# Free Quark Searches

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## Quark Production Cross Section — Accelerator Searches

| X-SECT ($cm^2$) | CHG (e/3) | MASS (GeV) | ENERGY (GeV) | BEAM | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|---|---|---|
| <1.3E−36 | ±2 | 45–84 | 130–172 | $e^+e^-$ | 0 | ABREU | 97D | DLPH |
| <2.E−35 | +2 | 250 | 1800 | $p\overline{p}$ | 0 | [1] ABE | 92J | CDF |
| <1.E−35 | +4 | 250 | 1800 | $p\overline{p}$ | 0 | [1] ABE | 92J | CDF |
| <3.8E−28 | | | 14.5A | $^{28}$Si–Pb | 0 | [2] HE | 91 | PLAS |
| <3.2E−28 | | | 14.5A | $^{28}$Si–Cu | 0 | [2] HE | 91 | PLAS |
| <1.E−40 | ±1,2 | <10 | | $p,\nu,\overline{\nu}$ | 0 | BERGSMA | 84B | CHRM |
| <1.E−36 | ±1,2 | <9 | 200 | $\mu$ | 0 | AUBERT | 83C | SPEC |
| <2.E−10 | ±2,4 | 1–3 | 200 | $p$ | 0 | [3] BUSSIERE | 80 | CNTR |
| <5.E−38 | +1,2 | >5 | 300 | $p$ | 0 | [4,5] STEVENSON | 79 | CNTR |
| <1.E−33 | ±1 | <20 | 52 | $pp$ | 0 | BASILE | 78 | SPEC |
| <9.E−39 | ±1,2 | <6 | 400 | $p$ | 0 | [4] ANTREASYAN | 77 | SPEC |
| <8.E−35 | +1,2 | <20 | 52 | $pp$ | 0 | [6] FABJAN | 75 | CNTR |
| <5.E−38 | −1,2 | 4–9 | 200 | $p$ | 0 | NASH | 74 | CNTR |
| <1.E−32 | +2,4 | 4–24 | 52 | $pp$ | 0 | ALPER | 73 | SPEC |
| <5.E−31 | +1,2,4 | <12 | 300 | $p$ | 0 | LEIPUNER | 73 | CNTR |
| <6.E−34 | ±1,2 | <13 | 52 | $pp$ | 0 | BOTT | 72 | CNTR |
| <1.E−36 | −4 | 4 | 70 | $p$ | 0 | ANTIPOV | 71 | CNTR |
| <1.E−35 | ±1,2 | 2 | 28 | $p$ | 0 | [7] ALLABY | 69B | CNTR |
| <4.E−37 | −2 | <5 | 70 | $p$ | 0 | [3] ANTIPOV | 69 | CNTR |
| <3.E−37 | −1,2 | 2–5 | 70 | $p$ | 0 | [7] ANTIPOV | 69B | CNTR |
| <1.E−35 | +1,2 | <7 | 30 | $p$ | 0 | DORFAN | 65 | CNTR |
| <2.E−35 | −2 | < 2.5–5 | 30 | $p$ | 0 | [8] FRANZINI | 65B | CNTR |
| <5.E−35 | +1,2 | <2.2 | 21 | $p$ | 0 | BINGHAM | 64 | HLBC |
| <1.E−32 | +1,2 | <4.0 | 28 | $p$ | 0 | BLUM | 64 | HBC |
| <1.E−35 | +1,2 | <2.5 | 31 | $p$ | 0 | [8] HAGOPIAN | 64 | HBC |
| <1.E−34 | +1 | <2 | 28 | $p$ | 0 | LEIPUNER | 64 | CNTR |
| <1.E−33 | +1,2 | <2.4 | 24 | $p$ | 0 | MORRISON | 64 | HBC |

[1] ABE 92J flux limits decrease as the mass increases from 50 to 500 GeV.
[2] HE 91 limits are for charges of the form $N\pm1/3$ from 23/3 to 38/3.
[3] Hadronic or leptonic quarks.
[4] Cross section $cm^2/GeV^2$.
[5] $3\times10^{-5}$ <lifetime $< 1\times10^{-3}$ s.
[6] Includes BOTT 72 results.
[7] Assumes isotropic cm production.
[8] Cross section inferred from flux.

## Quark Differential Production Cross Section — Accelerator Searches

| X-SECT ($cm^2sr^{-1}GeV^{-1}$) | CHG e/3 | MASS (GeV) | ENERGY (GeV) | BEAM | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|---|---|---|
| <4.E−36 | −2,4 | 1.5–6 | 70 | $p$ | 0 | BALDIN | 76 | CNTR |
| <2.E−33 | ±4 | 5–20 | 52 | $pp$ | 0 | ALBROW | 75 | SPEC |
| <5.E−34 | <7 | 7–15 | 44 | $pp$ | 0 | JOVANOV... | 75 | CNTR |
| <5.E−35 | | | 20 | $\gamma$ | 0 | [9] GALIK | 74 | CNTR |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| <9.E−35 | −1,2 | | 200 | *p* | 0 | NASH | 74 | CNTR |
| <4.E−36 | −4 | 2.3–2.7 | 70 | *p* | 0 | ANTIPOV | 71 | CNTR |
| <3.E−35 | ±1,2 | <2.7 | 27 | *p* | 0 | ALLABY | 69B | CNTR |
| <7.E−38 | −1,2 | <2.5 | 70 | *p* | 0 | ANTIPOV | 69B | CNTR |

[9] Cross section in $cm^2$/sr/equivalent quanta.

## Quark Flux — Accelerator Searches

The definition of FLUX depends on the experiment

(a) is the ratio of measured free quarks to predicted free quarks if there is no "confinement."
(b) is the probability of fractional charge on nuclear fragments. Energy is in GeV/nucleon.
(c) is the 90%CL upper limit on fractionally-charged particles produced per interaction.
(d) is quarks per collision.
(e) is inclusive quark-production cross-section ratio to $\sigma(e^+e^- \to \mu^+\mu^-)$.
(f) is quark flux per charged particle.
(g) is the flux per $\nu$-event.
(h) is quark yield per $\pi^-$ yield.
(i) is 2-body exclusive quark-production cross-section ratio to $\sigma(e^+e^- \to \mu^+\mu^-)$.

| FLUX | | CHG (e/3) | MASS (GeV) | ENRGY (GeV) | BEAM | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|---|---|---|---|
| <1.6E−3 | b | see note | | 200 | $^{32}$S–Pb | 0 | [10] HUENTRUP | 96 | PLAS |
| <6.2E−4 | b | see note | | 10.6 | $^{32}$S–Pb | 0 | [10] HUENTRUP | 96 | PLAS |
| <0.94E−4 | e | ±2 | 2–30 | 88–94 | $e^+e^-$ | 0 | AKERS | 95R | OPAL |
| <1.7E−4 | e | ±2 | 30–40 | 88–94 | $e^+e^-$ | 0 | AKERS | 95R | OPAL |
| <3.6E−4 | e | ±4 | 5–30 | 88–94 | $e^+e^-$ | 0 | AKERS | 95R | OPAL |
| <1.9E−4 | e | ±4 | 30–45 | 88–94 | $e^+e^-$ | 0 | AKERS | 95R | OPAL |
| <2.E−3 | e | +1 | 5–40 | 88–94 | $e^+e^-$ | 0 | [11] BUSKULIC | 93C | ALEP |
| <6.E−4 | e | +2 | 5–30 | 88–94 | $e^+e^-$ | 0 | [11] BUSKULIC | 93C | ALEP |
| <1.2E−3 | e | +4 | 15–40 | 88–94 | $e^+e^-$ | 0 | [11] BUSKULIC | 93C | ALEP |
| <3.6E−4 | i | +4 | 5.0–10.2 | 88–94 | $e^+e^-$ | 0 | BUSKULIC | 93C | ALEP |
| <3.6E−4 | i | +4 | 16.5–26.0 | 88–94 | $e^+e^-$ | 0 | BUSKULIC | 93C | ALEP |
| <6.9E−4 | i | +4 | 26.0–33.3 | 88–94 | $e^+e^-$ | 0 | BUSKULIC | 93C | ALEP |
| <9.1E−4 | i | +4 | 33.3–38.6 | 88–94 | $e^+e^-$ | 0 | BUSKULIC | 93C | ALEP |
| <1.1E−3 | i | +4 | 38.6–44.9 | 88–94 | $e^+e^-$ | 0 | BUSKULIC | 93C | ALEP |
| <1.6E−4 | b | see note | | see note | | 0 | [12] CECCHINI | 93 | PLAS |
| | b | 4,5,7,8 | | 2.1A | $^{16}$O | 0,2,0,6 | [13] GHOSH | 92 | EMUL |
| <6.4E−5 | g | 1 | | | $\nu,\overline{\nu}$ | 1 | [14] BASILE | 91 | CNTR |
| <3.7E−5 | g | 2 | | | $\nu,\overline{\nu}$ | 0 | [14] BASILE | 91 | CNTR |
| <3.9E−5 | g | 1 | | | $\nu,\overline{\nu}$ | 1 | [15] BASILE | 91 | CNTR |
| <2.8E−5 | g | 2 | | | $\nu,\overline{\nu}$ | 0 | [15] BASILE | 91 | CNTR |
| <1.9E−4 | c | | | 14.5A | $^{28}$Si–Pb | 0 | [16] HE | 91 | PLAS |
| <3.9E−4 | c | | | 14.5A | $^{28}$Si–Cu | 0 | [16] HE | 91 | PLAS |
| <1.E−9 | c | ±1,2,4 | | 14.5A | $^{16}$O–Ar | 0 | MATIS | 91 | MDRP |
| <5.1E−10 | c | ±1,2,4 | | 14.5A | $^{16}$O–Hg | 0 | MATIS | 91 | MDRP |
| <8.1E−9 | c | ±1,2,4 | | 14.5A | Si–Hg | 0 | MATIS | 91 | MDRP |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| <1.7E−6 | c | ±1,2,4 | | 60A | $^{16}$O–Hg | 0 | | MATIS | 91 | MDRP |
| <3.5E−7 | c | ±1,2,4 | | 200A | $^{16}$O–Hg | 0 | | MATIS | 91 | MDRP |
| <1.3E−6 | c | ±1,2,4 | | 200A | S–Hg | 0 | | MATIS | 91 | MDRP |
| <5E−2 | e | 2 | 19–27 | 52–60 | $e^+e^-$ | 0 | | ADACHI | 90C | TOPZ |
| <5E−2 | e | 4 | <24 | 52–60 | $e^+e^-$ | 0 | | ADACHI | 90C | TOPZ |
| <1.E−4 | e | +2 | <3.5 | 10 | $e^+e^-$ | 0 | | BOWCOCK | 89B | CLEO |
| <1.E−6 | d | ±1,2 | | 60 | $^{16}$O–Hg | 0 | | CALLOWAY | 89 | MDRP |
| <3.5E−7 | d | ±1,2 | | 200 | $^{16}$O–Hg | 0 | | CALLOWAY | 89 | MDRP |
| <1.3E−6 | d | ±1,2 | | 200 | S–Hg | 0 | | CALLOWAY | 89 | MDRP |
| <1.2E−10 | d | ±1 | 1 | 800 | $p$–Hg | 0 | | MATIS | 89 | MDRP |
| <1.1E−10 | d | ±2 | 1 | 800 | $p$–Hg | 0 | | MATIS | 89 | MDRP |
| <1.2E−10 | d | ±1 | 1 | 800 | $p$–$N_2$ | 0 | | MATIS | 89 | MDRP |
| <7.7E−11 | d | ±2 | 1 | 800 | $p$–$N_2$ | 0 | | MATIS | 89 | MDRP |
| <6.E−9 | h | −5 | 0.9–2.3 | 12 | $p$ | 0 | | NAKAMURA | 89 | SPEC |
| <5.E−5 | g | 1,2 | <0.5 | | $\nu,\overline{\nu}\,d$ | 0 | | ALLASIA | 88 | BEBC |
| <3.E−4 | b | See note | | 14.5 | $^{16}$O–Pb | 0 | [17] | HOFFMANN | 88 | PLAS |
| <2.E−4 | b | See note | | 200 | $^{16}$O–Pb | 0 | [18] | HOFFMANN | 88 | PLAS |
| <8E−5 | b | 19,20,22,23 | | 200*A* | | | | GERBIER | 87 | PLAS |
| <2.E−4 | a | ±1,2 | <300 | 320 | $\overline{p}p$ | 0 | | LYONS | 87 | MLEV |
| <1.E−9 | c | ±1,2,4,5 | | 14.5 | $^{16}$O–Hg | 0 | | SHAW | 87 | MDRP |
| <3.E−3 | d | −1,2,3,4,6 | <5 | 2 | Si–Si | 0 | [19] | ABACHI | 86C | CNTR |
| <1.E−4 | e | ±1,2,4 | <4 | 10 | $e^+e^-$ | 0 | | ALBRECHT | 85G | ARG |
| <6.E−5 | b | ±1,2 | 1 | 540 | $p\overline{p}$ | 0 | | BANNER | 85 | UA2 |
| <5.E−3 | e | −4 | 1–8 | 29 | $e^+e^-$ | 0 | | AIHARA | 84 | TPC |
| <1.E−2 | e | ±1,2 | 1–13 | 29 | $e^+e^-$ | 0 | | AIHARA | 84B | TPC |
| <2.E−4 | b | ±1 | | 72 | $^{40}$Ar | 0 | [20] | BARWICK | 84 | CNTR |
| <1.E−4 | e | ±2 | <0.4 | 1.4 | $e^+e^-$ | 0 | | BONDAR | 84 | OLYA |
| <5.E−1 | e | ±1,2 | <13 | 29 | $e^+e^-$ | 0 | | GURYN | 84 | CNTR |
| <3.E−3 | b | ±1,2 | <2 | 540 | $p\overline{p}$ | 0 | | BANNER | 83 | CNTR |
| <1.E−4 | b | ±1,2 | | 106 | $^{56}$Fe | 0 | | LINDGREN | 83 | CNTR |
| <3.E−3 | b | $>\lvert\pm 0.1\rvert$ | | 74 | $^{40}$Ar | 0 | [20] | PRICE | 83 | PLAS |
| <1.E−2 | e | ±1,2 | <14 | 29 | $e^+e^-$ | 0 | | MARINI | 82B | CNTR |
| <8.E−2 | e | ±1,2 | <12 | 29 | $e^+e^-$ | 0 | | ROSS | 82 | CNTR |
| <3.E−4 | e | ±2 | 1.8–2 | 7 | $e^+e^-$ | 0 | | WEISS | 81 | MRK2 |
| <5.E−2 | e | +1,2,4,5 | 2–12 | 27 | $e^+e^-$ | 0 | | BARTEL | 80 | JADE |
| <2.E−5 | g | 1,2 | | | $\nu$ | 0 | [14,15] | BASILE | 80 | CNTR |
| <3.E−10 | f | ±2,4 | 1–3 | 200 | $p$ | 0 | [21] | BOZZOLI | 79 | CNTR |
| <6.E−11 | f | ±1 | <21 | 52 | $pp$ | 0 | | BASILE | 78 | SPEC |
| <5.E−3 | g | | | | $\nu_\mu$ | 0 | | BASILE | 78B | CNTR |
| <2.E−9 | f | ±1 | <26 | 62 | $pp$ | 0 | | BASILE | 77 | SPEC |
| <7.E−10 | f | +1,2 | <20 | 52 | $p$ | 0 | [22] | FABJAN | 75 | CNTR |
| | | +1,2 | >4.5 | | $\gamma$ | 0 | [14,15] | GALIK | 74 | CNTR |
| | | +1,2 | >1.5 | 12 | $e^-$ | 0 | [14,15] | BELLAMY | 68 | CNTR |
| | | +1,2 | >0.9 | | $\gamma$ | 0 | [15] | BATHOW | 67 | CNTR |
| | | +1,2 | >0.9 | 6 | $\gamma$ | 0 | [15] | FOSS | 67 | CNTR |

[10] HUENTRUP 96 quote 95% CL limits for production of fragments with charge differing by as much as ±1/3 (in units of e) for charge $6 \leq Z \leq 10$.

[11] BUSKULIC 93C limits for inclusive quark production are more conservative if the ALEPH hadronic fragmentation function is assumed.

[12] CECCHINI 93 limit at 90%CL for $23/3 \leq Z \leq 40/3$, for 16$A$ GeV O, 14.5$A$ Si, and 200$A$ S incident on Cu target. Other limits are $2.3 \times 10^{-4}$ for $17/3 \leq Z \leq 20/3$ and $1.2 \times 10^{-4}$ for $20/3 \leq Z \leq 23/3$.

[13] GHOSH 92 reports measurement of spallation fragment charge based on ionization in emulsion. Out of 650 measured tracks, 2 were consistent with charge $5e/3$, and 4 with $7e/3$.

[14] Hadronic quark.

[15] Leptonic quark.

[16] HE 91 limits are for charges of the form $N \pm 1/3$ from 23/3 to 38/3, and correspond to cross-section limits of 380$\mu$b (Pb) and 320$\mu$b (Cu).

[17] The limits apply to projectile fragment charges of 17, 19, 20, 22, 23 in units of $e/3$.

[18] The limits apply to projectile fragment charges of 16, 17, 19, 20, 22, 23 in units of $e/3$.

[19] Flux limits and mass range depend on charge.

[20] Bound to nuclei.

[21] Quark lifetimes $> 1 \times 10^{-8}$ s.

[22] One candidate $m$ <0.17 GeV.

## Quark Flux — Cosmic Ray Searches

Shielding values followed with an asterisk indicate altitude in km. Shielding values not followed with an asterisk indicate sea level in kg/cm$^2$.

| *FLUX* (cm$^{-2}$sr$^{-1}$s$^{-1}$) | *CHG* (e/3) | *MASS* (GeV) | *SHIELDING* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|---|---|---|
| < 9.2E−15 | ±1 | | 3800 | 0 | [23] AMBROSIO | 00C | MCRO |
| <2.1E−15 | ±1 | | | 0 | MORI | 91 | KAM2 |
| <2.3E−15 | ±2 | | | 0 | MORI | 91 | KAM2 |
| <2.E−10 | ±1,2 | | 0.3 | 0 | WADA | 88 | CNTR |
| | ±4 | | 0.3 | 12 | [24] WADA | 88 | CNTR |
| | ±4 | | 0.3 | 9 | [25] WADA | 86 | CNTR |
| <1.E−12 | ±2,3/2 | | −70. | 0 | [26] KAWAGOE | 84B | PLAS |
| <9.E−10 | ±1,2 | | 0.3 | 0 | WADA | 84B | CNTR |
| <4.E−9 | ±4 | | 0.3 | 7 | WADA | 84B | CNTR |
| <2.E−12 | ±1,2,3 | | −0.3 * | 0 | MASHIMO | 83 | CNTR |
| <3.E−10 | ±1,2 | | 0.3 | 0 | MARINI | 82 | CNTR |
| <2.E−11 | ±1,2 | | | 0 | MASHIMO | 82 | CNTR |
| <8.E−10 | ±1,2 | | 0.3 | 0 | [26] NAPOLITANO | 82 | CNTR |
| | | | | 3 | [27] YOCK | 78 | CNTR |
| <1.E−9 | | | | 0 | [28] BRIATORE | 76 | ELEC |
| <2.E−11 | +1 | | | 0 | [29] HAZEN | 75 | CC |
| <2.E−10 | +1,2 | | | 0 | KRISOR | 75 | CNTR |
| <1.E−7 | +1,2 | | | 0 | [29,30] CLARK | 74B | CC |
| <3.E−10 | +1 | >20 | | 0 | KIFUNE | 74 | CNTR |
| <8.E−11 | +1 | | | 0 | [29] ASHTON | 73 | CNTR |
| <2.E−8 | +1,2 | | | 0 | HICKS | 73B | CNTR |
| <5.E−10 | +4 | | 2.8 * | 0 | BEAUCHAMP | 72 | CNTR |
| <1.E−10 | +1,2 | | | 0 | [29] BOHM | 72B | CNTR |
| <1.E−10 | +1,2 | | 2.8 * | 0 | COX | 72 | ELEC |
| <3.E−10 | +2 | | | 0 | CROUCH | 72 | CNTR |
| <3.E−8 | | | 7 | 0 | [28] DARDO | 72 | CNTR |
| <4.E−9 | +1 | | | 0 | [29] EVANS | 72 | CC |
| <2.E−9 | | >10 | | 0 | [28] TONWAR | 72 | CNTR |
| <2.E−10 | +1 | | 2.8 * | 0 | CHIN | 71 | CNTR |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| <3.E−10 | +1,2 | | | 0 | [29] | CLARK | 71B | CC |
| <1.E−10 | +1,2 | | | 0 | [29] | HAZEN | 71 | CC |
| <5.E−10 | +1,2 | | 3.5 * | 0 | | BOSIA | 70 | CNTR |
| | +1,2 | <6.5 | | 1 | [29] | CHU | 70 | HLBC |
| <2.E−9 | +1 | | | 0 | | FAISSNER | 70B | CNTR |
| <2.E−10 | +1,2 | | 0.8 * | 0 | | KRIDER | 70 | CNTR |
| <5.E−11 | +2 | | | 4 | | CAIRNS | 69 | CC |
| <8.E−10 | +1,2 | <10 | | 0 | | FUKUSHIMA | 69 | CNTR |
| | +2 | | | 1 | [29,31] | MCCUSKER | 69 | CC |
| <1.E−10 | | >5 | 1.7,3.6 | 0 | [28] | BJORNBOE | 68 | CNTR |
| <1.E−8 | ±1,2,4 | | 6.3,.2 * | 0 | [26] | BRIATORE | 68 | CNTR |
| <3.E−8 | | >2 | | 0 | | FRANZINI | 68 | CNTR |
| <9.E−11 | ±1,2 | | | 0 | | GARMIRE | 68 | CNTR |
| <4.E−10 | ±1 | | | 0 | | HANAYAMA | 68 | CNTR |
| <3.E−8 | | >15 | | 0 | | KASHA | 68 | OSPK |
| <2.E−10 | +2 | | | 0 | | KASHA | 68B | CNTR |
| <2.E−10 | +4 | | | 0 | | KASHA | 68C | CNTR |
| <2.E−10 | +2 | | 6 | 0 | | BARTON | 67 | CNTR |
| <2.E−7 | +4 | | 0.008,0.5 * | 0 | | BUHLER | 67 | CNTR |
| <5.E−10 | 1,2 | | 0.008,0.5 * | 0 | | BUHLER | 67B | CNTR |
| <4.E−10 | +1,2 | | | 0 | | GOMEZ | 67 | CNTR |
| <2.E−9 | +2 | | | 0 | | KASHA | 67 | CNTR |
| <2.E−10 | +2 | | 220 | 0 | | BARTON | 66 | CNTR |
| <2.E−9 | +1,2 | | 0.5 * | 0 | | BUHLER | 66 | CNTR |
| <3.E−9 | +1,2 | | | 0 | | KASHA | 66 | CNTR |
| <2.E−9 | +1,2 | | | 0 | | LAMB | 66 | CNTR |
| <2.E−8 | +1,2 | >7 | 2.8 * | 0 | | DELISE | 65 | CNTR |
| <5.E−8 | +2 | >2.5 | 0.5 * | 0 | | MASSAM | 65 | CNTR |
| <2.E−8 | +1 | | 2.5 * | 0 | | BOWEN | 64 | CNTR |
| <2.E−7 | +1 | | 0.8 | 0 | | SUNYAR | 64 | CNTR |

[23] AMBROSIO 00C limit is below $11 \times 10^{-15}$ for $0.25 < q/e < 0.5$, and is changing rapidly near $q/e$=2/3, where it is $2 \times 10^{-14}$.
[24] Distribution in celestial sphere was described as anisotropic.
[25] With telescope axis at zenith angle 40° to the south.
[26] Leptonic quarks.
[27] Lifetime $> 10^{-8}$ s; charge ±0.70, 0.68, 0.42; and mass >4.4, 4.8, and 20 GeV, respectively.
[28] Time delayed air shower search.
[29] Prompt air shower search.
[30] Also $e/4$ and $e/6$ charges.
[31] No events in subsequent experiments.

## Quark Density — Matter Searches

| *QUARKS/ NUCLEON* | *CHG (e/3)* | *MASS (GeV)* | *MATERIAL/METHOD* | *EVTS* | *DOCUMENT ID* | | |
|---|---|---|---|---|---|---|---|
| <1.17E−22 | | | silicone oil drops | 0 | [32] LEE | 02 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| <4.71E−22 | | | silicone oil drops | 1 | [33] HALYO | 00 |
| <4.7E−21 | ±1,2 | | silicone oil drops | 0 | MAR | 96 |
| <8.E−22 | +2 | | Si/infrared photoionization | 0 | PERERA | 93 |
| <5.E−27 | ±1,2 | | sea water/levitation | 0 | HOMER | 92 |
| <4.E−20 | ±1,2 | | meteorites/mag. levitation | 0 | JONES | 89 |
| <1.E−19 | ±1,2 | | various/spectrometer | 0 | MILNER | 87 |
| <5.E−22 | ±1,2 | | W/levitation | 0 | SMITH | 87 |
| <3.E−20 | +1,2 | | org liq/droplet tower | 0 | VANPOLEN | 87 |
| <6.E−20 | −1,2 | | org liq/droplet tower | 0 | VANPOLEN | 87 |
| <3.E−21 | ±1 | | Hg drops-untreated | 0 | SAVAGE | 86 |
| <3.E−22 | ±1,2 | | levitated niobium | 0 | SMITH | 86 |
| <2.E−26 | ±1,2 | | $^4$He/levitation | 0 | SMITH | 86B |
| <2.E−20 | >±1 | 0.2–250 | niobium+tungs/ion | 0 | MILNER | 85 |
| <1.E−21 | ±1 | | levitated niobium | 0 | SMITH | 85 |
| | +1,2 | <100 | niobium/mass spec | 0 | KUTSCHERA | 84 |
| <5.E−22 | | | levitated steel | 0 | MARINELLI | 84 |
| <9.E−20 | ± <13 | | water/oil drop | 0 | JOYCE | 83 |
| <2.E−21 | > \| ± 1/2 \| | | levitated steel | 0 | LIEBOWITZ | 83 |
| <1.E−19 | ±1,2 | | photo ion spec | 0 | VANDESTEEG | 83 |
| <2.E−20 | | | mercury/oil drop | 0 | [34] HODGES | 81 |
| 1.E−20 | +1 | | levitated niobium | 4 | [35] LARUE | 81 |
| 1.E−20 | −1 | | levitated niobium | 4 | [35] LARUE | 81 |
| <1.E−21 | | | levitated steel | 0 | MARINELLI | 80B |
| <6.E−16 | | | helium/mass spec | 0 | BOYD | 79 |
| 1.E−20 | +1 | | levitated niobium | 2 | [35] LARUE | 79 |
| <4.E−28 | | | earth+/ion beam | 0 | OGOROD... | 79 |
| <5.E−15 | +1 | | tungs./mass spec | 0 | BOYD | 78 |
| <5.E−16 | +3 | <1.7 | hydrogen/mass spec | 0 | BOYD | 78B |
| <1.E−21 | ±2,4 | | water/ion beam | 0 | LUND | 78 |
| <6.E−15 | >1/2 | | levitated tungsten | 0 | PUTT | 78 |
| <1.E−22 | | | metals/mass spec | 0 | SCHIFFER | 78 |
| <5.E−15 | | | levitated tungsten ox | 0 | BLAND | 77 |
| <3.E−21 | | | levitated iron | 0 | GALLINARO | 77 |
| 2.E−21 | −1 | | levitated niobium | 1 | [35] LARUE | 77 |
| 4.E−21 | +1 | | levitated niobium | 2 | [35] LARUE | 77 |
| <1.E−13 | +3 | <7.7 | hydrogen/mass spec | 0 | MULLER | 77 |
| <5.E−27 | | | water+/ion beam | 0 | OGOROD... | 77 |
| <1.E−21 | | | lunar+/ion spec | 0 | STEVENS | 76 |
| <1.E−15 | +1 | <60 | oxygen+/ion spec | 0 | ELBERT | 70 |
| <5.E−19 | | | levitated graphite | 0 | MORPURGO | 70 |
| <5.E−23 | | | water+/atom beam | 0 | COOK | 69 |
| <1.E−17 | ±1,2 | | levitated graphite | 0 | BRAGINSK | 68 |
| <1.E−17 | | | water+/uv spec | 0 | RANK | 68 |
| <3.E−19 | ±1 | | levitated iron | 0 | STOVER | 67 |
| <1.E−10 | | | sun/uv spec | 0 | [36] BENNETT | 66 |
| <1.E−17 | +1,2 | | meteorites+/ion beam | 0 | CHUPKA | 66 |
| <1.E−16 | ±1 | | levitated graphite | 0 | GALLINARO | 66 |
| <1.E−22 | | | argon/electrometer | 0 | HILLAS | 59 |
| | −2 | | levitated oil | 0 | MILLIKAN | 10 |

[32] 95% CL limit for fractional charge particles with $0.18e \leq |Q_{residual}| \leq 0.82e$ in total of 70.1 mg of silicone oil.

[33] 95% CL limit for particles with fractional charge $|Q_{residual}| > 0.16e$ in total of 17.4 mg of silicone oil.

[34] Also set limits for $Q = \pm e/6$.

[35] Note that in PHILLIPS 88 these authors report a subtle magnetic effect which could account for the apparent fractional charges.

[36] Limit inferred by JONES 77B.

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