MEASUREMENTS OF σ_{tot}, $d\sigma_{el}/dt$, AND EVENT DISTRIBUTIONS IN $\bar{p}p$ AND pp COLLISIONS AT $\sqrt{s}$ = 31, 53, AND 63 GEV

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(Presented by G. Carboni)

Experiment R210 has been designed with the primary aim of measuring precisely $\sigma_{tot}(\bar{p}p)$ and $\sigma_{tot}(pp)$ over the ISR energy range. The experiment is also equipped with small-angle detectors which allow us to measure $d\sigma_{el}/dt$, and with a system of drift chambers and scintillation hodoscopes to measure charged multiplicities and angular distributions of emitted secondaries. Data have been collected at $\sqrt{s}$ = 31, 53, and 63 GeV. Results at 53 GeV have already been published -- results at 31 and 63 GeV must still be considered preliminary.

The total cross-section is obtained by measuring simultaneously the total interaction rate and the ISR luminosity: $\sigma_{tot} = R_{tot}/L$. Excellent machine performance and accurate calibrations of the beam displacement scale allowed us to attain a better than 1% accuracy in $\bar{p}p$ runs. Our data reproduce well the old ISR results, except at $\sqrt{s}$ = 63 GeV, where, however, the agreement is good if we restrict the comparison to total-rate results only. We plan to collect more data at this energy in order to clarify this point. The difference $\Delta\sigma_{tot} = \sigma_{tot}(\bar{p}p) - \sigma_{tot}(pp)$ is positive over the range measured, showing conclusively that $\sigma_{tot}(\bar{p}p)$ increases in the ISR energy range. As expected from Regge phenomenology, $\Delta\sigma_{tot}$ behaves as $s^{-\frac{1}{2}}$. This result disfavours exotic possibilities, such as odderons, which would have a different s dependence. Both $\bar{p}p$ and pp data, moreover, favour a $\ln^2 s$ behaviour for σ_{tot}, and the extrapolation of this behaviour to the Collider agrees well with the result of UA4.

The elastic cross-section has only been analyzed at 53 GeV, and all the elastic cross-section parameters are the same for $\bar{p}p$ and pp, and consistent with geometrical scaling. Extrapolation of the elastic rate to measure the total cross-section via the optical theorem gives good agreement with the total-rate method.

As far as particle distributions are concerned, we focus our attention more on the comparison of $\bar{p}p$ and pp than on absolute numbers, since most instrumental effects disappear in the comparison. In single-particle pseudorapidity distributions, a small excess (5%) is observed in the central region for $\bar{p}p$. Moreover, the average charged multiplicity $<n_{ch}>$ is 2% higher for $\bar{p}p$ than for pp. Both $\bar{p}p$ and pp distributions satisfy KNO scaling fairly well.

A more interesting quantity is the difference of $\bar{p}p$ and pp topological cross-sections $\Delta\sigma_n$. The mean charged multiplicity of this distribution is 30-40% higher than $<n_{ch}>$ for the individual reactions, and this effect occurs at all energies. The normalized form $<n>\Delta\sigma_n/\Delta\sigma_{tot}$ is not fitted by the KNO function, but the distribution is similar to that obtained for annihilation at lower energy and for e^+e^- reactions.

A further difference in $\bar{p}p$ is the presence of an excess in the two-particle correlation function around 90^0. The excess (roughly the same at the three energies measured) has a very short pseudorapidity range ($\Delta\eta = \pm 0.3$) compared to the classical short-range correlation ($\Delta\eta = \pm 1$). This effect depends on the multiplicity of the event, being present only for those multiplicities corresponding to the largest values of $\Delta\sigma_n$, suggesting that it is related to the "annihilation" mechanism, which still seems to be important at these energies.

MEASUREMENT OF σ_{TOT} , $\left.\frac{d\sigma}{dt}\right)_{EL}$ AND EVENT DISTRIBUTIONS IN p-p AND $\bar{p}$-p COLLISIONS AT $\sqrt{s}$ = 31, 53, 63 GeV

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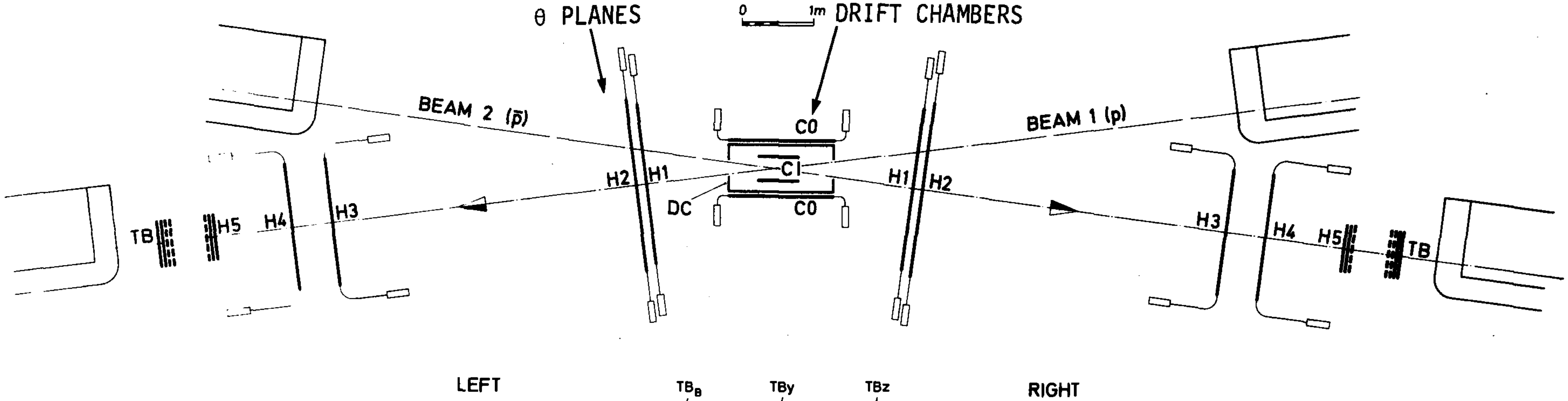
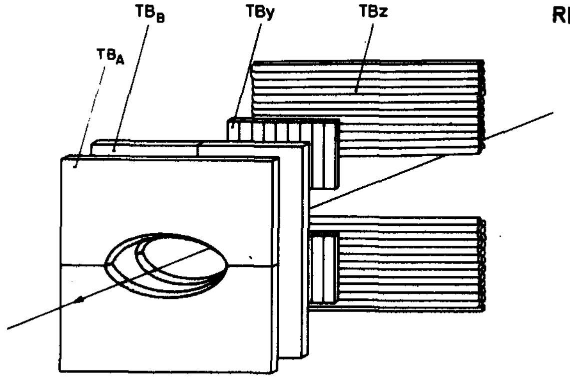
ISR EXP.'T R210 CERN-NAPOLI-PISA-STONY BROOK

PUBLISHED:

P.L. 108 B (1982) 145 } σ_{tot} , $\sqrt{s}$ = 53 GeV
P.L. 113 B (1982) 87 }
(P.L. 113 B (1982) 347 αα /αp ELASTIC)
P.L. 115 B (1982) 495 ELASTIC , $\sqrt{s}$ = 53 GeV





$$T = HIT_L * HIT_R$$

$$HIT = (TB_A \cdot TB_B + H5_A \cdot H5_B + H4 \cdot H3 + H2 \cdot H1 + C0 \cdot CI)$$

LUMINOSITY MONITORS:

$H5_L \cdot H5_R$

$H34_L \cdot H5_R$

$H34_L \cdot TB_R$

TOTAL CROSS SECTION

$$\boxed{\sigma_{TOT} = R_{TOT} / \mathcal{L}}$$

$\underline{R_{TOT}}$

- we measure ~ 95 % of all collisions. extrapolate elastic and diffractive-like inelastic to correct for the loss

TRIGGER: (LEFT) * (RIGHT)

$$\text{LEFT} = H_1 \cdot H_2 + H_3 \cdot H_4 + H_5 + TB + e_I$$

MEASURE :
- TOF's between all left-right hodoscope pairs
- (ϑ, φ) for all charged particles
- live time (Rate $= N/\tau_{LIVE}$)

$\underline{\mathcal{L}}$

- Choose a monitor, M, (hodoscope pair), and measure σ_M in Van der Meer's method

$$\sigma_M = \frac{1}{K} \int R_M(\delta)\, d\delta$$

(K ← ISR disp. scale acc. ±0.2% (K. Potter))

and

$$\mathcal{L} = \frac{R_M}{\sigma_M}$$

In $\bar{p}p$ runs large unbalance in beam currents (~10 A p – 2-4 mA $\bar{p}$)

⇓

large background from beam-gas & beam-pipe

⇓

Background subtraction performed by variation of luminosity (vertical steering):

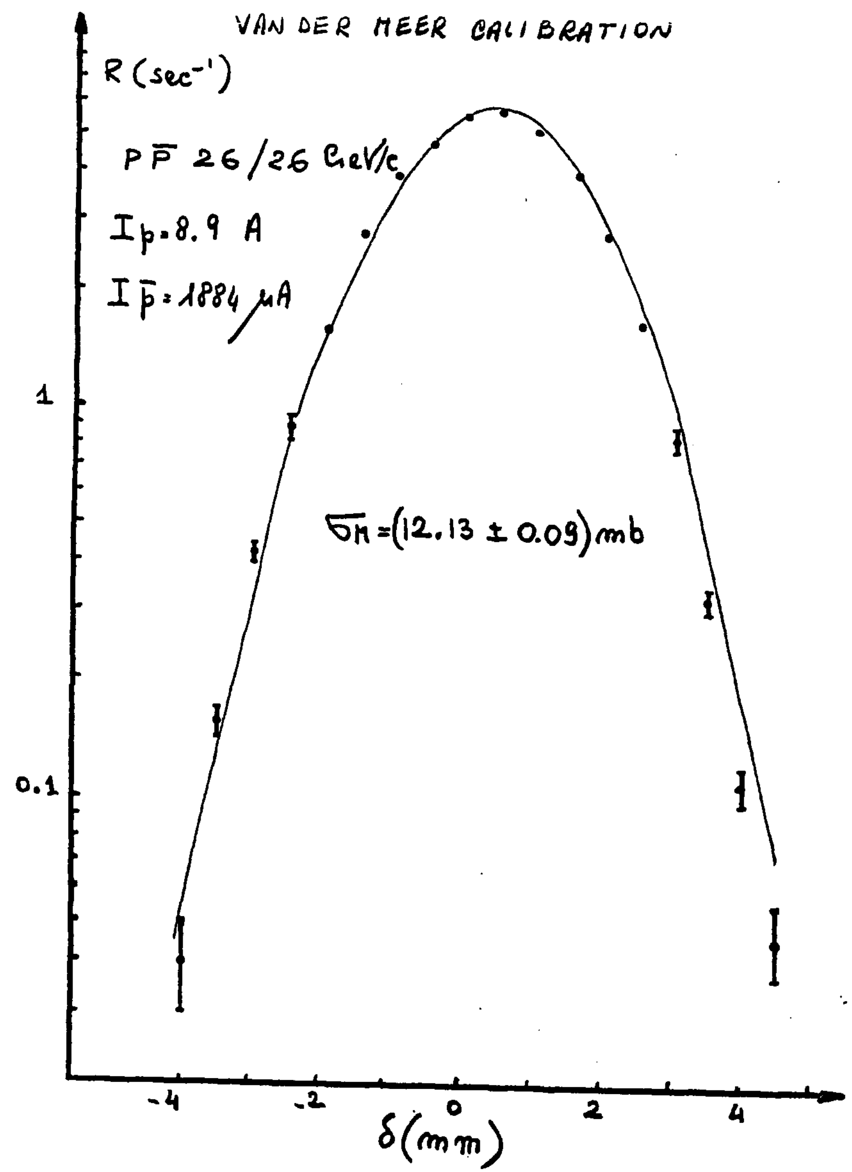
$$\sigma_{tot} = \frac{\Delta R_{tot}}{\Delta L}$$

Beams at full overlap = background + signal

Beams separated = background

The luminosity monitor has to be free as possible from beam-gas background

↓



EXTRAPOLATION TO R_{TOT}

1) ELASTIC : $\Delta\sigma_{EL} = \int_{\Delta\Omega} \left.\frac{d\sigma}{dt}\right)_{EL} \cdot dt$

- EXPLOIT OPTICAL THEOREM TO FIX $\left.\frac{d\sigma}{dt}\right)_{t=0}$
- $\Delta\sigma_{EL} \propto p^2_{ISR}$
- RATHER INSENSITIVE TO THE VALUE OF ELASTIC SLOPE

2) INELASTIC : (SINGLE DIFFRACTIVE)

FOR EVENTS WITH A PARTICLE ON ONE SIDE $\vartheta > 2°$ PLOT MAXIMUM t^* $(= p^2_{ISR}\,\vartheta^2)$ OF OPPOSITE SIDE.

INTEGRATE OVER THE UNCOVERED $\Delta\Omega$

$\Delta\Omega = 10^{-4}$ sr

$\theta_{MIN} = 0.2°$

RUN CONDITIONS IN I2

DATE	I_p (A)	$I_{\bar{p}}$ (mA)	$\mathcal{L}$ ($cm^{-2}s^{-1}$)	$\int \mathcal{L}dt$ (cm^{-2})	$\sqrt{s}$ (GeV)
10/81	10	3.0	4×10^{26}	4×10^{32}	53
4/82	12	3.4	10^{27}	4×10^{32}	63
5/82	11	4.2	10^{27}	7×10^{32}	31
6/82	12	4.0	$6\cdot10^{26}$	4×10^{32}	53

p-p runs taken immediately before $\bar{p}$-p runs.

Note: 1 mA = 2×10^{10} $\bar{p}$

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SUMMARY OF σ_{TOT} RESULTS

c. m. ENERGY (GeV)		σ_{obs} (mb)	$\Delta\sigma_{el}$ (mb)	$\Delta\sigma_{inel}$ (mb)	σ_{TOT} (mb)	$\Delta\sigma_{TOT}$ (mb)
30.6	p-p	39.3 ± 0.1	0.509 ± 0.03	0.231 ± 0.02	40.04 ± 0.20	2.3 ± 0.3
	$\bar{p}$-p	41.5 ± 0.3	0.588 ± 0.03	0.247 ± 0.02	42.33 ± 0.3	
52.8	p-p	40.75 ± 0.20	2.0 ± 0.1	0.51 ± 0.03	43.26 ± 0.2	1.44 ± 0.44
	$\bar{p}$-p	42.13 ± 0.4	2.05 ± 0.1	0.52 ± 0.03	44.7 ± 0.4	
62.3	p-p	41.37 ± 0.11	2.82 ± 0.14	0.50 ± 0.03	44.68 ± 0.22	0.57 ± 0.3
	$\bar{p}$-p	41.85 ± 0.30	2.87 ± 0.15	0.535 ± 0.03	45.25 ± 0.3	

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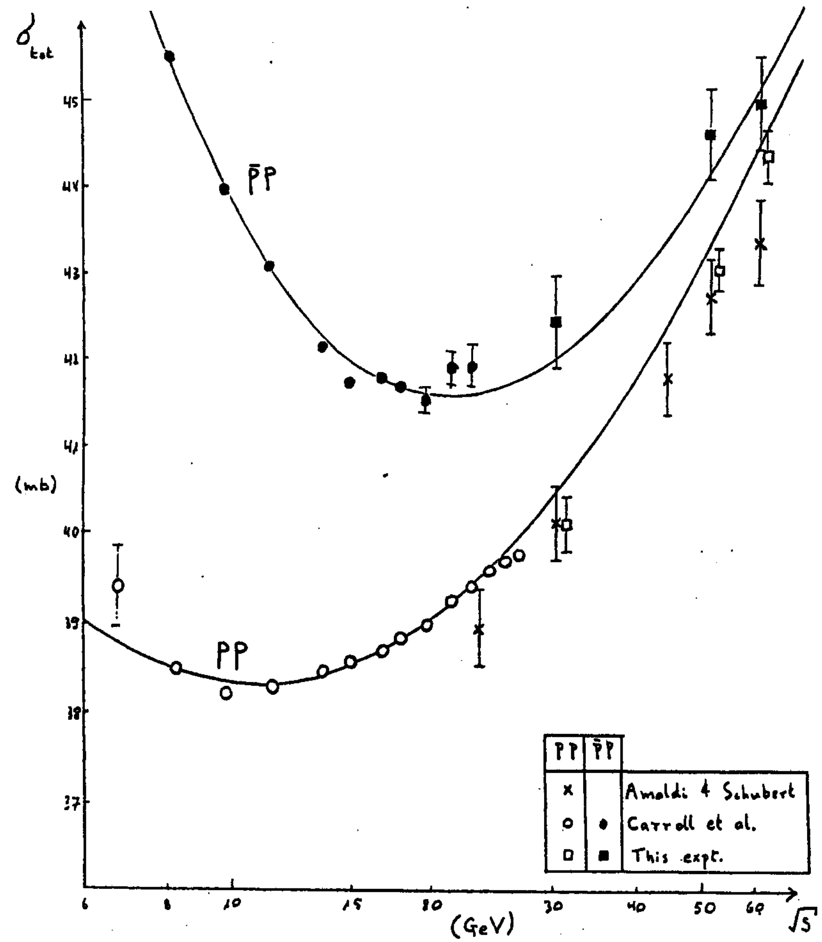

FIT : $\sigma_{tot}(pp) = \sigma_0 + \gamma \cdot \ln^2(s/s_0)$

$\sigma_{tot}(\bar{p}p) = \sigma_0 + \gamma \cdot \ln^2(s/s_0) + \beta \cdot s^{\alpha-1}$

$1-\alpha = 0.58$

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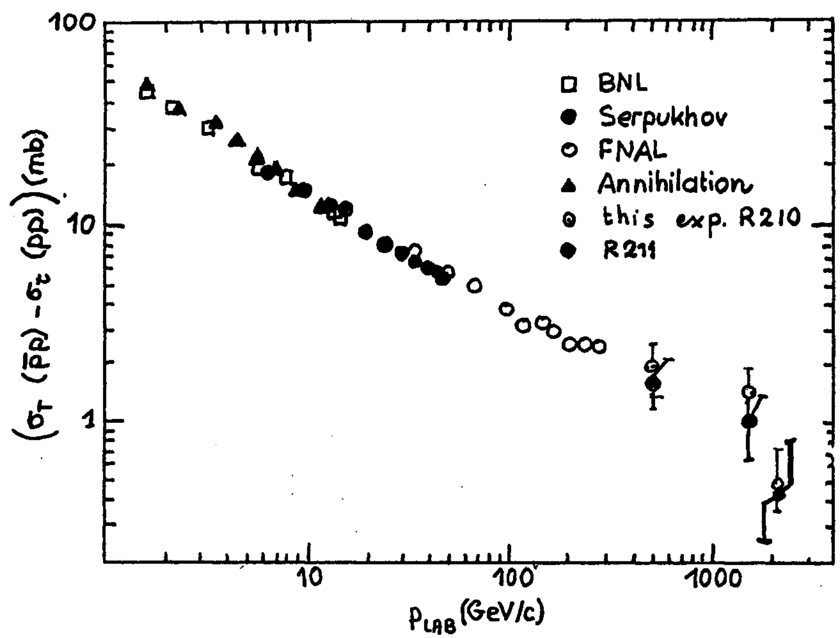

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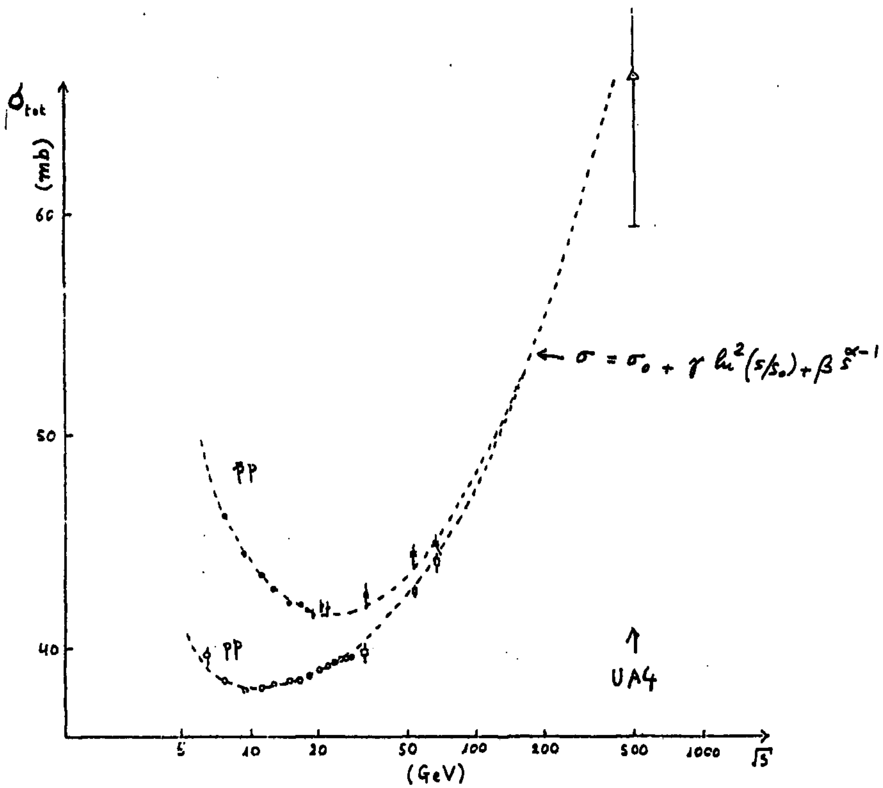
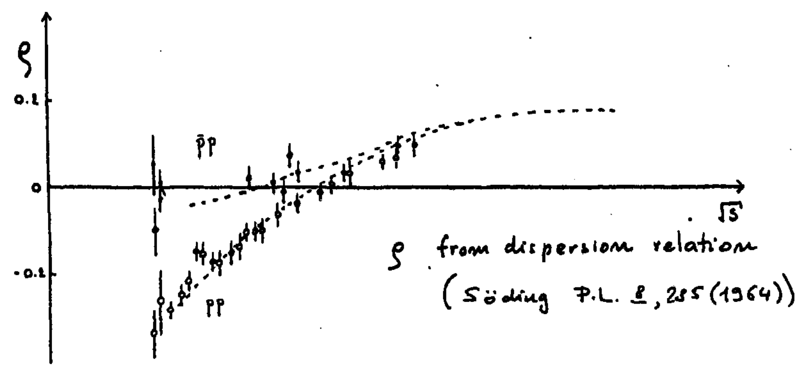




ELASTIC SCATTERING $|t| < 0.05\ GeV^2$

1) TRIGGER $\equiv TB_L * TB_R$

2) REJECT EVENTS WITH PARTICLES AT LARGE ANGLES

3) FIND COLLINEAR HITS

Bkgnd (NON-COLLINEAR EVENTS) < 6% TOT

MULTIPLE HITS OCCURRED IN 31% OF CASES. THE EVENT IS KEPT IF THE MOST COLLINEAR PAIR SATISFY 3).

$\sqrt{s} = 53$ GeV	p – p	$\bar{p}$ – p	
b (GeV^{-2})	13.09 ± 0.37 ± 0.21	13.92 ± 0.37 ± 0.22	
σ_{EL} (mb)	7.79 ± 0.13 ± 0.11	7.89 ± 0.17 ± 0.11	
$\sigma_{TOT}^{O.T.}$ (mb)	43.34 ± 0.29 ± 0.13	44.86 ± 0.44 ± 0.13	
	43.28 ± 0.17 ± 0.13	44.77 ± 0.30 ± 0.18	*
$\sigma_{EL} / \sigma_{TOT}$	0.180 ± .003 ± .003	0.176 ± .004 ± .003	
b / σ_{TOT} ($GeV^{-2} mb^{-1}$)	0.302 ± .009 ± .005	0.310 ± .009 ± .005	
b' (GeV^{-2}) ($0.09 < \lvert t \rvert < 1.0\ GeV^2$)	10.34 ± 0.19 ± 0.06	10.68 ± 0.20 ± 0.06	

* COMBINED WITH TOTAL RATE METHOD

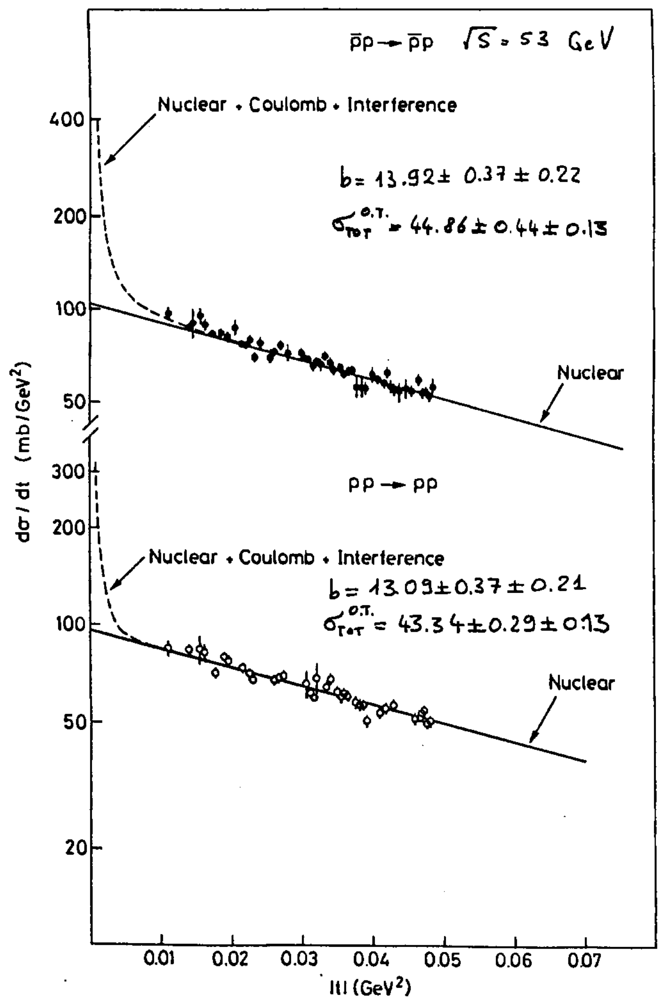


Fig. 3

PSEUDORAPIDITY AND MULTIPLICITY DISTRIBUTIONS

SELECTION :

TRIGGER = $(TB + H5 + H34)_L * (TB + H5 + H34)_R$ { forward cone trigger

$\gtrsim 90\%$ of inelastic events

TWO SETS OF DATA :

a) COUNTERS $|\eta| \leq 5.$

b) CHAMBERS $|\eta| \leq 2.$

RAW DATA NO CORRECTIONS FOR :

- SECONDARY INTERACTIONS
- δ-RAYS , CONVERSIONS
- BINNING
- K_0 , Λ

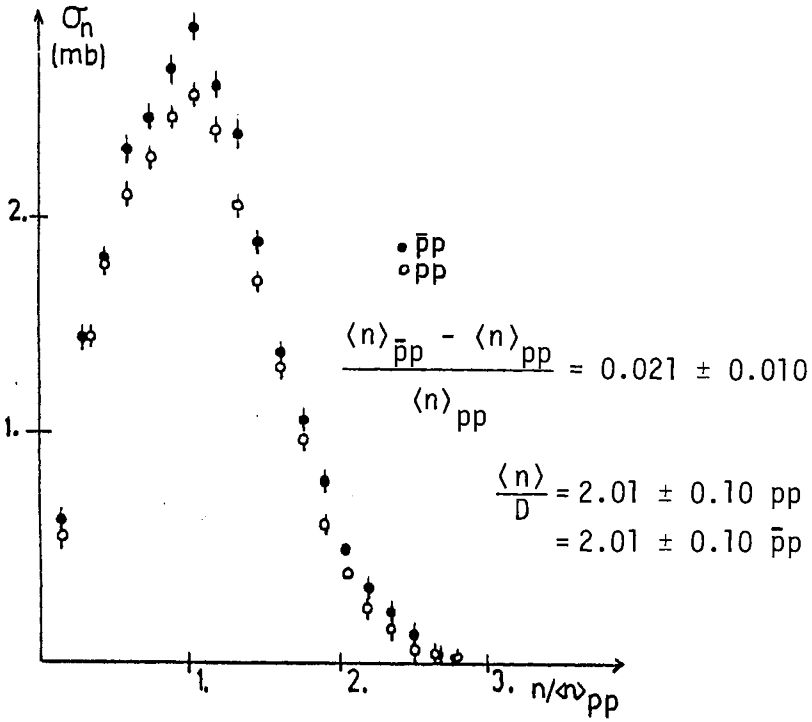
FOCUS DIFFERENCES in $\bar{p}p$ and pp in :

$$\rho_1(\eta) = \frac{1}{\sigma_I} \frac{d\sigma}{d\eta} \qquad \rho_n(\eta) = \frac{1}{\sigma_n} \frac{d\sigma_n}{d\eta}$$

$$R_2(\eta_1, \eta_2) = \frac{\rho_2(\eta_1, \eta_2)}{\rho_1(\eta_1) \cdot \rho_1(\eta_2)} - 1.$$

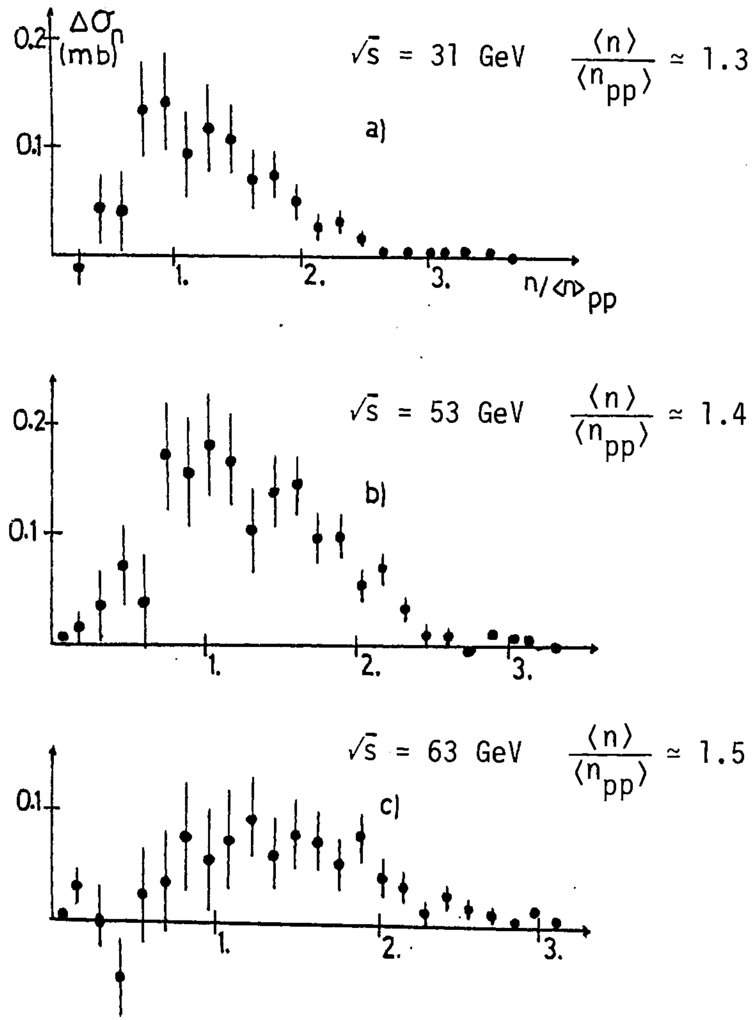
σ_n

MULTIPLICITY DISTRIBUTIONS $\sqrt{s}$ = 31 GeV

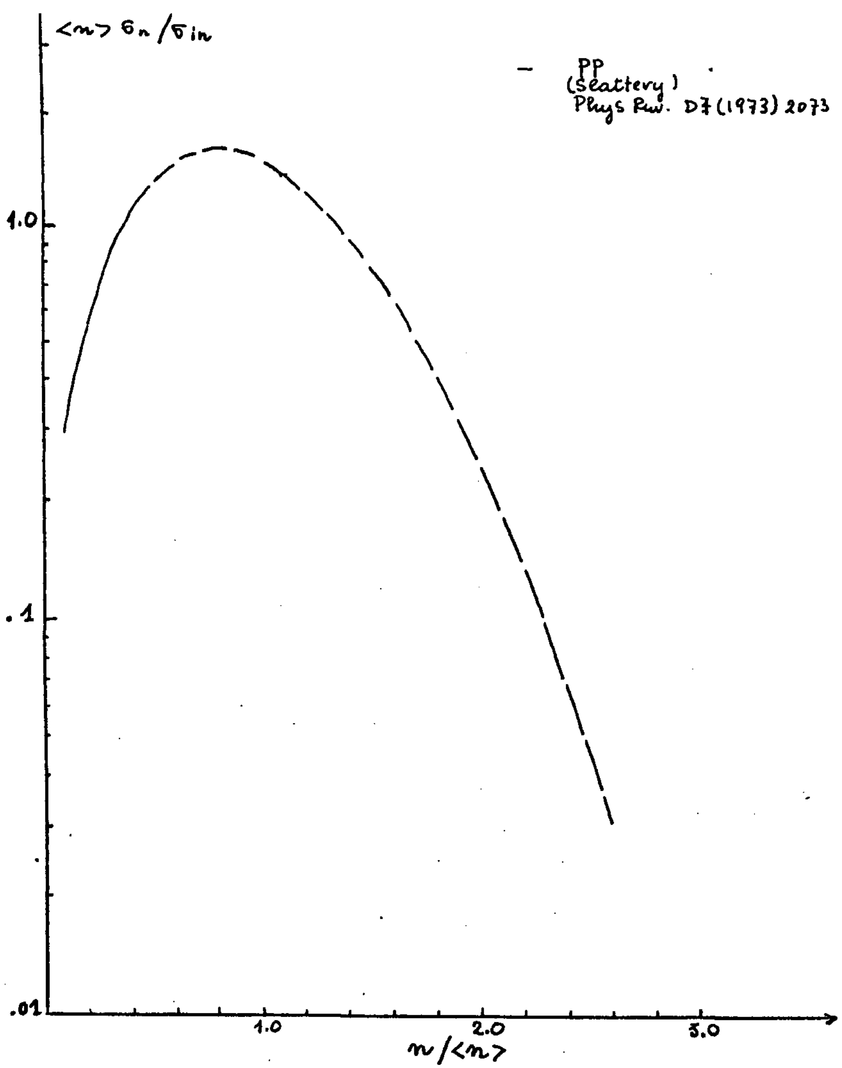


DIFFERENCES OF TOPOLOGICAL CROSS-SECTIONS

$\bar{p}p$ - pp R210

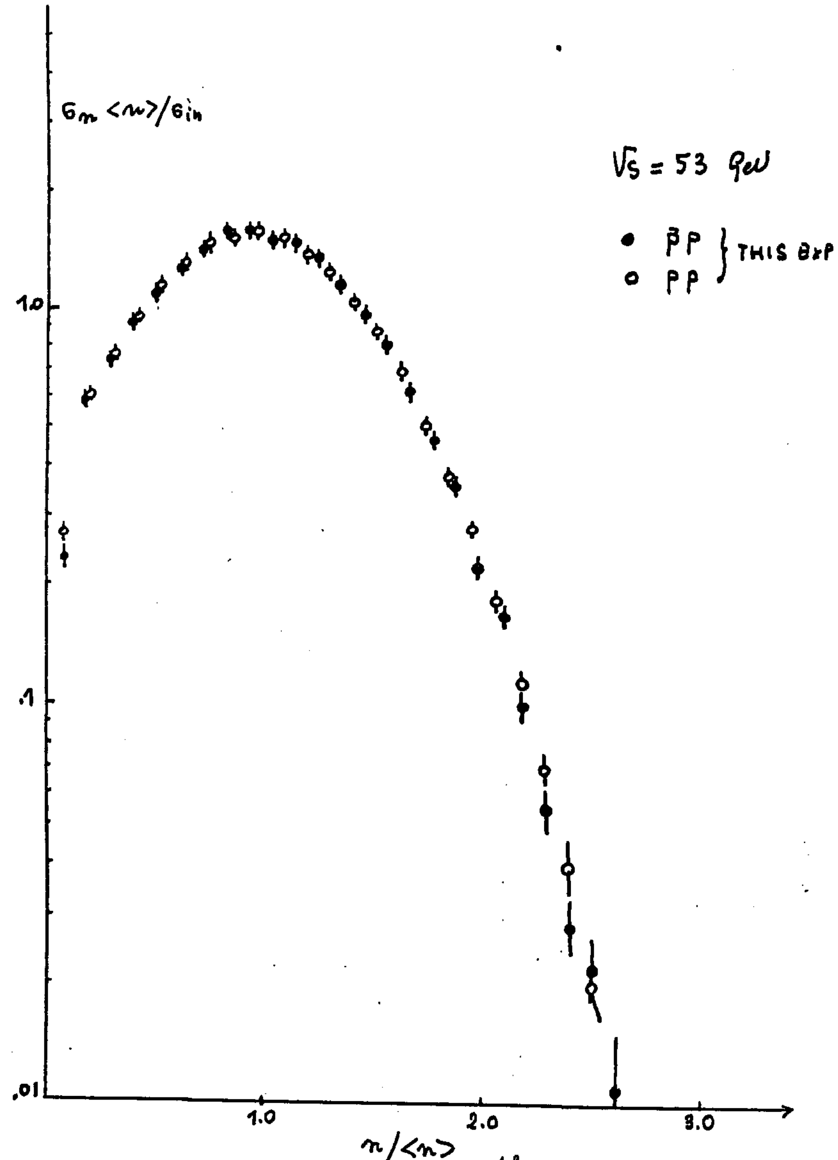


KNO



<n> σn/σin
PP
(Slattery)
Phys Rev. D7 (1973) 2073
1.0
.1
.01
1.0
2.0
3.0
n/<n>

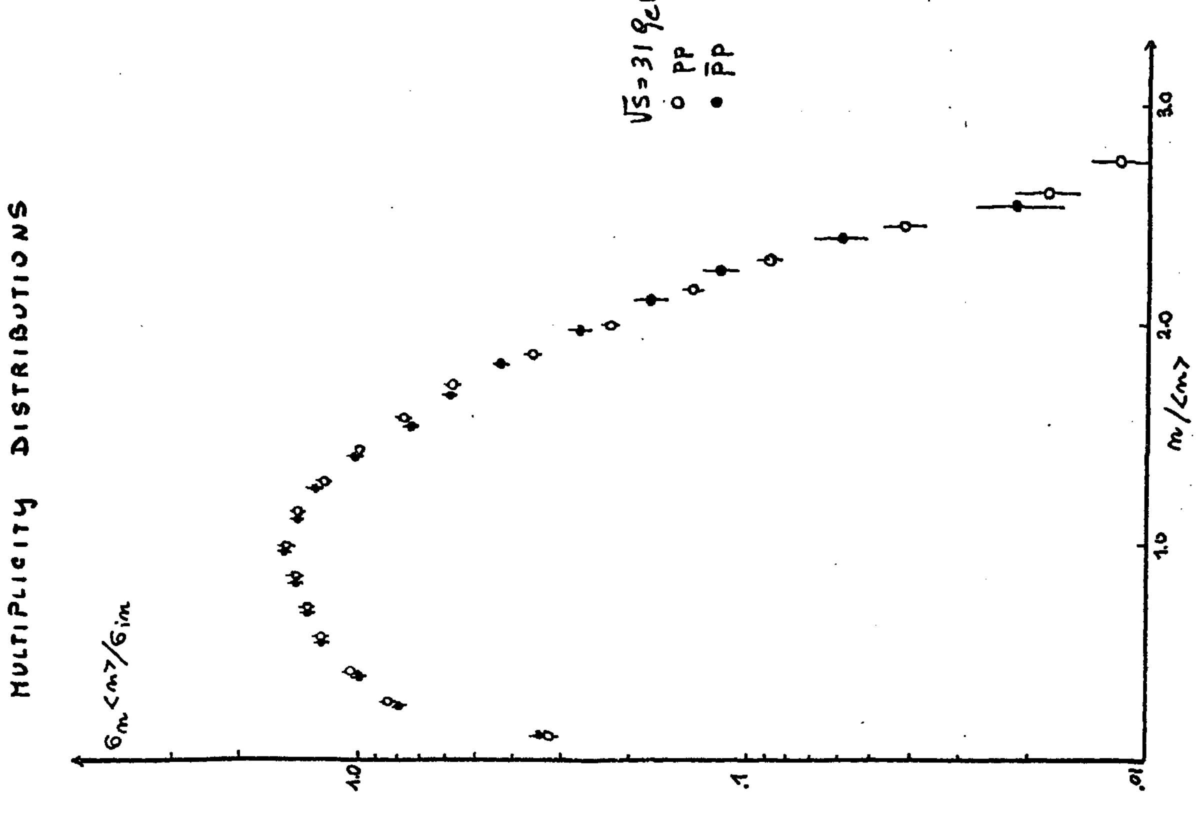
-17-

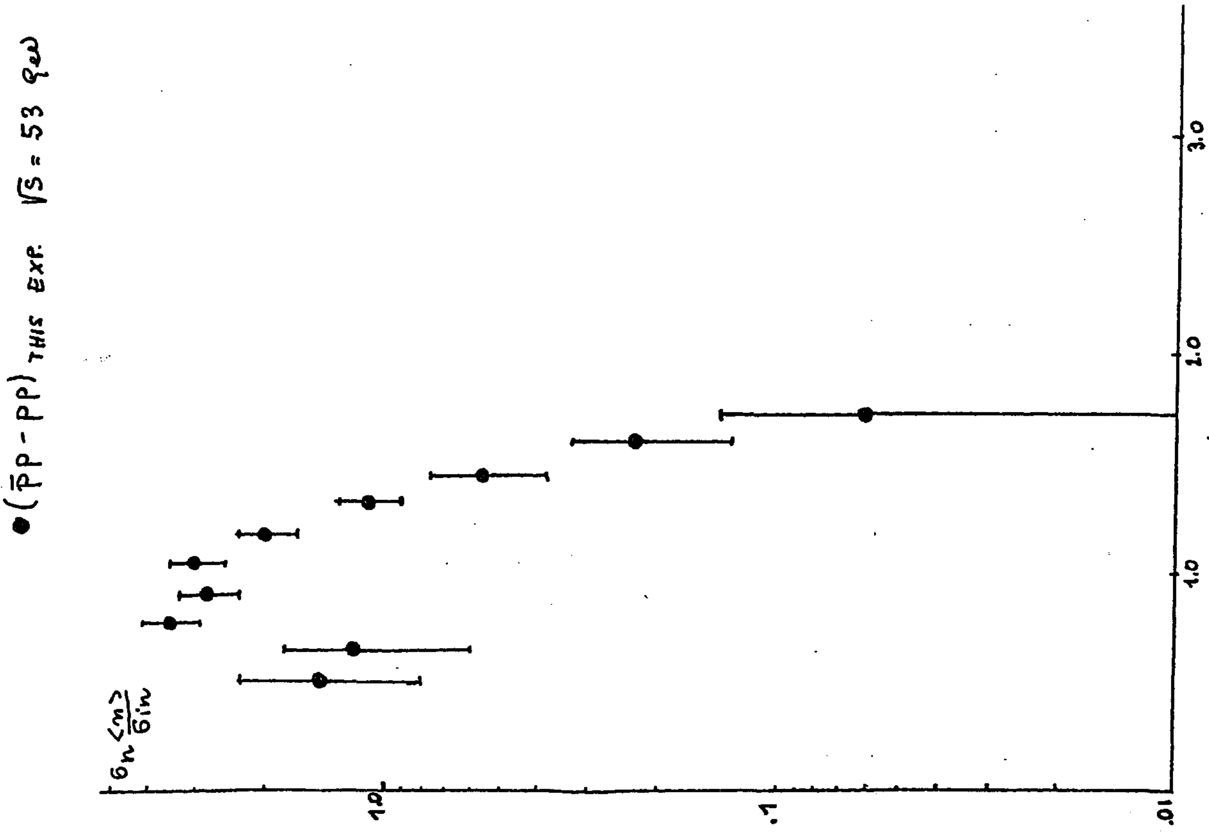


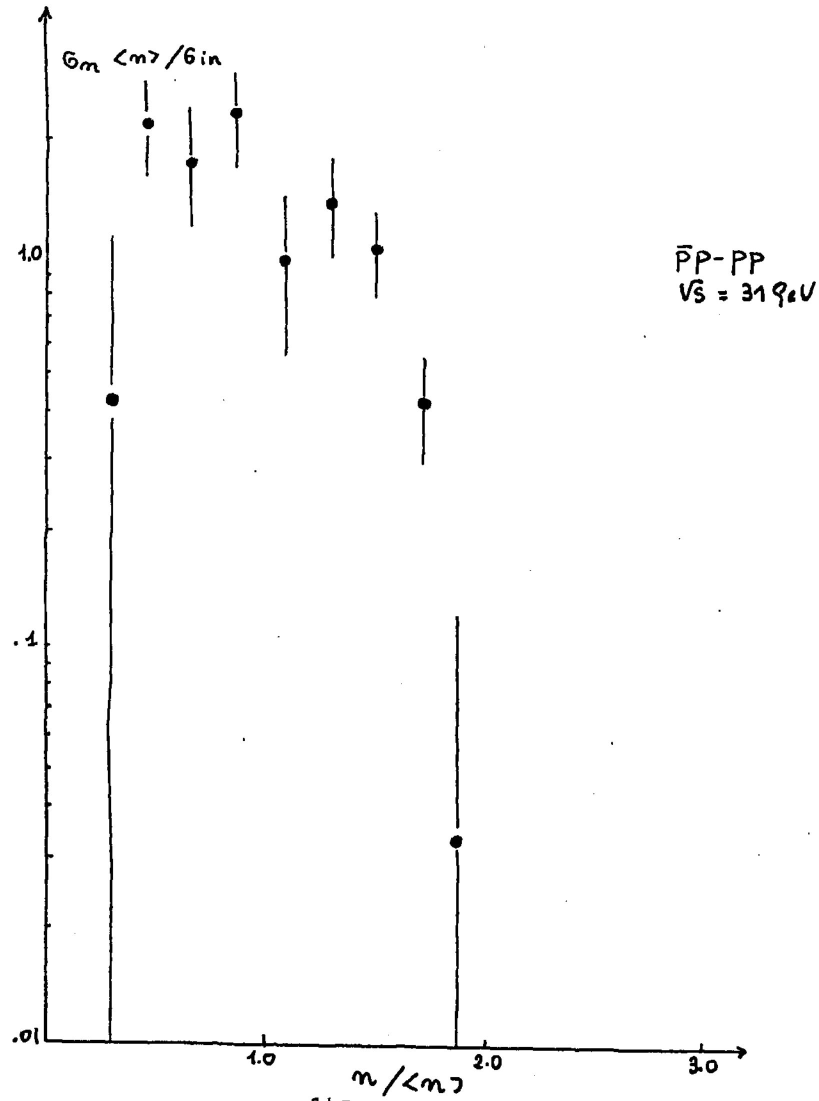
σn <n>/σin
√s = 53 GeV
p̄p
pp
THIS EXP
1.0
.1
.01
1.0
2.0
3.0
n/<n>

-18-

MULTIPLICITY DISTRIBUTIONS

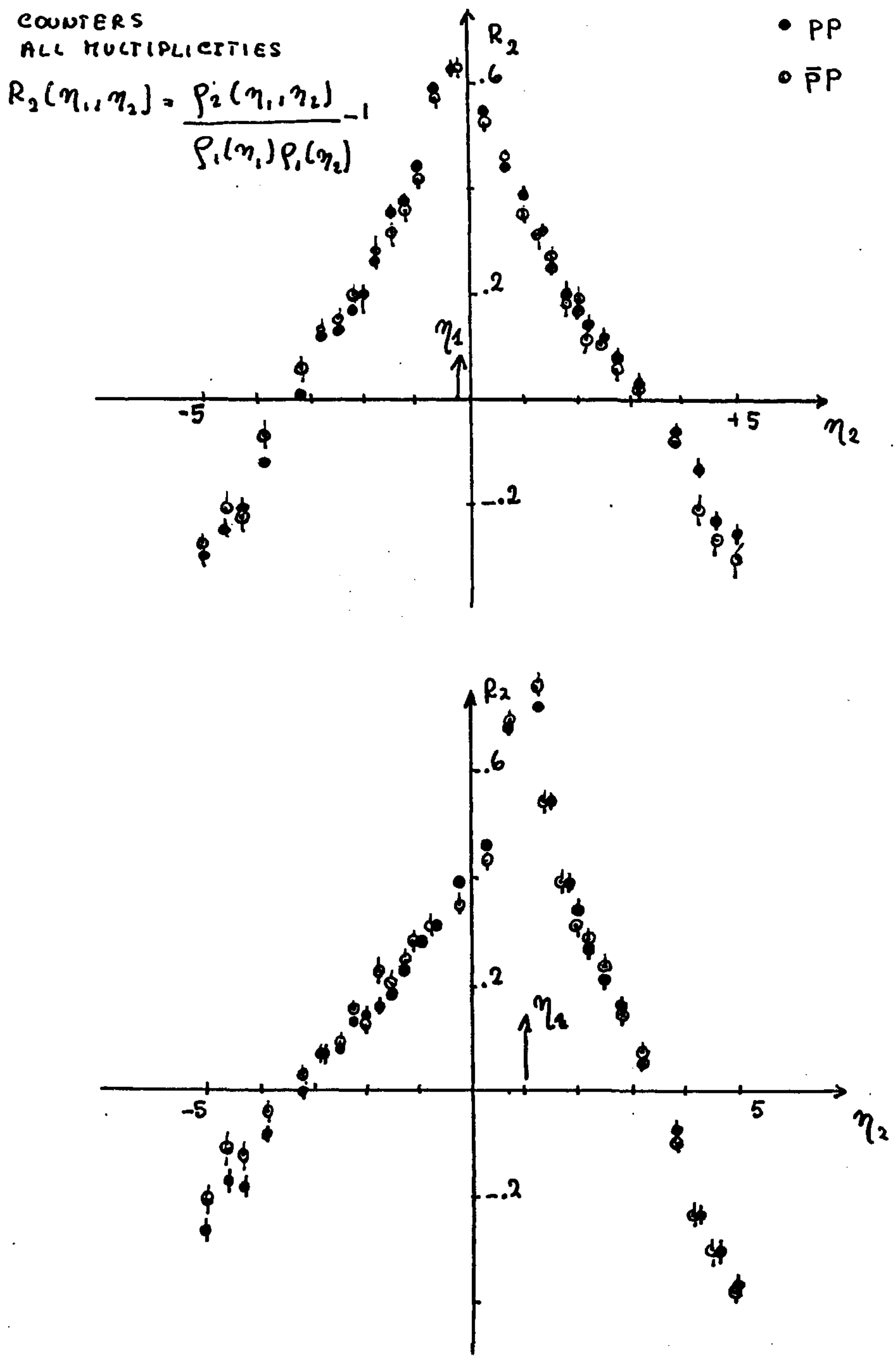






σn <n>/σin
1.0
.1
.01
1.0
2.0
3.0
n/<n>
p̄p-pp
√s = 31 GeV

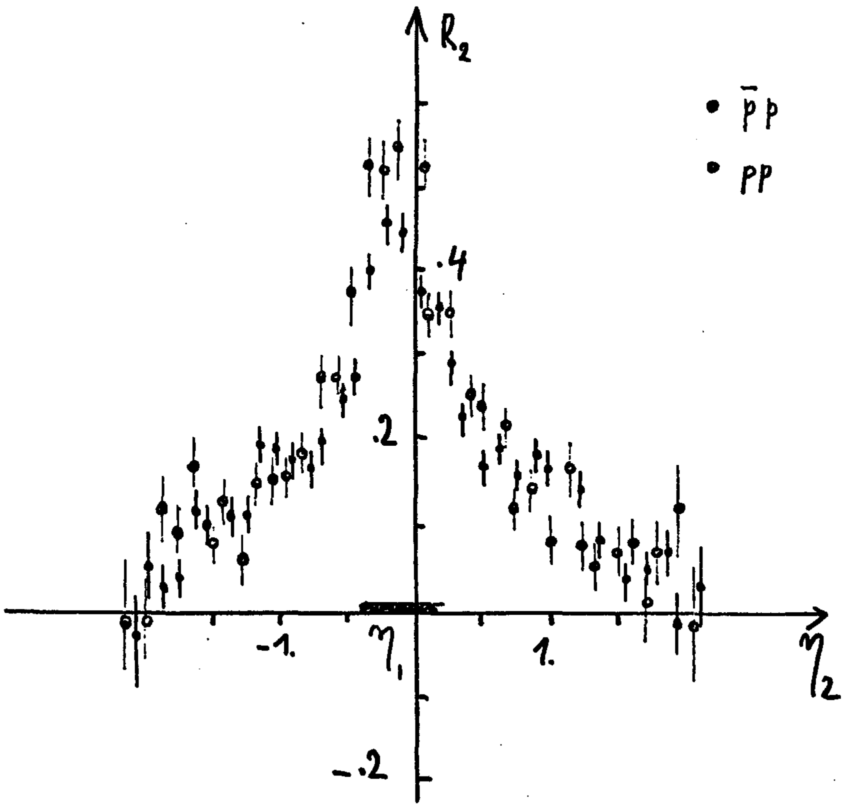
TWO-BODY CORRELATIONS $\sqrt{s}$ = 31 GeV



INCLUSIVE TWO-BODY CORRELATIONS $\sqrt{s} = 31$ GeV

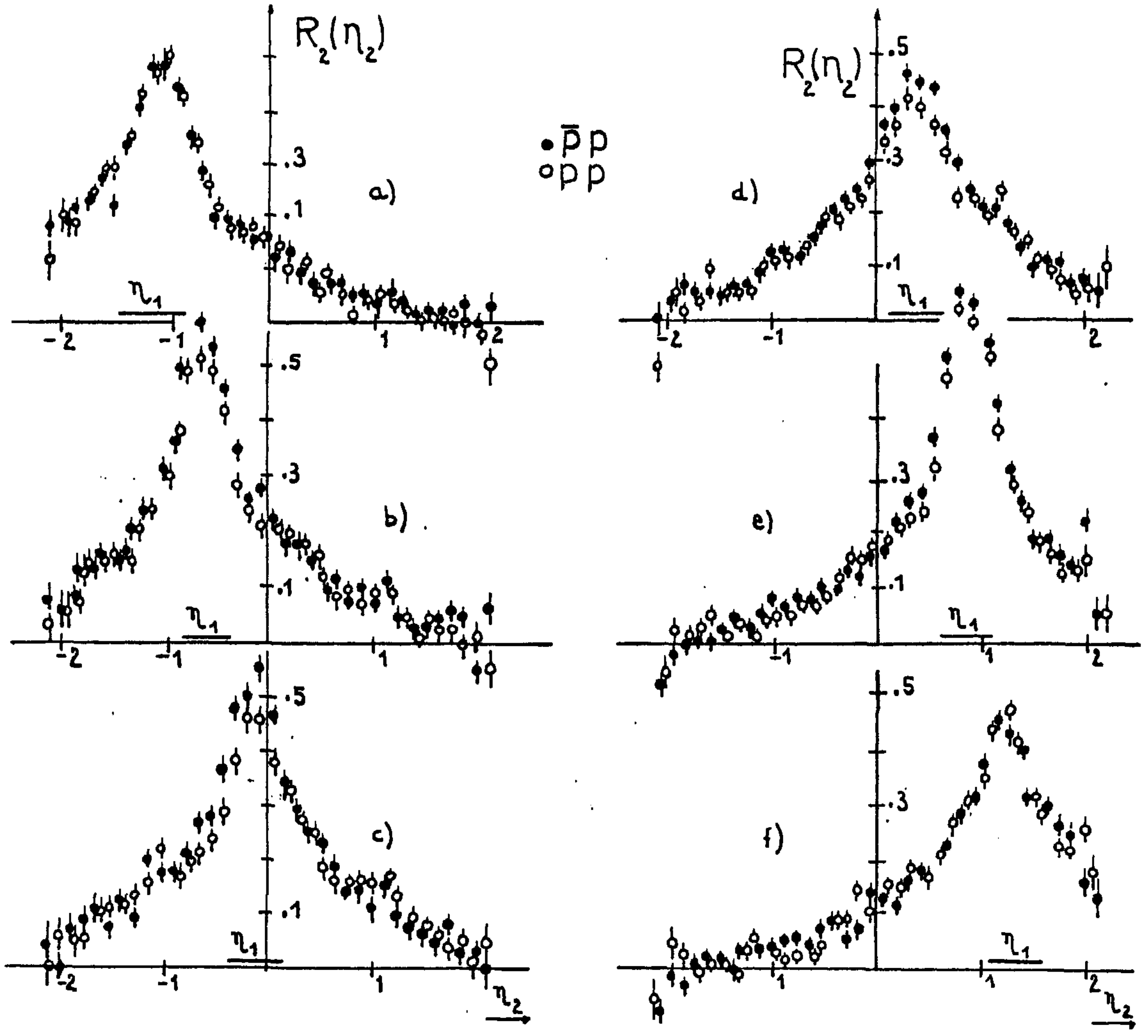
(CHAMBERS) R210

$|\eta| < 2.$

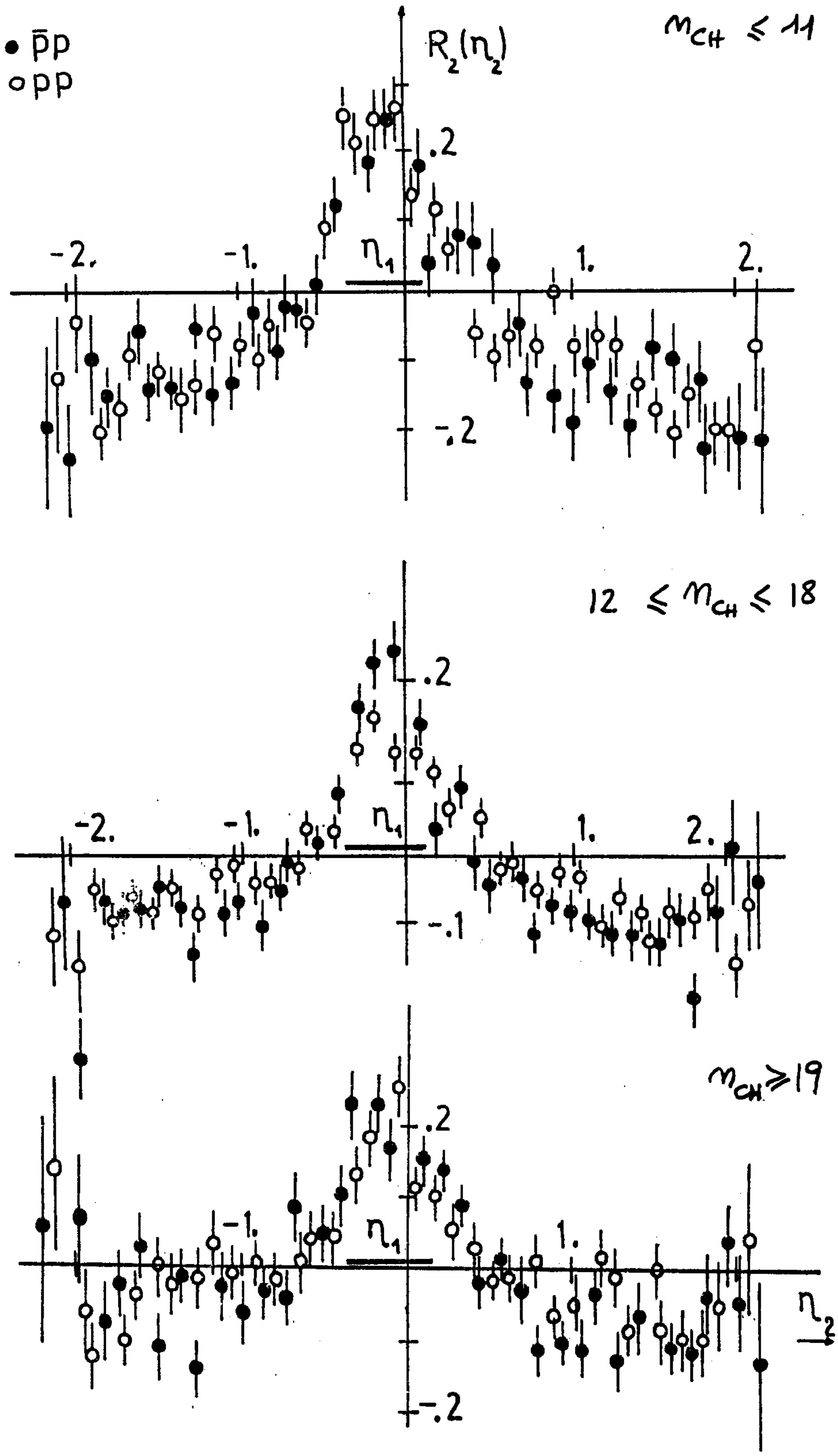


$$R_2(\eta_1, \eta_2) = \frac{\rho_2(\eta_1, \eta_2)}{\rho_1(\eta_1) \cdot \rho_1(\eta_2)} - 1.$$

TWO-BODY CORRELATIONS $\sqrt{s}$ = 31 GeV (INCLUSIVE)
(CHAMBERS)



TWO-BODY CORRELATIONS $\sqrt{s}$ = 31 GeV (SEMI-INCLUSIVE)
(CHAMBERS) $|\eta| < 2$



CONCLUSIONS

A) Total cross-section

1) σ_{TOT} rising as $\ln^2 s$

2) $\Delta\sigma$ positive, but $\rightarrow 0$

$$\Delta\sigma \propto s^{\alpha-1} \quad \text{with } \alpha = 0.47.$$

B) Elastic cross-section

1) b rising with s ($\ln^2 s$)

2) geometrical scaling

$\frac{b}{\sigma_{TOT}}$, $\frac{\sigma_{el}}{\sigma_{TOT}}$ indep. from s

C) Inelastic collisions

1) $\frac{\rho_1(\bar{p}p)}{\rho_1(pp)}$ $\begin{cases} \simeq 1.05 & |\eta| \leq 2.5 \\ \leq 1 & |\eta| \geq 3 \end{cases}$

2) $R_2(\bar{p}p) > R_2(pp)$ → very short range correlations (0.3) → central region ($|\eta| < 1.5$)

KNO scaling violated ↓   KNO scaling OK ↙ ↘

3) $\langle n_{\Delta\sigma_n} \rangle > \langle n_{pp} \rangle, \langle n_{\bar{p}p} \rangle$

↳ hint for the existence of "annihilation process" (similar to other very inelastic processes?)