# Presentation of beneficiaries and partners

RADNEXT Kick Off Meeting – 19-21 May 2021
https://indico.cern.ch/event/983095/
https://indico.cern.ch/event/1029314/

# 2

# Université de Liège – Centre Spatial de Liège

Alain Carapelle

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

# Université de Liège – Centre Spatial de Liège (CSL)

- Space technology research/test center (certification ISO9001 & EN9100)
- Manpower : ~ 100
- CSL is a European Space Agency (ESA) certified test center
- Space radiation activities: composite shielding, Jupiter JUICE mission testing, test according to ESA standards...
- For JUICE mission: facility to test NASA & CNES instruments under $e^-$ (study of induced signals):
  - Adjustable low flux from 0 to 6000 $e^-/cm^2.s$
  - 0 to 3.5 MeV
  - In situ ultra high resolution electron spectrometer
  - Mass spectrometer for residual gas analysis
  - Vacuum and cryogenic environment available
  - … you are welcome at our facility

# Université de Liège – Centre Spatial de Liège (CSL)

Involvement in Radnext

WP 7 Cumulative radiation effects on electronics,

- Task 7.1 Study of TID effect , sub task 1.2: **X-Ray/γ $^{60}$Co dosimetry (FGDOS, Radfet)**
- Task 7.2: Study of TNID effect, sub task 2.1: **TNID test procedure**

**Contact point: Alain CARAPELLE a.carapelle@uliege.be**

# 3

# KU Leuven

Paul Leroux

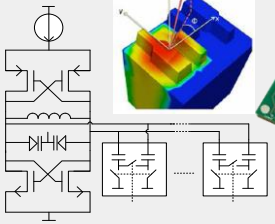
RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

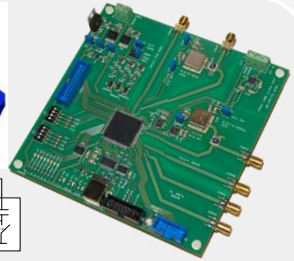
https://indico.cern.ch/event/1029314/

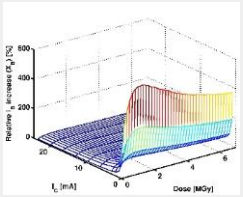

# KU LEUVEN ADVISE research lab

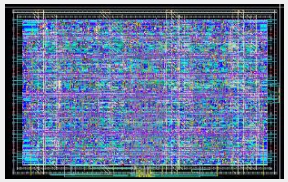

## Expertise: radhard IC design



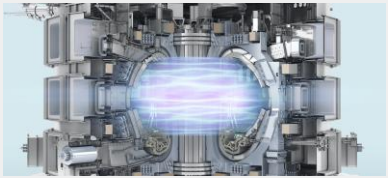






## Typical applications



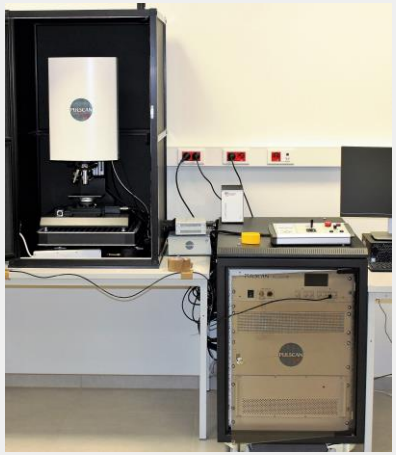
*NA1* - Communication, dissemination, exploitation and training

**Role in RADNEXT**

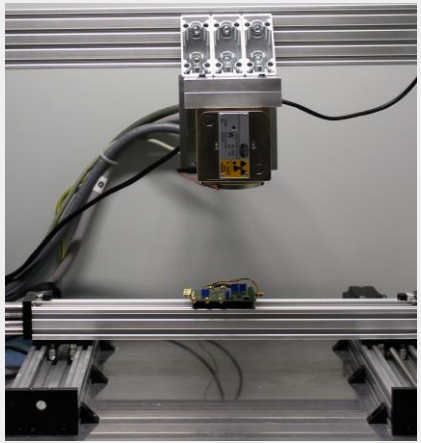
*JRA2* – Remote radiation testing of digital integrated circuits and FPGAs

# Radiation and cryo testing

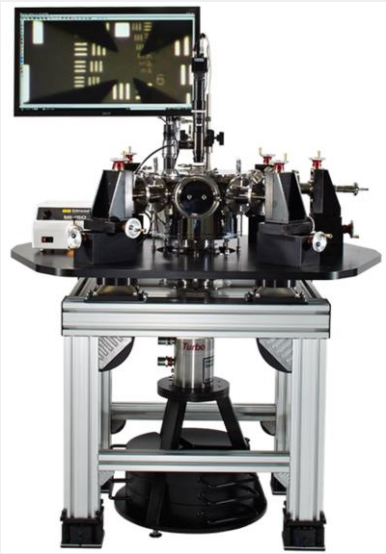
## TPA laser testing



## TID testing: X-ray



## Cryo probe station



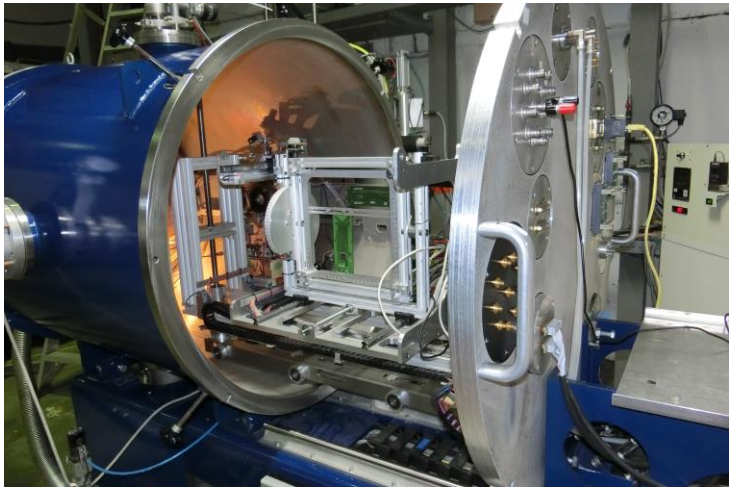
# 4
# Université Catholique de Louvain-la-neuve

Nancy Postiau

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/



UCLouvain

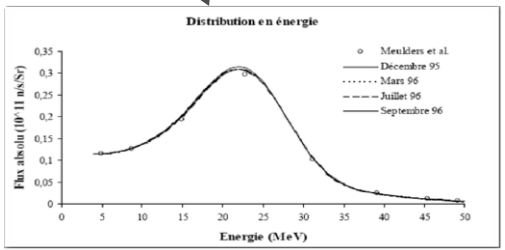
CRC Louvain-la-Neuve Belgium

RADNEXT

# UCLouvain contribution

- Transnational beam time access : **280h over the 4 years project**
- K=110 Cyclotron
- Beam available at UCLouvain
  - Heavy ions cocktail
  - Protons up to 62MeV
  - Neutrons

| Ion | Energy | Range | LET |
|---|---|---|---|
| | [MeV] | [µm] | [MeV/(mg/cm²)] |
| $^{13}C^{4+}$ | 131 | 269,3 | 1,3 |
| $^{22}Ne^{7+}$ | 238 | 202 | 3,3 |
| $^{27}Al^{8+}$ | 250 | 131,2 | 5,7 |
| $^{36}Ar^{11+}$ | 353 | 114,0 | 9,9 |
| $^{53}Cr^{16+}$ | 505 | 105,5 | 16,1 |
| $^{58}Ni^{18+}$ | 582 | 100,5 | 20,4 |
| $^{84}Kr^{25+}$ | 769 | 94,2 | 32,4 |
| $^{103}Rh^{31+}$ | 957 | 87,3 | 46,1 |
| $^{124}Xe^{35+}$ | 995 | 73,1 | 62,5 |



# 6
# Paul Scherrer Institut

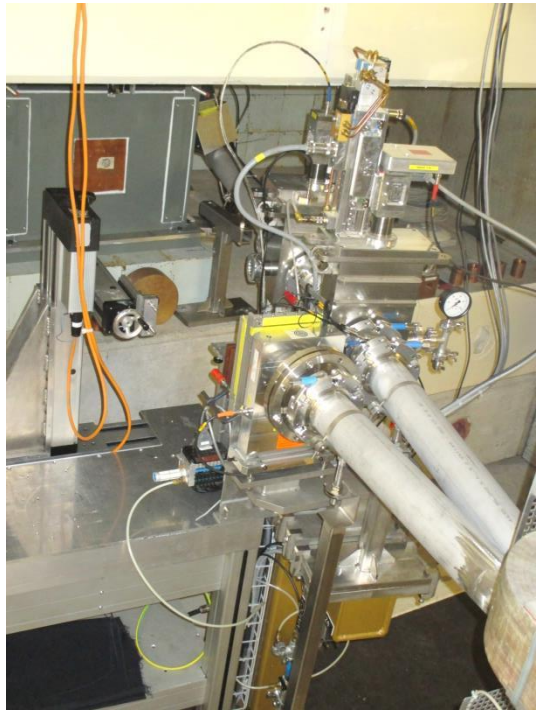
Wojciech Hajdas
RADNEXT Kick Off Meeting – 19-21 May 2021
https://indico.cern.ch/event/983095/
https://indico.cern.ch/event/1029314/


# Proton Irradiation Facility PIF / PSI

- Belongs to PROSCAN accelerator
- Enables studies of radiation effects in electronics
- Used for characterization of detectors and dosimeters
- Provides realistic space environment on-ground
- Offers wide range of energies and intensities

- Application oriented facility
- Flexible, user specific test arrangement
- Fast setup and uncomplicated operation

- Part of PSI large facilities complex:
  protons, neutrons, gammas, pions, electrons ...



# 7
# ELI Beamlines

Roberto Versaci

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

# ELI Beamlines – Inst. of Physics – ASCR

- Scientist-in-Charge: R. Versaci (roberto.versaci@eli-beams.eu)
- Activities: WP4/NA3 (future facilities), WP8/JRA4 (complementary modeling tools)
- New EU funded laser laboratory, going to move to ELI-ERIC
- Both user-facility and in-house research
- ~10 beamlines (at different commissioning levels)
- Divers particle types and energies, including mixed fields
- Core characteristics: short pulses, high dose rates
- Radiation damage to electronics primer at laser facilities
- MC expertise, new in laser facilities

# 8

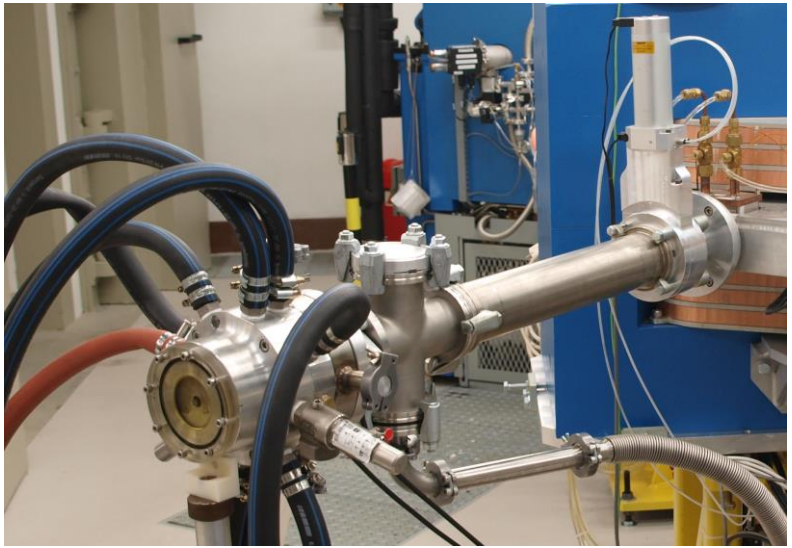
# NPI CAS

Mitja Majerle

RADNEXT Kick Off Meeting – 19-21 May 2021

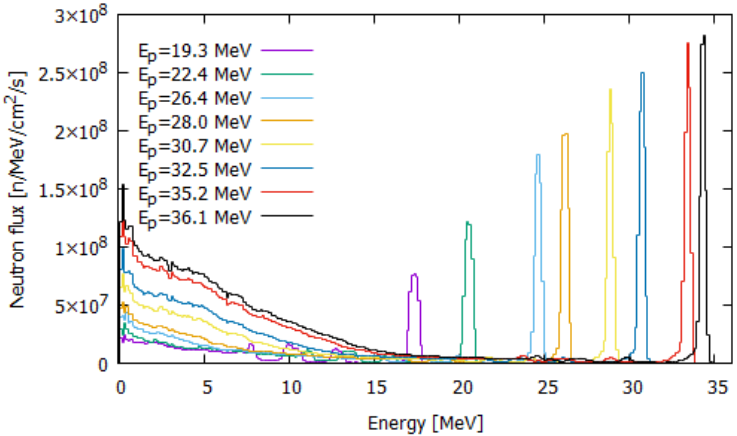
https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

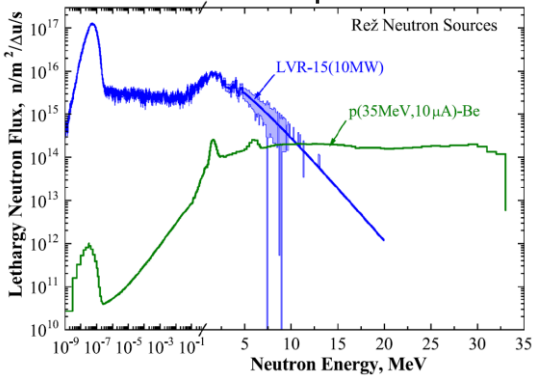


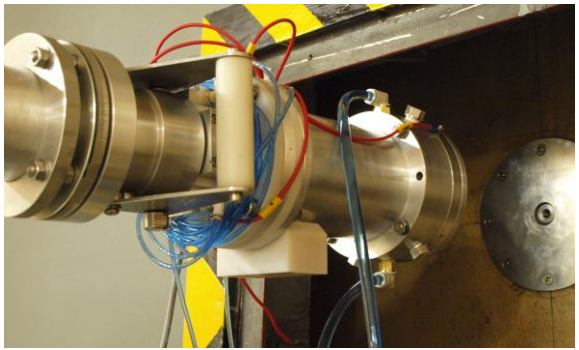
- Continuous neutron spectra: electronic hardness tests, DPA studies, material benchmarks, NAA
- U120M, p(35MeV)+Be(0.5-8mm), $10^{11}$n/cm$^2$/s
- TR24, p(24MeV)+Be(8mm), $10^{12}$n/cm$^2$/s – first tests

QM neutron spectra, p+Li(0.5mm)




p+Be neutron spectrum and reactor spectrum



p+Be(0.5mm) neutron source installed in front of collimator

- Quasi-monoenergetic neutron spectra: neutron cross section measurements
- U120M, p(12-35MeV)+Li(0.5-2mm), $10^9$n/cm$^2$/s
- Proton irradiation, beam size 1-10cm, 1-$10^9$p/cm$^2$/s

# 9

# GSI/FAIR facility

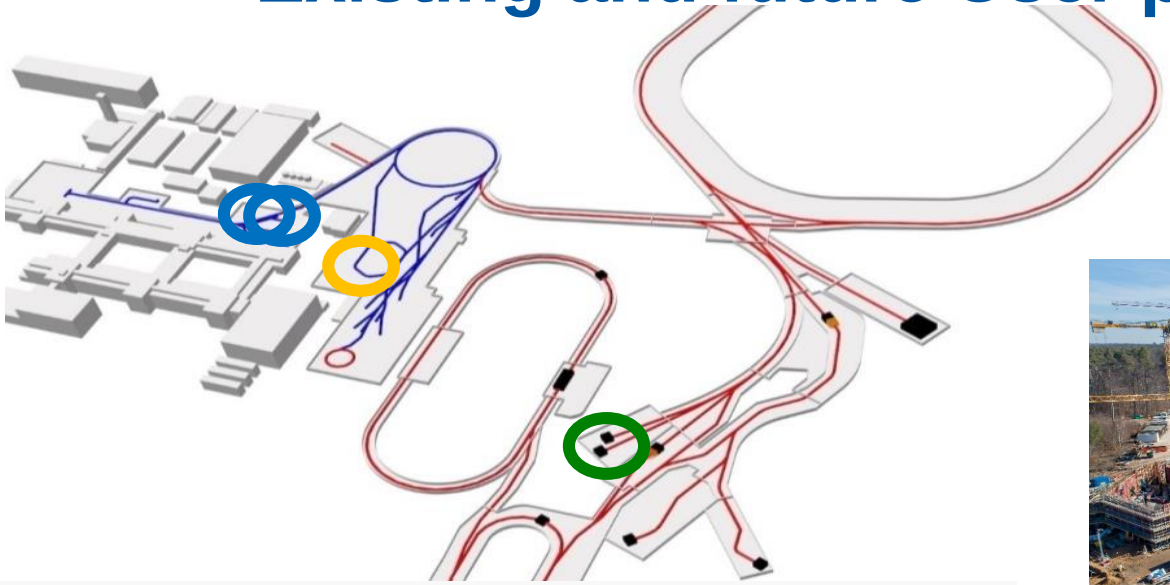
Marco Durante & Christina Trautmann

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

# Existing and future User platform



construction site FAIR, Feb. 2021

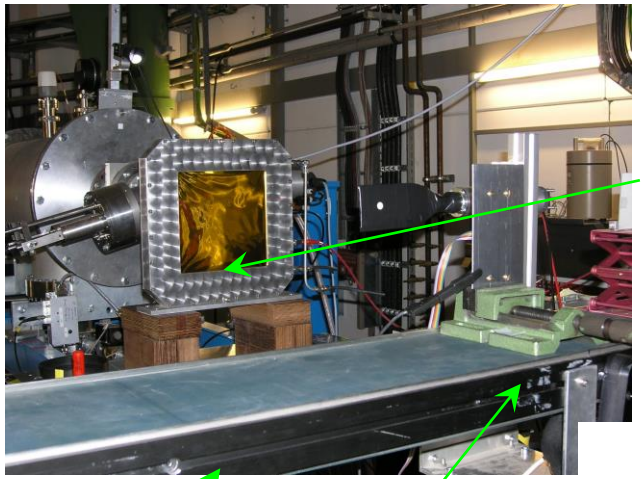
| UNILAC | SIS-18 | SIS-100 |
|---|---|---|
| 3-11 MeV/u | 80-1000 MeV/u | 0.1–10 GeV/u |
| **M-Branch beamline X0 microprobe** | **Cave A GSI high energy cave** | **APPA Cave FAIR high energy cave** |
| | | **beam >2025** |

# Application of the FAIR Facility to Space Radiation Research

# (FAIR-EXPRO)

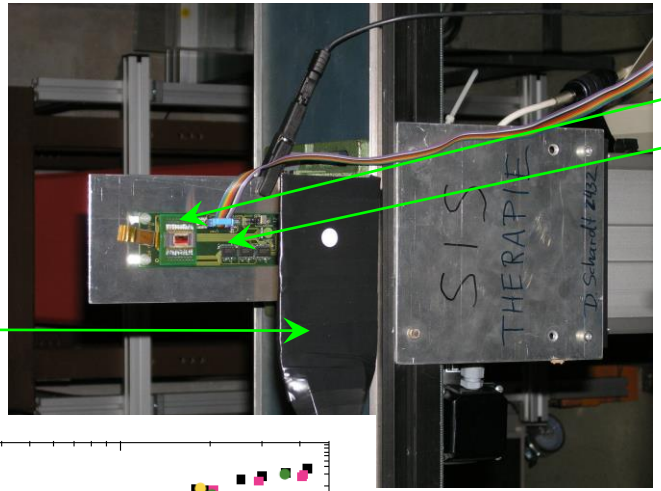
ESA RFP-D/IPL-PTS/MV/2013.723


# High-energy cave (80-1000 MeV/n)



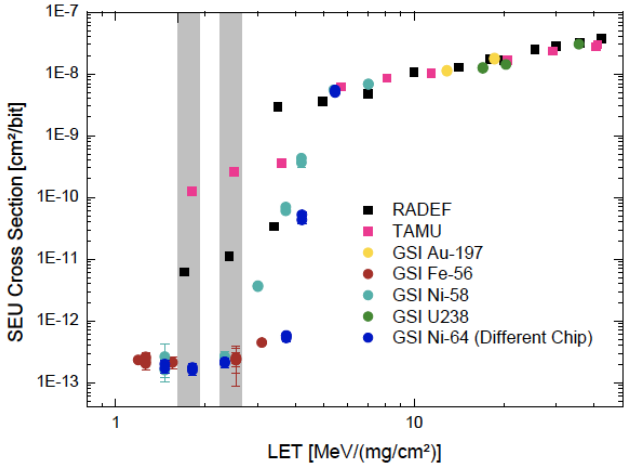
Ion chamber

Scintillation counter




ESA SEU monitor (with motherboard)

Belt conveyor with target holder (bench vice)




Höffgen *et al.*, *IEEE Trans. Nucl. Sci*. 2012

TA= 8 shifts

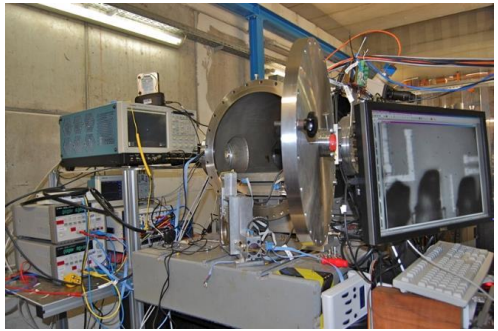
Fraunhofer INT

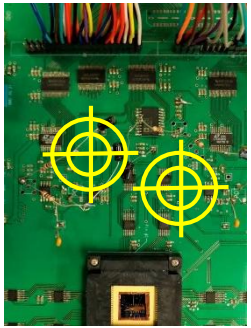
RADNEXT

# Irradiation experiments with swift heavy ions at UNILAC/GSI

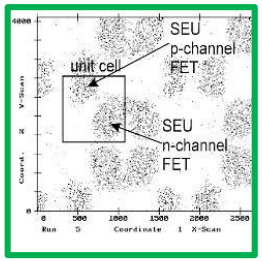
## available UNILAC beams: C - U ions, $E_{max}$ 11.4 MeV/u, range 50-100 µm

### Microprobe: targeting with single ions





- Irradiation in vacuum
- Targeting precision ~ 1µm
- Rate 1000 ions/s
- in-situ testing




### M-branch: irradiation with defocused beam

- area ~ 5 cm x 5 cm
- Fluences $10^4$ – $10^{12}$ i/cm$^2$
- Irradiation in vacuum
- in-situ analysis

TA= 16 shifts

# 10

# HZDR

Anna Ferrari

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

HZDR

HELMHOLTZ ZENTRUM
DRESDEN ROSSENDORF

RADNEXT

# 11

# Fraunhofer INT

Jochen Kuhnhenn

RADNEXT Kick Off Meeting – 19-21 May 2021

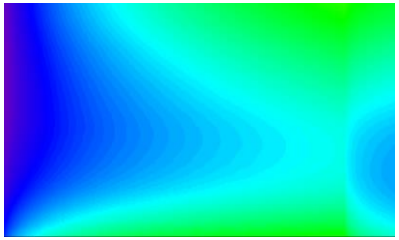
https://indico.cern.ch/event/983095/

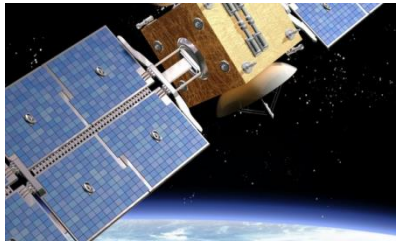
https://indico.cern.ch/event/1029314/


# Fraunhofer INT – Who we are

- Our Mission: Investigation and application of the effects of ionizing radiation on optical and electronic components and systems

| Experimental Investigations | Radiation effects consulting | Operation of irradiation facilities | Simulation of radiation environment |
|---|---|---|---|
| • Planning, execution and analysis of irradiation tests<br>• Characterization of the radiation sensitivity<br>• Extensive measurement equipment for optics and electronics | • Consulting on the execution of standard conform tests<br>• Consulting on the selection of appropriate parts<br>• Consulting on the hardening of components and systems | • Three Co-60 facilities in-house for TID tests<br>• Neutron generator in-house for SEE and displacement tests<br>• Pulsed Laser system for SEE tests | • Radiation transport<br>• Model calculations<br>• Definition of environment<br>• Determination of mission dose<br>• Calculation of shielding |





# Fraunhofer INT – RADNEXT involvement

- Our project involvement:
  - Deputy-WP leader in WP3-NA2
  - Contributor in WP3-NA2, Task 3.1
    WP Coordination and Communication
  - Contributor in WP3-NA2, Task 3.2
    “User Support and Access Requests Management”

- Our facility contribution
  - 60 hours at our 14 MeV Neutron generator

- Our people contribution:
  - Jochen Kuhnhenn and Stefan Höffgen (+ as many as needed)

# 12

# Physikalisch Technische Bundesanstalt

Benjamin Lutz

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/


Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

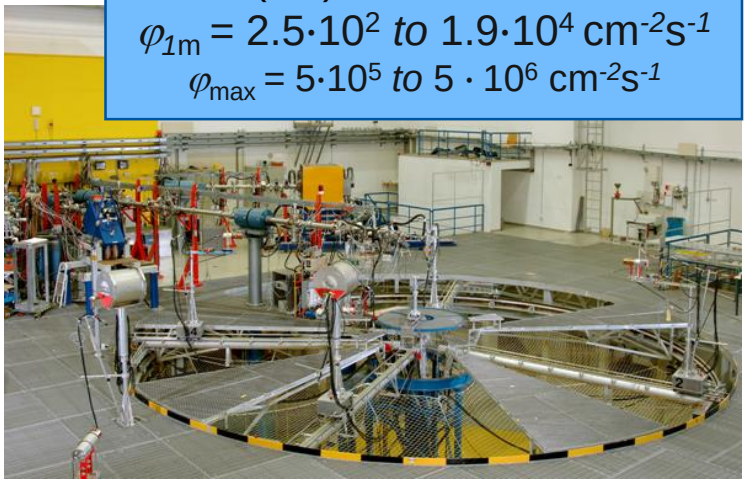
- National Metrology Institute of Germany
- Traceable measurements of neutron radiation
- Neutron reference fields at the:
  **PTB Ion Accelerator Facility (PIAF)**
  - Monoenergetic neutrons
  - Quasi-monoenergetic neutrons (8-14 MeV)
  - Collimated neutron beams with broad energy distribution (white neutrons)
  - Ion microbeam (≈ 3 µm FWHM)
- TA offering: 90h (total) for 3 slots

- TA Contact: Benjamin Lutz
  neutronenmetrologie@ptb.de

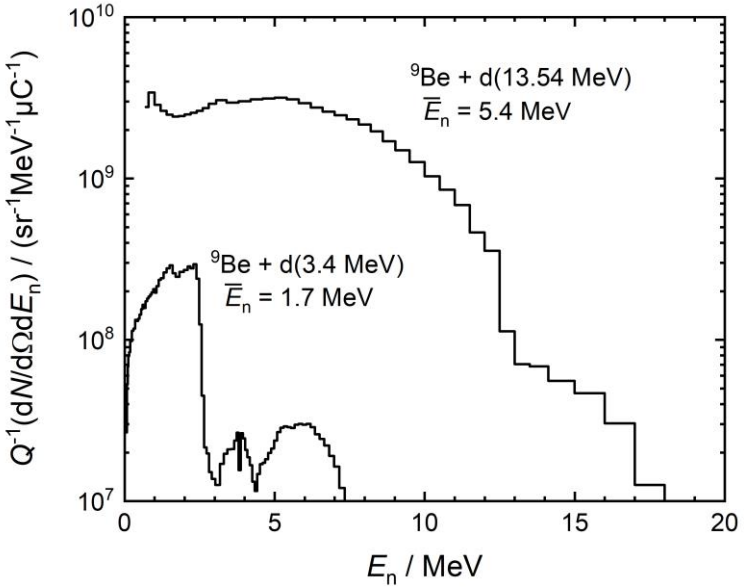
**Monoenergetic Neutrons**

$^{45}$Sc (p,n) $^{45}$Ti : 8, 27 keV
$^{7}$Li (p,n) $^{7}$Be: 0.03 – 0.7 MeV
T (p,n) $^{3}$He: 0.7 – 4 MeV
D (d,n) $^{3}$He: 4 – 15 MeV
T (d,n) $^{4}$He: 14 – 19 MeV

$\varphi_{1m} = 2.5 \cdot 10^{2}$ *to* $1.9 \cdot 10^{4}$ cm$^{-2}$s$^{-1}$
$\varphi_{max} = 5 \cdot 10^{5}$ *to* $5 \cdot 10^{6}$ cm$^{-2}$s$^{-1}$



# PIAF white neutron fields




$\varphi$ < $10^{8}$ cm$^{-2}$s$^{-1}$ @ SUP

**Collimated Neutron Beams with Broad Energy Distributions**

$^{9}$Be + d (13.5 MeV) :< $E_n$ > ≈ 5 MeV
$^{9}$Be + p (19.0 MeV) :< $E_n$ > ≈ 10 MeV

High intensities
Pulsed beams on 30 m flight path

# 13

# Carl von Ossietzky University

Bjorn Poppe

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

CARL VON OSSIETZKY
UNIVERSITÄT
OLDENBURG

RAD NEXT

# Division for Medical Radiation Physics
## Carl von Ossietzky University/Pius-Hospital Oldenburg

Pius-Hospital, Medical Campus University of Oldenburg

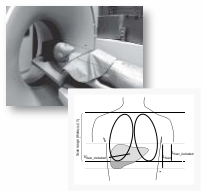
H.K Looe

B. Delfs

B. Poppe

# Radiation/Particle Detection and Transport Calculations

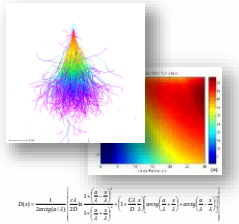
**Radiology**



Dose Optimization and Calculation

**H. von Boetticher**

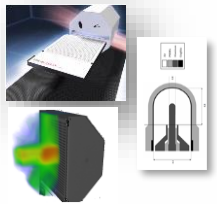
**Modelling**



Monte Carlo and Analytical Methods

**H.K. Looe**

**Radiation Detection**



Detectors, Flux, Dose, Activity, Signal-Theory

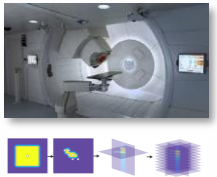
**B. Poppe**

**Space Environment**


Radiation, Small Bodies, Instrumentation

**G. Drolshagen**

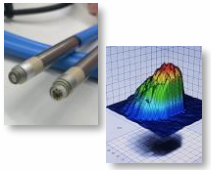
**Particles and Protons**



2D Dosimetry, Non Reference Dosimetry

**B. Poppe + T. Stelljes**

**Extreme Beams**



2D Dosimetry, Non Refererence Dosimetry

**B. Poppe + B. Delfs**

all areas strongly connected

KVSF Kompetenzverbund Strahlenforschung

NAR

Universität Bremen

UberKnife Zentrum Norddeutschland

EURAMET

esa

umcg

university of groningen KVI

CERN

RAD NEXT

UHDpulse

OREGON HEALTH & SCIENCE UNIVERSITY OHSU

- > members app 40: (4 Habil/PI, 4 physicists, 18 Phd students,…)
- > 100 Peer Reviewed papers
- DIN norms, AAPM –TGs, UN-group

PTB Messen ▪ Forschen ▪ Wissen

RADSAGA

RAD NEXT

Tasks in RADNEXT:

# WP05-JRA1 Radiation monitors, dosimeters and beam characterization

- Correlation Matrix (beam data needed for users and facilities)
- “Harmonization“ of beam data reporting
- „Traceable“ Dosimetry (with standard detectors)

**Goal:**
Improve comparability of user measurements at different facilities

# 14

# Centro de Laseres Pulsados

Luca Volpe

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

CLPU

CENTRO DE LÁSERES PULSADOS

RADNEXT

# Laser-driven particle beams Irradiation for space applications

Beneficiary = Centro de Laseres Pulsados (https://www.clpu.es/)

Scientist in charge = Luca Volpe


CLPU
CENTRO DE LÁSERES PULSADOS

RADNEXT

# *The Centro de Laseres Pulsados*

## CLPU is:

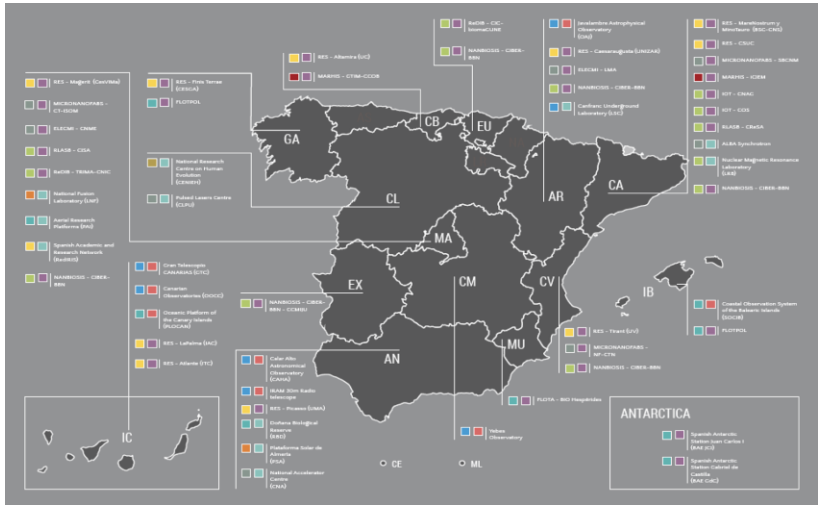
- a user facility opened to national & international users
- a ICTS Technical and Scientific unique Infrastructure
- Radiactive authorized installation IRA-3254

**Funded by:**

50 % Ministry of science and Innovation

45 % region of Castilla y Leon

5 % University of Salamanca




VEGA III

Energy 30 Joules

Power 1 PW

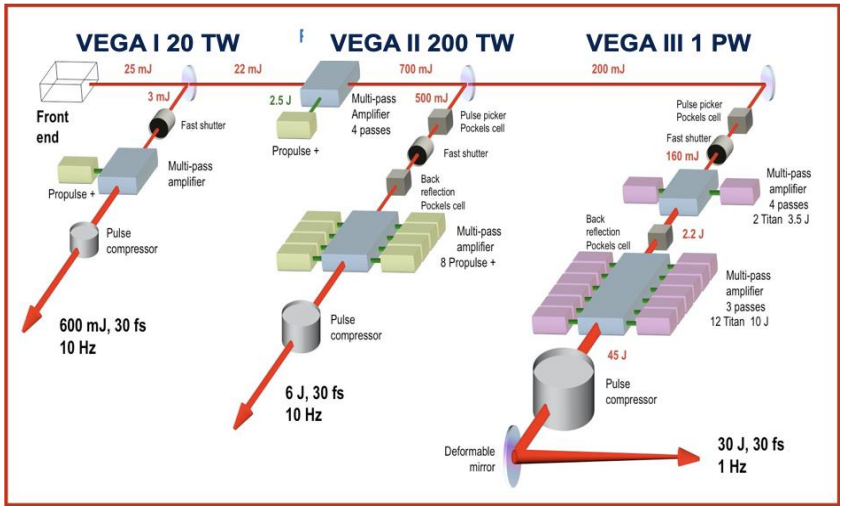
Rep rate 1 Hz

VEGA II

Energy 6 Joules

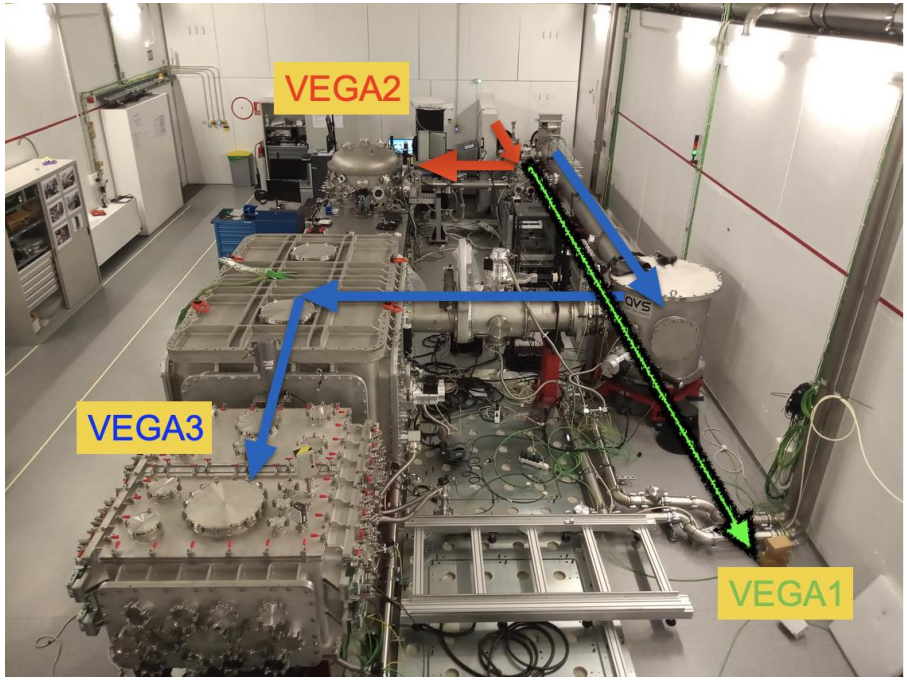
Power 200 TW

Rep rate 10 Hz



# **WP10 (TA 2)** *Proton and heavy ion and alternative beam irradiation*

- **Offered particle beams:**
  - Proton beam
    - Energy 10-20 MeV
    - Charge ~ nC/ps
    - Divergence 0.3-0.4 rad (~ 20˚)
  - Electron beam up to
    - Energy 300-400 MeV
    - Charge ~ pC/fs
      - Divergence 10-20 mrad (~ 1˚)
- **Offered access time**
  - 150 hours
  - Number of projects ~ 3
  - Number of Users ~ 6



# 15

# Universidad Carlos III de Madrid

Luis Entrena

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

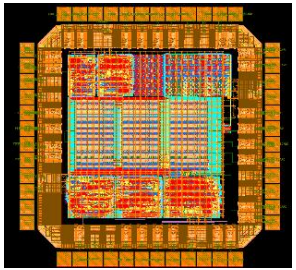
uc3m | Universidad Carlos III de Madrid

RADNEXT

# Universidad Carlos III de Madrid

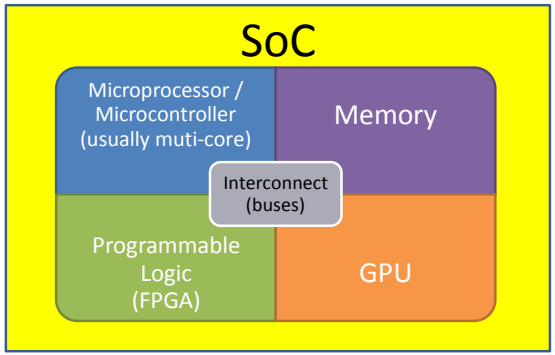
## Microelectronics Design & Applications Group

- Leader: **Luis Entrena**
- Staff: 8 Prof.
- Research lines
  - Microelectronic design: ASIC, FPGA and SoC
  - Radiation effects
  - Radiation hardening and error mitigation
  - Validation and formal verification of error mitigation techniques
  - Hardware acceleration



# UC3M Role in RADNEXT

- WP06/JRA2 co-leader
  - System level radiation qualification methodology
  - Focus on
    - System-on-Chip (SoC)
    - COTS devices
  - Goals
    - Benchmarking
    - Increase observability and diagnosis
    - Compare results with respect to particles/ions, energies, benchmarks, technologies, etc.
    - Remote testing



# 16
# Universidad de Sevilla

Yolanda Morilla

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

Centro Nacional de Aceleradores

UNIVERSIDAD DE SEVILLA

RADNEXT

Centro Nacional de Aceleradores

Public joint center (US/CSIC/JA) placed in Sevilla (Spain)

Spanish ICTS (singular scientific and technological infraestructure)
Interdisciplinary research

RADNEXT beneficiary – Universidad de Sevilla

RADNEXT involvement – Low energy proton facilities

## RADNEXT – WP10-TA2

**Availability for transnational access:**
**200 hours**
**Monday to Friday, maximum 10 hours/day**

**Scientists-in-charge:**
**Yolanda Morilla & Pedro Martín-Holgado**

**3 MV Tandem Pelletron (NEC):**

- $^{1}H^{+}$ ~600 keV to 6 MeV (FWHM 0.2 - 0.03 %)
- Energy steps in tens of keV available  Flux range: ~ $10^{3}$ to ~ $10^{12}$ p/cm$^{2}$s
- H [LET(Si) ~0.2 - 0.05 MeV-cm$^{2}$/mg / Range ~7-300 microns]
- Spot beam size (usually focused on 1cm$^{2}$)
- Maximum uniform irradiated área (scanning systems):16x20 cm$^{2}$
- Vacuum system (P ~ $10^{-6}$ mbar)
- Manual tilt available
- Several opto-electrical feedthroughs

**Compact 18/9 Cyclotron (IBA):**

- $^{1}H^{+}$ 18 MeV (FWHM 1 – 3 %); $^{1}H^{+}$ 16 - 10 MeV (by using degraders)
- H [LET(Si) ~0.02 - 0.04 MeV-cm$^{2}$/mg / Range ~700-2000 microns]
- External beam line. (Possibility to couple vacuum chamber)
- Maximum achievable uniform irradiated area at 10 MeV (Ø 3.5 cm)

**Others available beams:**

- LE Heavy ions and neutrons
- Co-60 Gamma irradiation system (RadLab)

# 17
# RADiation Effects Facility, RADEF, Jyväskylä

Heikki Kettunen

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/


# RADEF offers 80 h of beam time/year

- **Heavy ion beams**

  Old cocktail (14 GHz ion source since 2005)

  9.3 MeV/n: N, Ne, Ar, Fe, Kr, Xe

  New cocktails (18 GHz HIISI ion source since 2019)

  10 MeV/n: Ar, Kr, Au

  16.3 MeV/n: O, Ne, Ar, Fe, Kr, Xe

  22 MeV/n: O, Fe, Kr

- **Proton beams**

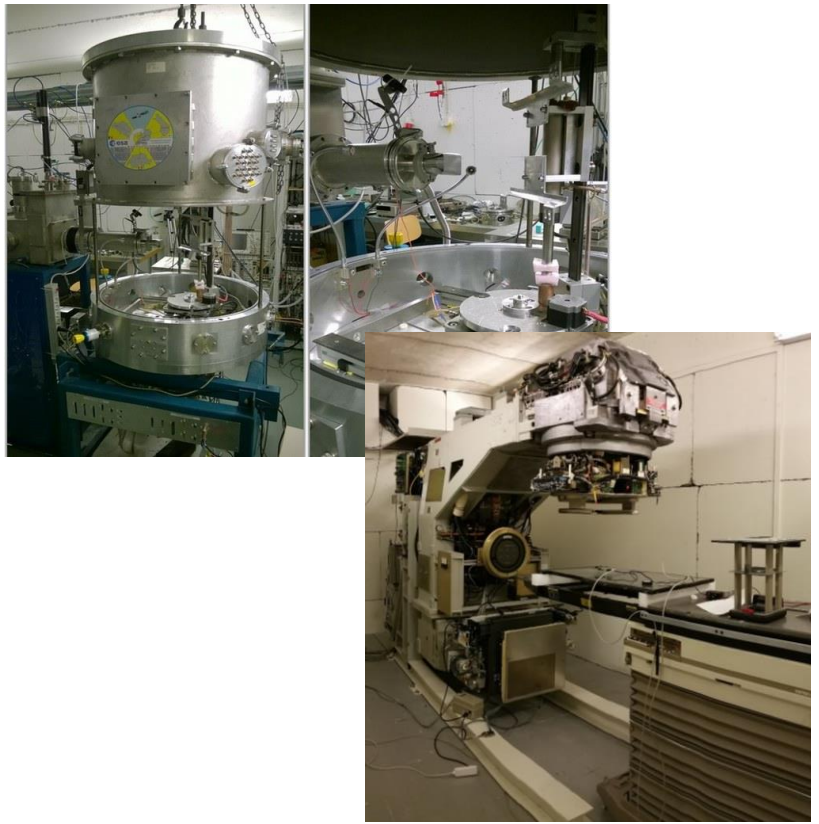
  Proton beams up to 55 MeV

  Low energy proton beams down to 0.5 MeV

- **Photon and Electron beams**

  Electrons: 6, 9, 12, 16, 20 MeV

  Photons: 6 and 15 MV Bremsstrahlung radiation



Contact person: heikki.i.kettunen@jyu.fi

https://www.jyu.fi/accelerator/radef

# 18

# CNES: Centre National d'Etudes Spatiales


Françoise Bezerra – Radiation Expert
Julien Mekki – Head of the Environment & New Devices Office
RADNEXT Kick Off Meeting – 19-21 May 2021
https://indico.cern.ch/event/983095/
https://indico.cern.ch/event/1029314/

cnes

RAD NEXT

## Description of the participant

CNES, Centre National d'Etudes Spatiales, the French space agency

5 major spheres of intervention:

ARIANE – SCIENCES – OBSERVATION – TELECOMMUNICATIONS - DEFENCE

Widely involved in the definition/realization/use of radiation tests on electronic devices.

Continuously manages activities in a view of improving test methods and facilities in partnership with other agencies (e.g. ESA), space industry and/or facilities.

## Role in the project

**WP2 (NA1)** Communication, Dissemination, Exploitation and Training:
*CNES will support the network activity related to training and link to industry.*

**WP10 (TA2)** Proton, heavy ion and alternative beams and irradiation :
*CNES is WP leader - coordination of access for the users to selected facilities.*

# 19

# CNRS - LPSC

Annick Billebaud

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

# The GENESIS facility at CNRS/LPSC, Grenoble, FR

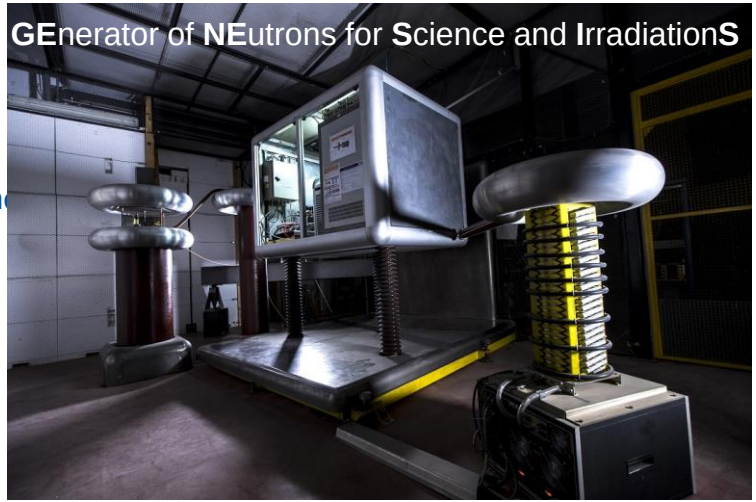
***(A. Billebaud, LPSC)***

- **LPSC** (Laboratory of Subatomic Physics and Cosmology) is a lab from IN2P3 of CNRS
- **GENESIS** is one of the **IN2P3 technological platforms:** it is an accelerator based **fast neutron source**
- The accelerator: **GENEPI2**: 220 keV deuterons onto a T or D solid target *(originally designed for reactor physics and ADS exp. !)*
- Since 2016: ECR source: DC beam only
- Provides 15.2 or 3.1 MeV neutrons (@0°)

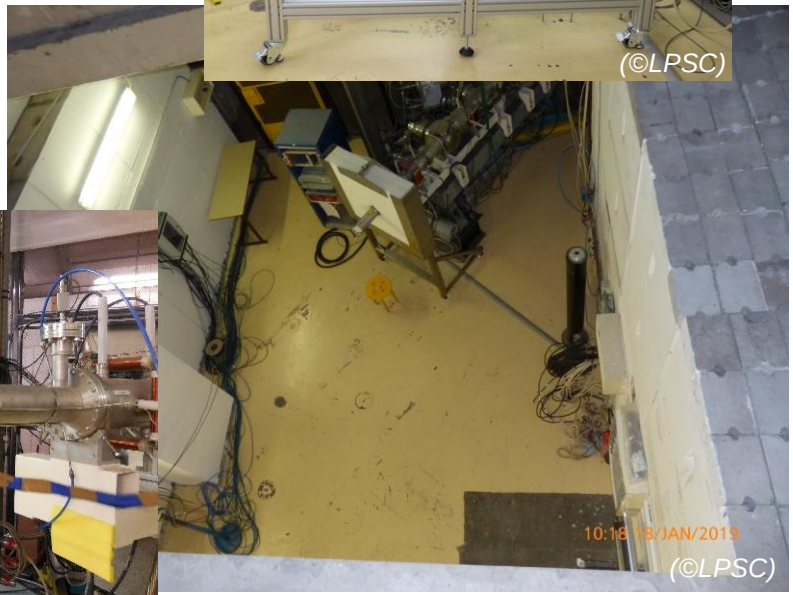
| <Energy> | Max. beam current | Absolute intensity | **Max Flux (at 1 cm)** |
|---|---|---|---|
| 14.2 MeV | 150 µA ±2% | $8\times10^{9}$ n.s$^{-1}$ | **$5.10^{7}$ n.cm$^{-2}$.s$^{-1}$** |

- **RADNEXT TNA:** 100 hours/year (~3 weeks, i.e. a week/quarter except Summ

- **The GENESIS team**
  - **Operational manager:** B. Cheymol
  - **Scientific coordinator:** A. Billebaud => RADNEXT contact
  - **Team and operators:** M. Baylac, T. Cabanel, A. Curtet, E. Labussière, S. Rey
- **Contact:** GENESIS@lpsc.in2p3.fr
- **Web:** http://lpsc.in2p3.fr/GENESIS



- **For users**
  - **X-Y table, with remote control**
  - Irradiation Dosimetry monitoring provided (~15%)
  - Users area in the accelerator control room (new !)
  - Cables for experiments : (bunker ➔ control room): 20 BNC, 15 SHV, 5 Ethernet
  - Network plugs in users area
  - On request help for mounting or installation of experiments can be studied and provided
- **Current users:**
  - Academic (~20%)
  - Industry (~80%)
- **Mainly for microelectronics**
  - SEE studies
  - Component tests


# 20

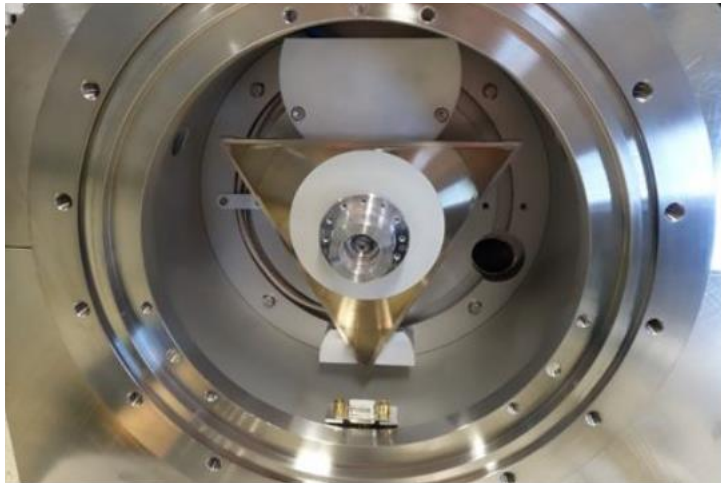
# ESRF

Ennio Capria

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/



ESRF

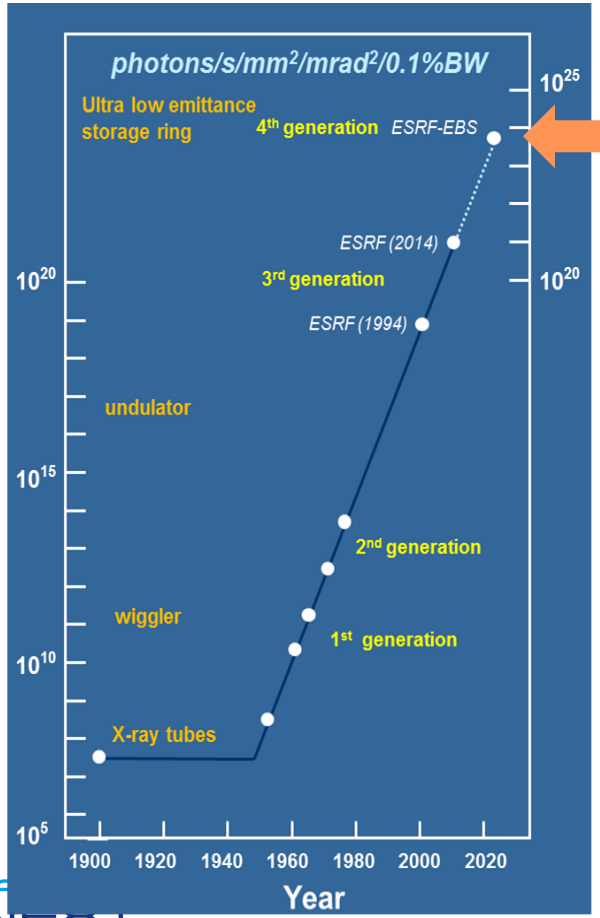
The European Synchrotron

RADNEXT

# An international cooperation

| 13 Member states: | Contribution to the budget in % |
|---|---|
| France | 27.5 % |
| Germany | 24 % |
| Italy | 13.2 % |
| United Kingdom | 10.5 % |
| Russia | 6 % |
| Benesync (Belgium, The Netherlands) | 5.8 % |
| Nordsync (Denmark, Finland, Norway, Sweden) | 5 % |
| Spain | 4 % |
| Switzerland | 4 % |
| **9 Associate countries:** | |
| Israel | 1.75 % |
| Austria | 1.75 % |
| Centralsync (Czech Republic, Hungary, Slovakia) | 1.05 % |
| Poland | 1 % |
| Portugal | 1 % |
| India | 0.66 % |
| South Africa | 0.3 % |

# The ESRF, the first 4th generation synchrotron in the world

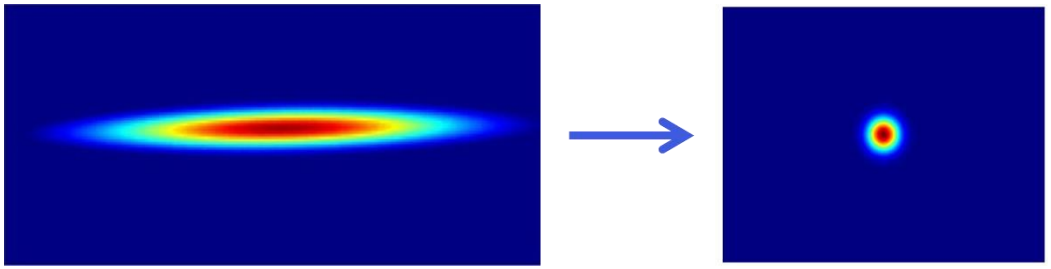



ESRF-EBS
EXTREMELY BRILLIANT SOURCE

**Hybrid 7 Bend Achromat lattice**

P. Raimondi et al.

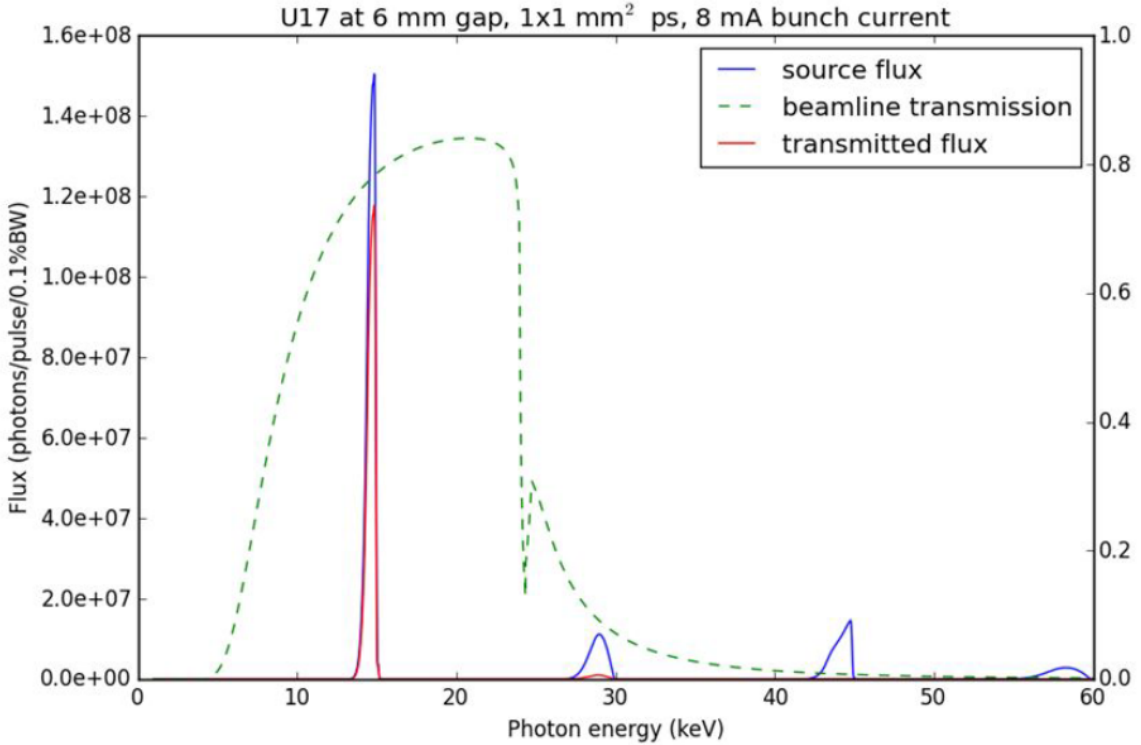
**4nm.rad** **100pm.rad**



Ultra low emittance high energy storage ring

**100x Brilliance**

# Focused X-ray pulses on ID09




PINK BEAM: 15-20keV
Brilliance $1.8 \times 10^{22}$ ph/s/0.1%bw/mm$^2$/mrad$^2$

Beam spot size: 30um
$1.2 \times 10^{11}$ ph/pulse
<150ps pulse duration
The energy of the pulse is 300 uJ

**Emulation of Heavy Ions effects with a much higher penetration depth**

# 24

# ISAE Supaero

Vincent Goiffon

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

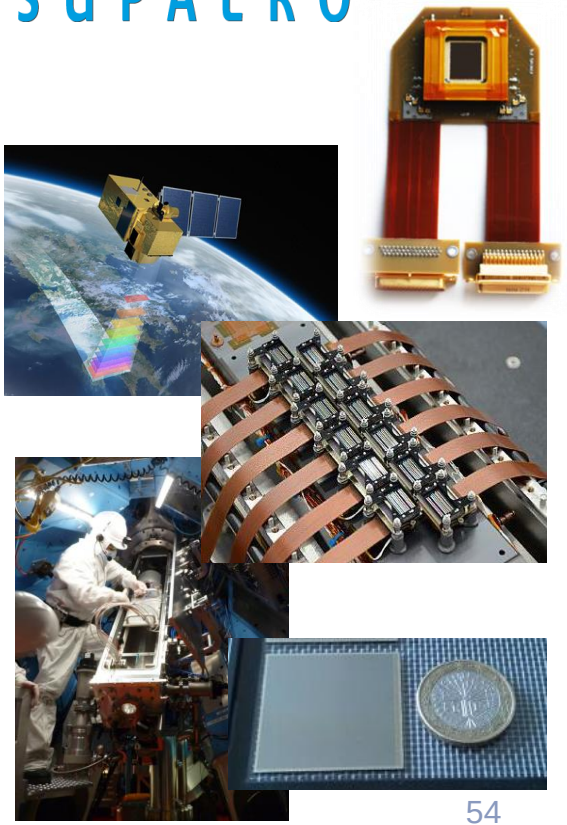
https://indico.cern.ch/event/1029314/


# ISAE-SUPAERO Presentation

- Public Institute dedicated to **Aerospace Higher Education Programs and Research** *(part of the University of Toulouse)*

- **The Institute:**
  - ≈ 1700 students on campus (graduate and post graduate)
  - Staff ≈ 400 persons including ≈ 130 researchers

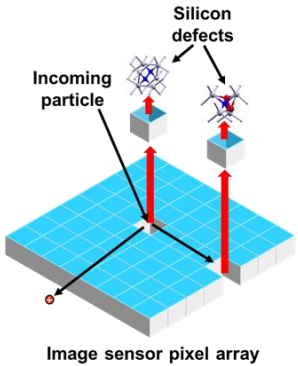
- **The Image Sensor Research Group**
  - Permanent staff = **10 persons** (5 Professors/Researchers)
  - PhD students and Research Fellows ≈ 10 persons
  - Developing/Studying/Modelling **CMOS Image Sensors** for Space, Nuclear, Military & Scientific applications for 25+yrs



# ISAE-SUPAERO Presentation

- **On-Site Facilities**
  - CMOS IC **CAD workstations**
    - From Material/Technology Simulation to Analog/Digital IC design and simulation
  - Test and Measurement **Clean Rooms**
  - **Image Sensor Test Benches**
  - Semiconductor Device, Defect and Integrated Circuit **Characterization Equipment**
  - 320 kV high dose rate **X-ray Irradiator**


- **Role in RADNEXT**
  - Co-Leader of WP7
    - **Cumulative radiation effects on electronics**
  - In Charge of the **TNID** subtask
  - Lead Scientist: Prof. Vincent Goiffon




# 5
# TRIUMF

Camille Bélanger-Champagne, Ewart Blackmore,
Cornelia Hoehr, Mike Trinczek

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/


TRIUMF

# Canada's Particle Accelerator Centre

400 staff
200 students & post-doctoral researchers

1100 scientific visitors from 39 countries per year


Discovery, accelerated

RAD NEXT

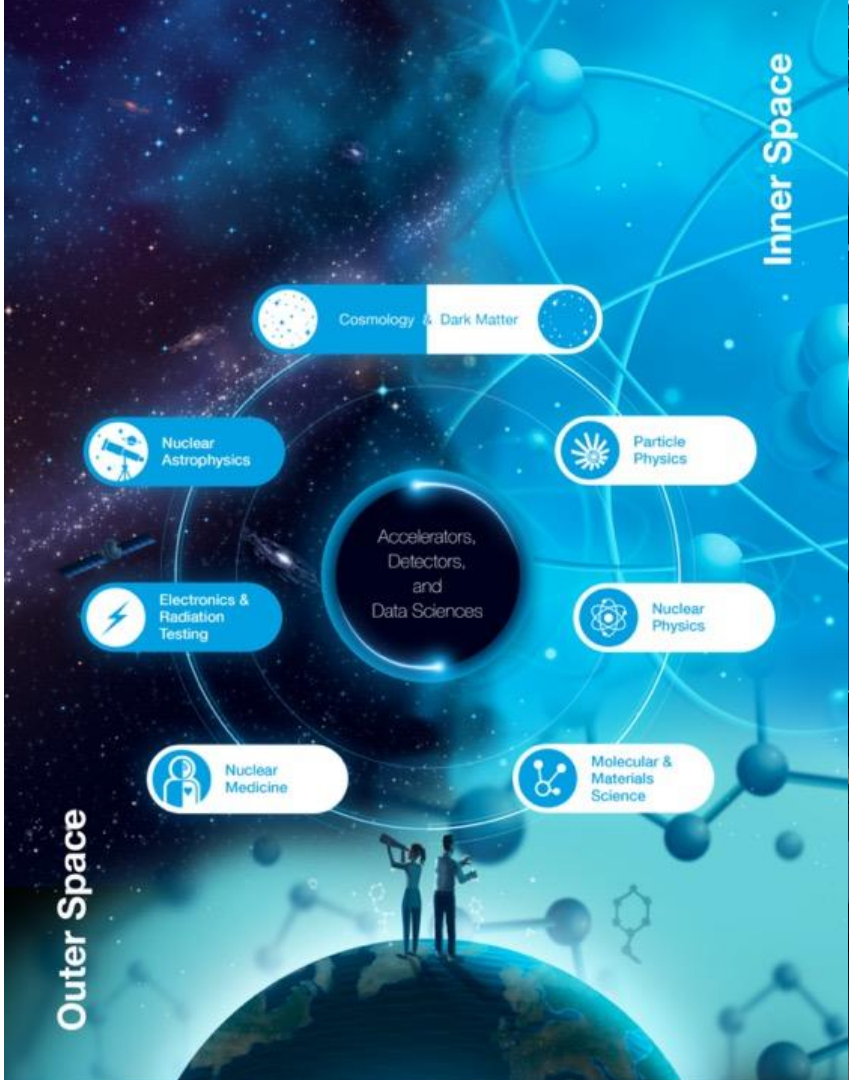
TRIUMF

**TRIUMF develops, builds and operates**

- particle accelerator systems,
- detector systems,
- data science systems

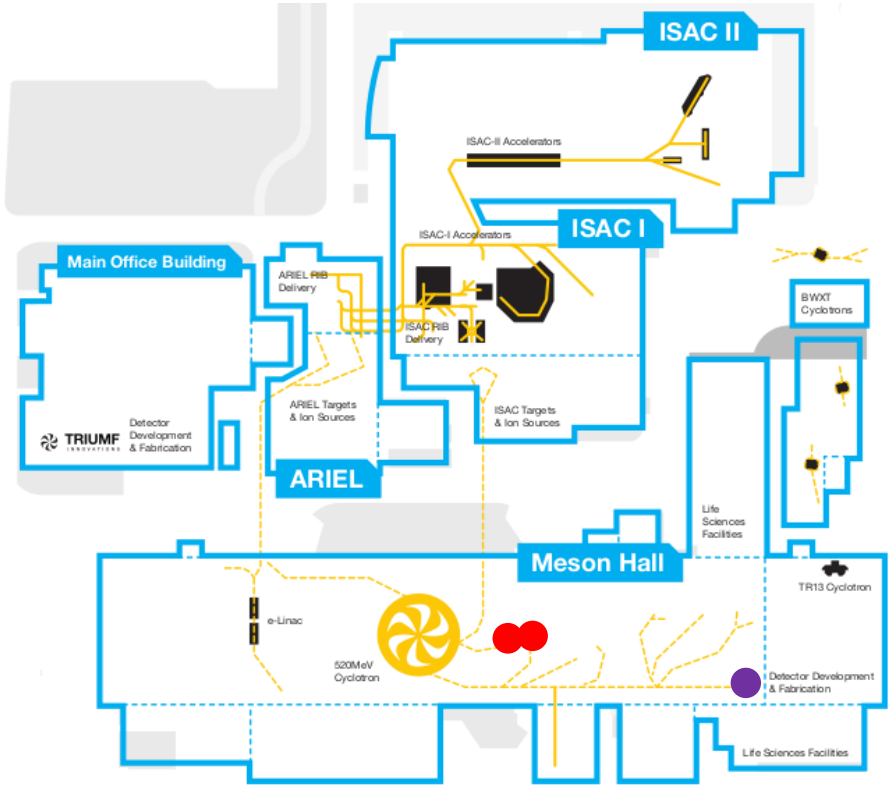
**for research in the fields of**

- nuclear physics,
- particle physics,
- nuclear astrophysics,
- nuclear medicine,
- molecular and material sciences,
- electronics radiation testing,
- cosmology & dark matter.



# PIF & NIF: proton and neutron irradiation facilities

- Main cyclotron: $H^-$ operation, typically 3 simultaneous beams
- Extracted beam energies: 63-480 MeV
- RADNEXT transnational access facility:
  - 92 hours of atmospheric-spectrum-like neutron beam
  - 120 hours of 480 MeV proton beam
  - Contacts:
    - C. B.-Champagne (cbchampagne@triumf.ca)
    - M. Trinczek (trinczek@triumf.ca)
- Co-leader: WP05 Radiation monitors, dosimeters and beam characterization
  - Contact:
    - C. Hoehr (choehr@triumf.ca)




● Proton or neutron beam

● Neutron beam

# 1

# CERN

Rubén Garcìa Alìa

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/


# 21
# GANIL

Xavier Ledoux - Marie-Helene Moscatello

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

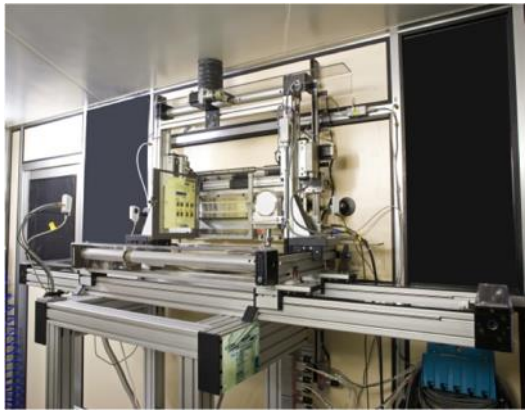
# GANIL – Heavy ions

**GANIL ION BEAM MAINLY USED FOR RADIATION TESTS**

| Ion | Energy (MeV/u) | LET Min (MeV.cm²/mg) | Range (µm) | LET max (MeV.cm²/m) | Range (µm) |
|---|---|---|---|---|---|
| $^{36}$Ar | 27 | 5,4 | 445 | 9,9 | 113 |
| $^{86}$Kr | 60 | 11,0 | 1223 | 42,1 | 27 |
| $^{129}$Xe | 50 | 26,5 | 685 | 64,3 | 35 |
| $^{208}$Pb | 29 | 72,7 | 258 | 97,6 | 64 |

Opened mobile frame

Closed mobile frame



Standard sample holder

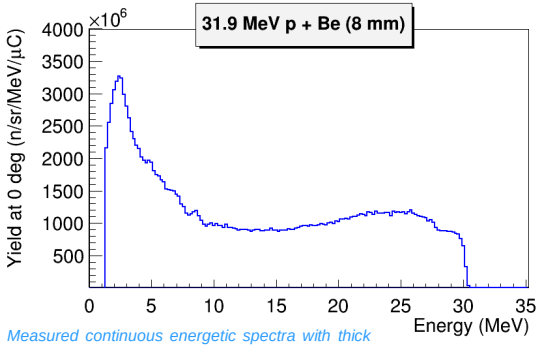
Precise alignement with laser
Various degraders for beam LET tuning

**Irradiation in air**
**Ion Flux from 10 p/s/cm² to 2.10⁴ p/s/cm²**

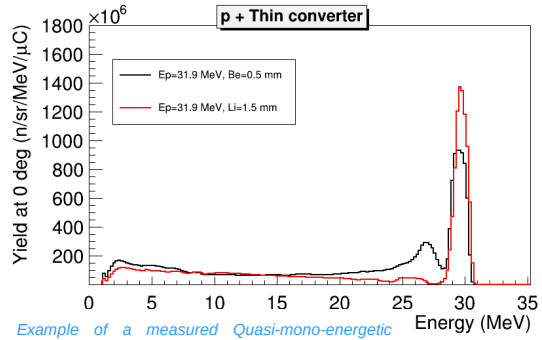
Many other possibilities for beams and set-ups (several caves available) – to be discussed for each experiment

- Scientific Coordinator: Marie-Hélène MOSCATELLO moscatello@ganil.fr
- **158 hours available for experiments with heavy ion beams**

# GANIL – NFS – neutrons (and lights ions)




*Measured continuous energetic spectra with thick Be converter and proton beam*



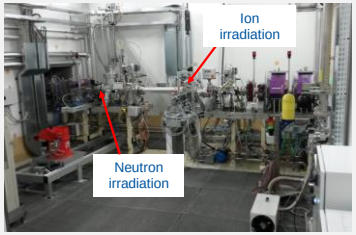

*Example of a measured Quasi-mono-energetic spectra with thin Be or Li converter and proton beam*

**White neutron beams (up to 40 MeV)**

**Quasi-monoenergetic neutron beams from 1 to 31 MeV**

**Converter room :**
- neutron production
- irradiation capability

(neutrons and ions)




**Time-of-flight hall :**
- collimated neutron beam
- pulsed beam for time-of-flight measurements


**Ion Beams in NFS for industrial applications and radiation tests**

| Ion | Energy (MeV/u) | Intensity µA |
|---|---|---|
| p | 33 | 50 |
| d | 20 | 50 |
| Ions up to $^{58}$Ni, $^{78}$Kr | 14,5 | tens |

- Scientific Coordinator : Xavier LEDOUX xavier.ledoux@ganil.fr
- **90 hours available for experiments with neutron beams**

***Participation to WP05 Task 5.3.3 Characterization of neutron fields***

# 22

# Institue Laue Langevin

Manon Létiche, Caroline Boudou

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

NEUTRONS FOR SOCIETY

NANOELEC.

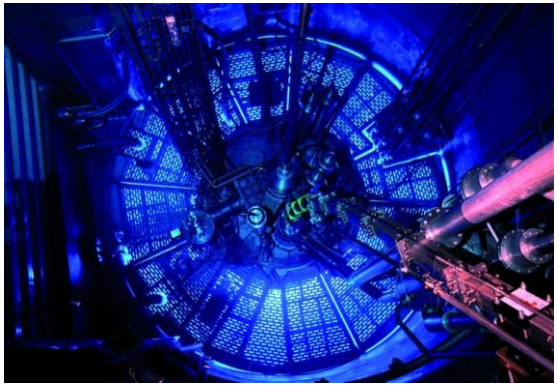
RADNEXT

# The ILL in key numbers

- Founded in 1967, the ILL is a research structure operating the powerful high flux reactor in the world (58 MW) to provide neutrons for research.
- Budget 2019: 101 M€ (France 25%, Germany 25%, United Kingdom 25%, other countries 25%), 523 employees.
- More than 150 scientific experts and 30 instruments for academic users and industries.
- Around 850 experiments are performed and 1200 scientist visitors per year.


- ✓ Material and engineering
- ✓ Biology and health
- ✓ Chemistry
- ✓ Crystallography
- ✓ Liquids and glasses
- ✓ Magnetism
- ✓ Soft matter
- ✓ Particle and nuclear Physics

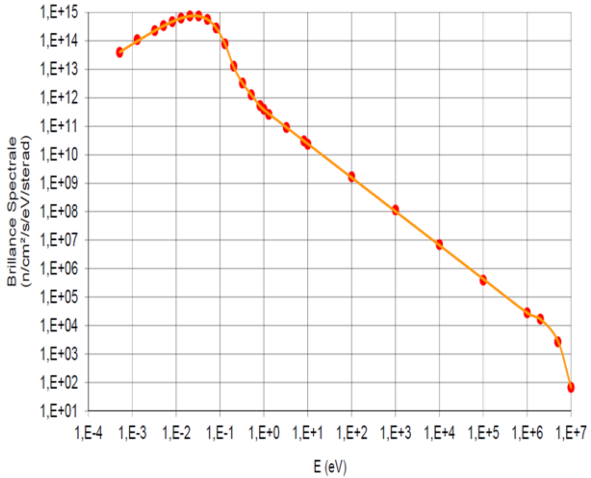
+ production of radio-isotopes



# The role of the ILL in RADNEXT

- Role: Provide **thermal neutron**
- Facility: **T**hermal and **E**pithermal **N**eutron **I**rradiation **S**tation (**TENIS**)
- Scientist in charge: Manon Létiche
- Contact address: letiche@ill.eu or industry@ill.eu
- Characteristics:
  - Fission spectrum
  - Captured flux: 2,86x10$^{9}$ n/cm$^{2}$/s (thermal + epithermal neutrons)
  - Square beam of 50x50 mm$^{2}$
  - (x,y) motorized mechanical translation for sample alignment
- Access mode : 100h through **TransNational Access**
- Reactor cycles:
  - 2021: 24/08 – 13/10
  - 2022: long shutdown a restart is foreseen in December

Beam spectrum



# 23
# IROC Technology SA

Dan Alexandrescu
RADNEXT Kick Off Meeting – 19-21 May 2021
https://indico.cern.ch/event/983095/
https://indico.cern.ch/event/1029314/

# Partner #23: IROC Technologies SA (IROC)

- French SME, located in Grenoble, founded in 2020 as a spinoff of CNRS
- Provide solutions for Reliability and Functional Safety Management
- Strong experience on Single Events in microelectronics
- Recognized SEE solutions supplier for TSMC (OIP), Samsung (SAFE), GlobalFoundries and many other foundries, component providers and system integrators in aerospace, automotive, networking, HPC and medical

- Contribution to RADNEXT:
  - Industrial qualification of irradiation facilities (all types, all effects - SEE & TID)
    - through use of advanced test devices
  - Corelation of simulation and experimental results
  - Board and system-level testing; radiation as a fault injection mechanism

# 25

# Université Jean Monnet

Sylvain Girard

RADNEXT Kick Off Meeting – 19-21 May 2021

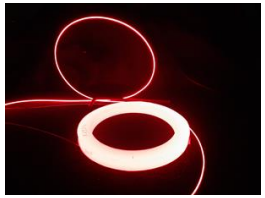
https://indico.cern.ch/event/983095/

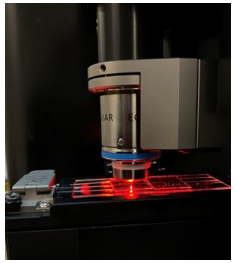
https://indico.cern.ch/event/1029314/


# Université Jean Monnet Saint-Etienne (UJM)

- UJM (MOPERE team of LabHC, 5 permanent researchers) will lead WP05-JRA1, participate in WP07-JRA3
- Scientist in charge: Sylvain Girard, sylvain.girard@univ-st-etienne.fr

- MOPERE main expertise concerns the **radiation vulnerability and radiation hardening studies of photonic & optoelectronic technologies**
  - Bulk glasses, Sol-Gel Materials, Optical fibers and Fiber Sensing
  - Optical and Illumination Systems for rad-hard cameras
  - Point and Distributed fiber-based dosimeters





- MOPERE main tools: **2 X-ray machines** (160kV, 220kV) with T control (-100°C to 400°C), multiple femtosecond laser platforms, spectroscopic tools, fiber-related interrogators and systems.

- Coordinator of RADMEP EMJMD (with JYU, KUL and UM): https://master-radmep.org/
- Member of PHOTON HUB project: https://www.photonhub.eu/

# 26

# Université de Montpellier

Frédéric Saigné

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

# Université de Montpellier

## Radiation effects on devices and circuits

2 laboratories involved : (5 researchers, 1 technician)



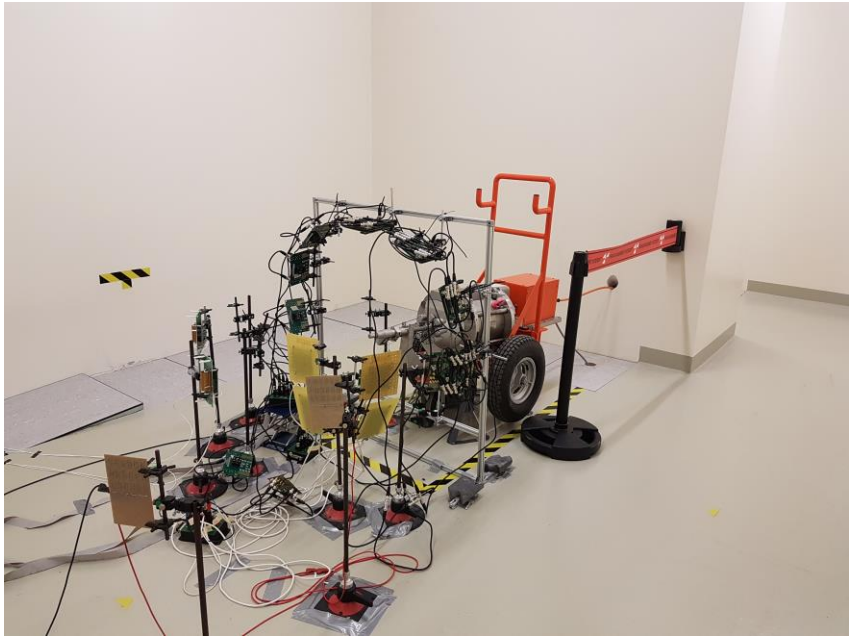
WP leaders :

- WP6 (JRA2) Luigi Dilillo “ Standardization of system level radiation qualification methodology “
- WP7 (JRA3) Jérome Boch ” Cumulative radiation effects on electronics ”
- WP8 (JRA4) Frédéric Wrobel ” Complementary modelling tools ”

Participation to WP5 (JRA1) ” Radiation monitors, dosimeters and beam characterization”

Co-WP leader : WP1 Frédéric Saigné « Project Management »

# Université de Montpellier



Co60 source


X-Rays 320 eV

*Image Source: PRESERVE platform Université de Montpellier*

*The University of Montpellier PRESERVE platform has been funded thanks to the financial support of the Region Occitanie and the European Regional Development Fund.*

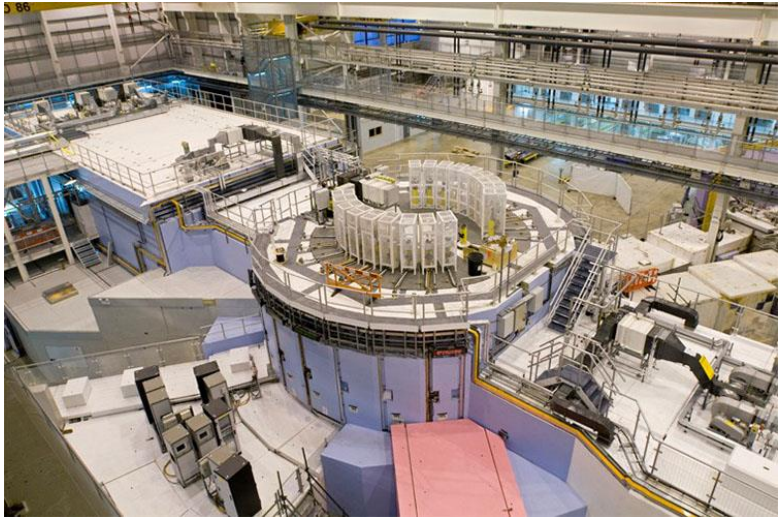
# 27
# UKRI-STFC

Carlo Cazzaniga, Maria Kastriotou, Chris Frost

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/



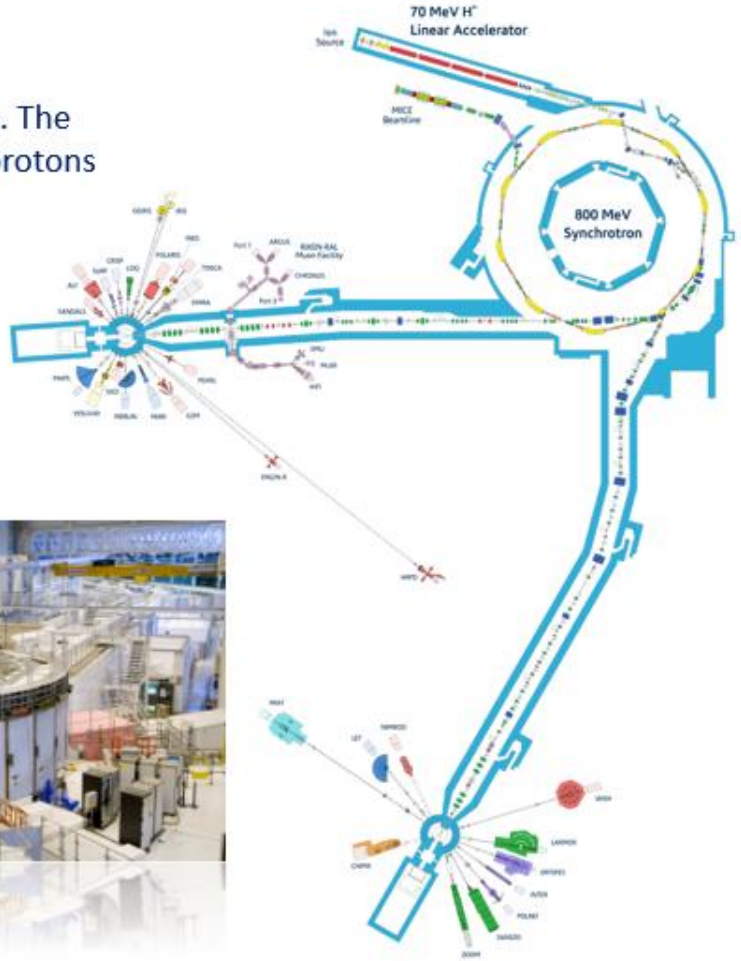
UKRI Science and Technology Facilities Council

RADNEXT


Rutherford Appleton Laboratory
Oxfordshire, UK

# Neutron Facilities

**Spallation Neutron Sources** are based around particle accelerators. The UK's ISIS Neutron Source uses a proton synchrotron to accelerate protons to 800MeV (about 84% the speed of light).

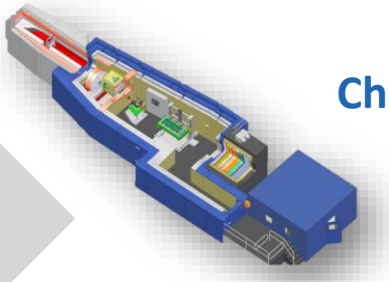



Science and Technology Facilities Council

# Suit of beams at Rutherford Appleton Laboratory for testing of microelectronics


**Atmospheric**

- Representative to the application
- Ground level and avionics applications
- Agreement with the standards

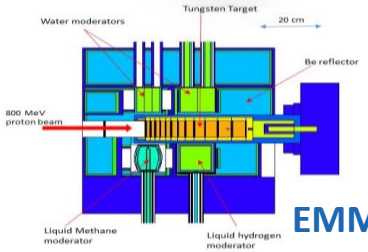


**ChipIr**

**620 h**

**Thermals**

- Always present for the thermalization of fast neutrons
- COTS devices where boron can be present




**140 h**

**EMMA**

**Muons**

- Main component of cosmic rays
- Low SEE cross sections
- Research in view of scaling of electronics

**150 h**

**RAL-RIKEN**

# 28

# ENEA

Salvatore Fiore

RADNEXT Kick Off Meeting – 19-21 May 2021

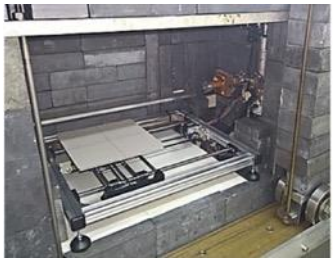
https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

Agenzia nazionale per le nuove tecnologie,
l'energia e lo sviluppo economico sostenibile

# ENEA (IT)

**ENEA**: Italian R&I institute for energy, environment and sustainable economic development
**Fusion and Nuclear Safety department: reference Italian fusion research coordinator**
Two research centres in **Rome area**, several **irradiation facilities**:

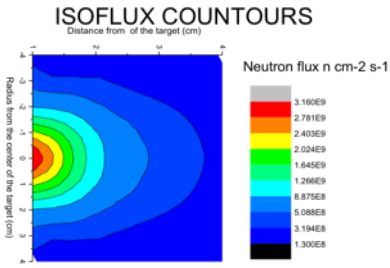



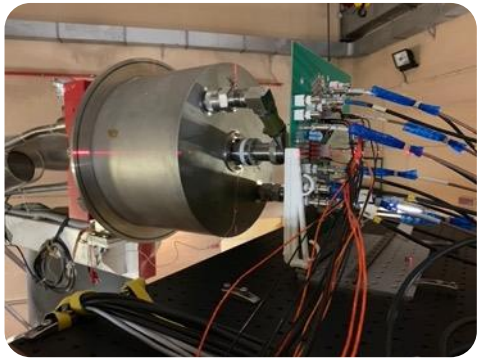

Scientist in charge: **Salvatore Fiore**

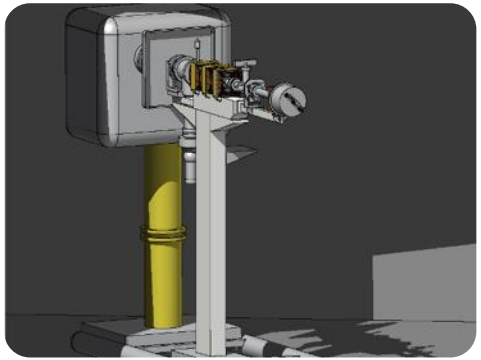
- **WP3-NA2 coordination**: Transnational Access Management and Harmonization
- **Transnational Access coordination** role in RADNEXT

# ENEA – Frascati Neutron Generator FNG

- 14 MeV D-T monoenergetic neutron source, max yield $10^{11}$ n/s
- Maximum usable flux $5 \times 10^{9}$ n/cm$^2$s
- Large hall, low backscattering, low thermal n contamination
- FLUKA and MCNP full facility simulations, setup model integration
- passive and active dosimetry, ISO 9001





**550 beam time hours committed to RADNEXT Transnational Access**

# 29

# Università degli studi di Padova

Marta Bagatin

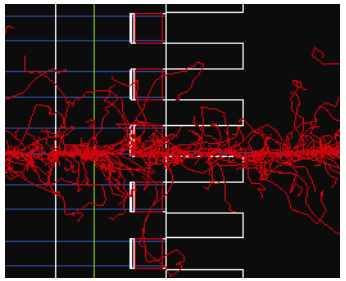
RADNEXT Kick Off Meeting – 19-21 May 2021

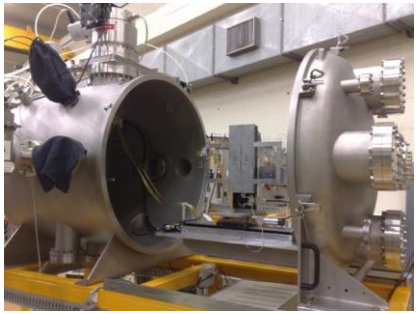
https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/


# Università degli Studi di Padova (UniPD)

- **RREACT** group at Information Engineering Dept.: research on **electronics reliability**, focus on **radiation effects**
  - Staff: 1 Full Prof (A. Paccagnella), 1 Assoc Prof (S. Gerardin), 1 Assist Prof (M. Bagatin)
  - Collaborations: semiconductor companies (Micron, STMicro, …), space agencies (ASI, ESA, NASA), research institutes (CERN, ITER, …), companies/univ across the globe
- **Field of activity**
  - Non-volatile memories: Floating gate (3D NAND Flash), emerging technologies (RRAM, PCM) for mainstream and critical applications (space, medical, …)
  - Tecnologies for zero-FIT applications (automotive)
  - Complex devices (uP, ASICs) for space applications
  - Advanced CMOS technologies for extreme environments e.g. CERN, ITER
  - Innovative devices (tunnel FETs, organic thin film transistors, …)
- **Capability**: radiation tests, simulations, modeling/predictions, identification of mitigation strategies
- **Role in RADNEXT**: Development/test of a **dosimeter/SEU monitor based on 3D NAND Flash memories (WP5)**





# 30

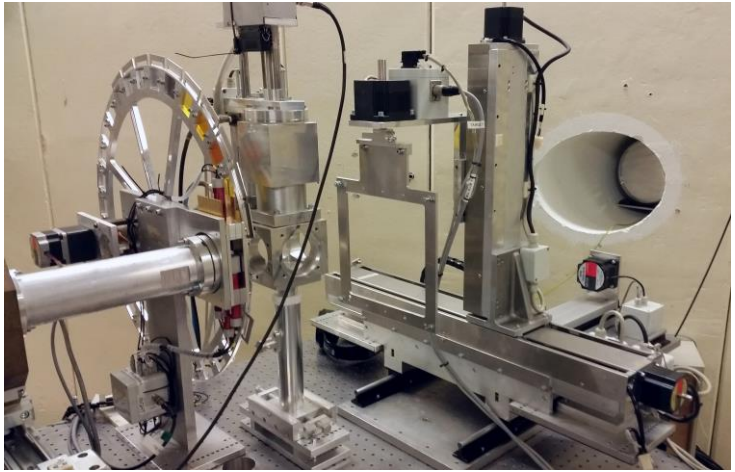
# University of Groningen

Brian N. Jones, Marc-Jan van Goethem,
Sytze Brandenburg

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/



# PARTREC proton and heavy ion irradiation facility

- Our facility offers a wide array of beams and energies with the option of scattering or scanning in air
- www.partrec.nl
- New investment, including new beamline for medical research
- Transnational access being offered (475 hours)
- Beams available: 190 MeV protons, 90 MeV/amu (H, He, C, O, Ne) or 30 MeV/amu heavy ion cocktail (O, Ne, Ar, Kr, Xe)
- Experimental beamline(s):
  - In-air setup
  - In-vacuum setup (depending on enough demand)
- Technical questions: irradiations@kvi.nl

partrec

# 31

# Uppsala University

Alexander Prokofiev

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

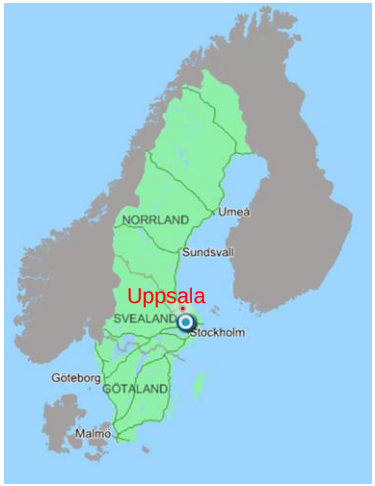
https://indico.cern.ch/event/1029314/

UPPSALA
UNIVERSITET

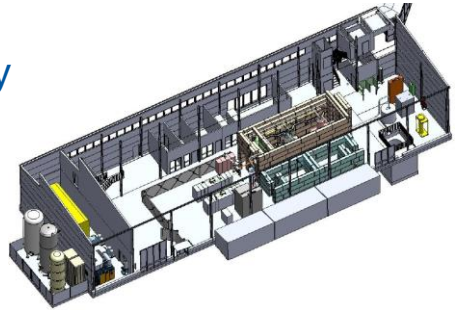
# Uppsala University and its involvement in RADNEXT (I)

*Who are we?*

- The university is founded 1477, one of the oldest in Europe.
- has ranked among the world's 100 best universities in several high-profile international rankings
- has over 50,000 students and more than 7,000 employees




- Long-term tradition in radiation facilities and research in radiation sciences
- Experience in / techniques for physical characterization of particle beams
- Has, or has had partnerships with the majority of entities active in RADNEXT
- Infrastructure for radiation work / accelerator developments: the FREIA laboratory →



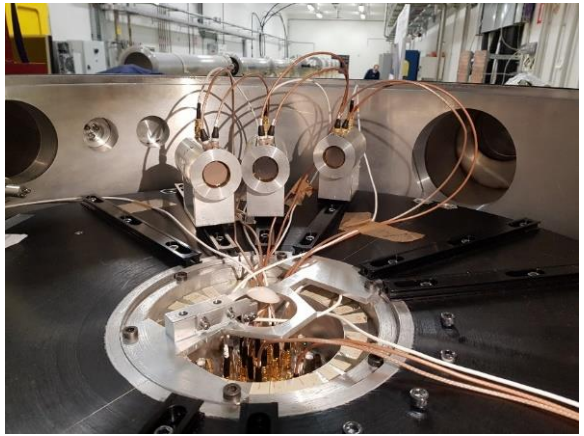
Contact: alexander.prokofiev@physics.uu.se

# Uppsala University and its involvement in RADNEXT (II)

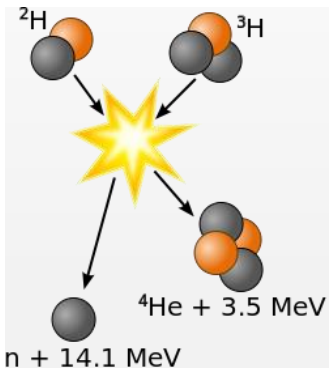
*Actual work packages / tasks / facilities*

- **WP05-JRA1: Radiation monitors, dosimeters and beam characterization**
  - **Task 5.3 : Innovative instrumentation applied to RADNEXT facilities**
    - Sub-Task5.3.3 - *Characterization of neutron fields at the emerging NFS facility*

The key partner: GANIL



- **WP9-TA1: Neutron, muon and mixed-field spallation facilities and irradiation**
  - **The NESSA neutron facility**
    - **NESSA** = **NE**utron **S**ource in upp**SA**la
    - Neutron energy:14 MeV
    - Yield: ≥$4 \cdot 10^{10}$ n/s
    - Flux: from ≥$10^9$ n/cm$^2$/s to single neutrons/cm$^2$/s
    - Planned amount of beam time for TA: ≥100 hours




# 32
# Seibersdorf Laboratories

Peter Beck

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

SEIBERSDORF LABORATORIES

RAD NEXT

# 33

# DLR

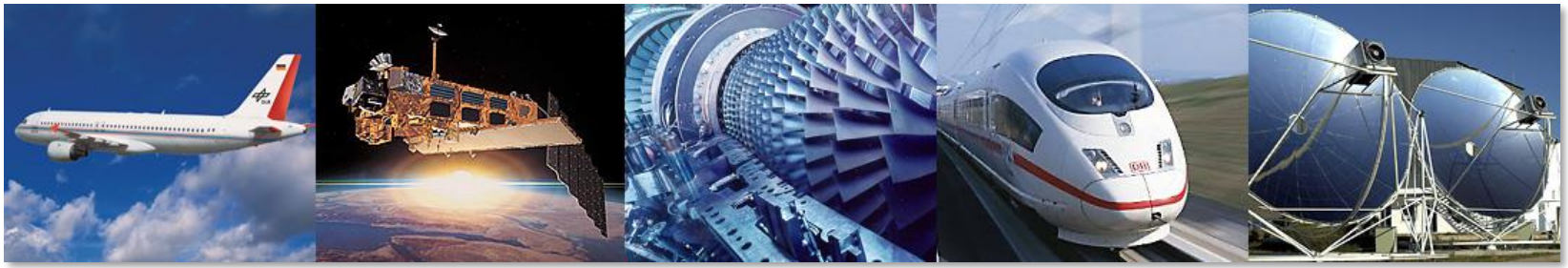
Jan Budroweit

RADNEXT Kick Off Meeting – 19-21 May 2021

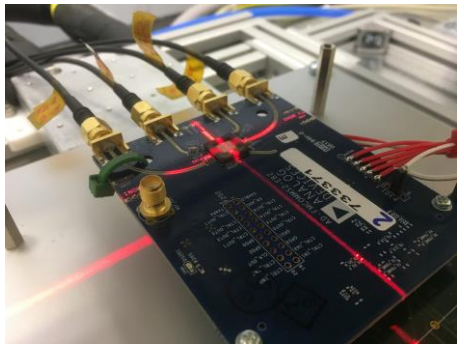
https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/


# DLR - German Aerospace Centre



- ***Research Institution***
- Space Agency
- Project Management Agency



# DLR - Locations and Employees

- 9000 employees across
  54 institutes and facilities at
  - 30 sites

- Offices in Brussels, Paris,
- Tokyo and Washington D.C

# Contributions to RADNEXT

- Associated partner to RADNEXT
- Joint Research Activities - WP06 Standardization of system level radiation qualification methodology

  - Radio frequency integrated circuits (RFIC) and agile RF transceiver
  - System in Package (SiP) architectures (for RF Systems)
  - Integrated and hybrid technologies such as SoCs (e.g. Zynq-7000, UltraScale+)
  - Machine learning for failure detection
  - Distributed on-board-computer (OBC) architecture for satellite systems

# 34

# ALTER TECHNOLOGY TÜV NORD

Gonzalo Fernandez-Romero

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

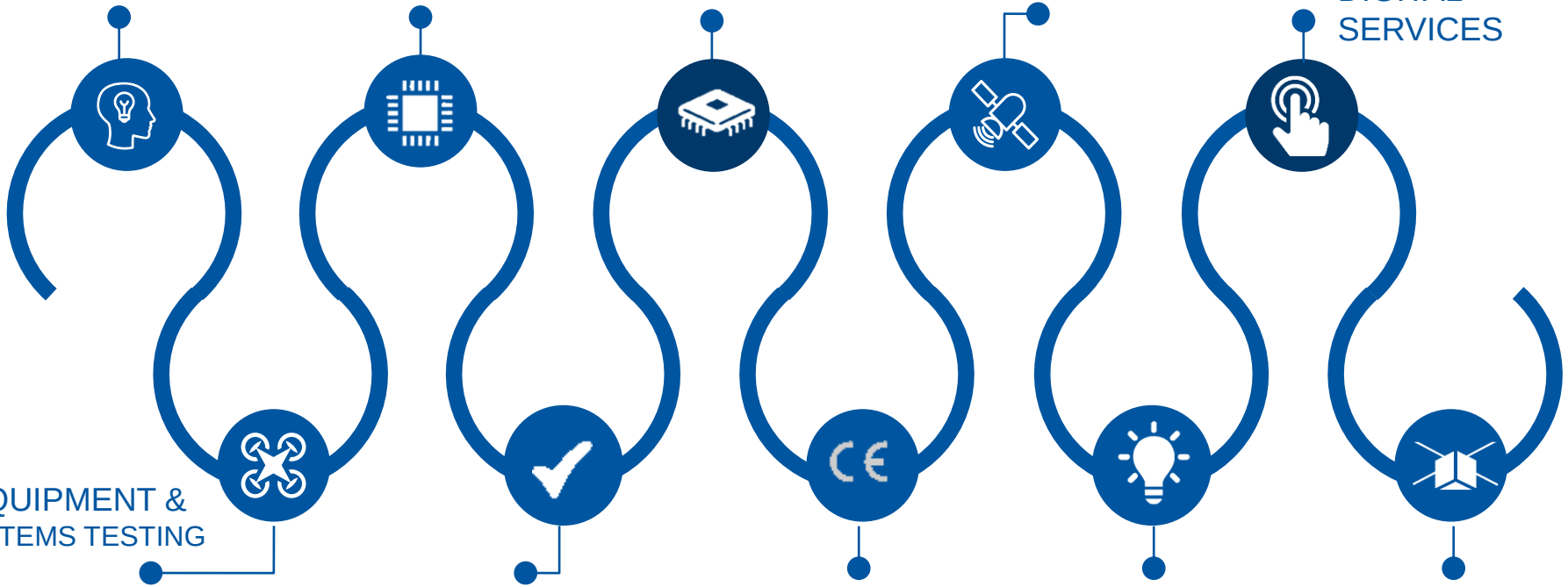
https://indico.cern.ch/event/1029314/

ALTER TECHNOLOGY

RAD NEXT

# ALTER Group Services

ALTER TECHNOLOGY



# ALTER TECHNOLOGY TÜV NORD

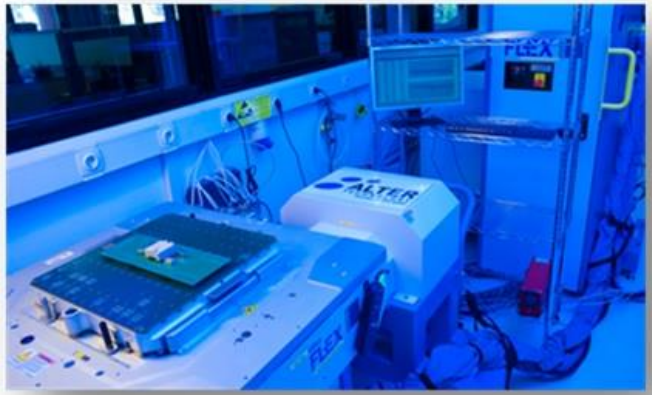
Experts in radiation testing on components and systems: engineering, plans development, test set-up, sample preparation, test execution and data análisis.

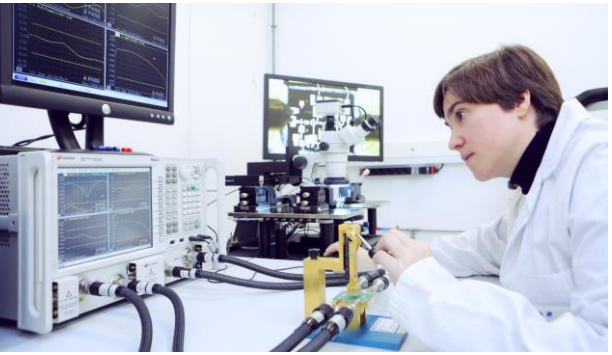
**Performed test:**

- TID at RadLab (
- TNID / DD
- SEE, all kind: SEU; SEL; ...
- SEE-Laser Test
- Neutron test
- Test at system / equipment level

**Test performances:**

- RadLab
- Wide and advance electrical test capabilities
- Virtual Lab
- Several accreditation, including DLA laboratory suitability for TID Test



**ALTER TECHNOLOGY in supporting the RADNEXT network providing experience in the radiation field and its industrial perspective on the topic.**

ALTER TECHNOLOGY

ALTER TECHNOLOGY SPAIN

ALTER TECHNOLOGY FRANCE

ALTER TECHNOLOGY UK

gonzalo.fernandez@altertechnology.com

# 35

# INTA Space Radiation Laboratory

Maite Alvarez

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

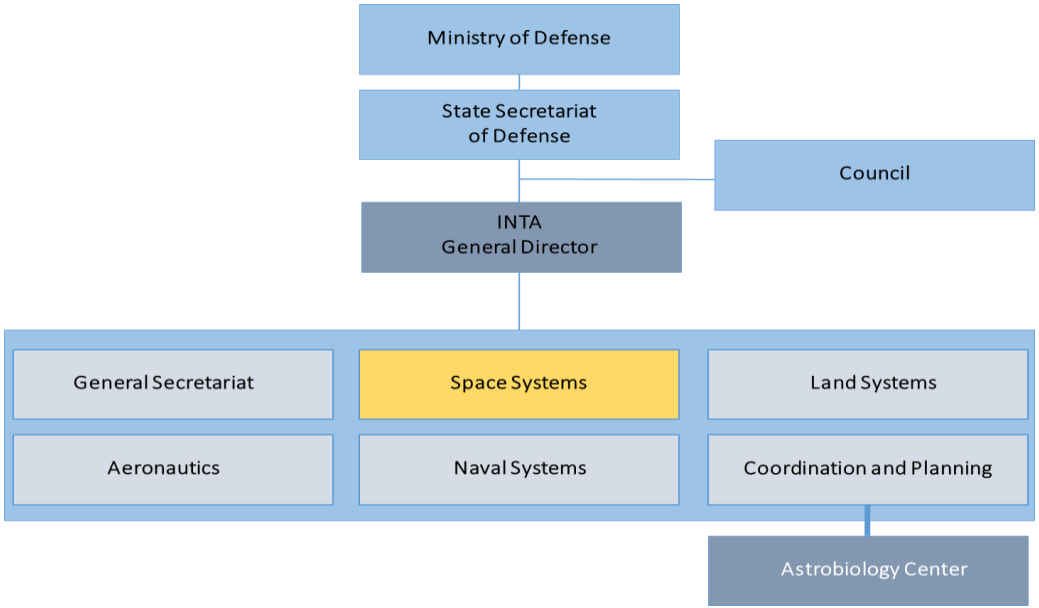
https://indico.cern.ch/event/1029314/

GOBIERNO DE ESPAÑA | MINISTERIO DE DEFENSA

INSTITUTO NACIONAL DE TÉCNICA AEROESPACIAL

The National Institute for Aerospace Technology (**INTA**), founded in 1942, is a Public Research Organization (OPI) specialized in aerospace Research and Development. INTA has more than 1,500 employees, of which more than 1,000 are dedicated to R+D+i activities.


The **Space Radiation Laboratory** involved in RADNEXT project belongs to the Payload and Space Science Department in the Space Systems Directorate.



# Space Radiation Laboratory

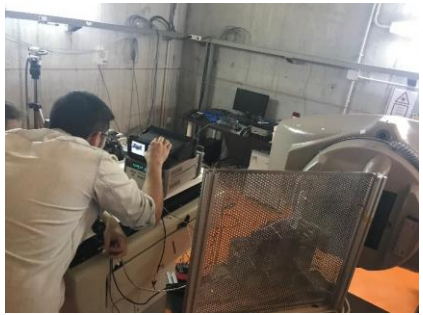
**EXPERTISE in RHA**

- Space Radiation Group has performed more than 20 radiation test on more than 80 components in national and international facilities. Results have been presented in Space Radiation Conferences (RADECS, NSREC).
- Design and calibration of radiation monitors for Space missions

**MAIN ACTIVITIES**

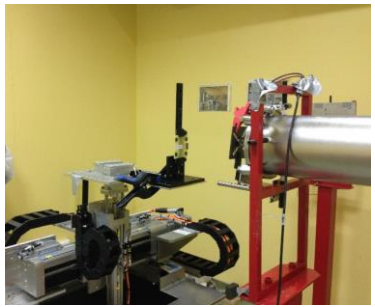
- Space mission radiation environment specification & requirements.
- Radiation effects on **COTS** (Commercial off the shelf), materials and emerging technologies:
  - Risk assessment and Mitigation Techniques (shielding, design techniques, redundancy,..).
  - Radiation testing: Total Ionizing Dose (TID), Single Event Effects (SEE) & Displacement Damage (DD).

Total Ionizing Dose (TID) test performed at Universidad de Santiago de Compostela (USC, España).



Heavy Ion test performed at Université Catholique Louvain (UCL, Bélgica).

Low energy proton radiation test performed at Centro Nacional de Aceleradores (CNA, Sevilla).



# 36

# 3DPlus

Pierre Wang

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/


# 37

# AIRBUS

Renaud Mangeret

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

# Airbus in RADNEXT

- Airbus is Europe's largest and most innovative defence and space company.
  - Airbus Defence and Space is part of Airbus Group, which also has a strong interest in the monitoring of radiation effects linked to atmospheric radiations
- Airbus, as a space systems provider, shall implement a strong Radiation Hardness Assurance (RHA) process
  - RHA is strongly relying on accelerator ground testing to demonstrate the usability of electronic devices in space programs
- Airbus intends to bring industrial needs and knowledge of a space and avionics system provider to the consortium, at any stage when this is requested.
  - Can provide its fitting needs in terms of accelerator characteristics, accounting for the most modern RHA methodologies which now include testing at board and/or system levels,
  - Can review/contribute in the list of test candidates delivered by the various members of the consortium, and,
  - Provide with support to test plans / test reports thanks to its extensive heritage in terms of radiation expertise in general and testing in particular.

# 38

# ATRON

Arnaud Chapon

RADNEXT Kick Off Meeting – 19-21 May 2021

https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/

# ATRON METROLOGY

## Calibration of radiation survey meters:

Patented method, without radioactive source,

Use the braking rays of electrons accelerated at few MeV as the source of calibration.

- ✓ High metrological requirements,
- ✓ Compliance with ISO 17025 standard,
- ✓ Realistic continuous spectrum at MeV-scale.

## Various irradiation services (e-beam and X-rays)

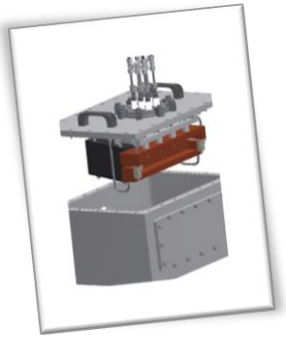
# ATRON METROLOGY

**e-beam**

From 0.2 to 3.5 MeV

From ~1 pA to 1 mA
(Up to $6\times10^{15}$ e-/s)

Beam spot size ~1 $mm^2$



*X conversion target*

**X-rays**

From 10 µrad/h to 50 krad/h
= 0.1 µGy/h – 500 Gy/h

Volumes up to few $m^3$
(irradiation room size is 3×6 $m^2$)

# 39

# Mines ParisTech

Pierre Jouvelot

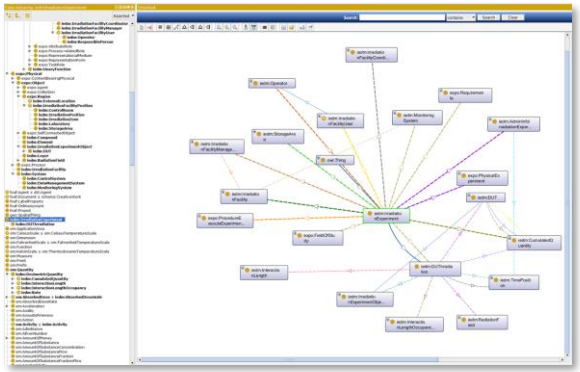
RADNEXT Kick Off Meeting – 19-21 May 2021

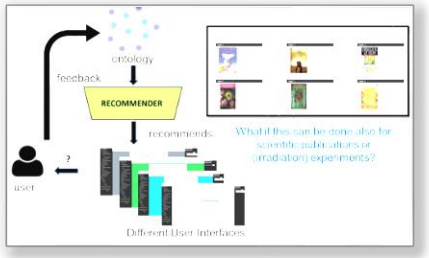
https://indico.cern.ch/event/983095/

https://indico.cern.ch/event/1029314/


# MINES ParisTech
# PSL University (France)

- Top French engineering school for its research activities, created in 1783
- Fields of interest: energy, material sciences, maths, finance, social sciences,…
- Computer Science, including:
  - Modelling, data management, software systems (ontologies, DSL, Machine Learning, formal methods)
- CERN / IRRAD collaboration, since 2017:
  - Ontology for Irradiation Experiment Data Management
  - Ontology-based automatic Web applications generation
  - Recommender systems for UI personalization





# Thanks for your attention!

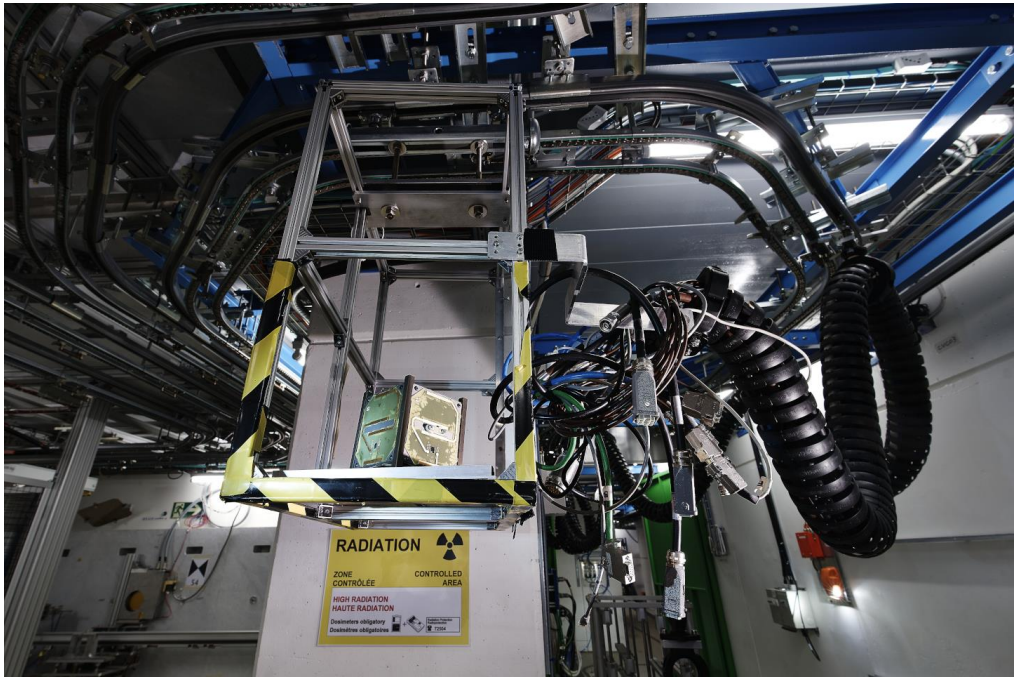



*Image Source: CERN*