investiamo nel vostro futuro

STAR

(Southern Europe Thomson Back-Scattering Source for Applied Research)

State of the Art

Project PON MaTeRiA

Materials and Technologies for Applied Research

Riccardo Barberi – University of Calabria

UNIVERSITÀ DELLA CALABRIA

MaTeRiA
materiali, tecnologie e ricerca avanzata

CNISM

MaTeRiA

EU/National Funding

PON "Ricerca e Competititvità" 2007 – 2013

Scientific responsible: Prof. Mauro Ghedini

MaTeRiA is a joint project aimed at developing a **new Research Infrastructure** inside the **University of Calabria campus area**

Partners: **UniCal**, The University of Calabria & **CNISM**, Italian Consortium on Physical Sciences of Matter (1300 reasercher from 39 universities)

Funding €15.7 M€ | 8.4 M€ STAR source - CNISM
| 6.6 M€ Laboratories and building – UniCal
| 0.7 M€ Master program – UniCal

Start Date: January 1st, 2012 **End Date**: July 31st, 2015

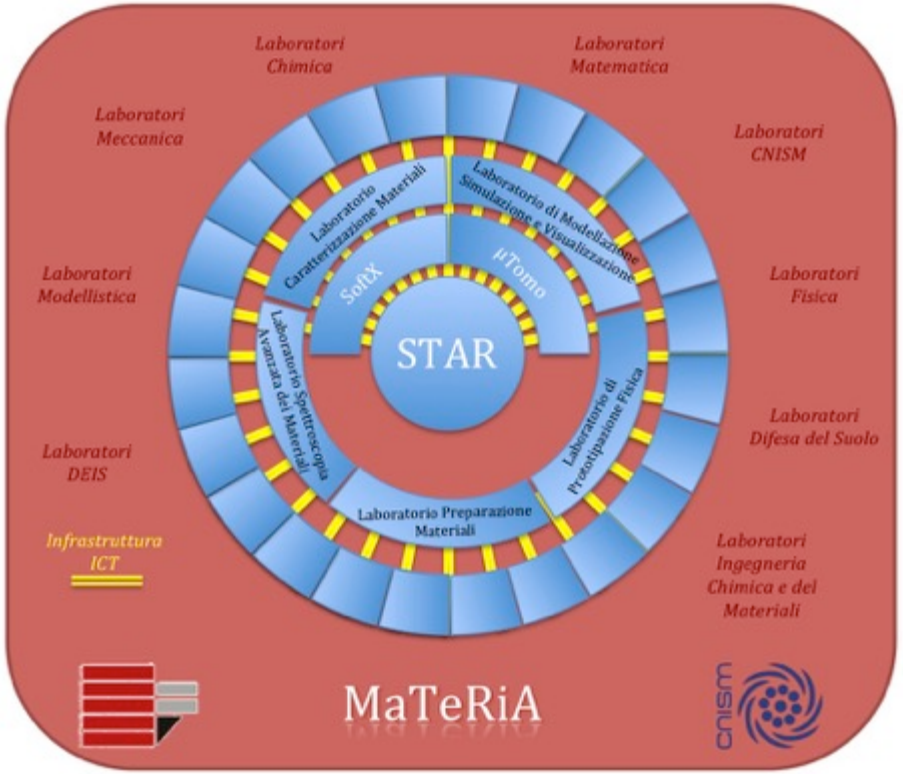
The highly specialized laboratories that constitute MaTeRiA will be organized in three progressive levels

First level. **STAR** (**S**outhern Europe **T**homson Back-Scattering Source for **A**pplied **R**esearch) equipped with the beam-line **µTomo**.

Second level laboratories:

1. **Preparation and characterization**
2. **Characterization of mechanical and other physical properties**
3. **Modeling and simulation**
4. **Prototyping**
5. **Advanced spectroscopy**

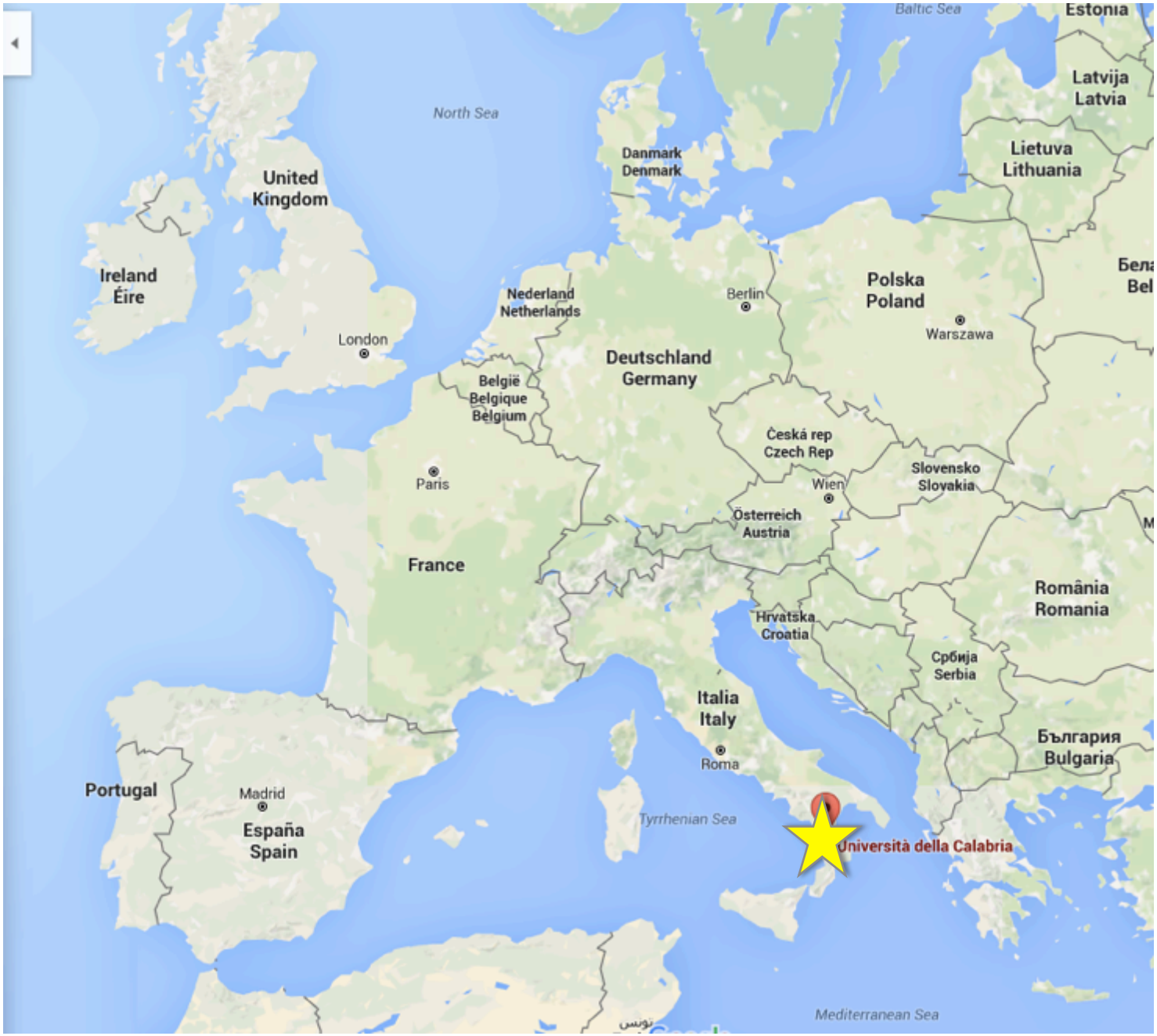
Third level. Network of existent departmental laboratories



UNIVERSITÀ DELLA CALABRIA

MaTeRiA
materiali, tecnologie e ricerca avanzata

cnism


Baltic Sea
Estonia
Latvija
Latvia
North Sea
Danmark
Denmark
Lietuva
Lithuania
United
Kingdom
Ireland
Éire
Nederland
Netherlands
Berlin
Polska
Poland
Warszawa
London
Deutschland
Germany
België
Belgique
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Česká rep
Czech Rep
Slovensko
Slovakia
Paris
Wien
Österreich
Austria
France
România
Romania
Hrvatska
Croatia
Србија
Serbia
Italia
Italy
Roma
България
Bulgaria
Portugal
Madrid
España
Spain
Tyrrhenian Sea
Università della Calabria
Mediterranean Sea

i. **STAR**, Rende (Italy), a typical Thomson Source for X-ray generation in the 20 − 100 keV range, devoted to radiological imaging of pre-clinical studies and cultural heritage studies: electron recoil effects are absolutley negligible in this case, where X-ray flux and moderate bandwidth are the key factors (hence maximum luminosity);

ii. **ELI-NP-GBS**, Magurele-Bucharest (Romania), a typical Inverse Compton Source for nuclear photonics and photo-nuclear physics devoted to generate maximum spectral density photon beams in the 1 − 20 MeV energy range: here electron recoil is small but non negligible (actually larger than the requested narrow bandwidth);

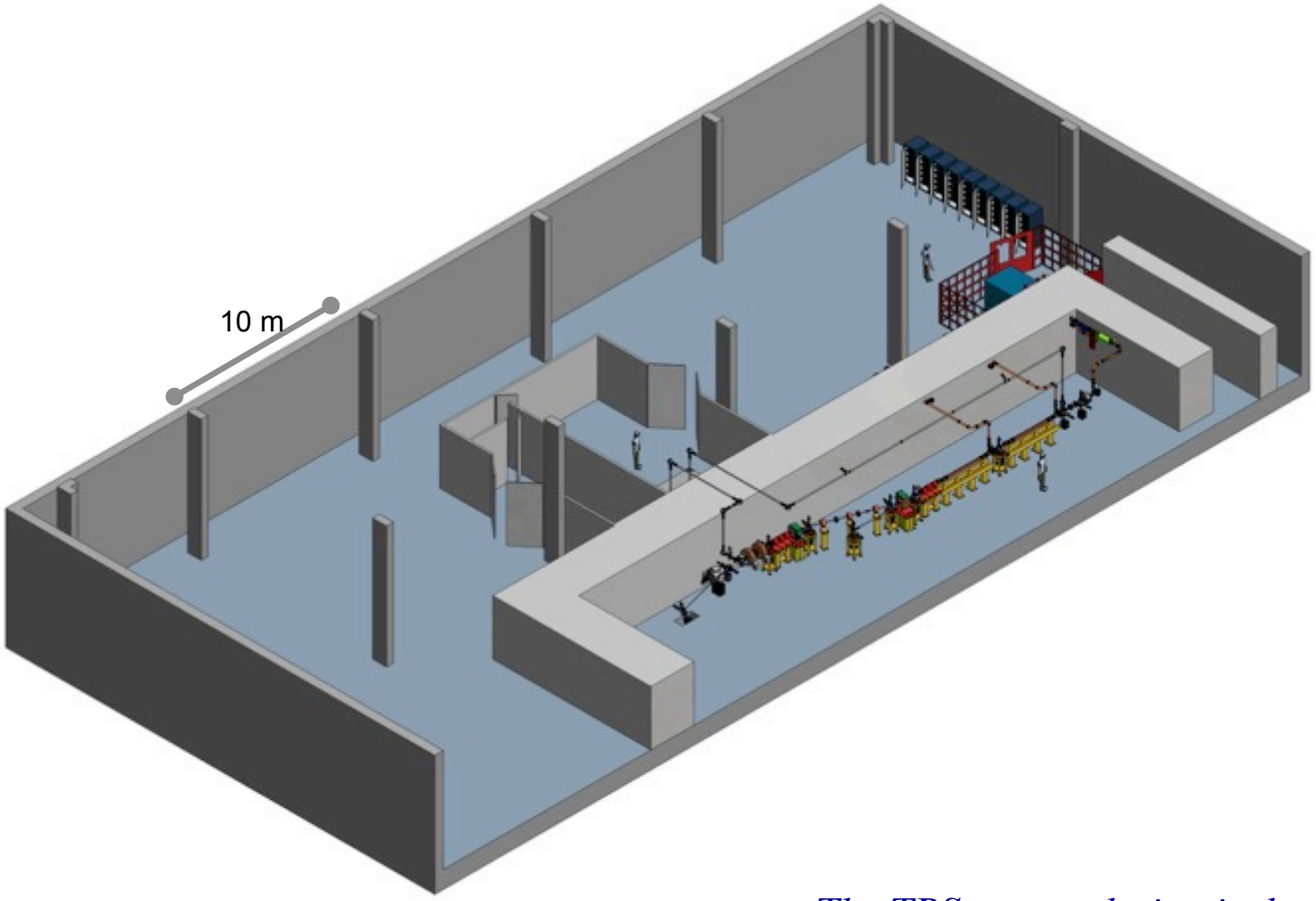
iii. **XFELO-γ**, Menlo-Park-CA (USA), a FEL based Inverse Compton Source for hadronic physics experiments generating up to 7 GeV photons by back-scattering a 12 keV FEL beam by a 7 GeV electron beam circulating in a storage ring: here electron recoil is dominant and strongly affects the bandwidth and intensity of the photon beam. The comparison between analytical predictions and simulation results underline impressively the predicted effect of decreasing the sensitivity of bandwidth to the electron beam emittance by a factor scaling with the inverse of recoil, in such a way that a stronger focusing of the electron beam can be applied without spoiling the bandwidth. As well known this is not possible in low recoil regimes.

STAR

STAR is located in the campus of the University of Calabria
The source is placed inside a specifically designed hangar

STAR

(SOUTHERN EUROPE THOMSON BACK-SCATTERING SOURCE FOR APPLIED RESEARCH)



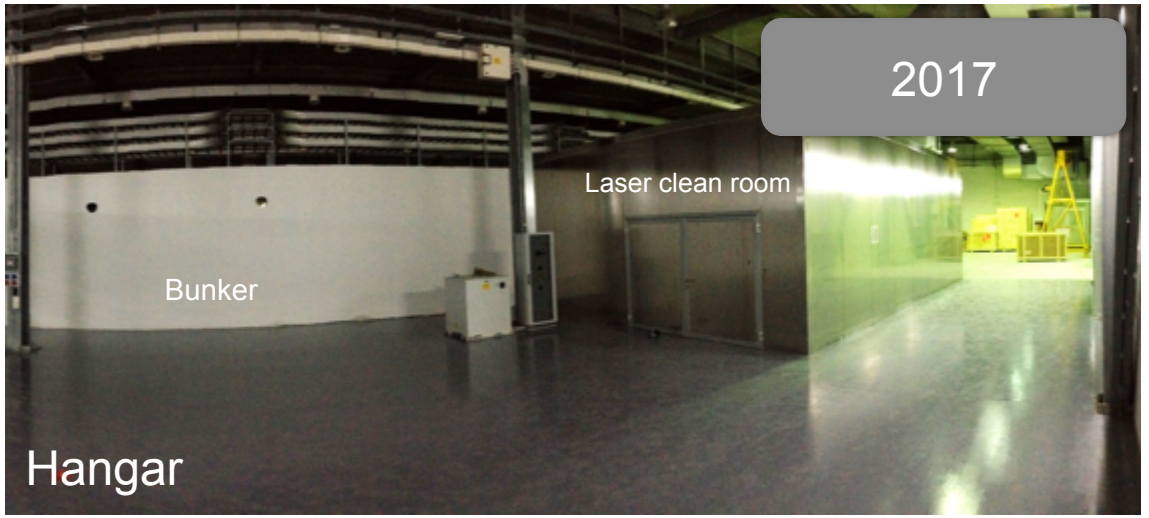
STAR project is aimed at the construction of an advanced Thomson source of **monochromatic tunable**, **ps-long**, **polarized** X-ray beams, ranging from **20 to 140 keV.** The project is pursued in collaboration among: Univ. della Calabria, CNISM, **INFN** and **Sincrotrone Trieste**. The X-rays will be devoted to **experiments of matter science, cultural heritage, advanced radiological imaging with micro-tomography capabilities**.

The TBS source design is developed by

INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati

STAR


RF power station




STAR


Air conditioning system

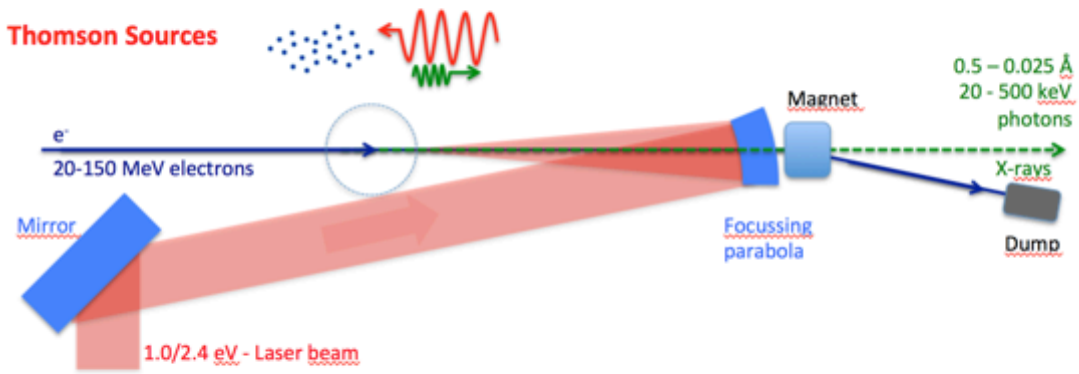
The Bunker (37x12x3.5h m) hosting STAR is located inside the Hangar (50x25x6.7h m) together with the clean room for the power laser and the experimental station µTomo.
Three satellite structures are connected to the Hangar: the control room and the electrical and air conditioning systems.
Shields have been designed for electron energies up to 350 MeV, while a series of seismic measurements have completely characterized ground vibrations under operating conditions.


N
Google earth
Termini e condizioni d'uso

STAR


CNR
2017
Engineering
STAR
MaTeRiA Labs
SILA Labs
Physics
CNISM
INFN

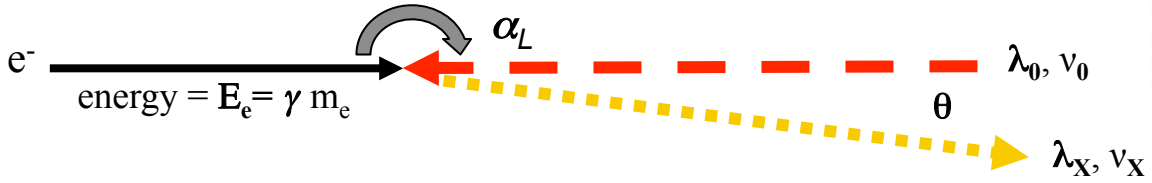
Thomson backscattering X ray source



Courtesy of Luca Serafini

THOMSON BACK-SCATTERING SOURCES

Linear (Single Photon) THOMSON BACK-SCATTERING



$$\nu_X = \nu_0 \frac{1-\beta\cos\alpha_L}{1-\beta\cos\theta} \approx \nu_0 \frac{4\gamma^2}{1+\theta^2\gamma^2} \approx 4\gamma^2\nu_0$$

$for\ \alpha_L = \pi\ (scatt.angle) \qquad and$

$\theta << 1 \quad or \quad \theta = 0\ (obs.angle)$

Examples

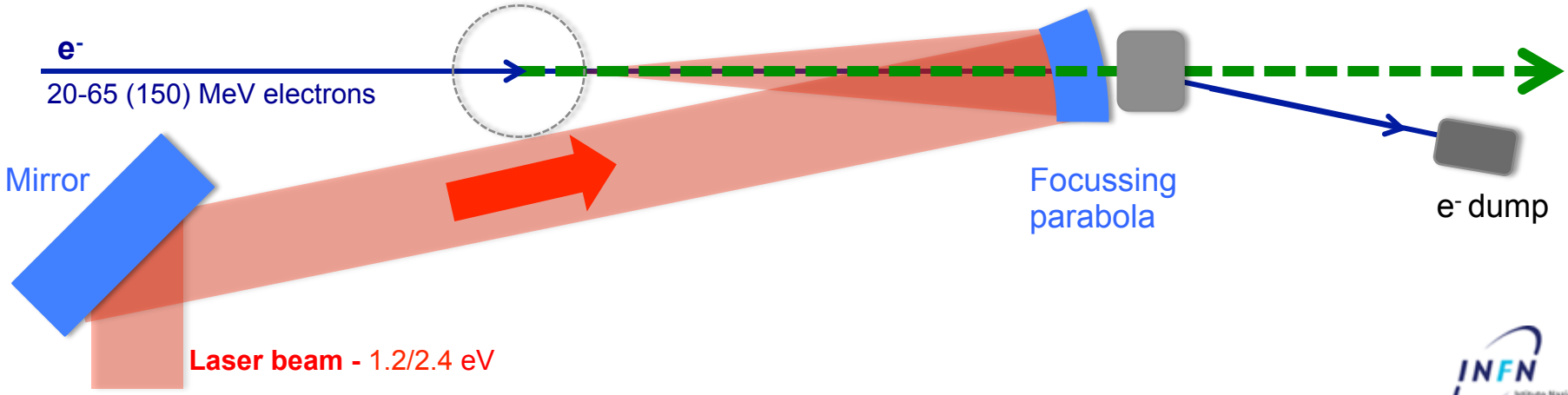
E_e= 1 GeV ; λ_0=1μm, E_0=1.24 eV — λ_X=6 x10^{-2} pm, E_X=20 MeV

E_e= 200 MeV ; λ_0=1μm, E_0=1.24 eV — λ_X=1.56 pm, E_X=800 keV

E_e= 29 MeV ; λ_0=0.8μm, E_0=1.5 eV — λ_X=0.5 Å, E_X=20 keV

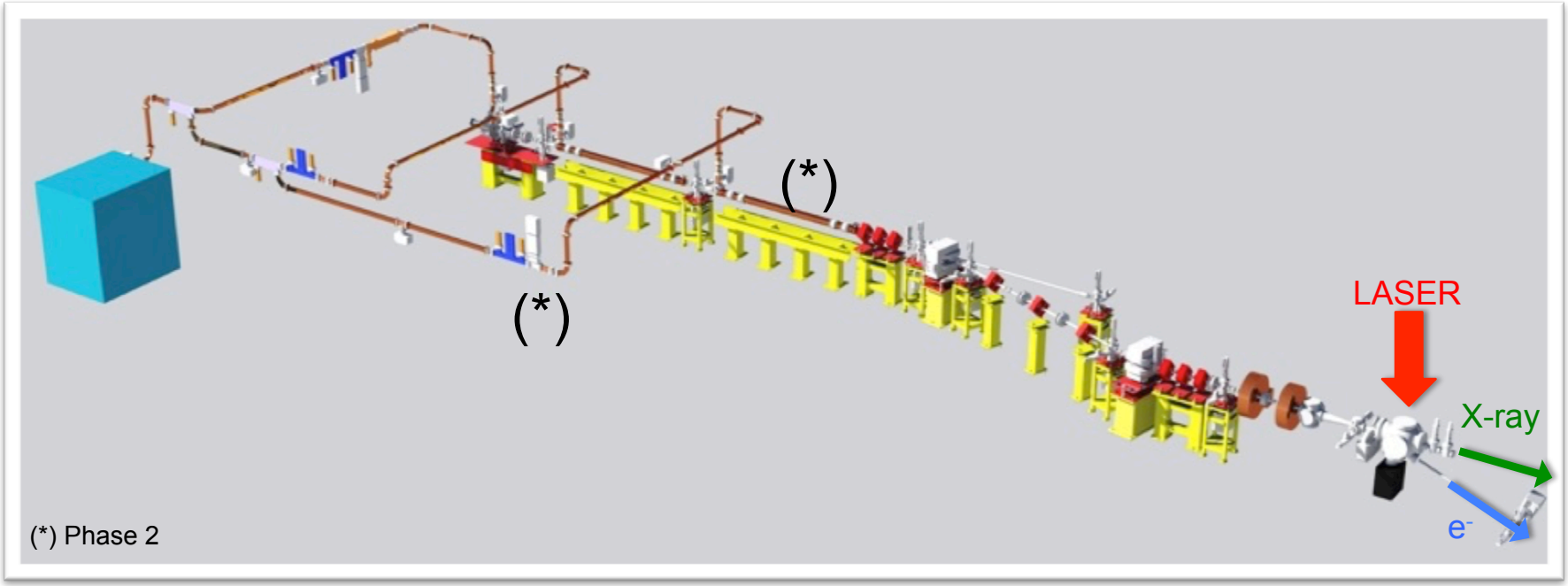
Thomson Scattering (TS) X-Ray sources are attracting strong attention, mainly by a strong flexibility, compactness and less expensive, respect to the synchrotron sources.
The TS is the electromagnetic process in which each electron absorbs one (linear Thomson scattering) or more (nonlinear Thomson scattering) photons from a laser pulse, emitting one photon. If the electrons are ultra-relativistic the scattered radiation is frequency upshifted and it is emitted forward with respect to the particles motion, with a small aperture cone, proportional to the inverse of the Lorentz relativistic factor.

STAR case



Courtesy of ***Luca Serafini***

STAR LAYOUT



One S-band RF Gun at 100 Hz will produce electron bunches boosted up to **60 MeV** by a 3m long S-band TW cavity. A **dogleg** will bring the beam on a parallel line, shielding the X-ray line from the background radiation due to Linac dark current. The peculiarity of the machine is the ability to produce high quality electron beams, with low emittance and high stability, allowing to reach **spot sizes around 15-20 microns**, with a pointing jitter of the order of a few microns. The collision laser will be based on **a Yb:YAG 100 Hz high quality laser system**, synchronized to an external photo-cathode laser and to the RF system to better than **1 ps time jitter**.

A. Bacci, *et al.*: *The STAR project*. 5th International Particle Accelerator Conference (IPAC), Dresden, Germany; 06/2014

Courtesy of ***Dennis T. Palmer***

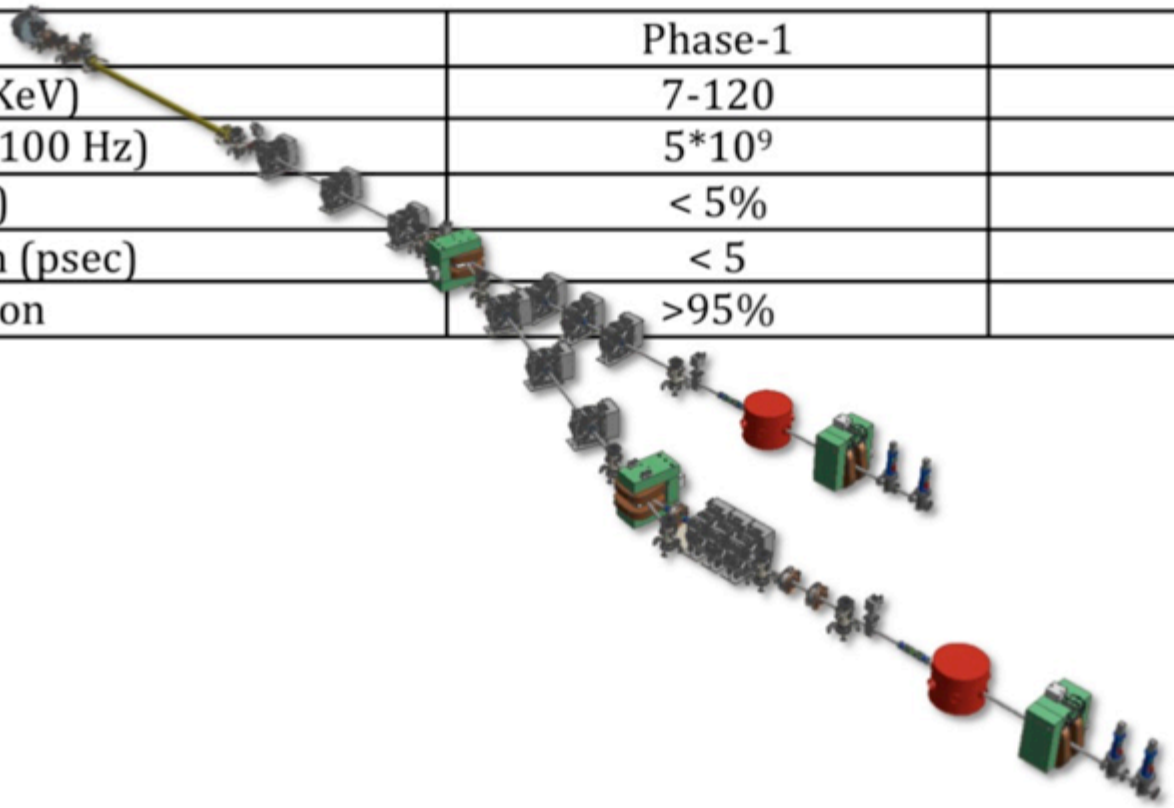
STAR main specifications

RF and Laser repetition rate: 100 Hz

Phase 1 (present budget 7 M€) : non recirculation, single bunch mode
Phase 2 : multi-bunch, laser recirculation (>50 turns),
X-band corrector, 2nd accelerating section

Table 1: X-ray beam characteristics

	Phase-1	Phase 2
Photon energy (KeV)	7-120	7-240
Photons/sec (@ 100 Hz)	$5*10^9$	10^{12}
Bandwidth (rms)	< 5%	<2%
Rms Pulse length (psec)	< 5	<5
Linear Polarization	>95%	>98%



STATUS OF THE STAR PROJECT

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D. Alesini, M. Bellaveglia, F. Bisesto,B. Buonomo, G. Di Pirro, A. Esposito, F. Iungo, J. J. Beltrano, G. Borgese, A. Gallo, A. Ghigo, L. Pellegrino, A. Stella, C. Vaccarezza, INFN/LNF,Roma, Italy;
A. Cianchi, Univ. Tor Vergata, Roma, Italy;
R. G. Agostino, R. Barberi, M. Ghedini, F. Martire, and C. Pace, UNICAL, Arcavacata di Rende, Cosenza, Italy;
G. Dauria, A. Fabris, and M. Marazzi, Elettra/Sinc. Trieste, Trieste, Italy

Abstract

This paper reports on the final design and the work in progress on the STAR project (IPAC2014:WEPRO115), which is under construction at the Univ. of Calabria (Italy). The project is devoted to the construction of an advanced Thomson source of monochromatic tunable, ps-long, polarized X-ray beams, ranging from 40 up to 140 KeV . At present the buildings and main plants have been completed as the acquisition of main components: the RF photo-injector, the accelerating section, laser systems for collision and photo-cathode, RF Power Source and magnets are ready to start installation and site acceptance tests. The design of laser lines is complete and simulated by ZEMAX, aiming to minimize energy losses, optical distortions and providing a tunable experimental setup as well. The RF power network is close to be tested, it's based on a 55MW (2.5us pulse) S-band Klystron driven by a 500kV Pulse Forming Network based modulator and a Low Level RF system, running at 100 Hz. The Control System is been designed using EPICS and allows to manage easily and fastly each machine parameter. We expect to start commissioning the machine by the end of 2016 and obtain the first collisions within the first part of 2017.

7th International Particle Accelerator Conference 2016

PHOTOINJECTOR EMITTANCE MEASUREMENT AT STAR

Bacci†, I. Drebot, L. Serafini, V. Torri, INFN/Milan, Italy;
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UNICAL, Arcavacata di Rende, Cosenza, Italy;
G. Dauria, A. Fabris, and M. Marazzi, Elettra/Sinc. Trieste, Trieste, Italy

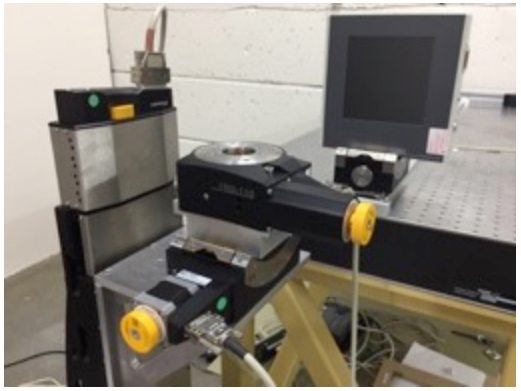
Abstract

STAR is an advanced Thomson source of monochromatic and tunable, ps-long, polarised X-ray beams in the 40-140 keV range. The commissioning has started at the U. of Calabria (Italy). The light source is driven by a high-brightness, low-emittance electron beam produced in a LINAC allowing for the source tunability and spectral density. This note reports on an emittance measurement schema based on the insertion of a slit mask in the vacuum chamber dedicated to the photocathode laser entrance. Results of the simulation of the measurement technique are reported, and the use of the data for the optimisation of the accelerator performance are detailed. The experimental setup and the application developed in EPICS for image recording and analysis are also described.

µTomo beamline

X-ray microtomography setup
Innovative aspects:
µTomo fully exploits the diffraction limited, monochromatic and tunable STAR X-rays:

- Phase contrast images are obtained by using the X-ray beam
- Chemically resolved radiography for an efficient quantitative analysis by means of the X-ray tunability
- Hard X-ray are used for high Z elements mapping

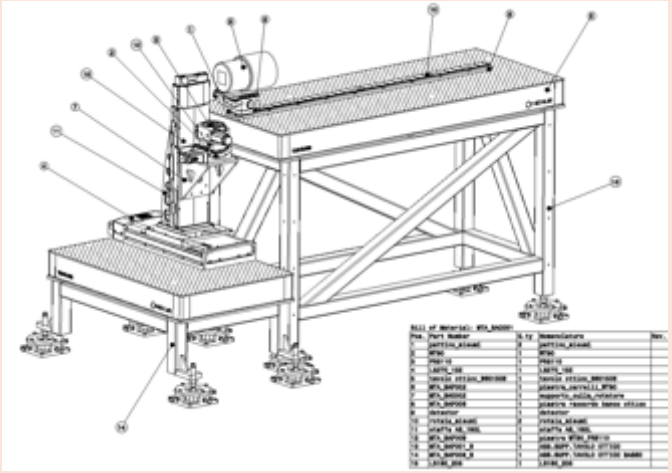


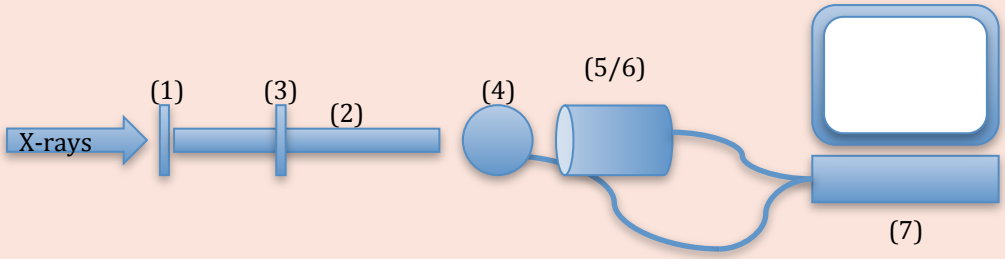
Experimental techniques:

- PHase Contrast (PHC) radiography
- Chemically resolved radiographic images
- Micro-tomography and holotomography

① **Front end**
② **X-ray transfer line**
③ **Slits**
④ **Sample-holder (2 translations + 3 rotations)**
⑤ **Detectors pair for high/low energy X-rays**
⑥ **Detector stage (3 translations + 2 rotations)**
⑦ **Data acquisition system**

Elettra Sincrotrone Trieste

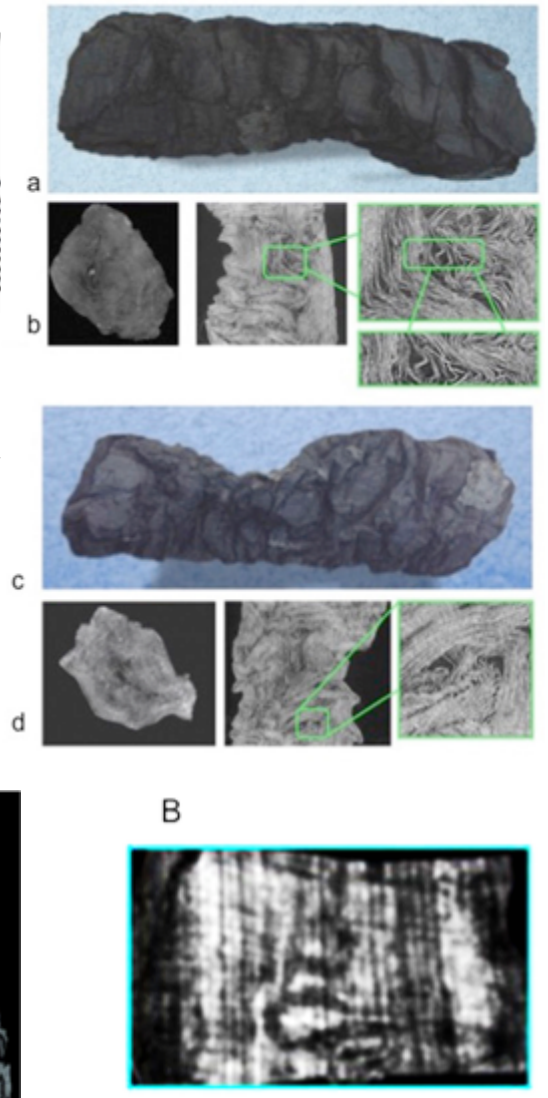


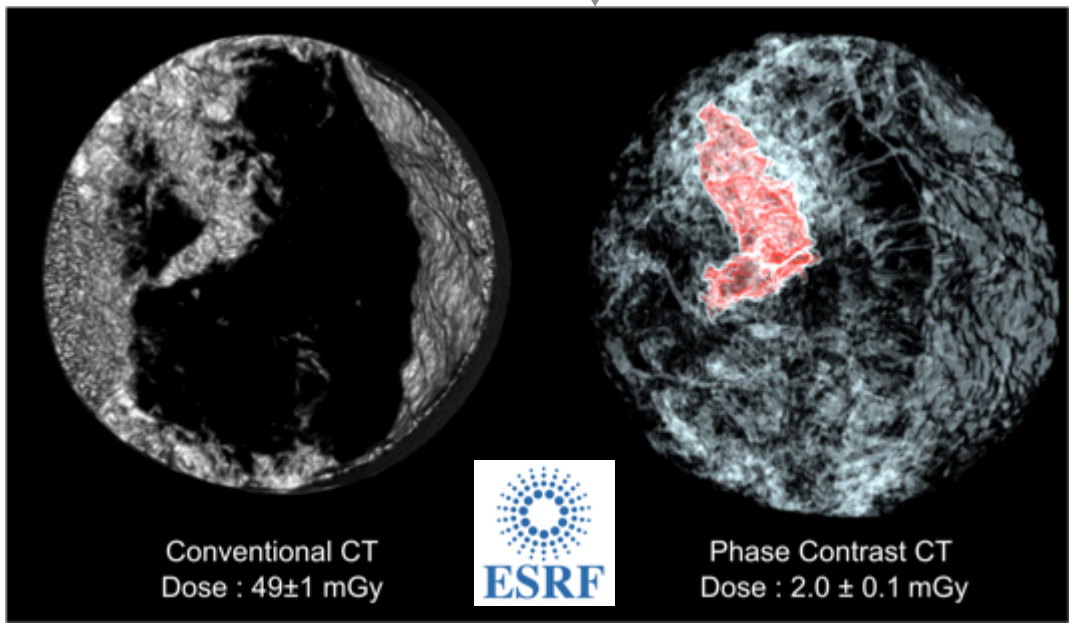


Experimental station µTomo

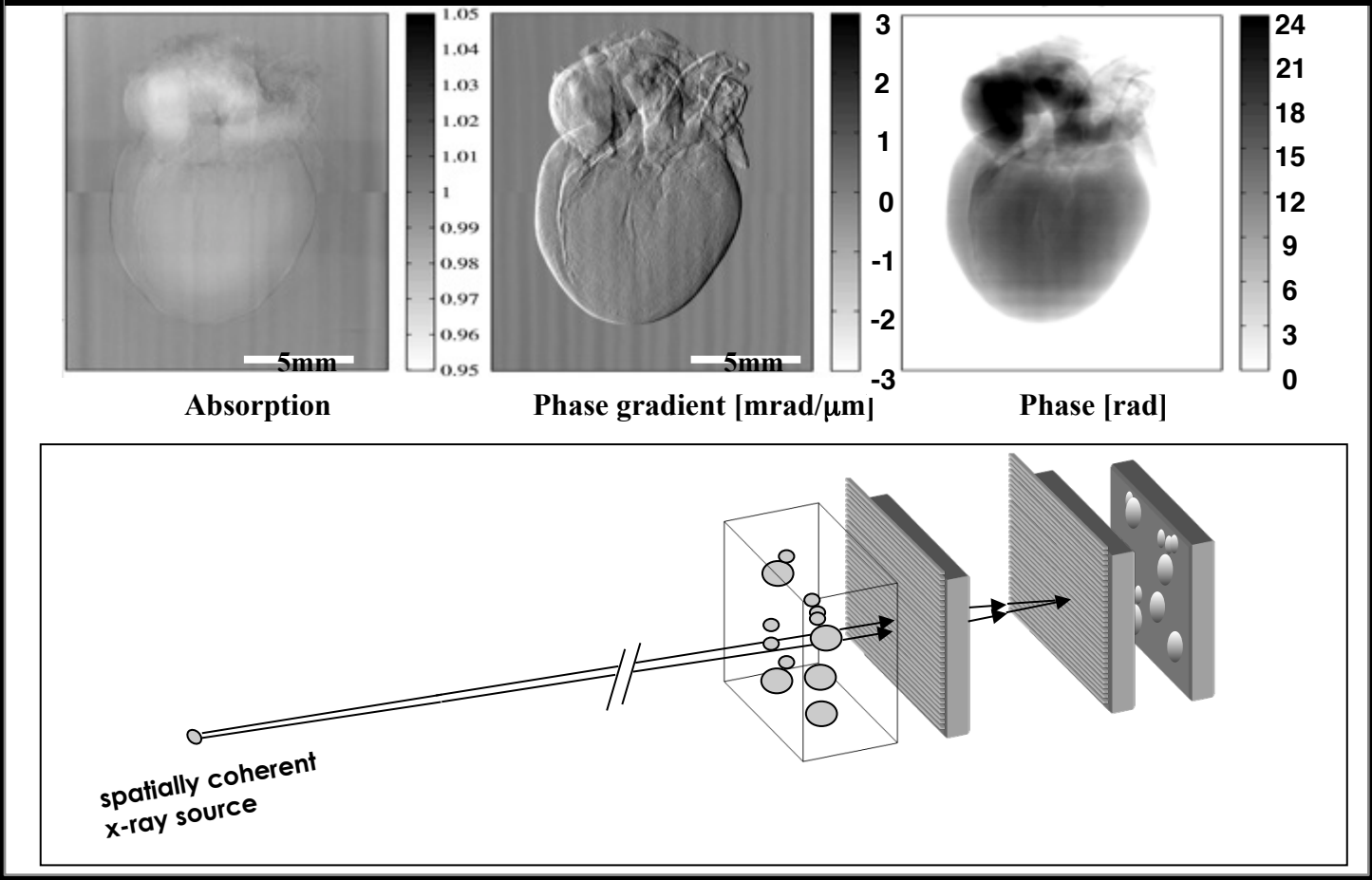
Application fields:

- **Cultural heritage**
- **Bio-medicine**
- ***Smart manufacturing***





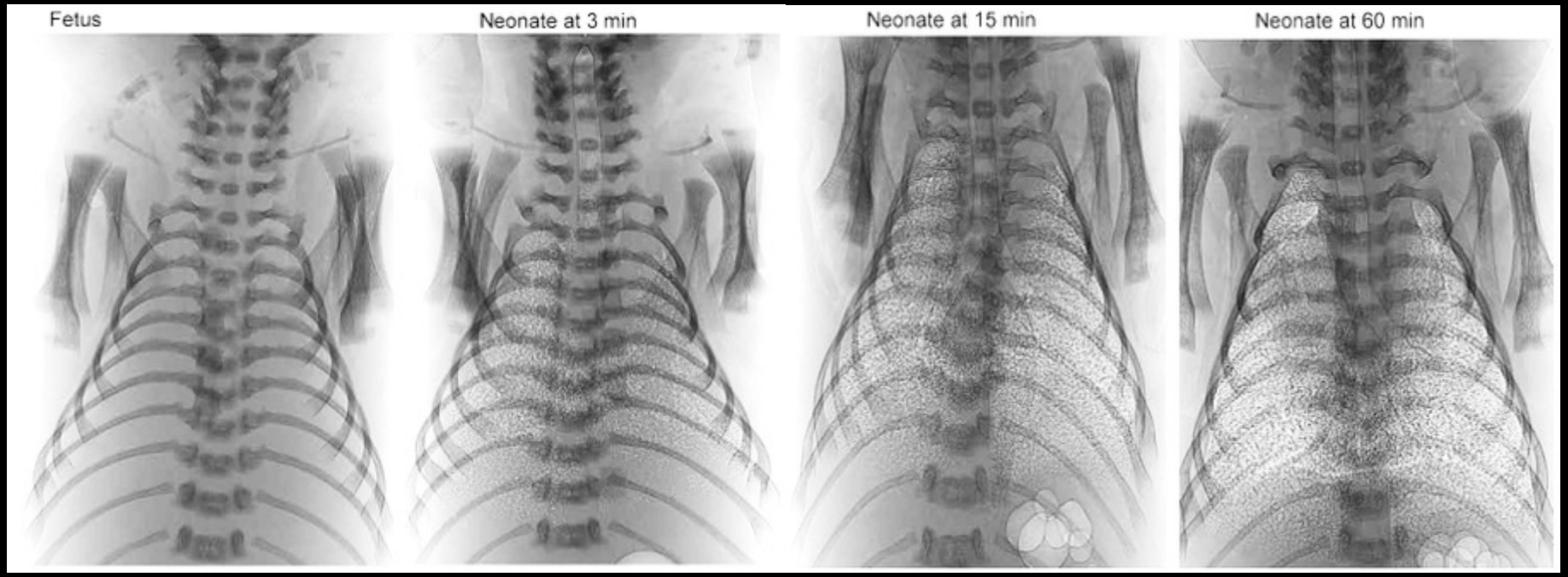
Application: High resolution radiography



Comparison between amplitude and phase contrast in a rat hearth taken at the ESRF synchrotron. The phase contrast is obtained using a two grating interferometer which provides quantitative measurement of the phase (courtesy of C. David, PSI Viligen Switzerland)

Application:
Time resolved phase-contrast micro-radiography

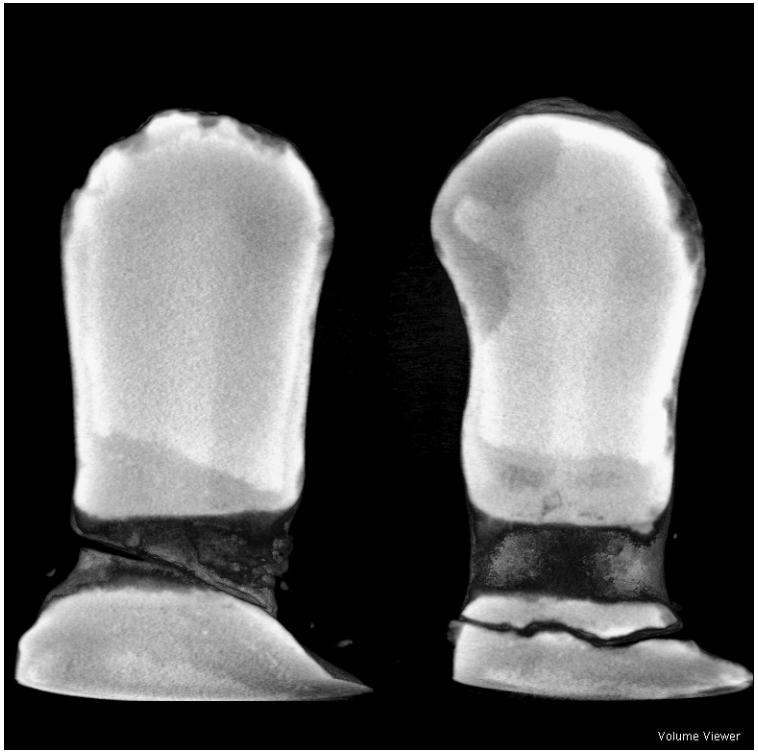
20B2 beamline at Spring8 - 25 keV



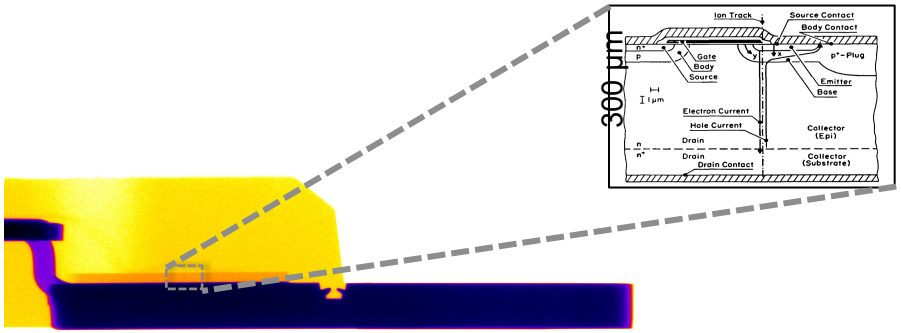
Images of the flow of air into the lungs of a neonatal rabbit using X-ray phase-contract imaging. The phase contrast permits the visualization of the air entering the animal's lungs during its first breaths. (S.B. Hooper et al., Clinical and Experimental Pharmacology and Physiology, 36, pp. 117–125 [91])

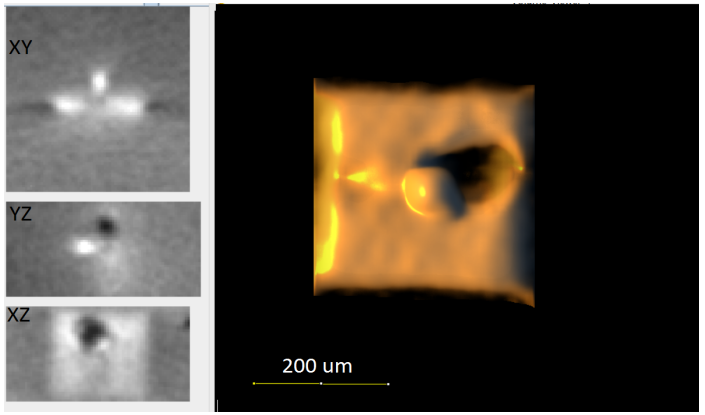
Star:
Tomography of ancient finds

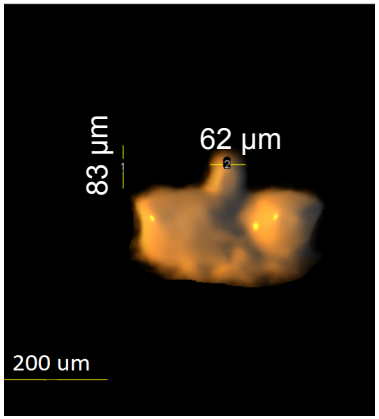
Campione ROS 1 - Bucita - RS 001



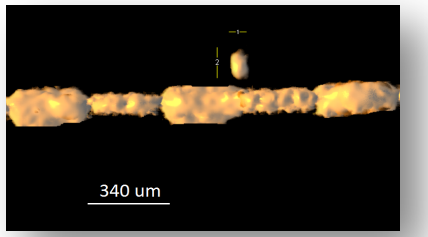
Star:
Tomography of a mosfet after a burnout event







Sample #8



Segmented ROI µCT @ µTomo

STAR NEXT

NATIONAL STEERING COMMITTEE – STAR-Lab

Institutions	*Members*
CERIC	Carlo Rizzuto - ***President***
UniCal	Riccardo Barberi
CNISM	Ezio Puppin
INFN	Luca Serafini
INSTM	Andrea Caneschi
CNR	Massimiliano Dibitetto
Elettra – ST	Marco Marazzi

Targets

- EU and National funding for STAR facility evolution (higher flux, higher X-ray energies, …) and new beamlines (Small angle X-ray scattering, X-ray Diffraction, …)
- Connection to the European Research Infrastructure network
- User-community driven implementation of techniques
- Establish a user-community looking to Europe and other Mediterranean countries

COGESTAR

The Management Committee of STAR

5 members Unical + 5 members CNISM

THANK YOU FOR YOUR ATTENTION