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Simulation of Be light emission at PISCES B: tracking of metastable states in the 3D Monte-Carlo impurity transport code ERO

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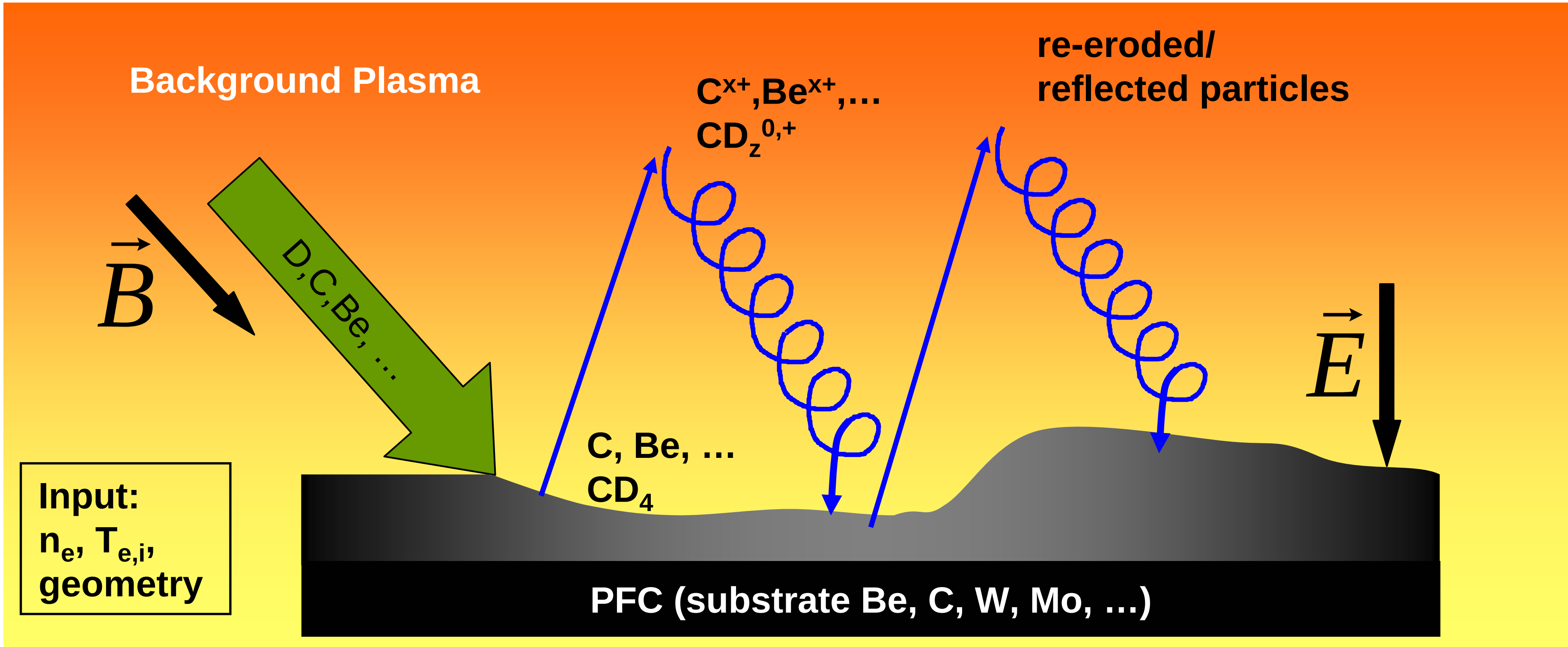
3D MC impurity transport code ERO



Local transport:

- ✓ ionisation, dissociation
- ✓ friction (Fokker-Planck), thermal force
- ✓ Lorenz force (including ExB component)
- ✓ cross-field diffusion

Plasma-surface interaction:

- ✓ physical sputtering/reflection
- ✓ chemical erosion (CD_4)
- ✓ (re-)erosion and (re-)deposition
- ✓ HMM and TRIDYN surface models

ERO modelling strategy

Code development:

- *PSI & transport*
- *material mixing*
- *castellated surfaces*
- *atomic data, ADAS*

Benchmarking:

- *PISCES-B (with beryllium)*
- *TEXTOR*
- *JET,*
- *AUG,*
- *…*

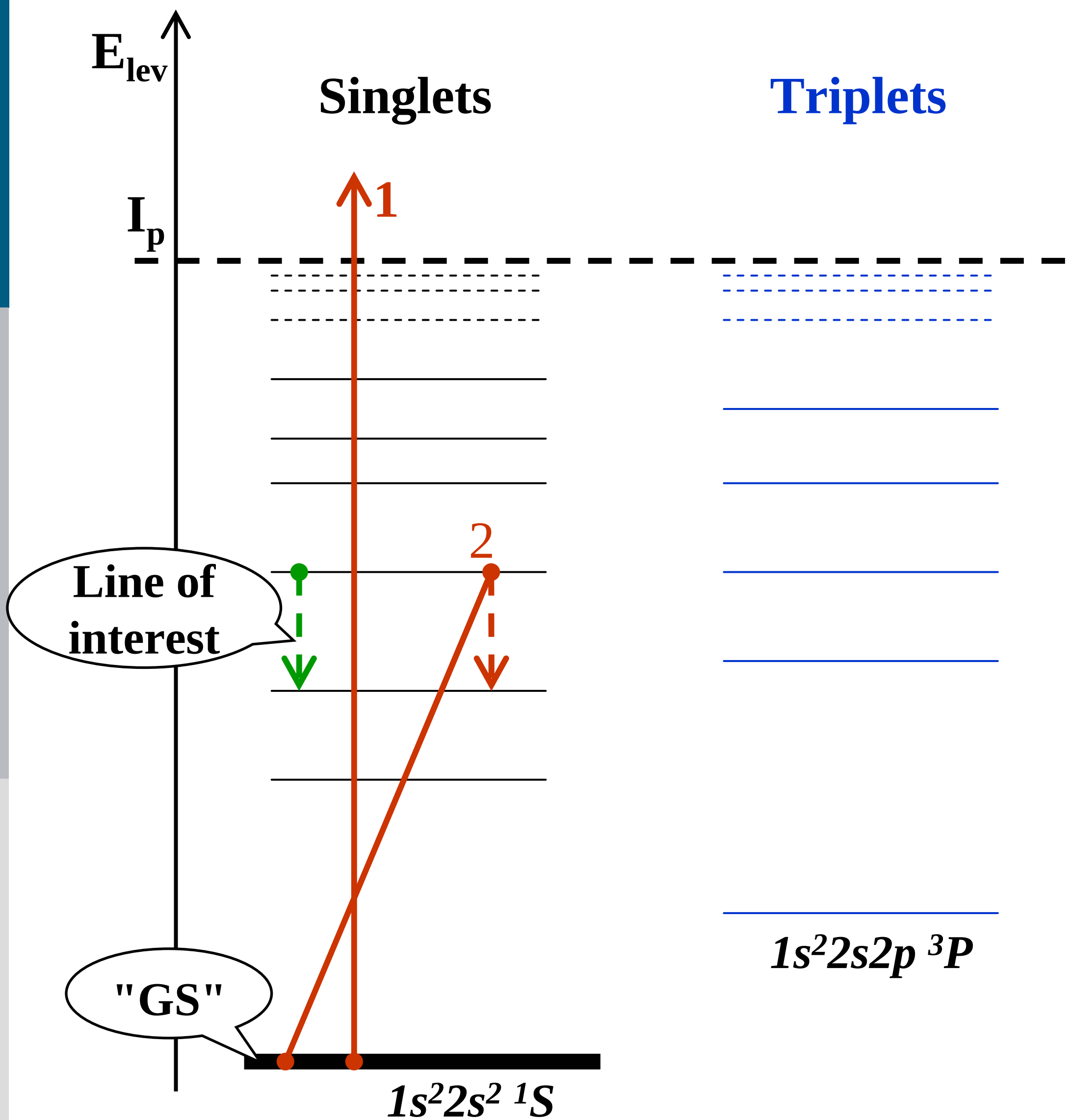
Estimations for ITER:

- *tritium retention*
- *target & limiter lifetime*
- *impurities into plasma*

Coupling with other codes:

- *plasma parameters from: e.g. B2-Eirene, Edge-2D*
- *surface mixing: TriDyn, MolDyn*

BeI – '2 level' approximation scheme



Effective rates:

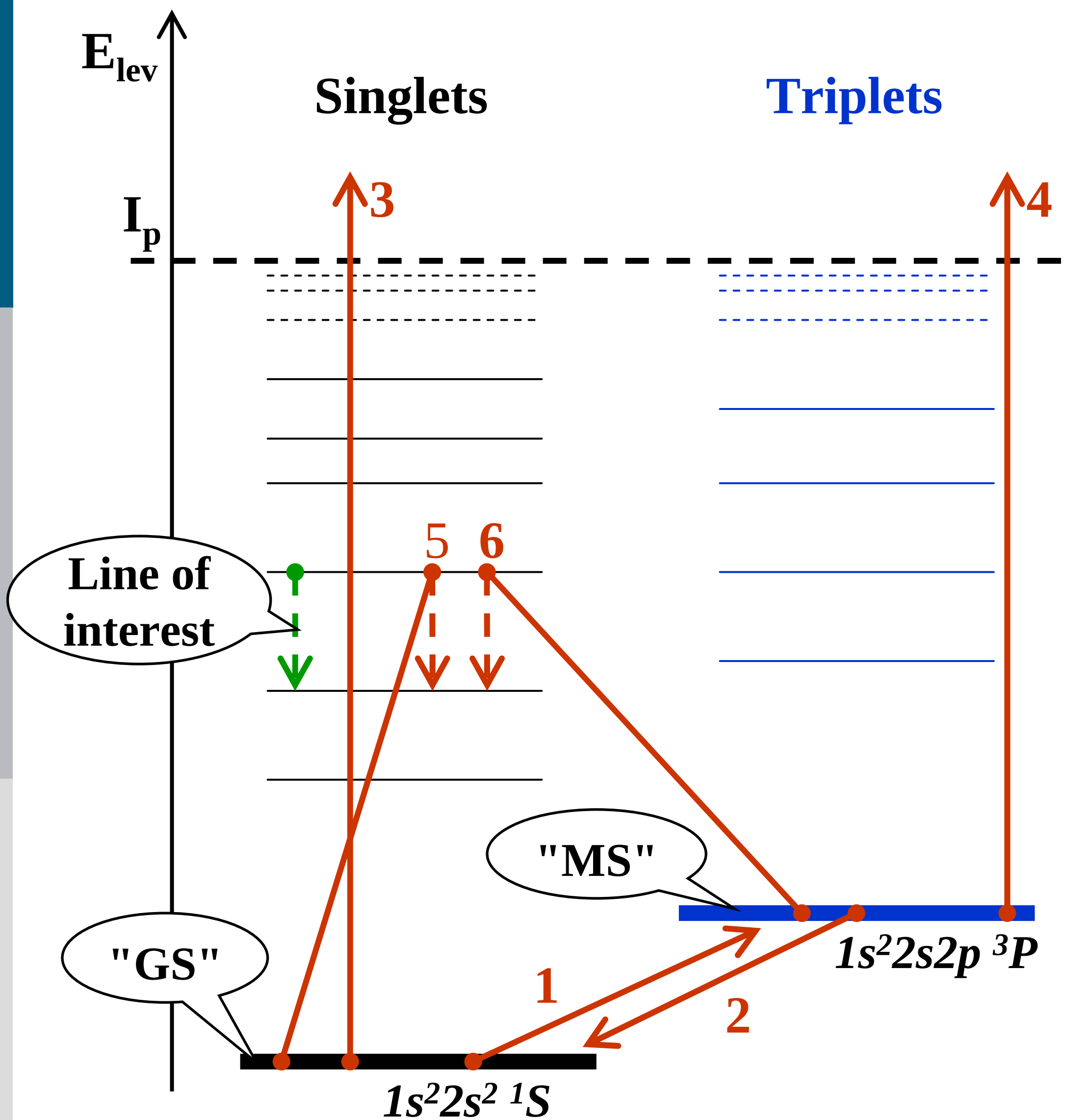
1) <IzG> - ionization from "GS"

2) <IG> - line intensity, assuming full population of "GS"

One effective PEC (photon efficiency coefficient) for each line + effective ionization

Effective rates represent all possible transitions including cascades, however not the 'slow' evolution of level populations.

BeI – 1 MS approximation scheme



Effective rates:

1) <ExGM> - excitation from "GS" to "MS"

2) <ExMG> - deexcitation from "MS" to "GS"

3) <IzG> - ionization from "GS"

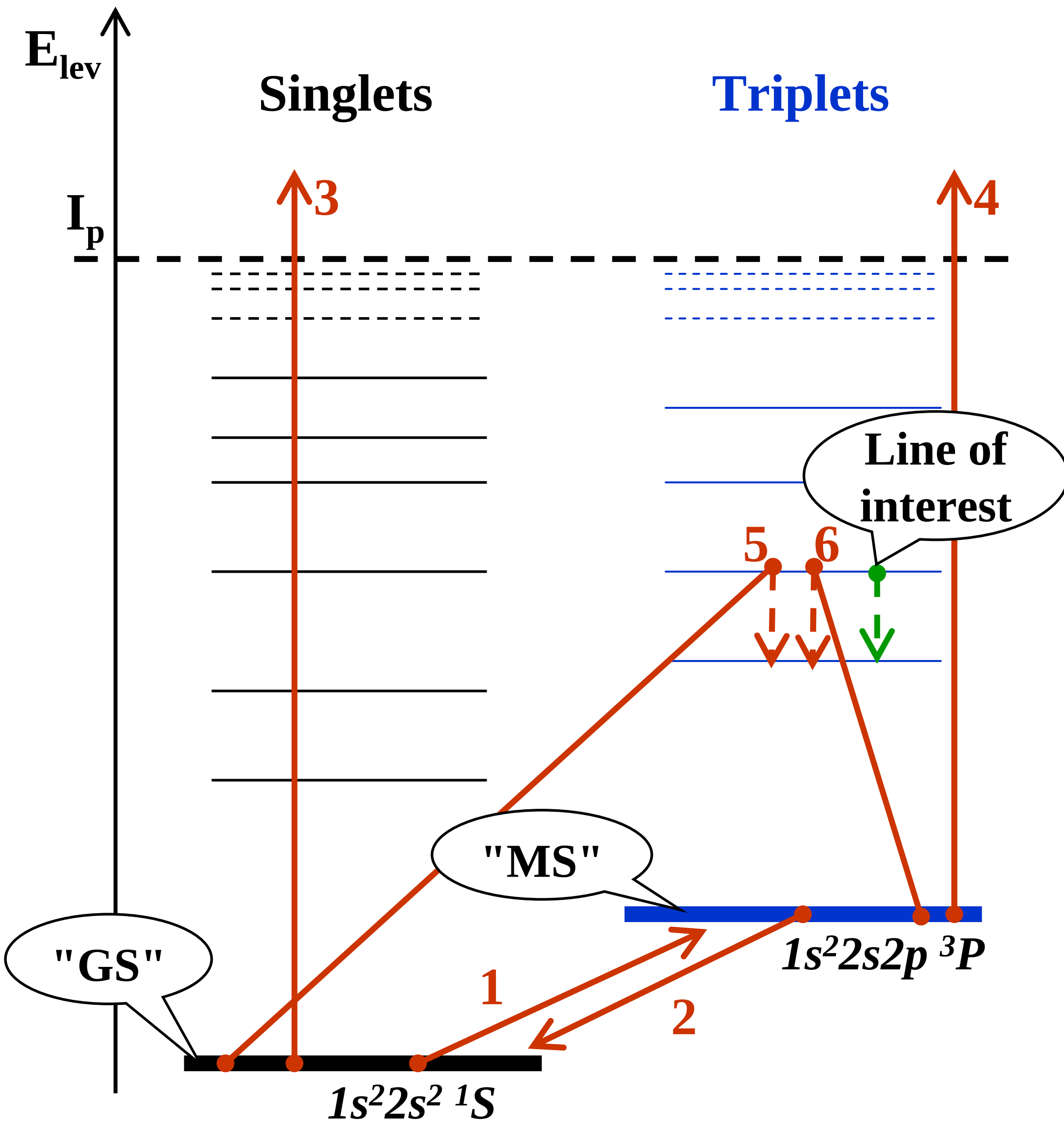
4) <IzM> - ionization from "MS"

5) <IG> - line intensity, contribution from "GS"

6) <IM> - line intensity, contribution from "MS"

5, 6 are individual for every line of interest!

BeI – 1 MS approximation scheme



Effective rates:

1) <ExGM> - excitation from "GS" to "MS"

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3) <IzG> - ionization from "GS"

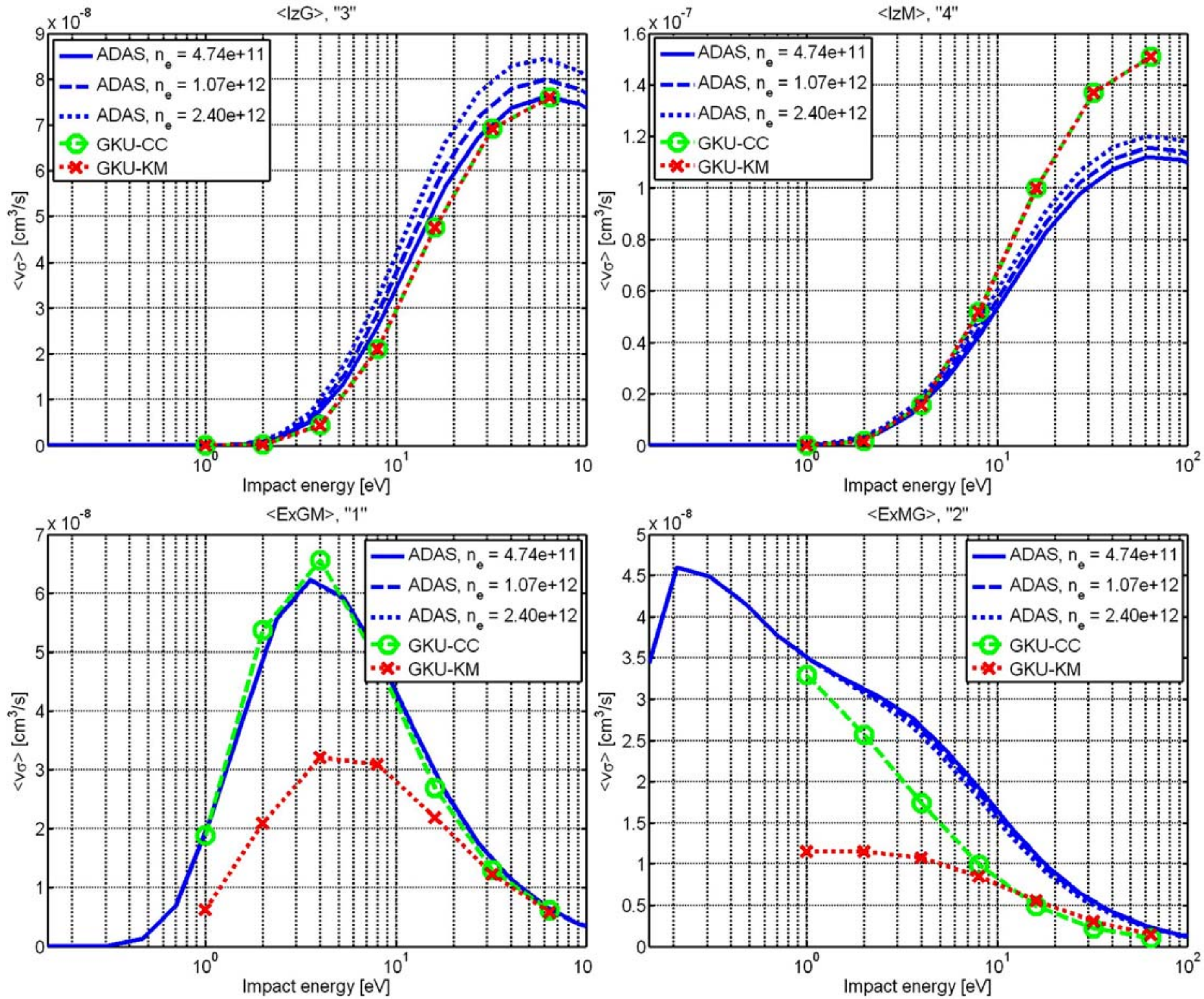
4) <IzM> - ionization from "MS"

5) <IG> - line intensity, contribution from "GS"

6) <IM> - line intensity, contribution from "MS"

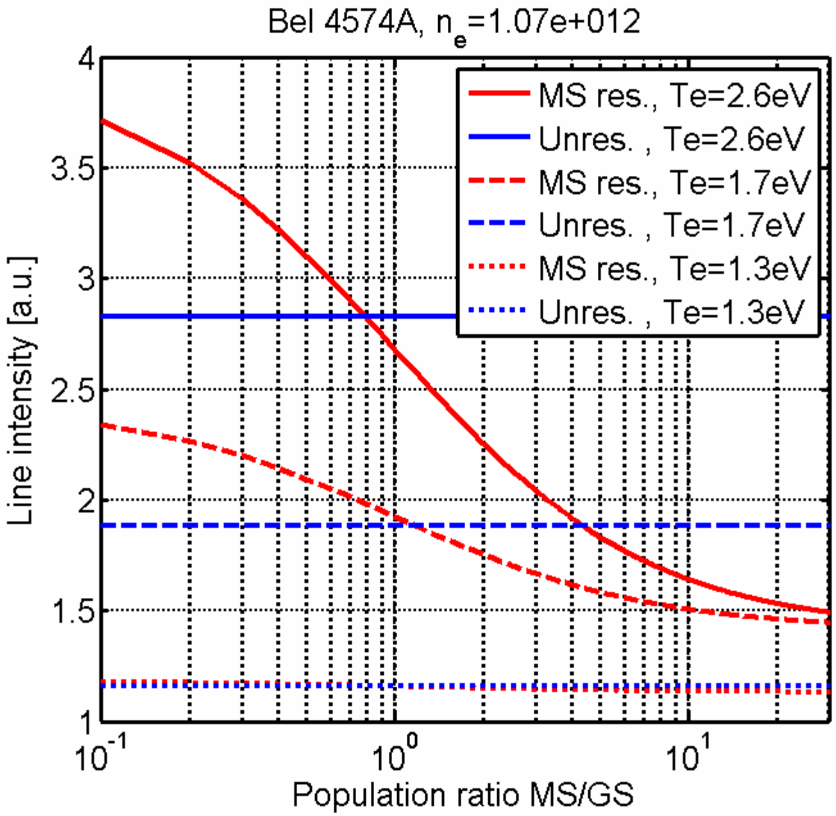
5, 6 are individual for every line of interest!

Effective rates from ADAS and GKU

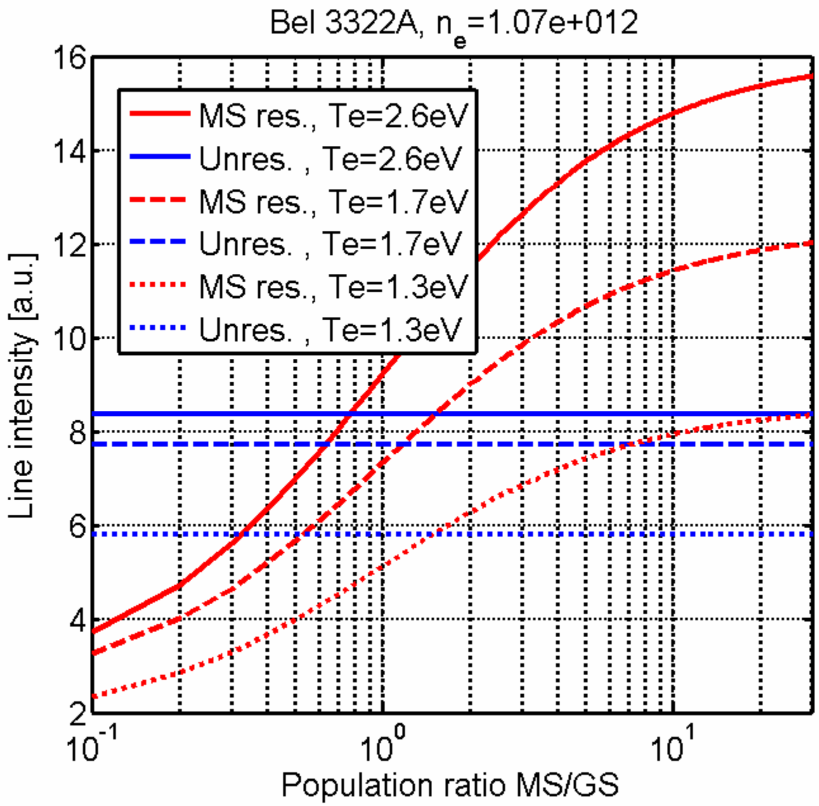


Line intensities – MS population

Singlet

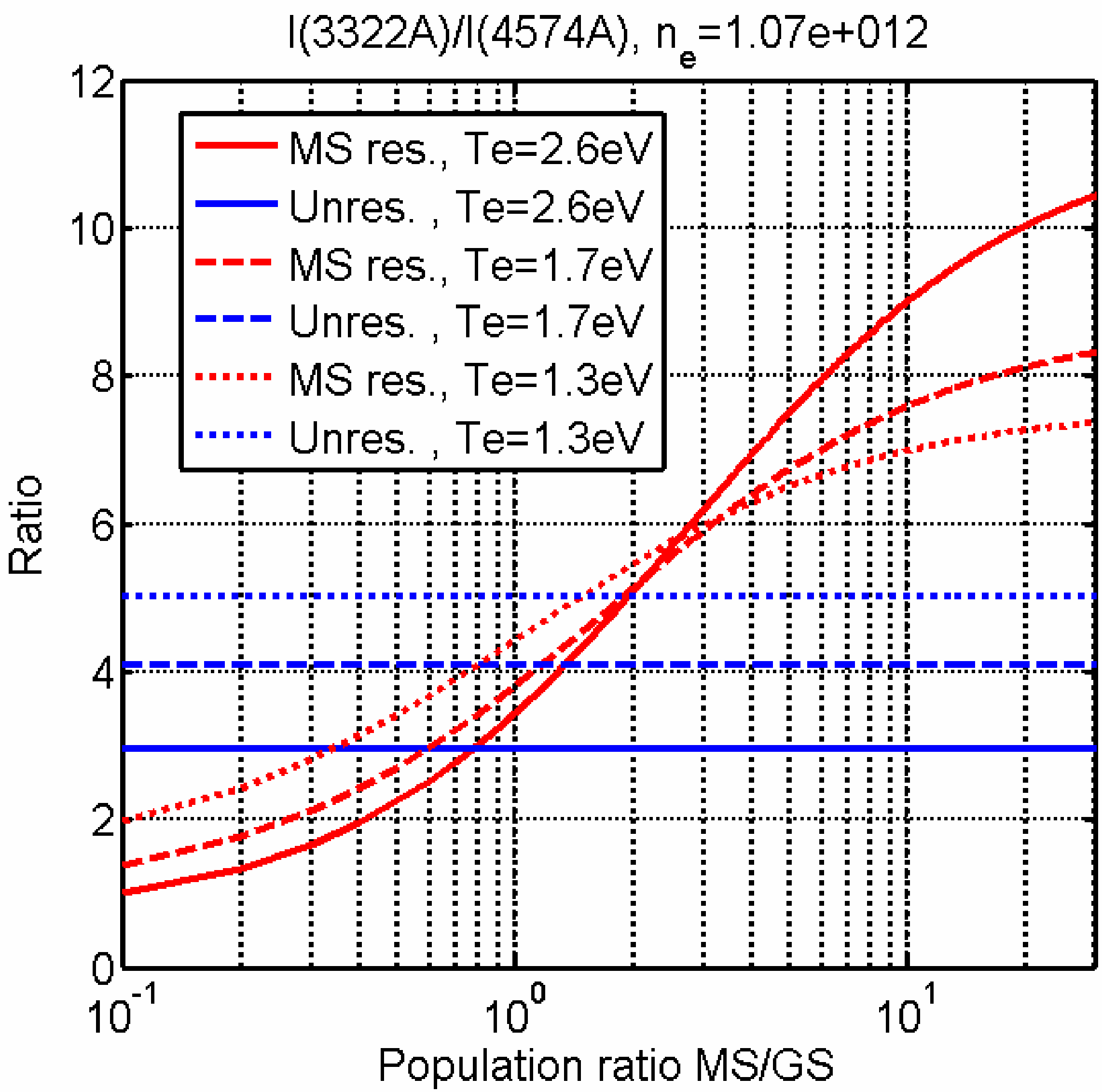


Triplet



$$I \sim N_{GS} \cdot \underbrace{\langle v\sigma \rangle_{GS} (n_e, T_e)}_{\text{Large for singlets}} \cdot n_e + N_{MS} \cdot \underbrace{\langle v\sigma \rangle_{MS} (n_e, T_e)}_{\text{Large for triplets}} \cdot n_e$$

Triplet to singlet ratio – MS population



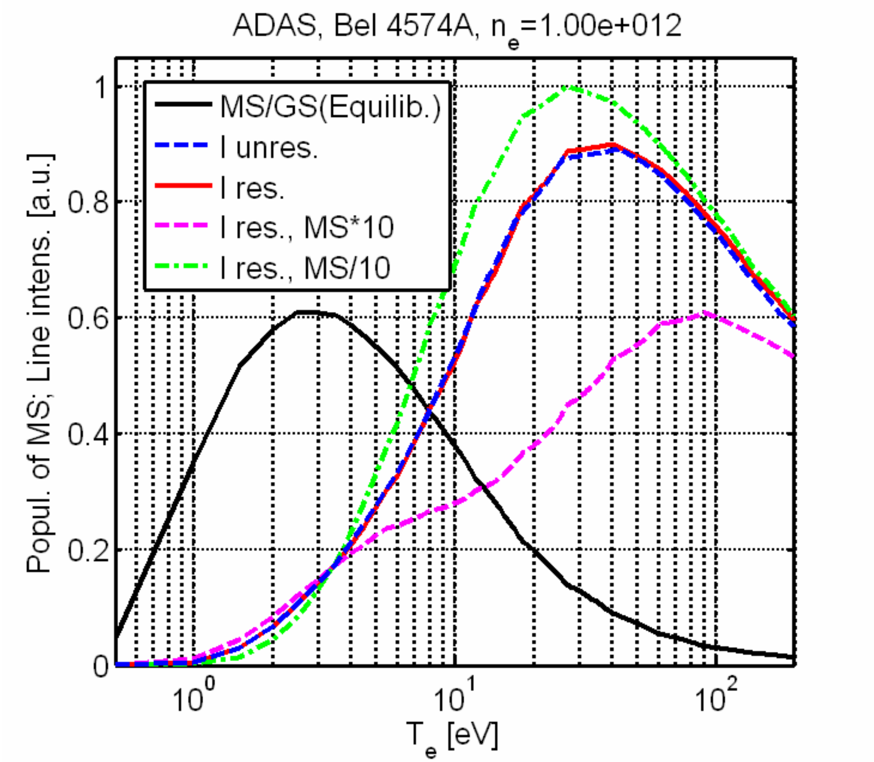
Uncertainty within a factor of about 9 (statistical weight ratio of MS/GS)

MS population can be influenced by

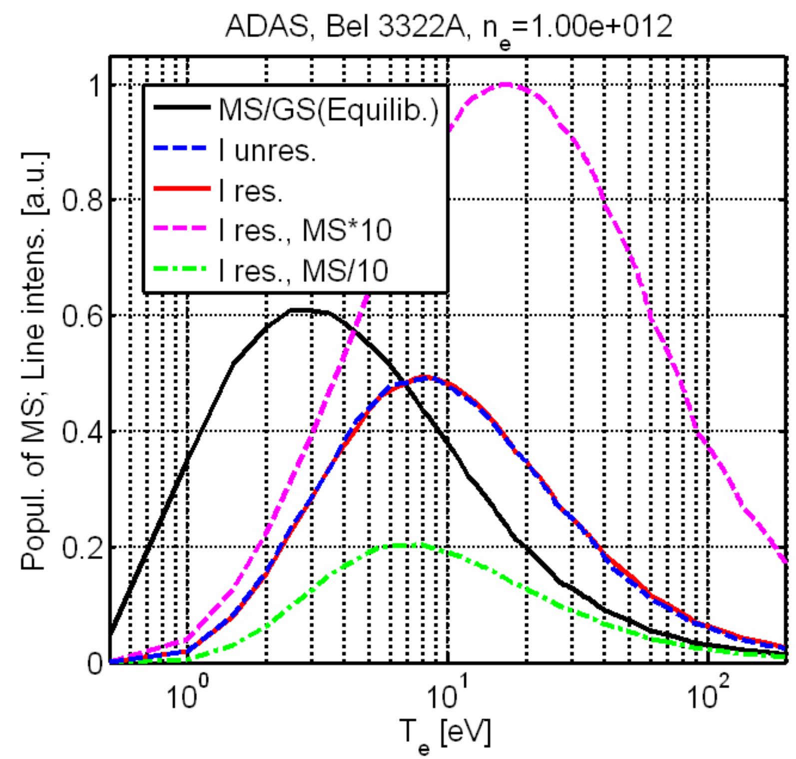
- ***Physical sputtering***
- ***Be-D molecules formation/decay***

Line intensities – stationary approach

Singlet



Triplet



$$\begin{cases} \underbrace{0 \equiv}_{\substack{stationary\\approach}} \dfrac{dN_{GS}}{dt} = -\langle ExGM \rangle N_{GS} - \langle IzG \rangle N_{GS} + \langle ExMG \rangle N_{MS} \\ dN_{GS} + N_{MS} = 1 \end{cases} \Rightarrow \frac{N_{MS}}{N_{GS}} = \frac{\langle ExMG \rangle}{\langle ExGM \rangle + \langle IzG \rangle}$$

Line intensities – dynamic approach

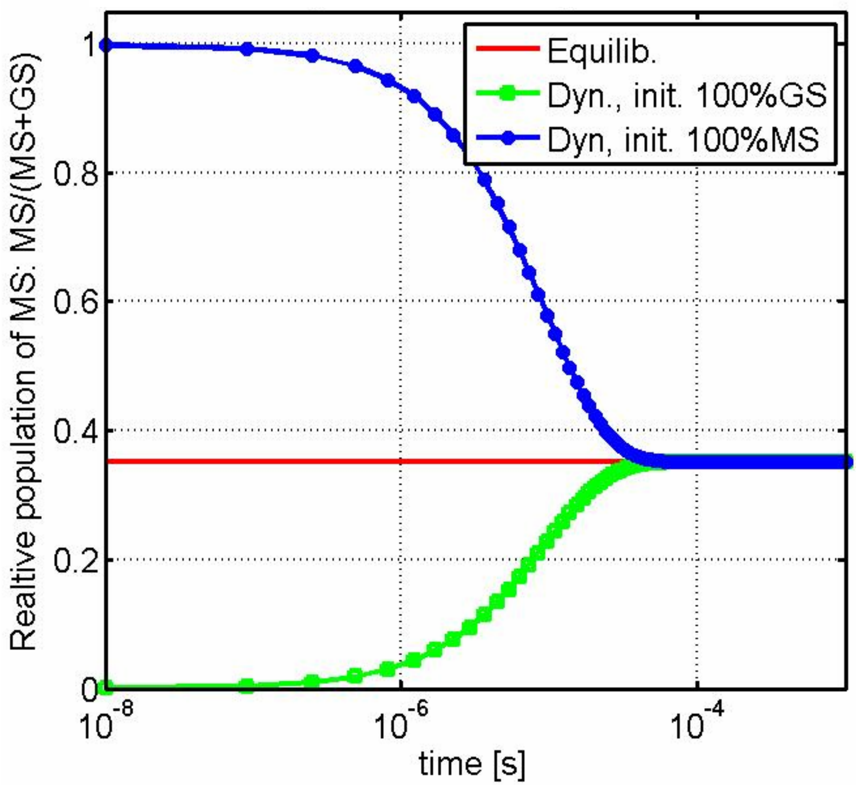
$$\begin{cases} \dfrac{dN_{GS}}{dt} = -\langle ExGM \rangle N_{GS} - \langle IzG \rangle N_{GS} + \langle ExMG \rangle N_{MS} \\ \dfrac{dN_{MS}}{dt} = -\langle ExMG \rangle N_{MS} - \langle IzM \rangle N_{MS} + \langle ExGM \rangle N_{GS} \end{cases}$$

Analytical solution

$(C_{1i}, C_{2i}, \lambda_p, \lambda_m$ determined by rates$)$:

$$dN_i(t) = C_{1i}\exp(-\lambda_p t) + C_{2i}\exp(-\lambda_m t)$$

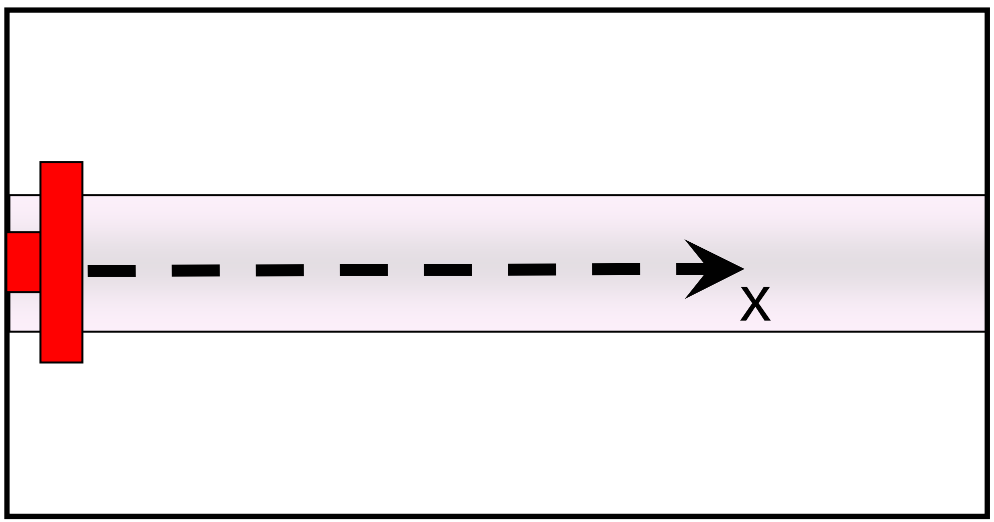
ADAS; T_e=1eV, $n_e=2*10^{12}cm^{-3}$



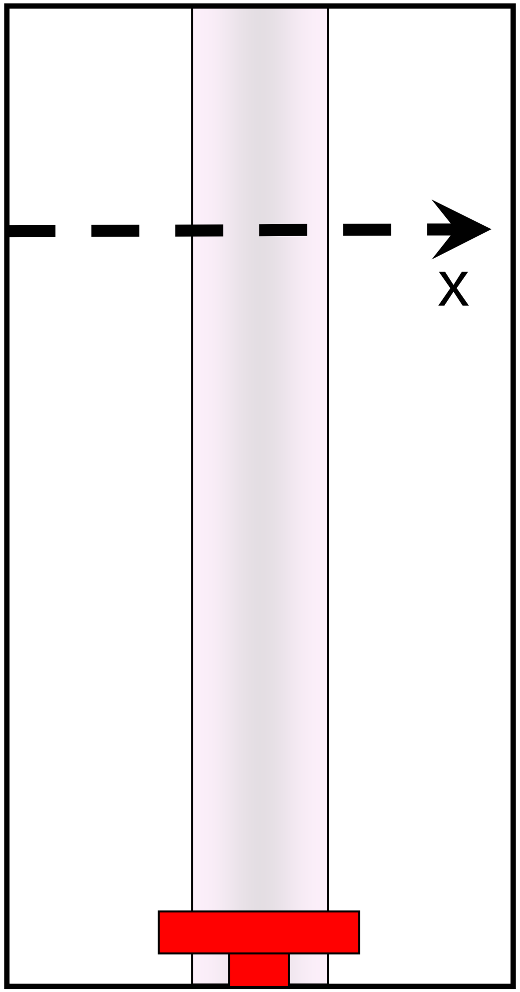
Relaxation time between MS and GS is 10^{-5}-10^{-4}s

Profiles direction - illustration

Be sputtering from target



Be injection cross plasma

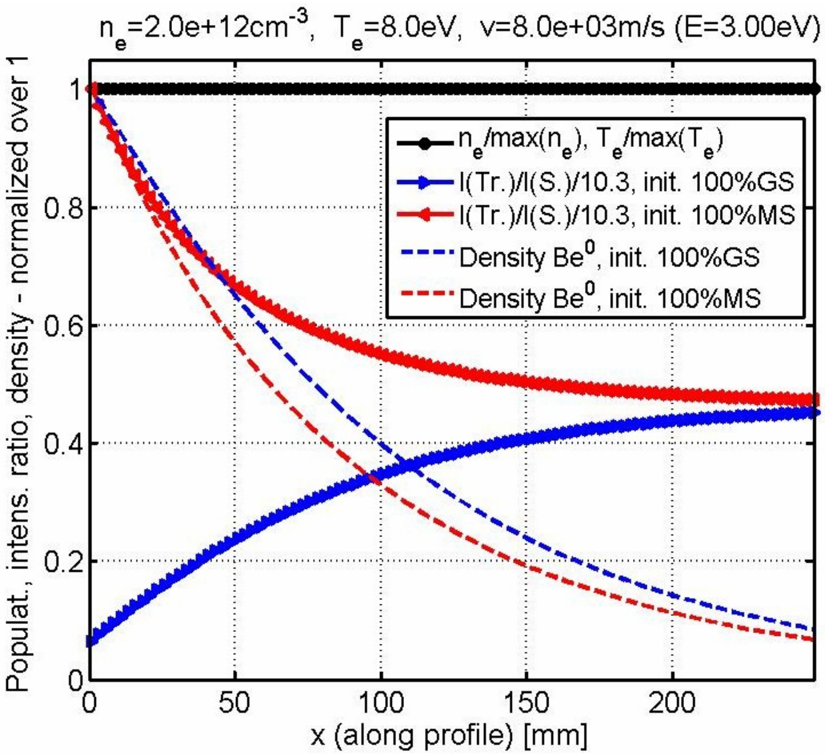


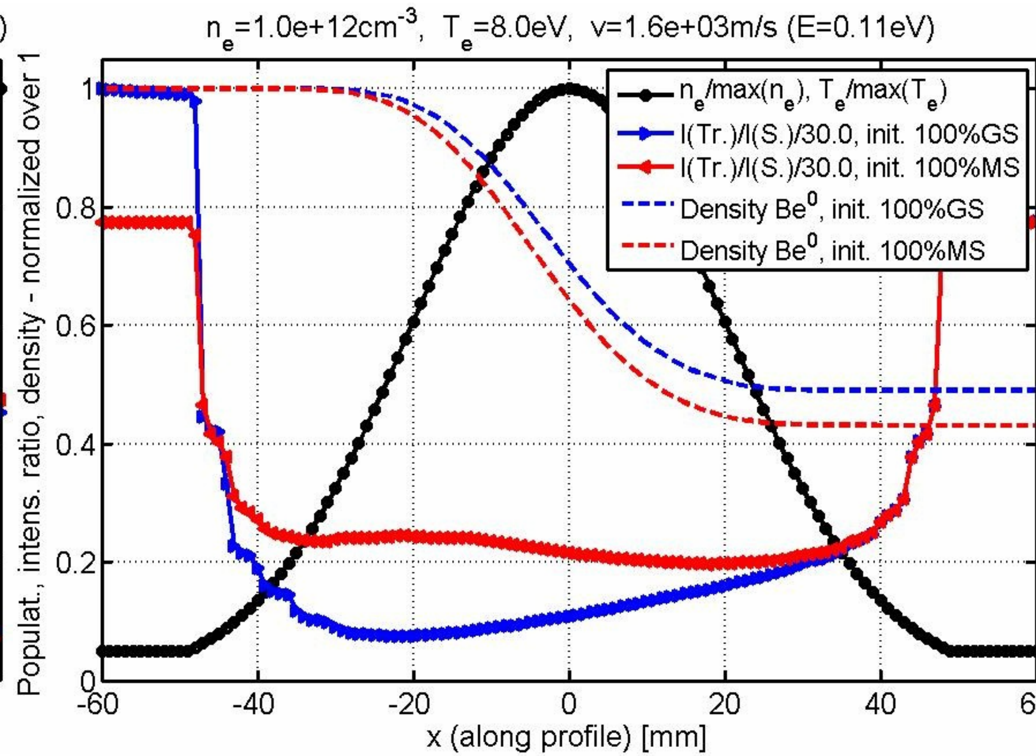
MS implementation into ERO – effect illustration

A narrow monoenergetic beam of Be^0, comming through plasma.

Relevant for sputtering from Be target . . .

Relevant for seading from Be oven . . .





Initial MS population and plasma parameters gradient strongly affect:
1) Triplet/singlet line intensity ratio (4573A and 3322A)
2) Be^0 density (MS population affects ionization)

Summary & Outlook

- Recently the tracking of **metastable state** in BeI was **provided** for the 3D MC **ERO** impurity transport code.

- This **effect** was shown to be **of importance** for simulation of Be **light emission** and **transport** e.g. in **PISCES-B** linear divertor simulator.

- The improved model should be further **tested** by comparison with **dedicated** spectroscopic **experiments** at PISCES-B.

- Influence of **physical sputtering** on initial **MS population** should be studied.

- In future **MS-tracking** should be **included** in simulations of Be experiments at JET, JULE-PSI and for **ITER predictions**.

- **MS tracking** for **other species**, for which it is of importance, should be provided.

End