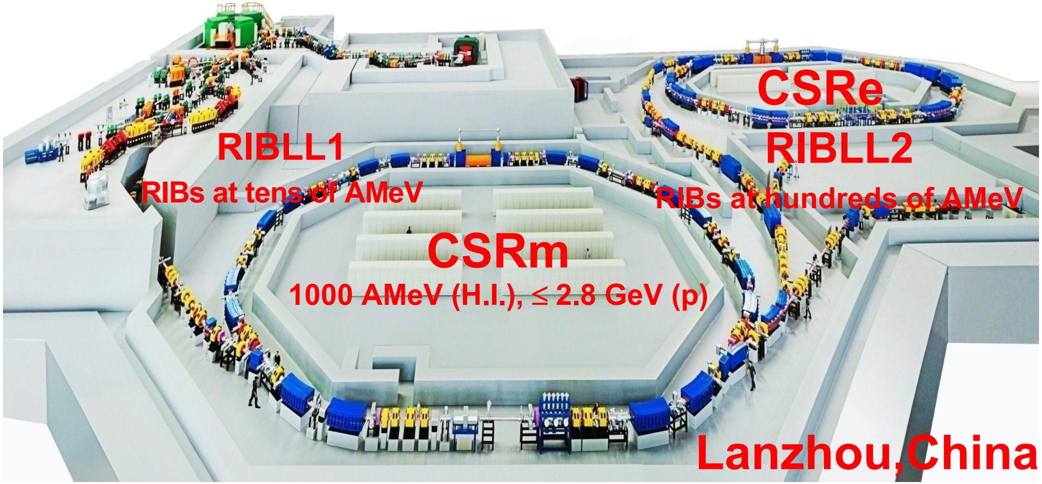
Upgrading the IMS by measuring velocity of stored ions



Ruijiu Chen, of behalf of CSRe mass measurement collaboration
GSI,&IMP-CAS,2018.3.14

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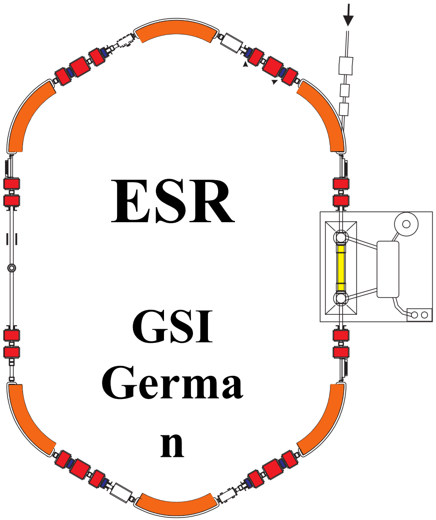
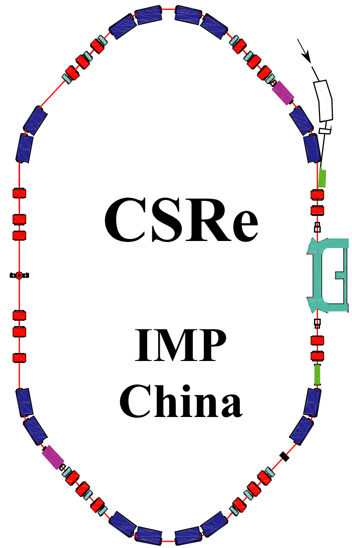
I.1 Motivations:





	ESR(GSI)	CSRe(IMP)	R3-Ring(RIKEN)
Circumference[m]	103.36	128.80	56.13
Bp [Tm, max]	0.5--10	0.6--8.4	--6.43
ΔB/B	$\leq 2\times10^{-6}$	$\leq 5\times10^{-5}$	$\leq 10^{-6}$

I.2 Motivations:

The principle of IMS:

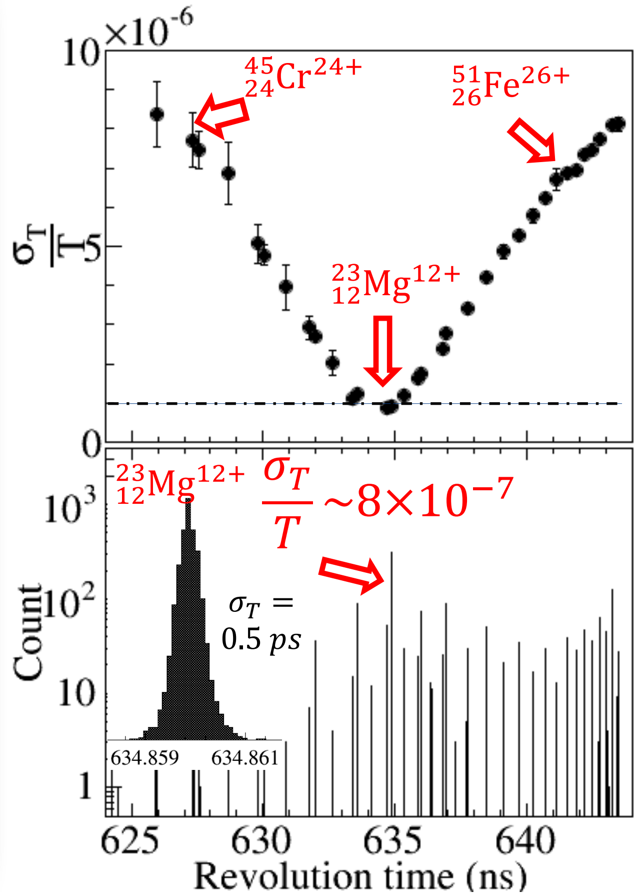
$$\frac{\Delta T}{T} = \frac{1}{\gamma_t^2}\frac{\Delta(m/q)}{m/q} + \left(\frac{\gamma^2}{\gamma_t^2} - 1\right)\frac{\Delta v}{v}$$

Isochronous condition:

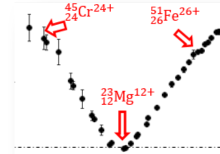
$$\gamma = \gamma_t$$

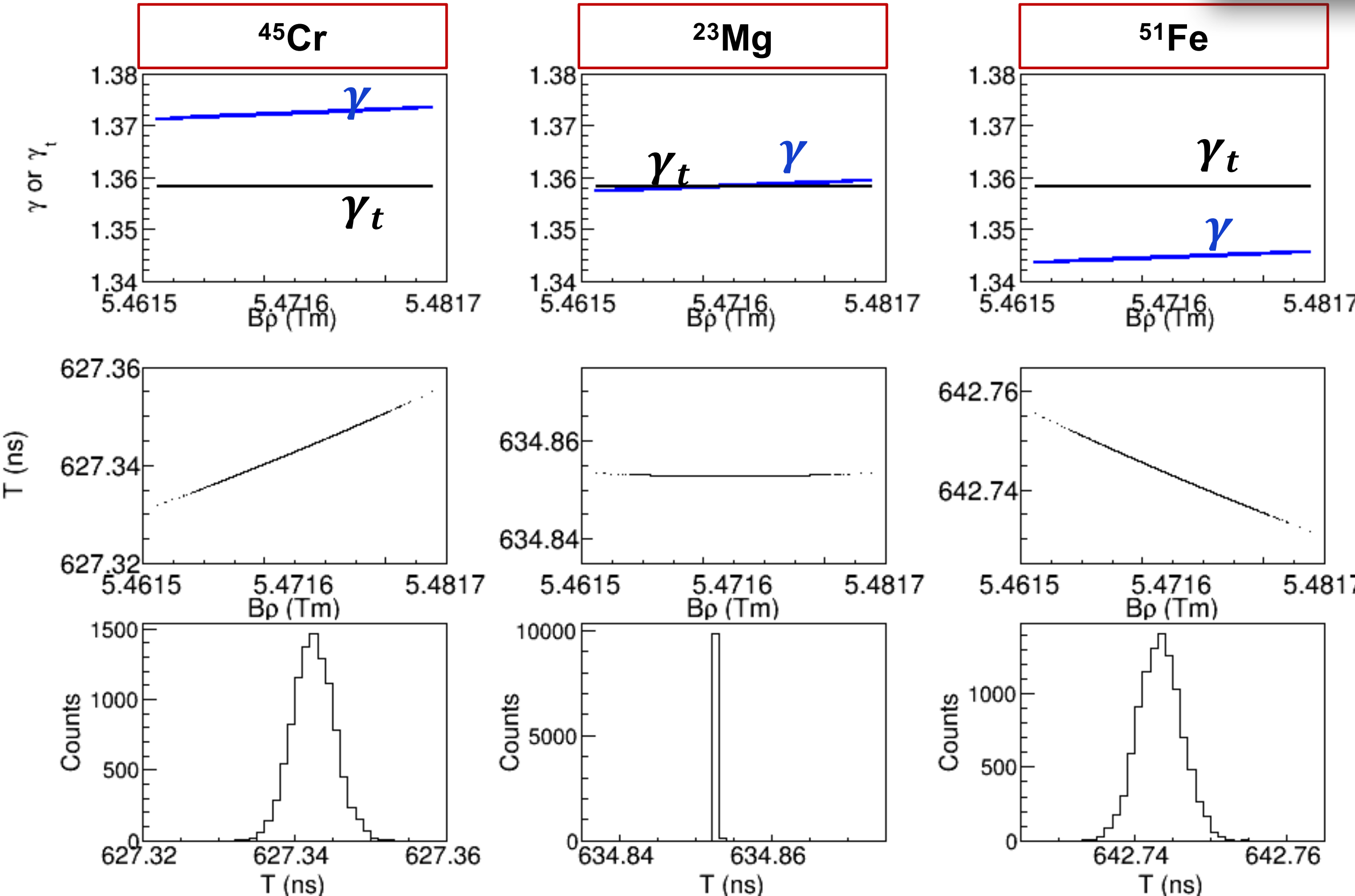
For the ions of the same species:

$$\frac{\Delta T}{T} = \left(\frac{\gamma^2}{\gamma_t^2} - 1\right)\frac{\Delta v}{v} = \left(\frac{1}{\gamma_t^2} - \frac{1}{\gamma^2}\right)\frac{\Delta(B\rho)}{B\rho}.$$



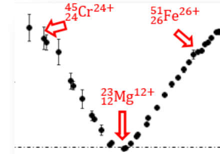
$$\frac{\Delta T}{T} = \left(\frac{1}{\gamma_t^2} - \frac{1}{\gamma^2}\right)\frac{\Delta(B\rho)}{B\rho}$$

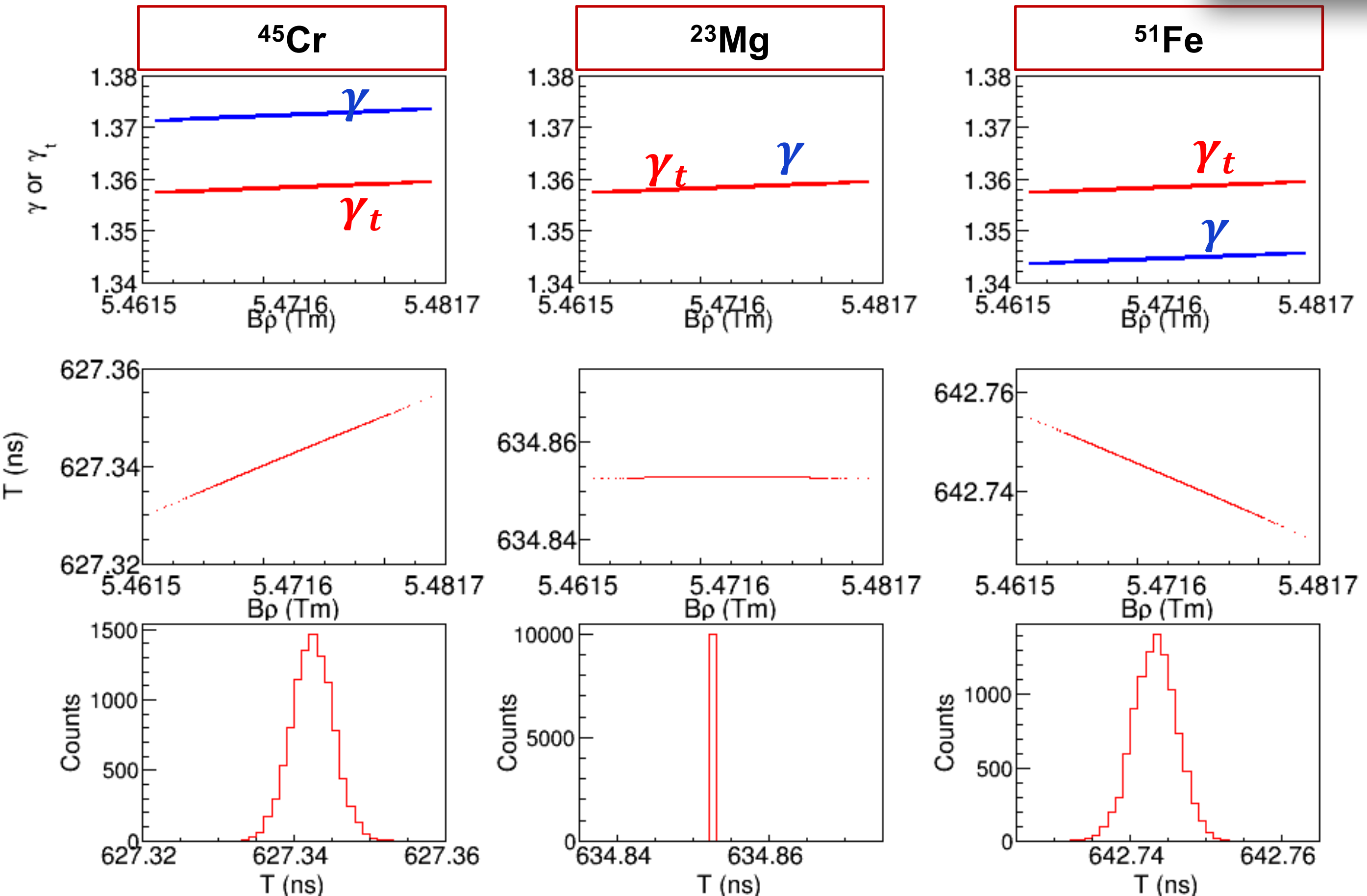




I.3 Motivation:

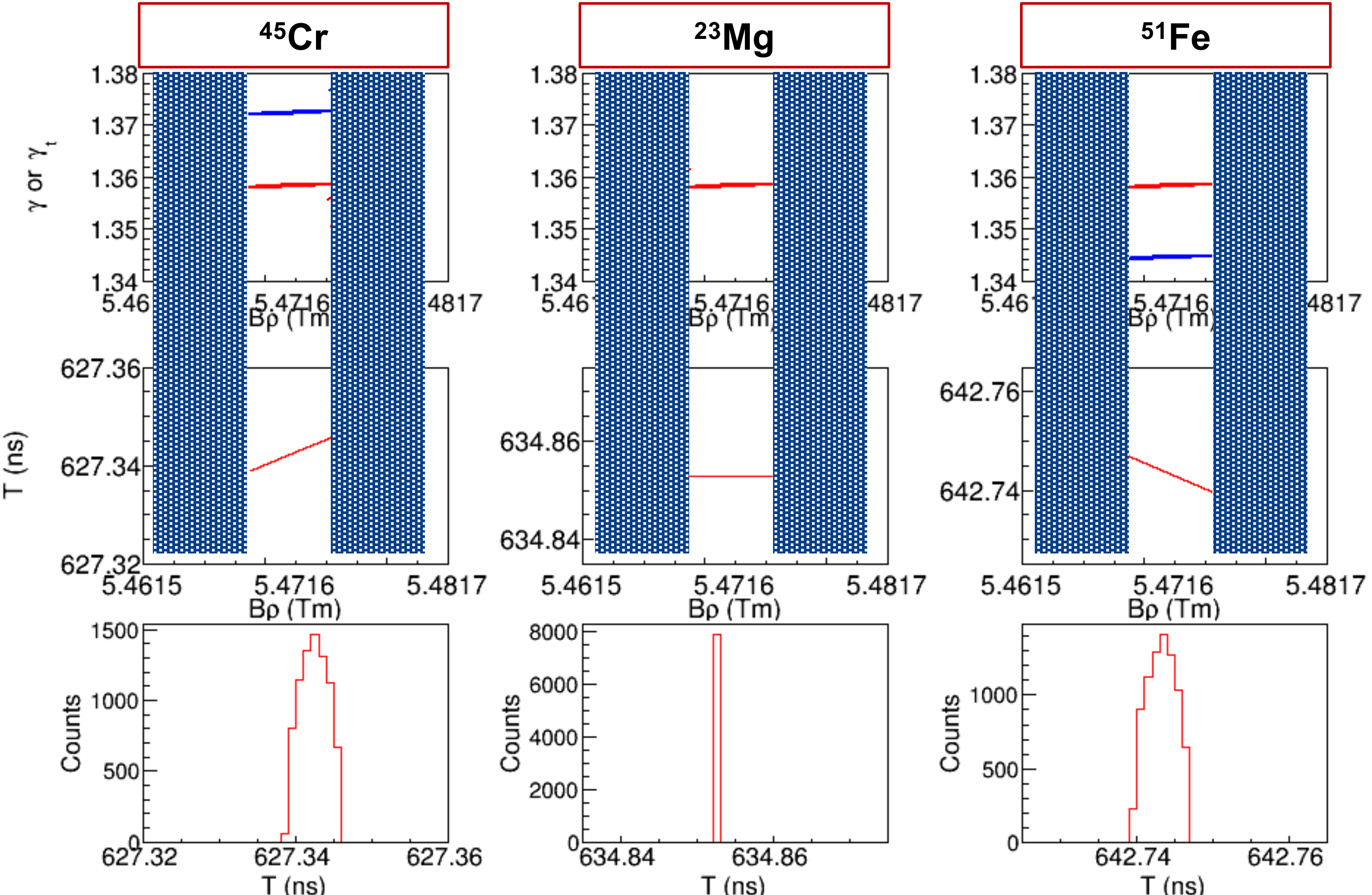
Method 1: Improved IMS by tuning γ_t





I.3 Motivation:

Method 2: Improved IMS by reducing acceptance.



I.3 Motivation:

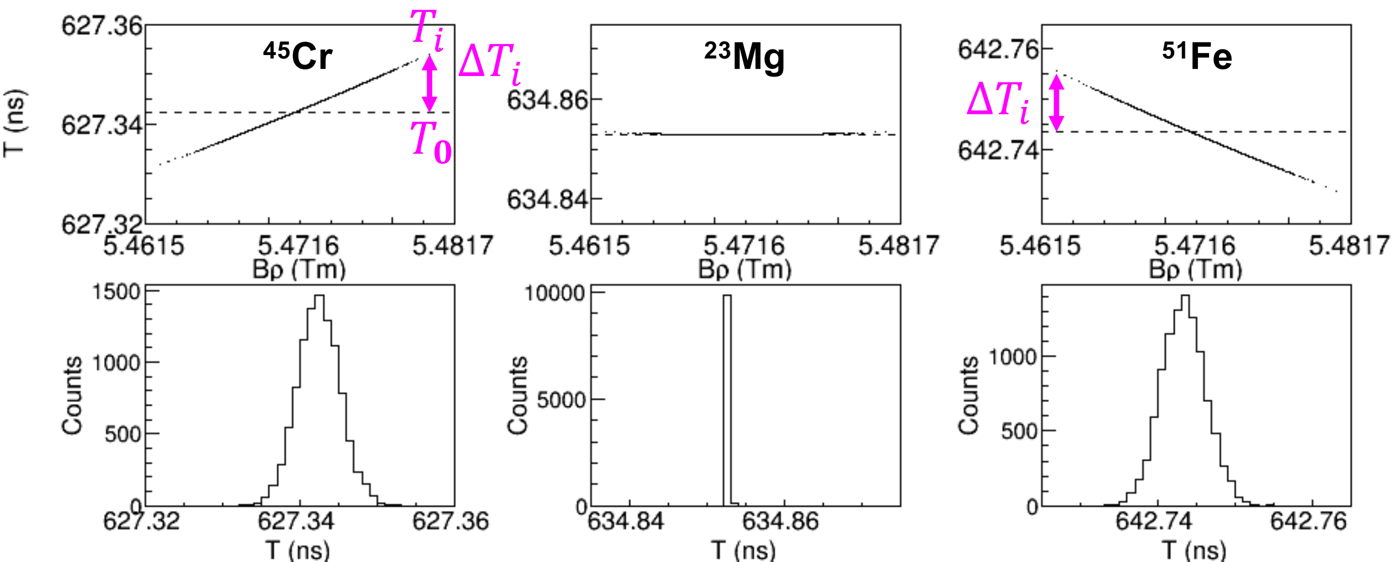
Method 3: measuring velocity.

Principle

$$\frac{\Delta T}{T} = \left(\frac{\gamma^2}{\gamma_t^2} - 1\right)\frac{\Delta v}{v} \Rightarrow \frac{T_i - T_0}{T_i} = \left(\frac{\gamma_i^2}{\gamma_t^2} - \mathbf{1}\right)\frac{v_i - v_0}{v_i}$$

See NIMB 378,311 (2016) for detailed Formula.

$$\Rightarrow \quad T_0 = T_i - \Delta T_i \qquad \Delta T_i = \left(\frac{\gamma_i^2}{\gamma_t^2} - \mathbf{1}\right)\frac{v_i - v_0}{v_i} T_i$$



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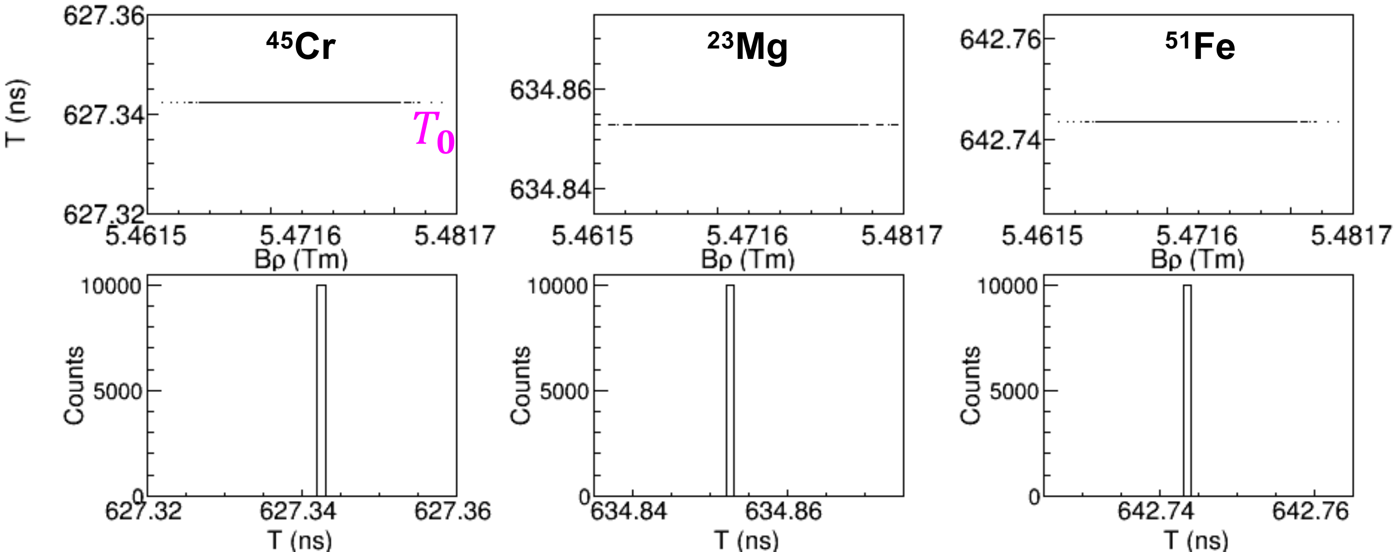
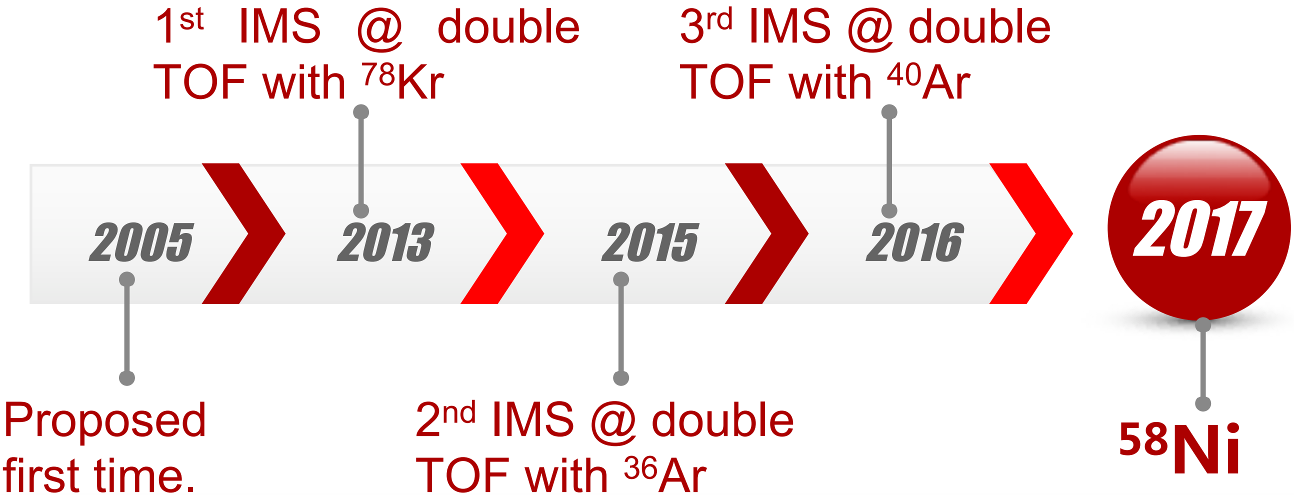


1.4 History of IMS@double TOF

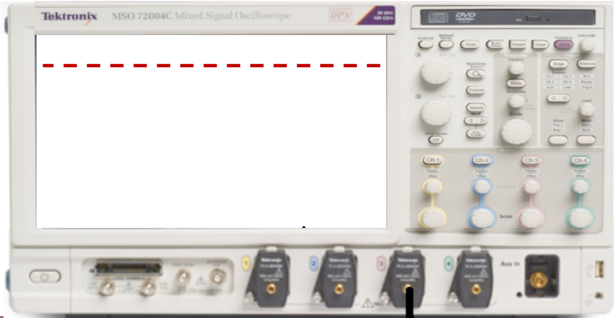


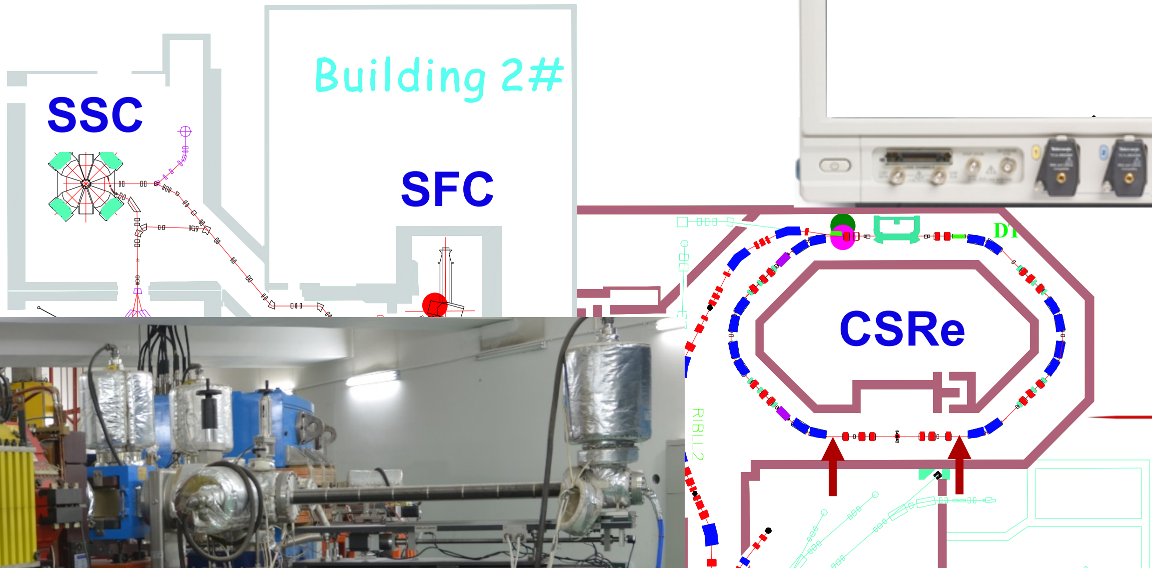
Advantages:

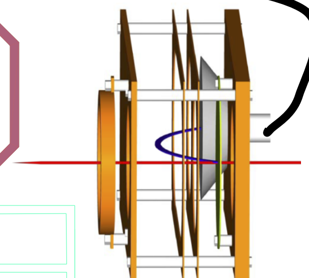
- Improve resolution for all nuclei.
- Don't lose valuable statistics.

H Geissel and Yuri; JPG31(2005)S1779;
A. Dolinkskii et al.,NIMB266(2008)4579;
YM Xing et al., Phys. Scr. T166 (2015) 014010;
X Xu et al.,CPC 39(2015)2015; P Shuai et al;NIMB 376(2016)311;

2 the HIRFL-CSR Lanzhou,China







TOF detector

$L = 18034\,(1)mm$

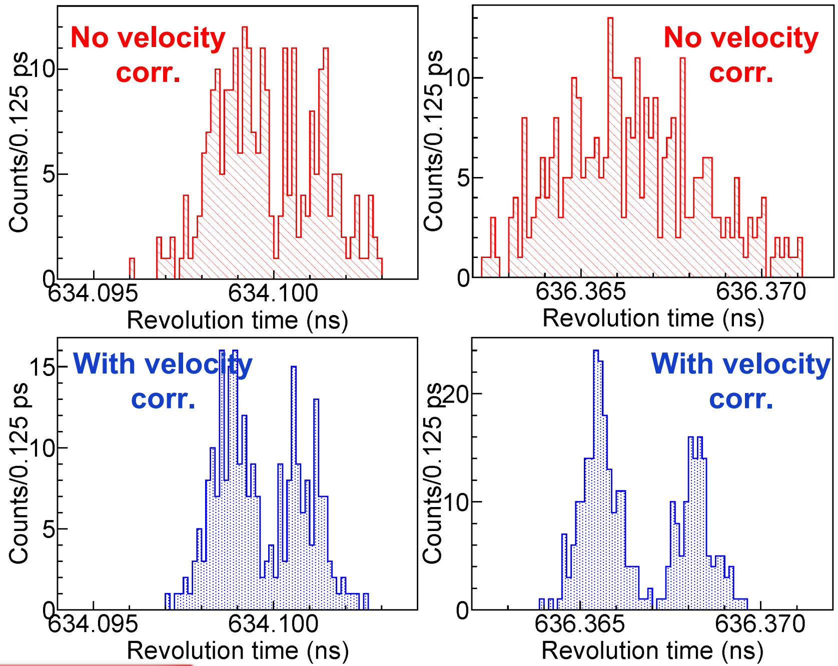
TOF~88 ns

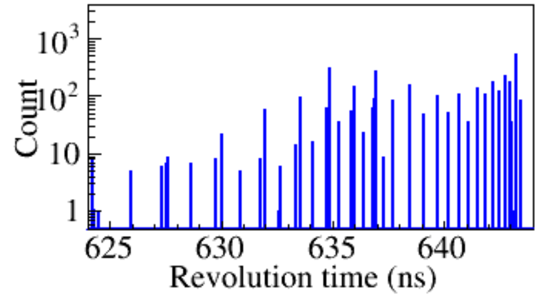
$\sigma_T = 18\,ps, {}^{\sigma_v}/_{v} \sim 5 * 10^{-5}$

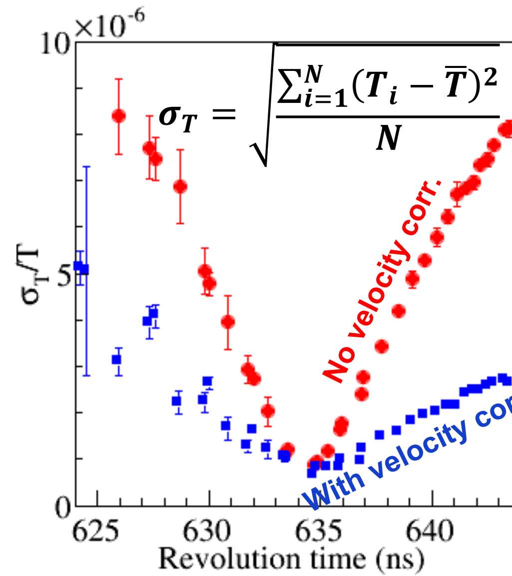
3.1 Revolution time

The ground state and isomer of ^{44}V and ^{52}Co

^{44}V g.s. + is.(~270keV) | ^{52}Co g.s. + is.(~380keV)

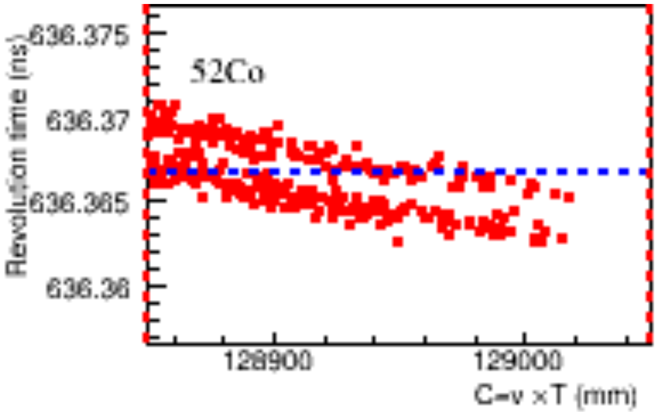


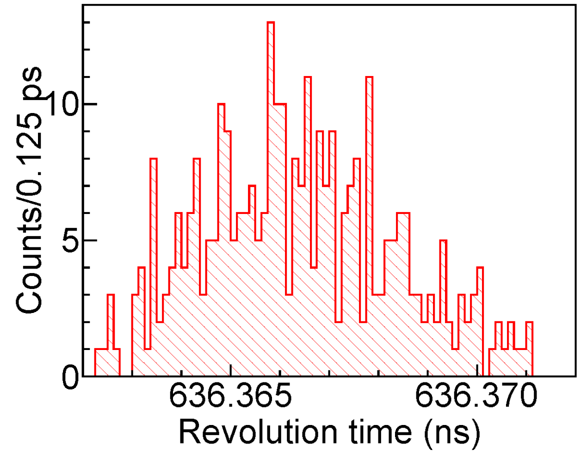


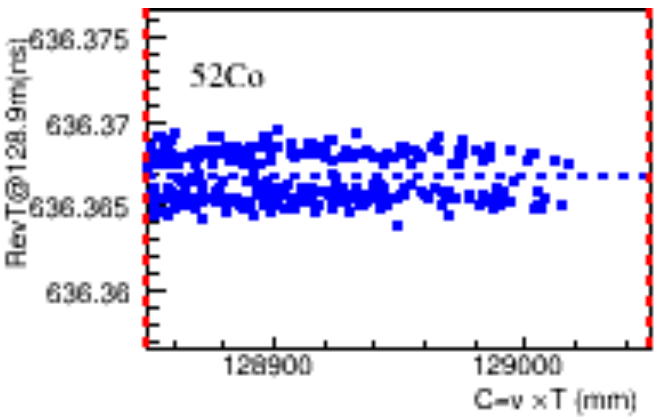


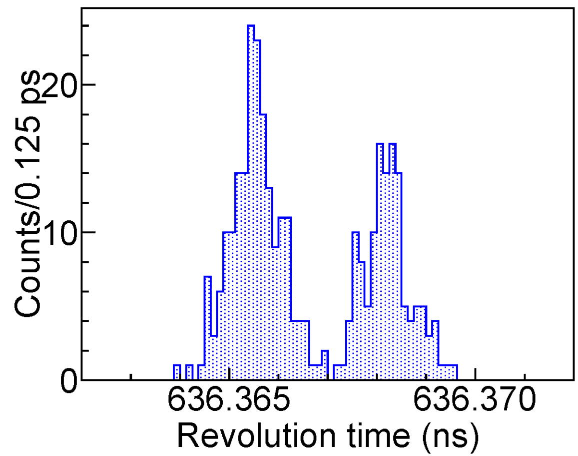
Setting

2017.12.24 21:00~12.26 7:00,34 hours, $^{58}Ni^{19+}$(428.05MeV/u,$7\times10^7\,pps$)+ 15mm Be, $B\rho_{RIBLL2-CSRe} = 5.4713\,Tm$, $\gamma_t = 1.36$.


52Co
Revolution time (ns)
636.375
636.37
636.365
636.36
128900
129000
C=v ×T (mm)

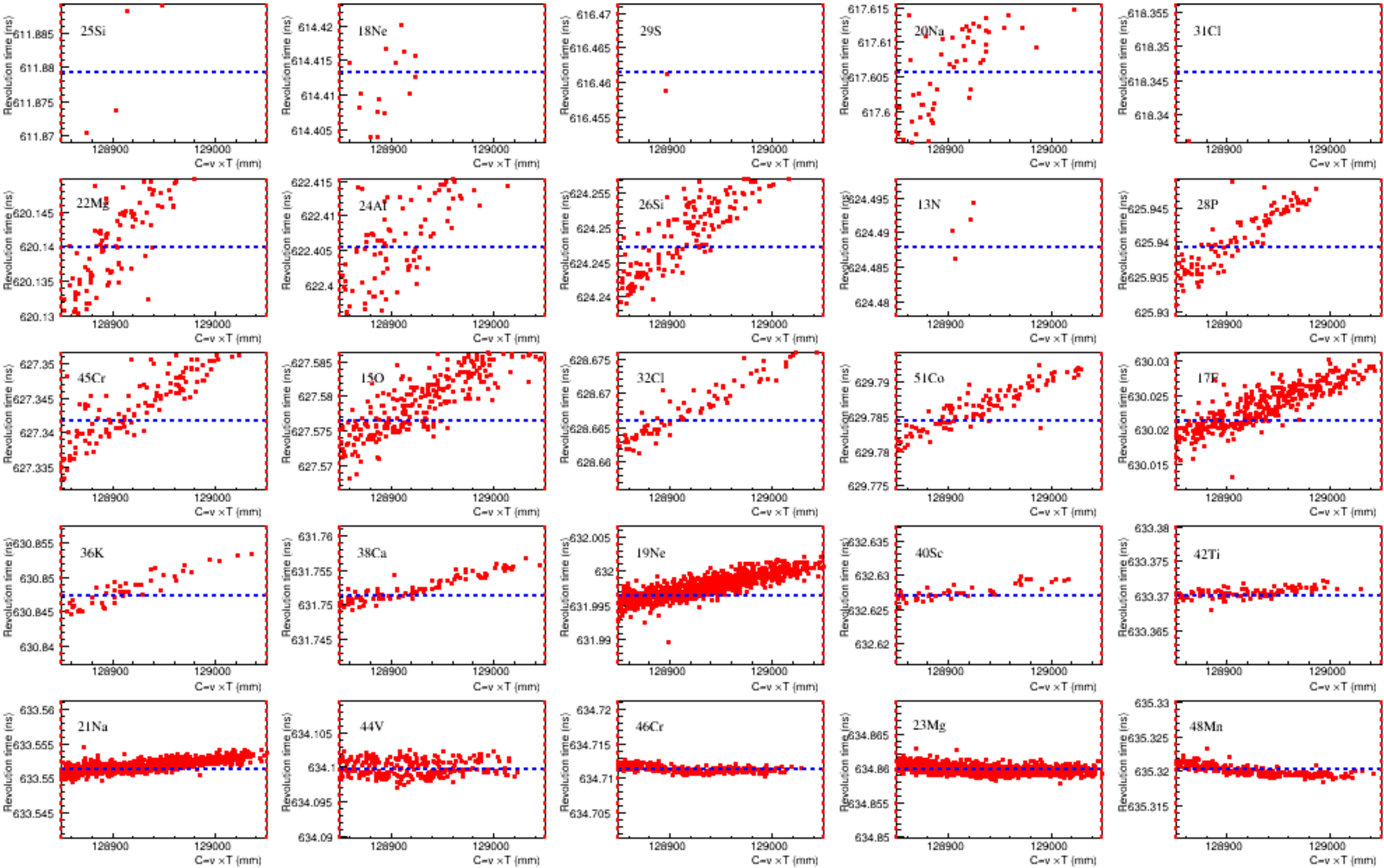

Counts/0.125 ps
0
5
10
636.365
636.370
Revolution time (ns)


52Co
RevT@128.9m(ns)
636.375
636.37
636.365
636.36
128900
129000
C=v ×T (mm)


Counts/0.125 ps
0
10
20
636.365
636.370
Revolution time (ns)

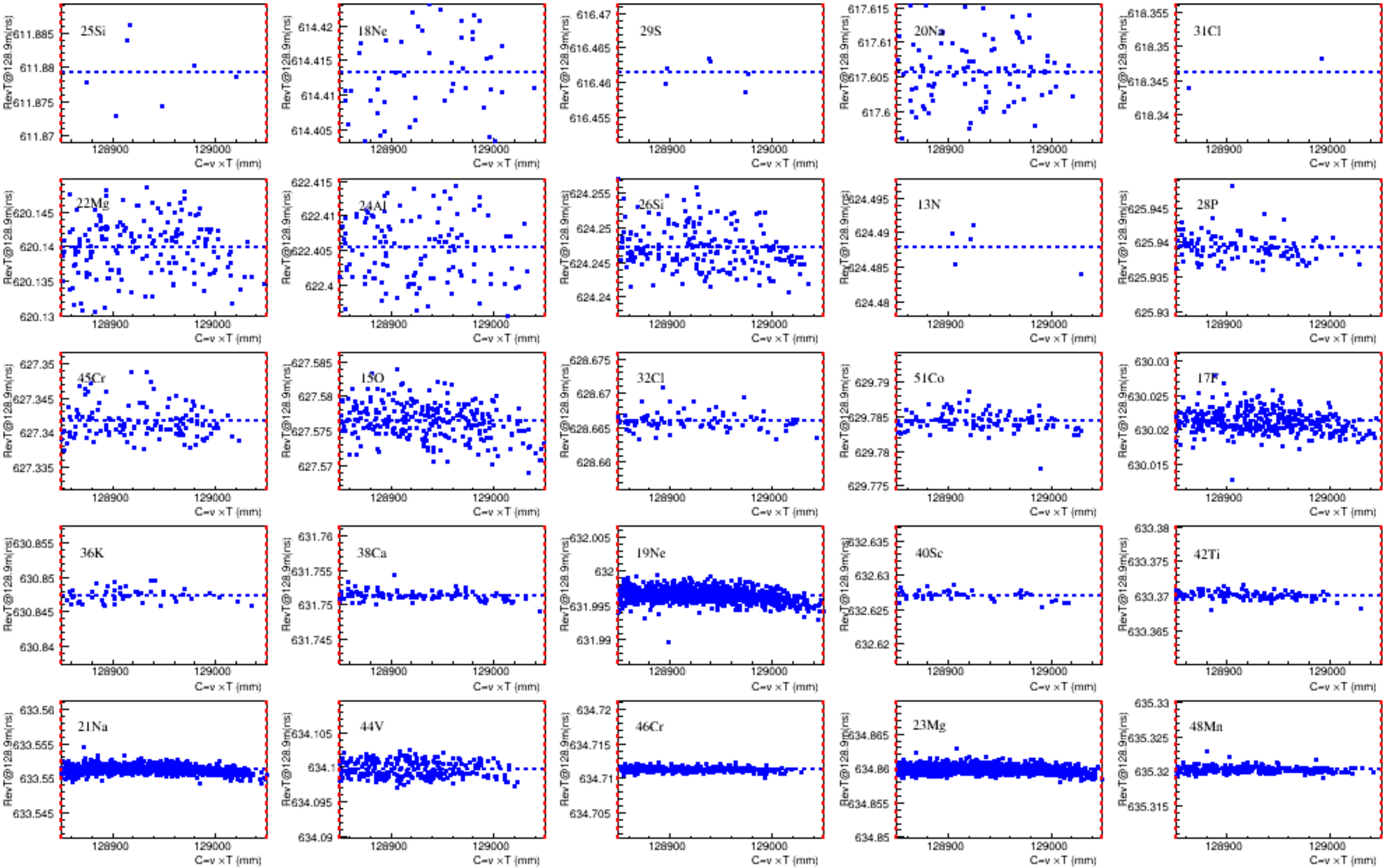
3.2 Revolution time vs orbital length

No velocity correction



3.2 Revolution time vs orbital length

With velocity correction



3.2 Revolution time

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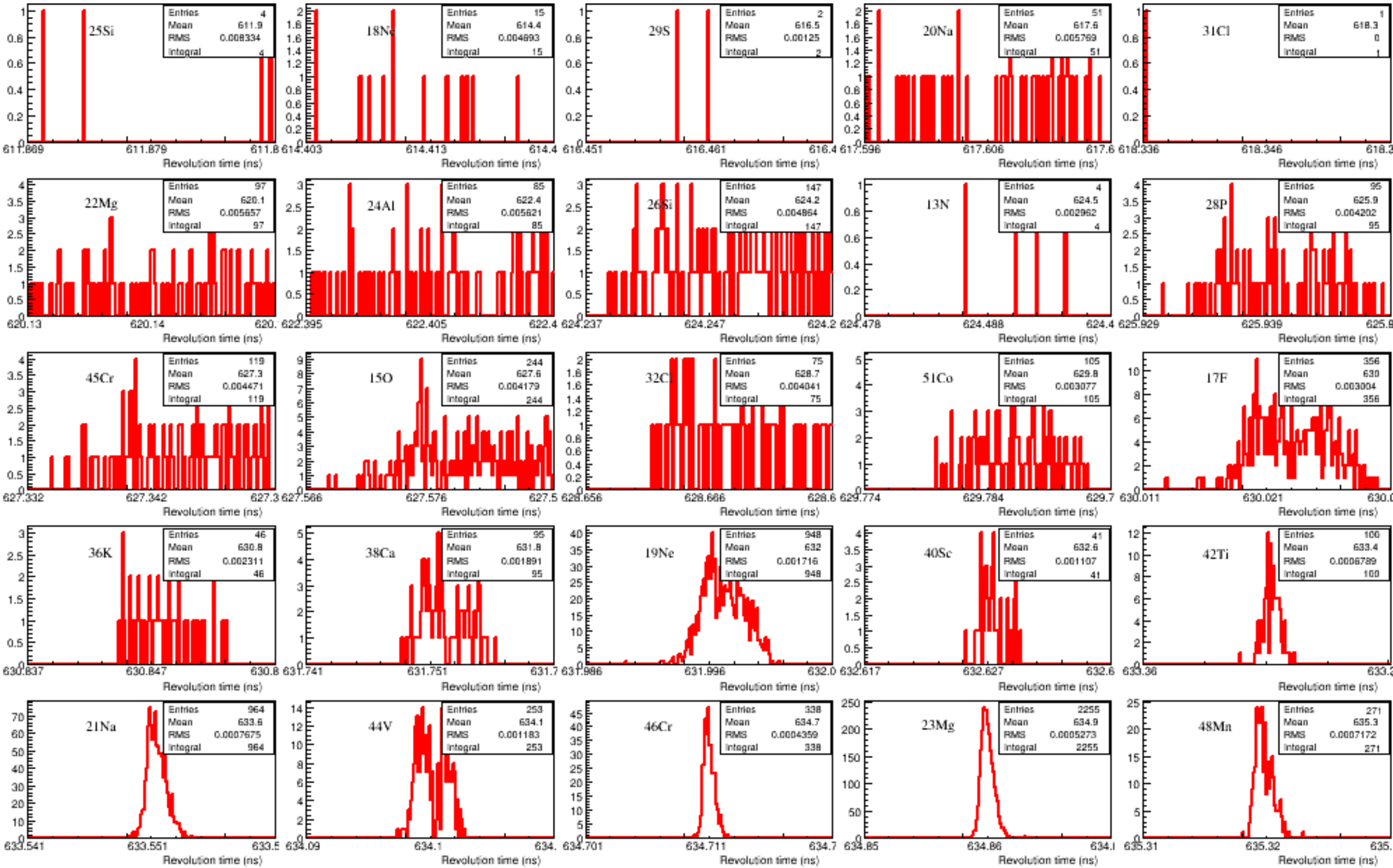

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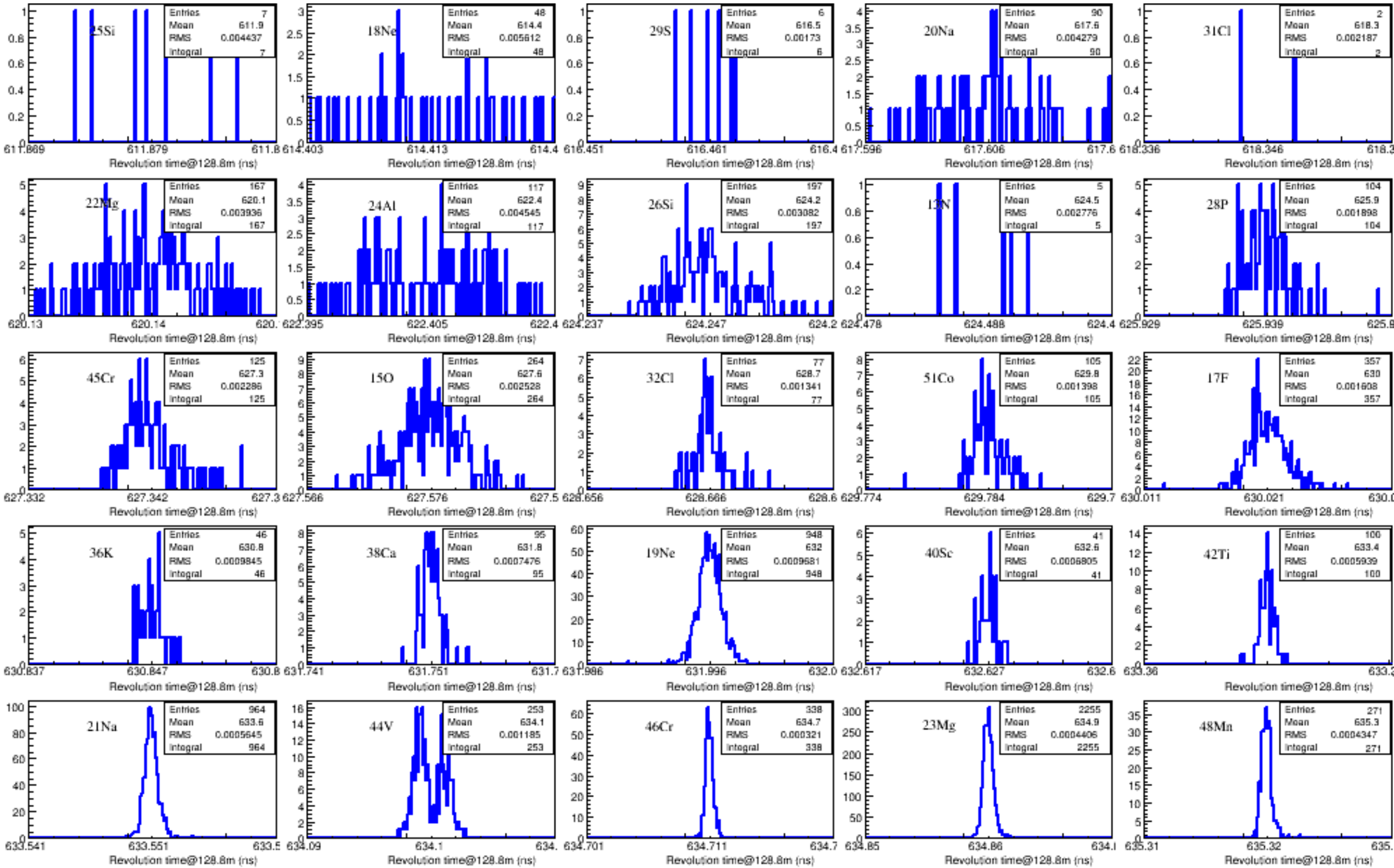

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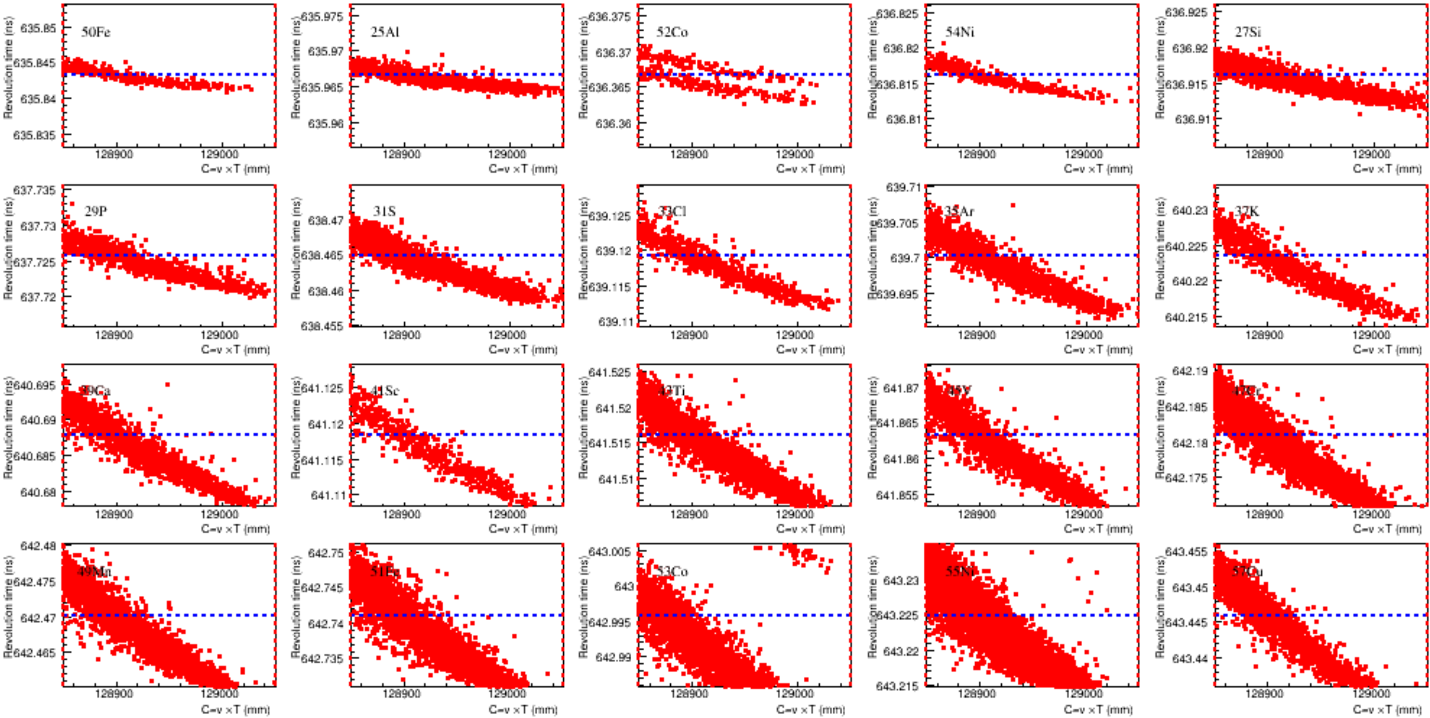

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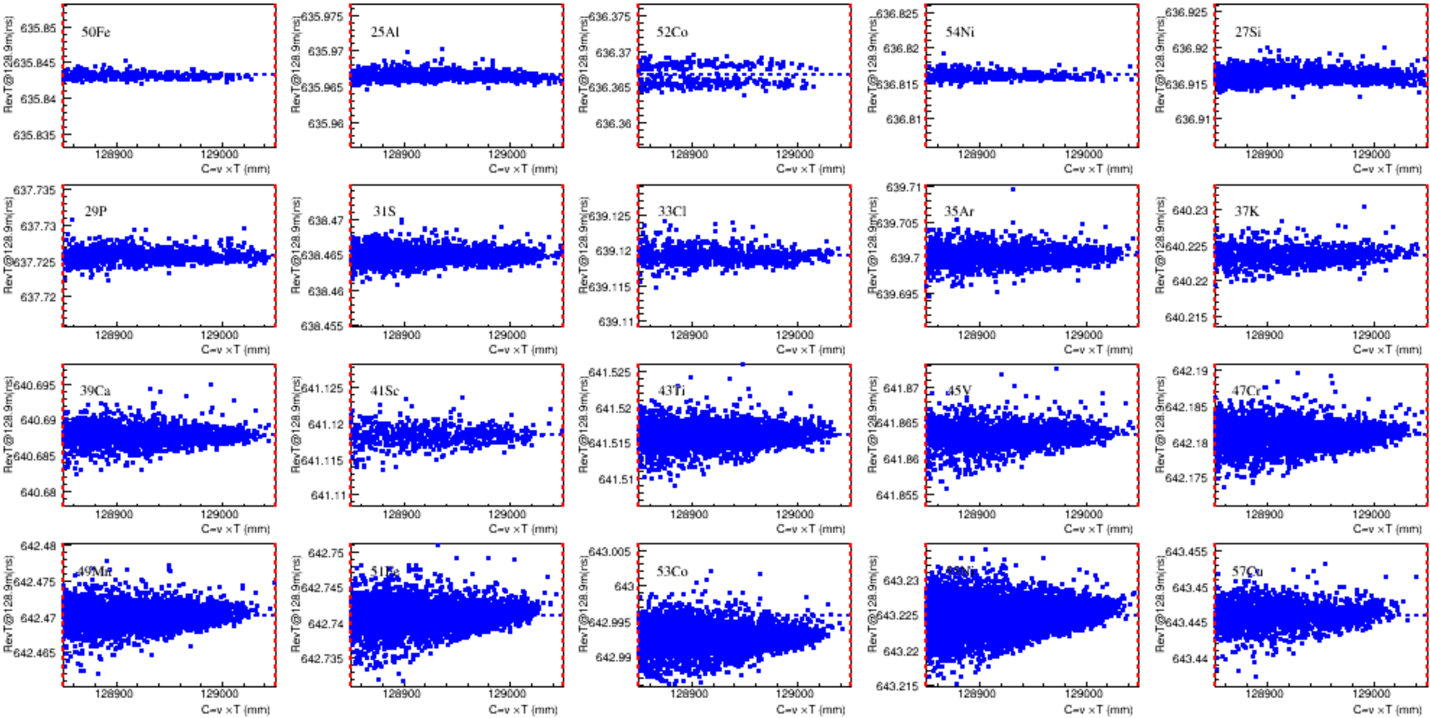
With velocity correction



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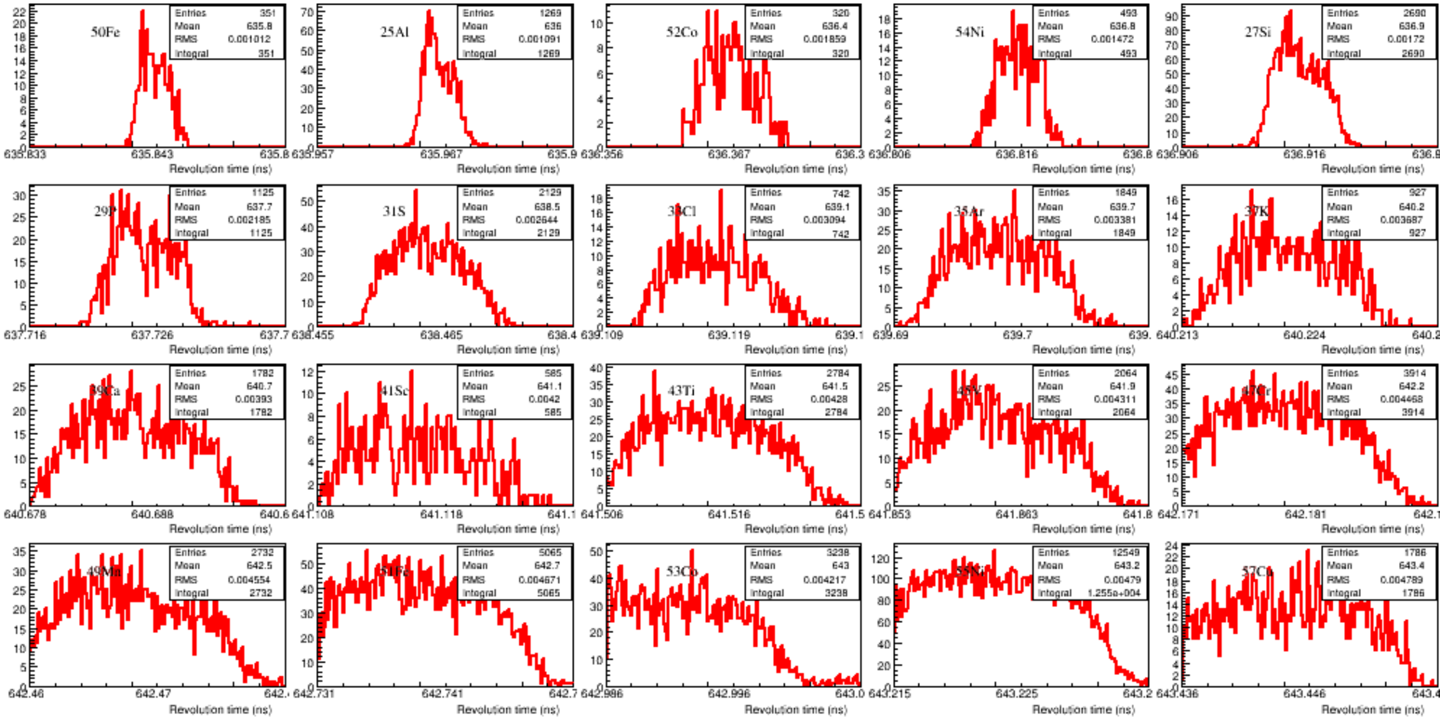
No velocity correction



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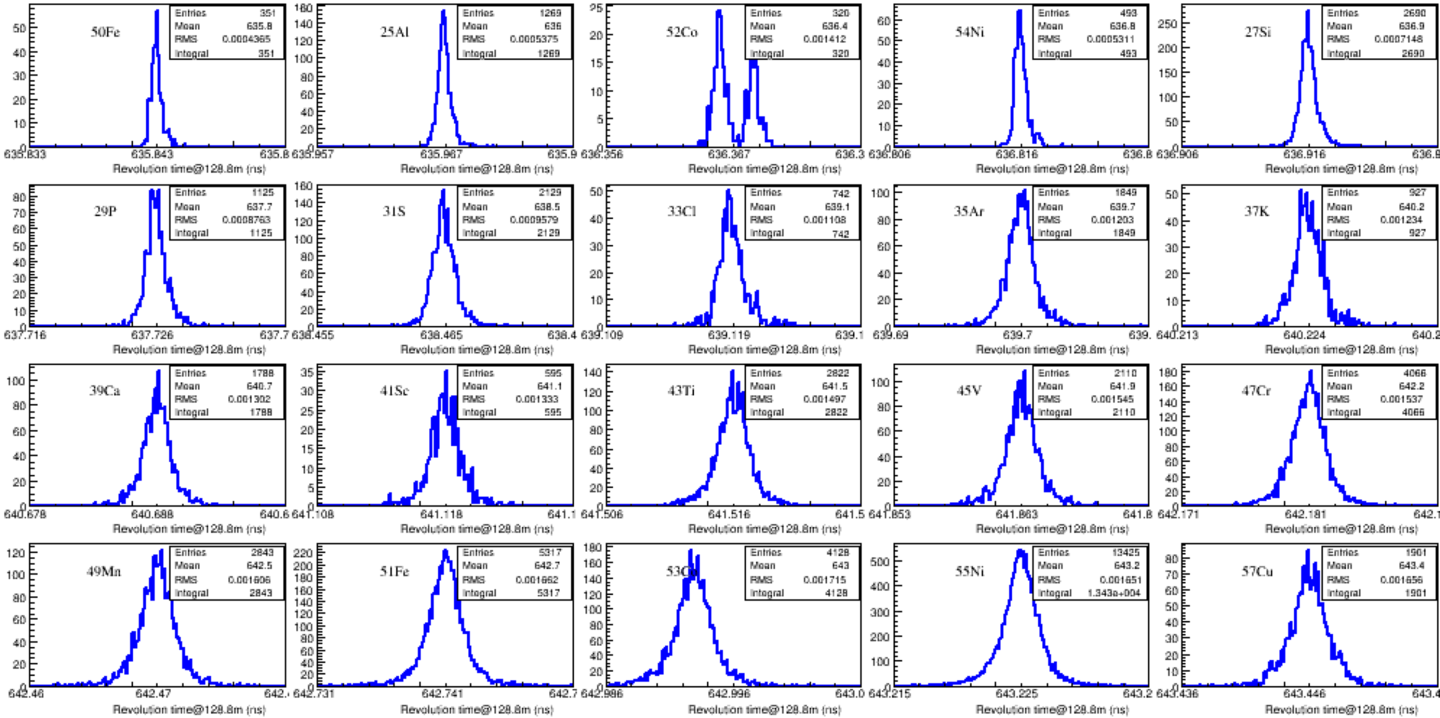
With velocity correction



4. Summary

- **The isochronous mass spectrometry was successfully upgraded by measuring the velocity of stored ions using two time-of-flight detectors at Lanzhou. The precision of velocity** $\sigma_v/_v \sim 10^{-5}$ **was achieved.**
- **The resolution is improved by velocity measurement. The data analysis is still going on.**

CSRe mass measurement collaboration

H. S. Xu, Y. H. Zhang, M. Wang, X. L.Tu, P. Shuai, X. L. Yan, R. J. Chen, X. Xu, B. S. Gao, C. Y. Fu, X. H. Zhou,Y. J. Yuan, J. W. Xia, J. C. Yang, X. C.Chen, Z. G. Hu, X. W. Ma, R. S. Mao, B. Mei, G. Q. Xiao, H. W. Zhao, T. C. Zhao, W. L. Zhan (IMP-CAS, Lanzhou, China)

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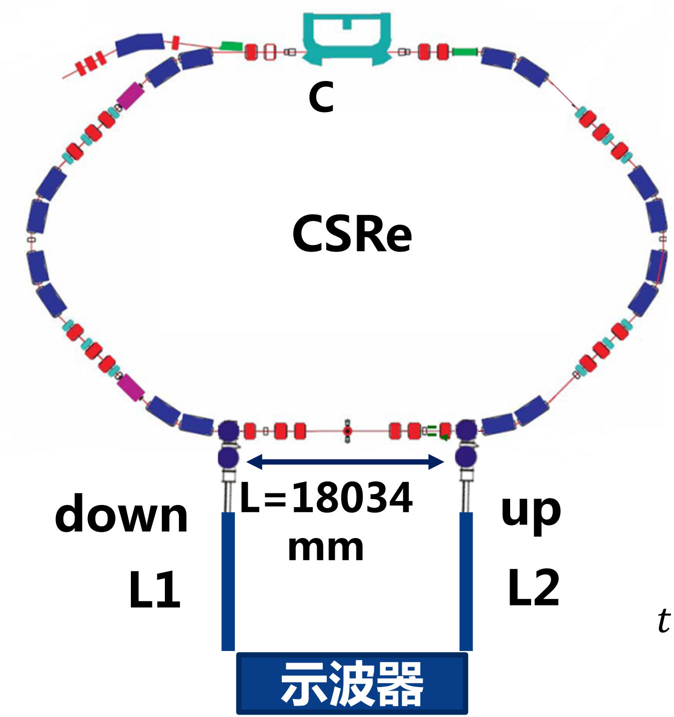
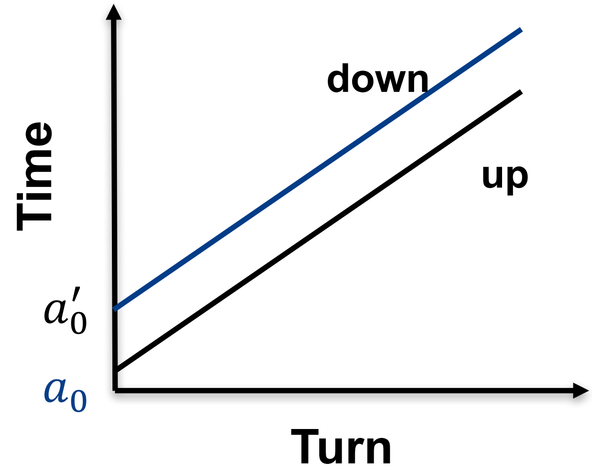
Thanks.

2.2





$$time_{up} = a_0 + a_1 Turn + a_2 Turn^2$$

$$time_{down} = a_0' + a_1' Turn + a_2' Turn^2$$