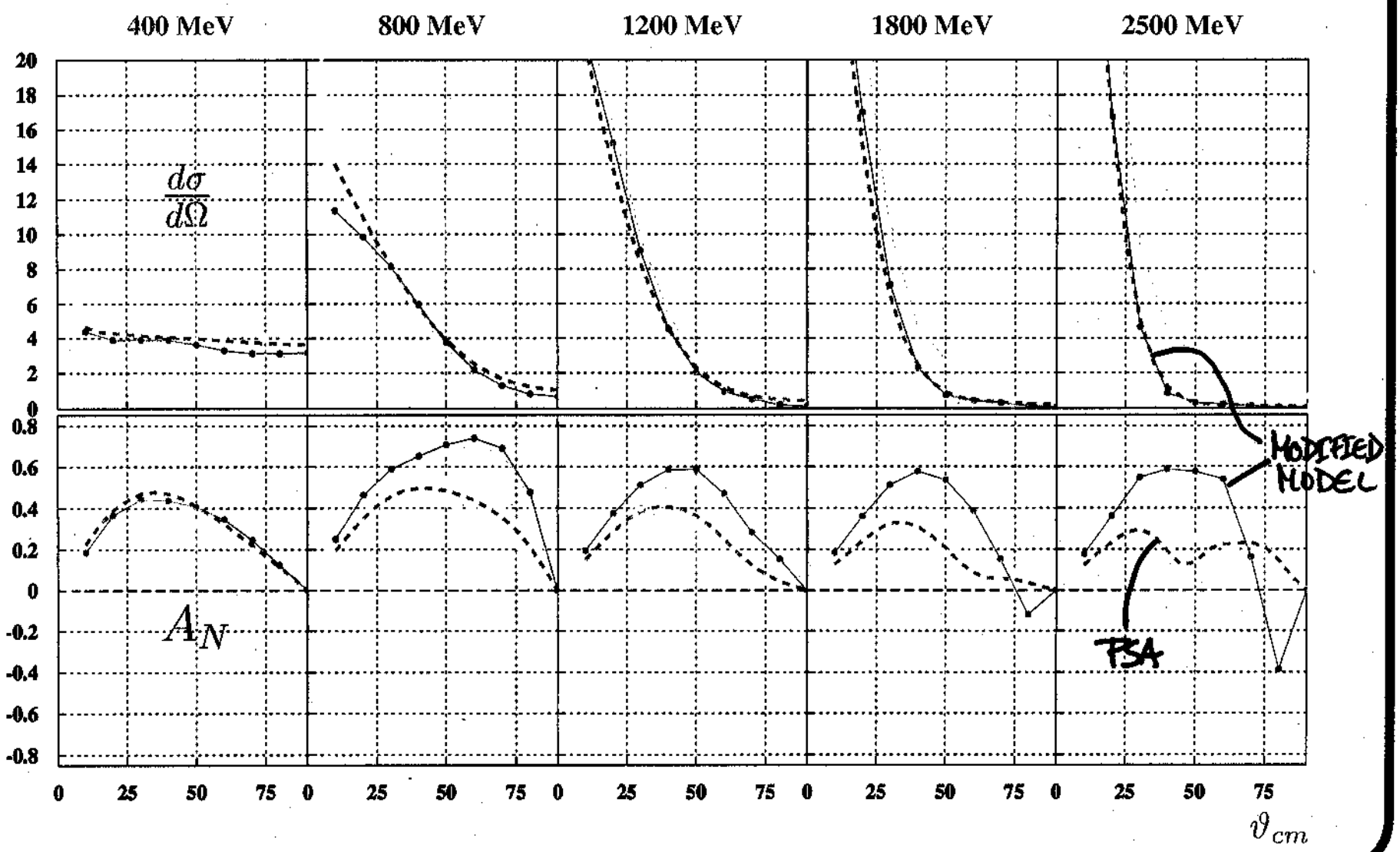
NOTICE: we do not use a different pot. in each partial wave (cf. Jeremy).


MODIFIED MODEL
80
70
60
50
40
30
20
10
0
(mb)
0
1000
2000
3000
4000
5000
(KeV)
TOTAL
ELASTIC

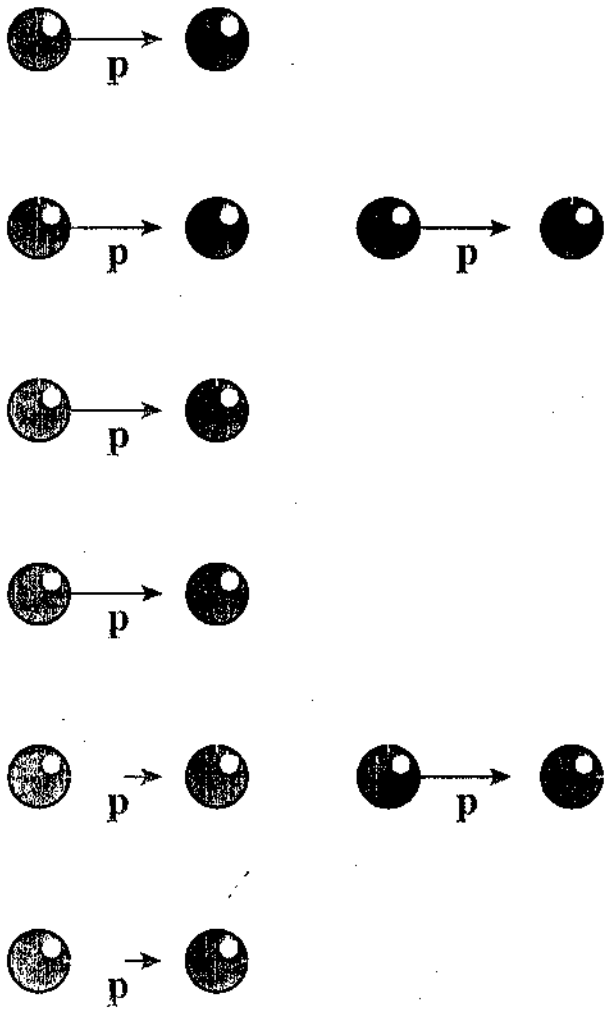
SPIN OBS:

More Problems

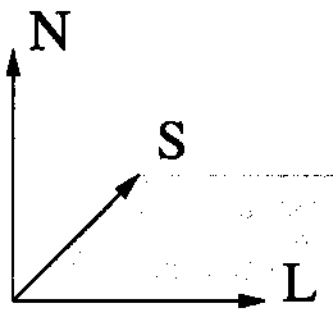
MESON EXCHANGE MODELS ABOVE 300 MeV



More Polarization



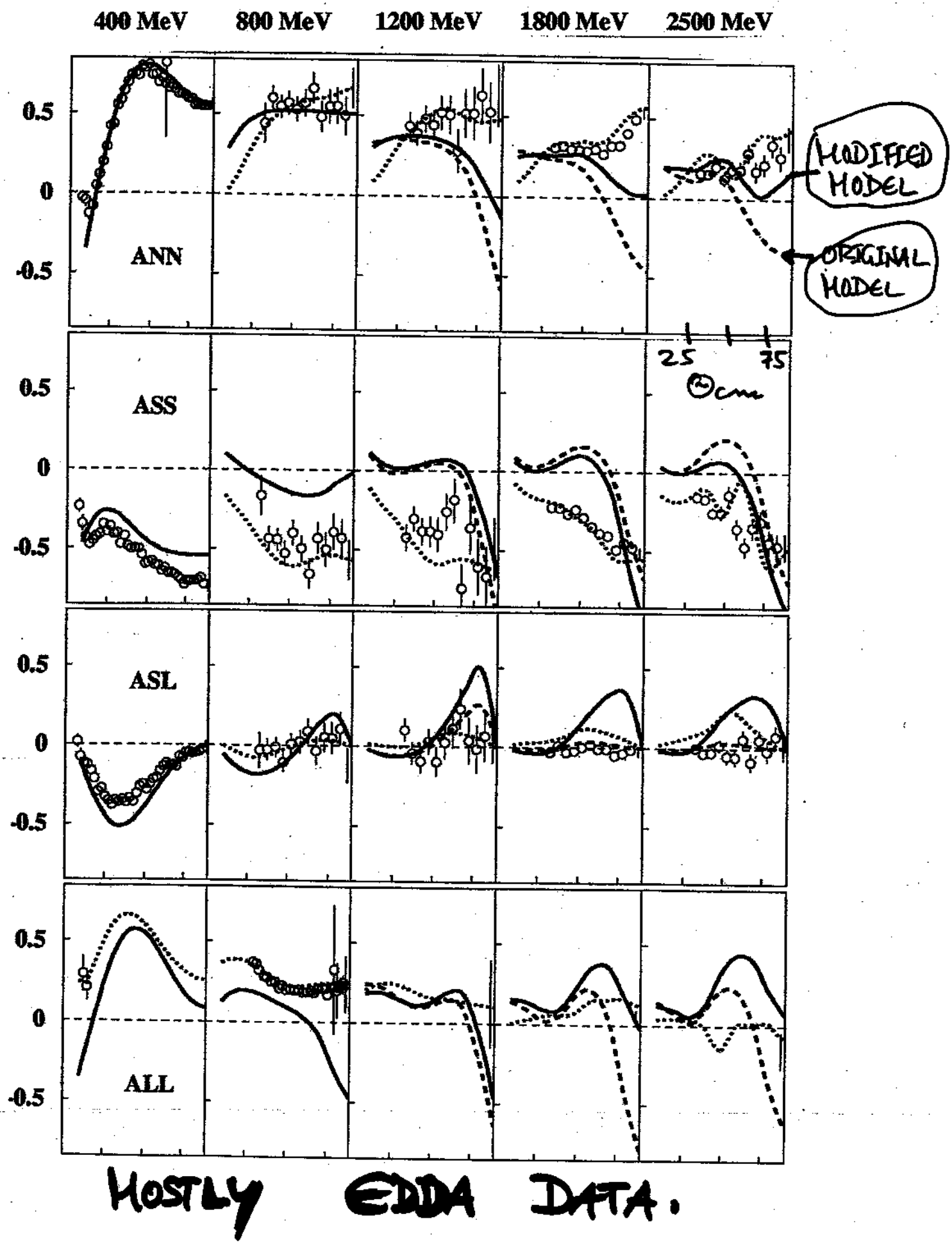
scattering plane $\vec{L}$, $\vec{S}$ and $\vec{N}$



P denotes beam polarization

Q denotes target polarization

$$\begin{aligned}\frac{d\sigma}{d\Omega}/I_0 = 1 &+ A_N \cdot (P_N + Q_N) \\ &+ A_{NN} \cdot P_N \cdot Q_N \\ &+ A_{SS} \cdot P_S \cdot Q_S \\ &+ A_{SL} \cdot (P_L \cdot Q_S + P_S \cdot Q_L) \\ &+ A_{LL} \cdot P_L \cdot Q_L\end{aligned}$$


400 MeV
800 MeV
1200 MeV
1800 MeV
2500 MeV
0.5
0
-0.5
ANN
ASS
ASL
ALL
MODIFIED MODEL
ORIGINAL MODEL
25
75
θcm
MOSTLY EDDA DATA.

THE MODEL PARAMETERS

- MESON - NUCLEON Coupling Constants

- MESON - NUCLEON FF: $\left(\frac{\Lambda_\alpha^2 - m_\alpha^2}{\Lambda_\alpha^2 + t^2}\right)^{n_\alpha}$

for $\pi, \delta, \omega, \sigma, \eta$:

$\approx$ 10 parameters.

VARIATION OF THESE PARAMETERS DOES

NOT

LEAD TO OVER-ALL IMPROVEMENT.

SUMMARY UP TO THIS POINT:

- Historically, there are established "theories" for the NN Interaction at
  - low and
  - high energies;

  Two separate cultures.

- RECENT EXPERIMENTAL Activity in the few-GeV region at SATURN and COSY (Jülich, GERMANY) has drawn attention to the TRANSITION Region.

- These new data confirm the wrong asymptotic behavior of vector-meson exchange at energies $T_{lab} \gtrsim 1.5$ GeV

● NN Model for the Transition:

- divide out the wrong high energy behavior of W-exchange (factor: $\frac{4M^2}{S}$); affects traditional low-energy meson-models negligibly!

- phase in high-energy opt. pot.: $\propto S$

⇒ RECONCILATION of low and high energy!

⇒ TOTAL CROSS SECTIONS RIGHT.

- HOWEVER SPIN OBS ABOVE $\approx$ 1 GeV WRONG!

EVEN A_N !

WHAT IF IT ?

INVOKE QCD?

PERTURBATIVE QCD (pQCD):

$$A_N \equiv 0$$

QUARK INTERCHANGE MODEL:

$$A_{NN}(90°) = \frac{1}{3}$$

BOTH IS NOT TRUE UP TO VERY HIGH ENERGIES. !!

ALAN KRISCH & CO.

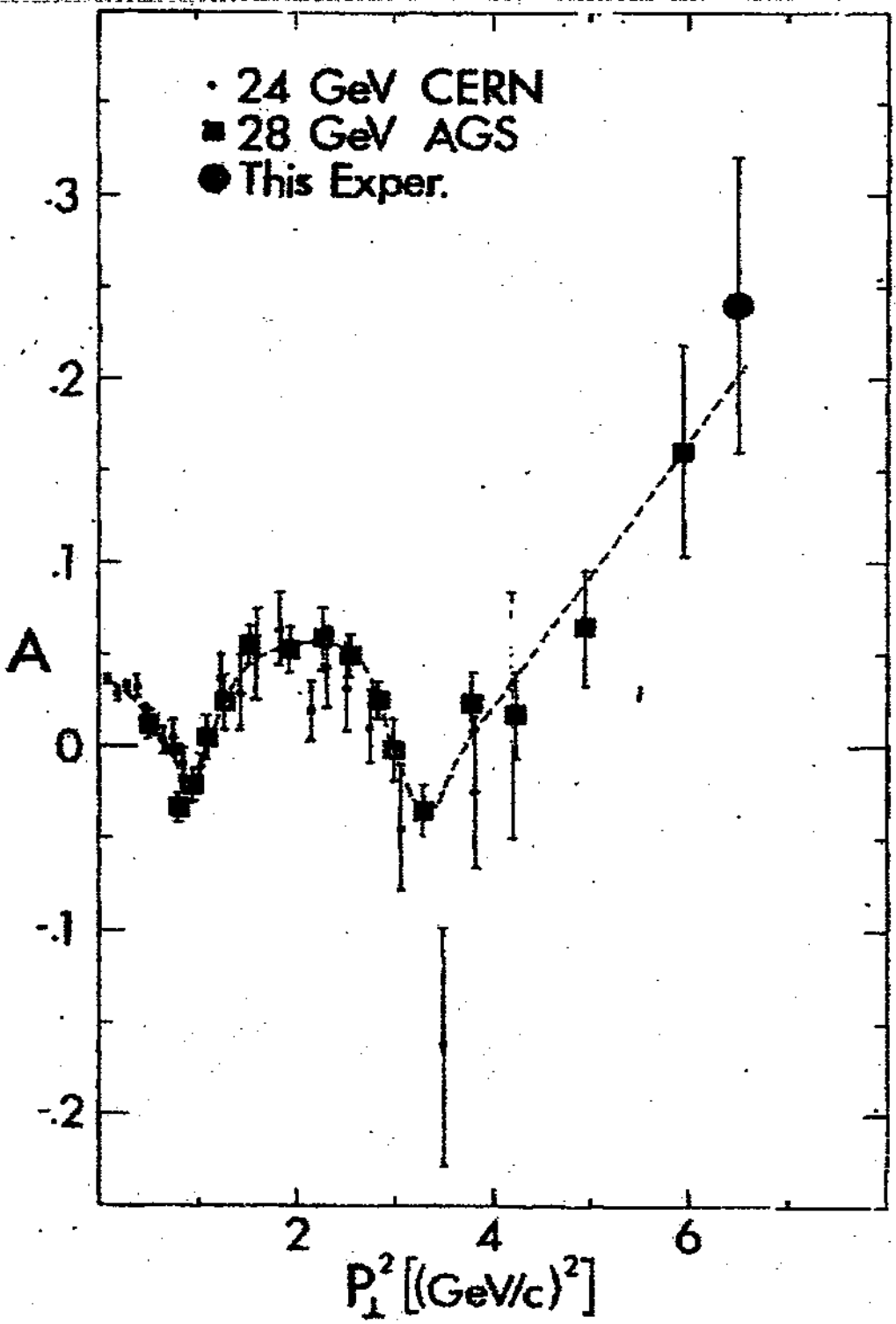
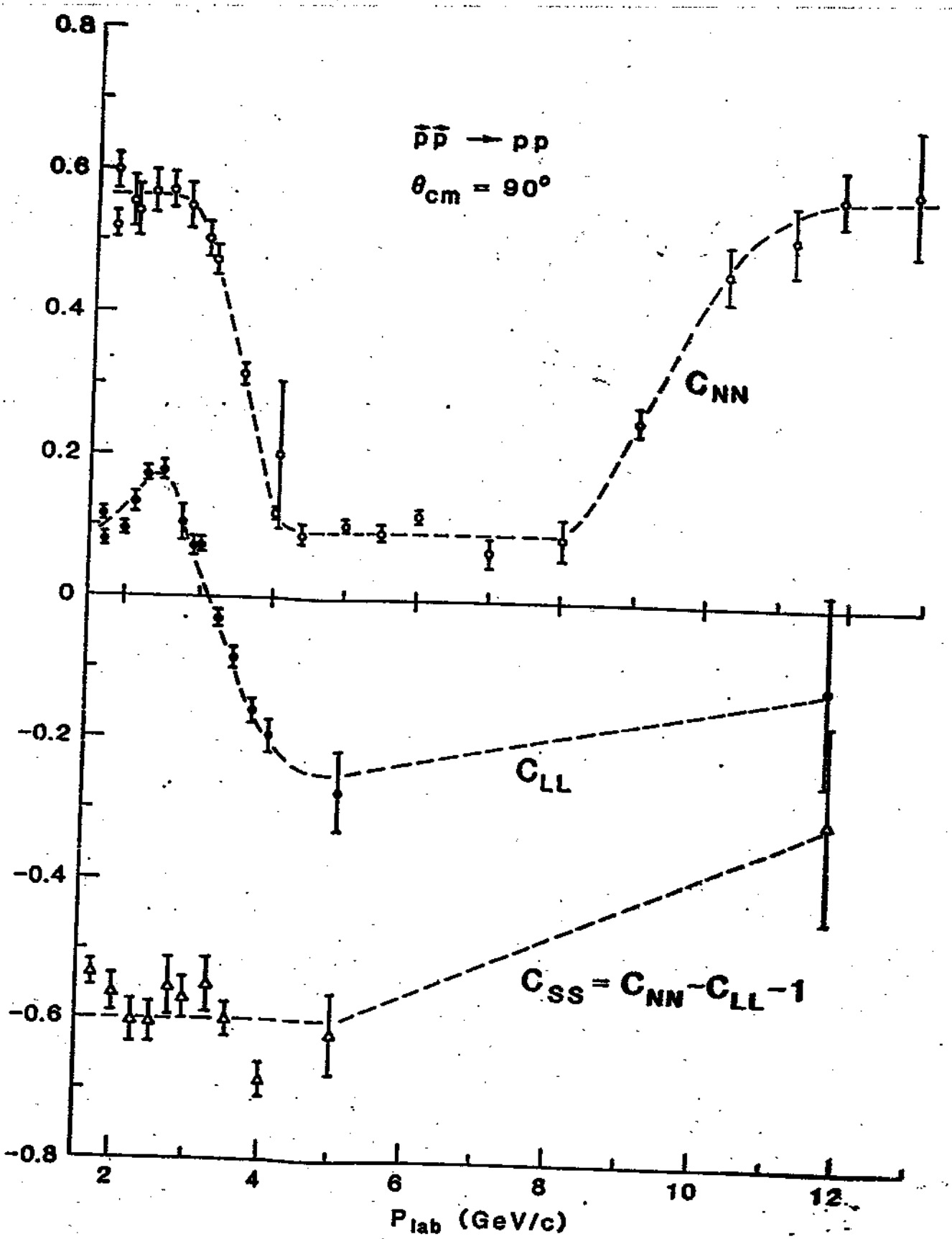


FIG. 2. Analyzing power for proton-proton elastic scattering plotted as a function of $P_\perp{}^2$. Some adjacent AGS data points have been combined. The curve is a hand-drawn line to guide the eye.


$\vec{p}\vec{p} \rightarrow pp$
$\theta_{cm} = 90°$
C_{NN}
C_{LL}
$C_{SS} = C_{NN} - C_{LL} - 1$
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
2
4
6
8
10
12
P_{lab} (GeV/c)

- THE MESON MODEL IS WRONG.
- pQCD IS WRONG.

$\Longrightarrow$ IT IS CERTAINLY AN INTERESTING REGION

(A NON-PERTURBATIVE REGIME FOR WHICH WE DO NOT HAVE A WORKING MODEL.)

TRY LATTICE QCD WHEN POSSIBLE.

FINAL CONCLUSION:

THIS IS A DEFEAT OF THEORY.

BUT A TRIUMPH OF EXPERIMENT!!