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PEOPLE
MARIE CURIE ACTIONS

International Outgoing Fellowships (IOF)
Call: FP7-PEOPLE-2009-IOF

PART B

"ARTLHCFE"
Accurate Real-time Tracking inside LHC Full Events

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B1. SCIENTIFIC AND TECHNOLOGICAL QUALITY (maximum 8 pages)

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

Research objectives against the background of the state of the art and the results hoped for. - An unprecedented set of events will dominate the experimental exploration of the fundamental constituents of the Universe in the next years; at the top of the list is the Physics programme at CERN's Large Hadron Collider (LHC), followed by its upgrade called the Super LHC (SLHC). LHC is in an excellent position to give conclusive answers to many open questions of fundamental physics: observation of the Higgs boson and verification of the symmetry breaking at the electroweak scale. The limit of the Standard Model will be probed at energy frontiers not directly explored before, verifying the theory on the mass hierarchy problem and the origin of the CP asymmetry. Over the next years an impressive harvest of data will be collected and analyzed at LHC. At the same time R&D at the technological frontier will be pursued for SLHC.

These areas of research will have heavy quarks as well as tau-leptons – the so-called third fermion generation - in the cooling fireball after each collision. TEvents rich in heavy flavours and tau-lepton are particularly relevant to test the limit of the SM and study its possible extensions**.** Tracking devices play an essential role in this and in particular the Silicon devices that are becoming the preponderant tracking technology. On the other side the electronics required to process the signal from the detectors is taking a very important role, and it must be state of the art. The most interesting processes, in fact, are very rare and hidden in an extremely large levels of background. Implementing the most powerful selections in real time is therefore essential to fully exploit the physics potential of experiments where only a very limited fraction of the produced data can be stored on tape. A drastic real-time data reduction must be obtained. This makes on-line event reconstruction a critical component of any hadron collider experiment. The trigger must be extremely intelligent and powerful. This project directly addresses the main technological challenges of hardware, software and data surrounding heavy flavour and tau-jets tagging, and tracking issues at trigger level.

The CDF experiment at the Tevatron accelerator in the Fermilab Laboratory, near Chicago (USA), is the best of the state-of-the-art for triggering at a hadron collider. It has a very strong tradition in this field, since a large part of the trigger has been implemented with dedicated hardware, and has been operational for many years, constrained to work within very short latencies (few μs). It has been upgraded during the 20-year CDF life, to exploit technology advances. Very powerful devices are now available, among them the Silicon Vertex Tracker (SVT). It is the most powerful trigger processor operating at a collider experiment so far and it is a perfect baseline for our project. My scientist-in-charge and I were part of the team that worked on it and my host institutions (Frascati, Chicago) and Pisa, where I'm actually, had a leading role in its design, construction, commissioning and management. It performs online track reconstruction in the silicon detector (SVX) and the central drift chamber (COT) with sufficient accuracy, almost the offline resolution, to identify tracks from b-quark decays by their large impact parameters (IP>100 μm). SVT had and still has an extremely significant impact on the CDF physics program. It has been essential for the B^0_s mixing frequency measurement, new heavy baryon and meson observations, and the first observation of the rare charmless decay modes of the B^0_s. These extremely challenging measurements and their first observations would have been completely out of reach without SVT. Since the B-physics has a limited rate budget, the better purity allows CDF to increase by several orders of magnitude its efficiency for the hadronic B decay modes. Historically, B-physics events have been selected at hadron colliders by triggers based on lepton identification. Trigger selections based on the reconstruction of secondary decay vertices greatly increase the b-quark identification efficiency and allow collecting otherwise inaccessible hadronic decay modes. The availability of the hadronic decay modes at CDF determined the different quality of the CDF and D0 B^0_s mixing measurements. Also for high-P_T physics CDF has demonstrated the possibility of successfully using purely hadronic channels in the study of the top quark, in Higgs searches, and even in the reconstruction of the Z^0 boson, thanks to the secondary vertex b tagging.

The 2009 W.K.H. Panofsky Prize was awarded to the SVT creator, Luciano Ristori, recognizing "the leading role ….. enabling broad advances in knowledge of the top quark, b-hadrons, and charm-hadrons….". SVT is a high-performance "supercomputer" using a combination of two technologies: powerful FPGAs (Field Programmable Gate Arrays) working with standard-cell ASICs (Application-Specific Integrated Circuits) for utmost gate integration density. Optimal partitioning of complex algorithms on a variety of computing technologies proved to be a powerful strategy, which turned CDF into a major player in the field of B-physics, on par with dedicated experiments operating at e^+e^- colliders.

We hope to build on the success of SVT in a second generation processor, Fast Track (FTK) that will be much more advanced to cope with the extreme complexity of the LHC new detectors and the extreme working conditions of the new LHC accelerator. FTK should also extend its physics reach from B-physics to high-P_T physics involving the most important High Energy Physics (HEP) searches, first of all the Higgs (SM or SUSY) searches. Let's compare the Tevatron and LHC machines to explain the increase of complexity of events and, as a consequence, of the tracking detectors. The CDF collision rate is ~2 MHz and at the instantaneous luminosity (ILum) of 3×10^{32} cm^{-2} sec^{-1} the average number of soft, not-interesting interactions per bunch crossing (pile-up) is 6 (396 ns bunch spacing). The LHC environment will be much more demanding: a bunch spacing of 25 ns at high ILum (10^{34} cm^{-2} sec^{-1}) produces ~ 25 pile-up interactions. The LHC upgrade (SLHC), with the recently proposed scenario of a 50 ns bunch spacing, will produce a pile-up of hundreds of events at the ILum of 10^{35} cm^{-2} sec^{-1}.

We can exploit a very important advantage: on the technological side, 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 extremely hard conditions of high data rates and limited processing time. Since the kind of background suppression we need at trigger level is becoming similar to that of the usual offline analysis, the offline quality is required to be applied at trigger level. I will show that our goal is challenging, but it is not a dream.

Description of the state-of-the-art of the research topic. - Triggering at a hadron collider requires a drastic real-time data reduction. 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 (at LHC L2 and L3 can be called High Level Trigger, HLT).

This task has found in CDF its best implementation and experience up to now. The strategy of the "optimal mapping of a complex algorithm in different technologies" has been pursued at the best level to build online tracking Supercomputers that required excellent technological skills. SVT was built for B-physics at the Tevatron intermediate ILum RUN IIA (10^{32} cm^{-2} sec^{-1}). It was upgraded to keep up with the increasing Tevatron luminosity and to be extended at RUN IIB with luminosities approaching $3\text{x}10^{32}$ cm^{-2} sec^{-1}. SVT reconstructs all tracks with P_T above 2.0 GeV/c with the maximum spatial resolution allowed by the silicon vertex detector.

The SVT architecture, the Associative Memory and FTK, the new processor **-** There is an enormous difference in the use of tracking detector information at trigger level in the CDF and LHC experiments. While CDF has always intensively exploited tracking from 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. Tracking at CDF is provided by powerful processors at L1 and L2: the L1 eXtremely Fast Tracker (XFT) and the already mentioned L2 SVT. XFT finds L1 tracks with P_T above 1.5 GeV/c in the COT (96% efficient), Pt resolution sigma($1/P_T$) = 1.7% and angular resolution sigma(φ_0)=5 mrad. In addition to being used in the L1 trigger decision, the XFT tracks are distributed to SVT where the Associative Memory (AM, a dedicated VLSI device) associates them to the hits on the five silicon detector layers. FTK has been studied for 10 years as a *second generation* device, as precise as SVT, but much more able to provide typical offline tracking performance. While SVT covers only the central region ($|\eta|<1$) and its efficiency is affected by many cracks, FTK exploits the whole ATLAS tracker ($|\eta|<2.5$) and implements "overlap regions" at any detector subdivision, where the border could create inefficiencies. FTK finds 3-D tracks, while in SVT the measurement along the beam (z coordinate and polar angle θ) is extremely uncertain. FTK uses a much larger number of very precise silicon layers (8 strip layers and 3 pixel layers, for a total of 14 independent coordinates, to be compared to the 5 silicon strip layers of SVT) to be very effective in rejecting fake tracks even in very crowded conditions. FTK is more than 90% efficient for μ and more than 85% for π, with a χ^2 cut severe enough to reduce the fake rate to a negligible level even at very high luminosities.

The tracking algorithm, both in SVT and in the new FTK, is subdivided into 2 sequential steps of increasing resolution. In step 1 a dedicated device, called Associative Memory (AM), finds track candidates with low spatial resolution, called roads. In step 2, the real tracks are searched within the roads and fitted to determine their parameters with the best resolution (sigma(IP)=35 μm, sigma ($1/P_T$) = 0.3 % and sigma(φ_0)=1 mrad measured on CDF data). Tracks with P_T>2 GeV/c in SVT and P_T>1 GeV/c in FTK are finally selected to tag secondary vertexes.

These algorithms can be implemented using different technologies. Commercial CPUs offer flexibility, standardization and ease of upgrade but they are slow. The CPU flexibility is a great advantage for the full resolution tracking, because it must handle many variables and specific situations such as local corrections, alignment effects, exceptions etc. However programmable logic available today is flexible enough to successfully replace the CPUs even in high resolution computations. A coarse resolution pattern recognition, however, does not profit very much from CPU flexibility. A large fraction of the CPU time needed to reconstruct high energy physics events is wasted in data sorting with a lot of random accesses to a large storage that contains all the tracker data. By contrast, the AM perform the most CPU intensive part of the pattern recognition, consisting of a very large number of regular and highly structured loops of simple logical operations, always identical, with dedicated highly parallel structures. The AM exploits the idea of a pattern matching algorithm based on pre-calculated and stored track candidates, which are compared in parallel with the actual event.

The first basic AM chip was made with ASIC full-custom technology and was specific to the 5-layer CDF silicon detector. In particular, it is unsuitable for the complexity of the tracking detectors of the LHC. Any redesign would imply a large investment in terms of time, personnel, and costs. For simple applications, we designed a low density AM chip based on the essential characteristics of the programmable devices available on the market (FPGA). The use of commercial FPGAs allows easy development and an easy update of the project. The final production can use up-to-date custom technology. It is also easy to test and debug the prototype. Programmable chips are 100% tested at the factory. System performance can be studied with the full device simulator provided by the manufacturer. Boundary-scan, supported by last generation FPGAs, allows a full test of printed board connections. The only aspect for which programmable devices are inferior to a full custom ASIC is the achievable logic density. In some cases, such as the AM chip, ASICs can still be the better technology. 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. To minimize the required human and monetary investment, the circuit description is done using high-level languages, independent of the hardware substrate and compatible with an easy and automatic recompilation into standard-cell chips. We followed this strategy developing the new AM as a standard-cell chip. Now it is playing a key role in the upgraded SVT and is the baseline for FTK, the next more powerful processor.

SVT and FTK include important pre/post processing functions, complementary to the intensive pattern-recognition. Pre-processing corresponds to (a) cluster finding in the silicon data (FTK needs roughly 3 crates of 9U VME boards called Data Formatters, DF); (b) smart database for immediate retrieval of full resolution information (FTK needs roughly 48 9U VME boards, called Data Organizers, DO). Post-processing includes (a) the track fitting (FTK needs roughly 8 9U VME boards called Track Fitters, TF) and (b) equivalent-road, duplicate-track cleanup (FTK needs roughly 16 9U VME boards called Road Warrior and Hit Warrior, RW and HW). The most important function is the track fitting, which refines the candidate tracks in order to determine the track parameters with the full detector resolution. The TF makes use of methods based on local linear approximations and learn-from-data techniques for online misalignment corrections. The fit calculation consists of many scalar products. The SVT experience and the FTK simulation show that the approximations introduced to maximize the speed do not significantly affect the fit performance.

Upgrades to the CDF trigger have been necessary as the Tevatron instantaneous luminosity increased. The increasing luminosity results in more complex events since the rate of interactions is greater than the rate of beam crossings, resulting in multiple interactions in most events (pile-up). The more complex events require more trigger processing time, in particular the track trigger, reducing the amount of data CDF can record. As already mentioned, the SVT was upgraded to keep up with the increasing luminosity of the Tevatron and this work was perfect R&D for FTK. The most relevant changes were: (a) a 40 times larger AM, implemented as a 0.18 μm standard-cell; (b) all the SVT pre/post functions have been implemented in the same general purpose board, the PULSAR. 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 has been used in many applications, even outside CDF. Our goal for future applications is to exploit as much as possible this idea of a standard board used in many applications, even outside the L2: a standard system could work both at L1 and L2. Standardization will reduce costs and manpower needed to develop and maintain the system.

The SVT upgrade was completed finally with the GigaFitter, a very new track fitter, a good starting point for the FTK fitting needs. The GigaFitter is a single Pulsar board enhanced by four mezzanines able to replace 16 9U VME boards in CDF. The algorithm core has been implemented in a modern FPGA chip placed on each mezzanine. A single chip contains memories for a total of several Mbytes, and hundreds of

18x25-bits multipliers and adders (DSP arrays). The clock runs up to 500 MHz. The DSP-like processors, packaged in large number inside modern FPGAs, can perform many fits in parallel reducing the time necessary to fit a set of coordinates almost to zero.

The scientific, technological or socio-economic reasons for carrying out further research in the field covered by the project. - The first very general reason is the HEP research advancement. It 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 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 collider facilities and will influence the philosophy of science and more broadly human thought. Moreover, these HEP experiments are becoming so incredibly complex and expensive that my specific work in the trigger and Super-Computer research area becomes every day more important to increase the efficiency for sample collection and save money. These experiments, as explained below, need enormous computing power, and ideas for making them powerful at low cost are very important.

I think that there are important reasons also outside HEP. The electronics we use in our work is extremely flexible and powerful, but also underused and not well enough known. The strategy of the "optimal mapping of a complex algorithm in different technologies" is a general approach that can speed up enormously any kind of calculation by providing the capability of a high degree of parallelism. The trend of using a combination of CPUs and FPGAs for systems continuously requiring increasing computing power has been expanding not only in physics experiments, but even in non-academic fields, like for example financial applications. It could be very important in the area of medical imaging for real time, fast diagnosis, when the patient is under examination. It can be very relevant for astrophysical and meteorological calculations. It could be fundamental for neurophysiologic studies of the brain or for security applications. The use of this electronics is more difficult than the use of a multi-core CPU, since it requires the FPGA hardware and the knowledge of computer-aided-design (CAD) tools. It requires the capability to exploit these instruments at the highest level. The power of the result is a strong function of the creativity and experience of the designer. For this reason I think the HEP work in this area is important for showing the potential of these devices and spreading the skills needed to use them efficiently. If people become expert with these tools the world computing power could make an incredible jump and we could save money (less expensive systems), energy (minor consumption), and space (much more compact systems).

<u>Information on interdisciplinary / multidisciplinary aspects of the proposal</u>.

As a spin-off of our online development activity, we want to produce a crate of electronics where the Associative Memory along with all FPGA ancillary logic will be used for offline studies and applications outside HEP. These are embryonic lower priority ideas, so they will take some of my fellowship time only in the third year, during reintegration in Italy, when the FTK project should be in an advanced state.

a) Real time image analysis has undergone a rapid development in the last few years, due to the increasing computational power available at low cost. However computing power is still a limiting factor for some high quality applications. High-resolution medical image processing, for example, is strongly demanding for both memory (~250 MB) and computational capabilities to allow 3D processing in affordable time. The last few decades have actually seen revolution after revolution in the field of imaging; 3D and 4D imaging being the latest to join the bandwagon. Virtual endoscopy with 3D CT is now in the field for some time. The advent of newer xMATRIX technology in ultrasonography by Philips Healthcare now makes virtual endoscopy in its live volume imaging mode possible. We propose the reduction of execution time of image processing exploiting the computing power of parallel arrays of FPGAs. We want to use our online 2-D clustering algorithm devised for cluster reconstruction in the ATLAS pixel detector. It finds clusters of contiguous pixels above a certain programmable threshold and processes them to produce measurements that characterize their shape. We can measure the size of the spot, but we can also measure quantities of interest in medical applications, like how circular or irregular the spot is. It is a fast general-purpose algorithm for high-throughput clustering of data "with a two dimensional organization". The algorithm is designed to be implemented with FPGAs but it can also profit from cheaper custom electronics. The key feature is a very short processing time that scales linearly with the amount of data to be processed. This means that clustering can be performed in pipeline with the image acquisition, without suffering from combinatorial delays due to looping multiple times through the whole quantity of data. The algorithm can be extended to 3-D images.

b) The associative memory processor for real-time pattern matching applications can be used for brain studies. The brain is certainly the most complex, powerful and fast processing engine and its study is very challenging. The most convincing models that try to validate brain functioning hypothesis are extremely similar to the real time architectures we developed for HEP. A multilevel model seems appropriate also to describe the brain organization to perform a synthesis that is certainly much more impressive than what done in HEP triggers. The AM pattern matching function has demonstrated to be able to play a key role in high rate filtering/reduction tasks. We want to test the AM device capability as the first level of this process, dedicated to external stimuli pre-processing. We follow the conjecture of reference [Punzi & Del Viva (2006) Visual features and information theory JOV 6(6) 567]: the brain works by dramatically reducing input information by selecting for higher-level processing and long-term storage only those input data that match a particular set of memorized patterns. The double constraint of finite computing power and finite output bandwidth determines to a large extent what type of information is found to be "meaningful" or "relevant" and becomes part of higher level processing and longer-term memory. I will use an AM-based processor for a hardware implementation of fast pattern selection/filtering of the type studied in these models of human vision and other brain functions (see the work plan in section B4 for a more detailed description).

Research methodology

The research methodology is described for the 3 main objectives of my work: (A) design optimization, FTK tests on real data (B) development of software for management, monitoring, diagnostics and control of FTK (C) development of the physics case and application of new complex analysis on collected data to confirm the advantages predicted by the FTK use.

A) Dedicated trigger hardware usage has been recently reduced for future experiments, in particular at LHC, in favour of large, commercial CPU farms to reduce the risks associated with dedicated hardware. Often the dedicated hardware is considered powerful but difficult to upgrade and inflexible. We have shown in CDF that the use of FPGAs and ASICs does not suffer from these disadvantages if the design and the commissioning is pursued with the correct methodology. Board standardization and FPGA flexibility allowed rapid system improvement since we could reuse 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 fully tested on real data, using a parasitic connection to the experiment, before being included in the real data taking stream. A phased installation was chosen: boards were replaced gradually, exploiting the short quiet time between the end of one accelerator store and the beginning of the next one. 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 replacing 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 follow the same procedure developing FTK and gradually introducing its use in ATLAS.

Hardware design, optimization - A large effort will be required at the beginning to optimize and standardize the architecture as much as possible and to produce all the needed firmware and software. After that later improvements will be much easier. Feedback obtained from data analysis will be implemented in the online process almost in real time, increasing the purity of the selected data. The accelerator time schedule is uncertain and its uncertainty can influence the development schedule of the FTK project. FTK optimization can be longer or shorter depending on the experimental needs and the rate of funding for the project. I include in the following list all the critical items, even if some of them belong to a preliminary optimization phase and some of them could (1) be complete when the fellowship starts or (2) still be of great interest since data taking could bring new important insights that will require a final tuning. In any case they are relevant to understand the system's critical points.

<u>Specify, build and test the internal FTK data paths needed for the LHC design luminosity</u>: We will determine the number of each kind of board in FTK using the expected number of silicon hits in each detector layer at full luminosity. This will allow us to balance the parallel data busses within FTK and thus minimize the number and complexity of the boards in the system. Simulation is the main tool in this area, but the first data analysis will certainly reduce the uncertainties, allowing the final tuning.

<u>Determine the optimal size of the AM system, build and test AM system</u>: there is a trade-off between the width of the pattern recognition roads (governing the size of the associative memory banks) and the number of required track fits due to hit combinatorial (impacting the complexity or latency of the track fitter boards).

We will make the choice by optimizing with regard to cost and event execution time. Again the first data taking will be important to check our simulation-based results.

Produce specifications for each board, design them and insure consistency among them: define and distribute the functions of each board.

Optimize data transfer from FTK to level-2: We will study how to use the event buffers where the FTK output has to be organized to best exploit the FTK potential. This includes interacting with the ATLAS Trigger-DAQ group to understand what new features and components might be available on the FTK timescale, for example switch-based collection and new hardware. We can start with the existing boards and upgrade to better systems in the future.

Develop the physical layout: fibers, crates, cables: using the state-of-the-art simulation we specify the size of the FTK system, understand where it would fit in the experiment and what its needs will be for services. Data taking will provide a check of the hypothesis and will allow later tuning during construction.

Test, commissioning - To understand system issues and develop the needed control software for FTK, we plan to start very early a parasitic commissioning of a small proto-FTK, based on prototypes already available. It will be able to reconstruct tracks only inside a thin azimuthal slice of detector. This will be a "*FTK vertical slice*" in the sense that it will be functionally complete, from the detector inputs up to the track output available for the L2 CPUs (vertical) but small (operating on a detector slice).

B) The *vertical slice* will be a very powerful tool for software development. We already have a complete set of software tools for CDF. However we need to learn the ATLAS environment and adapt our system to the new experiment's needs. The vertical slice will provide early interaction between us and the experiment. We will be able to test all the important features before FTK production begins and make any needed changes.

C) It is very important to develop a strong physics case for FTK and after that verify with data the expected physics gain. The most important reason for early track reconstruction is selection of events containing third-generation fermions, either a b quark or a τ lepton. For the former, the level-1 trigger selects a generic jet; for the latter, a narrow jet. In either case, there is enormous background from QCD jets. Discrimination of the signal from background relies in large part on track information – in b jets the presence of a secondary vertex or tracks with large impact parameter, in τ jets an isolation region devoid of tracks surrounding a small cone containing no more than 3 tracks. There is in the ATLAS baseline an existing plan to execute such algorithms, but for multi-jet events this could take considerably longer than the allotted 20 milliseconds, especially at full LHC luminosity. In this case, in order to satisfy the requirement on the level-2 execution time averaged over all level-1 triggers, the fraction of level-1 triggers assigned to jets would have to be limited. Having the reconstructed tracks at the beginning of level-2 processing could allow most of the background jet events to be quickly rejected, thus dramatically decreasing the average level-2 execution time for b-jet triggers. This would permit a larger fraction of the level-1 bandwidth to be assigned to jet triggers if the physics requires it, for example if the dominant characteristic of the new physics is multiple b-jets rather than electrons or muons. Moreover, the level-2 processing time could then be used for applying other necessary event selection criteria. Important examples of CPU-intensive usage of tracks, other than *b*-tagging and τ-identification, are: (1) primary vertex identification, (2) high-P_T lepton isolation using only tracks above a P_T threshold coming from the high-P_T primary vertex (avoiding pile-up tracks in evaluating isolation), and (3) B-physics events, where final state hadrons have to be found outside of the specific regions identified by leptons (Regions of Interest, ROIs).

We will study the performance of FTK at design LHC luminosity for both individual objects and complete events. For the former, we will determine the ID efficiency and mistag probability for both *b*-jets and hadronically decaying τ-leptons. We will compare these with the performance using offline tracking. We will also compare with the current level-2 tracking. With the additional level-2 CPU time, more sophisticated tagging algorithms can be carried out, obtaining better performances. We will also study FTK's ability to determine the high-P_T primary vertex and help identify isolated leptons (e and μ), including the advantage at high luminosity of basing isolation on tracks above a P_T threshold that point to the high-P_T primary vertex.

We will also select a few processes to demonstrate the capability of FTK in complicated events. These will include $Z\rightarrow bb$ for a calibration channel, $Hbb\rightarrow 4b$'s for events whose distinguishing characteristic is multiple secondary vertices, vector boson fusion to a Higgs decaying to tau-tau to quantify the hadronic tau capability. Finally we were also requested by the collaboration to test the $B\rightarrow K^*\mu\mu$ to demonstrate FTK's capability in *B* physics, where the possibility to extend the trigger identification using tracks out of the μ RoI could increase the signal acceptance. The importance of B physics at high luminosity is uncertain now but the early study on data in this channel will help to clarify it and will improve our understanding of the inner detector performance. We will study basic FTK performance at three luminosities: low luminosity (no pile-up), 10^{34}, and 3×10^{34}. The standard *WH*(120 GeV/c^2 mass) samples will be used to determine tracking efficiency, fake track rates, helix parameter resolution, and the *b*-tag efficiency versus mistag probability. For the τ-tag studies, we will use the *Hqq* samples. We will compare FTK performance with that of the level-2 CPU farm.

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

The experience gained at CDF is precious to LHC. The philosophy of performing almost offline selections at rates of the order of 20-40 kHz at LHC, or even more, is absolutely new. The idea of using dedicated mixed-technology Supercomputers is innovative in a world where the use of dedicated hardware has been strongly reduced. As already underlined there is an enormous difference in the use of tracking detector information at trigger level in the CDF and LHC experiments. Our proposal to transfer the CDF experience to LHC fits perfectly in this scenario. We want to improve the functionality of the online tracking to match the LHC luminosity increase and to foster the use of these powerful online processors to more complex applications in the future. New and outstanding multi-technology Supercomputers increase the discovery potential of current and future HEP experiments. They will use FPGAs and ASICs to complement CPUs. CPU-based sequential reconstruction programs usually waste the CPU flexibility when carrying out a serialization of long simple repetitive logical operation sequences, that once optimized will remain largely unchanged. The problem is generally referred to as the "combinatorial challenge". Supercomputers beat the combinatorial challenge with powerful dedicated programmable devices, where parallelism can be exploited to the maximum level. They take full advantage of the parallel nature of most combinatorial problems by comparing the event to pre-calculated "expectations" at once. Thus the FTK can be considered a highly parallelized extension of the front end, executing only data unpacking and solving the huge hit combinatorial problem to filter out the few relevant track hits from the plethora of silicon data coming from all of the low P_T tracks and noise. The HLT CPUs, freed of the huge tracking job, could more easily exploit offline-quality algorithms to increase rejection power, solve high-level-object combinatorial problems, or make intensive use of tracks in all selection algorithms.

The developed devices will be general enough to be adapted to other research fields where efficient and fast real time reconstruction of data is needed, as described in section "**Scientific and technological quality**".

Timeliness and relevance of the project

This is an important time to demonstrate to the high energy community the capability of the FTK online tracker. The very precise LHC silicon detectors, which contain hundreds of thousands or millions of channels, increase the problem of complete tracking in large numbers of high multiplicity events. With tens or hundreds of particles produced by multiple primary collisions and traversing many detector layers in all directions, this is a formidable challenge even for off-line analysis. The feasibility of complete high-quality tracking for real time event selection has been considered impossible in LHC experiments at very high rates. As a consequence, real-time tracking is planned for a limited detector region or on a small subset of events, selected previously using other detectors. Many physicists dismiss the possibility of complete on-line tracking in LHC experiments because they see the problem as too formidable. The goal of this research is to change this opinion by demonstrating that up-to-date technology, exploited with suitable organisation and algorithms, permits the development of high-performance tracking triggers sensitive to secondary vertices and complex structures like taus.

The FTK strategy has a particularly relevant impact now that the LHC community is starting to consider the design of new architectures for the SLHC upgrade, even before being able to see the first LHC data. The CDF experience with data, in particular the online tracking at CDF and the FTK R&D project, could have a significant impact on the discussion of future architectures.

Host scientific expertise in the field (outgoing and return host)

***Outgoing host** - U. of Chicago and Enrico Fermi Institute*: The U. of Chicago elementary particle physics faculty are members of both the Department of Physics and the Enrico Fermi Institute, an interdisciplinary institute covering experimental and theoretical particle physics, astrophysics and cosmology, cosmic-ray physics, and cosmo-chemistry. There are very close connections with Fermilab and Argonne National Laboratory since the U. of Chicago operates both laboratories. The Institute has a mechanical design group along with a machine shop and two high-bay areas for construction of large detector components.

There are Tier-2 and Tier-3 computing clusters for ATLAS and a large computing complex for CDF.

They have a world famous electronics design group that has produced major electronic systems for all of the experiments in which they have participated. At present, there are 8 tenured faculty members in experimental particle physics plus distinguished faculty in astrophysics, cosmology, and theory. Most of these faculty members have had major leadership roles in their experiments. The faculty are working on CDF, ATLAS, ILC (accelerator and detectors), the Double- Chooz reactor neutrino experiment, completion of data analysis for the KTeV CP violation experiment, the VERITAS gamma-ray observatory, the Pierre Auger high energy cosmic ray experiment, the COUPP dark matter experiment, the Dark Energy Survey experiment, a number of experiments studying the Cosmic Microwave Background, and the novel application of particle physics devices to medical imaging. Recent examples of large mechanical construction include ATLAS, Double-Chooz, the JPARC experiment, and KTeV. Large electronics systems both for triggering and data acquisition were built at Chicago for CDF, ATLAS, the JPARC experiment, and KTeV. The fellow supervisor in Chicago, Prof. Melvyn J. *Shochet,* is the present chair of the High Energy Physics Advisory Panel (HEPAP), which advises the U.S. government (Department of Energy and National Science Foundation) on the current and future programme in elementary particle physics. He was also elected to the U.S. National Academy of Sciences. The present Deputy Director of Fermilab, Young-Kee Kim, also Professor at the University of Chicago, is part of the FTK project. For several decades, U. of Chicago has been among the top 10 departments in Physics and has a long list of famous physicists as faculty members. The 28 Nobel prize winners in physics who were either students or faculty at the University of Chicago are the proof of the extraordinary research level in Physics at Chicago.

Return host - *Istituto Nazionale di Fisica Nucleare* (INFN). INFN is an organization dedicated to the study of the fundamental constituents of matter, and conducts theoretical and experimental research in the fields of subnuclear, nuclear, and astroparticle physics. Fundamental research in these areas requires the use of cutting-edge technologies and instrumentation, which the INFN develops both in its own laboratories and in collaboration with the world of industry. These activities are conducted in close collaboration with the academic world. INFN is a major player in international HEP research and Laboratori Nazionali of Frascati is the main INFN laboratory. INFN has a particular impact in hadron collider physics: it strongly contributes to all LHC experiments and has been member of the CDF experiment since 1980, having played a particularly important role in the SVT project. The idea of real-time b-quark selection in the CDF experiment was born in 1985 inside INFN by Prof. Luciano Ristori, for which he was awarded the 2009 Panofsky prize of the American Physical Society. The FTK idea for LHC was born in INFN in 1998. INFN also had a leading role in the CDF b-quark trigger definition and evolution and finally the CDF B-physics analyses. The Univeristy of Chicago has been, since the beginning, INFN's major collaborator in this work.

Quality of the group/supervisors (outgoing and return host)

Prof. Melvyn J. Shochet has worked in CDF since the beginning with an extraordinary impact on the most important aspects of CDF: trigger, data analysis, and experiment management. His group has always trained superb graduate and undergraduate students and post docs, many of whom have become tenured faculty members at major universities: Dan Amidei, Myron Campbell, and David Gerdes at the Univeristy of Michigan, Aaron Roodman at the Stanford Linear Accelerator Center, Morris Swartz at Johns Hopkins University, Claudio Campagnari at the University of California at Santa Barbara, Tony Liss at the University of Illinois, Jay Hauser at the University of California at Los Angeles, Sarah Eno and Greg Sullivan at the University of Maryland, Tsyoshi Nakaya at Kyoto University, Taka Maruyama at Tsukuba University, and Kohei Yorita at Waseda University.

Dr. A. Annovi has worked for the FTK project since the beginning with essential contributions to design and technological developments, to demonstrate the potential of the FTK provides and to convince the ATLAS collaboration of the usefulness of this project. He had a leading role in the proposal and approval of the SVT upgrade, where he was the team leader during production, installation and commissioning. He has recently obtained a staff position at Frascati National Laboratories. He has experience in data analysis at CDF and is main author of several works that range from QCD measurements, B-physics measurements, exotics searches and diboson physics that is a key step in the path toward the Higgs. He has experience training physicists and engineers: P. Giovacchini, B. Simoni and M. Lamalfa (engineers), Laurea with INFN– now at STMicroelectronics Srl, Milan & Catania, S. Torre (now at La Branche, London) and several students now enrolled as graduate students.

In Italy, more than 50 students got their Master/Laurea and PHD working on our real time tracking project and related physics, finding after that interesting positions in European-USA institutions or industries.

B2. TRAINING (maximum 2 pages)

Clarity and quality of the research training objectives for the researcher

Training objectives of the proposal

- Very advanced use of programmable logic (FPGAs). High level firmware development (VHDL and Verilog description language), simulation & test capabilities, timing & implementation optimization.
- Development of code for the level 2 CPUs at very advanced level, to optimize the final level 2 decision.
- "Cost versus performance" evaluation and comparison of different technologies: VLSI devices, FPGAs, commercial CPUs.
- LHC trigger selections knowledge and study of its dependence on the accelerator luminosity. Understanding bandwidth and processing problems. Efficiency and rejection power optimization.
- Capability to realize new triggers exploiting the hardware upgrades.
- Understanding of the ATLAS online/offline tracking system problems, relative solutions and standardization of the system to be able to transfer the best of this technology to the future. Capability to improve flexibility and ease of use for the trigger devices, to allow application to different experiments with minimum tailoring and minimum engineering effort.
- Development of a complete set of diagnostic tools, to be used within the ATLAS monitoring system but also in future applications.
- Realization of simple expert systems to monitor and find problems in the system.
- Exercise automation of technological follow-up of digital electronics developments, producing clean project descriptions by high level languages and automatic compilation into the most advanced devices at time of construction. This will simplify further developments and applications to future experiments.
- Apply my CDF analysis experience to the new, more complex ATLAS environment. Learn the most innovative multivariate analysis techniques, such boost decision trees for the search of very rare events.
- Capability to adapt the experience gained on "supercomputers" developed for HEP to pattern recognition problems outside HEP, such as medical imaging.

How the objectives can be beneficial for the development of an independent research career.

On returning to Italy I expect to be able to manage the Frascati responsibility in FTK. I will manage a small group of people working with me for hardware production and related physics study.

Relevance and quality of additional scientific training as well as of complementary skills offered - Adding different/complementary scientific competencies to the fellow career.

The U. of Chicago is one of the world's great intellectual communities and it is enormously stimulating in many different fields. It is very easy to attend at seminars and classes of extremely high interest and quality. I list some of the extraordinary results to give an idea of the interest and variety of ideas developed there.

It was at Chicago that REM sleep was discovered and carbon-14 dating was developed. Scientists laid the mathematical foundations of genetic evolution; executed the first controlled, self-sustaining nuclear chain reaction; conceived the study of black holes; and performed the nation's first living-donor liver transplant. Researchers there have also expanded our understanding of dinosaur evolution; reconstructed the evolution of the early universe in astonishing detail; proved that chromosomal defects can lead to cancer; and pioneered scientific archaeology of the ancient Near East. Eighty-two recipients of the Nobel Prize have been students, researchers, or faculty there. Since 1979, 13 of Chicago's faculty have been honored with the prize—four in physics, eight in economics, and one in literature. Creative writers and scholars have recently won the Pulitzer prize, the National Medal of Science, the Grammy award, and the MacArthur Foundation "genius" grant, among other major awards. Even undergraduates have the opportunity to study with a Nobel winner.

Moreover, the U. of Chicago manages, supports, and engages with two major federal research centers where cutting-edge science is always underway: Argonne National Laboratory and the Fermi National Accelerator Laboratory. It is very easy to get in contact with new research fields and to enlarge personal interests. Not only are fundamental in HEP experiments done at Fermilab, but also scientific tools for HEP are developed there: (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. It collaborates closely with scientists from industry and universities around the world to advance all of these fields; its technology has 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.

Argonne is a leader in addressing the nation's critical scientific and technological problems. It has five major mission areas: (1) conducts basic experimental and theoretical scientific research in the physical, life, and environmental sciences; (2) operates world-class research facilities like the Advanced Photon Source; (3) enhancing the nation's energy resources: Argonne's scientists and engineers are working to develop and evaluate advanced energy technologies; (4) developing new ways to manage and solve the nation's environmental problems and to promote environmental stewardship; (5) National Security has increased in significance in recent years for the nation and for Argonne research. Argonne capabilities developed over the years for other purposes are helping counter the threats of terrorism.

Also LNF in Italy offers a lot of opportunities: not only is the large laboratory in Frascati the focus for a lot of conferences, seminars and scientific contacts, but it is located very near Rome where 3 Universities find a common structure in the INFN for high energy physics. Almost all modern HEP experiments are present in the Roman area and share experiences and structures. Training and courses are offered for computing, electronics and others skills. The University La Sapienza, founded by Pope Boniface VIII in 1303, with its current 145,000 students, is the largest university in Europe. It carries out scientific research in various fields, achieving important results, both on a national and an international level. 111 Departments and 30 Institutes are devoted to scientific research. In addition, Sapienza houses laboratories of the main national scientific institutes. The branches involved cover all fields of knowledge, from basic research to technical branches and classical studies, historical, philosophic and economic-juridical subjects, from sociology to psychology, from communication sciences to medicine. In the field of physics, the heritage of the members of the “Via Panisperna” group – led by the Nobel Prize Enrico Fermi – has been extended to quantum physics, physics of disordered systems, astrophysics. Theoretical physics has teachers like N. Cabibbo, L. Maiani, G.Parisi, G. Altarelli, G. Martinelli. Cultural resources, energy, environment, nanotechnologies, cell therapy, gene therapy, design, aerospace, nautical science are just some of the many scientific assets recognized as peaks of excellence in this University. There are presently over 150. Ph.D. programs.

Host expertise in training experienced researchers in the field and capacity to provide mentoring/tutoring (outgoing and return host)

The work style in the Enrico Fermi Institute is wonderful. Organization and continuous scientific discussions are the bases of the high research productivity of the relatively small, but excellent research groups. Each member has individual responsibilities and is required to discuss its work weekly with the rest of the group. Seminars in front of the whole scientific community of the institute are periodically required. This style is a strong stimulus to acquire clarity, independence, management capability, and presentation skills.

The Italian community in FTK has worked for a long time in CDF collaborating with the Chicago group. The working style is similar, characterized by a strong communication/discussion between all group members, and providing a continuous stimulus to improve “leadership capability”. Presentations at conferences are strongly encouraged, even the dissemination of ideas and results not currently popular in the HEP community (FTK, for example, suffered for some time of the large LHC online farms competition).

Both the outgoing and return institutions areas are intellectually very active and offer seminars and possible interactions on a wide range of topics in high energy physics, technological areas related to the experiments/accelerators, and also in totally different fields. 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.

B3. RESEARCHER (maximum 7 pages which includes a CV and a list of main achievements)

Research experience

Comprehensive description of research experience.- My main research activity started with my PhD studies. Since that time I worked on competitive heavy flavour physics at hadron colliders, in particular for the CDF and ATLAS experiments. My PhD thesis and also the work as a post-doc covered the two main subjects briefly described below in a. and b. Before the PhD period I had a totally different experience, described in c.:

a. Advanced trigger hardware techniques for on-line selection of b-quarks; I worked in the collaboration that made possible the SVT tracking processor for reconstructing tracks in the silicon detector within 20us using the full silicon resolution and providing a measurement of transverse impact parameter with offline spatial resolution. I worked from the beginning with the same collaboration on the second generation processor (R&D) for the LHC experiments, FTK, to provide offline-quality tracking at the level-1 output event rate, which means about 100kHz.

b. Study of charmless decays of B-hadrons at CDF; thanks to the SVT processor, the CDF II experiment was the first one to observe fully hadronic decays of the bottom quark at a hadron collider. The peak of the B^0_s decaying into 2 hadrons is one of the most important CDF II B-physics results. SVT allowed collecting a pure data sample, applying cuts on track transverse momentum and impact parameter. The measurement is complex because we need to separate signals that apparently cannot be separated in a very large background; this requires an advanced and powerful analysis technique. Using both a high capability trigger and a refined analysis it was possible to extract world class measurements in the B-physics area at CDF.

c. During my thesis before the PhD I gained knowledge about the use of large area gaseous detectors at ATLAS. In particular I studied how the toroidal magnetic field present in the muon spectrometer interferes with the muon system auto-calibration algorithm. The auto-calibration goal is to evaluate, without using special working condition, the correct function relating the particle signal arrival time with the distance between the charged track, passing through a drift-tube, and the drift-tube centre. This relation is called r(t) function. I studied how the Lorentz-angle, bending the drift paths of the electrons and the ions, changes the r(t) relation with respect to the case without the magnetic field. The Lorentz-angle delays the signal arrival time. The large non-uniformity of the magnetic field changes the r(t) function according to the position where the avalanche starts. For this reason it is not possible to have a unique r(t) function for the whole muon detector. In the thesis I compared two different approaches: (1) parameterization of the magnetic field effect, (2) internal segmentation of the detector into regions small enough to have a uniform magnetic field within each. The effect was studied using the GARFIELD simulation. I performed a preliminary parameterization of the delay due to the Lorentz-angle. With this parameterization, it was possible to evaluate, using the ATLAS magnetic field map, the size of the regions having sufficient uniformity, and as function of their size, the integrated luminosity needed to collect a sample large enough for calibration. This preliminary study showed that the subdivision into sectors has good performance, but in some conditions too fine a segmentation is needed. This segmentation would require a large time to collect the calibration sample. The parametric approach was shown more practical. The results were documented my Thesis and in the ATLAS note: ***"The calibration of the MDT tubes and the effects of the magnetic field"***, P. Bagnaia and G. Volpi. **ATL-COM-MUON-2005-001**. In this period I participated in the ATLAS test-beam at CERN to monitor and measure the performance of the μ chamber gas system.

Scientific/professional CV: - academic achievements – list of other professional activities – any other relevant information

Education:

Grant Student, Rome, University "La Sapienza", Department of Physics (1996-2004)

- September 2004 - Graduated in Physics (106/110). Title "Study of the muon chamber calibration of the ATLAS experiment at CERN", Supervisor Prof. P. Bagnaia.

Grant PhD Student, Siena University, Department of Physics (2004 - October 2007)

- Development of sophisticated data analysis tools at CDF for B-physics studies
- Development of online diagnostic for SVT. Furnisher of software for pattern evaluation and FIT constants production, within the GigaFitter project
- Data taking management as CDF "Acquisition Control Expert"

- First definition of the FTK architecture and relative FTK simulation development.
- Acquisition of FTKsim Responsibility.
- June 2008 – PHD in Physics (grade excellent). Title: "Rare decays of B mesons and baryons at the Tevatron and the LHC", Supervisors Prof. G. Punzi and Dr. M. A. Ciocci.

Post-PhD Position, Pisa University Department of Physics (from November 2007 up to now)

- November 2007 - June 2008, Contract with the department to continue (a) the FTKSim design to evaluate the FTK performances, (b) the creation of new algorithms when the simulation showed important performance limitation, (c) CDF analysis of B hadronic channels, (d) CDF data taking.
- July 2008 – July 2010, INFN-University co-funded Post-PhD position with the same charges of previous period.
- September 2008 - June 2009, teaching Assistant University of Pisa, Department of Engineer - Physics Course (bachelor's degree).

Other work experiences

- 2001 - 2002 Occasional collaboration for the development of web-sites.

Personal skills and competences

- **Courses** – INFN Grid School, October 6-9, 2008

Operative Systems, Programming languages and Scientific Software

- Good knowledge of Windows systems from version 9x to the latest version.
- Very good knowledge of GNU/Linux systems, derived by RedHat and Debian management systems. Good ability as user and as administrator, with knowledge of the common tools used for these tasks: shell scripting in BASH and TCSH, grep, AWK, and other tools.
- Very good knowledge of the C/C++ language and other common languages: Java, Python, Perl, VisualBasic and FORTRAN, used usually in conjunction with the most common scientific libraries.
- Knowledge of advanced programming schemes like multi-threading programming.
- Good knowledge of debugging and code testing tools: GDB, Valgrind and profiling software.
- Very good knowledge of languages used to create documents and to present results in different formats: LATEX, PHP, HTML, XML, and CSS. Good knowledge of Java-Script, used to build web-sites using AJAX technique.
- Advanced user of the ROOT framework
- Participation to its development, since the version 5.12, adding new features and correcting bugs.
- Basic knowledge of the simulation framework GEANT4, of the gaseous detector analysis software GARFIELD and of the GRID environment.
- Good knowledge in the use of Mathematica and the statistical analysis framework R.
- Good knowledge of the common software bundles for personal productivity: Windows Office and Open Office.

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

I describe in the following my specific activity in the three most important areas of my work (three major achievements).

(a) I made a very important contribution to the analysis of charmless decays of B-hadrons. In this analysis eight different decay channels (decay modes of B^0, B^0_s, and Λ^0_b hadrons, decay products in the two body charmless decay, referred also as $B \rightarrow hh$) have mass peaks that overlap one another; for this reason the signal separation needs the use of a very refined statistical analysis that combines kinematics and particle identification, exploiting the very good CDF mass resolution. The decay modes are extracted using a maximum likelihood fit with 5 input variables: the candidate mass in the two π hypothesis, the momentum of the tracks, and the energy loss in the central drift chamber for each track. With the increase in the data sample collected by CDF, the possibility to observe the rarest channels is enhanced. To exploit this opportunity we need a precise knowledge of the mass line shape for each decay signal. This knowledge increases the power to separate a rare signal lying in the tail of the more abundant decays. I studied in depth the discrepancies in the b-meson mass distribution between the CDF detailed Monte Carlo and the data. The study showed that these differences were due to the soft-photons emitted in Final State Radiation, an effect not included in a reliable way in the detailed Monte Carlo. I developed a new parametric Monte Carlo which had the same quality in the mass line shape and other kinematics distributions used in the analysis, and offered some additional features. In particular this new tool was faster than the detailed Monte Carlo, and it was possible to add the FSR effect using recent analytical formulas. I implemented a technique that reduced the impact of FSR uncertainties from about 5% to less than 1%, which improved the statistic significance of rare decay modes, in particular for the previously unseen B^0_s->K π mode. My tool has become a standard CDF tool and was used also in other analyses sensitive to the mass line shape, as in the B→DK analysis, or in the B→μ μ analysis where the B→hh modes are a physics background.

The mass templates produced with this tool, in fact, had better agreement with the data than the CDF Monte Carlo. It was included in the B→h+h− analysis update for the 1 fb^{-1}, where for the first time the $B^0_s \rightarrow K^-\pi^+$ and Λ^0_b charmless decays were observed, and it was also used in other analyses. Using the B→hh analysis framework then I finalized the measurements of the branching fraction and CP asymmetry for the charmless Λ^0_b decays: $\Lambda^0_b \rightarrow p\,\pi^-$ and $\Lambda^0_b \rightarrow pK^-$. These are the first observations and measurements for these decay channels and are the most original part of my PhD thesis. The Λ^0_b analysis with respect to the $B^0_s \rightarrow K^-\pi^+$ analysis required me to make many modifications. Taking into account the different production mechanisms of the Λ^0_b, I defined a different set of analysis cuts to reduce the systematic uncertainties. For this reason I needed to recalculate all the probability distribution templates and to perform a different set of checks to validate the fit results. The decay of spin 1/2 and the presence of a proton (anti-proton) in the final state necessitated: (a) taking into account the impact of the polarization in the systematic uncertainty, (b) calculating the related detector efficiency and corrections. I carried out these measurements; I presented and defended them in the collaboration up through the process where they were approved as official CDF results.

This work is documented in many internal notes: *"A Fast Monte Carlo for generation of accurate kinematics templates of non-leptonic B and D decay"*, G. Volpi, CDF-Note 8800; the work on the two-body charmless decay modes, important for validating effective theories and excluding beyond standard model theories, is documented in: "*Measurement of the efficiency ratio epsilon(K-π+)/epsilon(K+π-) from D0→Kpi decays*", M.J. Morello, G. Punzi, G. Volpi, CDF-Note 8463; "*Branching Ratios and CP asymmetries in B→hh decays from 1fb-1*", M.J. Morello, G.Punzi, D. Tonelli, G. Volpi, CDF-Note 8464; "*Measurement of the CP-violating asymmetry in $\Lambda_b \rightarrow p\pi$ and →pK decays using 1/fb*", M.A. Ciocci, M.J. Morello, G. Punzi, D. Tonelli, G. Volpi, CDF-Note 8992. I presented my analysis and I was chosen to represent CDF at the conferences [1], [2], [3], [4], [5] listed below. The results were published in a., and c. of the list below. The tools I developed were important for all the publications in the Physical Review listed below.

(b) In the framework of the FTK R&D I worked to evaluate the FTK impact on rare channel studies in ATLAS. The application of the SVT idea in ATLAS showed some important new issues and challenges, due to the larger complexity of the ATLAS inner detector geometry, the larger number of input channels and the higher efficiency required for this "second generation processor". First of all I had an important role in the development of the whole processor simulation (FTKSim) that is able to reconstruct fully simulated events in ATLAS (Athena). I introduced algorithms to understand and solve problems that arose, i.e. majority logic, ghost-track handling, and new features needed because of the different geometry with respect to CDF (i.e. silicon module overlap, detectors highly segmented along the beam direction, etc..). With FTKSim it is possible to estimate the number of tracks needed to produce the AM pattern set and the main processor parameters needed to evaluate the size and cost of the hardware. It is also possible to evaluate the tracking and timing performances. The preliminary results showed that the system can reconstruct all three-dimensional track parameters with a resolution and efficiency very close to off-line performance, but with a much greater speed than any CPU based algorithm. I used FTKSim to study the physics case for B0s→μμ. Preliminary results, (presented by me at IEEE RT07, see .6 below) showed that we can increase the trigger acceptance by a factor three or better using FTK in ATLAS. I also worked to understand the impact of FTK on b-tagging performance at L2 developing a trigger to select the calibration sample Z→bb. The very interesting results reported in ***"Study on Z->bb measurement"**, A. Annovi, I. Vivarelli, and G. Volpi, phys-pub-2006-006,* showing that even at low luminosity it will be possible to use this calibration sample to monitor the b-jet resolution and energy scale.

(c) The FTK work is based on the solid experience gotten with data taking and trigger studies related to the use of SVT for B-physics. I was Acquisition Control Expert (ACE), a very important role in the CDF data-taking shifts in the control room which allowed me to acquire knowledge about the very complex data acquisition and trigger system in a hadron collider experiment. The ACE, in fact, is responsible for the data taking (running the entire trigger and data acquisition systems). I also developed software for SVT monitoring and I participated in the definition-study of triggers for B-physics: in CDF there is a wonderful continuity between hardware design, continuous trigger upgrades, criteria definitions, checks of data efficiencies and background rates, and analysis of signals. The Two Track Trigger was the most important for my B-physics samples. It is very powerful: events with at least two tracks with large impact parameter (IP) and P_T above 2 GeV/c are selected. The invariant mass distribution is reconstructed online using the selected track pairs with large IP and the K_s and D^0 peaks are observed in a single run. They are so clean that we monitor the track efficiency run by run using the D^0 signal reconstructed on the fly. The requirement of large IP tracks reduces the level of background by several orders of magnitude, while keeping the efficiency for the B→hh signal at a few percent level. The purity of the selected sample is enormously increased.

Finally I also provided software for the GigaFitter (GF) project. I participated in the GF physics case study using the SVT simulation and I studied the pattern banks and the fit constants to be used with the new device in order to increase the SVT global track efficiency. My SVT work is documented in the publications .k and .l.

Moreover, our efforts to expand the use of our Supercomputers outside HEP are producing the first results: I will present the use of the 2-D clustering algorithms for real time image reconstruction at the conference Imaging Technologies in Biomedical Sciences (*ITBS 2009,* see conference 8. below).

Results in the form of funded projects, publications, patents, reports, invited participation in conferences etc., taking into account the level of experience.

CONFERENCES WHERE I PRESENTED MY WORK OR REPRESENTED MY COLLABORATION

1. ***"Measurement of Branching Fractions and A(CP) of the Λ^0_b->pπ and Λ^0_b->pK Modes at CDF II"***, *APS April Meeting, Jacsonville (Fl, USA) April 14-17 2007;*
2. *"**Measurement of Branching Fractions and A(CP) of the Λ^0_b->pπ and Λ^0_b->pK Modes at CDF II"** presented at annual meeting of the Italian Physical Society (Società Italiana di Fisica, SIF), Pisa (Italy), September 24-29 2007*;
3. ***"The Fast Track Processor Performances for Rare Decays at the ATLAS Experiment"***, *IEEE RT07, Batavia (Il, USA) April 29 - March 2 2007*, published on IEEE TNS [i];
4. ***"Rare and Charmless decays of b-hadrons at CDF"***, *IFAE 2008 Bologna (IT), March 26-28 2008*;
5. ***"Rare hadronic b-decays at CDF II"***, *Incontri di fisica del b, Cagliari (IT), April 3-4 2008*;
6. ***"γ from $B^0_s \to h^+h^-$"***, *5th CKM International Workshop, Rome (IT), September 9-13 2008.*
7. ***"Rare charmless decays at Tevatron"***, *IFAE 2009, Bari (IT), April 15-17 2009.*
8. ***"The Fast Tracker Architecture for the LHC baseline luminosity"***, *EPS 2009 (Krakow, Poland), July 16-23 2009*;
9. ***"A fast FPGA-based clustering algorithm for real time image processing"***, *ITBS 2009 September 13-16, Milos Island, Greece.*

PUBLICATIONS

Since January 2006 I am on the CDF collaboration author-list. There are about 150 publications. Here are those where my contribution was important and the publications related to SVT and FTK:

a. ***"Rare and charmless decays of b- and c-hadrons at CDF",*** By CDF Collaboration (G. Volpi *for the collaboration*). **Nuovo Cim.123B:818-820,2008***;*
b. ***"Search for the Decays $B^0_s \to e^+ \mu^-$ and $B^0_s \to e^+e^-$ in CDF Run II",*** *CDF Collaboration* ***Phys.Rev.Lett.102:201801, 2009;***
c. ***"Observation of New Charmless Decays of Bottom Hadrons",*** *CDF Collaboration* ***Phys.Rev.D79:011104,2009;***
d. ***"First Flavour-Tagged Determination of Bounds on Mixing-Induced CP Violation in B^0_s ---> J/ψφ Decays",*** *CDF Collaboration.* ***Phys.Rev.Lett.100:161802,2008***;
e. ***"Search for $B^0_s \to \mu^+\mu^-$ and $B^0_d \to \mu^+\mu^-$ decays with 2fb^{-1} of p anti-p collisions",*** *CDF Collaboration.* ***Phys.Rev.Lett.100:101802, 2008;***
f. ***"Observation of B0(s) - anti-B0(s) Oscillations",*** *CDF Collaboration.* ***Phys.Rev.Lett.97:242003,2006;***
g. ***"Measurement of the Λ^0_b Lifetime in $\Lambda^0_b \to J/\psi\, \Lambda^0$ in p anti-p Collisions at s**(1/2) = 1.96-TeV",*** *CDF Collaboration.* ***Phys.Rev.Lett.98:122001,2007;***
h. ***"First observation of heavy baryons Σ_b and Σ_b^*",*** *CDF Collaboration.* ***Phys.Rev.Lett.99:202001,2007;***
i. ***"The Fast Track Processor Performances for Rare Decays at the ATLAS Experiment".*** E. Brubaker et al. *RT2007-PS2C003, Apr 2007. Presented by me at 15th IEEE Real Time Conference* 2007 (RT 07), *Batavia, Illinois, 29 Apr - 4 May 2007. Published in* ***IEEE Trans.Nucl.Sci.55:145-150,2008.***
j. ***"A hardware track finder for the ATLAS trigger",*** A. Annovi et al. . *Published in* ***Nuovo***

Cim.123B:981-983,2008;

k. ***"The GigaFitter for Fast Track Fitting Based on FPGA DSP Arrays"**, 2007 IEEE Nuclear Science Symposium Conference Record, N43-1, page 2115-2117;*

l. *"**On-line tracking processors at hadron colliders: the SVT experience at CDF II and beyond"**, J. Adelman et al., Nuclear Instruments and Methods in Physics Research A 581 (2007) 473–475*

Independent thinking and leadership qualities

Activities that reflect initiative, independent thinking, project management skills and leadership. -- I couldn't manage a real group in the past, only following single students for short periods, but I always worked with a large degree of autonomy, from the beginning of my research activity.

During my thesis I was the first to study the ATLAS μ spectrometer performance under operational conditions. The previous study was only based on test beam conditions. This raised new problems and the need to deeply change all the software tools in order to include the Lorentz-angle effect in the ATLAS MDT tube simulation. My results were used as a basis for later studies.

The PhD gave me the opportunity to complete my training in CDF, a very dynamic collaboration that strongly favours independence. CDF offers the wonderful opportunity to work on real data and many different analyses where leadership can be developed, since each one has its own issues to analyze. I faced many extremely challenging problems related to sophisticated data analysis. I made an important, original contribution to the knowledge of the detector performance, allowing higher precision in the measurement of rare decay modes.

Also in the FTK collaboration I was largely independent and able to solve a lot of specific problems. In particular my contributions were focused on the development of the track-fitting algorithm and in the study of the removal of duplicate tracks. I developed so much software and became such a simulation expert that I was chosen to be responsible for the FTKSim package.

The potential for future development of the applicant. – I will be able to complement my strong software background with very valuable hardware experience. I will learn how to best exploit modern programmable logic. I will learn how to develop a complex electronic project from design through production. I will have to interact with industry to manage board production and assembly. I will have to request, manage and report on project funds. The University of Chicago is a perfect place to learn.

Moreover, the tracking technique we are developing for the L2 ATLAS trigger will have an important impact on the development of ideas for L1 tracking that is being considered for the SLHC phase II upgrade. The FTK experts are seen as important consultants for this new project. I will interact with the new collaboration, sharing with them my software and my experience. Even the physics case study performed for L2 at lower luminosity can be partially used for the L1 tracking physics case at luminosities 10 times larger.

Match between the fellow's profile and project

The applicant's skills and experience in relation with the proposed project. – The match is impressive. I was trained inside a wonderful experiment at the Tevatron, the largest hadron collider prior to the LHC. FTK offers me a most natural scientific continuity and challenge both (a) on the technological side in applying tracking algorithms and solving full event reconstruction in a much more complex environment and (b) on the physics side, since with the first LHC data I will be able to further develop my analysis skills that I learned at CDF doing B-physics. This analysis will be important not only for physics results, but also to make an early measurement of the silicon tracking performance at ATLAS and to check with real data the FTK studies done with simulation. The early analysis of data will provide important information on the effectiveness of the baseline and new trigger techniques.

The two points (a) and (b) are strongly coupled and since I have experience in both areas I can play an important role in FTK. In fact the technical capability of triggering on events with very high rejection factors is not sufficient to motivate their development unless it can be shown that the analysis of the data collected by these triggers is feasible and the further background rejection needed to extract the signals is achievable. Trigger upgrades are often considered "unnecessary" because exploiting the additional trigger efficiency at the analysis level is difficult. Given the high rejection factors already achieved at trigger level and the difficult hadronic environment, the reconstruction of events in the off-line stage is particularly challenging. My experience inside the Pisa-Siena group in the reconstruction of rare decay modes is good experience in the necessary offline techniques; it suggests that reconstruction of rare channels with an initial signal-to-background of order 10^{-10} at production is indeed possible.

The presence of a rich set of two-body B0/B0s/Λ_b modes in the same mass range offered a great opportunity for physics measurements, but also required sophisticated analysis methodology. The CDF invariant mass resolution and particle identification resolution are insufficient to perform an event-by-event separation of the decay modes. Therefore, a carefully optimized selection and an unbinned likelihood fit combining kinematics and particle identification was needed to extract physics measurements for each mode. CDF published the first measurement of a charmless Bs→hh mode (B0s→K+K-), opening an exciting new area, that nicely complemented the existing measurements on the B0, B+, to which CDF is adding its own contributions: new branching ratio and CP asymmetry measurements in both charmless and charmed modes are underway, with expected resolutions similar to current Y(4s) measurements.

With the increase of available Tevatron data sample and the application of increasingly refined analysis methodology, another central topic of current HEP research is getting within reach at CDF: the Higgs sector. A lot of the power in the search comes from associated boson production, WH and ZH, especially in the low Higgs mass range, which is favoured by the latest electroweak measurements. Production of di-boson pairs, which has many analogies with WH, ZH production, has already been observed at CDF, thanks to the use of a statistical optimization of the selection similar to what is done in some B analyses. The increase in luminosity is now bringing to the high-pt analyses some issues similar to those previously encountered in B physics, and the introduction of selective triggers and refined likelihood-based analysis is yielding important progress in Higgs searches.

Very-low execution time algorithm development, simulation studies and identifying new trigger strategies will have high priority at LHC as soon as the instantaneous luminosity of the machine starts to grow. Further increase of rejection power in the new trigger systems developed in this project and the very high LHC event densities call for a similar offline "reality check" to verify the feasibility of such high rejections and to develop tools adequate to these ambitious analyses. My experience in the Pisa-Siena groups covers all these issues.

In conclusion, I already have extensive knowledge of the project and the necessary techniques to develop it and extract important physics results. I have software technical skills very relevant for our proposal and I have demonstrated organization and managerial capabilities being the FTKSim responsible physicist and helping new personnel joining FTK. I have been on the project from the beginning with Pisa and I helped the growing collaboration.

Potential for reaching a position of professional maturity

The Enrico Fermi Institute organization is such that I will be strongly pushed to discuss/plan before and defend my work after. I will learn about management: supervision, organization of a team, presentation of the work in conferences. The goal coming back is that I participate in new proposals and work as referee for other group proposals. After the fellowship, I will have the competencies to attain such a position. These items will be part of my work: writing documentation, negotiations with industrial firms, financial planning and resource management. I will also participate in the effort to broaden the collaboration for new projects. The activity in USA will allow me to improve my capability for independent thinking and my managerial skills.

Moreover, I am in a very good position since I am going to work on the FTK project, where I am one of the few experts. I gained so much knowledge working in CDF and in particular in SVT, that I think it will be easy for me to have a leadership position in the future. As described in my work-plan, I plan to gain important responsibility in my home institution, Frascati. Frascati has a large and skilled group, with a solid experience in the construction of the ATLAS detector, in particular the μ chambers. I will open in Frascati a new challenging construction project and I will have a leading position in the final design and production, commissioning, and maintenance of the hardware. I also expect to lead a group made of engineers and technicians involved in the project. I will have strong support in Frascati since other groups there are strongly interested in using modern electronics and Super-Computer techniques. Students in Physics will work with me in the analysis and FTK performance evaluation for their theses. I also expect to gain a permanent position in Frascati.

Potential to acquire new knowledge

My past experience is limited to software and my activity has been based mainly in Italy. The Enrico Fermi Institute in Chicago is a wonderful opportunity for my work. Professor Melvyn J. Shochet and the Enrico Fermi Institute have worked in the CDF trigger and have been a very important part of the SVT and Pulsar projects since the beginning. The Enrico Fermi Institute is very attractive for its courses, seminars and for its research in Physics. The Enrico Fermi Institute has also a very good electrical engineering group. It has extensive experience in electronics design. Engineers in these groups have extensive experience on projects with CDF, in particular with SVT and the Pulsar project for the Level 2 trigger selection. The Argonne laboratory is also near Chicago and will offer me the opportunity to learn and interact on electronics. The

ATLAS experiment would be a wonderful environment to move my career ahead and to increase the international dimension of my knowledge. The ATLAS collaboration is much larger than the CDF one. The ATLAS TDAQ system is a very complex architecture based on several different technologies where I could easily acquire new knowledge. The FTK dedicated device is probably the most powerful but least flexible computing component of the system. I can learn the use of programmable logic, but also the efficient use of HLT processors and modern multi-core CPUS or GPUs to be able to compare the potential of different technologies.

I will start my physics studies in ATLAS in B-physics, since I want to exploit my past experience. However as the instantaneous luminosity increases I will be ready to move my refined Likelihood-based analysis to the Higgs searches that could be challenging also at LHC, especially if the SM Higgs is really light as expected.

A creative area for me would be understanding the ATLAS trigger selection criteria and analyzing their dependence on the accelerator luminosity, in order to find firmware/software optimizations. This is high-level work that starts from an understanding of the physics problems and goes all the way to the development of hardware-firmware-software solutions. A clear example is the b-quark selection at L2. The impact parameter resolution of tracks found by FTK decreases as the luminosity increases. As a consequence, the purity of the level-2 selected samples decreases and more selective b-tagging criteria may be required in the HLT farm to control trigger rates.

My final goal (and for our group more generally) is to learn as much as possible about problems of online tracking systems so we 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 more complex conditions or experiments (for example ATLAS at SLHC).

I will be able to learn which diagnostic tools should be developed during these years of data taking. All the chips we have in FTK have boundary scan capabilities and we can access information through the VME interface. We have standalone programs that check the connectivity on the boards. The acquired experience on monitoring and maintaining the system will be of great importance for more complex future applications.

We should prepare to use the latest digital electronics developments by writing algorithms in high level languages so that they can be automatically compiled into the most advanced devices at time of construction. This approach was adopted during the SVT upgrade to make the best long-term exploitation of the initial designing efforts, simplifying further developments and applications to future generation experiments.

The experience I can gain working for 2 years on the ATLAS trigger will be very important for the work I can do when I return to INFN Frascati. I will be able to evaluate the best technology to implement an algorithm or different parts of it comparing cost and performance of dedicated VLSI devices, programmable logic or CPUs. Some mixture of these technologies may be the best choice as is now the case for tracking triggers at CDF. This experience is of particular value if we consider that this kind of knowledge is substantially missing in Italy. We are experiencing a backward situation, in which electronics is so powerful that high energy experiments could easily implement real time selections at very high rates (very fast algorithms) with offline precision, but very little is done in this direction, possibly because the community is not aware of the potential of available electronics.

I will be able to disseminate to the Italian high energy physics community my experience, will be able to exploit my research results and I will be able to contribute to the future of this field.

I can apply all what I learn also outside of HEP, in any field where computing power is a real issue. I will have the possibility, as described in my work-plan for the third year, to learn about totally new fields of application like medical imaging and brain studies.

B4. Implementation (maximum 6 pages)

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

Level of experience of the outgoing host institution on the research topic proposed – The impact of the University of Chicago Department of Physics in experimental particle physics has been impressive since the institute's birth in 1893 when A. A. Michelson (Nobel Prize in 1907), the most outstanding American scientist of the time, came to Chicago. He saw to the appointment of Robert A. Millikan and Arthur H. Compton (both Nobel Prizes). Millikan's fame came from the oil drop experiment he did at Chicago, establishing in a dramatic way the discrete value of the electric charge, whose value he measured with extraordinary precision. He won the Nobel Prize for measuring the charge of the electron and providing, by means of the photo-electric effect, an experimental proof of the photon's existence. Arthur Compton came to Chicago in 1923, fresh from his discovery of the quantum nature of the scattering of X-rays by electrons, an effect which helped establish the ideas of quantum mechanics. In 1930, Compton's scientific interest and the stamp of the Physics Department shifted from precision X-ray measurements to cosmic rays. His very productive group of investigators in cosmic rays included at various times such men as Luis Alvarez, Pierre Auger, Marcel Shein, and Volney Wilson.

At the end of the Second World War, Enrico Fermi produced with his scientific team the first self-sustaining nuclear chain reaction and again established the Department as one of the leading centers of physics. Fermi's influence was very great. He was equally at home with both theory and experiment. Theoretical physics came to play a major role at Chicago. The subsequent Nobel Prizes that can be directly ascribed to Fermi's influence -- to Chen Ning Yang and Tsung-Dao Lee , to Owen Chamberlain , to Maria Goeppert-Mayer and Murray Gell-Mann -- were in theoretical as well as in experimental physics. Fermi inspired excellence in teaching and close teamwork with graduate students, providing the training of the next generation of great scientists.

A large number of discoveries and scientific contributions were made by members of the Physics Department during the following decades. Mark Inghram pioneered the application of mass spectrometers to determine nuclear constants, which led to the discovery of new isotopes. S.Chandrasekhar developed the basic theoretical framework for understanding much of stellar structure, radiative transfer, galactic dynamics, astrophysical plasmas, and the properties of rotating black holes. He received the Nobel Prize in 1983. Herbert Anderson discovered that one of the fundamental particles of nature, the proton, has an excited state. Eugene Parker predicted the solar wind, an outward flow of charged particles from the sun. John Simpson, in satellite experiments, confirmed the existence of the solar wind. He also linked the production of interplanetary deuterium and tritium with solar flares. Peter Meyer discovered the ratios of intensities of cosmic ray components, thus providing a clue to understanding the origin of cosmic rays. Yoichiro Nambu's ideas on spontaneous breakdown of symmetries have had a profound impact on the development of elementary particle physics, and he was awarded the Nobel Prize in 2008. Gregor Wentzel made important contributions to quantum electrodynamics, the gauge problem in superconductivity, and our understanding of strange particles. Robert R. Wilson built the Fermi National Accelerator, one of the most powerful instruments for probing the structure of elementary particles. The present view of particle physics, that quarks and leptons are the basic constituents of matter, has been a long time coming. Part of the basis for this view originated here at the University's Synchrocyclotron. In the 1950s Enrico Fermi, Herbert Anderson, and others found out much about pi mesons and discovered excited states of the proton. Valentine Telegdi and his students carried out many remarkable experiments on weak interactions. Later James Cronin (Nobel Laureate 1980) and several young University of Chicago physicists joined in the experiments at Argonne National Laboratory and Fermi National Accelerator Laboratory uncovering phenomena giving strong support to the matter quark-lepton view.

International collaborations (participation in projects, publications, patents and any other relevant results) – All the groups involved with my fellowship (both in Chicago and in Italy) have participated in CDF, many of them from the beginning. 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 outside the USA. Some important discoveries and measurements have been performed at CDF, such as the discovery of the top quark (1995), the most precise measurements of top and W masses, the more recent discovery of the Σ_b baryon and the observation of the B^0_s oscillations.

Both the Chicago group and the Italian FTK community in CDF, have recently joined the ATLAS experiment at LHC. ATLAS is a "virtual United Nations" of 37 countries. 2500 physicists come from more than 169 universities and laboratories and include 700 students. ATLAS is one of the largest collaborative efforts ever attempted in the physical sciences. The ATLAS detector consists of four major components: (a) inner tracker, particularly relevant for my project - measures the momentum and the trajectory of each charged particle; (b) calorimeter - measures the energies carried by the particles; (c) muon spectrometer - identifies and measures muons; (d) magnet system – it bends charged particles as function of the momentum allowing its measurement. The proton-proton interactions in the ATLAS detectors will create a huge dataflow. In order to digest this data we need: (a) the trigger system, for which my proposal is an upgrade - selecting 100 interesting events per second out of 1000 million others; (b) the data acquisition system - channelling the data from the detectors to storage; (c) the computing system - analysing 1000 Million events recorded per year.

Available facilities and their adequacy to the research project – Both Chicago and Frascati have participated in ATLAS since the beginning, well before FTK had been conceived and proposed. Chicago had an important role in the construction of the ATLAS Tile Calorimeter system, in particular for the fast readout electronics, while Frascati had an important role in the muon spectrometer construction. Both groups are involved in development of ATLAS software and in grid computing. Chicago is the site of a U.S. Tier 2 and Frascati is the site of an Italian proto-Tier 2 computing center. Both centers are entirely dedicated to ATLAS.

My project involves electronics together with analysis and the Electronics Design Group of the Enrico Fermi Institute in Chicago is superb. The role of the "eshop" is to work with students and faculty members on cutting edge electronic design helping them to design, route, build and test boards under the supervision of an electronics engineer. The eshop makes available electronic design automation (EDA) software and test equipment, enabling the users to fully simulate any part before the actual construction and test it once it has been completed. Past electronics systems designed and built in the eshop are currently being used in experiments worldwide and the Pulsar project and part of SVT belong to this list.

Also LNF in Frascati has a service for electronics development. It works for both experiments and accelerator control. Moreover, the ATLAS Frascati group has expert engineers and technicians that will collaborate on the project. For this reason the LNF management is very interested to our state-of-the-art experience that will provide a positive interaction with the local facility. Both the outgoing and return hosts are rich in instrumented laboratories for large system assembly, testing and related software development.

Capacity to provide training in complementary skills that can further aid the fellow in the reintegration period – The Chicago area is characterized by an extraordinary active University and 2 National Laboratories (Fermilab and Argonne). This favourable situation enhances the chances to acquire complementary skills. Specific trainings are organized for University staff. I find interesting: (1) **Diversity**: topics include appreciating differences related to race, culture, age, gender, sexual orientation, and ethnicity. (2) **Information Technology**: training opportunities sponsored by Networking Services and Information Technology and University Human Resources Management on desktop computing and networking technologies. (3) **Management Development** : how to supervise employees and manage ongoing departmental functions or events (e.g., meetings; strategic planning; organizational change). (4) **Personal Development**: financial planning and retirement, wellness/personal growth. (5) **Teaching and Learning**: hands-on support, training, and guidance in areas such as using the learning management system, creating digital audio and video resources, designing scholarly applications, exploring and implementing new technologies, publishing streaming video, or engaging in remote collaboration and video conferencing. (6) **Workplace Skills**: courses on written and oral communication skills, customer service, time management, and career development. (7) **SCRS Workshops**: Workshops offered to University of Chicago students on academic skills, mental health, and well-being topics.(8) **SCC Workshops:** Student Care Center Workshops with Courses on “Lung Health” and “Quick & Easy Cooking Classes”.

Available infrastructures and whether these can respond to the needs set by the execution of the project. – The project will have its execution in Chicago (Enrico Fermi Institute in collaboration with the Argonne and Fermilab Laboratories), in Frascati (LNF with the collaboration of other INFN sites, in Rome, Ferrara and Pisa) and at CERN, in the ATLAS experiment itself. The infrastructures of all these sites are excellent, in terms of space, instrumentation, contacts with industries and capability to support the fellow’s work with internal services. In particular the electronics services are extremely good in USA and Italy, as well as at CERN. They have extensive experience in electronics design from printed circuit boards to firmware for programmable devices (PLDs, FPGAs, DSPs) and to design of full custom ASICs. They can provide support of the fellow’s work ranging from technical support for modifications on printed circuit boards to providing tools for simulation and compilation of firmware for programmable devices.

The <u>European return host's</u> qualities and capabilities to absorb and make use of the experience *gained by the returning fellow should be described.* **–** As already mentioned in section B1, the USA working style and the important position at LHC of the FTK project itself (due to the fact that it covers the online tracking area, missing in low level triggers in LHC) will provide me important capabilities, very useful for my reintegration in Italy. Moreover the advanced electronics training, will provide me knowledge very uncommon in Italy, which will help me to find a good position. It is not easy to do research in Italy, since the available positions are really few and a lot of young physicists are constrained to go outside in Europe or even in the USA. I think this fellowship is the best to increase my possibilities.

The Roman area, where I was graduated, constitutes the most important HEP area in Italy and the LNF, situated south of Rome, is the largest laboratory of the INFN (national institute for nuclear physics). I expect this fellowship will maximize my possibilities of reintegration by coming back here. The LNF laboratory is organized into three sub–structures: the Accelerator Division, the Research Division and the Administration, for a total of about 380 staff members. The Accelerator Division runs the DAΦNE accelerator complex, an e+ e– storage ring, used to produce ϕ mesons at a high rate. It recently improved its luminosity with the implementation of the innovative Crab Waist idea (P. Raimondi). Three experiments, KLOE, FINUDA, and SIDDHARTA, study the ϕ decays, the charged and neutral kaon decays, the kaonic nuclei, produced when a negative kaon is absorbed in a nucleus, and the properties of any other particle produced in the ϕ decay chain. Among the most important results obtained, in the framework of the DAΦNE scientific program, we mention the measurements of Vus by the KLOE collaboration, important for verifying the unitarity of the CKM matrix and the measurement of the hadronic contribution to g-2. The measurement of the x–ray spectrum of kaonic hydrogen in DEAR and the observation of the first events from hypernucleus decays in FINUDA are also among the scientific highlights. A linear accelerator (the Linac) accelerates electrons and positrons to fill the storage rings. The very clean electron and positron beams, with variable energy in the interval between 50MeV and 850MeV, variable intensity from 1 to 10^{10} electrons per bunch, at a rate of 50 Hz, can be deflected into an experimental area, the Beam Test Facility (BTF), where also a photon–tagged beam, of variable energy, is available. The BTF facility is continuously used by internal and external users. Last year, for instance, the photon calorimeter of the AGILE satellite was calibrated using the energy tagged photon beam, and also the properties of several detectors, used by the LHC experiments, were measured.

The Accelerator Division participates to the construction of the CNAO (national center of oncological adroterapy), a 1.2 GeV proton-synchrotron is used for cancer therapy in Pavia. A free electron laser, named SPARC, is being assembled at LNF, in collaboration with ENEA. The scientific goal of the SPARC project consists in producing 10 ps electron bunches, with emittance smaller then 2 mm mrad, able to induce the self amplified green synchrotron laser light in the magnetic undulator placed downstream the electron gun. A very intense LASER, able to produce 200 TW of 0.8 micron wave length for 10 fs (the Frascati Laser for Acceleration and Multidisciplinary Experiments, FLAME) is being assembled nearby the SPARC linac. The possibility to accelerate bunch of electrons in the plasma waves produced by the light in a gaseous target will be explored. Physicists and engineers of the Accelerator Division also participate at the research and development in the field of accelerator technology. The construction of CTF3, the CLIC Test Facility at CERN, the TTFII, the Tesla Test Facility at DESY, the work for the future World Linear Collider and the study for a possible future Super B–factory as well, are part of our research program. The DAΦNE accelerator produces synchrotron radiation light used by many experimental groups. The most intense infrared light from a synchrotron source is available at DAΦNE. At the moment we have three lines running, the Infra Red line, the X ray line and the UV line, a second x-ray lines is under construction. More than a hundred users, in the contest of the European research funding TARI program, used this facility last year.

The Research Division is composed of physicists and engineers working in many experiments at LNF, at CERN (ATLAS, LHCb, DIRAC), at FNAL (CDFII), at SLAC (BABAR), at JLAB (AIACE), at DESY (HERMES), in Grenoble (GRAAL), at the Laboratori Nazionali del Gran Sasso – LNGS (OPERA, ICARUS), at Cascina (VIRGO), in space born experiments within the WIZARD program, and also, locally, searching for gravitational waves with a cryogenic bar (NAUTILUS).

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

Implementation and management of the fellowship at host institutions for <u>both phases</u> - practical arrangements that can have an impact on the feasibility and credibility of the project. **–** I will have in Chicago an office with computing capability and access to the Tier2-Tier3 computing facilities, to continue the development of the system simulation and to finalize development of the physics cases. I will be allowed to use CADs for electronic board design (Mentor Graphics software) and for chip design (Altera software). The eshop personnel will introduce me to these tools and help when necessary. I will use the laboratory for electronic tests, provided of racks with independent test stands, oscilloscopes, digital analyzer, and computers and terminals for access, control, monitoring of the available test stands. We will use standard 9U VME crates for board housing and the VME protocol for CPU-crate communication. A laptop will be available with CAD software to download new firmware directly through Boundary Scan.

At CERN, for parasitic tests of the vertical slice, we will have similar facilities, but the work will be more complex because of the interaction with the experiment. In the control room the shift team, helped by others experts, has the responsibility for the data taking. It is not possible to predict now when and how much easy will be for people working on the proto-FTK to obtain from the shift crew the capability to perform online tests. This part of the program to be executed at CERN is presently the less defined in its details.

At LNF in Frascati the same instrumentation will be available as in Chicago. The test stands and test software exploit the long experience developed at CDF. There is uniformity of standards at the two insitutions: CPU interfaces, crate organization, basic packages to develop software (a lot of software is already available), basic boards for providing data input and collection output (the Pulsar and the Merger boards developed at CDF provide the standard connections to the prototypes under test). In this way everything done in one institution can be easily repeated and checked in the other. Moreover the exchange of information between Chicago, Pisa and Frascati is very strong. We have weekly video meetings in which all the FTK institutions connect to discuss and plan the near term work.

Feasibility and credibility of the project, including work plan

Work plan that includes the goals that can help assess the progress of the project. – I participated from the beginning in the long R&D study for the FTK project, focusing onthe architecture definition and its performance evaluated by simulation. FTK is now close to approval and in 2010 the construction phase should start and last for 4 years. It will be characterized by (a) a hardware design phase, during which the final optimization will be done, especially to reduce execution time as much as possible while maintaining processor performance (b) the insertion of a small proto-FTK in the experiment to collect data in parasitic mode so that we can learn with real data about FTK timing performance and start to develop the control and monitoring software, (c) analysis of the ATLAS data to verify the FTK physics improvement, (d) testing new prototypes and their commissioning. The construction/commissioning phase will be at least 4 years.

My work, focused on software part in the past, will continue in architecture optimization through simulation and data analysis, and will be completed with strong participation in the construction, installation, and testing of the hardware that will be built in Frascati (the production of mezzanines for the 2-D clustering in the ATLAS pixel detectors).

The goals for the Outgoing phase in Chicago are:

1) Continue with the simulation studies for the final definition and optimization of the architecture, which will drive important decisions on the boards to be constructed. They can be organized in many different ways, each one offering particular advantages. These studies will also check the performance of the system at the SLHC Phase II luminosity, 10^{35} cm^{-2} sec^{-1}.
2) Learn the use of FPGAs and apply the gained experience to the 2-D clustering algorithm for pixels. Complete the design and participate in the tests. Evaluate the relative costs of the FPGA solution and a small standard cell device.
3) Interact with the ATLAS group at Argonne that will work on the Data Formatter mother board where the Frascati mezzanine will be placed.
4) Participate in the track fitting development, the Chicago responsibility, especially to transfer the Italian experience gained in the GigaFitter built for the CDF experiment in Pisa. Comparison of the FPGA computing capabilities to the new GPUs computing boards.
5) As soon as ATLAS data taking starts I will analyze the channels $B^0_s \rightarrow K^*\mu\mu$ and $\Lambda^0_b \rightarrow \Lambda_0\mu\mu$, applying my experience gained in CDF. I will be able to measure directly on data the efficiency of the baseline trigger for those channels and evaluate with FTK simulation run on real data the gain provided by FTK. Early B physics studies will provide me with a deep understanding of the performance of the ATLAS inner detector, which will be important to the success of FTK. I also will complete my studies at CDF (tails of my analysis). My choice of B physics is not driven by the importance this sector can have at high luminosity. This is uncertain now and the output of my work inside the B ATLAS group on real

data will clarify if really it can be pushed ahead in a high pile-up environment. My choice is mainly driven by the desire to apply my past experience to the new experiment. If the FTK schedule will be shorter than the accelerator schedule for high luminosity, FTK could be available at intermediate luminosities where it could have a large impact on ATLAS B physics.

6) As soon as the ATLAS experiment is stable enough in data taking to allow the Proto-FTK to be exercised with parasitic input data, I will apply significant effort to develop the software for maintenance/control/diagnostic, exploiting the SVT experience gained at Fermilab and learning all the new features of the online ATLAS experiment.

Points number (1), (2) and (3) certainly will be part of the first fellowship year, even if they could extend into the second one and even third one, since new ideas and unexpected detector or collider conditions could influence the final design and its optimization. The feasibility of points (4) and (5) is more difficult to predict since the luminosity increase at the LHC has an uncertain schedule. However I think that during my second fellowship year the probability to have enough data and to be able to install a proto-FTK in parasitic mode should be high, and even during the first year it is not excluded.

During the outgoing phase I will spend time mainly in Chicago, but also it will be necessary to spend some time at CERN in the ATLAS experiment and in Frascati-Pisa since I will be an important contact point between the two main components of the FTK collaboration, Italy and USA.

The goals for the Reintegration phase in Frascati are:

1) We hope to have at that time a final or almost-final version of the mezzanine and test it thoroughly in the vertical slice before starting production.
2) The production of mezzanines for the 2-D clustering algorithm in the pixels, handling all the necessary contacts with the industries. Depending on the LHC schedule, the commissioning and testing of the whole system could be part of the third year.
3) Analysis: completion of B-physics studies (described in point 5 of the outgoing section).
4) Use of a our processors to analyze 2-D images for other applications outside HEP: (a) we will choose a picture and we count how many times each possible 3x3 pixel pattern appears in the picture. We will store in the associative memory only the ones that appear in the frequency range defined by the conjecture of reference [Punzi & Del Viva (2006) Visual features and information theory JOV 6(6) 567] and finally we will use our processor to filter the image. We will also apply the 2-D clustering algorithm to the filtered image to find spots and analyse their shape. We will measure execution times. Effects on reconstruction quality due to bit losses in the input or different shape patterns or different pattern frequency range selections can be studied quickly in the future to provide real time input to higher level analysis systems. This would be a first step in an activity that could become important when FTK is almost ready.

The work plan includes participation in conferences and related paper production. I plan at least two technological conference contributions (IEEE or similar) in 3 years and more than two technological papers.

I plan also at least one contribution to physics conferences and the production of the related proceedings.

Work on FTK allows qualification for ATLAS membership. After one year I will be allowed to enter the ATLAS default author list and sign the full ATLAS physics output.

The work plan also includes frequent presentations of the work inside the TDAQ/Physics group and seminars to the ATLAS collaboration or Frascati high energy community. It will include also supervision/tutoring of Italian students working in ATLAS.

Arrangements made in terms of supporting the reintegration phase of the fellow providing a career development plan. – This project is a wonderful opportunity for my career. I have acquired experience in CDF on B-physics analysis and advanced online tracking techniques applied to sophisticated trigger selections, but I never had the occasion to manage a small group of people. My participation in FTK as an expert will allow me to have new important roles in FTK, in particular when I will be back in Frascati, where I will be the most expert and involved in the project. I expect that this fellowship will allow me to be the leading person in the FTK project in Frascati, to manage the related funds, to coordinate the analysis of young people in this field and to coordinate the work of one engineer and few technicians for FTK production, commissioning and maintenance. This will be very important for gaining a permanent position in Italy.

My outgoing phase will be important for broadening my experience. Even though I was deeply involved in all of the trigger studies involving both SVT and FTK R&D, my contribution was always limited to software: analysis of collected data or simulation studies of proposed architectures. I did not have the opportunity to work on hardware and the Enrico Fermi Institute in Chicago will a perfect place to learn it. Moreover the University of Chicago working style is also perfect for learning how to handle a group and a project.

Where appropriate, describe the approach to be taken regarding the intellectual property that may arise from the research project.

Inside INFN, publication on international journal is the standard way for communicating, research results. In the past we used IEEE TNS and NIM for technological publications and Physical Review Letters for Physics results.

Practical and administrative arrangements and support for the hosting of the fellow (outgoing and return host)

Practical arrangements in Chicago to host a researcher coming from another country. What support will be given to him/her to settle into their new host country (in terms of language teaching, help with local administration, obtaining of permits, accommodation, schools, childcare etc.)

The University of Chicago is the sixteenth largest employer in the Chicago metro area. It is an international, multi-ethnic community of 10,000 employees from as near as Chicago and as far as India, Nigeria, China, France, and Mexico. The International Affairs office provides guidance for international applicants.

The University is organized to provide “benefits” to the worker: (a) Continuing education opportunities, (b) Tuition support (c) Four health plan options (d) Wellness facilities (e) Programs for child care, elder care, and housing assistance (f) Domestic partnership benefits (g) help for housing in Hyde Park.

The University of Chicago offers an array of resources to help employees balance work responsibilities and everyday life, including childcare and eldercare resources, transportation assistance, and employee assistance resources.

The University is committed to working with the community and the Chicago Police Department to prevent crime and improve public safety in the university area. The University of Chicago Police Department has more than 140 professionally trained officers with full police powers to serve University students and staff, as well as community members. In addition, the University partners with the city of Chicago as well as neighbourhood organizations to improve transportation and other aspects of community life.

The host of the return phase should explain which measures are planned for the successful re-integration of the researcher. – LNF is a place where a large number of visitors attend from outside, so it is organized to host foreign physicists. Help is provided for housing and administrative problems. Moreover, the INFN central administration is actually there.

In my case practical arrangements and support for the reintegration is not an issue, since the Roman area is where I come from and where my family lives, so I am absolutely expert of all practical aspects about reintegration in Italy.

B5. IMPACT (maximum 2 pages)

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

The fellow's potential of acquiring (complementary) competencies and skills during the fellowship, their impact on the prospects of reaching and/or reinforcing a position of professional maturity, diversity and independence.

This project will allow me to increase my experience in both electronics and high energy physics and this will make my professional curriculum more complete. As an experimental physicist, in fact, 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 I will gain with the fellowship, the experience acquired developing tools for online and offline data processing will be very useful at LHC for early data studies and for long range, efficient data taking planning.

I will complete my goals working in a totally new environment. I will know many LHC physicists, not only in Italy, but also at CERN, working in direct contact with the TDAQ group. I will learn from their experience, specifically developed on the ATLAS architecture. I expect that joining my experiences on CDF data and their experience on ATLAS TDAQ will produce interesting results.

My curriculum will be general enough (electronics, advanced analysis techniques) to fit also on other spin-off projects, such as medical applications and brain simulation studies. I hope to become able to propose a project based on the experience acquired into our Super-Computer HEP activity, spreading our knowledge in new areas where computing power is a real issue.

I've already worked at Fermilab in the past, but only for brief periods. The period I will spend in Chicago will allow me to learn "the USA working style" from a very good group, staying closely and continuously in contact with them. I hope to improve my English and my communication skills.

Explain how the newly acquired skills and knowledge will be transferred from the Third Country to the return host – Italian and USA research worlds are very different in many aspects. My group (some of them have spent a lot of time in Fermilab and some time at the University of Chicago) hopes to be able to influence the Italian research style not only (a) with acquired technical knowledge on tracking systems and data analysis, which will be certainly very relevant as already explained above, but also (b) in trying to convince people that many aspects of the USA research organization would produce a beneficial impact on the Italian research. So my group favours this kind of fellowship in the USA, not only to improve the technological skills, but also to enlarge the diffusion of the "USA style" in Italy. We think that these fellowship help Italians to appreciate the beneficial effect on research of:

(a) the capability of exercising priorities, the capability to choose and focus on what is more relevant and more important. We think this helps to get important results;
(b) the flexibility of the USA research style, the capability to move towards new ideas if they appear to be very promising, without being rigidly hampered by previous established plans, when they are revealed to be obsolete;
(c) the capability to discuss deeply a new proposed project and intermediate steps of approved projects.
(d) the mobility of young researchers and the consequences on the recruitment mechanisms. In USA a researcher cannot complete two following steps of his education in the same University. This mechanism enriches the researcher and brakes local dependency mechanisms that can interfere with pure meritocratic criteria during recruitment.

Contribution to career development or re-establishment

Fellowship contribution in the medium- and long-term to the development of the Fellow's career – Even if a research career will not be possible in Italy, the fellowship will develop characteristics that will help in research institutes in other European countries or in industry. The acquired skills described above, apply to many other different fields outside HEP and will help the fellow not only initially to fine a position, but also later during his career development.

In the case of a fellow returning to research, how will his/her re-establishment be helped by the fellowship?

As already mentioned, we think that this fellowship will provide managerial and independent thinking skills that not only will improve the probability of obtaining a staff research position in Italy, but also will broadly advance my career. This is also due to the specific nature of the project, which is totally innovative, since it covers the online tracking area at very high rates, which is so far missing in the LHC environment. The specific project has also wide capability of application outside of HEP, and this characteristic increases the fellow's possibilities.

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

What is the likelihood of continuing the collaboration between the two hosts after the end of the fellowship?

I will be inserted in projects common to INFN and the University of Chicago. This is a stable beneficial collaboration which started at the beginnings of the CDF experiment (1985-86) and produced a lot of beautiful achievements.

I would like to be part of this collaboration and to reinforce it. Having mobility between Illinois, Italy and CERN, I will be an important connection in this collaboration. We planned some time ago to work together on supercomputing and microelectronics at LHC, exporting our CDF experience. We are starting now to see the results of this long standing activity.

Supercomputers like the ones used in CDF can have wide applications even outside of high energy physics. For this reason this is a research project favouring the continuation and even expansion of the collaboration.

Contribution to European excellence and European competitiveness

How will the fellowship contribute to the European excellence and European competitiveness?

Our main goal is the use of our supercomputers (upgraded with the latest available technologies) in the baseline ATLAS configuration and future more complex applications. Our asymptotic, very challenging goal is to standardize a single processor that can work on both L1 and L2 applications at future high energy physics experiments.

Interest is growing around this project: the FTK collaboration does exist for the L2 application. It is a very high level international collaboration, including USA institutions like the Chicago, University of Illinois, and Argonne Laboratory. Recently a Japanese institution, Waseda, did join FTK.

The FTK project popularity is quickly increasing in Europe and its influence on L1 tracking ideas is strong, both for the physics case and the technological developments. The interest for similar technology applied at L1 has been shown by the Italian SLIM5 collaboration first ["The associative memory for the self-triggered SLIM5 silicon telescope", the Slim5 collaboration, Nuclear Science Symposium Conference Record, 2008. NSS '08. IEEE19-25 Oct. 2008 Page(s):2765 – 2769] and is growing quickly at LHC. We think that our influence is going to increase resulting in improved physics capability of the LHC experiments.

Benefit of the mobility to the European Research Area

Describe how the proposed mobility will be beneficial to the European Research Area and explain why the mobility is genuine. Genuine mobility is considered as moving from a MS/AC to a Third country allowing the researcher to work in a significantly different geographical and working environment; different from the one in which he has already worked before.

We think the experience of our students and researcher in USA is very important under many aspects, as described above. It can really improve our Italian research organization, or even society.

B6. ETHICAL ISSUES

The project I'm presenting in this application doesn't have any ethical issue as confirmed by the answers in the following table.

ETHICAL ISSUES TABLE

(Note: Research involving activities marked with an asterisk * in the left column in the table below will be referred automatically to Ethical Review)

*	Does the proposed research involve human Embryos?		NO
*	Does the proposed research involve human Foetal Tissues/ Cells?		NO
*	Does the proposed research involve human Embryonic Stem Cells (hESCs)?		NO
*	Does the proposed research on human Embryonic Stem Cells involve cells in culture?		NO
*	Does the proposed research on Human Embryonic Stem Cells involve the derivation of cells from Embryos?		NO
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	YES	

*	Does the proposed research involve children?		NO
*	Does the proposed research involve patients?		NO
*	Does the proposed research involve persons not able to give consent?		NO
*	Does the proposed research involve adult healthy volunteers?		NO
	Does the proposed research involve Human genetic material?		NO
	Does the proposed research involve Human biological samples?		NO
	Does the proposed research involve Human data collection?		NO
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	YES	

	Does the proposed research involve processing of genetic information or personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?		NO
	Does the proposed research involve tracking the location or observation of people?		NO
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	YES	

	Does the proposed research involve research on animals?		NO
	Are those animals transgenic small laboratory animals?		NO
	Are those animals transgenic farm animals?		NO
*	Are those animals non-human primates?		NO
	Are those animals cloned farm animals?		NO
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	YES	

	Does the proposed research involve the use of local resources (genetic, animal, plant, etc)?		

	Is the proposed research of benefit to local communities (e.g. capacity building, access to healthcare, education, etc)?		NO
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	YES	

	Research having direct military use		NO
	Research having the potential for terrorist abuse I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	YES	NO

ENDPAGE

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PART B

"ARTLHCFE"