Curriculum vitæ
Sabato Leo

Contact Information

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Personal informations

Citizenship – Italian

Current position

July 2013–Current – Postdoctoral Research Associate, University of Illinois at Urbana-Champaign.

Education

Jan 2010–Sep 2013 – Ph. D. student in Physics, University of Pisa.
Thesis: "Measurement of CP violation in $B_s^0 \to J/\psi\phi$ decays using the full CDF data set".
Advisors: Prof. G. Punzi (University of Pisa), Dr. D. Tonelli (Fermilab/CERN).
Oct 2007–Oct 2009 – Master degree in Physics, University of Pisa, with top marks and highest honors.
Thesis: "On the resolution in a measurement of dijet invariant mass when searching for associated WZ production with CDF".
Advisors: Prof. G. Bellettini (University of Pisa), Dr. G. Velev (Fermilab).
Oct 2002–Nov 2005 – Bachelor degree in Physics, University of Salerno, with top marks and highest honors.
Thesis: "Una rete per la rivelazione di particelle cosmiche ad altissima energia: il Progetto EEE" (in Italian).
Advisors: Prof. S. De Pasquale, Prof. G. Grella (University of Salerno).
Sep 1997–Jul 2002 – High School diploma, Roccapiemonte (SA), with top marks.

Professional experience

Jul 2015–Current – CDF analysis internal reviewer.
Jul 2012–March 2013 – Involved in LHCb experiment operations at CERN.
Jan–Sep 2010 – Teaching assistant in the Electrostatics and Magnetism course for 2nd year undergraduates in Engineering, University of Pisa.
Aug–Sep 2009, 2010, 2011, 2014 – Supervisor of Fermilab summer interns.
Aug–Sep 2008 – Summer intern within the DOE/INFN Summer Exchange Program at Fermilab, Batavia IL, USA.

Awards & Fellowship

Springer Thesis Award 2013 – Ph.D. Thesis nominated by the University of Pisa as the best thesis in physics of 2013 and published by Springer

Universities Research Association Fellowship – Visiting Scholars Program Spring 2014

Conference talks

May 2015 – "CDF results on CP-violation in charm", CHARM 2015, Detroit, MI, USA.
Mar 2015 – "Heavy flavor at the Tevatron", Les Rencontres de Physique de la Vallee d'Aoste, La Thuile, Aosta valley, Italy.
Sep 2014 – "Search for CPV in $D^0 \to hh$ at CDF", 8^{th} International Workshop on the CKM Unitarity Triangle, Vienna, Austria.
Mar 2013 – "Searches for New Physics In Charm and Bottom Decays", Rencontres de Moriond:QCD and High Energy Interactions, La Thuile, Aosta valley, Italy.
Jun 2012 – "Searches for BSM physics through CP violation at CDF", at the XIth International Conference on Heavy Quarks and Leptons (HQL 2012), Prague, Cžech Republic.
Apr 2012 – "Final measurement of B_s^0 mixing phase in the full CDF Run II data set", at the Incontri di Fisica delle Alte Energie (IFAE2012), Ferrara, Italy.
Feb 2012 – "Searches for New Physics through B CPV processes", at the Lake Louise Winter Institute 2012, Lake Louise, Canada.

Invited seminars

"Status of the next generation Muon g-2 experiment"
Mar 9th 2015 – EPFL, Lausanne, Switzerland
Mar 13th 2015 – Queen Mary University of London, London, England
Mar 17th 2015 – University of Pisa, Pisa, Italy

Schools

Aug 2012 – "69^{th} Scottish Universities Summer School in Physics" St. Andrews, Scotland (with presentation in poster session).
Aug 2010 – "The CERN-Fermilab Hadron Collider Physics Summer Schools", Fermilab, USA.
Jun 2010 – "VII Workshop on the Nuclear, Subnuclear and Applied Physics Software", Alghero, Italy.
Aug 2008 – "Accelerated C++: A Short Course in Practical Programming" Fermilab, USA.

Languages

Italian – Native
English – Fluent
French, Spanish, Greek – Basic

Computer/ Hardware skills

Operating Systems – Windows, Mac OSX, Unix/Linux
Office applications – Microsoft Office Suite, Open Office Suite, LaTeX
Web design – HTML 4.01/CSS, Java
Programming languages – C/C++, shell scripting, Fortran, Python, VHDL
Scientific software – LabVIEW, Origin, Matlab, ROOT, Mathematica, R
Database – SAM(Serial Access to Metadata), SQL
Engineer software – ISE suite Xilinx, Vivado suite Xilinx
Hardware – μTCA Technology, AMC, FPGAs
Tektronix products – Oscilloscope and TimeJitter analysis tool

Research Interests

Physics, Statistics, Algorithms, Machine Learning, Montecarlo Simulations, Database, FPGAs, Finance, Bioinformatics –

Research activity

BSc thesis – I pursued a two-months project on ultra high energy cosmic rays based on bibliographic research and defense of a short thesis. The origin and production mechanism of ultra high-energy (E> 10^{19} eV) cosmic rays is still uncertain but important in that it may reveal useful information on fundamental questions in cosmology and particle physics. Such cosmic rays are not directly observable. Their existence is inferred from effects such as showers of secondary particles produced by their interaction with the atmosphere, which extend over surfaces in excess of 10^3 km^2. I joined the HEP group in Salerno to pursue feasibility studies on a proposed experiment, the"Extremely Energy Event (EEE) project", designed to detect such events using a large network of "telescopes" scattered all over the italian peninsula. The proposed detectors consisted in dedicated ionization chambers with synchronized triggering and data acquisition. I got familiar with the theoretical and phenomenological status of cosmic rays research and with the at that time available measurement techniques and detectors, with an emphasis on those more suited to the EEE project.

From mid-2008 to mid-2012, I conducted my research in the Collider Detector at Fermilab (CDF) experiment. This is a collaboration of about 450 physicists from more than 50 institutions in 12 countries that built and operated a large multipurpose solenoidal magnetic spectrometer, surrounded by 4π projective calorimeters and fine-grained muon detectors, to study 1.96 TeV proton-antiproton collisions provided by the Tevatron collider since March 2001 through September 2011.

I joined CDF for two months as a summer intern in August 2008, within a small group of colleagues working on an upgrade of the online event selection system (trigger). The goal was improving the resolution of the online missing transverse energy information. The missing transverse energy is a calorimetric quantity that reveals the presence of neutrinos in the final states, providing information on their kinematics. An improved missing-transverse-energy resolution allows more efficient triggering of events involving neutrinos, such as leptonic W and Z decays or hypothetical supersymmetric particles, without increasing the needed trigger bandwidth. My main contribution was to check the efficiency and rate of the improved trigger, as it ran in parallel to the default trigger in real data, and explore avenues to implement a similar trigger selection in earlier stages of the trigger decision chain.

Master thesis – In November 2008 I started my one-year long Master degree's project (see Ref. (**g**)) under the supervision of Prof. G. Bellettini and Dr. G. Velev. The goal was to improve the resolution on the reconstructed invariant mass of heavy particles decaying into high-energy hadron jets, as an intermediate step toward measurements of associated WZ production cross sections. Diboson production at the Tevatron is a rare process that competes with large backgrounds, but it provides a key benchmark channel for Higgs boson searches, which have similar experimental signatures. Any improvement in dijet mass resolution can significantly improve the significance of the reconstructed Higgs boson signal.
Initially, my main responsibility was to optimize the resolution of a jet-jet resonance by complementing the calorimeter information with information from the tracker. For mis-measured calorimeter jets, and for jets fragmenting with a large charged-to-neutral particles ratio, the jet axis is better determined using the tracker than the CDF calorimeter. I obtained improvements in dijet mass resolution of a few % in simulated samples. In addition, I developed jet energy corrections specific for different event topologies. The combined effect produced an improvement in dijet mass resolution of up to 5%, depending on event topology. Finally, I developed an algorithm to identify and merge jets originated from final-state gluon radiation, and determined their impact on dijet mass resolution. Such studies initiated the development of more sophisticated techniques (see Ref. (**c**)) that are now standard in current CDF analyses for diboson and Higgs searches.

Ph. D. thesis – In January 2010, I was admitted as a Ph. D. student at the University of Pisa after a national selection based on written and oral exam. I spent the first year in attending the courses and passing the exams, participating in CDF operations and teaching assistance, and continuing the studies on dijet mass resolution. I served as data-taking operation leader (DAQ and monitoring expert) of the CDF four-people shift crew in 45 8-hours-long shifts throughout 3 months. I also specialized my previous jet resolution studies toward the $Z \to b\bar{b}$ process. The goal was to use Z bosons decays to develop, gauge, and optimize algorithms to improve the reconstruction and energy resolution of b-quark jets, to be applied in searches for low-mass Higgs bosons. The identification and rate measurement of the $Z \to b\bar{b}$ process has long been a major experimental challenge at the Tevatron because of the overwhelming QCD background, limited dijet mass resolution, and trigger bandwidth constraints. The signal would appear as a broad enhancement over a large, steeply-falling background, whose modeling is complicated by the sculpting from trigger requirements applied to control the rate. I explored new discriminating variables to statistically extract signal from background, such as those derived from three-dimensional angular distributions between the jet directions.

Because the results were not as promising as expected, and efficient ad-hoc b-jet calibrations in Higgs searches had been derived using other methods, in the second year I redirected my research interests toward flavor physics. Under the supervision of Dr. D. Tonelli and Prof. G. Punzi, I joined a group of 6 people that had just formed to pursue the final CDF measurement of *CP* violation in the time-evolution of flavor tagged $B_s^0 \to J/\psi\phi$ decays (see Refs. **(b)**, **(CN.II)**, **(1)**).

The dynamics of B_s^0 mesons offers rich opportunities to probe non-standard-model physics. It probes the poorly-known V_{ts} coupling of the quark-mixing matrix and its exploration has not reached in extension and precision the level needed to strongly constrain the existence of non-standard model physics. The $B_s^0 \to J/\psi\phi$ process involves the interference between the amplitude of direct decay and decay preceded by flavor-oscillations. The *CP*-violating relative phase between the amplitudes is observable, and sensitive to non-standard-model contributions in B_s^0–$\overline{B}_s^0$ mixing. The magnitude of this phase in the standard model (SM) is predicted to be suppressed down to the *per mille* level by the quark-mixing matrix hierarchy. This makes the $B_s^0 \to J/\psi\phi$ decay amongst the most promising indirect probes for physics beyond the SM: observation of significantly larger *CP*-violating effects would provide a theoretically solid evidence of new physics. The first such measurement, finalized in early 2008 by CDF, showed a 1.5σ departure from the SM, confirmed shortly after by D0. The combined 2.2σ effect attracted some interest, until more recent results from CDF, D0 and LHCb showed an improved agreement with the SM.

When I started my thesis project, the latest CDF measurement of the mixing phase had just been finalized with half the data then available. My thesis work extends the analysis to the entire CDF data sample, corresponding to about 10 fb^{-1}, and introduces a few improvements in the analysis technique. The measurement consists of a multivariate likelihood fit to the time evolution of B_s^0 and $\overline{B}_s^0$ decays into $J/\psi(\to \mu^+\mu^-)\phi(\to K^+K^-)$ final states. To increase the sensitivity on the B_s^0 mixing phase, the time evolution of mesons produced as B_s^0 or $\overline{B_s^0}$ is fit separately using flavor tagging algorithms. Similarly, angular distributions between final-state particles are used in the fit to statistically separate decays occurred in different states of relative J/ψ-ϕ orbital angular momentum.

Along with another student, I was the main analyzer in charge of this measurement. I actively contributed to all parts of the analysis, from data and simulation processing to the validation of the fit and the extraction of the final results with systematic uncertainties, routinely reporting the status of my progress in internal CDF meetings. My specific contribution focused on calibrating and optimizing the flavor tagging algorithms. The production flavor of pair-produced bottom-strange mesons is determined by using two different algorithms: the opposite side tagger (OST) algorithms infer the initial flavor of the meson from the decay products of

the b hadron produced by the other b quark in the event; the Same Side Kaon Tagger (SSKT) algorithms deduce the production flavor exploiting charge-flavor correlations of the neighboring kaons produced in the fragmentation process. I fully calibrated the OST algorithms performance by determining the probability of wrongly-tagging the meson using 82 000 $B^{\pm} \to J/\psi(\to \mu^{+}\mu^{-})K^{\pm}$ decays fully reconstructed in the same data as the signal. Because the $B^{\pm}$ does not oscillate, the OST tag is compared with the actual flavor, known from the charge of the $K^{\pm}$ meson. A scale factor that matches the predicted mistag probability to the one observed in data is then extracted. I newly introduced a threshold on the decay-time of the B^{+} sample that allowed an improved, more symmetric tagging performance between bottom and antibottom mesons. The consequent use of a single scale factor reduced the parameters of the final fit to the mixing phase. Additionally, my studies of the variations of tagging performance as a function of data-taking time and instantaneous luminosity allowed a reduction of the systematic uncertainties. In addition, given the lack of an abundant calibration sample in the latest part of the data, I proposed not to use SSKT in those data and I quantitatively showed with realistic simulation that the impact of that choice was minor in the final results.
Preliminary results on the mixing phase with the full CDF data set were finalized in early 2012 (see Refs. **(CN.II)**) and I was the first to show them in public, at the Lake Louise Winter Institute. They feature a 50% improvement in the mixing phase determination with respect to the previous CDF measurement. The value of the phase is consistent with the SM and with determination from other experiments. The results also include among the world's best determination of B_s^0 lifetime, width difference and polarization amplitudes. The results have been perfected and extended during summer 2012 and the resulting letter to Physical Review was promptly published (see Refs. **(1)**) and already collected more than 40 citations.

LHCb operations – Having enjoyed my flavor physics project at CDF, I wished to continue along this research path in the LHCb experiment. In July 2012, I relocated to CERN for a few months. I joined the high-level trigger working group. Under the guidance of Dr. J. Albrecht (CERN), I worked on extending and improving the offline and online monitoring of track qualities and trigger performances in view of the 2014 luminosity upgrade. This included studying in detail a large set of tracking- and trigger-related distributions, defining reference samples and quality criteria, and proposing a smaller set of informative distributions for inclusion in standard monitoring tools. In addition, I got involved in data taking operations as high-level trigger on-call expert and data-quality shifter.

Postdoctoral research – As a postdoc at University of Illinois I keep pursuing my precision physics interests working on the new Muon g-2 experiment at Fermilab. Within the Intensity Frontier research program, the g-2 experiment has the potential to unveil not yet discovered particles or interactions that may be hiding in the vacuum. The experiment under construction at Fermilab's new Muon Campus, will use the Fermilab accelerator complex to produce an intense beam of muons traveling at nearly the speed of light. The highly polarized muon beam will be confined in a superconductive magnetic ring. By detecting the energy and the arrival time of electrons emitted in muon decays, we will be able to measure the gyromagnetic factor g (or as matter of fact the anomaly a_{μ} =g-2 throughout the measurement of muon spin precession frequency ω_a) of the muon. Any discrepancy between the g-2 value measured with high precision and its theoretical prediction will signify the existence of yet undiscovered particles. In 2001 the muon g-2 experiment at Brookhaven National Laboratory found a tantalizing greater-than-3-sigma (standard deviation) discrepancy between the theoretical calculation and the measurement of the muon g-2. Fermilab experiment aims to a four-fold increase in the measurement's precision, with a projected sensitivity of more than 5-sigma.

As a **Postdoctoral research associate** at University of Illinois my main responsibility is the clock and controls system (CCC) for the g-2 experiment. The CCC system provides time-base and triggers to detectors and various other subsystems and primarily consists of off-the-shelf components. We purchased a GPS-disciplined oscillator, which is supposed to provide the principal Clock signal. The GPS Clock produces a 10 MHz output signal which is fed to a frequency synthesizer providing a shifted ω_a Clock of 40 MHz plus a small offset (ϵ) that will be blinded. The 40 + ϵ MHz clock is then bi-phase mark encoded along with trigger signals (commands) by mean of an FPGA-based board using μTCA technology. Distribution of clock and commands will use an optical fanout system developed at CERN and again based on FPGA and μTCA technology.

In order to avoid systematic bias on precession frequency measurement, the distributed Clock is required to be stable against systematic phase shifts or timing drifts to under 10 ps over a time length of 700 μs.
I performed extensive studies aimed at exploring the performances of the CCC system components. The observed systematic phase shift for single components and subsets of the entire system is found to be limited to few ps as demanded by design requirements. Recently, I performed investigations on the entire system timing performance confirming that the CCC system meets design timing requirements.
Additionally, I devote a limited amount of time in simulations/analysis work.
My efforts focus on evaluating corrections to decay electron time and energy spectra due to "lost muons". By lost muon we refer to muons escaping storage ring before the decay. Muons can indeed follow orbits intersecting ring materials and eventually interact with them. Muons can finally spiral inward the ring due to the energy lost in the interaction with ring materials.
In the E821 BNL experiment this effect ranged from 1% to 0.1% per lifetime as they were looking at early to late decay times respectively. As consequence of those losses the fit of data returned a biased lifetime measurement and, despite the small muon losses correlation to ω_a frequency, muon losses shifted the frequency measurement by 0.18 ppm as evaluated using data-driven corrections.
In the new g-2 experiment at Fermilab this effect is expected to be smaller. However a carefully investigation of the occurrence of such events using detailed experimental simulations will help understanding their real impact on the final measurement. Nevertheless, in order to perform these studies we need to setup the entire analysis framework and routines which will be used once the g-2 experiment will provide the first set of data.

Last but not least, I keep producing physics results by maintaining a limited, but productive **data analysis activity in CDF**. I conducted the first Tevatron search for indirect CP violation in $D^0 \to K^+K^-$ and $D^0 \to \pi^+\pi^-$ decays using the full Run II data set, corresponding to 9.7 fb^{-1} of integrated luminosity and collected by the trigger on displaced tracks. Exploiting the strong $D^{\star +} \to D^0\pi^+$ decay to identify the flavor of the neutral charmed meson at production time, I measured in each decay mode the asymmetry in several decay-time bins between the numbers of charm and anticharm decays. By fitting the yield asymmetry as a function of decay time with a linear function, I measured the amount of indirect CP violation, which is linked to the effective-lifetime asymmetry A_Γ, by $A_{CP}^{ind} = -A_\Gamma$. The analysis yields the second world best results (2), which contribute to improve the global bounds on indirect CP violation in charm. It has been published as a letter to Physical Review D (**Phys. Rev. D** 90, 111103 (2014)).
My most recent ongoing analysis effort aims at the first world measurement of charm production asymmetry in hadron colliders. The analysis will use the same data samples used to measure the effective-lifetime asymmetry and the same analysis tools. Additionally, triggered by the very recent tetraquark discovery claimed by the DZero experiment, I'm leading an investigation aimed to confirm or refute the discovery.

Publications

As a member of the CDF and LHCb collaborations I co-authored more than 100 papers published in Phys. Rev. Lett. and Phys. Rev. D. In the following I list only the public and internal documents to which I gave a direct, personal contribution

Physics papers

(1) T. Aaltonen *et al.* (CDF Collaboration), "Measurement of Bottom Strange Meson Mixing Phase in the Full CDF Data Set", the paper resulting from my thesis, which is cited in that paper arXiv:1208.2967, also published as a letter in Physical Review, **Phys. Rev. Lett.** 109, 171802 (2012) and received more than 40 citations up to date.

(2) T. Aaltonen *et al.* (CDF Collaboration), "Measurement of indirect CP-violating asymmetries in $D^0 \to K^+K^-$ and $D^0 \to \pi^+\pi^-$ decays at CDF", arXiv:1410.5435, also published as a letter in Physical Review D, **Phys. Rev. D** 90, 111103 (2014)

Conference proceedings

(CP.I) S. Leo (for the CDF Collaboration), "CDF results on CP-violation in charm", proceedings for CHARM 2015, arXiv:1508.07048.

(CP.II) S. Leo (for the CDF Collaboration), "Heavy flavor at the Tevatron", proceedings for Les Rencontres de Physique de la Vallee d'Aoste 2015, Nuovo Cimento C, DOI: 10.1393/ncc/i2015-15131-1.

(CP.III) S. Leo (for the CDF Collaboration), "Search for CPV in $D^0 \to hh$ at CDF", proceedings for the 8^{th} International Workshop on the CKM Unitarity Triangle, arXiv:1411.0623.

(CP.IV) S. Leo, "Searches for New Physics in Bottom Hadron Decays at the Tevatron", proceedings for "48th Rencontres de Moriond on QCD and High Energy Interactions", "Auge, Etienne" editor, 2013, INSPIRE-1268711

(CP.V) S. Leo (for the CDF Collaboration), "Searches for BSM physics through CP violation at CDF", proceedings for HQL 2012, arXiv:1207.6728v1.

(CP.VI) S. Leo (for the CDF Collaboration), "Final measurement of B_s^0 mixing phase in the full CDF Run II data set", proceedings for IFAE 2012, arXiv:1207.6727v1.

Conference notes

(CN.I) CDF Collaboration, "Measurement of indirect *CP*-violating asymmetries in $D^0 \to K^+K^-$ and $D^0 \to \pi^+\pi^-$ decays at CDF ", CDF Public Note 11117.

(CN.II) CDF Collaboration, "Measurement of the B_s^0 Mixing Phase in B_s^0 to $J/\psi\phi$ Decays Using the Full Run II Data Sample", CDF Public Note 10778.

Internal CDF notes and theses

(a) S. Leo *et al.*,"Measurement of effective-lifetime *CP*-violating asymmetry in two-body charm meson decays", CDF Note 11106

(b) S. Leo *et al.*,"An Updated Measurement of the *CP*-Violating Phase betas in 9.6 fb-1 of Data", CDF Note 10722

(c) S. Leo *et al.*,"On Jet-Specific Energy Corrections", CDF Note 10623

(d) S. Leo *et al.*,"Jet studies on the $WZ \to l\nu(>= 3)j$ sample", CDF Note 9944

(e) S. Leo *et al.*,"On the Resolution of a Dijet Invariant Mass Measurement Using Charge Track Jets", CDF Note 9943

(f) S. Leo, "Measurement of CP-Violating Phase in the $B_s^0 \to J/\psi\phi$ Decay at CDF", PhD thesis.

(g) S. Leo, "On the resolution in a measurement of dijet invariant mass when searching for associated WZ production with CDF", Master thesis.

(h) S. Leo, "Una rete per la rivelazione di particelle cosmiche ad altissima energia: il Progetto EEE", Bachelor thesis.

References

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