TABLE II – continued from previous page	TABLE II – continued from previous page	TABLE II – continued from previous page	TABLE II – continued from previous page
Model $\rho_0 = E_0 = K_0 = K' = J = L = K_{sym} = Q_{sym} = K_{\tau,y} = m^*$	Model - R K K I I I K O K	Model $\rho_0 = E_0 = K_0 = K' = J = L = K_{sym} = Q_{sym} = K_{\tau,v} = m^*$	Model $p_0 = E_0 = K_0 = K' = J = L = K_{\text{sym}} = K_{T,N} = m^*$
MSk1 [174] 0.157 -15.83 233.73 379.97 30.00 33.92 -200.02 448.66 -348.39 1.00	Model $p_0 = E_0 = K_0 = K = J = L = K_{BYB} = V_{BYB} = K_{T,V} = m$	SkT5a [180] 0.164 -16.00 201.69 436.81 37.00 98.53 -24.97 99.88 -402.76 1.00	SVII [184] 0.143 -15.79 366.44 -164.51 26.96 -10.16 -488.90 149.74 -423.36 1.00
MSk2 [174] 0.157 -15.83 231.65 386.21 30.00 33.35 -203.44 449.71 -347.94 1.05	5KH [168] 0.100 -15.95 247.95 331.21 29.50 00.39 -40.50 351.10 -322.23 0.65	SkT6a [180] 0.161 -15.96 235.95 383.15 29.97 30.85 -211.53 472.36 -346.54 1.00	SV-K218 [115] 0.161 -15.90 218.23 403.15 30.00 34.62 -206.87 401.58 -350.65 0.90
MSk3 [174] 0.157 -15.79 233.25 379.01 28.00 7.04 -283.52 615.65 -314.33 1.00	SK13 [168] 0.130 -15.63 235.79 301.95 30.09 129.33 159.57 11.73 -405.74 0.56	SkT7a [180] 0.161 -15.94 235.64 372.22 29.52 31.12 -209.85 439.35 -347.42 0.83	SV-K226 [115] 0.160 -15.90 225.82 392.14 30.00 34.09 -211.92 401.84 -357.27 0.90
MSk4 [174] 0.157 -15.79 231.17 385.26 28.00 7.20 -284.05 610.93 -315.24 1.05	Ski0 [199] 0.159 -16.69 246.11 520.56 29.90 55.24 -40.11 516.12 -524.20 0.04 CLM [199] 0.160 15.77 916.61 996.00 90.75 40.94 149.81 999.94 956.01 0.70	SkT8a [180] 0.161 -15.94 235.70 372.37 29.92 33.72 -187.52 476.25 -336.59 0.83	SV-K241 [115] 0.159 -15.91 241.07 364.54 30.00 30.95 -230.77 416.01 -369.66 0.90
MSk5 [174] 0.157 -15.79 231.17 385.26 28.00 7.57 -282.55 607.93 -315.36 1.05	SkM [122] 0.100 -10.11 210.01 300.09 30.13 45.34 -146.51 323.34 -300.91 0.19 SkM [100] 0.160 15.77 216.61 286.00 20.02 45.78 155.04 220.47 240.00 0.70	SkT9a [180] 0.160 -15.88 234.91 370.97 29.76 33.74 -185.62 471.98 -334.76 0.83	SV-kap00 [115] 0.160 -15.90 233.44 379.15 30.00 39.44 -161.78 446.94 -334.34 0.90
MSk5* [119] 0.156 -15.78 243.74 346.15 28.00 7.02 -290.66 595.12 -322.81 0.80	SkM [199] 0.100 -15.11 210.01 300.09 30.03 40.10 -155.94 330.41 -049.00 0.19 SkM1 [101] 0.160 15.77 216.61 286.00 25.17 25.97 288.80 012.87 290.72 0.70	SkTK [203] 0.168 -16.70 253.28 346.18 35.57 41.59 -221.79 527.94 -414.46 0.61	SV-kap02 [115] 0.160 -15.90 233.44 379.21 30.00 35.54 -193.19 431.91 -348.69 0.90
MSk6 [174] 0.157 -15.79 231.17 385.35 -05.00 -9.63 -05.00 591.40 04.00 1.05		SKX [204] 0.155 16.05 271.06 207.42 21.10 33.18 252.12 379.69 414.81 0.99	SV-kap06 [115] 0.160 -15.91 233.45 379.33 30.00 29.33 -249.75 388.84 -378.10 0.90
MSk7 [175] 0.157 -15.80 231.22 38 27 9.40 274.6 592.08 315.28 1.05		SI o [204] 0. 55 .86 26 27 30 33 8 238.39 6.93 -402.51 1.01	SV-mas07 [115] 0.160 -15.89 233.54 356.93 30.00 52.15 -98.77 365.68 -331.96 0.70
MSk8 [175] 0.157 -15.80 229.31 39, 27 8.26 280.0 597.59 117 19 1.10	SkO' 160 -177 222.36 -20 1.95 68.94 -22.3	s m [204] 0.159 .04 23 0.48 31 .3.08 -242.76 73 -384.00 0.97	SV-mas08 [115] 0.160 -15.90 233.13 371.28 30.00 40.15 -172.38 397.44 -349.35 0.80
MSk9 [175] 0.157 -15.80 233.33 379. 28 10.36 -270.2 589.06 315. 7 1.00	SkP 163 000 97 43 0.00 19.68 -266.6 308.3 1.00	8 [5 [205] 0.161 .76 20 42 31 9 -197.10 5 0 -332.38	SV-mas10 [115] 0.159 -15.91 234.33 383.22 30.00 28.04 -252.50 408.07 -374.87 1.00
MSkA [176] 0.153 -15.99 313.33 17 30 57.17 -135.3 197.74 153.13 1.79	SKR 05 159 -15.78 5.98 78.76 1.32 53.0 -122 310.8 -364 0.3	Six 0 [205] 0.162 .81 20 42 35 6122 81 32 -383.37 0.96	SV-sym28 [115] 0.163 -16.47 240.86 392.55 28.47 6.29 -305.94 584.47 -333.41 0.90
MSL0 [101] 0.160 -16.00 230.00 380.32 30.00 6 0 -99.33 4.29 -360.11 0.80	SkS1 [196] 0.161 -15.86 228.43 382.76 28.75 30.52 -218.69 379.24 -350.66 0.86	Skxs25 [205] 0.161 -15.87 202.92 -440.88 39.60 100.10 -50.28 145.99 -440.88 0.96	SV-sym32 [115] 0.159 -15.94 233.81 380.11 32.00 57.07 -148.79 257.70 -398.44 0.90
NRAPR [177] 0.161 -15.85 225.65 362.54 32.78 59.63 -123.32 371.61 -385.32 0.69	SkS2 [196] 0.161 -15.89 229.02 382.73 29.23 37.84 -218.07 270.03 -381.86 0.85	Skz-1 [128] 0.160 -16.01 230.08 365.25 32.00 54.14 -184.08 217.03 -422.99 0.70	SV-sym34 [115] 0.159 -15.97 234.07 380.82 34.00 80.95 -79.08 111.28 -433.08 0.90
PRC45 [178] 0.145 -15.82 367.58 -165.69 51.01 141.52 -23.01 92.05 -935.89 1.00	Sk53 [196] 0.161 -15.88 228.83 382.62 28.84 51.74 -157.38 154.06 -381.30 0.85	Skz0 [128] 0.160 -16.01 230.08 365.24 32.00 35.10 -242.20 405.16 -397.08 0.70	SV-tls [115] 0.160 -15.89 233.30 379.03 30.00 33.22 -218.42 403.90 -363.79 0.90
RATP [179] 0.160 -16.05 239.52 349.83 29.26 32.39 -191.23 440.70 -338.28 0.67	SkS4 [196] 0.163 -15.88 228.08 385.45 28.35 23.28 -238.42 438.06 -338.77 0.87	Skz1 [128] 0.160 -16.01 230.08 365.25 32.01 27.67 -242.40 535.38 -364.50 0.70	T [171] 0.161 -15.93 235.66 382.44 28.35 27.18 -206.76 462.91 -325.76 1.00
Rs [171] 0.158 -15.59 237.42 34 5 869.2 22 -400.7 0.78	S3 SC1 1.161 5.8. 234 380.50 28. 0.1 12.03 ( 32 -312.) 1.00	Skz2 [128] 0.160 16.01 230.07 105.2 32.01 81 -25 682.63 33.83 0.70	
Sefm068 [180] 0.160 -15.92 240.11 34 89 25431.10 59 1190.8 0.68	SkSC2 0.161 5.90 23 381.60 24. 11 0 -228.22 . 9 -276. 1.00	Skz3 [12] 0.160 16.01 230.0 365.26 2.01 6 -30 794.95 9.08 0.70	
Sefm074 [180] 0.160 -15.81 240.10 35 5 88. 14 58436.1 0.74	SkSC3 0.161 5.85 2 380.32 27296.20 64 -299.75 0	Skz4 [178] 0.160 12.01 230. 365.26 1.01 240 923.89 2.24 0.70	T13 [1 01 304.78 32.00 49.53 -108.06 487.57 -326.69 0.70
Sefm081 [180] 0.161 -15.69 237.04 35 30 7939.54 66396.4 0.81	SkSC4 0 0161 5.87 23 380.79 28 -2 -329.4 708 -320.7 1.00	SLy0 222 0.160 -15.97 229. 364.01 1.98 47116 508.9 3 0.70	
Sefm09 [180] 0.161 -15.55 240.06 24	SkSC40 [157] 0.161 -1557 234.74 -579 2700 -9.61 -595.05 725.55 -250.10 1.60	SLY [206] 0.160 15.99 229.81 864.3 81.99 47.0 -110 80 86 -32 U	T16 [152] 0.161 -16.01 230.01 365.68 22.00 49.45 -108.75 487.24 -226.83 0.70
Sefm1 [180] 0.161 -15.40 240.07 346.34 24.81 59.55 -46.89 81.53 -318.28 1.00	SkSC5 [200] 0.161 -15.85 234.50 380.34 30.99 -6.97 -375.08 799.41 -344.58 1.00	SLy2 [206] 0.161 -15.99 229.92 364.21 32.00 47.46 -115.13 506.52 -324.69 0.70	T21 [152] 0.161 -16.03 230.01 366.49 32.00 49.77 -108.03 483.25 -327.37 0.70
SGI [181] 0.154 -15.89 261.75 297.93 28.33 63.86 -51.99 194.46 -362.49 0.61	SkSC6 [200] 0.161 -15.92 235.41 382.13 24.57 11.00 -226.26 501.80 -274.39 1.00	SLy230a [45] 0.160 -15.99 229.89 364.18 31.99 44.32 -98.22 602.87 -293.91 0.70	T22 [152] 0.161 -16.02 230.01 365.95 32.00 49.57 -108.50 485.74 -327.04 0.70
SGII [181] 0.158 -15.60 214.65 380.91 26.83 37.63 -145.90 330.41 -304.90 0.79	SkSC10 [200] 0.161 -15.96 235.89 383.08 22.83 19.13 -172.77 394.81 -256.47 1.00	SLy2306 [45] 0.160 -15.97 229.91 363.10 32.01 45.97 -119.72 521.50 -322.92 0.69 SLy2 [06] 0.160 15.04 220.51 262.56 21.07 45.26 121.00 524.75 222.92 0.69	T23 [152] 0.161 -16.01 230.01 365.63 32.00 49.59 -108.27 485.95 -326.97 0.70
SGOI [182] 0.168 -16.63 361.59 -37.36 45.20 99.76 -155.64 144.36 -764.53 0.61	SkSC11 [201] 0.161 -15.87 234.72 380.79 28.80 -2.12 -329.49 708.23 -320.20 1.00	SLy3 [206] 0.160 -15.94 229.51 362.36 31.97 45.36 -121.90 524.75 -322.39 0.70 SLy4 [907] 0.160 15.07 990.01 969.11 99.00 45.04 110.79 591.59 999.89 0.69	T24 [152] 0.161 -16.01 230.01 365.37 32.00 49.85 -107.22 484.00 -327.14 0.70
SGOII [182] 0.168 -16.70 253.28 346.18 93.98 246.02 -119.57 272.39 -1259.44 0.61	SkSC14 [199] 0.161 -15.92 235.41 382.13 30.00 33.13 -202.83 454.93 -347.84 1.00	SLy5 [207] 0.161 -15.99 220.02 264.16 22.01 48.15 -112.76 500.67 -225.28 0.70	T25 [152] 0.161 -15.99 230.01 364.24 32.00 49.12 -109.21 491.85 -326.16 0.70
SI [27] 0.155 -15.99 370.38 -152.32 29.24 1.22 -461.84 141.44 -469.66 0.91	SkSC15 [199] 0.161 -15.88 234.93 381.17 28.00 6.72 -284.47 618.21 -313.89 1.00	SLy6 [207] 0.150 15.02 22.52 00110 02.01 0.10 112.10 0.000 02000 0.10 SLy6 [207] 0.150 15.02 220.96 260.24 21.06 47.45 112.71 510.62 222.02 0.60	T26 [152] 0.161 -15.98 230.01 363.48 32.00 48.76 -110.15 495.92 -325.64 0.70
SH [27] 0.148 -15.99 341.40 -15.76 34.16 50.02 -265.72 104.75 -568.17 0.58	SkSP.1 [119] 0.162 -15.90 230.02 502.64 28.00 -289.55 662.66 -316.92 0.80	SLy7 [207] 0.158 -15.90 220.75 250.22 21.00 46.04 -114.24 517.14 -222.60 0.69	T31 [152] 0.161 -16.02 230.01 366.28 32.00 49.75 -108.00 483.82 -327.27 0.70
SIII [183] 0.145 -15.85 355.37 -101.38 28.16 9.91 -393.73 130.45 -456.01 0.76	SkT [202] 0.148 -15.40 333.36 -29.01 33. 807 9.95 0.60	SLy8 [206] 0.160 -15.97 229.89 363.27 32.00 47.18 -115.59 509.88 -324.09 0.70	$T32\ [152] \qquad 0.161  -16.03  230.01  366.39  32.00  50.28  -106.20  478.97  -327.80  0.70$
SIII* [184] 0.148 -16.07 361.15 -107.94 31.97 28.70 -358.37 84.84 -539.13 0.78	SkT1 [113] 0.161 -15.98 236.16 383.52 32.02 -13 318.99 8 1.00	SLv9 [206] 0.151 -15.80 229.84 350.42 31.98 54.86 -81.42 462.35 -326.92 0.67	T33 [152] 0.161 -16.02 230.01 366.10 32.00 49.66 -108.23 484.88 -327.13 0.70
SIV [183] 0.151 -15.96 324.55 68.84 31.22 63.50 -136.72 79.45 -504.22 0.47	SkT2 [113] 0.161 -15.94 235.73 382.67 32. 5613 318.66 18 1.0	v10 [207] 0.156 -15.90 229.68 358.32 31.90 38.51 -142.18 591.23 -313.17 0.68	T34 [152] 0.161 -16.02 230.01 366.28 32.00 50.10 -106.81 480.71 -327.60 0.70
Sk1' [185] 0.155 -15.99 370.38 -152.32 29.35 35.34 -259.16 141.44 -485.71 0.91	SkT3 [113] 0.161 -15.95 235.74 382.70 31. 55 -13	MC1 [156] 0.137 -14.00 328.76 -143.78 29.68 -6.70 -504.25 218.08 -461.10 0.93	T35 [152] 0.161 -16.00 230.01 364.84 32.00 49.59 -107.85 487.05 -326.74 0.70
SK255 [68] 0.157 -16.33 254.93 350.09 37.40 95.05 -58.33 94.23 -498.11 0.80	SkT4 [113] 0.159 -15.96 235.50 382.94 35.24 35.49 -2 97.84 6	MC2 [156] 0.140 -14.29 330.10 -121.75 28.70 8.67 -408.41 145.55 -463.63 0.83	T36 [152] 0.161 -15.99 230.01 364.51 32.00 49.05 -109.62 491.98 -326.20 0.70
SK272 [68] 0.155 -16.28 271.51 305.31 37.40 91.67 -67.78 134.36 -514.70 0.77	SkT5 [113] 0.164 -16.00 201.69 436.81 37.00 98.53 -2 99.88 -	SOMC3 [156] 0.161 -15.98 366.97 -130.22 45.78 91.80 -210.95 163.48 -794.33 0.82	T41 [152] 0.162 -16.06 230.01 368.36 32.00 50.60 -106.02 473.67 -328.60 0.70
SkA [186] 0.155 -15.99 263.16 300.13 32.91 74.62 -78.46 174.54 -441.08 0.61	SkT6 [113] 0.161 -15.96 235.95 383.15 29.97 30.85 -21 1 1.	QMC600 [157] 0.174 -15.74 217.00 388.62 34.38 46.38 -215.16 396.85 -410.40 0.81	T42 [152] 0.162 -16.05 230.01 368.04 32.00 50.70 -105.51 473.28 -328.59 0.70
Ska25s20 [187] 0.161 -16.07 220.75 413.45 33.78 63.81 -118.22 314.13 -381.56 0.98	SkT7 [113] 0.161 -15.94 235.64 372.22 29.52 31.12 -20.55 10.55 -347.42 0.83	SQMC650 [157] 0.172 -15.57 218.11 376.75 33.65 52.92 -173.15 349.74 -399.28 0.78	T43 [152] 0.162 -16.04 230.01 367.39 32.00 50.57 -105.66 475.23 -328.31 0.70
Ska35s15 [187] 0.158 -16.01 238.89 378.88 30.56 30.60 -222.90 481.99 -357.96 1.01	SkT8 [113] 0.161 -15.94 235.70 372.37 29.92 33.72 -187.52 476.25 -336.59 0.83	SQMC700 [157] 0.171 -15.49 222.20 369.94 33.47 59.06 -140.84 313.84 -396.85 0.76	T44 [152] 0.161 -16.02 230.01 365.91 32.00 50.05 -106.76 481.62 -327.45 0.70
Ska35s20 [187] 0.158 -16.08 240.27 378.65 33.57 64.83 -120.32 284.54 -407.11 1.00	SkT9 [113] 0.160 -15.88 234.91 370.97 29.76 33.74 -185.62 471.98 -334.76 0.83	SQMC750 [157] 0.171 -15.60 222.86 365.83 33.75 64.67 -117.51 288.41 -399.38 0.74	T45 [152] 0.161 -16.02 230.01 366.10 32.00 49.66 -108.24 484.73 -327.16 0.70
Ska35s25 [187] 0.158 -16.14 241.30 378.94 36.98 98.89 -23.57 97.46 -461.60 0.99	SkT1* [113] 0.162 -16.20 238.95 388.75 32.31 56.58 -136.66 322.86 -384.07 1.00	SSk [51] 0.161 -16.16 229.31 375.38 33.50 52.78 -119.15 482.24 -349.42 0.72	140 [102] 0.101 -10.00 230.01 304.75 32.00 49.93 -106.59 484.25 -327.00 0.70
Ska45s20 [187] 0.156 -16.08 260.21 330.55 33.39 66.21 -119.99 251.77 -433.13 1.02	SkT3* [113] 0.162 -16.20 238.95 388.76 31.97 56.32 -133.65 316.82 -379.93 1.00	SV [183] 0.155 -16.05 305.70 175.78 32.82 96.09 24.17 48.00 -497.11 0.38	TE2 [122] 0.102 -10.05 230.01 367.96 32.00 50.69 -105.52 473.55 -328.55 0.70
SkB [186] 0.155 -15.99 263.16 300.13 23.88 47.54 -78.46 174.54 -309.50 0.61	SkT1a [180] 0.161 -15.98 236.16 383.52 32.02 56.18 -134.83 318.99 -380.68 1.00	SV-bas [115] 0.160 -15.91 233.45 379.28 30.00 32.37 -221.75 410.93 -363.36 0.90	152 [152] 0.101 -10.00 240.01 305.07 32.00 50.08 -105.55 473.55 -328.55 0.70
Skl1 [188] 0.160 -15.95 242.75 346.14 37.53 161.05 234.67 -328.02 -502.01 0.69	SkT2a [180] 0.161 -15.94 235.73 382.67 32.00 56.16 -134.67 318.66 -380.48 1.00	SV-min [115] 0.161 -15.91 221.76 403.08 30.66 44.81 -156.57 389.56 -343.99 0.95	T54 [152] 0.101 -10.02 200.01 300.21 32.00 50.03 -100.39 481.50 -327.50 0.70 T54 [152] 0.161 16.09 390.01 966.79 93.00 50.97 106.96 478.71 937.85 0.70
Sk12 [188] 0.158 -15.78 240.93 339.70 33.37 104.33 70.69 51.62 -408.21 0.68	SkT3a [180] 0.161 -15.95 235.74 382.70 31.50 55.31 -132.05 313.43 -374.14 1.00	SVI [183] 0.143 -15.76 363.64 -153.50 26.88 -7.34 -471.30 146.04 -424.18 0.95	104 [104] 0.101 -10.00 200.01 000.13 32.00 30.21 -100.30 478.11 -327.85 0.10 Continued on next name
Skl3 [188] 0.158 -15.98 258.19 303.86 34.83 100.53 73.04 211.54 -411.80 0.58	SkT4a [180] 0.159 -15.96 235.50 382.94 35.45 94.13 -24.46 97.84 -436.19 1.00	Continued on next page	Continued on next page
Continued on next page	Continued on next page		

		ТА	ABLE II – co	ntinued from	previous	page					ТА	BLE II –	continued	from previ	ous page																						
Model	ρο	Eo	Ko	K' = J	L	$K_{sym}$	$Q_{sym} = K_{\tau,y}$	<i>m</i> *	Model	00	Ea	Ke	<i>K'</i>	1	L K.		an K					Τ/	BLE VII – con	tinued from	previous pa	go					Т	ABLE VII – c	ontinued from	previous page			
MSk1 [174]	0.157	-15.83	233.73	379.97 30.	00 33.92	-200.02	448.66 -348.	.39 1.00	SkT5s [180]	0.164	-16.00	201.69	436.81	37.00	853 -2	4.97 (	0.88 -40	2.76 1.00	Model		90	$E_0$	K <sub>0</sub> m*	K'	J	L <sub>0</sub> K	o Q	$K^0_{\pi,w}$ $K^0_{\pi,w}$	Model	Po	$E_0$	K <sub>0</sub> m*	K'	J I	$K_{sym}^0$	$Q^0_{\rm sym}$	$K^0_{\tau,v}$
MSk2 [174]	0.157	-15.83	231.65	386.21 30.	00 33.35	-203.44	449.71 -347.	94 1.05	SkT6a [180]	0.161	-15.96	235.95	383.15	29.97	0.85 -21	1.53 45	2.36 -34	6.54 1.00	RMF404	[80] 0.	153 -	16.30	231.99 0.72	478.64	32.50	93.11	17.78	88.39 -348.78	NL4 [92]	0.148	-16.16	270.34 0.6	-193.75	36.24 11	4.92 99.72	180.84	4 -672.14
MSk3 [174]	0.157	-15.79	233.25	379.01 28.	00 7.04	-283.52	615.65 -314	.33 1.00	SkT7a [180]	0.161	-15.94	235.64	372.22	29.52	1.12 -20	9.85 43	9.35 -34	7.42 0.83	RMF405	[80] 0.	153 -	16.30	233.99 0.72	470.83	32.50	93.10	17.50	85.94 -353.76	NLB [93]	0.148	-15.77	421.02 0.6	-727.93	35.01 10	8.26 54.94	-132.35	5 -781.79
MSk4 [174]	0.157	-15.79	231.17	385.26 28.	00 7.20	-284.05	610.93 -315.	24 1.05	SkT8a [180]	0.161	-15.94	235.70	372.37	29.92	3.72 -18	7.52 41	6.25 -33	6.59 0.83	RMF406	[80] 0.	153 -	16.30	233.99 0.78	520.06	32.50	89.75	-5.80	58.72 -344.85	NLB1 [78]	0.162	-15.79	280.44 0.63	-108.61	33.04 10	2.51 76.15	107.80	) -578.59
MSk5 [174]	0.157	-15.79	231.17	385.26 28.	00 7.57	-282.55	607.93 -315.	36 1.05	SkT9a [180]	0.160	-15.88	234.91	370.97	29.76	3.74 -18	5.62 41	1.98 -33	4.76 0.83	RMF407	[80] 0.	153 -	16.30	229.99 0.73	493.83	32.50	92.50	13.42	82.67 -342.96	NLB2 [78]	0.163	-15.79	245.58 0.53	-542.60	33.10 11	1.30 158.94	289.13	3 -754.77
MSk5* [119]	0.156	-15.78	243.74	346.15 28.	00 7.02	-290.66	595.12 -322.	81 0.80	_SkTK [203]	0.168	-16.70	253.28	346.18	35.57 4	1.59 -22	1.79 52	27.94 -41	4.46 0.61	RMF408	[80] 0.	153 -	16.30	231.99 0.73	486.58	32.50	92.48	13.15	80.44 -347.78	NLC [93]	0.148	-15.77	224.46 0.63	278.13	35.02 10	7.97 76.91	235.59	) -437.12
MSk6 [174]	0.157	-15.79	231.17	385.26 28.	9.63	-2 <mark>.</mark> 33	1.49 -316.	.05 1.05	SKX [204]	0.155	-16.05	271.06	297.42	31.10 3	3.18 -25	2.12 35	9.69 -41	4.81 0.99	RMF409	180 0.	0		233.99 0.73	479.45	32.50	92.47	12.88	78.25 -352.46	NLD [94]	0.148	-15.77	343.21 0.7	) 75.49	35.01 10	1.52 13.53	-12.22	2 -573.26
MSk7 [175]	0.157	-15.80	231.22	385.36 27.	95 9.40	-2 63	2.09		SF ce [204]	155	-1 86	26 .4	94 7		3.48 -23	8.39 3!	8 0	2.5 1	RMP		D	.30	10.0	472.46	32.50	0.0		09 357		0.1	16.0	00.00 0.70	600.49	30.00 8	7.02 33.20	161.25	5 −227.65
MSk8 [175]	0.157	-15.80	229.31	391.01 27.	93 8.26	-2 .01	7.1	4 1.10	SF m [1]	0.109	-1 04	23 9	80 8	AL20	2.08 -24	6 42	8 8	4. 0		n 0.	170	- 30		403.50	32.50	91.34	.00	27 31 B		0 0		0.00 0.7	675.54	30.00 8	6.95 33.27	170.92	2 -194.74
MSk9 [175]	0.157	-15.80	233.33	379.16 28.	00 10.36	-2.23	9.06 0	57	Skxs15 [205]	0.161	-15.76	201.10	424.57	31.88	4.79 -19	7.10 51	6.30 -33	18 0.9	DAIDAG	1901 0	153	16.20	022.00 0.74	493.32	93,50	01.87		21.00 971.00		0.1	16.0	0.00 0.7	591.82	30.00 8	7.45 33.01	156.01	1 -232.93
MSkA [176]	0.153	-15.99	313.33	138.15 30.	35 57.17	-135.34	197.74 -453.	.13 0.79	Skxs20 [205]	0.162	-15.81	201.95	425.56	35.50	7.06 -12	2.31 32	8.52 -38	3.37 0.96	RMF413	1801 0.	153 -	16:30	235.99 0.74	480.94	32.50	91.87	8.33	69.99 -355.62	NLM4 [89]	0.160	-16.00	300.00 0.7	196.02	30.00 8	6.25 17.69	22.57	7 -443.46
MSL0 [101]	0.160	-16.00	230.00	380.32 30.	00 60.00	-99.33	224.29 -360.	.11 0.80	Skxs25 [205]	0.161	-15.87	202.92	-440.88	39.60 10	0.10 -5	0.28 14	15.99 -44	0.88 0.96	BMF415	1801 0	153 -	16.30	229.98 0.75	505.92	32.50	91.33	5.00	70.28 -342.01	NLM5 [89]	0.160	-16.00	200.00 0.53	-216.98	30.00 10	3.18 179.44	524.64	4 -551.60
NRAPR [177]	0.161	-15.85	225.65	362.54 32.	78 59.63	-123.32	311.61 -385.	32 0.69	Skz-1 [128]	0.160	-16.01	230.08	365.25	32.00 1	4.14 -18	4.08 🥢	m -	2.99 0.70	RMEAN	1801 0.	18	16.30	221.98 _0.75	500.17	22.50	01 23	4.82	68.54 -346.19	NLM6 [89]	0.160	-16.00	200.00 0.70	600.49	40.00 11	7.02 33.20	161.24	4 -317.57
PRC45 [178]	0.145	-15.82	367.58	165.69 51.	01 141.52	1 100	97		Sh [ ]	160	-10 11	137 6	65.24	2.00 \$	50 4	2.20	w L	0.70	RMF4D	OI CO	Ζ.	16.30	29 9 75	1.5	2.5	80	4.58	66. (0.2)	LR.			320.48 0.63	3 -216.23	38.90 11	9.09 62.11	26.63	3 -732.77
RATP [179]	0.160	-16.05	239.52	349.83 29.	26 32.39	23	44 70 8	0.67	Sk [17	160	-1	23 18	365.25	2.01 2	7 4	2.40	5 -	4.5 0.70	R117415	0 0	12 -	16.30	23 8 75	1.0	2.5	29	4.34	65. 54.2	н 196	.147		285.23 0.60	0 -279.28	36.45 11	5.38 95.72	139.44	4 -709.55
Rs [171]	0.158	-15.59	237.42	348.46 30.	82 86.39		22	78	Skz2 [128]	0.160	-16.01	230.07	365.23	32.01 1	6.81 -25	9.66 62	2.63 -33	3.83 0.70	RMF419	[80] 0.	153 -	16.30	229.99 0.76	511.79	32.50	90.79	1.31	65.98 -341.39	AS	150		262.94 0.60	-57.53	42.07 13	1.59 94.22	195.27	7 -724.10
Sefm068 [180]	0.160	-15.92	240.11	347.11 88.	57 254.43	-32.10	59.40 -1190.	.85 0.68	Skz3 [128]	0.160	-16.01	230.09	365.26	32.01 1	2.96 -24	1.91 79	4.95 -29	9.08 0.70	RMF420	[80] 0.	153 -	16.30	231.99 0.76	506.88	32.50	90.78	1.09	64.47 -345.23	NLSH [90]	0.146	-10.35	355.05 0.00	400.50	30.13 11	3.68 79.83	-23.79	7 -795.00 0 - 207.80
Sefm074 [180]	0.160	-15.81	240.10	350.15 33.	40 88.73	-33.14	58.41 -436.	.12 0.74	Skz4 [128]	0.160	-16.01	230.08	365.26	32.01	5.75 -24	0.86 92	3.89 -26	6.24 0.70	RMF421	[80] 0.	153 -	16.30	233.99 0.76	502.11	32.50	90.76	0.86	62.99 -348.96	NLZ [67]	0.151	-10.18	172.04 0.50	422.39	41.72 13	5.91 140.19	511.02	2 -335.60
Sefm081 [180]	0.161	-15.69	237.04	356.66 30.	76 79.39	-39.54	66.74 -396.	41 0.81	SLv0 [206]	0.160	-15.97	229.66	364.01	31.98 4	7.11 -11	6.23 50	8.68 -32	4.23 0.70	RMF422	[80] 0.	153 -	16.30	229.99 0.77	518.27	32.50	90.27	2.17	62.86 -340.38	002001	0.151	-16.05	991.69 0.6	412.31	41.07 19	0.02 140.02 0.02 46.02	151.94	- a13.10
Sefm09 [180]	0.161	-15.55	240.06	349.75 27.	78 69.96	- 00	70 58		-sLy 206	0.165	5.99	29.8	4.3	31.99	7.0 -	5.49 50	36 32	4.27 0.70	R F42	50] 0	13 -	It.ad	1.99 0.7	1.26	.50	90 -	-2.38	1.57 -3 .86			16.95	245.07 0.7	906.44	41.85 19	0.05 07.75	02.49	9 -509.45
Sefm1 [180]	0.161	-15.40	240.07	346.34 24.	81 59.55	.89	87 🔁 18	1.00	45y 20r	0.1	5.99	29.9	4.2	32.00	7.4 -1	5.13 50	52 - 32	4.69 0.70	RMF42	80 0	53	10.00	5.99 /9	3.99	.50	19	9.88	3.59 -3 12		0	16 51	210.07 0.11	499.84	49.95 19	1.48 -1.08	49.56	6 _532.01
SGI [181]	0.154	-15.89	261.75	297.93 28.	33 63.86		194	49-0.61	SLy230 45]	.160	-15.99	229.89	364.18	31.9 4	4132 -9	8.22 60	2.87 -29	3.91 0.70	RMF425	[80] 0.	153 -	16.30	247.99 0.79	523.21	32.50	89.20 -	0.06	52.90 -1 .07	P 080 1081	0.162	-15.84	250.02 0.8	590.94	20.62 10	9.78 -14.16	59.59	9 -440.99
SGII [181]	0.158	-15.60	214.65	380.91 26.	83 37.63	-1-13.90	330.41 -304.	90 0.79	SLy230b [45]	0.160	-15.97	229.91	363.10	32.01 4	5.97 -11	9.72 52	21.50 -32	2.92 0.69	RMF426	[80] 0.	153 -	16.30	249.99 0.79	522.57	32.50	89.19 -	10.24	52.23 -358.93	01 [99]	0.148	-16.10	241.86 0.6	-8.70	36.44 11	5.71 105.65	266.72	2 -592.77
SGOI [182]	0.168	-16.63	361.59	-37.36 45.	20 99.76	-155.64	144.36 -764.	53 0.61	SLy3 [206]	0.160	-15.94	229.51	362.56	31.97 4	5.36 -12	1.90 52	14.75 -32	2.39 0.70	RMF427	[80] 0.	153	16.30	235.98 0.80	546.20	32.50	88.83 -	11.67	58.05 -339.04	RMF301 [80]	0.153	-16.30	253.86 0.7	489.08	32.50 8	9.87 -6.25	49.30	0 -372.34
SGOII [182]	0.168	-16.70	253.28	346.18 93.	98 246.02	-119.57	272.39 -1259.	.44 0.61	SLy4 [207]	0.160	-15.97	229.91	363.11	32.00 4	5.94 -11	9.73 52	1.53 -32	2.83		-*	153 -	16.30	98 .0	5 82	32.50	88.81 -	11.85	57.43 -341.04	RMF302 [80]	0.153	-16.30	249.71 0.7	502.35	32.50 8	9.66 -7.35	51.33	3 -364.94
SI [27]	0.155	-15.99	370.38	152.32 29.	24 1.22	-4, 8	d1.4 -	66-703	s (5 - 1	161	-1 - 69	22 2	6 6	2.01 4	8 1	76 -30	-32	5.38 0.70	R P429	[30] 0.	15 -	16.30	2 99	54 90	50	88	2.6	56.84 ~342.95	RMF303 [80]	0.153	-16.30	248.88 0.7	504.91	32.50 8	9.62 -7.57	51.73	3 -363.46
SII [27]	0.148	-15.99	341.40	-15.76 34.	16 50.02	-2 1	14.7 86	17-0-0	8 [1 ]	159	-1 92	22 6	50	91 / 4	7 5 1	1 1 0	-32	3.03 0.69	R F430	[80] 0.	15 -	16.30	2 99 80	54 3	50	8 0 -	12.1	56.26 -344.77	RMF304 [80]	0.153	-16.30	248.04 0.78	507.43	32.50 8	9.57 -7.78	52.13	3 -361.98
SIII [183]	0.145	-15.85	355.37	101.38 28.	16 9.91	-393.73	130.45 -450.	01 0.76	SLy7 [207]	0.158	-15.90	22 15	359.22	31. 4	6.9 -11	4.34 51	7.14 -32	2.60 0.69	MF431	[80] 0.	153 -	16.30	243.98 0.55	5 62	32.00	88.78	12.30	-346.50	RMF305 [80]	0.153	-16.30	246.37 0.78	512.37	32.50 8	9.49 -8.21	52.92	2 -359.04
SIII* [184]	0.148	-16.07	361.15	107.94 31.	97 28.70	-358.37	84.84 -539.	.13 0.78	SLy8 [206]	0.160	-15.97	229.89	363.27	32.00 4	7.18 -11	5.59 50	9.88 -32	4.09 0.70	RMF432	[80] 0.	153	16.30	245.98 0.80	545.86	32.50	88.77 -	12.53	55.19 -348.16	RMF306 [80]	0.153	-16.30	244.69 0.75	517.18	32.50 8	9.41 -8.63	53.72	2 -356.09
SIV [183]	0.151	-15.96	324.55	68.84 31.	22 63.50	-136.72	79.45 -504.	22 0.47	SLy9 [206]	0.151	-15.80	229.84	350.42	31.98 5	4.86 -8	1.42 46	52.35 -32	6.92 0.67	RMF433	Isul U.	153 -	16.30	247.90 0.80	546.26	32,50	88.76 -	12.70	54.68 -349.73	RMF307 [80]	0.153	-16.30	243.84 0.79	519.54	32.50 8	9.37 -8.84	54.11	1 -354.63
Sk1' [185]	0.155	-15.99	370.38	152.32 29.	35 35.34	-259.16	141.44 -485.	.71 0.91	SLy10 [207]	0.156	-15.90	229.68	358.32	31.90 \$	8.51 -14	2.18 59	01.23 -31	3.17 0.68	RMF 434	jeuj u. N O	153 -	15.30	249.99 0.80	540.81	32.50	88.74 -	7.10	54.19 -351.22	RMF308 [80]	0.153	-16.30	242.99 0.7	521.85	32.50 8	9.32 -9.04	54.50	∂ <u>-353.15</u>
SK255 [68]	0.157	-16.33	254.93	350.09 37.	40 95.05	-58.33	94.23 -498.	.11 0.80	SQMC1 [156]	0.137	-14.00	328.76	-143.78	29.68	6.70 -50	4.25 21	18.08 -46	1.10 0.93	R5K1* [8	n 0.	100 -	10.04	216.60 0.79	005 90	30.03	81.75	-7.42	66.77 -297.98 55.84 400.50	RMF309 [80]	0.153	-16.30	241.30 0.7	526.40	32.50 8	9.24 -9.45	55.28	8 -350.22
SK272 [68]	0.155	-16.28	271.51	305.31 37.	40 91.67	-67.78	134.36 -514.	.70 0.77	SQMC2 [156]	0.140	-14.29	330.10	-121.75	28.70	8.67 -40	8.41 14	15.55 -46	3.63 0.83	SMET1 I	1001 0	158	19.80	173 14 0.63	456 57	17.57	55.94	87.98	151.11 -100.85	RMF310 [80]	0.153	-16.30	238.75 0.75	532.98	32.50 8	9.12 -10.04	56.45	5 -345.82
SkA [186]	0.155	-15.99	263.16	300.13 32.	91 74.62	-78.46	174.54 -441.	08 0.61	SQMC3 [156]	0.161	-15.98	366.97	-130.22	45.78 9	1.80 -21	0.95 16	3.48 -79	4.33 0.82	SMET2 I	1001 0	162	13.78	211.31 0.65	970.11	17.38	59.79	50.97	187 74 - 188 71	RMF311 [80]	0.153	-16.30	237.89 0.7	535.10	32.50 8	9.08 -10.24	56.83	3 -344.35
Ska25s20 [187]	0.161	-16.07	220.75	413.45 33.	78 63.81	-118.22	314.13 -381.	56 0.98	SQMC600 [157]	0.174	-15.74	217.00	388.62	34.38 4	6.38 -21	5.16 39	6.85 -41	0.40 0.81	SRK3M5	[101] 0.	150 -	16.00	299.86 0.55	-966.33	23.49	82.45 1	16.76	96.88 -613.65	RMF312 [80]	0.153	-16.30	237.03 0.79	537.20	32.50 8	9.04 -10.44	57.22	2 -342.89
Ska35s15 [187]	0.158	-16.01	238.89	378.88 30.	56 30.60	-222.90	481.99 -357	96 1.01	SQMC650 [157]	0.172	-15.57	218.11	376.75	33.65	2.92 -17	3.15 34	19.74 -39	9.28 0.78	SRK3M7	[101] 0.	150 -	16.00	299.95 0.75	363.93	28.73	79.69	-2.56	24.62 -384.00	RMF313 [80]	0.153	-16.30	235.31 0.8	541.28	32.50 8	8.96 - 10.82	57.98	8 -339.96
Ska35s20 [187]	0.158	-16.08	240.27	378.65 33.	57 64.83	-120.32	284.54 -407.	.11 1.00	SQMC700 [157]	0.171	-15.49	222.20	369.94	33.47 5	9.06 -14	0.84 31	13.84 -39	6.85 0.76	VT [81]	0.	153 -	16.09	172.74 0.59	482.84	39.72	126.83 1	30.05	542.92 -276.41	RMF314 [80]	0.153	-16.30	234.43 0.8	543.28	32.50 8	8.92 -11.01	58.36	∂ –338.47
Ska35s25 [187]	0.158	-16.14	241.30	378.94 36.	98 98.89	-23.57	97.46 -461.	60 0.99	SQMC750 [157]	0.171	-15.60	222.86	365.83	33.75	4.67 -11	7.51 28	8.41 -39	9.38 0.74					$\sigma^{3} + \sigma^{4} + i$	ad models (t	type 3)				RMF315 [80]	0.153	-16.30	234.01 0.8	544.27	32.50 8	8.91 -11.10	58.55	5 -337.76
Ska45s20 [187]	0.156	-16.08	260.21	330.55 33.	39 66.21	-119.99	251.77 -433.	.13 1.02	SSk [51]	0.161	-16.16	229.31	375.38	33.50 5	2.78 -11	9.15 48	\$2.24 -34	9.42 0.72	BM-A [10	02] 0.	179 -	15.17	188.32 0.61	436.32	19.62	51.88 -	18.05 -	-36.02 -209.14	RMF316 [80]	0.153	-16.30	233.57 0.8	545.22	32.50 8	8.89 -11.20	58.74	4 -337.02
SkB [186]	0.155	-15.99	263.16	300.13 23.	88 47.54	-78.46	174.54 -309.	50 0.61	SV [183]	0.155	-16.05	305.70	175.78	32.82 9	6.09 2	9.17 4	8.00 -49	7.11 0.38	BM-B [10	02] 0.	156 -	13.47	170.77 0.64	504.54	17.42	45.46 -	15.61	-5.33 -154.06	RMF317 [80]	0.153	-16.30	232.70 0.8	547.17	32.50 8	8.85 -11.38	59.12	2 -335.55
SkI1 [188]	0.160	-15.95	242.75	346.14 37.	53 161.05	234.67	-328.02 -502.	01 0.69	SV-bas [115]	0.160	-15.91	233.45	379.28	30.00 \$	2.37 -22	1.75 41	0.93 -36	3.36 0.90	BM-C [10	02] 0.	142 -	12.36	163.10 0.65	547.19	16.01	41.49 -	14.20	7.05 -123.94	RMF401 [80]	0.153	-16.30	229.99 0.7	477.86	32.50 9	3.79 23.04	100.51	1 -344.81
SkI2 [188]	0.158	-15.78	240.93	339.70 33.	37 104.33	70.69	51.62 -408.	21 0.68	SV-min [115]	0.161	-15.91	221.76	403.08	30.66 4	4.81 -15	0.57 38	9.56 -34	3.99 0.95	DJM [102	η ο.	172 -	14.81	244.73 0.57	-147.54	20.21	62.95	32.66 -	102.43 -383.00	RMF402 [80]	0.153	-16.30	231.99 0.7	469.28	32.50 9	3.77 22.74	97.75	5 -350.20
SkI3 [188]	0.158	-15.98	258.19	303.86 34.	83 100.53	73.04	211.54 -411.	80 0.58	SVI [183]	0.143	-15.76	363.64	-153.50	26.88	7.34 -47	1.30 14	10.04 -42	4.18 0.95	-								Contine	ied on next page	RMF403 [80]	0.153	-16.30	229.99 0.7	486.57	32.50 9	3.13 18.06	90.88	5 -343.67
							Continued on 1	sext page								Ca	nunued or	next page	10																Cor	tinued on	n next page

Два явления, связанные с <sup>8</sup>Ве: УРОВЕНЬ ХОЙЛА в <sup>12</sup>С и <sup>8</sup>Ве аномалия

# $p + \frac{7}{3}Li \rightarrow \frac{8}{4}Be^* \rightarrow \frac{7}{3}Li + p$ $p + \frac{7}{3}Li \rightarrow \frac{8}{4}Be^* \rightarrow \frac{4}{2}He + \frac{4}{2}He$ $p + \frac{7}{3}Li \rightarrow \frac{8}{4}Be^* \rightarrow \frac{8}{4}Be + \gamma$

АТОМКІ эксперимент A.Krasznahorkay et. al. (ниже приводятся и обсуждаются результаты АТОМКІ) Поиск проявления массивной частицы в ядерных переходах. Идея Вильчека и др. в 70-х.

#### Примеры поиска скаляра в ядерных переходах

$$p(1.88 \text{ MeV}) + {}^{19}F \to \alpha + {}^{16}O^*(6.05)$$
  
 ${}^{16}O^*(6.05) \to {}^{16}O(GS) + \phi$ 

Kohler et al PRL 33, 1628 (1974)

Freedman et al. PRL 52, 240 (1984)

 $p + {}^3H \rightarrow {}^4He(20.1) \rightarrow 4He(GS) + \phi$ 

Только ограничения на массу и константу связи. В ядерных переходах искали и аксионы. Работ много, например, в ПИЯФ

Search for axions emitted in nuclear magnetic transitions A.V. Derbin, A.I. Egorov, I.A. Mitropolsky, V.N. Muratova, S.V. Bakhlanov, L.M. Tukhkonen (St. Petersburg, INP). 2002. 5 pp. Published in Phys.Atom.Nucl. 65 (2002) 1302-1306, Yad.Fiz. 65 (2002) 1335-1339

## $p + \frac{7}{3}Li \rightarrow \frac{8}{4}Be^* \rightarrow \frac{8}{4}Be + \gamma$ MACCA Li-7 : 6533.83 MeV



State	$m \ ({ m MeV})$	$\Delta E \ ({\rm MeV})$	$\Gamma ~({\rm keV})$	$\Gamma_{\gamma} (eV)$	$J_T^P$
$^{8}\mathrm{Be}$	7454.85	0			$0^{+}_{0}$
${}^{8}\mathrm{Be}^{*}$	7473.00	18.15	138	1.9	$1_{0}^{+}$
${}^{8}\mathrm{Be}^{*\prime}$	7472.49	17.64	10.7	15	$1_{1}^{+}$



Протоны - Ван-Де-Грааф (Тандетрон) 2MB, 1 мкА Тонкая литиевая мишень Li<sub>2</sub>O на алюминиевой полоске



 $Br\left({}^{8}_{4}Be^{*} \rightarrow {}^{8}_{4}Be + \gamma\right) \approx 1.5 \cdot 10^{-5}$ 



the e+e- spectrometer with five DSSD+ $\Delta E$  – E detector telescopes. The target is evaporated onto 10 µm Al strip foil spanned between 3 mm thick perspex rods to minimize the scattering and external pair creation in the vicinity of the target. The beam pipe is shown in black around which the  $\Delta E$  and the DSSD detectors are arranged. The 1 mm thick  $\Delta E$  detectors are shown in violet and red, while the E scinillators in yellow and their light guides are in blue. Распределение по углу между электроном и позитроном **θ** полезно для определения мультипольности ядерного перехода при изучении парной внутренней конверсии









Сканирование по энергии налетающих протонов и по переменной у |y|<0.5 и |y|>0.5  $T^{+} - T^{-}$ = $\frac{}{T^+ + T^-}$ Т – Кин. Энергии

электрона и позитрона

Отклонение наблюдается при энергии протонов, необходимой для резонансного возбуждения уровня, и при близости энергий электронов и позитронов |y|<0.5 Переход между уровнями ядра с испусканием массивной частицы, распадающейся на два лептона. Масса

$$m_{ee}^2 \approx (1-y^2)E^2sin^2rac{\sigma}{2}$$

$$E = T^+ + T^- + 2m_e$$





#### РЕЗУЛЬТАТЫ 2016 года с модернизированным детектором





# Воспроизведен результат для уровня 18.15 МэВ и проявился тот же эффект при распаде уровня 17.64 МэВ



С учетом двух переходов масса сдвигается ближе к 17 Мэв Обнаруженный эффект до настоящего времени не удалось объяснить в рамках стандартной ядерной физики

# Выход за рамки стандартной модели – новый легкий БОЗОН с массой 17 МэВ

### • не скаляр

 Псевдоскаляр, аксиальный вектор и вектор не запрещены симметриями.

Псевдоскаляр ограничен экспериментально поисками АКСИОНА. *f<sub>a</sub>*[GeV]



 Аксиальный вектор – трудно интерпретировать сложность ядерных расчетов

Изоскалярный переход. Взаимодействие с векторным током

$$J_{\mu} = \frac{1}{2} e \varepsilon \overline{N} \gamma_{\mu} N + \dots \qquad \varepsilon = \varepsilon_{p} + \varepsilon_{n}$$

$$\frac{Br({}^8_4Be^* \rightarrow {}^8_4Be + X) \cdot Br(X \rightarrow e^+e^-)}{Br({}^8_4Be^* \rightarrow {}^8_4Be + \gamma)} \approx 5.8 \cdot 10^{-6}$$

 $Br(X \rightarrow e^+e^-) = 1$  Пренебрегаем v и ү

В первом приближении ядерный матричный элемент сокращается в отношении ширин

$$\frac{\Gamma(Be^* \to BeX)}{\Gamma(Be^* \to Be\gamma)} \approx (\varepsilon_p + \varepsilon_n)^2 \left| \frac{p_X}{p_\gamma} \right|^3 \approx 5.8 \cdot 10^{-6}$$
Заряд в единицах е  $\varepsilon \approx |\varepsilon_p + \varepsilon_n| \approx 0.011$ 

Связь Х с электронами

$$\Gamma(X \rightarrow e^+e^-) \approx \varepsilon_e^2 \alpha \frac{m_X^2 + 2m_e^2}{3m_X} \sqrt{1 - \frac{4m_e^2}{m_X^2}}$$

Распад в детекторе на длине несколько сантиметров. Для описания наблюдаемого эффекта

 $|\varepsilon_e| \ge (1\div 2)\cdot 10^{-5}$ 

## темный фотон

- Существующие ограничения:
- NA48/2 распад  $\pi^0 \rightarrow \gamma A \rightarrow \gamma e^+ e^-$
- Рассеяние электронов
   (beam dump & pair spectrometer)
   E141, A1, APEX







Аннигиляция: BABAR, KLOE





исключен экспериментом NA48

В более общем случае легкого (масса 17 МэВ) калибровочного векторного бозона, не связанного с электромагнитными зарядами, можно оценить константы связи из Ве и из NA48 через аномалию. Тогда

> $\varepsilon_u + \varepsilon_d \approx 0.004$   $2\varepsilon_u + \varepsilon_d \approx 0.0008$  $\varepsilon_p \approx 0.0008$   $\varepsilon_n \approx 0.01$

**Protophobic vector boson (Feng et al)** 

## ПЕРСПЕКТИВЫ



MESA: eA->eA2e - 2020 VEPP3: e+e- -> gamma A' Darklight: ep-> epe+e- 2020 HPS : eA-> eAe+e- 2020 MU3e: \mu ->3e 2019-2020 • Если возможность существования бозона с массой 17 МэВ в любом варианте теории будет исключена



экспериментально, как объяснить результат АТОМКІ?

 Поскольку 6.8 о аргумент серьезный, либо необходим аналогичный эксперимент, либо указания на ошибки в эксперименте ATOMKI