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EXPERIMENTAL METASTABLE  
LIFETIMES AT DESIREE STORAGE RING –  
FIRST STOP : BARIUM

Henrik Hartman  
Malmö University, Sweden

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# Collaborators

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*Latvia University, Riga, Latvia*

**Paul Martini, Jose E. Navarro Navarrete, John Alexander, Mikael Björkhage, and Henning Schmidt**  
*Stockholm University, Sweden*

**Dag Hanstorp**  
*Gothenburg University, Sweden*





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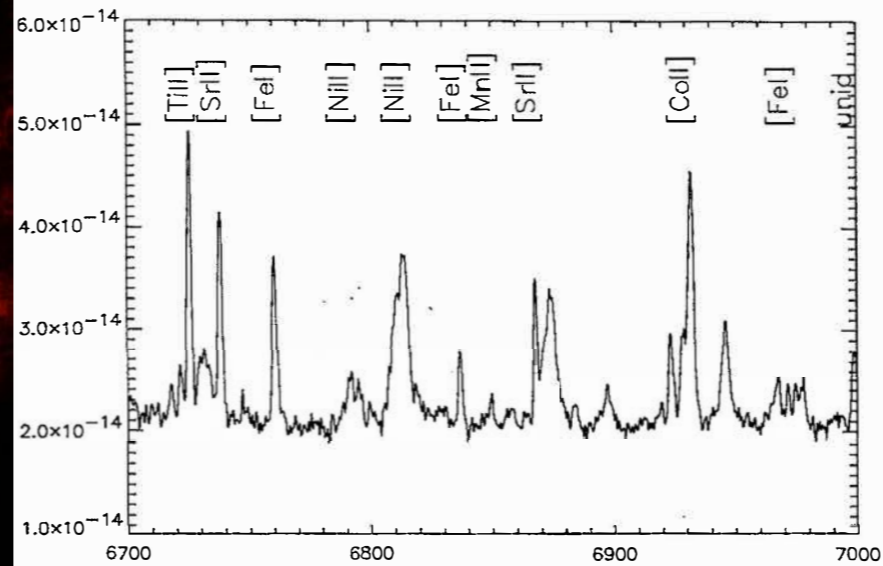
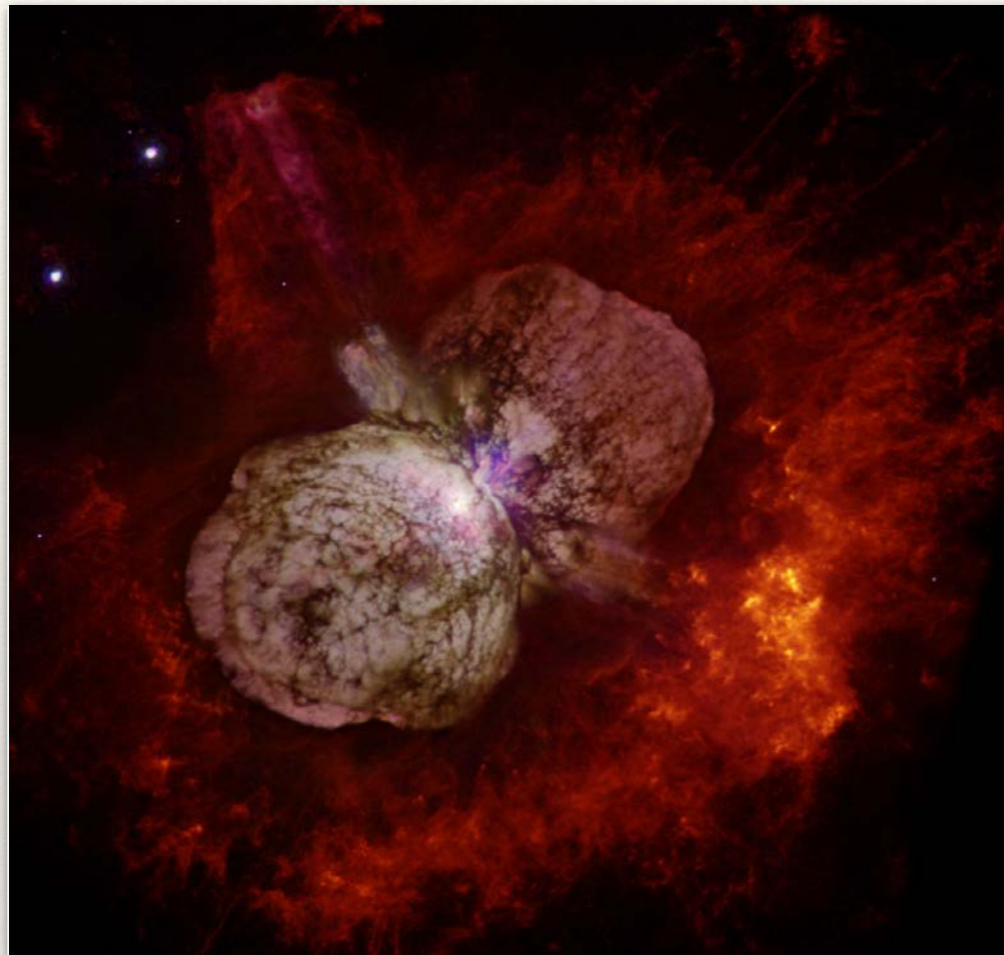
# Outline

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- ❖ Parity forbidden lines as probes of astrophysical conditions
- ❖ Lifetime measurements through laser probing, and pumping, of stored ions
- ❖ Preliminary results for Ba II



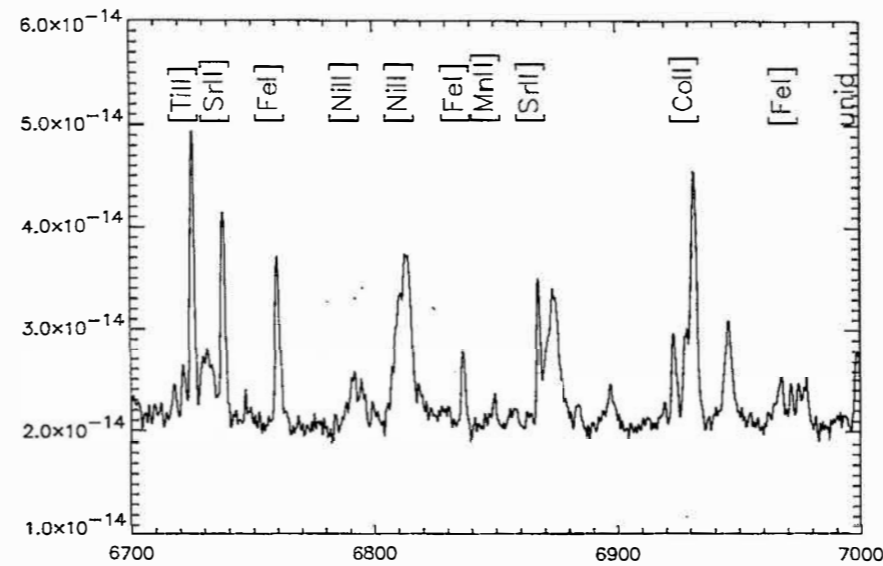
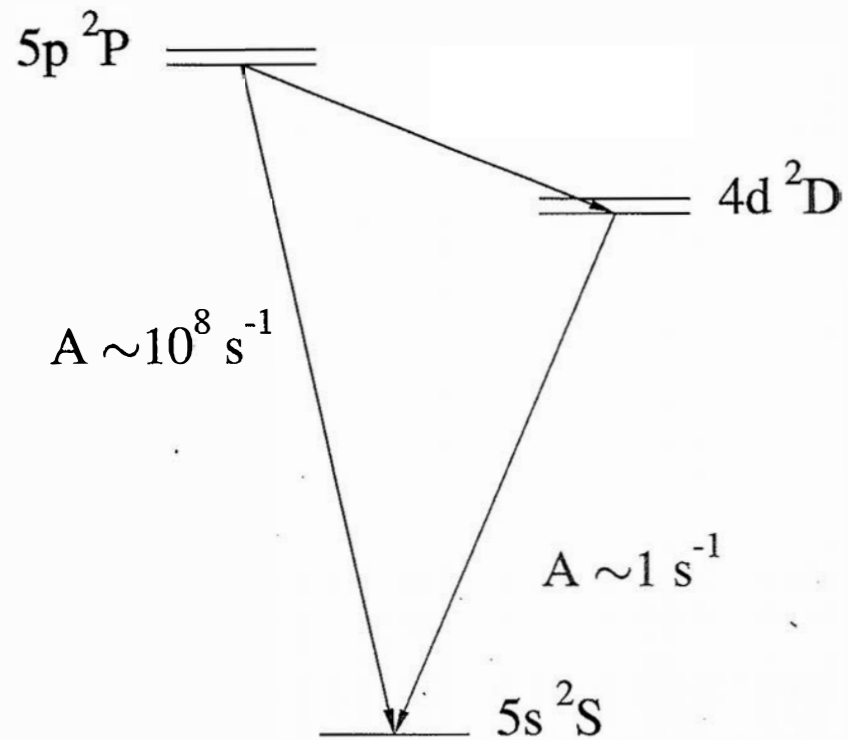
# Forbidden lines as probes of conditions of astrophysical plasmas



Strontium Filament of Eta Carinae showing forbidden lines from iron group elements and SrII.

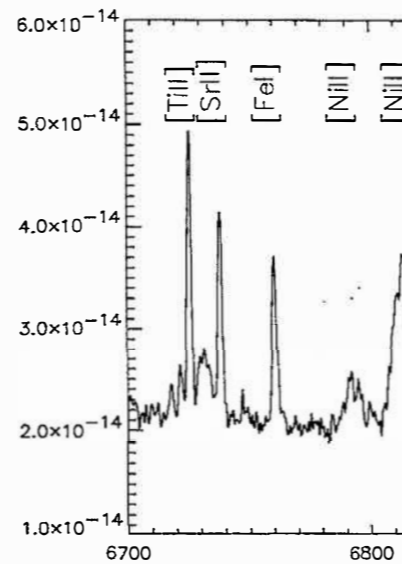
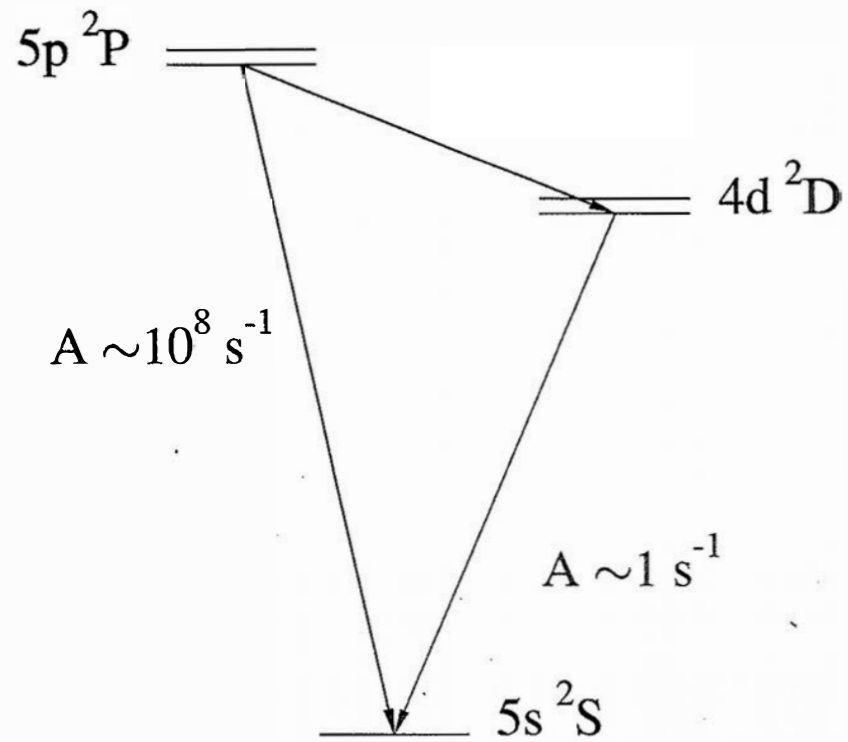


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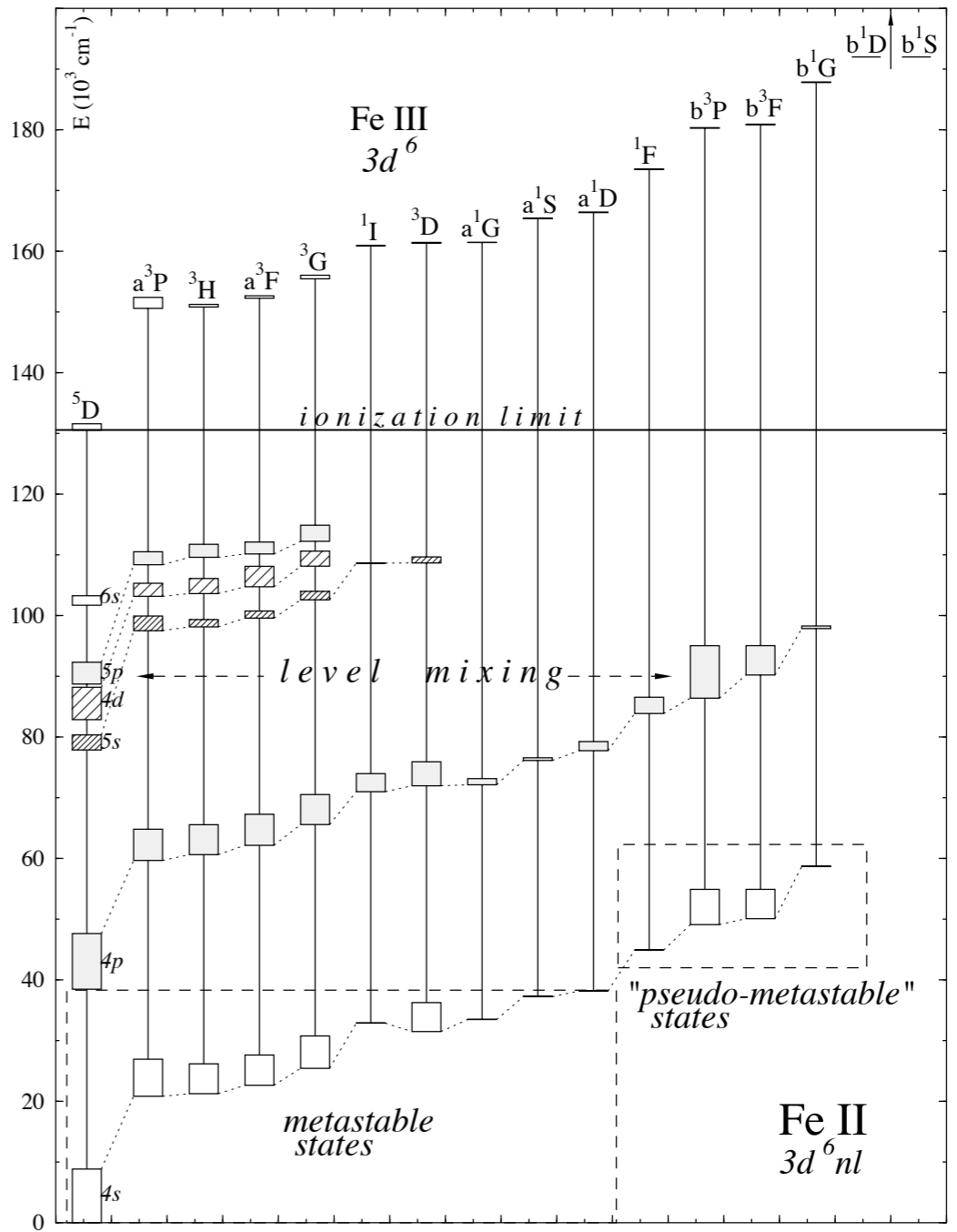


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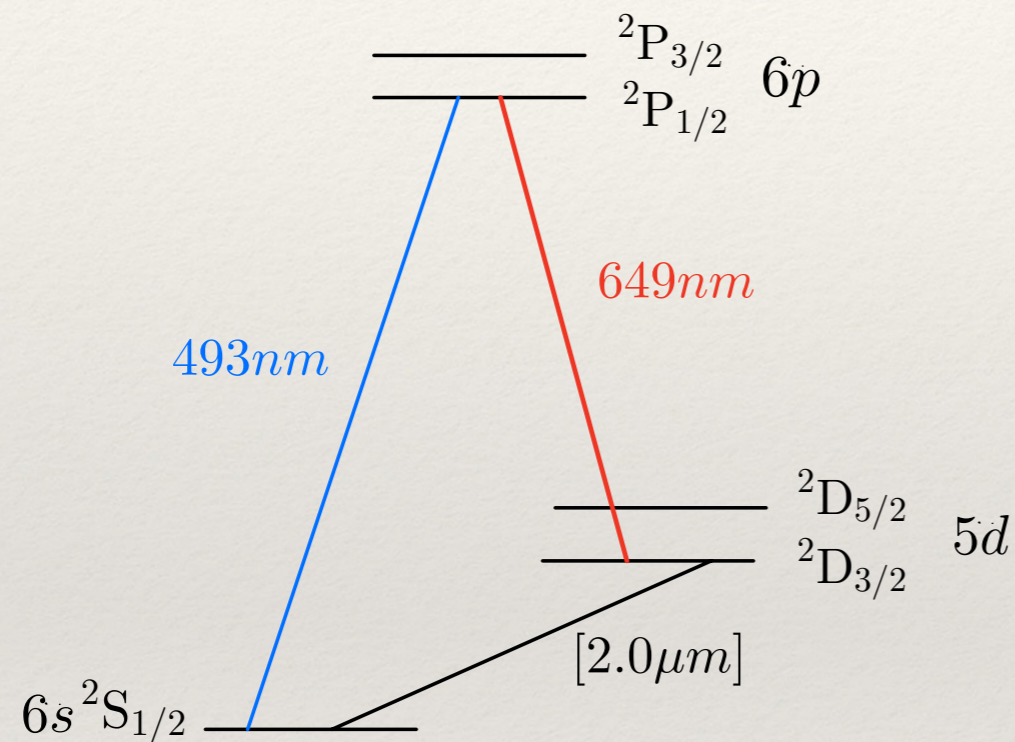


Strontium Filament of I lines from iron group elements





# Singly ionized barium - Ba II



Singly ionized barium has two metastable states in the 5d configuration.

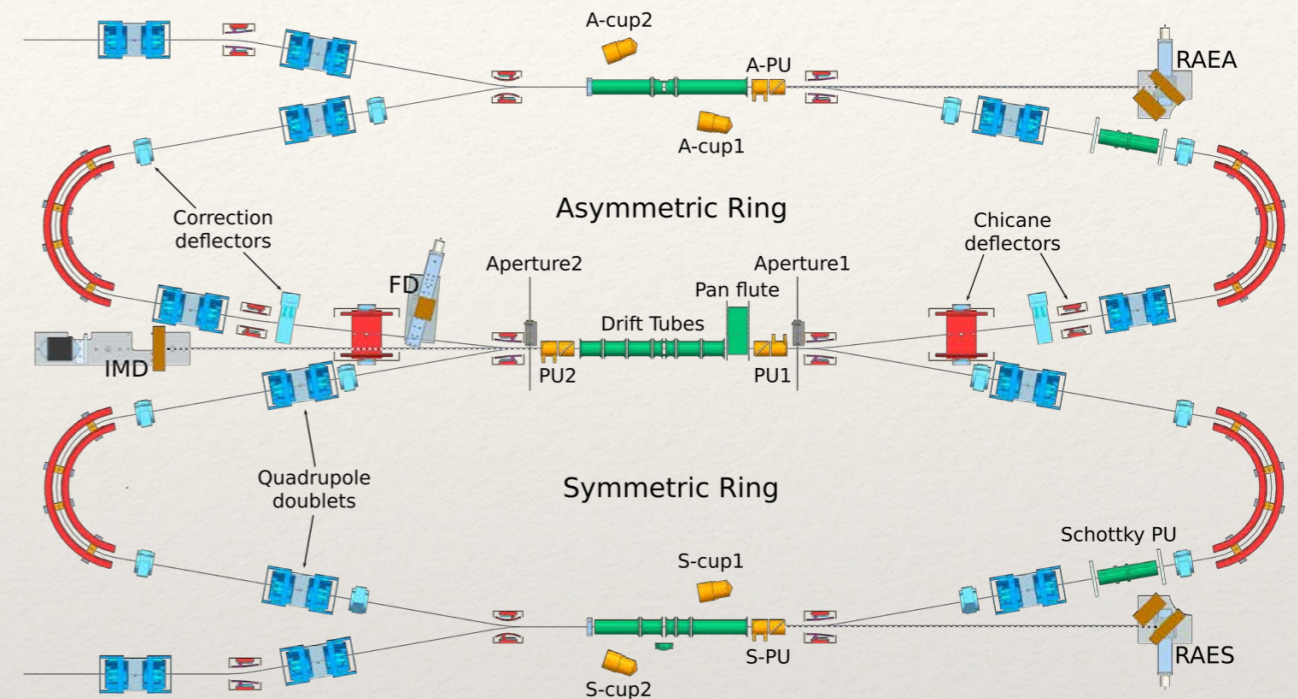
Expected lifetimes:

$$5d^2D_{5/2} : 32s$$

$$5d^2D_{3/2} : 83s$$



# DESIREE storage rings

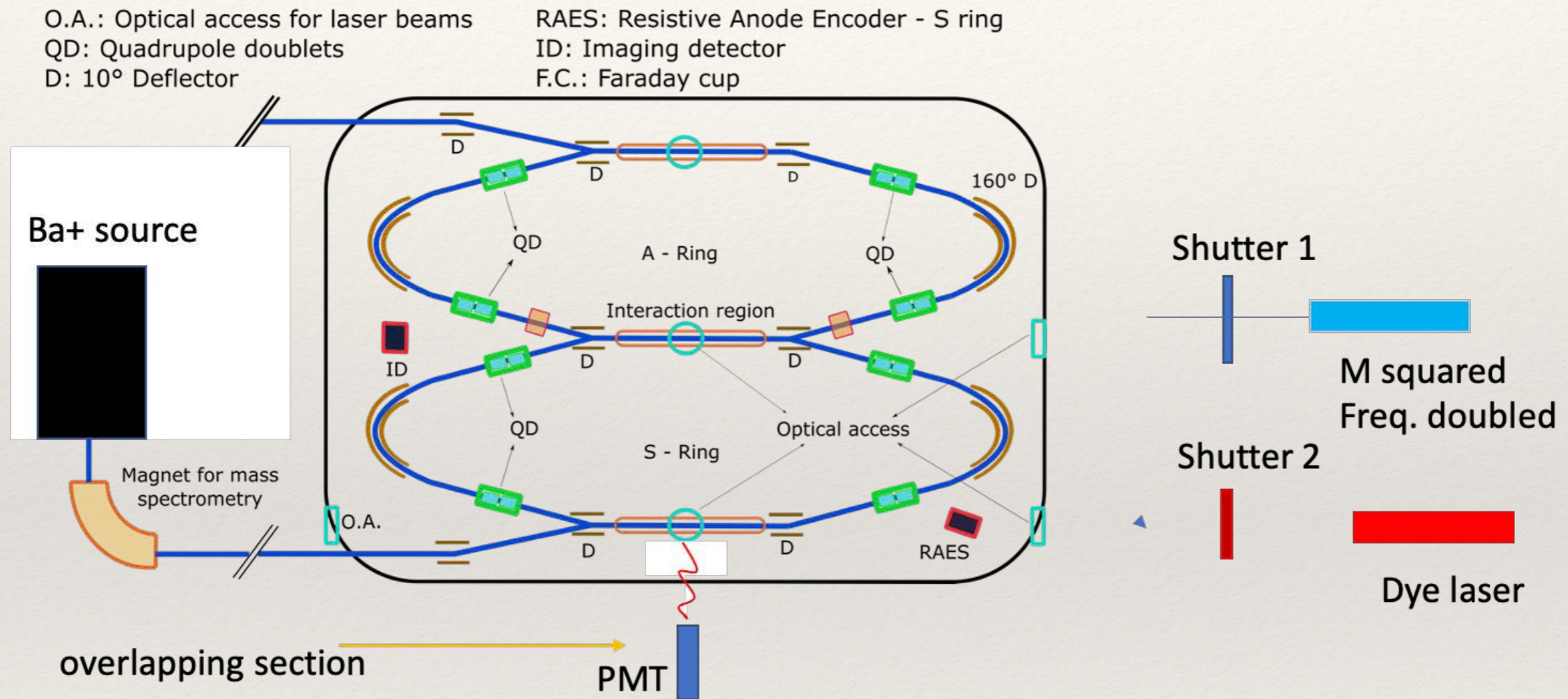


DESIREE is a cryogenically cooled compartment under ultra-high vacuum.  
The ions are stored and directed with electrostatic elements.

National research infrastructure : <http://www.desiree-infrastructure.com>

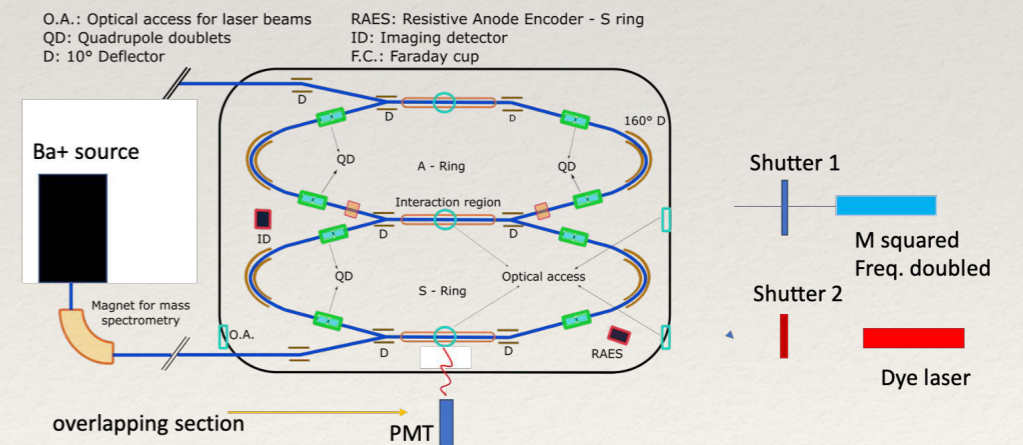
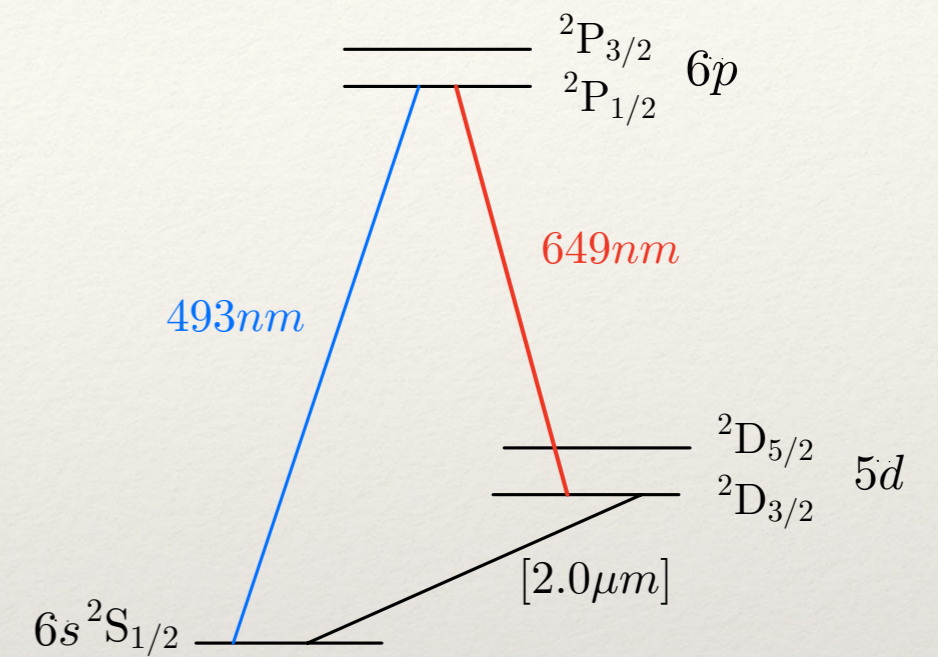


# DESIREE storage rings





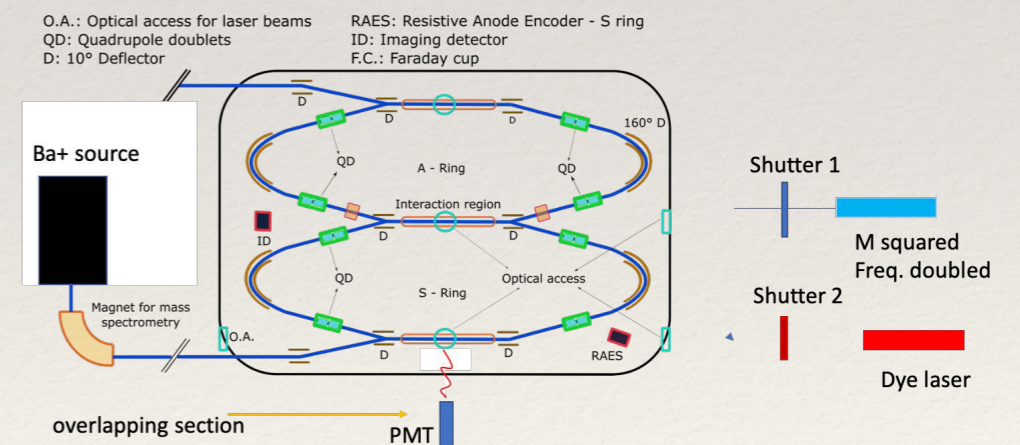
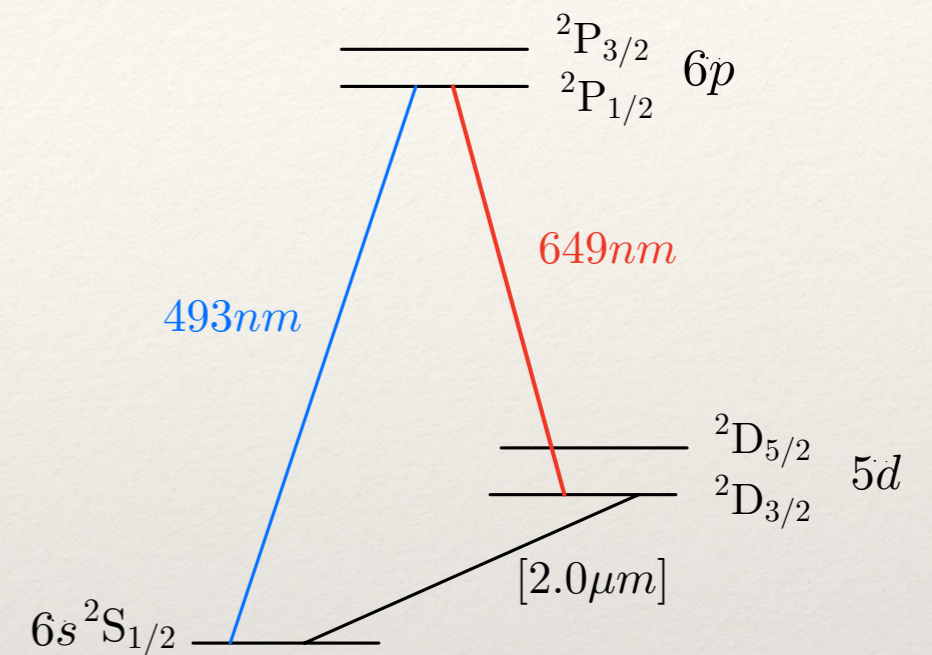
# Experimental technique for lifetime measurements





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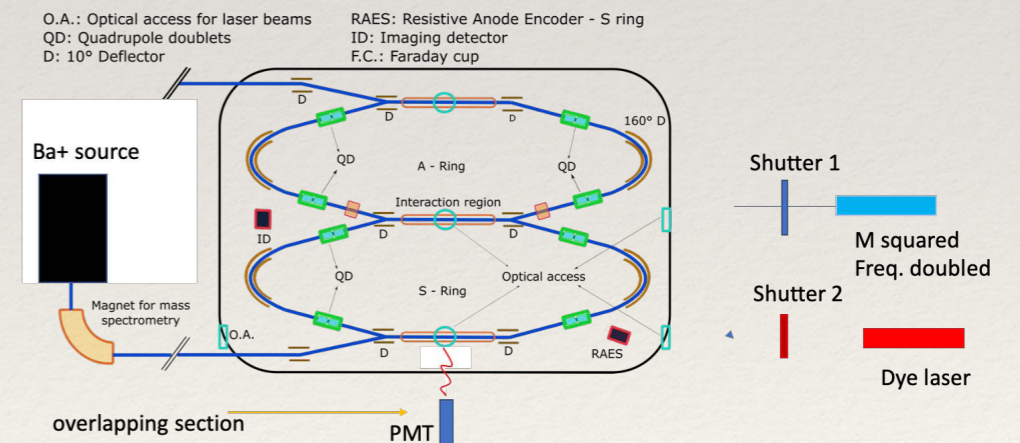
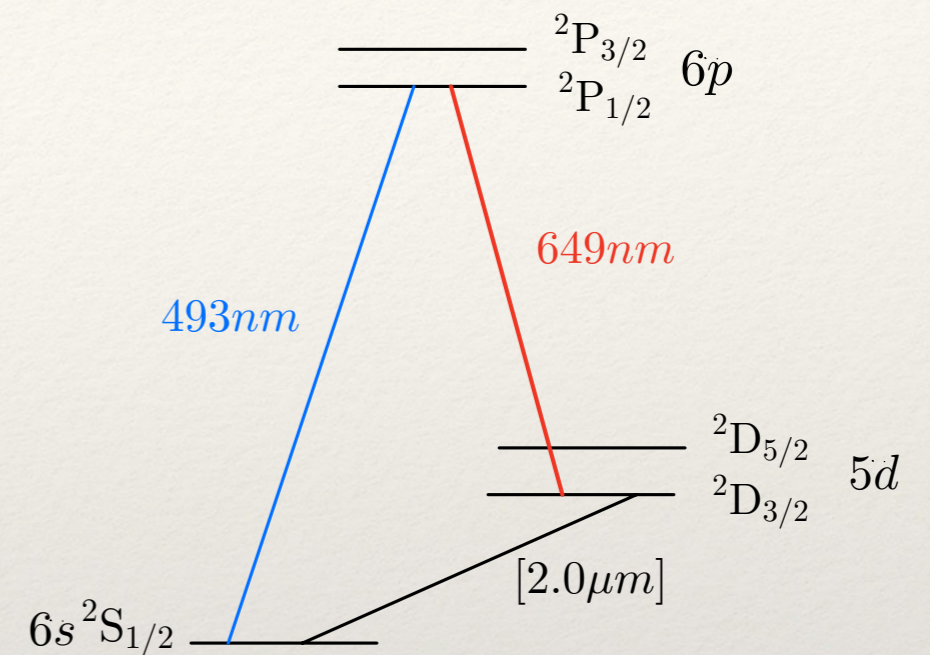
- ❖ A red laser at 649 nm probes the population of the metastable  $5d^2D_{3/2}$  level.





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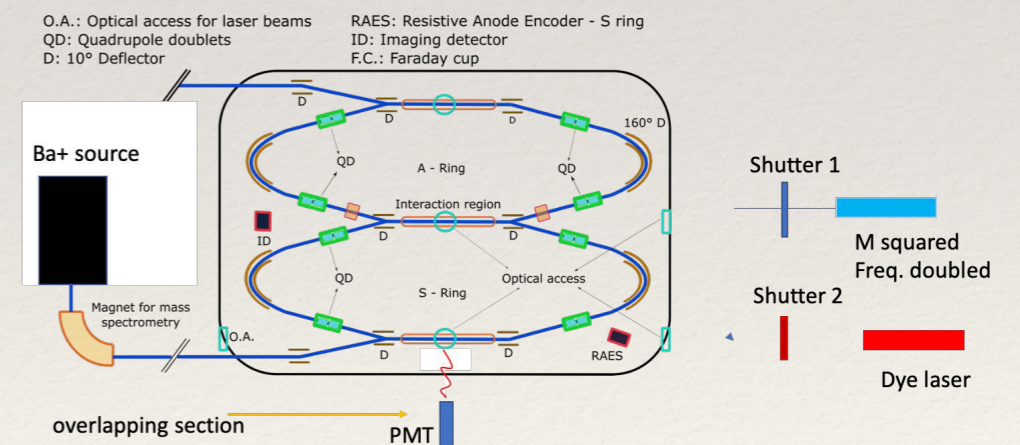
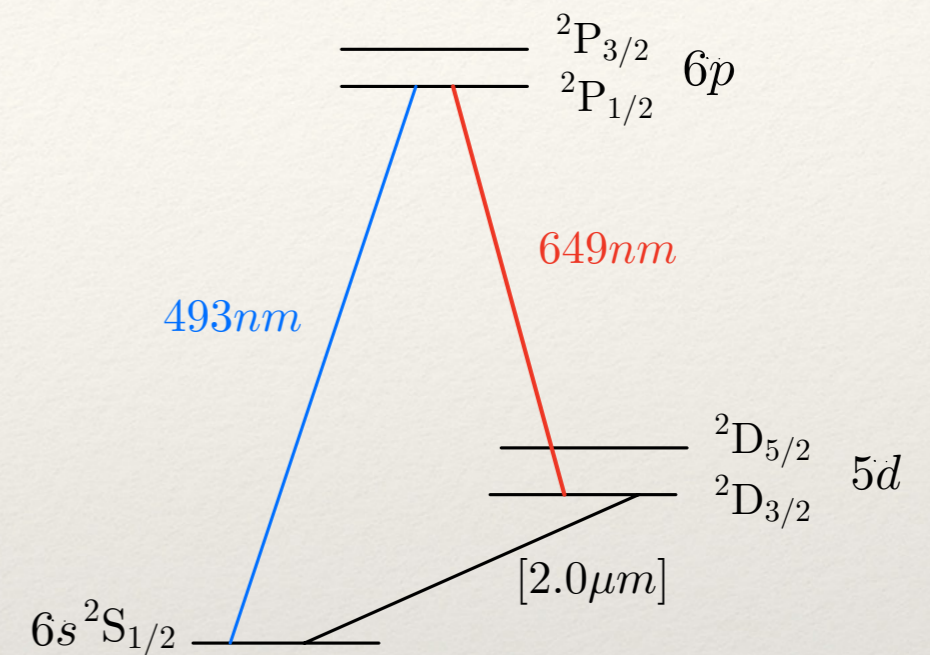
- ❖ A red laser at 649 nm probes the population of the metastable  $5d^2D_{3/2}$  level.
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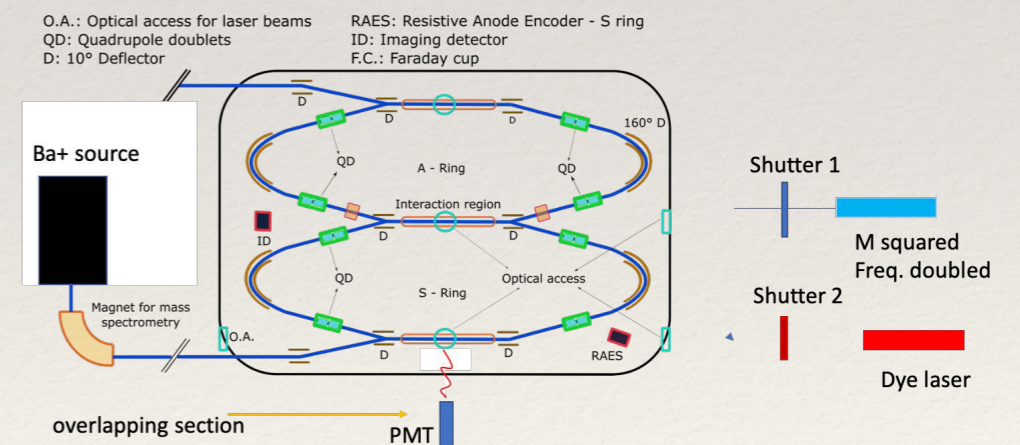
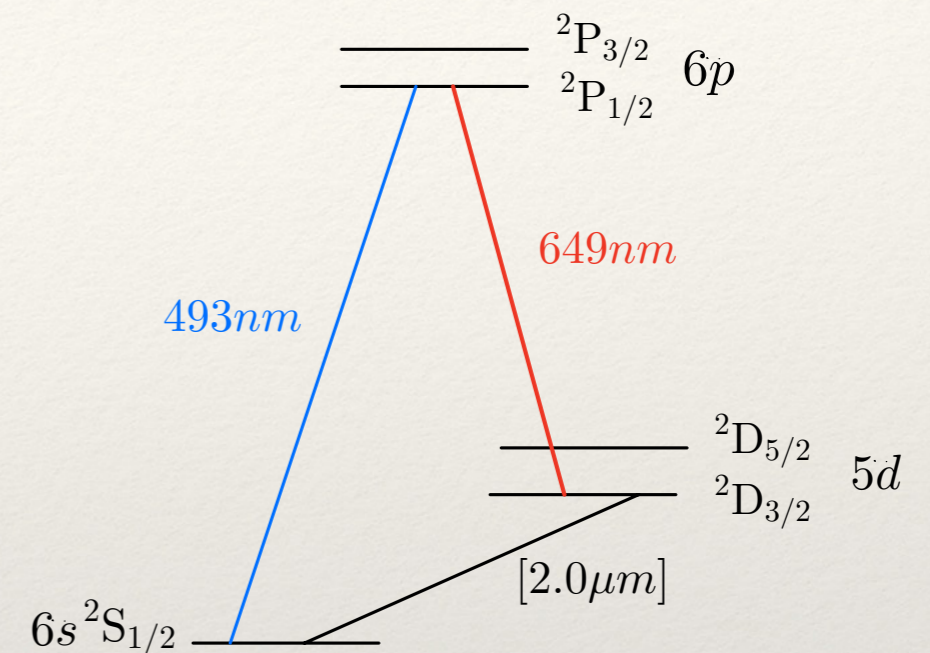
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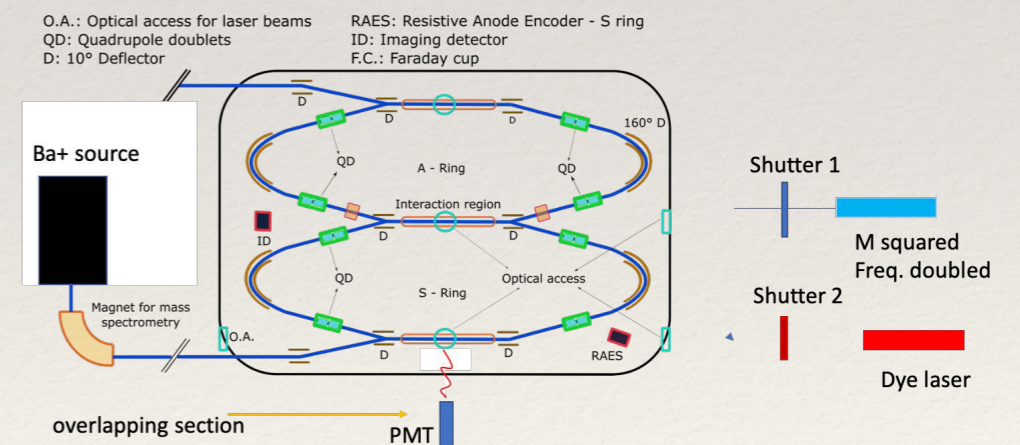
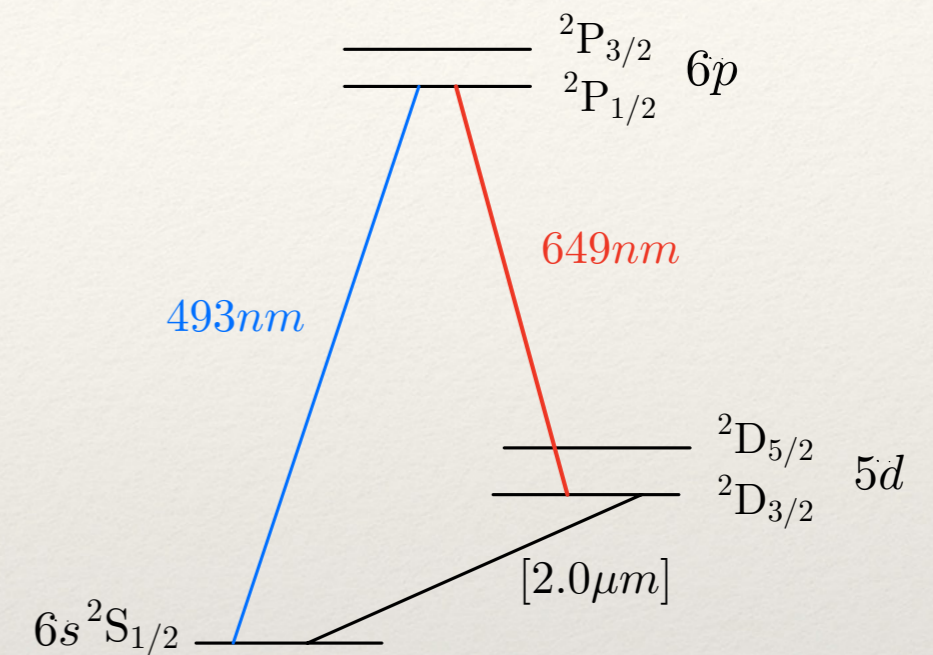
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- ❖ Repeated probing of the metastable population, with different time delays after pumping, build up the lifetime curve





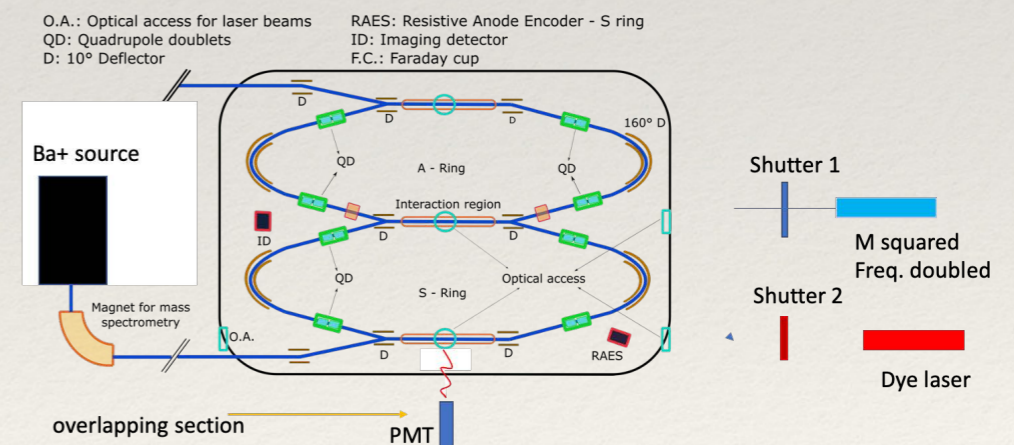
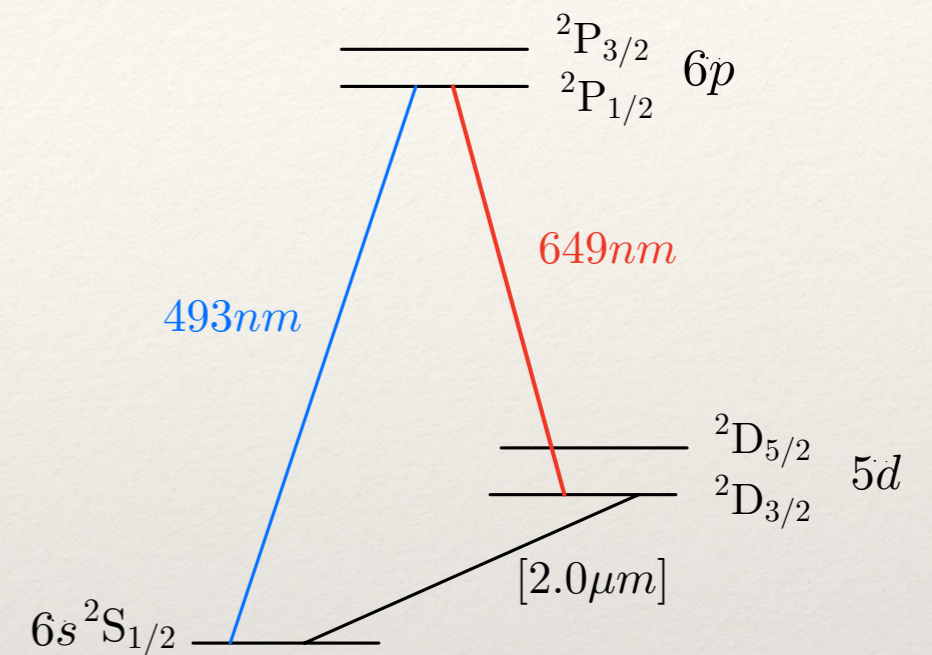
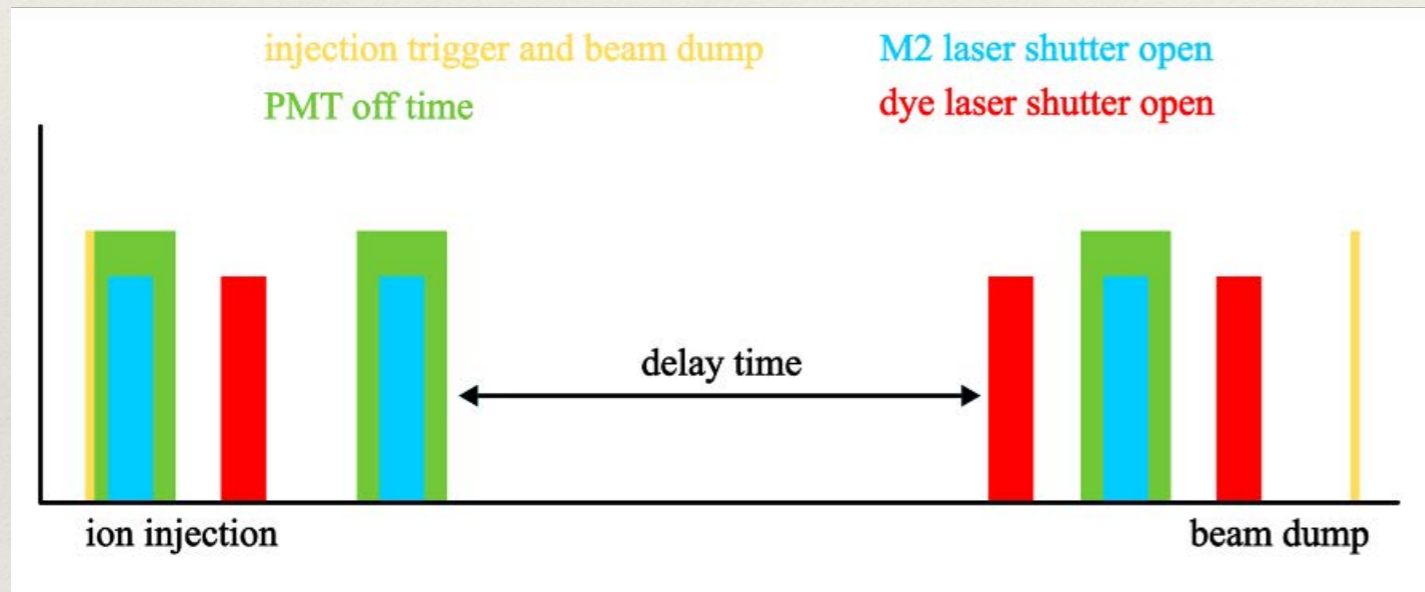
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- ❖ Repeated probing of the metastable population, with different time delays after pumping, build up the lifetime curve
- ❖ Normalization and monitoring of the changes in number of stored ions population is crucial.



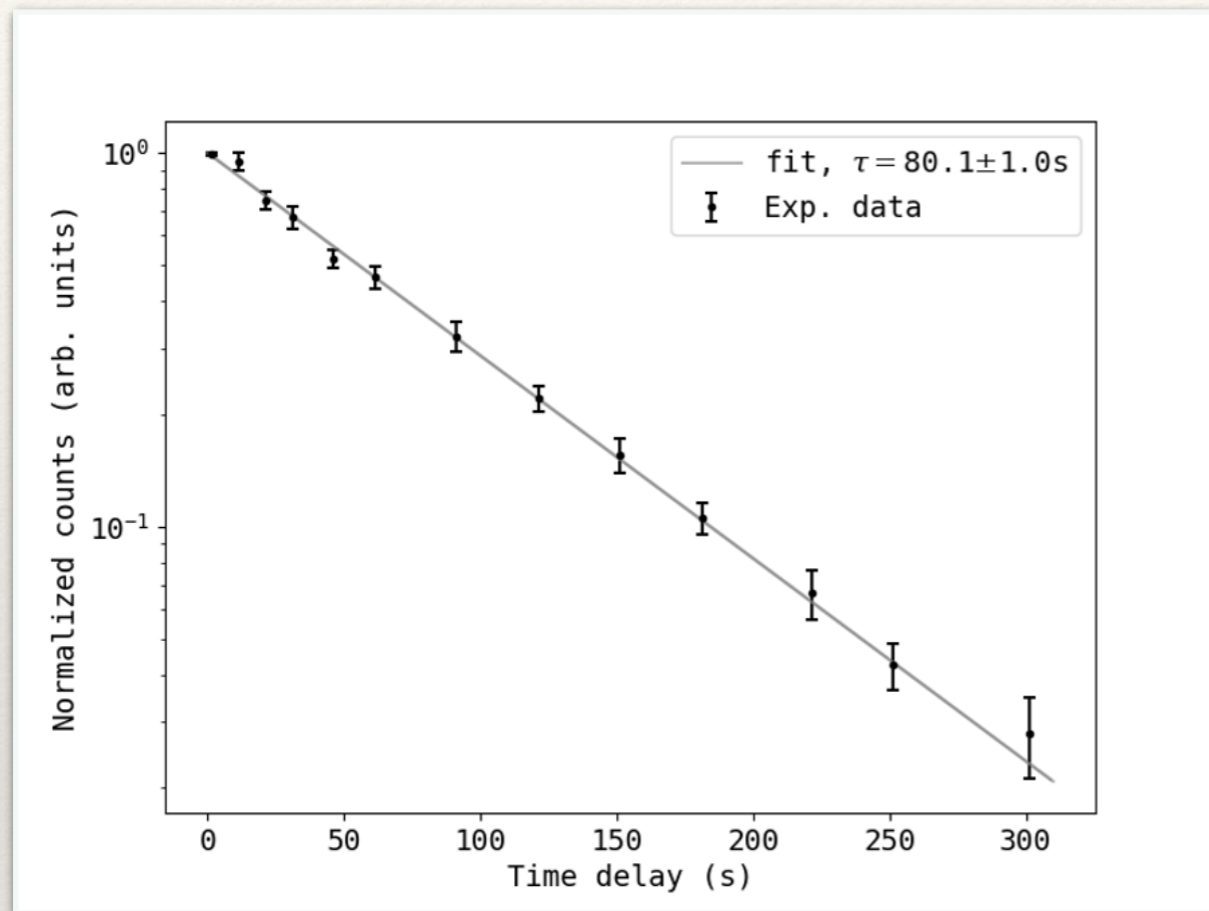


# Experimental technique for lifetime measurements





# Preliminary results for Ba II : $5d^2D_{3/2}$



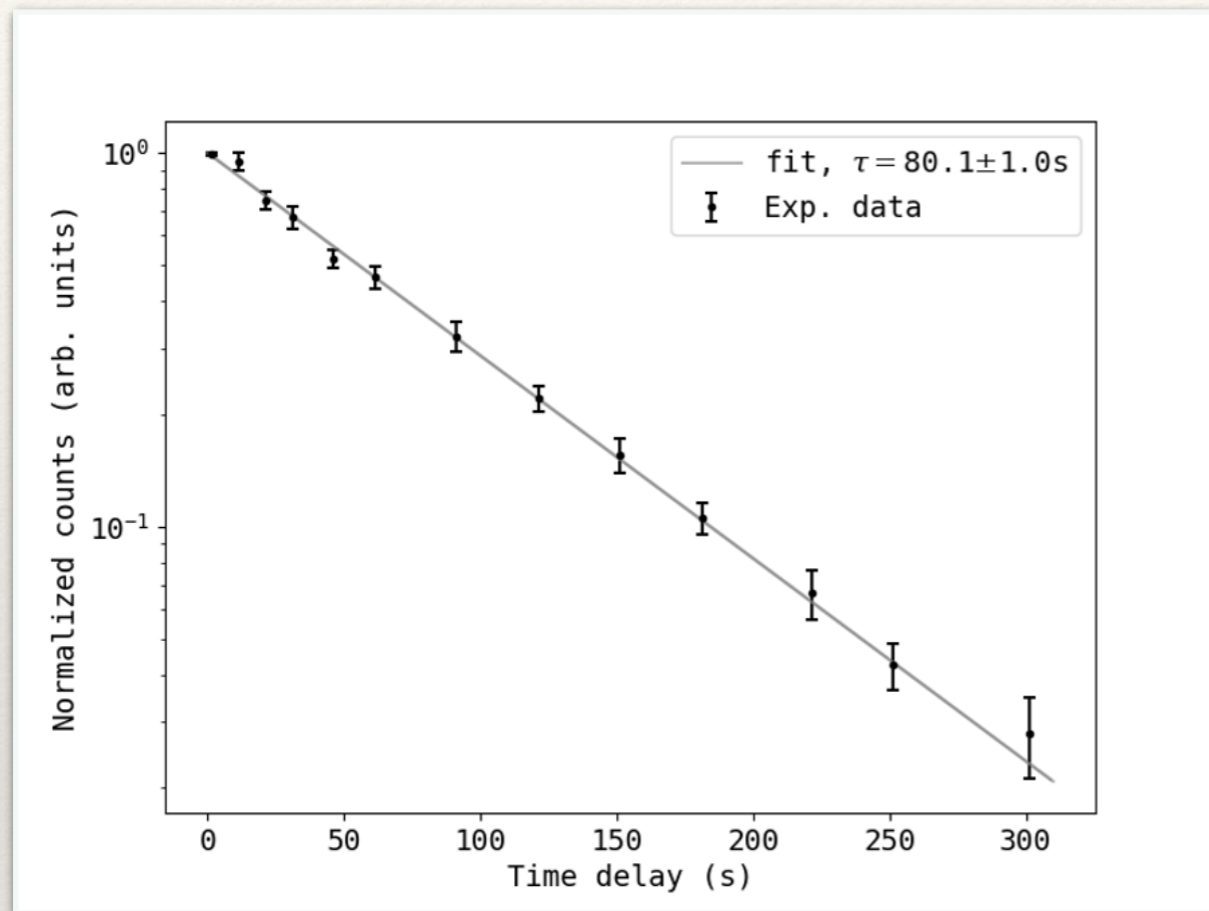
The pump-probe technique has successfully been developed for the Ba<sup>+</sup> ions at DESIREE.

- Ion beam lifetime measured to 500s.
- Effect from repopulation and cascades is very small.
- An uncertainty of a few percent can be reached for ideal systems.
- For  $5d^2D_{3/2}$  we reach a lifetime  $\tau = 80 \pm 1$  s

Technique will be applied to more complex systems such as FeII and Ni II with astrophysical importance .



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Available for application:

<http://www.desiree-infrastructure.com>







# Parity forbidden lines in near-IR

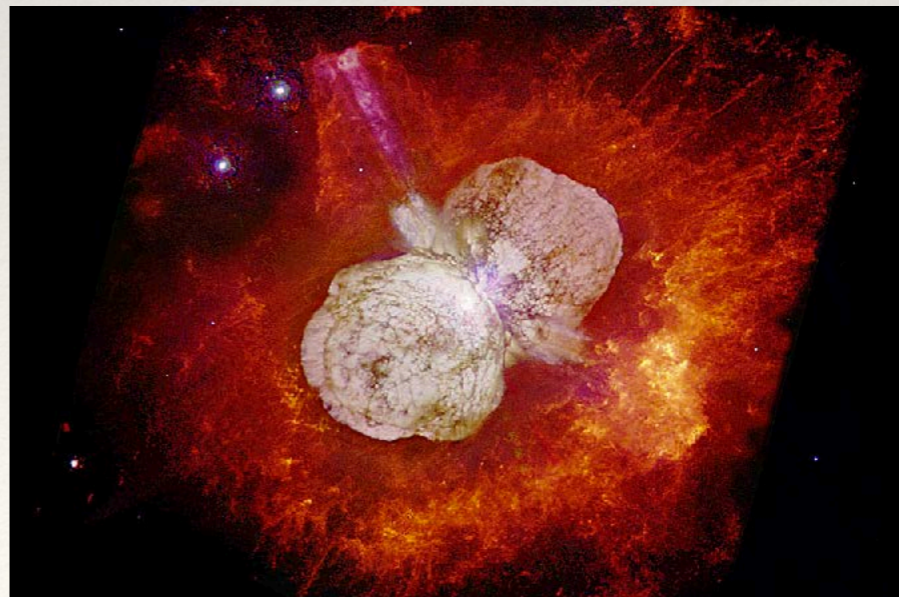
An important class of infrared lines are parity forbidden transitions (E2 and M1), observed in nebula and low density plasmas.

*Low transition rates (  $A$  around  $1\text{ s}^{-1}$ )*

*Long radiative lifetimes (several seconds)*

*Sensitive to collisions*

Have relied on calculated transition rates, but can be measured using selective methods at storage rings (e.g. CRYRING and DESIREE @ Stockholm university, Sweden) combined with astronomical observations of low-density plasmas (Eta Carinae).





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# Previous results

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## ❖ Experiments:

Gurell (2007) : 89.4(156)

Nagourney (1997) : 79.8(46)

## ❖ Theory

L. Filippin et al (2018) : 83.86(15)

U.I. Safranova (2017) : 81.4(14)

E. Iskrenova-Tchoukova (2008) : 81.5(12)

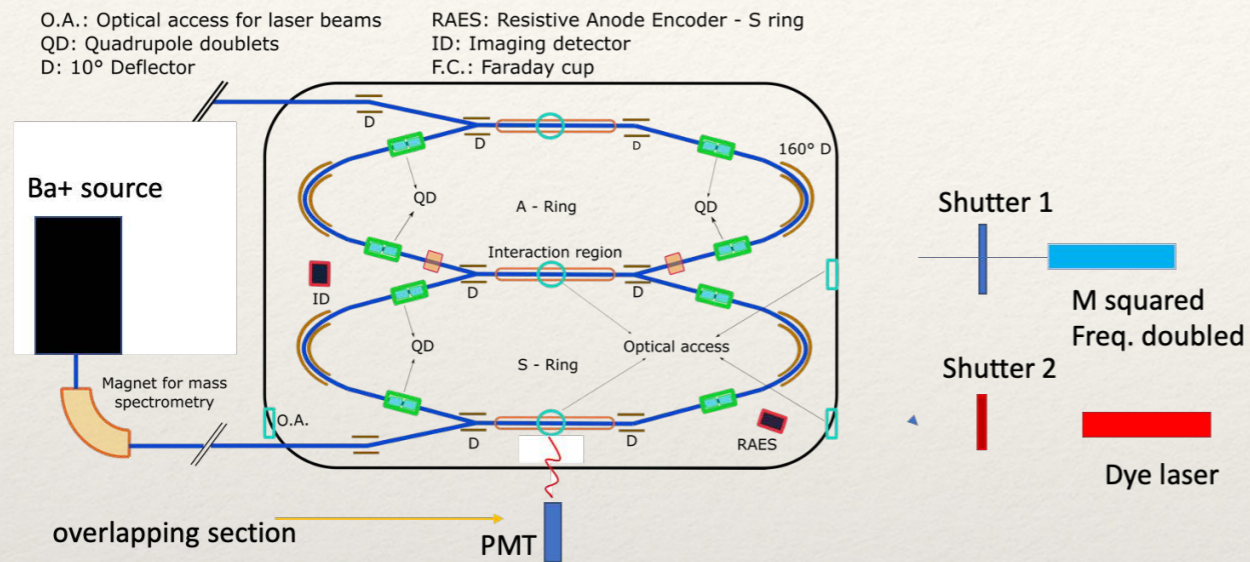
Gurell (2007) : 82.0

B. K. Sahoo (2006) : 80.086(714)

V. A. Dzuba (2001) : 81.5



# Doppler Tuning of the ion beam through acceleration





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