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Usage of ADAS data in the Monte Carlo codes for particle transport simulations in plasma *(on example of ERO code)*

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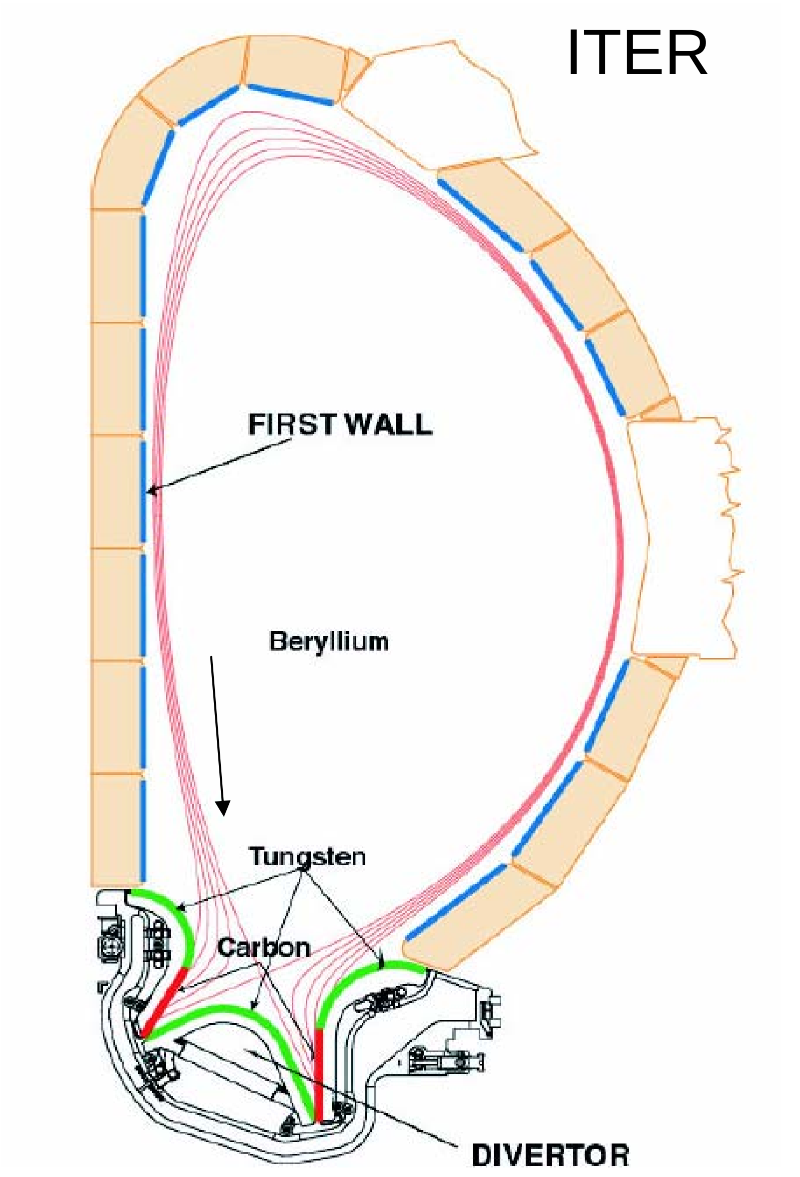
Special thanks for contributions from A.Kirschner, D.Reiter, R.Ding and D.Matveev

Motivation:

plasma-surface interaction (**PSI**) in fusion devices

ITER – first wall materials



700 m^2 beryllium first wall

- **low Z**
- **oxygen getter**

100 m^2 tungsten baffles, dome

- **high Z**
- **low sputtering**

50 m^2 graphite CFC target plates

- **no melting**

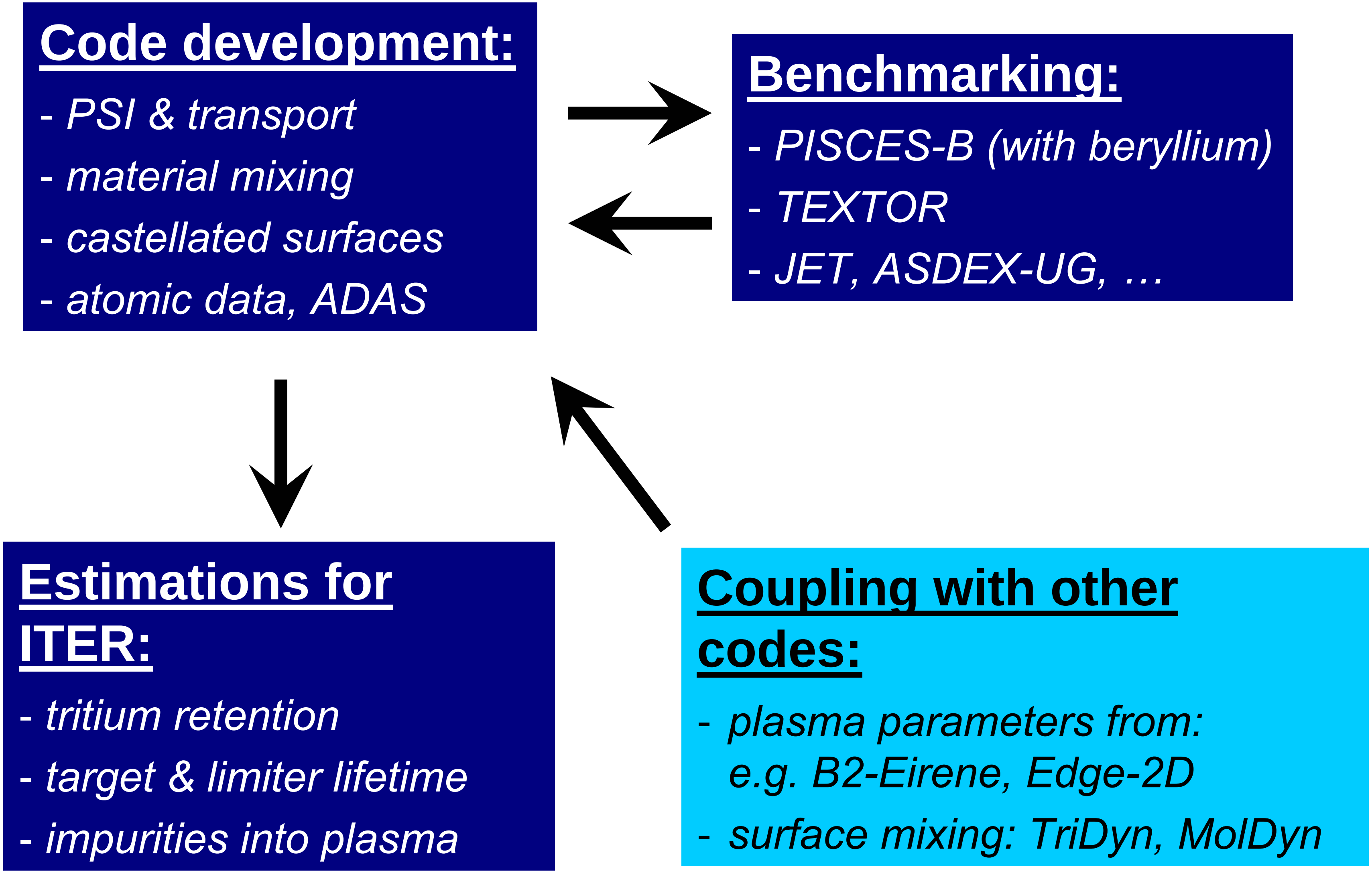
Erosion of wall materials, transport and re-deposition →

- Lifetime & tritium retention

- Material mixing effects

Plasma-surface interaction in divertor can determine the ***ITER availability*** *. . .*

ERO modelling strategy



Code development:

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

Benchmarking:

- PISCES-B (with beryllium)
- TEXTOR
- JET, ASDEX-UG, …

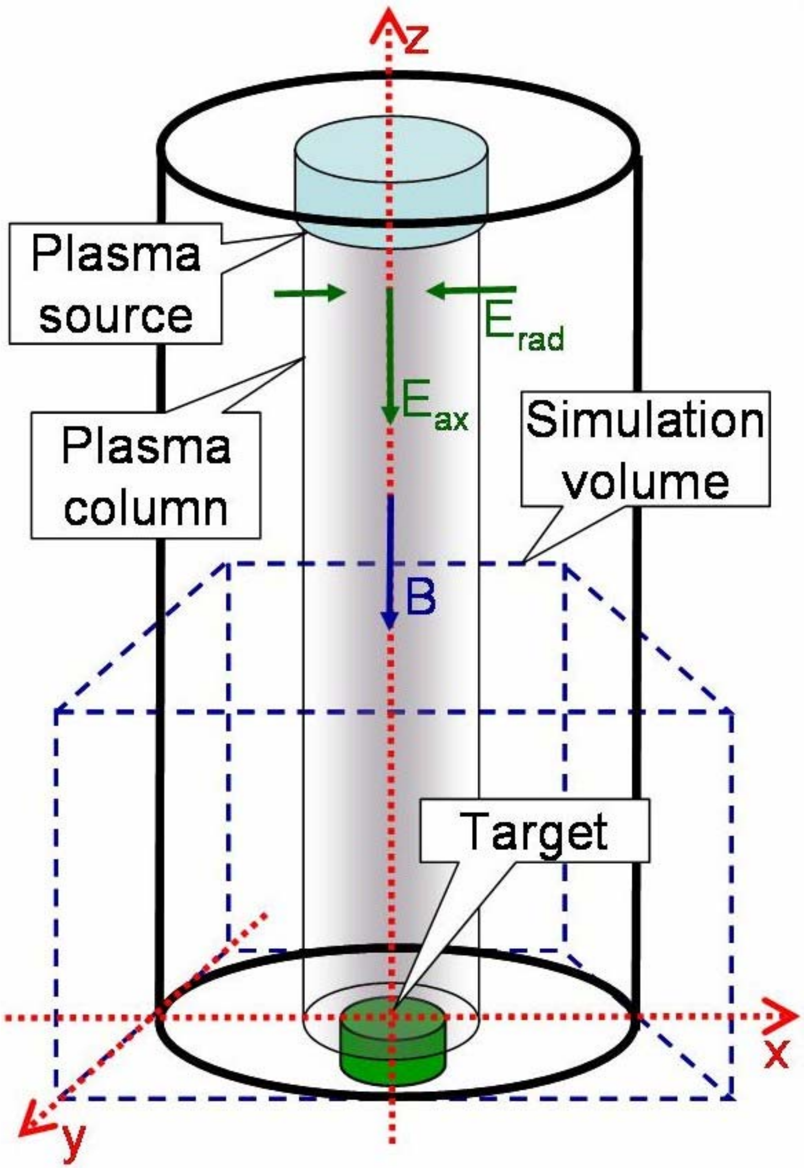
Estimations for ITER:

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

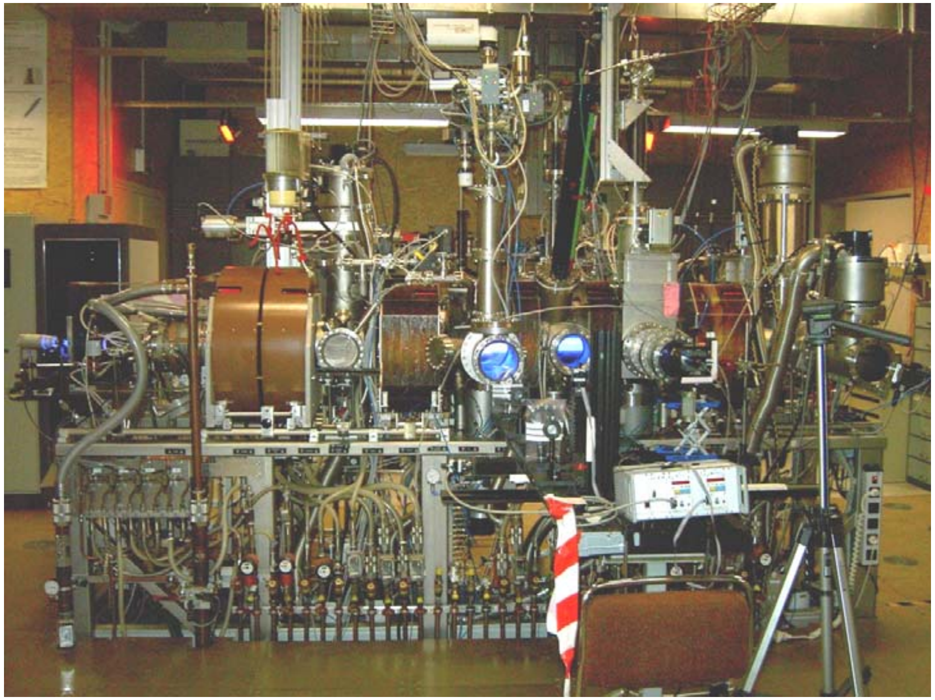
Coupling with other codes:

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

Linear devices – benchmarking experiments

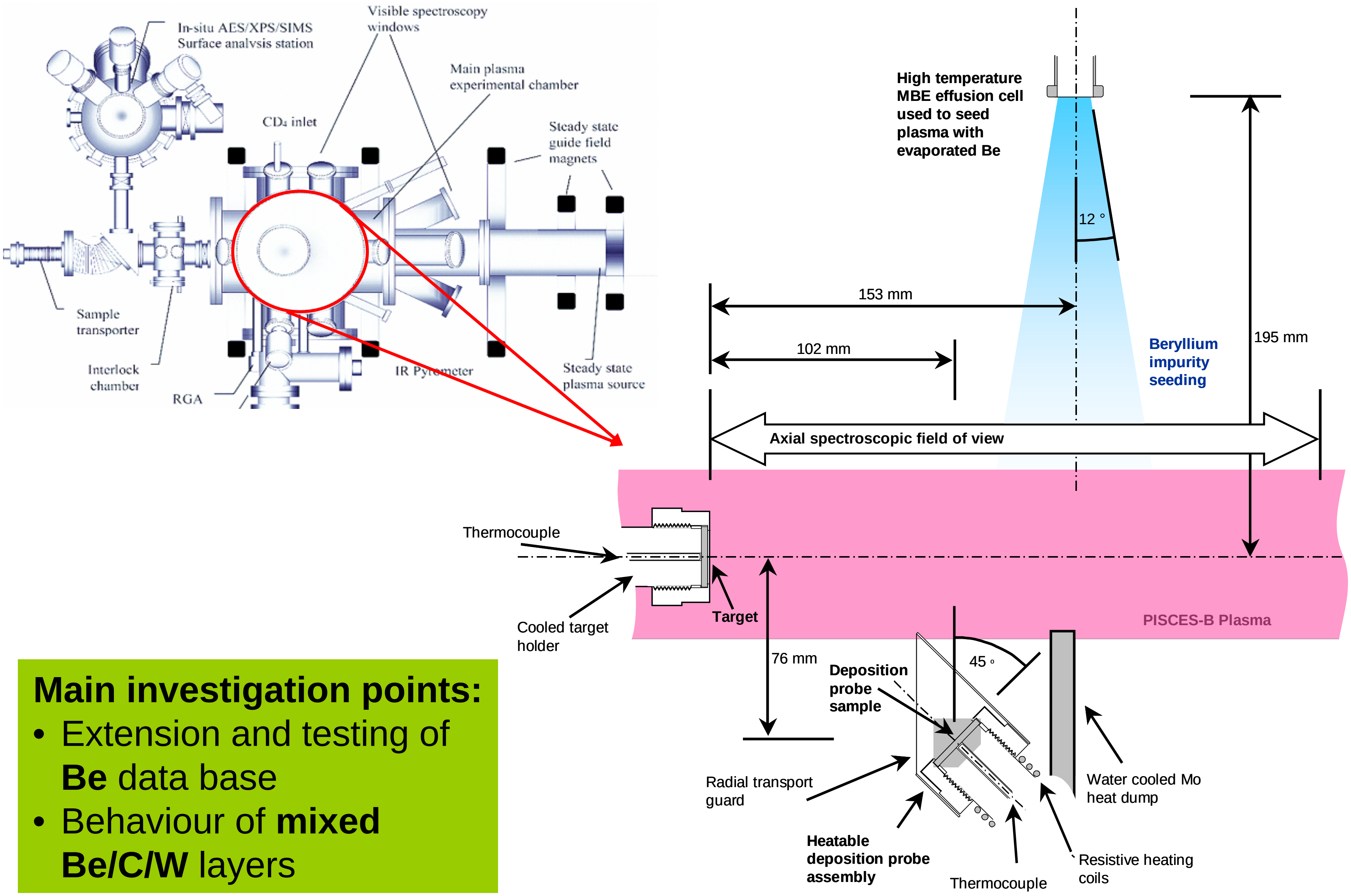


- Less complicated geometry than a tokamak
- Continues operation
- Plasma conditions relevant for ITER divertor



PSI-2 facility (Berlin). Planned to be transferred to FZ Jülich in 2009.

Be experiments at PISCES-B



Main investigation points:

- Extension and testing of **Be** data base
- Behaviour of **mixed Be/C/W** layers

Outline

- **Monte-Carlo (MC) method**
  - Error estimation
  - Random generators
- **Edge plasma and PSI simulations**
  - B2-EIRENE code (SOLPS)
  - ERO code
  - ERO light emission model
  - ERO – PSI modelling (TRIM, TRIDYN, MolDyn)
  - Elastic collisions
  - HYDKIN database
- **ERO – examples of application**
  - Hydrocarbon injection at TEXTOR (D/XB)
  - Test limiters – W and C
  - Be spectroscopy patterns at PISCES-B
  - ITER predictions (divertor plates lifetime, tritium retention)
- **Technical issues (ERO) – paralleliazation, benchmarking**

Monte Carlo basics

MC method – error estimation 1

For numeric calculation of κ-dimensional integral error (“guaranteed error”) can be estimated as

$$\delta \sim dA \cdot N^{-1/\kappa}$$

$$\delta < 0.01 dA \Rightarrow N \geq 100^{\kappa}$$

Already by κ=5 really challenging number! . .

Monte-Carlo approach – let’s use mathematical expectation!

$$M(s_i) = \int_G f(P)dP = I(f), \qquad s_i = f(P_i)$$

$$S_N(f) = \frac{1}{N}\sum_{j=1}^{N} s_j \quad \Rightarrow M(S_N) = I(f), \; D(S_N(f)) = \frac{1}{N} D(f)$$

Chebyshev inequality:

$$\delta \sim \left| S_N(f) - I(f) \right| \leq \sqrt{D(f) / \eta N} \Leftrightarrow P = 1 - \eta$$

$$\eta = 0.01 \Rightarrow \delta \sim 10\sqrt{D(f)/N}$$

Any pair of s_i independent from each other!

$$D(\overline{S_N}) \leq D(S_N) = D(f)$$

MC method – error estimation 2

More precise estimation is based on central limit theorem:

$$\frac{|S_N(f)-I(f)|}{\sqrt{D(f)/N}} \sim \rho(y) = \frac{1}{2\pi}\int_{-\infty}^{y}\exp\left(-\frac{t^2}{2}\right)dt$$

All s_i are fully independent!

$$|S_N(f)-I(f)| \le \sqrt{D(f)/N} \sim \rho_0(y) = 1-\frac{1}{2\pi}\int_{y}^{\infty}\exp\left(-\frac{t^2}{2}\right)dt$$

$$|S_N(f)-I(f)| \le 3\sqrt{D(f)/N} \qquad \mathrm{P} = 0.997$$

$$|S_N(f)-I(f)| \le 5\sqrt{D(f)/N} \qquad \mathrm{P} = 0.99999$$

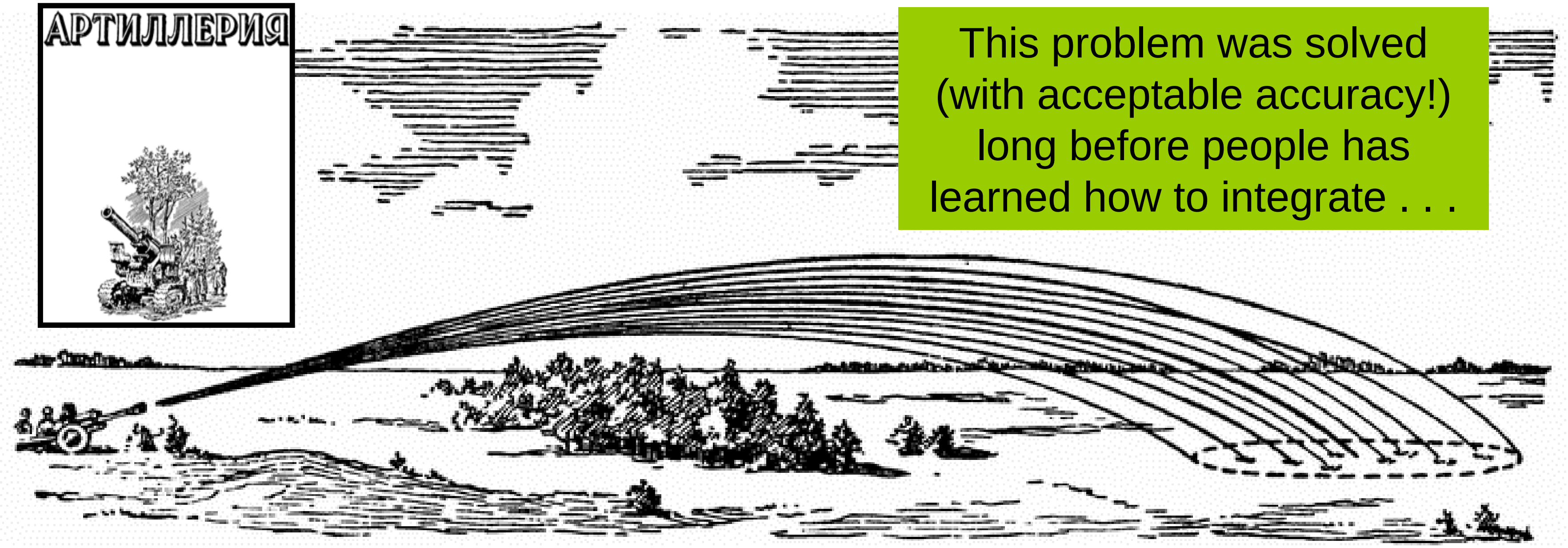
<u>Some demotivation</u>: *D(f)* should be kept small!..

<u>2 main ways to improve performance</u>:

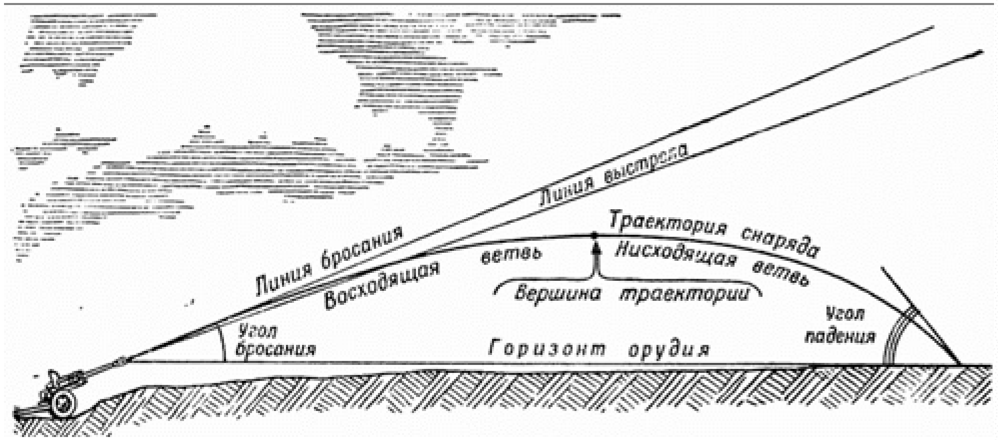
1) Choice of integration points distributed as *g(P)* e.g. such that *f(P)/g(P)=const*.

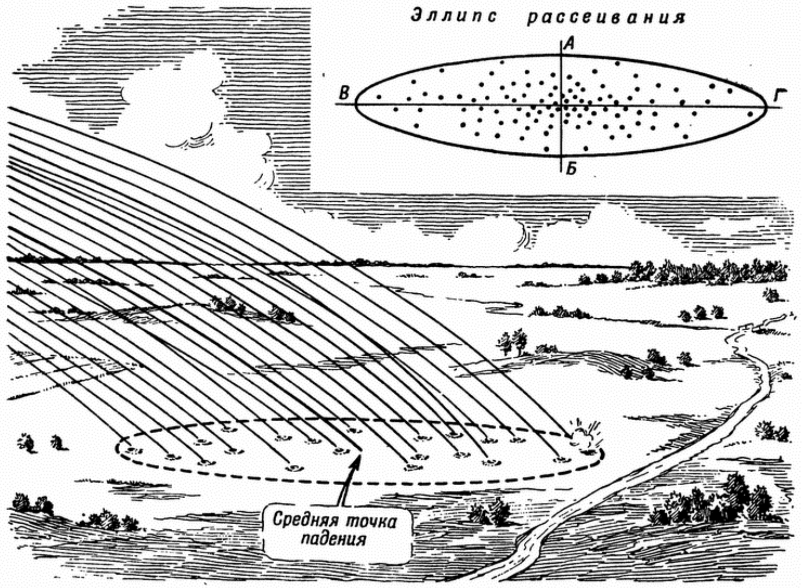
2) Separate the integration region into sections with various dispersion.

MC method – practical shooting

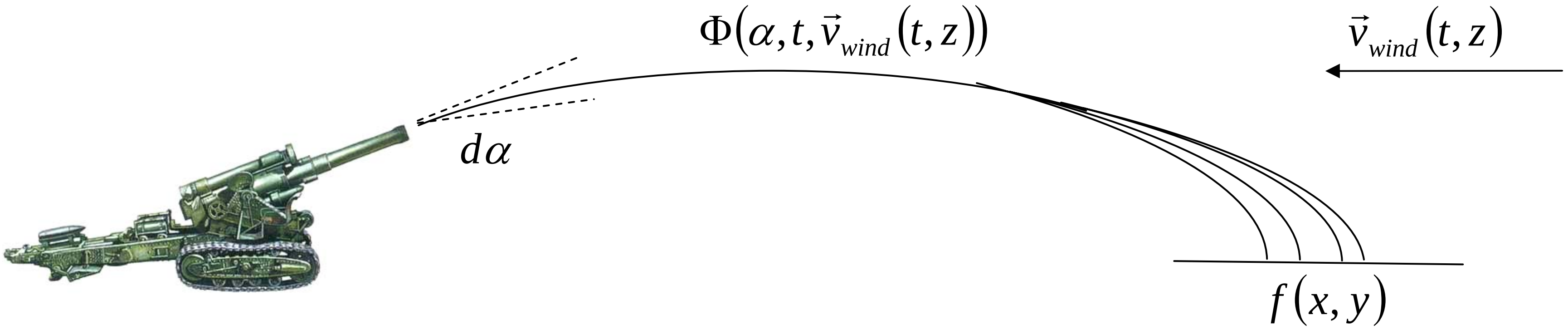


This problem was solved (with acceptable accuracy!) long before people has learned how to integrate . . .





MC method – practical shooting



Determined solution:

$$f(x,y)=\oint\left(\int\Phi(\alpha,t,\vec{v}_{wind}(t,z))dt\right)\cdot d\alpha$$

α – solid angle!

Monte-Carlo solution:

α – correct distributed arbitrary value

s_i – how many trajectories come to $[x_i \pm dx, y_i \pm dy]$

Typical task – find dispersion.

Determined solution: 2 more integrations by x,y

MC solution: just find dispersion of S_N . . .

Obviously, trajectory of a plasma particle is much more complicated!

MC formulation – elementary processes

Let’s assume that on specie can act processes 1, 2, …

$$\frac{dN}{dt} = \langle v\sigma_1\rangle n_e \cdot N + \langle v\sigma_2\rangle n_e \cdot N + \ldots$$

$$\beta = n_e\left(\langle v\sigma_1\rangle + \langle v\sigma_2\rangle + \ldots\right)$$

$$\int \frac{dN}{N} = \int \beta dt \Rightarrow -\ln N = \beta t + C$$

$$N_{t=0} = 1 \Rightarrow C = 0$$

$$N = \exp(-\beta t)$$

$$P_{\mathrm{change}} \sim \frac{\Delta N}{N} = \Delta N = 1 - \exp(-\beta\Delta t)$$

$$P < .?. > \xi \in [0,1]$$

Monte-Carlo approach: decision is taken based on comparing of probability P with random generated value ξ.

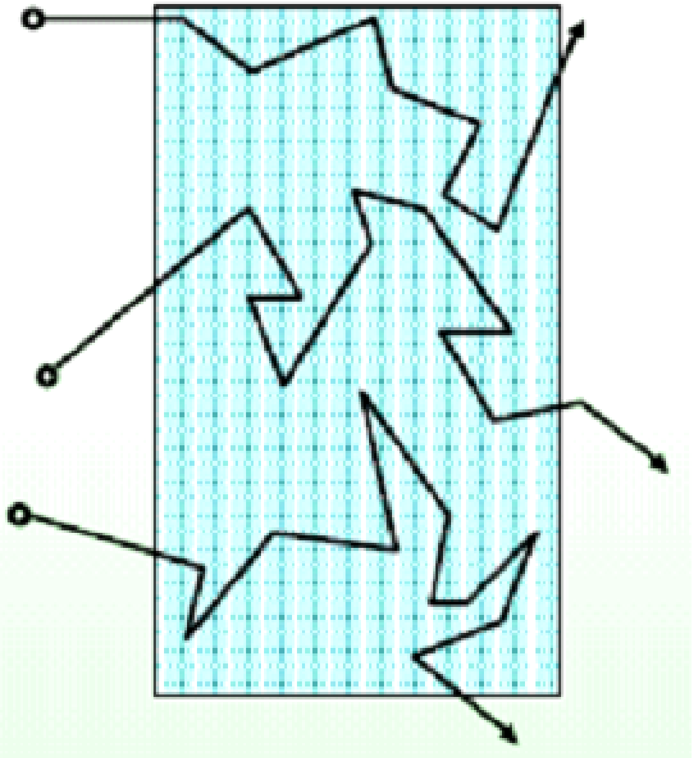
$$P_{\textbf{no}\ \mathrm{change}} \sim \frac{\Delta N}{N} = \Delta N = \exp(-\beta\Delta t)$$

More convenient in this case.

Decision concerning which of processes 1, 2, … has occurred can be taken based on additional random value $\xi_{2.}$

Summary of MC method advantages

- Calculation error does not depend directly on the problem dimensionality
- Usually the mathematical expressions are relatively simple (free from additional integrations)
- Realisation of many physical processes like particle movement is very natural and straightforward. It is easy to control the reasonability of intermediate results.
- Easy to treat complicated 3D geometries.
- MC method is quite time consuming, however very suitable for parallelisation.

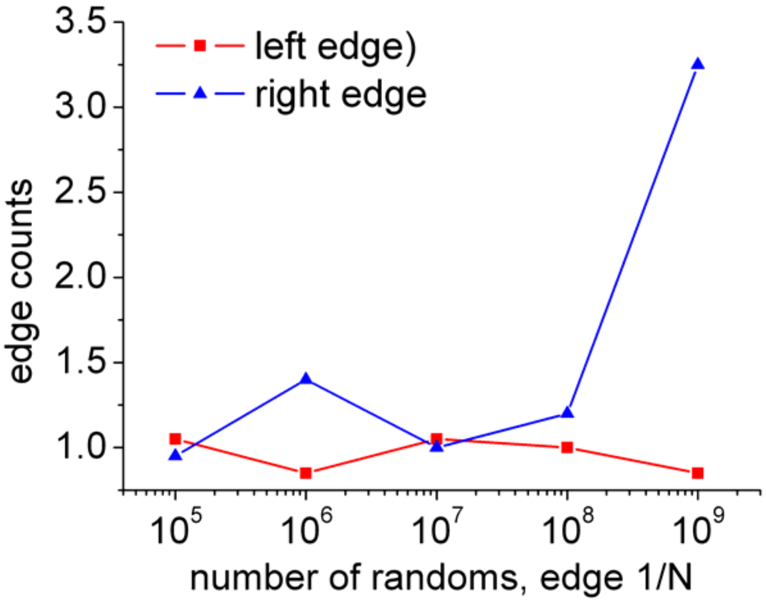


MC – random generator challenges

1) Generated numbers are fully independent!
   - No or at least very long period.
   - Generated numbers are equally distributed along [0,1]
2) Generator does not consume too much CPU time
3) It is possible to reproduce the generation exactly

Example

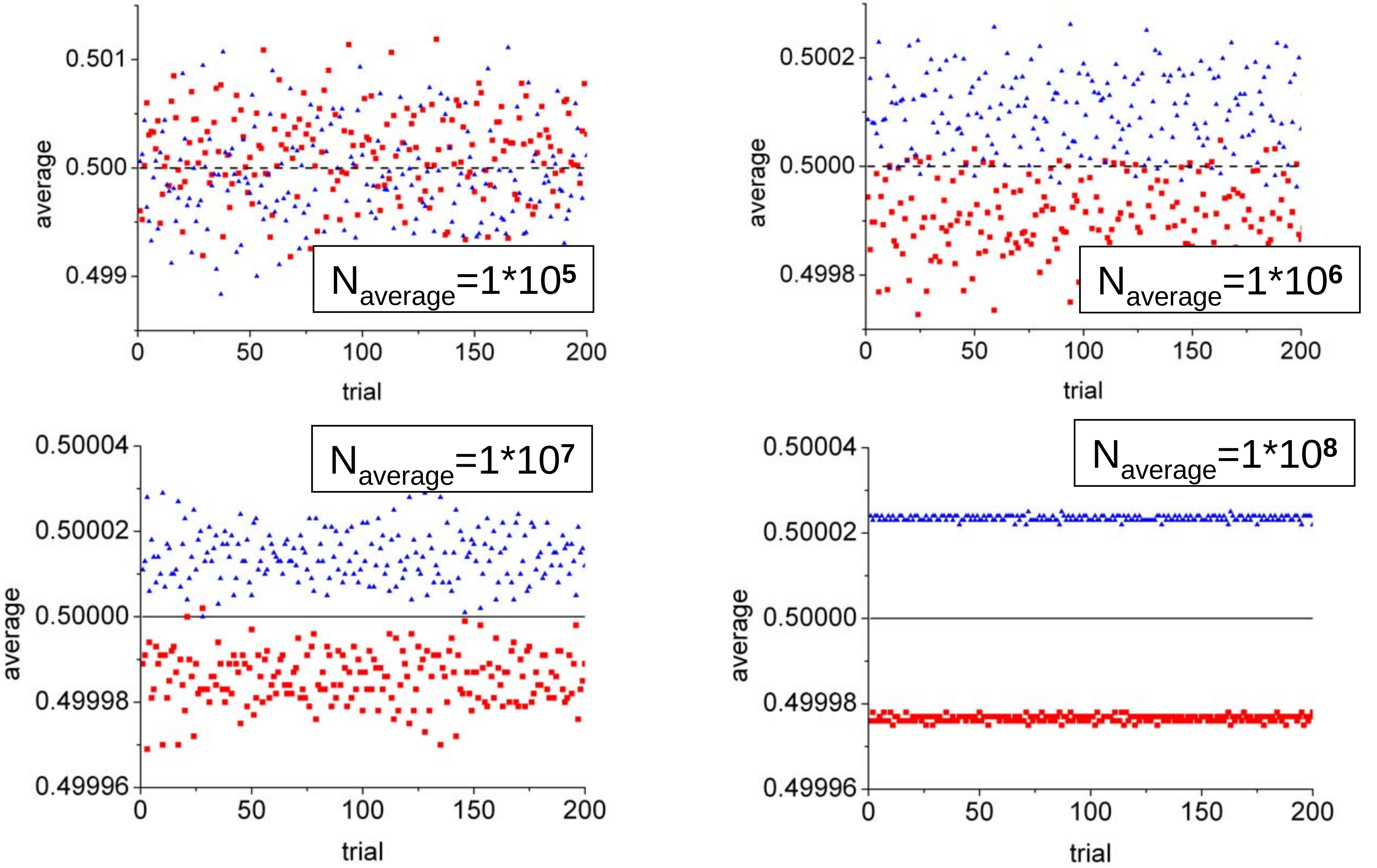
For N uniformly distributed random numbers the average number of hits, <n>, in the ranges (0,ε) and (1-ε,1) should be equal to ε·N. If we select ε=1/N, then <n>=1.



A specific algorithm must be tested together with the random number generator being used regardless of the tests which the generator has passed . . .

MC – RG negative example

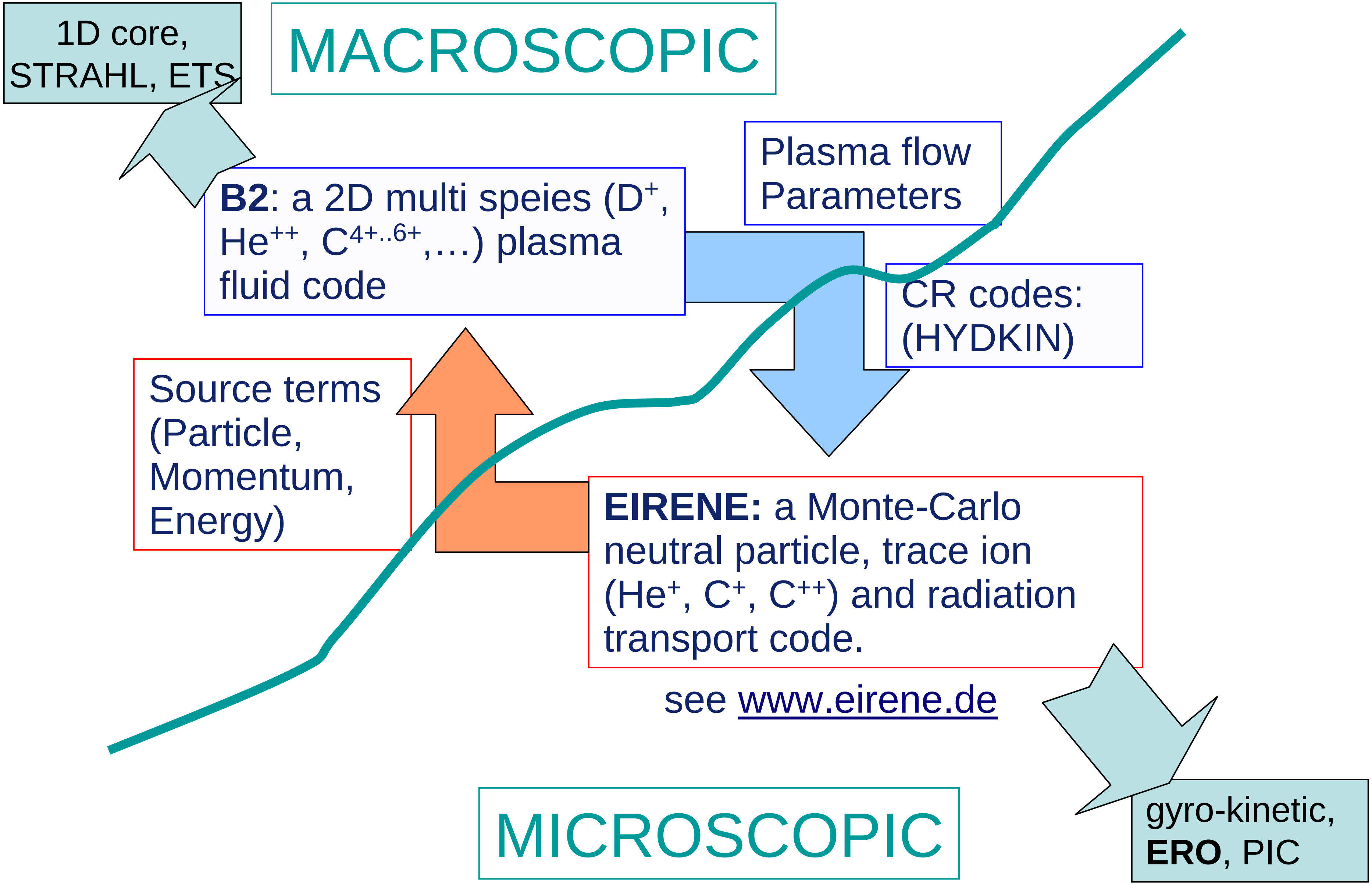
“Not optimal” random generator – combination of 3 recurrent formulas from “Numerical recipes”. Average of **odd (blue)** and **even (red)** numbers.



Plasma simulations,

EIRENE and ERO codes

Codes for fusion plasmas



1D core,
STRAHL, ETS

MACROSCOPIC

Plasma flow
Parameters

B2: a 2D multi speies (D$^+$, He^{++}, C$^{4+..6+}$,…) plasma fluid code

CR codes:
(HYDKIN)

Source terms
(Particle,
Momentum,
Energy)

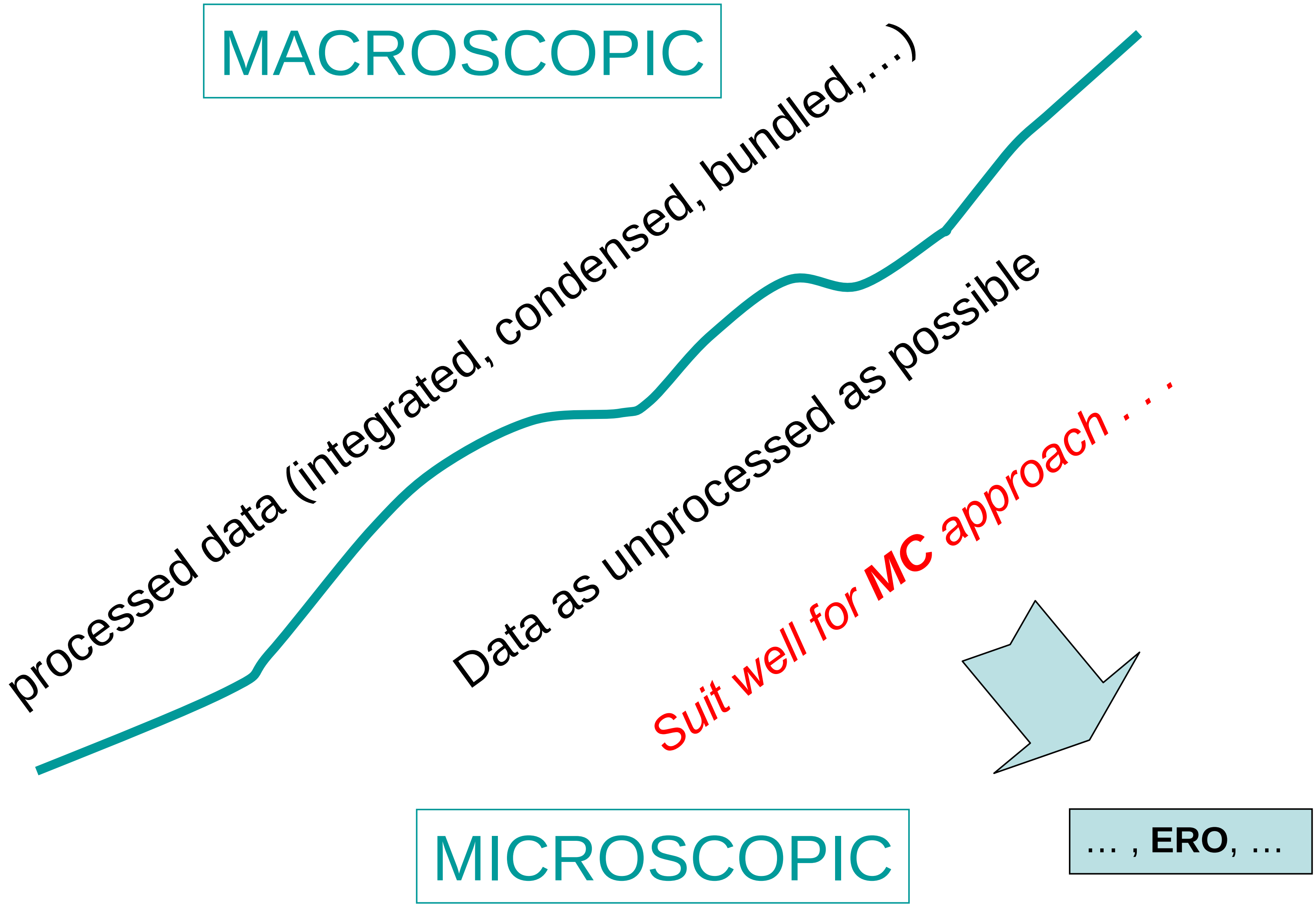
EIRENE: a Monte-Carlo neutral particle, trace ion (He$^+$, C$^+$, C^{++}) and radiation transport code.

see www.eirene.de

MICROSCOPIC

gyro-kinetic,
ERO, PIC

Codes for fusion plasmas



MACROSCOPIC

processed data (integrated, condensed, bundled,…)

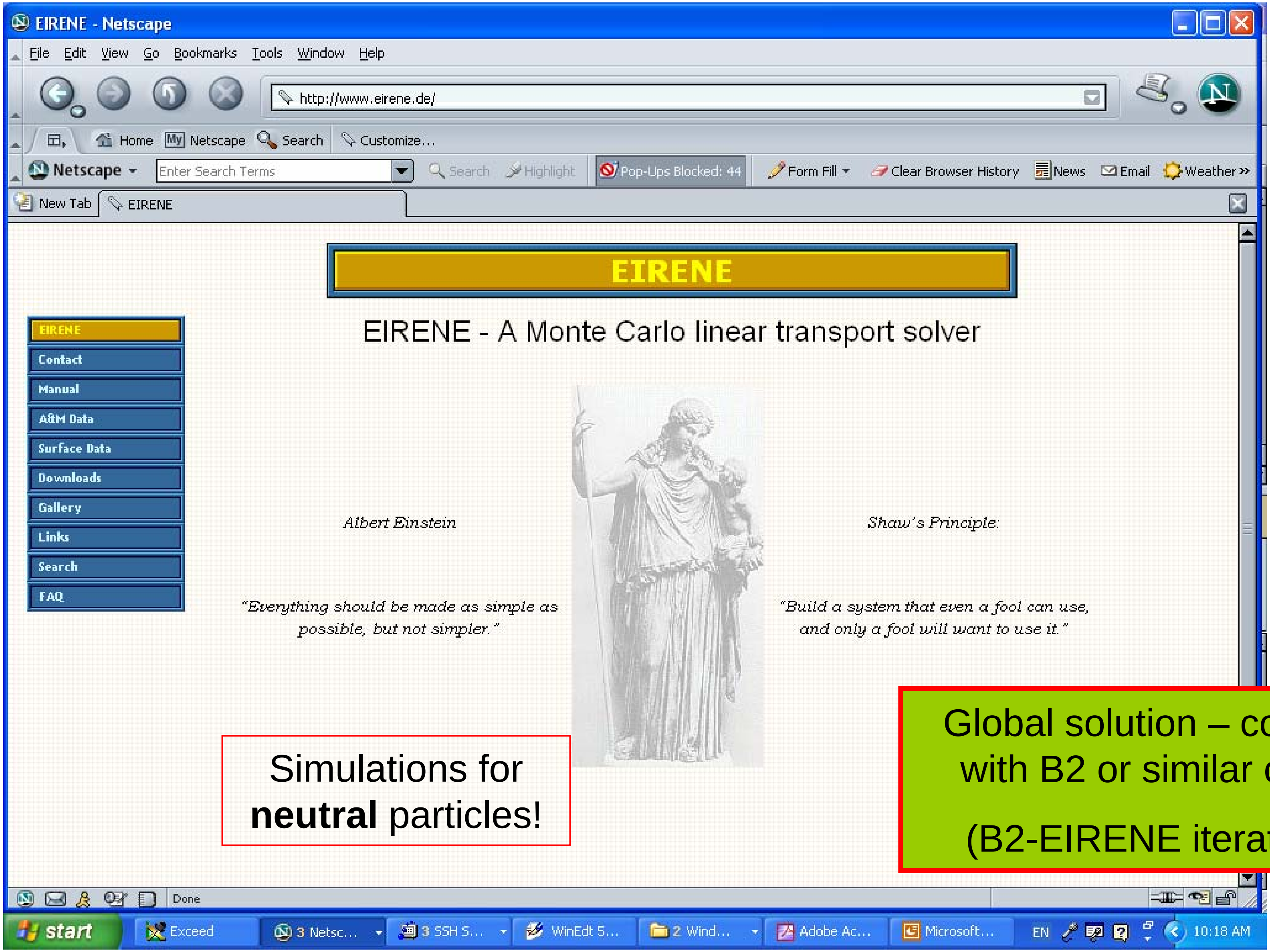
Data as unprocessed as possible

Suit well for **MC** approach . . .

MICROSCOPIC

… , **ERO**, …

EIRENE code



EIRENE

EIRENE - A Monte Carlo linear transport solver

Albert Einstein

"Everything should be made as simple as possible, but not simpler."

Shaw's Principle:

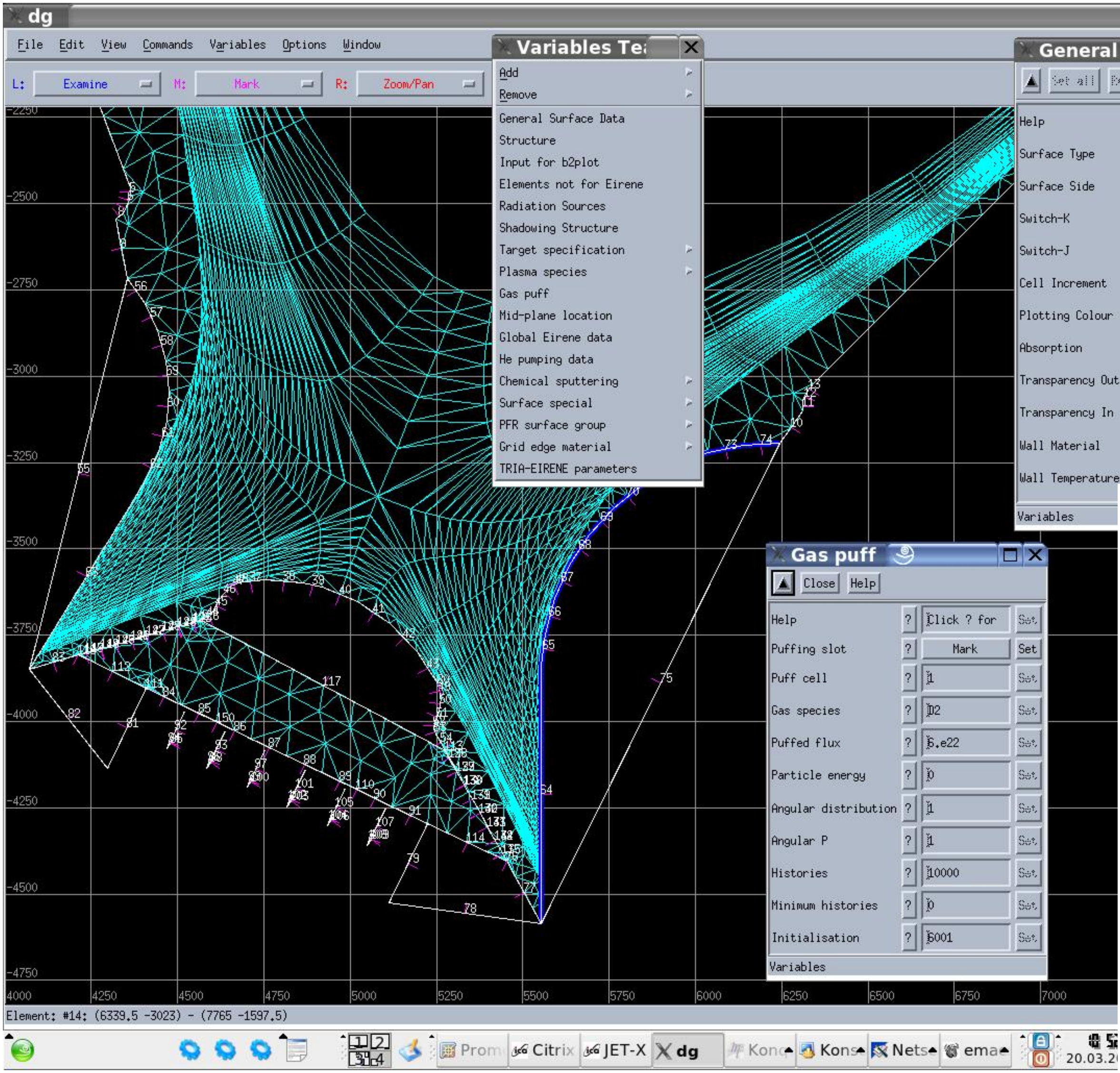
"Build a system that even a fool can use, and only a fool will want to use it."

Simulations for **neutral** particles!

Global solution – coupling with B2 or similar codes

(B2-EIRENE iterations)

EIRENE – mesh generation



General Surface Data:

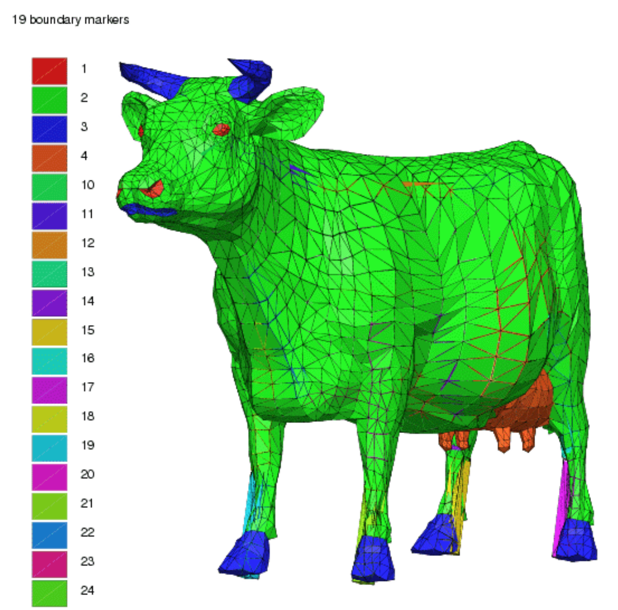
Help: Click ? for
Surface Type: 1
Surface Side: 2
Switch-K: 0
Switch-J: 0
Cell Increment: 0
Plotting Colour: 1
Absorption: 0
Transparency Out: 0
Transparency In: 0
Wall Material: C
Wall Temperature:

Gas puff:

Help: Click ? for
Puffing slot: Mark
Puff cell: 1
Gas species: D2
Puffed flux: 6.e22
Particle energy: 0
Angular distribution: 1
Angular P: 1
Histories: 10000
Minimum histories: 0
Initialisation: 6001

```
Element: #14: (6339.5 -3023) - (7765 -1597.5)
```

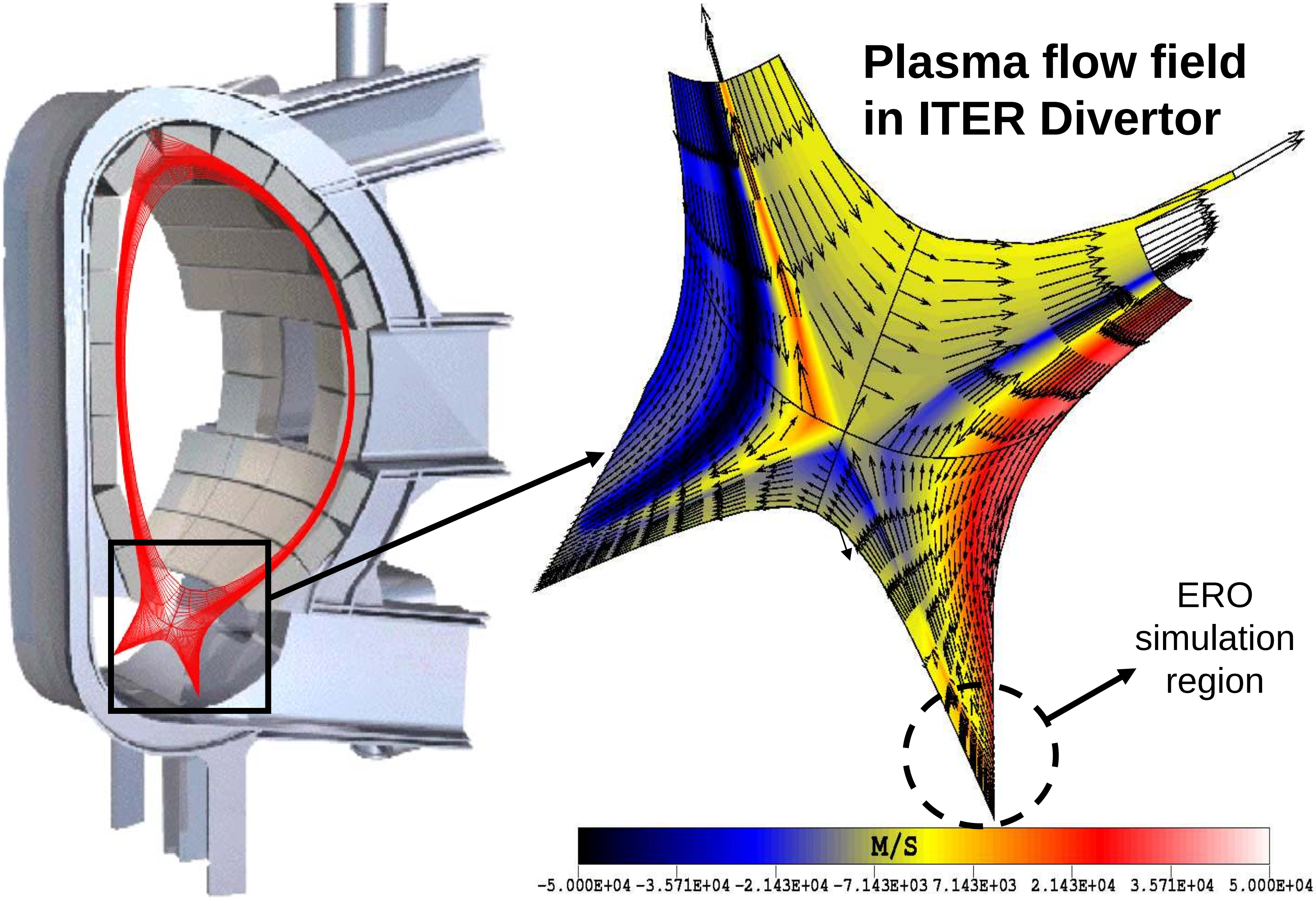
Tetrahedral Mesh Generator and 3D Delaunay Triangulator


19 boundary markers

🟥	1
🟩	2
🟦	3
🟧	4
🟩	10
🟪	11
🟧	12
🟩	13
🟪	14
🟨	15
🟦	16
🟪	17
🟨	18
🟦	19
🟪	20
🟩	21
🟦	22
🟥	23
🟩	24

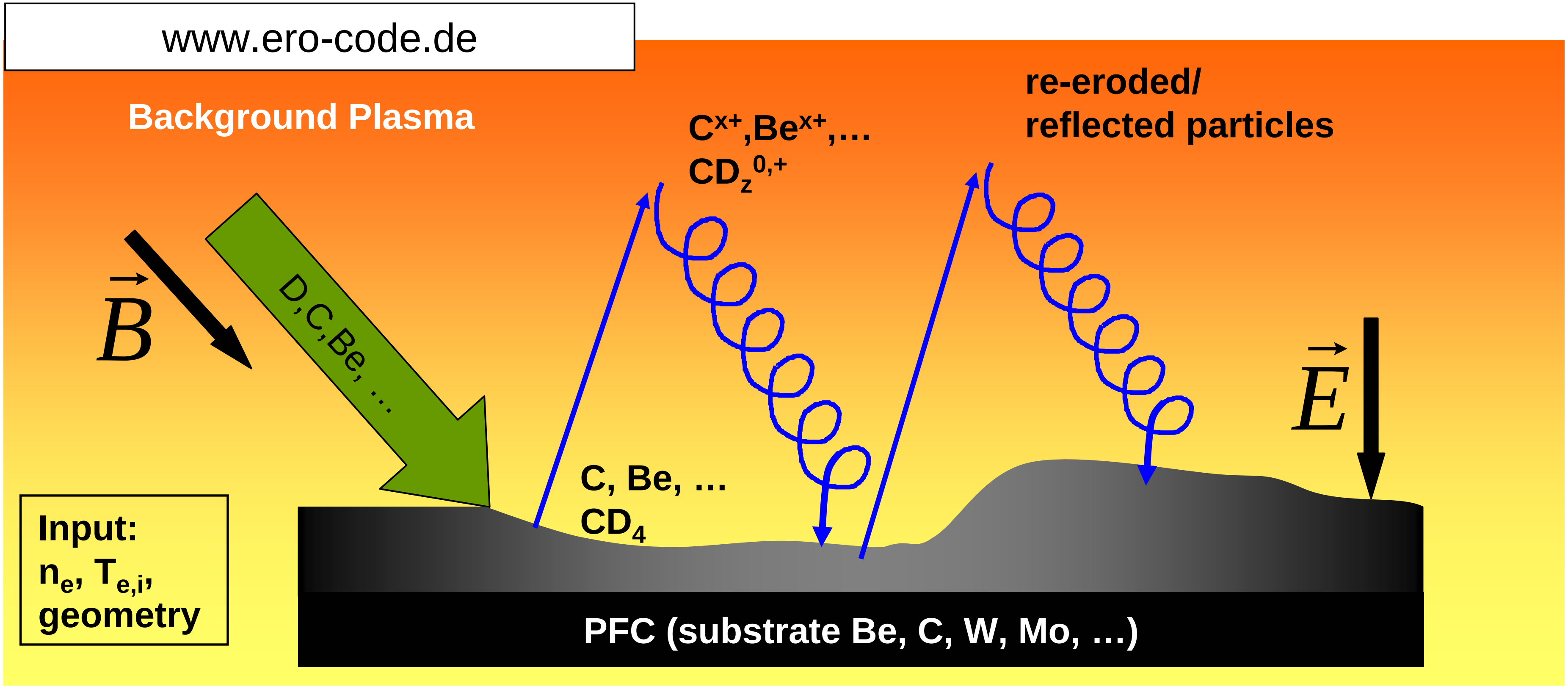
For ITER: 2D GUI, CAD – EIRENE available

EIRENE – simulation region



ERO code

3D MC impurity transport code ERO



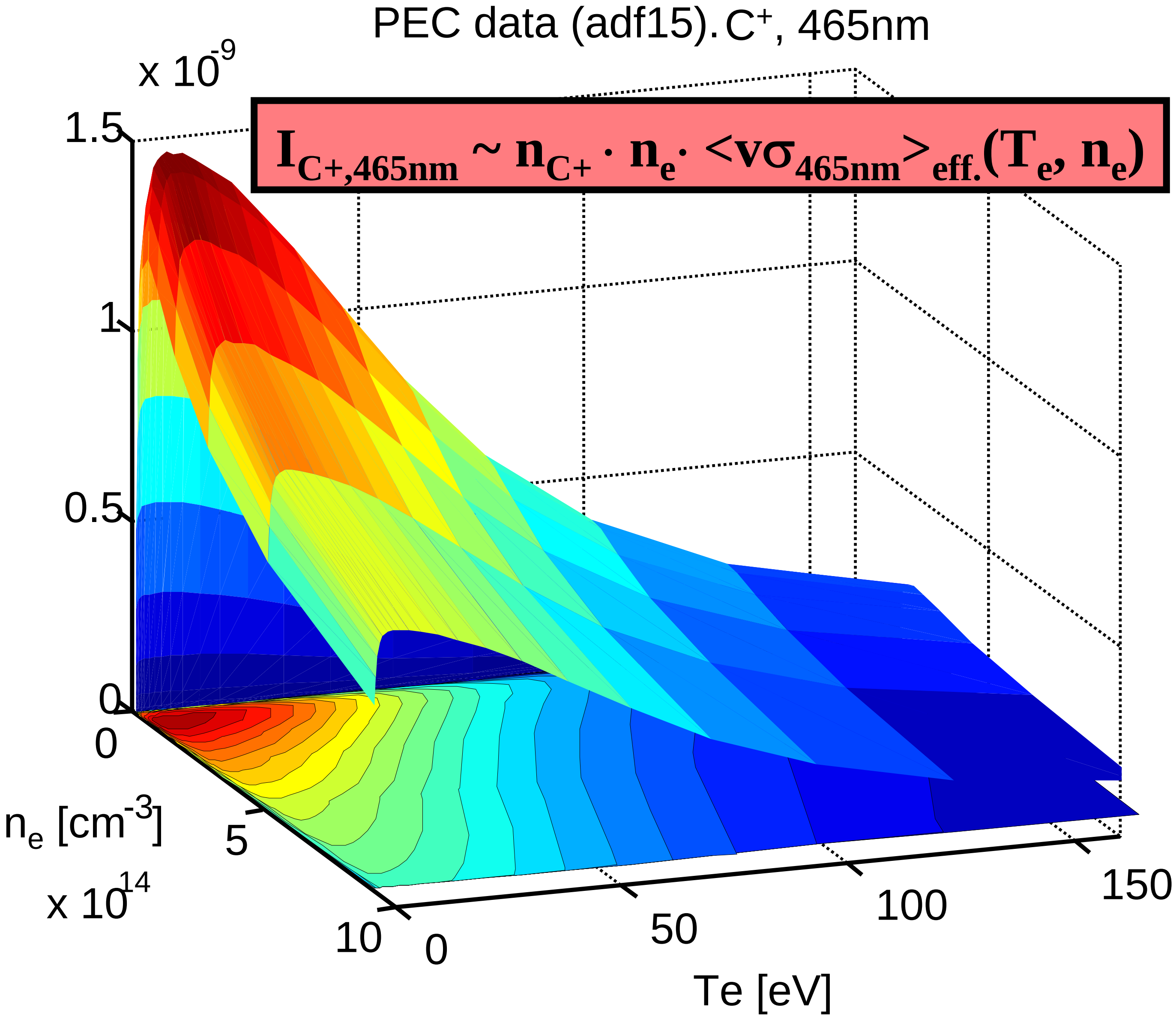
Local transport:

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

Plasma-surface interaction:

- ✓ physical sputtering/reflection
- ✓ chemical erosion (CD_4)
- ✓ (re-)erosion and (re-)deposition
- ✓ NEW: coupling with **TRIDYN**

ERO: calculation of light emission

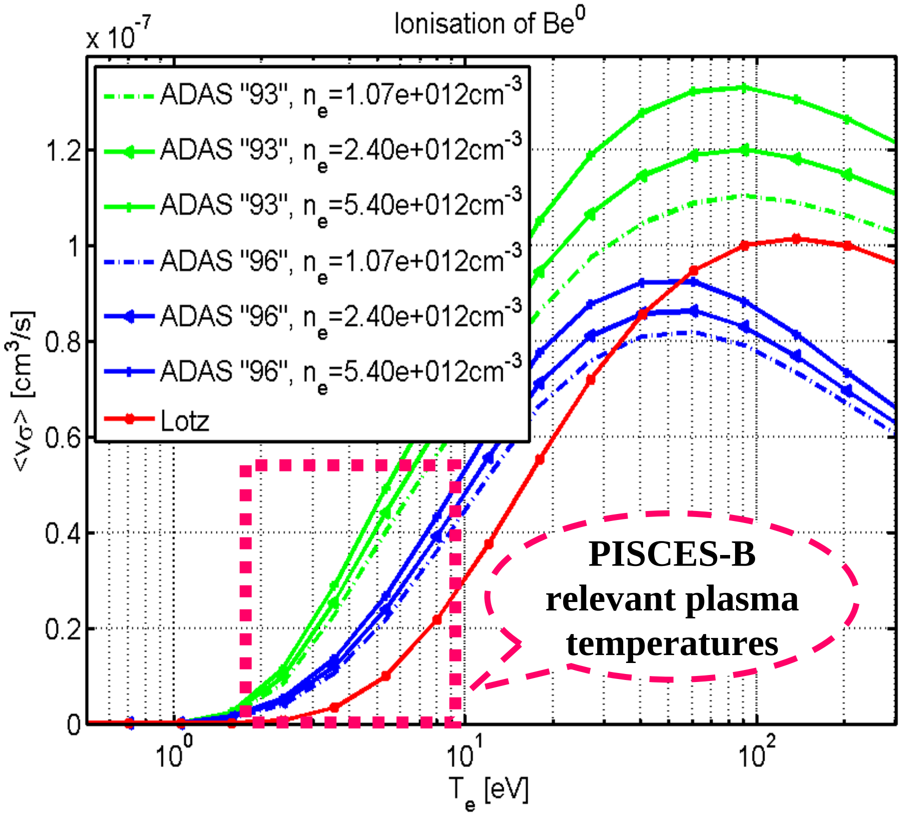

PEC data (adf15). C^+, 465nm

$$I_{C+,465nm} \sim n_{C+} \cdot n_e \cdot \langle v\sigma_{465nm} \rangle_{eff.}(T_e, n_e)$$

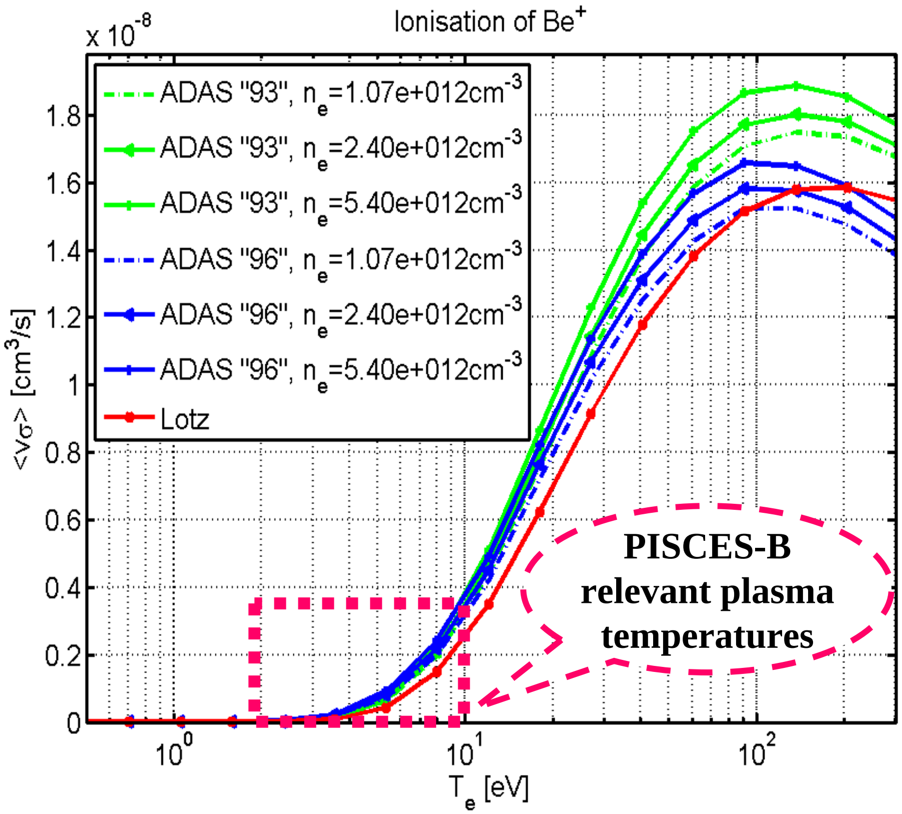
At first, ERO calculates the **3D density** distribution of respective species . . .

This **stationary** approach implies that both excitation and emission acts happen inside the volume cell at hand.

ADAS data: effective ionization of Be



PISCES-B relevant plasma temperatures

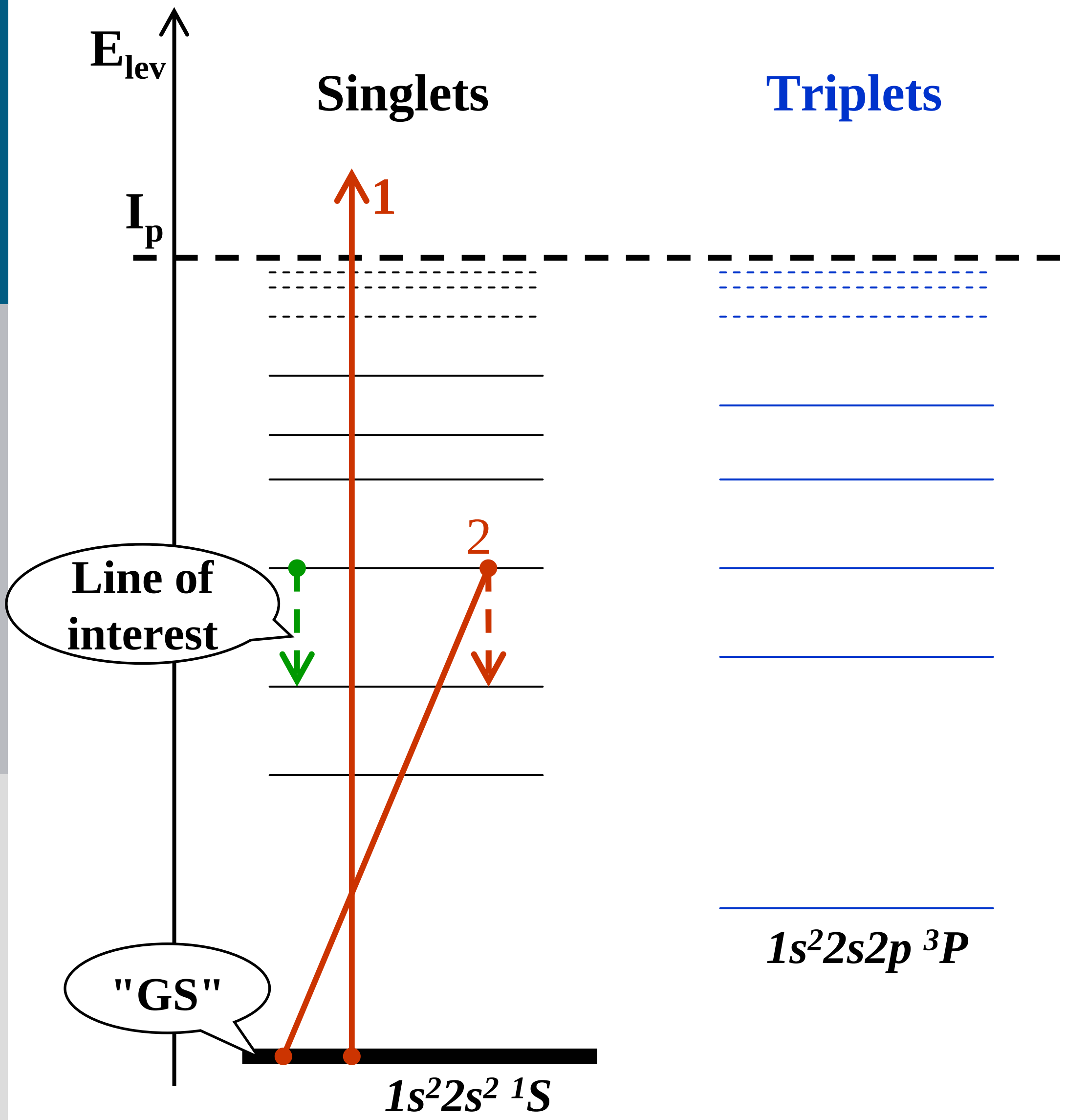


PISCES-B relevant plasma temperatures

ERO database of **atomic data** is continuously updated according to the respective changes in the **ADAS.**

The **density dependence** of **effective rates** was shown to be of importance in a number of cases.

BeI – '2 level' approximation scheme



<u>Effective rates:</u>

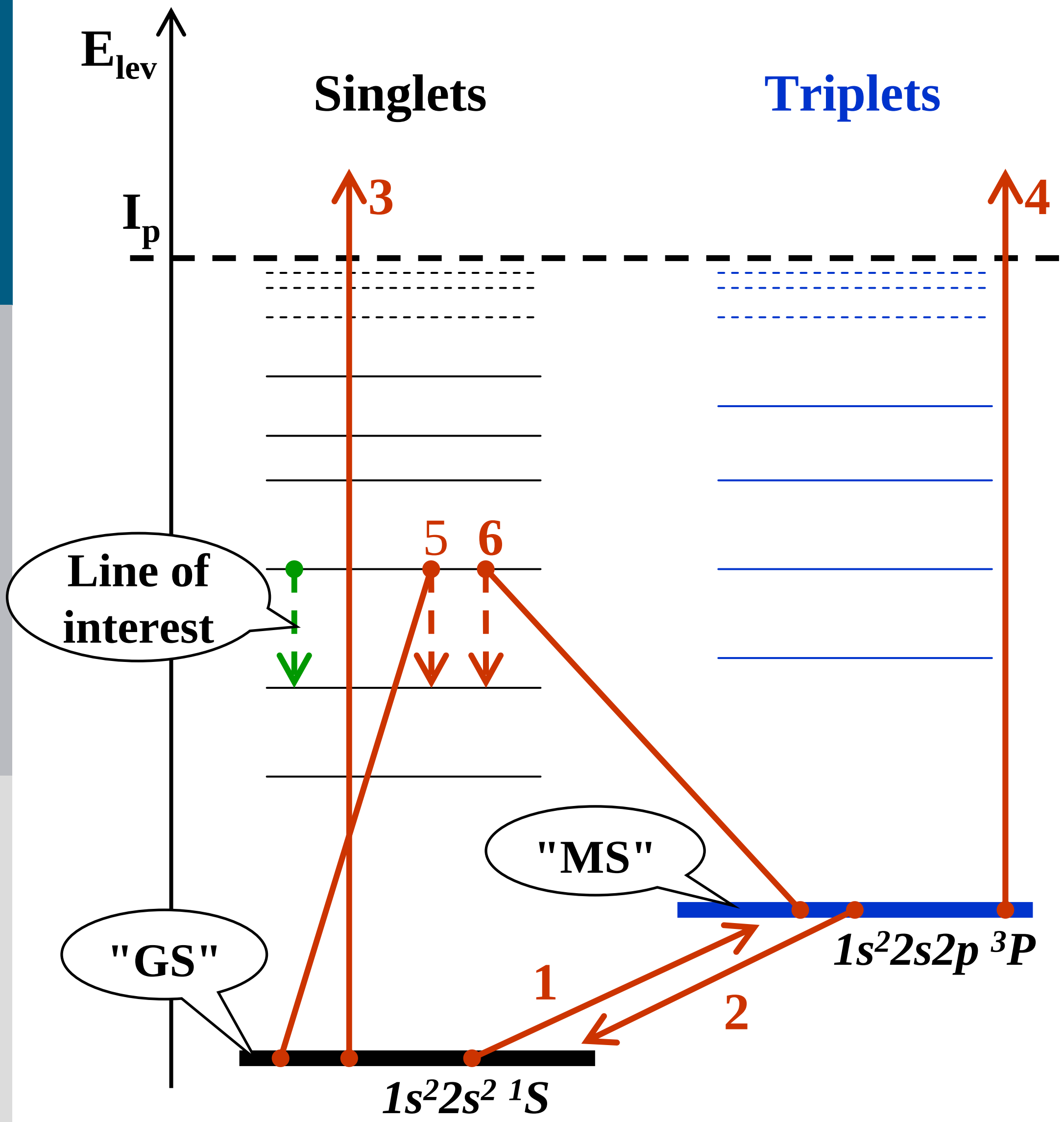
1) <IzG> - ionization from "GS"

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"

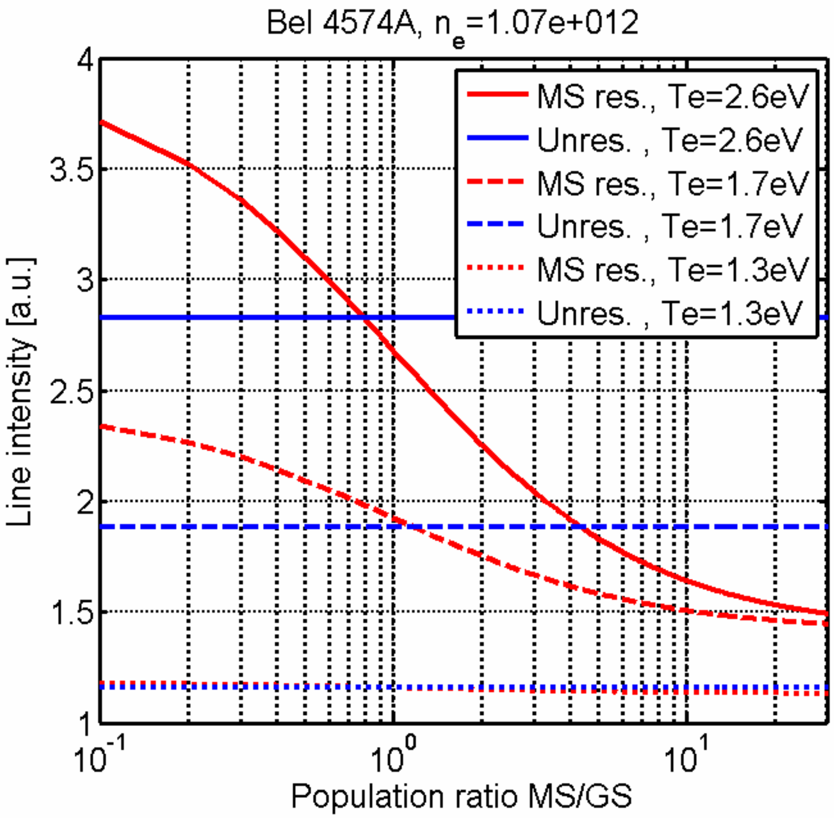
5) <IG> - line intensity, contribution from "GS"

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

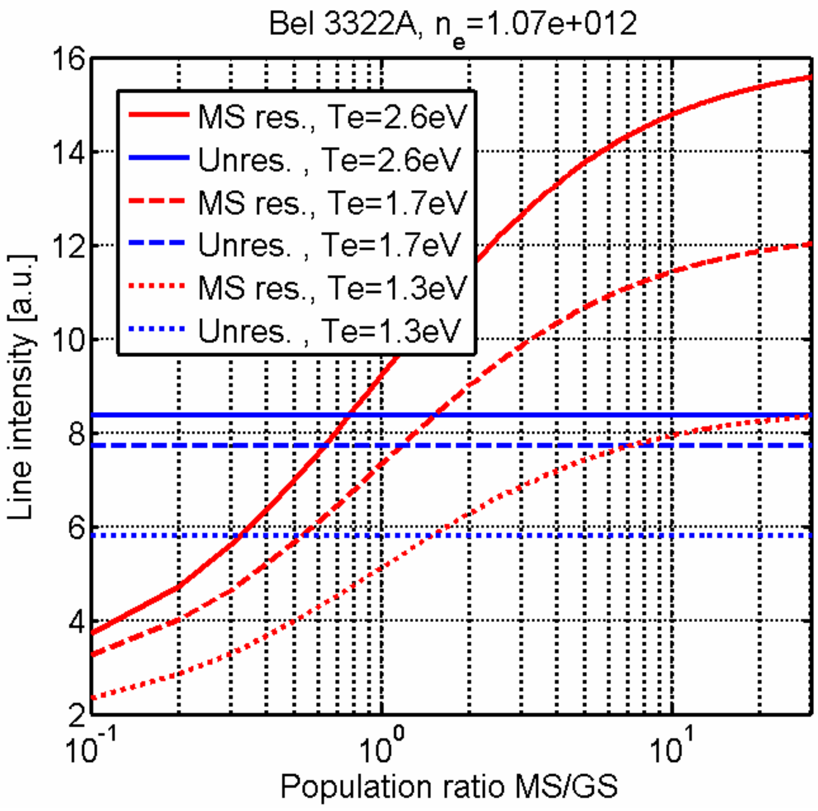
5, 6 are individual for every line of interest!

Line intensities – MS population

Singlet



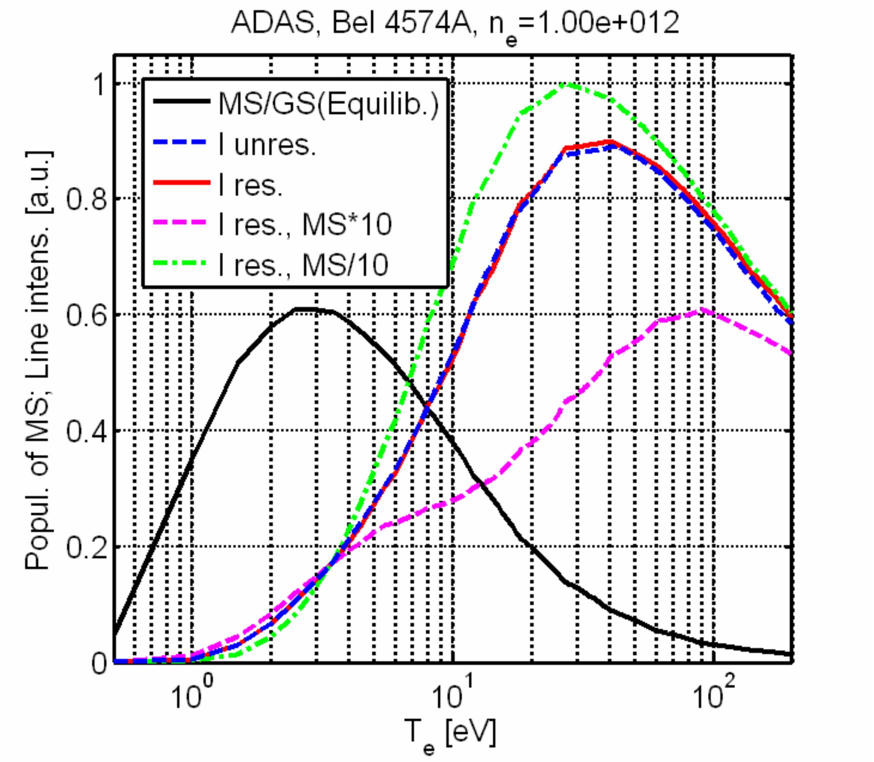
Triplet



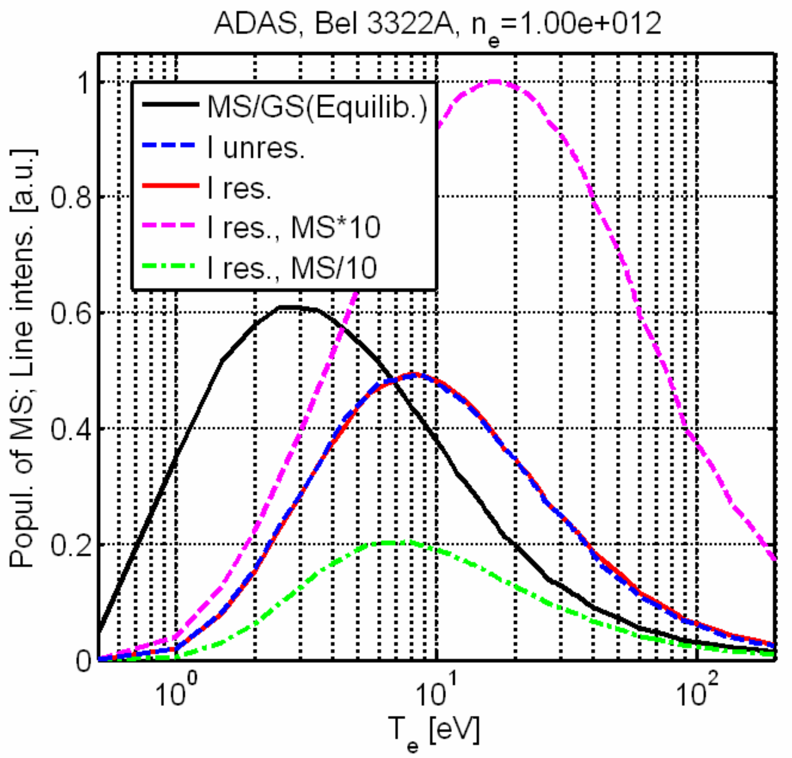
$$I \sim N_{GS}\cdot\underbrace{\left\langle v\sigma\right\rangle_{GS}\left(n_e,T_e\right)}_{\text{Large for singlets}}\cdot n_e + N_{MS}\cdot\underbrace{\left\langle v\sigma\right\rangle_{MS}\left(n_e,T_e\right)}_{\text{Large for triplets}}\cdot n_e$$

Line intensities – stationary approach

Singlet



Triplet



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

Line intensities – dynamic approach

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

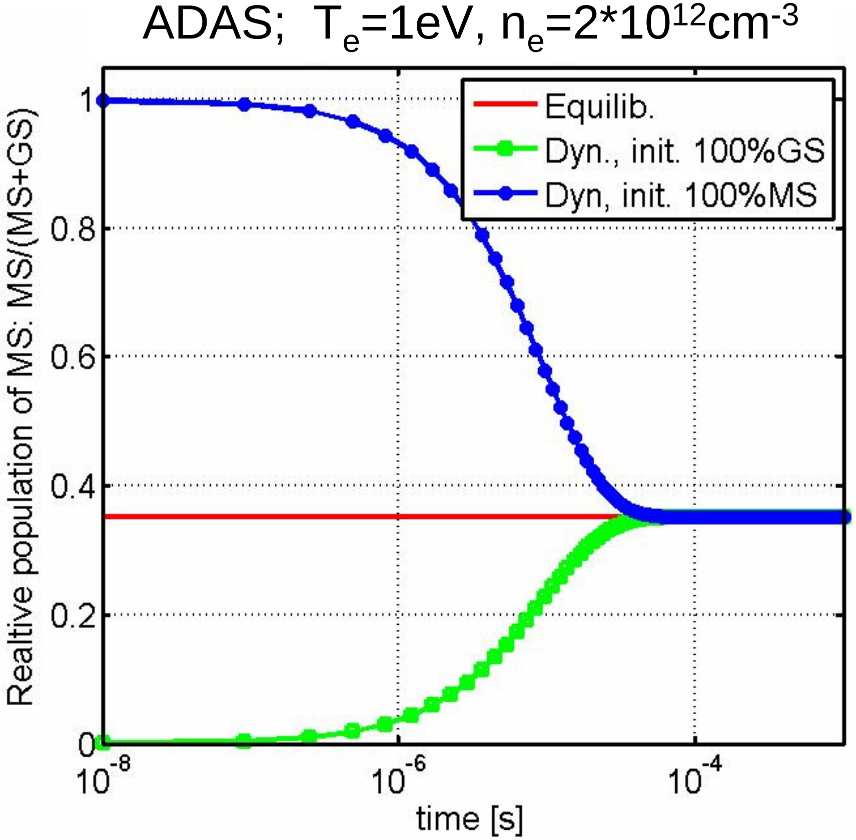
Analytical solution

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

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

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

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



Higher hydrocarbons

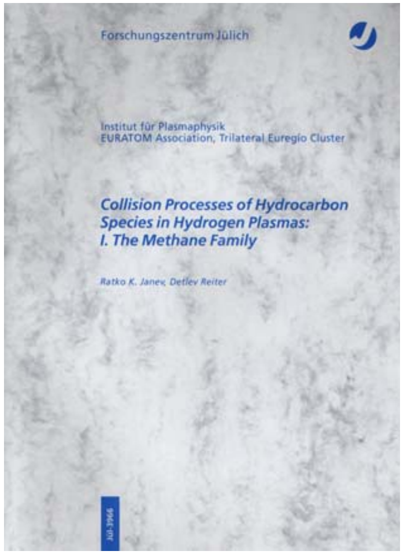
(chemical reaction chains and D/XB for CH)

HYDKIN

Hydride Collision Databases for Technical Plasmas and Fusion Plasmas

Reviewed Database Series 2002-….,
FZ-Jülich (R. Janev, D. Reiter), www.eirene.de www.hydkin.de

Methane (CH_y)



Forschungszentrum Jülich

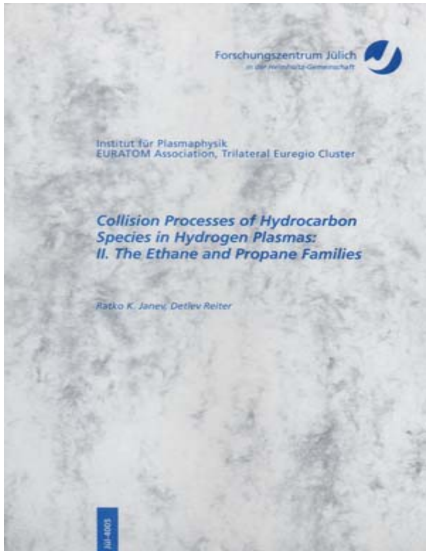
Institut für Plasmaphysik
EURATOM Association, Trilateral Euregio Cluster

Collision Processes of Hydrocarbon Species in Hydrogen Plasmas: I. The Methane Family

Ratko K. Janev, Detlev Reiter

JUEL 3966, Feb 2002
Phys. Plasmas,
Vol 9, 9, (2002) 4071

C_2H_y C_3H_y



Forschungszentrum Jülich
in der Helmholtz-Gemeinschaft

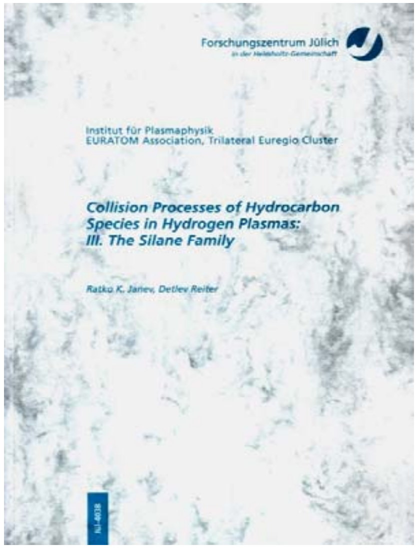
Institut für Plasmaphysik
EURATOM Association, Trilateral Euregio Cluster

Collision Processes of Hydrocarbon Species in Hydrogen Plasmas: II. The Ethane and Propane Families

Ratko K. Janev, Detlev Reiter

JUEL 4005, Oct. 2002
Phys. Plasmas,
Vol 11,2, (2004) 780

Silane (SiH_y)



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Institut für Plasmaphysik
EURATOM Association, Trilateral Euregio Cluster

Collision Processes of Hydrocarbon Species in Hydrogen Plasmas: III. The Silane Family

Ratko K. Janev, Detlev Reiter

JUEL 4038, Mar. 2003
Contr. Plas.Phys,
47, 7, (2003) 401-417

$p, H, H^-, H_2, H_2^+, H_3^+$

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in der Helmholtz-Gemeinschaft

Institut für Plasmaphysik
EURATOM Association, Trilateral Euregio Cluster

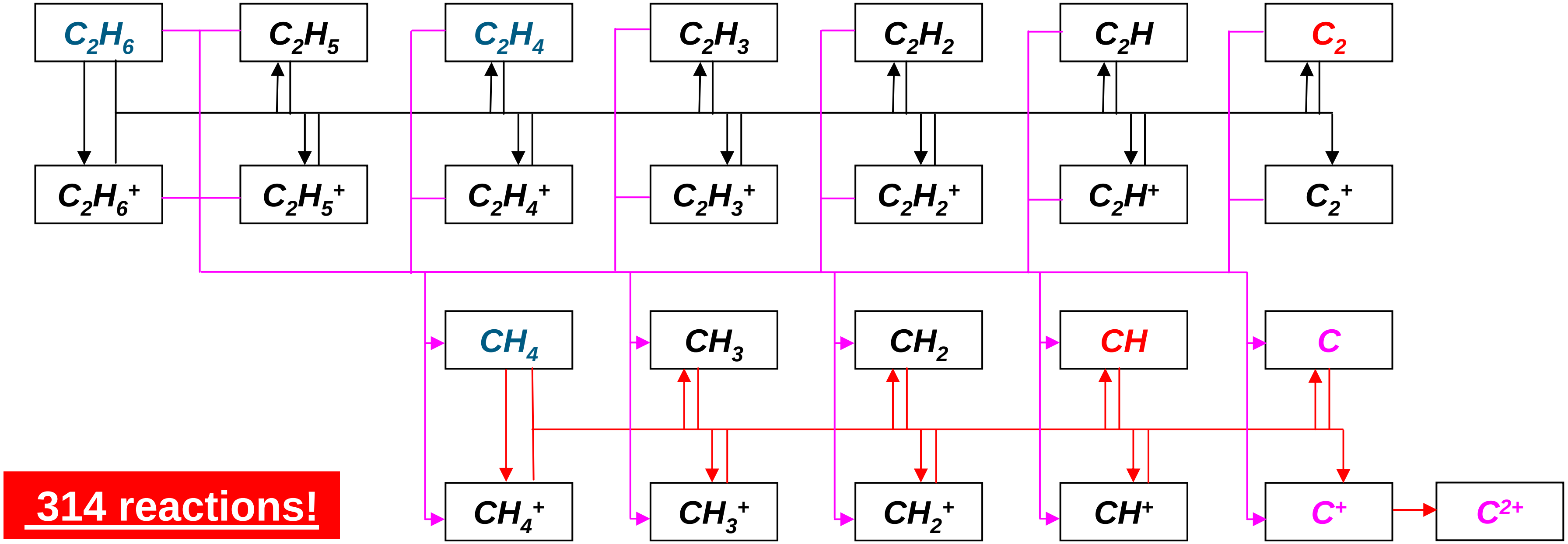
Collision Processes in Low-Temperature Hydrogen Plasmas

Ratko K. Janev, Detlev Reiter, Ulrich Samm

JUEL 4105, Dec. 2003
Encycl. Low. Temp.
Pl. 2007 (in russian)

C-H database in ERO code

Reaction chains of hydrocarbon molecules (Janev / Reiter)



314 reactions!

Emission data

CII, CIII ⇐ **ADAS**

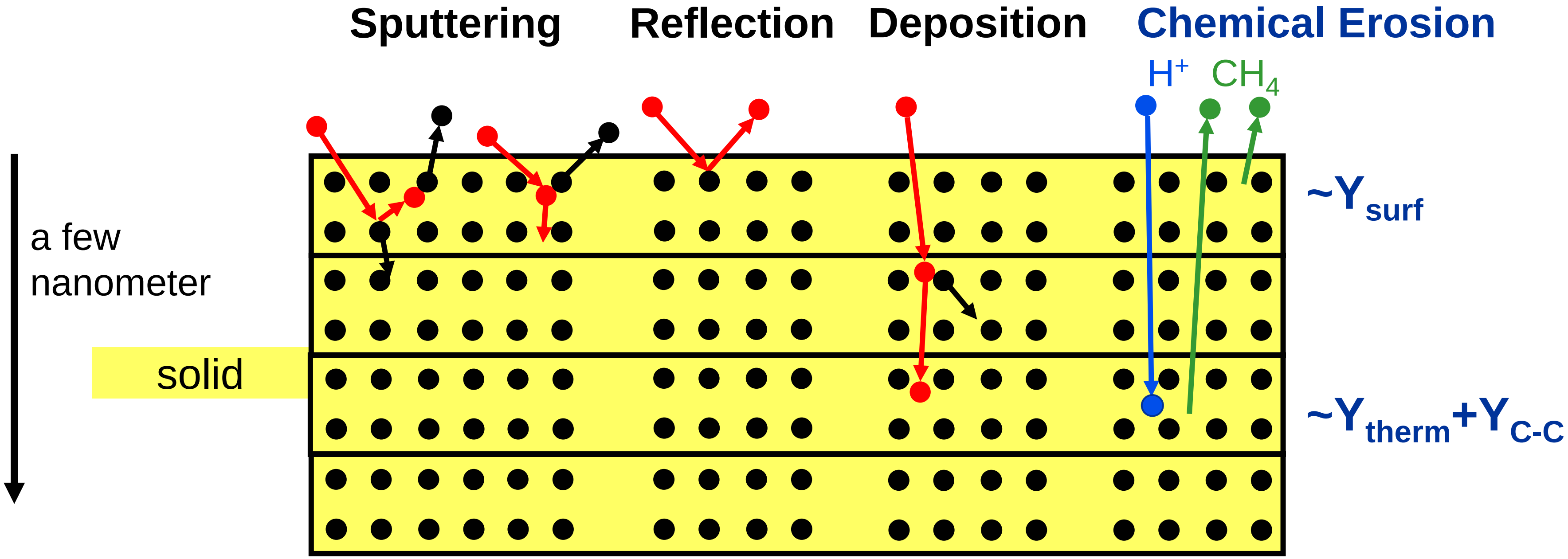
CH A-X, C_2 d-a ⇐ **U. Fantz et al. 2005**

Probably this is not enough . . .

Surface data,
PSI part of ERO

PSI – 1: main processes and TRIM code

Monte-Carlo method: TRIM code (Eckstein et al.)



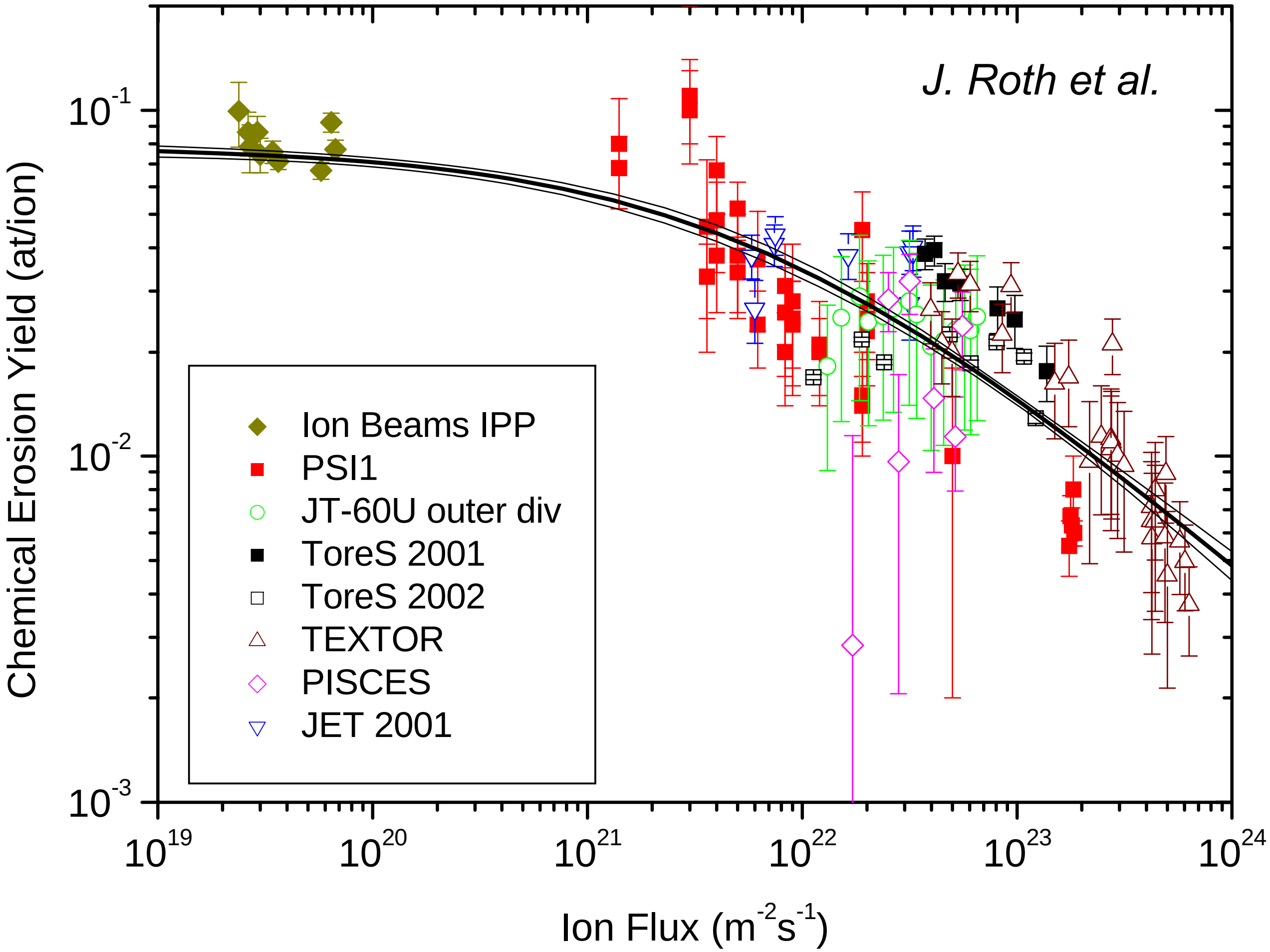
TRIM : TRansport of **I**ons in **M**atter (TriDyn, SDTrimSP)

- using random numbers (e.g. to decide whether collision or not): “Monte-Carlo”
- **binary collisions** between impinging ion and target atoms

  (elastic, screened Coulomb-potential) ⇒ collision cascades
- inelastic electronic energy loss
- **output: reflection coefficients/ physical erosion yields / concentration-depth profiles / layer growth**

PSI – 2: chemical sputtering

Chemical sputtering yield in dependence on impinging flux



Chemical sputtering decreases with increasing flux

Chemical sputtering depends on surface temperature, contance, morphology, . . .

Flux dependence is predicted by model of thermal reaction cycle.

Elastic collisions

Elastic collisions in ERO

Elastic neutral collisions (ENC):

- MC formulation : during time step dt the tracked particle experienses an alastic collition acoording to a random number $\xi, \xi \in [0,1]$:

$$\xi > \exp(-\langle \sigma v \rangle * n_{ntrl} * dt)$$

- The rates $\langle \sigma v \rangle$ are calculated using the routines by A.Pigarov

- The direction of particles is assumed to be opposite to each other and arbitrary in the center of mass system

- For linear devices $n_{ntrl} = n(D_2)$ is often assumed to be uniform in the volume

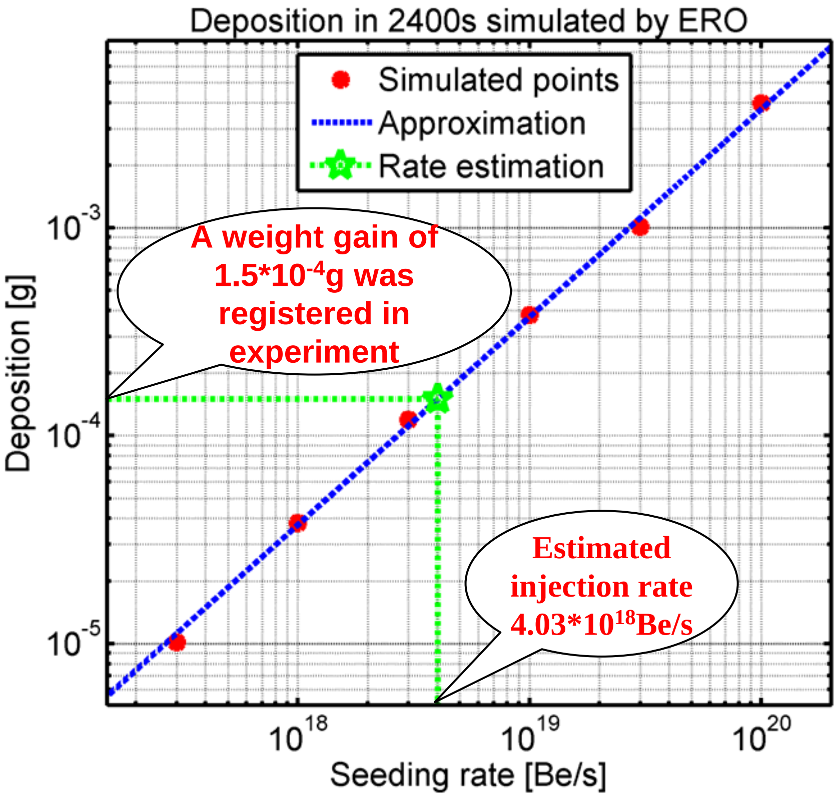
1) In case of injection simulations ENC lead to broadening of the beam

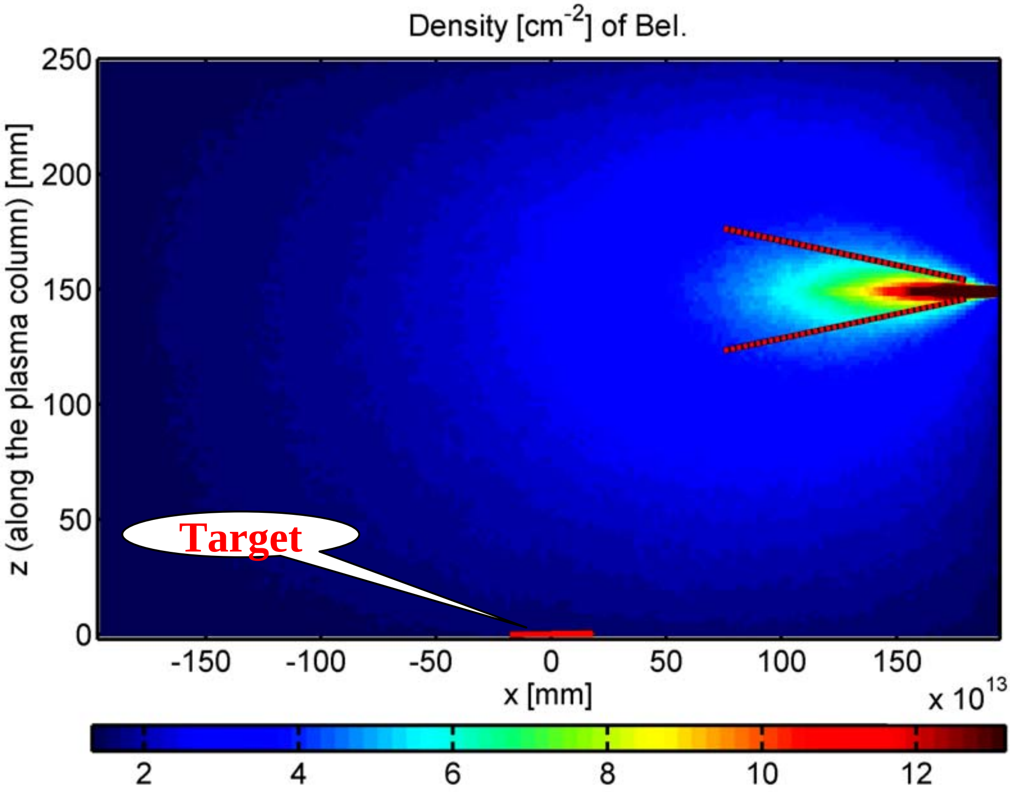
2) ENC lead to an increase of hydrocarbon re-deposition

3) For neutral density B2-EIRENE calculations are necessary . . .

Benchmark of elastic collisions model

Be injection w/o plasma . . .



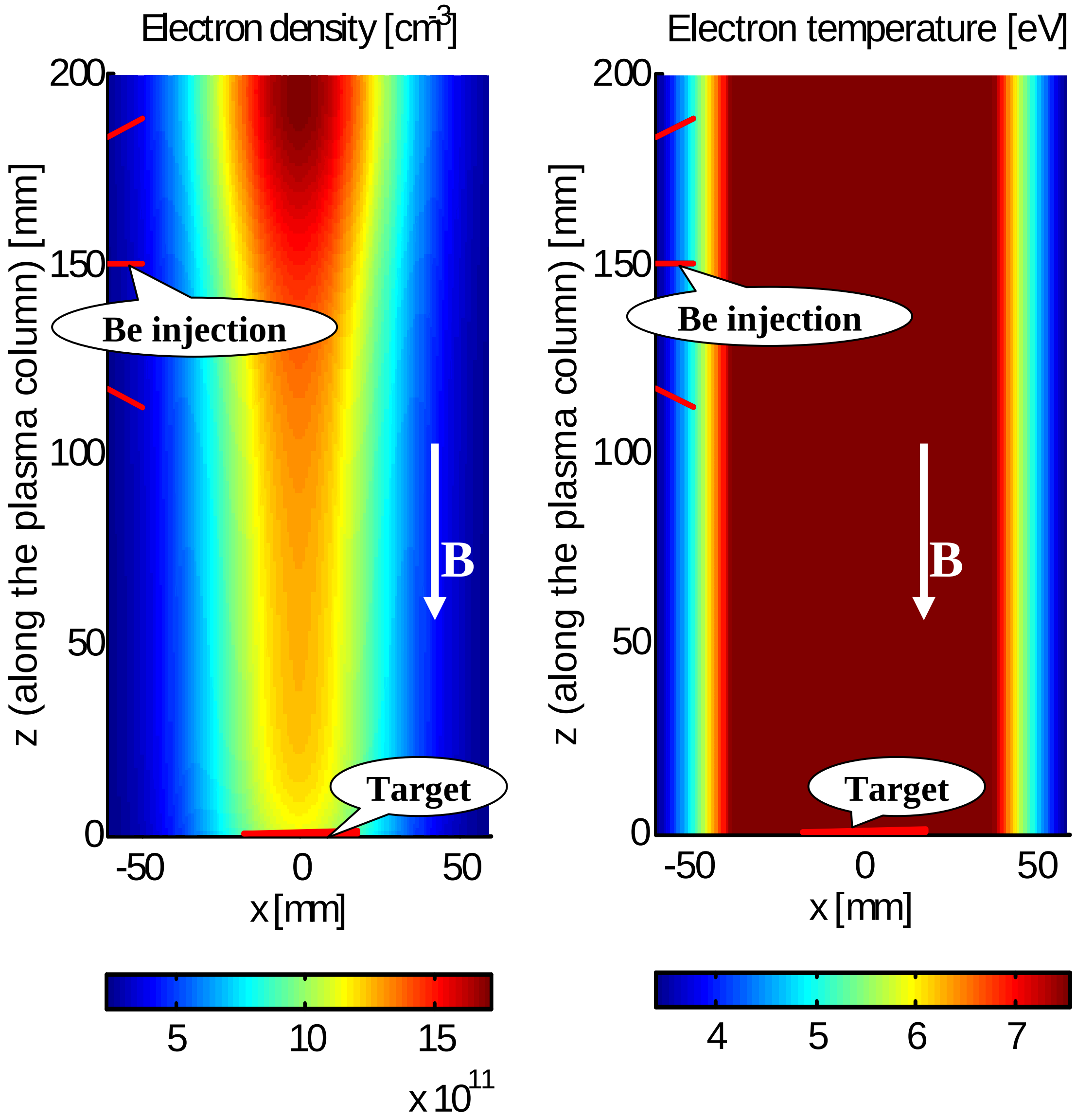


2g of Be is spent in more than 10 hours of oven operation. This gives a rate of about - **$3.7*10^{18}$Be/s**.

W/o elastic collision with neutrals there would be no Be at target!

Examples of ERO application

Plasma parameters at PISCES-B



- Plasma column width is about **5cm**
- Vessel radius is about **20cm** filled with neutral gas
- Be comes into the volume from injection or (and) as a result of Be target erosion

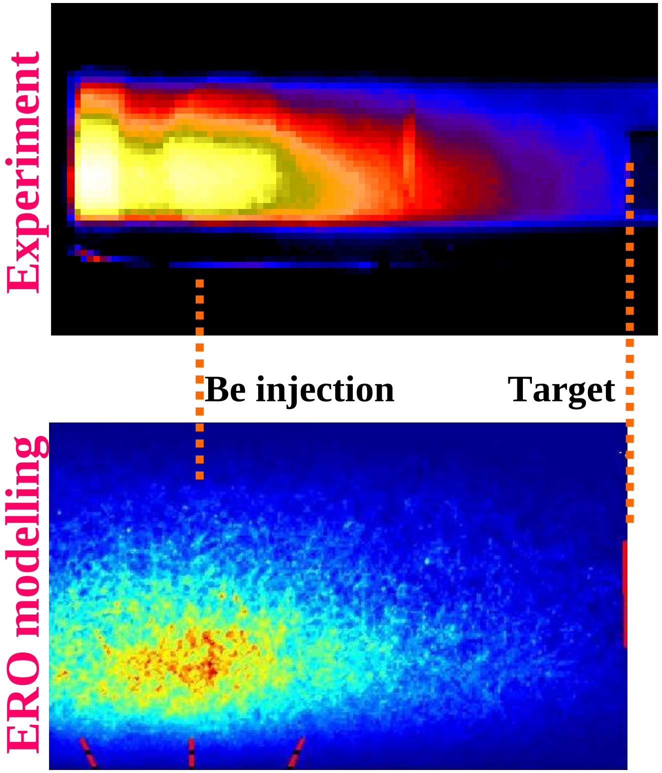
Be spectroscopy at PISCES

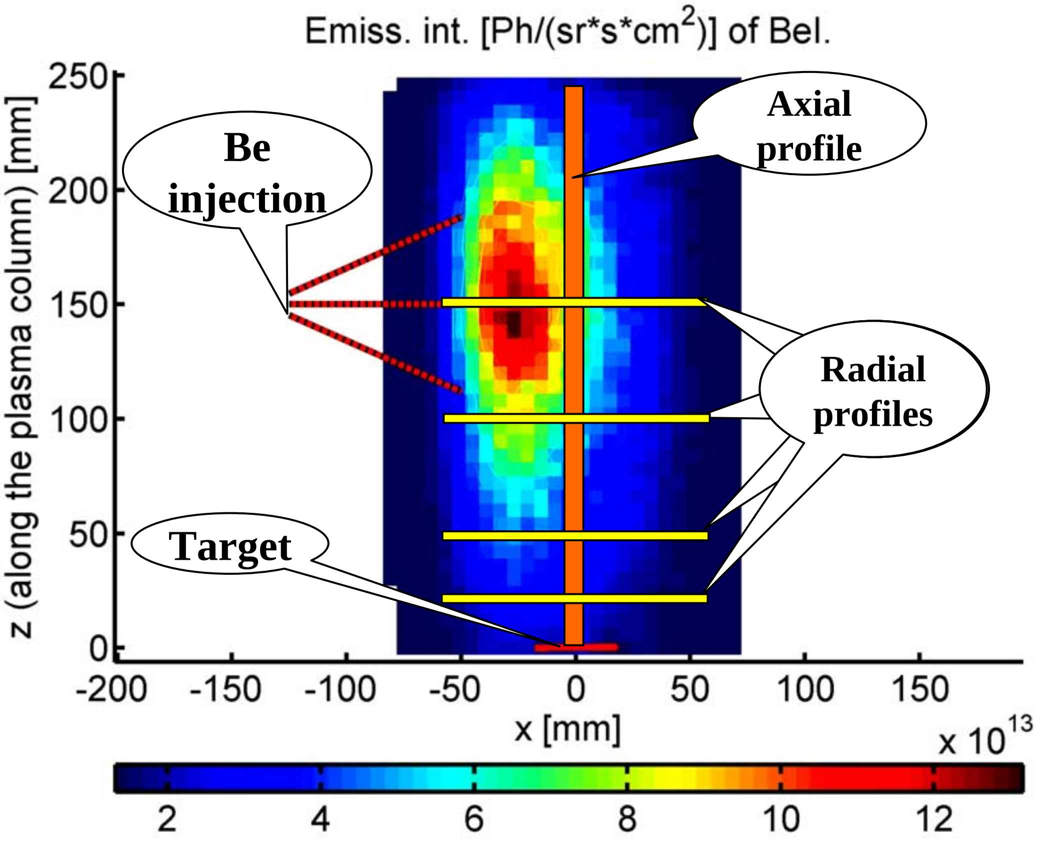
BeI, BeII emission is registered:

by 2D camera

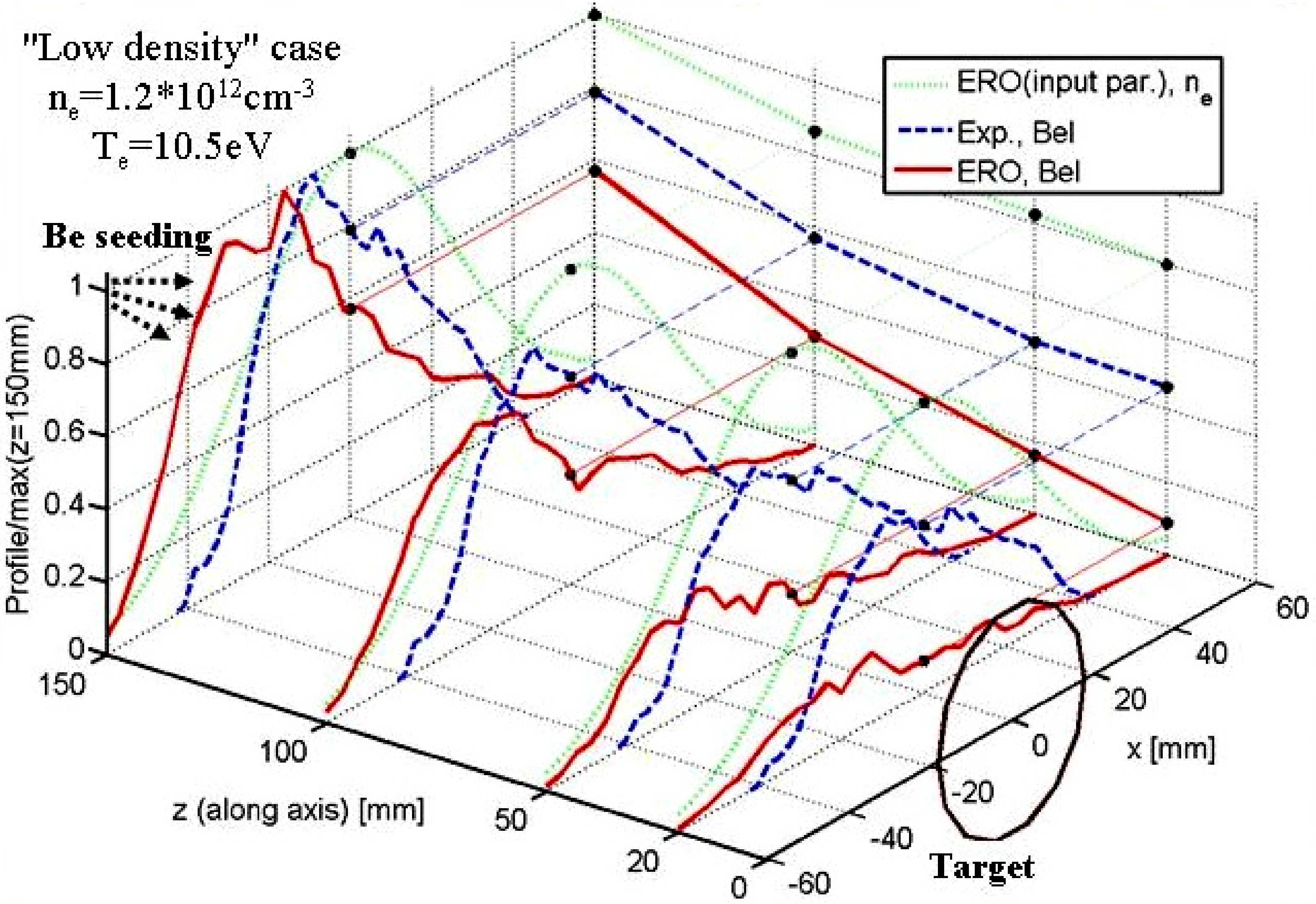
"Low density case"
($1.2*10^{12}cm^{-3}$, T_e=10.5eV)

by spectrometer with a spatial resolution (the radial profile position and direction can be varied)





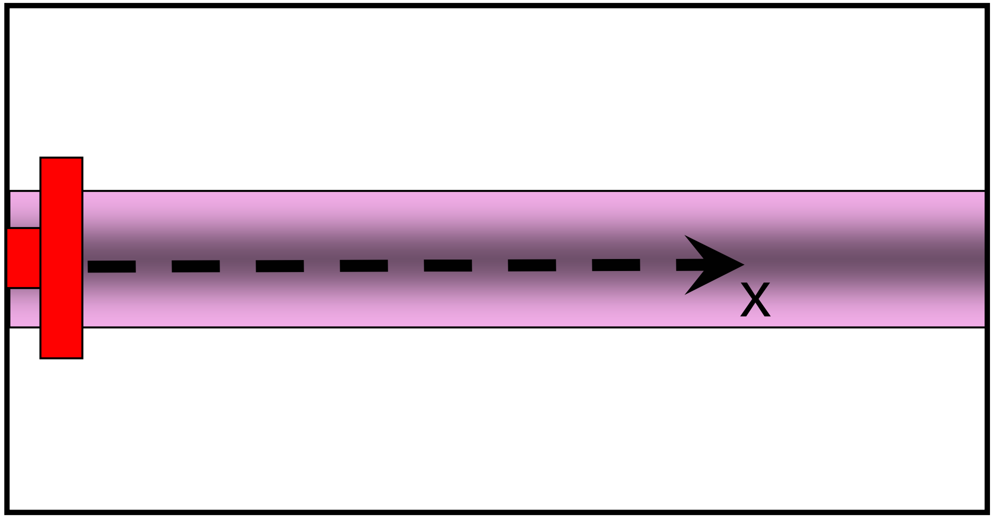
Neutral Be emission 457nm (injection)



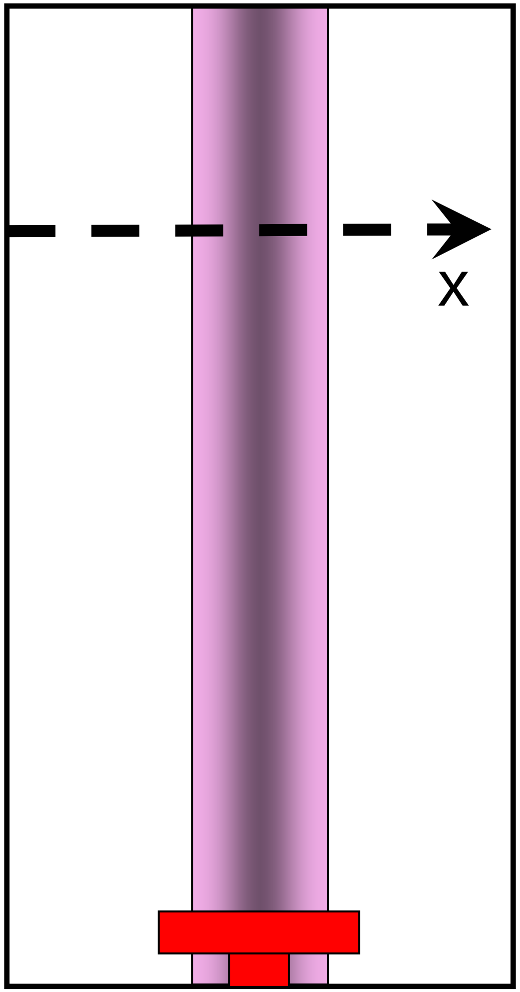
The ERO modelling is in a good agreement with experiment (PSI-2008)

Profiles direction - illustration

Be sputtering from target



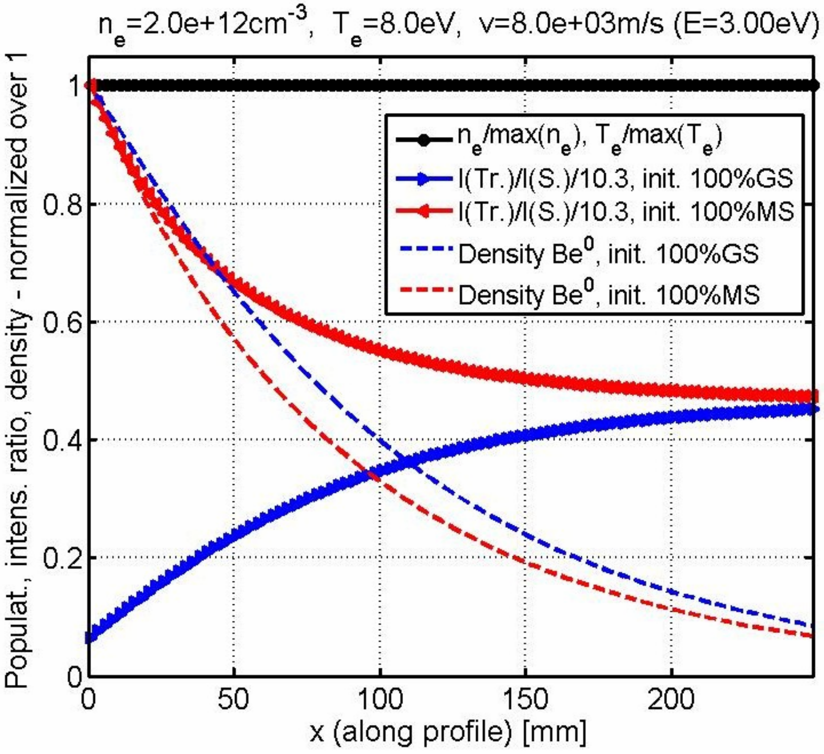
Be injection cross plasma



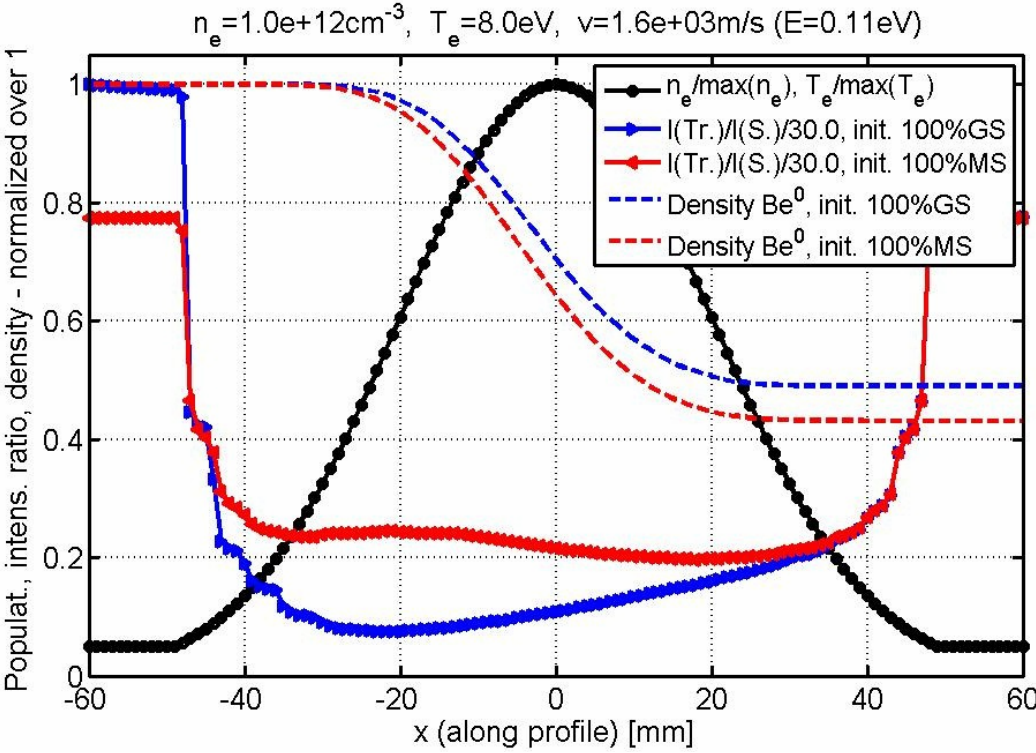
MS implementation into ERO – effect illustration

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

Relevant for sputtering from Be target . . .

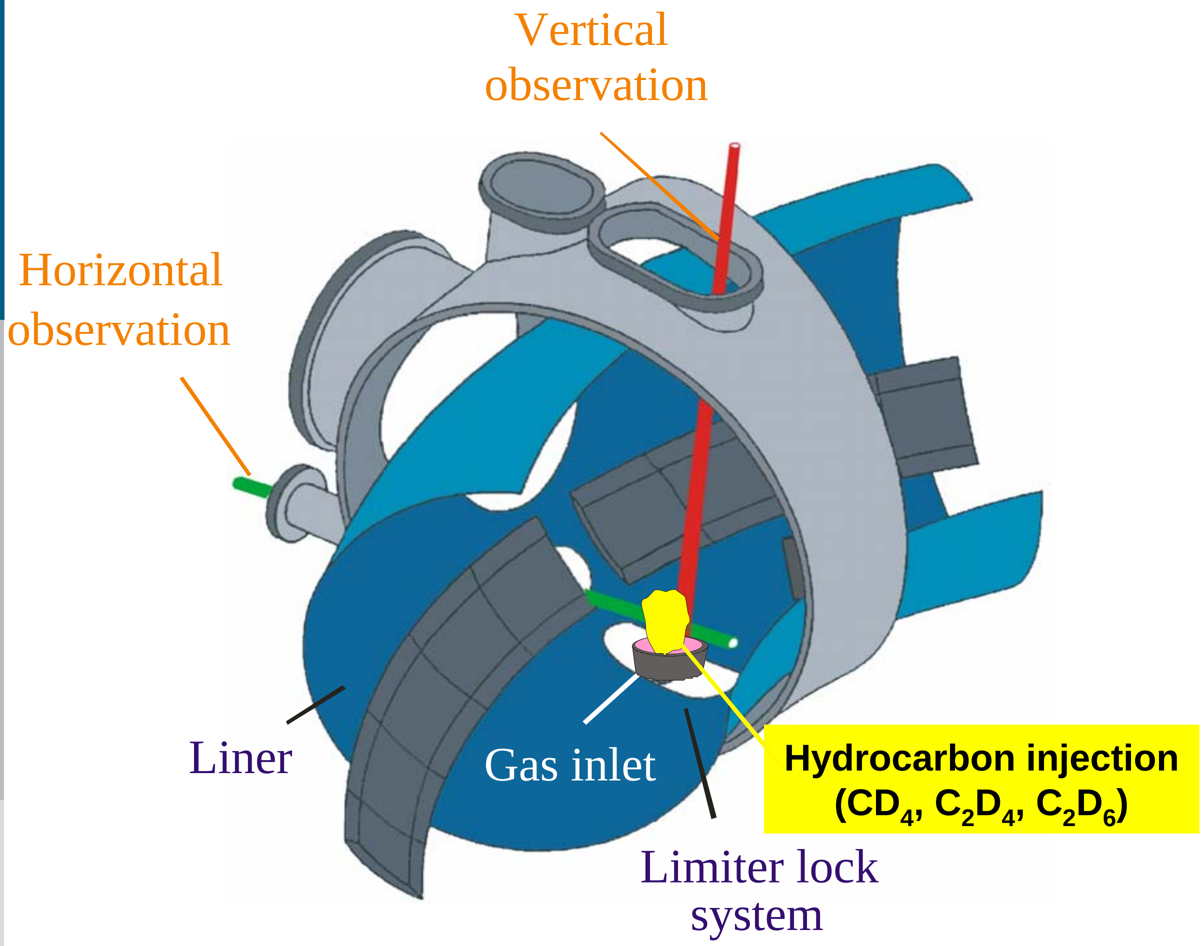


Relevant for seading from Be oven . . .



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)

Modelling of experiments with nozzle

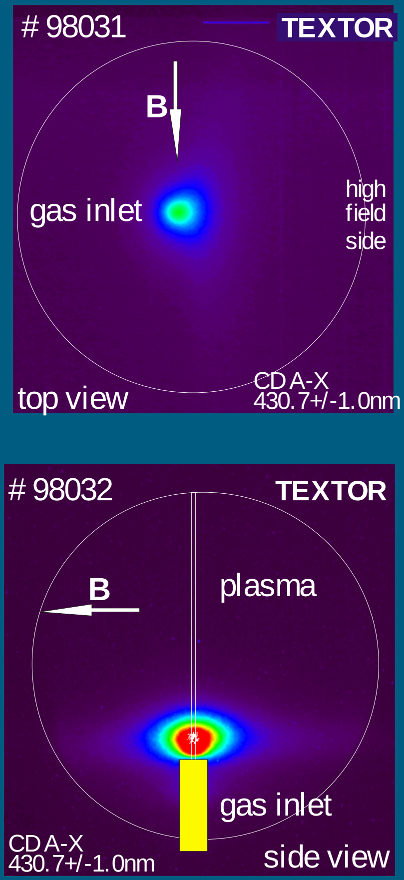


Hydrocarbon injection (CD_4, C_2D_4, C_2D_6)

$$\left[\frac{D}{XB}\right]^{CD_4 \to CD}_{A-X} = \frac{\Gamma_{CD_4}}{\phi^{CD}_{A-X}}$$

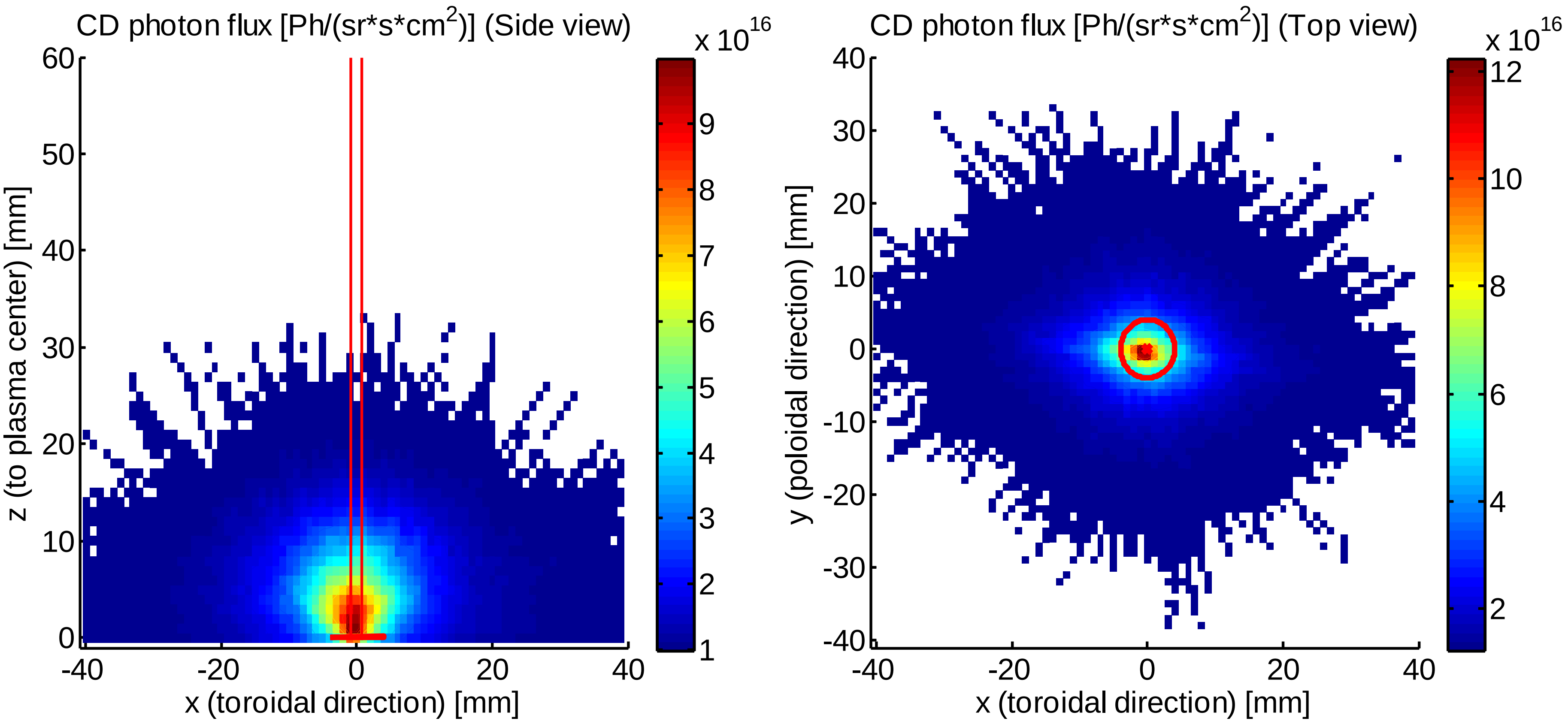
CD light emission

(CD_4 injection)



Modelling of experiments with nozzle

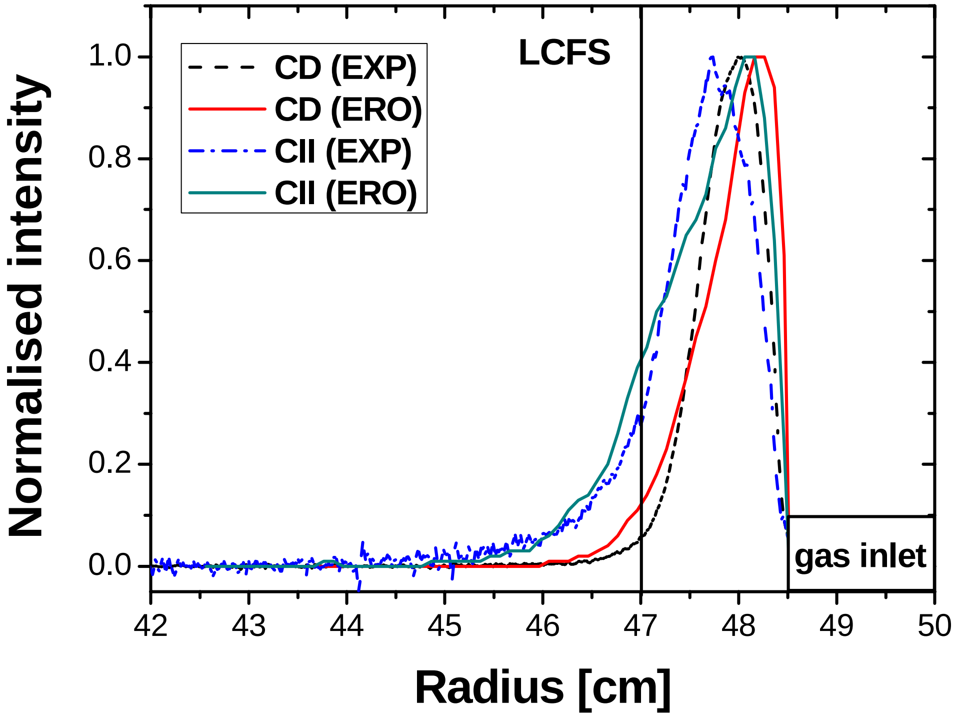
Modelled 2D light emission of CD A-X band from CD_4 injection at TEXTOR



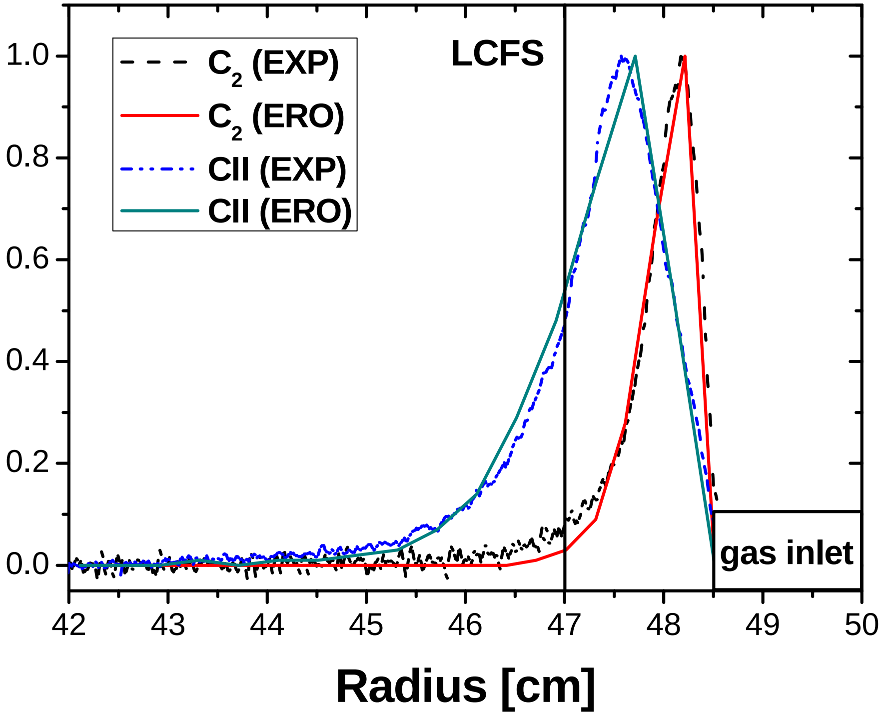
LCFS at 15 mm above inlet tip
T_e (LCFS) = 55 eV

Modelling of experiments with nozzle

Modelling vs. experiment: radial profiles of CD, C_2 and CII emission



CD_4 injection



C_2D_4 injection

Good agreement between modelled and observed penetration depths

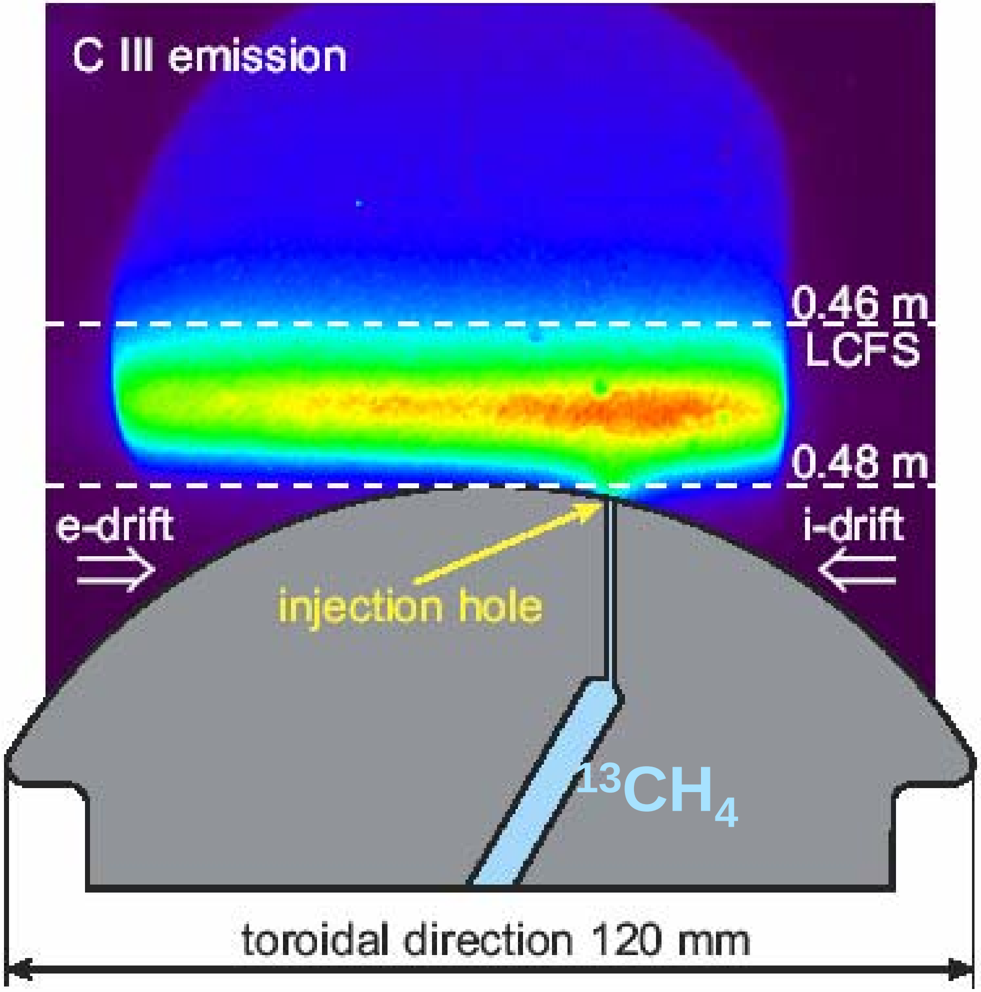
Modelling of experiments with nozzle

Comparison of effective D/XB values for CD A-X and C_2 d-a

Injected species	D/XB (CD A-X band)		D/XB (C_2 d-a band)	
	Experiment	ERO	Experiment	ERO
CD_4	36	65	930	-
C_2D_4	31	80	48	45
C_2D_6	27	76	65	62

Modelling of experiments with spherical limiters

$^{13}CH_4$ injection experiments: deposition and erosion of carbon layers



A. Kreter

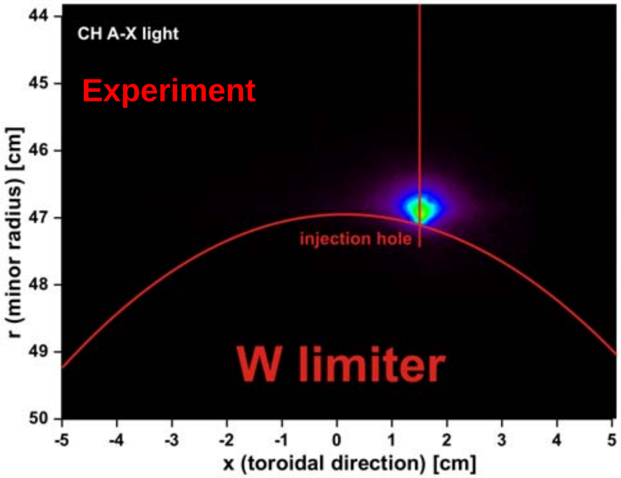
-In-situ observation of light emission above test limiter (dissociation products of CH_4).

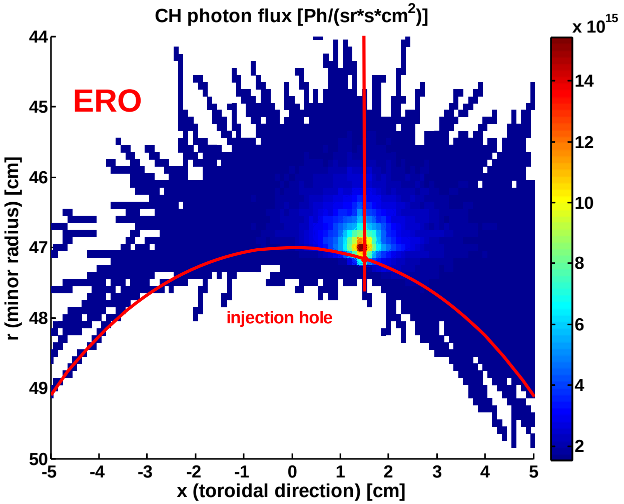
- Post-mortem surface analysis of ^{13}C (and ^{12}C) deposition.

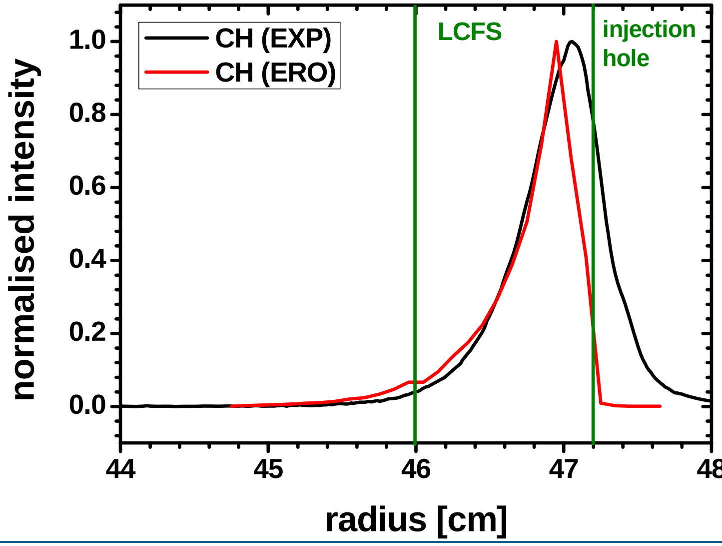
Spherical limiters – spectroscopy patterns

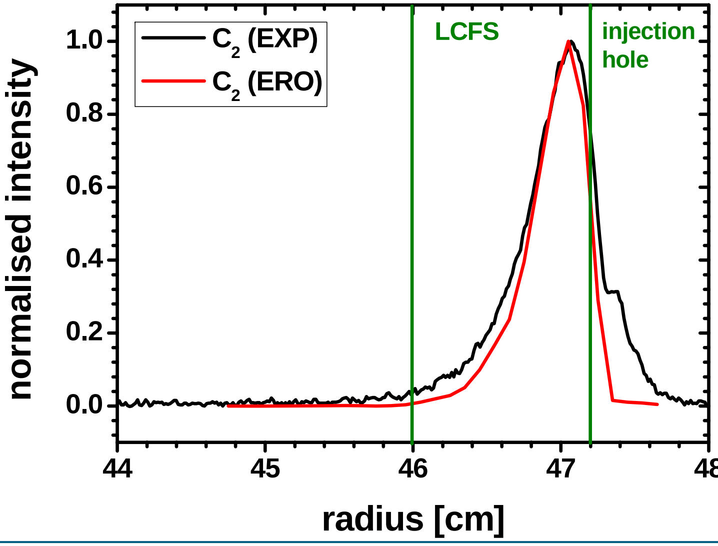
Comparison of light emission: benchmark for n_e, T_e

$^{13}C_2H_4$ injection



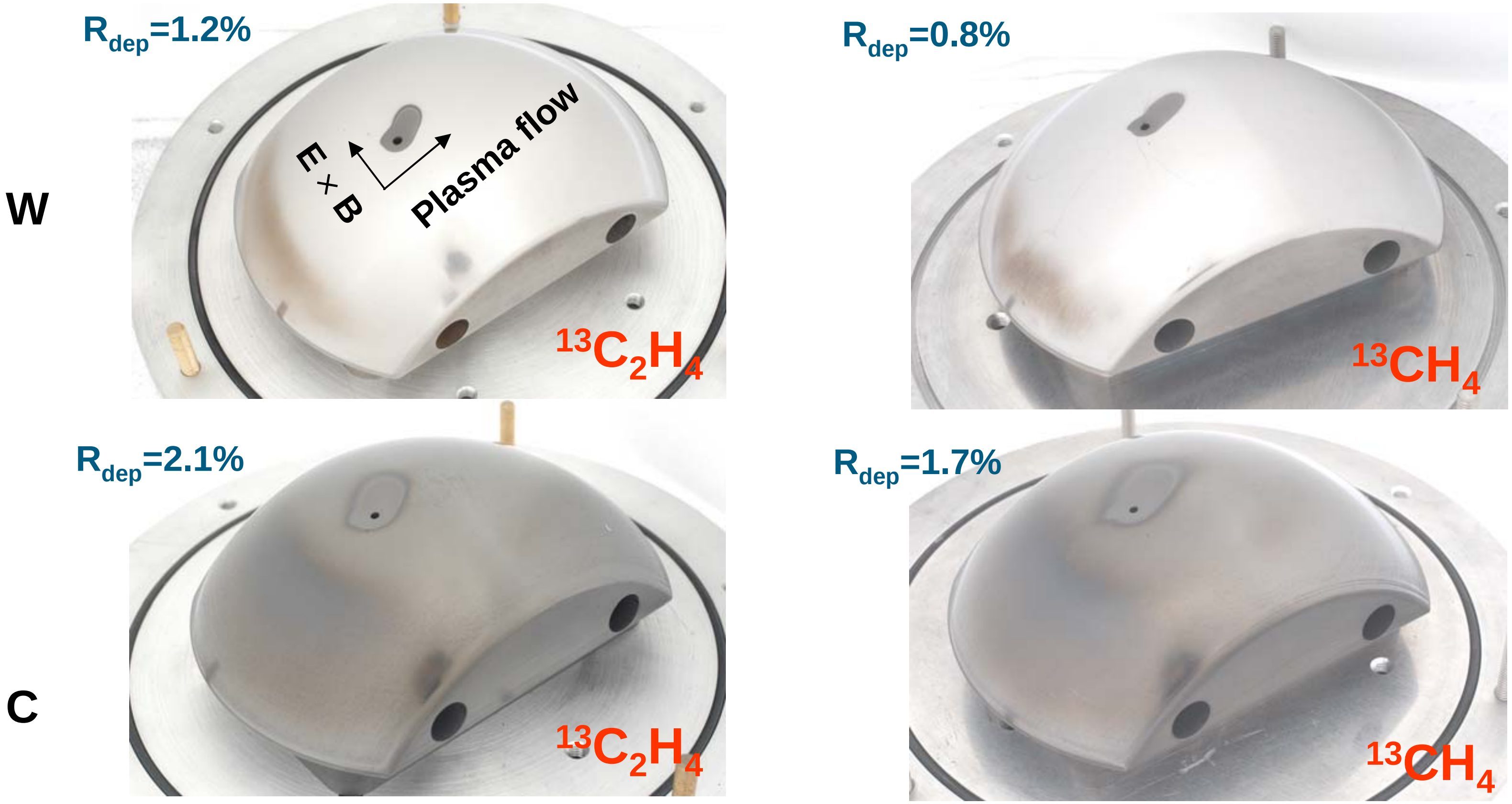






Modelling of experiments with spherical limiters

Injection of $^{13}C_2H_4$ and $^{13}CH_4$ through C and W limiters
^{13}C deposition measured by NRA



Local ^{13}C deposition efficiency R_{dep} = $\dfrac{\textit{Locally deposited } ^{13}C}{\textit{injected } ^{13}C}$

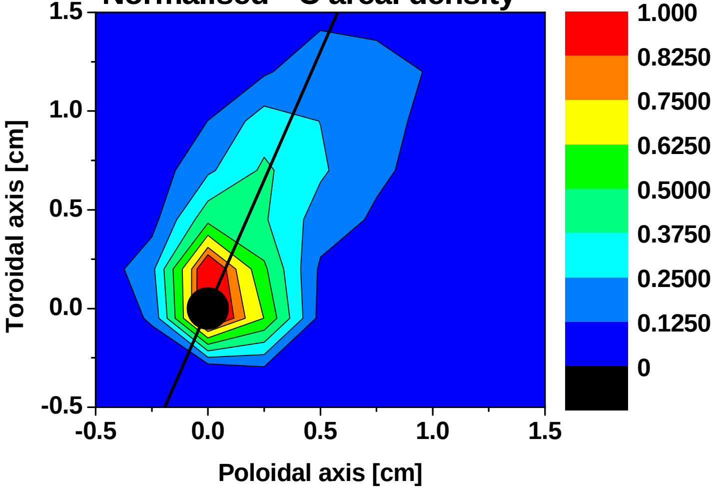
R_{dep} is higher for $^{13}C_2H_4$ than for $^{13}CH_4$ and higher on C than on W limiter

Modelling of experiments with spherical limiters

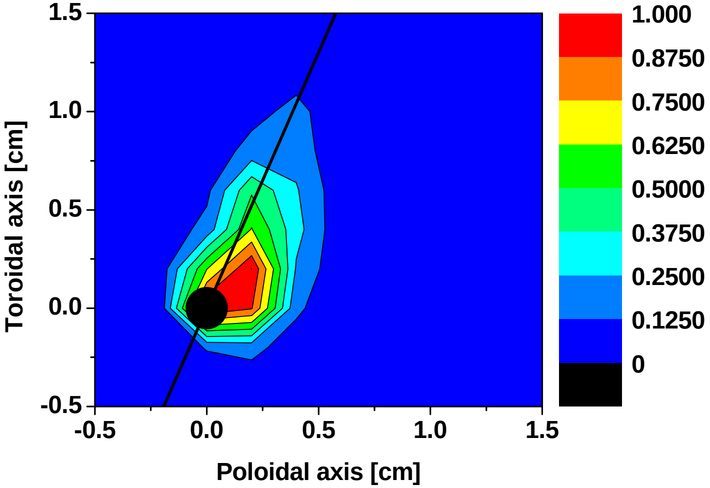
$^{13}CH_4$ injection through graphite limiter

Experiment

Normalised ^{13}C areal density



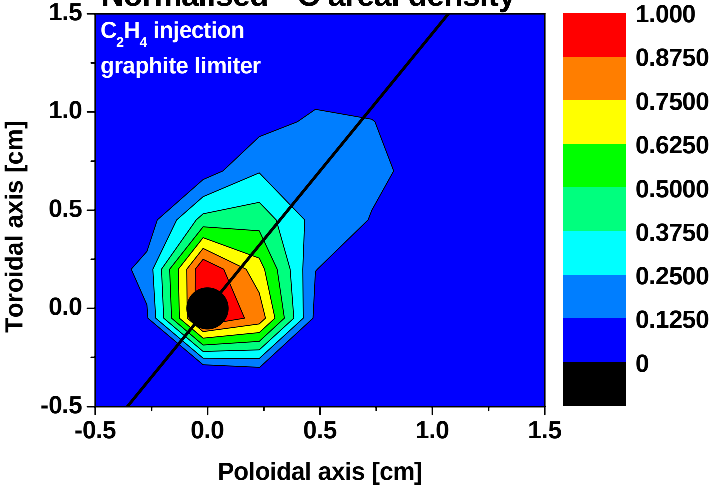
Modelling



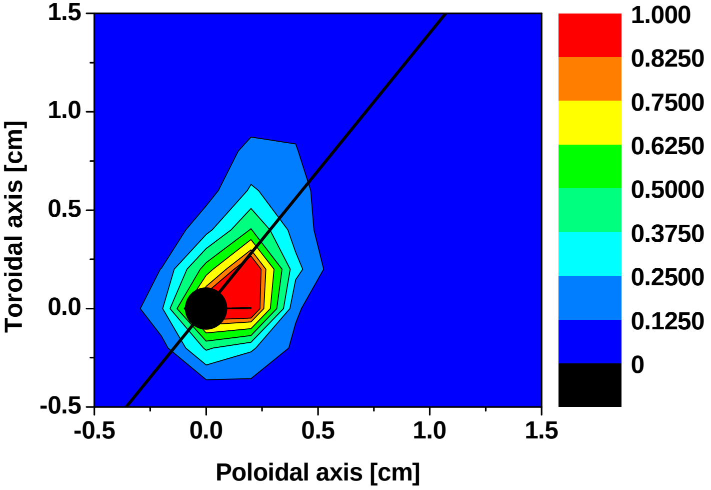
$^{13}C_2H_4$ injection through graphite limiter

Experiment

Normalised ^{13}C areal density



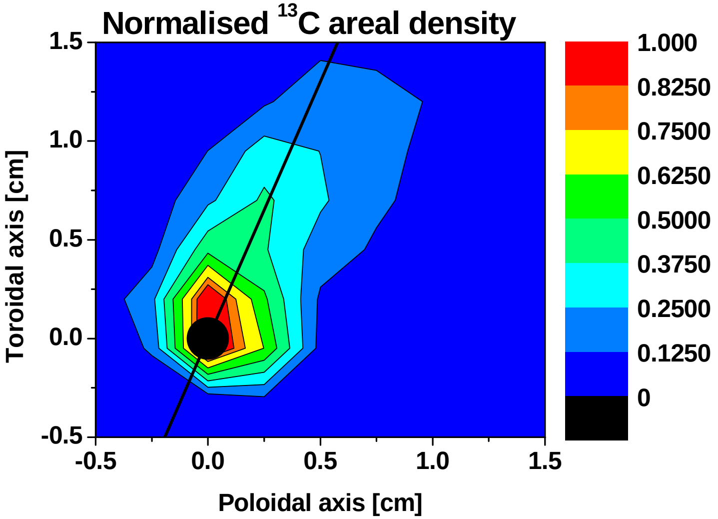
Modelling



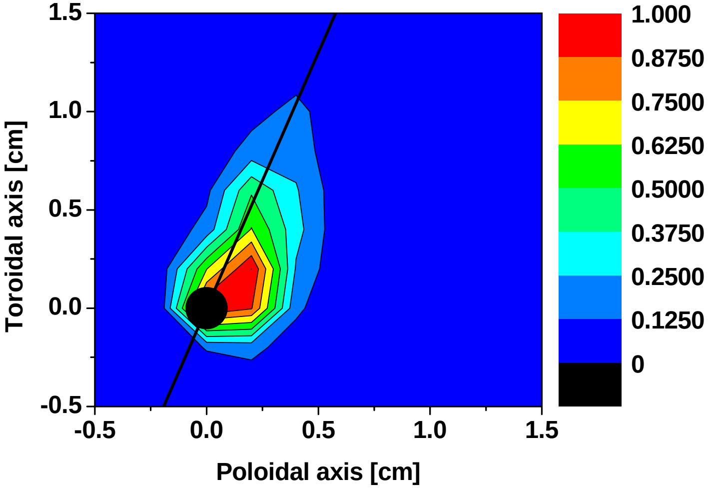
Modelling of experiments with spherical limiters

$^{13}CH_4$ injection through graphite limiter

Experiment

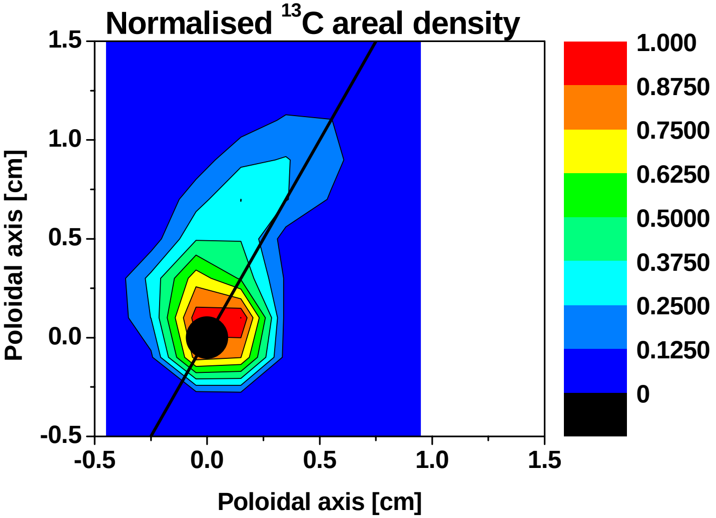


Modelling

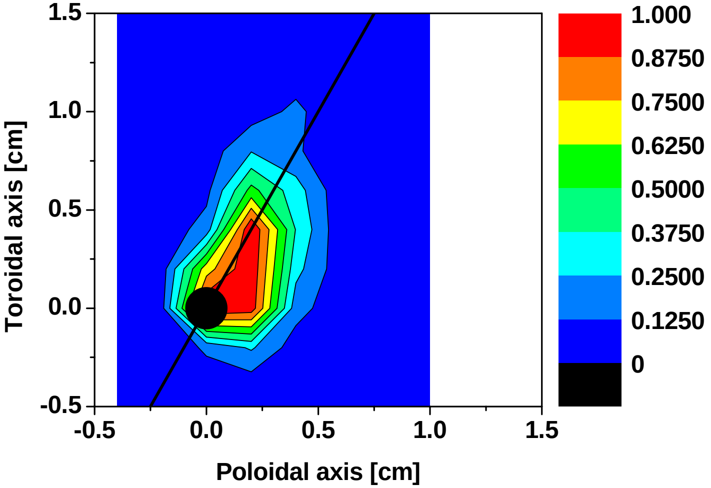


$^{13}CH_4$ injection through tungsten limiter

Experiment



Modelling



Spherical limiters – deposition efficiency

$$\text{Local } ^{13}\text{C deposition efficiency } R_{dep} = \frac{\textit{Locally deposited } ^{13}C}{\textit{injected } ^{13}C}$$

Gas	Limiter	R_{dep}	
		Experiment	ERO
$^{13}CH_4$	C	1.7 %	1.9 %
	W	0.8 %	1.1 %
$^{13}C_2H_4$	C	2.1 %	2.3 %
	W	1.2 %	1.3 %

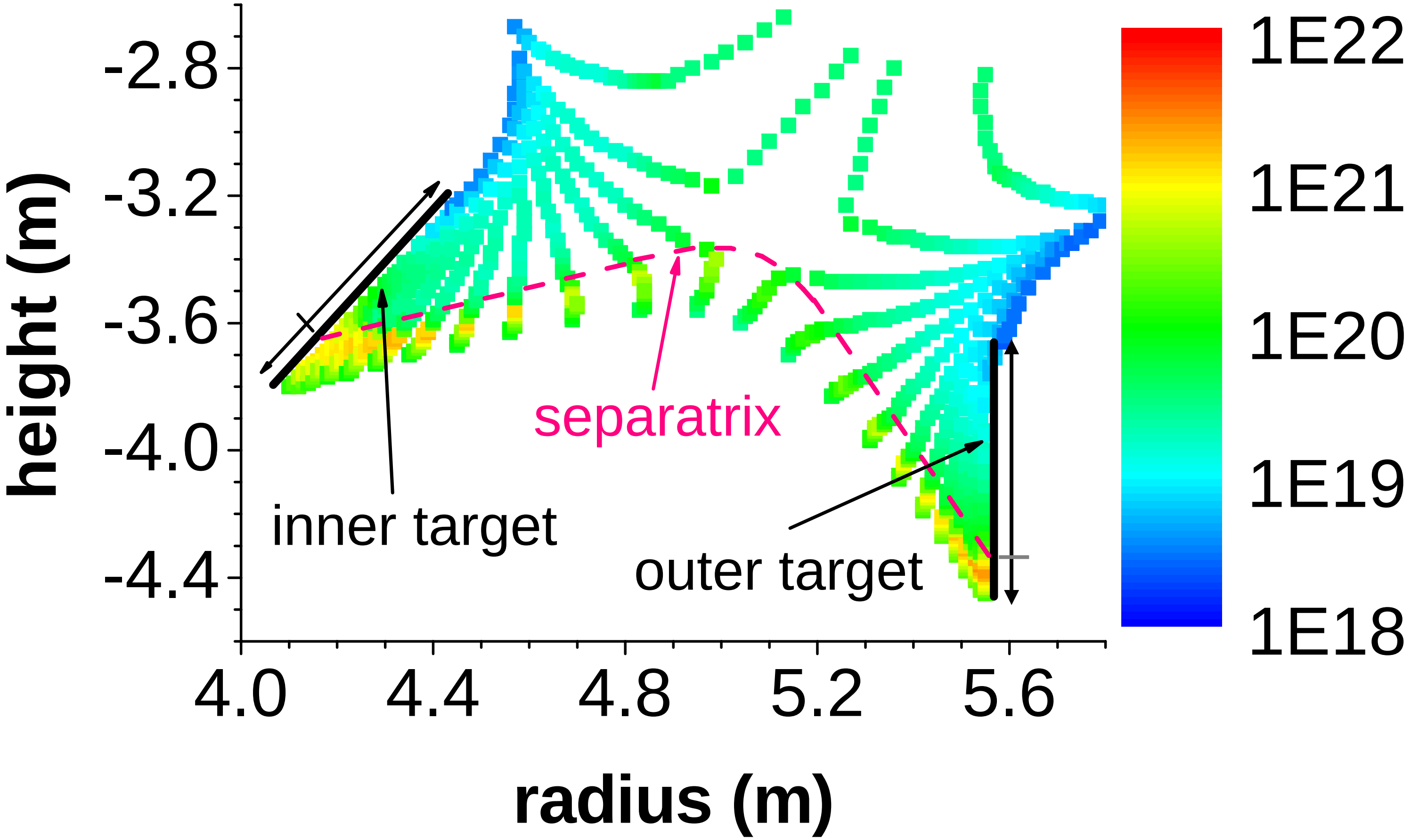
S_{eff} = 0.15
Y_{enh} = 15%

- Good agreement between experiment and modelling
- The dependency on substrate material and gases on R_{dep} is reproduced with ERO

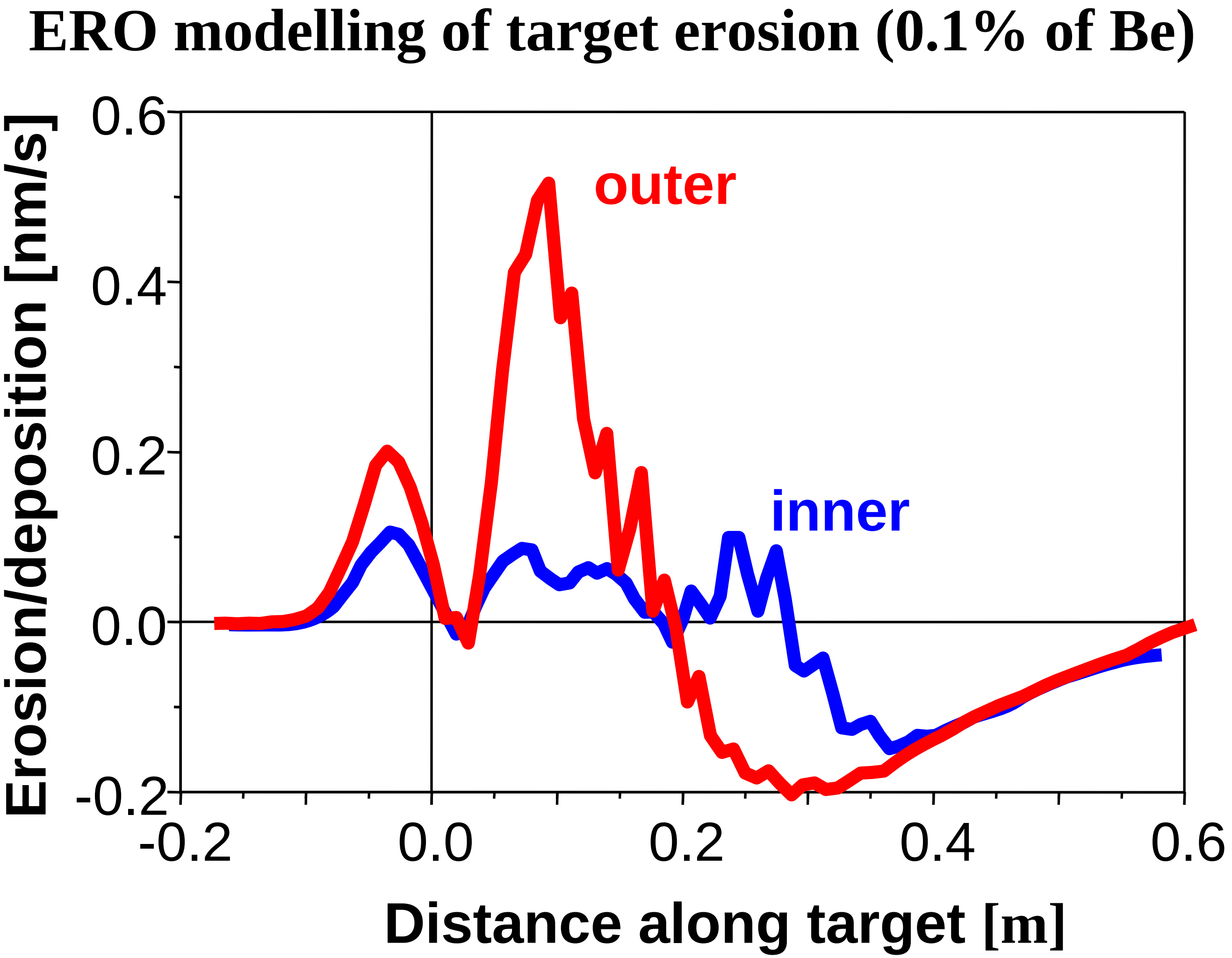
ITER availability

ERO for ITER – plasma parameters

B2-EIRENE simulations



ERO: life time of ITER divertor plates

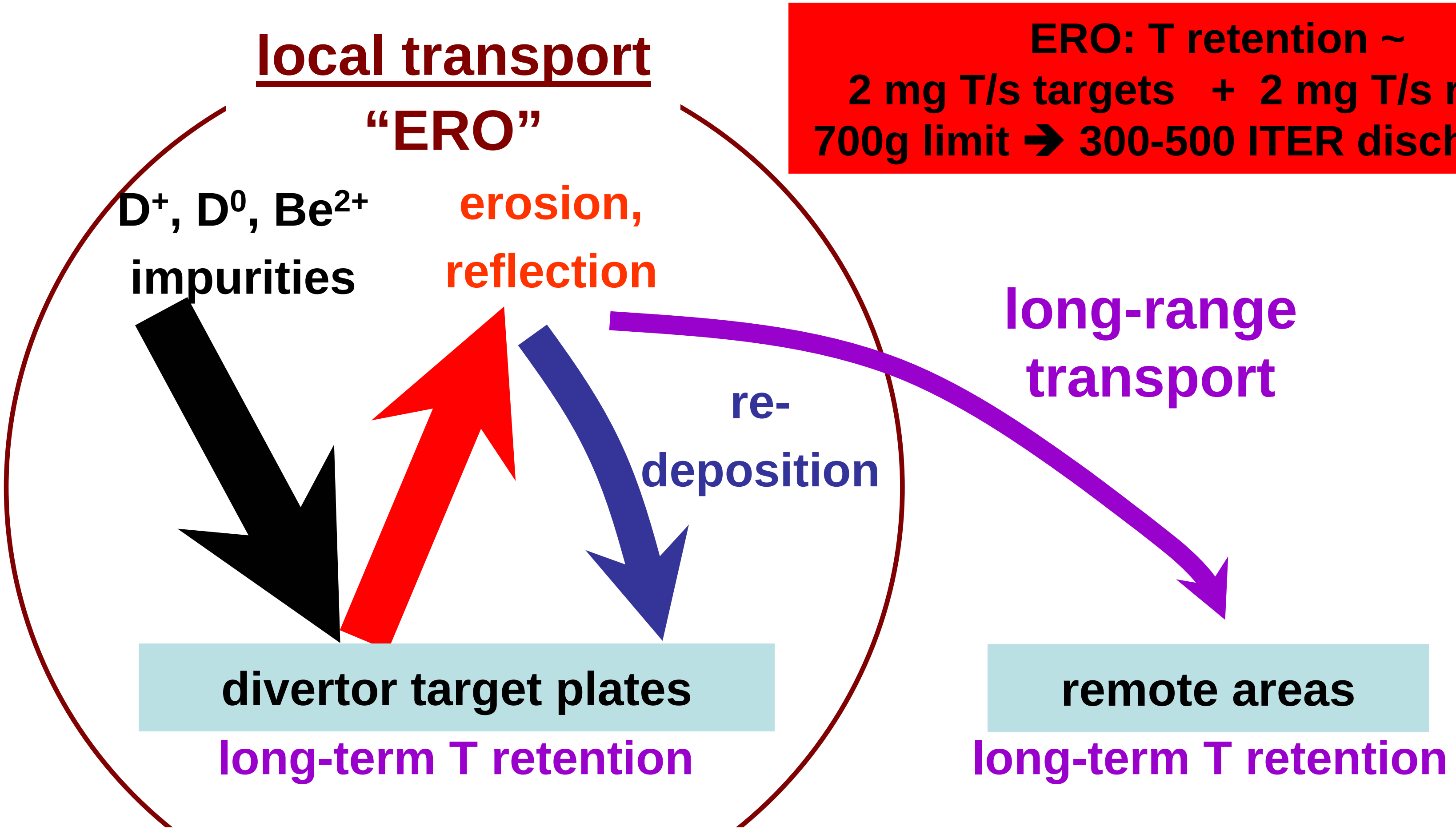


Target plates (0.5 cm) should survive at least 6900 discharges

Sweeping of strike point can increase lifetime

ERO: tritium retention in ITER

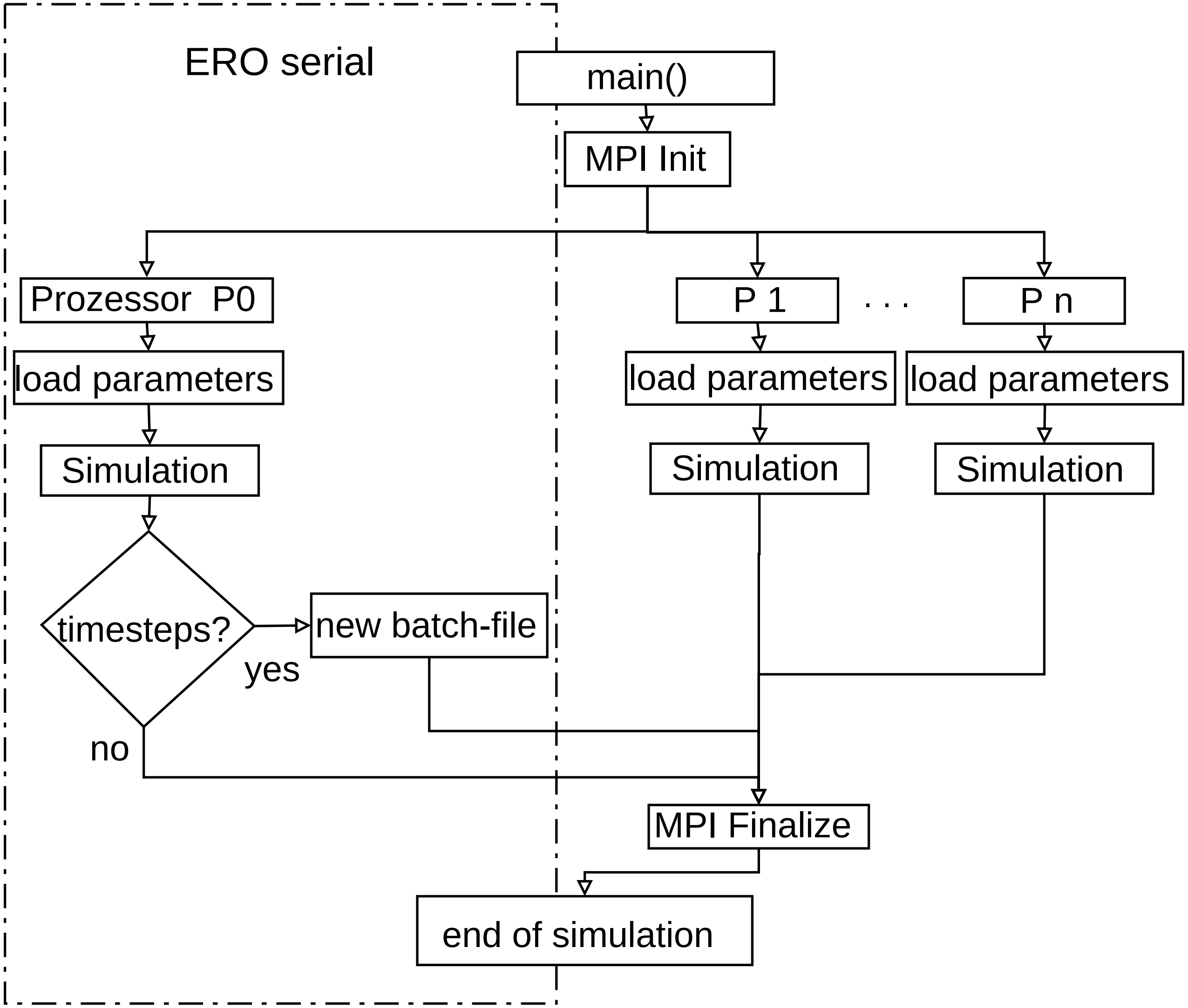
ERO: T retention ~
2 mg T/s targets + 2 mg T/s remote
700g limit ➔ 300-500 ITER discharges?!



ERO:
- local transport near to divertor plates
- background plasma as input (B2 Eirene)
- layer formation (C and Be) ⇒ T retention using T/C, T/Be

Technicalities

Parallelization: parametric (MPI)



ERO serial

main()

MPI Init

Prozessor P0

load parameters

Simulation

timesteps?

yes

new batch-file

no

P 1

. . .

P n

load parameters

Simulation

load parameters

Simulation

MPI Finalize

end of simulation

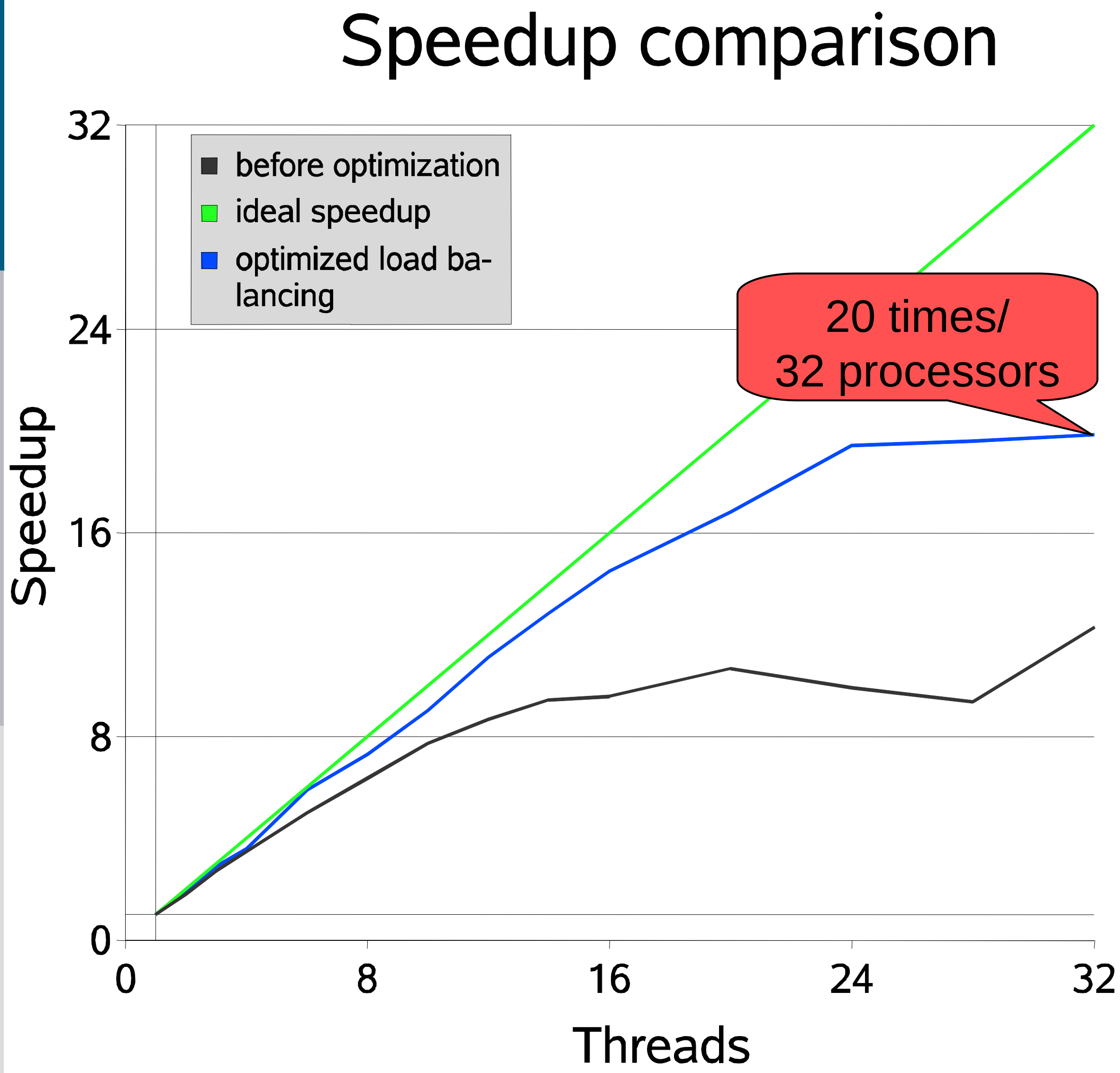
N ERO runs are substituted by 1 run on N processors ***(calculation time remains the same!)***

Each processor gets modified parameter file, working directory, generates all usual ERO output files.

For automatization a special “**starter**” program is developed

Data exchange between processors is minimal – MPI (message passing interface) is optimal

Parallelization: shared memory



Processors get portions (“chunks”) of MC test particles for calculation

Particles are not fully independent!

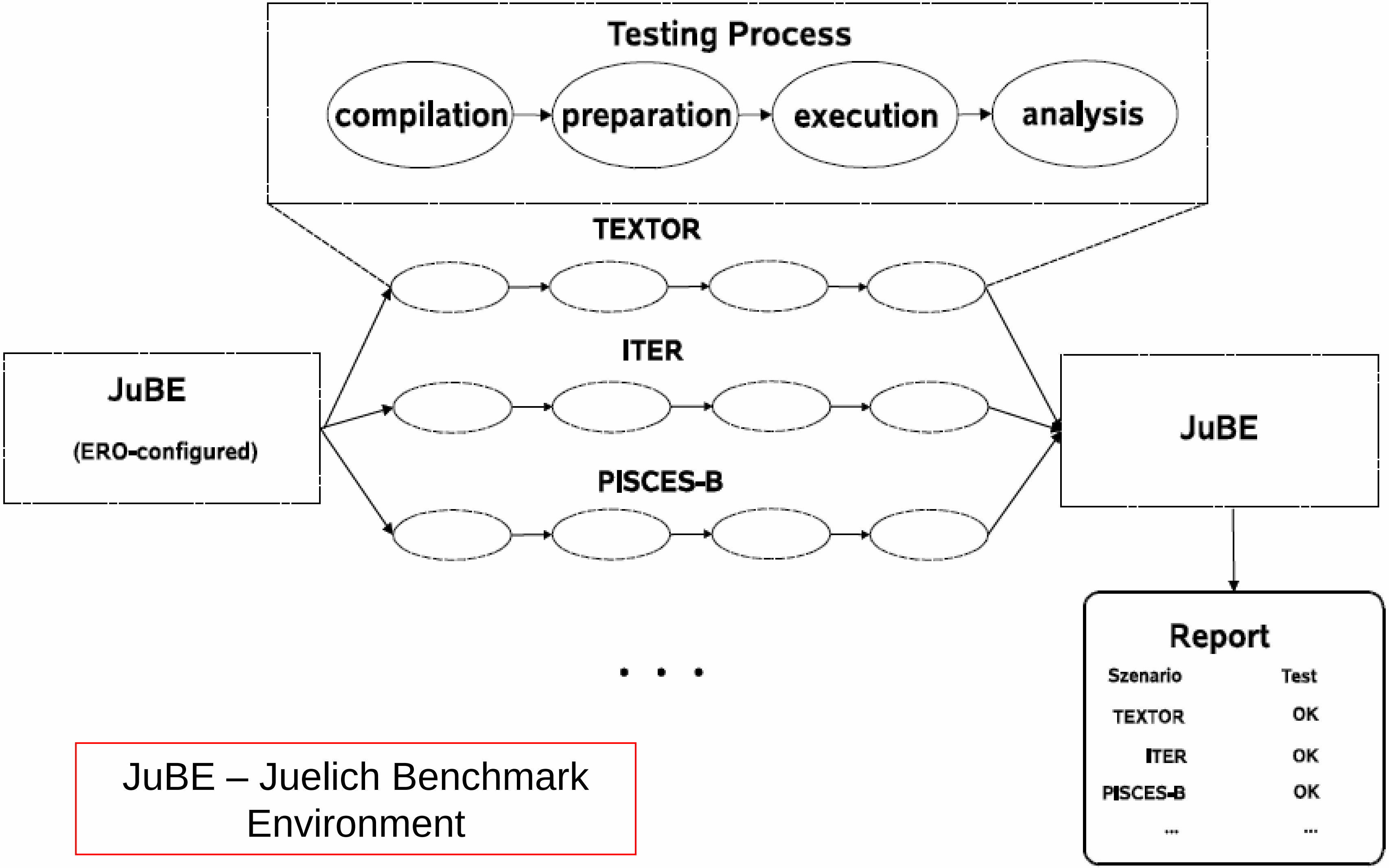
They change the volume and surface meshes (occupying most part of memory used by ERO)

Shared memory (OpenMP) approach is optimal

Optimization:

- Minimization of serial part
- Processor load balancing
- Cashe memory usage

Automatic testing system for ERO

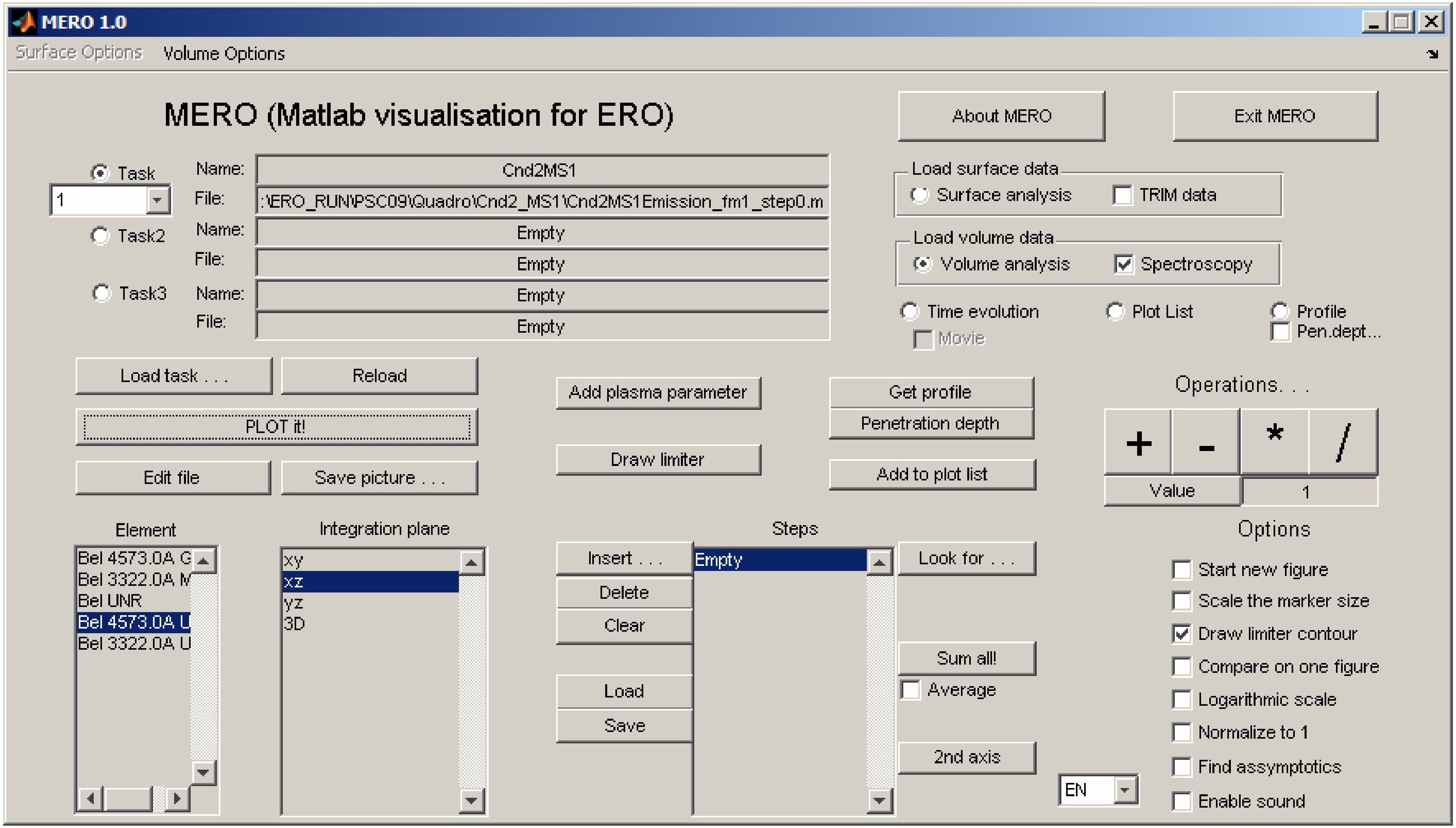


Szenario	Test
TEXTOR	OK
ITER	OK
PISCES-B	OK
...	...

JuBE – Juelich Benchmark Environment

Visualization: MERO

(Matlab visulalization GUI for ERO)



MERO (Matlab visualisation for ERO)

● Task 1
Name: Cnd2MS1
File: :\ERO_RUN\PSC09\Quadro\Cnd2_MS1\Cnd2MS1Emission_fm1_step0.m

○ Task2
Name: Empty
File: Empty

○ Task3
Name: Empty
File: Empty

Load surface data
○ Surface analysis ☐ TRIM data

Load volume data
● Volume analysis ☑ Spectroscopy

○ Time evolution
☐ Movie
○ Plot List
○ Profile
☐ Pen.dept...

Value: 1

Element
Bel 4573.0A G
Bel 3322.0A M
Bel UNR
Bel 4573.0A U
Bel 3322.0A U

Integration plane
xy
xz
yz
3D

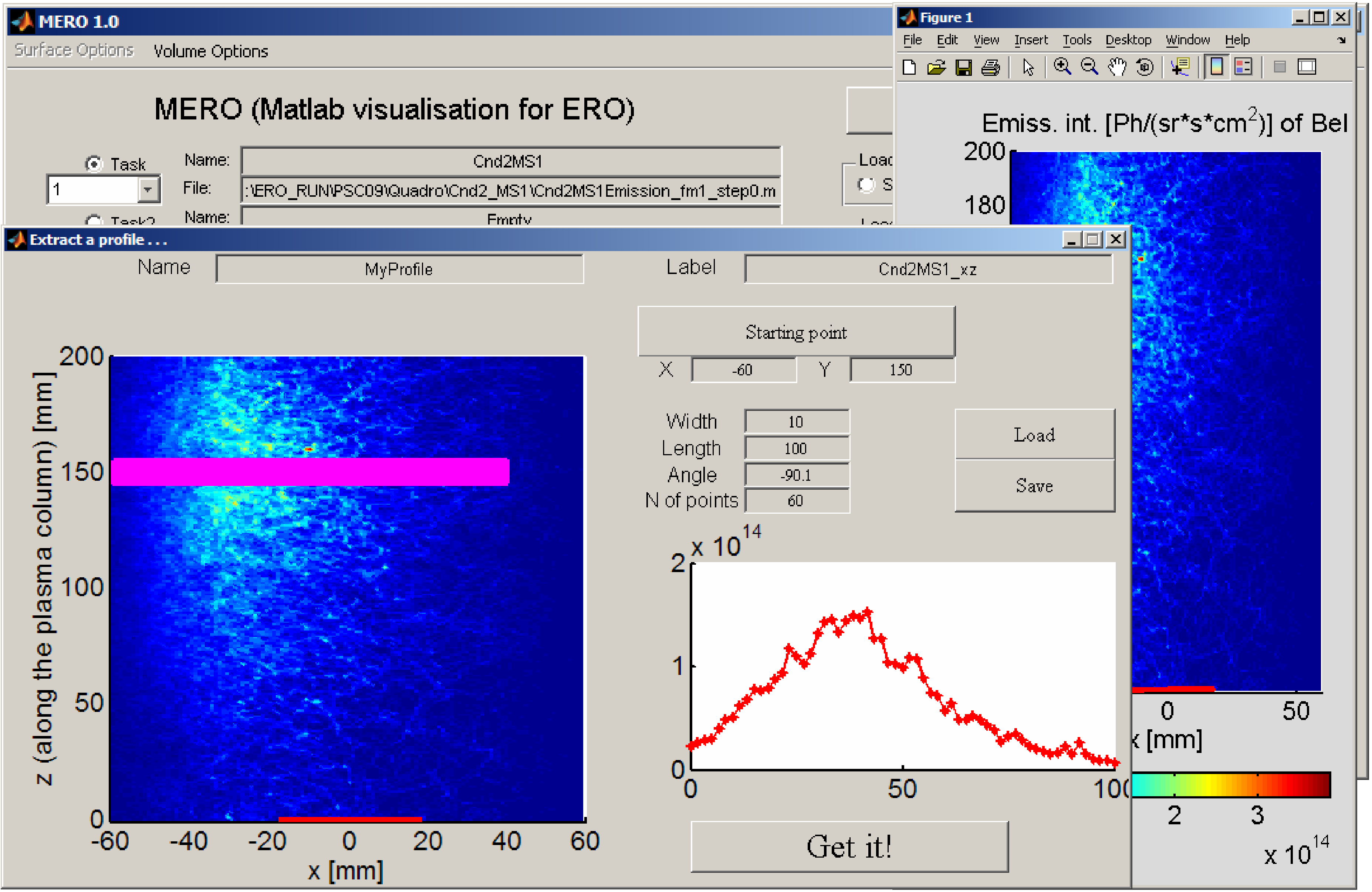
Steps
Empty

☐ Average

EN

Options
☐ Start new figure
☐ Scale the marker size
☑ Draw limiter contour
☐ Compare on one figure
☐ Logarithmic scale
☐ Normalize to 1
☐ Find assymptotics
☐ Enable sound

Visualization: MERO



MERO 1.0

MERO (Matlab visualisation for ERO)

● Task 1 — Name: Cnd2MS1 — File: :\ERO_RUN\PSC09\Quadro\Cnd2_MS1\Cnd2MS1Emission_fm1_step0.m

○ Task2 — Name: Empty

Extract a profile . . .

Name: MyProfile

Label: Cnd2MS1_xz

Starting point — X: -60, Y: 150

Width: 10

Length: 100

Angle: -90.1

N of points: 60

Figure 1

Emiss. int. [Ph/(sr*s*cm^2)] of BeI

In spite of a summary . . .

How important is ADAS for ERO?

1) **Ionization/recombination** processes directly influence the particle **transport** in plasma.

2) For some species (e.g. H) **opacity** is not zero – radiation is an energy **transport channel**.

3) Spectroscopy gives **indispensable information** for model **benchmarking** (both qualitative and quantitative).

End