

CSNSM LIBRA Partner

Gabriel CHARDIN

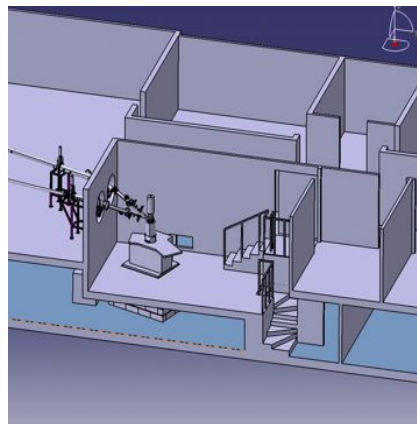
CNRS/IN2P3/CSNSM and Paris-Sud University

Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse

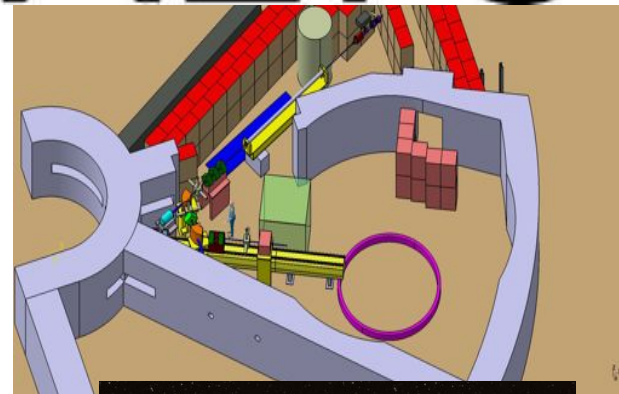


- **Research groups on:**

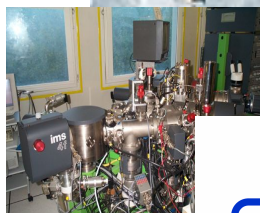
- Nuclear structure
- Ion beams and materials
- Atomic mass spectroscopy
- Nuclear astrophysics
- Micrometeorites
- Dark Matter search
- Cryogenic detectors
- Other activities...



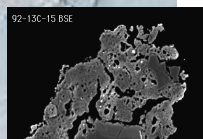
ALTO



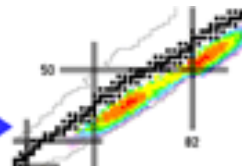
Projects



Consortium
STARDUST

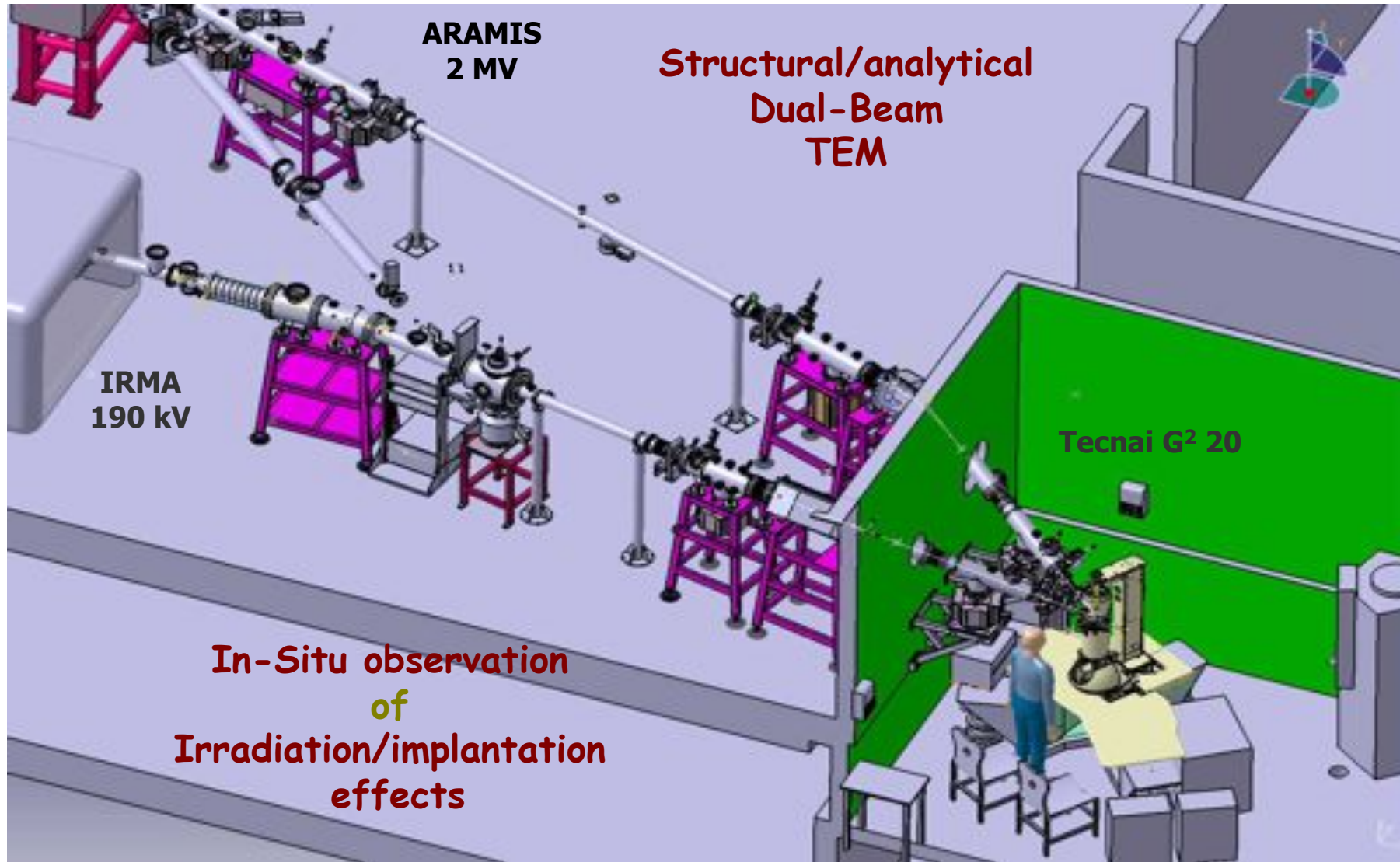


Spiral 2



INTEGRAL

JANNuS at CSNSM/Orsay – General view



JANNuS experiment: Orsay site
TEM in situ dual beam implantation



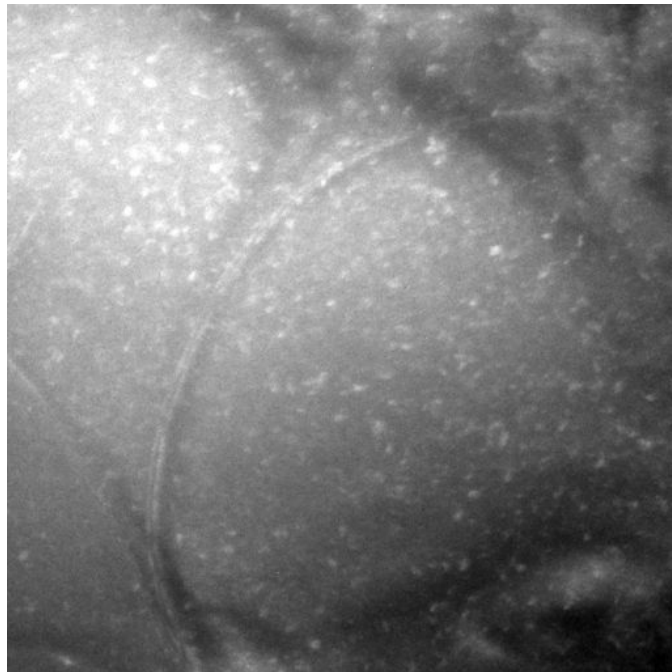
TEM: FEI Tecnai 200 kV, LaB₆ gun

Acquisition system: GATAN ES500 camera, top mounted & fast negatives

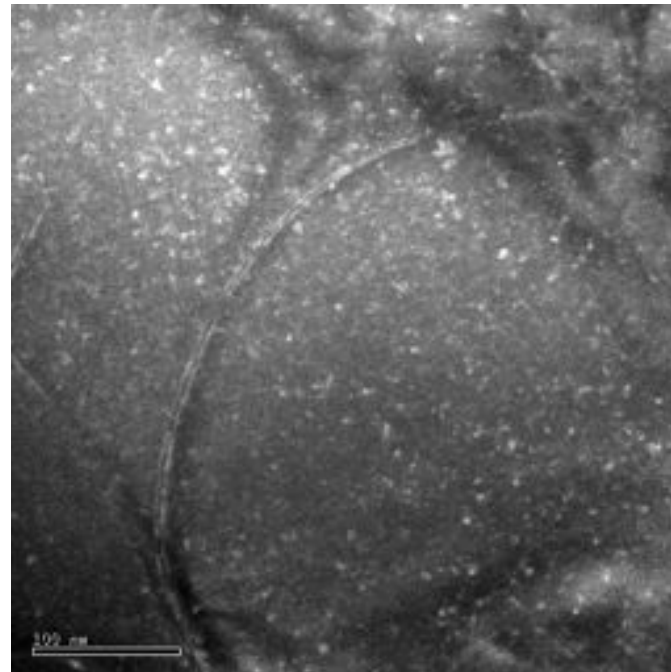
Implantation lines: left one is from IRMA (190 kV), right one is from ARAMIS (2 MV)
connected at 22° to TEM, with metallic bellows to reduce vibration transmission

Contrast Performance with GIF

installed on 200 kV TEM



Unfiltered image



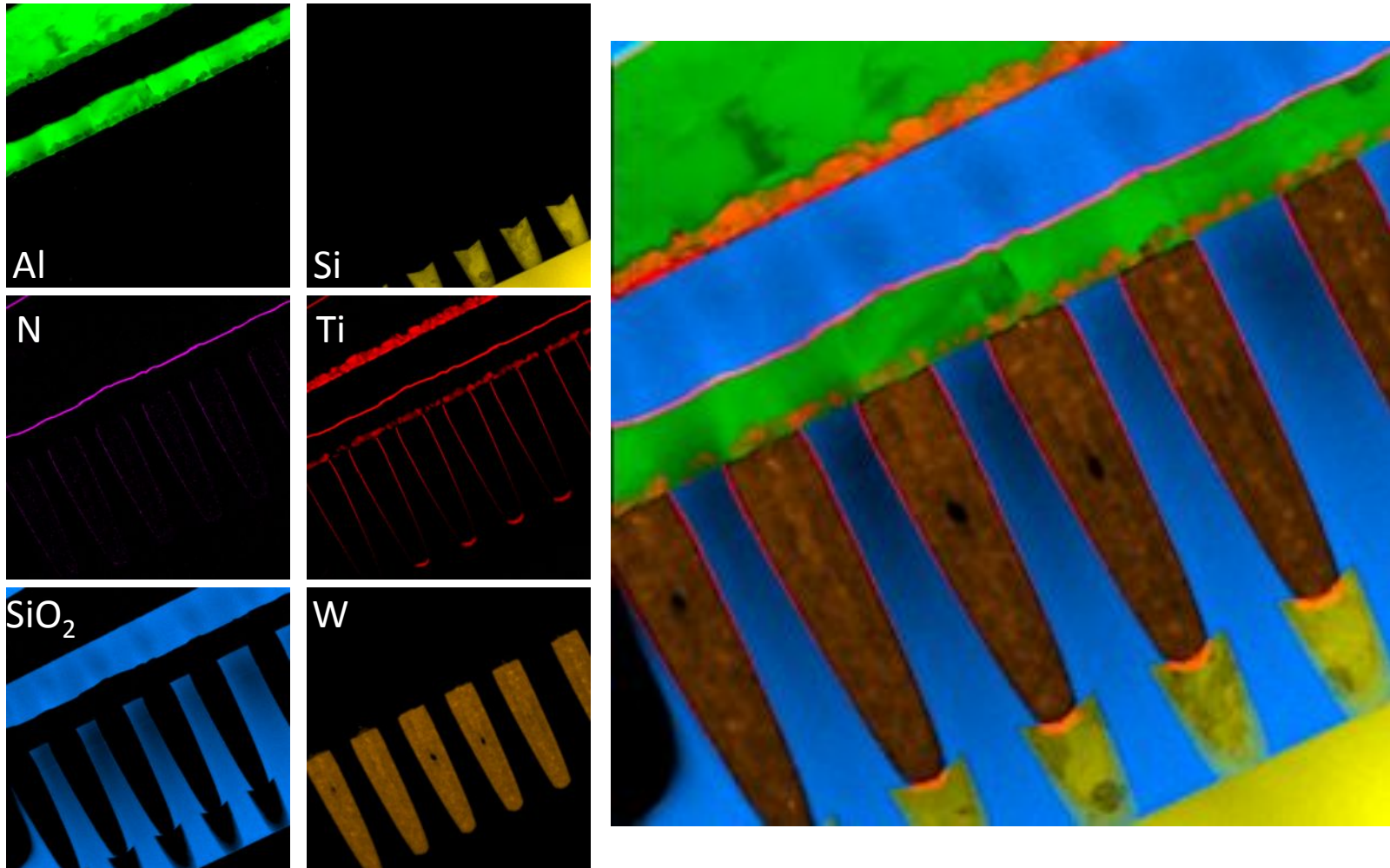
Filtered image

Strained
Ni-based
Superalloy
WB $g=220$
Filter :
Zero loss
20eV

Cliché
B. Décamps

GATAN: EELS imaging and analysis

- ◆ EELS imaging
 - ◆ Gives information and contrast based on specimen composition



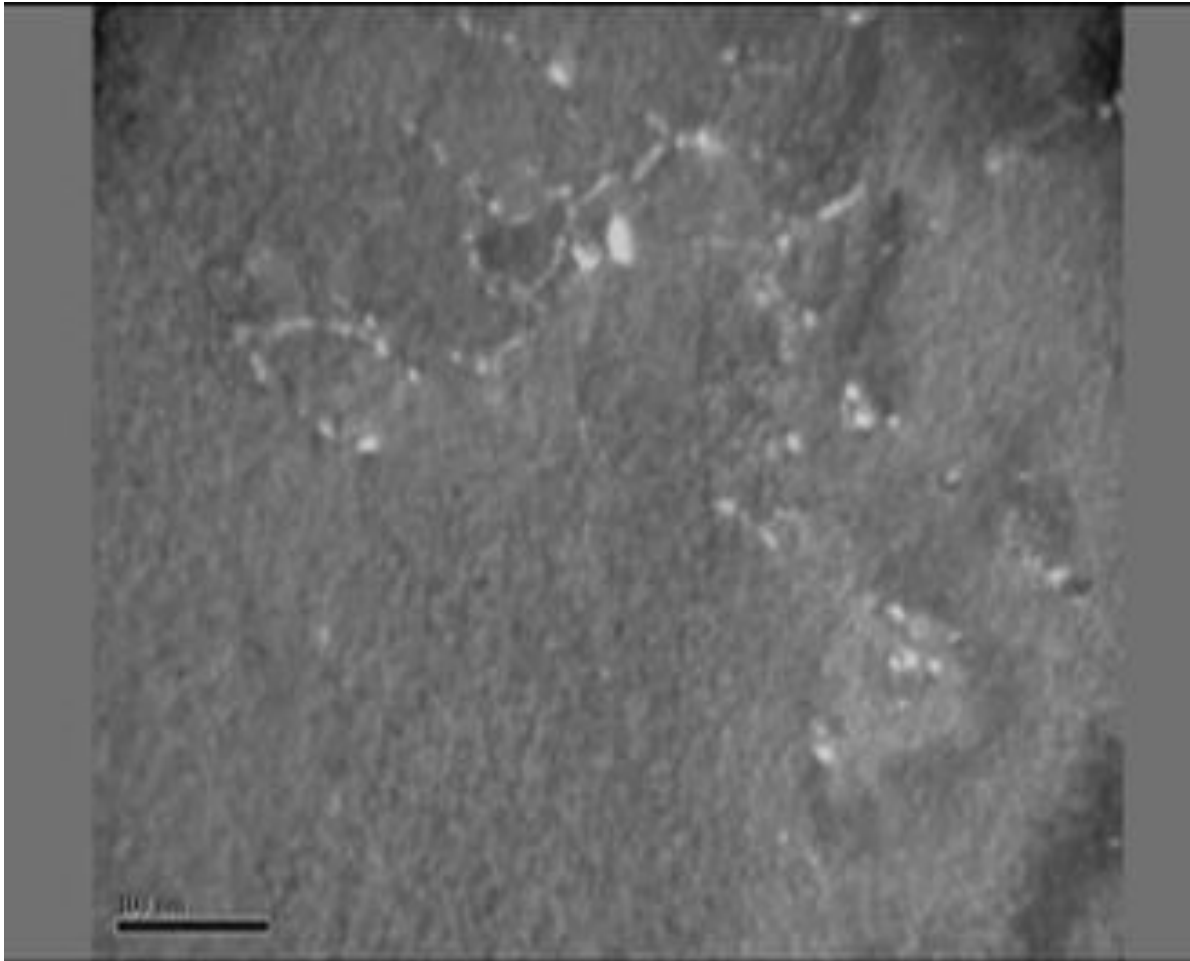
First experiments at JANNuS Orsay (2009)

- **A study of rare gas bubble nucleation mechanisms in uranium dioxide**
C. Sabathier CEA/Cadarache (11-15 may 09); local contact: O. Kaitasov
- **In situ observations of selective ion-induced grain growth in thin metal films**
M. Seita ETHZ (15-19 june 09); local contact: F. Fortuna
- **Role of the defects on CoSi₂ nucleation in Si**
F. Fortuna CSNSM (22-26 june 09); Local contact: F. Fortuna
- **Primary damage in Fe(Cr) alloys**
R. Schaublin EPFL (25-29 may 09; local contact: B. Décamps
- **In situ TEM investigations of irradiation-induced self organization**
R. Averback Urbana Champain (6-10 july 09; local contact: B. Décamps

In-situ dynamic study

Beam coming from IRMA inside TEM

Single beam Fe 300 KeV on UHP Fe



Accelerated X 50

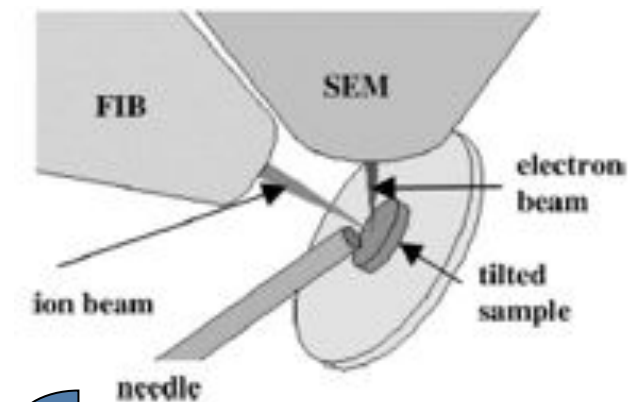
TEM
weak beam
dark field
 $g(4g)$, $g=\{110\}$

FIB (Focused Ion Beam) at CSNSM (Minerve nanofabrication facility)

Dual-Beam system

Coupling with a Scanning Electron Microscope:
imaging during ion structuration

FIB imaging : Detection of secondary electrons
produced by ion beam



Gas injection

Ion beam assisted deposition
Ex. : W, Pt

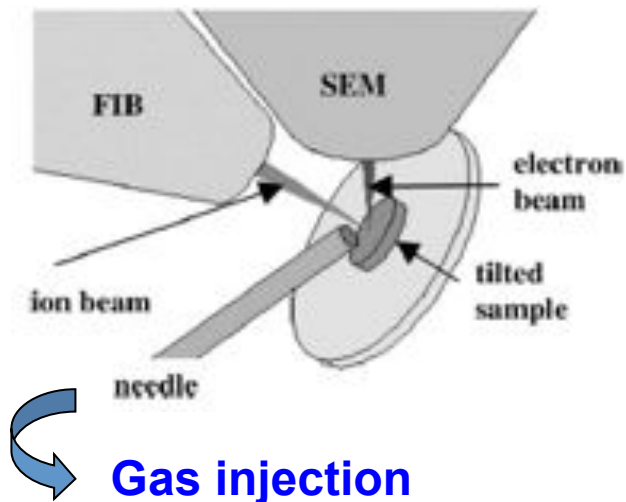


FIB (Focused Ion Beam) at CSNSM (Minerve)

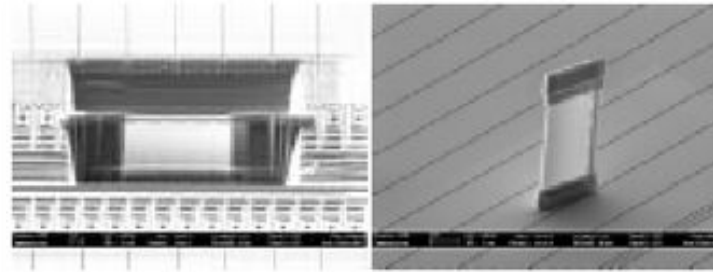
Dual-Beam system

Coupling with a Scanning Electron Microscope: imaging during ion structuration

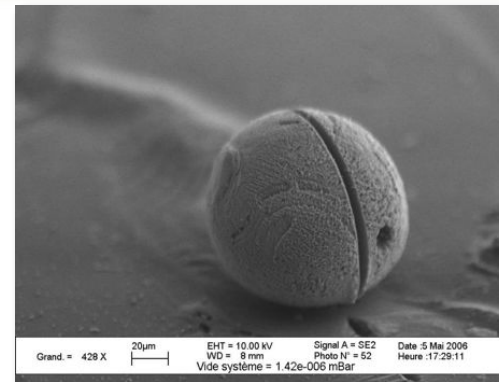
FIB imaging : Detection of secondary electrons produced by ion beam



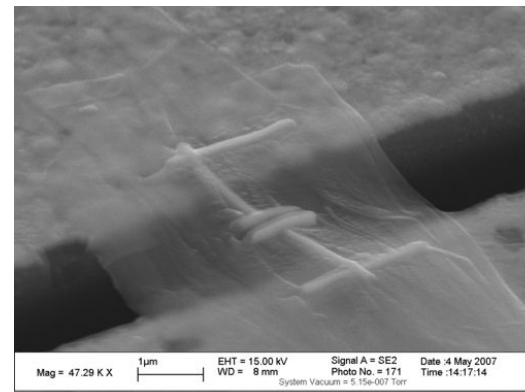
Ion beam assisted deposition
Ex. : W, Pt



Thin samples for TEM analysis



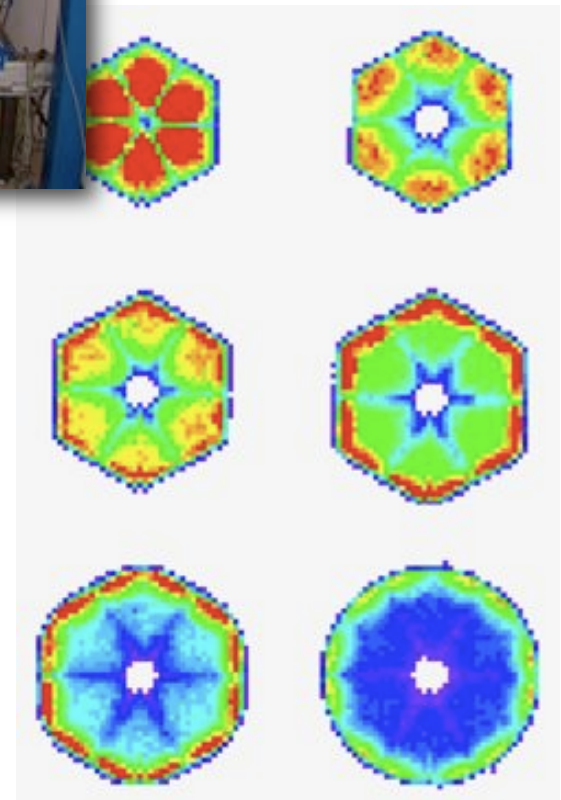
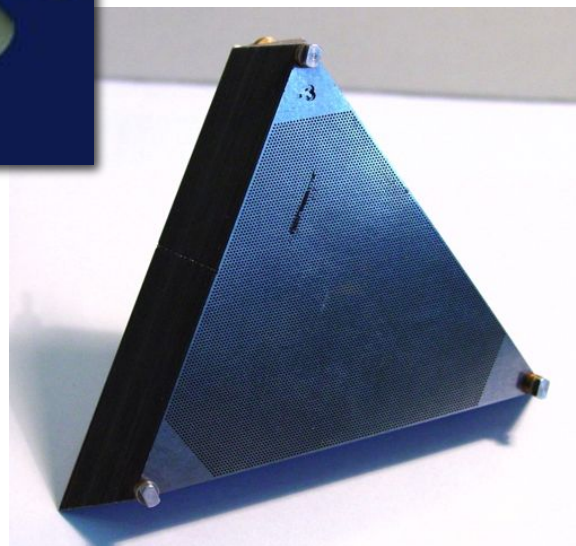
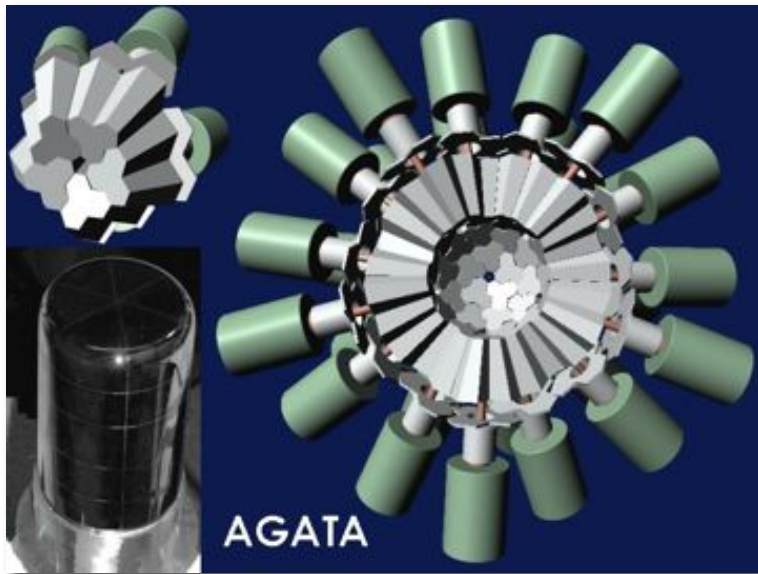
Clean cutting of micrometeorites



Fabrication of Nanostructures
(collaboration with H. Bouchiat LPS)

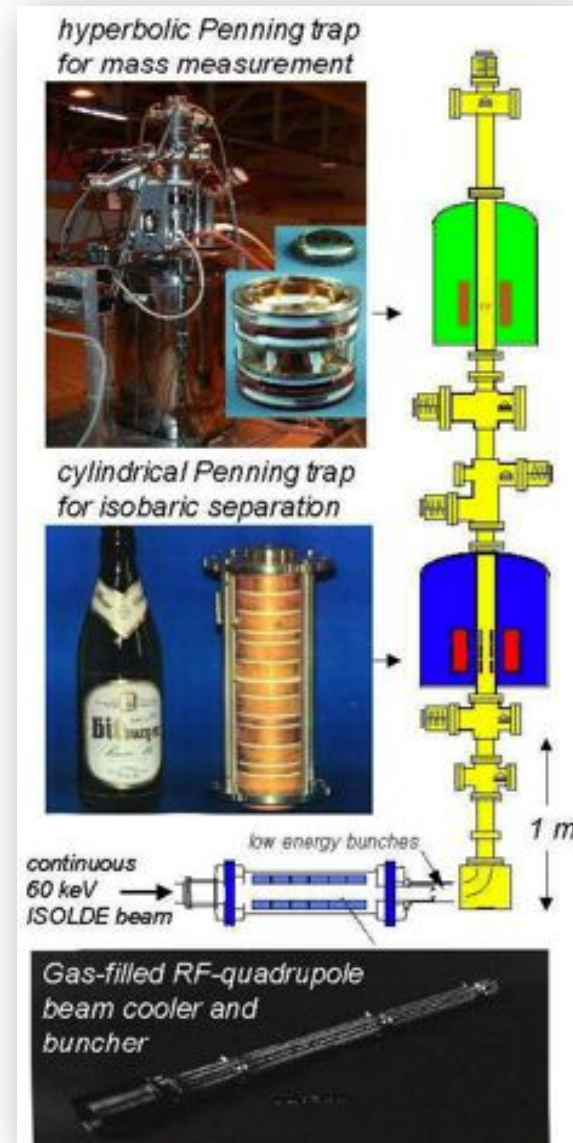
Major projects at CSNSM

- AGATA
(gamma-ray tracking)



Atomic mass measurements

- Mass spectrometers
- Penning and Paul traps
- Developpements for SPIRAL-2
- Towards the gravitational mass measurement of antihydrogen (CEA, CNRS, ETHZ, CERN, Tokyo collaboration) ?



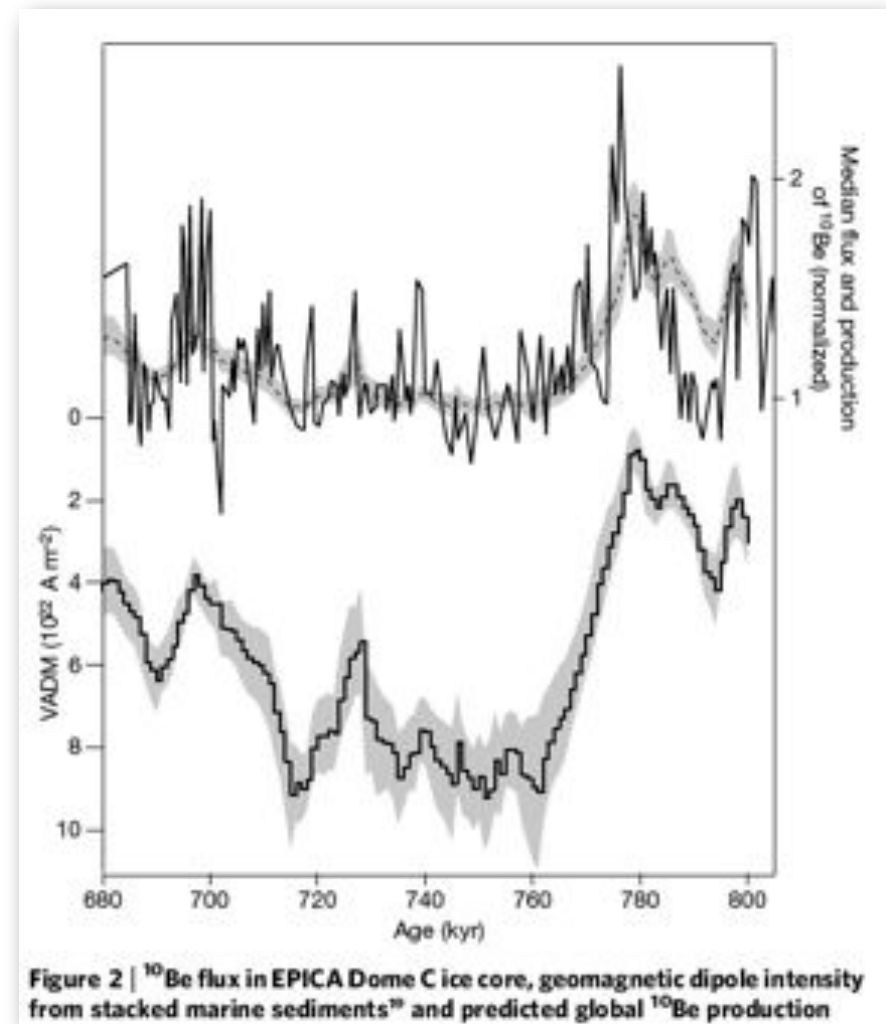
Descartes prize for EPICA

- EPICA : European Project for Ice Drilling in Antarctica
- Ice drilling 3260 meters deep
- Looking backwards to $\approx 800\,000$ years on the Earth climate
- How to calibrate the timescale for deep drillings ?
- Measure cosmogenic production of ^{10}Be in CSNSM (G. Raisbeck)



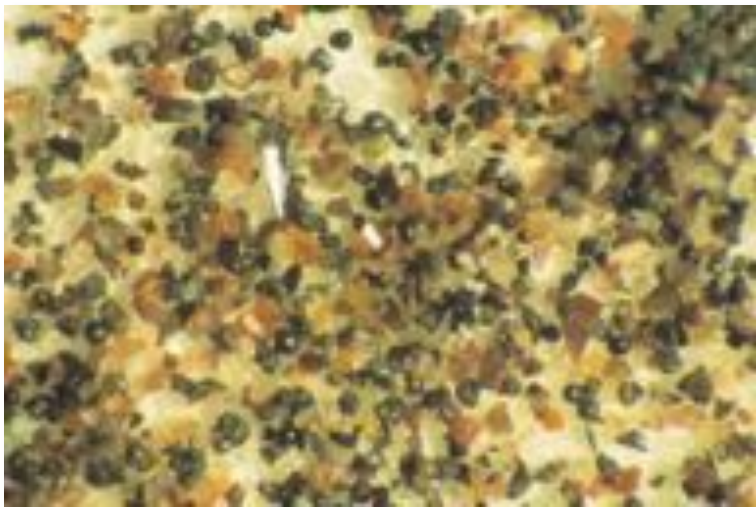
Descartes prize for EPICA

- CSNSM contribution for EPICA : calibration of time scale by comparison of ocean sediments and ice drilling
- Measurement of cosmogenic ^{10}Be : correlation between increased ^{10}Be at inversion of terrestrial magnetic dipole

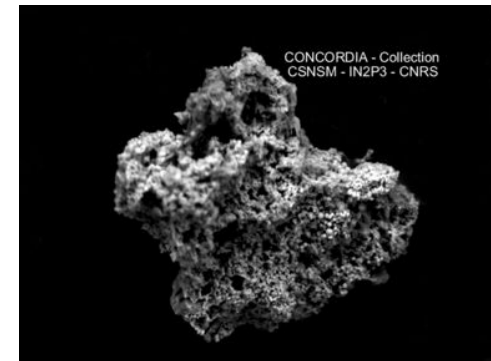
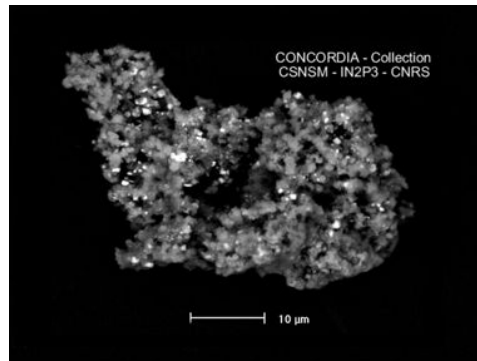
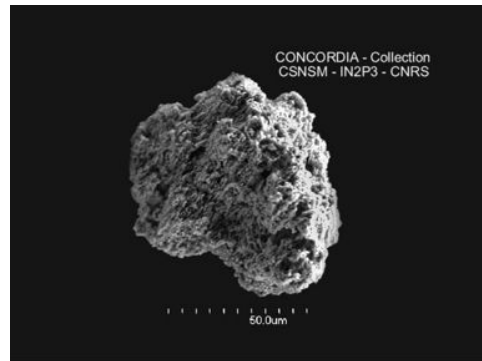
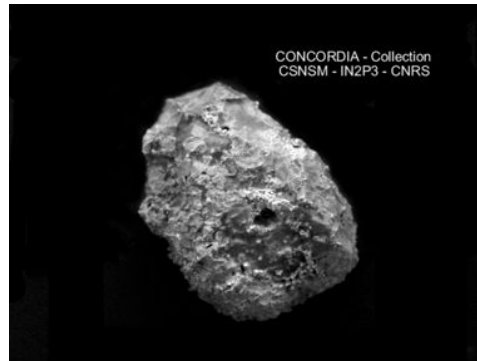
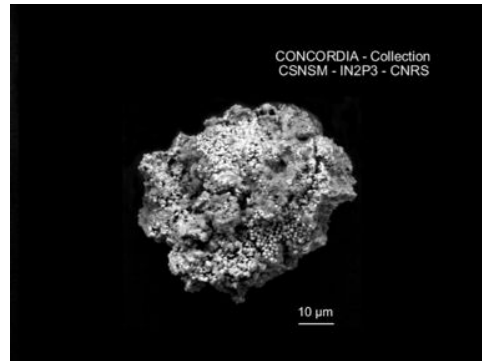


Astrophysics (micrometeorites)

- Unique collection of > 2000 micrometeorites gathered at Concordia
- Isotopic composition analyzed at the micron level using SIM (see figure below)
- Micro-manipulation and cutting of micrometeorites using ion beams (Focused Ion Beam, FIB)
- See DVD « Cosmic dust » by Jean Duprat et al.

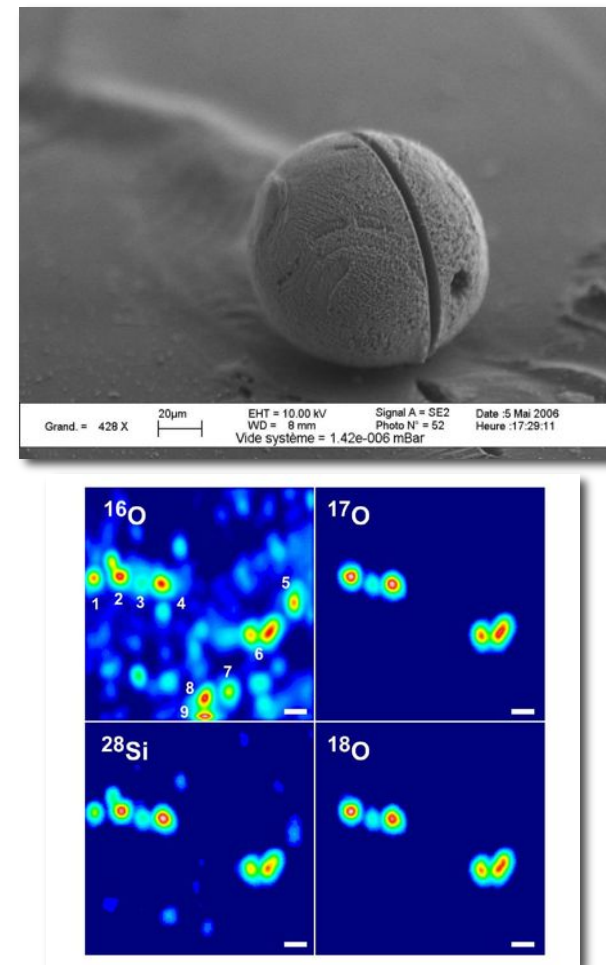


Examples of micrometeorites



Planetology - Cometology (micrometeorites)

- Unique collection micrometeorites gathered at Concordia
- Isotopic composition analyzed at the micron level using SIM (see figure below)
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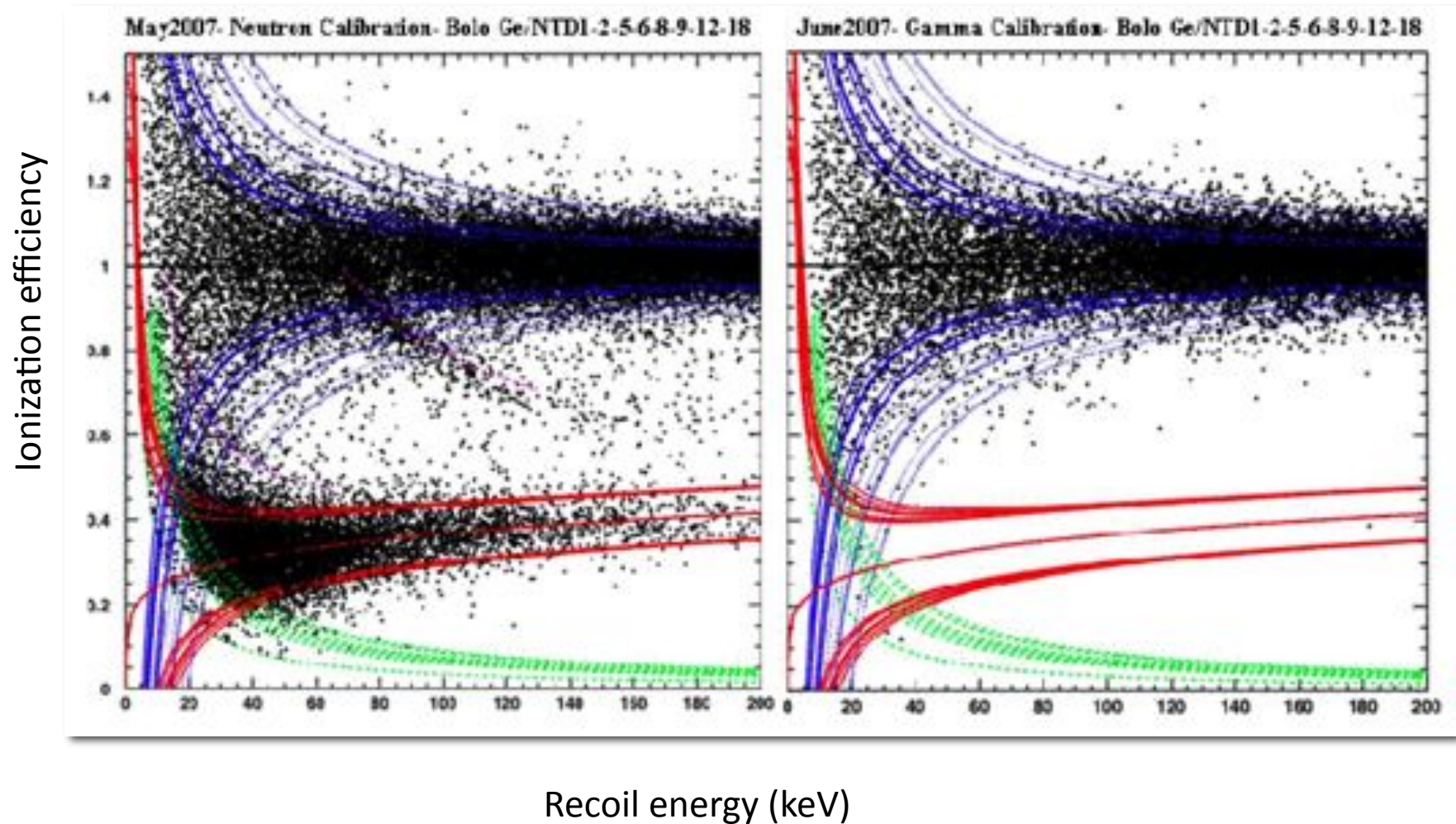


WIMP direct detection at CSNSM

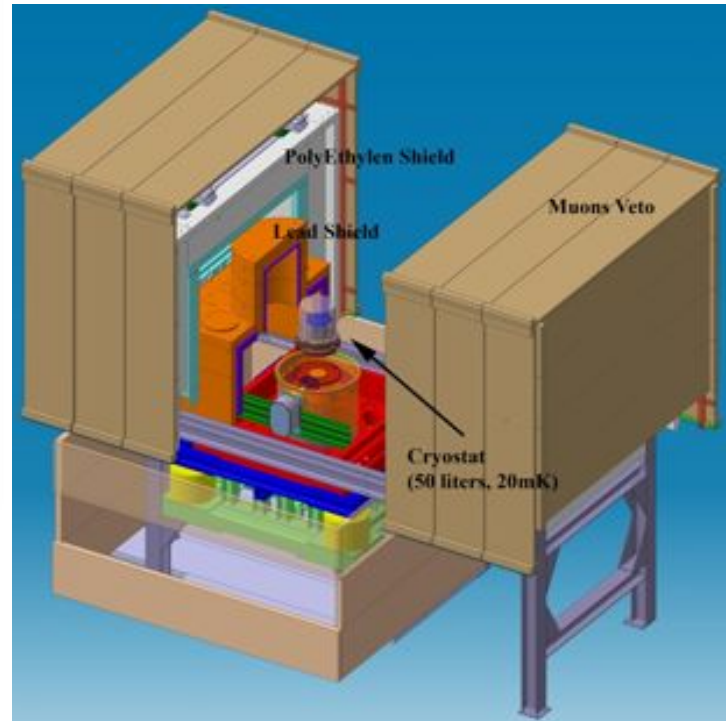
- EDELWEISS-2
 - Test stage of EURECA (major European WIMP expt)
 - Innovative cryogenic solutions
(dilution cryostat 100 liters at 10 millikelvin)
 - InterDigit detectors for EDELWEISS
 - Future : EURECA 150 kg first stage, then 1 ton
 - Fabrication of cryogenic detectors as major contribution of CSNSM to EURECA

WIMP detection

Identification of small number of nuclear interactions



CSNSM in EDELWEISS and EURECA



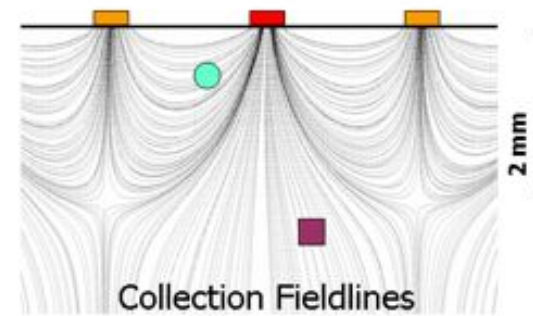
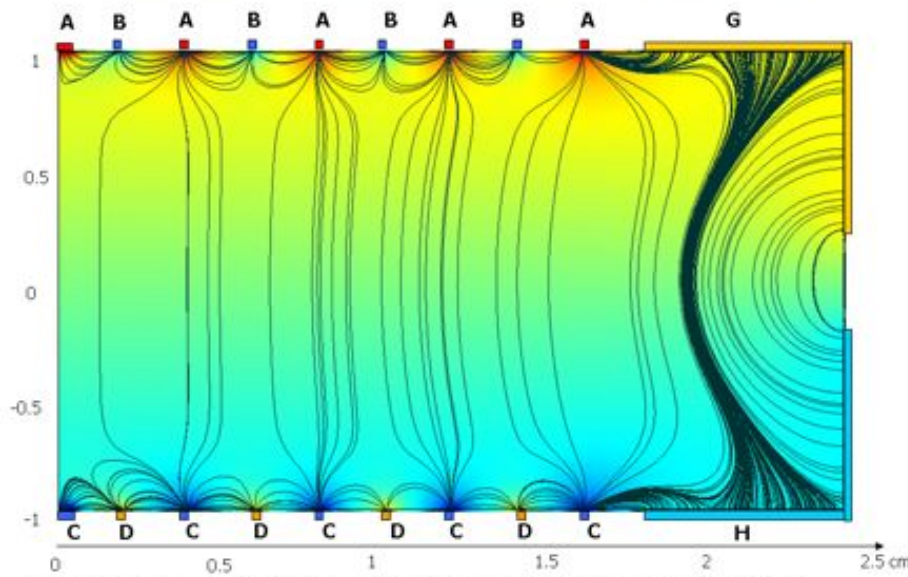
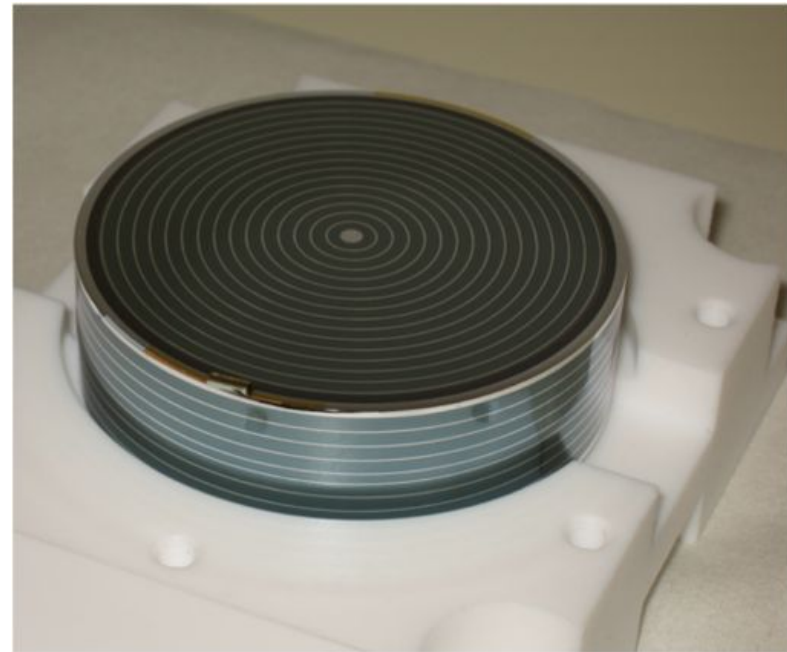
- Conception, fabrication and test of present detectors of EDELWEISS experiment
- Sensitivity at the best world level already demonstrated (pending publication)
- Major contribution to EURECA tonne-scale WIMP detection experiment (approved for Design Study by ASPERA european coordination)

Interdigit detector

400 gram Ge detector

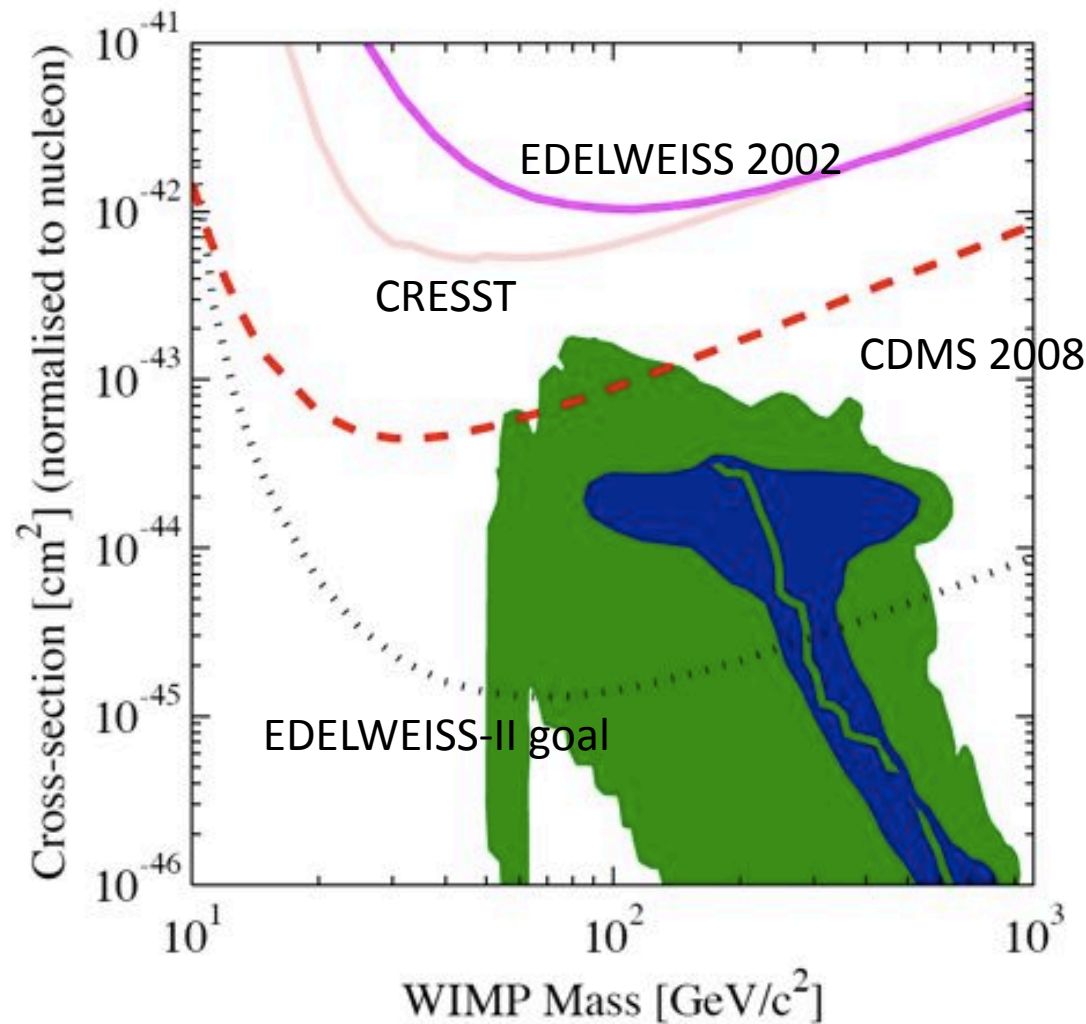
A. Broniatowski et al.

Physics Letters B 681 (2009) 305–309



- Identification of surface interactions (main limitation of Ge detectors)
- Vertical field lines for volume events, horizontal field lines for surface events
- **Extremely clean identification and rejection of surface interactions**

Dark Matter sensitivity EDELWEISS and EURECA

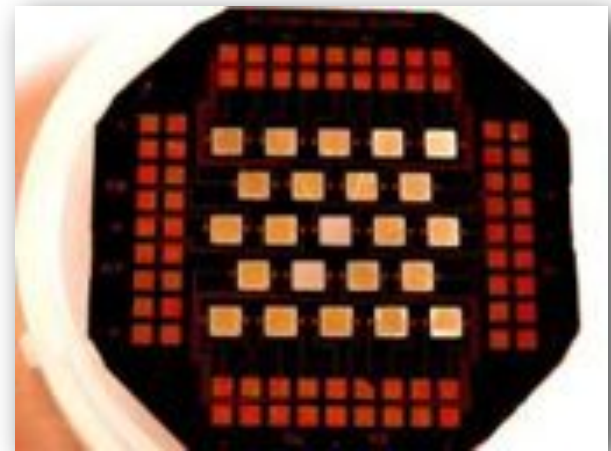
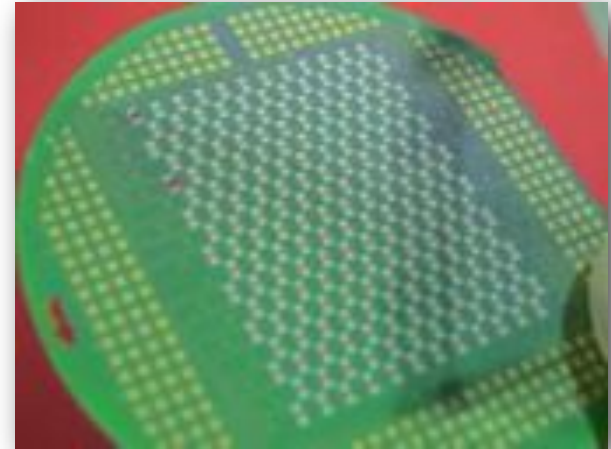


CDMS 2008 =
120 kg.j 0 evts > 10keV
~ 240 kg.j 0 evts > 20keV

Edelweiss-II expected to
Reach sensitivity below
10⁻⁸ picobarn end 2010

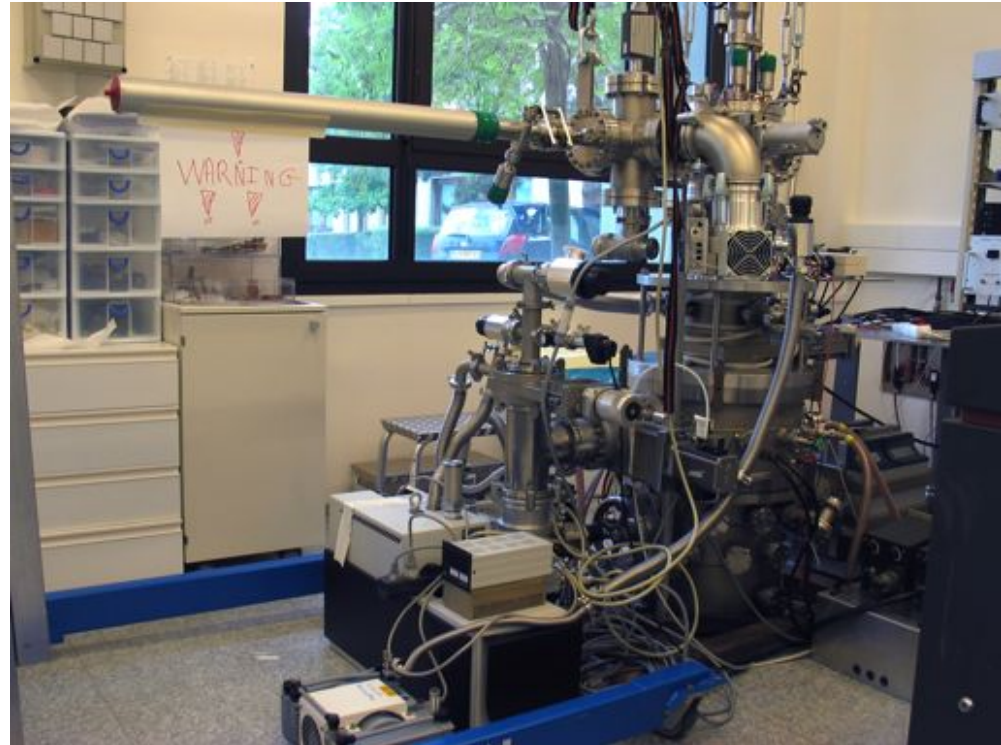
Matrices of microbolometers

- DCMB, first matrices of bolometers
 - CNES funding (French Space Agency)
 - Strong collaboration with Minerve (nanofabrication)
- Scientific objectives
 - Olimpo, BRAIN Dome C
 - CMB polarization
 - Sunyaev Zeldovich (SZ), millimeter waves
- Collaboration with Néel Institute Grenoble, APC Paris, IAS, Minerve, ...

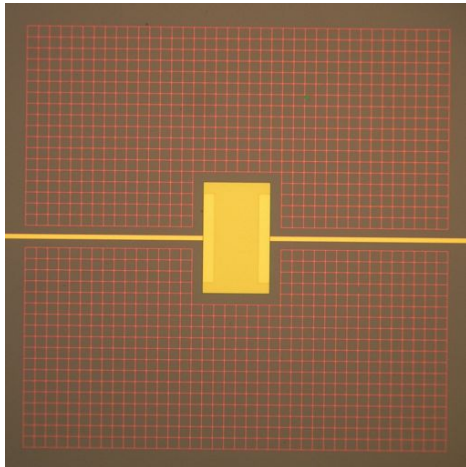


NbSi thin film fabrication

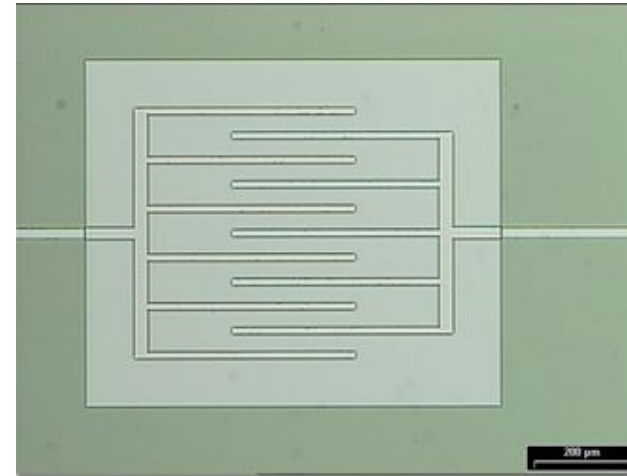
- ❑ Co-evaporation of pure Nb and Si
- ❑ Sample rotation at 3 RPM
- ❑ Evaporation rate 3 \AA s^{-1}
- ❑ Composition reproducibility $< 0.1\%$
- ❑ Sample size :
2 inches – 4 inches
- ❑ Thermal control



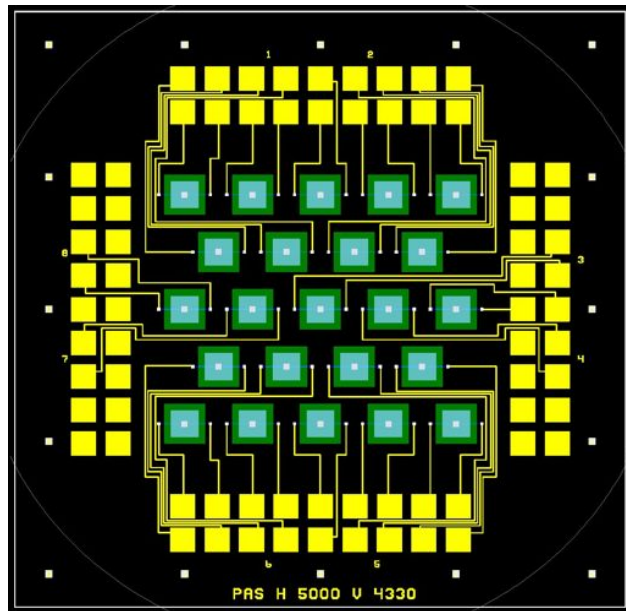
NbSi co-evaporation at CSNSM / Orsay



- High impedance NbSi sensor
(200 μm X 400 μm X 100 nm)
- Grid absorber 2X2 mm² ($Z_C = 377 \Omega$)



TES NbSi sensor
($x = 15\%$, $T_c = 335 \text{ mK}$, $R_n \sim 0.8 \Omega$)



- ❑ Classical architecture on full or structured LS-Si₃N₄ membranes
- ❑ Deep etching process developed at IEF / Orsay or standard wet etching can be used (KOH, TMH)
- ❑ NbSi thermometers :
 - Anderson insulator for Nb < 9%
 - TES for Nb > 12% (adj. T_c 50 mK – 1K)

Conclusions

- CSNSM presents a vast set of interdisciplinary activities
- Assembled around nuclear physics, important activities in:
 - astrophysics
 - solid state physics
 - physics of materials
 - solid state physico-chemistry
 - micrometeorites – planetary origin
 - cryogenic detectors for physics and astrophysics
- Original contributions, mostly instrumental, but also data analysis and modelisation
- Physics using ion beams: JANNuS program, matter structuration under irradiation, novel materials