EURO-LABS

EUROpean Laboratories for Accelerator Based Sciences

Research Infrastructures for Nuclear and Particle Physics

WP 4: Access to Research Infrastructures for Detector R&D

Task 4.3. Irradiation Facilities

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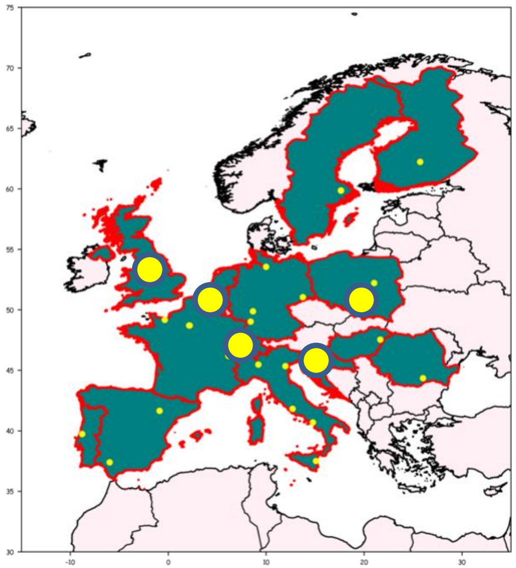
for the Task 4.3. team

Kick Off Meeting EURO-LABS, 3-5 October 2022, Bologna

Task 4.3: Irradiation Facilities

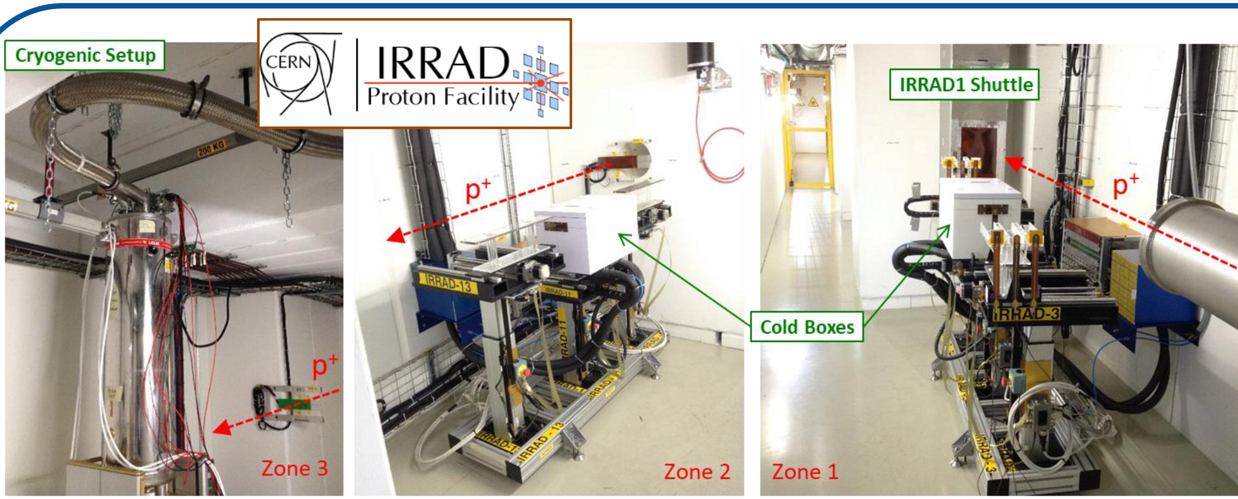
WP4 aims at providing TA to various facilities having energetic beams and **irradiation facilities**. These measurements are necessary to study the effect of detectors and associated equipment in-beam, required for the detectors upgrades for operation at the HL-LHC and construction of new detectors for the future.

- Task 4.1. (TA): Test beams (CERN, DESY, PSI)
- Task 4.2. (TA): Detector characterizations (RBI, ITAINNOVA)
- **Task 4.3. (TA): Irradiations**
  - 4.3.1. **CERN IRRAD facility** (Geneva, Switzlerand)
  - 4.3.2. **CERN GIF++ facility** (Geneva, Switzerland)
  - 4.3.3. **JSI TRIGA reactor** (Ljubljana, Slovenia)
  - 4.3.4. **IFJ PAN AIC-144 cyclotron** (Kraków, Poland)
  - 4.3.5. **UCLouvain CRC** (Louvain-la-Neuve, Belgium)
  - 4.3.6. **Birmingham MC40 Cyclotron** (Birmingham, UK)
- Task 4.4.: Service improvements



Task 4.3. provides TA to six leading irradiation facilities in Europe with proton, neutron or mixed field sources, as well as with gamma rays. The facilities cover the actual radiation fields in high energy hadron collisions in a representative manner. In addition, some are offering single event effect testing opportunity for electronics. Main users originate from the hadron collider community, with the emerging R&D for FCC-hh requiring extremely high fluences in excess of 10^{17} $n_{eq}cm^2$.

CERN IRRAD and GIF++ Facilities

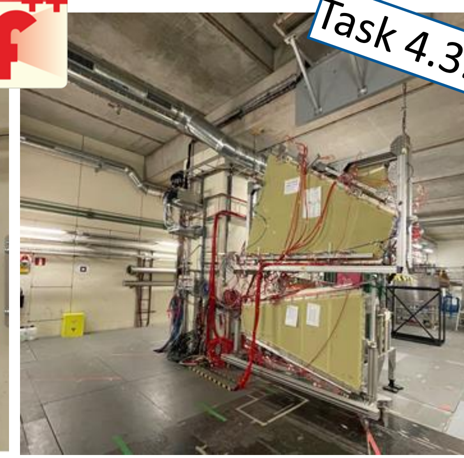


Task 4.3.1

- **24 GeV/c protons**
  - 400ms spills
- **~1×10^{16} p/cm^2/5days**
  - beam spot: 12x12mm^2 FWHM
- **1 shuttle system** (small samples)
- **9 irradiation tables**
  - 6x room temperature
  - 2x cold boxes (-25°C)
  - 1x cryogenic setup (1.9K)

IRRAD: radiation test of solid-state/calorimetry detector components, electronics (DD,SEE), materials for HL-LHC

- **^{137}Cs γ-ray source** 12 TBq (today)
- max. rate **~2.5 Gy/h** @ 0.5m
  - attenuator system 1:50’000
- **2 symmetric radiation field**
  - ±37º wide angle collimators
  - >100m^2 floorspace for DUTs
- **μ-beam** (100 GeV; ~10^4/spill)
  - gas infrastructure available



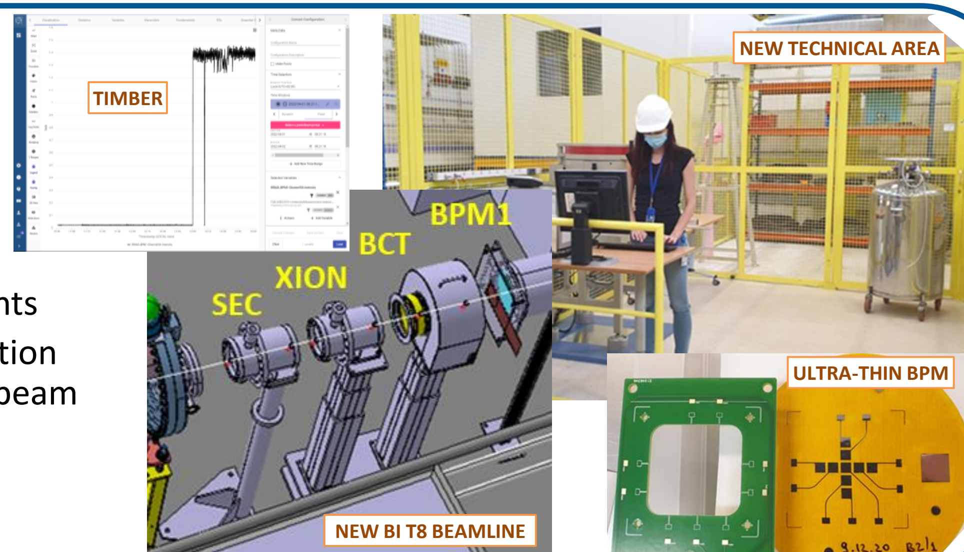
Task 4.3.2

GIF^{++}: radiation (& beam performance) test of muon detector systems, electronics (TID), gas mixtures for HL-LHC

4.3.1 CERN IRRAD – Latest News

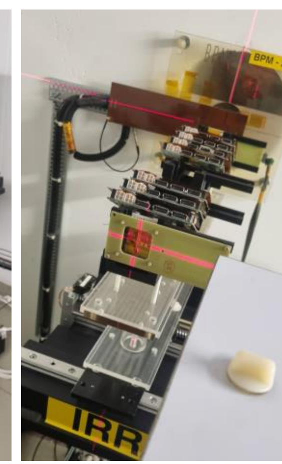
Main LS2 improvements (19-22)

- New **Technical Area** and **Measurement Lab**
- Additional **Spectrometry Station** bld. 157
- New **BI on T8 for Intensity** Measurements
- **Ultra-thin BPM** devices for Profile Measurements
- New (open source) **control software** for irradiation equipment (tables + shuttle) and improved T8 beam **data exchange with CCC**
- **Data Management** (samples traceability, etc.)
- …



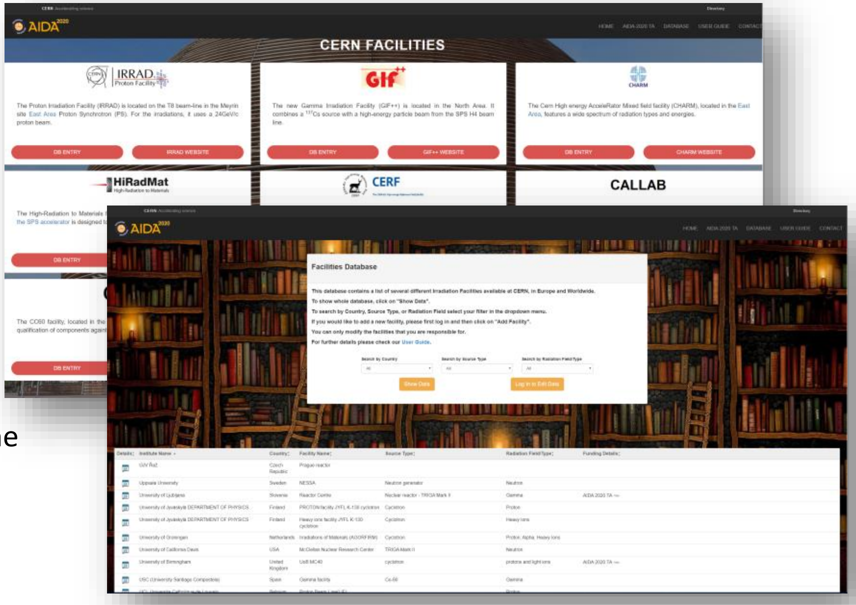
User experiments 2022

- 34 experiments (359 samples) registered
- Users: ATLAS ITk pixel & strips, ATLAS Reliance, ATLAS HGTD, CMS pixel, CMS HGCAL, CMS DP sensors, LHCb ECAL, LHCb LAPPD, EP-RD, RD53, RD50, EP-ESE, TE-MSC, EN-EL, R2E, AIDAinnova.
- 303 samples processed until end August 2022

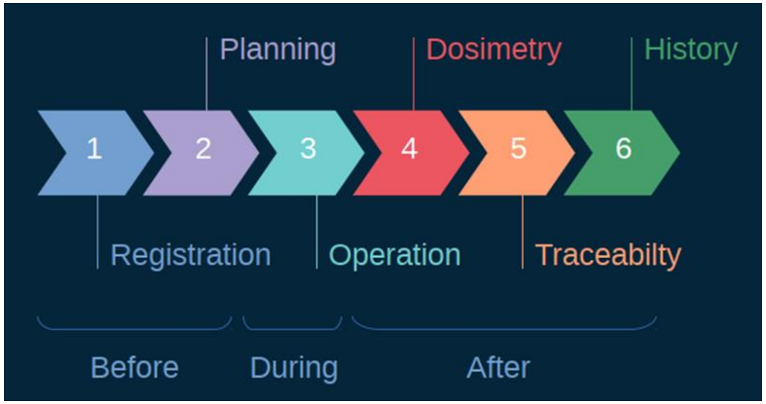


CERN Facilities - User support

- **CERN Irradiation Facilities Database**
  - www.cern.ch/irradiation-facilities
  - **CERN portal + database of worldwide facilities**
  - Knowledge of available external facilities important:
    - to complement in-house means (R&D, qualification, etc.)
    - to increase testing availability (shutdown periods, etc.)
  - Entries maintained by the facility coordinators:
    - **more than 220 entries to date!**
    - automatic reminders for maintaining the information over time
  - Tool developed within EU-project AIDA-2020



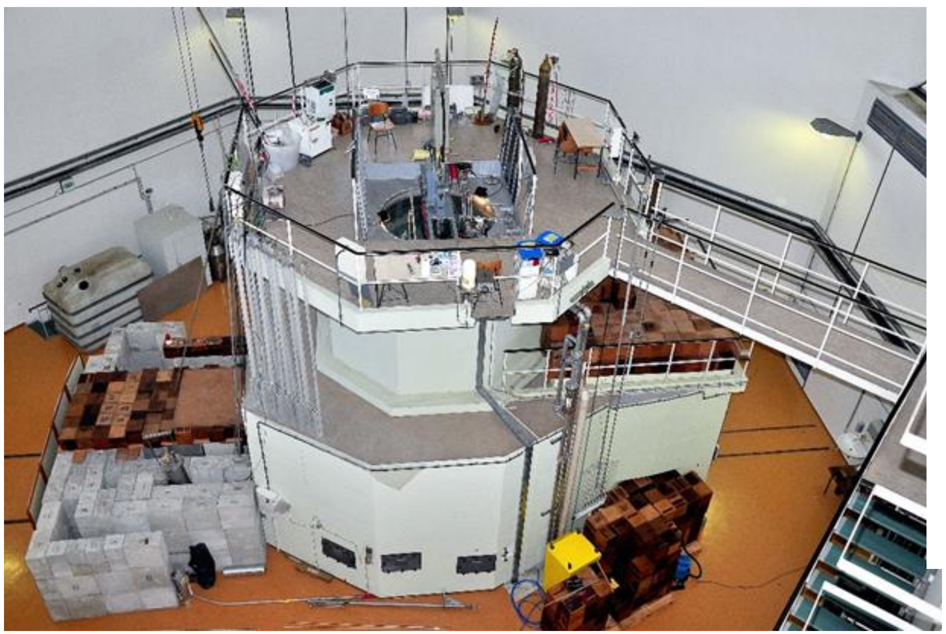
- **Irradiation Experiments Data Management**
  - www.cern.ch/irrad-data-manager
  - **A web application for the follow-up of the full irradiation experiment workflow:**
    - **manages users, samples, experiments, logistics, … data**
    - operational for CERN-IRRAD, being deployed for GIF++
  - Being improved, new functionalities being added:
    - development continues thanks to the synergies with ongoing and new EU-funded projects



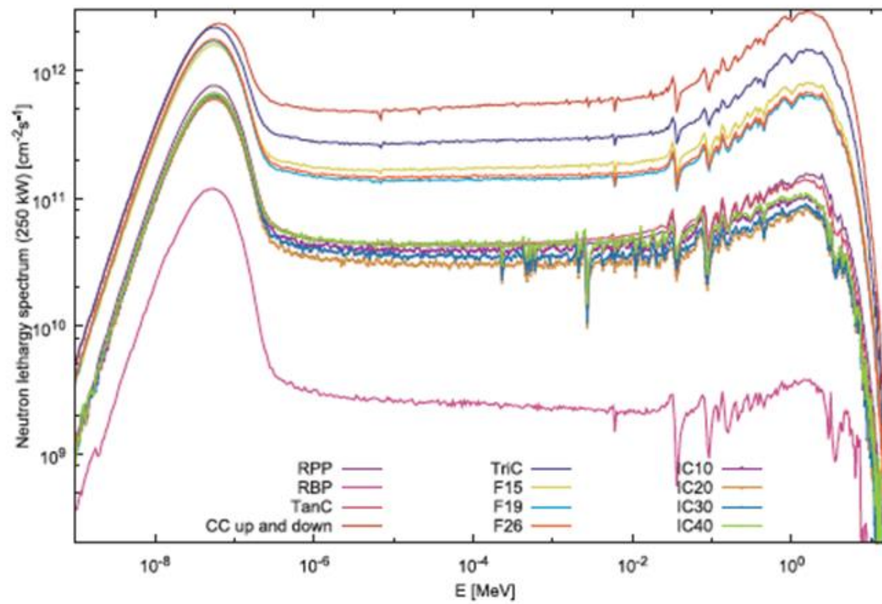
4.3.3. Jožef Stefan Institute TRIGA Reactor

- TRIGA Mark II reactor
  - research nuclear reactor near Ljubljana, Slovenia
  - built in 1966 (General Atomics), reconstructed in 1991
  - power can be set between ~ 1 W and 250 kW
    → neutron flux scales with power
  - several irradiation channels

Jožef Stefan Institute
Ljubljana, Slovenia



- neutron spectra in different irradiation channels



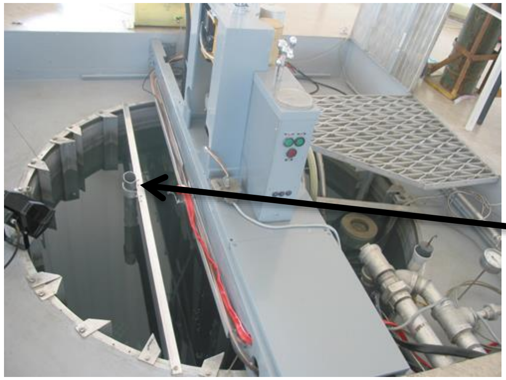
K. Ambrožič et al., *Applied Radiation and Isotopes* 130 (2017) 483-488

More info about irradiation channels: https://ric.ijs.si/en/info-za-uporabnike/lastnosti-obsevalnih-kanalov

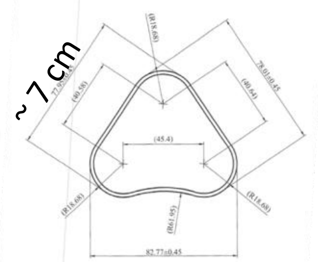
4.3.3. Jožef Stefan Institute TRIGA Reactor

Jožef Stefan Institute
Ljubljana, Slovenia

- TRIGA Mark II reactor
  - samples are inserted to the core through vertical channels from the reactor platform

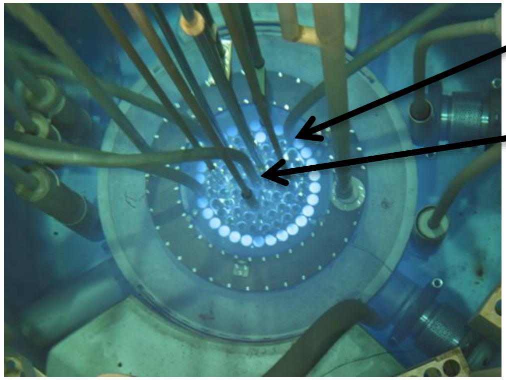


TIC channel
ϕ_{max} = **3.6 ·10^{12} n$_{eq}$cm^{-2}s^{-1}**



TIC channel shape

- core (under ~ 5 m of water)

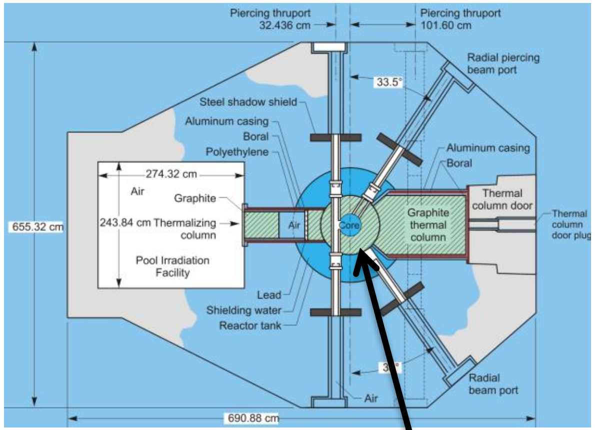


Chanel F19
ϕ_{max} = **1.5·10^{12} n$_{eq}$cm^{-2}s^{-1}**

Central channel
ϕ_{max} = **6 .7·10^{12} n$_{eq}$cm^{-2}s^{-1}**

Irradiation containers

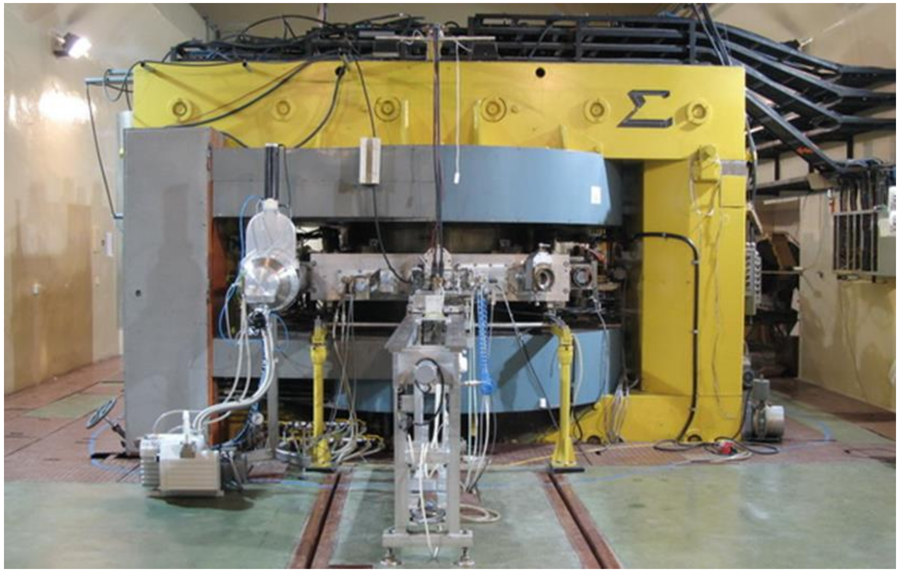
- horizontal channel for larger objects (AIDA WP15.5)
- ϕ_{max} = **4.8 ·10^{11} n$_{eq}$cm^{-2}s^{-1}**

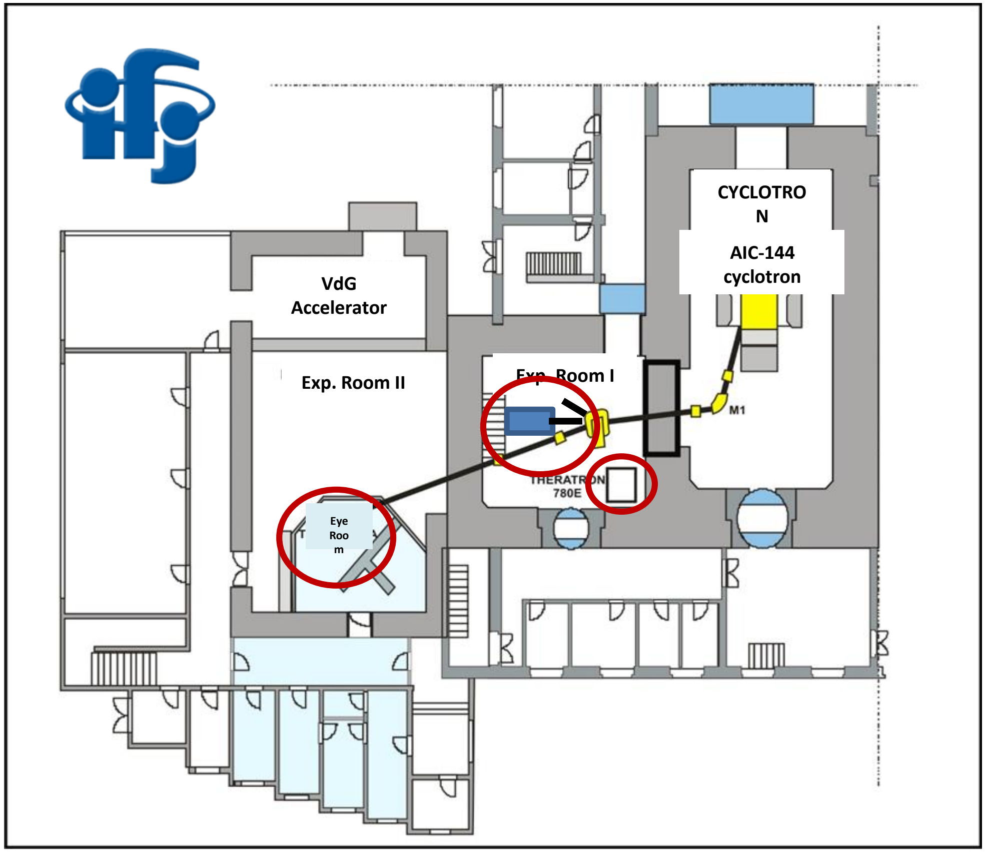


- sample inserted next to the core from the side

4.3.4. IFJ PAN AIC-144 cyclotron facility

- AIC-144 cyclotron



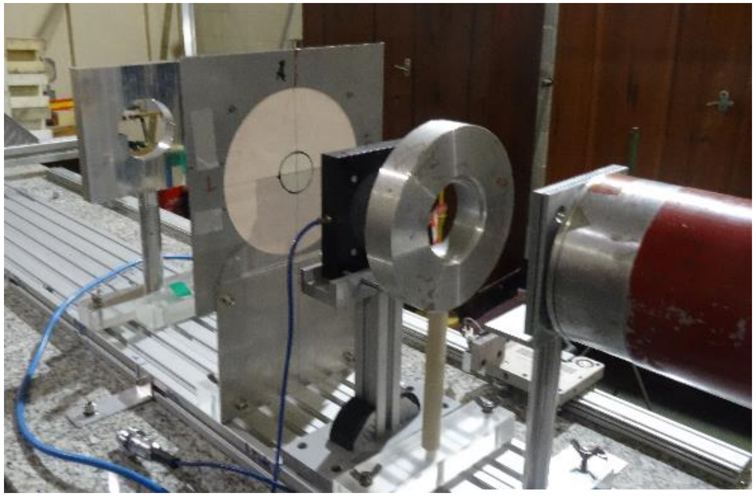


BEAM PARAMETERS:
Energy 60 MeV; RF 26.26 MHz;
Beam macro structure 50 Hz, macro pulse length 0.5 ms, beam current 80 nA *(110nA)*

4.3.4. IFJ PAN AIC-144 cyclotron facility

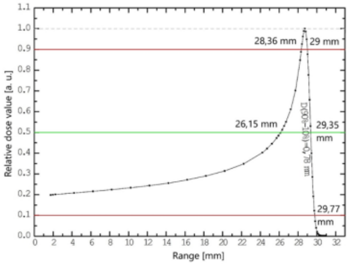
- IFJ PAN Optical lines at the AIC-144 cyclotron building

Exp. Room I ***/Small field horizontal beam line/***

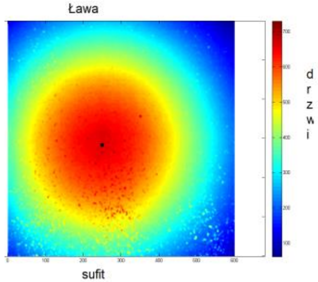


Exp. Room II ***/Small field horizontal beam line/***

Energy: 60 MeV (*10MeV-60MeV*);
Proton beam current: 2nA – 100nA;
Transmission to the experimental room 60-65% of extracted beam;
Spot size: ~ 10mm (1σ, estimated);
Flatness ≥ 15% (±10%);
High proton beam intensity and irradiation field configuration flexibility;



Depth dose distribution



Beam profile

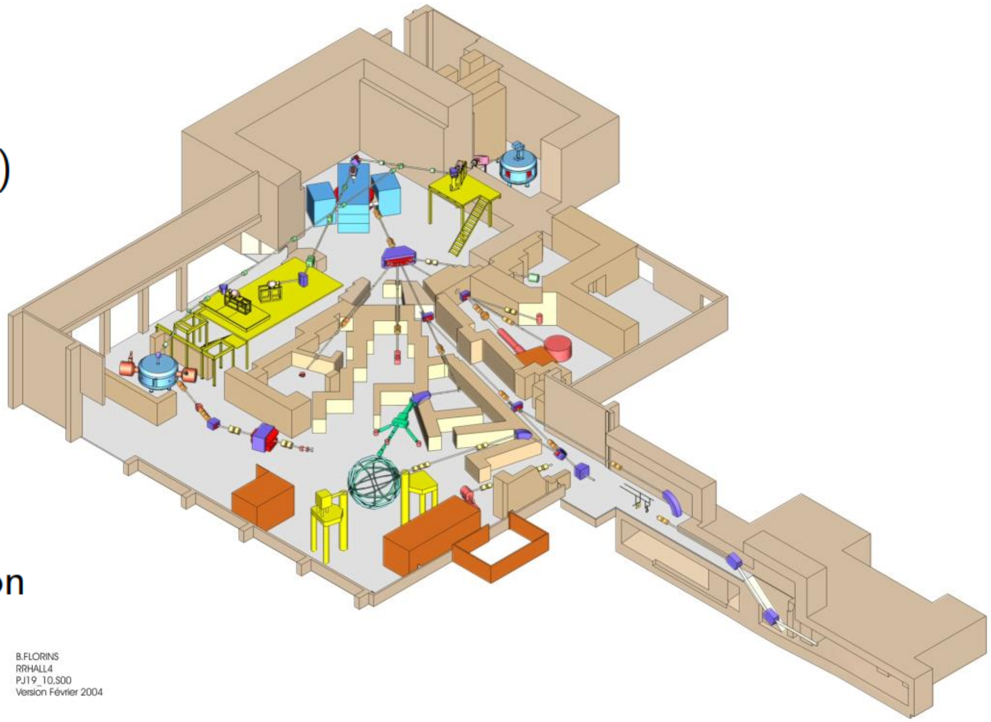
Energy: 0-58 MeV;
Dose rate: 0.001 – 1 Gy/s (measured in water);
Single scattering;
Beam field size: ≤ 40 mm;
Field homogeneity ≥ 5%;
Min flux of protons: 5e5 p/cm2·s (50MeV);
Typical flux: 1e8 – 1e9 p/cm2·s;
Irradiation in SOBP available;
Sample positioning precision (> 0.1 mm);

4.3.5. CRC facilities at Louvain-la-Neuve

- Centre de Ressources du Cyclotron (CRC)
  - Institut de Recherche en Mathématique et Physique (IRMP)
  - Center for Cosmology, Particle Physics and Phenomenology (CP3)

Three irradiation facilities focused in measuring the response of electronic components to single event effects

- NIF: Neutron Irradiation Facility
  - Broad spectrum neutrons (0-50 MeV)
  - Flux: $3 \times 10^9 n/(cm^2\ s)$
- LIF: Proton Irradiation Facility
  - Protons 10-62 MeV
  - Flux: $2 \times 10^8 p/(cm^2\ s)$
- HIF: Heavy-Ion Irradiation Facility
  - Heavy Ion "cocktail"
  - Electronic failures induced by radiation



4.3.5. CRC facilities at Louvain-la-Neuve

HIF characteristics

- Heavy ion cocktail covering a wide range of LET and ranges.
  - Fully characterisation of SEE response of electronic components.
  - Fast ion changing (few minutes)
- Beam flux is variable between a few ions/s.cm^2 and $\sim 10^4$ ions/s.cm^2
  - Online monitoring $\rightarrow$ high precision in fluence delivered
- Redundant metrology
  - Fluence and energy
  - Moving frame, alignment system
  - ESA SEU monitor: 4x4 Mbit SRAM (Atmel AT60142F) arranged in a square region of 24mm x 24mm
- Beam homogeneity of 10% on a 25 mm diameter.
- Standard mechanical interface and feedthroughs
- Irradiations are done in vacuum and for most of the ions naked chips are needed.

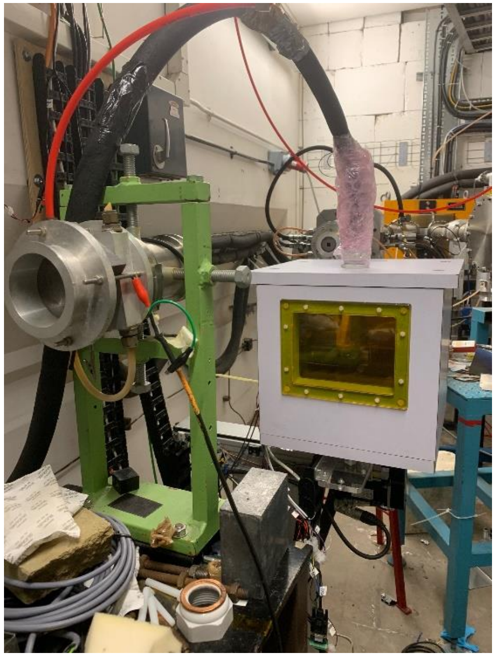
4.3.5. CRC facilities at Louvain-la-Neuve

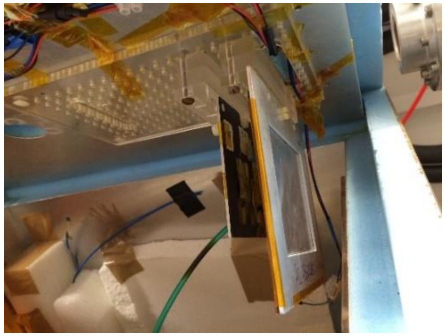
HIF "cocktail"

M/Q	Ion	DUT energy [MeV]	Range [μm Si]	LET [MeV/(mg/cm^2)]
3.25	$^{13}C^{4+}$	131	269.3	1.3
3.14	$^{22}Ne^{7+}$	238	202.0	3.3
3.37	$^{27}Al^{8+}$	250	131.2	5.7
3.27	$^{36}Ar^{11+}$	353	114.0	9.9
3.31	$^{53}Cr^{16+}$	505	105.5	16.1
3.22	$^{58}Ni^{18+}$	582	100.5	20.4
3.32	$^{84}Kr^{25+}$	769	94.2	32.4
3.32	$^{103}Rh^{31+}$	957	87.3	46.1
3.54	$^{124}Xe^{35+}$	995	73.1	62.5

4.3.6. UoB MC40 Cyclotron - Birmingham

- **27 MeV** proton beam, operating at a current of **100 – 400 nA.**
- Collimated square beam spot of **10 mm × 10 mm**.
- Samples mounted inside N2 flushed cold box (typ. **RH < 10%**), maintained at **−27C** (possible to reach -40C).
- Cold box mounted on tracking stage capable of both **static positioning** and **periodic scanning** during irradiation.
- 300 µm of Al foil shielding in front box entrance window to block low energy component of beam.
- Samples to be irradiated are mounted on Al plate (2 mm thick) attached to the lid of the cold box.
- Typically able to deliver up to a few 10^{15} n_{eq}/cm^2 over samples of a few cm^2 in one day.





4.3. Irradiation Facilities

- Irradiations
  - 6 RI's covering a broad range of particles and fluences
  - special campaigns foreseen for 1e17++ ballpark

Infrastructure short name	Sub-task number	Installation name	Source	Particle	Energy (in MeV)	Φ_{Max} part $s^{-1}cm^{-2}$
CERN	4.3.1	IRRAD	PS	Protons	24000	10^{10}
	4.3.2	GIF++	^{137}Cs	Gamma	0.662	14 TBq
JSI	4.3.3	TRIGA Mark III	Reactor	Neutrons	<10 (Watt spectrum)	6.7×10^{12} n_{eq}
IFJ_PAN	4.3.4	AIC-144 Cyclotron	Cyclotron	Protons	10-60	10^{12}
UCLouvain	4.3.5	CRC NIF, LIF, HIF	Cyclotron	Neutrons	0-50 (cont.)	3×10^{9}
				Protons	10-62	2×10^{8}
				Heavy Ions	110 Q^2/M	10^{4}
UoB	4.3.6	MC40 Cyclotron	Cyclotron	Protons	27	3×10^{12}

WP4.3 Deliverables

- Each RI delivers Access Units (~beam hours) to Projects with Users
- Two access modes: physical/remote access
  - Physical: users at RI (user support)
  - Remote: users send samples to RI (handling, shipment)

Task	WP name	Institute	Facility	Access Units	Users	Projects	User support
Test Beams	WP4.1.1	CERN	PS & SPS	8736	504	56	yes
	WP4.1.2	DESY	TESTBEAM	8640	120	30	yes
	WP4.1.3	PSI	PiM1/UCN	5376	136	32	yes
Detector Characterization	WP4.2.1	RBI	RBI-AF	504	24	12	yes
	WP4.2.2	ITAINNOVA	EMCLab	800	56	14	yes
Irradiations	WP4.3.1	CERN	IRRAD	4000	65	16	yes/remote
	WP4.3.2	CERN	GIF++	4060	74	14	yes
	WP4.3.3	JSI	TRIGA	700	150	50	remote
	WP4.3.4	IFJ-PAN	AIC-144	800	140	28	yes/remote
	WP4.3.5	UCL	HIF/LIF/NIF	100	20	10	yes
	WP4.3.6	UoB	MC40	300	36	12	remote

Task 4.3 Budget

Task name	WP label	EC + CH + UK	EC
Test Beams	WP4.1	1,033,300	855,175
Detector Characterization	WP4.2	236,420	236,420
Irradiations	WP4.3	1,074,713	908263
Service Improvements	WP4.4	740,675	606,800
Total Budget	**WP4**	**3,085,108**	**2,606,658**

- EC allocation for Task 4.3. of 908 kEUR
  – Supplemented by CH and UK contributions from their national funds to reach 1 MCHF.

How to Apply for TA?

Point of discussion for the kick-off meeting

- Single entry point foreseen
  - EURO-LABS web page in development
- Generic review procedure in WP4:
  - *The scientific RI coordinator checks the technical requirements and eligibility of applications. Then the **EURO-LABS WP4 User Selection Panel** gets notified the application and decides on the allocation of resources.*
- Some facilities require additional approval by their Scientific Committees (CERN, PSI…)
  - e.g. CERN:
    - *The selection of users proceeds through the review procedure that is already in place at CERN: Requests for more than two weeks (one week) of beam time at the PS (SPS) have to be examined and recommended by the "PS and SPS experiments committee"; those requests which concern R&D projects for the upgrade of LHC experiments are considered by the "LHC experiments committee". Both are international committees composed of well-known experts in particle physics, they meet typically five times per year and report to the CERN "Research Board". Shorter requests for beam time are usually easier to fulfil. They are examined, in accordance with the present CERN procedure, by the "CERN PS and SPS physics coordinator". Where appropriate the requests are discussed with the DESY and PSI test beam coordinators and the EURO-LABS management. In all cases, the selected requests for test beam at the PS or SPS are sent to the USP for endorsement and allocation of EURO-LABS resources.*

4.3. Summary

- EURO-LABS from HEP detector perspective
  - TA complement to AIDAinnova
  - follow up of successful TA in AIDA and AIDA2020

- **Access to irradiation facilities tailored to HEP detector R&D**
  - 6 first class European irradiation facilities participating
    - **CERN IRRAD facility** (Geneva, Switzlerand)
    - **CERN GIF++ facility** (Geneva, Switzerland)
    - **JSI TRIGA reactor** (Ljubljana, Slovenia)
    - **IFJ PAN AIC-144 cyclotron** (Kraków, Poland)
    - **UCLouvain CRC** (Louvain-la-Neuve, Belgium)
    - **Birmingham MC40 Cyclotron** (Birmingham, UK)
  - Offering **9960 AU = 9960 hours of irradiation** in the coming 4 years **free of charge!**

SPARE SLIDES

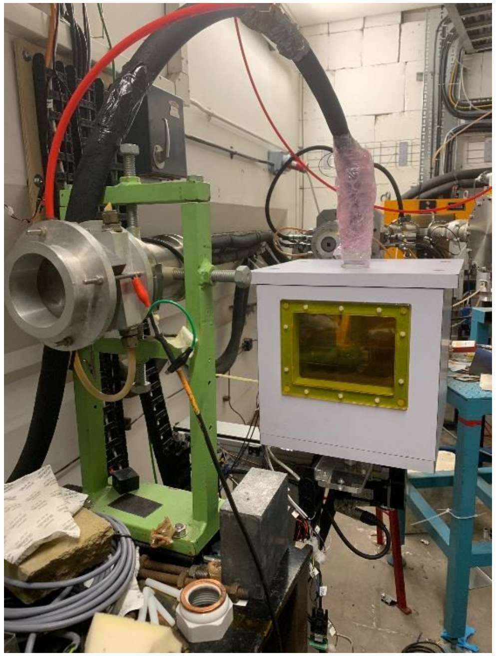
WP4.4 Service Improvements

- Aimed at improving access to RI for EURO-LABS
  - Each RI proposed improvements with maximum impact on user access
  - Improvements have to be ready in Y2 of the project
  - EC contributions are matched by RI's own funding, typically exceeding EC
  - Supplemented by WP4 (!) of AIDAinnova

CERN TB, IRRAD & GIF++	Data base handling of beam time and irradiation requests
DESY Test Beams	Precision motion stages for large detector setups
PSI Test Beams	Beam monitor
RBI-AF	Ion beam focusing lens
ITAINNOVA	Cooling System and Graphical User Interface for EMC test station
CERN IRRAD	Beam profile monitor
JSI TRIGA	Cadmium shielding in the tangential channel
IFJ PAN AIC-144	2-D scanning table for irradiation
UCL CRC	Test chamber for the heavy ion irradiation facility
UoB MC40	Scanning system upgrade for high fluence delivery

4.3.6. UoB MC40 Cyclotron - Birmingham

- Within EURO-LABS UoB will be offering 300 hours of beam time.
  - One day per month
- Typically able to deliver up to a few 10^{15} n_{eq}/cm^2 over samples of a few cm^2 in one day.



- Service improvements planned to reach higher fluences (see task 4.4.).
  - Higher scanning speed, improved cooling to fully exploit beam current capability (up to 1uA).
  - Aim to have upgrade completed at M24.