# J/Ψ production and TGD

M. Pitkänen
Email: matpitka6@gmail.com.
http://tgdtheory.com/.

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**Abstract**

## Contents



# 1 Introduction

A new anomaly has been discovered by LHCb collaboration (see http://tinyurl.com/mjucnwl). The production of J/Ψ mesons in proton-proton collisions in the Large Hadron Collider (LHC) at CERN does not agree with the predictions made by a widely used computer simulation, Pythia. The result comes from CERN's LHCb experiment studying the jets of hadrons created as protons collide at 13 TeV cm energy.

These jets contain large numbers of J/Ψ mesons consisting of charmed quark and a charmed anti-quark. The LHCb measured the ratio of the momentum carried by the J/Ψ mesons to the momentum carried by the entire jet. They were also able to discriminate between J/Ψ mesons created promptly (direct/prompt production) in the collision and J/Ψ mesons that were created after the collision by the decay of charmed hadrons produced by jets (jet production).

Analysis of the data demonstrates that PYTHIA - a Monte Carlo simulation used to model high-energy particle collisions - does not predict correctly the momentum fraction carried by prompt J/Ψ mesons. The conclusion is that the apparent shortcomings of PYTHIA could have a significant effect on how particle physics is done because the simulation is used both in the design of collider detectors and also to determine which measurements are most likely to reveal information about physics beyond the Standard Model of particle physics. Heretic could go further and ask whether the problem is really with Pythia: could it be with QCD?

The TGD explanation for the finding is same as that for strangeness enhancement in p-p collisions [?] in the same energy range at which the de-confinement phase transition is predicted to occur in QCD. In TGD one would have quantum criticality for a phase transition from the ordinary $M_{107}$ hadron physics to $M_{89}$ hadron physics with hadronic mass scale by a factor 512 higher than for ordinary hadrons. The gluons and quarks at quantum criticality would be dark in the sense of having $h_{eff}/h = n = 512$. Also $1/n$-fractional quarks and gluons are possible.

TGD predicts besides ordinary bosons two additional boson generations, whose family charge matrices in the space of fermion families are hermitian, diagonal and orthogonal to each other to the unit charge matrix for ordinary bosons, and most naturally same for all bosons. The charge matrices for higher generations necessarily break the universality of fermion couplings. The model for strangeness enhancement and the violation of lepton universality in B-meson decays predicts that the bosonic family charge matrix for second generation favours decays to third generation quarks and dis-favors decays to quarks of first and second generation. This predicts that the rate for prompt production of J/Ψ is lower and jet production rate from $b$-hadron decays is higher than predicted by QCD.

## 1.1 The prediction for prompt production of J/Ψ does not conform with the Pythia simulation

The abstract of the article [?] published in Phys Rev Letters (see `http://tinyurl.com/l3xnxtj`) gives a more technical summary about the discovery (see `http://tinyurl.com/l3xnxtj`).

*The production of J/Ψ mesons in jets is studied in the forward region of proton-proton collisions using data collected with the LHCb detector at a center-of-mass energy of 13 TeV. The fraction of the jet transverse momentum carried by the J/Ψ meson,* $z(J/\Psi) \equiv p_T(J/\Psi)/p_T(jet)$*, is measured using jets with* $p_T(jet) \geq 20$ *GeV in the pseudorapidity range* $2.5 \leq \eta(jet) \leq 4.0$*. The observed z(J/Ψ ) distribution for J/Ψ mesons produced in b-hadron decays is consistent with expectations.*

*However, the results for prompt* $p_T(J/\Psi)$ *production do not agree with predictions based on fixed-order non-relativistic QCD. This is the first measurement of the* $p_T$ *fraction carried by promp*$_T$ *J/Ψ mesons in jets at any experiment.*

Some explanation about the basic notions are needed before continuing.

1. Pythia is a simulator producing QCD predictions in p-p, p-N, and N-N collisions. The collisions are extremely complex so that this kind of simulation involves uncertainties. QCD model involves distribution functions for partons inside hadron and fragmentation functions for jets telling the probabilities for production of various hadrons from the jet initiated by quark or gluon. Furthermore, at energy range believed to correspond to the transition from confined phase of quarks and gluons to quark-gluon plasma the modelling becomes especially difficult. Situation is made even more difficult by the fact that the quark-gluon plasma (QGP) does not look like plasma but more like ideal fluid with long range correlations. The problem might with QCD itself.

2. There are two mechanisms for J/Ψ production.

   (a) In direct/prompt production J/Ψ is produced in gluon annihilation. Two gluons from the colliding nucleons annihilate to quark pair either via intermediate gluon or by quark exchange. For this mechanism the production is fast, there is large transverse polarization of J/Ψ reflecting the polarization of gluon pair fusing to $c\overline{c}$ pair, and J/Ψ events are isolated in the momentum space.

   (b) TIn jet production of J/Ψ mesons come from the decays of b-hadrons (hadrons containing b-quarks) resulting in the fragmentation of b-jets to hadrons. The mechanism is slow since $c$ quark results from the weak decay of b quark.

3. LHCb team measures the ratio of the transversal momentum of the part of jet consisting of J/Ψ mesons to the transverse momentum of the jet. This is consistent with the jet model. The team manages also to separate the jet production from prompt production and concludes that prompt production is smaller than predicted by Pythia.

The heretic questions are following. Could the direct production be smaller than predicted by QCD? Could b-quarks giving rise to jets containing more b-hadrons than QCD predicts?

## 1.2 TGD inspired model

Before going to the model it is good to explain some background.

1. Rather recently I proposed a TGD inspired model explaining the enhanced strangeness production observed in p-p collisions [?] [?]. TGD predicts 3 generations for all bosons and the family charge matrices act in the triplet representation defined by 3 fermion families for what could be called family-SU(3) acting as a spectrum generating group.

   The additional two boson generations necessarily violate the universality of standard model interactions since they must be orthogonal with each other and with the charge matrix of ordinary bosons. The strongest assumption is that the charge matrices are identical for all bosons (including Higgs, photon, and even graviton).

I have talked for years about scaled-up copy of hadrons assignable to the Mersenne prime $M_{89} = 2^{89} - 1$ (ordinary hadron physics would correspond to $M_{127}$). The mass scale for the hadrons of $M_{89}$ hadron physics would 512 times that for ordinary hadron physics and in the first approximation the masses of the scaled up hadron physics would be 512 those of the ordinary hadron physics. There are indications for roughly 10 bumps identifialbe as $M_{89}$ hadrons and having the predicted masses.

If second generation gluons prefer to decay to a quark pair of third generation ($t$ or $b$ pair), strangeness enhancement can be understood qualitatively since the third generation quarks would decay to $c$ and $s$ quarks by weak boson emission and $c$ quarks in turn would decay to $s$ quarks, which are rather long-lived.

2. The violation of the universality would take place also for weak interactions. Second generation of weak bosons in turn explain the anomalous CP violation and the violation of the lepton universality observed in the decays $b$-mesons. Also now it is essential that the second generation of weak bosons prefers to decay to a pair of third generation leptons, that is $\tau$ pair. Also the anomaly of muon's anomalous magnetic moment and different values of charge proton radius deduced from hydrogen atom and muoniums atom could be understood in terms of the violation of lepton universality induced by the same mechanism [?].

For these reasons and also because both $c$ quark and $s$ quark correspond to the second quark generation, it is interesting to see whether the too low yield of prompt $c$ quarks and perhaps too high yield of $c$ quarks from jets could be understood in terms of second generation of gluons preferring to decay to $b$ quark pair and having reduced coupling to first and and second fermions.

Let us look what the assumptions of this model could be.

1. Second generation gluons are somehow created in the collision, and they fuse to quark pair. $t$ quark pairs (if kinematically possible) and $b$ quark pairs are preferred due to their charge matrix in family-space for fermions. The decay to first and second generation quark pairs would disfavored by the properties of the charge matrix. This could be enough to explain why direct production is reduced and jet production enhanced. Situation would be very similar to strangeness enchancement which should be due to the jet production.

2. Deconfinement phase transition is believed to produce QGP. The behavior of the QGP candidaate produced at RHIC and LHC is however not that of QGP. The presence of this phase even in p-p collisions looks rather strange. The TGD based model for enhanced production of strange hadrons assumes that the quantum criticality for deconfinement corresponds to that for the transition to QCD for second generation gluons. Quantum criticality for a phase transition from $M_{107}$ hadron physics to $M_{89}$ hadron physics would be in question.

   Quantum criticality corresponds to a creation of phase with non-standard value $h_{eff}/n = n$ of Planck constant, and $n = 512$ would imply that the Compton length of second generation gluons with given energy 512 longer than for ordinary gluons: this would be a counterpart for long range quantum fluctions at quantum criticality. The counterpart for the mass scale $\Lambda_{QCD}$ wuld be by a factor 512 higher than its value in ordinary QCD and correspond to a mass scale about 75 GeV slightly higher tham the mass of $M_{89}$ pion.

3. If quantum criticality is accepted and family-charge matrices are universal , the fusion mechanism would produce from dark $M_{89}$ gluons a pair of dark $M_{89}$ quarks with preferring to decay to $b$ or $t$ quark pair and disfavoring decays to lower generation quark pairs. These quarks would transform to ordinary quarks and after that the situation would be as in ordinary QCD.

What charge matrices could look like?'

1. Ordinary gauge bosons correspond by universality to charge matrix $(1, 1, 1)$. All charge matrices are orthogonal to each other and thos for second and third generation bosons are

hermitian, diagonalmatrices with vanishing trace. The simplest proposal for second generation charge matrix is as matrix proportional to hyper charge matrix $Y = (-1/3, -1/3, 2/3)$. Third generation charge matrix is proportional to $I_3 = (1/2, -1/2, 0)$. The coupling by hypercharge matrix would be two times stronger than by isospin matrix and favor decays of gluons to third generation quarks. This guess might hold true in absence of topological mixing of the partonic topologies with genus $g = 0, 1, 2$.

Topological mixing for fermions would cause mixing of fermion families depending on the charge state of fermion: $U$ resp. $D$ type quarks are mixed by unitary matrix $U$ resp $D$. For first generation neutral weak bosons and gluons the charge matrices are not affected. For higher generations one has $Q_i \rightarrow UQU^\dagger$ and $Q_i \rightarrow DQ_iD^\dagger$. For charge weak bosons one has $Q_i \rightarrow UQ_iD^\dagger$ giving for the lowest generation CKM matrix $CKM = UD^\dagger$ and its along for higher generations. CKM matrix would therefore show itself in the couplings. If one accepts the identification of charge matrices as $Y$ and $I_3$ the model predicts the couplings apart from the normalization of these matrices.

A comment about a long standing problem related to the fractionization of quantum numbers is in order although it is not absolutely relevant for the recent situation. One can consider two interpretations for what $h_{eff}/n = n$ means depending on whether the quantum numbers are fractionized or not. The first option works for the above model and second option leads to strange results.

1. Charge fractionization means that the unit of charge (say spin) is scaled down by $1/n$, $h_{eff}/h = n$. The dark matter fermion with all $n$ sheets of covering containing $1/n$-fractional fermion is analogous to a full Fermi sphere and has non-fractional quantum numbers. Also fractional filling is possible. Total quantum numbers must be however fractional and one has anyonic states consisting of several fractional particles [**?**]. The transition to ordinary phase at single particle level is possible only for a particle with full Fermi sphere. Otherwise anyons with complementary Fermi spheres must fuse to give ordinary particles.

   For years ago I proposed that pairs formed by dark fractional particle and its complement assignable to a pair of biomolecules could have meant the emergence of symbolic dynamics at molecular level and of what might be called molecular sex. This could correspond to the assignment of fractional proton triplets to DNA codon and its complementary fractional triplet to conjugate codon. DNA double strand would represent the visible part of molecular marriage of dark DNA sequences.

2. Half-odd integer value of the total angular momentum for the many-anyon system guarantees that the action of $2\pi$ rotation in Minkowski space is consistent with the ordinary statistics. One can also consider rotations a the level of space-time surface. For $n$-fold covering only the $M^4$ rotation of $n \times 2\pi$ acting on point of space-time surface has the usual effect and one can say that the particle has fractional spin at space-time level.

3. There is however an objection to fractionization. The original idea behing hierarchy of Planck constants was that the energy $E = hf$ associated with frequency $f$ is scaled up to $E = h_{eff}f$. For cyclotron frequencies $f_c \propto qB/m$. Suppose transition to dark phase occurs and all sheets are filled. The fractionizations of $q$ and $m$ compensate each other. If $B$ has the original values at all $n$ sheets, the cyclotron energies increases by factor $n$ as required. One has $n$ copies of the original space-time sheet carrying the original magnetic field so that a kind of space-time correlate for Bose-Einstein condensation is in question.

How the second generation gluons could be generated at quantum criticality?

1. Could ordinary gluons make a direct single particle transition to dark second generation gluons with ordinary quantum numbers or could they decay to dark fractional gluons of second generation? For both options the gluon distributions of incoming nucleons appear in the convolution giving the cross section for gluon fusion as function of collision energy. If this assumption is not made, the distribution functions would be replaced by their analogs for the intermediate state created in the collision and having weak dependence on colliding particles. This might be tested experimentally.

2. Depending on whether one approaches critical energy range from below or above, $M_{107} - M_{89}$ quantum criticality means that either the ordinary $M_{107}$ or $M_{89}$ hadron physics becomes unstable. Long range quantum fluctuations correspond to the scaling of the correlation length by $h_{eff}/h = n = 512$. The quantum critical phase would be hybrid of these two hadron physics. This hybrid nature would resolve the paradox due to the fact that two distinct phases become single phase at criticality.

   There should exist some critical parameters such as collision energy, whose variation induces the transition and the bosonic counterparts of elementary particle vacuum functionals [**?**] in the moduli space of partonic 2-surfaces should change in the transition. What would happen at the level of partonic 2-surfaces? Certainly their size for ordinary $M_{89}$ hadrons would be by a factor 1/512 smaller.

# REFERENCES