9th Shivalik HEPCATS (High Energy Physics, Cosmology, Astronomy: Theory and Simulations)

Saturday 27 January 2024 - Sunday 28 January 2024

IISER Mohali

Book of Abstracts

Contents

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Steep potentials in Warm Inflation

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Steep potentials in cold inflation leads to power-law type inflation where inflation does not exit gracefully as long as one considers standard general relativity. Warm inflation, a variant inflationary paradigm to the standard cold inflation scenario, can accommodate steep potentials very easily. Not only inflation gracefully exits in these Warm Inflationary scenarios, but they also lead to observationally viable models. Warm inflation with steep potentials can also be on par with the recently proposed Swampland Conjectures in String Theory, which makes them viable model of inflation which can be constructed within String Landscapes. In this talk we will discuss such aspects of Warm Inflation with steep potentials.

arXiv no: 2005.01122 [gr-qc], 2007.15268 [hep-th], 2212.13914 [astro-ph.CO]

2

Heavy quark dynamics via Gribov-Zwanziger approach

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In this work, we investigate the momentum-dependent drag and diffusion coefficient of heavy quarks (HQs) moving in the quark-gluon plasma (QGP) background. The leading order scattering amplitudes required for this purpose have been obtained using the Gribov-Zwanziger propagator for the mediator gluons to incorporate the non-perturbative effects relevant to the phenomenologically accessible temperature regime. The drag and diffusion coefficients so obtained have been implemented to estimate the temperature and momentum dependence of the energy loss of the HQ as well as the temperature dependence of the specific shear viscosity (η/s) of the background medium. Our results suggest a higher energy loss of the propagating HQ compared to the perturbative estimates, whereas the η/s is observed to comply with the AdS/CFT estimation over a significantly wider temperature range compared to the perturbative expectation.

4

Discovery of rare decay modes at the Belle and Belle II experiment.

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We will present the study of rare decay modes B+ → Ds*+h0 and B+ → D+h0, where h0 denotes the neutral mesons (η and K0) using a data sample of the Belle experiment. These rare decay modes are poorly measured in the world, and we first time studied them using the full Belle data collected at an
asymmetric KEKB e+e- collider situated at Tsukuba, Japan. Along with rare decay modes, we will report improved measurements in the branching fraction of the color-suppressed decays B0 → D0 h0. We will also present the sensitivity study of B0−>D_{s}ˆ{0}/piˆ{0} modes with the Belle and Belle II experiment.
In the absence of a significant signal yield, an upper limit at the 90% confidence level is given for each signal decay mode. We present the first search result for the B+→D+η decay mode. The obtained upper limits are 20 times more stringent than the previous one. We report the most precise measurement to date of the branching fraction for the B0→D0 K0 decay mode.

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Detector and physics simulation using heavy ion collisions at NICA-SPD

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The space-time picture of hadron formation in high-energy collisions with nuclear targets is still poorly known. The tests of hadron formation was suggested for the first stage of SPD running. They will require measuring charged pion and proton spectra with the precision better than 10%. A research has been carried out to check feasibility of such studies at SPD. In this work, $^{12}C - ^{12}C$ and $^{40}Ca - ^{40}Ca$ heavy ion collisions at center of mass energy of 11 GeV/nucleon were simulated using the SMASH event generator. Firstly, the generator-level events were studied. The distribution of track multiplicities and momentum distributions of different types of charged particles were obtained. Secondly, the generated events passed through the full reconstruction using the SpdRoot framework. At this stage particles were identified using dE/dx measurement and time-of-flight information. It allowed us to estimate charge track multiplicities in the tracking system and purities of charge particles spectra. The results on multiplicity are important to estimate occupancies in the tracking system, while the results on the pion and proton momentum spectra show that particle identification should be acceptable for validation of hadron formation models. This is the first study of moderate ion collisions for the SPD Collaboration.

Keywords: Hadron formation effects, Heavy ion collision, SMASH, NICA-SPD, Rapidity, Charged track multiplicity, Particle physics event generator.

6

Entanglement and Chaos near Critical Point in Strongly Coupled Gauge Theory

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We perform a holographic study of the high and low temperature behaviour of logarithmic negativity (LN) in a large N strongly coupled thermal field theory with critical point, having a well defined gravity dual known as 1RC black hole. The bulk theory accommodates a dimensionless parameter ξ, proportional to the charge of the 1RC black hole. Holographically, $\xi \to 2$ limit ensures an existence of a critical point in the dual boundary theory. We show that the logarithmic negativity in low and high temperature limits enhances with increasing ξ. We holographically explore the correlation between two identical copies of thermal field theory with critical point forming a thermofield double state (TFD) by computing the thermo mutual information (TMI). TMI shows an increasing behaviour with respect to the width of the boundary region. Furthermore, we study the chaotic behaviour of the field theory by analyzing a shock wave in the dual eternal 1 RC black hole and then estimate the degradation of TMI. The rate of such disruption of TMI slows down as the value of critical parameter ξ takes higher values.

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Holographic Thermal Correlators for Hyperbolic CFTs

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We use holography to compute the exact form of retarded Green's functions for a scalar operator with conformal dimension Δ in a thermal CFT and in its related counterpart with chemical potential in $R^1 \times H^3$. In our analysis, we recast the wave equation of a scalar field in the normal form of Heun's equation in the dual gravity theories described by the AdS hyperbolic blackhole and its charged version. Heun's equation is identified to the semiclassical limit of the BPZ equation for a five-point correlator with one degenerate field insertion in the Liouville theory on the Riemann sphere. The crossing symmetry of conformal block in the Liouville theory eventually gives rise to a set of connection formulas among the solutions of Heun's equation evaluated at different regular singularities. We use the connection formula to reproduce the leading order behaviors of the scalar field near the horizon as well as near the boundary and achieve the exact form of the retarded thermal Green's function. We show a recipe to obtain the exact retarded Green's function for a thermal CFT dual to AdS blackbrane from a high-temperature limit accompanied by a complex mapping on AdS hyperbolic blackhole. Moreover, we show the retarded Green's function for the boundary CFT of Rindler AdS spacetime admits a free integer parameter.

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Pole-Skipping and Chaos in Too MUCH Hot QCD

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In this conference, I will discuss the question we have addressed whether the thermal QCD is chaotic or not. In our recent results, we have found that QCD is unusually chaotic above de-confinement temperature using its M-theory dual up to $O(R^4)$ corrections. The gauge invariant combination $Z_s(r)$ of scalar metric perturbation is found to possess an irregular singular point at the horizon radius. Via using Pole skipping techniques we have computed the chaos characteristics i.e., Lyapunov exponent (λ_L) and Butterfly velocity (v_b) from a specific value of imaginary frequency and momentum, this makes the the horizon as regular singular point. The imaginary frequency and momentum

can be read off via truncating the incoming modes of $Z_s(r)$ as a power series near r_h, gives a missing pole satisfying the condition $C_{n,n+1} = 0$, $detM^{(n)} = 0''$, $n\epsilon Z^+$, for our case it is satisfied for a single $n \geq 3$ depending on the values of the string coupling g_s, number of (fractional) $D3$ branes $(M)N$ and flavor $D7$-branes N_f in the parent type IIB setup, e.g., for the QCD(EW-scale)-inspired $N = 100, M = N_f = 3, g_s = 0.1$, and found the missing pole at $n = 3$. Preventing the isotropy along R^3 the $Z_s(r)$ receives no higher order correction, which makes the $_L$, v_b unrenormalized up to $O(R^4)$ in M theory.

9

Analytic three-dimensional primary hair charged black holes and thermodynamics

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We present and discuss new families of primary hair charged black hole solutions in asymptotically anti-de Sitter space in three dimensions. The coupled Einstein-Maxwell-scalar gravity system, that carries the coupling $f()$ between the scalar and Maxwell fields is solved, and exact hairy black hole solutions are obtained analytically. The hairy solutions are obtained for three different profiles of the coupling function: (i) $f() = 1$, corresponding to no direct coupling between the scalar and Maxwell fields, (ii) f(ϕ)=eˆ{−ϕ}, and (iii) $f() = e^{-^2/2}$; corresponding to non-minimal coupling between them. For all these couplings the scalar field and curvature scalars are regular everywhere outside the horizon. We analyze the thermodynamics of the hairy black hole and find drastic changes in its thermodynamic structure due to the scalar field. For $f() = 1$, there exists a critical value of the hairy parameter above which the charged hairy black hole exhibits the Hawking/Page phase transition. In contrast, no such phase transition occurs below this critical value. Similarly, for $f() = e^{-}$ and $f() = e^{-^2/2}$, the hairy solution exhibits a small/large black hole phase transition for the above critical values of the hairy parameter. Interestingly, for these couplings, the thermodynamic phase diagram of three-dimensional hairy charged black holes resembles that of a higher-dimensional RN-AdS black hole, albeit with two second-order critical points.

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Some calculations on Hawking radiation

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I shall develop some calculations for local formulation of black hole radiation using near horizon and on the horizon geometry.

11

Axial charmonium production in $e^-e^+ \to \gamma^* \to H' + H''$ at $\sqrt{s} = 10.6$ GeV at B-factories

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We have studied the production of ground and excited axial charmonia in processes, $e^-e^+ \rightarrow h_c(nP)+\eta_c(n'S)$, and $e^-e^+ \rightarrow \chi_{c1}(nP)+h_c(n'P)$ [1] for $n, n' = 1, 2$, through leading order (LO) tree-level diagrams $\sim O(\alpha_{em}\alpha_s)$, which proceed through exchange of a virtual photon and an internal gluon line connecting two quark lines in the triangle quark loop part of the diagram at center of mass energy, $\sqrt{s} = 10.6GeV$. We employ the framework of 4×4 Bethe-Salpeter equation, and calculate their cross sections [1], which are compared with recent NRQCD and Relativistic quark model calculations. For both the above processes, we have drawn plots of total cross sections versus $\sqrt{s}$ for $n, n' = 1, 2$, as well as plots of differential cross section versus $cos\Theta$ at different center of mass energies. These studies might be of interest for future experiments at B-factories, since h_c, η_c, and χ_{c1}, h_c production might provide opportunities for observing h_c with higher statistics in future. Also our cross sections may provide guidance for future experiments at B-factories.
Reference:
[1] M.Narang, S.Bhatnagar, Few-Body Syst. 64, 82 (2023).

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Broadband spectral and temporal study of TeV blazar TXS 0518+211

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Blazars are the most powerful subclass of active galactic nuclei and are observed across the entire electromagnetic spectrum, from radio to high-energy (HE) to very high-energy (VHE) gamma ray. In this work, we have examined the long-term behavior of the bright TeV gamma-ray TXS 0518+211. We constructed a multi-wavelength light curve of this source using Swift-XRT/UVOT and Fermi-LAT data. Subsequently, we divided the entire light curve into 11 different epochs, labeled from Epoch-A to Epoch-K, based on the simultaneous observation optical-UV observations. Low flux states (e.g. Epoch-A, Epoch-E, etc.) can be well described by a simple one-zone SSC (synchrotron self Compton) model. However, we encountered a challenge with Epoch-I, where the X-ray flux is relatively high compared to the optical and gamma-ray flux, indicating an orphan X-ray flare. This feature, particularly pronounced in Fermi-LAT data below 4 GeV, is challenging to explain using the simple one-zone model. A two-zone model can account for this behavior. Very high-energy observation during X-ray flares are crucial for understanding the two-zone emission scenario. Therefore, it is encouraged to observed this source in the VHE range. The possible time range for VHE observation can be anticipated from the quasi-periodic-like variability nature of the source.

13

Two-loop form factors for Dark Matter annihilation to colored Standard Model particles

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A UV complete model where the Dark Matter (DM) particle interacts with gluons via a colored scalar mediator provides a viable phenomenological model that can be tested at hadron colliders. While Mono-jet signatures are relevant for Collider searches, zero-jet processes would mean complete annihilation of Standard Model (SM) particles to DM particles, which contribute to relic-density of DM. We look at the DM annihilation to SM colored particles which, at leading order, is a loop induced process in our model. We compute two-loop amplitudes in QCD which contribute to the process. Decomposing the amplitude in terms of Form factors and making use of the projector technique, scalar Feynman Integrals are obtained. Further, with the help of the IBP identities, an analytical expression for amplitude is obtained in terms of Master Integrals. The amplitude is made UV finite by Counterterm Renormalization. We will discuss preliminary results for the cases of massless and massive mediators. Our results can be used to predict DM pair production at hadron colliders and DM annihilation to SM colored particles at next-to-leading order in QCD.

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Low Earth orbit satellite's orbit disintegration due to perturbations and predictions using machine learning.

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Astrodynamics is a discipline that encompasses the mechanical characteristics of spacecrafts. This study focuses on the analysis of perturbation effects on the anticipated trajectory of a satellite in a low-earth orbit. Solar Radiation Pressure and Aerodynamic Drag are the two perturbation forces that have been determined through the utilization of a module constructed on a High-Performance Orbit Propagator (HPOP) and the Cannonball method. In this study, the primary Keplerian orbital characteristics were employed to analyze a simulated Low-Earth satellite orbit. Visualization of the satellite's trajectory and ground tracks at a designated altitude will be shown along with the comparative analysis of satellite monitoring station locations, with a primary focus on the Northern and Southern regions of the sub-continent. We shall discuss the revisit time and look angles by utilizing specific coordinates for the monitoring station locations. Other section of the current study elucidates the methodology for computing perturbation and its impact on the projected trajectory, illustrating the variance in the orbit, which is followed by the utilization of Machine Learning(ML) techniques in predicting behavioral patterns through the implementation of parametric predictive modeling.

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Dark Matter:Initial Steps Decoded

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DARK MATTER:
INITIAL STEPS DECODED

I think most of you all know much about dark matter ,but it's origin is still a mystery .
Do you believe that dark matter is formed due to stars or force present in atoms .The dark matter was formed during big bang. let me explain .
Did you ever know that a black hole mass M would exert same or identical gravitational pull as the

star with mass M. Then how does the light that's produced at the core of the star, with mass M, will escape the gravitational pull from the centre but can't escape the gravitational pull of black hole with mass M but both exert same gravitational pull.
Now a doubt might arise that is any other force is interacting with black hole .Yes ,a external force is interacting that's dark matter ,and this dark matter weakly interacts with other matter but it can highly interact with the space fabric itself.
Let's learn how dark matter originates from scratch.

The force between nucleus of atom and electron gets stronger with increase in distance up to some extent[weak nuclear force].Few of galaxies exerted extra gravitational pull for the stars or that are far from the central black hole . Like force between nucleus and electron .

Now when a star capable of becoming black hole fuses hydrogen or other elements or other elements . Not only star capable of becoming black holes fuses elements ,but all stars fuses elements.(Example : hydrogen into helium)the heat and energy liberated in this process will escape in the form of light and heat ,but the force between nucleus and electron and nucleus and protons [weak and strong nuclear force] gets trapped in a star ,over time this force increases but is unable to react or interact, this energy is dark matter. All stars fuses the elements, and in every stars negligible amount of dark matter gets released per fusion and this dark matter never clumps because the process of clumping in continuously being disrupted by the energy released by the star. After the star dies the dark matter gets clumped because there is no energy to disrupt this process, in a star, that is large enough to create black hole[the larger stars fuses more Hydrogen elements resulting to the formation more dark matter ,but in small star less Hydrogen elements will be fused resulting to formation of less dark matter] the dark matter gets clumped and turns it into black hole, but in a star that is not enough large to create black hole the dark matter will be less so it turns into white dwarf star or will enter other phase like red giant. After a star ,that is larger enough to turn into black hole ,dies it turns into black hole with the help of dark matter and rules universe.
Another question might arise that if this is the case then how did the dark matter exist before the existence of stars this is because after few seconds of big bang the universe was soup of hot quarks and gluons later the neutrons ,electrons ,protons were formed and the weak and strong nuclear force got clumped forming dark matter

There is another proof for the existence of dark matter apart from the fast movement of stars that are far from black holes than expected and at that speed the stars reach escape velocity and should get thrown out from galaxies but they were fast as well as stable in galaxy [this was previously told but not with this details] second proof is gravitational lensing was stronger than expected [the expected was calculated using normal matter] but the gravitational lensing was stronger but all the mass of normal matter was correct yet gravitational lensing was stronger this proves both that something(dark matter)is disturbing the gravitational lensing and the existence of dark matter

Note: The proposed dark matter doesn't interact with the space fabric the way how massive objects interact and create gravitational waves instead they interact in different way which results in different information when we think it interacts in same way how massive bodies interacts due to which the information when measured may change .
Moreover dark matter is scale dependent which means it interacts in different way when dark matter is less and in different way when dark matter is more

ADDITIONAL INFORMATION:
One of the hypothesis about how the universe might end is "The Big Rip" hypothesis but it is fake because it states that the space fabric itself will tare or rips because the universe would have stretched so mush that the fabric itself become into pieces, but the space fabric is stable at the infinitely dense points[black holes] so it means it can be stable even if it is stretched infinitely so big rip just can't occur

There is another hypothesis that if big rip occurs it will be conformed that the black holes are not infinitely dense because space fabric was stable near black holes.
So only one can be true,
Case 1
either space fabric can sustain and stable even if it is stretched infinitely or
Case 2
just the black holes are not infinitely dense hence the space fabric can be stable to that limited stretched and vulnerable to infinite stretched that causes Big Rip .So either space fabric can sustain

the infinite stretch (Example black hole) or just black holes are not infinitely dense and in this case big rip can occur

There is one special case where black holes have infinite density which means all the energy is in infinitely dense point which is similar case in big bang which means it gives birth to a new big bang and acting like a portal or wormhole to that universe

Conclusion
In a star with mass M, light can escape from the core but in black hole with mass M light can't escape because dark matter interacts

The force between nucleus and electron will get trapped in star and become dark matter

This dark matter is highly reactive with space fabric .
This force later interacts with star after it's death and help in to become black hole

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Origin of magnetic fields during inflation and their subsequent evolution

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Magnetic fields are found everywhere in the universe, including in intergalactic space. One possible mechanism for producing seed magnetic fields is by assuming a breaking of conformal invariance during inflation. I shall describe this mechanism as well as the evolution and certain quantum measures of these magnetic fields in some inflationary models of interest.

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Marginally trapped surfaces in pure gauss bonnet gravity

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The higher order theories like Lovelock's and Gauss-Bonnet theories(GB) are unique as they required no extra field beyond GR and holds the property of field equation for order not greater than second order. The GB theory arise when order is 2 in Lovelock's action. We studied the formation and evolution of the marginally trapped surfaces and collapsing shell for n-dimension space time during the gravitational collapse of spherical

symmetric dust and viscous fluid matter. We took different density profiles as a initial data to examine the effect of higher dimension on the formation of marginally trapped surfaces and collapsing shell in Pure GB gravity.

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Some Properties of Black holes using Covariant Phase Space formalism.

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The covariant phase space formalism is used to understand the dynamics of black holes. Here we will present some properties of black holes which emerges out in this formalism.

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Fermi-LAT gamma-ray spectral and temporal state during VHE episodes of FSRQs

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In this talk, I'll present my on-going work on the nine FSRQs which were detected at very high energies (VHE, E>100 GeV). Using the Fermi-LAT data, we attempt to explore the source behavior during VHE emission by comparing with spectral, temporal, and statistical behavior during non-VHE time. We have also compared the outcomes from all the sources and seek out the patterns and distinctions in the observable properties. I will also give detailed review on the emission processes of the FSRQs.

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Two-loop master integrals for di-jet production with massive internal loops

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Dijet production is a key QCD process at the Large Hadron Collider, utilised for measuring the running of the strong coupling constant, determining parton distribution functions, and searching for BSM signals. Therefore, precise theoretical predictions for its cross-section are of utmost importance. In my talk, I will discuss the analytical evaluation of non-trivial 2-loop master integrals, which comprise elliptic curve(s) and appear in the NNLO QCD corrections to the dijet production. I will

briefly outline the technical aspects related to their evaluation, discuss the employed methodology, and provide a glimpse of the final results.

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Spectro-temporal study of Jet Emission: Insight into Relativistic Particle Spectra

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Astrophysical jets associated with compact objects are sites of most extreme physical conditions with emission detected up to TeV gamma-rays, implying ultra-relativistic particles. Despite significant progress and general understanding, the origin and extent of particle spectrum is yet to be fully understood. In this talk, we will present results from study of simultaneous broadband modeling of optical to X-ray emission and its implications on relativistic particle spectra as well as the underlying Physical processes.

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Opening Remards

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Break

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Lunch

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Break

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ALP at the future ep colliders

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In Beyond Standard Model (BSM) theories, Axion-Like Particles (ALPs) are hypothesized to be Pseudo-Nambu-Goldstone bosons that have spontaneously broken the global Peccei-Quinn (PQ) symmetries at very high energies. Due to the approximated symmetry shifts, the ALPs are naturally lighter compared to the electroweak or QCD particles. Future high-precision experiments may be able to find ALPs that have masses that are well below the GeV scale, but future high-energy lepton and hadron colliders may also be able to search for the heavier ALPs. Therefore, this establishes them as the prime targets for future experiments that are aimed at the discovery of new physics that goes beyond the known and widely accepted Standard Model (SM) of particle interactions. In this work, we investigate the possibility of detecting ALP via the charged and neutral current processes at future ep colliders. We probe couplings of ALP with photon and weak bosons (W and Z) of SM using angular observables and give constraints on these couplings which may direct the community to compare possibilities at various colliders.