Golden Years

1967

50 golden years ago

Table 1.1

REST MASSES OF THE MOST STABLE ELEMENTARY PARTICLES

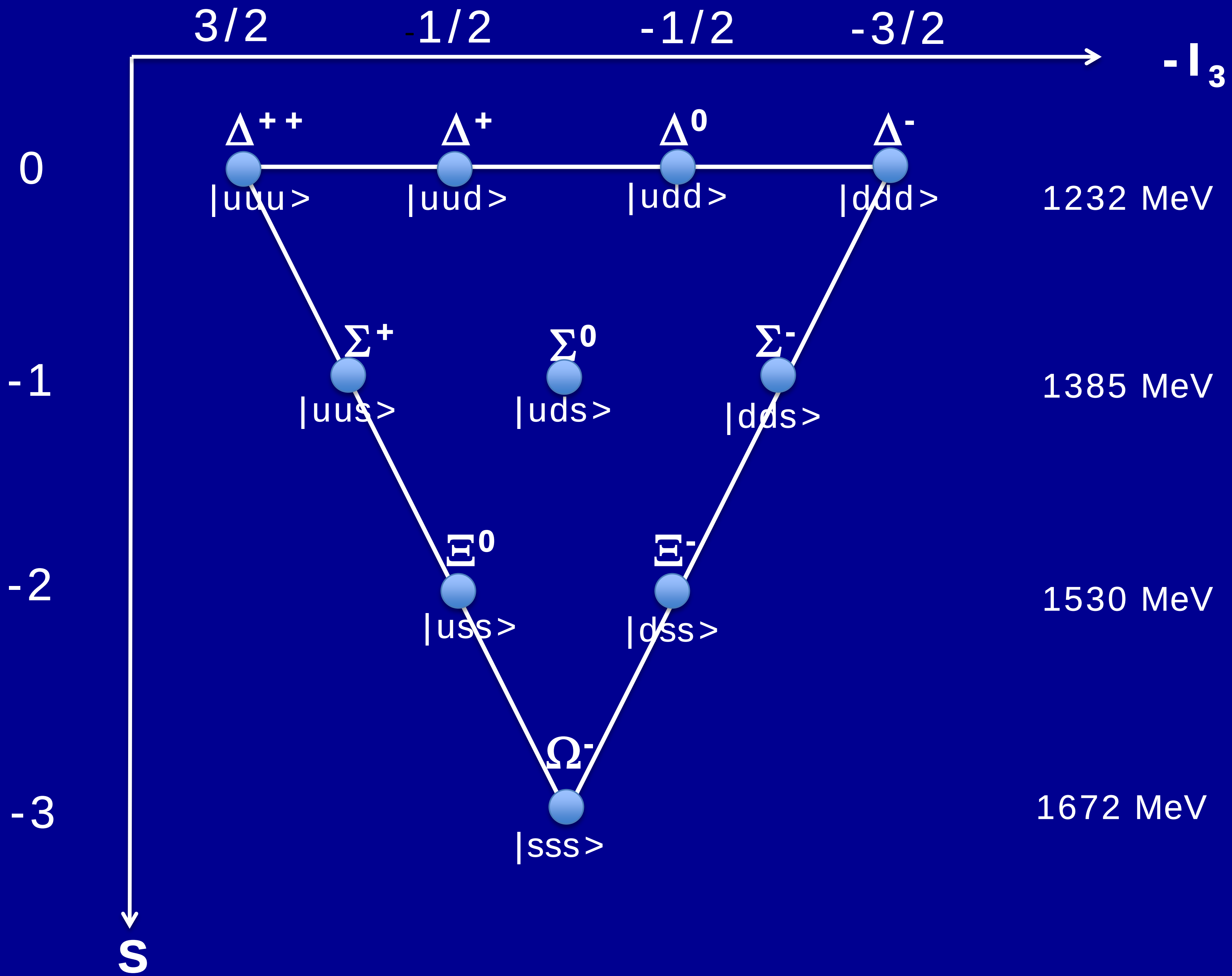
Particle	Symbol*	Rest mass, Mev
Photon	$\gamma(\overline{\gamma} \equiv \gamma)$	0
Neutrino	$\nu_e, \nu_\mu(\overline{\nu}_e, \overline{\nu}_\mu)$	0
Electron	$e(e^+)$	0.51
Mu meson	$\mu^-(\mu^+)$	106
Pi meson	$\pi^+(\pi^-)$	140
	$\pi^0(\overline{\pi^0} \equiv \pi^0)$	135
K meson	$K^+(K^-)$	494
	$K^0(\overline{K^0})$	498
Eta meson	$\eta^0(\overline{\eta^0} \equiv \eta^0)$	548
Proton	$p(\overline{p})$	938.2
Neutron	$n(\overline{n})$	939.5
Λ Hyperon	$\Lambda(\overline{\Lambda})$	1115
Σ Hyperon	$\Sigma^+(\overline{\Sigma^-})$	1192
	$\Sigma^0(\overline{\Sigma^0})$	1194
	$\Sigma^-(\overline{\Sigma^+})$	1197
Ξ Hyperon	$\Xi^0(\overline{\Xi^0})$	1310
	$\Xi^-(\overline{\Xi^+})$	1320
Ω Hyperon	$\Omega^-(\overline{\Omega^+})$	1676

* Antiparticle symbol in parenthesis.

1.10 Velocity Addition

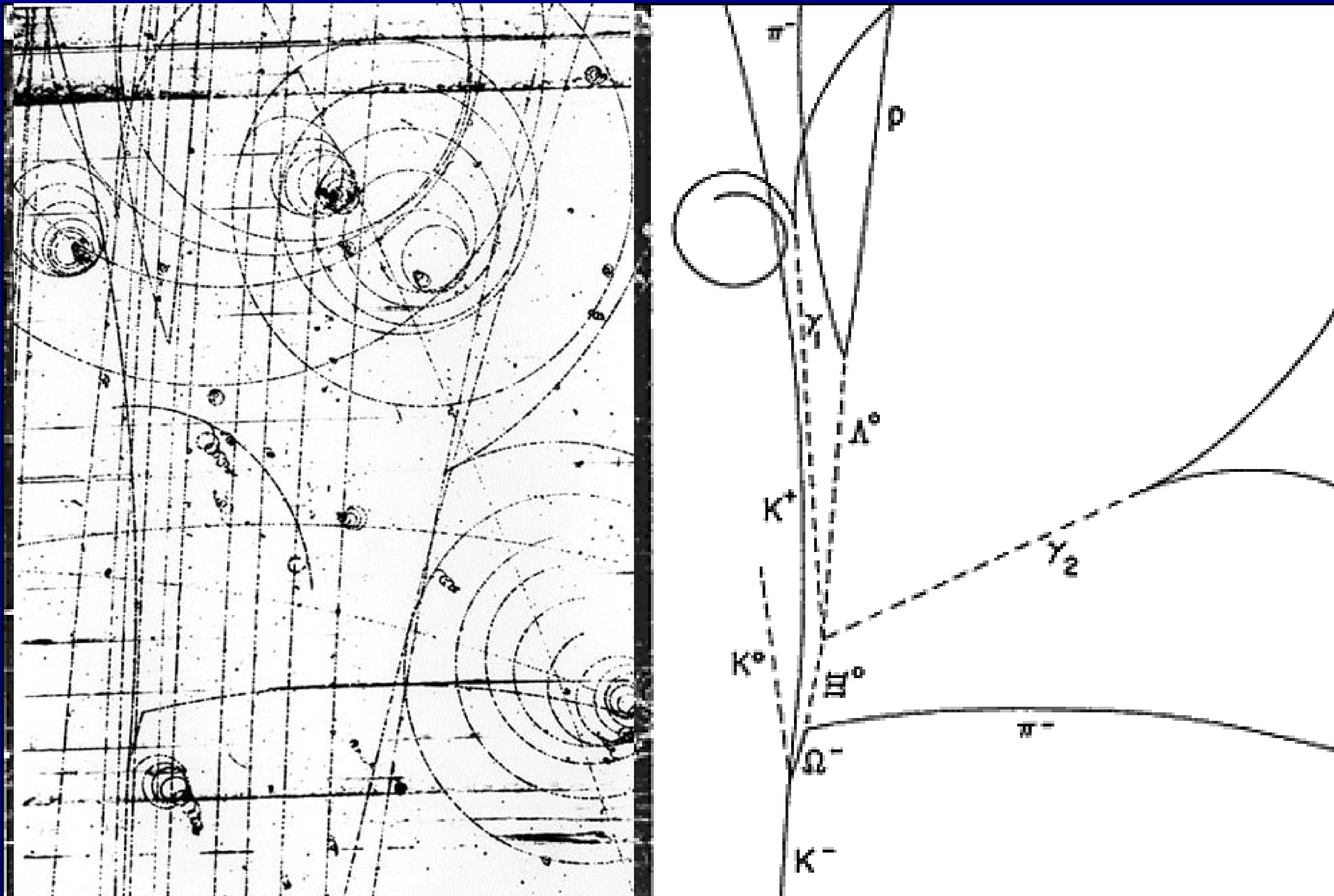
One of the postulates of special relativity states t
free space has the same value for all observers, reg
tion. But "common sense" tells us that, if we thr
sec from a car moving at 80 ft/sec, the ball's spee
130 ft/sec, the sum of the two speeds. Hence we
light emitted in a frame of reference S' in the
velocity v relative to another frame S will have a s
in S, contradicting the above postulate. "Commo
as a guide in science than it is elsewhere, and we

From: Concepts of Modern Physics (Beiser, Revised Edition, **1967**)



3/2
1/2
-1/2
-3/2
-I3
0
-1
-2
-3
S
Δ++
Δ+
Δ0
Δ-
|uuu>
|uud>
|udd>
|ddd>
1232 MeV
Σ+
Σ0
Σ-
|uus>
|uds>
|dds>
1385 MeV
Ξ0
Ξ-
|uss>
|dss>
1530 MeV
Ω-
|sss>
1672 MeV

$K^- p \rightarrow \Omega^- K^+ K^0$



ELSEVIER

Nuclear Physics B

Volume 142, Issue 3, 25 September 1978, Pages 205–219

Ω^- produced in K^-p reactions at 4.2 GeV/*c*

Amsterdam-CERN-Nijmegen-Oxford Collaboration R.J. Hemingway*, R. Armenteros, C. Dionisi, Ph. Gavillet, A. Gurtu**, S.O. Holmgren***, M.J. Losty[a], J.C. Marin, M. Mazzucato, L. Montanet

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B. Foster, P. Grossmann, P.R. Lamb[·], J.L. Lloyd, J. Wells[··]

[d] Nuclear Physics Laboratory, University of Oxford, [b]Oxford, UK

Received 23 May 1978, Available online 18 October 2002

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http://dx.doi.org/10.1016/0550-3213(78)90197-9

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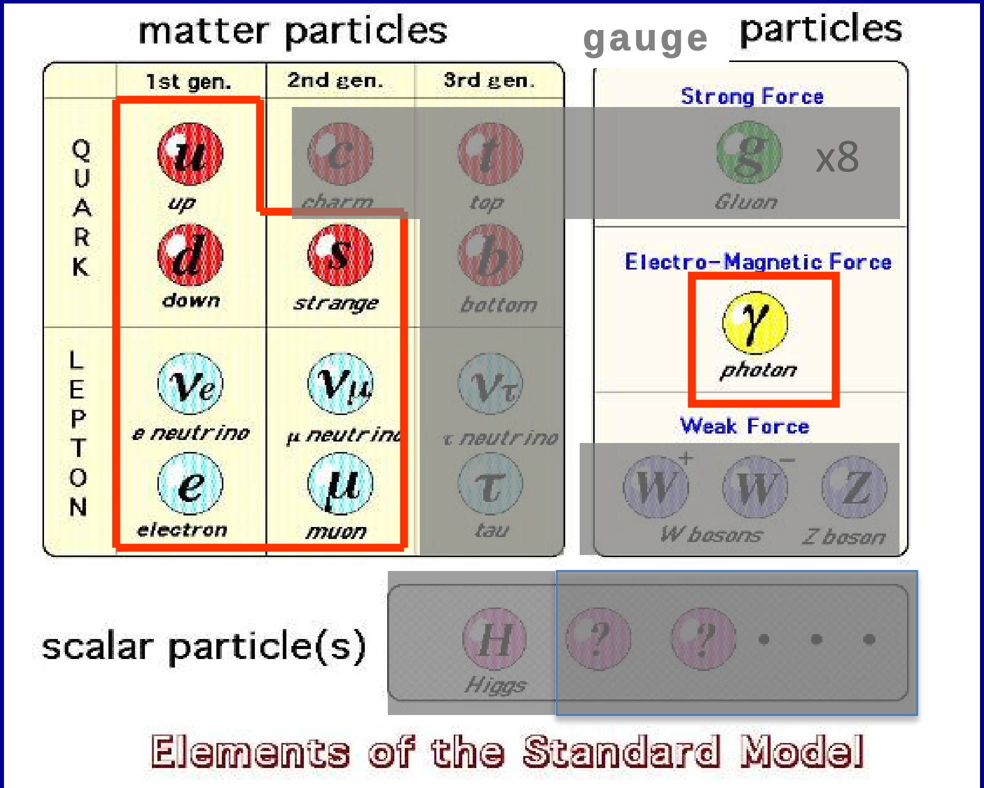
Abstract

Forty Ω^- events have been observed in a large (133 events/βb) experiment at 4.2 GeV/*c* incident K^- momentum. Thirty nine of the events come from the three-body reaction $K^-p \to \Omega^- K^+ K^0$. The Ω^- is mainly produced in the forward hemisphere (direction of the incident K^-). The lifetime is measured to be $\tau = (0.75_{+0.14-0.11} \times 10^{-10}$ sec substantially less than the Particle Data Group value of $(1.3_{-0.3}^{+0.2}) \times 10^{-10}$ sec. The mass is determined to be 1671.7 ± 0.6 MeV, in good agreement with other determinations. The decay asymmetry parameter α (for the decay mode $\Omega^- \to \Lambda K^-$) is found to be −0.2 ± 0.4.

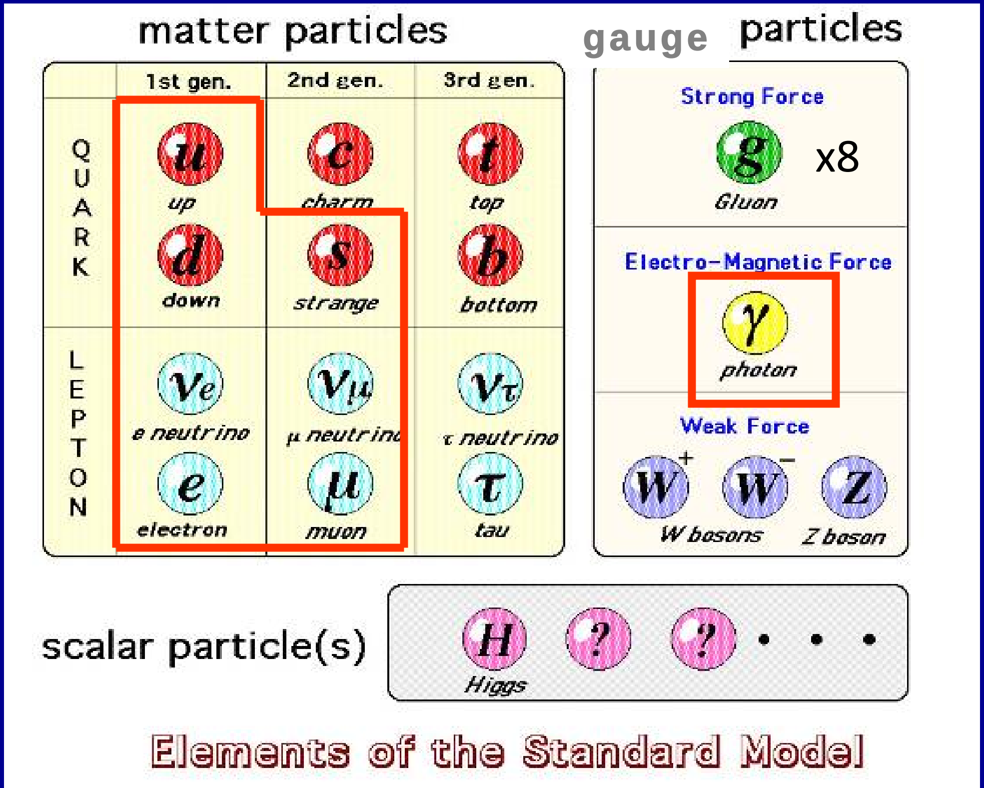
Experimental situation

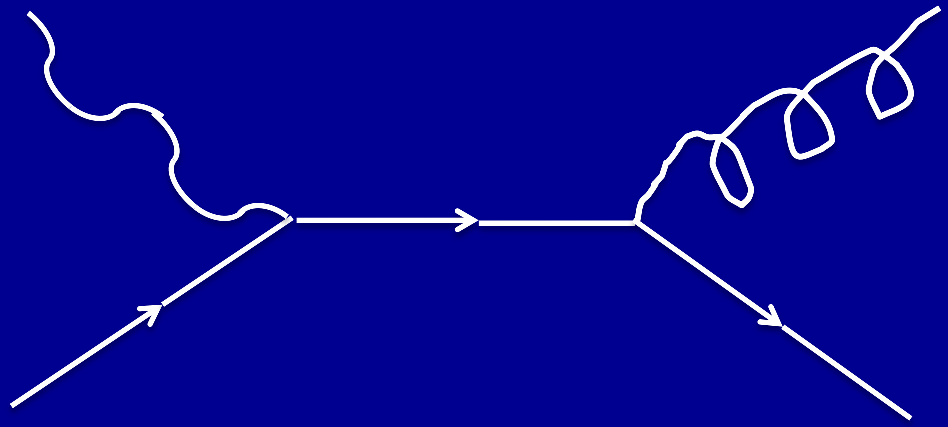
1971



There is more than represented in this cartoon !
– interactions & ? – will come back to it

Experimental situation now





QCD Compton effect

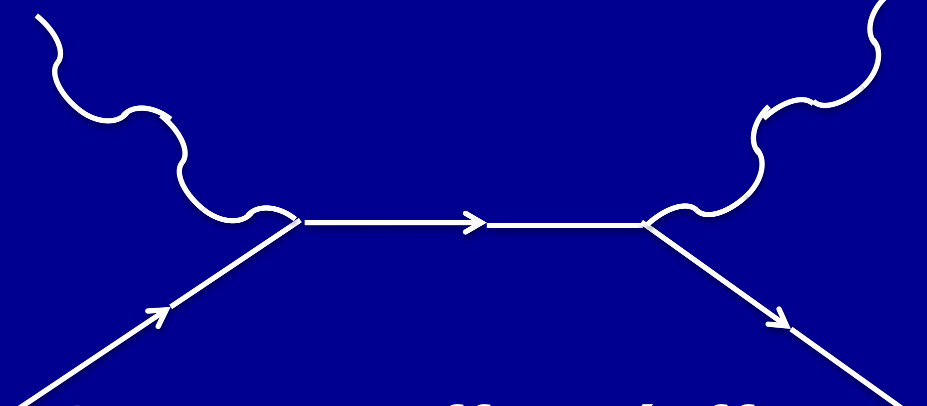
Physics Letters B

Volume 168, Issues 1–2, 27 February 1986, Pages 163–169

Open Access

High energy photoproduction of large transverse-momentum π^0 mesons: A quantitative test of QCD

NA14 Collaboration



QED Compton effect (off quarks)

ELSEVIER

Physics Letters B

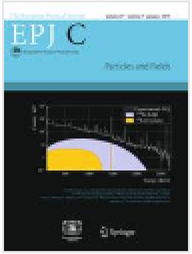
Volume 152, Issues 5–6, 14 March 1985, Pages 419–427

Open Access

Measurement of deep inelastic Compton scattering of high energy photons

NA 14 Collaboration P. Astbury[c], E. Augé[d], R. Barate[b], P. Bareyre[g], P. Benkheiri[e], D. Bloch[l], P. Bonamy[g], P. Borgeaud[g], B. Bouquet[d], J.M. Brom[l], J.M. Brunet[f], H. Burmeister[b], M. Burtchell[c], S. Costa Ramos[e], F. Couchot[d], B. D'Almagne[d], M. David[g], A. De Bellefon[f], A. De Lesquens[g], P. Dello Russo[l, 1], A. Duane[c], J.P. Engel[l], J. Engelen[b], A. Ferrer[d], T.A. Filippas[a], E. Fokitis[a], P. Frenkiel[f], E.N. Gazis[a], J. Giomataris[a], M. Gorski[k], P. Gregory[c], W. Guryn[d, 2], J.L. Guyonnet[l],

⊞ Show more



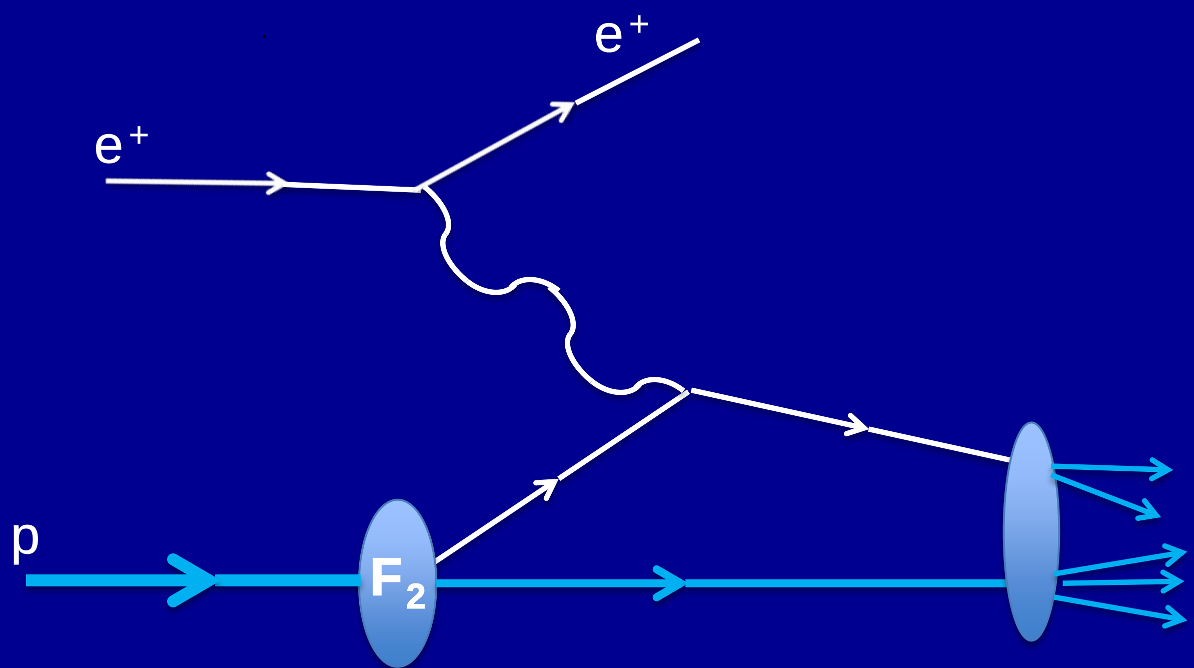
The European Physical Journal C - Particles and Fields
July 2001, Volume 21, Issue 3, pp 443–471

Measurement of the neutral current cross section and $\mathbf{F_2}$ structure function for deep inelastic $\mathbf{e^+p}$ scattering at HERA

Authors | Authors and affiliations

The ZEUS Collaboration, S. Chekanov et al.

Double Angle method
Bentvelsen, Kooijman ,(E)



LEP

- **Three (light) neutrino species**
- **Gauge structure of the electroweak interaction**
  SU(2)xU(1)
- **Prediction of the topquark mass**
- **Gauge structure of QCD**
  SU(3)
- **Limits (on the Higgs mass)**

Experimentation in High Energy Physics

Multi-Wire Proportinal Chambers (Charpak, 1967+1, Nobel Prize 1992) Nuclear Instruments and Methods 62 (1968) 202 - 26.

- MWPC, drift, MDT, honeycomb, straw

Semiconductor (Si) trackers

- Si strip, pixels

Calorimeters

- Compensating Uranium/Scint cals

Cherenkov detectors

- RICH

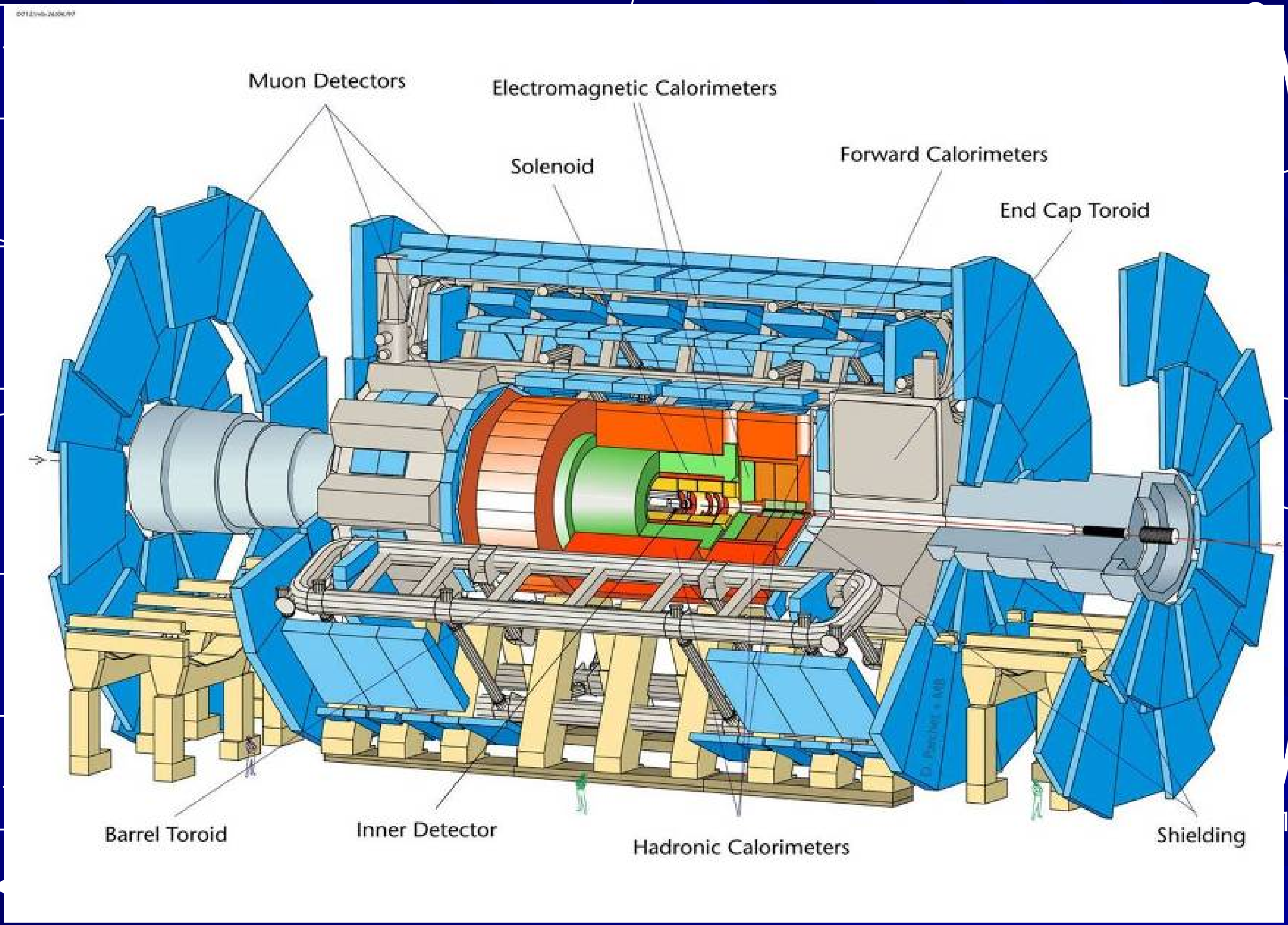
Mechanical ‘system’ design

(Front end) **electronics**, ascics, deep sub-micron technology, 250 nm for LHC expts (initially)

Triggering, data-acquisition, (grid) **computing**

All these technologies mastered by Nikhef at state of the art level and beyond

Colliding beams at the Large Hadron Collider



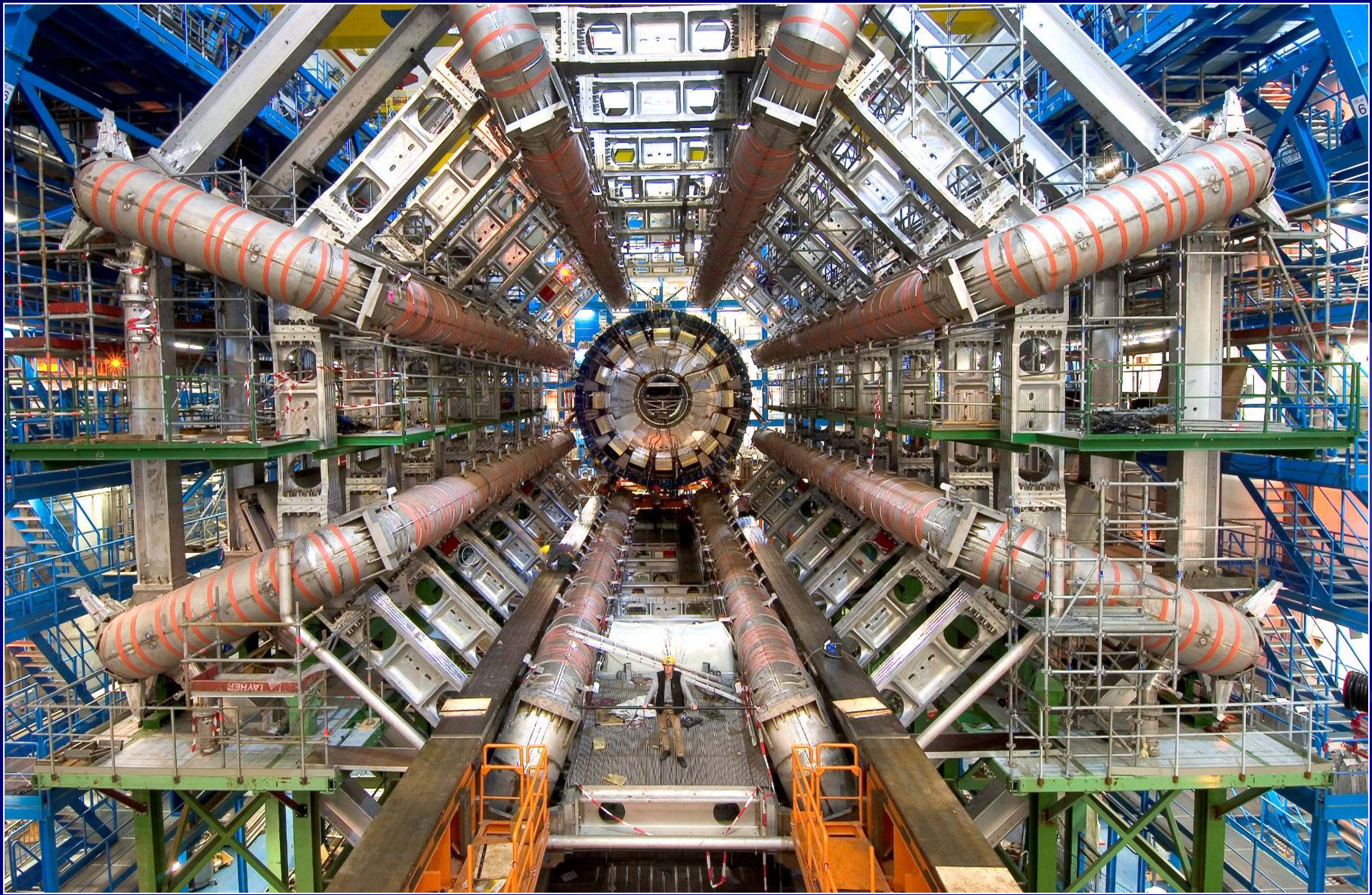
One billion, 10^9 collisions per second, hundreds of particles per collision.
Write O(100) events = O(100 MB) to storage medium/second

Point 1 - UX15 vault demolition of central pillar - September 20, 2000 - CERN ST-CE

De inauguratie

Barrel Toroid installation status

The mechanical installation is complete, electrical and cryogenic connections are being made now, for a first in-situ cool-down and excitation test in spring 2006



Dipoles

waiting to be installed in the tunnel

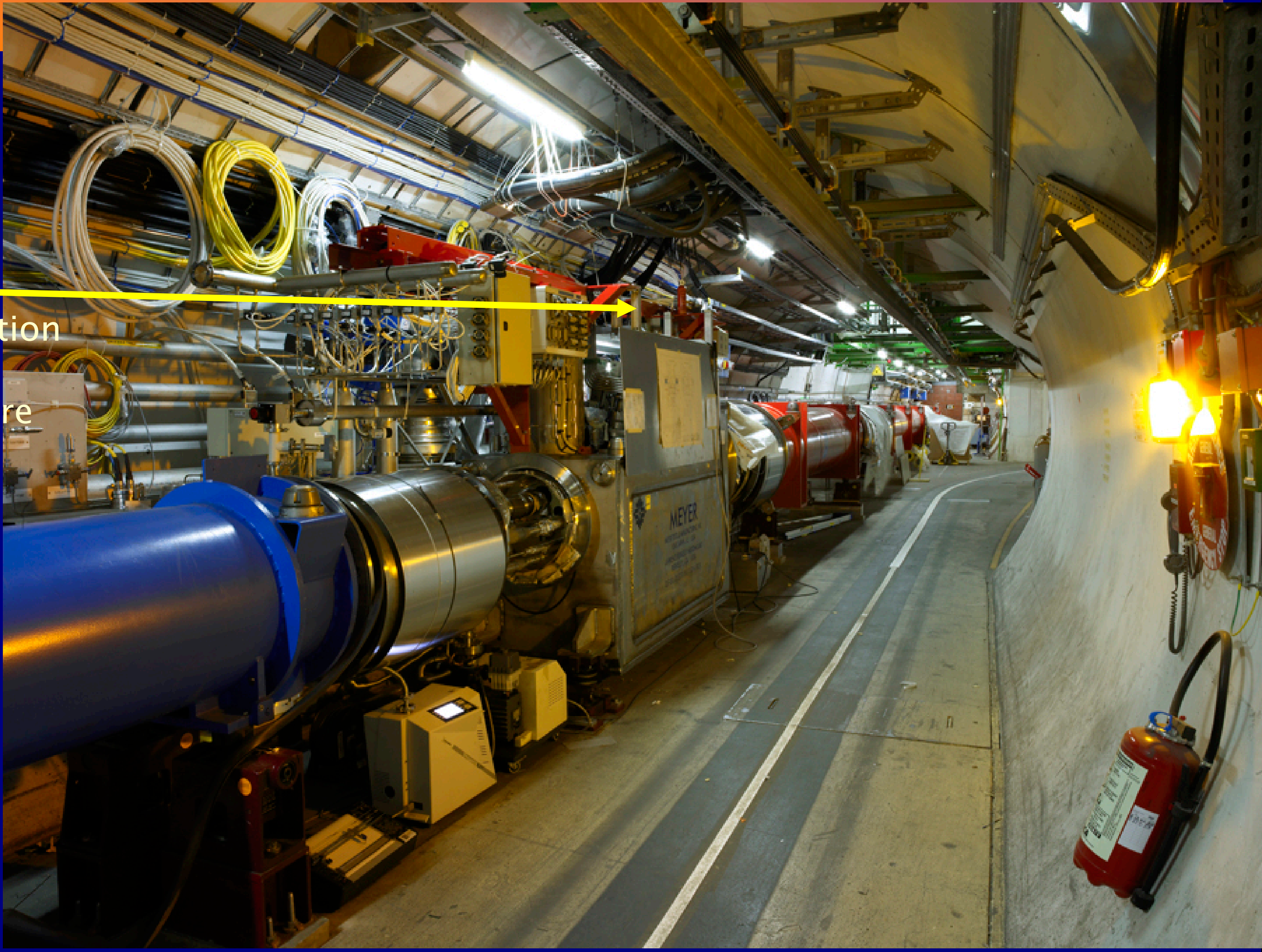

1954-2004
CERN


A

In the tunnel

Beam delivery towards interaction point

Current distribution using
High Temperature Supercondutor current leads



Minutes before the first circulating beam, September 10, 2008

Dipole-dipole interconnect: electrical splices

Politics and Policy

Public - Private


CERN welcomes
President Pervez Mush

Welkom op CERN

Dr R. Plasterk
Minister van Onderwijs, Cultuur en Wetenschappen
Koninkrijk der Nederlanden

Research & Discovery

Technology

R&D, Application, Transfer

Training

Collaborating

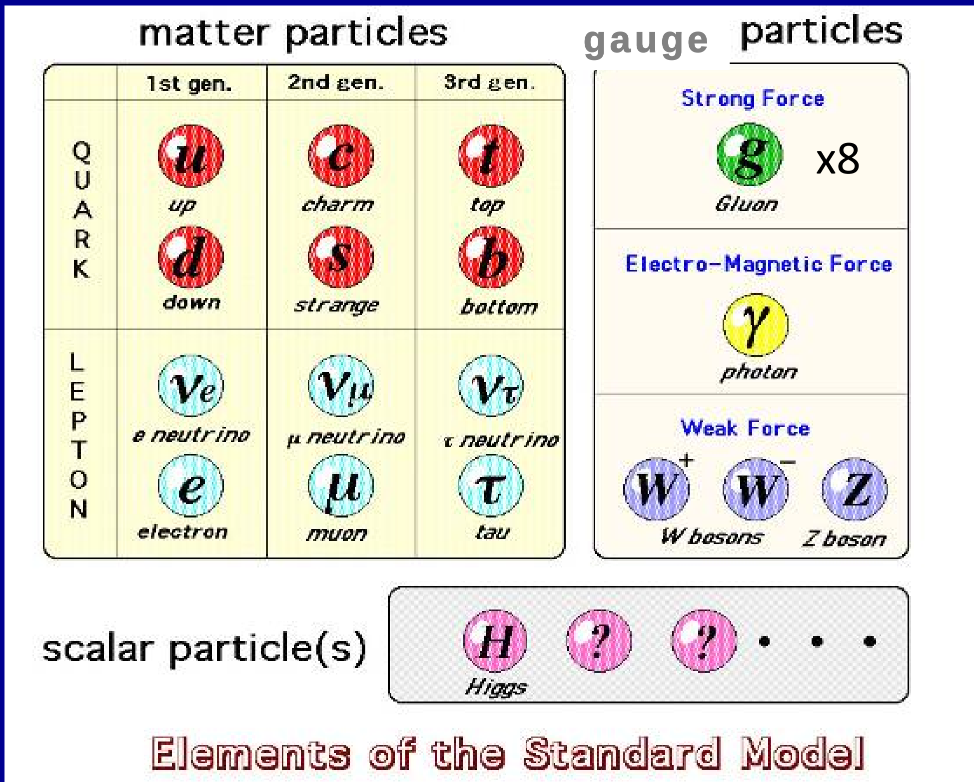
October 25, 2007

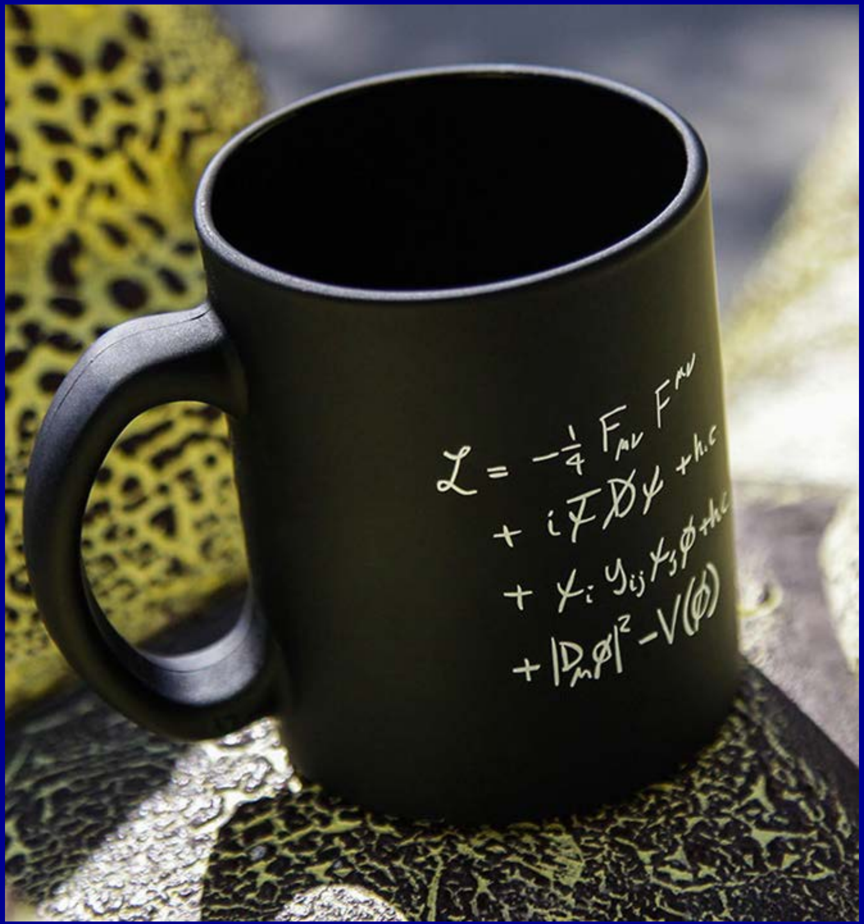
Kenniscoalitie – Nationale Wetenschapsagenda

$$
\begin{gathered}
-\frac12\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \frac14 g_s^2 f^{abc} f^{ade} g^b_\mu g^c_\nu g^d_\mu g^e_\nu + \\
\frac12 i g_s^2 (\bar q^\sigma_i \gamma^\mu q^\sigma_j) g^a_\mu + \bar G^a \partial^2 G^a + g_s f^{abc}\partial_\mu \bar G^a G^b g^c_\mu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu - \\
M^2 W^+_\mu W^-_\mu - \frac12 \partial_\nu Z^0_\mu \partial_\nu Z^0_\mu - \frac{1}{2c_w^2} M^2 Z^0_\mu Z^0_\mu - \frac12 \partial_\mu A_\nu \partial_\mu A_\nu - \frac12 \partial_\mu H \partial_\mu H - \\
\frac12 m_h^2 H^2 - \partial_\mu\phi^+\partial_\mu\phi^- - M^2\phi^+\phi^- - \frac12\partial_\mu\phi^0\partial_\mu\phi^0 - \frac{1}{2c_w^2} M\phi^0\phi^0 - \beta_h[\frac{2M^2}{g^2} + \\
\frac{2M}{g}H + \frac12(H^2+\phi^0\phi^0+2\phi^+\phi^-)] + \frac{2M^4}{g^2}\alpha_h - igc_w[\partial_\nu Z^0_\mu(W^+_\mu W^-_\nu - \\
W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu - \\
W^-_\nu\partial_\nu W^+_\mu)] - igs_w[\partial_\nu A_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu(W^+_\mu\partial_\nu W^-_\mu - \\
W^-_\mu\partial_\nu W^+_\mu) + A_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - \frac12 g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu + \\
\frac12 g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2c_w^2(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) + \\
g^2 s_w^2(A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w[A_\mu Z^0_\nu(W^+_\mu W^-_\nu - \\
W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-] - \\
\frac18 g^2\alpha_h[H^4+(\phi^0)^4+4(\phi^+\phi^-)^2+4(\phi^0)^2\phi^+\phi^-+4H^2\phi^+\phi^-+2(\phi^0)^2H^2] - \\
gMW^+_\mu W^-_\mu H - \frac12 g\frac{M}{c_w^2}Z^0_\mu Z^0_\mu H - \frac12 ig[W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) - \\
W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)] + \frac12 g[W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) - W^-_\mu(H\partial_\mu\phi^+ - \\
\phi^+\partial_\mu H)] + \frac12 g\frac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) - ig\frac{s_w^2}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) + \\
igs_wMA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\frac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) + \\
igs_wA_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \frac14 g^2 W^+_\mu W^-_\mu[H^2 + (\phi^0)^2 + 2\phi^+\phi^-] - \\
\frac14 g^2\frac{1}{c_w^2}Z^0_\mu Z^0_\mu[H^2+(\phi^0)^2+2(2s_w^2-1)^2\phi^+\phi^-] - \frac12 g^2\frac{s_w^2}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- + \\
W^-_\mu\phi^+) - \frac12 ig^2\frac{s_w^2}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \frac12 g^2 s_w A_\mu\phi^0(W^+_\mu\phi^- + \\
W^-_\mu\phi^+) + \frac12 ig^2 s_w A_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\frac{s_w}{c_w}(2c_w^2-1)Z^0_\mu A_\mu\phi^+\phi^- - \\
g^1 s_w^2 A_\mu A_\mu\phi^+\phi^- - \bar e^\lambda(\gamma\partial + m_e^\lambda)e^\lambda - \bar\nu^\lambda\gamma\partial\nu^\lambda - \bar u_j^\lambda(\gamma\partial+m_u^\lambda)u_j^\lambda - \\
\bar d_j^\lambda(\gamma\partial+m_d^\lambda)d_j^\lambda + igs_wA_\mu[-(\bar e^\lambda\gamma^\mu e^\lambda) + \frac23(\bar u_j^\lambda\gamma^\mu u_j^\lambda) - \frac13(\bar d_j^\lambda\gamma^\mu d_j^\lambda)] + \\
\frac{ig}{4c_w}Z^0_\mu[(\bar\nu^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar e^\lambda\gamma^\mu(4s_w^2-1-\gamma^5)e^\lambda) + (\bar u_j^\lambda\gamma^\mu(\frac43 s_w^2 - \\
1-\gamma^5)u_j^\lambda) + (\bar d_j^\lambda\gamma^\mu(1-\frac83 s_w^2-\gamma^5)d_j^\lambda)] + \frac{ig}{2\sqrt2}W^+_\mu[(\bar\nu^\lambda\gamma^\mu(1+\gamma^5)e^\lambda) + \\
(\bar u_j^\lambda\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d_j^\kappa)] + \frac{ig}{2\sqrt2}W^-_\mu[(\bar e^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar d_j^\kappa C^\dagger_{\lambda\kappa}\gamma^\mu(1+ \\
\gamma^5)u_j^\lambda)] + \frac{ig}{2\sqrt2}\frac{m_e^\lambda}{M}[-\phi^+(\bar\nu^\lambda(1-\gamma^5)e^\lambda) + \phi^-(\bar e^\lambda(1+\gamma^5)\nu^\lambda)] - \\
\frac g2\frac{m_e^\lambda}{M}[H(\bar e^\lambda e^\lambda) + i\phi^0(\bar e^\lambda\gamma^5 e^\lambda)] + \frac{ig}{2M\sqrt2}\phi^+[-m_d^\kappa(\bar u_j^\lambda C_{\lambda\kappa}(1-\gamma^5)d_j^\kappa) + \\
m_u^\lambda(\bar u_j^\lambda C_{\lambda\kappa}(1+\gamma^5)d_j^\kappa] + \frac{ig}{2M\sqrt2}\phi^-[m_d^\lambda(\bar d_j^\lambda C^\dagger_{\lambda\kappa}(1+\gamma^5)u_j^\kappa) - m_u^\kappa(\bar d_j^\lambda C^\dagger_{\lambda\kappa}(1- \\
\gamma^5)u_j^\kappa] - \frac g2\frac{m_u^\lambda}{M}H(\bar u_j^\lambda u_j^\lambda) - \frac g2\frac{m_d^\lambda}{M}H(\bar d_j^\lambda d_j^\lambda) + \frac{ig}{2}\frac{m_u^\lambda}{M}\phi^0(\bar u_j^\lambda\gamma^5 u_j^\lambda) - \\
\frac{ig}{2}\frac{m_d^\lambda}{M}\phi^0(\bar d_j^\lambda\gamma^5 d_j^\lambda) + \bar X^+(\partial^2-M^2)X^+ + \bar X^-(\partial^2-M^2)X^- + \bar X^0(\partial^2 - \\
\frac{M^2}{c_w^2})X^0 + \bar Y\partial^2 Y + igc_wW^+_\mu(\partial_\mu\bar X^0X^- - \partial_\mu\bar X^+X^0) + igs_wW^+_\mu(\partial_\mu\bar YX^- - \\
\partial_\mu\bar X^+Y) + igc_wW^-_\mu(\partial_\mu\bar X^-X^0 - \partial_\mu\bar X^0X^+) + igs_wW^-_\mu(\partial_\mu\bar X^-Y - \\
\partial_\mu\bar YX^+) + igc_wZ^0_\mu(\partial_\mu\bar X^+X^+ - \partial_\mu\bar X^-X^-) + igs_wA_\mu(\partial_\mu\bar X^+X^+ - \\
\partial_\mu\bar X^-X^-) - \frac12 gM[\bar X^+X^+H + \bar X^-X^-H + \frac{1}{c_w^2}\bar X^0X^0H] + \\
\frac{1-2c_w^2}{2c_w}igM[\bar X^+X^0\phi^+ - \bar X^-X^0\phi^-] + \frac{1}{2c_w}igM[\bar X^0X^-\phi^+ - \bar X^0X^+\phi^-] + \\
igMs_w[\bar X^0X^-\phi^+ - \bar X^0X^+\phi^-] + \frac12 igM[\bar X^+X^+\phi^0 - \bar X^-X^-\phi^0]
\end{gathered}
$$

If you were to start today...

Experimental situation





There is more than represented in this cartoon !
– interactions & ? –

$$\mathcal{L} =$$

1

$$-\frac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \frac{1}{4}g_s^2 f^{abc}f^{ade} g^b_\mu g^c_\nu g^d_\mu g^e_\nu + \frac{1}{2}ig_s^2(\bar q^\sigma_i \gamma^\mu q^\sigma_j)g^a_\mu + \bar G^a \partial^2 G^a + g_s f^{abc}\partial_\mu \bar G^a G^b g^c_\mu$$

2

$$- \partial_\nu W^+_\mu \partial_\nu W^-_\mu - M^2 W^+_\mu W^-_\mu - \frac{1}{2}\partial_\nu Z^0_\mu\partial_\nu Z^0_\mu - \frac{1}{2c_w^2}M^2 Z^0_\mu Z^0_\mu - \frac12 \partial_\mu A_\nu \partial_\mu A_\nu - \frac12 \partial_\mu H \partial_\mu H - \frac12 m_h^2 H^2 - \partial_\mu\phi^+\partial_\mu\phi^- - M^2\phi^+\phi^- - \frac12\partial_\mu\phi^0\partial_\mu\phi^0 - \frac{1}{2c_w^2}M\phi^0\phi^0 - \beta_h\left[\frac{2M^2}{g^2} + \frac{2M}{g}H + \frac12(H^2+\phi^0\phi^0+2\phi^+\phi^-)\right] + \frac{2M^4}{g^2}\alpha_h - igc_w[\partial_\nu Z^0_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - igs_w[\partial_\nu A_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + A_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - \frac12 g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu + \frac12 g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2c_w^2(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) + g^2s_w^2(A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w[A_\mu Z^0_\nu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-] - \frac18 g^2\alpha_h[H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2\phi^+\phi^- + 4H^2\phi^+\phi^- + 2(\phi^0)^2H^2] - gMW^+_\mu W^-_\mu H - \frac12 g\frac{M}{c_w^2}Z^0_\mu Z^0_\mu H - \frac12 ig[W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) - W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)] + \frac12 g[W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) - W^-_\mu(H\partial_\mu\phi^+ - \phi^+\partial_\mu H)] + \frac12 g\frac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) - ig\frac{s_w^2}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) + igs_wMA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\frac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) + igs_wA_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \frac14 g^2 W^+_\mu W^-_\mu[H^2 + (\phi^0)^2 + 2\phi^+\phi^-] - \frac14 g^2\frac{1}{c_w^2}Z^0_\mu Z^0_\mu[H^2+(\phi^0)^2+2(2s_w^2-1)^2\phi^+\phi^-] - \frac12 g^2\frac{s_w^2}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- + W^-_\mu\phi^+) - \frac12 ig^2\frac{s_w^2}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \frac12 g^2 s_w A_\mu\phi^0(W^+_\mu\phi^- + W^-_\mu\phi^+) + \frac12 ig^2 s_w A_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\frac{s_w}{c_w}(2c_w^2-1)Z^0_\mu A_\mu\phi^+\phi^- - g^1 s_w^2 A_\mu A_\mu\phi^+\phi^-$$

3

$$- \bar e^\lambda(\gamma\partial + m_e^\lambda)e^\lambda - \bar\nu^\lambda\gamma\partial\nu^\lambda - \bar u^\lambda_j(\gamma\partial + m^\lambda_u)u^\lambda_j - \bar d^\lambda_j(\gamma\partial + m^\lambda_d)d^\lambda_j + igs_wA_\mu\left[-(\bar e^\lambda\gamma^\mu e^\lambda) + \frac23(\bar u^\lambda_j\gamma^\mu u^\lambda_j) - \frac13(\bar d^\lambda_j\gamma^\mu d^\lambda_j)\right] + \frac{ig}{4c_w}Z^0_\mu\left[(\bar\nu^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar e^\lambda\gamma^\mu(4s_w^2 - 1 - \gamma^5)e^\lambda) + (\bar u^\lambda_j\gamma^\mu(\tfrac43 s_w^2 - 1 - \gamma^5)u^\lambda_j) + (\bar d^\lambda_j\gamma^\mu(1 - \tfrac83 s_w^2 - \gamma^5)d^\lambda_j)\right] + \frac{ig}{2\sqrt2}W^+_\mu[(\bar\nu^\lambda\gamma^\mu(1+\gamma^5)e^\lambda) + (\bar u^\lambda_j\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d^\kappa_j)] + \frac{ig}{2\sqrt2}W^-_\mu[(\bar e^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar d^\kappa_j C^\dagger_{\lambda\kappa}\gamma^\mu(1+\gamma^5)u^\lambda_j)]$$

4

$$+ \frac{ig}{2\sqrt2}\frac{m_e^\lambda}{M}[-\phi^+(\bar\nu^\lambda(1-\gamma^5)e^\lambda) + \phi^-(\bar e^\lambda(1+\gamma^5)\nu^\lambda)] - \frac g2\frac{m_e^\lambda}{M}[H(\bar e^\lambda e^\lambda) + i\phi^0(\bar e^\lambda\gamma^5 e^\lambda)] + \frac{ig}{2M\sqrt2}\phi^+[-m^\kappa_d(\bar u^\lambda_j C_{\lambda\kappa}(1-\gamma^5)d^\kappa_j) + m^\lambda_u(\bar u^\lambda_j C_{\lambda\kappa}(1+\gamma^5)d^\kappa_j] + \frac{ig}{2M\sqrt2}\phi^-[m^\lambda_d(\bar d^\lambda_j C^\dagger_{\lambda\kappa}(1+\gamma^5)u^\kappa_j) - m^\kappa_u(\bar d^\lambda_j C^\dagger_{\lambda\kappa}(1-\gamma^5)u^\kappa_j] - \frac g2\frac{m^\lambda_u}{M}H(\bar u^\lambda_j u^\lambda_j) - \frac g2\frac{m^\lambda_d}{M}H(\bar d^\lambda_j d^\lambda_j) + \frac{ig}{2}\frac{m^\lambda_u}{M}\phi^0(\bar u^\lambda_j\gamma^5 u^\lambda_j) - \frac{ig}{2}\frac{m^\lambda_d}{M}\phi^0(\bar d^\lambda_j\gamma^5 d^\lambda_j)$$

5

$$+ \bar X^+(\partial^2 - M^2)X^+ + \bar X^-(\partial^2 - M^2)X^- + \bar X^0\left(\partial^2 - \frac{M^2}{c_w^2}\right)X^0 + \bar Y\partial^2 Y + igc_wW^+_\mu(\partial_\mu\bar X^0 X^- - \partial_\mu\bar X^+ X^0) + igs_wW^+_\mu(\partial_\mu\bar Y X^- - \partial_\mu\bar X^+ Y) + igc_wW^-_\mu(\partial_\mu\bar X^- X^0 - \partial_\mu\bar X^0 X^+) + igs_wW^-_\mu(\partial_\mu\bar X^- Y - \partial_\mu\bar Y X^+) + igc_wZ^0_\mu(\partial_\mu\bar X^+ X^+ - \partial_\mu\bar X^- X^-) + igs_wA_\mu(\partial_\mu\bar X^+ X^+ - \partial_\mu\bar X^- X^-) - \frac12 gM\left[\bar X^+X^+H + \bar X^-X^-H + \frac{1}{c_w^2}\bar X^0X^0H\right] + \frac{1-2c_w^2}{2c_w}igM[\bar X^+X^0\phi^+ - \bar X^-X^0\phi^-] + \frac{1}{2c_w}igM[\bar X^0X^-\phi^+ - \bar X^0X^+\phi^-] + igMs_w[\bar X^0X^-\phi^+ - \bar X^0X^+\phi^-] + \frac12 igM[\bar X^+X^+\phi^0 - \bar X^-X^-\phi^0]$$

*The Standard Model Lagrangian derived from Diagrammatica, **a theoretical physics reference written by Nobel Laureate Martinus Veltman**.*

(Thomas Gutierrez, California Polytechnic State University;

In his dissemination of the transcript, he noted a sign error he made somewhere in the equation. Good luck finding it!)

Reserve

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Moon shadow observation with ANTARES and KM3NeT neutrino telescope

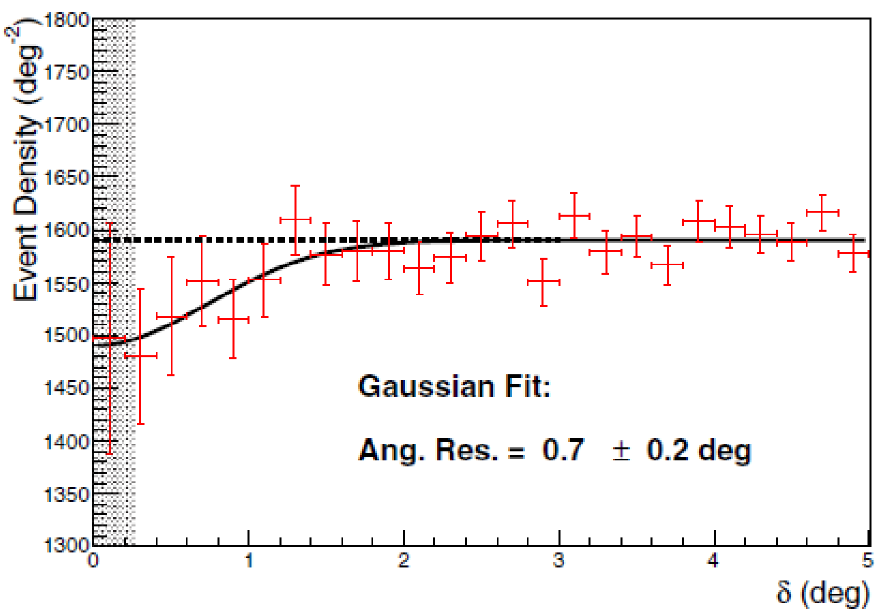

Figure 1. Event density of muons after selection cut versus the angular distance from the Moon centre.