



ICHEP 2022 Newsletter – Addendum to Day 1 (07/07/2022)

Neutrino Physics

A wide variety of interesting topics were covered in the first day of the Neutrino session. T2K and NOva presented the most recent results both on oscillations and on neutrino interactions, innovative reconstruction methods and plans for upgrade. Medium energy physics results with MINERvA and beam flux measurements with NA61/SHINE were also shown. DUNE presented its physics program and several talks focused on specific aspects. And we had an "appetizer" on experiments measuring the neutrino fundamental properties: AMoRE, HoLMES and ECHO. In addition, we were updated on the status of many interesting projects and we heard new ideas in theory and phenomenology. All the speakers gave excellent presentations, the discussion was very fruitful and the technical support was excellent! We are looking forward to the next two days.

ICHEP 2022 Newsletter - Day 2 (08/07/2022)



Beyond the Standard Model

In the second day session, new results for SUSY searches at the LHC and future facilities were presented, with a lot of attention to the challenging scenarios, like compressed spectra or low-rate processes - stau production. Clearly, Run 3 will bring a whole new sensitivity in these cases.

Prospects of searches for baryon number violation at future facilities at the ESS in Lund and by the DUNE detector have been presented. Precise QED calculations make possible the search for new physics in ortho-positronium and in semileptonic tau decays. CPT and Lorentz symmetries are given as granted in physics textbooks, but it is important to test them thoroughly in experiments involving antiprotonic pionic atoms and with deep inelastic scattering at ZEUS experiment.

Finally, in the last session, the LHC strikes back! Theoretical models that can be discovered or closed at the LHC or at the future colliders have been shown. The most updated searches performed by the ATLAS and CMS Collaborations in a variety of final states were presented. The searches that show some tension with respect to the SM are the search for high mass resonances decaying in two Higgs bosons in $bb\tau\tau$ channel, and the $A \rightarrow ZH$ search with the ATLAS detector; the $X \rightarrow VV/VH$ in the all hadronic channel with the CMS detector. Small excesses observed, individually with low significance, in the four lepton and gamma-gamma channels could be explained by a second Higgs resonance. With the increased statistics of the LHC Run3, we will confirm or resolve these small discrepancies.

Higgs Physics

On Friday the Higgs sessions moved beyond the standard model, and into the future. We started the day with a session dedicated to Extended Higgs sectors, with plenty of interesting results covering the many faces of BSM Higgs searches, followed by more theoretical discussions on interesting models to look for at LHC. The afternoon flash-forwarded us to the future, with a thorough discussion of the next facilities and their excellent capabilities to explore electroweak symmetry breaking and characterize the Higgs boson in detail. The last session of the day - and of the Higgs parallel session in this ICHEP edition - focused on theory: with two dedicated, longer summary talks on the state of the art of theory predictions followed by additional discussions on specific topics.

Joint session between Higgs and Beyond the Standard Model

The joint Higgs-BSM session focused on the searches for new Higgs bosons in addition to the one discovered 10 years ago. Experimental results hinting on a possible new particle presence in the region around 100 GeV sparked a lot of excitement and motivated several theory talks with dedicated model-building to explain new scalar at 100 GeV and to address other anomalies, like recent CDF W mass measurement.

Accelerators

In the second day of the Accelerator Session there have been 5 extensive talks covering a wide panorama of future accelerators, providing details about the projects, timelines, challenges, needed R&D, costs and technical difficulties. Four of these talks covered projects ranging from the already approved (HL-LHC), over mid-term projects already in a mature state (ILC, CLIC, FCC-ee, CEPC) to longer term, challenging machines like Muon Colliders.

A detailed report about the HL-LHC status was given, with the operational scenarios including peak and integrated luminosity evolution with time, levelling techniques, beam parameters

schemes, crossing angle options and optic scenarios. The impact on the various experiments was also discussed.

A full overview of the linear collider projects: CLIC with the novel two-beam accelerators and ILC based on well-known 1.3 GHz Superconducting RF, including the various foreseen energy stages with the respective layouts, status of the studies, timelines, costs, sustainability, carbon footprint impact and technical challenges were discussed.

FCC-ee is considered a first stage towards the FCC-hh project, as suggested by the European Strategy. An overview of the technical options including possible layouts, machine detector interface and alternative RF systems was given together with an estimate of the costs and a tentative timeline which could start around 2045 to be followed by FCC-hh some 25 years later.

A very interesting presentation was also given on the Muon Collider project, showing the status of the studies and R&D needed for its construction, and the advantages with respect to other projects in terms of construction and operational cost (power consumption). The main challenges of the project were described, including background from muons decay and large flux of neutrinos, beam quality from the injector and muon cooling.

Additional to these presentations, a very relevant summary of the Snowmass'21 discussion on future facilities in the US was given. The main areas of activity were described (accelerators for neutrinos, for rare processes and dark matter, future colliders, and accelerator R&D) and a list of proposed projects was shown. The task forces put in place to drive the studies and the comparison between the various proposed machines were introduced together with their mandate. The overall strategy is focused on a wide R&D and accelerator design effort both at the US National level and in co-operation with other projects proposed abroad with the aim of developing design reports on collider options by the next Snowmass in 2029-30.

Heavy Ions

The Friday session focused on jet physics in heavy ion collisions. STAR and ALICE reported hadron-jet and photon-jet acoplanarity measurements. A significant modification of jet azimuthal angle distribution with respect to the trigger particles is observed with low p_T (10-20 GeV) jets reconstructed with the anti- k_T $R=0.4$ clustering algorithm. This intriguing signal quietly disappears as one increases the jet p_T or reduces the resolution parameter R to 0.2. Possible effects associated with this phenomenon include medium response to fast parton, medium induced momentum broadening, and hard scattering off QGP quasi-particles. CMS and ATLAS also reported analyses on the inclusive and photon-tagged jet substructure. The inclusive jet substructure revealed the impact of QGP on the hard scattered partons and indicated that narrower jets are more likely to pass the selection on jet p_T in the data analysis, where the photon-tagged jet results are with smaller selection bias effects. Finally, a calculation of the jet energy loss process in e+A SIDIS was presented connecting the interests in parton energy loss in HIC to the future EIC. In the second part of the afternoon flow results from ALICE, ATLAS, CMS and LHCb were discussed. LHCb showed results of charged and neutral particle distributions in different collision systems, showing the reach to different regions of Bjorken- x . ALICE and CMS showed the first results about femtoscopic correlations in LHC Run 3 commissioning data.

Quark and Lepton Flavour Physics

Morning sessions have been dedicated to lepton flavour. Belle and Belle-II presented the most recent results in the study of the tau lepton decays, and in particular in the search for invisible

particles beyond the Standard Model in the final states. Prospects for the search of Lepton Flavour Violation in muon decays have also been presented with status reports from the Mu3e and MEG-II experiments that are almost ready to produce their first physics results. The control of theoretical predictions for their main backgrounds was proposed too, in a talk from theorists. The MACE experiment, dedicated to the study of muonium-to-antimuonium conversion, also reported its status and prospects. The second session of the morning has been dedicated to the anomaly in the muon magnetic moment, $g-2$. Several models have been presented by theorists to explain the deviation from the Standard Model by 4.2 standard deviation of the measurement performed by the Muon $g-2$ experiment.

Afternoon sessions have been devoted to semileptonic beauty hadron decays, with BaBar, Belle, Belle-II and LHCb presenting their most recent measurements in this sector, including searches for violation of Lepton Flavour Universality and quantities sensitive to $|V_{ub}|$ and $|V_{cb}|$. Talks from theorists covered all the tools needed to interpret the measurements in terms of the CKM-matrix elements: from lattice QCD, to HQET, to parametrisation of factors. In addition, the interpretations of current results in terms of contributions from physics beyond the Standard Model have been presented.

New results of the second day:

- Extractions of V_{ub} and V_{cb} from Belle II and tests of lepton universality.

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

In the second day of the session dedicated to operations and upgrades of present detectors, talks were mainly focused on performances of LHC detectors in Run 2 and preparation for LHC Run 3. Strategies to mitigate effects of aging and bandwidth limitation at high pileup in silicon trackers were presented. Similarly, techniques to master sensor aging in calorimeters, as well as electronics upgrades and new algorithms - including ML techniques - to handle events with large pileup and detector occupancy were described. Overall, the expected performances of LHC detectors in Run 3 were shown to be at least as good as in previous Runs - in many cases even better. Detector and readout upgrades for LHCb and Alice were described which will allow LHCb to cope with the planned increase in luminosity, actually outperforming with respect to Run2, and extend particle identification capabilities of Alice at low transverse momentum, as well as minimum bias statistics. A full session was dedicated to strategies for luminosity measurements in Run 2 by the four LHC experiments, including new dedicated detectors for Run 3 and prototypes to be tested in Run 3 and aimed at HL-LHC. Commissioning of old and new detectors with cosmics, pilot beam data collected at the end of 2021, and recent 900 GeV collisions were reported, together with first events at 13.6 TeV. The LHC experiments are ready for and eager to record and study new collisions at unprecedented center of mass energy in the years to come.

Astroparticle Physics and Cosmology

Formal Theory

The second day of the formal theory session began with a series of talks related to QCD. Lorenzo Maio presented work on the phase diagram of QCD in a strong magnetic field, and Mohammad Ahmady explained applications of holographic QCD and a t' Hooft equation to hadron spectroscopy. This was followed by a talk by Piotr Bargiela explaining recent progress

on three-loop four-particle QCD amplitudes. Claudio Bonanno then spoke on the QCD topological susceptibility, while six-meson amplitudes in QCD-like theories were the subject of a talk by Tomas Husek. Finally, in this section, Matteo Marcoli spoke about the automation of subtractions for the so-called antenna function in scattering amplitudes.

Many of the talks in the second half of the session were more formal in their subject-matter. Pietro Longhi explained work on instanton-related phenomena in 4d $N=2$ quantum field theories beyond the weak-coupling regime, and then Juan Ramos introduced a construction of a large family of solvable lattice models based on WZW models. Marco Rossi outlined a constructive approach to the ODE/IM correspondence via the Marchenko equation; this correspondence also featured in Daniele Gregori's talk which explained a novel application to quasi-normal modes of black holes. Returning to the subject of gauge theories, Tommaso Macrelli spoke on the role of colour-kinematics duality, the double copy and homotopy algebras in Yang-Mills amplitudes, and finally Oliver Witzel explained work on the renormalisation group beta function and anomalous dimensions in strongly-coupled gauge-fermion systems.

As on the first day, all talks were well received and were animated by enthusiastic questions, only limited by the amount of time available.

Top and EW Physics

The morning session was dedicated to the discussion of top-antitop quark pair production in association with other particles. New measurements of various processes were presented by ATLAS and CMS including a fresh ATLAS measurement of single top production in association with a photon. These were complemented with several talks presenting improved theoretical predictions incorporating full off-shell effects and/or absolute mass threshold resummation in $t\bar{t}W$, $t\bar{t}H$ and four top production, the former process being especially poignant given the consistently large measured cross section across several analyses in recent years. The first afternoon session focused on the measurement of top quark properties. ATLAS and CMS presented their top mass measurements using the full run 2 dataset via various direct and indirect methods, including a new CMS result that has achieved the most precise single measurement to date, with a remarkable precision of 380 MeV. Other highlights include measurements of the central-forward charge asymmetries in $t\bar{t}b$ and $t\bar{t}+\gamma$, $t\bar{t}b$ energy asymmetry, top polarization in single top production and boosted top quark production, many of which were accompanied by novel SMEFT interpretations. On the theory side, the results of a recent NNLO calculation for top pair production including a B-hadron in the final state were presented. The session was closed with two talks presenting the connection between spin correlations and measures of quantum entanglement in top pair production in the SM and the SMEFT. In the final evening session, we heard about recent precision calculations of high mass Drell-Yan at the LHC and initial state radiation effects at electron positron colliders. We were also introduced to the LUXE experiment, a proposed facility to probe QED in its non-perturbative regime. Later, a new technique to measure the beam polarization at an electron positron B-factory using tau polarimetry was presented. Looking to the future, we heard about prospects and experimental techniques for probing top quark and EW physics at future electron-proton colliders as well as quark pair production at the ILC.

Strong Interactions and Hadron Physics

During the second day of the conference, several topics were covered in the QCD session, spanning all the range from the low energy precision studies to the highest energies that have been achieved in laboratory.

A significant tension persists between the experimental measurement of the $g-2$ of the muon and the theoretical prediction based on the data-driven approach for the HVP contribution, while the former is in better agreement with the predictions based on Lattice QCD. The differences between the two theoretical approaches have to be understood and numerous innovative experimental and the theoretical methods are being developed.

Reports from various facilities at CERN, Fermilab and Frascati, described studies probing QCD in a soft regime, as well as studies accessing meson and baryon (production and intrinsic) properties. Nucleon electromagnetic form factors have also been studied theoretically through a Lattice QCD approach. Studies of heavy flavour and quarkonium production have been reported by the LHC experiments, complemented by reports on improvements of the theoretical predictions for such processes.

A new algorithm for the jet reconstruction has been proposed, as well as several approaches for the jet tagging and for studying their substructure. Improvements of the parton shower algorithms, by including higher order contributions or through machine learning approaches, have the potential of enhancing the precision of experimental studies. Further improvements of the Monte Carlo event generators were achieved, by including quark spin effects in the hadronisation model and through improved underlying event tunes enabled by experimental measurements.

Dark Matter

The Dark Matter parallel session track on Friday morning featured interesting theoretical developments in the field of Dark Matter model building and a joint session with the Astroparticle Physics track on Axion physics. During the afternoon, interesting results have been presented on various Dark Matter interpretations using cosmic rays data from experiments such as AMS, MAGIC, FERMI-LAT, neutrino detection experiments such as ANTARES and Icecube, as well as different galactic and extragalactic sources such as AGNs and Neutron Stars.

Neutrino Physics

The second day on neutrinos started with several talks on recent MicroBoone results. Important news were reported on the Near and Far detectors of the Short Baseline Neutrino Program with the SBND TPC now complete, and ICARUS currently taking data with both BNB and NuMI beams.

We were updated on oscillation results based on the full data set collected by DayaBay, the impressive progress on the construction of the JUNO detector, and a possible neutrino program on a new reactor plant in Turkey. The reactor anomaly keeps a large community actively working in refining anti-neutrino flux models.

Studies about the origin of neutrino oscillations and the absolute neutrino masses, as well as nuclear medium effects in lepton-nucleus scattering were presented. Highlights from experiments measuring coherent nuclear scattering of reactor anti-neutrino were given. The large attendance and lively discussions confirm the broad interest in the neutrino physics.

Education and Outreach

Honor where honor is due, the first session was dedicated to the numerous and exciting Italian outreach projects that make Italy a leader in particle physics, ranging from Escape Rooms to theater & open air events! A few of them will be in the city during the conference, so check these efforts out this weekend when you have a chance. Listening to the gems of outreach efforts in Italy was a good appetizer to what turned out to be an excellent morning of Outreach and Education talks. The attentive people in room 03 then shifted attention to the second part of this parallel session, education, and witnessed the growing spread and variety of connections, master classes, LEGO detectors, and toolkits. Particle physics is now accessible to many diverse audiences, including even the youngest: babies and their parents with them. There also are informative abstracts on particle physics communication, education, and outreach presented in the poster session.

Equality, Diversity and Inclusion

The Equality, Diversity and Inclusion (EDI) session was dedicated to taking stock of where the community stands in the matter. We heard about the evolution of demographics in the 4 LHC large experiments and also at INFN, along various dimensions. Globally, progresses are not striking. However, results are promising with a better representation of women within the early career group, visibility of women as presenters at conferences and in leadership positions. Measures were presented that have been put in place to improve inclusiveness in the workplace / within collaborations. Those measures range from strong communication / awareness raising on the ethical framework to training of collaboration members and their management on the issues at stake. They also cover implementation of frameworks to support a respectful environment and improve D&I in appointments of leadership positions. We also heard about an innovative and transformative mentoring program, put in place at INFN that has the ambition to contribute to institutional changes. The complex question of collecting data on dimensions that are not collected in all institutions, e.g. non-binary gender, ethnicity, came up several times during the session. Finally, the need to work in network was underlined as key to advancement in this important area.

Computing and Data handling

The first sessions of the Computing and Data Handling track covered diverse topics across event generation, simulation, reconstruction, triggers and analysis. A major theme in all areas is the increasing use of machine learning that improves physics (better!) and computing (faster!) performance. That spans new fast simulation methods, improved particle id and novel graph-based tracking algorithms. From HL-LHC experiment upgrades to small experiments, these new codes also need to target diverse heterogeneous hardware, with FPGAs and GPUs used to reduce costs and/or latency. The track looked at improving data handling as well, from ALICE analysis trains to MuG-2 accessing petabytes of data for their analysis. Improving human efficiency is also not forgotten, with many improvements in ROOT to make analysis easier to write and faster to execute, faster fitting in RooFit and new Python tools like pyhf covered.

Detectors for Future Facilities, R&D, novel techniques

The Friday morning started with an overview of the future circular electron-positron colliders experiments: detector requirements and expected performance have been presented. The required outstanding tracking capability calls for large-area, low-material-budget detectors;

this has been addressed by contributions on the R&D program for drift chambers and TPCs. The Particle Identification potential of those technologies has also been presented. Contributions on Micro Pattern Gaseous Detectors covered the final part of the morning, focusing on performance, rate capability, aging tests and frontend electronics developments. Friday afternoon was dedicated to calorimetry, with the first session focusing on optical readout of crystals and fibers. Future Higgs factory requirements motivate the quest for solutions combining excellent energy resolution with superior imaging capabilities through fine 3D segmentation. In the nearer future, the LHCb upgrade puts emphasis on ambitious timing goals too, relevant for future colliders as well. The evening session showed that high granularity in calorimeters - and muon systems - continues to present challenges not only for hardware integration, but also for simulation, reconstruction and triggering and provides a development ground for advanced deep learning techniques and their hardware implementation.

Poster Session

With more than 300 contributions, either live or online, the ICHEP 2022 poster session covered a wide range of HEP topics providing a very different variety of artistic presentations. All the Conferences' sessions are represented with several posters, guaranteeing an exchange of ideas with colleagues working on all the different research fields. Also, be ready for the best posters awards! They will be given soon!