ENEA | ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

La rete ASIF
e il contributo ENEA

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Convegno ENEA – INFN: collaborazioni in essere e sviluppi futuri. ENEA Frascati R.C., November 5, 2024.

Summary

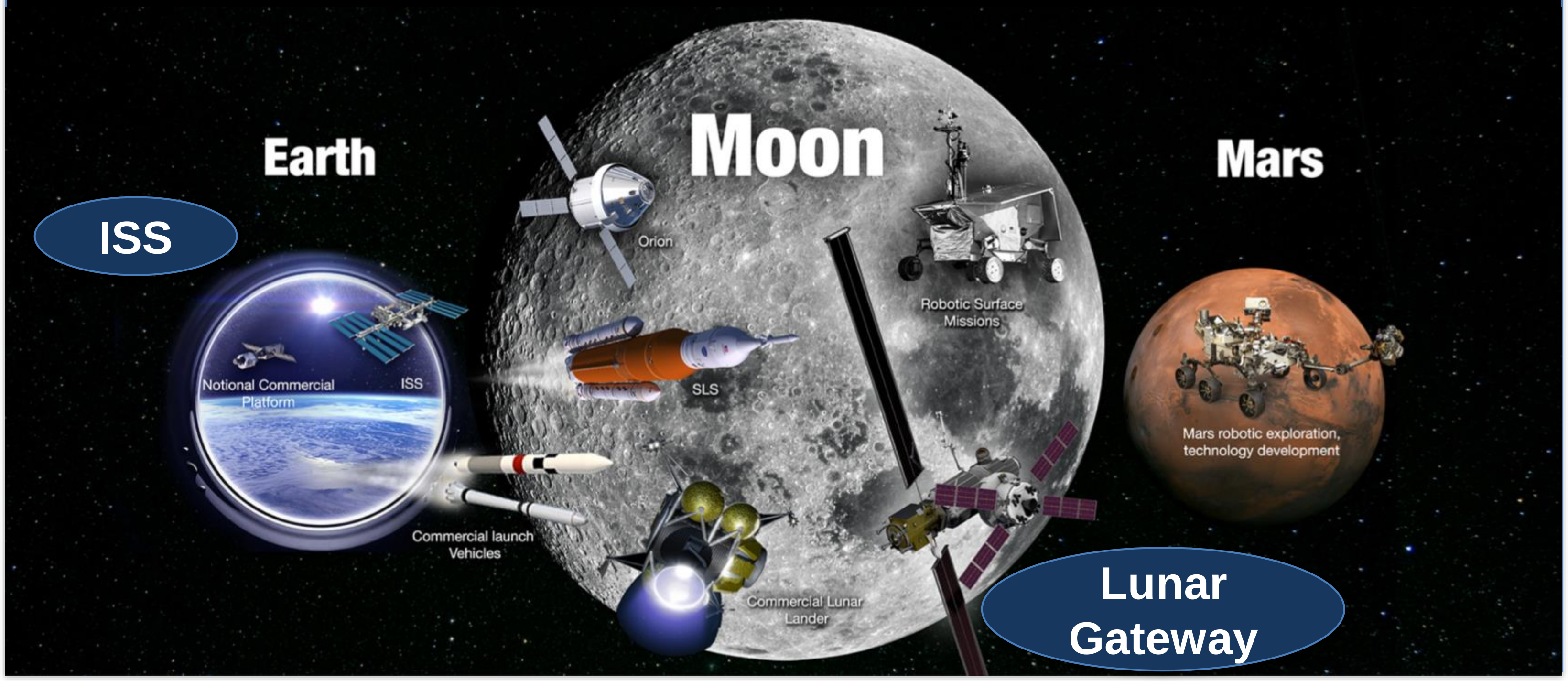
- The ASIF Program: objectives
- The ENEA irradiation plants and facilities
- ENEA – INFN collaborations

The Space exploration: challenges and opportunities

Now
EARTH RELIANT
Earth-Based Support: high
Return to Earth: hours

2020s – 2040s
PROVING GROUND
Earth-Based Support: Limited
Return to Earth: days

2050s
EARTH INDIPENDENT
Earth-Based Support: Negigible
Return to Earth: months

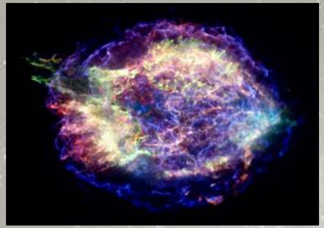


Advanced technologies, economic opportunities, private companies involvement

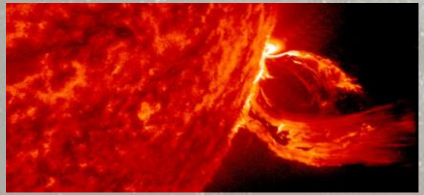
New Space Economy

Space environment: primary and secondary radiations

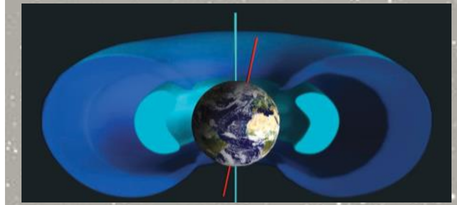
Radiation sources



Galactic Cosmic Rays



Solar Particles Events



Earth radiation belts

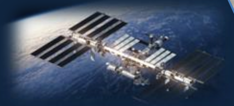
Primary particles

87% protons
12% Helium
1% Heavy nuclei
100 MeV – 100 GeV

92% protons
6% Helium
2% Heavy nuclei
keV – 100 MeV

Electrons &
Protons
1 MeV – 100 MeV

Shielding



Secondary radiations

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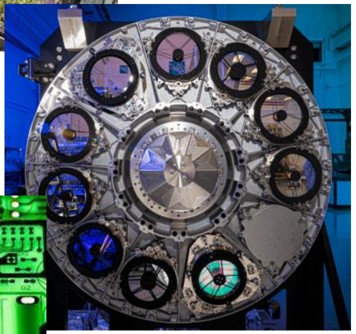
NUClear Dept.

Gamma rays
Neutrons
Protons
Electrons
X-rays
Recoil heavy nuclei

Damage on materials, instruments, living organisms



The ASIF Program

Agenzia Spaziale Italiana

ASIF: ASI Supported Irradiation Facilities Program

to establish an interactive and coordinated set of the Italian irradiation facilities (ENEA, INFN, UniMiB)

Private Companies
Public users

Standard ESA-ESCC qualification
Electronic components and devices

to grow the knowledge of the space radiation environment
Radiation damage, simulation and modelling tools, EEE supply chain

to develop and validate new test configurations and protocols

Phase 1 (2017-2019)

- Selection of facilities
- Standardization of the facilities and operating procedures
- Dosimetry

Phase 2 (2022-2025)

- Number facilities increase *(INFN)*
- Standardization, dosimetry
- Interactive portal implementation (ASIF gateway)

The ASIF Program: ASIF gateway

The **ASIF gateway website** provides comprehensive about:

- technical information of the different facilities:
- conditions of use;
- availability and beam time booking tool.

http://www.asif.asi.it/

handled by
Milano Bicocca University
(Physics Dept.)

ENEA

The ASIF Program: research and testing at ENEA

QUALIFICATION TESTS

Electrical and electronic components and devices (*standard ESA-ESCC, MIL*)

TOTAL IONIZING DOSE (TID; gamma)

DISPLACEMENT DAMAGE DOSE (DDD, TNID; neutrons, protons)

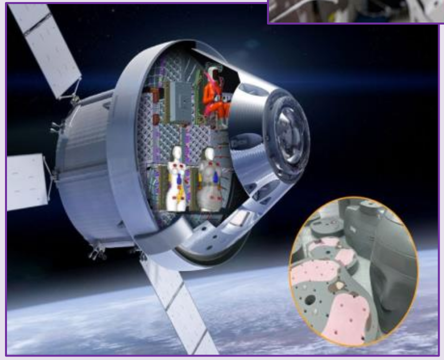
SINGLE EVENT EFFECTS (SEE; heavy ions, neutrons, protons)

RADIATION HARDNESS & DAMAGE

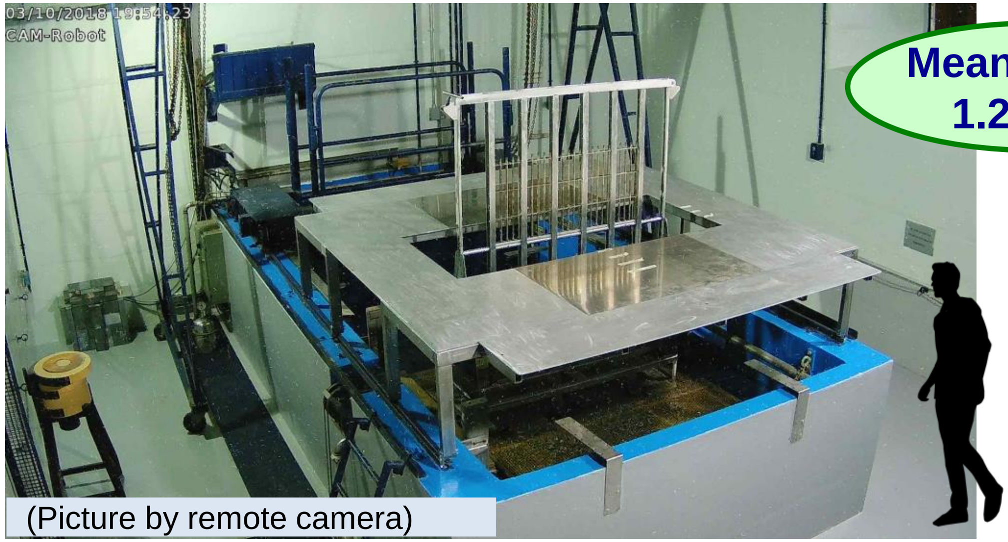
- **Materials (optics, polymers, solid matrices)**
- **Systems, sensors**
- **Instruments**

DOSIMETRY

Innovative active and passive dosimetric systems



The ASIF Program:
Calliope gamma facility (ENEA Casaccia R.C.)



(Picture by remote camera)

Mean energy: 1.25 MeV

Pool-type irradiation facility equipped with a ^{60}Co gamma source in a large volume (7×6×3.9 m^3) shielded cell

maximum dose rate (November 2024):* *5 kGy/h

Cherenkov effect around the 25 source rods in the plane rack (active area: 41 cm x 75 cm)

Maximum allowed activity: 3.7x10^{15} Bq (100 kCi)

- **Irradiation tests at different dose rates, atmospheric and temperature conditions and under bias.**
- **Online tests and remote acquisition.**
- **Irradiation and dosimetric certifications.**
- **ISO 9001; ISO 17025 (by 2024).**
- **Traceability system (ID/QR code)**

ISO 9001

Simultaneous stress tests

Thermal vacuum chamber (TVC, limited sizes)

Random Positioning Machine (RPM) for altered gravity test

Dosimetric laboratory

Fricke dosimeter (20 - 200 Gy)
Absolute dosimeter

Red-Perspex, radiochromic, Thermo Luminescent Dosimeter (TLD), Alanine – ESR, electronic RADFET dosimeters, on-line dose-rate sensors;
MCNP and Fluka simulation gamma field.

Characterization laboratory

Optical and spectroscopic techniques (UV-VIS, FTIR, PL, Micro Raman, ESR)

Accelerated ageing tests, thermal treatments (annealing)

ESCC 22900 (5)

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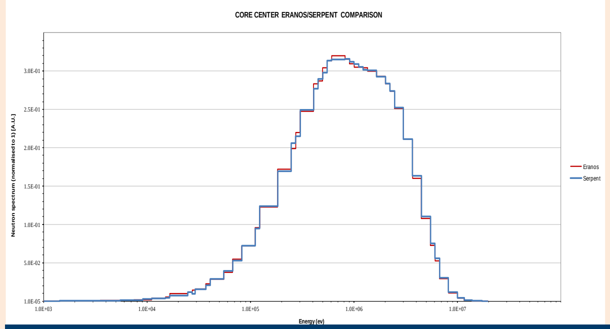
The ASIF Program: TAPIRO research reactor (fast neutrons, Casaccia R. C.)

Max neutron flux: 3 10^{12} $ncm^{-2}s^{-1}$

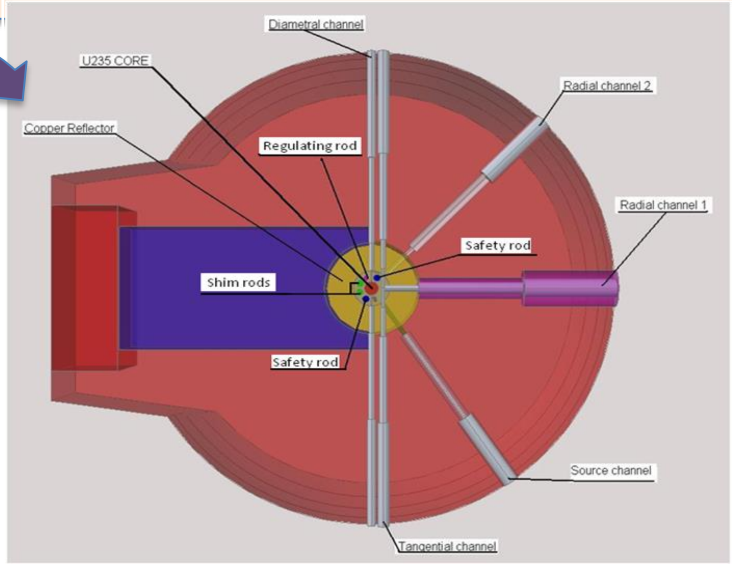
Fast neutron source, based on the concept of Argonne FSR, first criticality in 1971.



Neutron spectrum at the diametral channel (core center)

Core:
- **fuel**: U-Mo alloy (98,5% wt of U), enrichment 93.5 % ^{235}U
- **maximum thermal power of 5 kW.**

ISO 9001

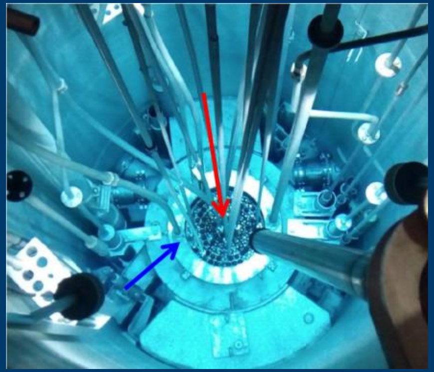


TAPIRO experimental channels (different sizes)

DUT placed in one of the channels selected based on sample size, required spectrum, fluence, etc.

The ASIF Program: TRIGA RC-1 research reactor (thermal neutrons, Casaccia R. C.)

Thermal pool reactor, based on the TRIGA MARK II design by General Atomic.



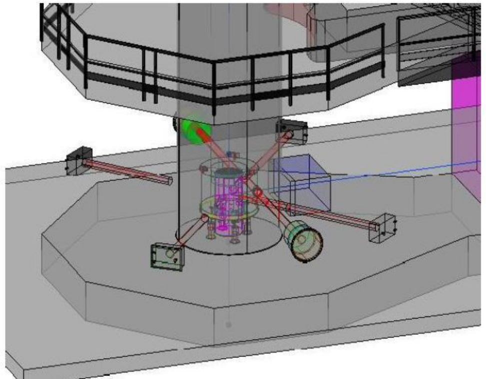
Central irradiation channel and Lazy Susan

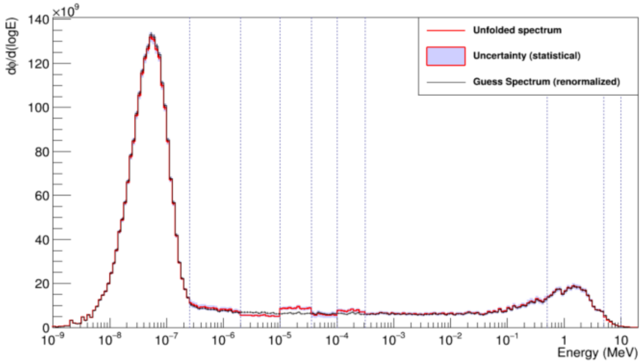
Core:

- **111 elements** (standard TRIGA fuel element, enriched at **20% in ^{235}U**) in aluminum vessel 7 meters deep, filled with demineralized water (moderating, cooling and shielding).
- **maximum thermal power of 1 MW**.

ISO 9001

Several in-core and ex-core experimental channels (neutron and gamma field)





Neutron spectrum at the Lazy Susan

Channel description	Neutron flux ($ncm^{-2}s^{-1}$)
Lazy Susan	$2.00\ 10^{12}$
Pneumatic transfer system(rabbit)	$1.25\ 10^{13}$
Central channel	$2.68\ 10^{13}$
Thermal column collimator	$\sim 1\ 10^{6}$
Tangential piercing channel	$\sim 1\ 10^{8}$

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The ASIF Program: Frascati Neutron Generator (FNG, Frascati R. C.)

Linear electrostatic accelerator, in which up to 1 mA D^+ ions are accelerated to hit a tritiated target

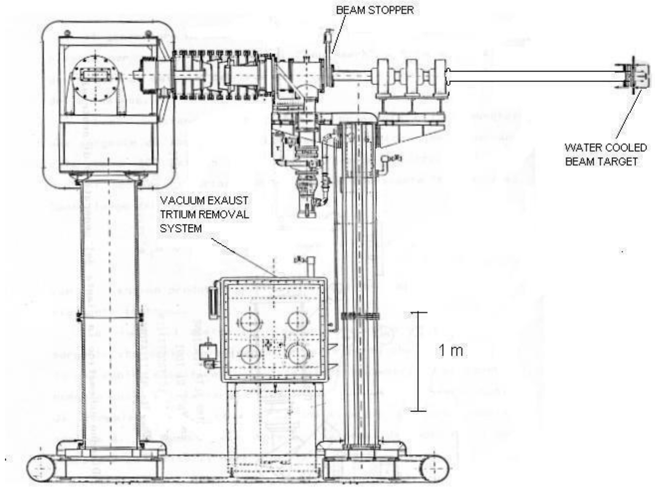
Two different operating conditions

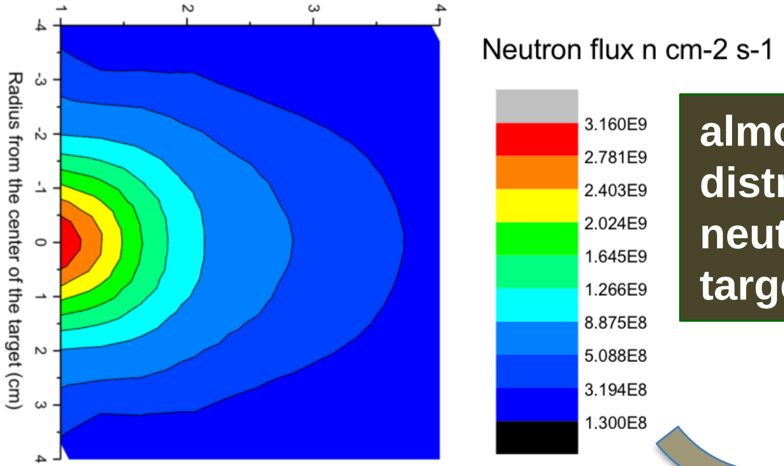
	D-T operation	**D-D operation**
Neutron yields (accuracy 3%) **Energy**	1 10^{11} n/s max. **14 MeV**	1 10^{9} n/s max. **2.5 MeV**
Flux vs irradiation volume	10^7/s/(4* π*m^2)	10^5/s/(4* π*m^2)

Max. flux:
$5x10^9$ n/(cm^{2}s)

ISO 9001

Target





almost isotropic spatial distribution of the 14 MeV neutrons emitted by the target

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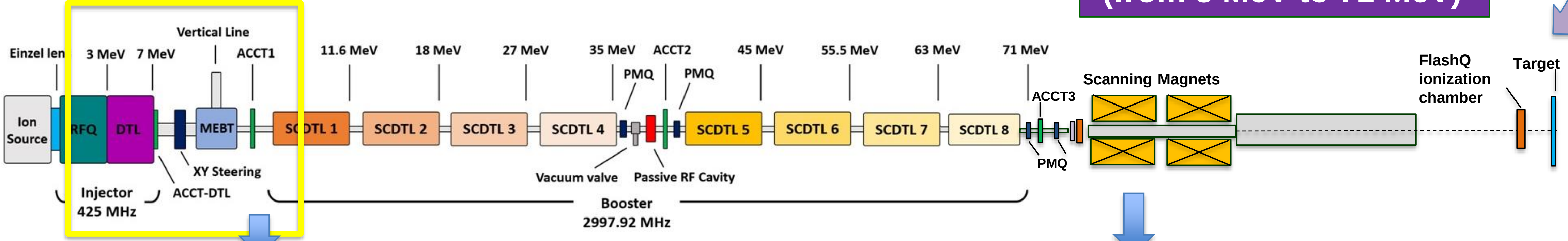
The ASIF Program: TOP-IMPLART proton linear accelerator (Frascati R. C.)

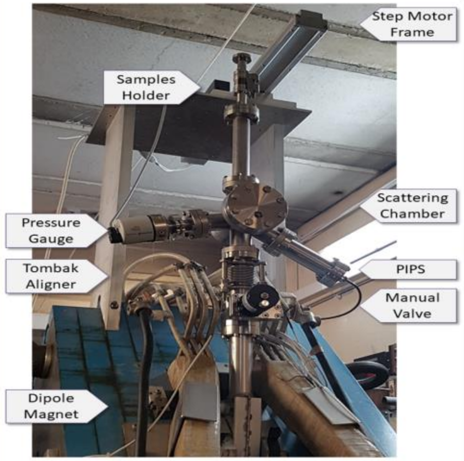
Pulsed proton linac

max. energy of 71 MeV and maximum intensities of 4.5 10^8 protons per pulse.

Modular structure (from 3 MeV to 71 MeV)



Vertical line:



beam properties

Pulse length	15 to 60 μs
Pulse repetition frequency	25 Hz
Flux per pulse	10^6 to $2 \cdot 10^7$ p/cm²/pulse
Pristine energy from the injector	3 -7 MeV
Energy on target	1 - 6 MeV
Beam diameter on target (max.)	16 mm
Transverse homogeneity on target	± 5 %

Horizontal line:

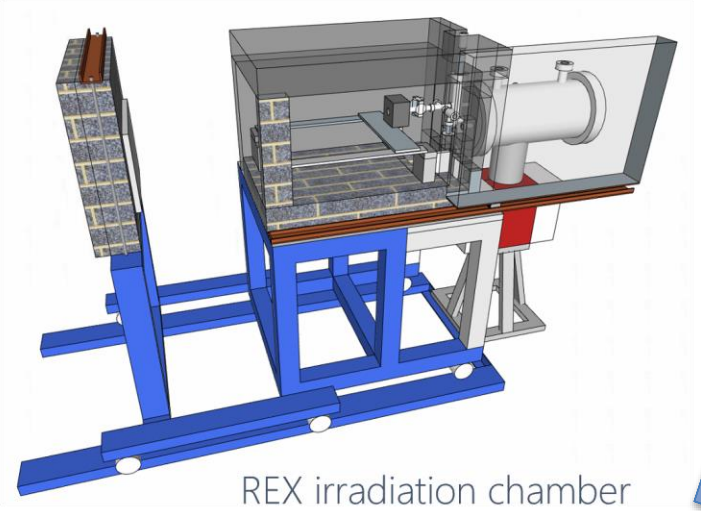
beam properties

Pulse length	2.4 μs
Pulse repetition frequency	25 Hz
Protons per pulse (max)	4.5 10^8 p/pulse
Pristine energies on target	61 -70 MeV
Pencil beam spot size (FWHM)	17 mm
Maximum flux on a 10 x 10 cm² area	1.1E+08 p/cm²/s

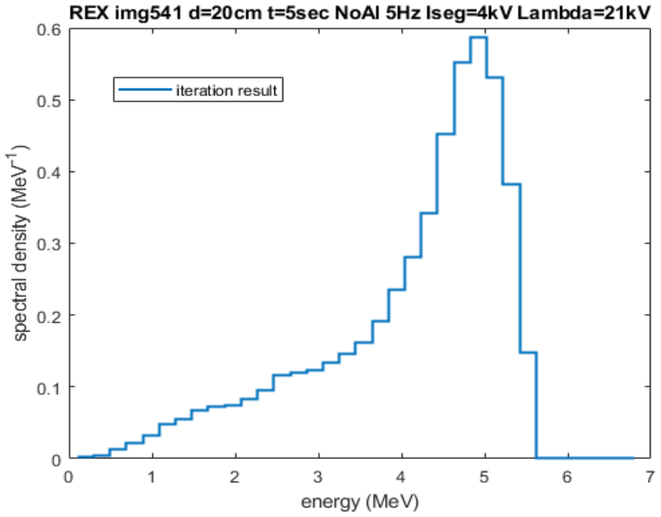
The ASIF Program: REX electron linacs accelerator (Frascati R. C.)

REX: Removable Electron to X-ray source
(Max energy: 5 MeV)

Pulse lenght	3 μs
Pulse current (max)	150 mA
Electrons per pulse (max)	$2.95 \cdot 10^{12}$
Pulse Repetition Frequency	20 Hz
Average current (max)	9 μA
Electrons per second (max)	$5.6 \cdot 10^{13}$
Electron beam size 5 cm from the linac exit (FWHM)	20 mm



REX irradiation chamber
(40 x 40 x 80) cm³



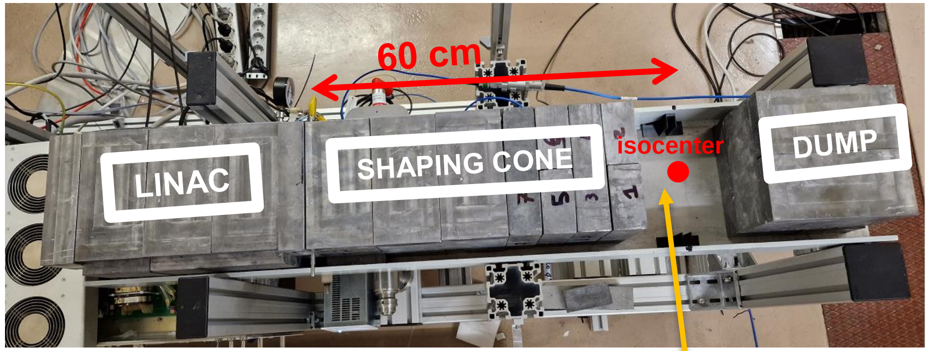
The irradiation chamber can be equipped with a **remote positioning system** to scan the specimens for the complete exposure to the beams.

The ASIF Program: TECHEA electron linear accelerator (Frascati R. C.)

TecHea

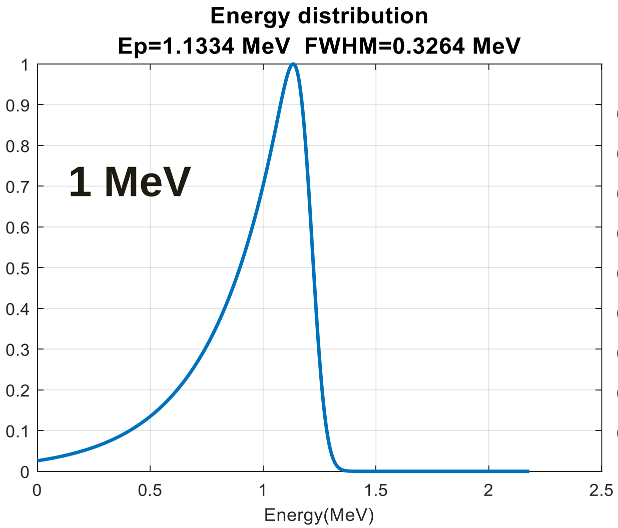
Prone Breast System prototype

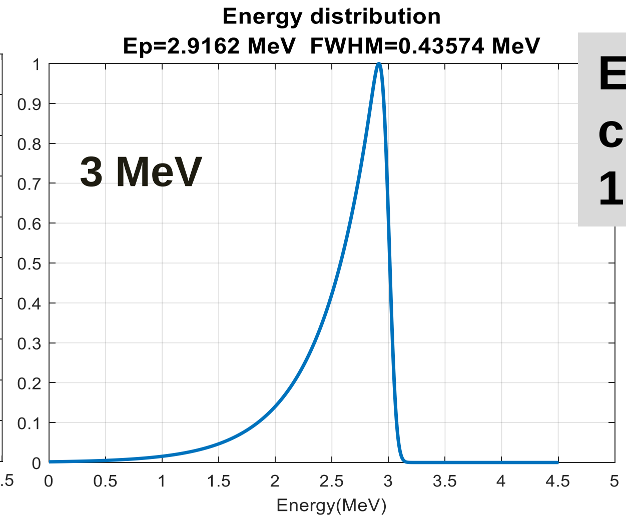
Converted from X rays to electrons configuration



Target in fixed position

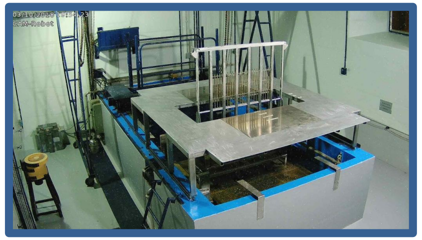
Parameter	Value
Rotation angle of the beam source	270°
Source-isocenter distance	60 cm
Treatment couch position	fixed
Electron beam energy	3 MeV
Dose rate at isocenter	1.5 Gy/min
Maximum spot diameter	14 cm





Energy can be changed in the range 1-3 MeV

ENEA – INFN: past and current collaborations



Calliope facility

TAPIRO reactor

FNG

PAST COLLABORATIONS

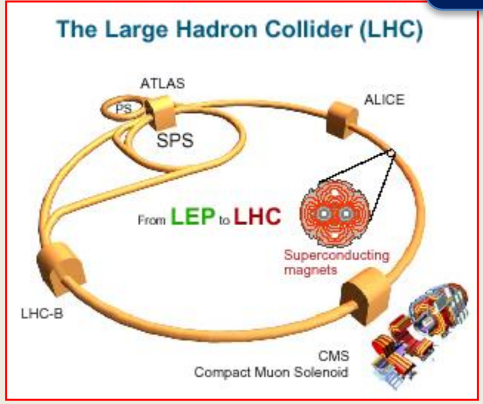
ORIONE	APOLLO
ATLAS	LIMADOU - 2
SMOG	AMS
CMS	Mu2E

Dosimetry, scintillators, sensors, optical fibers, polymers…

CURRENT COLLABORATIONS

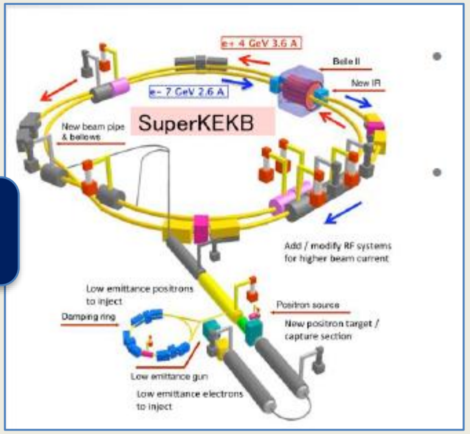
Phase 2 - CMS

LHC, CERN



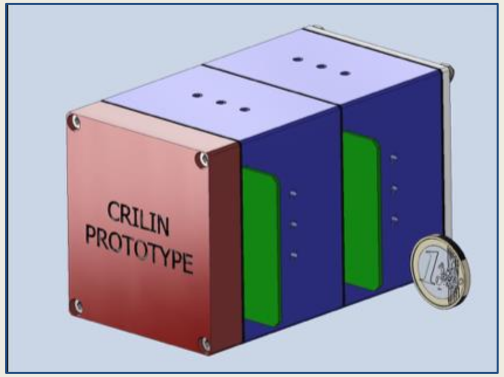
BELLE II

SUPERKEKB, Japan



MuCol

LHC, CERN



MuCol

Thank you for your attention

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