

# Technical and Physics report

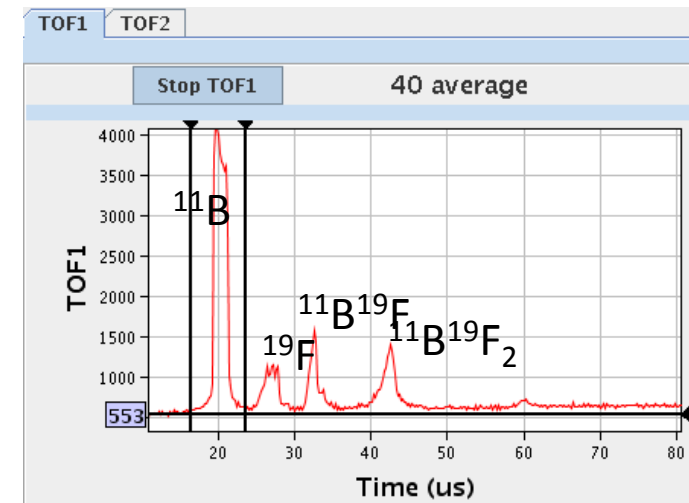
Richard Catherall  
Karl Johnston



# $^8\text{B}$ beams tests in REX low energy

- Following the 2015 beam development on  $^8\text{B}$ :
  - Boron must be extracted as a fluoride,
  - Higher yield value on  $\text{BF}_2$  form (yield estimated from  $\beta$  and  $\gamma$ )
  - This year: injection into REX:  $^{11}\text{B}^{19}\text{F}_2^{1+}$   
→  $^{11}\text{B}^{4+}$ 
    - Space charge effect on trap (decrease of efficiency with higher beam current),
    - Flat trap, cooling on  $A=30$  only 9% efficiency,
    - TOF: many breakups in trap,
    - EBIS might accept all masses.
  - When taking  $^8\text{B}^{19}\text{F}_2^{1+}$  into the trap, radioactive beam is seen after the separator with Geiger counter
  - No date to restart production of nanostructured targets is defined yet

Yields (ions/ $\mu\text{C}$ )	
8B	$\sim 1e3$
8BF	$\sim 7e2$
8BF2	$\sim 2e4$
8BF3	$\sim 4e2$



Courtesy to J Pitters, FJC Wenander



# ISOLDE RILIS: Operation in 2016



**120** days of RILIS operation so far  
(mostly 24-hr operation)

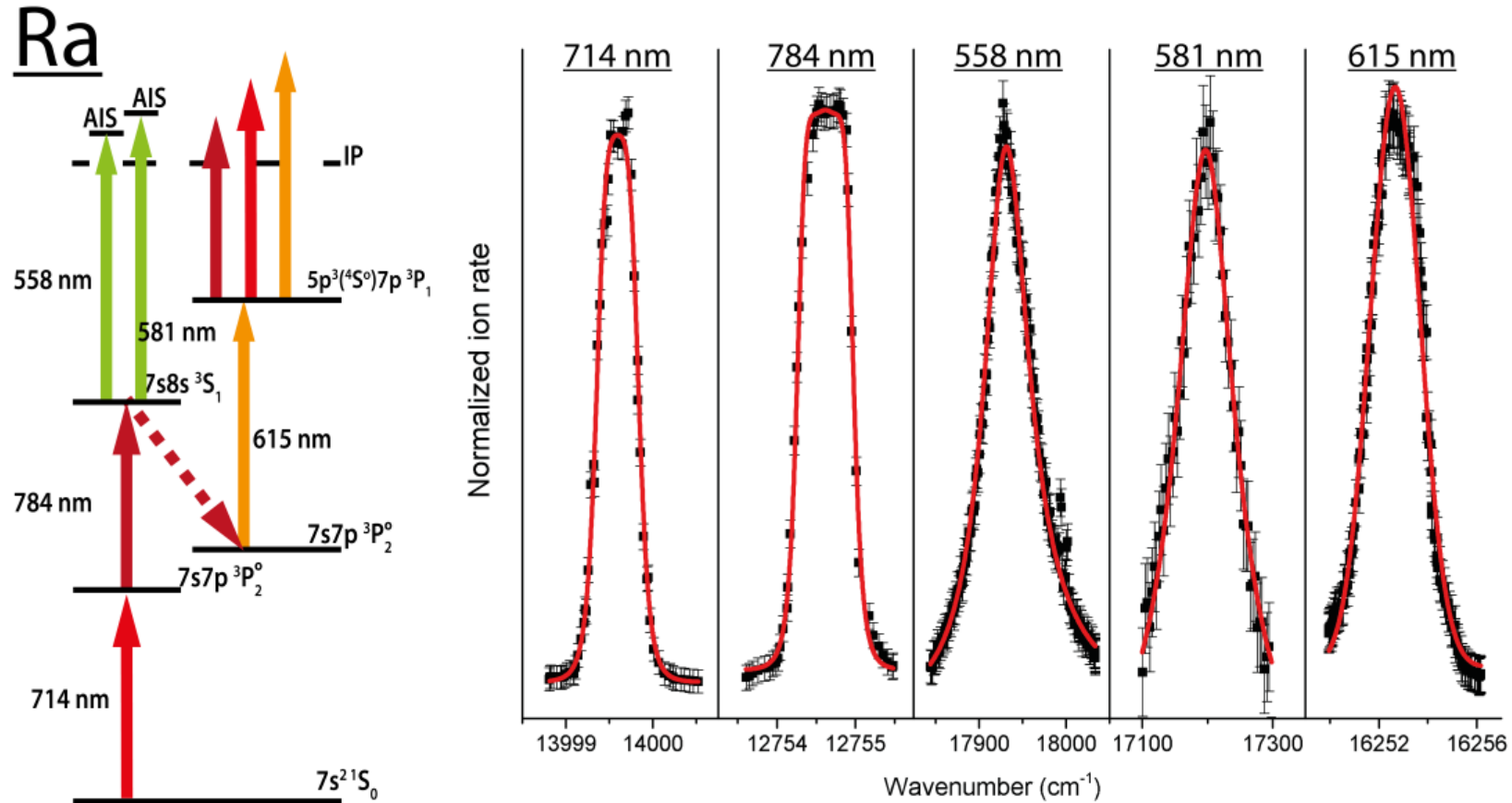
**22** separate RILIS runs

**15** different elements

**3** RILIS physics runs  
(RILIS as a spectroscopy tool during ion beam production)

**100 %** record for on-time setup of RILIS

**1** laser failure which required a factory repair  
(it did not adversely affect operation)

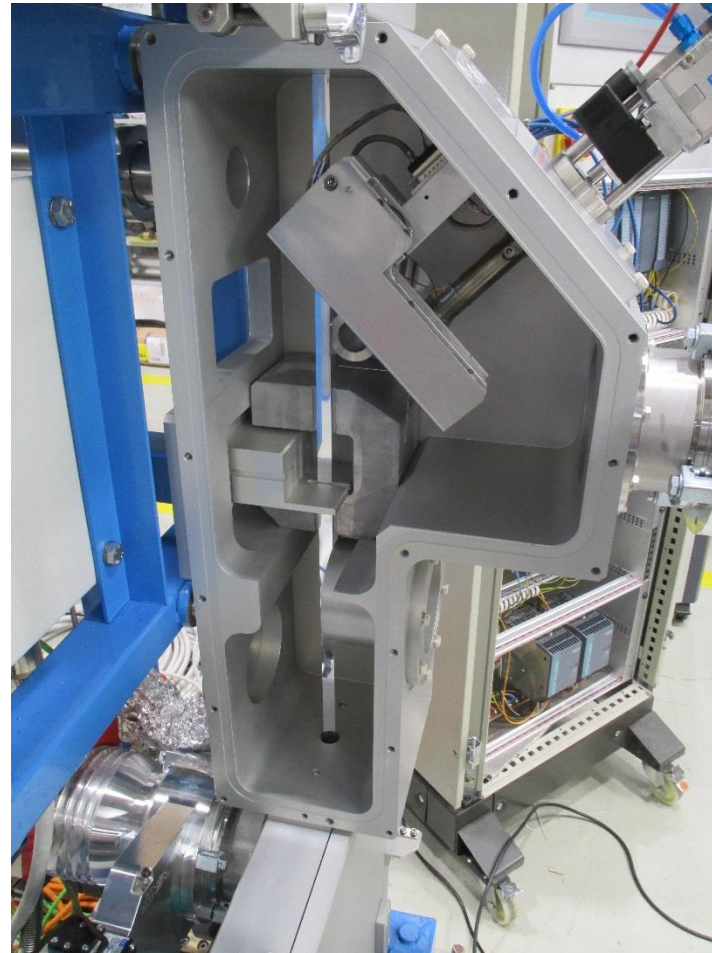
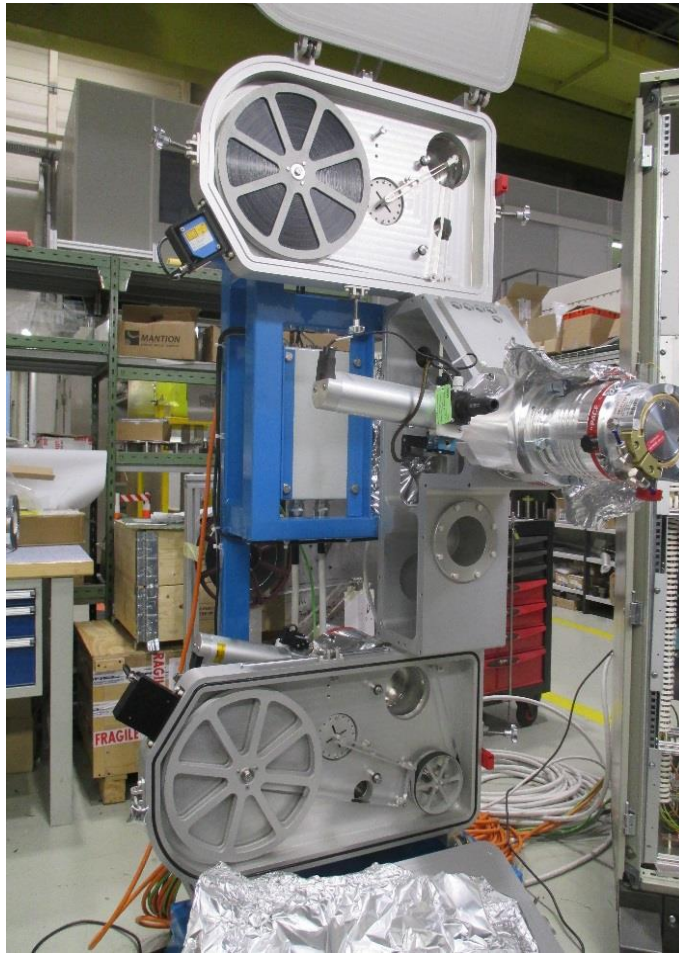


**3x** enhancement w.r.t surface ionization

**1<sup>st</sup>** RILIS scheme to use optical pumping inside the hot cavity

**2** new Autoionizing states were discovered

# Fast Tape Station



Tape station in situ at LA2  
Mechanics work  
Detectors work  
Due to a combination of delays and availability of beam..Insufficient time for testing  
Request to schedule test runs next year as opposed to “finding” time  
Tape station to remain at LA2

# MEDICIS-Phase I

Main tasks during EYETS :

Several non conformities of the ventilation of Class A building 179 will be fixed during YETS

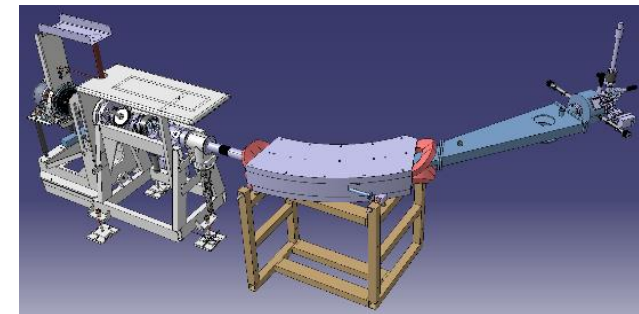
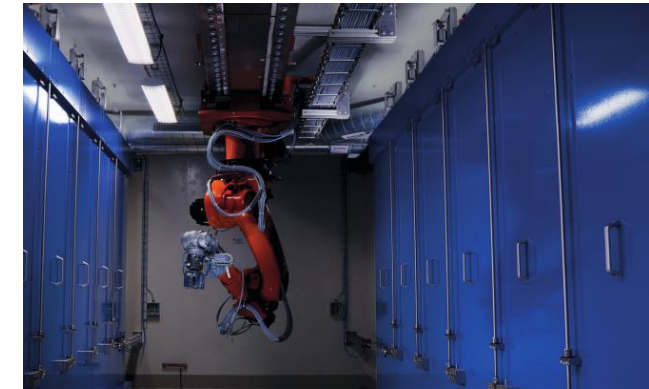
Electrical safety network will be installed:  
upgrade of existing UPS + connection  
to diesel back-up network

Robots and storage : commissioned for end of 2016

Front-end and separator : ongoing

Installation foreseen beginning 2017

Main issues to define the start-up date in 2017:  
controls and collection chamber





# GPS

Leaking target#2

(Weeks 14-46)

	April				May				June			July			August		September								
Wk	14	15	16	17	18	19	20	21	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	
Mo	COLLAPSE Ca	#547 Ucx - Ta	#562 Ti - Ta	#565 Ta - W	#548 LOI42	#549 LOI41	#569 Ucx - Ta	#572 Ucx - n Ta	#577 Pb HP	#578 Th - n	TEO	#575 Nano Ucx CP	#577 Pb HP	#577 Pb HP	ISS15	ISS15	ISS15	ISS80 SIC - HP	#5004 Nano Ucx CP	#5004 Nano Ucx CP	#5004 Nano Ucx CP	ISS28	ISS28	#505 Ta - W	
Tu	ISS47	Tech stop	RDX	ISS453 Mg	ISS528	ISS481	ISS487	ISS501	Tech stop	ISS578	ISS488	ISS602 (Hg) (Bio)	TISO	ISS609 (He) (IDG)	ISS588	ISS515	ISS585	ISS585	ISS528	ISS528	ISS528	ISS528	ISS528	ISS528	ISS528
We	#561 7Be	Tech stop	RDX	ISS453 Mg	Ascension	ISS481	ISS487	ISS501	ISS578	ISS488	ISS602 (Hg) (Bio)	TISO	ISS609 (He) (IDG)	ISS588	ISS515	ISS585	ISS585	ISS528	ISS528	ISS528	ISS528	ISS528	Tech stop	ISS528	
Th	ISS593 7Be			Ascension	For May 1	ISS481	ISS487	ISS501	ISS578	ISS488	ISS602 (Hg) (Bio)	ISS575 Nano Ucx CP	ISS609 (He) (IDG)	ISS588	ISS515	ISS585	ISS585	ISS528	ISS528	ISS528	ISS528	ISS528	ISS528	ISS528	
Fr				For May 1		ISS481	ISS487	ISS501	ISS578	ISS488	ISS602 (Hg) (Bio)	ISS575 Nano Ucx CP	ISS609 (He) (IDG)	ISS588	ISS515	ISS585	ISS585	ISS528	ISS528	ISS528	ISS528	ISS528	ISS528	ISS528	
Sa					ISS528			ISS501	ISS578	ISS488	ISS602 (Hg) (Bio)	ISS575 Nano Ucx CP	ISS609 (He) (IDG)	ISS588	ISS515	ISS585	ISS585	ISS528	ISS528	ISS528	ISS528	ISS528	ISS528	ISS528	
Su	Be RILIS			Mg RILIS	Dy RILIS	Be RILIS		Mn RILIS	n RILIS	Al RILIS															

← HIE-1

	April				May				June			July			August		September								
Wk	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Mo						#568 Ucx - n Graphite	#571 Zn - HP	#569 Ucx - n Ta	ISS474	Tech stop	ISS579 Ba	#573 Ucx - n Ta	ISS608	#574 Ucx - n Ta	ISS609	ISS609	ISS609	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta
Tu	#563 Ucx					#568 Ucx - n Graphite	#571 Zn - HP	#569 Ucx - n Ta	ISS474	Tech stop	ISS579 Ba	#573 Ucx - n Ta	ISS608	#574 Ucx - n Ta	ISS609	ISS609	ISS609	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta
We	Modulation tests	Tech stop				#568 Ucx - n Graphite	#571 Zn - HP	#569 Ucx - n Ta	ISS474	Tech stop	ISS579 Ba	#573 Ucx - n Ta	ISS608	#574 Ucx - n Ta	ISS609	ISS609	ISS609	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta
Th		ISS532			Ascension	ISS605			ISS474	Tech stop	ISS579 Ba	#573 Ucx - n Ta	ISS608	#574 Ucx - n Ta	ISS609	ISS609	ISS609	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta
Fr		Cr			For May 1	N			ISS474	Tech stop	ISS579 Ba	#573 Ucx - n Ta	ISS608	#574 Ucx - n Ta	ISS609	ISS609	ISS609	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta
Sa			Cu			Se			ISS474	Tech stop	ISS579 Ba	#573 Ucx - n Ta	ISS608	#574 Ucx - n Ta	ISS609	ISS609	ISS609	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta
Su				N					ISS474	Tech stop	ISS579 Ba	#573 Ucx - n Ta	ISS608	#574 Ucx - n Ta	ISS609	ISS609	ISS609	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta	X Ucx - Ta

Leaking target#1

Leaking target#3...

Leaking target#4...

Leaking target#5...



# Context on leaking targets...

Demand on Ucx targets is very high. ~70% of Low energy beam requests requesting Ucx units. Need to maintain some reserve for HIE-ISOLDE period. Limited to ~ 12 actinide units per year. Try to combine a Ucx unit to serve two long runs.

## Leak #1:

- Week 22 Target #563:
  - UCx + neutron convertor. Re-used target from beginning of year. Had already received ~5e18 protons. Had already delivered excellent beams to ISOLTRAP and CRIS.
  - Re-used for Mn run due to lack of availability of new units, or less-used backup.
  - Experiment was able to take beam from separate Mn run on GPS. About 1.5 shifts were lost.

## Leak #2:

- Week 22 Target #569:
  - UCx + neutron convertor. Second part of long run for Mossbauer spectroscopy. 6e18 protons taken.
  - Had already delivered good beams for Mn. Developed leak during In run. About 3 shifts were lost.

## Leak #3:

- Week 24 Target #572:
  - UCx + neutron convertor. Second part of run for IDS. 5e18 protons taken.
  - Had already provided excellent In beams for IDS. Developed leak during Ba run. **About 2 shifts taken; 8 shifts lost.**
  - **Biggest loss of physics in 2016 due to leaking target.**

## Leak #4:

- Week 33 Target #579:
  - UCx. Target used for Ra beams for CRIS. Had already been used for Al beams for COLLAPS.
  - Leak developed at the end of very successful Ra run. About 3 hours of beam lost.
  - Target had taken 6e18 protons.

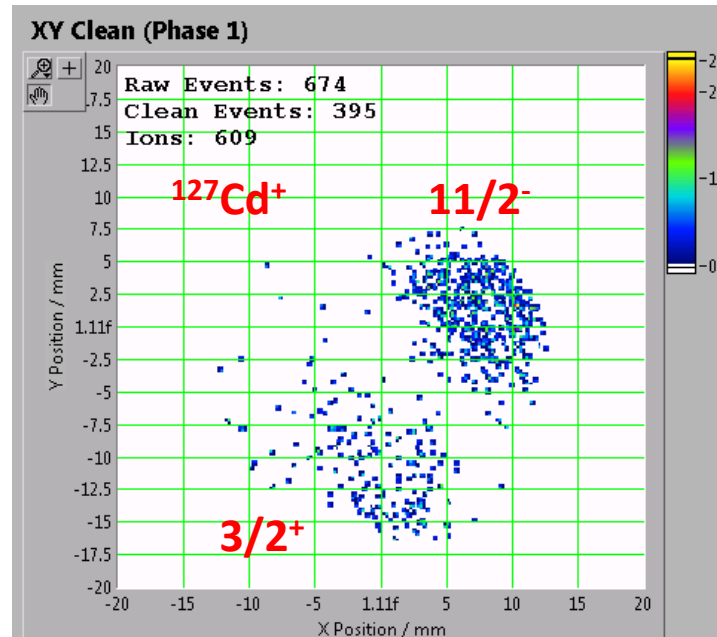
## Leak #5:

- Week 35 Target #573:
  - UCx. Target which had already been used for Bi beams. 2<sup>nd</sup> Bi run. Target was requested due to Bi mass marker.
  - Had taken 5e18 protons. No shifts were lost. Backup was available.

# Separation of $^{127}\text{Cd}$ isomers by PI-ICR

- The excitation energy of the  $11/2^-$  state in  $^{127}\text{Cd}$  is not known, nor the ordering with respect to the  $3/2^+$  ground state.
- Because the states are short-lived ( $<400$  ms), they cannot be separated by the conventional TOF-ICR technique (unless highly-charged ions are used).
- Using PI-ICR it is relatively easy to separate them.

Spin identification from intensity ratio (and comparison to less exotic isotopes with known ordering).



separation after 200 ms phase evolution in the precision trap

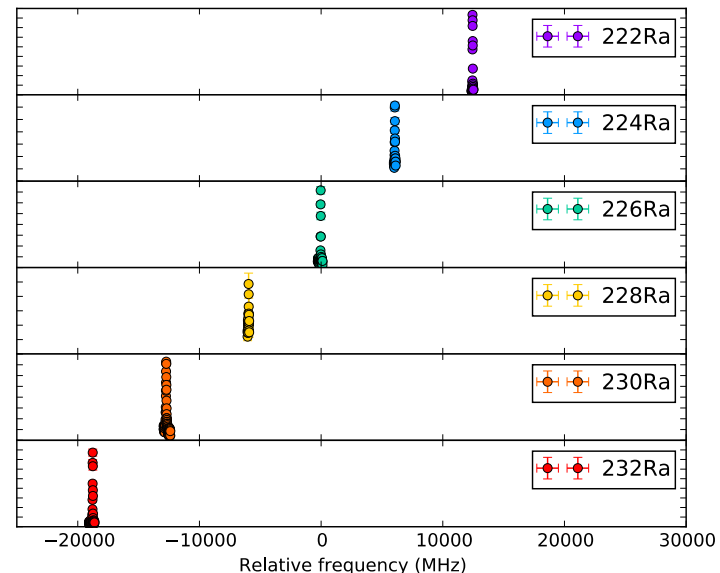
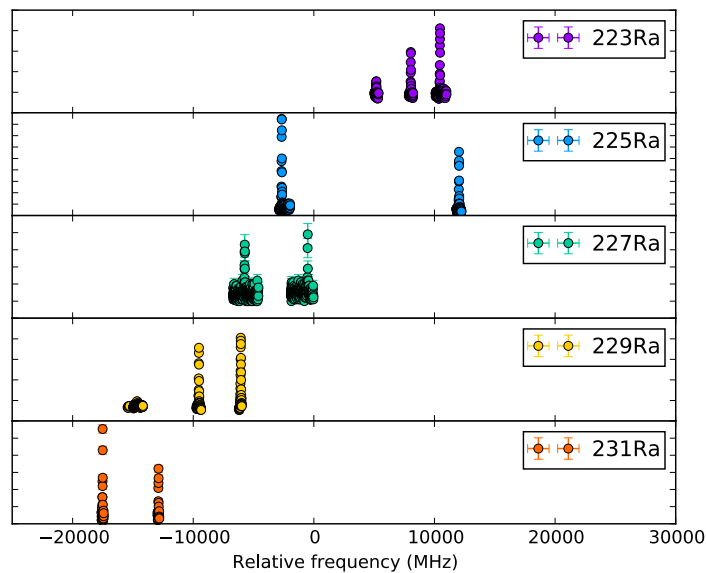
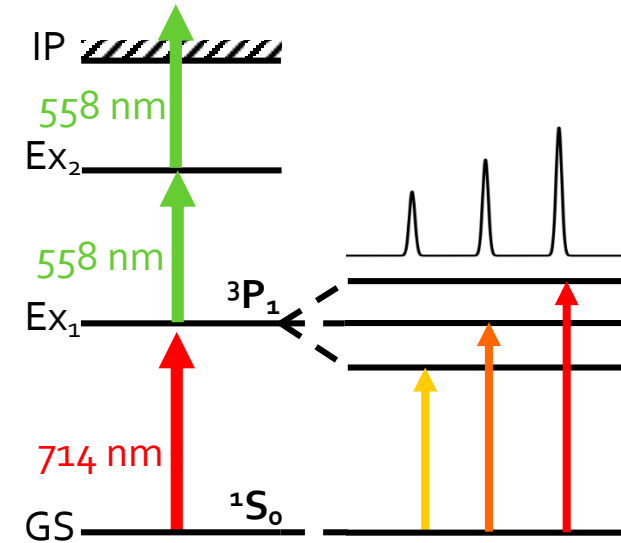
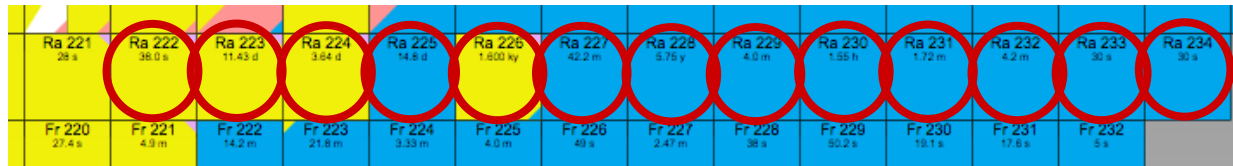
ISOLTRAP run IS574, July

Thanks for Vladimir Manea



# The CRIS experiment: Highlights with neutron-rich nuclei

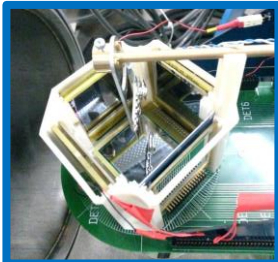
- High resolution collinear resonance ionization spectroscopy of neutron-rich **radium isotopes**
- **Aim:** Study spins, electromagnetic moments, isotope shifts
- **Outcome:** Studied HFS of 12 isotopes  $^{214,222-232}\text{Ra}$ 
  - **Hints of a resonance for  $^{233,234}\text{Ra}$  (limit of neutron-rich production from UCx target)**



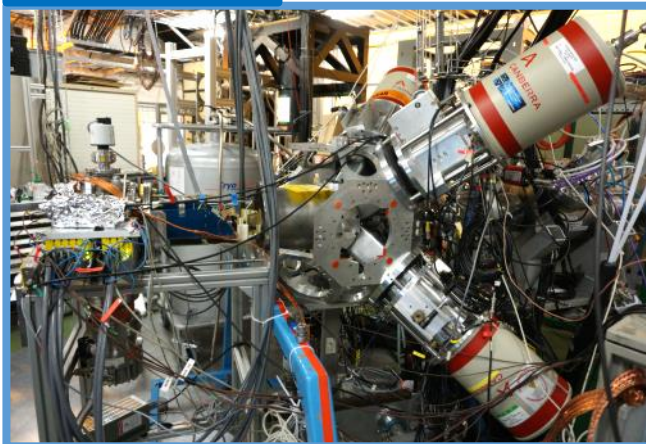
Thanks to Kara Lynch

**IS609:** Study of beta-delayed neutron decay of  $^8\text{He}$  using the newly commissioned IDS Neutron Detector

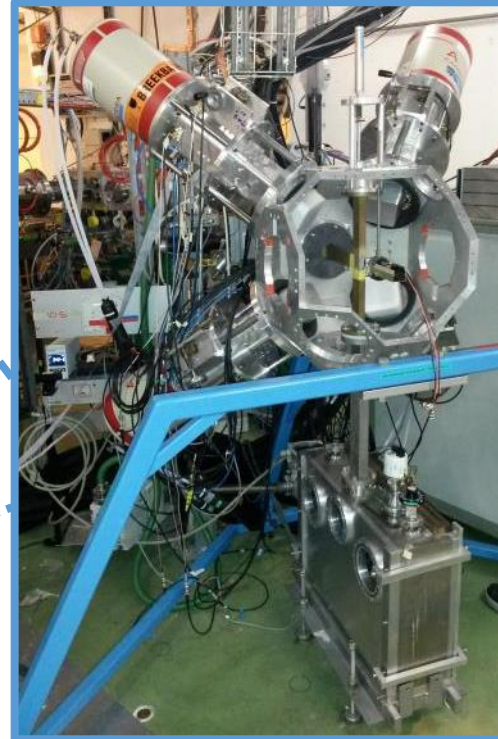
### Neutron Spectroscopy



### Particle Spectroscopy

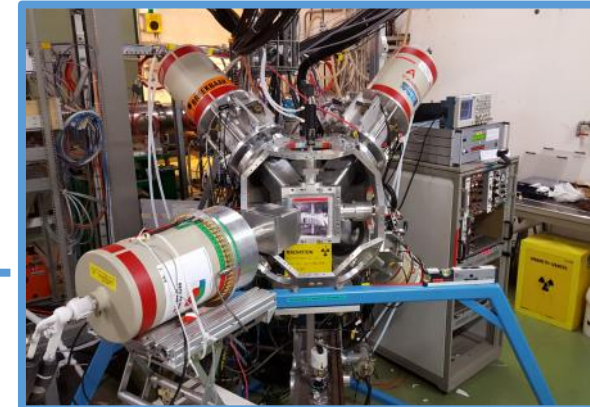


# ISOLDE Decay Station 2016



**IS588:** Study of core breaking and octupole low-spin states in  $^{207}\text{Tl}$  through gamma and beta spectroscopy of  $^{207,208}\text{Hg}$

### High beta-gamma efficiency

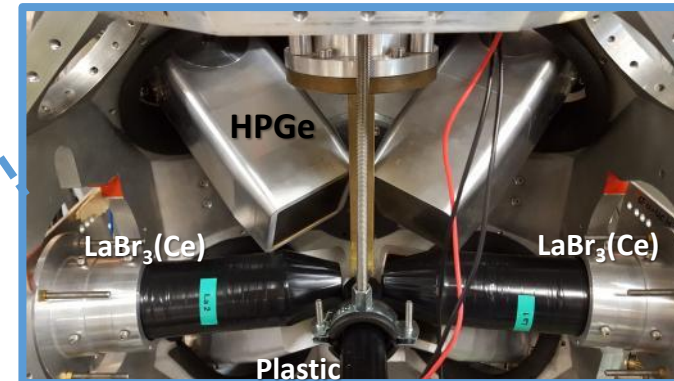


**IS610:** Gamma-ray and fast-timing spectroscopy of nuclei around the doubly-magic  $^{132}\text{Sn}$  nucleus

**IS474:** Fast-timing studies of nuclei below  $^{68}\text{Ni}$  populated in the  $\beta$ -decay of Mn isotopes

**IS579:** Study of octupole deformation in n-rich Ba isotopes

### Fast-timing studies



**IS605:** Absolute measurement of the  $\beta\alpha$  decay of  $^{16}\text{N}$ , with significance for astrophysically important CO reaction. Particle detection was performed using silicon strip detectors of varying thicknesses.

Thanks to  
Razvan  
Lica

# TIS with emission channeling

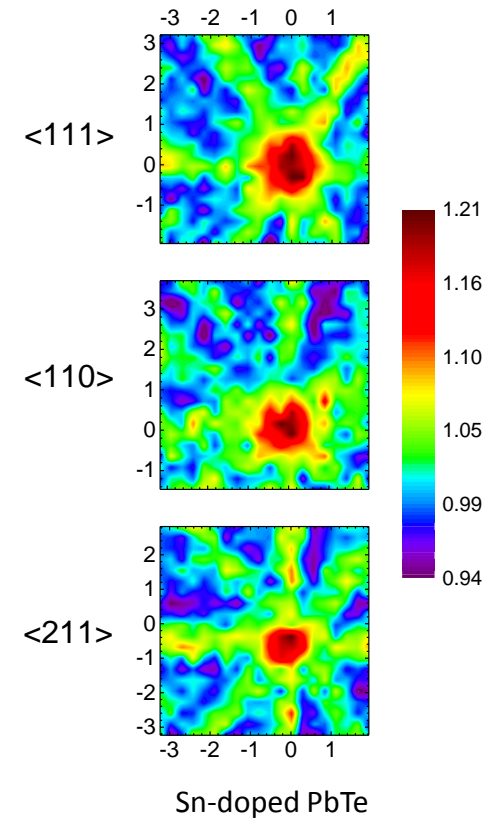
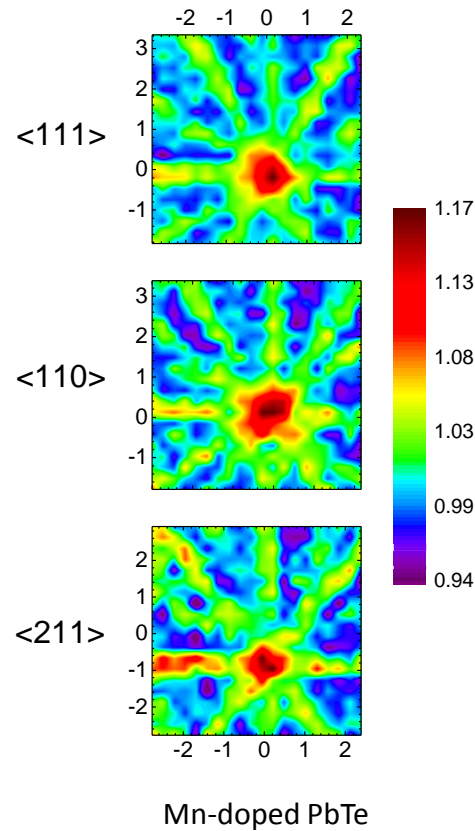
Successful emission channeling measurements on topological insulators



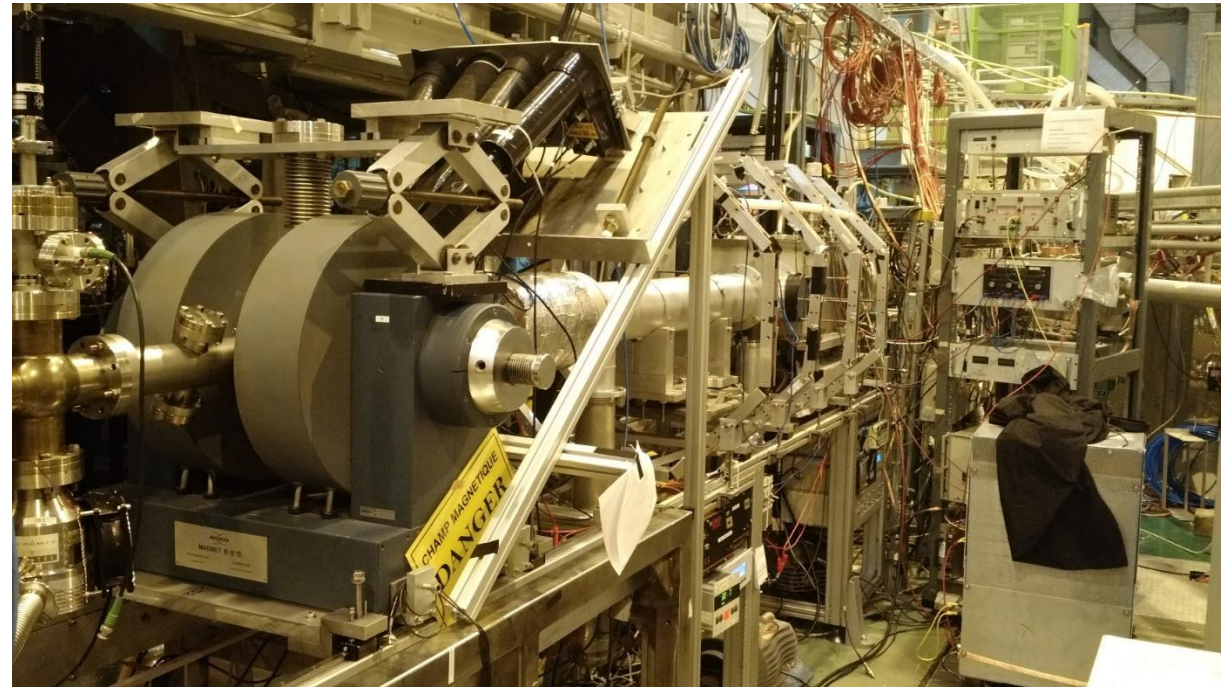
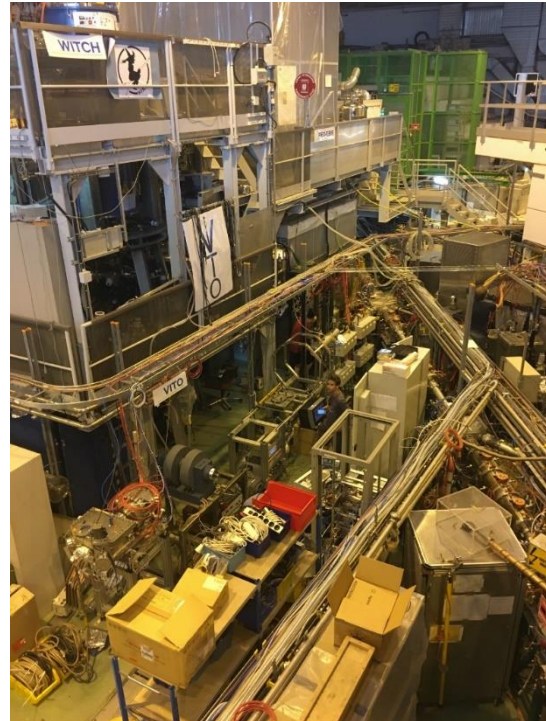
Scientific Background on the Nobel Prize in Physics 2016

TOPOLOGICAL PHASE TRANSITIONS AND  
TOPOLOGICAL PHASES OF MATTER

compiled by the Class for Physics of the Royal Swedish Academy of Sciences



# Installation of the VITO beamline



First tests done in September and October

# HIE ISOLDE runs in a nutshell

GPS

HRS

September			October			November					
35	36	37	38	39	40	41	42	43	44	45	46
#XXX Ucx Ta	setup IS562 (LE)	setup IS562 (LE)	#565 Ta-W	26	setup IS557 (LE)	setup IS557 (LE)		IS561 9Li @ 6.8MeV/u			
29	5	12	IS528 19		3	10	17	24	31	7	14
IS604 IS589 REX tests	setup IS562 (LE)	setup LINAC 110Sn @ 4.5MeV/u	IS528	HIE-ISOLDE (HRS)	setup IS557 (LE)	setup LINAC 78Zn @ 4MeV/u		#587 Ta - W	#586 UCx - Ta		
	jeune	Tech stop	IS528		setup LINAC 108Sn @ 4.5MeV/u						
#582 LaC Ta	IS562 108Sn @ 4.5MeV/u	110Sn @ 4.5MeV/u	IS528	#584 Ucx q n	IS557 80Zn @ 4MeV/u	IS557 78Zn @ 4MeV/u					
Stable beam Xt01			HIE-ISOLDE (HRS)					setup LINAC 9Li @ 7.2MeV/u	setup IS559 (LE)	IS559 66Ni @ 4.5MeV/u	
Stable beam Xt01								IS561 9Li @ 6.8MeV/u	Setup Linac 66Ni @ 4.5MeV/u		
	Sn RILIS		Dy RILIS		Zn RILIS	Zn RILIS			Ni RILIS	Ni RILIS	Ni RILIS

September			October			November				
35	36	37	38	39	40	41	42	43	44	45
	LOI168?	LOI168?	setup IS548 (LE)				#586 Ucx Ta			
29	5	12	19	26	3	10	17	24	31	7
	LOI168?		setup IS548 (LE)		#566 CaO - CP		setup IS551 (LE)		#591 W block	#588 UCx Ta
		583 Ucx - CP	Setup Linac 142Xe @ 4.5MeV/u			HIE-ISOLDE (GPS)	Colls: IS580; IS528; IS578			
	jeune		IS548: 142Xe @ 4.5MeV/u				Setup Linac 132Sn @ 5.5MeV/u			
IS608	HIE-ISOLDE (GPS)	HIE-ISOLDE (GPS)			HIE-ISOLDE (GPS)		IS551 132Sn @ 5.5MeV/u			
LOI168?						IS601				
Bi RILIS							Sn RILIS	Sn RILIS		

Broken 9-gap Amplifier. Only 110Sn possible

RILIS laser window required replacement. Only 78Zn possible.

Difficult setup. Transmission and alignment questions. First test of XT02

Delay due to repair of Amp; leaking target. 15 shifts instead of 30

SnS molecular beam...machine at full energy for first time: 5.5MeV/u

Regular trips of SC cavities: users can reset.  
Regular trips of 7-gap...15 mins each time...  
Extremely heavy load on operators for each run...

# Introduction:



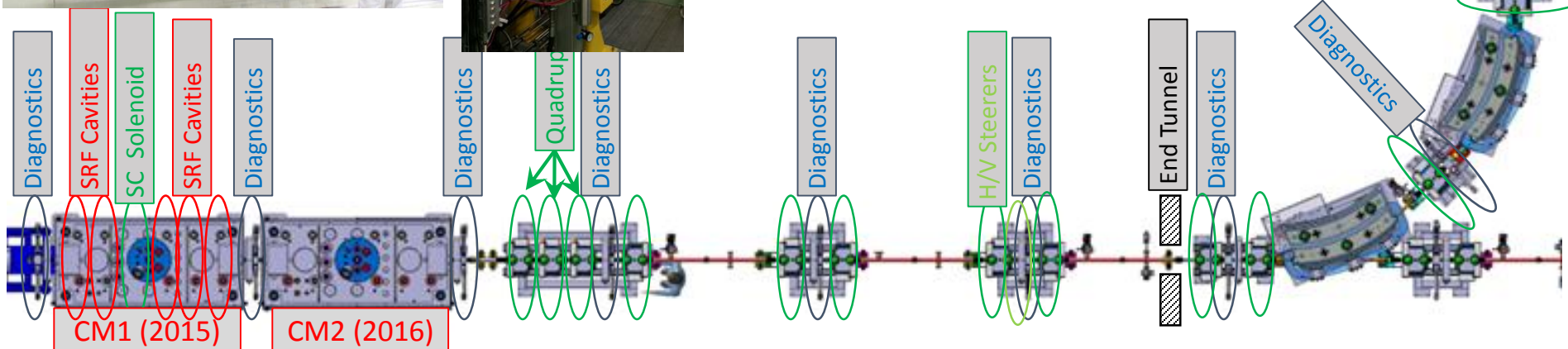
The HIE-ISOLDE super conducting linac and HEBT lines:

- Phase 1B of HIE-ISOLDE completed in 2016: two cryomodules (5 x QWR cavities, 1 x SC solenoid in each cryomodule) and two High Energy Beam Transfer lines (HEBT)
- Quarter Wave Resonators (QWR): copper substrate with niobium sputtered surfaces ( $\beta_g = 0.103$ ,  $E_{acc} = 6$  MV/m)
- Cryomodule: common insulation and beam vacuum



	Maximum beam energy [MeV/u]			
Phase:	1A	1B (*)	2A	2B
Completed	2015	2016	2017	2018
Cryomodules	1	2	3	4
HEBTs	2	2	3	3
A/q = 2.5	5.6	8.6 (7.7*)	11.5	14.2
A/q = 4.33	4.4	6.1 (5.6*)	7.9	9.6

\* Limit because of field emission in some cavities





# Operations during the Physics Campaign:



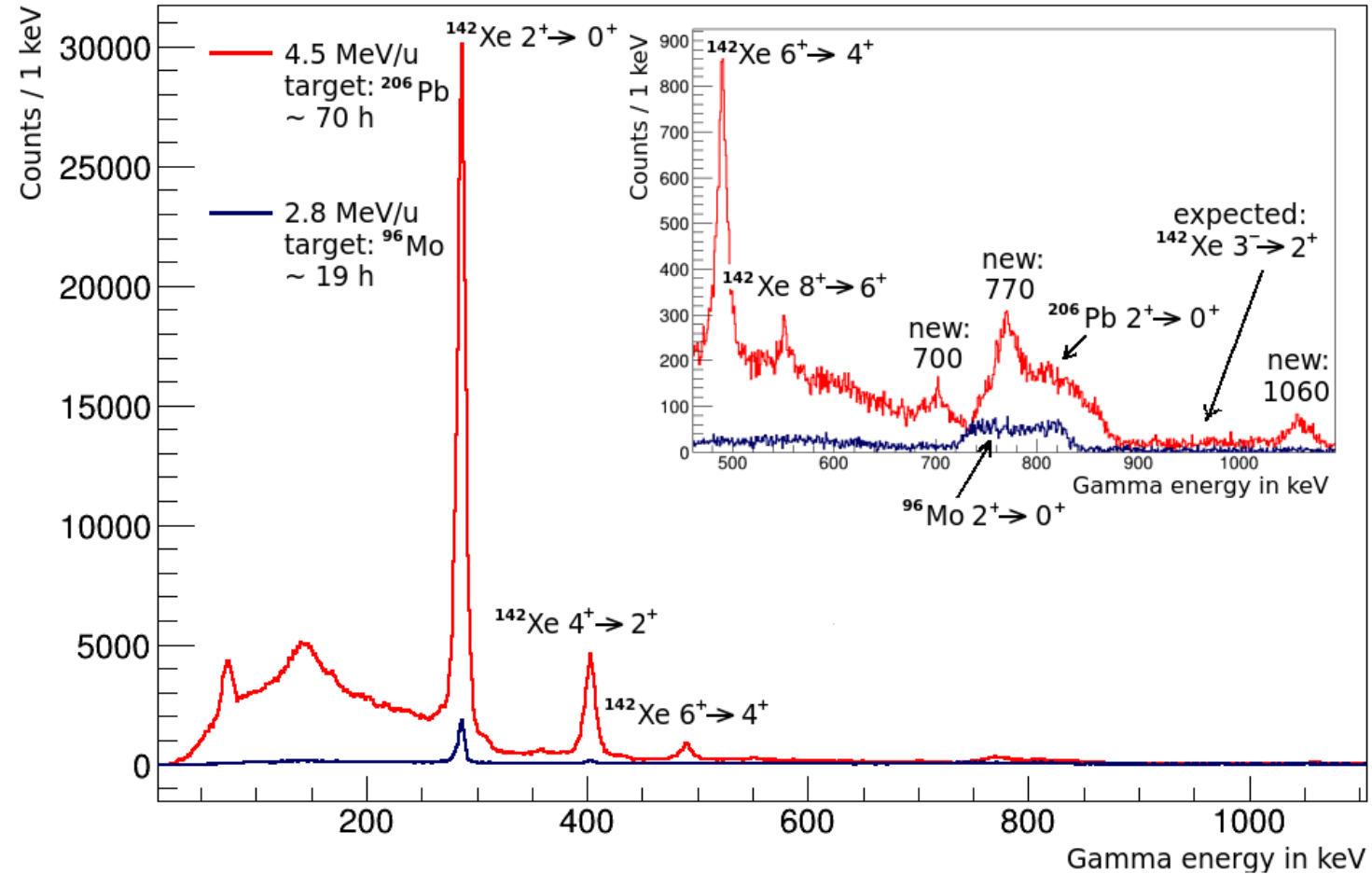
- **From Sep. 2<sup>nd</sup>** with the delivery of stable beam to the Miniball Spectrometer for testing purposes
- **Will finish on wk. 46** when the PSB stops delivering protons and last measurements with stable beams are completed

Experiment #	IS562	IS548	IS557	IS551	IS561	IS559
RIB	<sup>110</sup> Sn	<sup>142</sup> Xe	<sup>78</sup> Zn	<sup>132</sup> Sn	<sup>9</sup> Li	<sup>66</sup> Ni
Energy [MeV/u]	4.5	4.5	4.3	5.5	6.8 (7.2 req)	4.5
Target	GPS	HRS	GPS	HRS	GPS	GPS
Exp. Station	Miniball Spect.	Miniball Spect.	Miniball Spect.	Miniball Spect.	Scattering Chamber	Miniball Spect.
Start date	Sep. 9 <sup>th</sup>	Sep. 26 <sup>th</sup>	Oct. 10 <sup>th</sup>	Oct. 19 <sup>th</sup>	Oct. 28 <sup>th</sup>	Nov. 4 <sup>th</sup>
End date	Sep. 18 <sup>th</sup>	Oct. 2 <sup>nd</sup>	Oct. 16 <sup>th</sup>	Oct. 26 <sup>th</sup>	Nov. 1 <sup>st</sup>	Nov. 14 <sup>th</sup>
Length [hours]	115	100	130	130	70	

Approximately 90 hours of beam at HIE-ISOLDE energies during the whole 2015 campaign!

# Preliminary data from $^{142}\text{Xe}$ for IS548

Doppler corrected with respect to Xe



Courtesy of corinna Henrich

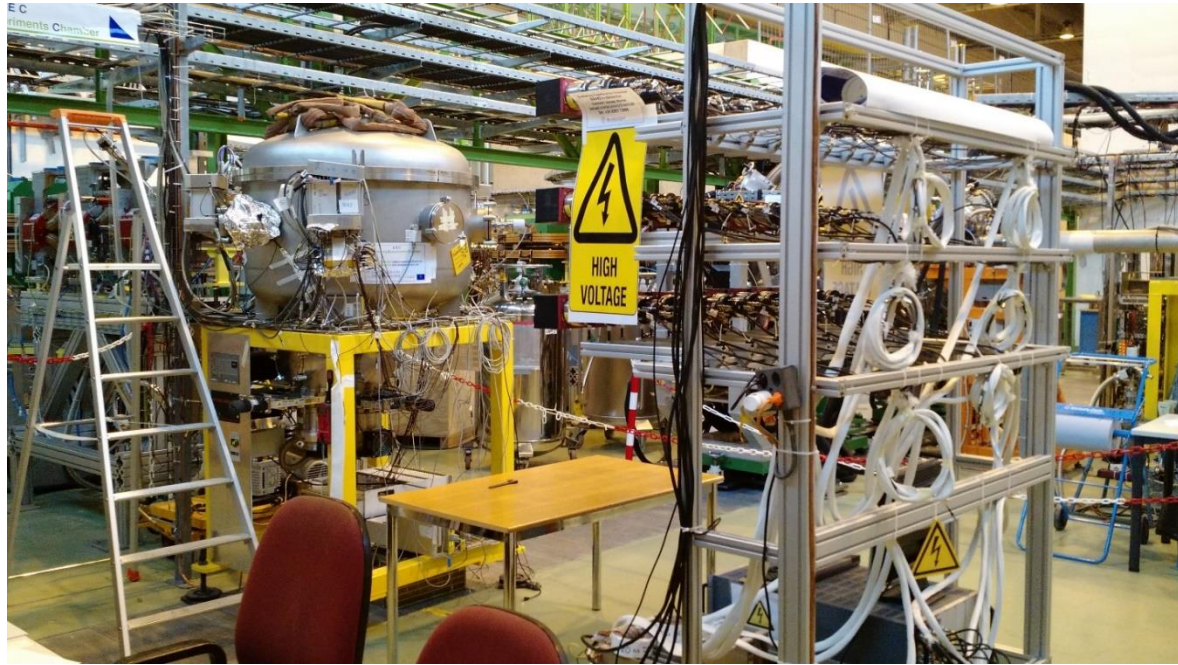
$^{110}\text{Sn}$  beams @ 4.5MeV/u: Sept 9<sup>th</sup> 2016



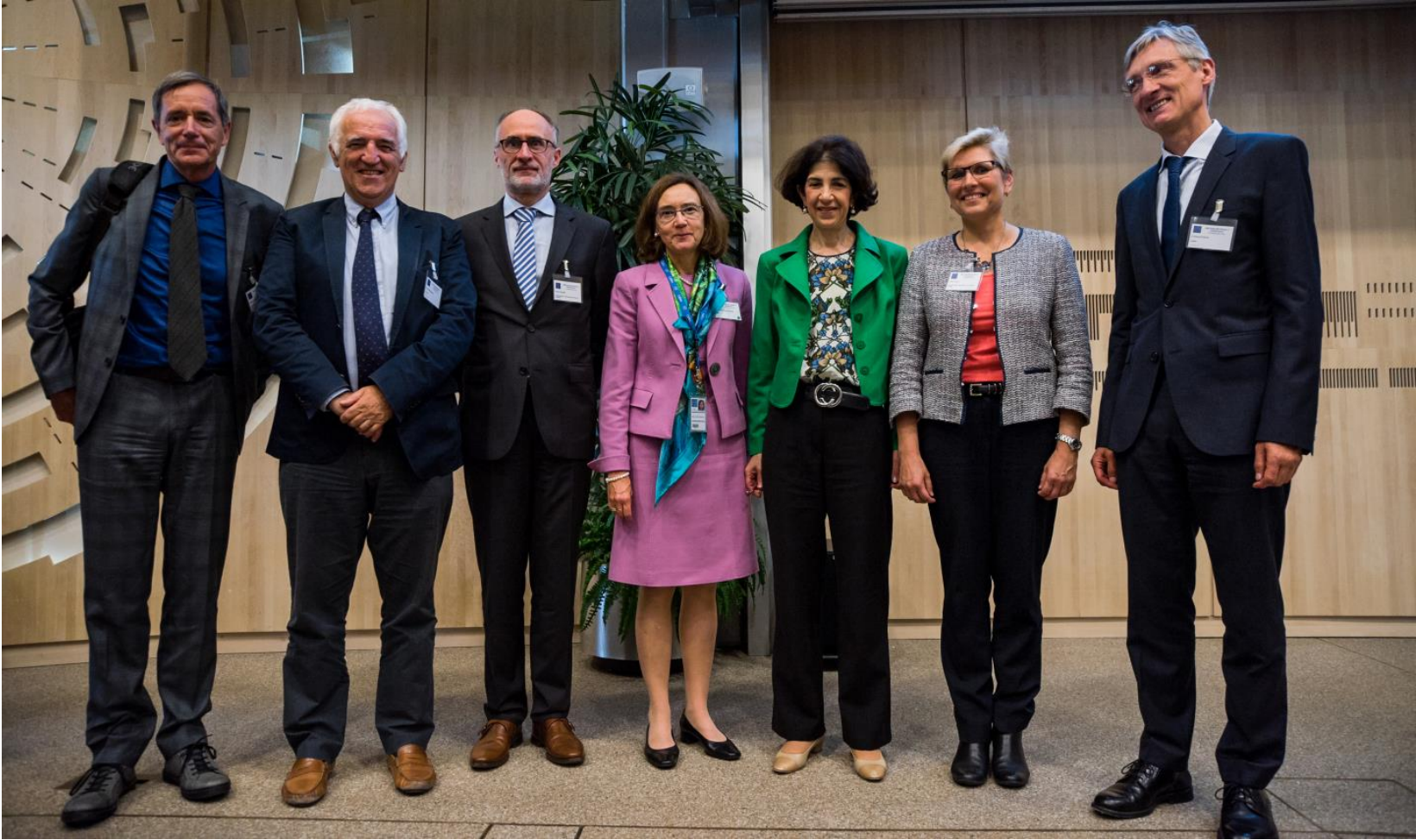
1 week of operation exceeded 2015 running hours (~ 3 weeks)



${}^9\text{Li}$  beams @ 6.8MeV/u: Oct 28<sup>th</sup> 2016

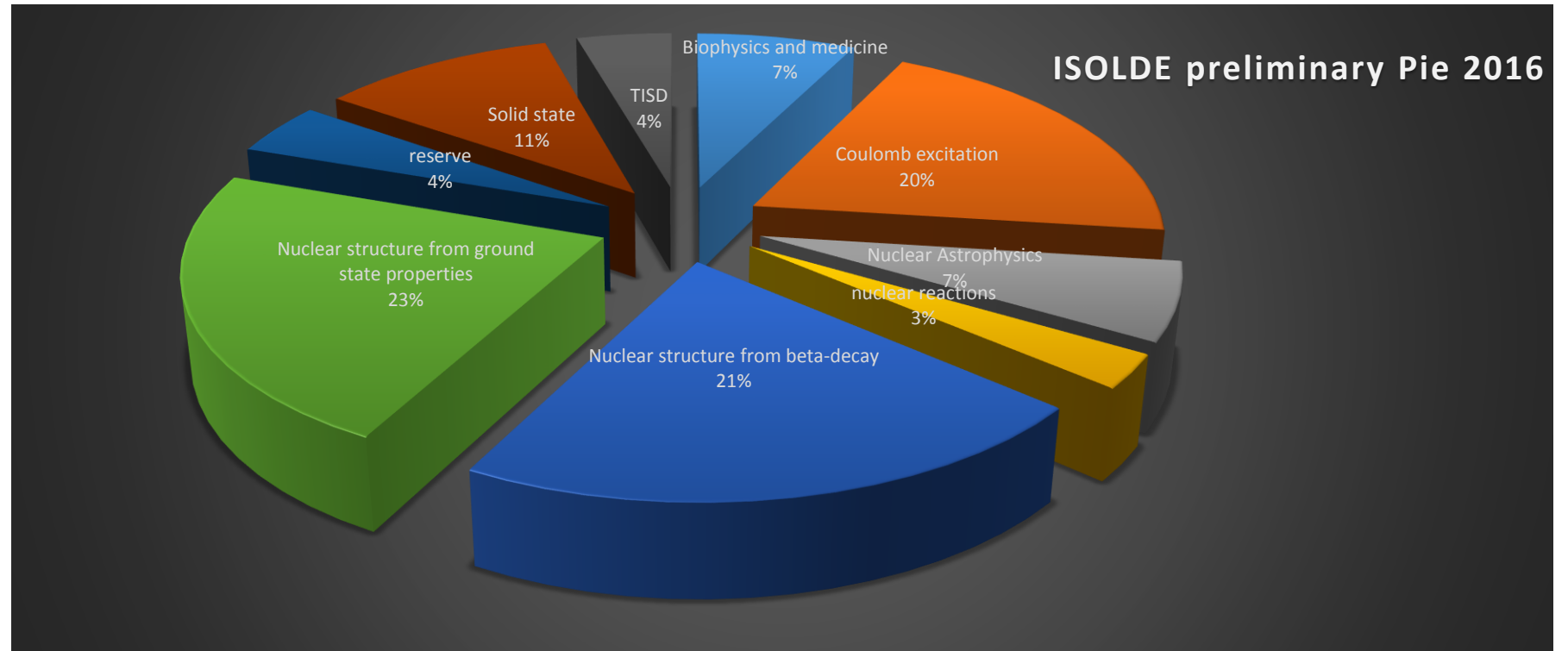


# Celebration of end of Phase I: 28<sup>th</sup> September 2016



# Preliminary counting

Row Labels	Sum of Shifts delivered
BIO	4
COLLAPS	27
CRIS	14
Gandalph	6
HIE ISOLDE (MB)	67
HIE ISOLDE (Scattering)	9.5
IDS	57
Irradiation	3
ISOLTRAP	36
MEDICAL	21
SSP	37
TAS	10
TISD	15
VITO	6
Windmill; ISOLTRAP	28
<b>Grand Total</b>	<b>340.5</b>



46 experiments

	Apr			May				June					
Wk	14	15	16	17	18	19	20	21	22	23	24	25	26
Mo	3	10	Easter Mon 17	24	May Day 1	8	15	22	29	White 5	12	19	26
Tu		Recommissioning with beam											
We													
Th		ISOLDE, nTOF, EA, AD						Ascension					
Fr		NA setup											
Sa		G. Friday											
Su													

Beam available to LHC (Apr 17)  
 Start EA, NA, AD physics (May 18)  
 Start LEIR (May 19)  
 ions to PS (June 24)  
 ions to SPS (June 26)

	Oct			Nov				Dec					
Wk	40	41	42	43	44	45	46	47	48	49	50	51	52
Mo	2	9	16	23	30	6	13	20	27	4	11	18	Xmas 25
Tu													
We													
Th						North Area xeon physics (8 weeks (inc. 2 weeks set-up))							
Fr													
Sa													
Su													

End 2017 (Dec 31)  
 End of run (06:00) (Dec 31)

**Scheduling plan for 2017 not yet fixed!** Continuous block of HIE-ISOLDE not feasible from operations (or users viewpoint). To be discussed during shutdown.