SEARCH FOR NEW PARTICLES AT PETRA

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1. Search for New Quarks

An energy scan in steps of $\Delta W = 30$ MeV has been performed in the region $38.7 < W < 46.78$ GeV. The combined values of $R = \sigma_{had}/\sigma_{\mu\mu}$ of the four experiments CELLO, JADE, MARK J and TASSO are shown in Fig. 1.

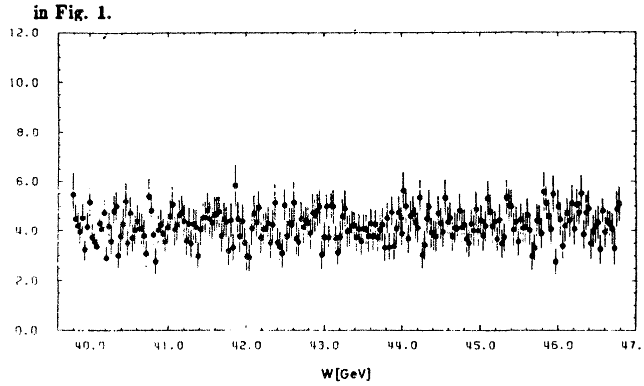


Fig. 1 : $R = \sigma_{had}/\sigma_{\mu\mu}$ in the energy region scanned as obtained from the combined data from CELLO, JADE, MARK J and TASSO

The upper limits on $\Gamma_{ee} \cdot B_{had}$ at the 95 % CL for a possible narrow resonance are given in Table 1 for the individual experiments and the combined data.

Table 1 :

	$\Gamma_{ee} \cdot B_{had}$ [keV]	W [GeV]
CELLO	< 2.9	42.94
JADE	< 1.9	42.56
MARK J	< 2.5	44.00
TASSO	< 2.5	42.62
all four combined	< 1.0	45.84

With $B_{had} \sim 0.8$ one expects for a Q=2/3 quark $\Gamma_{ee} \cdot B_{had} \sim 3.6$ keV. Thus the 95 % CL limit $\Gamma_{ee} \cdot B_{had} \sim 1.0$ keV from the combined data rules out the existence of a $t\bar{t}$ resonance in the energy region covered. The average R - values in the energy range $38.7 < W < 46.78$ GeV are given in Table 2.

Table 2 :

	R
CELLO	$4.04 \pm 0.10 \pm 0.31$
JADE	$4.13 \pm 0.08 \pm 0.14$
MARK J	$4.16 \pm 0.07 \pm 0.24$
TASSO	$4.13 \pm 0.10 \pm 0.20$
all four combined	4.12 ± 0.04

The data are compatible with the five quark (u,d,s,c,b) expectations ($< R >= 4.07$) and clearly rule out open top production ($< R >= 5.5$). The sensitivity for the production of new quarks is increased when the event shape is analyzed rather than the hadronic cross section only. The Table 3 shows the 95 % CL limits of the threshold energies for a new quark as obtained from the experiments using different analysis methods.

Table 3 :

	Selection		threshold W[GeV] for quarks of $Q = 2/3$	$Q = 1/3$
CELLO	Aplanarity	> 0.10	46.6	45.4
MARK J	Thrust	< 0.75	46.7	
TASSO	Aplanarity	> 0.13	46.5	45.8 step
			46.0	45.0 $\beta(3-\beta^2)/2$

Finally the inclusive lepton yield at large transverse momentum relative to the thrust axis may be compared to the expectations from the semileptonic decay of a heavy quark. Thus one obtains for the top quark, using a semileptonic branching ratio of 10 %, mass limits of 22.9 GeV (CELLO, e, μ) and 22.3 GeV (MARK J, μ) respectively at the 95 % CL.

2. Search for Free Quarks

The JADE Collaboration has used their high statistics multihadron data sample at $14 < W < 44$ GeV to search for fractionally charged stable particles. From the measurement of dE/dx and apparent momentum, upper limits for the inclusive cross section $\sigma(e^+e^- \rightarrow q\bar{q}X)$ for Q=1/3 and Q=2/3 charged particles were derived (see Fig. 2).

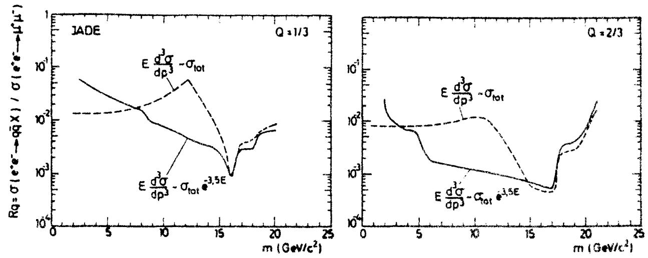


Fig. 2 : 95 % CL upper limits for the production cross section for free quarks obtained from the JADE data.

3. Search for Excited Electrons

An excited electron would give an additional contribution to the reaction $e^+e^- \rightarrow \gamma\gamma$ due to the e^* exchange and thus modify the angular distribution. No deviation from the QED cross section has been observed, giving the following 95 % CL limits on the cutoff parameter Λ.

Table 4 :

	Λ [GeV]
CELLO	62
JADE	62
MARK J	70
TASSO	61

In the low M_{e^*} mass region more stringent limits on the $(e^*e\gamma)$ coupling constant λ can be obtained from studying the reactions $e^+e^- \rightarrow ee^*$ and $e^+e^- \rightarrow e^*e^*$. The 95 % CL limits derived from the e^* search in the $(e^{\pm}\gamma)$ mass distributions are shown in the Fig. 3 for the JADE and MARK J data. Also shown are the limits as given by the cutoff parameter Λ from the reaction $e^+e^- \rightarrow \gamma\gamma$.

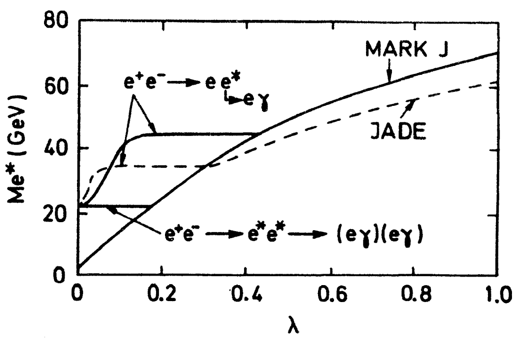


Fig. 3 : 95 % CL limits on the $e^*e\gamma$ coupling constant λ as function of the mass M_{e^*}.

4. Search for Excited Muons

JADE and MARK J performed a detailed study of the reaction $e^+e^- \rightarrow \mu^*\mu \rightarrow (\mu\gamma)\mu$. No deviation in the $(\mu\gamma)$ mass distribution from the QED expectation has been found. The 95 % CL limits on the $(\mu^*\mu\gamma)$ coupling constant λ are shown in Fig. 4.

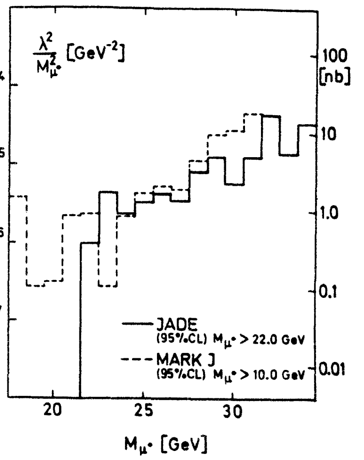


Fig. 4 : 95 % CL limits on the $(\mu^*\mu\gamma)$ coupling constant

5. Search for a Scalar Boson

Motivated by the findings of the UA1 and UA2 experiments of an apparent excess of radiative Z_o decays, various explanations have been put forward to interpret this anomalous large rate $\Gamma_r = \Gamma(Z_o \rightarrow e^+e^-\gamma) \sim$ 20 MeV. In a model of composite leptons and quarks, the events may be interpreted being due to the decay $Z \rightarrow X\gamma \rightarrow e^+e^-\gamma$ with (a) scalar / pseudoscalar particle(s) X ($\epsilon = 1, 2$) and a suggestive mass range $40 < M_X < 50$ GeV.

All four PETRA experiments have searched for narrow resonances in the reactions $e^+e^- \rightarrow e^+e^-, \mu^+\mu^-, \tau^+\tau^-, q\bar{q}$ and $\gamma\gamma$. The 95 % CL limits on $\epsilon\Gamma_{ee} \cdot B_{ii}$ are given in Table 5.

Table 5:

	$\epsilon\Gamma_{ee}B_{ee}$ [keV]	$\epsilon\Gamma_{ee}B_{\mu\mu}$ [keV]	$\epsilon\Gamma_{ee}B_{\tau\tau}$ [keV]	$\epsilon\Gamma_{ee}B_{had}$ [keV]	$\epsilon\Gamma_{ee}B_{\gamma\gamma}$ [keV]	$\epsilon\Gamma_{ee}$* [keV]
CELLO	9.9	5.6	7.0	8.7	2.6	28.1
JADE	20.0			5.6	7.8	73.4
MARK J		4.5		8.7	3.7	25.9 (14.0) **
TASSO	21.0	6.0		7.5	9.6	50.1

* Assuming $\Gamma_{ee} = \Gamma_{\mu\mu} = \Gamma_{\tau\tau}; \Gamma_{\nu\nu} = 0$;
** Obtained from a global fit to the reactions $e^+e^- \rightarrow \mu\mu, q\bar{q}$ and $\gamma\gamma$.

In close analogy to VDM the decay $X \rightarrow \gamma\gamma$ can be related to the radiative decay $Z \rightarrow X\gamma$ giving the prediction $\epsilon \cdot \Gamma_{ee} \cdot B_{\gamma\gamma} \sim 2$ MeV or $\epsilon\Gamma_{ee} > 2$ MeV. The limits are between 2 and 3 orders of magnitude below the expected values. Using again the VDM prediction, a broad resonance within the PETRA energy range can be excluded as well. For the total width Γ_X one obtains unreasonably large values $\Gamma_X > 100$ GeV. For X boson masses above the PETRA energy range a sizeable contribution is expected for the reaction $e^+e^- \rightarrow e^+e^-$. The 95 % CL limits on the combined partial widths as obtained from the CELLO data are shown in Fig. 5. In addition the lower limit on Γ^2_{ee}, as deduced from Γ_r using the VDM relation, is shown as well. Both limits are compatible with each other.

More stringent limits on the production of a scalar boson with $M_X > W$ may be obtained from fits to the differential cross sections. Assuming a universal coupling α_H to fermions, one can relate $\Gamma_{\gamma\gamma}$ to Γ_{ee} via VDM. The $\gamma\gamma$ data from CELLO (TASSO) exclude a scalar boson with $\Gamma_r >$ 30(40) MeV at the 95 % CL. Combining the results from $e^+e^- \rightarrow \gamma\gamma$ and $e^+e^- \rightarrow e^+e^-$, a scalar boson is restricted to the range $48 < M_X <$ 65 GeV with a fermion coupling $\alpha_H < 10^{-3}$. Furthermore a value of $\Gamma_r > 20$ MeV is excluded at the 95 % CL.

6. Search for Charged Higgs $H^{\pm}$

In the minimal standard $SU(2) \times U(1)$ model the Higgs boson is needed to incorporate masses. Extended models predict in addition to the neutral H^o charged Higgs particle $H^{\pm}$. The results of the four PETRA experiments are shown in Fig. 6. The boundaries in the (m_H, B_r) plane represent the 95 % CL limits obtained.

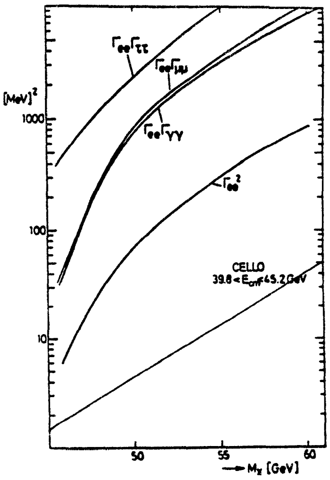


Fig. 5 : 95 % CL limits for the combined partial widths as function of the scalar boson mass M_X.

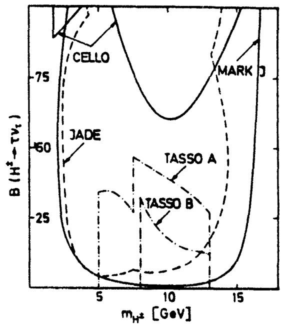
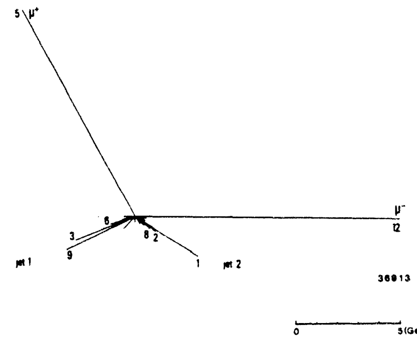


Fig. 6 : 95 % CL limits of the branching ratio B_r as a function of the Higgs mass $M_{H^\pm}$.

7. Peculiar CELLO Event

In a search for isolated muons in multihadronic events, the CELLO collaboration has found at a c.m. energy of W = 43.45 GeV a peculiar event with 2 opposite charged, isolated and high energetic muons (p = 11.0 GeV/c and 12.6 GeV/c) and 2 hadron jets, each jet opposite to one of the muons.



For the invariant masses one obtains $M_{q\bar{q}}$ = 17.3 GeV for the jet pair and $M_{\mu^+\mu^-}$ = 20.4 GeV for the $\mu^+\mu^-$ pair respectively. The event is extremely planar, the aplanarity being A = 0.003 and $< p_\perp^{out} >$ = 270 MeV/c. Within errors the total detected energy is compatible with the c.m. energy of W = 43.45 GeV, and almost all energy is due to charged particles. With the transverse momenta of the muons relative to the thrust axis of 7.2 GeV/c and 4.2 GeV/c respectively, the probability for this event to originate from semileptonic decays of heavy quarks or hadron punch through or decay is $< 8 \cdot 10^{-4}$.

From QED processes of order α^4, the expected yield of events for various mass regions $M_{\mu^+\mu^-}$ and $M_{q\bar{q}}$ is shown in Fig. 7.

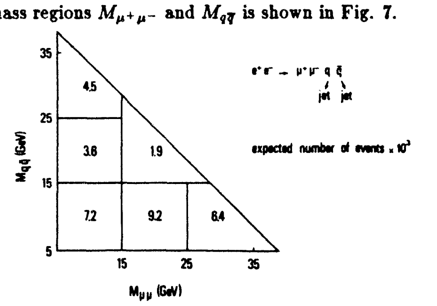


Fig. 7 : Number of expected events for the process $e^+e^- \rightarrow \mu^+\mu^-q\bar{q}$ as function of $\mu^+\mu^-$ and $q\bar{q}$ masses.

With both masses $M_{\mu^+\mu^-}$ and $M_{q\bar{q}}$ being large, the probability to observe one event of this process is less than $3.2 \cdot 10^{-4}$. Thus at most 10^{-3} events of this kind are expected from convential processes.

SUPERSYMMETRIC PARTICLE SEARCHES AT PETRA

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In the simplest hypotheses of supersymmetry,[1] leptons and quarks will have partners of spin 0. Likewise, fermion partners to the vector mesons of forces are needed. No doublet of known particles exists to support these fundamental postulates.

PETRA is best suited for such searches, having reached highest energies in e^+e^- collisions up to 46.8 GeV.

Specific event signatures were searched for in the data and compared to e.m. calculations considering the threshold behavior. New limits are given; previous work is cited in ref. 2.

Scalar muons, $\tilde{\mu}$

These were searched for by studying acoplanar muon pairs[3,4,5,6] from the reaction $e^+e^- \to \mu^+\mu^-\tilde{\gamma}\tilde{\gamma}$, where the photinos escape undetected. For instance, the expected number of events with acoplanarity $\xi > 30°$ for 113 pb^{-1} in 32.6 GeV $< \sqrt{s} <$ 46.8 GeV is estimated by MARK-J as shown in Fig. 1. No event is observed, excluding $\tilde{\mu}$ up to 20 GeV for a light $\tilde{\gamma}$.

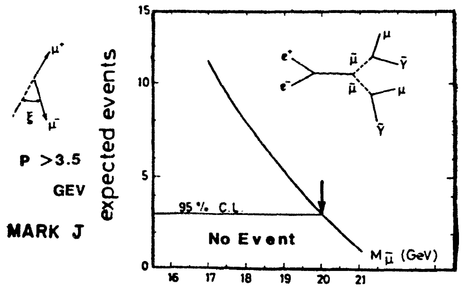


Fig. 1. MARK-J limit for scalar muon mass.

JADE searched for $\tilde{\mu}$'s which decay into massive photinos, which are either stable or decay into gamma rays. The excluded mass region is shown in the $m_{\tilde{\mu}}$, $\mu_{\tilde{\gamma}}$ plane in Fig. 2, which also shows the mass region excluded for the stable $\tilde{\mu}$.

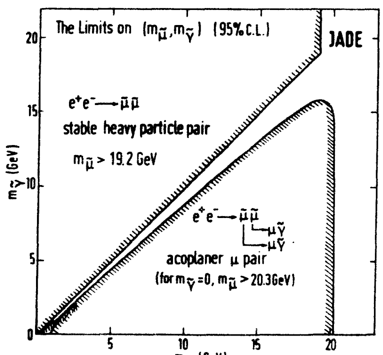


Fig. 2. Excluded domain for $\tilde{\mu}$ and $\tilde{\gamma}$ for the case of stable photinos.

Scalar electrons, $\tilde{e}$

These were searched for by several methods. If they are lighter than the beam energy, they can be produced in pairs.[7] When each $\tilde{e}$ decays into an electron and photino (goldstino), they will result in acoplanar electron pairs. The acoplanarity angle ξ distribution depends on the mass of the $\tilde{e}$'s. Finding no event with $\xi > 30°$, MARK-J[8] sets the limit $m_{\tilde{e}} >$ 22.5 GeV for the easiest case $m_{\tilde{\gamma}} = 0$, and $\tilde{e}$ is the lighter of $\tilde{e}_R$ and $\tilde{e}_L$.

If the $\tilde{e}$ is heavier than the beam energy it can be produced[9] in the reaction $e^+e^- \to e\tilde{e}\tilde{\gamma}$. The cross section for this reaction is small and is peaked when the electron is scattered in the very forward direction. A single electron is observed coming from the decay of the $\tilde{e}$. If the $\tilde{e}$ is too heavy to be produced by either of these reactions or the photinos (goldstinos) are so heavy that decay electrons do not obtain sufficient momenta to be detected, the radiative photino pair annihilation $e^+e^- \to \gamma\tilde{\gamma}\tilde{\gamma}$ gives a limit on the mass of the $\tilde{e}$. In this case the detected signal is a single gamma ray. Results of CELLO[3] and JADE[10] are shown in Fig. 3 and 4.

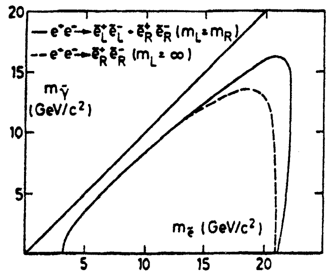


Fig. 3. CELLO limits on $m_{\tilde{e}}$ vs. $m_{\tilde{\gamma}}$

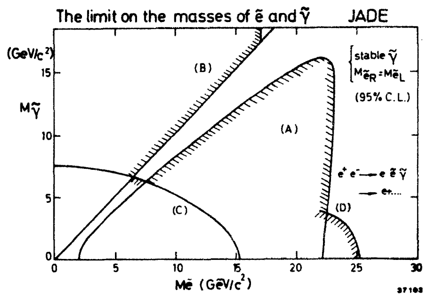
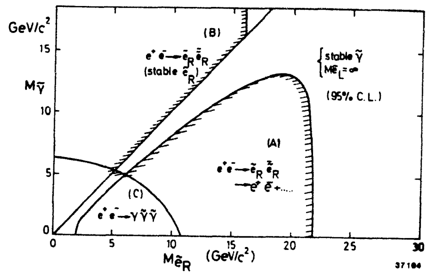


Fig. 4. Limits on $m_{\tilde{e}}$ for different $m_{\tilde{\gamma}}$ assuming
A) acoplanar ee from ee $\to \tilde{e}\tilde{e}$,
B) ee $\to \tilde{e}\tilde{e}$ stable
C) ee $\to \gamma\tilde{\gamma}\tilde{\gamma}$
D) ee $\to e\tilde{e}\tilde{\gamma}$



Same for $m_{\tilde{e}_R} < m_{\tilde{e}_L}$

Scalar tau, $\tilde{\tau}$

A similar analysis for scalar tau has been made in connection with a search for charged Higgs particles.[3,11,12] The mass limit is 14-16.5 GeV.

Scalar quark, $\tilde{q}$

These are produced similarly to scalar leptons, with decays like (a) $q \to q\tilde{\gamma}$ or (b) $\tilde{q} \to q\tilde{g} \to qq\bar{q}\tilde{\gamma}$, depending on the mass of the gluino. In the first case an acoplanar hadron event with a missing transverse momentum will be produced and in the second case a spherical hadron event will be produced. JADE studied these possibilities and obtained a lower limit for the $m_{\tilde{q}}$ of 21.4 (case a) and 18.8 GeV (case b).

Photino, $\tilde{\gamma}$

Photinos are taken to be produced by the exchange of $\tilde{e}$. If each photino decays into a photon and a goldstino, the observed final state will be a photon pair with degraded energies. The acoplanarity of the two photons will be large for a heavy photino. This is not observed. All PETRA experiments[13] are summarized in Fig. 5, which shows the excluded photino mass as a function of the $\tilde{e}$ mass assuming a short lifetime for the photino. If the lifetime is longer than 10^{-9} second, the detection efficiency for the two photons becomes too small. Therefore a very light photino cannot be excluded because of the Lorentz factor.

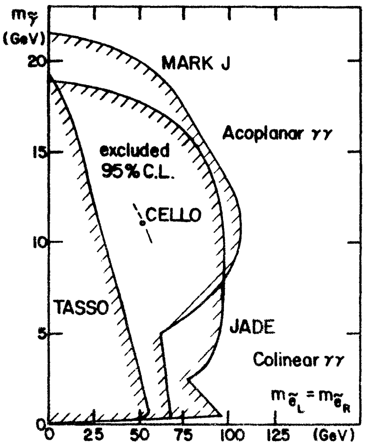


Fig. 5. The limit on the photino mass for different $m_{\tilde{e}}$, assuming a short lifetime of the photino.

Zino, $\tilde{Z}$

A zino can be produced by the reaction $e^+e^- \to \tilde{Z}\tilde{\gamma}$ by $\tilde{e}$ exchange. The zino decays into $\ell\bar{\ell}\tilde{\gamma}$ or $q\bar{q}\tilde{\gamma}$ $(q\bar{q}\tilde{g})$, where $\tilde{g}$ is a gluino. CELLO[14] studied the $ee\tilde{\gamma}$ mode. JADE[15] looked for all possible decay channels simultaneously and MARK-J[16] studied the $ee\tilde{\gamma}$ and $\mu\mu\tilde{\gamma}$ modes. In Fig. 6 and 7 the excluded zino mass is shown as a function of the $\tilde{e}$ mass.

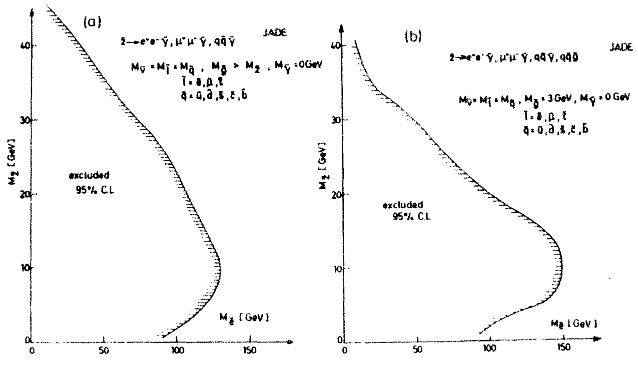
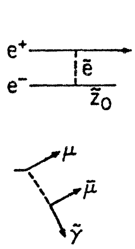


Fig. 6: Excluded region of $\tilde{Z}$ and $\tilde{e}$ mass (a) without and (b) with gluino effects for $m_{\tilde{\gamma}} = 0$.



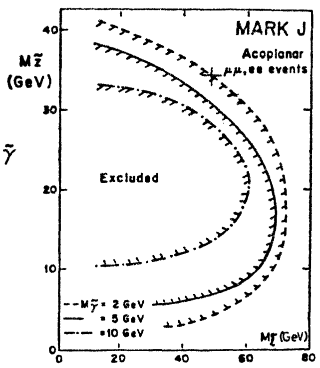


Fig. 7. Excluded region of $m_{\tilde{Z}}$ vs. $m_{\tilde{e}}$ for different photino mass. 10% decay branching ratio assumed.

Wino, $\tilde{W}$

MARK-J[16] deduced a mass limit of the fermion partner of the W from the absence of acoplanar ee and μμ. The excluded mass region is shown in Fig. 8.

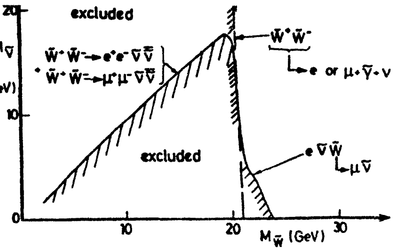


Fig. 8. Limits on $\tilde{W}$ mass from various processes.

Higgsino, $\tilde{H}$

The fermion partner of the charged Higgs particle appears similar to the heavy sequential leptons.[17] A pair will produce an event which has a lepton opposite to a hadron jet, or two acoplanar hadron jets. Evidence for such a particle has not been observed[18] and a limit for the mass is extended to 21.5 GeV by MARK-J. We summarize the 95% CL lower limits[a] on the mass (GeV) of SUSY particles:

	Spin	CELLO	JADE	MARK-J	TASSO	Assumptions
$\tilde{e}$	0	21	21.8	22.5	-	
		21.2	25.2	-	16.6	e_L, e_R degen.
$\tilde{\mu}$	0	16	20.3	20	-	
		-	21	-	16.4	μ_L, μ_R degen.
$\tilde{\tau}$	0	15.3	14	16.5	-	
$\tilde{q}$	0	-	18.8[b]	-	-	
$\tilde{\gamma}$	1/2	16	18	21	7	$m_{\tilde{e}} \simeq 40$ GeV
$\tilde{Z}$	1/2	22.4	35	35	-	$m_{\tilde{e}} \simeq 50$ GeV
$\tilde{W}$	1/2	-	-	22	-	$m_{\tilde{\nu}} = 0$
$\tilde{H}$	1/2	16.3	20.6	21.5	15.5	

[a] In most cases it is assumed that the lowest SUSY particle is light and states are not degenerate.
[b] For $m_{\tilde{g}} > m_{\tilde{q}}$ the limit is 21.4 GeV.

We thank the PETRA groups and the DESY directorate.

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SEARCH FOR NEW NEUTRAL PARTICLES IN e^+e^- ANNIHILATIONS AT 29 GeV

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This paper describes a search for a new neutral particle L^o in the production process:

$$e^+e^- \rightarrow \overline{L^o}L^o \quad [L^o \rightarrow e^{\pm}X^{\mp}(\nu)]$$

where X is a minimum ionizing particle such as a pion or a muon. The search was carried out with the High Resolution Spectrometer (HRS) at PEP at a c.m. energy of 29 GeV. The total integrated luminosity for the data presented here is 106±5 inverse picobarns. The detector has been described in detail elsewhere.[1] Features of the HRS important to this search include charged-particle tracking over 90 percent of the full solid angle in a 1.6 T solenoidal magnetic field, and measurements of electromagnetic shower energy with a lead-scintillator calorimeter which covers the angular intervals $|\cos\theta| < 0.60$ and $0.70 < |\cos\theta| < 0.96$ where θ is the angle with respect to the beam direction. Showers are located by proportional wires (PWC's) with a position resolution of ±2 cm.

Events were selected which contained at least one isolated charged-particle pair $e^{\pm}X^{\mp}$. Each event was required to satisfy the following criteria:

a) The observed number of charged particles ≥ 4 and the sum of the magnitudes of the charged particle momenta $\Sigma|p| > 7$ GeV/c.

b) $|\cos\theta| < 0.866$ and momentum $p > 1.0$ GeV/c for each particle in the pair.

c) Sum of magnitudes of momenta $4.5 < (P_e + P_X) < 17.0$ GeV/c.

d) Opening angle of pair $< 60^o$.

e) No other charged particle or photon with $E_\gamma > 0.1$ GeV in the hemisphere centered on the momentum vector of the pair.

In addition, shower counter information was used to select the electron and the minimum ionizing particle.

A total of 7 events were found satisfying all of the criteria. One of the events was rejected from consideration since it was completely consistent with the higher-order QED reaction $e^+e^- \rightarrow e^+e^-\mu^+\mu^-$. The characteristics of the remaining 6 events are listed in the table below.

Event	Pair	$e^{\pm}$ P (GeV/c)	$X^{\mp}$ P (GeV/c)	$e^{\pm}X^{\mp}$ Mass (GeV)	Opposite Jet N_{ch}	Opposite Jet ΣP_{ch}	Opposite Jet ΣE_γ
1	e^+X^-	5.43	9.09	1.68	4	3.1	9.4
2	e^-X^+	2.07	2.75	0.33	2	5.2	3.3
3	e^-X^+	7.02	4.31	1.30	>4	>10.5	>1.5
4	e^+X^-	5.84	2.83	1.04	6	11.4	3.3
5	e^-X^+	3.49	2.34	0.81	2	3.0	10.2
6	e^+X^-	2.55	2.70	1.58	6	7.5	6.7

Note: $e^{\pm}X^{\mp}$ masses are calculated using $m_e = m_X = 0$. N_{ch} ≡ number of charged particles; ΣP_{ch} ≡ sum of magnitudes of charged particle momenta; ΣE_γ = sum of calorimeter energies not associated with charged tracks.

There are several known processes including semi-leptonic decays of charmed mesons and misidentification of hadrons as electrons which also satisfy the selection criteria. These known sources shown in the table below are expected to yield 5.5±2.2 events.

	Source	Expected Number of Events
(a)	$D^o \rightarrow K^{\pm} e^{\mp}\nu$ $\rightarrow K^o_L\pi^{\pm}e^{\mp}\nu$	1.1 ± 0.6
(b)	$D^{\pm}\pi^{\mp} \rightarrow K^o_L\ e^{\pm}\nu\pi^{\mp}$	1.4 ± 0.7
(c)	(Interacting $X^{\pm}$)$X^{\mp}$	1.4 ± 0.3
(d)	$(X^{\pm}\pi^o)X^{\mp}$	0.4 ± 0.2
(e)	$e^{\pm}X^{\mp}$ (missed γ's)	1.2 ± 0.4
	Total	5.5 ± 2.2

The six events that are actually observed can thus be attributed entirely to background and do not indicate the existence of a new neutral particle. We have examined these events for the possible production of a long-lived heavy sequential neutrino but no resolvable decay vertices are observed.

The results of this analysis are summarized in the table below which gives 90 percent confidence level upper limits for $(\sigma_L + \sigma_{\bar{L}})\cdot B(e^{\pm}X^{\mp}\nu)$ as a function of the mass and mean decay path of the particle L. The quoted limits are for the case where $X^{\mp}$ is a muon. If the minimum-ionizing particle is a pion, then the limits are 20% higher.

Mass of L (GeV)	Mean Decay Path (cm)	Detection Efficiency	Observed Events	Expected back-grounds	$\sigma\cdot B$ (nb)
1-3	<1	0.29	6	5.5±2.2	20×10^{-5}
4-6	<1	0.24†	0	<1	9×10^{-5}
2	10	0.26	0	<1	8×10^{-5}
5	10	0.22	0	<1	10×10^{-5}
2	20	0.20	0	<1	11×10^{-5}
5	20	0.16	0	<1	14×10^{-5}

†Includes requirement $m_{eX} > 2$ GeV

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*On behalf of the HRS collaboration

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EVIDENCE FOR A MASSIVE STATE IN THE RADIATIVE DECAYS OF THE UPSILON

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ABSTRACT: Evidence is presented for a state, which we call ζ, with a mass M = (8322 ± 8 ± 24) MeV and a line width Γ < 80 MeV (90% confidence level) obtained using the Crystal Ball NaI(Tl) detector at DORIS II. The branching ratio to this state from the Υ(1S) is of order 0.5%.

It has been realized for some time that precision measurements of the radiative decay of the various quarkonium states provide a powerful tool with which to search for hypothetical particles, such as gluonic mesons[(1)], Higgs bosons[(2)], or supersymmetric particles[(3)]. We report here such an investigation using Υ(1S) and Υ(2S) data that were obtained using the Crystal Ball NaI(Tl) detector[(4)] installed in the DORIS II storage ring at DESY. The data samples consist of about 100K produced Υ(1S) ($\int\mathcal{L}dt$ = 10.7 pb^{-1}) and of about 200K produced Υ(2S) (64.5 pb^{-1}). The ability of the Crystal Ball detector to resolve and measure monochromatic γ's in the DORIS II environment has been demonstrated[(5)]. The results reported here were obtained using algorithms and subtraction techniques optimized for the region of E_γ from ∿ 700 to ∿ 2000 MeV. Other energy regions are still under investigation.

Below we describe two analyses of the reaction $\Upsilon \rightarrow \gamma X$ in which we search for monoenergetic photons signaling the production of a state X. The first analysis uses a sample of events at the Υ(1S) energy which has been selected for multihadron decays by efficiently removing beam gas, cosmic rays, e^+e^-X and QED events (including radiative $\gamma\tau\bar{\tau}$ events). The efficiency for selecting multihadron events is found to be ϵ_h = (0.90 ± 0.05). The resulting sample contains contributions from Υ(1S) and continuum decays approximately in the ratio of 2.5 to 1.

"Good" photons were selected by removing charged particles, photons with showers contaminated by energy depositions from nearby particles, and photons resulting from π^0decay. The π^0's were identified as either a pair of clearly separated photons or as a single cluster formed by the two merged photon showers. The general character of these cuts has been discussed in detail previously[(4,6)]; however, for the region of E_γ studied here many of these previously used cuts needed considerable refinement. The resulting inclusive photon spectrum from the Υ(1S) (fig. 1) was fitted using a line shape measured at 1.5 GeV[(4)], variable amplitude and mean, a fixed $\sigma_E/E = 0.027/E^{1/4}$ (in GeV) (our expected resolution for photons in a multihadron environment) and a background polynomial of order 3. The fit yielded a 4.0 standard deviation signal of (89.5 ± 22.5) counts at E_γ = (1074 ± 9) MeV (statistical error only, an overall scale error of 2% on the energy is yet to be applied). By variation we find $\sigma_E/E = 0.028^{+0.013}_{-0.009}/E^{1/4}$, consistent with our expected resolution. No other line in fig. 1 can be fitted, consistent with our resolution, with a significance of more than 2.2 standard deviations.

Additional cuts designed to enhance multihadronic decays of the ζ were developed by the use of Monte Carlo simulations of the process $\Upsilon(1S) \rightarrow \gamma\zeta$, $\zeta \rightarrow$ 2 hadron jets: total multiplicity between 9 and 20 (only particles with energy deposition greater than 50 MeV are counted); charged multiplicity ≥ 2; neutral multiplicity ≤ 12; total energy deposited in the NaI(Tl) ≤ 8000 MeV; sphericity of the event ≥ 0.16. While charm quark jets were used as a model, jets due to lighter quarks or gluons lead to very similar results. Fitting as above (fig. 2) now yields a significance of 4.2 standard deviations for the signal with parameters

$$\begin{aligned} E_\gamma &= (1072 \pm 8 \pm 21)\ \text{MeV} \\ M &= (8319 \pm 10 \pm 24)\ \text{MeV} \\ \text{Counts} &= 87.1 \pm 20.5 \\ \chi^2 &= 24.8 \text{ for 41 degrees of freedom.} \end{aligned} \quad (1)$$

The efficiency for this selection was investigated in a few ways. First we used a γ-jet-jet Monte Carlo simulation for various fixed photon energies and jet-jet models ($u\bar{u}$, $c\bar{c}$, gg). Second we superimposed Monte Carlo generated photons onto real hadronic events at the c.m. energy of interest (Υ(1S) or Υ(2S)). The various methods show systematic differences (fig. 3), causing a large contribution to the systematic error of the efficiency. Therefore we estimate a photon efficiency near 1 GeV of (18 ± 10)% leading to a branching ratio

$$B[\Upsilon(1S)\rightarrow\gamma\zeta,\zeta\rightarrow\text{hadrons}] = (0.47 \pm 0.11 \pm 0.26)\%. \quad (2)$$

A number of checks were made to ensure that the signal was not instrumental or induced by the analysis procedure. First all the cuts used to obtain the inclusive photon spectrum of fig. 1 were removed one at a time; this procedure indicated that none of the cuts used had anomalous effects. Second, by dividing the data appropriately, no preference for a particular period or geometrical region could be detected. Correlations between γ-energy and the triggers generated by the events containing the candidate γ's were found to be essentially constant moving from below to beyond the region of $E_\gamma = 1$ GeV. Off-resonance data, Monte Carlo 3g and $q\bar{q}$ events, and random beam cross events were subjected to the same analysis procedure and showed no significant fluctuations near 1 GeV. Finally, J/Ψ data taken at SPEAR and analyzed by the same program showed no narrow line at about 1 GeV.

The Υ(2S) data set, analyzed similarily to the Υ(1S) sample, does not show any narrow line (fig. 4). This is strong evidence that the signal from the 1S is not artificially induced. However, a signal for the ζ from the cascade $\Upsilon(2S)\to\pi\pi\Upsilon(1S)$, or $\gamma\gamma\Upsilon(1S)$, is expeced. A fit using a fixed width $\sigma_E/E = 0.033$ (taking account of the Doppler broadening) leads to an upper limit of 70 events (90% c.l.) at $E_\gamma = 1072$ MeV. This is consistent with an expectation of 53 ± 13 events based on the observed signal on the Υ(1S). No peak is observed either for the direct process $\Upsilon(2S) \to \gamma + \zeta$ (8.32 GeV), i.e. at $E_\gamma = 1556$ MeV. While the detection efficiency (fig. 3) has rather large systematic uncertainties as mentioned before, the ratio of efficiencies ε(1070 MeV)/ε'(1560 MeV) is uncertain to about 10% of this ratio. Thus we find an upper limit $\frac{B[\Upsilon(2S) \to \gamma + \zeta]}{B[\Upsilon(1S) \to \gamma + \zeta]} < 0.22$ (90% c.l.).

The second analysis was motivated by a possible Higgs interpretation of the signal described above for which the decay into $\tau^+\tau^-$(2) might be substantial. Disregarding the motivational bias, this data set can be viewed as a set of low multiplicity events orthogonal to the multihadronic sample. A new preselection was performed on all the recorded Υ(1S)-region triggers by requiring a total energy of at least 1200 MeV and at least two particles in the detector. As in the first analysis, an initial set of cuts was applied to arrive at an inclusive photon spectrum in the E_γ-region of 700 to 2000 MeV. Care was taken not to exclude $\gamma\tau\bar{\tau}$ events, using Monte Carlo calculation as a guide. QED-background was substantially reduced by exploiting the correlation of the γ with the beam direction (strong in the case of radiative QED and weak for a possible ζ related $\gamma\tau^+\tau^-$ final state). In addition e^+e^-X events, beam gas interactions, and cosmic **ray** events were excluded. The remaining series of cuts was derived from the Monte Carlo simulation of $\Upsilon(1S) \to \gamma\zeta \to \gamma\, \tau^+\tau^-$. In essence these cuts were boundary tunings (both in the one and two dimensional distributions) of such variables as thrust, multiplicity, event track-alignment, transverse momentum to the beam, etc., determined by the $\gamma\tau^+\tau^-$ like configuration. In particular, a total multiplicity requirement of less than 9 guarantees no overlap with the results of (1). A check with the Monte Carlo was made by evaluating the efficiency of the sum of all these cuts for Monte Carlo $\gamma\tau^+\tau^-$ events for 10 discrete values of E_γ between 600 and 2000 MeV. The efficiency distribution obtained is approximately constant (at 24%) from 700 to 1500 MeV, and then drops off to ∿ 18% at 2000 MeV. A fit to the final signal (fig. 5) with σ_E/E fixed at $2.7\%/E^{1/4}$, yields a 3.3 standard deviation signal with the following parameters:

$$\begin{aligned} E_\gamma &= (1062 \pm 12 \pm 21)\ \text{MeV} \\ M &= (8330 \pm 14 \pm 24)\ \text{MeV} \\ \text{Counts} &= 23^{+7.9}_{-7.2} \\ \chi^2 &= 29.9 \text{ for 41 degrees of freedom,} \end{aligned} \qquad (3)$$

in excellent agreement with the values recorded in (1). Fitting with a variable width yields a $\sigma_E/E = 0.034^{+0.027}_{-0.012}/E^{1/4}$, consistent with the expected resolution. These results are statistically independent of those shown in (1). The combined significance of both peaks is thus greater than 5 standard deviations. The observed peaks are consistent with the known Crystal Ball resolution function at $E_\gamma \sim 1$ GeV, which is an asymmetric Gaussian of FWHM (64 ± 5) MeV[4]. Unfolding this resolution from the combined observed FWHM (82 ± 23) MeV yields a 90% c.l. upper limit on the intrinsic ζ width of 80 MeV.

To obtain a value for $B[\Upsilon(1S) \to \gamma\zeta]$ which includes final states contributing to the second signal and not to the first we assume as a model that the ζ has two kinds of decay, represented by $c\bar{c}$ and $\tau\bar{\tau}$ MonteCarlo models. The data is found to be consistent with these models and indicates that inclusion of low multiplicity $\tau\bar{\tau}$ like final states will increase the branching ratio (2) by about 20%. Using the $c\bar{c}$ Monte Carlo alone to model both signals results in a poor fit to the data (2-3 standard deviation disagreement). However, this may be due to an inadequate $c\bar{c}$ Monte Carlo. It must be emphasized that we do not prove that the ζ decays into $c\bar{c}$ and $\tau\bar{\tau}$, we only show consistency with the model used as an aid in extracting the signal of (3).

We have also looked for a possible signal from $\Upsilon(1S) \to \gamma\zeta \to \gamma\tau^+\tau^-$ where $\tau^\pm \to e^\pm\nu\nu$, $\tau^\mp \to \mu^\mp\nu\nu$. An upper limit of 0.2% (90% c.l.) for $B[\Upsilon(1S) \to \gamma\zeta, \zeta \to \tau^+\tau^-]$ has been found, compatible with the signal from the second analysis even if that were entirely due to a $\tau\bar{\tau}$-decay of the ζ. Additionally, an upper limit of 3.2×10^{-4} (90% c.l.) for the branching ratio $B[\Upsilon(1S) \to \gamma\zeta, \zeta \to e^+e^-]$ has been determined.

In conclusion we have observed two statistically independent signals at the same mass; one of 4.2 and the other of 3.3 standard deviations. The fact that both peaks appear at the same position with a compatible width supports the hypothesis that we are seeing the same state in two different channels; then the combined significance of both peaks is greater than 5 standard deviations. Both our signals have widths consistent with the detector energy resolution. The weighted averages for the parameters of this new state, herein named ζ, are

$$E_\gamma = (1069 \pm 7 \pm 21)\ \text{MeV}$$
$$M = (8322 \pm 8 \pm 24)\ \text{MeV}$$
$$\Gamma < 80\ \text{MeV (90\% c.l.)}$$
$$B[\Upsilon(1S) \to \gamma\zeta] \sim 0.5\%.$$

The interpretation of this new state as the neutral Higgs boson expected in the standard model gives a disagreement of approximately two orders of magnitude between this observed branching ratio and that predicted. This branching ratio can be accomodated in some extensions of the standard model, e.g. two-Higgs doublet models. A less model-dependent quantity is the ratio $\frac{B[\Upsilon(2S) \to \gamma\zeta]}{B[\Upsilon(1S) \to \gamma\zeta]}$, in which the strength of the Higgs' coupling to b-quarks cancels out; in either model this ratio is predicted to be ~ 1.0[2], while our upper limit is 0.22, in apparent disagreement. Further, given the limited statistics of the experiment, it cannot be proven that the mode $\zeta \to \tau\bar{\tau}$ exists, although our analysis is consistent with it.

* For more detail see C. Peck et al. (CB Collaboration) DESY 84-064/SLAC-PUB 3380 (1984); contributed paper to this conference no. 918.

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(1) See e.g. J.D. Bjorken, Proc. Summer Inst. on Particle Physics, 1980, SLAC-224.
(2) F. Wilzek, PRL 39, 1304 (1977); J. Ellis et al., Pl 83B, 339 (1979); S. Weinberg, PRL 36, 294 (1976); H.E. Haber, G.L. Kane, PL 135B, 196(1984).
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(5) J. Irion et al., SLAC-PUB-3325.
(6) C.D. Edwards, Ph.D.Thesis, CALT-68-1165.
(7) Lund-MC version 5.2; cf. B. Andersson et al., PRep 97, 33 (1983).

Figure Captions

Fig. 1: $\Upsilon(1S) \to \gamma$ + high multiplicity
Fig. 2: $\Upsilon(1S) \to \gamma$ + high mult., with "physics" cuts
Fig. 3: γ efficiency for $\Upsilon(2S)$
(almost identical for $\Upsilon(1S)$)
Fig. 4: $\Upsilon(2S) \to \gamma$ + high multiplicity
Fig. 5: $\Upsilon(1S) \to \gamma$ + low multiplicity

Fig. 1

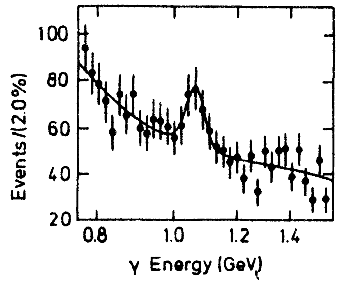


Fig. 2

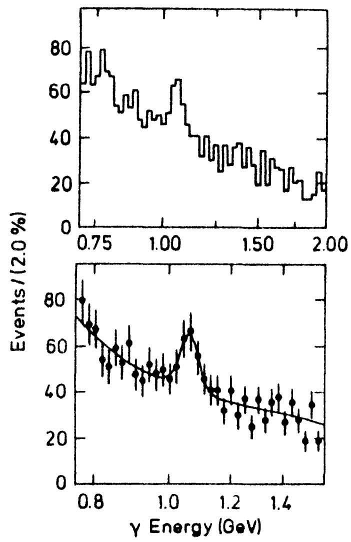


Fig. 3

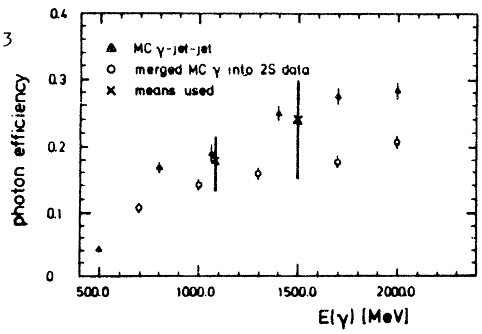


Fig. 4

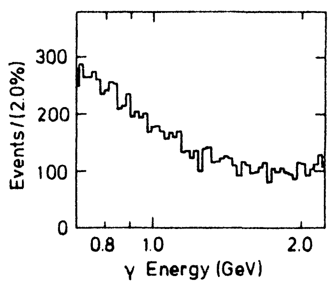
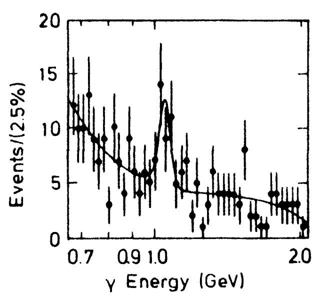


Fig. 5



SEARCH FOR SUPERSYMMETRIC ELECTRONS AND PHOTONS

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A search for supersymmetric particle production has been performed using the MAC detector at PEP at $\sqrt{s}$=29 GeV. The reactions which have been studied are: (1) $e^+e^- \rightarrow e^\pm \tilde{e}^\mp \tilde{\gamma} \rightarrow e^\mp$ and (2) $e^+e^- \rightarrow \tilde{\gamma}\tilde{\gamma}\gamma \rightarrow \gamma$. The searches involve triggering the detector on either a single electron or a single photon. Reaction 1 is a process for the production of a real single selectron and hence is limited to $m_{\tilde{e}} \leq \sqrt{s}$. Reaction 2, on the other hand, is the radiative production of a real photino pair via selectron exchange and hence sets bounds on combinations of the selectron and photino masses. However, for the special case of massless photinos, the limit on the selectron mass is limited only by backgrounds and luminosity and not by the beam energy.

The MAC group has previously published a limit on the selectron mass based on reaction 1 and the present report describes an update of the previous experiment.

The detector is set to trigger on single electrons above a threshold energy and the energy spectrum of the electrons is measured. A search region corresponding to the expected spectrum from reaction 1 is then defined and a cross section or upper limit is then determined from the number of single electron events found in this region. The analysis requires a central drift chamber track with $|\cos\theta| \leq .75$, p>1 GeV/c and associated electromagnetic shower energy > 2 GeV.

Two running periods with different veto capabilities for additional energy were used:

1) $\theta_{veto} \geq 9°$ $\quad \int \mathcal{L} dt = 36$ pb^{-1}
2) $\theta_{veto} \geq 5°$ $\quad \int \mathcal{L} dt = 77$ pb^{-1}

The observed energy distributions of single electrons are consistent with $e^\pm$ expected from $e^+e^-\gamma$ events. Fig. 1 shows the energy spectrum corresponding to data set 1. Electrons produced by $\tilde{e}$ decay are expected to have $E_e > 8$ GeV.(see insert, Fig. 1)

The combined data from both data sets establishes a cross section limit $\sigma \leq .017$ pb at 90% CL. The relation between cross section and selectron mass for the MAC acceptance yields:

$$m_{\tilde{e}} > 24 \ GeV \ if \ m_{\tilde{e}L} \gg m_{\tilde{e}R} \ or$$

$$m_{\tilde{e}} > 25 \ GeV \ if \ m_{\tilde{e}L} = m_{\tilde{e}R}.$$

Reaction 2, $e^+e^- \rightarrow \tilde{\gamma}\tilde{\gamma}\gamma$ involving the detection of a single photon, requires only that the photino is non-interacting in the detector. This reaction also permits $m_{\tilde{\gamma}} = 0$ as a possibility, but in general the mass limits set by the experiment will be a contour with $m_{\tilde{e}}$ and $m_{\tilde{\gamma}}$ as variables.

There are backgrounds to the above process from radiative Bhabha scattering and radiative neutrino pair production. There can also be single photons from beam gas interactions and beam spill. The detector is made to trigger on an EM shower with $|\cos\theta| < 0.7$, and to veto on anything else that has $\theta \geq 5°$. A special small angle tagging system covers the region $5° \leq \theta \leq 10°$ and consists of a segmented lead-proportional chamber system. This system has a veto efficiency of order 1 - 10^{-4}. The experimental acceptance with the above minimum veto angle defines a search region for the photon of $E_{\perp min} \geq$ 2.5 GeV. The present analysis uses $E_\perp \geq 3$ GeV in order to stay well away from possible backgrounds from radiative Bhabha events. Radiative neutrino production becomes the dominant source of single photons at higher energies. The PEP and PETRA energy regions are well matched to the search for $m_{\tilde{e}}$ in the ≤ 50 GeV energy range since the photon yields in the search region will not be dominated by radiative neutrino production.

The measured energy spectrum is shown in Fig. 2 with the search region indicated on the figure. The data correspond to $\int \mathcal{L} dt$=80 pb^{-1}. One event is observed in the search region at $E_\perp$=5.3 GeV. The expected backgrounds are: $\nu\bar{\nu} \approx 0.5$ event, $\tau\tau\gamma \approx .05$ event, and $ee\gamma \approx 0.1$ event. If the expected radiative neutrino yield is assumed to be 0.5 event, the 90% CL limits obtained for $m_{\tilde{e}}$ and $m_{\tilde{\gamma}}$ are shown in Fig 3 for $m_{\tilde{e}L} \gg m_{\tilde{e}R}$. The specific case of $m_{\tilde{\gamma}} = 0$ yields:

$$m_{\tilde{e}} > 28.5 \ GeV \ for \ m_{\tilde{e}L} \gg m_{\tilde{e}R} \ and$$

$$m_{\tilde{e}} > 36.5 \ GeV \ for \ m_{\tilde{e}L} = m_{\tilde{e}R}.$$

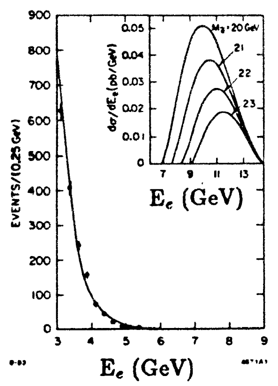

FIG. 1

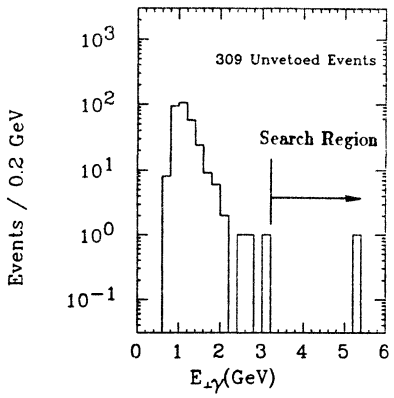

FIG. 2

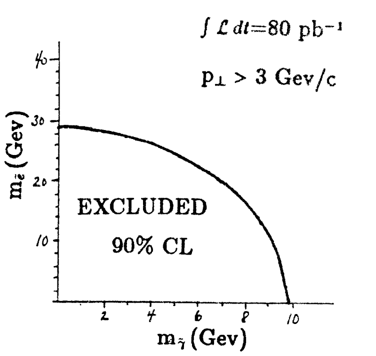

FIG. 3

SEARCH FOR HIGGS SCALARS IN UPSILON DECAYS

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We have searched for the decay of Υ's into a monochromatic photon either alone[1], excluding the existence of the axion to >99.99% c.l., or accompanied by other particles[2] as a signal for the reaction $\Upsilon \to \gamma$+Higgs, with null result. While we are not sensitive to the branching ratios (BR) predicted by the standard model, we can put limits on the lowest Higgs mass and the ratio of the vacuum expectation values for more complex models. Our results are also compared with the observation of $\psi \to \gamma + \xi(2.2)$ by MARK III at SPEAR[3] and the observation by the Crystal Ball at DORIS[4] of $\Upsilon \to \gamma + \zeta(8.3$ GeV).

The standard model of the electroweak interaction requires the existence of a scalar neutral particle, the Higgs meson (H). Theory cannot predict the mass of the Higgs and searches for these elusive states remain unsuccessful and to a large extent inconclusive. The number of Higgs can become large in many attempts to go beyond the standard model and suggestions have been put forward that neutral Higgs with masses in the few GeV range might exist. Vector mesons (V) consisting of heavy $q\bar{q}$ pairs decay according to $V \to H + \gamma$ with a BR given by $BR(V \to \gamma + H) = [BR(V \to \mu\mu) M_q^2 G_F^2/(\alpha\pi\sqrt{2})](1 - M_H^2/M_V^2)$

Because of the dependence of the BR on the quark mass squared, Υ decays are at present the most profitable hunting grounds for light Higgs'.

Experimentally, meaningful searches require sensitivity to a large class of possible final states. For $M_{Higgs} < M_{charmonium}$, for instance, the Higgs decays predominantly into strange quarks or muons. For heavier Higgs', up to the Υ mass, the dominant decays are $\tau\bar{\tau}$ and $c\bar{c}$ pairs.

For models with two Higgs mesons, the BR above changes by a factor $x^2 = [\langle\phi_1\rangle/\langle\phi_2\rangle]^2$, where $\langle\phi\rangle$ are the v.e.v. of the fields ϕ. Moreover in the decays of $(c\bar{c})$ and $(b\bar{b})$ states, the same factor x^2 might appear in both cases or factors of x^2 and $1/x^2$ might apply to $(c\bar{c})$ and $(b\bar{b})$ respectively. Thus, comparison of searches from J/ψ and Υ decays can only be made in the context of a model.

We have searched for monochromatic photon signals from Υ and Υ' decays[4] using the CUSB detector at CESR, both in the inclusive photon spectrum from multihadron final states and in final states consisting of 2 charged particles plus photon. No signal has been observed. We therefore can only quote upper limits for $BR(\Upsilon \to \gamma + X)$. Figure 1 shows such limit as obtained from the inclusive spectrum rom Υ decays.

Indicated in the figure are the scaled value for $\Upsilon \to \gamma + \xi(2.2)$, assuming the same enhancement for ψ and Υ decays. Also indicated is the result of the Crystal Ball for $\Upsilon \to \gamma + \zeta(8.3)$. While their central value is considerably higher then our upper limit, given the large quoted systematic uncertainty in the estimate of the BR, the inconsistency becomes marginal.

Similar results are obtained from Υ' decays, where we are in agreement with the Crystal Ball that there is no significant signal for $\Upsilon' \to \gamma + \zeta$, either via cascade to the Υ or directly to less than 0.7% and 0.15% respectively.

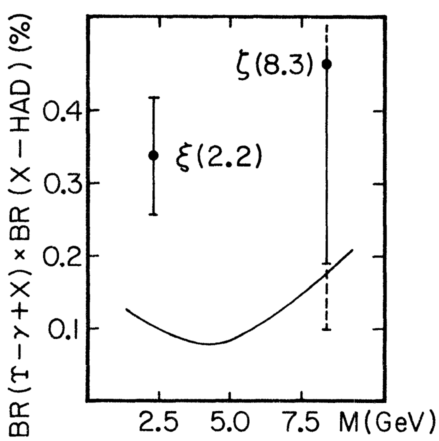

Figure 1. 90% c.l. upper limit for $BR(\Upsilon \to \gamma X)$ vs M(X).

Our search for a monochromatic photon signal in the $\Upsilon \to \gamma + 2$ charged particles is limited at present to recoiling masses of less than ≈6 GeV. We obtain the limit $BR(\Upsilon' \to \gamma + \xi)BR(\xi \to 2ch.part.) < 4\times10^{-4}$ compared to the value 5.5×10^{-4} for $BR(\Upsilon \to \gamma + \xi)BR(\xi \to K^+K^-)$ scaled from the ψ, assuming the same enhancement over the standard model. We conclude therefore that if the ξ(2.2) is indeed a very light Higgs produced with a BR ≈10 times larger than predicted by the standard model, it is not produced in Υ decays with the same enhancement.

Our null results can be used to set upper limits on the value of the ratio x as function of the possible Higgs mass, as shown in figure 2.

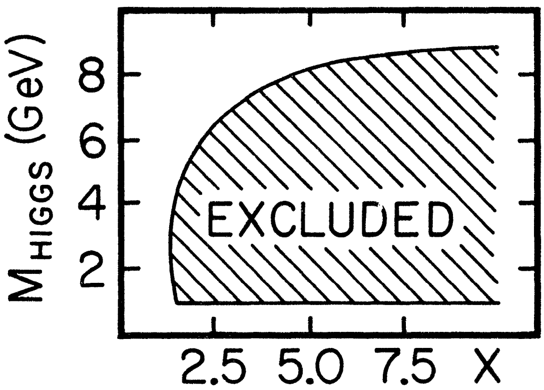

Figure 2. Excluded region for M_H and x^2.

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SEARCH FOR NEW PARTICLES AT VEPP-2M

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This talk describes briefly two experimental searches for new particles performed at the VEPP-2M e^+e^- collider in Novosibirsk.

The first one was aimed to look for light particles with a fractional charge $Q = 2/3$ produced exclusively in the reaction $e^+e^- \to q\bar{q}$. Experimental data collected with the OLYA detector in the c.m. energy range from 1.0 up to 1.4 GeV was used corresponding to the integrated luminosity of 1.2 pb^{-1}.

Events of the reaction $e^+e^- \to q\bar{q}$ have been searched for in a sample of $5 \cdot 10^5$ colinear events, $3 \cdot 10^4$ of them being due to $e^+e^- \to \mu^+\mu^-$. The minimum value of the sum of pulse heights in six scintillation counters among all colinear events was 4.78A, where A was a pulse height from a minimum ionizing particle. For relativistic particles with a charge 2/3 the mean value of this sum must be equal to 3.2 A. Absence of events with small pulse heights allows to place an upper limit on the production of fractionally charged particles shown in Fig. 1. For quark masses less than 0.4 GeV the obtained limits are by two orders of magnitude lower than those in earlier experiments /1,2/. Close values of the limits were obtained by Mark-II for masses from 1.0 to 2.8 GeV /3/.

In Ref. 4 an attempt has been made to reconcile modern QCD conceptions with the existence of free quarks. By dashed curves we show in Fig. 1 the values of $R = \sigma(q\bar{q})/\sigma_{\mu\mu}$ predicted by this model for 1.2 GeV (curve 1) - the average energy of our experiment and 5.2 GeV (curve 2) - that of the Mark-II. One can see that our values of upper limits rule out the model of Ref. 4 at quark masses below 0.4 GeV. This conclusion is unaffected if one takes into account quark interaction with a detector material.

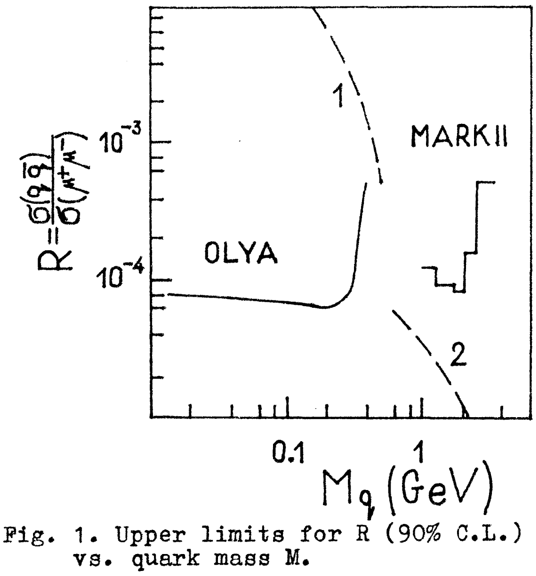

Fig. 1. Upper limits for R (90% C.L.) vs. quark mass M.

The second experiment looked for a heavy electron (HE) suggested by Low /5/ and produced in the reaction $e^+e^- \to e^{\mp}e^{\pm *}$, $e^{\mp *} \to e^{\mp}\gamma$. To this end the information collected with the NaI(Tl)detector in the ϕ -meson energy range 1.0-1.05 GeV has been used. Data processing of an event sample corresponding to 1.3 pb^{-1} found 10^4 events with one photon and one electron at large angles /6/. These events were due to the process of Compton scattering of a quasireal photon by a colliding electron - a particular case of single Bremsstrahlung when one of the initial particles was deflected at a small angle $\sim 1/\gamma$ and escaped detection. This kinematics is very favourable for the HE production. Such HE will reveal itself as a peak in a distribution over a $e\gamma$ mass with a width determined by an apparatus resolution. Since the experimental distribution in $m_{e\gamma}$ agrees with QED and contains no peaks, one can place an upper limit for the constant of $e^*e\gamma$ coupling λ in the HE mass range 500-900 MeV. The obtained limits are shown in Fig. 2 and are by a factor of 5 better than in previous experiments /7,8/.

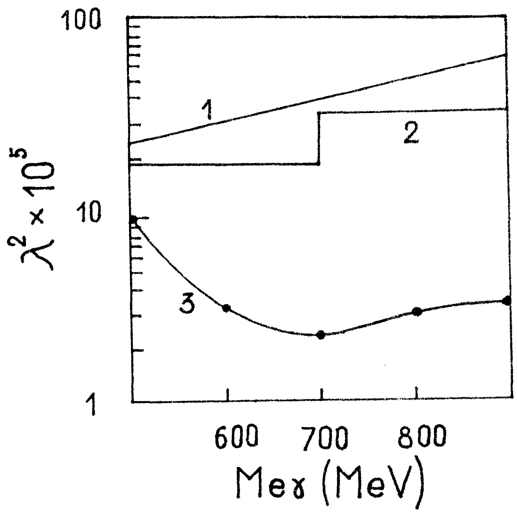

Fig. 2. Upper limits for λ (95% C.L.) vs. HE mass.

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EXPERIMENTAL LIMITS ON THE PRODUCTION OF FRACTIONALLY CHARGED PARTICLES

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A search for fractionally charged Q=1/3 (2/3) particles produced in (anti)neutrino-nucleus and in proton-nucleus collisions was performed using the scintillator system of the CHARM neutrino detector at the CERN SPS.

Events with low ionizating tracks have been searched for in (anti)neutrino induced events by selecting different event-topologies:

1. the quark is produced and detected in the CHARM detector. It is allowed to have visible secondary interactions (re-interaction case);
2. the quark is produced in the 1000 tons CDHS detector located immediately in front of the CHARM apparatus and is detected by the CHARM scintillator system. To escape from CDHS detector fractionally charged particles must on average traverse an amount of material corresponding to one interaction lenght for sigma-inelastic = = 175 micro-barns.

No quark candidate has been found in this search and corresponding upper limits for quark production have been computed.

The result for case 1 is shown in Fig.1 and 2 for Q=1/3 and Q=2/3 respectively. The two bands correspond Q masses of 1 and 10 GeV respectively and they indicate the 90% CL upper limits for the re-interaction case. The lower and upper limits of these bands correspond to different production models.

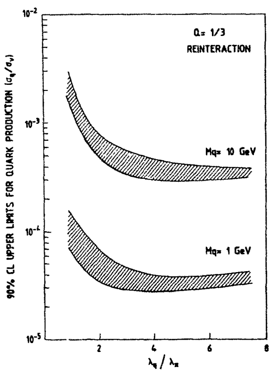

Fig. 1

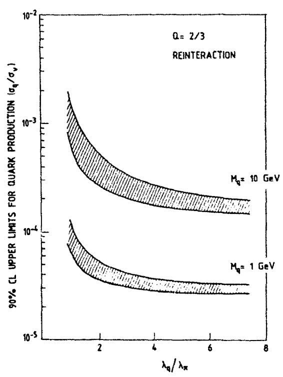

Fig. 2

The 90% CL upper limits for the production cross section of type 2 fractionally charged particles is given in Table 1.

TABLE 1

BEAM	CHARGE	90% CL UPPER LIMIT
NEUTRINO	1/3	1.0 10^{-5}
	2/3	2.7 10^{-5}
ANTINEUTRINO	1/3	1.7 10^{-5}
	2/3	3.0 10^{-5}

Fractionally charged particles were also searched for in p-Cu collisions using the experimental data collected in the 1982 beam dump exposure. The fractionally charged particle has to penetrate a muon shield corresponding to one interaction lenght for sigma-inelastic = 10 micro-barns before it is detected in the CHARM apparatus. The corresponding E-loss in the shield is 45 and 180 GeV for charge 1/3 and 2/3 respectively. No candidate for fractionally charged particle was detected in the CHARM apparatus. The corresponding 90% CL upper limits for quark production are shown in Fig.3 and 4 for Q=1/3 and Q=2/3 respectively. The curves A and B refer to two different production models. Limits obtained in conventional experiments are also shown.

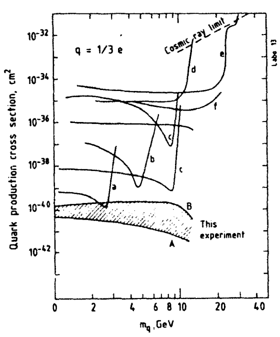

Fig. 3

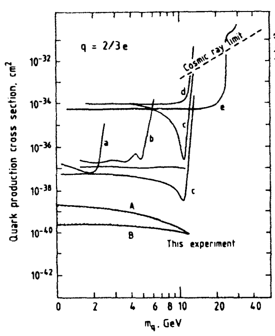

Fig. 4

SEARCH FOR RIGHT-HANDED CURRENTS IN MUON DECAY*

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The measurement of positrons near the end point of their momentum spectrum when polarized muons decay has enabled us to set stringent new limits on the admixture of right-handed (V+A) contributions to the dominant (V-A) interaction in muon decay.[1] During the course of this experiment we also made an improved determination of the anisotropic shape parameter δ which further restricts possible S, T, and P couplings in this fundamental process.

The M-13 surface muon beam at the TRIUMF cyclotron was the source of the highly polarized positive muons. They were stopped in thin, pure metal targets of Al, Cu, Ag and Au to minimize depolarization effects. The decay positrons were momentum analyzed with a high resolution spectrometer system consisting of magnets and position sensitive detectors. (Fig. 1.)

Two largely independent methods were used to search for V+A effects. In the first we measured the rate of positrons emitted in a direction opposite to the muons' spin as a function of their momentum when the stopping target was immersed in a 1.1 T longitudinal magnetic field.[2] This kinematic region is particularly sensitive to V+A effects because the dominant V-A interaction causes the positron rate to vanish there when $x = \frac{Pe^+}{Pe^+(max)} = 1$. In the second method the stopping muons were subjected to a weak transverse magnetic field (≈100 gauss) and the amplitude of the resulting μSR signal was used to look for the effects of right-handed currents. The experimental quantity extracted from these measurements is the combination of muon decay parameters $P_\mu\xi\delta/\rho$.[3]

The results obtained with both of these methods are consistent and can be combined to give the limit $P_\mu\xi\delta/\rho \geq 0.9966$ at the 90% confidence level. Our measurement represents about an order of magnitude improvement over the best previous measurement.[4] (Fig. 2.) In terms of decay amplitudes we find that $(V+A)/(V-A) \leq 0.029$ (90% CL). If it is assumed that an intermediate vector boson, W_R, which couples right-handedly to leptons and quarks mediates this interaction, then our result suggests the mass limit $M_{W_R} > 470$ GeV/c^2 if there is no left-right mixing and $M_{W_R} > 400$ GeV/c^2 if left-right mixing is allowed. It should be noted that all of the limits quoted here are only relevant if the mass of the associated right-handed neutrino is less than about 10 MeV/c^2.

The δ parameter was determined by extending the μSR measurements near x = 1 downward to well below x = 0.5 where the observed asymmetry changes sign.

Our very preliminary result for δ, which already represents a factor 2 improvement over the best previous measurement[5] is 0.748 ± 0.004 (statistical) ± 0.003 (systematic) consistent with the expected value of 3/4. Ultimately we expect to reduce the combined statistical and systematic errors to the 0.003 level.

The results of this experiment have implications in a number of other areas. For example, from the fact that $\xi\delta/\rho \geq \xi\delta P_\mu/\rho \geq 0.9966$ we deduce that the tensor couplings $(G_T + G_{T'})^2 \leq 0.027$ and the scalar and pseudo-scalar couplings $(G_S - G_P)^2 + (G_{S'} - G_P)^2 \leq 0.054$.[1] Our measurement of the vanishing endpoint of the momentum spectrum of positrons emitted opposite to the muon spin direction can be used to set a limit on flavor family symmetry breaking assuming a model proposed by Wilczek.[6] We find the branching ratio $\Gamma(\mu \to e + f)/\Gamma(\mu \to e\nu\bar{\nu}) \leq 6 \times 10^{-6}$ where f is a massless axion-like Nambu-Goldstone boson which breaks the flavor symmetry. From the point of view of possible composite structure for leptons and quarks, our result can be used to set limits on the energy scale, Λ, at which certain types of compositeness might show up. Following the analyses of Peskin,[7] and Lane and Barany,[8] we find that Λ must be greater than about 2-3 TeV, where a more exact value depends on the assumptions used.

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Fig. 1.

Plan view of the muon polarimeter. P1-P3 are proportional wire chambers, D1-D4 are drift chambers, and S1-S3 are scintillators. The trigger is T1·T2, where T1 is P1·S1·P2·$\overline{V1}$·$\overline{P3}$·$\overline{S2}$ at the μ^+ stopping time, T2 is P3·S2·S3·$\overline{P1}$·$\overline{S1}$·$\overline{V1}$·$\overline{P2}$·$\overline{V2}$ at the μ^+ decay time, and V1 and V2 are veto scintillators surrounding S1 and S2 respectively (not shown).

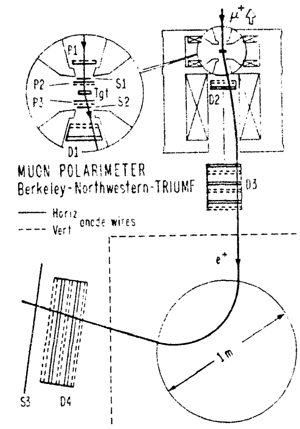

Fig. 2.

Comparison of the results of this experiment with the previous world-average.