Isidor Isaac Rabi, Nobel-prize winning Hungarian-American physicist,

on the discovery of the muon (1934)

“Who ordered that?”

Enrico Fermi, Nobel-prize winning
Italian-American physicist

“If I could remember the names
of all these particles, I'd be a botanist. ”

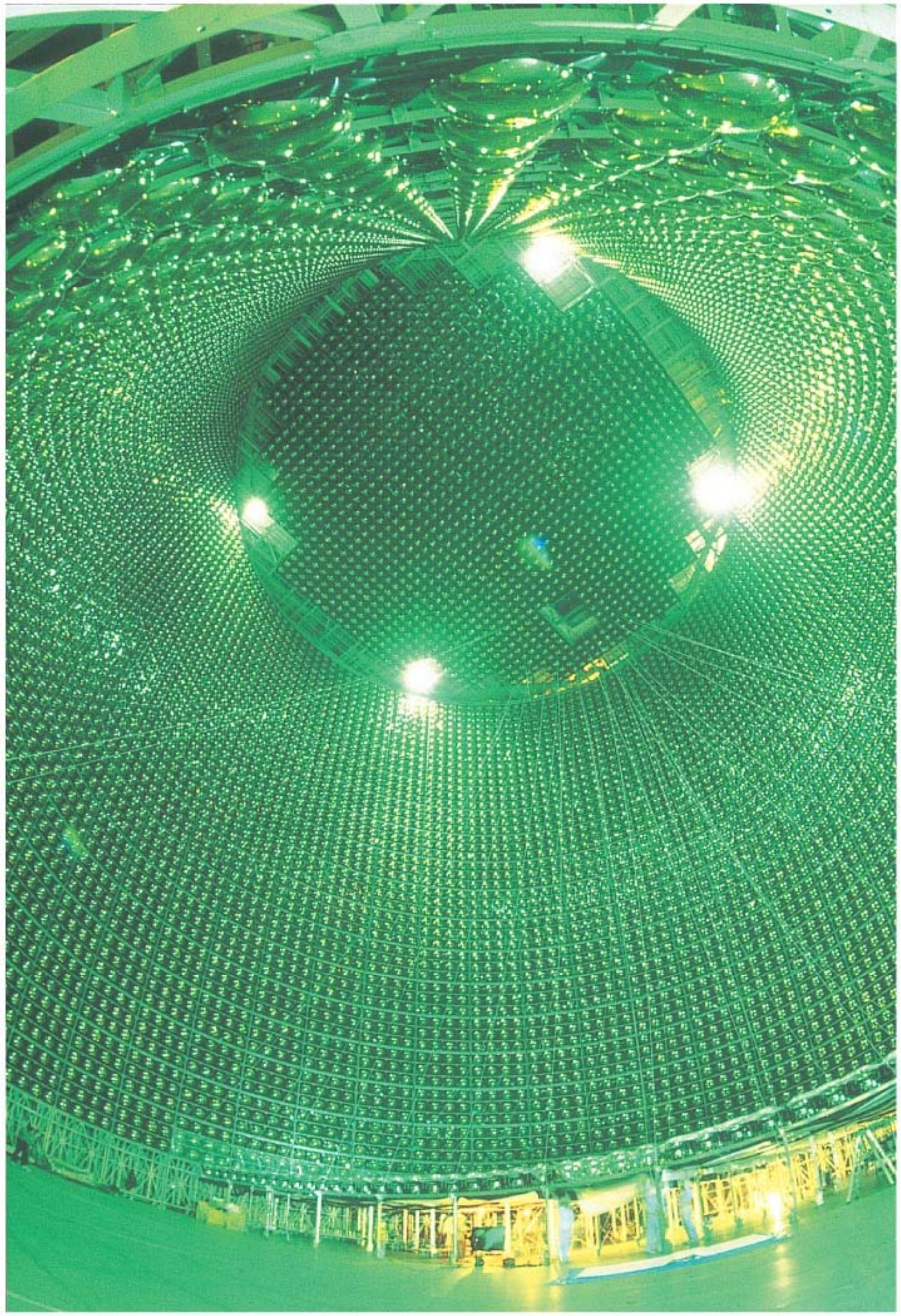


Table 44.2 The Six Leptons

Particle Name	Symbol	Antiparticle	Mass (MeV/c^2)	L_e	L_μ	L_τ	Lifetime (s)	Principal Decay Modes
Electron	e^-	e^+	0.511	+1	0	0	Stable	
Electron neutrino	ν_e	$\overline{\nu}_e$	$<3 \times 10^{-6}$	+1	0	0	Stable	
Muon	μ^-	μ^+	105.7	0	+1	0	2.20×10^{-6}	$e^- \overline{\nu}_e \nu_\mu$
Muon neutrino	ν_μ	$\overline{\nu}_\mu$	<0.19	0	+1	0	Stable	
Tau	τ^-	τ^+	1777	0	0	+1	2.9×10^{-13}	$\mu^- \overline{\nu}_\mu \nu_\tau$ or $e^- \overline{\nu}_e \nu_\tau$
Tau neutrino	ν_τ	$\overline{\nu}_\tau$	<18.2	0	0	+1	Stable	

Q41.4

Which of the following reactions obey the principle of conservation of lepton numbers?

1. $\pi^- \rightarrow \mu^- + \nu_\mu$bar
2. π^0 -> $\mu^- + e^+ + \nu_e$

A. 1 and not 2

B. 2 and not 1

C. Both

D. Neither

Table 44.3 Some Hadrons and Their Properties

Particle	Mass (MeV/c^2)	Charge Ratio, Q/e	Spin	Baryon Number, B	Strangeness, S	Mean Lifetime (s)	Typical Decay Modes
Mesons							
π^0	135.0	0	0	0	0	8.4×10^{-17}	$\gamma\gamma$
π^+	139.6	+1	0	0	0	2.60×10^{-8}	$\mu^+\nu_\mu$
π^-	139.6	−1	0	0	0	2.60×10^{-8}	$\mu^-\overline{\nu}_\mu$
K^+	493.7	+1	0	0	+1	1.24×10^{-8}	$\mu^+\nu_\mu$
K^-	493.7	−1	0	0	−1	1.24×10^{-8}	$\mu^-\overline{\nu}_\mu$
η^0	547.3	0	0	0	0	$\approx 10^{-18}$	$\gamma\gamma$
Baryons							
p	938.3	+1	$\frac{1}{2}$	1	0	Stable	—
n	939.6	0	$\frac{1}{2}$	1	0	886	$pe^-\overline{\nu}_e$
Λ^0	1116	0	$\frac{1}{2}$	1	−1	2.63×10^{-10}	$p\pi^-$ or $n\pi^0$
Σ^+	1189	+1	$\frac{1}{2}$	1	−1	8.02×10^{-11}	$p\pi^0$ or $n\pi^+$
Σ^0	1193	0	$\frac{1}{2}$	1	−1	7.4×10^{-20}	$\Lambda^0\gamma$
Σ^-	1197	−1	$\frac{1}{2}$	1	−1	1.48×10^{-10}	$n\pi^-$
Ξ^0	1315	0	$\frac{1}{2}$	1	−2	2.90×10^{-10}	$\Lambda^0\pi^0$
Ξ^-	1321	−1	$\frac{1}{2}$	1	−2	1.64×10^{-10}	$\Lambda^0\pi^-$
Δ^{++}	1232	+2	$\frac{3}{2}$	1	0	$\approx 10^{-23}$	$p\pi^+$
Ω^-	1672	−1	$\frac{3}{2}$	1	−3	8.2×10^{-11}	Λ^0K^-
Λ_c^+	2285	+1	$\frac{1}{2}$	1	0	2.0×10^{-13}	$pK^-\pi^+$

Q41.4

Which of the following reactions obey the principle of conservation of baryon number?

1. n + p -> n + p + p + pbar
2. n + p -> n + p + pbar

A. 1 and not 2

B. 2 and not 1

C. Both

D. Neither

Nobel Prizewinners Gell-Mann and Richard Feynman (shown here in 1969) have been "working together separately" at Caltech since 1955.

By the time Gell-Mann introduced the Eightfold Way, more than 100 particles had been produced by bombarding atomic nuclei with the use of high-energy accelerators. No longer was the term "elementary" reserved for the proton, neutron, and electron; and physicists searched for relationships that would at least enable them to classify the particles. The hope was to produce a theoretical structure comparable with Mendeleev's periodic table of the elements. Gell-Mann's Eightfold Way theory was the greatest breakthrough in this effort. It provided a scheme for classifying subatomic particles into several families of eight or ten members each, according to such characteristics as spin, parity, and electrical charge.

When the known particles were arranged according to the scheme of the Eightfold Way, one family that should have had ten members was found to have only nine. One particle required by the theory was missing, but Gell-Mann was able to predict all of the distinguishing characteristics of the particle.

Working from Gell-Mann's predictions, a team of 33 scientists at the Brookhaven National Laboratory set out to look for the missing particle, using the 33 BeV proton accelerator. Since the particle could not be found without knowing exactly what to look for and where to look for it, the discovery of the missing particle, omega minus, by the Brookhaven team in 1964 was widely acclaimed as a striking confirmation of the Eightfold Way. Gell-Mann's theory had passed a test that could mark a turning point in particle physics.

Table 44.4 Properties of the Three Original Quarks

Symbol	Q/e	Spin	Baryon Number, B	Strange-ness, S	Charm, C	Bottom-ness, B'	Topness, T
u	$\frac{2}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	0	0	0
d	$-\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	0	0	0
s	$-\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	-1	0	0	0

Table 44.3 Some Hadrons and Their Properties

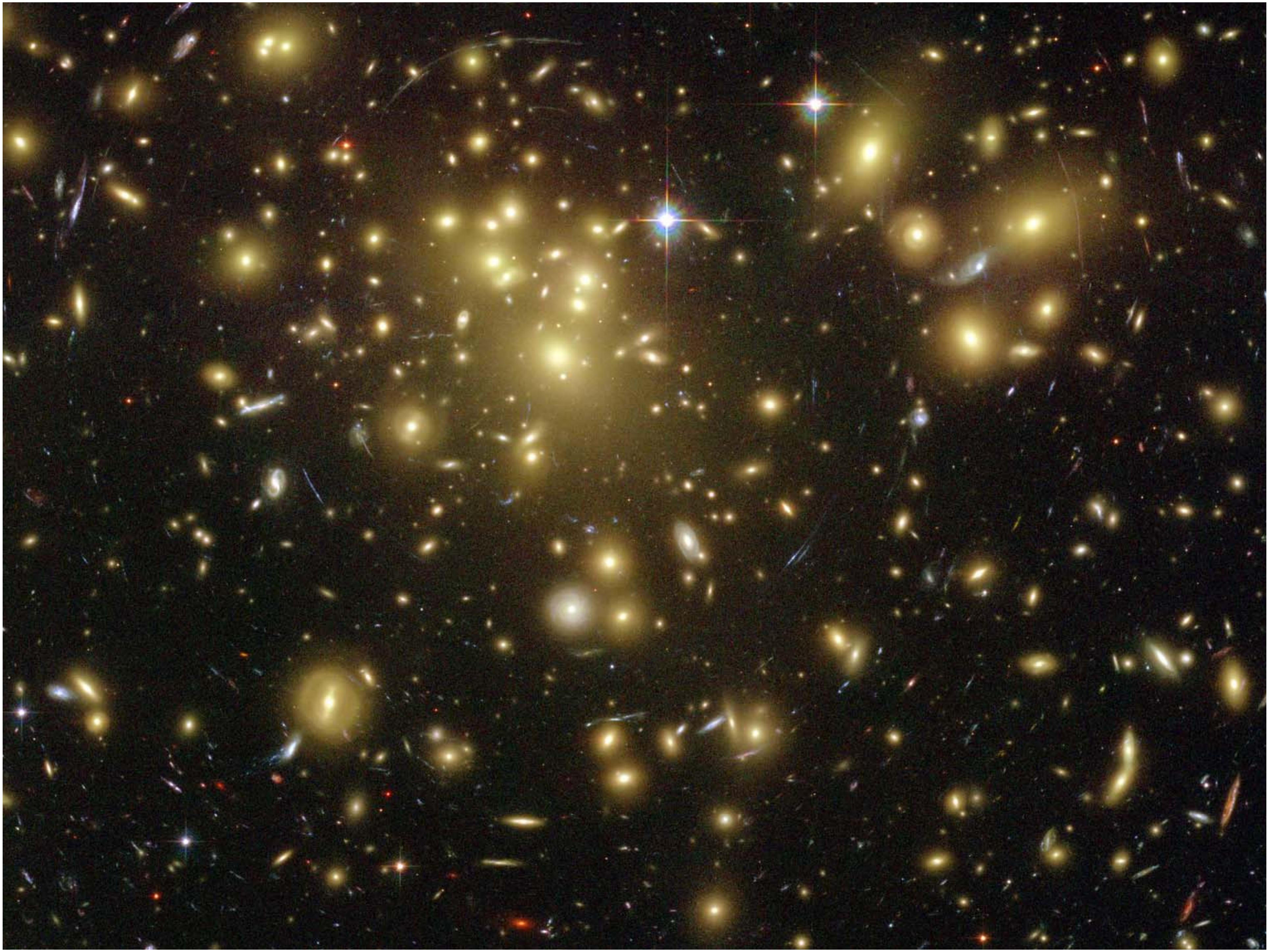
Particle	Mass (MeV/c^2)	Charge Ratio, Q/e	Spin	Baryon Number, B	Strangeness, S	Mean Lifetime (s)	Typical Decay Modes	Quark Content
Mesons								
π^0	135.0	0	0	0	0	8.4×10^{-17}	$\gamma\gamma$	$u\bar{u}$, $d\bar{d}$
π^+	139.6	+1	0	0	0	2.60×10^{-8}	$\mu^+\nu_\mu$	$u\bar{d}$
π^-	139.6	−1	0	0	0	2.60×10^{-8}	$\mu^-\bar{\nu}_\mu$	$\bar{u}d$
K^+	493.7	+1	0	0	+1	1.24×10^{-8}	$\mu^+\nu_\mu$	$u\bar{s}$
K^-	493.7	−1	0	0	−1	1.24×10^{-8}	$\mu^-\bar{\nu}_\mu$	$\bar{u}s$
η^0	547.3	0	0	0	0	$\approx 10^{-18}$	$\gamma\gamma$	$u\bar{u}$, $d\bar{d}$, $s\bar{s}$
Baryons								
p	938.3	+1	$\frac{1}{2}$	1	0	Stable	—	*uud*
n	939.6	0	$\frac{1}{2}$	1	0	886	$pe^-\bar{\nu}_e$	*udd*
Λ^0	1116	0	$\frac{1}{2}$	1	−1	2.63×10^{-10}	$p\pi^-$ or $n\pi^0$	*uds*
Σ^+	1189	+1	$\frac{1}{2}$	1	−1	8.02×10^{-11}	$p\pi^0$ or $n\pi^+$	*uus*
Σ^0	1193	0	$\frac{1}{2}$	1	−1	7.4×10^{-20}	$\Lambda^0\gamma$	*uds*
Σ^-	1197	−1	$\frac{1}{2}$	1	−1	1.48×10^{-10}	$n\pi^-$	*dds*
Ξ^0	1315	0	$\frac{1}{2}$	1	−2	2.90×10^{-10}	$\Lambda^0\pi^0$	*uss*
Ξ^-	1321	−1	$\frac{1}{2}$	1	−2	1.64×10^{-10}	$\Lambda^0\pi^-$	*dss*
Δ^{++}	1232	+2	$\frac{3}{2}$	1	0	$\approx 10^{-23}$	$p\pi^+$	*uuu*
Ω^-	1672	−1	$\frac{3}{2}$	1	−3	8.2×10^{-11}	Λ^0K^-	*sss*
Λ_c^+	2285	+1	$\frac{1}{2}$	1	0	2.0×10^{-13}	$pK^-\pi^+$	*udc*

Table 44.1 Four Fundamental Interactions

Interaction	Relative Strength	Range	Mediating Particle: Name	Mass	Charge	Spin
Strong	1	Short ($\sim$1 fm)	Gluon	0	0	1
Electromagnetic	$\frac{1}{137}$	Long ($1/r^2$)	Photon	0	0	1
Weak	10^{-9}	Short ($\sim$0.001 fm)	$W^{\pm}$, Z^0	80.4, 91.2 GeV/c^2	$\pm e$, 0	1
Gravitational	10^{-38}	Long ($1/r^2$)	Graviton	0	0	2

Table 44.5 Properties of the Six Quarks

Symbol	Q/e	Spin	Baryon Number, B	Strange-ness, S	Charm, C	Bottom-ness, B'	Topness, T
u	$\frac{2}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	0	0	0
d	$-\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	0	0	0
s	$-\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	-1	0	0	0
c	$\frac{2}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	$+1$	0	0
b	$-\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	0	$+1$	0
t	$\frac{2}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	0	0	$+1$



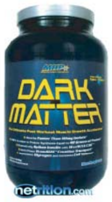
The Dark Side of Rutgers

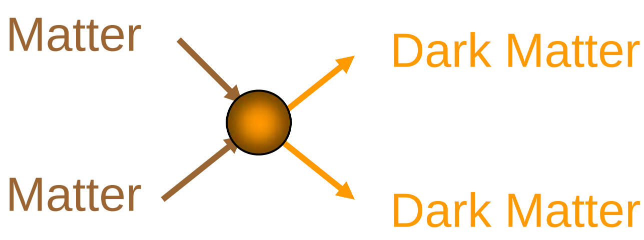
      

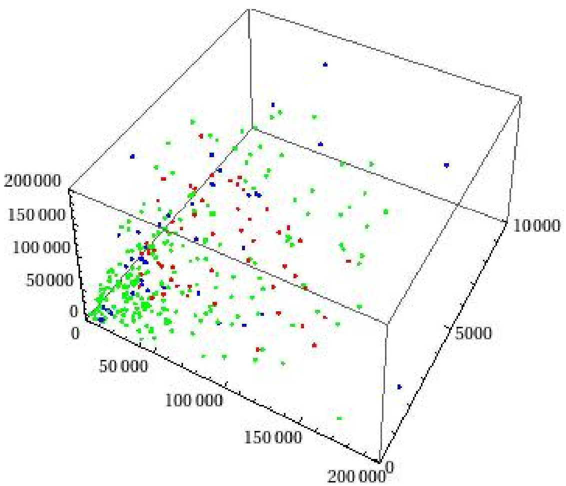
Faculty + Physicists: Chuck Keeton, Jerry Sellwood,Ted Williams, Tad Pryor, Jack Hughes, Eric Gawiser, Andrew Baker, and Saurabh Jha, Slawomir Piatek, Felipe Menanteau, Ben Dilday, Nick Bond

Students: Ross Fadely, Eve LoCastro, Michael Solway, Jean Walker, Chelsea Sharon, Curtis McCully, Brett Salmon

Rutgers Search for Dark Matter at the LHC



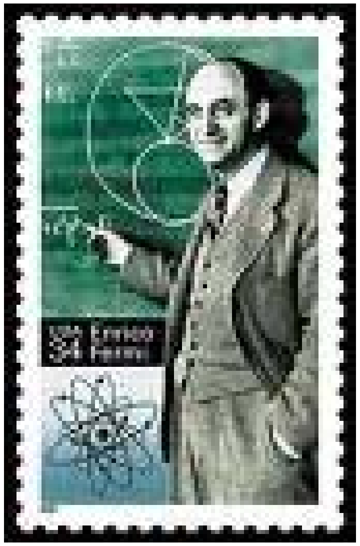




Reproduce Reactions 10^{-12} After Big Bang → Dark Matter

Extract Mass, Spin, and Couplings of Dark Matter Directly from Data

Enrico Fermi, Nobel-prize winning
Italian-American physicist,



“Before I came here I was confused about this subject. Having listened to your lecture I am still confused. But on a higher level. ”