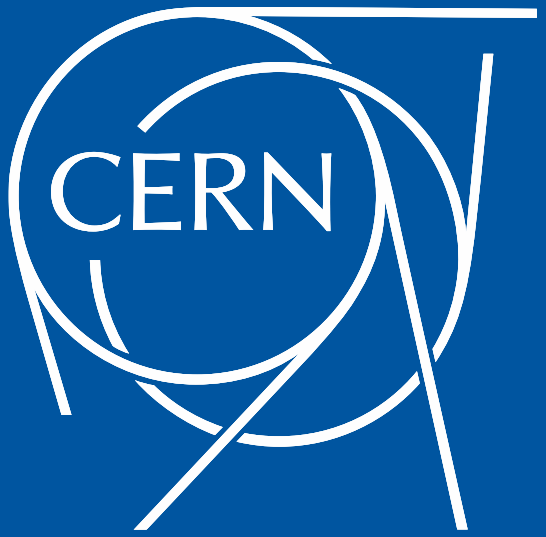

CERN

# Advanced MR-ToF technology for collinear laser spectroscopy and beam purification at ISOLDE

Markus Vilén
CERN

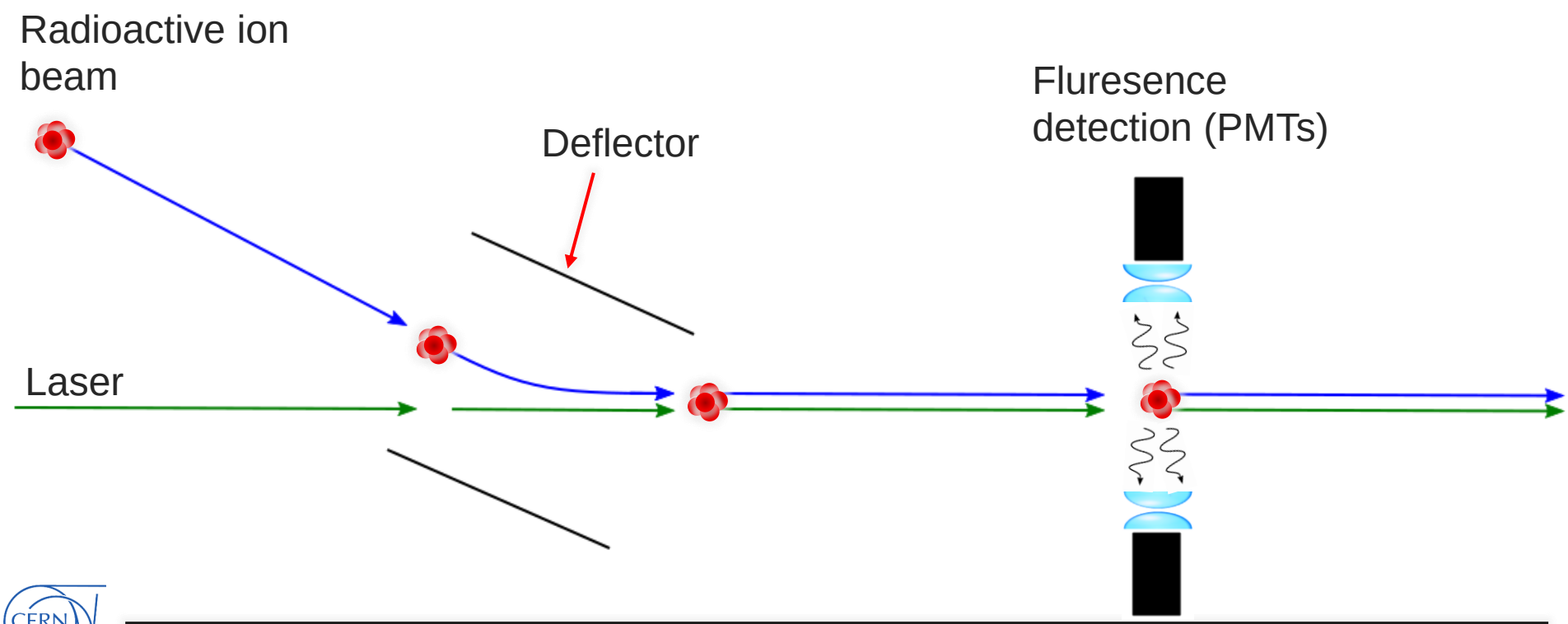
# Outline:

- MIRACLS
  - Novel approach to Collinear Laser Spectroscopy (CLS)
  - First physics case
  - Why build a new setup?
- ISOLDE MR-ToF
  - General purpose mass separator
  - Performance
- Benefit of simultaneous development of the two projects
- Summary

# MIRACLS

(Multi Ion Reflection Apparatus For Collinear Laser Spectroscopy)

***See previous talk by L. Vazquez-Rodriguez***



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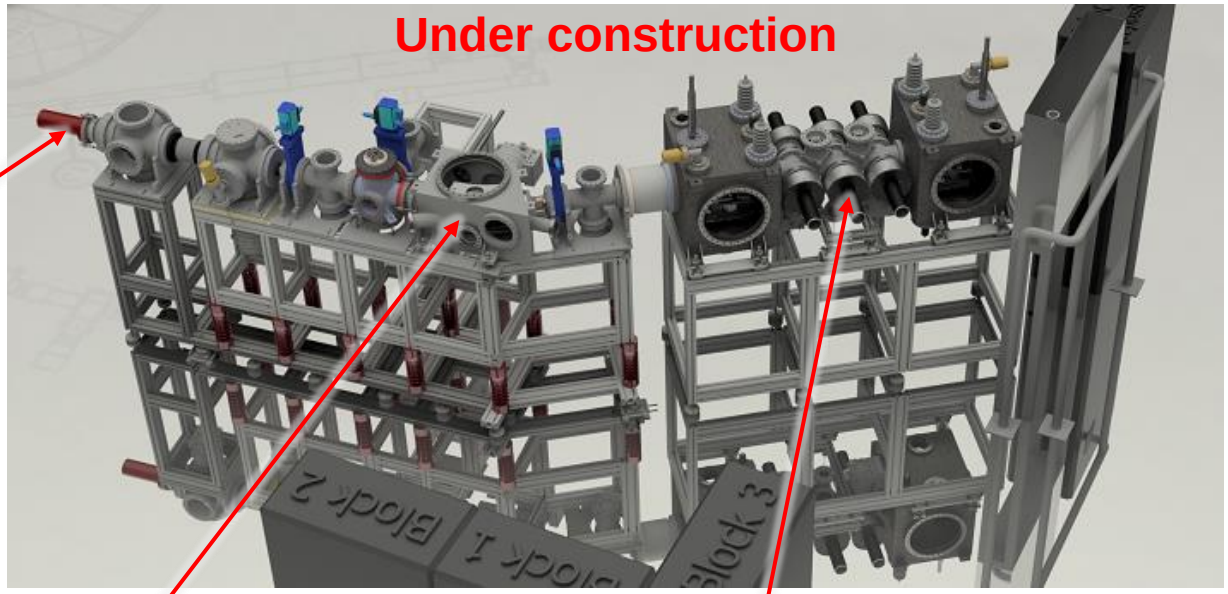

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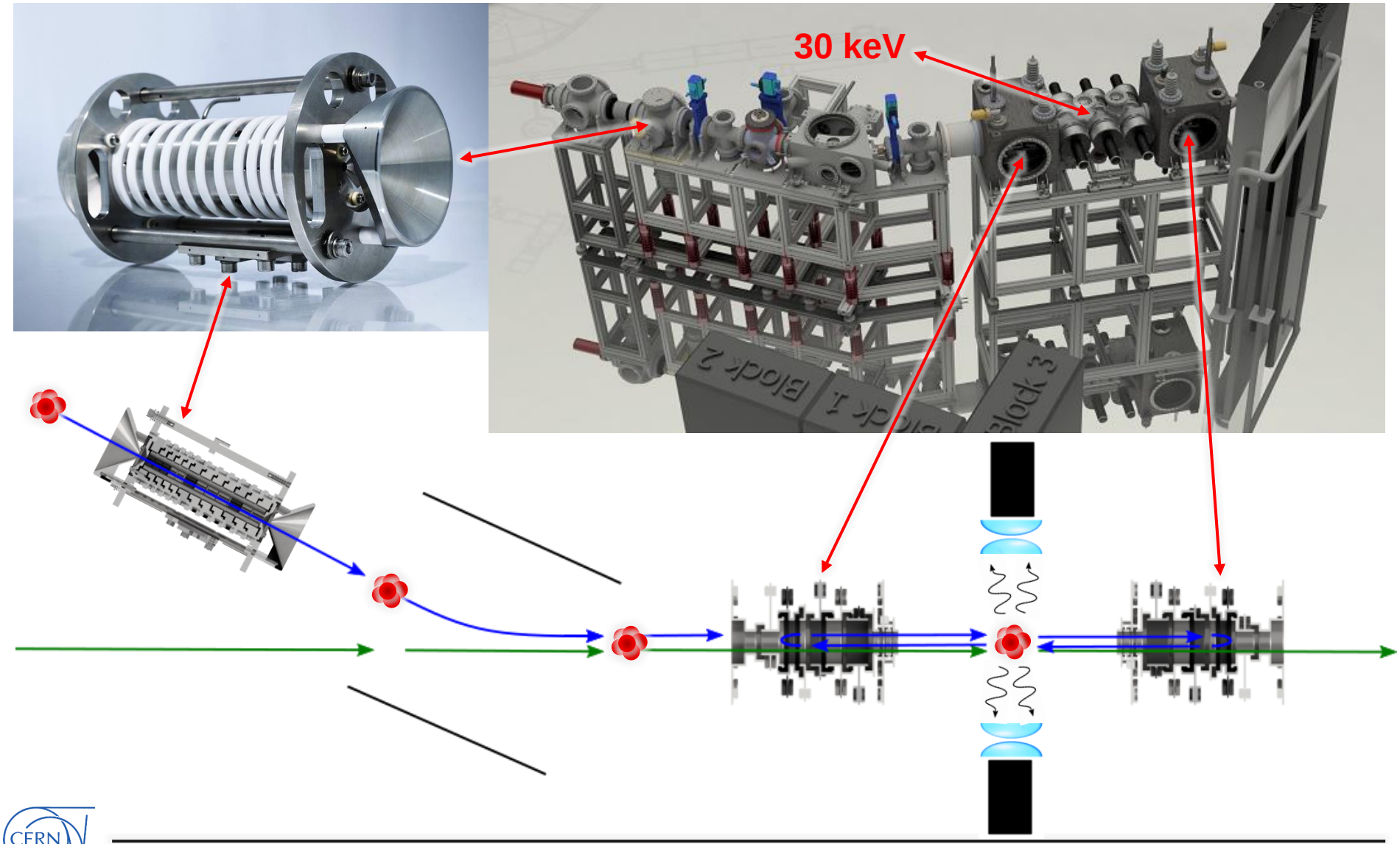

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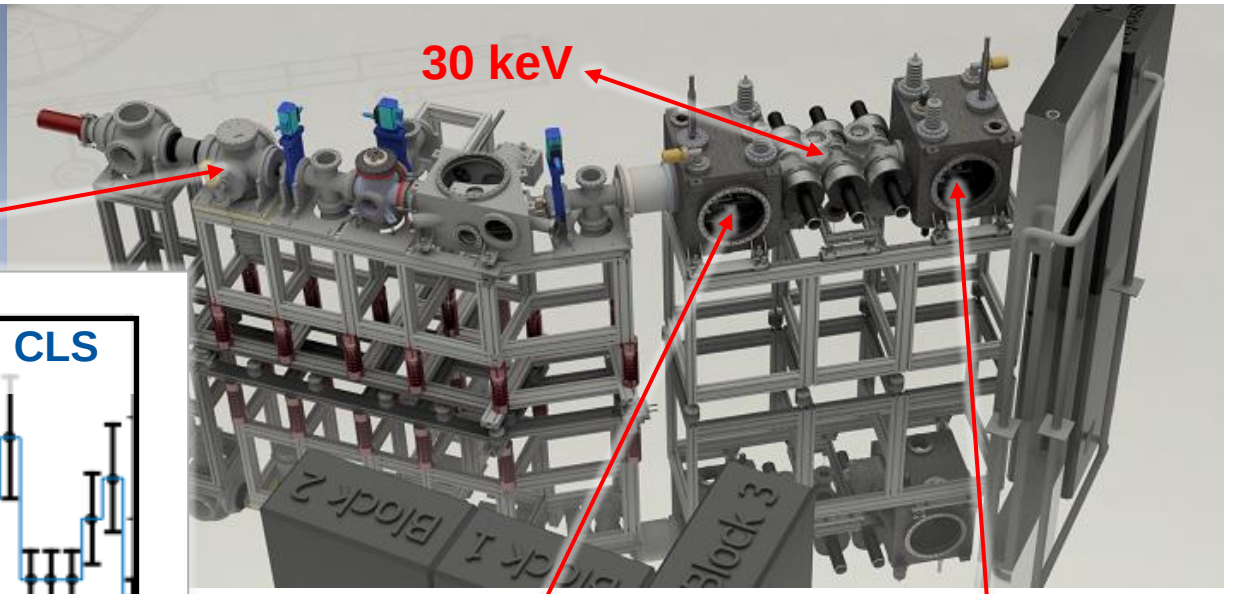
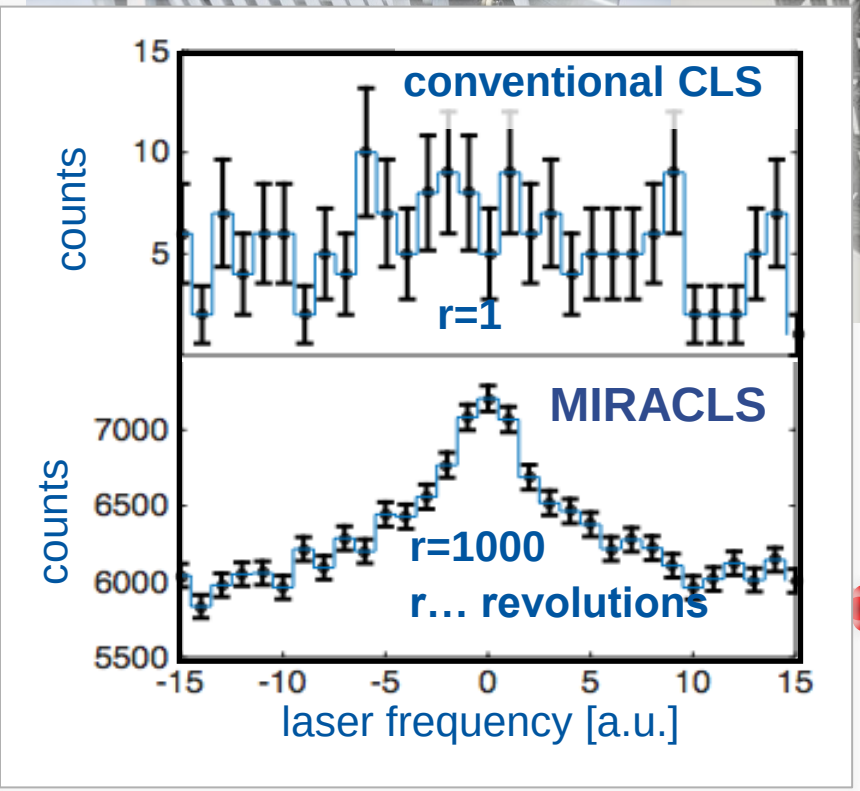
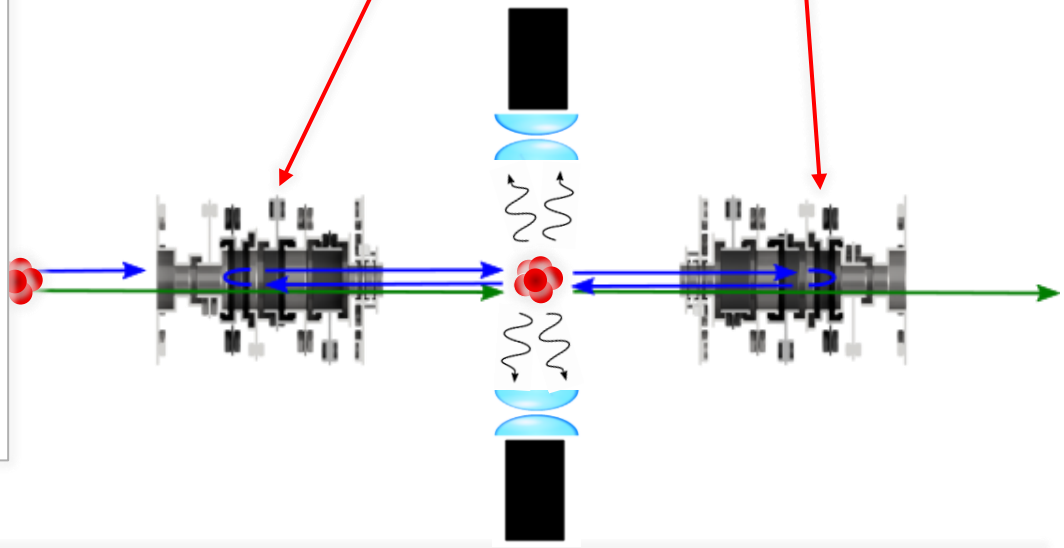
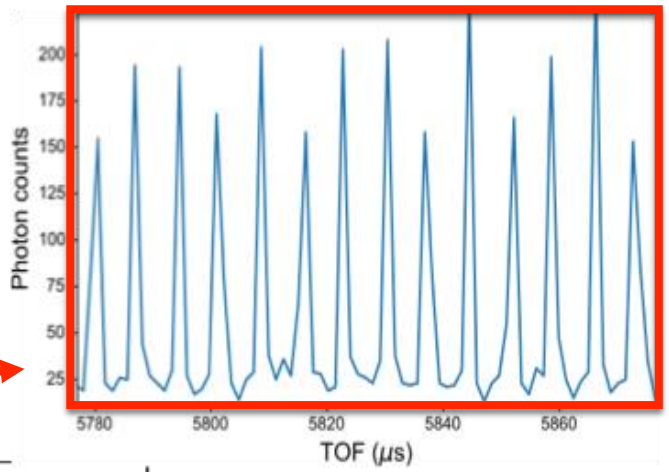


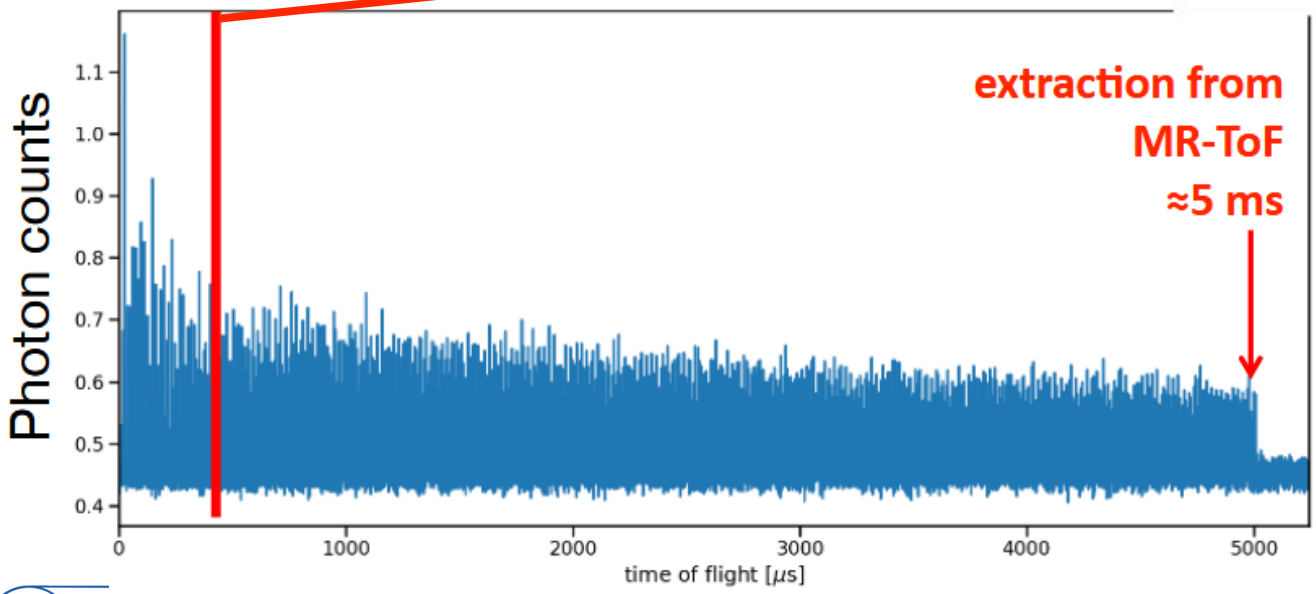



# Proof-of-Principle

- Proof-of-principle campaign successfully completed
  - 2 keV beam energy
  - Systematic studies to validate CLS in an MR-ToF device
  - Development of stray light (background) suppression
  - Work beyond closed 2-level systems
- New MIRACLS setup
  - Increase beam energy to 30 keV for reduced Doppler broadening

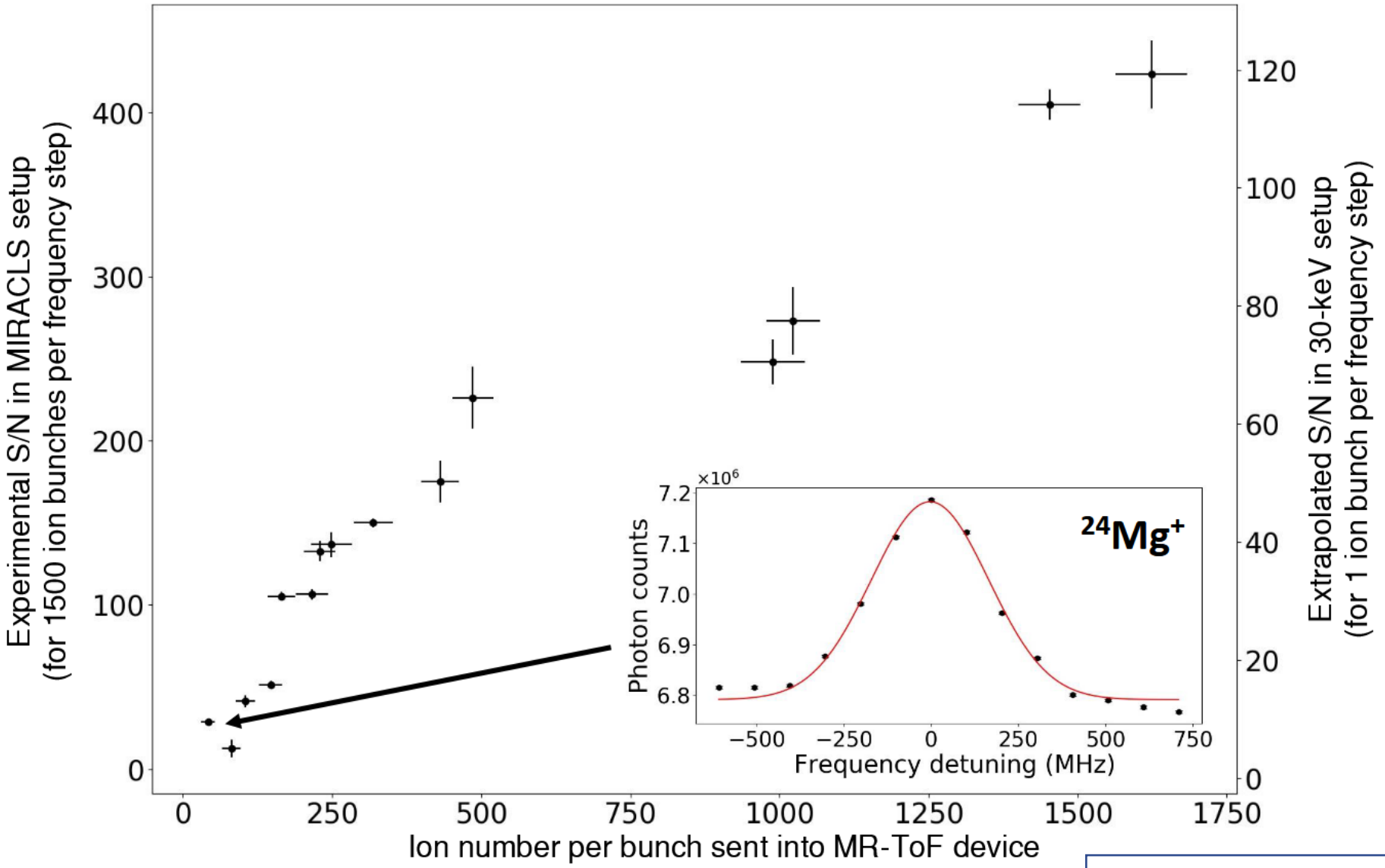




*S. Sels et al., Nucl. Instr. Meth. B 463, 310 (2020)*
*F. Maier et al., Hyperfine Interact. 240, 54 (2019)*
*S. Lechner et al., Hyperfine Interact 240, 95 (2019)*
*V. Lagaki et al., Acta Phys. Pol. B 51, 571 (2020)*
*V. Lagaki et al., Nucl. Inst. Meth. A 1014, 165663 (2021)*
*V. Lagaki et al., in preparation*

# Performance gain for CLS

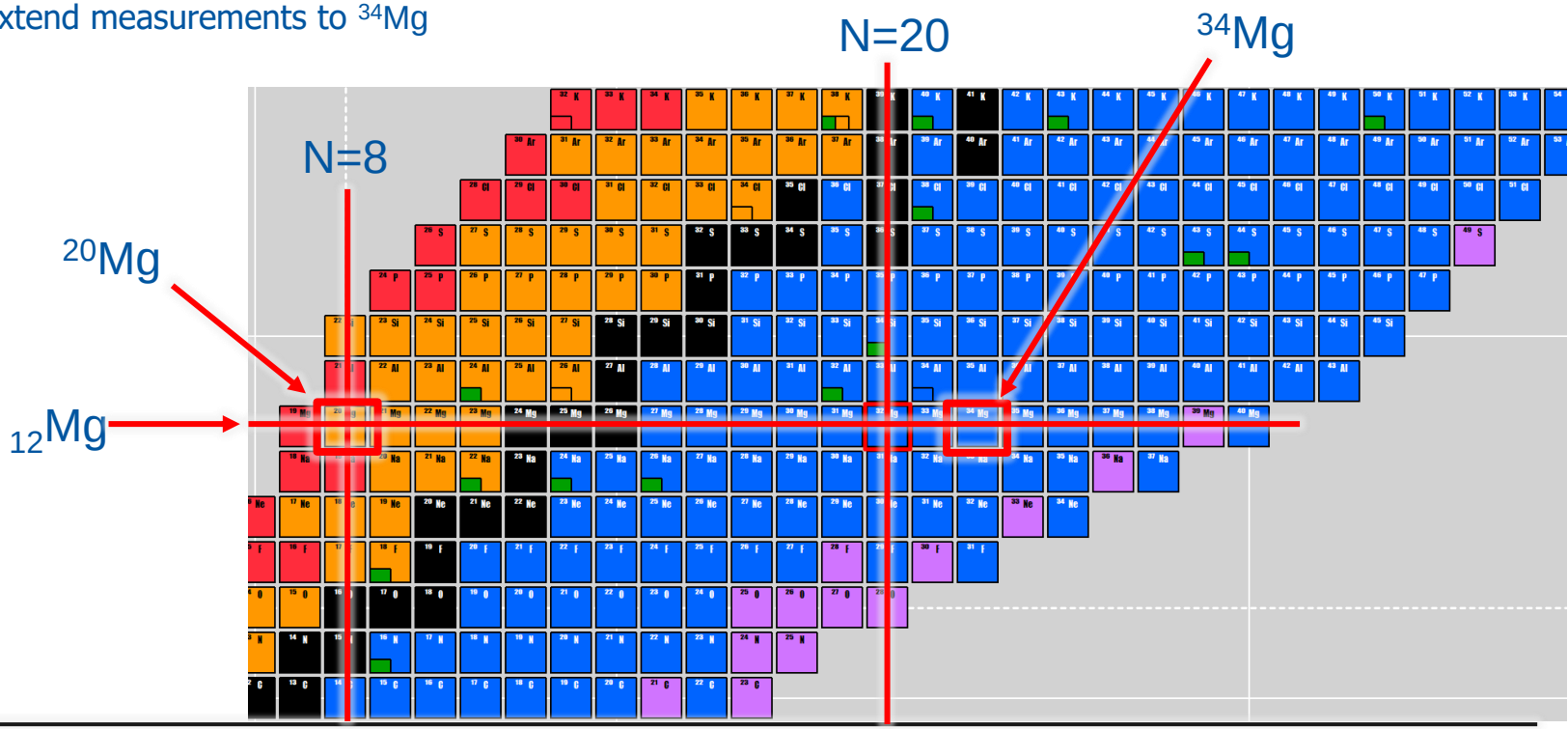



*V. Lagaki et al., in preparation*

# First physics case

- Determine rms charge radii for $^{20,34}$Mg, scheduled for 2022
- Island of Inversion around N=20
  - Anomalous masses and spins discovered already in the 1970s [1,2]
- Disappearing N=20 shell closure for Na, Mg, Al [3]
  - Shell model level inversion for $^{31,32}$Mg
  - Extend measurements to $^{34}$Mg


*[1] C. Thibault, et al. Phys. Rev. C, 12:644–657, Aug 1975*
*[2] G. Huber, et al. Phys. Rev. C, 18:2342–2354, Nov 1978*
*[3] G. Neyens, et al. Eur. Phys. J. Special Topics 150, 149–153 (2007)*

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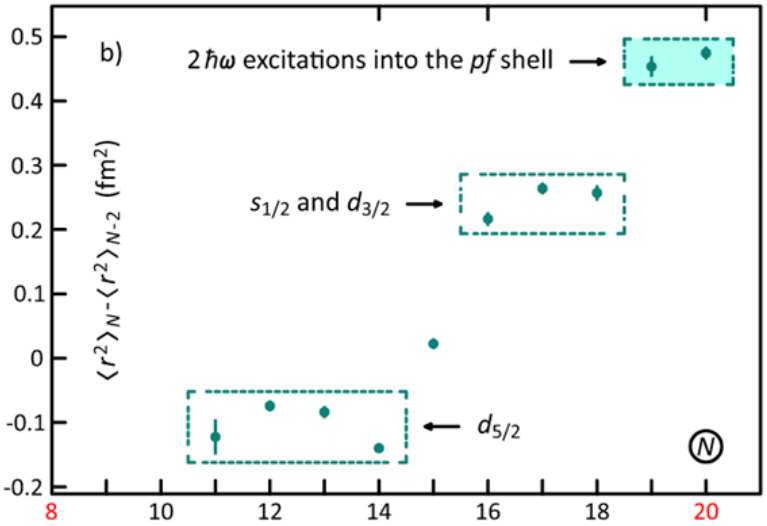


Experimental nuclear differential mean square charge radii.
Figure from D. T. Yordanov, et al., Phys. Rev. Lett., 108:042504, Jan 2012.

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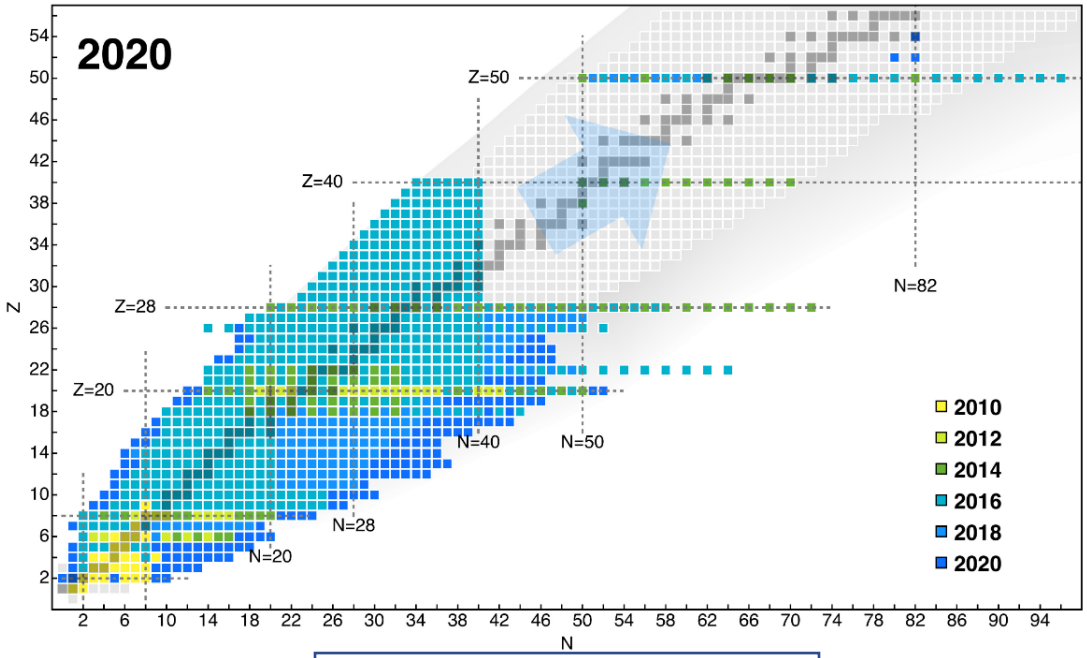
- Disappearing N=20 shell closure for Na, Mg, Al [3]
  - Shell model level inversion for $^{31,32}$Mg
  - Extend measurements to $^{34}$Mg
- Robust shell closure at N=8
  - Extend measurements to $^{20}$Mg
- Ab-initio modeling
  - New open-shell Mg nuclei have recently become available
  - Curious nuclear properties at a suitable mass range


*[1] C. Thibault, et al. Phys. Rev. C, 12:644–657, Aug 1975*
*[2] G. Huber, et al. Phys. Rev. C, 18:2342–2354, Nov 1978*
*[3] G. Neyens, et al. Eur. Phys. J. Special Topics 150, 149–153 (2007)*


*H. Hergert, Front. Phys., 8:379 (2020)*


STAR6

# Outline:

- MIRACLS
  - Novel approach to Collinear Laser Spectroscopy (CLS)
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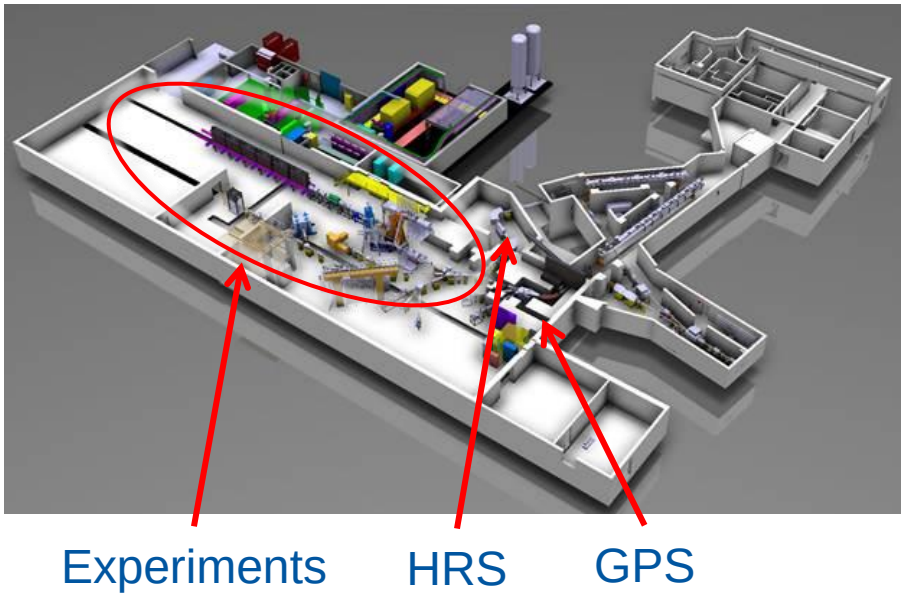
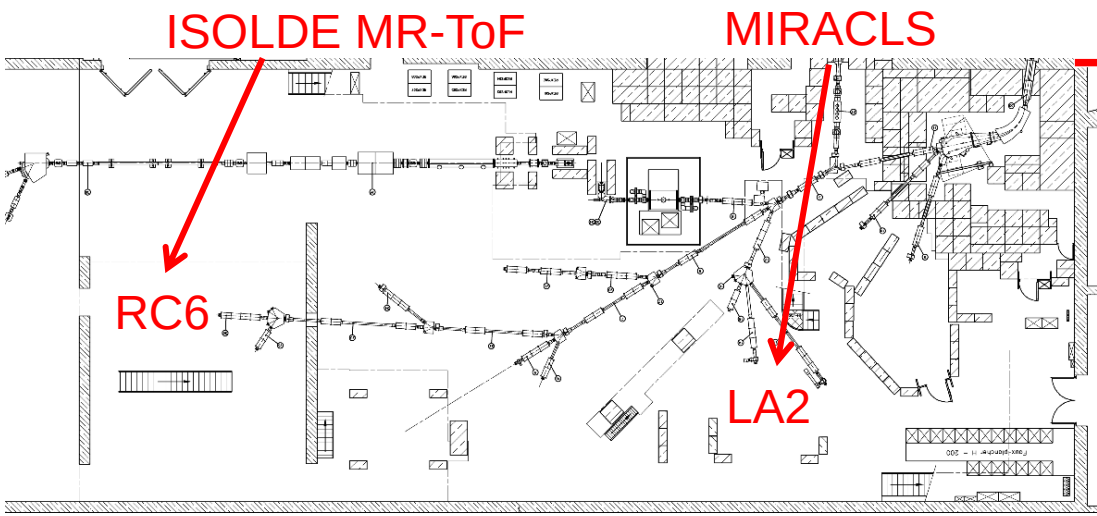
# Beam purification at ISOLDE

- Two magnetic mass separators, GPS and HRS
  - Mass resolving powers R of 800 and 6000 [1]
  - Fast & high ion capacity
- Higher R needed for isobaric purification
  - Experiments far away from stability
  - solid state physics, medical isotopes (e.g. rare earth region)
- Requirements
  - High ion capacity per unit time
  - R > 10^5
  - Fast processing, < 1 ms cycle time
  - Compact system

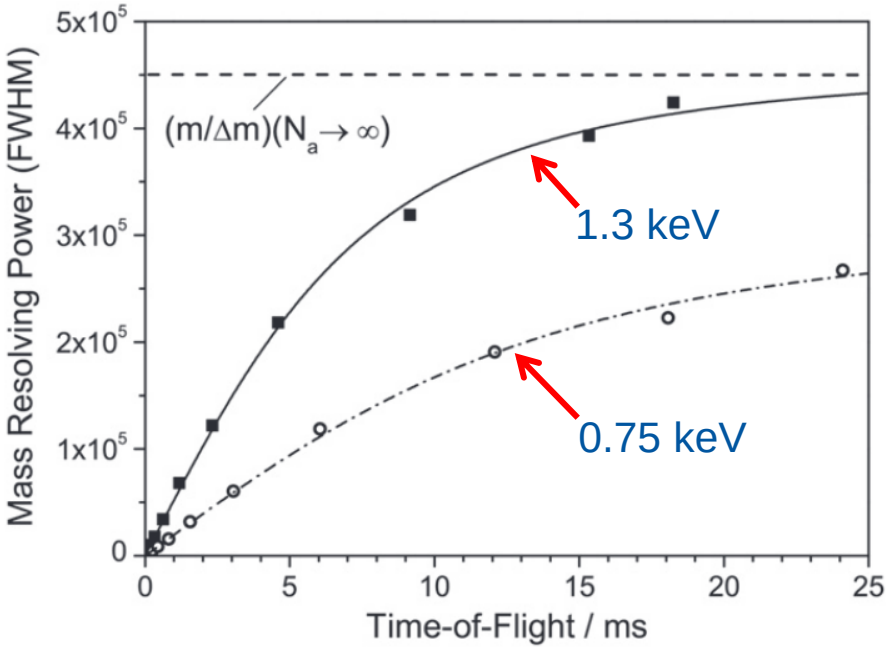
→ 30 keV MR-ToF MS with improved beam preparation



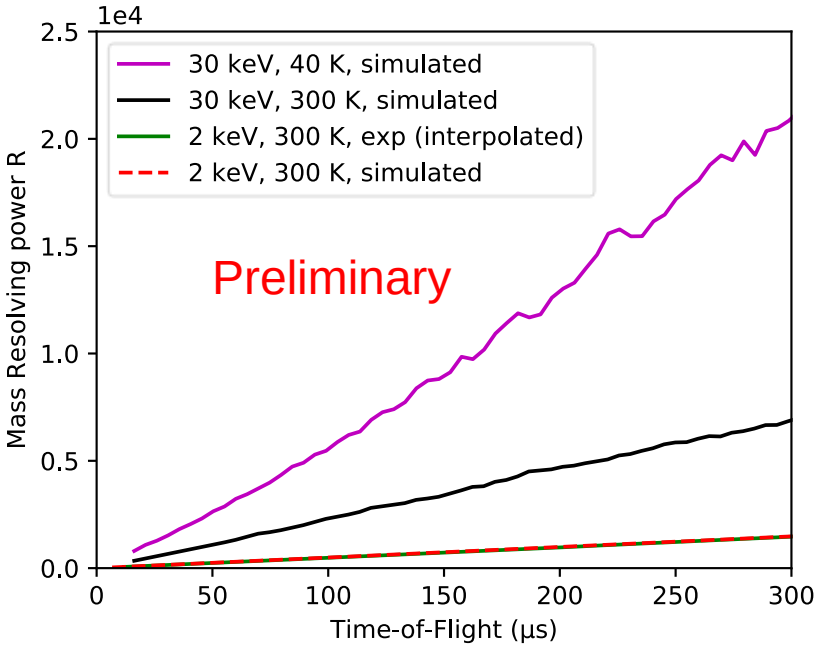



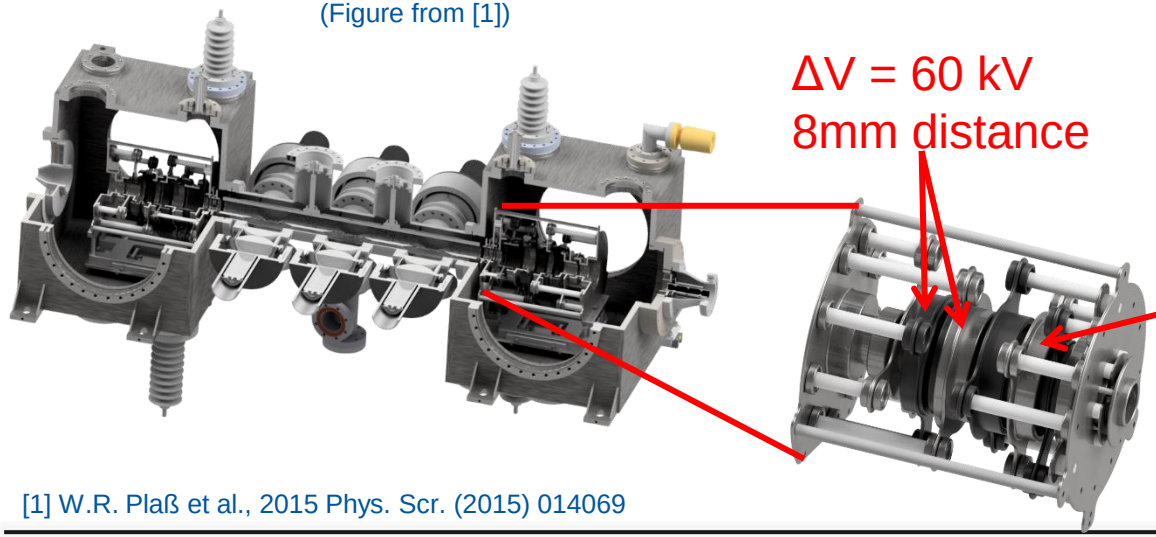

[1] R. Catherall, et al., J. Phys. G: Nucl. Part. Phys.44 (2017) 094002

# Mass resolving power R




(Figure from [1])

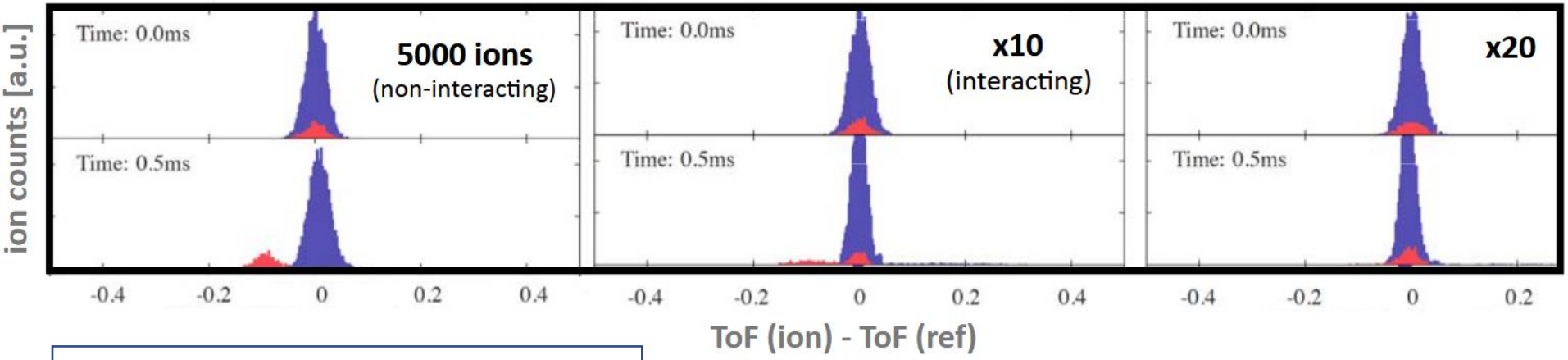


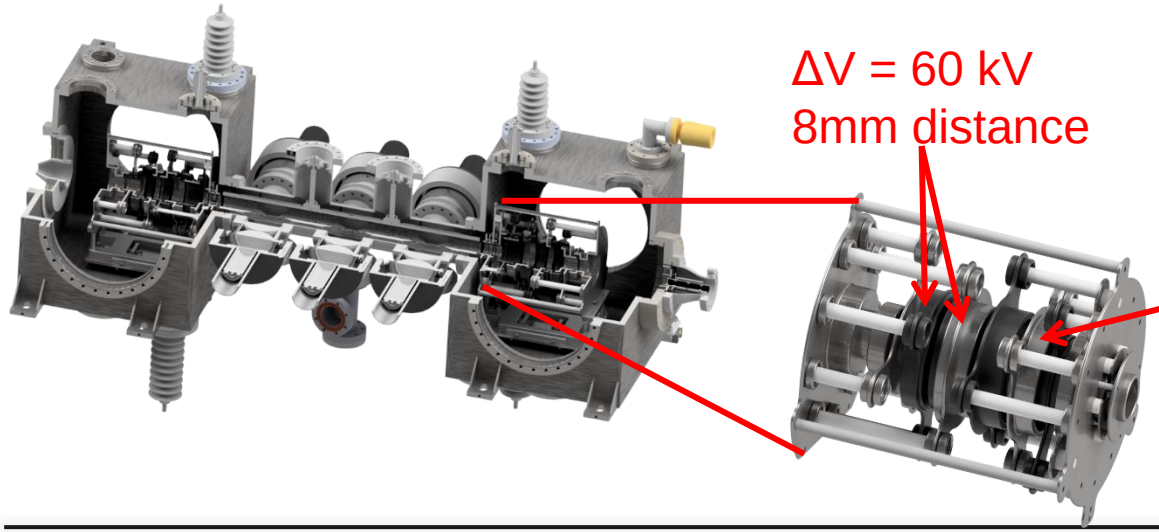

[1] W.R. Plaß et al., 2015 Phys. Scr. (2015) 014069

# Ion capacity

**Simulation:**




*M. Rosenbusch et al., AIP Conf. Proc. 1521, 53 (2013)*

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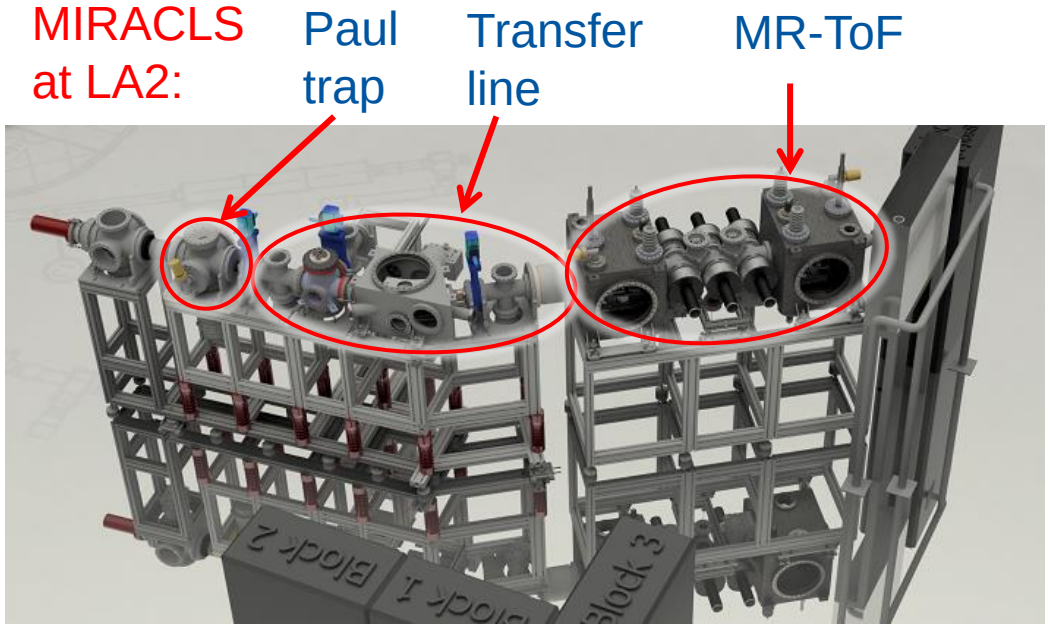
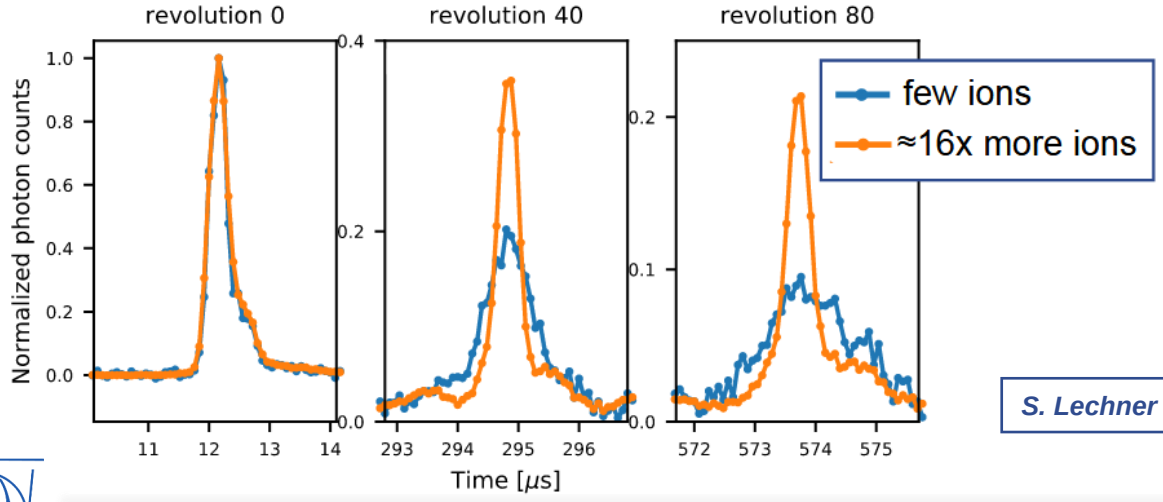
# Simultaneous development

- Shared Paul trap and MR-ToF device
- Fluoresence detection as non-destructive diagnostics
  - Revolution-by-revolution monitoring
  - Optimisation of operating parameters
  - Space charge studies
- Laser-cooled ion samples
  - Optimal cooling
  - See talk by F. Maier

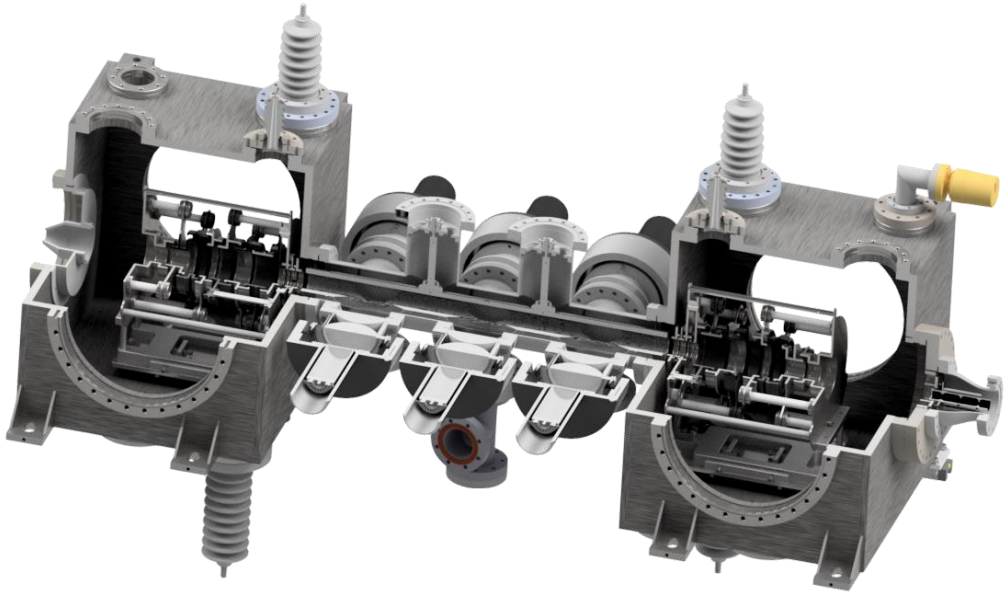



*S. Lechner et al., Hyperfine Interact 240, 95 (2019)*

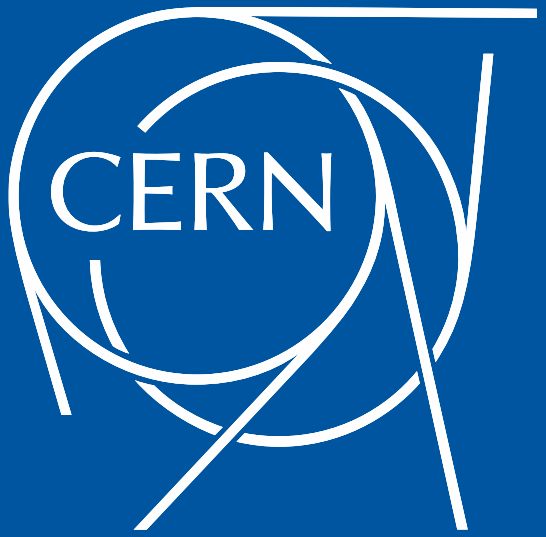
# Summary

- MIRACLS under construction
  - Novel approach to fluorescence-based CLS
  - Improved sensitivity via trapping 30-keV ion bunches
  - First physics in 2022
- ISOLDE MR-ToF
  - General-purpose isobaric beam purification system
  - R = 10^5 in < 1 ms
  - Improved ion capacity
- Synergy between projects
  - Shared ion traps
  - Novel beam diagnostics
  - Laser cooling



# Thank you for your attention!

L. Croquette, F. Buchinger, P. Fischer, S. J. Freeman, C. Kanitz, S. Lechner, F. Maier, P. Plattner, G. Neyens, W. Nörtershäuser, L. Schweikhard, R. Simpson, M. Vilén, F. Wienholtz, S. Malbrunot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