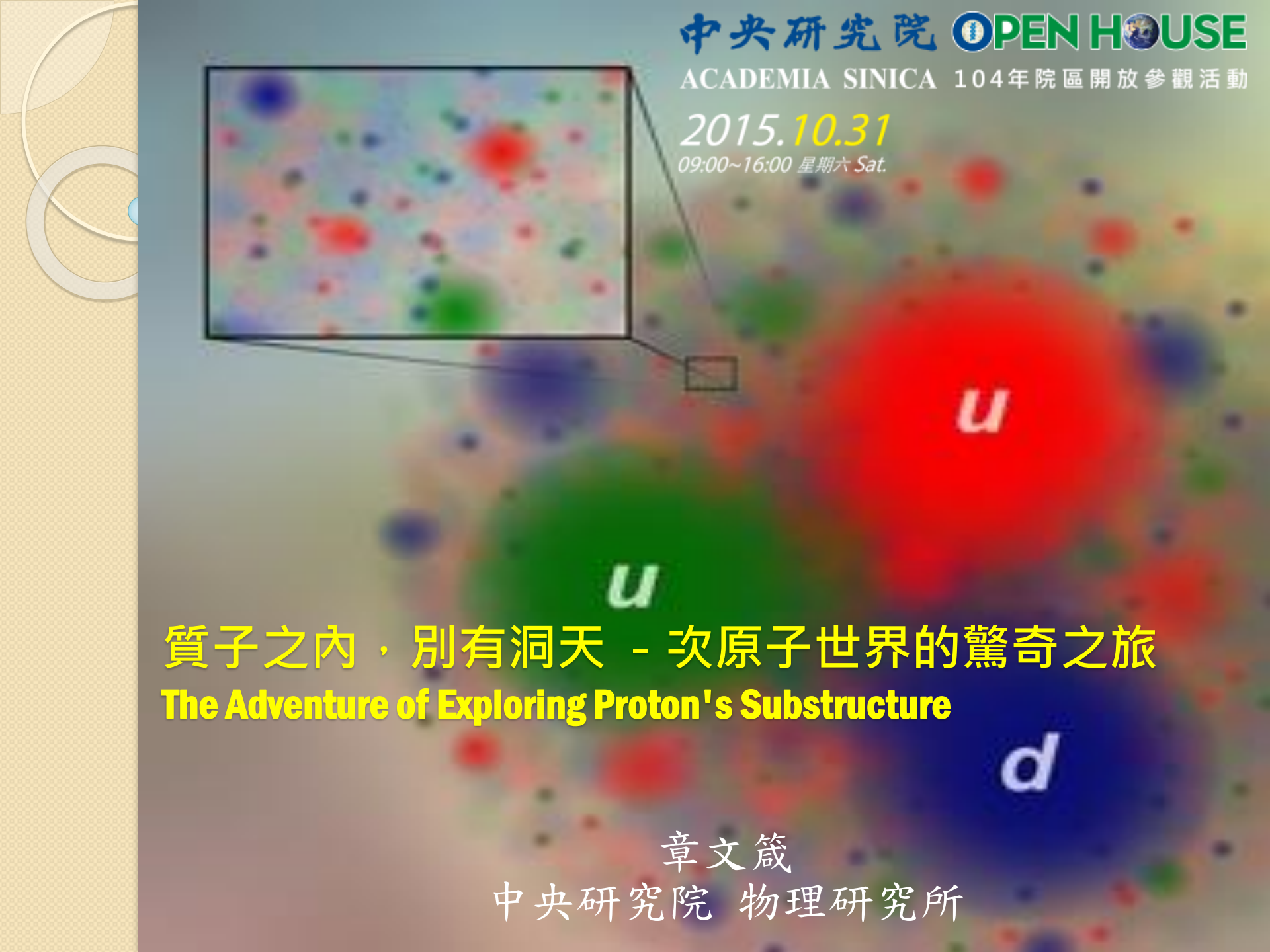


質子之內，別有洞天 - 次原子世界的驚奇之旅

The Adventure of Exploring Proton's Substructure

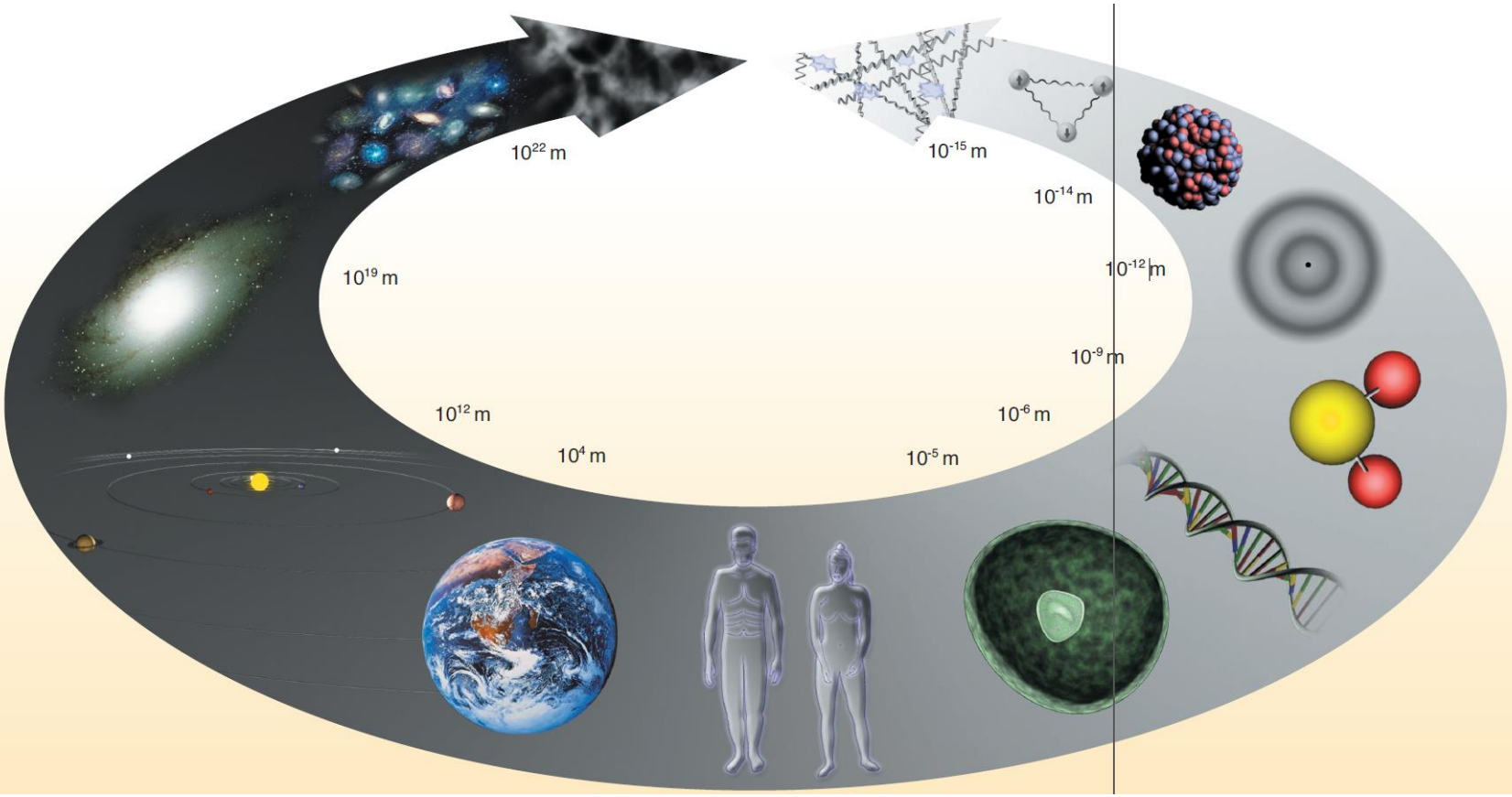
章文箴
中央研究院 物理研究所

物理（大英百科全書）

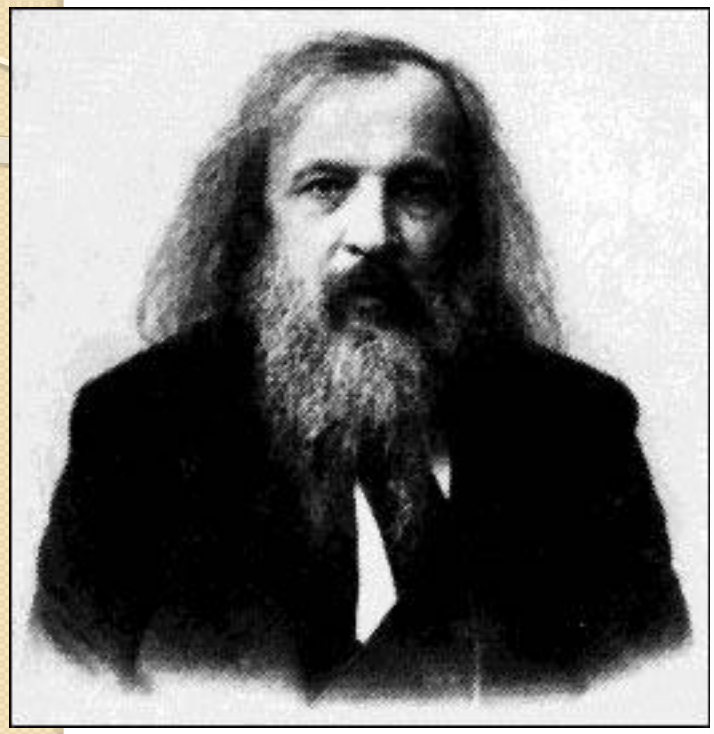
- 探討物質結構，和可觀察宇宙基本成分及其作用方式的科學。
  (science that deals with the structure of matter and the interactions between the fundamental constituents of the observable universe.)

物理學探討模式

- 「化約論」：構成粒子、作用方式



門得列夫（Dmitri Mendeleev）：元素週期表 (1860)



PERIODIC SYSTEM OF THE ELEMENTS IN GROUPS AND SERIES.

Series	GROUPS OF ELEMENTS								
	0	I	II	III	IV	V	VI	VII	VIII
1	—	Hydrogen H 1·008	—	—	—	—	—	—	
2	Helium He 4·0	Lithium Li 7·03	Beryllium Be 9·1	Boron B 11·0	Carbon C 12·0	Nitrogen N 14·04	Oxygen O 16·00	Fluorine F 19·0	
3	Neon Ne 19·9	Sodium Na 23·05	Magnesium Mg 24·3	Aluminium Al 27·0	Silicon Si 28·4	Phosphorus P 31·0	Sulphur S 32·06	Chlorine Cl 35·45	
4	Argon Ar 38	Potassium K 39·1	Calcium Ca 40·1	Scandium Sc 44·1	Titanium Ti 48·1	Vanadium V 51·4	Chromium Cr 52·1	Manganese Mn 55·0	Iron Fe 55·9 / Cobalt Co 59 / Nickel Ni 59 (Cu)
5		Copper Cu 63·6	Zinc Zn 65·4	Gallium Ga 70·0	Germanium Ge 72·3	Arsenic As 75	Selenium Se 79	Bromine Br 79·95	
6	Krypton Kr 81·8	Rubidium Rb 85·4	Strontium Sr 87·6	Yttrium Y 89·0	Zirconium Zr 90·6	Niobium Nb 94·0	Molybdenum Mo 96·0	—	Ruthenium Ru 101·7 / Rhodium Rh 103·0 / Palladium Pd 106·5
7		Silver Ag 107·9	Cadmium Cd 112·4	Indium In 114·0	Tin Sn 119·0	Antimony Sb 120·0	Tellurium Te 127	Iodine I 127	
8	Xenon Xe 128	Cæsium Cs 132·9	Barium Ba 137·4	Lanthanum La 139	Cerium Ce 140	—	—	—	— — —
9		—	—	—	—	—	—	—	
10	—	—	—	Ytterbium Yb 173	—	Tantalum Ta 183	Tungsten W 184	—	Osmium Os 191 / Iridium Ir 193 / Platinum Pt 194·9 (Au)
11		Gold Au 197·2	Mercury Hg 200·0	Thallium Tl 204·1	Lead Pb 206·9	Bismuth Bi 208	—	—	
12	—	—	Radium Rd 224	—	Thorium Th 232	—	Uranium U 239		

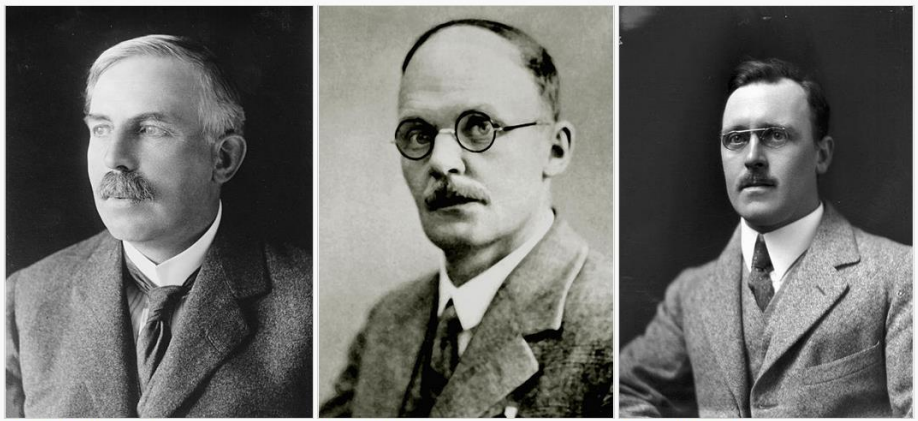
HIGHER SALINE OXIDES

R	R_2O	RO	R_2O_3	RO_2	R_2O_5	RO_3	R_2O_7	RO_4

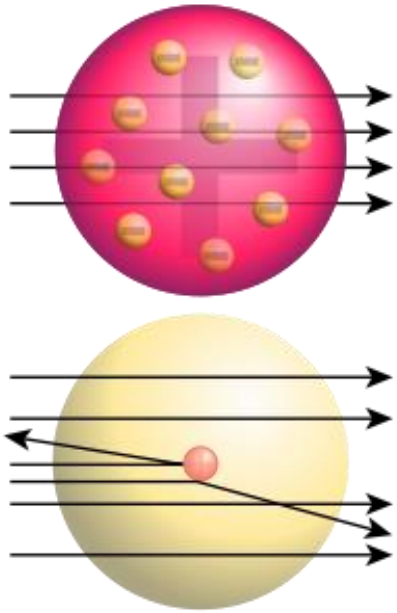
HIGHER GASEOUS HYDROGEN COMPOUNDS

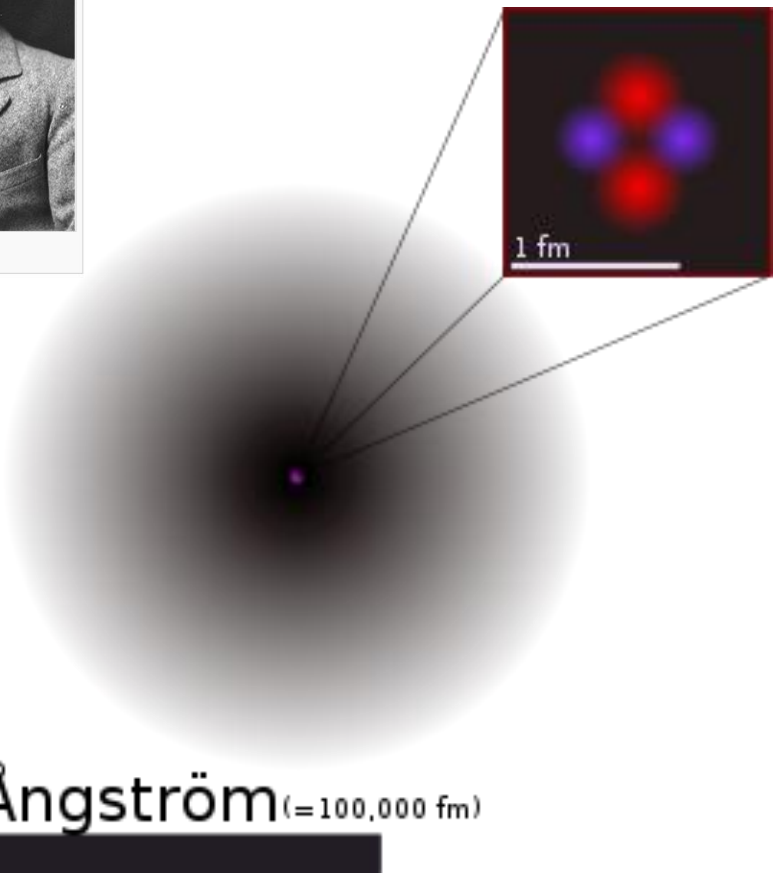
				RH_4	RH_3	RH_2	RH	

拉塞福散射實驗: 原子核結構 (1913)

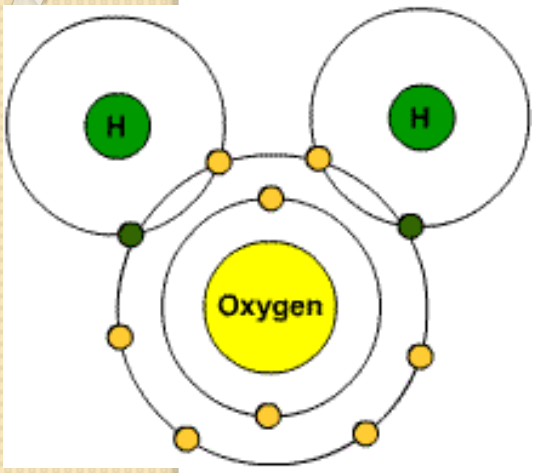


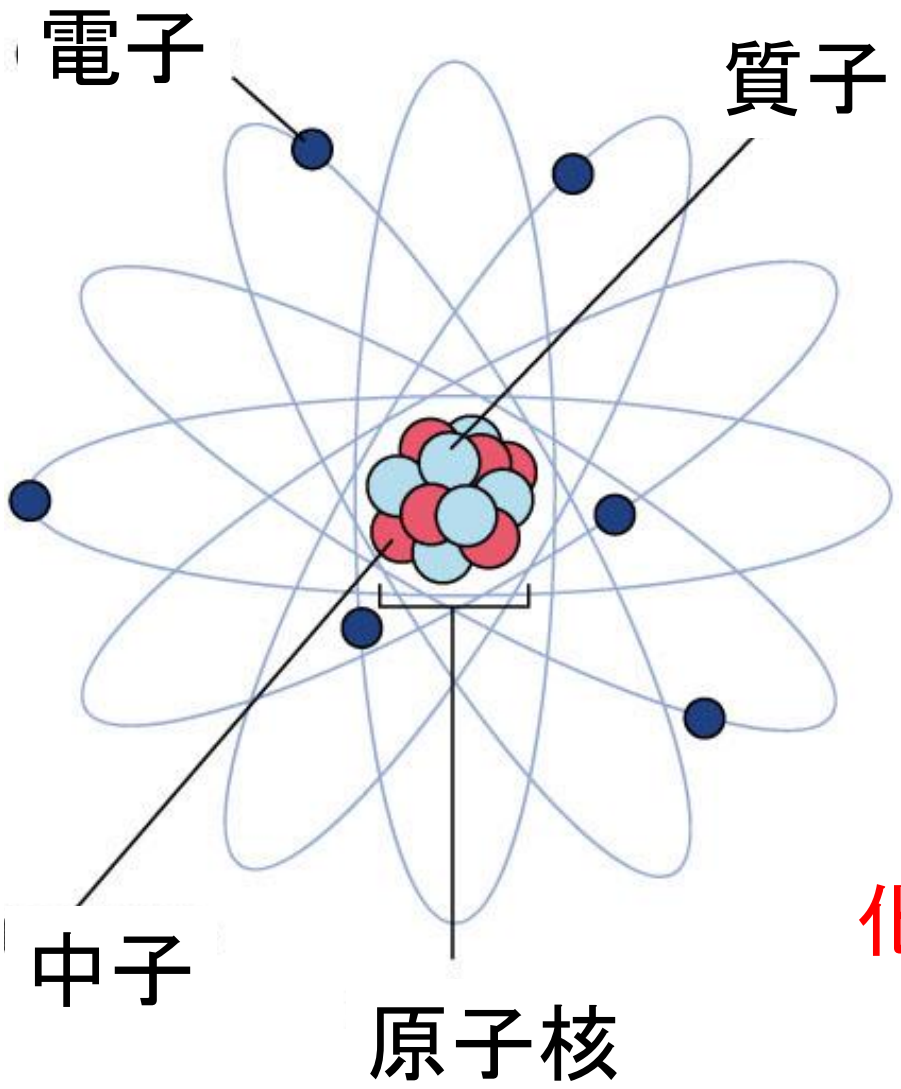
Ernest Rutherford　Hans Geiger　Ernest Marsden





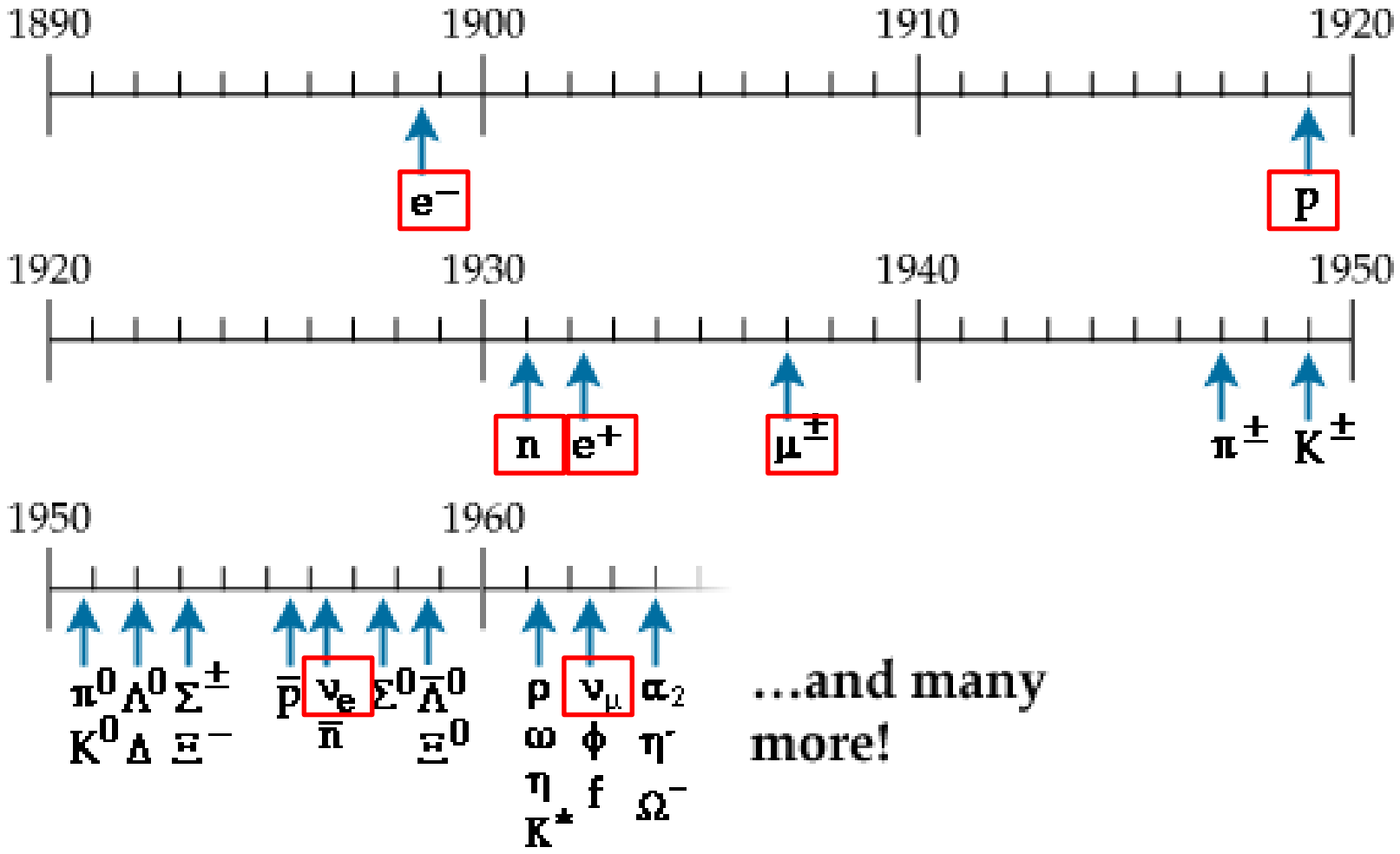
原子結構和化學性質





化繁為簡

基本粒子:
1898 – 1964



Murray Gell-Mann: 夸克模型 (1964)

Volume 8, number 3 PHYSICS LETTERS 1 February 1964

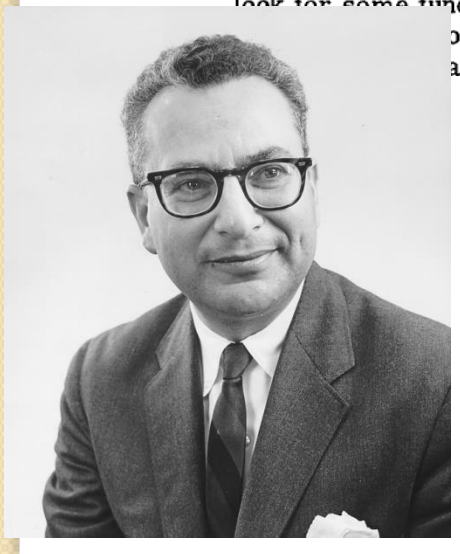
A SCHEMATIC MODEL OF BARYONS AND MESONS *

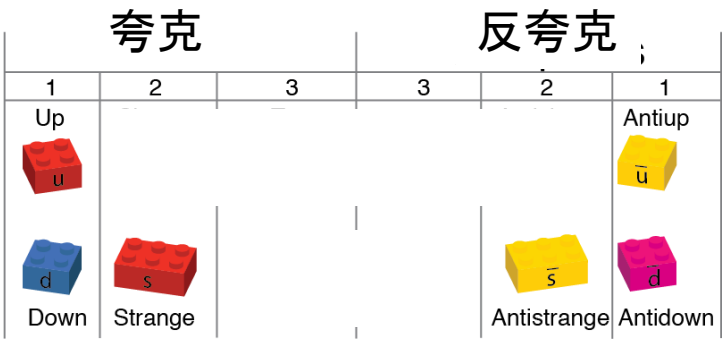
M. GELL-MANN
California Institute of Technology, Pasadena, California

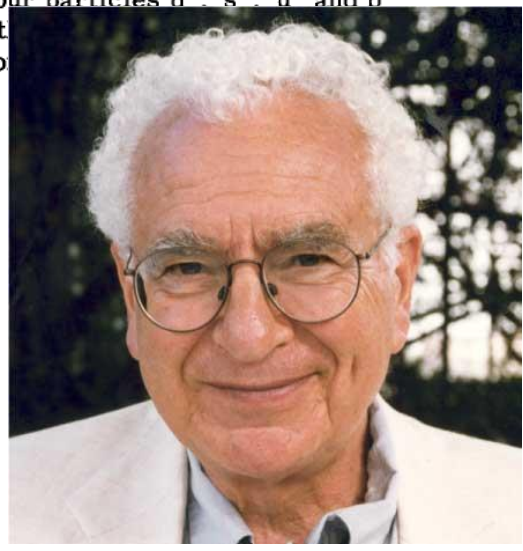
Received 4 January 1964

If we assume that the strong interactions of baryons and mesons are correctly described in terms of the broken "eightfold way" [1-3], we are tempted to look for some fundamental explanation of the situa-
omised approach is the purely dy-
ap" model for all the strongly in-

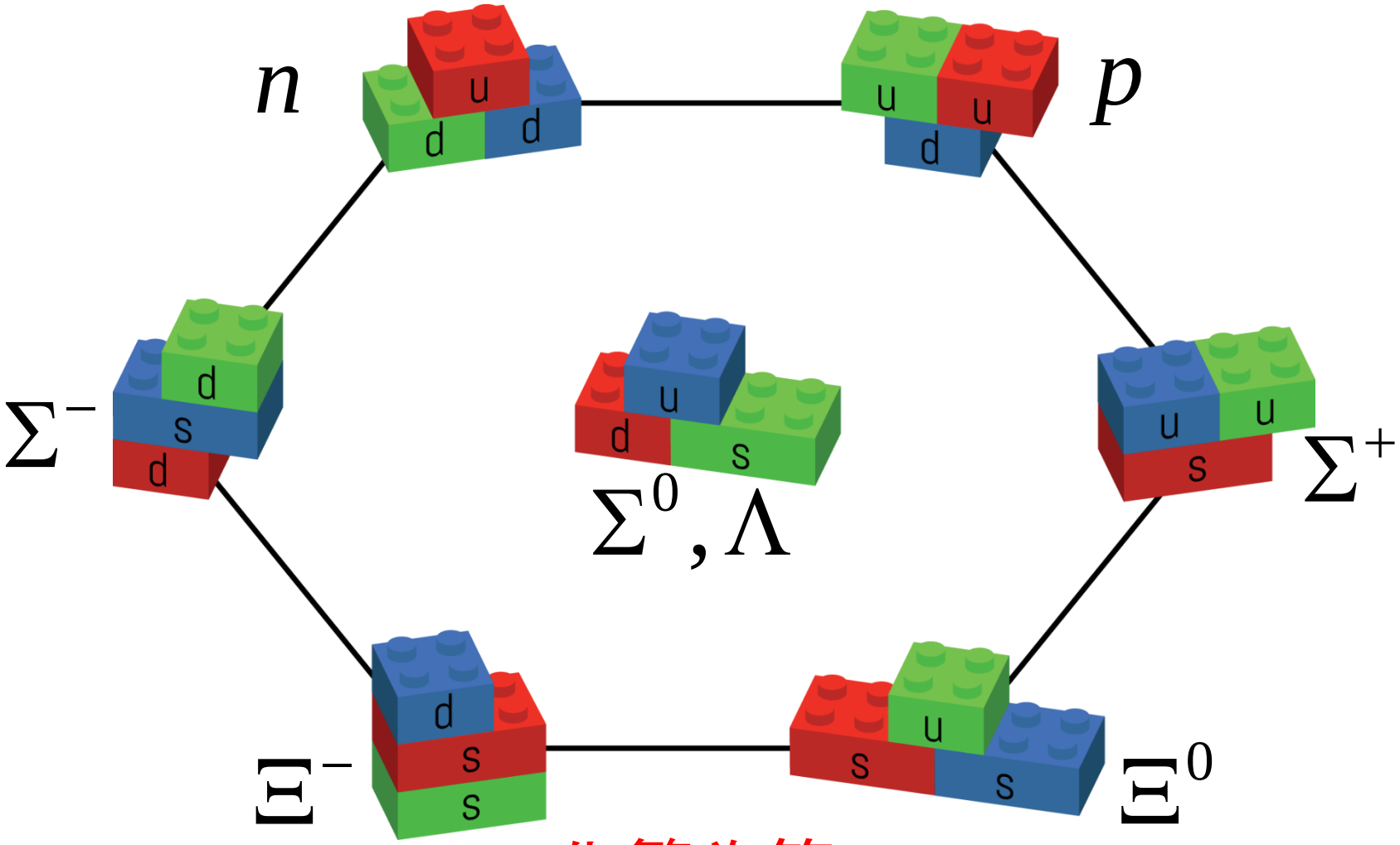
ber $n_t - n_{\bar{t}}$ would be zero for all known baryons and mesons. The most interesting example of such a model is one in which the triplet has spin $\frac{1}{2}$ and $z = -1$, so that the four particles d^-, s^-, u^0 and b^0 exhibit a parallel wit
A simpler and mo





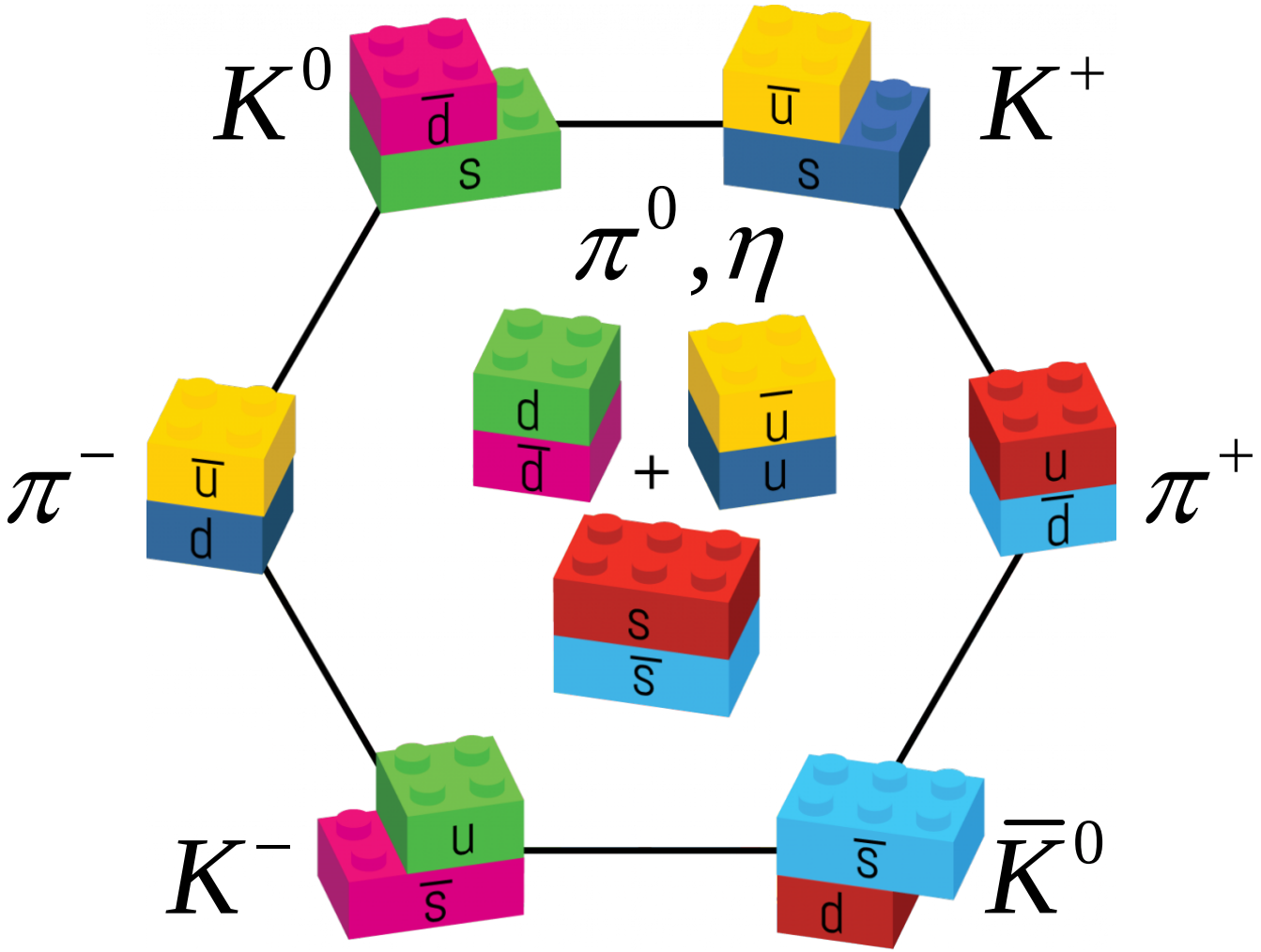


重子八重態 (自旋=1/2)



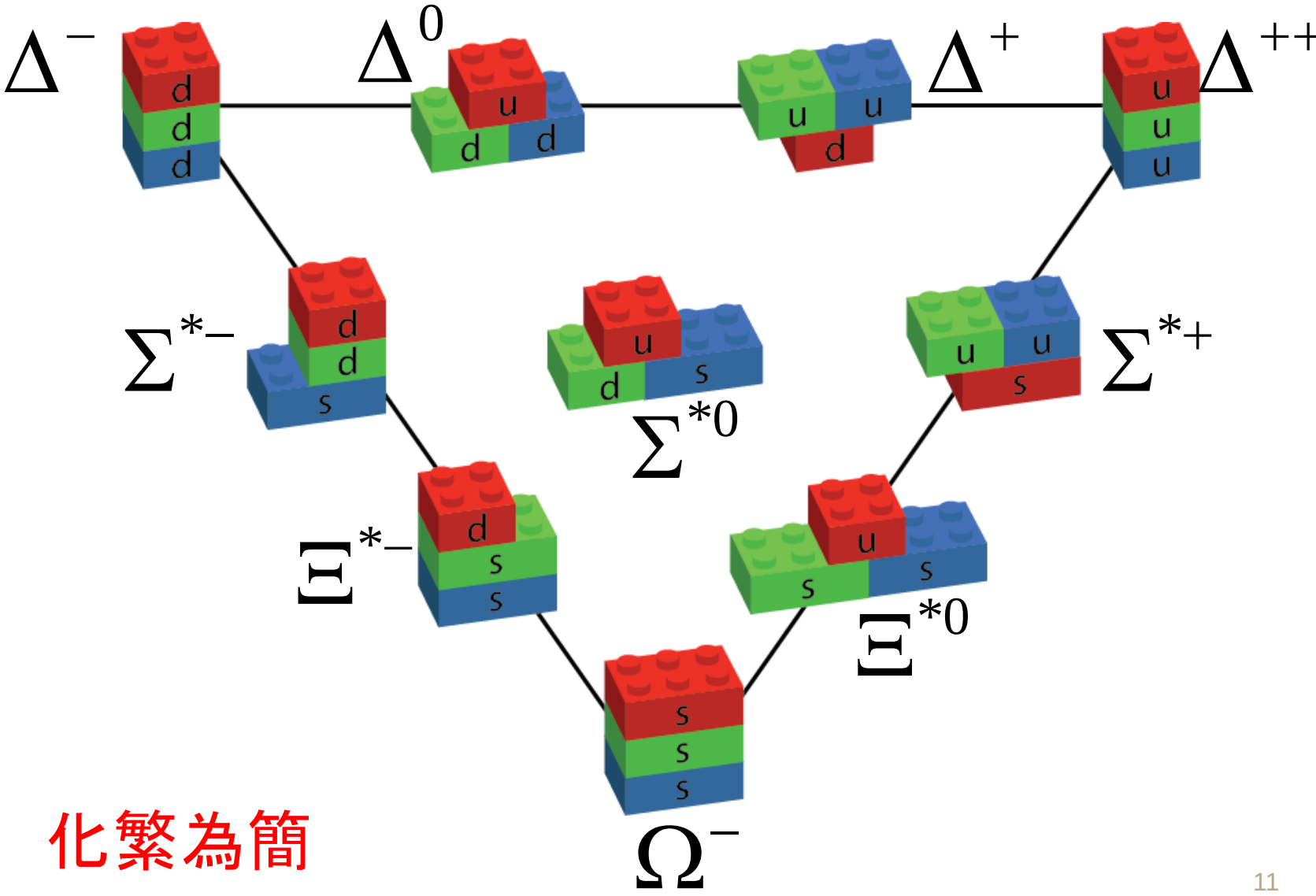
化繁為簡

介子八重態 (自旋=0)



化繁為簡

重子十重態 (自旋=3/2)



化繁為簡

Ω^-(1964) 的發現

VOLUME 12, NUMBER 8 PHYSICAL REVIEW LETTERS 24 FEBRUARY 1964

OBSERVATION OF A HYPERON WITH STRANGENESS MINUS THREE*

V. E. Barnes, P. L. Connolly, D. J. Crennell, B. B. Culwick, W. C. Delaney,
W. B. Fowler, P. E. Hagerty,† E. L. Hart, N. Horwitz,† P. V. C
J. K. Kopp, K. W. Lai, J. Leitner,† J. L. Lloyd, G. W. London,‡
R. B. Palmer, A. G. Prodell, D. Radojičić, D. C. Rahm, C. R. Ri
J. R. Sanford, R. P. Shutt, J. R. Smith, D. L. Stonehill, R. C. St
M. S. Webster, W. J. Willis, and S. S. Yamar
Brookhaven National Laboratory, Upton, New Yor
(Received 11 February 1964)

It has been pointed out[1] that among the multitude of resonances which have been discovered recently, the $N_{3/2}^*(1238)$, $Y_1^*(1385)$, and $\Xi_{1/2}^*(1532)$ can be arranged as a decuplet with one member still missing. Figure 1 illustrates the position of the nine known resonant states and the postulated tenth particle plotted as a function of mass and the third component of isotopic spin. As can be seen from Fig. 1, this particle (which we call Ω^-, following Gell-Mann[1]) is predicted to be a negatively charged isotopic singlet with strangeness minus three.[2] The spin and parity should be the same as those of the $N_{3/2}^*$, namely, $3/2^+$. The 10-dimensional representation of the group SU_3 can be identified with just such a decuplet. Consequently, the existence of the Ω^- has been cited as a crucial test of the theory of unitary symmetry of strong interactions.[3,4] The mass is predicted[5] by the Gell-Mann–Okubo mass formula to be about 1680 MeV/c^2. We wish to report the observation of an event which we believe to be an example of the production and decay of such a particle.

length of ~10^6 feet.
partially analyzed t
teristic decay mode
The event in ques
the pertinent measu
Table I. Our interp

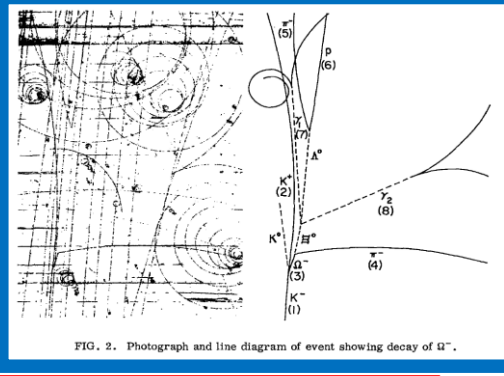


FIG. 2. Photograph and line diagram of event showing decay of Ω^-.

$$K^- + p \to \Omega^- + K^+ + K^0$$
$$\Xi^0 + \pi^-$$
$$\Lambda^0 + \pi^0$$
$$\gamma_1 + \gamma_2$$
$$e^+ + e^-$$
$$e^+ + e^-$$
$$\pi^- + p. \qquad (1)$$

From the momentum and gap length measurements, track 2 is identified as a K^+. (A bubble density of 1.9 times minimum was expected for this track while the measured value was 1.7 ± 0.2.) Tracks 5 and 6 are in good agreement with the decay of a Λ^0, but the Λ^0 cannot come from the primary interaction. The Λ^0 mass as

夸克模型

Physics

The Nobel Prize in Physics 1969

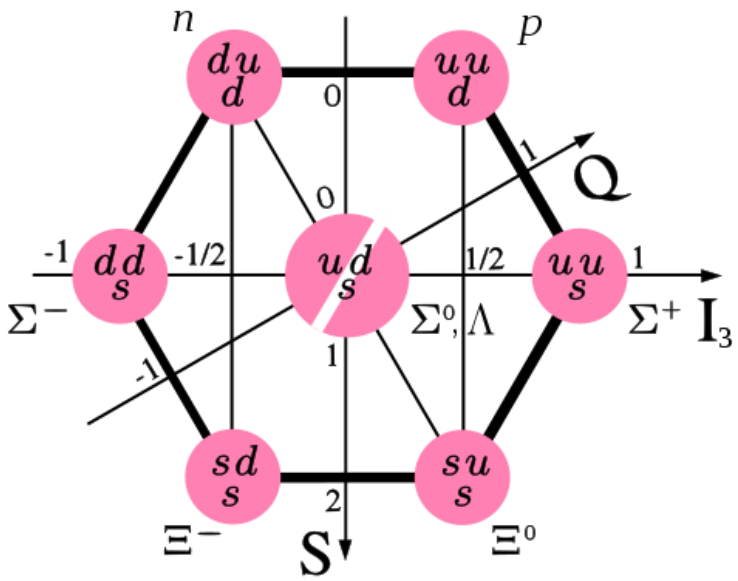
"for his contributions and discoveries concerning the classification of elementary particles and their interactions"

Murray Gell-Mann

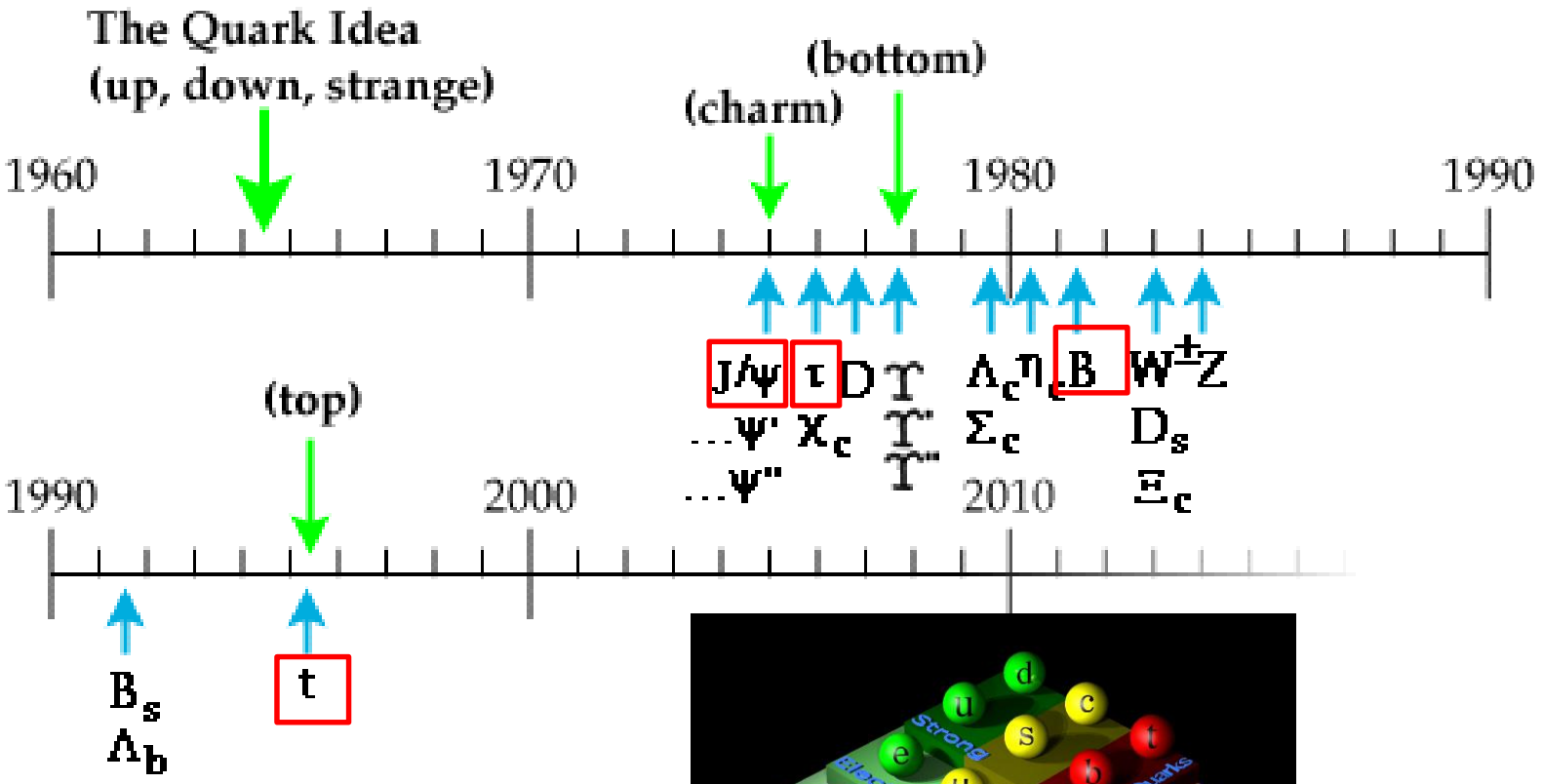
USA

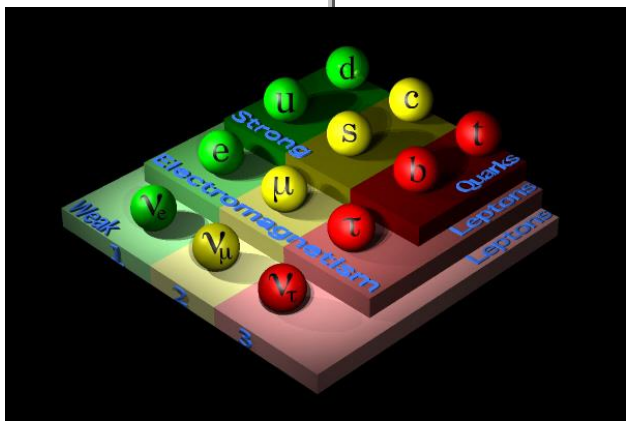
California Institute of Technology (Caltech)
Pasadena, CA, USA

b. 1929



基本粒子和新種類夸克: 1964 – 2010





The Nobel Prize in Physics 1976

Burton Richter, Samuel C.C. Ting

Share this: 2

The Nobel Prize in Physics 1976

Burton Richter

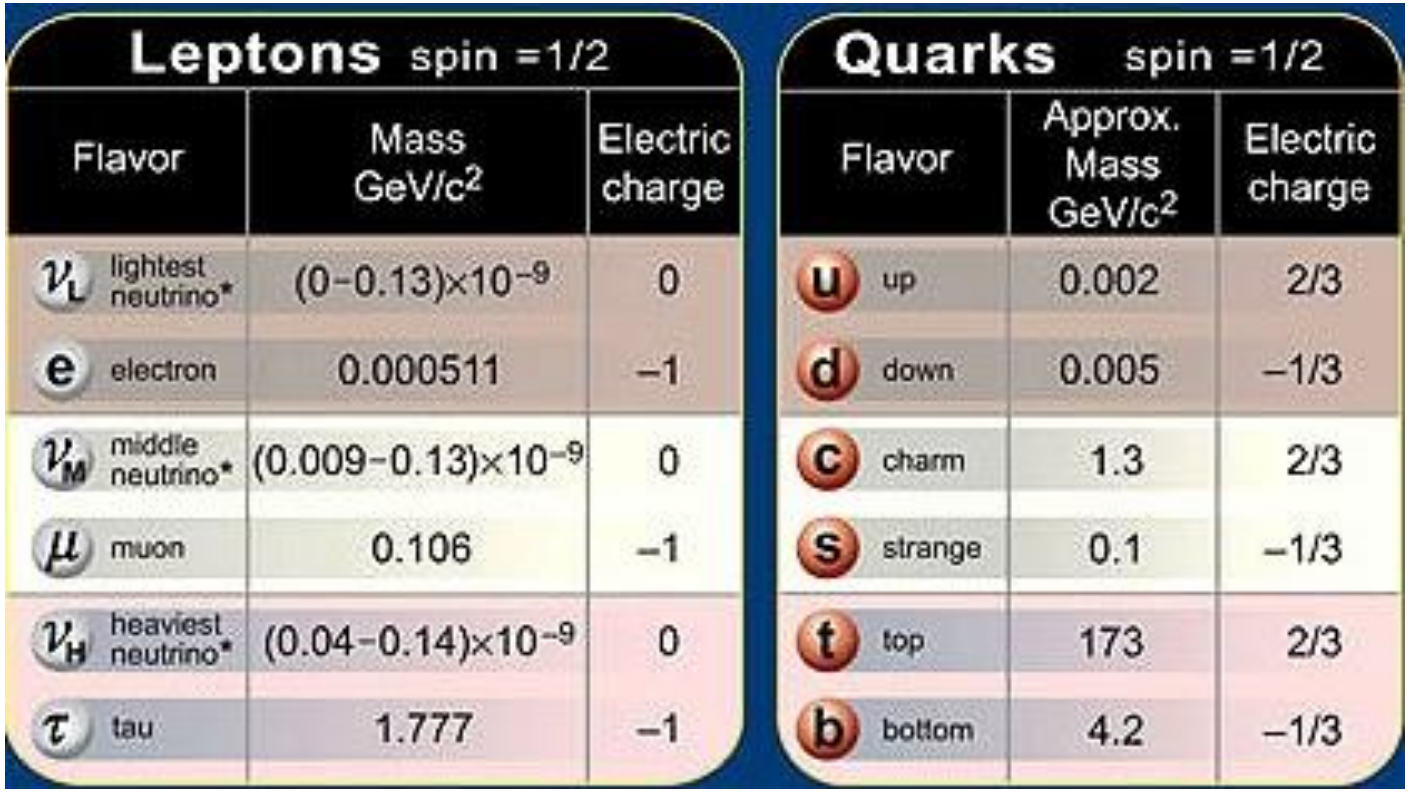
Prize share: 1/2

Samuel Chao Chung Ting

Prize share: 1/2

The Nobel Prize in Physics 1976 was awarded jointly to Burton Richter and Samuel Chao Chung Ting *"for their pioneering work in the discovery of a heavy elementary particle of a new kind"*

夸克、輕子家族



Leptons spin =1/2

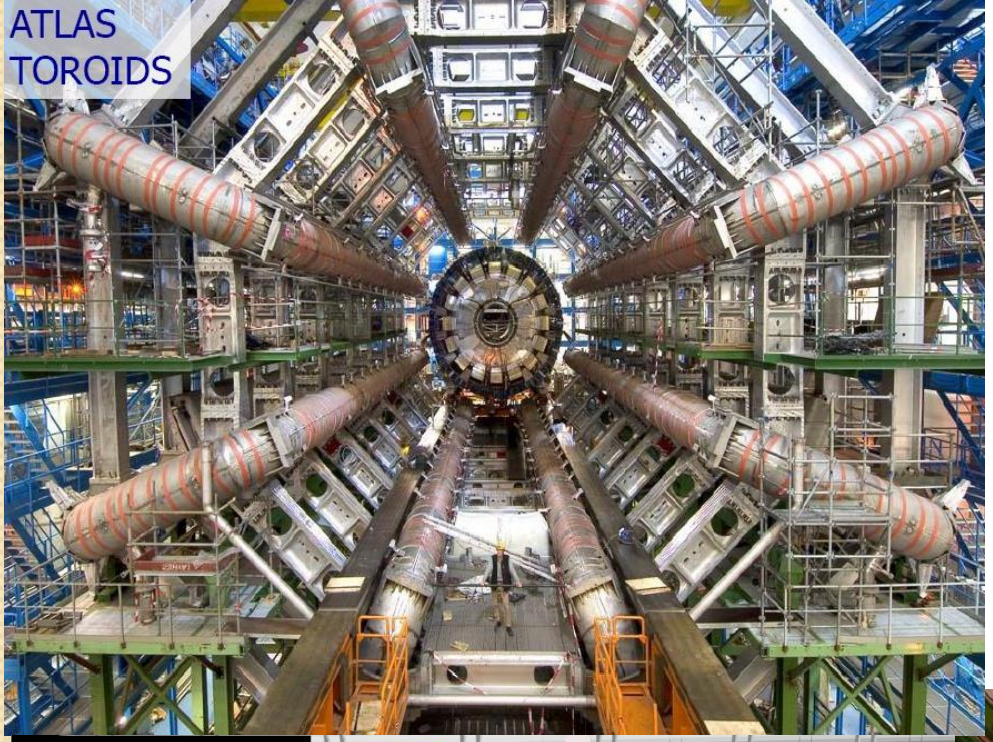
Flavor	Mass GeV/c^2	Electric charge
ν_L lightest neutrino*	$(0-0.13)\times10^{-9}$	0
e electron	0.000511	−1
ν_M middle neutrino*	$(0.009-0.13)\times10^{-9}$	0
μ muon	0.106	−1
ν_H heaviest neutrino*	$(0.04-0.14)\times10^{-9}$	0
τ tau	1.777	−1

Quarks spin =1/2

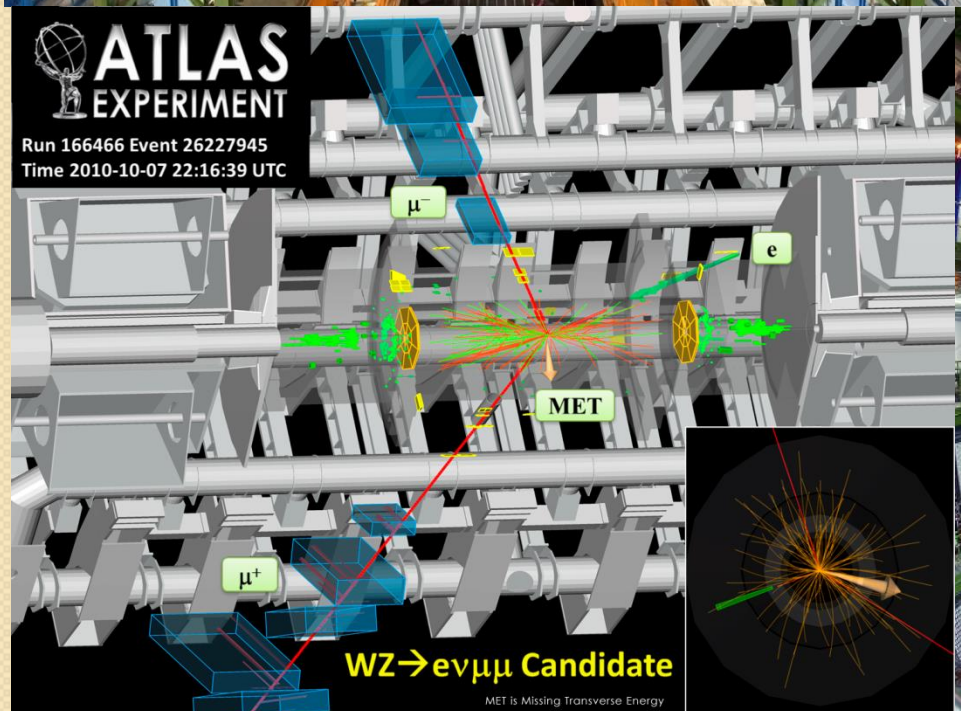
Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.002	2/3
d down	0.005	−1/3
c charm	1.3	2/3
s strange	0.1	−1/3
t top	173	2/3
b bottom	4.2	−1/3

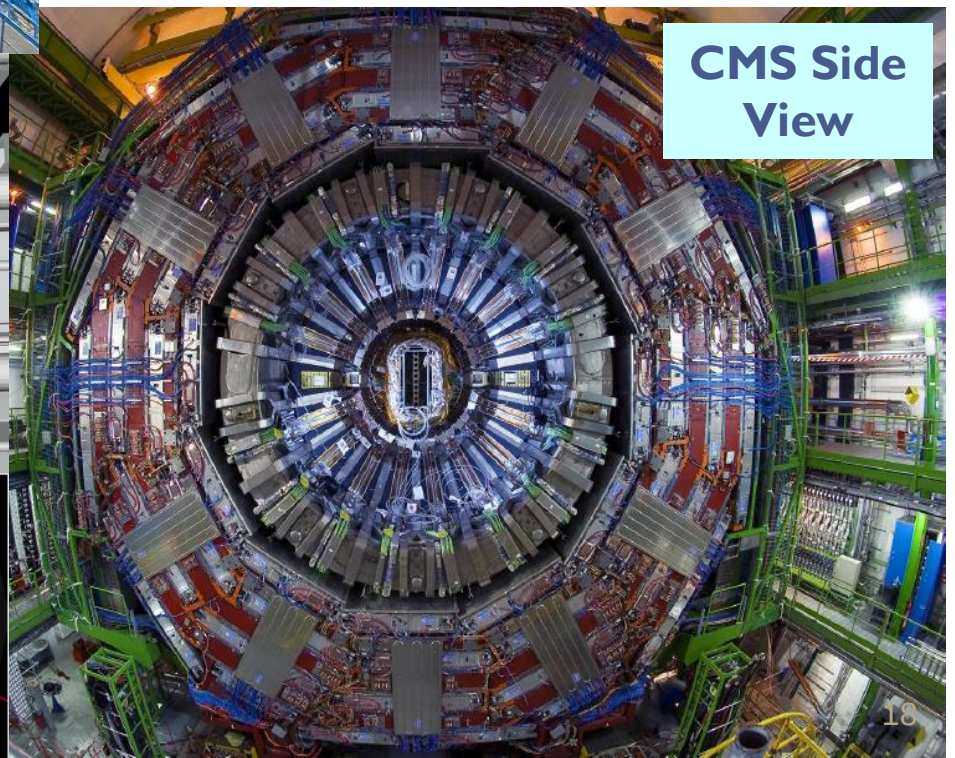
歐洲核子研究組織CERN大強子實驗

- Higgs
- New Physics

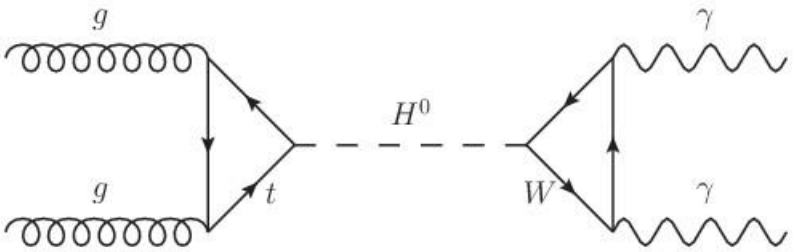

ATLAS
TOROIDS

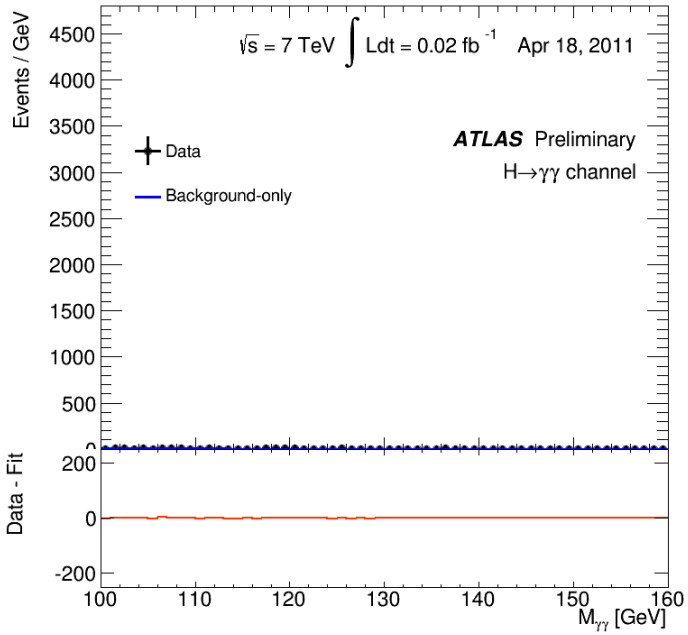

DCS
Control Room

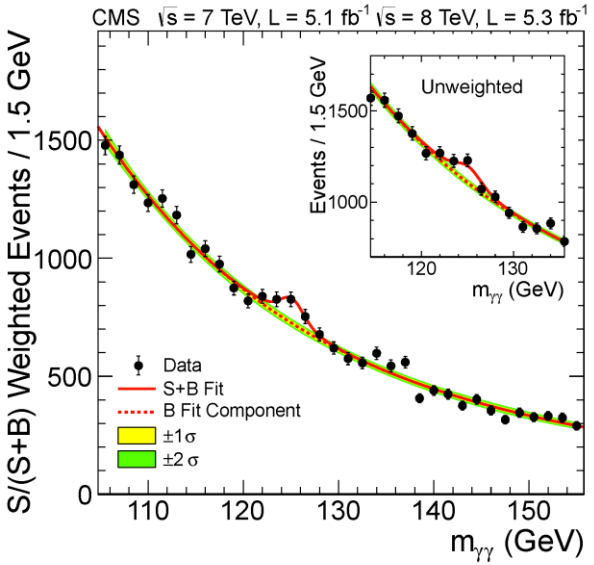

ATLAS
EXPERIMENT
Run 166466 Event 26227945
Time 2010-10-07 22:16:39 UTC
μ⁻
e
MET
μ⁺
WZ→eνμμ Candidate
MET is Missing Transverse Energy


CMS Side
View

希格氏粒子的發現（2012）







The Nobel Prize in Physics 2013
François Englert, Peter Higgs

The Nobel Prize in Physics 2013

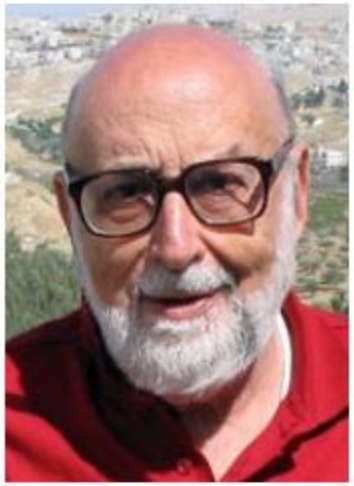


Photo: Pnicolet via Wikimedia Commons

François Englert

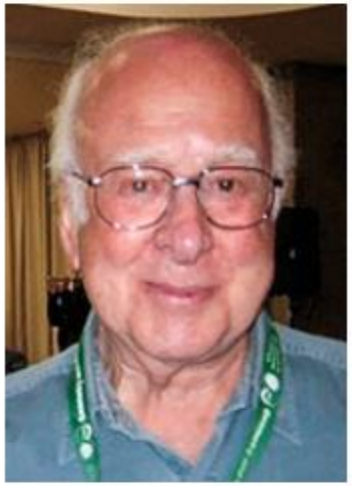
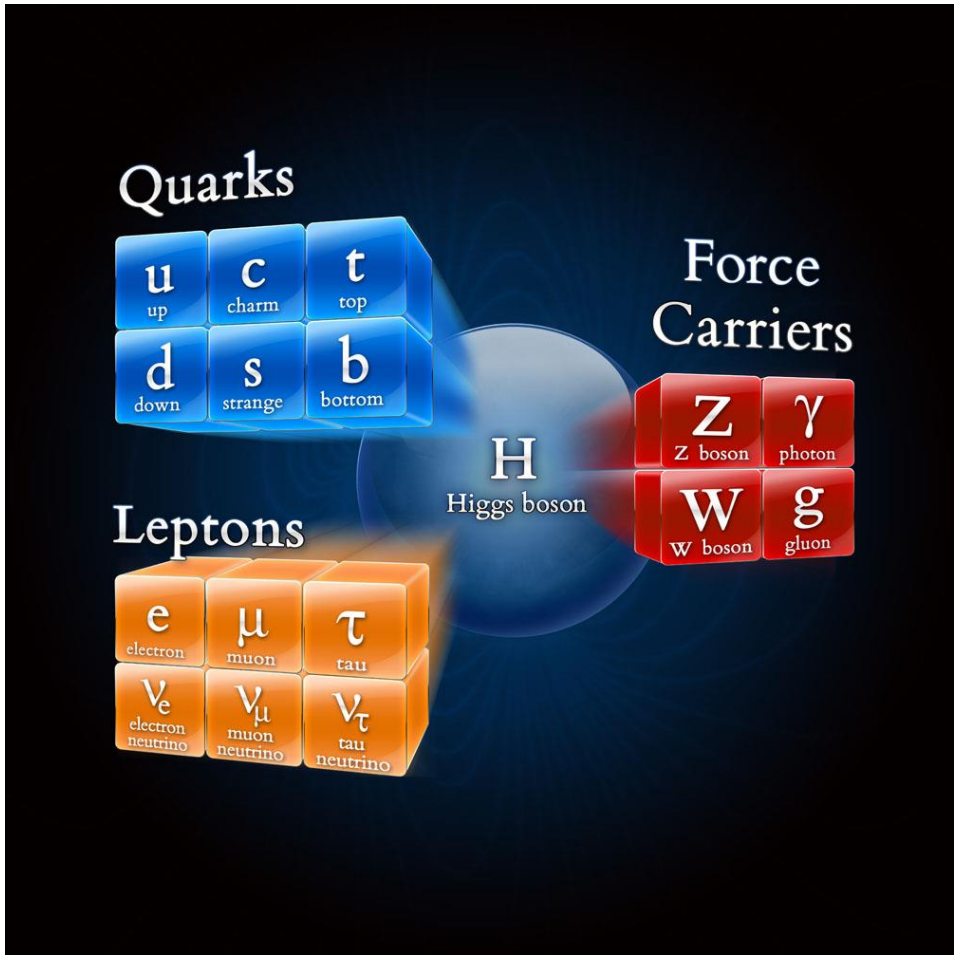


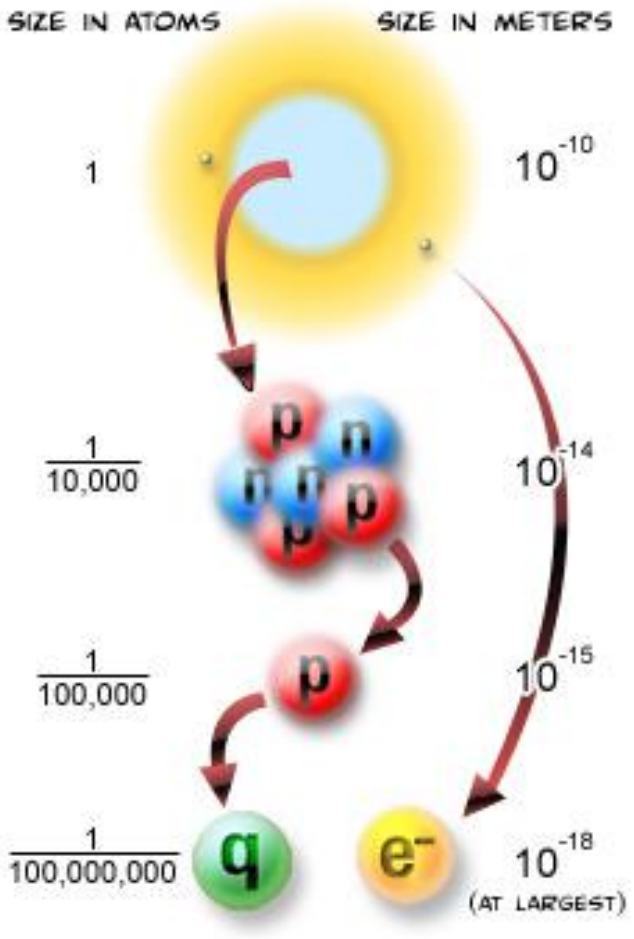
Photo: G-M Greuel via Wikimedia Commons

Peter W. Higgs

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs ***"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"***

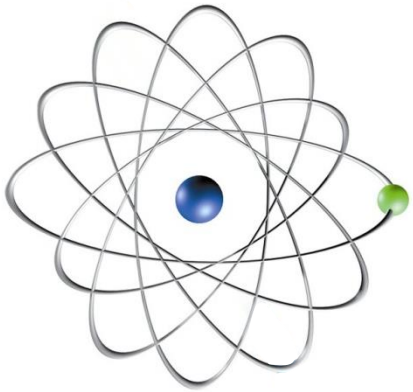
基本粒子標準模型


Quarks
u up
c charm
t top
d down
s strange
b bottom
Leptons
e electron
μ muon
τ tau
νe electron neutrino
νμ muon neutrino
ντ tau neutrino
H Higgs boson
Force Carriers
Z Z boson
γ photon
W W boson
g gluon


SIZE IN ATOMS
SIZE IN METERS
1
10^-10
1/10,000
10^-14
1/100,000
10^-15
1/100,000,000
10^-18
(AT LARGEST)
p
n
q
e⁻

組合系統的質量

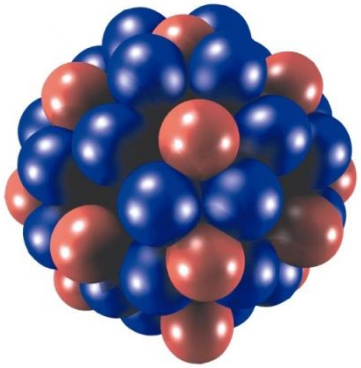
原子
10^{-10} m



$M \approx \Sigma m_i$

binding energy
effect $\approx 10^{-8}$

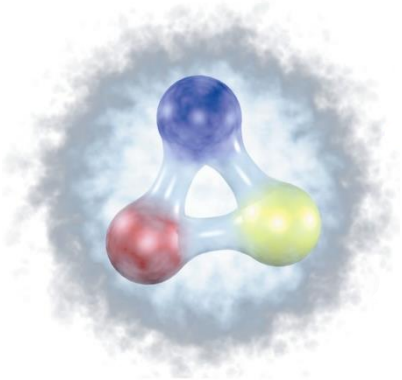
原子核
10^{-14} m



$M \approx \Sigma m_i$

binding energy
effect $\approx 10^{-3}$

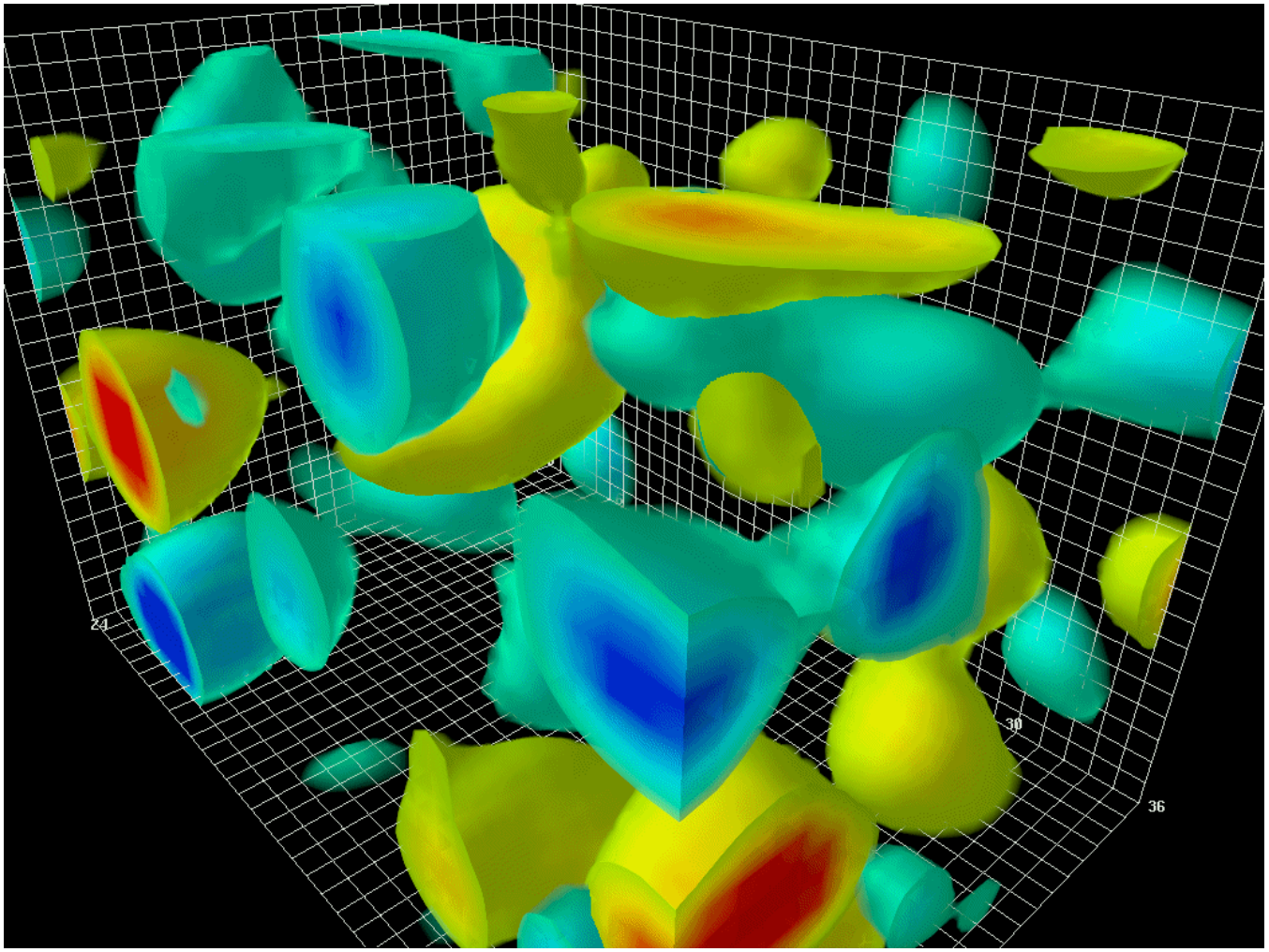
質子
10^{-15} m



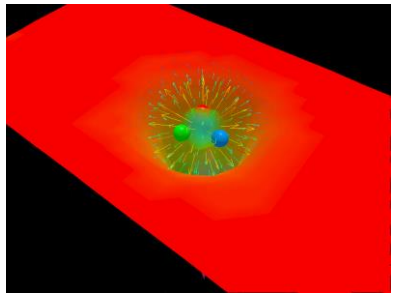
$M \gg m_i$

質子的質量為 980 MeV，但 u, d夸克的質量卻只有5-10 MeV?
"mass without mass" (Wilczek)

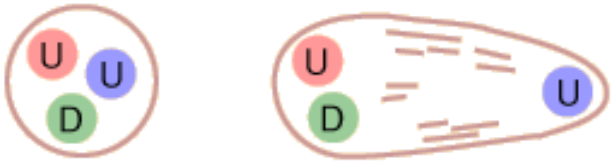
膠子（強交互作用的交換粒子）

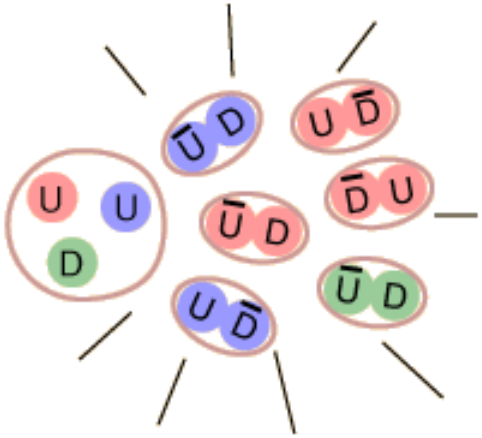


強交互作用力



- **夸克禁閉**(Quark Confinement): 無單獨夸克存在





- **漸近自由**(Asymptotic Freedom):

$$\alpha_s(E) = \frac{12\pi}{(33 - 2n_f)\ln\left[\frac{E^2}{\Lambda^2}\right]}$$

n_f = number of quarks active in pair production (up to 6)

Λ = experimentally determined parameter, ≈ 0.2 GeV

$$E \to \infty, \ \alpha_s \to 0.$$

夸克聚合體：強子（重子&介子）

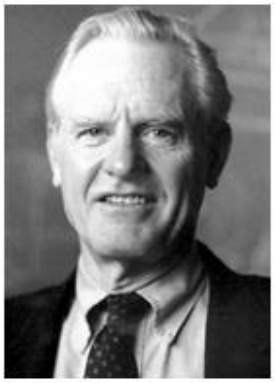
Baryons qqq and Antibaryons $\bar{q}\bar{q}\bar{q}$ Baryons are fermionic hadrons. These are a few of the many types of baryons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
p	proton	**uud**	1	0.938	1/2
$\bar{\mathbf{p}}$	antiproton	$\bar{\mathbf{u}}\bar{\mathbf{u}}\bar{\mathbf{d}}$	–1	0.938	1/2
n	neutron	**udd**	0	0.940	1/2
Λ	lambda	**uds**	0	1.116	1/2
Ω^-	omega	**sss**	–1	1.672	3/2

Mesons $q\bar{q}$ Mesons are bosonic hadrons These are a few of the many types of mesons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c^2	Spin
π^+	pion	$\mathbf{u\bar{d}}$	+1	0.140	0
$\mathbf{K^-}$	kaon	$\mathbf{s\bar{u}}$	–1	0.494	0
ρ^+	rho	$\mathbf{u\bar{d}}$	+1	0.776	1
B^0	B-zero	$\mathbf{d\bar{b}}$	0	5.279	0
η_c	eta-c	$\mathbf{c\bar{c}}$	0	2.980	0

夸克存在的實驗證據：深度非彈性電子散射

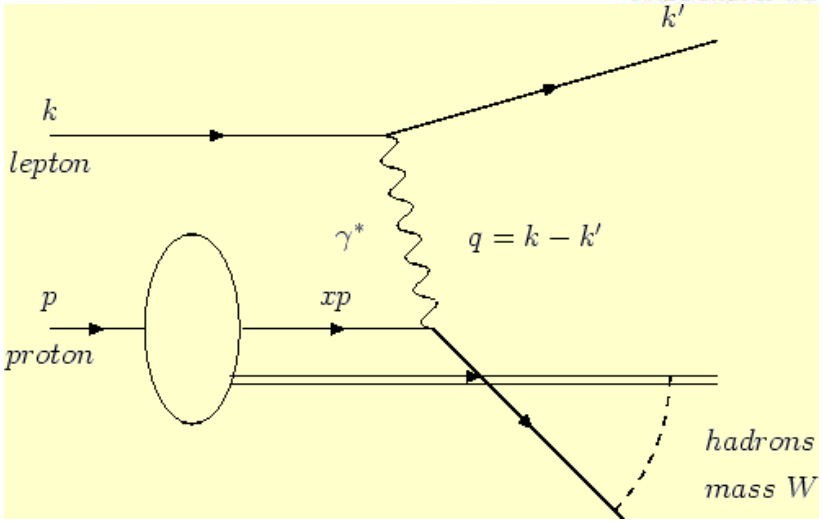
The Nobel Prize in Physics 1990

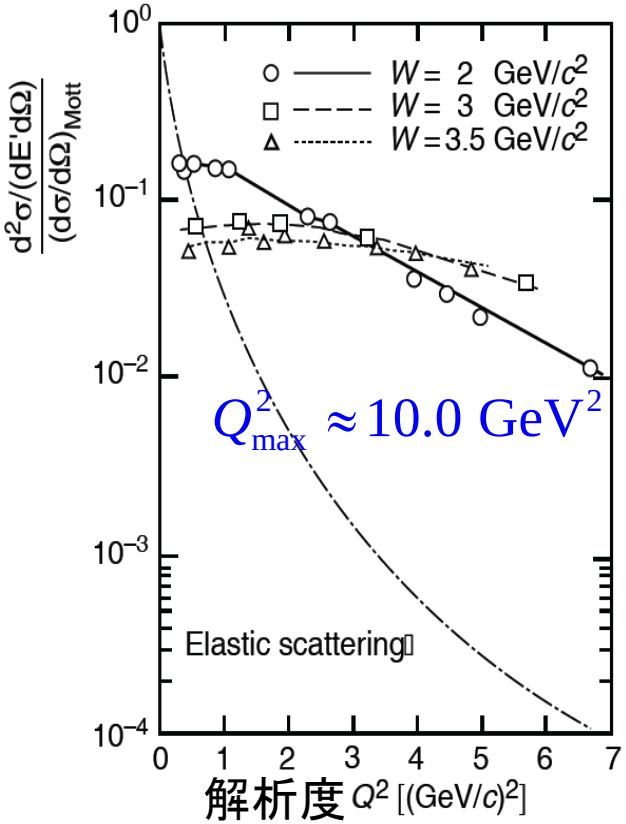
Jerome I. Friedman
Prize share: 1/3



Henry W. Kendall
Prize share: 1/3

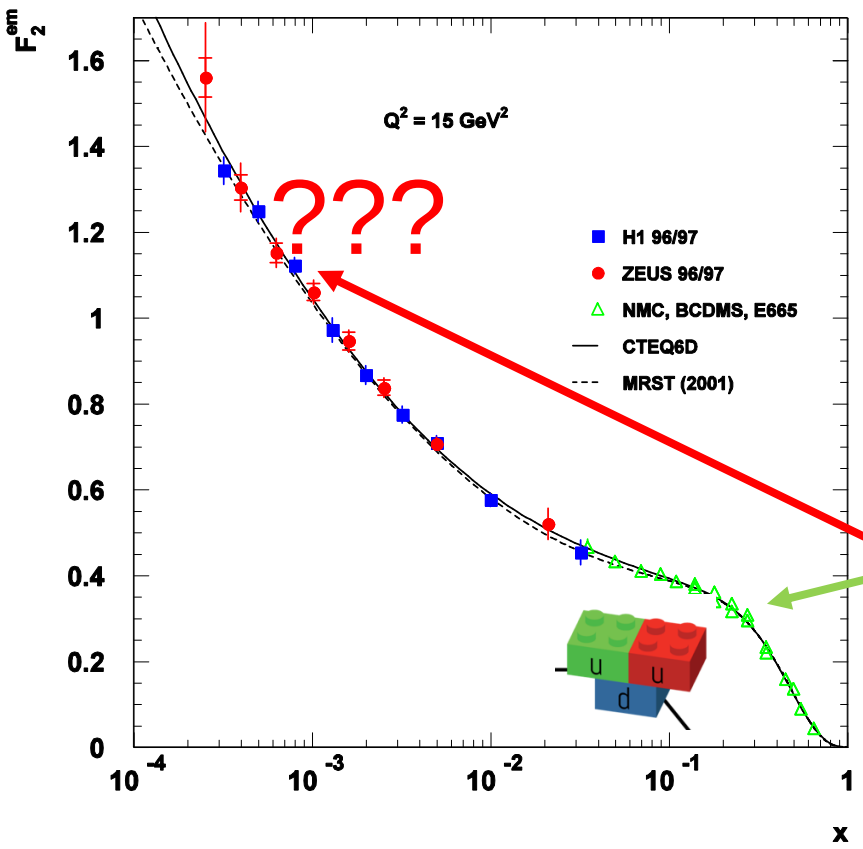
Photo: T. Nakashima
Richard E. Taylor
Prize share: 1/3

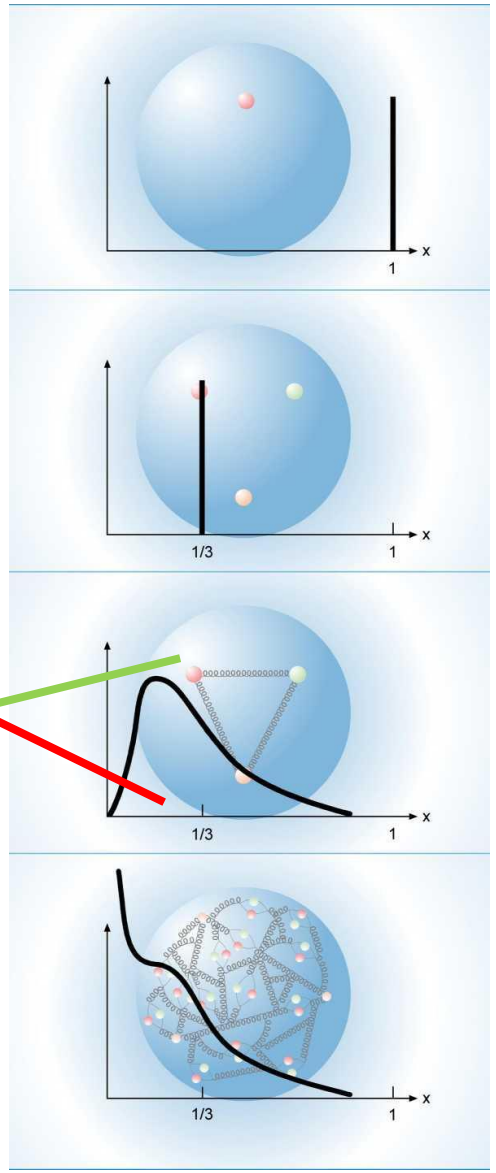




x: 被撞擊粒子的動量比例

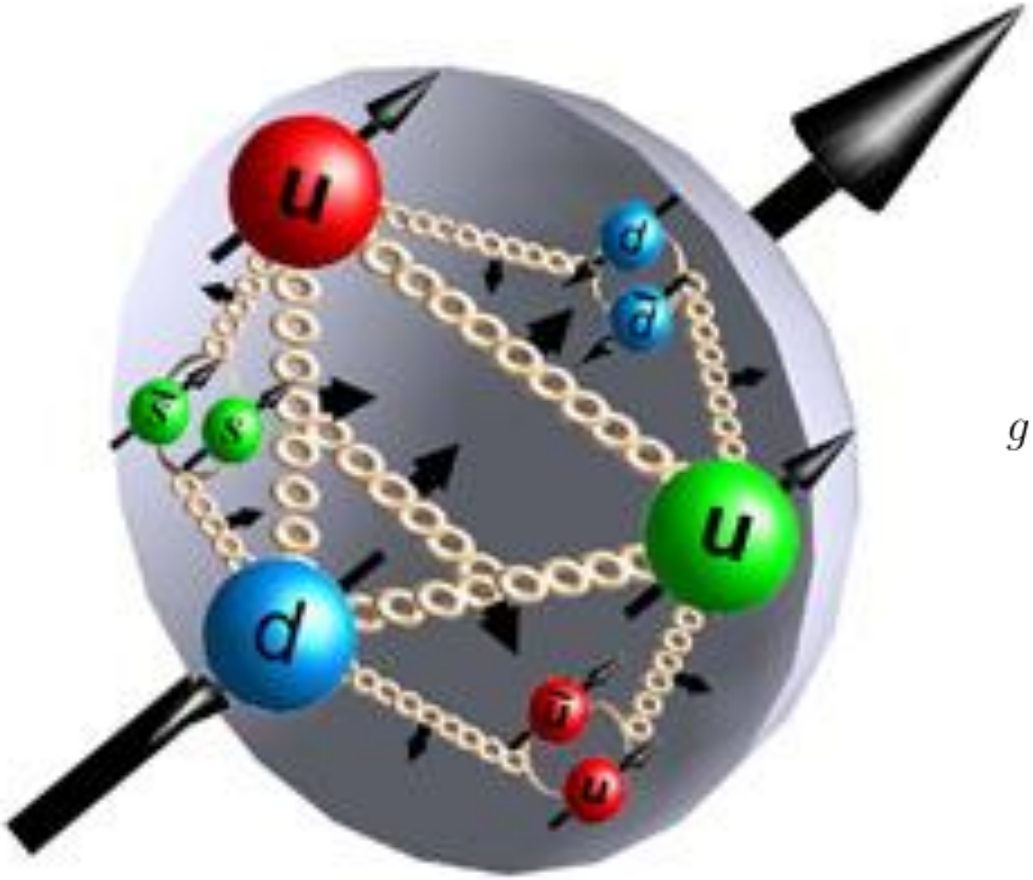
質子的結構粒子動量分布

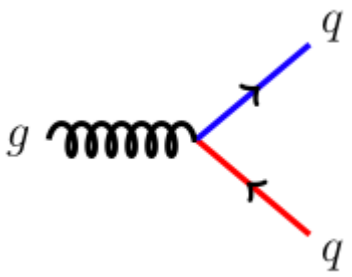




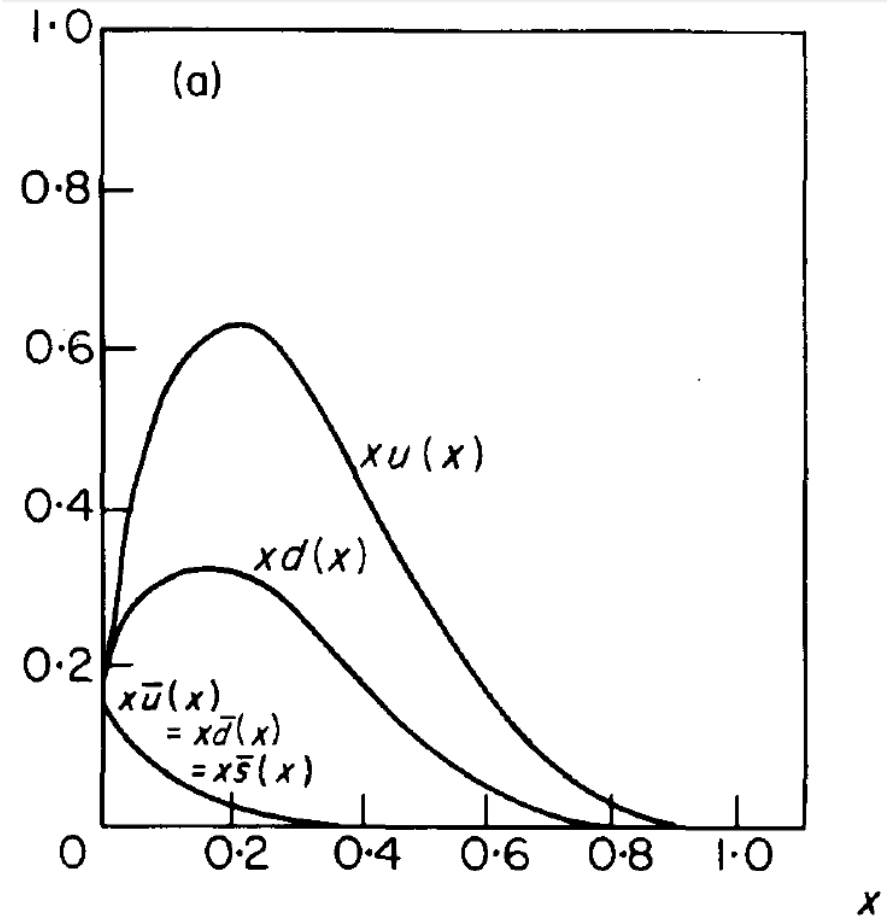
Q^2 提高解析度

質子內部的反夸克 $(\bar{u}, \bar{d}, \bar{s}, \ldots)$



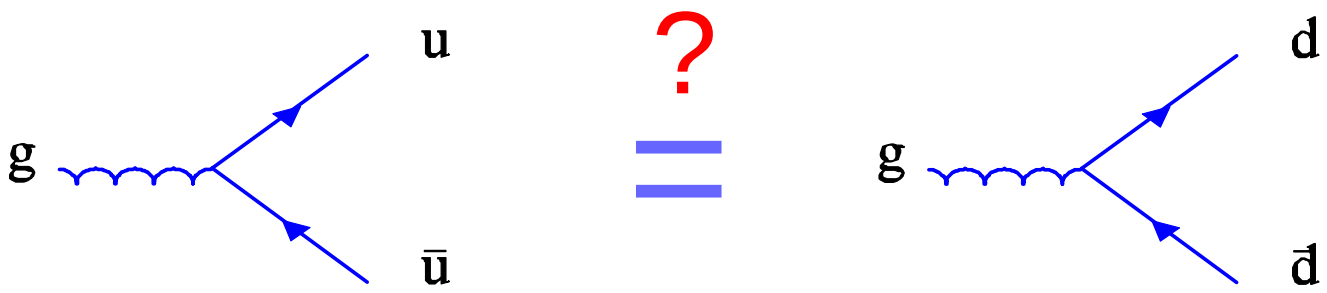


質子內部的反夸克 $(\bar{u}, \bar{d}, \bar{s}, \ldots)$



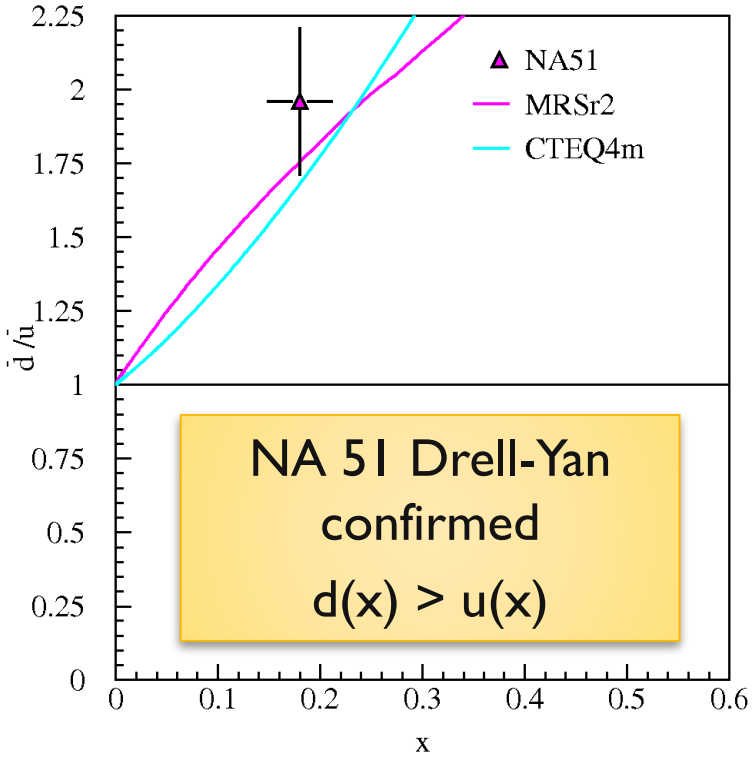
F.E. Close, “An Introduction to Quarks and Partons”

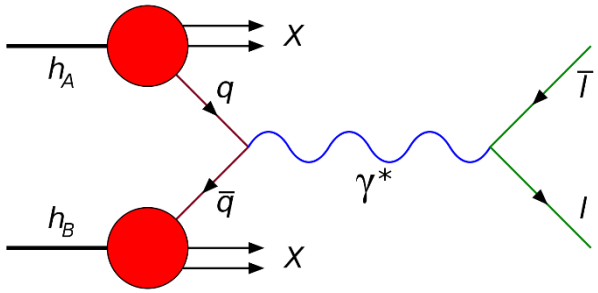
$\bar{u}$和$\bar{d}$有完全相同的分布狀態嗎？



反夸克分布差異測定

- Naïve Assumption: $\bar{d}(x) = \bar{u}(x)$
- NMC (Gottfried Sum Rule):
  $\int_0^1 \left[\bar{d}(x) - \bar{u}(x)\right] dx \neq 0$
- NA51 (Drell-Yan, 1994):
  $\bar{d} > \bar{u}$ at $x = 0.18$





反夸克分布差異測定

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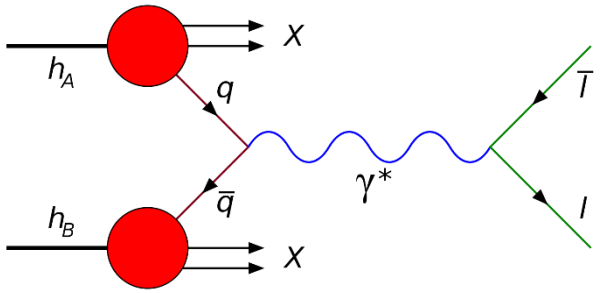
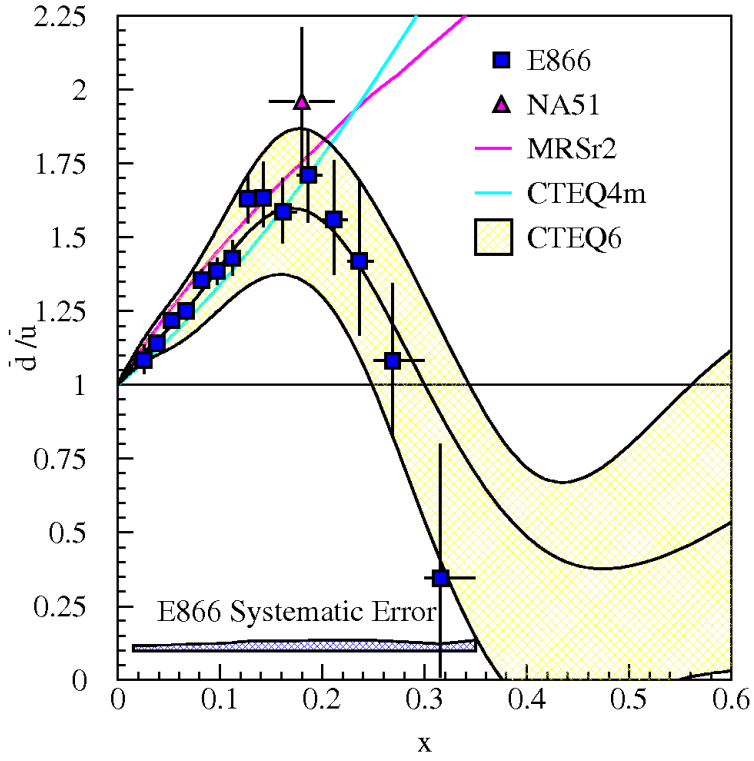
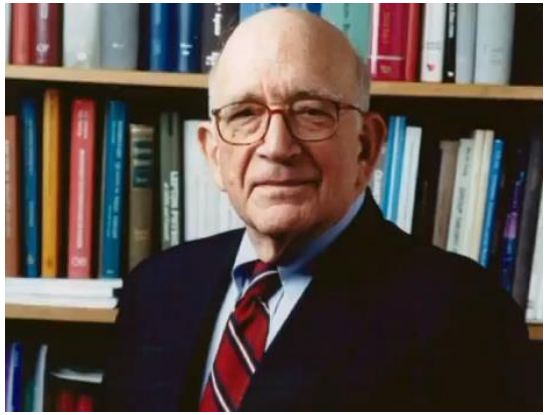
  $\bar{d} > \bar{u}$ at $x = 0.18$
- E866/NuSea (Drell-Yan, 1998):
  $\bar{d}(x)/\bar{u}(x)$ for $0.015 \leq x \leq 0.35$

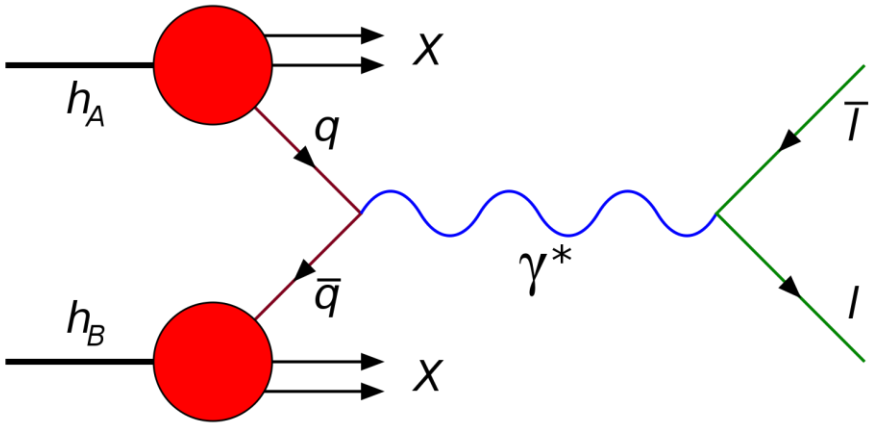




強子撞擊中Drell-Yan 過程 (1970)

S.D. Drell and T.M. Yan, PRL 25 (1970) 316





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Ithaca NY 14853

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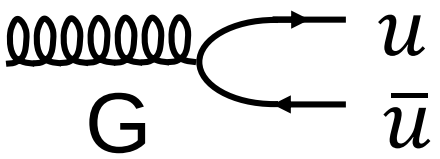
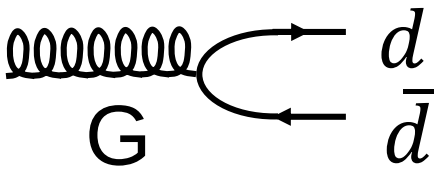
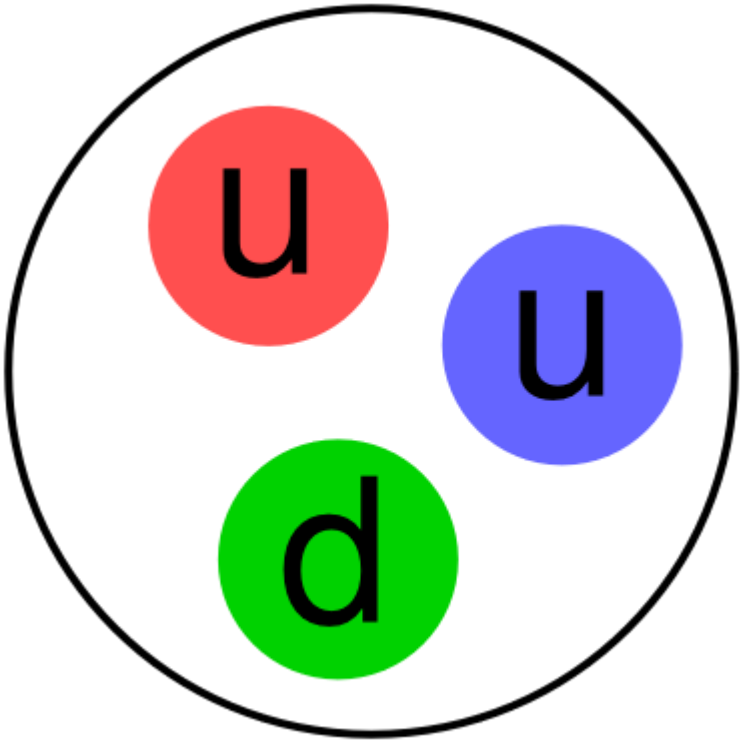
BS, 1960, National Taiwan University. Ph.D., 1968, Harvard University. Research Associate, Stanford Linear Accelerator Center, 1968-70. Assistant Professor, Physics, Cornell University, 1970-76. Associate Professor, Physics, Cornell University, 1976-81. Professor, Physics, Cornell University, 1981-present. Visiting appointments at: Stanford Linear Accelerator Center, 1973-74. Theory Division, CERN, 1977-78. Physics Department, National Taiwan University, 1986. Institue of Physics, Academia Sinica, Taipei, Taiwan, 1991-92. National Center of Theoretical Sciences, Hsinchu, Taiwan, 1997. Alfred Sloan Fellow, 1974-78. Fellow, American Physics Society.

為何 $\bar{u}(x) \neq \bar{d}(x)$？價夸克影響



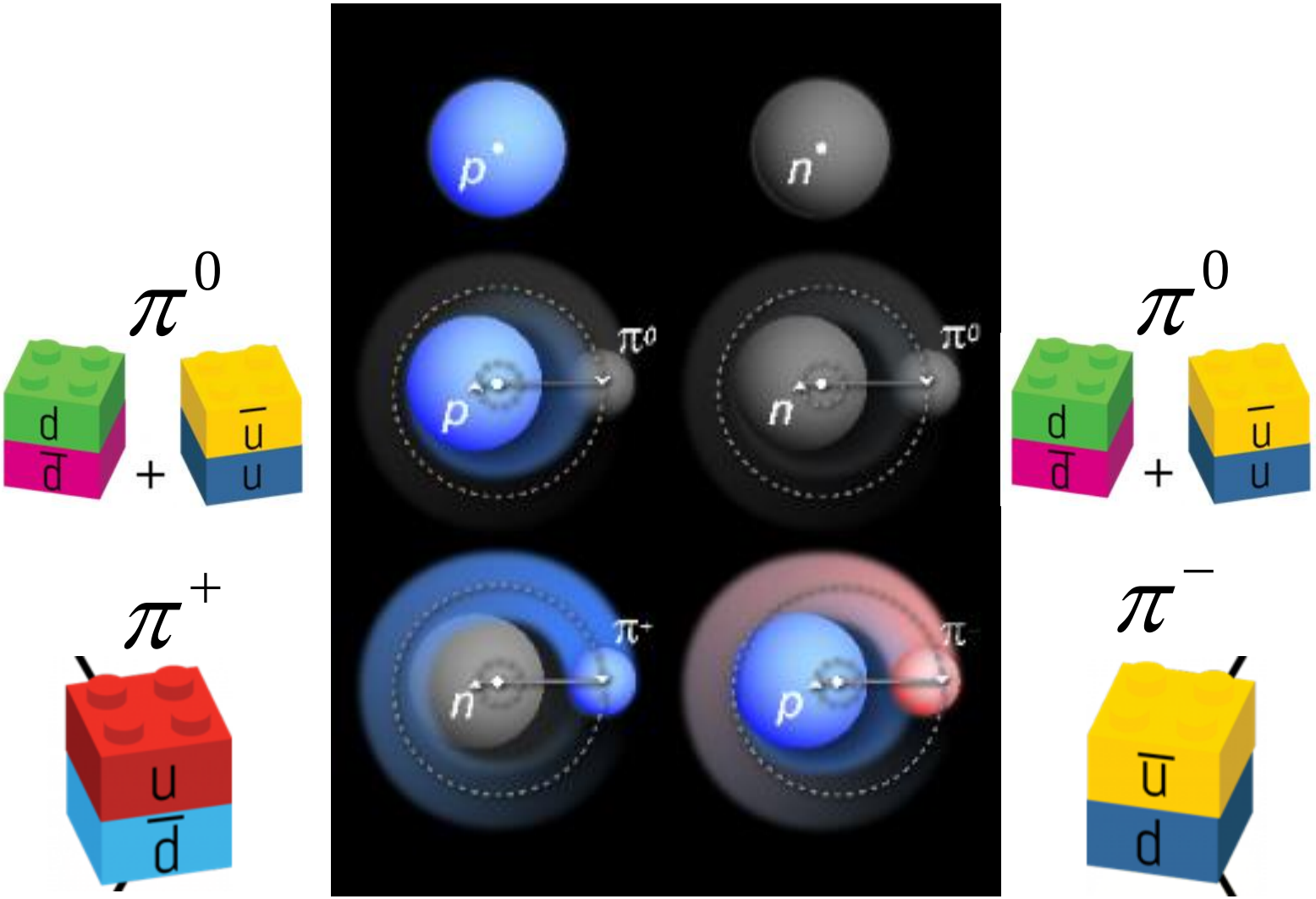
庖立不相容效應



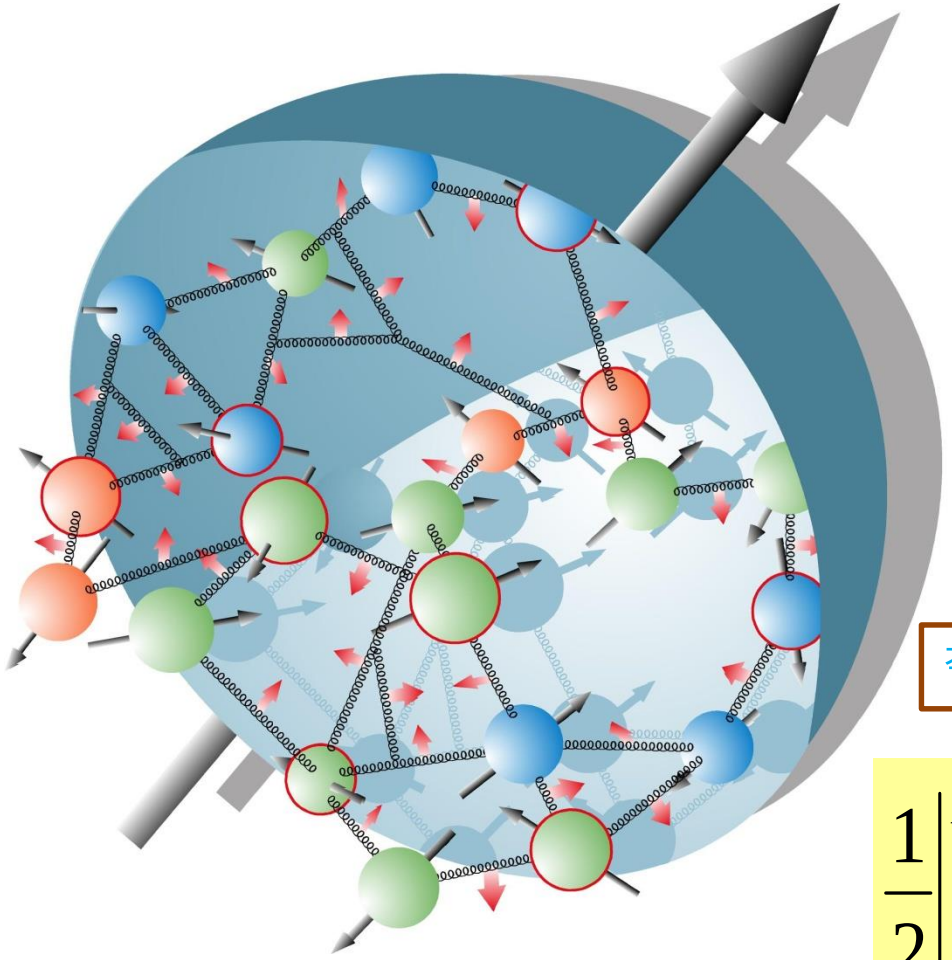


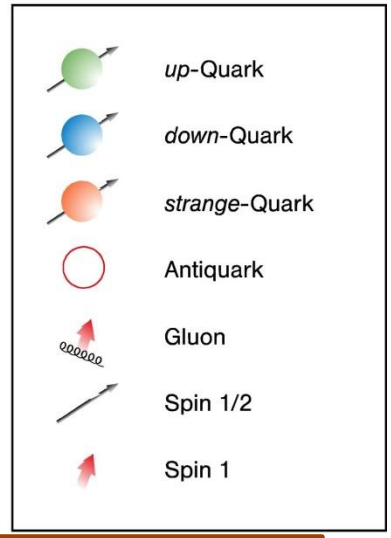
為何 $\bar{u}(x) \neq \bar{d}(x)$？介子雲

$$p \to N\pi;\ \pi^+ : \pi^0 : \pi^- = 2:1:0$$



質子自旋(s=1/2)





夸克自旋(~30%)

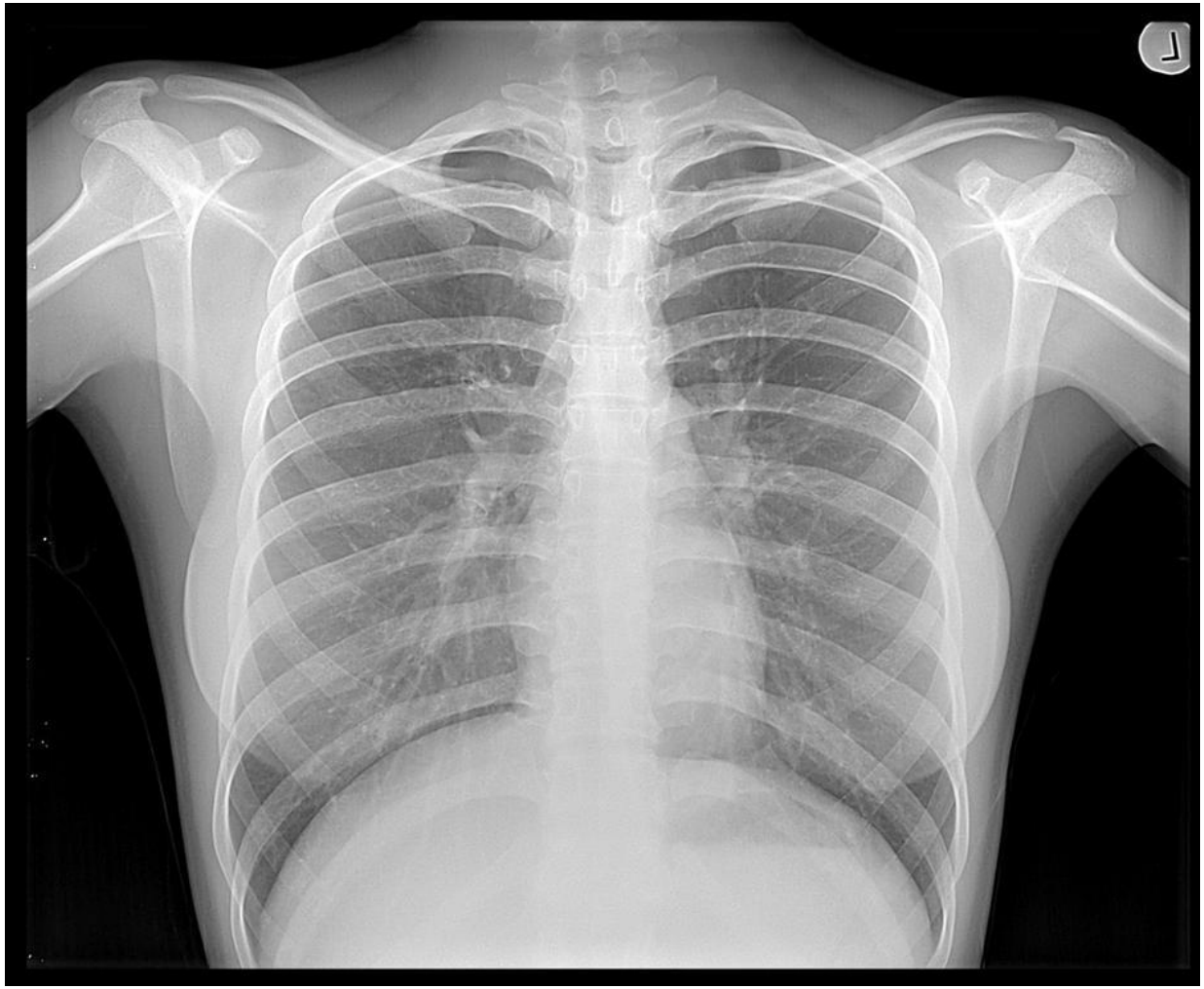
膠子自旋(~0)

$$\frac{1}{2}\Big|^{proton} = \frac{1}{2}\Delta\Sigma + \Delta g + L_q$$

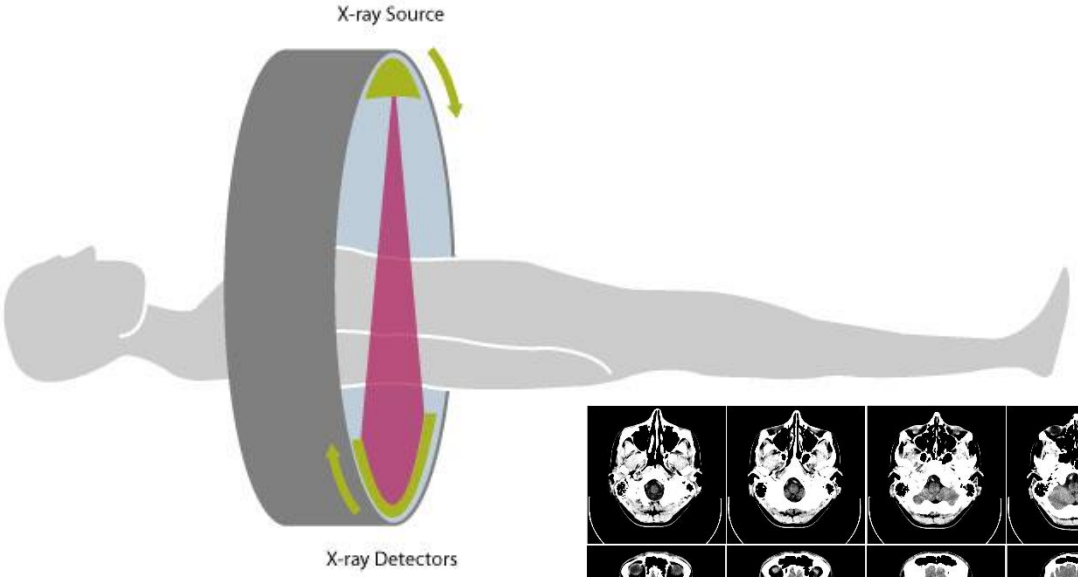
軌道角動量

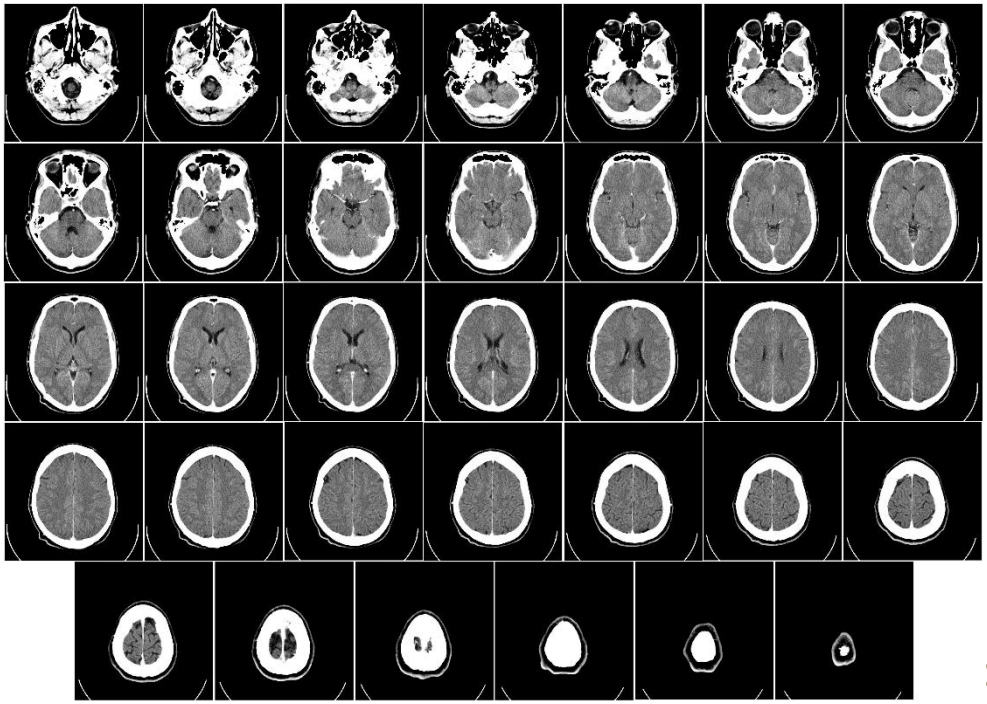
$$\overrightarrow{L_Z} = \overrightarrow{r_T} \times \overrightarrow{P_T}$$

X光圖（無深度資訊）



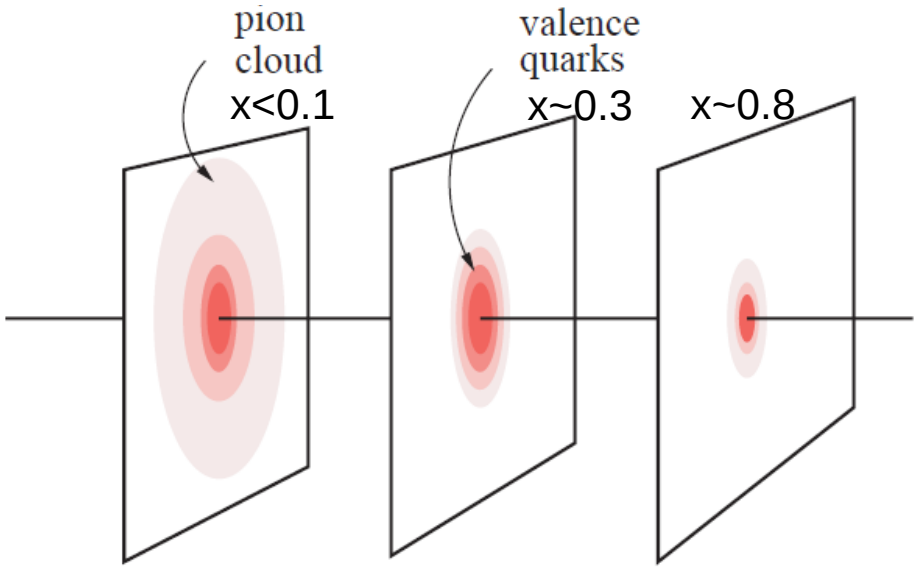
電腦斷層掃描（橫向分布）

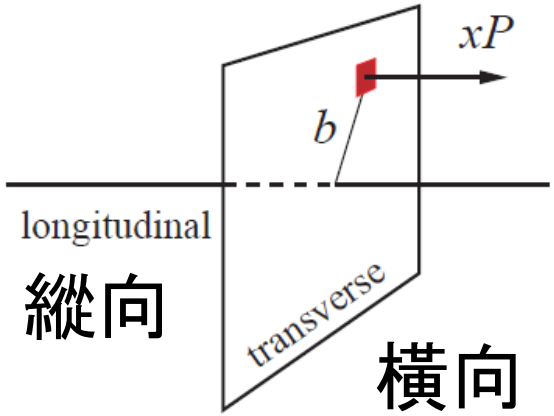




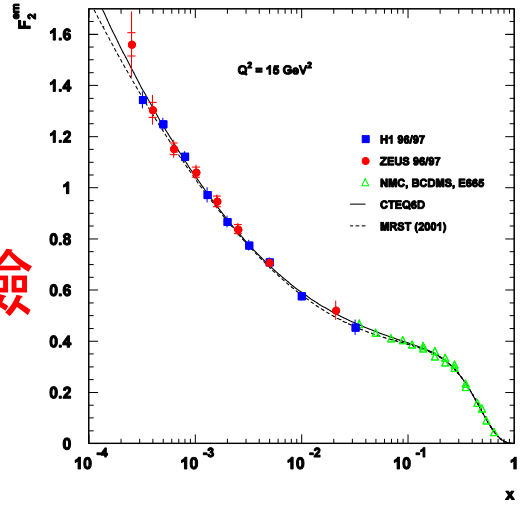
質子構成粒子的橫向位置分布 $\vec{r_T}$

介子雲　價夸克

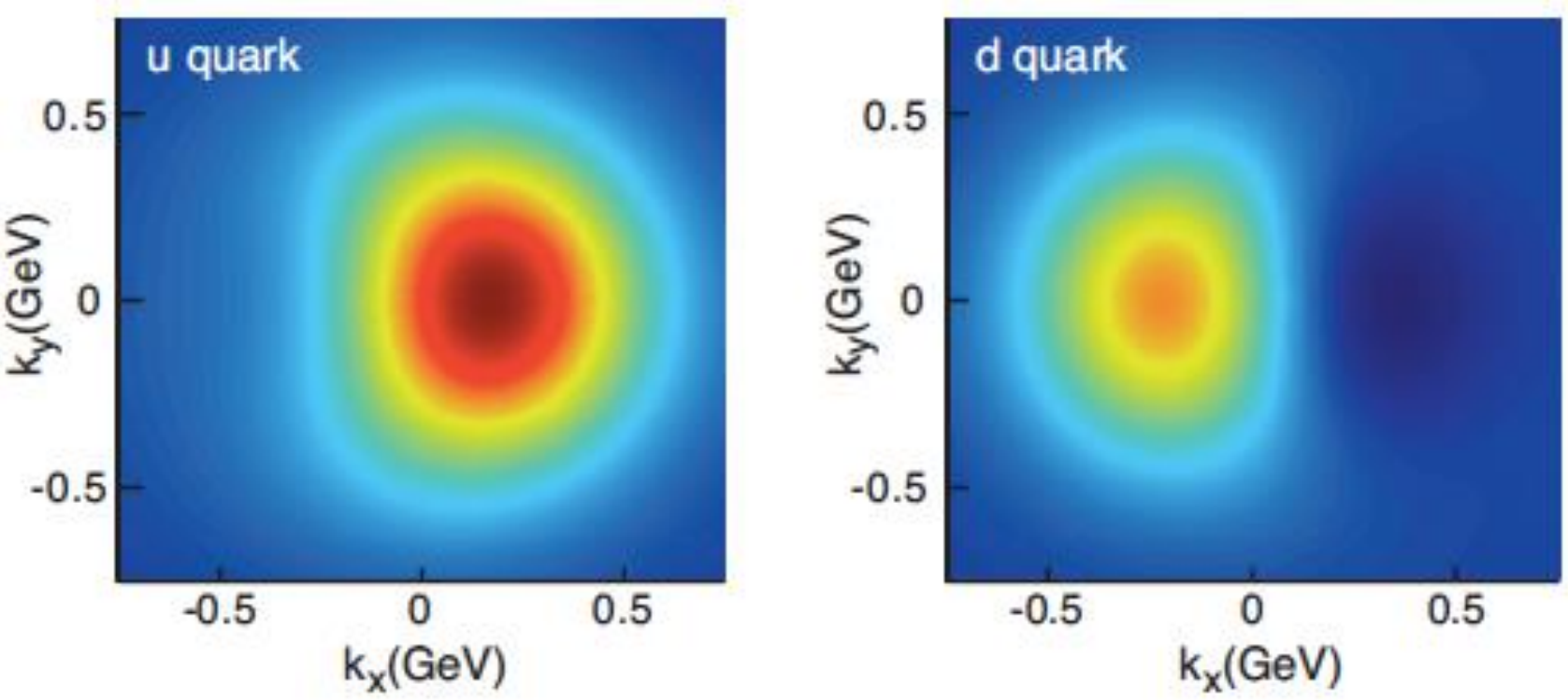




深度虛光子康普敦散射實驗

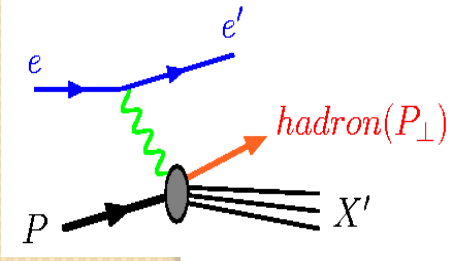


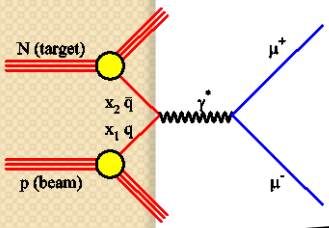
質子構成粒子的橫向動量分布 $\overrightarrow{P_T}$



橫向極化靶實驗

質子構成粒子的分布





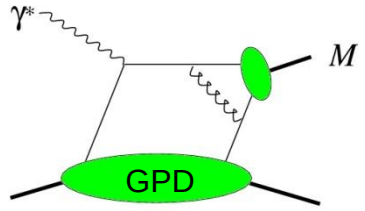
Wigner Distribution

$W(\vec{r}, x, \vec{k}_T)$

$\int d\vec{r}$

$\int e^{i\vec{q}\cdot\vec{r}} d\vec{r} d\vec{k}_T$

Ji, PRL91,062001(2003)



$\xi = q^z / 2E_q,\ t = -\vec{q}^2$

Transverse Momentum Dependent PDF $f(x, \vec{k}_T)$

Generalized Parton Distr.

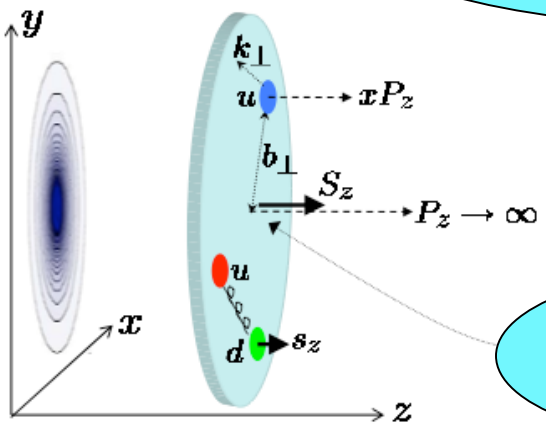
$F(x, \xi, t)$

$\int d\vec{k}_T$

$\int dx$

PDF

$f(x)$



Form Factors

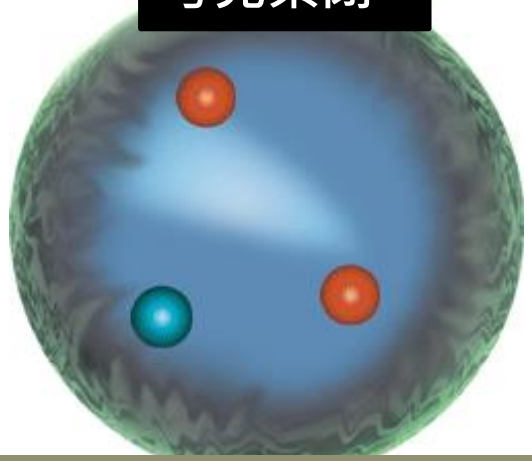
$F_1(t), F_2(t)$

高能物理重要研究課題

質量的來源

In the Standard Model for fundamental particles

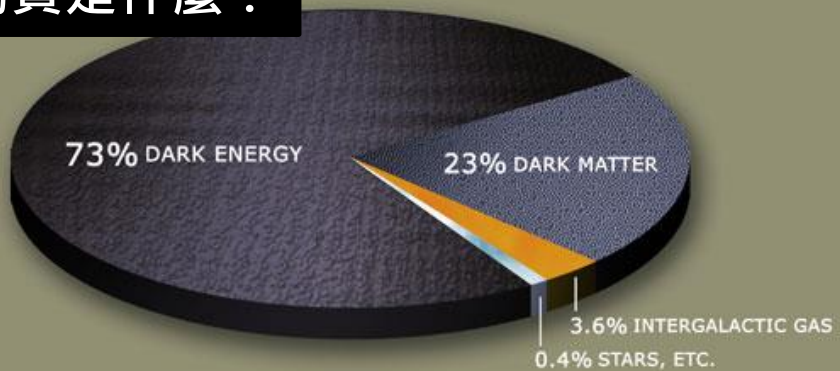
夸克禁閉



反物質到哪兒去了？

Matter and antimatter were created in the Big Bang. Why do we now see only matter except for the tiny amounts of antimatter that we make in the lab and observe in cosmic rays?

暗物質是什麼？



中研院物理所中高能實驗團隊

Collider Physics

Search for new particles and new physics

CDF
1993~ 2011
李世昌、鄧炳坤、
侯書雲、王嵩銘

ATLAS
1999~
李世昌、鄧炳坤、
侯書雲、王嵩銘

Astroparticle Physics

Search for antimatter, dark matter and new form of matter

AMS
1995~
李世昌、灰野禎一、林志勳

Neutrino Physics

Probing the Universe through neutrinos

TEXONO
1996~
王子敬、李世昌

Nuclear Physics

Probing nucleons by GeV photons and protons

LEPS, SeaQuest
1999~
章文箴

Instrumentation

From experimental support to the development of novel detectors

朱明禮、林志勳

GRID Computing

Asian grid center for WLCG

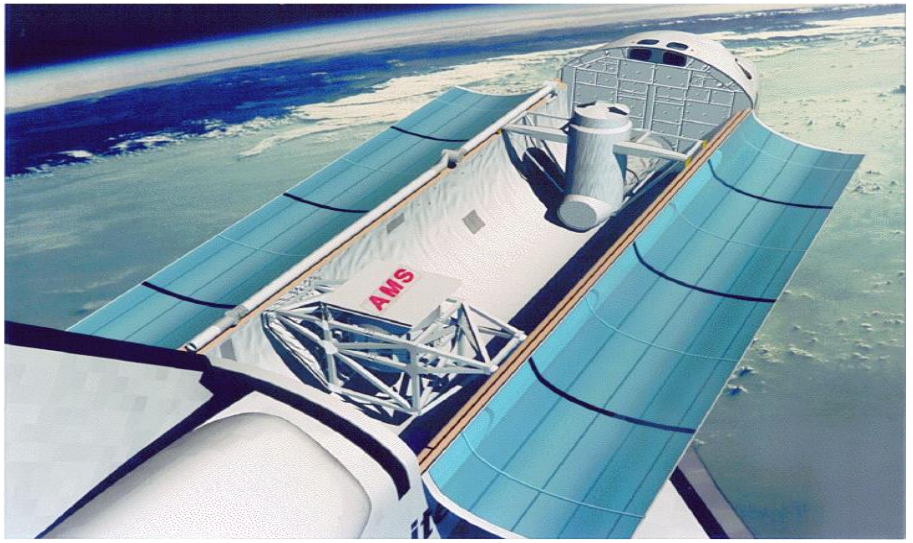
林誠謙、李世昌

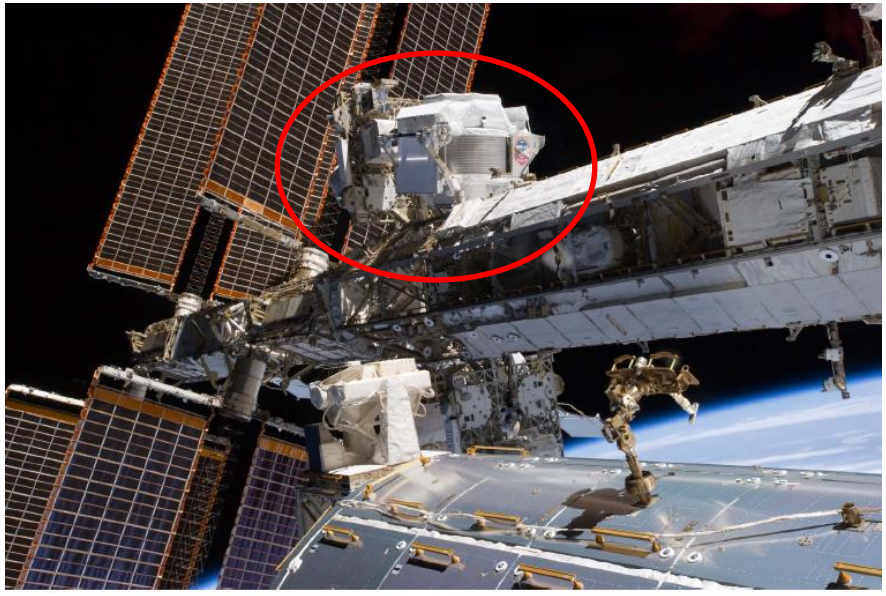
Interdisciplinary Research

A small accelerator for supporting and pioneering researches in nano-, bio- and medical-sciences

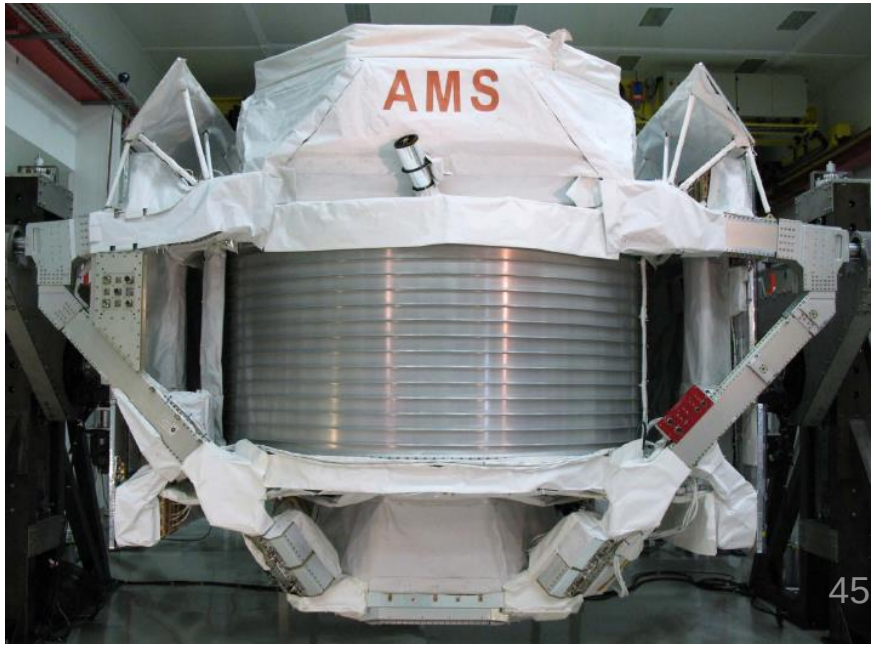
余岳仲、鄧炳坤

AMS 太空磁譜儀 *(AS, NCU ,CSIST, NSPO, NCKU, NTHU)*



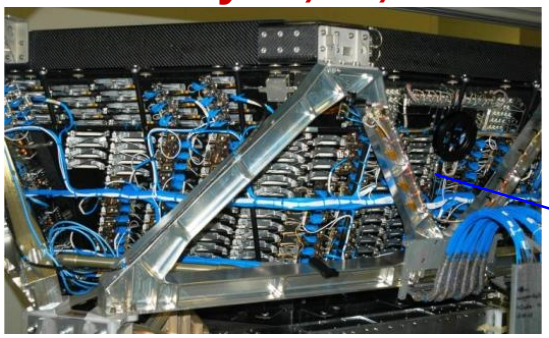


AMS on the ISS truss. May 19, 2011

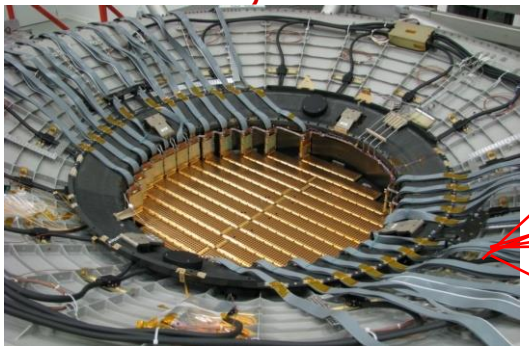


AMS 太空磁譜儀

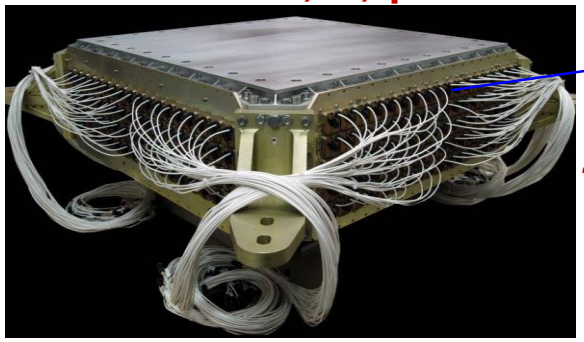
TRD
Identify e^+, e^- , Z



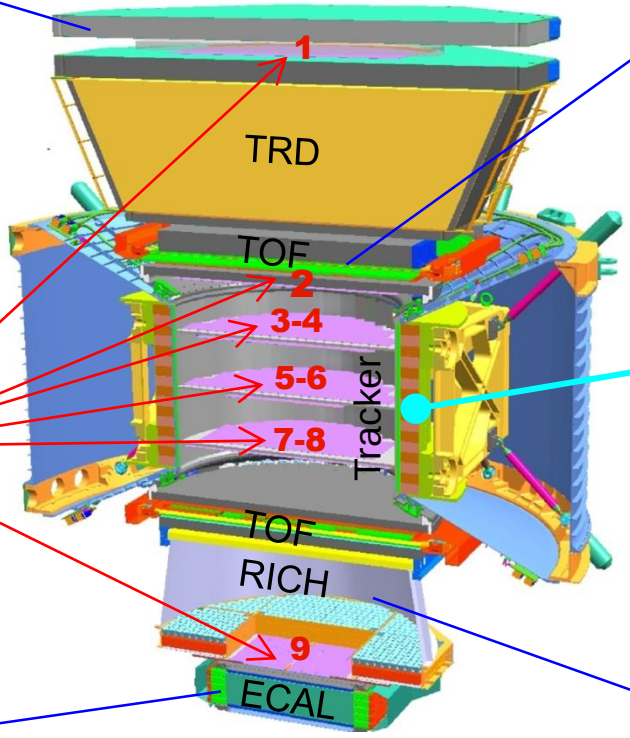
Silicon Tracker
Z, P



ECAL
E of e^+, e^-, γ



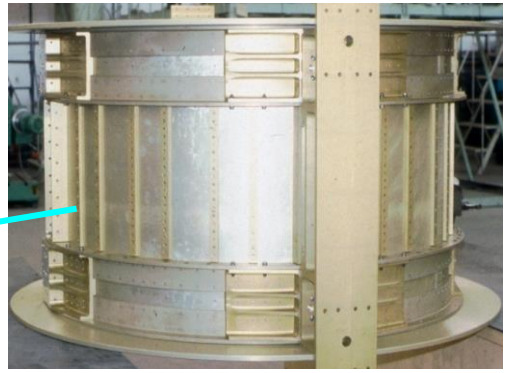
Particles and nuclei are defined by their charge (**Z**) and energy (**E ~ P**)



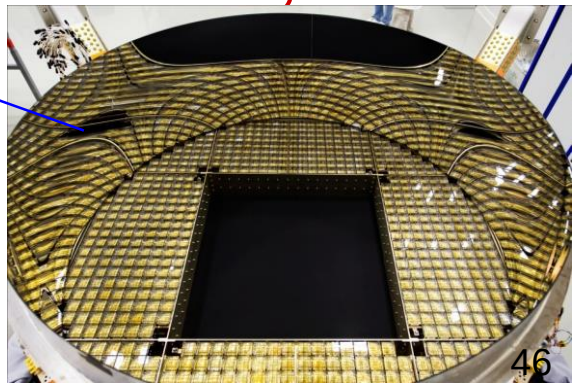
***Z, P** are measured independently by the Tracker, RICH, TOF and ECAL*

TOF
Z, E

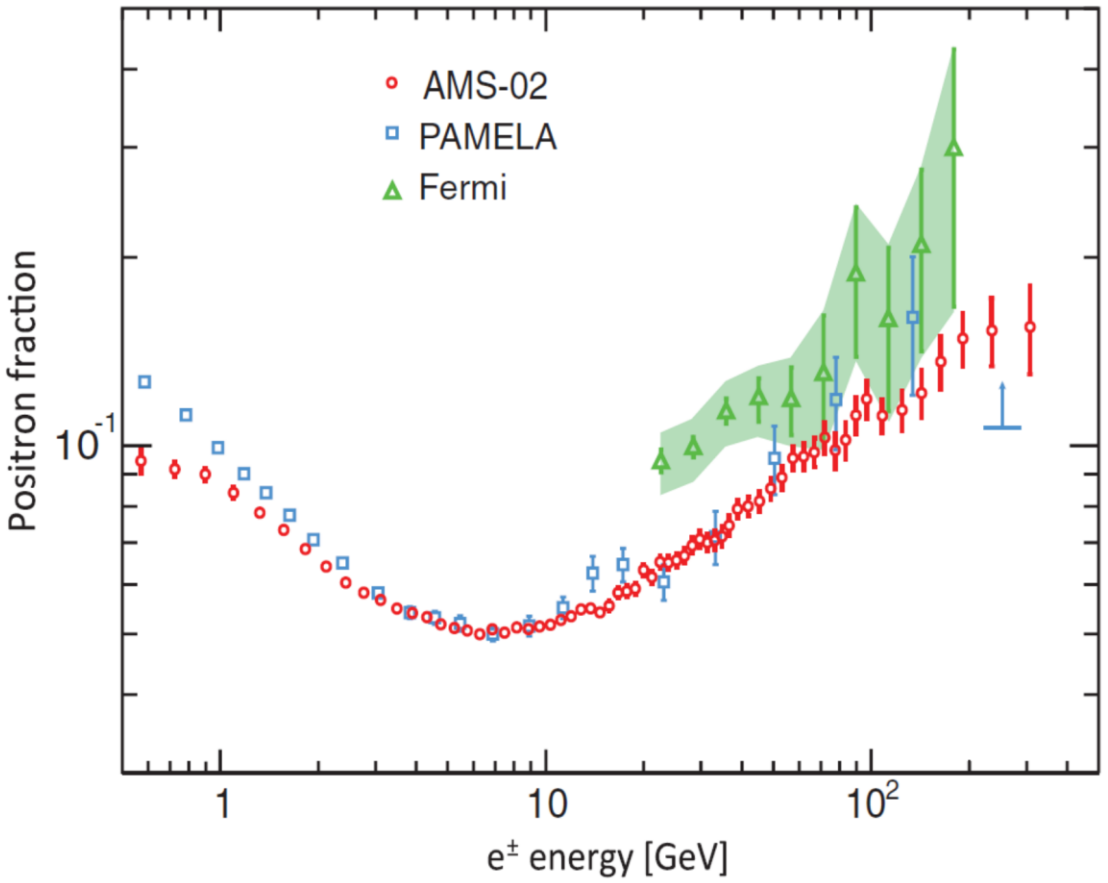
Magnet
±Z



RICH
Z, E



宇宙射線中正電子的比例



Phys. Rev. Lett. 110, 141102 (2013)

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Search for new particles and new physics

CDF
1993~ 2011
李世昌、鄧炳坤、
侯書雲、王嵩銘

ATLAS
1999~
李世昌、鄧炳坤、
侯書雲、王嵩銘

Astroparticle Physics

Search for antimatter, dark matter and new form of matter

AMS
1995~
李世昌、灰野禎一、林志勳

Neutrino Physics

Probing the Universe through neutrinos

TEXONO
1996~
王子敬、李世昌

Nuclear Physics

Probing nucleons by GeV photons and protons

LEPS, SeaQuest
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章文箴

Instrumentation

From experimental support to the development of novel detectors

朱明禮、林志勳

GRID Computing

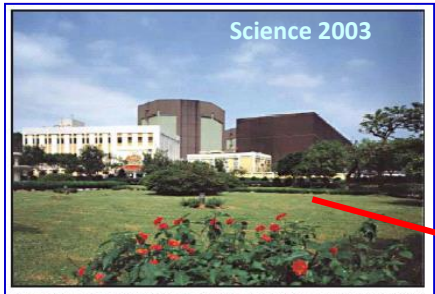
Asian grid center for WLCG

林誠謙、李世昌

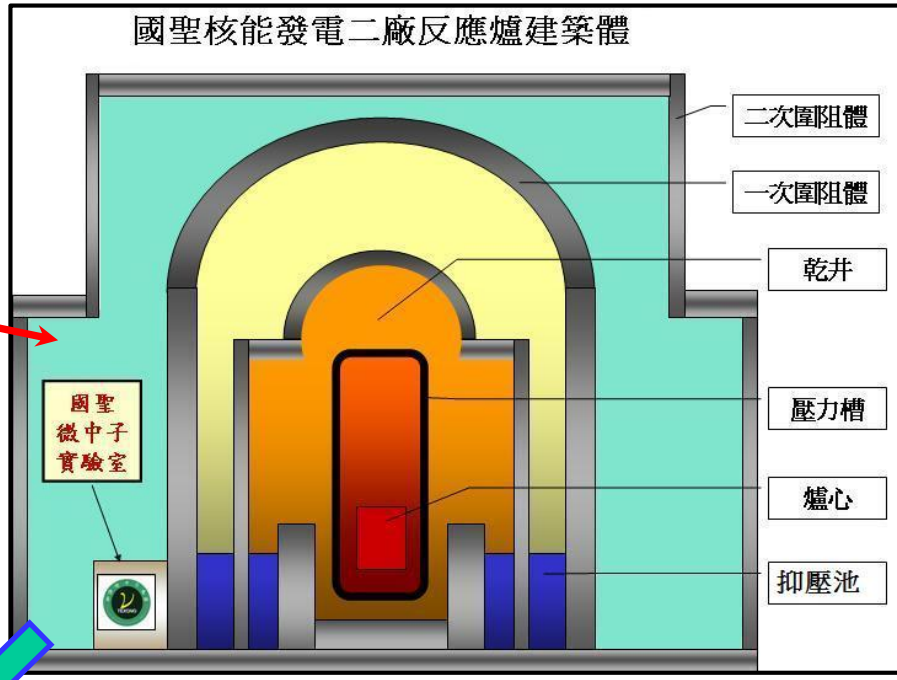
Interdisciplinary Research

A small accelerator for supporting and pioneering researches in nano-, bio- and medical-sciences

余岳仲、鄧炳坤



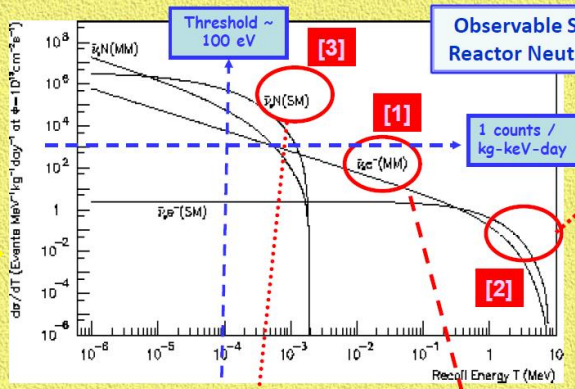
Powerful collaboration. Scientists from Taiwan and mainland China are studying neutrino emissions from this nuclear power plant outside Taipei.

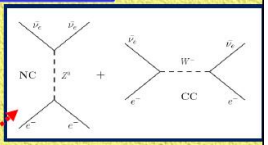


28 m from core#1 @ 2.9 GW

Neutrino Properties & Interactions at Reactor

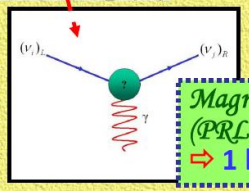
quality ⟵ Detector requirements ⟶ mass





Standard Model & NSI νe Scattering
(2⊗ PRD10;PRD12)
⇨ 200 kg CsI(Tl)

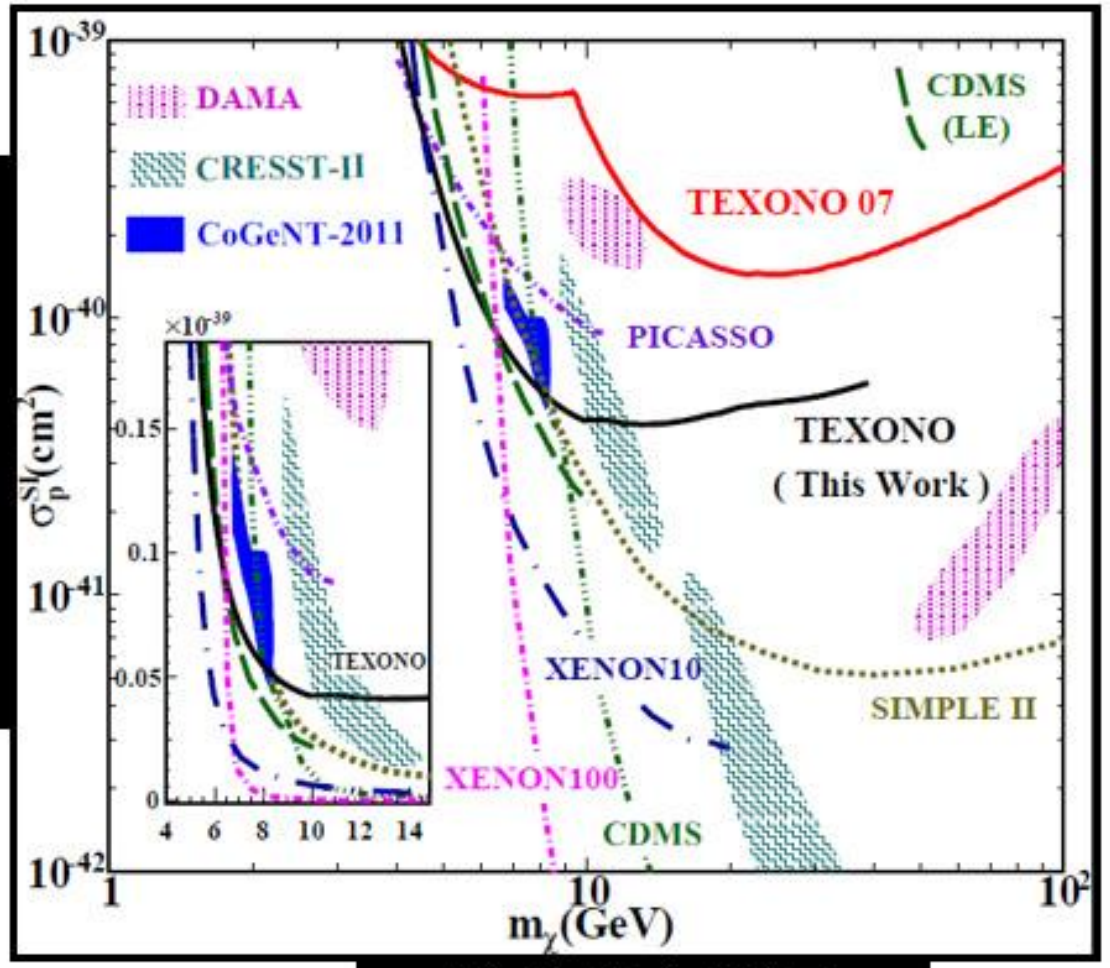
νN Coherent Scattering
⇨ Dark Matter Searches (PRD-RC09)
⇨ sub-keV O(kg) ULEGe / PCGe



Magnetic Moments
(PRL03,PRD5,PRD07)
⇨ 1 kg HPGe

Interaction Probability between Dark and Ordinary Matter

暗物質與標準物質交互作用機率



暗物質之質量

Dark Matter Mass

Phys. Rev. Lett. 110, 261301 (2013)

中研院物理所中高能實驗團隊

Collider Physics

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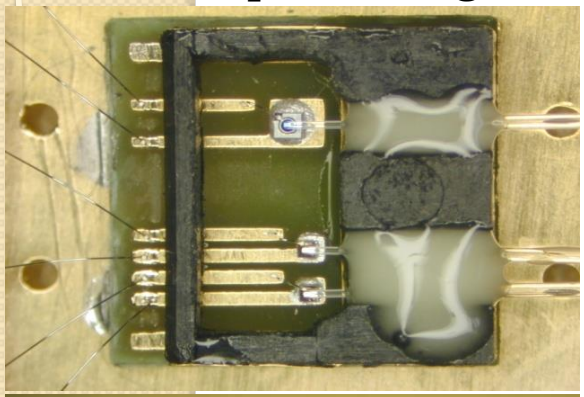
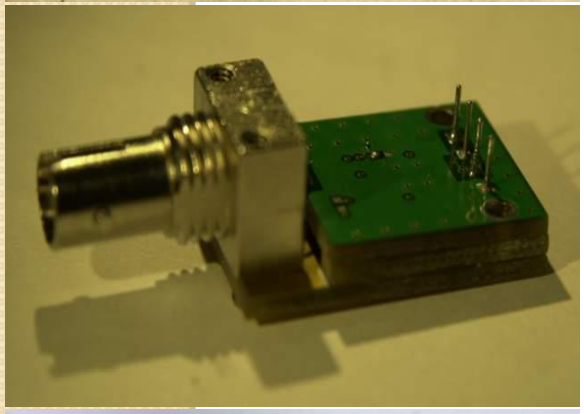
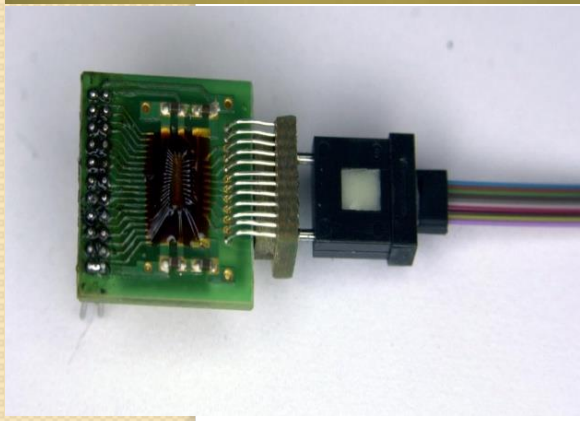
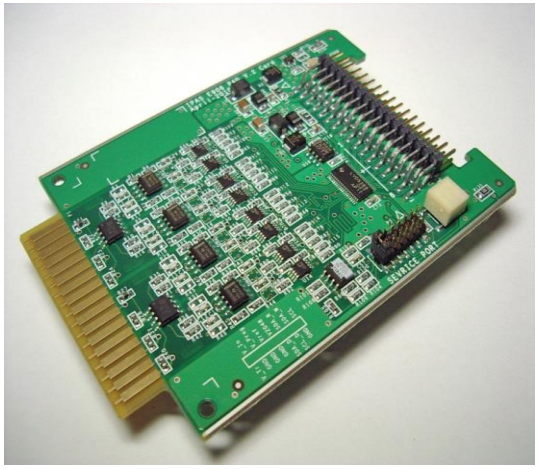
快速電子元件研發

ATLAS Opto-Packages

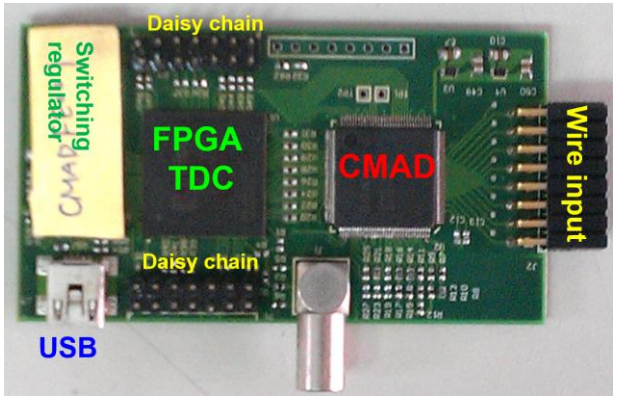




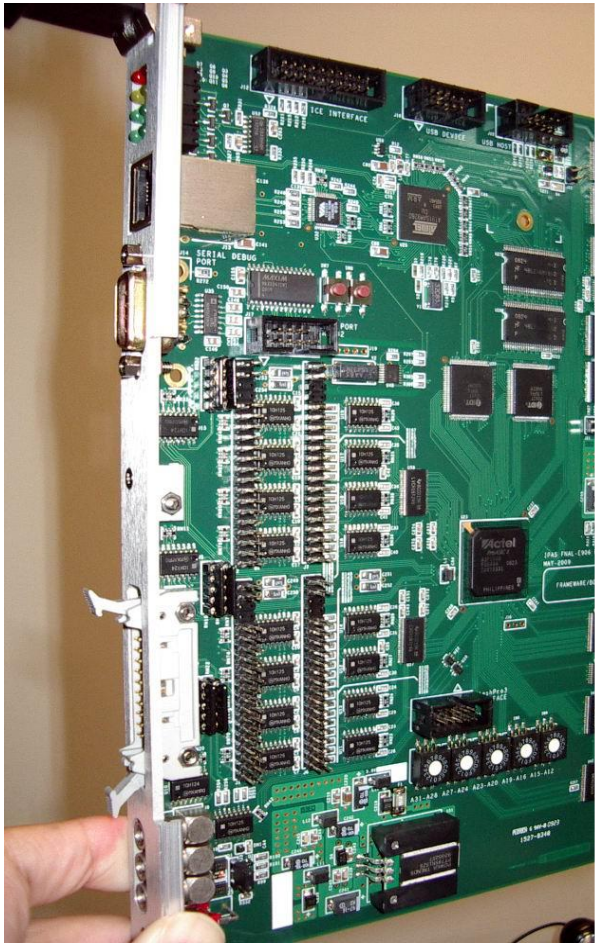




E906 PreAmp card



COMPASS FEM prototype



E906 VME CR card

Academia Sinica drives e-science in Asia-Pacific

The Academia Sinica Grid Computing Centre (ASGC) in Taipei is currently the only LCG Tier-1 Centre in the Asia-Pacific area, with 400 KSI2K computing capacity, 50 TB disk space and a 35 TB tape library dedicated to the LCG. Since 2004, Academia Sinica has provided the services of a regional operation centre (ROC), site monitoring, virtual-organization (VO) support, middleware deployment, certificate authority (CA) and global Grid-user support (GGUS – mainly first-line support and FAQs). The centre supports not only Tier-2 sites locally, but also Grid operations in South Korea, Singapore and other Asia-Pacific countries that are not supported by other Tier-1 sites.

To support service and data challenges, a maximum 1.6 Gbit/s transmission rate was achieved in the 2 Gbit network bandwidth between CERN and ASGC in June 2005. During the CMS service challenge, ASGC received 20 TB of data from CERN at an average rate from 14 July to 14

Grid tutorial at the Academia Sinica Grid Computing Centre.

ASGC Tier-1 Centre provided 12% of the LCG-2 computing jobs, second only to the 14% of CERN in the ATLAS data challenge in 2004. Academia S T si a th

CERN COMPUTER NEWSLETTER

Volume XL, issue 4 September–October 2005

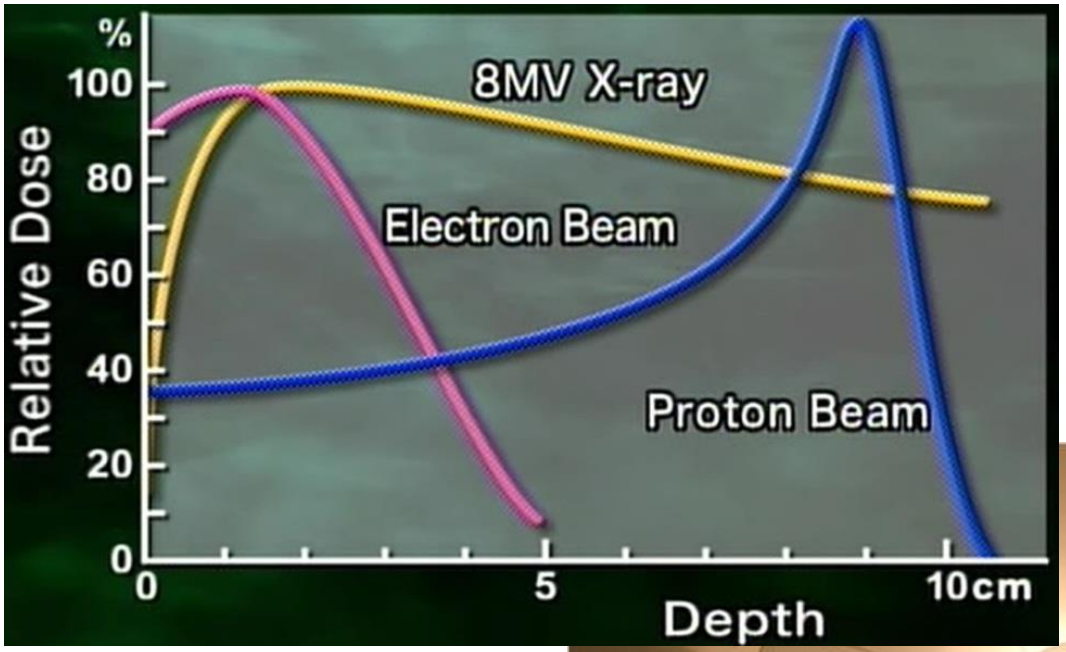
collaboration and sharing of information by taking advantage of e-science applications in the Asia-Pacific area. ASGC is also working with different partners to help form and support application-driven e-science communities in the Asia-Pacific region, to improve the next-generation research infrastructure and build up the e-science applications. Hosting

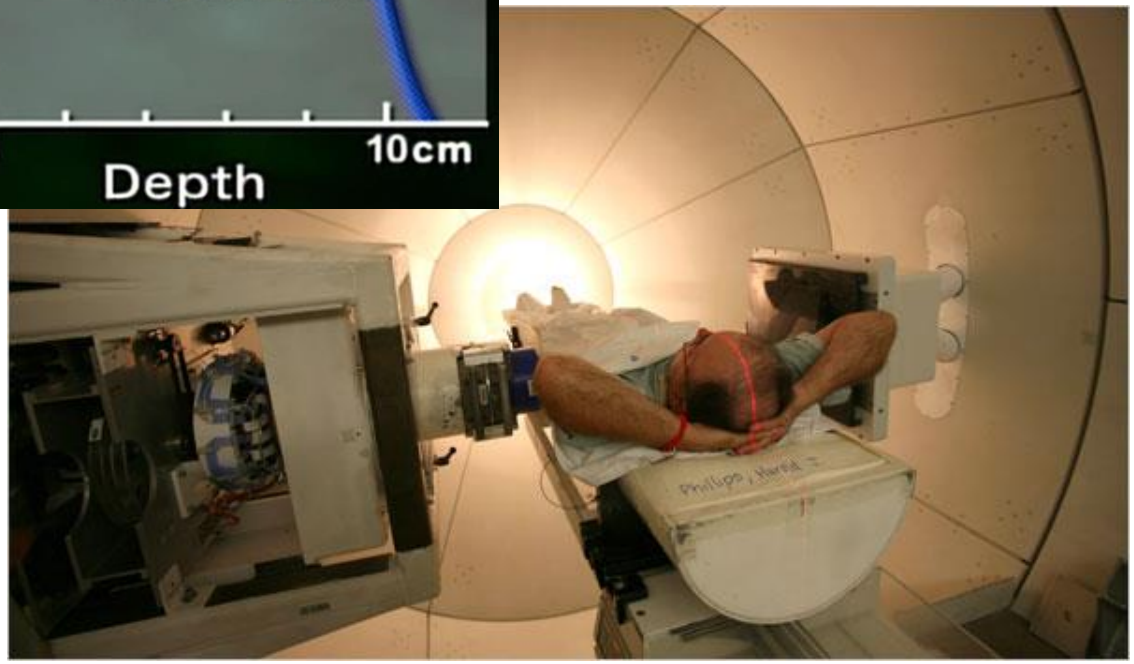
6

ASGC TWGrid

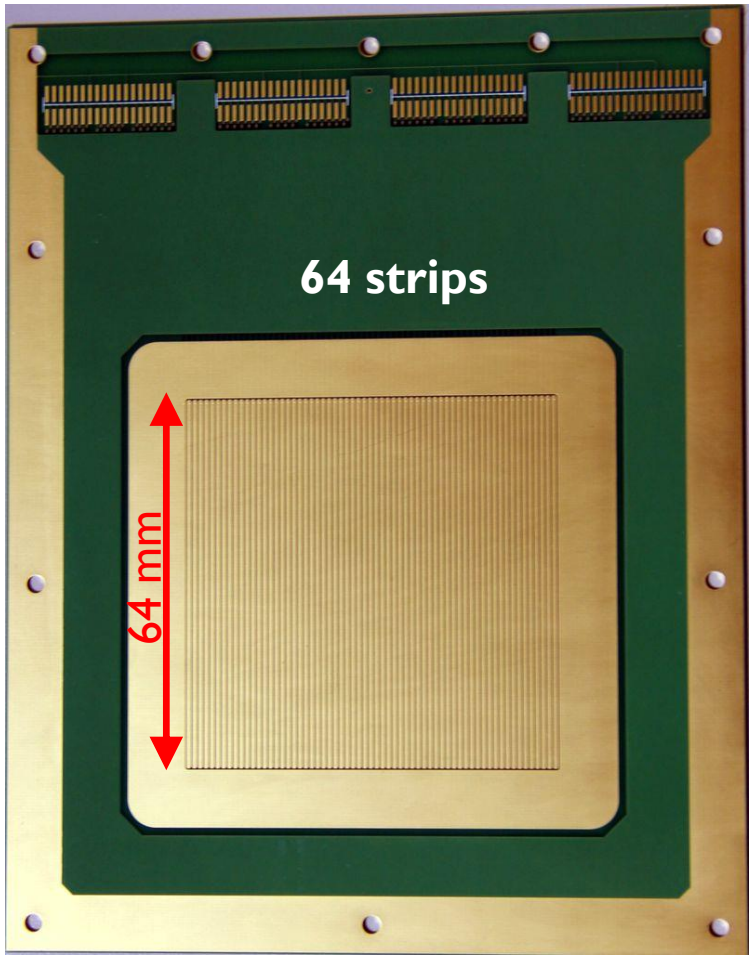
網格（雲端）運算

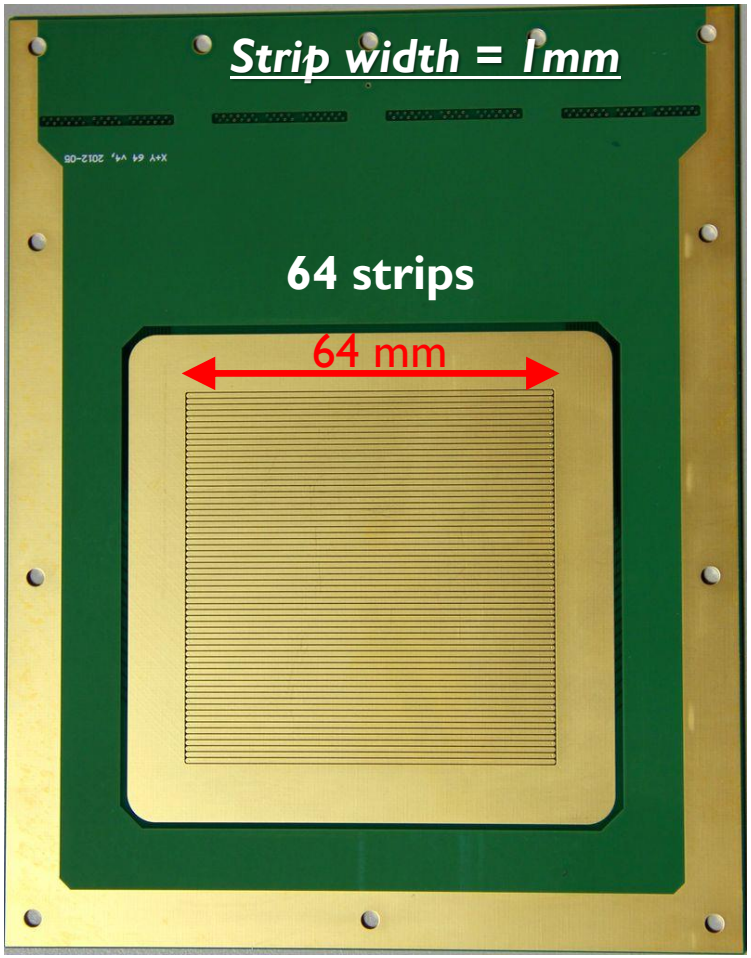
質子治療技術 (Proton Therapy)



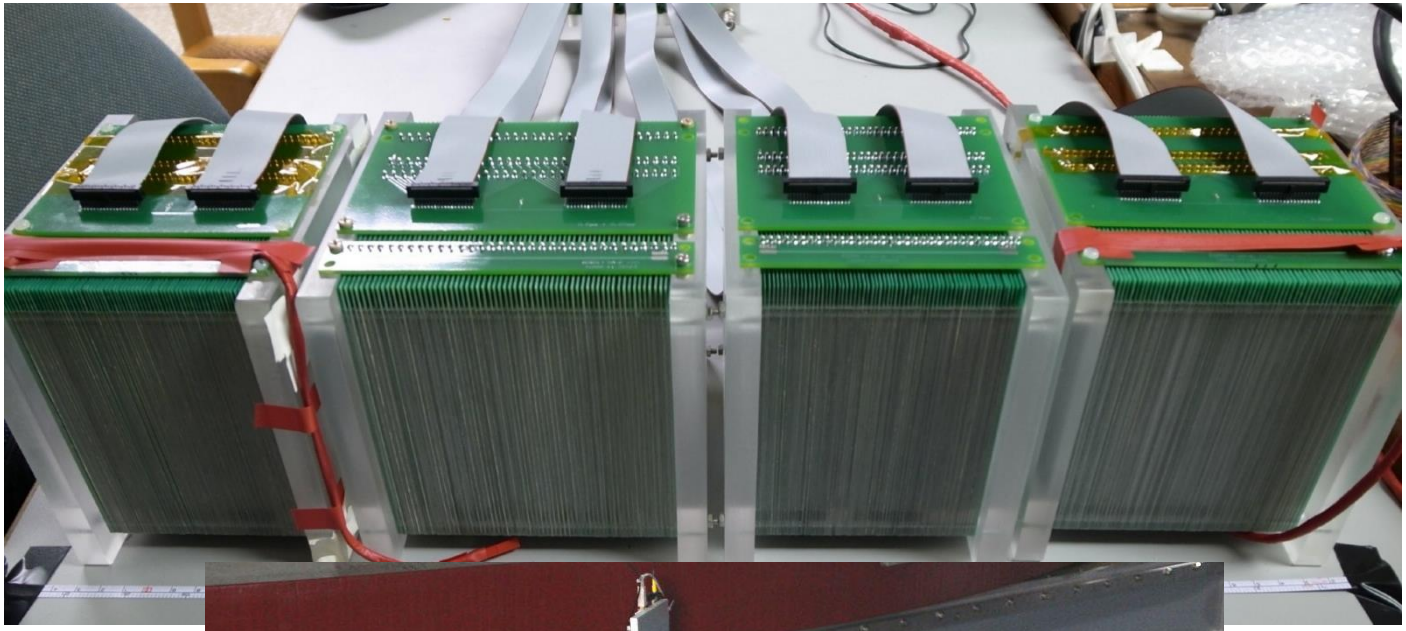


帶電粒子位置偵測器

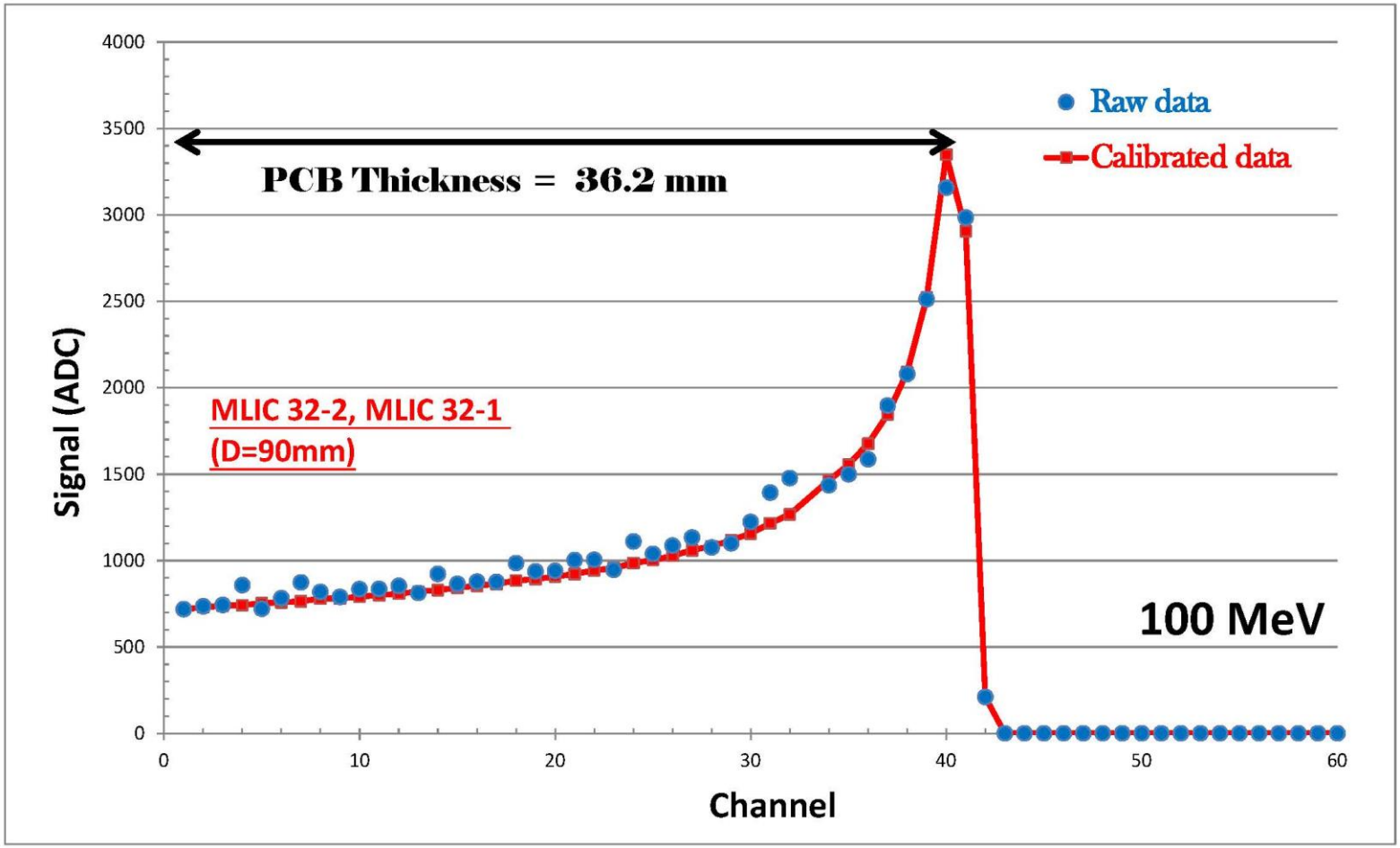




多層帶電粒子測定儀



質子射束在水中能量損失與深度的關係



結論

- 高能物理是基礎科學的前沿，透過探索最小尺度下基本構成粒子和作用方式，期盼達到「化繁為簡」。
- 質子的內部除了夸克外，還有豐富多樣的膠子和反夸克成分。我們對於質子結構粒子分布的測量，正從1維進入多維。
- 高能物理仍有許多未解之謎，我們相信這會是一趟「驚奇之旅」，歡迎加入！