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IC/76/79
INTERNAL REPORT
(Limited distribution)

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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 LEPTON INTERACTIONS AND NEW PARTICLES

6 - 9 July 1976

P A R T I I

(Contributions)

MIRAMARE - TRIESTE

July 1976

e^+e^- PHYSICS AT FRASCATI

E. Iarocci

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RECENT RESULTS at the FRASCATI e^+e^- STORAGE RING (ADONE)

TOPICS:

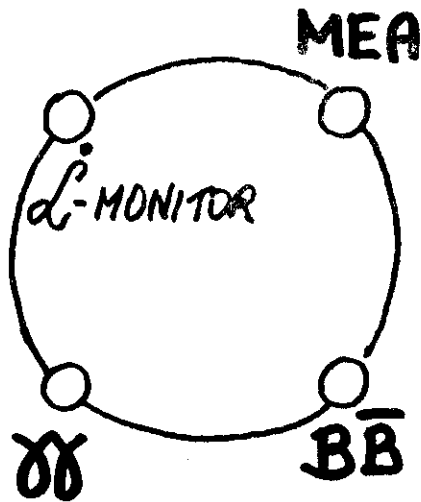
1. MACHINE and EXPERIMENTAL. SET-UP
2. RESULTS on the J/ψ (3.1 GeV) PARTICLE
3. SEARCH for J/ψ -LIKE RESONANCES
in the MASS REGION 2.5 - 3.0 GeV
4. TOTAL CROSS SECTION for $e^+e^- \rightarrow \text{hadrons}$
in the TOTAL C.M. ENERGY REGION $W=1.9-3.1$ GeV
5. FUTURE DEVELOPMENTS

ADONE PERFORMANCES

NATURAL W RANGE : 1.2 - 3.0 GeV

FORCED to the LIMIT to REACH the T/4

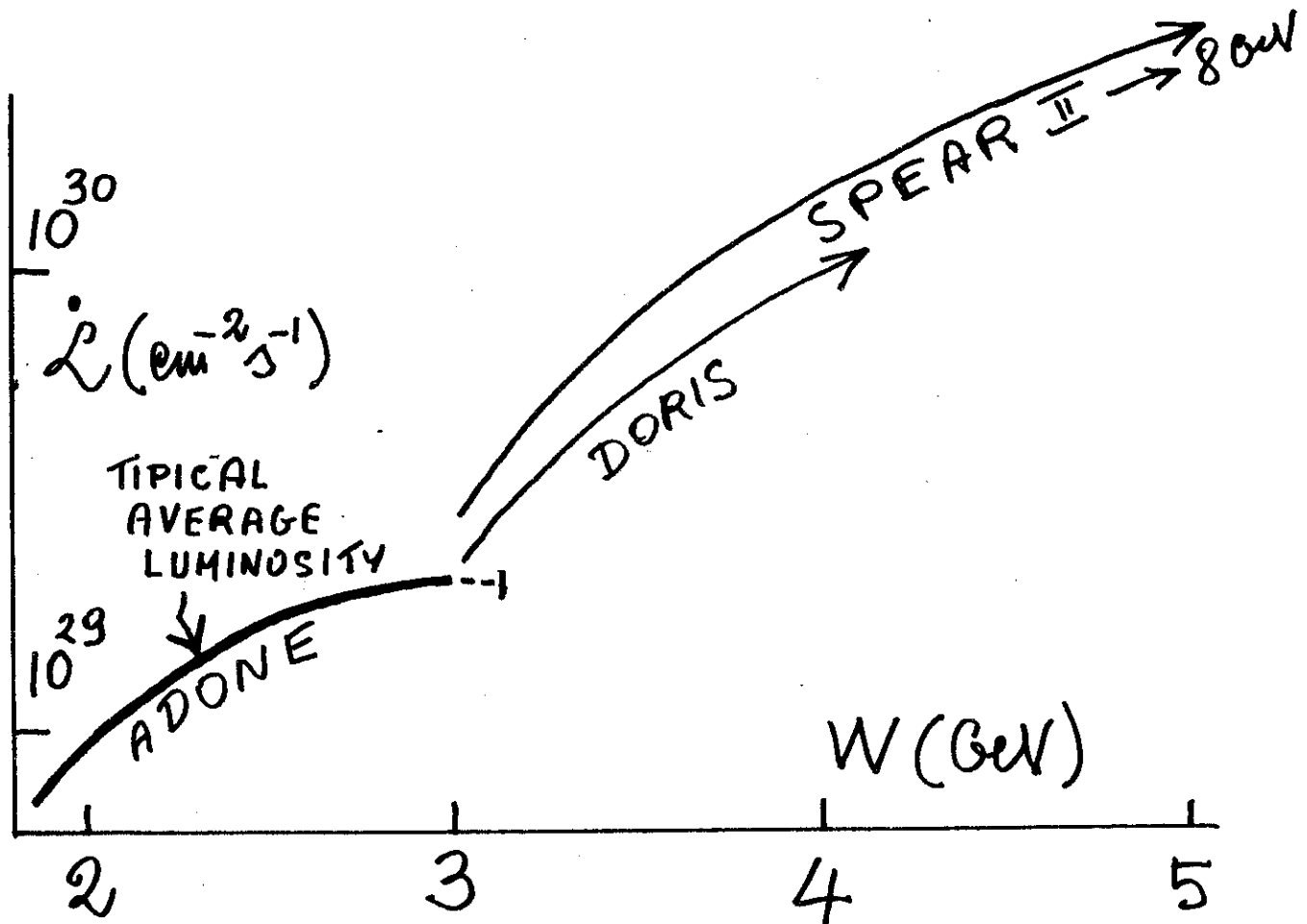
4 INTERACTION REGIONS - 3 EXPERIMENTS RUNNING:



BB GROUP $\equiv$ FRASCATI - NAPOLI - PISA
- ROMA - STONY BROOK coll.

xx GROUP $\equiv$ FRASCATI - ROMA coll.

MEA GROUP $\equiv$ FRASCATI - NAPOLI -
- PADOVA - ROMA coll.



LIST of AUTHORS

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XX

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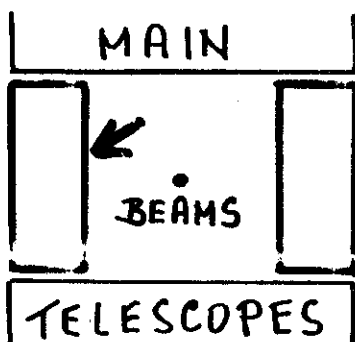
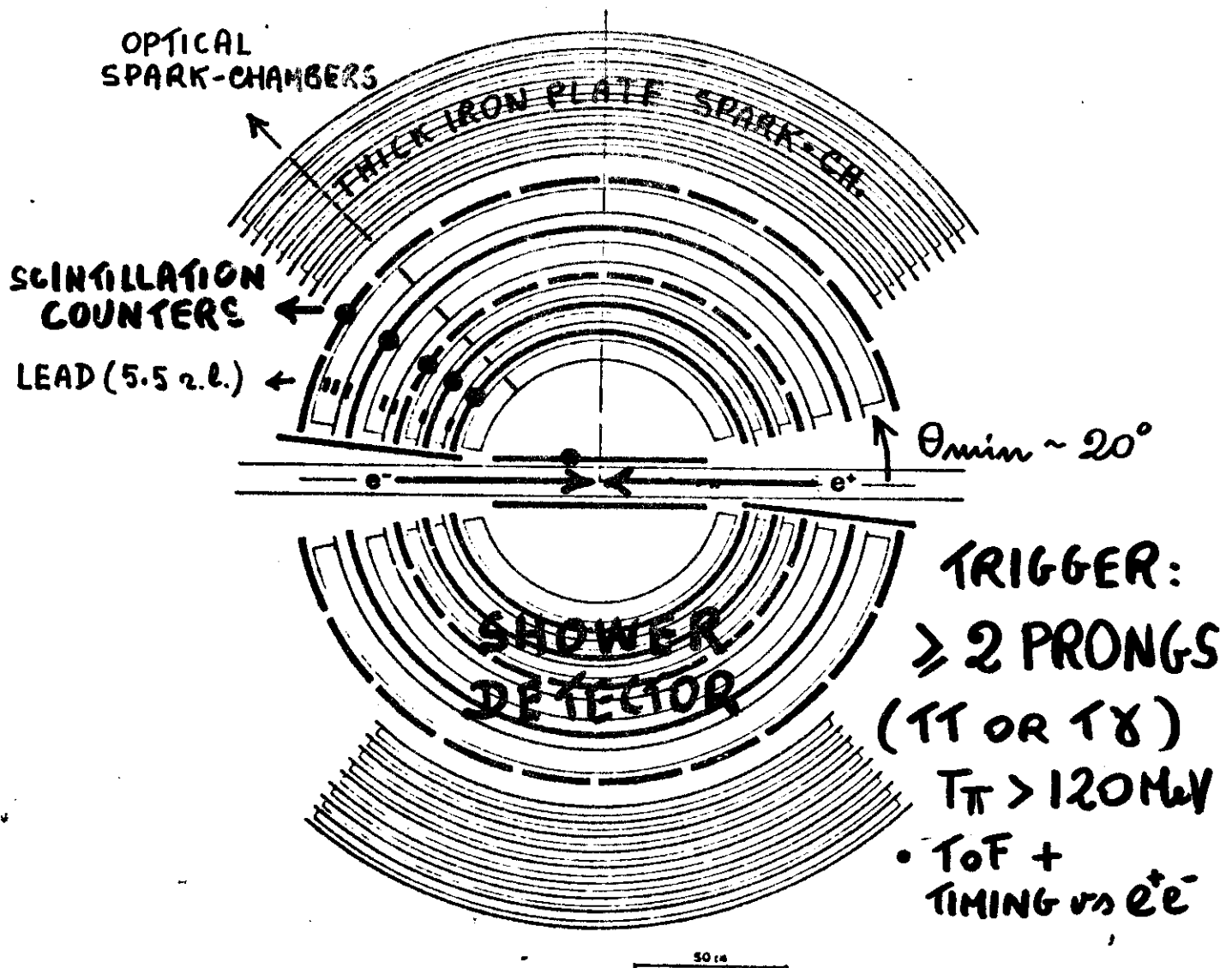
XX DETECTOR

$$\Delta\Omega_{\text{TRIGGER}} = 0.4 \times 4\pi \text{ sr}$$

$$\Delta\Omega_{\text{TRACKING}} = 0.66 \times 4\pi \text{ sr}$$



CH. TRACKS and PHOTONS



SET-UP COMPLEMENTED by

2 CIRCULAR SIDE TELESCOPES

(magnetostrictive spark-chambers,
counters, lead: 3 modules)

$$\Delta\Omega = 0.15 \times 4\pi \text{ sr}$$

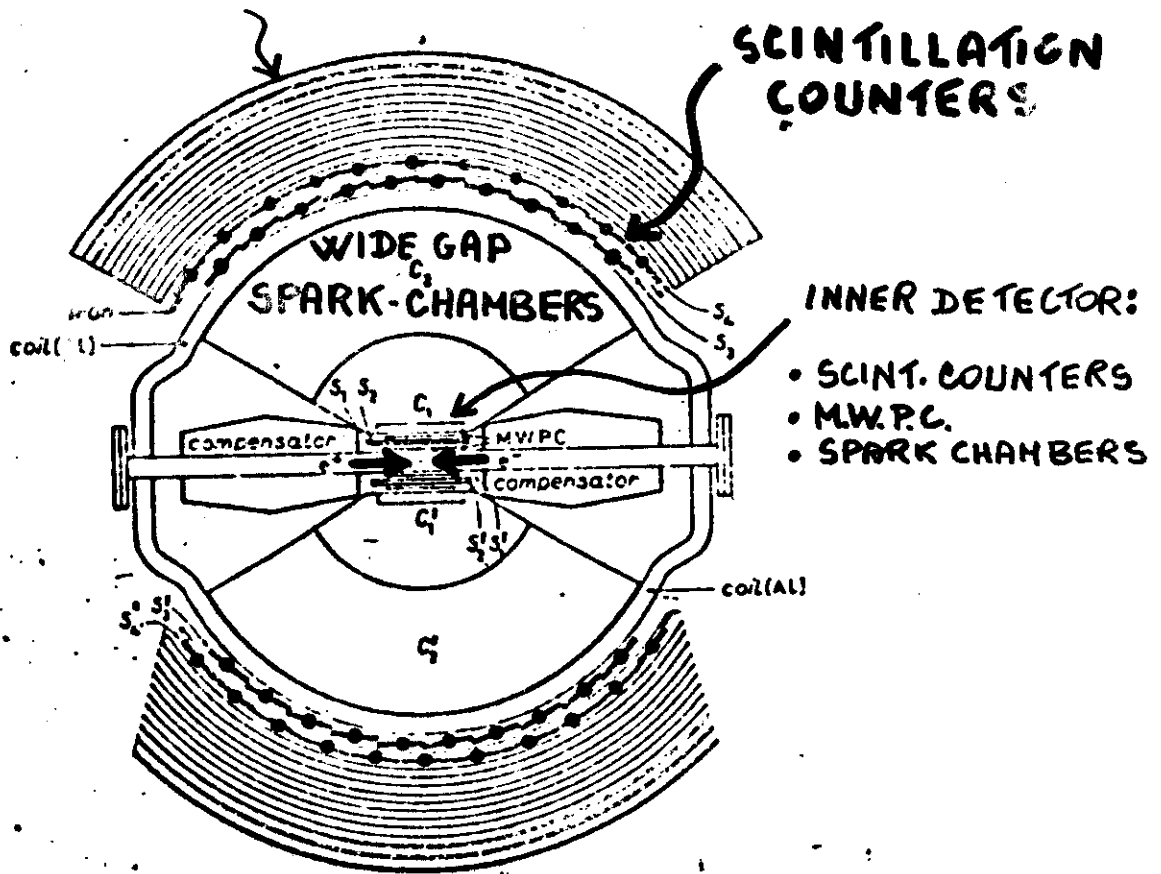
MEA DETECTOR

$$\Delta\Omega = 0.4 \times 4\pi \text{ sr}$$

$$B(\perp \text{ BEAM}) = 2.5 \text{ kG}$$

$$\Delta p/p_{\pi} = 8\% \text{ at } 1 \text{ GeV}$$

THICK PLATE SPARK-CHAMBERS



TRIGGER: ≥ 2 CH. PARTICLES

$$T_{\pi} > 120 \text{ MeV}$$

• TOF + TIMING vs e^+e^-

B $\bar{B}$ DETECTOR



SCINTILLATION COUNTERS:

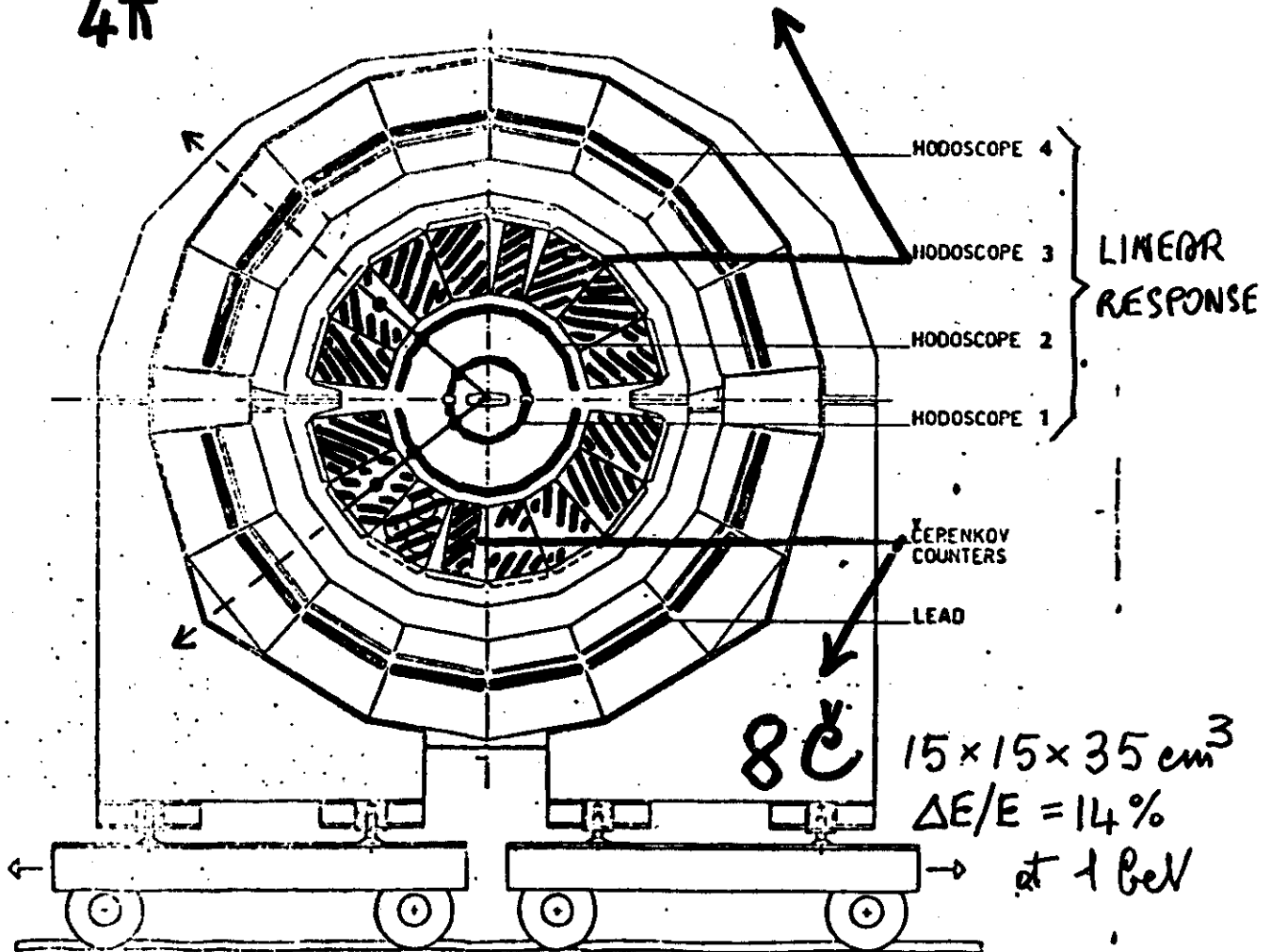
4 HODOSCOPES

→ 16 TELESCOPES

$$\frac{\Delta\Omega}{4\pi} = 75\%$$

LIQUID SCINT. COUNTERS

35 g/cm^2 , $\Delta E/E = 20\%$ at 100 MeV



TRIGGER: ≥ 2 CH. PRONGS

• $T_\pi > 75 \text{ MeV}$

• T. of F. + TIMING vs e^+e^-

ADONE RESULTS on the J/ψ PARTICLE

SOME PREVIOUS RESULTS:

$$\begin{array}{lcl}
 J/\psi \rightarrow \text{hadrons} : \Gamma_h = 59 \pm 24 \text{ KeV} & \left\{ \begin{array}{l} \sigma_2 : \sigma_4 : \sigma_6 : \sigma_8 = \\ = 32 \pm 5 : 49 \pm 8 : 18 \pm 3 : 1 \pm 0.6 \end{array} \right. & \\
 \rightarrow e^+e^- : \Gamma_e = 4.6 \pm 0.8 \text{ KeV} & \left\{ \begin{array}{l} \langle M_c \rangle = 3.8 \pm 0.3 \\ \langle M_o \rangle = 3.1 \pm 0.7 \end{array} \right. & \\
 \rightarrow \mu^+\mu^- : \Gamma_\mu = 5.0 \pm 1.0 \text{ KeV} & & \\
 \rightarrow \pi^0\gamma : \Gamma_{\pi^0\gamma}/\Gamma < 0.5\% \text{ (90\% c.l.)} & & \\
 \rightarrow \eta\gamma : \Gamma_{\eta\gamma}/\Gamma < 1.6\% \text{ (")} & & \\
 \rightarrow \eta'\gamma : \Gamma_{\eta'\gamma}/\Gamma_h < 1.7\% \text{ (")} & &
 \end{array}$$

LAST REVIEW by

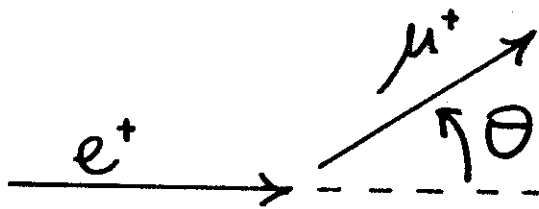
C. Bemporad, 1975 LEPTON-PHOTON SYMPOSIUM,
Stanford University

RECENT WORK on:

$$\begin{array}{l}
 J/\psi \rightarrow \mu^+\mu^- \\
 \rightarrow \eta'\gamma
 \end{array}$$

MEA GROUP: ANGULAR DISTRIBUTION for $e^+e^- \rightarrow J/\psi \rightarrow \mu^+\mu^-$

A FIRST SET OF EVENTS SEEMED TO EXHIBIT an
ENERGY DEPENDENT FORWARD-BACKWARD ASYMMETRY
AROUND J/ψ PEAK (HOWEVER OVERALL AVERAGE
WAS CONSISTENT WITH ASYMMETRY = const. = 0)



$$F \equiv N_{\mu\mu} \text{ with } \cos\theta > 0$$

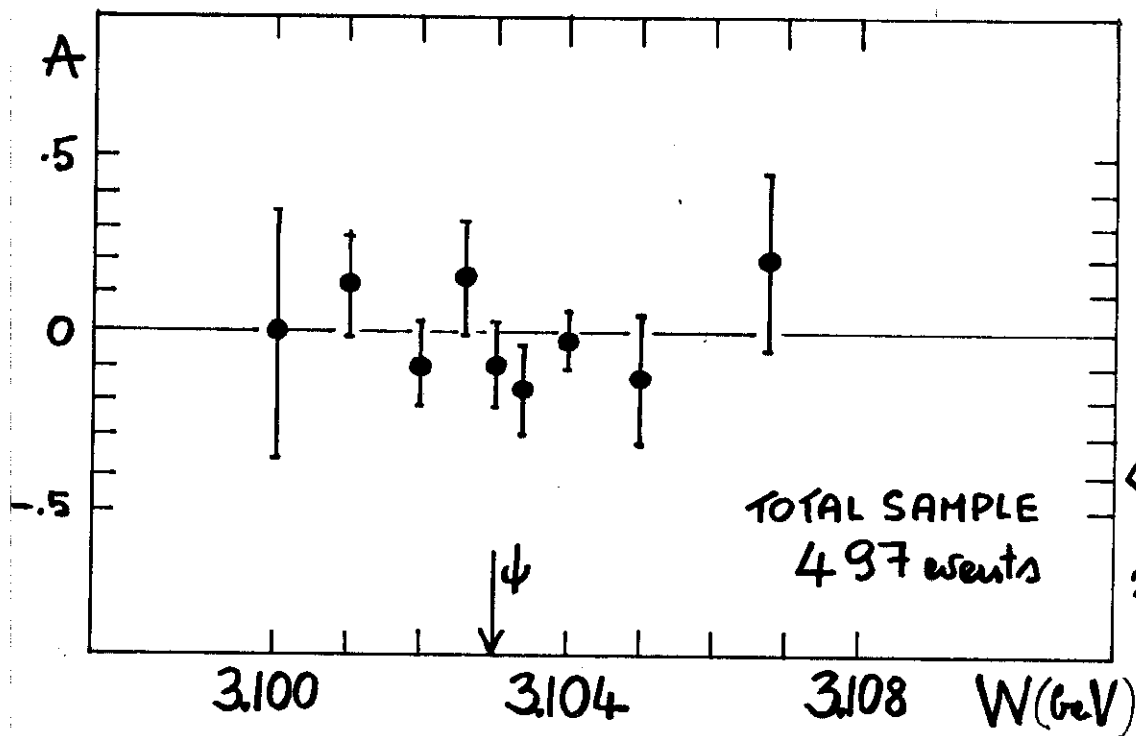
$$B \equiv \text{ " " " " } < 0$$

$$\text{ASYMMETRY PARAMETER} \equiv A = \frac{F - B}{F + B}$$

NO INSTRUMENTAL BIAS COULD BE FOUND

A NEW SAMPLE of 348 EVENTS SHOWS
NO ASYMMETRY (ENERGY DEPENDENT)

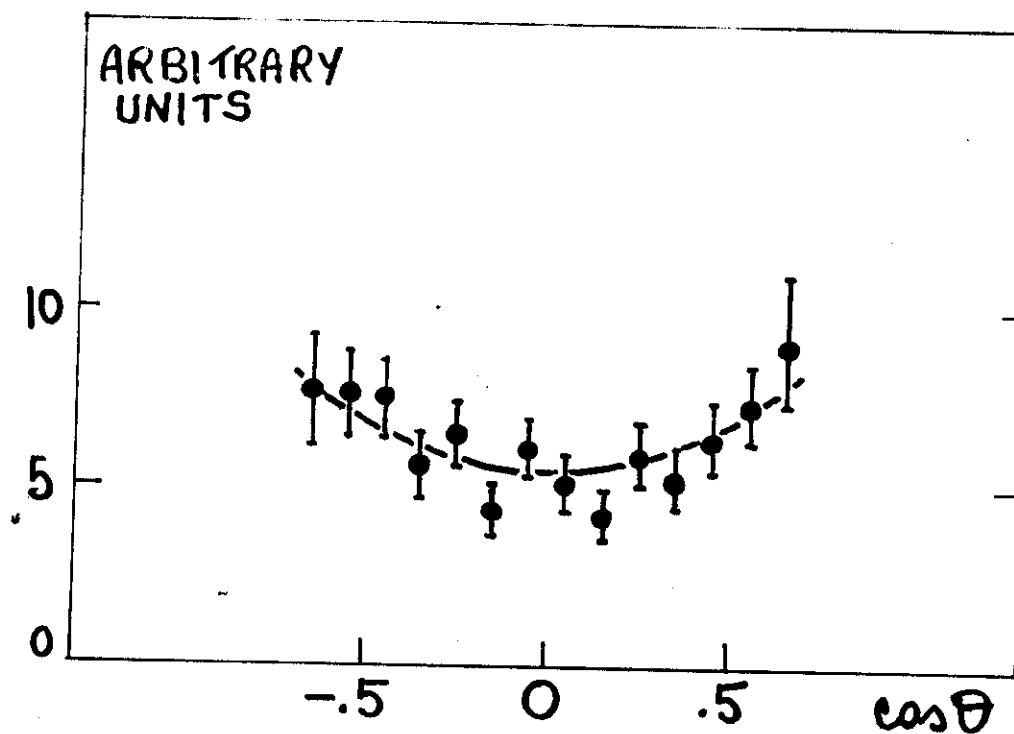
MEA. $J/\psi \rightarrow \mu^+ \mu^-$



A vs W

$$\langle A \rangle = 0.03 \pm 0.05$$

$$\chi^2 = 5.4 / \text{g.d.f.} \quad (80\% \text{ c.l.})$$



ANGULAR
DISTRIBUTION

vs

$$1 + \cos^2 \theta$$

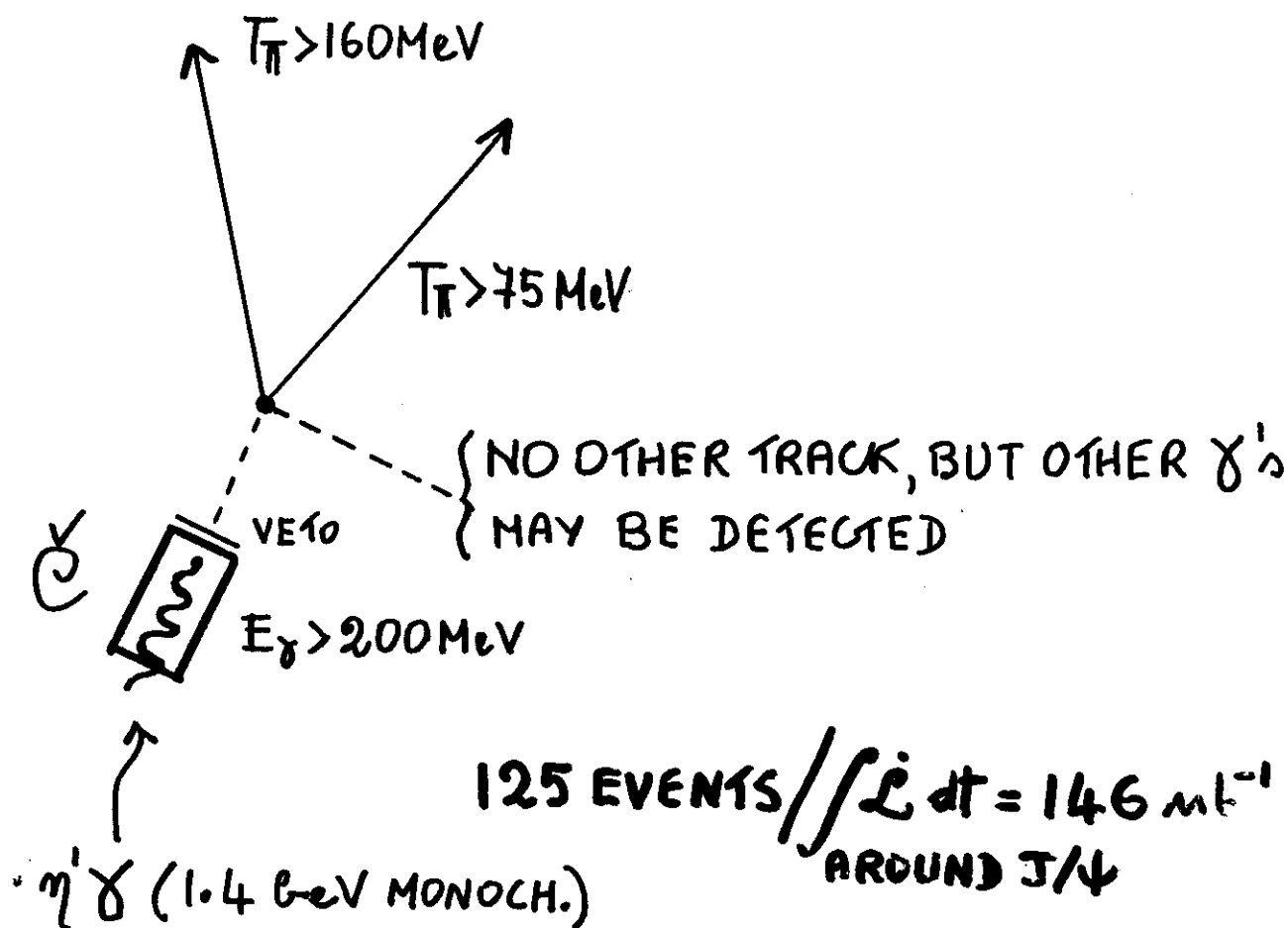
DISTRIBUTION

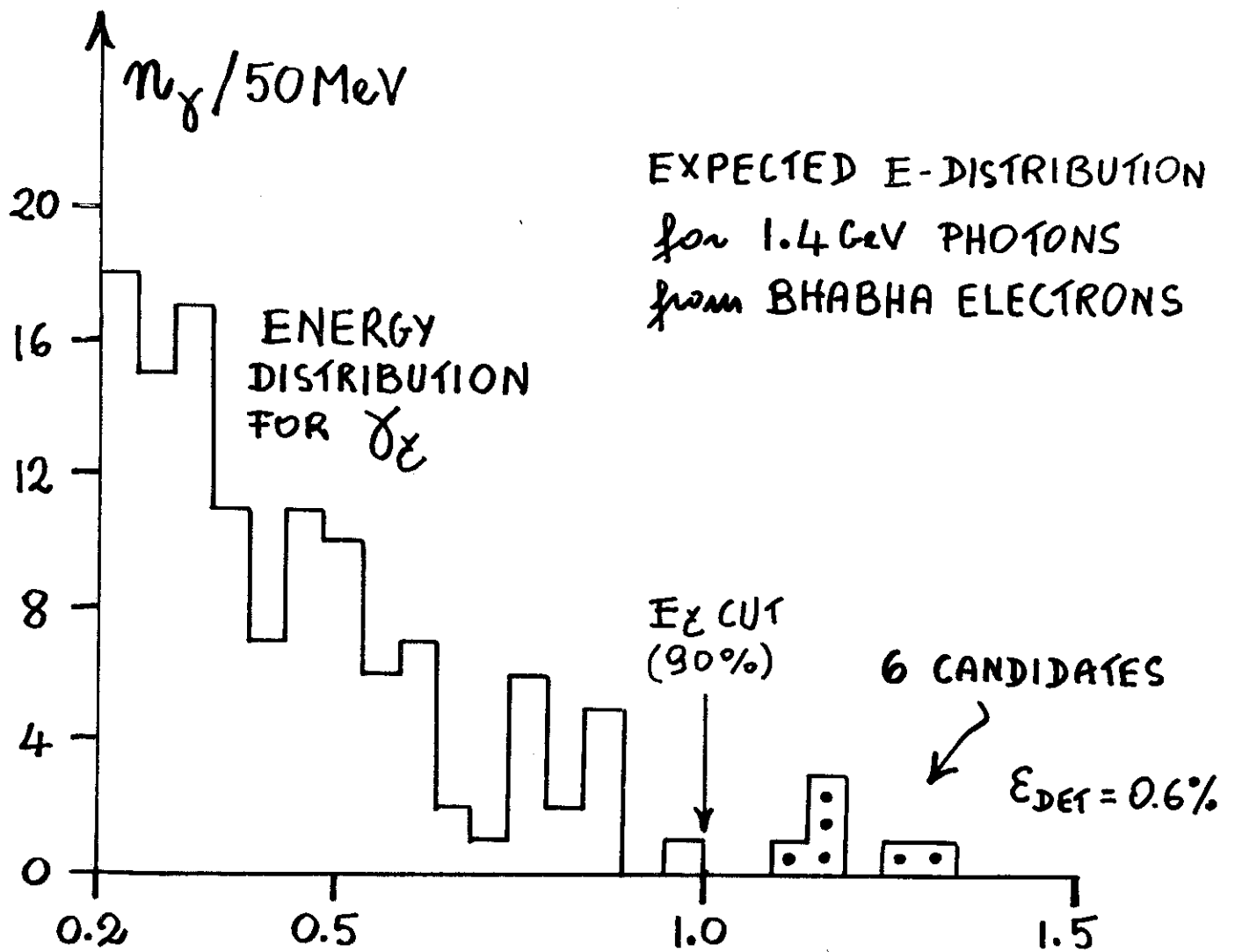
B $\bar{B}$ GROUP: SEARCH for the RADIATIVE DECAY

$$J/\psi \rightarrow \eta' \gamma$$

$$\xrightarrow[b.r.]{81\%} \pi^+ \pi^- + \text{anything}$$

SELECTED CONFIGURATIONS:





6 EVENTS $\rightarrow \int \sigma_{\eta'\gamma} dW < 135 \text{ mb} \times \text{MeV (90\% c.l.)}$
(RADIATIVE CORRECTIONS TAKEN INTO ACCOUNT)

- BACKGROUND FROM $J/\psi \rightarrow \rho^0 \pi^0$:

B.R. MEASURED at SPEAR: $\sim 0.4\% \Rightarrow 3.5 \text{ EV. EXPECTED}$

- TAKING INTO ACCOUNT POSSIBLE FLUCTUATIONS of this NUMBER:

$$\rightarrow \int \sigma_{\eta'\gamma} dW < 85 \text{ mb} \times \text{MeV (90\% c.l.)}$$

- FROM KNOWN WIDTH of J/ψ :

$$\rightarrow \Gamma(J/\psi \rightarrow \eta'\gamma) < 0.5 \text{ KeV (90\% c.l.)}$$

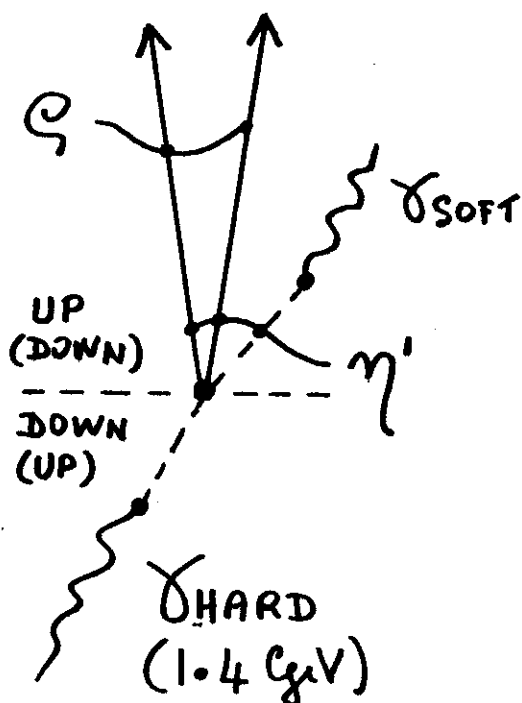
(*) Review of Particle Properties, Rev. of Mod. Phys. 48, 1 (1976)

XX GROUP: SEARCH for the RADIATIVE DECAY

$$J/\psi \rightarrow \eta' \gamma$$

$$\xrightarrow{27\% \text{ b.r.}} \rho^0 \gamma$$

- FINAL STATE $\equiv \pi^+ \pi^- \gamma \gamma \rightarrow$ O-C FIT POSSIBLE
- $\pi^+ \pi^-$ and $\pi^+ \pi^- \gamma$ INVARIANT MASSES CALCULATED and REQUIRED to be CONSISTENT with ρ and η' MASSES
- SELECTED EVENT CONFIGURATION:



NO OTHER PARTICLE DETECTED
in the TOTAL $\Delta\Omega = 0.8 \cdot 4\pi \text{ sr}$

[this CHOICE FAVOURS the
SEARCHED REACTION
AGAINST ORDINARY
 $J/\psi \rightarrow$ hadronic DECAYS]

$$\epsilon_{\text{DET}} = 6\%$$

60 EVENTS SELECTED

- DIRECTIONS of the 4 PRONGS of EACH EVENT WERE MEASURED $\rightarrow$ the MOMENTUM BALANCE CONDITION WAS TESTED

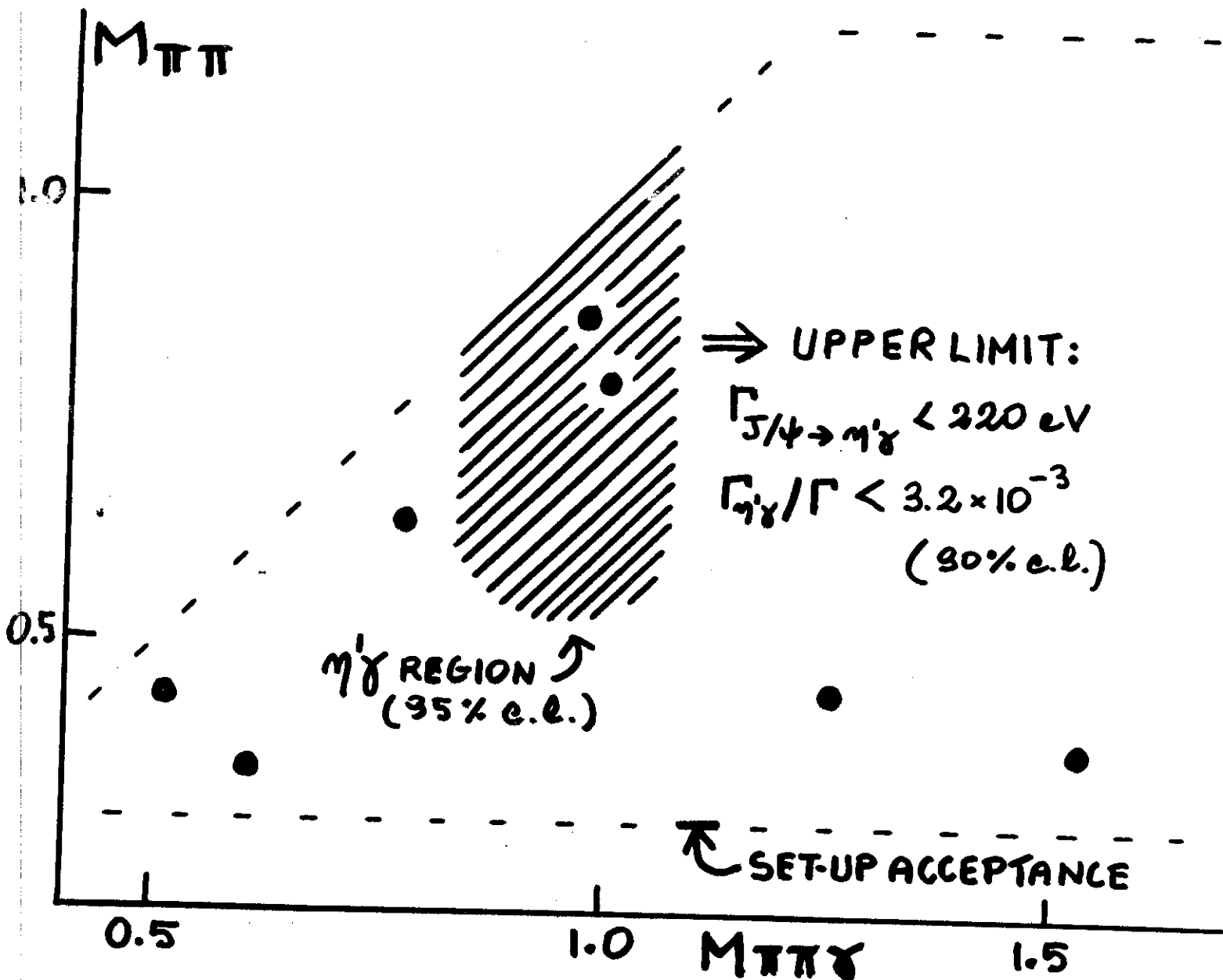
- ASSUMING that NO OTHER PRONG ESCAPED
DETECTION and $2T \equiv \pi^+ \pi^-$:
the ENERGIES of the 4 PRONGS were CALCULATED (CERN)
TESTING COMPATIBILITY with

- OBSERVED RANGE (TRACKS)
- SHOWER FEATURES (PHOTONS)

(ROUGH ENERGY CALIBRATION from $e e \rightarrow \gamma \gamma, e \gamma$ EVENT.)

→ 7 EVENTS SURVIVED

CALCULATED: $\pi^+ \pi^-$, $\pi^+ \pi^- \gamma_{\text{SOFT}}$ INV. MASSES



BY ~ SIMILAR METHOD:

SEARCH FOR HADRONIC RADIATIVE DECAYS

$$J/\psi \rightarrow \eta_c \gamma \left\{ \begin{array}{l} \varphi \gamma \rightarrow K^+ K^- \\ \rho \gamma \rightarrow \pi^+ \pi^- \\ \pi^+ \pi^- \gamma, K^+ K^- \gamma \end{array} \right.$$

$$2.4 \leq M_{\eta_c} \leq 3.0 \text{ GeV}$$

$$B(J/\psi \rightarrow \eta_c \gamma) \cdot B(\eta_c \rightarrow \phi \gamma) < 1.3\%$$

$$\mathcal{B}(T/\psi \rightarrow \eta_c \gamma) \cdot \mathcal{B}(\eta_c \rightarrow \rho \gamma) < 2.7\%$$

$$B(J/\psi \rightarrow \eta_c \gamma) \cdot B(\eta_c \rightarrow \pi\pi\gamma) < 3.2\% \quad 2.8 \leq M_{\eta_c} \leq 3.0$$

" " $< 2.7\%$ $2.6 \leq " \leq 2.8$

" " $< 5\%$ $2.4 \leq u \leq 2.6$

ALL LIMITS : 90% a.l.

SEARCH for J/ψ -LIKE RESONANCES in $e^+e^- \rightarrow \text{hadrons}$ BETWEEN 2.5 and 3.0 GeV ($B\bar{B}$, Υ , MEV)

MASS REGIONS 1.9 - 2.5 and 3.0 - 3.1 GeV
ALREADY EXPLORED $\rightarrow$ UPPER LIMITS ESTABLISHED

$$\Sigma \equiv \int (\sigma - \sigma_{\text{NON RES}}) dW < 0.1 \Sigma_{J/\psi}$$

Σ MEASURED INTEGRATING the OBSERVED
CROSS SECTION over $> \Gamma_{\text{MACHINE}}$ THEN SUBTRACTING NON RES.
BACKGROUND and CORRECTING for RADIATIVE EFFECTS

SEARCH in the 2.5 - 3.0 GeV RANGE

- IN $\Delta W = 1 \text{ MeV}$ STEPS $[\Gamma_{\text{MACHINE}} = 0.31 \times W^2 (\text{GeV}) \text{ MeV}]$
- with $\int \mathcal{L} dt \approx 0.4 \text{ nb}^{-1}/\text{STEP}$ (F.W.H.M.)

RELATIVE $\mathcal{L}$ -MONITOR:

SMALL ANGLE BHABHA SCATTERING (MACHINE)

ABSOLUTE NORMALIZATION:

WIDE ANGLE e^+e^-

NO SIGNIFICANT SIGNAL FOUND

within the SENSITIVITY of EXPERIMENTS

EVENT SELECTION:

$B\bar{B}$: • 2 CH. TRACKS ACOPLANAR vs BEAMS
($T_{\pi} > 160 \text{ MeV}$)

OR > 2 CH. TRACKS

- $> 400 \text{ MeV}$ TOTAL ENERGY LOSS in the LIQUID SCINT. HODOSCOPE:

this CALORIMETRIC REQUIREMENT OPTIMIZES

SIGNAL to BACKGROUND RATIO on the J/ψ

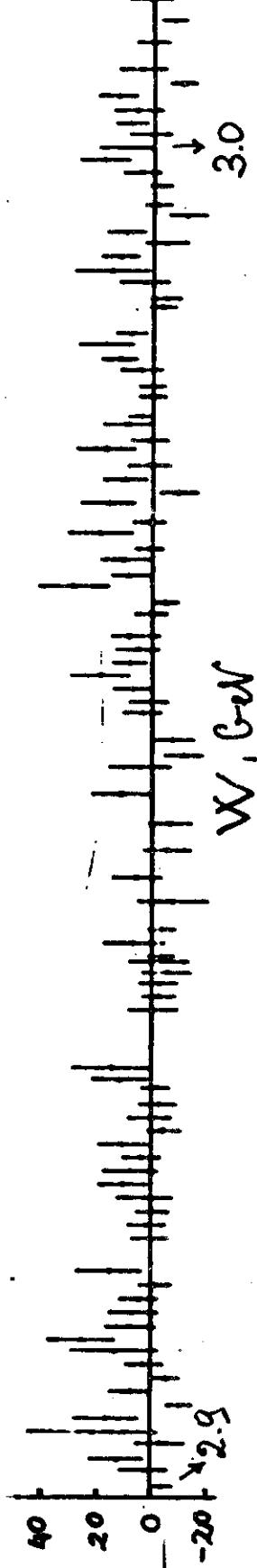
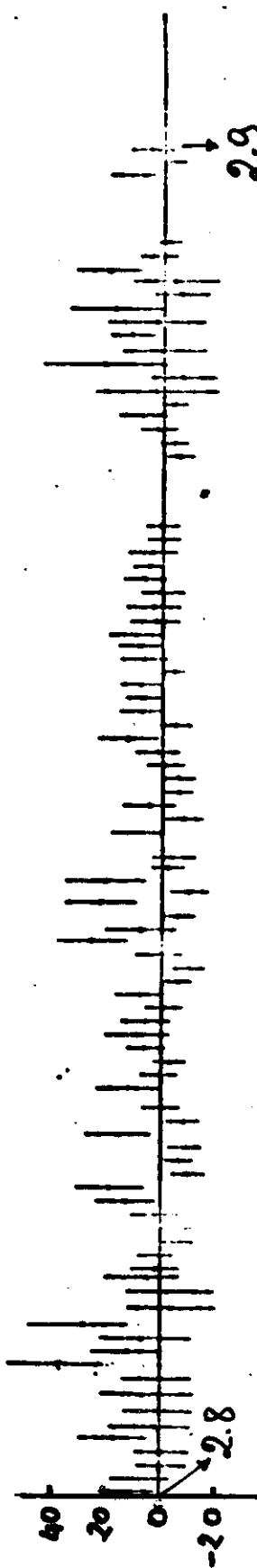
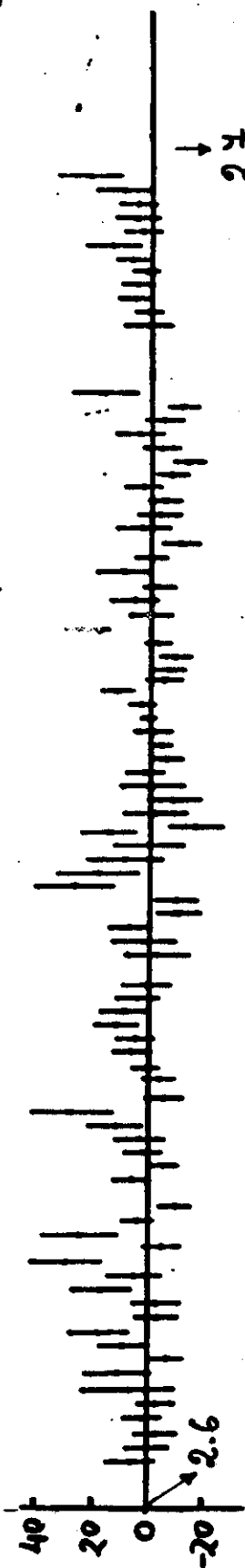
- STATISTICAL SUBTRACTION of RESIDUAL BACKGR.

$\gamma\gamma$: ≥ 3 PRONGS (≥ 2 CHARGED)
($T_{\pi} > 120 \text{ MeV}$)

MEA : 2 CH. TRACKS ACOPLANAR vs BEAMS ($> 10^\circ$)
($T_{\pi} > 130 \text{ MeV}$)
OR > 2 CH. TRACKS

AGAINST : COSMIC RAY + BEAM-GAS BACKGROUND
2-PHOTON PROCESSES
COLLINEAR PAIRS

EE: RELATIVE YIELD for $e^+e^- \rightarrow \text{hadrons}$



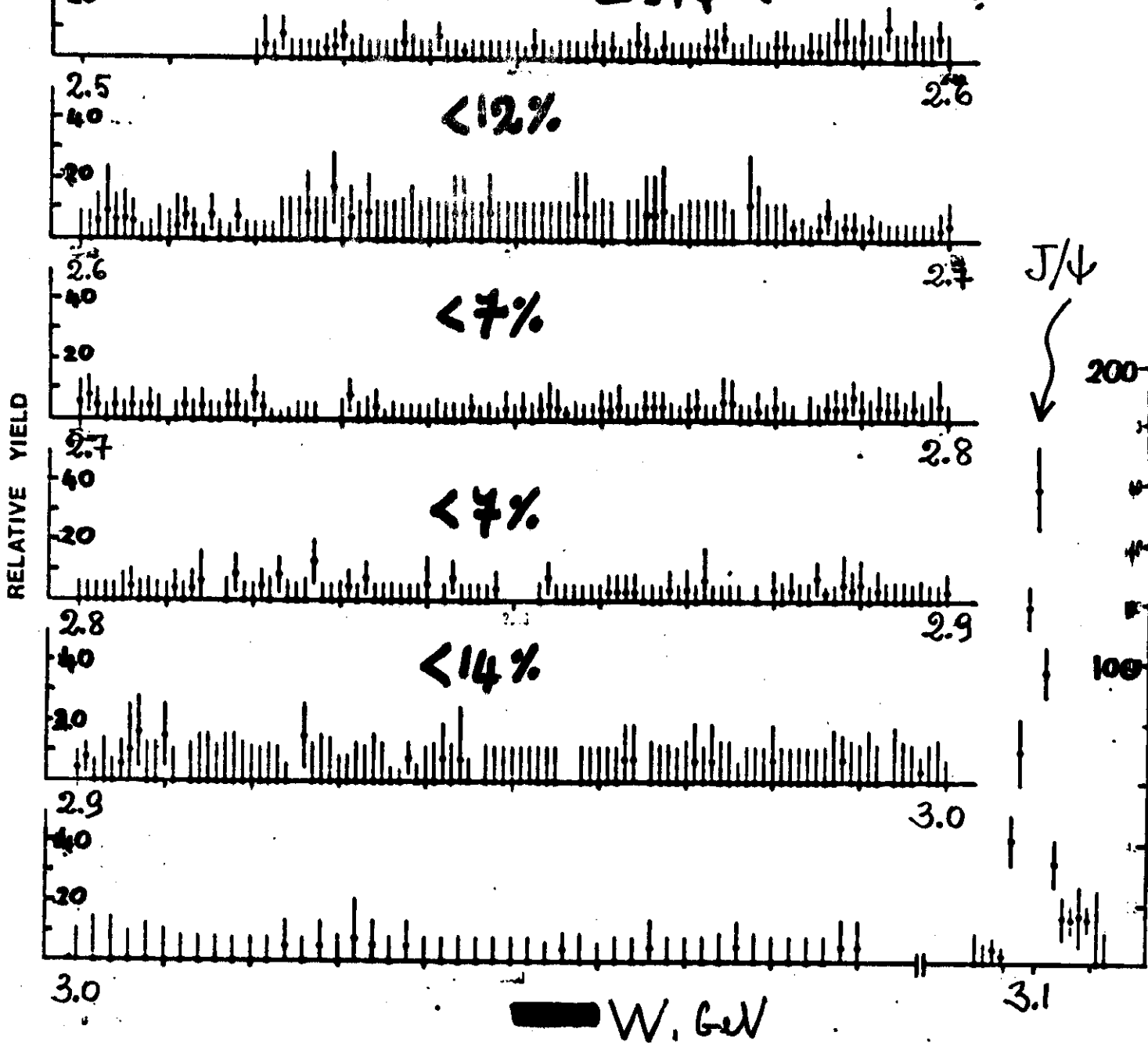
$\Sigma < 0.1 \Sigma J$
(90% a.l.)

$J/4$



W, G-M

MEASUREMENT OF RELATIVE YIELD FOR $e^+e^- \rightarrow \text{hadrons}$
 $\Sigma < 6\% \quad \Sigma J/\psi \text{ (90\% c.l.)}$

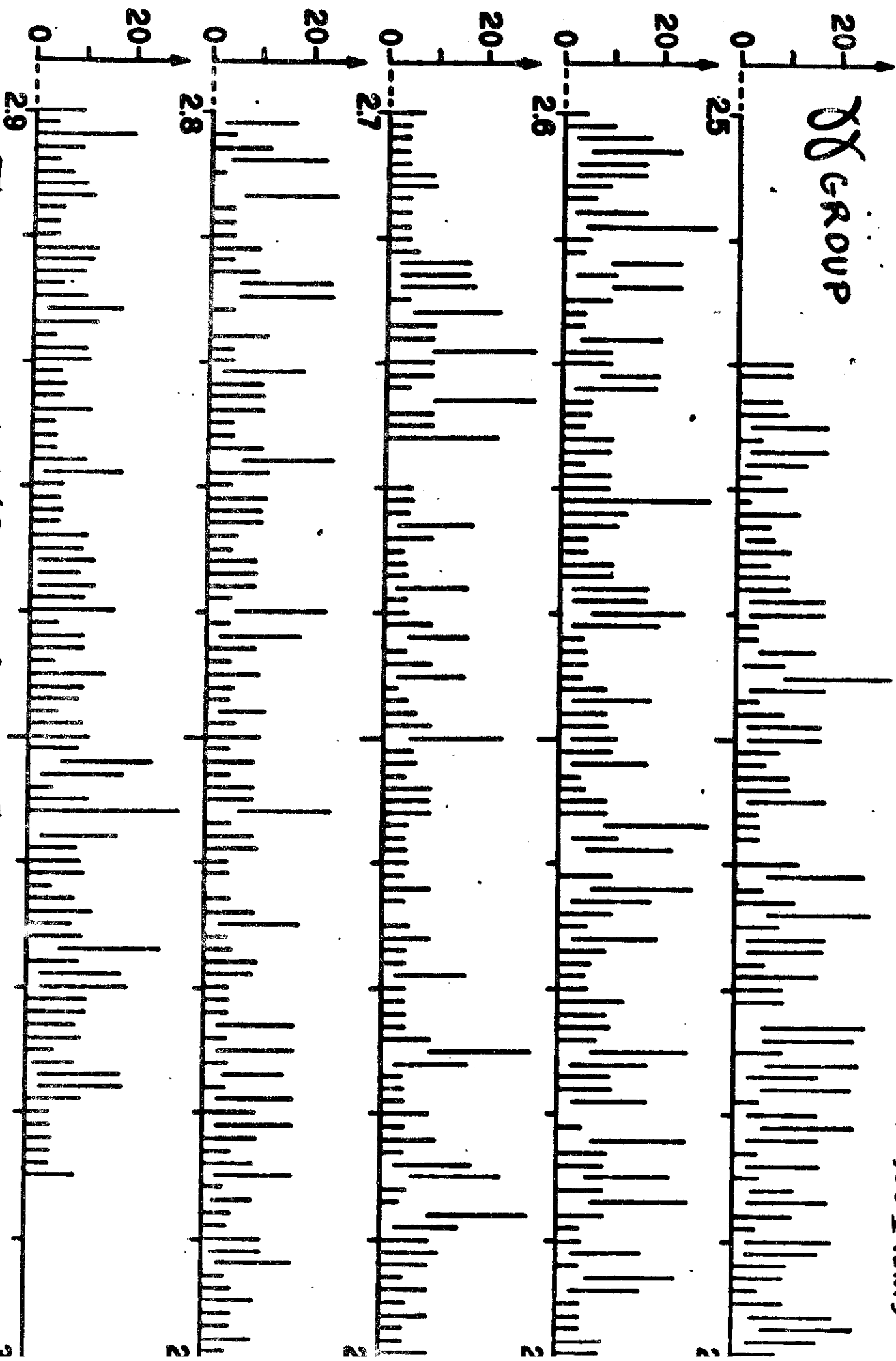


~ 200 EVENTS

~ 500 EVENTS

Σ GROUP

RELATIVE YIELD



$\Sigma < 480 \text{ mb. MeV (30\% c.e.)}$ $\pi_{10.3} \Sigma < 0.05 \Sigma_{T/4} W(\text{GeV})$

**$\gamma\gamma$ GROUP: TOTAL CROSS SECTION
for $e^+e^- \rightarrow \text{hadrons}$
BETWEEN 1.9 and 3.1 GeV**

**ANALYSIS of ~ 1000 Events FROM THOSE
COLLECTED in the ENERGY SCAN**

**SELECTION of EVENTS: ≥ 3 PRONGS $\rightarrow$ J^{ψ} like
 ≥ 2 CHARGED**

**2-PRONG EVENTS IGNORED DUE TO HEAVY
BEAM-GAS BACKGROUND CONTAMINATION**

**SINGLE BEAM RUNS ALLOW SUBTRACTION of
RESIDUAL BACKGROUND on 3-PRONG EVENTS**

**-EVENTS CLASSIFIED ACCORDING to T- γ MULTIPLICITIES:
at any GIVEN W RANGE $\rightarrow (m_T, m_\gamma)_{\text{OBS}}$ MATRIX.**

**-PROBLEM: FIND a SET of HADRONIC FINAL STATES,
TOGETHER with their RELATIVE WEIGHTS, SUCH
to REPRODUCE the $(m_T, m_\gamma)_{\text{OBSERVED}}$ MATRIX.**

$\rightarrow$ DETECTION EFFICIENCIES ARE NEEDED

• FOR ANY T- γ CONFIGURATION

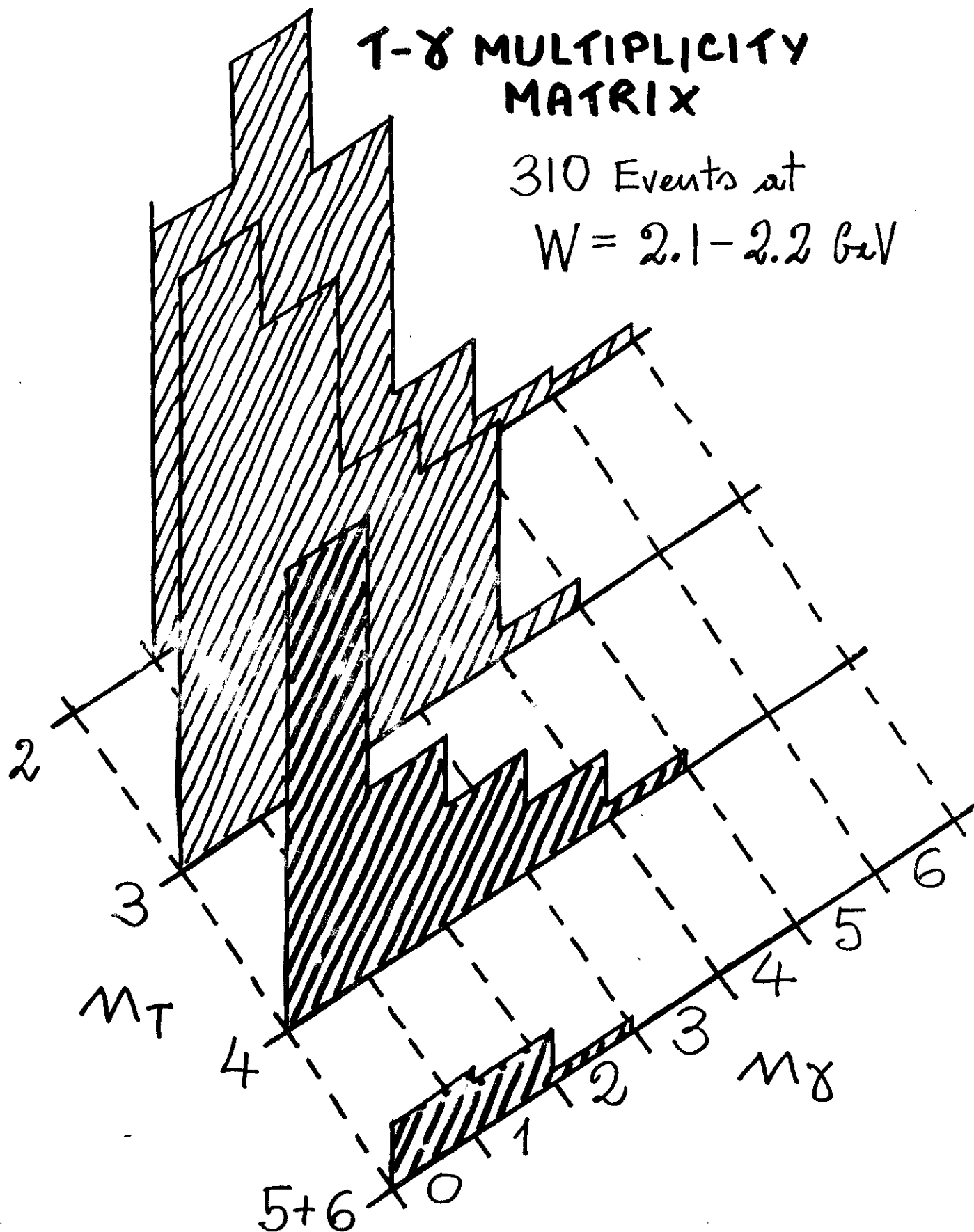
• FROM ANY POSSIBLE REACTION:

**CALCULATED by a MONTECARLO SIMULATING
EVENTS and DETECTOR**

T- $\bar{\gamma}$ MULTIPLICITY MATRIX

310 Events at

$W = 2.1 - 2.2 \text{ GeV}$



LIMITATIVE ASSUMPTIONS

(FORCED by the DETECTOR FEATURES):

- ALL PARTICLES ARE π 's, with
- I.P.S. MOMENTUM DISTRIBUTION

ALL FINAL STATES $m\pi^+ + n\pi^-$ CONSIDERED
with $m+n \equiv$ TOTAL π MULTIPLICITY ≤ 8

$\langle E_{DET} \rangle$ RANGES BETWEEN $20 \div 24\%$
THROUGHOUT the EXPLORED ENERGY RANGE

THE SET of DETECTION EFFICIENCIES,
AND the $(m_T, m_Y)_{OBS}$ MATRICES:

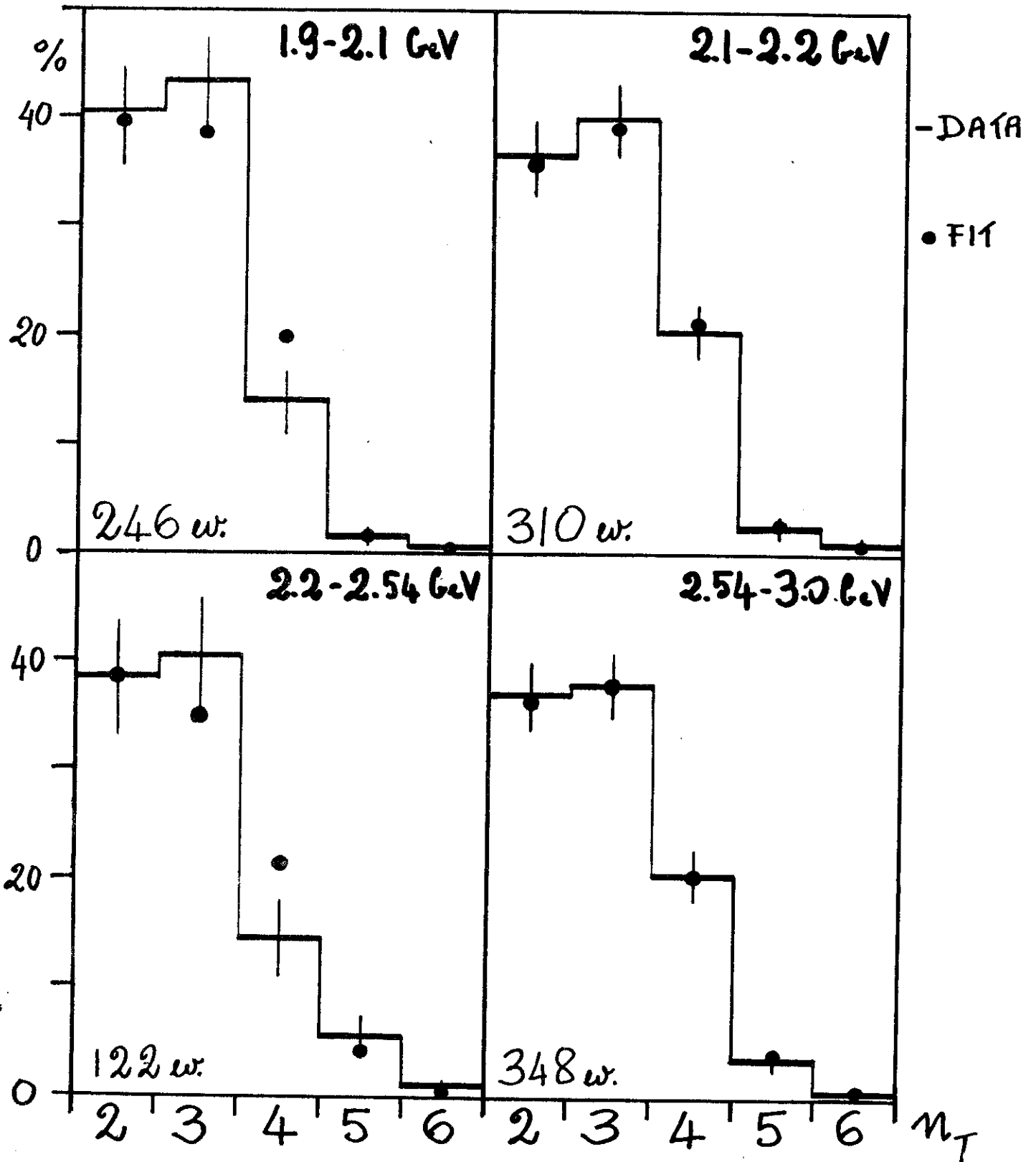
→ OVERDETERMINED SET of EQUATIONS

AN OVERALL FIT PROCEDURE ALLOWS to GET
SOLUTIONS, REASONABLY REPRODUCING
the $(m_T, m_Y)_{OBS}$ MATRICES

STABLE and RELIABLE QUANTITIES from the FIT:

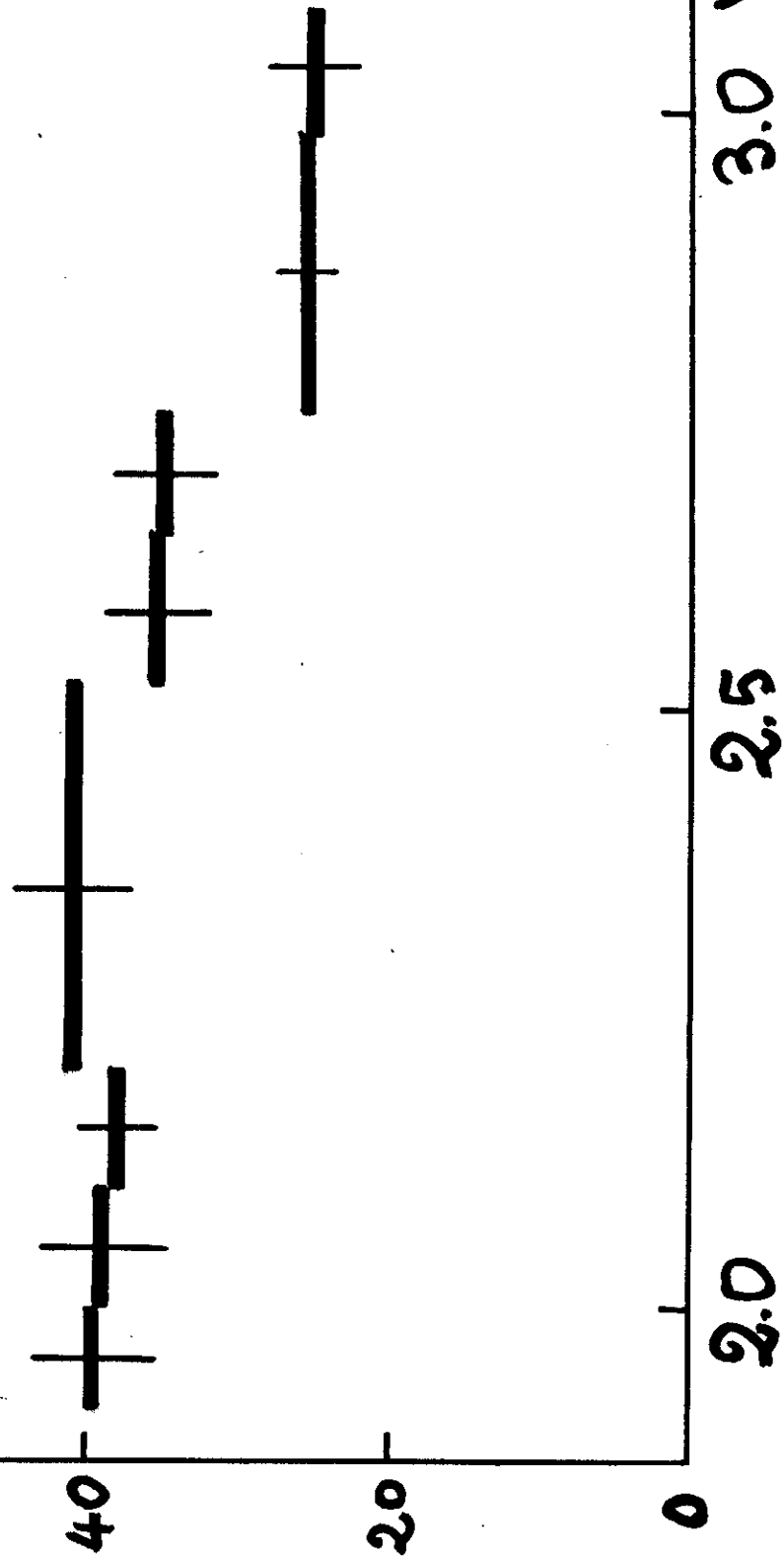
- TOTAL CROSS SECTION, $\sigma_{TOT}(W)$
- AVERAGE CHARGED MULTIPLICITY, $\langle m_c \rangle$
- " NEUTRAL " , $\langle m_o \rangle$

CHARGED MULTIPLICITY DISTRIBUTIONS



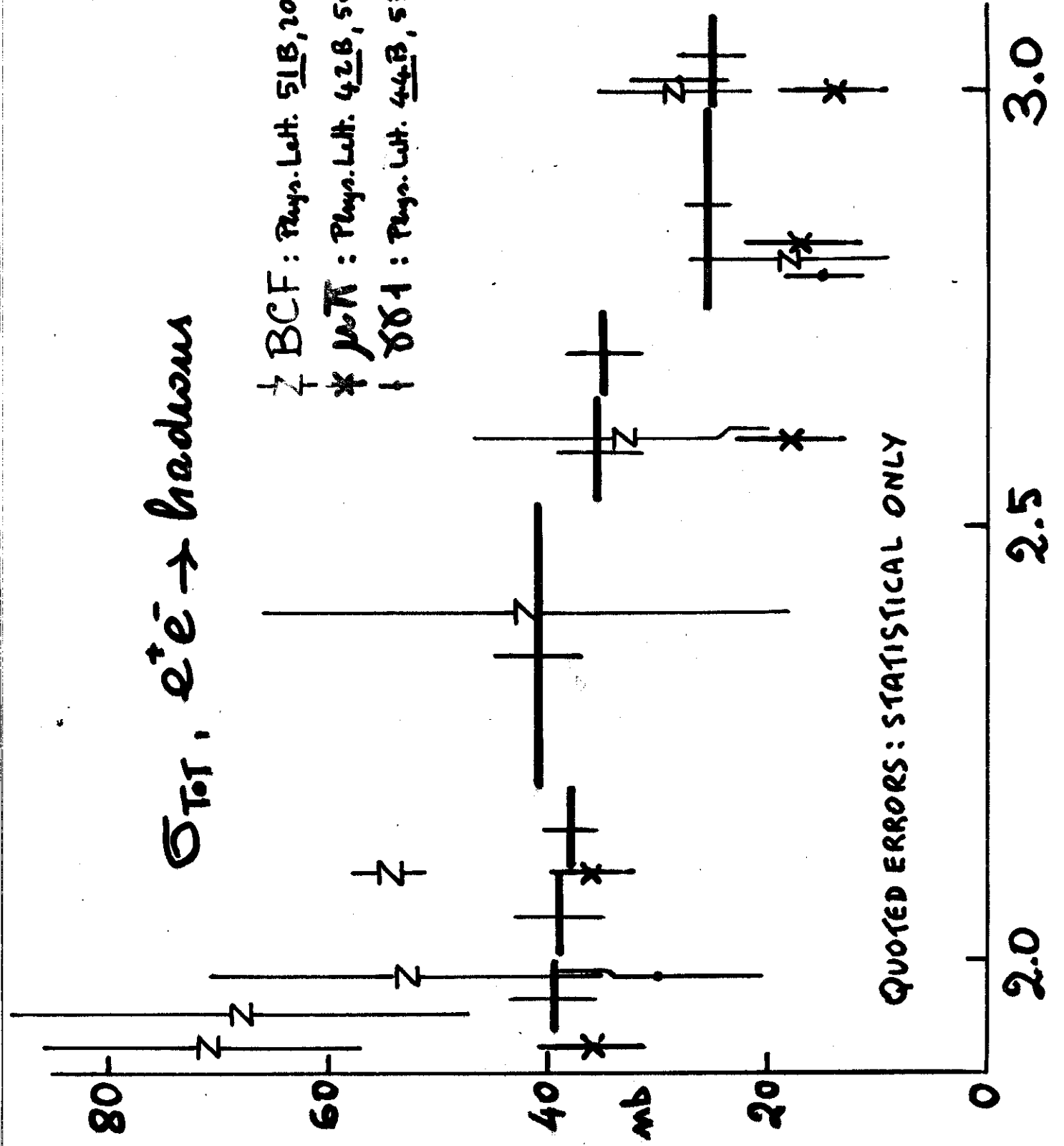
$\sigma_{\text{tot}}, e^+e^- \rightarrow \text{hadrons}$

QUOTED ERRORS: STATISTICAL ONLY

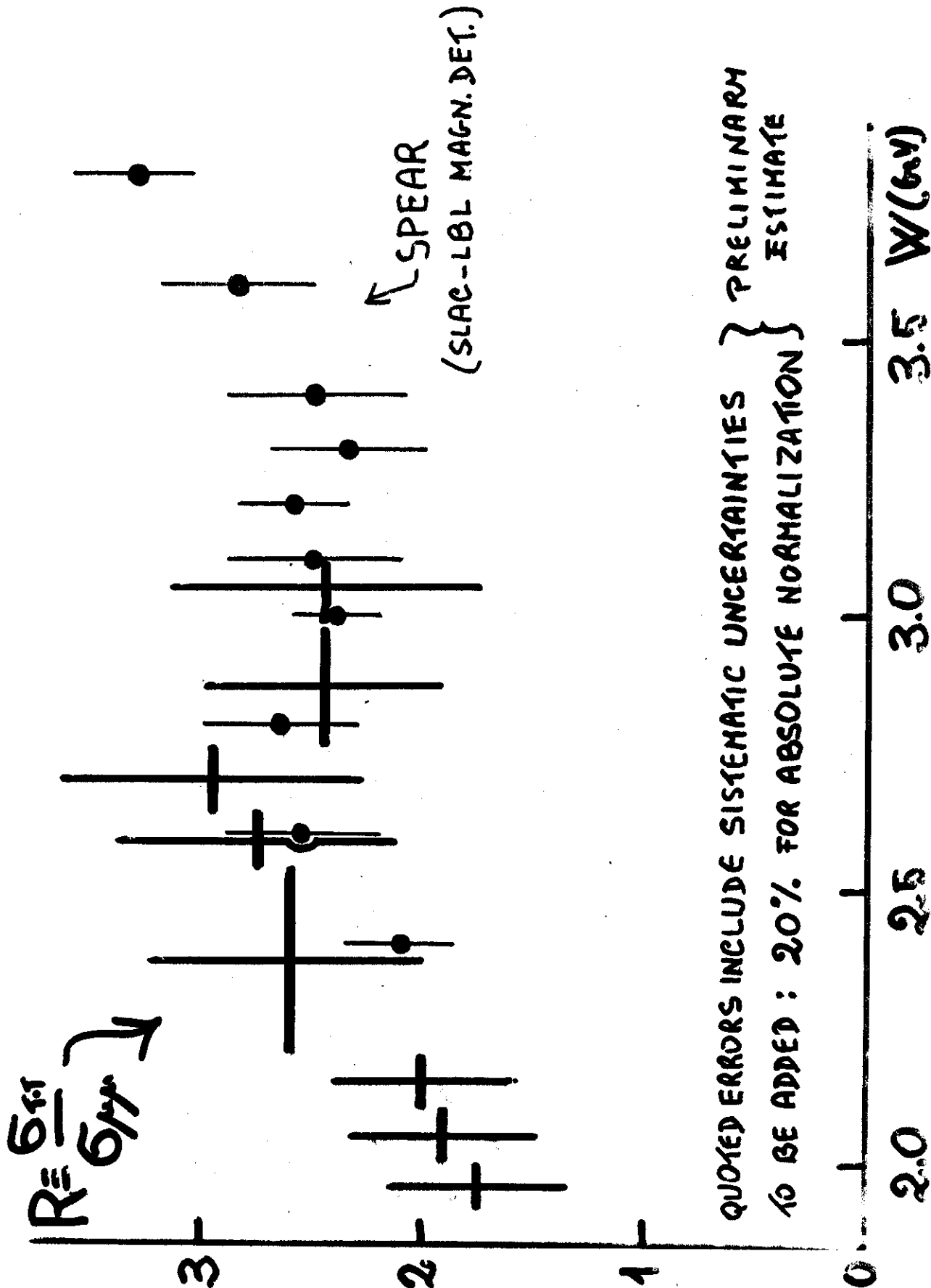


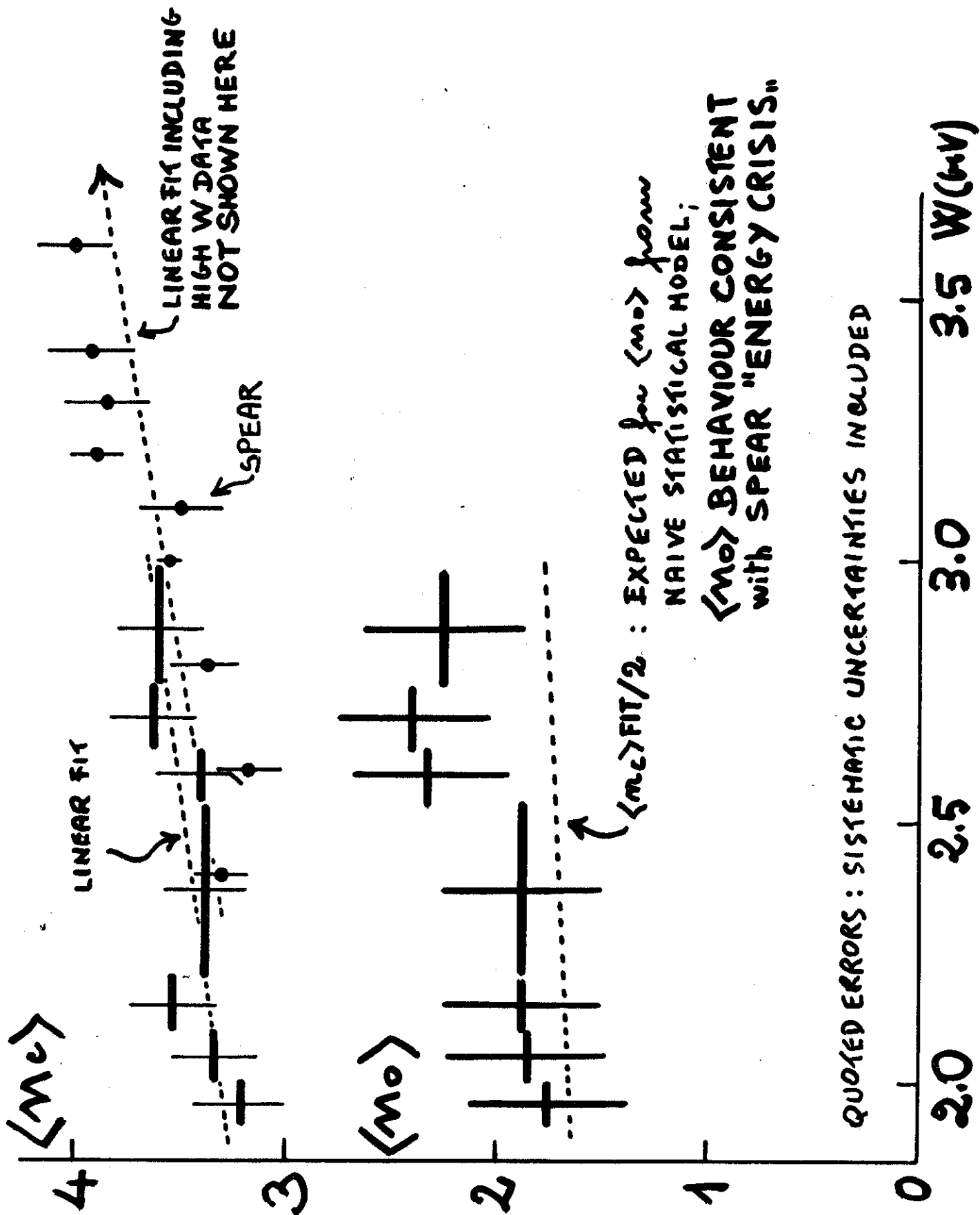
$\sigma_{\text{TOT}}, e^+e^- \rightarrow \text{hadrons}$

$\frac{1}{2}$ BCF: Phys. Lett. 51B, 200 (1974)
 $\ast$ μon : Phys. Lett. 42B, 501 (1972); 47B, 80 (1973)
 $\dagger$ $\delta\delta 1$: Phys. Lett. 44B, 533 (1973)



XX Group





ANALYSIS IN PROGRESS on

HEA GROUP: σ_{TOT} for $e^+e^- \rightarrow \text{hadrons}$
(INCLUSIVE MOMENTUM DISTRIBUTIONS)

π, K TIME-LIKE F.F.

$\gamma\gamma$ GROUP: TOPOLOGICAL CROSS SECTIONS
for $e^+e^- \rightarrow \text{hadrons}$

2-PHOTON INTERACTIONS

Q.E.D.: $e^+e^- \rightarrow e^+e^-\gamma$

WHAT NEXT AT ADONE

PRESENT EXPERIMENTS ($\gamma\gamma$, MEA, $B\bar{B}$) ARE GOING TO CONCENTRATE ON THE ENERGY REGION 1.2 - 2.1 GeV
LOOKING FOR: • J/ ψ -LIKE RESONANCES

- $\phi'(\?)$, $\phi''(1.6)$, $\rho'(1.25)$, ...
- TIME-LIKE FORM FACTORS (π , K, P, ...)

A RATHER LONG ADONE SHUT DOWN IS FORESEEN IN ORDER TO INSTALL:

- SYNCHROTRON LIGHT FACILITY
- LASER - e-BEAM SCATTERING DEVICE (POL. γ BEAM)
- NEW R.F. CAVITY

IN THE MEANTIME A SUBSTANCIAL IMPROVEMENT SHOULD BE MADE ON THE MEA DETECTOR:

- NEW INNER DETECTOR (MWPC + COUNTERS)
- NEW OUTER DETECTOR (MWPC OUTSIDE COIL)
- NEW COMPENSATING COILS

IN ORDER TO REACH:

$$\Delta\Omega_{\text{TRACKING}} \simeq 0.65 \times 4\pi \text{ sr for CH.} + \gamma$$