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

e^+e^+ PHYSICS AT ENERGIES ≤ 3 GeV

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e^+e^- PHYSICS AT TOTAL ENERGIES $\sqrt{s} < 3$ GeV

MACHINES OPERATING IN THIS ENERGY RANGE :

- VEPP-2 (NOVOSIBIRSK)
- ACO (ORSAY)
- ADONE (FRASCATI)

(with some overlapping SPEAR)

EXHAUSTIVE REVIEWS BY

- V. SILVESTRINI - XVI INT. CONF. H.E.P. - Batavia 72
- K. STRAUCH - BONN CONF. 1973

IN THIS REPORT EMPHASIS ONLY ON RECENT RESULTS (essentially from Adone) - EXPERIMENTAL DETAILS OMITTED UNLESS NECESSARY -

TOPICS :

- Q.E.D. WITH e^+e^- RINGS
- TWO-PHOTON PROCESSES
- FORM FACTORS
- MANY HADRON PRODUCTION

Q.E.D. WITH e^+e^- RINGS

1. $e^+e^- \rightarrow e^+e^-$
   $\mu^+\mu^-$
   $\gamma\gamma$

AGREEMENT WITH Q.E.D. $\pm 10\%$

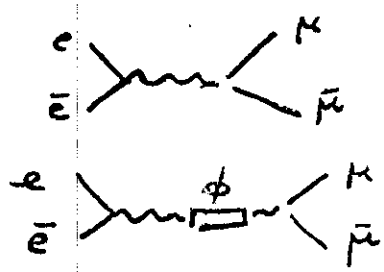
FOR INSTANCE: AGREEMENT WITH Q.E.D.

$\sigma(e^+e^-) \pm 4\%$

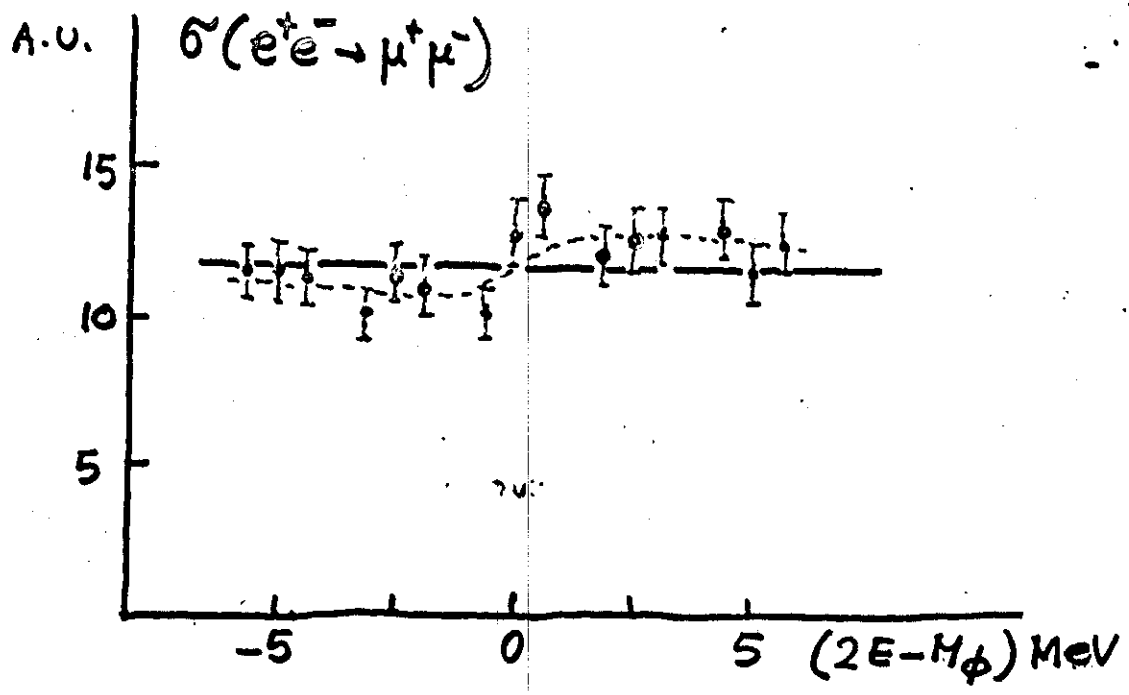
$\frac{d\sigma}{d\Omega} \pm 2\%$ ANGULAR DISTRIBUTION

EXTENSIVELY STUDIED IN ABSOLUTE RATES AND ANGULAR DISTRIBUTIONS. AGREEMENT (WITHIN THE EXPERIMENTAL ACCURACIES) WITH Q.E.D. IS FOUND WHEN RADIATIVE CORRECTIONS ARE PROPERLY TAKEN INTO ACCOUNT.

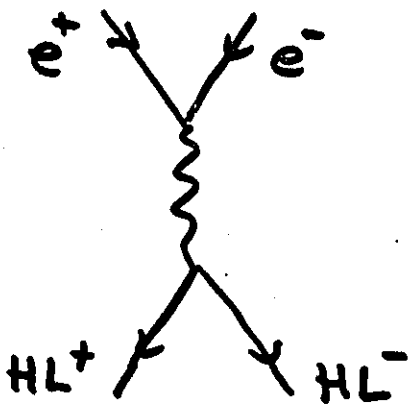
INTERESTING BEHAVIOUR OF THE $e^+e^- \rightarrow \mu^+\mu^-$ CROSS SECTION AROUND THE ϕ ENERGY [ACO 1971]



INTERFERENCE



2. HEAVY LEPTON SEARCH IN e^+e^- REACTIONS



HEAVY LEPTONS OF ANY KIND CAN BE PRODUCED VIA THE ONE-PHOTON CHANNEL ; SUCH AS :

E^+ from (E^+, ν_e, e^-) electron-like

M^+ from (M^+, ν_μ, μ^-) muon-like

L^+ with leptonic number different from e, μ, and proper neutrinos

IF H.L. ARE POINT LIKE DIRAC PARTICLES THE RELEVANT EXPERIMENTAL PECULIARITY OF THE REACTION $e^+e^- \to HL^+ + HL^-$ IS THAT :

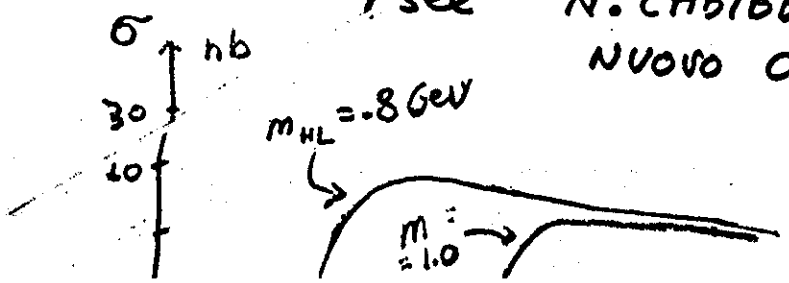
a) FOR $E \gg M_{HL}$

$$\sigma(e^+e^- \to HL^+ + HL^-) \approx \sigma(e^+e^- \to \mu^+\mu^-) = \frac{2 \cdot 10^{-32}}{E^2} \text{ cm}^2$$

(that is relatively high count. rates)

b) THRESHOLD-LIKE PATTERNS ARE EXPECTED FOR σ AS A FUNCTION OF THE ENERGY

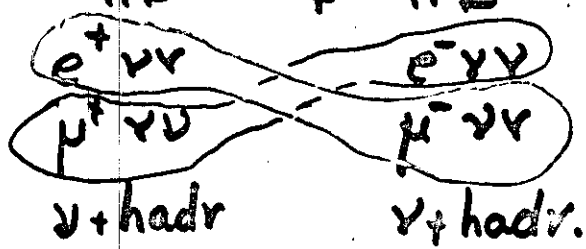
(see N. CABIBBO + R. GATTO NUOVO CIM. 20, 185 (1960))



$e^+e^- \to HL^+ + HL^-$

THE CLEANEST WAY TO LOOK FOR H.L.'S IN e^+e^- EXPERIMENTS IS TO CONSIDER DECAY MODES IN WHICH μ'S AND e'S ARE INVOLVED. INFACT HADRONIC CHANNELS COULD BE HEAVILY CONTAMINATED BY OTHER COMPETING REACTIONS

$$e^+e^- \to HL^+ + HL^-$$



(mixed $\mu^\pm e^\mp$ final state channels are considered) non colinear
non coplanar

References:

BCF
- V. Alles-Borelli et al. Lett. Nuovo Cim. 4, 1156 (70)
- M. Bernardini et al. - XVI INT. CONF. H.E.P. Batavia, Ill., 1972
- M. Bernardini et al. - Nuovo Cim. 17A, 383 (1973)

Frascati
- F. Ceradini et al. - INFN INT. REP. 495 (1973)

RESULTS:

BCF $0.6 < E_{BEAM} < 1.5$ GeV

IN INTEGR. LUMINOSITY $\simeq 450\ nb^{-1}$ ($1\ nb^{-1} = \frac{1}{33}$ ($10^{-33}\ cm^{-2}$))

NO TRUE μe PAIR FOUND

$e^+e^- \to HL^+ + HL^-$

BCF : CONCLUSIONS

a) IF THE H.L. IS COUPLED ONLY TO ORDINARY LEPTONS (universal weak coupling constant)

$$m_{HL} \geq 1{,}45 \text{ GeV} \quad (95\% \text{ c.l.})$$

b) IF THE H.L. IS UNIVERSALLY COUPLED TO BOTH ORDINARY LEPTONS AND HADRONS

$$m_{HL} \geq 1{,}0 \text{ GeV} \quad (95\% \text{ c.l.})$$

MP GROUP : NO EVENT FOUND

(μe) mixed channel detected

EXAMPLE OF EXPECTED EVENT RATES

M_{HL} GeV	H new l.nr.	TYPE OF LEPTONS E electr. like	M muon like
0.8	8.2	8.1	8.5
1.0	4.5	4.6	4.7
1.4	0.7	0.6	0.6

$$m_{HL} \geq 1.15 \text{ GeV}$$

(95% c.l.)

Q.E.D.

WIDE ANGLE e^+e^- BREMSTRAHLUNG

$$e^+e^- \to e^+e^-\gamma$$

[$\gamma\gamma$ GROUP] Ref. C. Bacci et al. Phys. Lett. 44B, 530 (73)

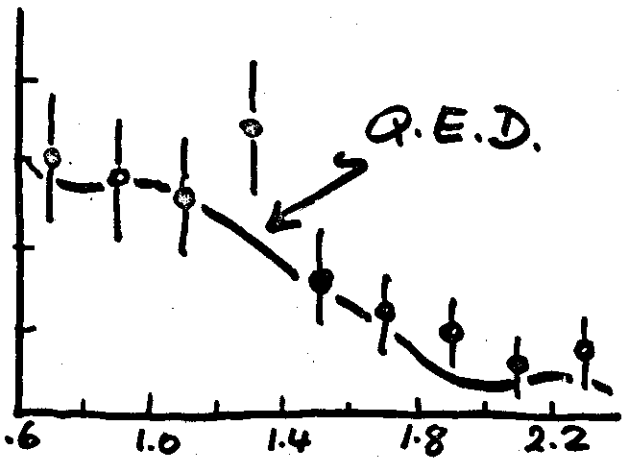
AGREES WITH Q.E.D. PREDICTIONS

THE SAME DATA HAVE BEEN ANALYZED IN ORDER TO SET A LIMIT TO THE EXISTENCE OF A HEAVY EXCITED ELECTRON e^*

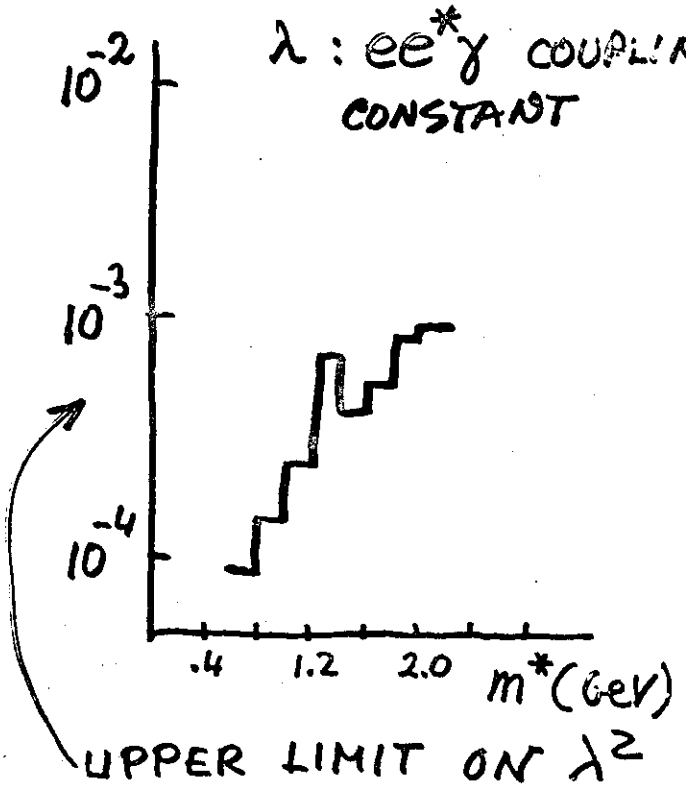
$$e^+e^- \to e^*e$$
$$\hookrightarrow e\gamma$$

[as suggested in : F.E. Low - P.R.L. 14, 238 (65)]

THE INVARIANT MASS DISTRIBUTION OF THE $(e^\pm, \gamma)$ SYSTEM AGREES WITH THE Q.E.D. PREDICTIONS

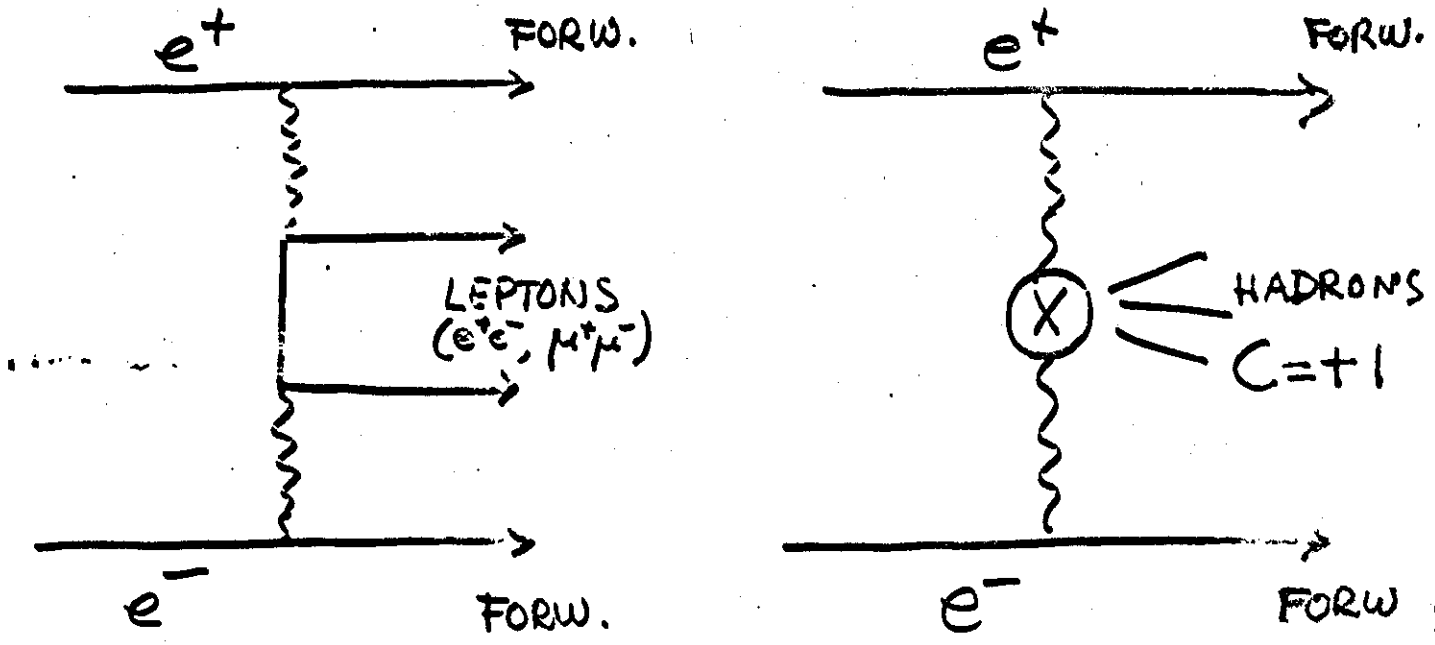


$(e^\pm\gamma)$ INVARIANT MASS



2. TWO-PHOTON PROCESSES

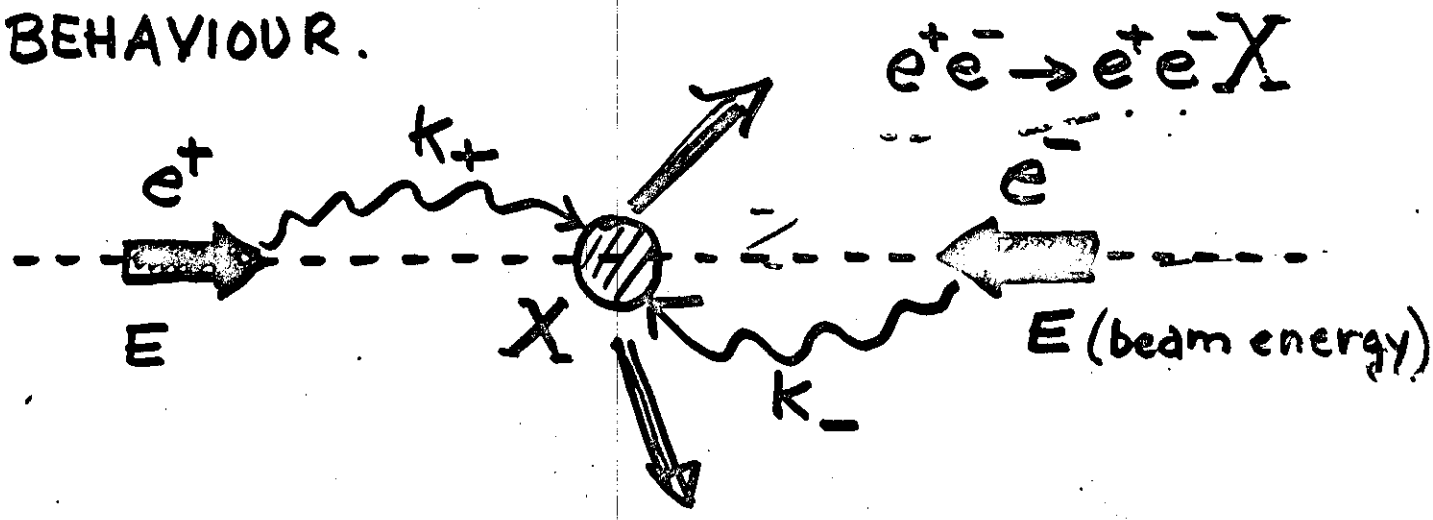
$$e^+e^- \to e^+\gamma\, e^-\gamma \to e^+e^- X$$



BOTH THE INCOMING e^+e^- IRRADIATE A PHOTON.
THESE TWO QUASI-REAL PHOTONS INTERACT AND MATERIALIZE INTO A SYSTEM X.

TWO PHOTON PROCESSES DEPRESSED BY A FACTOR α^2 WITH RESPECT TO THE ONE-PHOTON ANNIHILATION GRAPHS BUT A LOGARITHMIC INCREASE OF THE CROSS SECTION WITH THE ENERGY MAKES THIS PROCESS IMPORTANT.

TWO-PHOTON PROCESSES ENERGY BEHAVIOUR.



EQUIVALENT PHOTON APPROXIMATION (E.P.A.): both the incident $e^\pm$ are replaced by uncorrelated equivalent photon spectra:

$$P(k)\,dk = \frac{2\alpha}{\pi}\,\frac{dk}{k}\,L\left(\frac{2k}{\sqrt{s}}, s\right)$$

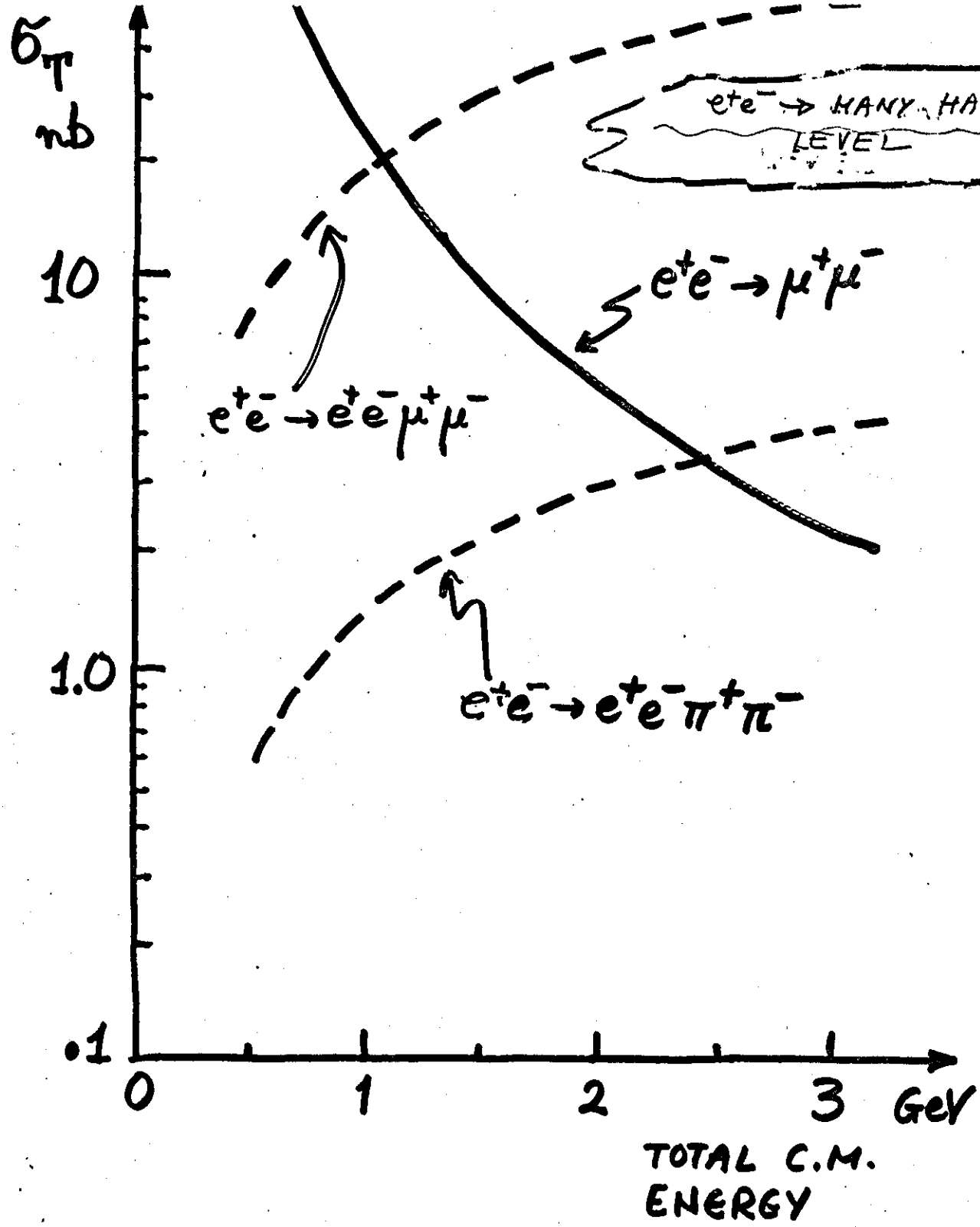
$$L(x,s) = \frac{1}{4}\left[1+(1-x)^2\right] \ln \frac{s}{4m_e^2}$$

where $\sqrt{s}$ = TOTAL ENERGY OF THE e^+e^- SYSTEM

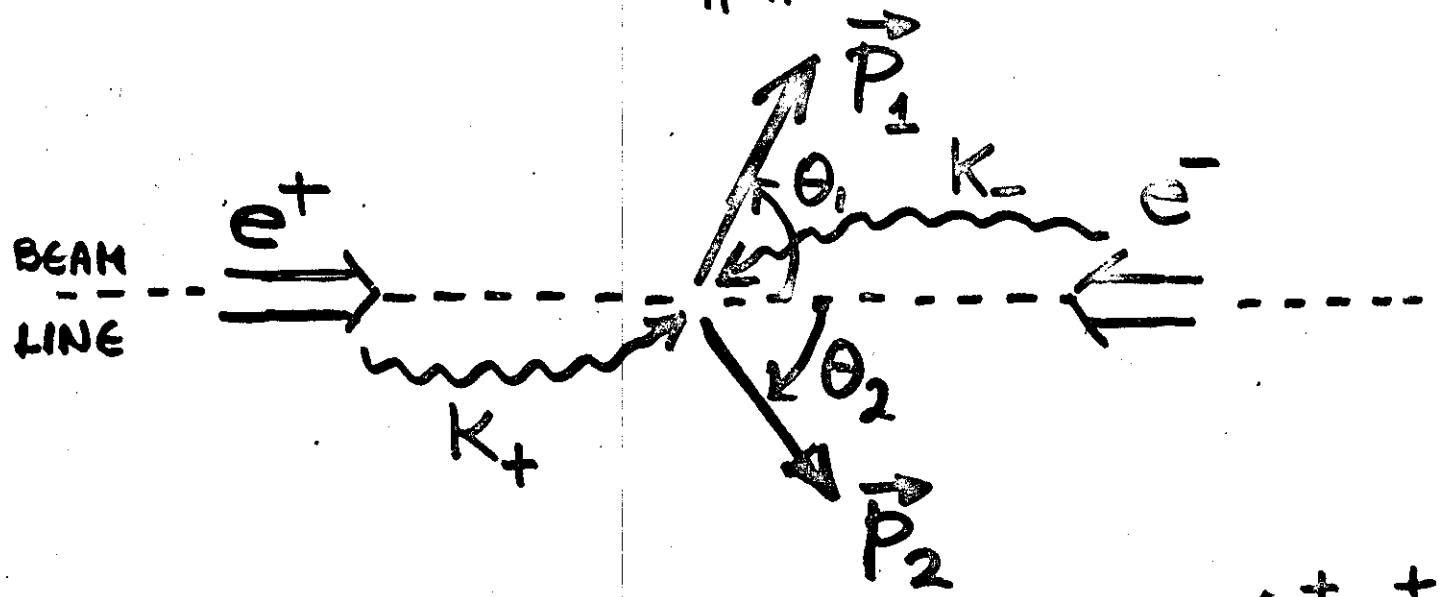
$\sigma_T(e^+e^- \to e^+e^- X)$ ACCORDING TO E.P.A.:

$$\sigma_T = \frac{1}{2}\left(\frac{\alpha}{\pi} \ln \frac{s}{4m_e^2}\right)^2 \int_{th}^{s} \frac{ds'}{s'} f\left(\frac{s'}{s}\right) \sigma_{\gamma\gamma \to X}$$

$$f(y) = \frac{1}{2}(2+y)^2 \ln \frac{1}{y} - (1-y)(3+y)$$


σ_T
nb
10
1.0
.1
0
1
2
3
GeV
TOTAL C.M.
ENERGY
$e^+e^- \to$ MANY HADRONS
LEVEL
$e^+e^- \to \mu^+\mu^-$
$e^+e^- \to e^+e^-\mu^+\mu^-$
$e^+e^- \to e^+e^-\pi^+\pi^-$

$e^+e^- \to e^+e^-\, e^+e^-$ KINEMATICS
$\mu^+\mu^-$
$\pi^+\pi^-$



1, 2 : WIDE ANGLE EMITTED PARTICLES $(e^\pm, \mu^\pm,$
(COPLANAR ($|\Delta\phi| < 10°$) WITH THE BEAMS)

β = WIDE ANGLE PARTICLES C.M. VELOCITY

$$|\beta| = \frac{|K_+ - K_-|}{K_+ + K_-} = \frac{\operatorname{sen}(\theta_1+\theta_2)}{\operatorname{sen}\theta_1 + \operatorname{sen}\theta_2}$$

(C.M. ASSUMED MOVING ALONG THE BEAM AXIS)

K_+ AND K_- ARE DETERMINED (AT ADONE) BY MEASURING THE ENERGIES OF THE FORWARD EMITTED e^+, e^- WITH A PROPER MOMENTUM ANALYSING DEVICE (TAGGING

REFERENCES ON EXPERIMENTAL WORKS ON TWO-PHOTON PROCESSES :

EACTION :

$\bar{e} \to e^+\bar{e}e^+\bar{e}$ Balakin et al. [NOVOSIBIRSK]
Phys. Letters 34B, 328, 663 (1971)

[ADONE]

$\to e^+\bar{e}e^+\bar{e}$ ($\gamma\gamma$) C. Bacci et al. - Lett. N.C. 3, 709 (71)
$e^+\bar{e}\mu^+\mu^-$ ($\mu\pi$) G. Barbiellini et al. - LNF 73/63 (73) + Phys. Rev. Letters
($\gamma\gamma$) C. Bacci et al. - LNF 73/50 (73)
($\mu\pi$) F. Ceradini et al. - Jour. Phys C2, (74)
($\gamma\gamma$) G. Salvini - Journ. Phys. C2, (74)

$\to e^+\bar{e}\pi^+\pi^-$ ($\mu\pi$) S. Orito et al. Phys. Letters 48B, 380 (74)

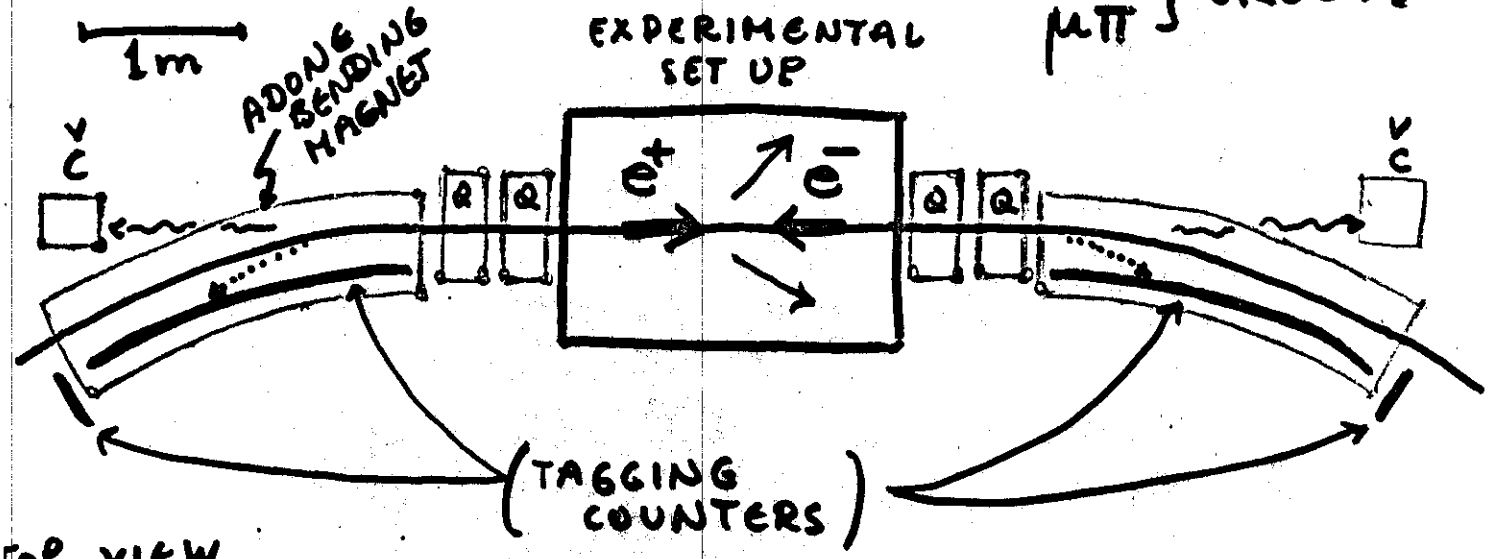
$\to e^+\bar{e}(mh)$ ($\mu\pi$) G. Barbiellini et al. - LNF-74/10 (74) submitted to Lett. N. Cim.

FOR REFERENCES ON THEORY SEE :

- N.A. Romero, A. Jaccarini, P. Kessler (1969) Compt. Rend. Ac. Sc. Paris 269B, 153.
- S.J. Brodsky, T. Kinoshita, H. Terazawa Phys. Rev. Letters 25, 972 (70)
- H. Terazawa - Rev. Mod. Physics

ADONE : FORWARD $e^{\pm}$ TAGGING SYSTEM

$\gamma\gamma$ } ADONE GROUPS
$\mu\pi$ }



TOP VIEW

MOMENTUM ACCEPTANCE : (0,2 − 0,85) E
E = beam energy.

GEOMETRICAL EFFICIENCY : ~ 50%

MOMENTUM RESOLUTION $e^{\pm}$: ± 5 %

PHOTON ENERGY KNOWN TO ± 60 MeV

$\gamma\gamma$ INVARIANT MASS $M_{\gamma\gamma} = 2\sqrt{K_+ K_-}$

KNOWN TO ± 90 MeV (double tagging events)

TAGGING SYSTEM DESCRIBED ON :

G. Barbiellini and S. Orito - FRASCATI REPORT LNF 71/17 (1971)

$e^+e^- \to e^+e^-e^+e^-$

NOVOSIBIRSK : DETECTED WIDE ANGLE COPLANAR e^+e^- PAIRS. COPLANARITY ANGLE DISTRIBUTION IN AGREEMENT WITH QED PREDICTION (E.P.A.)

ADONE : (TOTAL ENERGY AVERAGE = 2.7 GeV)

i) BOTH THE FORWARD e^+e^- DETECTED IN COINCIDENCE WITH THE WIDE ANGLE e^+e^- PAIR

12 EVENTS IN $\mathcal{L}_{TOT} = 290\ nb^{-1}$ $(\mu\mu)$

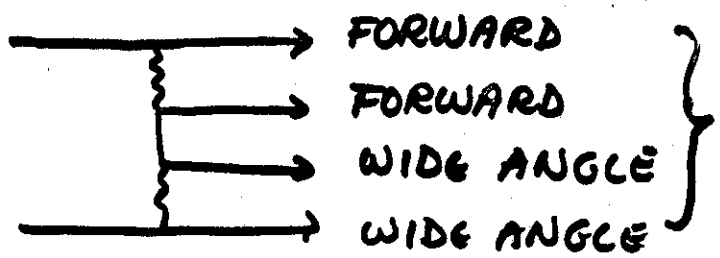
[E.P.A. EXPECTED NUMBER: $11,6 \pm 1,1$

RELATIONSHIP $\beta(\theta_1, \theta_2) = \beta(K_+, K_-)$ TESTED]

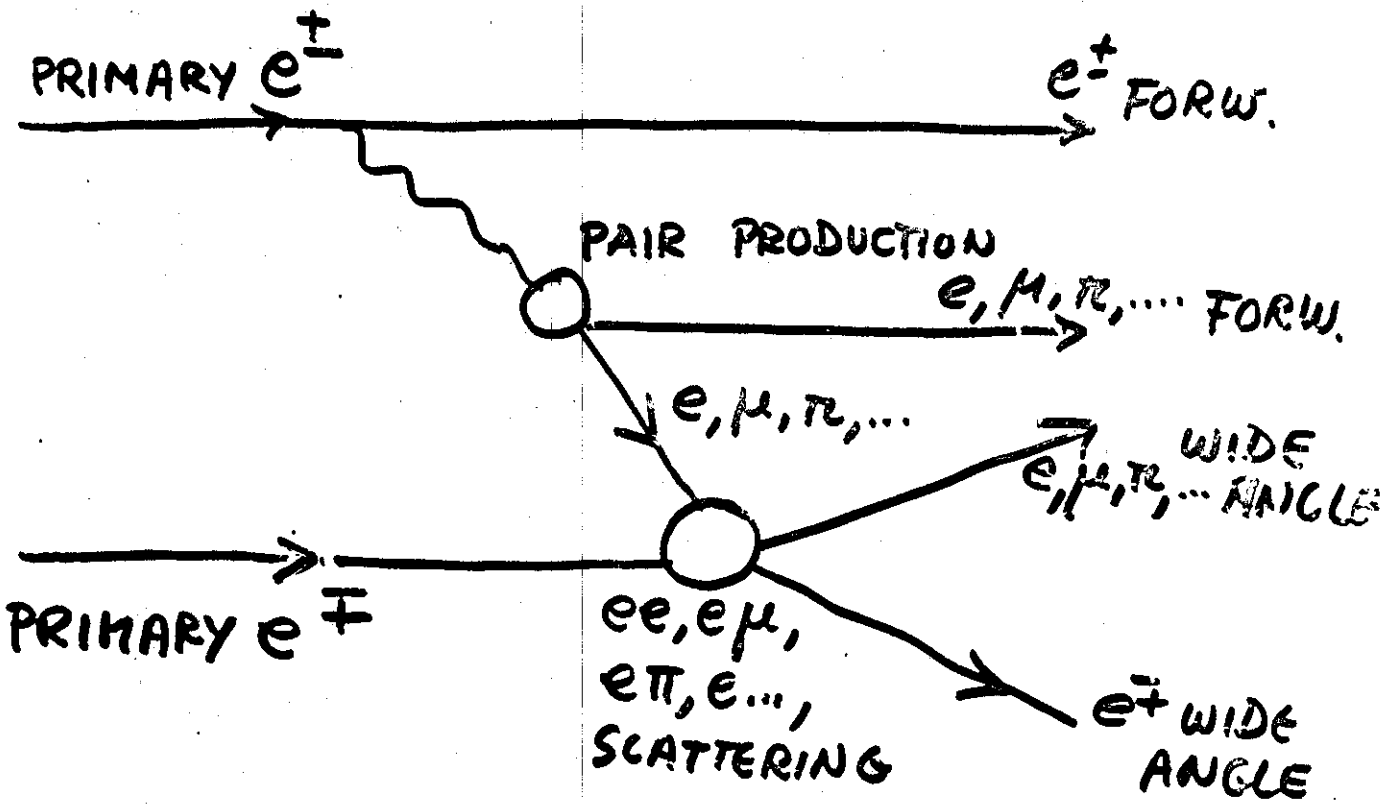
ii) ONLY "ONE" FORWARD $e^\pm$ DETECTED IN COINCIDENCE WITH THE WIDE ANGLE e^+e^- PAIR

44 EVENTS IN $\mathcal{L}_{TOT} = 168\ nb^{-1}$ (ee)

[$\beta = \beta(\theta_1, \theta_2)$ DISTRIBUTION IN AGREEMENT WITH E.P.A. PREDICTIONS - VIRTUAL PHOTON CONTRIBUTION EVIDENTIATED :



DEEPLY VIRTUAL PHOTON CONTRIBUTION :



IN PRINCIPLE SUITABLE IN ORDER TO
INVESTIGATE $e-\mu$, $e-\pi$, $e-K$,
SCATTERING.

$e^+e^- \to e^+e^-e^+e^-$

ADONE : ($\langle 2E \rangle = 2.7$ GeV)

iii) ONLY "ONE" FORWARD $e^\pm$ DETECTED, PLUS WIDE ANGLE PAIR
64 EVENTS IN $\mathcal{L}_{TOT} = 290\ nb^{-1}$ (μR)

[CALCULATED THE ENERGY OF THE PHOTON POSSIBLY ASSOCIATED WITH THE UNDETECTED FORWARD $e^\pm$ AND A SEPARATION MADE BETWEEN $\gamma\gamma \to e^+e^-$ EVENTS FROM Q.R.P. AND V.P. RESPECTIVELY. THE COMPARISON WITH THE E.P.A. EXPECTATIONS IS SATISFACTORY:

CONTRIBUTION	OBSERVED EVENTS	EXPECTED EVENTS
→ Q.R.P.	$49 \pm (6) \pm 7$	41 ± 5
→ V.P.	$15 \pm (6) \pm 4$	18 ± 9

↑ Systematic errors in parenthesis

$e^+e^- \rightarrow e^+e^-\mu^+\mu^-$ (ADONE)

$\langle 2E \rangle = 2,7$ GeV

$\Sigma_{tot} = 290$ nb^{-1} ($\mu\pi$ GROUP)

i) ONLY ONE FORWARD $e^\pm$ DETECTED

20 EVENTS

[E.P.A. EXP. = 28 ± 3]

COUNTING RATE AGREES WITH E.P.A.

i) BOTH THE FORWARD $e^\pm$ DETECTED

10 EVENTS

[E.P.A. EXP. = 11 ± 1]

KINEMATICAL CONSTRAINTS ALL SATISFIED (angles and ranges of the μ's measured). IN PARTICULAR THE TRANSVERSE MOMENTUM IS BALANCED (Maximum allowed unbalance $\Delta P_T = 15$ MeV/c).

(Energies $2E = 2,6 - 2,8 - 3.0$ GeV)

AGREEMENT WITH E.P.A.

$e^+e^- \to e^+e^-$ + HADRONS (C=+1)

(μπ) GROUP

EXPERIMENTAL REQUIREMENTS :

- both the forward e^- detected ;
- 2 prongs fully developing in the opposite wide angle telescopes ;
- no collinearity ;
- nuclear interactions in the wide angle prongs (scattering or unbalance of the transverse momentum when stopping) ;
- non e.m. showering behaviour.

EXPERIMENTAL RESULTS : $\begin{cases} \langle 2E \rangle = 2.7 \text{ GeV} \\ \mathcal{L}_{TOT} = 350 \text{ nb}^{-1} \end{cases}$

REACTION $e^+e^- \to$	COPLANARITY	EVENTS	$M_{\gamma\gamma}$ ($\gamma\gamma$ INVARIANT MASS $\Delta M_{\gamma\gamma} = \pm 90$ MeV) (MeV)
$e^+e^-\pi^+\pi^-$	$\Delta\phi < 5°$	3	600 ($\pi\pi$)
			650 ($\pi\pi$)
	$\langle\Delta\phi\rangle = 1°,3$		1300 (?)
e^+e^- + MORE THAN 2 HADRONS	$\Delta\phi > 8°$	2	800
			1400

$e^+e^- \to e^+e^-$ + (C=+1 HADRONIC STATE) ANALYSIS. (in principle)

IF A SHARP RESONANCE R (mass M_R, $J = 0, 2, \ldots$, $C=+1$, 2γ decay width $\Gamma_{R\to\gamma\gamma}$) IS PRODUCED, THE TOTAL CROSS SECTION:

$$\sigma_T(e^+e^- \to e^+e^- X) = \frac{1}{2}\left(\frac{\alpha}{\pi}\ln\frac{s}{4m_e^2}\right)^2 \int_{TH}^{s} \frac{ds'}{s'} f\left(\frac{s'}{s}\right) \sigma_{\gamma\gamma\to X}$$

BECOMES

$$\sigma(e^+e^- \to e^+e^- R) = \frac{8(2J+1)}{M_R^3}\alpha^2 \Gamma_{R\to\gamma\gamma} f(\varepsilon)$$

THEREFORE A MEASUREMENT OF $\sigma(e^+e^- \to e^+e^- R)$ IS A TOOL TO MEASURE $\Gamma_{R\to\gamma\gamma}$ ONCE M_R, Γ (total width) AND J ARE KNOWN

POSSIBLE CANDIDATES FOR THE ADONE DATA:

$\pi^+\pi^-$ ε : $J^{PC} = 0^{++}$; $M_\varepsilon \simeq 660$ MeV ;

$\Gamma_\varepsilon \simeq 600$ MeV

many hadrons η' : $J^{PC} = 0^{-+}$; $M_{\eta'} = 958$ MeV

$\Gamma_{\eta'} \leq 2$ MeV

BUT, NON RESONANT CONTRIBUTIONS FROM THE $\gamma\gamma \to$ HADRONS PROCESSES ARE TO BE EVALUATED IN ORDER TO ISOLATE THE RESONANT PART.

ASE $e^+e^- \to e^+e^-\pi^+\pi^-$
2 EVENTS ($M_{\gamma\gamma} = 600, 650$ MeV)

Born term calculations for $\gamma\gamma \to$ had
cannot explain this rate. Thus,

IF THE CHAIN IS ASSUMED TO BE:

$e^+e^- \to e^+e^- \varepsilon$
$\varepsilon \to \pi^+\pi^-$

THEN:

$$\Gamma_{\varepsilon\to\gamma\gamma} = \underline{10^{+12}_{-8}\ \text{keV}}$$

CASE $e^+e^- \to e^+e^-(\pi^+\pi^- + \ldots)$ $M_{\gamma\gamma} = \underline{800 \pm 90}$ MeV

(1) EVENT
non resonant contribution
unknown

$\Gamma_{\eta'\to\gamma\gamma}$

$= \underline{11}^{+15}_{-8}$ keV { if the event comes from $\gamma\gamma \to \eta' \to \ldots$

≤ 33 keV (95% c.l.) { if the event comes from $\gamma\gamma \to$ hadron non resonant

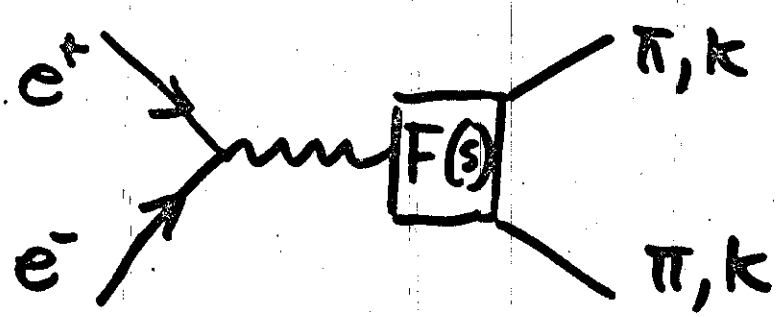
ELECTRO MAGNETIC STRUCTURE OF HADRONS. TIME-LIKE FORM FACTORS

MESON FORM FACTORS:

THE TIME-LIKE REGION OF FOUR-MOMENTUM TRANSFERS OF THE E.M. FORM FACTORS OF π'S AND K'S IS INVESTIGATED VIA THE e^+e^- ANNIHILATION REACTIONS

$$e^+e^- \to \pi^+\pi^-$$
$$e^+e^- \to K^+K^-$$

IN ONE-PHOTON APPROXIMATION:



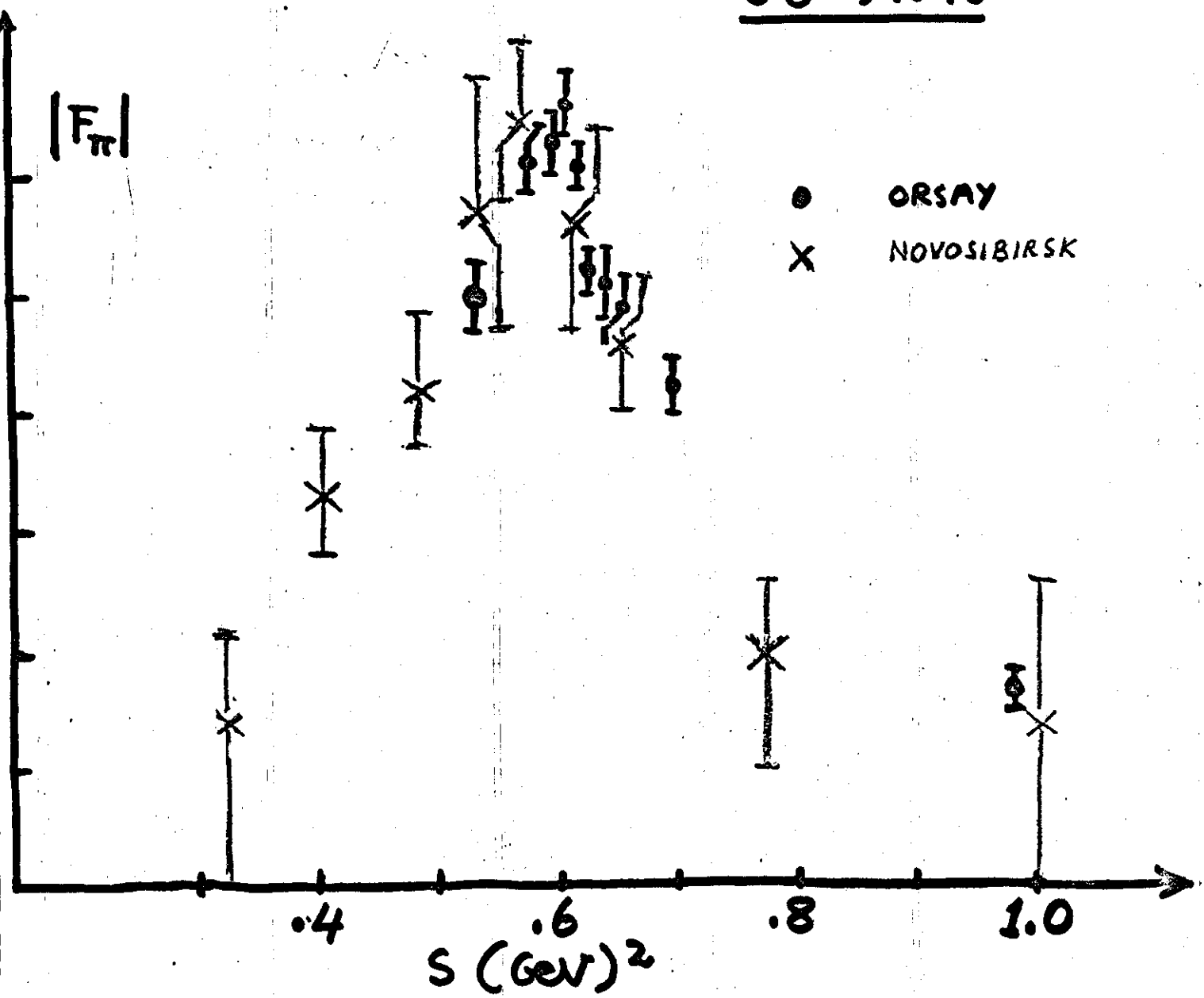
$$\frac{d\sigma}{d\Omega} = \frac{\pi\alpha^2}{4}\,\frac{\beta_{\pi,K}^3}{q^2}\,\left|F_{\pi,K}(q^2)\right|^2 \operatorname{sen}^2\theta$$

$$\sigma = \frac{\pi\alpha^2}{3}\,\frac{\beta_{\pi,K}^3}{q^2}\,\left|F_{\pi,K}(q^2)\right|^2$$

IT IS WELL KNOWN THAT THE $q^2 < 1\ (\mathrm{GeV/c})^2$ REGION IS DOMINATED BY THE PRODUCTION OF UNSTABLE VECTOR MESONS ρ, ω, ϕ -

THE VECTOR MESON ROLE SHOWS UP VERY CLEARLY WITH BUMPS IN THE e^+e^- ANNIHILATION CROSS SECTIONS JUST AT THE KNOWN VECTOR MESON MASSES IN THE REACTION CHANNELS ACCESSIBLE VIA THE VECTOR MESON DECAYS.

$e^+e^- \to \pi^+\pi^-$



$e^+e^- \to \pi^+\pi^-$ at $q^2 < 1\ (GeV/c)^2$

ORSAY + NOVOSIBIRSK

MAIN FEATURES :

- σ_{PEAK} $(s = M_\rho^2)$ RELATIVELY HIGH

  (ORDER OF 1000 nb)

- ρ-ω INTERFERENCE EFFECTS PRESENT

- GOUNARIS-SAKURAI TYPE OF PION FORM FACTOR EXPRESSION SATISFACTORILY FITS THE EXPERIMENTAL DATA WITH THE FOLLOWING VALUES FOR THE PARAMETERS :

  $M_\rho = 772.3 \pm 5.9$ MeV

  $\Gamma_\rho = 135.8 \pm 15.1$ MeV

  $\sqrt{B(\omega \to \pi\pi)} = 0.17 \pm 0.05$

  $\phi = (88.3 \pm 15.8)^\circ$ relative phase of the $\rho \to \pi\pi$ and $\omega \to \pi\pi$ amplitudes

  $B(\rho \to e^+e^-) = (4.2 \pm 0.4)\ 10^{-5}$

  $\Gamma(\rho \to e^+e^-) = (5.8 \pm 0.5)$ KeV

  $g_{\rho e}^2/4\pi = 2.38 \pm 0.18$

  $g_{\rho\pi\pi}^2/4\pi = 2.60 \pm 0.32$

A POSSIBLE ESTIMATE OF THE ρ TAIL AT HIGHER ENERGIES $(q^2 > 1\ (GeV/c)^2)$ FOLLOWS FROM THES GOUNARIS-SAKURAI FIT.

$e^+e^- \to K^+K^-$ at $q^2 < 1$ (GeV/c)^2

(ORSAY - NOVOSIBIRSK)

- THE ϕ PRODUCTION DOMINATING MECHANISM HAS BEEN ALSO EVIDENTIATED BY EXCITATION CURVES OF THE OTHER POSSIBLE DECAY CHANNELS $\phi \to K_S^0 K_L^0$, $\phi \to \pi^+\pi^-\pi^0$.

- THE RELEVANT PARAMETERS ARE THE FOLLOWING:

	ORSAY	NOVOSIBIRSK
$\sigma(e^+e \to \phi \to all)$ at $s = M_\phi^2$	$(4.99 \pm 0.40)\,\mu b$	$(3.96 \pm 0.35)\,\mu$
$\Gamma(\phi \to e^+e^-)/\Gamma(\phi \to all)$	$(3.52 \pm 0.28)\,10^{-4}$	$(2.81 \pm 0.25)\,10^{-4}$
$\Gamma(\phi \to e^+e^-)$	(1.49 ± 0.12) KeV	(1.31 ± 0.12) KeV

THE $q^2 > 1$ (GeV/c)^2 REGION OF THE π AND K FORM FACTOR HAS BEEN INVESTIGATED AT

NOVOSIBIRSK : V.E. BALAKIN et al.
VEPP-2 PHYS. LETTERS 41B, 205 (72)

ORSAY : B. JEAN-MARIE, G. PARROUR
ACO RI-73-7 (1973)
Un. Paris-Sud Rep.

FRASCATI
ADONE

: V. ALLES-BORELLI et al.
(BCF group) PHYS. LETTERS 40B, 433 (72)

M. BERNARDINI et al.
(BCF) PHYS. LETTERS 44B, 393 (73)

M. BERNARDINI et al.
(BCF) PHYS. LETTERS 46B, 261 (73)

G. BARBIELLINI et al.
(MIT GROUP) LETTERE N. CIM. 6, 557 (73)

$e^+e^- \to \pi^+\pi^-$ / K^+K^- at $q^2 > (1\ \mathrm{GeV}/c)^2$ ($1.4 < q^2 < 9\ (\mathrm{GeV}/c)^2$)

IN DETECTING THE REACTION
$e^+e^- \to h^+ + h^-$ $\quad h$ = HADRON
NO π/K SEPARATION IS POSSIBLE
ABOVE $q^2 \simeq 3\ (\mathrm{GeV}/c)^2$

(this limit will be extended to 4-5 $(\mathrm{GeV}/c)^2$ with the second generation Adone set-up (MEA) now in operation)

THEREFORE A DIRECT MEASUREMENT OF $|F_\pi|$ AND $|F_K|$ HAS BEEN PERFORMED ONLY UP TO $q^2 \simeq 2.6\ (\mathrm{GeV}/c)^2$ (BCF)

IN THIS q^2 REGION $N(K^+K^-) \approx N(\pi^+\pi^-)$ (BCF)
IN AGREEMENT WITH THE SU3 AND LINEAR, ZERO-WIDTH POLE TERMS FOR THE KNOWN VECTOR MESONS:

$$\frac{N(K^+K^-)}{N(\pi^+\pi^-)} = \frac{\beta_K^3}{\beta_\pi^3} \frac{\left(\frac{1}{2}P_\rho + \frac{1}{6}P_\omega + \frac{1}{3}P_\phi\right)^2}{P_\rho^2}$$

WHERE $P_{\rho,\omega,\phi} = \dfrac{m^2_{\rho,\omega,\phi}}{m^2_{\rho,\omega,\phi} - s}$

$$\beta_{\pi,K} = (1 - 4m^2_{\pi,K}/s)^{1/2}$$

BCF RESULT :

AT $\sqrt{s} = 1.5$, 1.6 , 1.7 GeV

$$R = \frac{\sigma(e^+e^- \to K^+K^-)}{\sigma(e^+e^- \to K^+K^-) + \sigma(e^+e^- \to \pi^+\pi^-)} = .53 \pm .13$$

$e^+e^- \to \pi^+\pi^-$ / K^+K^- at $q^2 > 1$ (GeV/c)^2

- IF THE VALIDITY OF THE SU3 PREDICTION ON THE RATIO $N(K^+K^-)/N(\pi^+\pi^-)$ IS ASSUMED TO HOLD AT HIGHER q^2 (that is $3 < q^2 < 9$ (GeV/c)^2) THEN A SEPARATION OF PIONS FROM KAONS CAN BE DEDUCED AND FROM THE MEASURED EVENTS:

$$e^+e^- \to h^\pm + h^\mp$$

$|F_\pi|$ AND $|F_K|$ CAN BE CALCULATED.

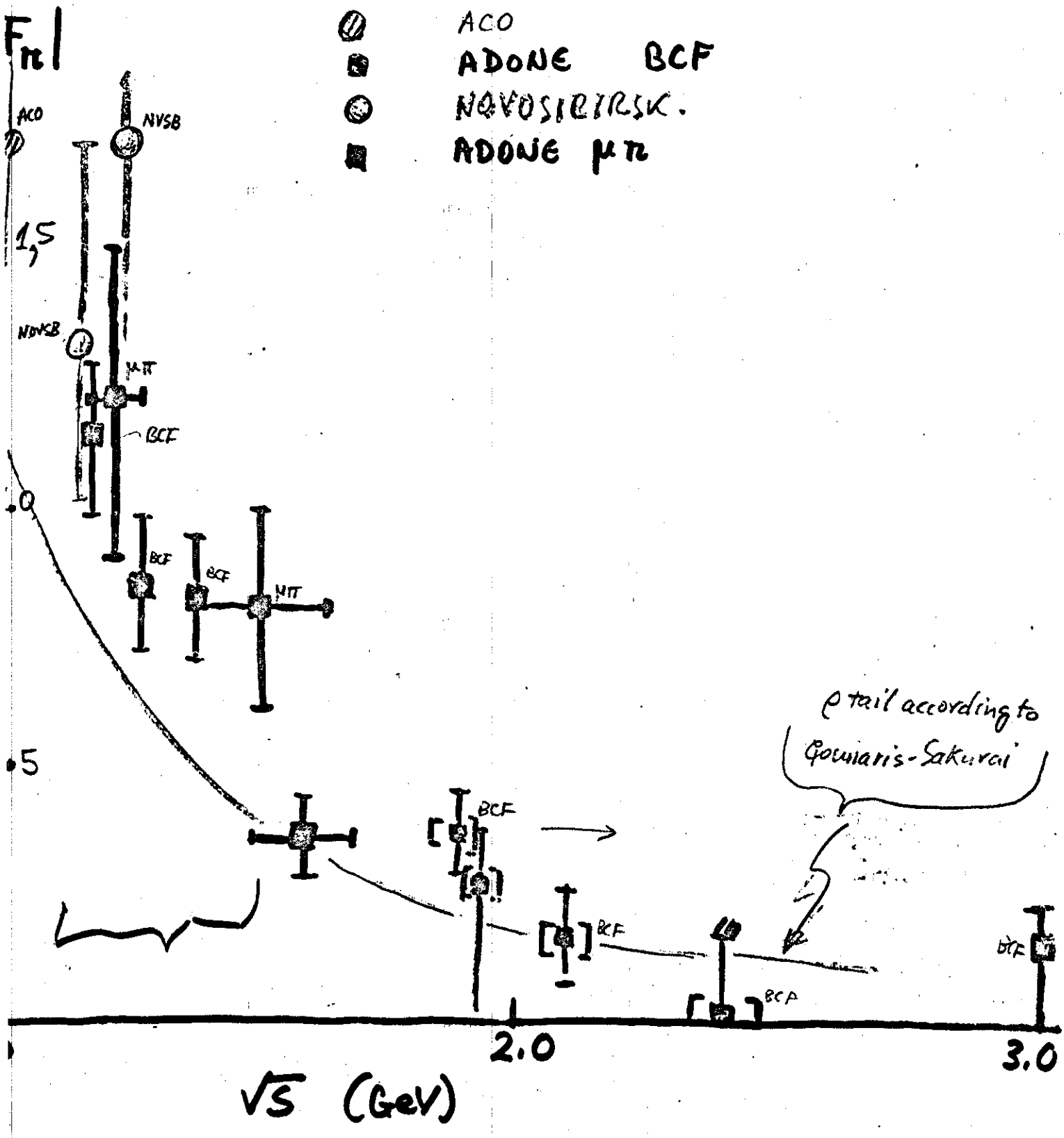
- THE VALUES OF $|F_\pi|$ AND $|F_K|$ FOR $q^2 > 3$ (GeV/c)^2 ARE THEREFORE MODEL DEPENDENT AND ARE REPRESENTED IN BRACKET IN THE FIGURES.

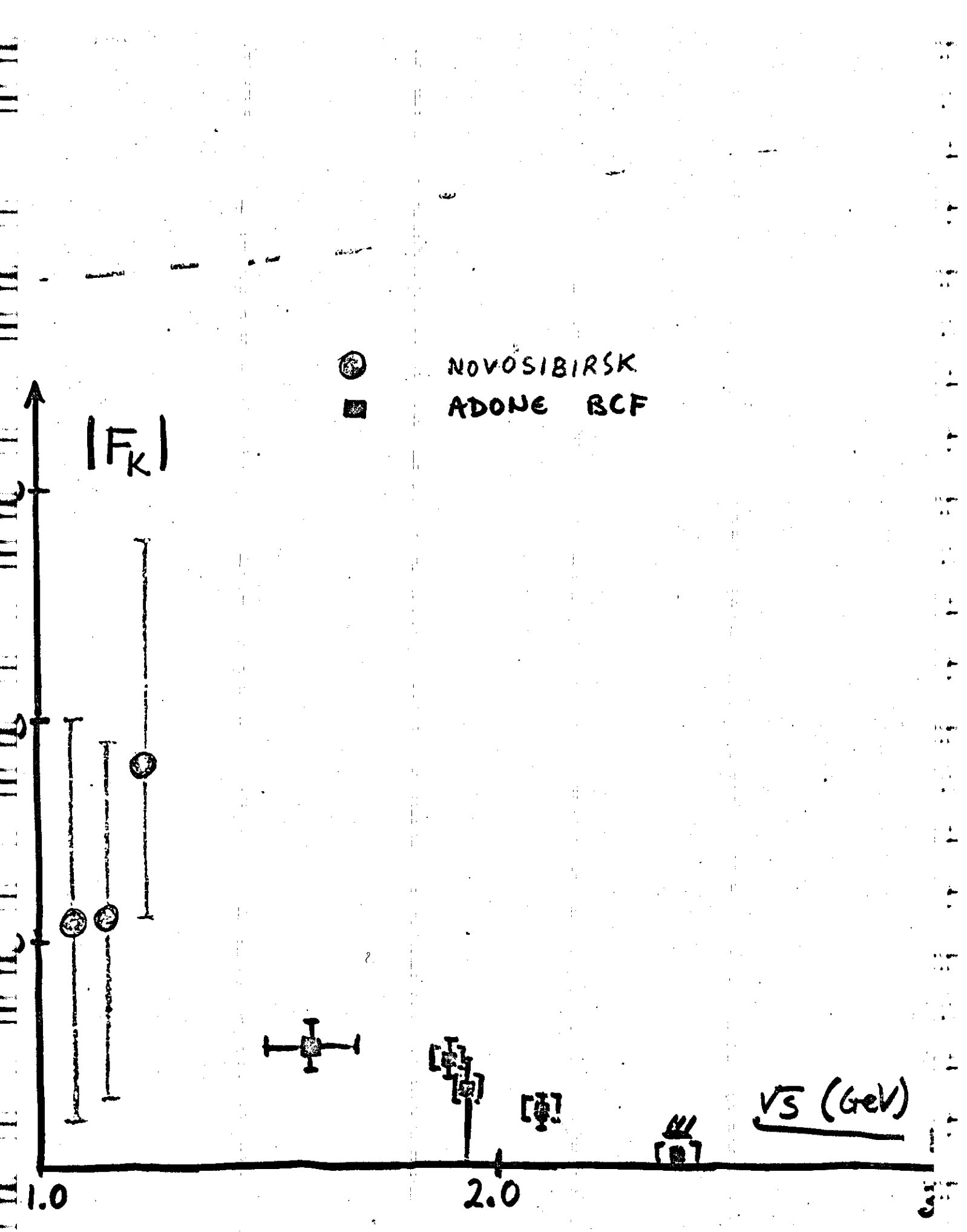
- <u>COMMENTS</u>:

  i) the cross sections are in the range <u>$10 \div 0{,}1$ nb</u> for both reactions;

  ii) the total analyzed number of events is:

~ 16	NOVOSIBIRSK
~ 110	BCF ADONE
~ 30	$\mu\pi$ ADONE


ACO
ADONE BCF
NOVOSIBIRSK.
ADONE μπ
Fπ|
ACO
NVSB
1,5
NOVSB
μπ
BCF
BCF
BCF
μπ
1,0
,5
ρ tail according to
Gounaris-Sakurai
BCF
BCF
BCF
BCF
2.0
3.0
√s (GeV)


NOVOSIBIRSK
ADONE BCF
$|F_K|$
1.0
2.0
$\sqrt{s}$ (GeV)

COMMENTS ON $|F_\pi|$ AND $|F_K|$ FOR $q^2 > 1\ (GeV/c)^2$:

- THE TAILS OF THE KNOWN VECTOR MESONS (ρ, ω, ϕ) CLEARLY AFFECT THE π AND K FORM FACTORS AT HIGH ENERGY.

- THE GOUNARIS-SAKURAI TAIL IS REPORTED AS A REASONABLE INDICATION OF THE IMPORTANCE OF THE ρ TAIL. DIFFERENT ESTIMATES OF THE KNOWN VECTOR MESON TAILS AT HIGHER ENERGIES MAY BE DONE [Renard - PM/73/3 - Montpellier: France (published in Phys. Lett.)
G. Bonneau + F. Martin - Nuovo Cim. 13A, 413 (73)]

- THIS UNCERTAINTY CLEARLY AFFECTS ANY POSSIBLE INTERPRETATION OF DISCREPANCIES BETWEEN THE EXPERIMENTAL DATA AND THE PREDICTIONS FOR THE TAILS.

- FOR INSTANCE THE $|F_\pi|$ EXPERIMENTAL POINT IN THE ENERGY REGION $1.2 \leq 2E \leq 1.4$ GeV LIE SYSTEMATICALLY ABOVE THE GOUNARIS-SAKURAI PREDICTION FOR THE ρ-TAIL - 35 obs. / 15 exp. G.-S. (BCF)

- THIS COULD INDICATE EITHER:
  i) THE EXISTENCE OF HIGHER VECTOR MESONS ρ',
  OR:
  ii) A MORE COMPLEX STRUCTURE OF THESE TAILS WITH INELASTIC EFFECTS FOLDED IN -

IT SEEMS, HOWEVER, THAT NEW POSSIBLE VECTOR MESONS (IF ANY) ARE NOT VERY STRONGLY COUPLED WITH THE $\pi\pi$ CHANNEL (WHICH IS THE ONE INVESTIGATED WITH THE PION FORM FACTOR).

IT COULD ALSO BE THAT THESE NEW VECTOR MESONS ARE NOT STRONGLY COUPLED TO THE PHOTON (WITH RESPECT TO THE ρ FOR INSTANCE)

THEREFORE THE "PION FORM FACTOR" IS GOING, WITH SCANTY STATISTICS, TO INFORM US ON A COMPLEX SITUATION CONCERNING THE HADRONIC NATURE OF THE PHOTON VIA $\pi\pi$ DECAYS OF 1^{--} STATES.

A COMPLEMENTARY APPROACH TO THE PROBLEM IS THE STUDY OF 1^{--} STATES VIA MORE FREQUENT DECAYS, THAT IS THE MEASUREMENT OF EXCLUSIVE MANY HADRON CHANNELS IN A EXCITATION CURVE TYPE OF STUDY.

PROTON FORM FACTOR FROM $e^+e^- \to p\bar{p}$

DATA HAVE BEEN TAKEN AT ADONE
[G. Di Giugno et al.
Lettere N. Cim. 2, 813 (1971)

AT $2E = 2.1$ GeV (kinetic energy of the proton ~ 100 MeV)

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{8s}\beta_p \left\{(1+\cos^2\theta)\,|G_M|^2 + \frac{4M_p^2}{s}\,\mathrm{sen}^2\theta\,|G_E|^2\right\}$$

($G_{M,E}$: Sachs form factors)

AT THRESHOLD ($s = 4M_p^2$) IT HAS TO BE
$G_E = G_M$

IF $G_E = G_M = G$ HOLDS TRUE AT $s = 4\times(1.05)^2\ \mathrm{GeV}^2$

$$\frac{d\sigma}{d\Omega} \simeq \frac{\alpha^2}{4s}\beta_p\,|G|^2$$

EXPERIMENTAL RESULT BASED ON
25 ± 6 WELL IDENTIFIED $p\bar{p}$ PAIRS

$$\sigma_T = (0,91 \pm 0,22)\ \mathrm{nb}$$

IF $G_E = G_M = G \Rightarrow$ $\boxed{|G| = 0.27 \pm 0.04}$

PROTON FORM FACTOR

- FURTHER MEASUREMENTS ARE IN PROGRESS AT ADONE

  [NAPOLI - PISA - FRASCATI COLLABORATION]

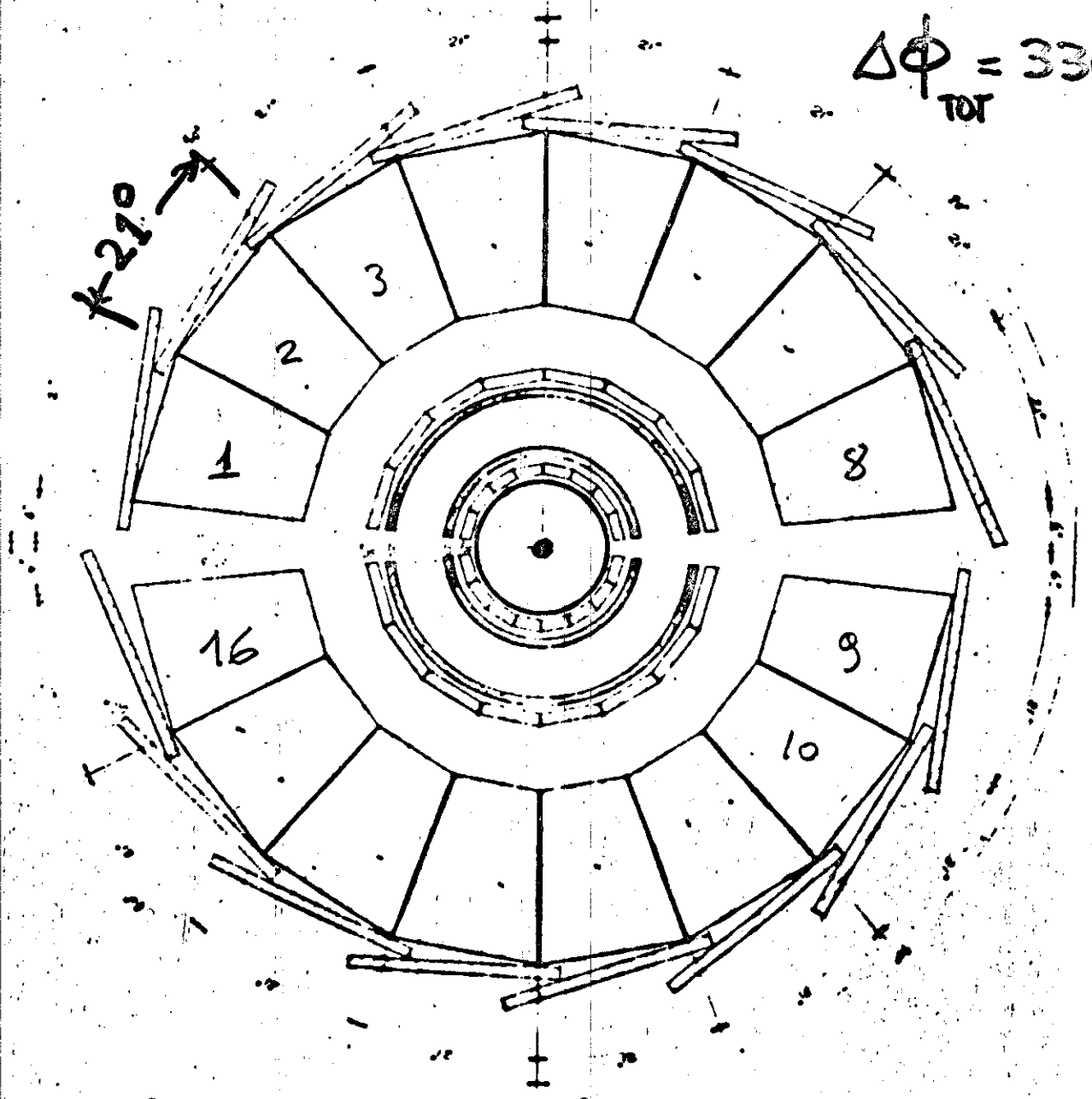
  WITH A NEW SET UP, AT LOWER ENERGIES [first experimental point at $2E = 2.0$ GeV] IN ORDER TO MEASURE THE THRESHOLD BEHAVIOUR OF $|G|$.

- THE GROUP IS RUNNING NOW AT ADONE WITH A TOTAL LUMINOSITY GOAL OF 500 nb^{-1} AT $2E = 2.0$ GeV ($\approx$ 10 weeks effective running time) [only a part of the set-up is active at the moment - It will be completed after this first data taking].

$e^+e^- \to B\bar{B}$

$30° < \theta < 150°$

$\Delta\phi_{TOT} = 330°$



4 HODOSCOPES (SPARK CHAMBERS MAGNETOSTRICTIVE READ-OUT)

FIG. 1

COUNTING RATE :

($2E = 2{,}1$ GeV

$e^+e^- \to p\bar{p}$

$\mathcal{L} \simeq 2 \cdot 10^{29}\ cm^{-2}\ s^{-1}$) $\to$ 0,4 events / hour

$\to L_D \sim 6$ events / day

t. e^+e^- → MANY HADRONS

A FUNDAMENTAL RESULT OF THE FIRST SERIES OF EXPERIMENTS PERFORMED AT ADONE IN THE PERIOD 1970-72 WAS THE DISCOVERY OF AN ABUNDANT PRODUCTION OF MANY HADRON STATES.

REFERENCES :

- PROC. XV H.E.P. INT. CONF. - KIEV (1970)
  G. Barbiellini et al. LNF-70/38 (1970)
  B. Bartoli et al. - - N.C. 70A, 615 (1970)
  R. Wilson final report
- PROC. INT. CONF. E.P.S. ON MESON RESONANCES Bologna 1971
  B. Borgia et al. (presented by M. Conversi)
  C. Bacci et al. (" " G. Salvini)
  V. Alles-Borelli et al " " A. Zichichi
- B. Bartoli et al. Phys. Letters 36B, 598 (1971)
- " " " " Phys. Rev. 6D, 2374 (1972)
- C. Bacci et al. Phys. Letters 38B, 551 (1972
- L.M. Kurdadze et al. Phys. Letters 42B, 515 (1972
- M. Grilli et al. Nuovo Cim. 13A, 593 (1973)
- F. Ceradini et al. Phys. Letters 47B, 80 (1973

PROC. XVI H.E.P. INT. CONF., Batavia. Ill (1972)
- V. Alles-Borelli et al
- F. Ceradini et al } see V. Silvestrini
- C. Bacci et al } invited talk.....

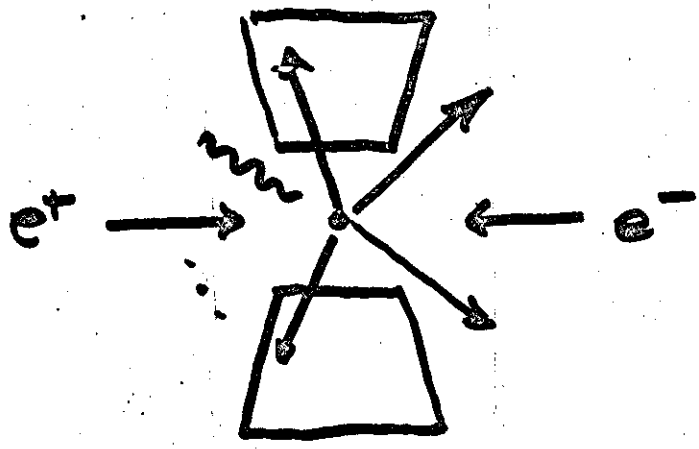
e^+e^- → MANY HADRONS

- FIRST GENERATION EXPERIMENTS NOT WELL SUITED TO FACE AN UNEXPECTED ABUNDANT MANY HADRONS PRODUCTION

∴ ONLY A VERY FEW PARTICULAR REACTION CHANNELS COULD BE IDENTIFIED AND ONLY GLOBAL (AND MODEL DEPENDENT) INFORMATION COULD BE ACHIEVED FOR THE MANY HADRONS PRODUCTION. (such as σ_T, $\langle n_{ch} \rangle$)

$e^+e^- \rightarrow$ MANY HADRONS

- SMALL SOLID ANGLE ($\Delta\Omega \simeq 1$ sr. at Adone) LETS AN IMPORTANT FRACTION OF THE PRODUCED PARTICLES TO ESCAPE DETECTION



POSSIBLE REACTIONS:

$e^+e^- \rightarrow$

$\pi^+\pi^-\pi^0$
$\pi^+\pi^-\pi^0\pi^0$
$\pi^+\pi^-\pi^+\pi^-$
$\pi^+\pi^-\pi^+\pi^-\pi^0$
⋮

- THE LACK OF KNOWLEDGE OF THE MOMENTA DOES NOT ALLOW TO ESTIMATE WHAT IS MISSING.

- SOME ASSUMPTIONS NEEDED IN ORDER TO EVALUATE THE MULTIPLICITIES AND CONTENT OF THE VARIOUS REACTION CHANNELS AND TO CALCULATE CROSS SECTIONS.

$e^+e^- \rightarrow$ MANY HADRONS

EVIDENCE FOR :

1. HADRONIC NATURE OF THE FINAL STATE PARTICLES
   (pulse height analysis, non showering behaviour, nuclear interactions etc)
   SMALL ($\lesssim 10\%$) CONTAMINATION FROM μ'S OR e's POSSIBLE. (see BCF calibration data E.P.S. Bologna 1971)
2. ONE PHOTON ANNIHILATION MECHANISM
   (2γ processes ruled out by kinematics and σ as measured)

- π vs K DISTINCTION IMPOSSIBLE
- FINAL STATE PARTICLES CORRELATIONS UNKNOWN (IN GENERAL)

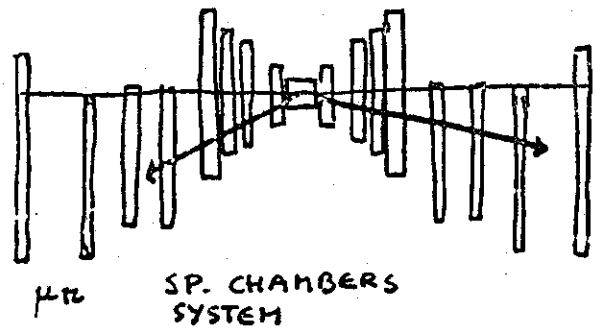
COMMON ASSUMPTIONS IN THE ANALYSES :
- K's NEGLECTED
- IPS MOMENTUM DISTRIBUTION ALMOST ALWAYS ASSUMED
- MAXIMUM π'S MULTIPLICITY FIXED "A PRIORI" (8-10 DEPENDING ON THE ENERGY)

$e^+e^- \to$ MANY HADRONS (2E < 3 GeV)
TOTAL CROSS SECTIONS

SEVERAL ANALYSES HAVE BEEN PERFORMED

π GROUP [Recent References :
- F. Ceradini et al. - Phys. Lett. 47B, 80(
- More recent analysis . in publication

ANALYSIS :
- AT LEAST 2 CH. PARTICLES IN THE OPPOSITE TELESCOPES;



- PHOTONS NEGLECTED (trigger and analysis
- $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ CHANNEL ISOLATED (knowing all the angles of 4-prongs events, a "0 C π fit" allows subtraction of higher multiplicity channels)
- $e^+e^- \to \pi^+\pi^-$ + neutrals CHANNEL ISOLATE (from the 2-detected prongs events since the ratio between the probability of detecting 2 prongs and the prob. for 3 or 4 prongs is al independent on the particular produced channel)

π ANALYSIS :

- EFFICIENCIES CALCULATED UNDER VARIOUS EXTREME HYPOTHESES (e^+e^-, $\omega\pi^0$, IPS, $p\bar{p}$ RATIOS FOR THE REACTION CHANNELS, ONLY EVEN NUMBER OF PIONS PRODUCED, etc.)

- σ_T ($e^+e^- \to$ many hadrons) CALCULATED WITH THE ABOVE EFFICIENCIES, AVERAGE VALUES CONSIDERED AND SYSTEMATIC ERRORS ASSIGNED AS FROM THE DIFFERENT EFFICIENCIES.

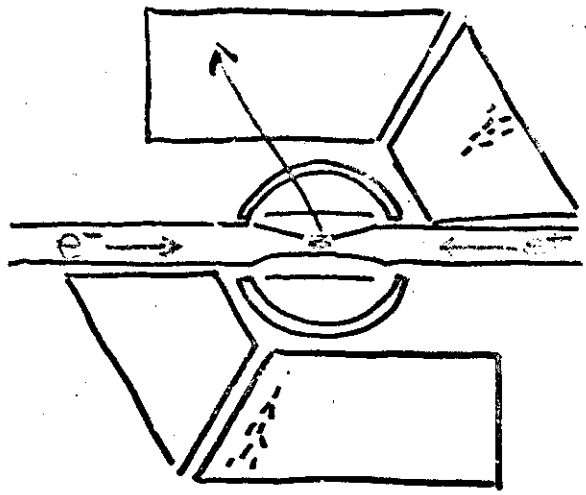
- CAUTION : $\mu\pi$ TRIGGER REQUIREMENT (2 ch particles in opposite telescopes) makes channels such as $\omega\pi^0$, practically UNDETECTABLE at high energy ($2E > 1.6$ GeV)

  $\therefore$ σ_T^{meas} cannot take into account possible contributions from such channels.

γ GROUP [Recent Ref. C. Bacci et al. Phys. Lett. 44B, 533 (73)]

- TRIGGER REQUIREMENTS : 3 OBJECTS AT LEAST ONE CHARGED

$\gamma\gamma$ GROUP at least 3 out of 4 telescopes firing :

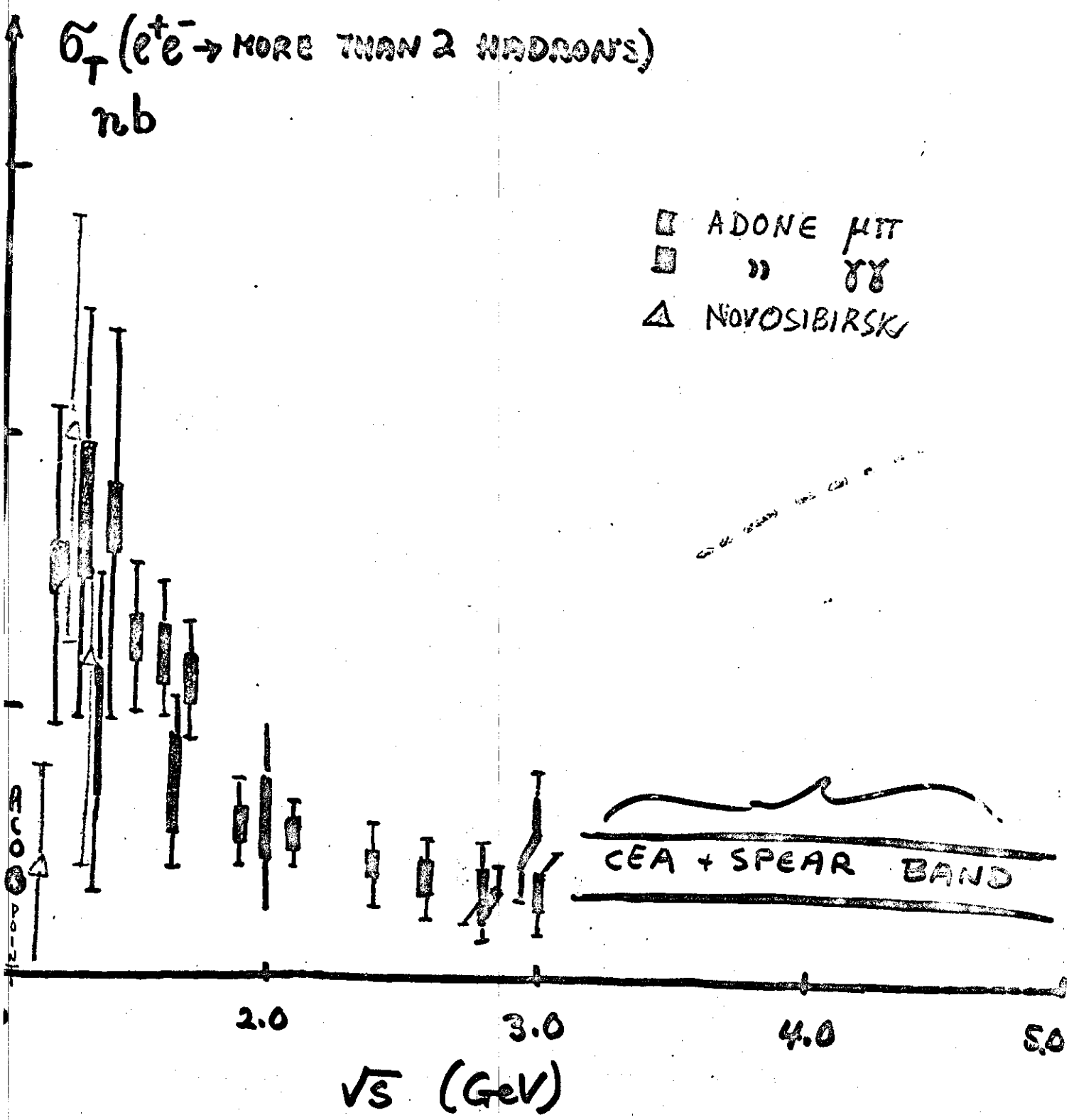


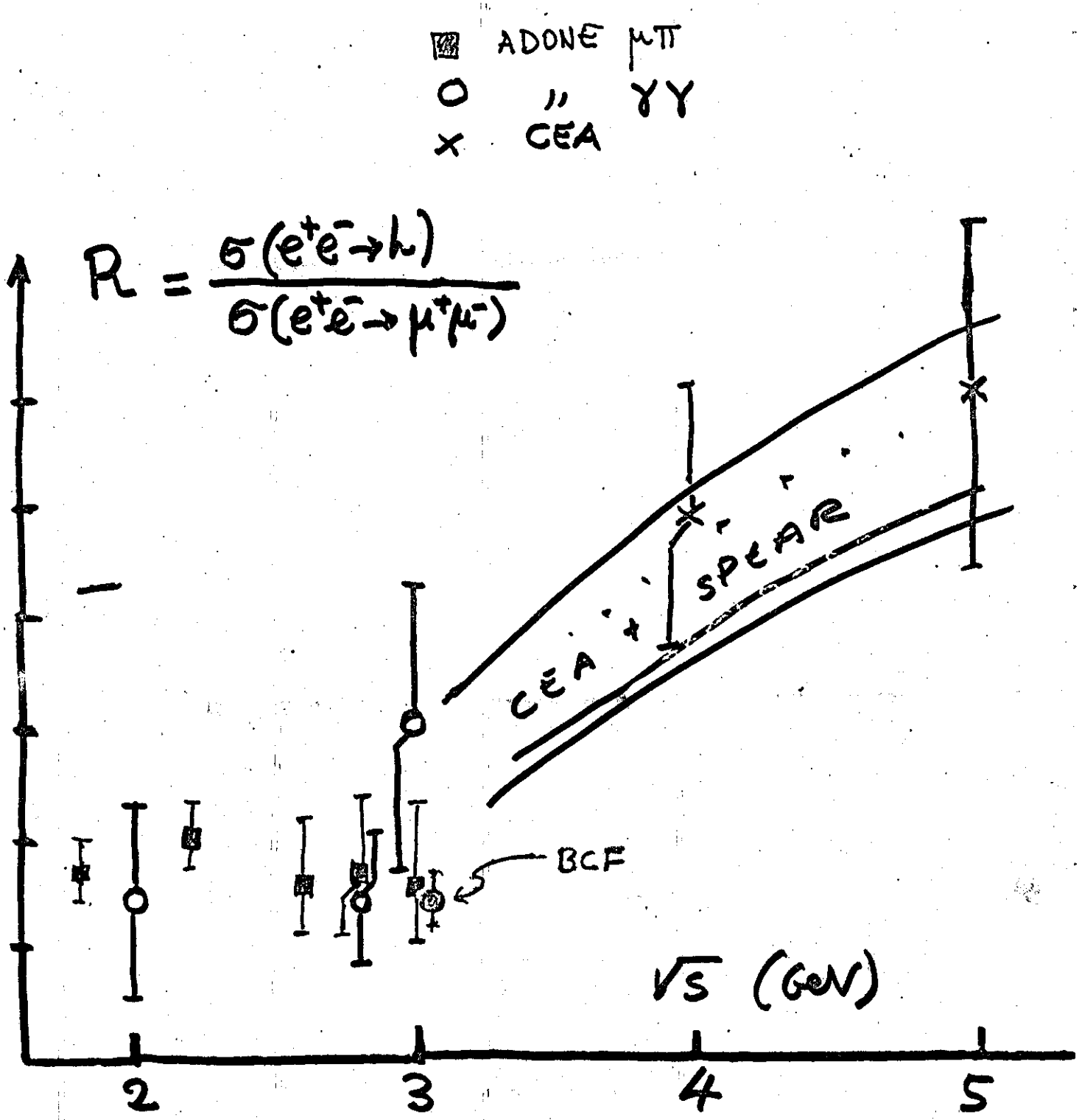
- THE SYSTEM

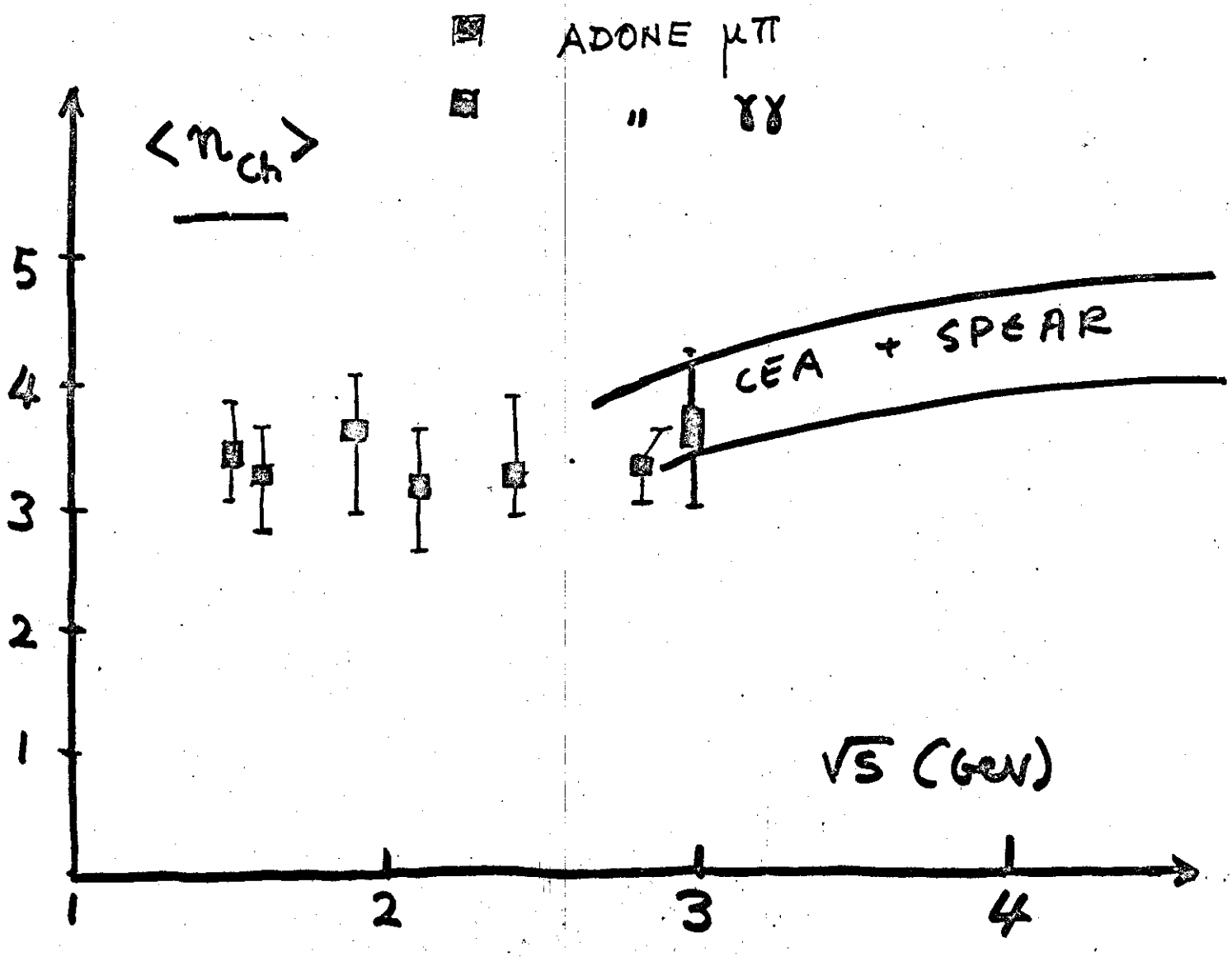
$$N_c = L \sum_i \varepsilon_{ic} \sigma_i$$

HAS BEEN SOLVED (where N_c is the number of detected events in a configuration C, σ_i is the cross section for producing i pions, and ε_{ic} are the relative detection efficiencies)
$\sigma_i > 0$ REQUIRED

- POOR STATISTICS MAKES THE PARTIAL CROSS SECTIONS σ_i'S NOT WELL DETERMINED WHEREAS $\sigma_T = \sum \sigma_i$ TURNS OUT TO BE STABLE AND RELIABLE.


$\sigma_T (e^+e^- \to$ MORE THAN 2 HADRONS)
nb
ADONE μπ
» γγ
NOVOSIBIRSK
CEA + SPEAR BAND
2.0
3.0
4.0
5.0
√s (GeV)


ADONE μπ
" γγ
CEA
$R = \frac{\sigma(e^+e^- \to h)}{\sigma(e^+e^- \to \mu^+\mu^-)}$
CEA + SPEAR
BCF
√s (GeV)
2
3
4
5

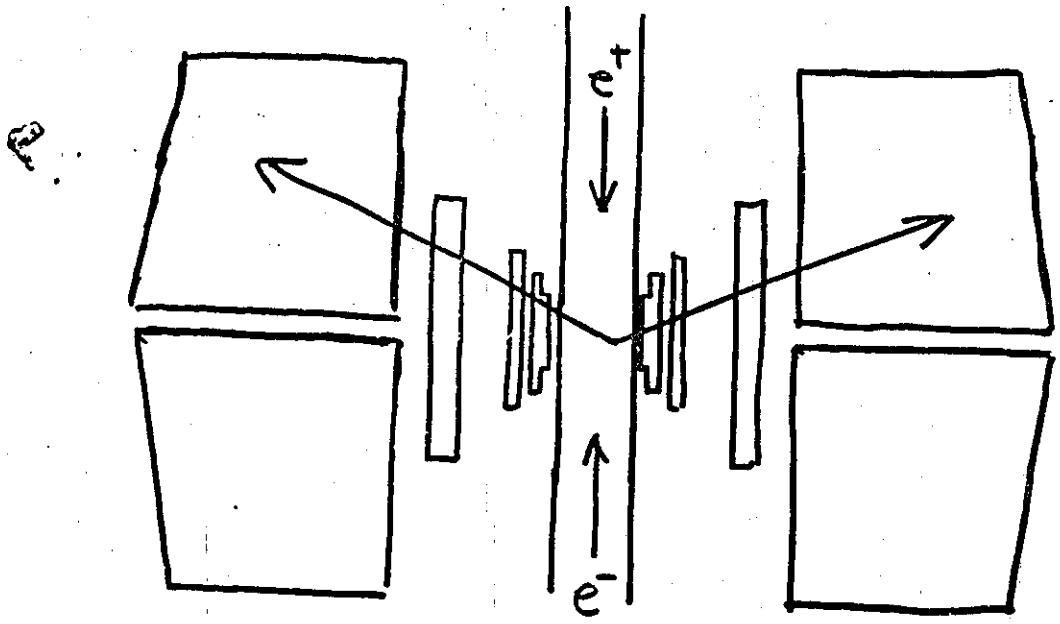

ADONE μπ
" γγ
$\langle n_{ch} \rangle$
CEA + SPEAR
5
4
3
2
1
$\sqrt{s}$ (GeV)
1
2
3
4

$e^+e^- \rightarrow$ MANY HADRONS ($2E < 3$ GeV)

σ_T

BCF GROUP : References : V. Alles-Borelli et al.
- XVI INT. CONF. ON H.E.P. BATAVIA, ILL. (1972)
- INTER. DISCUSSION MEETING ON e^+e^- ANNIHILATION, BIELEFELD, GERM. (1973)

SET-UP : $45° < \theta < 135°$ $\quad \frac{\Delta\Omega}{4\pi} \approx 20\%$



BCF ANALYSIS :
- MULTIPLICITIES OF THE HADRONIC FINAL STATE DERIVED FROM $p\bar{p}$ DATA AT REST. (phase-space corrections take into account different energies) AND IN AGREEMENT WITH THE EXPERIMENTAL DATA ON DETECTED CONFIGURATIONS.
-

BCF ANALYSIS

- $1.2 < \sqrt{s} < 1.7$ GeV
  $100 < \sigma_T < 190$ nb
  } higher than $\mu\pi + \gamma\sigma$

- $2 < \sqrt{s} < 3$ GeV
  $1 < \sigma_T < 40$ nb
  }

- $\sigma(e^+e^- \to h) = a s^n$ FIT

  GIVES $n = -(1.62 \pm 0.08)$

- $R: \dfrac{\sigma(e^+e^- \to h)}{\sigma(e^+e^- \to \mu^+\mu^-)} = (1.35 \pm 0.20)$

  AT $\sqrt{s} = 3$ GeV

5. e^+e^- → MANY HADRONS

EXCLUSIVE CHANNELS

- THE REACTION $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$

$\mu\pi$: G. Barbarino et al. Lett. Nuovo Cim. 3, 19

F. Covadini et al. Phys. Lett. 43B, 34

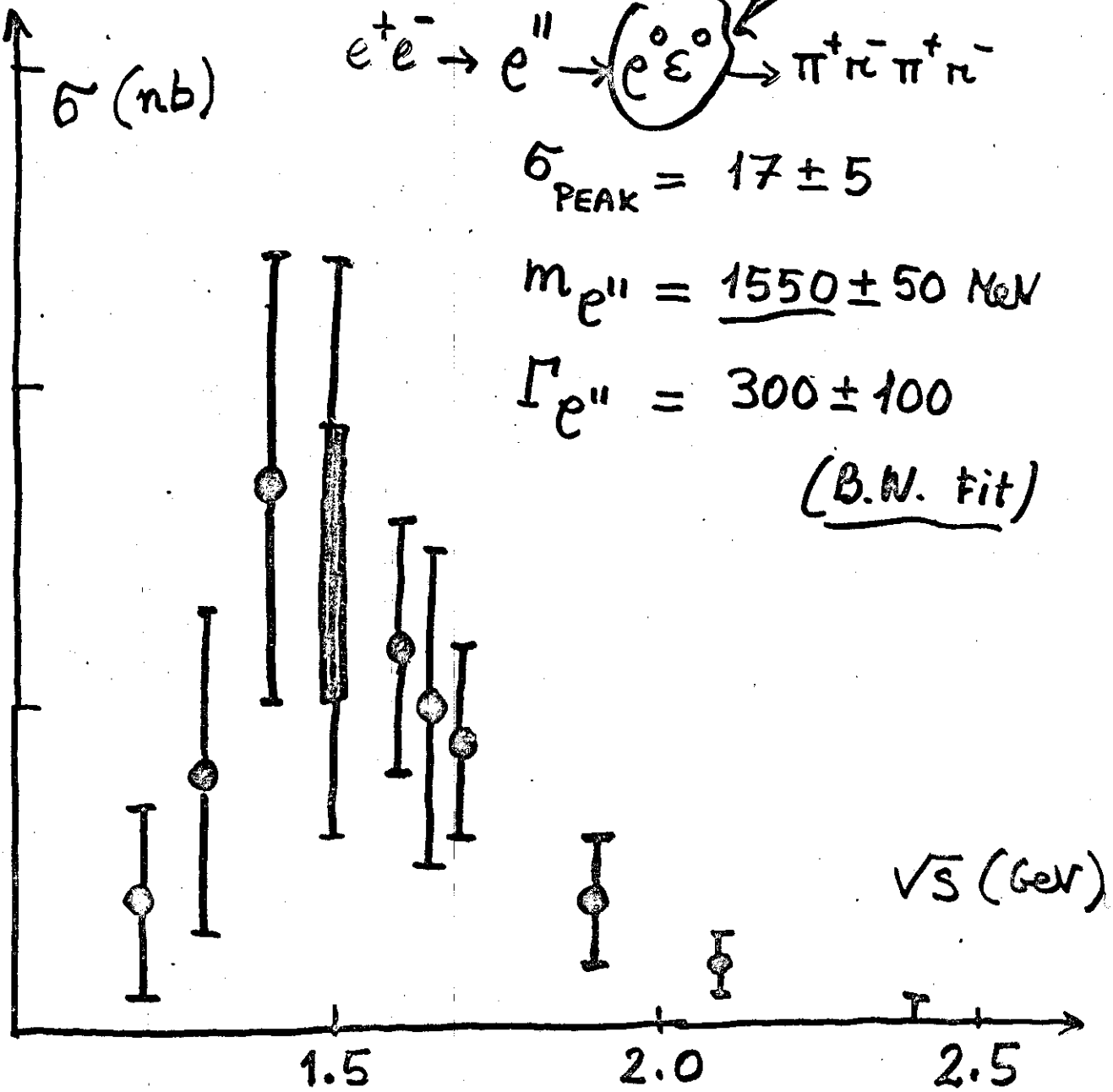
HAS BEEN ISOLATED ("0C" FIT ON THE MEASURED ANGLES OF THE 4 DETECTED PARTICLES).

- ONCE THE BKG FROM HIGHER MULTIPLICITY CHANNELS IS SUBTRACTED, THE FOLLOWING EVENTS REMAIN:

$\sqrt{s}$ (GeV)	L (nb^{-1})	EVENTS $e^+e^- \to 4\pi^\pm$
1.2	5.1	0
1.3	5.8	2
1.4	11.0	6
1.5	27.0	10
1.6	40.0	12
1.65	19.5	6
1.7	40.0	11
1.9	43.5	4
2.1	163.0	6
2.4	49.7	1

- THE SCATTER PLOT ANALYSIS OF $M(\pi_1,\pi_2)$ VS. THE INVARIANT MASS OF THE REMAING PAIR π_3,π_4, AND THE CONFIGURATION DISTRIBUTION IN THE 2 TELESCOPES OF THE SET-UP SUGGEST THE CHAIN: $e^+e^- \to e''(1,6) \to e^\circ e^\circ$

e'' : $J^{PC} = 1^{--}$; $I^G = 1^+$



$e^+e^- \to e'' \to (\rho^0\varepsilon^0) \to \pi^+\pi^-\pi^+\pi^-$

$\sigma_{PEAK} = 17 \pm 5$

$m_{e''} = \underline{1550} \pm 50$ MeV

$\Gamma_{e''} = 300 \pm 100$

(B.N. fit)

- IF THE $e'' \to \rho^0\varepsilon^0$ IS THE DOMINANT DECAY CHANNEL, THEN $(e'' \to \pi^+\pi^-\pi^+\pi^-) \simeq 2\,(e'' \to \underline{\pi^+\pi^-\pi^0\pi^0})$ AND THE e'' COUPLING CONSTANT CAN BE ESTIMATED TO BE :

$$\frac{f^2_{e''}}{4\pi} = 18 \pm 5$$

PRESENT KNOWLEDGE ABOUT $\varrho''(1,6)$

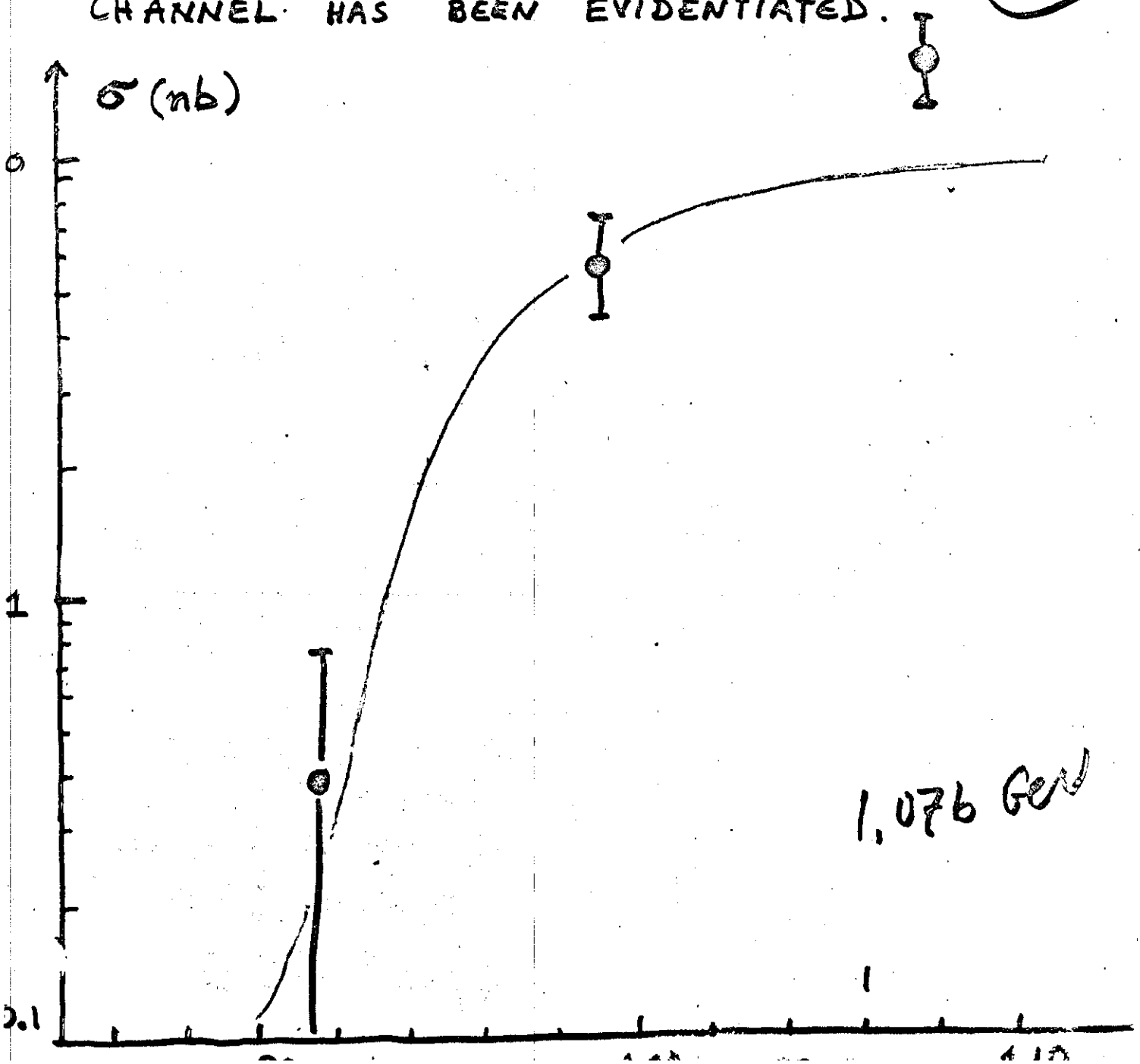
REACTION	J^P	I^G	M	Γ
$e^+e^- \to \varrho'\varepsilon$	1^-	1^+	1550	300 ←
$\gamma p \to \varrho^0\pi\pi p$ γ POL. SLAC	1^-	1^+	1500	~600
	$\frac{\Gamma(\varrho''\to\pi\pi)}{\Gamma(\varrho''\to all)} < 0.2$			
$\pi^- p \to \pi^+\pi^-\pi^- n$ $\pi\pi$ PHASE SHIFT ANALYSIS CERN MUN.	1^0	1^0	1590 ± 20	180 ± 50
	$\frac{\Gamma(\varrho''\to\pi^+\pi^-)}{\Gamma(\varrho''\to all)} = .25 \pm .02$			

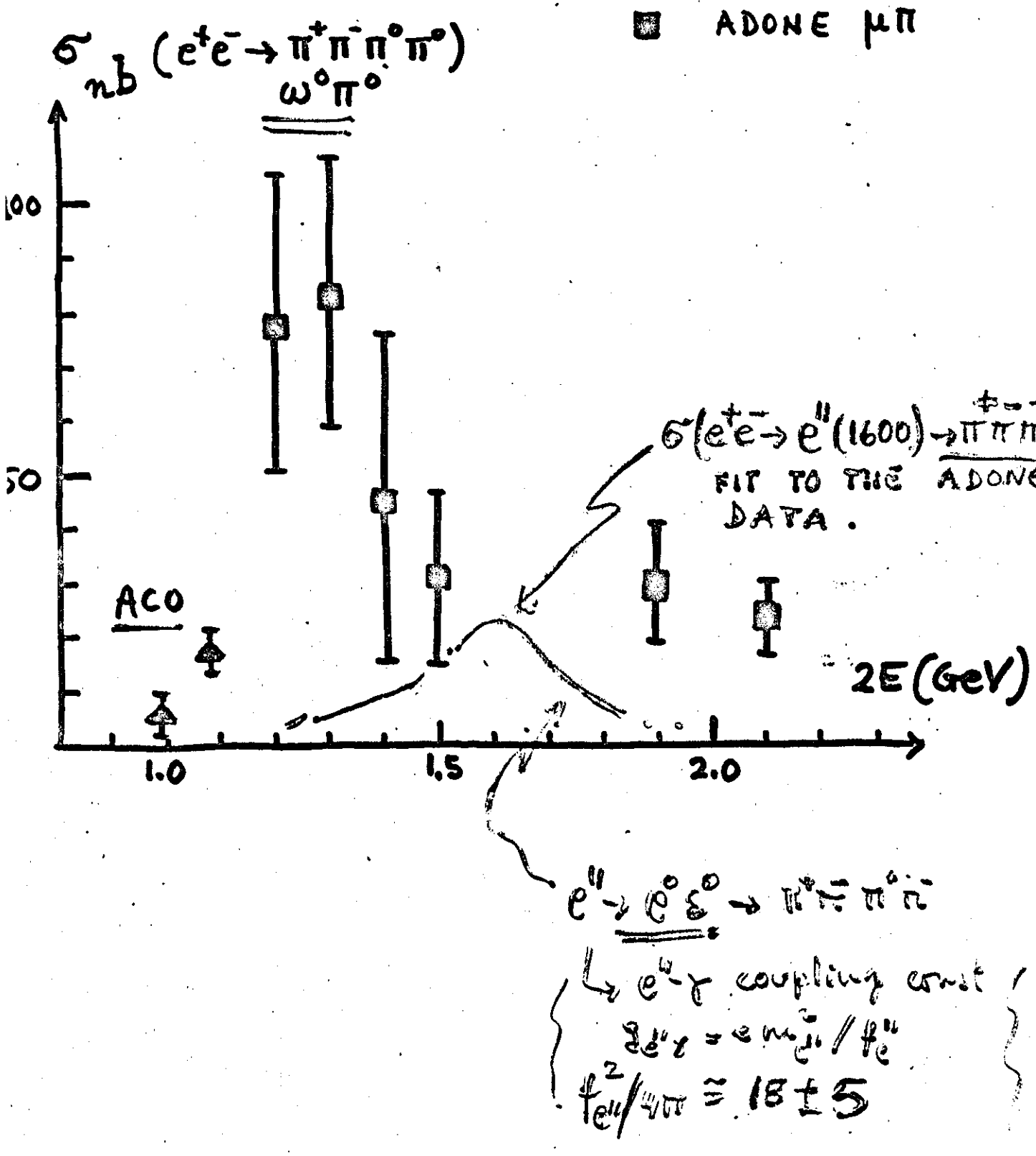
$e^+e^- \to \pi^+\pi^-\pi^0\pi^0$

- THE REACTION $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$ HAS BEEN CLEARY DETECTED AT ACO

[G. Cosme et al. - 1973 Bonn Conference]

WHERE A THRESHOLD EFFECT FOR THE $\omega\pi^0$ CHANNEL HAS BEEN EVIDENTIATED.




σ nb (e⁺e⁻ → π⁺π⁻π°π°)
ω°π°
ADONE μπ
100
50
ACO
σ(e⁺e⁻ → e''(1600) → π⁺π⁻π⁺π⁻)
FIT TO THE ADONE DATA.
2E (GeV)
1.0
1.5
2.0
e'' → e°ε° → π⁺π⁻π°π°
↳ e^ω-γ coupling const.
g e''γ = e m²_ω / f_e''
f²_e''/4π ≅ 18 ± 5

$e^+e^- \to \pi^+\pi^-\pi^0\pi^0$

AT ADONE ($\mu\pi$) GROUP SUCCEDED IN ISOLATING THE EVENTS GENERATED BY REACTIONS IN WHICH ONLY 2 CHARGED PIONS WERE PRODUCED

(the subtraction of the background due to channels with at least 4 charged particles turns out to be fairly model independent) $e^+e^- \to \pi^+\pi^-$ + any. mom.

THE CONTRIBUTIONS FROM

$e^+e^- \to \pi^+\pi^-\pi^0$

$e^+e^- \to \pi^+\pi^- 3\pi^0$

ARE NEGLIGIBLE

1.6 GeV

THE CONTRIBUTION FROM $\rho'' \to \pi^+\pi^-\pi^0\pi^0$ IS ESTIMATED FROM THE $e^+e^- \to \rho'' \to \pi^+\pi^-\pi^+\pi^-$ POINTS (AND $\rho'' \to \rho^0\varepsilon^0$ ASSUMED TRUE) AND SUBTRACTED.

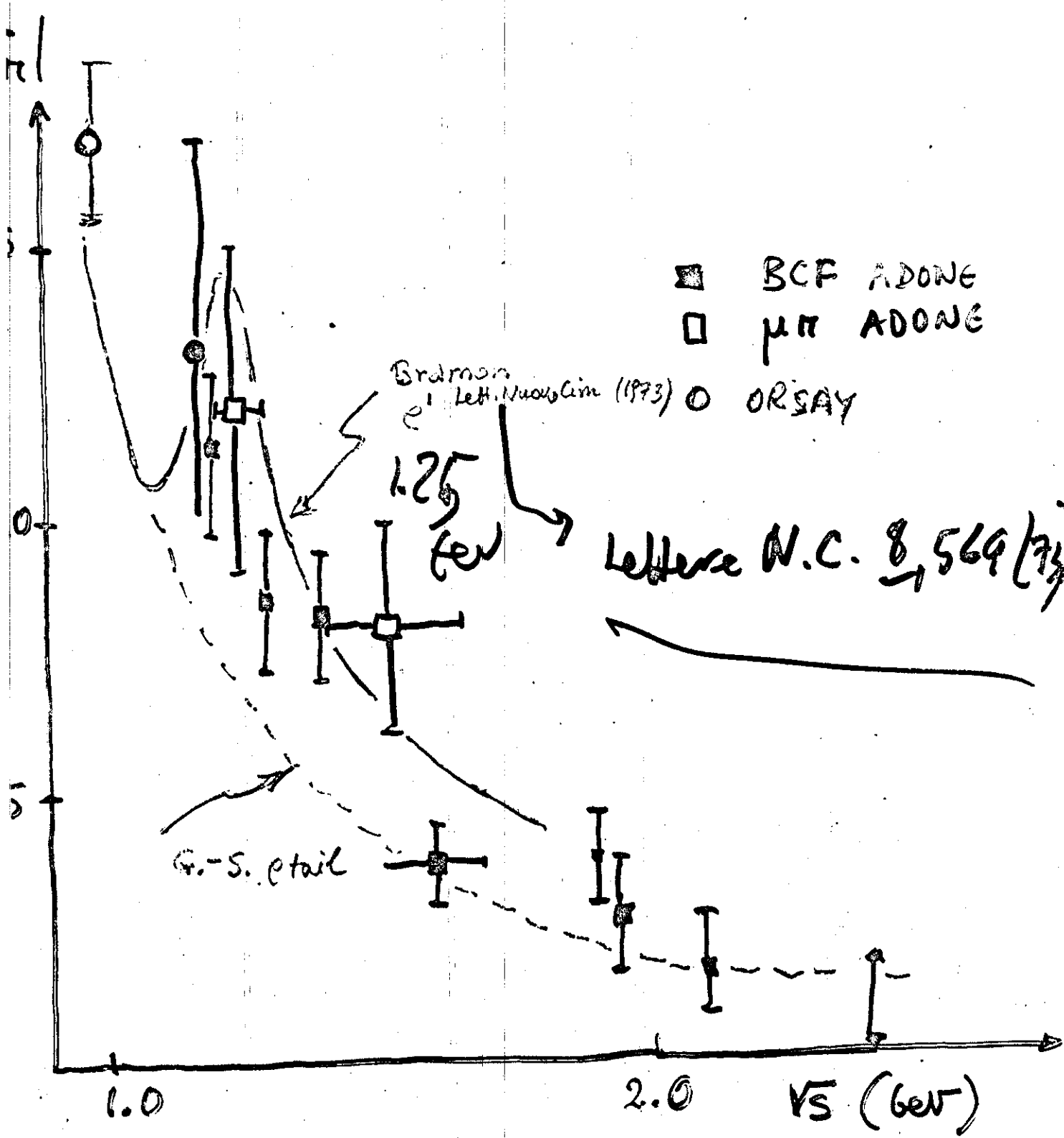
THE RESIDUAL 2-PRONGS EVENTS HAVE BEEN TREATED AS IF THE DOMINANT CHANNEL IS $\omega^0\pi^0$ IN THE ENERGY REGION 1.2 - 1.4 GeV (as suggested by the ACO results at 1.076 GeV).

[1.2 ÷ 1,5) GeV

THE CROSS SECTION $\sigma_{e^+e^-\to\pi^+\pi^-\text{neutral}}$ SO OBTAINED (not very different if IPS is used instead of $\omega^0\pi^0$) IS MUCH HIGHER (~ 70 nb) AT 1.2-1.3 GeV THAN THE CORRESPONDING ACO VALUE (17 nb) AT 1.076 GeV.

THIS CONCLUSION SEEMS TO HOLD IN SPITE OF THE SCANTY STATISTICS AND OF THE CLEAR LIMITATIONS OF THE ANALYSIS.

IS THIS AN INDICATION OF THE PRESENCE OF THE $\rho'(1250) \to \omega^0\pi^0$??


BCF ADONE
μπ ADONE
Bramon et al. Lett. Nuovo Cim (1973)
ORSAY
1.25 GeV
Lettere N.C. 8, 569 (73)
G.-S. tail
1.0
2.0
√s (GeV)

e^+e^- → MANY HADRONS

HADKA

- IN DEC. 1973 A MULTIWIRE PROPORTION CHAMBER CILINDRICAL SET-UP HAS STARTED TAKING DATA

- IT CAME FROM DESY, WHERE IT WENT BACK AFTER HAVING COLLECTED DATA AT $2E = 1.6$ GeV AND $2E = 1.95$ GeV ON THE REACTION: e^+e^- → many hadrons

- AUTHORS:

H. Mehrgardt	Desy	
P. Waloschek	"	
H. Willutzki	"	
G. Winter	"	
E. Iarocci	Frascati	

- EXPERIMENTAL ARRANGMENT

$$\theta_{min} = 23^\circ$$

$$\frac{\Delta\Omega}{4\pi} \simeq 80\%$$

- SOFT TRIGGER REQUIREMENTS: at least 2 charged particles in L (& configuration) 40 MeV minimum kin. energy.

DAXIAL TO
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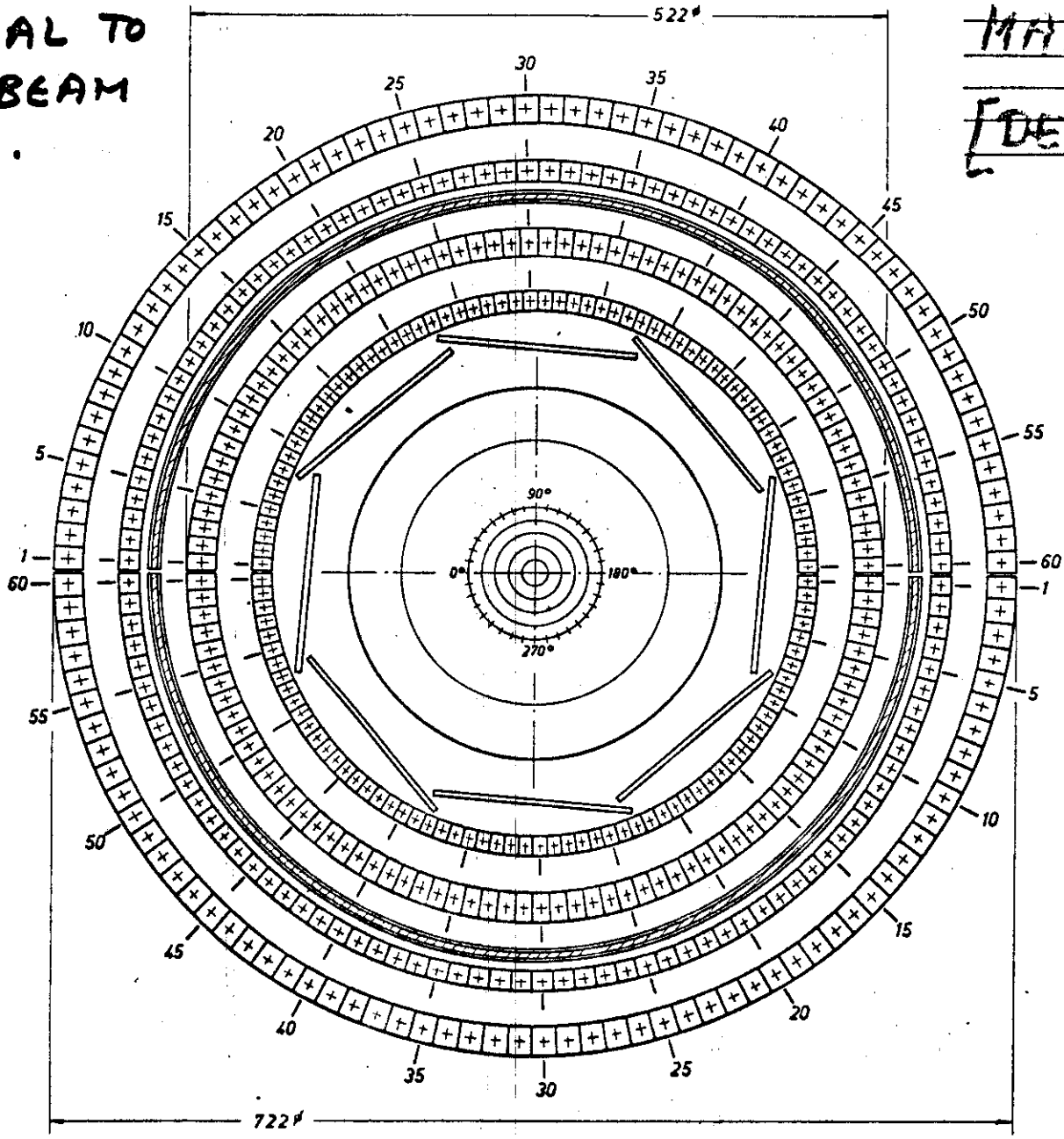
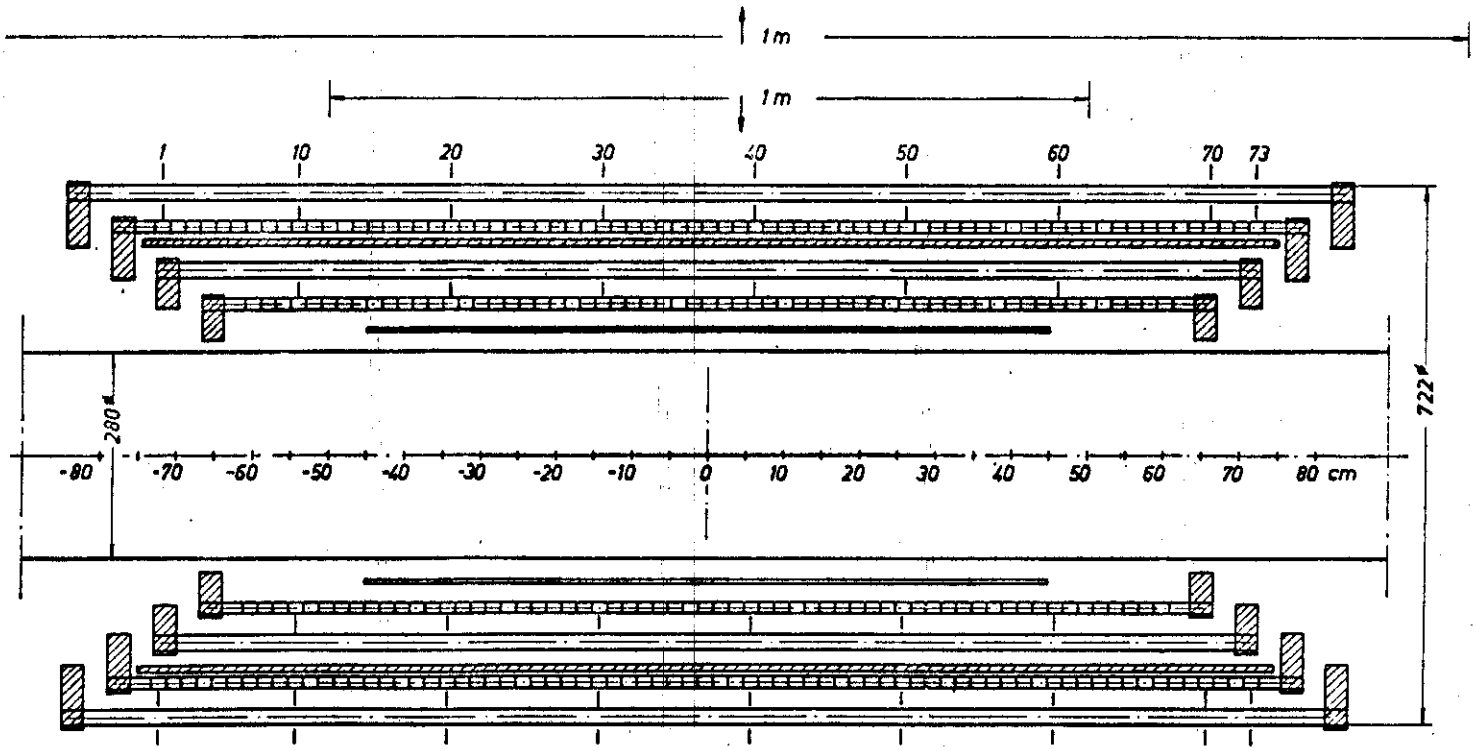
MADA

[illegible]





MΔDKA

Concl.:

a) 2×800 MeV:

(1) $\sigma_{\pi^+\pi^-\pi^+\pi^-} = (18.7 \pm 5.5)$ nb (incl 20% monitor)

(2) $\sigma_{\pi^+\pi^-\pi^0\pi^0} = (20 \pm 10)$ nb

(3) $\sigma_{\pi^+\pi^-\pi^+\pi^-\pi^0} = (6 \pm 4)$ nb

$\sigma_{\pi^+\pi^-\pi^0\pi^0\pi^0} < 2$ nb

$\sigma_{6\pi} < 2$ nb

Rem: $\sigma_{\pi^+\pi^-\pi^0}$ is not detected with enough acceptance values between 0 and 40 nb as comp.

b) 2×980 MeV: calculations still in progress

(1) $\sigma_{tot} - \sigma_{\pi^+\pi^-\pi^0} \approx (16 \pm 5)$ nb > 4.5 nb seen

$\sigma_{\pi^0+X} \sim 10$ nb > 2 nb seen

seen cross sections, fit missing: (strong correlations)

$\sigma_{\pi^+\pi^-\pi^0\pi^0}$	~ > 6 nb
$\sigma_{\pi^+\pi^-\pi^+\pi^-}$	~ 4 nb
$\sigma_{\pi^+\pi^-\pi^+\pi^-\pi^0}$	~ 1 nb
$\sigma_{\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-}$	~ 2 nb
$\sigma_{\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0}$	~ > 2 nb

all others are small ($\pi^+\pi^-\pi^0$ assumed (5 ± 3) nb)

c) - prop. ch, 4π - Detector works around ADONE pipe

- Selection logic works (Backgr ≈ good events)

- harder trigger (T_π) needed

PRESENT SITUATION AT ADONE

REMARKS:

FIRST GENERATION OF EXPERIMENTS ⇒ AT ADONE

INTERESTING RESULTS in spite of: APPARATA RATHER INADEQUATE TO FACE THE ABUNDANT MULTI-HADRON PRODUCTION (ΔΩ, no momentum analysis, π/K discrim. etc.)

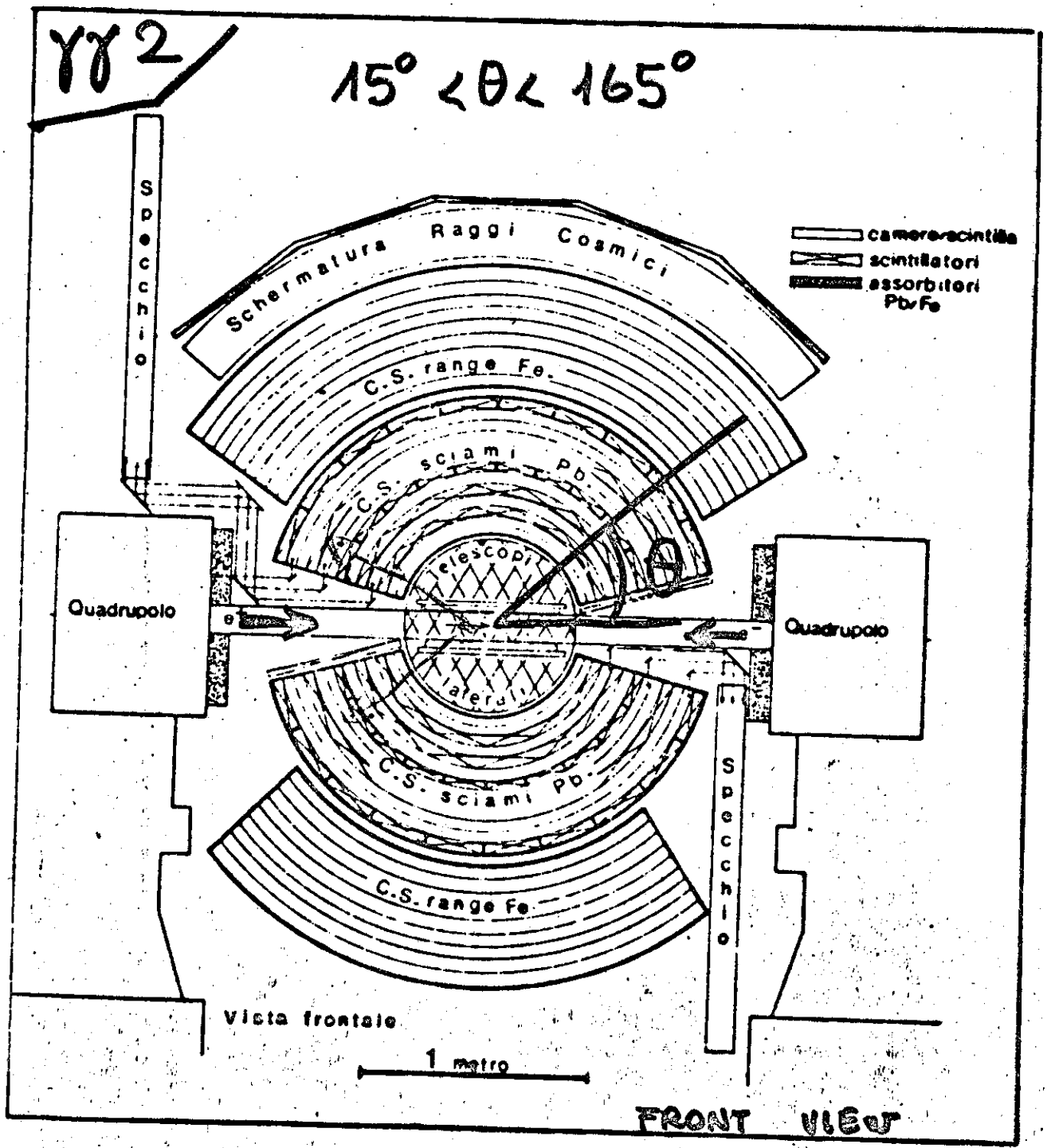
NEXT STEPS NEEDED TO: ⇒

- IDENTIFY SEPARATE REACTION CHANNELS
- GIVE RELATIVE RATES AMONG CHANNELS
- ESTABLISH CORRELATIONS
- MULTIPLICITIES
- etc.

∴ SECOND GENERATION EXPERIMENTS

γγ2

$15° < \theta < 165°$



γγ2

FIG. 1

$\left(\frac{\Delta\Omega}{4\pi}\right)_{TRIGGER} \approx 75\%$

SL. 3,4

MEA:

$B = 4{,}5$ KGAUSS
DIAMETER $= 2\,m$
HEIGHT $= 2\,m$
$(\Delta\Omega/4\pi)_{CH.AN.} \simeq 40\%$
$(\Delta\Omega/4\pi)_{\gamma} \simeq 27\%$

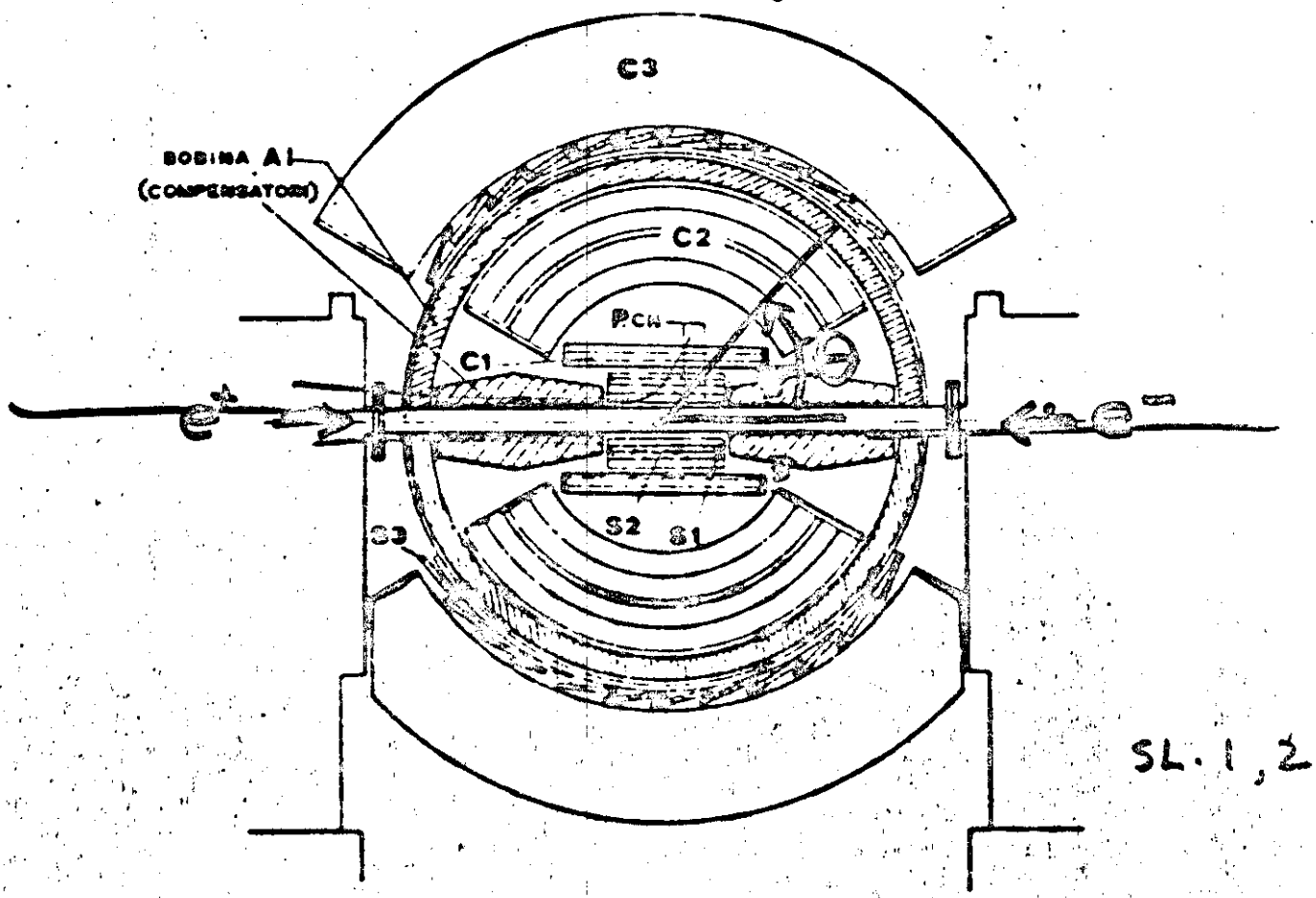


FIG. 1 - Sezione del dispositivo MEA con campo magnetico trasversale ai fasci. - C3: camere a scintilla di ferro; S3, S2, S1: scintillatori; C2: camere a scintilla a larga gap; C1: camere a

$30^\circ < \theta < 150^\circ$

$\frac{\Delta p}{p} = 2\%$ AT $p = 1$ GeV/c