Early Developments: Particle Physics Aspects

Claus Grupen

Siegen University

History
The golden years
Cosmic harvest of elementary particles
Interlude of accelerators
Renaissance of cosmic rays
Accelerators in the sky

History

1895 Wilhelm Conrad Röntgen

Discovery of X rays

1896 Henri Antoine Becquerel

Discovery of radioactivity

1912 Victor Franz Hess

Discovery of cosmic rays

Particles or rays?

The New York Times

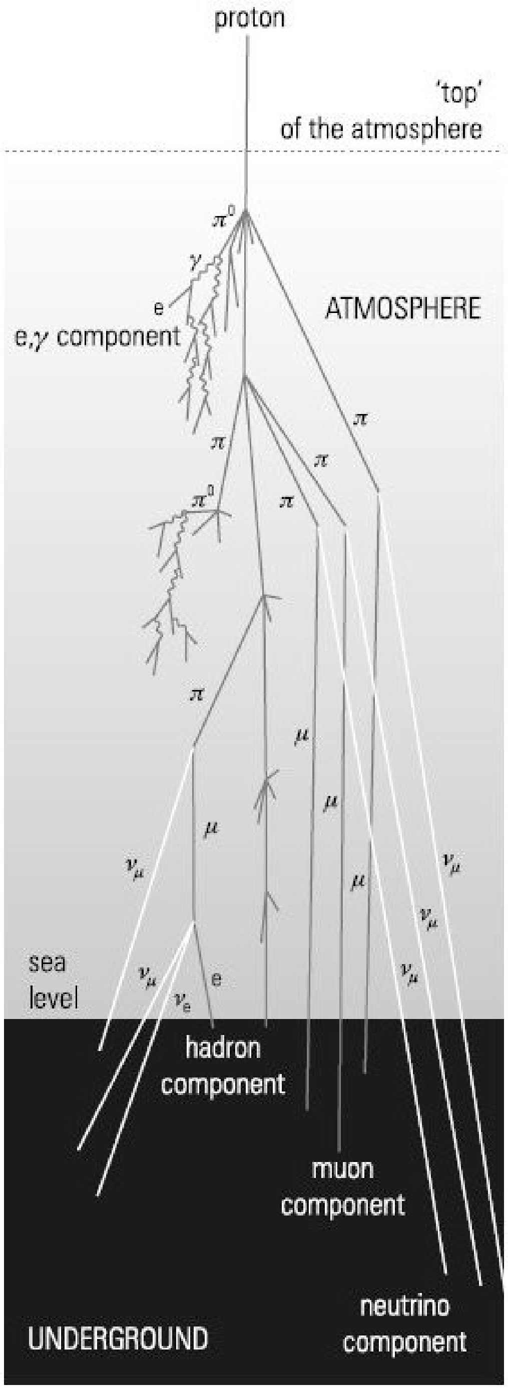
VOL. LXXXII....No. 27,370. December 31, 1932

MILLIKAN RETORTS HOTLY TO COMPTON IN COSMIC RAY CLASH

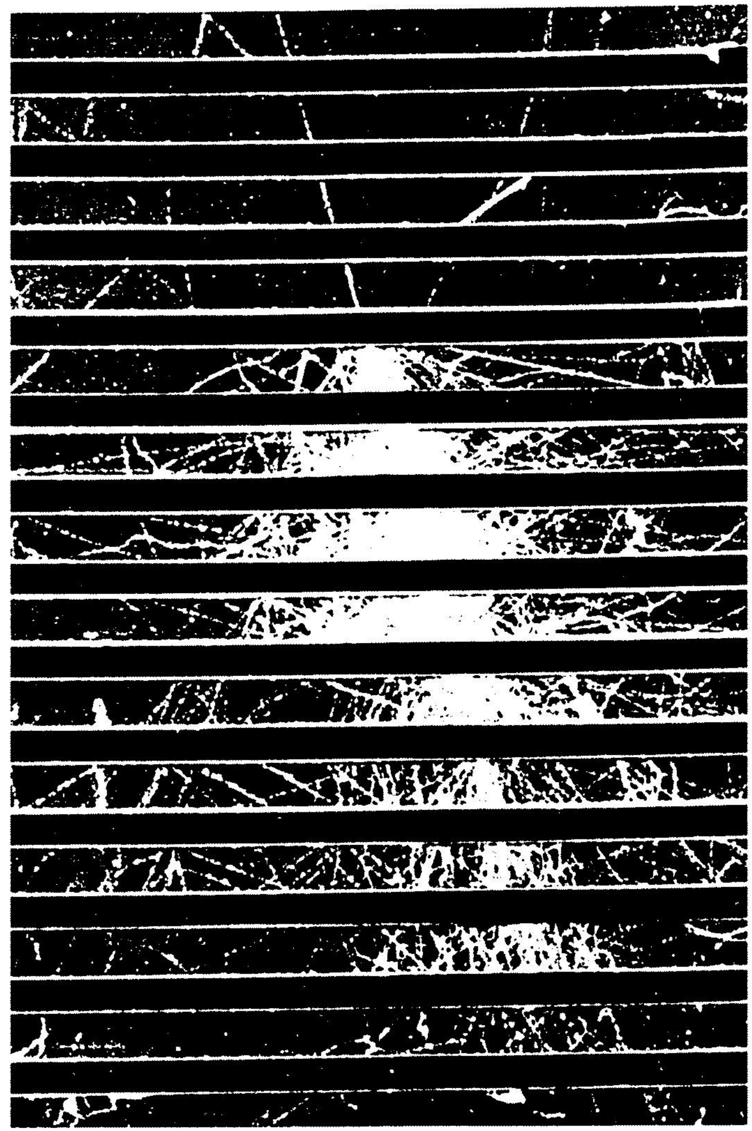
Debate of Rival Theorists Brings Drama to Session of Nation's Scientists.

THEIR DATA AT VARIANCE

New Findings of His Ex-Pupil Lead to Thrust by Millikan at 'Less Cautious' Work.



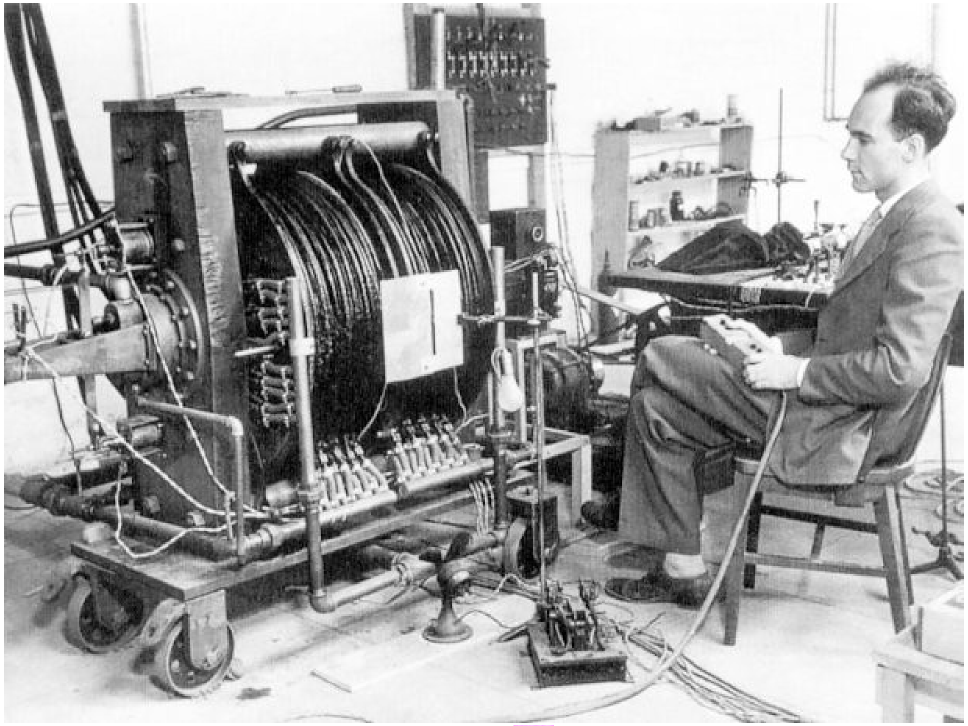
Cosmic ray induced cascade

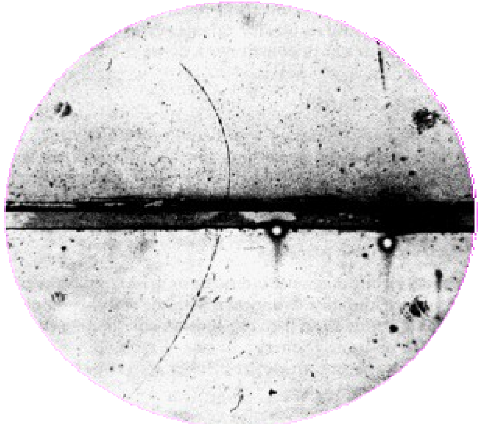


3027 m altitude; ~10 GeV proton

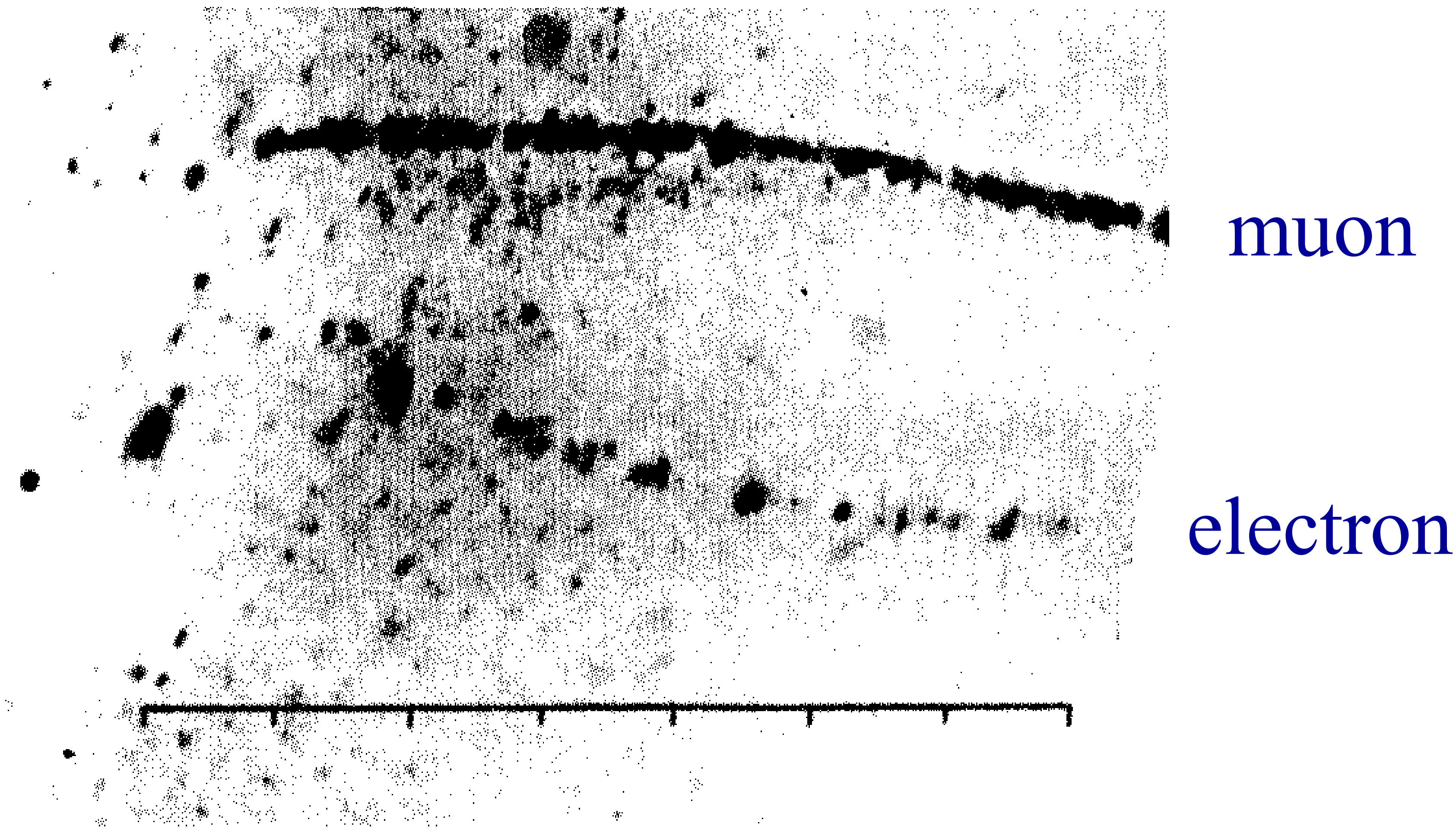
Fretter 1949

The golden years: discovery of the positron 1932

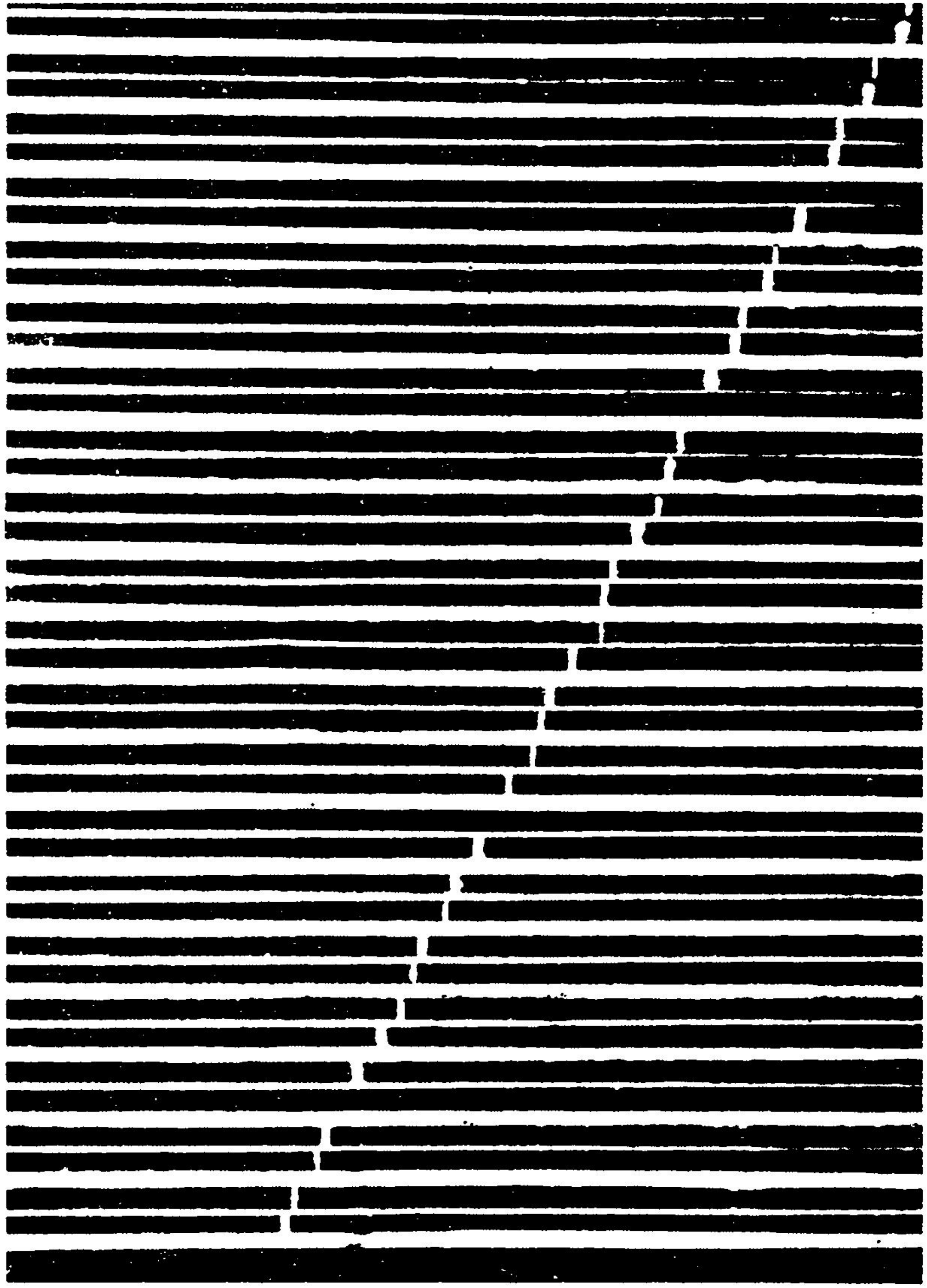




First indication of the muon by Paul Kunze in Rostock in 1932



Discovery of the muon by Anderson and Neddermeyer 1937



Muon in a multiplate spark chamber (V.S. Kaftanov 1963)

Is the mu-meson (muon) the particle postutated by Yukawa in 1935 to mediate the strong interaction?

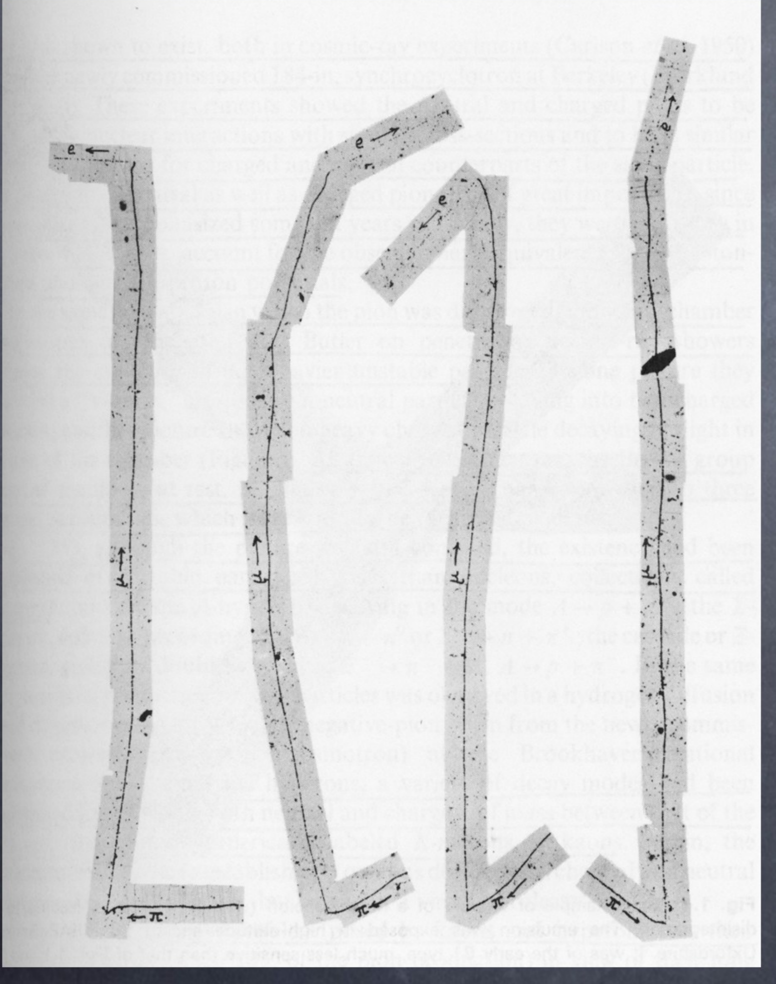
Predicted mass: about 200 times the electron mass
Expected lifetime: about 250 nanoseconds

Problem 1: the mu-meson had no strong interactions
Problem 2: the correct lifetime (corrected by L.W. Nordheim in 1939) of about 25 nanoseconds was too short for the mu-meson.

The mu-meson is not the Yukawa particle; it is a new lepton, the muon!

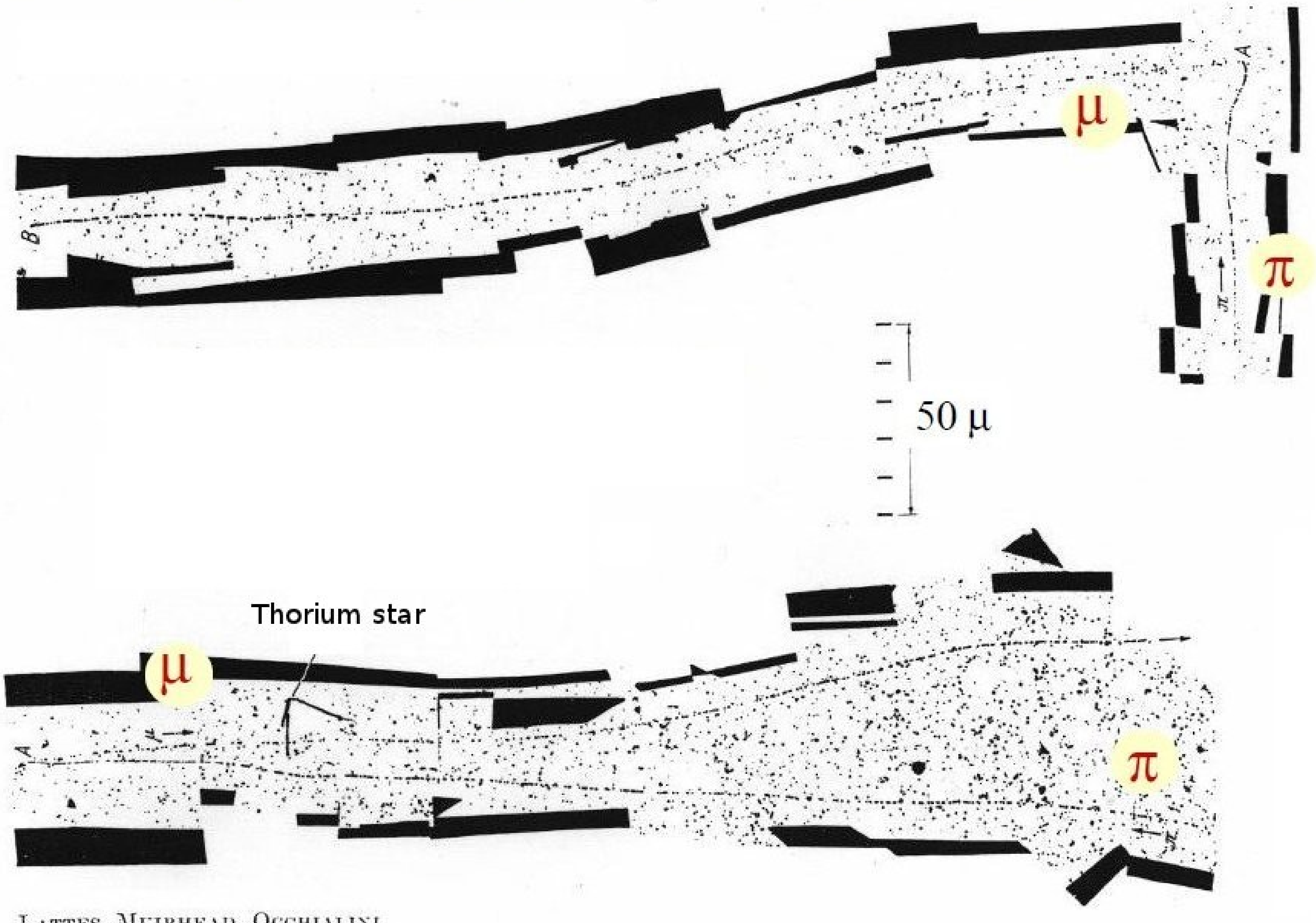
Pion discovery 1947: Perkins, Powell, Occhialini, Lattes and Muirhed

Nobel Prize 1950

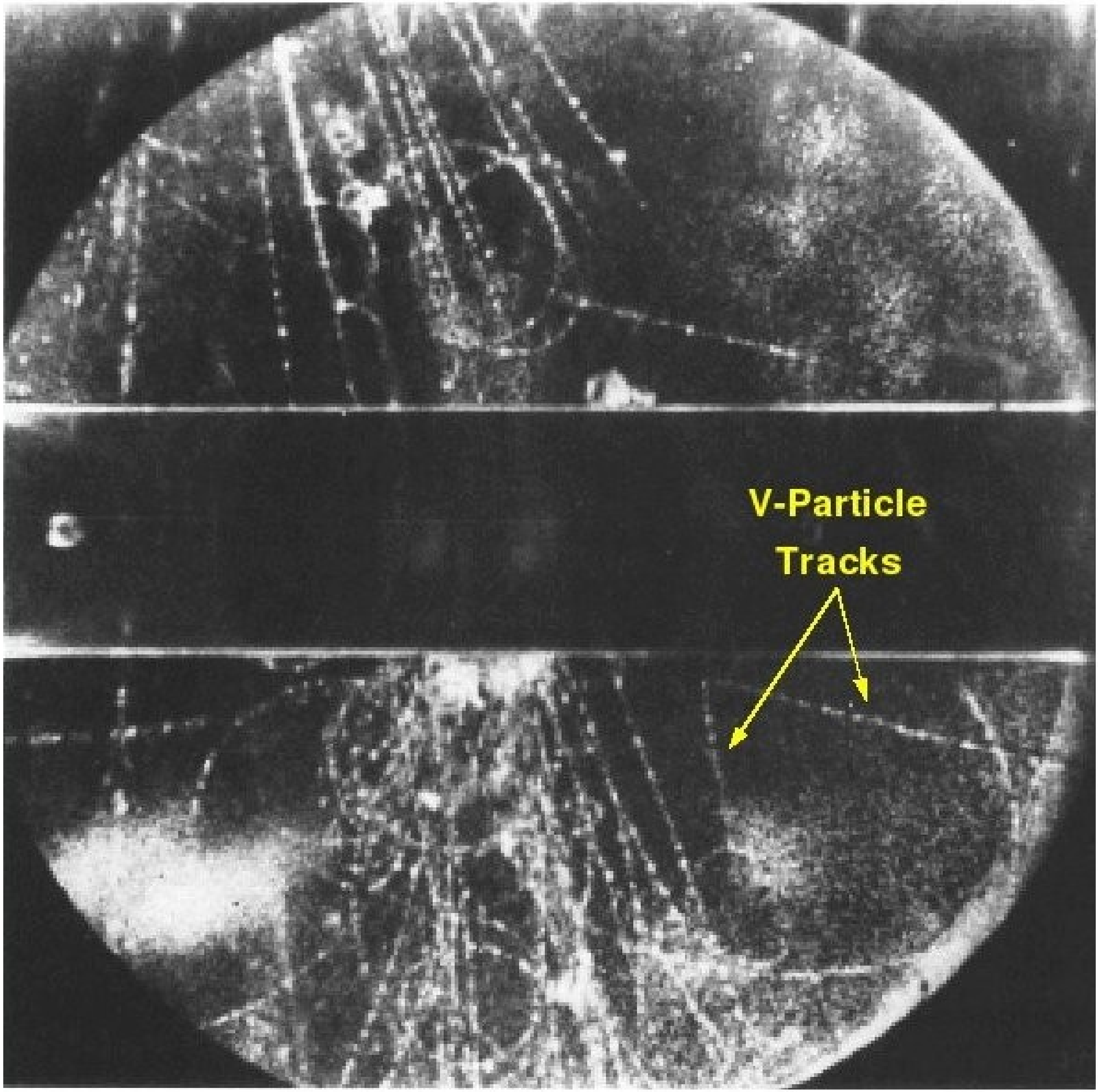


Powell

Discovery of $\pi \to \mu + \nu_\mu$ (C.F.Powell : 1947)

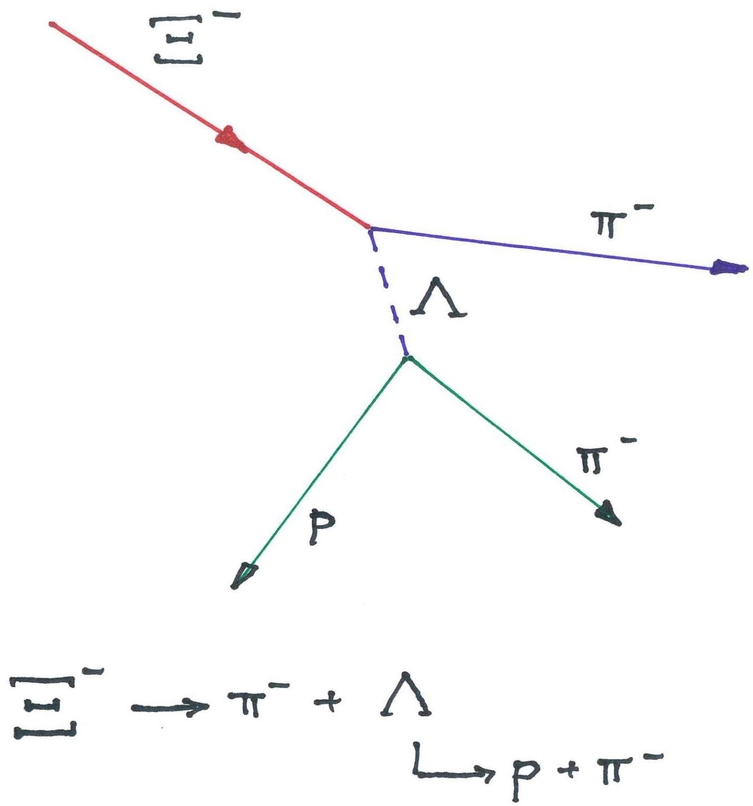


LATTES, MUIRHEAD, OCCHIALINI and POWELL; Nature 159, 694 (1947).



Neutral Kaon Discovery 1947 Rochester and Butler

Discovery of the Ξ minus



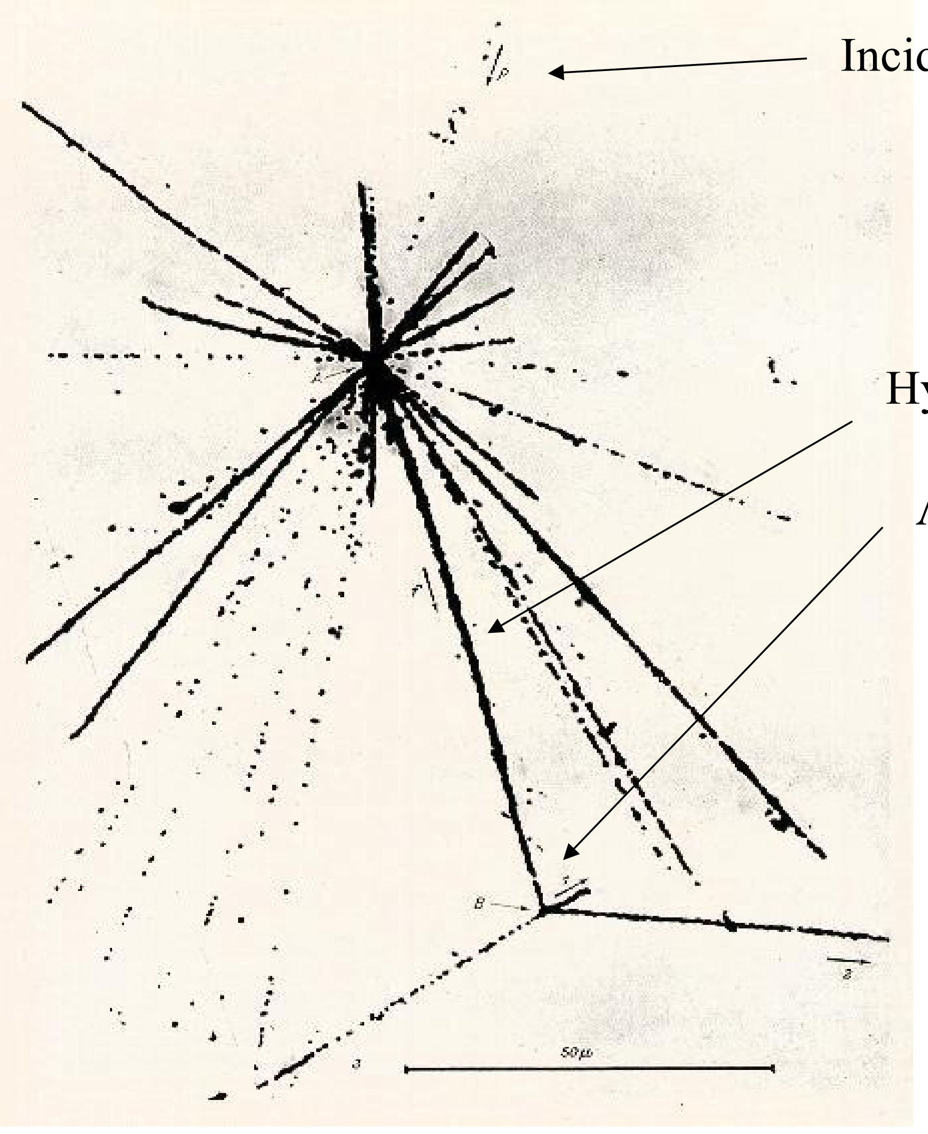
Manchester cloud chamber group;

Pic du Midi

1952

From F. Close, M. Marten and Chr. Sutton "The particle Explosion" Oxford University Press 1987

Observation of a Λ in cosmic rays



M. Danysz and J. Pniewski Phil. Mag. 44 (1953) 348

Another Lambda evidence

Armenteros, R.; Barker, K.H.; Butler, C.C.; Cachon, A.;
The Properties of Neutral V-Particles
Phil. Mag. **42** (1951) 1113;

Evidence for particles decaying into proton and pion and another V particle decaying into a pair of charged pions
in a cloud chamber at 2867 m altitude

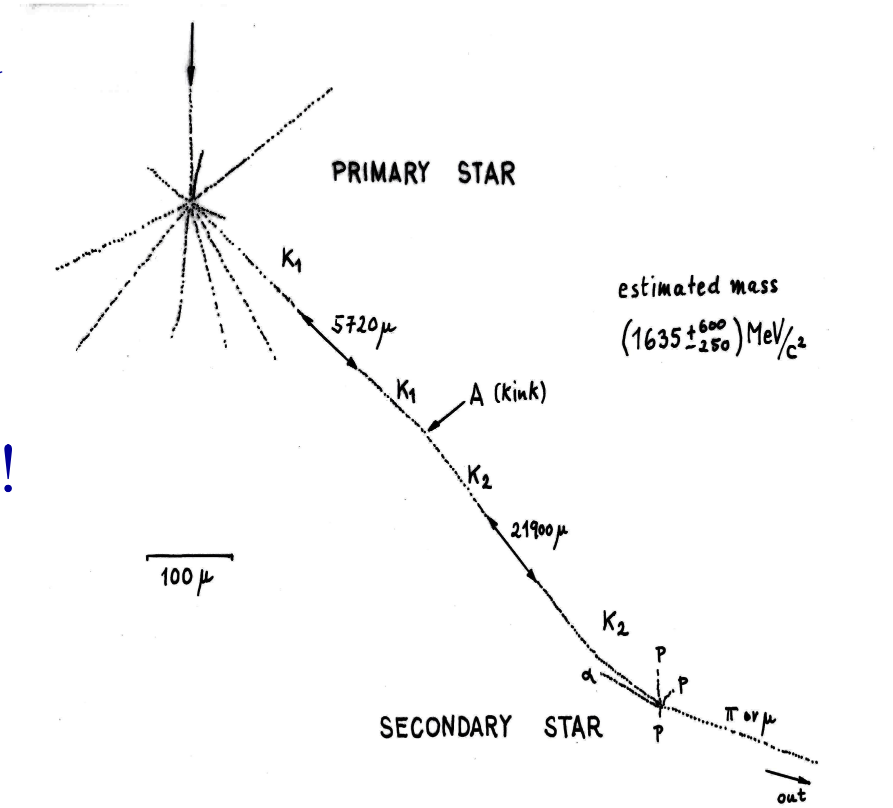
Discovery of the Σ^+

Bonetti, A.; Levi-Setti, R.; Panetti, M.; Tomasini, G.;
Observation of the Decay at Rest of a Heavy Particle
Nuovo Cim. 10 (1953) 345;

Study of decays in nuclear emulsions exposed at high altitude (Genoa and Milan group). Observation of a particle heavier than the proton.

The missing link in the quark model

It is believed that an unidentified track found in 1954 in a stack of nuclear emulsions exposed to cosmic rays at 100 000 ft altitude by Yehuda Eisenberg was the path of an Omega minus! M. Gell-Mann: “Perhaps it (the Omega minus) could explain the old Eisenberg event ...”



Y. Eisenberg; Phys. Rev. 96 (1954) 541

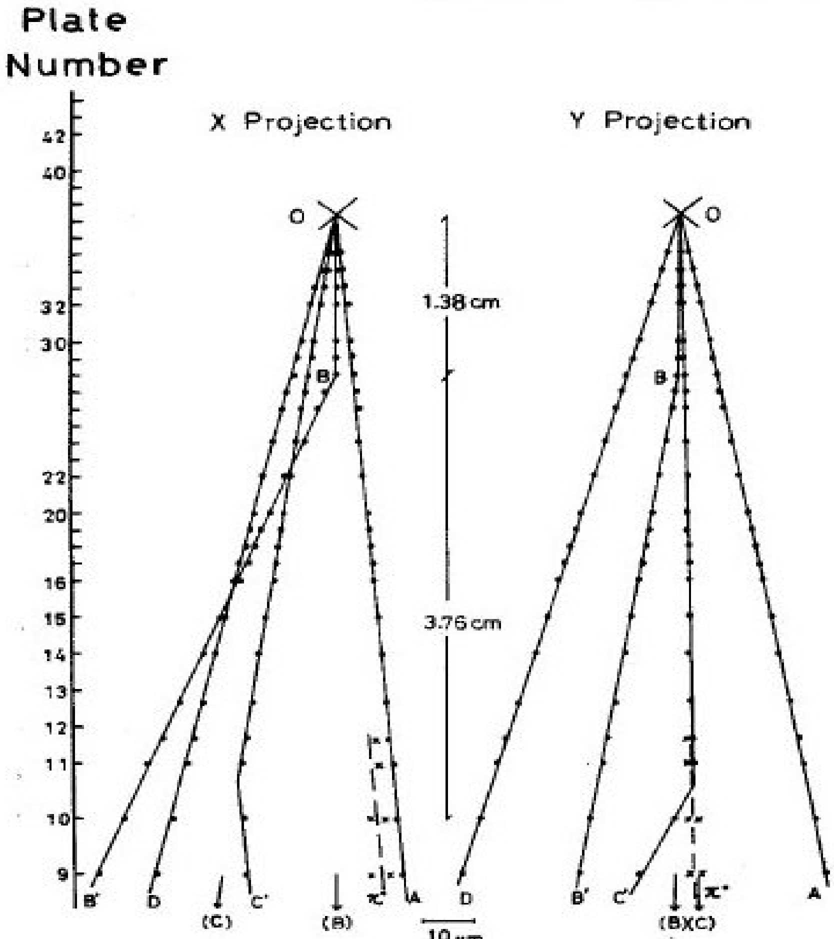
Alvarez:

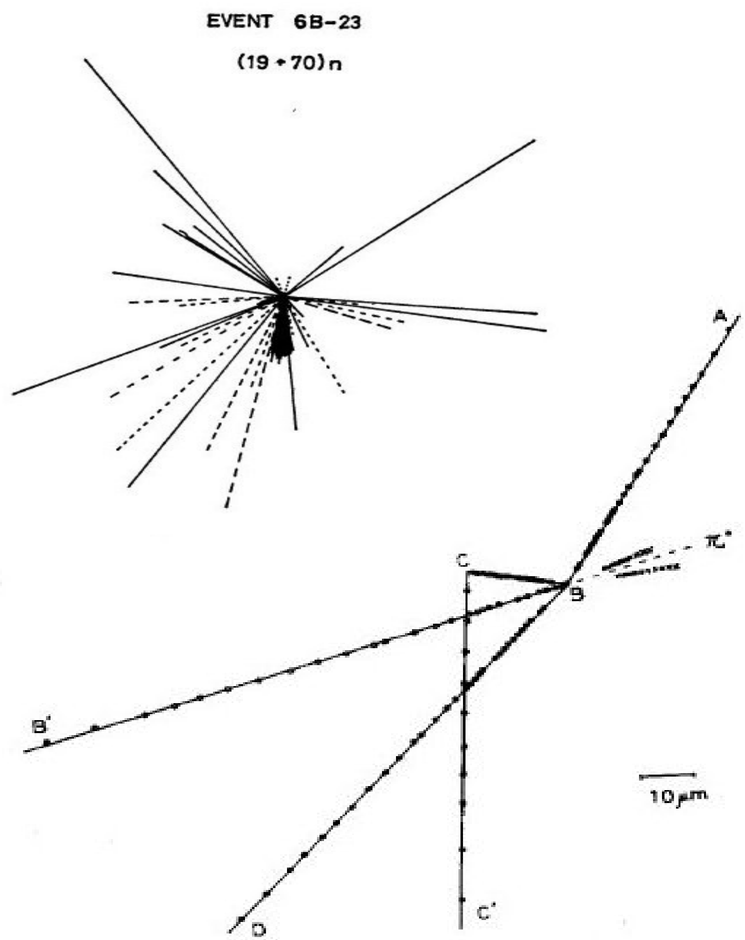
the Ω interacted with an Ag nucleus to give $K^- \, \Xi \, Ag$.

Discovery of X-particle (K.Niu : 1971)

Emulsion stack on a jet cargo air plane;
Estimated mass ~ 2 GeV; short-lived;
Two-body decay with pi-zero?

The charm ?!!





z Projection

'Discoveries' which turned out to be incorrect

APS » Journals » Phys. Rev. Lett. » Volume 23 » Issue 12

Phys. Rev. Lett. 23, 658–659 (1969)

Evidence of Quarks in Air-Shower Cores

C.B.A. McCusker and I. Cairns

… old cloud chamber tracks

Proton decay experiment in the Kolar gold fields

Krishnaswamy, M. R. ; Menon, M. G. K. ; Mondal, N. K. ; Narasimham, V. S. ; Sreekantan, B. V. ; Hayashi, Y. ; Ito, N. ; Kawakami, S. ; Miyake, S. (1983) *Proton decay experiment in the Kolar gold fields* American Institute of Physics Conference Proceedings, 96 (1). pp. 168-174. ISSN 0094-243X

mean lifetime of protons is about 8×10^{30} years.

S. Miyake et al. 1983

Poor spatial resolution, difficult reconstruction

'Discovery' of the Centauro?

Y. Fujimoto et al. (Brazil-Japan Collaboration) 1972
… many charged hadrons but virtually no neutrals ...

Phys. Rev. D 68, 052007 (2003) [5 pages]

Solution to the Centauro puzzle

V. Kopenkin, Y. Fujimoto and T. Sinci

… instrumental effect; poor alignment of the upper and lower emulsion chamber

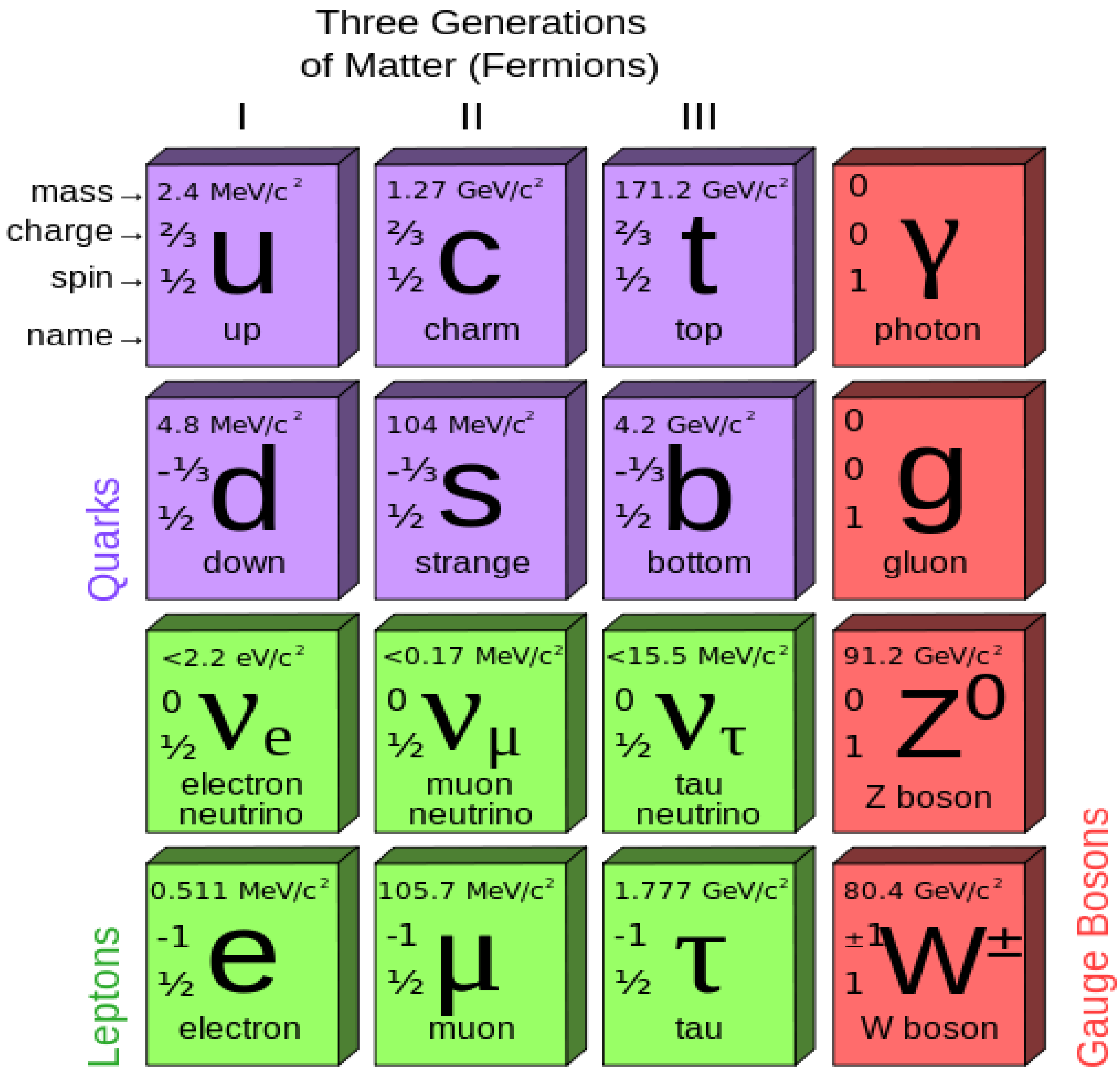
Accelerators and Storage Rings take over

Electron neutrino:
Cowan and Reines 1956

Muon neutrino :
Lederman, Schwartz, Steinberger 1962

Tau and Tau neutrino
Perl 1975

Gluon, DESY 1979 …. to name a few

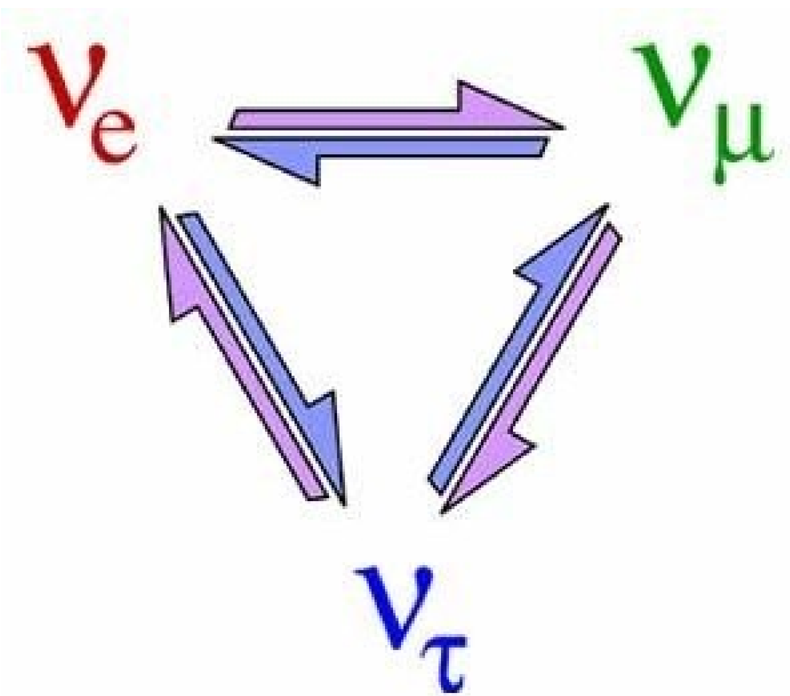

Three Generations
of Matter (Fermions)
I
II
III
mass →
charge →
spin →
name →
2.4 MeV/c²
⅔
½
u
up
1.27 GeV/c²
⅔
½
c
charm
171.2 GeV/c²
⅔
½
t
top
0
0
1
γ
photon
Quarks
4.8 MeV/c²
-⅓
½
d
down
104 MeV/c²
-⅓
½
s
strange
4.2 GeV/c²
-⅓
½
b
bottom
0
0
1
g
gluon
<2.2 eV/c²
0
½
νe
electron
neutrino
<0.17 MeV/c²
0
½
νμ
muon
neutrino
<15.5 MeV/c²
0
½
ντ
tau
neutrino
91.2 GeV/c²
0
1
Z0
Z boson
Leptons
0.511 MeV/c²
-1
½
e
electron
105.7 MeV/c²
-1
½
μ
muon
1.777 GeV/c²
-1
½
τ
tau
80.4 GeV/c²
±1
1
W±
W boson
Gauge Bosons

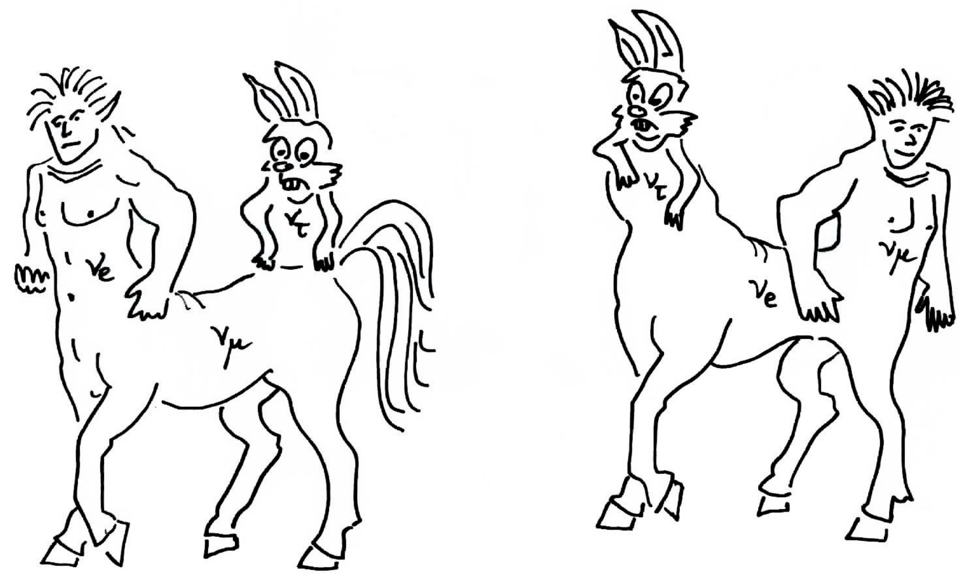
Renaissance of Cosmic Rays

Ray Davis jun.

from 1967

Neutrino-Oscillations





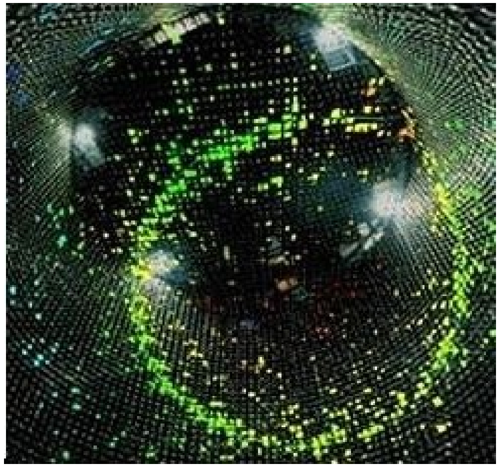
animalistic oscillations

Dependent on the mixing angle and the difference of the masses squared

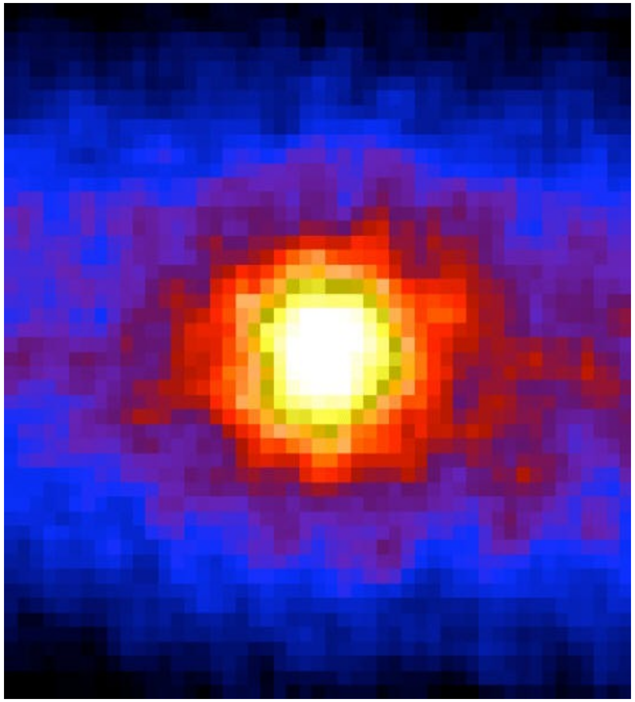
Super-Kamiokande Experiment

Masatoshi Koshiba

Cherenkov-Ring



Sun in the light of neutrinos



Supernova 1987 A

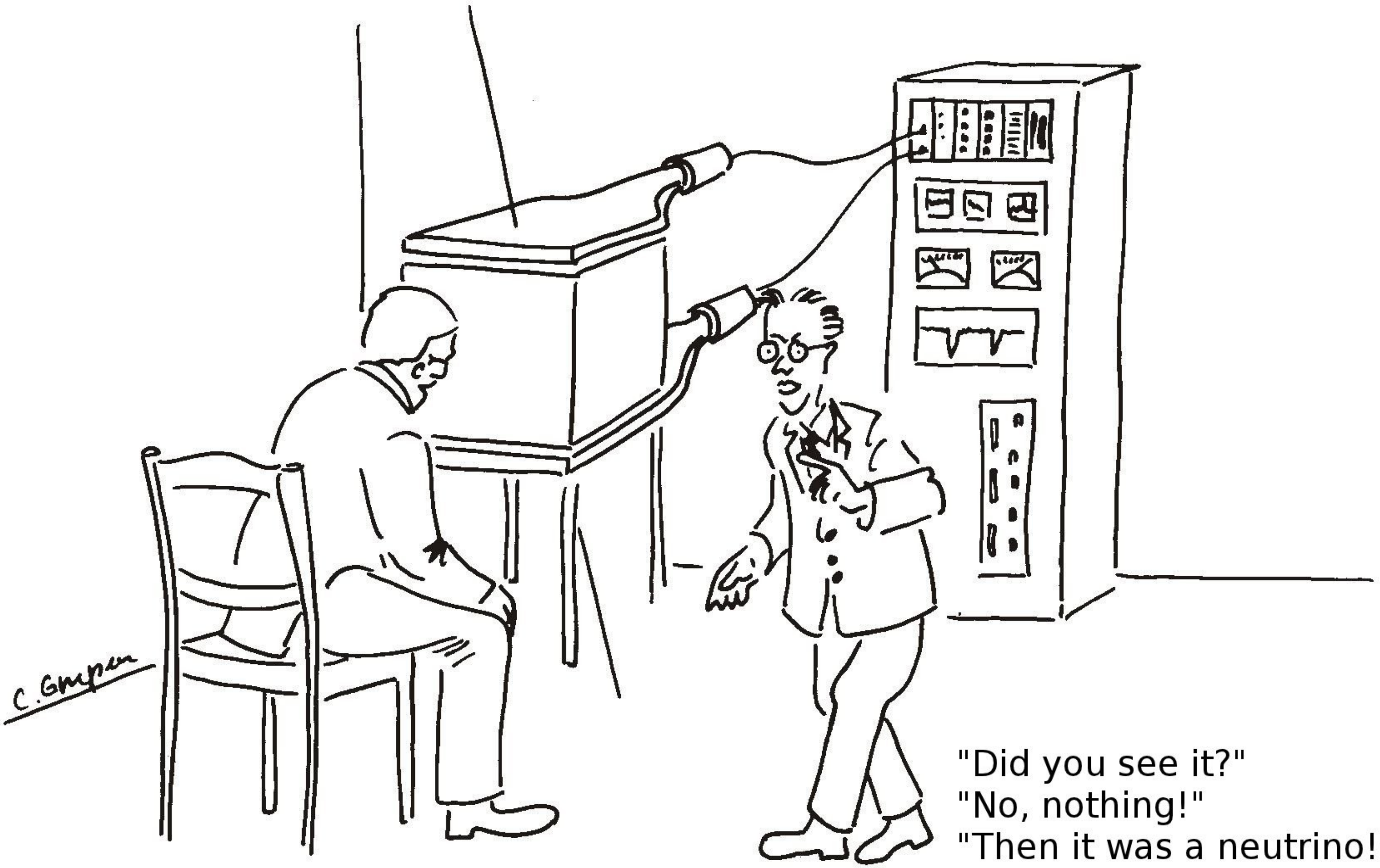
Supernova 1987 A

Supernova-Explosion
in the Large Magellanic Cloud
Distance 170 000 light years

energy output 6×10^{46} Joule
(energy consumption 10^{21} Joule per year
for the whole world)

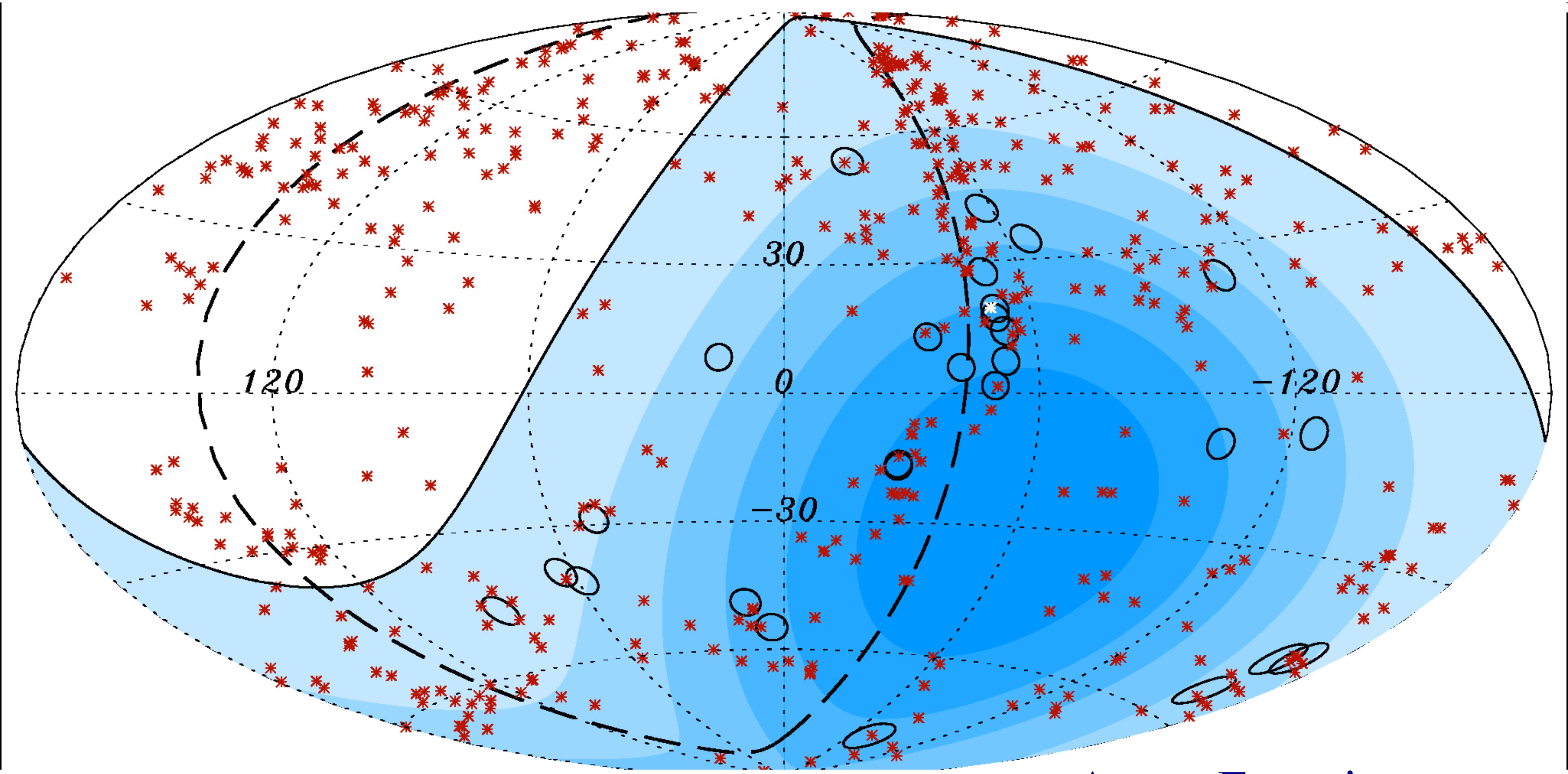
10^{58} neutrinos, only 19 measured in IMB and Kamiokande

Problems to measure neutrinos



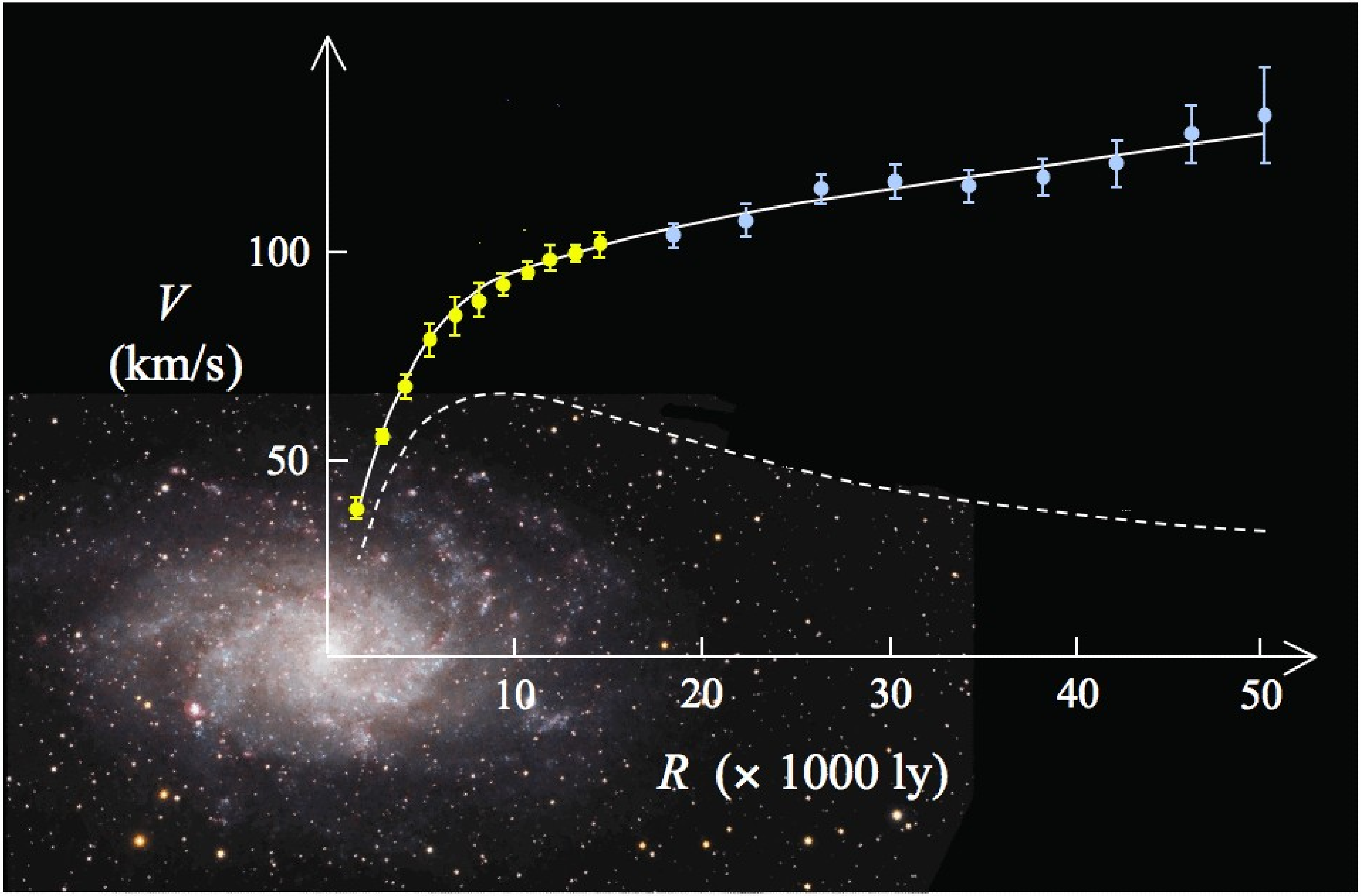
Origin of Cosmic rays?

Where are the sources?



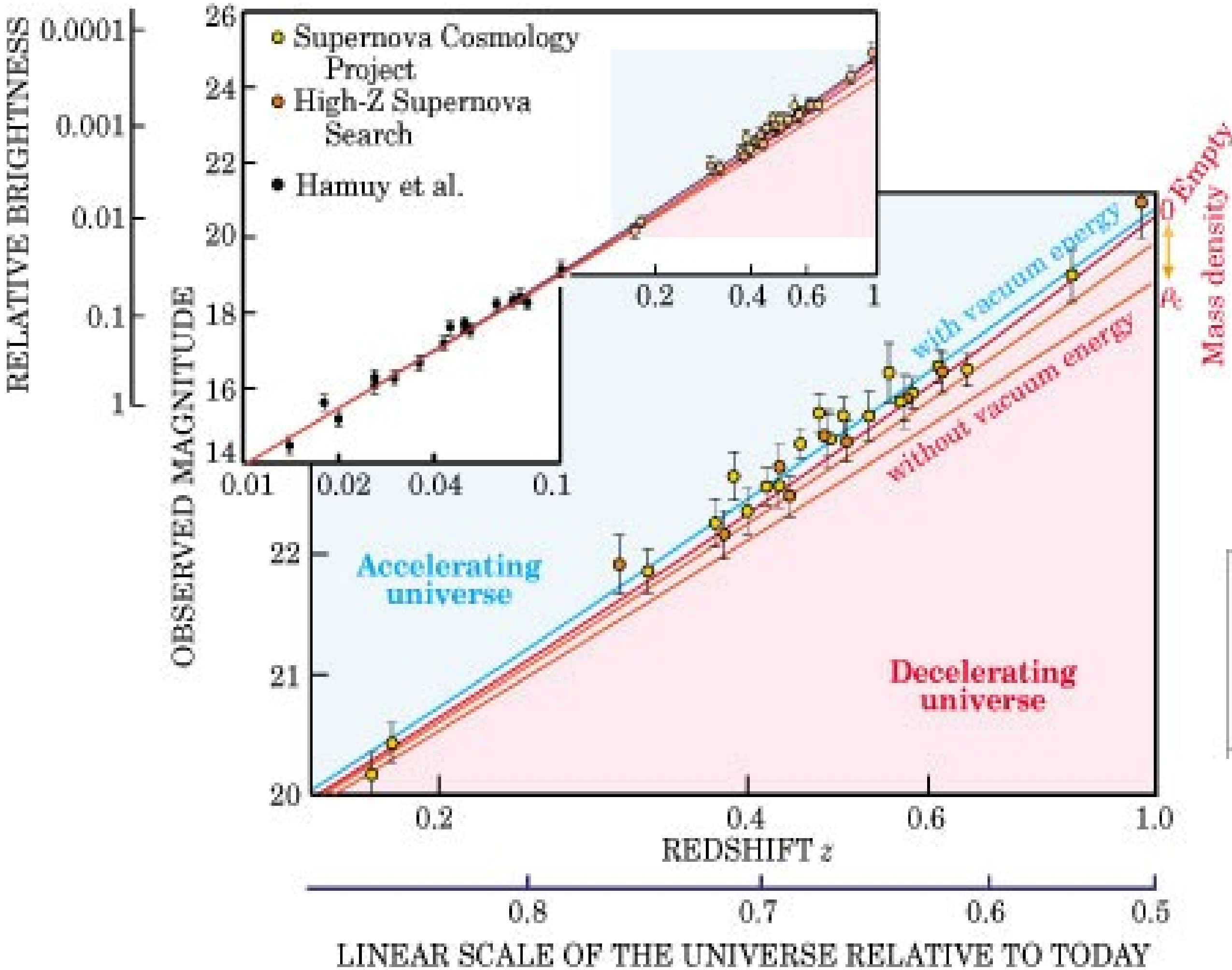
Auger Experiment

Evidence for dark matter



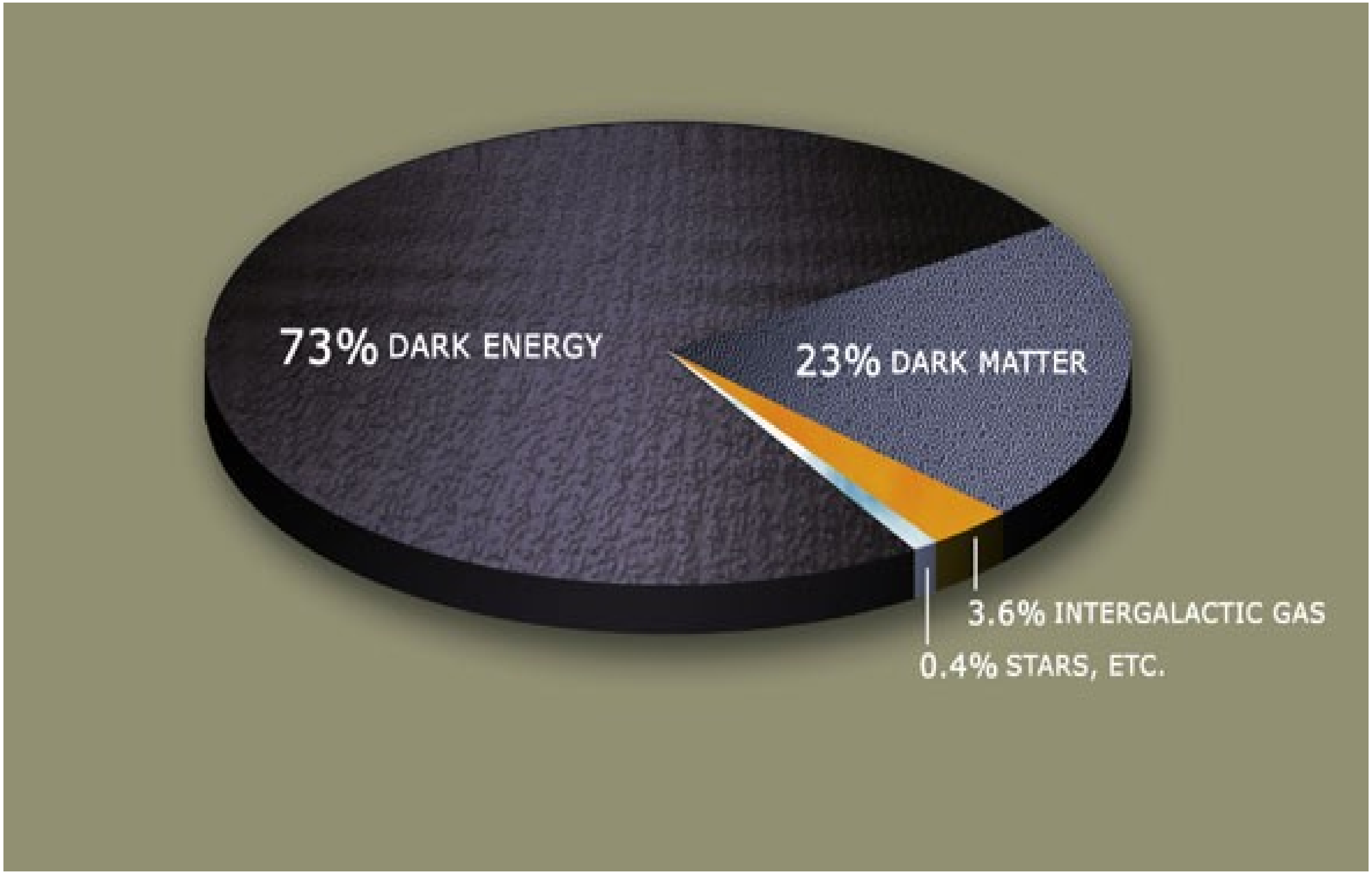
M33

Dark matter, dark energy



$$z = \frac{\lambda_{obsv} - \lambda_{emit}}{\lambda_{emit}}$$

What makes up the Universe?



Outlook

Cosmic rays is the birthplace of elementary particles

Since 1987 we experience a Renaissance of cosmic rays:

Neutrino astronomy
Gamma-ray astronomy
Particle astronomy at the highest energies
Gravitational wave astronomy (to come)

The highest energies provided by Nature
will never be reached at accelerators

Cosmic rays will continue to be a lab without competition