

## Nuclear lifetime modifications in hot and dense plasmas



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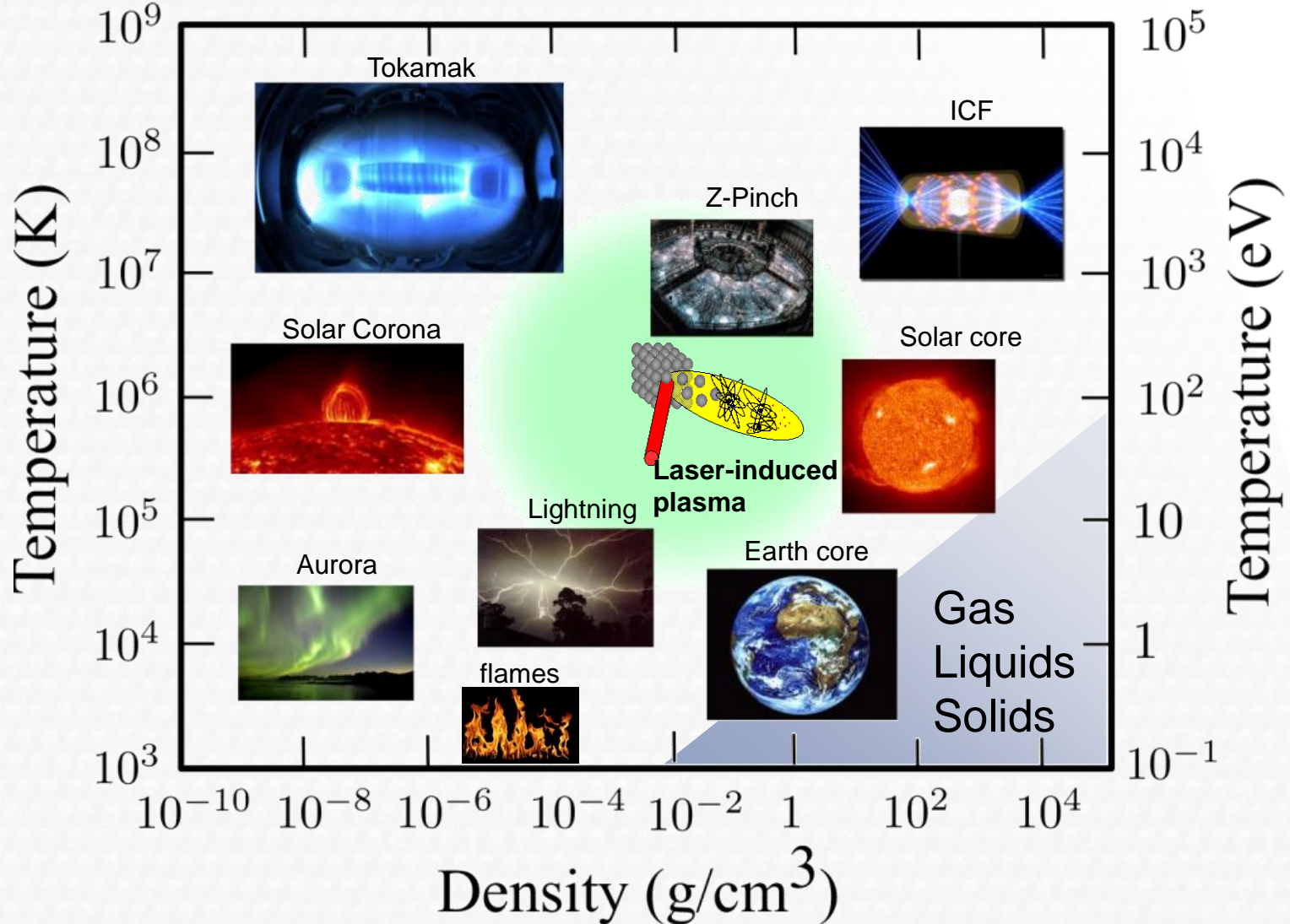
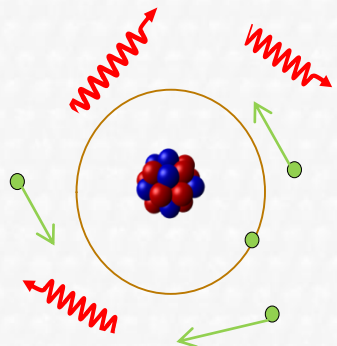


M.Gugiu, F.Negoita

# Laser-induced plasma

The 4th state of matter (99.9% visible matter)

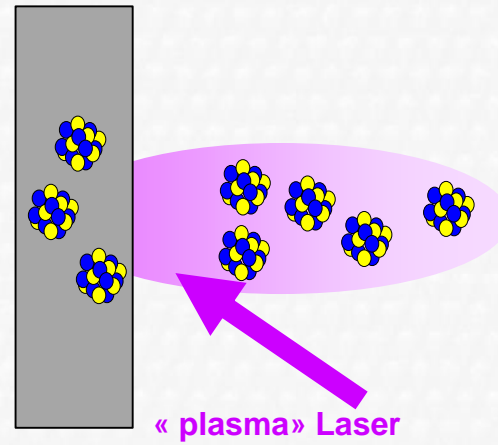
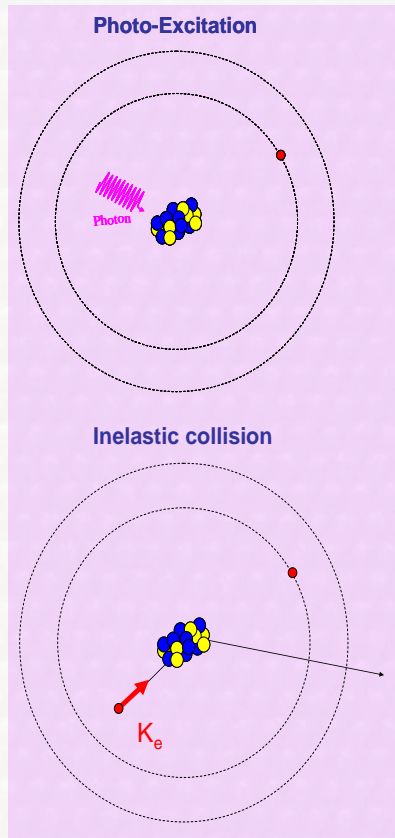
Plasma =  
ions  
+ free electrons  
+ photons



# Laser-induced plasma

- Nuclear processes in plasma

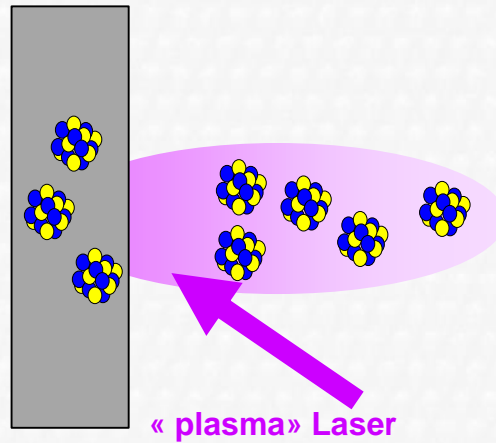
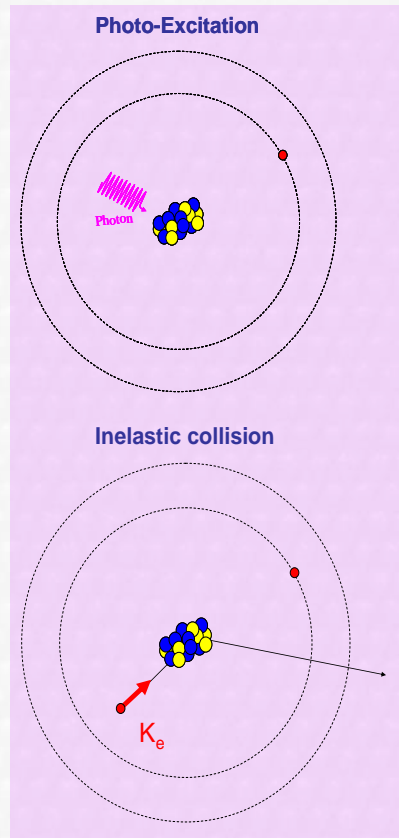
## Involving plasma particles



# Laser-induced plasma

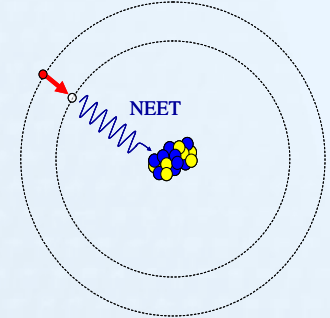
## ■ Nuclear processes in plasma

### Involving plasma particles

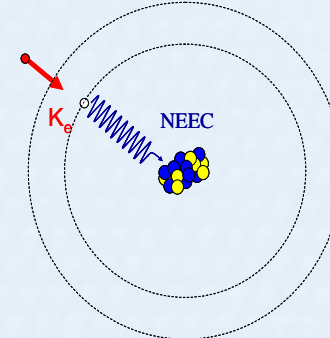


### Involving atomic electrons

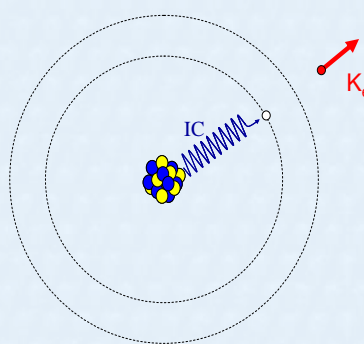
#### Nuclear Excitation by Electronic Transition NEET



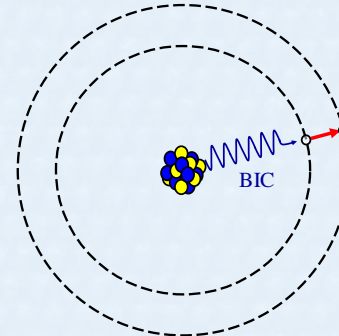
#### Nuclear Excitation by Electron Capture NEEC



#### Internal Conversion : IC



#### Bound Internal Conversion : BIC

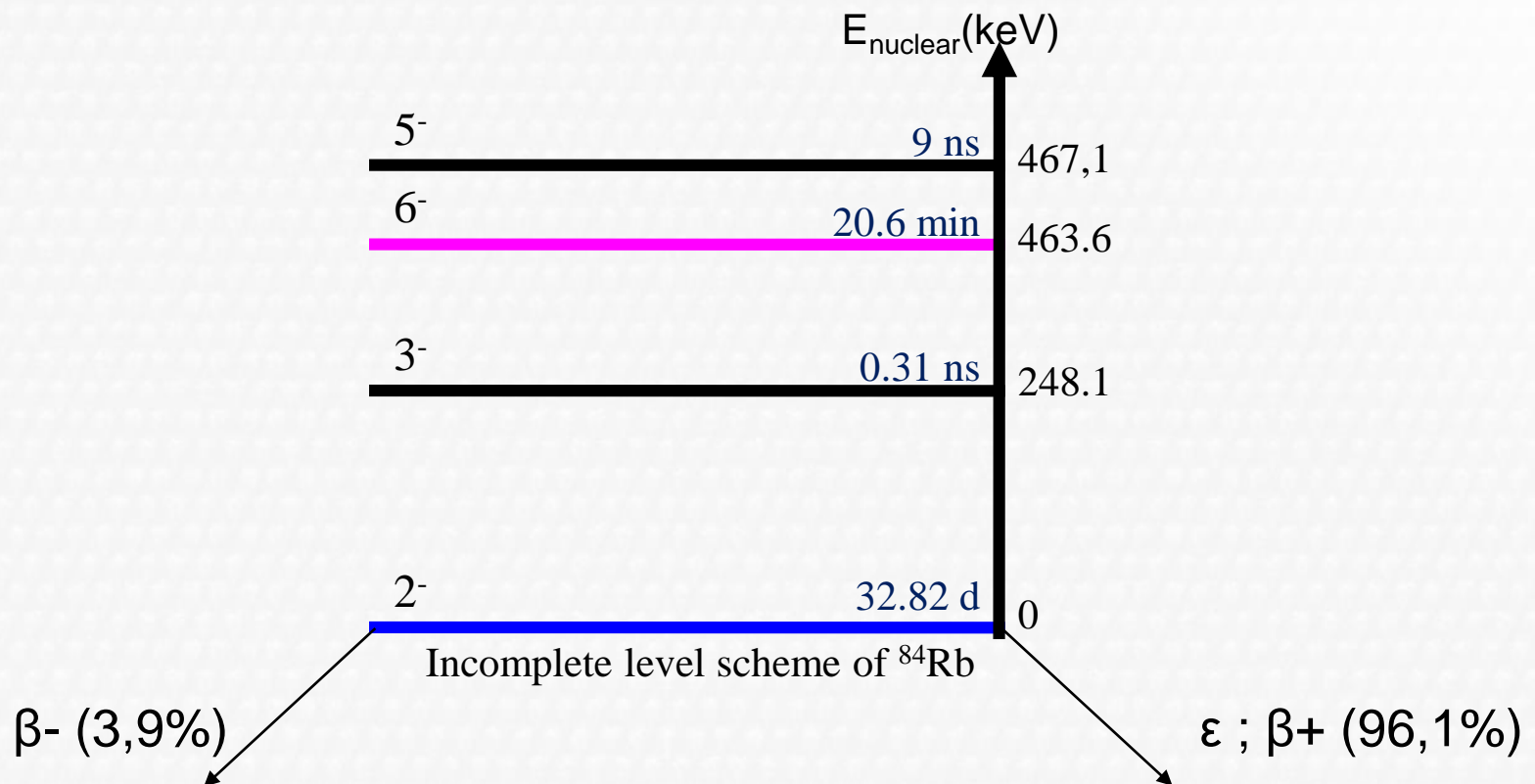




# Nuclear Lifetime modifications : the $^{84m}\text{Rb}$ case

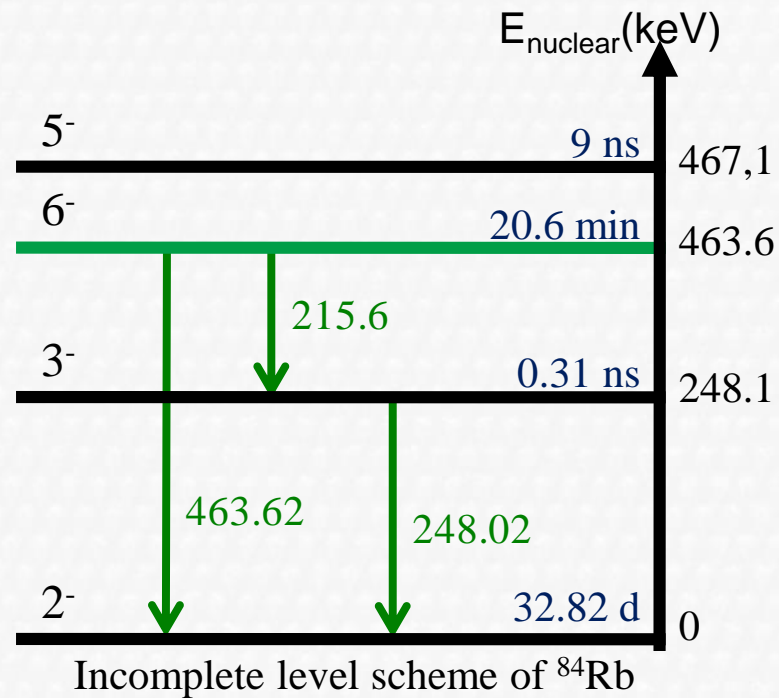
•  $^{84}\text{Rb}$ : non stable nucleus

- Ground state ( $J^\pi=2^-$ ,  $T_{1/2}=32.82$  days)
- Isomeric state ( $J^\pi=6^-$ ,  $T_{1/2}=20.6$  min)



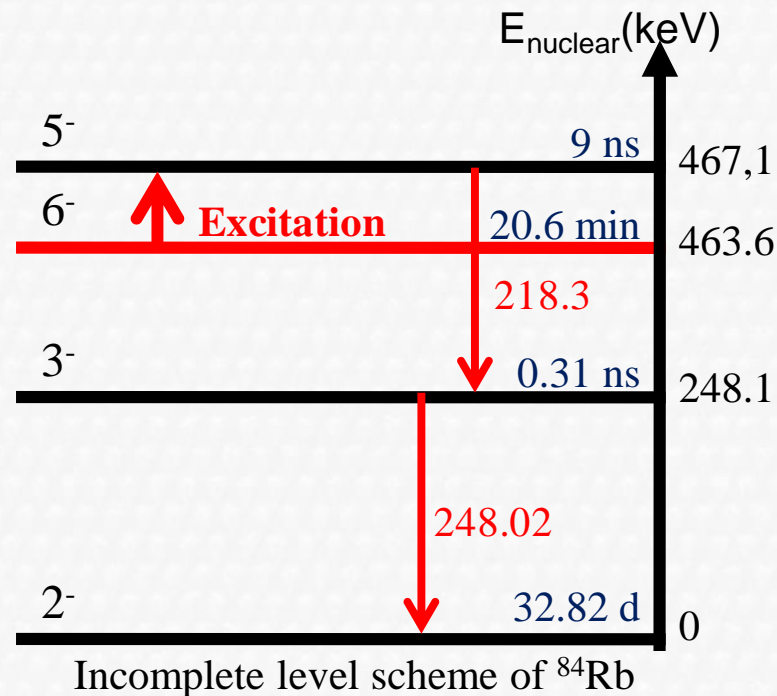
# Nuclear Lifetime modifications : the $^{84m}\text{Rb}$ case

- Depopulation process of isomeric state
  - In neutral atom : « normal decay»



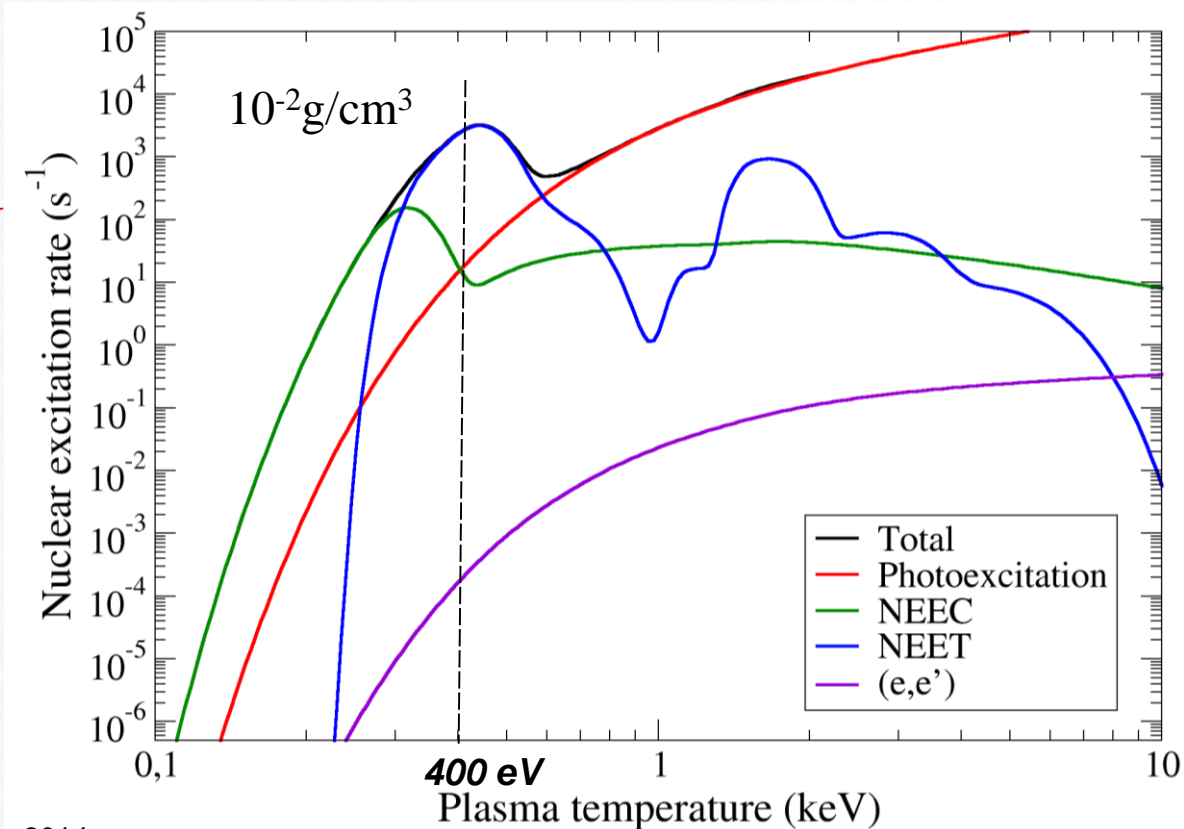
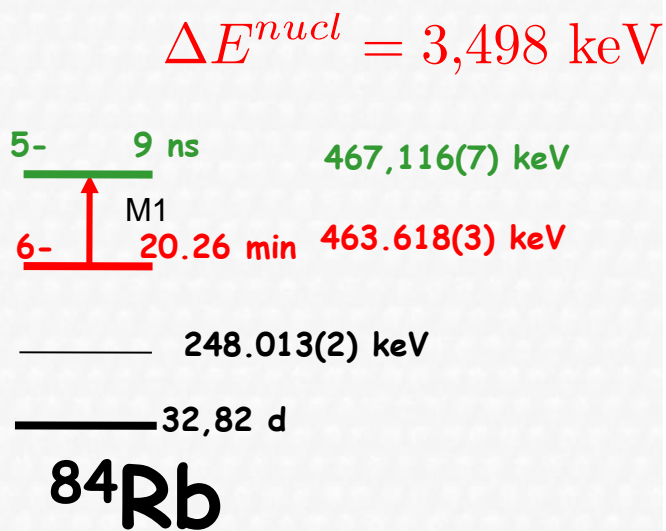
# Nuclear Lifetime modifications : the $^{84m}\text{Rb}$ case

- Depopulation process of isomeric state
  - In neutral atom : « normal decay»
  - 3,5 keV excitation to  $5^-$  state
    - Fast De-excitation via  $5^-$  state  $\rightarrow T_{1/2}$  modified !!!



# Nuclear Lifetime modifications : the $^{84\text{m}}\text{Rb}$ case

Plasma requirement : Temperature ( $\sim 200\text{-}1000$  eV), density ( $\sim 10^{-2}\text{g/cm}^3$ )



D. Denis-Petit, PhD thesis, University of Bordeaux, 2014  
 D. Denis-Petit et al., submitted to PRC (2017)

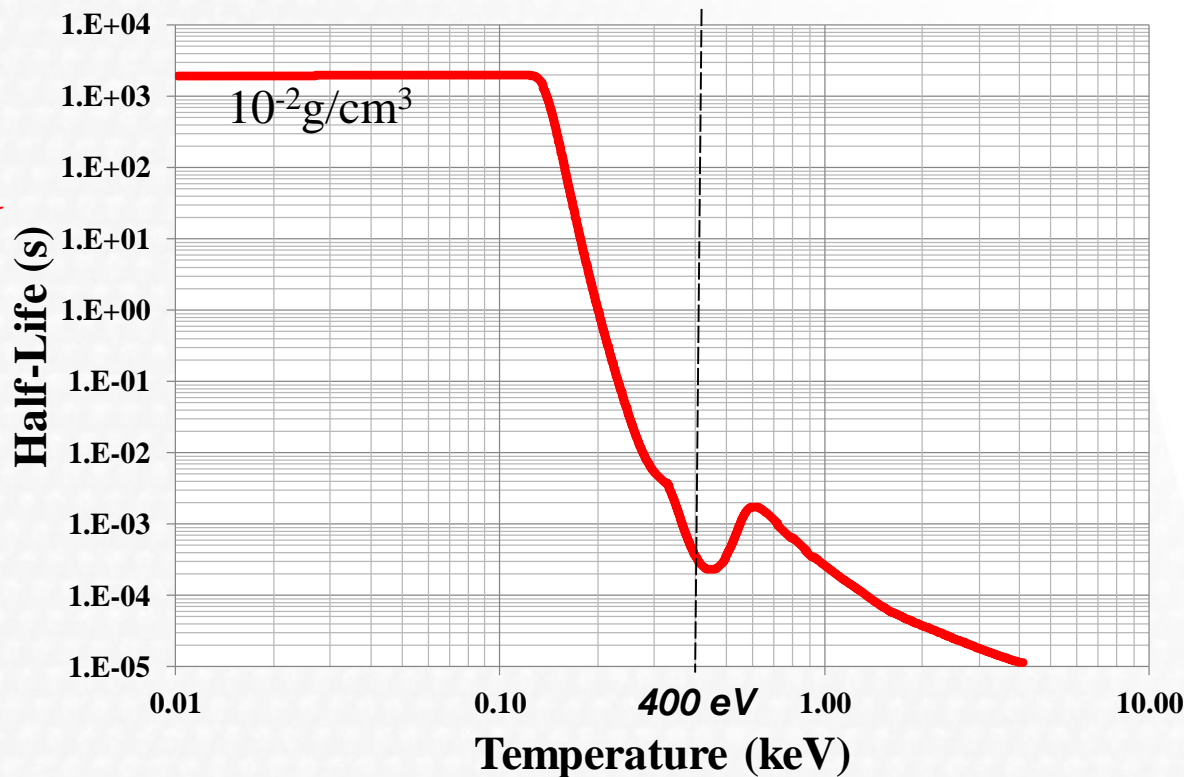
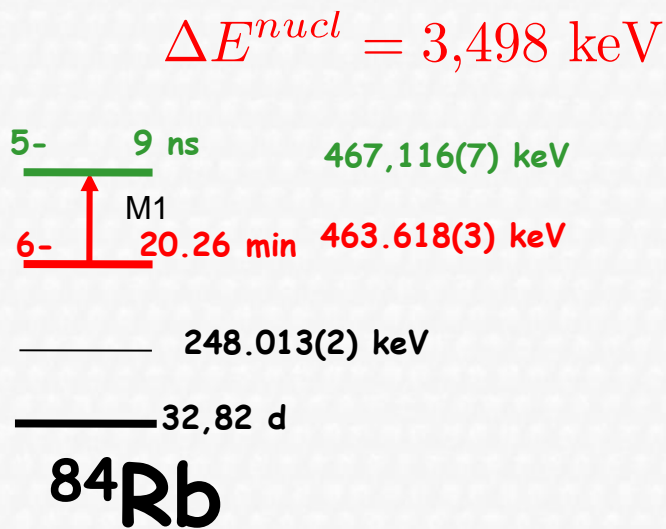
ISOMEX calculations of excitation rates of  $^{84\text{m}}\text{Rb}$  in a plasma, as functions of its temperature (in the **LTE approximation**).

→ Apparent half-life modification



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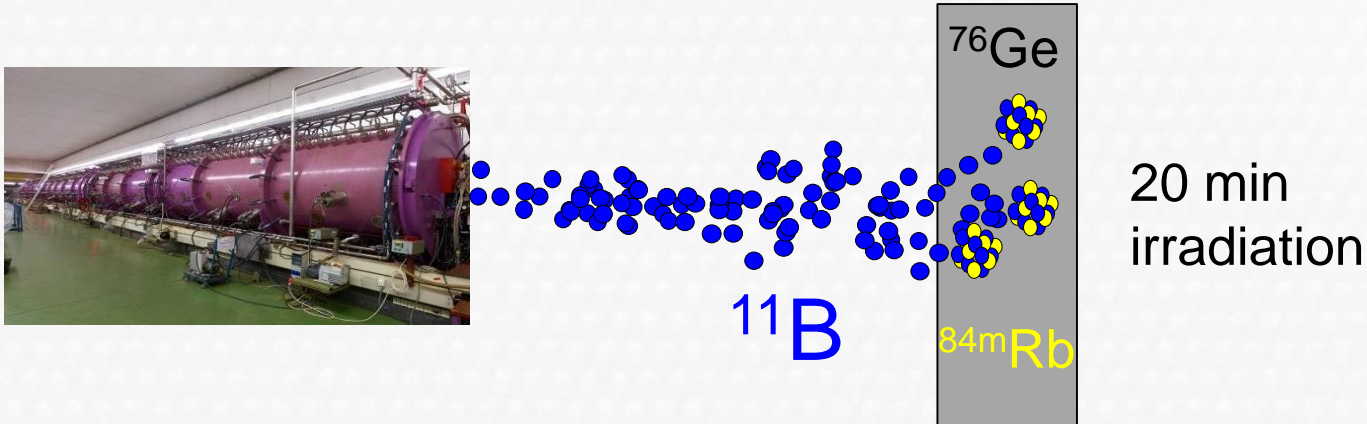


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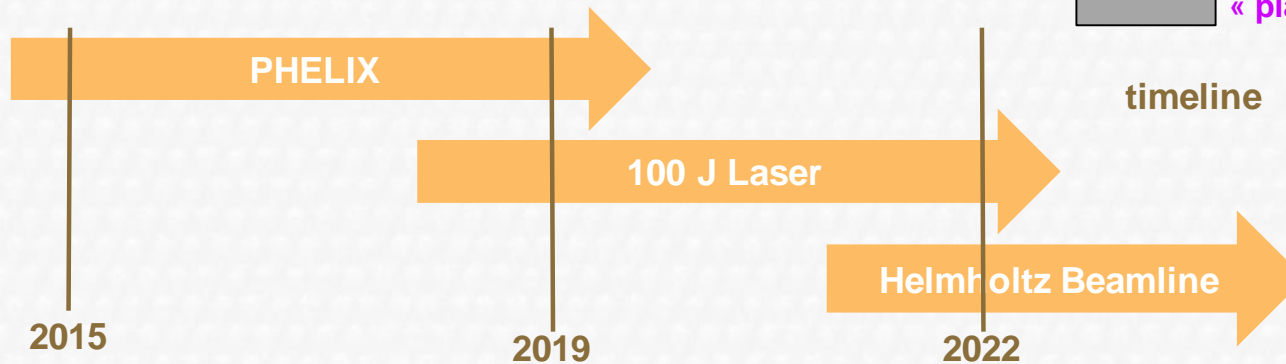
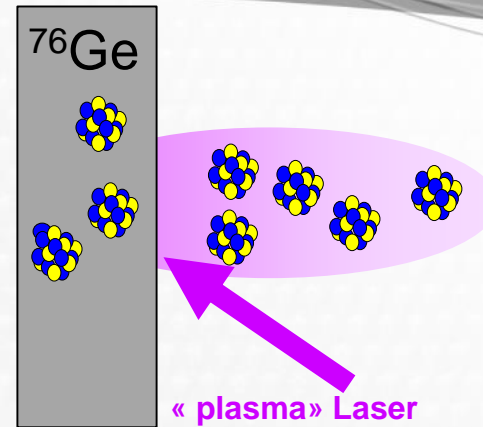
# FAIR : accelerator + high power laser

- Particle beam from accelerator : isomeric target production



# FAIR : accelerator + high power laser

- High power laser : plasma production

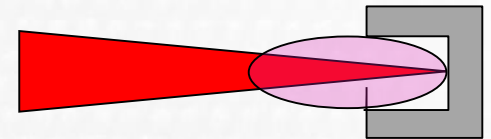


Temperature (~200-1000 eV)  
density (~ $10^{-2}$ g/cm<sup>3</sup>)

	Pulse energy	Pulse duration max	Repetition rate	Wavelength
PHELIX	150 J	1,5 ns	1/(90 min)	500 nm
100 J	100 J	20 ns	1/(10 min)	500 nm
Helmholtz Beamline	~10 kJ	~10 ns	1/(10 min)	500 nm

# Conclusion

- Apparent nucleus property changing in plasma because of :
  - Nuclear excitation / deexcitation changing with temperature
  - High electromagnetic fields present ( $E \sim 10^{11} \text{V/cm}$  ;  $B \sim 1000 \text{T}$ )
- FAIR : unique facility with accelerator and high power lasers
  - In situ production of large range of targets
  - Laser induced hot and dense plasma



➔ For the very next years : improvement of plasma temperature

- ✓ PHELIX experiment in 2012 :  $6 \cdot 10^{14} \text{W/cm}^2$  on RbCl ;  
only  $T = 270 \text{ eV}$  LTE ( $\sim 1.4 \text{ keV}$  NLTE)  
→ need to increase the plasma temperature

