ICHEP 2022 Newsletter – Addendum to Day 2 (08/07/2022)

Astroparticle Physics and Cosmology

The Friday morning session started with a contribution on LHCf measurements on proton-proton collisions relevant for astroparticle and cosmic ray physics. The session continued with several astrophysical and cosmological aspects of dark matter, both from experimental and theoretical perspectives, covering fermionic WIMP dark matter but also dark matter consisting of bosonic scalar fields. The day continued with the joint session Astroparticle Physics and Cosmology-Dark Matter on axions. After a review of astrophysical searches of ultralight dark matter, several experimental efforts including BabyIAXO, MADMAX, BREAD and those at IBS-CAPP have been presented.

ICHEP 2022 Newsletter - Day 3 (09/07/2022)

Beyond the Standard Model

Despite being early morning on a Saturday, the first BSM session contained lively discussion of lots of new results from the ATLAS and CMS collaborations on search for BSM phenomena in various resonant and nonresonant final states, including leptoquark scenarios. Both experiments have been exploiting new techniques ranging from machine learning classifiers to data scouting, and have pushed previous limits much further in many models. An interesting excess in a CMS search for leptoquarks coupling to tau lepton and b quark generated some excitement and certainly requires further scrutiny in Run 3, and comparison with a corresponding result from the ATLAS experiment.

The potential of current and upcoming SM Drell-Yan measurements to improve future searches by constraining PDF uncertainties was also discussed and it highlights the key role precision measurements will play in future BSM searches.

After a short break, we continued with a diverse set of talks for long-lived particles and unconventional signatures at present and future facilities. An ATLAS search reports some intriguing excess in the search of slow particles looking at large dE/dx. Run 3 new collected data and improved analysis methods will shed some light on this discrepancy.

Part of the first afternoon session focused on axion searches. Axions are hypothetical particles introduced to solve the so-called strong-CP problem and are searched for in various experiments (BABAR, JUNO, Captain-Mills). No evidence of axions has been reported, and proposed future experiments will increase the axion search phase space.

Finally, heavy neutral leptons searches have been presented both at collider experiments (BABAR, ATLAS and CMS) as well as in neutrino designed experiment detectors like MicroBoone and IceCube.

In conclusion, the Beyond Standard Model sessions during the first three days of ICHEP2022 have presented the most updated results and theoretical developments in direct searches of physics beyond the Standard Model. No evidence has been observed so far, but various small discrepancies need to be further investigated in the future, for example with the upcoming LHC Run 3.

Heavy Ions

Exciting new results were shown by the ALICE, ATLAS, LHCb and CMS collaborations on open heavy-flavour and quarkonia. The new results on prompt Jpsi and Psi(2S) in Pb-Pb collisions show clear signs of regeneration at low transverse momentum, while at high transverse momentum a clear suppression due to energy loss is visible. The Y(3S) is observed for the first time and the measurement confirms the sequential Y(nS) suppression. A significant Jpsi suppression is observed by the STAR collaboration in isobaric and Au-Au collisions at RHIC energies. While flow-like effects are observed for the Jpsi in p-Pb collisions, brand new results show that no flow is observed in pp collisions. The new differential measurements on Z boson production in p-Pb collisions will provide further constraints on nPDF calculations. For the latter the nCTEQ collaboration showed huge improvements on the reduction of uncertainties thanks to adding heavy-flavour, quarkonia and neutrino measurements to the global fits. ALICE showed new results on the production of long and short living resonances, both in heavy-ion and pp collisions. LHC Run3 data are needed to establish if an hadronic phase in pp can be claimed. A comprehensive presentation on ATLAS jets measurements greatly enriched the daily session. ATLAS also showed measurements of gamma-gamma fusion processes in ultra-peripheral Pb+Pb collisions, which are providing experimental constraints beyond the HI

physics, like the one on the anomalous magnetic moment of the tau lepton and to the coupling of intermediate axion-like particles. Results from beam energy scan program by STAR experiment and beam energy dependent fluctuation studies by NA61/SHINE experiment were presented which provide input for understanding the QCD phase diagram. Measurements of azimuthal correlations using Belle, ALEPH and HERA data were also presented which provide input to understand the origin of flow phenomena in hadronic systems.

Quark and Lepton Flavour Physics

Third day sessions have been dedicated to electroweak, radiative and rare decays of beauty hadrons. The Belle, Belle-II, CMS and LHCb experiments presented their most recent results about: branching fractions and photon polarisation in radiative decays, searches for very rare decays and decays violating the lepton flavour conservation, anomalies in the angular analyses and tests of lepton flavour universality in electroweak decays. New models and methods on how to interpret these flavour anomalies in terms of Standard Model or physics beyond it have been shown. The UTFit collaboration showed the latest constraints on the Unitary Triangle of the CKM matrix and on possible contributions of physics beyond the Standard Model in ΔF=2 transitions. In the last session of the day, new ways to combine information from flavour physics in the low- and high-pT regimes were discussed, and also how to test if neutrinos are Majorana particles in rare kaon decays. Finally the prospects in flavour physics for a future FCC-ee collider have been presented.

New results of the third day:

- CMS full Run-2 analysis of B → mumu decays, resulting in world-best single measurement of B(B0s→mumu)
- Searches for B0→K* tau mu and B → p mu decays at LHCb
- Observation of B0 → 4 protons and evidence of B0s → 4 protons by LHCb
- Belle II first measurement of the inclusive branching fraction of B→Xs gamma

Operation, Performance and Upgrade (Incl. HL-LHC) of Present Detectors

Saturday morning was devoted to trigger strategies for the just-started LHC Run3 and in view of HL-HLT. For ATLAS and CMS, the overall aim is to extend event selection capabilities to exotic signatures like long-lived particles and to improve on the Run2 performance even in presence of larger event pile-up. These purposes are reached via various upgrades based on state-of-the-art computing technologies (GPUs, FPGAs, etc.), custom electronics, and new selection algorithms including NN and others ML algorithms. LHCb moved to a triggerless data acquisition scheme followed by a SW-only, high-level event selection with final calibration already in Run3.

The first part of the afternoon was dedicated to the main upgrades to the ATLAS, CMS and LHCb muon detector systems, namely the New Small Weel of ATLAS, commissioned for Run 3, new GEM detectors under development and construction for CMS, and new electronics and technology (micro-RWell chambers) for the muon systems of LHCb in Run3 and from 2033, respectively. Their purpose is to increase the muon systems redundancy, sustain high radiation doses as expected at HL-LHC, and maintain or even increase past excellent detection and trigger performances.

The second part of the afternoon was dedicated to readiness and upgrades to the forward proton detector systems of both ATLAS and CMS, the Monopole & Exotics Detector At LHC (MoEDAL), and the KAPAE experiment in Korea dedicated to CPT violation studies with positronium.
A huge amount of work was reported, demonstrating the vitality and dedication of the entire community.

Astroparticle Physics and Cosmology

The morning was devoted to neutrinos. The impact of non-standard interactions (NSI) to the neutrino contribution to the relativistic degrees of freedom, of the connection between early universe cosmology and searches for long-lived particles (LLPs) at the LHC and alternative solutions to the strong CP problem and their phenomenological implications were discussed. The results from the ANTARES and Baikal-GVD neutrino telescopes were shown, with hints for astrophysical neutrinos compatible with the diffuse flux measured by IceCube. The principle of detection of neutrinos from core collapse Supernovae with neutrino telescopes were also discussed.
In the following session on large scale structure, a series of talks were devoted to the Euclid mission, designed to constrain the properties of dark energy and gravity via weak gravitational lensing and galaxy clustering, reviewing the instrumental design, expected performance on main cosmological parameters and the legacy science prospects. Alternative measurements of baryonic acoustic oscillations and the prospects of the DESI mission were then discussed.
Perspectives for the space-based LISA interferometer were discussed, from primordial gravitational waves, tests on the expansion of the Universe as well as on the velocity of gravitational wave propagation. Primordial black holes were then discussed as laboratories for new fundamental physics
The day was closed by reviews of the results from the Pierre Auger, ALPACA, DAMPE, CALET and Tibet ASgamma experiments. The future perspectives for the HERD facility were then discussed. The high precision results on galactic cosmic ray fluxes of individual primary and secondary elements contains important information on the physics of the acceleration sources and of the propagation in the magnetized intergalactic medium. The observed properties of ultrahigh energy cosmic ray induced air showers provides important links to our understanding of strong interaction physics.

Formal Theory

The third day of the formal theory session was characterised by different extensions/generalisations of the standard model (SM). It began with Gian Carlo Rossi's talk on an extension of the SM by extra dynamically-generated operators/particles. This was followed by a talk by Nicolò Masi explaining a possible extension of the colour SU(3) into G(2) (as an automorphism of octonions). Then there was a series of talks on GUTs: Giacomo Cacciapaglia unified the couplings at infinity via a 5D KK theory; Elizabeth Dodson presented a possible discrepancy originating inl the Froehlich-Morchio-Strocchi mechanism in a simplified model; Gregory Patellis analysed some phenomenological consequences of an E(8) 10D theory on a flag manifold; and Joe Davighi realised a unification via electroweak flavour symmetry. In addition Davide Meloni illustrated recent progress on the use of modular

symmetries for solving the flavour problem (mass hierarchies, fermion mixing). Many questions were asked.

Strong Interactions and Hadron Physics

The 3rd day comprised several distinct strong-interaction physics topics. Progress on different fronts in the field of transverse-momentum distributions (TMD) was reported. Highlights include the recent global fit at N3LL accuracy of quark TMDs and studies of the impact of model assumptions, e.g. flavor dependence and PDF uncertainties used, on the goodness of such fits. The role of TMDs in Monte Carlo simulations were also discussed. Experimental results from from HERA were shown, and future measurements from the electron-ion collider will shed light on TMDs with greater precision.

The focus then shifted to recent advancements in spectroscopy, particularly of heavy, multi-heavy, and exotic hadrons. A series of new results on the spectroscopy of excited charm and beauty mesons and baryons was presented. Further measurements on the existence of tetraquarks, pentaquarks, and hybrid hadrons were also presented, and their properties and structure discussed. We are now seeing for the first time results on exotic hadrons with strangeness. The T_cccc(6900) has been confirmed by independent experiments, and in addition two new fully charmed tetraquarks have been reported. The proliferation of excited and exotic states has reinvigorated the theoretical work on understanding the binding mechanisms of these hadrons from fundamental QCD. The importance of understanding the binding properties and production mechanisms has been emphasized, and we saw the ongoing work towards providing precision measurements of the strong two-body and three-body interactions between nuclei.

Dark Matter

In the Dark Matter parallel session of Saturday we covered experiments aiming at direct detection of DM. In the morning we focused on detectors with extremely low threshold dedicated to low mass WIMPs, then NaI experiments for scrutiny of the DAMA signal, and new ideas for directional detection of DM-induced recoils.

In the afternoon session, we had a status report from liquid noble detectors, notably with the LZ collaboration showing their first results, with a new best limit in the WIMP-nucleon Spin-Independent cross section.

The session has been concluded with an interesting proposal to have a shared Dark Matter Data Center.

Neutrino Physics

Great Neutrino day also during the third day!!

The morning session started with riveting results on solar and geo-neutrinos with Borexino at LNGS. Then there was a series of talks on water Cherenkov detector, covering different aspects of this technique, from strategies to reduce background and systematic errors to methodologies for efficiency improvement in SK, HK and T2K. Successful sea operations of the KM3NeT neutrino telescopes ARCA and ORCA were presented, together with some preliminary results. The morning session proceeded with the optimization of the Protvino-to-

ORCA project and with the description of the TAMBO detector that will search for astrophysical tau neutrinos in the Andes. Finally, the progress of the NEXT project and of the PandaX-4T detector were presented.
The first of afternoon's sessions was devoted to 0nu2beta decay experiments. CUORE at LNGS presented its most recent results based on 1 t yr of TeO2 exposure running the largest dilution refrigerator at millikelvin temperature. CUPID0 has successfully proven the scintillating bolometer technique achieving interesting results and paving the way to CUPID, which will exploit the dual readout technology in the CUORE's cryostat. With its unsurpassed energy resolution and background free search GERDA has set stringent constraints on the half-life of Ge-76 0νββ decay. Building on GERDA's and Majorana's legacy, LEGEND-200 in the GERDA cryostat is now in commissioning at LNGS with data-taking beginning later this year. LEGEND-1000 will be a ton-scale experiment, either at SNOLAB or at LNGS, aiming at a quasi-background free operation up to 10 ton-years of exposure, for unambiguous discovery of 0νββ decay at half-lives beyond 10^28 years. KamLAND-Zen 800 presented interesting results based on larger exposure and improved analysis, and the plan with KamLAND2-Zen (1ton of enriched Xenon) to look deeper into the inverted mass ordering.
The last session was brief but not less interesting. Firstly, the description and the validation plan of an innovative procedure to reduce of Tl208 background for Zr96 neutrino double beta decay experiment using topological information of Cherenkov lights was reported. Secondly, the phenomenology of the possible electromagnetic property in case of supernova neutrinos and the expected sensitivity of the next-generation neutrino experiment was presented.

Education and Outreach

Saturday was an all-day marathon for Outreach and Education, where a broad range of themes was covered :
A natural starting point was "lessons from the pandemics" : how did scientific collaborations adapt to reach their public ? Which online tools and activities were developed and how much of this effort is worth continuing ? Now that the public is coming back, four major visitor centers around the globe were then discussed : the Pierre Auger Observatory, the Bruno Touschek center in Frascati, KEK's 50 anniversary and the Science Gateway project at CERN.
The next chapter was science communication. The ATLAS and CMS collaborations discussed their strategies, as well as INFN with ScienzaPerTutti, a science communication website that celebrates 20 this year. The Asimov prize was presented for the first time, and the CERN Courier editor Matthew Chalmers closed the morning with an insightful overview of how historically the decision-making of future colliders was discussed between scientists, funding agencies, and the wider world. The topic of communicating future collider efforts generated a lively discussion, which was an excellent pre-lunch aperitif.
The afternoon was open for "science and society" and public engagement projects. Two mature Art-Science projects were presented, in Italy and in the UK. The REINFORCE initiative is also now deployed : experts from gravitational waves, the neutrino KM3Net telescope, muography and the ATLAS experiment joined forces and tools to bring citizen science up to a new scale. Sustainability white paper, collaboration with sociology on gender issues and more generally relations to society were then discussed, bringing a long and fertile day to a close.

Equality, Diversity and Inclusion

The second Equality, Diversity and Inclusion (EDI) session provided an opportunity to learn how to foster a culture of inclusion in the HEP environment through experience sharing and recommendations from studies and research.

We learnt about the new 25x25 strategy developed by CERN. This is its first target-based initiative with objectives, among others, to achieve a proportion of 25% of women in its employees' population by 2025 with endorsement at the highest level of the Organisation and concrete community proposed actions to embed D&I in all HR processes, leadership and communication.

Underrepresentation of women in STEM disciplines was also discussed from the perspective of research, challenging the simplistic explanation: "it is a math skill issue". Women are generally well represented in fields locally defined as service-oriented and considered safe; however, the definition of "service-oriented and safe" is strongly related to the culture, which in turn strongly influences individual choices. A recent US-based study demonstrates that it is not by lack of interest that women give up a scientific academic career but because of the difficulty to combine work and family life. Contractual conditions were also mentioned as a push-out factor.

In that same area of gender equality, the work of GENERA was presented. GENERA is an active sharing experience network, comprising physicists, social scientists and practitioners. Its vision is to support, coordinate and improve gender equality (policies) in physics research organisations in Europe and worldwide. An important pillar of gender equality in research and innovation, on which GENERA tries to raise awareness, is that the gender dimension must be embedded in research and teaching content.

And on that point we heard how some physics teachers adapt their teaching material to make visible a greater diversity of past and present physicists, change the narrative and representations in physics textbook, also taking into account the notion of diversity as intersectional. Two presentations reported on the inequitable research environment for women and minorities. On this point, the report on the Snowmass exercise, carried out in the US within the particle physics community, shed an important light. Its DEI group produced a rich body of knowledge ranging from an evaluation of the social climate in the field, to developing strategies in education and outreach towards marginalised communities, and observations on how to improve personal wellness and lifestyle. The "Snowmass" report discusses as well the still very low participation of Africa and Latin America in the field of particle physics. The need for cultural and structural changes within the international HEP community to open equitable access and success for Africa was also the topic of a single talk. We learnt of capacity building actions at all levels of the education system, but more effective and equitable partnerships for institutions and individuals are still to be developed. Finally throughout the two sessions, it was acknowledged that research institutions and organisations are paying increasing attention to diversity and inclusion, and that many have adopted diversity charters. However, recommendation is made that a greater attention be put to equality and equal opportunity.

Computing and Data handling

Detectors for Future Facilities, R&D, novel techniques

The last day of the parallel session began with recent developments of solid-state devices for radiation dosimetry and vertexing in high-energy physics experiments. At future accelerators,

radiation hardness and picosecond timing resolution are highly important to cope with the harsh environment and high event rate; the latest results from the TimeSpot collaboration have been shown. Photon detectors and their applications for particle identifications have also been covered; R&D for RICH, TORCH for LHCb, and TOF system for future Higgs factories were presented.

In the second part of the day, detecting technologies and system designs from interesting experiments with very different physics goals were introduced. Neutrino physics is tackled from different experimental proposals: atmospheric neutrinos can be studied with 51 kiloTon magnetized iron calorimeter at iCAL, Hyper-Kamiokande and Dune will study neutrinos from accelerators with water Cherenkov and LAr TPC detectors respectively, IceCube-Gen2 will expand the study for extragalactic neutrinos with an upgraded grid of photon detectors in Antarctica, and Res-NOVA will detect neutrinos with archeological Pb-based cryogenic detector. An innovative neutrino detection technique that exploits opaque liquid scintillators has also been presented.

Dark matter will be hunted by CYGNO using a gaseous TPC with optical readout, and by FLArE with a LAr TPC at LHC. Similar searches have also been proposed with bulky and low-threshold kinetic inductance detectors by the BULLKID collaboration. The BDX collaboration search for light dark matter at the intensity frontier, taking advantage of the 11 GeV, 100 uA CEBAF electron beam dump, and a PbWO4-base ECal; The FASER experiment at LHC uses mostly refurbished detectors for dark photon search; The NUSES space mission has two payloads, one probes high energy neutrinos and cosmic rays through observation of atmospheric Cherenkov light, the other to measure flux in lower energy range; The LUXE system at XFEL has high precision detection of electron, positron and photon that are produced in collisions of a laser and an electron beam, aiming to study non-linear QED; The ECCE is a more comprehensive detection system for chromodynamics study at EIC.