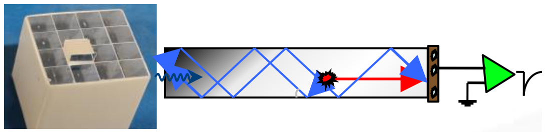
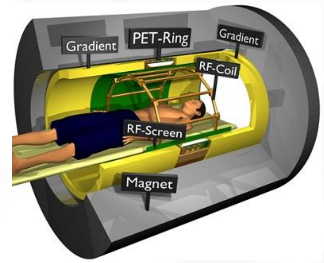
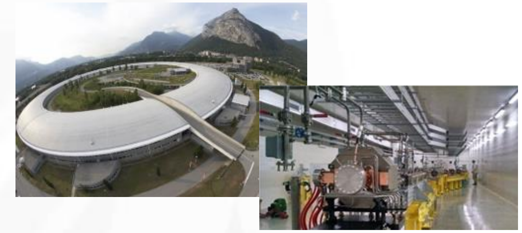
Medical Physics

Vision/Research lines/Social Impact

Medical Physics Vision



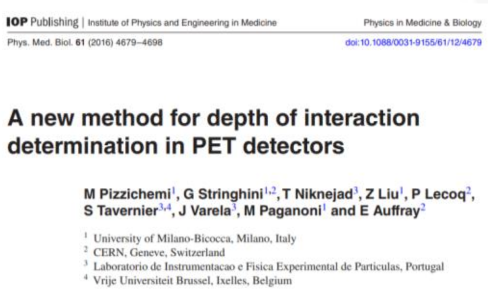




L1. Sensors/ Signal processing

L2. Imaging systems/ multimodal image processing and decision support systems

L3. Imaging infrastructures and automatic classification



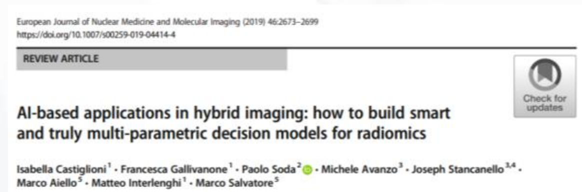
IOP Publishing | Institute of Physics and Engineering in Medicine — Physics in Medicine & Biology

Phys. Med. Biol. 61 (2016) 4679–4698 — doi:10.1088/0031-9155/61/12/4679

A new method for depth of interaction determination in PET detectors

M Pizzichemi[1], G Stringhini[1,2], T Niknejad[3], Z Liu[1], P Lecoq[2], S Tavernier[3,4], J Varela[3], M Paganoni[1] and E Auffray[2]

[1] University of Milano-Bicocca, Milano, Italy
[2] CERN, Geneve, Switzerland
[3] Laboratorio de Instrumentacao e Fisica Experimental de Particulas, Portugal
[4] Vrije Universiteit Brussel, Ixelles, Belgium



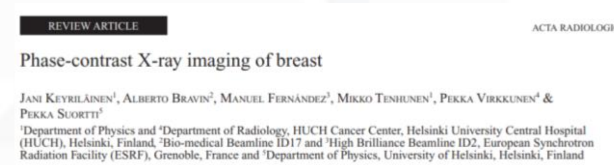
European Journal of Nuclear Medicine and Molecular Imaging (2019) 46:2673–2699
https://doi.org/10.1007/s00259-019-04414-4

REVIEW ARTICLE

Check for updates

AI-based applications in hybrid imaging: how to build smart and truly multi-parametric decision models for radiomics

Isabella Castiglioni[1] · Francesca Gallivanone[1] · Paolo Soda[2] · Michele Avanzo[3] · Joseph Stancanello[3,4] · Marco Aiello[5] · Matteo Interlenghi[1] · Marco Salvatore[5]



REVIEW ARTICLE — ACTA RADIOLOGICA

Phase-contrast X-ray imaging of breast

Jani Keyriläinen[1], Alberto Bravin[2], Manuel Fernández[3], Mikko Tenhunen[1], Pekka Virkkunen[4] & Pekka Suortti[5]

[1]Department of Physics and [4]Department of Radiology, HUCH Cancer Center, Helsinki University Central Hospital (HUCH), Helsinki, Finland, [2]Bio-medical Beamline ID17 and [3]High Brilliance Beamline ID2, European Synchrotron Radiation Facility (ESRF), Grenoble, France and [5]Department of Physics, University of Helsinki, Helsinki, Finland

Combination of advanced imaging sensors, image processing and imaging infrastructure with newly available AI algorithms can significantly impact in medicine

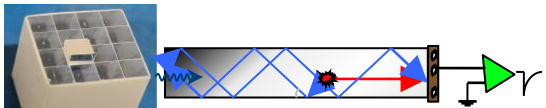
Empirical medicine

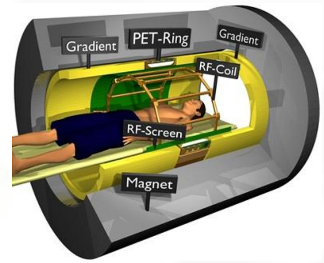
Stratified medicine

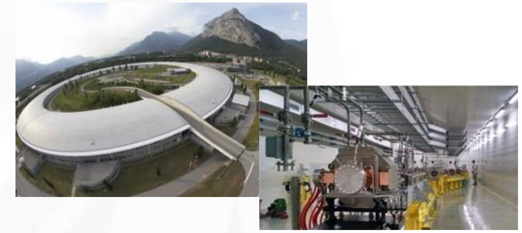
Personalised (or individualised) medicine

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

Medical Physics Research Lines and impact







L1. Sensors/ Signal processing

L2. Imaging systems/ multimodal image processing and decision support systems

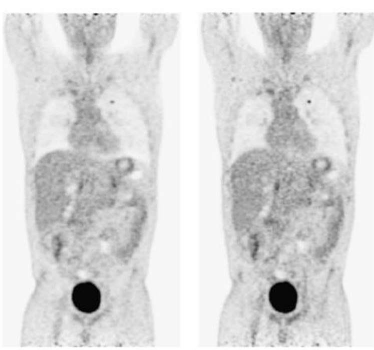
L3. Imaging infrastructures and automatic classification

Better timing
Better spatial localization

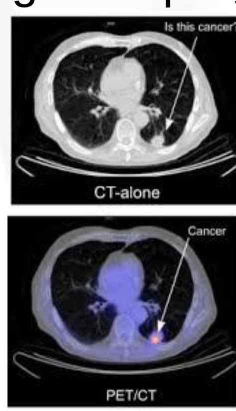
Association between complex image content and clinical outcome

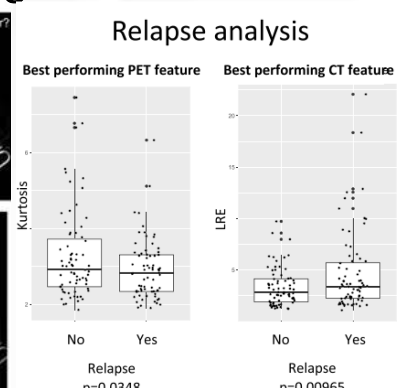
Better signal
Less noise

Improved lesion detectability

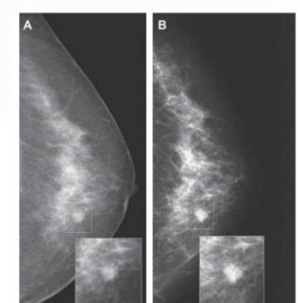


Improved medical diagnosis/prognosis and decision



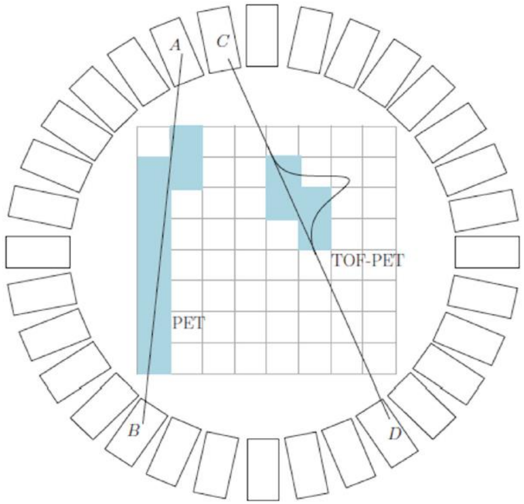


Improved lesion detectability/ classification



L1. Sensors/ Signal processing

Better timing
PET with Time of flight (TOF) info



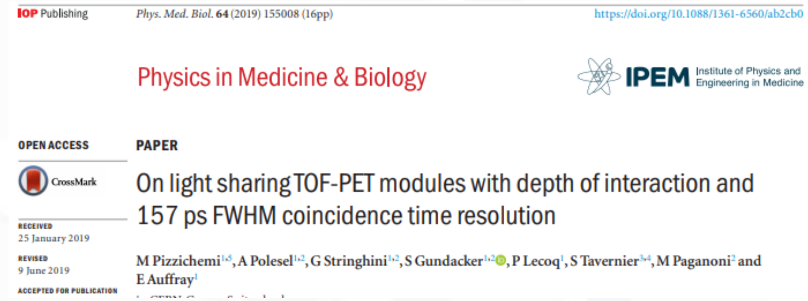
Compute the difference in time of arrival of gammas Δt

$$\Delta x = c\frac{\Delta t}{2}$$

$$SNR_{TOF} \sim \sqrt{\frac{D}{\Delta x}} \cdot SNR_{CONV}$$

Time resolution (ns)	Δx (cm)	TOF NEC gain	TOF SNR gain
0.1	1.5	26.7	5.2
0.3	4.5	8.9	3.0
0.6	9.0	4.4	2.1
1.2	18.0	2.2	1.5
2.7	40.0	1.0	1.0

Pushing coincidence time resolution down to 150 ps and including Depth of Interaction (DOI) info


IOP Publishing Phys. Med. Biol. 64 (2019) 155008 (16pp) https://doi.org/10.1088/1361-6560/ab2cb0
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IPEM Institute of Physics and Engineering in Medicine
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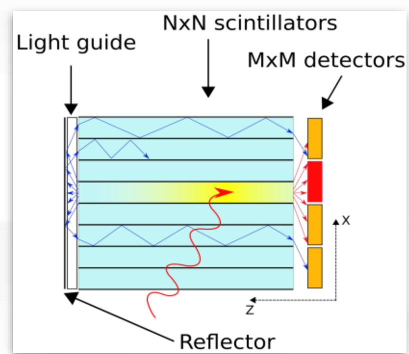
RECEIVED 25 January 2019
REVISED 9 June 2019
ACCEPTED FOR PUBLICATION

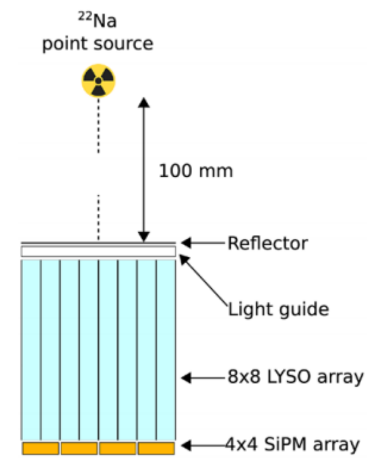
PAPER

On light sharing TOF-PET modules with depth of interaction and 157 ps FWHM coincidence time resolution

M Pizzichemi[1,5], A Polesel[1,2], G Stringhini[1,2], S Gundacker[1,2], P Lecoq[1], S Tavernier[3,4], M Paganoni[2] and E Auffray[1]

a piece of glass, 12.8 × × 12.8 1 mm3

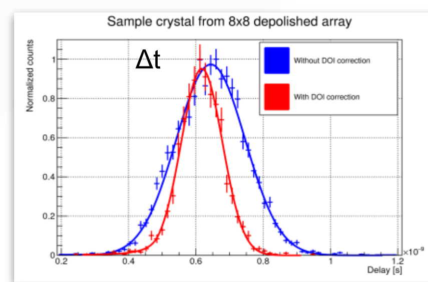




Very good timing properties

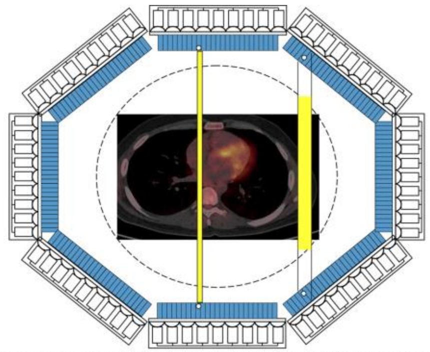
	Array type	Crystals dim. [mm³]	DOI res. FWHM [mm]
d=3mm	8x8	1.5x1.5x15	3.7 ± 0.1
d=0.25mm	8x8	1.5x1.5x15	2.8 ± 0.1

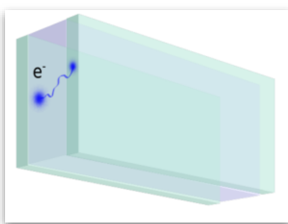
Improved lesion detectability (>25)

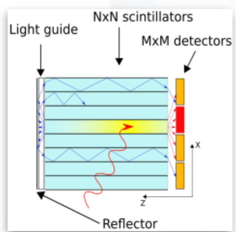


L1. Sensors/ Signal processing

Improving accuracy in crystal identification (including DOI info)







Faster light production

DOI measurement

Time resolution (ns)	Δx (cm)	TOF NEC gain	TOF SNR gain
0.1	1.5	26.7	5.2
0.3	4.5	8.9	3.0
0.6	9.0	4.4	2.1
1.2	18.0	2.2	1.5
2.7	40.0	1.0	1.0

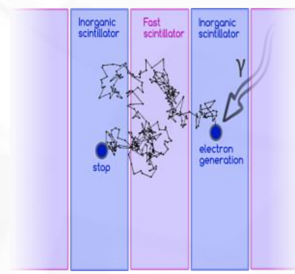
Pushing coincidence time resolution down to 10 ps with accurate DOI info

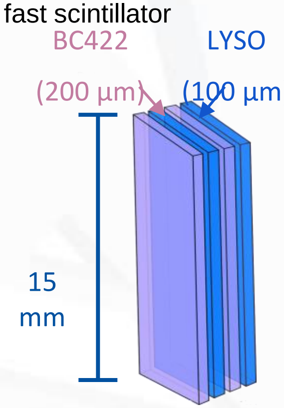
Depth of Interaction information encoding in a sampling scintillator detector geometry

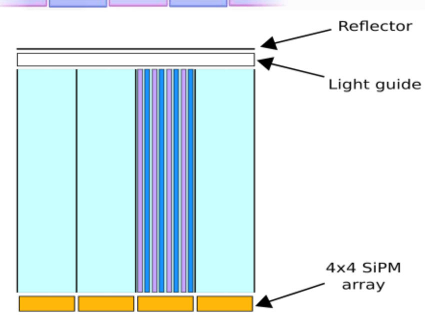
Marco Pizzichemi, Rosana Martinez Turtos, Stefan Gundacker, Andrea Polesel, Marco Paganoni, Paul Lecoq, and Etiennette Auffray

Heterostructure in a crystal array

Energy sharing between inorganic and fast scintillator





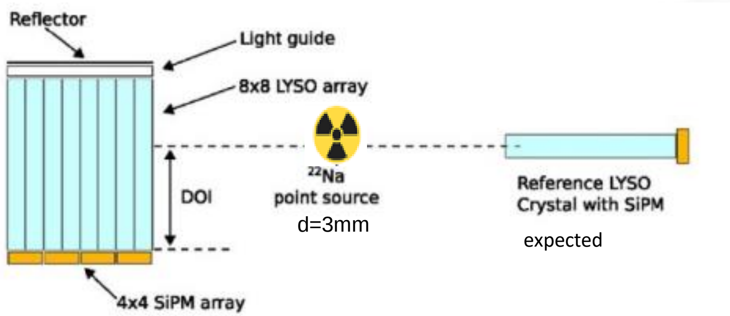


Excellent timing properties

Improved lesion detectability and quasi-direct image reconstruction

L1. Sensors/ Signal processing

use of AI to improve sensor DOI resolution



	15	23	31	39	47	55	63
	14	22	30	38	46	54	62
5	13	21	29	37	45	53	
4	12	20	28	36	44	52	
3	11	19	27	35	43	51	59
2	10	18	26	34	42	50	58
1	9	17	25	33	41	49	
0	8	16	24	32	40	48	

(a) 8×8 crystal array

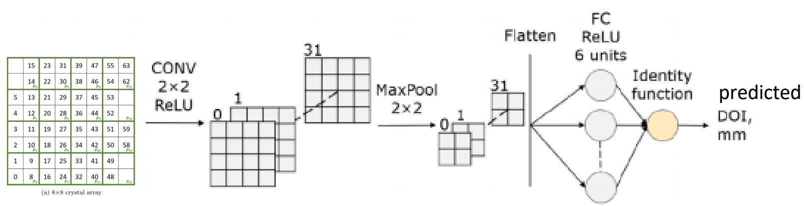
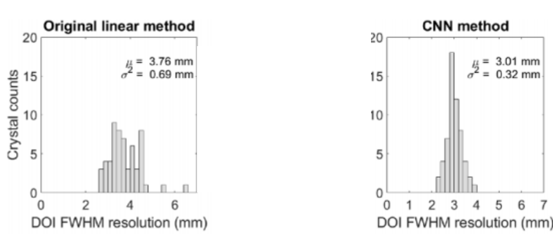


Figure 4. The architecture of the CNN. The network receives 16 integrated charge values arranged in a 4× 4 matrix as an input (in green). The ReLU is employed as an activation function on the convolutional (CONV) and the FC layer. The output layer (in yellow) uses the identity function.



(a) (d)

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PUBLISHED 28 August 2020

PAPER

Improving depth-of-interaction resolution in pixellated PET detectors using neural networks

Artem Zatcepin[1,5], Marco Pizzichemi[2], Andrea Polesel[2,3], Marco Paganoni[3], Etiennette Auffray[2], Sibylle I Ziegler[1,4] and Negar Omidvari[1,6]

1 Department of Nuclear Medicine, Klinikum rechts der Isar, Technical University of Munich, Ismaninger Str. 22, 81675 Munich, Germany
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3 University of Milano-Bicocca, Milan, Italy
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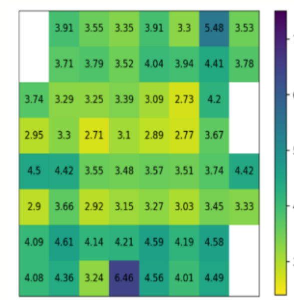
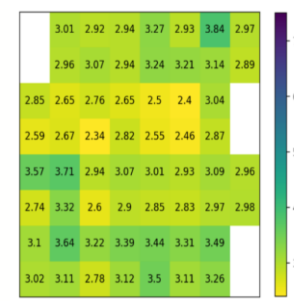
6 Current address: Department of Biomedical Engineering, University of California at Davis, 1 Shields Avenue, Davis, CA 95616, United States of America.

d=3mm



(a) Original method, μ=3.76 mm

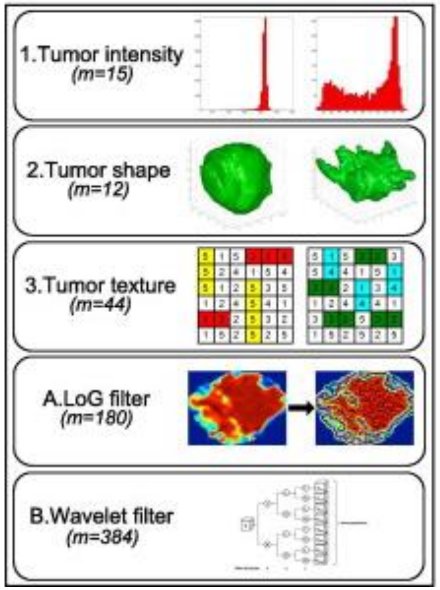


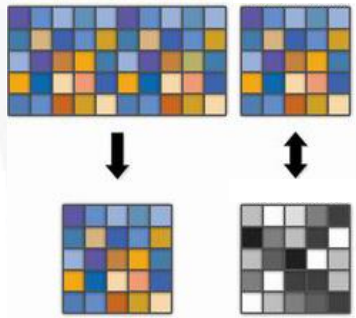
(d) CNN, μ=3.01 mm

Significant improvement in LYSO DOI resolution, especially for edge crystals (err from 3.76 to 3 mm)

Beneficial impact on image quality, especially for organ dedicated PET scanners

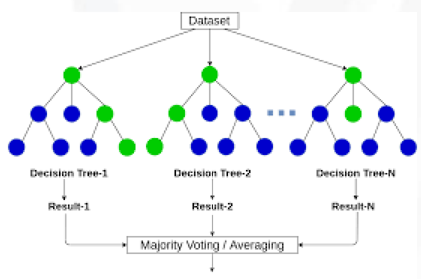
Selecting combination of structural and functional features of local disease from expert-domain (developing representation methods - radiomics)





clinical outcome (malignant/ benign)

Using such features to train machine learning to predict disease clinical outcome (developing machine learning predicting models)



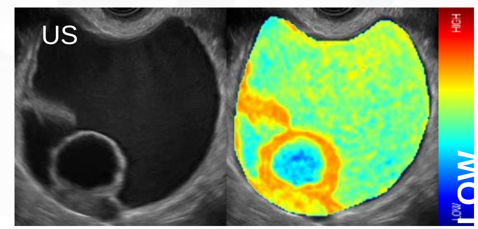
Explainable AI output for clinicians

Journal of Ultrasound
https://doi.org/10.1007/s40477-020-00503-5

ORIGINAL PAPER

The Adoption of Radiomics and machine learning improves the diagnostic processes of women with Ovarian MAsses (the AROMA pilot study)

Valentina Chiappa[1] · Giorgio Bogani[1] · Matteo Interlenghi[2] · Christian Salvatore[3] · Francesca Bertolina[1] · Giuseppe Sarpietro[1] · Mauro Signorelli[1] · Isabella Castiglioni[4] · Francesco Raspagliesi[1]



Gynecologic Oncology 161 (2021) 838–844
Contents lists available at ScienceDirect
Gynecologic Oncology
journal homepage: www.elsevier.com/locate/ygyno

Using rADioMIcs and machine learning with ultrasonography for the differential diagnosis of myometRiAL tumors (the ADMIRAL pilot study). Radiomics and differential diagnosis of myometrial tumors

V. Chiappa[a,*], M. Interlenghi[b], C. Salvatore[b], F. Bertolina[a], G. Bogani[a], A. Ditto[a], F. Martinelli[a], I. Castiglioni[c,1], F. Raspagliesi[a,1]
[a] Gynecologic Oncology, Fondazione IRCCS Istituto Nazionale Tumori di Milano, Italy
[b] DeepTrace Technologies S.R.L., Milan, Italy
[c] Dipartimento di Fisica G. Occhialini, University of Milan-Bicocca, Milan, Italy

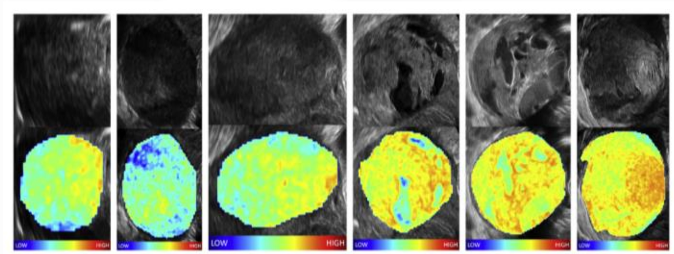
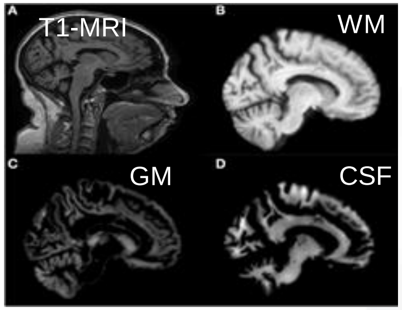


Fig. 2. Local spatial distribution of the feature Entropy evaluated on the Gray-Level Co-occurence Matrices: Sarcoma (2 a,b,c) and Myoma (2 d,e,f).

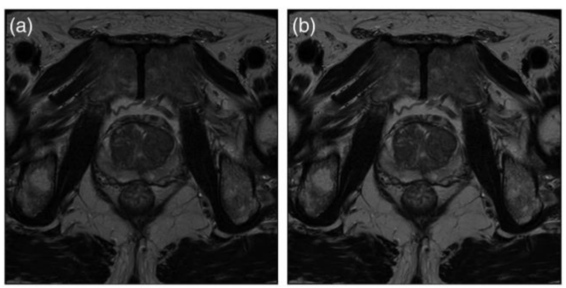
New disease biomarkers from imaging for diagnosis

L2. Imaging systems/ multimodal image processing and decision support systems

Selecting features from expert-domain
(developing tissue segmentation methods)



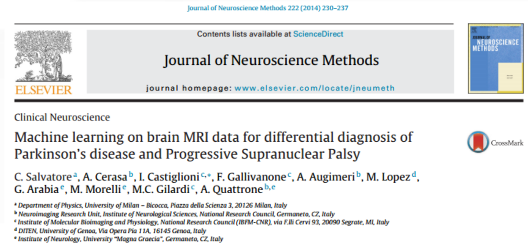
Developing signal/image pre-processing
from expert-domain
(developing image harmonization methods)



No image normalization   Nyul normalization

Table 3 Evaluating the effect of pre-processing on classification and Segmentation tasks in terms of validation accuracy. Bolded values indicate the improved results.

Task	Image type	Criteria	With pre-processing (%)	No pre-processing (%)
Classification	MR	Accuracy	**73.30**	68.74
	CT	Accuracy	**82.28**	77.72
Segmentation	MR	Mean Abs. Err.	**2.73**	47.64
		Dice	**98.64**	81.74
	CT	Mean Abs. Err.	**3.68**	19.99
		Dice	**98.25**	95.25


Journal of Neuroscience Methods 222 (2014) 230–237

Contents lists available at ScienceDirect

Journal of Neuroscience Methods

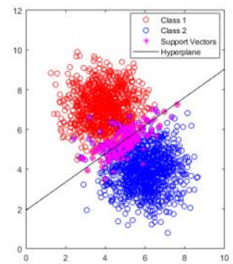
journal homepage: www.elsevier.com/locate/jneumeth

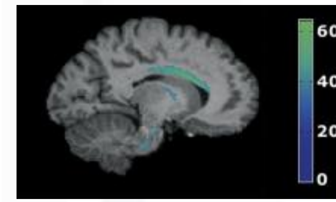
Clinical Neuroscience

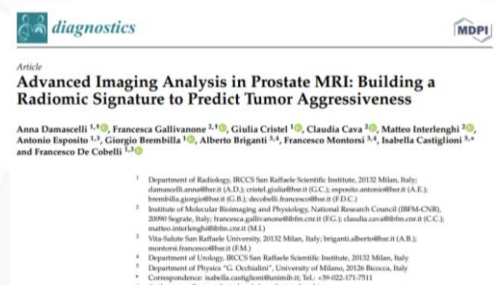
Machine learning on brain MRI data for differential diagnosis of Parkinson's disease and Progressive Supranuclear Palsy

C. Salvatore[a], A. Cerasa[b], I. Castiglioni[c,*], F. Gallivanone[c], A. Augimeri[b], M. Lopez[d], G. Arabia[e], M. Morelli[e], M.C. Gilardi[c], A. Quattrone[b,e]

[a] Department of Physics, University of Milan – Bicocca, Piazza della Scienza 3, 20126 Milan, Italy
[b] Neuroimaging Research Unit, Institute of Neurological Sciences, National Research Council, Germaneto, CZ, Italy
[c] Institute of Molecular Bioimaging and Physiology, National Research Council (IBFM-CNR), via F.lli Cervi 93, 20090 Segrate, MI, Italy
[d] DITEN, University of Genoa, Via Opera Pia 11A, 16145 Genoa, Italy
[e] Institute of Neurology, University "Magna Graecia", Germaneto, CZ, Italy






diagnostics

MDPI

Article

Advanced Imaging Analysis in Prostate MRI: Building a Radiomic Signature to Predict Tumor Aggressiveness

Anna Damascelli [1,†], Francesca Gallivanone [2,†], Giulia Cristel [1], Claudia Cava [2], Matteo Interlenghi [2], Antonio Esposito [1,3], Giorgio Brembilla [1], Alberto Briganti [3,4], Francesco Montorsi [3,4], Isabella Castiglioni [5,*] and Francesco De Cobelli [1,3]

1. Department of Radiology, IRCCS San Raffaele Scientific Institute, 20132 Milan, Italy; damascelli.anna@hsr.it (A.D.); cristel.giulia@hsr.it (G.C.); esposito.antonio@hsr.it (A.E.); brembilla.giorgio@hsr.it (G.B.); decobelli.francesco@hsr.it (F.D.C.)
2. Institute of Molecular Bioimaging and Physiology, National Research Council (IBFM-CNR), 20090 Segrate, Italy; francesca.gallivanone@ibfm.cnr.it (F.G.); claudia.cava@ibfm.cnr.it (C.C.); matteo.interlenghi@ibfm.cnr.it (M.I.)
3. Vita-Salute San Raffaele University, 20132 Milan, Italy; briganti.alberto@hsr.it (A.B.); montorsi.francesco@hsr.it (F.M.)
4. Department of Urology, IRCCS San Raffaele Scientific Institute, 20132 Milan, Italy
5. Department of Physics "G. Occhialini", University of Milano, 20126 Bicocca, Italy

* Correspondence: isabella.castiglioni@unimib.it; Tel.: +39-022-171-7511

† Authors equally contributed and share first authorship.

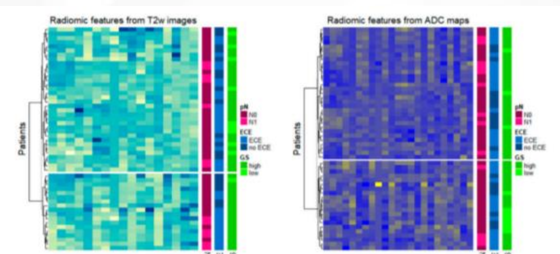
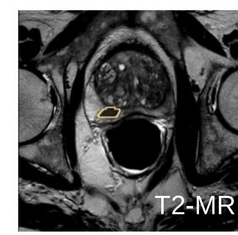
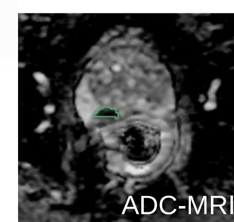


Figure 2. Radiomic patterns obtained on T2w images (**left**) and ADC maps (**right**); the dendrogram at the left side represents the patient' grouping obtained from the clustering procedure; annotation at the right side represent the distribution of Gleason Grade Group (GGG), extracapsular extension (ECE), and nodal stage (pN) status in the groups.

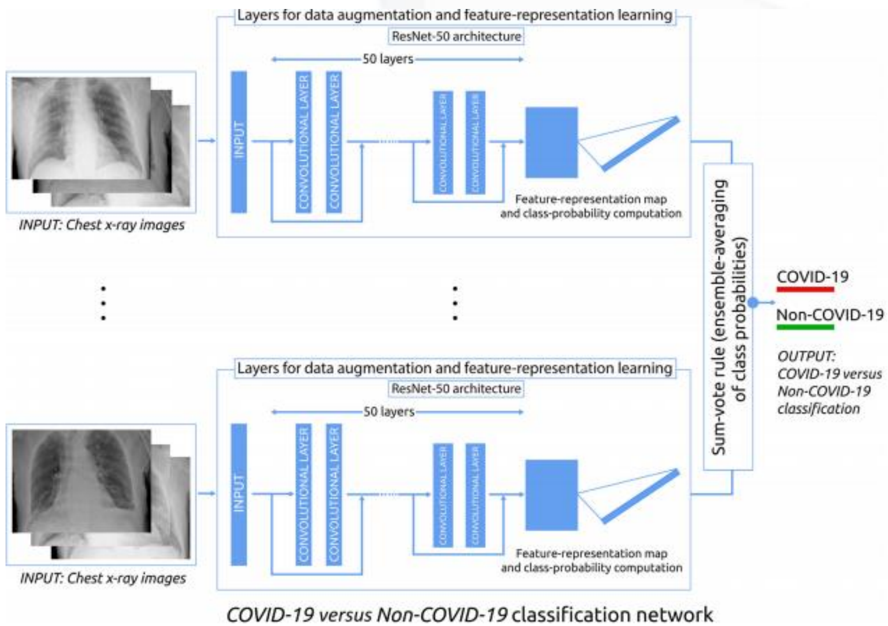
region growing segmentation

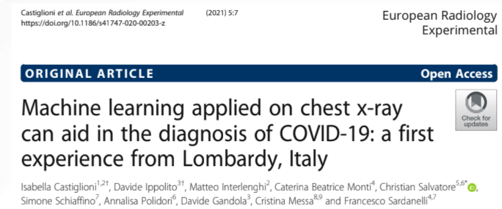




New disease biomarkers from imaging for prognosis

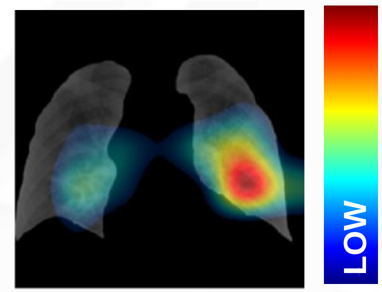
Developing Computer Aided Diagnosis (CAD)/
Decision Support Systems (DSS)
for intensive/urgent/critical care

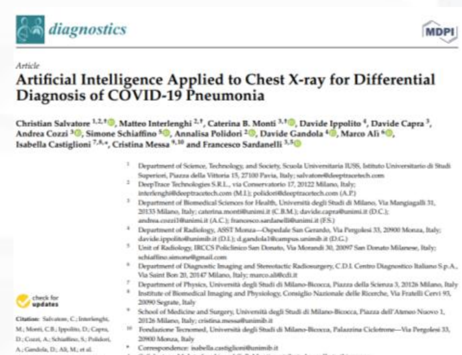



Castiglioni et al. European Radiology Experimental (2021) 5:7
https://doi.org/10.1186/s41747-020-00203-z
European Radiology Experimental
ORIGINAL ARTICLE Open Access

Machine learning applied on chest x-ray can aid in the diagnosis of COVID-19: a first experience from Lombardy, Italy

Isabella Castiglioni, Davide Ippolito, Matteo Interlenghi, Caterina Beatrice Monti, Christian Salvatore, Simone Schiaffino, Annalisa Polidori, Davide Gandola, Cristina Messa and Francesco Sardanelli



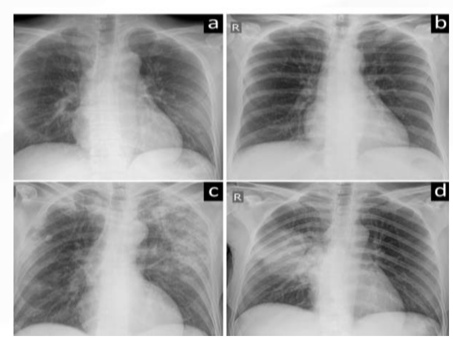

diagnostics
MDPI

Article
Artificial Intelligence Applied to Chest X-ray for Differential Diagnosis of COVID-19 Pneumonia

Christian Salvatore, Matteo Interlenghi, Caterina B. Monti, Davide Ippolito, Davide Capra, Andrea Cozzi, Simone Schiaffino, Annalisa Polidori, Davide Gandola, Marco Alì, Isabella Castiglioni, Cristina Messa and Francesco Sardanelli

Covid-19 pneumonia

no pneumonia



other viral pneumonia

Bacterial pneumonia

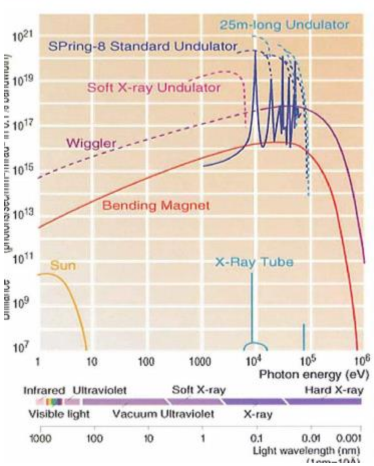
Fast automatic diagnosis and differential diagnosis

L3. Imaging infrastructures and automatic classification

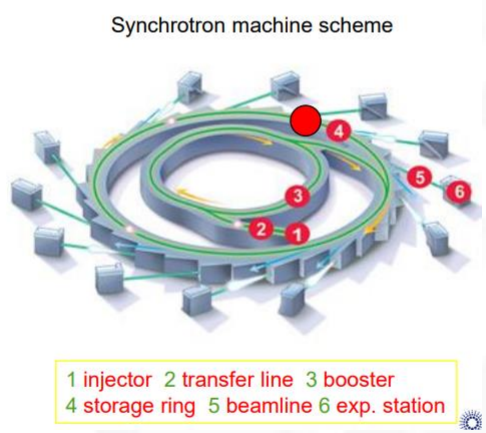
X-ray Phase Contrast Imaging (PCI) at Biomedical beamline (ID17) of the European Synchrotron (ESRF, France)

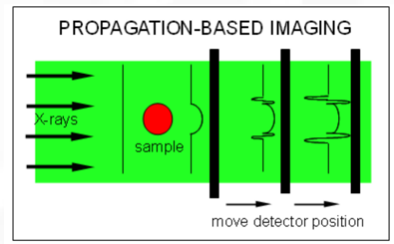
-image contrast derives from the perturbations of the X-ray wave-front induced by the presence of an object along its propagation path, in addition to the x-ray absorption exploited in conventional radiography.
-superior image contrast and sensitivity with respect to standard X-ray attenuation (soft tissues)

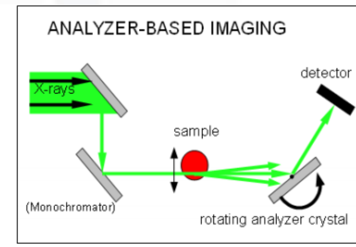
SR is a very intense source of radiation from Infra Red to hard X-rays

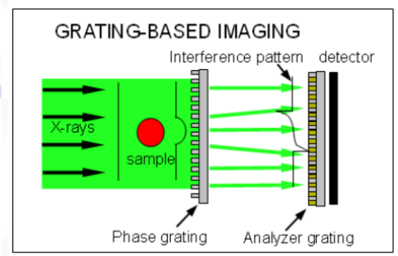


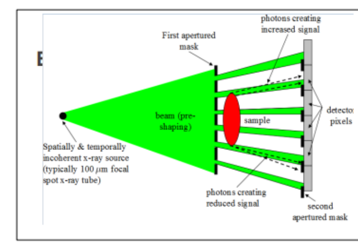
SR is produced by electrons with relativistic energies circulating in a ring











The detection systems include a portfolio of detectors to perform multiscale imaging, with pixel size from 0.65x0.65 µm2 (PCO.Edge.5.5 + 10X optics) to 75x75 µm2 (Eiger2-CdTe single photon counting)

High-contrast and sensitive images at quasi-histological resolution

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

L3. Imaging infrastructures and automatic classification

X-ray PCI for clinical diagnosis from CT to histology image resolution

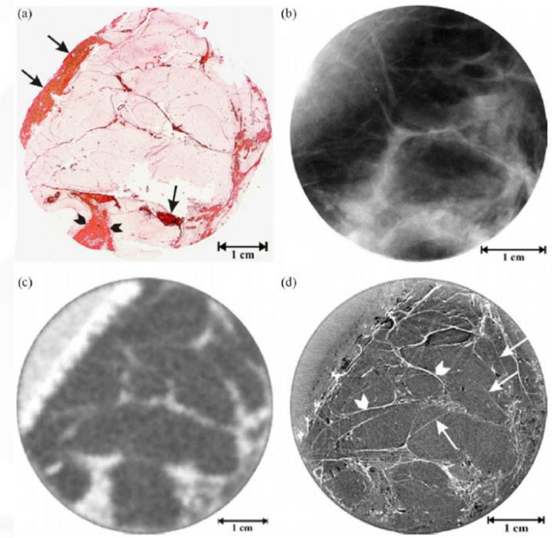
IOP Publishing Journal of Physics D: Applied Physics
J. Phys. D: Appl. Phys. 46 (2013) 494007 (12pp) doi:10.1088/0022-3727/46/49/494007

Phase-contrast x-ray imaging of the breast: recent developments towards clinics

P Coan[1,2], A Bravin[3] and G Tromba[4]

[1] Department of Clinical Radiology, Ludwig Maximilians University, Munich, Germany
[2] Department of Physics, Ludwig Maximilians University, Garching, Germany
[3] European Synchrotron Radiation Facility (ESRF), Grenoble, France
[4] Elettra-Sincrotrone Trieste SCpA, Trieste, Italy

histology eusina image MG image

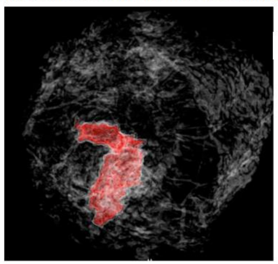


CT image PCI image

PNAS

High-resolution, low-dose phase contrast X-ray tomography for 3D diagnosis of human breast cancers

Yunzhe Zhao[a,1], Emmanuel Brun[b,c,1], Paola Coan[c,d], Zhifeng Huang[a], Aniko Sztrókay[d], Paul Claude Diemoz[c], Susanne Liebhardt[d], Alberto Mittone[c], Sergei Gasilov[c], Jianwei Miao[a,2], and Alberto Bravin[b,2]



PNAS | November 6, 2012 | vol. 109 | no. 45 | 18293

Phase contrast CT
+ iterative reconstruction method

Dose = 2.0 ± 0.1 mGy
25 times dose saving vs clinical breast CT at same resolution

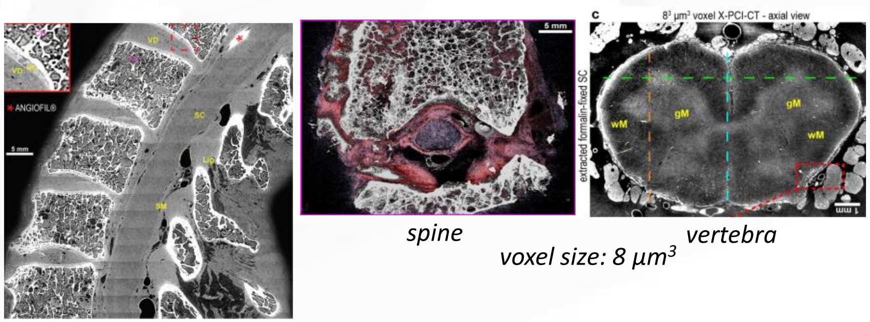
Radiology ORIGINAL RESEARCH • MUSCULOSKELETAL IMAGING

High-Spatial-Resolution Three-dimensional Imaging of Human Spinal Cord and Column Anatomy with Postmortem X-ray Phase-Contrast Micro-CT

Giacomo E. Barbone, MSc • Alberto Bravin, PhD • Alberto Mittone, PhD[1] • Sergio Grosu, MD • Jens Ricke, MD • Guido Cavaletti, MD • Valentin Djonov, MD • Paola Coan, PhD

From the Department of Medical Physics, Faculty of Physics, Ludwig-Maximilians-Universität München, Am Coulombwall 1, D-85748 Garching, Germany (G.E.B., P.C.); European Synchrotron Radiation Facility, Grenoble, France (A.B., A.M.); Department of Radiology, University Hospital, Ludwig-Maximilians-Universität München, Munich, Germany (G.E.B., S.G., J.R., P.C.); Experimental Neurology Unit, School of Medicine and Surgery, University of Milano-Bicocca, Monza, Italy (G.C.); Milan Center for Neuroscience, University of Milano-Bicocca, Milan, Italy (G.C.); and Institute of Anatomy, University of Bern, Bern, Switzerland (V.D.). Received April 15, 2020; revision requested May 15; final revision received August 7; accepted September 1. **Address correspondence to** P.C. (e-mail: *paola.coan@physik.uni-muenchen.de*).

Supported by the Deutsche Forschungsgemeinschaft (Cluster of Excellence)-Munich Center for Advanced Photonics (EXE158), International Max Plank Research School of Advanced Photon Science (IMPRS-APS), and European COST Action CA16122 in the form of a networking STSM Travel Grant.



spine *vertebra*

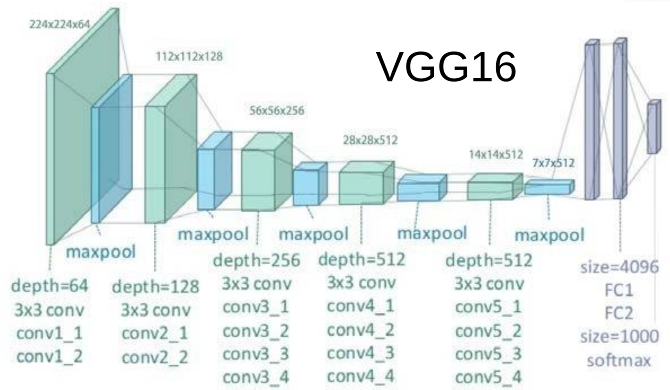
voxel size: 8 μm³

bony vertebral bodies and soft-matter structures within spinal cords, vertebral disks and spinal fat and muscles,voxel size: 46 μm³

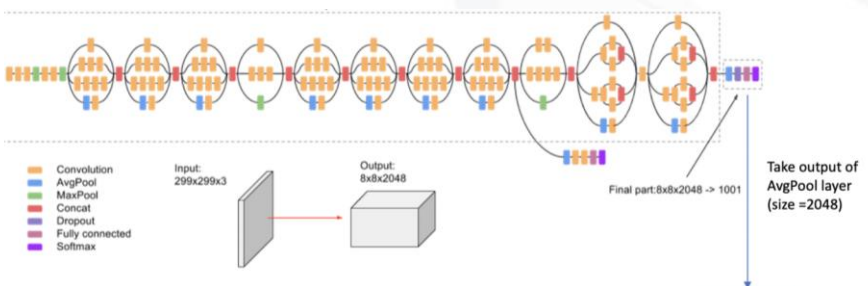
Better lesion detectability and interpretation

L3. Imaging infrastructures and automatic classification

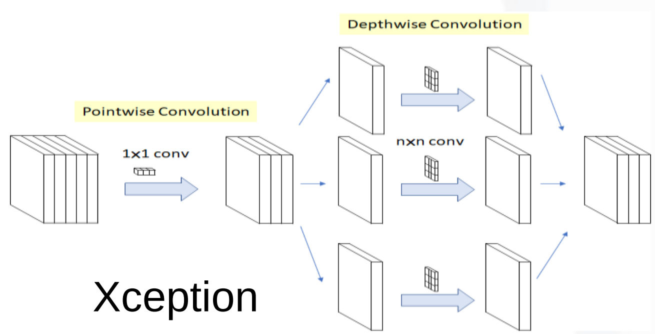
X-ray PCI combined with AI to speed and improve image reading



VGG16



Inception V3



Xception

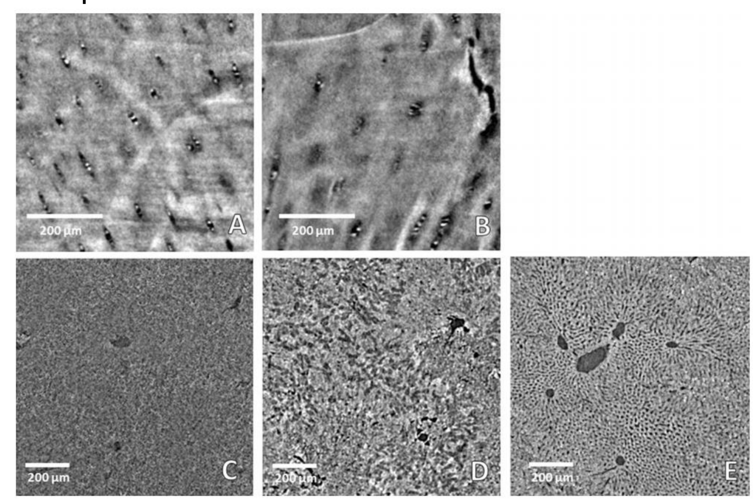
scientific reports

OPEN **Convolutional neuronal networks combined with X-ray phase-contrast imaging for a fast and observer-independent discrimination of cartilage and liver diseases stages**

Johannes Stroebel[1], Annie Horng[2,5], Marco Armbruster[2], Alberto Mittone[3,4], Maximilian Reiser[2], Alberto Bravin[3] & Paola Coan[1,2,3]

sagittal PCI CT images of a healthy cartilage sample

osteoarthritic cartilage sample with a small crack of the tissue visible on the right side



Healthy liver

fibrotic liver

fat liver

automatic diagnostic classification

Collaborations

CRYSTAL CLEAR

CERN

IBFM

ESRF
The European Synchrotron

STAR
Southern Europe TBS x-ray source for Applied Research

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Azienda Ospedaliera San Gerardo

OSPEDALE SAN RAFFAELE

I.R.C.C.S. Policlinico San Donato
Gruppo San Donato

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