This chapter represents the most recent (2014) view about particle massivation in TGD framework. This topic is necessarily quite extended since many several notions and new mathematics is involved. Therefore the calculation of particle masses involves five chapters. In this chapter my goal is to provide an up-to-date summary whereas the chapters are unavoidably a story about evolution of ideas.

The identification of the spectrum of light particles reduces to two tasks: the construction of massless states and the identification of the states which remain light in p-adic thermodynamics. The latter task is relatively straightforward. The thorough understanding of the massless spectrum requires however a real understanding of quantum TGD. It would be also highly desirable to understand why p-adic thermodynamics combined with p-adic length scale hypothesis works. A lot of progress has taken place in these respects during last years.

\vm{\it 1. Physical states as representations of super-symplectic and Super Kac-Moody algebras}\vm

The basic constraint is that the super-conformal algebra involved must have five tensor factors. The precise identification of the Kac-Moody type algebra has however turned out to be a difficult task. The recent view is as follows. Electroweak algebra $U(2)_{ew} =SU(2)_L\times U(1)$ and symplectic isometries of light-cone boundary ($SU(2)_{rot}\times SU(3)_c$) give 2+2 factors and full supersymplectic algebra involving only covariantly constant right-handed neutrino mode would give 1 factor. This algebra could be associated with the 2-D surfaces X^2 defined by the intersections of light-like 3-surfaces with $\delta M^4_{\pm}\times CP_2$. These 2-surfaces have interpretation as partons.

For conformal algebra there are several candidates. For symplectic algebra radial light-like coordinate of light-cone boundary replaces complex coordinate. Light-cone boundary $S^2\times R_+$ allows extended conformal symmetries which can be interpreted as conformal transformations of S^2 depending parametrically on the light-like coordinate of R_+. There is infinite-D subgroup of conformal isometries with S^2 dependent radial scaling compensating for the conformal scaling in S^2. K\"ahler-Dirac equation allows ordinary conformal symmetry very probably liftable to imbedding space. The light-like orbits of partonic 2-surface are expected to allow super-conformal symmetries presumably assignable to quantum criticality and hierarchy of Planck constants. How these conformal symmetries integrate to what is expected to be 4-D analog of 2-D conformal symmetries remains to be understood.

Yangian algebras associated with the super-conformal algebras and motivated by twistorial approach generalize the super-conformal symmetry and make it multi-local in the sense that generators can act on several partonic 2-surfaces simultaneously.   These partonic 2-surfaces generalize the vertices for the external massless particles in twistor Grassmann diagrams \cite{Yangian}. The implications of this symmetry are yet to be deduced but one thing is clear: Yangians are tailor made for the description of massive bound states formed from several partons identified as partonic 2-surfaces. The preliminary discussion of what is involved can be found in \cite{Yangian}.

\vm{\it 2. Particle massivation}\vm

Particle massivation can be regarded as a generation of thermal mass squared and due to a thermal mixing of a state with vanishing conformal weight with those having higher conformal weights. The obvious objection

is that Poincare invariance is lost. One could argue that one calculates
just the vacuum expectation of conformal weight so that this is not case.
If this is not assumed, one would have in positive energy ontology
superposition of ordinary quantum states with different four-momenta and
breaking of Poincare invariance since eigenstates of four-momentum are not
in question. In Zero Energy Ontology this is not the case since all states
have vanishing net quantum numbers and one has superposition of time
evolutions with well-defined four-momenta. Lorentz invariance with respect
to the either boundary of CD is achieved but there is small breaking of
Poincare invariance characterized by the inverse of p-adic prime p
characterizing the particle. For electron one has $1/p=1/M_{127}\sim 10^{-38}$.

One can imagine several microscopic mechanisms of massivation. The
following proposal is the winner in the fight for survival between several
competing scenarios.

\begin{enumerate}

\item Instead of energy, the Super Kac-Moody Virasoro (or equivalently
super-symplectic) generator L_0 (essentially mass squared) is thermalized
in p-adic thermodynamics (and also in its real version assuming it exists).
The fact that mass squared is thermal expectation of conformal weight
guarantees Lorentz invariance. That mass squared, rather than energy, is
a fundamental quantity at CP_2 length scale is also suggested by a
simple dimensional argument (Planck mass squared is proportional to $\hbar$
so that it should correspond to a generator of some Lie-algebra (Virasoro
generator L_0!)). What basically matters is the number of tensor factors
involved and five is the favored number.

\item There is also a modular contribution to the mass squared, which can
be estimated using elementary particle vacuum functionals in the conformal

modular degrees of freedom of the partonic 2-surface. It dominates for
higher genus partonic 2-surfaces. For bosons both Virasoro and modular
contributions seem to be negligible and could be due to the smallness of
the p-adic temperature.

\item A natural identification of the non-integer contribution to the
mass squared is as stringy contribution to the vacuum conformal
weight (strings are now \blockquote{weak strings}). TGD predicts Higgs particle and
Higgs is necessary to give longitudinal polarizations for gauge bosons. The
notion of Higgs vacuum expectation is replaced by a formal analog of Higgs
vacuum expectation giving a space-time correlate for the stringy mass
formula in case of fundamental fermions. Also gauge bosons usually
regarded as exactly massless particles would naturally receive a small mass
from p-adic thermodynamics. The theoretetical motivation for a small mass
would be exact Yangian symmetry which broken at the QFT limit of
the theory using GRT limit of many-sheeted space-time.

\item Hadron massivation requires the understanding of the CKM mixing of
quarks reducing to different topological mixing of U and D type quarks.
Number theoretic vision suggests that the mixing matrices are rational or
algebraic and this together with other constraints gives strong constraints
on both mixing and masses of the mixed quarks.

\end{enumerate}

p-Adic thermodynamics is what gives to this approach its predictive power.

\begin{enumerate} \item p-Adic temperature is quantized by purely number theoretical constraints (Boltzmann weight $exp(-E/kT)$ is replaced with p^{L_0/T_p}, $1/T_p$ integer) and fermions correspond to $T_p=1$ whereas $T_p=1/n$, $n>1$, seems to be the only reasonable choice for gauge bosons.

\item p-Adic thermodynamics forces to conclude that CP_2 radius is essentially the p-adic length scale $R \sim L$ and thus of order $R \simeq 10^{3.5} \sqrt{\hbar G}$ and therefore roughly $10^{3.5}$ times larger than the naive guess. Hence p-adic thermodynamics describes the mixing of states with vanishing conformal weights with their Super Kac-Moody Virasoro excitations having masses of order $10^{-3.5}$ Planck mass.

\end{enumerate}