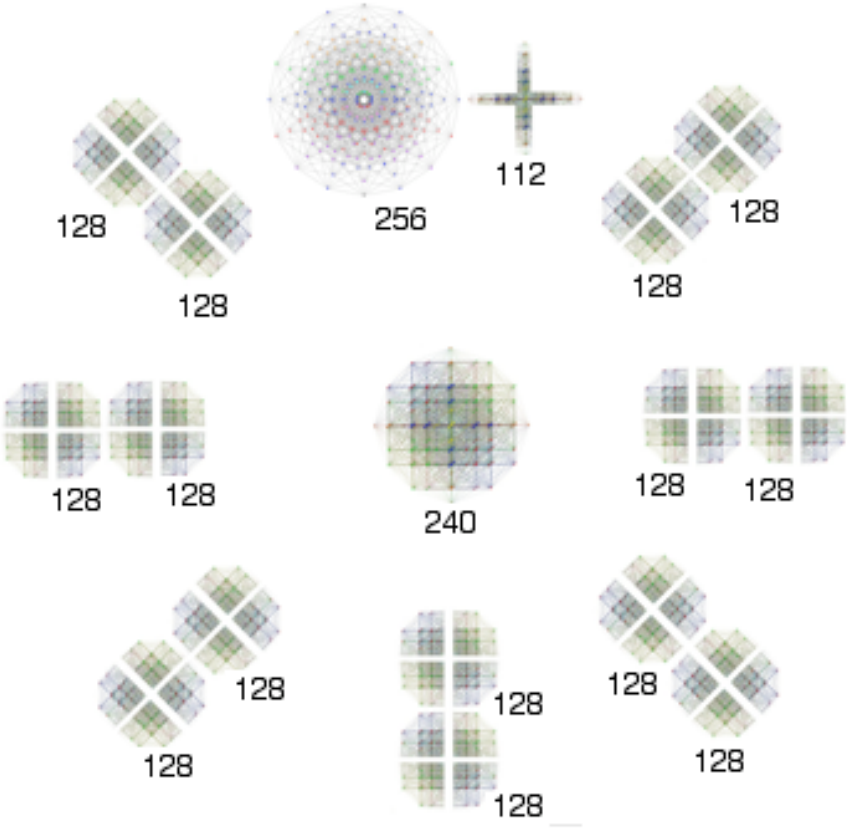
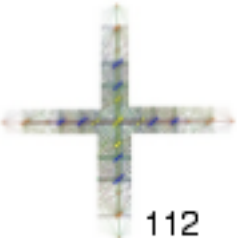
E8 Physics

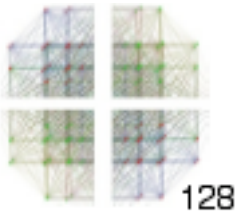
by Frank D. (Tony) Smith, Jr. – September 2009



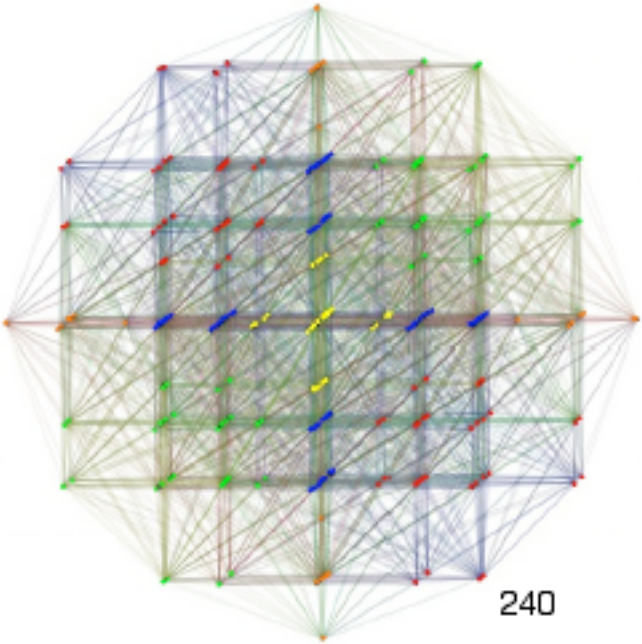
The First and Second shells of an E8 lattice have 240 and 2160 = 112 + 256 + 7(128+128) vertices.
The 256 is an 8-HyperCube with vertices
(+/-1, +/-1, +/-1, +/-1, +/-1, +/-1, +/-1, +/-1) of which
one checkerboard half represents the 128 +half-spinors of D8 and the other mirror image checkerboard half represents the 128 -half-spinors of

D8.
The 112 represents the 112 root vectors of 120-dim D8.
Each of the 7 pairs of 128 are also representations of the 128 +half-spinors and 128 -half-spinors of D8.
The 112 can be combined with any of the 128





to form the 240 of the First Shell of an E8 latttice



that represents the 112 + 128 = 240 root vectors of E8.
There are 7 pairs of 128 in the Second Shell. Each choice of a pair from which to get a 128 to combine with the 112 produces one of the 7 independent E8 lattices.

You can also choose half of the 256 to combine with the 112 to form an 8th E8 lattice. Although the 8th E8 lattice is not independent of the 7, it is useful in constructing a physics model based on 8-Brane spacetime that in the continuum limit at low (compared to Planck) energies has M4 x CP2 Kaluza-Klein structure. Denote the 7 independent E8 lattices by 1E8, 2E8, 3E8, 4E8, 5E8, 6E8, and 7E8 and the 8th E8 lattice by 8E8.

Note that each of the 8 E8 lattices uses only one of the 128 of a pair (or one half of the 256), and that it corresponds to one of the D8 half-spinor spaces. Physically, the chosen 128 represents Fermion Particles and AntiParticles of one generation, so the E8 contains one generation of Fermion Particles and AntiParticles (the second and third generations emerge at low energies). The 128 not chosen represents one antigeneration of Fermion Particles and AntiParticles, so the E8 does not contain a Fermion antigeneration. Therefore, the E8 model has realistic chirality properties. The 128 spinors can represent space spinors and be anticommuting with the E8 Lie algebra commutation relations still preserved, as Pierre Ramond pointed out in hep-th/0112261 (pages 13,14) with respect to F4 and Spin(9).

My goal in this paper is to explain how this E8 model is realistic and overcomes the acknowledged shortcomings of Garrett Lisi's E8 model of arXiv 0711.0770 which model was the motivation for me to work on this E8 model. I think that Garrett Lisi should get full credit for doing the basic ground-work for the E8 model.
I hope that this paper shows to its readers that the E8 model and its AQFT constitute a complete realistic theory that satisfies Einstein's criteria (quoted by Wilczek in the winter 2002 issue of Deadalus) :
"… a theorem which at present can not be based upon anything more than upon a faith in the simplicity, i.e., intelligibility, of nature: there are no arbitrary constants … that is to say,
nature is so constituted that it is possible logically to lay down such strongly determined laws that within these laws only rationally completely determined constants occcur …".

The remainder of this paper consists of the following sections:

10 spacetime Dimensions of 26-dim Bosonic Strings
16 Fermionic Dimensions of 26-dim Bosonic Strings
Closed Bosonic String World-Lines
Quaternionic M4 x CP2 Kaluza-Klein
Calculations of Masses, Force Strengths, etc
-for detailed results of the calculations etc, see web book at
http://www.tony5m17h.net/E8physicsbook.pdf and
www.valdostamuseum.org/hamsmith/E8physicsbook.pdf
AQFT
EPR Entanglement

10 spacetime Dimensions of 26-dim Bosonic Strings:

An 8-Brane is constructed as a superposition of all of the 8 E8 lattices.
Each 8-Brane represents a local neighborhood of spacetime.
Global spacetime is a collection of 8-Branes parameterized by two real variables a , b that are analagous to the conformal dimensions (1,1) that extend (1,3) Minkowski physical spacetime of Spin(1,3) to the (2,4) Conformal spacetime of Spin(2,4) = SU(2,2).
Physical Gauge Bosons link an 8-Brane to a successor 8-Brane along the World Line of that Gauge Boson as follows:
A Gauge Boson emanating from only the 8E8 lattice in the 8-Brane is a U(1) Electromagnetic Photon;
A Gauge Boson emanating from only the 8E8 and the 4E8 lattice in the 8-Brane is a U(2) Weak Boson (note that their common 8E8 unifies the Electromagnetic Photon with the Weak Bosons);
A Gauge Boson emanating from only the 5E8, 6E8, and 7E8 lattices in the 8-Brane is a U(3) Gluon;
A Gauge Boson emanating from only only the 8E8 lattice and the 1E8, 2E8, and 3E8 lattices in the 8-Brane is a U(2,2) = U(1)xSU(2,2) = U(1)xSpin(2,4) Conformal Gauge Boson that gives Gravity by the MacDowell-Mansouri mechanism.

16 Fermionic Dimensions of 26-dim Bosonic Strings:

We now have constructed the 10 dimensions of the base manifold of 26-dim Closed Unoriented Bosonic String Theory, as well as the Gauge Bosons of the Standard Model plus Gravity, in which Strings are physically interpreted as World-Lines,
with relatively large Closed Strings corresponding to World-Lines of particles that locally appear to be free
and relatively small Closed Strings corresponding to paths of virtual particles in the Path Integral Sum-Over-Histories picture.

To describe the one fundamental generation of Fermion Particles and AntiParticles of the E8 model add, to the 10 dimensions we already have, a 16-dimensional space that is discretized by Orbifolding it with respect to the 16-element discrete Octonionic multiplicative group
{+/-1,+/-i,+/-j,+/-k,+/-E,+/-I,+/-J,+/-K}
to reduce the 16-dim Fermionic representation space to 16 points {-1,-i,-j,-k,-E,-I,-J,-K;+1,+i,+j,+k,+E,+I,+J,+K}
for which Fermion Particles (nu, ru, gu, bu, e, rd, gd, bu)
are represented by {-1,-i,-j,-k,-E,-I,-J,-K}
and the corresponding Fermion AntiParticles
are represented by {+1,+i,+j,+k,+E,+I,+J,+K}.

Now our E8 model has realistic first-generation Fermions as well as a base manifold with the Standard Model plus Gravity (M4 x CP2 Kaluza-Klein spacetime, with its 4-dim physical spacetime, and the second and third generations of Fermions, emerge at low temperatures when a preferred Quaternionic substructure freezes out from the high-temperature Octonionic structure).

Closed Bosonic String World-Lines:

Interaction of Closed Bosonic Strings as World-Lines looks like Andrew Gray's idea in quant-ph/9712037
"… probabilities are … assigned to entire fine-grained histories … this new formulation makes the same experimental predictions as quantum

field theory …"
so it seems that physical results of Bosonic String Theory can be interpreted as:

String Tachyons can be physically interpreted as describing the virtual particle-antiparticle clouds that dress the orbifold Fermion particles (As Lubos Motl said in his on 13 July 2005: "... closed string tachyons ... can be localized if they appear in a twisted sector of an orbifold ... tachyons condense near the tip which smears out the tip of the cone which makes the tip nice and round. ..." and as Bert Schroer said in hep-th/9908021: "... any compactly localized operator applied to the vacuum generates clouds of pairs of particle/antiparticles ...").

String spin-2 Gravitons can be physically interpreted as describing a Bohm-like Quantum Potential and what Penrose (in "Shadows of the Mind" (Oxford 1994) with respect to Quantum Consciousness) describes as "… the gravitational self-energy of that mass distribution which is the difference between the mass distributions of … states that are to be considered in quantum linear superposition …".

The 128 in the 240 of the E8 model breaks up into two 64-element things.
One 64 = 8x8 represents the 8 Dirac gamma covariant components (with respect to high-energy 8-dim spacetime) of each of the 8 fundamental first-generation Fermion Particles;
the other 64 = 8x8 represents the 8 Dirac gamma covariant components (with respect to high-energy 8-dim spacetime) of each of the 8 fundamental first-generation Fermion AntiParticles.

The 112 in the 240 of the E8 model breaks up into three parts: a 64 plus a 24 plus a dual 24.
The 64 = 8x8 in the 112 represents 8 Dirac gammas for the 8 dimensions of high-energy spacetime;
the 24 represents the 24 root vectors of a 28-dim D4 Lie algebra whose generators include those of the Standard Model Gauge Bosons;
the dual 24 represents the 24 root vectors of a second 28-dim D4 Lie algebra whose generators include those of the conformal U(2,2) that

produces Gravity.

Quaternionic M4 x CP2 Kaluza-Klein:

At this stage, the E8 model differs from conventional Gravity plus Standard Model in four respects:
1 - 8-dimensional spacetime
2 – two Spin(8) gauge groups from the two D4 in 112
3 - no Higgs
4 - 1 generation of fermions

These differences can be reconciled as follows:

Introduce (freezing out at lower-than-Planck energies) a preferred Quaternionic 4-dim subspace of the original (high-energy) 8-dim spacetime,
thus forming an 8-dim Kaluza-Klein spacetime M4xCP2
where M4 is 4-dim physical spacetime and CP2 is a 4-dim intrernal symmetry space.

Let the first Spin(8) gauge group act on the M4 physical spacetime through the SU(3) subgroup of its U(4) subgroup. As Meinhard E. Mayer said (Hadronic Journal 4 (1981) 108-152): "… each point of … the … fibre bundle … E consists of a four-dimensional spacetime point x [in M4] to which is attached the homogeneous space G / H [SU(3) / U(2) = CP2] … the components of the curvature lying in the homogeneous space G / H [= SU(3) / U(2)] could be reinterpreted as Higgs scalars (with respect to spacetime [M4])
…
the Yang-Mills action reduces to a Yang-Mills action for the h-components [U(2) components] of the curvature over M [M4]
and
a quartic functional for the "Higgs scalars", which not only reproduces the Ginzburg-Landau potential, but also gives the correct relative sign of the constants, required for the BEHK … Brout-Englert-Higgs-Kibble … mechanism to work. …".

So, freezing out of a Kaluza-Klein M4xCP2 spacetime plus internal symmetry space produces a classical Lagrangian for the SU(3)xU(2) = SU(3)xSU(2)xU(1) Standard Model including a BEHK Higgs mechanism.

Let the second Spin(8) gauge group act on the M4 physical spacetime through its Conformal Subgroup U(2,2) = Spin(2,4). As Rabindra Mohapatra said (section 14.6 of Unification and Supersymmetry, 2nd edition, Springer-Verlag 1992): "… gravitational theory can emerge from the gauging of conformal symmetry … we start with a Lagrangian invariant under full local conformal symmetry and fix conformal and scale gauge to obtain the usual action for gravity. …".
At this stage, we have reconciled the first 3 of the 4 differences between our E8 Physics Model and conventional Gravity plus the Standard Model.
As to the fourth, the existence of 3 generations of fermions, note that the 8 first generation fermion particles and the 8 first generation antiparticles can each be represented by the 8 basis elements of the Octonions O, and that the second and third generations can be represented by
Pairs of Octonions OxO and
Triples of Octonions OxOxO, respectively.
When the unitary Octonionic 8-dim spacetime is reduced to the Kaluza-Klein M4 x CP2, there are 3 possibilities for a fermion propagator from point A to point B:
1 – A and B are both in M4, so its path can be represented by the single O;
2 – Either A or B, but not both, is in CP2, so its path must be augmented by one projection from CP2 to M4, which projection can be represented by a second O, giving a second generation OxO;
3 – Both A and B are in CP2, so its path must be augmented by two projections from CP2 to M4, which projections can be represented by a second O and a third O, giving a third generation OxOxO.

Therefore, all four differences have been reconciled, and
our classical Lagrangian E8 Physics Model describes Gravity as well as the Standard Model with a BEHK Higgs mechanism.

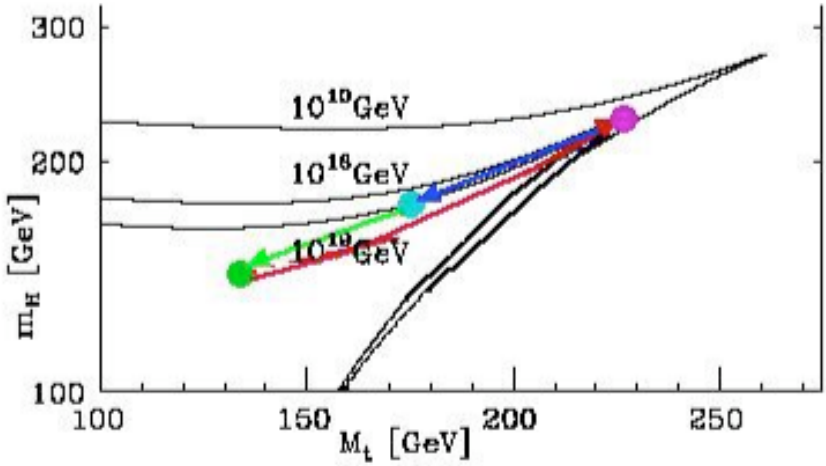
Calculations of Masses, Force Strengths, etc:

However, for our classical Lagrangian E8 Physics Model to be said to be complete and realistic, it must allow us to calculate such things as Force Strengths and Particle Masses that are consistent with experimental and observational results. To do that, we use the results of Hua in his book "Harmonic Analysis of Functions of Several Complex Variables in the Classical Domains". (Similar use of the work of Hua was made years ago by Armand Wyler, and recently by a few others, such as Carlos Castro.)

Hua's calculated volumes related to kernels and Shilov boundaries are the key to calculation of Force Strengths and Particle Masses. For example, the Lagrangian term for each of the Forces is integrated over the M4 physical spacetime base manifold, but each of the Four Forces sees M4 in terms of its own symmetry, consequently with its own measure which measure is proportional to Hua-calculated volumes. Since M4 was formed by a freezing out of a Quaternionic structure, M4 is a 4-dimensional manifold with Quaternionic structure and therefore can be seen as one of Joseph Wolf's 4 equivalence classes:
for Electromagnetism: T4 = U(1)^4
for Weak Force: S2 x S2 = SU(2) / U(1) x SU(2) / U(1)
for Color Force: CP2 = SU(3) / U(2)
for Gravity: S4 = Spin(5) / Spin(4) = Sp(2) / Sp(1)xSp(1)
When we also take into account the relevant volumes related to the curvature term in the Lagrangian for each force,
and the masses involved for forces with gauge bosons related to mass,
the calculations produce results that are reasonably close to experimental observation:

Force Strengths:
Gravity = 5 x 10^-39
Electromagnetic = 1 / 137.03608
Weak = 1.05 x 10^-5
Color at 245 MeV = 0.6286
Renormalization gives Color at 91 GeV = 0.106
and including other effects gives Color at 91 Gev = 0.125

Tree-level fermion masses (Quark masses are constituent masses due to a Bohmian version of Many-Worlds Quantum Theory applied to a confined fermion, in which the fermion is at rest because its kinetic energy is transformed into Bohmian PSI-field potential energy.):
Neutrinos: Me-neutrino = Mmu-neutrino = Mtau-neutrino = 0 at tree-level (first order corrected masses are given below)
Electron/Positron Me = 0.5110 MeV
Up and Down Quarks Md = Mu = 312.8 MeV
Muon Mmu = 104.8 MeV
Strange Quark Ms = 625 MeV
Charm Quark Mc = 2.09 GeV
Tauon Mtau = 1.88 GeV
Beauty Quark Mb = 5.63 GeV
Truth Quark Mt = 130 GeV ground state - 8-dimensional Kaluza-Klein spacetime with Truth-Quark condensate Higgs gives a 3-state system with a renormalization line connecting the 3 states:



(see hep-ph/0307138 for background for chart immediately above)
Low ground state:
Higgs = 146 GeV and T-quark = 130 GeV
Medium Triviality Bound state:
Higgs = 176-188 GeV and T-quark = 172- 175 GeV
High Critical Point state:
Higgs = 239 +/- 3 GeV and T-quark = 218 +/- 3 GeV

Weak Boson Masses (based on a ground state Higgs mass of 146 GeV):
M_W+ = M_W- = 80.326 GeV;
M_Z0 = 80.326 + 11.536 = 91.862 GeV

Kobayashi-Maskawa parameter calculations use phase angle d13 =
= 1 radian (unit length on a phase circumference) to get the K-M matrix:

	d	s	b
u	0.975	0.222	0.00249-0.00388
c	-0.222-0.000161i	0.974-0.0000365i	0.0423
t	0.00698-0.00378i	-0.0418-0.00086i	0.999

Corrections to the tree-level neutrino calculations give neutrino masses
nu_1 = 0
nu_2 = 9 x 10^(-3)eV
nu_3 = 5.4 x 10^(-2) eV
and
the neutrino mixing matrix:

	nu_1	nu_2	nu_3
nu_e	0.87	0.50	0
nu_m	-0.35	0.61	0.71
nu_t	0.35	-0.61	0.71

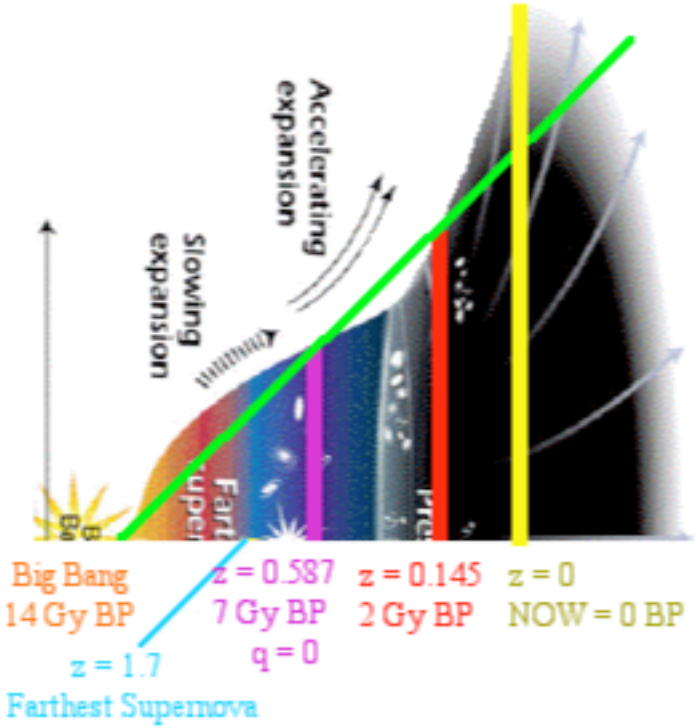
The mass of the charged pion is calculated to be 139 MeV
based on a Kerr-Newman Black Hole model of the pion and its constituent quark-antiquark pair. The pair of Black Holes form a Toroidal Black Hole for which the Torus is an Event Horizon that is (1+1)-dimensional with a timelike dimension which carries a Sine-Gordon Breather whose soliton and antisoliton are the quark and antiquark. The physically relevant Sine-Gordon solution for which the first-order weak coupling expansion is exact gives the ratio of quark constituent mass to the pion mass.

The Neutron-Proton mass difference is calculated to be 1.1 Mev
based on the down quark having virtual states related to the strange quark and the up quark having virtual states related to the charm quark, and the higher probability of strange quark states emerging from the nucleon sea.

The ratio Dark Energy : Dark Matter : Ordinary Matter
for our Universe at the present time is calculated to be:

0.75 : 0.21 : 0.04

based on the Conformal Gravity model of Irving Ezra Segal
and the 15 generators of the Conformal Group Spin(2,4) = SU(2,2)
10 = 6 Lorentz plus 4 Special Conformal = Dark Energy
4 Translations = Dark Matter Primordial Black Holes
1 Dilation = Ordinary Matter mass from Higgs
and the evolution of that basic ratio 10 : 4 : 1 = 0.67 : 0.27 : 0.06
as our universe has expanded



Details of calculations and discussion of some things that here are oversimplified can be found in my free pdf book "E8 and Cl(16) = Cl(8) x Cl(8)" which is available at
http://www.tony5m17h.net/E8physicsbook.pdf and
http://www.valdostamuseum.org/hamsmith/E8physicsbook.pdf

AQFT:

Since the E8 classical Lagrangian is Local, it is necessary to patch together Local Lagrangian Regions to form a Global Structure describing a Global E8 Algebraic Quantum Field Theory (AQFT).
Mathematically, this is done by using Clifford Algebras (others now using Clifford algebras in related ways include Carlos Castro and David Finkelstein) to embed E8 into Cl(16) and using a copy of Cl(16) to represent each Local Lagrangian Region. A Global Structure is then formed by taking the tensor products of the copies of Cl(16). Due to Real Clifford Algebra 8-periodicity, Cl(16) = Cl(8)xCl(8) and any Real Clifford Algebra, no matter how large, can be embedded in a tensor product of factors of Cl(8), and therefore of Cl(8)xCl(8) = Cl(16). Just as the completion of the union of all tensor products of 2x2 complex Clifford algebra matrices produces the usual Hyperfinite II1 von Neumann factor that describes creation and annihilation operators on the fermionic Fock space over C^(2n) (see John Baez's Week 175), we can take the completion of the union of all tensor products of Cl(16) = Cl(8)xCl(8) to produce a generalized Hyperfinite II1 von Neumann factor that gives a natural Algebraic Quantum Field Theory structure to the E8 model.

EPR Entanglement:

For the E8 model AQFT to be realistic, it must be consistent with EPR entanglement relations. Joy Christian in arXiv 0904.4259 "Disproofs of Bell, GHZ, and Hardy Type Theorems and the Illusion of Entanglement" said: "… a [geometrically] correct local-realistic framework … provides exact, deterministic, and local underpinnings for at least the Bell, GHZ-3, GHZ-4, and Hardy states. … The alleged non-localities of these states … result from misidentified [geometries] of the EPR elements of reality. … The correlations are … the classical correlations among the points of a 3 or 7-sphere … S3 and S7 … are … parallelizable …
The correlations … can be seen most transparently in the elegant language of Clifford algebra …". The E8 model AQFT is based on the parallelizable Lie group E8 and related Clifford algebras,
so the E8 model seems consistent with EPR.