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Highlights from IPAC '18

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[IPAC18](#)

A selection of highlights from the results presented during IPAC18



MC1 circular and linear colliders

Stephen Brooks (BNL) foray into the possible future of accelerators was a walk on the wild side. The idea of a single particle collider was presented as a possibility to achieve diffraction limited TeV beams to bridge a potential "energy desert" between current technology and the next energy regime of interest to the HEP community. Relevant technological and theoretical challenges and their possible solutions were discussed, including multiple ideas for overcoming emittance growth from synchrotron radiation, focusing beams (via gravitational

lensing!) and obtaining nucleus-level alignment. The talk concluded with a perspective on how we can reduce the cost of future accelerators, ideas which are equally relevant to current accelerators. Well cited and researched yet presented in a light-hearted manner, Brook's musings gave excellent food for thought and an optimistic view of the future of accelerator physics & engineering.

MC2 Photon Sources and Electron Accelerators

Michael Spata (Jlab) described the Jefferson Laboratory 12 GeV upgrade of CEBAF which completed in the Fall of 2017 and just began full power operation in April, 2018. Mike detailed many of the challenges they faced including installation and operation of the new 4kW Central Helium Liquefier, field emission limitations in the cryomodules, component failures as operations ramped up, and operation at maximum gradient to achieve the full energy reach. Despite these, full power beam, roughly 1 MW, is being delivered to all four halls including the new Hall D using a new 750 MHz separator. Impressive results!

James Rosenzweig (UCLA) introduced the concept and progress of an All Optical 5th Generation Light Source. In this scheme, a TW laser pulse is split in two, and half is used to accelerate high quality electron bunches as they co-propagate in a tapered undulator (IFEL), and half strikes the accelerated electron beam head on. The back-scattered (ICS) photons are shifted to much shorter wavelength. Recirculation of the original laser beam enables high efficiency of energy transfer to and from the electron beam. The combination of IFEL and ICS leads to a compact, tunable multi-MeV gamma-ray source with special characteristics (polarization, harmonics, etc) that uses no RF acceleration. Rosenzweig reported successful demonstration of the all-optical source at the RUBICONICS test stand at UCLA.

MC3 Novel Particle Sources and Acceleration Techniques

Marlene Turner (CERN) described progress at the AWAKE experiment at CERN. AWAKE has the goal of using a high energy proton beam to drive generate a plasma wake and then to use this wake to accelerate an electron beam. The AWAKE team has done a great job demonstrated self-modulation of the proton beam and measured the formation of the plasma wakefield! The team has installed the equipment to test the acceleration of an injected electron beam which is expected to be completed in 2018.

Felicie Albert (LLNL) gave an excellent talk describing an application of the laser wakefield acceleration technology, namely the generation of betatron x-rays. She discussed two operating regimes: a long pulse laser operating in the self-modulation regime and a short-pulse laser operating in the blowout regime. She then described the use of the approach to enable new measurements at LCLS and elsewhere. Great results using the new LPWA technology!

MC 4 Hadron Accelerators

Jonathan Bagger (TRIUMF director) described the evolution of TRIUMF from its founding in 1968 by three BC universities and the construction of the 500 MeV H- cyclotron, through the construction of the ISAC NC and SRF linear accelerators and development of the Rare Ion Beam program, to the present day with 20 member universities, users drawn from 38 countries, an annual budget of Ca\$100 million, and a string of spin-off companies (most recently cyclotron-based production of Tc-99m by ARTMS). During that time the lab has diversified from HEP muon factory to nuclear physics, materials science and nuclear medicine, and staging post for experiments at CERN, KEK, etc. The most recent additions to the site are the Ultra-Cold Neutron facility and the Advanced Rare IsotopE Laboratory (ARIEL) whose 100 kW electron linac and 50 kW proton beamline and new target stations leading to a RIB switchyard augments the ISAC experimental facility. ARIEL will help answer the question “What is the astrophysical origin of the heavy elements?” through the elaboration of slow and rapid neutron capture processes far from the line of stable nuclides that occur in star burning and explosive events. A recent development has been the confluence of data from gravitational wave observatories that suggest neutron star mergers as an important site for the r-process that supplements or supersedes core-collapse super novae.

Sergei Nagaitsev (FNAL) described "The Path to LBNF," the Long Baseline Neutrino Facility which is actually three parallel paths: one for the proton beams (PIP-II), one for the detector which will be located in the Homestake mine in South Dakota (DUNE) 1300 km from Fermilab, and one for the facilities at Fermilab and Homestake (LBNF). The goal is game changing physics discoveries in the neutrino sector including leptonic CP violation and the mass hierarchy, the ability to observe neutron star and black hole formation, and nucleon decay. The three projects will engage more than 175 institutions from around the world.

Mei Bai (GSI Darmstadt) gave an overview of the activities to restart the accelerator facility after a two-year's shutdown and run them for FAIR phase 0 with the goal to fulfill the needs of scientific community and the FAIR accelerators and detector development. GSI has to resume the delivery of a variety of ion beams ranging from proton up to uranium for multi research areas ranging from nuclear physics to applications. GSI faces a number of challenges in re-commissioning its existing circular accelerators with brand new control system and upgrade of beam instrumentations, as well as in rising failures of aging components and systems. Mei explained the significant upgrade measures of the heavy ion synchrotron SIS18, that will run the worldwide highest beam intensities for Uranium for future FAIR operation.

MC5 Beam Dynamics and Electromagnetic Fields

Masamitsu Aiba (PSI) gave a comprehensive review of top-up injection schemes as have been used in electron ring colliders since the 1980s and synchrotron light sources since the 90's. The conventional scheme, wherein the injected beam is separated from the stored beam at the

time of injection, relies on a closed orbit bump achieved with kicker magnets and a septum. Modern schemes aim at using less dynamic aperture, no disturbance to the stored beam, and 100% injection efficiency. These include off-energy injection onto a dispersed orbit, injection via a sextupole kicker magnet with no orbit bump, bunch-by-bunch injection with a fast kicker directly onto the equilibrium orbit, and longitudinal variants of the last in which the phase and energy is offset or 2nd or 3rd harmonic cavities are used to create a large-amplitude damped synchrotron oscillation of the injected beam while the circulating beam is un-disturbed. Aiba finished his talk with highlights of recent R&D on kickers and septum magnets.

Valery Telnov (Budker Institute) introduced a cautionary note with his exposition of bremsstrahlung at future e+e- colliders that will influence beam lifetime. Effect is parametrized by product, K , of beam rigidity and size. Previous descriptions have concentrated on two regimes: synchrotron radiation ($K \gg 1$) and so-called short-magnet radiation ($K \ll 1$). Telnov introduced formulae for the intermediate regime (K order 1) and described how they apply to next generation colliders such as FCC-ee, in contrast to the present generation (e.g. Super KEKB) where SR in the arcs dominates.

Tessa Charles (University of Melbourne) introduced the method of “caustics” to understand and optimize longitudinal beam dynamics problems. Caustic lines are an envelope of trajectories or its projection onto another surface. Examples occur in bunch compression schemes and result in the familiar “rabbits ears”, or as Charles calls them “current horns” at the leading and trailing edges of bunches. Charles quantifies the caustic in terms of the R_{56} matrix elements and then proceeds to minimize the horns in linacs and chicanes and as a means to reduce coherent synchrotron radiation effects in recirculation arcs.

MC6 Beam Instrumentation and Feedback

Timothy Maxwell (SLAC) provided an overview of the entire beam instrumentation for LCLS-II organized according to four challenges posed by the beam parameters and the corresponding equipment arrayed to meet them. High power versus the beam confinement system (BCS) which employs Cherenkov fiber and diamond beam loss detectors and cavity-type current monitors along with more conventional components. A key and common feature of the BCS is self-test and “keep alive”. High rate and complex beam time structure versus the phase reference and timing generators that encode metadata for use by the diagnostic devices. High x-ray brightness that is maintained by a suite of high-precision beam position monitors, single-shot view screens and 1/2 m/s fast wires. Recent addition include button BPMs in cryomodules and x-band cavity BPMs near undulators. Coherent OTR is suppressed based on measurements with an optical camera setup designed at PSI. Maxwell also described pico and femto second bunch length monitors relying on ceramic gaps and coherent edge radiation, respectively.

Transverse feedback as applied to hadron and electron rings were exemplified by talks on the suppression of Transverse Mode Coupling Instability (TMCI) in the SPS by Wolfgang Hofle

(CERN) using wideband feedback, and a wide ranging review of digital feedback in ring-type electron collider and photon sources by Takeshi Nakamura (Spring 8). The archetype feedback has a front end, a feedback processor and a driver. Nakamura charted progress from 2004 to the present day: the replacement of DSP with FPGA, the optimization of FIR filters to introduce phase-shift and F/B and remove DC offset, the replacement of down sampling with direct wide analog B/W ADCs. He described also a recent challenge: to provide simultaneous damping of high current singlet bunches and low current bunch trains as are requested by some synchrotron radiation users.

MC7 Accelerator Technology

Morten Jensen (ESS) outlined the variety of RF power sources used in the ESS proton linac. These range from 30 kW solid state amplifiers in the MEBT, 200 kW tetrodes for the SC spoke cavities, through 3 MW pulsed klystrons for the NC RFQ and DTL and 1.2 MW klystrons for the SC medium-beta cavities, to 1.2 MW Inductive Out Tubes (IOTs) for the high-beta cavities. Of particular significance is the development of the first-ever MW-class IOTs in collaboration with L3 and Thales/CPI. The motivation is to reduce the electrical power consumption and operating costs. For many years, klystrons are the workhorse RF source with DC to RF conversion efficiency of 65% when operated in saturation. However, the efficiency typical at the operating point is about 55%. Contrastingly, IOTs with power ratings of 10-100kW have been the mainstay of the telecommunications industry and achieve near-linear gain across their power operating range and 70% efficiency at the operating point. Integrated over the lifetime, this 15% difference in efficiency results in significant savings particularly at high duty factor. Jensen reported on the successful development of 700 MHz multi-beam IOTs. 10 gridded electron guns are placed in a circle, the beams pass into a single cavity with 10 separate interaction gaps and single RF output. Testing performed at CERN confirmed the predicted efficiencies and the world-record IOT performance of 1.2 MW output for 8.3 kW input power. Pending the development of a production series, the accelerator community may have a new RF workhorse.

MC8 Applications of Accelerators

Will Kleeven (IBA) described the Rhodotron compact industrial CW electron accelerator producing intense beams with energies in the range from about 1 to 10 MeV. In principle, average beam powers can range from 10 kW to almost 1 MW. Main industrial applications are polymer cross-linking, sterilization, food treatment and container security scanning. Kleeven introduced hard-edge analytic models for the transvers and longitudinal optics, for machine parametrization, and then continued to full 3D modelling of the magnetic field and TEM-mode RF cavity for particle tracking – leading to full 3D tracking with space-charge. Because of the low energy and 2-10 mA beam current, fringe field and Coulombic effects must be carefully modelled to achieve high efficiency.

The Louis Costrell Awards session was took place Thursday afternoon before the conference banquet. Awards were handed to the three winners of the student poster prizes, Alysson

Gold, Marco YY, and ZZ and then prizes were made to three winners of the IEEE Particle Accelerator Science and Technology (PAST) award and three winners from the American Physical Society (APS) Division of Physics of Beams (DPB). The IEEE PAST awardees include: Herman Gruner, founding director of Jefferson Laboratory, who gave a great talk motivating accelerator R&D and urged us to continue pushing the boundaries of what is technically possible; Sandra Biedron, Professor at University of New Mexico, who talked about the wonderful particle accelerator community and urged us to communicate what we do to the rest of the world; and Martina Martinello, Wilson Fellow at Fermilab, who described her PhD studies focused on the understanding of high-Q operation and reduced surface resistance in new SRF cryomodules. The APS DPB awardees include: Spencer Gessner, a CERN Fellow, who described his PhD work to generate a hollow plasma channel for positron beam acceleration using the FACET facility at SLAC; Sergey Antipov, a CERN Fellow, who described his PhD studies on instabilities driven by the electron cloud trapped in combined function magnets in the Fermilab Recycler; and Alex Chao, Professor at Stanford University, who described his path to accelerator physics (a field that did not exist when he studied for his PhD) and many of the wonderful people with whom he has had the opportunity to engage over the years.

In the closing plenary talks in MC2 and MC1, Junko Yanu (LBNL) and Stefania Gori (Univ. Cincinnati) closed the conference with wonderful descriptions of the science enabled by free electron lasers (FELs) and the accelerator-based opportunities for searches for dark matter. The bright short-pulse beams from the x-ray FELs are enabling increased understanding of many processes that form the basis of everyday life including the structure of water, solid-state materials, and complex catalytic processes such as photosynthesis. This field of photon science is just beginning with the first facilities that are less than a decade old and new facilities that are becoming available every year. Similarly, the understanding of dark matter is one of the large outstanding problems of fundamental physics. The standard weakly-interacting massive particle (WIMP) paradigm has been explored for decades with little success. New accelerator experiments offer a unique opportunity to test the dark sector paradigm; studies range from searches at the LHC, KEK SuperB, and fixed target experiments will increase the sensitivity at the WIMP-scale and explore the possible low-mass candidates.