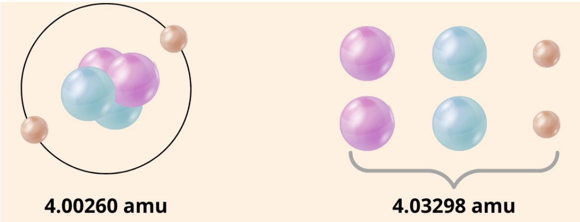
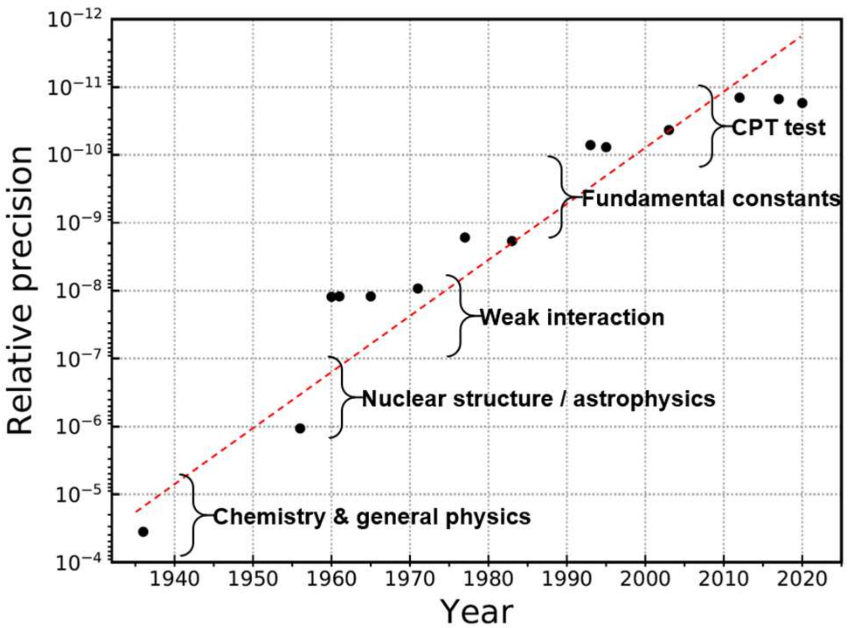
The Atomic Mass Evaluation (AME)
The HINA experiment – Collab TITAN

Sarah Naimi
IJCLab

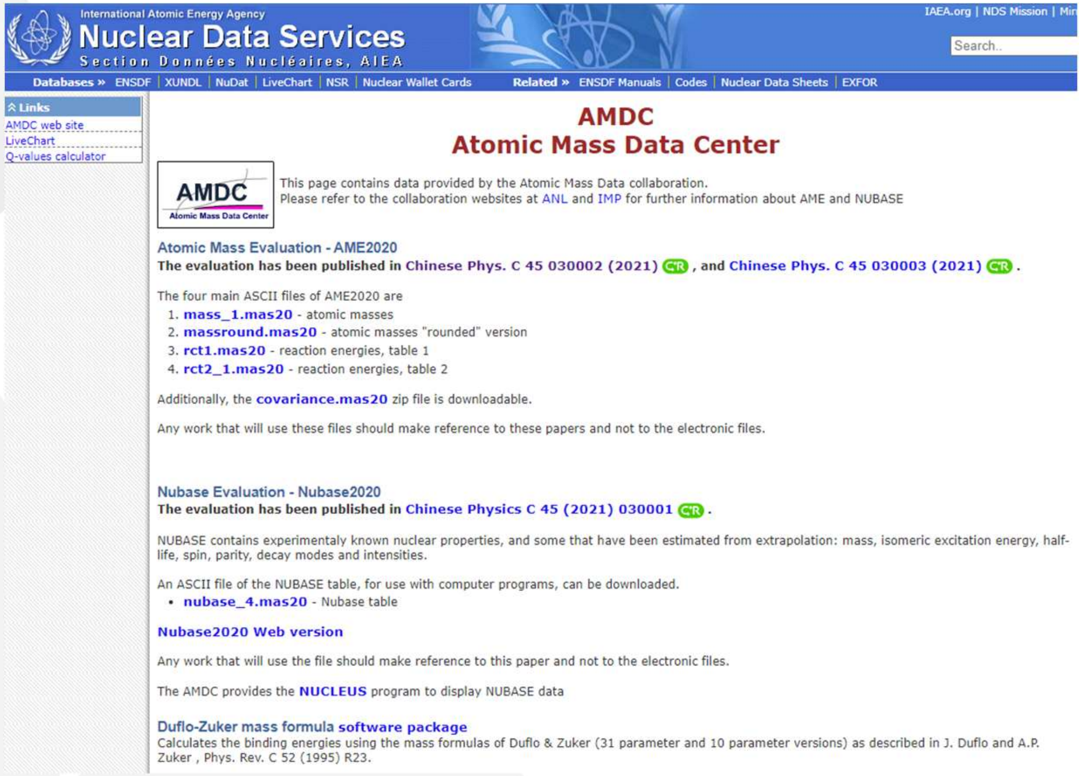
CNRS NPAT IRL Satellite Workshop April 23, 2026

$$AM = Zm_p + Nm_n + Zm_e - BE$$





Where do you get the atomic mass values?



Mass measurement:
☒ absolute mass
☑ connection between masses

All data available for 135Ba

68De17	162731	48	C8 N O H9-135Ba
68De17	117822	77	C11 H3-135Ba
68De17	154160	46	C12 H7-135Ba O
20De20	288.43	0.32	135Cs-135Ba
66Be10	-203860	20	135Ba-C10 H14
66Be10	1177	2	135Ba-134Ba
68De17	1161	70	135Ba-134Ba
68De17	1168	78	135Ba-134Ba
77Ko.A	6973.2	0.4	134Ba(n,g)135Ba
90Is07,Z	6972.17	0.18	134Ba(n,g)135Ba
93Bo01,Z	6971.84	0.17	134Ba(n,g)135Ba
93Ch21	6973.24	0.22	134Ba(n,g)135Ba
06Fi.A	6971.87	0.18	134Ba(n,g)135Ba
70Vo04	4746	15	134Ba(d,p)135Ba
53Li01	205	5	135Cs(B-)135Ba
71Ba18,*	1200	10	135La(B+)135Ba
66Be10	-1115	3	136Ba-135Ba
68De17	-1119	50	136Ba-135Ba
68De17	-1074	50	136Ba-135Ba
69Ge07	9106.4	0.8	135Ba(n,g)136Ba
90Is07,Z	9107.74	0.04	135Ba(n,g)136Ba
06Fi.A	9107.73	0.19	135Ba(n,g)136Ba
70Vo04	6886	15	135Ba(d,p)136Ba
10Mc04	3089.1	0.6	137Ba 35Cl-135Ba 37Cl
66Be10	143	3	137Ba-135Ba
68De17	69	63	137Ba-135Ba
68De17	106	46	137Ba-135Ba

Overdetermined systems

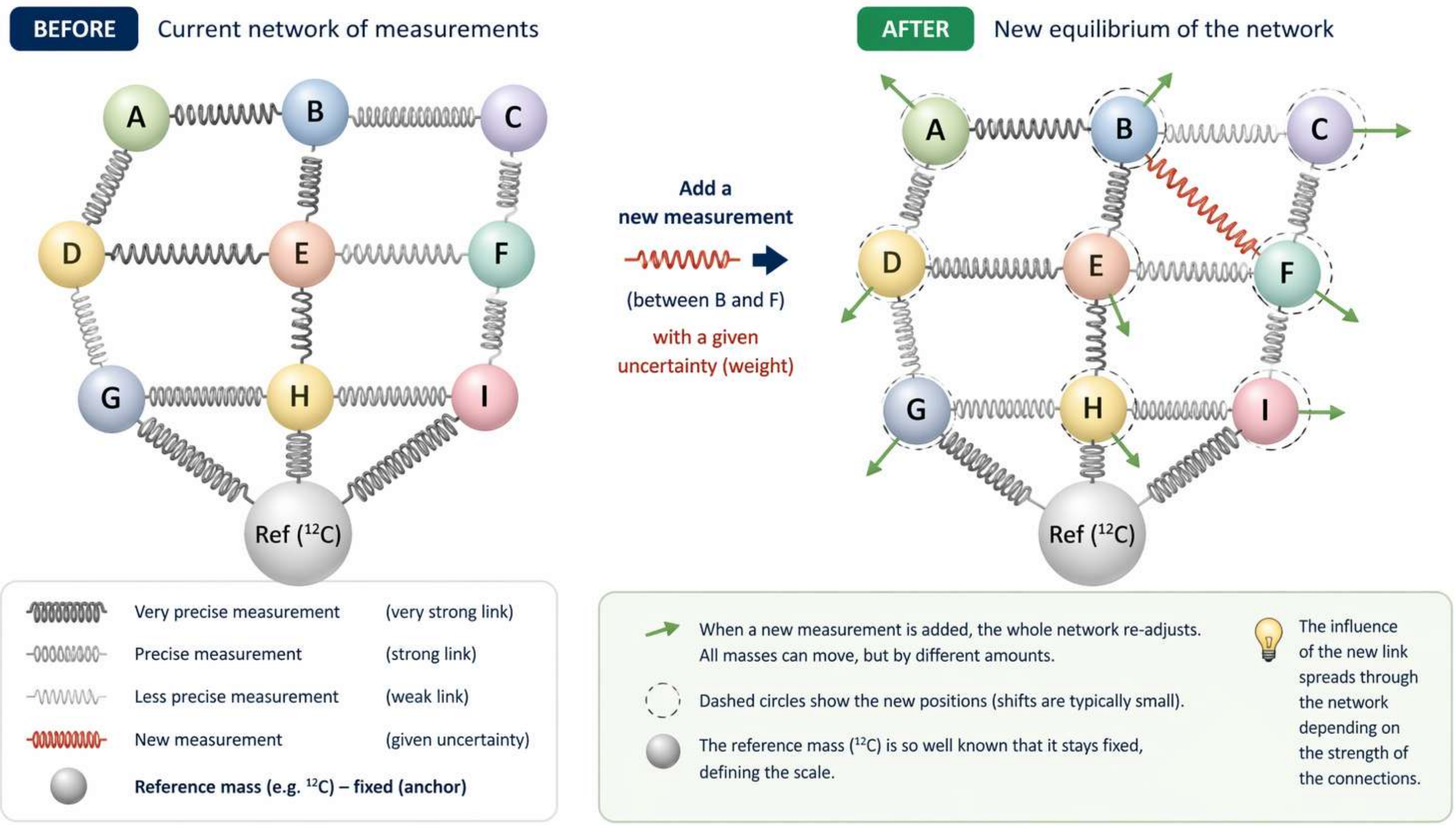
Least-squares method
find unique solution

Flow-of-information Matrix
Significance of uncertainties

Recommended masses are published in mass tables

Atomic Mass Evaluation: a network of Links

Masses are connected by measurements.
Adding a new measurement shifts all masses, depending on the weight of the link.



Brief history of AME (11 tables since 1955)

1955: A.H. Wapstra established least-squares method to solve the overdetermination problem

1986: G. Audi discovered the flow of information matrix

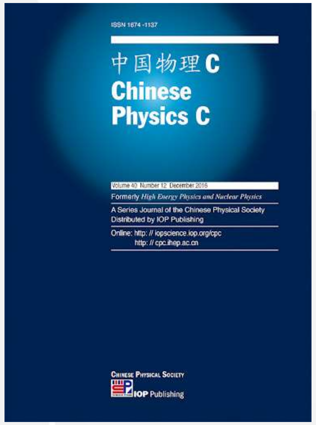
2006: A.H. Wapstra passed away

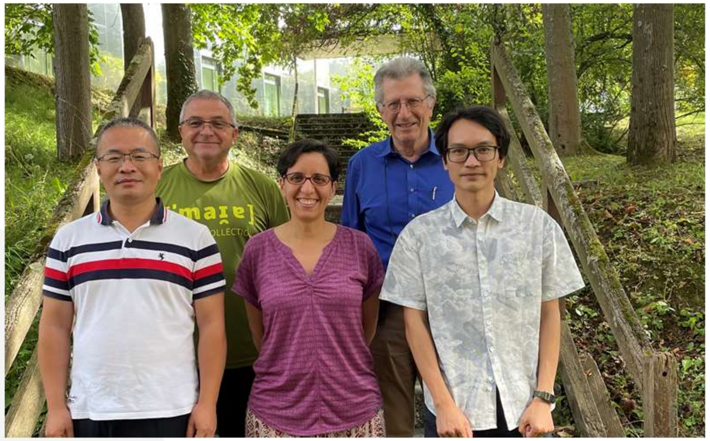
2008: G. Audi established the AME collaboration with China

Tables: **AME1955, AME1961, AME1964, AME1971, AME1977, AME1983, AME1993, AME2003, AME2012, AME2016, AME2020**

A.H. Wapstra (NIKHEF/Amsterdam)

Memorandum signing in China 2008





Collaboration meeting in Orsay Sep. 2023

Next collaboration meeting in Orsay May 2026

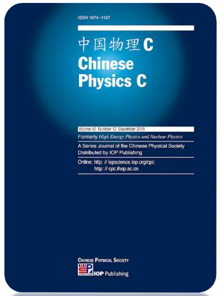
Recent History of the AME/NuBASE Collaboration

CPC(HEP & NP), 2012, **36**(12): 1603–2014 **Chinese Physics C** Vol. 36, No. 12, Dec., 2012

The AME2012 atomic mass evaluation *

(II). Tables, graphs and references

M. Wang[1,2,3], G. Audi[2,§], A.H. Wapstra[4,†], F.G. Kondev[5], M. MacCormick[6], X. Xu[1,7], and B. Pfeiffer[8,‡]



Chinese Physics C Vol. 41, No. 3 (2017) 030003

The AME2016 atomic mass evaluation *

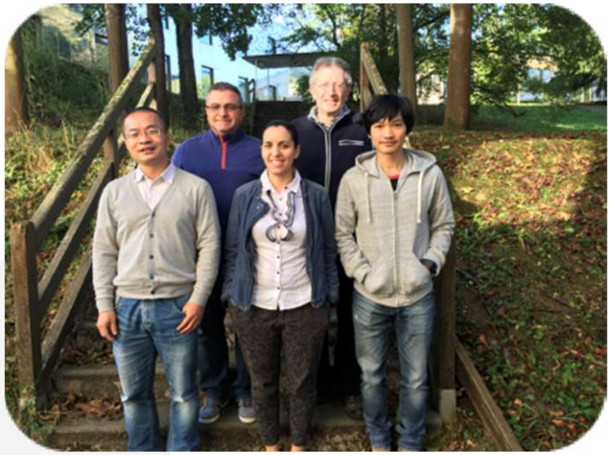
(II). Tables, graphs and references

Meng Wang (王猛)[1,2;1)] G. Audi (欧乔治)[3] F.G. Kondev[4] W.J. Huang(黄文嘉)[3] S. Naimi[5] Xing Xu(徐星)[1]

Kuwait 2013

coordinated by G. Audi (AME & NuBase)

Orsay 2016



coordinated by M. Wang (AME) and G. Audi (NuBase)

The most recent NuBASE and AME tables

The NUBASE2020 evaluation of nuclear physics properties**

F.G. Kondev [1,*], M. Wang (王猛)[2,3,*], W.J. Huang (黄文嘉)[2,4,5,6], S. Naimi[7], G. Audi (欧乔治)[6]

The AME2020 atomic mass evaluation **

(I). Evaluation of input data, and adjustment procedures

W.J. Huang (黄文嘉)[1,2,3,4] Meng Wang (王猛)[1,5,*] F.G. Kondev[6] G. Audi (欧乔治)[3] S. Naimi[7]

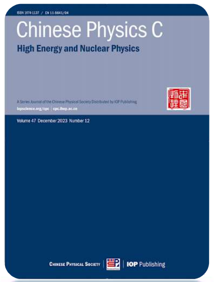
The AME2020 atomic mass evaluation **

(II). Tables, graphs and references

Meng Wang (王猛)[1,2,*] W.J. Huang(黄文嘉)[1,3,4,5] F.G. Kondev[6] G. Audi (欧乔治)[5] S. Naimi[7]

Coordinated by
M. Wang (AME)
and
F.G. Kondev (NuBase)

IOP science



since March 5, 2021
Nubase 41,117 downloads!
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Next edition AME2025
To be published Sep. 2026

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https://www-nds.iaea.org/amdc/ (IAEA)

http://amdc.impcas.ac.cn (IMP)

https://www.anl.gov/phy/atomic-mass-data-resources (ANL)

The HINA experiment @DESIR/GANIL

Highly charged Ions for Nuclear physics and Astrophysics

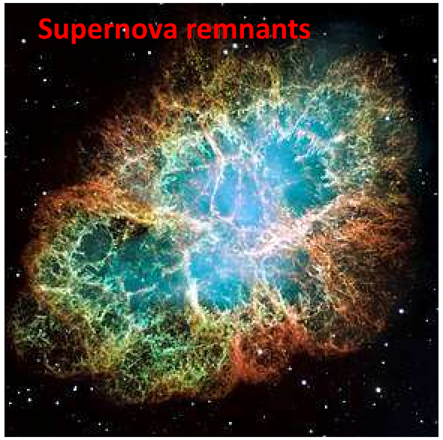
Polynesian Goddess of the
Moon and Stars

Hinaupoko Devèze

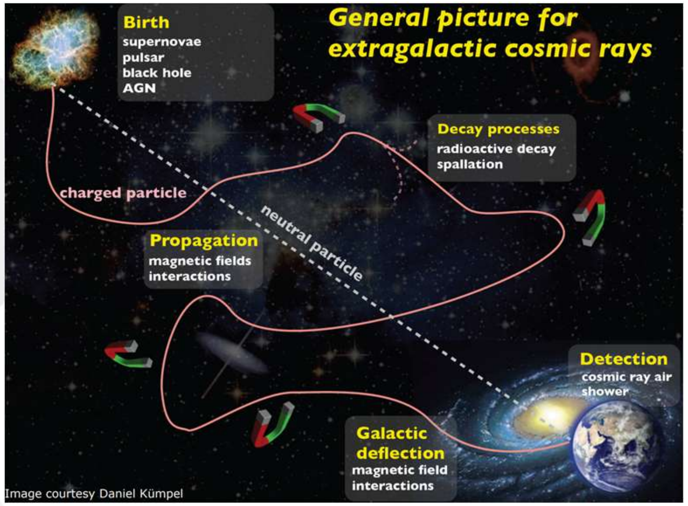
HINA

2025--2029

Where do we find them?



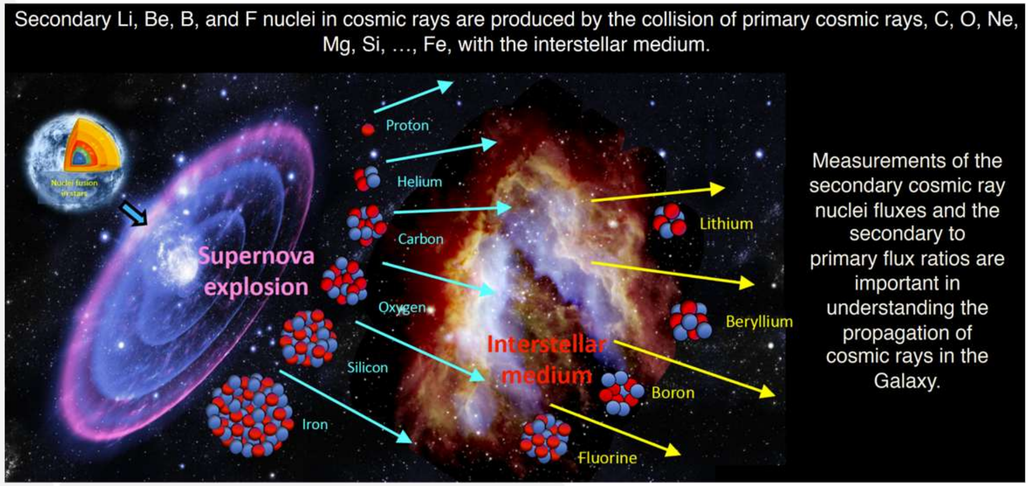
HINA: Nuclear decay of unstable HCIs



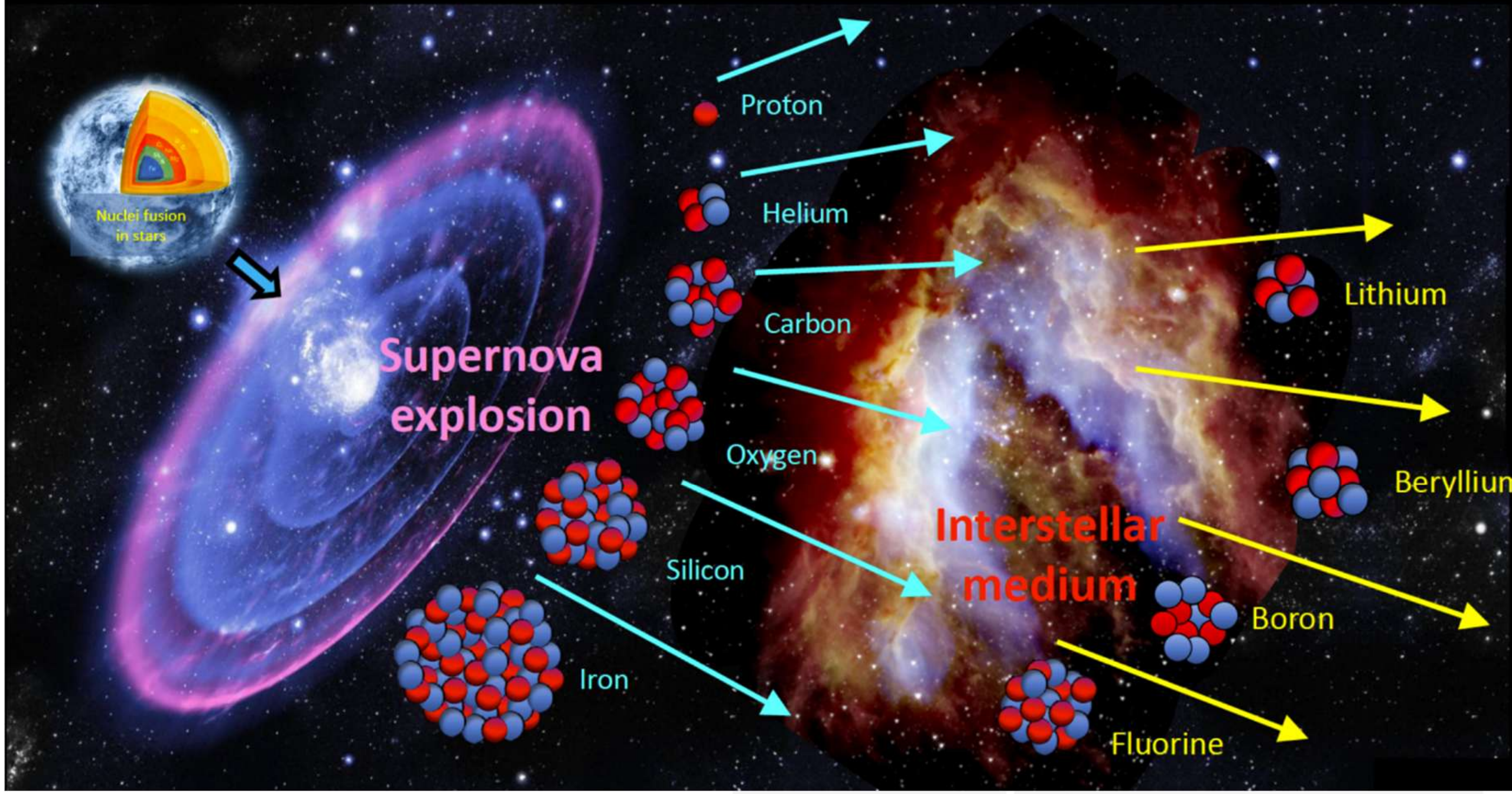
Measured H-,He- ^{140}Pr at GSI
Litvinov+, PRL, 2007
Orbital EC in H-like ions

$^{140}Pr^{58+}$ S = 1/2, I = 1 $\xrightarrow{EC}$ $^{140}Ce^{58+}$ I = 0, S = 1/2

$F = I + s \langle^{3/2}_{1/2}$ $\not\rightarrow$ / $\rightarrow$ $F = I + s = 1/2$

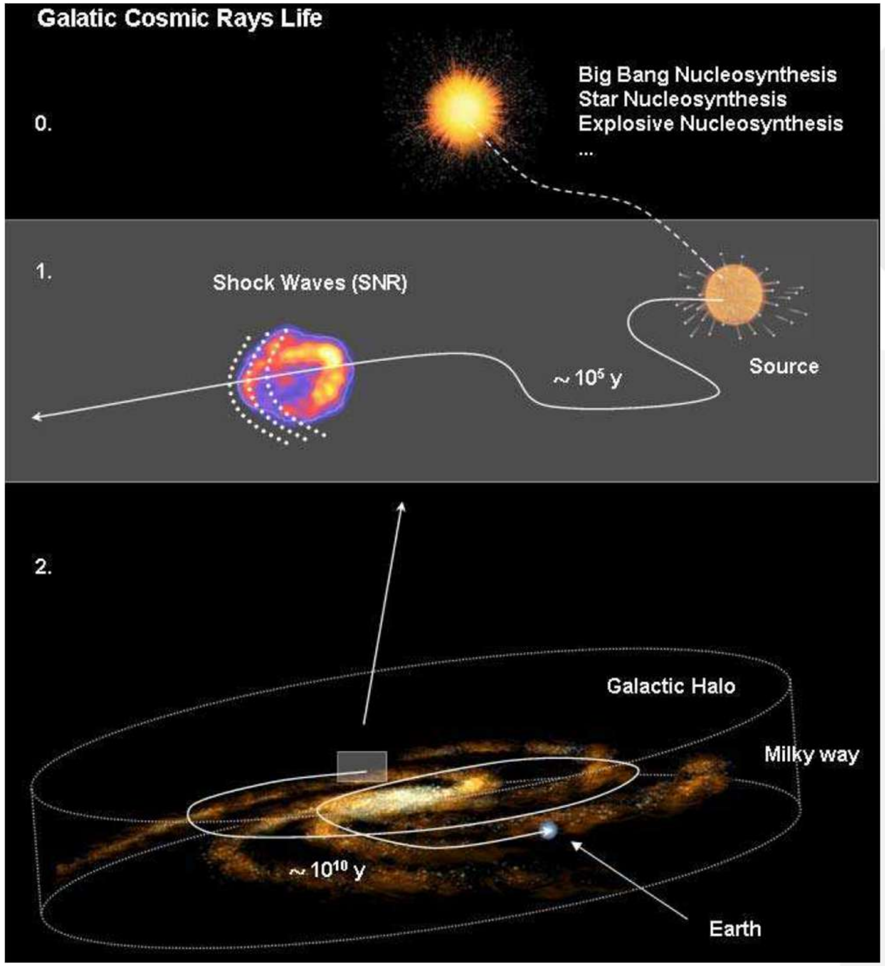


Secondary Li, Be, B, and F nuclei in cosmic rays are produced by the collision of primary cosmic rays, C, O, Ne, Mg, Si, …, Fe, with the interstellar medium.



Measurements of the secondary cosmic ray nuclei fluxes and the secondary to primary flux ratios are important in understanding the propagation of cosmic rays in the Galaxy.

Astronomic Clocks: Galactic Cosmic Rays



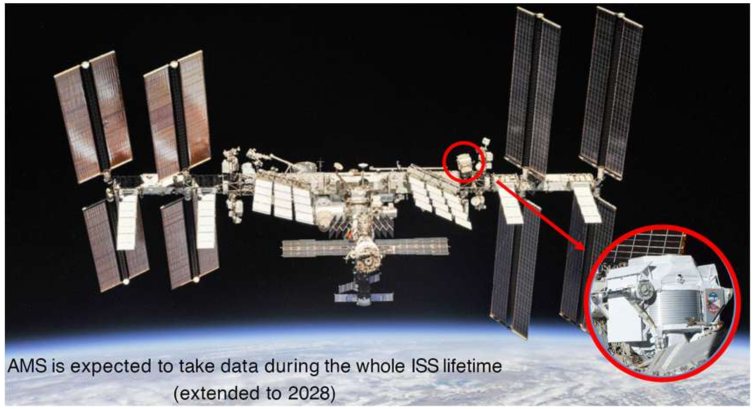
Most interesting GCRs (Astronomic Clocks)

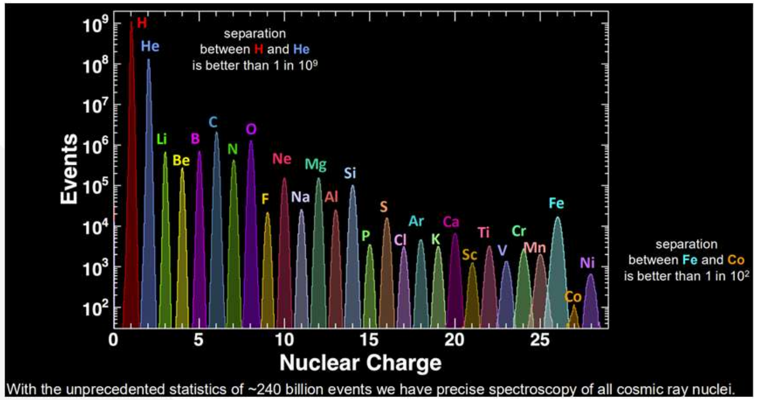
Nuclide	Decay Mode	Half-life
^{7}Be	K-capture	53 days
^{10}Be	β-	1.5 Myr
^{14}C	β-	5730 yr
^{26}Al	β+	0.87 Myr
	K-capture	4.0 Myr
^{36}Cl	β-	0.30 Myr
^{37}Ar	K-capture	35 days
^{41}Ca	K-capture	0.10 Myr
^{44}Ti	K-capture	49 yr
^{49}V	K-capture	330 days
^{51}Cr	K-capture	28 days
^{53}Mn	K-capture	3.7 Myr
^{54}Mn	K-capture	312 days
	β+	400 Myr
	β-	0.8 Myr b
^{55}Fe	K-capture	2.7 yr
^{56}Ni	K-capture	6.1 days
	β+	$\sim$ 1 yr
^{57}Co	K-capture	270 days
^{59}Ni	K-capture	76000 yr

A. Oliva PhD thesis 2007

Measurement is conducted at AMS-02 @ISS since 2011

https://ams02.space/





A.Oliva, talk in CRs and νs in MME conference, 2024

ANNUAL REVIEW OF NUCLEAR AND PARTICLE SCIENCE Volume 57, 2007

Review Article

Cosmic-Ray Propagation and Interactions in the Galaxy

Andrew W. Strong[1], Igor V. Moskalenko[2], and Vladimir S. Ptuskin[3]
Hide Affiliations
Affiliations:
[1]Max-Planck-Institut für extraterrestrische Physik, 85741 Garching, Germany; email: aws@mpe.mpg.de
[2]Hansen Experimental Physics Laboratory and Kavli Institute for Particle Astrophysics and Cosmology, Stanford University, Stanford, California 94305; email: imos@stanford.edu
[3]Institute for Terrestrial Magnetism, Ionosphere and Radiowave Propagation of the Russian Academy of Sciences (IZMIRAN), Troitsk, Moscow region 142190, Russia; email: vptuskin@izmiran.ru

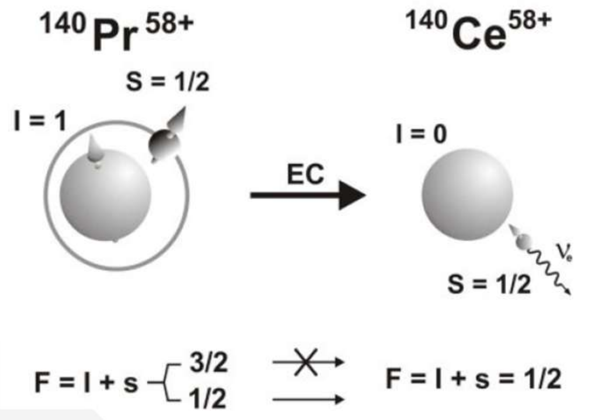
Starting with the heaviest primary nucleus considered (e.g. ^{64}Ni) the propagation solution is used to compute the source term for its spallation products, which are then propagated in turn, and so on down to protons, secondary electrons and positrons, and antiprotons. In this way secondaries, tertiaries etc. are included. (Production of ^{10}B via the ^{10}Be-decay channel is important and requires a second iteration of this procedure.) GALPROP includes K-capture and electron stripping processes, where a nucleus with an electron (H-like) is considered a separate species because of the difference in the lifetime. Since H-like atoms have only one K-shell electron, the K-capture decay half-life has to be increased by a factor of 2 compared to the measured half-life value. Primary electrons are treated

PHYSICAL REVIEW C **77**, 014306 (2008)

Orbital electron capture decay of hydrogen- and helium-like ions

Zygmunt Patyk,[1] Jan Kurcewicz,[2] Fritz Bosch,[3] Hans Geissel,[3] Yuri A. Litvinov,[3] and Marek Pfützner[2]
[1]*Soltan Institute for Nuclear Studies, Hoża 69, PL-00-681 Warsaw, Poland*
[2]*Institute of Experimental Physics, Warsaw University, Hoża 69, PL-00-681 Warsaw, Poland*
[3]*Gesellschaft für Schwerionenforschung (GSI), Planckstrasse 1, D-64291 Darmstadt, Germany*
(Received 3 August 2007; published 10 January 2008)

Measured H-,He- ^{140}Pr at GSI
Litvinov+, PRL, 2007



Ion	λ_{β^+} (sec^{-1})	λ_{EC} (sec^{-1})
^{140}Pr^{59+}	0.001 58(8)	...
^{140}Pr^{58+}	0.001 61(10)	0.002 19(6)
^{140}Pr^{57+}	0.001 54(11)	0.001 47(7)

Factor 2/3

HINA

Decay highly charged light ions

Trap-based setup

Nuclear physics
Astrophysics

High precision
New applications

HINA@GANIL

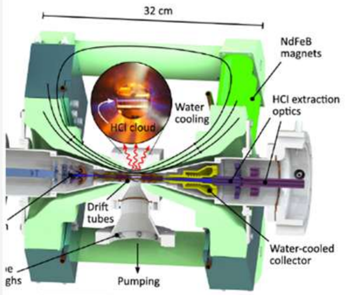
Cosmic Ray

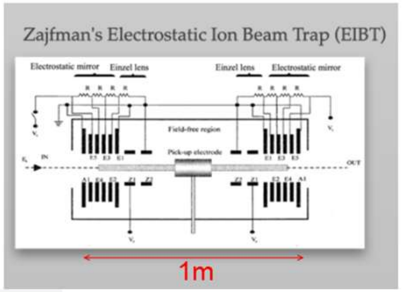
H-like ion	$I_i^{\pi_i} \to I_f^{\pi_f}$	μ/μ_N	δE (eV)	$\tau_{1/2}$	$T_{1/2}$
^{19}Ne	$\frac{1}{2}^+ \to \frac{1}{2}^+$	-1.89	0.004	3 d	17.3 s
^{37}Ar	$\frac{3}{2}^+ \to \frac{3}{2}^+$	$+1.15$	0.01	10 h	35 d
^{64}Cu	$1^+ \to 0^+$	-0.22	0.009	7 h	12.7 h
^{68}Ga	$1^+ \to 0^+$	$+0.01$	0.001	5 yr	67.7 min

EC on H-,He-&Li-like ions
Nuclear physics, CR & PNC?

Traps as alternative to storage rings
Smaller, cheaper, eco & "outperform"

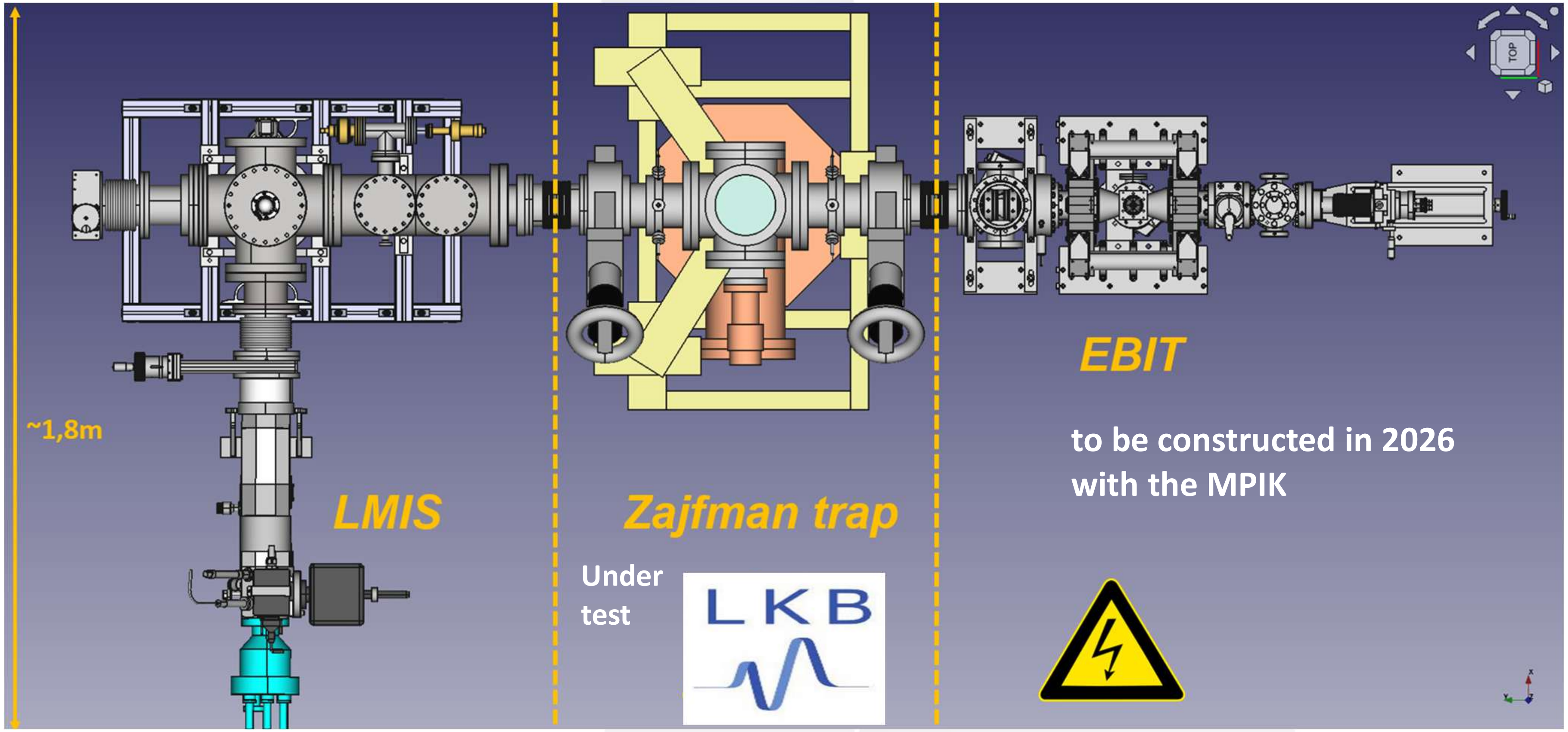
Focus on light ions



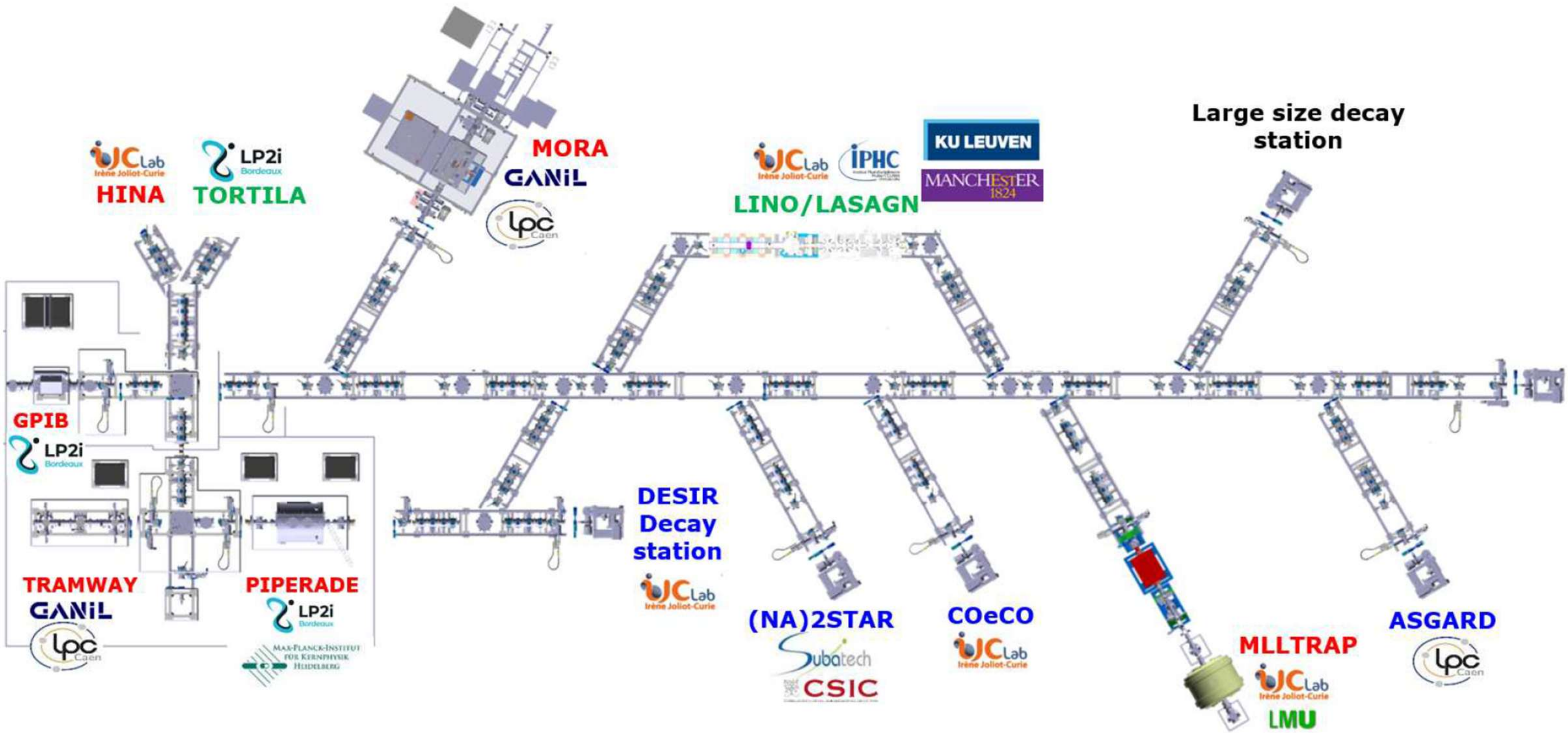


Preliminary HINA beamline @DESIR

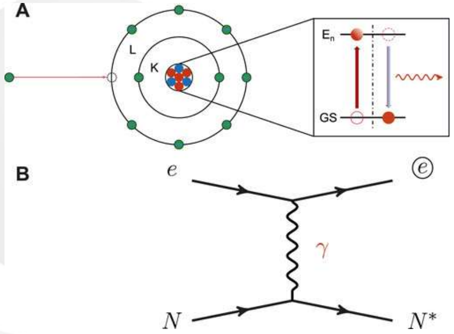
Pre-ANR	ANR Timeline 2025-2029				Post-ANR
Preparation HINA beamline Zajfman trap	EBIT construction	Assembly Detectors tests	Test EBIT w/ Ar beam	Production/trapping He-/H-like Cu,Ga beam	Experiments at DESIR



Preliminary beamline layout @DESIR

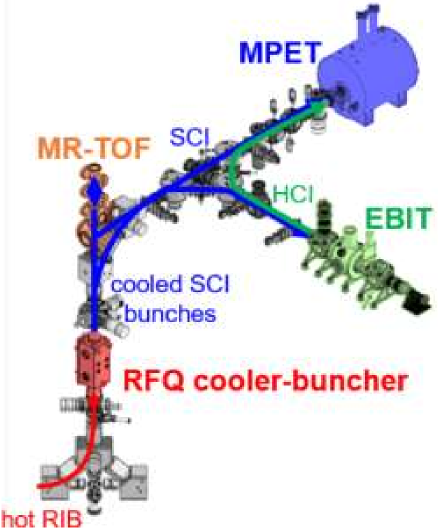


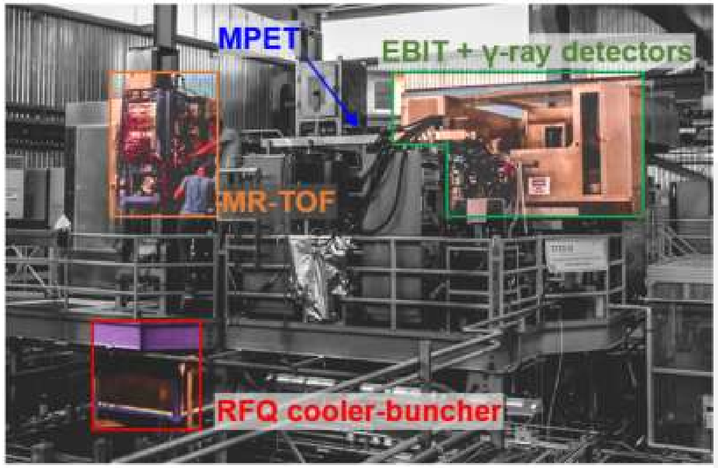
NEEC (Nuclear Excitation by Electron Capture)



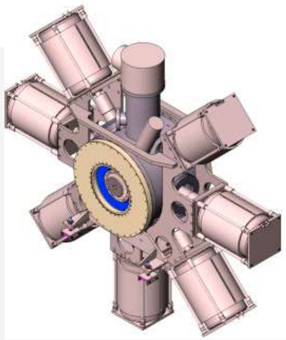
Energy storage:
nuclear battery?

Carol Jiseth
Ospina Umaña
(PhD candidate)





TITAN-EBIT: in-trap spectro



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