

LHCb-Pisa Preventivi 2015

. M.J.Morello – 2 luglio 2014

7/2/14



LHCb-Pisa Group

- Il gruppo e' stato fondato a
 Settembre 2012, da soli tre membri iniziali (Bedeschi/Punzi/Morello)
- In seguito si sono aggiunti
 3 senior + 2 post-doc.
- Attualmente 3 laureandi in Tesi
 Specialistica + 1 PhD student.
- F. Lionetto ha discusso la sua tesi di ^{Alessio Plucci} laurea in estate 2013.

LHCb-Pisa Group

Giovanni Punzi Franco Bedeschi John Walsh Franco Spinella Alberto Lusiani Michael J. Morello Simone Stracka Riccardo Cenci Pietro Marino Alessio Piucci Daniele Ninci Paola Mocci Team Leader - Associate Professor (UniPi) Dirigente di Ricerca (INFN) Primo ricercatore (INFN) Tecnologo (INFN) Assistant professor (SNS) Assistant professor (SNS) PostDoc (SNS) PostDoc (SNS) PhD student (SNS) Undergraduate student Undergraduate student



The LHCb experiment

- pp collisions at 7-8TeV
- Large b-quark production in the forward region
- Full b-hadrons spectrum
- Lpeak = $3-4 \times 10^{32}$ cm⁻²s⁻¹
- $L_{int}=3.1 \text{ fb}^{-1} \rightarrow (10^{12} \text{ bbar pairs})$





- Specialized b-physics and charm
- Forward single arm spectrometer
- Acceptance $2 < \eta < 5$





- VELO: Excellent vertex and IP resolution.
 - $\sigma(d) \approx 24 \ \mu m \text{ at } p_T = 2 \text{GeV/c},$
 - Lifetime resolution ≈ 45 fs $\approx 0.1 \tau (D_0)$



- Excellent tracking resolution: $\delta p/p = 0.4-0.6\%$ at 5-100 GeV.
- RICH very good particle identification for π and K.
- The polarity of the magnet is regularly reversed during data taking 7/2/14



Trigger System

- Level-0 (custom electronics)
 - 1MHz output
 - Largest $p_T(\text{or } E_T)$ of hadron/e/ γ/μ
 - − Typical tresholds $1.5 \rightarrow 3.5 \text{ GeV/c}$
- HLT (commercial CPUs)
 - Stage1: partial event reconstruction, selection based on IP, p_T on single track
 - Stage2: Full event reconstruction



Level-0

 $\mathsf{High}\text{-}\mathsf{p}_{\mathsf{T}}$ signals in calorimeter and muon systems

HLT1

Associate L0 signals with tracks, especially those in VELO displaced from PV

HLT2

Full detector information available Continue to look for inclusive signatures, augmented by exclusive selections in certain key channels.

Statistics — 194 papers

	Arxiv	Internal	Submitted	Accepted	Published	CONF	
	2010				2	7	
	2011				27	61	
	2012				57	34	
	2013				76	13	
	2014	22	10	4	18		
	P. Kopp	Penburg sek June 20, 20	80 70 60 50 40 30 20 10 0				 Published Accepted Submitted
L	нср	_	20	10 2011	2012 2013	2014	
	The provide the second	Koppenburg	PC summary		LH	Cb week, 20/06	/2014 [2/24

19 PAPERS SINCE LAST LHCB WEEK

- P. Koppenburg LHCb-Week June PAPER-2014-011 Effective lifetime measurements of the $B_s^0 \to K^+ K^-$, $B^0 \to K^+ \pi^-$ and $B_s^0 \to \pi^+ K^-$
- PAPER-2014-023 First measurement of the charge asymmetry in beauty-quark pair production [submitted to PRL, ar
- PAPER-2014-022 Search for CP violation in $D^{\pm} \rightarrow K_{S}^{0}K^{\pm}$ and $D_{S}^{\pm} \rightarrow K_{S}^{0}\pi^{\pm}$ decays [submitted to JHEP, arXiv:1406.2624]
- PAPER-2014-018 Observation of Z production in proton-lead collisions at LHCb [submitted to JHEP, arXiv:1406.2885]
- PAPER-2014-020 Observation of the decay $\Lambda_b^0 \rightarrow J/\psi p\pi^-$ [submitted to JHEP, arXiv:1406.0775]
- PAPER-2014-021 Precision measurement of the mass and lifetime of the Ξ_b^0 baryon [submitted to Phys.Rev.Lett., arXiv:1405.7223]
- PAPER-2014-004 Study of the kinematic dependencies of Λ_b^0 production in pp collisions and a measurement of the $\Lambda_b^0 o \Lambda_c^+ \pi^-$ branching fraction [submitted to JHEP, arXiv:1405.6842]
- PAPER-2014-015 Study of Υ production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}} = 5 \text{ TeV}$. [submitted to JHEP, arXiv:1405.5152]
- PAPER-2014-019 Measurement of the *CP*-violating phase ϕ_s in $\bar{B}^0_s \rightarrow J/\psi \pi^+\pi^-$ decays [submitted to Phys.Lett.B., arXiv:1405.4140]
- $PAPER-2014-016 \text{ Observation of the } B^0_s \rightarrow J/\psi K^0_S K^{\pm} \pi^{\mp} \text{ decay [submitted to JHEP, arXiv:1405.3219]}$
- PAPER-2014-013 Measurement of *CP* asymmetry in $D^0 \rightarrow K^- K^+$ and $D^0 \rightarrow \pi^- \pi^+$ decays [submitted to Phys.Lett.B., arXiv:1405.2797]
- PAPER-2014-010 Measurement of the Ξ_b^- and Ω_b^- baryon lifetimes [submitted to Phys.Lett.B., arXiv:1405.1543]
- PAPER-2014-012 Measurement of the resonant and *CP* components in $\bar{B}^0 \rightarrow J/\psi \pi^+\pi^-$ decay [submitted to Phys.Rev.D., arXiv:1404.5673]
- PAPER-2014-014 Observation of the resonant character of the $Z(4430)^-$ state [accepted by Phys.Rev.Lett., arXiv:1404.1903]
- PAPER-2014-009 Evidence for the decay $B_c^+ \rightarrow J/\psi 3\pi^+ 2\pi^-$ [accepted by JHEP., arXiv:1404.0287]
- PAPER-2014-008 Evidence for the decay $X(3872) \rightarrow \psi(2S)\gamma$ [submitted to Nucl.Phys.B., arXiv:1404.0275]
- PAPER-2014-007 Angular analysis of charged and neutral $B \rightarrow K \mu^+ \mu^-$ decays [JHEP 05 (2014) 082, arXiv:1403.8045]

PAPER-2014-006 Differential branching fractions and isospin asymmetries of $B \to K^{(*)} \mu^+ \mu^+$ decays [accepted by JHEP, arXiv:1403.8044]

PAPER-2014-005 Measurement of polarisation amplitudes and CP asymmetries in $B^0 \rightarrow \phi K^*(892)^0$ [JHEP 05 (2014) 069, інср

Patrick Koppenburg



Towards the new LHC run

CERN's accelerator complex schedule:

- June 2, 2014: restart of the Booster 0
- Mail from Rolf Heuer June 18, 2014: restart of the Proton Synchrotron (PS) 0
- Early July: powering tests at the Super Proton Synchrotron (SPS) 0
- Mid-July: Physics program to restart at the Isolde facility and at the PS 0
- Mid-August: Antimatter Physics program to restart at the Antiproton 0 Decelerator (AD).
- Mid-October: Physics Program to restart at the SPS. 0
- Early 2015: Beam back into the Large Hadron Collider (LHC) 0
- Spring 2015: Physics program to restart at the LHC experiments 0 7/2/14



Run2 conditions in 2015

		Design	2012	2015
Instantaneous	luminosity (cm ⁻² s ⁻¹)	2×10 ³²	4×10 ³²	~4×10 ³²
Energy (TeV)		14	8	13
Tue	01:53 Tue 01:53	40ू ≵ ? ≟ ⊑9st 40ू ≵ ? ≟ ⊑9	racka 50 stracka	25
langenbruch_eps2013.pdf -	- The LHCb trigger system: Performance and outlook	٩	1.6	~1
Future developments in the LHCI	ments: LHCb upgrade afte	er LS2	16 5	12
 Upgrade conditions: 1 MHz detector read 0.6 0.4 0.2 	$\mathcal{L} \sim 2 \times 10^{33} \mathrm{cm}^{-2} \mathrm{s}^{-1}$ lout bottleneck	l0 ²	at reduce	d pile-up
0	• 2·10 ³² LLT output • LOI 10 ³³ LLT output • LOI 10 ³³ LLT output • LOI 12.5 15 17.5 20 LO rate [MHz]	Beam 2 —	5 10	$-3\sigma_{\text{beam}}^{20}$ Beam 1
7/2/14	L0 rate MHz			

Commitments of Pisa group (July 2012)

- Contribute to maintaining, updating, and improving the trackingrelated software in order to fulfill the needs of the experiment, especially those regarding data taking.
- Future runs at higher collision energy are expected to put additional demands on the data processing system.

The planned LHCb upgrade for 2018 foresees an increased input rate to the HLT from now 1MHZ to 10-40MHz. <u>This requires a</u> <u>significantly faster running time of the HLT algorithms, in</u> <u>particular the vertex and main tracker reconstruction.</u> A part of the improved algorithms can be developed in the LS1 (2013/14) and then be tested in the 14TeV running period starting 2014/15.

G. Punzi 20/06/2012 - Preventivi 2013

Pisa is responsible for tracking sequence in preparation of 2015 Run II data taking. Simone Stracka (INFN simil-fellow) based at CERN since July 2013.



HLT Reconstruction review : Track Reconstruction Performance

Lead (tools, or other) group	Trigger
Other relevant groups (if any)	tracking
Task name	HLT Reconstruction review III
Task description	The reconstruction sequence in the trigger needs to be revisited and the track-by-track performance comparerd to offline is to be evaluated. The sequence is to be retuned according to the CPU budget available for 14TeV running and possible algorithm improvements are to be identified. The possibility of using HLT tracks to seed the offline reconstruction should be studied.
Estimated	0.5
Estimated total effort required (FTE)	0.5
Estimated total effort required (FTE) Deadline	0.5 winter 2013

HLT Reconstruction review : Tracking Sequence

Lead (tools, or other) group	Trigger
Other relevant groups (if any)	tracking
Task name	HLT Reconstruction review I
Task description	The technical implementation of the HLT tracking sequence needs to be revised and rewritten. The current flexibility should be maintained.
Estimated total effort required (FTE)	1.0
Deadline	winter 2013
People/groups currently involved	Pisa (Simone Stracka and Michael Morello) + CERN (Sebastian Neubert).



Full

HLT1 tracking performances

Timing evaluated on 2012 real data (8 TeV, 50 ns) To be rescaled by correction factor from MC (=1.3)



• The reconstruction sequence in the trigger was revisited and the track-by-track performance compared to offline evaluated.

• The sequence was retuned according to the CPU budget available for 13 TeV running (51 ms), with the introduction of new algorithms developed by the tracking group.



HLT1 tracking in Run2





Efficiency vs. Purity

Triggering on transverse plane

- Current HLT1 selection strongly based on 3D impact parameter cut
- Requires finding primary vertices
 - Sensitive to luminosity conditions
- In view of increasing energy and luminosity, we studied alternative selections:
 - Demonstrated powerful alternative selections based only on transverse quantities.
 - Faster to calculate and more robust.
 - Good for higher Luminosities.
 - Will be tested for 2015 run.



Federica Lionetto master thesis, "Selection of hadronic decays of heavy flavors at LHCb". By product of these studies we were asked to investigate a "two-track" inclusive HLT1 trigger line for charm physics.

7/2/14

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Preparing for data analysis in 2015

• Pisa recently joined LHC-b

- with strong interests in pursuing highstatistics measurements on charm physics (part of group culture).
- Charm performances will be already bandwidth-limited in 2015 Run 2;
 - Trigger selections crucial, and data analysis more complex than Run 1.
- Performed initial studies on $D^{+} D^{0}\pi^{+}$ aimed to A_{Γ} and Y_{CP} measurements:
 - Aiming at the lowest systematics achievable, with fully data driven approaches.





LHCb-Upgrade

- Major upgrade of all sub-detectors.
 - Installation scheduled in 2018-19 (LS2) e data taking in 2020
 - $L_{\text{peak}} = 2 \times 10^{33}$ (nearly x10 larger than 2012) and sqrt(s)=14TeV.
 - Implement 40 MHz (= bunch crossing frequency) detector readout.

O Goals

- 50 fb⁻¹ of data over 10 years.
- x10 decays with muons in the final state.
- x20 fully hadronic decays.
- Trigger Strategy for the Upgrade is almost unchanged in the baseline:
 - LLT \rightarrow throttle to reduce rate 1–40 MHz (calorimeter info for hadrons).
 - HLT \rightarrow more powerful (and expensive) farm. x10 faster than 2012.
 - Write on tape at 20-100KHz (5KHz in 2012)
 - Aim to remove LLT, and rely exclusively on software.

• No Phase II for LHCb at the moment.

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R&D on retina algorithm

- Full exploitation of HL-LHC is a great scientific challenge
- Data acquisition and reconstruction one of the toughest issues
- High pileup and complex events mean that it becomes harder and harder to trigger without tracking information, even at L0
 All LHC experiments are studying Level-0 tracking.
- Tracking at LHC crossing rate calls for specialized solutions
 - Large combinatorial problem, requires high parallelization.
 - In many cases, latencies are an issue due to need for buffering.

A "cellular" tracking algorithm

Inspired by mechanism of visual receptive fields [D.H. Hubel, T.N. Wiesel, J. Physiol. 148 (1959) 574],





November 17, 1999 INSTR99 - An Artificial Retina for Fast Track Finding - L. Ristori - INFN Pisa

- Basic algorithm proposed by Luciano Ristori back in 2000:
 - "An artificial retina for real-time track finding" [NIM A453 (2000) 425-429]

• Related to older "Hough transform" [P.V.C. Hough, Conf.Proc. C590914 (1959) 554]

- There are however, significant differences
 - Totally parallelize everything, no serialization until the tracks are found.
 - Interpolation of analog responses → saves internal storage. Also, makes it easier to deal with "missing layers".

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- $\frac{7}{2}$ Only a toy model at the time \rightarrow Need serious developments.



Retina-Tracking in a 3D geometry

- An array of pixel and strip detectors.
- Each detector plane provides a (x,y) p point at fixed z.
- Measure straight tracks in 3D (4 parameters)
- e.g.: u, v, z_0, d (impact parameter)
- In case of presence of magnetic field, an additional parameter *p* is sufficient.
- Does not need to assume B uniform, or perfect alignment.



V I





Simulated retin LHCb-Upgi





Colors show activation levels of the 22,500 retina cells (for small angle telescope). 7/2/14

Performance on Realistic LHCb MC at upgrade luminosity

Available as LHCb public note: LHCb-PUB-2014-026



- Accounts for all detector effects. Similar results for $L=2x10^{33}$ cm⁻²s⁻¹ (Average interactions/crossing v=7.6) and L=3x10³³ cm⁻²s⁻¹ (v=11.4).
- Efficiency/ghost rate performance comparable to offline reconstruction.
- All parameter resolutions are offline-grade
 7/2/14



LHCb-PUB-2014-026 May 23, 2014



Support documentation for the LHcb-Upgrade Trigger TDR. A specialized track processor for the LHCb upgrade

A. Abba¹, F. Bedeschi², F. Caponio¹, M. Citterio¹, A. Cusimano¹, A. Geraci¹, F. Lionetto², P. Marino², M.J. Morello², N. Neri¹, D. Ninci², A. Piucci², M. Petruzzo¹, G. Punzi², F. Spinella², S. Stracka², D. Tonelli³, and J. Walsh²,

¹ INFN Sezione di Milano and Politecnico of Milano, Milano, Italy ²INFN Sezione di Pisa, Scuola Normale Superiore, and University of Pisa, Pisa, Italy ³CERN, Geneva, Switzerland

Abstract

We propose a specialized processor dedicated to efficient real-time reconstruction of charged-particle tracks in the upgraded LHCb detector. The main purpose of this *track processing unit* is to relieve the event-filter farm from the repetitive, mechanizable calculations associated with the pattern-recognition task, providing it with more time for higher-level trigger functions. We develop a design based on a biology-inspired pattern-recognition algorithm implemented into modern fieldprogrammable-gate-array devices, yielding high-quality tracking at the full crossing rate, with submicrosecond latencies. This document describes the concept, technical implementation, simulation, performance, and costs of the project.

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TPU status and future

- Tremendous work done to move from a smart idea ("the artificial retina") to a complete design of a Track Processing Unit (TPU).
 - Tracking at 40MHz with offline-grade performances has been studied in detail and it looks feasible with a limited number of cells.
 - The collaboration seriously considered and reviewed it.
 - The default plan at the moment is still a Full Software Trigger.
- Our results turned out to be very promising and we are continuing the TPU development as a generic R&D for HL-LHC experiments (Phase II) in CSN5.



Other: Conferences

- O G. Punzi, A specialized processor for track reconstruction at the LHC crossing rate, INSTR14 Novosibirsk →[arXiv:1406.7220]
- P. Marino, Simulation and performance of an artificial retina algorithm for 40 MHz track reconstruction, WIT 2014 – Philadelphia
- S. Stracka, The LHCb Trigger System: Performance and Outlook, TIPP 2014

 Amsterdam
- P. Marino, The artificial retina processor for track reconstruction at the LHC crossing rate, ICHEP14 Valencia.
- Submitted abstract at TWEPP14 and at IEEE 2014 NSS/MIC, and SIF in Pisa.



Other

- Paper/Analysis Reviewers
 - M. Morello, Study of D_J meson decays to $D^+\pi^-$, $D^0\pi^+$ and $D^{*+}\pi^-$ final states in pp collisions, [J. High Energy Phys. 09 (2013) 145]
 - G. Punzi, Measurements of indirect CP asymmetries in $D^0 \rightarrow K^-K^+$ and $D^0 \rightarrow \pi - \pi +$ decays. [Phys. Rev. Lett. 112 (2014) 041801]
 - S. Stracka, Measurement of ratio of branching fractions of $\Lambda c^+ \rightarrow pK^+\pi^-/pK^-\pi^+$. (in progress)
 - M. Morello, Measurement of CP violation in the phase space of charmless three-body B[±] decays. (in progress)
- G.Punzi member of a small committee for the "Survey and prioritization of the Physics Program".



Students

- Studenti
 - Federica Lionetto (Laurea), Discussa a Luglio 2013
 - Selection of hadronic decays of heavy flavors at LHCb.
 - Alessio Piucci (Laurea) da discutere il 24 luglio 2014
 - Reconstruction of tracks in real time in the high luminosity environment at LHC.
 - Daniele Ninci (Laurea) da discutere a Sett/Ott
 - Implementazione della Retina su TELL62/StratixIII.
 - Maria Paola Mocci (Laurea) ha appena iniziato.
 - Pietro Marino (PhD SNS) discute a fine 2015.
 O Consegna pretesi a Ottobre.



Pisa Reading Institution

Reading responsibilities of Pisa, Italy

Status	ID	Contacts	Title	Details
030-Under review	QEE-Zplusbjet- 001	Murilo Rangel, Cedric Potterat	Study of forward \$Z\$+\$b\$ jet production in \$pp\$ collisions at \$\sqrt{s} = 7\$ TeV	more
030-Under review	BnoC- B2rhorho-001	Antonio Romero Vidal, Marc Grabalosa	B\rightarrow\rho\rho\$ branching fraction and longitudinal \$\rho\$ polarisation fraction	more
040-Waiting 1st draft	PAPER-2014- 040	Edwige Tournefier	Measurement of the \$\chi_b(3P)\$ mass and of the relative rate of \$\chi_{b1}(1P)\$ and \$\chi_{b2}(1P)\$ production	more
040-Waiting 1st draft	PAPER-2014- 029	Sergey Barsuk, Maxim Teklishyn	Measurement of \$\eta_c(1S)\$ production via ppbar via the decay \$\eta_c\to p\bar{p}\$	more
060 Waiting for second draft	PAPER-2014- 027	Ronan McNulty	Observation of double charmonia produced exclusively inside the LHCb detector in \$pp\$ collisions	more
110-Submitted to journal	PAPER-2014- 004	Laurence Carson, Rose Koopman	Study of the kinematic dependences of \$\Lambda_b^0\$ production in \$pp\$ collisions and a measurement of the \$\Lambda_b^0\to\Lambda_c^+\pi^-\$ branching fraction	more
120-Approved by journal	PAPER-2014- 012	Zhou Xing, Liming Zhang, Sheldon Stone	Measurement of the resonant and \$CP\$ components in \$\bar{B}^0 \to J/\psi\pi^+\pi^-\$ decay	more
130-Done	PAPER-2013- 061	<u>Rafael Silva Coutinho, Tom</u> <u>Latham</u>	Searches for Δ_b^0 and Δ_b^0 decays to $K_S^0 \rho_i^-$ and $K_S^0 \rho$ final states with first observation of the Δ_b^0 by $\Delta_b^0 \rho$	more
130-Done	PAPER-2013- 054	Marco Gersabeck, Chris Thomas	Measurements of indirect \$CP\$ asymmetries in \$D^0\to K^-K^+\$ and \$D^0\to\pi^-\pi^+\$ decays	more
130-Done	PAPER-2013- 047	Victor Egorychev, Ivan Polyakov	Observation of the decay \$B_c^+\to J/\psi K^+K^-\pi^+\$	more
130-Done	PAPER-2013- 044	Jacco de Vries, Niels Tuning	Observation of the decay \$B_c^+\to B_s^0\pi^+\$	more
130-Done	PAPER-2012- 056	Mark Whitehead, Tim Gershon	Search for the decay \$B^0_s \to D^{\ast\mp}\pi^\pm\$	more
130-Done	PAPER-2012- 043	<u>Matteo Palutan, Johannes</u> <u>Albrecht</u>	First evidence of the \$B^0_s \to \mu^+\mu^-\$ decay	more
130-Done	CONF-2013- 001	<u>Konstantinos Petridis, Mike</u> <u>Williams</u>	Measurement of the forward-central \$b\bar{b}\$ production asymmetry at LHCb	more

LHCb MasterClass





Agenda Masterclass di Pisa

Lunedi' 17 Marzo 2014

Sezione INFN di Pisa - Dipartimento di Fisica Universita' di Pisa

Sala Seminari 131 Piano Terra Edificio C

- 09:15 Apertura della Masterclass Dr. Sandra Leone, INFN Sezione di Pisa
- 09:30 Primo Seminario: preparazione per l'esercitazione al PC Introduzione alla fisica delle particelle elementari Dr. Michael Morello, Scuola Normale Superiore, Pisa Discussione
- 10:30 Secondo Seminario: preparazione per l'esercitazione al PC The beauty experiment : LHCb Dr. Pietro Marino, Scuola Normale Superiore, Pisa Discussione
- 11:30 Informazioni locali: Studiare fisica a Pisa Prof.Mauro Dell'Orso, Presidente del Corso di Laurea in Fisica dell'Universita' di Pisa
- 12:00-12:50 Pausa per il pranzo: spazio antistante laboratori edificio C (piano -1) Discussioni informali con i ricercatori e i tutors

Laboratorio di Informatica. Sala 250 primo piano Edificio C

13:00-15:30 Esercizio al PC: Misura della vita media del mesone D⁰
 13:00 Set up apparati e Introduzione, Alessio Piucci, Universita` di Pisa
 13:30 Gli studenti lavorano in coppie al PC
 15:00 Raccolta dei risultati, discussione e interpretazione

Videoconferenza Sala 131 Piano Terra Edificio C

16:00-17:00 Video Conferenza: collegamento con il CERN Presentazione dei partecipanti (tipicamente 4 - 6 sedi europee) Scambio di esperienze Combinazione dei risultati Video-quiz Discussione Compilazione questionario

17:00-17:15 FINE della Masterclass



D⁰ lifetime measurement





Persone e percentuali

	2014	2015	Posizione
F. Bedeschi	0.7	0.7	Dir. di Ricerca
R. Cenci		0.5	Post-Doc
A. Lusiani	0.3	0.7	Ricercatore
P. Marino	1.0	1.0	PhD
M.J. Morello	0.7	0.7	Ricercatore
G. Punzi	0.7	0.7	Prof. Associato
F. Spinella	0.15	0. (CSN5)	Tecnologo
S. Stracka	1.0	0.7	Post-doc
J. Walsh	0.7	0.7	Primo Ricercatore
Tot (FTE)	5.25	5.7	

M.P. Mocci		Laureanda
D. Ninci		Laureando
A. Piucci		Laureando



Richieste Finanziarie

Missioni		85 kEuro
Consumi	metabolismo	8.5kEuro
ТОТ		93.5kEuro