Les découvertes du charme.

« du charme caché au charme nu. »

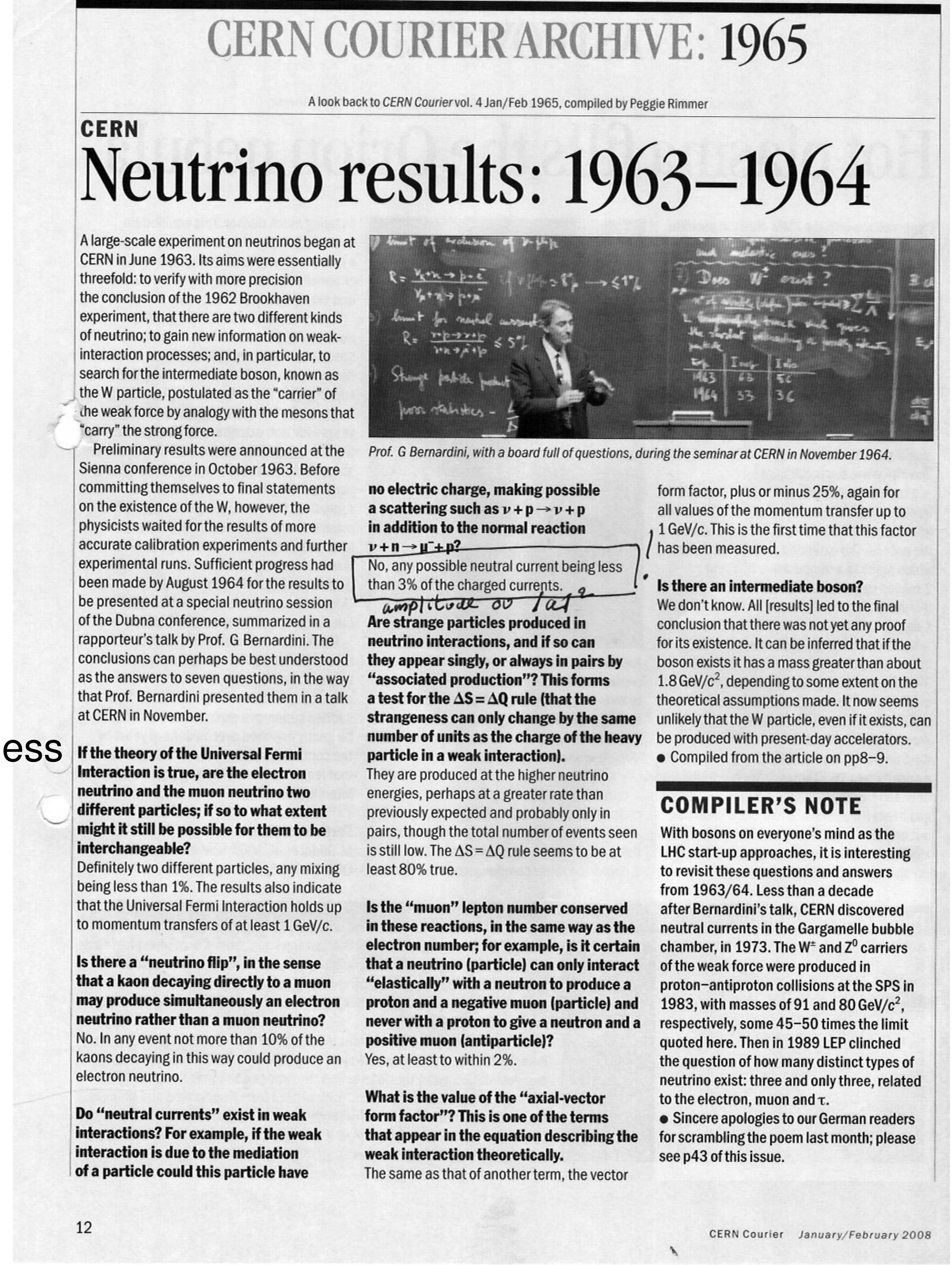
PLAN

-un panorama de la physique au début 1974.
-le détecteur magnétique SLAC/LBL au collisionneur SPEAR.
-la découverte du J/Ψ en novembre 1974.
-pourquoi J/Ψ et Ψ' sont-ils si étroits?
-propriétés des nouvelles particules.
-interlude : les événements e-mu(lepton lourd).
-interlude : les jets.
-les états intermédiaires du charmonium.
-les Kaons inclusifs.
-les mésons D.
-remarques finales.

Préhistoire

« il n'y a pas de courants neutres »
DEA(=Master2) 1965 A.L

« No, any possible neutral current being less than 3% of the charge currents. »



CERN COURIER ARCHIVE: 1965

A look back to *CERN Courier* vol. 4 Jan/Feb 1965, compiled by Peggie Rimmer

CERN

Neutrino results: 1963–1964

A large-scale experiment on neutrinos began at CERN in June 1963. Its aims were essentially threefold: to verify with more precision the conclusion of the 1962 Brookhaven experiment, that there are two different kinds of neutrino; to gain new information on weak-interaction processes; and, in particular, to search for the intermediate boson, known as the W particle, postulated as the "carrier" of the weak force by analogy with the mesons that "carry" the strong force.

Preliminary results were announced at the Sienna conference in October 1963. Before committing themselves to final statements on the existence of the W, however, the physicists waited for the results of more accurate calibration experiments and further experimental runs. Sufficient progress had been made by August 1964 for the results to be presented at a special neutrino session of the Dubna conference, summarized in a rapporteur's talk by Prof. G Bernardini. The conclusions can perhaps be best understood as the answers to seven questions, in the way that Prof. Bernardini presented them in a talk at CERN in November.

If the theory of the Universal Fermi Interaction is true, are the electron neutrino and the muon neutrino two different particles; if so to what extent might it still be possible for them to be interchangeable?
Definitely two different particles, any mixing being less than 1%. The results also indicate that the Universal Fermi Interaction holds up to momentum transfers of at least 1 GeV/c.

Is there a "neutrino flip", in the sense that a kaon decaying directly to a muon may produce simultaneously an electron neutrino rather than a muon neutrino?
No. In any event not more than 10% of the kaons decaying in this way could produce an electron neutrino.

Do "neutral currents" exist in weak interactions? For example, if the weak interaction is due to the mediation of a particle could this particle have no electric charge, making possible a scattering such as $\nu + p \rightarrow \nu + p$ in addition to the normal reaction $\nu + n \rightarrow \mu^- + p$?
No, any possible neutral current being less than 3% of the charged currents.

amplitude ou $|a|^2$

!

Prof. G Bernardini, with a board full of questions, during the seminar at CERN in November 1964.

Are strange particles produced in neutrino interactions, and if so can they appear singly, or always in pairs by "associated production"? This forms a test for the $\Delta S = \Delta Q$ rule (that the strangeness can only change by the same number of units as the charge of the heavy particle in a weak interaction).
They are produced at the higher neutrino energies, perhaps at a greater rate than previously expected and probably only in pairs, though the total number of events seen is still low. The $\Delta S = \Delta Q$ rule seems to be at least 80% true.

Is the "muon" lepton number conserved in these reactions, in the same way as the electron number; for example, is it certain that a neutrino (particle) can only interact "elastically" with a neutron to produce a proton and a negative muon (particle) and never with a proton to give a neutron and a positive muon (antiparticle)?
Yes, at least to within 2%.

What is the value of the "axial-vector form factor"? This is one of the terms that appear in the equation describing the weak interaction theoretically.
The same as that of another term, the vector form factor, plus or minus 25%, again for all values of the momentum transfer up to 1 GeV/c. This is the first time that this factor has been measured.

Is there an intermediate boson?
We don't know. All [results] led to the final conclusion that there was not yet any proof for its existence. It can be inferred that if the boson exists it has a mass greater than about 1.8 GeV/c^2, depending to some extent on the theoretical assumptions made. It now seems unlikely that the W particle, even if it exists, can be produced with present-day accelerators.
- Compiled from the article on pp8–9.

COMPILER'S NOTE

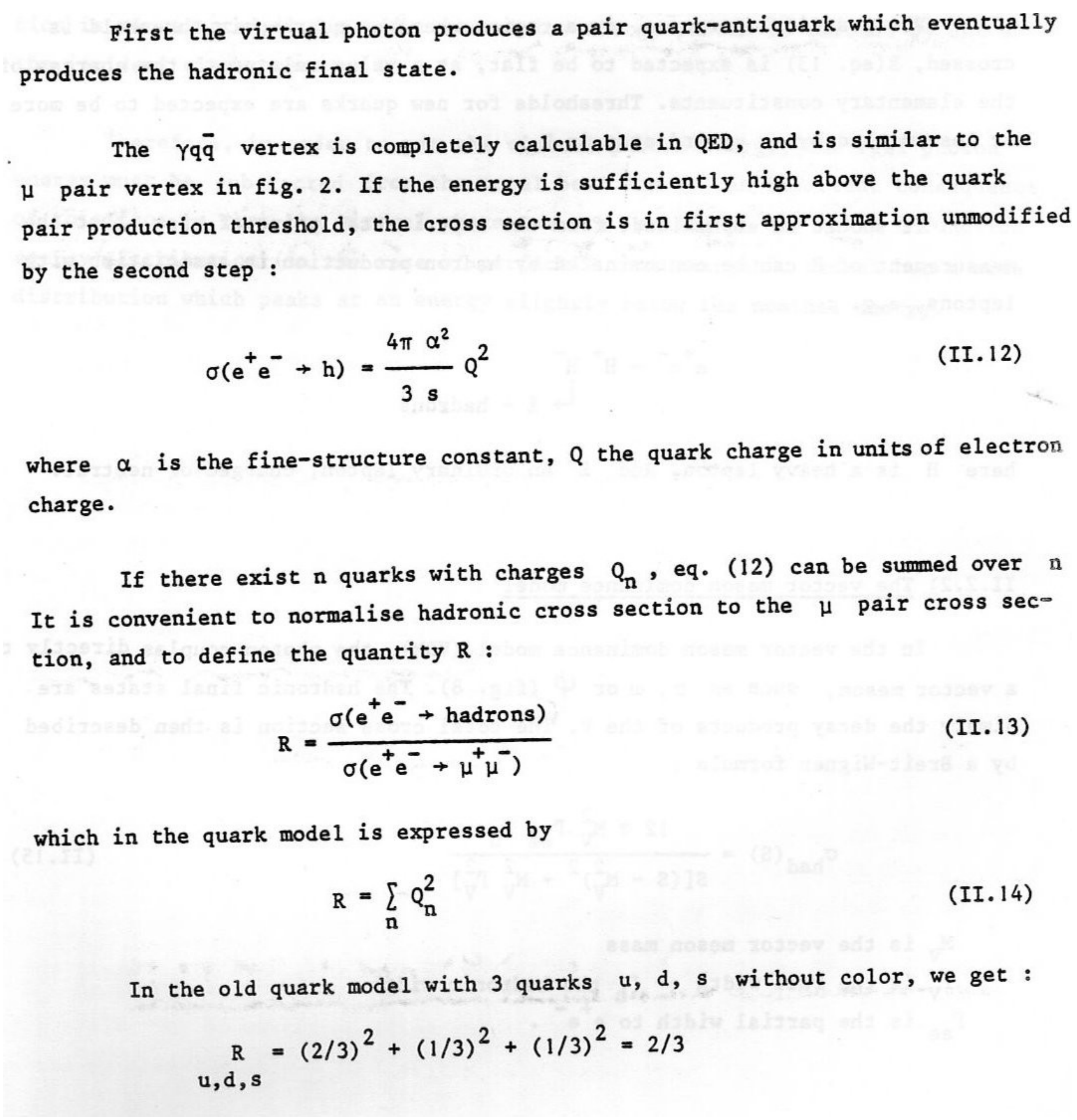
With bosons on everyone's mind as the LHC start-up approaches, it is interesting to revisit these questions and answers from 1963/64. Less than a decade after Bernardini's talk, CERN discovered neutral currents in the Gargamelle bubble chamber, in 1973. The $W^{\pm}$ and Z^0 carriers of the weak force were produced in proton–antiproton collisions at the SPS in 1983, with masses of 91 and 80 GeV/c^2, respectively, some 45–50 times the limit quoted here. Then in 1989 LEP clinched the question of how many distinct types of neutrino exist: three and only three, related to the electron, muon and τ.
- Sincere apologies to our German readers for scrambling the poem last month; please see p43 of this issue.

Un panorama de la physique au début 1974.

-modèle des quark constituants(u,d,s) ~OK
-souci spin-statistique(Δ^{++}=uuu) couleur?
-les quarks partons bien établis(DIS eN,νN, invariance d'échelle)
-la phénoménologie de Regge s'essouffle.
-Grands Pt, leptons, h
-théorie électro-faible(1967) avec GIM--> quark c(1970)
-renormalisabilité des Th. de Jauge non-abéliennes(T'Hooft, 1971)
-liberté asymptotique(1973)
-découverte des courants neutres(Gargamelle,1973)
-violation de CP: une 5$^{\text{ème}}$ force(superweak)(1)
-ch. à fils, verre au plomb, électronique, calorimètres...(Ch. à B décroissent)
-FNAL a démarré.
-le SPS est décidé, en construction.
-projets PEP, ep,...
-anomalies du rapport R=σ(e+e--->h)/σ(e+e--->μμ)
(Frascati, CEA, SPEAR/SLAC)

(1) Kobayashi-Maskawa(1973) passe assez inaperçu

R



First the virtual photon produces a pair quark-antiquark which eventually produces the hadronic final state.

The $\gamma q\bar{q}$ vertex is completely calculable in QED, and is similar to the μ pair vertex in fig. 2. If the energy is sufficiently high above the quark pair production threshold, the cross section is in first approximation unmodified by the second step :

$$\sigma(e^+e^- \to h) = \frac{4\pi\ \alpha^2}{3\ s} Q^2 \tag{II.12}$$

where α is the fine-structure constant, Q the quark charge in units of electron charge.

If there exist n quarks with charges Q_n , eq. (12) can be summed over n It is convenient to normalise hadronic cross section to the μ pair cross section, and to define the quantity R :

$$R = \frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)} \tag{II.13}$$

which in the quark model is expressed by

$$R = \sum_n Q_n^2 \tag{II.14}$$

In the old quark model with 3 quarks u, d, s without color, we get :

$$R_{u,d,s} = (2/3)^2 + (1/3)^2 + (1/3)^2 = 2/3$$

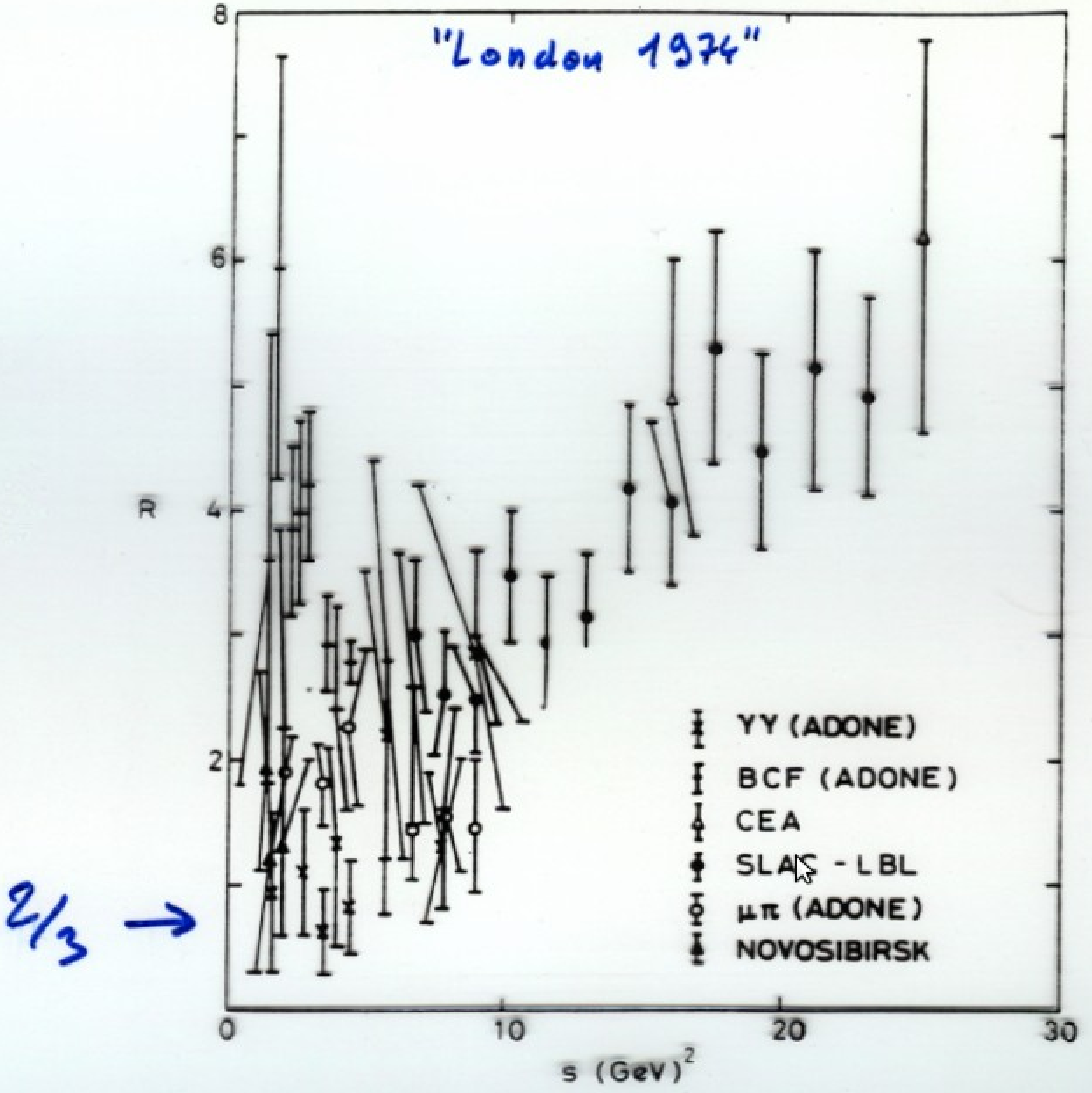
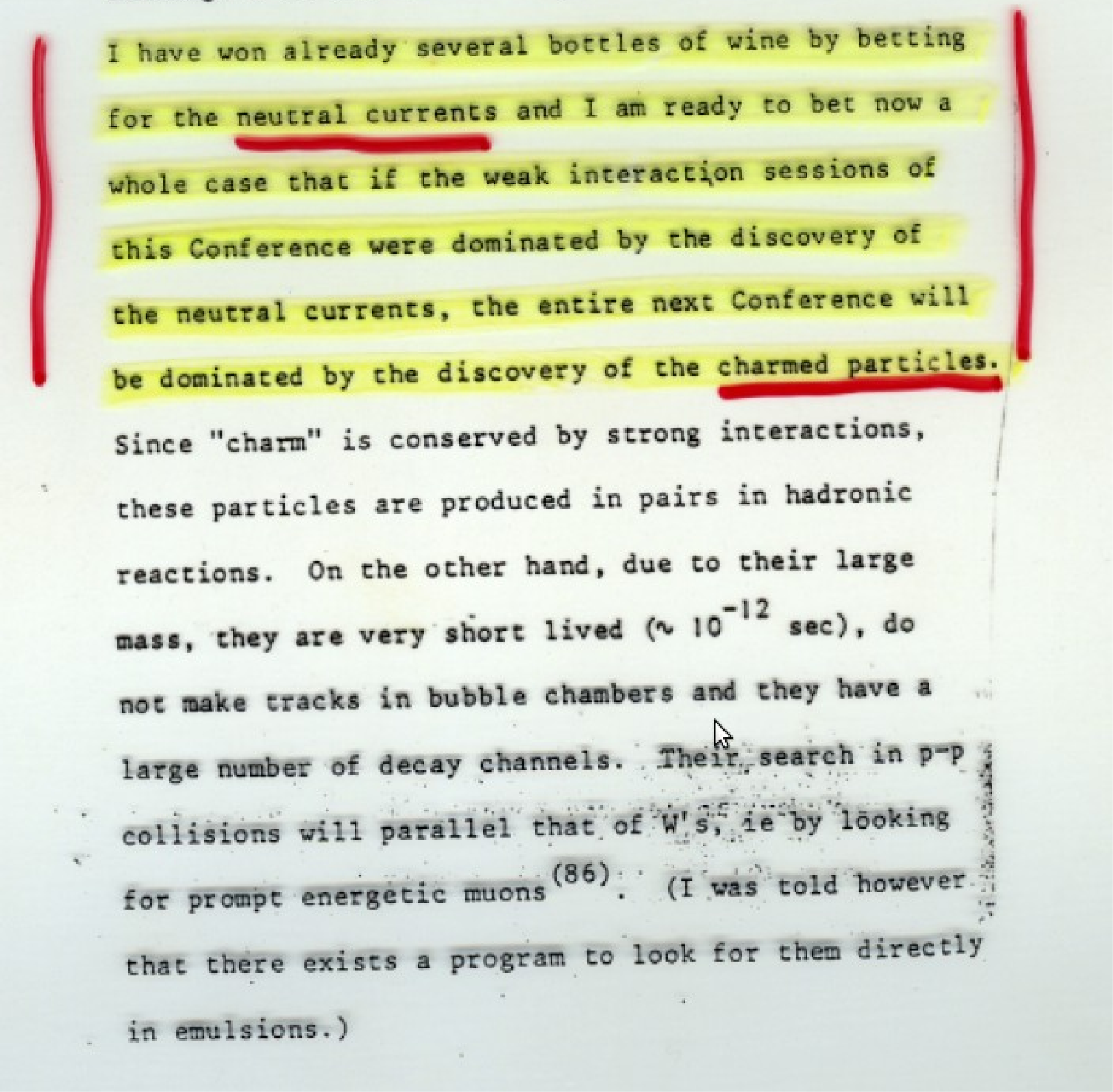


Fig. 4. All measurements of the ratio of σ_{TOT} to $\sigma_{\mu\mu}$ vs S, for S ≥ 1.5 (GeV)^2.

J. Iliopoulos Londres 74

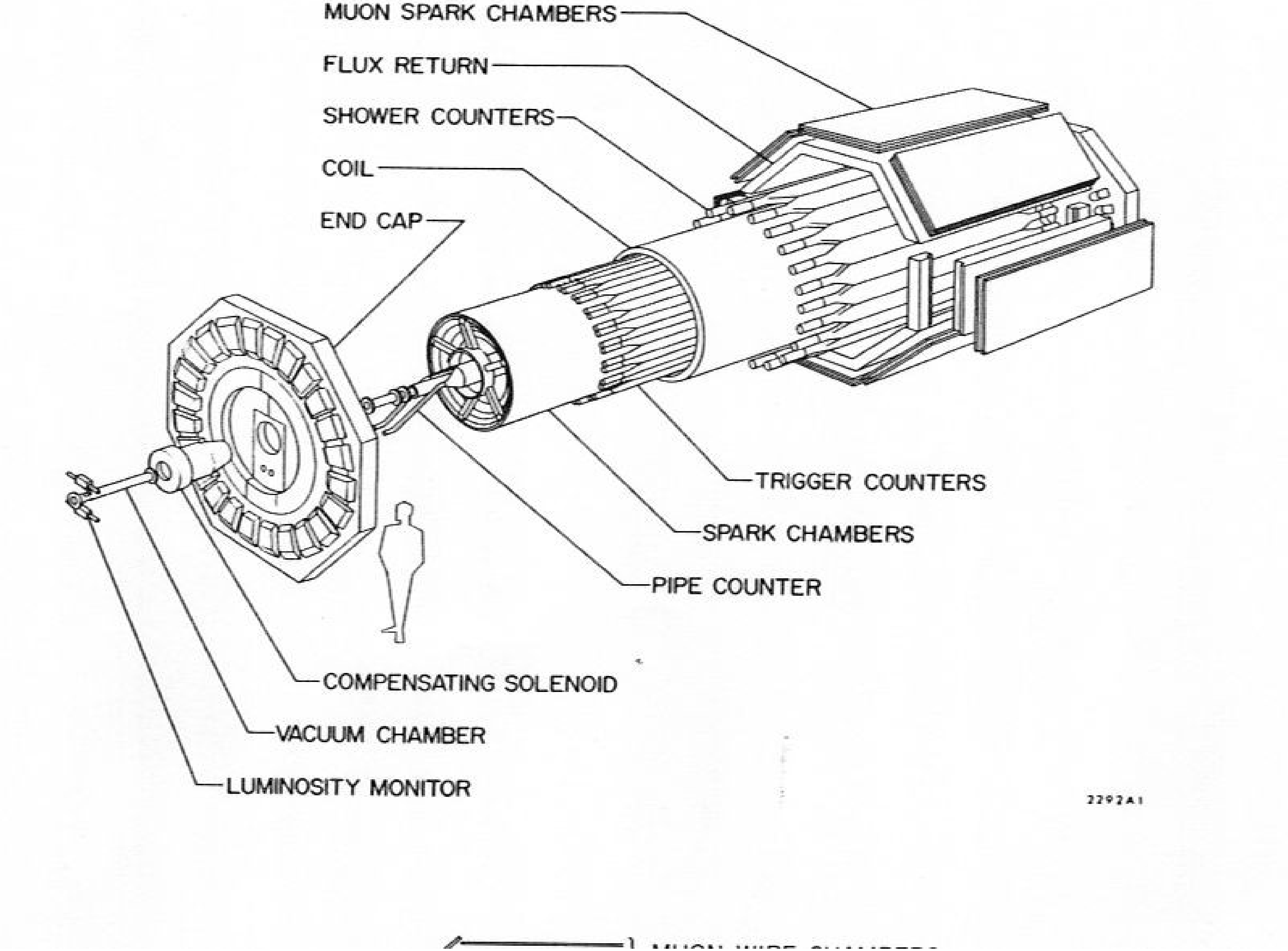
changing neutral currents of the form $K^0 \to \mu^+\mu^-$ or $K^+ \to \pi^+ \nu\bar{\nu}$, etc. It follows that the traditional SU(3) scheme is incompatible with the kind of theories we are discussing$^{(84)}$. The enlargement of the symmetry can go in different directions and from that point the predictions will depend on the particular model. In any case, new, as yet unobserved, hadronic states carrying new quantum numbers, are predicted. Their masses cannot be arbitrarily large$^{(85)}$ ($\sim$5 GeV is a reasonable guess) and although it is perfectly conceivable that they have escaped detection until now, their discovery, if they are there, is possible. I consider this prediction as the most crucial test of these ideas.

I will call these states collectively "charmed", although I do not restrict myself to the SU(4) model.

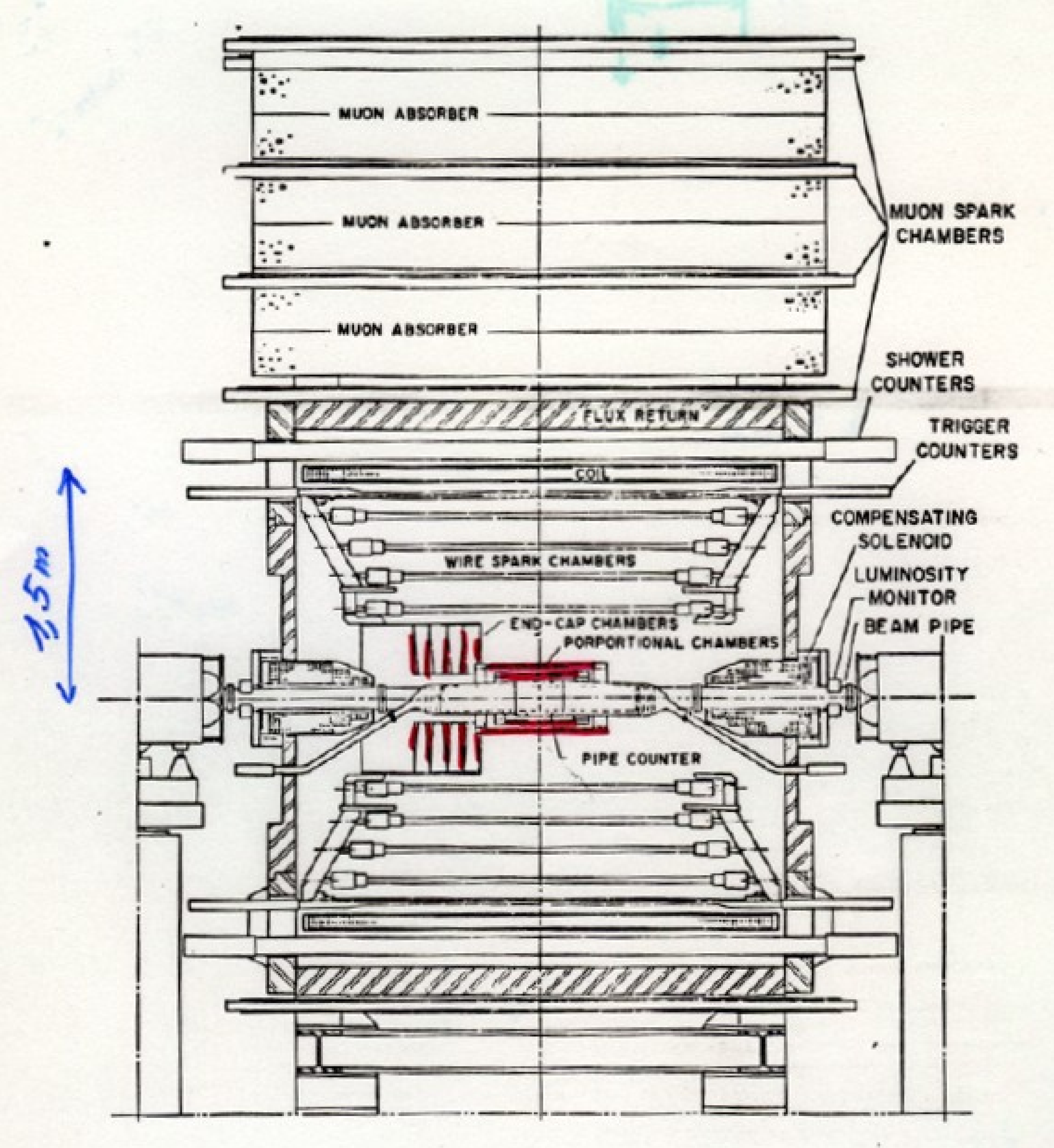


I have won already several bottles of wine by betting for the neutral currents and I am ready to bet now a whole case that if the weak interaction sessions of this Conference were dominated by the discovery of the neutral currents, the entire next Conference will be dominated by the discovery of the charmed particles. Since "charm" is conserved by strong interactions, these particles are produced in pairs in hadronic reactions. On the other hand, due to their large mass, they are very short lived ($\sim 10^{-12}$ sec), do not make tracks in bubble chambers and they have a large number of decay channels. Their search in p-p collisions will parallel that of W's, ie by looking for prompt energetic muons(86). (I was told however that there exists a program to look for them directly in emulsions.)

le détecteur magnétique SLAC/LBL au collisionneur SPEAR



Collaboration : ~ 35 physiciens, énorme pour l'époque.


MUON ABSORBER
MUON ABSORBER
MUON ABSORBER
MUON SPARK CHAMBERS
SHOWER COUNTERS
FLUX RETURN
TRIGGER COUNTERS
COIL
COMPENSATING SOLENOID
WIRE SPARK CHAMBERS
LUMINOSITY MONITOR
BEAM PIPE
END-CAP CHAMBERS
PORPORTIONAL CHAMBERS
PIPE COUNTER
≈ 5 m

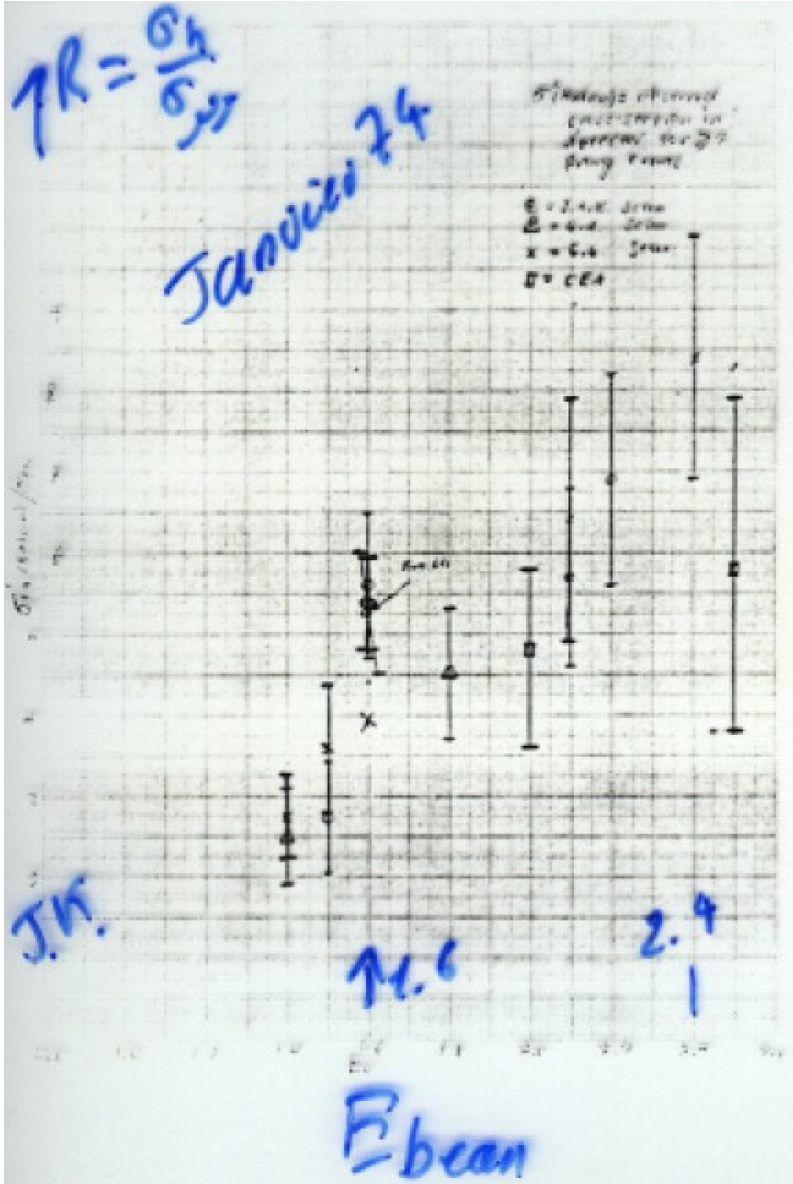


Fig. 3. *Preliminary results of cross-section determinations based on individual independent visual scans of the data at the indicated incident energies per beam. Errors shown are statistical only. The ordinate is R = σhadron/ σ(μμ) where σ(μμ) is calculated from quantum electrodynamics. σhadron was an 'operational definition' of the cross section based on observation of events of three or more prongs. [From notebook of John Kadyk, January, 1974.]*

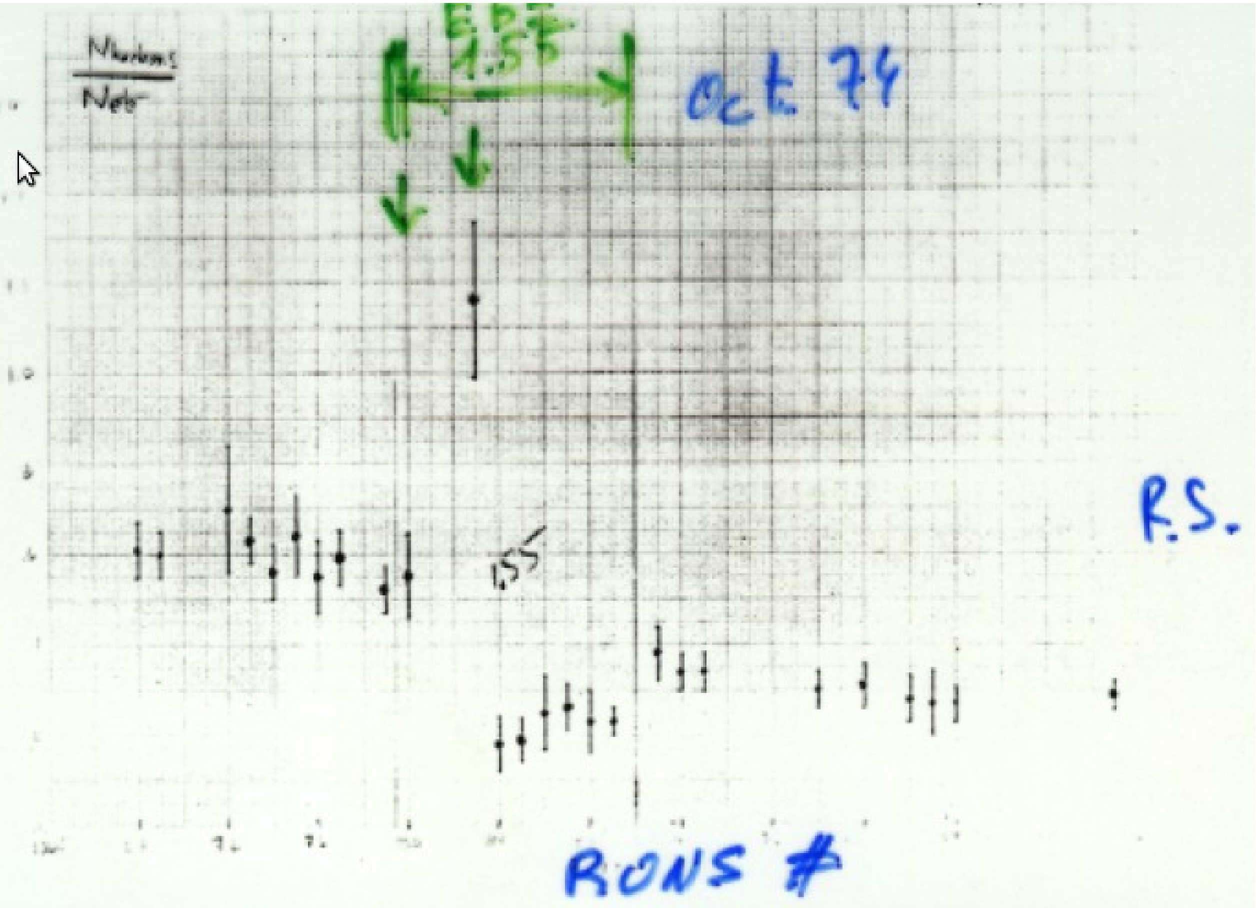
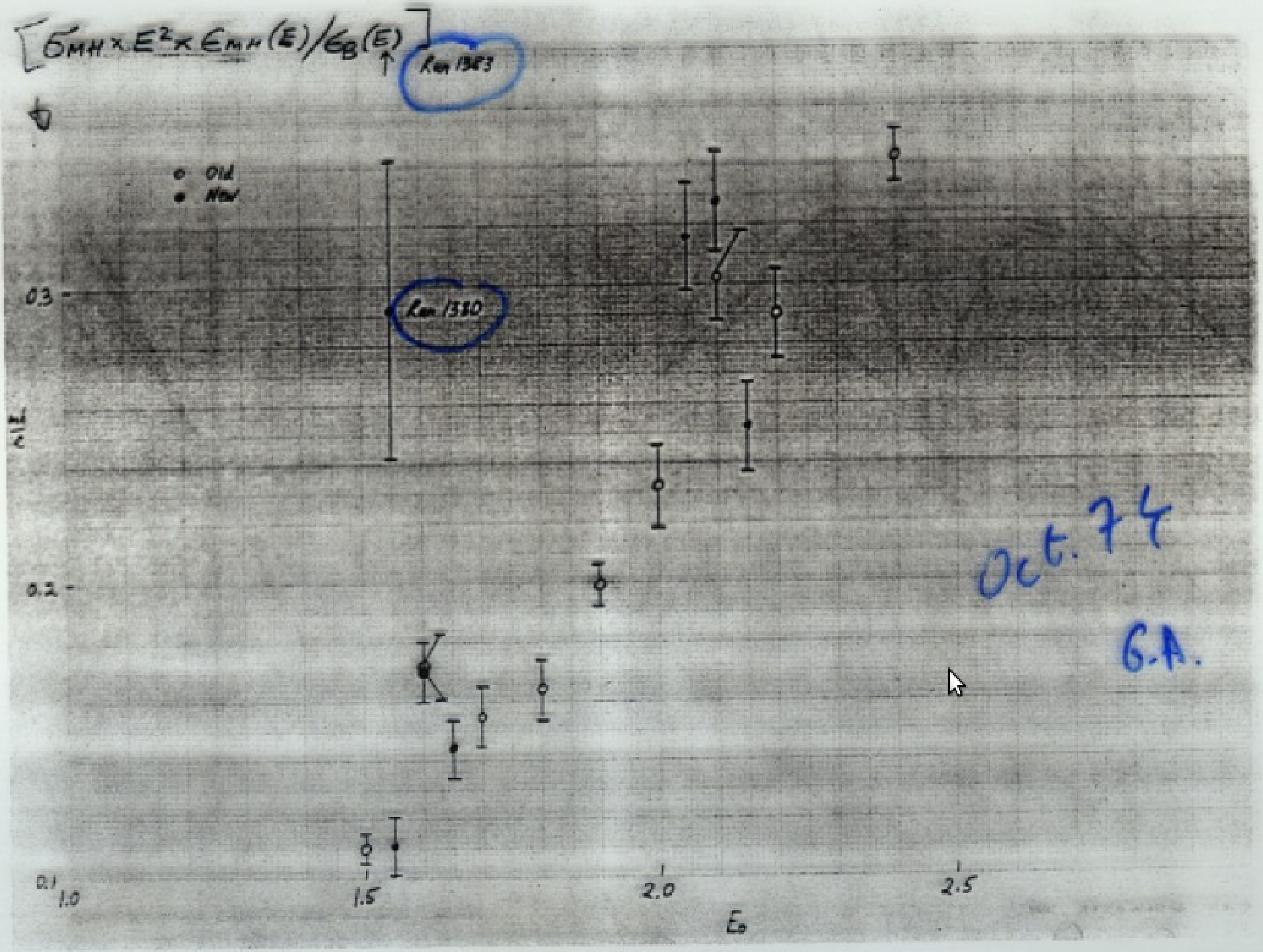


Fig. 4. *Cross section plotted as a function of run number. Runs 1380 through 1389 were at the nominal energy of 1.55 GeV per beam. As can be seen, runs 1380 and 1383 gave values for the cross section clearly higher than the other six runs at the same energy. These eight values of the cross section should not be compared directly with the other runs shown which were made at a different energy. [From notebook of Roy Schwitters, October, 1974.]*



Oct. 74

G.A.

Fig. 5 A quantity related to $R = \sigma'_{hadron}/\sigma(\mu\mu)$ is plotted as a function of beam energy. Runs 1380 and 1383 (off

Interprétation possible de ces runs anormaux:
1) il y a une résonance relativement étroite
2) les points bas sont en dessous de la résonance, les points hauts au-dessus, car l'énergie de SPEAR n'est pas contrôlée à quelques MeV près.

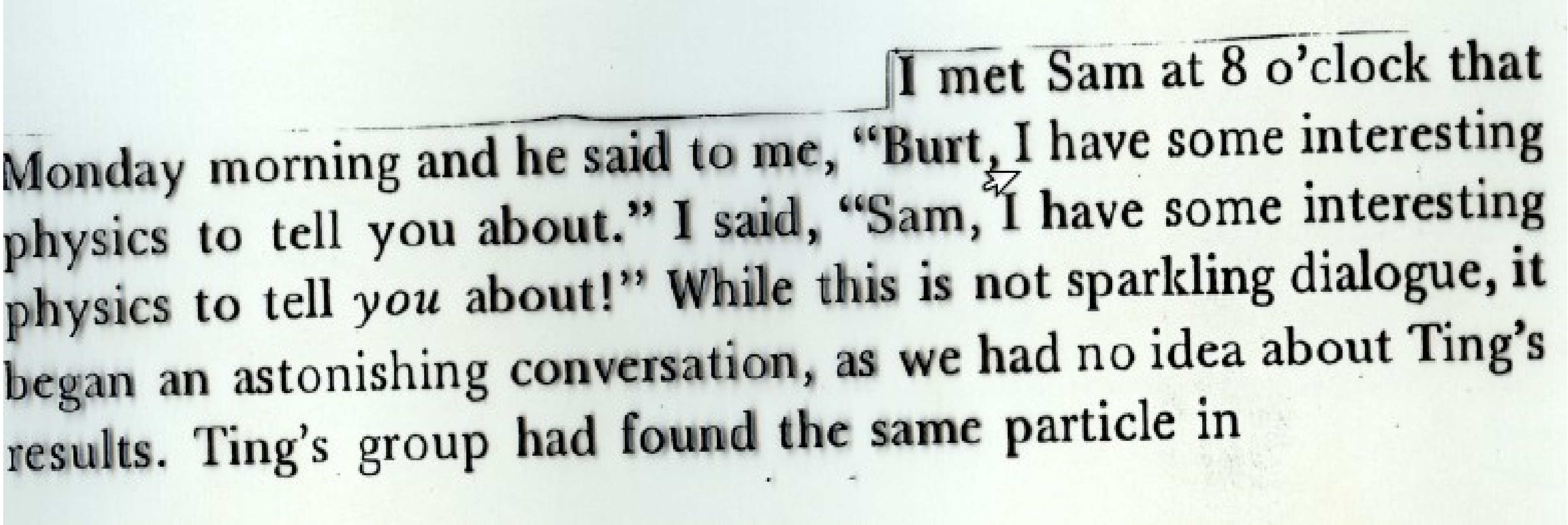
La semaine, SPEAR est pris par le développement machine pour la future montée en énergie, le week-end, c'est pour la physique.

...ainsi on arrive au samedi 9 novembre 74.

Scan durant la nuit : au matin, la résonance est bien là, ~90nb au dessus du fond de ~25 nb.

L'après-midi, 1600 nb!

Lundi 11 novembre 74, B.Richter rencontre S.Ting:



I met Sam at 8 o'clock that Monday morning and he said to me, "Burt, I have some interesting physics to tell you about." I said, "Sam, I have some interesting physics to tell *you* about!" While this is not sparkling dialogue, it began an astonishing conversation, as we had no idea about Ting's results. Ting's group had found the same particle in

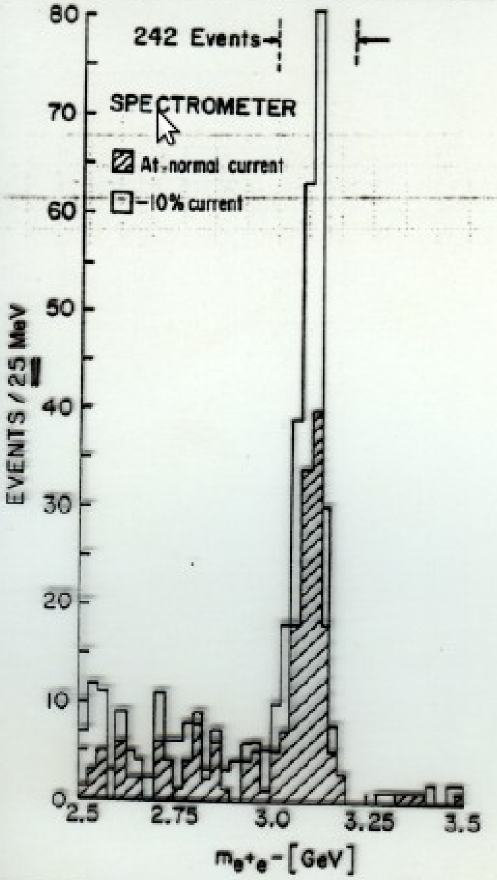
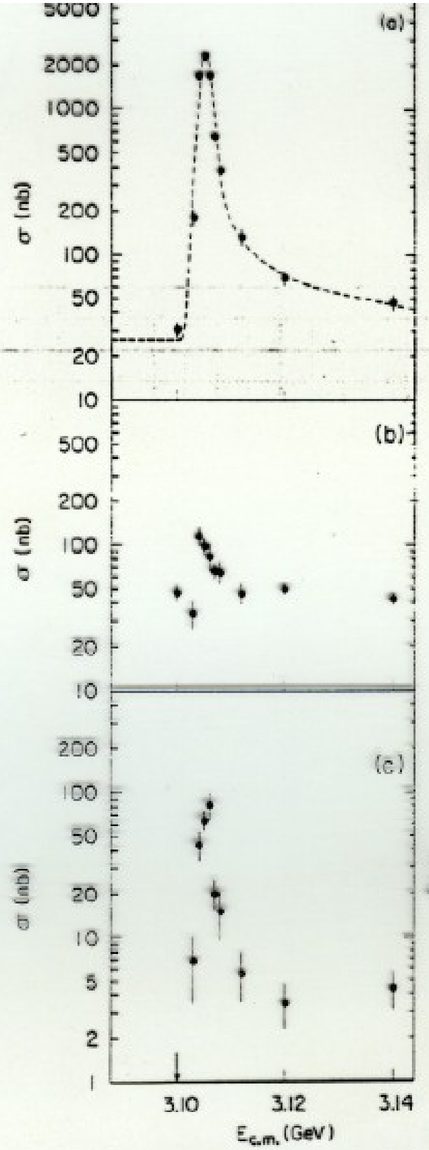


FIG. 2. Mass spectrum showing the existence of *J*. Results from two spectrometer settings are plotted showing that the peak is independent of spectrometer currents. The run at reduced current was taken two months later than the normal run.

$p + Be \rightarrow e^+e^- + \ldots$



hadrons

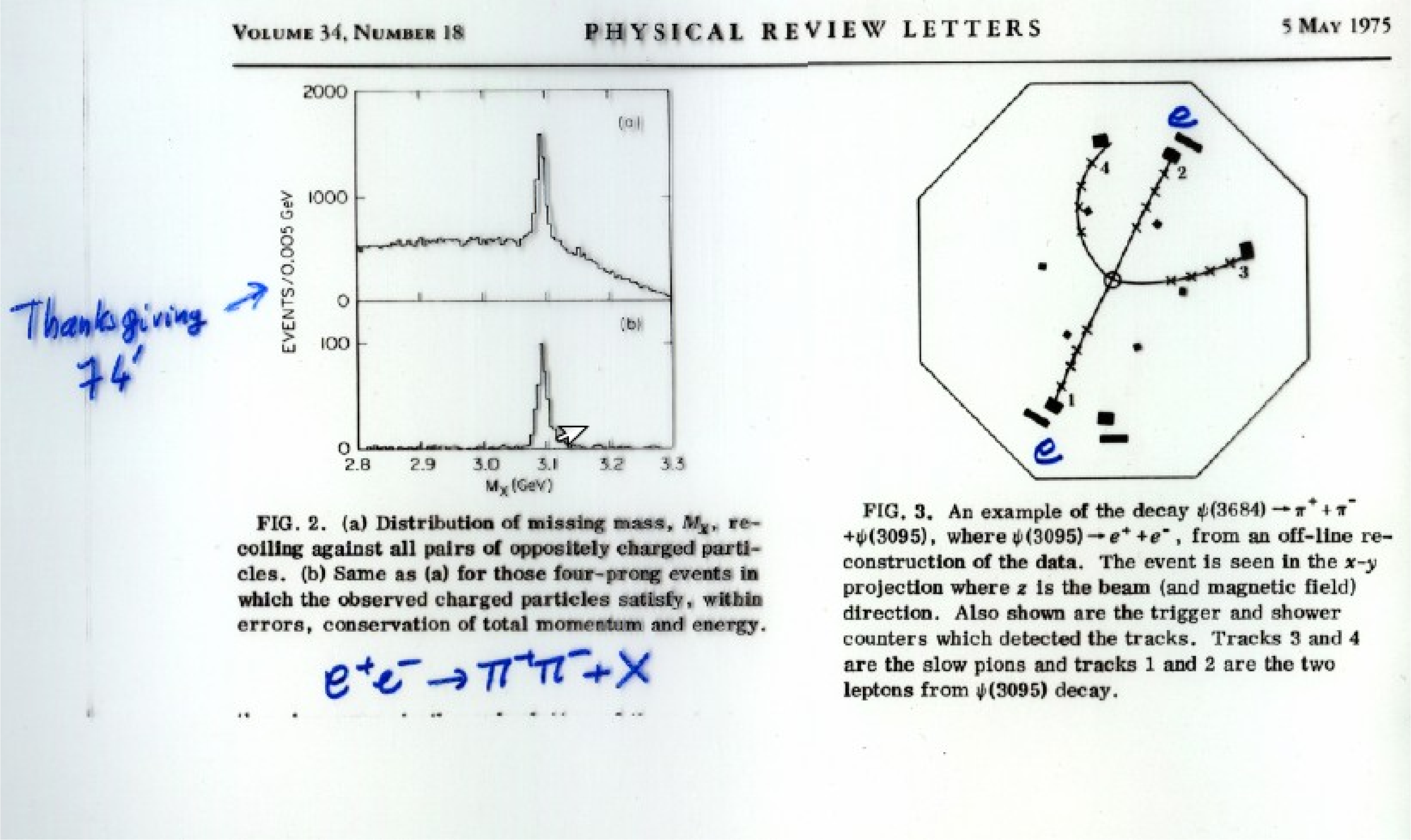
e^+e^-

$\mu^+\mu^-$

FIG. 1. Cross section versus energy for (a) multihadron final states, (b) e^+e^- final states, and (c) $\mu^+\mu^-$, $\pi^+\pi^-$, and K^+K^- final states. The curve in (a) is the expected shape of a δ-function resonance folded with the Gaussian energy spread of the beams and including radiative processes. The cross sections shown in (b) and (c) are integrated over the detector acceptance. The total hadron cross section, (a), has been corrected for detection efficiency.

$$e^+e^- \rightarrow \begin{cases} \text{hadrons} \\ e^+e^- \\ \mu^+\mu^- \end{cases}$$

PROPRIÉTÉS DES NOUVELLES PARTICULES



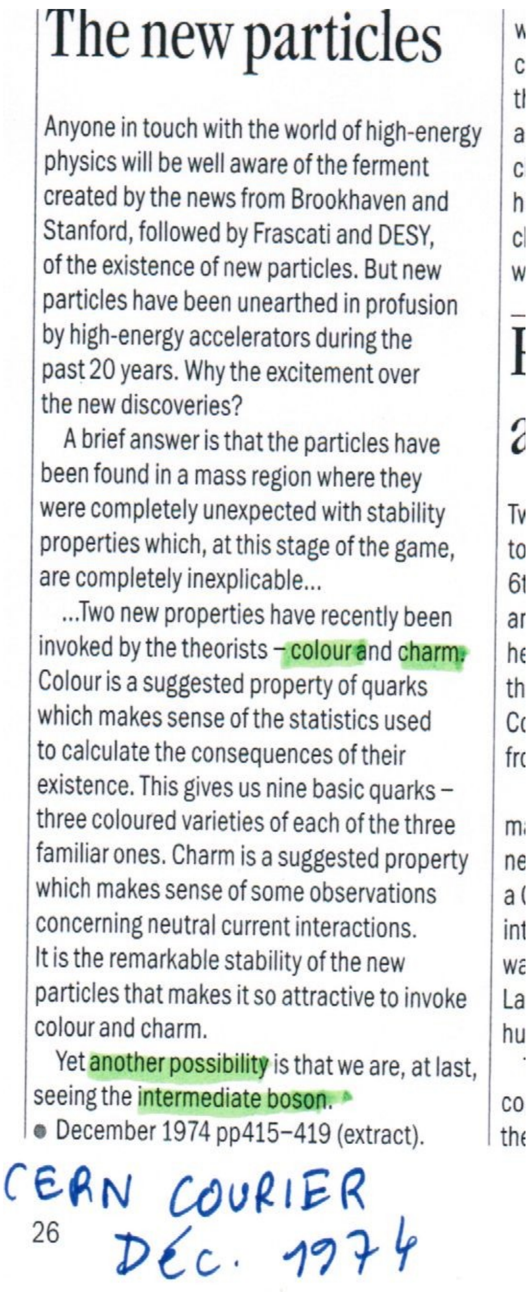
VOLUME 34, NUMBER 18 PHYSICAL REVIEW LETTERS 5 MAY 1975

Thanksgiving 74'

FIG. 2. (a) Distribution of missing mass, M_X, recoiling against all pairs of oppositely charged particles. (b) Same as (a) for those four-prong events in which the observed charged particles satisfy, within errors, conservation of total momentum and energy.

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

FIG. 3. An example of the decay $\psi(3684) \to \pi^+ + \pi^- + \psi(3095)$, where $\psi(3095) \to e^+ + e^-$, from an off-line reconstruction of the data. The event is seen in the x-y projection where z is the beam (and magnetic field) direction. Also shown are the trigger and shower counters which detected the tracks. Tracks 3 and 4 are the slow pions and tracks 1 and 2 are the two leptons from $\psi(3095)$ decay.



The new particles

Anyone in touch with the world of high-energy physics will be well aware of the ferment created by the news from Brookhaven and Stanford, followed by Frascati and DESY, of the existence of new particles. But new particles have been unearthed in profusion by high-energy accelerators during the past 20 years. Why the excitement over the new discoveries?

A brief answer is that the particles have been found in a mass region where they were completely unexpected with stability properties which, at this stage of the game, are completely inexplicable...

...Two new properties have recently been invoked by the theorists – colour and charm. Colour is a suggested property of quarks which makes sense of the statistics used to calculate the consequences of their existence. This gives us nine basic quarks – three coloured varieties of each of the three familiar ones. Charm is a suggested property which makes sense of some observations concerning neutral current interactions. It is the remarkable stability of the new particles that makes it so attractive to invoke colour and charm.

Yet another possibility is that we are, at last, seeing the intermediate boson.

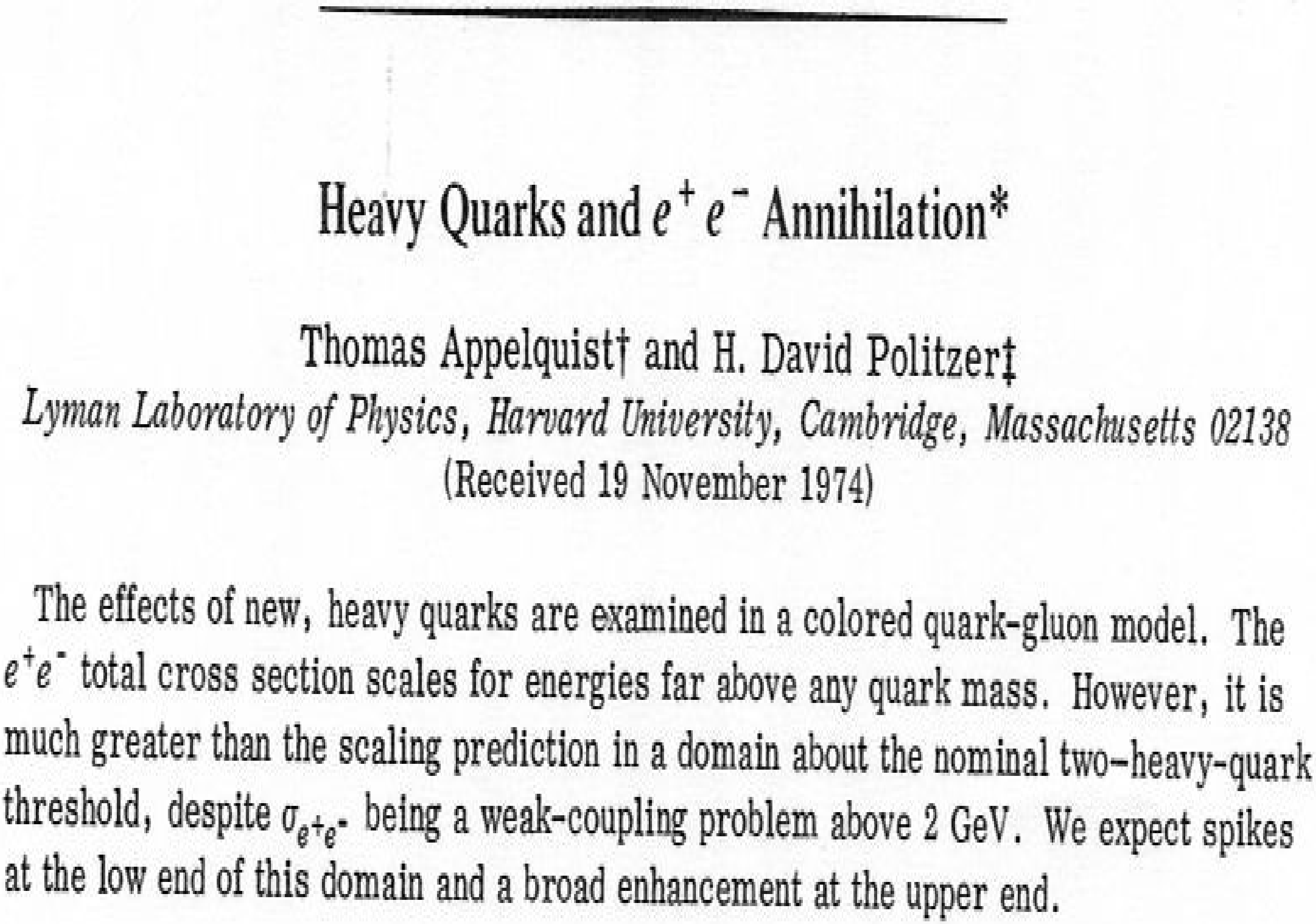
- December 1974 pp415–419 (extract).

CERN COURIER

26

DÉC. 1974

Pourquoi J/Ψ et Ψ' sont-ils si étroits?

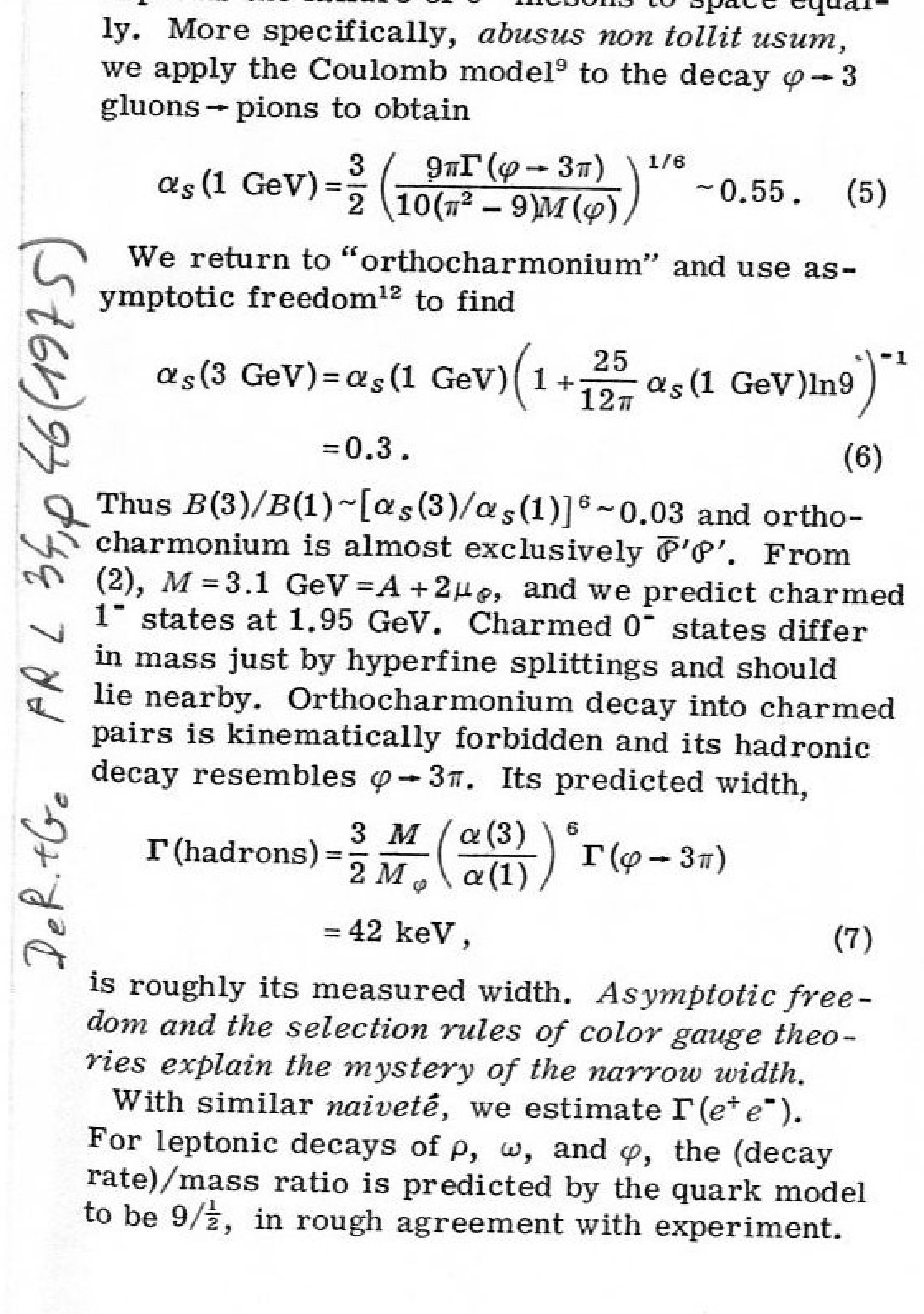


Heavy Quarks and e^+e^- Annihilation*

Thomas Appelquist† and H. David Politzer‡
Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts 02138

(Received 19 November 1974)

The effects of new, heavy quarks are examined in a colored quark-gluon model. The e^+e^- total cross section scales for energies far above any quark mass. However, it is much greater than the scaling prediction in a domain about the nominal two-heavy-quark threshold, despite $\sigma_{e^+e^-}$ being a weak-coupling problem above 2 GeV. We expect spikes at the low end of this domain and a broad enhancement at the upper end.



ly. More specifically, *abusus non tollit usum*, we apply the Coulomb model[9] to the decay $\varphi \to 3$ gluons $\to$ pions to obtain

$$\alpha_S(1\ \text{GeV}) = \frac{3}{2}\left(\frac{9\pi\Gamma(\varphi\to 3\pi)}{10(\pi^2-9)M(\varphi)}\right)^{1/6} \sim 0.55. \qquad (5)$$

We return to "orthocharmonium" and use asymptotic freedom[12] to find

$$\alpha_S(3\ \text{GeV}) = \alpha_S(1\ \text{GeV})\left(1+\frac{25}{12\pi}\alpha_S(1\ \text{GeV})\ln 9\right)^{-1}$$
$$= 0.3. \qquad (6)$$

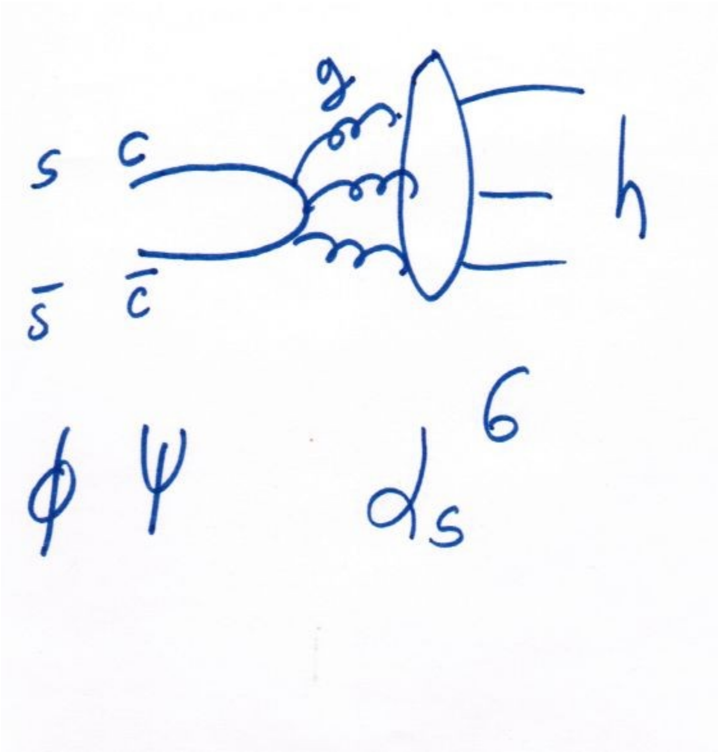
Thus $B(3)/B(1) \sim [\alpha_S(3)/\alpha_S(1)]^6 \sim 0.03$ and orthocharmonium is almost exclusively $\overline{\mathcal{P}}'\mathcal{P}'$. From (2), $M = 3.1\ \text{GeV} = A + 2\mu_{\varphi}$, and we predict charmed 1^- states at 1.95 GeV. Charmed 0^- states differ in mass just by hyperfine splittings and should lie nearby. Orthocharmonium decay into charmed pairs is kinematically forbidden and its hadronic decay resembles $\varphi \to 3\pi$. Its predicted width,

$$\Gamma(\text{hadrons}) = \frac{3}{2}\frac{M}{M_{\varphi}}\left(\frac{\alpha(3)}{\alpha(1)}\right)^6 \Gamma(\varphi\to 3\pi)$$
$$= 42\ \text{keV}, \qquad (7)$$

is roughly its measured width. *Asymptotic freedom and the selection rules of color gauge theories explain the mystery of the narrow width.*

With similar *naiveté*, we estimate $\Gamma(e^+e^-)$. For leptonic decays of ρ, ω, and φ, the (decay rate)/mass ratio is predicted by the quark model to be $9/\frac{1}{2}$, in rough agreement with experiment.

DeR. + Go PRL 34, p 46 (1975)



Le modèle du charme.

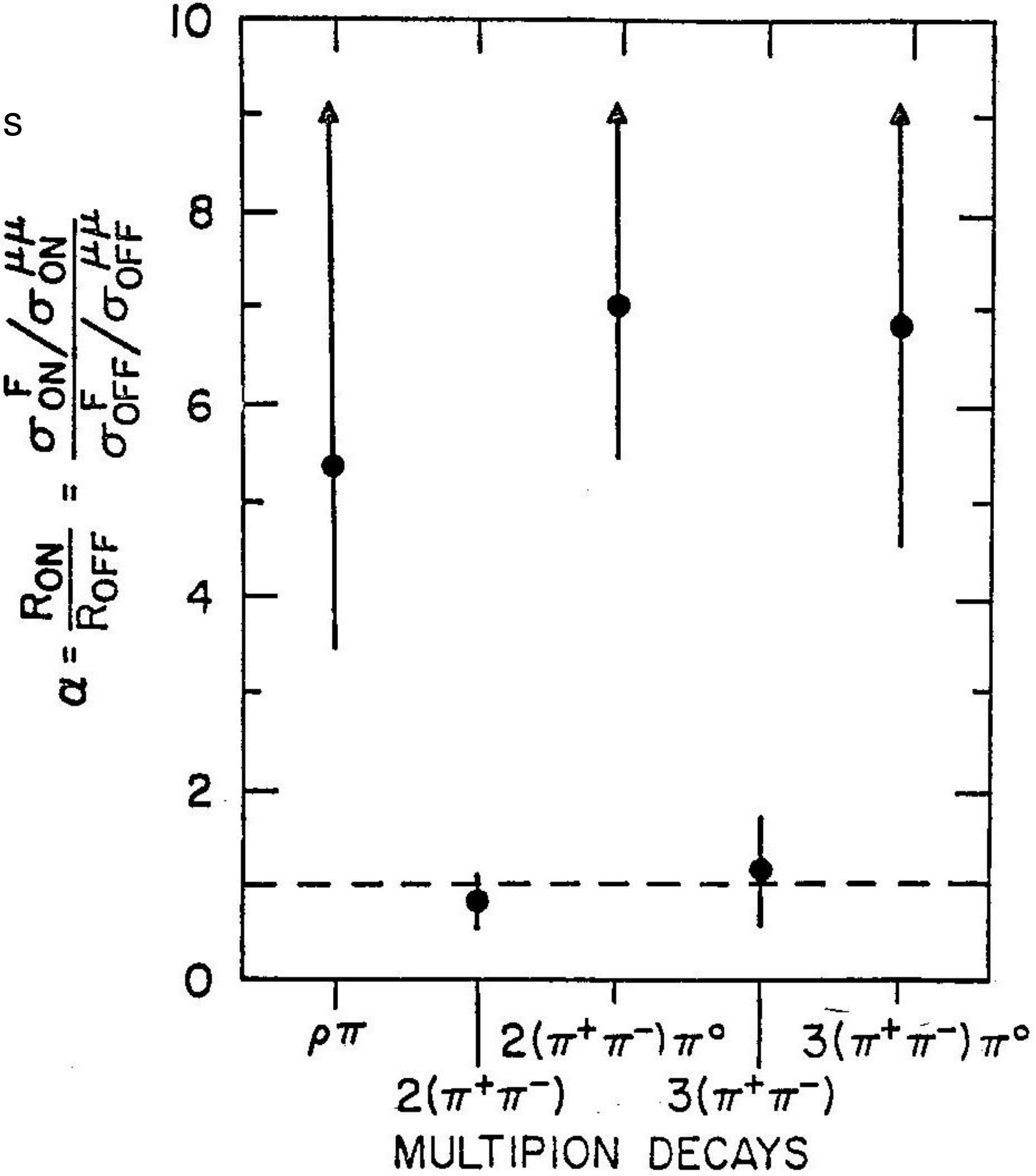
-charme nu:
    *états Knπ
    *leptons
    *kaons inclusifs
    *coïnc. K lepton
    *violation de parité(dés.faibles)
    *traces courtes(dés. Faibles)
    *ΔS = -ΔQ en exp. Neutrinos
    *dileptons en exp. Neutrinos
-charmonium: singulet SU(3) saveur
    *isosinglet
    *G -
    *états intermédiaires du charmonium
...

PROPRIÉTÉS DES NOUVELLES PARTICULES

ON: à la résonance
OFF: juste en dessous

La G-parité
est bien -, comme
attendu de
singulet de
SU(2)

B.Jean-Marie et al,



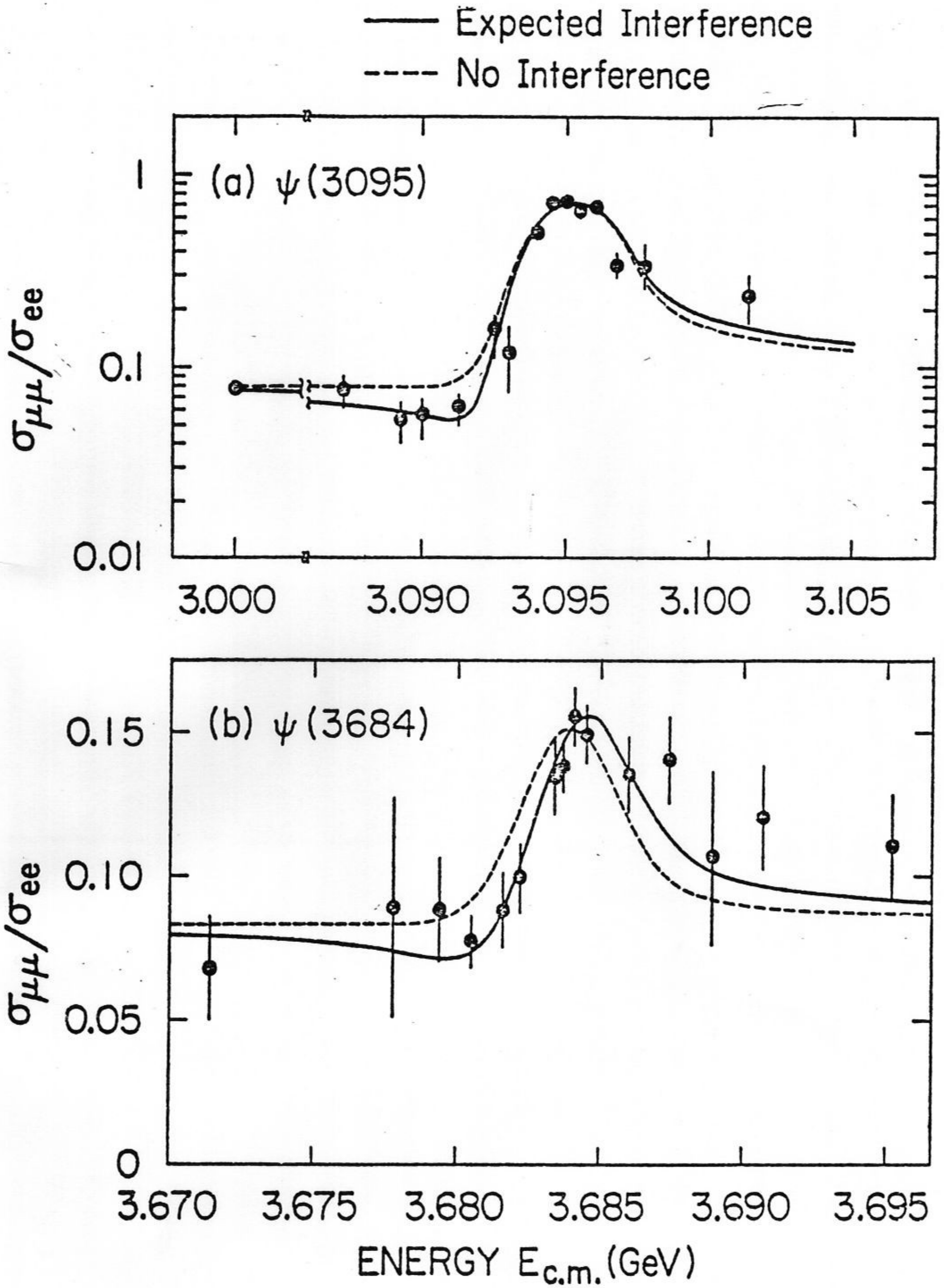
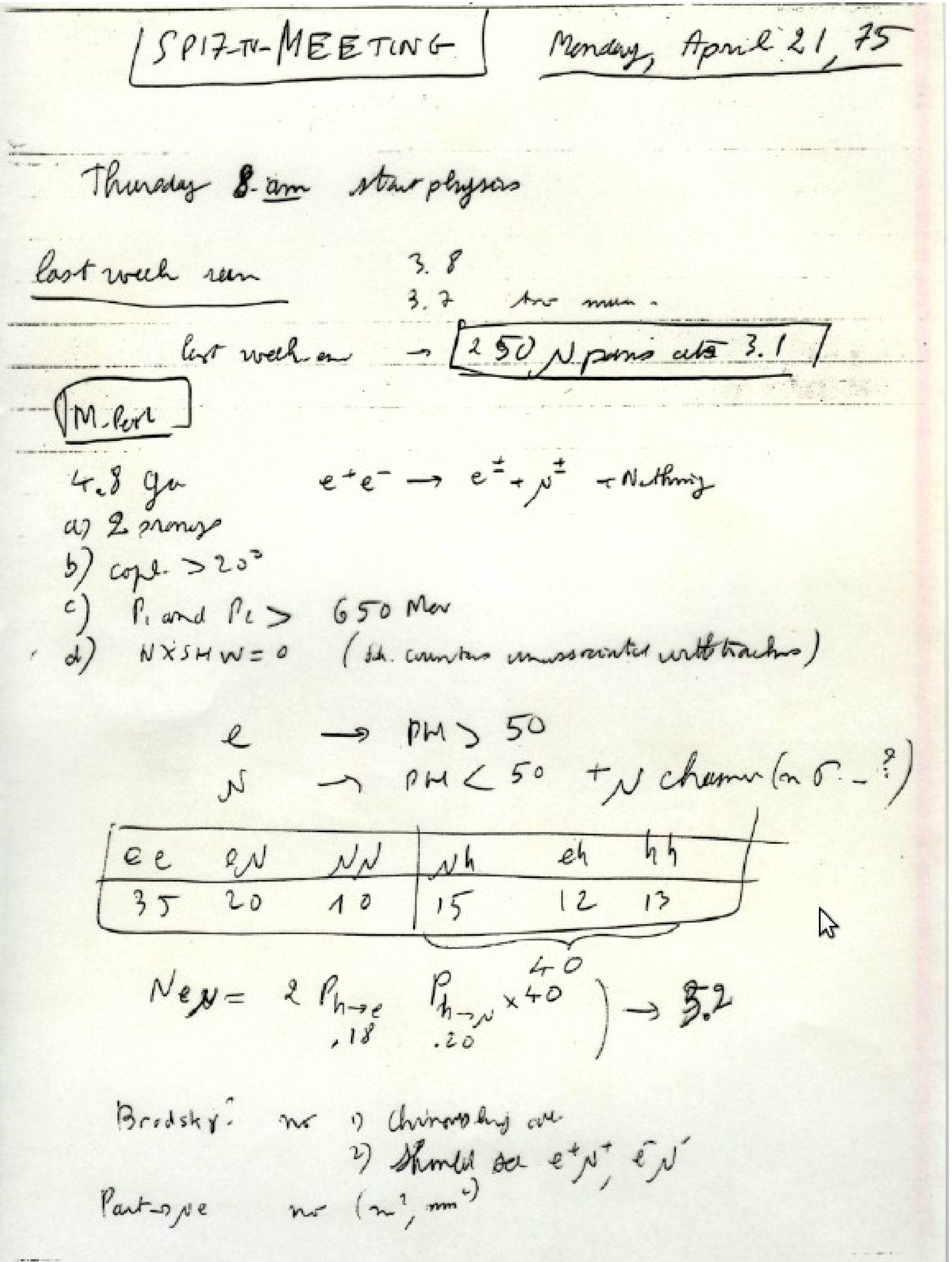

Expected Interference
No Interference
(a) ψ(3095)
$\sigma_{\mu\mu}/\sigma_{ee}$
1
0.1
0.01
3.000
3.090
3.095
3.100
3.105
(b) ψ(3684)
$\sigma_{\mu\mu}/\sigma_{ee}$
0.15
0.10
0.05
0
3.670
3.675
3.680
3.685
3.690
3.695
ENERGY $E_{c.m.}$ (GeV)

Fig. 21

...et dans le monde entier, la chasse au charme nu est lancée tous azimuths, et bien sûr à SPEAR!

INTERLUDE :
les événements e-μ



SP17-IV-MEETING

Monday, April 21, 75

Thursday 8-am start physics

last week run 3.8
3.7 two mun.

last week on → 250 μ pairs at 3.1

M. Perl

4.8 Gev $e^+e^- \rightarrow e^{\pm} + \mu^{\pm}$ + Nothing

a) 2 prongs
b) copl. > 20°
c) P_1 and P_2 > 650 Mev
d) NXSHW = 0 (sh. counters unassociated with tracks)

e → PH > 50
μ → PH < 50 + μ chamber (on 0 - ?)

ee	eμ	μμ	μh	eh	hh
35	20	10	15	12	13

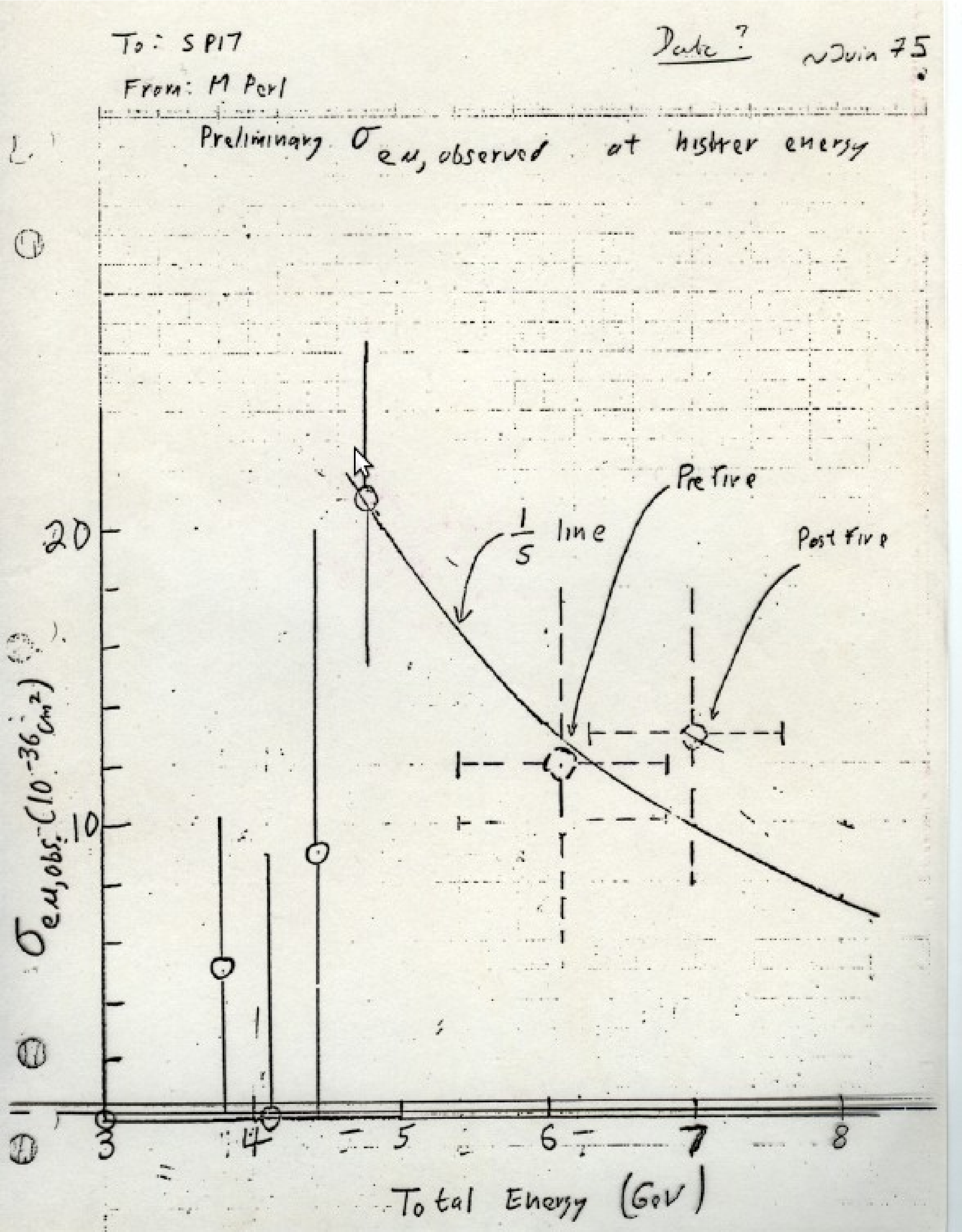
40

$$N_{e\mu} = 2 \underset{.18}{P_{h\rightarrow e}} \underset{.20}{P_{h\rightarrow \mu}} \times 40) \rightarrow 3.2$$

Brodsky: no 1) [illegible]
2) Should see $e^+\mu^+$, $e^-\mu^-$

Part-spe no (m^2, mm^2)

19



To: SP17

From: M Perl

Date ? ~Juin 75

Preliminary $\sigma_{e\mu}$, observed at higher energy

INTERLUDE :
découvertes des jets;
et ils viennent de spin 1/2

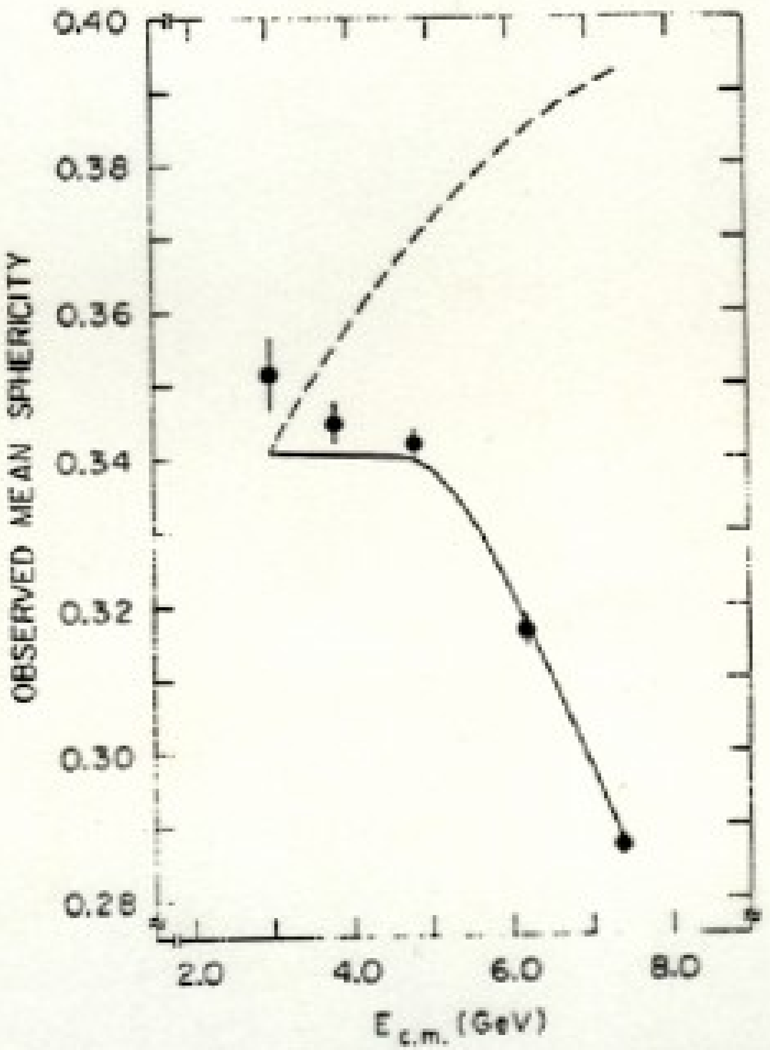


FIG. 1. Observed mean sphericity versus center-of-mass energy $E_{c.m.}$ for data, jet model with $\langle p_\perp \rangle = 315$ MeV/c (solid curve), and phase-space model (dashed curve).

1^{ére} application de
la polarisation naturelle
des faisceaux en collisionneurs
e+e-

(avant les mesures de masses
Y et Z.)

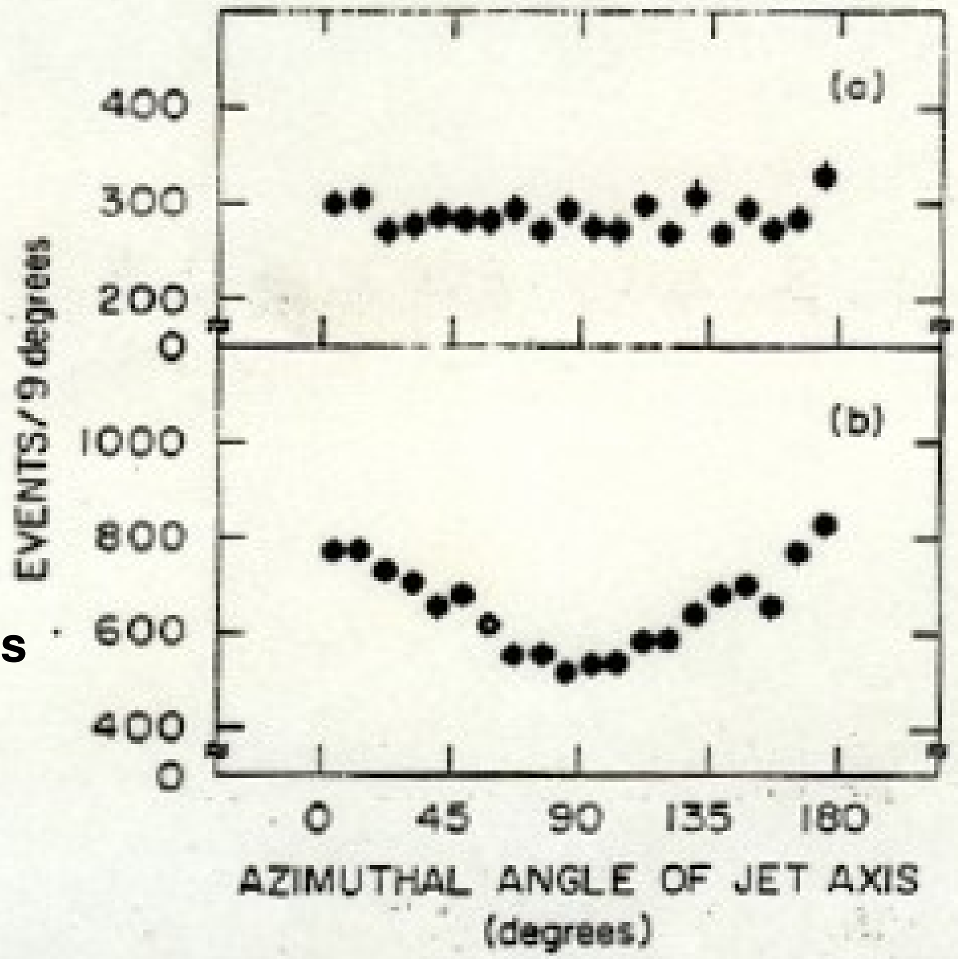


FIG. 3. Observed distributions of jet-axis azimuthal angles from the plane of the storage ring for jet axes with $|\cos\theta| \leq 0.6$ for (a) $E_{c.m.} = 6.2$ GeV and (b) $E_{c.m.} = 7.4$ GeV.

Retour au charme

Été 75

Ψ"(3.77)   manqué

Between these two regions in R, there is a very complicated transition region with indications of a richness of structure that we are only beginning to resolve.

A more detailed view of R in the 4 GeV region is presented in Fig. 9. The new and more extensive preliminary results (closed points) have a different impression

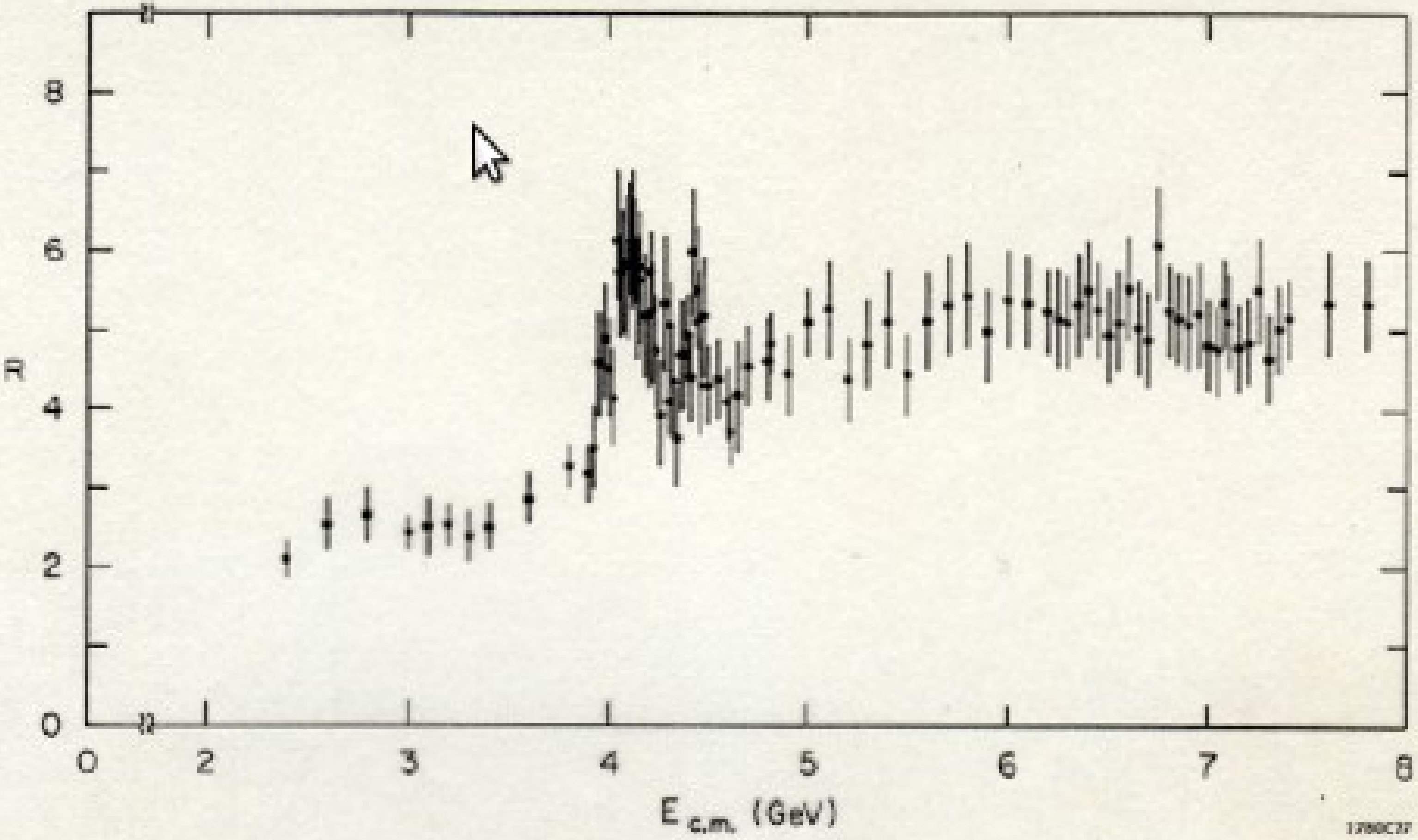


Fig. 8--R versus $E_{c.m.}$ in coarse steps. Combination of published results[13] and new preliminary results from SLAC/LBL collaboration.

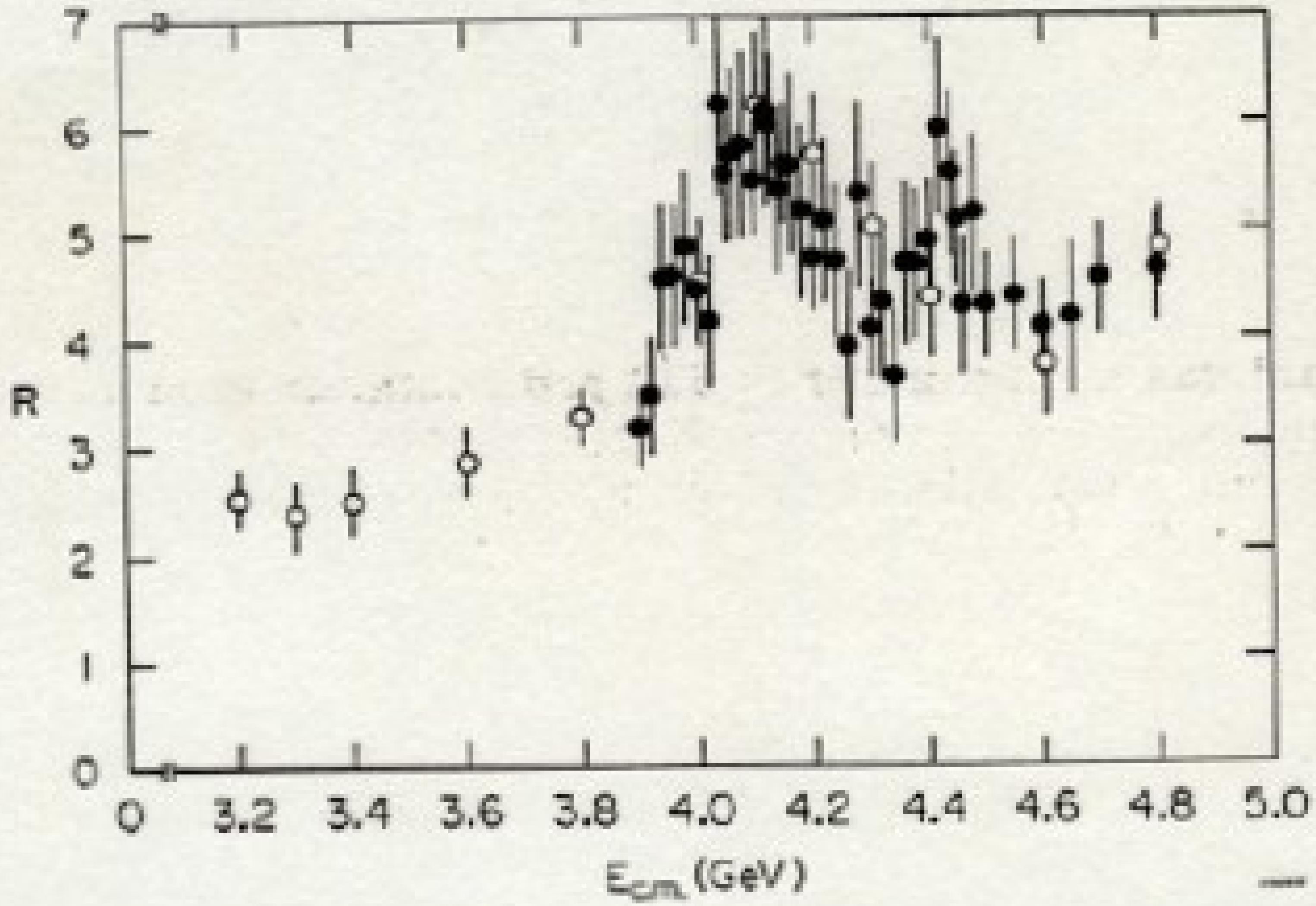


Fig. 9--R versus $E_{c.m.}$ in the 4 GeV region. Open points are from Ref. 13, closed points are new preliminary results.

K+- exclusifs

~été 75

G.Hanson et al,

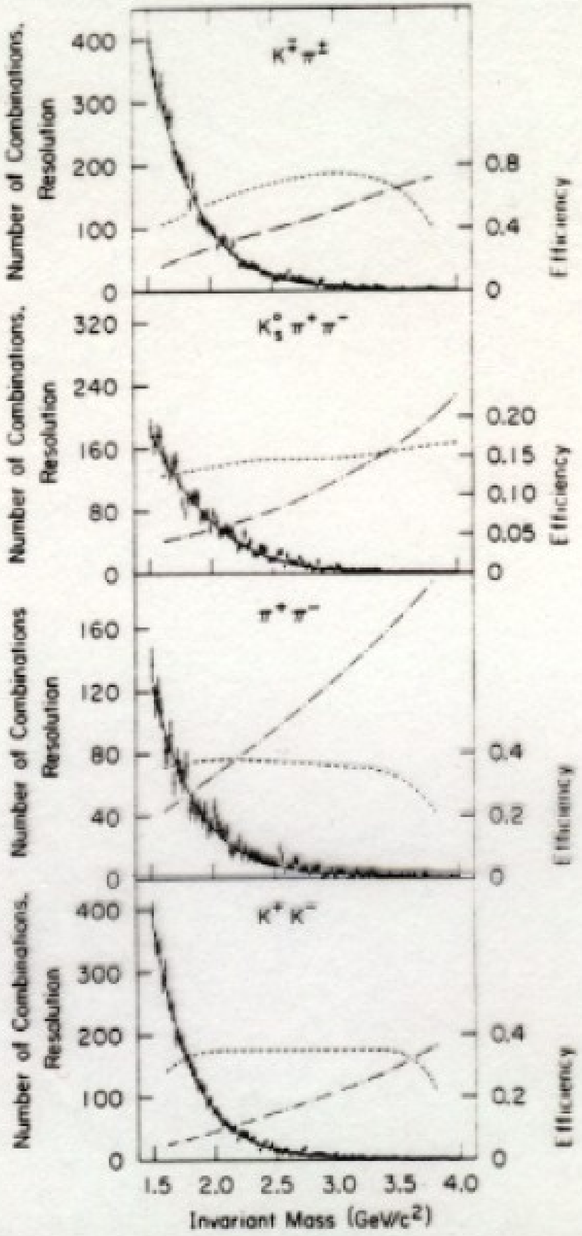


FIG. 1. Observed invariant-mass distributions in 25-MeV/c^2 bins for charge-0 combinations. The solid lines represent smooth curves fitted to the data. The detection efficiency (dashed curve) and measurement resolution in units of MeV/c^2 (dash-dotted curve) are also indicated. The left-hand scale is used for the number of combinations and the resolution and the right-hand scale is used for the efficiency.

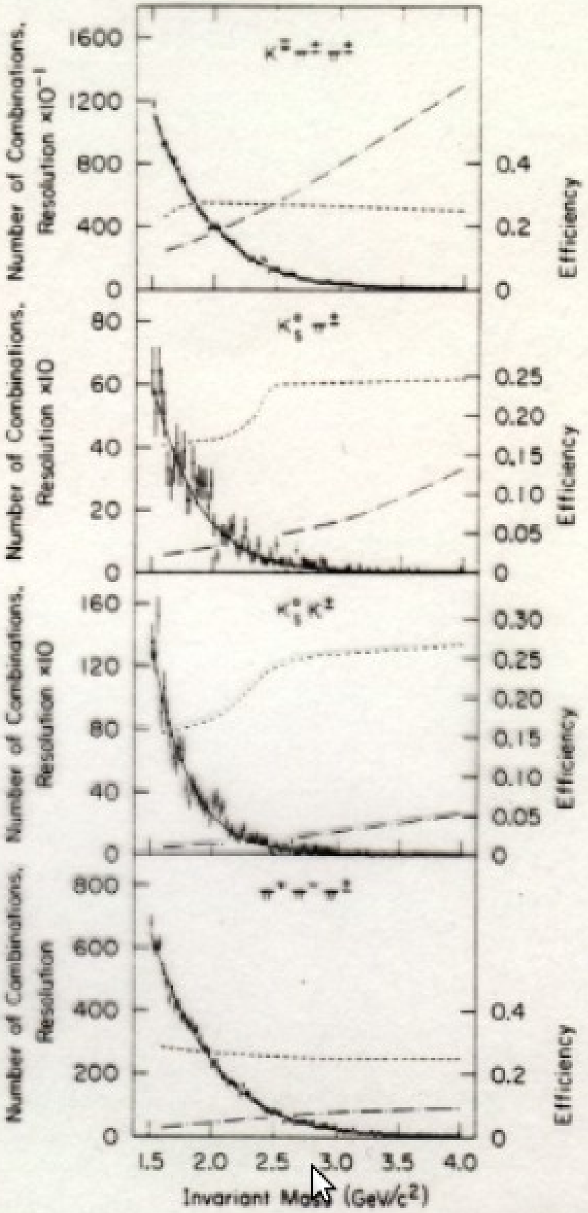


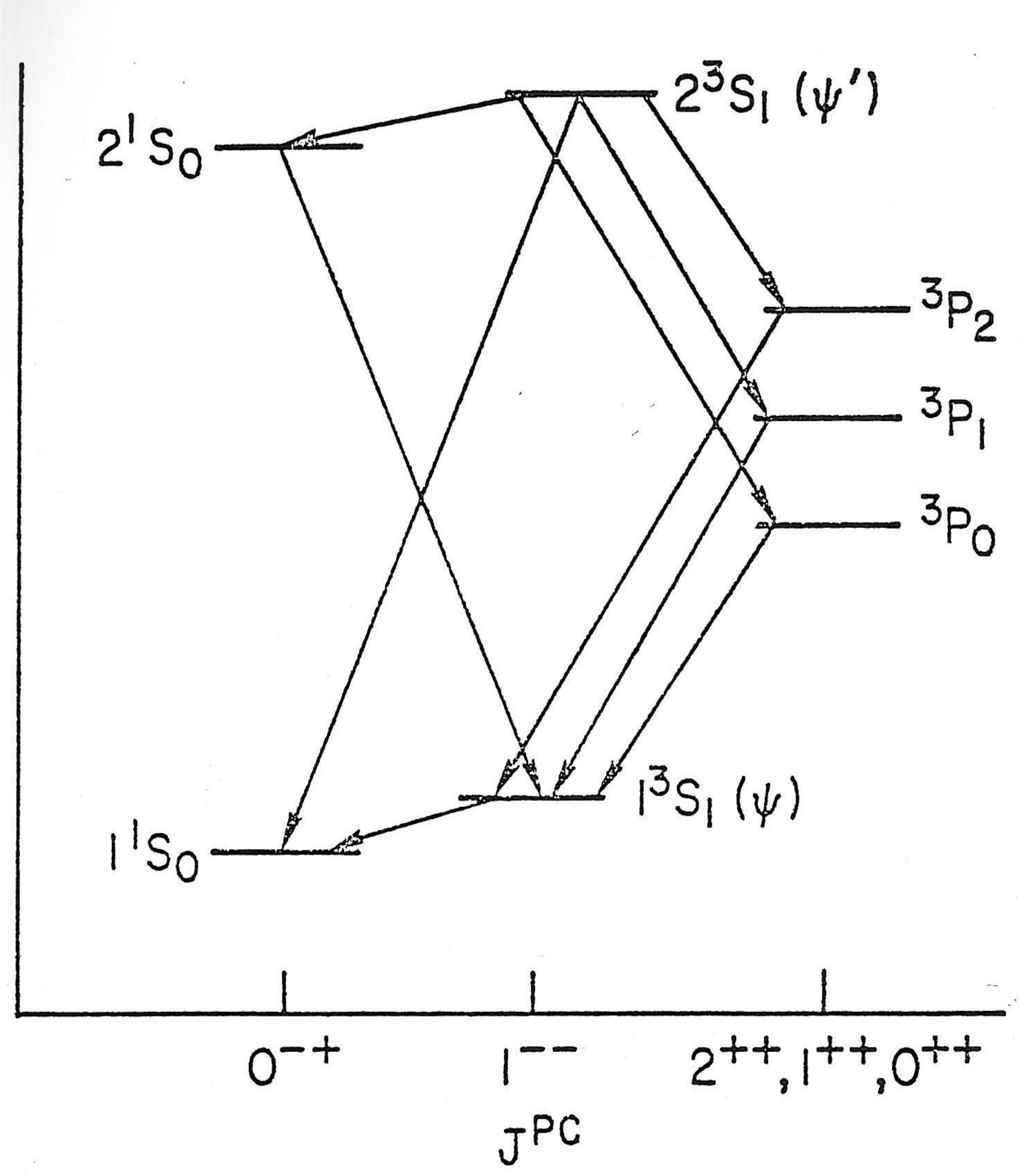
FIG. 2. Observed invariant-mass distributions in 25-MeV/c^2 bins for charge-± 1 combinations. The solid lines represent smooth curves fitted to the data. The detection efficiency (dashed curve) and measurement resolution in units of MeV/c^2 (dash-dotted curve) are also indicated. The left-hand scale is used for the number of combinations and the resolution and the right-hand scale is used for the efficiency.

Les états intermédiaires.

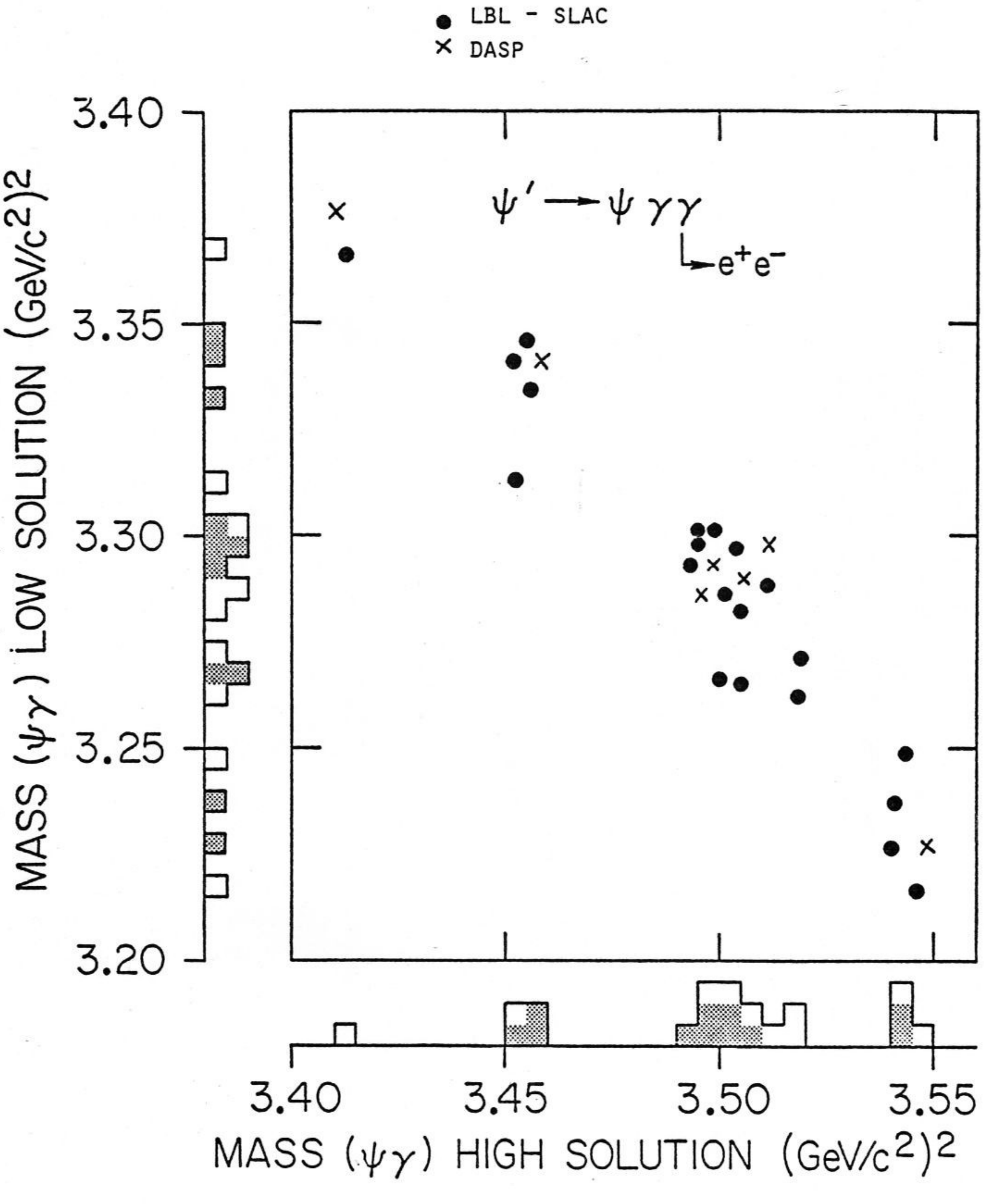
Spectroscopie attendue du charmonium: modes radiatifs.

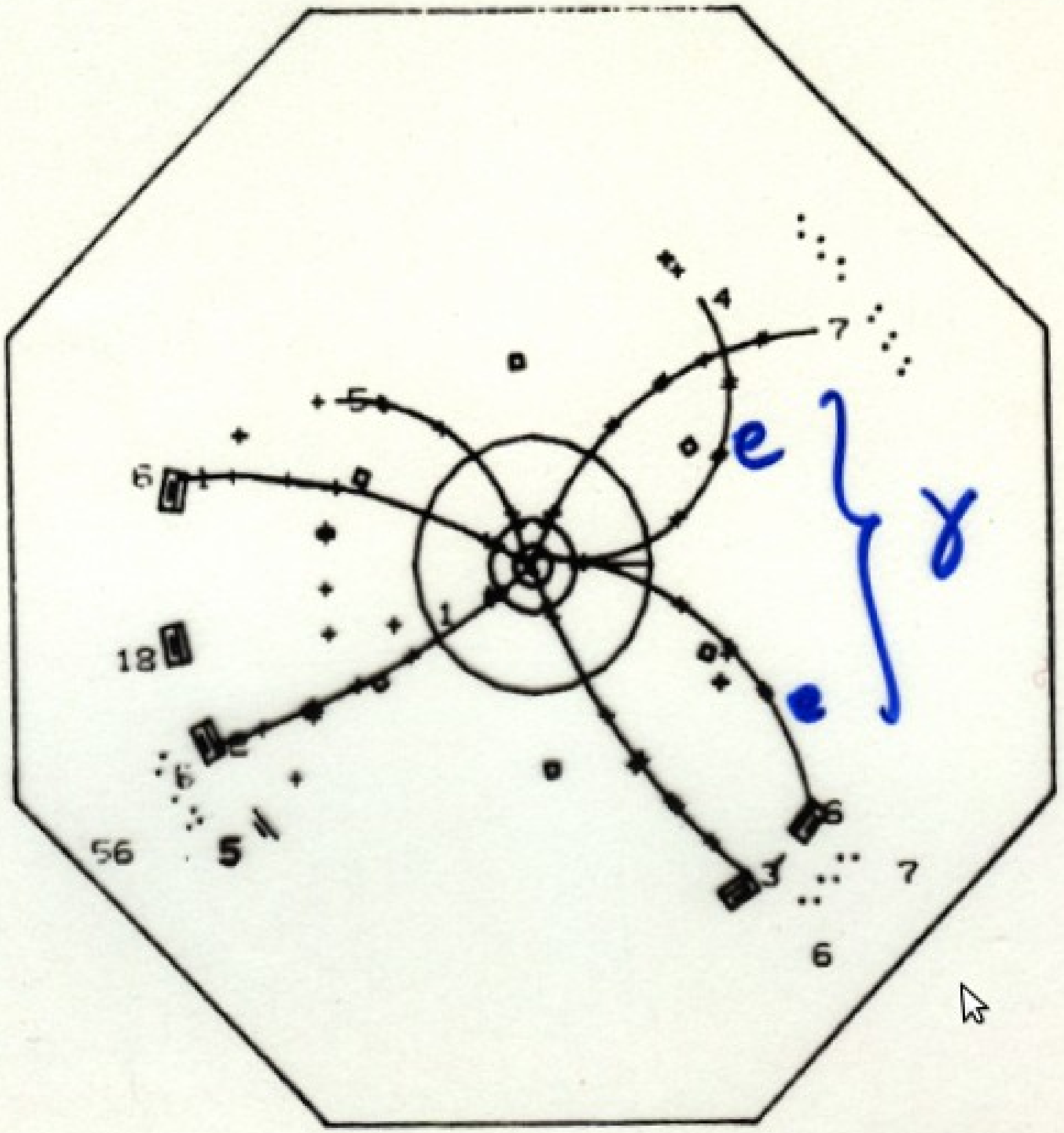
Le couplage faible entraîne un spectre quasi-coulombien.

Remarque : d'autres modèles fermion-antifermion prévoient ce genrede spectoscopie, pas seulement le charme.



Été 75 : I


● LBL - SLAC
× DASP
$\psi' \rightarrow \psi\gamma\gamma$
$\hookrightarrow e^+e^-$
MASS ($\psi\gamma$) LOW SOLUTION (GeV/c^2)^2
3.40
3.35
3.30
3.25
3.20
3.40
3.45
3.50
3.55
MASS ($\psi\gamma$) HIGH SOLUTION (GeV/c^2)^2



XBL 769-10473

Fig. 18. A typical event with a converted photon.

Été 75 : II

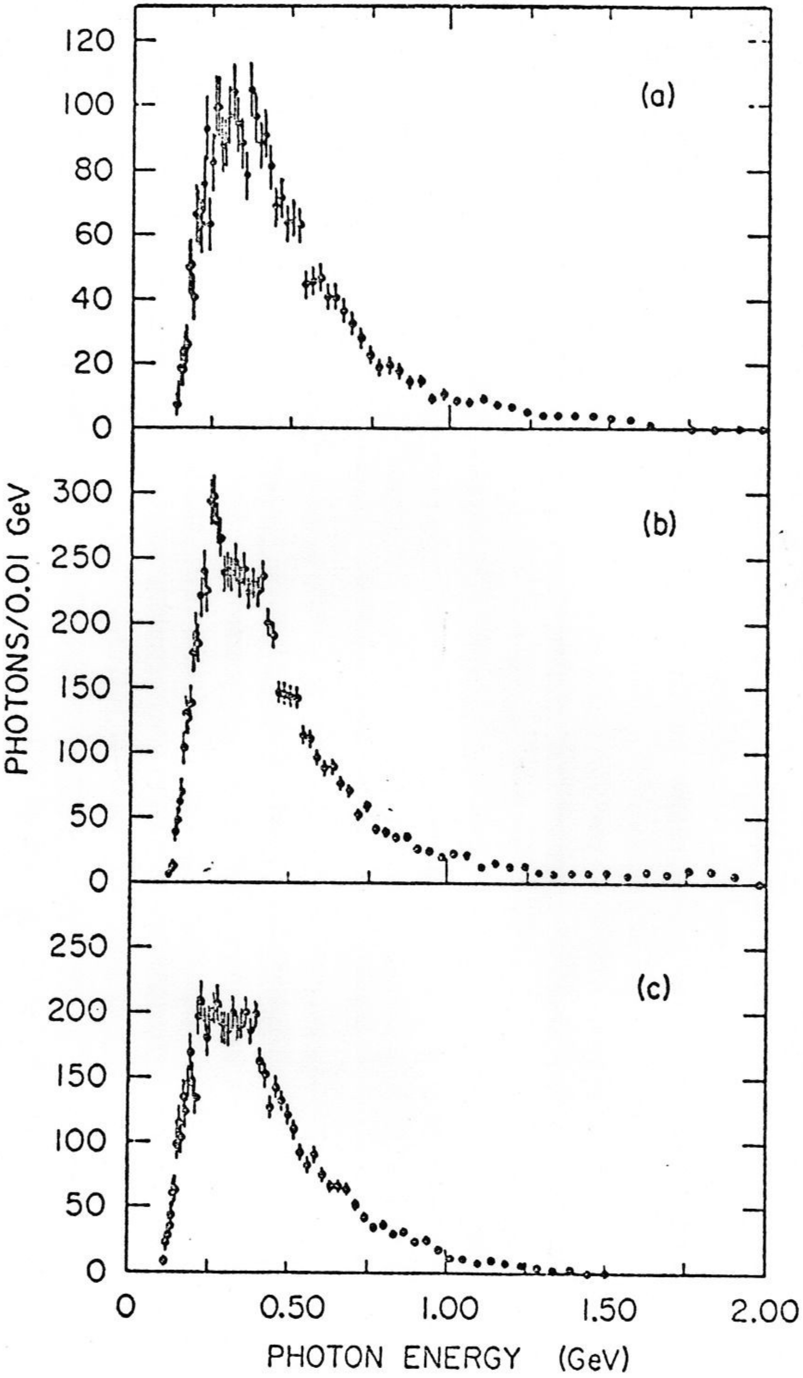
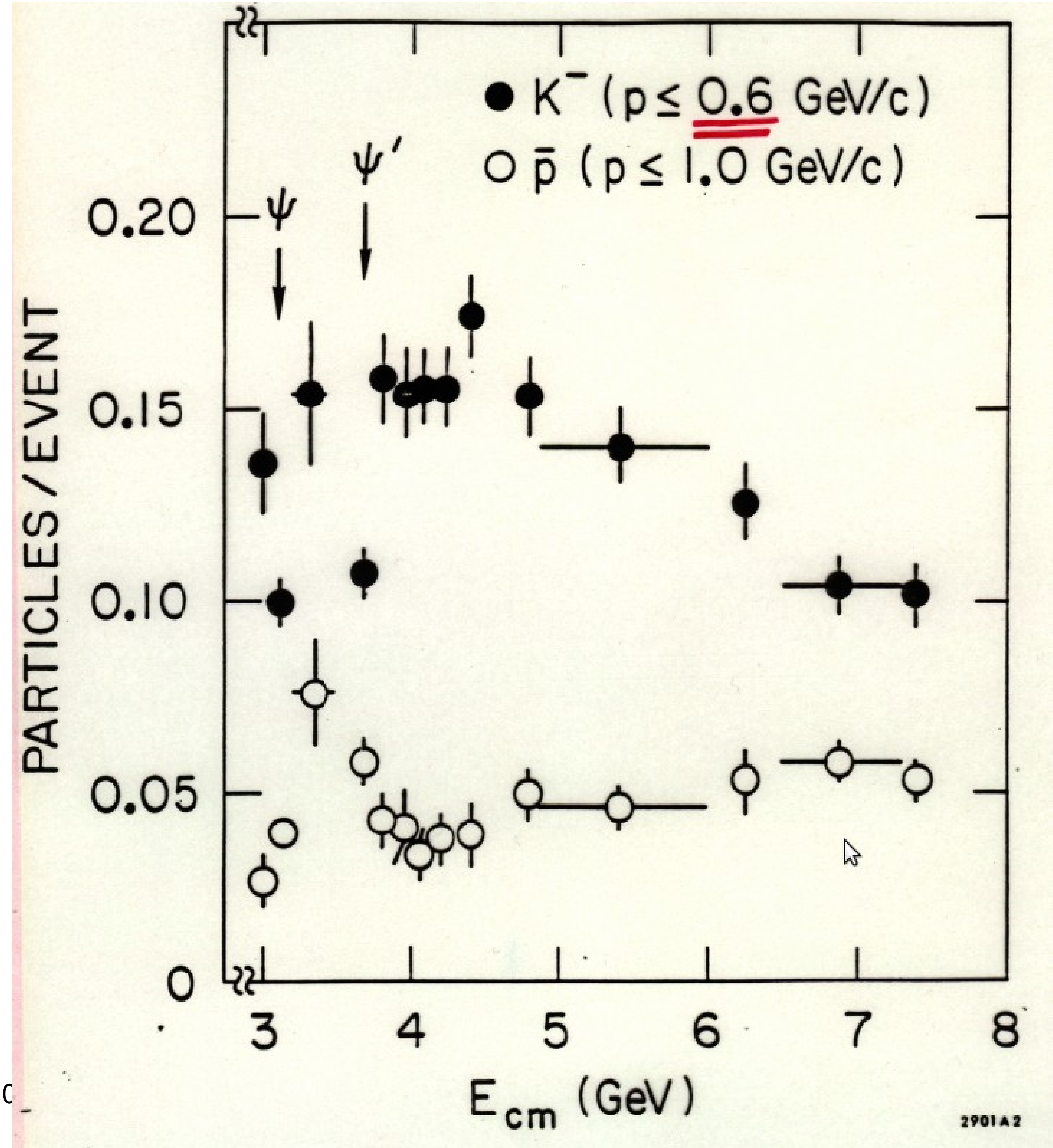


FIG. 38

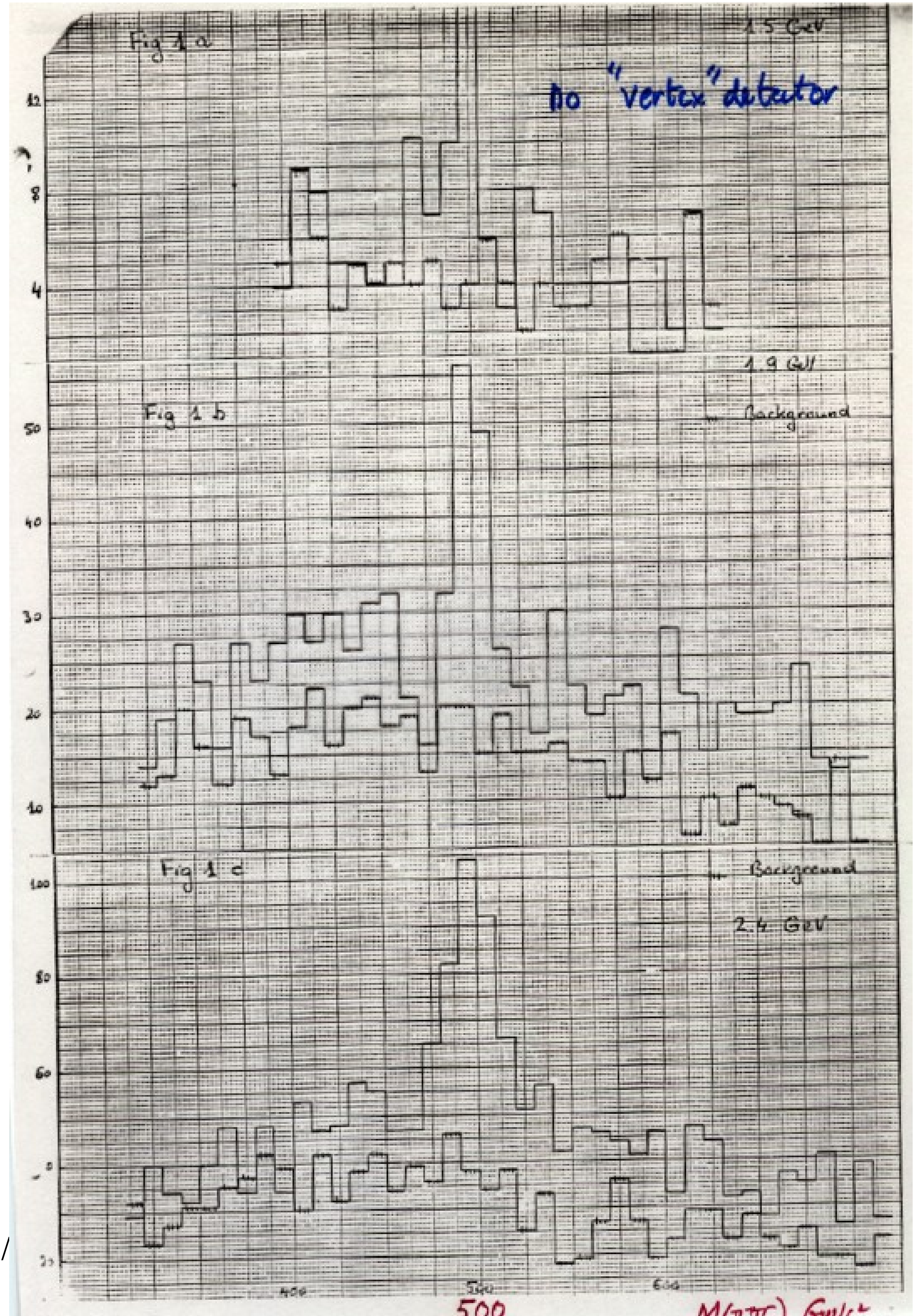
Les K inclusifs.

K chargés inclusifs
1975

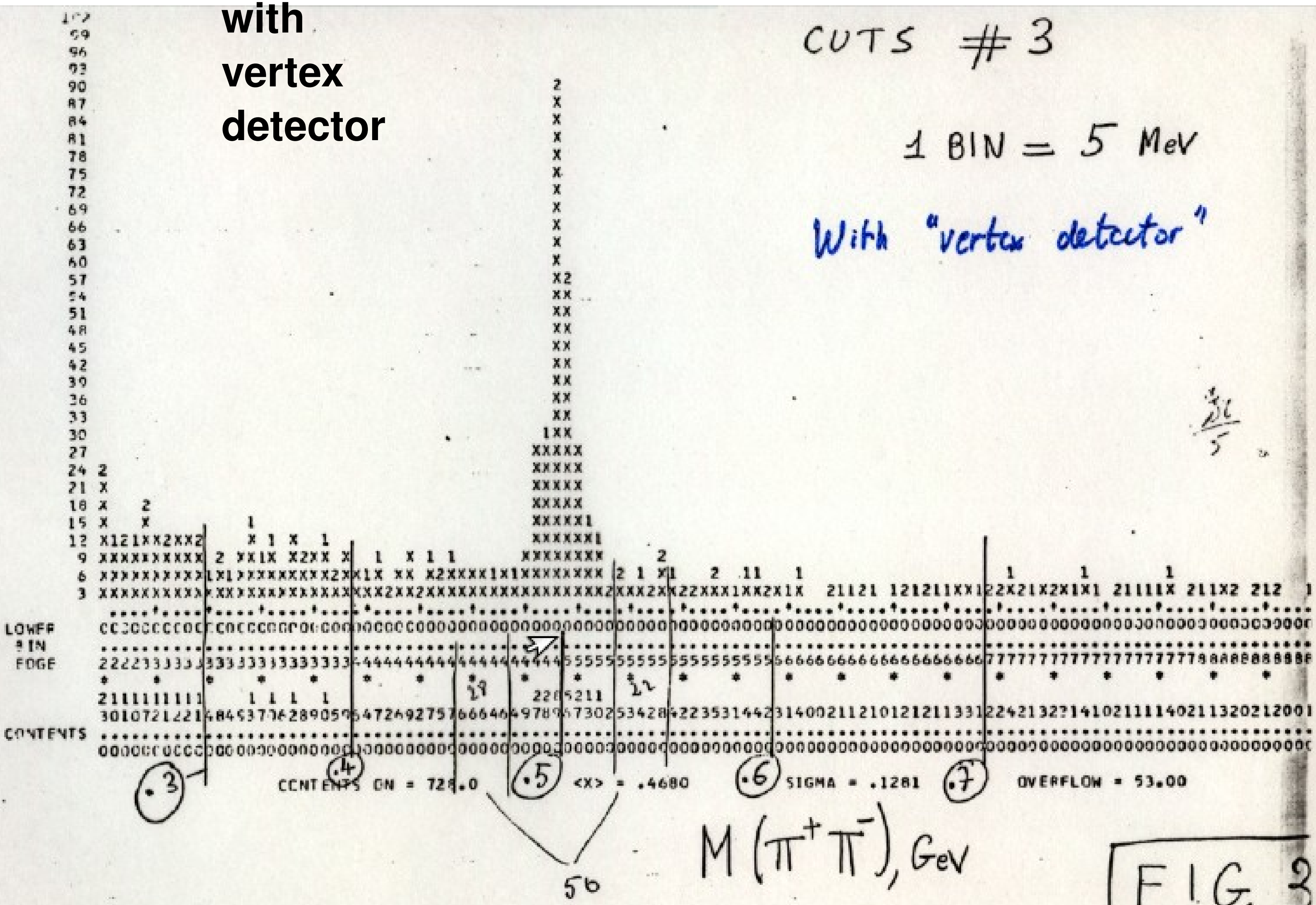
les Ψ sont différents, mais pas d'effet charme nu



NO vertex detector



with vertex detector



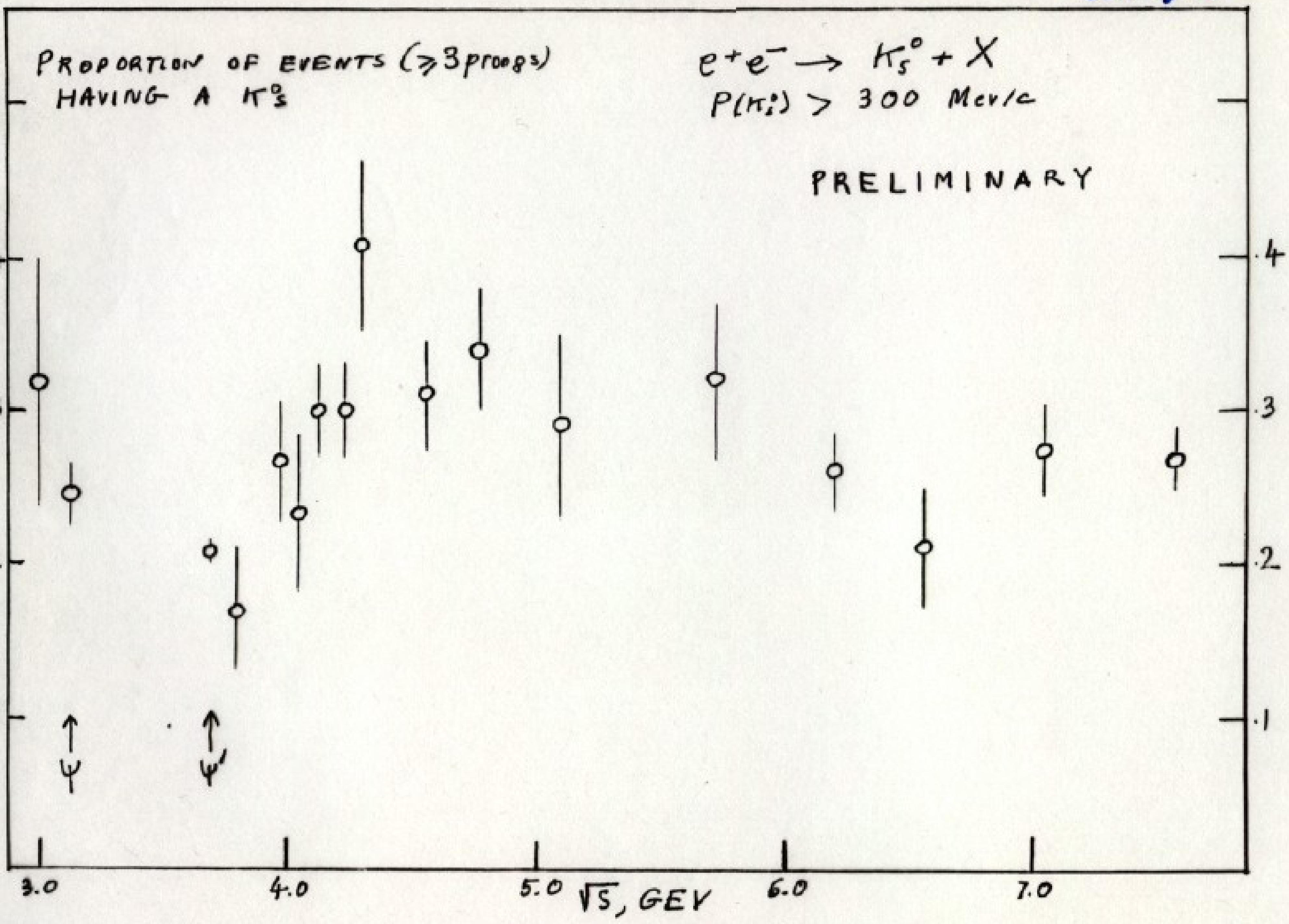
CUTS #3

1 BIN = 5 MeV

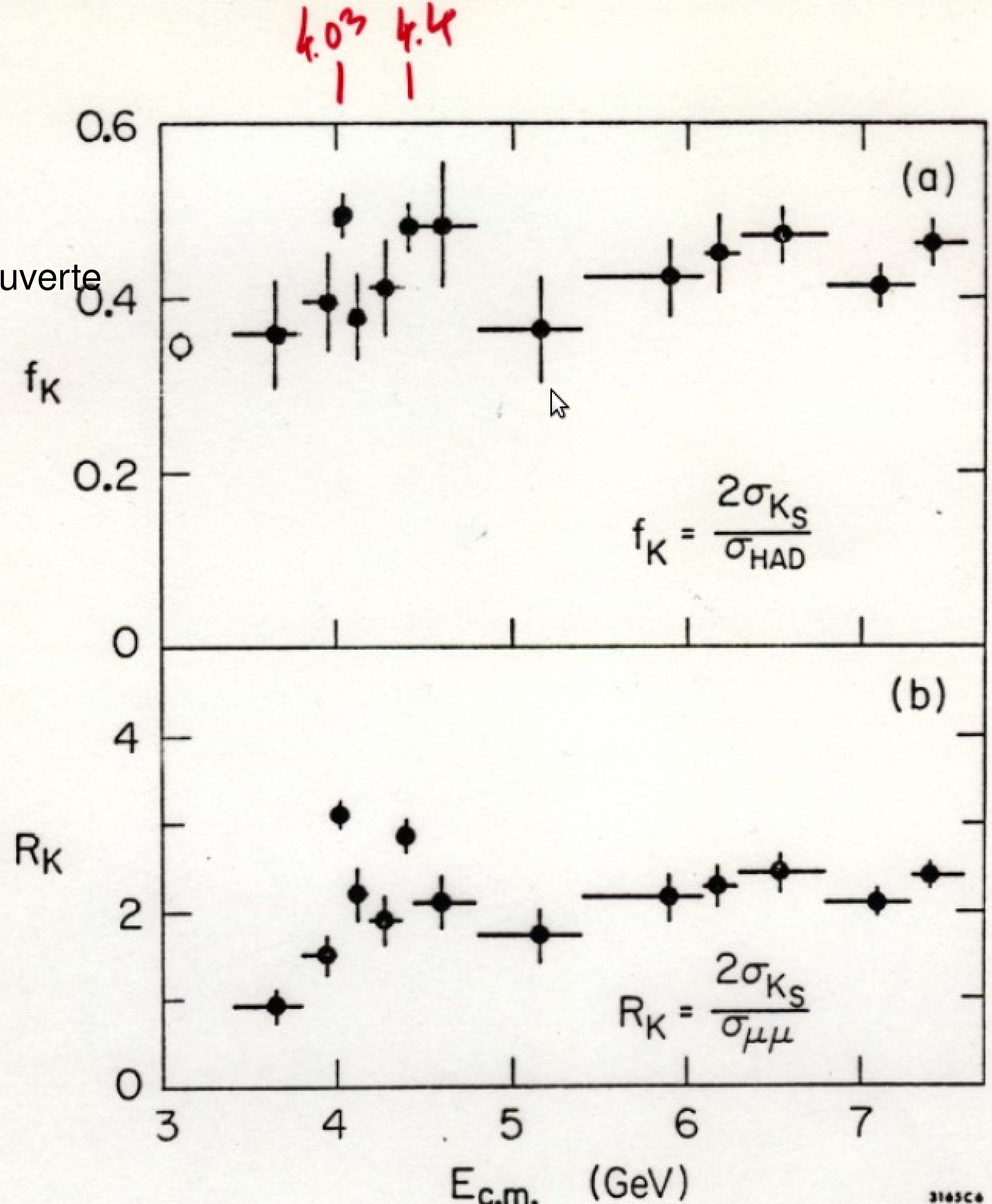
With "vertex detector"

FIG. 3

Jan 25, 76


PROPORTION OF EVENTS (≥3 prongs) HAVING A K^0_S
$e^+e^- \rightarrow K^0_S + X$
$P(K^0_S) > 300$ MeV/c
PRELIMINARY
.4
.3
.2
.1
ψ
ψ'
3.0
4.0
5.0
6.0
7.0
$\sqrt{s}$, GEV

K^0 inclusifs
après la découverte
du charme nu
en pics



V.Lüth et al,

K exclusifs(suite)

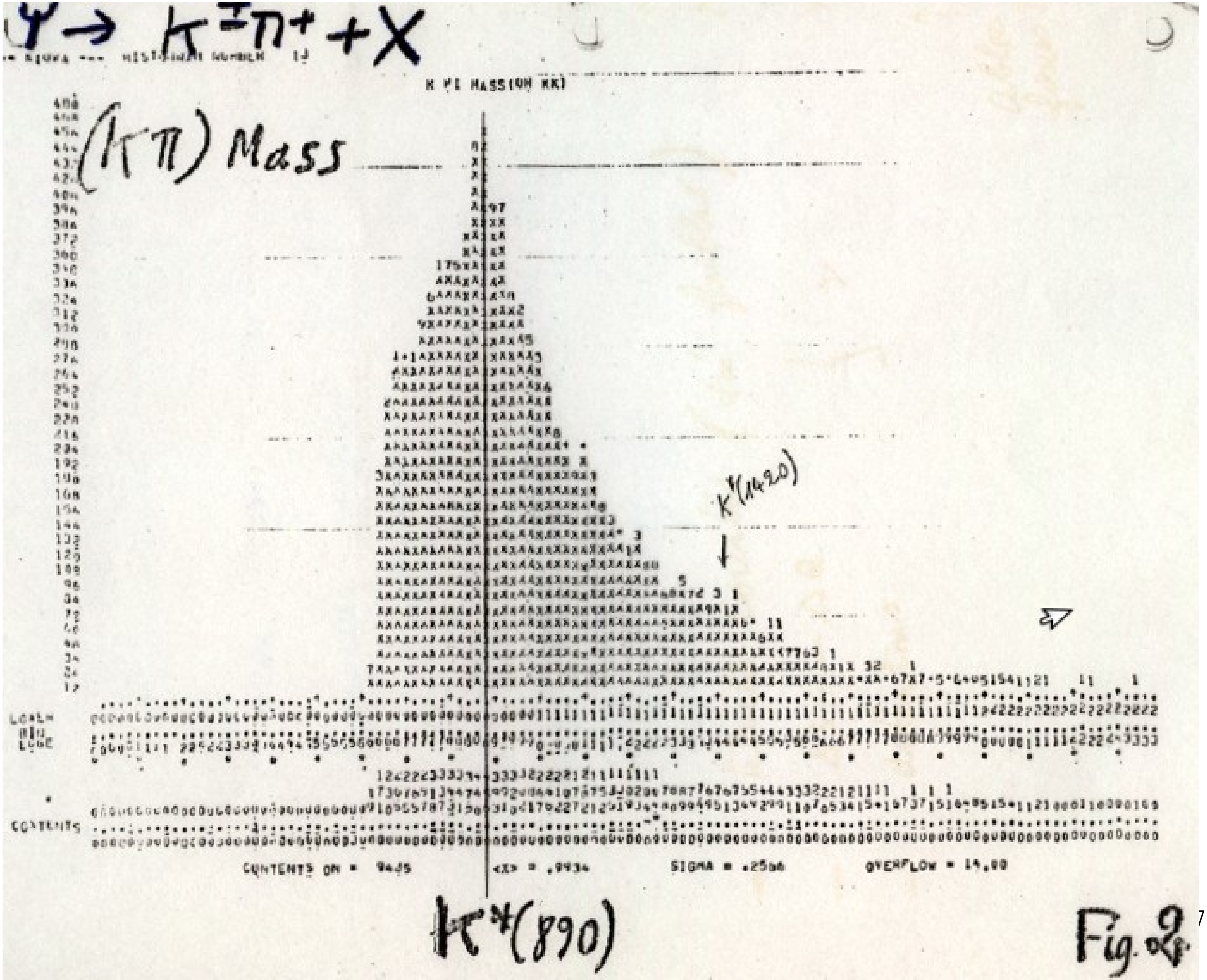
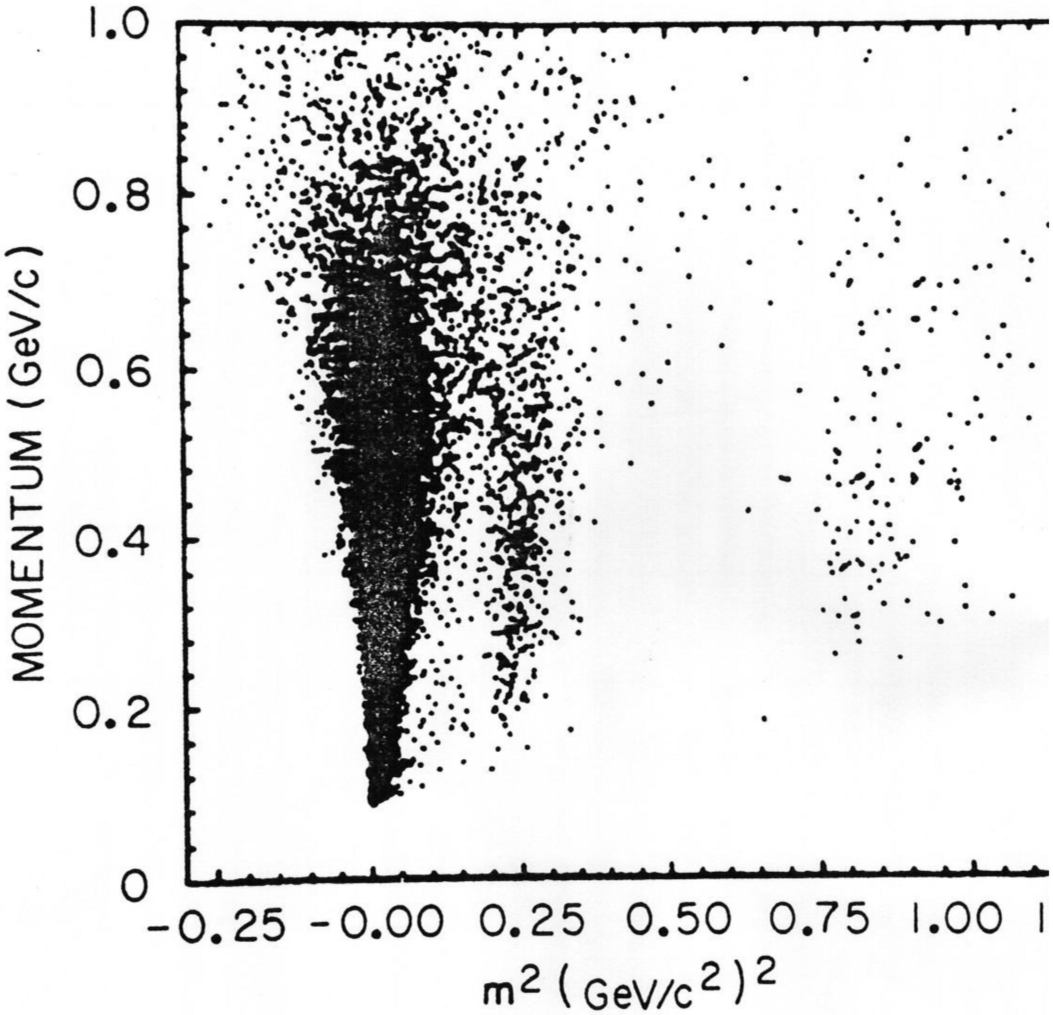
$\Psi \to K^{\mp}\pi^{\pm} + X$
HISTOGRAM NUMBER 13
K PI MASS(ON KK)
(Kπ) Mass
K*(1420)
LOWER BIN EDGE
CONTENTS
CONTENTS ON = 9435
<X> = .8934
SIGMA = .2566
OVERFLOW = 14.00
K*(890)

Fig. 2

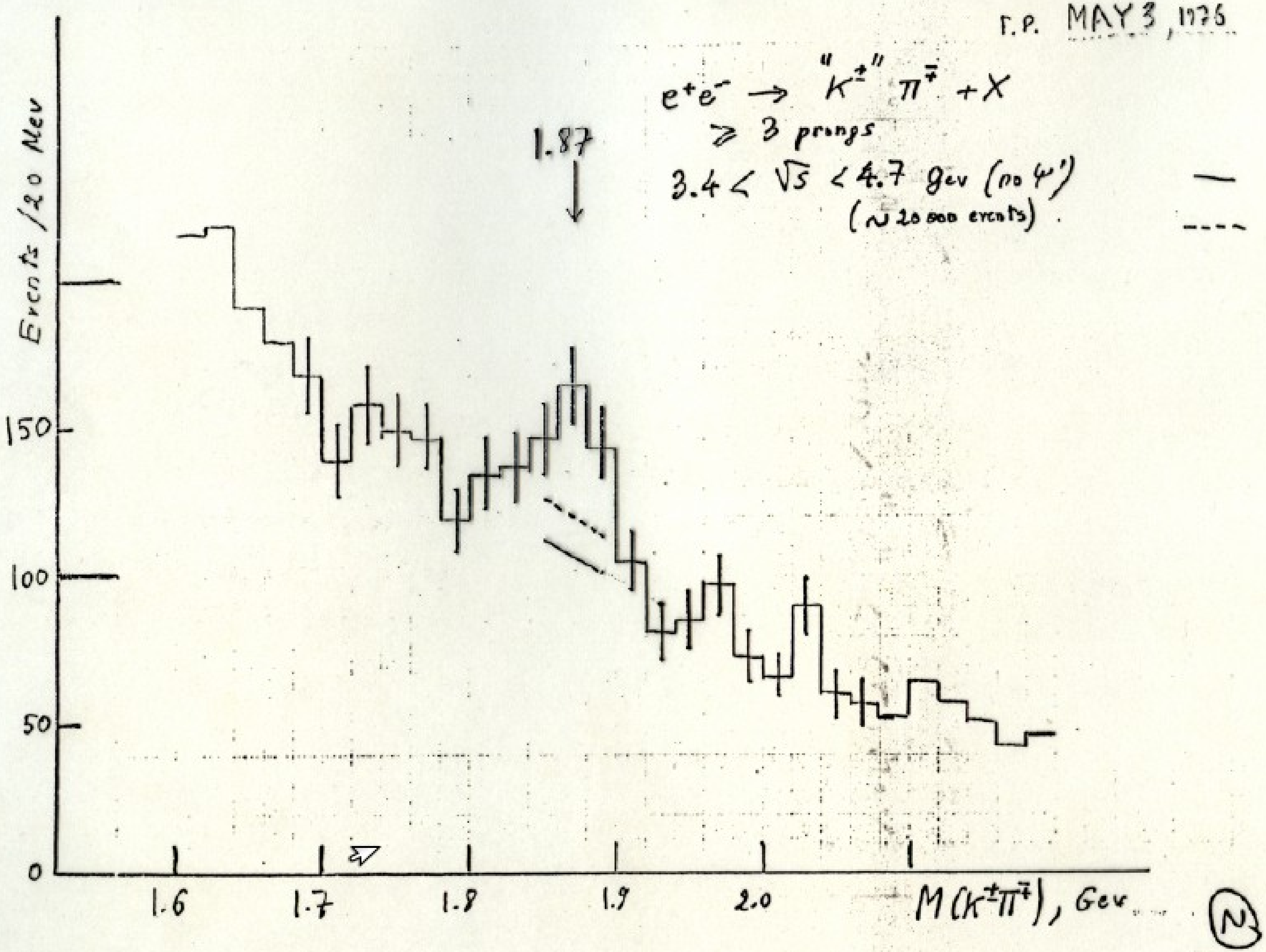


MEASURED FROM TIME OF FLIGHT IN TRIGGER COUNTERS

(L = 1.5 M/SINθ, $\sigma \sim 0.4$ NS)

FIG. 13

T.P. MAY 3, 1976



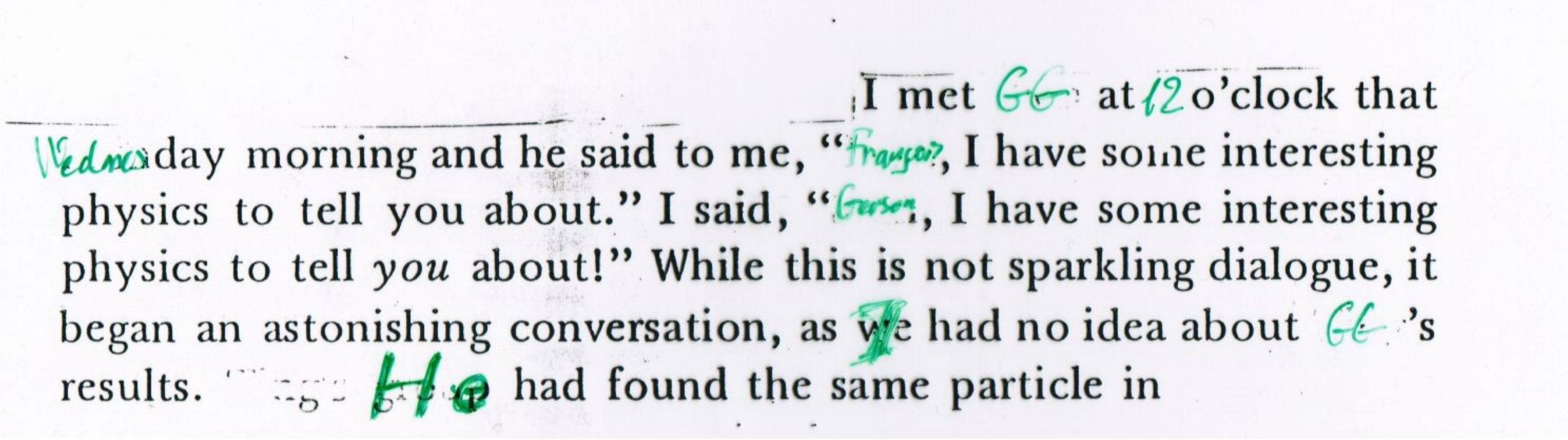
$e^+e^- \rightarrow$ "$K^{\pm}$" $\pi^{\mp} + X$

≥ 3 prongs

$3.4 < \sqrt{s} < 4.7$ gev (no ψ')

($\sim$ 20 000 events)

Mercredi 5 mai 76

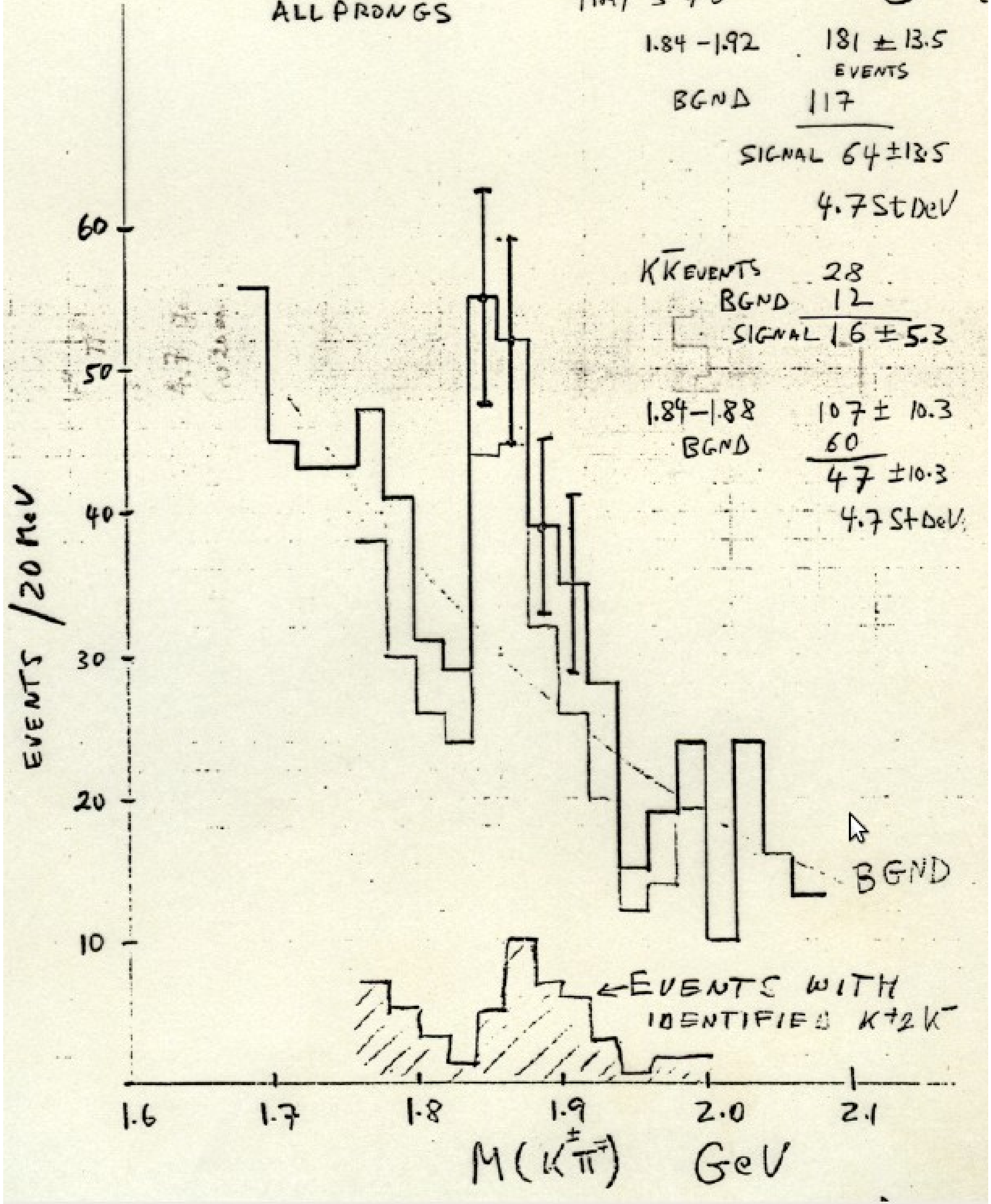


I met GG at 12 o'clock that Wednesday morning and he said to me, "François, I have some interesting physics to tell you about." I said, "Gerson, I have some interesting physics to tell you about!" While this is not sparkling dialogue, it began an astonishing conversation, as I had no idea about GG's results. He had found the same particle in

ALL PRONGS

MAY 3/76

①



1.84 − 1.92 181 ± 13.5 EVENTS

BGND 117

SIGNAL 64 ± 13.5

4.7 StDeV

$K\bar{K}$ EVENTS 28

BGND 12

SIGNAL 16 ± 5.3

1.84 − 1.88 107 ± 10.3

BGND 60

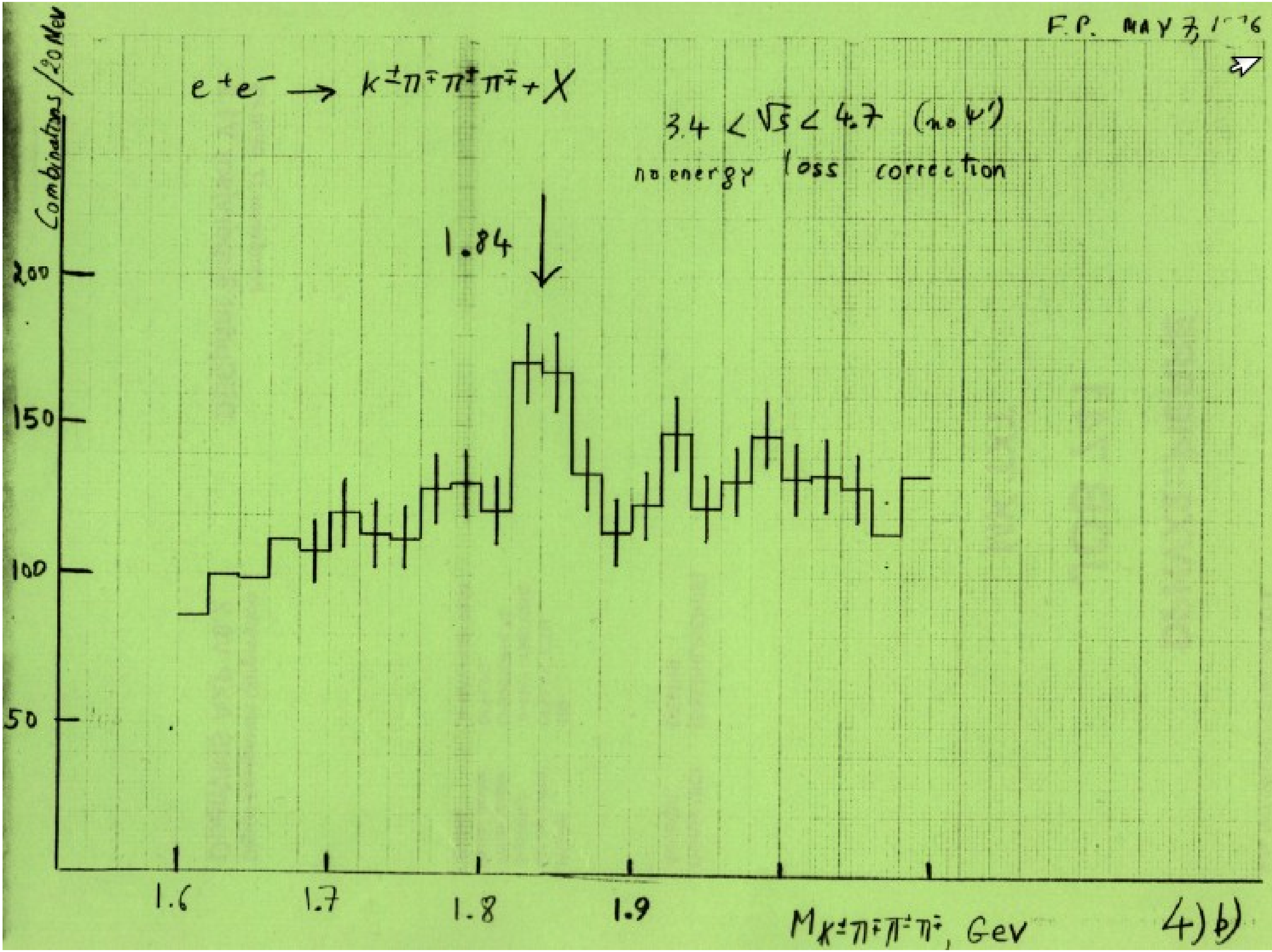
47 ± 10.3

4.7 StDeV

Vendredi 7 mai 76

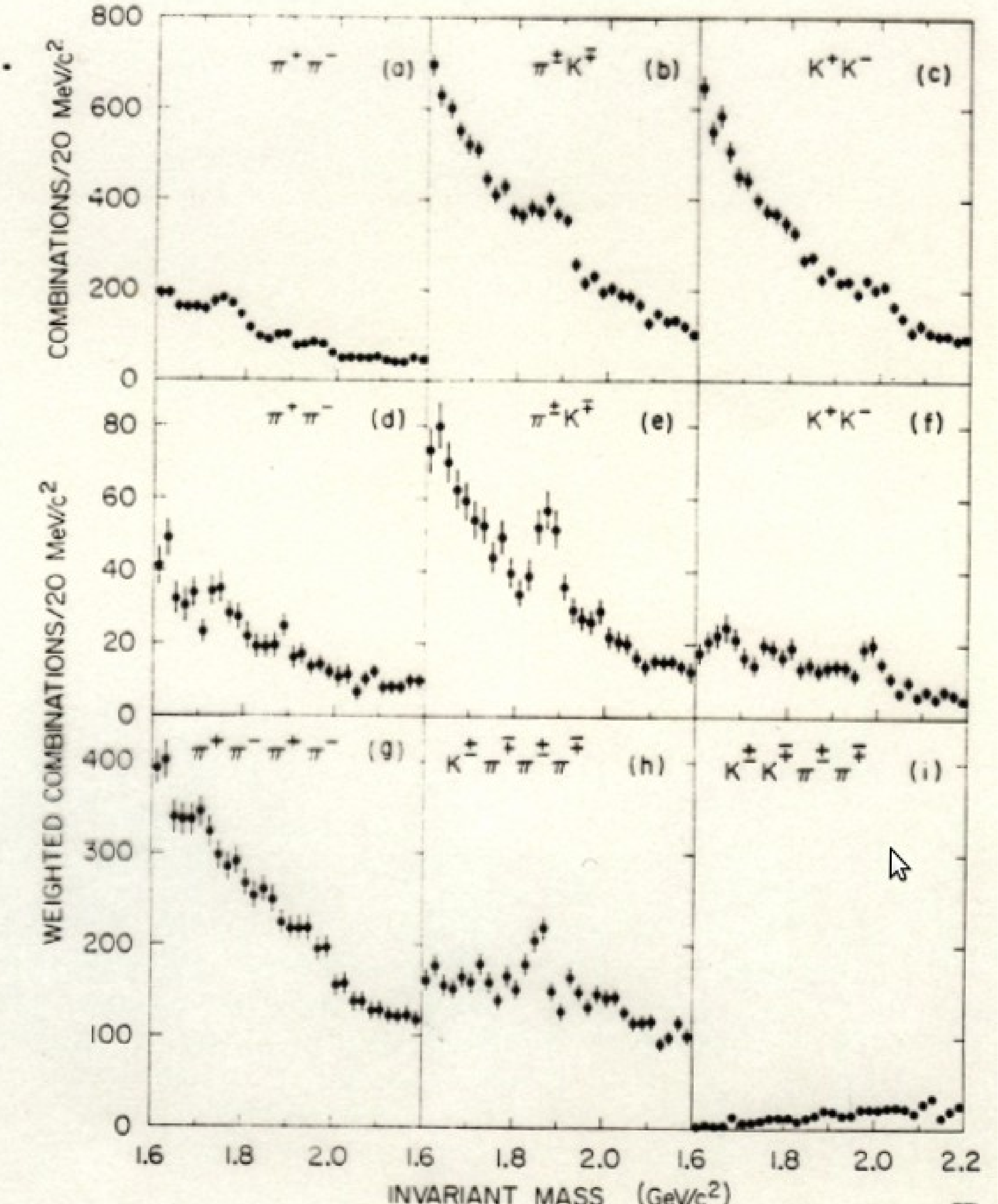
je monte au Lab dans la voiture de G.Gidal,
qui était déjà au courant du pic Kπ; il me dit :
« It would be nice to find another decay mode of
your resonance ».

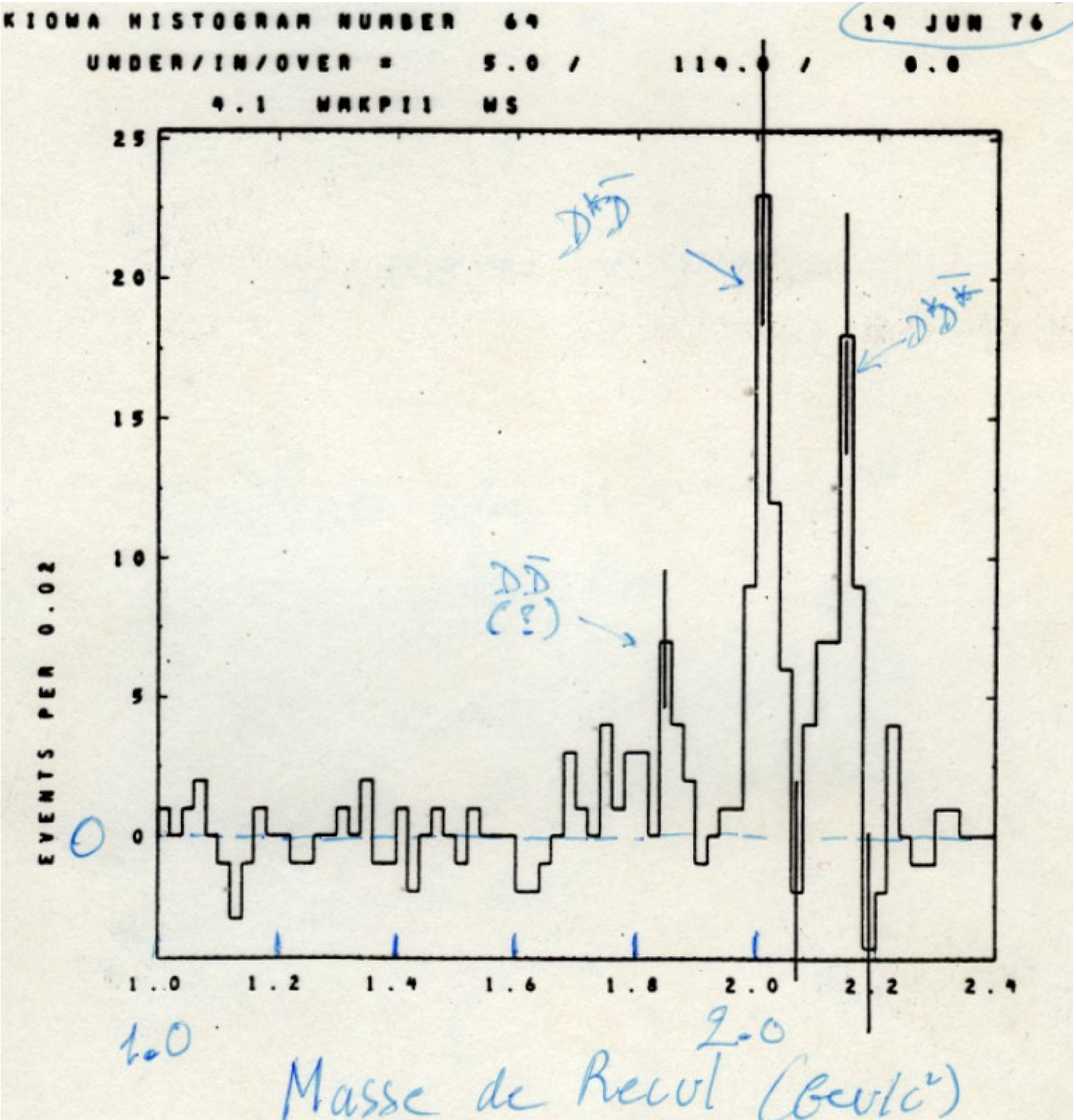
J'arrive au Lab et déplie mon listing du matin...



F.P. MAY 7, 1976

4) b)


COMBINATIONS/20 MeV/c²
WEIGHTED COMBINATIONS/20 MeV/c²
800
600
400
200
0
80
60
40
20
0
400
300
200
100
0
π⁺π⁻ (a)
π±K∓ (b)
K⁺K⁻ (c)
π⁺π⁻ (d)
π±K∓ (e)
K⁺K⁻ (f)
π⁺π⁻π⁺π⁻ (g)
K±π∓π±π∓ (h)
K±K∓π±π∓ (i)
1.6
1.8
2.0
1.6
1.8
2.0
1.6
1.8
2.0
2.2
INVARIANT MASS (GeV/c²)


KIOWA HISTOGRAM NUMBER 69
19 JUN 76
UNDER/IN/OVER = 5.0 / 119.0 / 0.0
4.1 WAKPI1 WS
EVENTS PER 0.02
25
20
15
10
5
0
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
$D^*\bar{D}$
$D^*\bar{D}^*$
$D\bar{D}$ (?)
0
1.0
2.0
Masse de Recul (GeV/c²)

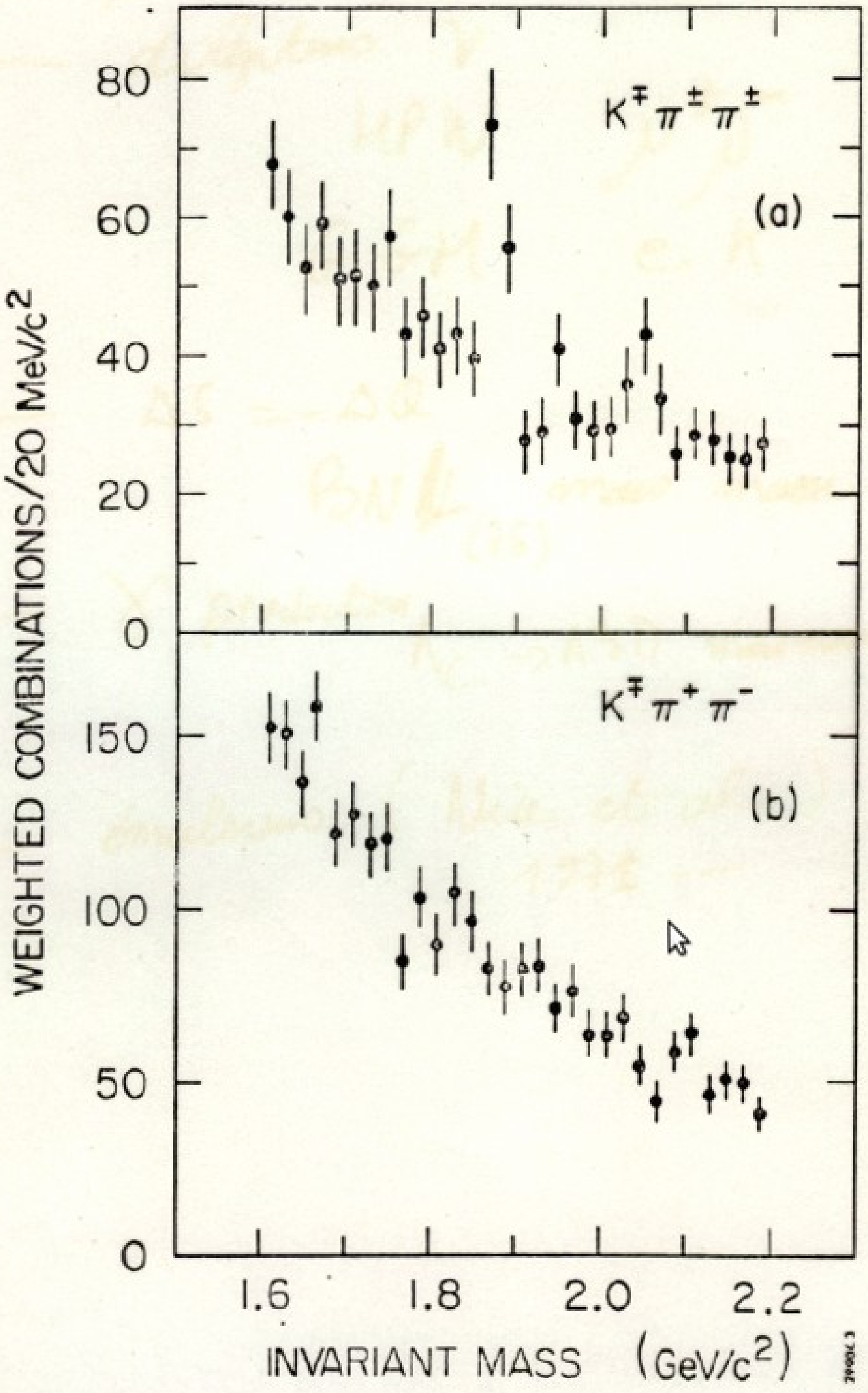


Fig. 45 Effective mass of the $K\pi\pi$ system at $\sqrt{s}$ = 4.03 GeV
a) $K^{\pm}\pi^{\mp}\pi^{\mp}$ (exotic) ; b) $K^{\pm}\pi^{\mp}\pi^{\pm}$ (non-exotic).

Désintégration faible?

1976 : la distribution de population dans le plot de Dalitz du Kpipi démontre la **violation de parité**, c.à.d. l'interaction faible(méthode Zemach appliquée ~20 ans plus tôt au K en 3pi - τ-θ puzzle)

si les 2 états de charge sont du même isomultiplet

RÉSUMÉ DES RÉSULTATS SUR LES PICS K$\pi\pi$:

-un pic étroit en $K^-\pi^+$,$K^-\pi^+\pi^-\pi^+$ (et $K^0\pi^-\pi^+$) à 1,86 GeV/c^2

-un pic étroit en $K^-\pi^+\pi^+$ exotique(non u,d,s) à 1,87 GeV/c^2

-masses de recul : >= masse du pic-->production associée
(et évidence pour un état excité à 2,01 GeV/c^2)

-pas de signal en dessous de 3,7 GeV c.m. --> production associée

-diagramme de Dalitz du $K^-\pi^+\pi^+$, il y a violation de parité

==> tout cela a une très bonne tête de **charme nu**.

après 1976 :
Psi" pur D Dbar, traces courtes, charme aux machines hadroniques,
Upsilon, confirmations du Tau.

REMARQUES FINALES.

J/Ψ

-**Avant la découverte, Lederman and co. avaient vu une anomalie très significative en expérience de production de dimuons.**
-dès l'annonce, le collissionneur ADONE à Frascati pousse son énergie au maximum et observe le J/Ψ
-l'analyse des données dileptons aux ISR montre une accumulation de 9(?) événements vers 3.1 Gev/c2 sans bruit de fond.
-l'analyse des données de SPEAR à 3.8 GeV c.o.m. des candidats à l'état final $4\pi^{+-}$ montre 2 bosses dans la distribution d'impulsion; interprétation probable : 3.8 -->photon radiatif+Ψ'--> $\Psi+\pi^{+}+\pi^{-}$ suivi de Ψ--> $l^{+}l^{-}$

Pour ce qui concerne le charme nu, comment une évidence aussi forte que 2 pics à 5 σ n'a-t-elle pas été précédée d'indications sérieuses...?

même avec statistique partielle et étalonnages préliminaires.

Autres effets expérimentaux (peut-être) dûs au charme:

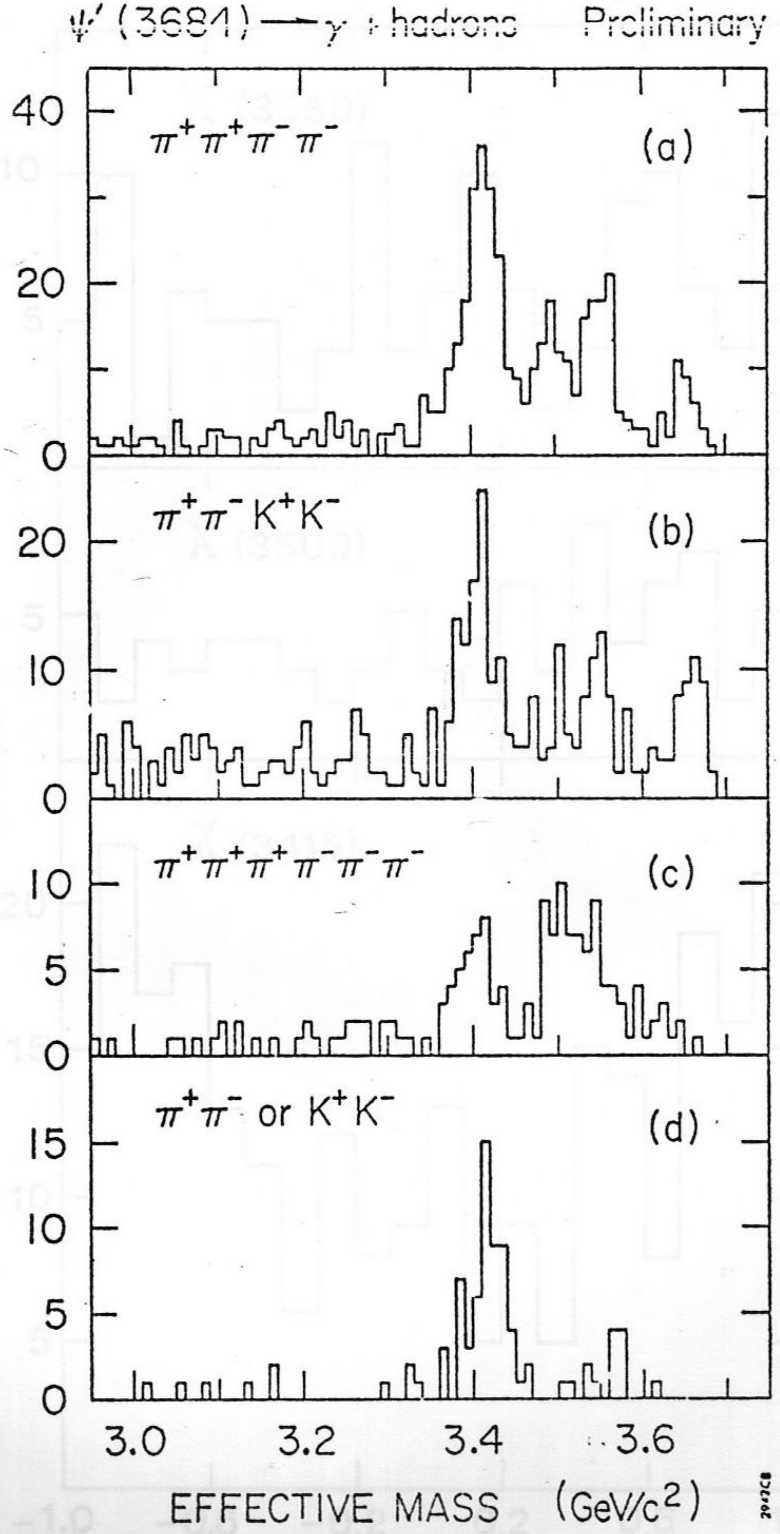
-Niu 1971, émulsions, production associée de traces courtes
-dileptons en neutrinos(HPW, 1974...,
-coïncidences K-lepton en neutrinos Gargamelle 1976
-1 événement de Ch à B candidat ΔS=-ΔQ 1976
-photoproduction de Λc-->Λ+3π masse?
-coïncidences K-lepton en e+e-(DESY, 1976)
...

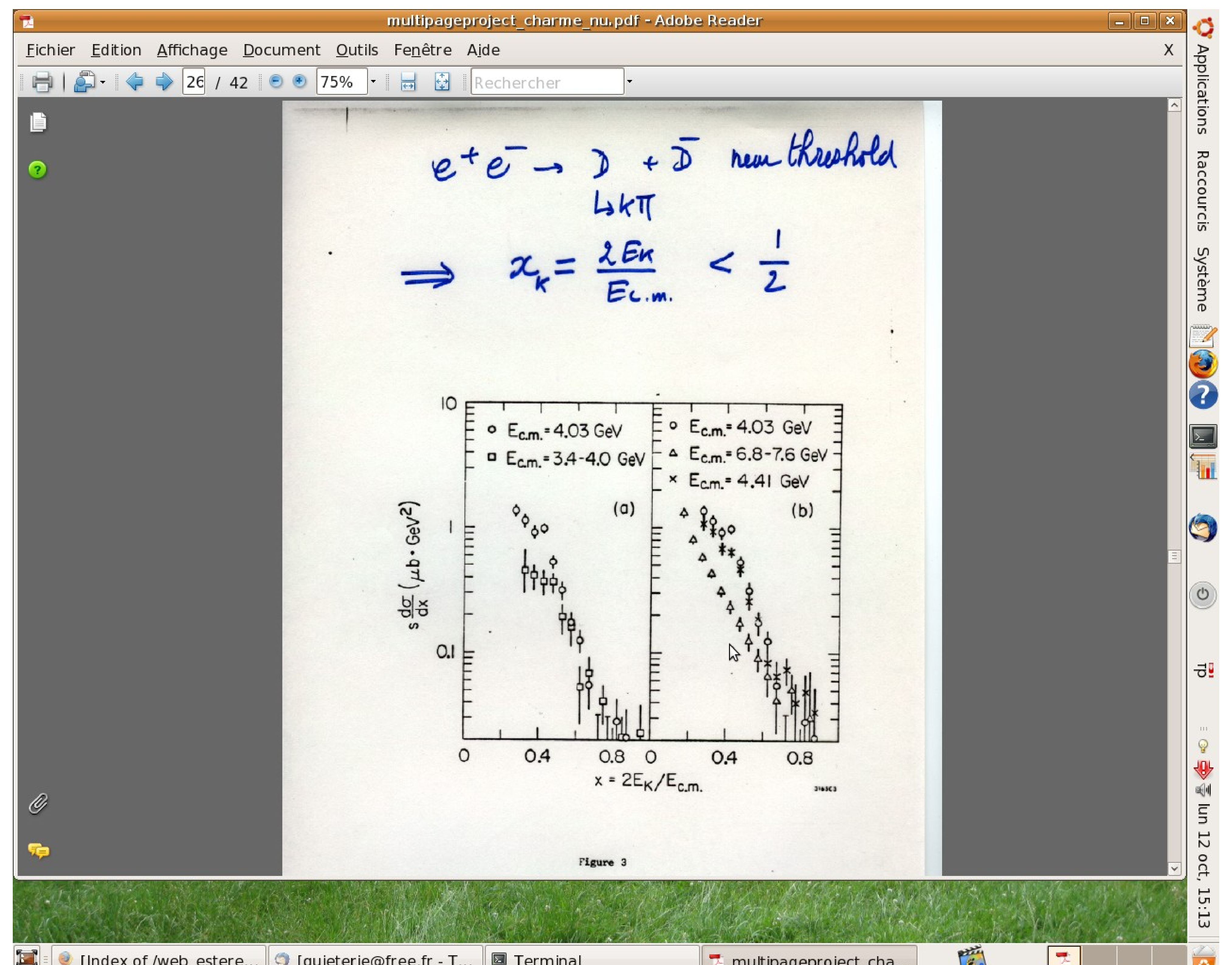
RÉSULTATS EXPÉRIMENTAUX "IMPORTANTS" DURANT ~40 ANS DE PHYSIQUE

-68-73 DIS, partons, invariance d'échelle(SLAC)
-73 courants neutres(CERN)
-nov 74 J/Psi, Psi'(SLAC,BNL)
-printemps75 : e μ --> tau(SLAC)
-printemps75 : jets u,d,s(SLAC)
-été 75 : états intermédiaires du charmonium(DESY,SLAC)
-mai-juin 76 : D0,D+ charme nu(SLAC)
-1977 : upsilons à FNAL
-1977 : confirmation du tau à DESY
-1978 : interférence électrofaible(SLAC)
-1979 : jets de gluons(DESY)
-1983 : W,Z(CERN)
-1983 : le b vit longtemps, ~1ps(SLAC)
-1989... MS(LEP, CERN) et ses corrections radiatives EW
-1995 : top(FNAL)
-200X: violation de CP à la Kobayashi-Maskawa.

Réserve

États intermédiaires en hadrons





$e^+e^- \to D + \bar{D}$ near threshold

$\hookrightarrow K\pi$

$$\Rightarrow x_K = \frac{2E_K}{E_{c.m.}} < \frac{1}{2}$$

Figure 3

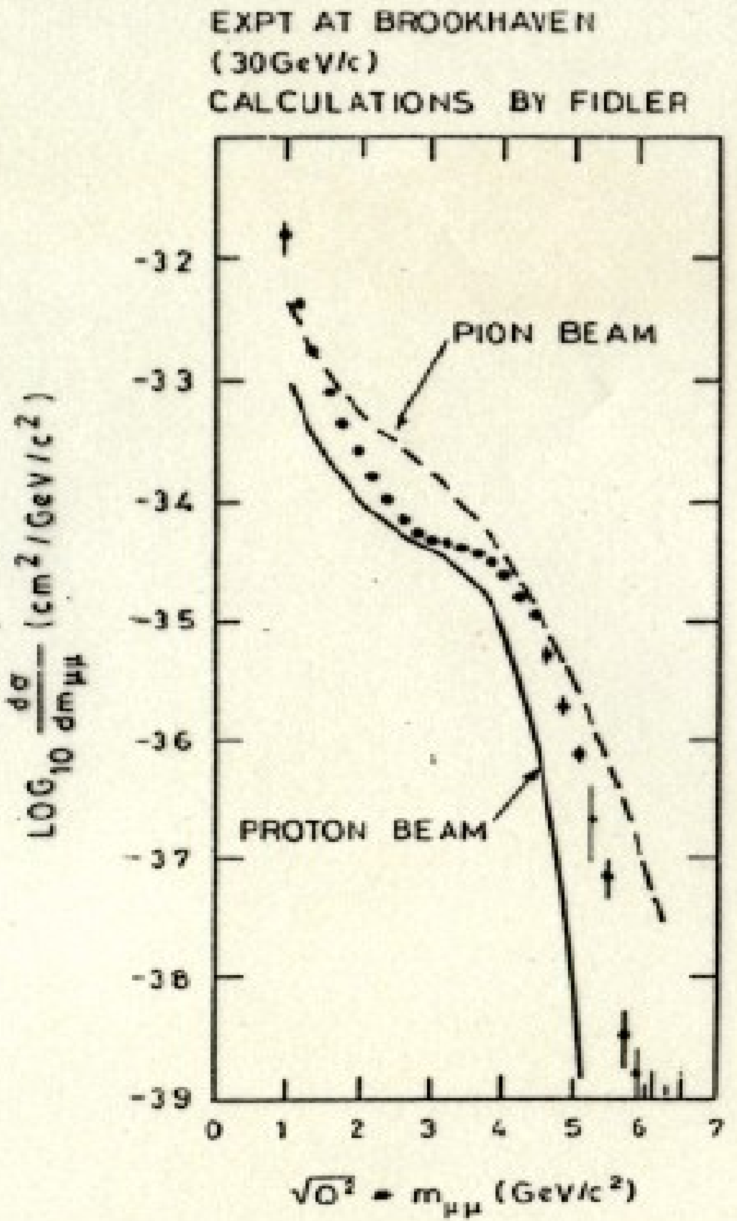

EXPT AT BROOKHAVEN
(30GeV/c)
CALCULATIONS BY FIDLER
PION BEAM
PROTON BEAM
$\log_{10} \frac{d\sigma}{dm_{\mu\mu}}$ (cm^2/(GeV/c^2))
-32
-33
-34
-35
-36
-37
-38
-39
0
1
2
3
4
5
6
7
$\sqrt{Q^2} = m_{\mu\mu}$ (GeV/c^2)

Fig. 3.2

Spectroscopie attendue du charmonium.

Le couplage faible entraîne un spectre quasi-coulombien.

Remarque : d'autres modèles fermion-antifermion prévoient ce genrede spectoscopie, pas seulement le charme.

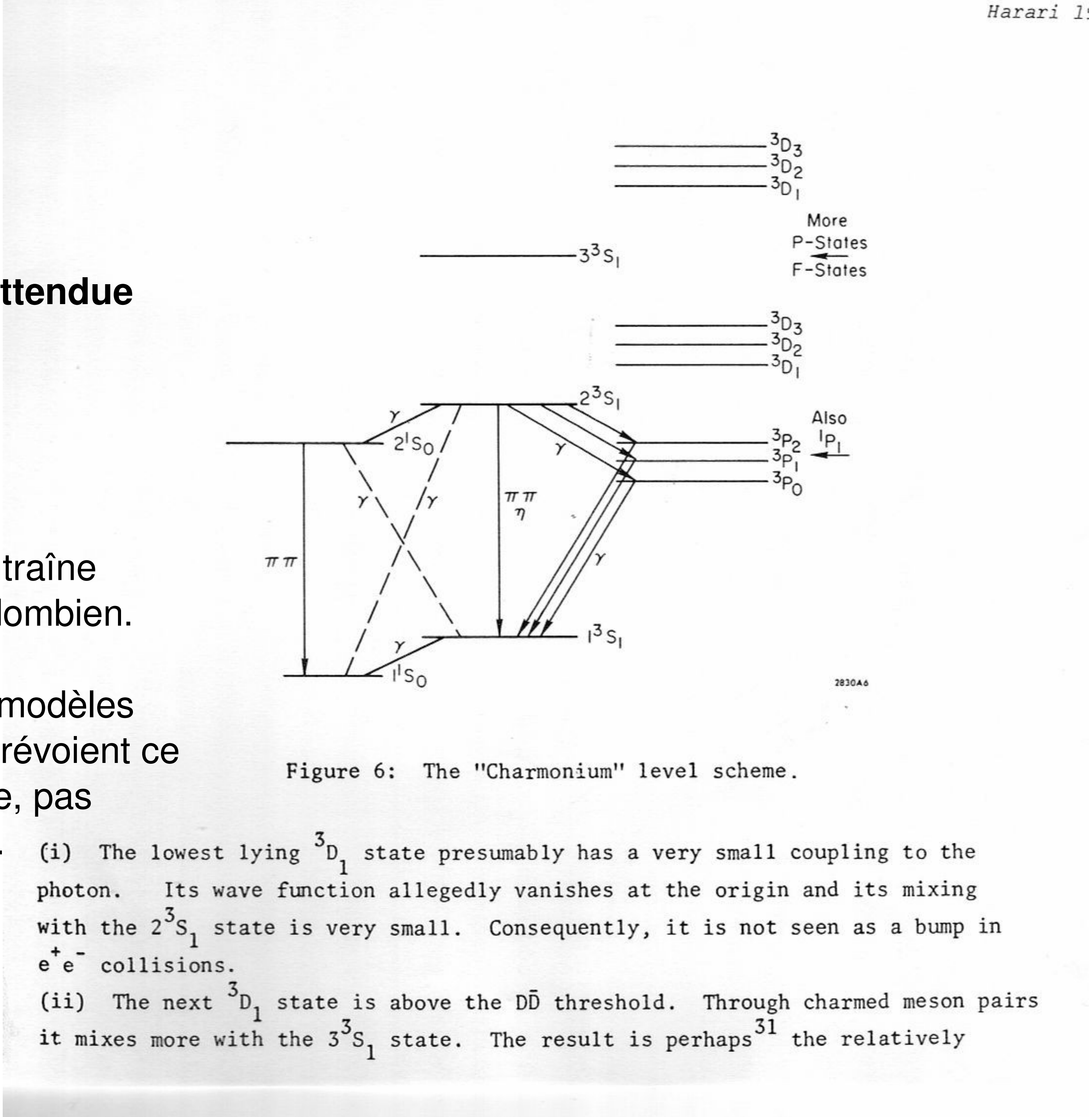


Figure 6: The "Charmonium" level scheme.

(i) The lowest lying $^3D_1$ state presumably has a very small coupling to the photon. Its wave function allegedly vanishes at the origin and its mixing with the 2^3S_1 state is very small. Consequently, it is not seen as a bump in e^+e^- collisions.

(ii) The next $^3D_1$ state is above the $D\bar{D}$ threshold. Through charmed meson pairs it mixes more with the 3^3S_1 state. The result is perhaps[31] the relatively