Particle Physics Phenomenology

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We give a summary of contributed talks and papers in the plenary, parallel and poster sessions of the XXIV ENFPC (Brazilian National Meeting on Particles and Fields) in the area of particle phenomenology.

1 Introduction

In the XXIV ENFPC were presented one plenary talk, three parallel talks, 15 oral communications and 27 posters on Phenomenology.

The research on phenomenology presented at XXIV ENFPC could be divided in some main domains: extensions of the standard model and searches; heavy quarks production, and models; high density QCD and nuclear dependence and models; perturbative and non-perturbative QCD; neutrinos, and cosmic rays.

We had presentations from researchers representing 16 brazilian institutions, from the south-east of Brazil, showing a strong regional concentration of the research in this field. Also, there were represented 12 foreign institutions, from plenary speakers to collaborators, demonstrating a high level of international interaction in our community.

The quality of oral presentations as well as the posters, and the degree of participation and discussions is increasing each year, which is one of the aspects to be considered by the funding agencies. The meeting is very relevant for MSc and PhD students, Pos-docs as well as for professors, and is quite representative of the area, although a higher level of participation of seniors in the field would be highly appreciated.

2 Plenary and Parallel Talks

In a very pedagogical plenary talk, we heard Prof. Xin-Nian Wang, from Lawrence Berkeley National Laboratory, explain the aspects of jet tomography of quark-gluon plasma [1]. The technique of jet tomography is particularly suitable for the analysis of heavy ions collisions, specially the study of the properties of the dense matter formed at Relativistic Heavy Ion Collider (RHIC). The high \( p_T \) partons degrade during their propagation in the dense medium since multiple scattering promotes radiative energy loss. This induces a suppression on high \( p_T \) spectra from jet fragmentation, which is known as jet quenching, already observed in \( Au - Au \) collisions at RHIC. Other aspects involved in the technique are the disappearance of back-to-back jet-like hadron correlations and the finite azimuthal anisotropy of high-\( p_T \) hadron spectra, also connected with jet quenching.

The implementation of jet tomography as a tool is related, on the theoretical side, with the calculation of radiative parton energy loss, which at RHIC is 30 times higher than in cold nuclei, and with the modified fragmentation function. It would provide valuable information on dense matter physical properties and possibly to extract the initial parton density, and formation time, using the effective total parton energy loss. The initial parton density is key information to provide initial conditions which is extremely relevant to determine the most suitable evolution equation for the partonic system, meaning the dynamics of QCD.

In the parallel talk on dynamics of dense partonic systems, Victor Gonçalves, from UFPel, evolved through the theoretical and phenomenological issues concerning high density QCD [2], like saturation, and their relation with the interface between perturbative and non-perturbative QCD. It was discussed how it relates with non-linear dynamics expressed in the parton evolution equations GLR, AGL, and BK [3]: this is not closed subject, and several related issues to provide information on initial conditions where addressed in the above plenary talk. It was also presented an interesting contribution of geometric scaling at DIS through the analysis of charm production at HERA.

We heard on KamLand data and the solution to the solar neutrino problem, by Pedro de Holanda, from UNICAMP [4]. The KamLand results present good agreement with predictions based on solar neutrino data. The result suppress positive sign oscillation and eliminates the solution of no oscillation. The best fit combining 84 experimental data from 5 experiments gives \( \Delta m^2 = 7.5 \times 10^{-5} \) eV\(^{-2}, \sin^2 2\theta = 0.9 \). The best fit splits LMA (Large Mixing Angle) region, and the low mass LMA is preferred, \( \Delta m^2 < 10^{-3} \) eV\(^{-2}, 99\% \) CL, and predict for SNO : CC/NC = 0.33 + 0.05 - 0.03.

The parallel talk presented by Pedro Galli Mercadante, from USP [5], addressed the search for supersymmetry at the Large Hadron Collider (LHC). The investigation concerns SUSY at electroweak scale which analysis at ATLAS and CMS is on the region of large scalar masses. It is a search for new physics at TeV scale and in the simplest
scenario, MSSM involves two superpartners ($m_H < 140$ GeV). Since for the Tevatron the limit for gaugino mass is $m_{1/2} < 200$ GeV, at LHC this limit goes to $m_{1/2} \lesssim 900$ GeV, and for the supersymmetric quarks $m_{squarks} < 2$ TeV, and $m_{gluino}(GMSB) < 2.9$ TeV (0.9 TeV at Tevatron). LHC has the potential to cover natural region in many SUSY scenarios and it is very exciting motivation for those searches.

3 Oral Communications and Posters

To summarize all the talks from parallel sessions and posters I adopted a personal point of view to separate and classify the works following what I considered their main subject, mostly related with the main domains mentioned in the Introduction. Obviously, this positioning has only the goal to systematize this review: a paper in several cases pertains to more than one subject.

We can identify a significant amount of work related with extensions of the Standard Model and the searches of new physics in new fundamental energy scales, still divided in some main subjects.

Several authors dedicated effort on the 3-3-1 model [6], which is a robust model for the physics at TeV scales with 3 triplets to generate lepton masses. Besides coinciding with the standard model at low energy, the model provides $N=1$ SUSY at energy scale $\mu(\approx 4$ TeV). In the contribution by A. G. Dias, C. A. de Sousa Pires, P. S. R. da Silva [7], it is shown that the global symmetries are satisfied in 3-3-1 with right-handed neutrinos. The breaking of Peccei-Quinn symmetry yields an invisible axion, as a candidate of cold dark matter (CDM). An another characteristic of 3-3-1 model is the existence of double charged Higgs boson, which was studied in weak sector limits and also giving high energy predictions [16]. The recombination mechanism, as opposite to the fragmentation, is considered to explain the large $x_F$ behavior of the charm production in $\pi N$ in the work by J.E. Magnin, C. Ávila, L.M. Mendoza-Navas [17]. The $J/\Psi$ cross section in elastic photo and electron-production is calculated non-perturbatively, employing the stochastic vacuum model, and also $\sigma_{\ell}/\sigma_{T}$, and $Q^2$ distributions, with good agreement, by E. Ferreira, H.G. Dosch [18]. Inclusive charm production at HERA $ep$ collider provides the study of large range of photon virtuality ($Q^2$), however the saturation momentum $Q^2_{sat}(x)$ ranges below the hard scale ($\mu^2 = 4m_c^2$). This aspect is explored, using two saturation models, showing a scaling $\tau = Q^2_{sat}(x)$, above the saturation limit, meaning a geometric scaling regime, in the work by V. P. Gonçalves, M.V.T. Machado and M.M Machado [19] The control channel $B^0 \to J/\Psi k^{+0}$ is proposed and analysed by L.S. de Paula and E.C. de Oliveira, in order to study systematics for the performance of the LHCb detector, including final state acceptance [20].

Heavy ion collisions, and $A$-dependence in high density QCD are very relevant subjects in the last years, partly motivated by the available and future data, mostly from RHIC, and the general interest on the possibility of the formation of the quark gluon plasma, as well as the aspect of saturation of the gluon distribution function required by unitarity. Several works addressed the rich phenomenology with nucleus from the high energy point of view.

Among them, some authors dedicated their interests to peripheral and ultraperipheral collisions. The calculation using saturation in the color dipole picture in two photon process from heavy ion ultraperipheral collisions, enhances the heavy quark production cross section following the work by V.P. Gonçalves and M.V.T. Machado [21]. The same authors considered two-photon process also to obtain double meson production in $A - A$, for RHIC and LHC, obtaining that the mechanism is a good discriminator among different proposed QCD dynamics [21]. The phenomenological saturation model is applied to deeply virtual Compton scattering,
Aiming to access nonperturbative region in QCD, through the solution of the Schwinger-Dyson equations, conducts to some solutions with frozen value of the coupling constant. This value is related with the β function (RG for pure non-Abelian theory) fixed point once dynamical gluon mass scale is invoked to satisfy the global minimum of energy, as presented by A. C. Aguilar, A. A. Natale, P. S. R. da Silva [34]. A novel regularization scheme is applied by R. L. S. Farias, O. A. Battistel, G. Krein to the finite Nambu-Jona-Lasinio model, in order to deal with divergent amplitudes, which is free of ambiguities and symmetry violations. The method is shown to be appealing since it allows a single mass scale to treat the divergent integrals in chiral symmetry breaking in connection with charge independence [35]. Phase-shift definitions in chiral perturbation theory and in Unitarization Program applied to pion-nucleon amplitudes moved the analysis of J. S. Borges Filho, I. P. Cavalcante, showing that UP amplitudes are more efficient to fix parameters, since less sensitive than ChPT [36].

The pions and kaons parton distribution function are studied by J. C. Sanabria, C. Avila and J. Magnin who present a parametrization for \( \pi(x, Q^2) \) and \( K(x, Q^2) \), fitting parameters using E615 and NA63 data [37].

Pentaquarks in the QCD sum rule framework were proposed to explain the state \( \Theta^+(1540) \) as \( [ud]^{2}s \), with good agreement, also suggesting the state \( [ud]'d \) to be compatible with \( N(1440) \), the Roper resonance, following the work by R.D. Matheus, F.S. Navarra, M. Nielsen, R. Rodrigues da Silva and S.H. Lee [38].

The interest in neutrino physics in our community is steadily increasing, with solid established collaborations and several relevant contributions.

Besides the already mentioned parallel talk [4] the contributions ranged from an introductory motivational review of flavor oscillation in vacuum and matter by G. A. Valdivieso and M. Guzzo [39] to a contribution on detection of very high energy neutrinos. In this work by C. A. de Moura Junior and M. Guzzo [40], it is shown the observational potential of the Pierre Auger Observatory to detect \( \nu_\tau \) with \( E_{\nu_\tau} \approx 1EeV \), from Double Bang events, meaning the interaction in the atmosphere of very high energy \( \nu \) from extragalactic sources, providing in some cases a second shower from \( \tau \) decay.

Considering a simulation of the conditions of experiment LSND, the oscillation \( \bar{\nu}_e - \bar{\nu}_e \) is calculating in a two families, and three families of neutrinos framework by C. Frigerio, V. M. de Aquino [41] with the goal to conciliate all available data.

The requirement of a heavy neutrino in see-saw mechanism is examined by R. S. Gomes and F. M. L. de Almeida Júnior concerning the possibility of detection in ATLAS of heavy Majorana neutrinos, basically \( q_i q_j \rightarrow e^+ e^- j j \) [42].

Solar neutrino problem solution known as LMA, related to the neutrinos oscillation enhanced by matter, is sensitive to random perturbations of the solar matter allowing M. Guzzo, P. C. de Holanda and N. Reggiani to show new regions of interest for KamLAND, the very low LMA [43].

The consideration of the particle rigidities in the cosmic...
ray spectrum implies heavier composition above the knee of
the spectrum and produces suppression of very high energy, $E_\nu > 10^{14}$ eV, diffuse neutrino fluxes, and consequently
t heir detection would be more difficult by the work by J. Candia, E. Roulet [44].

Combining the Earth velocity with respect to the cosmic
background radiation with the neutrino velocity distribution
generates a neutrino wavelength variation, which is mass
dependent, once detected on Earth. This provides a new
method of determination of the different neutrino masses by
the detection of the cosmic $\nu$ background, as proposed by
M. Makler and J. Rafelski [45].

The reaction channel $\gamma\gamma \rightarrow \pi^0 \rightarrow \nu_R \bar{\nu}_L (\nu_L \bar{\nu}_R)$ has its rate strongly suppressed in dense hadronic matter due to
multi-particle effects, for comprehensive analysis of right-
handed $\nu_L$, massive left-handed $\nu_\tau$ and massless $\nu_e'$. However,
this channel is the most efficient $\nu$ cooling process, applicable
to neutron stars, in the color-flavor-locked superconducting phase, following the contribution by F. Arretche,
A. Natale and D. N. Voskresensky [46].

A calculation of muon fluxes and muon charge ratio was
presented for energies from a few GeV to several TeV and Zenith angles from $0^\circ$ to $90^\circ$, applying depth-like ordered
exponential operator to solve the hadron diffusion equations.
The authors H. Portella, L. C. S. Oliveira, C. E. C. Lima,
and M. Gay Ducati, got very good agreement with data at sea level [47].

The fascinating project of the Extreme Universe Space
Observatory (EUSO) designed to operate in space, to ob-
serve and measure extensive air showers initiated by Ultra
High Energy Cosmic Rays (UHECR’s) was presented by J.
A. Muniz, R. Engel, J. A. Ortiz, T. K. Gaisser and T. Stanoev
[48]. Besides the high statistics expected, it contemplates the possibility to detect $\nu$ events above 10 EeV.

4 Concluding Remarks

The XXIV ENFPC was an exciting meeting showing more
maturity of the phenomenology area, although the regional
concentration and stability of the number of contributions.
The works presented comprehend 120 authors from Brazi-
lian institutions, 15 published papers, 8 submitted and/or
in the web, 19 in progress, as informed in the contributions.

We may ask where we are going, and as far as main sub-
jects presented it is noticeable the research on extensions of
the SM and searches, neutrino physics as a whole and very
high energy cosmic rays, nonlinear phenomena on high den-
sity QCD, and perturbative and nonperturbative calculations
on QCD analyzed from different aspects. I understand there
is room to improve the effort on astroparticle physics in gen-
eral as well as statistical methods in dense matter.

Acknowledgement

I would like to thank the Organizing Committee for the
kind invitation to present the summary talk on phenomeno-
logy. It was an excellent opportunity to have a deeper kno-
wledge of the scientific interests of our community. I apolo-
gize in advance if involuntarily one of the contributions was
not mentioned in this review.

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