

**NUSTAR week 2019**  
**23-27 Sep. 2019**  
**Gif-sur-Yvette, France**

# **ILIMA**

**Isomeric beams, Lifetimes and Masses**  
**status report and phase-0 program**

Taka Yamaguchi (Saitama Univ. Japan)  
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**Stockholm, Sweden:** S. Tashenov

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**Notre Dame, USA:** Z. Meisel

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**Beihang, Beijing, China:** B. Sun

**Saitama, Japan:** T. Suzuki, **T. Yamaguchi**

**Tsukuba, Japan:** A. Ozawa

**RIKEN, Japan:** T. Uesaka

**ANU Canberra, Australia:** M.W. Reed

**Jammu, India:** R. Devi



**114 scientists**  
**36 institutes**  
**20 countries**

**Spokesperson: T. Yamaguchi**

**Deputy Spokesperson: Yu.A. Litvinov**

**Project Manager: H. Weick**

# Isomeric beams, Lifetimes and MAsses

## Technical Proposal for the ILIMA Project

ILIMA

Isomeric Beams, Lifetimes and Masses

Collaboration

2<sup>nd</sup> Feb 2005

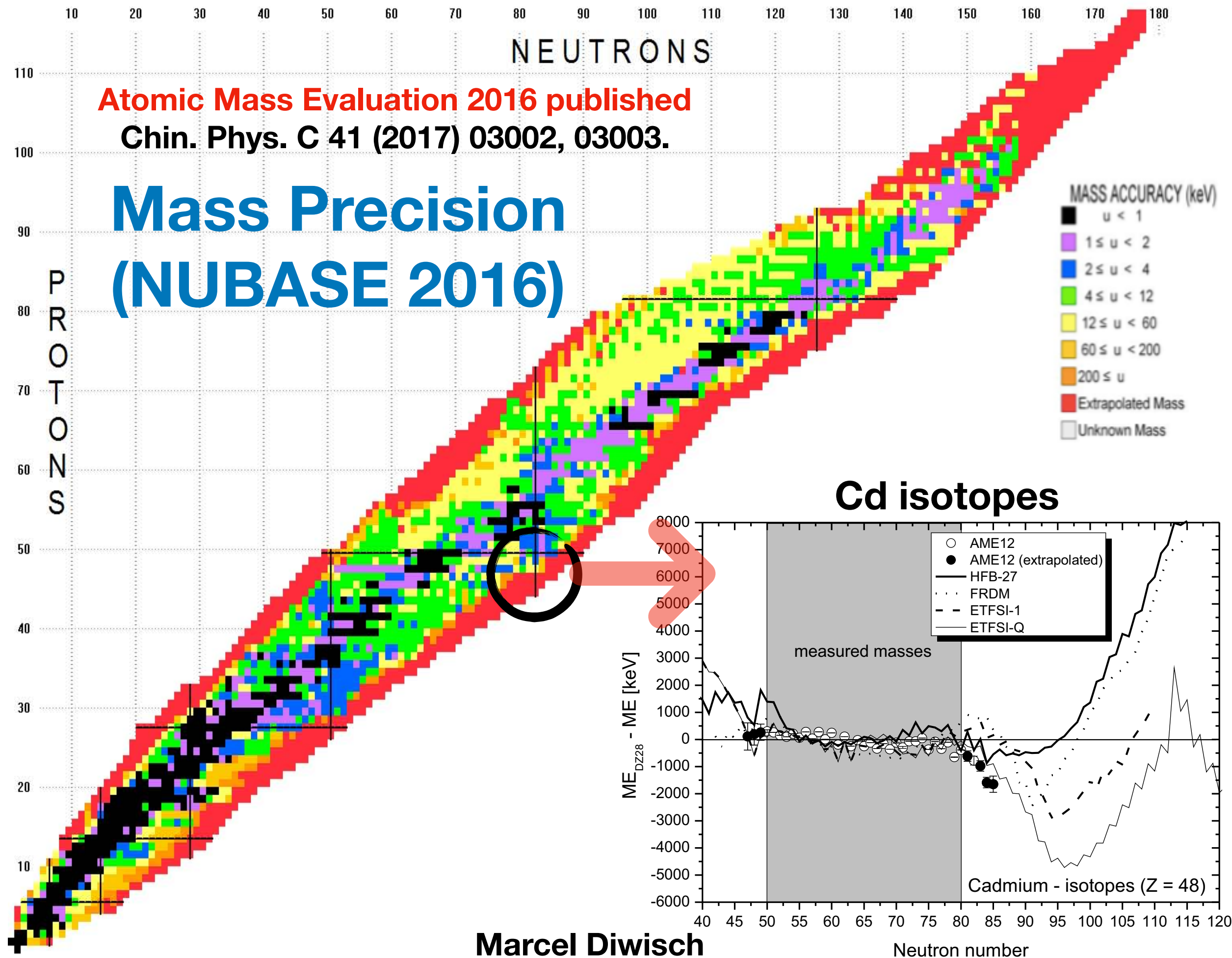
### Abstract:

Precision measurements of nuclear masses and lifetimes of stored exotic nuclei at relativistic energies and studies with isomeric beams are proposed. The planned experiments are a continuation of the successful experimental program at the present FRS-ESR facilities. The new Super-FRS-CR-RESR-NESR facility will yield access to interesting nuclei near and at the drip-lines which can not be accessed with the present facilities.

### Today's talk:

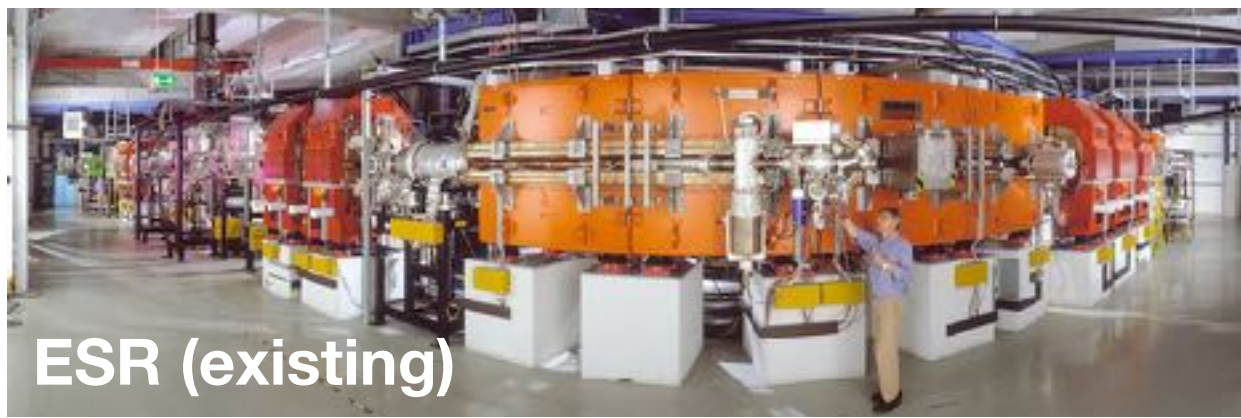
- **Overview of the ILIMA project**  
Mass measurements with SMS and IMS
- **Highlights at the FRS-ESR**  
New masses, bound-state beta decay, ...
- **Phase-0 programs**
- **More...**



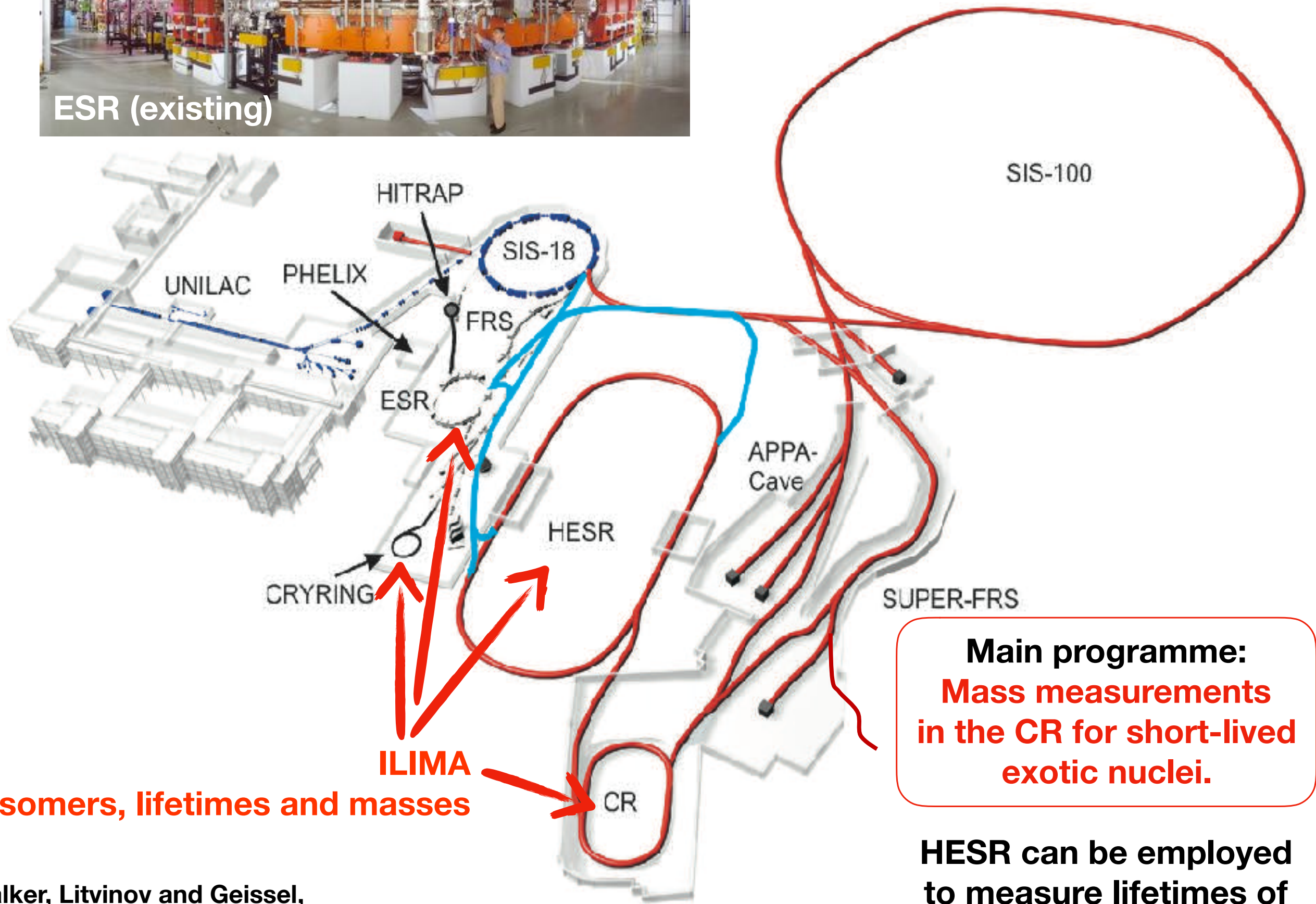


Marcel Diwisch





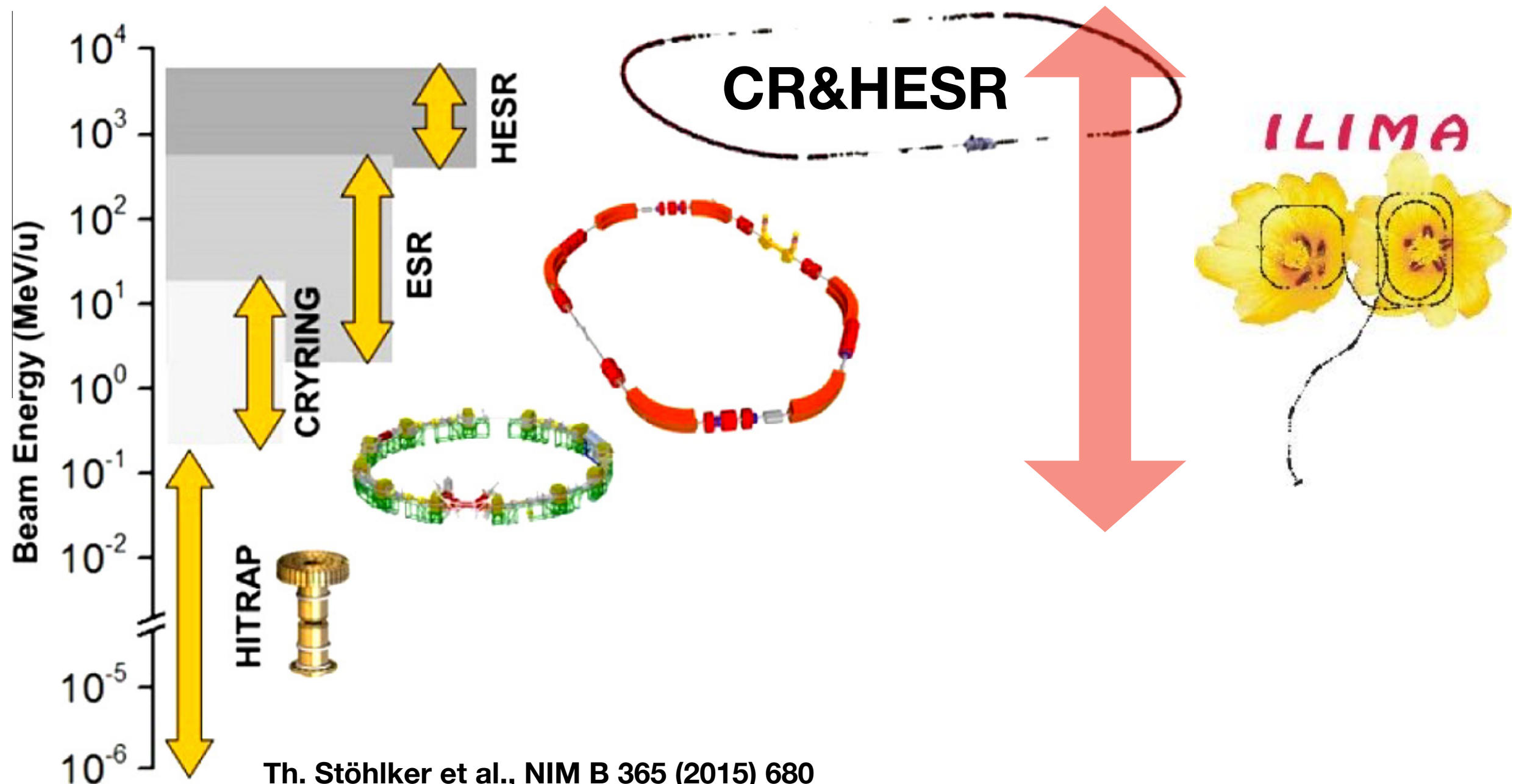
ESR (existing)



# Stored Ions in Wide Energy Range

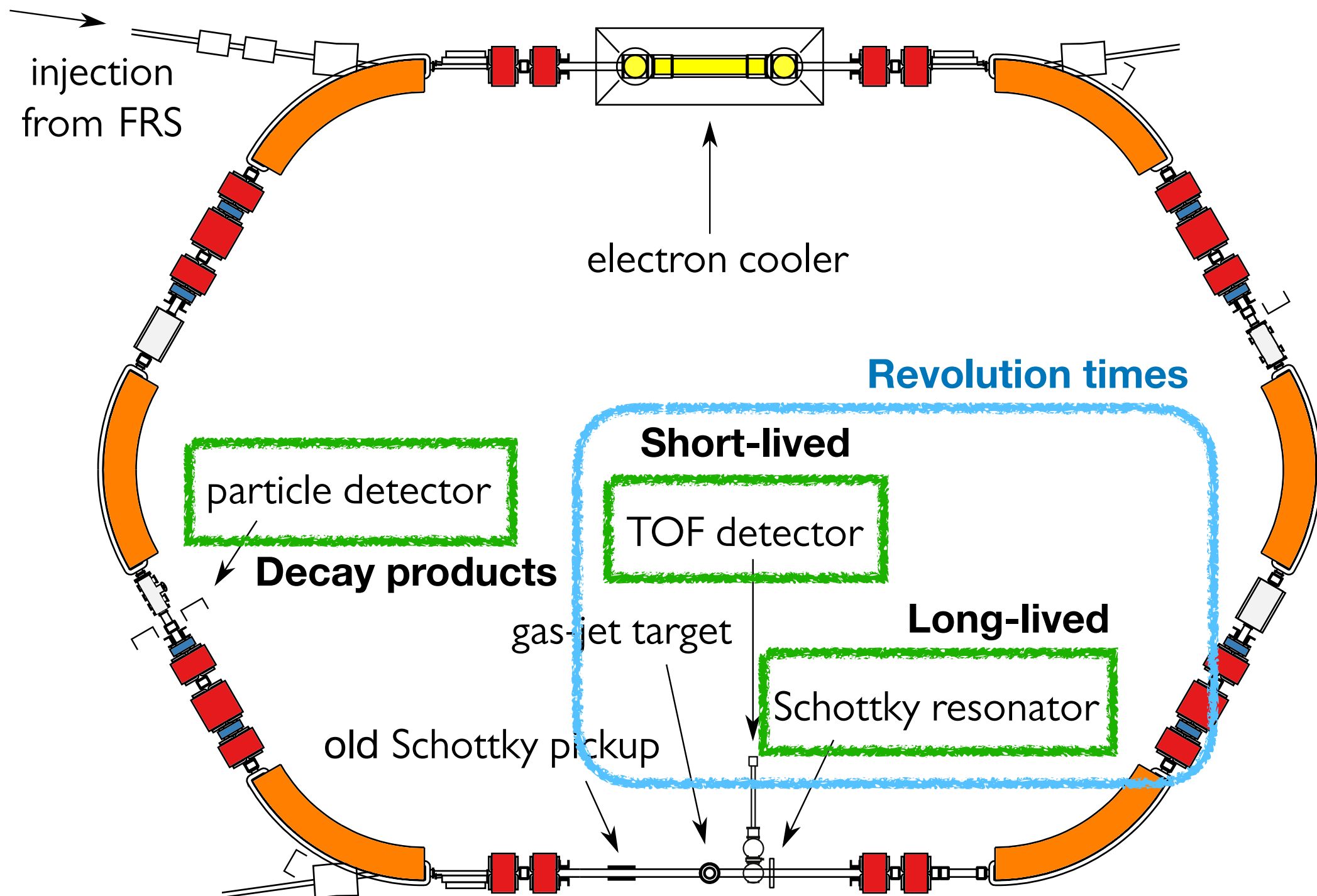
Highly charged exotic nuclei in storage rings

accuracy  $\sim 30$  keV  
half-life limit  $\sim 20$   $\mu$ s  
single-ion sensitivity/week



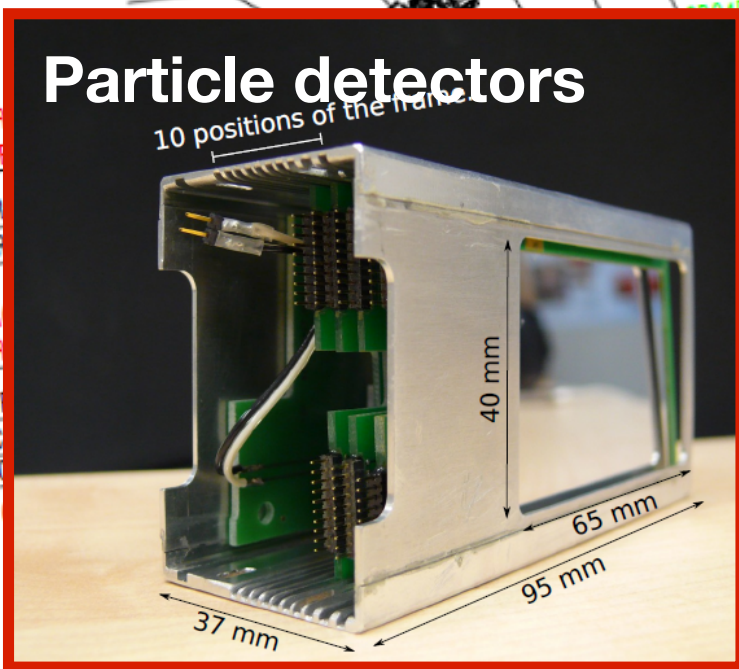
# Experimental Storage Ring ESR

## Main Detector Setup





## Particle detectors

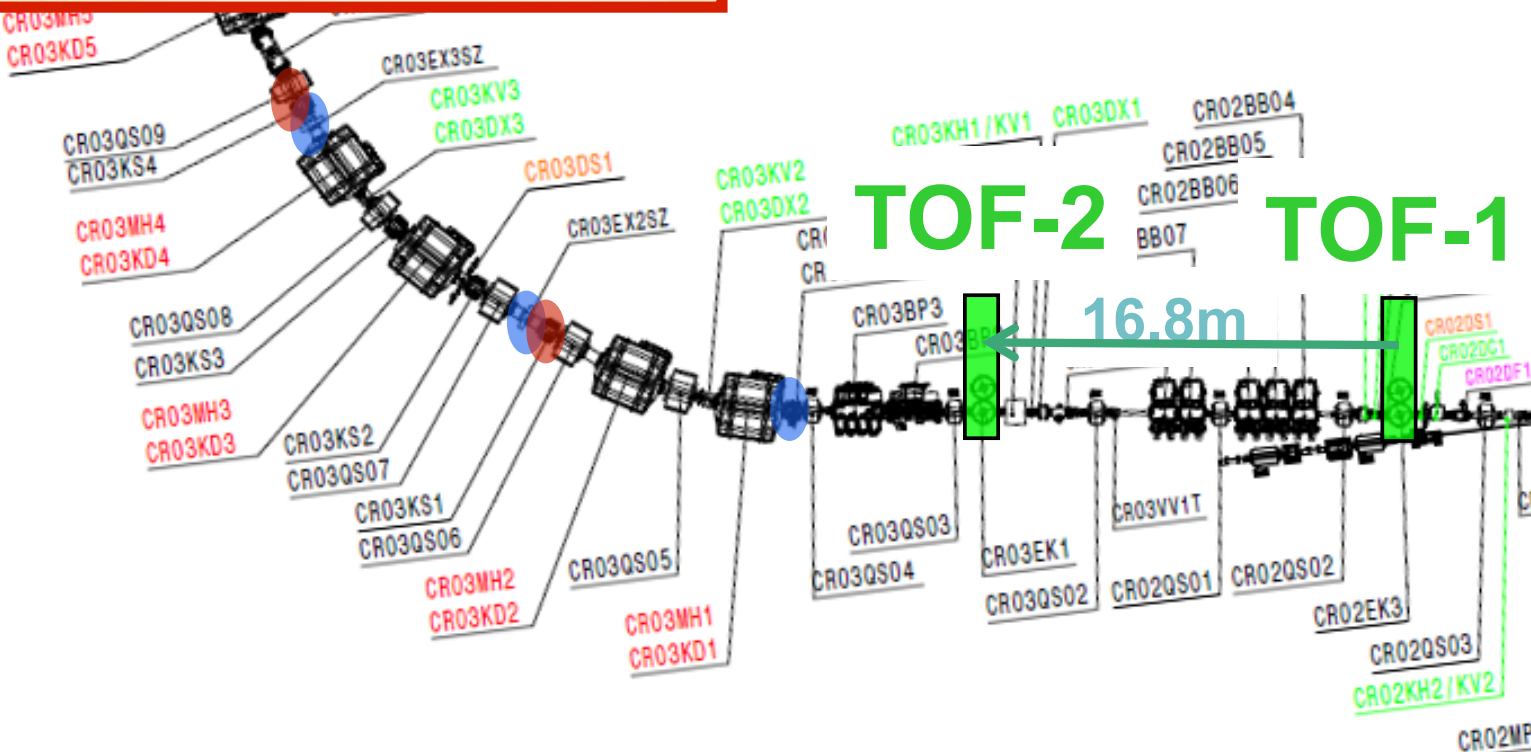


## ILIMA@CR

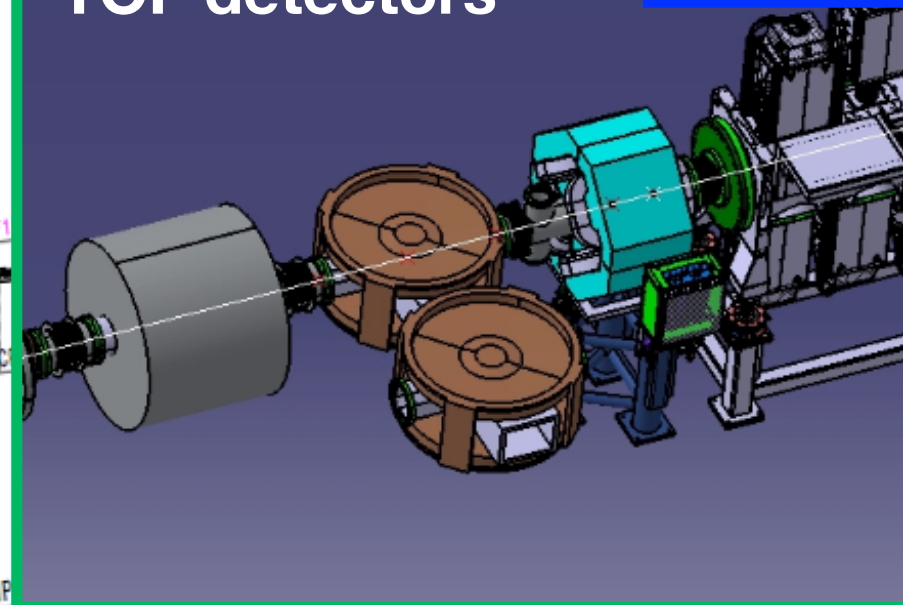
- Schottky pickups also horizontal and vertical
- Detector pockets
- ToF detectors



Schottky pickup



## TOF detectors



stand: 12.02.2016



# Working Group Status

- **TOF detector**

- N. Kuzminchuk-Feuerstein et al. NIM A 821 (2016) 160
- TDR approved
- Spec for in-kind contract approved

- **Schottky detector**

- New Schottky prototype installed in ESR
- TDR approved

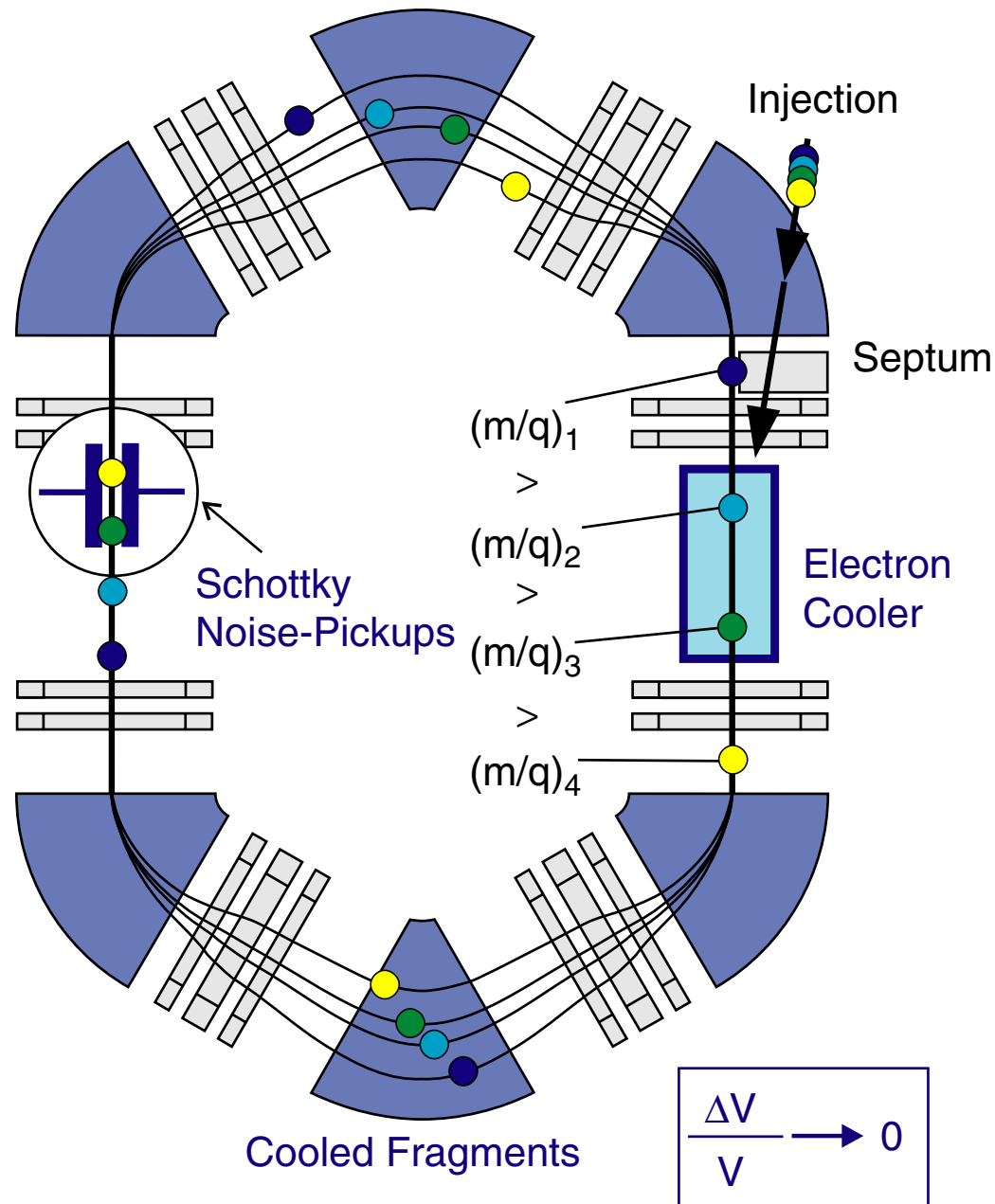
- **Heavy-ion detector**

- M.A. Najafi et al., NIM A 836 (2016) 1
- TDR approved



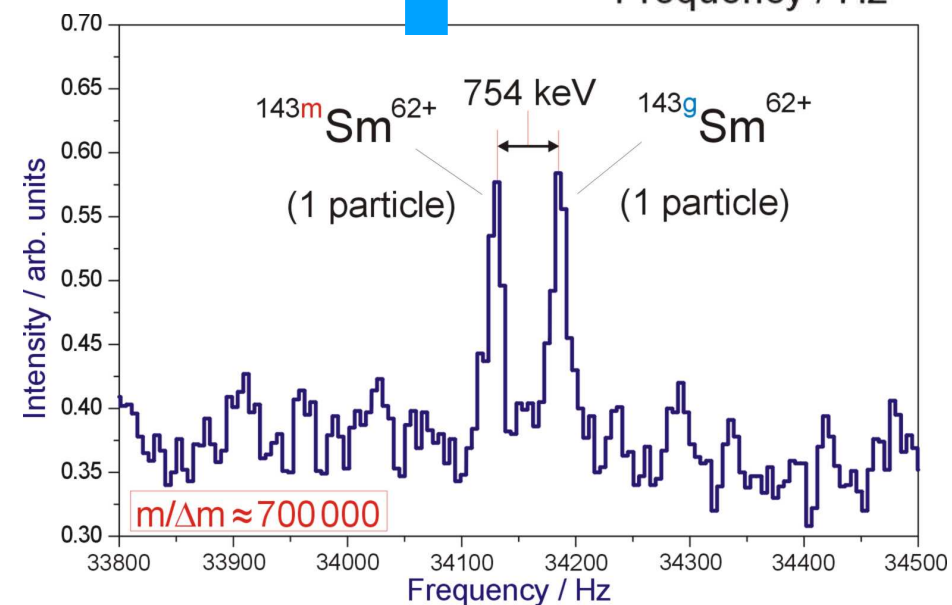
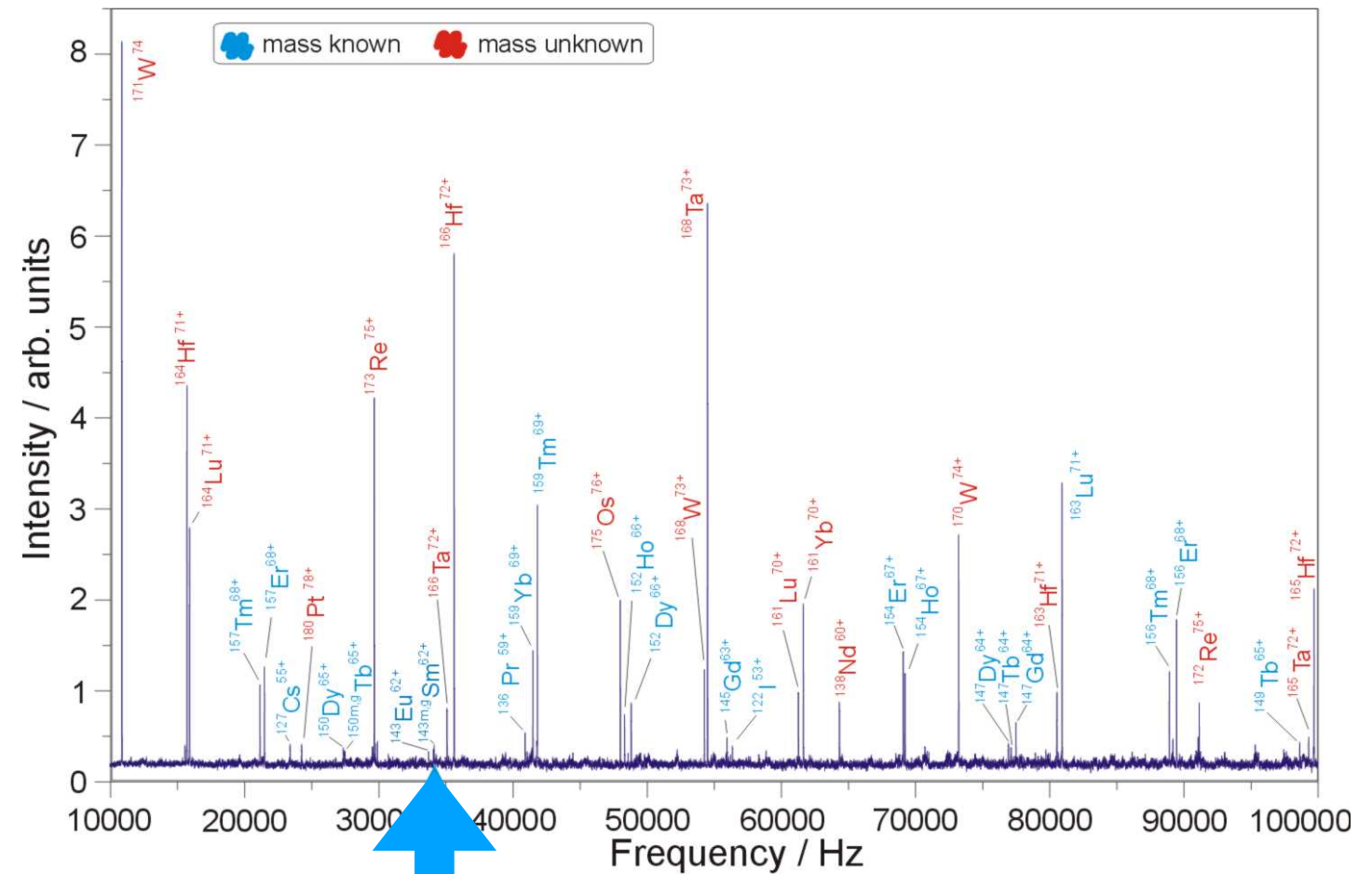
# SMS

## SCHOTTKY MASS SPECTROMETRY



**High resolving power**  
**Single-ion sensitivity**

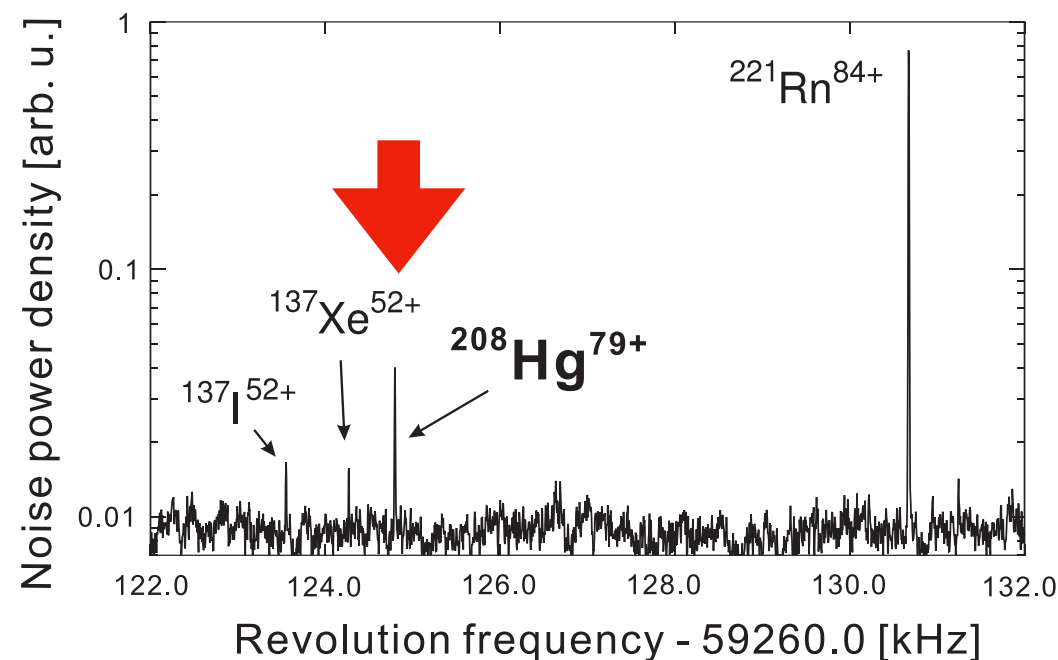
$$\frac{\Delta f}{f} = \frac{1}{\gamma_t} \frac{\Delta(m/q)}{m/q} + \cancel{\frac{\Delta v}{v} \left(1 - \frac{\gamma^2}{\gamma_t^2}\right)}$$



# Schottky Mass Measurement of the $^{208}\text{Hg}$ Isotope: Implication for the Proton-Neutron Interaction Strength around Doubly Magic $^{208}\text{Pb}$

L. Chen,<sup>1,2</sup> Yu. A. Litvinov,<sup>1,\*</sup> W. R. Plaß,<sup>1,2</sup> K. Beckert,<sup>1</sup> P. Beller,<sup>1</sup> F. Bosch,<sup>1</sup> D. Boutin,<sup>2</sup> L. Caceres,<sup>1</sup> R. B. Cakirli,<sup>3,4</sup> J. J. Carroll,<sup>5</sup> R. F. Casten,<sup>4,6</sup> R. S. Chakrawarthy,<sup>7</sup> D. M. Cullen,<sup>8</sup> I. J. Cullen,<sup>9</sup> B. Franzke,<sup>1</sup> H. Geissel,<sup>1,2</sup> J. Gerl,<sup>1</sup> M. Górska,<sup>1</sup> G. A. Jones,<sup>9</sup> A. Kishada,<sup>8</sup> R. Knöbel,<sup>1</sup> C. Kozhuharov,<sup>1</sup> S. A. Litvinov,<sup>1</sup> Z. Liu,<sup>9</sup> S. Mandal,<sup>1</sup> F. Montes,<sup>10</sup> G. Münzenberg,<sup>1</sup> F. Nolden,<sup>1</sup> T. Ohtsubo,<sup>11</sup> Z. Patyk,<sup>12</sup> Zs. Podolyák,<sup>9</sup> R. Propri,<sup>5</sup> S. Rigby,<sup>8</sup> N. Saito,<sup>1</sup> T. Saito,<sup>1</sup> C. Scheidenberger,<sup>1,2</sup> M. Shindo,<sup>13</sup> M. Steck,<sup>1</sup> P. Ugorowski,<sup>5</sup> P. M. Walker,<sup>9</sup> S. Williams,<sup>9</sup> H. Weick,<sup>1</sup> M. Winkler,<sup>1</sup> H.-J. Wollersheim,<sup>1</sup> and T. Yamaguchi<sup>14</sup>

— Highlight —

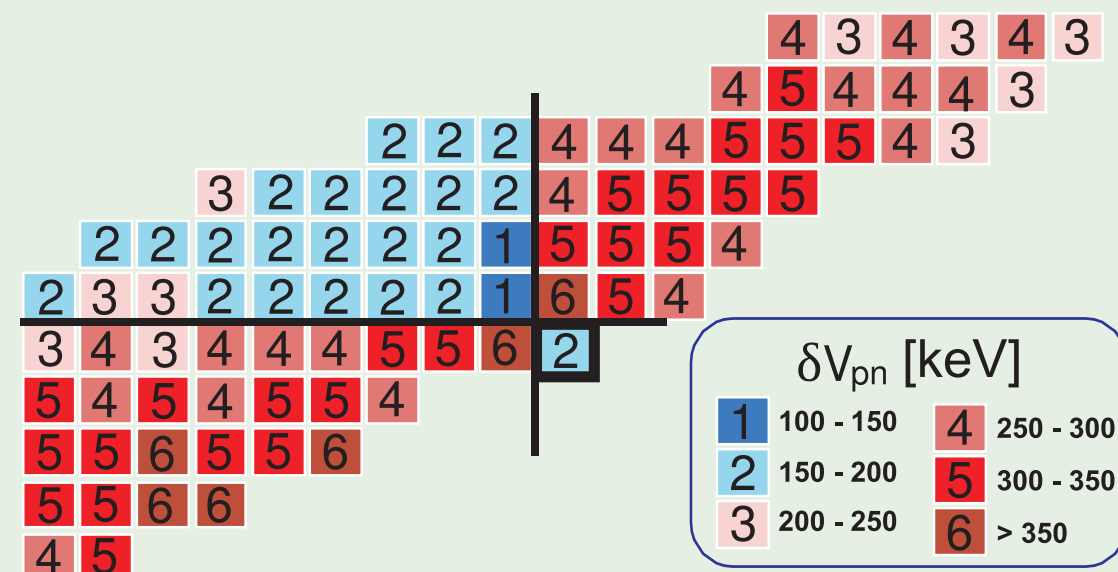


**Single ion sensitivity  
1 ion/week**

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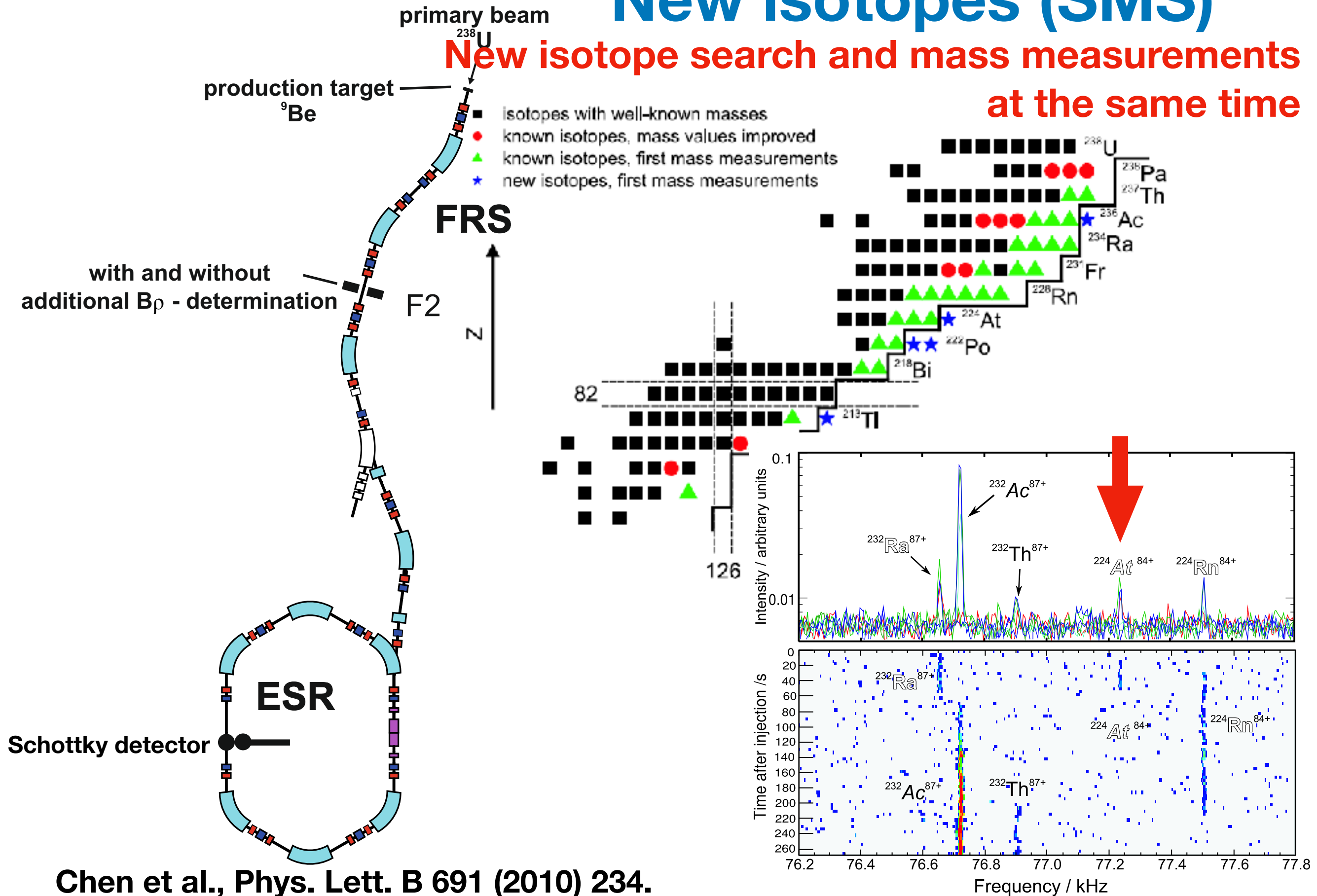
Articles published week ending 27 MARCH 2009

$$\delta V_{pn}(Z, N) = \frac{1}{4} [B(Z, N) + B(Z - 2, N - 2) - B(Z, N - 2) - B(Z - 2, N)],$$



# New isotopes (SMS)

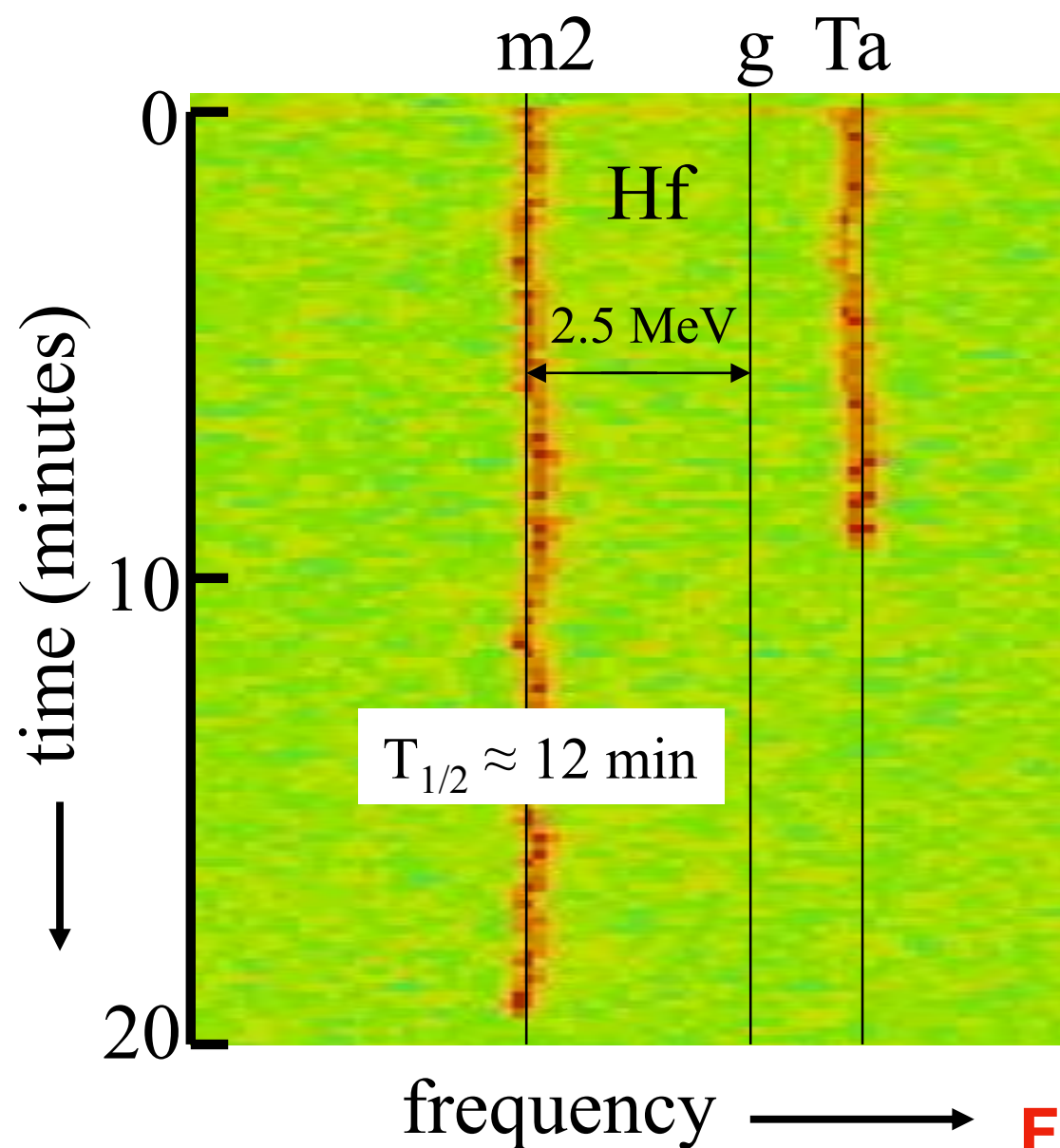
**New isotope search and mass measurements  
at the same time**



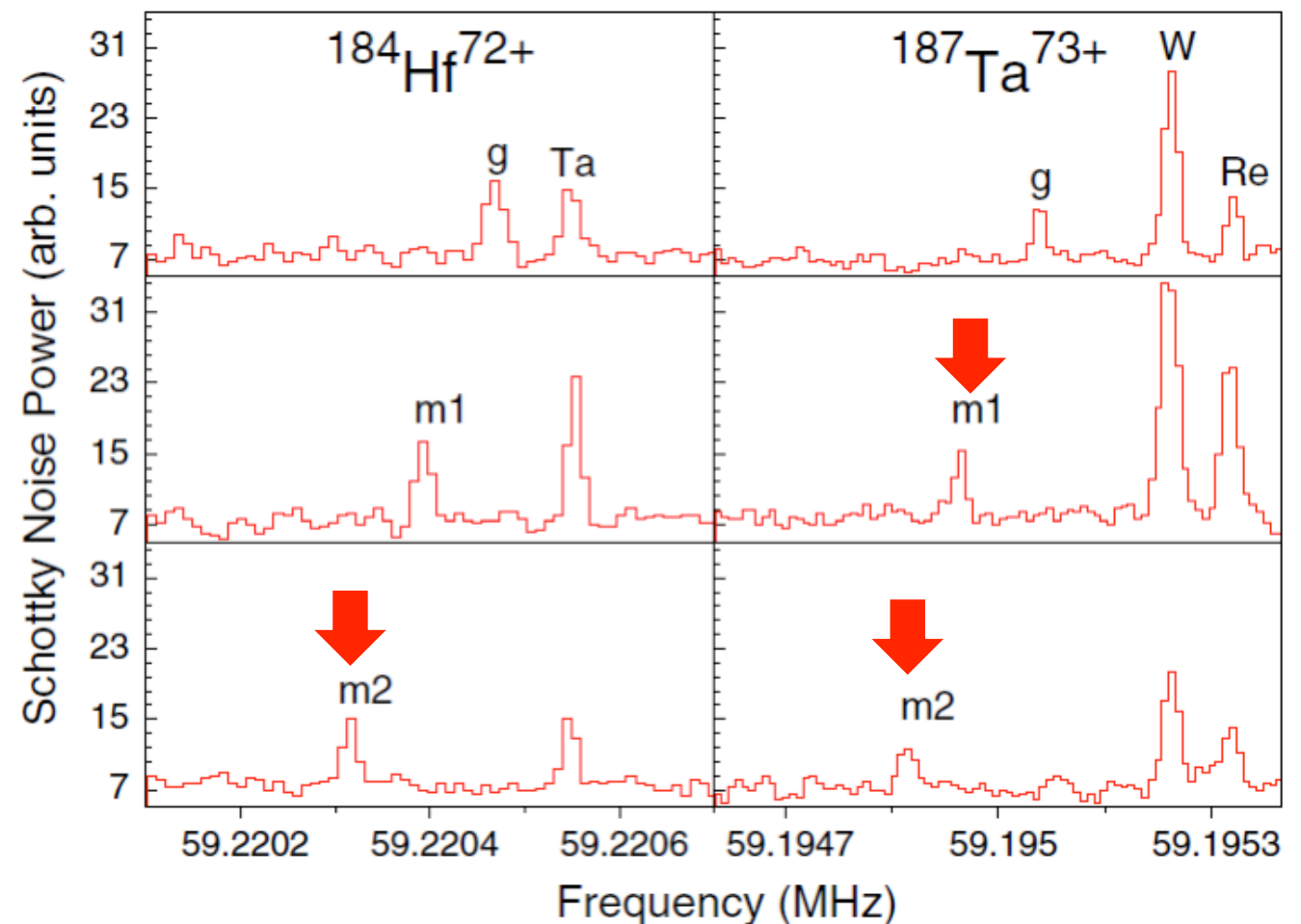


# FAIR Phase-0 Program

Long-lived isomers in the Experimental Storage Ring: study of  $^{186-188}\text{Hf}$  (search for new K-isomer) **Spokesperson: P. Walker**



Successful results of previous E048: **new isomers**

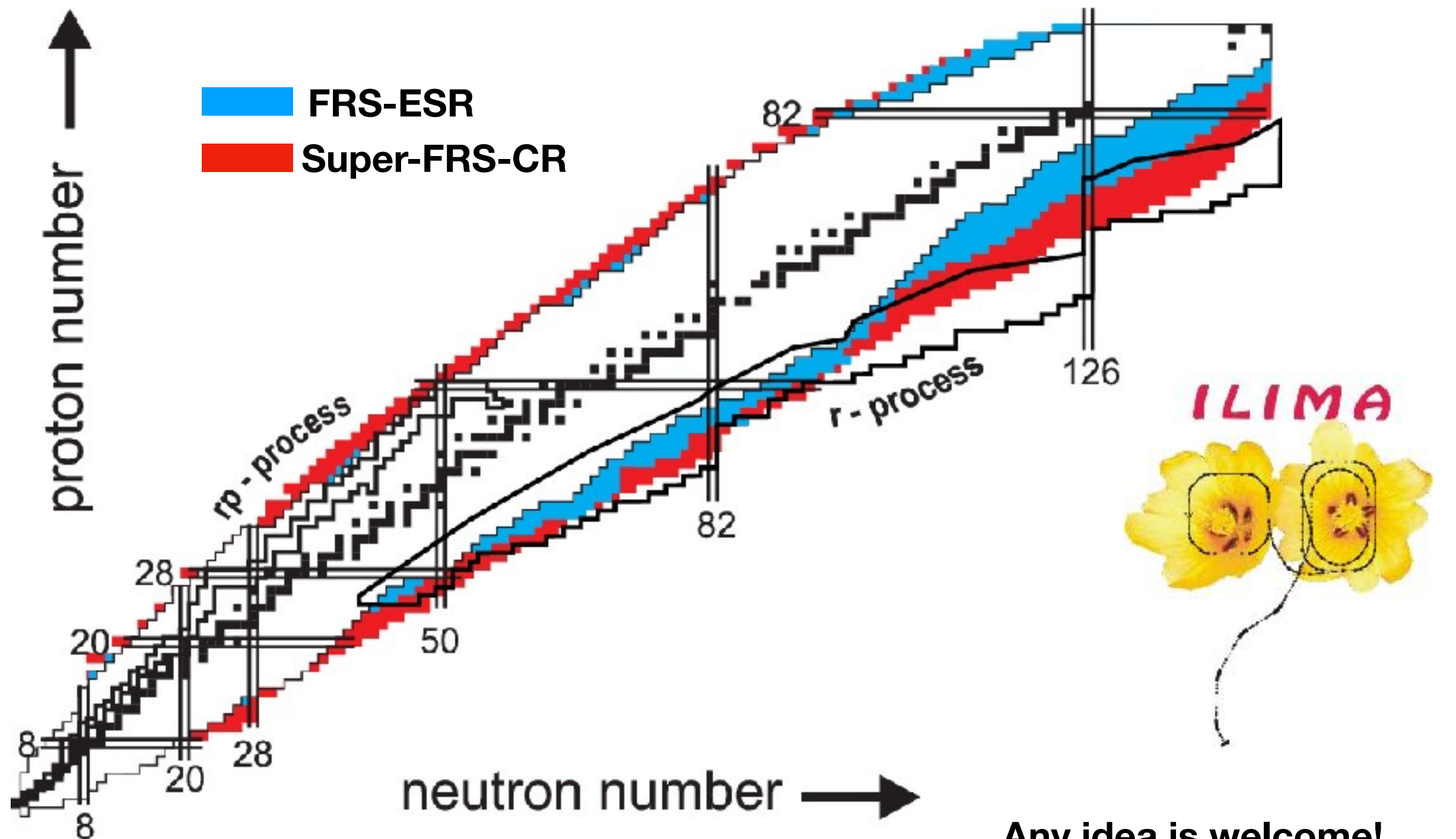


M.W. Reed et al., PRL105 (2010) 172501

M.W. Reed et al., PRC86 (2012) 054321

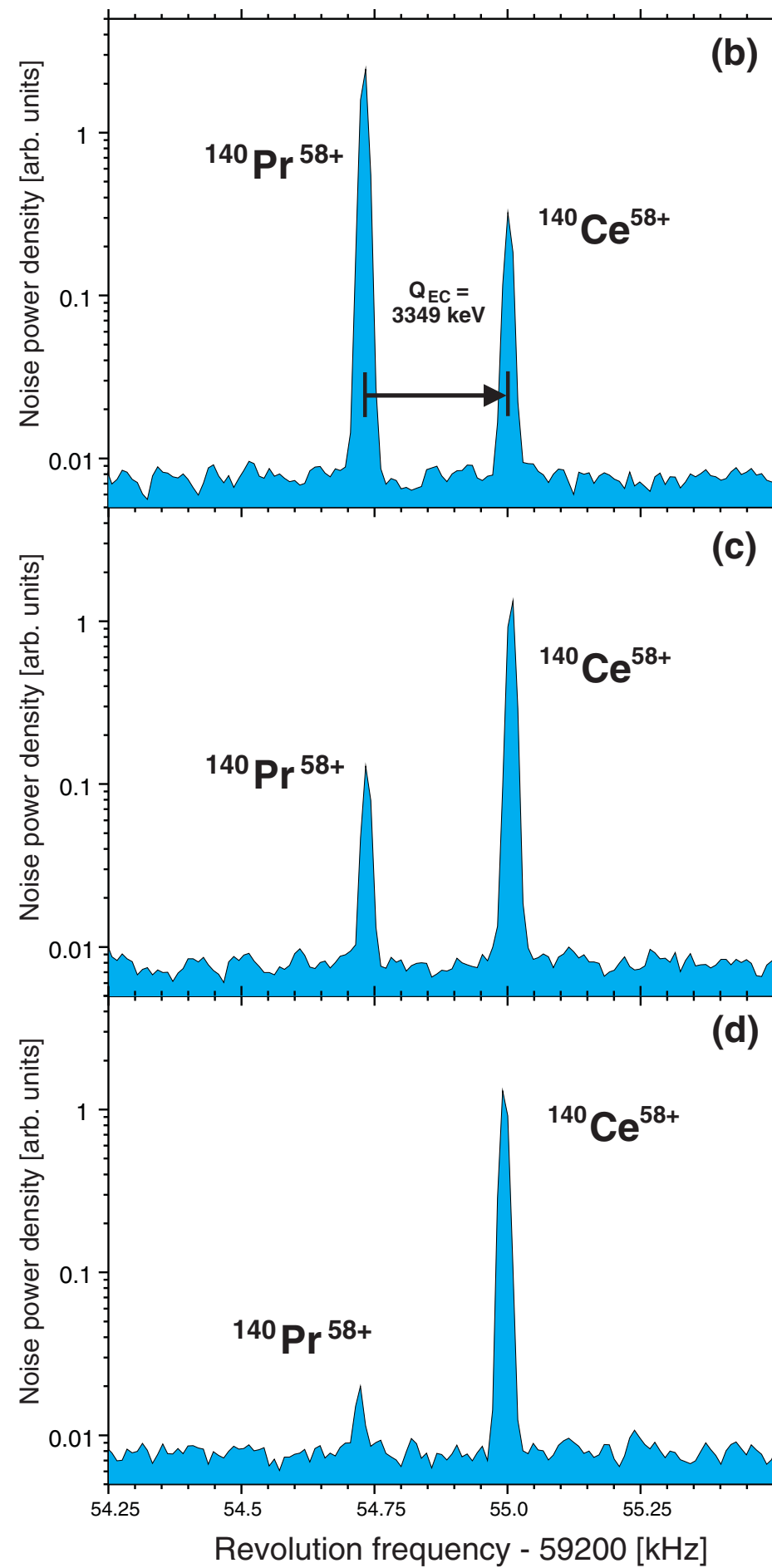
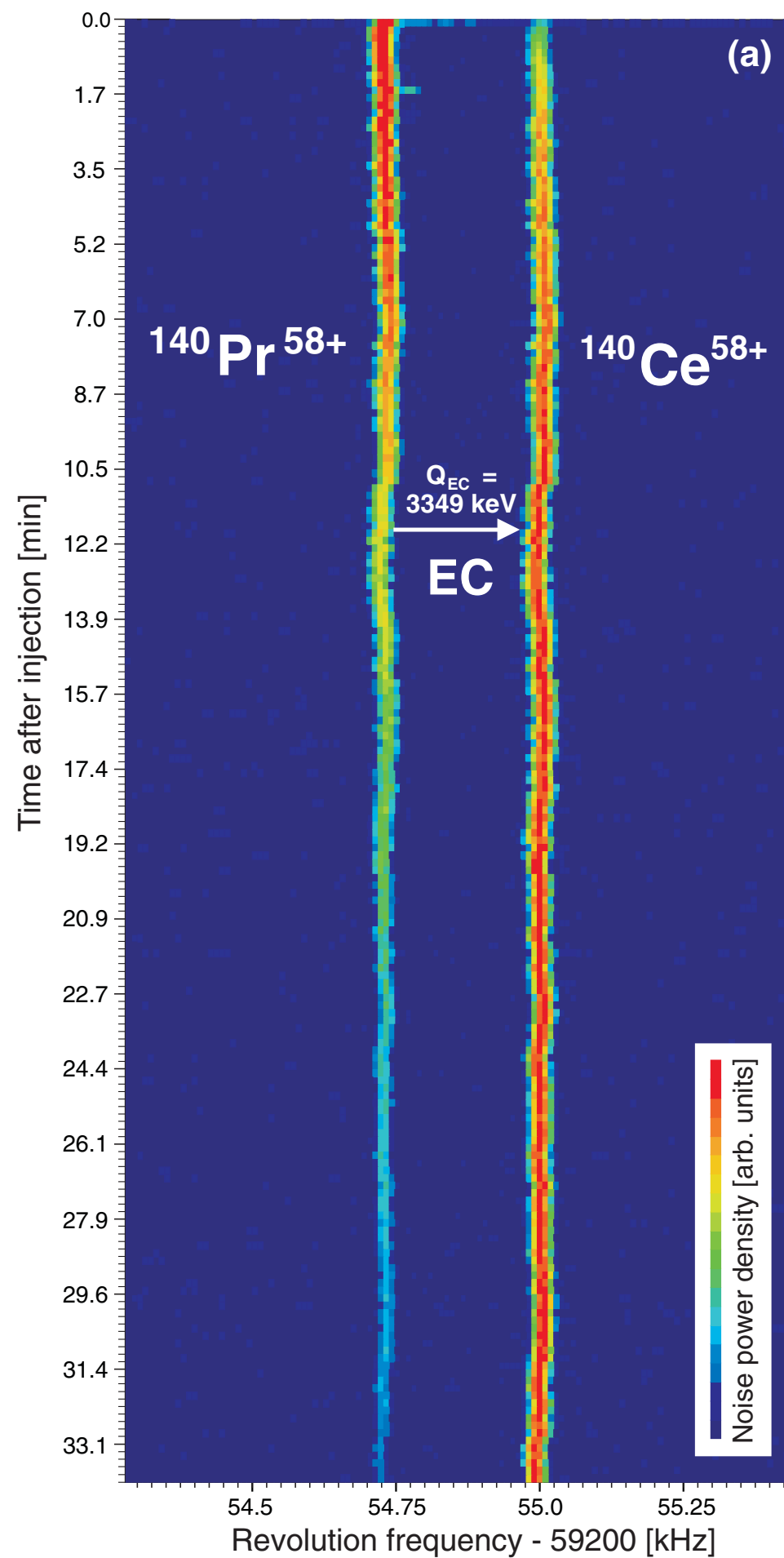
**First observation of m2 isomer, e.g.  $^{184}\text{Hf}$  case**  
**Long-lived beta-decaying isomer**

# Potential for new masses with ILIMA



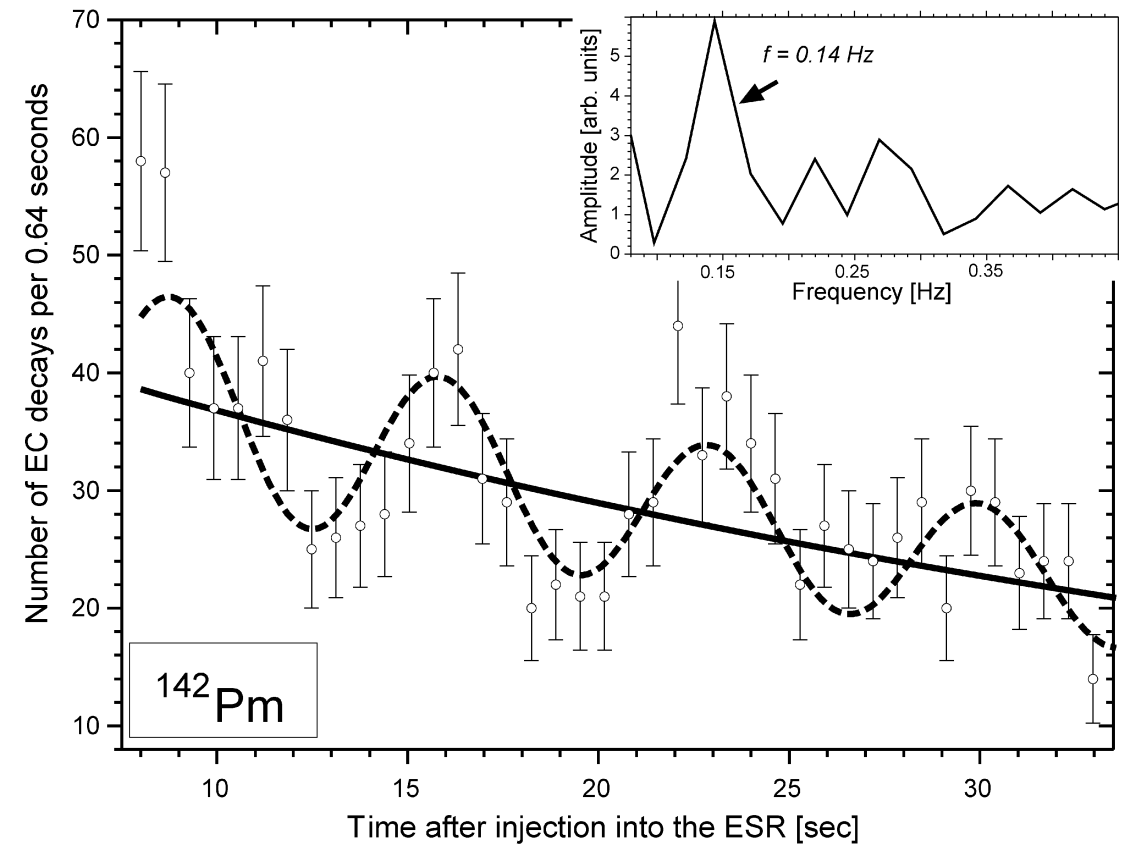
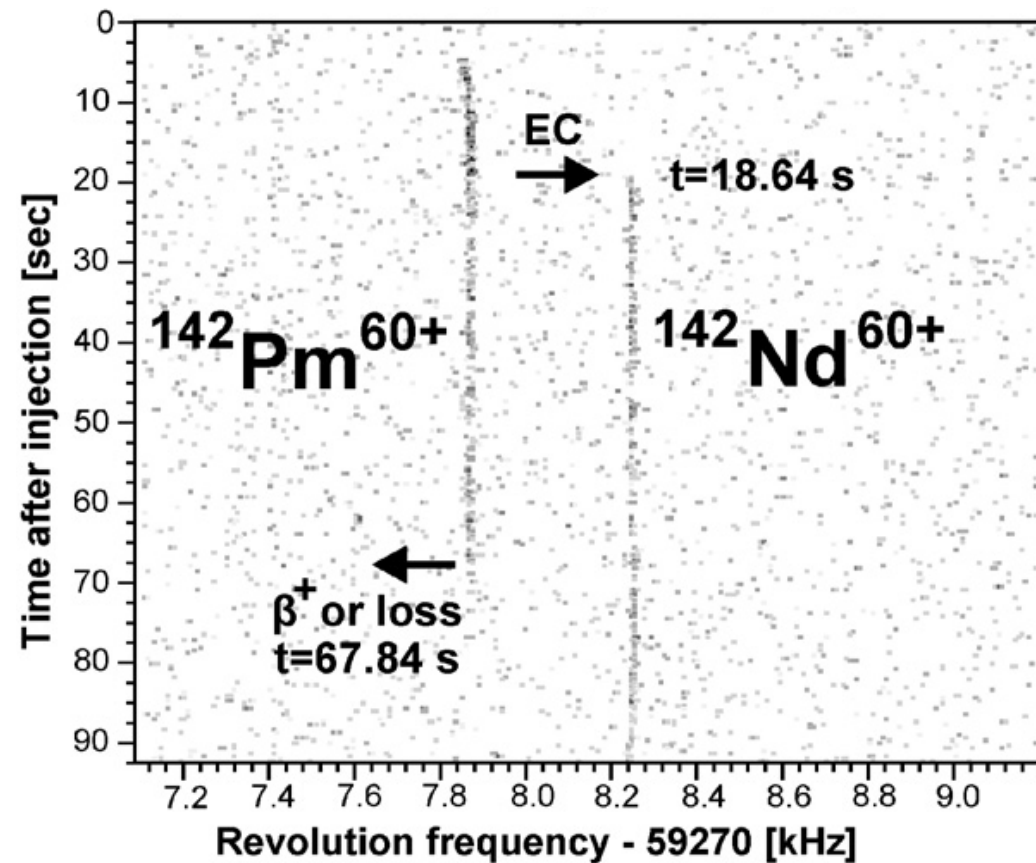
Any idea is welcome!  
Theoreticians also welcome!

**FAIR Phase-0 Beam Time has started**



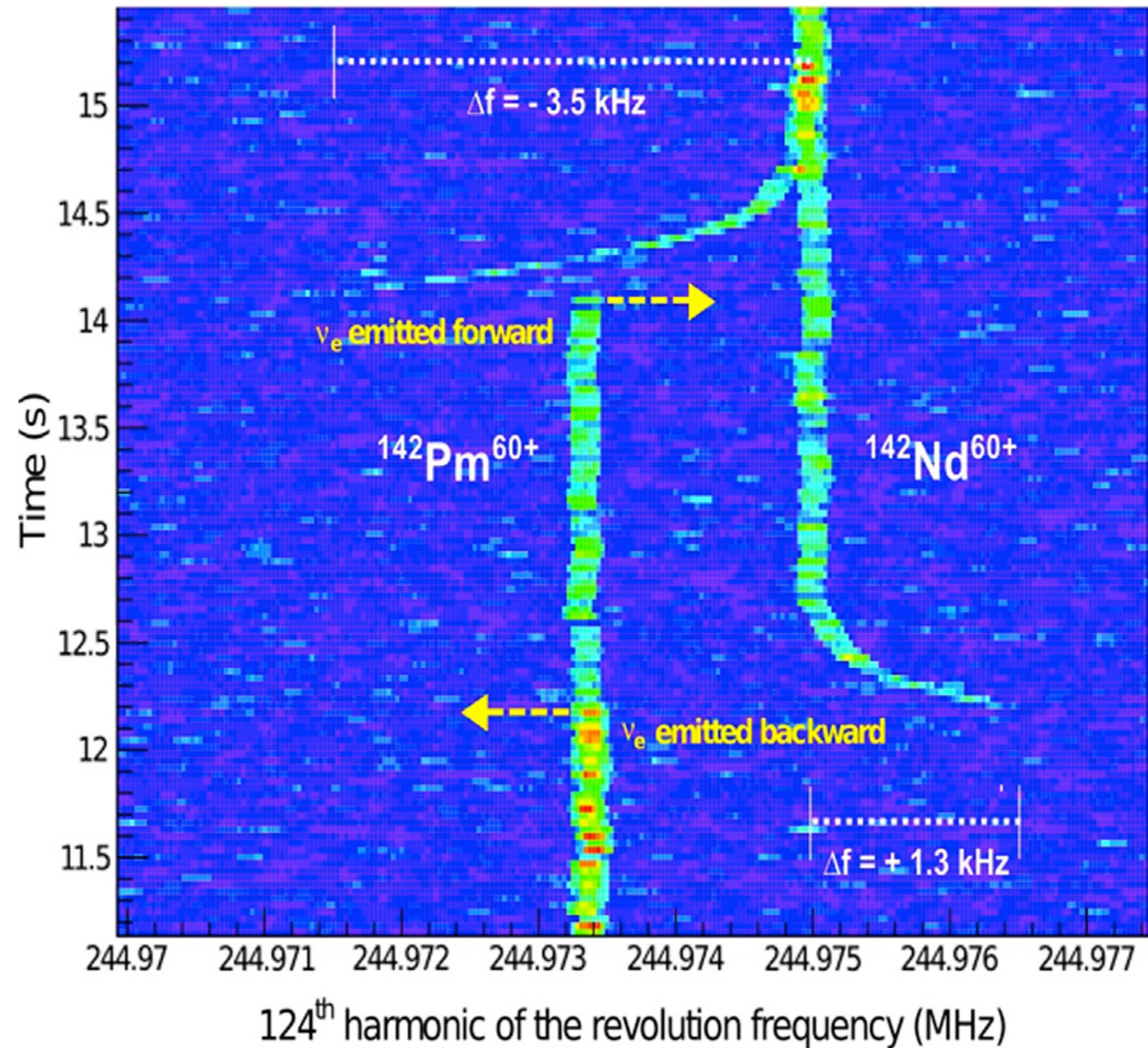
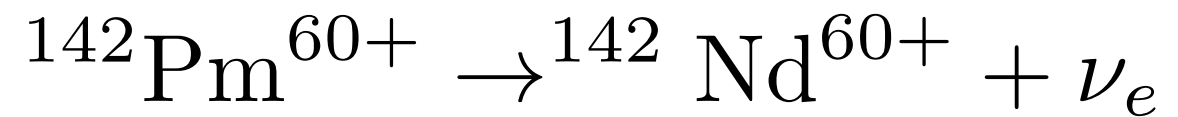
# Modulated electron capture decay of hydrogen-like $^{142}\text{Pm}$ ions

- Oscillation was observed in 2008



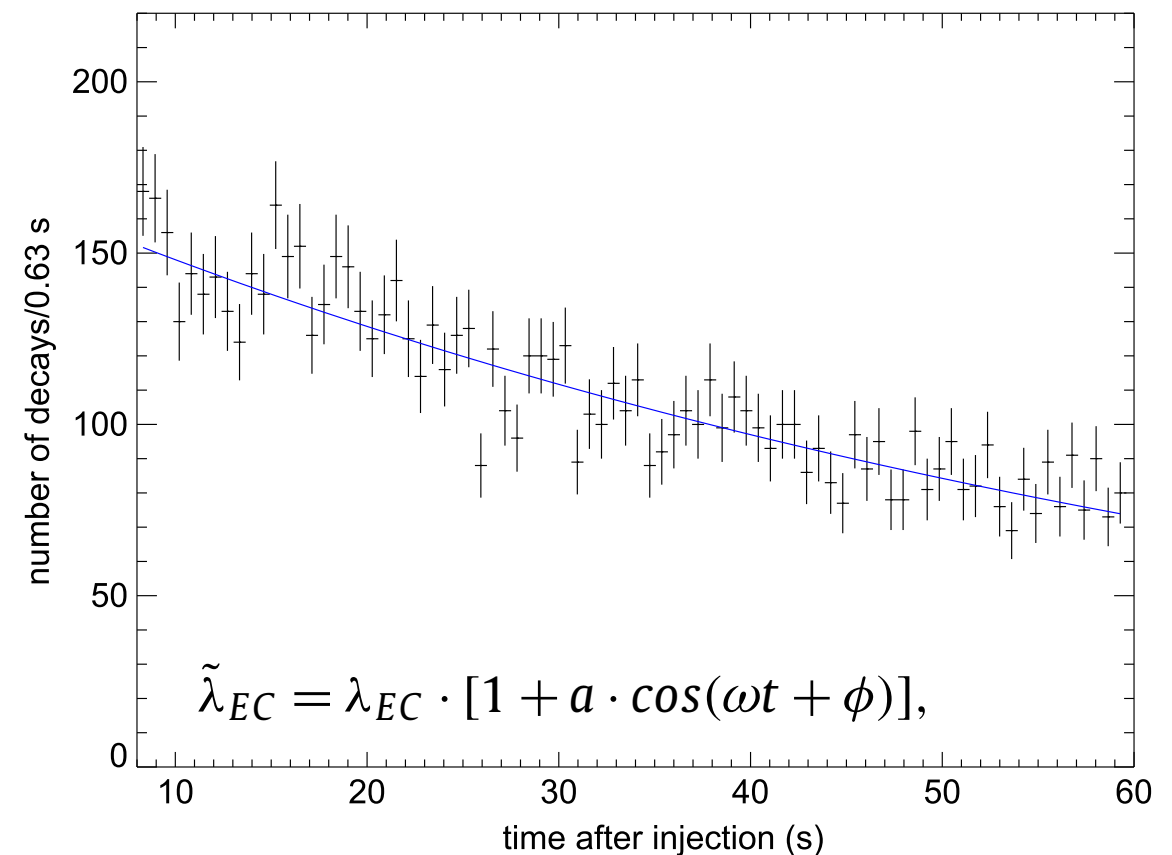
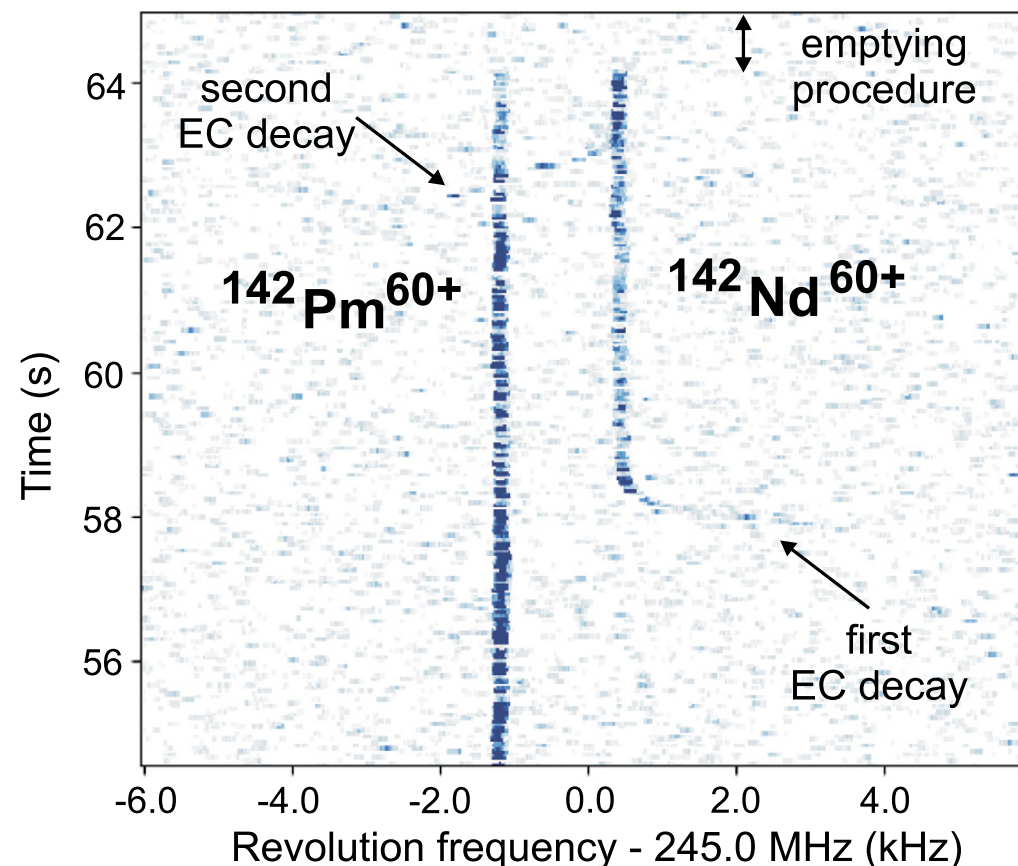


# Schottky Mass Spectrometry: Resonant Pickup



# New test of modulated electron capture decay of hydrogen-like $^{142}\text{Pm}$ ions

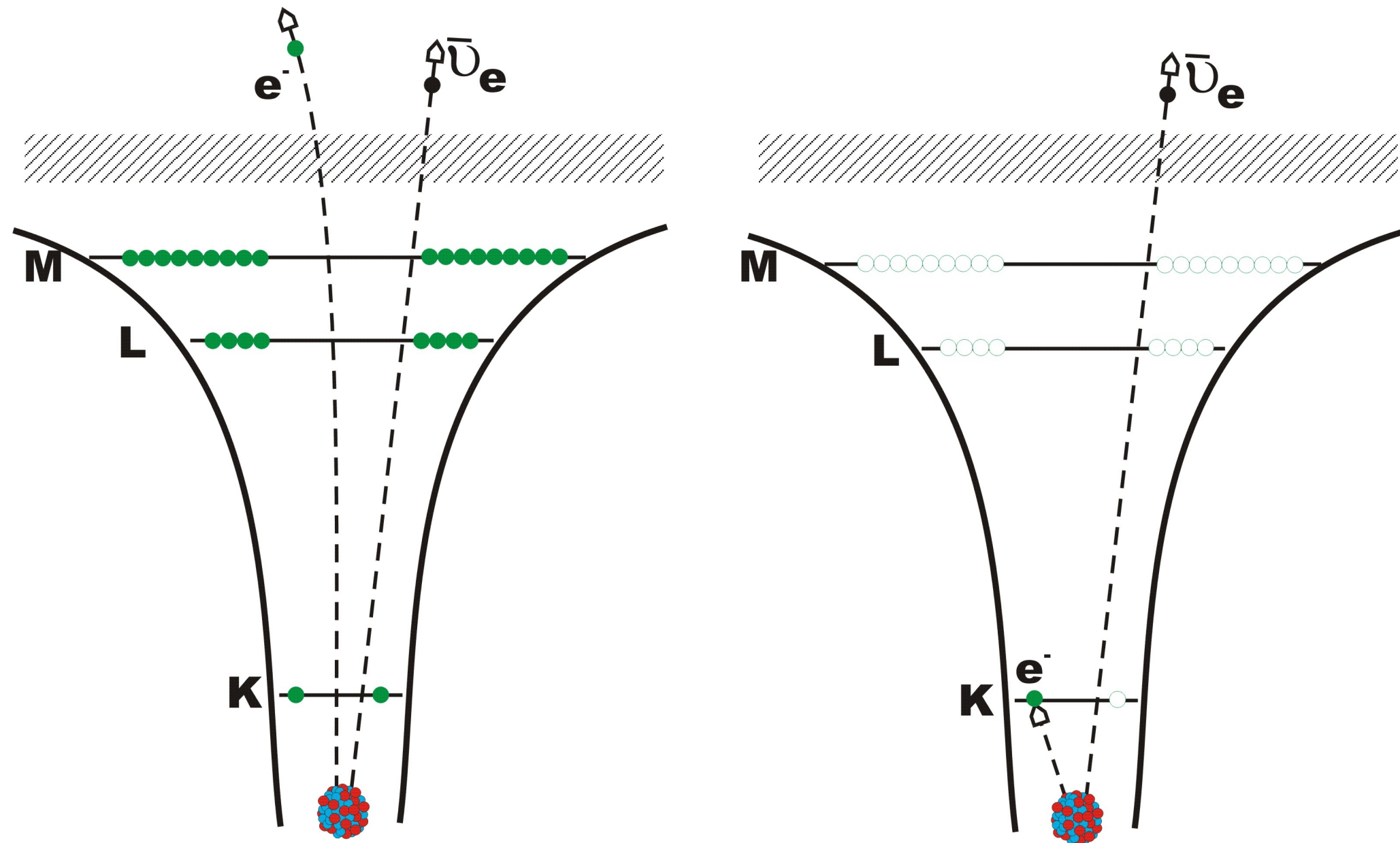
- Oscillation was not confirmed **PLB 797 (2019) 134800.**



Year		$\lambda(\Delta\lambda)$ [ $\text{s}^{-1}$ ]	$a(\Delta a)$	$\omega(\Delta\omega)$ [ $\text{rad s}^{-1}$ ]	$\phi(\Delta\phi)$ [rad]
2008	e	0.0170(9)		–	–
2008*	m	0.0224(42)	0.23(4)	0.885(31)	–1.6(5)
2008**	e	0.0124(2)		–	–
2010	m	0.0130(8)	0.107(24)	0.884(14)	+2.35(5)
2014 <sup>a</sup>	e	0.0126(7)	–	–	–
2014 <sup>m</sup>	e	0.0141(7)		–	–
2014 <sup>m</sup>	m	0.0141(9)	0.019(15)	1.04(26)	–3.1(2)

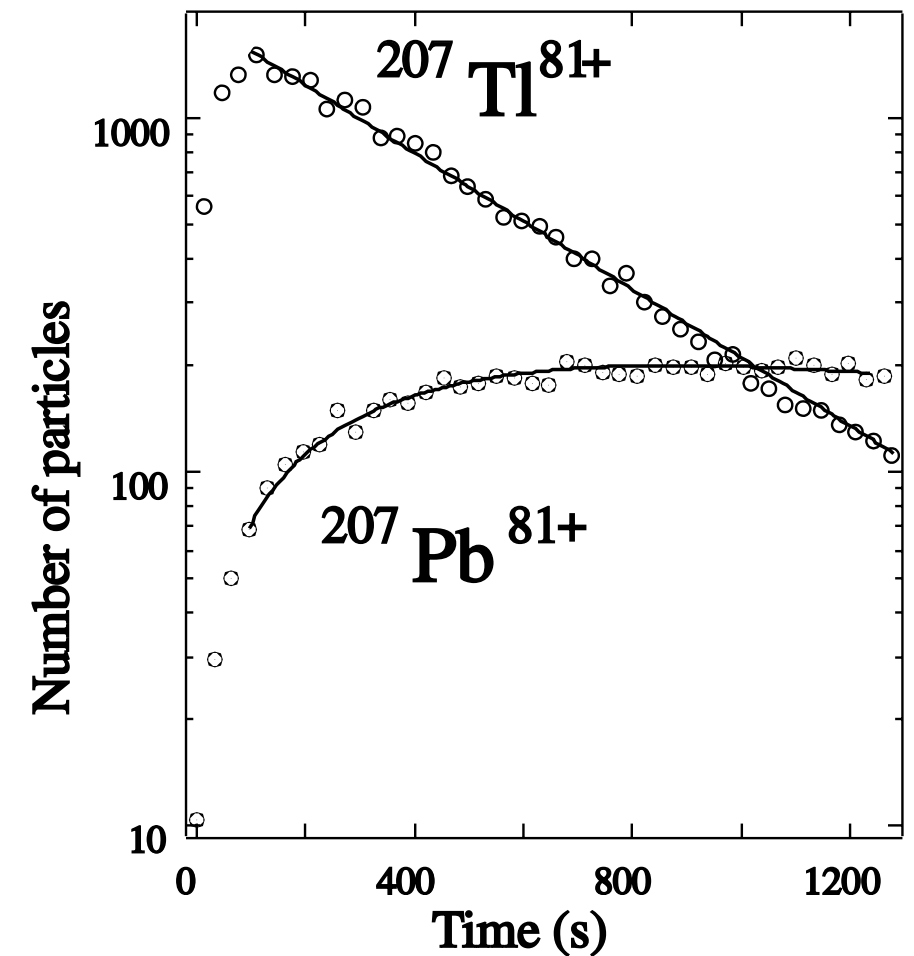
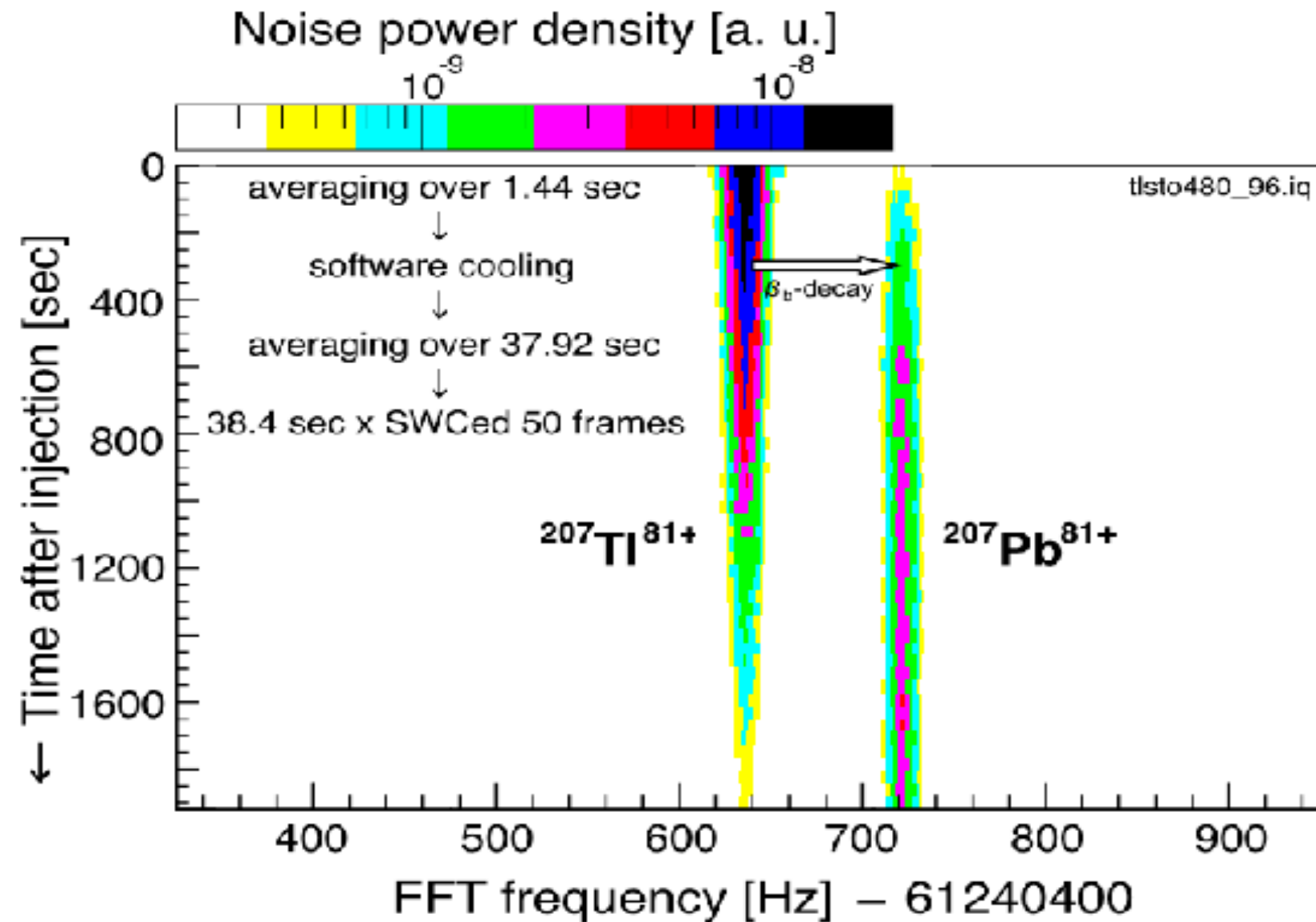


# Bound-State Beta Decay of Highly Charged Ions



Hot stellar environment

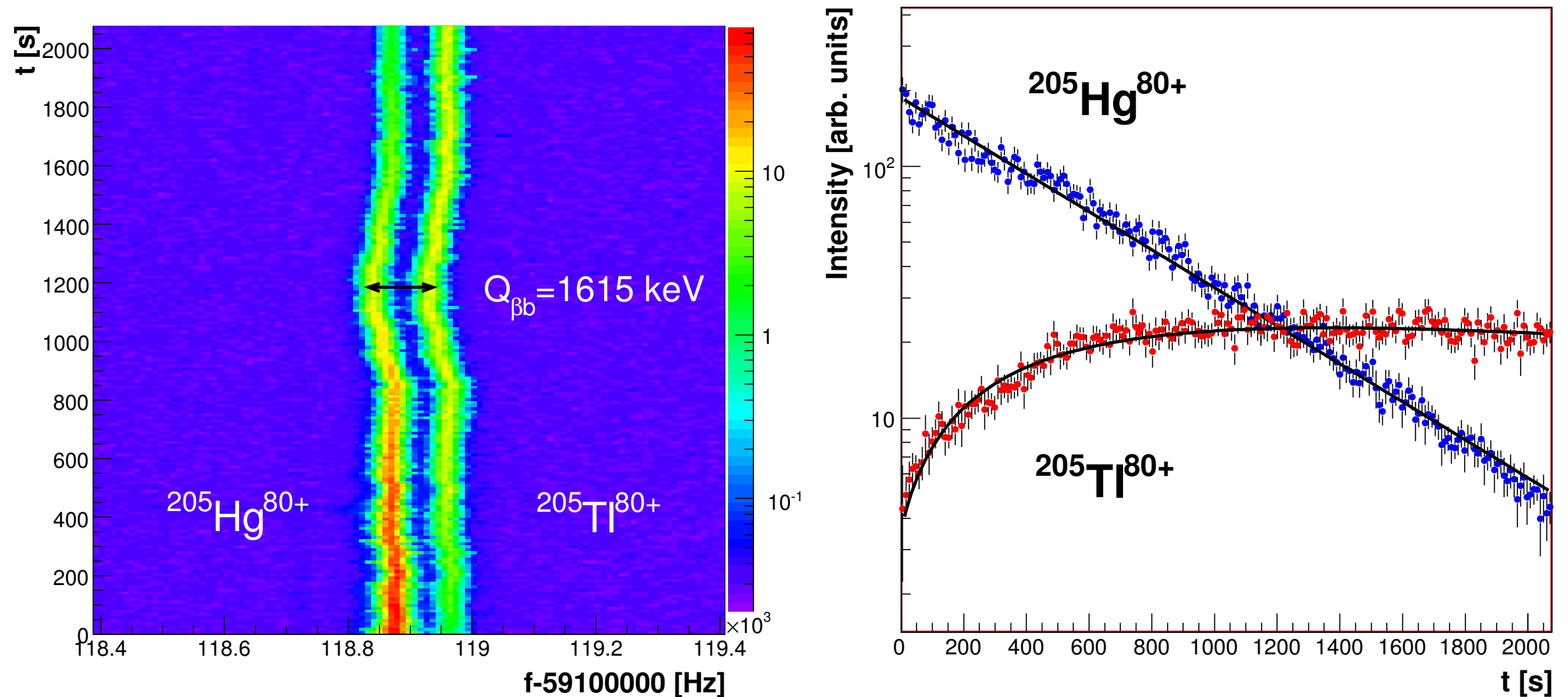
# Bound-State Beta Decay of Highly Charged Ions, Case 1



T. Ohtsubo et al., PRL 95 (2005) 052501.



# Bound-State Beta Decay of Highly Charged Ions, Case 2



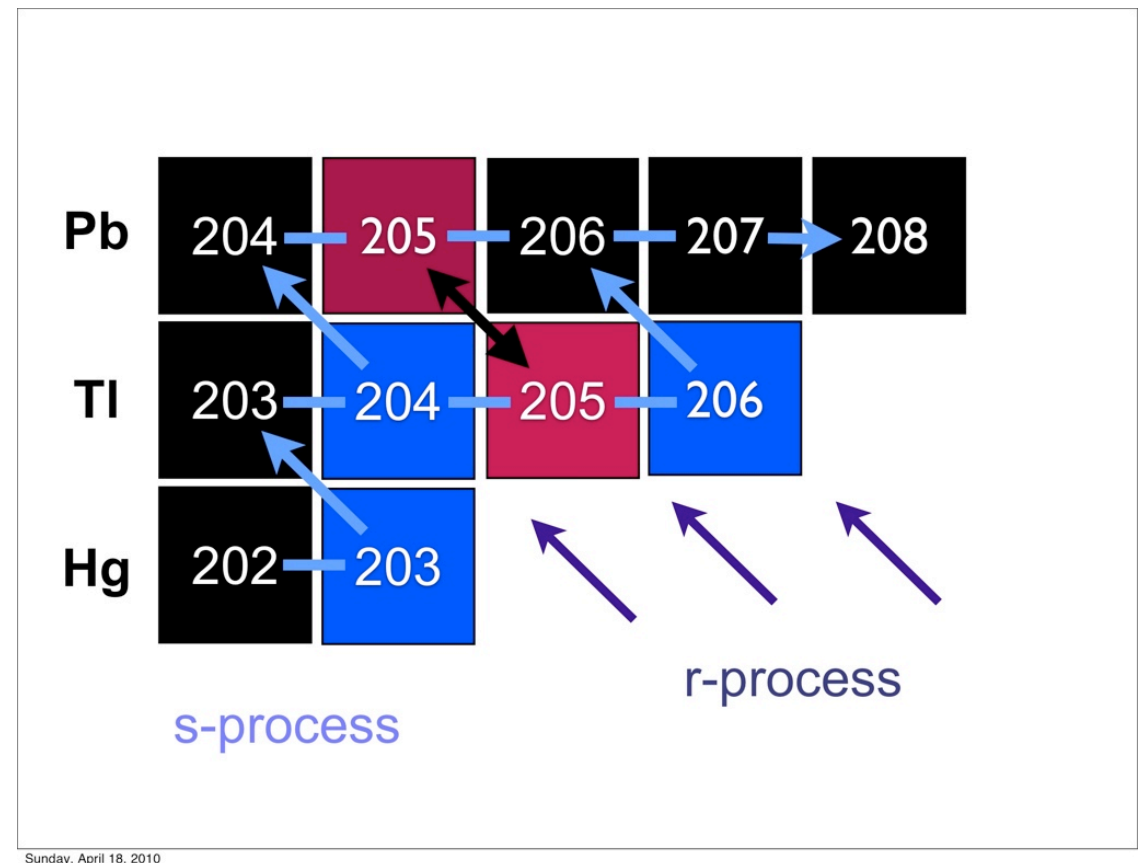
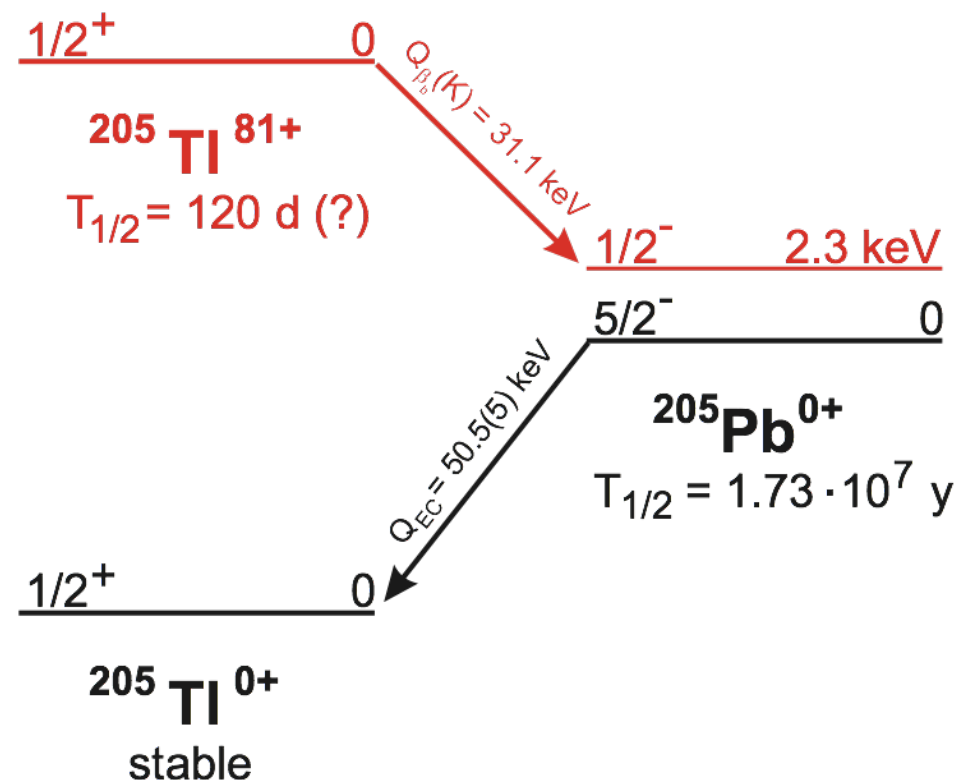
Ion	$\lambda_{\beta_b}$	$\lambda_{\beta_b}^{\text{th}}$	$\lambda_{\beta_c}$	$\lambda_{\beta_c}^{\text{th}}$	$\lambda_{\beta_c}^{\text{neut}}$	$Q_{\beta_b}$ [keV]
			$\times 10^{-4} [\text{s}^{-1}]$			
$^{205}\text{Hg}^{80+}$	3.7(3)	3.21	16.9(14)	22.1	22.5(4)	1615(3)
$^{207}\text{Tl}^{81+}$	4.2(4)	4.06	20.3(9)	23.7	24.2(1)	1511(6)
	4.29(29) <sup>a</sup>		22.9(12) <sup>a</sup>			

J. Kurcewicz, et al. Acta Phys. Pol. B 41 (2010) 525

# FAIR Phase-0 Program

Measurement of the bound-state beta decay of bare  $^{205}\text{Tl}$  ions

Spokesperson: Y. Litvinov



1.  $^{205}\text{Pb}/^{205}\text{Tl}$  pair as s-process cosmochronometer
2. The flux of solar pp neutrinos (LOREX project)



**ILIMA, SPARC, LOREX collaborations**

# IMS

*see next talk  
by Natalia*

## Isochronous Mass Spectrometry

# CSRe

(IMP, Lanzhou)

# Summary

- TDRs approved
  - Dual TOF system: **urgent for CR installation**
  - Schottky detector system
    - **Transverse Schottky** detector under development@GSI(+RIKEN)
  - Heavy-ion detector system @Munich
- Phase-0 program ongoing
  - **Tl-205 bound-state beta decay@ESR**
- **Lanzhou IMS with double TOF**: ongoing and very promising