中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences

INTERNATIONAL CONFERENCE ON ELECTROMAGNETIC ISOTOPE SEPARATORS AND RELATED TOPICS
EMIS XVIII
CERN GENEVA / SWITZERLAND / 16 - 21 SEPTEMBER 2018

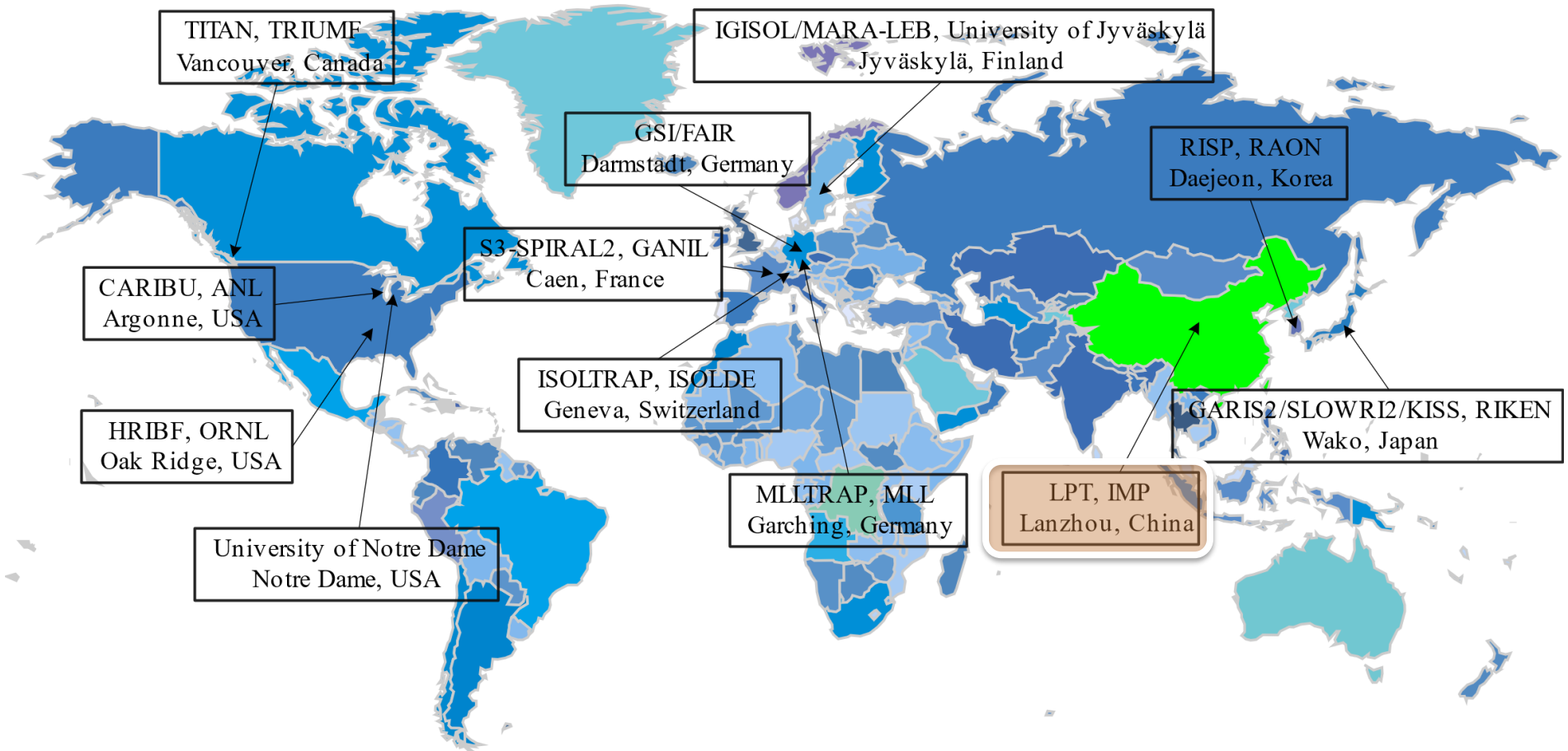
Design, Optimization and Construction of MRTOF-MS for LPT

Yulin Tian

- Motivation
- Setups (HIRFL, SHANS)
- Design, optimization of mass analyzer
- Present construction status of MRTOF-MS for LPT

20 Sept. 2018

MRTOF-MSs nowadays



High sensitivity

Non-scanning

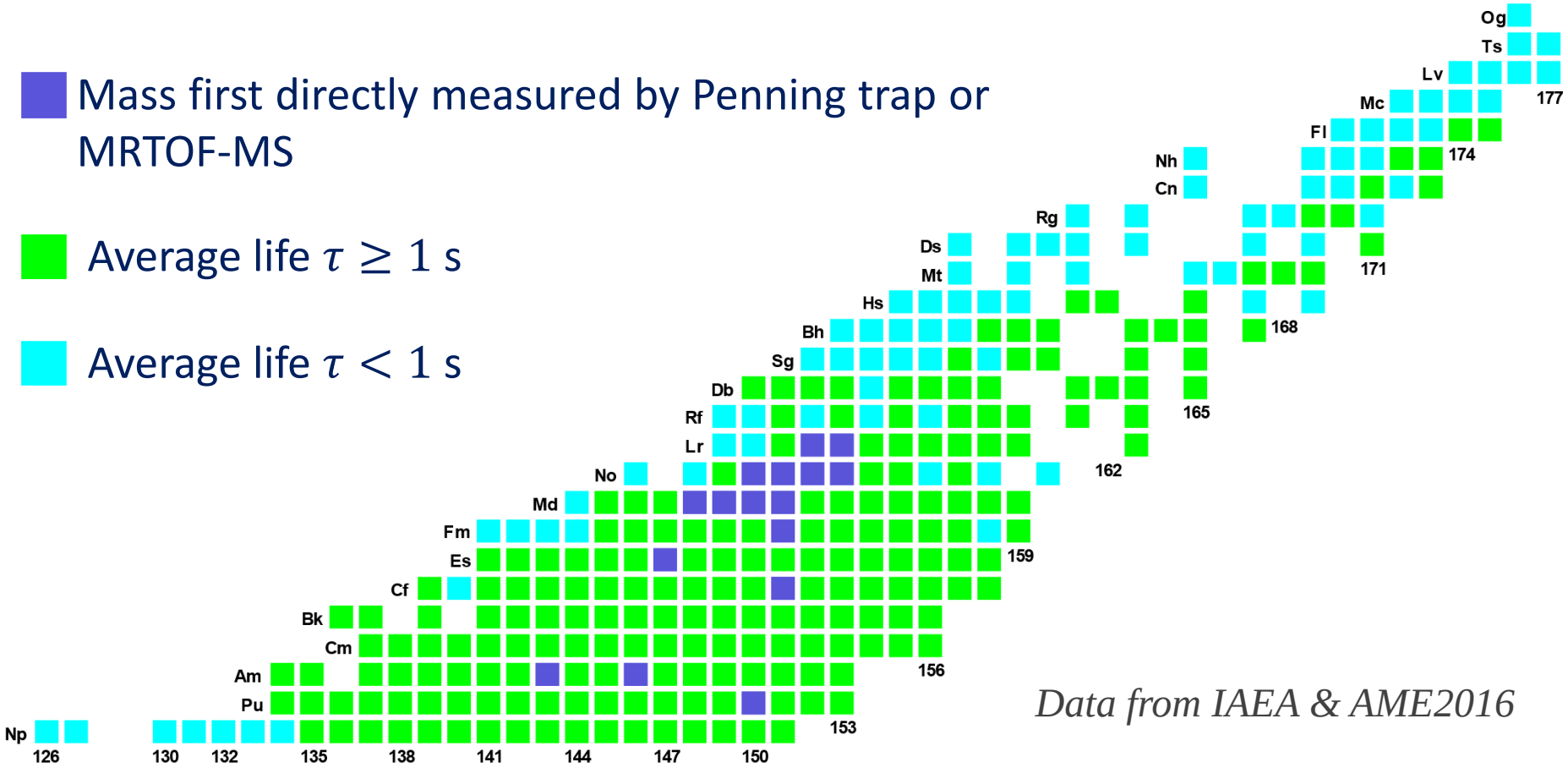
Large mass range

Short measurement time

Low construction cost……

Motivation

- Mass first directly measured by Penning trap or MRTOF-MS
- Average life $\tau \geq 1$ s
- Average life $\tau < 1$ s

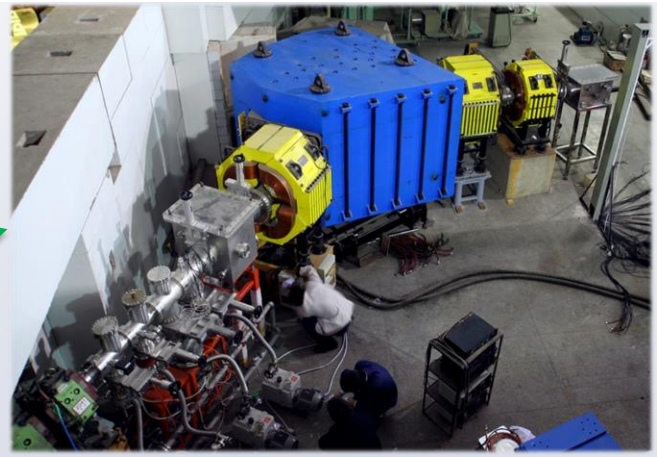


Data from IAEA & AME2016

To measure the mass value of fusion-evaporation products, especially for the transuranium nuclei, directly.

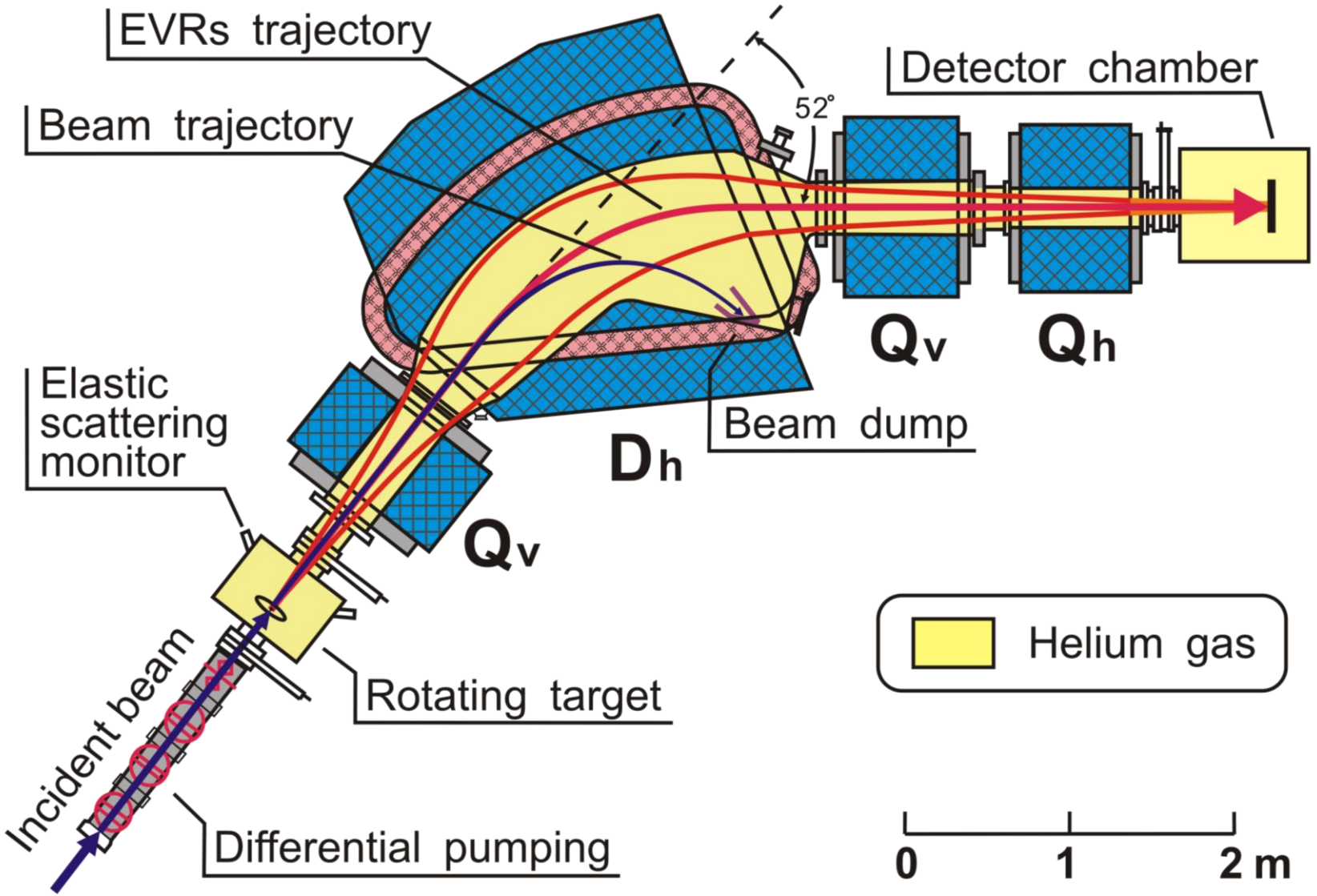
SHANS at HIRFL

Spectrometer for Heavy Atoms and Nuclear Structure



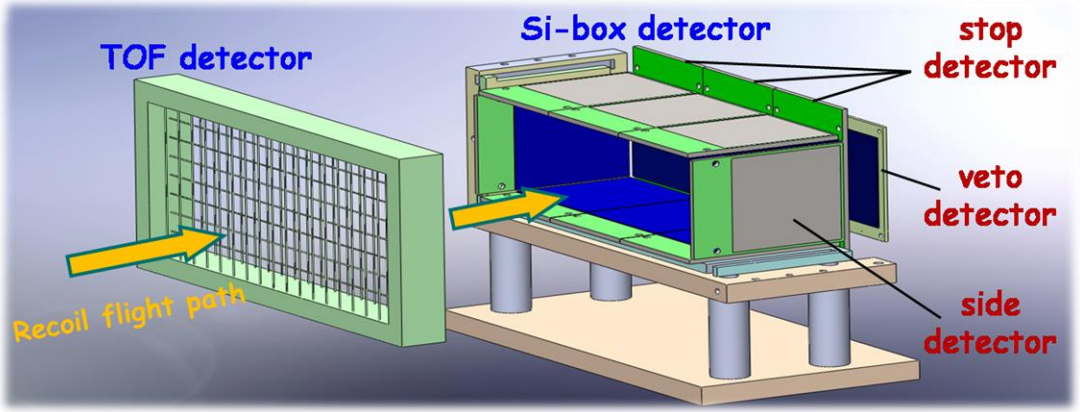
Heavy Ion Research Facility at Lanzhou

SHANS setup



Z. Y. Zhang, et al. (2013). NIMB. **317**: 315-318.

Nuclei from SHANS



[1] Z.Y. Zhang et al., Phys. Rev. C **89** (2014) 014308.

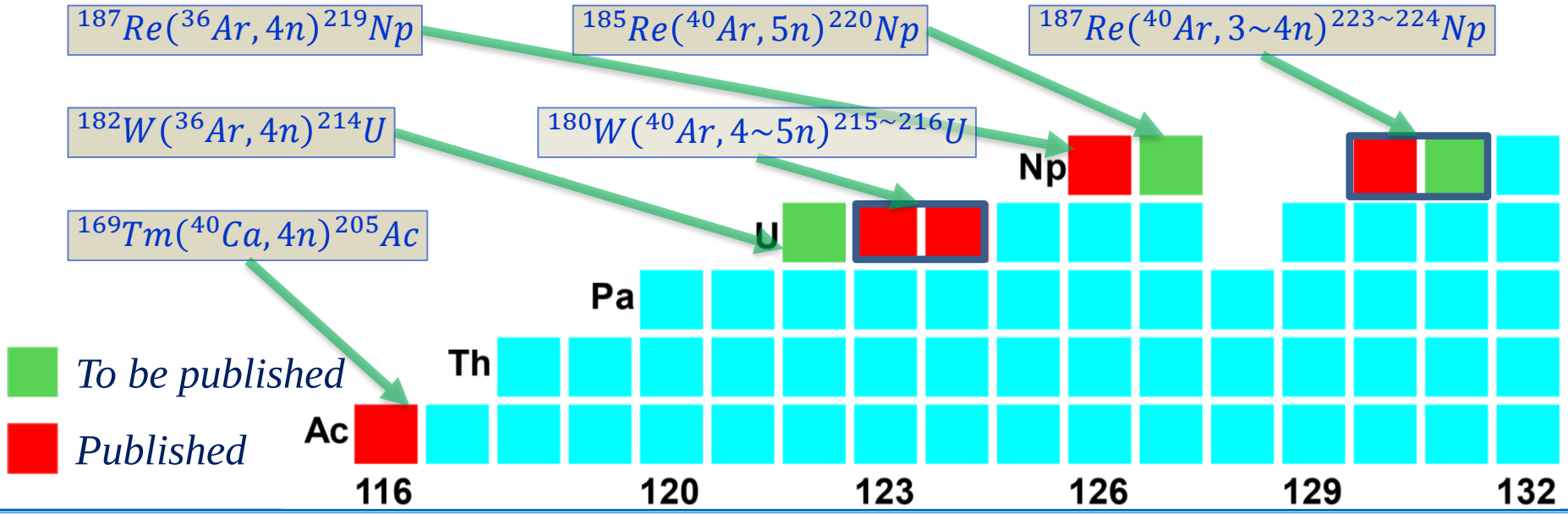
[2] L. Ma et al., Phys. Rev. C **91** (2015) 051302.

[3] H.B. Yang et al., EPJ A **51** (2015) 1-4.

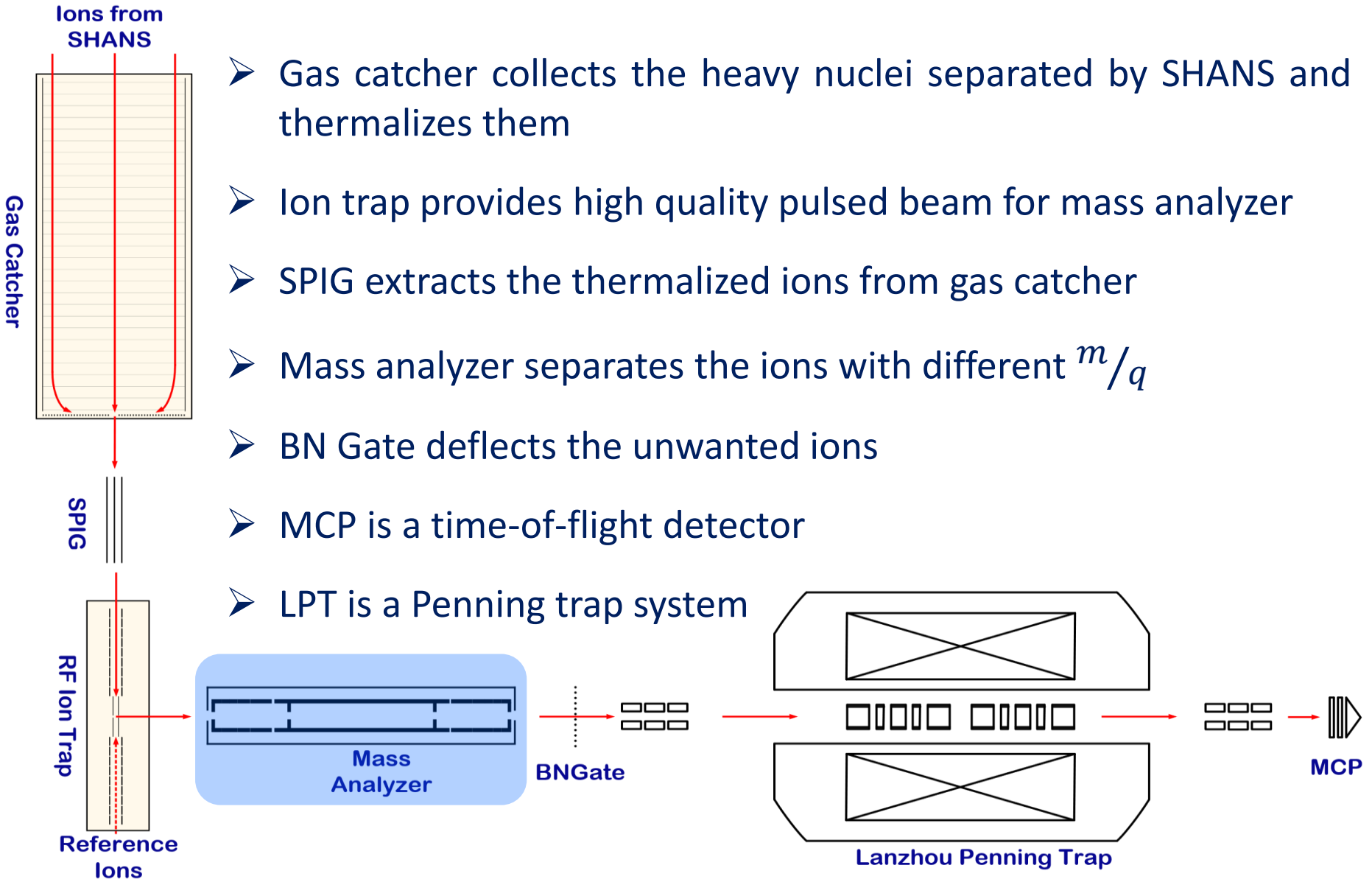
[4] M.D. Sun et al., Phys. Lett. B **771** (2017) 303-308.

[5] H.B. Yang et al., Phys. Lett. B **777** (2018) 212-216.

The reaction products are identified using spatial and time correlations between the implants and subsequent α decays.

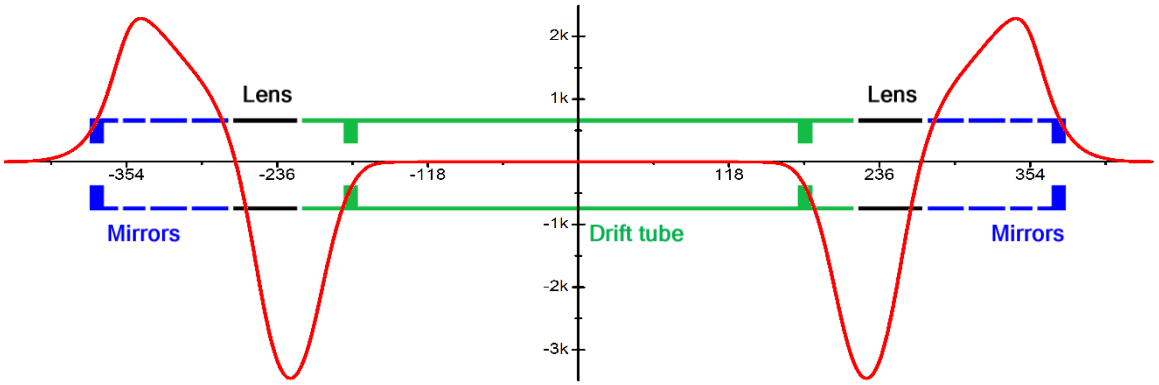


Layout of MRTOF-MS at SHANS

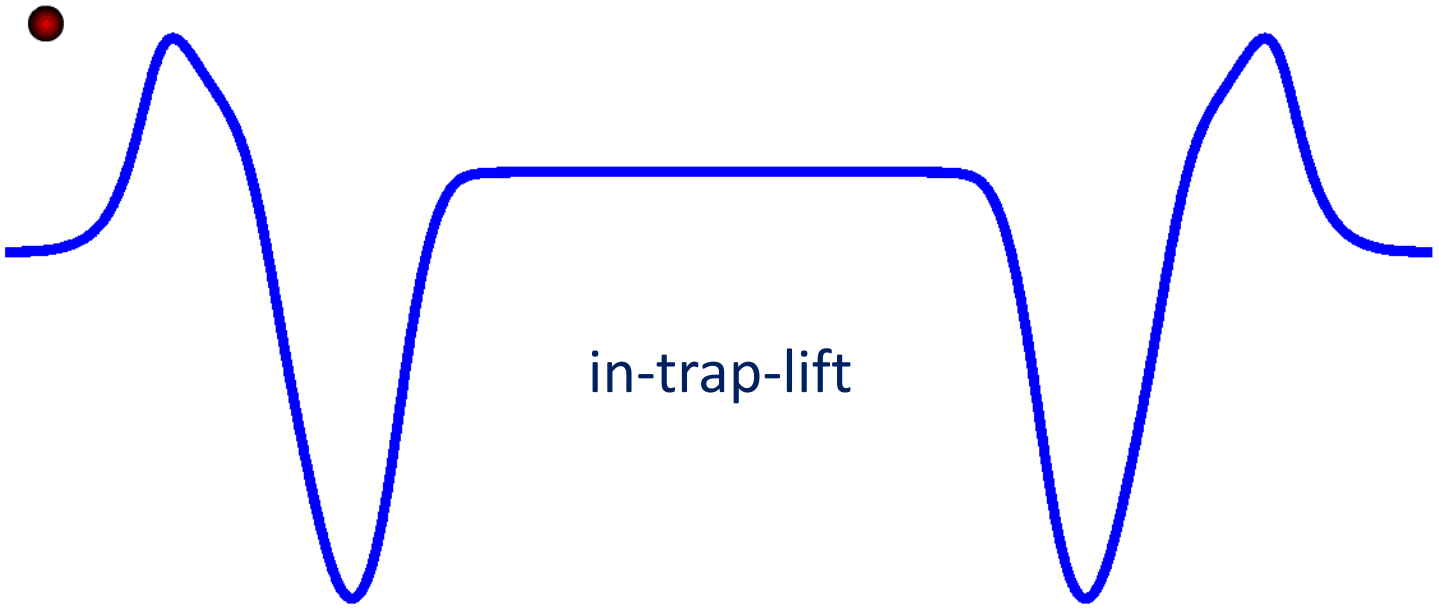


- Gas catcher collects the heavy nuclei separated by SHANS and thermalizes them
- Ion trap provides high quality pulsed beam for mass analyzer
- SPIG extracts the thermalized ions from gas catcher
- Mass analyzer separates the ions with different $^{m}/_{q}$
- BN Gate deflects the unwanted ions
- MCP is a time-of-flight detector
- LPT is a Penning trap system

Basic theory of MRTOF-MS



$$ToF = \alpha\left(\frac{m}{q}\right)^{1/2} + \beta$$



- Reference ions with well-known masses are needed
- Mass resolving power : $R = \frac{m}{\Delta m} = \frac{ToF}{2\Delta ToF}$

Optimization of MRTOF-MS

➢ Why?

--The initial conditions of a cluster are complex

--The parameter space is large, but the usable parameters are limited

➢ Goal?

--To find out the optimal parameters

➢ How?

--SIMION code for ion trajectory calculation

--Local code developed using C++ with Nelder–Mead simplex algorithm for parameter search

Optimization procedure

A model is created in the SIMION according to the configuration of the MRTOF-MS.

Global search: the initial parameters are elements from a potential matrix estimated roughly according to the knowledge of the beam optics.

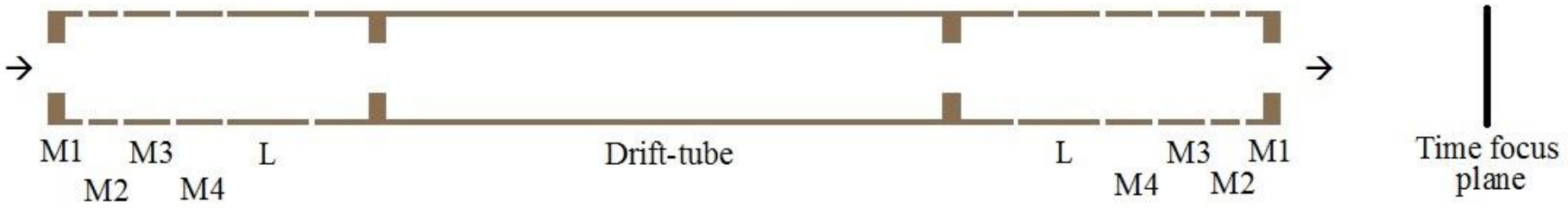
Local refine: inputting a few sets of relatively high resolving power from global search, a large number of local minima can be obtained and the best are chosen to be the optimal parameter sets.

Advantages: the best parameter sets can be found; easy to change or expand the configuration.

Disadvantage: very time consuming.

Optimization conditions

Geometry



	M1	M2	M3	M4	L	Drift-tube
Length (mm)	20	16	26	26	46	400
Diameter (mm)				60		

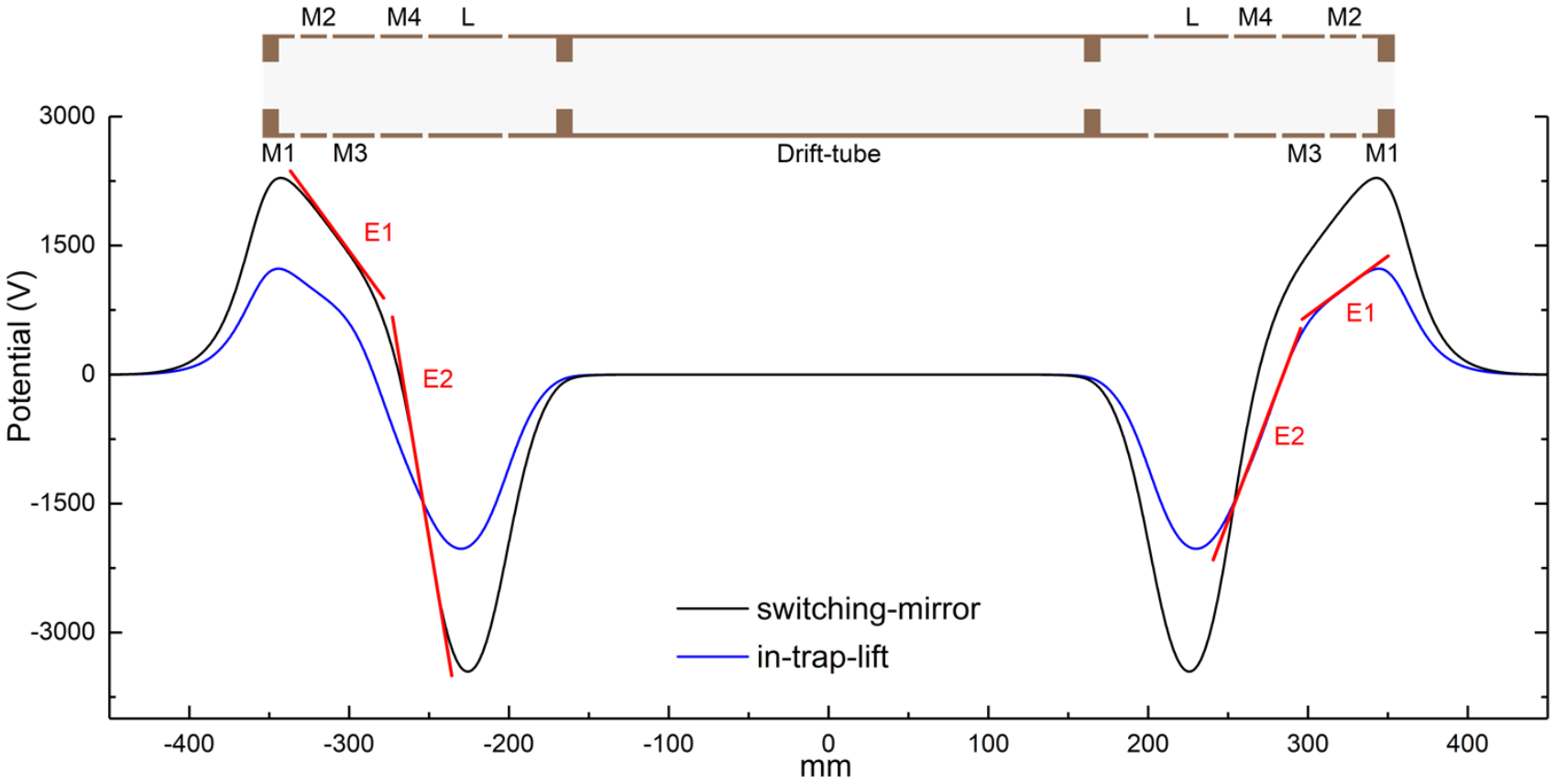
Initial conditions

	Kinetic energy		Position				Angle			
Ion	K (eV)	δK (eV)	x (mm)	δx (mm)	y (mm)	δy (mm)	a $(mrad)$	δa $(mrad)$	β $(mrad)$	$\delta\beta$ $(mrad)$
$^{40}Ar^{1+}$	1500	8.5	0	1	0	1	0	1.5	0	1.5

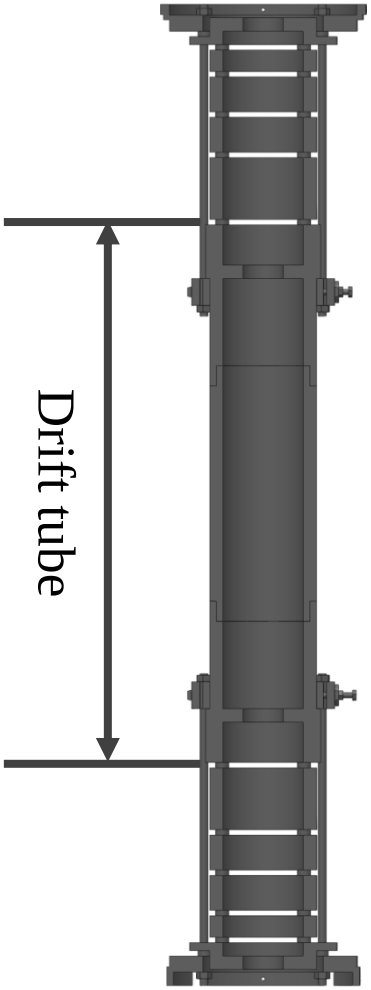
Potential optimization

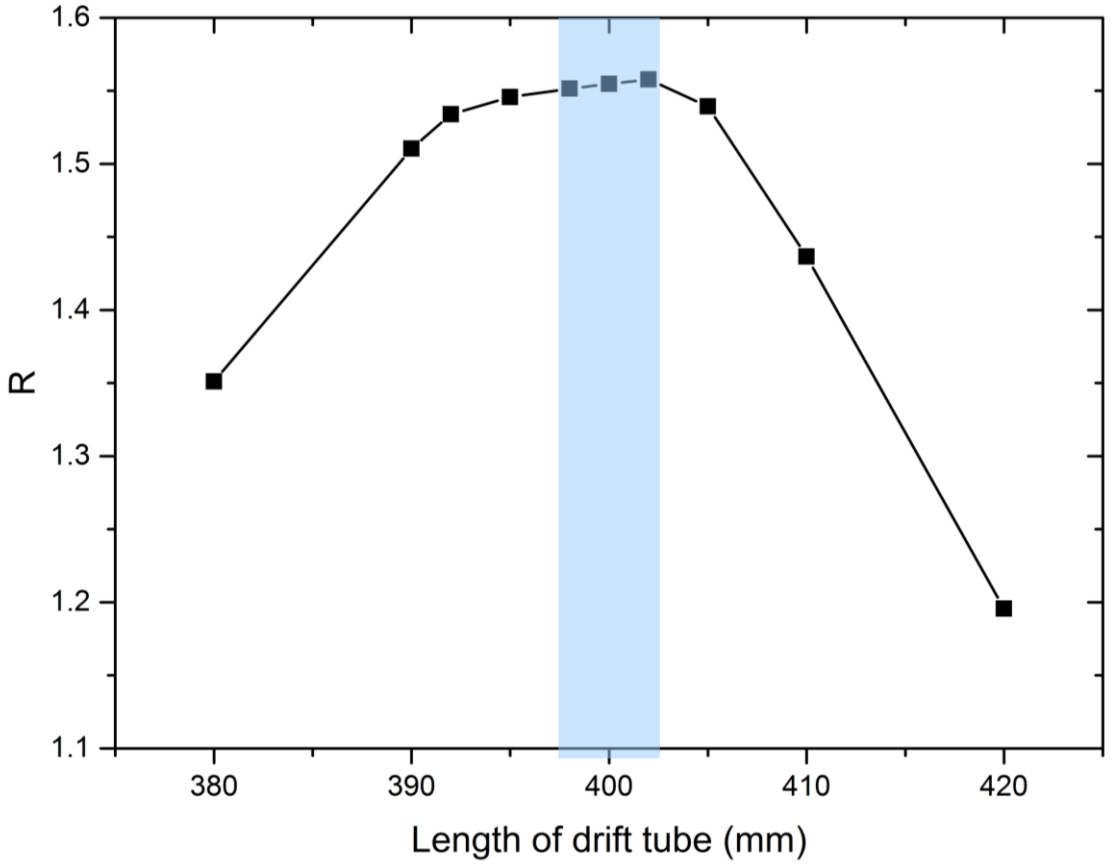
The optimal voltages can be found in different conditions (6.5 ms as example)

Elec. No.		M_1	M_2	M_3	M_4	L	Drift
Potential(V)	switching-mirror	2502.5	2002.2	1420.9	817.1	-4473.1	0
	in-trap-lift	1159.5	756.5	743.9	-1262.9	-2234.2	703.5



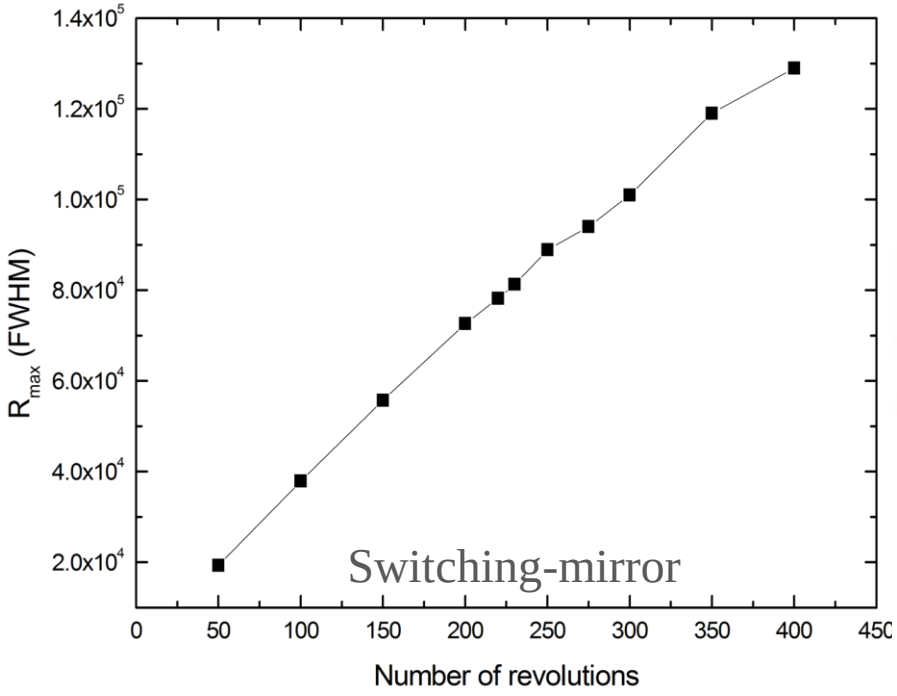
Length of the drift tube

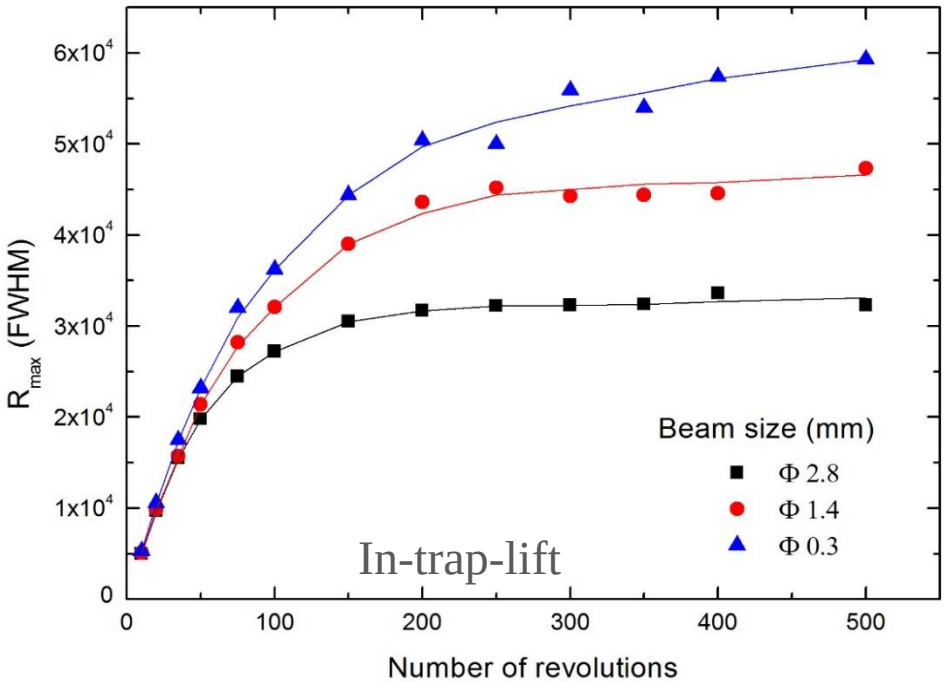




Optimal length ： 398-402 mm

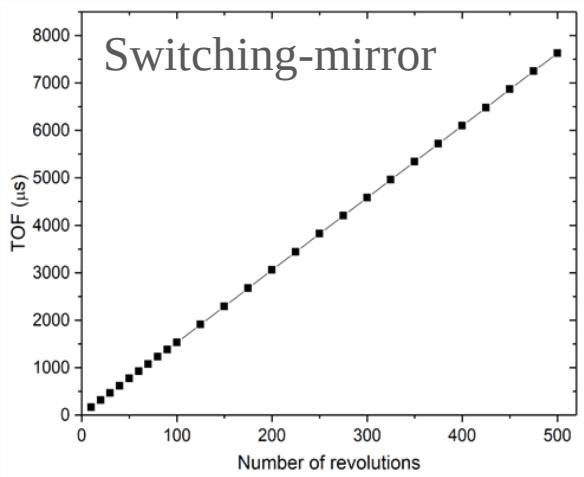
R_{max} at different revolutions

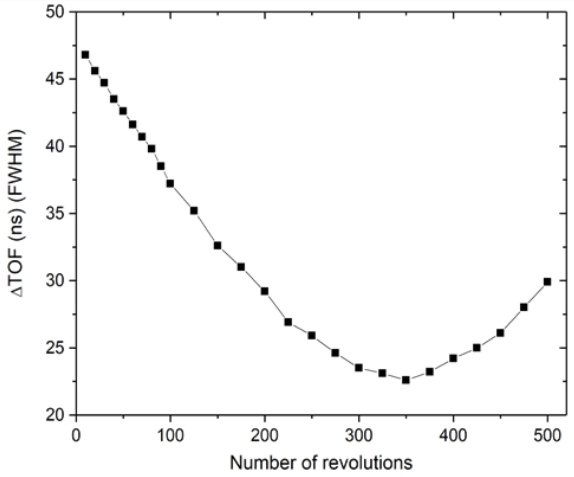


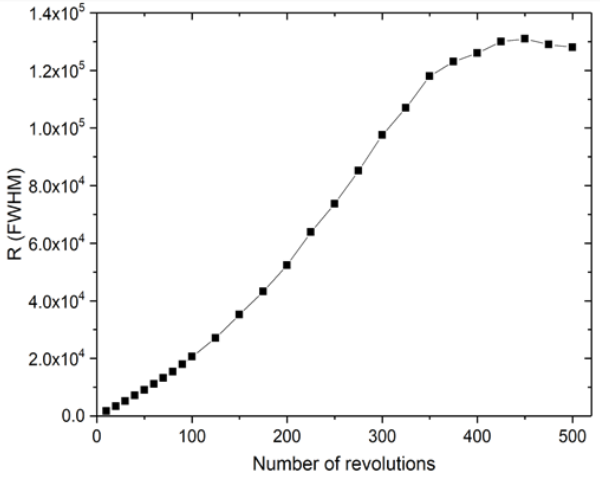


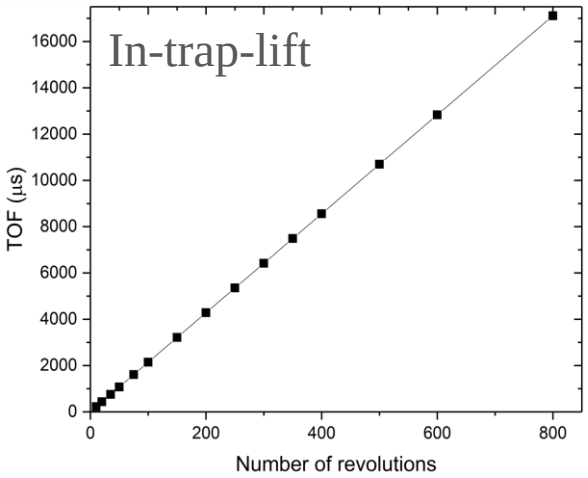
- The mass resolving power increases with the increase of revolution numbers
- Beam size affects R_{max} little at optimal parameter sets, but shows more significant influence at other set points

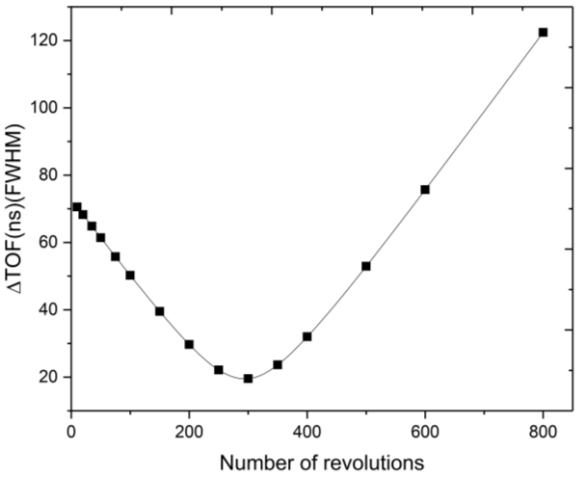
$TOF, \Delta TOF, R$ with fixed potentials (6.5 ms)

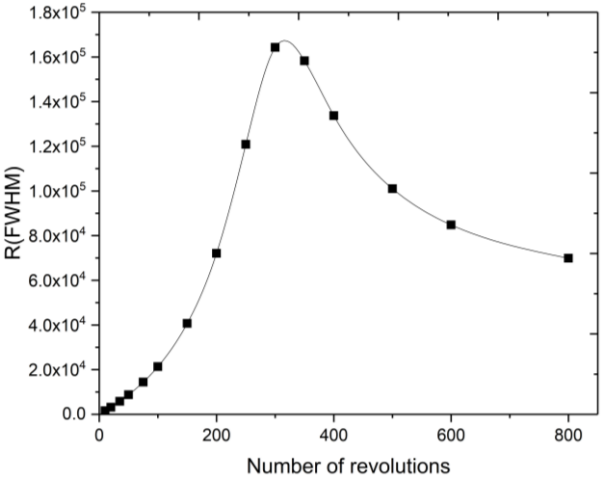






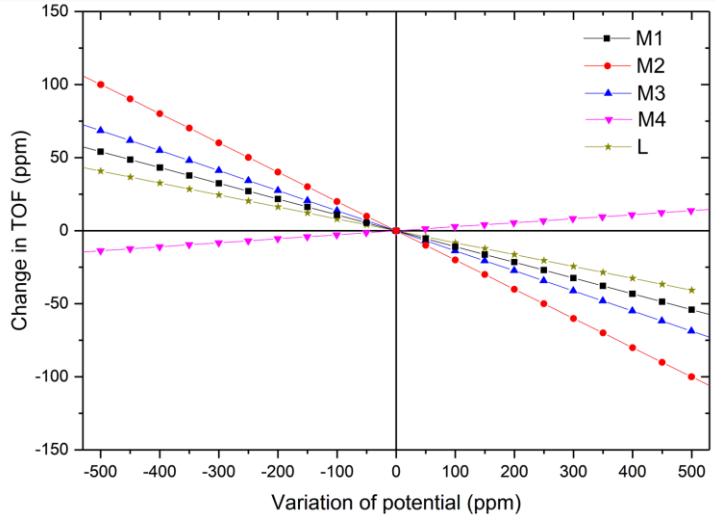


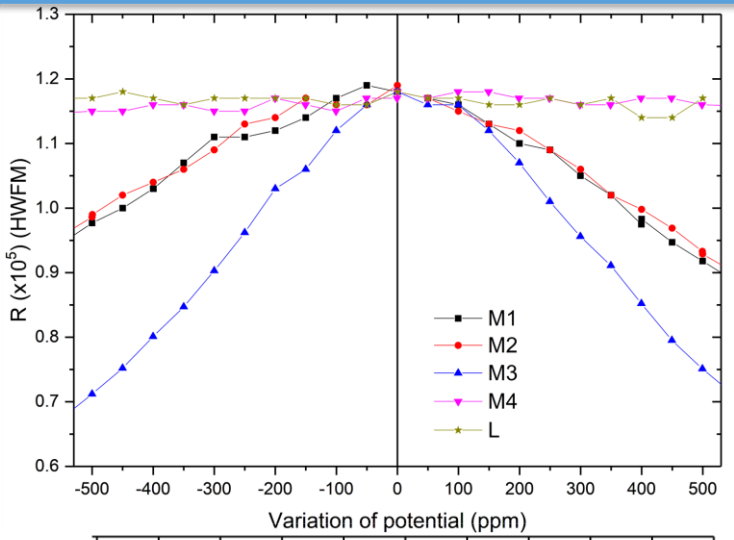


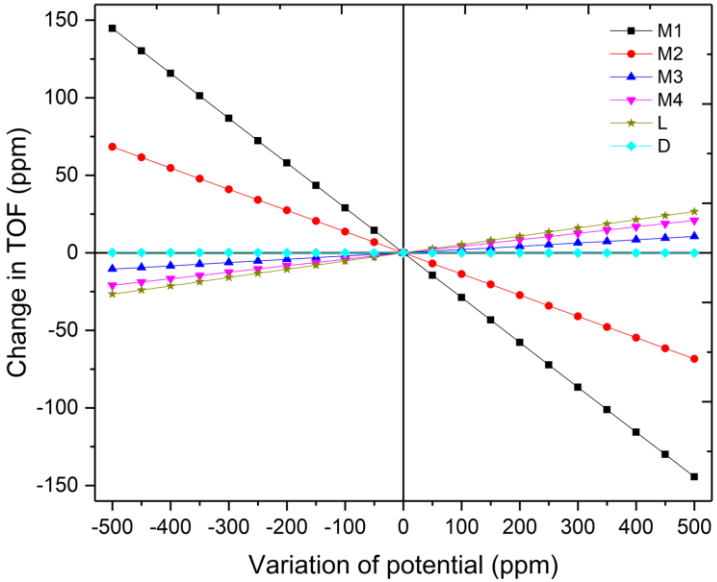


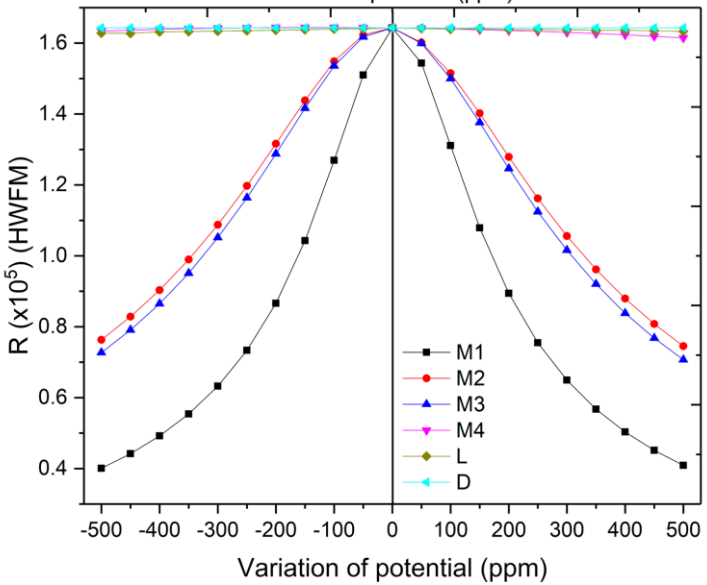
- TOF almost increases linearly with the increase of revolution numbers
- The temporal spread decreases until a minimum, $\approx 20\ ns$
- Resolving power $R > 10^5$

Potential inaccuracy influence



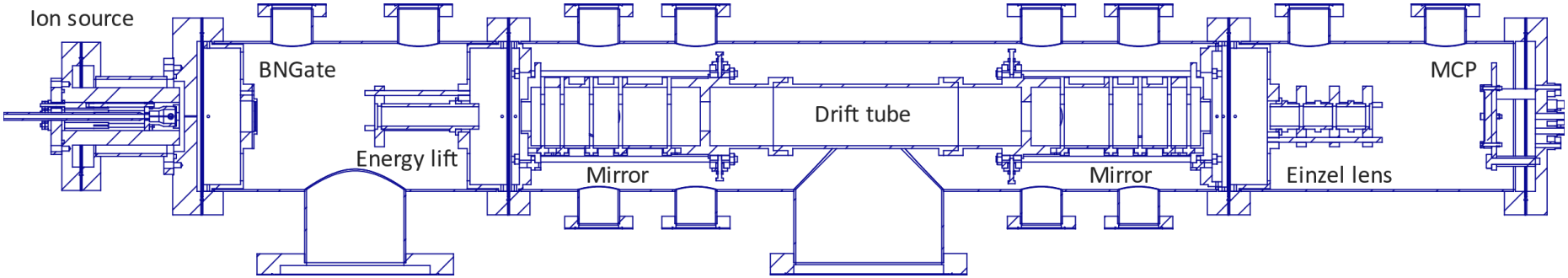


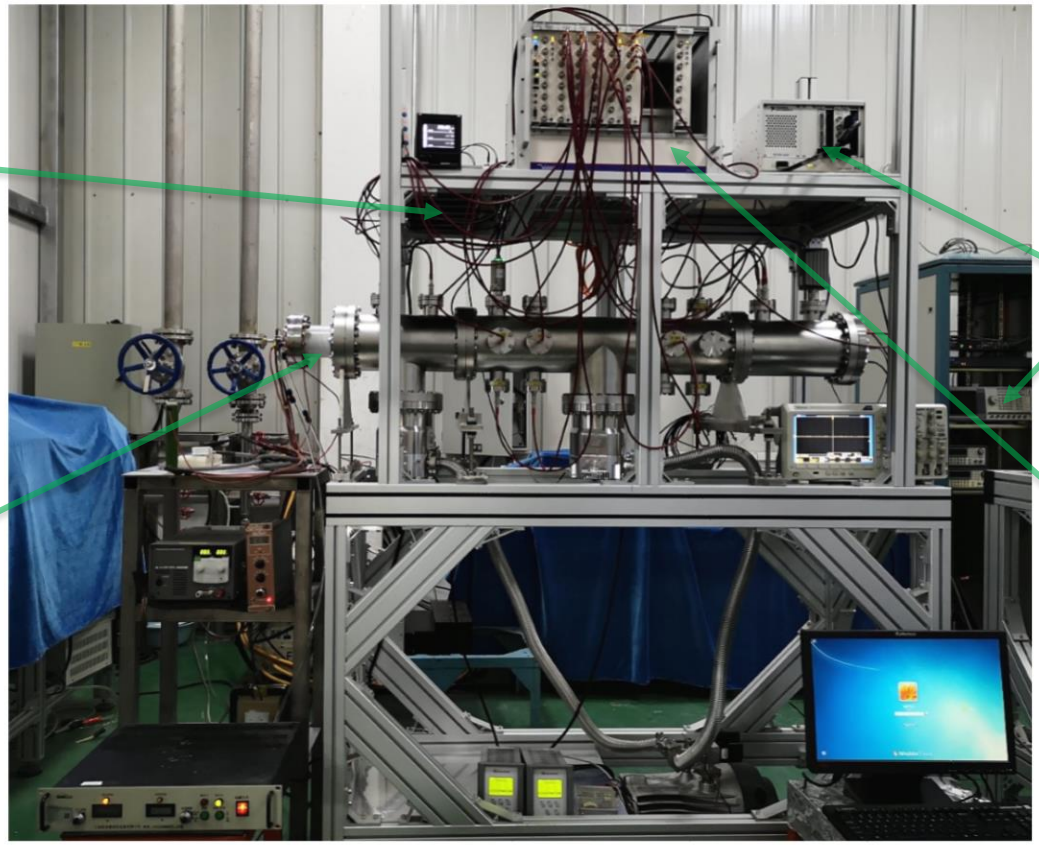




Potential inaccuracy on electrodes where the ions turn around shows more significant influence to mass resolving power.

Apparatus & status





Fast Switches

Ion Source

Multi-Channel Scaler

Timing System

Power Supplies

Conclusion

- An MRTOF-MS for LPT at SHANS/HIRFL is under construction
- A new method for MRTOF-MS design is presented. Geometry, potential parameters can be optimized
- R_{max} for 1.5keV $^{40}Ar^{1+}$ in a 4-electrodes mirror MRTOF-MS is >10,0000 both in switching-mirror and in-trap-lift modes

Collaborators

Wenxue HUANG, Yongsheng WANG, Junying WANG, Zaiguo GAN, Xiaohong ZHOU

Acknowledgement

Michiharu WADA, Ryan RINGLE, Peter SCHURY, Tommi ERONEN, Yuta ITO, Hiroari MIYATAKE ……

Thanks for your attention!