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PART B

“ITES”

B1. SCIENTIFIC AND TECHNOLOGICAL QUALITY

Scientific and technological quality, including any interdisciplinary and multidisciplinary aspects of the proposal

Research objectives against the background of the state of the art

The project objectives are: **(a)** the development of innovative High Energy Physics (HEP) tools and strategies optimized for both ***online*** and ***offline*** event selections at CDF; **(b)** the transfer to LHC of the experience gained at CDF.

The CDF experiment is located at the Tevatron hadron collider at Fermilab, a USA national laboratory near Chicago. At present, the Tevatron is the particle accelerator providing the highest center-of-mass energy collisions in the world. It accelerates protons and antiprotons, and then makes them collide head-on inside the CDF detector. LHC, currently in its starting phase, is a proton-proton accelerator located at CERN laboratories, near Geneva. It can accelerate beams of protons to a center-of-mass energy one order of magnitude greater than Tevatron.

The CDF detector is used to detect and collect the products of the proton-antiproton collisions of interest for physics research. The rate of collisions at CDF is a few million per second. Since it is impossible to readout and store data from all detector components at this rate, a real-time event reconstruction (*trigger*) is made to select the most interesting events for storage and later analysis (a rate of 100 Hz is written on tape). Real time event reconstruction is thus a critical component for any experiment at a hadron collider.

Digital electronics is becoming so powerful that the difference between the performance of the algorithms executed in real-time and in the offline analysis has been significantly reduced, even in the hadron collider extremely hard conditions. Implementing the most powerful selections in real time is essential to fully exploit the physics potential of experiments when the most interesting processes are very rare and hidden in extremely large levels of background.

We have already built high-performance Supercomputers for the CDF experiment at the Fermilab Tevatron, and we are proposing similar systems for LHC, using a combination of technologies: powerful FPGAs cooperating with standard-cell ASICs for utmost gate integration density. Optimal partitioning of complex algorithms on a variety of computing technologies demonstrated to be a powerful strategy. For example the selection of hadronic B meson decays done with this technology has made CDF one of the major players in the field of B-physics, on par with dedicated experiments operating at e^+e^- colliders. Recently the improvements of such technique has allowed to select jets containing a b quark without rely on leptons, which gives the possibility to investigate new physics phenomena (NP).

Very powerful *analysis tools* are also necessary to fully exploit the advantages offered by the new online selections. In particular CDF has the opportunity to search for the Higgs boson, a particle not observed yet and whose existence could explain the origin of particle masses within the Standard Model. If, as expected, this particle has a mass below 130 GeV, it decays prevalently into two jets with b quarks which are of difficult identification at the hadronic colliders. New analysis techniques optimized for small signal extraction among a high number of events will be investigated.

The proposed program will be a continuation of the OIF Marie Curie fellow POT which has already produced important results in this direction.

In addition to the short-term benefits expected at the Tevatron from the proposed program, pushing forward the ongoing CDF experience on offline-quality triggers and related analyses allows to accumulate on-the-field experience on high-rate hadronic environments. This experience will be precious when transferred to the very sophisticated future detectors that will operate soon at the LHC collider, when currently there is no experience on this field. The transfer of CDF experience to the future experiments is a relevant part of our program.

Expected results

The main expected result is the enhancement of the hadron collider physics reach in the search for new physics and in particular for the Higgs boson. However also technological advance will be an important result. We will implement ***fast***, ***exclusive***, ***offline-like*** selections for hadron collider triggers in order to achieve high background rejection factors and manageable trigger rates at the highest Tevatron and LHC instantaneous luminosities.

Description of the state-of-the-art of the research topic.

The CDF collision rate is ~2 MHz (396 ns bunch spacing) and at the instantaneous luminosity (ILum) of $3 \cdot 10^{32}$ cm^{-2} s^{-1} the average number of interactions per bunch crossing (pileup) is 6. The LHC environment will be more demanding: a bunch spacing of 25 ns at high ILum (10^{34} cm^{-2} s^{-1}) produces ~ 25 pileup interactions. The LHC upgrade (super-LHC, SLHC), with the recently proposed scenario of a 50 ns bunch spacing, will produce a pileup of hundreds of events (4 times larger than what expected with the originally proposed 12.5 ns bunch spacing) at the ILum of 10^{35} cm^{-2} sec^{-1}. Accommodating the limited writing-to-tape rate with the necessity of a first raw selection of the most interesting events is thus very challenging.

A multi-level trigger is an effective solution for an otherwise impossible problem. The level-1 (L1) trigger is based on custom processors and reduces the rate from ~2 MHz to ~30 kHz at CDF and from 40 MHz to ~100 kHz at LHC. The level-2 (L2) is based on dedicated hardware at CDF and standard CPUs at LHC. In both environments the L2 output rate is ~1 kHz. The Level-3 (L3) selection is performed by CPU farms, which write to tape about 100 events/s.

Implementing what may be called the "optimal mapping of a complex algorithm" to build efficient Supercomputers requires excellent technological skills. CDF has a very strong background in this field, since both L1 and L2 triggers have been implemented with dedicated hardware, and have been operational for many years, constrained to work within very short latencies (3.5 μs at L1 and 20 μs at L2). They have been upgraded during the 20-year CDF life, to exploit technology advances. Very powerful devices are now available at CDF: the L1 eXtremely Fast Tracker (XFT), the L2 Silicon Vertex Trigger (SVT) and the L2 calorimetric trigger.

The perfect baseline for our project is SVT, the most powerful trigger processor operating at a collider experiment so far. It performs online track reconstruction in the silicon detector (SVX) and the central drift chamber (COT), with sufficient accuracy to identify tracks from b-quark decays from their large impact parameters (IP>100 μm). SVT reconstructs all tracks with transverse momentum (Pt) above 2.0 GeV/c with the maximum spatial resolution allowed by the silicon vertex detector. It was originally built for B-physics at the Tevatron intermediate ILum RUN IIA (~10^{32} cm^{-2} sec^{-1}) and had an extremely significant impact on the CDF physics program. Allowing to trigger on displaced tracks, it increased by several orders of magnitude the efficiency for the hadronic B decay modes.

The SVT architecture and the Associative Memory at CDF - The eXtremely Fast Tracker (XFT) finds L1 tracks with Pt above 1.5 GeV/c in the Central Outer drift Chamber (COT) (96% efficient), Pt resolution $\sigma(1/Pt)$ = 1.7 % and angular resolution $\sigma(\varphi_0)$=5 mrad, where φ_0 is the azimuthal angle. In addition to being used in the L1 trigger decision, the XFT tracks are distributed to SVT which links them to the hits on the five silicon detector layers. The SVT algorithm is subdivided in 2 sequential steps of increasing resolution. In the step 1 a dedicated VLSI specific device, the Associative Memory (AM) has been designed and applied to associate the SVX hits and XFT tracks with low spatial resolution track candidates, called roads. In step 2, the real tracks are searched within the roads and fitted to determine their parameters (IP resolution 35 μm, $\sigma(1/Pt)$ = 0.3 % and σ (φ0)=1 mrad). Tracks with Pt>2 GeV and a large IP are finally selected to tag a secondary vertex. The basic Associative Memory chip was originally made with VLSI full-custom technology and it was specific of the CDF 5-layer silicon detector. In particular, it was unsuitable for the complexity of the tracking detectors of the future hadron colliders such as LHC. Since it was a full-custom chip, it couldn't be easily tailored to other experiments.

For applications requiring an extremely high pattern density, using a standard-cell ASIC can be a very good compromise between the easy design of an FPGA and the logic density of a full custom ASIC. We developed the new associative memory as a standard-cell chip. The new standard cell AM chip is now playing a key role in the upgraded SVT.

SVT includes important pre/post processing functions, complementary to the intensive pattern-recognition. Pre-processing corresponds to (a) cluster finding in the silicon data; (b) smart database (DB) for immediate retrieval of full resolution information. Post-processing includes (a) the track fitting (TF) and (b) duplicate-track cleanup. The most relevant function is the track fitting (TF), which refines the candidate tracks to determine full detector resolution track parameters. The TF makes use of methods based on local linear approximations and learn-from-data techniques for online misalignment corrections. The SVT experience shows that the approximations introduced to maximize the speed often do not significantly affect the fit performance.

The most relevant changes in the SVT upgrade were: (a) a 40 times larger AM, implemented as a 0.18 μm standard-cell ASIC; (b) all the SVT pre/post functions have been implemented in the same general purpose board, the PULSAR developed at CDF for the Level 2 data preprocessing. The general design philosophy of the PULSAR is based on a motherboard (with a few powerful FPGAs and SRAMs), which can be interfaced to many industrial standard links through custom mezzanine cards. The design is general and the PULSAR can be used in many applications, even outside CDF.

Also the low-level calorimetric triggers have achieved the SVT offline-quality. A PULSAR system integrated with CPUs has been produced and now allows high quality calorimetric triggers.

The upgrades described so far have provided new tools that can be used in the design of innovative triggers. These triggers extend the physics reach of the experiment, increasing the sensitivity to rare signal events such as the Higgs boson. The latest Top and W mass measurements at the Tevatron point to a relatively light Standard Model Higgs (M_H<180 GeV) and thus suggest that the Tevatron may find, or exclude, a light Higgs boson. The searches use two different strategies depending on Higgs mass. For M_H>130 GeV the Higgs decays predominantly in a pair of W bosons and this data are collected via a lepton trigger requiring 2 high momentum leptons. The background is relatively low and well under control in a hadronic environment. As of today the Tevatron has excluded a Higgs with a mass of 170 GeV and we expect to extend the exclusion region for 2009. When the Higgs has a mass lower that 130 GeV, H->b-bbar is the dominant decay channel. Since this channel has a production cross section times branching ratio about 7 orders of magnitude smaller than the direct b-bbar production, very efficient trigger system and powerful analysis tools are needed to be recognized. At the moment the Tevatron sensitivity goes from 10 to 3 times the Standard Model expectations as the mass runs from 100 to 130, where we expect the major benefits from this project.

Scientific, technological or socio-economic reasons for carrying out further research in the field covered by the project

High-energy physics research focuses on the fundamental nature of matter and energy, space and time. Any discovery in this field will help to deepen our understanding of nature and to answer to compelling questions about the origin of particle masses, the existence of new symmetries of nature as well as extra dimensions. Answers to such fascinating questions can be found at particle accelerators and colliders facilities and will influence the philosophy of science and the human being way of thinking.

Most Tevatron Run II data will be collected in the year 2009, and possibly in the year 2010 and beyond, if the proposed extension of the Tevatron run II is approved. The CDF Higgs discovery potential will be mainly determined by our ability to keep a high trigger efficiency in the face of the very high data rates expected for the next few years of data taking. This is particularly important for a thorough exploration of the low Higgs mass region that will be more difficult in the LHC higher-energy environment. At the same time, the expected large integrated luminosity of the Tevatron will allow high-statistic studies of the rare CP-violating processes. These are sensitive to complementary regions in the parameters space of the same new-physics phenomena accessible by high-pt processes. Both these crucial explorations are critically dependent on the capability to perform fast, exclusive, offline-like selections in the low-level triggers and to exploit them at analysis level. LHC will be the natural CDF continuation.

Information on interdisciplinary / multidisciplinary and/or inter-sectorial aspects of the proposal.

Since an SVT-like processor essentially performs data correlation searches preceded or followed by a processing stage, applications outside high-energy physics can be explored every time the flux of data to be processed is large and processing time is critical, such as imaging for medical diagnostics (when real time reconstruction is important), fast industrial process control or security screening. In particular this project will study the application of a SVT-like processor to the pattern recognition problem, based on the same optimization algorithms used at brain level to extract meaningful patterns from a large amount of information.

Research methodology

The research methodology is summarized in 3 main objectives: (a) complete the hardware upgrades at CDF and exploit them for new triggers, (b) develop and apply new complex analysis on data collected, (c) transfer of expertise to LHC.

a) Dedicated trigger hardware usage has been recently reduced for future experiments in favour of large, commercial CPU farms to reduce the risks of a hardware dedicated production. Often the dedicated hardware is considered powerful but difficult to upgrade and not flexible. We have shown in CDF that the use of FPGA and ASIC is highly convenient if the design and the commissioning is pursuit with the correct methodology. The board standardization and FPGA flexibility allowed very quick system design since we could use always the same hardware (Pulsar), just developing new firmware. The commissioning of the upgrades took place while the experiment was taking data.

A very careful test procedure was devised to reduce to a negligible level the impact of the commissioning on detector operation and functionality. Each new board was deeply tested on real data, in a parasitic connection to the experiment, before being allowed to enter in the real data taking stream.

A phased installation was chosen: boards were replaced gradually, exploiting the short quiet time between beam dump and new injection. This phased procedure allowed for quick recovery if there were failures, since each small change was immediately checked before going ahead. The chosen procedure shows that the high degree of organization and standardization inside the CDF hardware systems allows to replace pieces quite easily, even if the function performed by the processors is very complex. They can have the flexibility and ease of use necessary to allow many successful migrations to different configurations in very short times and in a smooth way.

We will complete the hardware and software in the L2 and L3 CPUs to better exploit the upgrades, following these methods. Feedback obtained from the data analysis will be implemented in the online process almost in real time increasing the purity of the selected data.

b) At CDF, the discovery or exclusion of the Higgs boson, the very precise measurement of Top and W mass, and other fundamental measurements in EW and QCD physics rely on the capability to select signal events with high efficiency and to extract them from the huge background. The variable distributions we have at our disposal are convoluted with the detector response, causing the information on the original particle to be degraded. Up to now, the usual approach was to select only the best reconstructed objects and to apply selection techniques based on sequential cuts on the variable distributions. This approach is being surpassed by multivariate analysis techniques which can exploit the subtle correlations present between the variables. Neural networks are beginning to be widely used in HEP analysis, as well as support vector classifiers and nearest neighbour methods. But

new methods for combining classifiers have been developed in the last decade and are largely unexplored in HEP. Boosted and bagged decision trees are tools which have shown better performances with respect to neural networks and kernel-based methods in terms of robustness and speed. These new techniques will be applied to the search of the Higgs boson, where we need to exploit at the maximum level all the information carried by the variables of the event, as we have to face with really small ratios between signal and background events.
Moreover a lot of information can be gained increasing the acceptance on the searched signals. The extension of the lepton coverage in the forward region of the detector and the improvement in b-jets identification allowed by the completion of the CDF trigger upgrade, will increase the acceptance on Higgs boson produced in association with a vector boson.
(c) Very similar methodology to what used in CDF and described in (a) will be used to transfer the hardware processors to LHC for L1 and L2 applications. We plan to use the standard cell AM chip produced for CDF for a preliminary study of tracking at L1 and produce a faster and denser version of associative memory that could be used at L1 and L2 in future applications. We plan to use or develop general purpose FPGA-based boards, extending the Pulsar philosophy, to implement all necessary functions around the associative memory. L1 and L2 applications have different latency, rate and precision requirements, however we plan to develop hardware pieces that can be combined successfully in both environments, obtaining a large degree of standardization, that will be a key issue to face the hardware complexity.

Originality and Innovative nature of the project, and relationship to the 'state of the art' of research in the fields

The experience gained at CDF completing the upgrades and studying their impact on the Higgs analysis, will be transferred to LHC experiments, where the data acquisition rates will be much more demanding. The philosophy of performing almost offline selections at rates of the order of 20-40 kHz at LHC, or even more, is absolutely new, like the idea of using dedicated mixed-technology Supercomputers is innovative in a world where the use of dedicated hardware has been strongly reduced. In particular there is an enormous difference in the use of tracking detectors information at trigger level in the CDF and LHC experiments. While CDF has always intensively exploited tracking since the lowest level selections, at LHC the L1 tracking is totally missing and a late use of tracking is made even in the High Level Trigger (HLT) filters. Our proposal to transfer the CDF experience to LHC fits perfectly in this scenario.
The developed device will be general enough to be adapted to other research fields where efficient and fast real time reconstruction of data is needed. A very innovative use will be the proposed application for MEPHISTO (Meaningful Extraction of Patterns in High-speed Information SysTems Optimization), a project proposing a new approach to the problems of pattern recognition in generic information-processing systems.

Timeliness and relevance of the project

CDF and Tevatron are almost in their final stage, but still producing high quality data with very good performances. By the end of 2009 (2010) more than 6 (8) fb^{-1} of data will be available to be analyzed with innovative strategies such as multivariate analysis techniques. This project in particular will focus on the Higgs searches with H->b-bbar , exploiting the increase in acceptance provided by the 2007 upgrades and the last installed upgrades during the first year of the project. The improvements in lepton and p_T coverage will help H->WW and W/ZH analysis to increase their acceptance on Higgs signal and thus improve the limit on the cross section. Every small improvement which can reflect in a greater acceptance to Higgs events will be extremely useful.
Moreover, CDF, in this late running period, is the ideal place where new technology can be tested on

real data taking. When our project will enter its second phase (from CDF to LHC), LHC will be at the second year of data taking, likely moving towards its maximum instantaneous luminosity ($10^{34}cm^{-2}s^{-1}$). At that time, both experiments will be fully aware of the response of their trigger systems to real data taking and it will be possible to propose trigger upgrades in order to improve the online selections.
In the next decades, due to LHC, the main scenario for high energy physics will be Europe. This project will allow to transfer to Europe the experience gained in USA. Moreover, I will be able to perform in the best possible way the transition from CDF to LHC, contributing to a well defined and fundamental topic as the development of new tools for online event selection.

Host scientific expertise in the field (outgoing and return host)
Fermilab: as part of the DOE (Department of Energy - USA) strategic goals, Fermilab's mission is to advance the understanding of the fundamental nature of matter and energy. Fermilab's world-class scientific research facility allows qualified researchers from around the world to conduct fundamental research at the frontiers of high-energy physics and related disciplines. Fermilab produced its first high-energy particle beam on March 1, 1972. Since then hundreds of experiments have used Fermilab's accelerators. Fermilab is operated by Universities Research Association, a consortium of 90 research universities.
Here is a selected list of active experiments from three main reasearch areas: (1) collider experiments, (2) neutrino physics and (3) astrophysics:
(1) Beams of protons and antiprotons collide at nearly the speed of light in Fermilab's Tevatron accelerator. Two huge detectors, CDF and DZero, both consisting of many different detection subsystems, are located in the Tevatron beamline. The detectors observe the collisions taking place at their centers and record all information for later analysis. Physicist look for new phenomena, including supersymmetry, extra dimensions and a mass-carrying particle called the Higgs boson.
(2) Fermilab is also home to two experiments using neutrino beams, MiniBooNE and MINOS. Both experiments search for neutrino oscillations, the transformation of one type of neutrino into another. Results from several experiments, including SuperKamiokande and the Sudbury Neutrino Observatory, have indicated that neutrinos have a very tiny mass. Investigating neutrino oscillations will shed more light on the phenomena of neutrino mass and the neutrino mixing process.
(3) Fermilab is also recognized worldwide as a laboratory where advances in particle physics, astrophysics and cosmology converge. Fermilab's 50 theoretical and experimental astrophysicists are actively involved in several astrophysical projects: (a) The Sloan Digital Sky Survey's 2.5 meter monitoring telescope, when completed, will provide scientists with a three-dimensional picture of the sky through a volume one hundred times larger than that explored to date, measuring positions, absolute brightnessess of and distances to millions of celestial objects and galaxies. (b) Fermilab physicists search for dark matter directly through the Cryogenic Dark Matter Search, an experiments located deep underground in Minnesota's Soudan Mine. It looks for weakly-interacting massive particles, or WIMPS, by directly detecting their interactions with ordinary matter. (c) The Pierre Auger Observatory studies the universe's highest-energy particles using a collection of particle detectors spread over an area the size of Rhode Island. The goal is determining the origin of these ultra-high-energy cosmic rays, particles that hit the earth's atmosphere with energies up to 100 million times higher than the Tevatron produces.
Here are few of the most important achievements takenfrom a long list of Fermilab discoveries

1. Observation of B_S Oscillations (CDF, 2006)
2. Discovery of the top quark – (CDF/D0, 1995)
3. Discovery of the bottom quark and subsequent studies of its properties - E288 collaboration, led by Nobel laureate Leon Lederman.

The impact of our new understanding can have profound consequences for the way we will live. A direct example is offered by MRI (Magnetic Resonance Imaging) technology that relies on the development of superconducting magnets for the Tevatron. The R&D projects spur the development of new technology in many other areas, including cooling-systems design, vacuum technology, electrical engineering and precision surveying methods. New technical solutions benefit disciplines such as medicine, astronomy, materials science and computer science.

The supervisor from Fermilab, Tiehui Ted Liu, got his B.S. in physics in 1985 from Nankai University in Tianjin, China, and M.S. in Theoretical Particle Physics in 1988 from Nankai and Inst. of High Energy Physics (Beijing). He came to US in 1990 to pursue his Ph.D at Harvard University, and got Ph.D in experimental Particle Physics in 1995 working on the CLEO experiment at Cornell University. From 1995-1997, he worked at Princeton University (as Dicke Fellow) on Belle experiment at KEK (Japan). From 1997-2000, he worked at Berkeley Lab on Babar experiment at SLAC. He joined Fermilab since 2000, first as Wilson Fellow then became a permanent scientist in 2004, working on CDF experiment. At CDF, he has been deeply involved in all aspects of the so called Pulsar project, the project to upgrade the CDF Level 2 trigger system. He initiated this project in 2001 and have been leading the effort. During 2005-2006, he was also in charge of the CDF Trigger Dataset and Working Group (TDWG), and the main goal of the TDWG is to optimize the entire trigger/DAQ system to maximize the physics reach for a wide range of physics programs at CDF.

Padova : the Department of Physics of Padova University is deeply involved in different areas of physics research.

1) As far as HEP with accelerators is concerned, Padova has been involved in CDF experiment since its very beginning. It had a crucial role in the development of the Silicon Vertex Detector (SVX) and of its upgrades, which allowed very precise track measurements, opening the path towards to fundamental discoveries in B-physics and to the discovery of top quark. It also took part to the recent upgrade of the calorimetric trigger, which will be fundamental in the last period of Tevatron data taking. CDF Padova group made the first measurement of top mass and cross section in the all-hadronic channel. Then it actively participated to the measurement of the B_S mixing frequency and determined the b-jet energy scale in the Z->b-bbar channel for the first time at a proton-antiproton collider.

In the past Padova was also responsible of the electronics for the UA1 upgrading programs and now is involved in the LHC experiment CMS, both on the hardware and analysis side.

2) Padova is also involved in astroparticle experiments such as MAGIC and GLAST. The MAGIC Padova group is currently involved in the activities regarding the enhancement of the electronics performances of the actual first MAGIC telescope and in particular for the second MAGIC telescope (called MAGIC II), under construction. Analysis currently carried on regard active galactic nuclei studies, dark matter indirect observation, gamma ray bursts and horizontal showers. The GLAST Padova group is involved in the tests of the LAT (Large Area Telescope) tracker modules and readout electronics. Very rare events such as neutrino interactions and proton decays can be studied at ICARUS experiment, a liquid argon drift chamber located at the Gran Sasso Laboratories. Padova has been involved in this experiment since its first beginning, responsible of the electronics readout chain and of the data acquisition system.

3) Nuclear physics in Padova includes a variety of research interests, such as nuclear structure at the limits of spin and isospin with gamma-ray methods, nuclear reaction mechanism with stable and radioactive nuclei, reaction dynamics at low, intermediate and ultra-relativistic energies, nuclear astrophysics and civil security applications of nuclear physics. Most of the current research is carried out by performing experiments at major international facilities, such as Legnaro Laboratories (Italy), CERN (Switzerland), GSI (Germany), GANIL (France). Major projects with which the Padova group

is involved is the Advanced Gamma-ray Tracking Array AGATA and the ALICE experiment at LHC. In addition, the group is heavily involved in some of the main Legnaro projects such as CLARA, EXOTIC, GASP and PRISMA and also leads programs of nuclear reactions at extreme low energy for stellar nucleosynthesis at the Gran Sasso Laboratory (LUNA).
The fellow supervisor at Padova, Donatella Lucchesi, graduated in Physics in Pisa in 1990 and has been part of CDF collaboration since 1992. As a member of the Pisa group she participated to the commissioning of the muon detector and to the measurement of the B_0 meson oscillating frequency. Then, in Padova, she collaborated to the silicon detector upgrade in 1998 and in parallel worked on the improvement of the hadronic trigger for B mesons. Since early 1999 to late 2003 she has been part of a LEP working group as responsible for world average of the difference between the Bs mesons lifetime performed by ALEPH, DELPHI, L3 and CDF experiments. From March 2005 she is the coordinator of the CDF Italian computing group, coordinating the work for the GRID transition. Since September 2006 she is the coordinator of the CDF Padova group and since May 1, 2007 she is co-head of computing of the CDF collaboration. Moreover she is one of the reviewers of the Italian CMS Collaboration since January 2008.

Quality of the group/supervisors (outgoing and return host)
The **Fermilab** CDF group has had many postdoctoral fellows working in the group since 1993 and many of them have found tenured or tenure track positions with a university or particle physics laboratory in USA, Europe or Asia. In particular, over the past few years, there have been many young people (students and postdocs) who have worked directly with Dr. Liu on CDF trigger upgrade projects, and they have been very successful. To give a few example, (1) Vadim Rusu (worked on Level 2 trigger upgrade as postdoc from U. of Chicago and then becomes Wilson Fellow at Fermilab), (2) Cheng-Ju Lin (worked on Level 2 trigger upgrade as postdoc at Fermilab then becomes research staff at Berkeley Lab), (3) Burkard Reisert (worked on Level 2 trigger upgrade as postdoc at Fermilab then becomes research staff at Max-Planck Inst. for Physics), (4) Chris Neu (worked on Level 2 trigger upgrade as postdoc from U. of Penn and then becomes assistant Professor at Univ. of Virginia, (5) Peter Wittich (worked on CDF trigger commissioning as well as Pulsar project in the early days as postdoc from U. of Penn and then becomes assistant Professor at Cornell University).
In **Padova** many physicists started they career working on high energy physics and then found interesting positions in european-USA institutions. Here are some examples: (1) N.Bacchetta, now researcher at the INFN in Padova. He was responsible for the SVX upgrade project at CDF and is now currently at CERN, member of the CMS Infrastructure Task Force. (2) T.Dorigo, graduated in Physics 1995 working on the top quark in the all-hadronic decay channel at CDF and then did his Ph.D. research on the search for Z boson decays to b quark pairs. As a post-doc in Harvard he built a part of the CDFII muon detector. He has been leader of the "Jet Corrections Working Group". He is now researcher at the INFN (Istituto Nazionale di Fisica Nucleare) and works on CMS experiment. (3) D.Lucchesi, as outlined in the previous section, is now researcher at the University of Padova. She participated to the Bs mixing analysis and is now leader of the CDF Padova group and co-head of the CDF computing group. (4) R.Rossin, graduated in 1998, working on the "Study of prototypes of silicon micro-strip sensors for the microvertex detector at CDF II experiment". After his Ph.D. ("Study of the process BS->J/psi eta at CDF") he got a post-doctoral fellowship at the University of Florida and now he is a post-doc at the University of California, working on CMS experiment. (5) L.Scodellaro, physcists, got his Ph.D working on "Perspectives for Higgs boson search in full hadronic final states at CDFII". Now he is a post-doc at IFCA (Instituto de Fisica de Cantabria) and is working on both CDF and CMS experiments.

B2. TRAINING

Clarity and quality of the research training objectives for the researcher

I expect to realize a list of important goals in my training at Fermilab. As far as the development of the tracking processors is concerned I will learn:

- the details of the functioning of the trigger system of a complex detector as CDF, how to accomodate the maximization of the physics reach (selection of interesting events) with the strict timing requirements imposed by the collision rate and the high luminosity scenario;
- how to perform the online test of the new tracking processor, how to develop an online monitor necessary to check the system behaviour during the test and during the official data taking;
- use of programmable logic at a very advanced level. The use of Pulsar boards requires high level firmware development (VHDL and Verilog description language), simulation capabilities, timing and implementation optimization, test capabilities.
- capability to evaluate cost versus performance of different technologies: VLSI devices, programmable logic, commercial CPUs.
- capability to improve flexibility and ease of use for the trigger devices, to allow application to different experiments with minimum tailoring and minimum effort.

On the analysis side, I expect to learn:

- the most innovative multivariate analsysis techniques, such boost decision trees, applied to the search of very rare events.
- capability to transfer these techniques to problems outside HEP.

In Padova I expect to

- deeply understand LHC trigger systems and acquire capability to make an efficient propose for an online tracking system, in terms of maximization of the physics reach and minimization of cost and time.
- adapt the experience gained on "supercomputers" developed for HEP to pattern recognition problems outside HEP, such as medical imaging.

Relevance and quality of additional scientific training as well as of complementary skills offered

Many complimentary fields are accessible working at Fermilab. It is very easy to get in contact with new research fields and to enlarge personal interests. In fact, high-energy physicists rely on four essential scientific tools all of them strongly represented in Fermilab: (1) powerful accelerators to create high-energy particle collisions, (2) superconducting magnets with advanced materials and design to guide particle beams, (3) sophisticated particle detectors with super fast readout technology to observe and record particle collisions, and (4) innovative computing solutions to store, access and analyze huge quantities of data. Fermilab is recognized for experience in pioneering success in parallel computing and willingness to try technically risky new directions. Fermilab collaborates closely with scientists from industry and universities around the world to advance all of these fields.
Fermilab offers seminars and possible interactions on a wide range of topics in high energy physics and technological aspects related to the experiments and accelerators. The fellow work will have the opportunity to be presented to a large and international scientific community. Independence and management capabilities are strongly encouraged and rewarded.
Padova too offers lots of possibilities: at the department of Physics many experiments covering various areas of physics research are present. High energy physics is very well represented by CDF, CMS and BABAR groups, sharing experiences and structures. Neutrino and astroparticle physics (AURIGA,GLAST,MAGIC, ICARUS) as well as nuclear (ALICE), applied and theoretical physics are present in Padova. A very skilled Electronic Group is also present, which strictly collaborates with physicists to realize the various electronic devices needed by the experiments. Training is offered

for computing, electronics and other skills, seminars are offered and required.

Host expertise in training experienced research in the field and capacity to provide mentoring/tutoring (outgoing and return host)
In Fermilab the work is organized by groups each concentrating on a specific subject (analysis or hardware). Each group has two conveners, who stay in charge for 2 years. Their responsability is to supervise the analysis/projects, ensuring to use common tools in order to minimize the effort and maximize the speed and the results. Every one or two weeks the group members meet to review the progress of the work, to make suggestions and/or corrections.
At Fermilab I will work in collaboration with the CDF Trigger group. The work planned and done will be daily discussed and planned with the supervisors and weekly presented by me and discussed in the trigger meetings, with the whole trigger group. On the analysis side, I will work in collaboration with the Higgs Discovery Group, which coordinates all the analysis devoted to Higgs boson searches. The group meets weekly to discuss the various analysis and to best address the efforts of the different groups.
In Padova, where I will become part of the groups involved in LHC experiments, the style is equivalent. My work will be discussed inside the group and regularly presented also in seminars outside the group.

B3. RESEARCHER

Research experience

Curriculum vitae

Education

Padova University (Italy), Department of Physics (1996-2002)

- March 2002 – Graduated in Physics (110/110 cum laude). Title of the thesis: *The detector Icarus T600. Analysis of the first data collected in Pavia.*
- The thesis focused on the calibration of the electronic readout chain of the detector Icarus T600, a liquid argon drift chamber designed to detect rare events such as neutrino interactions. The calibration factor obtained was then applied to a physics case, the measurement of the electron lifetime and the electron recombination factor in liquid argon.
- March-December 2002: contract with the Department of Physics to perform further studies on the readout chain response.

Trento University (Italy), Department of Physics (January 2003-January 2007)

- PhD in Physics. Title of the thesis: *Study of ttbar production in tau+jets channel at CDFII using neural networks*
- The thesis focused on the measurement of the cross section of the production of top-antitop pairs in a channel with a tau lepton and jets of particles in the final states. To achieve the best separation between signal and background a neural network approach was used.
- Teaching assistant, March 2004 – June 2004, C++ programming course (bachelor's degree)
- Post-PhD position at Trento University, Department of Physics (January 2006-January 2007). Optimization of top-antitop production cross section measurement in the tau+jets channel at CDF II

Padova University, Department of Physics (February 2007-present)

- Development of a trigger optimized for Higgs searches at CDFII
- Collaboration to the development of the new processor GigaFitter
- Teaching assistant, October 2007-January 2008, Physics course (Electromagnetism) (bachelor's degree)

Schools

- 55^{th} SUSSP Summer School on LHC Phenomenology, St.Andrews (Scotland), 17-29 August 2003
- CERN European School of High Energy Physics, Sant Feliu de Guixsol (Spain) 30^{th} May-12^{th} June 2004

Student supervision

- Supervisor of the master's degree thesis "Study and development of algorithms optimized to select H->b-bbar channel at CDFII" (March-October 2007)

Research results including patents, publications, teaching etc., taking into account the level of experience

My master degree thesis is about the calibration of the electronic readout chain of Icarus detector. Icarus is a multiwire proportional drift chamber designed to detect very rare events, such has neutrino interactions. It consists of two modules, each containing 300 tons of liquid argon. The modules were assembled and tested in Pavia (Italy). During my thesis internship I installed the readout electronics and tested it. The readout chamber consists of three parallel planes of wires with different orientations. Information is read both by electric charge on the first two readout planes encountered by drifting electrons and by electric charge collection on the last readout plane. The signals from the three planes, together with the measurement of the drift time, provide a full 3-D image reconstruction of the event. To calibrate the readout chain I applied test pulses to simulate signals ranging from

single minimum ionizin particle (~ 2 fC) to several tens of mip's (~ 90 fC). This allowed to extract the calibration factor and linearity as well as the wire to wire gain uniformity. The test pulse shape was a step function, simulating tracks running in parallel to the wire chambers. The calibration factor was then applied to the measurement of the electron lifetime and of the electron recombination factor in liquid argon. My thesis work is documented in the following notes internal to the Icarus collaboration: 1) *Considerations on the ICARUS read-out and on data compression*, ICARUS-TM/2002-05, 2) *A measurement of the electron lifetime and the electron recombination factor,* ICARUS-TM/2002-04. The complete test of the Icarus detector, included my thesis work, resulted in the following paper: *Design, construction and tests of the ICARUS T600 detector*, Nucl.Instr.Meth. A 527,329 (2004). The results of my thesis were presented at the Icarus collaboration at CERN and Padova.
During my PhD studies I could familiarize with the challenging problem of the selection and reconstruction of rare signal events, testing different techiques on real data collected at CDF.
The first task I worked on was the separation between signal (quark top events) and backgroud events by means of a Support Vector Classifier. The work is documented in the following paper: *Model Selection in Top Quark Tagging with a Support Vector Classifier*, Proceedings of the IEEE international conference on Neural Networks, Budapest, 2004.
Another technique I explored is the Nearest Neighbor Method, a classification method based on the simple rule of assigning to a sample of unknown class the same class label of its nearest neighbor according to a specific metric. The method was applied to correct the energy of the jets of particles originating from the hadronization of the b-quarks from the Higgs decay. The work is documented in the following CDF internal notes 1) *Narrowing the Higgs mass peak: the Hyperball algorithm*, CDF note 6450, 2) *Hyperballs user guide*, CDF note 6910, and was presented to the Jet Energy and Resolution Workshop held at Fermilab in October 2005. This work allowed me to gain experience on the object oriented programming techniques, in particular C++ language.
The main subject of my PhD thesis (and of my first year of PostDoc in Trento) was the top pair production cross section measurement in the channel whith a tau lepton and jets in the final state. I applied a neural network technique to try to separate top events from the background. I developed a technique based on two neural networks applied in cascade, the first trained with variables describing global features of the event, the second with variables describing specific properties of the tau lepton decaying hadronically into neutral and charged pions. The result was a good separation between signal and background (the ratio of signal events over background ones increased from 1/6000 to 1/3), a good efficiency on signal events and a cross section measurement in agreement with the theoretical value. Besides the PhD thesis, this work is also documented on the following documents: 1) *Top -> tau+jets event selection using neural networks*, CDF note 7745, 2) *t-tbar -> tau + jets selection using two neural networks in cascade*, CDF note 8443, and was presented at the VII RTN Workshop held in Prague (8-10 February 2006) and at the CDF Collaboration Meeting held in La Biodola (Elba Island, 2-10June 2006). For my studies on tau leptons, the Collaboration assigned me a talk to present the techniques currently used at Tevatron to online select tau leptons at the Charged Higgs Workhop (Prospects for Charged Higgs Discovery at Colliders) held in Uppsala (13-16 September 2006).
During the following two years in Padova I worked on the development of new trigger strategies aimed at increasing the acceptance for the Higgs boson, exploiting the recent upgrades undergone by the CDF trigger system in order to sustain high trigger rates due to Tevatron increasing luminosity. The upgrades, regarding the eXtreme Fast Tracker and the Level 2 jet clustering algorithm have provided new tools that can be used in the design of innovative triggers. I became part of the Higgs Trigger Task Force, established by CDF collaboration to evaluate and implement a trigger program that maximizes the experiment acceptance on the Higgs boson. Several trigger paths were developed

in this framework. Those I worked on are the DIJET_BTAG and the MET_DIJET triggers. The first combines calorimetric and tracking information to perform an online search of final state events containing two jets most likely produced by b quark hadronization. The selection of such events is of primary importance in the search for a light Standard Model (SM) Higgs boson (M_H < 135 GeV) decaying into a pair of b quarks, which is the dominant decay mode for a Higgs in the low mass range. Optimized for the search of a SM light Higgs boson, this trigger is also very efficient for Higgs searches in models beyond the SM, such as the Minimal Supersymmetric Standard Model extension. Fully efficient up to the highest instantaneous luminosity reached at Tevatron (3 10^{32} cm^{-2} s^{-1}), the DIJET_BTAG trigger allows a 40% increase in acceptance on a Higgs decaying into a pair of b quarks.
The MET_DIJET is a completely calorimetric trigger developed for the search of a SM Higgs produced in association with a W boson. The selection is based on the detection of two jets coming from the Higgs decay and the large missing transverse energy coming from the leptonic decay of the W. The MET_DIJET trigger has high efficiency (greater than 60%) for all the leptonic decay modes of the W boson and complements extremely well the high-pT lepton triggers thus significantly enhancing the SM Higgs reach at CDF.
The design of these trigger algorithms demands the best compromise between efficiency on signal events and background rejection, in order to mantain a cross section compatible with CDF trigger bandwidth. Moreover, it has been necessary to carefully study a signal selection able to meet the strict timing requirements of the CDF trigger system, especially at Level 2.
The work was presented in several meetings of the HTTF and is documented in the following CDF internal notes: 1) *Proposal for a b-jet tagging trigger*, CDF note 8826, 2) *Performances of the b-jet tagging trigger*, CDF note 9211, 3) *Study of a MET_JET trigger for WH to l-nu-b-bbar*, CDF note 8826 and in the following papers: 1) *Online b-jets tagging at CDF,* FERMILAB-CONF-07-109-E, 2) *Performances of a trigger based on b-jets tagging at CDFII*, 3) *A high quality trigger selection for the HW discovery channel at CDF*, both in the Proceedings of 2007 Nuclear Science Symposium and Medical Imaging Conference (Honolulu, Hawaii).
I presented the latest results of Standard Model Higgs searches at CDF in the talk "*Standard Model Higgs searches at CDF and D0*" at the *Incontri di Fisica alle Alte Energie* (Naples, 11-13 April 2007).
During the last year I also started to collaborate with Pisa University to the development of a next generation track fitter, the GigaFitter. The work is documented in the following paper: *The GigaFitter for Fast Track Fitting Based on FPGA DSP Arrays,* in Proceedings of 2007 Nuclear Science Symposium and Medical Imaging Conference (Honolulu, Hawaii).
As far as the analysis is concerned, currently I'm working on the limit on SM Higgs production in the inclusive channel H->b-bbar. The first studies on sample composition and signal-background separation were the subject of a master's degree thesis I supervised ("Development and study of algorithms optimized to select H -> b-bbar channel at CDFII").
During the period October 2007- January 2008 I've been teaching assistant at the bachelor's degree course "Electromagnetism".
In May 2008 I've been invited to present the latest CDF results at the "Società Italiana di Fisica (SIF, Italian Physics Society)" congress which will be held in Genova (22-26 September 2008).
Finally my submission "*Triggering on B-Jets at CDFII*" has been accepted for oral presentation in the 2008 Nuclear Science Symposium which will take place in Dresden (19-25 October 2008).

Since December 2003 I'm part of the CDF Run II author list. Among the 146 publications up to August 2008, I recall:

- *First Run II Measurement of the W Boson Mass.*

By CDF Collaboration (T. Aaltonen *et al.*). Aug 2007. 54pp.
Published in Phys.Rev.D77:112001,2008.
e-Print: arXiv:0708.3642 [hep-ex]

- *First observation of heavy baryons Sigma(b) and Sigma(b)*.*
  By CDF Collaboration (T. Aaltonen *et al.*). FERMILAB-PUB-07-318-E, Jun 2007. 8pp.
  Published in Phys.Rev.Lett.99:202001,2007.
  e-Print: arXiv:0706.3868 [hep-ex]
- *Precise measurement of the top quark mass in the lepton+jets topology at CDF II.*
  By CDF Collaboration (A. Abulencia *et al.*). FERMILAB-PUB-07-070-E, Mar 2007. 7pp.
  Published in Phys.Rev.Lett.99:182002,2007.
  e-Print: hep-ex/0703045
- *Observation of B0(s) - anti-B0(s) Oscillations.*
  By CDF Collaboration (A. Abulencia *et al.*). FERMILAB-PUB-06-344-E, Sep 2006. 9pp.
  Published in Phys.Rev.Lett.97:242003,2006.
  e-Print: hep-ex/0609040

Independent thinking and leadership qualities

During my university thesis I participated to the assembly of the readout chain and to its test. In particular, I was charged with the calibration of the electronic chain, in order to obtain the conversion factor between the observed hit area (in terms of ADC counts) and the deposited charge (in fC). This was a crucial task, necessary to convert thecollected signals into meaningful physical measurements. I applied the obtained results to two physics measurement: I measured the electron lifetime and electron recombination factor in liquid argon, obtaining results in good agreement with theoretical values.

I also proposed to the collaboration some possible upgrades of the Icarus DAQ systems, concerning the modification of the response function of the preamplifiers mounted on one of the readout boards and the increase of the gain of the front-end readout to reduce the contribution of digitalization to electronic noise.

The PhD allowed me to explore different sample classification techniques and to choose the best accordingly to the specific subject under study, the selection of events where a pair of top quarks decays into jets of particles and a tau lepton. The problem of discrimination of signal from background was successfully solved through a technique based on two neural networks applied in cascade, instead of the more common techniques based on single neural networks. Instead of training a single net with all the most discriminating variables, I trained two different networks, each aimed at identifying a specific feature of the signal: the first a top multi-jet like event, the second a tau lepton. This approach turned out to be much more effective compared to the traditional selection techniques and resulted in an increase of the signal to background ratio from 1/6000 to 1/3.

Then, as a post-doc in Padova and a member of the Higgs Trigger Task Force group, I had the responsability of the design and the implementation of two triggers exploiting the new features offered by the upgrade of the CDF trigger system. I was responsible of the project and of the commissioning of the triggers, performing tests and optimizations up to the complete reach of the design requirements. The triggers were presented to the collaboration, successfully approved and became official since Autumn 2007. They perfectly meet the design requirements, running up to the highest Tevatron luminosity without the need to be scaled and allowing a significative gain in Higgs boson acceptance with respect to previous algorithms.

In the meantime, I also supervised a master's degree thesis on the perspectives for inclusive H->b-bbar searches.

Match between the fellow's profile and project
This project is suited to a person having both electronics and physics backgrounds. As far as electronics is concerned, during my university thesis internship I had the possibility to learn in detail the functioning of the readout chain of the Icarus detector gaining experience in both analog and digital electronics.
During my PhD I could learn some of the most advanced methods currently used for classification problems, such as Support Vector Machine, Neural Networks and Nearest Neighbor Method and how to apply them to High Energy Physics signal selection. I faced with the problem of the extraction of rare signals from the background, exploiting all subtle correlations between the variables decribing the signal event. I also learned how to proper model the background and how to treat the systematic errors.
Finally, the work in Padova allowed me to learn the functioning of CDF trigger system, to face with the problems raised by the increase in instantaneous luminosity (higher occupancy of the detector resulting in higher trigger rates and thus greater deadtime and inefficiency) and to develop proper solutions. In particular the development of new trigger strategies required the capacity to find the best compromise between efficiency on the signal and background rejection, in order to increase the physics reach in a specific search channel (Standard Model Higgs searches in my case).
All the experience gained both in electronics and high energy physics analysis will be fundamental for this project. The GigaFitter installation and test requires good knowledge of CDF trigger and data acquisition systems and capacity to estimate on a physics case the impact of the new processor. These skills will be important in the following part of the project, devoted to the development of an online tracker for LHC experiments and to the application of highly parallel processors to other pattern recognition problems.

Potential for reaching a position of professional maturity
Up to now my activity has been limited to Italy, with just brief periods spent at Fermilab. This fellowship would allow me to carry on in Fermilab a complete project under my own responsability. Moreover, on the analysis side, I will actively collaborate with the analysis and the trigger groups present in Fermilab and thus have the possibility to hold a convenor position. This will greatly deepen my knowledge on both electronics and analysis techniques, as well as help me to develop the necessary leadership capabilities to coordinate a research group. The Fermilab laboratory and the CDF experiment would be a wonderful environment to move my career ahead and to give an international dimension to my knowledge as the CDF collaboration consists of 58 institutions from around the world and it counts experts in many fields of High Energy Physics.
The transfer of my knowledge to LHC and outside High Energy Physics experiments will further enhance my professional maturity, as it will require the capability to adapt the developed tools (online tracking processor, innovative event selection techniques) to a different and much demanding experimenal environment.

Potential to acquire new knowledge
As far as online data selection is concerned, I know how to design and implement a trigger, but I need to deepen my knowledge on the trigger system itself, in particular on the hardware side. The participation to the completion of GigaFitter project will allow me to learn he functioning of the electronics of the trigger system, to face the problem of the test of a new device on real data. I will learn how to develop a diagnostic tool to monitor the performances of such device. The acquired experience on monitoring and maintaining the system will be of great importance for more complex future applications. Staying permanently at Fermilab will allow me to follow the installation and the test from the very beginning and learn how to project a similar device for other experiments. I can

learn the use of programmable logic and the use of Level 2 processors to be able to compare the potentialities of different technologies. On this side my final goal is to learn as much as possible about problems of the CDF online tracking system so I can leverage future technological developments in microelectronics to suitable solutions for high energy physics. In this sense, I should understand how to improve flexibility and ease of use for the trigger system as a whole, to allow migration to different experiments with tailoring efforts. For example, the development of an online tracker for LHC will indeed allow me to put this into practice. We should exercise automation of technological follow-up of digital electronics developments, producing clean project descriptions using high level languages and automatic compilation into the most advanced devices at time of construction. This approach has already been adopted during the SVT upgrade to exploit to the best and for a long interval of time the initial designing efforts, simplifying further developments and applications to future generation experiments.

On the analysis side, neural networks are analysis tools currently wide used in High Energy Physics. My objective is to make experience on other innovative and more effective tools and to apply them to High Energy Physics problems.

B4. IMPLEMENTATION

Quality of infrastructure/facilities and international collaboration of host (outgoing and return host)

Fermilab

Level of experience of the outgoing host institution on the research topic proposed

The CDF (Collider Detector experiment at Fermilab) is an international collaboration of about 800 Physicists from about 30 American universities and National laboratories, plus about 30 groups from universities and national laboratories from Italy, Japan, UK, Canada, Germany, Spain, Russia, Finland, France, Taiwan, Korea, Switzerland, etc. Many important discoveries and measurements have been performed at Fermilab, such as the the discovery of the upsilon particle (1977) and the top quark (1995), the most precise measurements of top and W mass, the more recent discovery of the Sigma_b barion and the observation of the Bs oscillations. At Fermilab CDF physicists are organized into groups each concentrating on a specific subject (top and bottom quark physics, electroweak physics, QCD, exotic and higgs physics). Members of these groups share tools and experience on the most advanced analysis techniques. A Statistics Committee has been organized to address statistical issues of all the analysis.

Moreover at Fermilab there are two large electrical engineering groups having extensive experience in electronics design from printed circuit boards to firmware for programmable devices (PLDs, FPGAs, DSPs) and design of full custom ASICs. Engineers in these groups have great experience on projects with CDF, other high particle physics experiments, astrophysics experiments and accelerator control and monitoring systems. This experience includes design of printed circuits and firmware for the XFT and the XFT upgrade and Pulsar firmware for the SVT upgrade. These groups can provide support of the fellows work at Fermilab ranging from technical support for modifications to printed circuit boards to providing tools for simulation and compilation of firmware for programmable devices.

Available facilities

The high level facilities available to the researcher will be the CDF experiment itself. CDF is a 100-ton CDF detector (about 40' high by 40' x 40' base) at the Fermilab Tevatron collider built with the goal of measuring exceptional events out of the billions of collisions between protons (p) and antiprotons (p-bar). CDF is a complex detector, which measures most of the interesting particles that come out of the p-bar p collision. Several collisions occur every time p-bar and p bunches collide. Out of the millions of collisions per second, only a few are "hard" collisions, between constituents of the proton and antiproton and are interesting. I will work to optimize the event selection strategy (experiment trigger) and my work will be strongly related to the detector used to observe the events. Here follows a short description of the whole facility. CDF measures the particles produced in the event using several detector sub-systems. Starting from the beam collision point CDF consists of (1) a Silicon Vertex Tracker (SVX) which measures the position of charged particles with an accuracy of about few tens of microns on six layers providing an accurate determination of the track impact parameters, (2) a Central Outer Tracker (COT) which measures the position of a charged track in a large gas volume, and, based on the track curvature due to the magnetic field B=1.5 Tesla, also the momentum of the track, (3) the electromagnetic and hadronic calorimeters, consisting of lead or iron sheets sandwiched with scintillator to measure the energy of electrons, photons or hadrons, (5) an iron absorber, placed behind the calorimetry and used to absorb all hadronic showers, (6) muon chambers to measure the position of charged particles escaping the calorimeter. A fundamental part of the detector is the (7) trigger system which allows to record about 100 events per second out of the millions of collisions. All frontend electronics is fully pipelined, with onboard buffering for many beam crossings. Data from the calorimeters, the central tracking chamber, and the muon detectors are sent to the Level1 trigger system, which makes a decision based on them to hold the data for the Level2 trigger hardware. The Level1 trigger is a synchronous system with a decision reaching each front-end card at the end of the pipeline. Upon a Level1 trigger accept, the data on each front-end card are transferred to one of four local Level2 buffers. The second trigger level is an asynchronous system with an average decision time of 20 µs. A Level2 trigger accept flags an event for read out. Data are collected in DAQ buffers and then transferred via a network switch to a Level3 CPU node, where the complete event is assembled, analysed, and, if accepted, written out to tape. These events can also be viewed by online monitoring programs running on other workstations. Tracking processors at LVL1 (XFT) and LVL2 (SVT) are a relevant part of the trigger.

Capacity to provide training in complementary skills

As already outlined, at Fermilab many research areas are present. As far as CDF is concerned, I will strictly collaborate with the Trigger group and the Higgs Discovery Group, but other groups are present, involved in different areas of particle physics such as QuantumChromoDynamics, Electroweak, Exotic and Top physics. They all regularly organize meetings and collaborate to share tools and experiences.

The Fermilab Technical Division develops, designs, fabricates and tests accelerator and detector components. In the past it designed, built and tested over 400 magnets for Fermilab's new Main Injector and in more recent years it developed, built and tested the superconducting high-gradient quadrupoles for the LHC. It also leads the R&D for superconducting magnets for a possible very large hadron collider.

The Fermilab Computing Division develops and supports innovative and cutting edge computing solutions and services for Fermilab. It can offer experience and training in advanced networking, data handling, and grid computing.

Moreover, at Fermilab, a neutron therapy facility is present since 1976. Ongoing technical research includes improving techniques for treating advanced brain tumors, while clinical studies include the use of microcurrent therapy to minimize the side effects of radiation therapy.

Padova

Level of experience of the return host institution

INFN in Padova counts physicists involved in many research areas, both experimental and theoretical. Groups are present in particle physics with accelerators (CDF, CMS, BABAR), astroparticle and neutrino physics (AURIGA, GLAST, MAGIC, ICARUS) and nuclear physics (ALICE, AGATA, CLARA, EXOTIC, GASP and PRISMA). Several topics of research are carried on by theoretical physicists on particle and astroparticle phenomenology, nuclear physics, general relativity and gravitation and string theory. The exchange between experimental and theoretical groups is continuous and very prolific.

INFN Padova is located inside the Department of Physics of the University of Padova. The collaboration with other University Departments offers the possibility of high level intradisciplinary researches. In particular, the Department of Physics strictly collaborates with the Department of Electronics and Informatics Engineering. Collaboration with the Medicine Department is devoted to the development of instruments for medical applications, such as X and Gamma Ray high efficiency detectors.

Due to the contact with the University, teaching experience is possible and welcome, as well as student supervision.

Available facilities

Inside the Department an electronics laboratory is present, working in strict contact with experimental physicists to design, produce and test the electronic devices needed by the different experiments. A Silicon Detector Laboratory is also present, provided of a clean room fully equipped for silicon electronic devices assembly andtest.

Another high-level facility available to the researcher is the "Laboratori Nazionali di Legnaro", located near Padova, which propose, coordinate and conduct experimental and theoretical research

work in the field of fundamental nuclear physics, as well as in other sectors regarding the study of interactions between matter and radiation or particle beams. At present, there are four accelerating machines of differing potentialities in operation at the Laboratories. Among them, there is a linear heavy-ion superconductor resonant cavity accelerator that has been entirely designed, built and tested by the Laboratories' own staff.
INFN in Padova also counts a computing group, involved in the INFN Grid Project, to develop and deploy the Grid middleware services.

<u>Capabilities to absorb and make use of the experience gained by the returning fellow</u>
The experience I will gain in the third country can be fully exploited in Padova, where different groups involved in LHC experiments are present, working on both the analysis and the detector operations. LHC experiments lack of an online tracking processor able to provide tracking information in time for a Level 2 trigger decision. My experience on online tracking processors will thus be very useful for LHC: the physics potential of the experiments will be increased by the possibility to make trigger selections based on tracks. My knowledge can also be applied to interdisciplinary applications, such as devices suited to medical applications, in collaboration with the Padova and Pisa researchers involved in such activities.

Practical arrangements for the implementation and management of the project (outgoing and return host)

Fermilab - My work at Fermilab will be done directly on the CDF experiment where all the necessary facilities and arrangements are available. The hardware is installed in the trigger room that is also provided of oscilloscopes and many computers and terminals for access, control, monitoring.
A laptop is available with CADs to download directly through Boundary Scan any kind of necessary new firmware. Very near the trigger room two very useful laboratories are available. The laboratories are provided of digital analyzers and many racks providing resources for independent test stands. One test stand is private for SVT, others are allocated to the development of XFT, Level 2 (Pulsar) and various front-end systems. In the control room, placed immediately after the trigger room, the shift team, helped by others experts, has the responsibility of the data taking. It is very easy for people working on trigger issues to interact with the shift crew to obtain the capability to perform their tests and their work. The tests are planned weekly at the trigger meetings. Data collected in CDF are processed by a large computing facility located near the experiment building. It is easy to ask for specific high priority processings, to evaluate early the effect of a particular action. The data analysis is performed by physicists of the collaboration that work in the trailers located all around the experiment building or at their home institution. Analysis meeting on all items under process are weekly available at Fermilab. Again it is very easy, staying in Fermilab, to interact with any kind of ongoing analysis. The collection of so many facilities inside and all around the experiment building will make achievable and easy the implementation and management of the fellowship. The project will be the result of my interaction with many physicists, engineers and technicians belonging to CDF.
Padova – In Padova I will work in strict contact with physicists involved LHC experiments. A group working on CMS experiment is already present, working on the construction of the muon and of the tracking detectors. On the analysis side, the CMS group is working on the development of strategies for Higgs searches in H->WW and ttH channels.
On the hardware side, the Electronics Laboratory can provide all the necessary experience and tools to design and implement electronics circuits. The design of electronic circuits and the print on boards is made through Mentor Graphics software. The laboratory is equipped with all proper devices for Surface Mount Technology (Pick and Place machine and reflow soldering oven).
I will take advantage of all the facilities and the experience of the electronics laboratory to complete the development of an online track-finder for LHC experiments.

Feasibility and credibility of the project, including work plan

Work plan in Fermilab

The idea is to build and test at CDF a fast tracking processor suitable to very high luminosity scenarios, and then adapt it to the LHC environment. The processor (called GigaFitter) has already been designed and implemented on a preliminary board . The next step, part of this projects, is the test of the GigaFitter on real data at CDF and the study of its impact on the physics reach of the experiment . The GigaFitter is a next generation track fitter able to perform more than a fit per nanosecond. It has been designed to be used inside SVT at CDF, in order to enhance its capabilities during the high luminosity final data taking. Based on modern FPGA technology and rich of powerful DSP arrays, this device can reduce the track parameter reconstruction to few clock cycles and perform many fits in parallel. The objective is to provide CDF with a new track fitter with a greater computation power which will allow important improvements such as a wider lepton coverage and the extension of the SVT acceptance in both track transverse momentum p_T and impact parameter. Such a device has an architecture general enough to be adapted to other experiments, for example ATLAS/CMS at LHC, where real time tracking is much more difficult compared to CDF due to the higher bunch crossing rate (40 Mhz instead of 1.7 Mhz).

The working plan at Fermilab will consist of the following items:

- Development of the simulation of the GigaFitter track processor.
- Development of an online program to monitor the response of the GigaFitter. The program, once the hardware will be installed, will compare the response on real data to the simulation.
- Test of the GigaFitter on a subset of the SVT wedges (the SVT processor is subdivided into 12 independent engines each one working on a fraction of detector, called wedge). The GigaFitter will be installed in parasitic mode in order to be tested on real data without interfering with CDF data acquisition. Thanks to the parasitic acquisition, it will be possible to measure directly on data the improvements on SVT performances.
- Commissioning of the GigaFitter: check of the performances on real data, study of new trigger strategies based on the new capabilities offered by the greater acceptance in p_T and impact parameter. The final system will consist of a single GigaFitter board receiving the 12 wedge outputs . In this case the SVT system will be extremely more compact, since the actual twelve Track Fitter boards, followed by four final Merger boards necessary to build a single output for the CPU will be squeezed in a single Pulsar Board.
- Development of innovative analysis tools for H->b-bbar searches the low mass region. I will concentrate on the b-jet final state samples collected by the trigger I developed during my postDoc in Padova (Dijet_btag trigger).
- Participation to the design of an online tracking processor for CMS in collaboration with Fermilab physicists and engineers already involved in LHC experiments (at Fermilab a CMS group is present while the University of Chicago is already involved in the FastTrack project to develop an online track processor for ATLAS). I will adapt the SVT-GigaFitter architecture and technology to CMS experiment. Discrimination of the signal from the background relies in large part on track information, thus having the reconstructed tracks at the beginning of the Level 2 processing would allow most of the background events to be quickly rejected, increasing the physics reach potential of the experiment.

Work plan in Padova

In Padova the working plan will consist of the following items:

- Completion of the online tracking processor design for CMS.
- Implementation and first tests in collaboration with the CMS group in Padova, which is already involved in the silicon detector upgrade. In case the CMS silicon detector upgrade is

not approved yet, collaboration with Pisa group involved in the development of an online tracking processor forATLAS experiment (FastTrack).

- Transfer to CMS of the analysis techniques developed at CDF for Higgs searches at low mass.

The work plan includes participation in conferences and related paper production. I plan at least two technological conference contributions (IEEE or similar) and more than two technological papers in three years. I plan also at least two contribution to physics conferences and the production of related papers.
The work plan also includes frequent presentations to the work inside the Trigger and Higgs Discovery groups at CDF and inside the CMS group in Padova. During my permanence at Fermilab also plan to supervise students working in CDF.

Practical and administrative arrangements and support for the hosting of the fellow (outgoing and return host)
Fermilab is a well organized lab. It has been hosting visitors for decades and it has a turnover of hundreds of new visitors each year and help is available on virtually everything. Childcare and summer camps are provided inside the lab for children of employees and visiting users. Many recreation/cultural activities are also provided, including a gymnasium, a summer pool, and concert and film series. We report the content of the Fermilab web site providing all kind of informations for new Users. The 4 links at the end of the page are particularly useful to do all the necessary steps joining Fermilab the first time (help for visa, buying a car, getting the security number, finding a house, getting insurance etc. etc.).
Resources for Users (http://www.fnal.gov/pub/forphysicists/users/resources.html)
• Fermilab Safety Video- All Users are required to watch
• ID Cards - Each user at Fermilab must register with the Users' Office to get the ID car
• Visa Waiver program
• Apply for Computing Privileges - read and sign the Fermilab Policy on Computing
• Medical Insurance - Users' Office has applications for short-term medical insurance
• Rental Cars - available through the Users' Office
• Taxis – help for users
• Fermilab On-site Accommodations
• Off-site Accommodations and Local Restaurants
• Users Executive Committee (UEC) – The UEC represents the Fermilab User Community.
• Graduate StudentAssociation (GSA) - The GSA organizes classes, tours etc. etc.
• NALWO - The Fermi National Accelerator Women's Organisation
• Users' Center - The Users' Center is a place for people to socialize after work.
• Chez Leon - The Chez Leon restaurant located in the User Center Building
• Social Security Administration - Application for a social security number.
• Illinois Secretary of State (Driver's License) - Rules of the Road and a map
•Helpful Information for Users (1) Procedures for Experimenters (2) Guide for Newcomers (3) GSA'sGuide To Life at Fermilab (4) Fermilab's Recreation Office

The INFN section in **Padova**, located in the Department of Physics, offers solid and active research groups involved in many international experiments. The researcher is encouraged to regularly give seminars describing his/her activity inside his/her group as well as to the Deparment.
Beside physics research, teaching experience and supervision of graduate and PhD thesis are strongly encouraged, allowing the researcher to enrich his/her curriculum. All these activities will allow the researcher to successfully reintegrate in the return host.

B5. IMPACT

Potential of acquiring competencies during the fellowship to improve the prospects of reaching and/or reinforcing a position of professional maturity, diversity and independence, in particular through exposure to complementary skills training

This project will allow me to increase my experience on both electronics and high energy physics and this will make my professional curriculum more complete. As an experimental phycisists, infact, it is important to combine the knowledge of physics analysis techniques with the capability of finding the most appropriate technical instruments to perform a physics measurement.

The solid electronics background gained at Fermilab, the experience made developing tools for online data processing and performing an analysis on real data will be very useful at LHC. The transfer of my knowledge at LHC will start in Fermilab (project of a new online track processor for LHC experiments) and continue in Padova. I will perfectionate the project working in contact with LHC people already present in Padova Physics Department. But my curriculum will be general enough (electronics, multivariate analysis techniques) to suit to other projects, such as medical applications. I'll be able to study and propose a project based on the experience on fast data processors gained at Fermilab.

I've already worked at Fermilab in the past, but only for brief periods. The period I will spend at Fermilab will allow me to follow the experiment very closely and continuously. I will be able to hold responsability positions such as group convener, where the on-site presence is fundamental.

The CDF and Fermilab organization is such that I will be strongly pushed to discuss and plan before and defend my work after. I will exercise a management position: supervision, organization of a team, presentation of the work to conferences. The goal coming back is that I participate in new proposals and work as referee for other group proposals. After the fellow, I will have the competencies to attain such an important position. These items will be part of my work: writing documentation, negotiations with founders, financial planning and resource management. I will also participate in the effort to increase the team for the new project. This activity will allow me to improve my natural capability for independent thinking and my managerial capabilities.

Contribution to career development or re-establishment

This fellowship will allow me to reach a position of professional maturity. It will help me to learn how to propose a project, to define all its aspects (identify the problem, propose a solution, find the best tools to implement it, in terms of performances, costs, availability). As my intention is to return to research, this fellowship is fundamental to complete my curriculum, which currently lacks of an extended international experience.

I will have significant experience with programmable logic, standard cell technology and computer technologies. I will be able to evaluate cost and performance of different technologies as a function of different applications. This knowledge will give me an important role inside INFN. I will be particularly helpful choosing the right technology for online algorithm implementation. Moreover I will gain knowledge of hadron collider physics processes and the best strategies for online selection of such events. I will learn about monitoring/diagnostic/standardization problems for very complex electronic systems.

Potential for creating long term collaborations and mutually beneficial co-operation between Europe and the Third Country

The collaboration between Fermilab and INFN is a stable beneficial collaboration which started at the beginning of the CDF experiment (1985-86). I will be part of this collaboration and my permanence at Fermilab will help to reinforce it. We plan to work together in supercomputing and microelectronics, even after the CDF experiment will be closed (2009 or 2010). Supercomputers like

the ones used in CDF can have wide applications even outside of High Energy Physics where INFN is strongly involved (medicine, biology and environment monitoring).
Fermilab contributed to the construction of LHC (the superconducting high-gradient quadrupoles for the LHC interaction regions as well as the end-cap muon chambers for the CMS detector were built at Fermilab) and a CMS group has already been established. Thus it will be natural to continue the collaboration between Fermilab and INFN, to share experience and resources.

Contribution to European excellence and European competitiveness
Thanks to the LHC project, Europe will be the main scenario for High Energy Physics in the next decades. The experience gained in CDF about online tracking processors and innovative analysis techniques will be extremely useful in LHC in its early stage. With respect to LHC, at CDF I will have the possibility to face with the problems of real data taking and of analysis on real events. I will be able to disseminate to the european high energy physics community this experience and my research outcomes and thus contribute to future funding provision on this field.

B6. ETHICAL ISSUES

	YES	PAGE
Informed consent		
Does the proposal involve children?		
Does the proposal involve patients or persons not able to give consent?		
Does the proposal involve adult healthy volunteers?		
Does the proposal involve Human Genetic Material?		
Does the proposal involve Human biological samples?		
Does the proposal involve Human data collection?		
Research on Human embryo/foetus		
Does the proposal involve Human Embryos?		
Does the proposal involve Human Foetal Tissue / Cells?		
Does the proposal involve Human Embryonic Stem Cells?		
Privacy		
Does the proposal involve processing of genetic information or personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?		
Does the proposal involve tracking the location or observation of people?		
Research on Animals		
Does the proposal involve research on animals?		
Are those animals transgenic small laboratory animals?		
Are those animals transgenic farm animals?		
Are those animals cloned farm animalscloned fram animals?		
Are those animals non-humanprimates?		
Research Involving Developing Countries		
Use of local resources (genetic, animal, plant etc)		
Impact on a local community		
Dual Use and potential for terrorist abuse		
Research having direct military application		
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	YES	

ENDPAGE

PEOPLE
MARIE CURIE ACTIONS

International Outgoing Fellowships (IOF)
Call: FP7-PEOPLE-IOF-2008

PART B

"ITES"