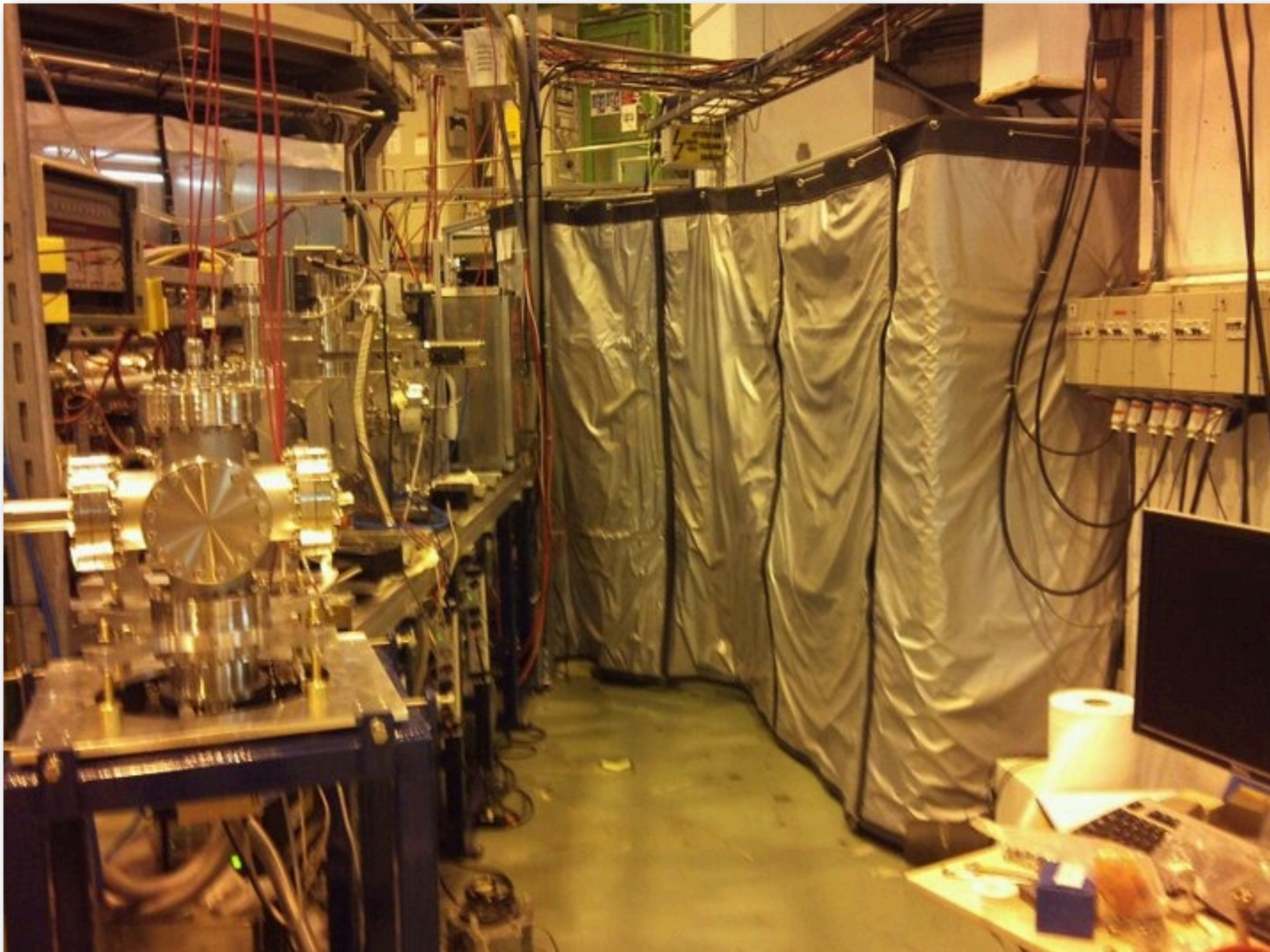
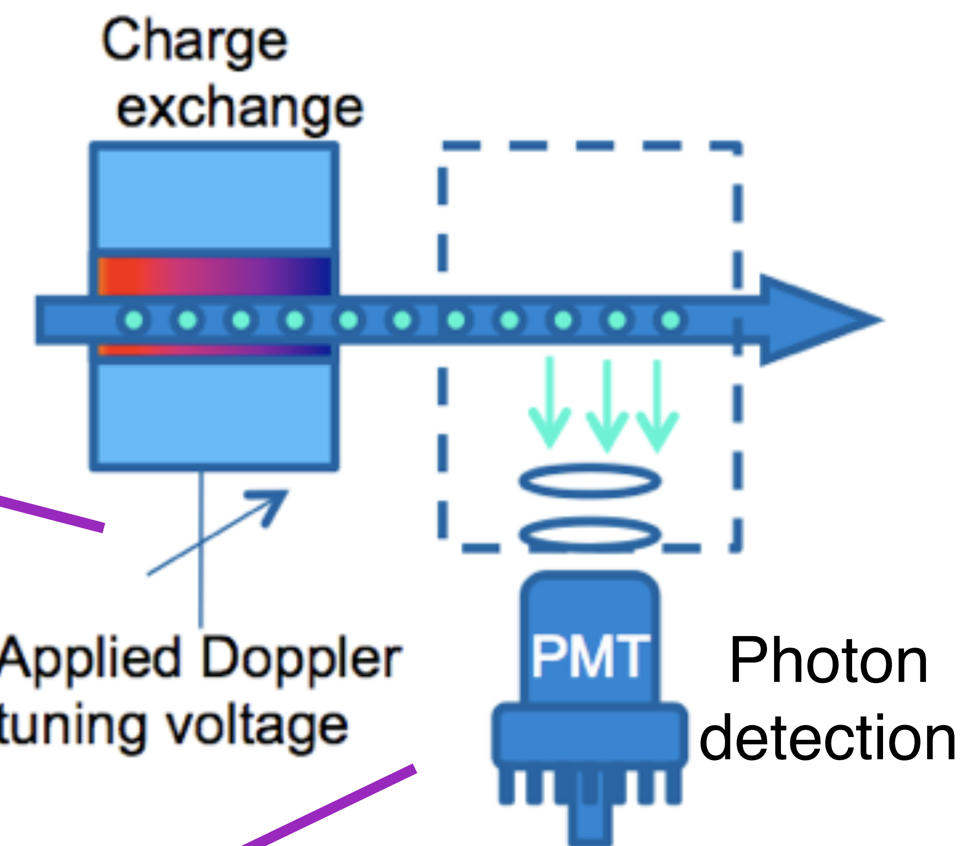
The CRIS experiment

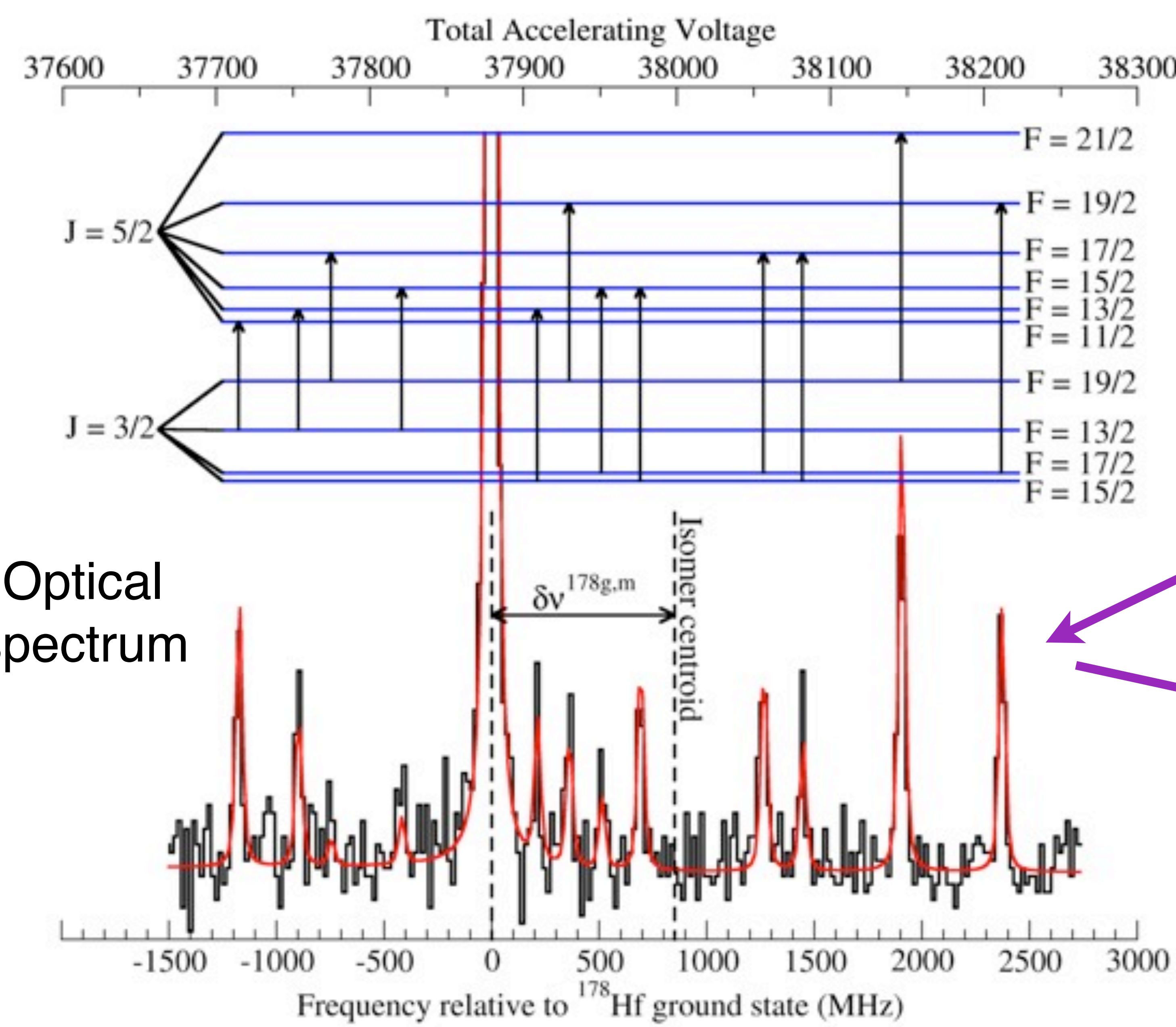


Collinear laser spectroscopy

$$\Delta E = \mathrm{const} = \delta(^1/_2 mv^2) \approx mv\delta v$$



Optical spectrum

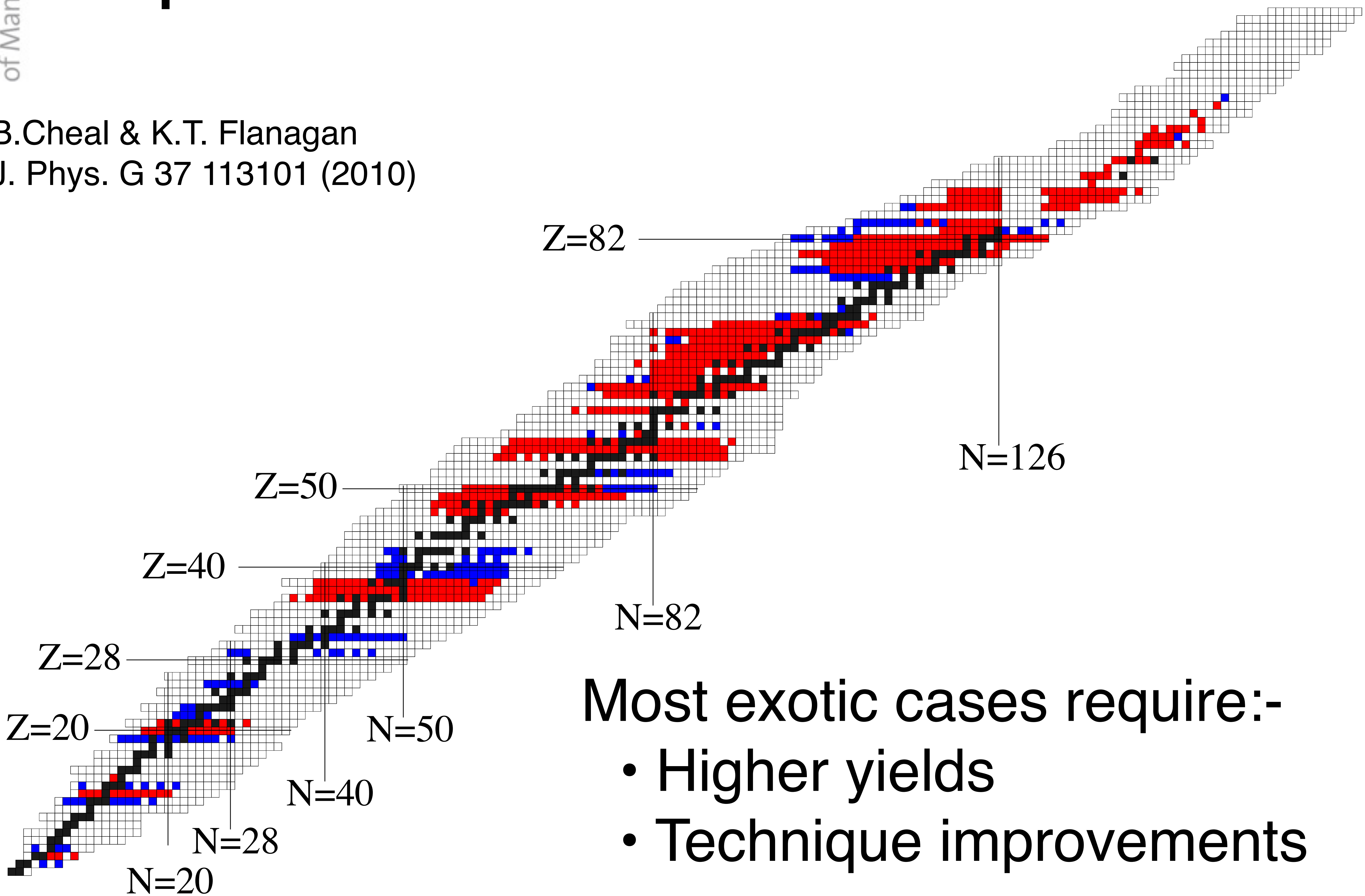


<u>Measure:-</u>

- μ
- Q_s
- $\delta\langle r^2 \rangle$
- spin

Optical measurements to date

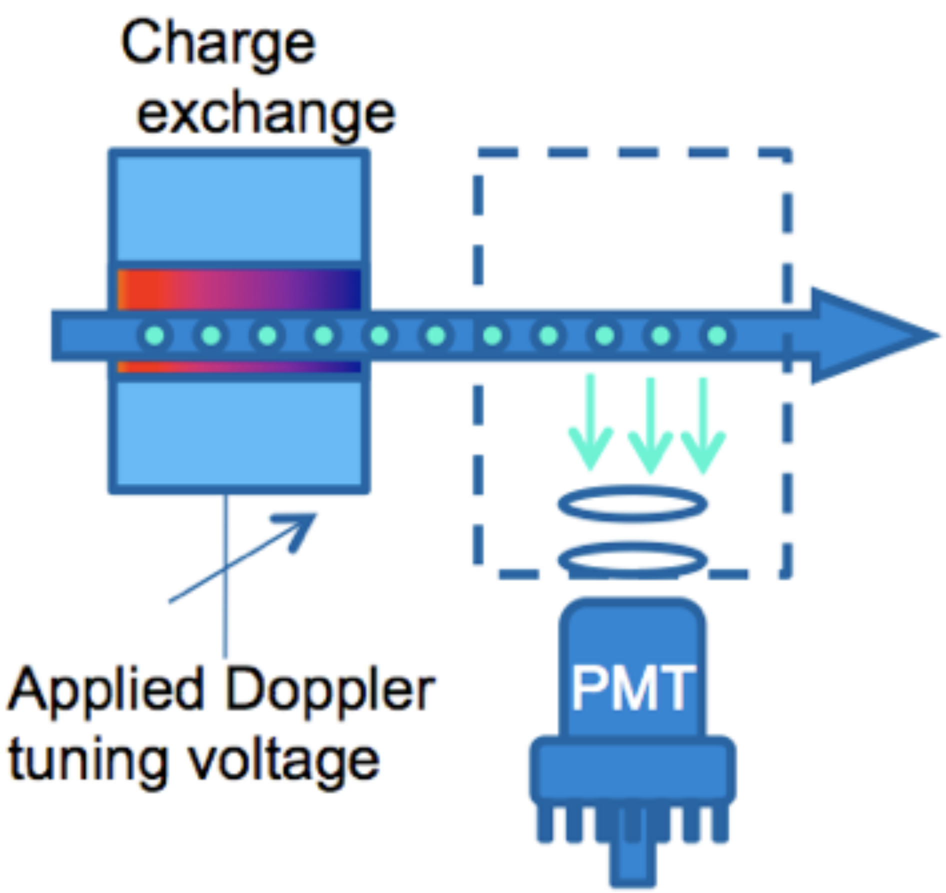
B.Cheal & K.T. Flanagan
J. Phys. G 37 113101 (2010)



Most exotic cases require:-

- Higher yields
- Technique improvements

What limits sensitivity?



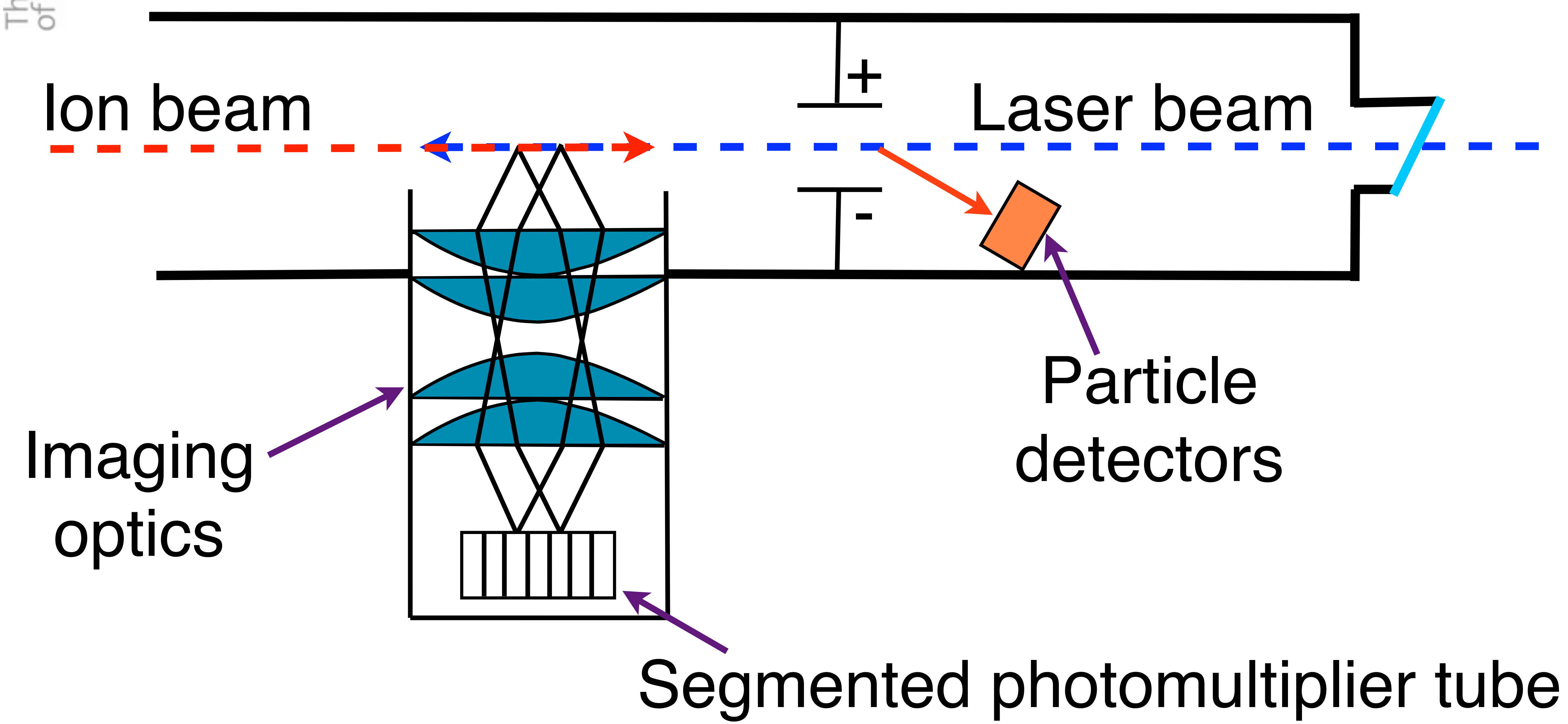
<u>Detection efficiency</u>

- Solid angle
- PMT

<u>Background</u>

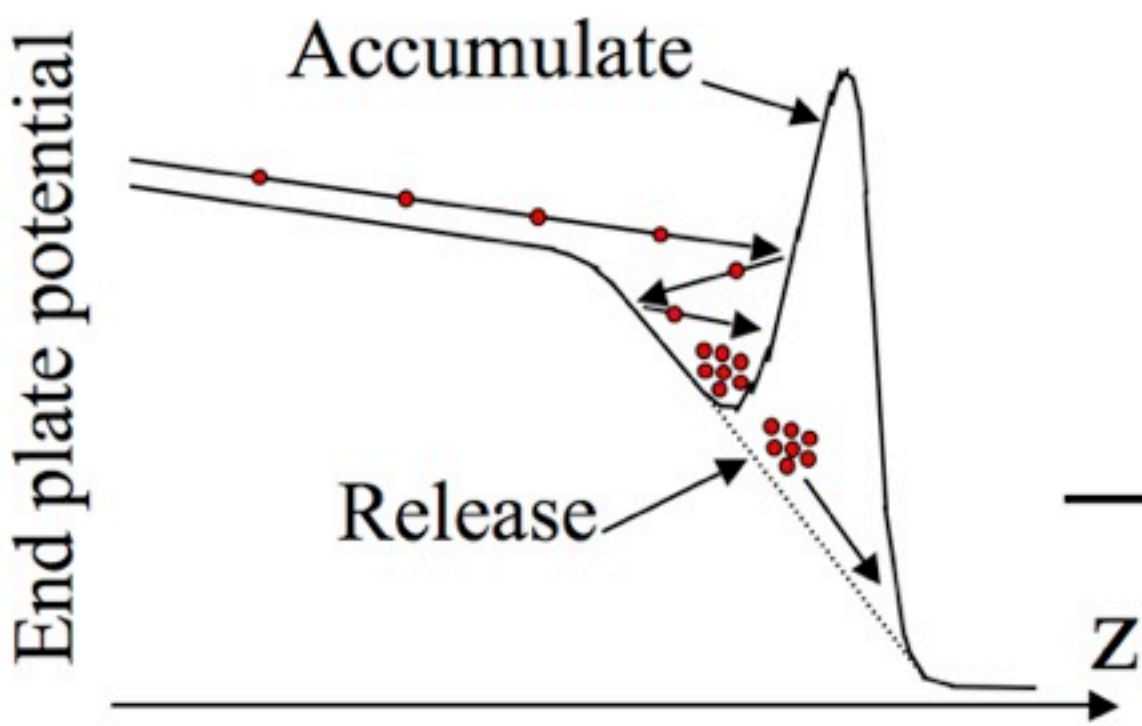
- Dominated by continuous laser scatter

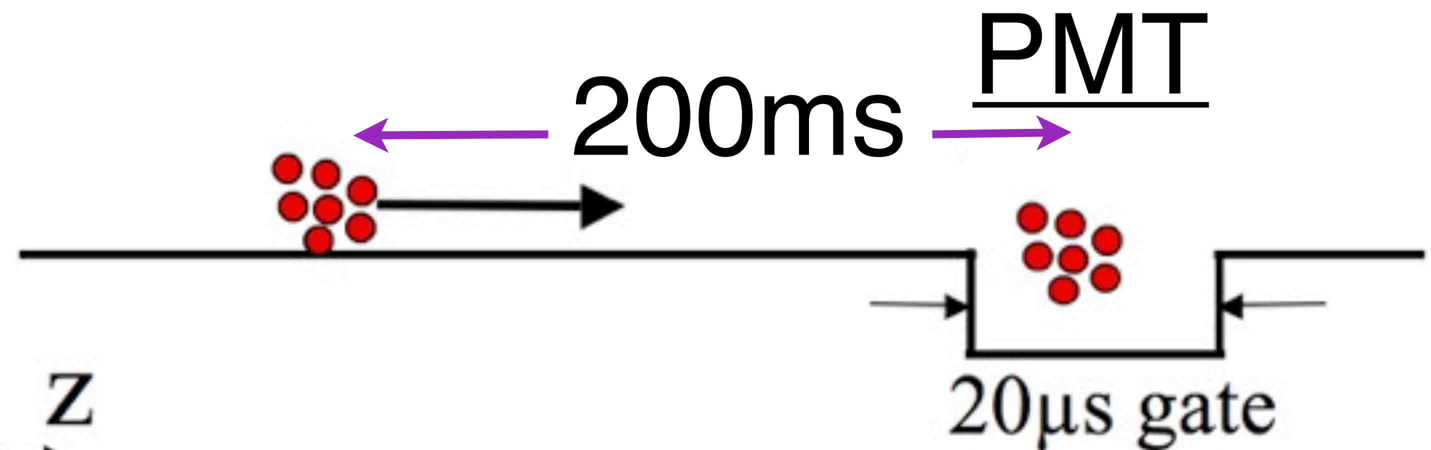
Suppressing background: PIC

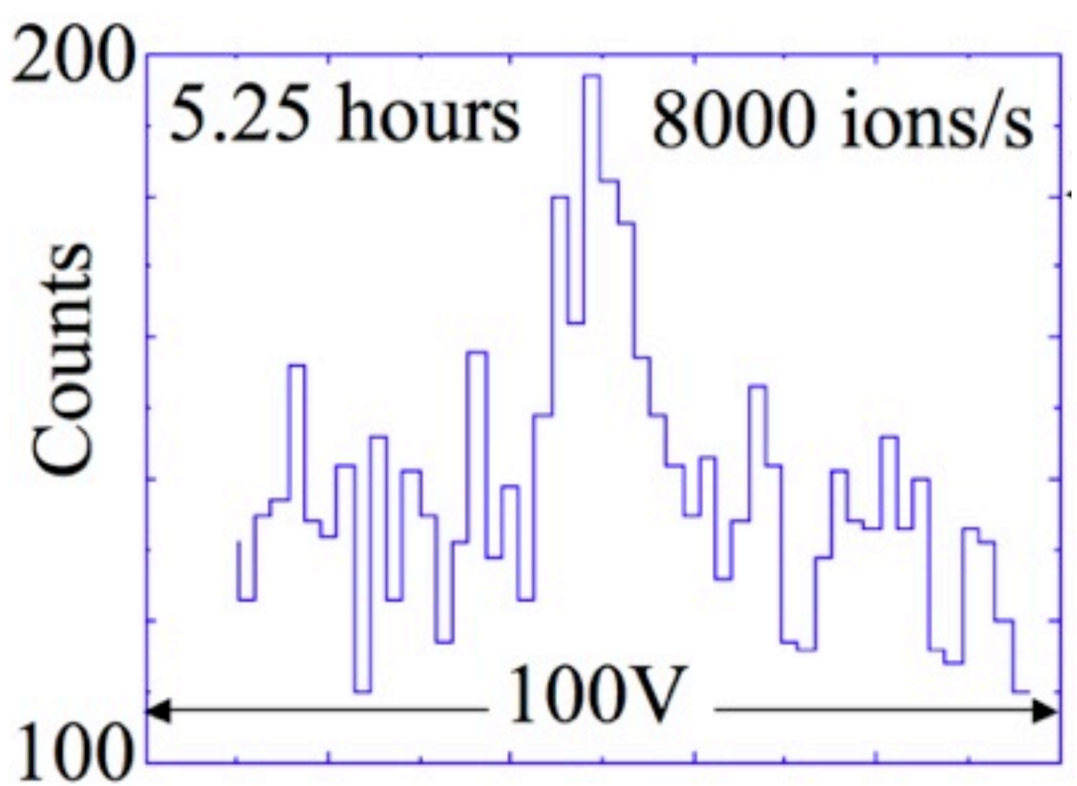


- Detect photons in coincidence with ion
- Isobaric contamination caused “false” coincidences

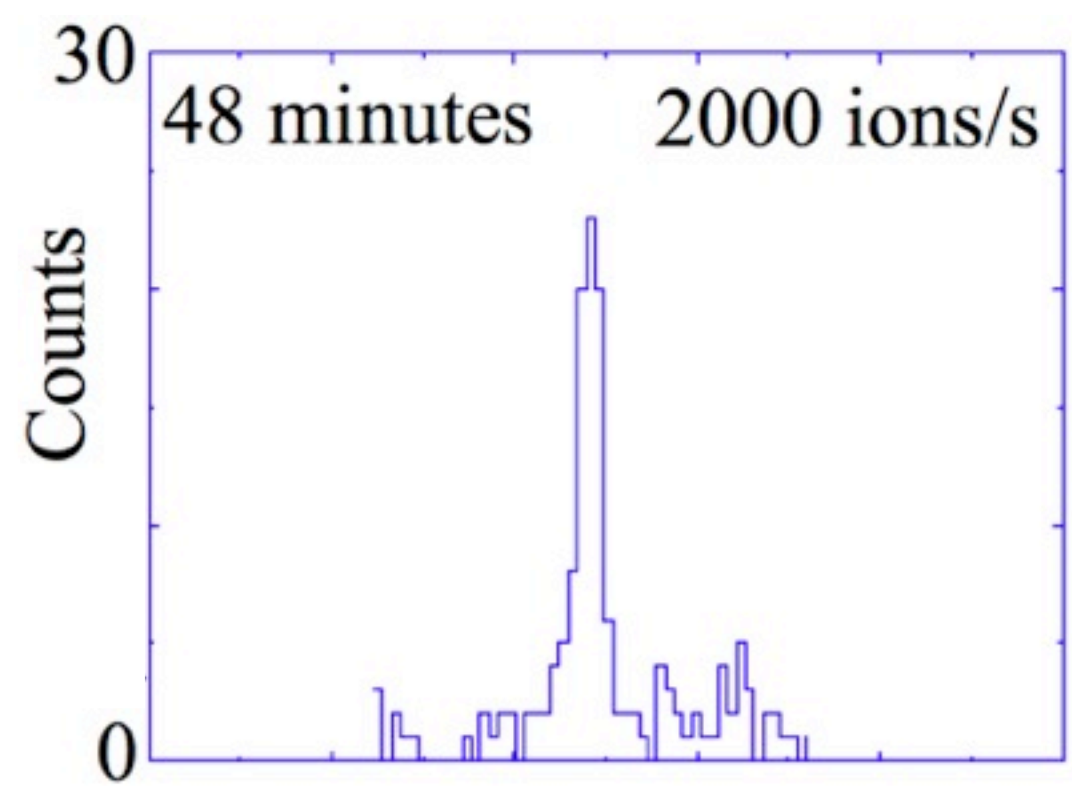
Bunching technique





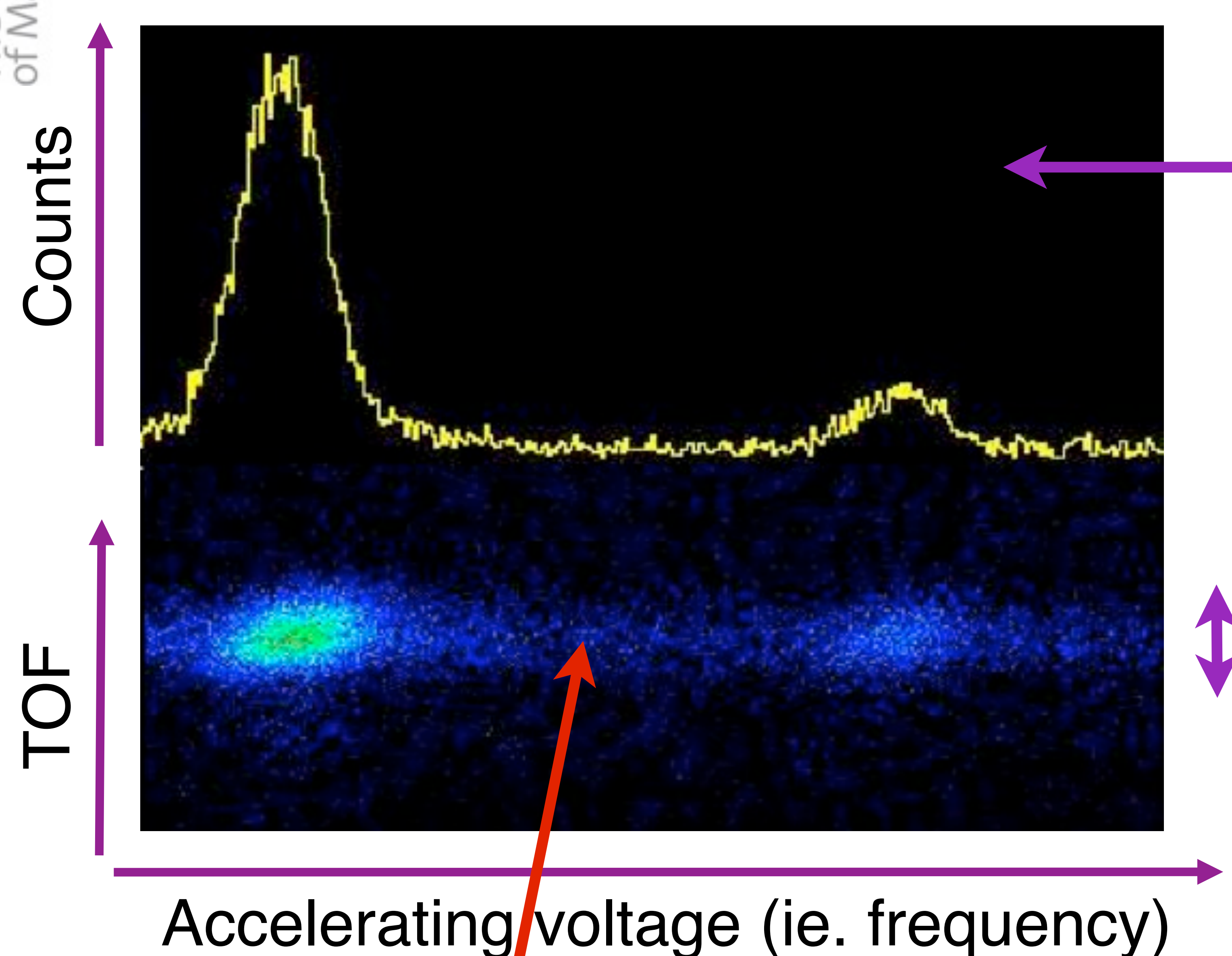


photon-ion coincidence



Ion-bunch gating

But: contaminants still a problem



Isobaric contaminants have same TOF (m/q dep.)

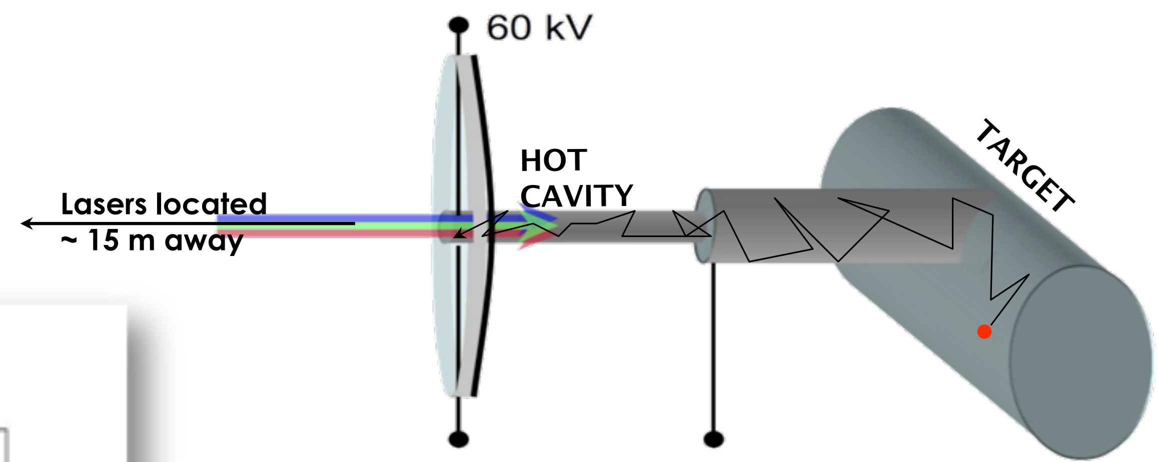
➔ Bunching doesn't help here

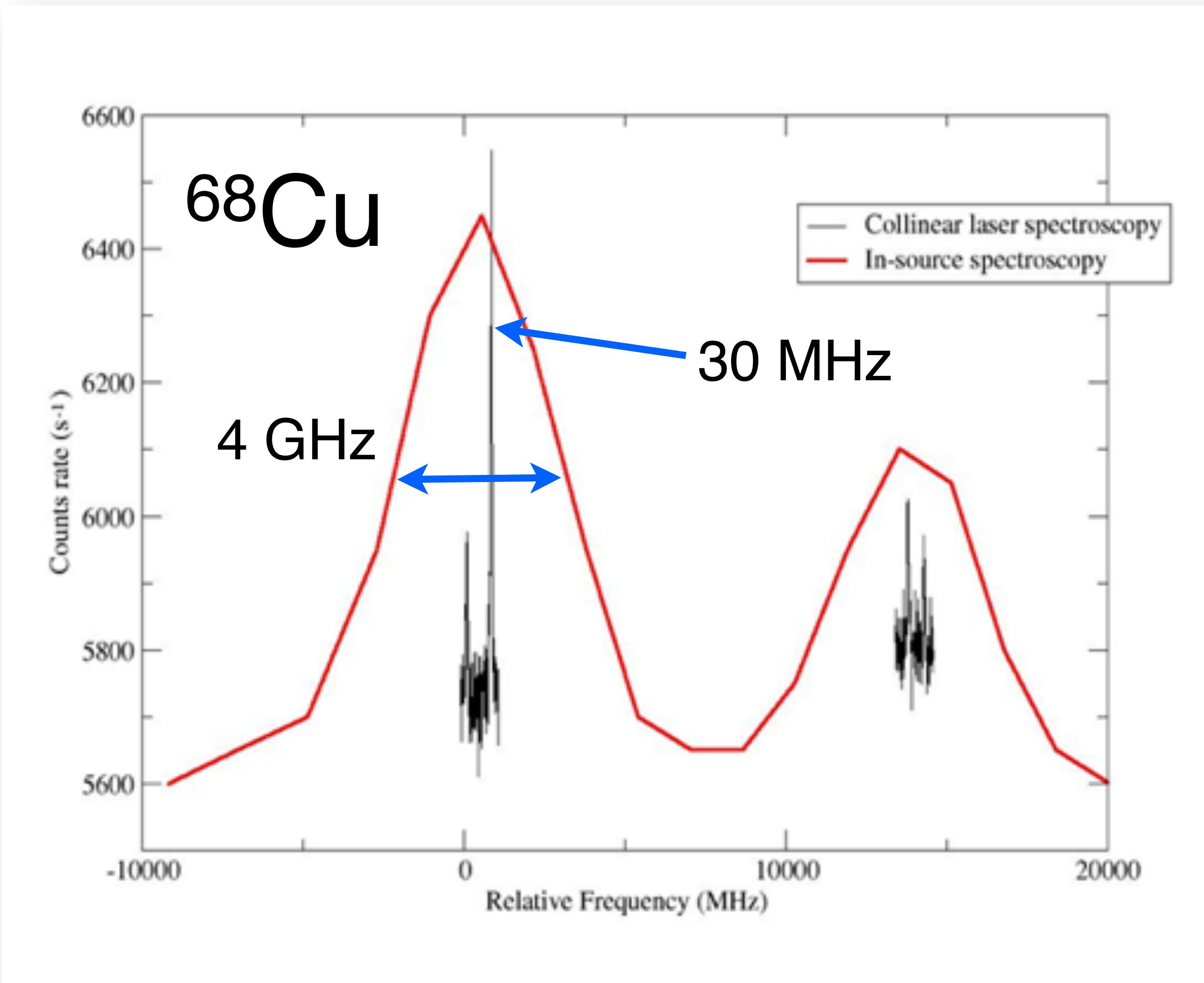
➔ Need *Z*-selectivity to separate

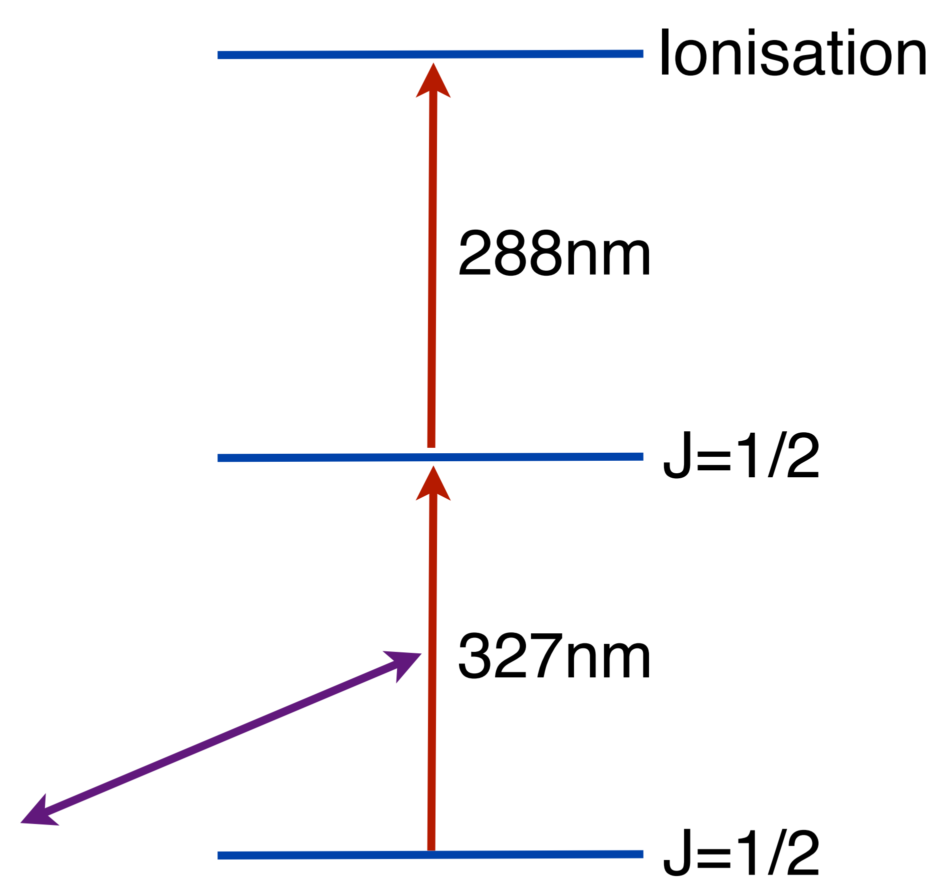
Non-optical detection methods

eg. Resonant Ionisation Laser Ion Source

- Sensitive detection
- Spectral broadening







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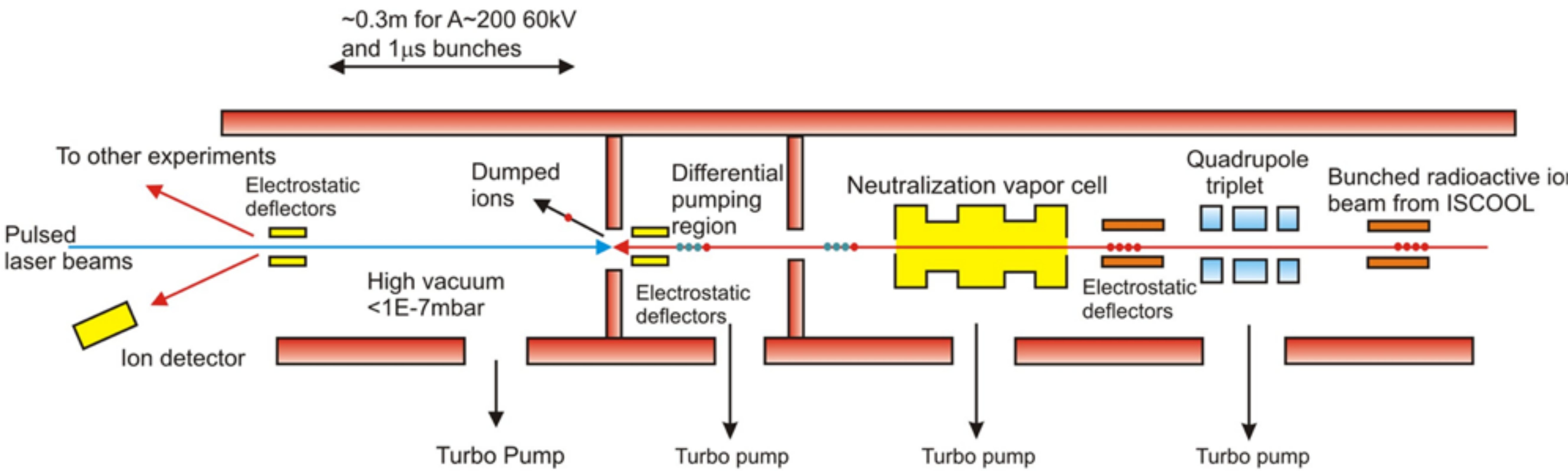
CRIS

Collinear resonance ionisation spectroscopy

Combines: { Sensitivity of RIS/particle detection
Resolution of collinear spectroscopy



Neutralisation, Resonant re-ionisation

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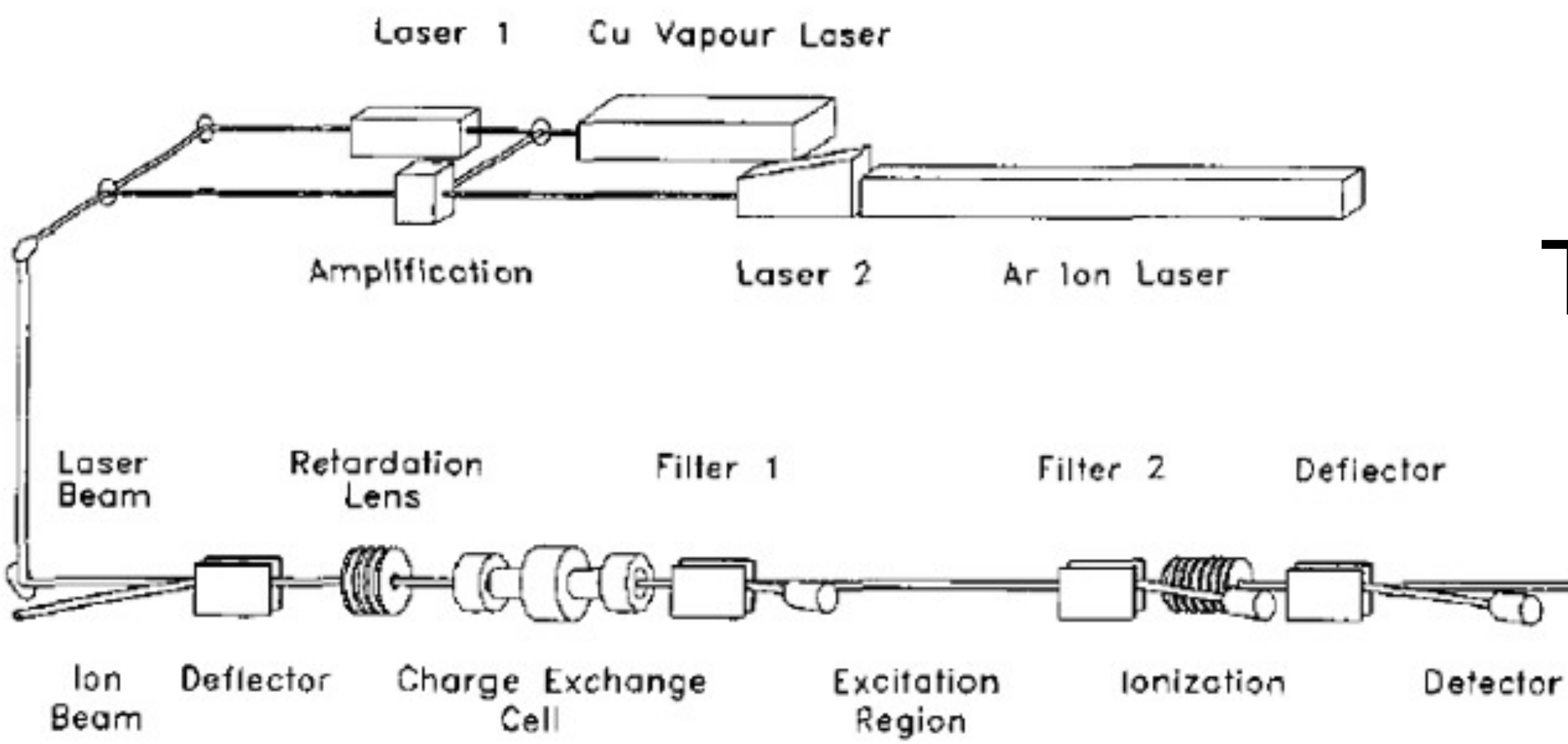
Requires a bunched beam

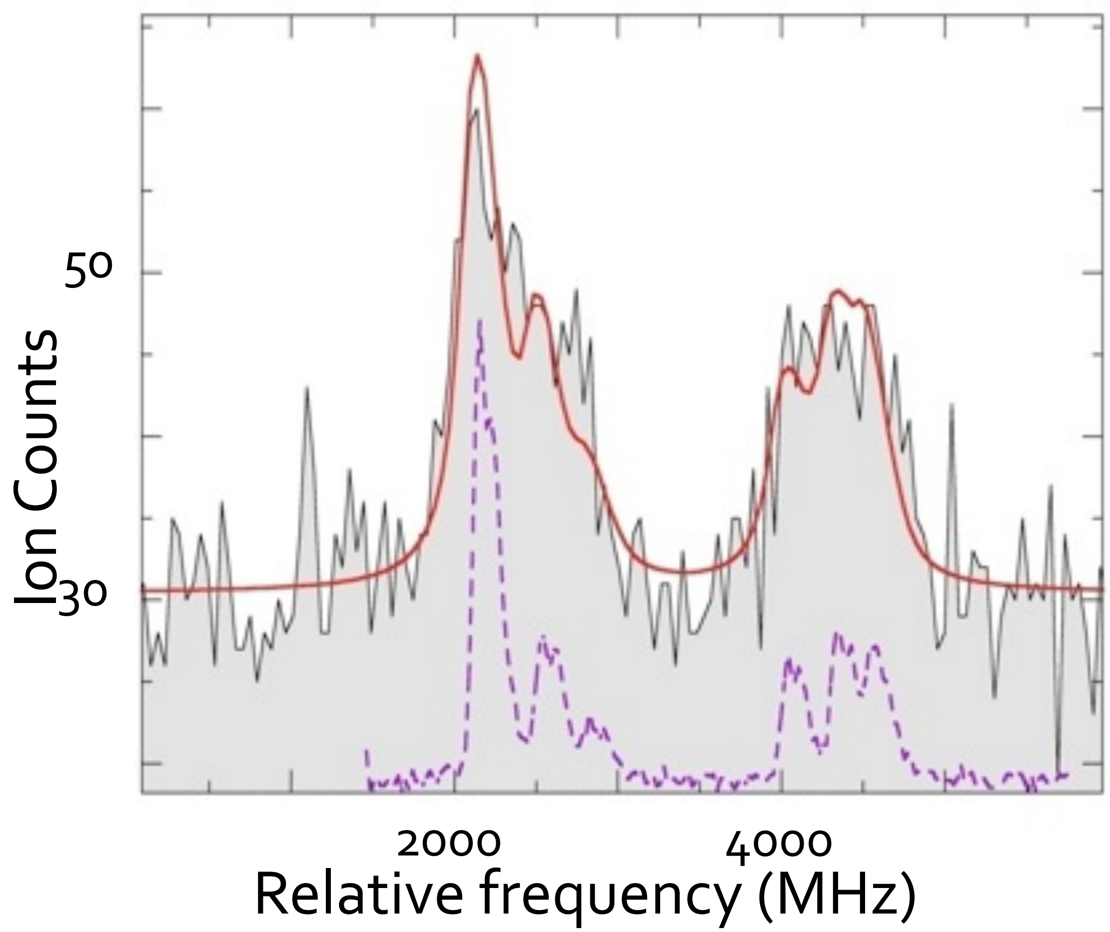


Total efficiency 1:100 000

Ch. Schulz et al., J. Phys. B, 24 (1991) 4831

Pulsed lasers but a continuous ion beam
➙ duty cycle losses

Preliminary “proof of principle”

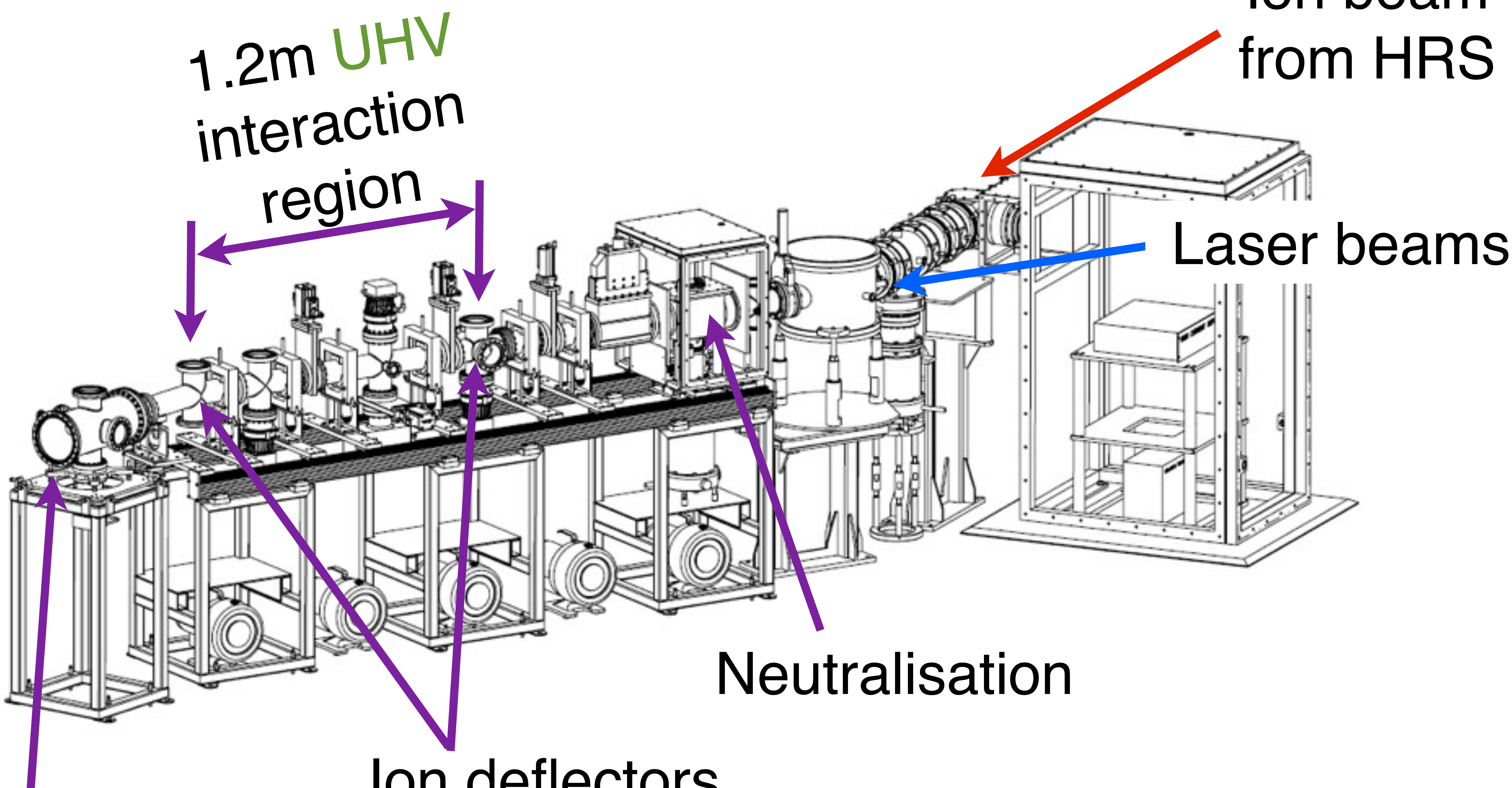


200 ions per bunch
6 scans
1:30 efficiency
(1000x)

Poor vacuum (10^{-5} mbar) ~5 non-resonant ions/bunch

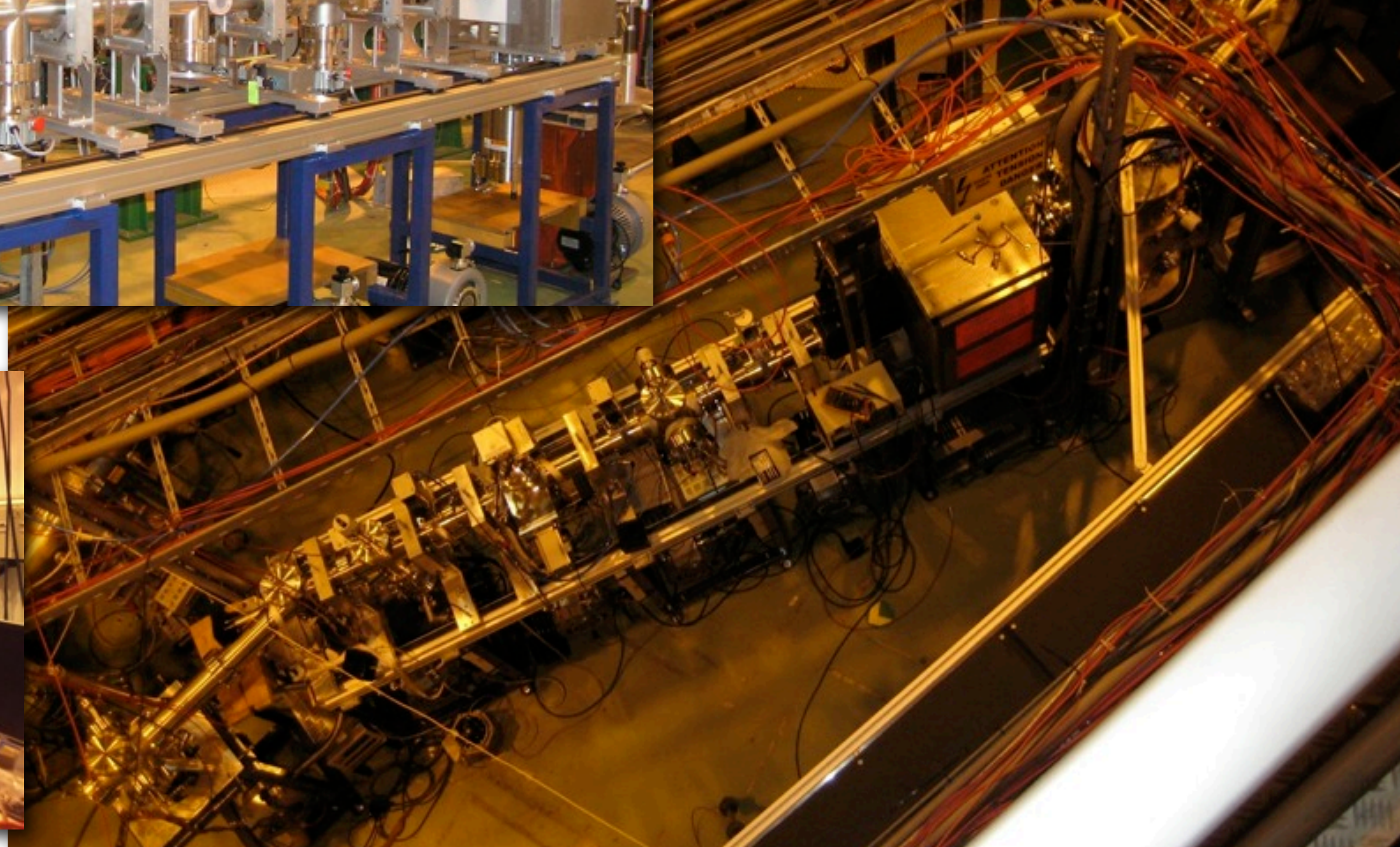
Bunch length > interaction region length

CRIS line design



Aim: ionise whole bunch with one “pulse”

CRIS line construction



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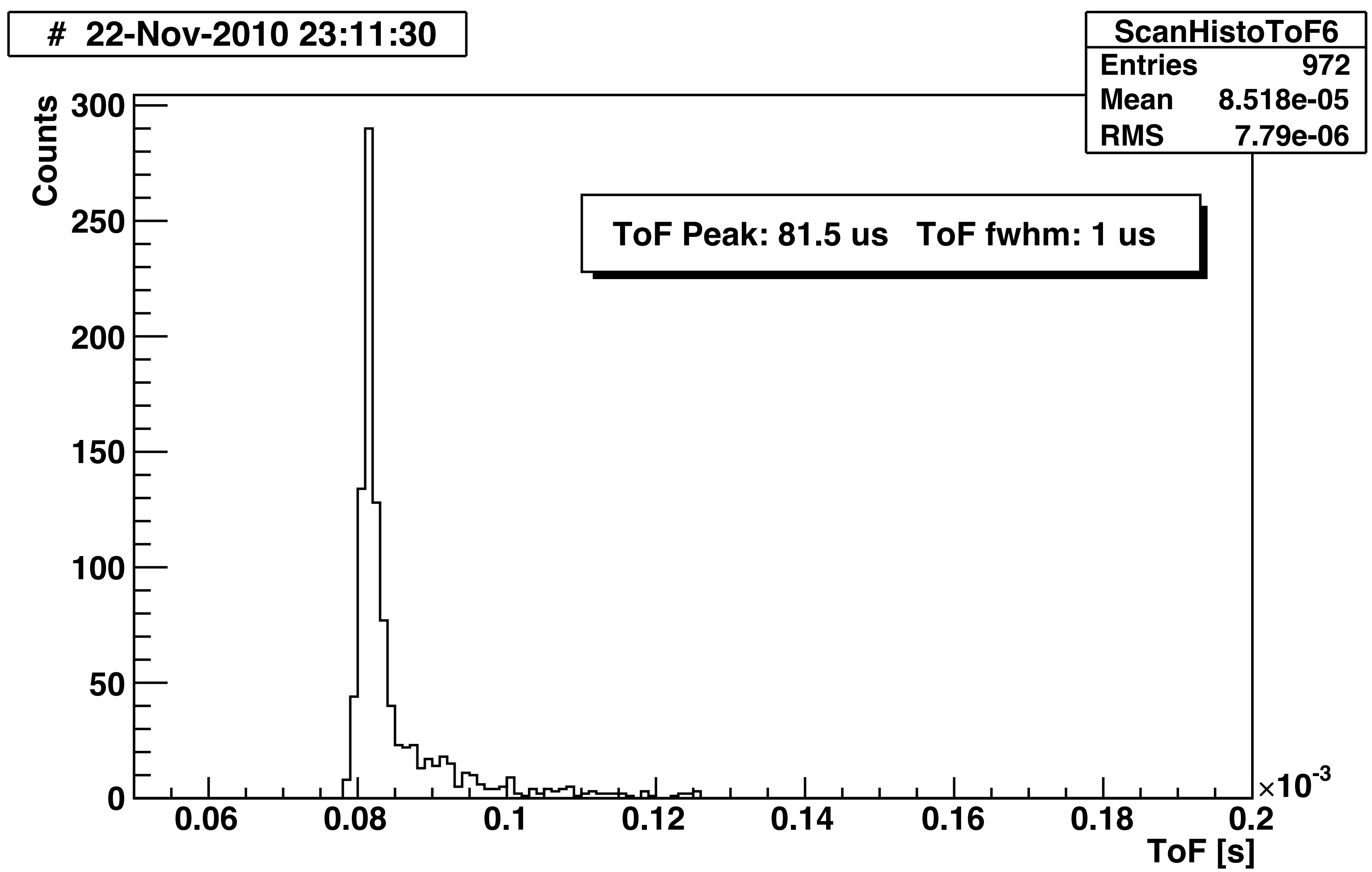
November tests

- Beam tuning (>70% to interaction region)
- Charge exchange (typically 75%)
- UHV ($< 5 \times 10^{-9}$ mbar)
- 1μs FWHM



K.M. Lynch

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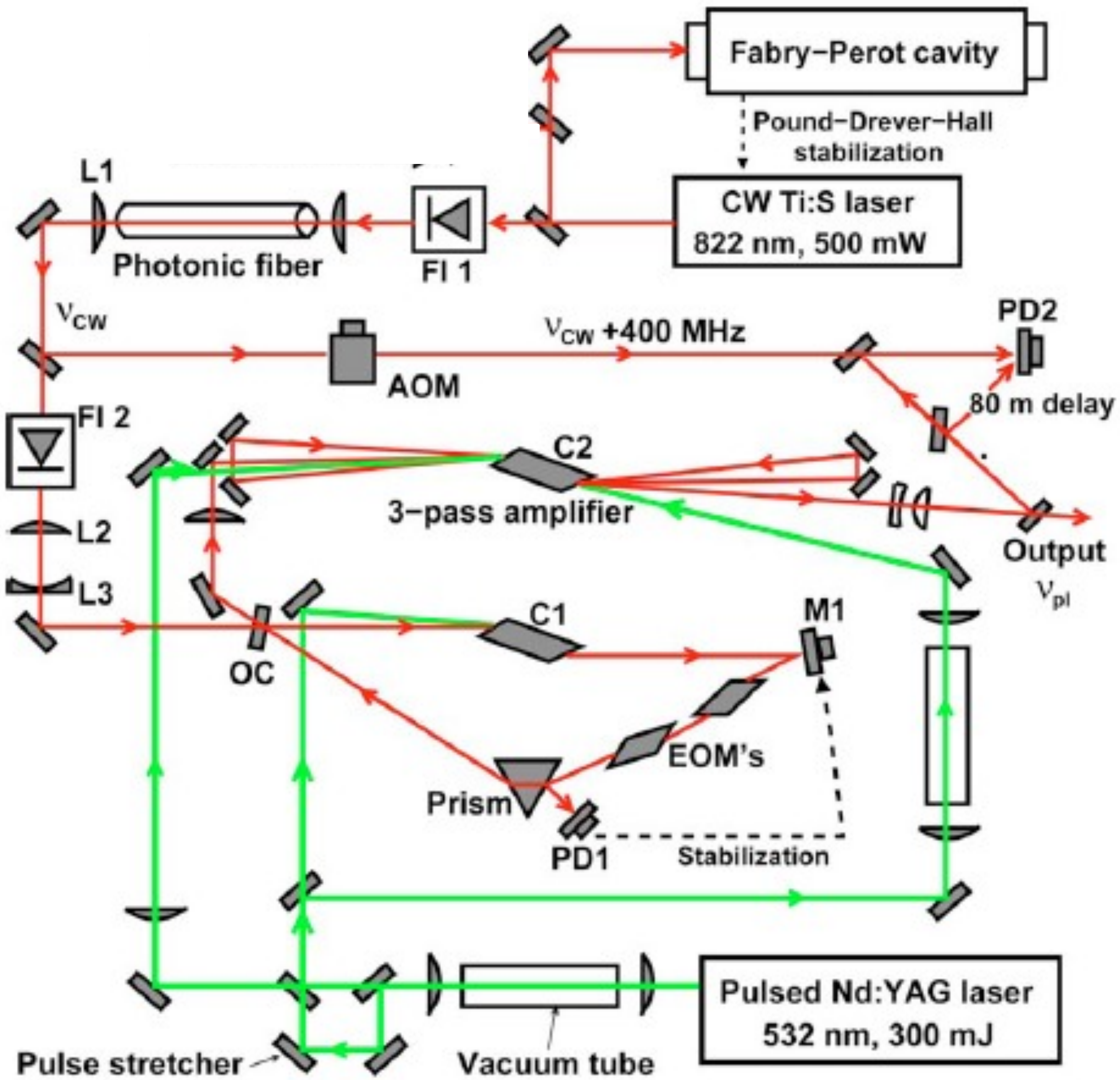
Laser problems, but a new system



Tested tuning range 726–941 nm
E=50–100 mJ

Replacing CW TiSa with a diode laser system (845nm, 300mW)

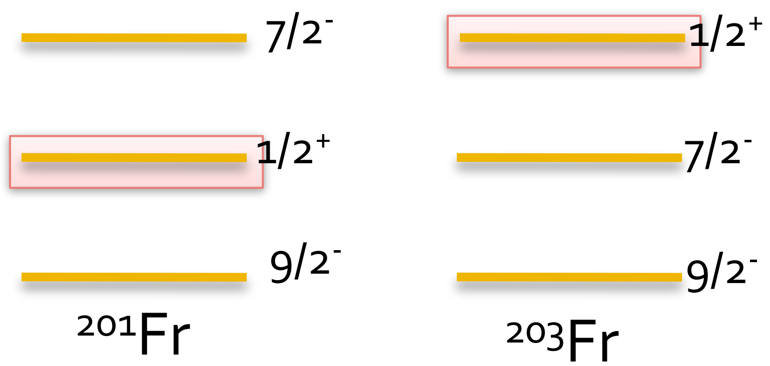
Turn key table top system with minimal interventions during operation.

Novel laser system for radioactive ion beam facilities

M. Hori and A. Dax OPTICS LETTERS 34, 1273 (2009)

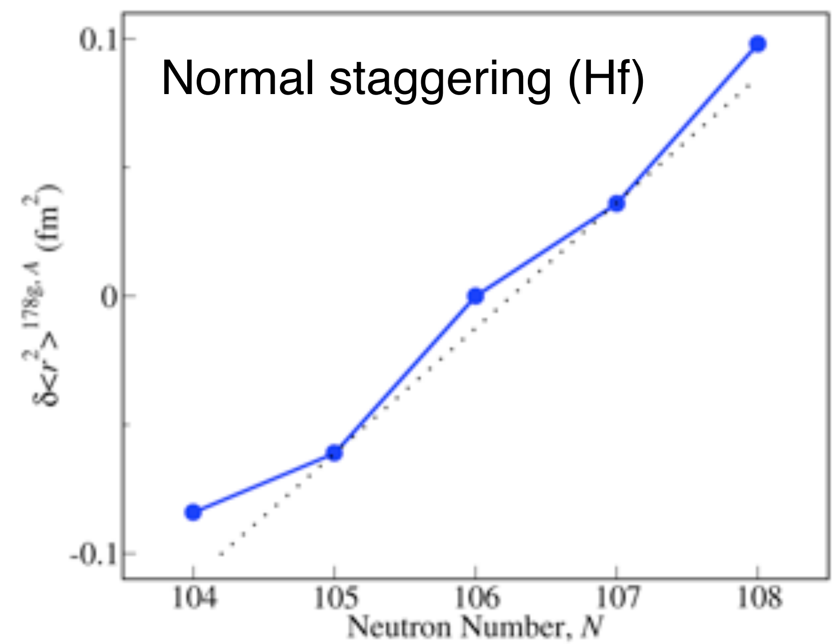
Spectroscopy of francium (Z=87)

Reordering of quantum states



Lowering of I=1/2+ intruder state with decreasing *N*.

Suggestion that ^{199}Fr has I=1/2+ ground state spin with an associated large oblate deformation.

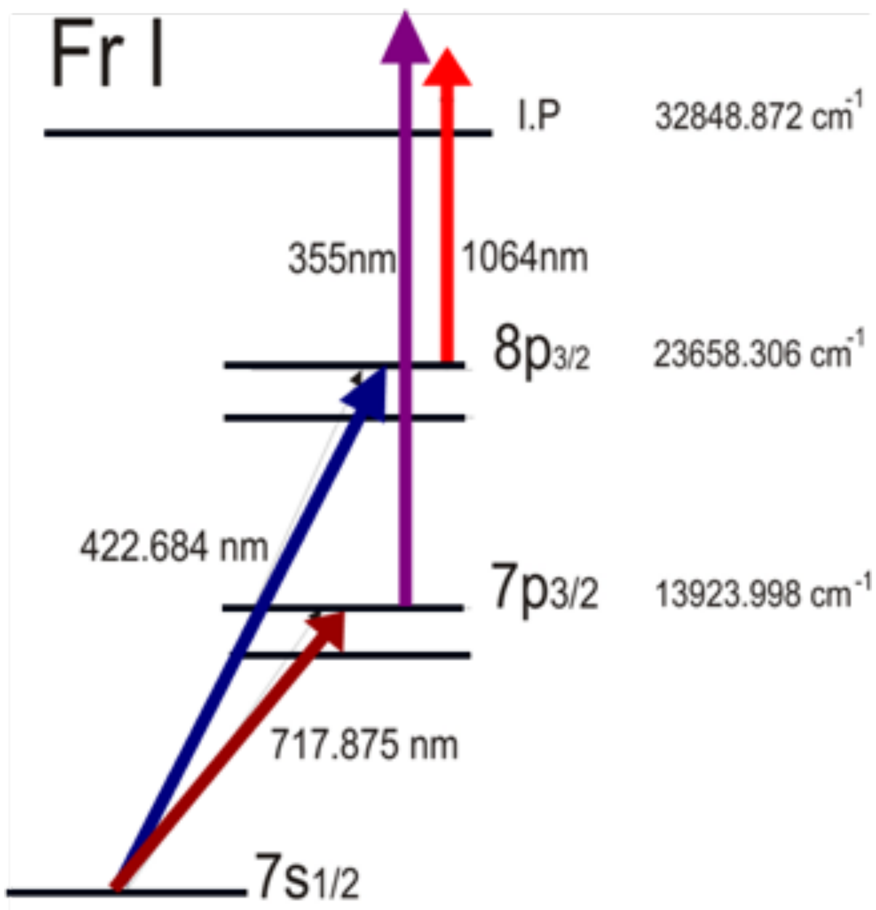


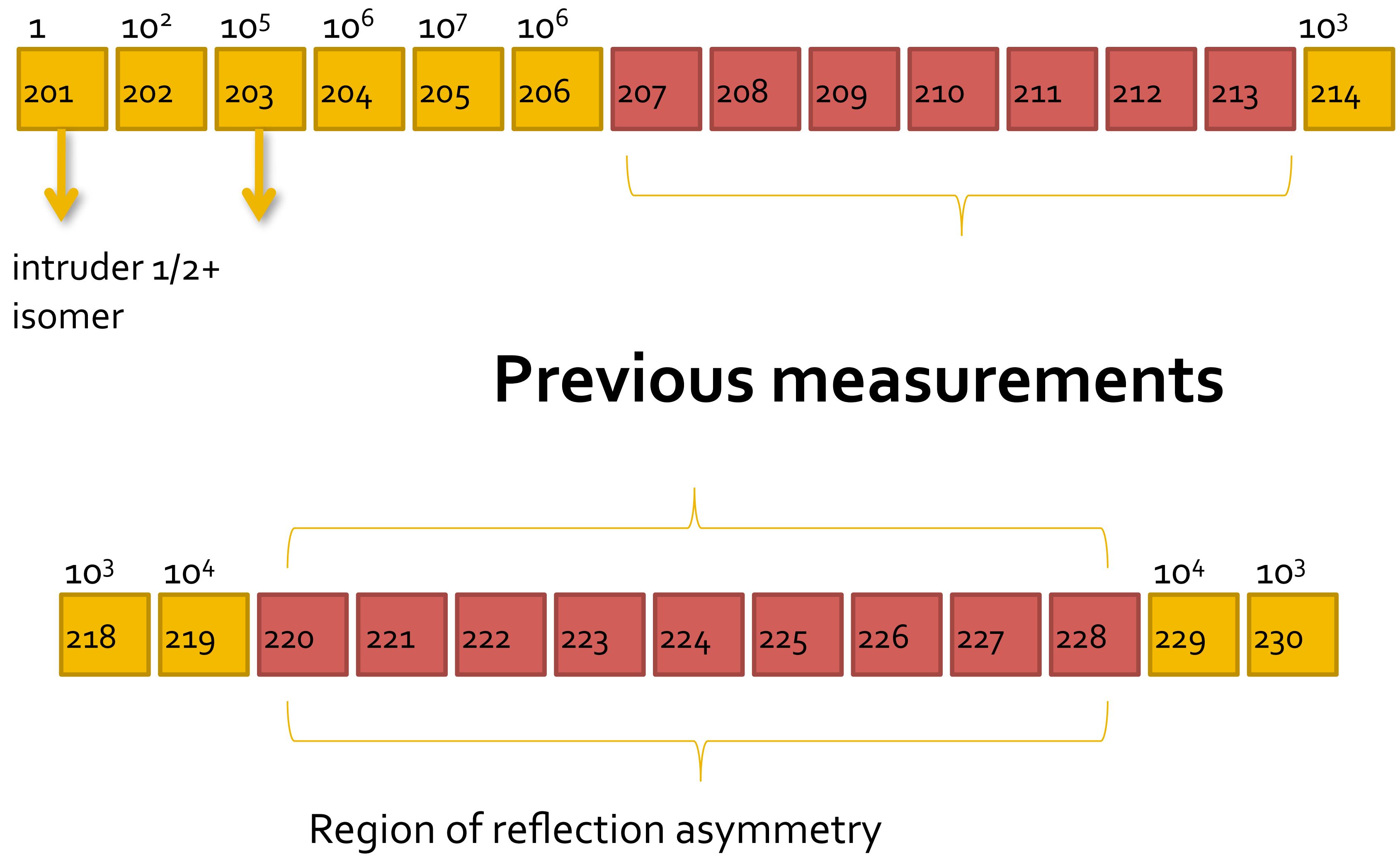
Region known to be characterised by reversal in odd-even staggering, which is attributed to presence of octupole-quadrupole deformation.

$$Q_s \rightarrow \langle \beta_2 \rangle$$

$$\langle r^2 \rangle \rightarrow \langle \beta_2^2 \rangle + \langle \beta_3^2 \rangle + \ldots$$

Spectroscopy of francium





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Summary

- Optical spectra provide μ, Q_s, δ<r^2>, spin
- Collinear resonance ionisation combines efficiency of particle detection with ~ resolution of collinear beams method
- Purpose-built beam line now constructed
- Can also be used to purify beams (Z)

Collaboration

J. Billowes, M. Bissell, F. Le Blanc, B. Cheal,
K.T. Flanagan, D.H. Forest, R. Hayano, M. Hori,
T. Kobayashi, G. Neyens, T. Procter, H.H Stroke,
G. Tungate, W. Vanderheijden, P. Vingerhoets, K. Wendt.