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Accelerator Physics Center at Fermilab :

History and Accomplishments (2007-2018)

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Abstract: Fermilab's Accelerator Physics Center (APC) was created in June 2007 with mission to carry out research and development to keep the US leading high-energy physics laboratory at the forefront of accelerator science, technology and facility operation. In support of the FNAL high-energy physics research mission, APC scientists and enginners conducted accelerator R&D aimed at next-generation and beyond accelerator facilities; provided accelerator physics support for existing operational programs and the evolution thereof; trained accelerator scientists and engineer and established experimental programs for a broad range of accelerator R&D that can be accessed by both Fermilab staff and the US and world HEP community. APC was a center-place for in-depth design, research and development efforts which allowed the Laboratory to make intelligent decisions on the ILC in the US, on the Muon Collider, as well as originate projects like PIP-II (through the Proton Driver/Project-X work), LHC-AUP (via LARP) and the IOTA/FAST R&D facility. APC was also the birthplace and host of many national and international collaborations and several educational/training programs in beam physics resulted in 27 PhD theses. In the Fall 2018, following an important milestone of the first beam circulating in the IOTA ring, the APC was re-organized into several departments in Accelerator Division, charged to carry out the accelerator physics research with IOTA/FAST beams and making it relevant for future upgrades of the Fermilab accelerator complex.

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I. HISTORY OF APC, ITS MISSION, ORGANIZATION AND LEADERSHIP

Fermilab's Accelerator Physics Center (APC) was created on June 1, 2007 – see Fig.1. Its mission was determined as:

1. Coordinate and conduct accelerator R&D aimed at next-generation and beyond accelerator facilities;
2. Provide accelerator physics support for existing operational programs and the evolution thereof;
3. Train accelerator scientists and engineers;
4. Provide leadership and coordination in establishing the necessary experimental programs for a broad range of accelerator R&D that can be accessed by both Fermilab staff and the world HEP community

The goal of the Accelerator Physics Center was to provide enhanced emphasis on, and support of, accelerator R&D activities aimed at Fermilab's future beyond the end of the current decade. The APC was to provide both a physical location and an organizational structure that can accommodate accelerator scientists and engineers, either from Fermilab or outside institutions. The APC contributed to the improvement of performance of the existing accelerator complex, and the development of new technologies and accelerator concepts that could enable new forefront facilities beyond the current decade. The scope of activities conducted within APC included support for Run II and the accelerator-based neutrino program at Fermilab, the International Linear Collider (ILC), the Large Hadron Collider (LHC), the High Intensity Neutrino Source (HINS), Muon Colliders, and longterm research in novel acceleration and instrumentation techniques. In support of this primary goal the APC also increased Fermilab involvement in the education of accelerator scientists and engineers.

The Accelerator Physics Center was responsible for coordinating and/or providing support for accelerator R&D at Fermilab including activities aimed at improvements to the existing complex (in 2007 it included the Tevatron 1.96 TeV cme proton antiproton collider, 150 GeV Main Injector, 8 GeV Recycler, 8 GeV Debuncher and Antiproton Accumulator, 8 GeV Booster and 400 MeV Linac), next-generation accelerator facilities, and advanced accelerator R&D aimed at the long term future. The APC provided support for the Accelerator Division, the Technical Division, and the ILC Program Office. The APC also collaborated with the Computing and Particle Physics Divisions as appropriate.

FIG. 1: APC inauguration celebration June 1, 2007 – left to right: Rodney Gerig, Head of Argonne Accelerator Institute; Vladimir Shiltsev, APC Director; Young-Kee Kim, Fermilab Deputy Director; Stephen Holmes, FNAL Associate Laboratory Director for Accelerators.

Specific programs that initially were organized and managed by the APC, in either a primary or supporting role, included:

- Accelerator physics support for Tevatron Collider Run II, Proton Plan, and SuperNuMI (supporting);
- Simulations, design support, and beam physics experiments for ILC (supporting);
- Development of instruments for, and coordination of participation in, commissioning and beam studies, operations, and upgrades at the LHC (primary);
- High Intensity Neutrino Source conceptual design and accelerator physics, including design and development of the experimental program at the Meson test facility (primary);
- Muon Collider and Neutrino Factory R&D, including design and development of experiments and test facilities (primary);
- Development of generic theoretical and simulation tools for advanced accelerator calculations in areas of energy deposition, beam-beam and space-charge effects, linac emittance evolution, etc. (primary, w/CD);

- Designing and coordinating programs of advanced accelerator R&D at the NML facility and possibly elsewhere (primary);
- Accelerator theory and education: Host the USPAS Office, Accelerator PhD program, Peoples Fellows, and other accelerator education initiatives (primary)

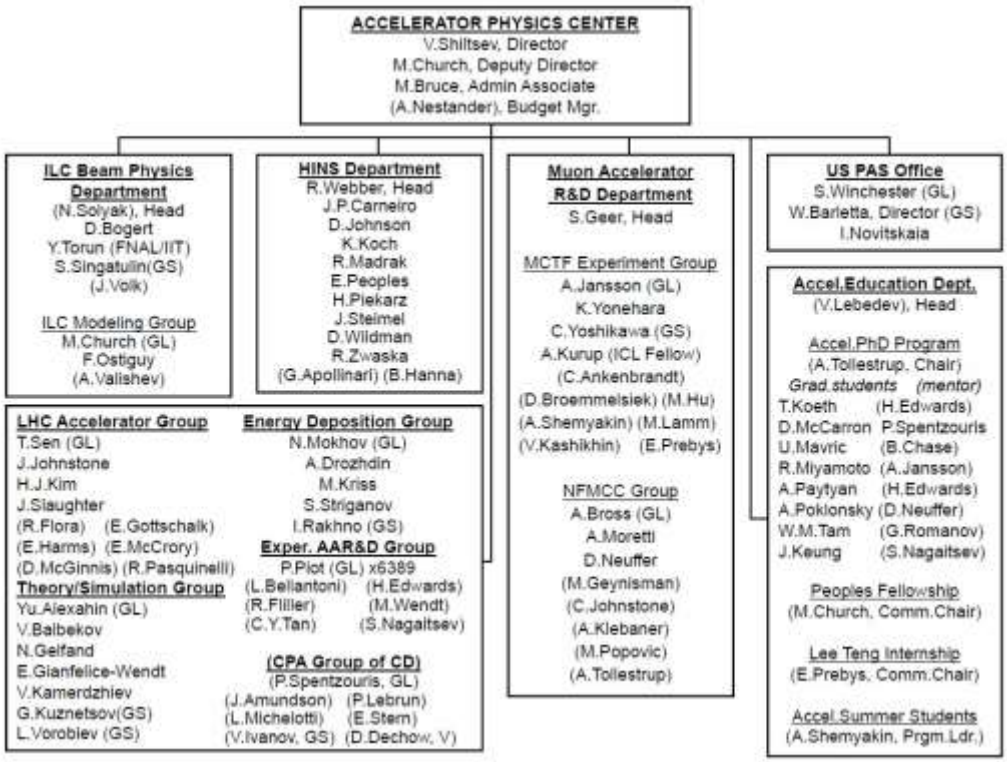

FIG. 2: The original org chart of APC (June-Dec 2007)

The APC was imagined as being comprised initially of a core of directly assigned persons, derived primarily from the existing AD/Accelerator Physics Department and augmented by significant numbers of participating staff from AD, TD, PPD, and CD - see Fig. 2. The initial number of direct assignments – 43, including 7 Guest Scientists - was expected to grow as the Collider Run II ends (Fig.3). A flow of persons both into and out of APC was generally anticipated as scientific and engineering assignments change, and/or the laboratory launches new accelerator construction projects. The APC had responsibility for coordination of inter-institutional collaborations in support of its mission. In particular, the APC will work closely with the Argonne Accelerator Institute to coordinate mutual undertakings in accelerator research.

Organizationally, the Accelerator Physics Center reported to the Associate Director for

Accelerators. Along with the Accelerator and Technical Divisions the APC comprised the Accelerator Organization at Fermilab – see Fig. 3. In October 2014, APC joined Accelerator Division as one of its four Sectors, without change in mission.

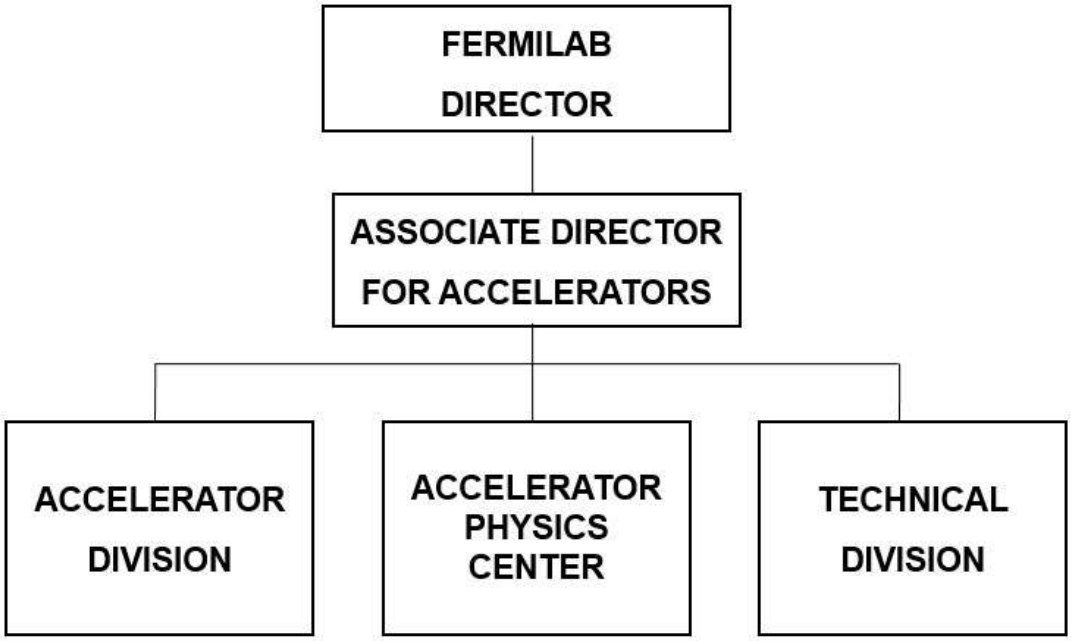

FIG. 3: Organization of the Fermilab accelerator Organization in 2007-2014.

An important role of the initial APC was to provide support to the ILC Program at Fermilab. It did this via the ILC Program Office in the same manner as the AD and TD at the time. Following its creation, the APC assumed direct responsibility for management and coordination of advanced accelerator R&D programs as described above. Both the AD and TD provided engineering and technical support for APC, and AD and TD staff did participate in APC activities. However, AD retained responsibility for systems integration, and the operations and maintenance of all beam-based accelerator facilities necessary to carry out the R&D program. Likewise, AD retained responsibility for operations and improvements to the accelerator facilities, and construction of new accelerator facilities in support of the Fermilab research program. In turn, APC provided support to AD in the execution of these responsibilities. TD retained the primary responsibility for developing the technology base for future accelerators and for providing support on major technical components required for ongoing operations and improvements to the existing complex. Initial composition of the APC included:

ILC Beam Physics Department (later - SCRF Machine Physics Department) – led by

N.Solyak; included ILC Modeling Group led by M.Church
Muon Accelerator R&D Department – led by S.Geer; included MCTF Experimental Group led by A.Jansson and NFMCC Group led by A.Bross
HINS Department – led by R.Webber
Theory/Simulations Group (later - Theory/Simulations Depratment) – led by Yu.Alexahin
LARP Accelerator Systems Group – led by T.Sen
Energy Deposition Group (later – Energy Deposition Department) – led by N.Mokhov
Experimental AARD Group – led by P.Piot
US PAS – led by S.Winchester and W.Barletta.

FIG. 4: APC 5th anniversary and Christmas party (December 2012).

Over the years, organizational structure of APC changed – reflecting shifting priorities of the Lab – and some Departments and Groups ceased to exist, or were transformed or new ones were created, including:

In 2009 – AARD Department led by M.Church;

In 2011 – Project X Office led by S.Holmes;

In 2011 – Experimental Beam Physics Department, with V.Shiltsev as initial Acting Head (later – A.Valishev) and two groups – Electron Beam Group led by A.Valishev and Proton Beam Group led by D.Wildman (later – by E.Prebys);

In 2012 – Muon Accelerator R&D Department was re-organized to be led by M.Palmer (later – P.Garbincius) and include RF Technology/MTA Group led by K.Jonehara and MICE/NF Group led by A.Bross;

In 2014 – IOTA/ASTA(FAST) Department led by A.Valishev with Injectors Group led by D.Broemmelsiek.

Besides the Office of US PAS, APC hosted several programs in Accelerator and Beam Physics education and training such as: Lee Teng Internship – jointly with ANL (led by E.Prebys in 2007-2017 and P.Garbincius since then); International Summer Internship/PARTI, later - Helen Edwards Internship (led by A.Shemyakin of AD in 2007-2012 and A.Valishev, 2013-2018); Fermilab Peoples Fellowship (led by M.Church in 2007-2010, L.Cooley of TD in 2010-2013 and S.Chattopadhyay in 2014-2017); and Joint Fermilab-University PhD Program in Accelerator Physics (led byA.Tollestrup of PPD in 2007-2008, E.Prebys in 2009-2011, V.Yakovlev of TD in 2012-2016 and R.Zwaska of AD in 2017-2018). APC hosted 5 Joint Appointments with NIU and IIT – see Appendix A, as well 11 Peoples Fellows, 3 US LARP Toohig Fellows and 2 ICL Fellows – see Appendix B and 27 PhD students two of which won the APS DPB Outstanding Doctoral Thesis Research in Beam Physics Award – see Appendix C. In 2007-2018, APC hosted more than 100 visitors and PhD or MSc students, over 100 summer students in the Lee Teng and Helen Edwards programs, about 3000 people attended semi-annual US PAS sessions.

Inaugural Director of APC was V.Shiltsev; and his Deputies were M.Church (2007-2009), R.Webber (2010), S.Holmes (2011-2013), E.Prebys (2014-2016) and P.Garbincius (2017-2018).

II. HIGHLIGHTS OF BEAM PHYSICS RESEARCH AT APC

APC scientists and engineers carried out experimental and theoretical research and development over a wide range of topics in accelerator and beam physics and technology. Their accomplishments were widely recognized by the community – see the list of APC professional recognitions, awards and prizes in Appendix D. APC studies published in 215 peer-review articles, including 27 in high-impact journals – See Appendix E. Results of the APC studies were used as an input for the discussions of the Fermilab Steering Group [see its Report, September 2007, at http://www.fnal.gov/pub/directorate/steering/index.shtml], of the P5 (Particle Physics Project Prioritization Panel) in 2008 [see *U.S. Particle Physics: Scientific Opportunities, A Strategic Plan for the Next Ten Years*, May 2008, http://www.science.doe.gov/hep/files/pdfs/P5_Report%2006022008.pdf], during the 2014 HEPAP P5 process [see *Building for Discovery* (P5 Report, 2014) at http://science.energy.gov/hep/hepap/reports/] and the 2015 HEPAP Accelerator R&D Subpanel meetings [see *Accelerating Discovery: A Strategic Plan for Accelerator R&D in the U.S.*, 2015 HEPAP Sub-panel report at http://science.energy.gov/hep/hepap/reports/]. Important contributions were made to the ILC CRD and TDR [see Behnke T *et al* 2013 *The*

International Linear Collider Technical Design Report, v.1: Executive Summary ILCREPORT-2013-040] in the US, to the Muon Collider design studies [see the JINST collection of reports and papers at], as well as in the Project-X CDR [see FERMILABTM-2557, June 2013] and the PIP-II CDR [see Lebedev V *et al* 2018 *The PIP-II Conceptual Design Report, v.0.02*, Fermilab document PIP-II-doc-113, February 2018, http://pxie.fnal.gov/PIP-II_CDR/default.htm], the High-Luminosity LHC Upgrade project [see *arxiv:1705.08830* https://arxiv.org/ftp/arxiv/papers/1705/1705.08830.pdf and references therein] and the IOTA/FAST R&D facility CDR [see Ref. [35] in Appendix E]. Experimental beam physics R&D was carried out at the operational accelerators at Fermilab and CERN as well as at a number of dedicated beam test facilities – see Fig.5.

FIG. 5: Beam facilities developed, constructed or supported by APC for the purpose of accelerator R&D: clockwise, from top left - a) the Fermilab NICADD Photoinjector Laboratory was an 18 MeV electron linac; b) the MuCool Test Area : 201-MHz test cavity installed next to 5 T solenoid in the foreground, which was also used for testing the smaller 805-MHz cavities under impact of 400 MeV proton beam; c) the Muon Ionization Cooling Experiment (MICE) at RAL (UK) operated with 200 MeV muons; d) 325 MHz HINS RFQ accelerated protons and H- particles to 2.5 MeV; e) 1.3 GHz SRF 300 MeV electron injector at FAST; f) IOTA ring will operate with up to 150 MeV/c electrons and 70 MeV/c protons.

Below we just outline major themes and accomplishments by the APC team. See Appendix F for commonly used abbreviations.

II.1. Experimental beam studies at the Tevatron Collider: APC took leading part in organization of a broad campaign of beam studies in the Tevatron and other accelerators in the Collider chain – both during the period of the Run II operation (until the Collider shutdown in Sep 2011) and during special end-of-Run II studies (led by A.Valishev et al). Many issues were studied – pioneering experiments with the Tevatron electron lenses for beam-beam compensation and beam collimation, bent crystal collimation, with longitudinal and transverse dynamics, beam-beam effects, beam instrumentation, ground motion, optics measurements with AC dipole, emittance growth, etc. Results of the studies were summarized in 20 papers published the *JINST Special Issue on Tevatron* - see at http://iopscience.iop.org/journal/1748-0221/page/extra.proc11 and, later, in two books - V. Lebedev, V. Shiltsev, Eds., *Accelerator physics at the Tevatron collider,* Springer (2014); and V. Shiltsev, *Electron lenses for supercolliders*, Springer (2016). See References [90, 115, 122, 134, 141-143, 145, 148, 160, 162-167, 177-179, 181, 185, 186, 203-205, 208, 212] in Appendix E.

II.2. Experimental, theoretical and design studies toward ILC : led by N.Solyak et al. Broad spectrum of beam dynamics issues in the ILC main linac and in the RTML (ring-tomain-linac) systems were considered including effects of cavities and magnet misalignments, RF focusing in SRF cryomodules, optimization of the SRF cavities shapes and other paramters, etc. Some of the issues were later studies with the ILC type beams at the FAST linac (see *II.7*). See References [24, 91, 209-211] in Appendix E.

II.3. Beam dynamics experiments at the A0 photoinjector (NICADD): led by P.Piot et al. New methods of beam and wakefield generation and pioneering experiments on the novel phase space manipulation techniques of the round beam transformation and longitudinal to transverse emittance exchange were developed and studied experimentally – see Fig. 5a. See References [107, 110, 118, 139, 168-170, 173, 176, 194, 196, 201, 202, 214] in Appendix E.

II.4. Electron cloud studies in Main Injector: led by R.Zwaska et al. Main features of the electron cloud effects in the Main Injector and Recycler rings and other machines were studied, as well several methods of the detection and mitigation of these effects. See References [25, 52, 79, 80-82, 108, 109] in Appendix E.

II.5. Experimental, theoretical and design studies toward a Muon Collider and Neutrino Factory: led by S.Geer, M.Palmer and A.Bross, et al. They were continuation of previous efforts and the MCTF and NFMCC groups under the US MAP and included design and simulation works as well as beam studies at the experimental facilities such as MTA at Fermilab and MICE at RAL - Fig. 5b and 5c. The studies have proven the design feasibility

and cost- and energy-effectiveness of a multi-TeV Muon Collider and several Neutrino Factory concepts. Most notable technical achievements include first-ever demonstration of *O*(10%) muon ionization cooling at MICE (A.Bross, et al) and novel techniques for substantial increase of RF accelerating gradient in copper RF cavities filled with H2 gas and/or with special surface treatment (K.Yonehara, D.Bowring, et al). Results of the studies were summarized in 16 papers published the *JINST Special Issue on Muon Accelerators* - see at http://iopscience.iop.org/journal/1748-0221/page/extraproc46. See also References [12, 13, 16-20, 56, 59, 66, 67, 72, 75, 83, 101, 103, 106, 114, 123, 175, 189, 191, 213] in Appendix E.

II.6. Development of high intensity HINS proton source and beam studies: led by R.Webber, J.Steimel, et al. Pulsed 325 MHz 2.5 MeV RFQ had been built and commissioned in the MDB building – See Fig.5d. Up to 9 mA of pulsed proton current was obtained and several innovative studies for intensity frontier accelerators were carried out:
a) "Six-Cavity Test' has demonstrated the use of high power RF vector modulators to control 6 RF cavities plus RFQ driven by a single high power klystron for acceleration (D.Wildman, et al.), b) energy stability of the 7 mA proton beam accelerated through the six cavities from 2.5 MeV to 3.4 MeV demonstrated; c) several diagnostics developments and tests were carried out together with RAL and Argonne (V.Scarpine, et al). The MDB setup finished operation in Jan. 2013 and will be re-used as IOTA proton injector in 2019. See References [85, 86, 94] in Appendix E.

II.7. Design studies, construction, commissioning and research at the FAST injector and IOTA Ring: was a major focus of the AARD/IOTA/ASTA/FAST teams led by M.Church, V.Shiltsev, A.Valishev et al. As the result unique accelerator R&D facility of IOTA at FAST was designed, built and commissioned – see Figs. 5d and 5e. The first beam out of 5 MeV injector was achieved in 2015, out of 50 MeV electron SRF injector - in 2016, out of 300 MeV 1.3 GHz SRF CM2 linac - in 2017 and the first electron beam circulated in IOTA - in August 2018. Installation and commissioning of the proton injector for IOTA is scheduled for 2019. World record beam acceleration gradient of 31.5 MeV/m was demonstrated in the CM2 in 2017. A number of beam dynamics studies were carried out with FAST beams in 2015-2018 led by P.Piot, et al. Strong scientific IOTA/FAST collaboration of 29 partner institutions, including LBNL, ORNL, ANL, etc, was formed and had annual Workshops/Collaboration Meetings since 2013. See References [1, 5, 11, 24, 28, 31, 35, 36, 51, 69, 102] in Appendix E.

II.8. Development of rapid cycling HTS-based magnets for proton RCSs: led by H.Piekarz, et al. It was demonstrated that in varying magnetic fields, the HTS conductors (tapes) have much lower AC losses compared to low temperature superconductors. Two fast cycling HTS-based super ferric magnet prototypes were built and showed record high ramp rate for SC magnets of 12 T/s. See References [77, 184] in Appendix E.

II.9. Development and applications of the energy deposition numerical modeling tools (MARS): led by N.Mokhov et al. The ED group developed a community standard modeling tool MARS, used by more than 300 users and 40 institutions in the US and world-wide and applied it for a broad spectrum of simulations for essentially all Fermilab projects, operational machines, targetry, collimation systems and experiments, many detectors and experiments worlds-wide. The most recent MARS15 version for particle interactions and transport in accelerator components was integrated with MADX-Polymorphic Tracking Code (PTC) unit. This allowed cross-talk between two codes for precise multi-turn modeling of beam loss and induced impact on accelerator components. See References [9, 10, 19, 33, 34, 43, 73, 83, 92, 99, 123, 128, 130, 131, 148-154, 156, 161, 177, 181-183, 187-189] in Appendix E.

II.10. Development of theoretical and numerical models of dynamics of high intensity beams: done by many members of the APC Theory and Modeling Group/department. Comprehensive studies covered all relevant phenomena and factors: space-charge effects (losses, emittance growth), longitudinal dynamics (capture, transition), injection issues (notching, capture, painting, …), coherent instabilities (resistive wall, e- cloud), RF optimization (acceleration, efficient loading), focusing optics (noises, periodicity), halo control (collimation, protection), beam instrumentation (fast, large range, feedbacks, etc). Seminal results were obtain in studies of Integrable non-linear optics (A.Valishev, et al), coherent beam stability (A.Burov, V.Balbekov, K.Y.Ng, et al), Landau damping with electron lenses and space-charge (V.Shiltsev, Yu.Alexahin, et al), beam phase-space manipulations (P.Piot, et al), beam-beam effects (Yu.Alexahin, T.Sen, A.Valishev et al), electron lenses for beam-beam and space-charge compensation and collimation (V.Shiltsev, G.Stancari, et al). See References [4, 6, 7, 8, 15, 25, 29, 30, 37, 46, 47, 51, 54, 62, 96, 98, 121, 122, 132, 135, 145, 157, 171, 185, 194, 195] in Appendix E.

II.11. Beam physics considerations for far-future colliders: carried out by several APC scientists and covered selected topics of efficient wakefield acceleration, technology and cost challenges of the colliders, channeling acceleration in crystals and carbon nanotubes, etc. See References [29, 42, 63, 89, 124, 125, 133, 172] in Appendix E.

III. CONCLUSION

Fermilab's Accelerator Physics Center was created in a critical time for the Laboratory and made timely contributions to beam physics research and development as well as design and analysis of possible future US accelerator-based high energy physics facilities. Input from the APC studies was presented and widely discussed during the 2014 HEPAP P5 process and by the 2015 HEPAP Accelerator R&D Subpanel. APC was a center-place for in-depth design, research and development efforts which allowed the Laboratory to make intelligent decisions on the ILC in the US, on the Muon Collider, as well as originate projects like PIP-II (through the Proton Driver/Project-X work), LHC-AUP (via LARP) and the IOTA/FAST R&D facility. APC was also the birthplace and host of many national and international collaborations and several educational/training programs in beam physics resulted in 27 PhD theses. In the Fall 2018, following an important milestone of the first beam circulating in the IOTA ring – construction of which was APC's the latest major project - the Accelerator Physics Center was re-organized into several departments in Accelerator Division, which will carry out the facility operation and the accelerator physics research with the IOTA/FAST beams. That R&D is expected to result in relevant physic breakthroughs and shape the future Fermilab accelerator complex upgrades.

IV. ACKNOWLEDGMENTS

Over the years of its existence, Fermilab's Accelerator Physics Center was encouraged by and greatly benefited from continuous support from the FNAL Directors Pierre Oddone and Nigel Lockyer, other leaders of the Laboratory such as Young-Kee Kim, Stephen Holmes and Stuart Henderson. Very fruitful were working relations with all the Fermilab Divisions and their leaders, such as Roger Dixon, Sergei Nagaitsev and Michael Lindgren (AD), Mark Ross, Giorgio Apollinari, Hasan Padamsee and Sergey Belomestnykh (TD), Vicky White and Panagiotis Spentzouris (CD/SCD), and others. Leadership and dedication of the APC Department Heads and Group Leaders were critical for the Center's scientific and organizational success.

About 100 lab employees, guests and joint appointees have worked at APC, more than 100 visitors and PhD or Master students, as well as more than 100 summer students were hosted by the Center. It is impossible to give them and our collaborators from other FNAL Divisions and other institutions proper credit in this short summary paper but their contributions to the APC mission are greatly appreciated. Special thanks go to several people who provided administrative and financial support to the Center – Margaret Bruce, Rosa Foote, Lisa Lopez and Ann Nestander.

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APPENDIX A: APC Joint Appointments

Prof. Philippe Piot - NIU (since 2008)

Prof. Young Min Shin – NIU (2010-2016)

Prof. Michael Syphers – NIU (since 2017)

Prof. Pavel Snopok – IIT (2010-2017)

Prof. Yagmur Torun – IIT (2007-2013)

APPENDIX B: APC Peoples Fellows, Toohig Fellows, ICL Fellows

2007-2018 Fermilab Peoples Fellows (latest first, now at)

Johnathan Jarvis	Fermilab
Daniel Bowring	Fermilab
Moses Chung	UNIST Korea
Markus Huening	DESY
Andreas Jansson	ESS
Andrea Latina	CERN
Philippe Piot	Northern Illinois University
Yin-e Sun	Argonne National Lab
Charles Tobin Thangaraj	Fermilab
Katsuya Yonehara	Fermilab
Robert Zwaska	Fermilab

US LARP Toohig Fellows (now at)

Dr. Miriam Fitterer, 2016-2018, now at Mannheim, Germany

Dr. Valentina Previtali, 2011-2013, now at Geneva, Switzerland

Dr. Ryoichi Miyamoto, 2008 - 2011, now staff at ESS (Lund, Sweden)

2010- 2011 Joint Fermilab-University College London Fellows

Dr. Ajit Kurup
Dr. Leo Jenner

APPENDIX C: APC/AD PhD Students (2007 - 2018)

27 PhD theses in beam physics on base of research at Fermilab's APC and AD supported either by the Joint Fermilab-University Accelerator PhD Program or directly by their Universities (name, year of degree, University):

Pavel Snopok	2007	Michigan State University
Phil Yoon	2007	University of Rochester
Alexei Poklonsky	2008	Michigan State University
Ryoichi Miyamoto	**2008**	**University of Texas, Austin**
2010 APS Outstanding Doctoral Thesis Research in Beam Physics Award Recipient		
Uros Mavric	2009	University of Ljubljana
Timothy Koeth	2009	Rutgers University
Dan McCarron	2010	Illinois Institute of Technology
W.-M. Tam	2010	Indiana University
Igor Tropin	2010	Tomsk University
Timothy Maxwell	2012	Northern Illinois University
Alexey Petrenko	2012	Budker Institute of Nuclear Physics
Arun Saini	2012	University of Delhi
Sergey Koshelev	2013	Bauman Moscow State Tech.
Meghan McAtteer	2014	University of Texas – Austin
Chris Prokop	2014	Northern Illinois University
Timofey Zolkin	2014	University of Chicago
Gene Kafka	2014	Illinois Institute of Technology
Ao Liu	2014	Indiana University
Jeffrey Eldred	2015	Indiana University
Francois Lemery	2015	Northern Illinois University
Sushantra Panuganti	2015	Northern Illinois University
Sergey Antipov	**2017**	**University of Chicago**
2018 APS Outstanding Doctoral Thesis Research in Beam Physics Award Recipient		
Alexei Halavanau	2018	Northern Illinois University
Alexey Kochemirovskiy	2018	University of Chicago
Matthew Andorf	2018	Northern Illinois University
Auralee Edelen	2018	Colorado State University
Tanaz Angelina Mohayai	2018	Illinois Institute of Technology

APPENDIX D: APC Prizes and Awards (2007-2018)

2015 APS/PRAB Robert H. Siemann Award - Vladimir Shiltsev

APS Outstanding Referees

Vladimir Shiltsev (2018)
Eliana Gianfelice-Wendt (2017)
Tanaji Sen (2013)

2016 RASA George Gamow Award - Vladimir Shiltsev

2015 Nuclear & Plasma Sciences Society Award - Jeffrey Eldred

APS Fellows

2017 - Alexei Burov
Citation: For contributions to the accelerator physics theory, including the theoretical foundations of the Tevatron Run II accelerator performance; for the development of the theory of instabilities for space charge dominated bunched beams; and for the development of analytical tools predicting instability thresholds.

2013 - Shekhar Mishra
Citation: For exceptional achievement in the creation and stewardship of international collaborations in accelerator and particle physics, especially in the Indian-American Agreement for Cooperation in the Area of Accelerator and Particle Detector Research and Development for Discovery Science.

2013 - Eric Prebys
Citation: For his important contributions to the physics of beams and his exceptional efforts to shape the US - CERN collaboration enabling successful physics programs at the LHC and charting a course for US involvement in future LHC upgrades.

2008 – Vladimir Shiltsev
Citation: For advancing the understanding of performance limitations in accelerators, in particular for seminal work on ground motion in electron-positron linear colliders and electron lens beam compensation in large hadron colliders.

Best Articles

December 2012 - Yin-e Sun and Philippe Piot recognized as *Outstanding PRST-AB Article* from 2011 for "Generation of relativistic electron bunches with arbitrary current distribution via transverse-to-longitudinal phase space exchange".

March 2009 – Vladimir Shiltsev, et al, "Experimental studies of compensation of beam-beam effects with Tevatron electron lenses" was chosen as *New Journal of Physics - Best of 2008*.

Health Physics Society

January 2008 - Nikolai Mokhov received the G. William Morgan Lecturer Award from the President and Board of Directors of the Health Physics Society.

Institute of Electrical and Electronics Engineers (IEEE) Senior Members

Elected in May 2014 :

Henryk Piekarz

Vladimir Shiltsev

Giulio Stancari

Robert Zwaska

APPENDIX E: APC peer-reviewed publications

Total of 215; including 27 high impact publication - in **bold**.

2018 [11]

[1] A. H. Lumpkin, R. Thurman-Keup, D. Edstrom, J. Ruan, N. Eddy, P. Prieto, O. Napoly, B. E. Carlsten, and K. Bishofberger, Submacropulse electron-beam dynamics correlated with higher-order modes in Tesla-type superconducting rf cavities, *Phys. Rev. Accel. Beams* **21**, 064401 (2018)

[2] J.-P. Delahaye et al., The NuMAX Long Baseline Neutrino Factory concept, *JINST* **13**, T06003 (2018)

[3] **Q. Gao, G. Ha, C. Jing, S. P. Antipov, J. G. Power, M. Conde, W. Gai, H. Chen, J. Shi, E. E. Wisniewski, D. S. Doran, W. Liu, C. E. Whiteford, A. Zholents, P.**

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APPENDIX F: Abbreviations

AD	Accelerator Division, Fermilab
ANL	Argonne National Laboratory
APC	Accelerator Physics Center, Fermilab
APS	American Physical Society
ASTA	Advanced Science and Technology Accelerator facility, FNAL
BNL	Brookhaven National Laboratory
CDR	Conceptual Design Report
CERN	European Organization for Nuclear Research
CM2	(SRF) Cryomodule 2 at FAST
DOE	US Department of Energy
DPB	APS Division of Physics of Beams
FAST	Fermilab Accelerator Science and Technology facility, FNAL
FNAL	Fermi National Accelerator laboratory
FNPL	Fermilab/NICADD Photoinjector Laboratory at FNAL
GeV	Giga Electron Volt
HEP	High Energy Physics
HEPAP	High Energy Physics Advisory Panel HINS
	High Intensity Neutrino Source
HL-LHC	High Luminosity LHC upgrade project, CERN
IIT	Northern Illinois Institute of Technology
ILC	International Linear Collider

IOTA	Integrable Optics Test Accelerator
LARP	US LHC Accelerator Research Program
LBNL	Lawrence Berkeley National Laboratory
LHC	Large Hadron Collider
LHC-AUP	LHC Accelerator Upgrade Project (part of HL-LHC)
MAP	US Muon Accelerator Program
MCTF	Muon Collider Task Force, FNAL
MDB	Meson Detector Building, FNAL
MeV	Mega Electron Volt
MICE	Muon Ionization Cooling Experiment at RAL
MTA	MuCool Test Area facility
NFMCC	Neutrino Factory and Muon Collider Collaboration
NICADD	Northern Illinois Center for Accelerator and Detector Development
NIU	Northern Illinois University
ORNL	Oak Ridge National Laboratory
PIP-II	Proton Improvement Plan – II project, FNAL
PPD	Particle Physics Division, Fermilab
P5	Particle Physics Project Prioritization Panel
RAL	Rutherford Appleton Lab, UK
RF	Radio Frequency
RFQ	Radio Frequency Quadrupole accelerator
SRF	Superconducting RF
SCD	Scientific Computing Division, Feermilab
TD	Technical Division, Fermilab
TDR	Technical Design Report
TEL	Tevatron Electron Lens
TeV	Tera Electron Volt