FRAISE: THE NEW FRAGMENT IN-FLIGHT SEPARATOR AT INFN-LNS

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The study of exotic nuclei is presently a challenge for nuclear physics. Indeed, exotic nuclei properties are useful to investigate nuclear structure models, features of the nuclear force and nuclear reactions important for nuclear astrophysics. These investigations can be helpful also to add a further constraint to the knowledge of the Equation of State of nuclear matter. Within this framework, various facilities have been developed worldwide with the aim to deliver Radioactive Ion Beams (RIBs). In the last 15 years, at Laboratori Nazionali del Sud of INFN (INFN-LNS) RIBs have been produced through the In-Flight Fragmentation method, using the in Flight Radioactive Ion Beams at LNS (FRIBs@LNS) facility. Presently, the ongoing project of the LNS (POTLNS), based on an upgrade of the Superconducting Cyclotron, aims to deliver light and medium masses nuclei with a power up to ≈ 10 kW. This project has brought a new perspective also for the production of RIBs. Indeed, the building of a new fragment separator, named FraISe (Fragment In-flight Separator), is underway to exploit primary beams with power of 2-3 kW for the production of high-intensity RIBs . We report the status and the perspectives of the FraISe facility. Moreover, R&D studies for new diagnostics and tagging devices will be also discussed.

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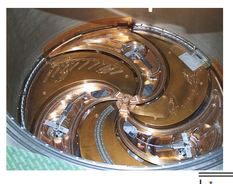
The **POTLNS project (https://potlns.lns.infn.it/it/)** aims at the production of high intensity ion beams and it consists of a set of upgrade actions of existing and operating devices designed for the basic research in Nuclear Physics

The upgrade of the Superconductive Cyclotron will provide stable ion beams with a power up to 10 kW . This will allow to obtain beams, for intermediate energies and for ions from carbon to argon, with intensity up to 10^{13} – 10^{14} pps

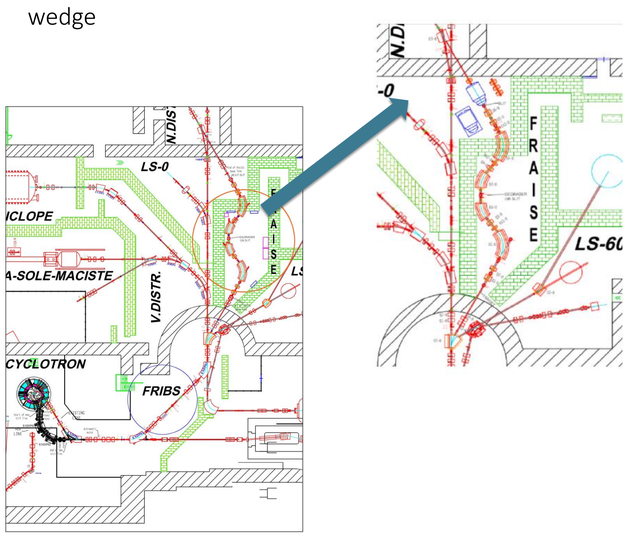


Ion	Energy (MeV/u)	Isource ($e\mu A$)	Iextr ($e\mu A$)	Iextr (pps)	Pextr (W)
$^{12}C^{5+}$	30	200	45 (6+)	4,7E+13	2700
$^{12}C^{4+}$	45	400	90 (6+)	9,4E+13	8100
$^{12}C^{4+}$	60	400	90 (6+)	9,4E+13	10800
$^{18}C^{6+}$	20	400	80 (8+)	6,2E+13	3600
$^{18}C^{6+}$	29	400	80 (8+)	6,2E+13	5220
$^{18}C^{6+}$	45	400	80 (8+)	6,2E+13	8100
$^{18}C^{6+}$	60	400	80 (8+)	6,2E+13	10800
$^{18}C^{7+}$	70	200	34.3 (8+)	2,7E+13	5400
$^{20}Ne^{7+}$	28	400	85.7 (10+)	5,3E+13	4800
$^{20}Ne^{7+}$	70	400	85.7 (10+)	5,3E+13	10280
$^{40}Ar^{14+}$	60	400	77.1 (18+)	2,7E+13	10280

P. Russotto et al., Journ. of Phys. Conf. Ser. 1014 (2018) 012016

FRAISE: a new FRAgment In-Flight SEparator @INFN-LNS

- 4 dipoles and 6 quadrupoles, arranged in a symmetrical configuration and 2 sextupoles to adjust the aberration effect
- maximum magnetic rigidity 3.2 *Tm*
- possibility of almost pure secondary beams through the use of a wedge

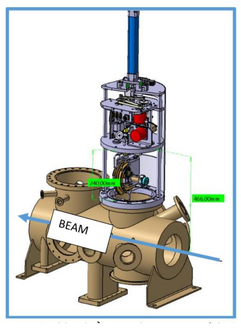


New fragmentation target

Also a new production target, copy of CLIM **(S. Grévy and R. Hue, in *24th World Conference of the International Nuclear Target Development Society - INTDS2008*, (Caen, France), Sep 2008)** will be used in the FRAISE facility

The target will be significantly activated, after and during experiments, and it will be impossible to remove it manually →a remote control system will be used in order to automatically proceed with the replacement of the target and its storage in an appropriate area

- Material target Beryllium or Carbon
- Thickness 100 to 1500 µm
- Max beam power 3 kW
- Max beam power deposited in the target 500 W
- Size of the beam deposited in the target is 1.5-5 mm^2
- Target rotation speed: 2000 revs/min



FRAISE diagnostics and tagging systems

Also a revision and improvement of the diagnostics and tagging systems are needed to measure features of the RIBs (Radioactive Ion Beams)→ **the systems will be versatile and useful for FRAISE and other facilities (i.e. GANIL)**

Inside a Fragment Separator:

- Need of a point-to-point measurement of cocktail intensity, relative composition, energy distribution, 2D profile, angular distribution during optimization
- Monitoring of beam properties, start time for event-by-event ToF/energy measurement during data taking

In the final set-up point:

- Need of event-by-event tagging of cocktail beam and trajectory measurement

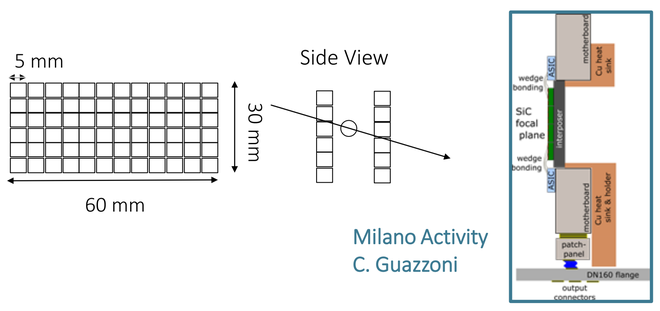
SiC is the new emerging technology for the future sensing and electronic devices fabrication

In the last years R&D on these materials and technologies was carried out @INFN

A feasibility study has already started, performing simulations and preliminary tests in order to evaluate the possibility of using SiC detectors

What we want to develop:

array of detectors based on SiC technology→ the single detection unity pad will be 5 × 5 mm^2 and 100 µm thick fully depleted SiC rad-hard multi-pad sensors: up to 10^7 pps over ≈ 144 channels with Δt ≈ 100 ps (≈0.1% precision on energy for 20 m base-of-flight) if 200 µm inter-pad dead zone, 10% dead area



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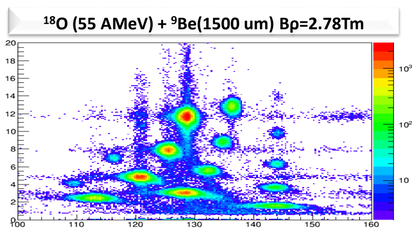
Tagging device for the CHIMERA beam line

actual CHIMERA line tagging for FRIBs facility: event-by-event tagging of cocktail beam, ΔE-ToF with MCP-DSSSD

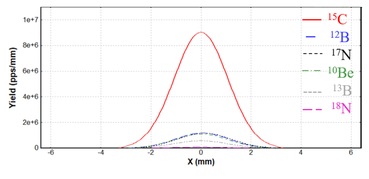


MCP: up to 10^5 pps, Δt ≈ 200-300 ps
DSSSD: max rate 200 kHz, but worsening of performances in ≈1 week with medium mass beam at 30 kHz; Overall Δt <≈1 ns
I. Lombardo et al., NIMB 215, 2011

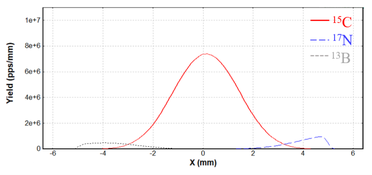
future CHIMERA line tagging for FRAISE: array of SiC detectors→ similar to diagnostics system

- Front-end: Custom multi/channel ASIC with charge preamplifier configuration and analog preprocessing optimized for amplitude and time measurements
- Full waveform digitizers and synchronization with CHIMERA/FARCOS DAQ

We performed also LISE++ simulations→ example of physics case: ^{18}O primary beam at 55 MeV/nucleon, 2 kW on a ^{9}Be target (1250 µm)

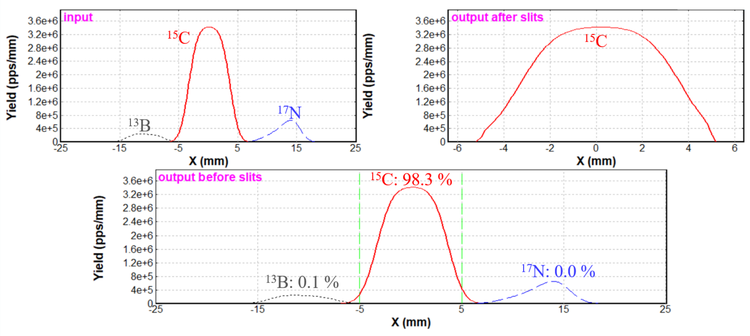


Simulation of spatial distribution of beam components, using a SiC detector placed after the exit slit

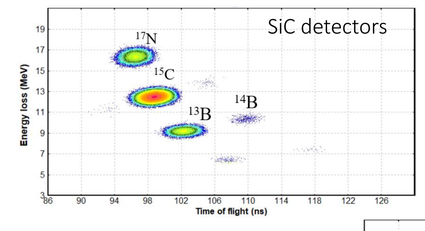


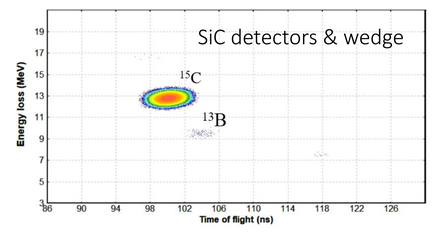
Simulation of spatial distribution using two SiC detectors, placed after the central and after the exit slit, respectively

In order to obtain a more pure beam and to completely avoid other contaminants, it is possible to insert a passive Al wedge with an optimized thickness



Using the ΔE-TOF method in which the first SiC detector provides the start signal and the second SiC the stop and the energy loss, one can obtain the identification of the cocktail beam





Tests with SiC detectors

First tests using 10 µm SiC detectors have been performed at INFN-LNS and Dipartimento di Fisica e Astronomia, "Ettore Majorana" using three peaks mixed α source

FEBEX digital electronics

Rotation angle ϑ=60

Perspectives

- Tests of new SiC prototypes 2021-2022
- Final project of electronic system devices (September 2022)
- Batch production 2022/2023

References

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