Research Executive Agency

7th Framework Programme for
Research, Technological
Development and Demonstration

Marie Curie International
Incoming Fellowships (IIF)

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A1: Summary

Proposal Number	622202	Proposal Acronym	RTTFUNPSAL

General Information

Proposal Title	Real time tracking for ultimate new physics searches at LHC

Marie Curie action-code	MC-IIF	Scientific Panel	PHY
Duration in months	24	Call identifier	FP7-PEOPLE-2013-IIF

Keywords (up to 200 characters)	High Energy Collider Physics, LHC, ATLAS, Trigger, Tracking

Descriptor 1	P101
Descriptor 2	P102
Descriptor 3	

Abstract (up to 2000 characters)

The goal of this project is the participation to the construction and the test for a high precision real-time tracker built for the ATLAS experiment: the Fast Track (FTK) processor. FTK can improve the capability of the ATLAS detector to select interesting events reach of heavy leptons or quarks within the enormous LHC background. It uses FPGA and ASIC chips to implement, real-time, complex track reconstruction algorithms. The track's trajectories are reconstructed in 3D, in few dozens of microseconds and the quality of the parameters is almost offline. FTK will increase the ATLAS discovery capability and will increase the precision of Higgs properties measurements. In parallel we will pursue challenging R&D & new real time computing ideas for more complex applications.

Has a similar proposal been submitted to a Marie Curie Action under this RTD Framework Programmes? ○ Yes ◉ No

Does this proposal include any of the sensitive ethical issues detailed in the Research Ethical Issues table of Part B? ○ Yes ◉ No

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Marie Curie International Incoming Fellowships (IIF)

A2: Participants

Proposal Number	622202	Proposal Acronym	RTTFUNPSAL	Participant Number	1

Information on organisations

If your organisation has already registered for FP7, enter your Participant Ident. Code	999992789
Organisation Legal name	ISTITUTO NAZIONALE DI FISICA NUCLEARE
Organisation short name	INFN

Administrative data

Street name	Via Enrico Fermi	Number	40
Town	FRASCATI	Postal Code/Cedex	00044
Country	IT		
Internet homepage	www.infn.it		

Status of your organization

Certain types of organisations benefit from special conditions under the FP7 participation rules.
The Commission also collects data for statistical purposes. The guidance notes will help you complete this section.

Please 'tick' the relevant box(es) if your organisation falls into one or more of the following categories

	Yes	No
Non-profit organisation	(•) Yes	( ) No
Public body	(•) Yes	( ) No
Research organisation	(•) Yes	( ) No
Higher or secondary education establishment	( ) Yes	(•) No
International organisation	( ) Yes	(•) No
International organisation of European Interest	( ) Yes	(•) No
Joint Research Center of the European Commision	( ) Yes	(•) No
Entities composed of one or more legal entities [European Economic Interest Group (Unité mixte de reserche) / Enterprise groupings]	( ) Yes	(•) No
Commercial Enterprise	( ) Yes	(•) No

Main area of activity (NACE code)	73.1

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1. Is your number of employees smaller than 250? (full time equivalent) ○ Yes ◉ No

2. Is your annual turnover smaller than € 50 million? ○ Yes ◉ No

3. Is your annual balance sheet total smaller than € 43 million? ○ Yes ◉ No

4. Are you an autonomous legal entity? ○ Yes ◉ No

You are NOT an SME if your answer to question 1 is "NO" and/or your answer to both questions 2 and 3 is "NO". In all other cases, you might conform to the Commission's definition of an SME. Please check the additional conditions given in the guidance notes to the forms

Following this check, do you conform to the Commission's definition of an SME? ○ Yes ◉ No

Contact point of the host organization

Scientist in charge (For the co-ordinator (participant number 1) this person is the one who the REA will contact in the first instance)

Family Name: Antonelli

First Name(s): Mario

Title: Dr. Gender: ◉ male ○ female

Position in the organisation: Staff researcher

Department/Faculty/Institute/Laboratory name/...: INFN - Laboratori Nazionali di Frascati

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Is the address different from the legal address? ○ Yes ◉ No

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Authorised representative to sign the grant agreement or to commit the organisation for this proposal

Family Name	Ferroni
First Name(s)	Fernando
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Position in the organisation	President
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Fax	+ 39 0668307924
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Is the address different from the legal address? (•) Yes ( ) No

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Town	Rome
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Country	IT

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A3: Participants

Proposal Number 622202 Proposal Acronym RTTFUNPSAL

Information on the researcher

Family Name	Kimura
Family Name at Birth	
First Name(s)	Naoki
Title	Dr.
Gender	(•) male ( ) female
1st Nationality	JP
2nd Nationality	
Date of birth (DD/MM/YYYY)	13/12/1979
Location of origin (Country)	JP

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Qualifications

University Degree	Date of award (DD/MM/YYYY)	31/03/2006
Doctorate (in progress)	Date of award (DD/MM/YYYY)	
Doctorate	Date of award (DD/MM/YYYY)	25/03/2009
Full time postgraduate research experience	Number of months	89
Other Academic qualifications	Date of award (DD/MM/YYYY)	

Place of activity/place of residence (previous 5 years - most recent one first)

Indicate the period(s) and the country/contries in which you have legally resided and/or had your main activity (work, status, ..) during the last 5 years up until the deadline for the submission of the proposal. The 5 years prior to the deadline should be covered.

Period from	Period to	Duration (days)	Country	
14/08/2008	14/08/2013	1827	JP	Remove

Total 1827

Add Row

Have you submitted or are you in the process of submitting another proposal for the Marie Curie Actions: IEF, IOF, IIF or CIG, or have you previously benefited of Community funding under Marie Curie Actions

○ Yes ◉ No

A4: Budget

Proposal Number 622202 Proposal Acronym RTTFUNPSAL

FUNDING REQUEST

Main / Return Phase		
Year	Full-time person-months	Type B Fixed-amount Fellowship (Y/N)
1	12	N
2	12	N
Return	0	N

Mobility allowance

Are you eligible for the family-related mobility allowance? ○ Yes ◉ No

Post-graduate Research Experience of the applicant at the deadline of the call. 4-10 years

STARTPAGE

PEOPLE
MARIE CURIE ACTIONS

International Incoming Fellowships (IIF)

Call: FP7-PEOPLE-2013-IIF

PART B

"RTTFUNPSAL"
Real time tracking for ultimate new physics searches at LHC

B1 RESEARCH AND TECHNOLOGICAL QUALITY (MAXIMUM 8 PAGES)

- Research and technological quality, including any interdisciplinary and multidisciplinary aspects of the proposal
- Appropriateness of research methodology and approach
- Originality and Innovative nature of the project, and relationship to the 'state of the art' of research in the field
- Timeliness and relevance of the project
- Host research expertise in the field
- Quality of the group/scientist in charge

B2 TRANSFER OF KNOWLEDGE (MAXIMUM 2 PAGES)

- Clarity and quality of the transfer of knowledge objectives
- Potential of transferring knowledge to European host and/or bringing knowledge to Europe

B3 RESEARCHER (MAXIMUM 7 PAGES WHICH INCLUDES A CV AND A LIST OF MAIN ACHIEVEMENTS)

- Research experience
- Research results including patents, publications, teaching, etc
- Independent thinking, leadership qualities, and capacity to transfer knowledge
- Match between the fellow's profile and project

B4 IMPLEMENTATION (MAXIMUM 6 PAGES)

- Quality of infrastructure/facilities and international collaborations of host
- Practical arrangements for the implementation and management of the research project*
- Feasibility and credibility of the project, including work plan
- Practical and administrative arrangements and support for the hosting of the fellow*

B5 IMPACT (MAXIMUM 4 PAGES)

- Potential for creating long term collaborations and mutually beneficial co-operation between Europe and the other Third Country
- Contribution to European excellence and European competitiveness through valuable transfer of knowledge
- Impact of the proposed outreach activities*

B6 ETHICS ISSUES (NO PAGE LIMIT)

MAIN ETHICAL ISSUES THAT MUST BE ADDRESSED

- Informed consent
- Human embryonic stem cells
- Privacy and data protection
- Use of human biological samples and data
- Research on animals
- Research in developing countries
- Dual use

B1 RESEARCH AND TECHNOLOGICAL QUALITY (MAXIMUM 8 PAGES)

- **Research and technological quality**

One of the basic questions of the human beings is what the physical matter is made of. To answer this question, particle physics has been trying to determine the fundamental constituents of the universe and the nature of their interactions. In the last thirty years much progress has been made in discovering these constituent particles and the rules of their interactions. All observed phenomena are described by what has come to be called the Standard Model of particle physics. Since the observation of the W and Z bosons and top quark, experimental particle physics has focused on searches for the remaining particle predicted by the Standard Model.

With the observation of the new particle, a good candidate to be the Higgs boson, in 2012 at CERN's Large Hadron Collider (LHC), nearly the full catalog of Standard Model particles has been directly observed. Next steps are related to the studies of the properties of the Higgs boson. Several studies are currently on going to precisely define the quantum numbers of the new particle, however, within the present experimental accuracy, the new resonance does exhibit characteristics that are fully compatible with the hypothesis that it is the Standard Model Higgs boson. The Higgs boson with a mass of $125GeV/c^2$ is a very special particle. First of all it looks like to be exactly in the mass range in which, at LHC we could directly access a large amount of its decay modes. Secondly, a light mass scalar, could in principle rule its self-interaction and the Yukawa interactions with fermions in such a way that the theory could remain weakly coupled up to the Planck scale without any dynamics appearing beyond the Electro-Weak scale. Although possible, this scenario would be severely constrained by the need that the couplings of the Higgs boson must be precisely tuned to very well predicted values. Even the slightest deviation from these values, once experimentally established, would be indirect evidence of new physics and would hint at the scale of energy at which the Standard Model could eventually break. And despite the great success of the Standard Model in describing the particles and interactions observed up to now, however there is a good theoretical motivation to believe that a new framework must come into play at approximately the TeV energy scale. And the Higgs mass value that has been found indicates that the Higgs potential will be metastable around the unification scale. It's is a hint that new physics might appear within the SLHC reach. Increasingly stringent measurements of the properties of particles and their interactions at the highest available energies, coupled with direct searches for phenomena not described by the Standard Model, are the main goal of modern experimental particle physics. These are very exciting times for particle physics. Next discovery will be big breakthrough for this field.

LHC, followed by its upgrade called the Super LHC (SLHC), has an excellent position in this research field. Huge data will be collected and analysed at LHC in next Run for precision measurements and to search rare events. At the same time R&D at the technological frontier will be pursued for SLHC. These areas of research will have heavy quarks as well as tau-leptons – the so-called third fermion generation - in the cooling fireball after each collision. Events rich in heavy flavours and tau-lepton are particularly relevant to test the limit of the Standard Model and study its possible extensions. Tracking devices play an essential role in this and in particular the Silicon devices that are becoming the preponderant tracking technology. On the other side the electronics required to process the signals from the detectors is taking a very important role, and it must be state of the art. The most interesting processes, in fact, are very rare and hidden in extremely large levels of background. Implementing the most powerful selections in real time is therefore essential to fully exploit the physics potential of experiments where only a very limited fraction of the produced data can be stored finally on tape. A drastic real-time data reduction must be obtained. This makes on-line event reconstruction a critical component of any hadron collider experiment. The trigger must be extremely intelligent and powerful. This project directly addresses the main technological challenges of hardware, software and data surrounding heavy flavour and tau-jets tagging, and tracking issues at trigger level.

The LHC collision rate is 40 MHz, in addition at the instantaneous luminosity of 3×10^{34} cm^{-2} sec^{-1} the average number of soft, not-interesting interactions par collision (pile-up) is ~60-80, and with the SLHC upgrade it will be even higher, ~300 pile-up. These not-interesting QCD interaction rate is ~10^{10} times bigger than the interesting interactions, Higgs events for example. Therefore collection of interesting interactions is very challenging at LHC/SLHC. A multi-level trigger is an effective solution for an otherwise impossible problem. The level-1 (L1) trigger is based on custom processors and reduces the rate from 40 MHz to 100 kHz. The Level-2 (L2) and Level-3 (L3) trigger selections, called High Level Trigger at LHC, are executed inside standard CPUs and reduce the rate from 100 kHz down to the final 400-1000 Hz for data-recording on tape. In L1 trigger, events are selected by fast, simple algorithms using the calorimetric measurement of the energy of the objects and very specific signatures from the muons. Then more complex algorithms are executed at L2 and L3 to collect the more characteristic interesting signals. However the L2 and L3 CPU's computing power is limited, so we can't exploit the full detector information at very high rate. Especially the track information of the particles can be used only late at L2. The Fast Tracker (FTK), that is the main topic of this application, is an upgrade project for the ATLAS experiment at LHC to reconstruct all track information in real time, and to provide the information to the L2 trigger. FTK allows the L2 trigger to collect the interesting events much more efficiently. Full real time tracking will be absolutely necessary for triggering in the high luminosity and high pile-up environment of the near future. On the technological side 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.

The tracking algorithm executed by FTK is subdivided into 2 sequential step of increasing resolution. In step 1 a dedicated device, called Associative Memory (AM), finds track candidates with low spatial resolution, called roads. In step2, the real tracks are searched within the roads and fitted to determine their parameters with the full resolution. 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. Programmable logic available today is flexible enough to successfully replace the CPUs even in high resolution computations. Coarse resolution pattern recognition, however, does not profit very much from CPU flexibility. A large fraction of the CPU time needed to reconstruct high energy physics events is wasted in data sorting with a lot of random accesses to a large storage the contains all tracker data. By contrast, the AM perform the most CPU intensive part of the pattern recognition, consisting of a very large number of regular and highly structured loops of simple logical operations, always identical, with dedicated highly parallel structures. The AM exploits the idea of a pattern matching algorithm based on pre-calculated and stored track candidates, which are compared in parallel with the actual event.

- **<u>Interdisciplinary and multidisciplinary aspects of the proposal</u>**

The first very general reason for carrying out further research in the field covered by the project is the HEP research advancement. The High Energy Physics (HEP) 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.

However, 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).

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

- **<u>Appropriateness of research methodology and approach</u>**

The FTK project offers a wonderful program for my IIF fellow, rich of important experiences that will reinforce my curriculum: (1) production of hardware, (2) installation and commissioning (3) data taking and analysis. The research methodology is described for the 3 main objectives of my work:

(A) Development and production

Dedicated trigger hardware usage has been recently reduced for future experiments, in particular at LHC, in favour of large, commercial CPU farms to reduce the risks associated with dedicated hardware. Often the dedicated hardware is considered powerful but difficult to upgrade and inflexible. Combination system of FPGA and ASIC can resolve the problem. FPGA flexibility allows rapid system improvement by just firmware changing. And low cost powerful ASIC chips make it possible to build highly parallelized trigger hardware, with a very uniform structure, whose development can be simplified at the level of a single important device. This device can be deeply simulated and tested before production, reducing at the minimum the risk. Large effort will be required for the hardware and firmware design and quality control of production. Especially firmware should have enough flexibility for future updates. We will test the companies that will produce our boards and after that we will go ahead with the full production.

(B) Installation and commissioning

The commissioning of the upgrades can take place while the experiment is taking data. A very careful test procedure is devised to reduce the impact of the commissioning on detector operation and functionality to a negligible level.
We wanted to gain experience on the ATLAS TDAQ system and test the integration of the FTK functions in the experiment during this complex design effort, well before production. To understand the system issues and to develop the needed control software, we did early parasitic commissioning of a small proto-FTK, based on existing prototypes and able to reconstruct tracks inside a narrow azimuthal slice (tower) of the detector. Parasitic commissioning means that there was no impact on normal ATLAS data taking, thanks to a duplicated additional output fiber provided for FTK by the tracking front-end. The data flow check could be disabled on the FTK channels allowing ATLAS to take data regardless of FTK status. The FTK output could be written to the calibration stream for offline studies. We call this proto-FTK a “vertical slice” because it is small (operating on a slice of the detector) but functionally complete from the detector inputs up to the track output available for the L2 CPUs.
Each new board is fully tested on real data, using a parasitic connection to the experiment inside the vertical slice, before being included in the real data taking stream. Therefore phased installation was chosen. Boards will be installed during longer shutdowns but can be replaced gradually, exploiting also the short shutdowns of the accelerator. This phased procedure allows for quick recovery if there are failures, since each small change is immediately checked before going ahead. The chosen procedure shows that the high degree of organization allows installation and replacing pieces quite easily, even if the function performed by the processors is very complex. They can have the flexibility and ease of use necessary to allow many successful migrations to different configurations in very short times and in a smooth way.

Important aspects in installation and commissioning phase are toughness and flexibility of the test procedures. The vertical slice will be a very powerful tool in commissioning phase.
Several software tools were and will be developed for data taking, most of them useful also for the final FTK project. The ATLAS experiment has a complex and extensive software infrastructure to configure, control and monitor its hardware components. We need to develop the code specific for our hardware within this infrastructure. We will develop our tools in a modern client/server architecture with plug-ins. This infrastructure has three main areas: “operation execution”, “operation request” and “configuration”. The “operation execution” area is where the actual low level code interacts with the hardware. The “operation request” area imports all the libraries for hardware interaction and exposes all functions to the user or other software tools. Various clients send requests to the server and translate the result to the user/software. We plan to write three clients: (a) command-line console, for fast scripting and tests during the development phase, (b) web application with AJAX interface, for high level monitoring and interaction, but independent of the ATLAS TDAQ infrastructure, (c) TDAQ segment to interact with the ATLAS TDAQ infrastructure and control our hardware from the standard ATLAS TDAQ software. All the “operation request” area is hardware independent and no new specific code must be written to add new hardware if the new hardware implements the abstract objects supported.

(C) Physics analysis

It is very important to develop a strong physics case for FTK and after that verify with data the expected physics gain. The most important reason for early track reconstruction is selection of events containing third-generation fermions, either a b quark or a τ lepton. For the former, the level-1 trigger selects a generic jet; for the latter, a narrow jet. In either case, there is enormous background from QCD jets. Discrimination of the signal from background relies in large part on track information – in b jets the presence of a secondary vertex or tracks with large impact parameter, in τ jets an isolation region devoid of tracks surrounding a small cone containing no more than 3 tracks. There is in the ATLAS baseline an existing plan to execute such algorithms, but for multi-jet events this could take considerably longer than the allotted 20 milliseconds, especially at full LHC luminosity. In this case, in order to satisfy the requirement on the level-2 execution time averaged over all level-1 triggers, the fraction of level-1 triggers assigned to jets would have to be limited. Having the reconstructed tracks at the beginning of level-2 processing could allow most of the background jet events to be quickly rejected, thus dramatically decreasing the average level-2 execution time for b-jet triggers. This would permit a larger fraction of the level-1 bandwidth to be assigned to jet triggers if the physics requires it, for example if the dominant characteristic of the new physics is multiple b-jets rather than electrons or muons. Moreover, the level-2 processing time could then be used for applying other necessary event selection criteria. Important examples of CPU-intensive usage of tracks, other than b-tagging and τ-identification, are: (1) primary vertex identification, (2) high-PT lepton isolation using only tracks above a PT threshold coming from the high-PT primary vertex (avoiding pile-up tracks in evaluating isolation), and (3) B-physics events, where final state hadrons have to be found outside of the specific regions identified by leptons (Regions of Interest, ROIs). We will study the performance of FTK at design LHC luminosity for both individual objects and complete events. For the former, we will determine the ID efficiency and miss identification probability for both *b*-jets and hadronically decaying τ-leptons. We will compare these with the performance using offline tracking. We will also compare with the current level-2 tracking. With the additional level-2 CPU time, more sophisticated tagging algorithms can be carried out, obtaining better performances. We will also study FTK's ability to determine the high-PT primary vertex and help identify isolated leptons (e and μ), including the advantage at high luminosity of basing isolation on tracks above a PT threshold that point to the high-PT primary vertex. Much work has been done using the simulation, but our main goal is now to study all these items on real data.

- **Originality and Innovative nature of the project**

The philosophy of performing almost offline selections at rates of the order of 100 kHz at LHC is absolutely new. The idea of using dedicated mixed flexible technology of ASIC and FPGA is innovative in a world where the use of dedicated hardware has been strongly reduced. We want to improve the functionality of the online tracking to match the LHC luminosity increase and to foster the use of these powerful online processors to more complex applications in the future. New and outstanding multi-technology increases the discovery potential of current and future HEP experiments. They will use FPGAs and ASICs to complement CPUs. CPU-based sequential reconstruction programs usually waste the CPU flexibility when carrying out a serialization of long simple repetitive logical operation sequences, that once optimized will remain largely unchanged. The problem is generally referred to as the "combinatorial challenge". Supercomputers beat the combinatorial challenge with powerful dedicated programmable devices, where parallelism can be exploited to the maximum level. They take full advantage of the parallel nature of most combinatorial problems by comparing the event to pre-calculated "expectations" at once. Thus the FTK can be considered a highly parallelized extension of the front end, executing only data unpacking and solving the huge hit combinatorial problem to filter out the few relevant track hits from the plethora of silicon data coming from all of the low 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.

- **Relationship to the 'state of the art' of research in the field**

The CDF (Collider Detector at Fermilab) experiment at the Tevatron accelerator in the Fermilab Laboratory, near Chicago (USA), has been the best of the state-of-the-art for triggering at a hadron collider. It has a very strong tradition in this field, since a large part of the trigger has been implemented with dedicated hardware, and has been operational for many years, constrained to work within very short latencies (few μs). It has been upgraded during the 20-year CDF life, to exploit technology advances. Very powerful devices were built, among them the Silicon Vertex Tracker (SVT). It is the most powerful trigger processor operating at a collider experiment so far and it is a perfect baseline for FTK project. It performed 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_S mixing frequency measurement, new heavy baryon and meson observations, and the first observation of the rare charmless decay modes of the B_S. These extremely challenging measurements and their first observations would have been completely out of reach without SVT. Since the B-physics has a limited rate budget, the better purity allows CDF to increase by several orders of magnitude its efficiency for the hadronic B decay modes. Historically, B-physics events have been selected at hadron colliders by triggers based on lepton identification. Trigger selections based on the reconstruction of secondary decay vertices greatly increase the b-quark identification efficiency and allow collecting otherwise inaccessible hadronic decay modes. The availability of the hadronic decay modes at CDF determined the different quality of the CDF and D0 B_S mixing measurements. Also for high-P_T physics CDF has demonstrated the possibility of successfully using purely hadronic channels in the study of the top quark, in Higgs searches, and even in the reconstruction of the Z boson, thanks to the secondary vertex b tagging. The 2009 W.K.H. Panofsky Prize was awarded to the SVT creator, Luciano Ristori, recognizing "the leading role ….. enabling broad advances in knowledge of the top quark, b-hadrons, and charm-hadrons….". SVT is a high-performance "supercomputer" using a combination of two technologies: powerful FPGAs working with standard-cell ASICs for utmost gate integration density. Optimal partitioning of complex algorithms on a variety of computing technologies proved to be a powerful strategy, which turned CDF into a major player in the field of B-physics, on par with dedicated experiments operating at electron colliders.

Already in SVT, the Associative Memory (AM) was the key device. The first basic AM chip was made with ASIC (Application-Specific Integrated Circuits) full-custom technology and was specific to the CDF experiment. In particular, it was unsuitable for the complexity of the tracking detectors of the LHC. Any redesign would have implied a large investment in terms of time, personnel, and costs. For simple applications, a low density AM chip was designed based on the essential characteristics of the programmable devices called the FPGA (Field-Programmable Gate Array) available on the market. The use of commercial FPGAs allows easy development and an easy update of the project. The final production can use up-to-date custom technology. It is also easy to test and debug the prototype. Programmable chips are 100% tested at the factory. System performance can be studied with the full device simulator provided by the manufacturer. Boundary-scan, supported by last generation FPGAs, allows a full test of printed board connections. The only aspect for which programmable devices are inferior to a full custom ASIC is the achievable logic density. In some cases, such as the AM chip, ASICs can still be the better technology. For applications requiring an extremely high "pattern" density, using a standard-cell ASIC can be a very good compromise between the easy design of an FPGA and the logic density of a full custom ASIC. To minimize the required human and monetary investment, the circuit description is done using high-level languages, independent of the hardware substrate and compatible with an easy and automatic recompilation into standard-cell chips. To follow this strategy AM chip has also been developed as a standard-cell chip.

- **<u>Timeliness and relevance of the project</u>**

After Higgs observation, one of the primary task is to probe the mechanism of electroweak gauge symmetry breaking by precise measurement of Higgs boson properties. Especially the measurement of couplings of Higgs boson is very interesting. The Standard Model (SM) Higgs couplings to fundamental fermions are proportional to the fermion masses, and the couplings to bosons are proportional to the squares of the boson masses. Therefore comparison of the coupling between fermions and boson is a very good test for both SM scenario and BSM scenario. An important additional test of the SM electroweak symmetry breaking is the measurement of the Higgs self-interactions. This is the most challenging measurement due to the small cross section and the large background due to two Higgs events from non-self-interaction. Key particles for these analyses are the b-quark and tau lepton, the third generation particles. Decay to b-quarks pair is ~50 % of all Higgs decay at 125 GeV Higgs mass. It is interesting to note that the main Higgs discovery channels are two photon channels and two Z boson channels even if they have less than total 2% branching ratio. This is clearly due to the fact that Higgs decaying to fermions channels is much more difficult to observe, due to the huge QCD background. Actually many Higgs events decaying to two fermions are rejected by the trigger level. As I mentioned above, FTK can save these events being able to recognize in the very short trigger latency the very characteristic track signature of b-quarks and tau leptons. FTK will improve substantially the measurement of Higgs couplings to fermions and will increase the probability of the validation of Higgs self-interactions via trilinear Higgs vertex using combinations of HH->4 b-quarks, bbττ, 4 τs channels. The FTK real time tracking is a very timely project for the coming physics target. 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.

Finally FTK technology confers a favour to outside of high energy physics field. Modern advanced measuring technology is producing a huge amount of information all around the world, while the standard computing power does not scale as well, so new kind of computing is required. Architecture of flexible hardware systems based on ASICs and FPGAs is able to provide highly parallelized processing by reasonable cost, and it will make it possible to process this huge amount of information.

- **<u>Host research expertise in the field</u>**

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

- **<u>Quality of the group/scientist in charge</u>**

The FTK group in Frascati is small, but it has people that had an important role since the beginning of FTK. The group had and has the leadership of many important parts of the FTK project: (1) the AMchip development and validation; (2) the production of the FTK input mezzanine (FTK_IM) (3) the FTK simulation package (4) the integration of FTK inside ATLAS.

The scientist in charge, Dr. M. Antonelli, is the team leader of the LNF ATLAS group composed of about 20 physicists working on analysis, computing activity, FTK upgrade, an muon system upgrade. He is active in High Energy Physics experiments since 1991. He is author of 468 published papers according to INSPIRE and corresponding author of about 25 papers. He has worked also in the ALEPH experiment at LEP, the KLOE experiment at DAFNE always coordinating crucial activities: ALEPH contact person in LEPSUSY and LEPEXOTICA WG, Quality coordinator of the control during the KLOE calorimeter construction, KLOE tracking group convener, KLOE kaon physics group convener, and Flavianet kaon group convener. He also participated to the e+ e- linear studies as ECFA/DESY convener of physics generators and he has the responsibility of the PDG review on the test of CPT symmetry. He has presented the activity in 30 talks at international conferences out of which: 6 review talks, 5 summary talks as convener of a parallel session, and 5 invited plenary talks. Mario has recently joined FTK leading the studies that aim to improve with the FTK tracks the missing transverse energy measurement at level 2.

Dr. A. Annovi has worked for the FTK project since the beginning with essential contributions to design and technological developments, to demonstrate the FTK potential and to convince the ATLAS collaboration of the usefulness of this project. He had a leading role in the proposal and approval of the SVT upgrade, where he was the team leader during production, installation and commissioning. His main activities in FTK were: overall design, study and simulation; board and FPGA design, simulation and test; design, simulation and test of a new VLSI Associative Memory chip (2004, 2012). He is the responsible of FTK integration inside Atlas, He has also experience in data analysis at CDF and is main author of a large number of CDF and ATLAS papers that range from QCD measurements, B-physics measurements, exotics searches and diboson physics that is a key step in the path toward the Higgs.

Dr. G. Volpi was also a key person for both SVT at CDF and FTK at ATLAS. He contributed strongly on competitiveness of the experiments both for the hardware and data studies. He is since many years the coordinator of the FTK simulation software, he had a fundamental role in the definition of the current system, being a reference for the whole FTK, he is the main important contact with the ATLAS TDAQ for the integration in the general experiment software. He did analysis of properties in rare decays where is important to use at the best the detector information and the knowledge of the processes to disentangle partially overlapping signals or between different theoretical hypothesis. In particular he lead the study of rare charmless decays of B-hadrons at CDF and participated to the search for the Higgs Boson at ATLAS in the 4 leptons decay mode.

Dr. Matteo Beretta, technological researcher, is the leader in the design and production of the FTK input mezzanine that receives data directly from the detector front-end and has to perform the 2-D clustering of the data coming from the pixel sensors; Matteo wrote the firmware of the first clustering algorithm. He is also the responsible of the custom cell in the AM chip and has the responsibility to integrate the serial comunication protocol within the AM chip.

The group has large training and mentoring experience for both physicists and engineers: P. Giovacchini, B. Simoni and M. Lamalfa (engineers), Laurea with INFN– now at STMicroelectronics Srl, Milan & Catania, S. Torre (now at La Branche, London) and several students now enrolled as graduate students. In Italy, more than 50 students got their Master/Laurea and PHD working on our real time tracking project and related physics, finding after that interesting positions in research institutions or industries.

B2 TRANSFER OF KNOWLEDGE (MAXIMUM 2 PAGES)

- **Clarity and quality of the transfer of knowledge objectives**

My scientific background and the recent experience of the group in Frascati where I could work with my IIF fellow will be complementary, so transfer of knowledge will be a natural outcome of my fellow.

The Frascati group worked for years in the R&D for the challenging FTK processor and acquired very advanced technological skills. They succeeded recently with the rest of the FTK collaboration to produce the FTK TDR and get the experiment approval for the FTK construction. FTK will open the possibility to collect purely hadronic physics samples, like 4-bs samples, that will produce new important physics tests not possible before, but will also bring new challenges never faced before, because of the complexity of the QCD background making difficult these studies.

The Frascati group did not focus on analysis recently, because of their leading role in the FTK technology development, while, as described in section B3, I developed a large experience on hadronic samples analysis where reliable background rejection factors of 10 orders of magnitude were necessary. I developed deep understanding of this extremely complex physics analysis at hadronic colliders by two generation's highest energy experiments, CDF and ATLAS. The Frascati group will find in me a great help to recover quickly the best knowledge on these analysis techniques and we will achieve great results together, exploiting at the best the hardware effort. On the other side I will learn a lot about the very advanced hardware knowledge on high technology of the INFN Frascati national laboratory. Frascati people know that I am a hard worker that can help a lot in the production and commissioning of FTK.

In the following I specify more some examples as the transfer of knowledge I have in mind:

Physics analysis methodology

The most difficult part of hadronic physics analysis is background estimation, it requires deep knowledge of data. I plan to provide my techniques for background estimation. I plan also to test them at trigger level, since I expect they can provide a good advantage. This is a task where the Frascati group could not work in the past, so they will gain with my experience.

Knowledge of Tau analysis and trigger

We are studying in Waseda the Higgs decaying to a pair of τs. We gained a lot of experience on this channel that is particularly relevant for the FTK application. We performed a detailed study of LV1 tau trigger. It will be important knowledge for the best use of FTK and fast tau analysis in Frascati.

Trigger improvement

We measured top quark pair production in full hadronic final state at ATLAS. This analysis is base line of non-leptonic event that have only quarks in final state included b-quark. As I mentioned in the section B1, the third generation particle like a b-quark is very important for future physics analysis. Even if my initial analysis was done with very low LHC luminosity at the beginning of the LHC run, I could learn that already most of all quarks final state events were rejected by very high energy thresholds of a too weak trigger. Knowledge gained from this analysis makes me perfect to search new trigger approaches built with the help of the FTK tracker.

I will make a proposal about new physics analysis using new ideas based on my experience and the FTK system. For example, very heavy new particle search as top quarks resonance is very challenging for the baseline ATLAS trigger. The top quarks from heavy new particle are hardly boosted, and all particles from top quarks are also boosted to same direction. As a result top quark is identified as single jet in current trigger, and it is difficult to separate from QCD jet, unless we have a technique to look carefully inside the single jet. Lepton from the top quark decay, that is the main standard trigger object of top quark, is not isolated, because the other quarks are very near, so it is rejected by L2 trigger as a non-isolated lepton, a cut that is necessary to reduce the rate of fake leptons from QCD. FTK provides the possibility to look carefully inside these very dense jets using track information: the jet from boosted top quark includes non-isolated lepton, b-quark jet and light flavour quark jets in a small region, only track information has the potential to classify these events using primary vertex tag and b-quark tag information. Because L2 trigger for this analysis can start from both L1 jet trigger and L1 muon trigger, we can collect enough data at L1 and our FTK track information can perform very efficiently at L2.

Let's come now to my learning goals in Frascati. INFN has great experience of hardware development with advanced technology through the CDF and ATLAS tracking trigger developments. The Frascati laboratory has also many other advanced researches and developments (see section B4). In my past short visits at INFN, I met many highly capable engineers. Therefore I feel certain I can learn many aspects of these advanced technology technics exploiting this IIF. Here are some examples of the expected transfer of knowledge from INFN:

Hardware design

I can learn many techniques for the hardware design by this IIF. That is the some detail object:

- ✓ PCB design technology (CADENCE software)
- ✓ Very advanced use of programmable logic (FPGAs)
- ✓ High level firmware development (VHDL and Verilog description language)
- ✓ Simulation & test capabilities, timing & implementation optimization.

I will learn "Cost versus performance" evaluation and comparison of different technologies: VLSI devices, FPGAs, commercial CPUs.

Implementation method for the new technology, commissioning and operation

It is great experience to be part of new technology implementation to a physics experiment like ATLAS. Commissioning and operation is a very important experience to learn about system redundancy and technology maintenance problems. I will profit of a group that already commissioned a similar processor at CDF. These experiences will provide me the needed skills to approach and lead a new future experiment with advanced technology.

Finally, under the guide of experts engineers I will learn to have contacts with Italian companies that will build the FTK input mezzanines. I will know them and their organization, I will learn how to manage them.

- **<u>Potential of transferring knowledge to European host and/or bringing knowledge to Europe</u>**

I have in mind to be a bridge between European and Japanese FTK Institutions and companies. Highly advanced hardware development in INFN and high level technology of European companies can make good collaboration with a lot of science experiments and some semiconductor research corporations in Japan. Application potentiality of flexible hardware systems with combination of FPGAs and ASICs and pattern recognition is very high. Experience and knowledge from this IIF are able to declare these technologies to the Japanese physics experiments and some company, and it will bring complementary advantages and benefits.

In addition I can help young European scientists and engineers to study or have training periods in Japan. I will keep connection to the Waseda University, since it has strong Business-Academia cooperation programs. There are schemes in the Japanese Government (MONBUKAGAKUSHO: MEXT) scholarship for foreign researchers and students in Waseda University Centre for International Education. So I can help to contact these programs as a tutor. I think it can be a very interesting experience for European students.

B3 RESEARCHER (MAXIMUM 7 PAGES WHICH INCLUDES A CV AND A LIST OF MAIN ACHIEVEMENTS)

- **Research experience**

Education and Professional Appointments/Employment:

2011 - now Assistant Professor
Waseda University, Faculty of Science and Engineering
ATLAS experiment: FTK development, measurement of top cross section

2009 – 2011 Junior Researcher
Waseda University, Research Institute for Science and Engineering
ATLAS experiment: FTK development, measurement of top cross section, SCT operation

March 2009 Ph.D in Physics. Title “Study of the Top Quark Production Mechanism in 1.96-TeV Proton –Antiproton Collisions”, Supervisor: Prof Fumihiko Ukegawa –University of Tsukuba, Ibaraki Japan

2006 – 2009 Student in Doctor’s Programs
University of Tsukuba, Graduate School of Pure and Applied Sciences
CDF experiment, Study of top quark production mechanism,
CDF run operation, Plug Pre-shower Detector Calibration

2004 – 2006 Student in Master’s Programs
University of Tsukuba, Graduate School of Pure and Applied Sciences
PMT study for the CDF detector,
Physics study by Monte Carlo simulation

Operative Systems, Programming languages and Scientific Software:

- ✓ Good Knowledge of Windows systems from version 9x to the latest version.
- ✓ Very good knowledge of GNU/Linux system, derived by Debian, Fedora, Ubuntu distribution.

  Good ability as user and as administrator, with knowledge of the common tools used for below tasks: Shell scripts in BASH and TCSH, Lisp, AWK and other tools.
- ✓ Very good knowledge of the C/C++ language and other common languages: Java, Python, Perl and FORTRAN, used usually in conjunction with the most common scientific libraries.
- ✓ Knowledge of advanced programming schemes like multi-threading programming.
- ✓ Knowledge of debugging and code testing by GDB.
- ✓ Very good knowledge of languages used to create documents and to present results: Latex, HTML, XML and PHP.
- ✓ Very good knowledge of Monte Carlo generators for the particle collider physics: Pythia, Herwig, AlpGen and MC@NLO.
- ✓ Very good knowledge of ROOT framework
- ✓ Good knowledge of the common software bundles for personal productivity: Windows Office and Open Office.

My research work has focussed on the breakthrough of rules governing the fundamental particles and their interactions, working at the most high energy hadron colliders available in the last 30 years, the Tevatron near Chicago (USA) and the LHC at CERN (Switzerland). Since the beginning of my research I worked on competitive top quark physics at the CDF experiment first, and at the ATLAS experiment after. These researches were measurements made to study deeply the Standard Model, with the main goal of understanding which physics is hidden beyond it. Additionally I worked on the trigger system development to increase the capabilities of my experiments to collect more efficiently large samples for future interesting physics analysis results. The subject of my master's degree, Ph.D and post-doctoral research is described below:

✓ Performance study of Photo Multiplier Tube (PMT) for the CDF detector

I worked on the PMT performance study during my master's degree. I did base calibration and performance check of all produced Multi-anode PMT for the Central Pre-Shower detector (CPR2) upgrade project for the 2004. CPR2 detector is the combination of the scintillator tiles, the Wave Length Shifter fibbers and PMTs. CPR2 is able to reject the fake electron produced by a pi0 photon. Checked performance (variability of output charge from 16 channels and cross talks) satisfied the requirements and so PMT's were installed in CDF. Then I studied the long time stability reproducing high luminosity environment conditions for some type of PMTs, using a simple test setup. I found unstable behaviour for the fine mesh PMT using the Time Of Flight (TOF) detector that used the same PMTs. The TOF is made of one scintillator bar and PMTs located around the beam pipe at 1.6 m. Main task of TOF detector is separation for low P_T π and K meson using difference of flight time. Its PMTs are exposed at 1.4 T magnetic fields, so fine mesh PMT that have resistance properties for the magnetism was chosen. The gain of the PMTs dropped about 40 % for high frequency inputs used to reproduce the high luminosity environment. I found that the reason of the gain drop was basically the charge up of the PMT's base due to the dynode damage. Finally the gain drop was resolved by increasing the applied voltage for the PMTs.

Study for the top pair production system at CDF experiment

The top quark was discovered at CDF and D0 experiment at Tevatron in 1995. The Tevatron was the only collider that could study the top quark at that time. My Ph.D thesis reported measurements of the production cross section of the top quark pair and identification of the initial state of the sub-process, whether it was a gluon-gluon pair or a quark anti-quark pair. The measurement of the production cross section is the most important for all analysis using this process, and also serves as a good test of the Standard Model. A measurement of the gluon fusion gives a knowledge of the gluon content of the proton at large values of x, as well as providing a test of the perturbative QCD calculations. In addition a large difference from expectations would indicate new physics behind the SM. The gluon fusion and quark annihilation have different top quark spin correlations. The two processes can be differentiated if we can access the top pair spin information. Because the top quark decays immediately, before hadronization, due to the short lifetime, the top quark spin information is preserved and transferred to its decay products. I used the angular correlations among decay products to infer the initial state of the sub-process. In the standard model, the top quark decays into a W boson and a b-quark almost 100% of the time. The W boson subsequently decays into either a pair of quarks or a lepton-neutrino pair. I used di-lepton channel final state where both Ws decay leptonically. Finally gluon fusion fraction was measured by fits of these leptons flight direction angle that indicate initial spin state. This was the first measurement of the gluon fusion fraction using the top quark pair spin correlation. Both measured values were consistent with the Standard Model expectations.

✓ Study for the silicon detector at ATLAS

My first research work as post-doct was a study for the semiconductor system (SCT) at ATLAS. SCT is the silicon strip tracker with 6 M strip channels, and it is also one of the inputs of the FTK processor. I measured the noise occupancy using the number of the hits that could not be associated to a real track. The residual hits were counted after the space point hits subtraction. The measured noise occupancy was consistent with the expected value calculated with full equivalent noise charge. My method can be used for the online noise occupancy measurement during the ATLAS operation.

✓ Top quark pair production cross section measurement at ATLAS

In the first phase of the ATLAS data taking, the study of the top quark was one of the highest priorities of the ATLAS physics program. In particular, the measurement of the top quark pair production cross-section is important because top pair events constitute a major background to several new physics scenarios. I measured the production cross-section in the full hadronic final state where both W bosons decay into jets, characterized by a nominal six-jet topology. Tow jets are required to be identified as originating from a b-quark using a secondary vertex b-tagging algorithm that identify the long lifetime of the b-quark. This channel has the advantage of a large branching ratio (46%) although it suffers from a huge QCD multi-jet background. The analysis was started by the very beginning of data taking at LHC, with low luminosity. Subsequently the trigger data collection became more difficult due to the luminosity increase. My work on FTK (see below) will have a large impact on this analysis and many others taking into account heavy flavours. My measured cross section was consistent with the Standard Model and it was combined to other decay channels for publication.

✓ **FTK study at ATLAS**

Currently I'm working on the FTK project at the Waseda University. I provided many contributions in different areas:

(1) I developed a standalone program that could simulate the FTK processing time measured on Monte Carlo generated events. FTK needs to provide the track information before the start of the L2 event analysis, so latency estimation is one of the important information to validate the FTK project. My work started from the reconstruction of the SVT latency in the CDF experiment where both data and simulation were available. After good consistency checks of SVT timing on data and simulation, I estimated the FTK latency including all the timing details of each board in the system. This process allowed me to gain a deep understanding of the whole FTK system. FTK was demonstrated to be enough fast for L2 trigger and my work was an important part of the FTK TDR.

(2) I participated to the design and test of the first prototype of the FTK input mezzanine, FTK_IM, the first FTK device found by the data coming from the detector. The small mezzanine has powerful FPGAs to perform 2D clustering of pixels and 1D clustering of strips and to find the best estimate of the position of the particle interaction in the silicon. This project is collaboration between Waseda and INFN Frascati, and is the reason of my travels to Frascati in the past.

(3) I participated to the vertical slice activities during 2012 developing the FTK_IM firmware and working on the setup of the AMBoard with which we could take the first FTK data. We checked the first real data inputs from the ATLAS detector selecting small regions (few silicon modules) that where connected by fibers to the FTK input mezzanines. We could show the capability of the group to insert hardware on the experiment without causing troubles to the data taking.

(4) Finally I worked for the production of Associative Memory banks. I optimized the method for bank production to make it faster and suitable for study of real, not just simulated data. I also participated to test AMboards that have been used in the vertical slice. I could acquire experience on the AMsystem in that occasion.

- **Research results including patents, publications, teaching, etc**

Invited Talks

Title "**Top quark production at ATLAS**",
Naoki Kimura On behalf of the ATLAS collaboration
16 th International Conference in Quantum Chromo Dynamics.
Montpellier, France. July 2012

Title "**A Fast Hardware Tracker for the ATLAS Trigger System**",
Naoki Kimura On behalf of the ATLAS TDAQ Group
6th International Workshop on Semiconductor Pixel Detectors for Particles and Imaging.
Inawashiro, Japan. September 2012

Title "**Top quark physics and Higgs search results at CDF experiment**"

Naoki Kimura for the CDF Collaboration
The physical Society of Japan 2010 Fall meeting
Fukuoka, Japan. September 2010

Title "**Measurement of the relative fraction of the gluon-gluon fusion in top-antitop production process at 1.96 TeV proton-antiproton collisions using CDF**"
Rencontres de Moriond EW
La Tuile, Italy. March 2009

Publication

I am on the author-list of CDF (2007-) and ATLAS (2009-) collaboration. I have more than 200 publications. Here are those where my contribution is important. At hadron colliders publications with data are signed by the whole collaboration and there is no definition of the main author. The author list is published in alphabetical order. CDF and ATLAS collaborations have respectively about 600, and 3000 physicists.

1. Search for the Standard Model Higgs boson in the H to tau+ tau- decay mode in sqrt(s) = 7 TeV pp collision with ATLAS
[ATLAS Collaboration] JHEP 1209 (2012) 070
2. Search for resonances decaying into top-quark pairs using fully hadronic decays in pp collisions with ATLAS at sqrt(s) = 7 TeV
[ATLAS Collaboration] JHEP 1301 (2013) 116

3. The Fast Tracker real time processor and its impact on muon isolation, tau and b-Jet online selection at ATLAS.
A. Andreani, N.Kimura (25th on 56).IEE Trans.Nucl.Sci.59(2012)348-357.

4. Measurement of the top quark pair cross section with ATLAS in pp collisions at sqrt(s) = 7 TeV using final states with an electron or a muon and a hadronically decaying tau lepton.
[Atlas Collaboration], Phys.Lett.B717(2012)89-108.

5. Evidence for a Mass Dependent Forward-Backward Asymmetry in top Quark Pair Production.
[CDF Collaboration], Phys.Rev.D83:112003,2011.

6. Measurement of the Top Pair Production Cross Section in the Dilepton Decay Channel in ppbar Collisions at sqrt s = 1.96 TeV
[CDF Collaboration] Phy.Rev.D82:052002,2010.

7. Enhancement of the ATLAS trigger system with a hardware tracker finder FTK.
A. Andreani, N.Kimura (23th on 51). JINST 5:C12037, 2010

8. A Measurement of the t anti-t Cross Section in p anti-p Collisions at s^(1/2) = 1.96-TeV using Dilepton Events with a Lepton plus Track Selection.
[CDF Collaboration] Phys.Rev.D79:112007, 2009.

9. Cross Section Measurements of High-p(T) Dilepton Fianl-State Processes Using a Global Fitting Method.
[CDF Collaboration] Phys.Rev.D78:012003, 208.

10. Search for Standard Model Higgs Boson Production in Association with a W Boson at CDF

[CDF Collaboration], Phys.Rev.D78:032008, 2008.

11. Precise measurement of the top quark mass in the lepton+jets topology at CDF II
[CDF Collaboration], Phys.Rev.Lett.99:182002, 2007

Teaching experience
Lectures of the Mechanics

2011- now, 22 hours/year, Waseda University, Faculty of Science and Engineering

I'm lecturing the classical dynamics using differential equation for the First-year student.

Seminar and exercise class for the physical mathematics

2011- now, 60 hours/year, Waseda University, Faculty of Science and Engineering

I managed this class that made up of exercise of the physical mathematics and student presentation by seminar for the first-year students.

Teacher: lab course. "optical circuit element"

2011- now, 90 hours/year, Waseda University, Faculty of Science and Engineering

I teach the basic elements and texture for the optical circuit element for third-year students.

Teaching Assistant: lab course "measurement of the muon lifetime"

2004-2006, 40 hours/year, Tsukuba University, Graduate School of Pure and Applied Sciences

I teach the measurement of the muon lifetime using simple detector of scintillators and PMTs for the third-year students.

- **Leadership qualities**

I could get very good leadership experience during my Ph.D. study at the CDF experiment during my analysis in the top quark sector. I studied the top quark production mechanism using the top spin correlations and I participated to the measurement of the top pair production cross-section including the best estimation of background. It was a very competitive research field, discussed in a large and aggressive group of physicists, however I could demonstrate the validity of my ideas and methods, despite my young age. We measured the cross section in several data sets with different luminosities and finally I was chosen to be one of the two leaders in the group. Using a lot of statistics I demonstrated that the old method to estimate the background reached critical limits for precision measurements. So I proposed a new method to keep high the quality of the analysis. The proposal was not accepted at the beginning, because all other analysis (mass measurement, resonance search, property measurements etc) using the same decay channel would have been strongly affected by this decision. I suggested a correction to the new background estimation method that positively combined data and Monte Carlo expectations. At the beginning also the new proposal was criticized. But I could demonstrate its robustness and the many improvements provided by it so that, finally, it was adopted. Our group could estimate the top pair production cross section and the results were published. My proposal has become a standard and was used by many other analyses based on this top channel decay. This was a research field where leadership capabilities were very important and I could exercise them.

Moving at Waseda, I was one of the few physicists in charge of the activation of an experimental particle physics laboratory at the Waseda University. A small group made by one associate professor and 2 post-doctoral researchers was in charge of activating by scratch this activity. I'm part of this group and I am leader of the ATLAS group. A total of 13 students joined the ATLAS group in the 5 years of laboratory activity, under my responsibility. Presently 2 PHD students are working on Higgs search using Higgs decaying to τ-leptons, 1 PHD student and 2 master's students are working on hardware development. First I educated the students by demonstration of my work in front. I assign tasks to the students, giving them strong motivation to grow. I give just suggestions and provide answers to their questions. I treat students as colleagues to keep their motivation and I do only the things that are too challenging for them, to make them confident that any problem can be solved. I coordinated the group as leader, and I achieved good results.

- **Independent thinking and capacity to transfer knowledge**

In my opinion, a foremost important point for the future science to get broad perspective and go ahead with respect the current situation, is a better cooperative framework of different scientific fields. Transfer of knowledge and cooperation is really the key point. For what is my personal experience I think today there is too little cooperation, especially in Japan. As an example I can mention that engineering and science in Japan have very little contacts. Working in physics experiments we have to face many problems of different origin, for which our nature of physicists is not enough specialized. It would be wonderful to share and discuss our problems with people of the specific sectors of the found problems. For example it was extremely difficult to share opinions or ask questions about electronics to an electronic engineer, even if he belongs to the same University. This difficulty may exist in Japan even in the same high energy physics field, between theorists and experimentalists.

The differences between Japan and Europe are so large that certainly transfer of knowledge will produce interesting results for both countries. Cooperation in Italy is more advanced, but the organization of the structures is lower. I think good connection between different scientific fields and very different cultures is a powerful tool for science and society advancement. I believe, knowledge transfer by personnel exchange like this IIF fellow allows to do, will bring good results. Our collaboration between Italy and Japan, already existing because we have a common development in the FTK_IM and the AM system, will be strongly reinforced. It will certainly allow to generate improvements in our specific project. Hopefully a large scientific cooperation between countries and different scientific fields will bring the sought discovery of new physics and new ideas for new experiments.

- **Match between the fellow's profile and project**

The match is impressive. I was trained inside CDF, a wonderful experiment at the Tevatron, the largest hadron collider prior to the LHC and the FTK project and team is also generated by the CDF story and culture. FTK offers us 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 new LHC data I will be able to further develop my analysis skill, the one that I learned at CDF and ATLAS doing top quark physics. These analysis will be important not only for physics results, but also to make an early measurement of the online tracking performance at ATLAS and to check with real data the FTK studies done with simulation. The early analysis of data will provide important information on the effectiveness of the baseline and new trigger techniques. The two points (a) and (b) are strongly coupled and since I have experience in both areas I can play an important role in FTK. In fact the technical capability of triggering on events with very high rejection factors is not sufficient to motivate their development unless it can be shown that the analysis of the data collected by these triggers is feasible and the further background rejection needed to extract the signals is achievable. Trigger upgrades are often considered "unnecessary" because exploiting the additional trigger efficiency at the analysis level is difficult. Given the high rejection factors already achieved at trigger level and the difficult hadronic environment, the reconstruction of events in the off-line stage is particularly challenging. My analysis experience will be important to clarify the FTK role on data analysis.

FTK will allow selection of purely hadronic events rich of b-quarks and hadronically decaying tau leptons. My experience in the top full hadronic channel is an extremely good experience in the necessary offline techniques; it suggests that reconstruction of rare interesting events with an initial signal-to-background of order 10^{-10} at production is indeed possible.

B4 IMPLEMENTATION (MAXIMUM 6 PAGES)

- **Quality of infrastructure/facilities and international collaborations of host**

The National Institute for Nuclear Physics (INFN) is the laboratory for nuclear, particle and astroparticle physics in Italy. It was founded on 8 August 1951, to continue the nuclear physics research tradition initiated by Enrico Fermi in Rome, in the 1930s.

The Roman area constitutes the most important HEP area in Italy and the Laboratori Nazionali di Frascati (LNF), situated south of Rome, is the largest laboratory of the INFN (national institute for nuclear physics). The LNF laboratory is organized into three sub–structures: the Accelerator Division, the Research Division and the Administration, for a total of about 380 staff members.

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

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

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

LNF is rich in instrumented laboratories for large system assembly, testing and related software development.

INFN have participated also in CDF, from the beginning. The CDF was an international collaboration of about 800 physicists from about 60 universities and National laboratories. 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 and the more recent discovery of the Σ_b baryon and the observation of the Bs oscillations.
The Italian FTK community in CDF, have also recently joined the ATLAS experiment at LHC. ATLAS is a “virtual United Nations” of 37 countries. 2500 physicists come from more than 169 universities and laboratories and include ~700 students. ATLAS is one of the largest collaborative efforts ever attempted in the physical sciences. The ATLAS detector consists of four major components: (a) inner tracker, particularly relevant for my project - measures the momentum and the trajectory of each charged particle; (b) calorimeter - measures the energies carried by the particles; (c) muon spectrometer - identifies and measures muons; (d) magnet system – it bends charged particles as function of the momentum allowing its measurement. The proton-proton interactions in the ATLAS detectors will create a huge dataflow. In order to digest this data we need: (a) the trigger system, for which my proposal is an upgrade - selecting few handreds interesting events per second out of 1000 million generated ones; (b) the data acquisition system - channelling the data from the detectors to storage; (c) the computing system - analysing 1000 Million events recorded per year.

The FTK project will have its execution by collaboration of Italy (LNF with the collaboration of other INFN sites), USA (Enrico Fermi Institute, University of Illinois, Argonne and Fermilab), Japan (Waseda University), France (LPNHE), Germany (University of Heidelberg), Switzerland (University of Geneve) and Australia (University of Melbourne), the ATLAS experiment itself at CERN. 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 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.

- **Practical arrangements for the implementation and management of the research project***

My project involves electronics together with analysis and the Electronics Design Group of INFN is superb. The role of the "eshop" is to work with students and faculty members on cutting edge electronic design helping them to design, route, build and test boards under the supervision of an electronics engineer. The eshop makes available electronic design automation (EDA) software and test equipment, enabling the users to fully simulate any part before the actual construction and test it once it has been completed. Past electronics systems designed and built in the eshop are currently being used in experiments worldwide and part of SVT belongs to this list. The service for electronics development works for both experiments and accelerator control. Moreover, the ATLAS Frascati group has expert engineers and technicians that will collaborate on the project. For this reason the LNF management is very interested to our state-of-the-art experience that will provide a positive interaction with the local facility.

I will have an office in LFN with computing capability and access to the Tier2-Tier3 computing facilities for development of the trigger for each physics cases and analyze the data collected by ATLAS. I will be allowed to use CADs for electronic board design (Cadence software) and for chip design (Xilinx ISE software). The eshop personnel will introduce me to these tools and help when necessary. I will use the laboratory for electronic tests, provided of racks with independent test stands, oscilloscopes, digital analyzer, and computers and terminals for access, control, monitoring of the available test stands. We will use standard 9U VME crates for board housing and the VME protocol for CPU-crate communication, and ATCA (Advanced Telecommunications Computing Architecture) crate and control shelf Manager Card. A laptop will be available with CAD software to download new firmware directly through Boundary Scan.

At CERN, for parasitic tests of the vertical slice, we will have similar facilities, but the work will be more complex because of the interaction with the experiment. In the control room the shift team, helped by others experts, has the responsibility for the data taking. It is not possible to predict now when and how much easy will be for people working on the proto-FTK to obtain from the shift crew the capability to perform online tests. This part of the program to be executed at CERN is presently the less defined in its details. At LNF the same instrumentation will be available. The test stands and test software exploit the long experience developed at CDF. There is uniformity of standards at the two 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. In this way everything done in one institution can be easily repeated and checked in the other. Moreover the exchange of information between Frascati and the other members of FTK is very strong. We have weekly video meetings in which all the FTK institutions connect to discuss and plan the near term work. Each one reports on his work and discusses the global advancement.

- **Feasibility and credibility of the project, including work plan**

I participated to the FTK project and the ATLAS experiment since 2009, focusing on the hardware development and hardware simulation for the FTK global latency estimation and in parallel for new physics search. FTK was officially approved by ATLAS experiment in 2010 to produce a TDR, and a TDR was submitted in the recent days. FTK is closely watched by many scientists in ATLAS experiment for the advanced future analysis. FTK installation will be start at 2014 and it will be consecutively increased for the enhancement of the LHC luminosity. Therefore this IIF period is very good timing for the final design optimization of hardware and mass production, and the commissioning and test of board and firmware. And also it is very good timing to declare the FTK performance with realistic trigger new approach.

Each functional electronic substrate board for FTK was designed by one or more collaborators and prototype boards are now produced, and they are going to be tested by each site. We also installed the Vertical Slice on the experiment to test the FTK insertion in the TDAQ using some new and some old prototypes. Tests performed with real data collected by ATLAS detector at CERN has very big meaning for FTK. Test succeeded to show that FTK can really fit in Atlas albeit using a part of the detectors, and also gave us the understanding of weak points of the system (especially for diagnostic and monitoring tools) and suggested improvements before mass production. These information are used to produce next generation of boards. We can test the new prototypes in the Vertical Slice intermittently, each time a new board is ready. This procedure gives feasibility and credibility to the project.

My work will be focused on hardware and firmware development in the first year, and I will add physics study with trigger design in the second year of this IIF. The details of work plan for this IIF phase are:

✓ Input mezzanine board production

The Input mezzanine board for FTK (FTK_IM) is a common responsibility of LNF and Waseda University. As already mentioned, it receives the hit position information from the silicon tracking detector, and clusters them to find the particle impact points with the best resolution to be sent to the next board. The FTK_IM will be in production phase during the first year of this IIF. The main work to be done is to test carefully the final design, to check the companies that have been chosen for production and finally the quality control for the produced boards. ATLAS experiment requires less than 10^{-15} error rate for objects that have to be installed.

✓ Firmware implementation for the Input mezzanine board

Full resolution's hits positions from the silicon detectors are clustered by firmware in FPGA on the FTK_IM. The quality of the online clustering algorithm is very important for the offline analysis, because any difference between offline and online impinges on the final efficiency on physics. There is enough time to perform perfect clustering on offline, but at trigger level, i.e. online, we have to perform a high quality task in a limited amount of time. So we cannot use exactly the same offline method. We implement high quality algorithm in the needed short latency exploiting largely the parallelism that we can implement inside FPGAs.

- ✓ **Associative memory development**

Pattern matching executed by the Associative memory is the crucial part of the FTK real time processing. I will have a chance to contribute to the last and newer versions of the Associative memory chip development. I plan to participate to final Associative memory chip tests, and ASIC technology will be a great experience for me. I will also continue to work on bank production and software development to allow easy use of the AM technology both at online level and offline for trigger simulation.

- ✓ **Installation and commissioning**

Obviously installation of produced FTK boards is a very important step for the project and I will be part of the team. Racks for our system installation are already available in ATLAS, and we can start installation and commissioning as soon as boards are produced. All the configuration, monitoring and diagnostic software for a correct functioning of the processor has to be developed. That won't be an easy task, however the experience gained with SVT in CDF and with the Vertical Slice in Atlas will certainly help. So we will do an efficient installation, commissioning and test, as described in section B1, using our past experience.

- ✓ **Trigger study for new physics search**

During installation and commissioning phase, we will have to define a whole set of new trigger criteria based on the intensive use of FTK tracks. Some possible trigger cases were already studied and showed very efficient recovering important physics samples. However they were simulation studies to show the effect of possible selections, while implementing the trigger in the TDAQ structure is a totally different task. In addition only a little subset of the whole amount of possibilities was successfully studied. Much more advanced usage of FTK can be proposed, studied and implemented. I will participate to this very important work and in addition I plan to make a my proposal for an advanced new trigger aiming to select the specific physics objects already described in section B1, very boosted top events.

- ✓ **Analysis using real data collected by ATLAS detector**

During the second half of 2015 FTK will start the operation using real data from the central part of the detector (Barrel). We can use the real data from FTK, and we can show the impact of FTK on data taking. It will give a foresight into the future physics analysis, and it will accelerate the more advanced approach of usage of FTK inputs. First my work will concentrated on performance measurement of the single trigger objects (b-jet, τ , lepton) by FTK. Especially efficiency difference between FTK and offline as a function of threshold (trigger turn-on curve) by real data is important value to show the impact for the physics. Then I will move to more specific physics analysis by combined trigger that mentioned before.

The work plan includes participation in conferences and related paper production. I plan at least a technological conference contributions (IEEE or similar) in 2 years and more than one technological papers. I plan also at least one contribution to physics conferences and the production of the related proceedings. The work plan also includes frequent presentations of the work inside the TDAQ/Physics group and seminars to the ATLAS collaboration or Frascati high energy community. It will include also supervision/tutoring of Italian students working in ATLAS and Japanese students that will visit LNF.

This project is a wonderful opportunity for my career and FTK collaboration. I have acquired experience in CDF on top physics analysis and in ATLAS on advanced tracking techniques applied to sophisticated trigger selections for b-quark decaying from top quark. My participation in FTK as an expert will allow me to have new important roles in FTK, in particular, where I will be the most expert and involved in the project. I expect that this fellowship will allow me to be the leading person for the FTK analysis in Frascati, to manage the related funds, to coordinate the analysis of young people in this field. I expect also to have an important role in production and commissioning, to be able to manage the companies that have to produce our hardware and to coordinate the work of one engineer and few technicians working in production, commissioning and maintenance.

This IIF phase will be important for broadening my experience. Even though I was deeply involved in physics analysis and FTK R&D, my contribution was basically limited to software: analysis of collected data or simulation studies of proposed architectures. Just recently, since a few years I started working on hardware development, and I know (due to the short visit to INFN) that this IIF will offer a tremendous amount of potential for my technology knowledge. . I did not have the opportunity to learn deeply on hardware and the LNF will a perfect place to learn. Moreover the LNF working style is also perfect for learning how to handle a group and a project. And I believe this IIF will also produce good results for the FTK projects and for the collaboration between Europe and Japan.

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

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

- **<u>Practical and administrative arrangements and support for the hosting of the fellow*</u>**

LNF is a place where a large number of visitors attend from outside, so it is organized to host foreign physicists. Help is provided for housing and administrative problems. Moreover, the INFN central administration is actually there.

INFN offers full social security benefits. It provides a high speed internet connection cable and wireless for all the affiliated researchers. A security badge is offered for each affiliated member who allows access to the university campus, the INFN offices and laboratories. The badge allows access even in weekends if necessary. The campus offers a free parking space for employees and researchers. It has an International Office to assist international researchers. Visa and Registration assistance if offered for EU and Non-EU citizens. Assistance is also offered for obtaining the Italian tax code (Codice fiscale).

There is also an accommodation office to assist students and researchers to find a suitable house or apartment. Single room accommodation is also offered for short initial periods inside the laboratory.

Services are available, like a library, a cafeteria, relaxing areas.

Near the laboratory are located the 3 universities of the roman area, offering libraries and courses of many different kind. It is possible to follow Italian language courses for international students during the year for different proficiency levels. Many sports and leisure activities are offered. The university has a Sports Centre where university members are not required to pay a fee. The positions near Rome offer an extraordinary number of opportunities. Numerous museums and historical sites are spread throughout the city of Rome. Many dining services, athletics sites, parking facilities are provided.

The Laboratory central position in Italy allows very easy communication with the most important Italian towns by fast trains. It is also extremely easy and chip to move to CERN, because of the many, direct, low-cost flights from both the two Roman airports,

B5 IMPACT (MAXIMUM 4 PAGES)

- **<u>Potential for creating long term collaborations and mutually beneficial co-operation between Europe and the other Third Country</u>**

Both Italy and Japan have participated in the CDF experiment at Tevatron since the beginning (1985) but only recently after the 2000 with the SVT and FTK activity a very good collaboration is born, just when we started the new High Energy Physics laboratory in Waseda.
Even if we did not work together during most of the CDF life, CDF gave us the comprehensive way of thinking and this was an important common background useful to expand a relationship of cooperation. Knowledge transfers with personnel exchange produces mutually beneficial cooperation. INFN got funds in 2010 from MIUR (Ministero dell'Istruzione, dell'Università e della Ricerca) applying to the CALL FOR PROPOSALS OF JOINT RESEARCH PROJECTS WITHIN THE EXECUTIVE PROGRAMME OF COOPERATION IN THE FIELD OF SCIENCE AND TECHNOLOGY BETWEEN JAPAN AND ITALY FOR THE YEARS 2010-2011. With this fund I could visit Frascati and Pisa for short periods, a couple of times per year for 3 years. A couple of students followed me during these visits. I was determinant starting this collaboration and participating to it, and I could reinforce it very much with this IIF fellow that would allow me to stay two years.

FTK project is in expansion, offering many different new research developments, so it is very natural to reinforce and increase our collaboration, an expansion to include new upgrade project and new physics analysis based on the acquired knowledge of the current and past projects.
I really think there are great capabilities for advanced flexible hardware technology using a combination of FPGA and ASIC. This is very promising field that we will face together reinforcing our collaboration. It is our goal also to make new collaborations for experiments outside of high energy physics field at colliders. One of my colleagues from CDF, for example, is starting to study dark matter in a Japanese experiment, and now he is active in XENON Dark Matt search experiment at Gran Sasso (Italy). He is interested to know our technology. Japan has very advanced laboratories and would be very interesting to expand our collaboration in that direction.

It comes near to stating the obvious that knowledge transfer with personal exchange like this IIF will develop science and technology much further. Knowledge by personal exchange in difference environment is extremely effective at producing new ideas. Those ideas will favour new collaboration on both sites of personal exchange.

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

- **<u>Contribution to European excellence and European competitiveness through valuable transfer of knowledge</u>**

The LHC was built by the European Organization for Nuclear Research (CERN). The latest technologies are concentrated in this accelerator and its experiments to bring ahead our knowledge of the Universe and to pursue great physics results. CERN is contributing to European excellence and European competitiveness. All countries in the world recognize the role of CERN research and are obviously very interested to contribute. I really want to give my personal contribution to this European excellence. Certainly the FTK project, that I have chosen to do it, has good chance to have a great impact on the CERN physics. It is a high technology project, very original, adopted by ATLAS, but also able to attract the attention of other experiments. It is also able to produce important spin-off outside of HEP. FTK can really be a proof of the European excellence, in an environment that already is excellent.

- ✓ Our main goal is the development of the very fast tracking system for the ATLAS trigger, and this system makes it possible to collect very interesting samples to produce physics results that would be very difficult to reach without FTK, due to the high luminosity environment. It will improve our knowledge of physics.

- ✓ Interest is growing around this project: the FTK collaboration is a very high level international collaboration, including European, USA, Japanese and Australian Institutions. The collaboration has the potentiality to still growing. I can reinforce the connection with Japan, I can favor exchange of students and try to disseminate the importance of our technology into the Japanese laboratories, searching also for new fields of applications, possibly exploiting also contacts with high technology Japanese companies.

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

- **Impact of the proposed outreach activities***

Researchers should ensure that their research activities are made known to society at large in such a way that they can be understood by no specialists, thereby improving the public's understanding of science. Direct engagement with the public will help researchers to better understand public interest in priorities for science and technology and also the public's concerns. Explanations of our most advanced science and technologies for the average citizen are very important issues to build-up for the future science and technologies developing.
The LNF has a very interesting plan for Outreach described at this web site: http://www.lnf.infn.it/user.html. A specific office for communication and education is dedicated to this very important task. The program includes meetings to speak of physics, lessons on physics, dissemination of educational scientific material, specific events in occasion of particularly interesting results, expositions with historical and scientific material, stages for students, summer camps on physics, schools, master classes, visits of the laboratory, open days, but also more generic cultural events like concerts and presentation of books.

I will participate to this plan, in particular giving seminars to young students, visiting schools, community organisations that will contact the laboratory. I will promote my research field or assist teachers in preparing and delivering teaching materials.
I will participate to the laboratory Open Day and to **Summer-Schools for** students to let them receive a first hand experience from my current research activities or wider scientific issues; I will prepare specific activities, lectures and simple experiments for the public.

B6 ETHICS ISSUES (NO PAGE LIMIT)

MAIN ETHICAL ISSUES THAT MUST BE ADDRESSED

- Informed consent
- Human embryonic stem cells
- Privacy and data protection
- Use of human biological samples and data
- Research on animals
- Research in developing countries
- Dual use

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

(Guidance notes on informed consent, dual use, animal welfare, data protection and cooperation with non-EU countries are available at: http://cordis.europa.eu/fp7/ethics_en.html#ethics_sd)

	Research on Human Embryo/ Foetus	YES	Page
	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	

	Research on Humans	YES	Page
	Does the proposed research involve children?	NO	
	Does the proposed research involve patients?	NO	
	Does the proposed research involve people 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	

	Privacy	YES	Page
	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	

	Research on Animals	YES	Page
	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	

	Research Involving Developing Countries	YES	Page
	Is any material used in the research (e.g. personal data, animal and/or human tissue samples, genetic material, live animals, etc) : a) Collected and processed in any of the ICPC countries? b) Exported to any other country (including ICPC and EU Member States)?	NO	
	I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	YES	

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

ENDPAGE

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PART B

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