IC/74/76
INTERNAL REPORT
(Limited distribution)

International Atomic Energy Agency

and

United Nations Educational Scientific and Cultural Organization

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

T O P I C A L M E E T I N G

ON THE PHYSICS OF COLLIDING BEAMS

20 - 22 June 1974

(SUMMARIES AND CONTRIBUTIONS)

MIRAMARE - TRIESTE

July 1974

ELASTIC AND INELASTIC ($p_T \lesssim 1$ GeV/c) PROCESSES AT THE ISR

U. Amaldi
CERN, Geneva, Switzerland.

1. Results of first generation experiments.

2. First data of second generation experiments.

3. A glance into the future.

1. RESULTS OF FIRST GENERATION EXPERIMENTS

1.1. SCALING OF INCLUSIVE SPECTRA_

1.2. EXISTENCE OF TWO INELASTIC COMPONENTS _

1.3. "SCALING" OF CORRELATION FUNCTIONS IN CR AND FR_

1.4. DIFFRACTIVE NATURE OF ELASTIC SCATTERING_

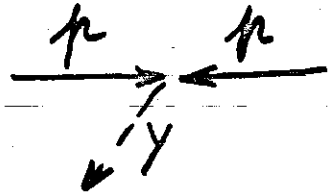
1.5. "EQUAL" INCREASE OF (SLOPE) b, σ_t, σ_{el}, σ_{in} _

$$\underline{x} = \frac{2p_L}{\sqrt{s}} \qquad -1 \leq x \leq +1$$

1.0. VARIABLES:

$$\underline{y} = \frac{1}{2} \ln \frac{E+p_L}{E-p_L} \qquad \Delta y_{max} \propto \ln s$$

COSMIC RAY RAP.: $\eta = -\ln \operatorname{tg} \frac{\theta}{2} \simeq y$ for $p_T^2 \gg m^2$

- y IS IN c.m. SYSTEM 

- $y_{LAB} \simeq y_{MAX} - y$; y_{MAX} = RAPIDITY OF INCOMING P = $= \ln\left(\frac{\sqrt{s}}{m_p}\right)$

p_{ISR}	$\sqrt{s}$	y_{MAX}
11.8	23.2	3.2
15.4	30.5	3.5
22.5	44.5	3.9
26.6	52.5	4.0
31.5	62.0	4.1

$\Delta y = 0.8$

INVARIANT CROSS-SECTION: $f(y, s, p_t) = E\frac{d\sigma}{d^3p}$

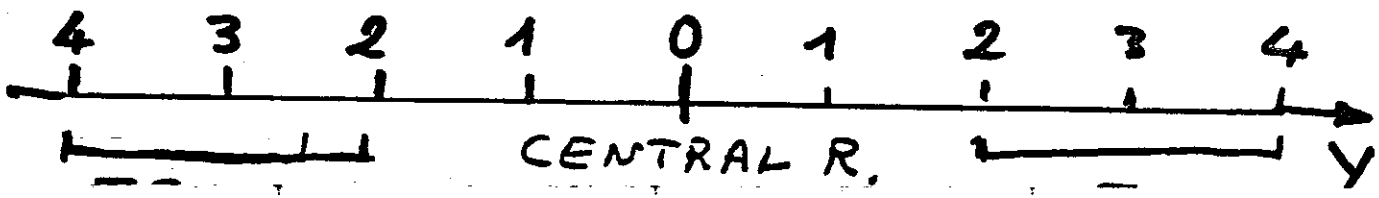
CORRELATION FUNCTION: $C(y_1, y_2) = \frac{1}{\sigma_{in}} \frac{d^2\sigma}{dy_1\, dy_2}$ } COMBINED PROBABILITY

$- \frac{1}{\sigma_{in}^2} \frac{d\sigma}{dy_1} \frac{d\sigma}{dy_2}$ } PRODUCT OF PROB.

NORMALIZED CORRELATION FUNCTION: $R(y_1, y_2) = \frac{C(y_1 y_2)}{\frac{1}{\sigma^2} \frac{d\sigma}{dy_1} \frac{d\sigma}{dy_2}}$

FRAGMENTATION REGION: $Y_{LAB} = Y_{MAX} - Y \leq 2$

CENTRAL REGION: $|Y| \leq 2$



1.1 SCALING OF INCLUSIVE SPECTRA

SCALING IDEA: $f(y, s, p_t) \rightarrow f(y_{LAB}, p_t)$

NTRIBUT:

BC

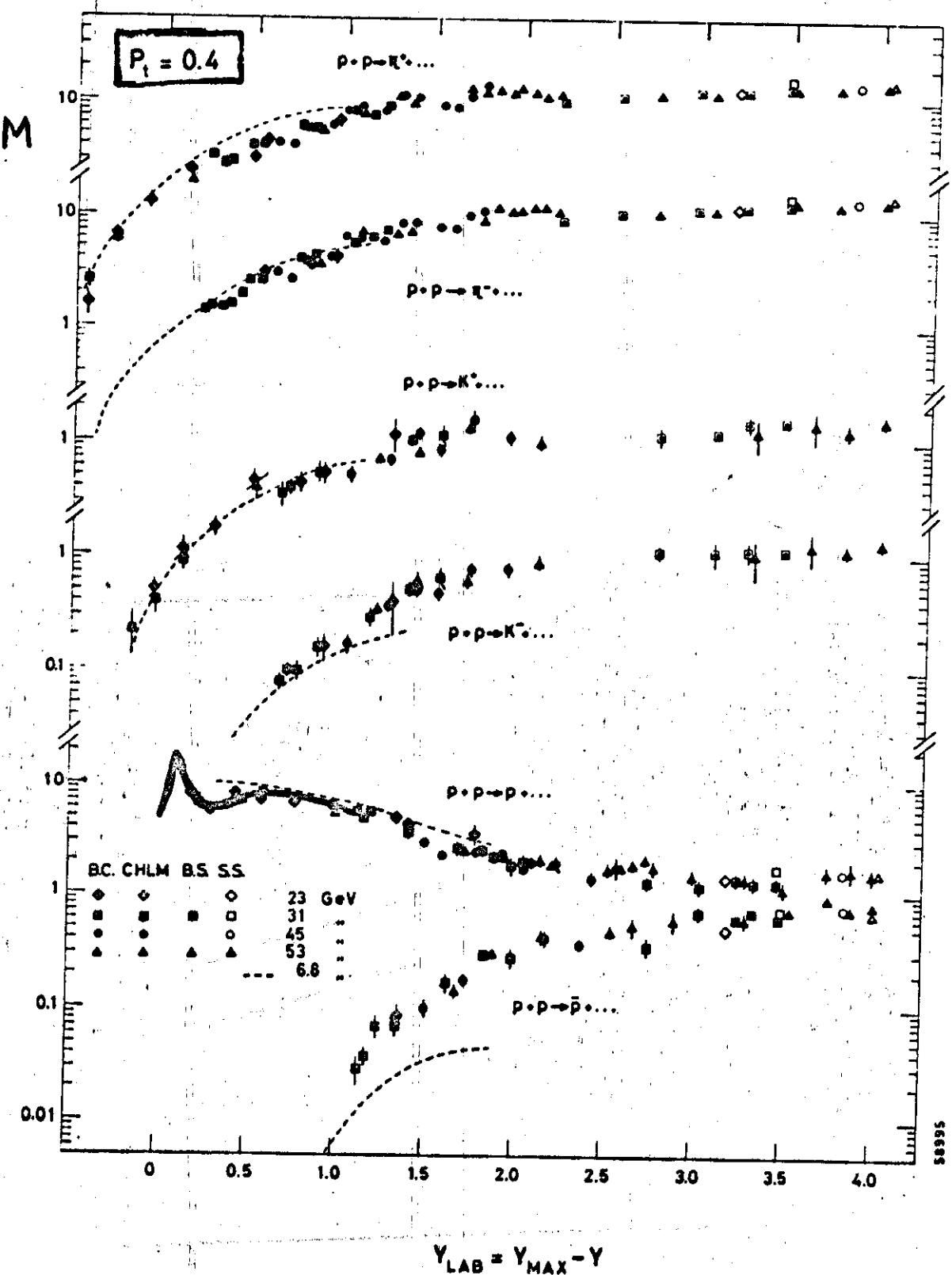
CHLM

BS

SS

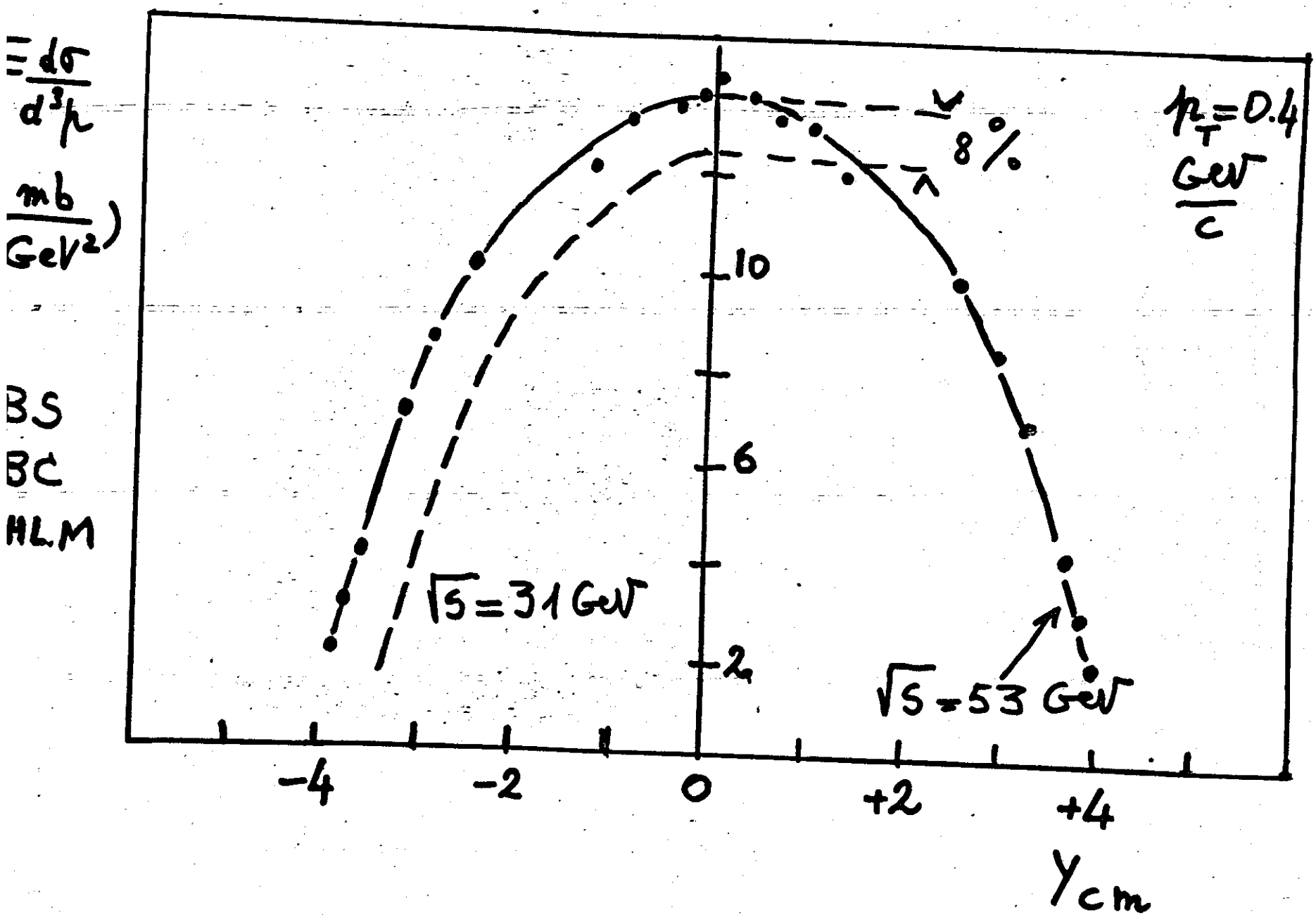
FR

CR



CR

$\Delta y_{max} = 0.6$



CONCLUSIONS:

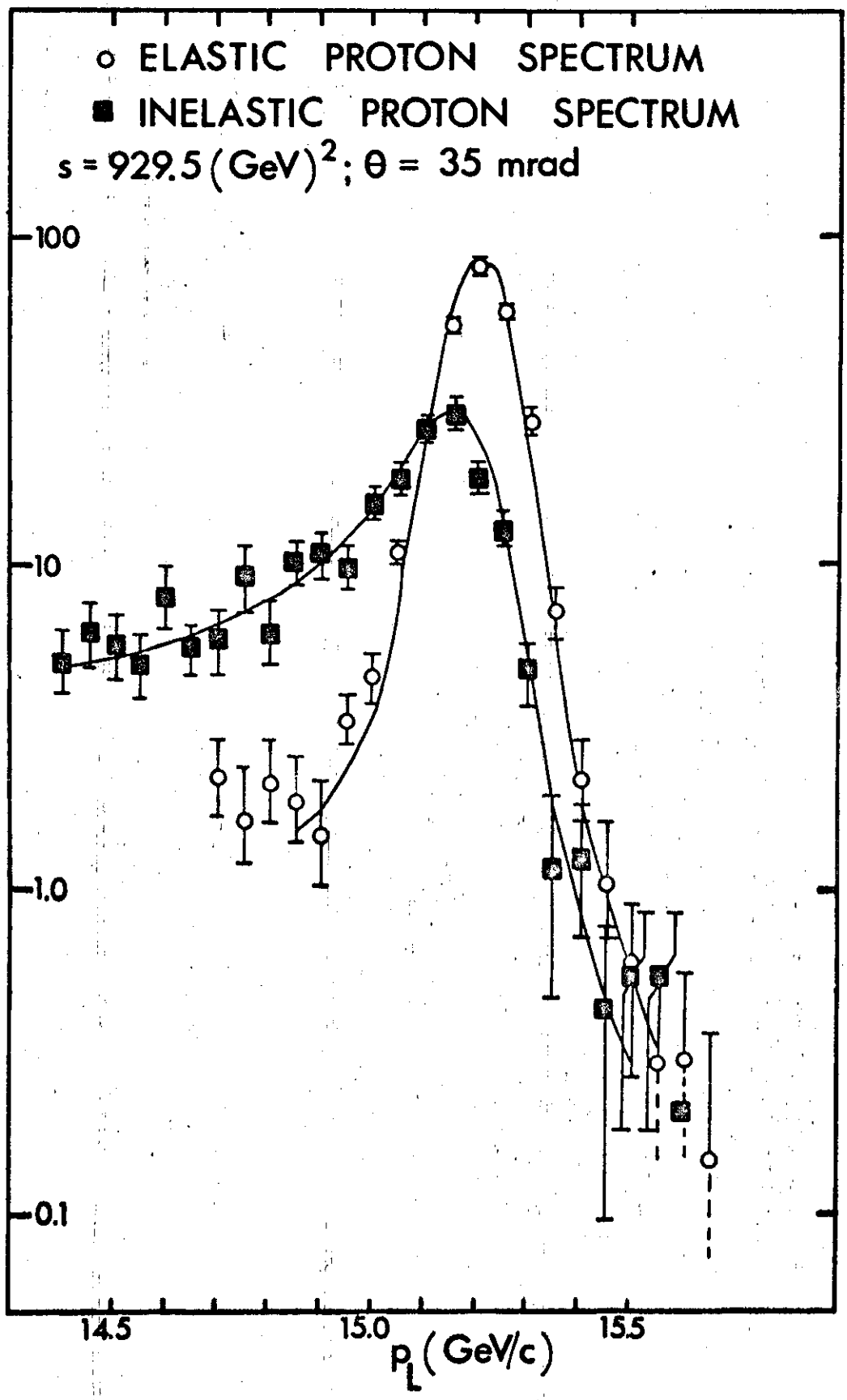
1. INCLUSIVE DISTRIBUTIONS SCALE IN THE ISR ENERGY RANGE AS A FUNCTION OF Y_{LAB} (TO ABOUT 10% ACCURACY).

2. THIS SEEMS TO BE VALID ALSO IN THE CENTRAL REGION. UNDER THIS ASSUMPTION, THE INVARIANT CROSS SECTION AT $y=0$ INCREASES BY $\sim 8\%$ IN THE ENERGY RANGE OF THE ISR.

3. IN LINEAR PLOT IT IS SEEN THAT THE CENTRAL "PLATEAU" IS NOT FLAT.

1.2 EXISTENCE OF TWO INELASTIC COMPONENTS

THE SINGLE DISSOCIATION COMP



CHLM

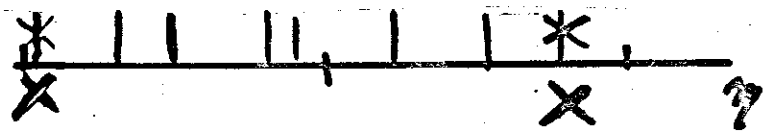
$b_B \simeq 5$

FIRST EVIDENCE FOR SINGLE DISSOC.

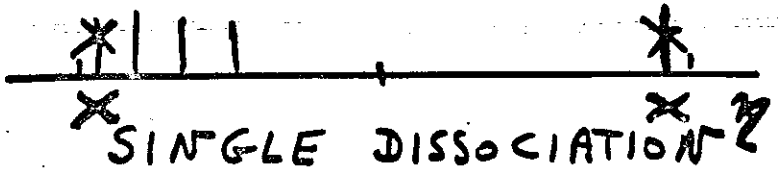
ANOTHER WAY OF SEPARATIN SINGLE DISSOCIATION:

PSB LARGE COVERAGE SET-UP MEASURES η -

NON SD EVENTS



PROTON

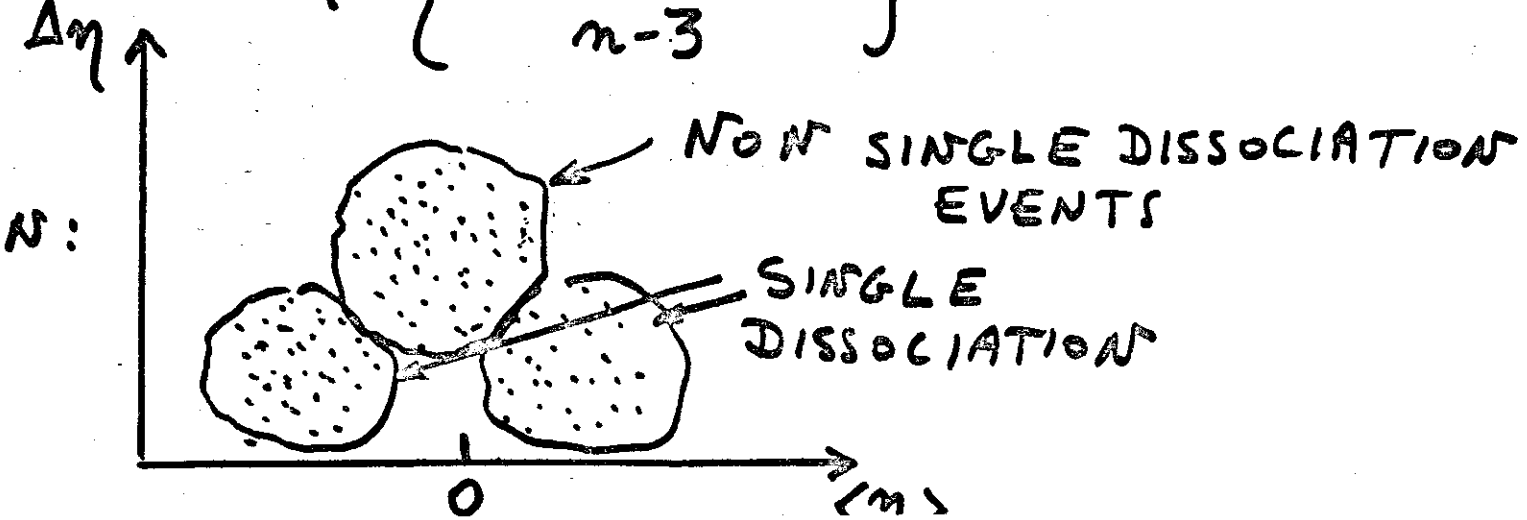


METHOD: FORGET THE EXTREME TRACKS IN η PLOT AND COMPUTE:

$$\langle \eta \rangle = \sum_{1}^{n-2} \frac{\eta_i}{n-2}$$ AVERAGE

$$\Delta\eta = \left\{ \frac{\sum [\eta_i - \langle \eta \rangle]^2}{n-3} \right\}^{1/2}$$ DISPERSION

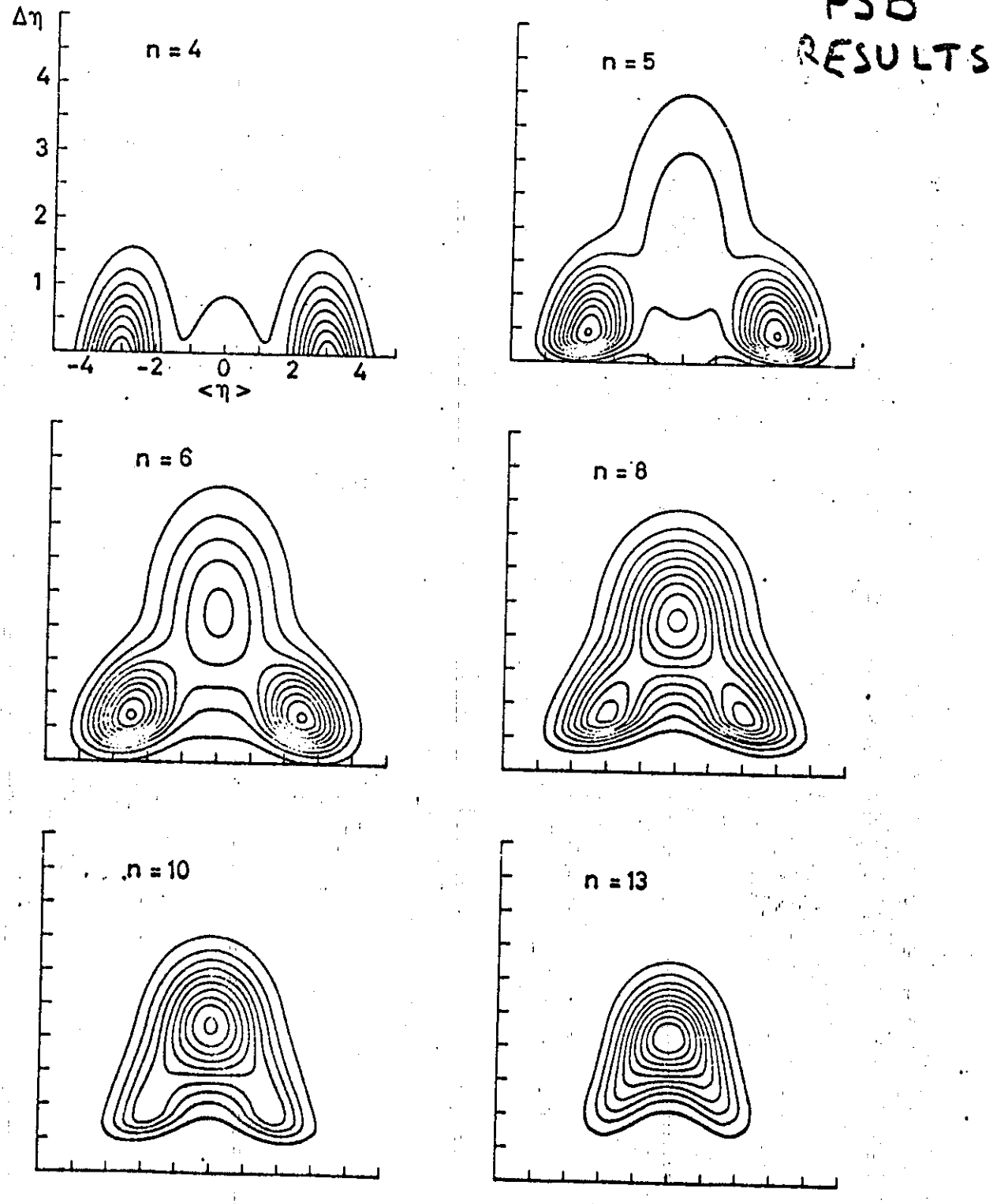
EXPECTATION:



DENSITY OF EVENTS

$P_{ISR} = 31.4$ GeV/c

PSB RESULTS

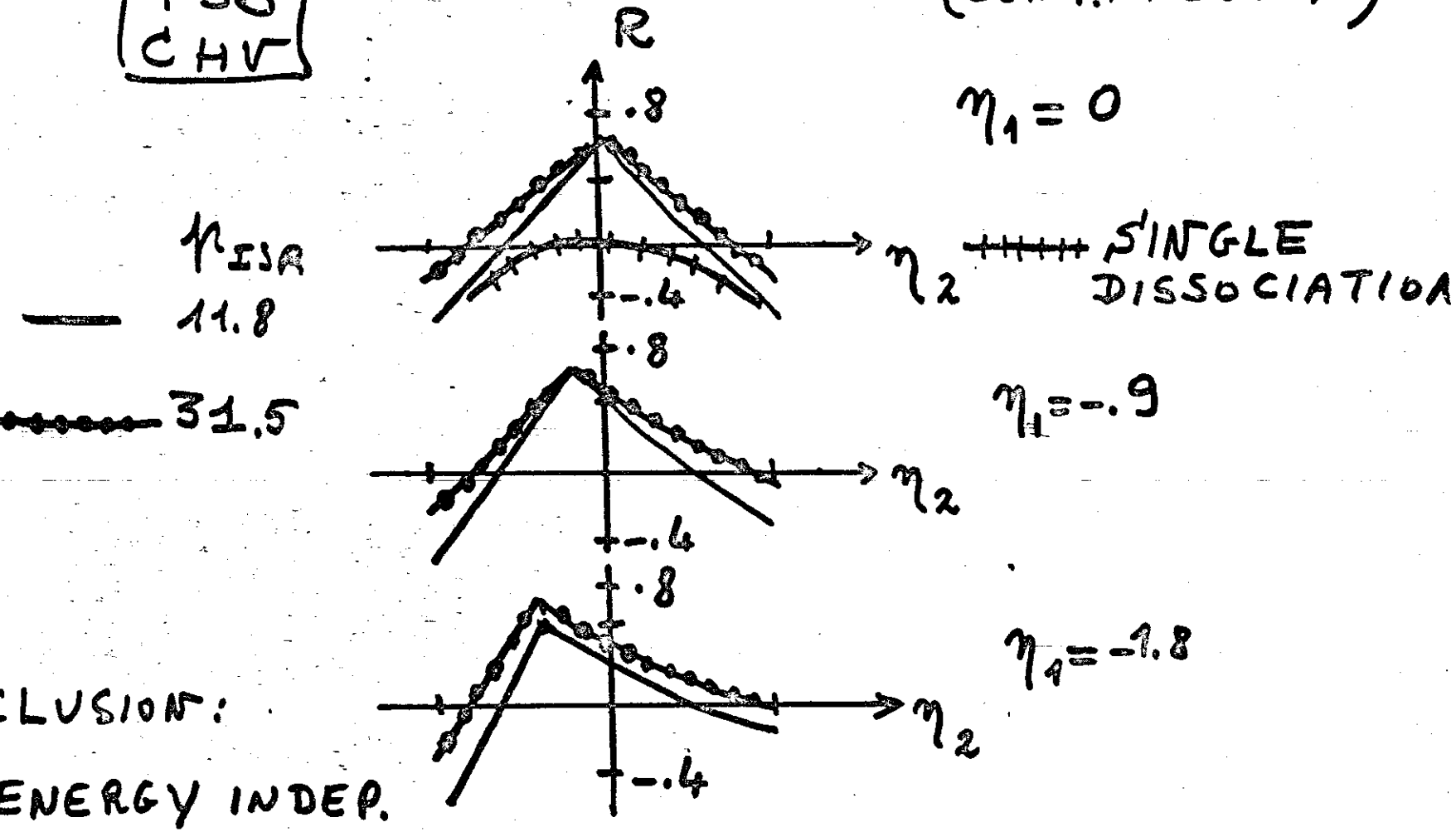


CONCLUSIONS : TWO COMPONENTS ARE CLEARLY SEEN. QUANTITATIVE WORK IN PROGRESS.

SCALING OF CORRELATION FUNCTION

PSB
CHV

(CENT. REGION)



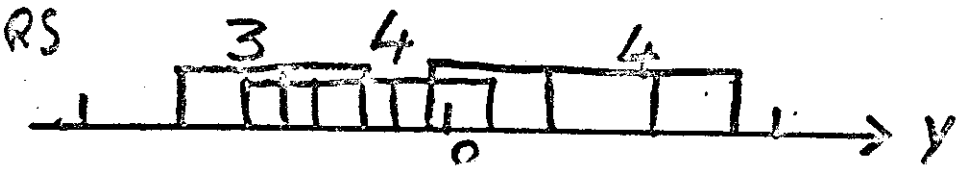
CONCLUSION:

R_0 = ENERGY INDEP.

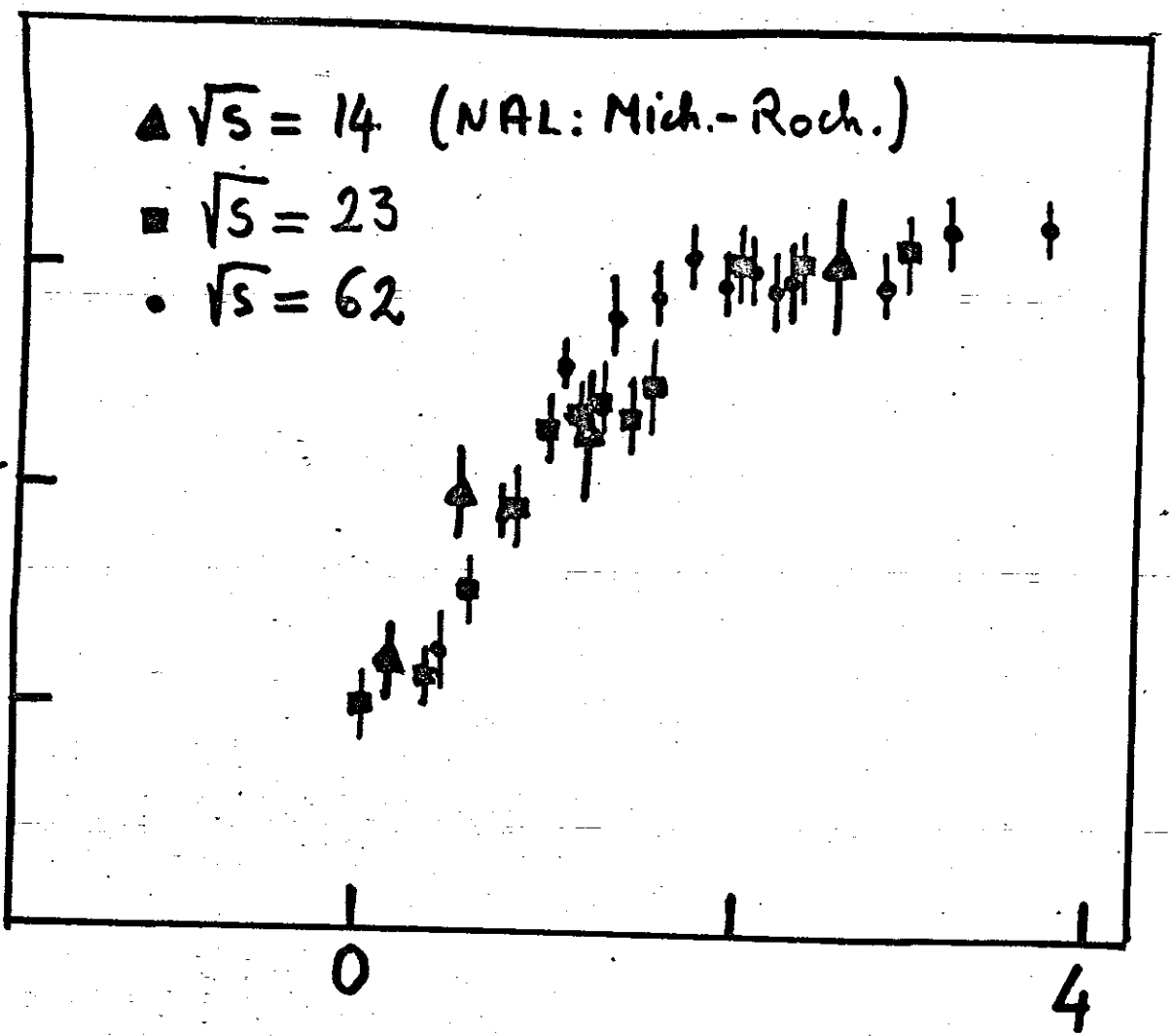
INTERPRETATION: SHORT RANGE ORDER IN CR

EX: 3 CLUSTERS

10 SUPERIMPOSED:

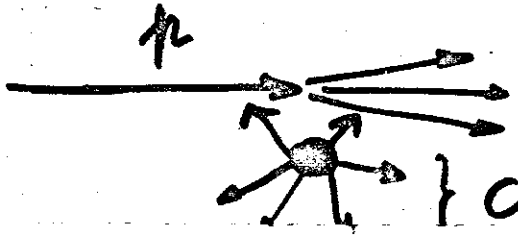


CORRELATION IN FRAGMENTATION REGION



PSB

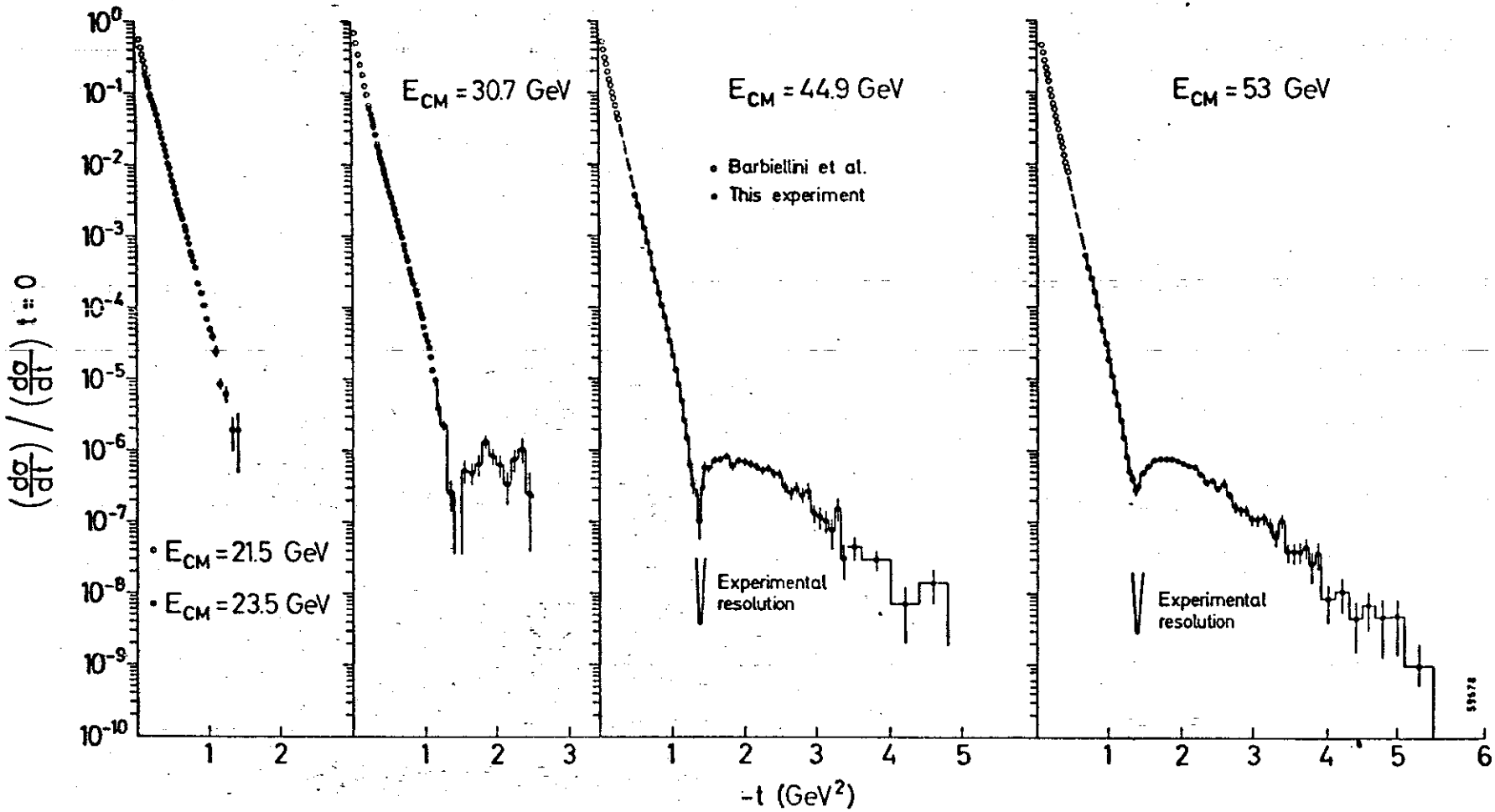
SIMPLE INTERPRETATION



} CORRELATIONS (AND NOT ONLY f)

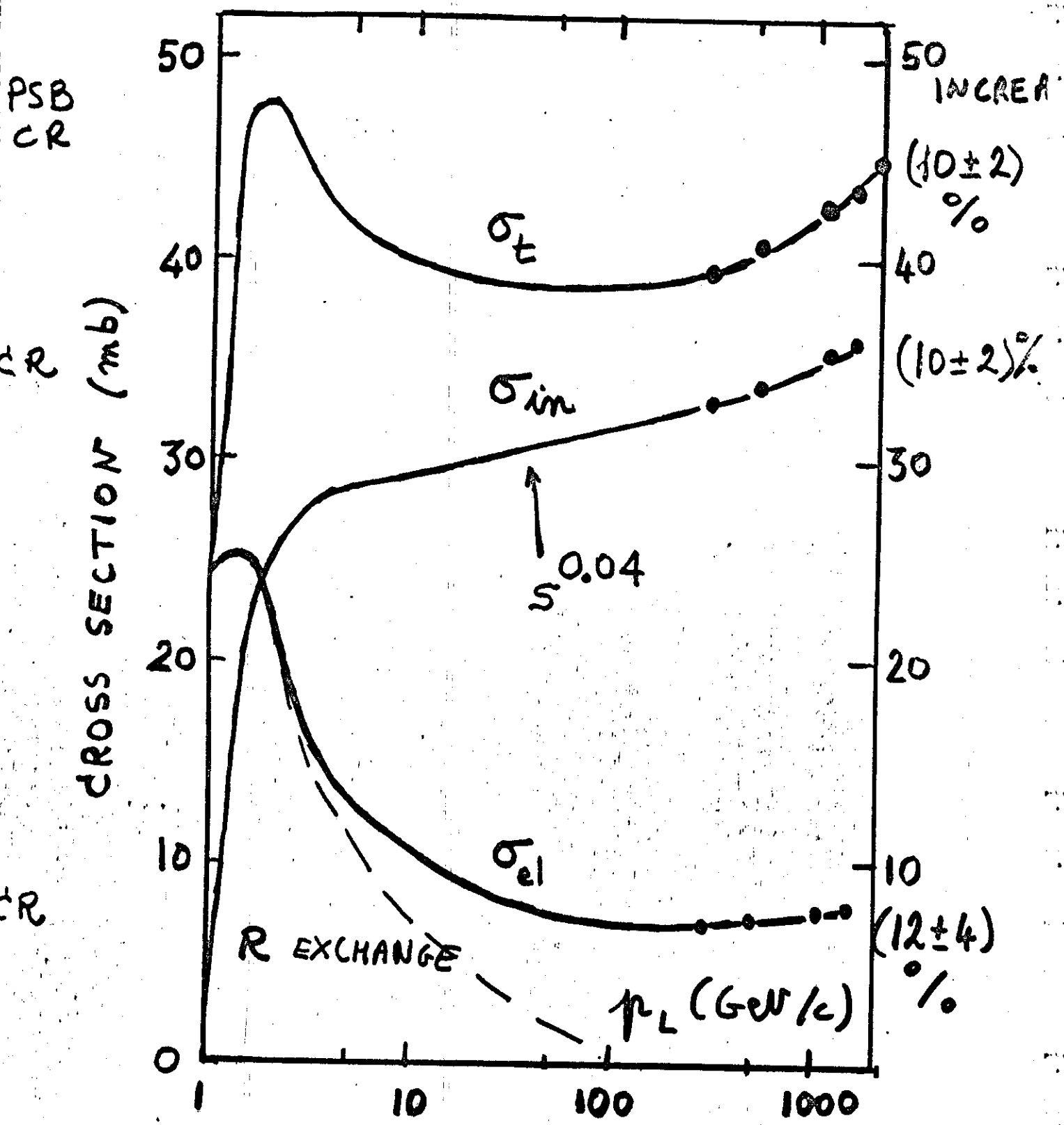
1.4 DIFFRACTIVE NATURE OF ELASTIC SCATTERING

ACGHT



OTHER RESULTS { CR : ρ - SLIGHTLY POSITIVE AT $\sqrt{s} \simeq 30$ GeV
ACGHT ; CR : SLOPE $b \propto \ln s$: + 8 % IN ISR RANGE.

1.5 INCREASE OF $\sigma_t, \sigma_{in}, \sigma_{el}$



CONCLUSION: IN THE ISR ENERGY RANG
THE FORWARD SLOPE b, AND THE
CROSS-SECTIONS σ_{in} σ_{el} σ_t INCREASE

1.6 SIMPLE PICTURES

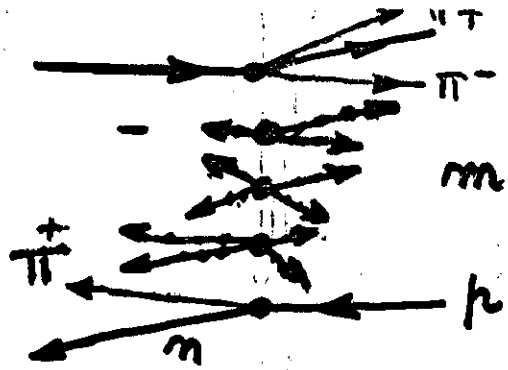
EMERGING PICTURE:

(1.) TWO TYPES OF EVENTS; TYPICALLY

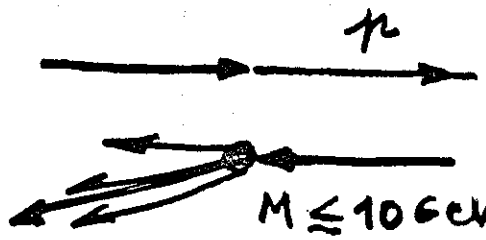
"PIONIZATION" EVENTS: 2 (OR 1) LEADING CLUSTER + 3-4 CENTRAL CLUSTERS, INDIPENDENT AND DECAYING ISOTROPICALLY. (MASS $\simeq$ 2 GeV).

"SINGLE DISSOCIATION" EVENTS IN WHICH MASSES UP TO $\sim$10 GeV ARE PRODUCED AND A PROTON REMAINS AT $x \simeq 1$.

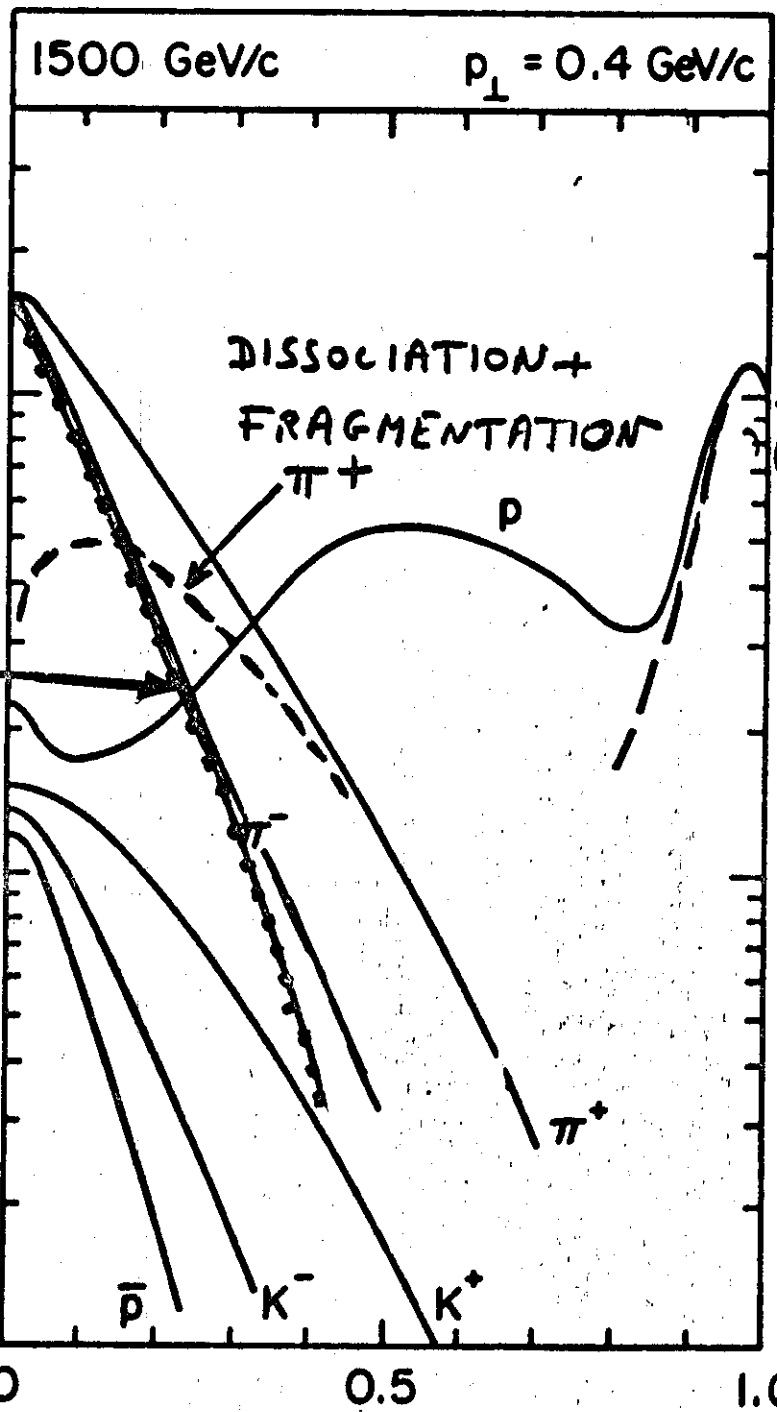
THE EXCESS OF POSITIVE CHARGES AT $x \simeq 0.5$ IS DUE DO THE DECAY OF <u>POSITIVE</u> LEADING CLUSTERS AND TO THE DECAY OF THE DISSOCIATING PROTON IN SINGLE DISSOCIATION. (NEXT FIGURE)



$m \simeq 2$ GeV



SINGLE DISSOCIATIC



AS MANY π^- AS π^+ IN CR

TRUE DIFFR. ?

2) DIFFRACTION SCATTERING → IMPACT PAR. a

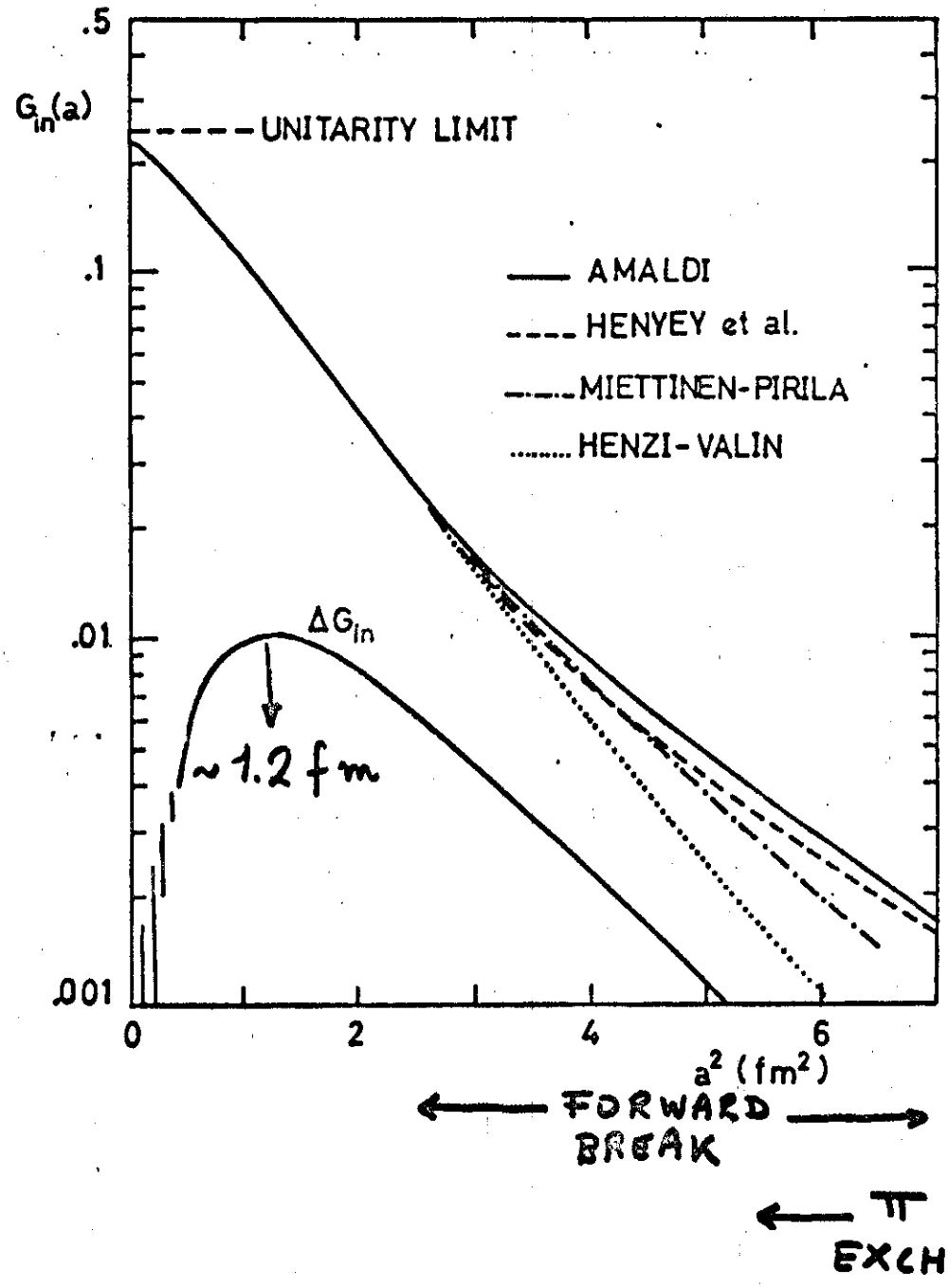
$$\mathrm{Im} f(a) = |f(a)|^2 + G_{in}(a)$$

$$\Sigma_n \quad n$$

$f(a=0) = 0.75$

FOR IMPACT PARAMETER $a=0$ ABSORPT. $\simeq 75\%$

OVERLAP FUNCTION DUE TO INEL. CHANNELS:



CONCLUSION: THE INCREASE OF σ_t COMES AROUND 1 fm

$\Delta\sigma_{in}$: PROPOSED MECHANISMS:

1) DIFFRACTION PRODUCTION OF LARGE M^2

ESTIMATED : $\Delta\sigma_{in} = 1-3$ mb

2) SRO PROCESSES $\Delta\sigma_{in} = 1.5-3$ mb

3) $B\bar{B}$ PRODUCTION

$\Delta\sigma_{in} \simeq 1-5$ mb

4) PARTON-PARTON INTERACTION

5) STOPPING PROTONS $\Delta\sigma_{in} \simeq 2$ mb

$\Delta\sigma_{exp} = (3.3 \pm 0.6)$ mb

$\Sigma = 6.-13.$ mb !!

QUESTION: IS ΔG_{in} "PERIPHERAL" ?

REMARK : NOT ONE SINGLE MECHANISM IS PROBABLY PRESENT.

2. FIRST DATA OF SECOND GENERATION EXPERIMENTS

2.1 SCALING OF INCLUSIVE SPECTRA.

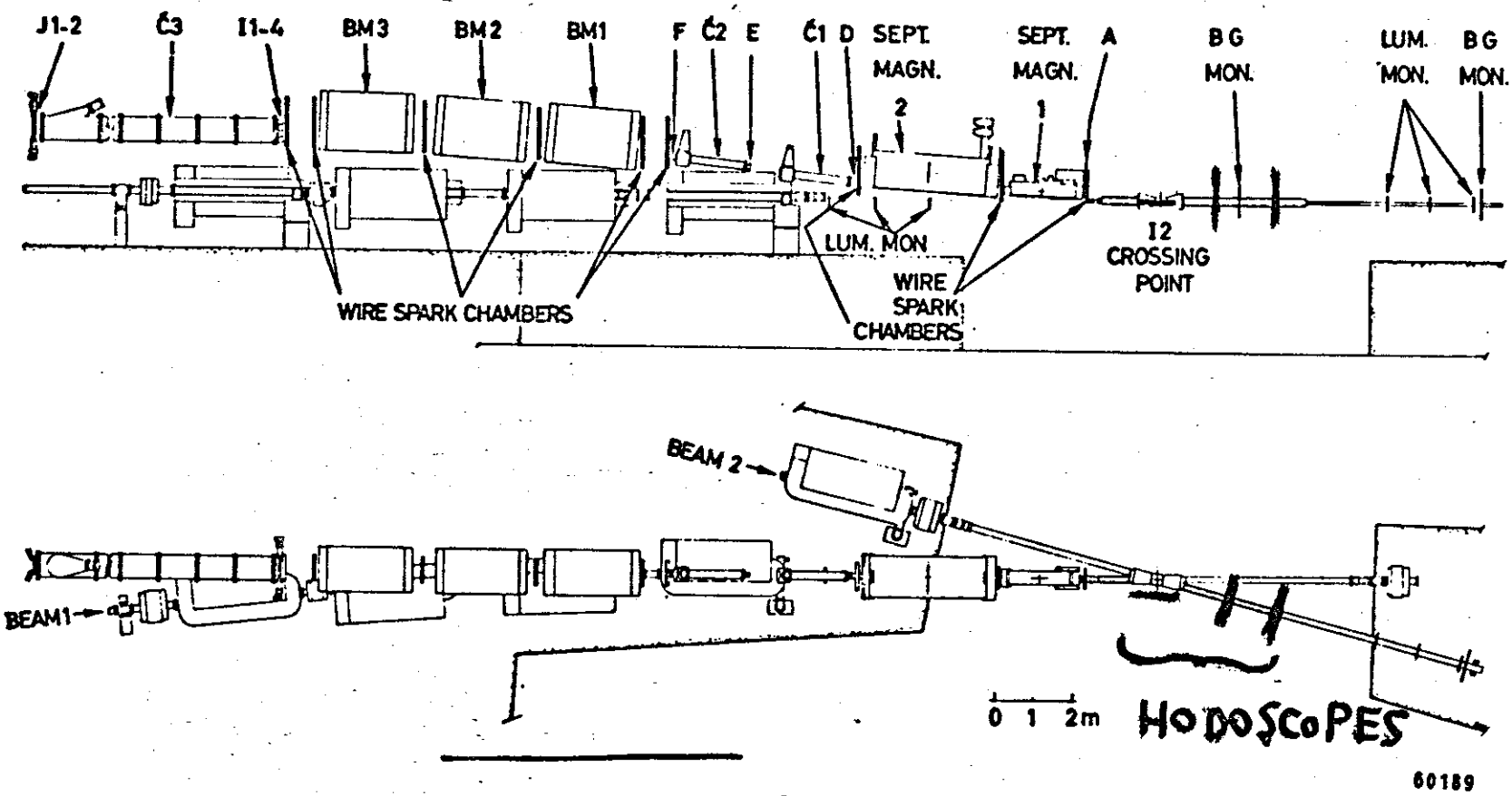
CR : BRITISH-MIT-SCANDINAVIAN I8

WORK ON ENERGY DEPENDENCE OF THE "PLATEAU"

2.2 THE SINGLE DISSOCIATION COMPONENT

NEW DATA FROM CHLM

CHLM SET-UP



KINEMATICS : $x = 1 - \frac{M^2}{s}$

↑ PROTONS M = EXCITED MASS

EXPLANATION OF THE RESULTS (NEXT FIGURE):

↕ IS THE y OF THE UNDISSOCIATE PROTON

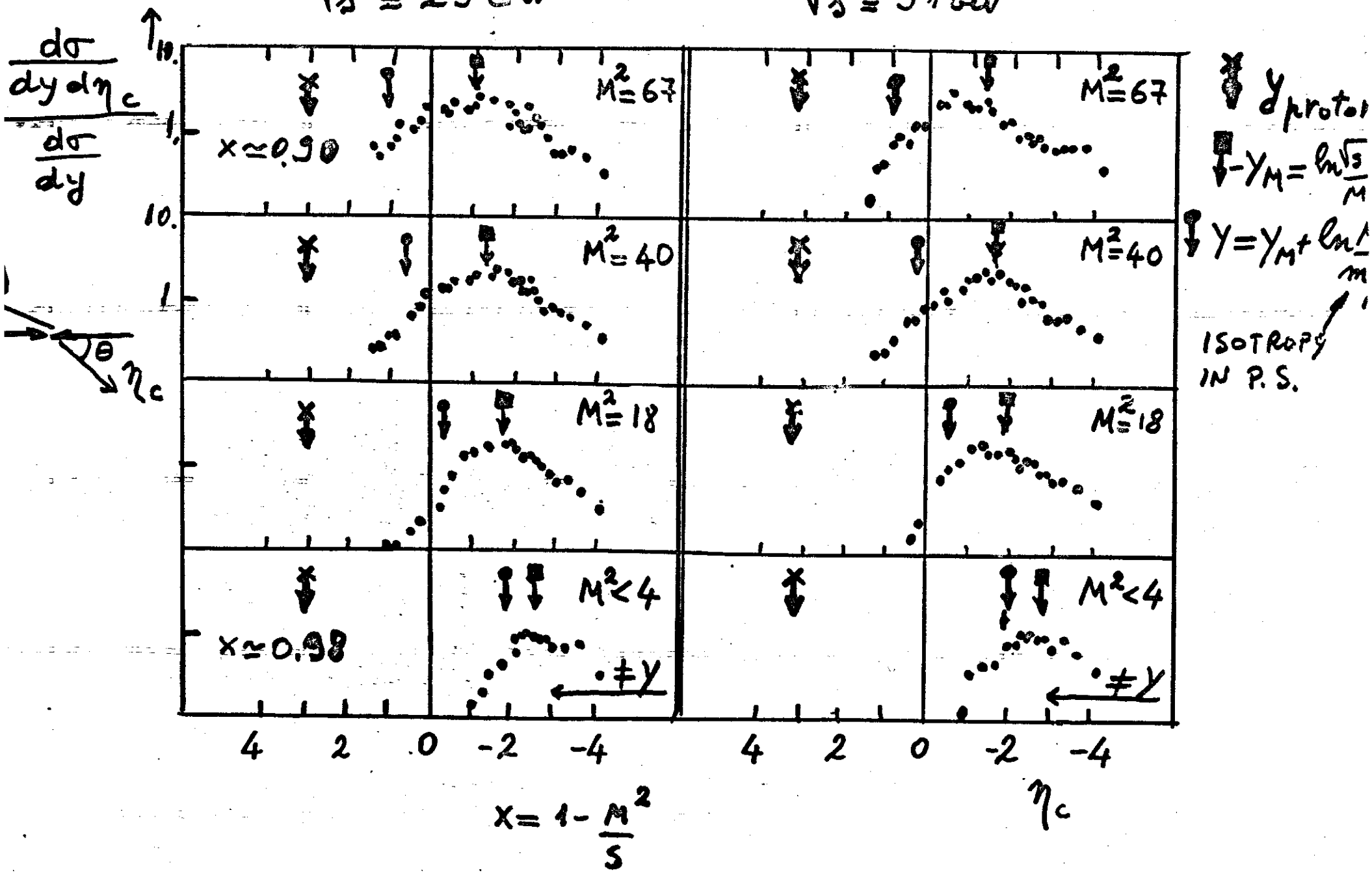
↕ FROM KINEMATICS THE y_M OF THE MASS CENTRE IS DETERMINED.

IF THE MASS M DECAYS ISOTROPICALLY THEN THE EDGE OF THE DECAY PRODUCTS IS

$$y_M + \ln \frac{M}{m_p}$$

INDICATED BY ↕ IN THE FIGURE.

DATA INDICATE THAT THIS IS THE CASE.


$\langle p_T \rangle = 0.45$ GeV/c
$\sqrt{s} = 23$ GeV
$\langle p_T \rangle = 0.75$ GeV/c
$\sqrt{s} = 31$ GeV
$\frac{d\sigma}{dy\,d\eta_c} \Big/ \frac{d\sigma}{dy}$
$M^2 = 67$
$M^2 = 40$
$M^2 = 18$
$M^2 < 4$
$x \simeq 0.90$
$x \simeq 0.98$
$\pm y$
θ
η_c
y_{proto}
$y_M = \ln \frac{\sqrt{s}}{M}$
$y = y_M + \ln$
ISOTROPY IN P.S.
$x = 1 - \frac{M^2}{s}$
η_c

CONCLUSIONS :

- THE CLUSTER IN SINGLE DISSOCIATION DECAYS NON UNIFORMLY IN RAPIDITY.
- EXPECTED "USUAL" CORRELATIONS WITHIN THE CLUSTER.
- MULTIPLICITY : M. JACOB WILL DISCUSS.

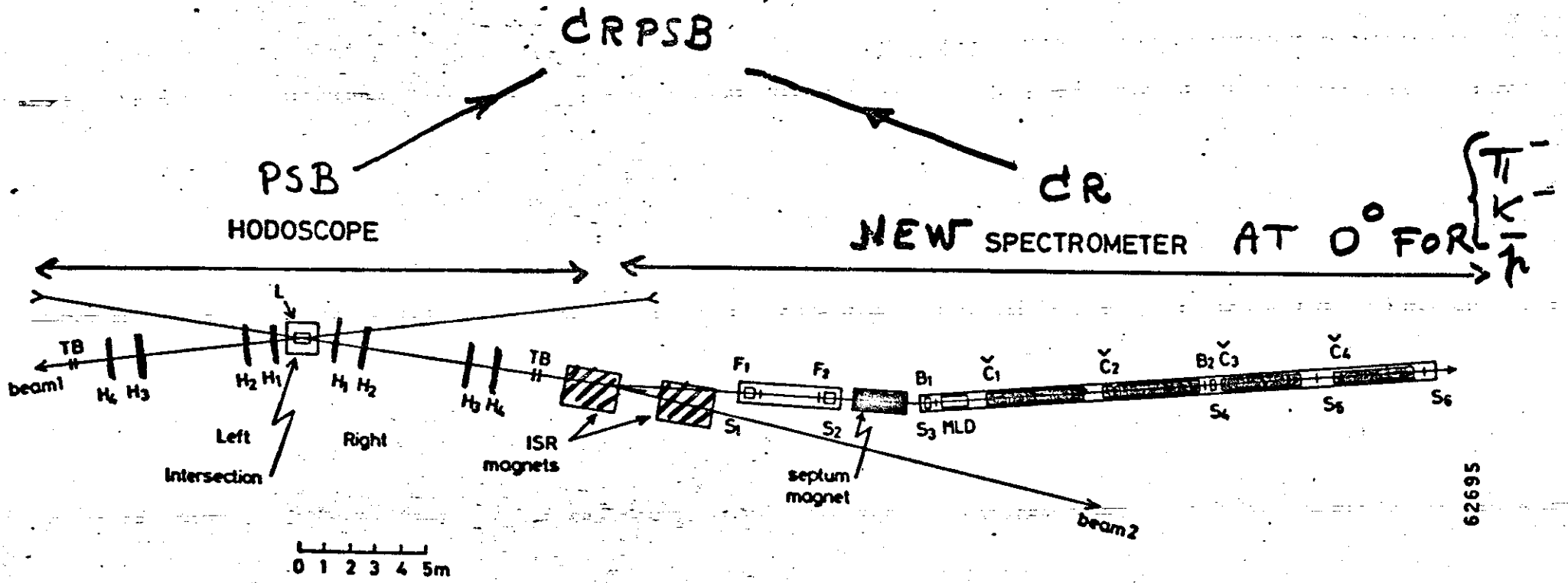
PSB - RECENT WORK IN THE $\langle \eta \rangle$, Δ PLANE TO SEPARATE QUANTITAVELY DISSOCIATION.

PRELIMINARY : $\sigma_{SD} \simeq$ CONST.

USSR-USA AT NAL : $p + D \rightarrow M + D$

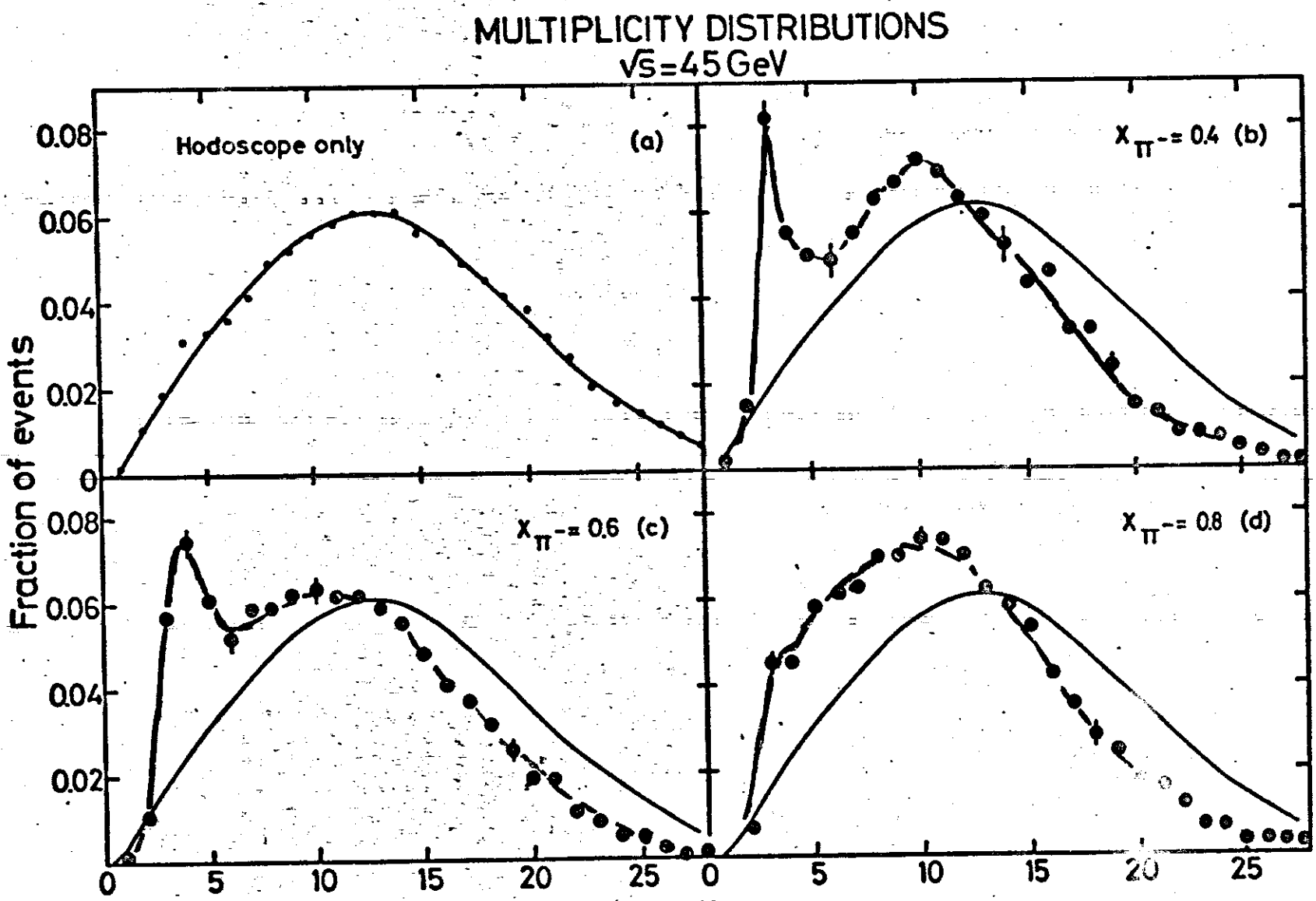
AGREES WITH $\frac{d\sigma}{dM^2} \propto \frac{1}{M^2} \longrightarrow \sigma \neq$ CONST.

2.3 CORRELATIONS IN FRAGMENTATION REGION



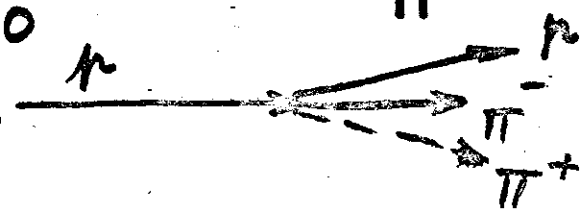
S_2
S_3
S_4

REQUIRING A π AT $X = .4, .6, .8$ CHANGES THE



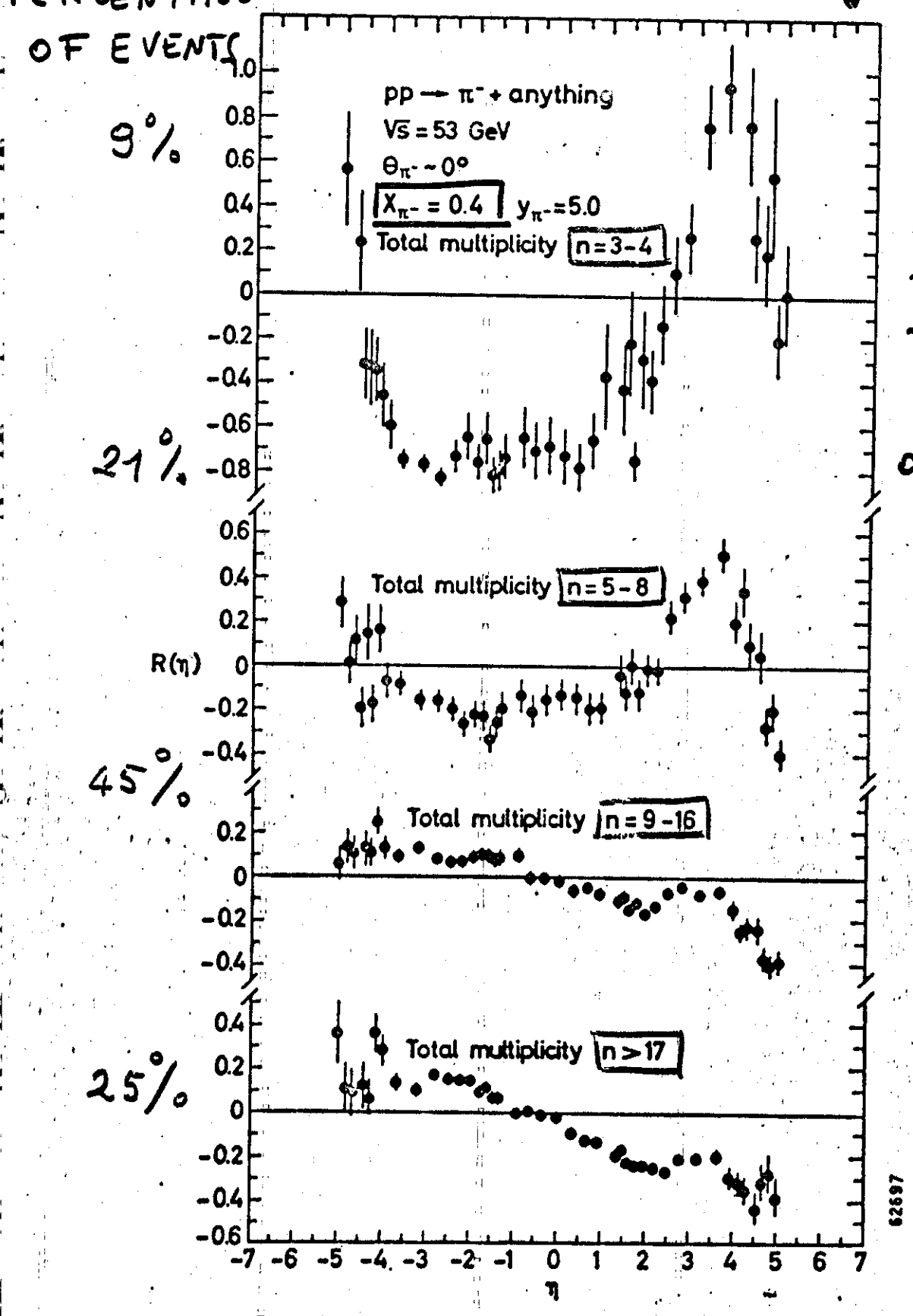
PICTURE: $\bar{\pi}$ AT $x \simeq 0$

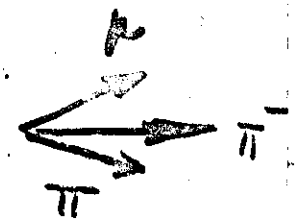
↓ FR SELECT DISSOC. EVENTS:



R-CORRELATIONS FOR π^- OF VARIOUS X-VALUES

SPECTROMETER SIDE

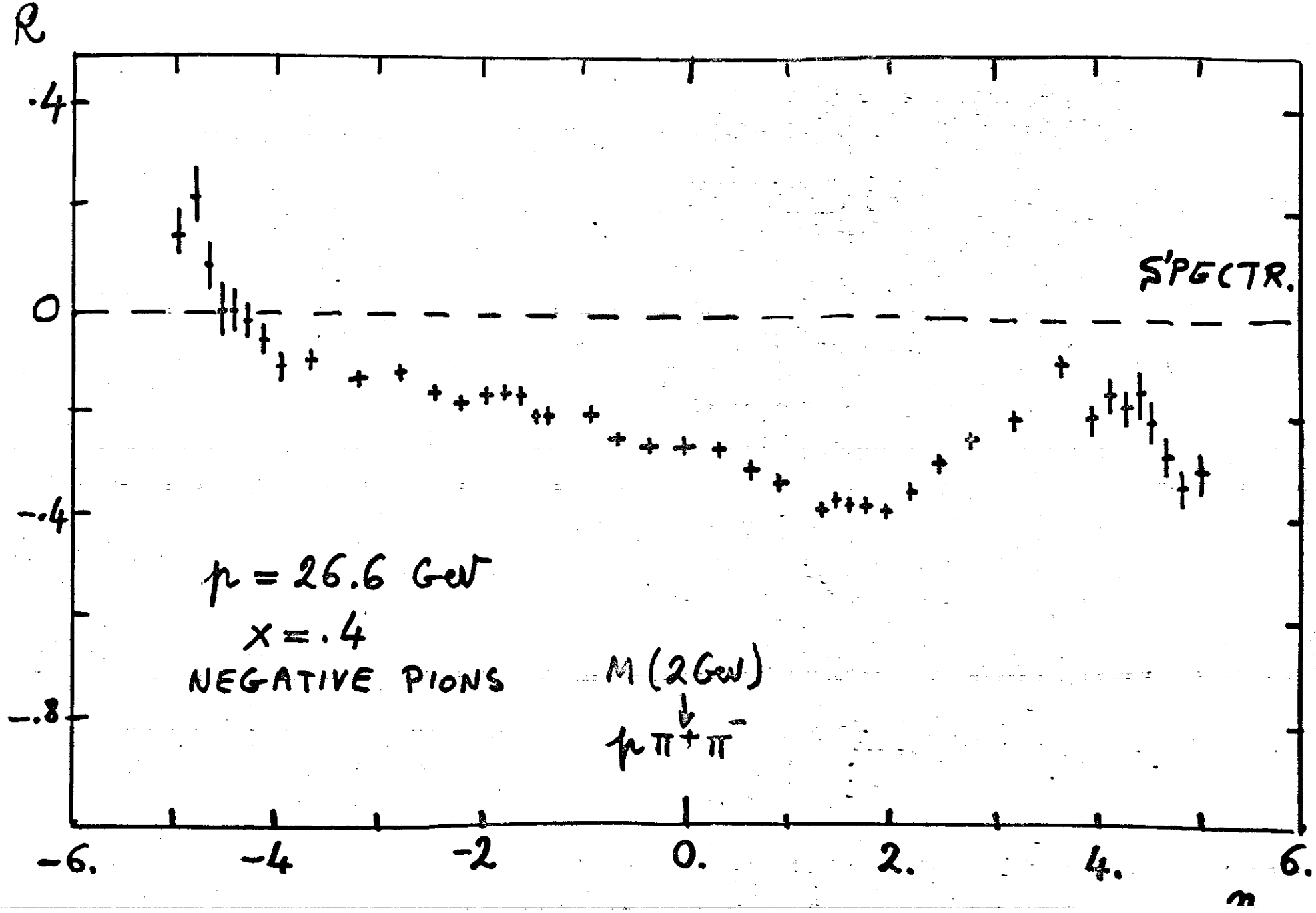


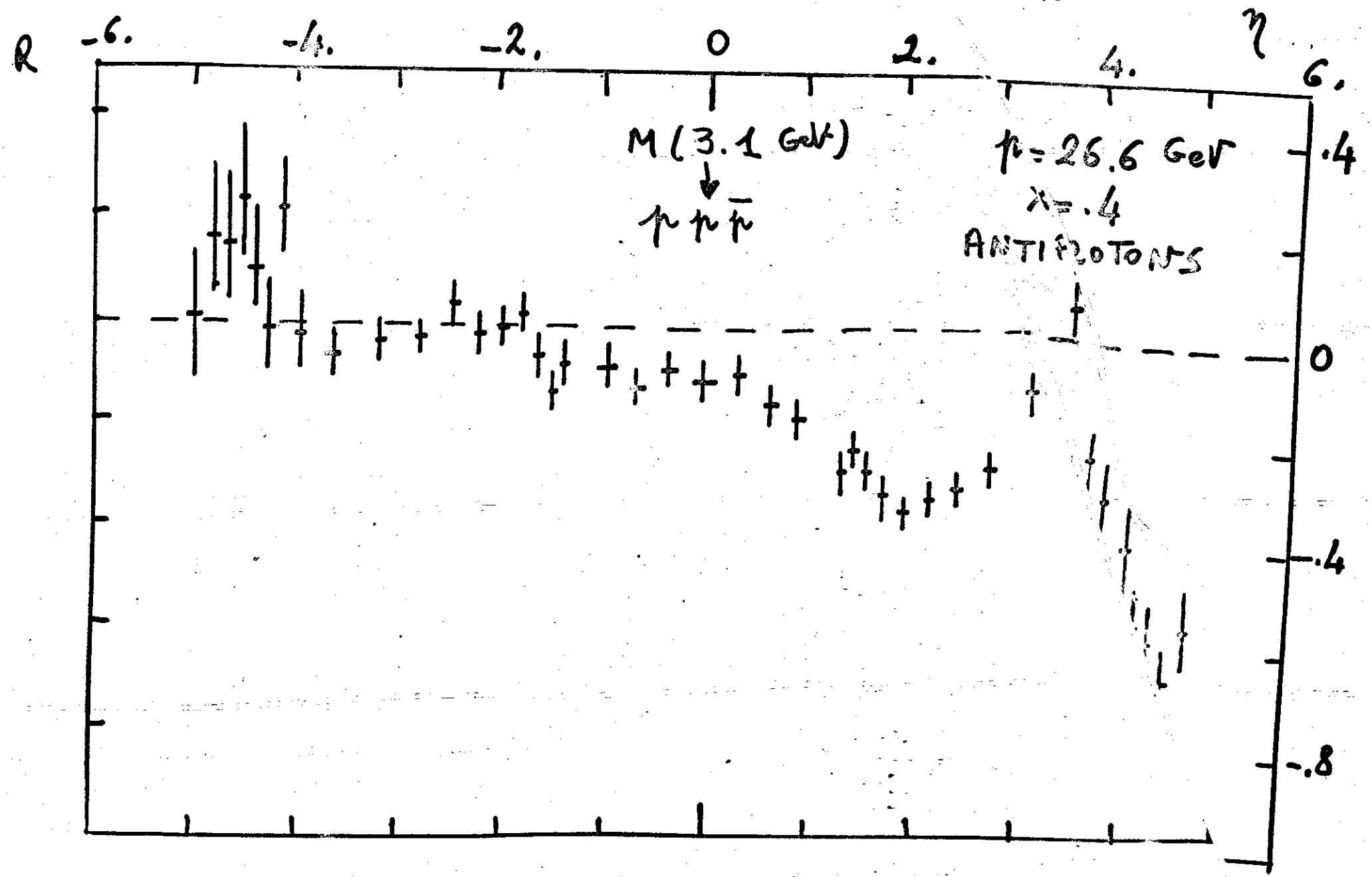


$M \simeq 2.0$ GeV

TO EXPLAIN THE VALUE $\eta \simeq 3.8$ OF THE PEAK.

π^- CORRELATIONS FOR ALL MULTIPLICITIES




R
-6.
-4.
-2.
0
2.
4.
6.
η
M(3.1 GeV)
p p̄
p = 26.6 GeV
x = .4
ANTIPROTONS
.4
0
-.4
-.8

NEGATIVE PARTICLES:

1. FOR $x \simeq 0.5$ SELECTING A π^- ONE HAS A STRONG CONTRIBUTION FROM DECAY OF THE TYPE

$$M(2\,\text{GeV}) \longrightarrow p\,\pi^+\pi^-$$

2. THIS SHORT RANGE EFFECT IS ALSO PRESENT WHEN AN $\bar{p}$ IS SELECTED. THE (FEW) $\bar{p}$ EVE AT $\eta \simeq 4$ SEEN TO BE DUE

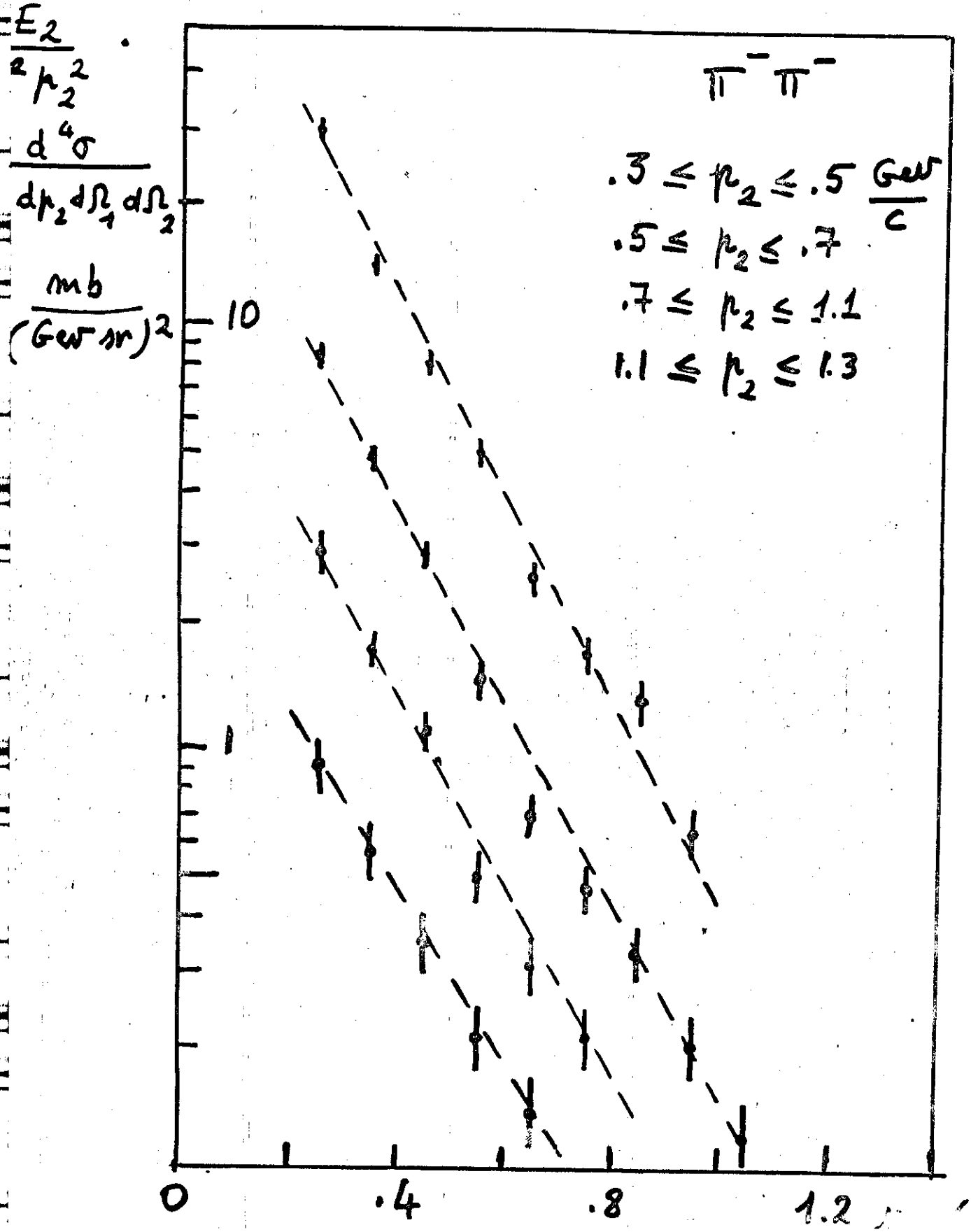
$$M(3.1\,\text{GeV}) \longrightarrow p\,p\,\bar{p}\,.$$

SACLAY GROUP : CORRELATIONS OF $\pi^-\pi^-$, $\pi^+\pi^-$, $\pi^+\pi^+$ AT 90° ON OPPOSITE SIDES.

THE RESULTS (NEXT FIGURE) SHOW THAT THE SLOPE OF THE DOUBLE DIFFERENTIAL CROSS-SECTION IN ONE OF THE MOMENTA (p_1) DOES NOT DEPEND UPON THE OTHER(S). SIMPLE INTERPRETATION : CLUSTER DECAY IN NOT TOO FEW PARTICLES.

2.4 CORRELATIONS IN THE CENTRAL REGION

SACLAY GROUP S_5



PSB : NEW RESULTS ON THE STUDY OF CORRELATIONS IN dR
FOR FIXED MULTIPLICITY n :

MEASURED : $C^n(\eta_1,\eta_2) = \frac{1}{\sigma_n}\frac{d^2\sigma}{d\eta_1 d\eta_2} - \frac{1}{\sigma_n^2}\frac{d\sigma}{d\eta_1}\frac{d\sigma}{d\eta_2}$

(BEFORE $R(\eta_1,\eta_2) = \frac{C(\eta_1,\eta_2)}{\frac{1}{\sigma_n^2}\frac{d\sigma}{d\eta_1}\frac{d\sigma}{d\eta_2}}$)

REASONS :

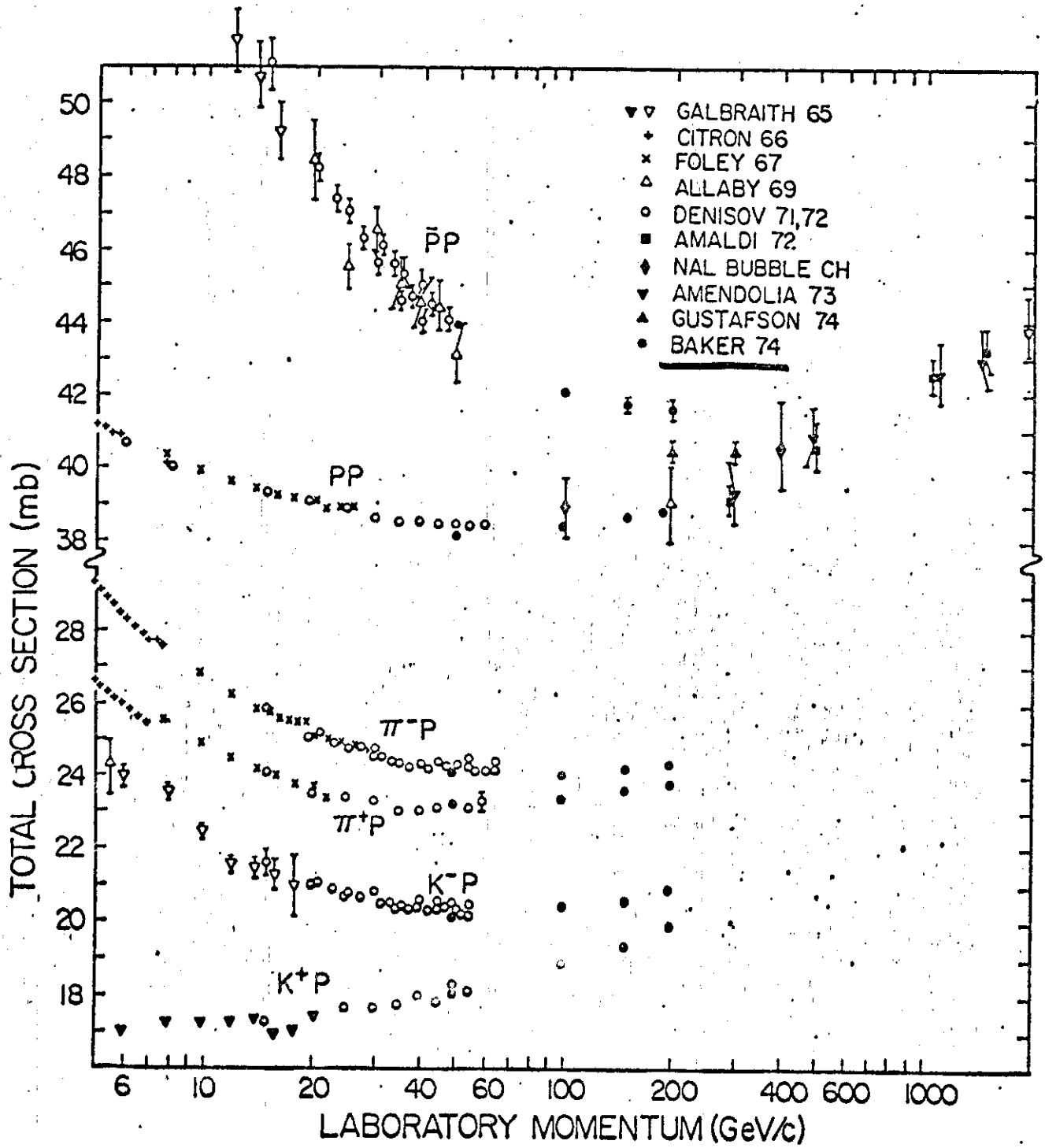
i) n Range : SINGLE DISSOCIATION IS NEGLIGIBLE

ii) MORE STRINGENT TEST OF SRO MODELS

(M. JACOB)- (WILL DISCUSS THE RESULTS)-

2.5 ENERGY DEPENDENCE OF σ_t

NEW RESULTS FROM NAL.
ALL CROSS-SECTIONS RISE!



I2 = INTERSECTION REGION 2.

3. A GLANCE INTO THE FUTURE

1. SINGLE PARTICLE SPECTRA BS; British-MIT, SCANDIN. (I2) (I8)
2. CORRELATIONS BROOKH - GRUM - ROME ; $\gamma\gamma$ CORR. (I1)
   - SFM: MIT - Orsay - Scandin. (I2)
   - CERN - AACHEN - MUNICH (I7)
   - SFM: CERN - Coll de Fr. - HEIDEL. - KARL. 2 ch. (I2
3. SINGLE DISSOCIATION AT SMALL t : 2 PROPOSALS TO BE DISCUSSED BY COMMITTE
4. EXCLUSIVE CHANNELS: CERN-UCLA : Δ^{++} (IN I6) - $\Delta\pi$
   SFM [CHOV : $p\pi^+\pi^-$, $n\pi^+$; PAVIA-PRINCETON : $\Delta^+\Delta^+$] (I2)
5. ELASTIC SCATTERING: ACGHT (IN I6)
   SFM : CHOV (I2)
6. TOTAL CROSS SECTION: CRPSB (IN I1) : NEW METHOD
   ACGHT (IN I6)
7. REAL PART, ÇR IN 1975