ISOLDE TISD 2024 year in review

Running period: 2 April – 8 December

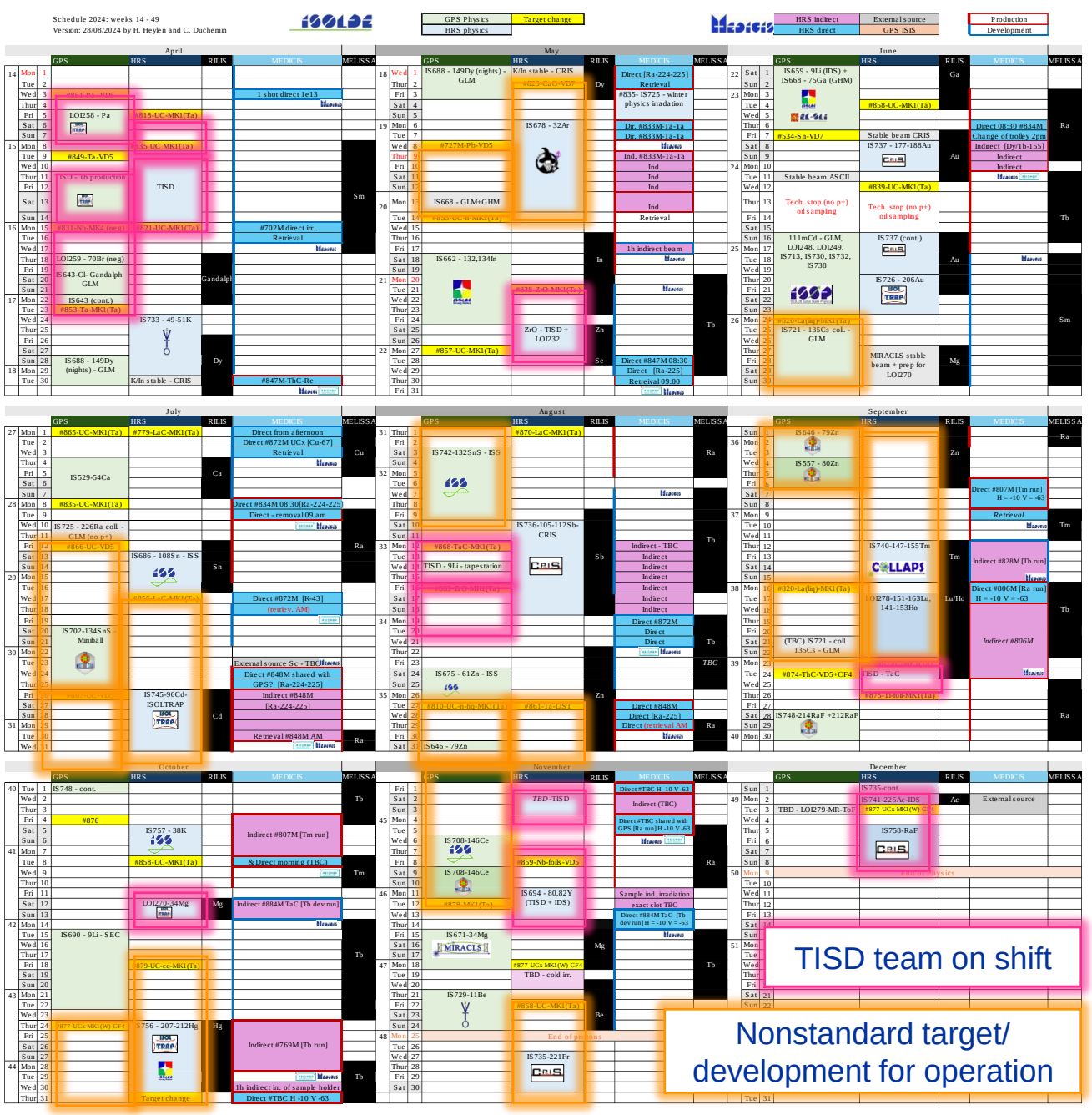
MD activities: HRS fast beamgate system, RP monitor proton scans, 2D proton scans

11 Target and Ion Source Development (TISD) beamtimes:

- Beam development: Pa, TbF_x, in-trap decay,
- New target materials: nano ZrO_x, TaC,

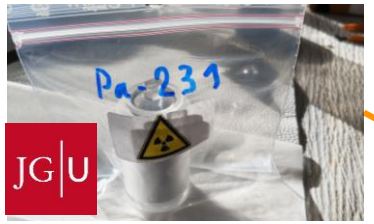
Beams for operation:

- First negative ions since LS2: Br^-, Cl^-
- Molecular beams: SnS, CeF_x, YF_x, RaF,
- Special target materials: Nb foils, Ti foils, nano CaO
- Special target units: #856 ΔT<20˚C, #861 LIST, #813 LIST, #810 hq, #879 cq, #820 liquid La



ISOLDE TISD 2024: April-June

LOI258: External sample collaboration, *first Pa beam at ISOLDE*



Protactinium chemistry at ISOLDE from external sources

September 22, 2023

M. Au[1,2], M. Athanasakis-Kaklamanakis[1,3], L. Nies[1], K. Blaum[4] C. Duchemin[1], Ch.E. Düllmann[2,5,6], C. M. Fajardo-Zambrano[3], P. F. Giesel[7], M. Heaven[8], L. Lambert[1], D. Lange[4], U. Köster[9], G. Neyens[3], D. Renisch[2,6], S. Rothe[1], Ch. Schweiger[4], L. Schweikhard[7], J. Stricker[2,6], W. Wojtaczka[3]

Liquid Pb

CaOx nano: One-day turnaround for backup target

HRS fast beamgates: Installation and commissioning

TISD TbF_x: Molecular Tb beams for medical applications

In-trap decay: MD and preliminary tests

GANDALPH: First (only) negative ion run since LS2

Schedule 2024: weeks 14 - 49
Version: 28/08/2024 by H. Heylen and C. Duchemin

GPS Physics | Target change
HRS physics

HRS indirect | External source
HRS direct | GPS ISIS

Production
Development

			April GPS	April HRS	April RILIS	April MEDICIS	April MELISSA
14	Mon	1					
	Tue	2					
	Wed	3	#851-Pa -VD5			1 shot direct 1e13	
	Thur	4					
	Fri	5	LOI258 - Pa	#818-UC-MK1(Ta)			
	Sat	6					
	Sun	7					
15	Mon	8		#835-UC-MK1(Ta)			
	Tue	9	#849-Ta-VD5				
	Wed	10					
	Thur	11	TISD - Tb production				
	Fri	12		TISD			
	Sat	13					Sm
	Sun	14					
16	Mon	15	#831-Nb-MK4 (neg)	#821-UC-MK1(Ta)		#702M direct irr.	
	Tue	16				Retrieval	
	Wed	17					
	Thur	18	LOI259 - 70Br (neg)				
	Fri	19					
	Sat	20	IS643-Cl- Gandalph GLM		Gandalph		
	Sun	21					
17	Mon	22	IS643 (cont.)				
	Tue	23	#853-Ta-MK1(Ta)				
	Wed	24		IS733 - 49-51K			
	Thur	25					
	Fri	26					
	Sat	27					
	Sun	28	IS688 - 149Dy (nights) - GLM		Dy		
18	Mon	29					
	Tue	30		K/In stable - CRIS		#847M-ThC-Re	

			May GPS	May HRS	May RILIS	May MEDICIS	May MELISSA
18	Wed	1	IS688 - 149Dy (nights) - GLM	K/In stable - RIS	Dy	Direct [Ra-224-225]	
	Thur	2		#823-CaO-VD7		Retrieval	
	Fri	3				#835- IS725 - winter physics irradiation	
	Sat	4					
	Sun	5					
19	Mon	6		IS678 - 32Ar		Dir. #833M-Ta-Ta	
	Tue	7				Dir. #833M-Ta-Ta	
	Wed	8	#727M-Pb-VD5				
	Thur	9				Ind. #833M-Ta-Ta	
	Fri	10				Ind.	
	Sat	11				Ind.	
	Sun	12				Ind.	
20	Mon	13	IS668 - GLM+GHM			Ind.	
	Tue	14	#855-UC-n-MK1(Ta)			Retrieval	
	Wed	15					
	Thur	16					
	Fri	17				1h indirect beam	
	Sat	18	IS662 - 132,134In		In		
	Sun	19					
21	Mon	20					
	Tue	21		#838-ZrO-MK1(Ta)			
	Wed	22					
	Thur	23					
	Fri	24					Tb
	Sat	25		ZrO - TISD + LOI232	Zn		
	Sun	26					
22	Mon	27	#857-UC-MK1(Ta)				
	Tue	28			Se	Direct #847M 08:30	
	Wed	29				Direct [Ra-225]	
	Thur	30				Retrieval 09:00	
	Fri	31					

			June GPS	June HRS	June RILIS	June MEDICIS	June MELISS
22	Sat	1	IS659 - 9Li (IDS) + IS668 - 75Ga (GHM)		Ga		
	Sun	2					
23	Mon	3					
	Tue	4		#858-UC-MK1(Ta)			
	Wed	5					
	Thur	6				Direct 08:30 #834M	Ra
	Fri	7	#534-Sn-VD7	Stable beam CRIS		Change of trolley 2pm	
	Sat	8		IS737 - 177-188Au	Au	Indirect [Dy/Tb-155]	
	Sun	9				Indirect	
24	Mon	10				Indirect	
	Tue	11	Stable beam ASCII				
	Wed	12		#839-UC-MK1(Ta)			
	Thur	13	Tech. stop (no p+) oil sampling	Tech. stop (no p+) oil sampling			Tb
	Fri	14					
	Sat	15					
	Sun	16	111mCd - GLM, LOI248, LOI249, IS713, IS730, IS732, IS738	IS737 (cont.)	Au		
25	Mon	17					
	Tue	18					
	Wed	19					
	Thur	20		IS726 - 206Au			
	Fri	21					
	Sat	22					
	Sun	23					
26	Mon	24	#820-La(liq)-MK1(Ta)				Sm
	Tue	25	IS721 - 135Cs coll. - GLM				
	Wed	26					
	Thur	27					
	Fri	28		MIRACLS stable beam + prep for LOI270	Mg		
	Sat	29					
	Sun	30					

TISD team on shift

Nonstandard target/beam development for operation

TISD ZrOx nano: Target material development

Liquid La: #820

M. Au

ISOLDE TISD 2024: July-August

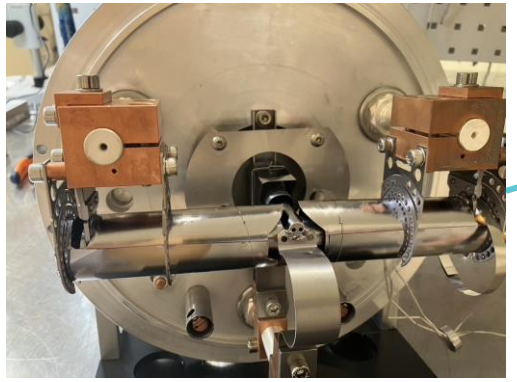
LIST Ta: offline development target as backup ~1 day turnaround

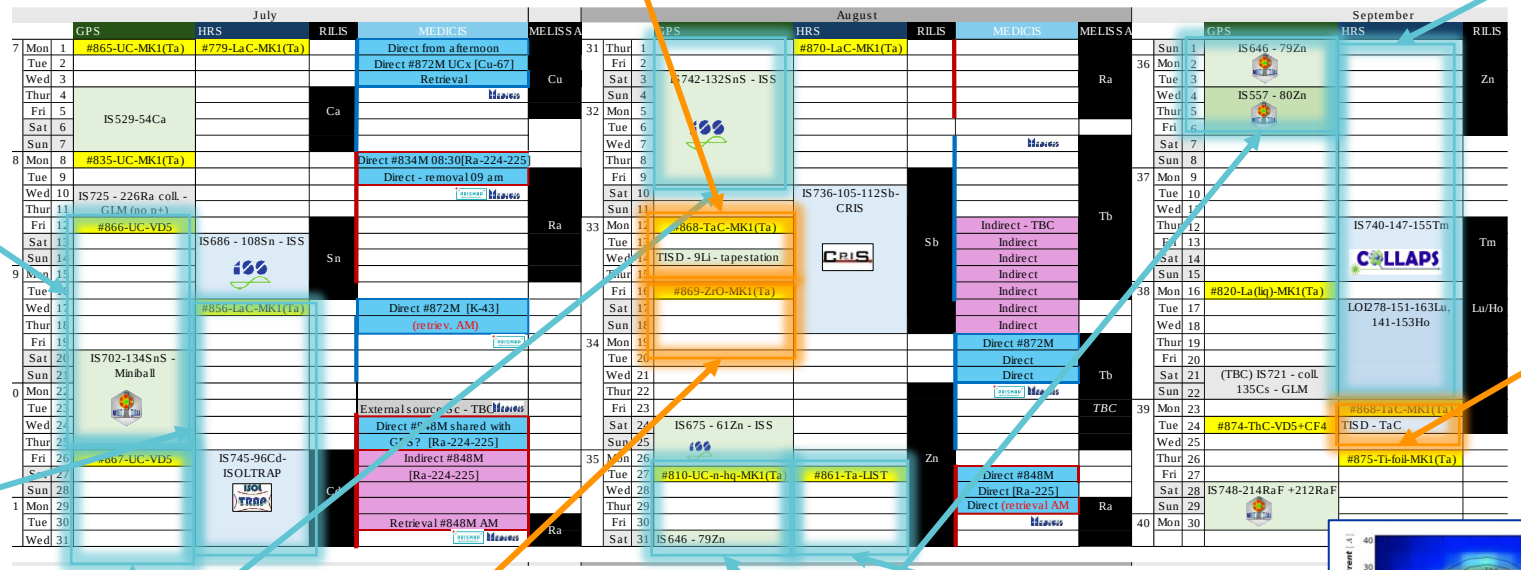
TISD TaCx: Target material development

SnS: sulphur oven development

TISD TaCx: Target material development

#856 for IS745: ΔT < 17°C



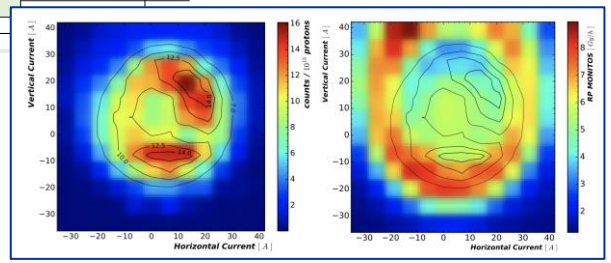


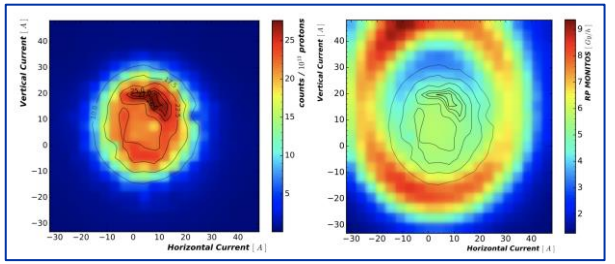
TISD ZrOx: Target material development

SnS: sulphur oven development

Hot quartz

LIST Ta





TISD team on shift

Nonstandard target/beam development for operation

RP monitor data and 2D proton scans

J.B. Frederiksen, M. Au, L. Le

https://cds.cern.ch/record/2908317

M. Au

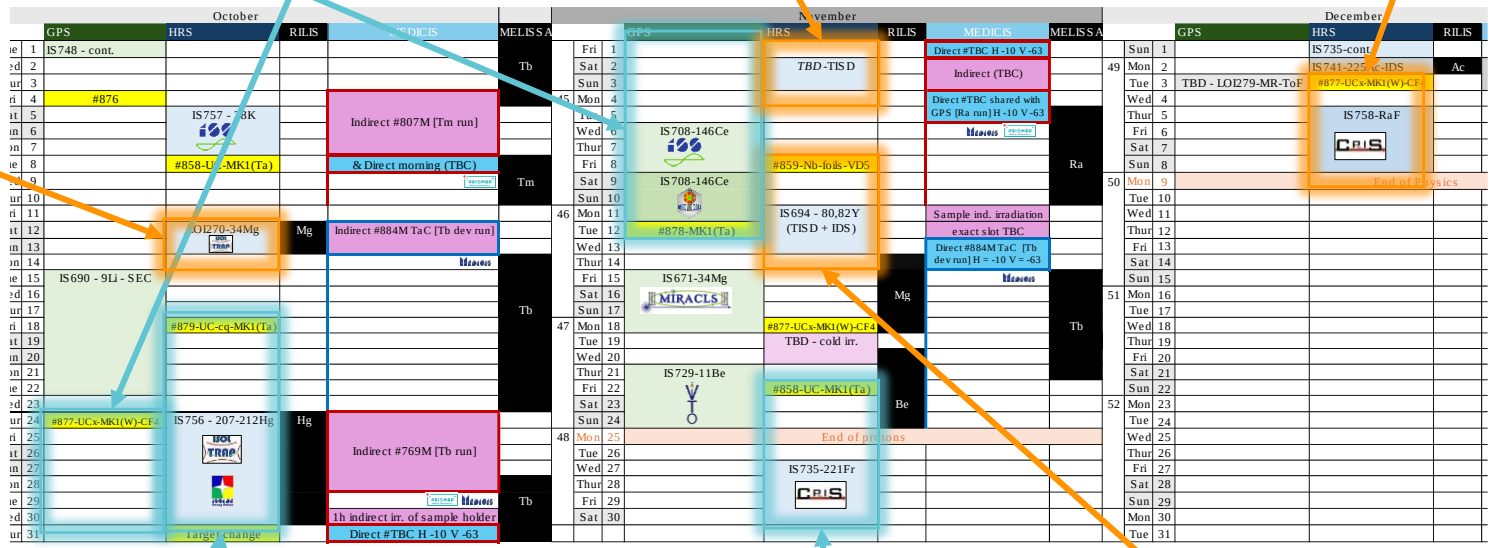
ISOLDE TISD 2024: October-December

LOI270 in-trap decay: beam development

CeF_x: molecular beam development

TISD: TbF_x from tantalum foils

RaF^-: negative molecules through double charge-exchange



Cold quartz

Nb foil target: target material development, yields for users

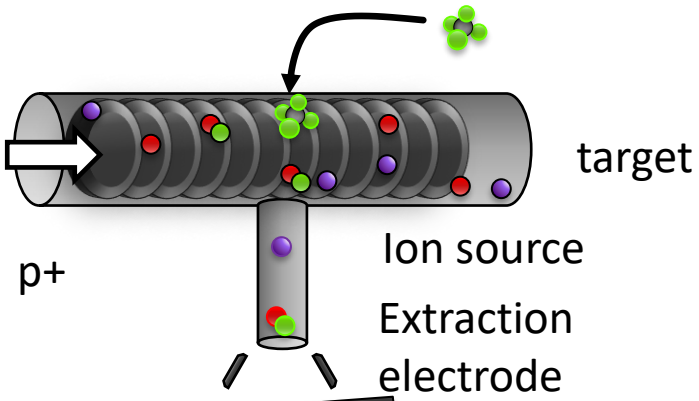
Winter physics: Fr from Ac decay

TISD team on shift

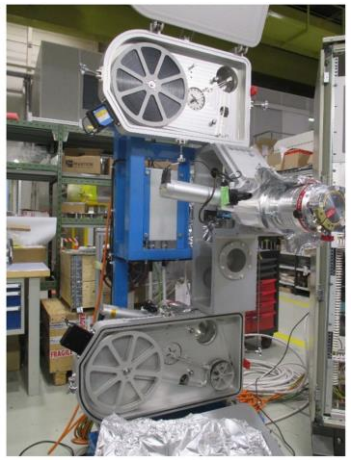
Nonstandard target/beam development for operation

M. Au

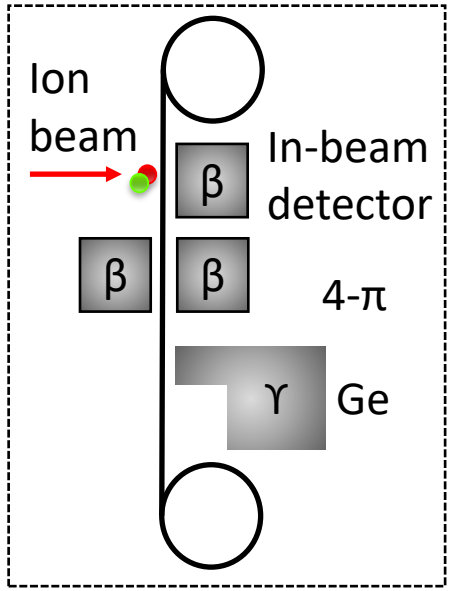
TISD online experiments



Catherall, R. et al. (2017) J. Phys. G. **44**, 9



ISOLDE FTS



- Contaminant ions
- Contaminant neutrals
- Isotope of interest
- Neutral molecule of interest
- Molecular ion of interest
- Reactive gas
- Buffer gas

ISOLDE HRS

Mass separator

ISOLDE LA1

collections chamber

ISOLTRAP RFQ-cb

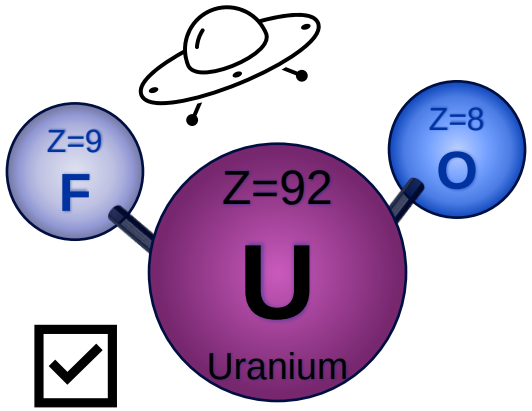
ISOLTRAP MR-ToF MS

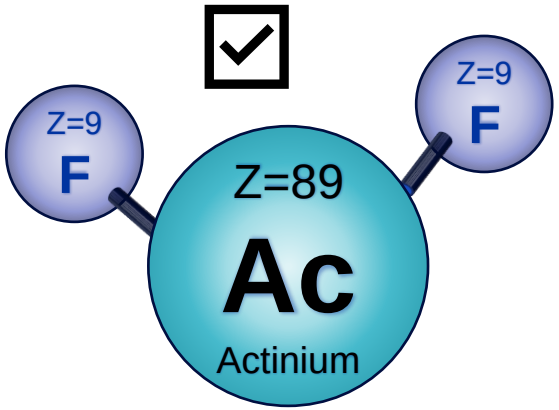
M. Au

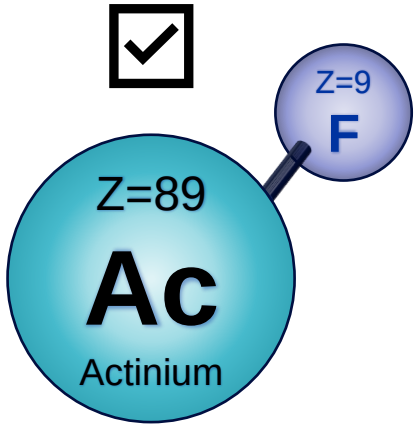
Fluoride beams current status

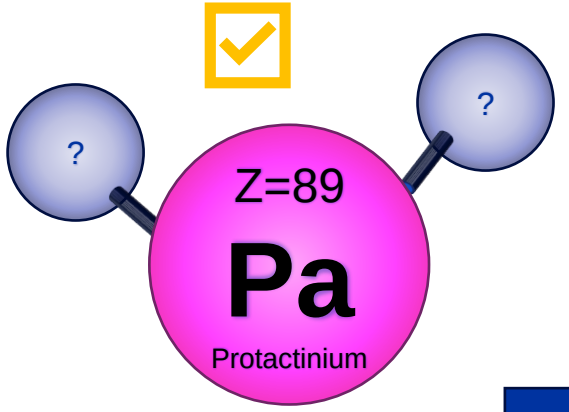
- RaF_x: developed, available*
- AcF_x: developed, available*
- NpF_x, PuF_x: observed
- PaF_x, PaO_x: external sources, development
- ThF_x, UF_x: long-lived only
- ScF_x, TbF_x: ongoing development
- VF_x: requested

Image published in EP Newsletter, CERN (2020)





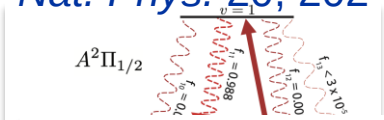


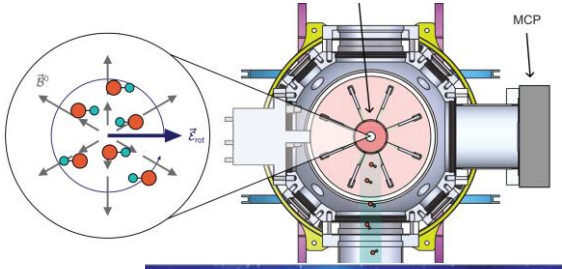


M. Au

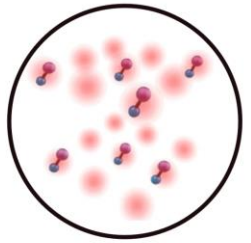
Fundamental Symmetries collaboration

Udrescu et al.,(2024) *Nat. Phys.* 20, 202





Roussy et al., *Science* 381, 46 (2023)



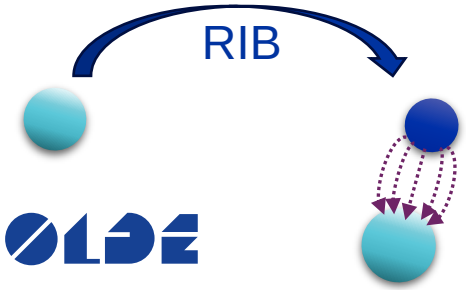
Athanasakis-Kaklamanakis et al.,(2024) *in preparation*

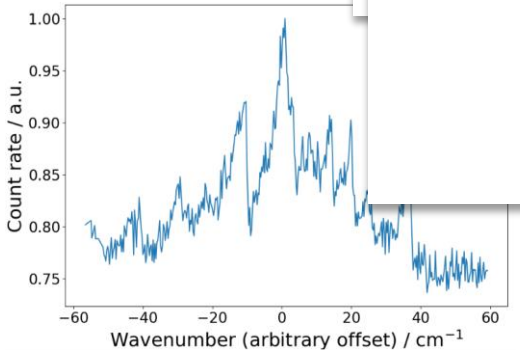
Fundamental Physics Research with Radioactive Molecules

22 April 2024

Executive Summary. Radioactive molecules provide opportunities to probe physics beyond the Standard Model and investigate still-unsolved questions of modern physics, including the origins of baryon asymmetry. Observables with sensitivity to charge-parity (CP)-violating effects such as electric dipole moments (EDMs) are specifically enhanced in radioactive molecules and require multiple probe systems to disentangle possible sources of CP-violation using complementary searches. The enclosed proposal

I., *Phil. Trans.* 3822 (2023)





Making radioactive molecules

- Beams, traps, targets

Characterizing radioactive molecules

- Spectroscopy, chemistry
- Properties and states

Work in progress

- *Fellow position closed*
- *collaboration*

Precision measurement

Techniques for bulk systems

M. Au

Developments in target materials

Sub-micron and nano materials development:
Valentina Berlin and Edgar Reis
CaO, ZrO_2, La_2O_3,UC_X,TaC,HfB,Ta foils…

Gas injection

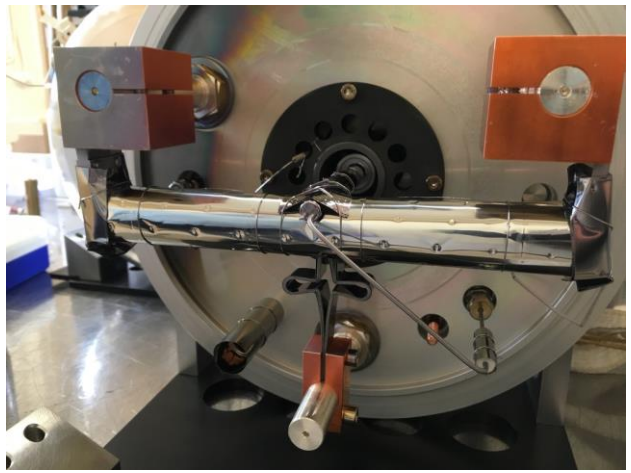
- Reactive/corrosive gases

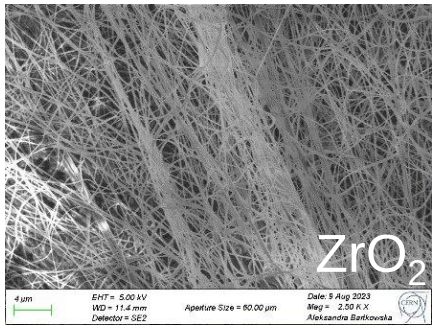
Reactants

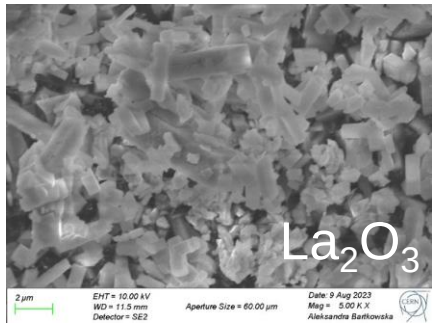
- Mass markers

Target materials

- Particle size
- Open porosity







Slides and pictures provided by V. Berlin, M. Au

Ion source developments

Molecular breakup and characterization studies

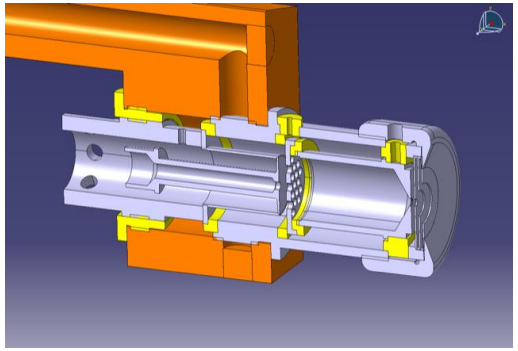
- FEBIAD-type ion sources [1,2]
- Electron energy and source optimization
- Ion source systematics

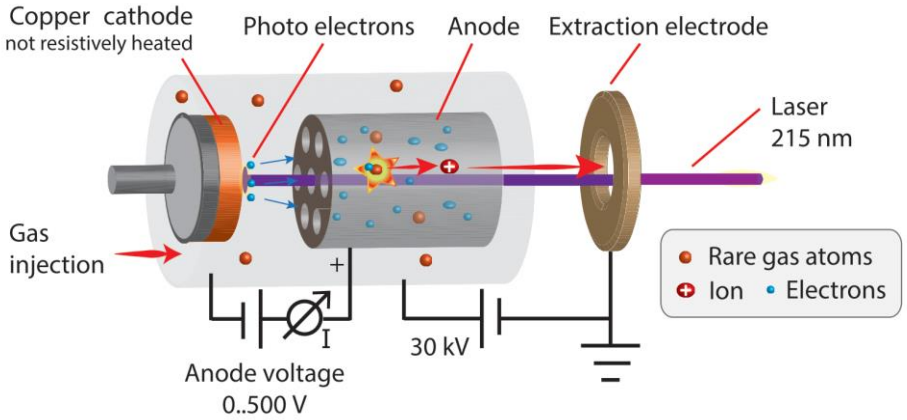
Photocathode ion sources [3]

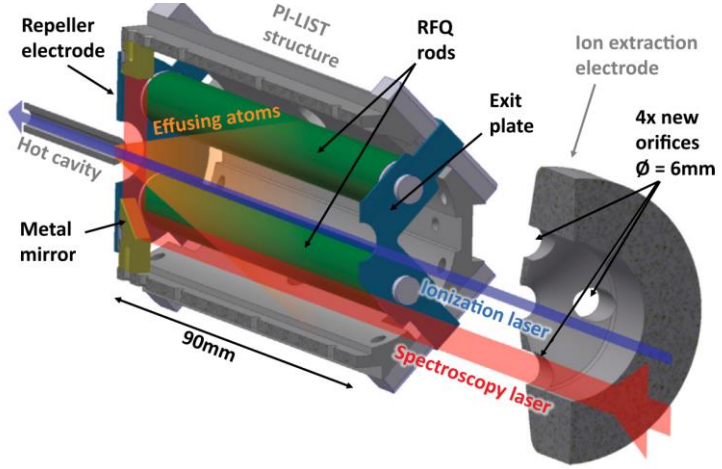
- Cold (room-temperature) environments

In-source spectroscopy [4]

- PI-LIST: sub-Doppler hot-cavity in-source spectroscopy
- CERN-ISOLDE implementation







[1] Maldonado (2023) PhD thesis
[2] Martinez Palenzuela (2020) PhD thesis
[3] Ballof . et al., 2022) *J. Phys.: Conf. Ser.* **2244** 012072
[4] Heinke et al. (2023) *NIM B.* **541** (8-12)

Slides and pictures provided by M. Au

Molecular ion beam production

Update on ISOLDE Offline 2

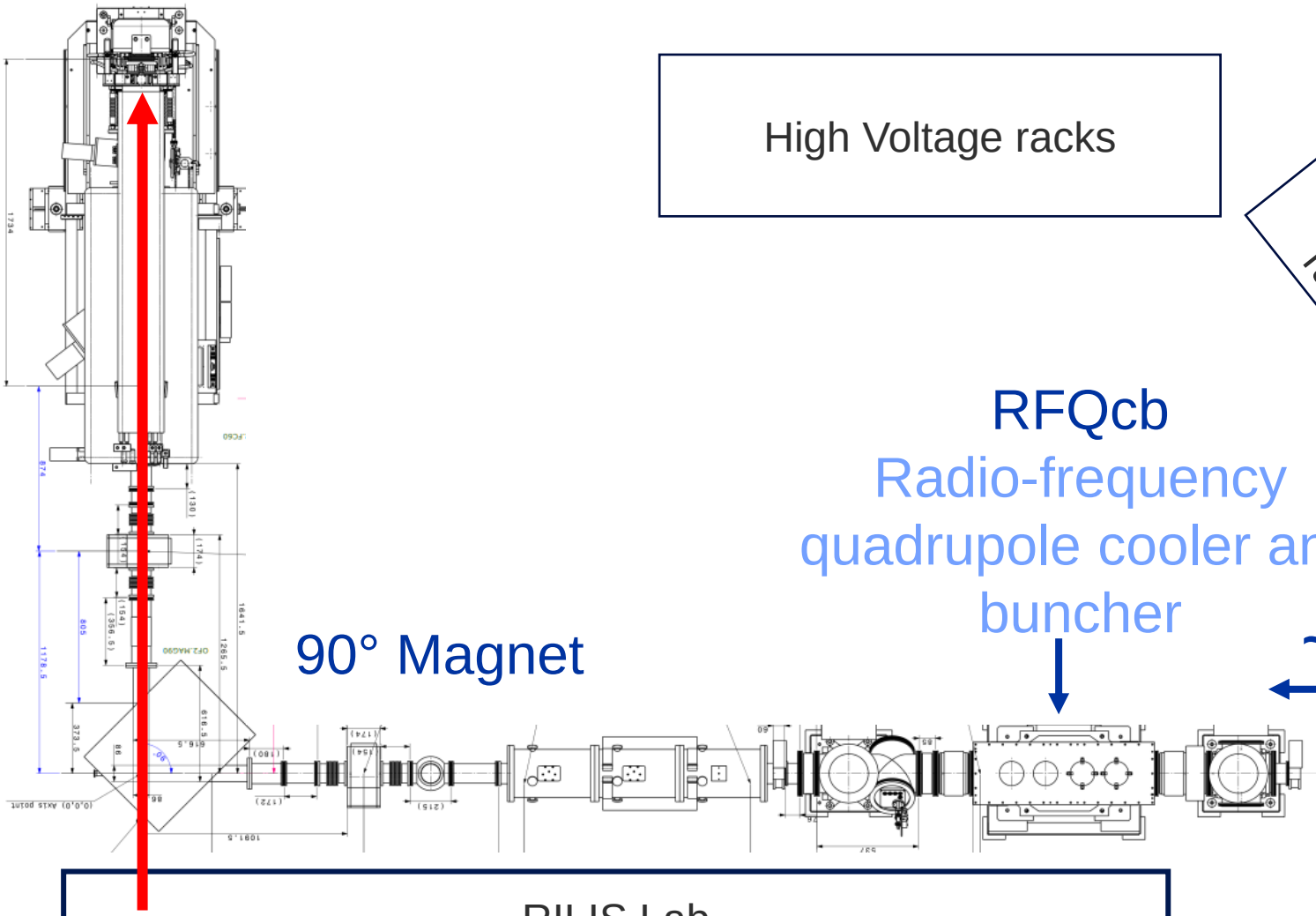
Justus Berbalk

CRIS Collaboration meeting 30-31 January 2025

Layout of OFFLINE 2

Ion source

Beamgate



High Voltage racks

High Voltage racks

RFQcb

Radio-frequency quadrupole cooler and buncher

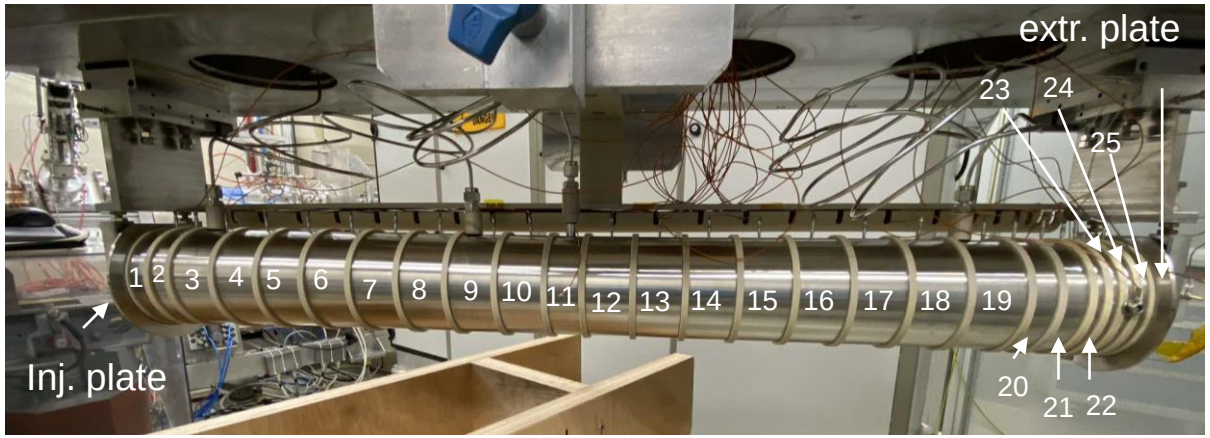
90° Magnet

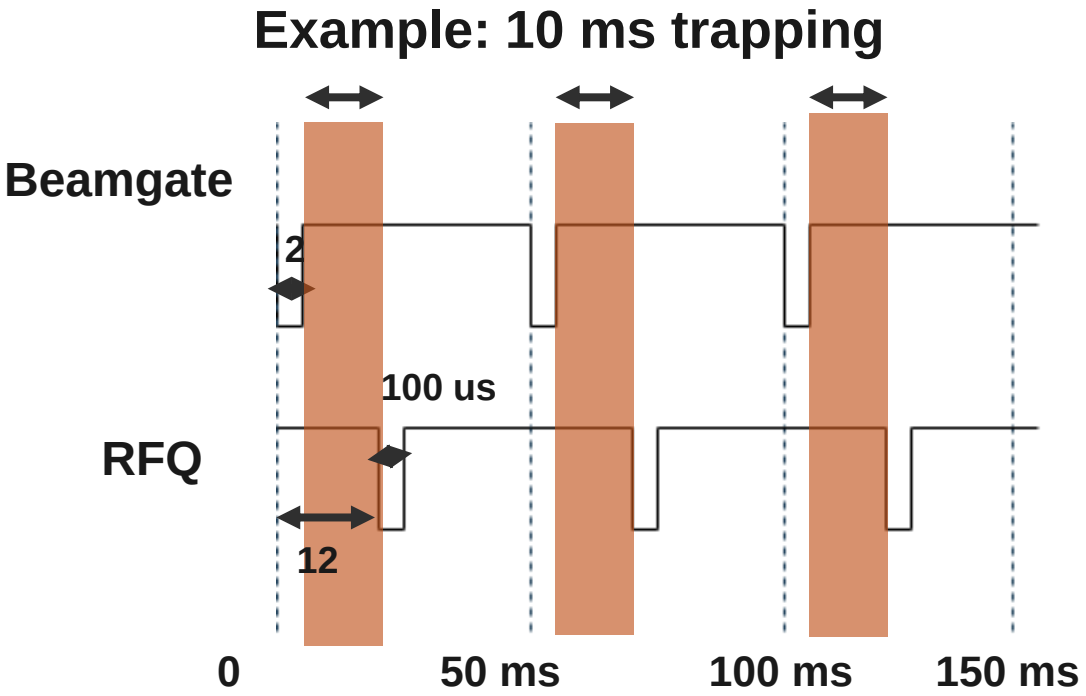
~ 2 m

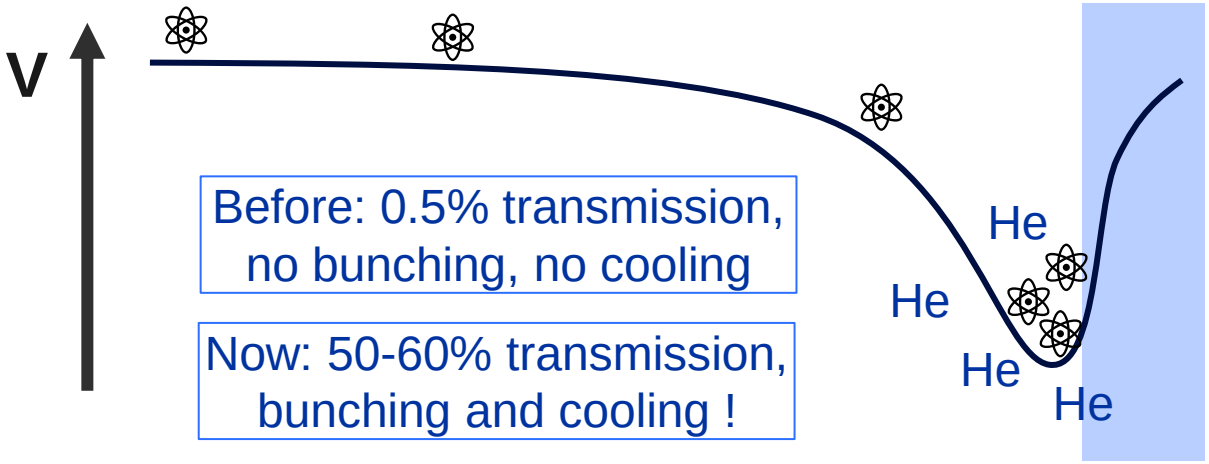
Magnetof

RILIS Lab

The radiofrequency quadrupole cooler-buncher (RFQcb)





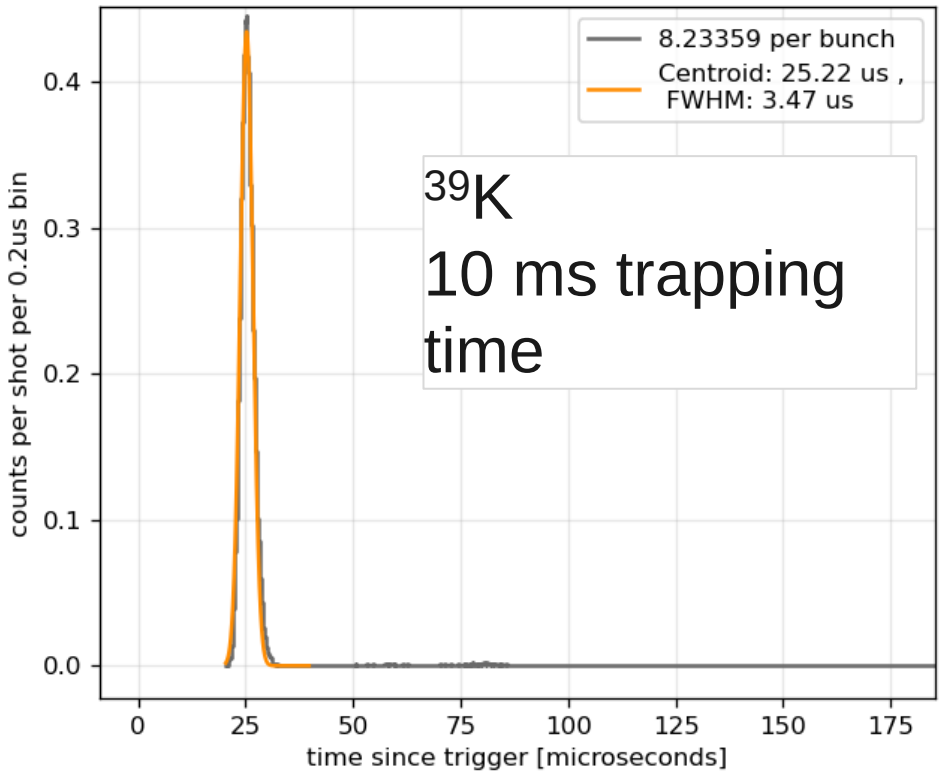


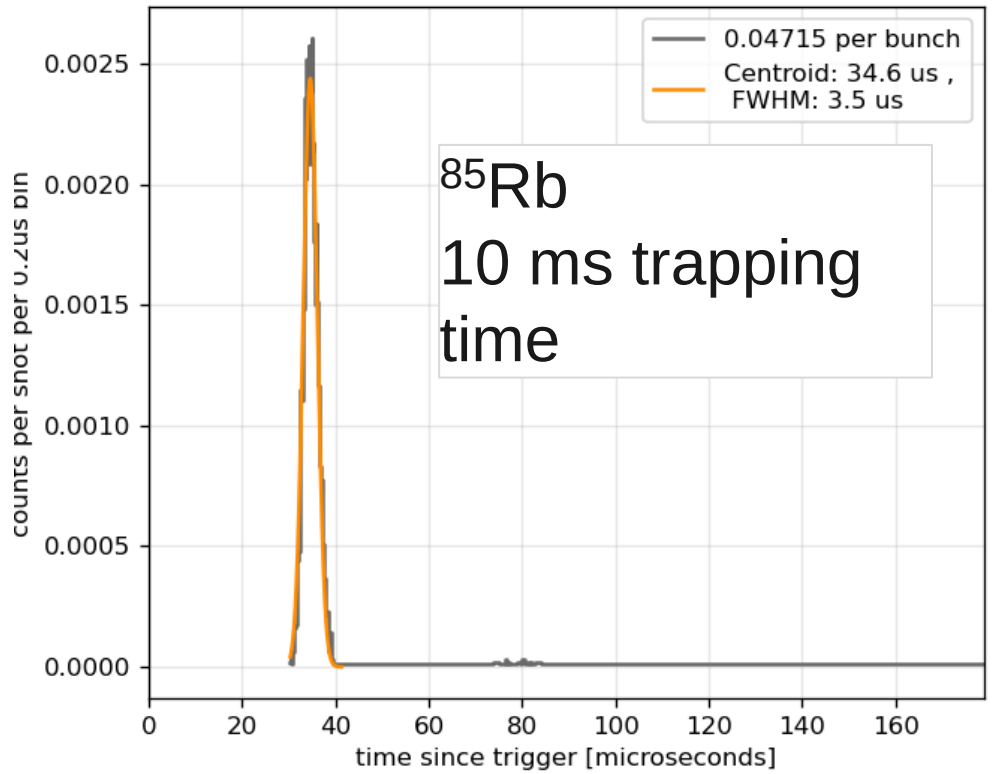
Before: 0.5% transmission, no bunching, no cooling

Now: 50-60% transmission, bunching and cooling !

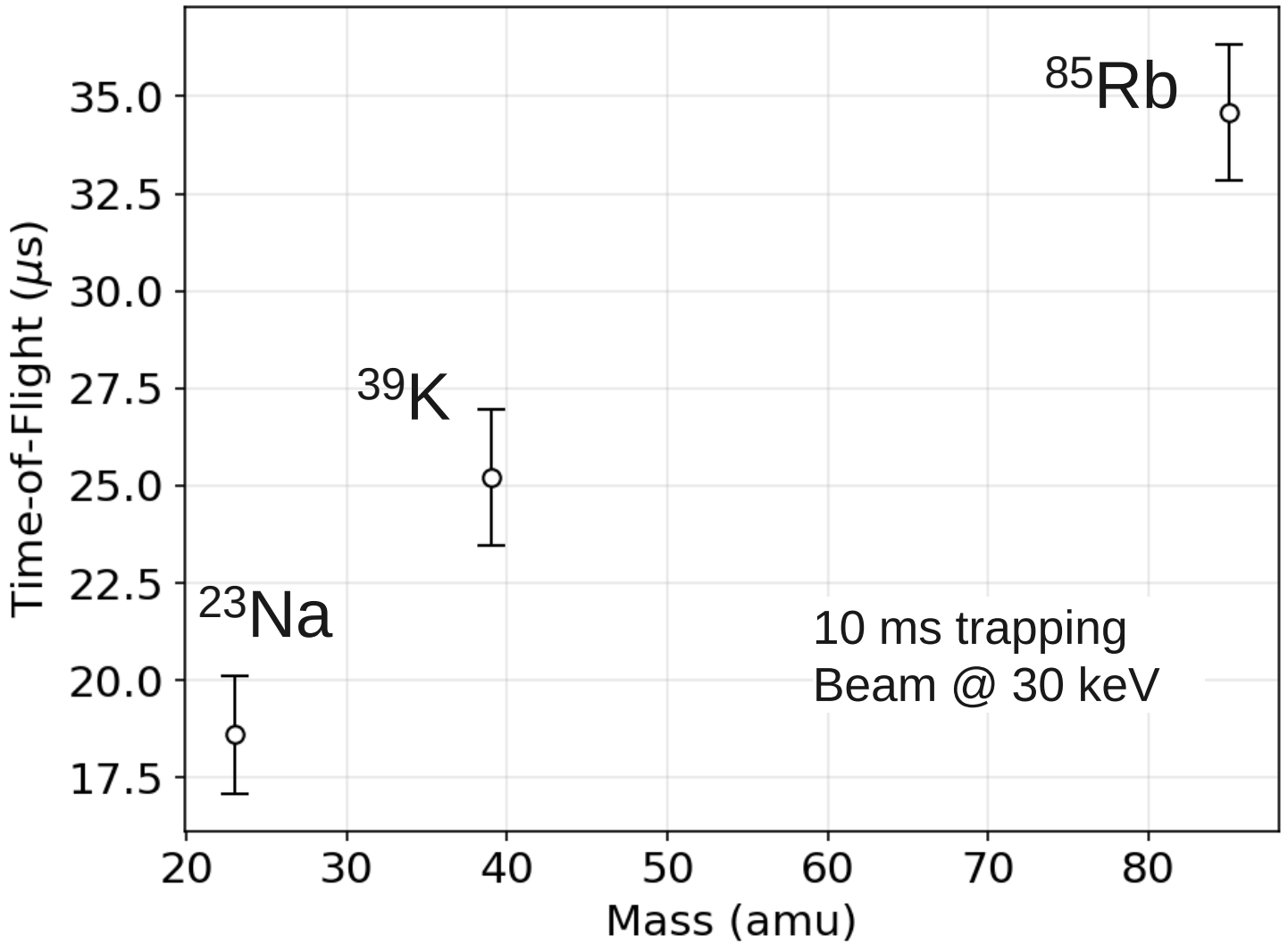
TTL signal of Quantum Composer switches endcap electrode potential via high-voltage, high-current Behlke switch

Different Time-of-Fight for different species





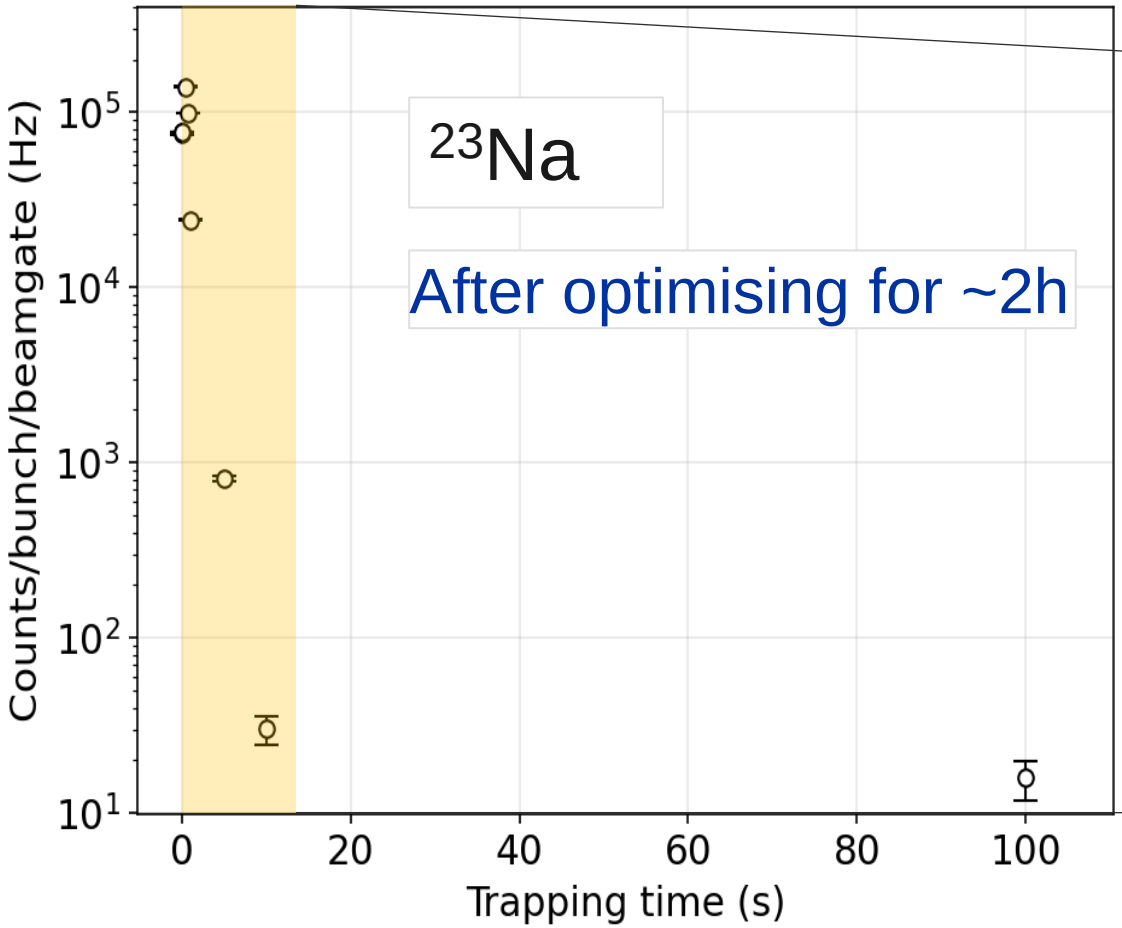
Time-of-Flight vs Mass

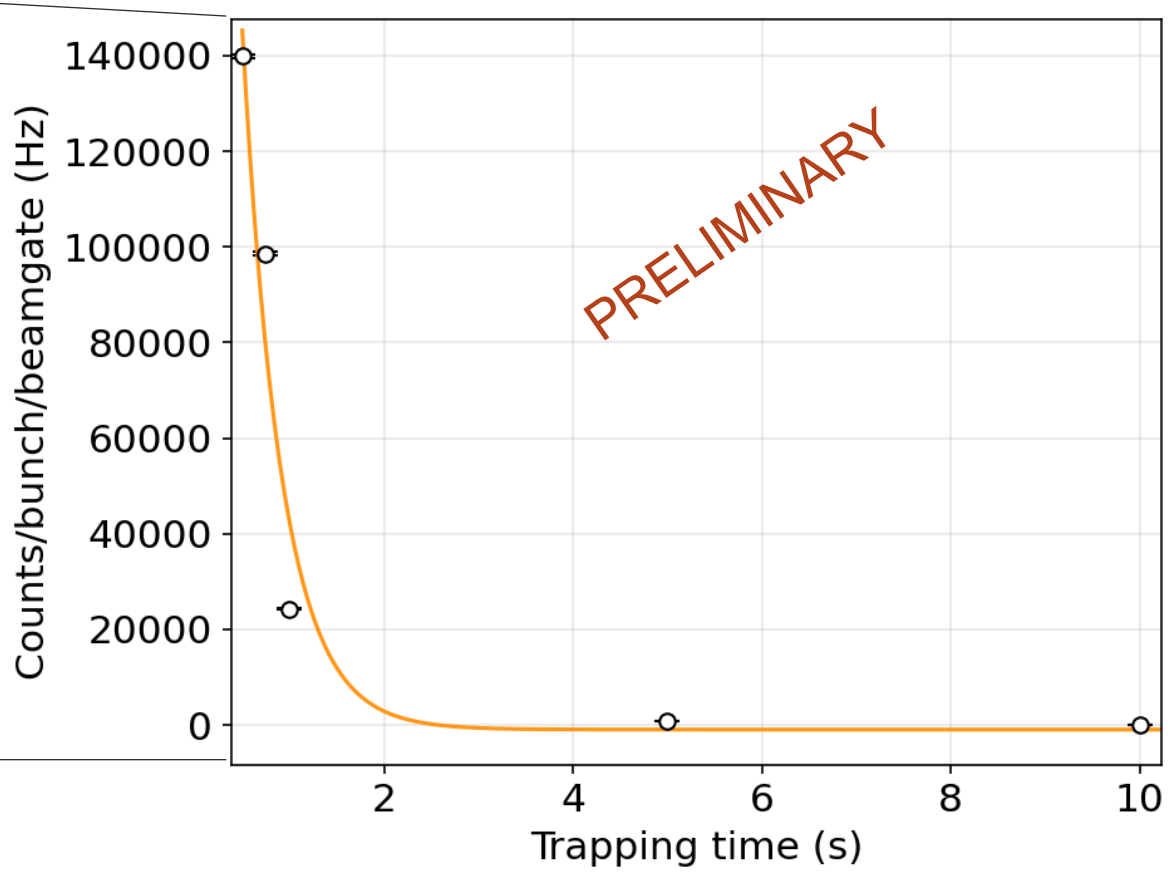


Time-of-flight calibration with hot plasma ion source ongoing at the moment

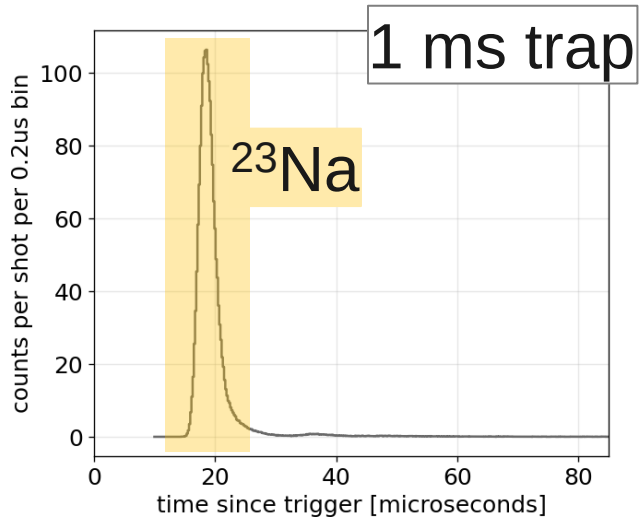
Trapping lifetime

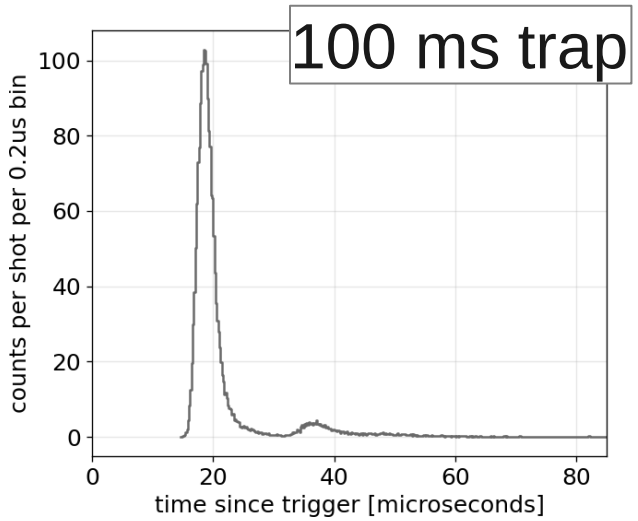
Counts per bunch per beamgate vs trap time

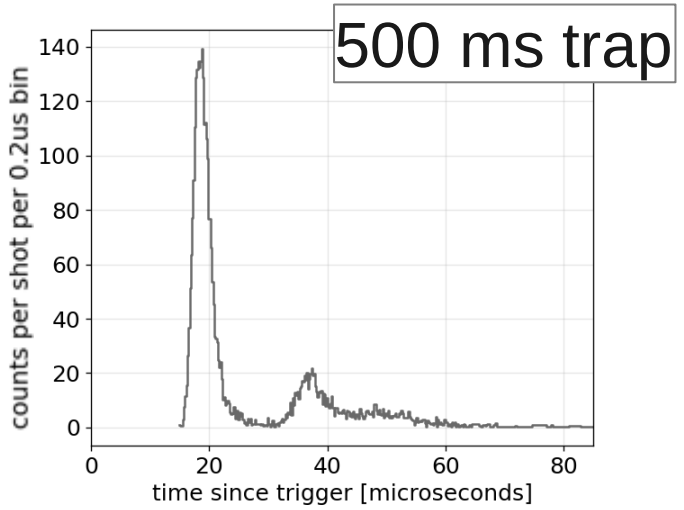


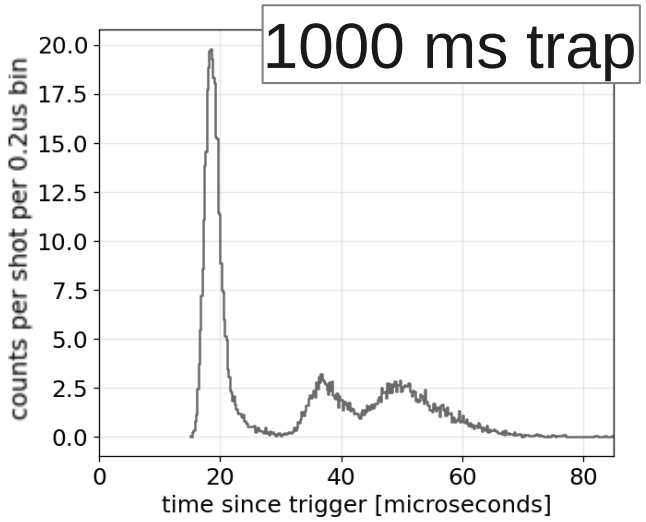


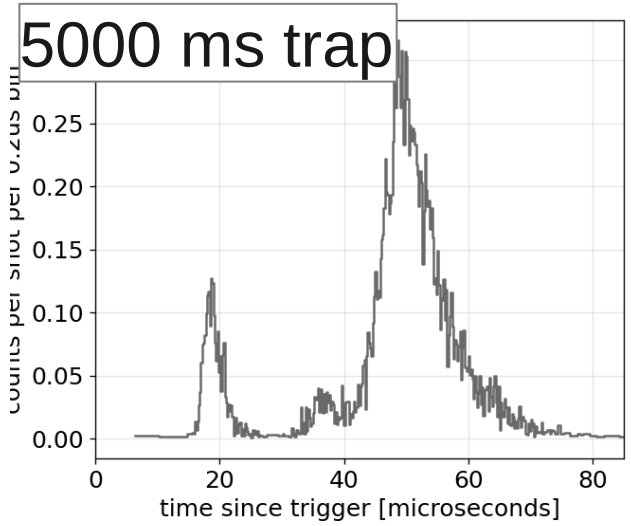
Long trapping times: molecule formation ?

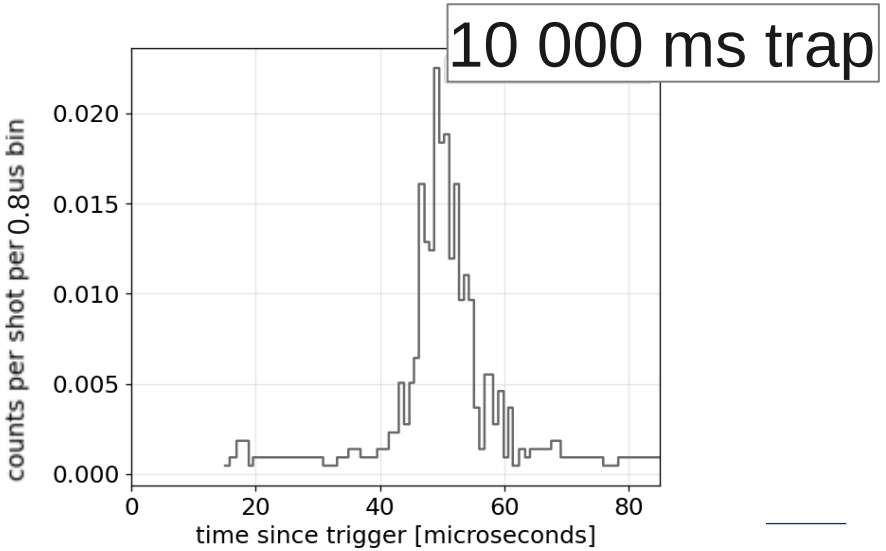












Under investigation

- Influence of the potential well shape on cooling-bunching
- Helium pressure
- Incoming beam and beam gate duty cycle: linearity tests for overflowing the trap

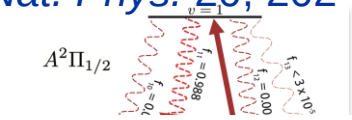
BG width [ms]	I on FC190 [pA]	rel. intensity
2	3.6	1
4	7.1	0.986
5	8.7	0.967
6	10.2	0.944
7	11.6	0.921
8	13.0	0.903
10	15.6	0.867
12	18.0	0.833
16	22.4	0.778
32	37.0	0.642

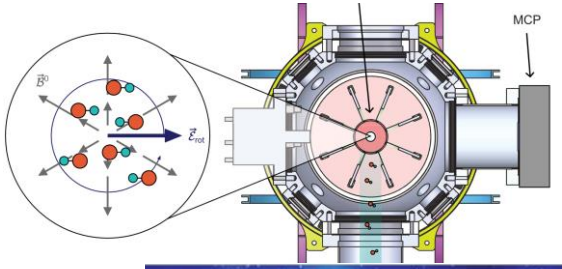
Towards high-precision molecular experiment at RIB facilities

Fundamental symmetries, Physics beyond colliders framework

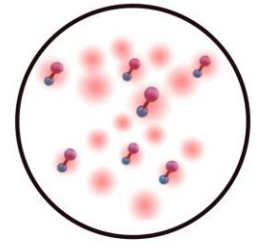
Fundamental Symmetries Collaboration

Udrescu et al.,(2024) *Nat. Phys.* 20, 202





Roussy et al., *Science* 381, 46 (2023)

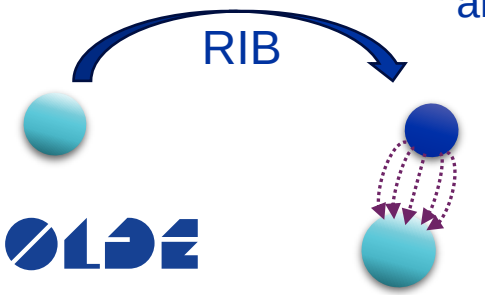


Fundamental Physics Research with Radioactive Molecules

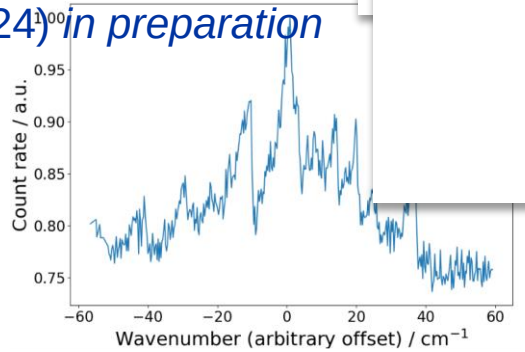
22 April 2024

Executive Summary. Radioactive molecules provide opportunities to probe physics beyond the Standard Model and investigate still-unsolved questions of modern physics, including the origins of baryon asymmetry. Observables with sensitivity to charge-parity (CP)-violating effects such as electric dipole moments (EDMs) are specifically enhanced in radioactive molecules and require multiple probe systems to disentangle possible sources of CP-violation using complementary searches. The enclosed proposal

I., *Phil. Trans.* 3822 (2023)



Athanasakis-Kaklamanakis et al.,(2024) *in preparation*



Making radioactive molecules

- Beams, traps, targets

Characterizing radioactive molecules

- Spectroscopy, chemistry
- Properties and states

Work in progress

- *Fellow position closed*
- *collaboration*

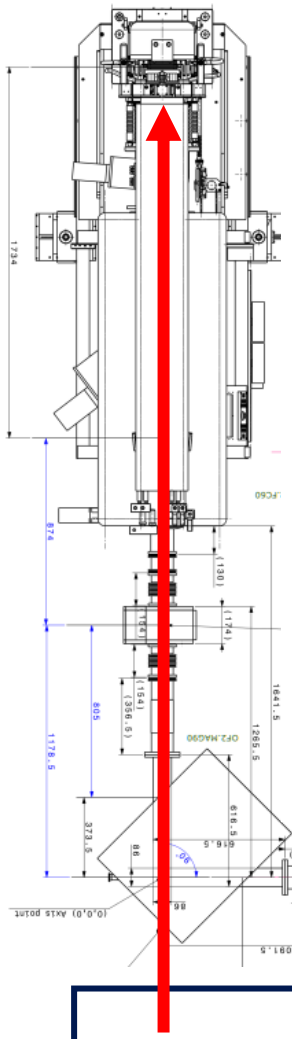
March 24-25
https://indico.cern.ch/e/FunSy

Precision measurement

Techniques for bulk systems

M. Au

Current layout



Ion source

Beamgate

High Voltage racks

High Voltage racks

Gas injection system

90° Magnet

RFQcb

~ 2 m

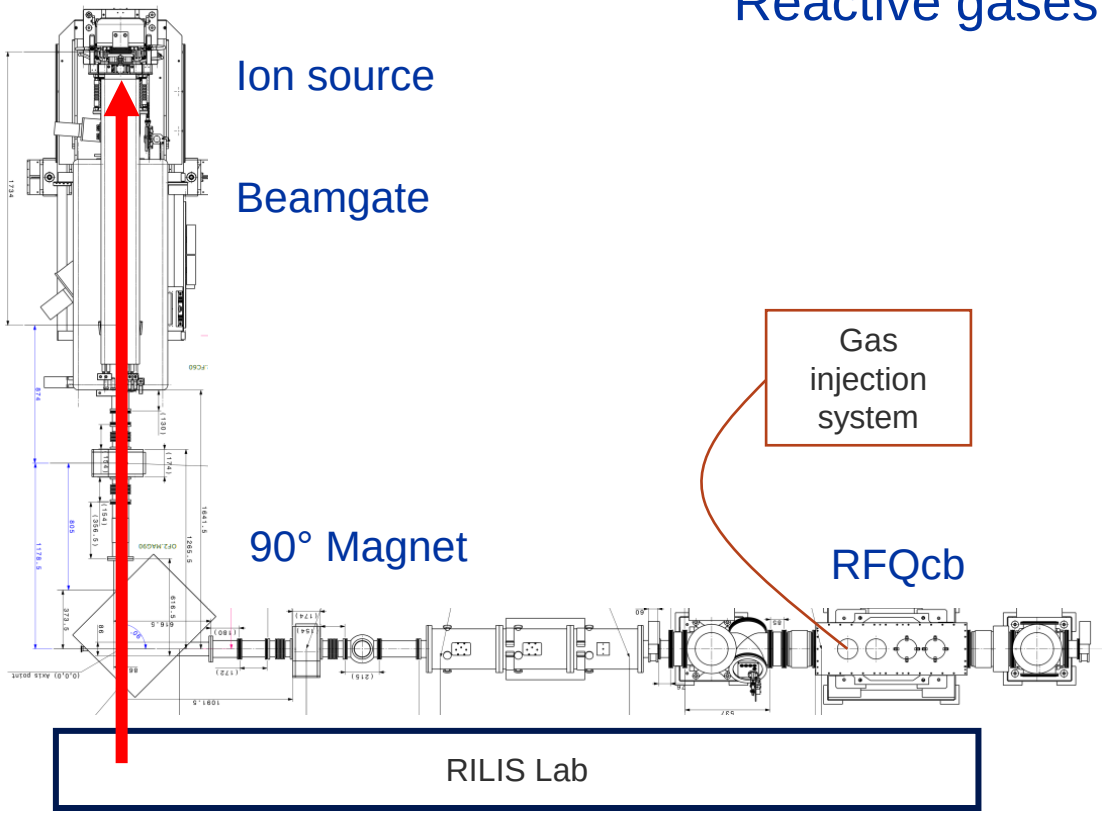
Magnetof

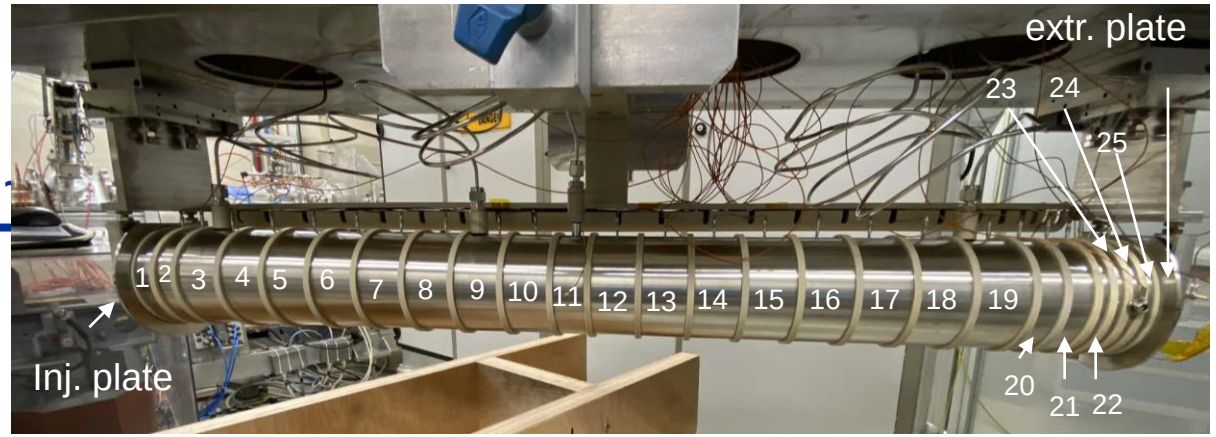
RILIS Lab

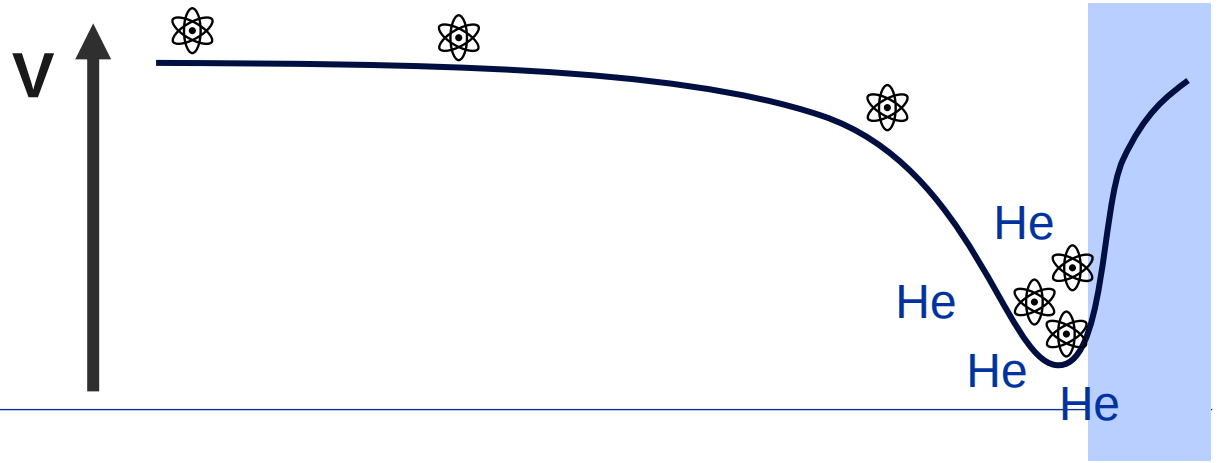
In trap formation of molecules via atomic RIB

Bridging the gap between high precision and RIB facilities

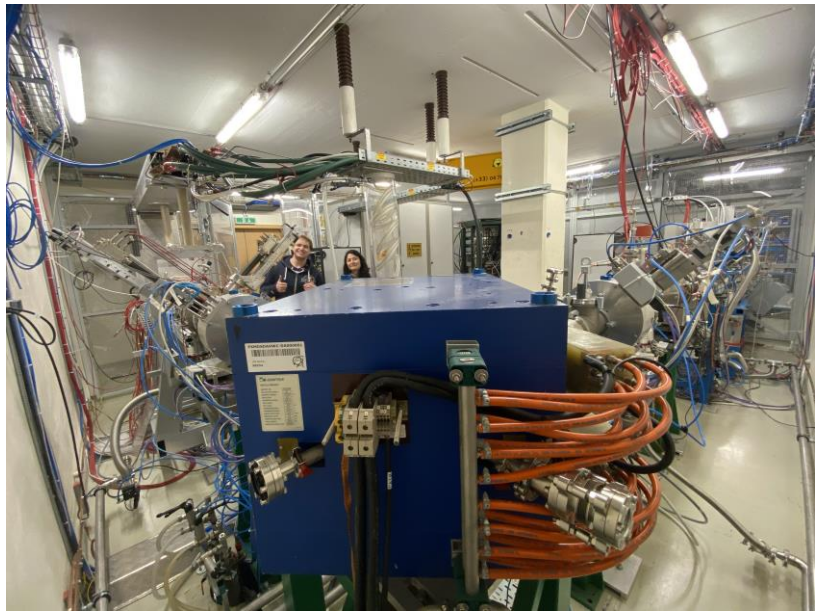
Reactive gases: CH_3OH, H_2O_2,H_2O,NH_3



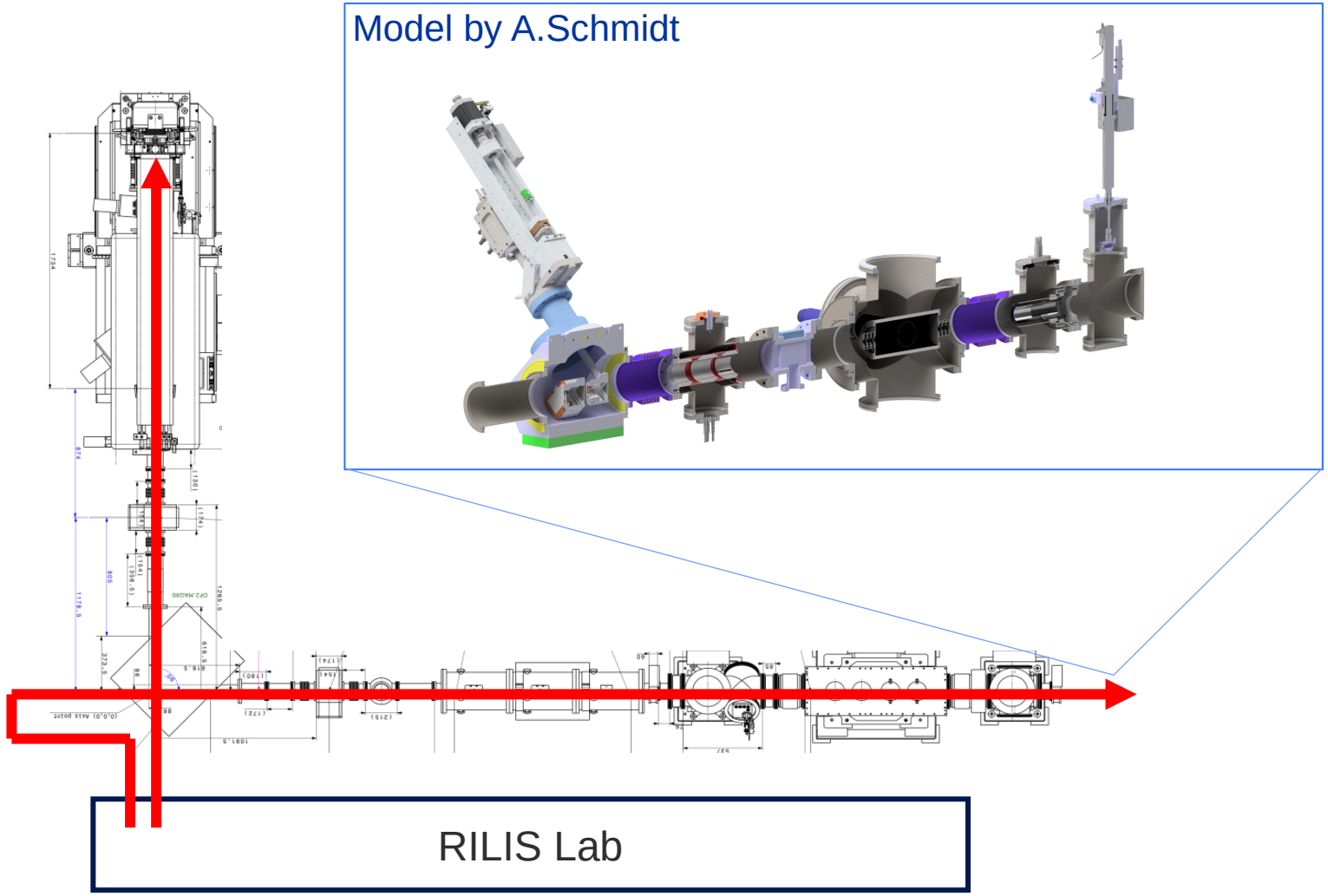




Projected new end of beamline



Hole in wall and second window through the magnet already exists !



New end of beamline: Phase one

Possible experiments:

Photodissociation of small molecules

- Molecular breakup of SrF+ for n-deficient Sn and In
- Dissociation thresholds
- Ionisation of neutrals ?
- Limited by ToF resolution (mass resolving power)

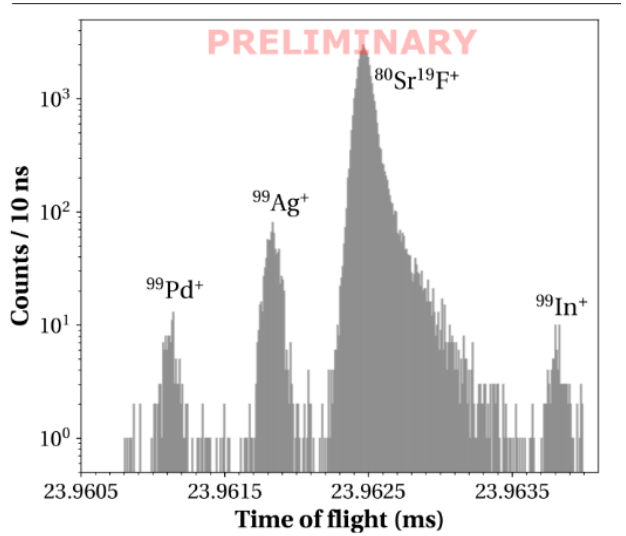
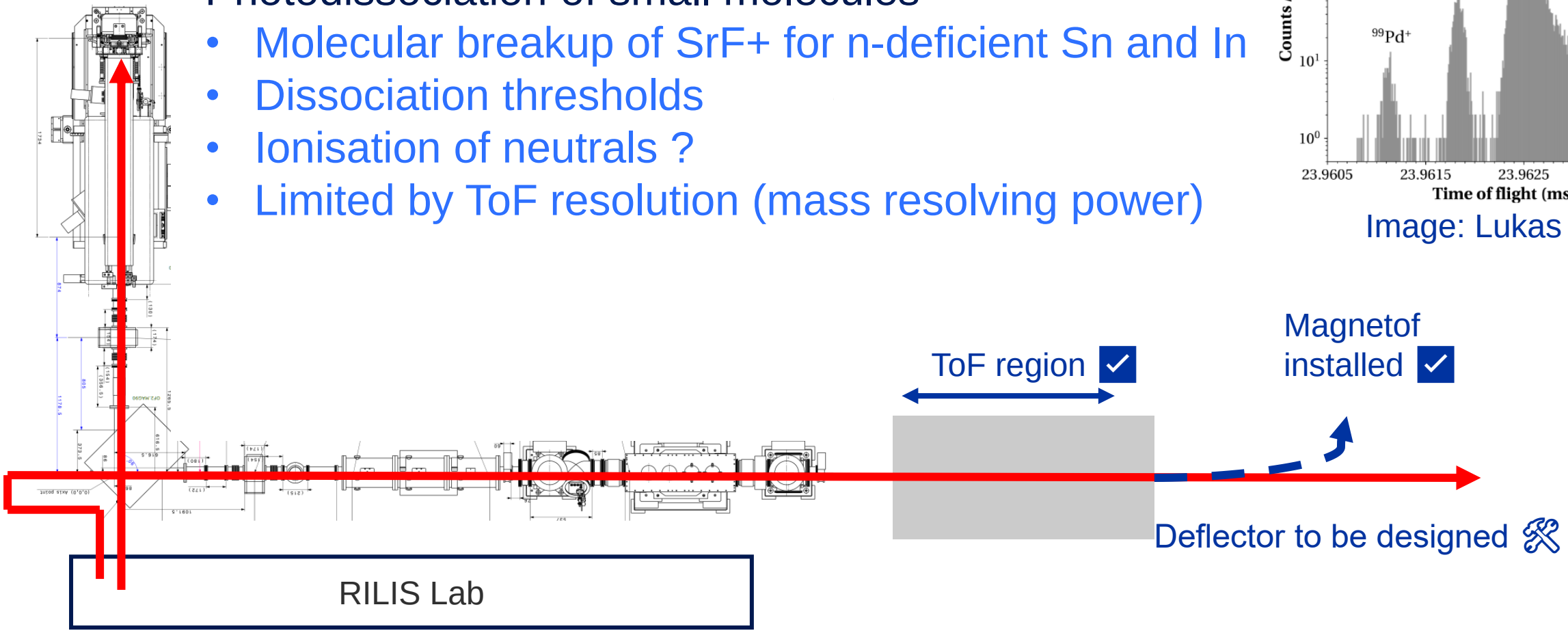


Image: Lukas Nies



New end of beamline: Phase two

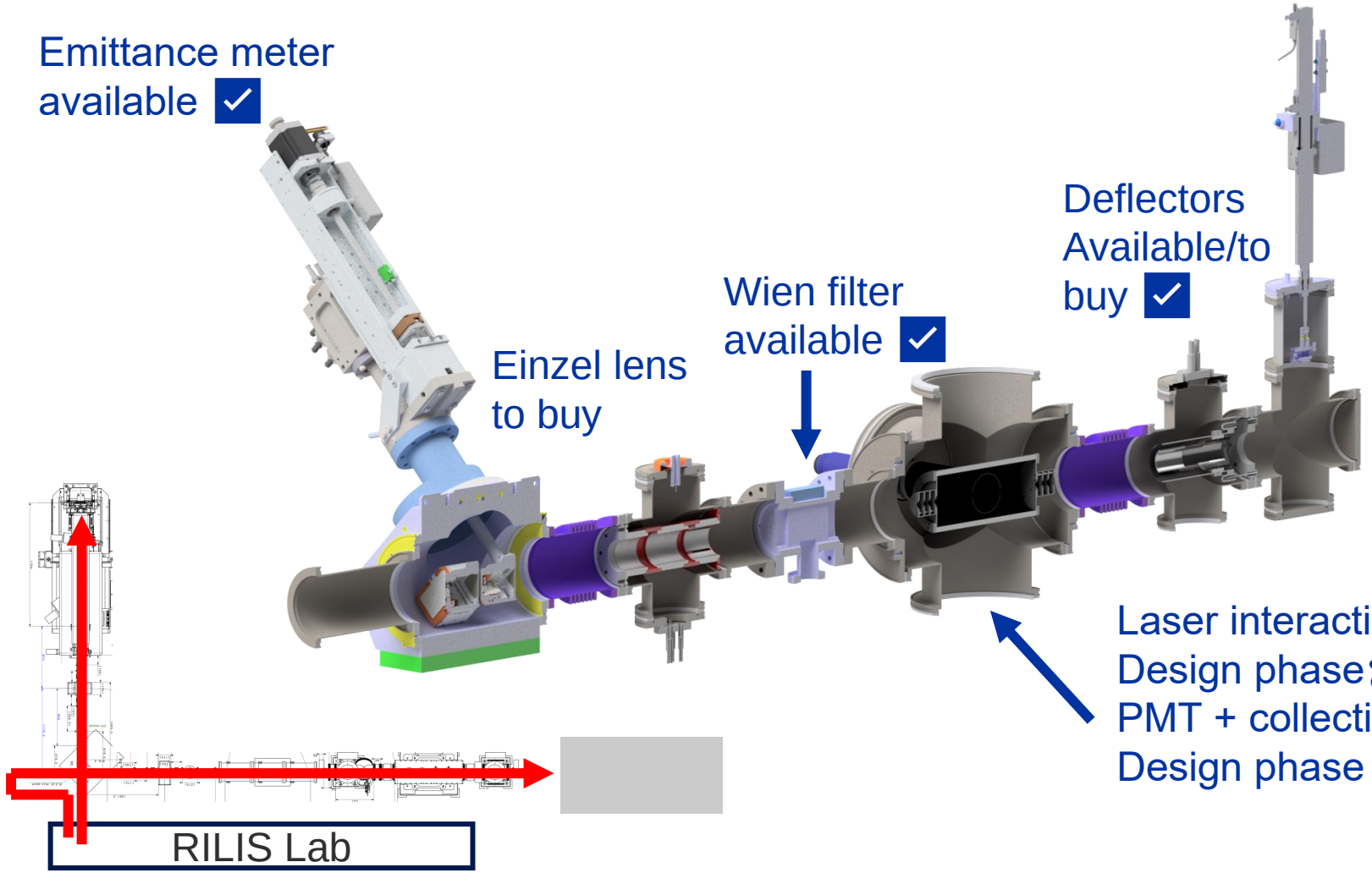
Magnetof installed ✓

Emittance meter available ✓

Deflectors Available/to buy ✓

Wien filter available ✓

Einzel lens to buy



Probing thermodynamics ensemble towards coherent state population for fundamental symmetry project

Funding refused by SY department

Laser interaction region
Design phase 🛠
PMT + collection optics
Design phase 🛠

Discussions with REBEL Lab
PI: Agi Koszorus

Model by A.Schmidt

Fluorescence and resonance-ion detection capabilities for ion beam manipulation

M. Au, M. Athanasakis-Kaklamanakis, J. Berbalk, K. Chrysalidis, A. Koszorus, J. R. Reilly, S. Rothe, A. Schmidt
CERN

Abstract
We propose to implement fluorescence and resonance-ion detection capabilities for beam manipulation and cooling, molecular formation studies, and molecular scheme development and characterization. A light collection and ion detection region at ISOLDE's Offline 2 facility will enable studies of in-trap molecular formation and dissociation, ion beam internal temperature investigations, optical pumping and scheme development towards studies of physics Beyond the Standard Model using atoms and molecules at radioactive ion beam facilities.

Funding refused by SY department (65k CHF)

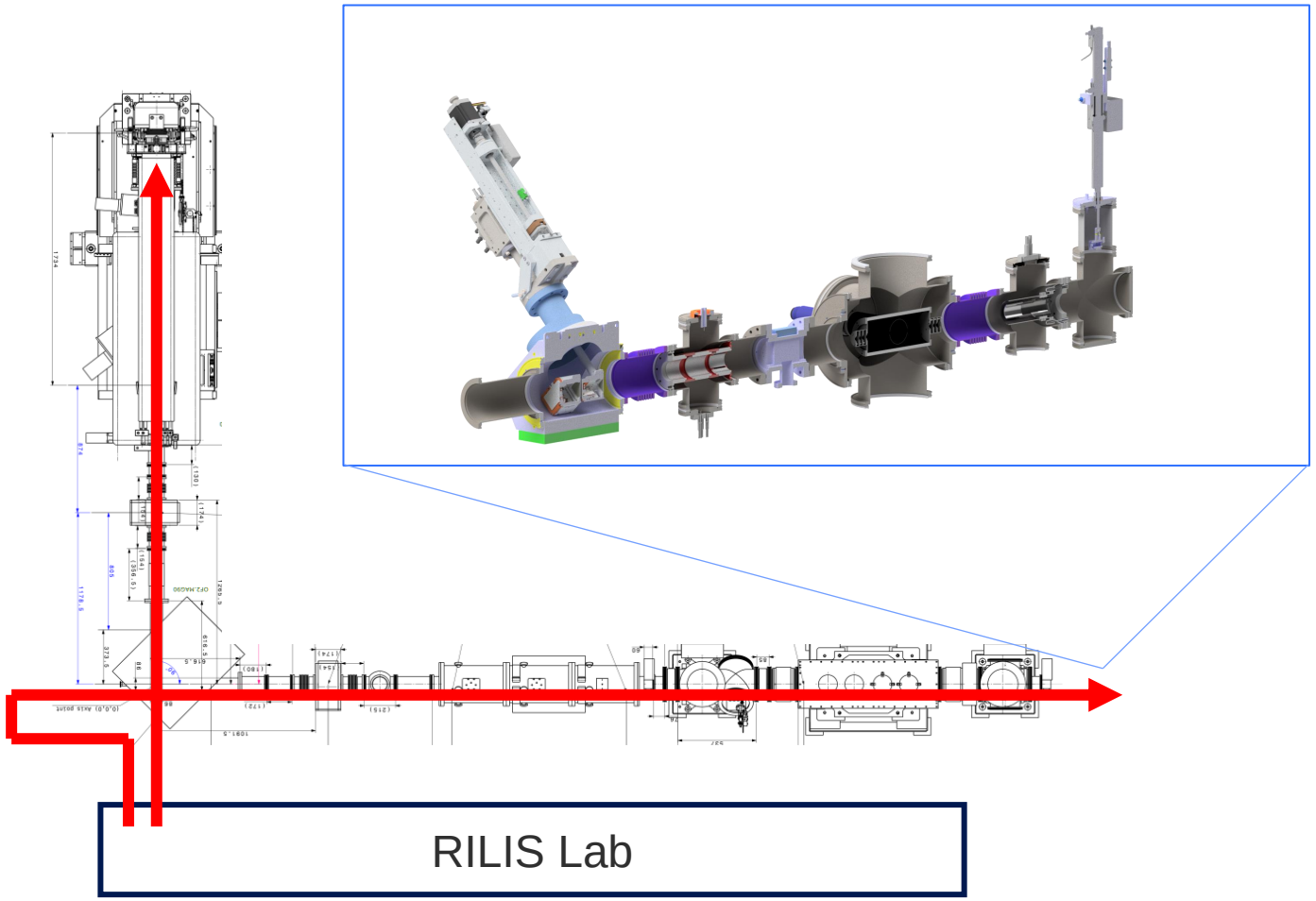
accessories and additional accessories and controls to be implemented in the first half of the second year.

Table A.1: Budget items

Item	Description	Estimated price (kCHF)
Vacuum chamber	KF100 cross	0.5
Vacuum pump	TMP700 and controller	6
Vacuum internal components	mounting and isolation, in-house[a]	2
Linear feedthrough	Pneumatic actuated	2
Mounting structure	in-house[a]	1
Actuation system	in-house[a]	1
Cabling and adapters		1
Controls system	in-house	1
Data acquisition software	in-house[b]	-
Switchable bipolar 4-ch. power supply	ISEG, already acquired	-
High-current high-voltage switch	already acquired	-
Photomultiplier tubes (PMTs) (2x)	Hamamatsu PMT R669	3
PMT holders	3D printed, water cooled, in-house	1
Anti-reflection coating		0.5
Aspheric lenses for photon imaging		1
Diode laser and control electronics	TOPTICA laser and DLCPro	25
Wavemeter	High Finesse WS7	20
Sum		65

[a] ISOLDE targets workshop and/or collaboration with TCD workshop.
[b] collaboration CERN LabVIEW team.

New end of beamline: Phase three



Long term :

- Pulsing/ramping RFQ to ground
- Pulsed drift tube
- MR-ToF
- Cryogenic trap, MOT
- **Your ideas**

?

Model by A.Schmidt

Acknowledgments

CERN:

Sebastian Rothe
Mia Au
Alex Schmidt
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Katherina Chrysalidis
Sebastian Rothe
Simon Stegeman
Edgar Reis
Matthias Grasser
Valentina Berlin
Serdar Usta
Patricija Kalnina
Isabel Frank
SY-STI-LP
SY-STI-RBS groups

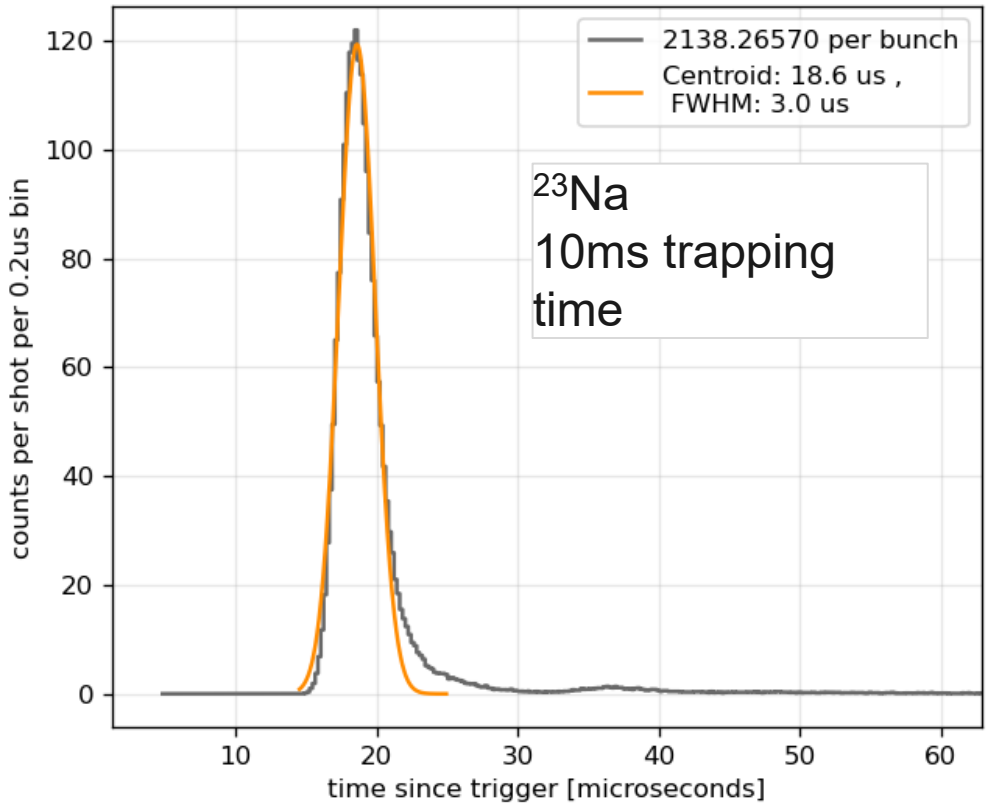
KU Leuven:

Gerda Neyens
Agi Koszorus
Ruben De Groote

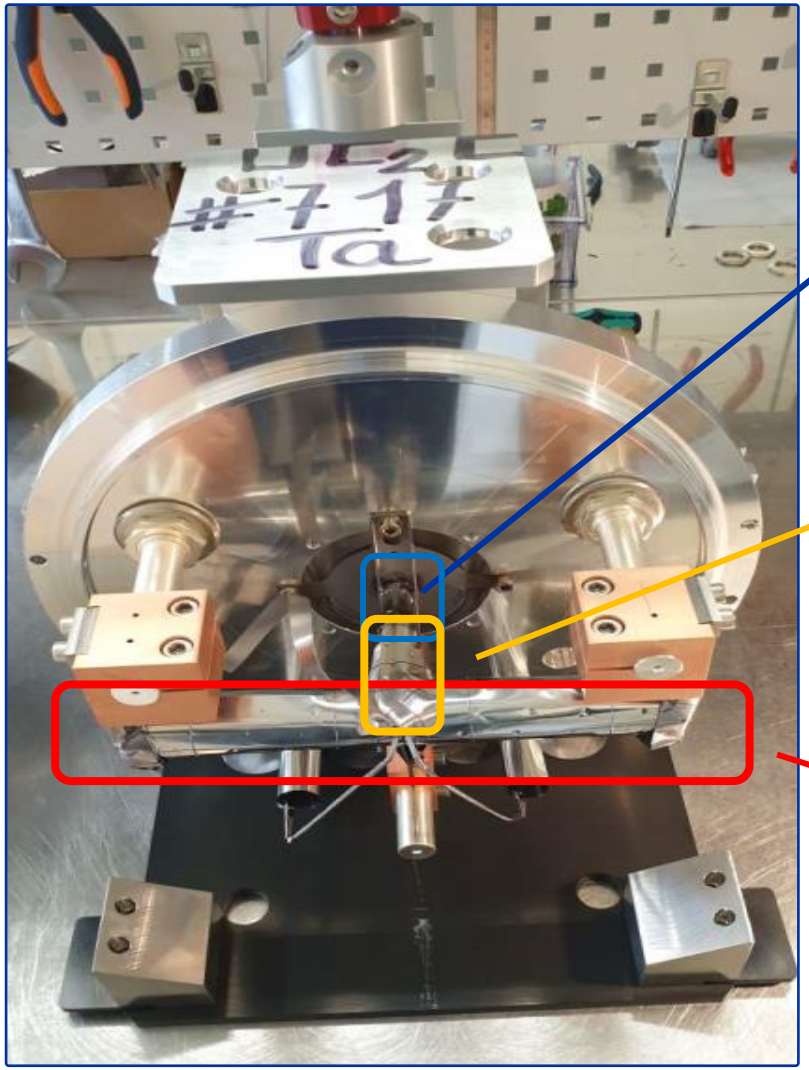
& the entire
IKS Nuclear Moments group

home.cern

Supplemental



Target unit



Ion source:
surface, laser, plasma, …

Transfer line
controls transport to ion source, Ta, Cu or quartz

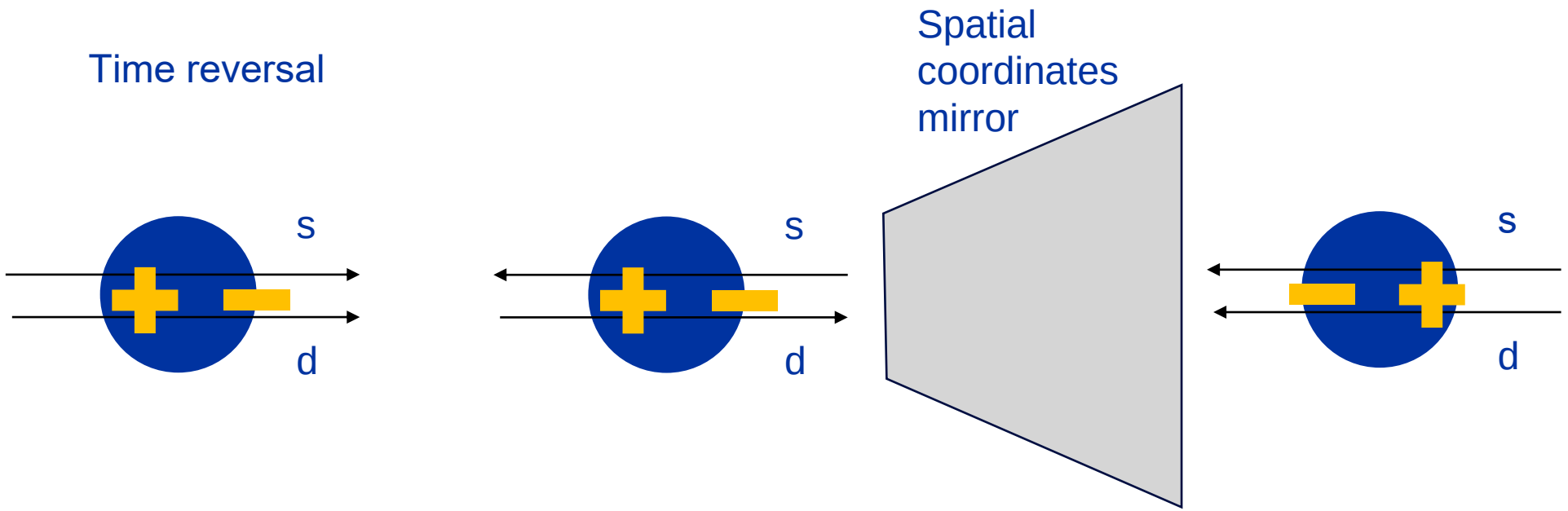
Target container
typically heated to ~2000º C

Each target is custom-tailored to the physics experiment

30+ targets per year!

Slides and pictures from V. Berlin

eEDM is symmetry violating



The sensitivity of an eEDM measurement d scales with

$$\delta d = \hbar/\epsilon\tau\sqrt{N}$$

where ϵ is the effective electric field,
τ the coherence time and N the total measurements