

The Fractional Quantum Hall Effect (FQHE)??

**A Periodic Many-body Quantum Matter Produced in an
Ultra-cold Quantum Degenerate Plasma:
Direct Observation of Fractional Elementary Charges**

François Michels and Klaus Müller-Dethlefs*#

***Emeritus Chair Professor of Physics and Chemistry**

***Founding Director of The Photon Science Institute, School of Natural Sciences**

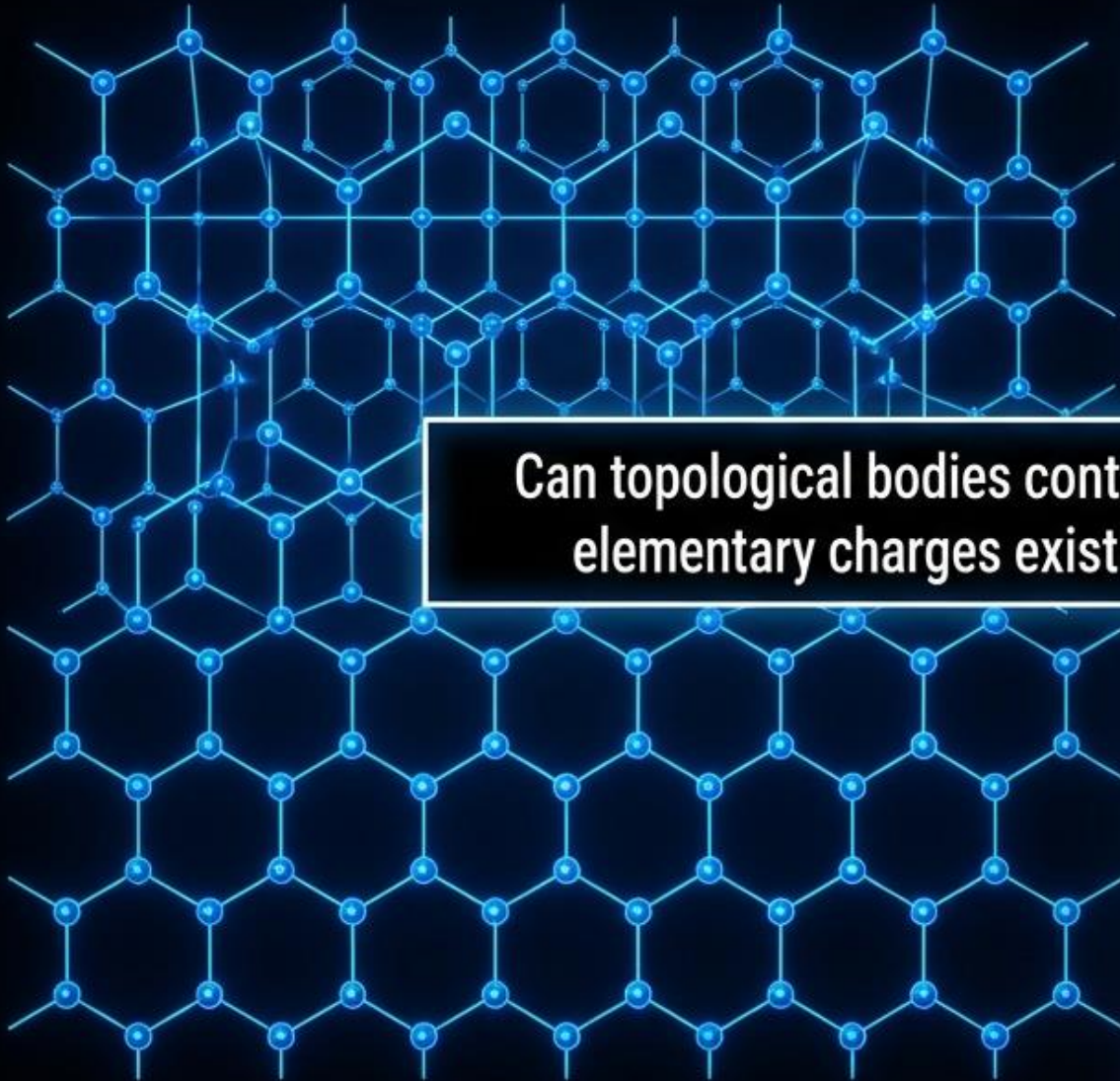
The University of Manchester, United Kingdom

#also at: School of Physics, Xi'an Jiaotong University, Xi'an, Shaanxi Province

ICAP29, Wuhan, People's Republic of China, 18th June 2026

The Classical Realm: Solid-State FQHE

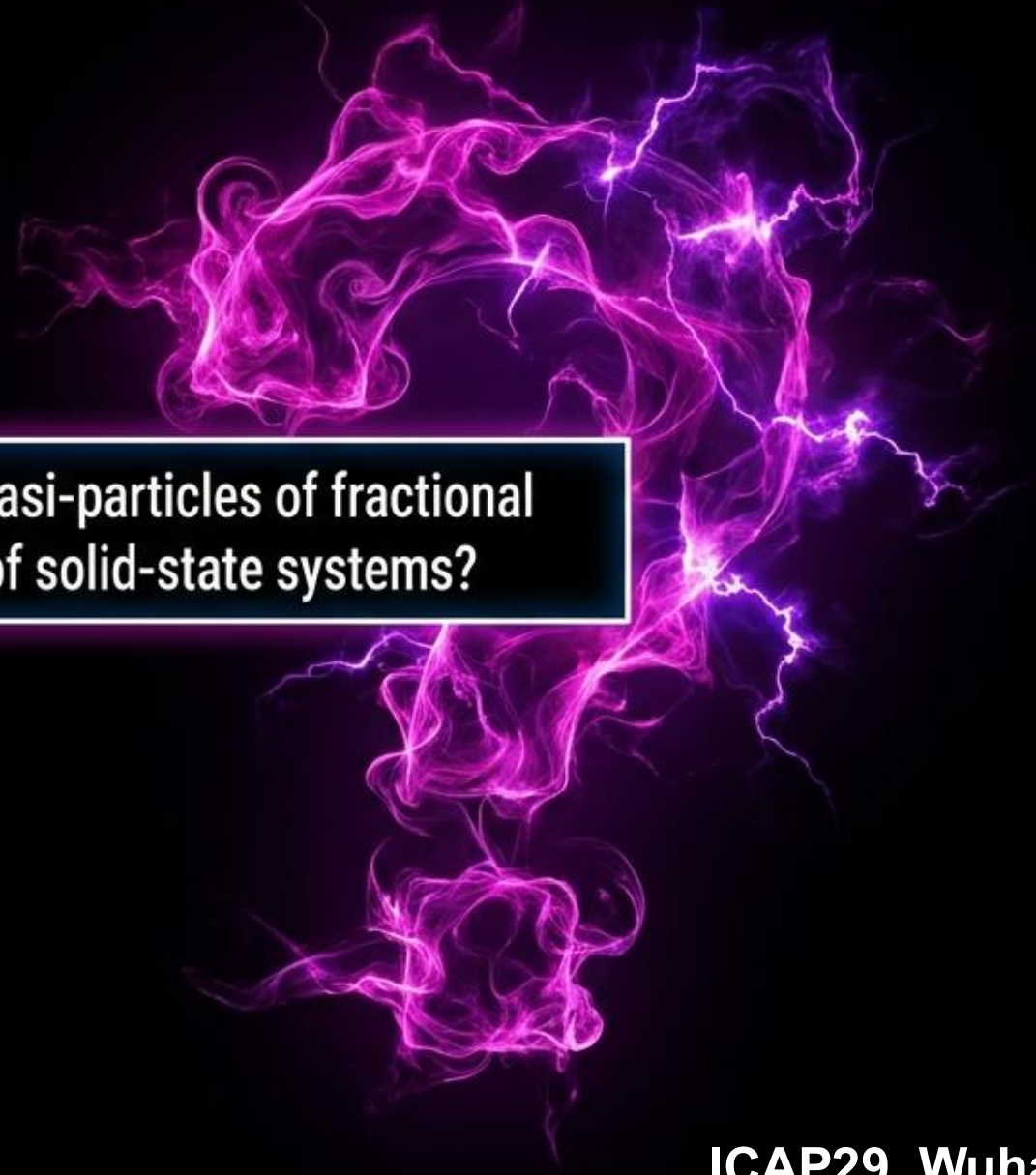
CRYSTALLINE ORDER: PERFECT LATTICE | $\nu = 1/3, 1/5, 2/5, 3/7$ | LOW TEMPERATURE STABILITY



Can topological bodies containing quasi-particles of fractional elementary charges exist outside of solid-state systems?

The Frontier: Ultra-Cold Plasma

FLUID DYNAMICS: AMORPHOUS CHAOS | UNEXPLORED REGIME | EXTREME CONDITIONS



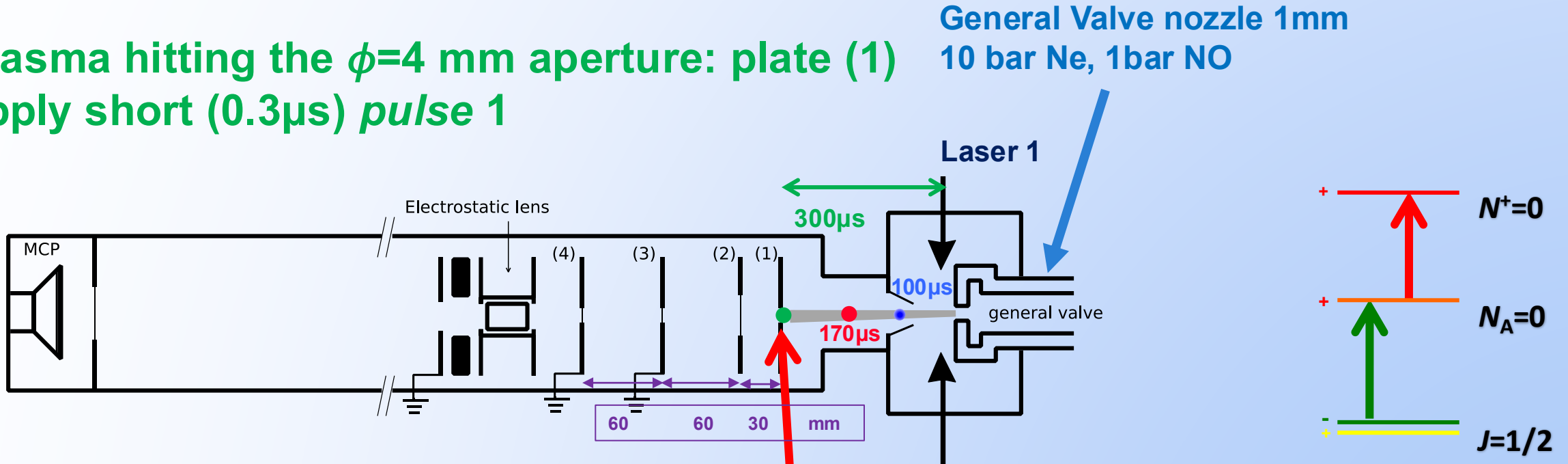
Collinear Experimental Set-up for time-of-flight (ToF) measurement

Density of plasma 1mm away from jet nozzle: $>10^{16} \text{ cm}^{-3}$

Expect extremely low electron temperature and quantum degeneracy

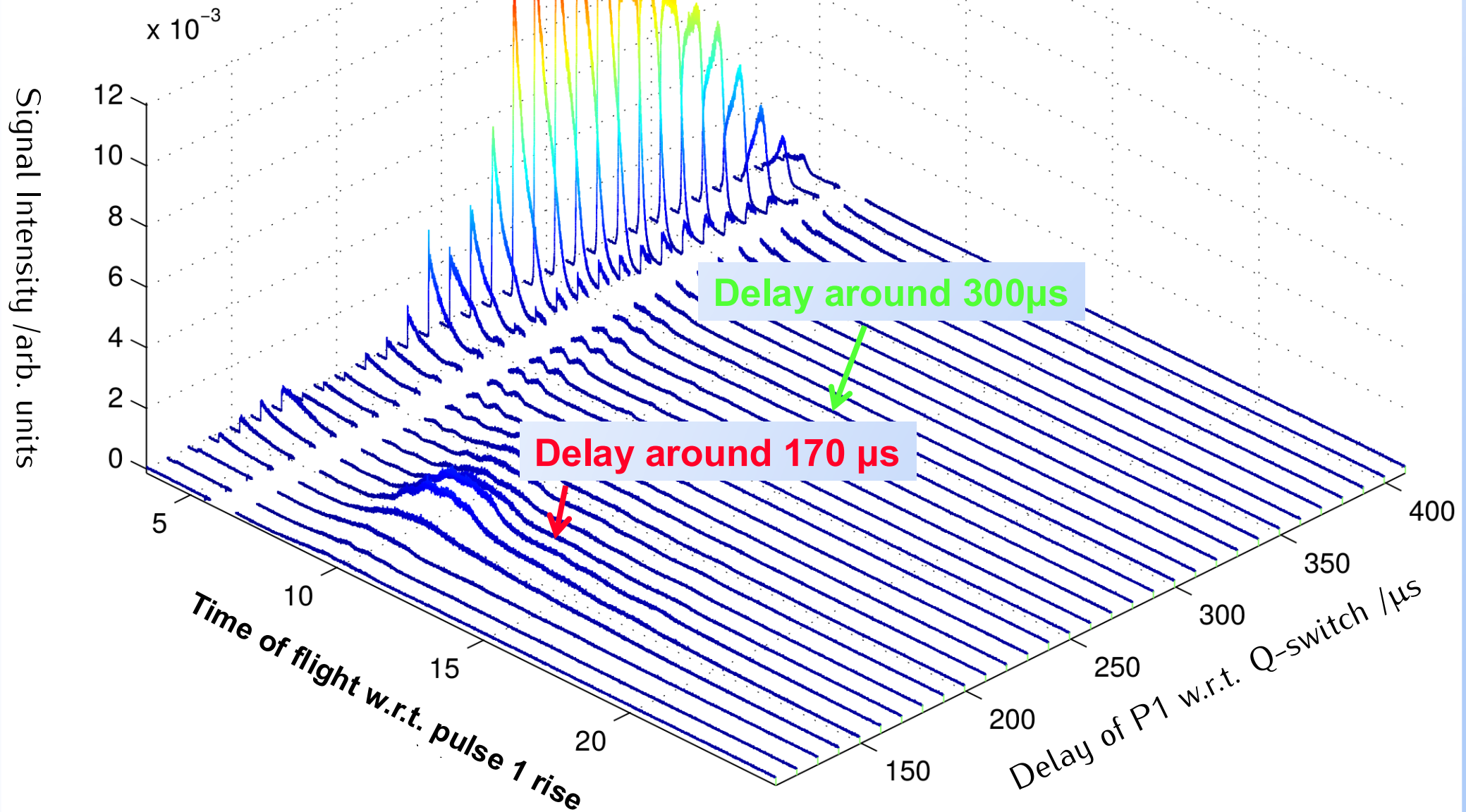
Plasma hitting the $\phi=4 \text{ mm}$ aperture: plate (1)
apply short ($0.3\mu\text{s}$) pulse 1

General Valve nozzle 1mm
10 bar Ne, 1bar NO

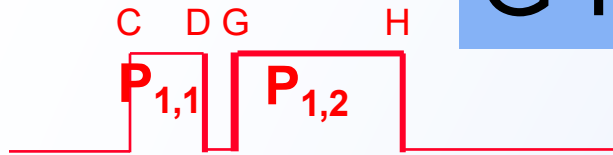


Long ($6\mu\text{s}$)+3.6 kV pulse on aperture 1

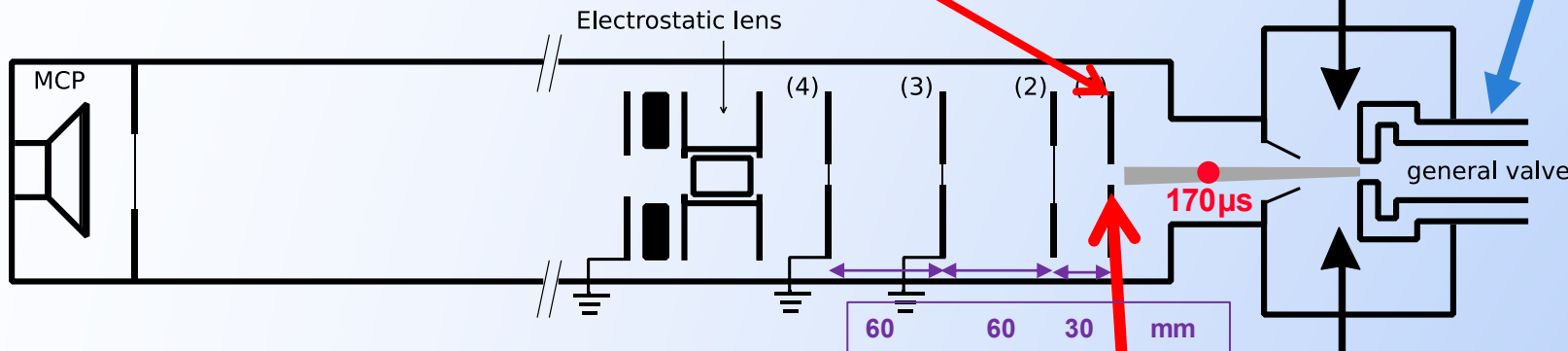
$$v_{\text{jet}} = .85\text{mm}/\mu\text{s}$$



C-D: width of $P_{1,1}=5.5\mu s$; D-G: gap of $0.2\mu s$
 G-H: width of $P_{1,2}=20.2\mu s$, *i.e.* long



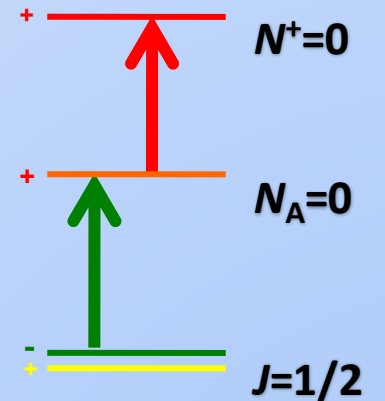
Double pulse $P_{1,1}$ - $P_{1,2}$ applied on E1
“plasma is sliced up”

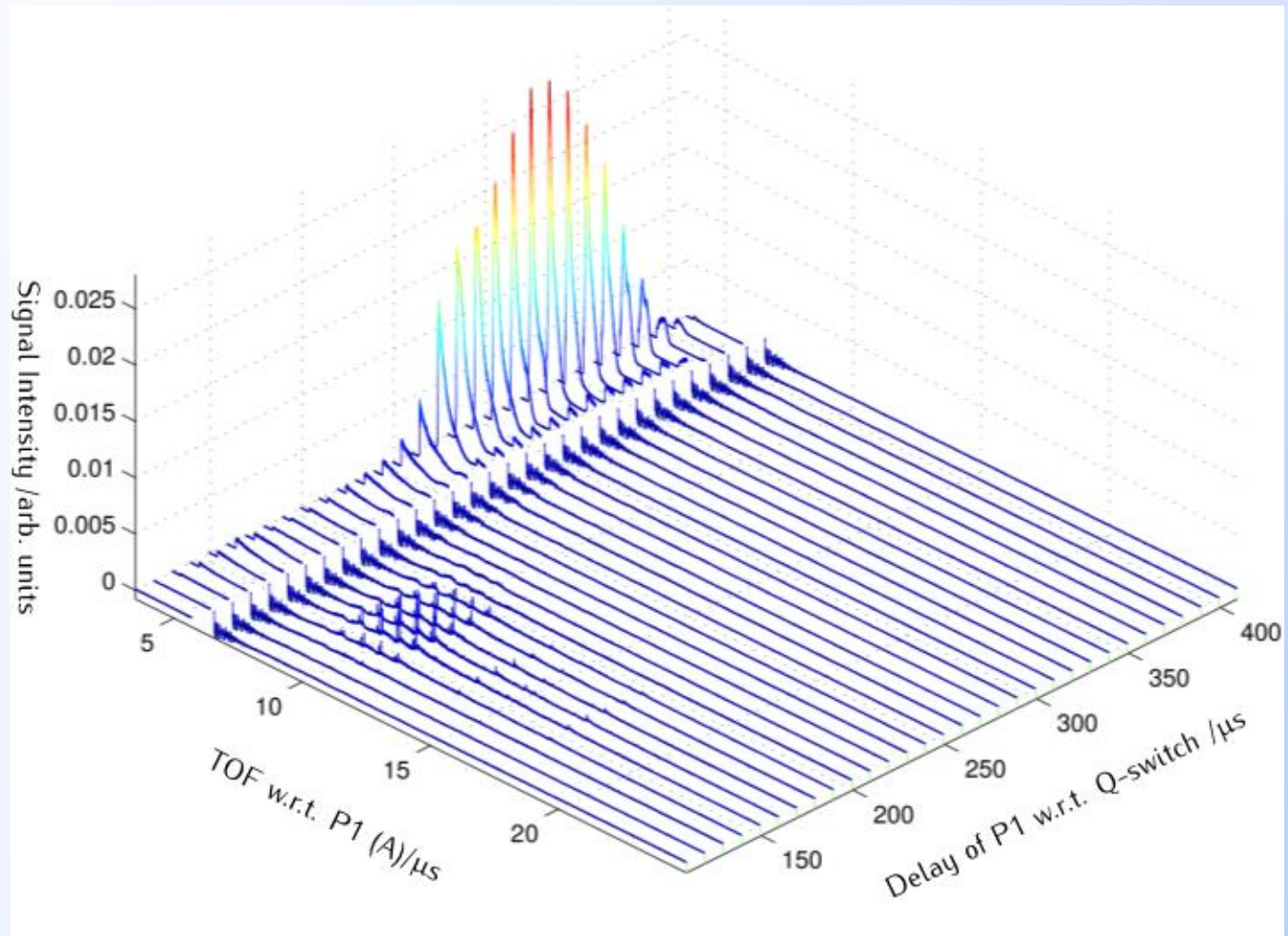


Long $(6\mu s)+3.6$ kV pulse on aperture 1

$v_{jet} = .85\text{mm}/\mu s$

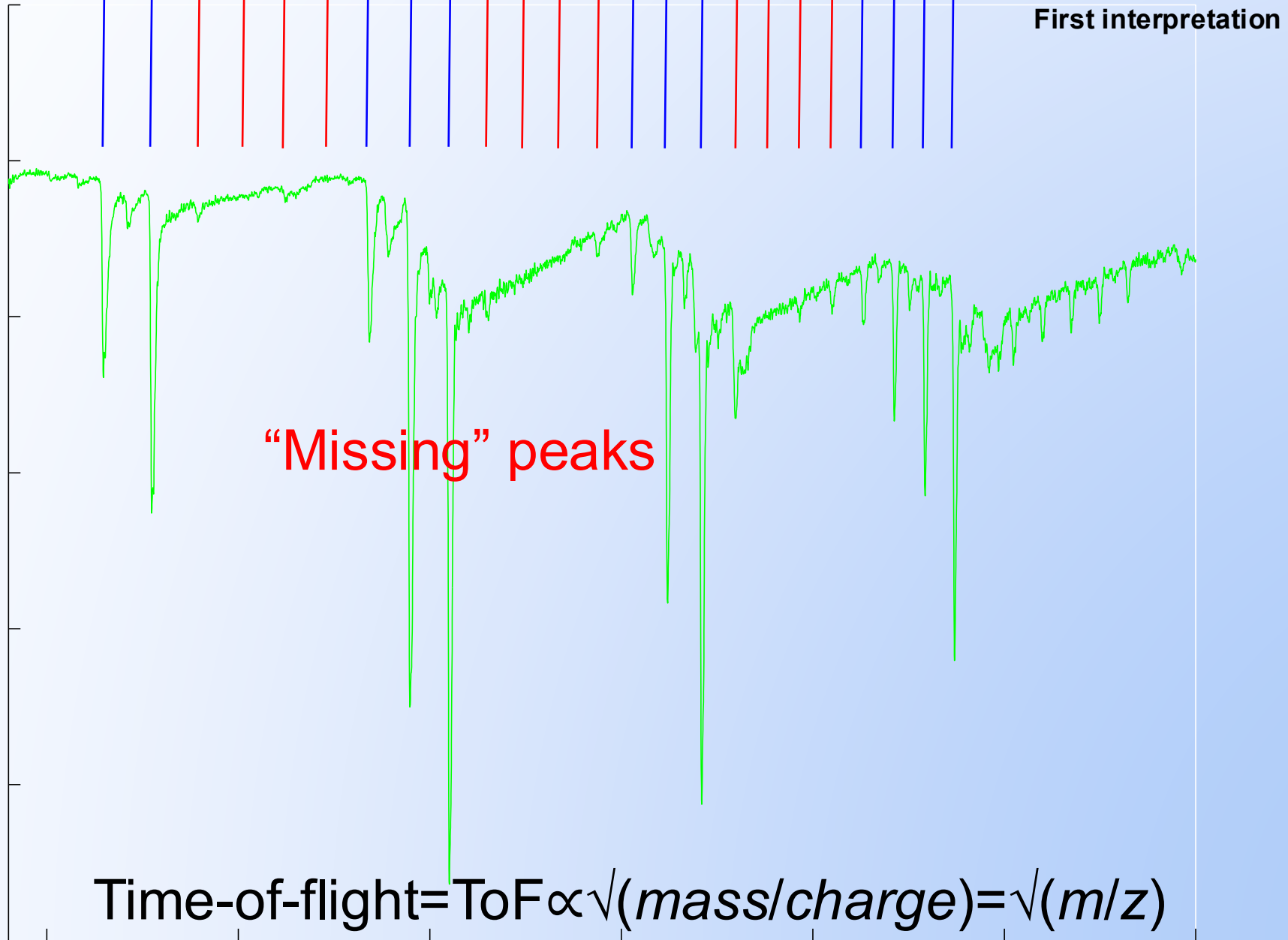
General Valve nozzle 1mm
 10 bar Ne, 1bar NO

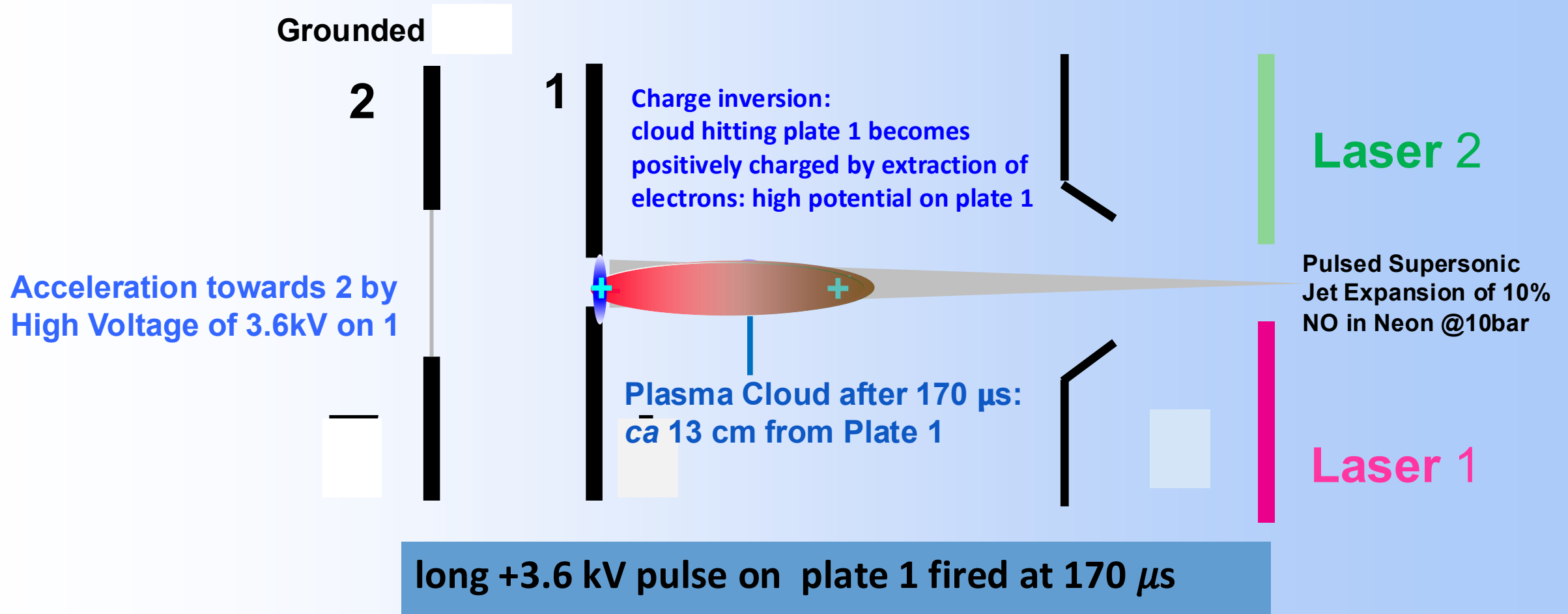




(m/z)/30: 7/6 11/6 14/6 3 in units of $m_{NO}=30u$

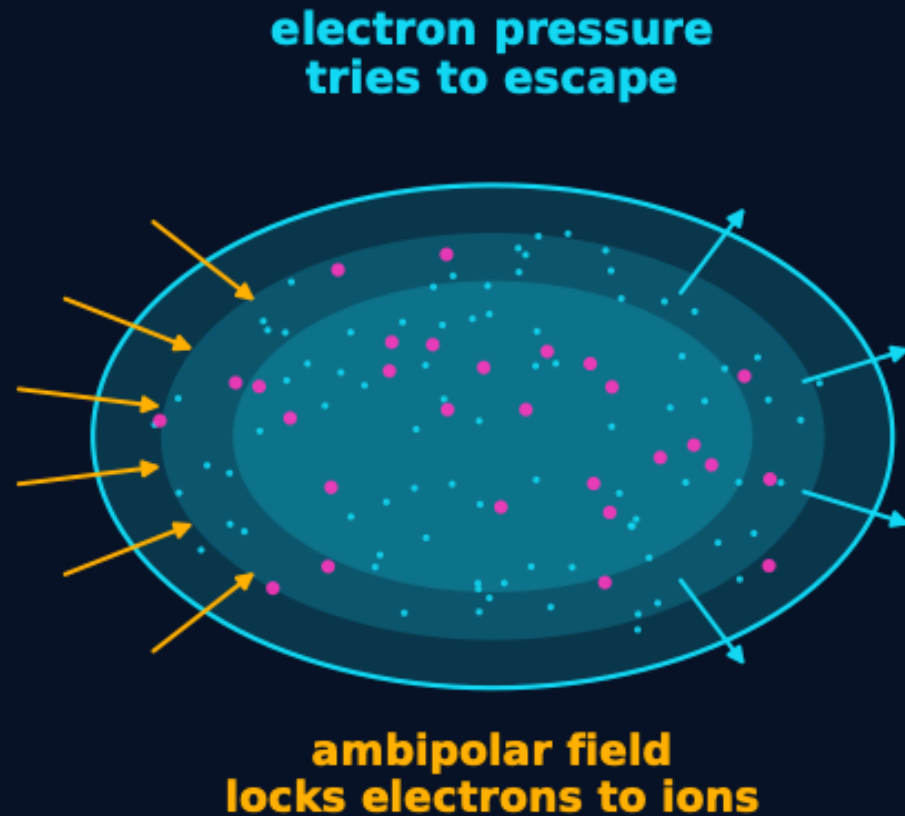
m/z: 35 55 70 90 /u





Plasma is separated into a negatively and positively charged cloud

Ambipolar diffusion: what it can prove



Expansion diagnostic:

Hot electrons accelerate ions

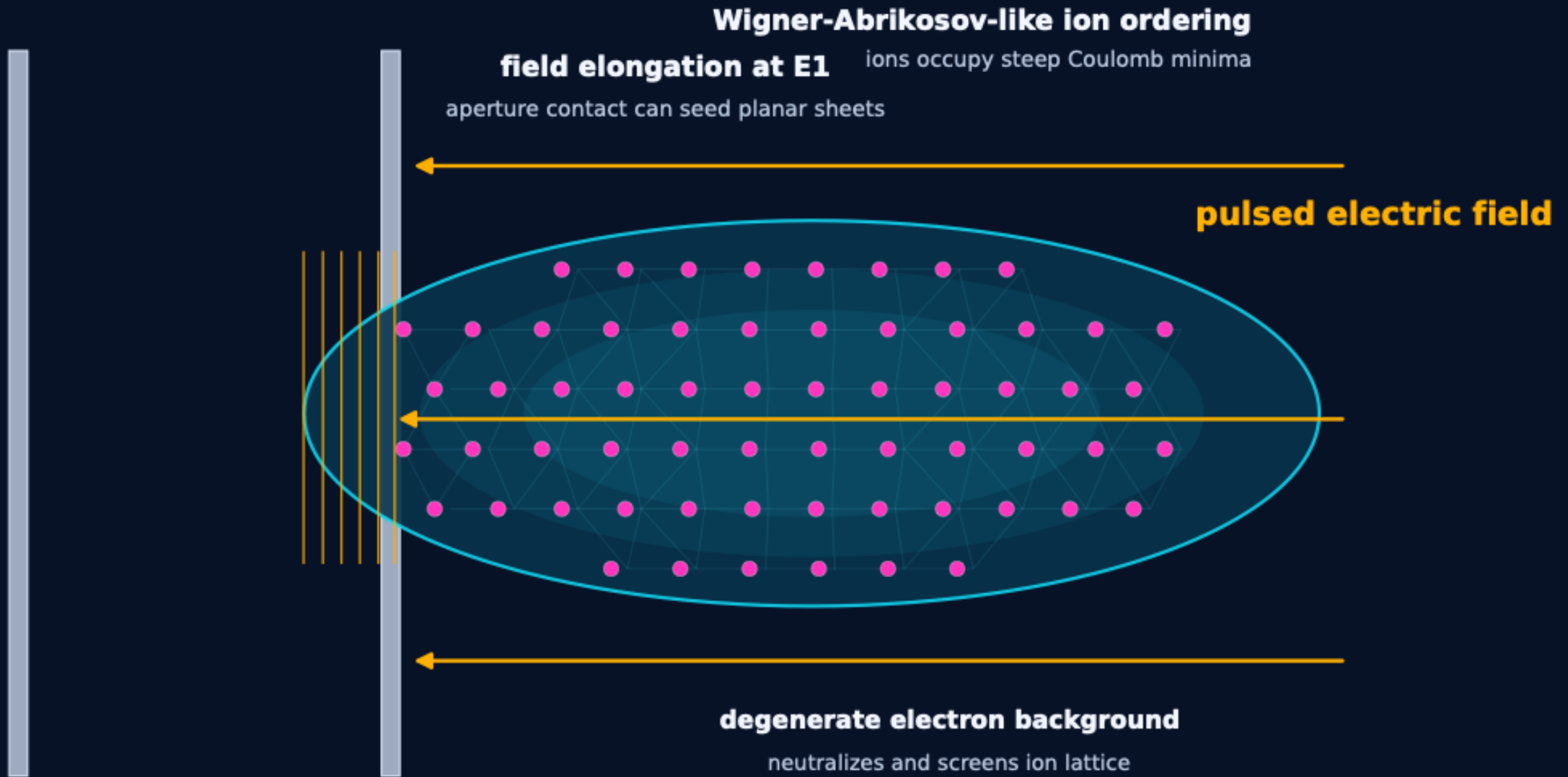
Slow expansion is evidence for low electron pressure

Cooling channel for electrons:

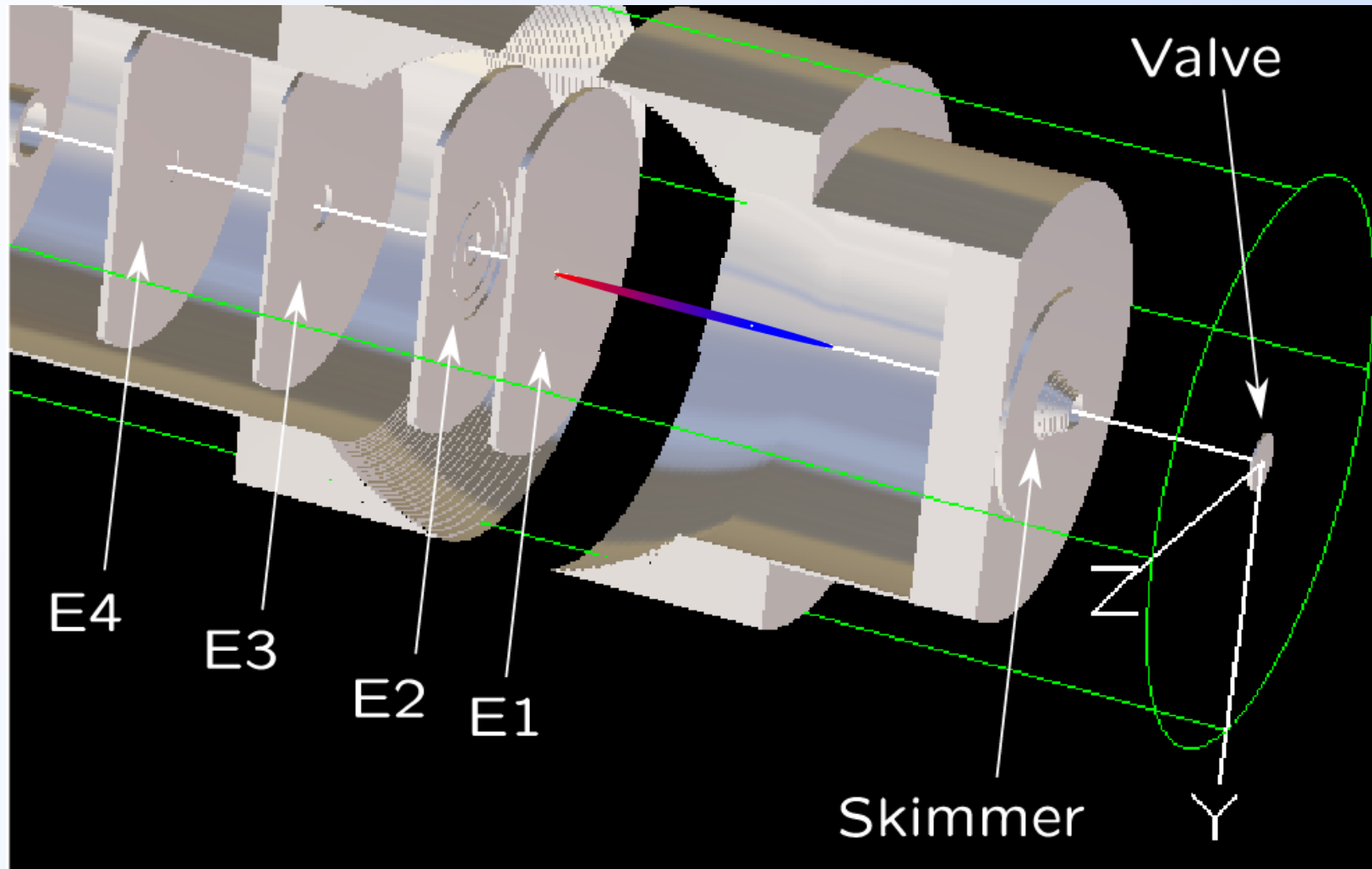
Ambipolar expansion can cool electrons adiabatically according to mass ratio of NO/electron

Expect electron temperature below $60 \mu\text{K}$

Wigner-Abrikosov ion crystal: ordering and pulsed-field slicing



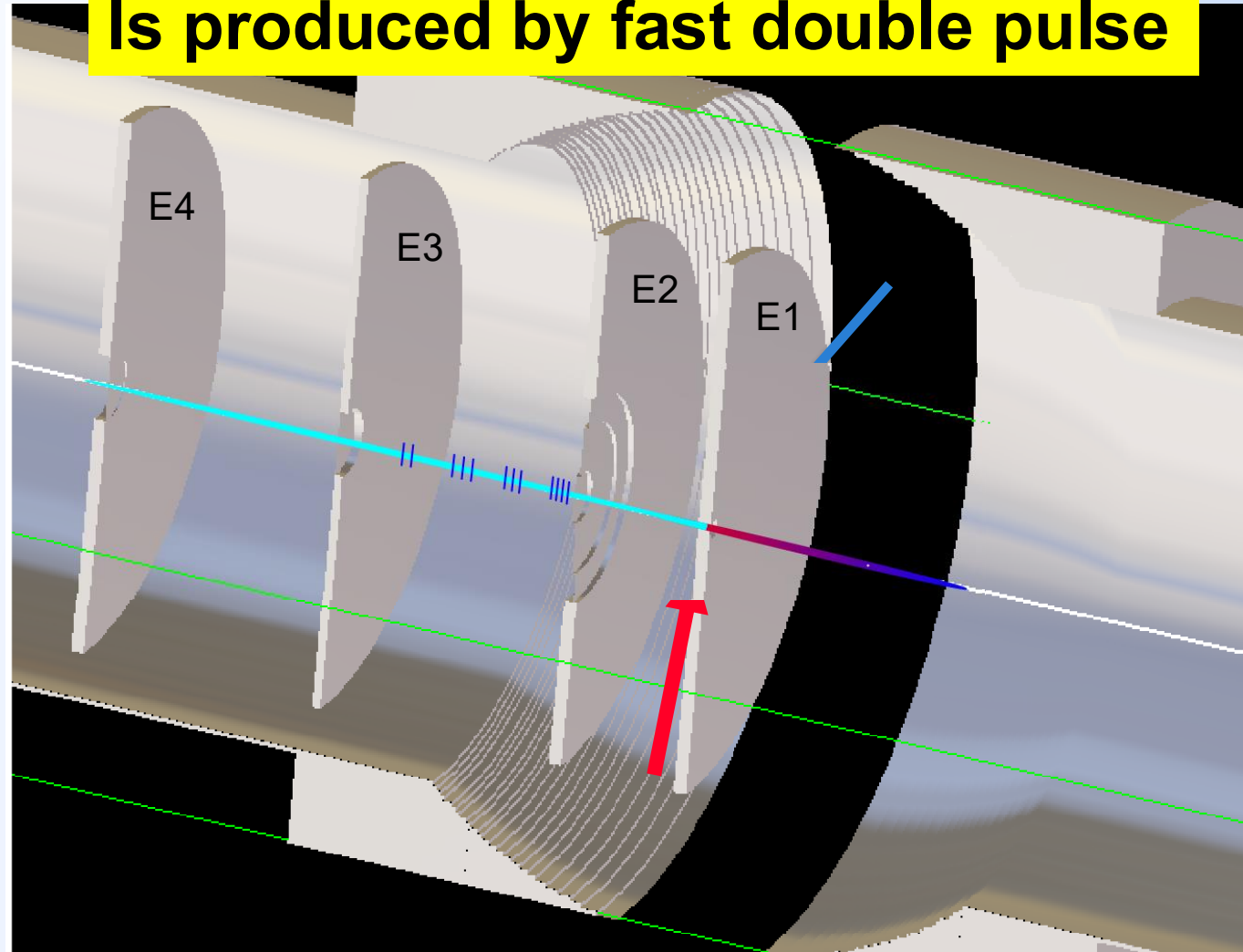
Wigner-Abrikosov *Ion Crystal* becomes elongated by the field

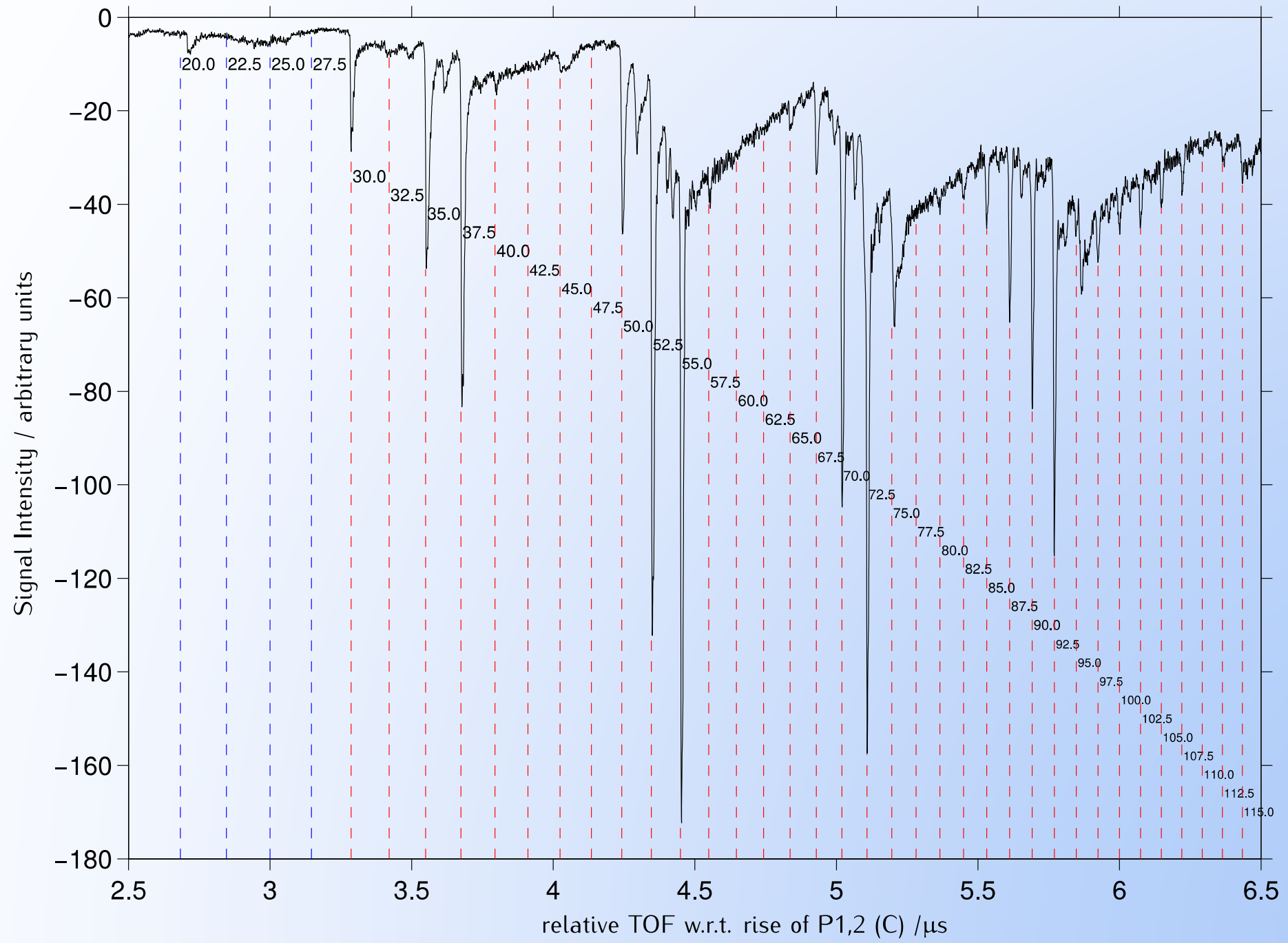


Negatively charged side of elongated system touches plate E1

The “slices” behave as objects with a *centre of mass* starting from first aperture plate E1

Phase relation and coherence
Is produced by fast double pulse





Periodic System of many-body ion-electron system

From $m/z=35$ to 92.5 u with $\delta=2.5$

35, 37.5

50, 52.5, 55

67.5, 70, 72.5

85, 87.5, 90, 92.5

Mass to charge ratio in units of M_{NO} , i.e. setting $M_{NO}=1$

$\frac{28}{24}, \frac{30}{24}, \frac{32}{24}, \frac{34}{24}, \frac{36}{24}, \frac{38}{24}, \frac{40}{24}, \frac{42}{24}, \frac{44}{24}, \frac{46}{24}, \frac{48}{24}, \frac{50}{24}, \frac{52}{24}, \frac{54}{24}, \frac{56}{24}, \frac{58}{24}, \frac{60}{24}, \frac{62}{24}, \frac{64}{24}, \frac{66}{24}, \frac{68}{24}, \frac{70}{24}, \frac{72}{24}, \frac{74}{24}$

Ion to electron ratio

$\frac{28}{4}, \frac{30}{6}, \frac{32}{8}, \frac{34}{10}, \frac{36}{12}, \frac{38}{14}, \frac{40}{16}, \frac{42}{18}, \frac{44}{20}, \frac{46}{22}, \frac{48}{24}, \frac{50}{26}, \frac{52}{28}, \frac{54}{30}, \frac{56}{32}, \frac{58}{34}, \frac{60}{36}, \frac{62}{38}, \frac{64}{40}, \frac{66}{42}, \frac{68}{44}, \frac{70}{46}, \frac{72}{48}, \frac{74}{50}$

Fractional Elementary Charges

$\frac{2}{14}$	$\frac{3}{15}$	$\frac{4}{16}$	$\frac{5}{17}$	$\frac{6}{18}$	$\frac{7}{19}$	$\frac{8}{20}$	$\frac{9}{21}$	$\frac{10}{22}$	$\frac{11}{23}$	$\frac{12}{24}$	$\frac{13}{25}$	$\frac{14}{26}$	$\frac{15}{27}$	$\frac{16}{28}$	$\frac{17}{29}$	$\frac{18}{30}$	$\frac{19}{31}$	$\frac{20}{32}$	$\frac{21}{33}$	$\frac{22}{34}$	$\frac{23}{35}$	$\frac{24}{36}$	$\frac{25}{37}$
$\frac{1}{7}$	$\frac{1}{5}$					$\frac{2}{5}$	$\frac{3}{7}$	$\frac{5}{11}$					$\frac{5}{9}$	$\frac{4}{7}$	$\frac{17}{29}$					$\frac{11}{17}$	$\frac{23}{35}$	$\frac{2}{3}$	$\frac{25}{37}$

Direct Observation of Topological Bodies of Quantum Matter containing Fractional Elementary Charges

Direct Observation of Topological Bodies of Quantum Matter containing Quasi-Particles of Fractional Elementary Charges

Laughlin-Jain Composite Fermion Theory:

Jain Series for the filling factor ν of Landau Levels LL

N = number of electrons in LLs, $2p$ = number of magnetic flux quanta

$$\nu = \frac{N}{2Np \pm 1}$$

$\frac{1}{7}$	$\frac{1}{5}$	$\frac{2}{5}$	$\frac{3}{7}$	$\frac{5}{11}$
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$\frac{5}{9}$	$\frac{4}{7}$	$\frac{17}{29}$
---------------	---------------	-----------------

$\frac{11}{17}$	$\frac{23}{35}$	$\frac{2}{3}$	$\frac{25}{37}$
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Laughlin/Jain p : 3 2 Jain+, p : 1 1 1
 N : 1 1 2 3 5

$\frac{1}{7}$	$\frac{1}{5}$	$\frac{2}{5}$	$\frac{3}{7}$	$\frac{5}{11}$
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$$\nu = \frac{N}{2Np+1}$$

Laughlin/Jain p : 3 2 Jain+, p : 1 1 1
 N : 1 1 2 3 5

$\frac{5}{9}$	$\frac{4}{7}$
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$\frac{2}{3}$

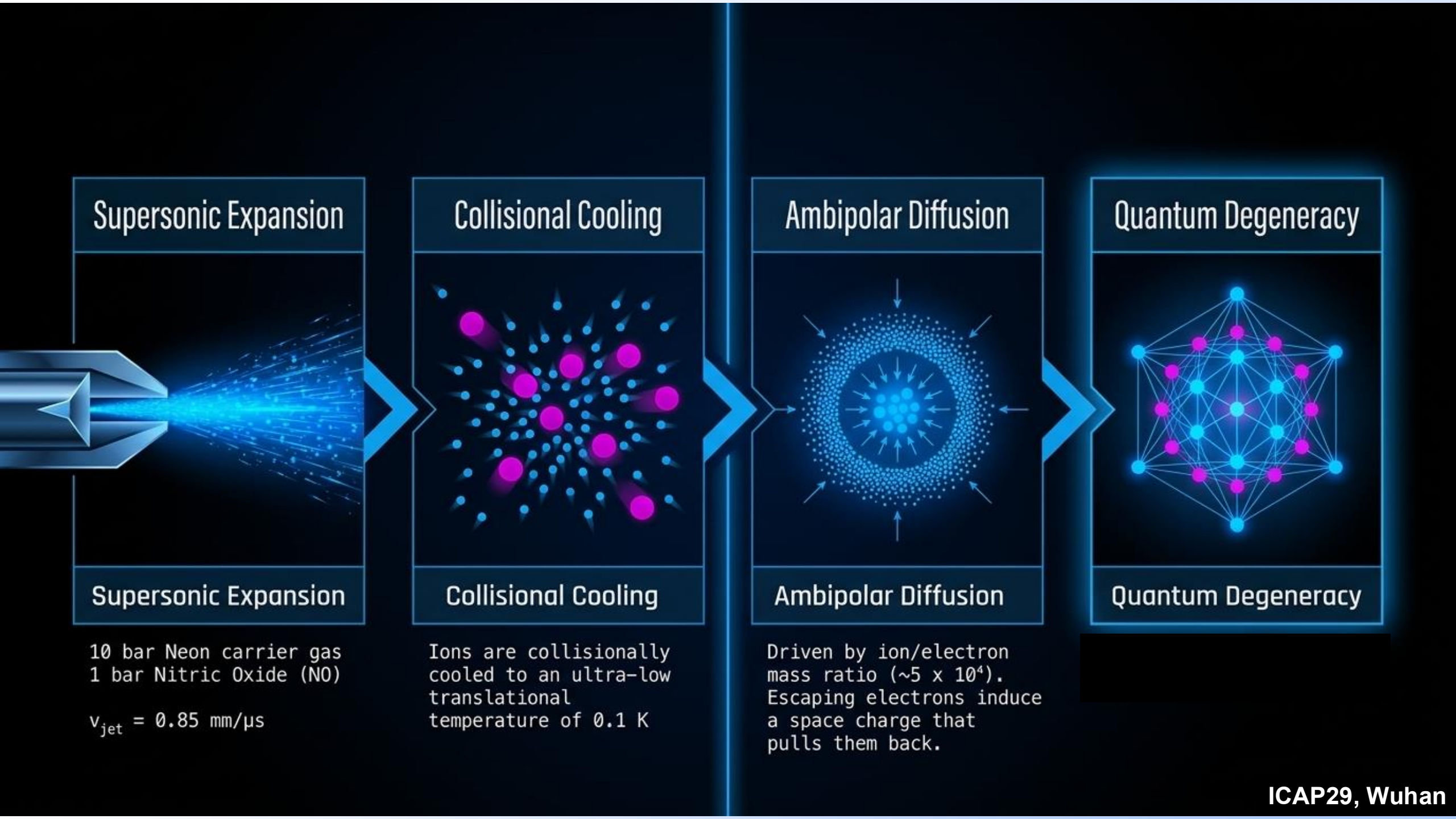
$$\nu = \frac{N}{2N-1}$$

Jain Hierachy:

$\frac{17}{29}$

$\frac{11}{17}$	$\frac{23}{35}$
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$\frac{25}{37}$



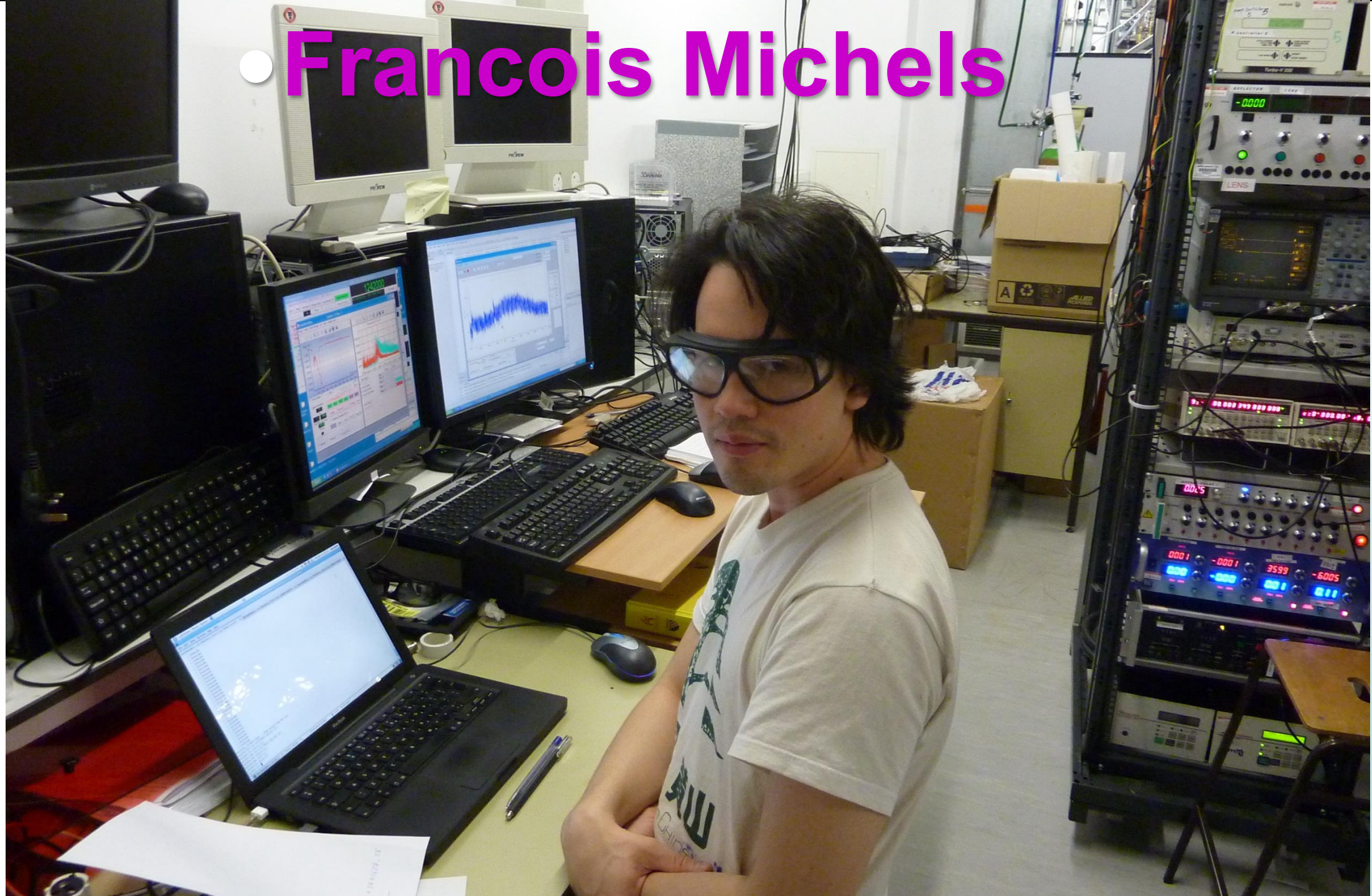
Wigner-Abrikosov crystal

The plasma electrons are quantum degenerate and ions form a *Wigner-Abrikosov crystal*

Electrons must be ultra-cold since plasma expansion is essentially explained by low ion temperature, the ions are collisionally cooled to *ca. 0.1K* by the Ne carrier gas:

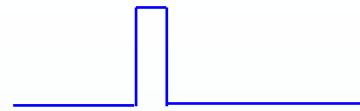
Ambipolar Diffusion now cools the electrons down driven by the ion/electron mass ratio $\approx 5 \cdot 10^4$

● Francois Michels

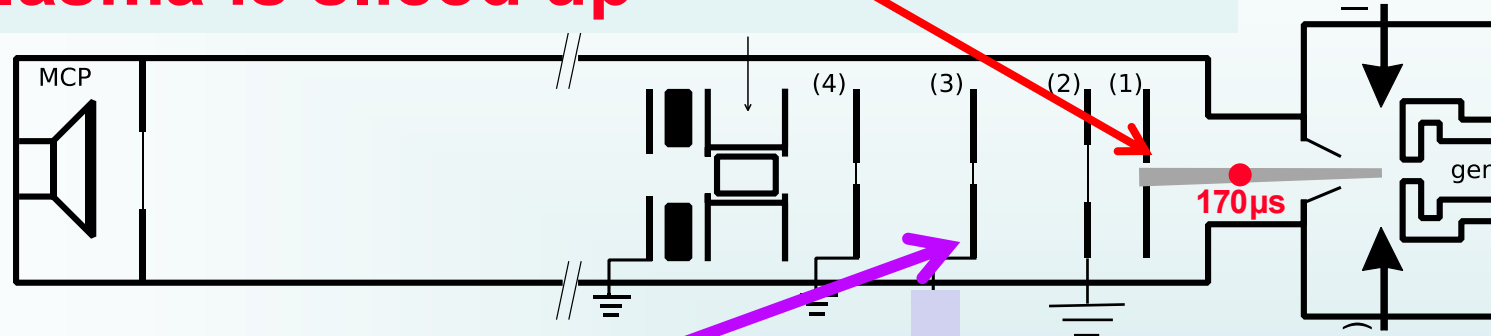




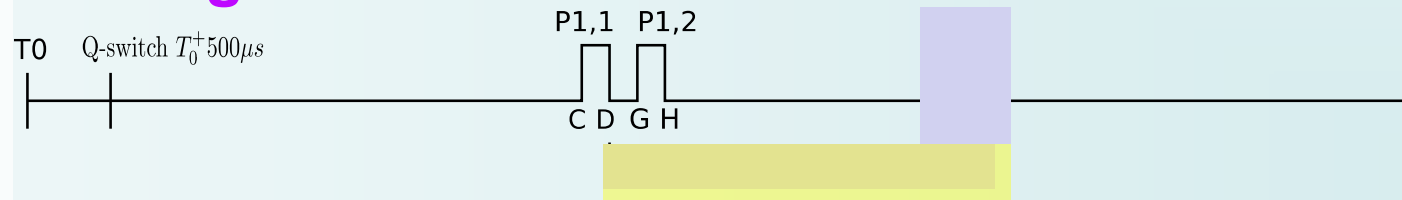
then pulse 3 is scanned in 10ns steps



Double pulse $P_{1,1}$ - $P_{1,2}$ applied on E1 plasma is sliced up



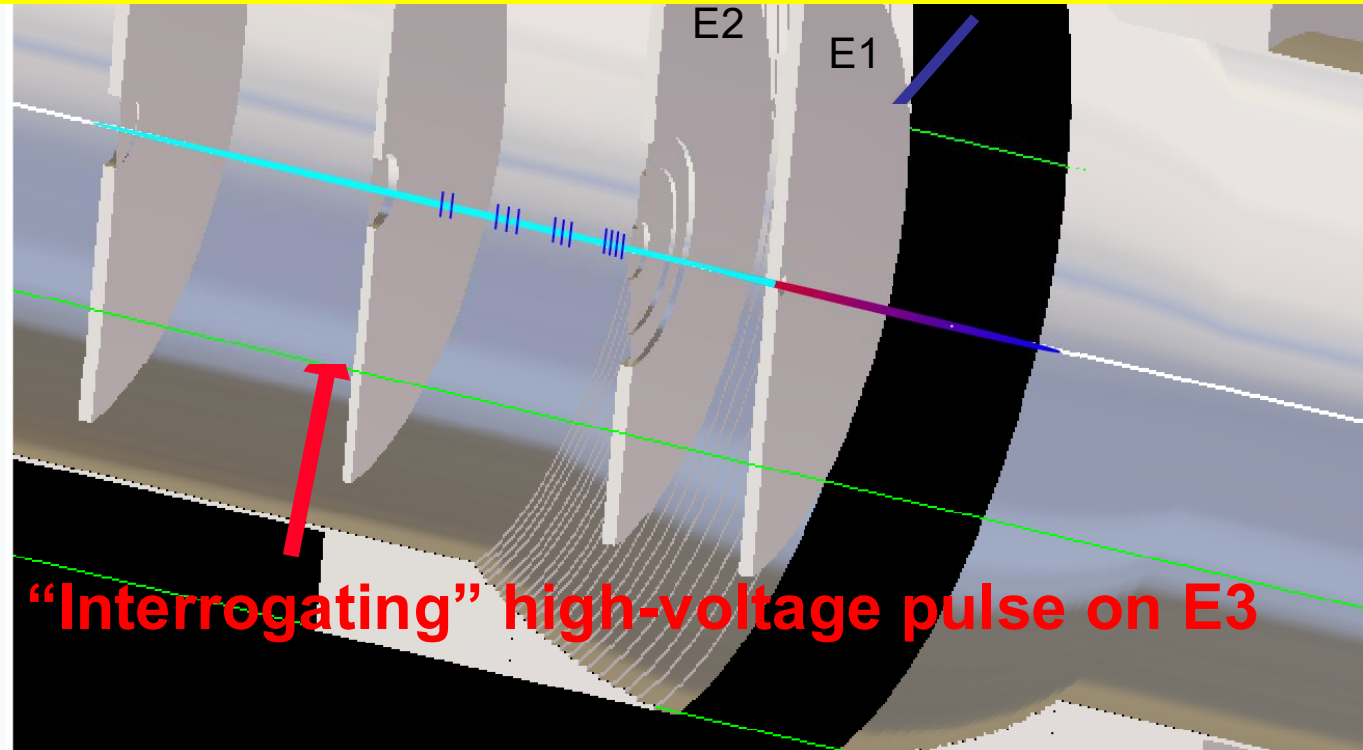
Introduce a +0.8kV pulse on E3
 “Slices” are measured
 Mass to charge ratio: m/z



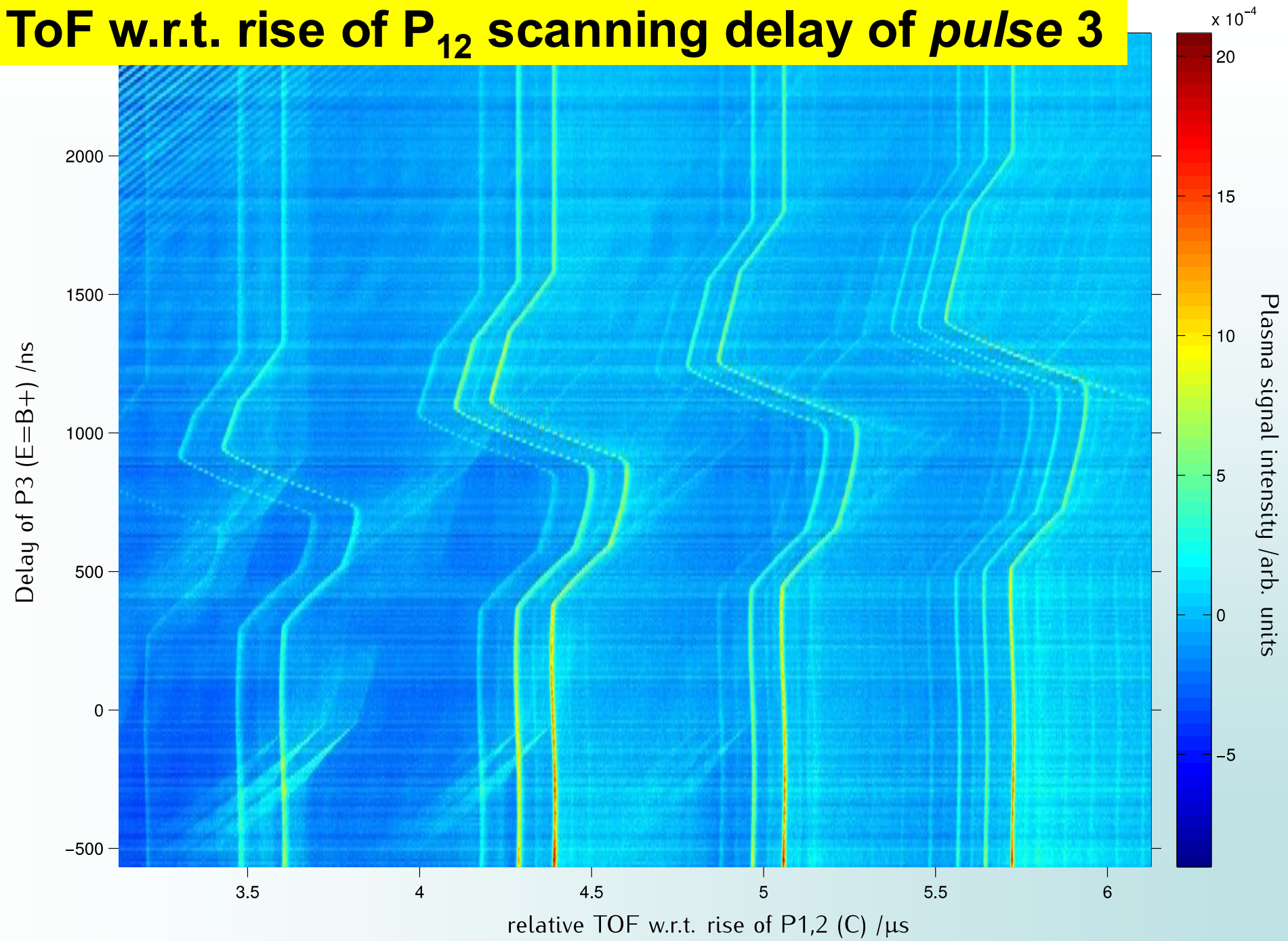
C-D: width of $P_{1,1} = 5.5\mu s$; D-G: gap of $0.2\mu s$
 G-H: width of $P_{1,2} = 20.2\mu s$, *i.e.* long

The “slices” behave as objects with a *centre of mass* and they are de- or accelerated by a pulsed field between E2 and E3, and E3 and E4

Topological Bodies could be rings with periodic potential provided by ions: The gaps are filled by fractional charges



ToF w.r.t. rise of P_{12} scanning delay of *pulse 3*



Black: measured; Red: Simion simulation

