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PEOPLE
MARIE CURIE ACTIONS

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

PART B

“POTERE”
”Precise Online Tracking in European Research Experiments

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B1. RESEARCH AND TECHNOLOGICAL QUALITY (maximum 8 pages)

Research 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: 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 analysed at LHC.

At the same time R&D at the technological frontier will be pursued for SLHC, since the detector's occupancy, already impressive today, will increase with the upgrades. The observation of interesting events will be more complicated than in the past. Not only they are rare and hidden in an extremely large background, but the single event will be confused by many overlapping soft events (pile-up). Let's compare the Tevatron (the previous generation hadron collider at Fermilab, Chicago) and LHC machines to explain the increase of event complexity and, as a consequence, of the detectors. The CDF collision rate (one of the two p-pbar experiments at the Tevatron) is ~2 MHz and at the instantaneous luminosity (ILum) of 3×10^{32} cm^{-2} sec^{-1} the average number of soft interactions per bunch crossing is 6 (396 ns bunch spacing). The LHC environment will be more demanding: a bunch spacing of 25 ns at high ILum (10^{34} cm^{-2} sec^{-1}) produces ~25 pile-up interactions. The SLHC could have a pile-up of hundreds of events at the ILum of 10^{35} cm^{-2} sec^{-1}.

Tracking devices play an essential role fighting against so high densities of particles, in particular the Silicon devices, the preponderant tracking technology today. On the other side the electronics required to process the detector signals is taking an important role. Implementing the most powerful selections in real time is 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 tracking issues at trigger level. We can exploit a very important advantage: 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. - The CDF experiment has been the best of the state-of-the-art for hadron collider triggering . It had a strong tradition in this field, since a large trigger part was implemented with dedicated hardware, and was operational for many years, constrained to work within very short latencies (few μs). It was upgraded during the 20-year CDF life, to exploit technology advances.

The hadron collider requires a multi-level trigger as 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 with an output rate of~1 kHz for both. The Level-3 (L3) is performed by CPU farms, which write to tape about 100 events/s (at LHC L2 and L3 are called High Level Trigger, HLT).

Very powerful devices are now available in CDF, among them the Silicon Vertex Tracker (SVT). It is the most powerful trigger processor operating at a collider so far and it is a perfect baseline for our project. I was part of the team that worked on it and my return host institution, Pisa, 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 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 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 using lepton identification. The online reconstruction of secondary decay vertices greatly increase the b-quark identification efficiency and allow collecting otherwise inaccessible hadronic decay modes. The hadronic decay modes available at CDF determined the quality of the CDF B^0_s mixing measurement. Also for high-P_T physics CDF successfully used purely hadronic channels in Higgs searches (Hbb→bbbb), 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 SVT 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 at e^+e^- colliders. 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 ILum and to be extended at RUN IIB with ILum approaching 3×10^{32} cm^{-2} sec^{-1}. SVT reconstructs all tracks with P_T> 2.0 GeV/c with the maximum spatial resolution allowed by the silicon vertex detector. We hope to build on the success of SVT a second generation processor, Fast Track (FTK), much more advanced to cope with the extreme complexity of the LHC new detectors and the extreme working conditions of the new 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 (Standard Model or SUSY) searches

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 $\sigma(\varphi_0)$=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 effective in rejecting fake tracks even in very crowded conditions. FTK is more than 90% efficient for μ and more than 80% 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 (σ(IP)=35 μm, $\sigma(1/P_T)$ = 0.3 % and $\sigma(\varphi_0)$=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 today is flexible enough to successfully replace the CPUs even in high resolution computations. A coarse resolution pattern recognition, however, does not profit much from CPU flexibility. A large fraction of the CPU time needed to reconstruct HEP events is wasted in data sorting with a lot of random accesses to a large storage containing all the data. By contrast, the AM performs the most CPU intensive part of the pattern recognition (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, 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 was unsuitable for the complexity of the LHC tracking . 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 programmable devices available on the market (FPGA). Commercial FPGAs allows easy development and update of the project. It is also easy to test and debug the prototype. Programmable chips are 100% tested at the factory. System performance can be fully simulated. Boundary-scan 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 an extremely high “pattern” density, a standard-cell ASIC can be a very good compromise between the easy FPGA design and the full custom ASIC logic density. To minimize the human and monetary investment, the circuit description uses high-level languages, independent of the hardware substrate and compatible with an easy recompilation into standard-cell chips. We developed the new AM as a standard-cell chip. It played a key role in the upgraded SVT and it was the baseline for FTK.

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 called Data Organizers, DOs. Post-processing includes (a) the track fitting, TF and (b) duplicate-track cleanup, called Hit Warrior (HW). FTK needs 128 Processing Units (PUs), each one made of a 9U VME board and an AUXiliary (AUX) card on the back. Each PU contains 10 Millions pattern AM on the front board and 4 DOs, 4 TFs and 4 HWs on the AUX board. One of the most important function is the TF, which refines the candidate tracks in order to determine the track parameters with the full detector resolution. It uses methods based on local linear approximations and learn-from-data techniques for online misalignment corrections. The fit calculation consists of many scalar products. Our experience in SVT & FTK shows that the approximations introduced for speed do not significantly affect the fit performance.

Upgrades to the CDF trigger have been necessary as the Tevatron instantaneous luminosity increased producing large pile-up. The more complex events require more trigger processing time, in particular the track trigger, reducing the amount of data CDF could 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 whose design philosophy 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 PULSAR has been used in many applications, even outside CDF. Our goal for FTK is to exploit as much as possible this idea of a standard board used in many applications: 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, (GF), a very new track fitter, a good starting point for the FTK fitting needs. The GF 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 containing memories for a total of several Mbytes, and hundreds of 18x25-bits multipliers and adders (DSP arrays) (500 MHz clock). 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).

Information on interdisciplinary / multidisciplinary aspects of the proposal. - As a spin-off of our online development activity, we would like to use our crate of electronics with the Associative Memory along with all FPGA ancillary logic for applications outside HEP:

(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. We propose the reduction of image processing execution time exploiting the computing power of parallel FPGAs arrays . We could use our online 2-D clustering algorithm devised for cluster reconstruction in the ATLAS pixel detector to find clusters of contiguous pixels above a programmable threshold and to process them to produce measurements that characterize their shape. We can measure the spot size, but also 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", designed to be implemented with FPGAs or cheaper custom electronics.

(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 challenging. The most convincing models that try to validate brain functioning hypothesis are extremely similar to the HEP real time architectures. A multilevel model seems appropriate 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 selecting for higher-level processing and long-term storage only those input data that match a particular set of memorized patterns (dramatic reduction). I will use an AM-based processor for a hardware implementation of fast pattern selection/filtering of the type studied in these human vision models (see the work plan in section B4 for a more detailed description) taking from there instructions to choose the "meaningful" or "relevant" info to be selected for higher level processing.

Appropiateness of research methodology and approach. - 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 trigger selections based on FTK tracks and new analysis on collected data to confirm the advantages predicted by the FTK use.

A) Dedicated trigger hardware usage has been recently reduced at LHC, in favour of large, commercial CPU farms to reduce the risks associated with it. 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 many times the same hardware (Pulsar) and same procedures, 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. We will follow the same procedure developing FTK and gradually introducing its use in ATLAS. 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. The LHC time schedule is uncertain producing uncertainty on the FTK schedule. FTK optimization can be longer or shorter depending on the experimental needs and the rate of funding. In any case I include in the following list the critical items concerning incoming years, they are relevant to understand the system's critical points.

Determine the optimal size of the AM system as a function of ILum: 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 for any luminosity by optimizing with regard to the size of the system and event execution time. FTK will grow with the LHC ILum.

Test, commissioning - To understand system issues and develop the needed control software, we plan to start early a parasitic commissioning of a small proto-FTK, able to reconstruct tracks inside a tower of the 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 but small (operating on a detector slice). While the new processor is designed for the most demanding LHC conditions and exploiting the best technology, we want to use already existing prototypes, developed in the past for CDF and Atlas, for our vertical slice. The EDRO board (Event Dispatch and Read-Out) receives on a clustering mezzanine (able to calculate the pixel and SCT cluster centroids) detector raw data on S-links. Initially they will be produced by a "pseudo front-end" (a CPU). The clusters are transferred to the AM board that finds roads, to be provided back to the EDRO. Initially the EDRO delivers back to the CPU the found roads using an S-link connection. In a second step the EDRO will have also the capability to associate roads with their internal clusters (DO function) to be provided to the TF that will be the GigaFitter taken by CDF. Our goal is to take the first data before next long shutdown.

B) The *vertical slice* will be a powerful tool for software development. We already had a complete set of software tools for CDF. We are learning adapting our system to the new experiment's needs. The vertical slice will provide early interaction between us and ATLAS. We will test all the new prototypes and important features before production begins and make any needed change.

C) FTK has a strong physics case We will verify with data the expected physics gain. We have shown that even single high Pt lepton triggers get in trouble into high pile-up conditions. They rely traditionally on calorimeter isolation to suppress backgrounds from real or fake leptons in hadronic jets. At high luminosity, with high pile-up calorimeter energy, this strategy deteriorates. If the isolation threshold is kept low for good background rejection, the lepton efficiency drops. If the threshold is raised, lepton efficiency is maintained, but at the price of decreased background rejection. An alternative strategy is to apply track-based isolation. For tracking, unlike calorimeter deposition, the pile-up and hard-scatter particles can be separated. We analyzed a track-based isolation using only FTK tracks that have a z0 close to that of the lepton candidate. Since QCD-produced b-bbar pairs and light-quark jets rates are much higher than those for isolated μ processes, it is critical to suppress them while maintaining high efficiency for isolated μs.

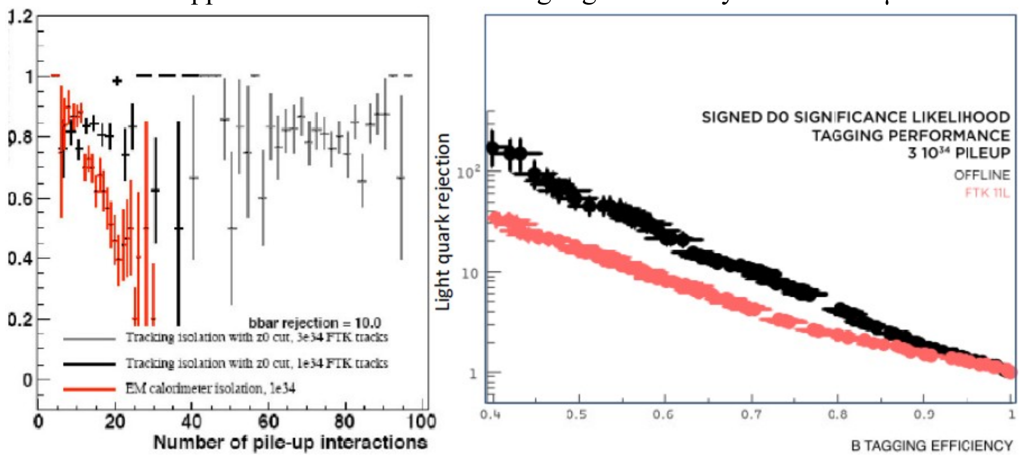

Figure 1: (a) The W→ μ efficiency using FTK track isolation (black) or EM calorimeter isolation (red) vs. the number of pile-up interactions. (b) The light-quark rejection vs. b-jet ε for offline (black) and FTK (red).

We set cuts so that the trigger rejection factor for bb events is 10. Fig. 1.a shows the isolated μ trigger efficiency as a function of the number of pile-up interactions (3×10^{34} cm^{-2} s^{-1}) using only EM calorimeter isolation (red points). The trigger efficiency quickly deteriorates with increasing pile-up. It is the same when the EM cell energy threshold is increased by a factor of two. Using FTK tracks to calculate the track-based isolation yields good trigger efficiencies for W→ μ events (black points). The efficiency as a function of pile-up is constant for a large number of pile-up events using FTK tracking (up to 100 pile-up events).

Other reasons for early track reconstruction is selection of events containing third-generation fermions, either

a b quark or a τ lepton. The level-1 trigger selects a generic jet for the former, a narrow jet for the latter. In either case, there is enormous background from QCD jets. Discrimination of the signal relies in large part on track information – in b jets the presence of a secondary vertex, in τ jets an isolation region devoid of tracks surrounding a signal cone with no more than 3 tracks. The FTK goal is to provide high efficiency on real objects and high rejection power on QCD fakes at very high event input rates, opening access to new phase space regions (low Pt b-jets and τ-jets) not accessible for the baseline architecture. High-quality FTK performances are provided for b-jets tagging. The figure 1.b shows the inverse of the probability to tag a light-quark jet as a b jet versus the b-tagging efficiency for WH events with 0 pile-up and 3×10^{34} pile-up. The τ algorithm based on FTK tracks is able to identify τ-jets in vector boson fusion qqH events (H mass=120 GeV, decaying into two hadronic τs) with an efficiency roughly 50% for 1-prong (one single track in the signal cone) and 60% for 3-prong decays (2 or 3 tracks in the signal cone) and efficiency on fake τs from QCD of 2×10^{-3} at a baseline ILum (10^{34} cm^{-2} s^{-1}). Good performances are maintained also for SLHC luminosities: roughly 30% for both single and triple prongs at 3×10^{34} cm^{-2} s^{-1}. The efficiency on QCD fake τs would be below 5×10^{-3} for single prongs and $\sim10^{-3}$ for triple prongs.
Other important examples of CPU-intensive track usage : (1) primary vertex, beam spot identification, (2) isolated heavily ionizing particles and (3) B-physics events, where final state hadrons have to be found outside of the specific regions identified by L1 objects (Regions of Interest, ROIs). We will perform these algorithms also with the vertical slice : (a) identification of the high-PT primary vertex and leptons (e and τ), including the track-based isolation. We will study its impact on Di-boson samples. (b) search of high ionizing particles requiring clean clusters in the pixels, characterized by high energy release. (c) $B\rightarrow K^*\mu\mu$ to demonstrate FTK's capability in *B* physics, to increase the acceptance.
As soon as the vertical slice will be large enough we will select a few processes to demonstrate the capability of FTK in complicated events. These will include $Z\rightarrow bb$ for a calibration channel, to be prepared for $Hbb\rightarrow 4b$'s for events whose distinguishing characteristic is multiple secondary vertices. and $Z\rightarrow \tau\tau$ to be ready for vector boson fusion production of Higgs decaying to τ-τ to quantify the hadronic τ capability.

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, 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 luminosity increase and to foster the use of these powerful online processors to more complex future applications. New and outstanding 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. 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 hits from the plethora of silicon data due to the low PT 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 HEP 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 was considered impossible, before the FTK proposal, 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 FTK proposal had a large impact on the ATLAS TDAQ community. The goal of this research is to continue 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 able to save isolation criteria in a environment where no object will be seen isolated in the calorimeter. FTK triggers will be also sensitive to secondary vertices and complex structures like τs.

The FTK strategy has a particularly relevant impact now that the LHC community is touching the effect on physics of very high pile-up conditions, and is also considering the design of new architectures for the SLHC upgrade. The CDF experience with data, in particular the online tracking at CDF and the FTK R&D project, had already a significant impact on the discussion of future architectures.

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

Outgoing host - *U. of Harvard*: with a rich history and a dedication to the pursuit of excellence, Harvard University offers unique learning experiences across a broad spectrum of academic environments. I will work at Harvard University's Laboratory for Particle Physics and Cosmology (LPPC). The LPPC provides computing facilities for data analysis, engineering support for detector R&D, and shops for the fabrication of detectors and their readout systems. While their educational efforts are primarily in graduate education, undergraduate students also work on projects at the LPPC. The faculty group leading the LPPC research program at Harvard includes 6 members.

The LPPC facilities are available to all the groups on an equal basis. Their engineers and shops are capable of designing and building state of the art detector systems and their associated readout electronics. They have produced both prototypes for detector R&D as well as complete major systems for all of their groups. Examples of projects completed in the machine shop include: the CDF Central Tracker Upgrade, CDF Central Muon System Extension, a redesigned Interaction Region for CLEO, and the NOMAD Hadron Calorimeter. They produced the ATLAS Muon Drift Tube chambers. The electronics shop has produced readout electronics for most of our detectors, most recently the CDF and CLEO silicon vertex detectors and the front end electronics for the MINOS far detector, and a tracking trigger upgrade for the BABAR detector. They have just completed the readout system for the ATLAS muon detector and have begun work planning the LSST and NOvA. In addition to engineering and shops, LPPC has workstations, personal computers, and associated peripherals which are available to all the groups for data analysis, documentation, and communication with collaborators. A video conferencing system also exists at LPPC for remote participation in meetings at the accelerator labs or at other universities.

Return host - *Department of Physics, University of Pisa*. In the Pisa Department of Physics the most large activity is dedicated to the study of the fundamental constituents of matter. It 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 are developed both in its own laboratories and in collaboration with the world of industry. These activities are conducted in close collaboration with the *Istituto Nazionale di Fisica Nucleare* (INFN) that is a major player in international HEP research. The University of Pisa had a particular impact in hadron collider physics: it strongly contributes to both Atlas and CMS experiments since the beginning and has been member of the CDF experiment since 1980, having played a particularly important role in the SVT project.

The CMS Tracker Inner Barrel (TIB) was designed/produced in Italy and integrated in the large Pisa infrastructures. Pisa is also ATLAS founder participating to the hadron calorimeter construction/commissioning. It has now a leading role in FTK. An important role is also taken in the ILC project (detector & machine R&D). The Heavy Flavour experiments are strongly represented both in the K and B sectors by Profs. I. Mannelli and M. Giorgi leaderships; the neutrino sector by the Chooz and Nomad collaborations, the rare decay experiments by the MEG and the proposed Na62 experiments, and gravitational wave physics by the VIRGO laboratory. A large activity is present for astroparticle physics (Glast, AMS, Cream, Magic, Antares and Nemo). All these activities are strongly supported by (a) a strong theoretical team: Prof. Barbieri and S. Strumia at Scuola Normale Superiore; Prof. Menotti for quantum gravity and Prof. Shore for the astroparticle physics sector at the University. (b) Large laboratory space are available for all different activities , (c) high-level infrastructures for electronics service (designing and production/test of boards), mechanics service (designing, developing, integrating detectors and large structures), high-technology (clean-rooms for silicon detectors with all necessary machines), computing (GRID) facilities.

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

Prof. Melissa Franklin is an experimental particle physicist and the Department Chair and Mallinckrodt

Professor of Physics at Harvard University. While working at the Fermi National Acceleration Laboratory in Chicago, her team found some of the first evidence for the existence of the top quark. Franklin was the first woman ever to gain tenure in the Harvard Physics Department. She worked in CDF since the beginning with an extraordinary energy and impact on data analysis and detector construction. Her group has always trained superb graduate and undergraduate students and post docs. She is part of Atlas now, and her group is responsible for data quality for the muon spectrometer and is a leading force in the study of the cavern background which is crucial for decision making for the upgrade to VLHC. Her group is also deeply enmeshed in three analyses, all concerning a search for the Higgs particle.

Prof. Mauro Dell'Orso has worked in CDF since the beginning and his most important impact was on trigger, in particular the SVT processor. The idea of a b-quark real time selection in the CDF experiment was born in Pisa in the 1985, from the work of Mauro Dell'Orso and Luciano Ristori. .The key idea that made it possible is the use of Associative Memories, as described above (see L. Ristori, M. Dell' Orso, "VLSI Structures for Track Finding" Nuclear Instrument and Methods in Physics Research, Volume A278). The group created in Pisa around this main idea proposed the Silicon Vertex Tracker (SVT) at CDF and got the approval. The first AMchip was debugged and validated by Mauro Dell'Orso, that found subtle rare problems and solved them. He participated actively to all phases of this project, from the test, to the commissioning to the physics case, training a lot of excellent new physicists. Mauro Dell'Orso was also one of the key persons proposing and defending the FTK processor at LHC, from its very beginning of the proposal starting in 1998. He contributed with many, very significant ideas, as for example the recent idea of "variable pattern resolution" (see Section B3 for its description)

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.
- Learning about the μreconstruction in the Atlas experiment, both online and offline, on particular learning from the Harvard group that has a large experience in this field.
- Participation to the first data taking of the FTK vertical slice and analysis of data to show the effect of the FTK track-based isolation on efficiency of important resonances. The Bosons (W and Z) will be used as benchmark.
- Capability to adapt the experience gained on "supercomputers" developed for HEP to pattern recognition problems outside HEP, such as medical imaging.
- Capability to duplicate the vertical slice at Harvard: a test stand has will be installed to be used by students at the LPPC.

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

Thanks to this fellow that guarantee me the capability to work for three years in this important project, I will gain an important role on the trigger Atlas experiment. I will profit of the knowledge of Harvard, a very advanced Institute and in particular of the work done with the Atlas Harvard group that is very expert on analysis technique, something that is missing in my curricula. Returning to Italy, or more generally to Europe, I expect to be able to find a good position in the research field I am expert. I would like to continue on the trigger issues, to have to manage a small group of people working with me for hardware production and related physics study.

Relevance and quality of additional research training as well as of transferable skills offered - Adding different/complementary scientific competencies to the fellow career. The most important scientific competence I will add to my curricula will be a deep experience in data analysis. The Harvard group is very advanced on the related techniques, while my experience on data analysis is marginal. However I will be able to gain scientific competencies also outside HEP.

Harvard is one of the world's great intellectual communities and it is enormously stimulating in many different fields. It is easy to attend at seminars and classes of extremely high interest and quality. I list just only the Nobel Prizes given to the faculty at Harvard of the last 10 years to give an idea of the interest and variety of ideas developed there.

(1) Jack Szostak, Physiology and medicine, 2009, "*for pioneering work in the discovery of telomerase, an enzyme that protects chromosomes from degrading". **(2) Al Gore Nobel Peace Prize, 2007**"for efforts to build up and disseminate greater knowledge about manmade climate change, and to lay the foundations for the measures that are needed to counteract such change".* **(3) Thomas C. Schelling Economics 2005** *"For having enhanced our understanding of conflict and cooperation through game-theory analysis".* **(4) Roy J. Glauber Physics 2005** *"For his contribution to the quantum theory of optical coherence".* **(5) Linda B.**

Buck Physiology or Medicine 2004 *For discoveries of "odorant receptors and the organization of the olfactory system".*

Also Pisa offers a lot of opportunities. The University and the Scuola Normale Superiore (SNS) find a common structure in the INFN for HEP. A large number of experiments (CDF, Babar, Atlas, CMS, Epsi, Kloe, MEG….) are present in Pisa and share experiences and structures. Training is offered for computing, electronics and others skills, seminars are offered and required.

The high-level educational capacity of the University and INFN for specific HEP items, is reinforced by the SNS and Scuola S. Anna. They offer a wide range of scientific possibilities in biology, chemistry, phyiscs, mathematics, Engineering, Life Science and even Law and Economics. The most interesting research fields that match our Super Computing research interests are (a) National Enterprise for nano Science and nanotechnology, Laboratory of Molecular Biology, Laboratory of Neuro-Biology at SNS. (b) Innovative Strategies in Biomedical Research, and Innovative Technologies at Sant'Anna. Innovative Technologies is particularly interesting since it includes the robotics and the real time laboratories in an very highly interdisciplinary program where students can specialize in four major areas of the Graduate School of Engineering, namely: (1) Bio-Robotics, including micro-engineering, biomedical engineering, bio-mimetic robotics, rehabilitation technologies and computer assisted surgery. (2) Embedded Systems, with emphasis on real-time systems and resource management. (3) Perceptual Robotics, with emphasis on telerobotics, cognitive robotics and virtual environments. (4) Telecommunications, especially referring to networks and photonic technologies.

Host expertise in training experienced researchers in the field and capacity to provide mentoring/tutoring (outgoing and return host). - The work style in the USA groups 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 best USA groups, like the Harvard one. 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 that for a long time have been very little popular in the HEP community (FTK, for example, suffered 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.

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. Here are some examples: PHD students and post-docs are in very good Universities like I. Sacco at Heidelberg, A. Belloni and P. Catastini at Harvard, S. Torre at UCL . Some of them are staff at CERN like E. Meschi, L. Moneta, some of them got a Marie Curie fellow on my same research items, like L. Sartori and S. Amerio. Many of them got a staff position at indudtries like F. Giordano at McKinsey&Company, A. Bardi at Kaiser in Livorno, G. Ferri at Novartis in Siena, P. Giovacchini, M. La Malfa, B.Simoni at STMicroelectronics S.r.l., M. Pietri at CommProve in Dublin . Many of them are staff in Italian research institutes like Donati, Gagliardi at the University, Signorelli, Annovi, Casarsa at INFN and Morello at SNS.

Harvard group trained excellent physicists that gained very good positions. In particular in the HEP and electronics field Harvard trained several people. Ted Liu, staff at Fermilab Laboratory, is one of the leading persons in FTK today. Bill Ashmanskas, who was crucial to the electronics of the SVT, is now working in medical imaging at University of Pennsylvania, Peter Hurst who is now working at Mit's Lincoln Labs, Phil Schlabach who now works in Fermilab's magnet division, Robyn Madrak, crucial to the building of the central tracking chamber in CDF, who now works in Fermilab's accelerator division.

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

Research experience

My main research activity includes subjects belonging to different fields, strongly motivated and logically connected by the main guide line of my work, which consists in convincing the scientific community of the importance of a dedicated hardware such as SVT used at CDF, for extremely fast (∼ 30μs) and high precision (i.e. off-line quality) pattern recognition at all hadron colliders. The possibility to perform high quality full on-line tracking is the indispensable ingredient for competitive physics at hadron colliders.
Since the beginning I worked on the development of tracking algorithms, their software and hardware implementation and applications in hadron collider experiments, in particular in the two experiments CDF and ATLAS where SVT had and FTK will have an important role. Section a. describes my work devoted to the study and optimization of the FTK architecture (Laurea Thesis) , Section b. describes my hardware work in CDF (Ph.D. thesis). During the same period I developed also a side project for the SLIM5 collaboration, devoted to show the importance of our pattern recognition techniques for L1 applications. This is described in section c. Section d. describes finally my responsibilities today in Atlas for the FTK project (post-doc work). Scientific results of these working periods are reported in the "Research results including patents, publications, teaching etc., taking into account the level of experience" section.

a. I developed the initial software for the simulation of the FTK processor (FTKsim) and participated to the performance studies in order to define and optimize the processor architecture for ATLAS. This simulation has been used intensively combined with the Athena, the Atlas full simulation to study the FTK physics case: b-jet and τ-jet tagging, lepton isolation (see section B1, Research Methodology). I personally used the FTKsim software to study the impact of FTK on Atlas B-physics, studying the selection of Bs meson rare decays at ATLAS, in particular the decay Bs→μμ.
b. From 2008 to 2010 I had the responsibility of the GigaFitter board, a new generation track fitter in the CDF experiment (see section B1). It was the latest upgrade of the SVT processor, the progenitor of FTK. I participated to the development of the project since the beginning up to the installation on the CDF experiment. I leaded the commissioning phase with all the necessary tests until the final approval from the collaboration. The CDF experiment has taken data with the active GigaFitter since March 2010.
c. During my Ph.D. I also took part in a R&D experiment, Slim5, that aimed to use the associative memories to build a self-triggering silicon detector telescope. It was an INFN Group 5 (technology R&D) project. The three year work (2006-2008) had the objective of improving the state of the art for self-triggering thin tracking systems for high energy physics applications. We used specifically built AM banks to be able to trigger on test beam particles not only observed by the silicon telescope but also crossing very small detectors called MAPs, whose performance studies where the main goal of the test beam. The bank has the goal to be uniformly efficient over a certain phase space where tracks must be detected. The efficiency of the bank is calculated simulating many tracks in the required acceptance and counting how many of them are detected by the bank. The better track
resolution is important in very noisy conditions since it helps to reduce the number of fake triggers (random coincidence of hits), but it requires much larger pattern banks to maintain a good track efficiency. We built a good resolution bank including only candidate tracks crossing the MAP, detector. While scintillator-based triggers where very inefficient collecting particles crossing the MAPs, our AM-based bank allowed to enrich the sample of interesting tracks crossing the involved small detectors under test. The trigger rate was reasonably lower, no deadtime was suffered for such rate, and a very pure MAPS track sample was collected in a short time. I participated to the development and test of the new associative memory board, a reconfigurable board that can work both in level 1 and level 2 trigger applications. This is an evolution of the CDF associative memory board that was designed only for level 2 applications. I was the responsible for the tracking trigger at the test beam in September 2008 at CERN, Geneva, Switzerland. I participated to the installation of the system and to the data acquisition, especially for the associative memory board.
d. I have two important tasks now in ATLAS: (a) design and validation of the new AMChip design (b) the responsibilities vertical slice (see section B1 for the description of these items).
(a) The R&D for the new AM chip (AMchip04) for FTK is an extremely important advancement step. On the technological side it is a challenging design: it uses a very advanced technology (TSMC 65 nm) compared to the one used in the past (UMC 180 nm) and it involves full custom design of a large memory

cell, along with development of control logic in standard cells. On the functional side it is very innovative since it introduces a new idea, the “pattern variable resolution idea”. Two important variables characterize the quality of the AM bank: its “coverage” and the level of “found fakes”. The coverage, which describes the geometric efficiency of a bank, is defined as the fraction of tracks that match at least one pattern in the bank. Given a certain road size, the coverage of the bank can be increased just adding patterns to the bank, while the number of found fakes unfortunately is roughly proportional to this number of patterns in the bank. Moreover, as the luminosity increases, the fake rate increases rapidly because of the increased silicon occupancy. To counter that, we must reduce the width of our roads to improve resolution. If we increase the road resolution using the current technology, the system would become very large and extremely expensive. The “variable resolution patterns” is an elegant solution to this problem. Each pattern and each detector layer within a pattern will be able to use the best resolution, but we will use a “don’t care” feature (inspired from ternary CAMs) to reduce the resolution when a lower resolution is more appropriate. In other words we can use patterns of variable shape. As a result we reduce the number of found fake roads, while keeping high the efficiency and avoiding the bank blow-up due to the improved resolution.

The main technological goal of this project is to provide a new higher density and low-power consumption chip for FTK. I am the coordinator of the detailed prototype simulation, maintaining a C++ functional description of the chip. The C++ program is able to produce extensive test vectors to validate the chip logic: both Verilog code for the test with digital simulation and test vectors for testing of the produced prototypes on a test stand. I am also responsible of the standard cell VHDL code. This code generates all the control logic and is derived from the VHDL code of the CDF AMchip. I have implemented the new functionalities of the chip and I am currently the responsible of this code and its synthesis in standard cell logic. The final chip assembly requires strong interactions between all the team members that developed different parts of this project. The full custom cells must be integrated in the standard cell logic and then the whole project must be placed and routed. The glue of the project is the global simulation. Every step must be verified by simulations, both detailed simulations of small parts of the design and global simulations with test vectors generated by the C++ code. I am the responsible for the actual “floorplanning”, “place and route” of the whole design and I will also coordinate the digital simulation efforts.

(b) I am the responsible of the vertical slice development and insertion in the TDAQ environment at CERN. I worked to export the CDF software in the ATLAS environment and I also worked for the AMboard firmware and the related control software. I am learning about the EDRO board.

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

Undergraduate studies:

- October 2004 “Laurea Triennale” (bachelor degree) in Physics, passing grade 105/110, Universita` di Pisa. Title of the thesis: “Fast Tracker: un trigger per esperimenti ai collider adronici con un processore hardware per la ricostruzione delle tracce”, advisor Prof. Mauro Dell'Orso.
- May 2006 “Laurea Specialistica” (master degree) in Physics, passing grade 108/110, Universita` di Pisa. Title of the thesis: “Selezione online di eventi ai collider adronici mediante ricostruzione delle traiettorie di particelle cariche", advisor Prof. Mauro Dell'Orso.
    - First definition of the FTK architecture and relative FTK simulation development.
    - Acquisition of FTKsim Responsibility.

Graduate studies*:*

- March 2010 PhD in Applied Physics - Universita` di Pisa. Title of the thesis: “GigaFitter at CDF: Offline-Quality Track Fitting in a Nanosecond for Hadron Collider Triggers”, advisor Prof. Mauro Dell'Orso.
    - Data taking management as CDF “Acquisition Control Expert” (2007)
    - Development of the Associative Memory trigger for the SLIM5 experiment, data taking in a test beam experiment (2008).
    - Development of the GigaFitter system for CDF's SVT upgrade (2008-2010).
    - Installation and commissioning of the GigaFitter system in the CDF experiment (2010).
    - Teacher assistant: course of “Experimental Physics” for the Bachelor in Energy Engineering (2009).

Post-doc position:

- July 2010 – July 2012: Post-doc position at the Pisa University Department of Physics for "Trigger and data acquisition systems for high energy physics experiments".
- Development of the new generation Associative Memory chip (AMchip04) inside FTK (2010).
- Coordination of the Vertical Slice effort inside FTK
- July 2011 – July 2012: CERN Associate position "Analysis of WW production in the experiment ATLAS at LHC and study of the improvement obtained with a lepton new track-based isolation trigger"

Personal skills and competences:

- 5-9 June 2008 High energy physics computing school: "V Seminario sul Software della Fisica Nucleare, Subnucleare ed Applicata", Alghero, Italia
- 12-22 August 2008 Hadron Collider Physics Summer School, Fermilab, USA

Operative systems, Programming languages and Scientific software:

- 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, sed, AWK, and other tools.
- Very good knowledge of the C/C++ language and other common languages: Java, Python, Ruby, used usually in conjunction with the most common scientific libraries.
- Knowledge of advanced programming schemes from low level software-hardware interaction to high level multi-threading and distributed 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.
- Advanced user of the ROOT framework for high energy physics analysis.
- Good knowledge of a wide range of EDA tools: Xilinx ISE, Altera Quartus, Leonardo Spectrum, Synopsys Design Compiler, Cadence Encounter, Cadence NCVerilog

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

I describe in the following my specific activity in the most important areas of my work.

a. The FTKsim software, that I greatly contributed to develop, has been used to study the FTK architecture and physics case. The results of the studies were included in the paper [P15] and in the Technical Proposal [P18]. They have been the fundamental results for the approval of FTK inside the ATLAS experiment. FTK reconstructs tracks with an offline-like quality at an event rate of 100 kHz. With FTKsim it was possible to define the dimension and cost of the processor and also the execution time of the algorithm as a function of the detector occupancy. I presented the architecture and performances of FTK at IEEE Real-Time conference 2010 [C2,P15], at ACES 2011 conference in Geneva (CERN) [C5] and at the national Societa` Italiana di Fisica conference 2010 [C4]. Using the FTKsim software package I have also defined a new trigger strategy [P22,P21] based on the selection of tracks with large impact parameter, to select efficiently the decay $Bs \rightarrow \mu\mu$. Using FTK and this new selection it's possible to increase of a factor three the amount of recorded physics events in this channel, compared to the baseline trigger.

b. I made important contributions to the CDF experiment: I participated actively to the operations spending a lot of time in control room and I provided long-standing improvements to its tracking trigger system (SVT). I was Acquisition Control Expert (ACE), a very important role in the CDF data-taking I could learn how much complex are the 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). My main task, however, was the GigaFitter development, a key element of the SVT tracker. Many important results of CDF would not have been possible without the SVT processor and its upgrades [C3, P12], especially in the B physics field: [P11, P10, P8, P9]. The GigaFitter is a new generation track fitter [P14,P13] able to perform fit computation at the rate of 10^9 tracks/sec. For this project I coordinated a group of 2 physics and 1 engineer. I was also the main developer of the firmware and the control/diagnostic software. I presented the results at TIPP09 conference [C1].

c. The Slim5 experiment required to push the associative memory to a new level of performance. The reconstruction strategy for level 1 tracks has to be planned along with the readout logic of the detector. For this reason I participated also to the integration of the ``data push'' architecture of the silicon telescope and the associative memory. During the test beam experiment of 2008 at CERN (Geneva, Switzerland) I participated to the installation of the whole system and to the data acquisition, especially for the associative memory board. For the first time the auto-triggering of a silicon telescope was allowed by the very rapid (few microseconds) observation of tracks in the detector, performed by the associative memory. I participated on the validation and analysis of data taken in the test beam [P24, P25, P23, P20, P19]. This activity for a L1 use of the AMchip has produced also proposals for LHC L1 triggers. I presented ideas for the CMS experiment [C7].

d. Concerning my most recent work in ATLAS, we have presentations and papers for both the AMchip design and the vertical slice project. The first one is object of interest not only for FTK, but also for other applications as explained in section B1. The "variable resolution idea" performances, in particular, has been recently simulated, implemented by me in the chip and submitted for publication [P26]. The vertical slice work also has been recently presented to the TIPP2011 conference [C8] and will be published on NIM.

CONFERENCES WHERE I PRESENTED MY RESULTS

[C1] S. Amerio et al. Gigafitter: Performance at cdf and perspective for future applications, 2009. 1st international conference on Technology and Instrumentation in Particle Physics (TIPP09), 11-17 March 2009, Tsukuba, Japan - **talk**.

[C2] A. Andreani et al. The fasttrack real time processor and its impact on μ isolation, τ and b-jet online selections at atlas, 2010. IEEE-NPSS 17th Real Time Conference, 24-28 May 2010, Lisboa, Portugal - **talk**.

[C3] F. Crescioli and the CDF collaboration. Trigger updates at CDF, 2008. Incontri di Fisica delle Alte Energie 2008, 26-28 March, Bologna - **talk**.

[C4] F. Crescioli and the FTK collaboration. The Fast Tracker real time processor and its impact on the □ isolation, τ & b-jet online selections at Atlas, 2010. Societa` Italiana di Fisica XCVI Congresso Nazionale Bologna, 20 - 24 september 2010 - **talk**.

[C5] F. Crescioli and the FTK Collaboration. The Fast Tracker Real Time Processor and Its Impact on the muon Isolation, τ & b-jet Online Selections at ATLAS, 2010. ACES 2011 Workshop - 9-11 March 2011, CERN, Geneva, Switzerland **poster**.

[C6] F. Crescioli and the Vertical Slice Group. The EDRO board connected to the Associative Memory: a Baby FastTracKer processor for the ATLAS experiment, 2011. TIPP 2011 Conference, 9-14 June 2011, Chicago, IL, USA – **talk**.

[C7] F. Palla, F. Crescioli, P. Catastini, M. Dell'Orso, and P. Giannetti. The CDF Associative Memory for a level-1 tracking system at CMS, 2007. IEEE-NPSS 15th Real Time Conference, 29 April - 4 May 2007, Fermilab, Batavia IL, USA **poster**.

[C8] Tipp2011 **talk**

PUBLICATIONS

Since January 2006 I am on the CDF collaboration author-list, and since February 2010 on the ATLAS author-list. There are about 200 publications. Here are those where my contribution was important and the publications related to SVT, FTK and SLIM5:

[P8] T. Aaltonen et al. Observation of New Charmless Decays of Bottom Hadrons. Phys. Rev. Lett., 103:031801, 2009.

[P9] T. Aaltonen et al. Measurements of Direct CP Violating Asymmetries in Charmless Decays of Strange Bottom Mesons and Bottom Baryons. Phys.Rev.Lett., 2011.

[P10] A. Abulencia et al. Observation of B 0 (s) -> K+ K- and Measurements of Branching Fractions of Charmless Two-body Decays of B 0 and Bs Mesons in ppbar Collisions at sqrt(s) = 1.96-TeV. Phys. Rev. Lett., 97:211802, 2006.

[P11] A. Abulencia et al. Observation of B/s0 anti-B/s0 oscillations. Phys. Rev. Lett., 97:242003, 2006.

[P12] J. Adelman et al. On-line tracking processors at hadron colliders: The svt experience at cdf ii and beyond. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 581(1-2):473-475, 2007. VCI 2007 - Proceedings of the 11th International Vienna Conference on Instrumentation.

[P13] S. Amerio et al. Gigafitter: Performance at cdf and perspective for future applications. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 623(1):540-542, 2010. 1st International Conference on Technology and Instrumentation in Particle Physics.

[P14] S. Amerio et al.. The gigafitter: A next generation track fitter to enhance online tracking performances at cdf. In Nuclear Science Symposium Conference Record (NSS/MIC), 2009 IEEE, pages 1143-1146, 2009.
[P15] A. Andreani et al. The fasttrack real time processor and its impact on μ isolation, τ
and b-jet online selections at atlas. In Conference Record of Real Time Conference (RT), 2010 17th IEEE-NPSS, pages 1-8, 24-28 May 2010.
[P16] A. Annovi et al. Associative memory design for the FastTrack Processor (FTK) at ATLAS. IEEE Real-Time 2010, May 24th - 28th, Lisbon, Portugal, 2010. To be published as Conference Record.
[P17] A. Annovi et al. The fast tracker architecture for the LHC baseline luminosity. In Proceedings of 2009 Europhysics Conference on High Energy Physics, July 16 - 22 2009. Krakow, Poland, PoS(EPS-HEP 2009) 136.
[P18] A. Annovi et al. FTK: a hardware track finder for the ATLAS trigger Technical Proposal, 2010. http://hep.uchicago.edu/ shochet/TP/.
[P19] G. Batignani et al. The associative memory for the self-triggered SLIM5 silicon telescope. In Nuclear Science Symposium Conference Record, 2008. NSS-08. IEEE, pages 2765-2769, October 2008.
[P20] S. Bettarini et al. The SLIM5 low mass silicon tracker demonstrator. Nucl. Instrum. Meth., A623:942-953, 2010.
[P21] E. Brubaker et al. *Performance of the Proposed Fast Track Processor for Rare Decays at the ATLAS Experiment*. IEEE Trans. Nucl. Sci., 55:145-150, 2008.
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Independent thinking and leadership qualities

Activities that reflect initiative, independent thinking, project management skills and leadership. – I always worked with a large degree of autonomy, from the beginning of my research activity. I had also important responsibilities.

During my Laurea thesis I had an important role on the FTK architecture study and I learned to develop a trigger for very rare Bs→μμ decays. During my Ph.D. I was the responsible of the GigaFitter project. The Ph.D. gave me the opportunity to complete my training in CDF, a very dynamic collaboration that strongly favours independence. CDF offered me the wonderful opportunity to work on real data and many different fields where leadership can be developed. I faced many extremely challenging problems during the GigaFitter design, test and commissioning. I made an important, original contribution to the data taking providing a device able to produce a high quality fit each nanosecond. The deep experience on FPGA's tools acquired during the GF development provided me a leadership position in the new AMchip standard cell design whose problems and methodologies are very similar. The experience developed on test stand diagnostic and monitoring for SLIM5, and during the GF commissioning, provided me easily a leading position for the vertical slice project. So I could start to work in ATLAS collaboration with a role largely independent

The potential for future development of the applicant. – I will be able to expand my past independency, based on my strong software and hardware background, with a very valuable leadership experience. I am responsible of a complex and ambitious program, the vertical slice, where I will learn to coordinate people from Italy, Japan and USA. It will evolve in the next 3 years overlapping perfectly my fellow. 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 CERN and the University of Harvard are perfect places 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 hardware 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. In particular I worked on data taking, trigger and online tracking optimization. FTK offers me the 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 LHC data I will be able to develop my analysis skills. 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 large experience in the first area and also I have seen many important analysis and results in CDF, 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 group in the reconstruction of rare decay modes is good experience in the necessary offline techniques.

With the increase of available Tevatron data samples and the application of increasingly refined analysis methodology, the Higgs sector has become the central topic of research at CDF. 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 and the introduction of selective triggers and refined likelihood-based analysis is yielding important progresses in Higgs searches. Recent results, as already cited, show also possible new physics in the WW sample, increasing a lot the interest for Di-boson samples. These samples will be particularly important for my work, as a benchmark for FTK performances and for physics studies. 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 group covers a lot of 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 and hardware technical skills very relevant for our proposal and I have demonstrated organization and managerial capabilities being the Vertical Slice responsible physicist and helping new personnel joining FTK. I have been on the project from the beginning with Pisa and I helped the collaboration to grow.

Potential for reaching a position of professional maturity

The Harvard Institute and the Atlas experiment organization at CERN 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. I will improve my capability to disseminate results and to present the work at conferences. The goal coming back is to be able to participate to new proposals and to 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 future 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 and CERN 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 maintain leadership positions in the future. As described in my work-plan, I plan to increase my responsibility in my home institution, Pisa. Pisa has a large and skilled group, with a solid experience in the construction of the ATLAS detector, in particular the Hadron calorimeter. I would like to open in Pisa a new challenging construction project and I will have a leading position in the final design and production, commissioning, and maintenance of the hardware. My group will be made of engineers and technicians involved in the project. I will have strong support in Pisa 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 performance evaluation for their theses. I also expect to gain a permanent position in Italy or more generally in Europe.

Potential to acquire new knowledge

My past experience has been based mainly in Italy. The Harvard Institute is a wonderful opportunity for my work. The Harvard Institute is very attractive for its courses, seminars and for its research in Physics. It has also a very good electrical engineering group. It has extensive experience in electronics design. 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 apply my knowledge of programmable logic, but also I can learn 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 channels that involve isolated high Pt leptons, since I want to exploit the impact that FTK will have on this physics. I will concentrate first on the observation of WW (Diboson more generally) events and as the instantaneous luminosity increases I will be ready to move my refined 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 analysing 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 years on the ATLAS trigger will be very important for the work I can do when I return to Pisa. I will have large experience evaluating 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 Department of Physics at Harvard is large and diverse. With 10 Nobel Prize winners to its credit, the distinguished faculty of today engages in teaching and research that spans the discipline and defines its borders, and as a result Harvard is consistently one of the top-ranked physics departments in USA.

The Department's greatest resources are the people that fill its classrooms, labs, and offices, as well as state-of-the-art facilities and an outstanding onsite research library. For undergraduate concentrators, graduate students, and postdoctoral researchers, Harvard features a complete range of opportunities to engage in world-class physics from theoretical to the experimental.

Research in the Department seeks to explore and explain fundamental questions that range from understanding the origin of the universe, including string theory, cosmology, and astrophysics, to understanding the visible world of colloids and the invisible world on an ever diminishing scale, from the mesoscale to the nanoscale, condensed matter, atomic and molecular and particle physics. The Laboratory for Particle Physics and Cosmology carries out forefront programs in high energy physics research and provides first-rate educational opportunities for students. LPPC's experimental programs are carried out at the major accelerator centers throughout the world and address important questions both within and beyond the Standard Model. LPPC has expanded its program to include astrophysics with the intention to study the fundamental properties of dark energy. Several collaborations and projects are also being carried out by Physics Department faculty and graduate students at Centers outside of Cambridge: the Fermi National Accelerator Laboratory; the CERN in Geneva; the Lawrence Livermore National Lab; the Soudan Mines in Northern Minnesota; and the National Institute of Standards and Technology.

Research in the Department is frequently interdisciplinary in nature thus the Department has strong links to the: Astronomy, Biophysics, Chemistry and Chemical Biology, and Molecular and Cellular Biology departments. The Department shares a particularly close relationship with the School of Engineering and Applied Science where cross cutting research in computational physics, electrical engineering and nanotechnology is ongoing.

The Harvard Physics Department also has a close relationship with MIT which is perhaps best represented by the Harvard/MIT Center for Ultracold Atoms.

With more than 50 affiliated faculty members and 170 graduate students and 230 undergraduates the Physics Department has a lively intellectual environment, and emphasis is placed on teaching and preparing undergraduates to be at the forefront of the next generation of physicists.

International collaborations (participation in projects, publications, patents and any other relevant results) – All the groups involved with my fellowship (both in Harvard and in Pisa) 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, a lot of very important B-physics results, of which examples are the discovery of the Σ_b baryon and the observation of the B^0_s oscillations.

The Italian and American FTK communities from 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) μ spectrometer - identifies and measures μs; (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 Harvard and Pisa have participated in ATLAS since the beginning, well before FTK had been conceived and proposed. Pisa had an important role in the construction of the ATLAS Tile Calorimeter system, while Harvard had an important role in the μ spectrometer construction. Both groups are involved in development of ATLAS software and in grid computing.

My project involves electronics, tests and commissioning together with analysis. The Electronics Design Group of the Harvard institute is superb and the CERN laboratory offers all the needed space to introduce and exercise FTK in the real TDAQ. The role of the "e-shop" 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 e-shop 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 .

Also Pisa has a service for electronics development. It has expert engineers and technicians that will collaborate on the project. For this reason the Pisa 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 and the site of the Atlas experiment 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 – Harvard University's LPPC, already well described in previous paragraphs and sections, will allow me to engage activities in their rich and diverse programmes. Their leading edge eletronics group as well as detector development and data analysis groups will provide me training also in complementary topics.

Furthermore Harvard offers a wide range of Research Facilities, Centers and Programs other than LPPC that can provide me additional training:

Biophysics - The primary objective of the program is to educate and train individuals with background in physical or quantititative science, especially chemistry, physics, computer science, or mathematics, to apply the concepts and methods of the physical sciences to the solution of biological problems. Owing to the interdepartmental nature of the program, a student's research options are increased greatly. Research programs may be pursued in any of the departments or hospitals mentioned.

Center for Nanoscale Systems (CNS) - The Center's scientific focus is on how nanoscale components can be integrated into large and complex interacting systems. It brings together the disciplines of chemistry, physics, engineering, materials science, geology, biology and medicine.

CNS is a member of the National Science Foundation’s National Nanotechnology Infrastructure Network (NNIN) initiative to create a national network of world-class facilities available to all researchers. The Center welcomes and encourages researchers from Harvard and beyond to take a look at the many facilities that it has to offer to assist in their research goals.

The Center for the Fundamental Laws of Nature - This interdisciplinary theoretical research center aims to advance our basic knowledge of the universe through the interactive collaboration of physicists, mathematicians, and cosmologists.

The Center for Ultracold Atoms (CUA) A joint venture with MIT, the CUA encompasses experimental and theoretical research in the following areas:

- Bose-Einstein condensates: development of new methods for manipulating and probing condensed atomic gases, ultracold interactions, and collision dynamics
- Atom optics: atom interferometry, atom waveguides, surface physics and quantum reflection, many body physics in lower dimensions
- Cryogenic Sources for BEC: creation of large condensates of alkalis and other atoms, sympathetic cooling, novel condensates, creation of intense hydrogen sources, and optical techniques for ultracold hydrogen.

Engineering and Physical Biology Program (EPB) - A joint venture between Physics, Engineering, Chemistry and Biology that focuses on determining how basic physical principles govern and explain biological processes. The program includes both experimental and theoretical work, including in vivo measurements of the effects of mechanical forces on cellular processes, as well as single molecule experiments, and physical models in non-living systems. Micro and nano-fabrication combined with new techniques for imaging and manipulation will provide a wealth of new information on the physical properties of biological systems at the cellular and sub-cellular level that will allow detailed comparisons between theory and experiment that has been previously unavailable.

Harvard-Smithsonian Center for Astrophysics (CfA) - The Center for Astrophysics combines the resources and research facilities of the Harvard College Observatory and the Smithsonian Astrophysical Observatory to study the basic physical processes that determine the nature and evolution of the universe.

Some of its pioneering achievements include:
- Development of instrumentation for orbiting observatories in space
- Ground-based gamma-ray astronomy
- The application of computers to problems of theoretical astrophysics, particularly stellar atmospheres

The Institute for Quantum Science and Engineering (IQSE) - The Mission of the IQSE is to foster cross-disciplinary research and education in new areas at the intersection of nanoscience, atomic physics, device engineering and computer science, that in various ways seeks to apply principles of quantum mechanics to advanced technologies.

Institute for Theoretical Atomic and Molecular Physics (ITAMP) - The Institute for Theoretical Atomic, Molecular and Optical Physics was established in November 1988 at the Harvard-Smithsonian Center for Astrophysics in order to address the critical shortage of theorists in atomic and molecular physics at major universities throughout the nation.

Materials Research Science and Engineering Center (MRSEC) - The Materials Research and Engineering Center is the focus of Harvard's long tradition of interdisciplinary materials research. Twenty-six faculty members from the the DEAS, the Departments of Physics, Chemistry and Chemical Biology, Molecular and Cellular Biology, and the Harvard Medical School participate in the Center.

Nanoscale Science Engineering Center (NSEC) - The Nanoscale Science and Engineering Center is a collaborative effort that combines "top down" and "bottom up" approaches to construct novel electronic and magnetic devices with nanoscale sizes and understand their behavior, including quantum phenomena.

Available infrastructures and whether these can respond to the needs set by the execution of the project. – The project will have its execution in Harvard , in Pisa (with the collaboration of other INFN sites, in Rome, Milan, Pavia, Bologna, Ferrara and Pisa) and for a good fraction of time 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 European return host's 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 increase my knowledge, already 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. Pisa is perfectly in line with my work during the fellow. The idea of a b-quark real time selection in the CDF experiment was born in Pisa.

The key idea that made it possible to perform real time selection of b-quarks is the use of Associative Memories, as described in section B1. The group created in Pisa (which included Mauro Dell'Orso, my scientist in charge, from the beginning) around this main idea proposed the Silicon Vertex Tracker (SVT) at CDF. The experience gained during the development and construction of the associative memory device in Pisa at the beginning of the 90's ("The AMchip, a Full-custom CMOS VLSI Associative Memory for Pattern Recognition", IEEE Trans. On Nucl. Sci. Vol 39, N4, 1992) was a very important step toward further development. It was the starting point for the following studies on different technologies: (a) FPGA technology used for a user-friendly, low-density associative memory ("A programmable associative memory for track finding" published in Nuclear Instruments and Methods in Physics Research, Volume 413, 1998); (b) third generation standard cell technology AM. The last step was made by a collaboration of the CDF Pisa group and the Pisa APE group. The experience of the APE group on standard cell technology has been very important for the recent upgrade to SVT upgrade. The upgrade was proposed and largely built by Pisa. The Pisa group also managed the associative memory chip and the board production for SVT and its upgrade. We have managed the production and assembly of hundreds of boards and thousands of AMchips. The experience of the Pisa group is not limited to the associative memory device. Many different 9U VME boards were developed for the original SVT processor, strongly based on the use of Field Programmable Gate Arrays (FPGA) and Complex Programmable Logic Devices (CPLD). Pisa has studied the density, complexity, and performance of these devices for many years, following an evolution that is well beyond the limits imagined just a few years ago. We prepared the test procedures to validate the chips and the boards and we performed the tests on the boards. We installed the system at Fermilab and developed the software for its management, monitoring and diagnostics. The group developed the physics case for the SVT proposal and a realistic simulation of the system to be able to predict the SVT capabilities to produce B-physics results. The performance of the system was as good as expected from the simulation. The system was installed efficiently and without particular problems. The original SVT system has taken data since the year 2000. The Pisa group participated actively in the data taking, the b-quark trigger definition and evolution and finally the B-physics analyses. In conclusion, the group had a dominant role in b-quark physics at the Tevatron and in the related technologies. It has vast experience in all phases of this project.

Practical arrangements for the implementation and management of the research 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 Harvard an office with computing capability and access to the Tier2-Tier3 computing facilities, to continue my software developments. I will be allowed to use CADs for electronic board design and for chip design. The e-shop personnel will help when necessary. I will have lab space to install a vertical slice where the Harvard students can perform their tests. I will use a laboratory both at Harvard and at Cern for electronic tests, provided of one rack with a VME crate , a oscilloscope, a 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.

Finally at CERN, for parasitic tests of the vertical slice, 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 Pisa the same instrumentation will be available as at Cern. The test stands and test software exploit the long experience developed at CDF. There is uniformity of standards at the FTK institutions: 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 Filar and Tilar boards 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 Cern, Pisa and Harvard will be very strong. We will 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 on the architecture definition and its performance evaluated by simulation. FTK has now be approved and in 2011 the construction, design phase has start and will last for at least 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 & learn with real data about FTK timing performance, to start developing the control and monitoring software inside TDAQ, to implement the new track-based lepton isolation and see its impact on boson samples (c) analysis of the ATLAS data to verify the FTK physics improvement, (d) testing new prototypes and their commissioning.

My work will focus first of all on the construction, installation, and testing of the vertical slice (I am the responsible of it), whose goal is data taking before the next long shutdown. I will install also a test stand in Harvard, exploiting the hardware we will get back from CDF after its end of data taking.

The goals for the Outgoing phase in Harvard with consistent periods spent at CERN, especially before the long 2013-2014 shutdown, are:

1) Apply my large experience on the use of FPGAs and test procedures to complete and make work the vertical slice test stand. This means to implement in the EDRO board the Data Organizer function, to add the GigaFitter function exploiting the CDF board and learn the use of 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.

2) Implement the connection of the vertical slice to CPUs through the use of the new boards Tilars, recently developed for TDAQ interconnection improvements.
3) As soon as the vertical slice data taking starts I will analyse the efficiency and the fakes for the high Pt lepton track-based isolation, evaluating the gain for boson and di-boson samples. I will also participate to the analysis of W/Z + 2 jets events to study di-boson events.
4) As soon as the Vertical slice is stable enough in data taking to allow 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. This work will clarify the path for a full FTK system integration.
5) 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 have also to check the performance of the system at the SLHC Phase II luminosity, 10^{35} cm^{-2} sec^{-1}.
6) The vertical slice will be also the place where the new prototypes developed for the final FTK, thought for the very high luminosity, will be tested before being approved by the experiment. I will be responsible of the test stand and integration of new boards. I will participate to the testing of new prototypes and their commissioning.
7) The vertical slice will be also installed and operated with my supervision at Harvard University.

Points number (1), (2), (3) and (4) certainly will be part of the first fellowship year, since they are strongly coupled to the idea of exploiting as much as possible the 2012 data taking. Point 5 is active since a lot of years, and is always important but I think to come back to it starting from the second year. Even during the third one it could be important. since new ideas and unexpected detector or collider conditions could influence the final design and its optimization. The activity of the point 6 will be important when new prototypes will start to be available (not before 2013). Point (7) is important because it will allow Harvard students to participate to the activities for the vertical slice development.
During the outgoing phase I will spend some time in Boston, but also it will be necessary to spend time at CERN in the ATLAS experiment, especially before the long shutdown.
The goals for the Reintegration phase in Pisa are:

1. We hope to have at that time a final or almost-final version of the new prototypes and test them thoroughly in the vertical slice before starting production.
2. The production of prototypes, 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: I will continue the analysis of the Outgoing phase (point 3 of previous section).
4. Try to use our processors to analyse 2-D images for other applications outside HEP: (a) we can 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 can 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.

The work plan also includes frequent presentations of the work inside the TDAQ/Physics group and seminars to the ATLAS collaboration or Pisa 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. –

I will have a large experience on programmable logic, standard cell technology and computer technologies. I will be able to evaluate costs and performances of different technology as a function of different applications. This knowledge will give me an important role inside INFN. I will be particularly helpful choosing the right technology for online algorithm implementation. Moreover I will gain knowledge of p-pbar physics processes and the best strategies for online selection of such events. I will learn about monitoring/diagnostic/standardization problems for very complex electronic systems. Moreover the interest for our technology is constantly increasing, touching new experiments like CMS and even LHCB, so I believe that the possibilities for an expert like me to find a position increase at the same time. Pisa has all these experiments that are interested. But even outside Pisa, all INFN centers in Italy do have at least one of the LHC experiments. I think the chances for me to get a permanent position would be strongly boosted by the experience of this Marie Curie fellow.

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

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 ….. 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.)

Harvard has a beautiful large campus near the Charles River. It has wide housing facilities, network and communications, bike facilities, accessibility, a lot of libraries, Museums and Galleries spread all around. It is provided of many dining services, athletics sites, parking facilities. Public security is assured by a lot of telephones that are distributed in the area and are connected directly to the police.

Harvard University is committed to providing effective policies, benefits, and services to help faculty achieve their career goals while meeting their family responsibilities. Faculty "quality of life" -- or how faculty across the University experience their workload, professional climate, opportunities, ability to manage work and personal responsibilities, and overall connection with the Harvard environment -- greatly impacts career success. In 2008, Harvard University was named one of the "100 Best" Organizations by Working Mother Magazine for the sixth year in a row. Its award-winning benefits and policies for working parents include: comprehensive health and dental insurance for employees and their families; childcare and eldercare benefits; and housing and transportation assistance. The Office of Faculty Development and Diversity (FD&D) works closely with the Vice President of Human Resources to ensure that faculty and staff benefit from theiir work-life policies and programs.

Harvard has many resources that support the housing and relocation needs of faculty.

Athletics facilities and resources are available to staff, faculty, students, alumni, and eligible family members. Annual or semester memberships, personal trainers, fitness classes, and various settings offer more options than most private gyms.

Harvard University provides also ESL (English as a second language classes for all), Visa support, medical insurance if necessary, library, access to all classes in the Faculty of Arts and Sciences, and music and art performances. I will have the opportunity to teach and to be trained to teach.

The host of the <u>return phase</u> should explain which measures are planned for the successful re-integration of the researcher. –

Pisa 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. I have been for a long time in Pisa before the fellow and I have a house there. Moreover my parent family is in Florence. Reintegration for me will be absolutely easy and desired.

B5. IMPACT (maximum 4 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 transferable 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.

The period I will spend in Boston 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, as I widely describes in the previous sections, 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, where relevant

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 find a position, but also later during his career development. The high technology involved in the program should help for a good position both in the industry and the research environment, since the work program should develop or reinforce rare competencies.

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

We had and continue to have important collaborations with the best USA Institutions. This is a stable beneficial collaboration which started at the beginnings of the CDF experiment (1985-86) and produced a lot of beautiful achievements. Harvard in particular has already been part of the FTK project and did an excellent work. Unfortunately FTK took an extremely long time to be approved and it is really difficult for young post-docs to get the due visibility in a not-approved project. For this reason the Harvard personnel left the project. Now FTK is approved and can offer also opportunity of data analysis, so we want to renew our collaboration, that was excellent in the past, with the Harvard University. We hope that we can work together on this challenge project for a long time, starting with the vertical slice in 2012 and going ahead with the whole project for the phase I and II of SLHC.

I would like to be part of this collaboration and to reinforce it. Having mobility between Boston, 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 and Fermilab 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. The Heidelberg Institution has joined our effort designing the new AMchip. 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 researchers in USA is very important under many aspects.
As described above, it can really improve our Italian research organization, or even society.
The Italian style is often too much against mobility. Each community wants to keep its researchers for ever. Often a person starts as student in a Institute and a particular group, becomes post-doc there, after that takes a

permanent position in the same group. This mechanism creates local dependency mechanisms that can interfere with pure meritocratic criteria during recruitment. The mobility of young researchers, as is implemented in USA, has an extremely beneficial impact in the Italian system. We have seen that young researches that have worked for a while in USA, have developed a different thinking and they exit out of the most rigid Italian mechanisms, creating a new Italian style.
Moreover USA research style pushes young people to independence and leadership, much more than what happens in Europe. It has a different funding mechanism and a different way to distribute responsibilities. Again young researchers that know the USA reality, usually coming back to Italy they push the Italian system towards new attitudes.
Each researcher in USA is strongly motivated to complete his professional competences, participating seriously to both an important hardware project and physics data analysis. In Europe instead the two competences are often separated: physicists belong often to two categories that are quite separated and often do not understand well each others: people that builds large hardware projects are usually very advanced on hardware technology, but they do not know much of the "experiment software" and people that perform data analysis or software developments, that are not conscious of the technological choices. Having a larger spectrum of competencies it is easier to communicate between the different sectors of experimental HEP. Again leaving some time in the USA research is a way to move to new, better organizations of the research. Not always the USA style is better than the European one, we certainly could bring examples in the opposite direction. However we think that the mobility is one of the best mechanisms to create evolution towards the best research organization, because it allows to compare very different realities..

Impact of the proposed outreach activities

We did outreach activity in the past to convince the LHC community that an hardware tracker is really an important tool for the hadron collider trigger. This was devoted mainly to the HEP community but allowed us to develop sites like this one
http://w3.ts.infn.it/cdf-italia/public/outreach/cdf_trigger.html
that could help to enlarge the knowledge of our Super Computers even outside HEP.
FTK is now approved, the outreach work can now be reinforced by results. In fact up to now our it was based on hypothetic performances based only on simulation results or on the successful story of the SVT tracker. In the next years the FTK vertical slice will offer the opportunity to give the first examples of the FTK potentialities on real data. In parallel the first real prototypes promising the capability to exploit best of the available technology will be produced and tested, giving a concrete proof of the computing capability we can provide.

We think now that we should reach the other fields outside HEP. One of the main goals we have is to convince the medical environment about the importance of Super Computing. Doctors are still very little interested, they even do not take into account the possibility that image reconstruction could be done at very high rates. They are so little interested that it is even hard to have some medical images from them to be able to apply our reconstruction algorithms and show the potentialities.
We think that we could have an important impact if we could find and measure variables about relevant spots in their images.

We will continue our outreach with descriptions in to web sites, participation to shows like the "night of the research" with posters, hardware material and speaking directly with visitors. We will continue to spend time searching doctors that could be interested to do a first step with us.

B6. Ethics 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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Marie Curie International Outgoing Fellowships (IOF)
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PART B

"ARTLHCFE"