Status of the LASPEC Prototype at TRIGA Mainz

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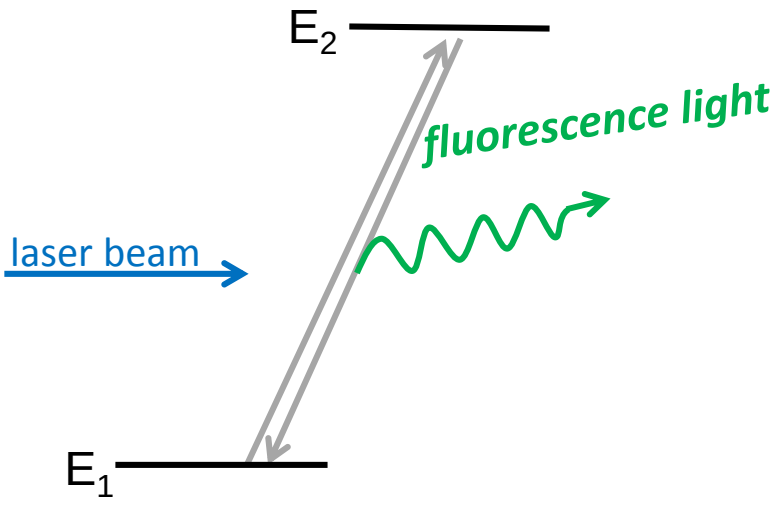
Outline

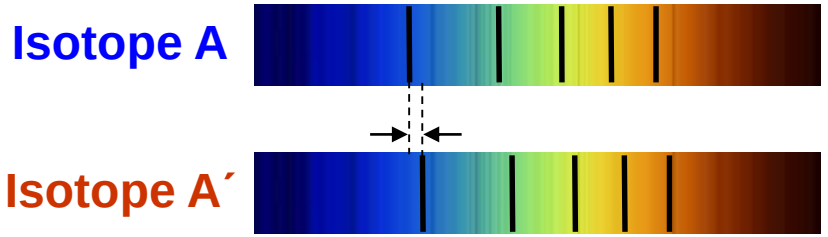
- Collinear laser spectroscopy (CLS)
  - Principle
  - Overview of LaSpec – CLS at FAIR
- TRIGA-SPEC development platform for LaSpec
  - Overview and status
  - Commissioning runs with stable Ca^{+}
  - Control system and DAQ
- Outlook

collinear laser spectroscopy – basic principle

resonant laser excitation and fluorescence detection

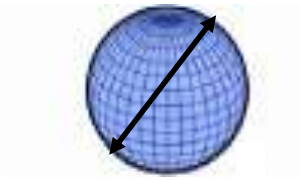


Isotope shift:

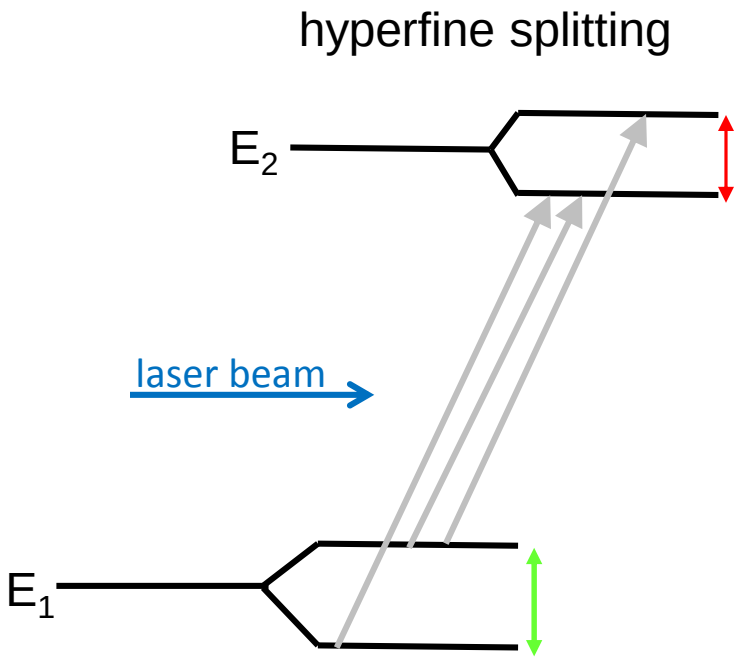


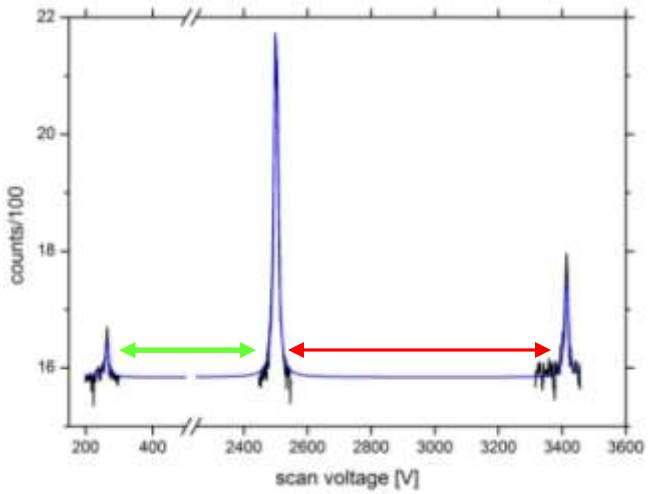
$$\delta\nu^{A,A'} = (K_{NMS} + K_{SMS}) \times \frac{A - A'}{AA'} + F \times \delta\langle r^2 \rangle^{A,A'}$$

charge radius



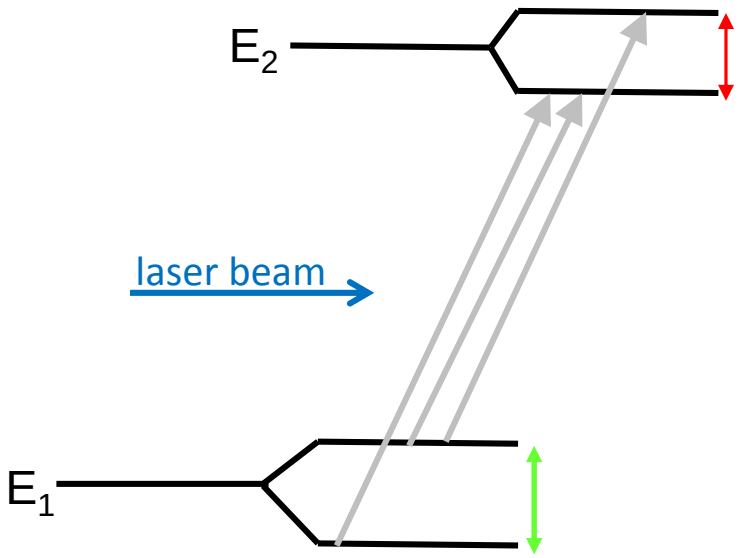
collinear laser spectroscopy – basic principle

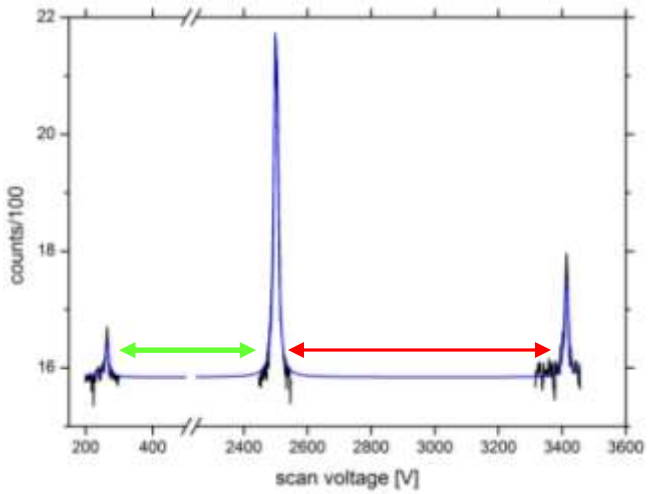




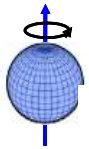
collinear laser spectroscopy – basic principle

hyperfine splitting



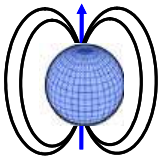


nuclear spin



$\mathbf{F} = \mathbf{I} + \mathbf{J}$

nuclear magnetic moment

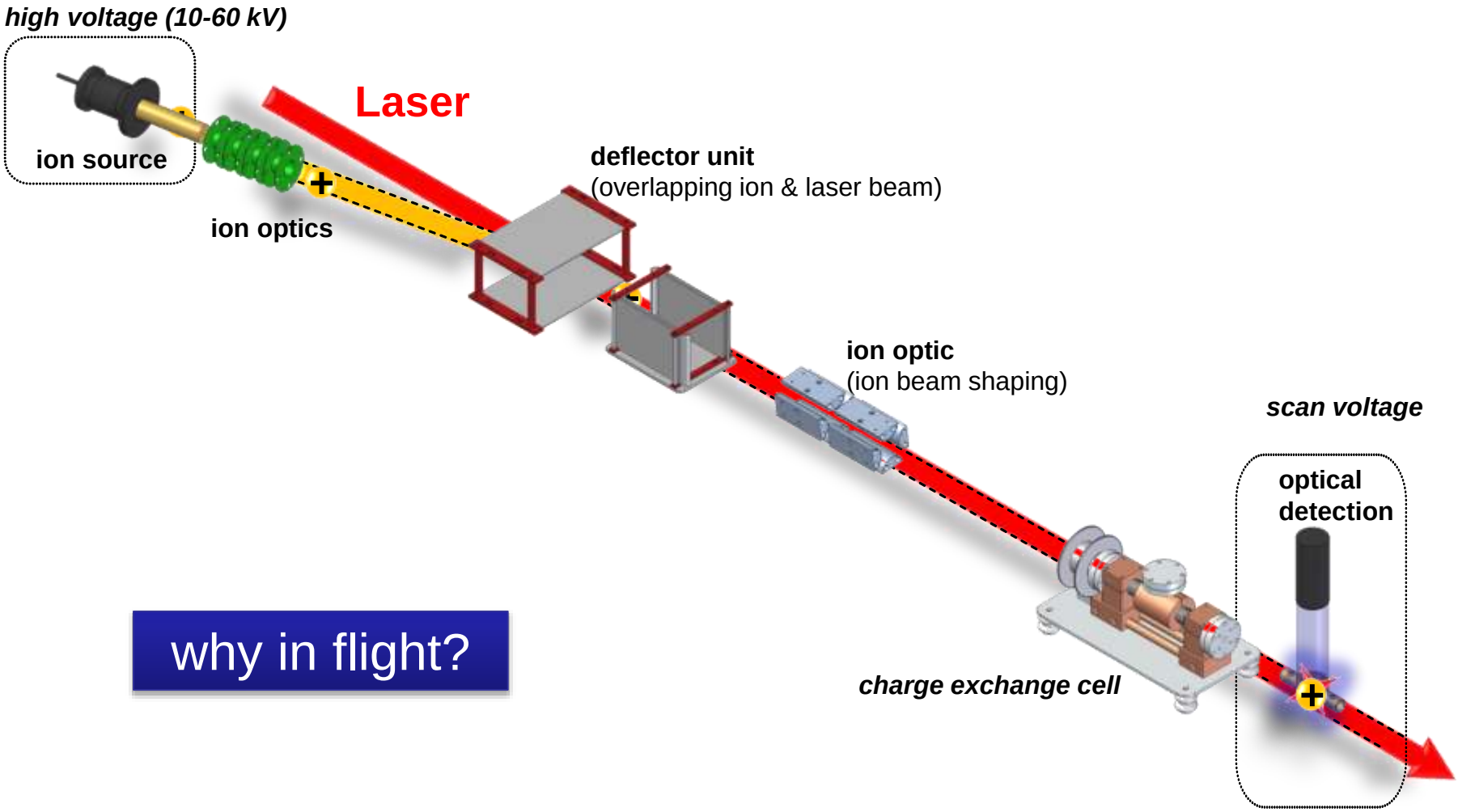


$A = \frac{\mu_I H(0)}{\mathbf{I}\,\mathbf{J}}$

electrical quadrupole moment

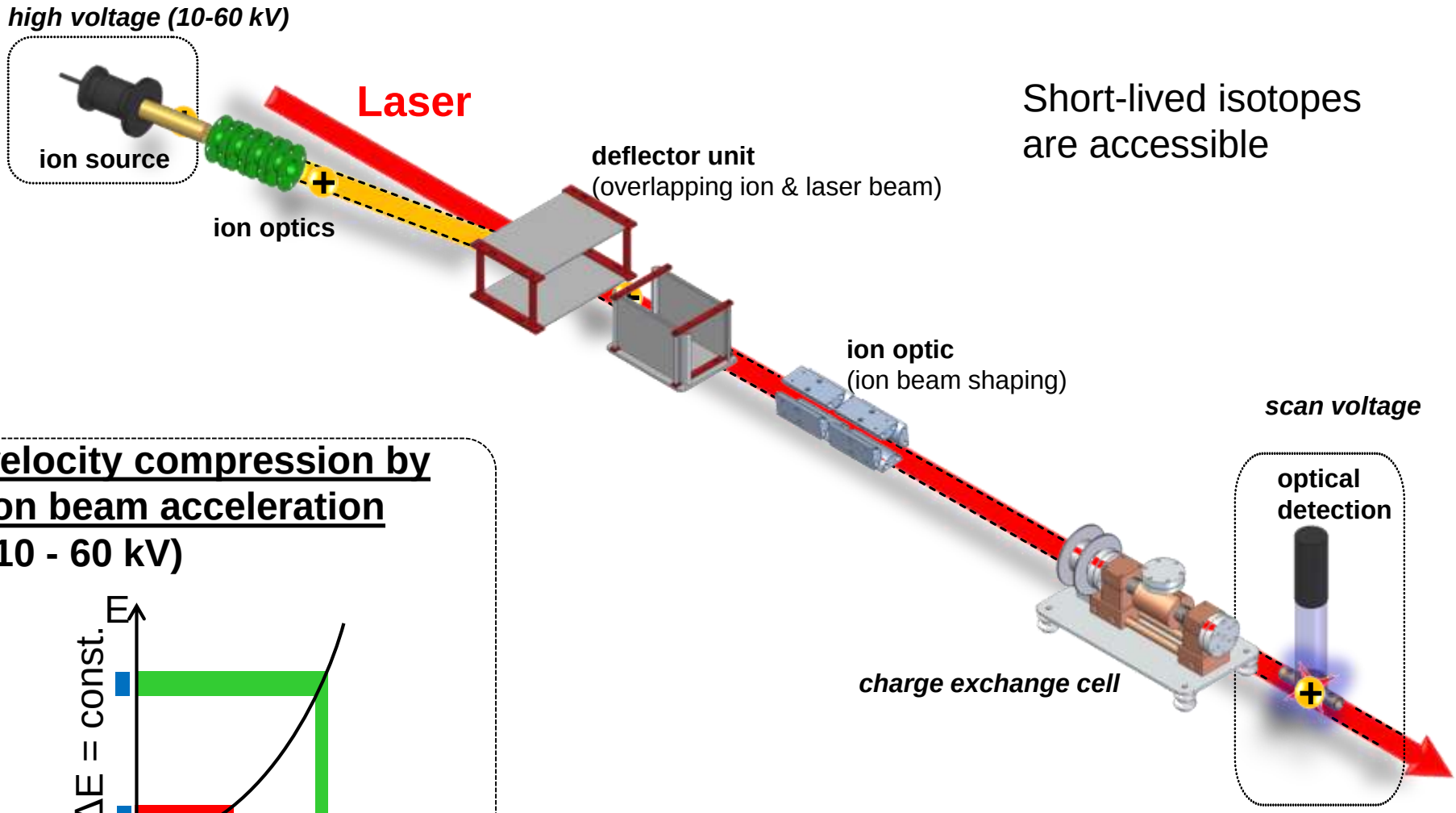
$B = e\,Q\,V_{zz}(0)$

CLS – typical setup



why in flight?

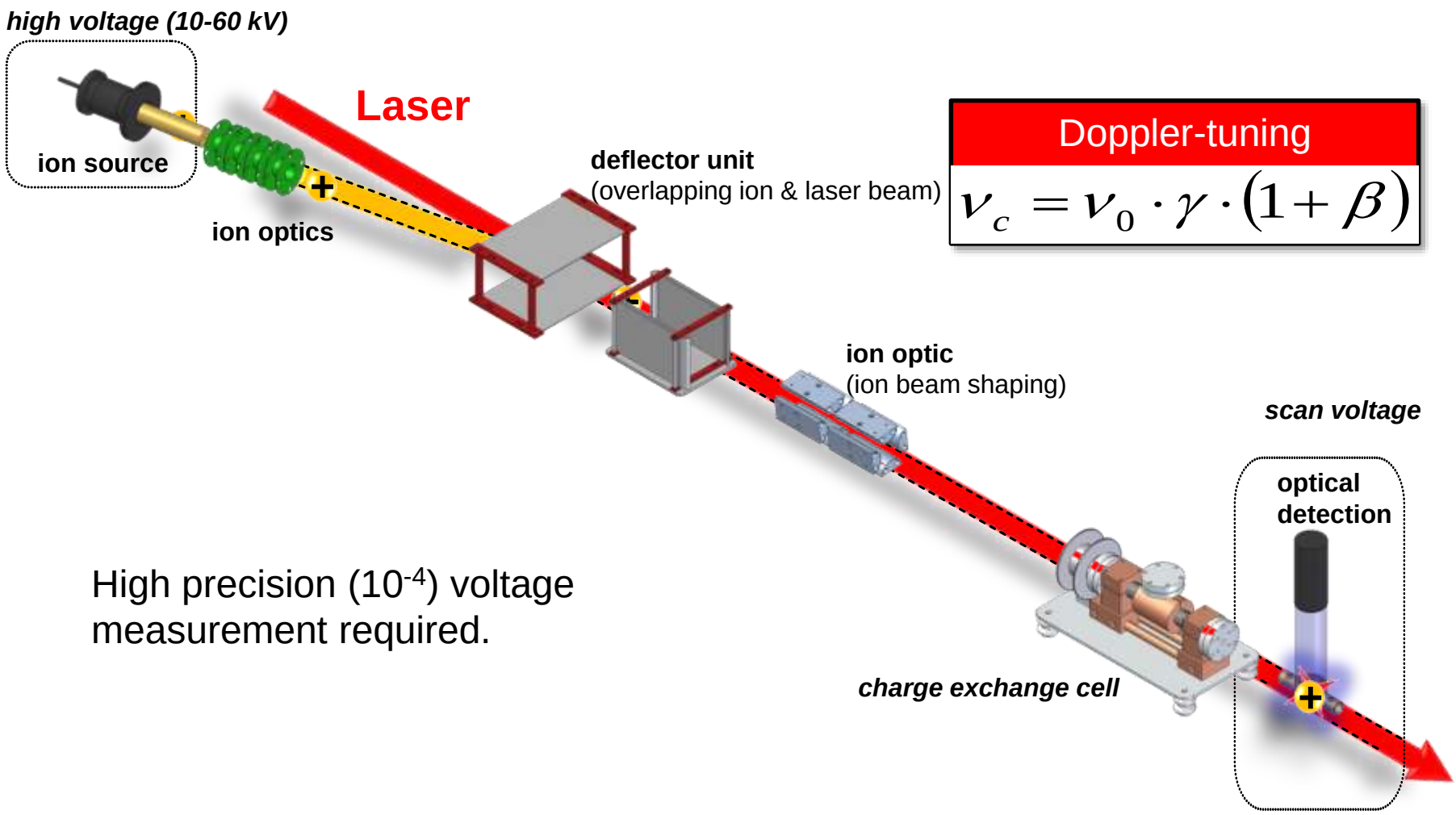
CLS – typical setup



Short-lived isotopes
are accessible

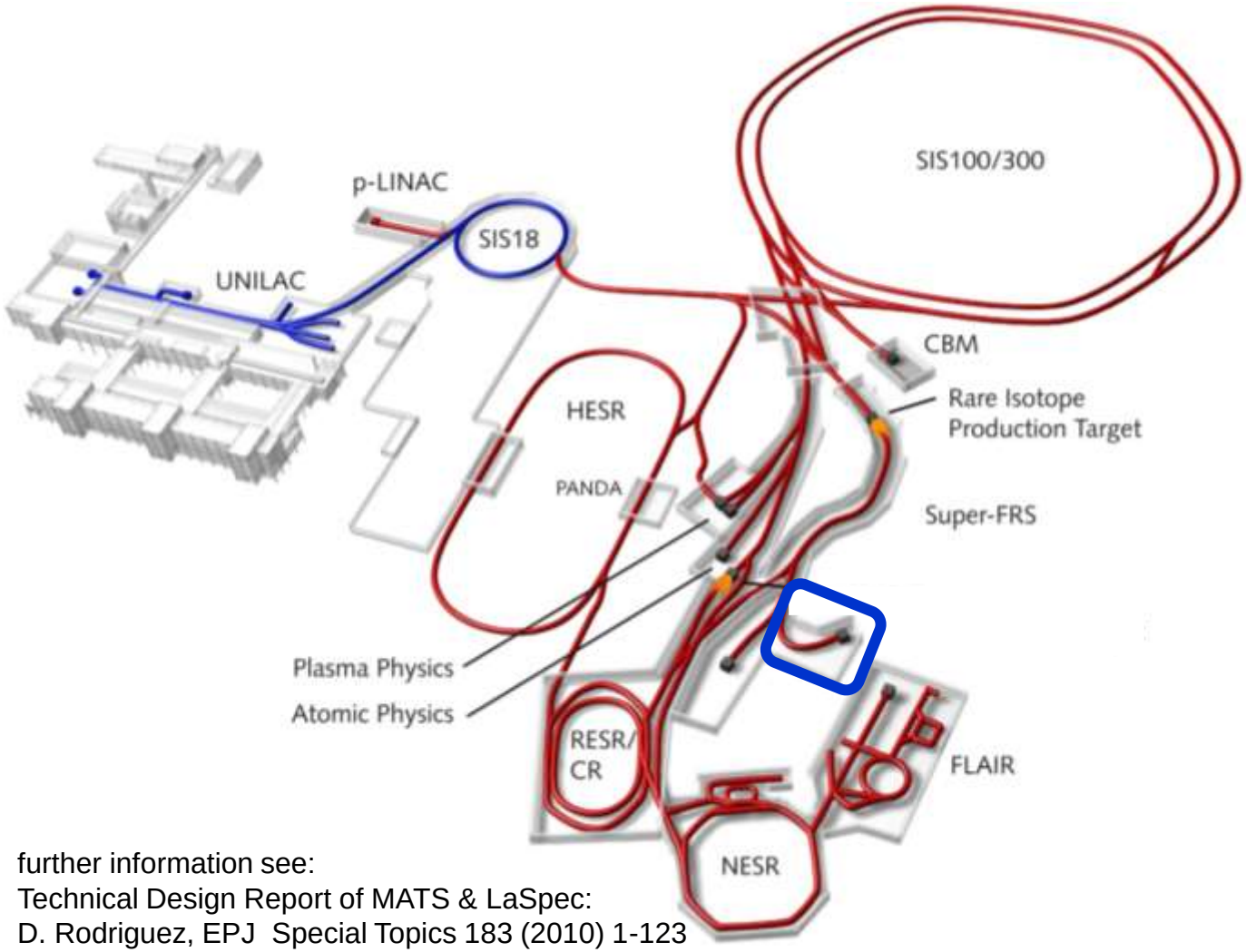
velocity compression by ion beam acceleration (10 - 60 kV)

CLS – typical setup



High precision (10^{-4}) voltage measurement required.

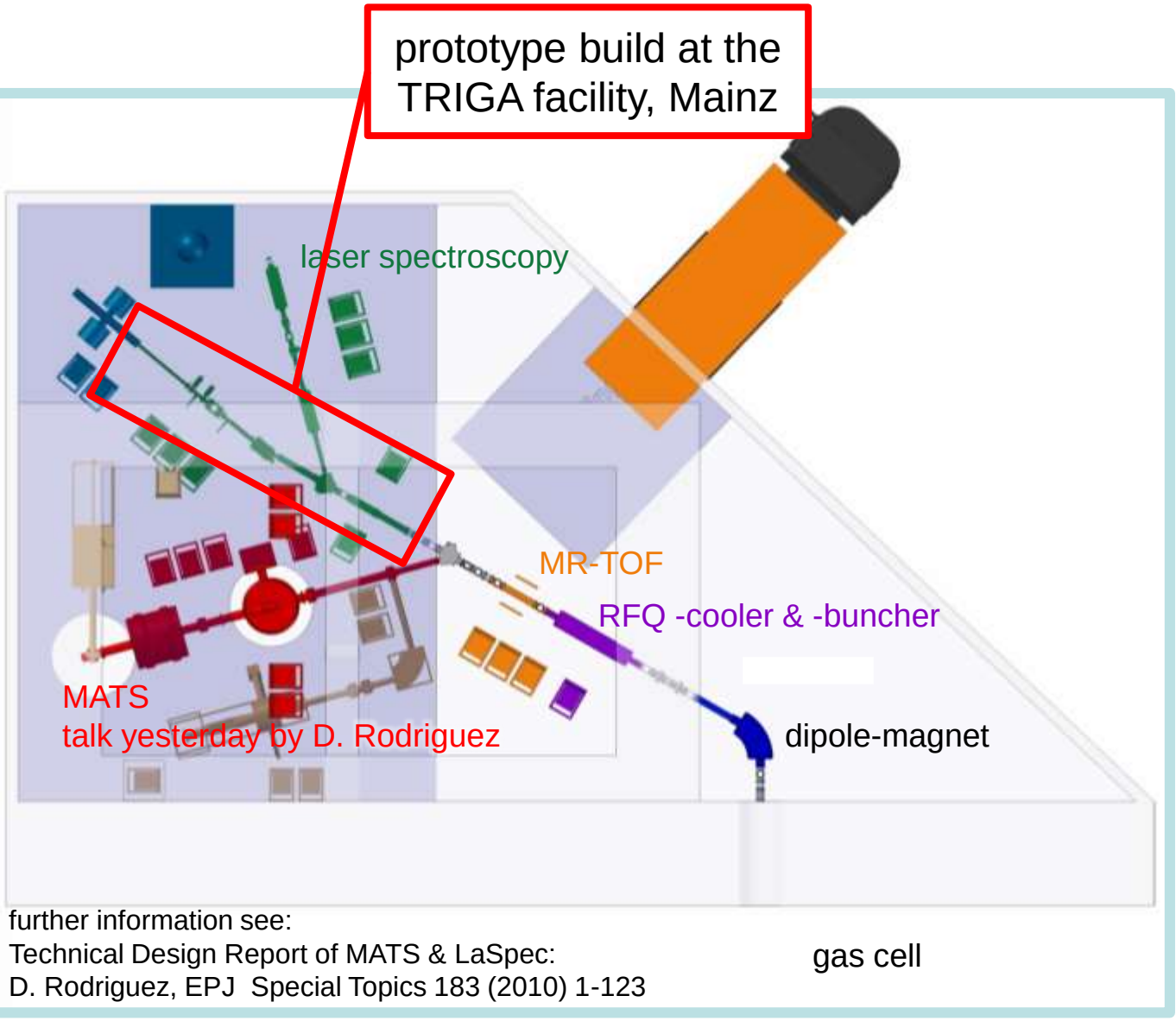
collinear laser spectroscopy - at FAIR



LaSpec
LEB @ FAIR

further information see:
Technical Design Report of MATS & LaSpec:
D. Rodriguez, EPJ Special Topics 183 (2010) 1-123

collinear laser spectroscopy - at FAIR



further information see:
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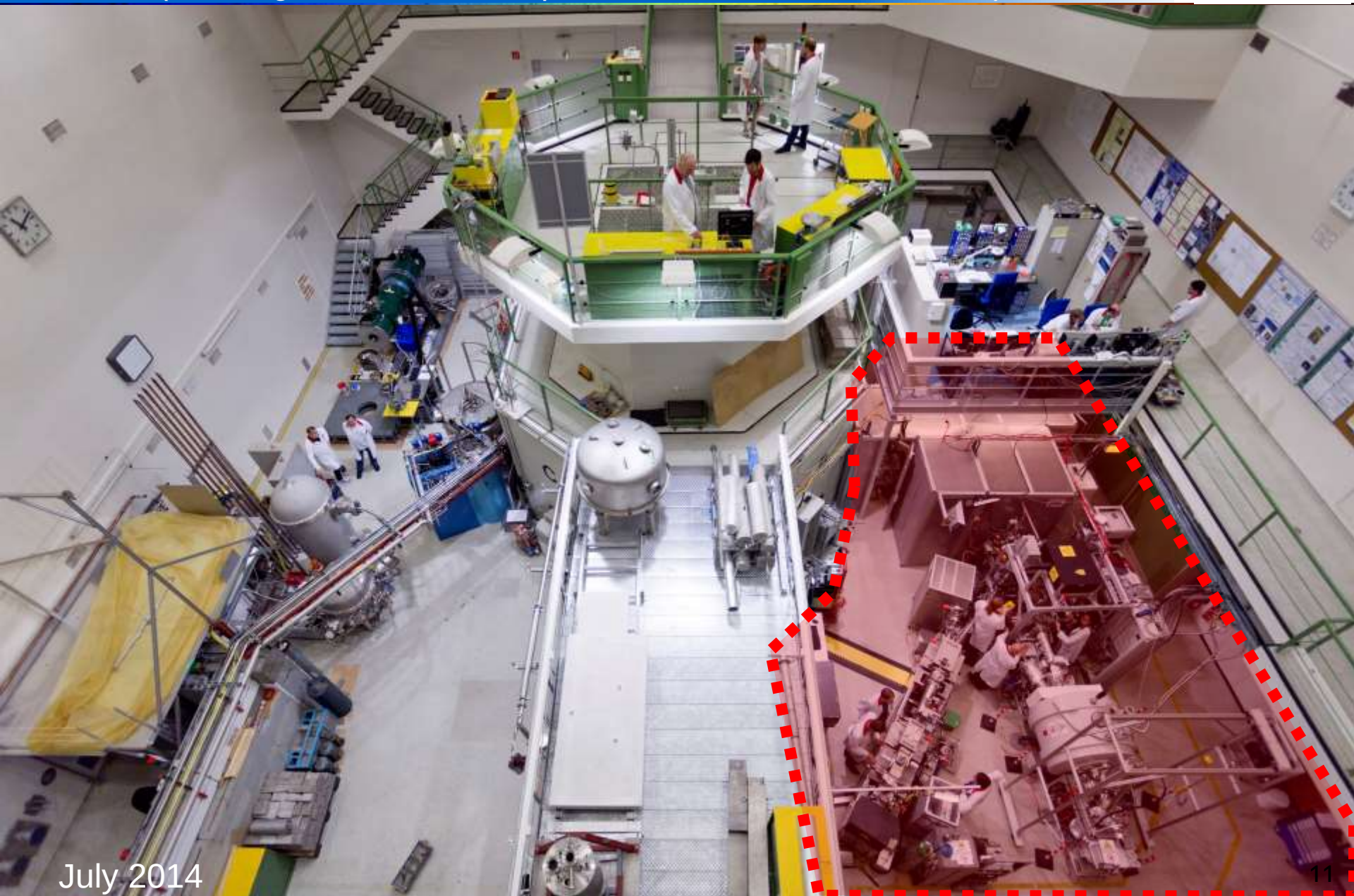
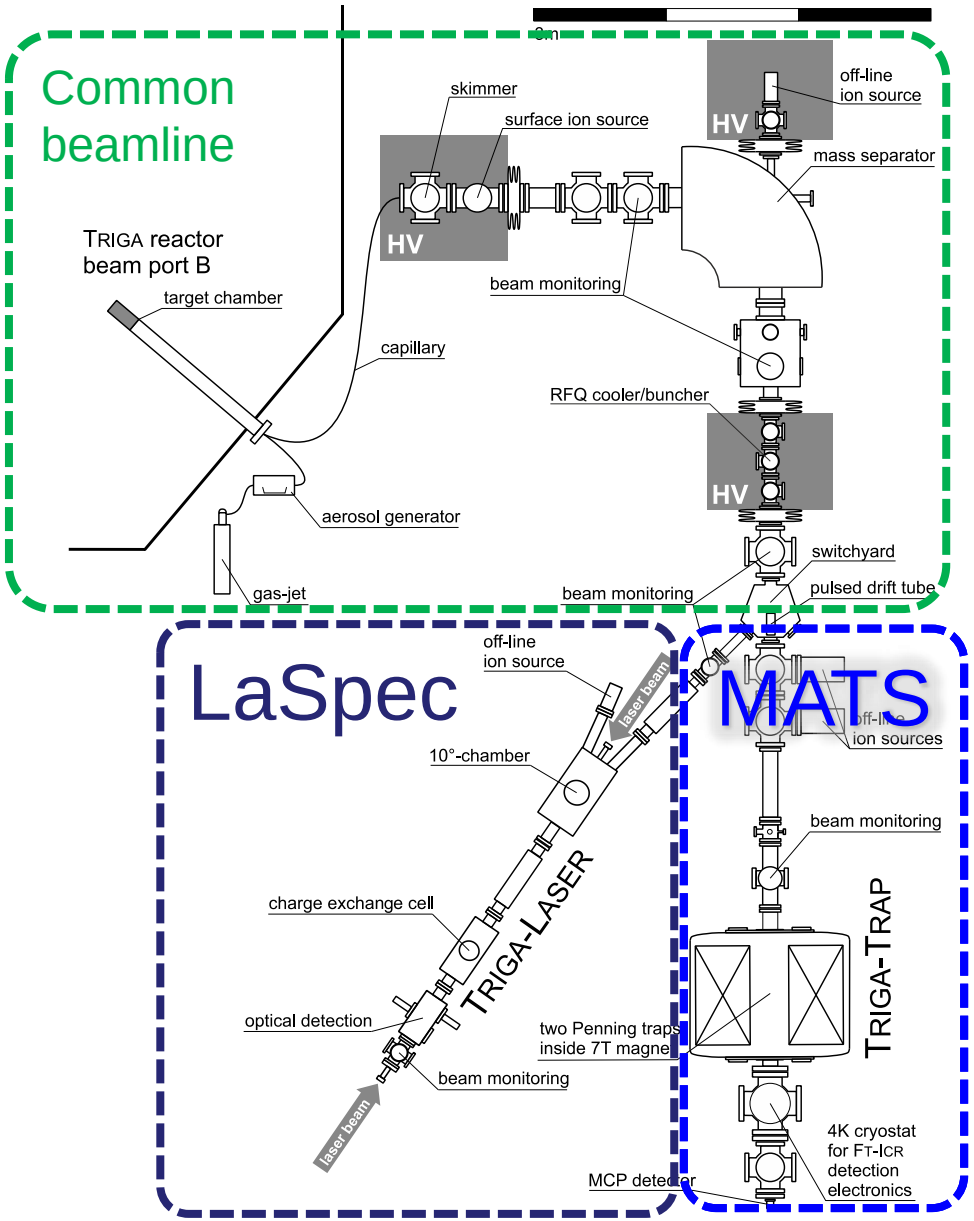
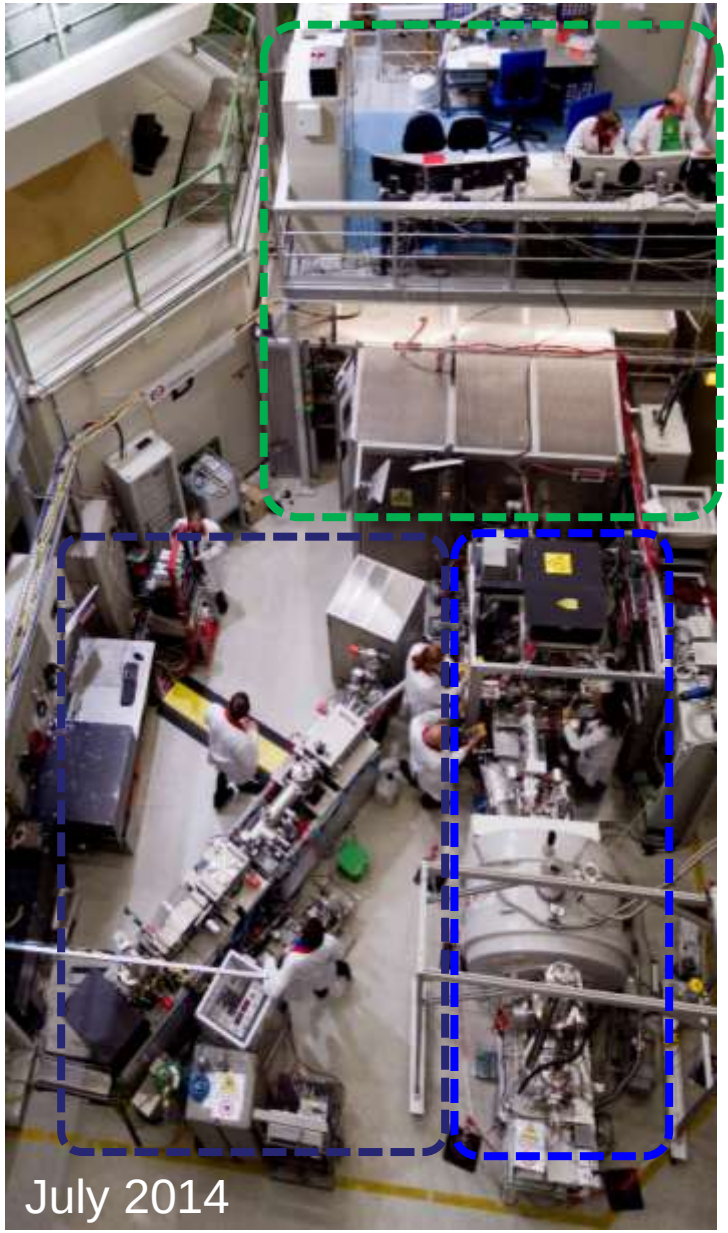
TRIGA –SPEC

(**T**raining, **R**esearch, **I**sotope Production, **G**eneral **A**tomic)



TRIGA-SPEC - Overview





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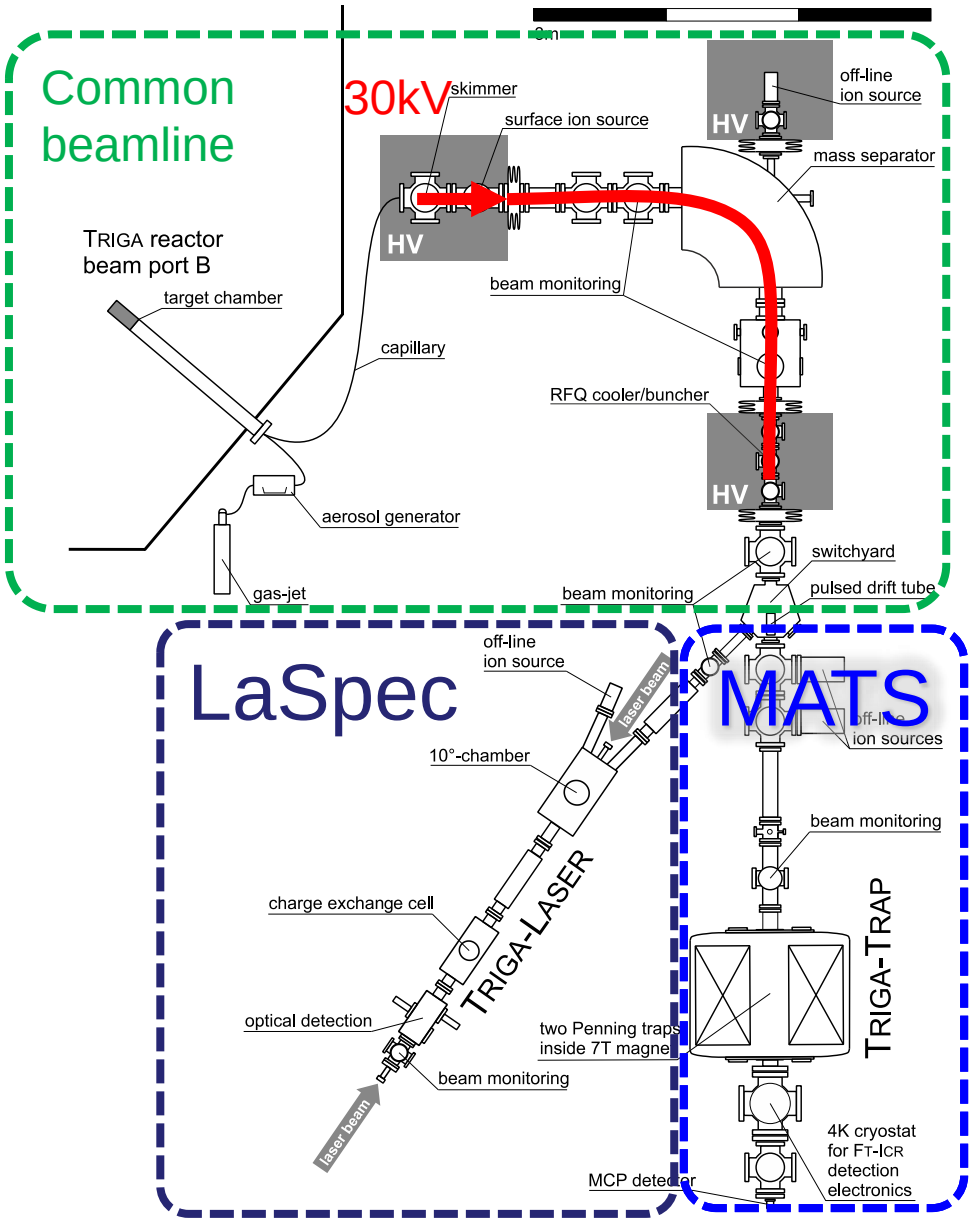

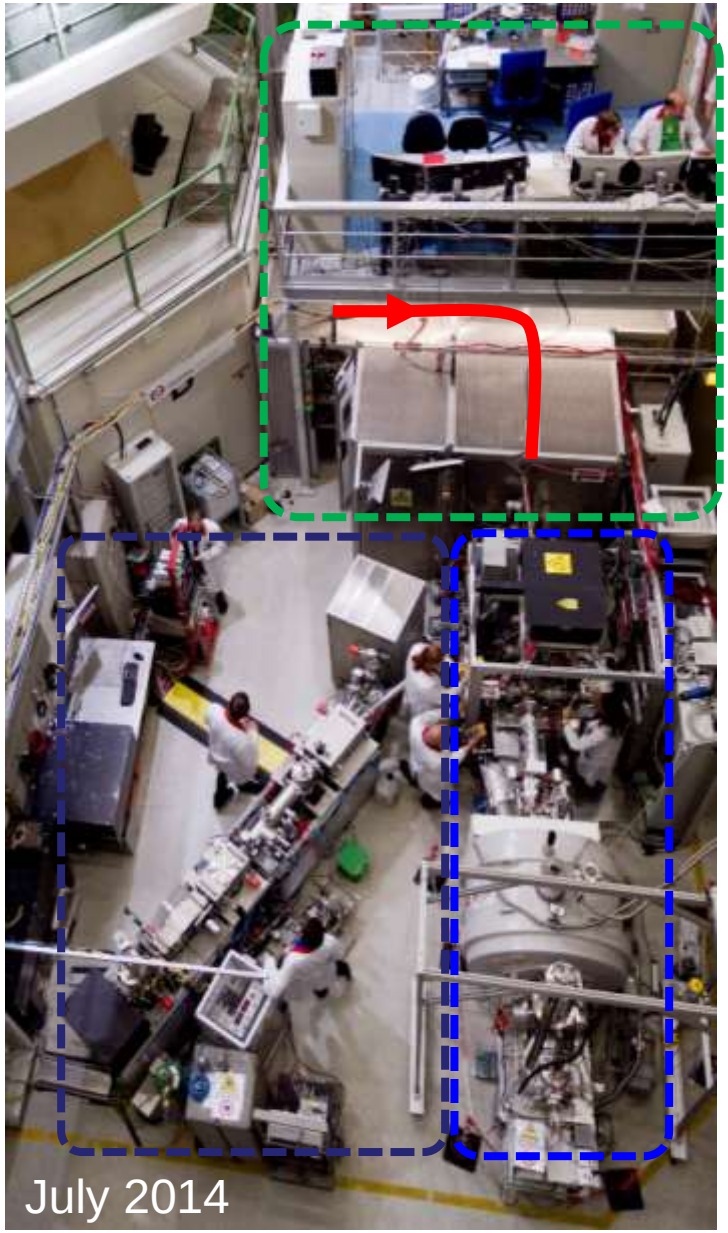

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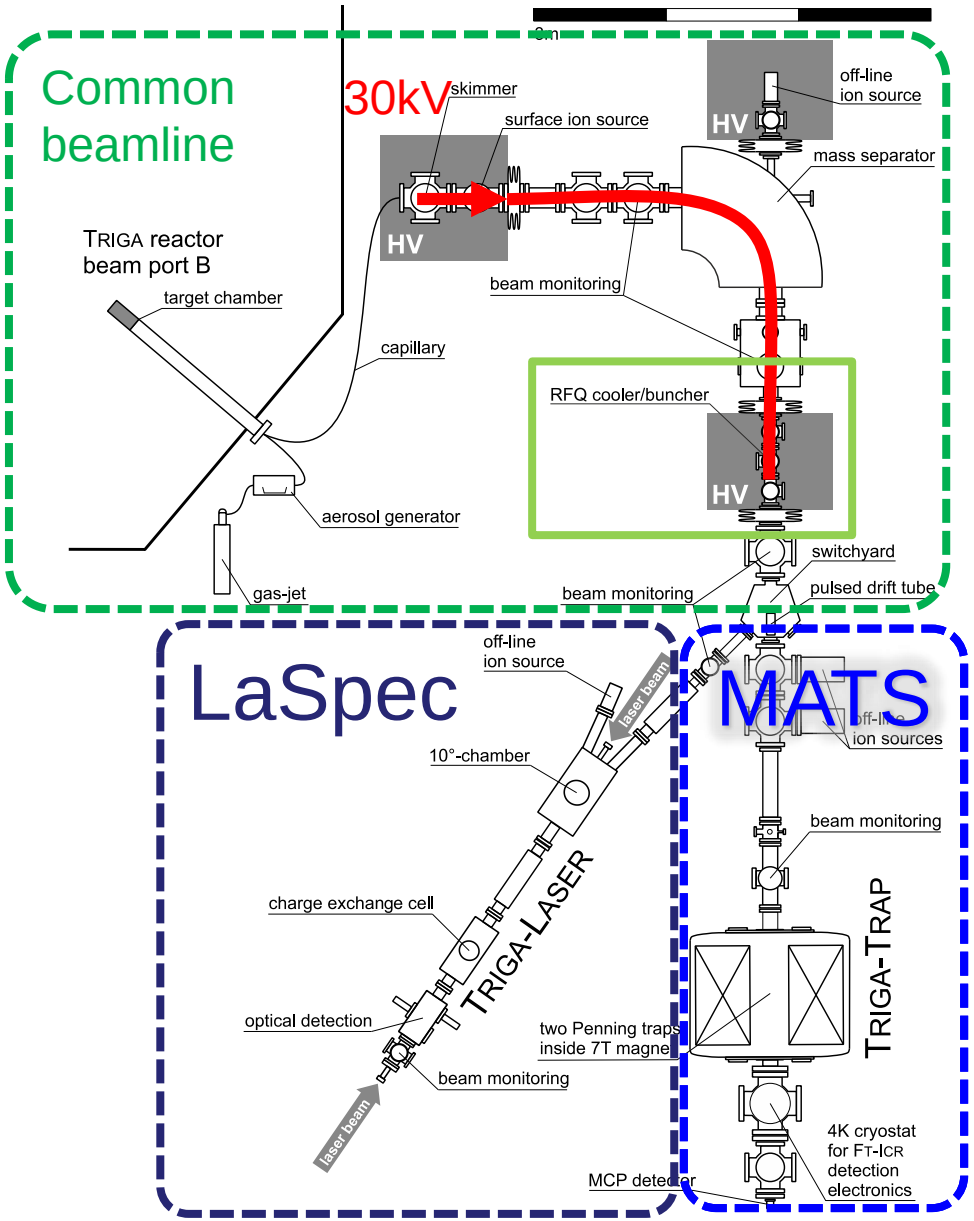
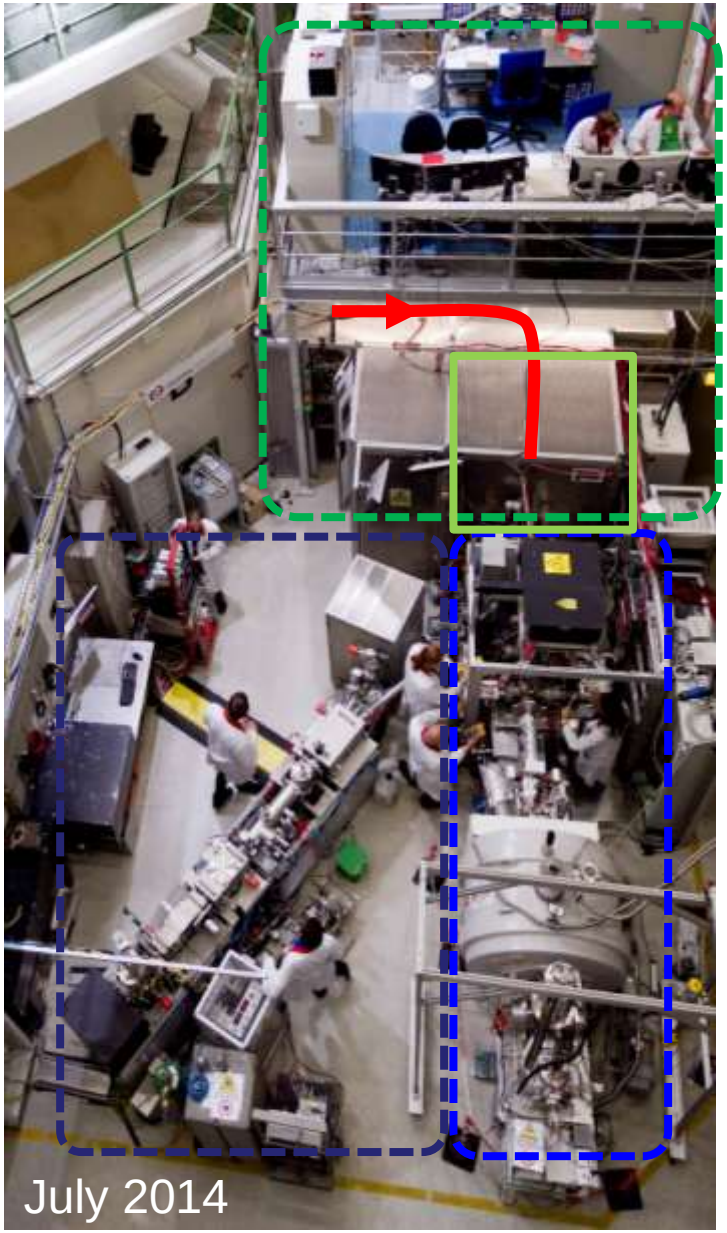
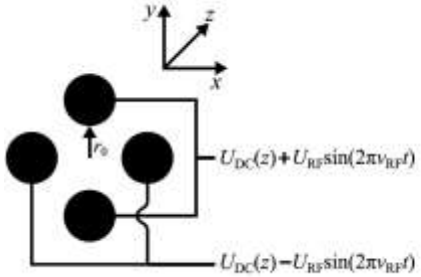


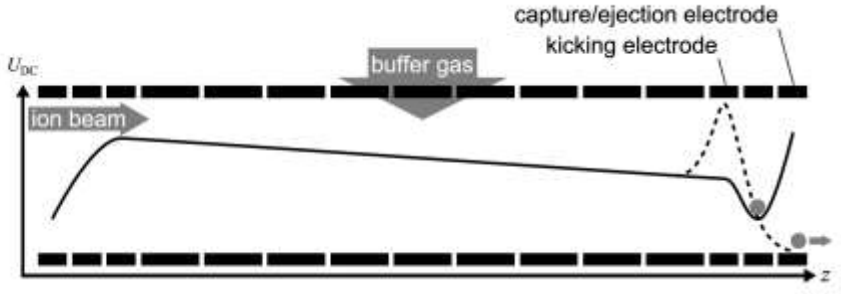


TRIGA-SPEC - Overview

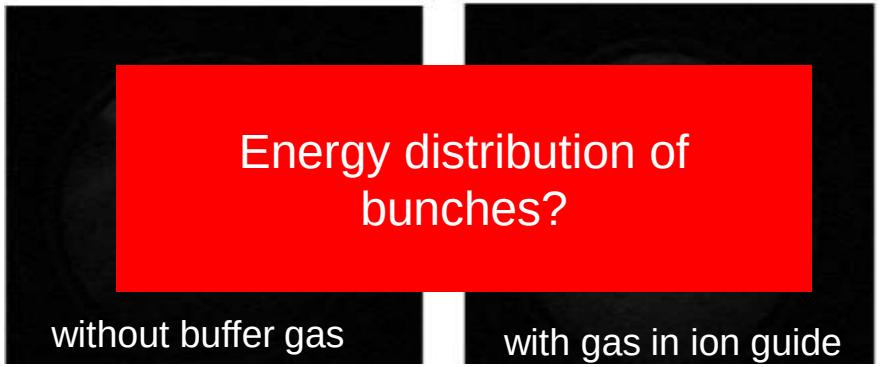
COLETTE
„cooler for emittance elimination“

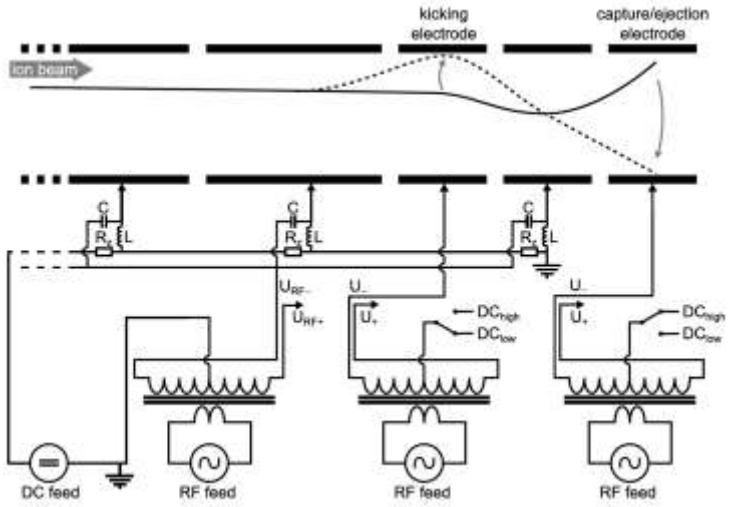
- used in MISTRAL until 2010 only in continuous-mode for beam cooling





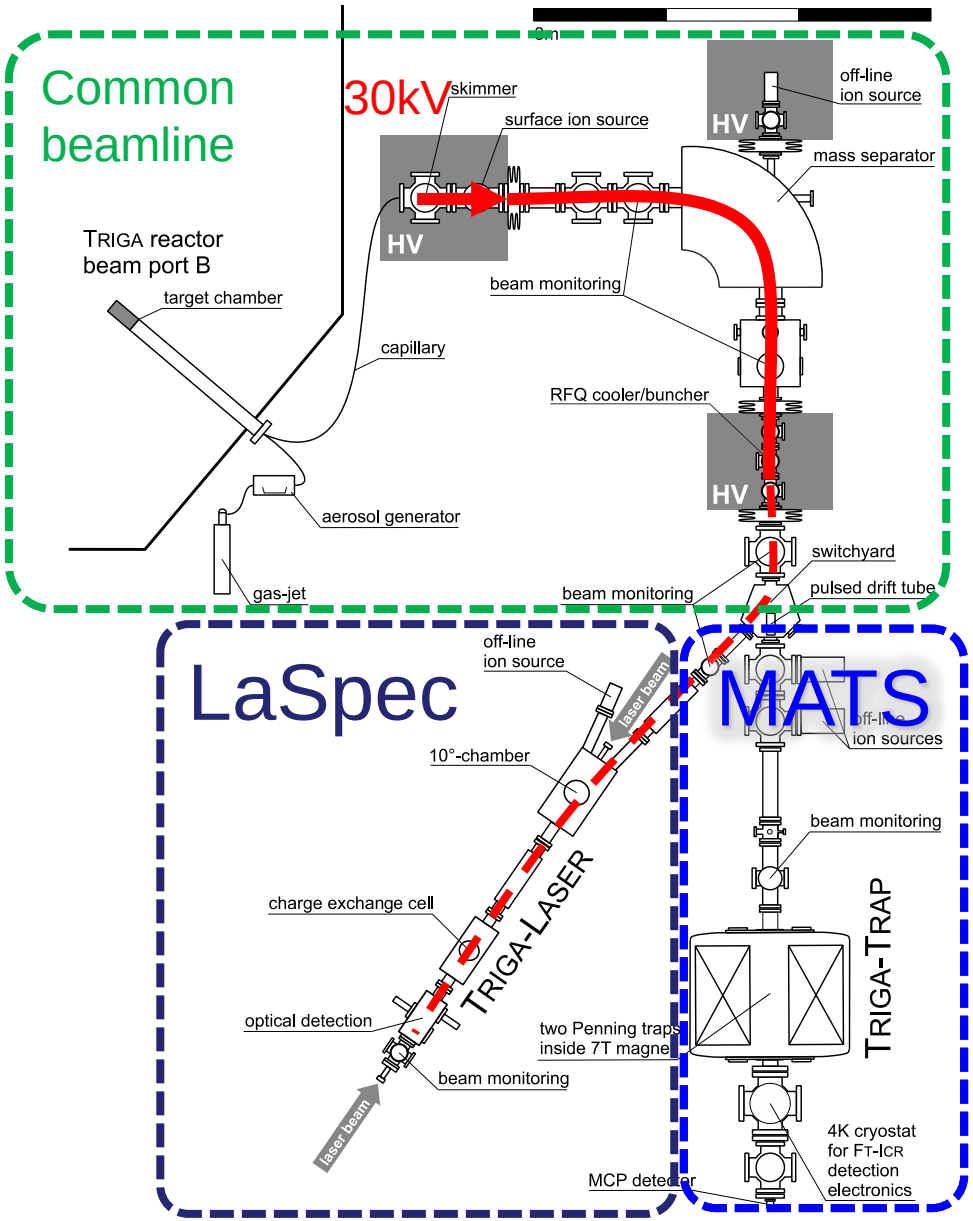
- axial confinement implemented at TRIGA-SPEC[1]

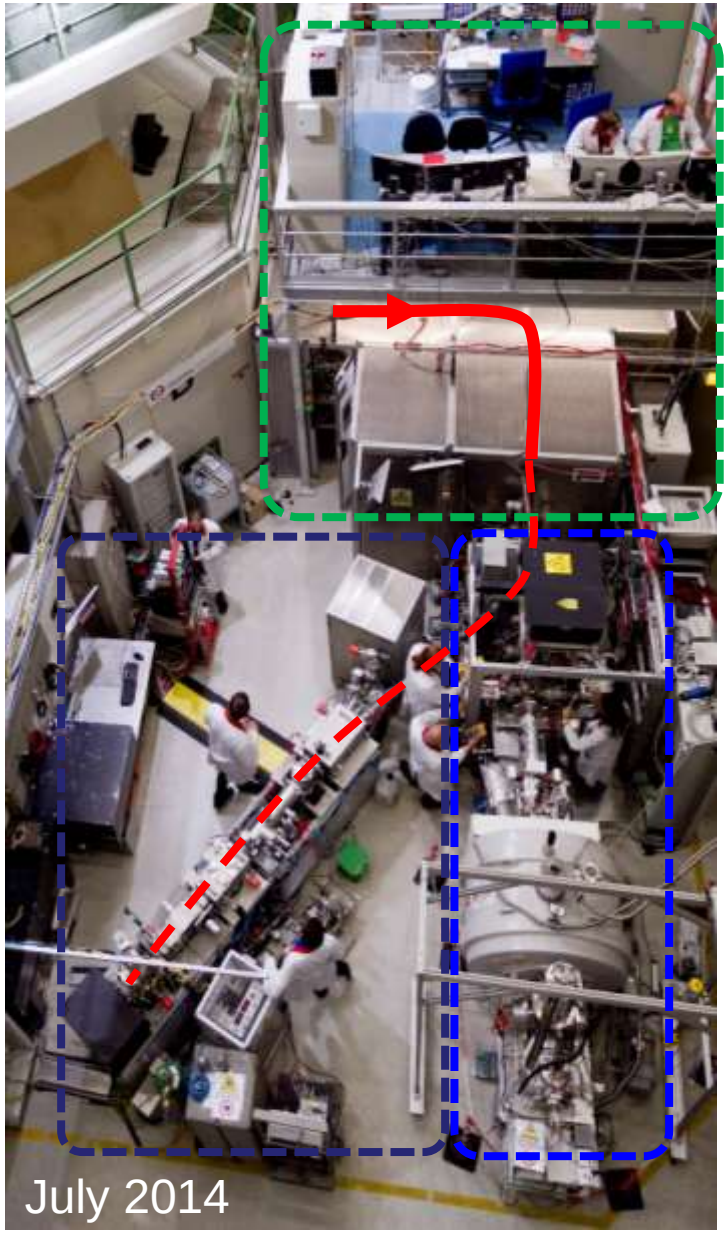




[1]T. Beyer, et al.: „An RFQ cooler and buncher for the TRIGA-SPEC experiment“, Appl. Phys. B (2014) 114:129–136

TRIGA-SPEC - Overview





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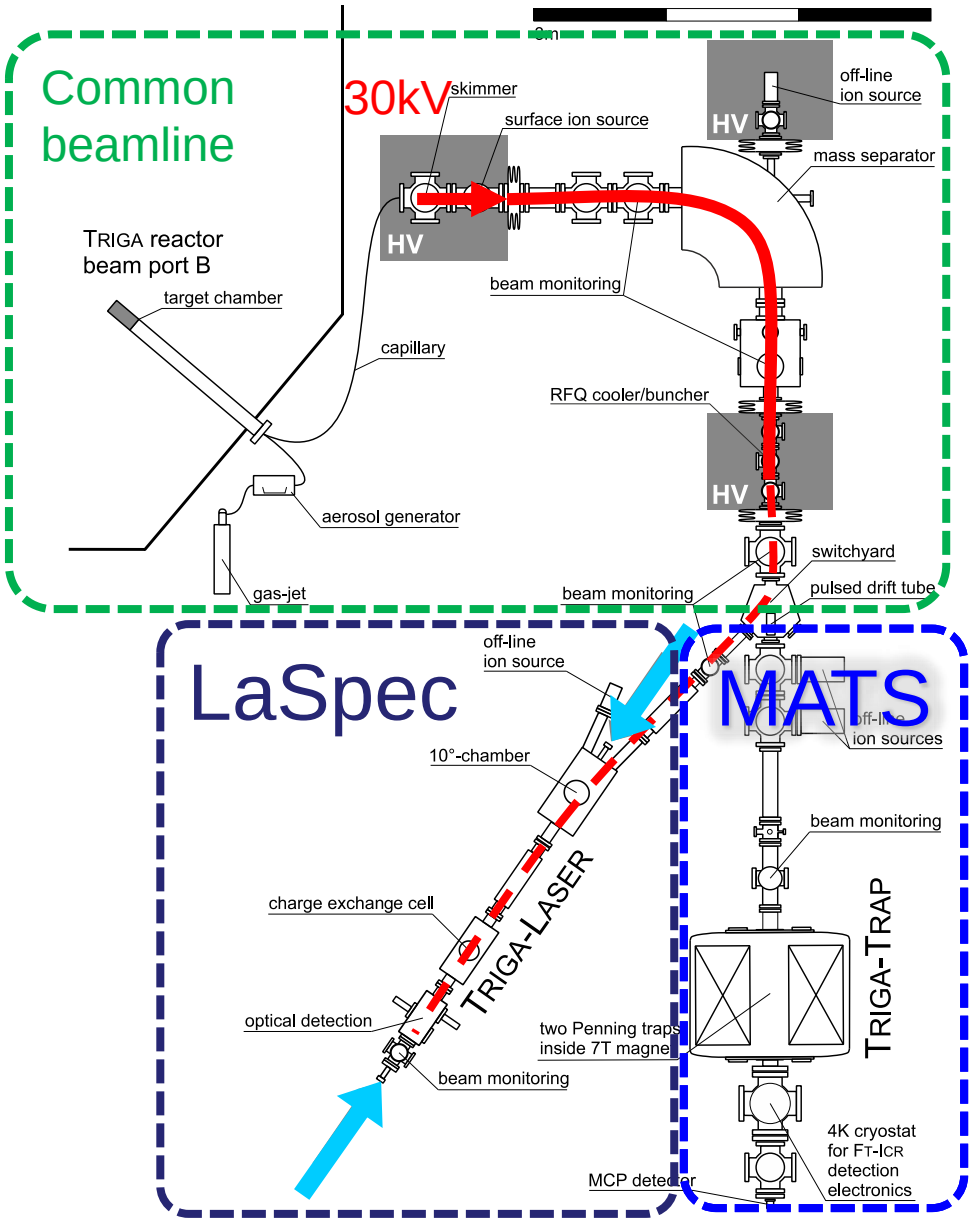
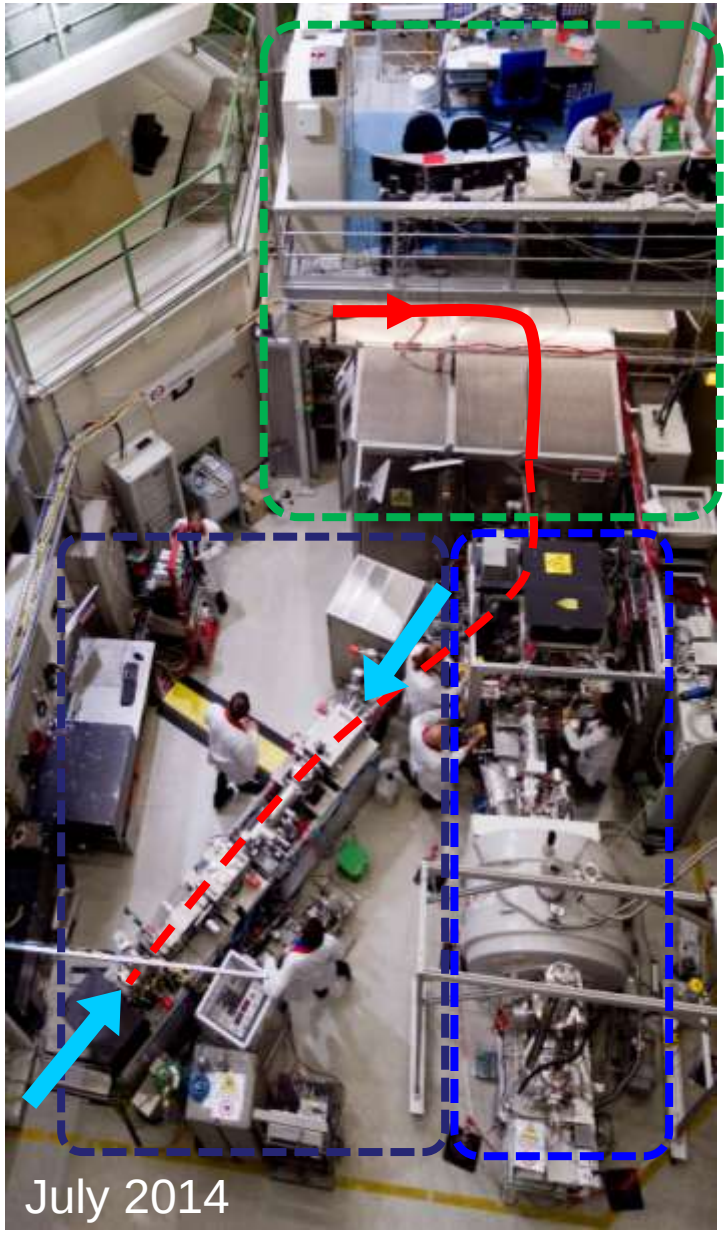
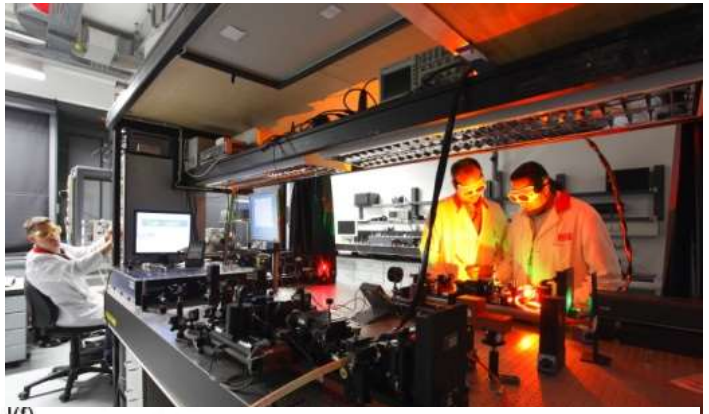


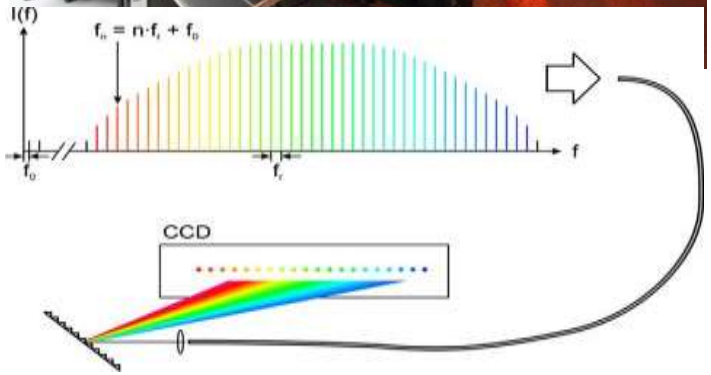


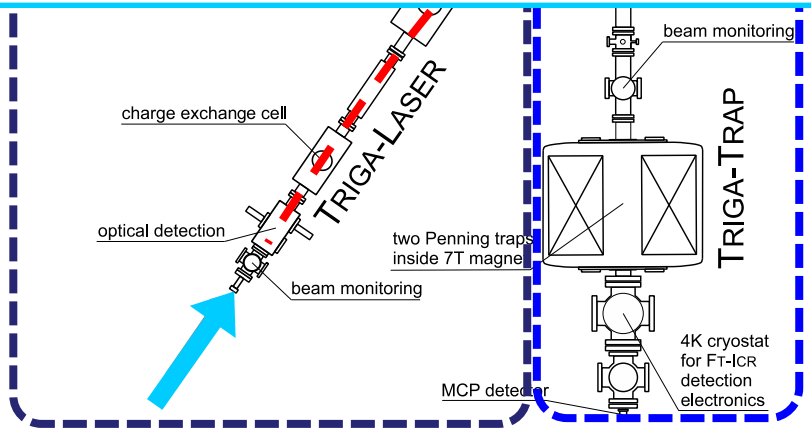
TRIGA-SPEC - Overview

Laser system

- Laser lab for stable environment
  - connection to reactor hall by 180 m single-mode optical fiber
    - ➢ 1x Vis-IR (760nm – 970nm), ≈ 55% transmission
    - ➢ 2x UV (380nm – 550nm), ≈ 40% transmission
  - Frequency measurement by frequency comb (acc. 10^{-14})







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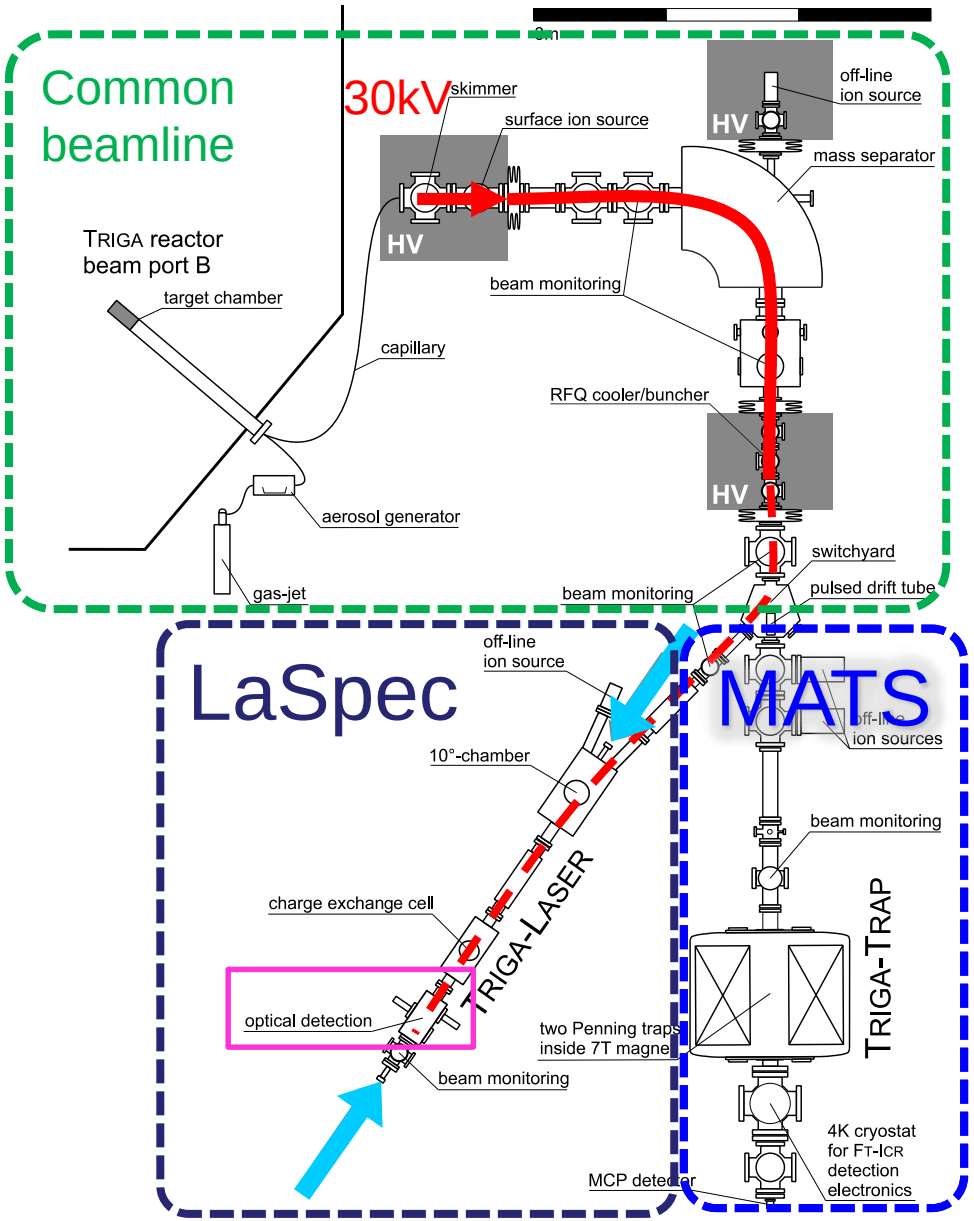
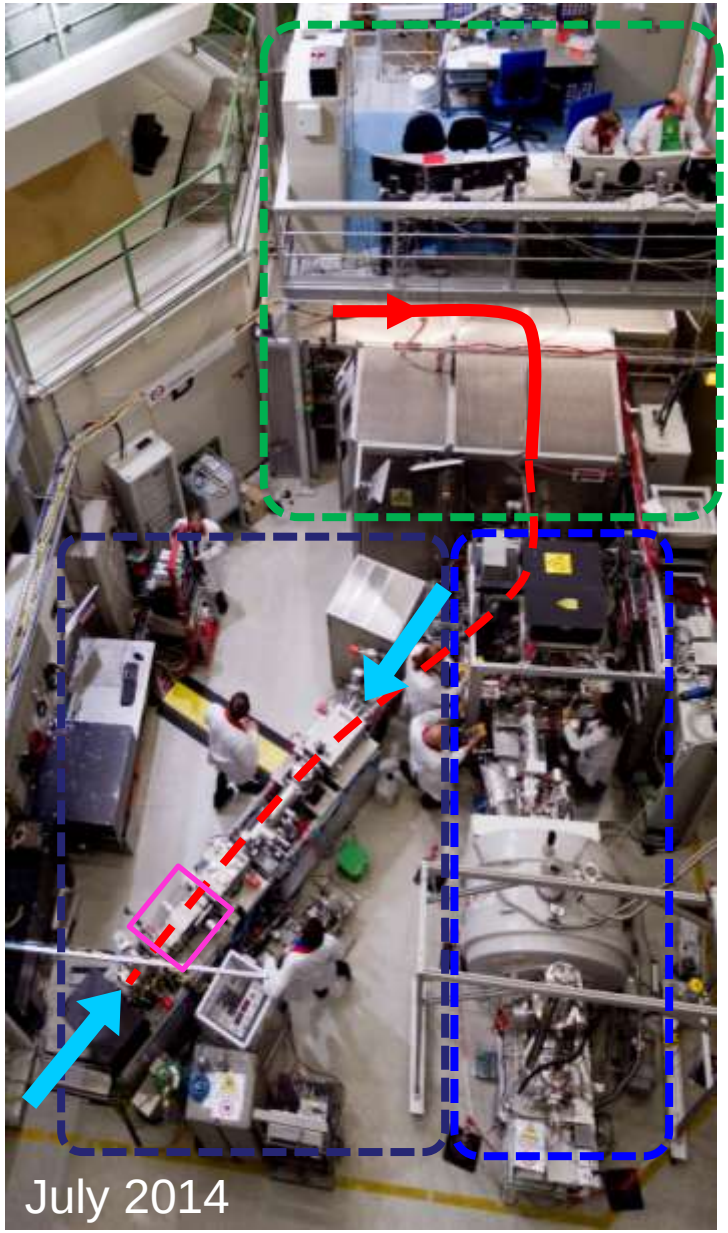




TRIGA-SPEC - Overview

Optical Detection

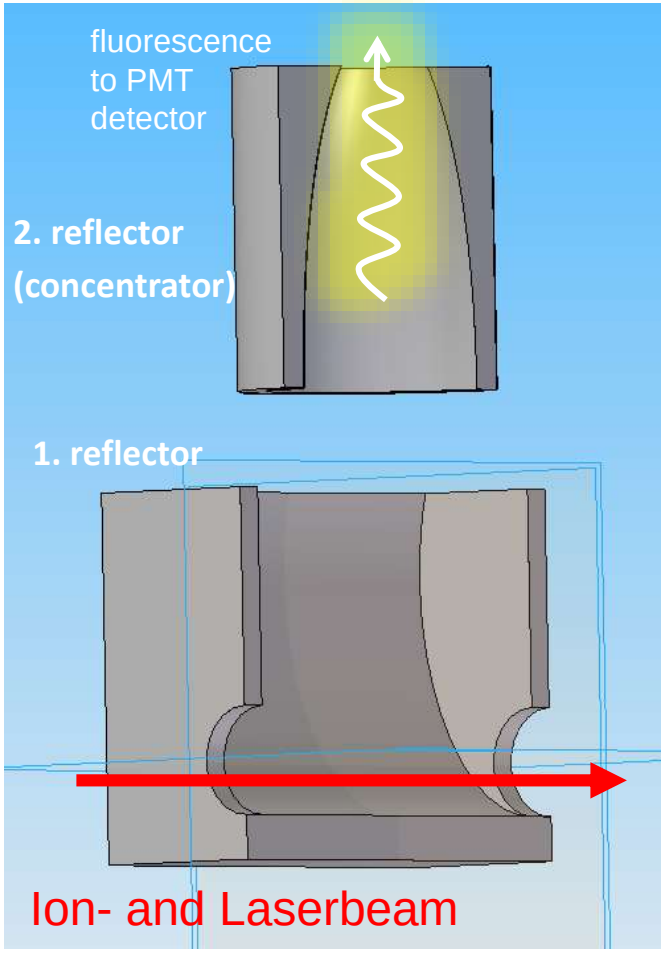
- 2 PMT's operating, 3rd PMT possible

Mirror System:

- Goal: separate background and fluorescence signals by applying non-imaging optics

2-stage reflector system:

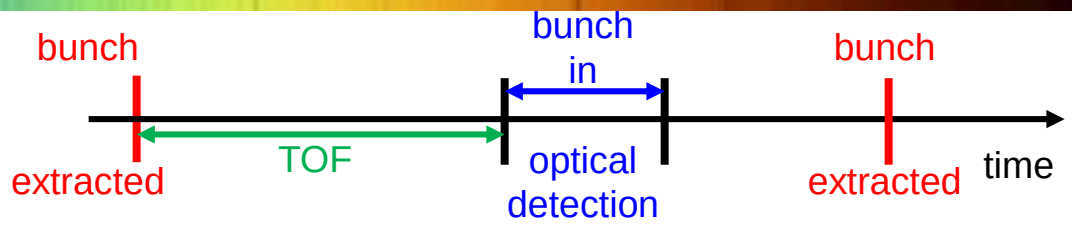
- 1st reflector, transversal selection: parabolic shaped copper mirror covered with high reflecting MIRO foil
- 2nd reflector, axial selection: parabolic concentrator

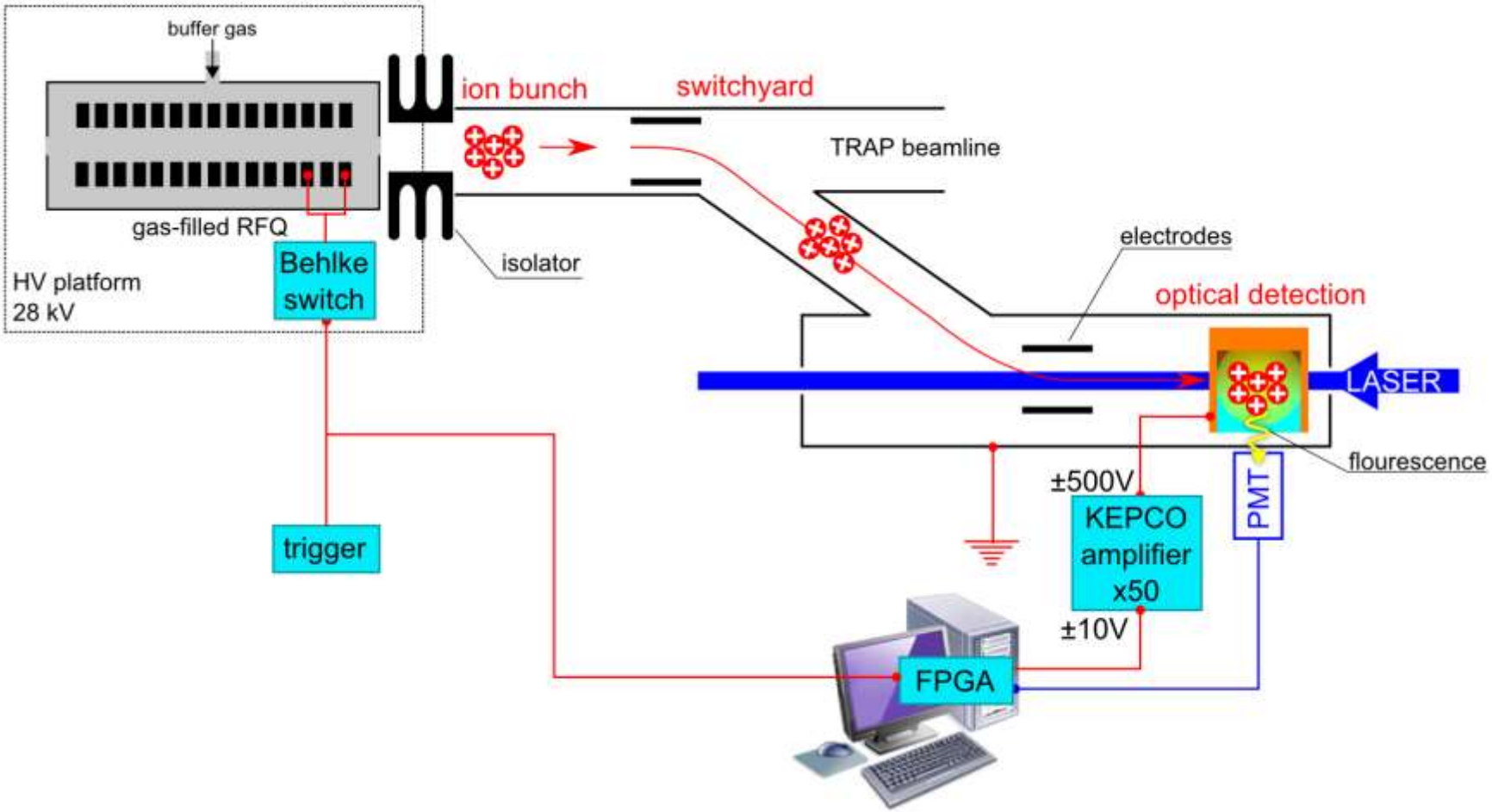


Diploma thesis Michael Hammen

University Mainz (2010)

Noise reduction by coincidence to bunch





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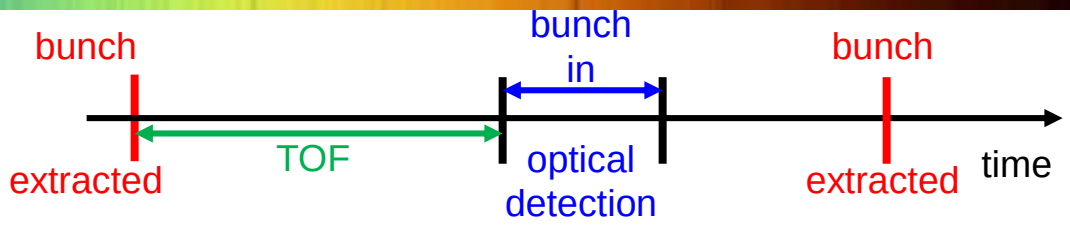
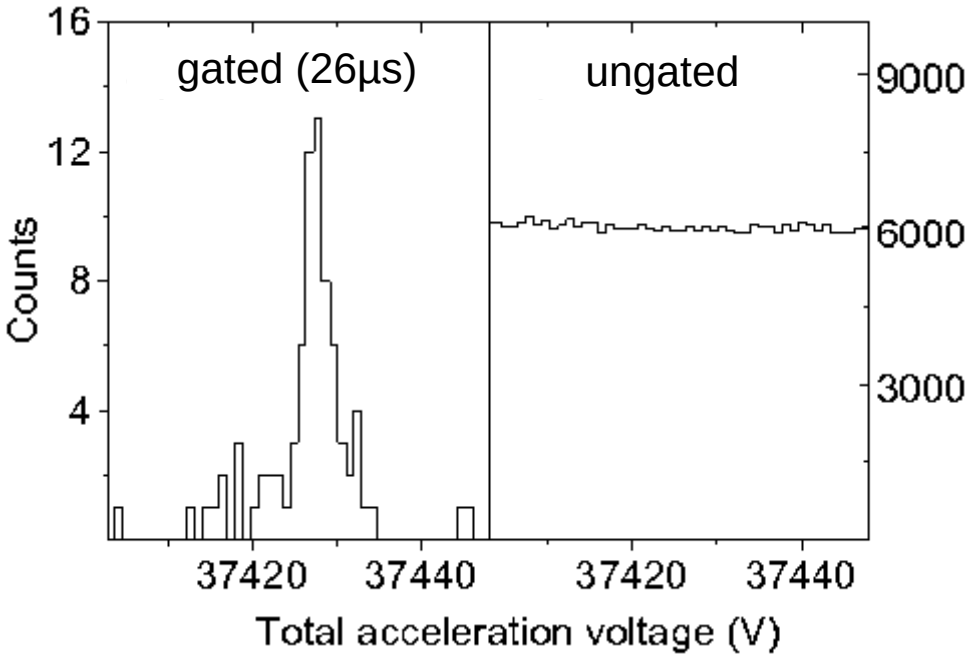




1300 $^{174}Hf^{+}$ ions/s

measured in 25 min (30s/Channel) at the IGISOL facility.

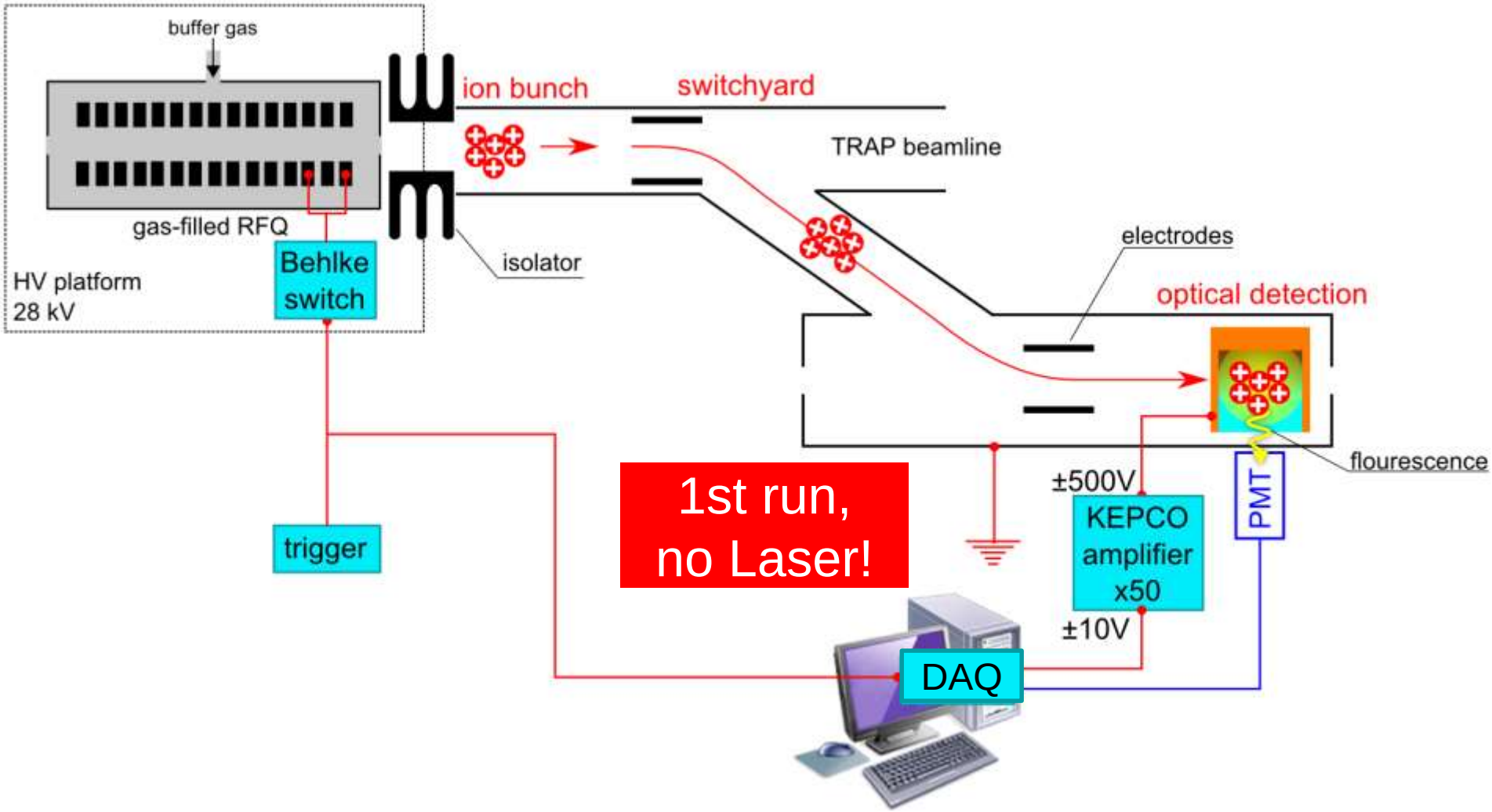
accumulation time: 500 ms
gate: 26 µs
Suppression factor: 18000

spectroscopy possible down to
≈ 100 ions/s

A. Nieminen, et al. „On-Line Ion Cooling and Bunching for Collinear Laser Spectroscopy", **Phys. Rev. Lett. 88, 094801 (2002)**

First results with residual gas afterglow of bunched beams at TRIGA-SPEC

Comissioning of the rfq with stable Ca^+-Ions



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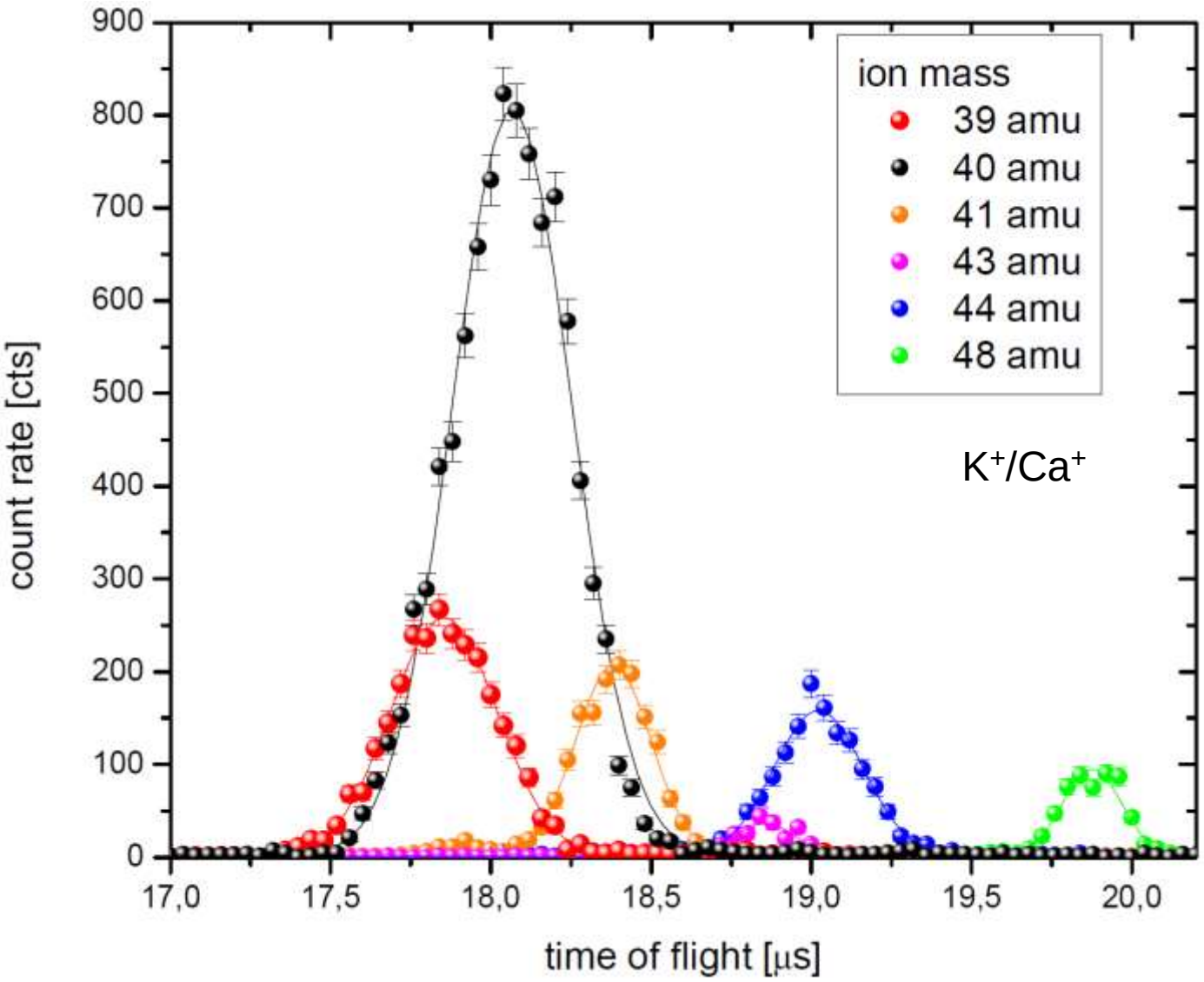

Diploma thesis Christian Gorges

University Mainz (2013)

First results with CLS on bunched beams at TRIGA-SPEC

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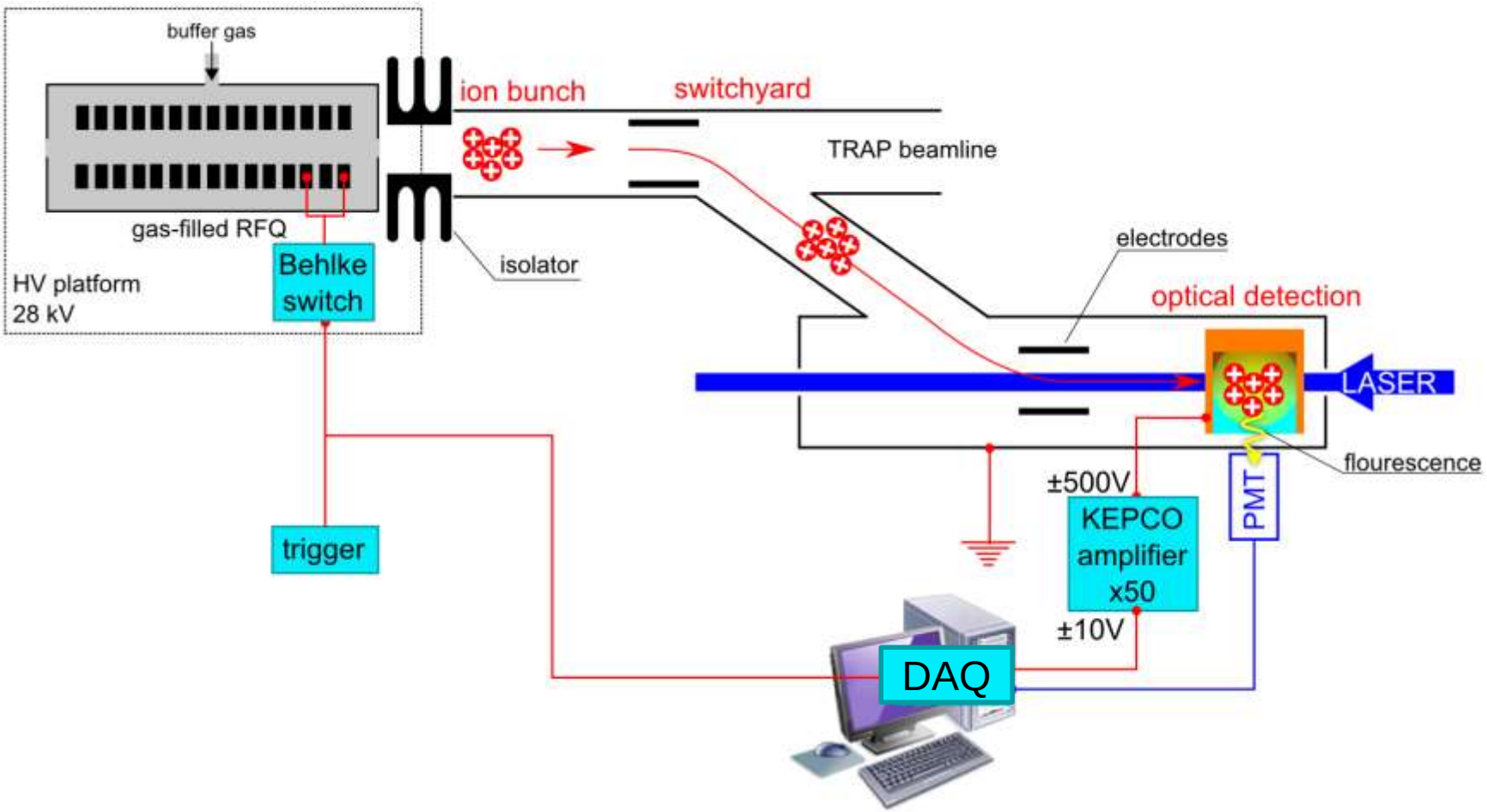
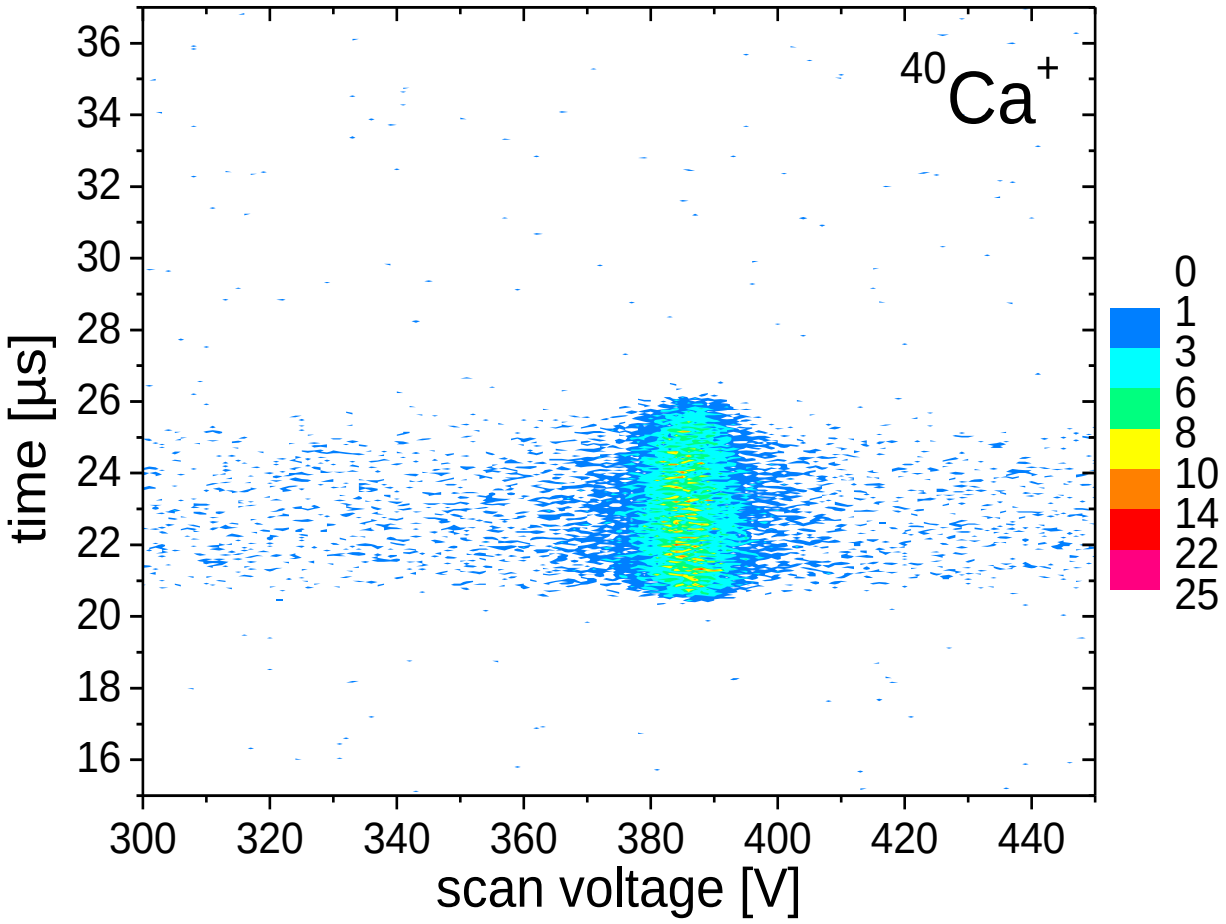


time resolved DAQ



Aim:

time resolved CLS (10ns res.)

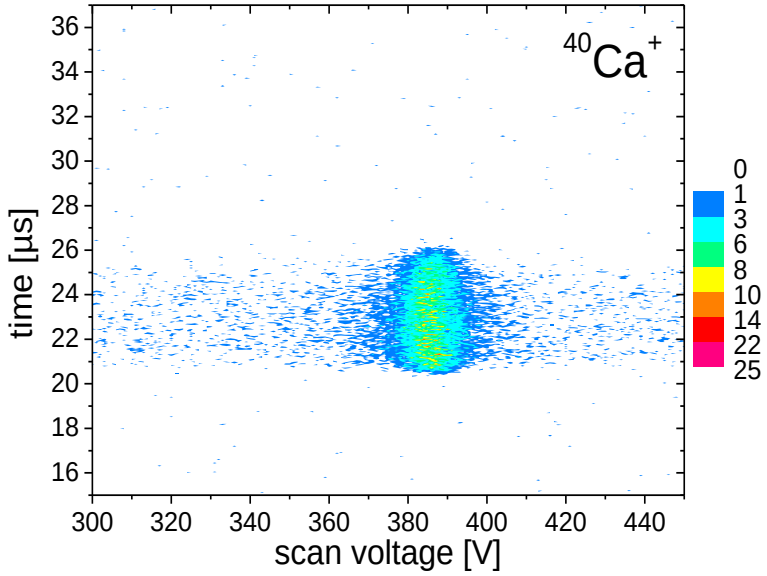
Required:

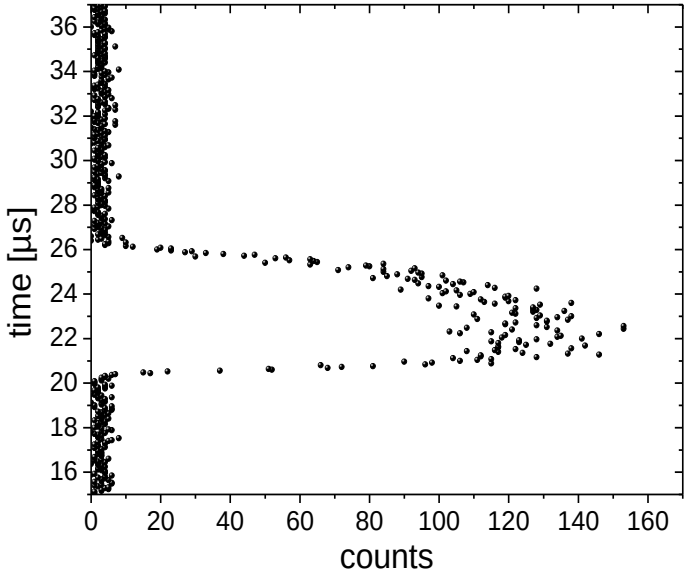
Multichannel Scaler in combination with Doppler-Tuning

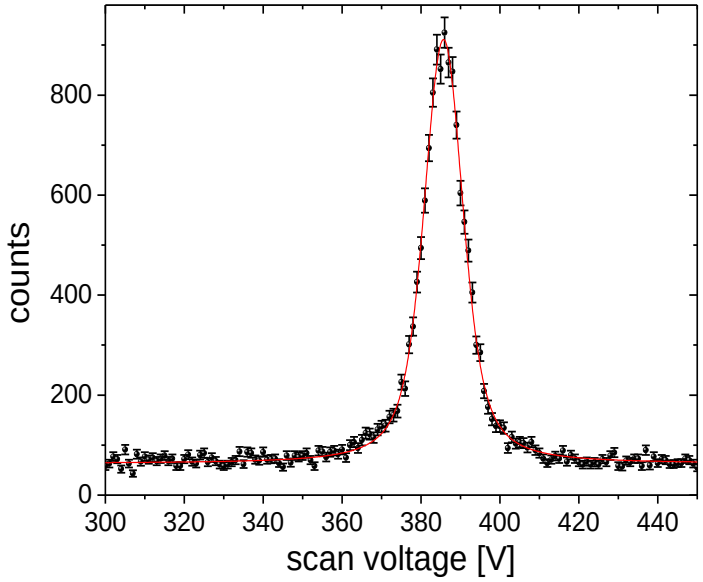
Used:

Virtex 2 – FPGA (onboard NI-PCI-card)

time resolved DAQ





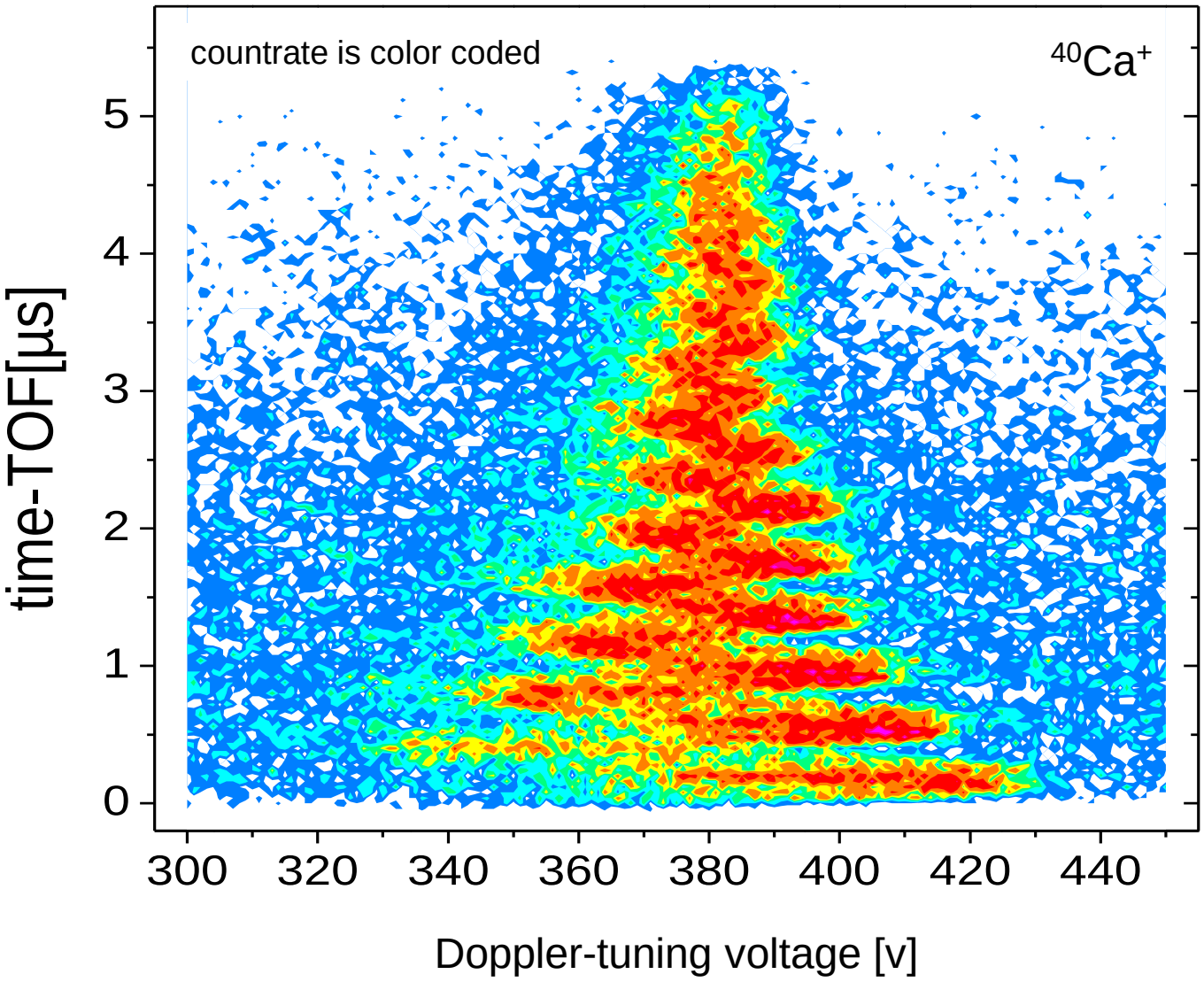


advantages:

- no hardware gates needed
  - ➢ software gates in analysis
- no time information is lost

First results with CLS on bunched beams at TRIGA-SPEC

Day 1: Oscillation of beam energy observed



frequency: appr. 3 MHz

oscillation in phase to extraction

First results with CLS on bunched beams at TRIGA-SPEC

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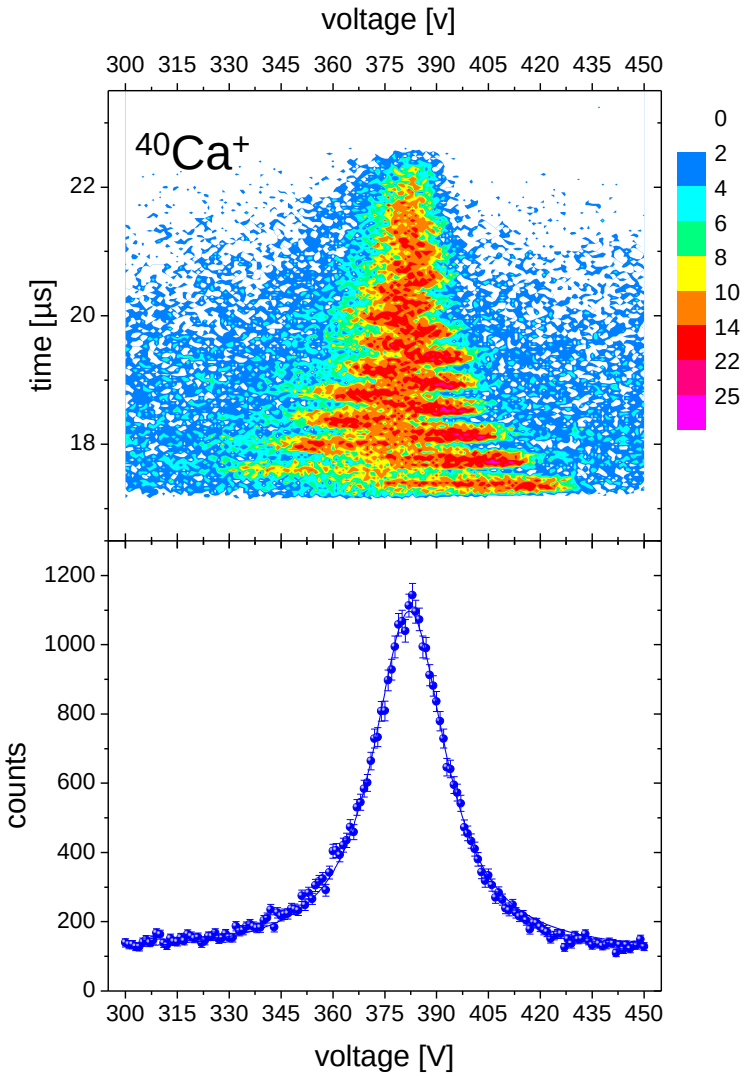
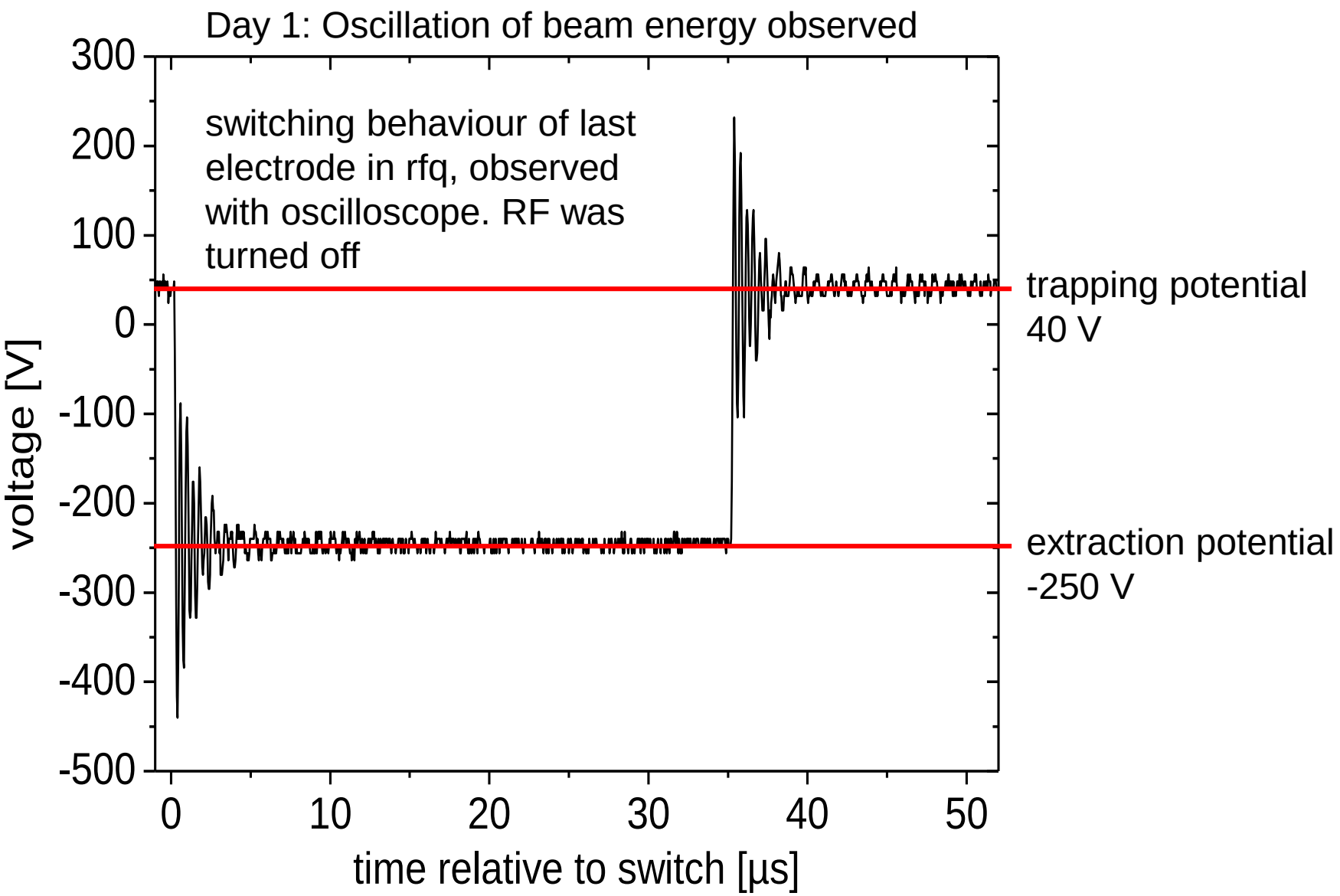


- Oscillation in projection not visible
- linewidth broadened to FWHM of:
  - 30 V
  - or 510 MHz

First results with cls on bunched beams at TRIGA-SPEC



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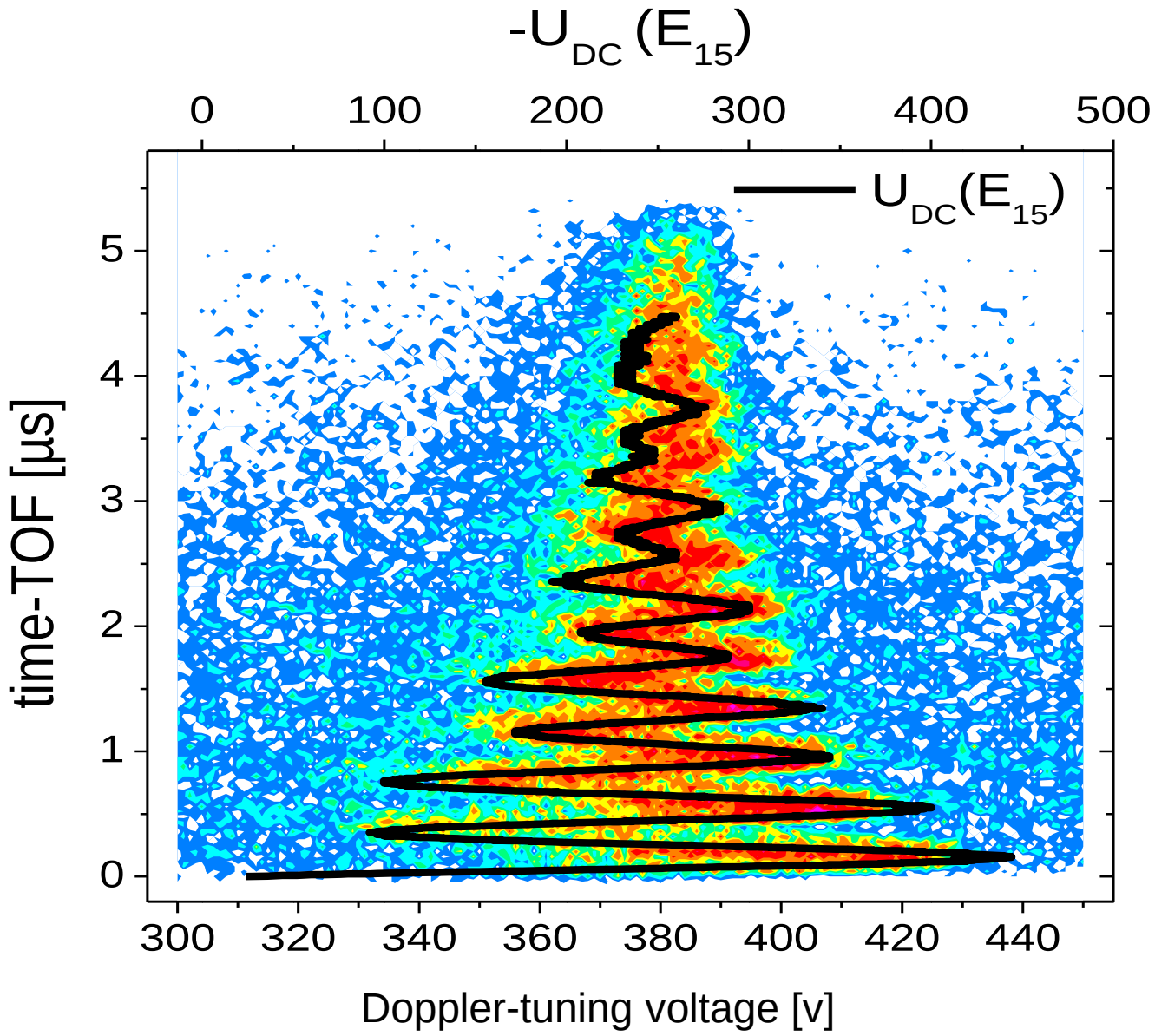

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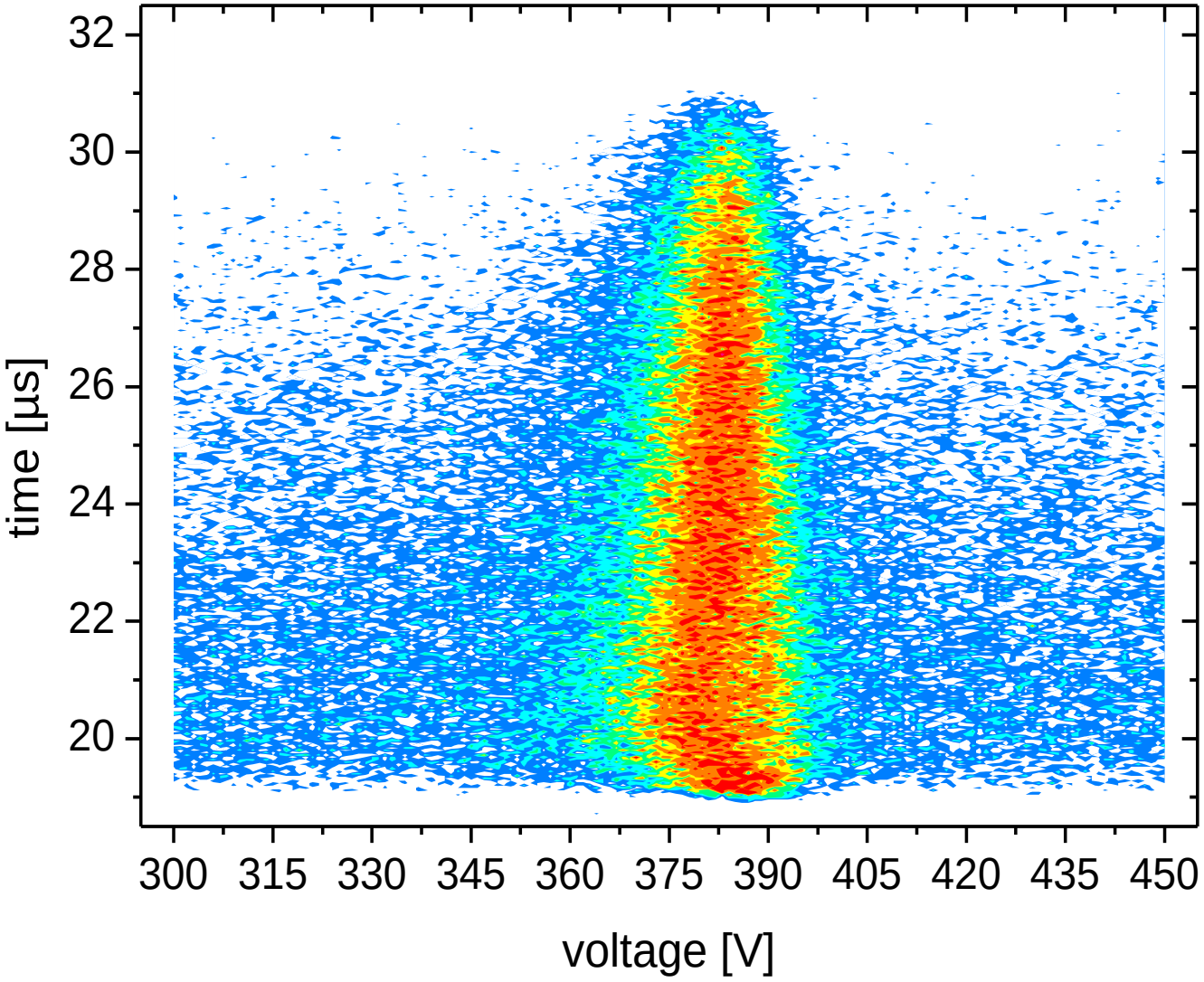
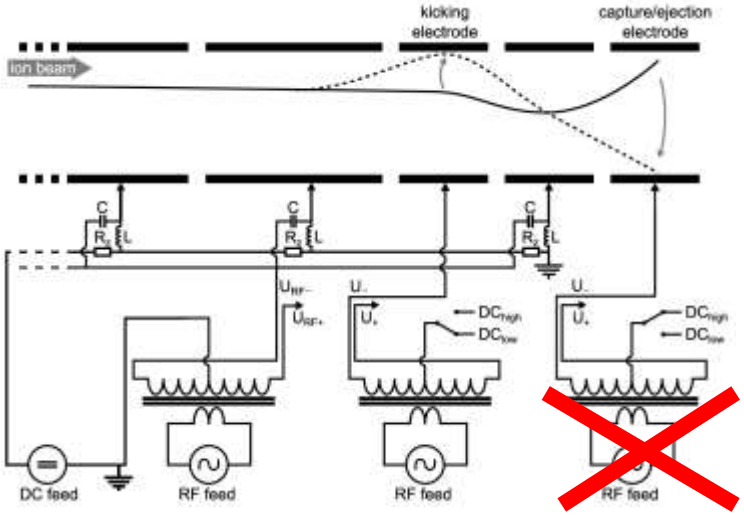


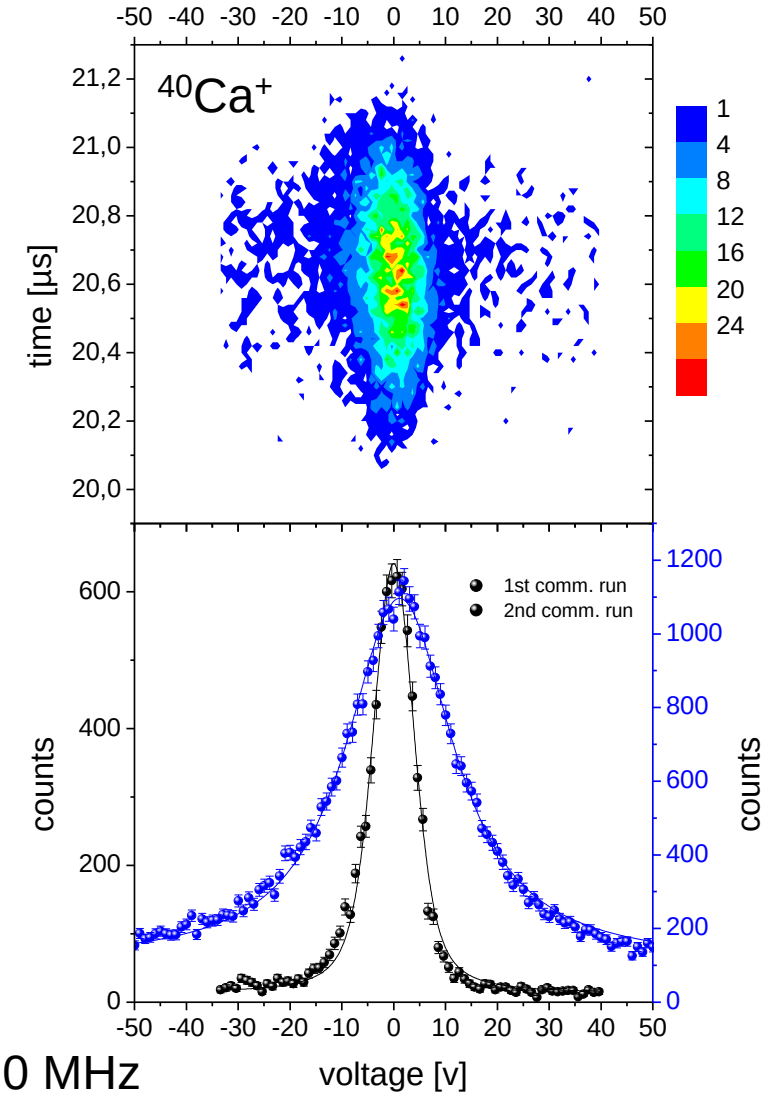
changing extraction potential to 0 V

- oscillation disappears
- bunch is longer
  - about 11.74µs

2nd comissioning run of COLETTE at TRIGA-SPEC

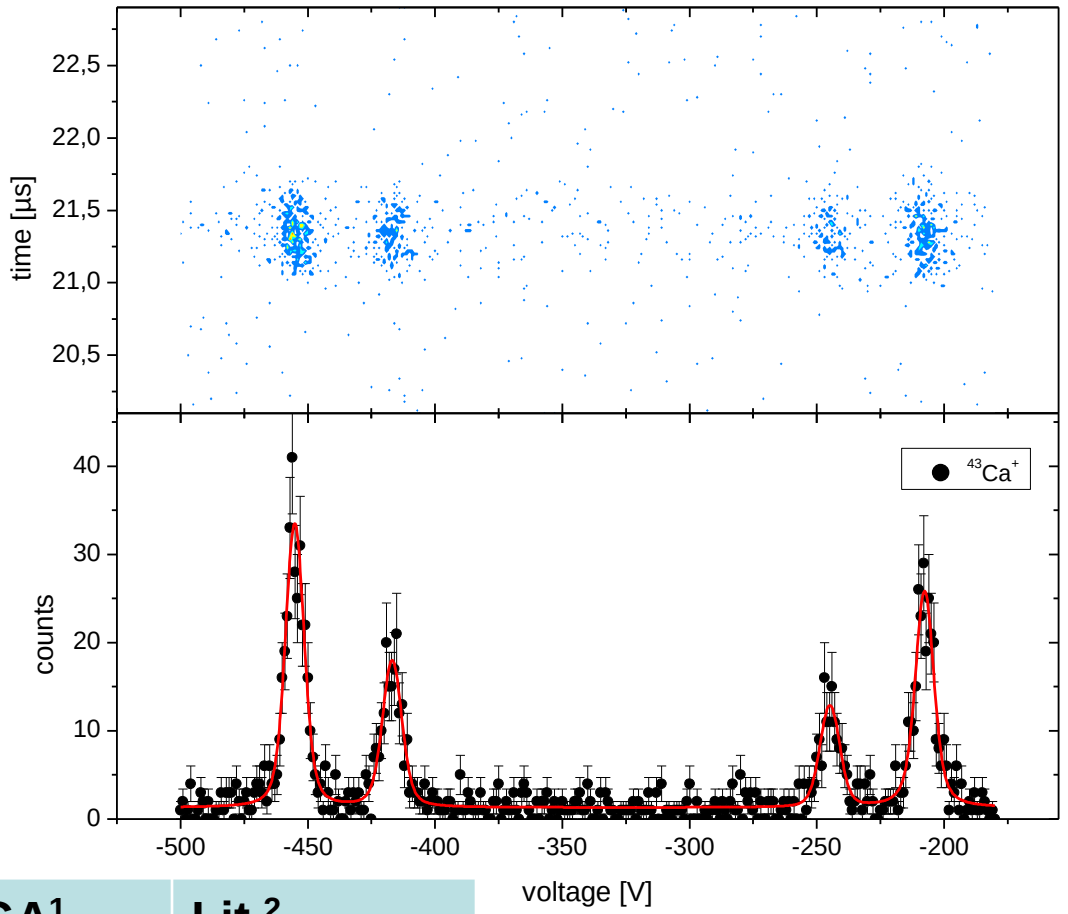
- Decoupling of RF at last electrode led to clean switching behaviour at extraction





FWHM in energyspread:
30 V corr. 510 MHz improved to 10 V corr. 170 MHz

2nd comissioning run of COLETTE at TRIGA-SPEC



$^{43}Ca^+$

A-Factors	TRIGA[1]	Lit.[2]
$A_{S1/2}$ (MHz)	-803.6(1.2)	-805(2)
$A_{P1/2}$ (MHz)	-145.1(1.1)	-145.5(1.0)

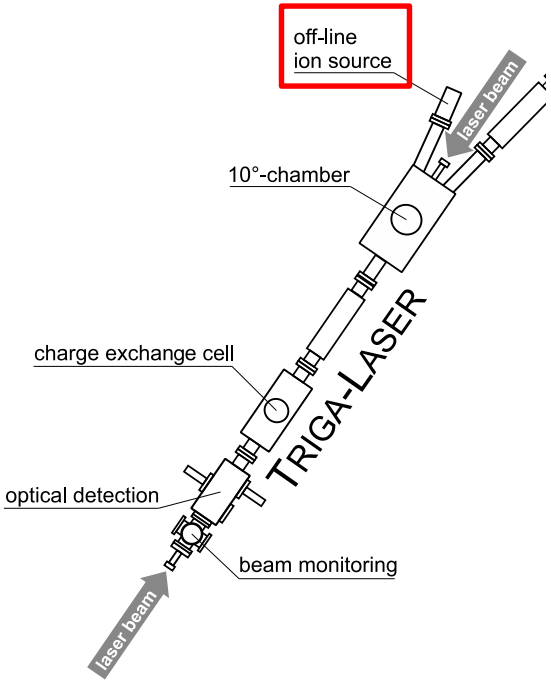
[1]Only Fit errors

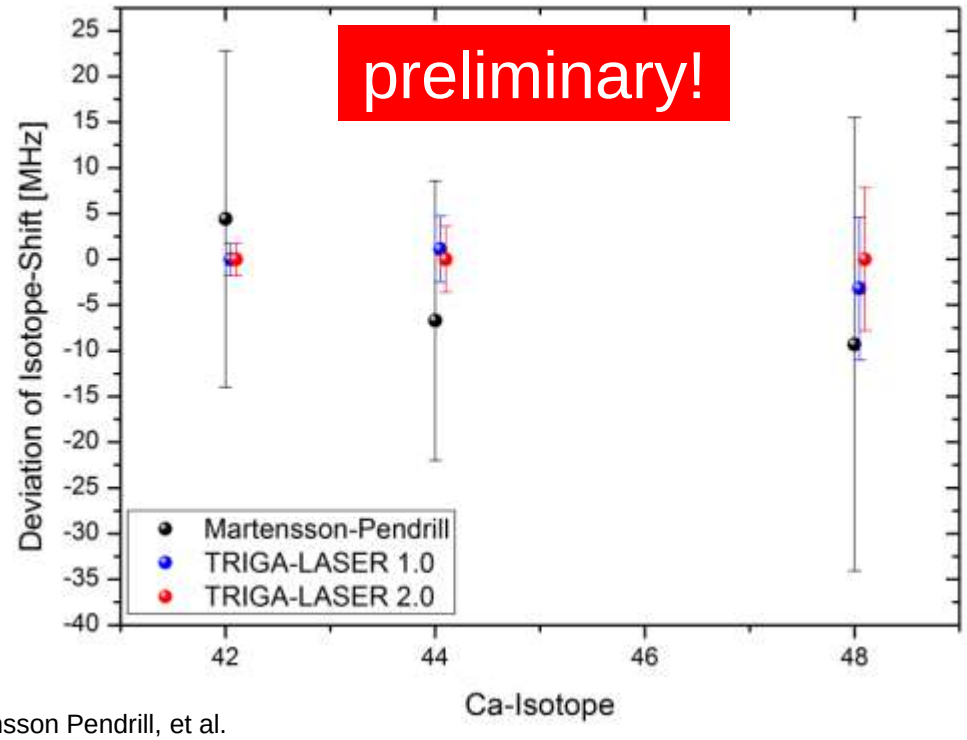
[2] R.E. Silverans , et al.
„Hyperfine structure constants of the CaII states 4s $^2S_{1/2}$ and 4p $^2P_{1/2,2/3}$ and the nuclear quadrupole moment of ^{43}Ca"
Z. Phys. D, Vol. 18 351-356 (1991)

Offline ion-source measurements at TRIGA-SPEC

Offline measurements:

High precision measurement of the Ca^+ 4s $^2S_{1/2} \rightarrow$ 4p $^2P_{3/2}$ transition isotope shift of $^{40\text{-}48}Ca^+$





Martensson Pendrill, et al.
Isotope shifts and nuclear charge radii in singly ionized $^{40\text{-}48}Ca$
PRA 45 4675(1992)

Further developments at TRIGA LASER

TRITON

(**TRI**GA py**T**hon c**ON**trol system)

- Python based Control System for all devices except the fast data acquisition
- SQL-Database in background
- Supported OS:
  - Windows 7, Linux and Mac
- status:
  - all beamline devices included in TRITON
  - **operational**
  - development ongoing

TILDA

(**TRI**GA-**L**aser **D**ata **A**cquisition)

- replacement of the current DAQ (Virtex-2, PCI) by an PXI-crate containing 2 Virtex-5 FPGA‘s
- aim:
  - time resolved cls with up to 5 PMT‘s, time resolution 10ns (100MHz)
  - fast experiment control, e.g. set the scan voltage or loading and extraction of rfq
- status:
  - first components delivered
  - programming started

Outlook

Upcoming Projects at TRIGA-SPEC

Short term:

- Development of new DAQ
- Modify offline ion source to 30 kV
- Establish collinear **and** anticollinear measurement
  - Measure isotope shift of stable Ca^+ with rfq
  - Investigate ion beam energy behind rfq

long term:

- Plasma ion source in common beamline
  - Investigation of short lived isotopes which are currently not ionisable with the surface ion source

Thank you, for your attention!

Thanks to our supporters:

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TECHNISCHE UNIVERSITÄT DARMSTADT

GSI Helmholtzzentrum für Schwerionenforschung