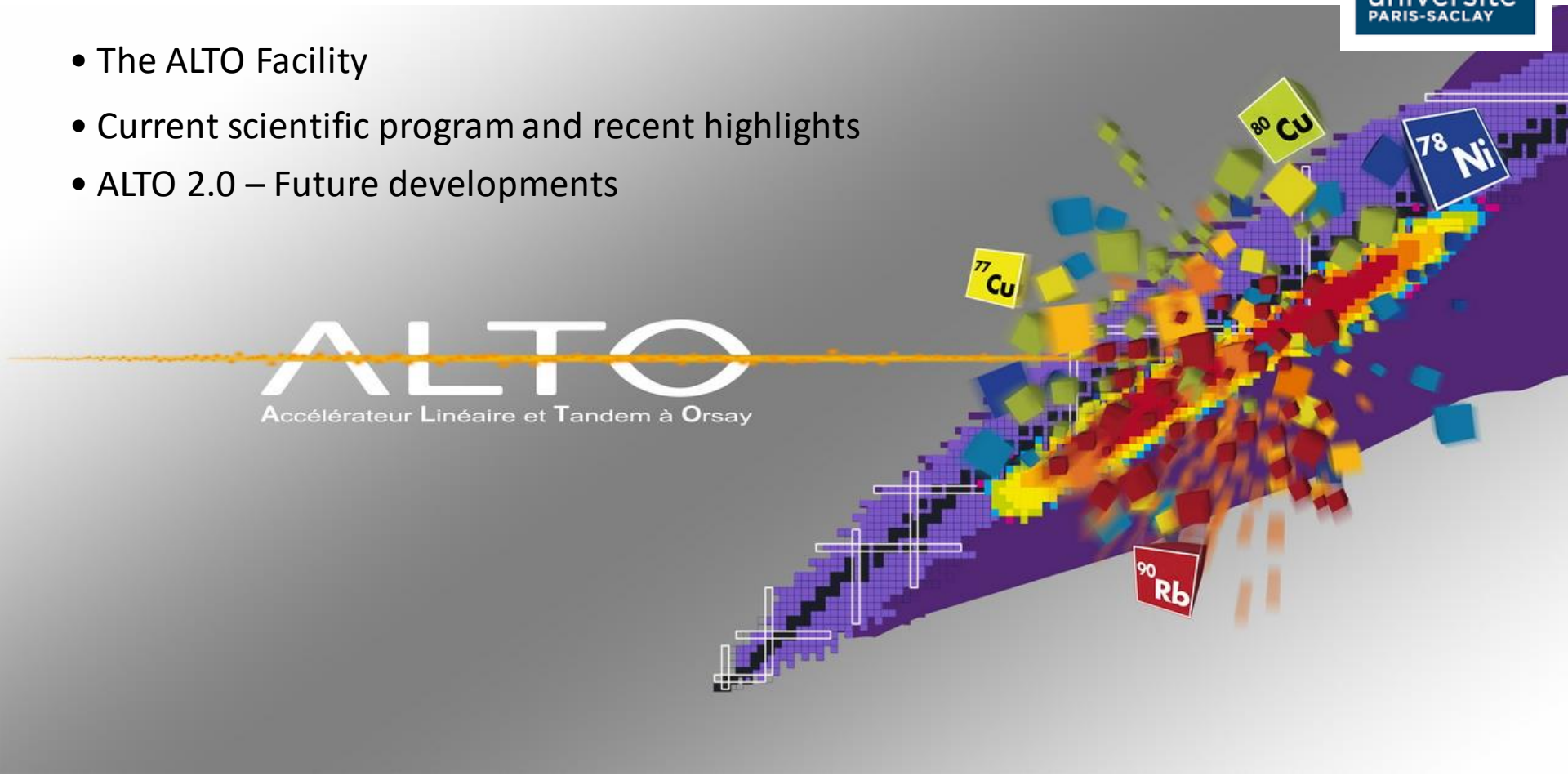
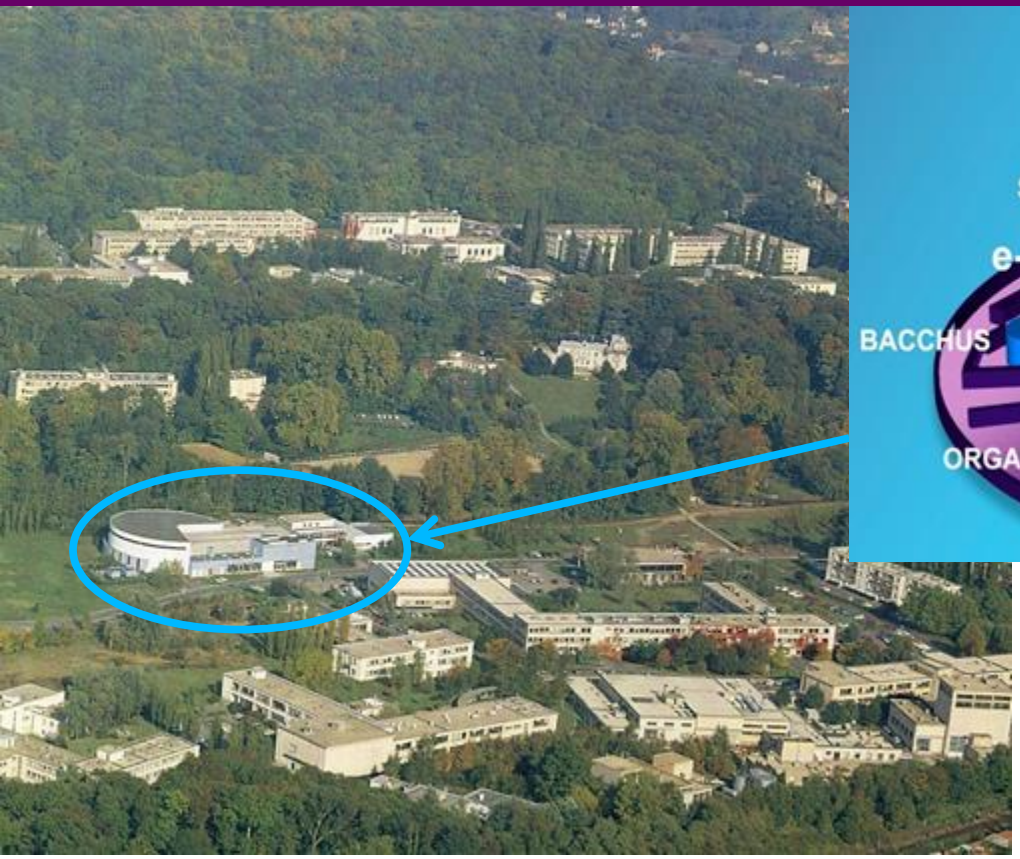
ALTO:
A photo-fission ISOL facility for nuclear structure studies

Jonathan Wilson
For the **ALTO facility**

- The ALTO Facility
- Current scientific program and recent highlights
- ALTO 2.0 – Future developments



The ALTO facility



	2014	2015	2016
Users	135	246	200
Beam-time	2232 h	3816 h	2544 h
	279 UT	477 UT	318 UT

ENSAR

CHANDA

ENSAR2

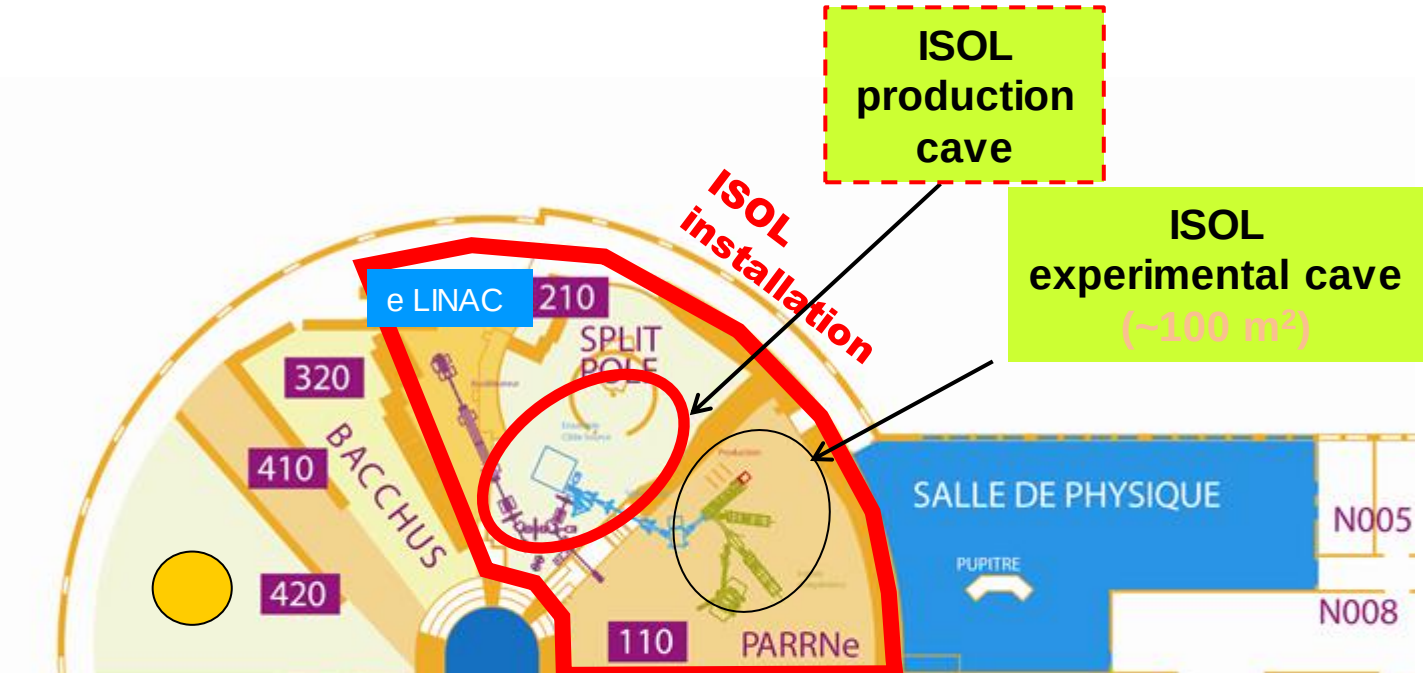
cnrs IN2P3 Les deux infinis

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

UNIVERSITÉ PARIS SUD

université PARIS-SACLAY

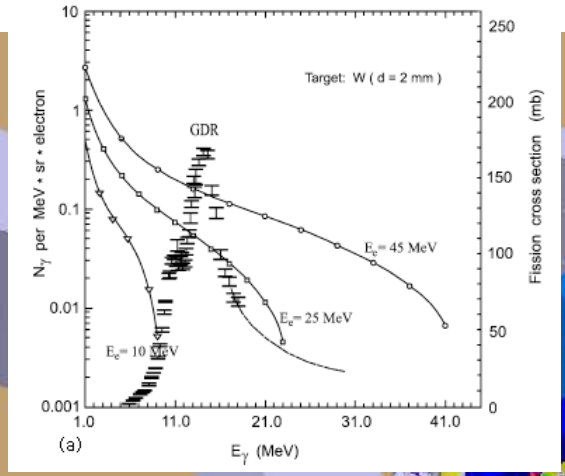
ISOL Experimental Areas



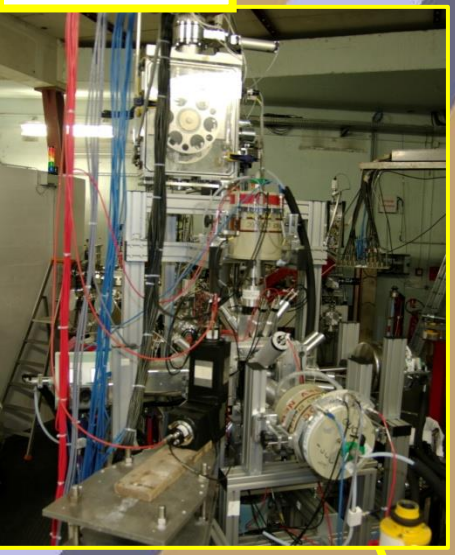
- **50 MeV** & **10 µA** e^- beam
- UCx target (~70g, ~140 pellets)
- Z selection with : **Surface/LASER ion source (RIALTO)**
- A/Q Selection with PARRNe -> mono-isotopic selection achievable

ALTO : the e-driven ISOL facility in Orsay

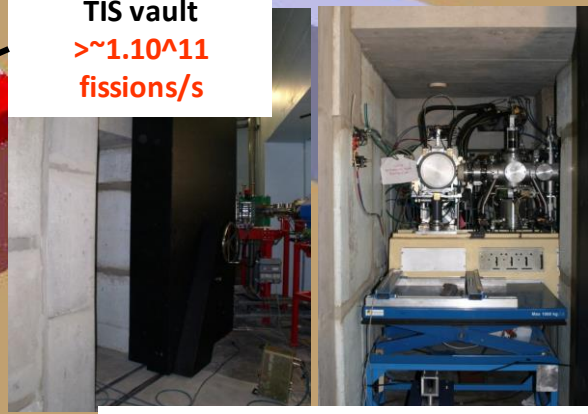
e-LINAC
10 µA 50MeV (former 1st section of the CERN LEP injector)



BEDO
beta decay spectroscopy



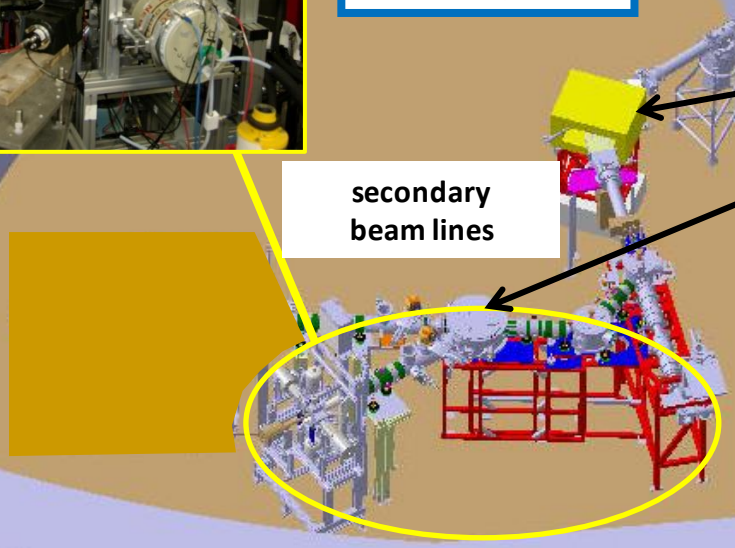
TIS vault
>~1.10^11 fissions/s



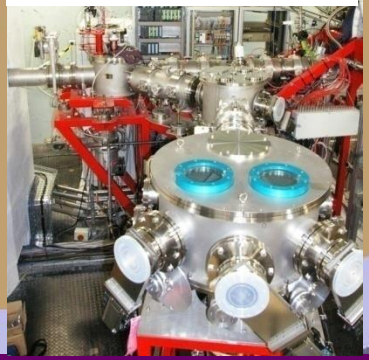
Hall 110
experimental setups

PARRNe
mass separator

secondary beam lines



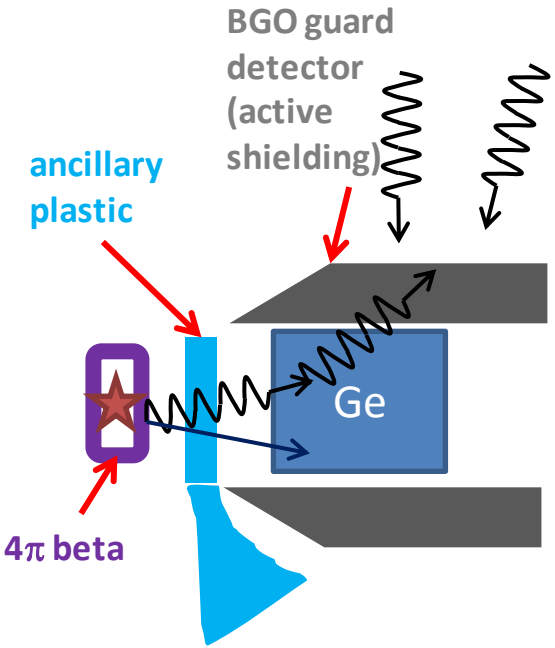
kicker - bender

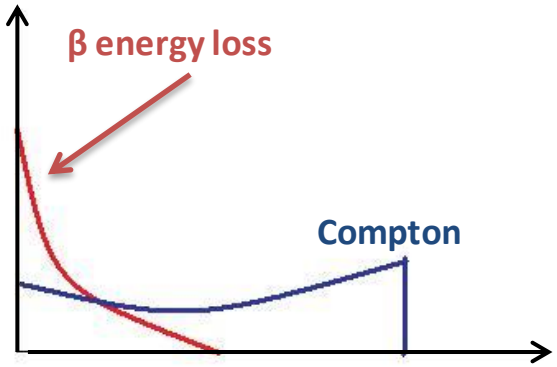


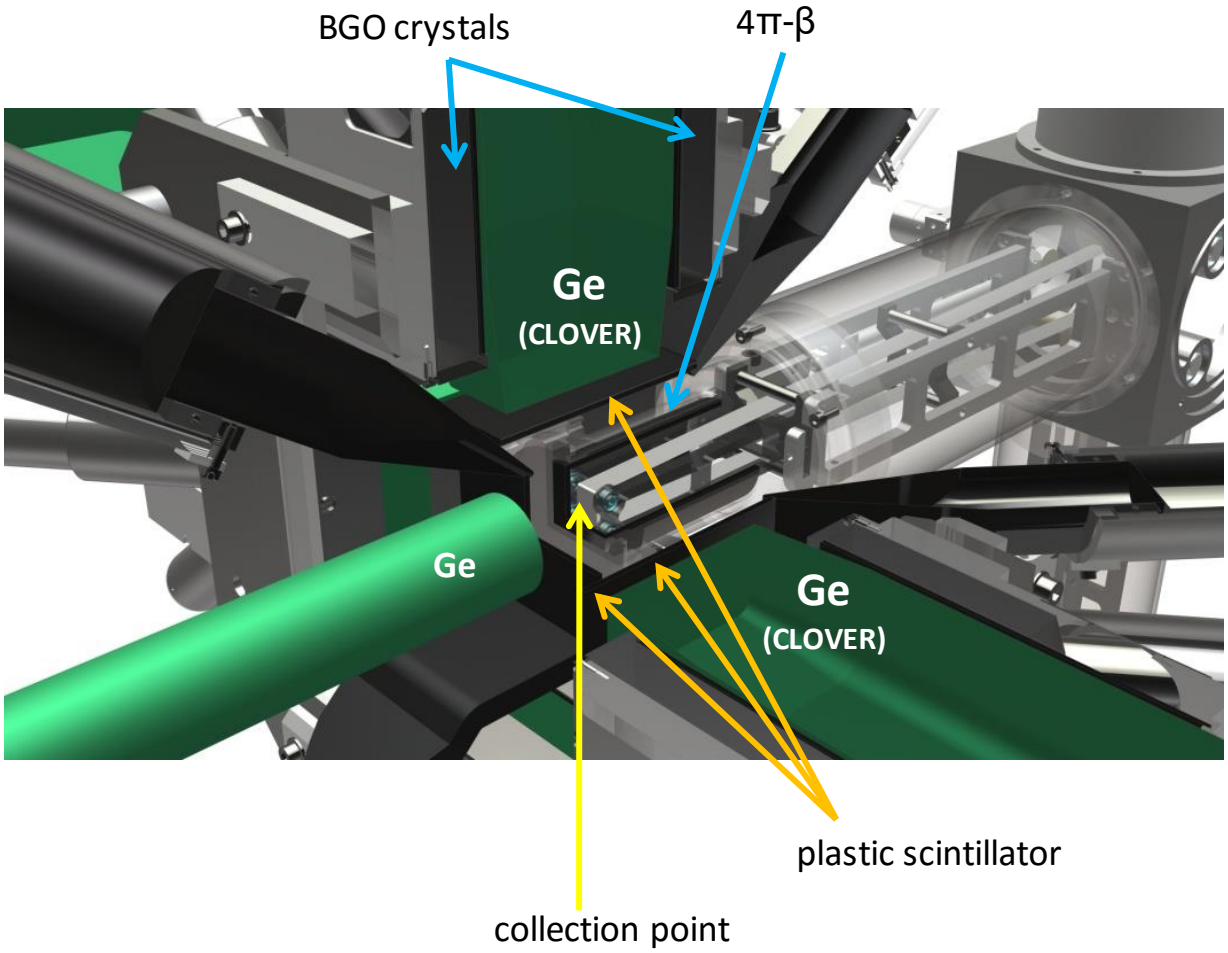
Target Ion-source ensemble

The BEDO "concept"

Selectivity : use of ancillaries → γ-background suppression





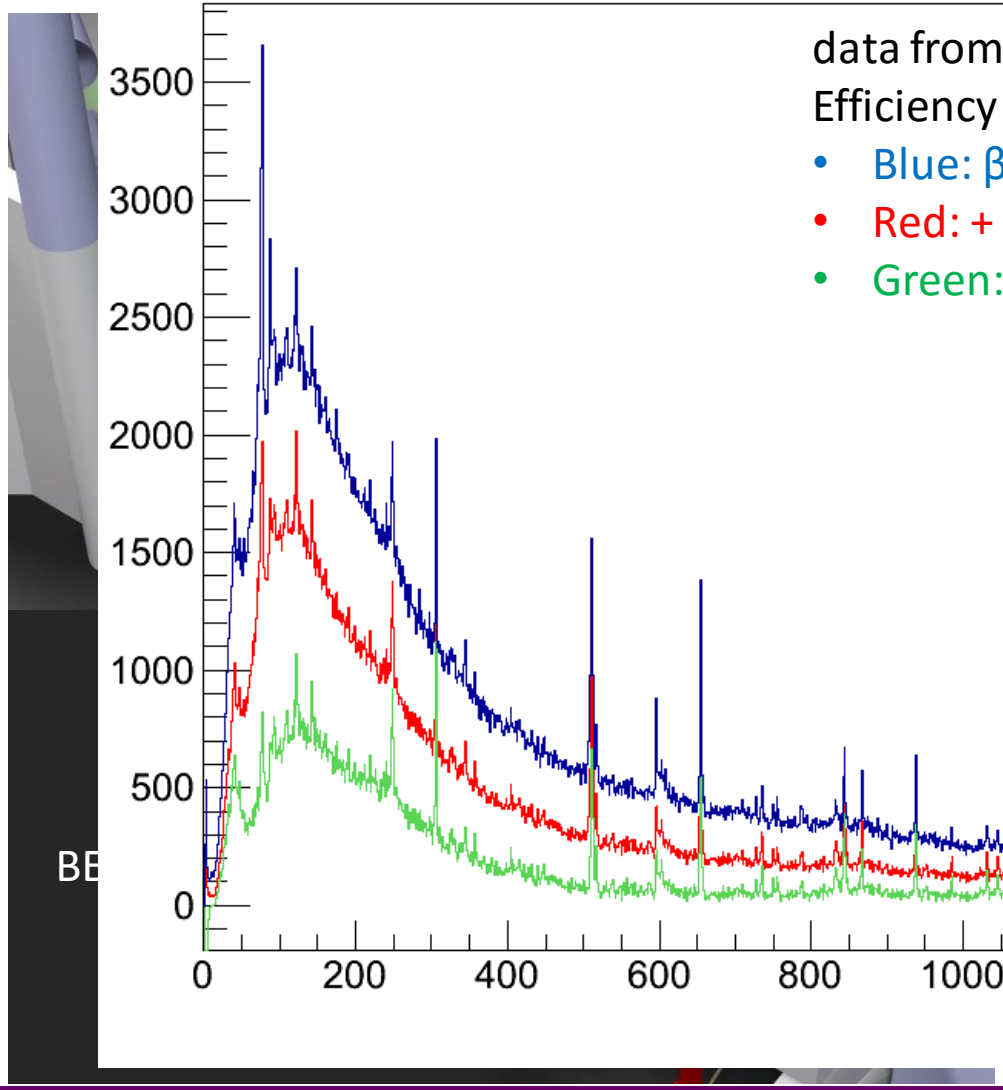


The BEDO "concept"

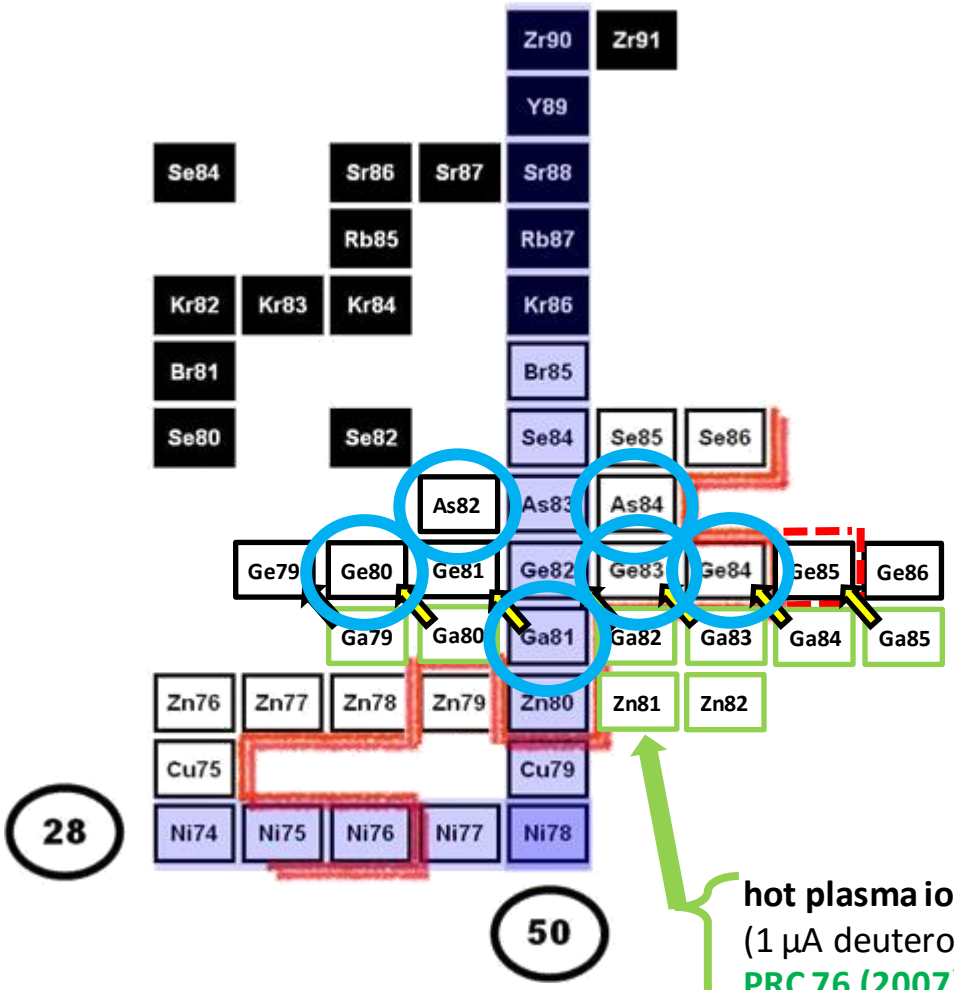
PARRNe on line mass separator

PARRNe β-decay and identification station

Tape station, Close packed geometry



More than a decade of β-decay spectroscopy at N~50 at the PARRNe on-line mass separator in Orsay



hot plasma ionization
(1 µA deuteron primary beam)
•O. Perru PhD –2004
Eur. Phys. J. A 28, 307 (2006)
(7 µA electron primary beam)
•A. Etile PhD CSNSM –2014
PRC 91 064317 (2015)

surface ionization
(2-4 µA electron primary beam)
•M. Lebois PhD –2008
PRC 80, 044308 (2009)
•B. Tastet PhD –2011
PRC 87, 054307 (2013)
•C. Delafosse PhD –ongoing
PRL 118 182501 (2016)

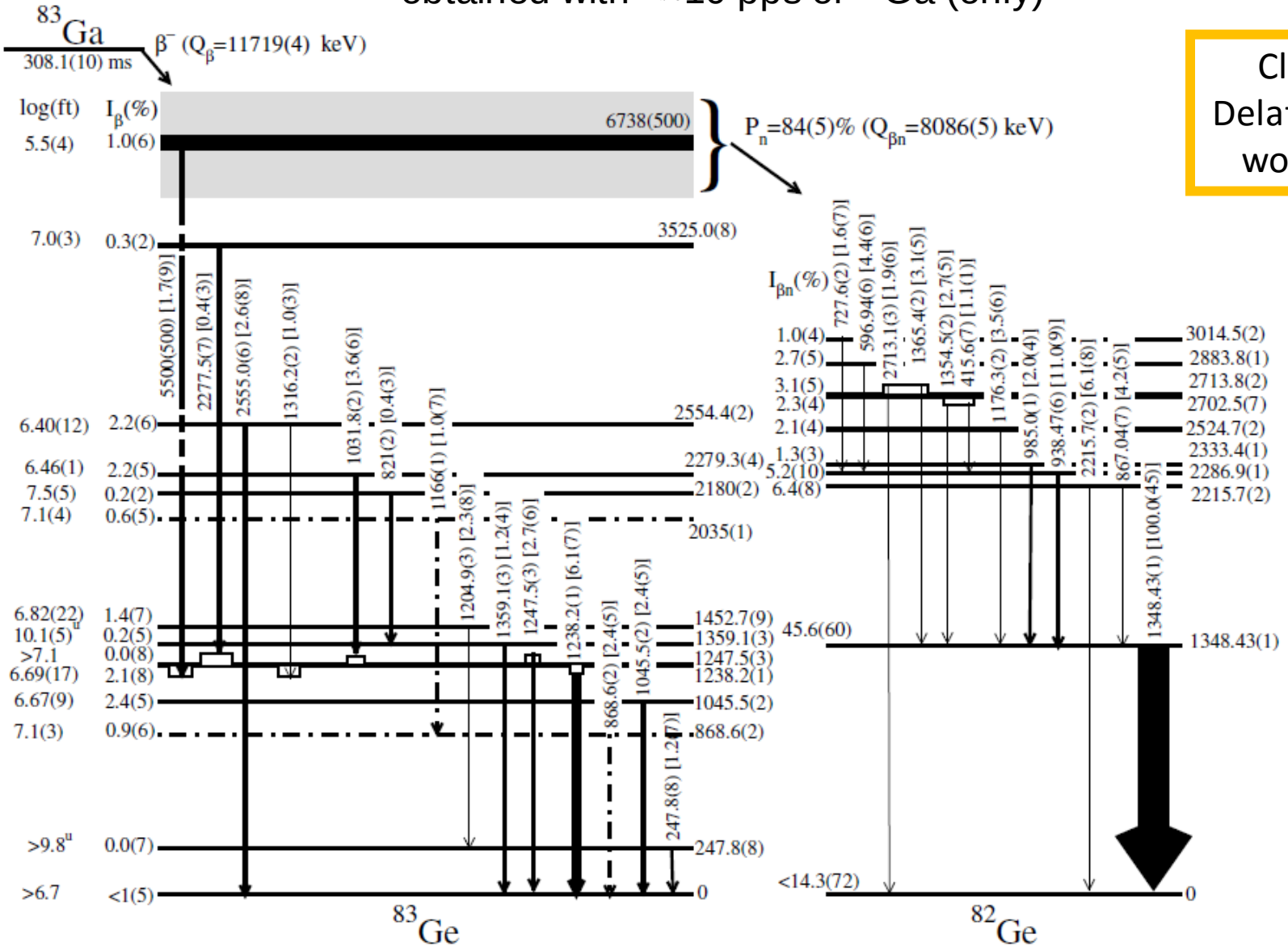
laser ionization
(10 µA electron primary beam)
•K. Kolos PhD –2012
PRC 88, 047301 (2013)
•D. Testov PhD –2014
NIM A815, 96 (2016)

hot plasma ionization
(1 µA deuteron primary beam)
PRC 76 (2007) 054312

And "spin-off's" elsewhere:
-LNL :Plunger + AGATA + PRISMA
-RIKEN: EURICA, MINOS campaigns
-GANIL Plunger + AGATA + VAMOS
LoI: SPES, SPIRAL2 phase 2

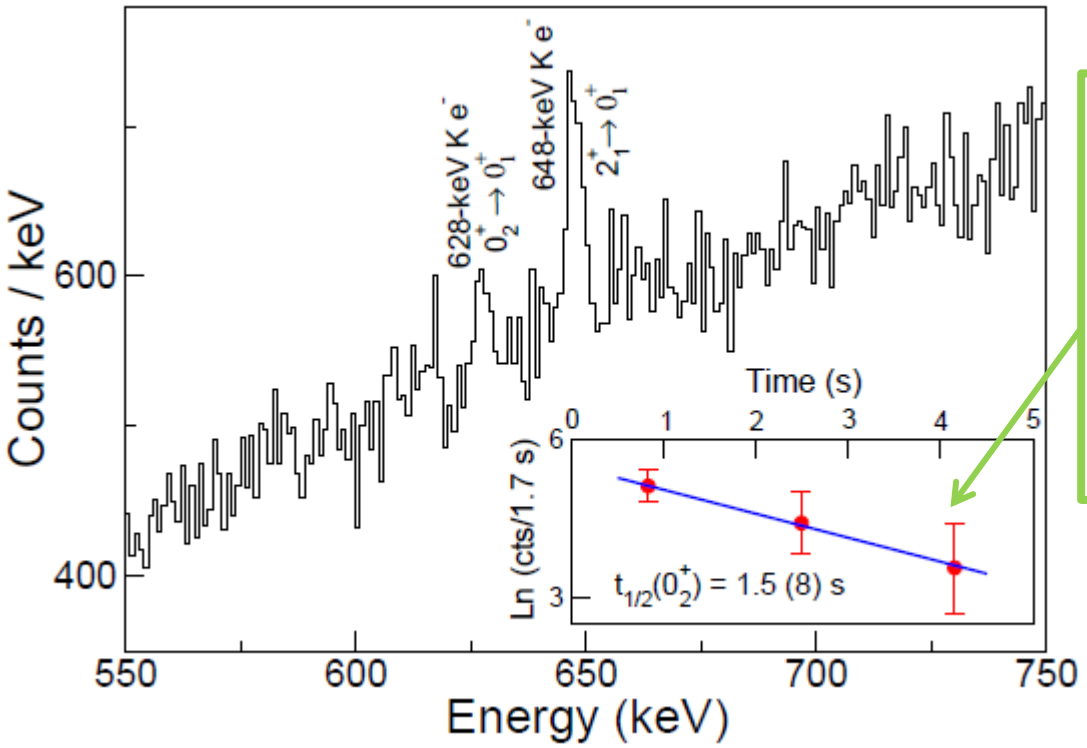
BEDO, photofission and "fine" spectroscopy

obtained with <≈10 pps of ^{83}Ga (only)



Clément Delafosse PhD work 2017

Recent Results on Shape Co-existence in the ^{78}Ni Region



Compatible with the $T_{1/2}$ for the **3** $^-$ isomer in **^{80}Ga**
[$T_{1/2}$(**3**$^-$)=1.3±0,2 s; Verney et al. PRC 87 (2013)]
A situation very similar : $0^+_2 \rightarrow 0^+_1$ populated in the **3**$^-$ **^{72}Ga** decay
[Rester et al. NPA 162 (1971)]

- Electron-Gamma spectroscopy reveals E0 transition in ^{80}Ge: evidence for a low-lying 0^+ state
- The 0^+ state is consistent with an intruder (2p-2h) excitation, suggesting shape coexistence in the N=50 region

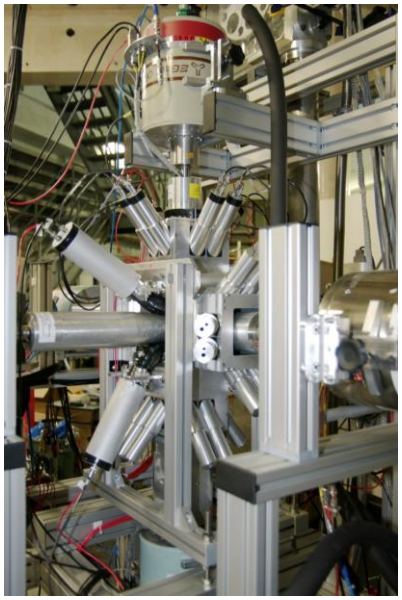
First Evidence of Shape Coexistance in the ^{78}Ni Region: Intruder 0^+_2 state in ^{80}Ge
A. Gottardo *et al.*, Phys. Rev. Lett. 116, 182501 (2016)

The BEDO "concept"

Modularity : 3 modes

installed on a dedicated beam line

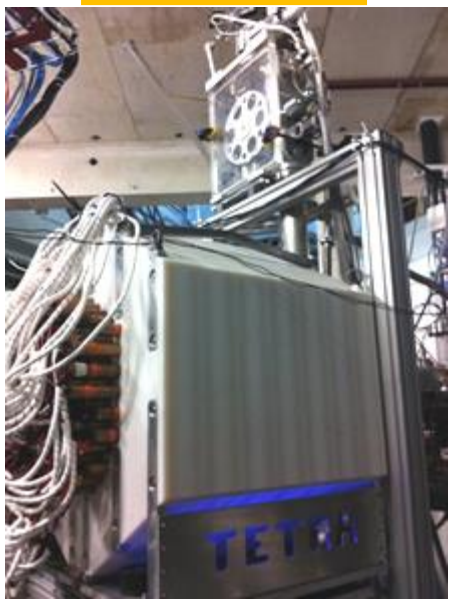
BEDO setup in gamma mode
can host 4 clovers



IPN, coll. CSNSM, IPHC

PhD: A. Etilé (CSNSM)
PRC 91, 064317 (2015)

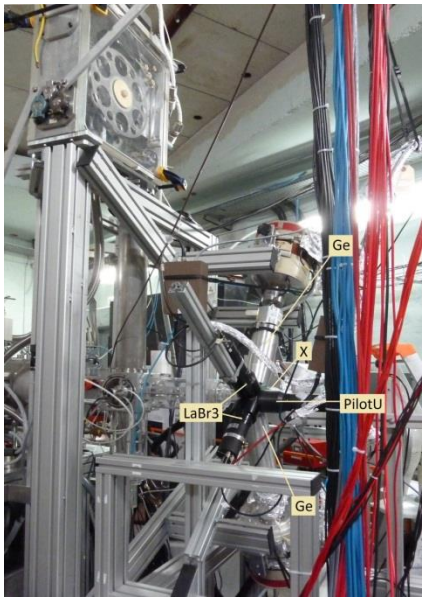
BEDO setup in neutron mode
Dubna neutron detector TETRA



IPN, coll. JINR (Russia), IPHC

PhD: D. Testov (IPN)
NIM A815, 96 (2016)

BEDO setup fast timing mode
LaBr3 + Ge



IPN, coll. CSNSM, TANDAR (Argentina), INRNE (Bulgaria)

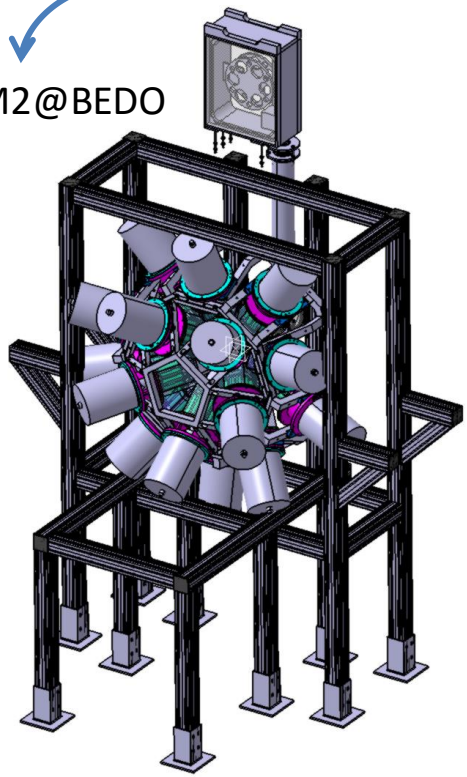
M.A.Cardona, D.Hojman, B.Roussière, I.Deloncle et al.

Long term plans for BEDO

multipolarity measurements

γ–angular correlations

ORGAM2@BEDO



4 EXOGAM@BEDO ?
BEDO@LIRAT ?

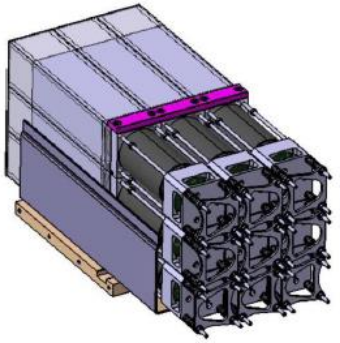
β-delayed spectroscopy beyond the neutron threshold

neutron energy measurements

high energy γ measurements

MONSTER ?

PARIS ?



ALTO Facility: The future of RIB

POLAREX

POLARization of EXotic nuclei:

- Study of highly polarized neutron rich nuclei
- ^{3}He-^{4}He cooling system to get 6 mK coupled to a 1T supraconductive magnet
- Aim to study nuclear structure in extreme conditions:
  - Multipolarity g-factor
  - Weak interaction test
  - Parity violation
- First measures soon

LINO

Laser Induced Nuclear Orientation:

- Aim to study hyper-fine structure to get:
  - nuclear nuclear ground-state spin
  - electromagnetic moments
  - Nuclear charge radius
  - β-NMR
- Spectroscopy and Nuclear orientation first for Ag isotopes.

MLLTRAP

- High precision mass measurement (< 10 keV)
- Double Penning trap mass spectrometer (PT-MS)
- Aim to study Ag isotopes first

TAS

Total Absorption Spectroscopy:

- Interesting for structure studies around Sn, and in particular to check the capability of the beta strength as anobservable to reflect:
  - neutron skin effects in nuclei,
  - collective modes,
  - Single particle excitations at low energy.
- β-decay heat in nuclear spent fuel
- Neutrino oscillation

Stable Beams: Experimental areas

γ-spectroscopy

ORGAM

MINORCA

PARIS

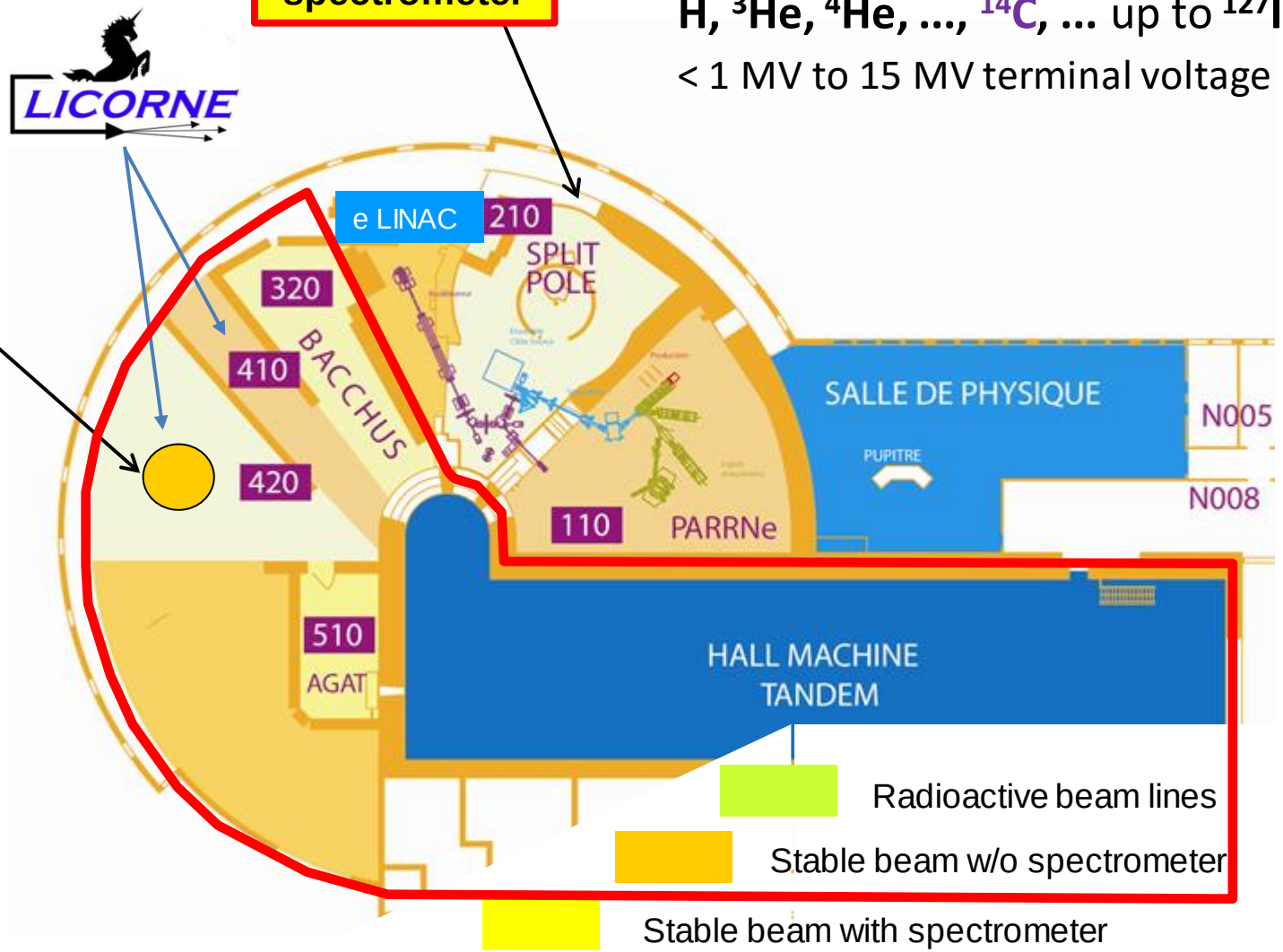
nu – ball

Split-Pole spectrometer

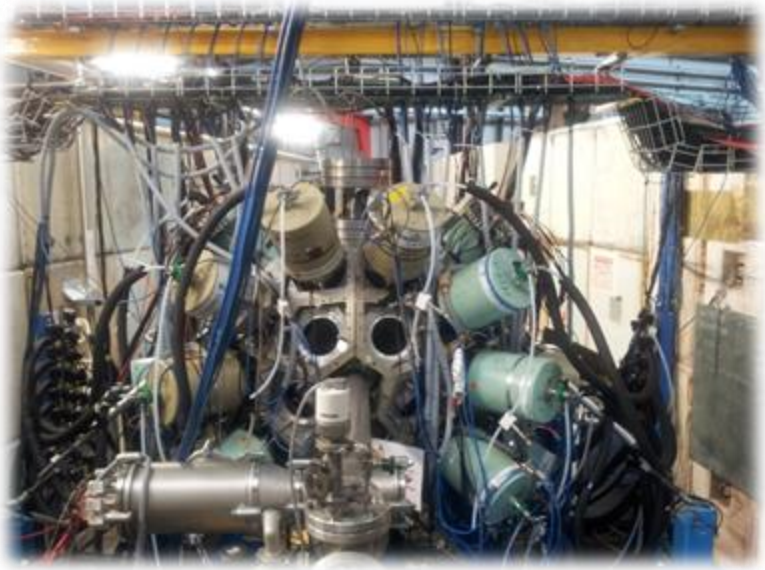
Tandem Beams:

H, ^{3}He, ^{4}He, …, ^{14}C, … up to ^{127}I

< 1 MV to 15 MV terminal voltage



MINORCA at ALTO (June 2014 – March 2015)



Campaign managers: I. Matea and G.G.

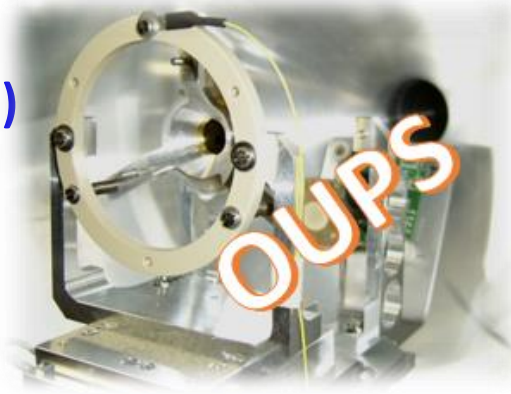
12 ORGAM *CS* HPGe x 0.1%

8 Miniball TC at ~14 cm from target

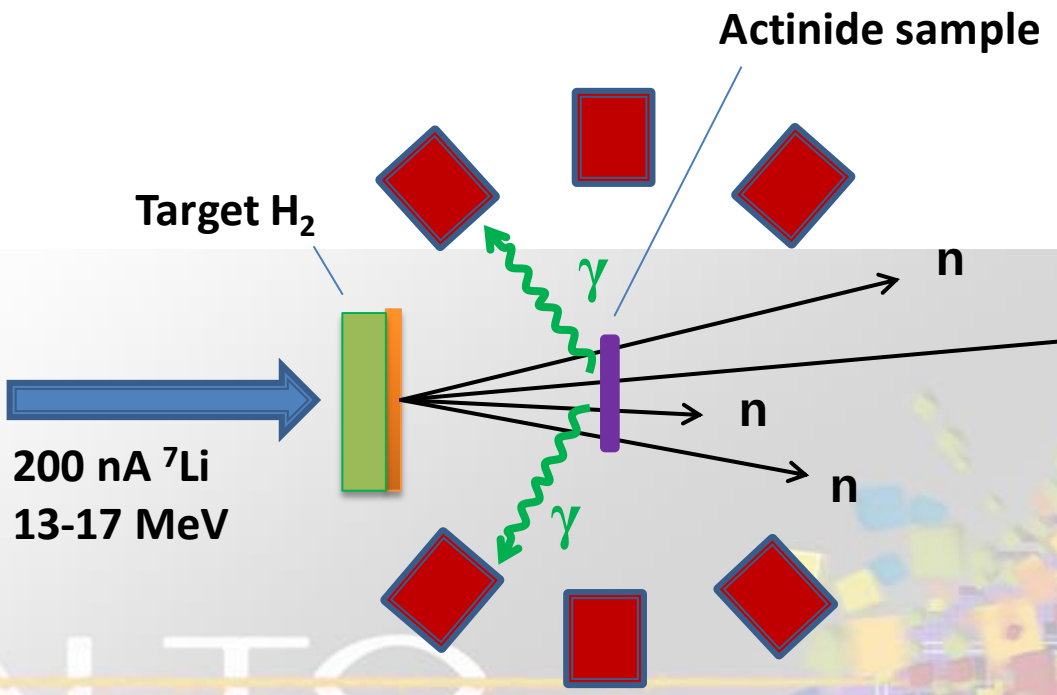
7.3% efficiency @ 1.33 MeV

ancillary detectors:

- Orsay plunger (OUPS)
- particle detectors
- DSSD



LICORNE: Neutron production in inverse kinematics



Lithium Inverse Cinematiques ORsay NEutron source

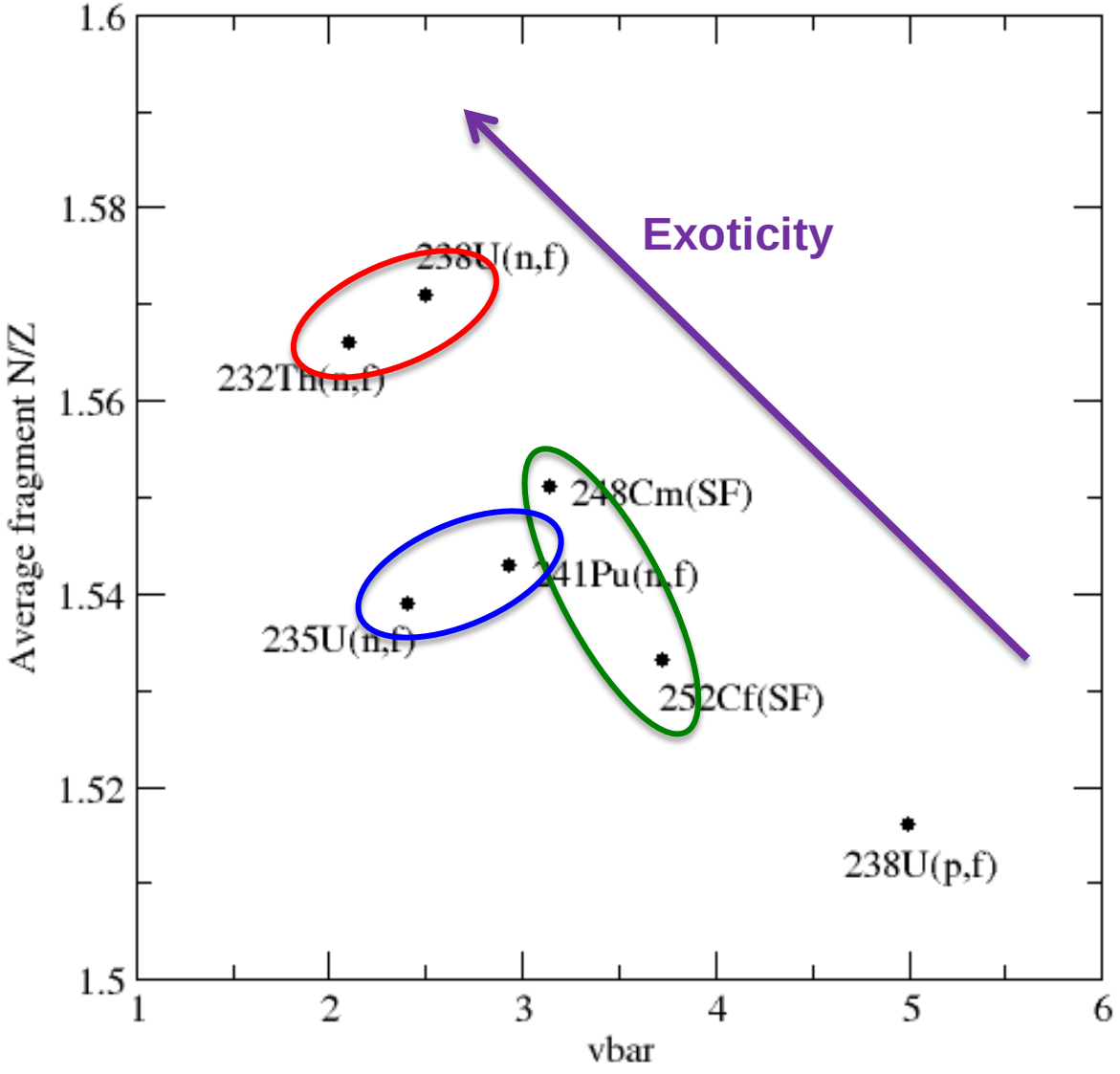
- reaction p(^{7}Li,^{7}Be)n using inverse kinematics
- Source of fast focused neutrons (between 0.5 and 4 MeV)
- NATURAL DIRECTIONALITY AND HIGH FLUX: 10^7 n/cm^2/s on target

Exotic Nuclei Production/Study from Fission Reactions

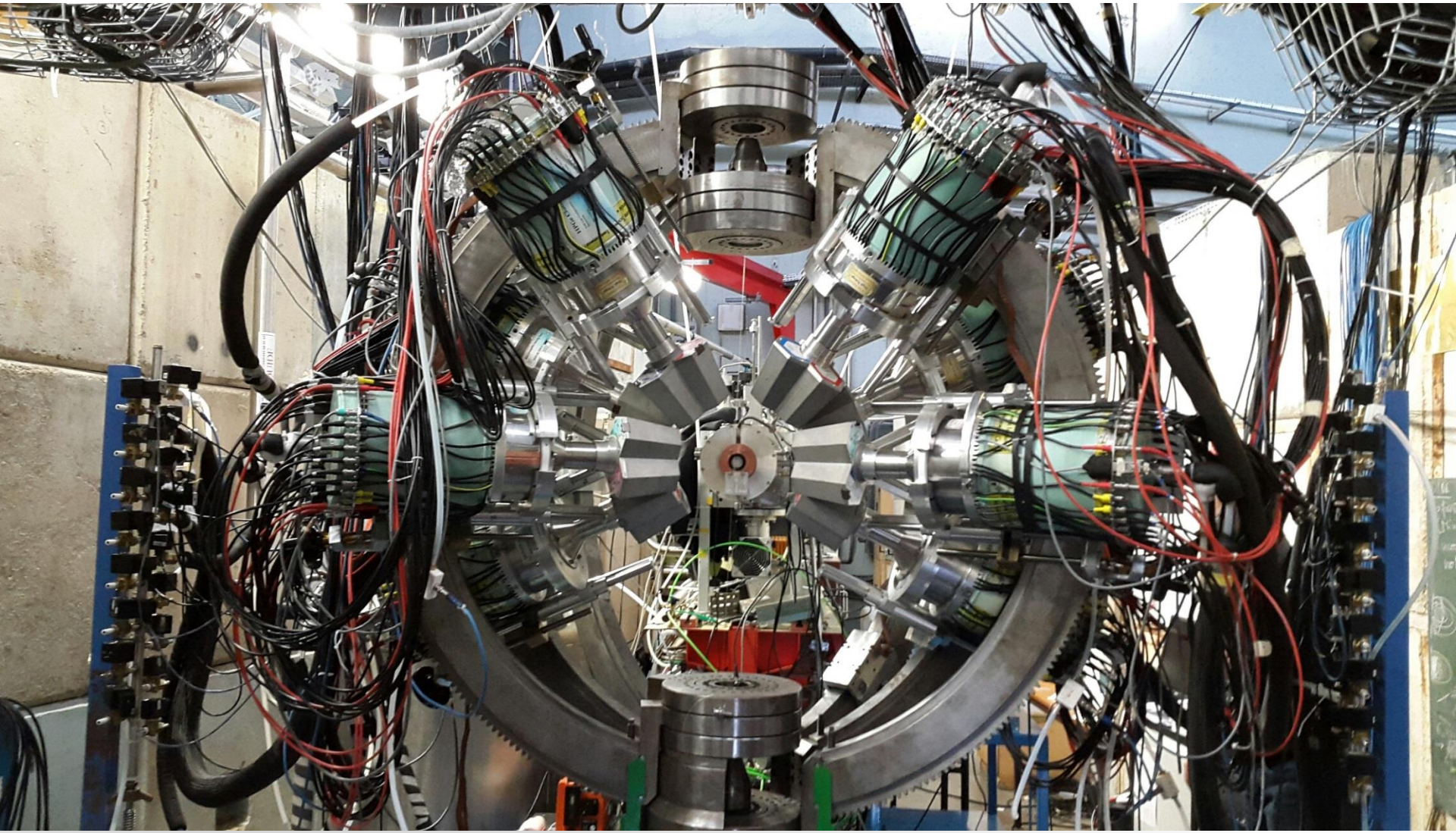
Spontaneous Fission
^{252}Cf(SF), ^{248}Cm(SF)
(Gammasphere, Euroball)

Fission induced by thermal neutrons
^{235}U(n_{th},f) ^{241}Pu(n_{th},f)
(EXILL Exogam@ILL)

Fission induced by fast ~2 MeV neutrons
^{238}U(n,f), ^{232}Th(n,f)
(LICORNE @ IPN Orsay)



Coupling of LICORNE + MINIBALL

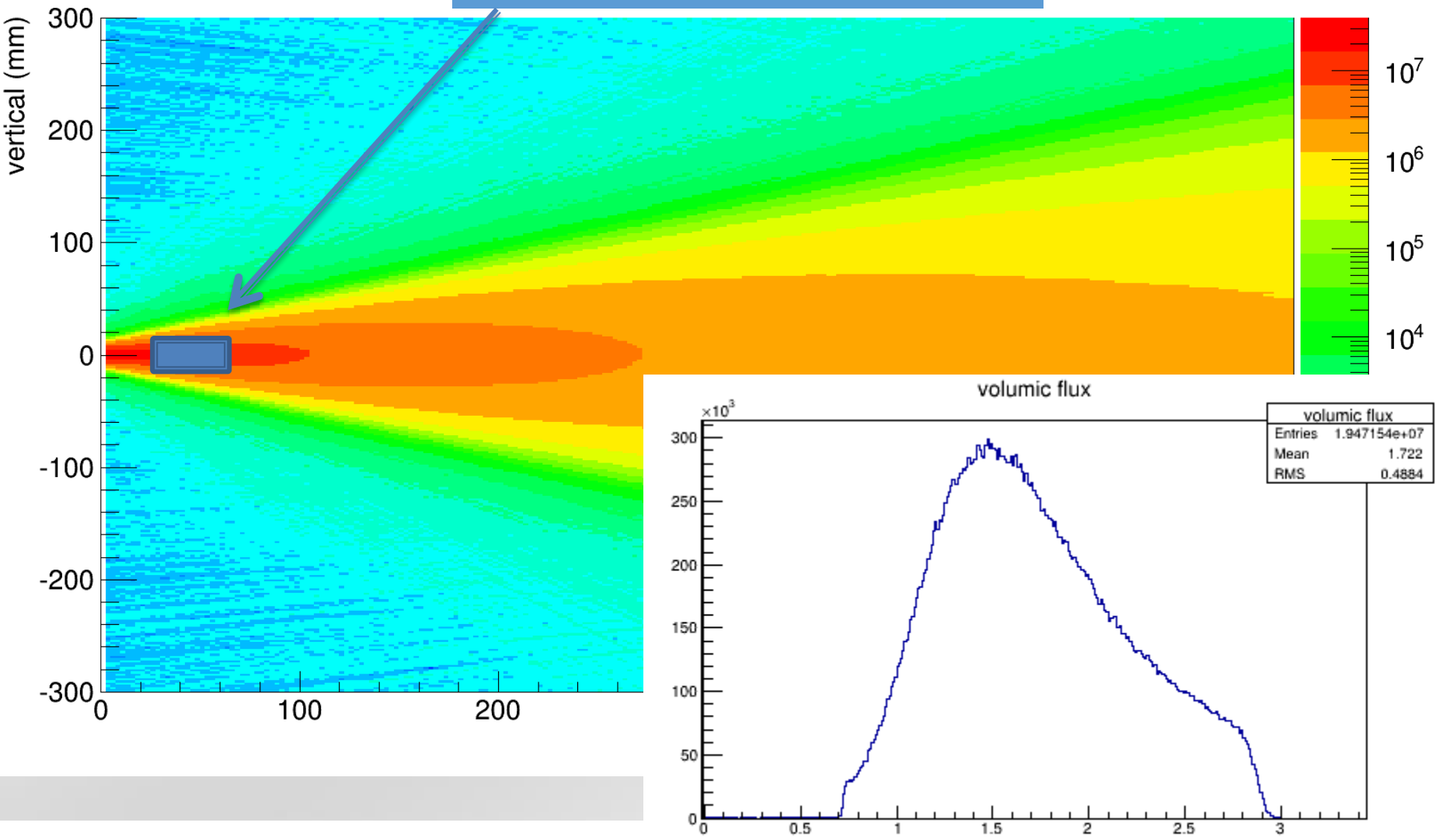


Coupling of LICORNE+MINIBALL

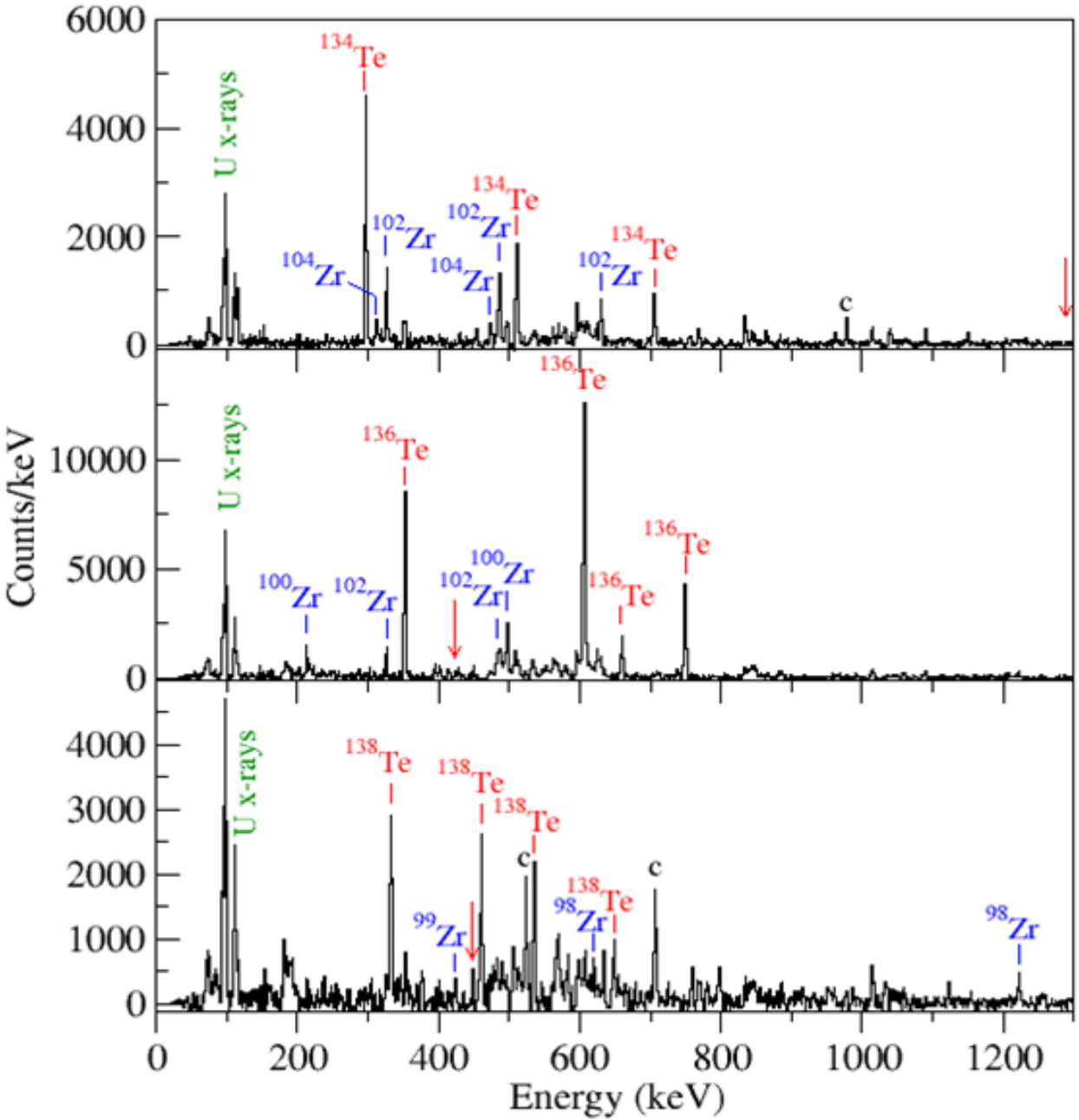
11 days of effective beam time: ~ 3 × 10^9 events with M_γ >= 3

Achievable Fission Rates

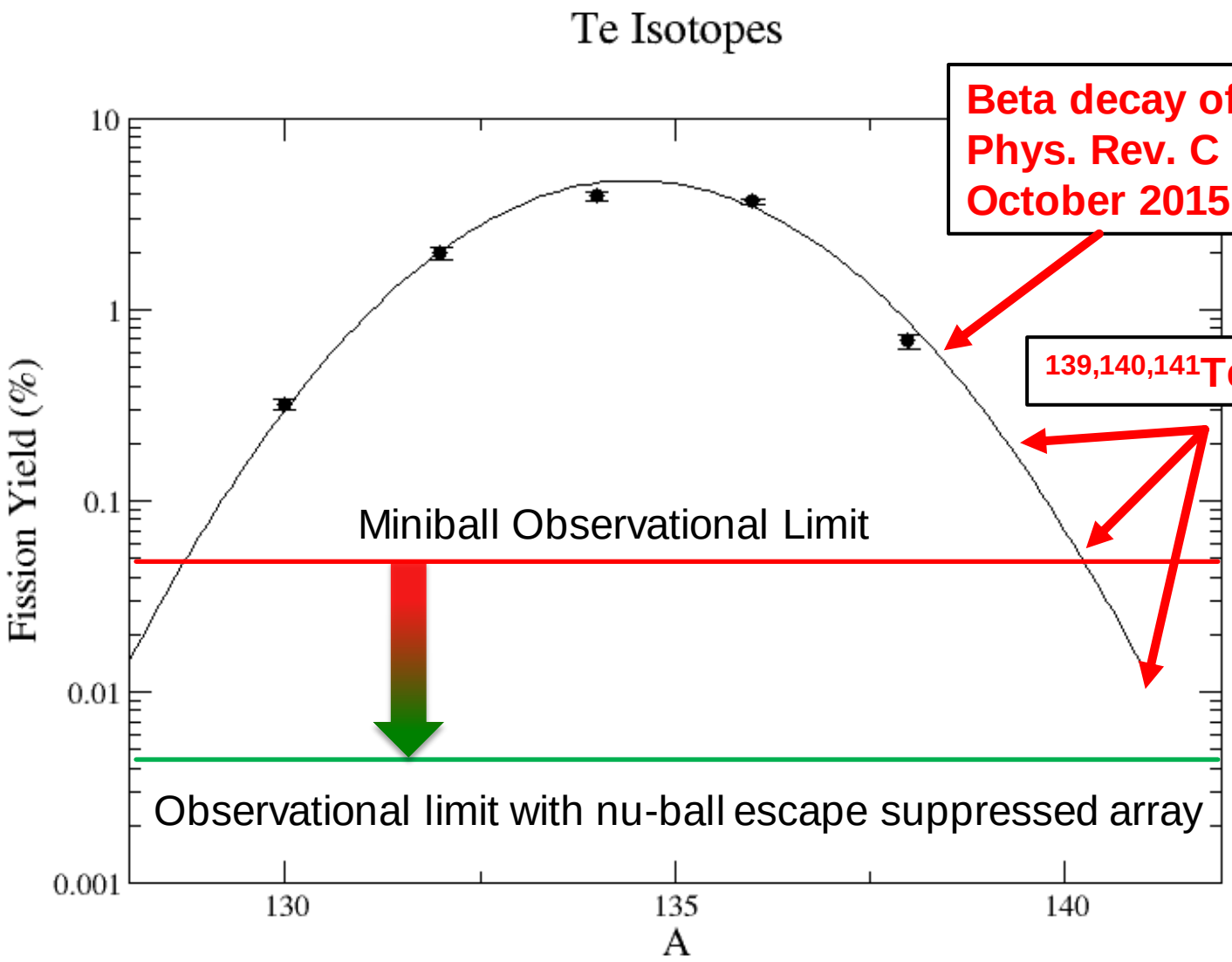
70 kHz fission rate for ^{238}U(n,f)
15 kHz fission rate for ^{232}Th(n,f)



How far from stability can we get?



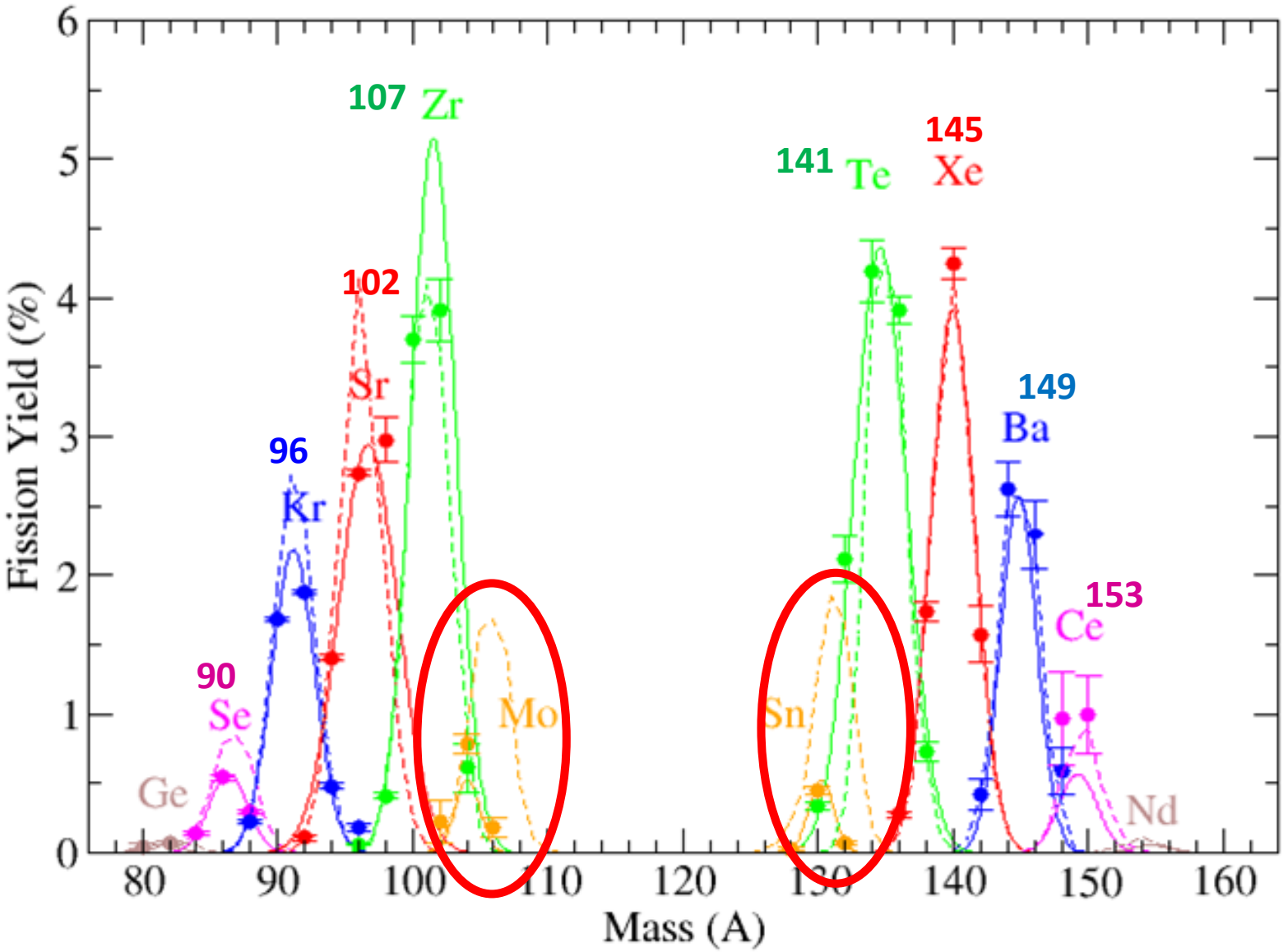
How far from stability can we get?



Beta decay of ^{138}Sb @ RIKEN
Phys. Rev. C 92, 044320, October 2015

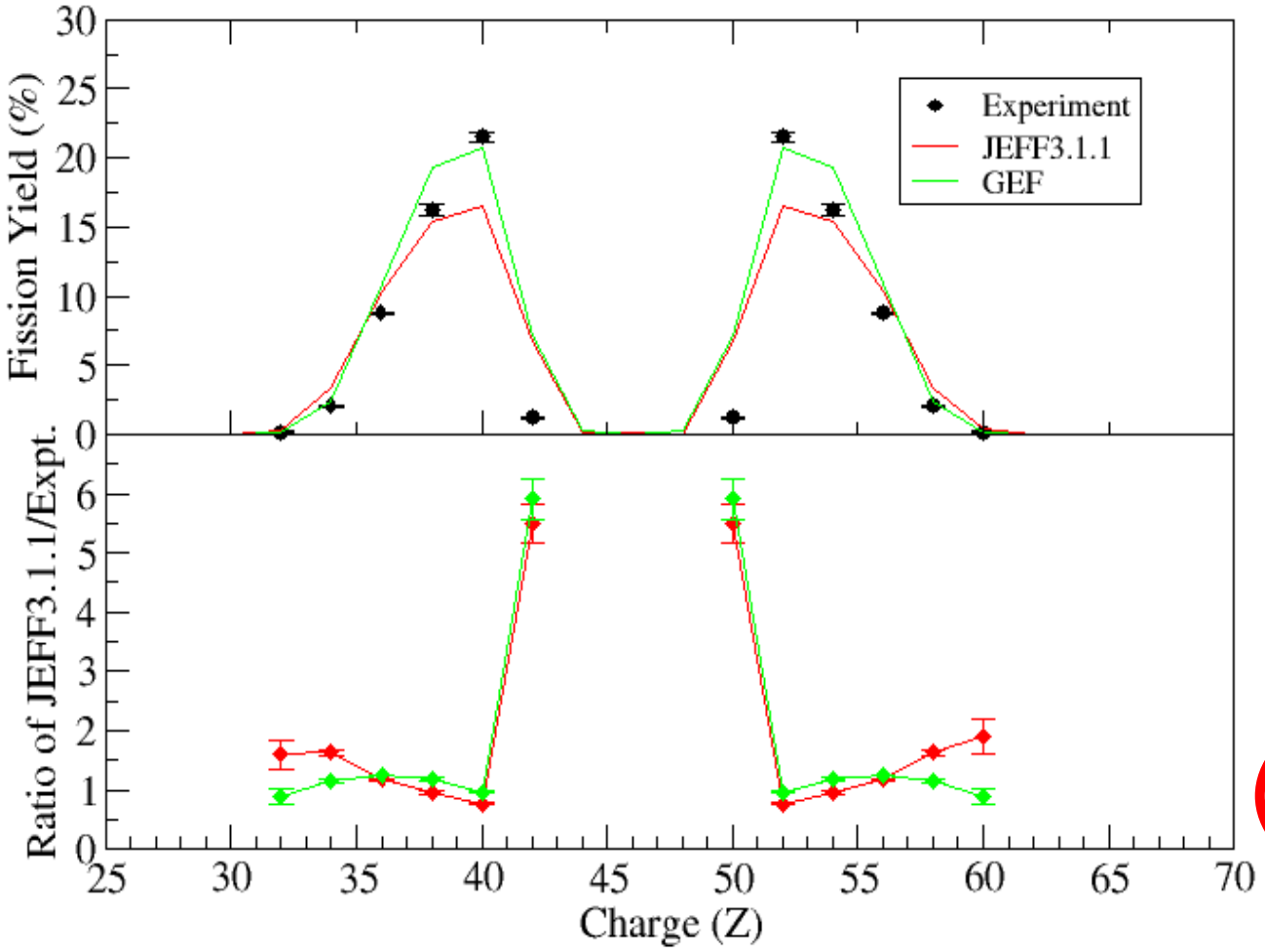
^{139,140,141}Te are observable

238U(n,f) Fission Yield Measurements



Anomalies in the Charge Yields of Fission Fragments from 238U(n,f)

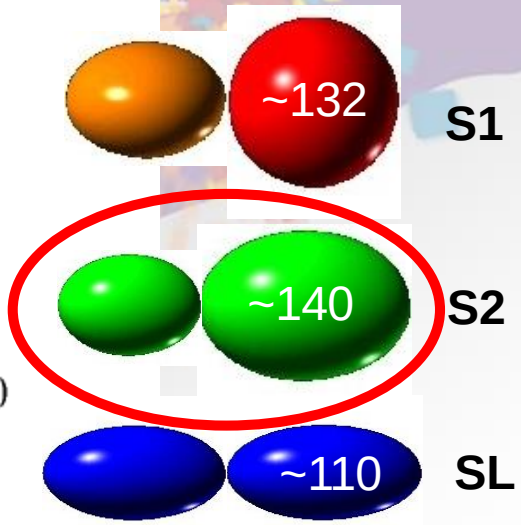
- **Measured charge yields for ^{238}U(n,f)show up to <u>600%</u> discrepencies between models and experiment!**



<u>Interpretation:</u>

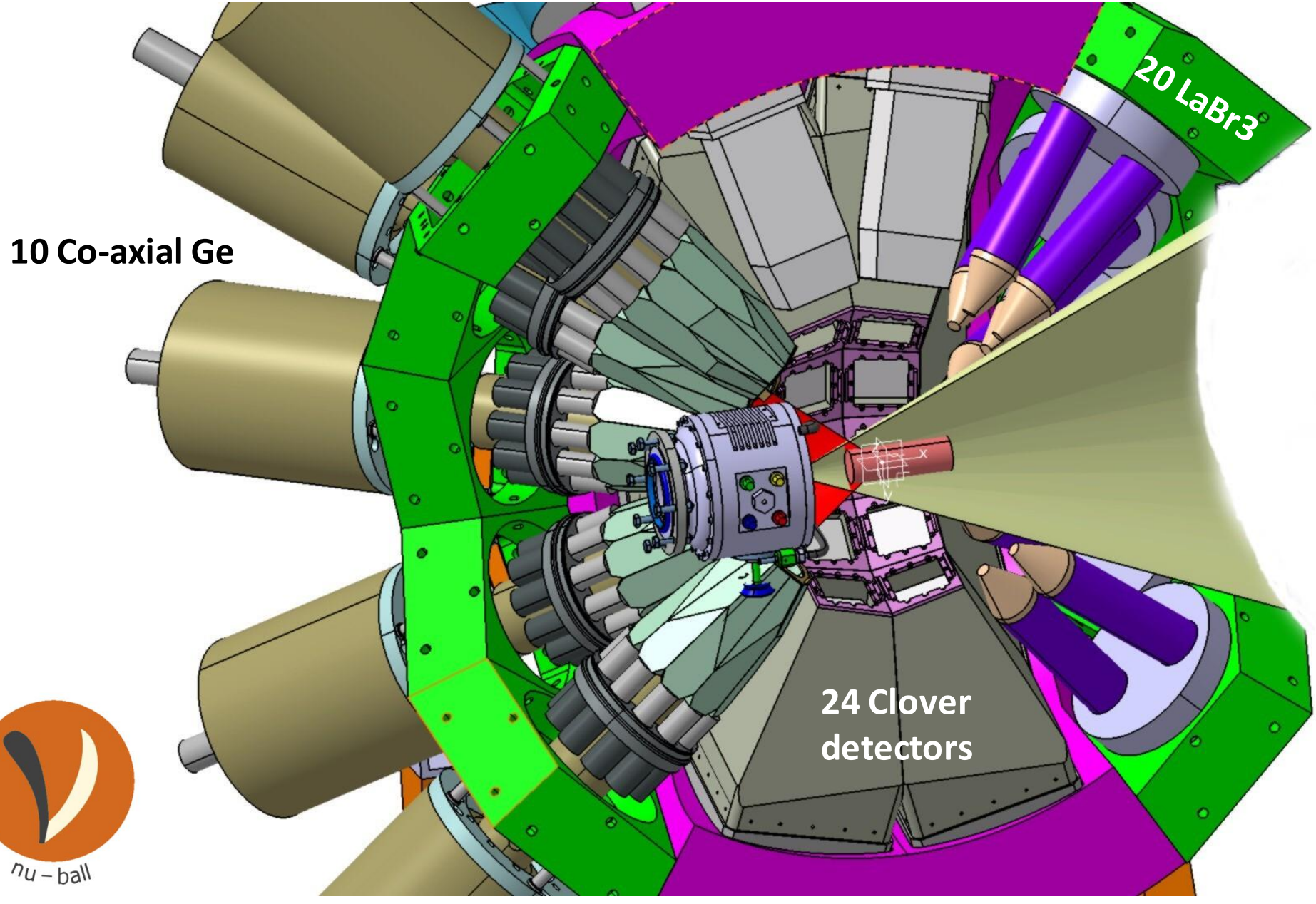
Spherical shell effects in the nascent fragments (S1) become much less important

Fission modes



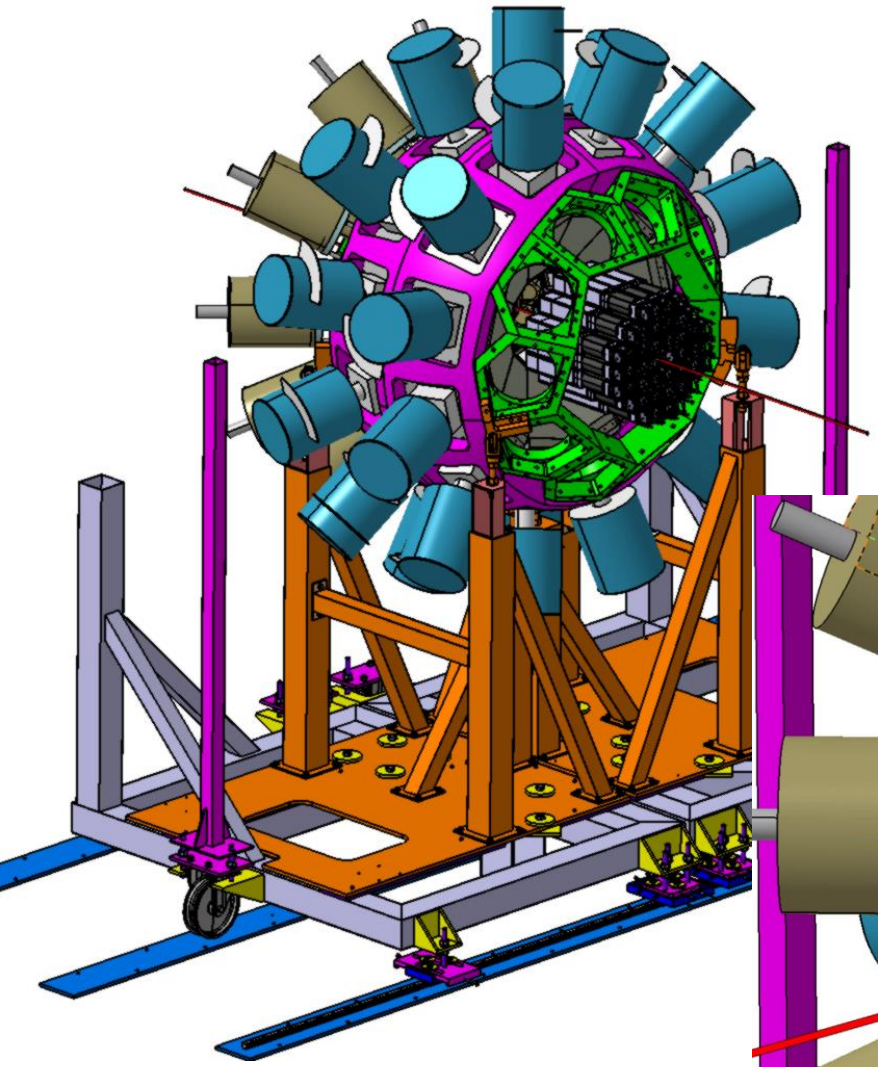
J.N. Wilson, M. Lebois, L. Qi et al., Phys. Rev. Lett. 118, 222501 (2017)

Nu-ball experimental campaign 2017/2018



nu – ball

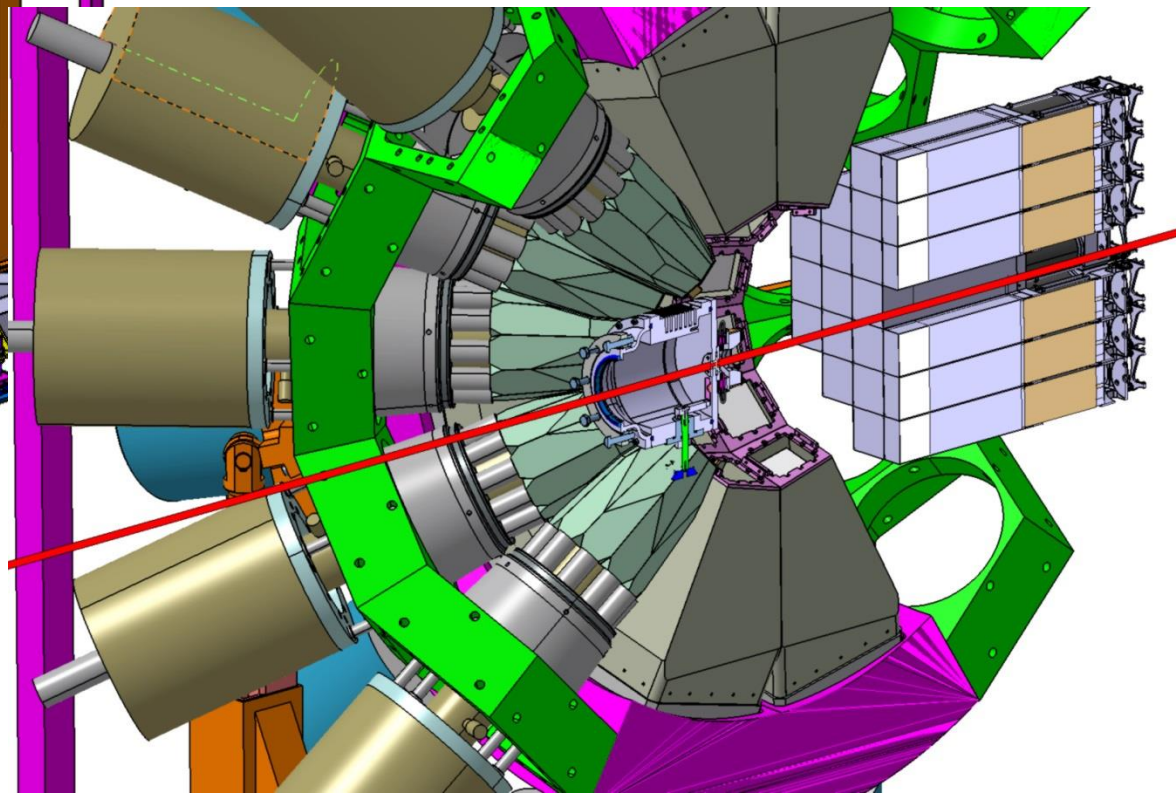
Coupling of nu-ball and PARIS



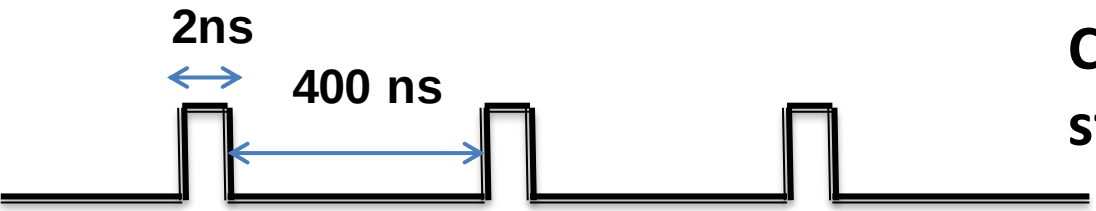
nu – ball

+

PARIS



Upgrade of the Tandem Buncher



Current Tandem beam time structure

- Advances in detectors (e.g. LaBr3): Excellent timing (~150ps) + Good E resolution
- Fast timing studies currently require Ge-LaBr3-LaBr3 coincidences
- Thus currently limited to strong tranitions in strongly populated nuclei

Buncher-LaBr3-Ge coincidences permit a huge increase in selectivity:
Increased statistics + ability to gate on short lived states

Phase I upgrade: Buncher Diagnostics TDC (1ns -> 50 ps). Tests planned summer 2017.
Goal: 500ps buncher resolution (equivalent to PARIS cluster time resolution)

Phase II upgrade: Buncher electronics/Hardware modifications.
Goal: 150 ps resolution (equivalent to the fastest LaBr3 detectors)

❑ **Strategic Importance** : ALTO as a centre for γ Fast Timing studies

ALTO2.0 – Preparing for the next decade

- **Physics** : Clear definition of the scientific program

- **Reliability**: Focus mainly on improvements for the RIB part

- **Environment** : Univ. Paris-Saclay, national and international level
Definition of a common strategy with GANIL/SPIRAL2

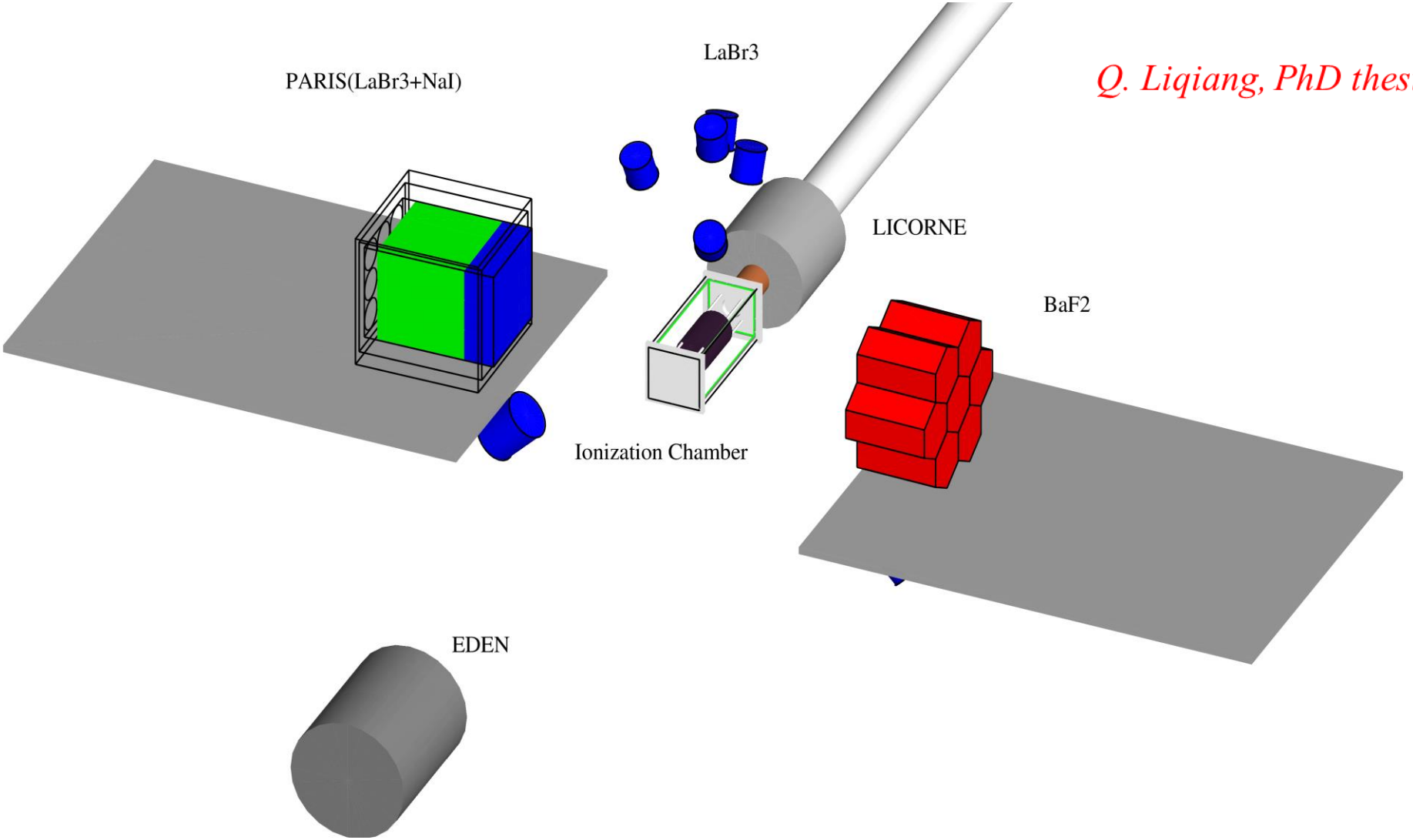
- **Applications** : Industrial applications and teaching at ALTO

- **General Status** : Planned for November 2017

Milestones:

- General Status. Nov 2017
- White Book Jan. 2018

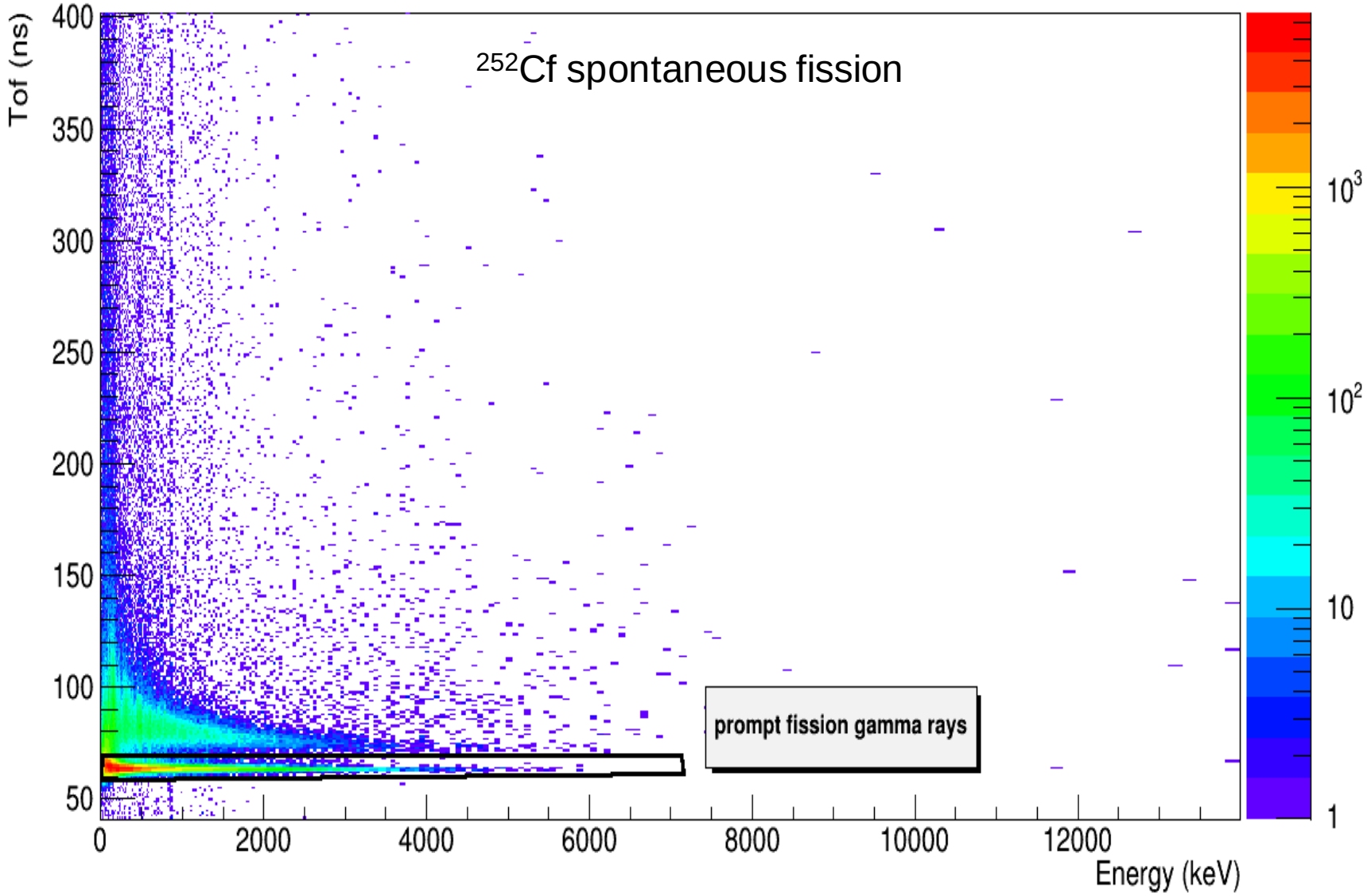
March 2016: Experimental Setup (Geant IV response model)



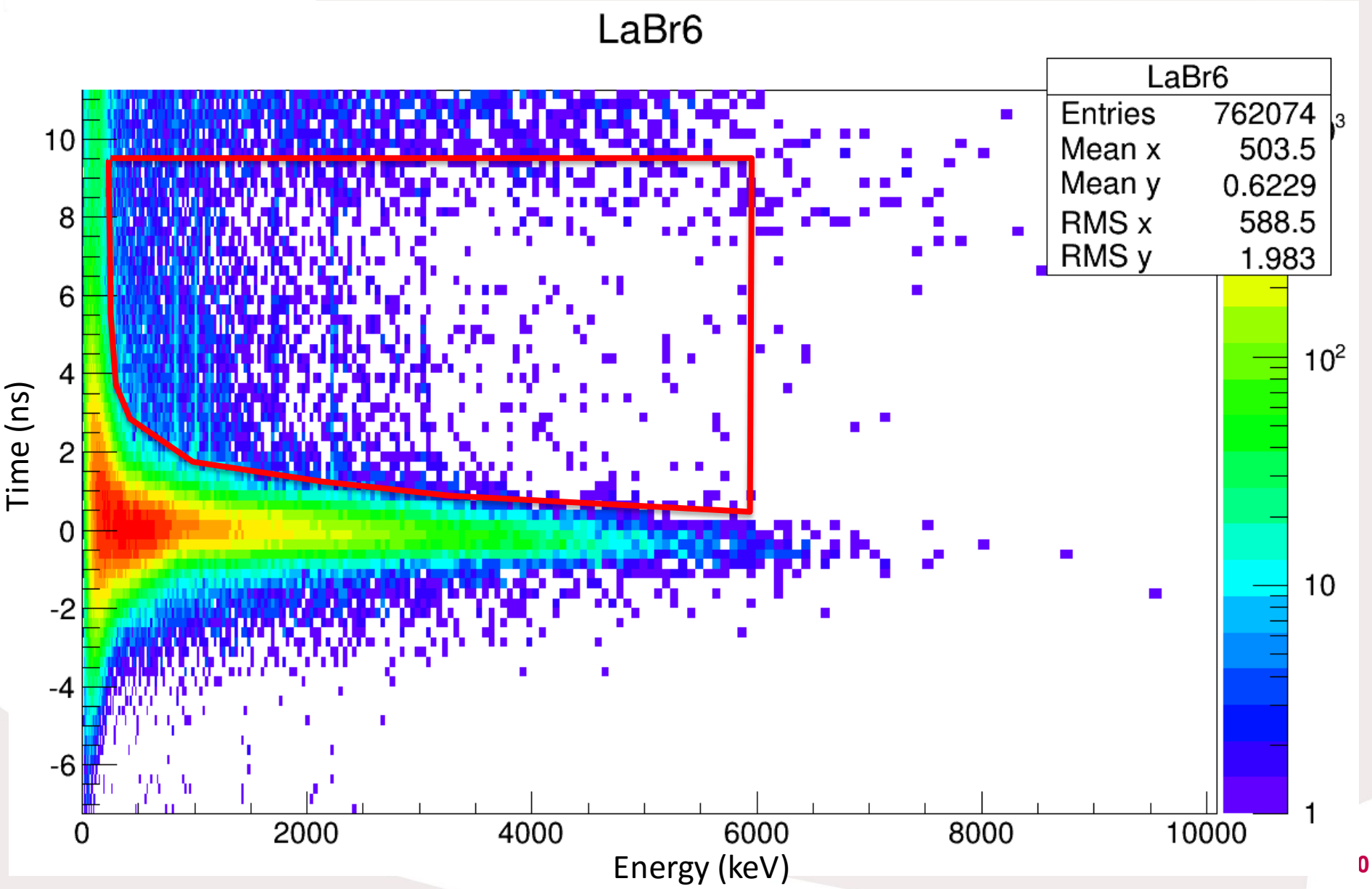
Q. Liqiang, PhD thesis

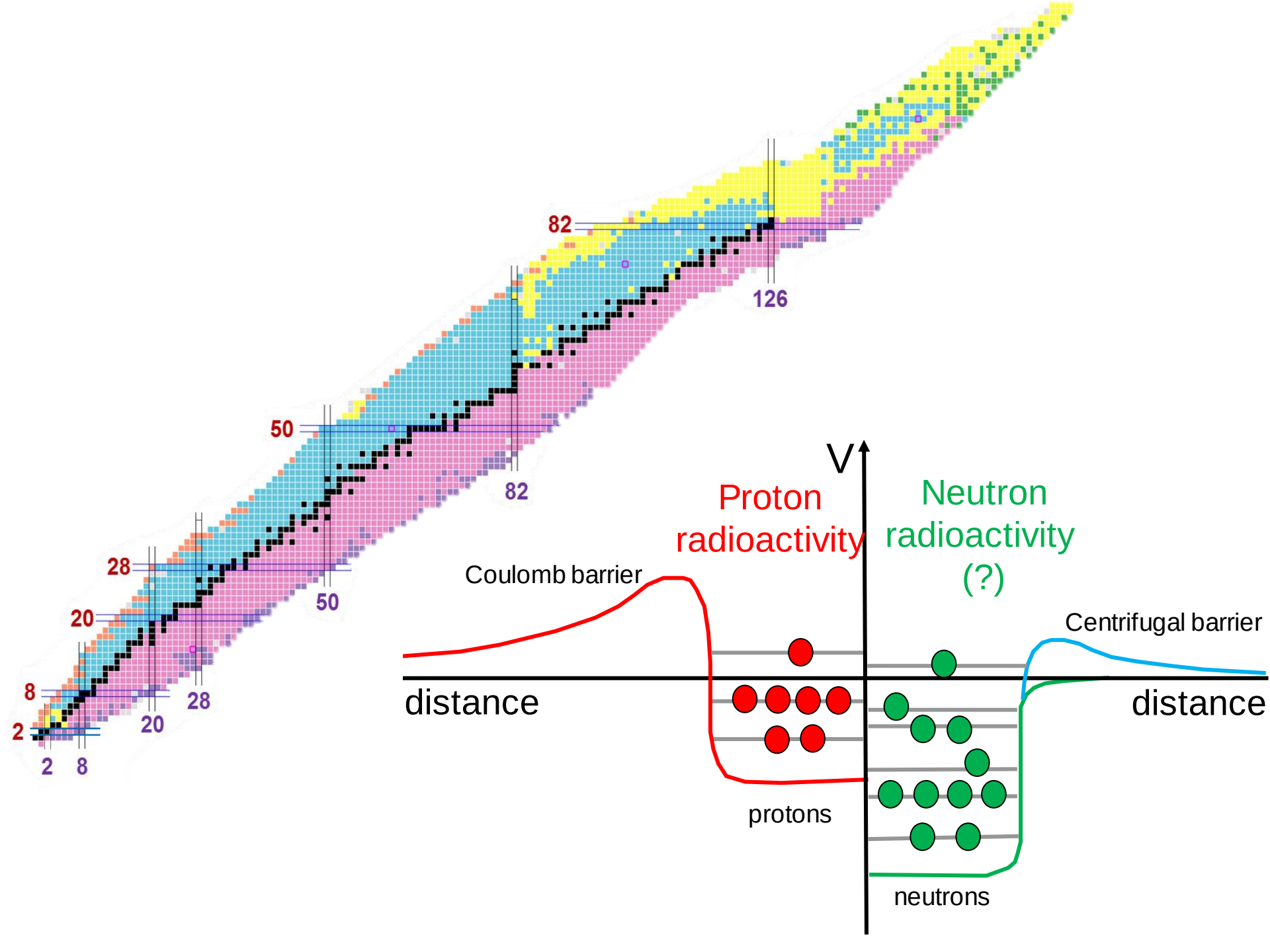
MARCH 2016 EXPERIMENT: DATA ANALYSIS (^{252}Cf STUDY)

Q. Liqiang, PhD thesis

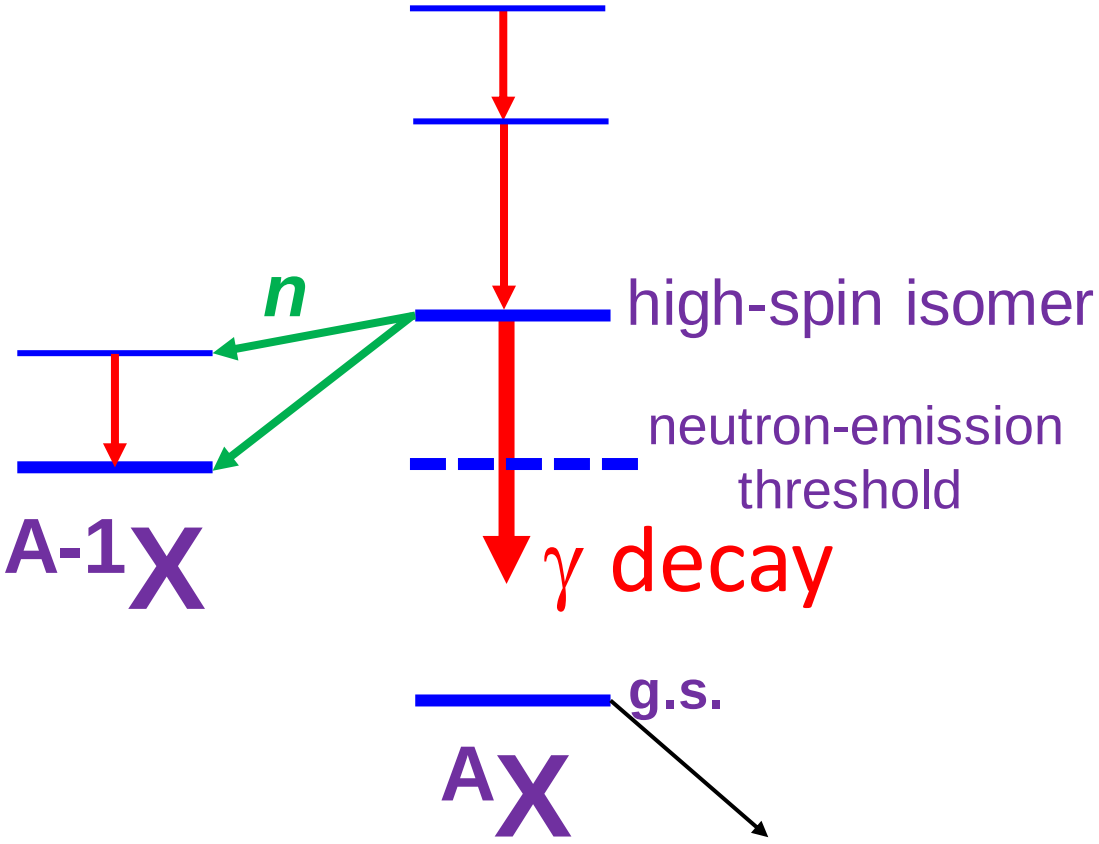


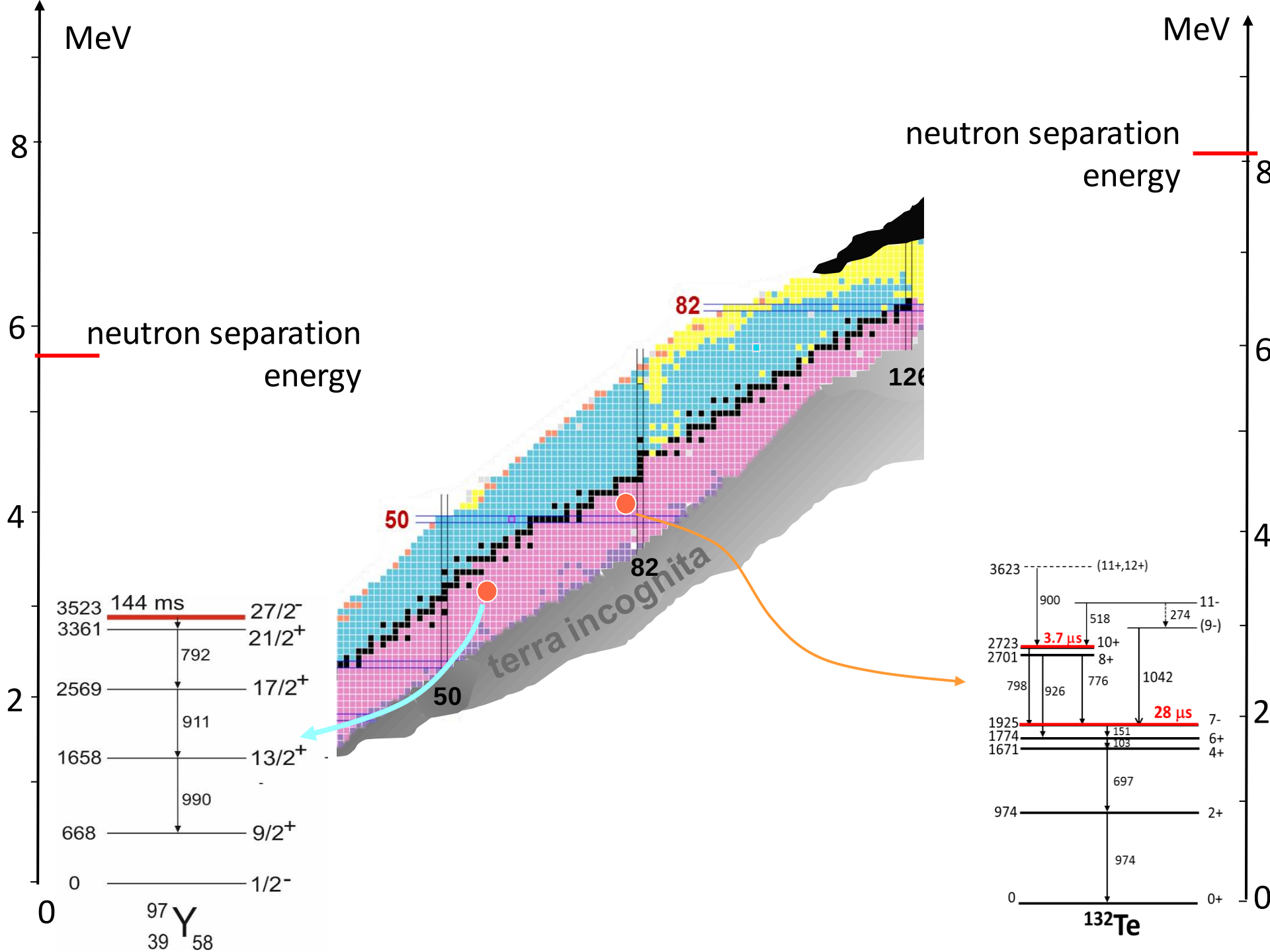
UNKNOWN SHORT LIVED ISOMERS




82
126
50
82
28
50
20
28
8
20
2
2
8
V
Proton
radioactivity
Neutron
radioactivity
(?)
Coulomb barrier
Centrifugal barrier
distance
distance
protons
neutrons

Neutron radioactivity




MeV
8
6
4
2
0
neutron separation energy
3523 144 ms 27/2⁻
3361 21/2⁺
792
2569 17/2⁺
911
1658 13/2⁺
990
668 9/2⁺
0 1/2⁻
97 39 Y 58
82
50
82
50
terra incognita
MeV
neutron separation energy
3623 (11+,12+)
900
518
274
11-
(9-)
2723 3.7 µs 10+
2701 8+
798
926
776
1042
1925 28 µs 7-
1774 6+
1671 4+
151
103
697
974 2+
974
0 0+
132Te

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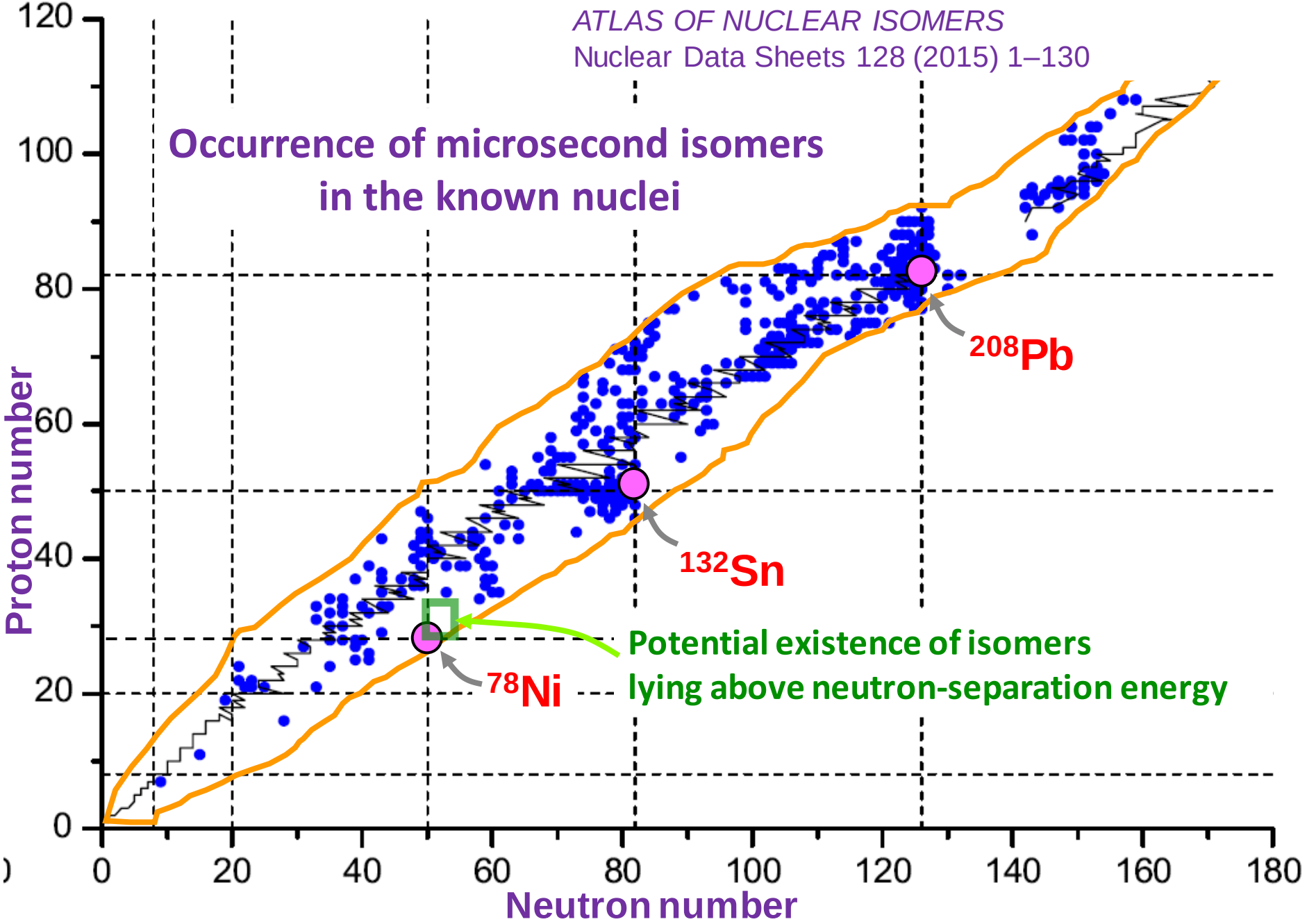

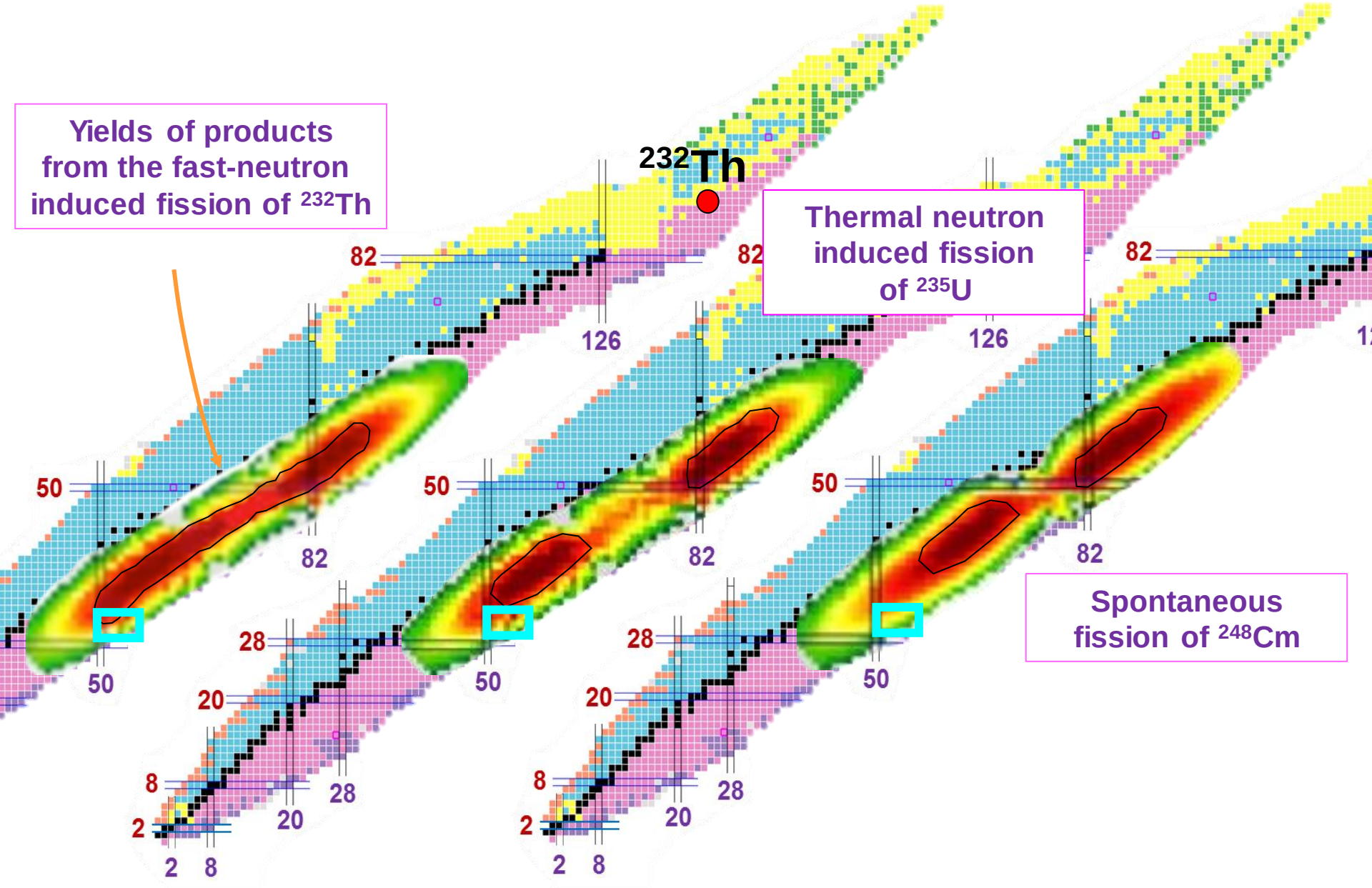
Yields of products from the fast-neutron induced fission of 232Th
232Th
Thermal neutron induced fission of 235U
Spontaneous fission of 248Cm
82
126
50
28
20
8
2