ICHEP2018

XXXIX International Conference on High Energy Physics, Seoul, July 4-11

Site: https://www.ichep2018.org Agenda: https://indico.cern.ch/event/686555/timetable/?view=nicecompact

Notes by N.Leonardo (comments to nuno@cern.ch)

The International Conference in High Energy Physics (ICHEP) being the major conference series in the field of high energy physics at large, it is compelling to try to capture the current highlights. Clearly, a five-page-long reduction of O(500) reports on a great number of topics could not aim at being anything close to complete. While reflecting a personal selection of highlights, I expect that the summary serves as a useful overview.

+ executive summary

on the one hand, the Standard Model, on occasion of its 50th anniversary, is doing great. It stands, until further notice, as an impressive and robust effective theory, up to the TeV scale. This has been just reinforced at its core with the direct observation of all main production and decay modes of the scalar, reported at the conference (six years after the scalar=Higgs discovery, itself announced at the 36th ICHEP edition). The recent direct observation of Yukawa interactions (to the third-family fermions), joined by CKM measurements with ever-increasing precision, is a milestone.

on the other hand, there are some conspicuous deviations between data and theory, emerging from precision measurements. Among all, the most exciting arguably arises in the flavor sector [1]. Namely: a standing, coherent set of so-called *flavor anomalies*, detected in independent sets of data and experiments, pointing in a consistent direction. As it should be always, more data will bring clarification; the excitement is however undoubtedly there already.

[1] while this specific remark reflects (admittedly) a personal view, it is one that is arguably shared broadly by the community as well; for example, this may be seen (mind the wall inscription) clearly reflected also in the poster for the next edition of the conference (see the figure below).

be reminded of the full agenda of the conference [2], containing also a summary talk. also recall that, on the flavor front, we had a week in advance of ICHEP our own BEACH gathering (hosted by LIP), rather enthusiastic, with a corresponding assessment [3].

[2] ICHEP 2018 agenda: https://indico.cern.ch/event/686555/timetable/?view=nicecompact, summary talk:https://indico.cern.ch/event/686555/contributions/3028101/attachments/1684690/2708530/Summary.pdf

[3] BEACH 2018 conference (http://www.lip.pt/beach2018/), summary talk: http://www.lip.pt/beach2018/pages/files/slides/7.1.4.pdf

terse (slightly technical / jargon-ish) notes (selected highlights) per area (broadly taken) follow:

+ scalar

observations were reported by ATLAS of H->bb decay and VH production; combining with earlier (recent) observations by CMS and ATLAS of H->tautau and ttH, amounts to direct confirmation of the couplings to all third generation fermions. couplings to second generation quarks on the other hand will be considerably more challenging (current limits on charm lie two orders of magnitude above SM expectation), while to 2nd generation leptons are within the LHC run2/3 reach (reported limits on the dimuon decay lie at level of ~2 x SM). ATLAS and CMS reported updates on di-Higgs production, towards constraining its all-important self-coupling, reaching a sensitivity of ~13 x SM. sensitives to other relevant processes include e.g. the decay to Z+gamma ~5 x SM, tH production ~10 x SM.

the scalar is now officially joining the b, EWK, top and other SM probes into the era of the "differential measurement". and while all seems to align well as ever with the SM expectation, the name of the game is to detect potential deviations through precision hinting towards BSM effects.

the LHC collaborations released pages of their highlights reported at the conference:

https://home.cern/scientists/updates/2018/07/lhc-news-seoul
https://atlas.cern/updates/atlas-news/key-results-ichep-2018
http://cms.cern/news/ICHEP-2018

+ other EWK SM probes

various measurements with increased precision of vector bosons, b and top quarks have been reported, confirming an impressive agreement with theory (and robustness of the SM as an effective theory up to TeV scale). perhaps worth highlighting is the reported observation of vector boson scattering (even if it would have been more exciting in absence of the Higgs, vis-a-vis unitarity), and study of quartic boson couplings.

some level of disagreement is nonetheless reported for several observables. e.g. in the EWK sector some tensions (<2sigma) are detected between direct measurements and global SM fits, e.g. CKM gamma angle (have now reached precision of 5 degrees), and mH (from mW and mt). interestingly, in the top sector, previously detected deviations in spin correlations reached now the 3 sigma mark. while hints of BSM effects could contribute to such deviations, the situation also calls for improved understanding of underlying mechanisms, as reflected in simulation tools, of EWK and QCD effects, to match the unprecedented level of precision that is being now attained in the data.

results reported use for the most part data up to year 2016 only, more data will facilitate further precision and exploration of rarer and FCNC processes, e.g. tttt, tZq, tHq.

+ QCD

studies of QCD are important in themselves, e.g. understand structure and formation of hadrons, behavior of hadronic matter at high temperatures/densities, as well as means of searching for new phenomena. studies pursued with different machines and energies (from few GeV to TeV). some of the puzzles being pursued include hadron spin (the 'proton spin crisis'), hadroproduction (challenge for effective models to describe cross sections and polarizations simultaneously), hot medium properties (challenge for effective models to describe collective behavior and energy loss simultaneously).

in the spectroscopy realm, some new hadrons have been reported, both expected (conventional) and unexpected (exotic), some with independent confirmation and others still lacking it, e.g. Bc(2S) and X(5568). the number of exotic (XYZP) states exceeding 30, more detailed measurements are reported to access their quantum numbers and help inferring their nature. for now, no model interpretation seem to offer a whole picture of the observed states.

in the heavy ion front, impressive advancements continue to be reported. using different collision types (AA, pA, pp, ep), systems (e.g. Pb, Xe, Ar), energies, probes (soft and hard). a variety of hadron states, some of which reconstructed for first time in ion collisions, provide a rich set of information on sequential melting (hidden flavor), energy loss mechanisms (and their dependence on mass/flavor), and collective behavior. QGP-like effects are detected also in smaller systems (pp, pPb) -- long range angular correlations, elliptic flow, melting, strangeness enhancement, all observed with an increasing trend with particle multiplicity, across collision systems. implies rupture w.r.t. traditional paradigm; small systems are more than just a baseline.

in theory front, lattice QCD entered precision era for simple systems (flavor, g-2, pdf) and beginning reliable calculations for larger systems (nuclei, for neutrino, dark matter).

+ direct searches

searches for direct production of BSM particles in LHC collisions are reported which explore a variety of final states and are interpreted within various SUSY and more exotic benchmark scenarios. no excess was reported, leading to improved exclusion limits; exclusion of higher masses expected to increase more slowly, once sufficient 13TeV data has been added to searches. limits depend on benchmark models adopted, ranging from ~ 0.1 to 10TeV in mass dimension, while other dimensions e.g. (couplings, lifetime) are also probed.

although perhaps some excesses with limited significance may be expected in data from statistical grounds, none sufficiently significant was found worth reporting at this time. after the non-confirmation of the 750GeV bump in the last edition of the conference, collaborations may well be opting to make use of the very large amount of data being collected before run's end, to study possible hints prior to reporting.

+ flavor

search for NP through precision. extensive set of measurement with exquisite precision. results from rare processes are worth highlighting.

strangeness, new results from NA62 (charged kaon), KOTO (neutral kaon), approaching SM expectations (~E-9); charm, observed (LHCb) rarest decay (neutral D to pair of hadrons and muons, ~E-7), various new channels observed with BESIII operating at threshold.

on the beauty front, besides the dimuon decay (aka 'golden channel for susy', ~E-9) at LHC, various observables of several b->sll (~E-8) decays investigated (LHC, Belle), with several deviations from theory detected; these include p5' (>3sigma), with some ongoing debate on the SM calculations; while not significant individually, the various deviations appear in a coherent pattern, such that a global fit (to all 100+ measurements) to effective couplings hint deviations around 5 sigma. tests of lepton flavor universality reported by various experiments (Belle, BaBar, LHC) in b->sll and b->clnu,

employing particularly robust observables, result in deviations of about 4 sigma. active model building trying to accommodate anomalies; with 'leptoquarks kind of trending right now'.

in addition to testing flavor universality, also searches for (charged) lepton flavor violation are pursued, through transitions of muons to electrons, with various efforts being prepared (MEGII, COMET, mu2e, mu3e), and through taus to muons (LHC, Belle, SHiP).

as for the longstanding tension of the anomalous magnetic moment of the muon, at the level of about 4 sigma, significant progress on theory and experiment sides has been reported or is planned; on theory front, advancements in lattice but also in form-factor determinations from electron-positron data are advancing, with a new global g-2 theory initiative jump started; on experimental front, particular anticipation is placed on the g-2 experiment at FNAL, which has started physics data taking with first results expected next year.

SuperKEKB is the first new collider since the LHC; BelleII having successful commissioning run, targeting 50/ab by 2025.

+ neutrinos

20 years since observation of neutrino oscillations, good prospects for studying CPV in lepton sector. T2K data already gives first CPV hint, with null sin(delta_cp) excluded at 2 sigma level. NOvA provides evidence (at 4 sigma level) of anti-nu_e appearance (from first anti-nu_mu beam). Normal hierarchy favoured by data, 3 experiments T2K, Nova, SK at 1-2 sigma each; inverted hierarchy disfavoured at 3 sigma level. MiniBooNE, with doubled dataset, reinforces LSND signal (yielding combined significance of 6 sigma) as hinting 3+1 (sterile) neutrinos. double beta decay observed for 12 nuclei; neutrinoless double beta decay searches pressing, reaching 100meV mark, with improved sensitivities reachable in medium and long term projects taking shape.

much detail also in Neutrino´2018 held a month earlier: https://www.mpi-hd.mpg.de/nu2018/programme

+ dark sector

searches for dark photons (that couple/mix with the SM counterpart) pursued at different colliders (incl. b factories, LHC), probe mass ranges from 0.01 to 100 MeV. corresponding processes with heavier bosons also probed.

dark matter searched at colliders through initial state radiation (e.g. photons at e+e-, EWK bosons and gluons at pp), or associated production, leading to mono-object plus missing-mass signatures, among others; limits reported for mass ranges from sub-GeV to TeV scales.

direct searches for dark matter pursued by multitude of experiments, ongoing and planned. among diverse paths probed. Axions and WIMPS are emphasized. Limits on WIMPS continue to be pushed at both high and low masses (and also approaching the 'neutrino floor'). most recent bound reported by XENON1T. The DAMA/LIBRA signal remains unresolved (high statistical significance, at 13 sigma level, but lacking independent confirmation, which is being pursued). Axions, offering to address two problems at once (strong CP, dark matter), are actively searched for in a variety of ways, with a fair number of projects also planned.

+ astro

new results from space-born experiments, covering cosmic rays up to TeV, have been reported. the rise with energy of the positron to electron flux, that had been initially detected by Pamela and extended in particular by AMS, remains as hint of primary origin, TeV dark matter, as seems not to be described by propagation models or astrophysical sources. change in positron flux at 1TeV, 2 sigma deviation from E-3 shape (5 sigma sensitivity expected through ISS lifetime ca. 2024). there is some discrepancy in the energy range from 100 to 800 GeV between different experiments. rigidity (p/Z) spectra similar for p, pbar, e+, differs from e-; differs between primary (p,He,C,O) and secondary (Li,Be,B) cosmic rays, with N flux (primary+secondary components) sitting in between; new results reported on secondary/primary (eg B/C) ratios. several unexpected results, improved theory predictions badly needed.

results on ground based telescope arrays and on ultra high energy cosmic rays also reported.

as for the new born paradigm of multi messenger astronomy; following the 2017 gravitational wave event detected by LIGO/Virgo and associated gamma rays subsequently detected by several detectors; the detection of the September 2017 IceCube 290TeV neutrino event then followed by associated photon observations in ground and space; are certainly important coordinated milestones, identifying and revealing complementary information about the sources of the detected astrophysical objects. The announcement of this latter event took place the day following ICHEP.

+ the next edition

Figure: The poster of the next edition of the conference, ICHEP 2020, to be held in Prague (https://www.ichep2020.org/). The diagram on the left, imprinted on the wall, illustrates one of the main processes and observables through which the so-called “flavor anomalies” are detected. This illustrates the relevance of such anomalies, and the excitement by the community at large, towards the goal of establishing signs of phenomena beyond the standard model of particle physics.