Nuclear sizes and density distributions

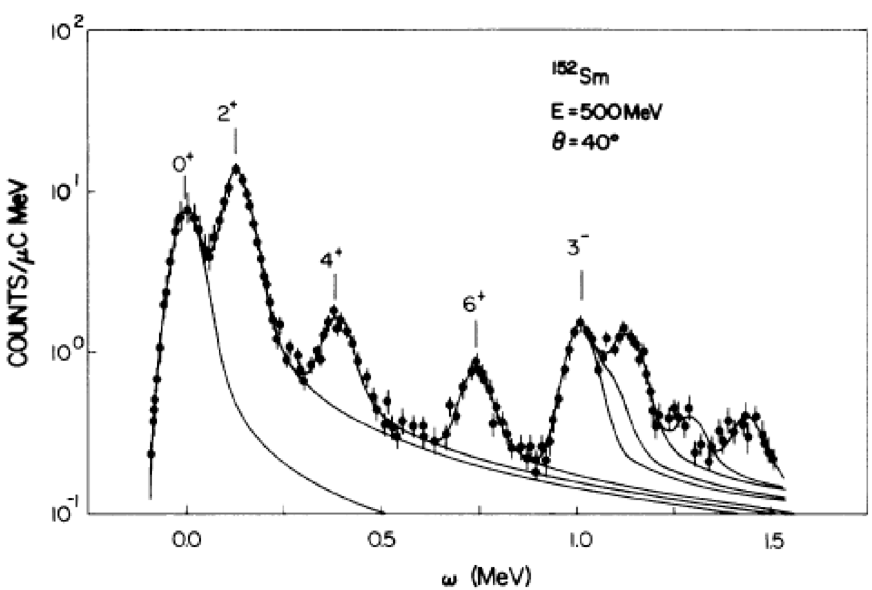
OBSERVABLES

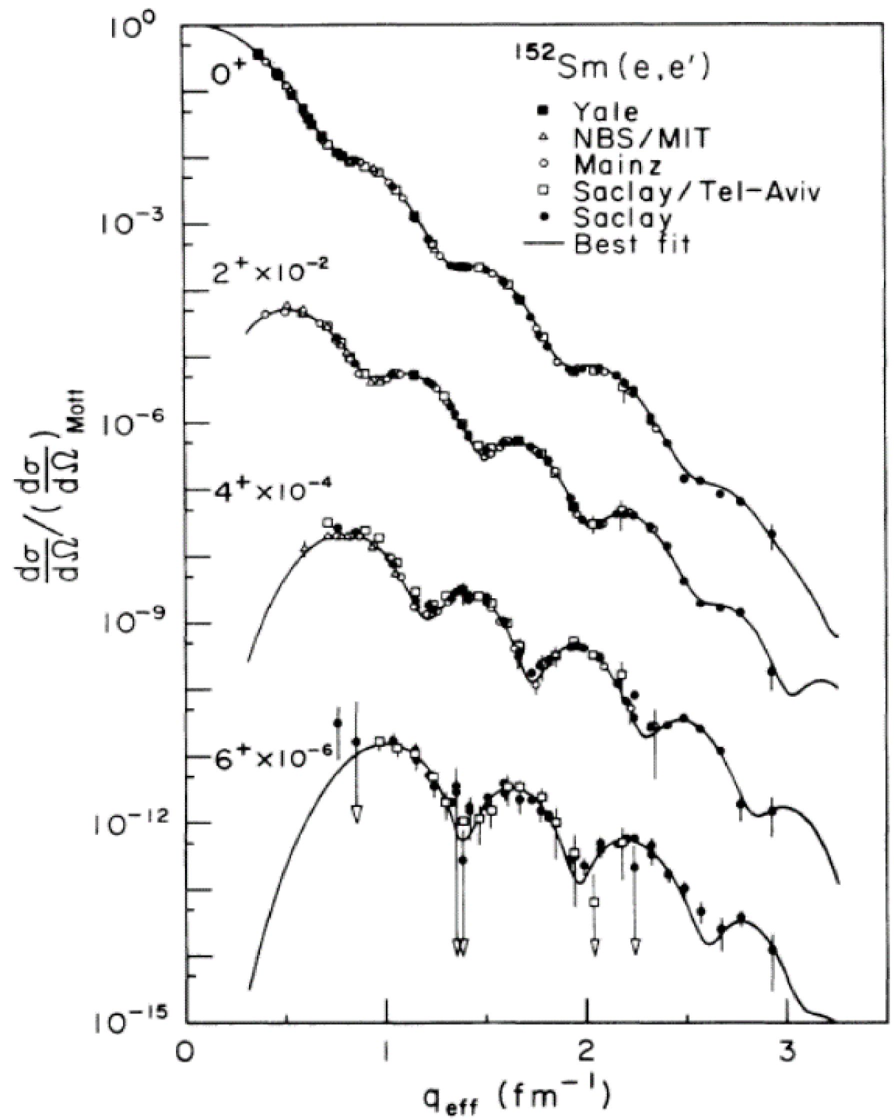
Observables **deduced quantities**	**Reactions** *(q: momentum transfer)*	**Type of nucleus**	**Required luminosity L**
r.m.s. charge radii	**(e,e)** *elastic at small q*	Light ($Z^2 \leq 100$)	L: 10^{24} $cm^{-2}s^{-1}$
Charge density distribution with 2 parameters ρ_{ch}	**(e,e)** *First min. in elastic form factor*	Light Medium Heavy	**L: 10^{28} 10^{26} $cm^{-2}s^{-1}$** **10^{24}**
Charge density distribution with 3 parameters ρ_{ch}	**(e,e)** *2^{nd} min. in elastic form factor*	Medium Heavy	**L: 10^{29} $cm^{-2}s^{-1}$** **10^{26}**
F_L, F_T Magnetic form factors→ Proton, neutron transition densities *Direct access to neutron-skin*	**(e,e)** *2^{nd} min. in elastic form factor*	Odd-even Medium Heavy	**L: $10^{30}$$cm^{-2}s^{-1}$** **$10^{29}$**
Energy spectra, width, strength, decays, collective excitations	**(e,e')**	Medium-Heavy	L: $10^{28\text{-}29}$ $cm^{-2}s^{-1}$
Extraction of the density distribution *using functionals (series of Fourier-Bessel functions ...)*	**(e,e)** **(e,e')**	Light Medium-Heavy	**(e,e) (e,e') L : $10^{30\text{-}31}$** **(e,e) (e,e') L ~$10^{29\text{-}30}$**
Spectral functions, correlations	**(e,e'p)**		$10^{30\text{-}31}$ **(e,e'p) L ~$10^{30\text{-}31}$** $cm^{-2}s^{-1}$

(e,e') experiments for gs and proton transition densities

152Sm 0+ gs
2+ 121.7818 keV 1.403 ns
4+ 366.4793 9 57.7 ps
0+ 684.751 21 6.10 ps
6+ 706.928 17
2+ 810.453 5
3- 1041.122 4

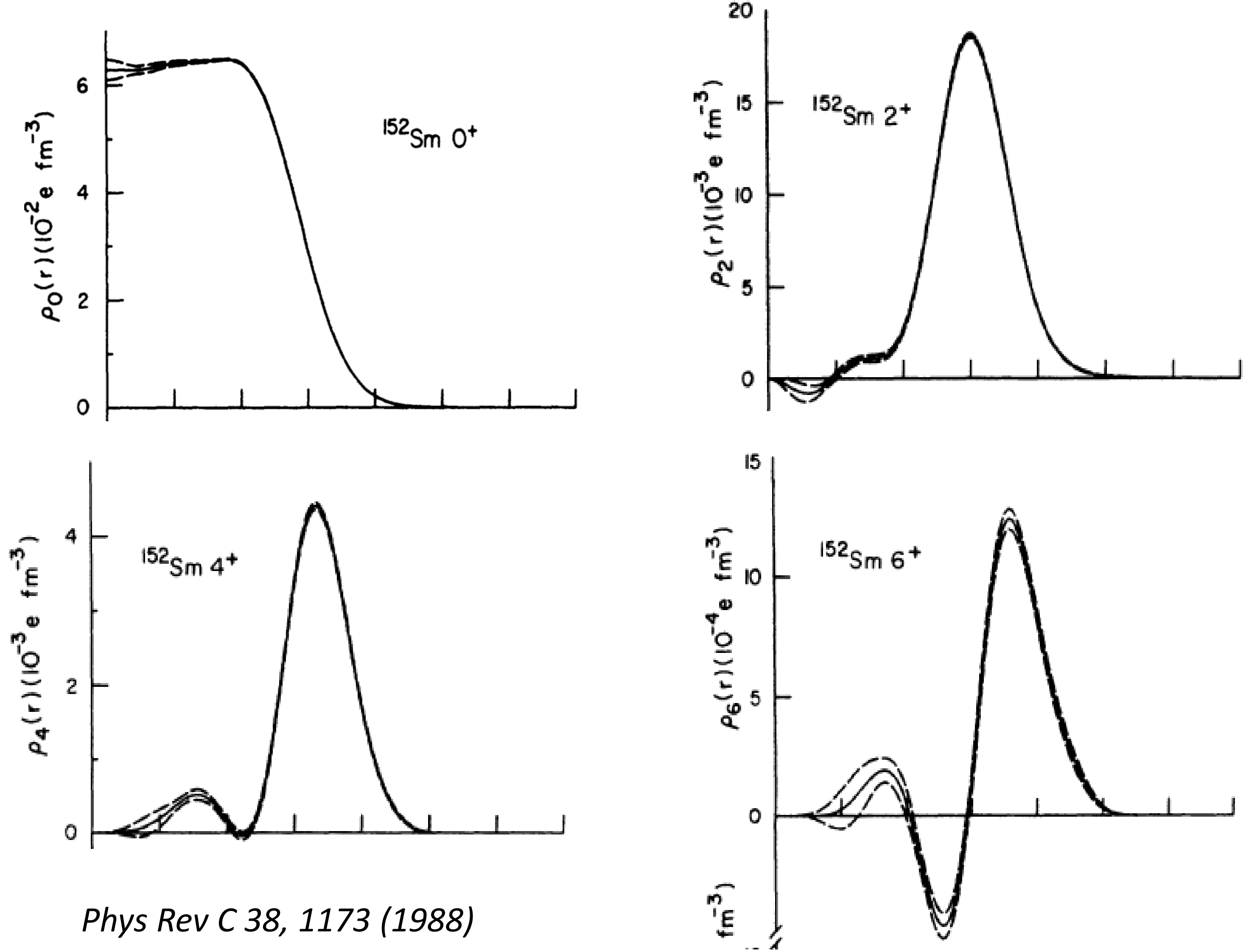
Phys Rev C 38, 1173 (1988)



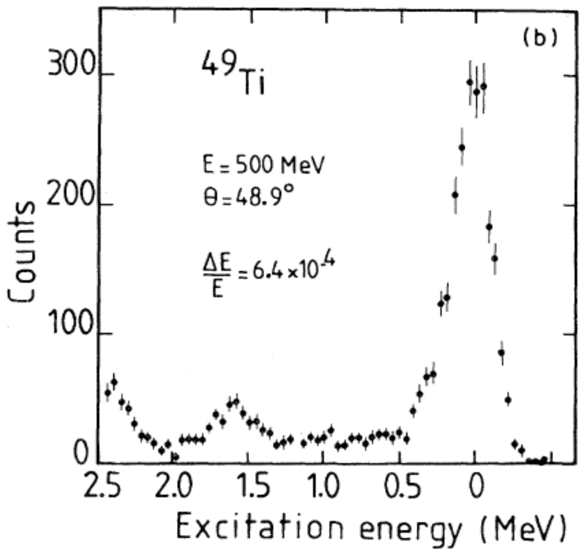


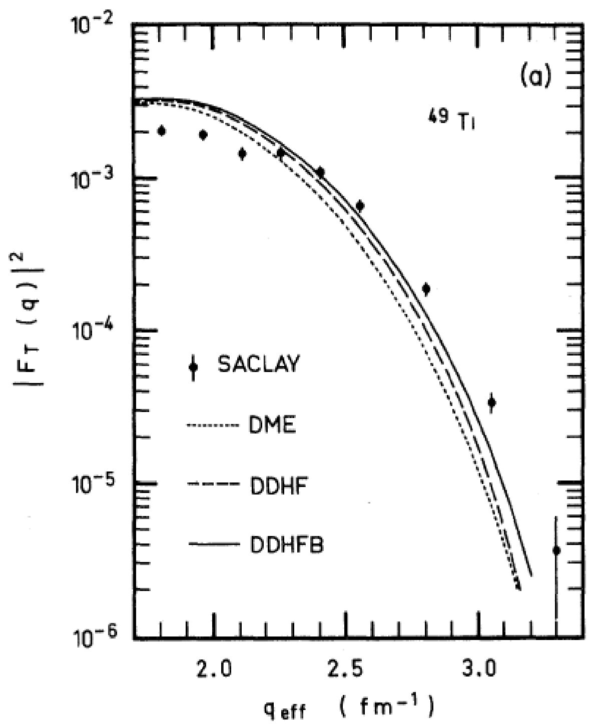
gs and proton transition densities from (e,e’) experiments

Transition charge densities for 0+, 2+, 4+, 6+
Comparison with a triaxial DD HFB calculation



Phys Rev C 38, 1173 (1988)





Neutron wave functions

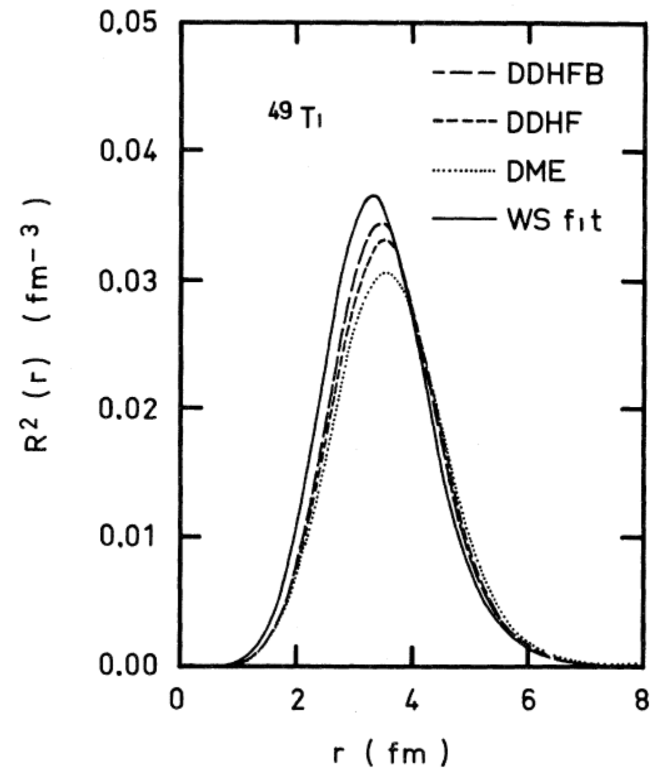


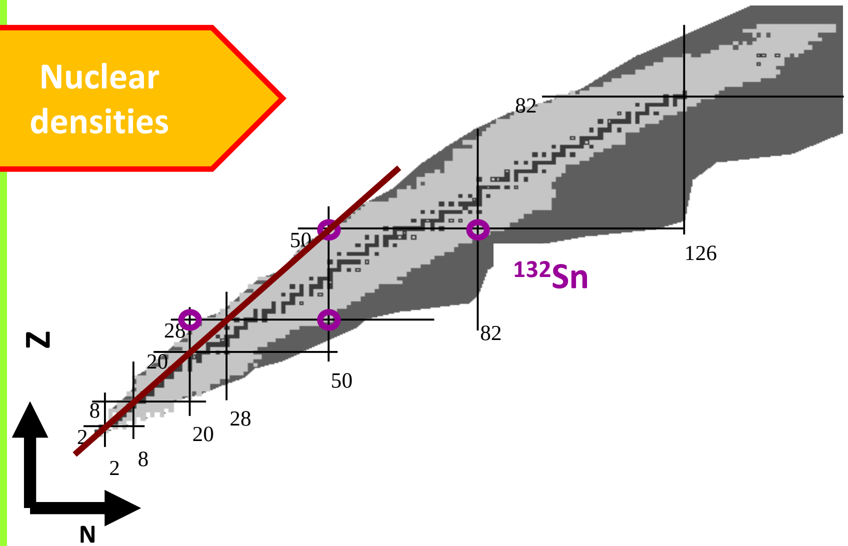
FIG. 17. $1f_{7/2}$ neutron wave functions of ^{49}Ti. The WS fit (solid line) is compared to DME (dotted), DDHF (short dashed), and DDHFB (long dashed) calculations.

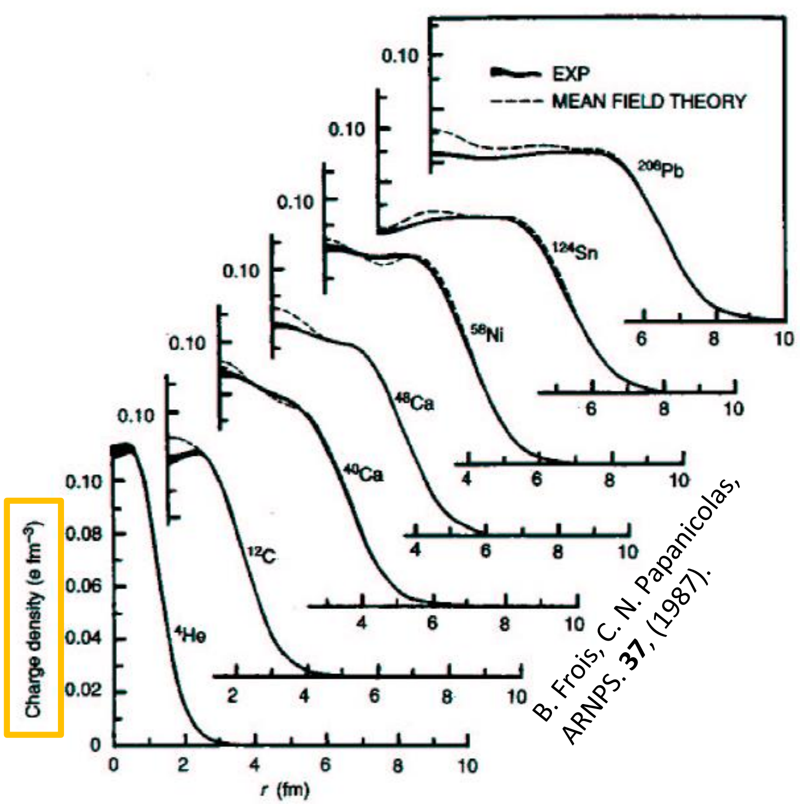
ALS measurements, PRC 25 (1982)

Densities to constrain nuclear theories

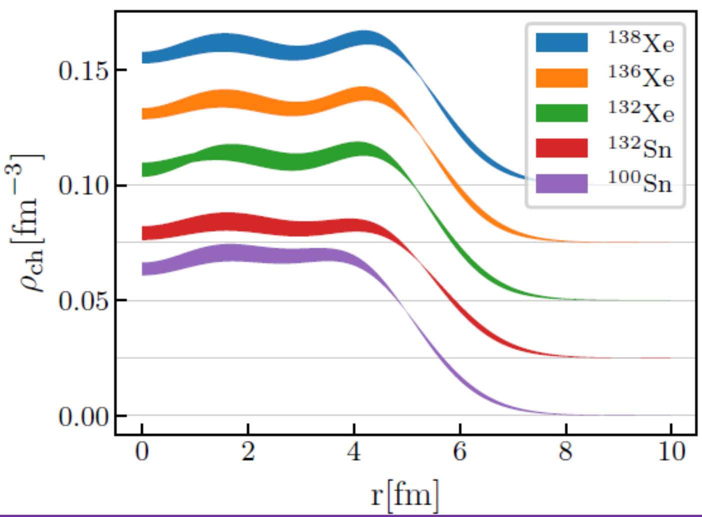
Building blocks of our knowledge on nuclear interactions

Nuclear densities





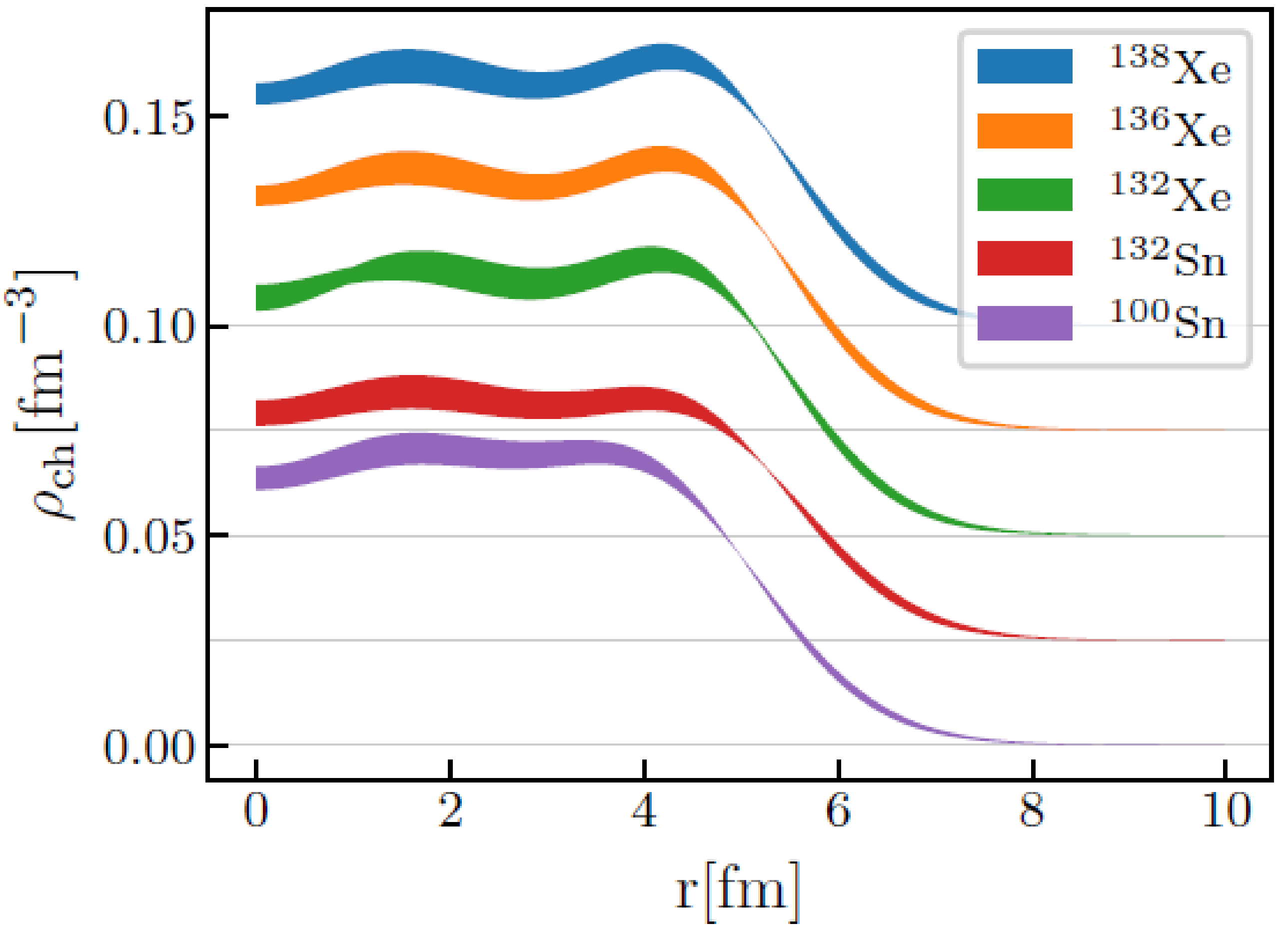
B. Frois, C. N. Papanicolas, ARNPS. **37**, (1987).



P. Arthuis, C. Barbieri ,et al., Arxiv-th:2002.02214v2

2020

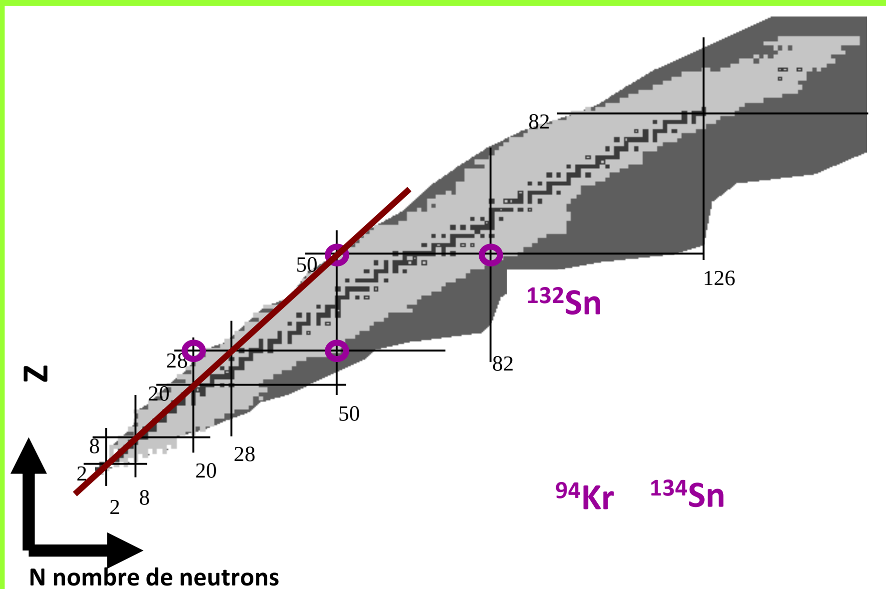
Ab initio computation of charge densities for Sn and Xe isotopes
P. Arthuis, C. Barbieri, M. Vorabbi, P. Finelli
https://arxiv.org/pdf/2002.02214v2.pdf

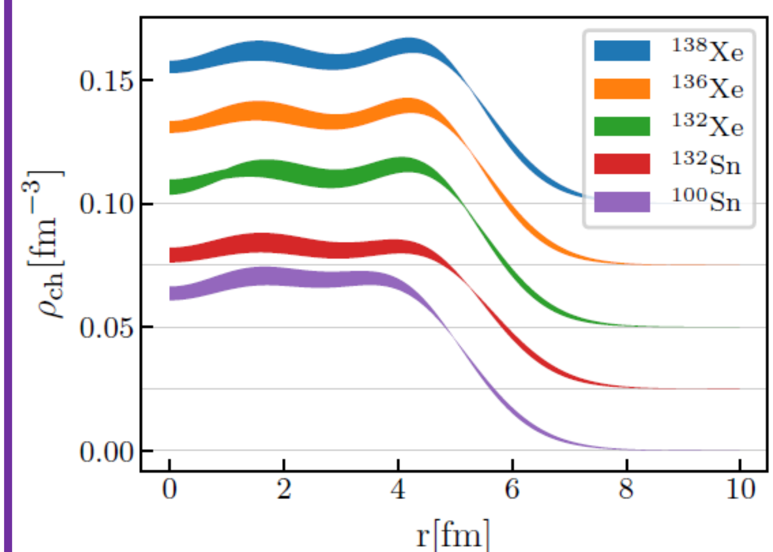


("coloured bands for the theoretical error associated with model space convergence")

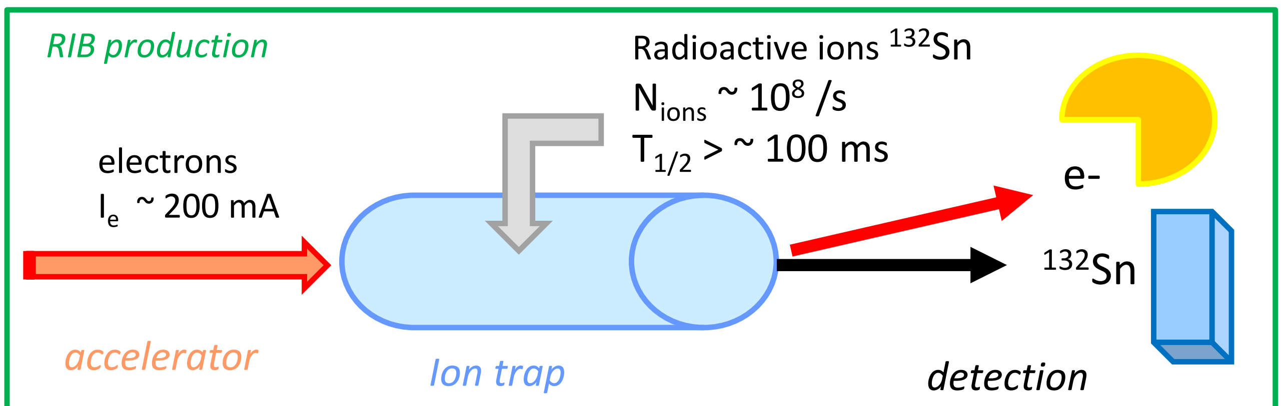
Programme of density measurements for exotic nuclei at GANIL

Table RIB





P. Arthuis, C. Barbieri ,M. Vorabbi, P. Finelli
https://arxiv.org/pdf/2002.02214v2.pdf



Working group

Electron scattering on radioactive ions at GANIL[2]
Grand Accélérateur National d'Ions Lourds et de Leptons

1st December 2020

Authors: A. Chancé[1,*], P. Delahaye[2,#], F. Flavigny[3,μ], V. Lapoux[1,μ], A. Matta[3,μ], V. Somà[1,t]
** engineer-physicist in beam dynamics; # physicist expert of ion trap techniques for beam production, μ physicist in structure studies via experiments of direct nuclear reactions; t physicist in nuclear structure theories*
antoine.chance@cea.fr;pierre.delahaye@ganil.fr;flavigny@lpccaen.in2p3.fr;
valerie.lapoux@cea.fr;matta@lpccaen.in2p3.fr;vittorio.soma@cea.fr

Contributors for discussions and future studies in 2021 about:
Radioactive ion beam RIB production
-multi-nucleon transfer, fusion-evaporation (*V.1, App. D.1*): I. Stefan[5], C. Theisen[1];
-fission; photofission (*V.1, App. D.3-4*): M. Fadil[2]
Radioprotection issues, production building: H. Franberg[2], X. Hulin[2] (***V.3***)
Radioactive ion beam production and interdisciplinary activities (working group): A. Drouart[1], G. de France[2]
Physics cases and ERL: A. Obertelli[4], D. Verney[5]
Discussions about ERL design and beam optics: W. Kaabi[5]

1. CEA-Saclay, Irfu 2. GANIL 3. LPC Caen 4. TU Darmstadt 5. IJCLab

Goals for Nuclear matter densities:
charge density profiles for RI
as done for stable nuclei

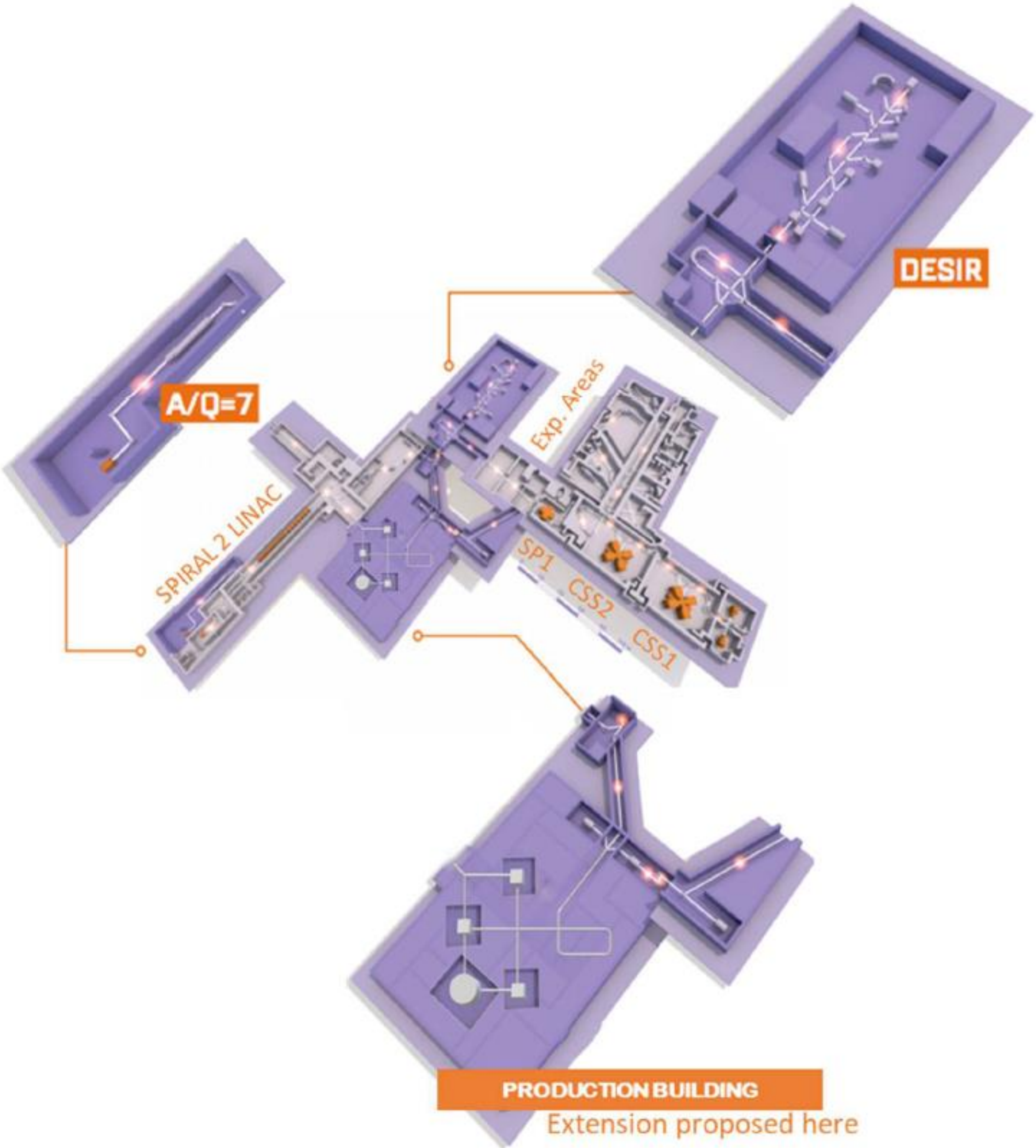
Outline

LIST OF POSSIBLE BEAMS

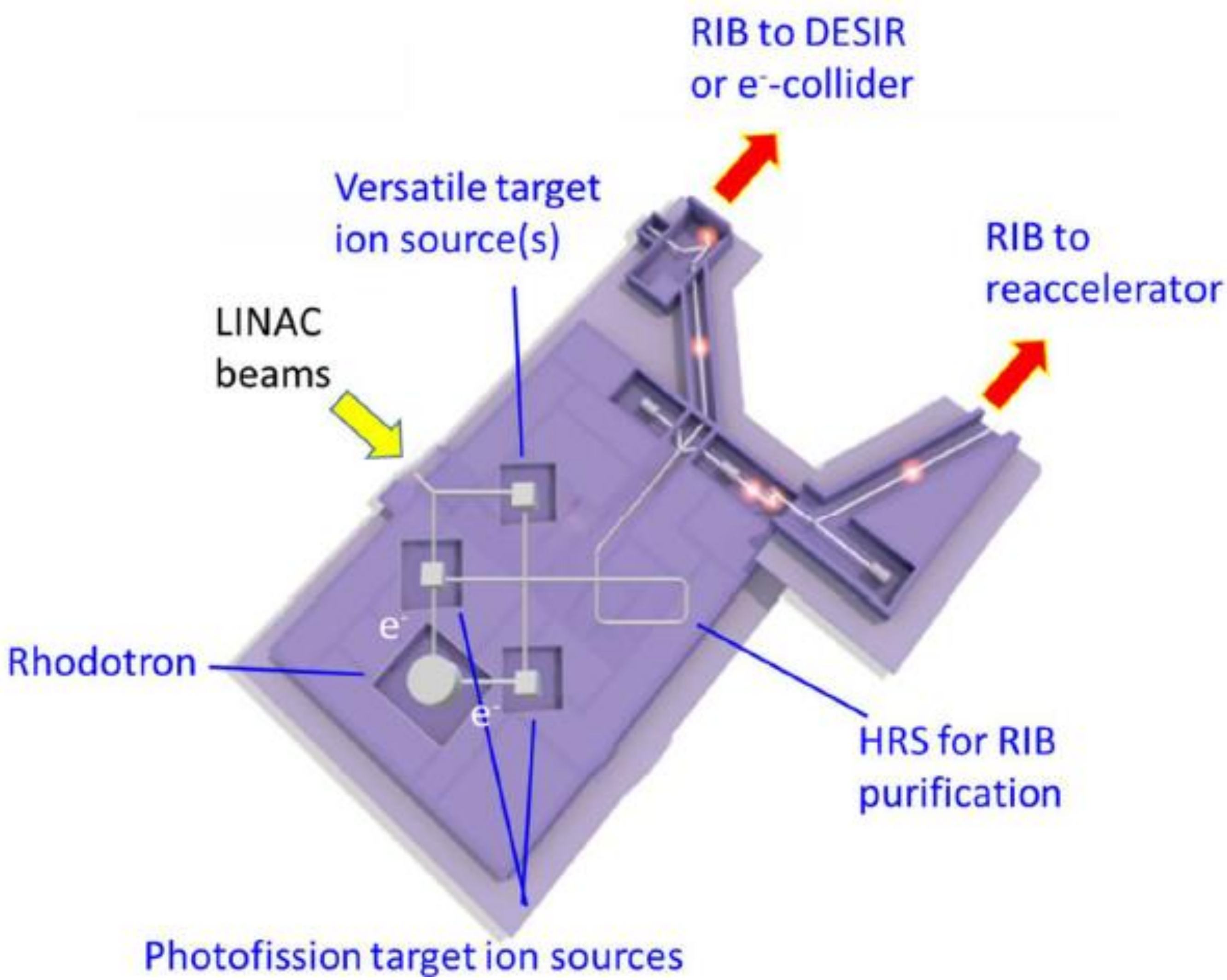
Facility	Beams, Intensities I	Reaction mechanism	When	Comments
SPIRAL 1	A < 80, I up to $\sim 10^9$ /s	Fragmentation	Many are ready, some to develop	Fusion evaporation possible
S3-LEB	Mid-heavy to heavy neutron deficient beams A >40 → ~270 I up to 10^6 /s	Fusion evaporation	Starting on-line development as of 2023 S^3 operation around 2026	
Gas cell/ production cave with **A/q=7 driver**	Light to heavy (N=126) neutron rich beams, with intensities up to 10^6 /s Neutron deficient heavy (A>200) ion beams, I up to 10^8/s Refractory fission fragments	Multinucleon transfer Fusion evaporation in inverse kinematics or using intense proton beams (not possible at S^3) Fusion fission reactions	* After A/q is ready > 2027 * ideally in the production building ~ > 2030?	*See* ***App. D.1*** contribution of C. Theisen
Fission fragments from **LINAC**	70 < A< 150 with intensities up to $\sim 10^9$ pps	Fusion reactions Light particle induced fission (p,d,3He,^{4}He)	Production building, ~> 2030?	See [***sp2Gan***] contribution of Delahaye et al. and ***App. D.3-4***
Fission fragments from **Rhodotron**		Photofission	Production building, ~> 2030?	

*Table V.1. Main production mechanisms as envisaged for the future of GANIL ([****sp2Gan****, ****sp7RFQ****]).*

PROPOSED LAYOUT FOR THE FUTURE OF GANIL

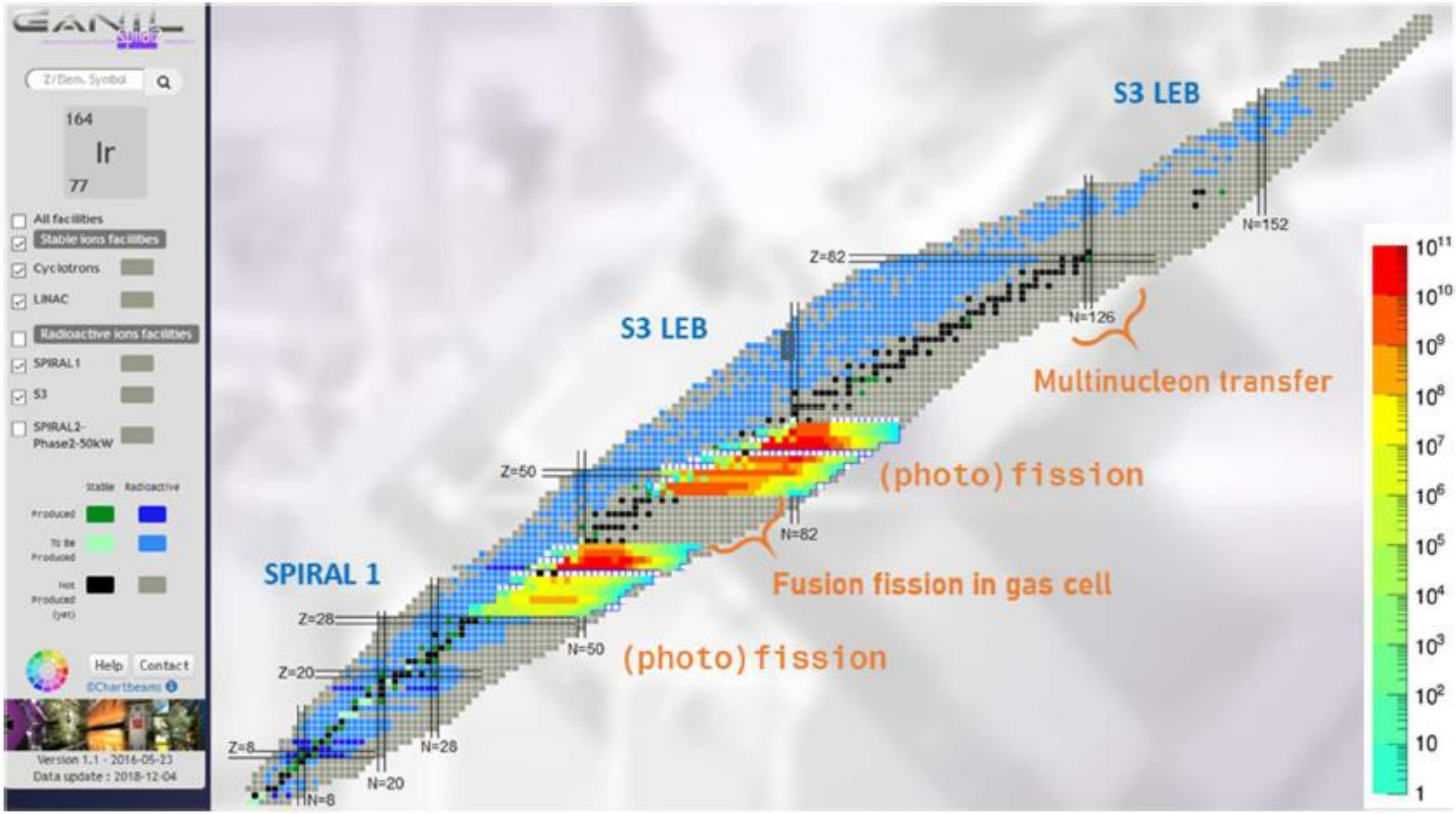


POSSIBLE LAYOUT FOR GANIL INSTALLATION



LIST OF POSSIBLE BEAMS

SPIRAL2 GANIL beams
https://u.ganil-spiral2.eu/chartbeams/



TIMELINE –project for e- RIB collisions

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Collaboration														to 2045++
International	Conceptual Design													
Groups			Photo-Fission source construction					Beam development and exploitation at DESIR						
			Ion trap			Ion trap construction and R&D								PHYSICS
				Electron facility final design					Electron facility construction					PROGRAM
					Detection design and R&D					Detection construction				at
														GANIL2

Letter to the committee "Future of the GANIL", April 2021
Synthesis and update of our proposal "e-RI collisions" for the future of GANIL
Electron scattering on radioactive ions at GANIL. [Research Report] 1st December 2020.
https://indico.in2p3.fr/event/20534/attachments/57082/85464/WG_EP_Dec2020v.pdf
⟨cea-03176547, v1⟩ https://hal-cea.archives-ouvertes.fr/cea-03176547v1

Prospectives 2016, ESNT workshops 2018/2019
2020 Working groups for Ganil future → e-RIB collisions
16 March 2020 – Contribution sent to the scientific committee
(*Lettre de mission des tutelles à M. Spiro*)
June 2020 : 2 WG
Proposal Report sent on Dec 1st, 2020
Authors : CEA Irfu A. Chancé, V. Somà, V. Lapoux,
P. Delahaye (Ganil), F. Flavigny, A. Matta (LPC Caen)
Electron scattering on radioactive ions at GANIL[2]
« *Grand Accélérateur National d'Ions Lourds et de Leptons* »
→ Feasibility : technical options, physics constraints
DAY1 1st measurements: ^{6}He, ^{94}Kr, $^{132-134}$Sn