

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
$<1.7\text{--}2.3\text{E-}39$	± 2	100–600	7000	$p\bar{p}$	0	¹ CHATRCHYAN 13AR	CMS
$<14\text{--}5.4\text{E-}39$	± 1	100–600	7000	$p\bar{p}$	0	¹ CHATRCHYAN 13AR	CMS
$<1.3\text{E-}36$	± 2	45–84	130–172	e^+e^-	0	ABREU 97D	DLPH
$<2\text{E-}35$	$+2$	250	1800	$p\bar{p}$	0	² ABE 92J	CDF
$<1\text{E-}35$	$+4$	250	1800	$p\bar{p}$	0	² ABE 92J	CDF
$<3.8\text{E-}28$			14.5A	$^{28}\text{Si-Pb}$	0	³ HE 91	PLAS
$<3.2\text{E-}28$			14.5A	$^{28}\text{Si-Cu}$	0	³ HE 91	PLAS
$<1\text{E-}40$	$\pm 1,2$	<10		$p, \nu, \bar{\nu}$	0	BERGSMA 84B	CHRM
$<1\text{E-}36$	$\pm 1,2$	<9	200	μ	0	AUBERT 83C	SPEC
$<2\text{E-}10$	$\pm 2,4$	1–3	200	p	0	⁴ BUSSIÈRE 80	CNTR
$<5\text{E-}38$	$+1,2$	>5	300	p	0	^{5,6} STEVENSON 79	CNTR
$<1\text{E-}33$	± 1	<20	52	$p\bar{p}$	0	BASILE 78	SPEC
$<9\text{E-}39$	$\pm 1,2$	<6	400	p	0	⁵ ANTREASYAN 77	SPEC
$<8\text{E-}35$	$+1,2$	<20	52	$p\bar{p}$	0	⁷ FABJAN 75	CNTR
$<5\text{E-}38$	$-1,2$	4–9	200	p	0	NASH 74	CNTR
$<1\text{E-}32$	$+2,4$	4–24	52	$p\bar{p}$	0	ALPER 73	SPEC
$<5\text{E-}31$	$+1,2,4$	<12	300	p	0	LEIPUNER 73	CNTR
$<6\text{E-}34$	$\pm 1,2$	<13	52	$p\bar{p}$	0	BOTT 72	CNTR
$<1\text{E-}36$	-4	4	70	p	0	ANTIPOV 71	CNTR
$<1\text{E-}35$	$\pm 1,2$	2	28	p	0	⁸ ALLABY 69B	CNTR
$<4\text{E-}37$	-2	<5	70	p	0	⁴ ANTIPOV 69	CNTR
$<3\text{E-}37$	$-1,2$	2–5	70	p	0	⁸ ANTIPOV 69B	CNTR
$<1\text{E-}35$	$+1,2$	<7	30	p	0	DORFAN 65	CNTR
$<2\text{E-}35$	-2	$<2.5\text{--}5$	30	p	0	⁹ FRANZINI 65B	CNTR
$<5\text{E-}35$	$+1,2$	<2.2	21	p	0	BINGHAM 64	HLBC
$<1\text{E-}32$	$+1,2$	<4.0	28	p	0	BLUM 64	HBC
$<1\text{E-}35$	$+1,2$	<2.5	31	p	0	⁹ HAGOPIAN 64	HBC
$<1\text{E-}34$	$+1$	<2	28	p	0	LEIPUNER 64	CNTR
$<1\text{E-}33$	$+1,2$	<2.4	24	p	0	MORRISON 64	HBC

¹ CHATRCHYAN 13AR limits assume pair-produced long-lived spin-1/2 particles neutral under $SU(3)_C$ and $SU(2)_L$.

² ABE 92J flux limits decrease as the mass increases from 50 to 500 GeV.

³ HE 91 limits are for charges of the form $N \pm 1/3$ from 23/3 to 38/3.

⁴ Hadronic or leptonic quarks.

⁵ Cross section cm^2/GeV^2 .

⁶ $3 \times 10^{-5} < \text{lifetime} < 1 \times 10^{-3}$ s.

⁷ Includes BOTT 72 results.

⁸ Assumes isotropic cm production.

⁹ Cross section inferred from flux.

Quark Differential Production Cross Section — Accelerator Searches

X -SECT ($\text{cm}^2\text{sr}^{-1}\text{GeV}^{-1}$)	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	JOVANOVA...	75 CNTR
<5.E-35			20	γ	0	¹⁰ 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	$\pm 1,2$	<2.7	27	p	0	ALLABY	69B CNTR
<7.E-38	-1,2	<2.5	70	p	0	ANTIPOV	69B CNTR

¹⁰ 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 $\sigma(e^+e^- \rightarrow \mu^+\mu^-)$.
- (f) is quark flux per charged particle.
- (g) is the flux per ν -event.
- (h) is quark yield per π^- yield.
- (i) is 2-body exclusive quark-production cross-section ratio to $\sigma(e^+e^- \rightarrow \mu^+\mu^-)$.

FLUX		CHG ($e/3$)	MASS (GeV)	ENERGY (GeV)	BEAM	EVTS	DOCUMENT ID	TECN
<1.6E-3	b	see note		200	$^{32}\text{S-Pb}$	0	¹¹ HUENTRUP	96 PLAS
<6.2E-4	b	see note		10.6	$^{32}\text{S-Pb}$	0	¹¹ 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	¹² BUSKULIC	93C ALEP
<6.E-4	e	+2	5-30	88-94	e^+e^-	0	¹² BUSKULIC	93C ALEP
<1.2E-3	e	+4	15-40	88-94	e^+e^-	0	¹² 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	¹³ CECCHINI	93 PLAS
	b	4,5,7,8		2.1A	^{16}O	0,2,0,6	¹⁴ GHOSH	92 EMUL
<6.4E-5	g	1			$\nu, \bar{\nu}$	1	¹⁵ BASILE	91 CNTR
<3.7E-5	g	2			$\nu, \bar{\nu}$	0	¹⁵ BASILE	91 CNTR

<3.9E-5	g	1		$\nu, \bar{\nu}$	1	¹⁶ BASILE	91	CNTR
<2.8E-5	g	2		$\nu, \bar{\nu}$	0	¹⁶ BASILE	91	CNTR
<1.9E-4	c		14.5A	²⁸ Si-Pb	0	¹⁷ HE	91	PLAS
<3.9E-4	c		14.5A	²⁸ Si-Cu	0	¹⁷ HE	91	PLAS
<1.E-9	c	$\pm 1,2,4$	14.5A	¹⁶ O-Ar	0	MATIS	91	MDRP
<5.1E-10	c	$\pm 1,2,4$	14.5A	¹⁶ O-Hg	0	MATIS	91	MDRP
<8.1E-9	c	$\pm 1,2,4$	14.5A	Si-Hg	0	MATIS	91	MDRP
<1.7E-6	c	$\pm 1,2,4$	60A	¹⁶ O-Hg	0	MATIS	91	MDRP
<3.5E-7	c	$\pm 1,2,4$	200A	¹⁶ O-Hg	0	MATIS	91	MDRP
<1.3E-6	c	$\pm 1,2,4$	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	$\pm 1,2$		60	¹⁶ O-Hg	0	CALLOWAY	89 MDRP
<3.5E-7	d	$\pm 1,2$		200	¹⁶ O-Hg	0	CALLOWAY	89 MDRP
<1.3E-6	d	$\pm 1,2$		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		$\nu, \bar{\nu} d$	0	ALLASIA	88 BEBC
<3.E-4	b	See note		14.5	¹⁶ O-Pb	0	¹⁸ HOFFMANN	88 PLAS
<2.E-4	b	See note		200	¹⁶ O-Pb	0	¹⁹ HOFFMANN	88 PLAS
<8E-5	b	19,20,22,23		200A			GERBIER	87 PLAS
<2.E-4	a	$\pm 1,2$	<300	320	$\bar{p} p$	0	LYONS	87 MLEV
<1.E-9	c	$\pm 1,2,4,5$		14.5	¹⁶ O-Hg	0	SHAW	87 MDRP
<3.E-3	d	-1,2,3,4,6	<5	2	Si-Si	0	²⁰ ABACHI	86C CNTR
<1.E-4	e	$\pm 1,2,4$	<4	10	$e^+ e^-$	0	ALBRECHT	85G ARG
<6.E-5	b	$\pm 1,2$	1	540	$p\bar{p}$	0	BANNER	85 UA2
<5.E-3	e	-4	1-8	29	$e^+ e^-$	0	AIHARA	84 TPC
<1.E-2	e	$\pm 1,2$	1-13	29	$e^+ e^-$	0	AIHARA	84B TPC
<2.E-4	b	± 1		72	⁴⁰ Ar	0	²¹ BARWICK	84 CNTR
<1.E-4	e	± 2	<0.4	1.4	$e^+ e^-$	0	BONDAR	84 OLYA
<5.E-1	e	$\pm 1,2$	<13	29	$e^+ e^-$	0	GURYN	84 CNTR
<3.E-3	b	$\pm 1,2$	<2	540	$p\bar{p}$	0	BANNER	83 CNTR
<1.E-4	b	$\pm 1,2$		106	⁵⁶ Fe	0	LINDGREN	83 CNTR
<3.E-3	b	$> \pm 0.1 $		74	⁴⁰ Ar	0	²¹ PRICE	83 PLAS
<1.E-2	e	$\pm 1,2$	<14	29	$e^+ e^-$	0	MARINI	82B CNTR
<8.E-2	e	$\pm 1,2$	<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			ν	0	^{15,16} BASILE	80 CNTR
<3.E-10	f	$\pm 2,4$	1-3	200	p	0	²² BOZZOLI	79 CNTR
<6.E-11	f	± 1	<21	52	pp	0	BASILE	78 SPEC
<5.E-3	g				ν, μ	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	²³ FABJAN	75 CNTR
		+1,2	>4.5		γ	0	^{15,16} GALIK	74 CNTR

+1,2	>1.5	12	e^-	0	15,16	BELLAMY	68	CNTR
+1,2	>0.9		γ	0	16	BATHOW	67	CNTR
+1,2	>0.9	6	γ	0	16	FOSS	67	CNTR

- ¹¹ HUENTRUP 96 quote 95% CL limits for production of fragments with charge differing by as much as $\pm 1/3$ (in units of e) for charge $6 \leq Z \leq 10$.
- ¹² BUSKULIC 93C limits for inclusive quark production are more conservative if the ALEPH hadronic fragmentation function is assumed.
- ¹³ CECCHINI 93 limit at 90%CL for $23/3 \leq Z \leq 40/3$, for 16A GeV O, 14.5A Si, and 200A S incident on Cu target. Other limits are 2.3×10^{-4} for $17/3 \leq Z \leq 20/3$ and 1.2×10^{-4} for $20/3 \leq Z \leq 23/3$.
- ¹⁴ 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 $7e/3$.
- ¹⁵ Hadronic quark.
- ¹⁶ Leptonic quark.
- ¹⁷ 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 $380 \mu\text{b}$ (Pb) and $320 \mu\text{b}$ (Cu).
- ¹⁸ The limits apply to projectile fragment charges of 17, 19, 20, 22, 23 in units of $e/3$.
- ¹⁹ The limits apply to projectile fragment charges of 16, 17, 19, 20, 22, 23 in units of $e/3$.
- ²⁰ Flux limits and mass range depend on charge.
- ²¹ Bound to nuclei.
- ²² Quark lifetimes $> 1 \times 10^{-8}$ s.
- ²³ 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 .

$FLUX$ ($\text{cm}^{-2}\text{sr}^{-1}\text{s}^{-1}$)	CHG ($e/3$)	$MASS$ (GeV)	$SHIELDING$	$EVTS$	$DOCUMENT ID$	$TECN$
$< 9.2E-15$	± 1		3800	0	²⁴ AMBROSIO	00C MCRO
$< 2.1E-15$	± 1			0	MORI	91 KAM2
$< 2.3E-15$	± 2			0	MORI	91 KAM2
$< 2.E-10$	$\pm 1,2$		0.3	0	WADA	88 CNTR
	± 4		0.3	12	²⁵ WADA	88 CNTR
	± 4		0.3	9	²⁶ WADA	86 CNTR
$< 1.E-12$	$\pm 2,3/2$		-70.	0	²⁷ KAWAGOE	84B PLAS
$< 9.E-10$	$\pm 1,2$		0.3	0	WADA	84B CNTR
$< 4.E-9$	± 4		0.3	7	WADA	84B CNTR
$< 2.E-12$	$\pm 1,2,3$		-0.3 *	0	MASHIMO	83 CNTR
$< 3.E-10$	$\pm 1,2$		0.3	0	MARINI	82 CNTR
$< 2.E-11$	$\pm 1,2$			0	MASHIMO	82 CNTR
$< 8.E-10$	$\pm 1,2$		0.3	0	²⁷ NAPOLITANO	82 CNTR
				3	²⁸ YOCK	78 CNTR
$< 1.E-9$				0	²⁹ BRIATORE	76 ELEC
$< 2.E-11$	$+1$			0	³⁰ HAZEN	75 CC
$< 2.E-10$	$+1,2$			0	KRISOR	75 CNTR
$< 1.E-7$	$+1,2$			0	^{30,31} CLARK	74B CC
$< 3.E-10$	$+1$	>20		0	KIFUNE	74 CNTR
$< 8.E-11$	$+1$			0	³⁰ 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	³⁰ 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	²⁹ DARDO	72	CNTR
<4.E-9	+1			0	³⁰ EVANS	72	CC
<2.E-9		>10		0	²⁹ TONWAR	72	CNTR
<2.E-10	+1		2.8 *	0	CHIN	71	CNTR
<3.E-10	+1,2			0	³⁰ CLARK	71B	CC
<1.E-10	+1,2			0	³⁰ HAZEN	71	CC
<5.E-10	+1,2		3.5 *	0	BOSIA	70	CNTR
	+1,2	<6.5		1	³⁰ 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	^{30,32} MCCUSKER	69	CC
<1.E-10		>5	1.7,3.6	0	²⁹ BJORNBOE	68	CNTR
<1.E-8	±1,2,4		6.3,.2 *	0	²⁷ 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

²⁴ AMBROSIO 00C limit is below 11×10^{-15} for $0.25 < q/e < 0.5$, and is changing rapidly near $q/e=2/3$, where it is 2×10^{-14} .

²⁵ Distribution in celestial sphere was described as anisotropic.

²⁶ With telescope axis at zenith angle 40° to the south.

²⁷ Leptonic quarks.

²⁸ Lifetime $> 10^{-8}$ s; charge $\pm 0.70, 0.68, 0.42$; and mass $> 4.4, 4.8, \text{ and } 20$ GeV, respectively.

²⁹ Time delayed air shower search.

³⁰ Prompt air shower search.

³¹ Also $e/4$ and $e/6$ charges.

³² No events in subsequent experiments.

Quark Density — Matter Searches

<u>QUARKS/ NUCLEON</u>	<u>CHG ($e/3$)</u>	<u>MASS (GeV)</u>	<u>MATERIAL/METHOD</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>
<1.17E-22			silicone oil drops	0	³³ LEE 02
<4.71E-22			silicone oil drops	1	³⁴ 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	³⁵ HODGES 81
1.E-20	+1		levitated niobium	4	³⁶ LARUE 81
1.E-20	-1		levitated niobium	4	³⁶ 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	³⁶ 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	³⁶ LARUE 77
4.E-21	+1		levitated niobium	2	³⁶ 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	³⁷ 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
- ³³ 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.
- ³⁴ 95% CL limit for particles with fractional charge $|Q_{residual}| > 0.16e$ in total of 17.4 mg of silicone oil.
- ³⁵ Also set limits for $Q = \pm e/6$.
- ³⁶ Note that in PHILLIPS 88 these authors report a subtle magnetic effect which could account for the apparent fractional charges.
- ³⁷ Limit inferred by JONES 77B.

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