

# 47th SLAC Summer Institute (SSI 2019)

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SLAC



## Book of Abstracts



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**Topical Conference / 8****Muon g-2****Corresponding Author:** carey@bu.edu**Poster Social / 9****On the Origin of the CMB****Author:** Greg Hood<sup>1</sup><sup>1</sup> *Retired***Corresponding Author:** cghood@alum.mit.edu

It is proposed that the source of the CMB arises from microwaves emitted from atoms at very low temperatures. The metric employed, an exact solution of the Einstein field equations, embraces the electrical interaction as well as the gravitational interaction. It is applied semi-classically to atomic spectra. The result is that a number of elements –hydrogen, nitrogen, carbon, chlorine, iron, boron, magnesium, silicon, nickel, cobalt –are predicted to emit millimeter length microwaves at temperatures in the 2 to 6 Kelvin range. The metals emit at or below 2K. If these totally unexpected emissions are confirmed, they would provide direct experimental evidence for the physical origin of the cosmic microwave background.

**Poster Social / 10****Search for new physics in heavy baryon decays****Author:** Martina Ferrillo<sup>1</sup><sup>1</sup> *University of Zurich***Corresponding Author:** martina.ferrillo@cern.ch

Semi-leptonic b-baryon decays provide a unique means to investigate Lepton Flavour Universality (LFU) at the LHCb experiment. Sensitivity to New Physics (NP) contributions could show up in the angular observables of the decay products. In this work, the decay amplitude of the process  $\Lambda_b \rightarrow \Lambda_c l \nu$  as a function of the squared di-lepton invariant mass and lepton helicity angle is studied. The angular analysis thus is performed to assess the feasibility of NP searches within this decay channel.

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**Angular Analysis of the B -> K\* mu mu decay at the LHCb Experiment****Author:** Felix Kress<sup>1</sup><sup>1</sup> *Imperial College (GB)*



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Recent observations of B decays hint at discrepancies with predictions of the otherwise overwhelmingly successful Standard Model of Particle Physics. These observations are extremely intriguing, as they can be interpreted in a coherent way in a number of new physics models by introducing a new vector particle, such as a  $Z'$  or a leptoquark.

This poster will concentrate on one of these measurements, the angular analysis of the rare decay  $B \rightarrow K^* \mu\mu$ , performed on data from the LHCb experiment. An introduction to the measurement will be given and the Run 1 results, which have a 3.4 sigma tension with the Standard Model prediction, will be presented. An overview of the current status of the update of this analysis with Run 2 data collected at the LHCb detector will be given.

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## PHYSICS BEYOND SM WITH KAONS FROM NA62

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The decay  $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ , with a very precisely predicted branching ratio of less than  $10 \exp(-10)$ , is one of the best candidates to reveal indirect effects of new physics at the highest mass scales. The NA62 experiment at the CERN SPS is designed to measure the branching ratio of the  $K^+ \rightarrow \pi^+ \nu \bar{\nu}$  with a decay-in-flight technique. NA62 took data so far in 2016-2018. Statistics collected in 2016 allowed NA62 to reach the Standard Model sensitivity for  $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ , entering the domain of  $10 \exp(-10)$  single event sensitivity and showing the proof of principle of the experiment. Thanks to the statistics collected in 2017, NA62 surpasses the present best sensitivity. The analysis strategy is reviewed and the preliminary result from the 2017 data set is presented.

A large sample of charged kaon decays into final states with multiple charged particles was collected in 2016-2018. The sensitivity to a range of lepton flavor and lepton number violating kaon decays provided by this data set improves over the previously reported measurements. Results from the searches for these processes with a partial NA62 data sample are presented.

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## SEARCHES FOR EXOTIC DECAYS WITH NA62

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The features of the NA62 experiment at the CERN SPS –high-intensity setup, trigger-system flexibility, high-frequency tracking of beam particles, redundant particle identification, and ultra-high-efficiency photon vetoes –make NA62 particularly suitable to search for long-lived, weakly-coupled particles within Beyond the Standard Model (BSM) physics, using kaon and pion decays as well as operating the experiment in dump mode.

The NA62 sensitivity for searches of Dark Photons, Heavy Neutral Leptons and Axion-Like Particles are presented, together with prospects for future data taking at the NA62 experiment.

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## Are there elementary particles or not — Inspiration from Buddhism book

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In flavor physics, an elementary particle refers to a subatomic particle with no sub structure, thus not composed of other particles. This definition sounds a little bit self-contradictory. How can the particle be an elementary particle if it cannot be measured by itself. Buddhist teacher S.N. Goenka describes Buddhadharma as a pure science of mind and matter. In one of the Buddhist books, there is a very inspiring saying. It is said that there is a net of pearls in the kingdom of Indra, which is arranged so that when you look at a pearl, you can see all the other pearls from its reflection. Similarly, every object in the world is not only itself, but includes all the other objects; in fact, it is other objects. In this saying, every object should have equal status, with no differentiation between elementary or non-elementary particles. All the particles dynamically interact with each other in a self-consistent manner. Therefore, the long-term debate on the really elementary particle may result from one reason: there is no elementary particle.

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## A near-minimal leptoquark model for reconciling flavour anomalies and generating radiative neutrino masses

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We introduce two scalar leptoquarks, the  $SU(2)_L$  isosinglet denoted  $\phi \sim (\mathbf{3}, \mathbf{1}, -1/3)$  and the isotriplet  $\varphi \sim (\mathbf{3}, \mathbf{3}, -1/3)$ , to explain observed deviations from the standard model in semi-leptonic  $B$ -meson decays. We explore the regions of parameter space in which this model accommodates the persistent tensions in the decay observables  $R_{D^{(*)}}$ ,  $R_{K^{(*)}}$ , and angular observables in  $b \rightarrow s\mu\mu$  transitions. Additionally, we exploit the role of these exotics in existing models for one-loop neutrino mass generation derived from  $\Delta L = 2$  effective operators. Introducing the vector-like quark  $\chi \sim (\mathbf{3}, \mathbf{2}, -5/6)$  necessary for lepton-number violation, we consider the contribution of both leptoquarks to the generation of radiative neutrino mass. We find that constraints permit simultaneously accommodating the flavour anomalies while also explaining the relative smallness of neutrino mass without the need for cancellation between leptoquark contributions. A characteristic prediction of our model is a rate of muon–electron conversion in nuclei fixed by the anomalies in  $b \rightarrow s\mu\mu$  and neutrino mass; the COMET experiment will thus test and potentially falsify our scenario. The model also predicts signatures that will be tested at the LHC and Belle II.

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## Measurement of $\Lambda_c^+$ polarization with an amplitude analysis of $\Lambda_c^+ \rightarrow p K^- \pi^+$ to obtain the magnetic dipole moment of charmed baryons

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In this work we aim at using LHCb data to measure the polarization of  $\Lambda_c^+$  through the three-body resonant decay  $\Lambda_c^+ \rightarrow p K^- \pi^+$ . This is part of a long-term project intended to measure the magnetic and electric dipole moments (MDM/EDM) of charmed baryons ( $\Lambda_c^+$  and  $\Sigma_c^+$ ).

The experimental method consists in measuring the polarization vector of the incoming particle and the precession angle after the particle travelled through a magnetic field. From that information we can infer the dipole moment of the baryon. This is challenging since charmed baryons have a very short lifetime, hence an intense magnetic field is needed to make the precession happen before the decay.

The proposal is to direct protons of the LHC or SPS beam towards a first crystal (target-converter) to produce the baryons. Then those baryons will be captured in a second crystal (bending crystal) which produce an effective magnetic field strong enough to make them precess.

In order to measure the precession angle, we need to know the polarization of the baryons before entering the bending crystal, and here is where LHCb data play a crucial role. Thanks to the SMOG system (System for Measuring Overlap with Gas) we can inject tiny quantities of gas in the VERTEX LOcator transforming LHCb into a fixed target experiment. This is unique at the LHC and it allows to reproduce the production conditions of the baryons before the bending crystal.

The measurement of  $\Lambda_c^+$  polarization is performed using the pNe data sample @69 GeV recorded in 2017. This is done via a 5-dimensional amplitude fit. The model used for the fit is based on the helicity amplitudes formalism, it is first tuned on the high statistics  $pp$  data sample available and then used to perform the measurement on the  $p$ -gas data sample.

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## Almost Inert Higgs Bosons at the LHC

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Non-minimal Higgs sectors are strongly constrained by the agreement of the measured couplings of the 125 GeV Higgs with Standard Model predictions. This agreement can be explained by an approximate  $Z_2$  symmetry under which the additional Higgs bosons are odd. This allows the additional Higgs bosons to be ap...

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## Amplitude relations in two body b-baryon decays using SU(3) symmetry

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The decays of  $b$ -baryons provide an interesting opportunity to test SU(3) flavor symmetries in the Standard Model. We study possible charmless decays of such anti-triplet  $b$ -baryons into an octet or decuplet baryon and a pseudoscalar meson using SU(3) flavor symmetry. The analysis holds for arbitrarily broken SU(3). By making some physical assumptions about the underlying transitions, we derive amplitude relations between several decay modes that are within the reach of future experiments.

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## Angular analysis of $B^+ \rightarrow K^{+*} \mu\mu$ decays at LHCb

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Flavor-changing neutral current  $b \rightarrow s$  quark transitions are forbidden in the Standard Model at tree level and occur at the lowest order as so-called box or penguin processes. Angular observables of such transitions probe the underlying Lorentz structure of the Standard Model. These observables are of particular interest and suitable for theory comparison since the predictions are only little affected by form-factor uncertainties.

LHCb reported on several  $b \rightarrow s$  quark flavor-changing neutral current transitions including  $B^0 \rightarrow K^{0*} \mu\mu$  decays with various  $K^*$  ( $\rightarrow K\pi$ ) decay modes.

These studies revealed tensions with the Standard Model predictions of an angular observable ( $P'_5$ ), hinting to a potential contribution from physics beyond the Standard Model.

We present the very first angular analysis of  $B^+ \rightarrow K^{+*} \mu\mu$  decays at LHCb. This channel is experimentally extremely challenging due to neutral particles present in the final state. The analysis is however an important complement to the  $B^0 \rightarrow K^{0*} \mu\mu$  measurements and will significantly contribute to understanding of the observed tensions.

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## zfit: scalable pythonic fitting

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Statistical modelling is a key element for HEP analysis. Currently, most of this modelling is performed with the ROOT/RooFit toolkit which is written in C++ and poorly integrated with the scientific Python ecosystem. zfit is a new alternative to RooFit, written in *pure* Python while still allowing to use HEP standard minimizers and file formats. Built on top of TensorFlow (a modern, high level computing library for massive computations), zfit provides a high level interface for advanced model building and fitting. It is also designed to be extendable in a very simple way, allowing the usage of cutting-edge developments from the scientific Python ecosystem in a transparent way.

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## B-Jet Energy Regression for Di-Higgs Searches

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Di-Higgs production (HH), where two Higgs are produced during a proton-proton collision, has yet to be observed at the Large Hadron Collider. This process has an extremely small cross-section and its observation will be one of the main goals of the High-Luminosity LHC. As the cross-section is so small, di-Higgs searches typically look for the case where at least one Higgs decays to the final state with the highest branching fraction, Higgs to bb (57%). The invariant mass of jets coming from the bottom quarks (b-jets) is an important observable used in HH searches to discriminate signal from non-resonant background processes. However, b-jets tend to be slightly miscalibrated relative to other jets due to the large fraction of B-Hadron semi-leptonic decays and out-of-cone effects. Here, we investigate a multi-variate regression to correct the b-jet energy and we demonstrate the improvements to the Higgs mass resolution by applying this additional calibration.

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## Long-distance effects in inclusive $\bar{B} \rightarrow X_d \ell^+ \ell^-$ decay

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Quark decays mediated by neutral currents are forbidden at tree level in the SM and are therefore sensitive to BSM corrections via indirect effects. The manifestation of these currents in *inclusive* decays such as  $\bar{B} \rightarrow X_{s(d)} \ell^+ \ell^-$  is particularly amenable to theoretical analysis, as *integrated* decay rates can be computed in an Operator Product Expansion. Local power corrections, resolved (nonlocal) power corrections and  $q\bar{q}$  resonances are nonperturbative effects that play an important role in the phenomenology of neutral semileptonic inclusive  $B$ -decays. We include these effects in predictions for the branching ratio, forward-backward asymmetry and CP asymmetry of the rare decay  $\bar{B} \rightarrow X_d \ell^+ \ell^-$ .

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## Design and Operation of the Forward Time Projection Chambers at NA61/SHINE

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Hadron production measurements are critical for making informed predictions of neutrino flux in accelerator-based neutrino experiments. The NA61/SHINE experiment at CERN's Super Proton Synchrotron (SPS) measures differential and total production cross sections for various reactions relevant to the generation of neutrino beams. Recently, to cover the previously un-instrumented forward region of NA61/SHINE's phase space, a series of three Time Projection Chambers (TPCs) were constructed and installed. These TPCs, which are subject to a significant particle intensity, feature a new tandem field cage design enabling rejection off-time particles. Cross-section measurements in this forward region are necessary for current and future accelerator-based neutrino experiments to achieve their physics goals.

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## Signatures of complex scalar field with chemical potential in primordial non-gaussianities

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Non-gaussianity in the primordial fluctuations is a promising sign of new physics beyond minimal inflationary models and is a probe into physics at energies as high as inflationary Hubble scale. Massive particles, through their coupling with inflaton field, can leave characteristic signatures in primordial non-gaussianities containing information about their mass and spin. The signal generally gets rapidly suppressed for masses greater than Hubble scale due to a Boltzmann-like suppression factor  $\sim e^{-\pi M/H}$ . This constrains the regime of observable new physics. In this work, we consider a model of a complex scalar coupled to the inflaton field via a chemical potential like term. We show that the addition of this term has an effect of overcoming the Boltzmann-like suppression by boosting particle production during inflation. We also evaluate the trispectrum to show a considerable enhancement in the magnitude of non-gaussianities in primordial fluctuations.

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## Neutrino Directionality at DUNE

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Liquid argon time-projection chambers (LArTPCs) are excellent neutrino detectors. Often neutrino energies are inferred by summing up the deposited energy in the detector. A LArTPC, on the other hand, has an extra handle - crisp tracks. Kinematic constraints, paired with traditional calorimetry, improve the energy reconstruction and allow for novel searches. This poster focuses on neutrino directionality - a way to determine whence the neutrinos came.

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## PRIMARY VERTEX RECONSTRUCTION AND SELECTION WITH THE ATLAS EXPERIMENT

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Increasing luminosity at the Large Hadron Collider (LHC) poses a challenge for primary vertex reconstruction and hard scatter (HS) identification in ATLAS. A rate of 70 or more inelastic proton-proton collisions per beam crossing was observed during the recently-completed Run 2 and even higher vertex density, or pile-up (PU), is expected in the future Run 3.

To meet this challenge and prevent performance degradation with rising PU density, ATLAS released new tools for vertex reconstruction: a Gaussian track density seed finder and an adaptive multi-vertex finder. The former constructs a simple but powerful analytic model of the track density along the beam axis to locate candidate vertices, and the latter applies a global approach to vertex finding and fitting, allowing vertices to compete for nearby tracks.

In addition, final state topologies in which the HS process does not have very high visible transverse momentum activity, e.g. Vector Boson Fusion (VBF) Higgs to invisible events, can result in a low selection efficiency as a function of PU density when relying upon the hardness of the HS vertex, as done in the standard approach. Thus, a new algorithm for primary vertex selection in VBF Higgs to invisible events was developed under the High Luminosity LHC conditions by exploiting the new forward tracking capabilities of the planned Run 4 ATLAS tracker upgrade and by integrating calorimeter information and introducing a new way to apply PU jet suppression methods for the selection of VBF jets.

This poster summarizes the key features and the performance of the new ATLAS vertex reconstruction and selection techniques under the Run 3 and Run 4 PU conditions.

**Projects / 62**

### **Team 9: $b \rightarrow sll$ BSM sensitivity**

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### **Team 13: 65 GeV top quark ?**

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### **Team 14: Leptonic $g-2$**

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### **Team 15: Measuring tau $g-2$**

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### **Team 16: VHE neutrinos from active galaxies**

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### **Team 17: Supernovae neutrinos at DUNE**

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### **Team 19: $\nu_e$ vs $\nu_\mu$ particle ID with Machine Learning**

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