



Kalte Ionen in kalten Elektronenstrahlen

Ein kleiner, kalter Weltraum im Labor

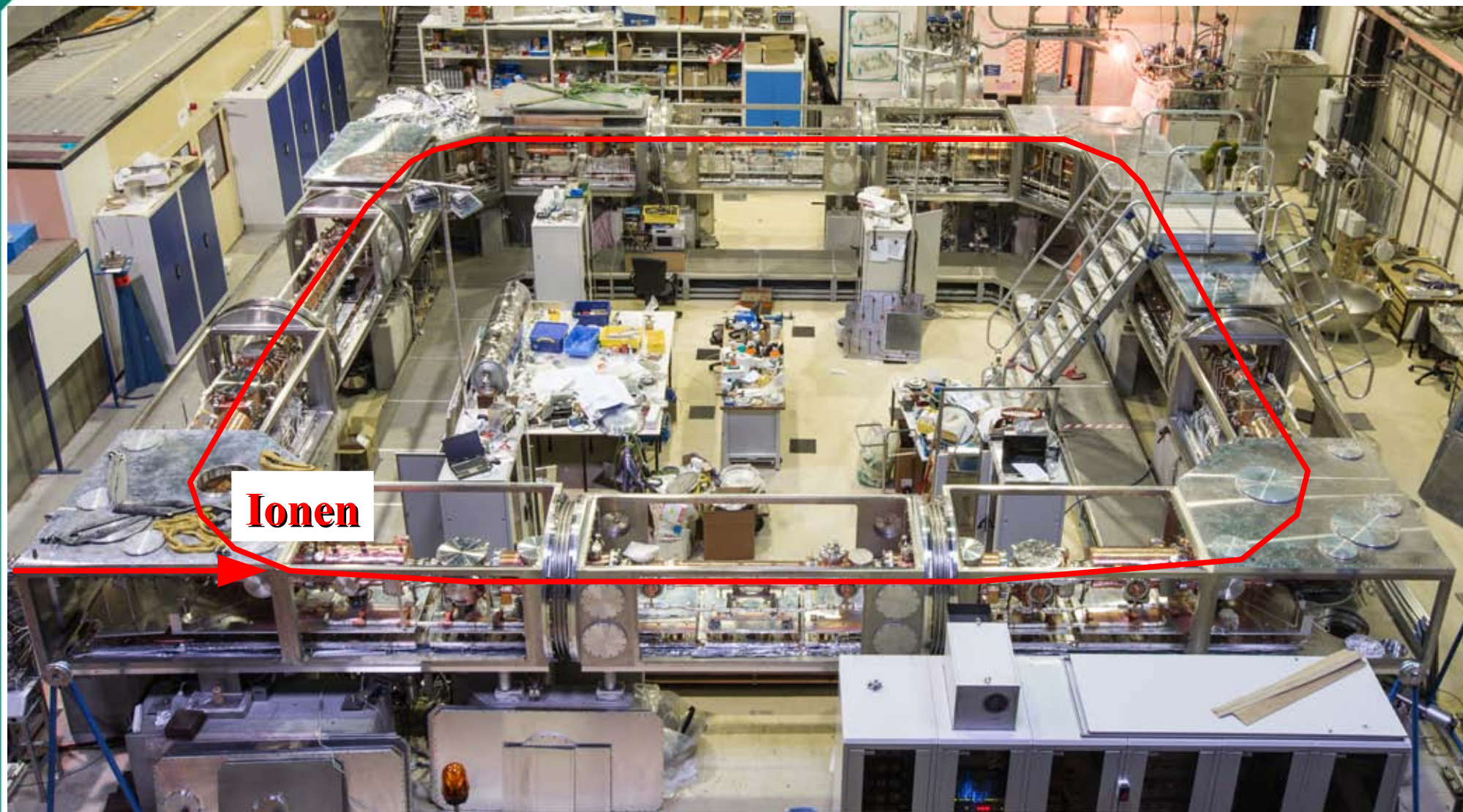
Claude Krantz

Max-Planck-Institut für Kernphysik



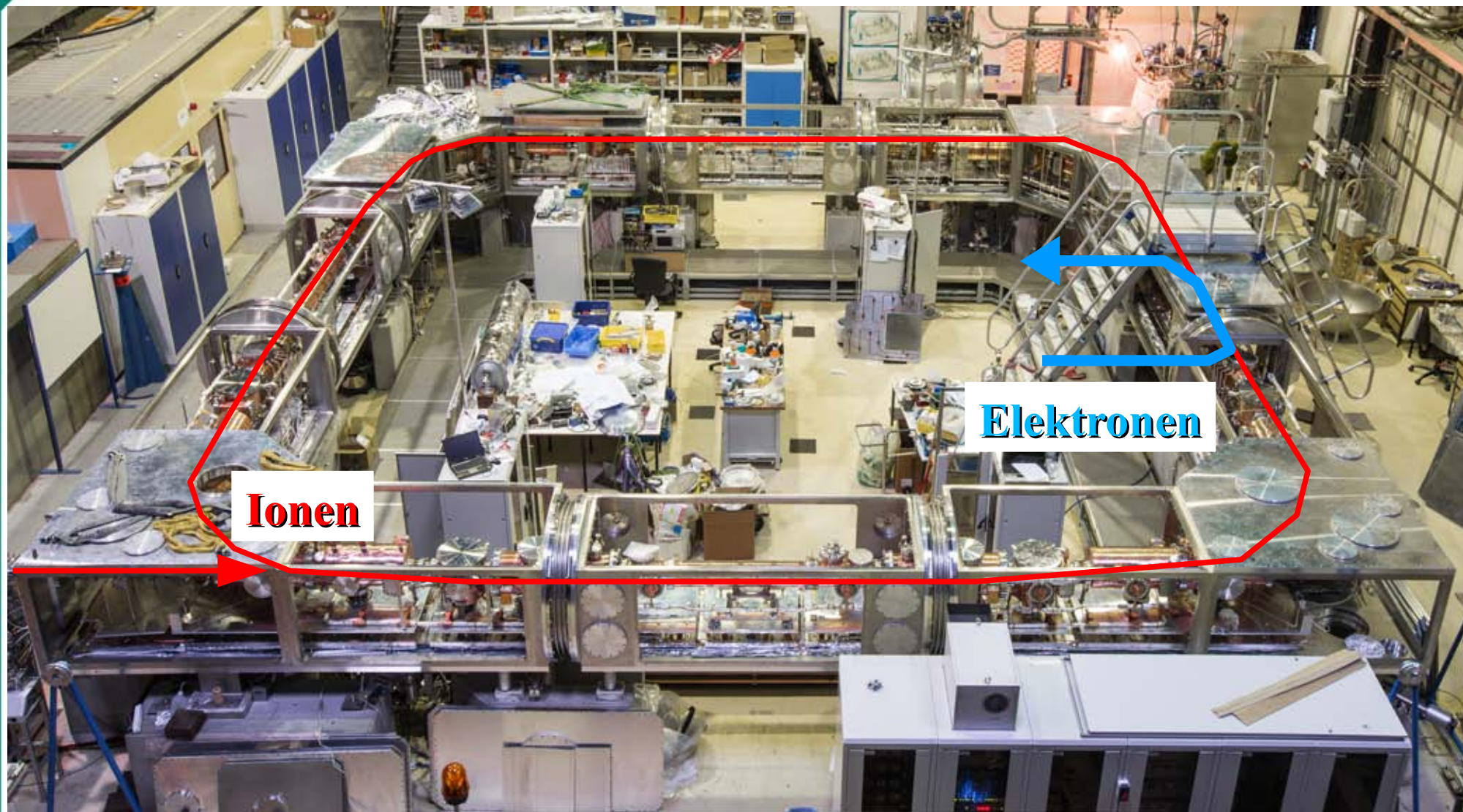
Der Speicherring CSR, Anfang 2014

(Experimentierhallen: F7 - F11)



Der Speicherring CSR, Anfang 2014

(Experimentierhallen: F7 - F11)



Der Speicherring CSR, Anfang 2014

(Experimentierhallen: F7 - F11)





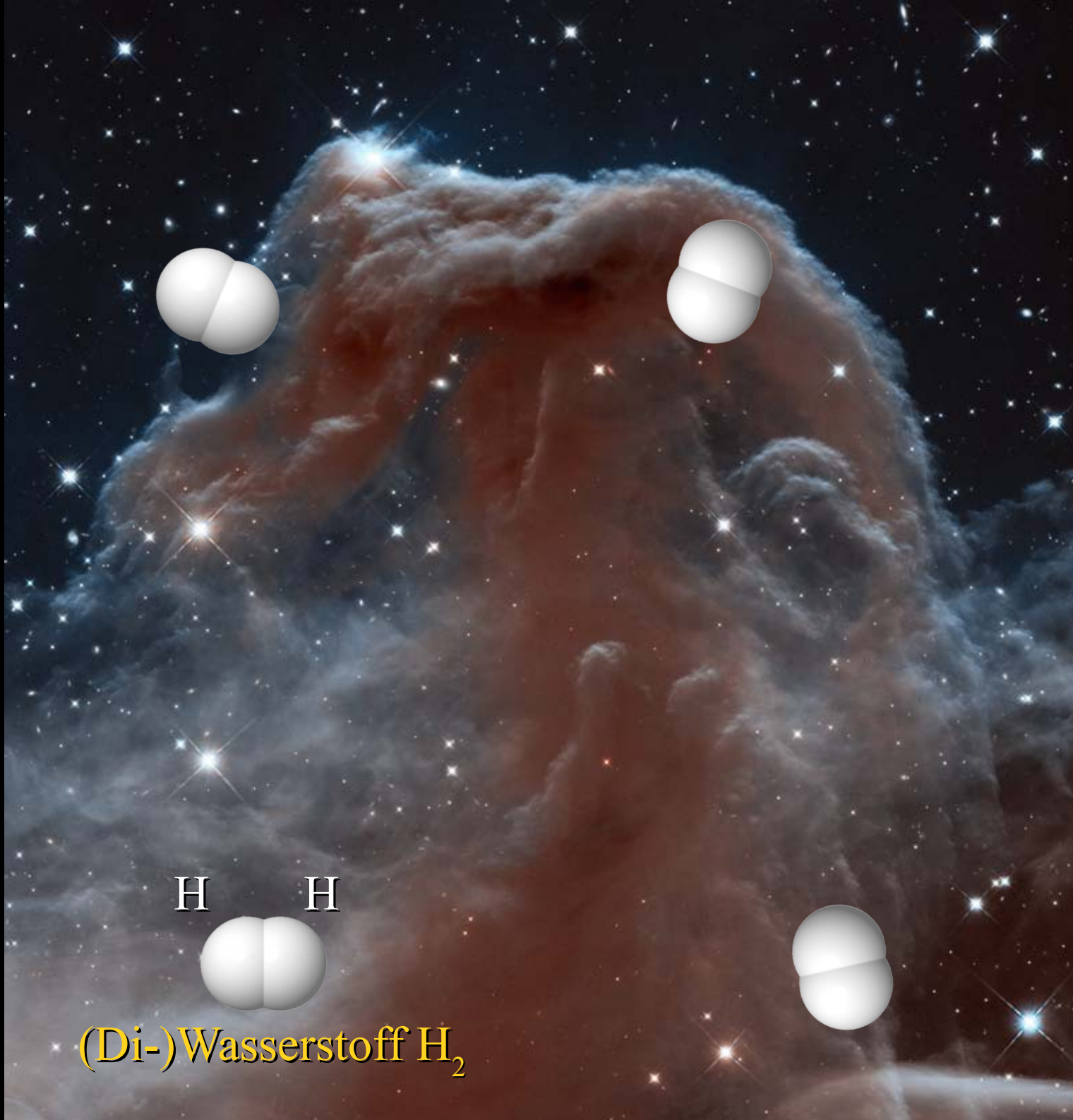




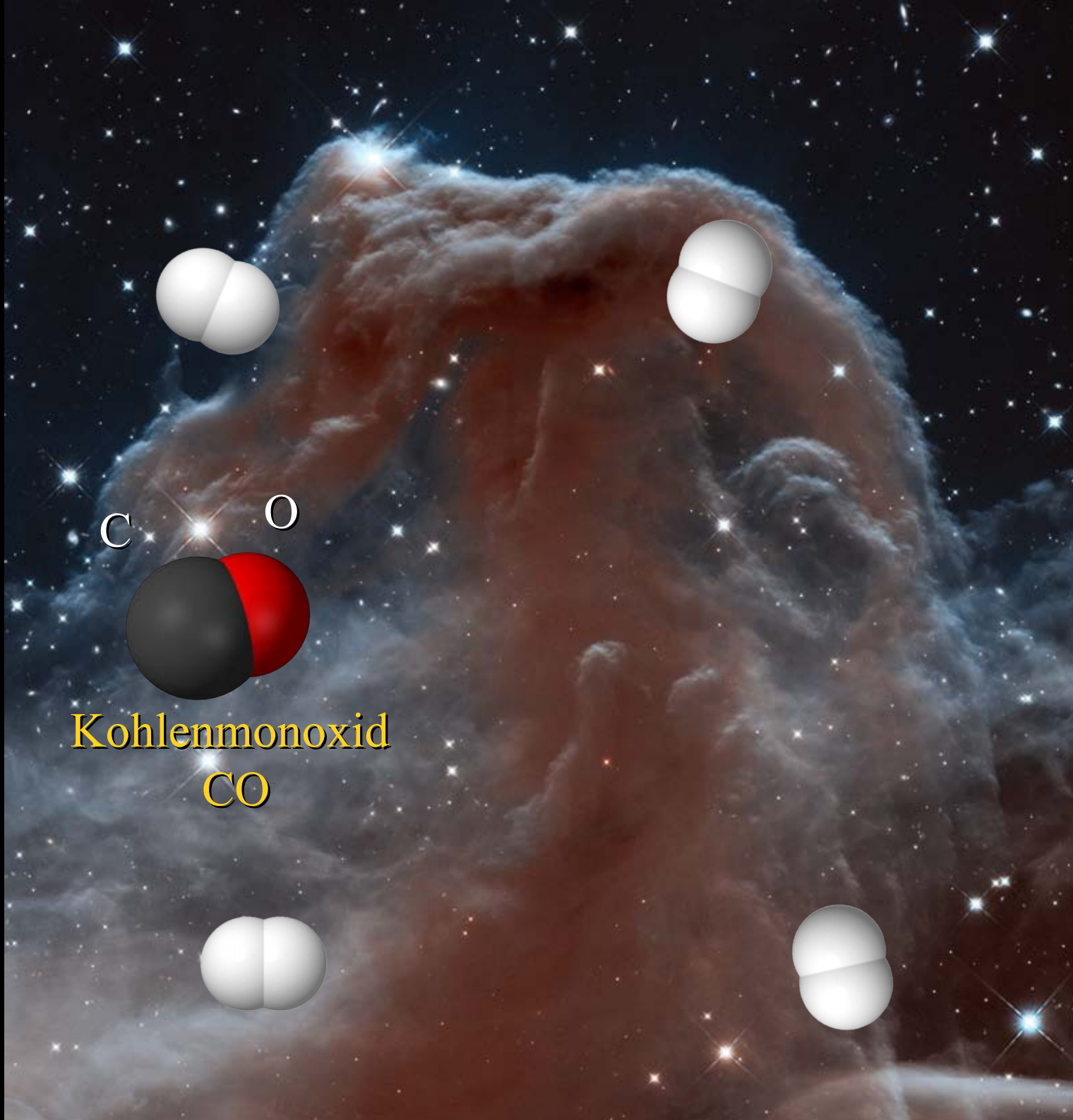
NASA/ESA Hubble Heritage



NASA/ESA Hubble Heritage

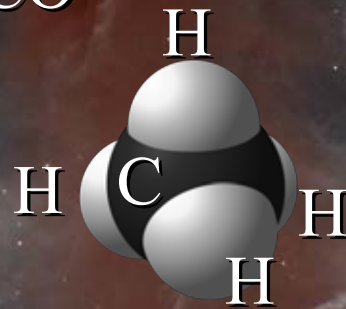


(Di-)Wasserstoff H₂

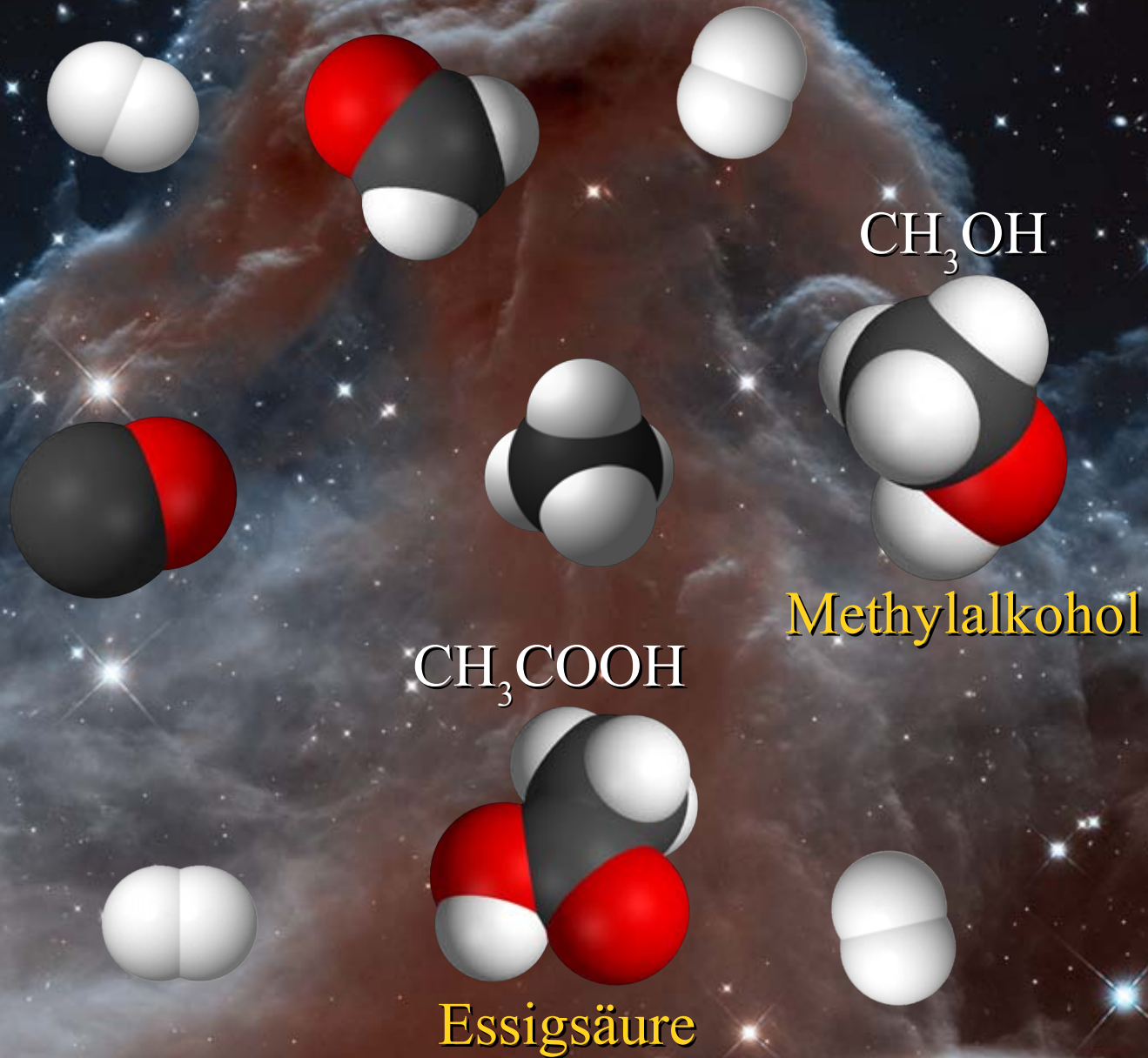


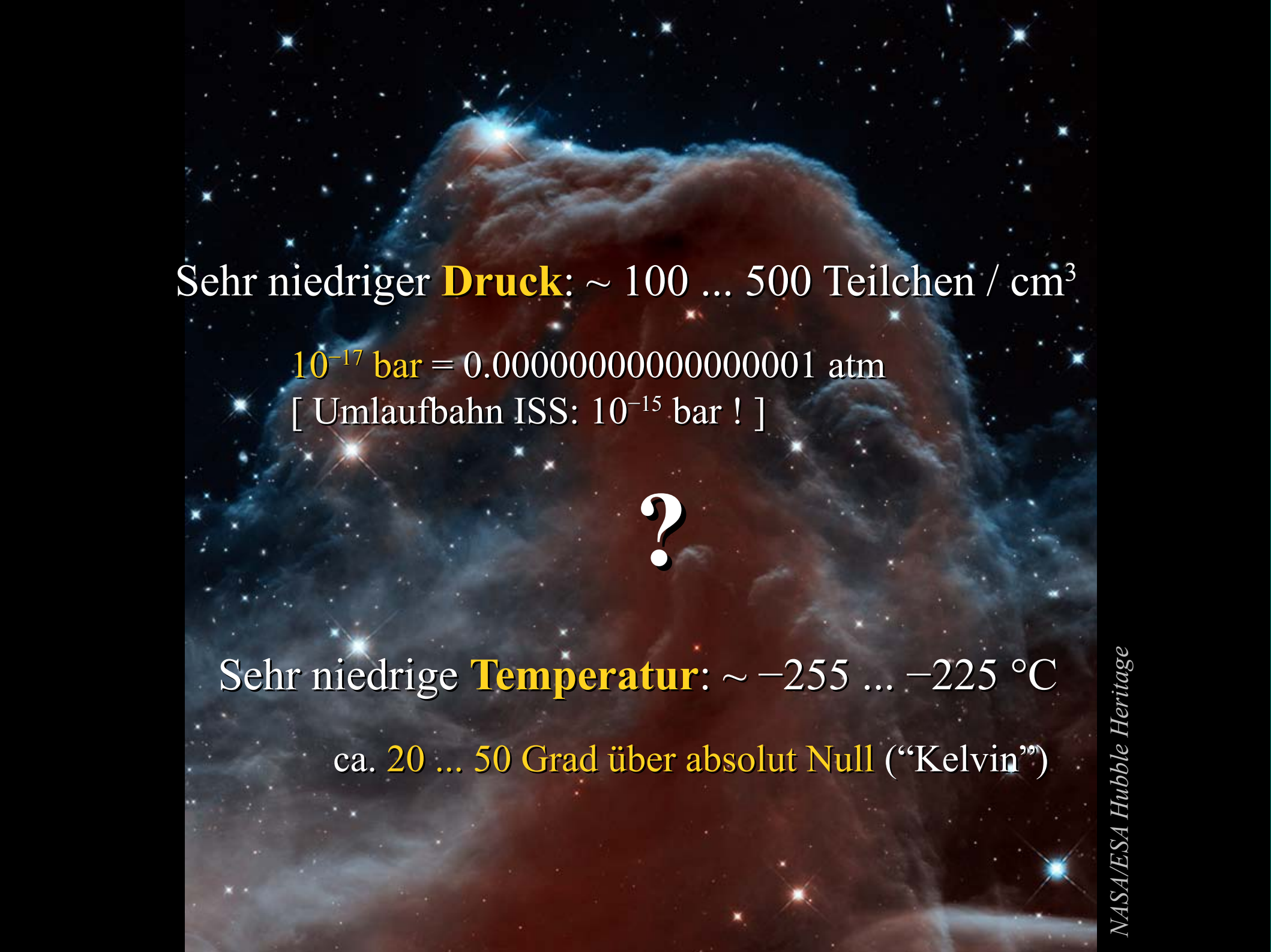
Kohlenmonoxid
CO

Formaldehyd



Methan
 CH_4





Sehr niedriger **Druck**: $\sim 100 \dots 500$ Teilchen / cm^3

10^{-17} bar = 0.000000000000000001 atm

[Umlaufbahn ISS: 10^{-15} bar !]

?

Sehr niedrige **Temperatur**: $\sim -255 \dots -225$ °C

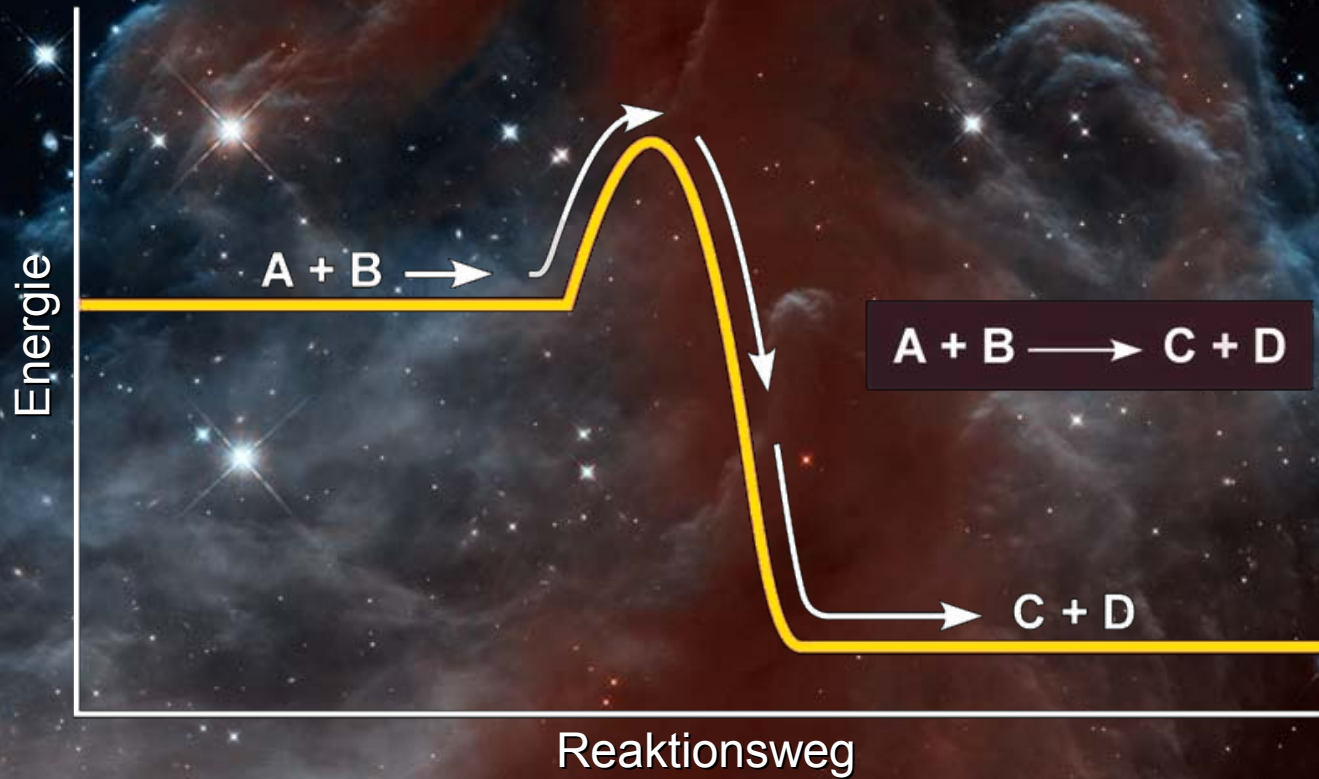
ca. 20 ... 50 Grad über absolut Null (“Kelvin”)

Eine **fast leere**, interstellare **Tiefkühltruhe!**



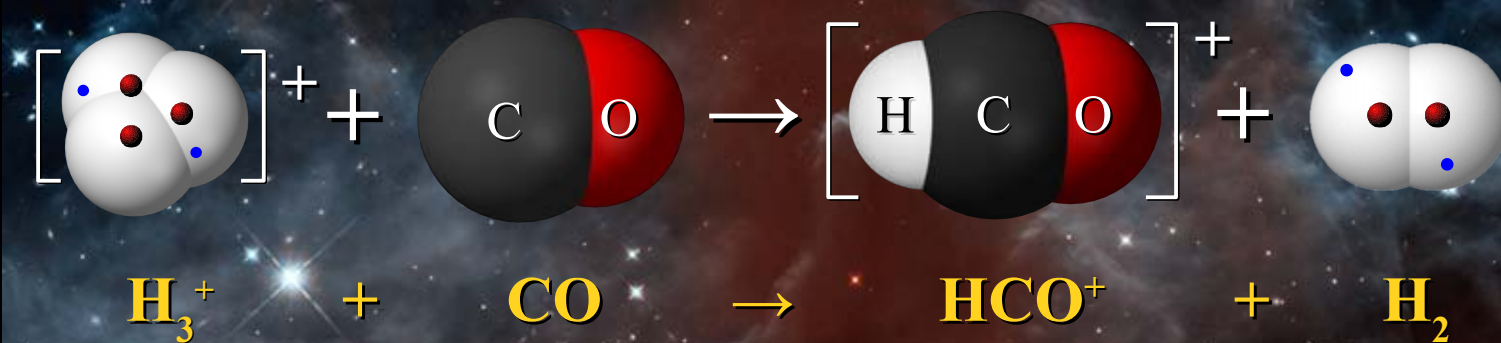
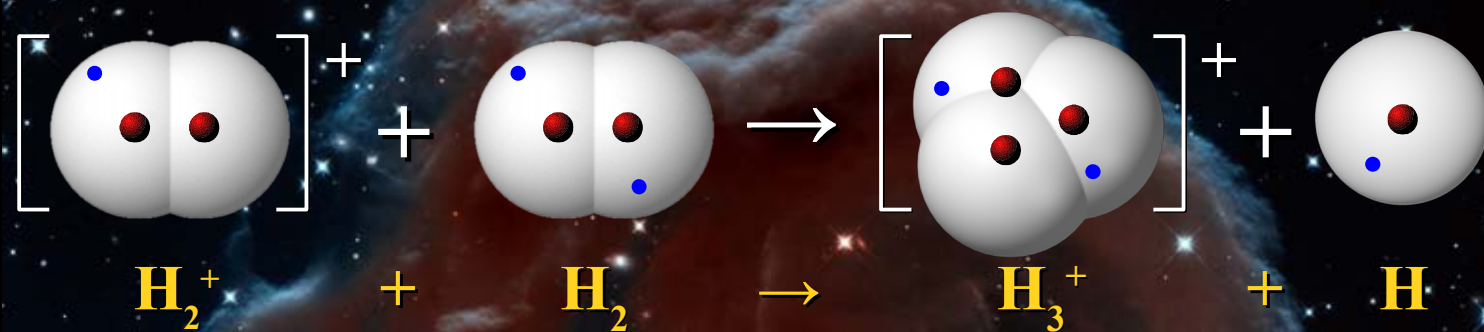
Wie entstehen hier **organische Moleküle**?

Auf der Erde: **Umgebungstemperatur** hoch genug
Molekülwolke: Eigentlich **viel zu kalt!**

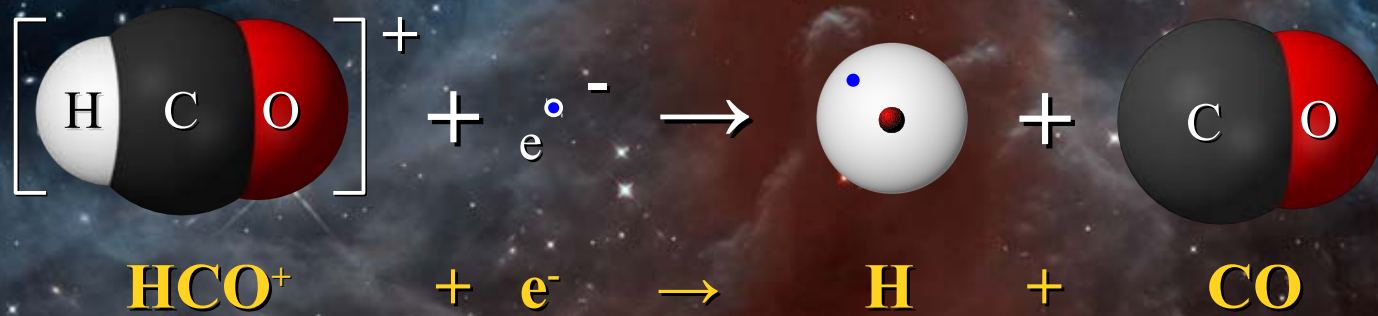
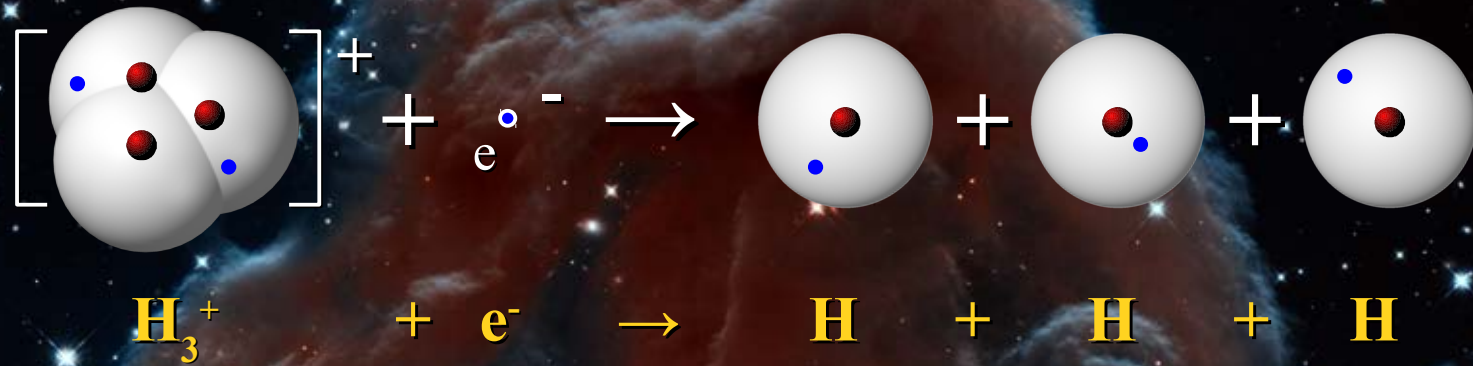


Geladene Moleküle (**Ionen**)

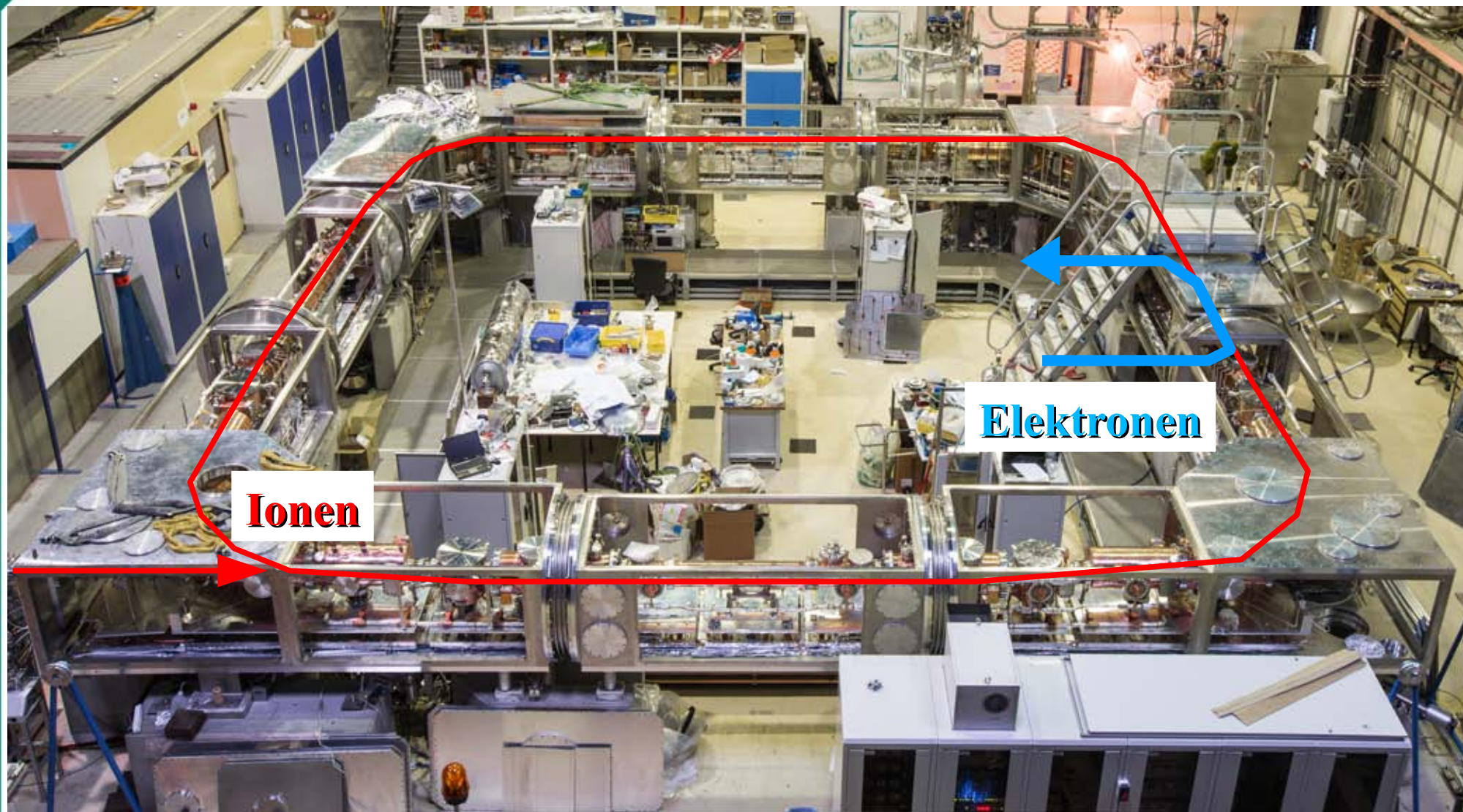




Rekombination mit **Elektronen**

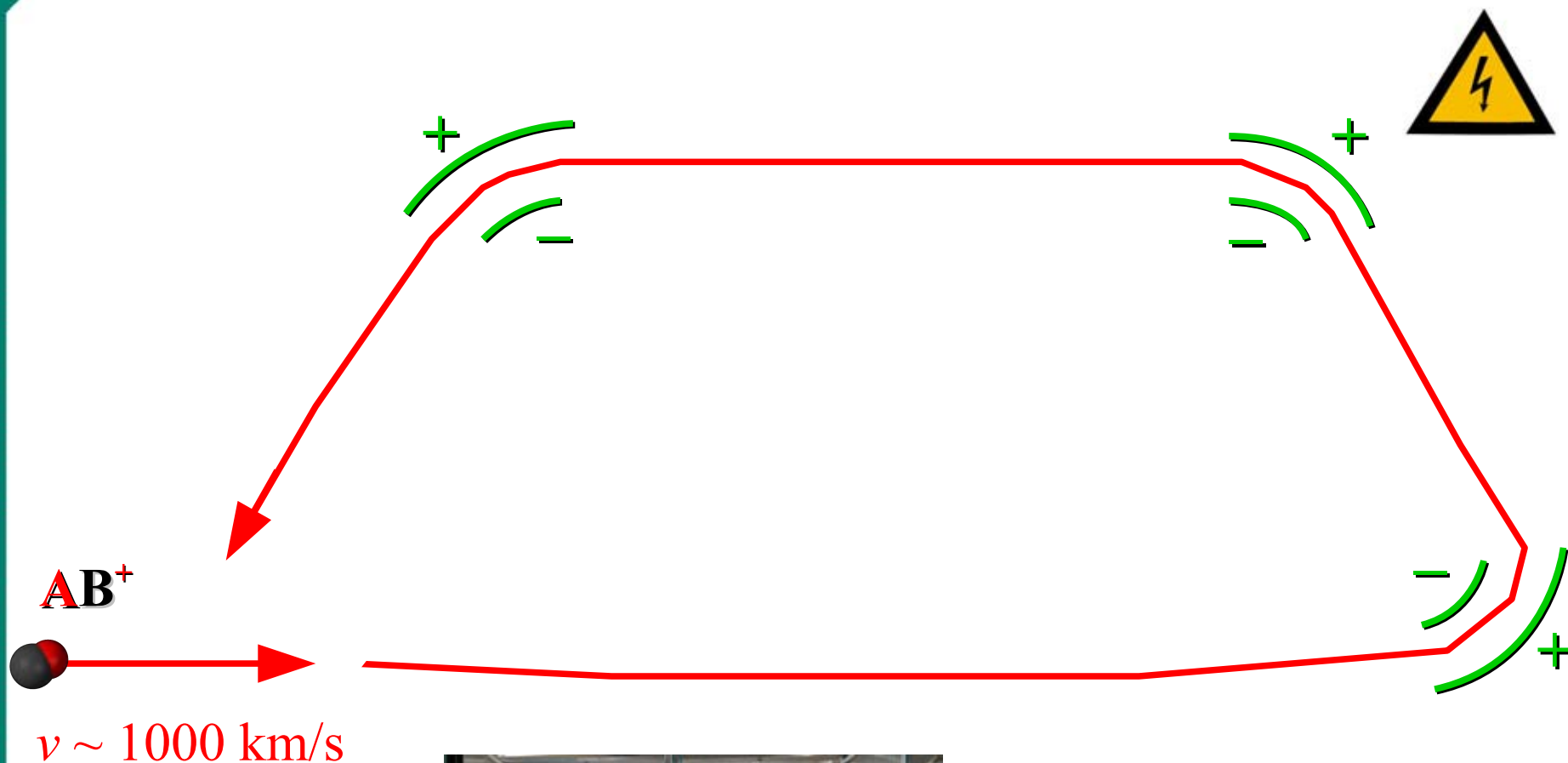


$$C_m H_n$$

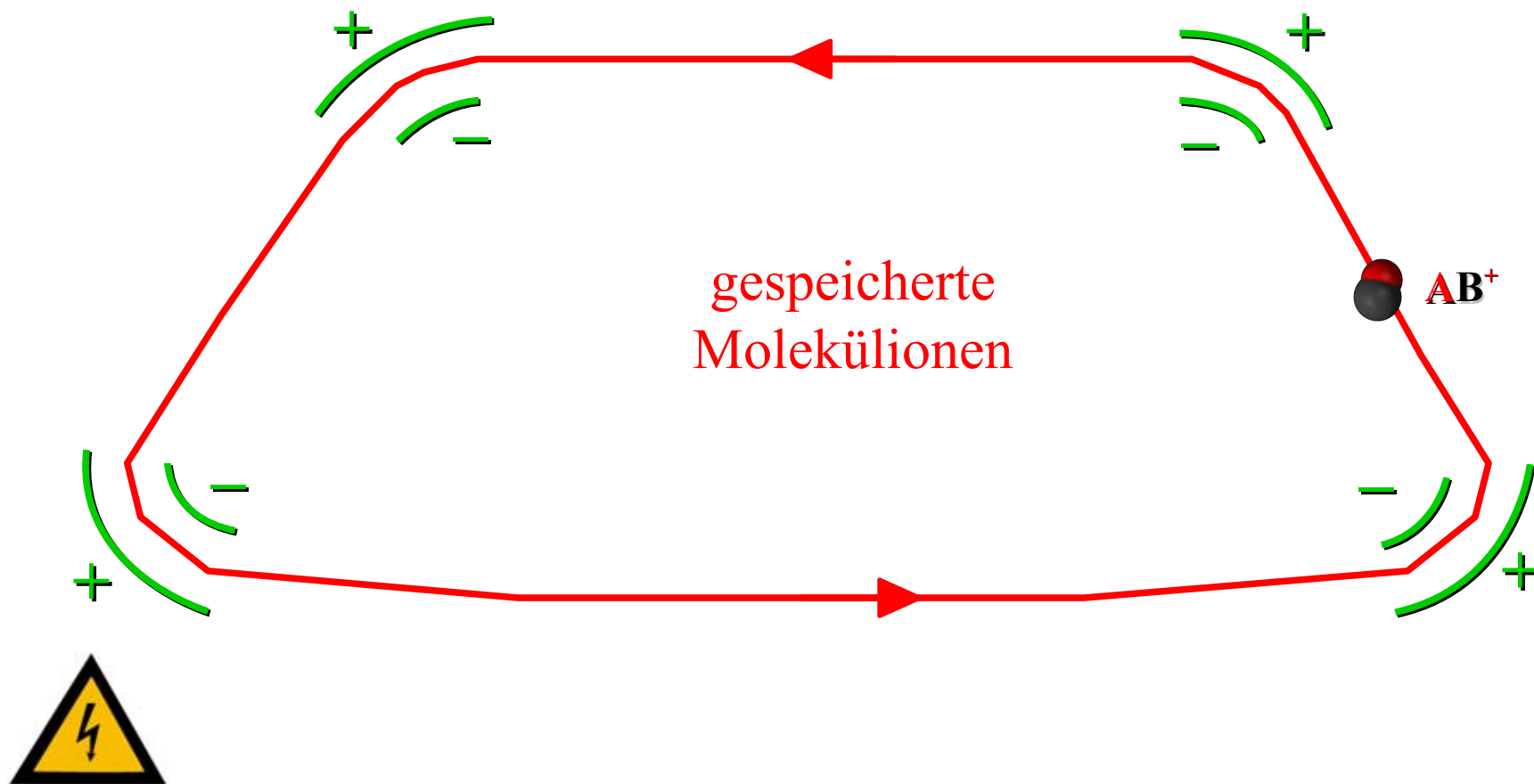
Der Speicherring CSR, Anfang 2014

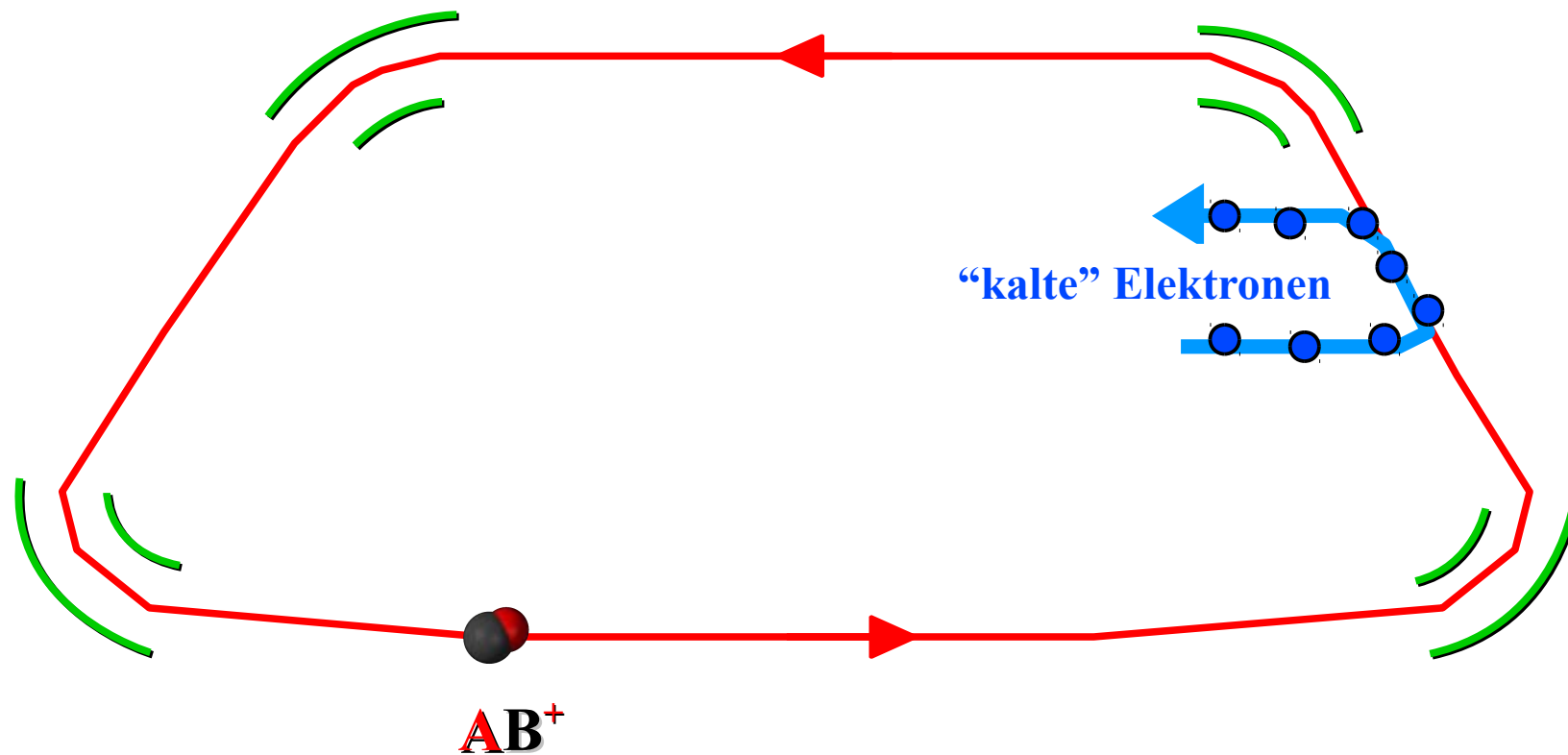
(Experimentierhallen: F7 - F11)



Rundgang Pos. F11, F12:

CSR-Ionenquelle und Beschleuniger
(300 kV)



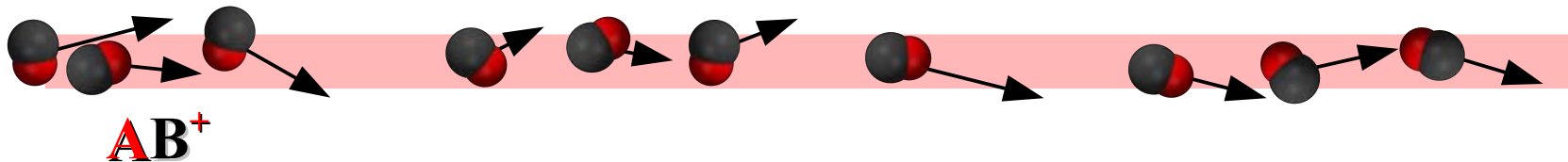




Elektronen-Kühlung

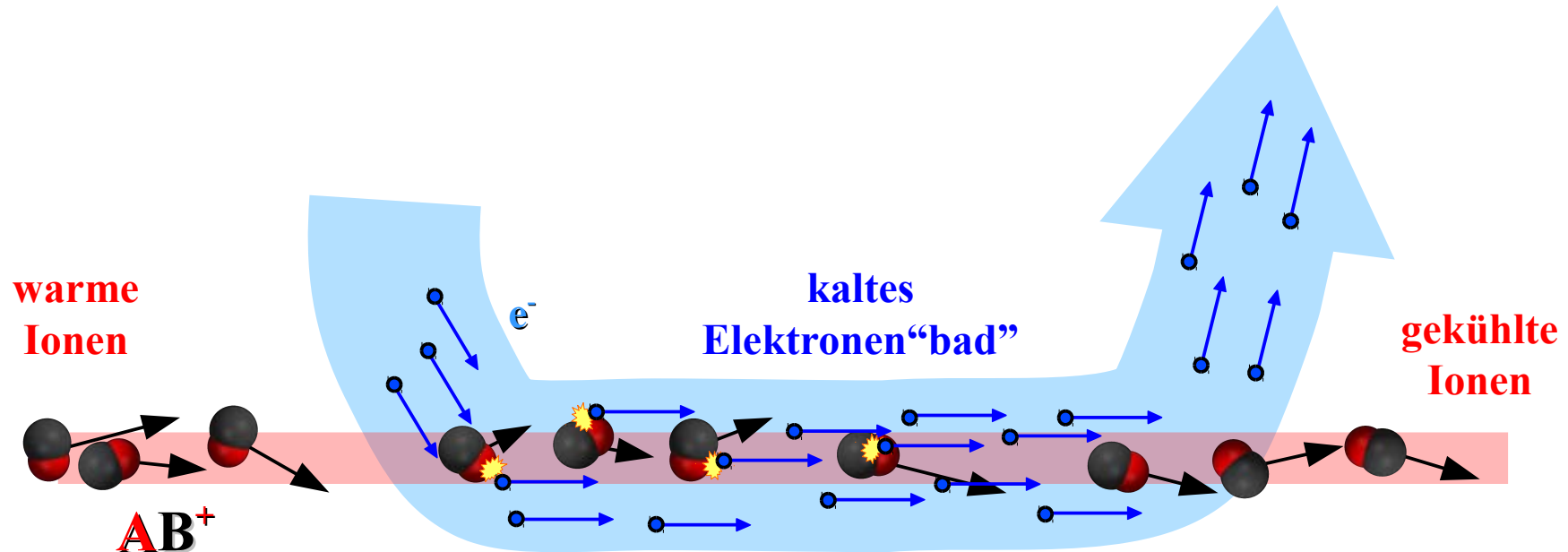
“Wärme ist **ungeordnete** Bewegung”

“**warme**”
Ionen

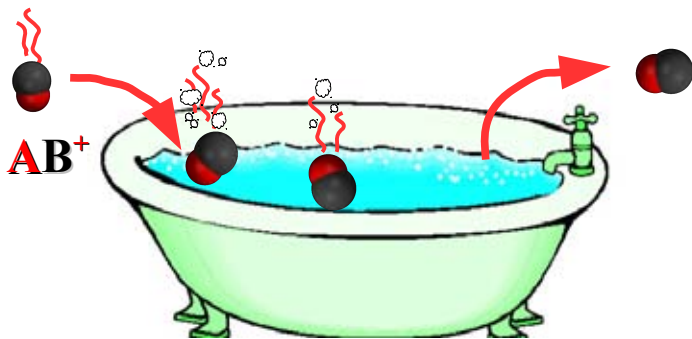


Zu Beginn: Unordnung des Ionenstrahls
~ **mehrere Tausend °C !**

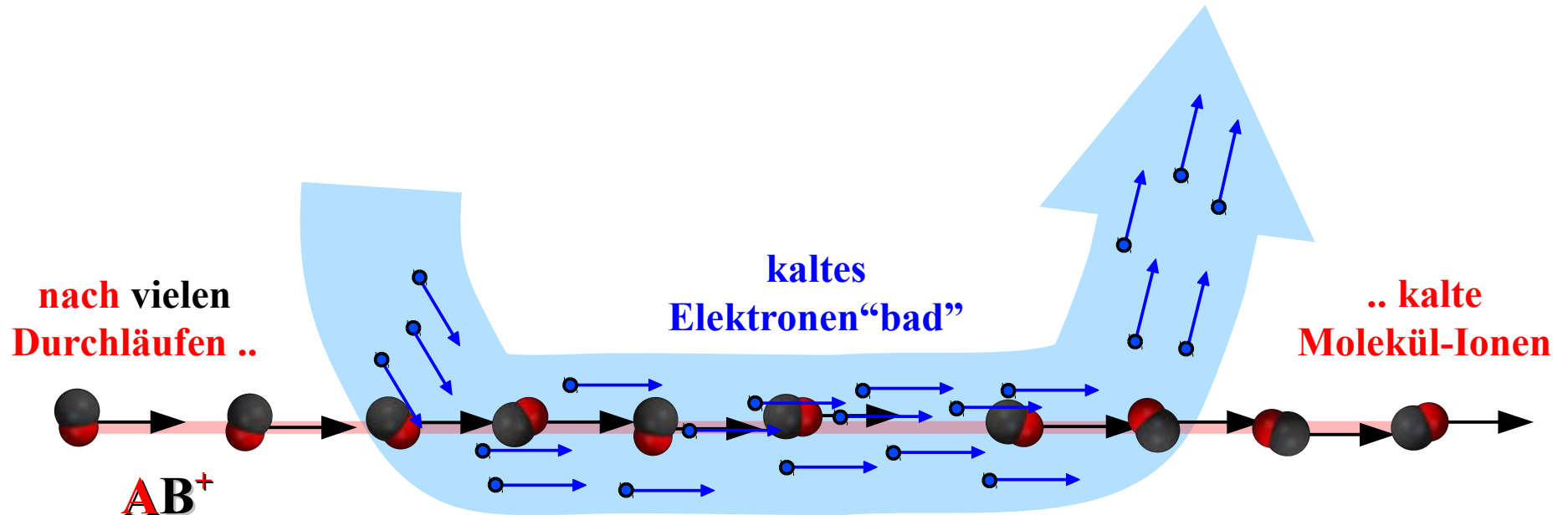
Elektronen-Kühlung



“Unordnung” des Elektronenstrahls
entspricht $T \sim -265^\circ\text{C}$

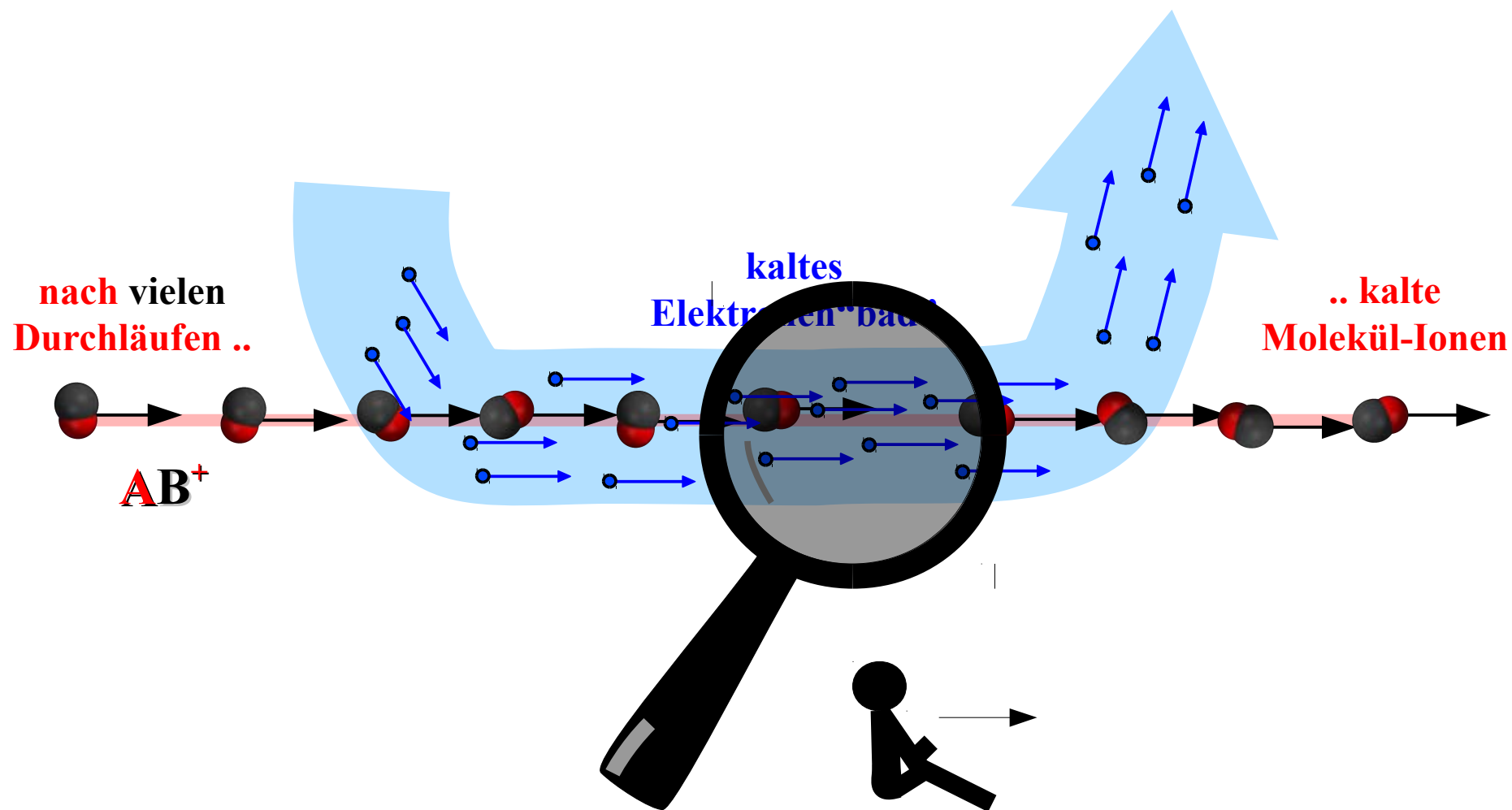


Elektronen-Kühlung

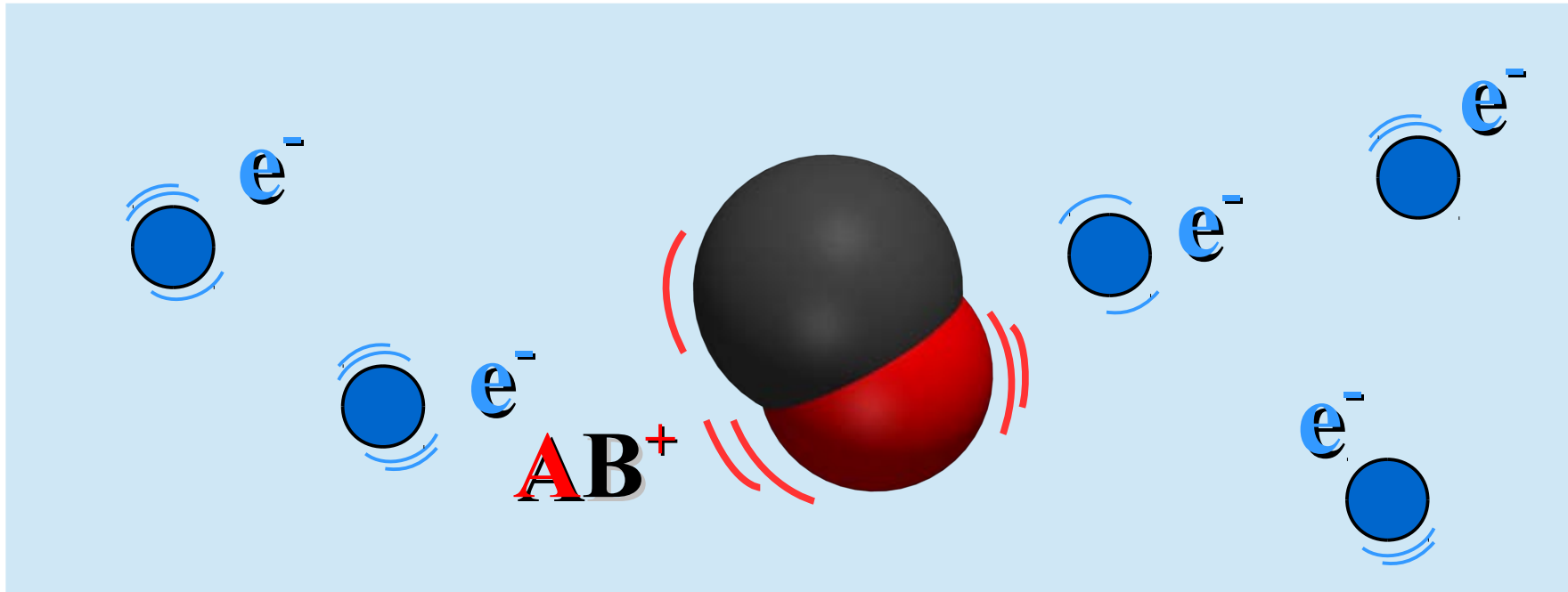


$$T_{\text{Ionen}} \approx T_{\text{Elektronen}} \approx -260^\circ\text{C}$$

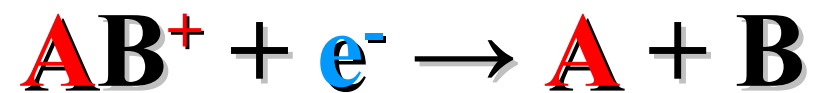
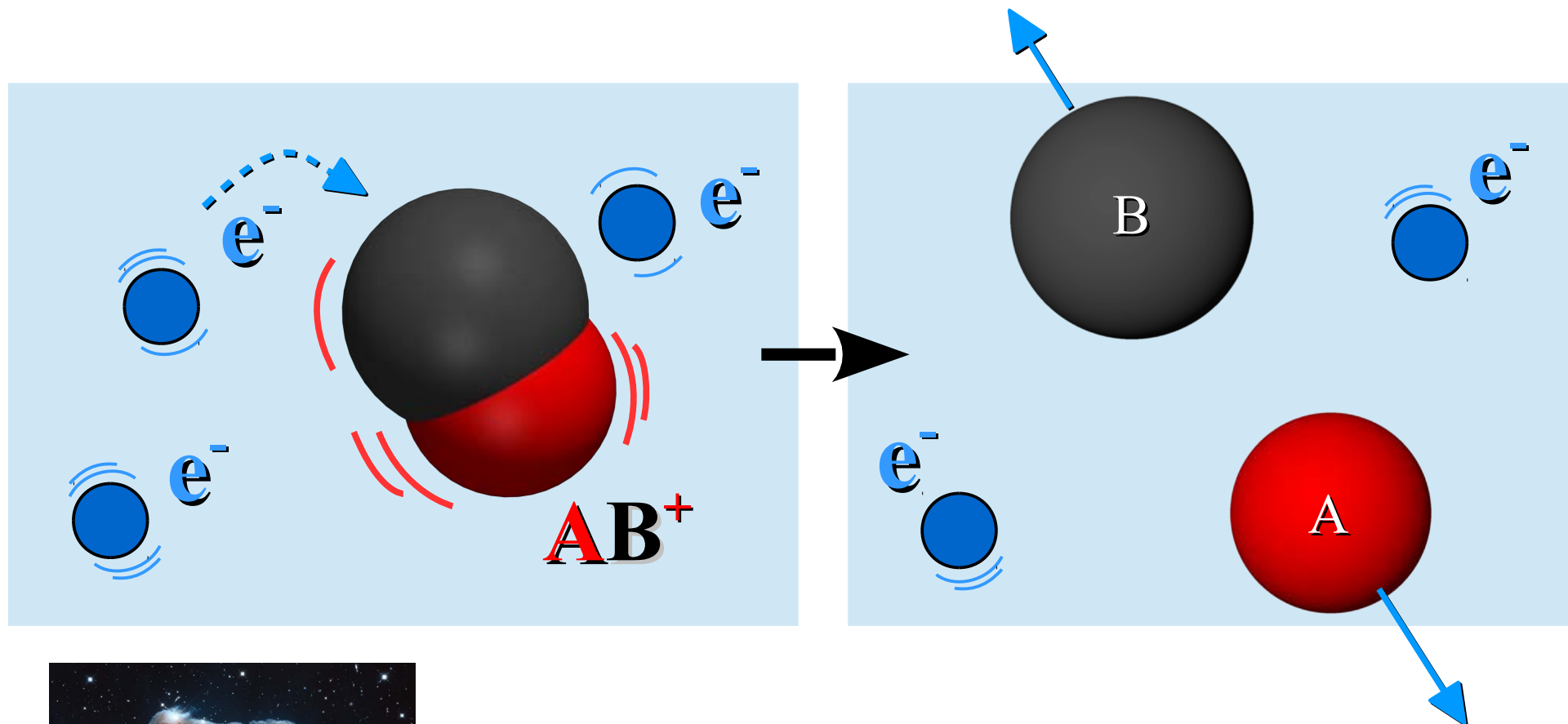
Elektronen-Kühlung

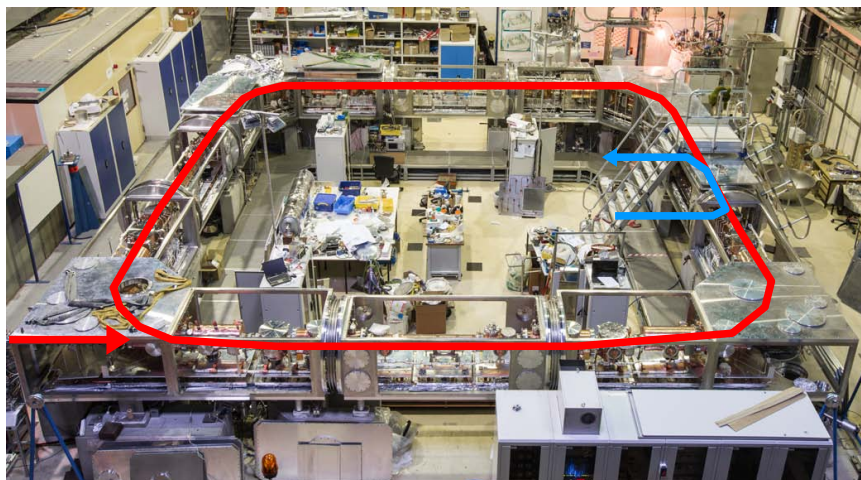


Aus Sicht des Ionenstrahls: Alle Teilchen praktisch **bewegungslos**.

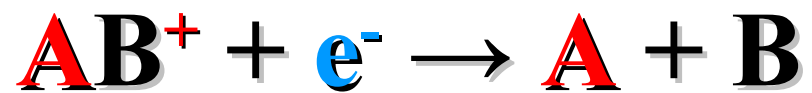
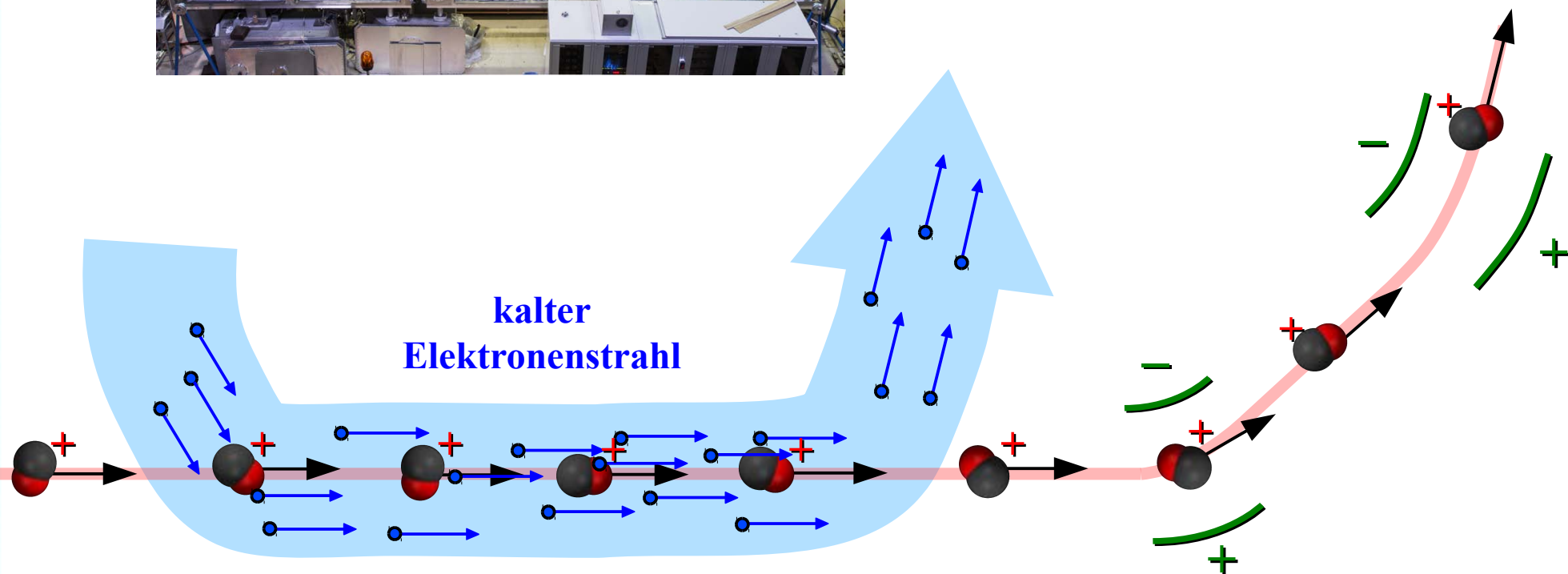


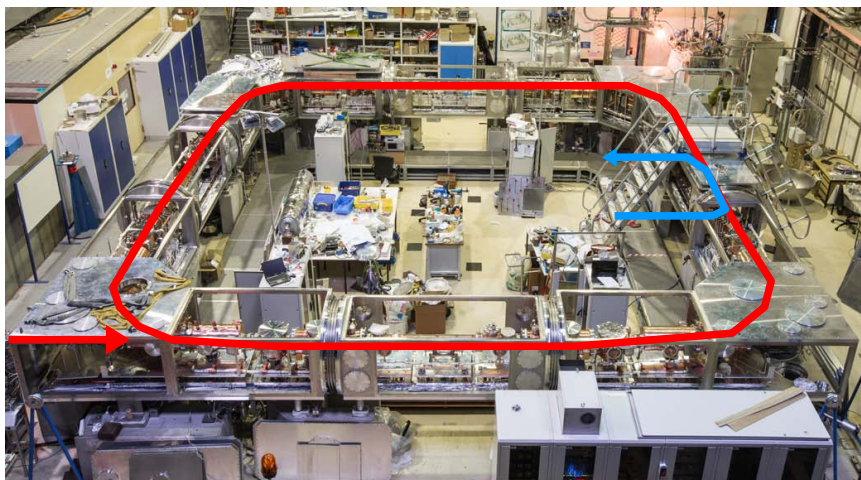
Ein -260°C kaltes Gemisch aus Ionen und Elektronen:
Eine kleine, kalte Molekülwolke im Labor!



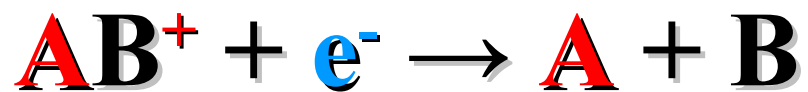
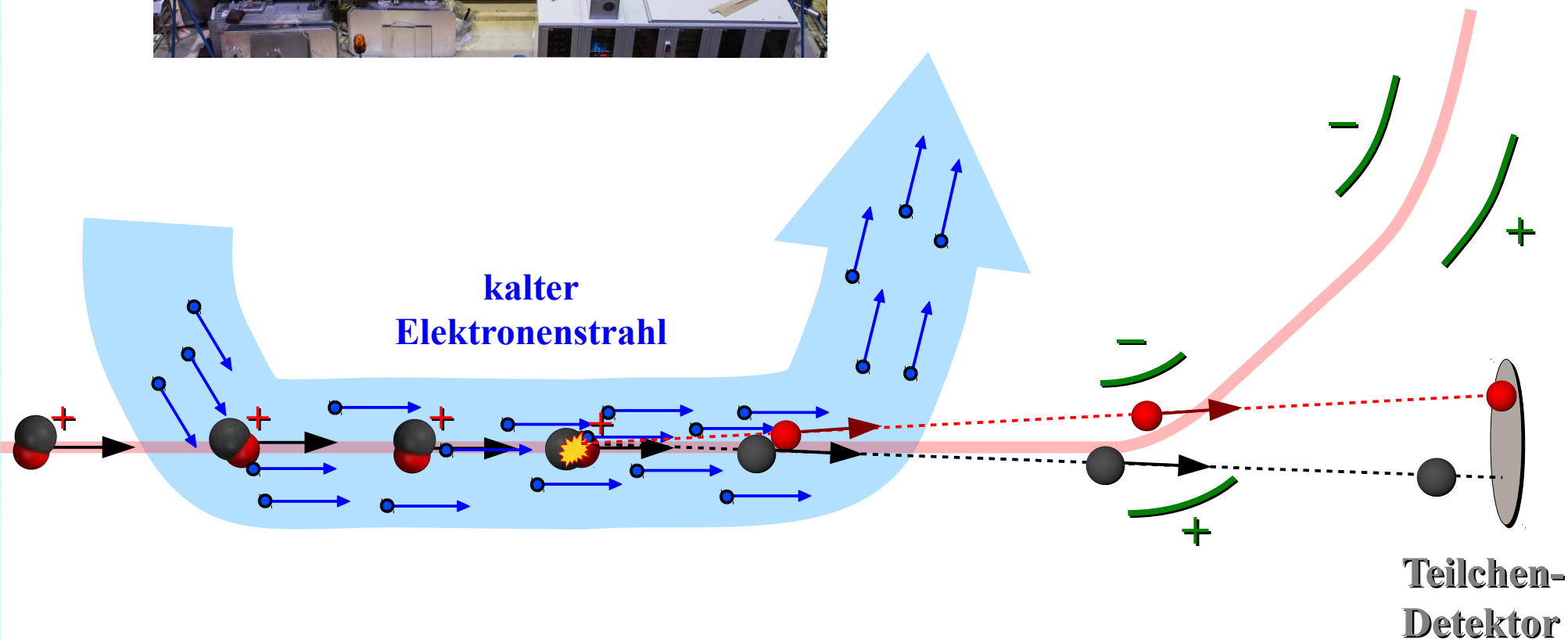


kalter
Elektronenstrahl





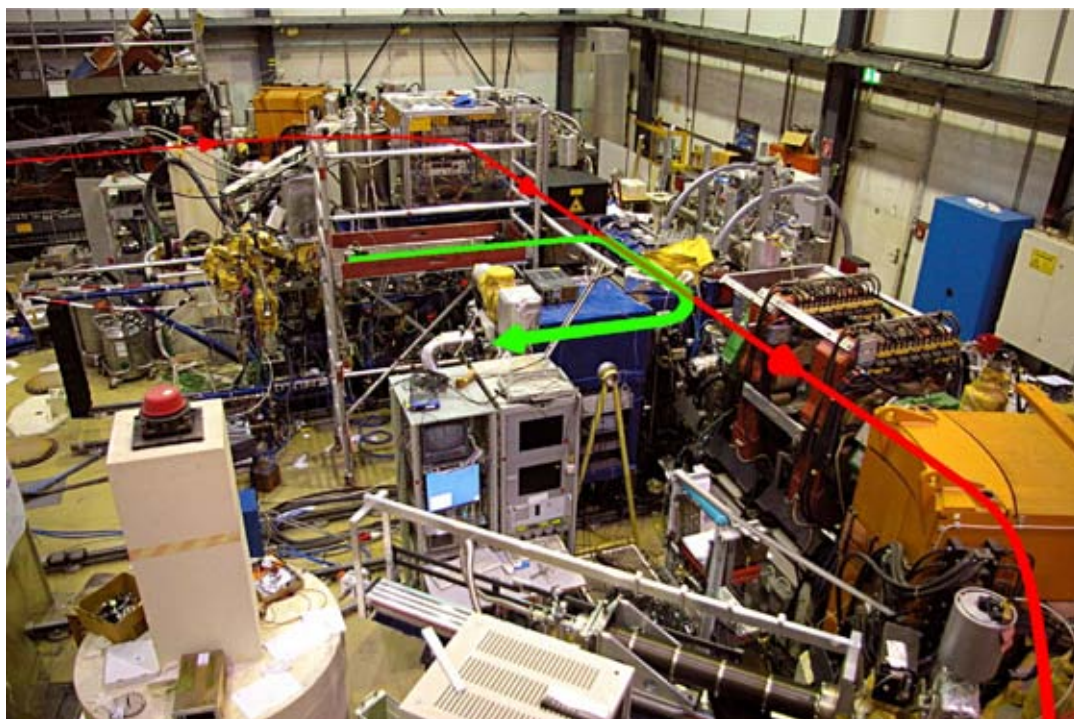
kalter
Elektronenstrahl



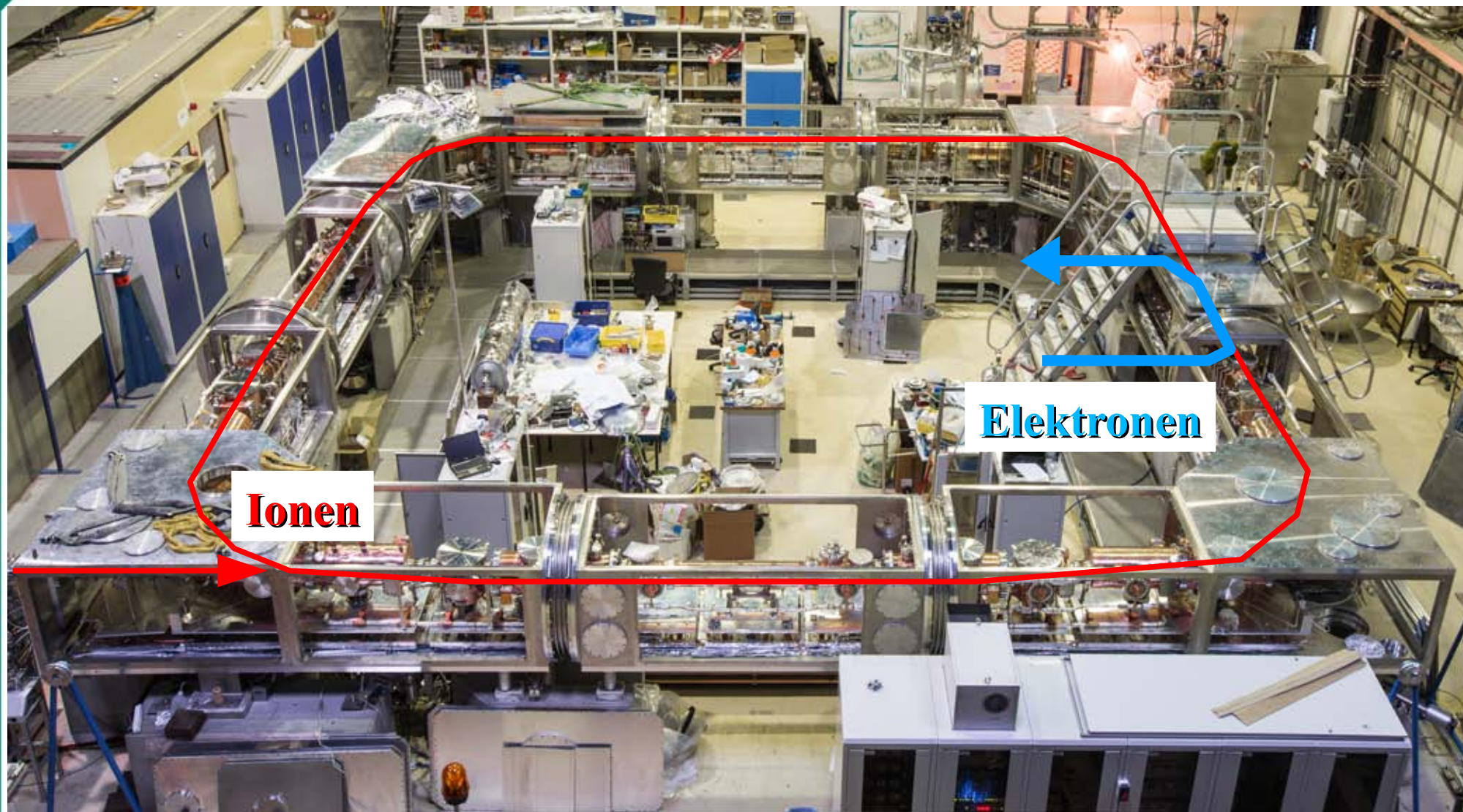


Ehemaliger Speicherring TSR
(1988-2012)

Rundgang:
Experimentierhalle F13



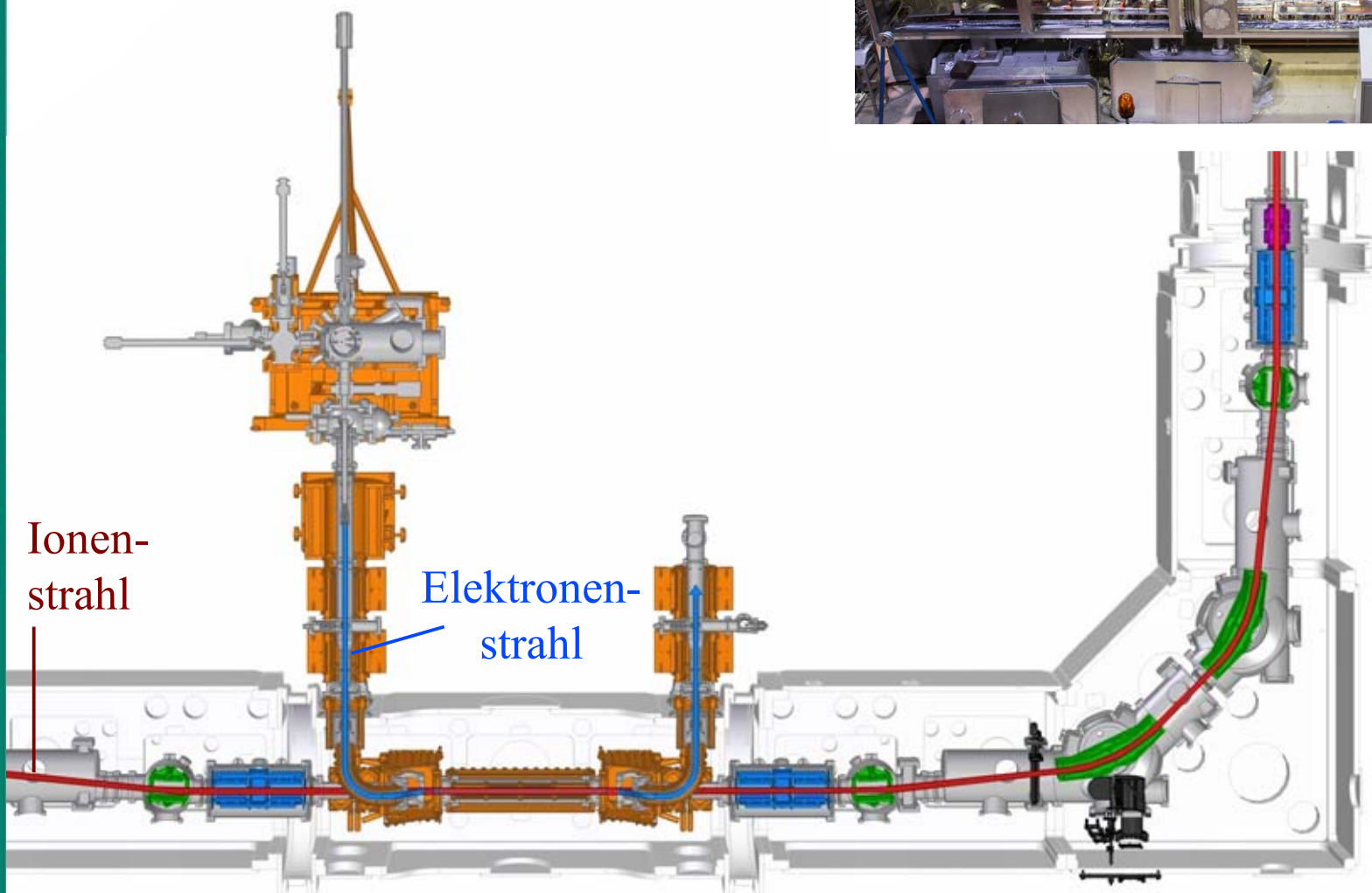
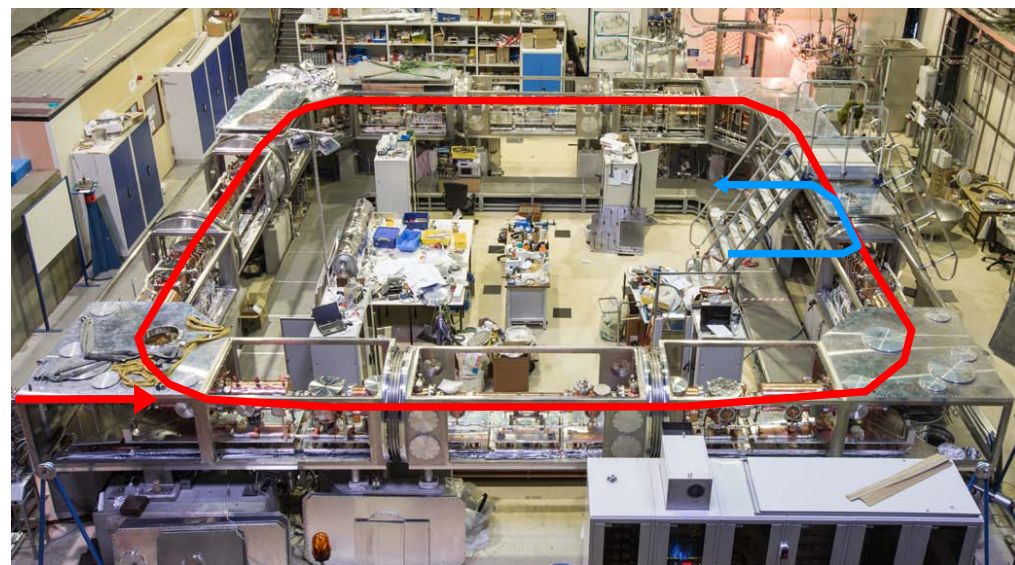
Kalter Elektronenstrahl



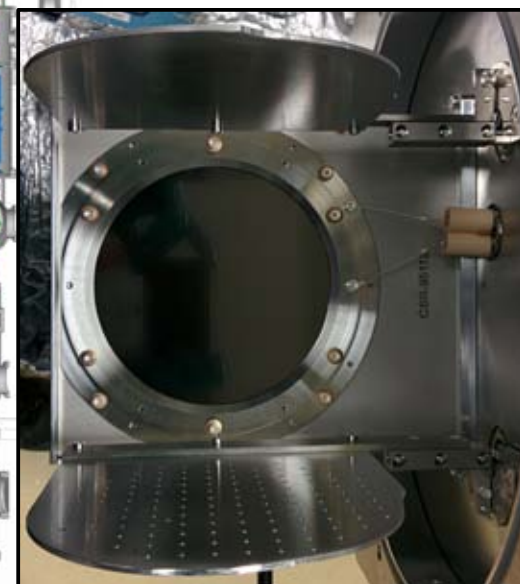
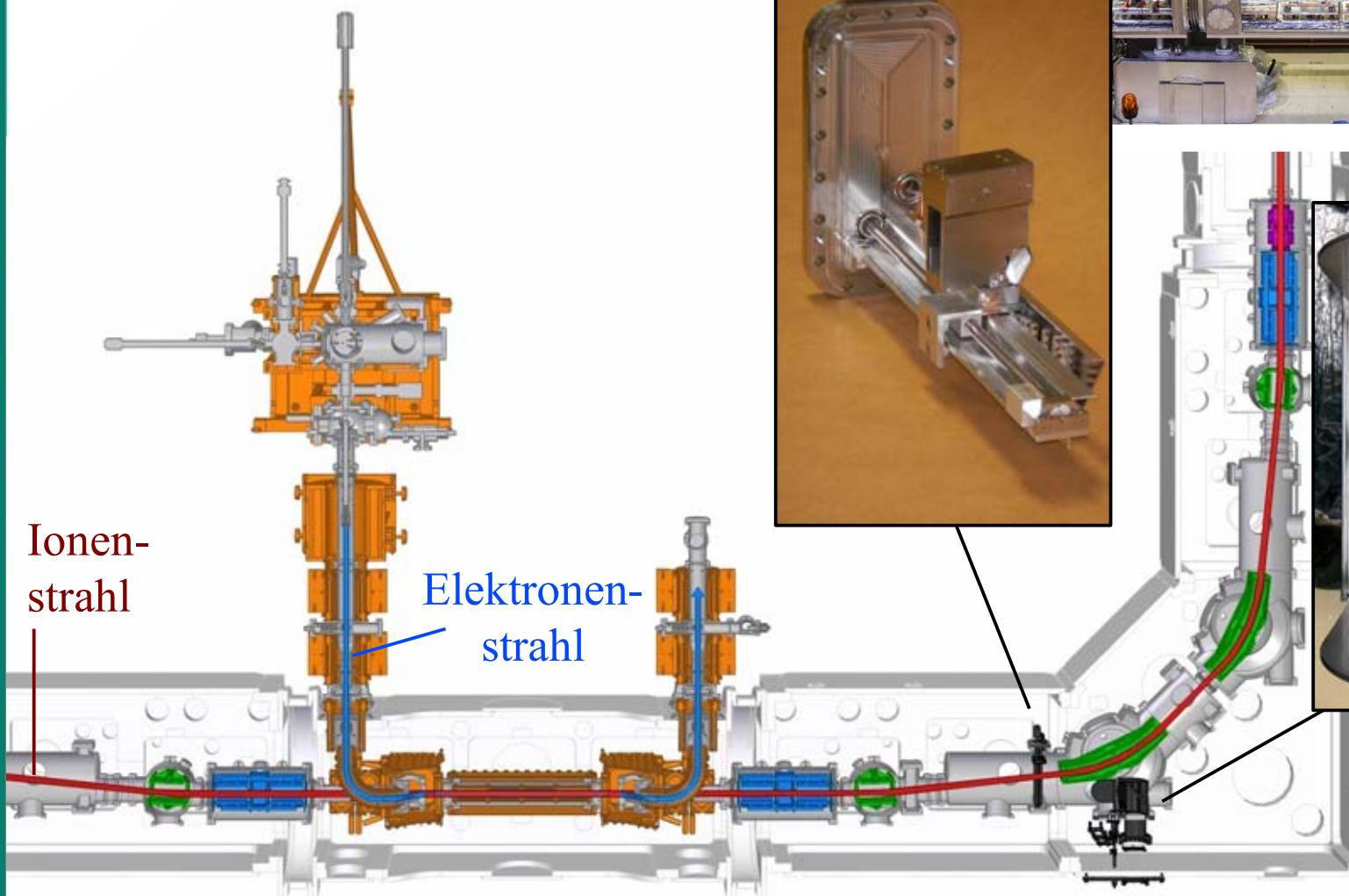
Der Speicherring CSR: **Ein extremes Vakuum bei -260°C**

(Experimentierhallen: F7 - F11)

Rundgang: Experimentierhalle F9



Rundgang: Experimentierhalle F9



Teilchen-
Detektoren



Vielen Dank!