Towards Single Atom (fixed) Targets which will open New roads in experimental Forward Physics (Jets)

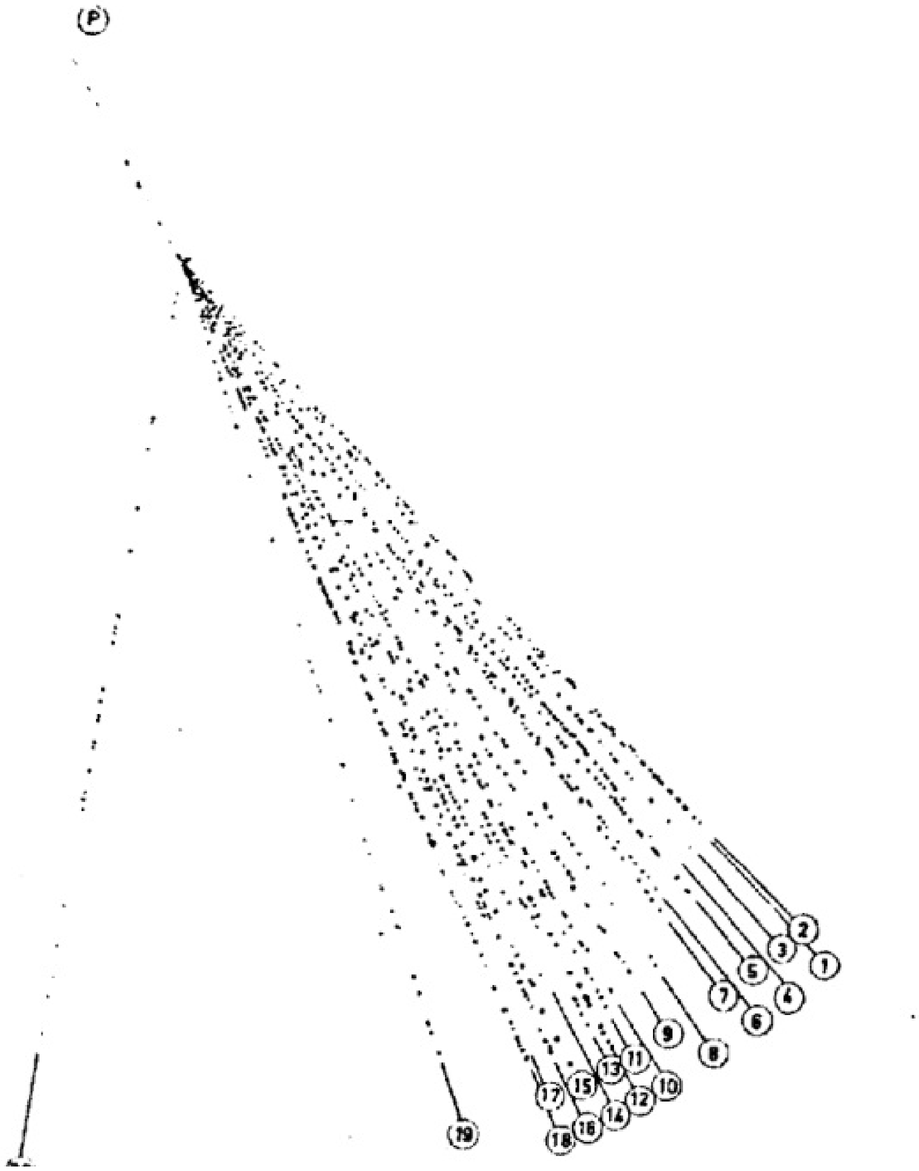
Luebbo von Lindern retired, MPG

1. Angular distribution of high multiplicity jets in cosmic rays.
2. Their Asymptotic behavior favors forward emission in CMS and allows high precision angular resolution for fixed target experiments.
3. Recent advances of laser-optics make it highly desirable to test how a Single atom target could be made and a new range of precision achieved.

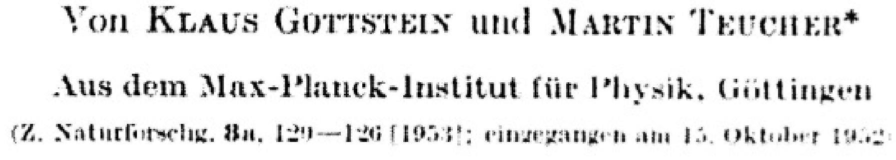
Any party interested to give or take more information, please let me know as long as no other means of communication are established: lvlold@aol.com

IV Workshop on QCD and Diffraction at the LHC joint with Forward Physics and Diffraction WG meeting
D-16, AGH UST, Cracow, 15. – 17. December 2014

1. Angular distribution of high multiplicity jets in cosmic rays.



„Star“ 0+20p, ca. 40 GeV
(Faksimile Drawing of projection)



Von Klaus Gottstein und Martin Teucher*

Aus dem Max-Planck-Institut für Physik, Göttingen

(Z. Naturforschg. 8a, 120—126 [1953]; eingegangen am 15. Oktober 1952)

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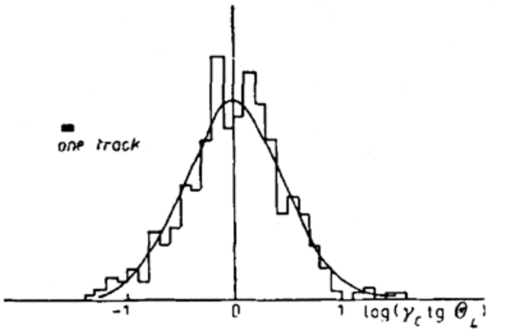

Fig. 1. – Differential angular distribution for jets in the energy interval 10^{10} eV to 10^{11} eV. The continous curve represents the best fit of a Gaussian curve to the experimental data with $\sigma = 0.46$.

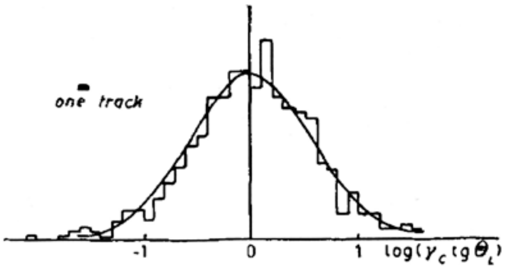

Fig. 2. – Differential angular distribution for jets in the energy interval 10^{11} eV to 10^{12} eV. The continous curve represents the best fit of a Gaussian curve to the experimental data with $\sigma = 0.55$.

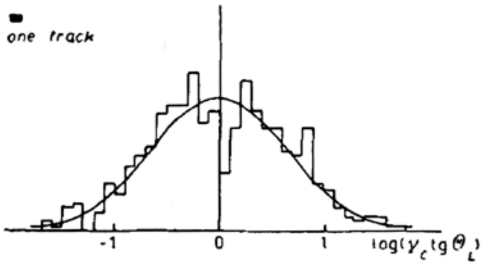

Fig. 3. – Differential angular distribution for jets in the energy interval 10^{12} eV to 10^{13} eV. The continous curve represents the best fit of a Gaussian curve to the experimental data with $\sigma = 0.66$.

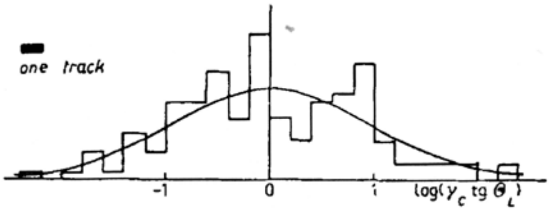

Fig. 4. – Differential angular distribution for jets with energy higher than 10^{13} eV. The continous curve represents the best fit of a Gaussian curve to the experimental data with $\sigma = 0.96$.

Nuclear Interactions in the Energy Region $(10^{10} \div 10^{14})$ eV.

P. Ciok, T. Coghen, J. Gierula, R. Hołyński, A. Jurak,
M. Mięsowicz and T. Saniewska

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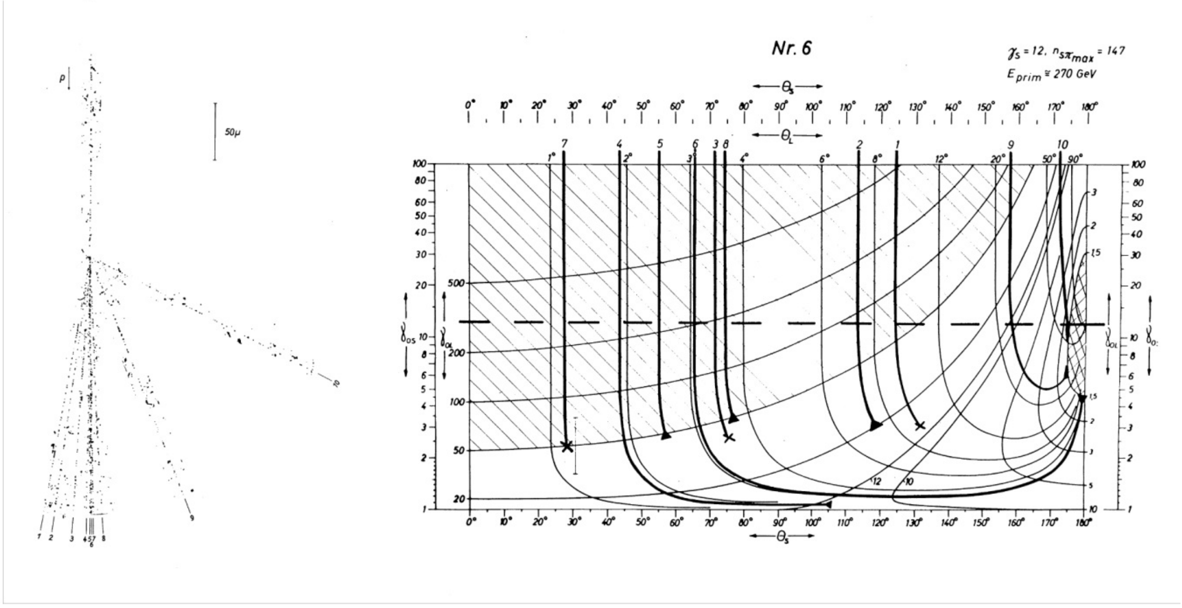
Institute for Physics of Czechoslovac Academy of Sciences - Praha

(ricevuto il 16 Luglio 1958)

2. Their Asymptotic behavior favors forward emission in CMS and allows high precision angular resolution for fixed target experiments.

**figure 1: Asymptotic kinematics in common CMS
at about 300 GeV lab.**

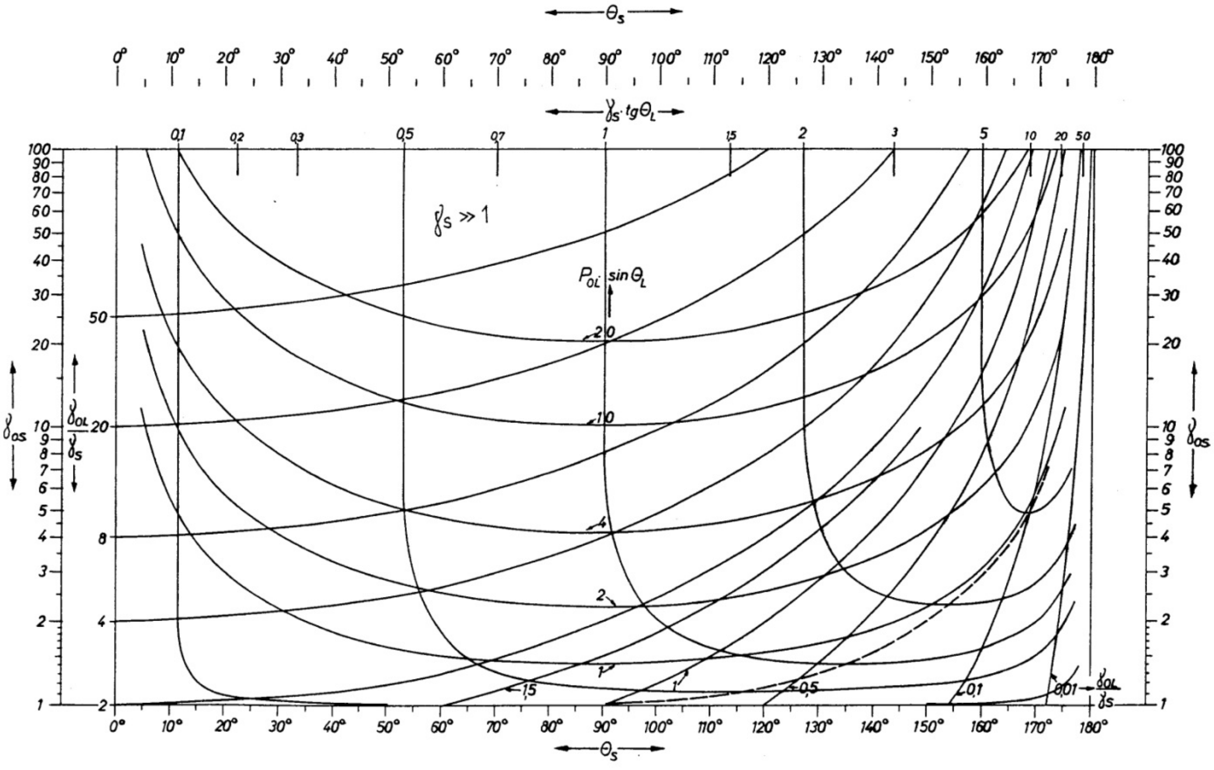
nucl. emulsion track numbers indicated **CMS** variables see fig. 2
10p – 0 - 0



Thick lines in plot correspond to observed tracks:
X : energy from multiple scattering
^ : lower limit of energy from multiple scatt.
cross hatched : area, where tracks would appear with higher than minimum ionisation
hatched : noise limit for multiple scattering

Poster ISVHECRY 2002 A tribute to the memory of Kurt Symanzik (1923-1983)
Thesis L. von Lindern, LMU Munich 1961, p. 10a, p. 138.

figure 2: Asymptotic behaviour of angular CMS distributions in terms of the jet variable γ_s tg Θ_L and the ratio γ_{oL}/γ_s for ultra high primary energy $\gamma_s >>> 1$.



γ_S = Lorentzfactor of center-of-mass-system (CMS)

γ_{oS} = Lorentzfactor of secondary particle in CMS

Θ_S = polar angle of secondary particle in CMS

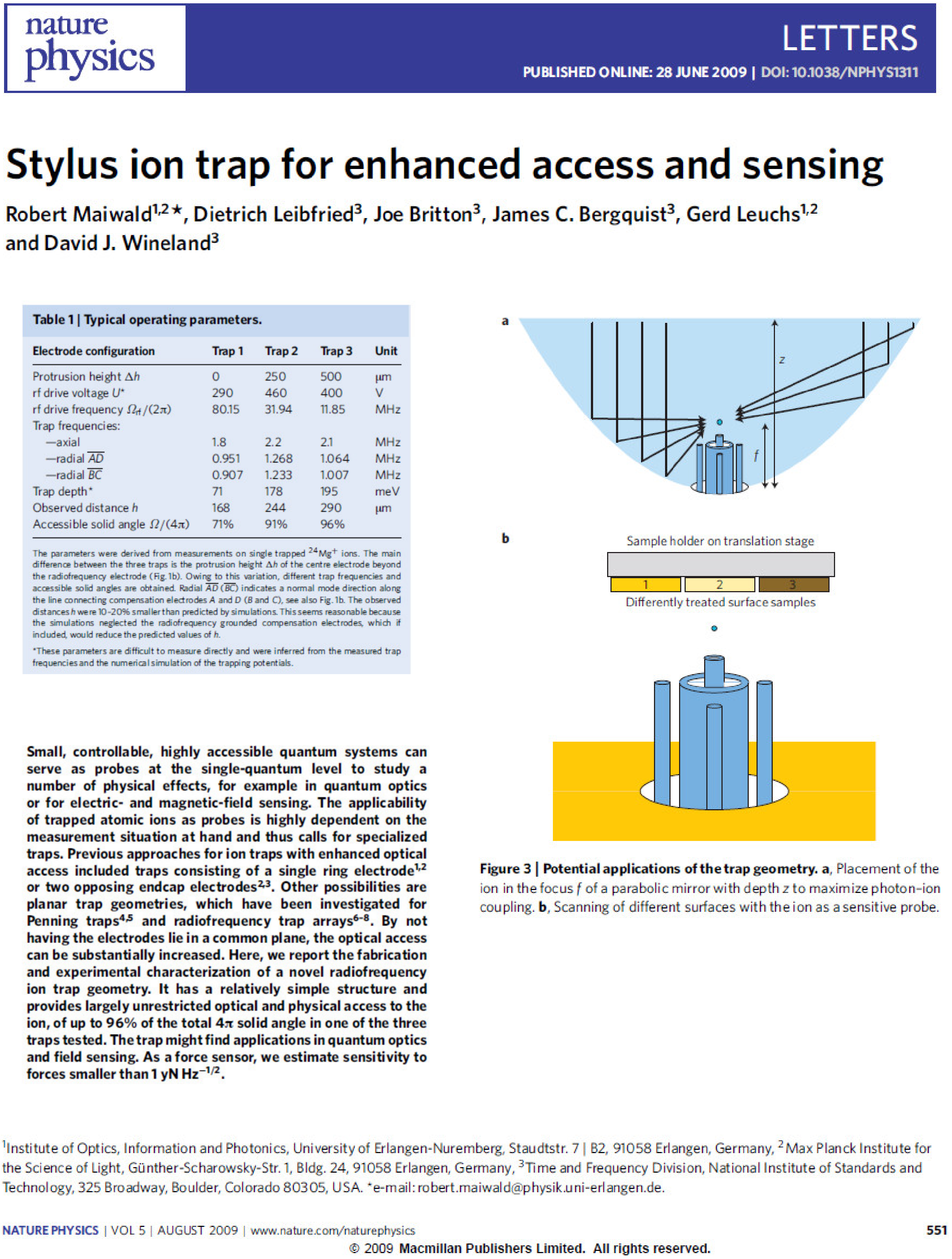
γ_{oL} = Lorentzfactor of secondary particle in lab-system

Θ_L = polar angle of secondary particle in lab-system

velocities β and momenta p correspondingly, mc^2 =

Poster ISVHECRY 2002 A tribute to the memory of Kurt Symanzik (1923-1983)
Thesis L. von Lindern, LMU Munich 1961, p. 130.

3. **Recent advances of laser-optics make it highly desirable to test how a Single atom target could be made and a new range of precision achieved.**



nature physics

LETTERS

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Stylus ion trap for enhanced access and sensing

Robert Maiwald[1,2]*, Dietrich Leibfried[3], Joe Britton[3], James C. Bergquist[3], Gerd Leuchs[1,2] and David J. Wineland[3]

Table 1 | Typical operating parameters.

Electrode configuration	Trap 1	Trap 2	Trap 3	Unit
Protrusion height Δh	0	250	500	μm
rf drive voltage U^*	290	460	400	V
rf drive frequency $\Omega_{rf}/(2\pi)$	80.15	31.94	11.85	MHz
Trap frequencies:				
—axial	1.8	2.2	2.1	MHz
—radial $\overline{AD}$	0.951	1.268	1.064	MHz
—radial $\overline{BC}$	0.907	1.233	1.007	MHz
Trap depth*	71	178	195	meV
Observed distance h	168	244	290	μm
Accessible solid angle $\Omega/(4\pi)$	71%	91%	96%	

The parameters were derived from measurements on single trapped $^{24}\mathrm{Mg}^+$ ions. The main difference between the three traps is the protrusion height Δh of the centre electrode beyond the radiofrequency electrode (Fig. 1b). Owing to this variation, different trap frequencies and accessible solid angles are obtained. Radial $\overline{AD}$ ($\overline{BC}$) indicates a normal mode direction along the line connecting compensation electrodes A and D (B and C), see also Fig. 1b. The observed distances h were 10–20% smaller than predicted by simulations. This seems reasonable because the simulations neglected the radiofrequency grounded compensation electrodes, which if included, would reduce the predicted values of h.

*These parameters are difficult to measure directly and were inferred from the measured trap frequencies and the numerical simulation of the trapping potentials.

Figure 3 | Potential applications of the trap geometry. a, Placement of the ion in the focus f of a parabolic mirror with depth z to maximize photon–ion coupling. **b**, Scanning of different surfaces with the ion as a sensitive probe.

Small, controllable, highly accessible quantum systems can serve as probes at the single-quantum level to study a number of physical effects, for example in quantum optics or for electric- and magnetic-field sensing. The applicability of trapped atomic ions as probes is highly dependent on the measurement situation at hand and thus calls for specialized traps. Previous approaches for ion traps with enhanced optical access included traps consisting of a single ring electrode[1,2] or two opposing endcap electrodes[2,3]. Other possibilities are planar trap geometries, which have been investigated for Penning traps[4,5] and radiofrequency trap arrays[6–8]. By not having the electrodes lie in a common plane, the optical access can be substantially increased. Here, we report the fabrication and experimental characterization of a novel radiofrequency ion trap geometry. It has a relatively simple structure and provides largely unrestricted optical and physical access to the ion, of up to 96% of the total 4π solid angle in one of the three traps tested. The trap might find applications in quantum optics and field sensing. As a force sensor, we estimate sensitivity to forces smaller than 1 yN Hz$^{-1/2}$.

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Superposition, Entanglement, and Raising Schrödinger's Cat

Nobel Lecture, December 8, 2012

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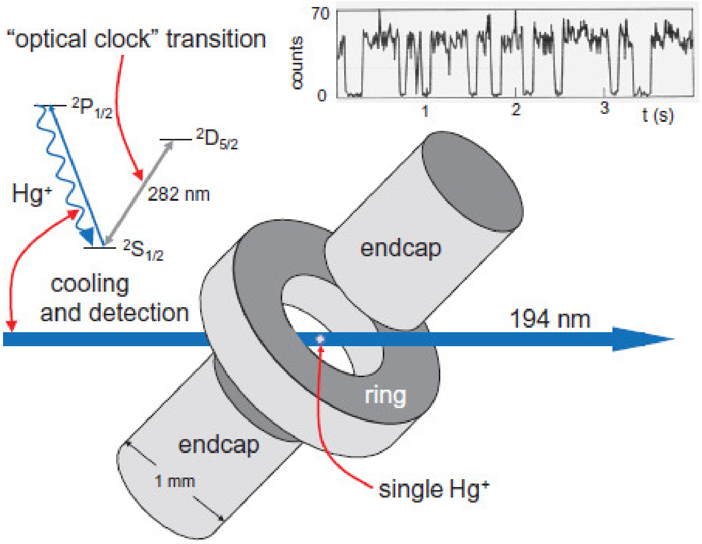

FIGURE 1. Schematic of the trap for single Hg⁺ ion studies. An RF potential is applied between the ring electrode and endcap electrodes (which are in common), forming an RF "pseudopotential" for the ion. The relevant Hg⁺ energy levels are indicated, including the narrow $^2S_{1/2} \rightarrow {}^2D_{5/2}$ "optical clock" transition. The data in the upper right-hand part of the figure show the number of 194 nm fluorescence photons detected in 10 ms detection bins vs. time when both transitions are excited simultaneously (Bergquist *et al.* 1986). Absence of detected counts indicates that the ion is in the $^2D_{5/2}$ state.

References and further readings:

http://www.nobelprize.org/nobel_prizes/physics/laureates/2012/wineland-facts.html

http://www.nobelprize.org/nobel_prizes/physics/laureates/2012/haroche-facts.html

Maiwald, D. Leibfried, J. Britton, J. C. Bergquist, G. Leuchs, David J. Wineland: Stylus ion trap for enhanced access and sensing. Nature Physics 5 (2009) 551-554

G. Leuchs: Inverse spontaneous emission of an atom in free space – an example of time reversal symmetry in optics: https://uwaterloo.ca/institute-for-quantum-computing/events/leuchs- inverse-spontaneous-emission-atom-free-space-example

Stefan Kuhr, Wolfgang Alt,Dominik Schrader,Martin Müller,Victor Gomer, Dieter Meschede. Science 2001 Vol.293 no. 2558 pp. 278 – 280 Deterministic Delivery of a Single Atom.

M. Weber, J. Volz, K. Saucke, C. Kurtsiefer,H. Weinfurter. Phys. Rev. A 73, 043406 (2006) Analysis of a single-atom dipole trap.

H. L. Bradt, M. F. Kaplon and B. Peters. Helv. Phys. Acta 23 (1950) 24-62

C. Castagnoli, G. Cortini, C. Franzinetti, A. Manfredini and D. Moreno Nuovo Cim. 14 (1953) 1539-1558

L. D. Landau. Izv. Akad. Nauk. SSSR 17 (1953) 51 transl. in D. ter Haar, Collected Papers of L.D. Landau, Pergamon Press, Ltd. 1965, pp. 569-585

K. Symanzik. Praktisch wichtige Formeln aus der Relativitätskinematik pp. 558- 564 in W. Heisenberg, Kosmische Strahlung. 2nd ed. 1953, Springer, Berlin-Göttingen, Heidelberg

M. Schein, R.G. Glasser, D.M. Haskin, Nuovo Cim. 2 (1955) 647.

L. v. Lindern. Nuovo Cim. 5 (1957) 491-501, Thesis Univ. München 1961, 151 p. and Nuovo Cim. 48 (1967) 289-302

P. Ciok, M. Danysz, J. Gierula, A. Jurak, M. Miesowicz, J. Penegr, J. Vrana, W. Wolter,. Nuovo Cim. 6 (1957) 1409

B.J. Edwards, J. Losty, K. Pinkau, D.H. Perkins, J. Reynolds, Phil. Mag.3 (1958) 2