Precision experiments at electron-positron collider Super Charm-Tau Factory

A contribution to the Update of the European Strategy for Particle Physics

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Addendum

A. Interested community

Inside Russia, core community developing the SCT project consists of representatives of Budker INP, Novosibirsk State University, PNPI, LPI, MIPT and MEPHI. Currently, negotiations are being performed with several Russian universities and research institutions.

The SCT project has also a clear support of the world-wide community of high energy physics experts. Letters of support for the SCT project were received from the following officials and prominent scientists: European Committee for Future Accelerators, Prof. Martin Perl (Nobel Prize in Physics 1995), Prof. Rolf Heuer (Director General of CERN 2009–2015), Dr. Atsuto Suzuki (Director General of the KEK Accelerator Laboratory 2006–2015), Prof. Guido Martinelli (Director of the International School for Advanced Studies (SISSA, Italy 2010–2015), member of the Scientific Policy Committee of CERN since 2015 onward, Prof. Gianpaolo Bellini (full professor at the University of Milano, Italy).

The first version of the conceptual design report for the SCT factory project was prepared in 2011 with participation of representatives of A. Humboldt U., DESY, INFN, Jozef Stefan Institute, LAL, Giessen U., Silesia in Katowice U., Ljubljana U., Maribor U., Rome Tor Vergata U., and Weizmann Institute of Science included in the authors list.

Budker INP signed a set of agreements with foreign research organizations to foster joint activities around the SCT project: Collaboration agreement with INFN (Italy) was signed in 2010; memorandum on cooperation with KEK (Japan) is signed 2011; memorandum of cooperation is signed with John Adams Institute for Accelerator Science (UK) in 2011; the collaboration agreement with JINR (Dudna) is signed in 2010.

Several European groups are involved in R&D for the SCT detector. INFN LNF group is involved in prototyping of the SCT inner tracker based on the micro-Resistive WELL technology. INFN Lecce group is involved in development of project of the SCT drift chamber. Giessen U. group is involved in a joint R&D for particle identification for PANDA and SCT experiments. SCT accelerator complex is being developed in communication with CERN, particularly, FCC-ee community.

The SCT factory was a part of the “Connecting Russian and European Measures for Large-scale Research Infrastructures” (CREMLIN) project (www.cremlin.eu) in 2015-2018 years. The CREMLIN project is funded by European Union´s Horizon 2020 program. Two workshops were held within the CREMLIN framework:

- CREMLIN CERN-BINP workshop for young scientists in e+e- colliders, 22-25 August 2016, CERN, Geneva, Switzerland
- CREMLIN WP7 “Super c-tau factory workshop”, 26-27 May 2018, Novosibirsk, Russia. The workshop was attended by about 40 non-Russian participants.

International Advisory Committee (IAC) of the SCT detector composed by 13 experts in high energy physics and particle detectors is formed: GRANCAGNOLO Francesco (INFN Lecce, Italy), KUDENKO Yury (INR, Moscow, Russia), LINSSEN Lucie (CERN, Switzerland), LUSIANI Alberto (Scuola Normale Superiore, Italy), MITCHELL Ryan (Indiana, USA), PENG Haiping (USTC, Hefei, China), PICH Antonio (IFIC, Univ. Valencia - CSIC, Spain), RITMAN James Lambrecht (Juelich, Germany), ROIG GARCES Pablo (Cinvestav, Mexico), SEFKOW Felix (DESY, Germany), WAS Zbigniew (IFJ PAN Cracow, Poland), YUAN Changzheng (IHEP, Beijing, China), and ZHAO, Zhengguo (USTC, Hefei, China). The first IAC meeting was held during the May 2018 workshop in Budker INP. The IAC stressed out a good expertise of Budker INP community in particle accelerator and detectors technologies, expressed strong support of the SCT project, and issued a list of recommendations. These recommendations compose the basis of the current activity.

It was decided to organize regular (one or two times per year) workshop reviewing status of the SCT project. The first workshop of this series (Joint workshop on future tau-charm factory) was held 4-7 December 2018 in LAL, Orsay, France. The physics program, detector and accelerator concepts of the SCT factory were reviewed during the workshop. The next workshop is tentatively planned to be held in LPI (Moscow) at Spring 2019.

Application for the continuation of the CREMLIN project (CREMLINplus) is being prepared at the moment. The SCT CREMLINplus working package includes the following partners: Budker INP, CERN, INFN, LAL, and Giessen U. In case the CREMLINplus is funded, the joint R&D activities will be fostered significantly.

Also, there is a joint activity of particle physics theorists for calculation of radiative corrections at the precision level required for the SCT factory. This group comprises representatives of Budker INP, Padova U., Pavia U., Parma U., and Pisa U.

Inclusion of the SCT factory in the European Strategy for Particle Physics will set a solid foundation for the listed activities.

B. Timeline

The SCT project roadmap implies construction and commissioning of the accelerator complex, the detector and building infrastructure of the SCT factory by the end of 2028 (Table 1). The building infrastructure comprises buildings, tunnels and halls for placing the equipment of the SCT factory as well as engineering systems and facilities for the complex operation: power supply, water cooling, gas supply etc.

Table 1. Timeline of the SCT project.

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029…
R&D											
Construction											
Mounting and commissioning											
Operation											

The SCT project timeline implies operation and upgrade of the accelerator complex and the detector within 10 years after commissioning. The upgrade is scheduled after five years (2034) in order to improve the performance and comply with the physics program that will probably be revised in the light of new discoveries. Data processing and obtaining new results will last another 4-5 years after the SCT factory shutdown.

C. Construction and operational costs

The construction cost is estimated based on experience of Budker INP in the detector and the accelerator construction and operation.

The total cost of the accelerator complex construction is 235 MEuro. It is supposed the Federal government covers 226 MEuro and the rest is covered from the off-budget funds of Budker INP. The total cost of detector construction is 180 MEuro with 103 MEuro being requested from the federal budget. Contribution of the foreign partners to the detector works is estimated at 54 MEuro and corresponds to about 30% of the total cost. The cost of building infrastructure is 75 MEuro. The total const of SCT factory is 490 MEuro. Budker INP already invested 23.3 MEuro from the off-budget funds in the injection complex for the SCT factory. Budget funds invested in the construction of the tunnel for the SCT factory are 11.6 MEuro.

Maintenance of the accelerator complex will require about 6 MEuro per year. The cost of accelerator complex upgrade after 5 years of operation is estimated to be 70 MEuro. The cost of the upgrade of the accelerator complex is to be covered by both federal budget and off-budget funds. The annual cost of detector operation is estimated at 3 MEuro. The detector upgrade will require about 50 MEuro shared in equal parts between the federal budget, off-budget sources of Budker INP and the international collaboration.

D. Networking and computing systems

The networking and computing infrastructure will play a substantial role in the experiment at the SCT factory. The data structure and the expected data size are determined by the SCT program, which is typical for a modern high energy physics experiment.

The raw event size is estimated as 30–50 kB. The computational complexity of the reconstruction of one event is estimated as 0.15-0.30 Gflops·sec/event, which is significantly less than the values typical of LHC detectors. The computational complexity of simulation of one event is estimated as 2–5 Gflops·sec/event. To ensure data processing, simulation and physical analysis, the total processing power of the data analysis system should be about 600 Tflops, with most of these resources required for Monte-Carlo simulation.

Assuming the total number of events of $2 \cdot 10^{12}$, the total amount of raw data, including the backup copy, for the entire duration of the experiment is estimated as 150 PB. The total volume of one copy of the least detailed processed data from the detector, directly used in physical analysis, for the entire duration of the experiment is estimated as 10 PB. Taking into account the opportunity to work with several versions of the processed and simulated data, the total amount of information storage is estimated as 240 PB. Due to the relative ease of the generation of highly-detailed processed data from the raw data, there is no need to organize long-term storage of the former.

It is quite reasonable to create an integrated system in which the storage system is centralized (performing the role of T0 in the WLCG model) and some of the computing resources are distributed. In this case, the remote resources will be used mainly for simulation and physics analysis, and the resources available within a centralized system for data reconstruction. Accordingly, the raw events constituting the bulk of the data will be stored in the central system, and several copies of the processed data, including simulation, will be stored both in the central system and at remote centres.

Computing resources of the detector comprise TDAQ, Detector Monitoring and Control, and Offline Data Processing systems. These systems are planned to be organized as two Data Centres, the first one located in the closest vicinity of the detector providing all the resources necessary for online detector operations, while the second one hosting offline data processing and storage and providing connectivity to remoted computing centres.

The standard software environment designed to support all types of software related to events reconstruction, detector simulation, monitoring and control of the detector subsystems and other tasks is proposed to be virtualized, in order to gain the following advantages provided by the hardware virtualization technology:

- high reliability and rapid recovery of the virtualized services
- low level isolation of different types of services from each other
- reproducibility with freezing of the configuration execution environment over periods of time such as the entire lifetime of detector experiment
- natural way of supporting heterogeneous computing systems, including cloud computing enabled environments.

Some modern Linux distributive proposed as a standard OS for the detector experiment, while XEN or KVM (both are non-commercial products) would be the most preferable choice for the standard virtualization platform to be deployed over the offline farm computing resources. To ensure collaborative teamwork when developing the detector software, it is planned to use a version control system, with the support of automatic testing systems and error tracking systems. Gaudi-based framework is planned to be used as the framework for developing software for reconstruction and simulation of experimental detector events, as well as for software high-level (software) trigger (HLT). The full detector simulation will be implemented based on the GEANT4 package with the framework used for data reconstruction.

At the early stages of the commissioning of the experiment and its networking and computing infrastructure, there is a connectivity to Supercomputer Network of Novosibirsk Scientific Centre (NSC/SCN) via dedicated 10 Gbps optical network. In the longer term, the high-speed access via dedicated link will be provided to the resources of geographically remote supercomputer centres, as well as resources of international scientific networks, international GRID-systems, and (if necessary) individual commercial cloud platforms. A dedicated external connectivity of the order of 10–40 Gbit/s will be enough to ensure the operation of the external centres. If the capacity of the external network links allows, the data storage system can be extended to store a copy of raw data on the geographically remote sites, thus reducing the risks of data loss due to a catastrophic event on one of the sites.

Due to quickly improving computing technologies, the final hardware commissioning plan should be established as late as possible to make it optimal. It is reasonable to install hardware in several waves according to the general progress of the experiment. The expected parameters of the infrastructure are shown in Table 2.

Table 2. The expected computing infrastructure parameters at different stages.

Time period	Preparation	Initial data taking	Regular operation
Computing power, Tflops	20	344	600
Disk capacity, PB	1	13	20
Tape capacity, PB	0.1	12	240
External connectivity, Gbit/s	1	10	10–40
Local connectivity, Gbit/s	10	10–20	10–40

Validation of the solutions proposed for various components of the networking and computing infrastructure of the detector experiment is going to be done via building and testing the prototypes for parts of the infrastructure, namely:

- The HDD/SSD-based high performance storage systems,
- The robotic tape libraries and tape media,
- The high-performance computing modules based on general purpose CPUs,
- The hybrid computing architectures making use of GPU/FPGA based solutions,
- The advanced wide-bandwidth networks.