Simple Probabilistic Approach to Evaluate Radioiodine Behavior at Severe Accidents: Application to PHEBUS Test FPT1

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OUTLINE

- what it is containment iodine modeling and why to try probabilistic approach to it
- various possible ways of probabilistic modeling of iodine behavior
- use of the containment iodine event tree for PHEBUS FPT1 analysis
- conclusions

INTRODUCTION

Probabilistic approach to containment iodine modeling

—What for?

- big uncertainties in deterministic modeling

different codes are giving "widespread" answers as for the volatile iodine concentrations in a (post)accident containment atmosphere —cf. ISP-41 F2

- also, a certain controversy exist today among the international research community about the relative importance of the processes leading to volatile iodine formation in containment (e.g. RI formation in atm, I oxidation by ozone)

Thus, simple probabilistic approach is proposed as a complement (or even as an alternative in some instances) to deterministic analyses of iodine behavior

main objective of this work

- to have a simple tool to assess the relative importance of selected processes and mechanisms governing iodine behavior at an accident

final goal is the characterization of uncertainties of the description of various processes in question

this would allow for identification of the processes contributing most significantly to the overall uncertainty of the predictions of iodine volatility in containment

for containment iodine behavior modeling, probabilistic approach has not been used (?), probably because of the role of kinetics of the governing processes: governing processes (reactions) are relatively slow, i.e. reaction rates (kinetics) are important —this is rather difficult to model

in this it differs from the RCS iodine behavior and from all other FPs behavior

chosen approach to probabilistic analysis

dedicated, small event tree to describe iodine behavior at an accident evaluated with the EVNTRE code

outcome of the evaluation is the fraction of volatiles (I2+RI) in containment atm (for a given path through the tree)

at equilibrium or maximum or whatever is needed

such fraction represents a single number which is a good indicator of the iodine volatility —example will be given for FPT1 iodine modeling

only containment part of the scenario progression is modeled by the tree (first question being about the source distribution of iodine to containment)

in principle, it would not be too difficult to encompass also the RSC iodine behavior —release from fuel and RCS transport and retention

CONTAINMENT IODINE EVENT TREE

COMPRISES —POTENTIALLY— ALL THE IMPORTANT CHARACTERISTICS (VALUES OF PARAMETERS ETC.) AND PROCESSES WHICH INFLUENCE IODINE BEHAVIOR

- initial distribution of I entering the containment among its various forms
- simplified aerosol depletion
- presence and nature of organic materials in containment
- sump water pH
- mass transfer of volatiles and sorption constants of I2
- temperatures, dose rates in containment
- Ag source to sump

AND ALSO SOME OTHERS

the most important processes are radiochemical reactions producing volatile iodine species (I2, RI) from non-volatile forms (I^-)

VARIOUS WAYS OF IODINE BEHAVIOR MODELING IN CONTAINMENT IODINE EVENT TREE

iodine behavior here = mostly (slow) formation of volatiles [speciation of iodine]

and their transport in containment

FOR INSTANCE, 3 DISTINCTIVE WAYS COULD BE THOUGHT OF (REAL CASE WOULD BE A MIXTURE OF SOME OF THEM)

- containment iodine code supplies some numbers to the tree before the tree evaluation
- sort of rough modeling of iodine behavior where, for example, oxidation of aq I^- is represented by a steady-state I2 conc (given known values of parameters controlling this) and other important processes also simplified

  simple models can then be called from within the tree during the tree evaluation using so called User Functions of the EVNTRE (some coding needed)

  probably the best way for the whole-plant analyses (PRA Level 2)
- cont iodine code calculating speciation of iodine for most of the tree outcomes called directly from within the tree

  —used in this work for FPT1 iodine behavior analysis (i.e. for analysis of iodine behavior in experiment)

CONTAINMENT IODINE CODE CALLED DIRECTLY FROM WITHIN THE TREE (again, a lot of extra coding to the EVNTRE User Functions needed)

- a set of selected input values to the code run can correspond to the given path through the tree
  - even the start and the end of the code calculation can be supplied for repeated blocks of the same or similar questions —different phases of the accident sequence (possibly with different boundary conditions) can be traced such a way

final oucomes of the tree evaluation are mass fractions of volatile iodine (I2+RI) in containment atm, as calculated by the iodine code —evaluated at the end of iodine code run

not all of the tree oucomes necessarily calculated by the code —some paths can lead to simple answers

both the number of paths through tree going to a particular outcome and the value (one) characterizing for instance, fraction of volatiles in atm (for a given path) can be, in principle, obtained in a single EVNTRE run

(so called "sampling" mode of EVNTRE run has been used)

containment iodine event tree —application to PHEBUS FPT1

French iodine containment code IODE (from the ASTEC suite of codes) was used

all the necessary coding to EVNTRE has been done under UNIX (LINUX) which enables great flexibility in calling the system (and, then, any UNIX script or any program, such as ASTEC) from EVNTRE

in containment iodine event tree for FPT1, some otherwise important questions are not asked: typically those about sump water pH and temperatures and dose rates in cont —no need here for sensitivity on those

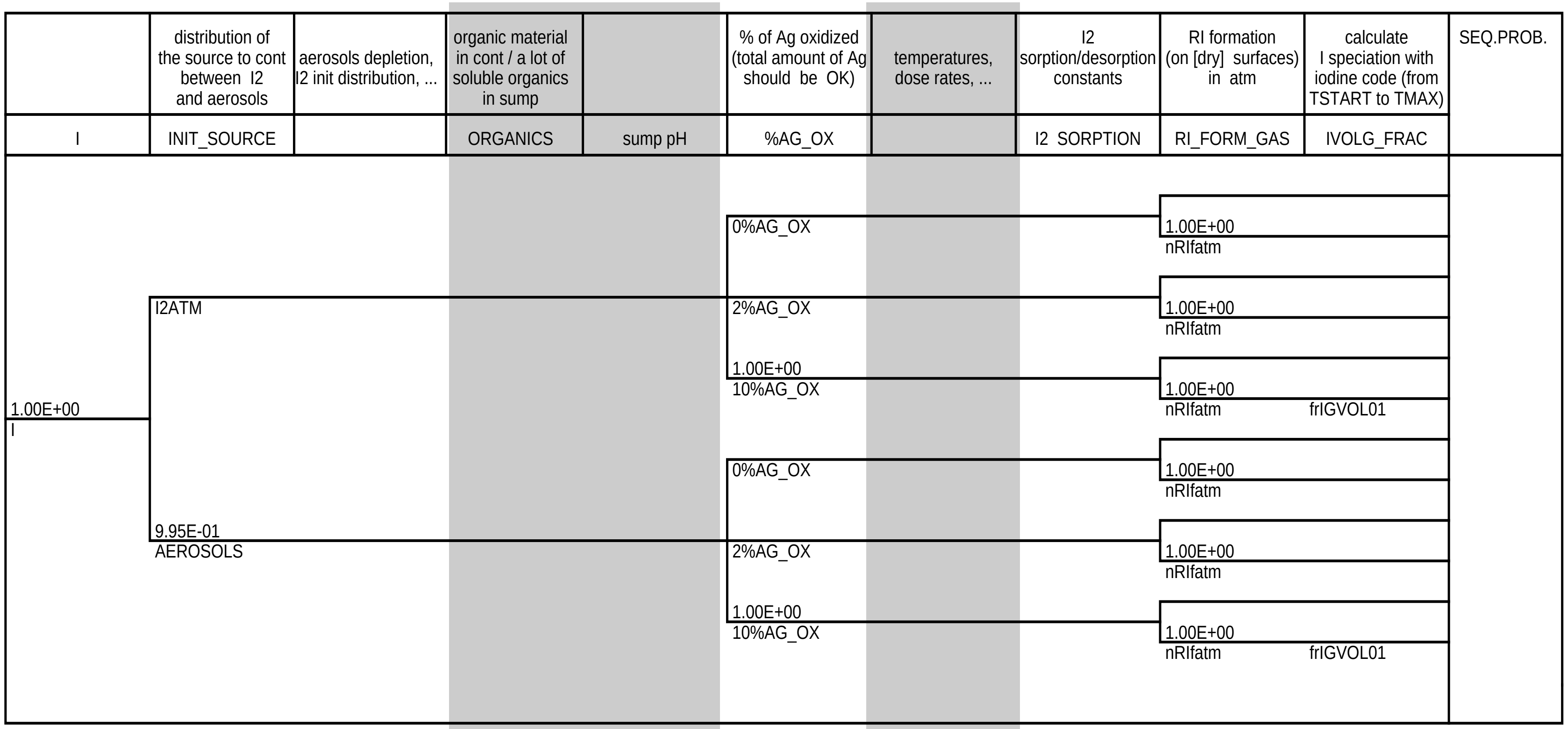
also, basic reactions in water (I^- radiolytic oxidation to I2, and I2 reduction) were not studied

principal reactions whose impact on iodine volatility in FPT1 was studied

- heterogeneous RI formation in gas phase of the containment
- reactions of AgI formation in sump

some sensitivity has been done also for mass transfer of volatiles and I2 sorption constants

containment iodine event tree —application to PHEBUS FPT1



CONTAINMENT IODINE EVENT TREE -PHEBUS FPT-1

PHEBUS FPT1 iodine experimental data for modeling

FPT1 iodine bundle inventory: 1.12g

total amount of iodine which got to containment: ~0.7g

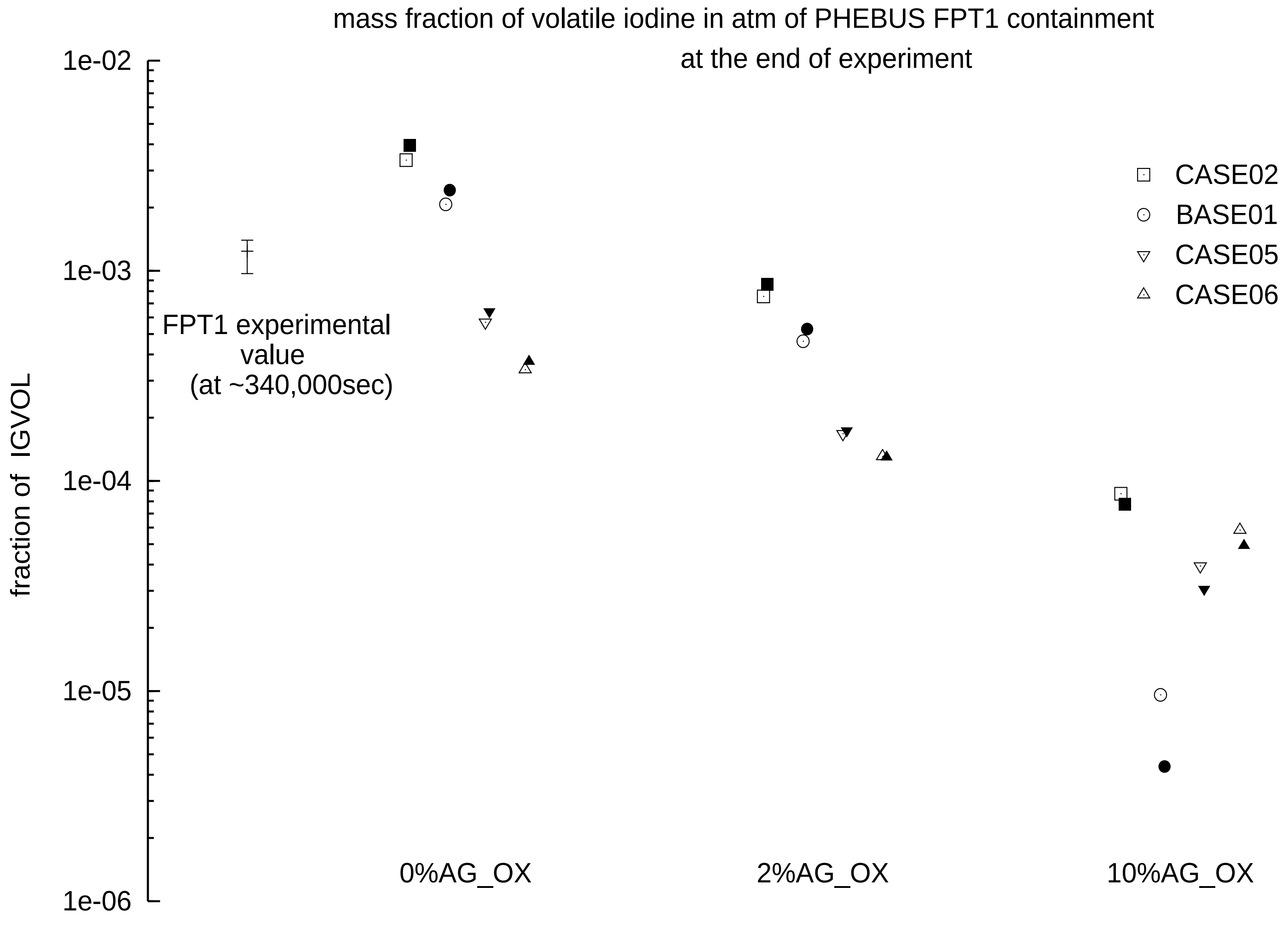
most of this iodine is coming to containment on aerosols —source of the gaseous iodine to containment represents less than 0.5% of the total iodine containment source

iodine source to sump (flow rates of aerosols) modeled —in accordance with ISP-46 calculations— in several separate draining events, last one being the washing of the containment hemispherical bottom (this last and biggest transfer of I to sump amounts to about 0.45g and this is a beginning of the "chemistry phase" of the experiment; during this phase containment was isolated)

Ag source to containment is modeled to be always ~42times that of iodine (constant silver/iodine ratio during each phase of the test)

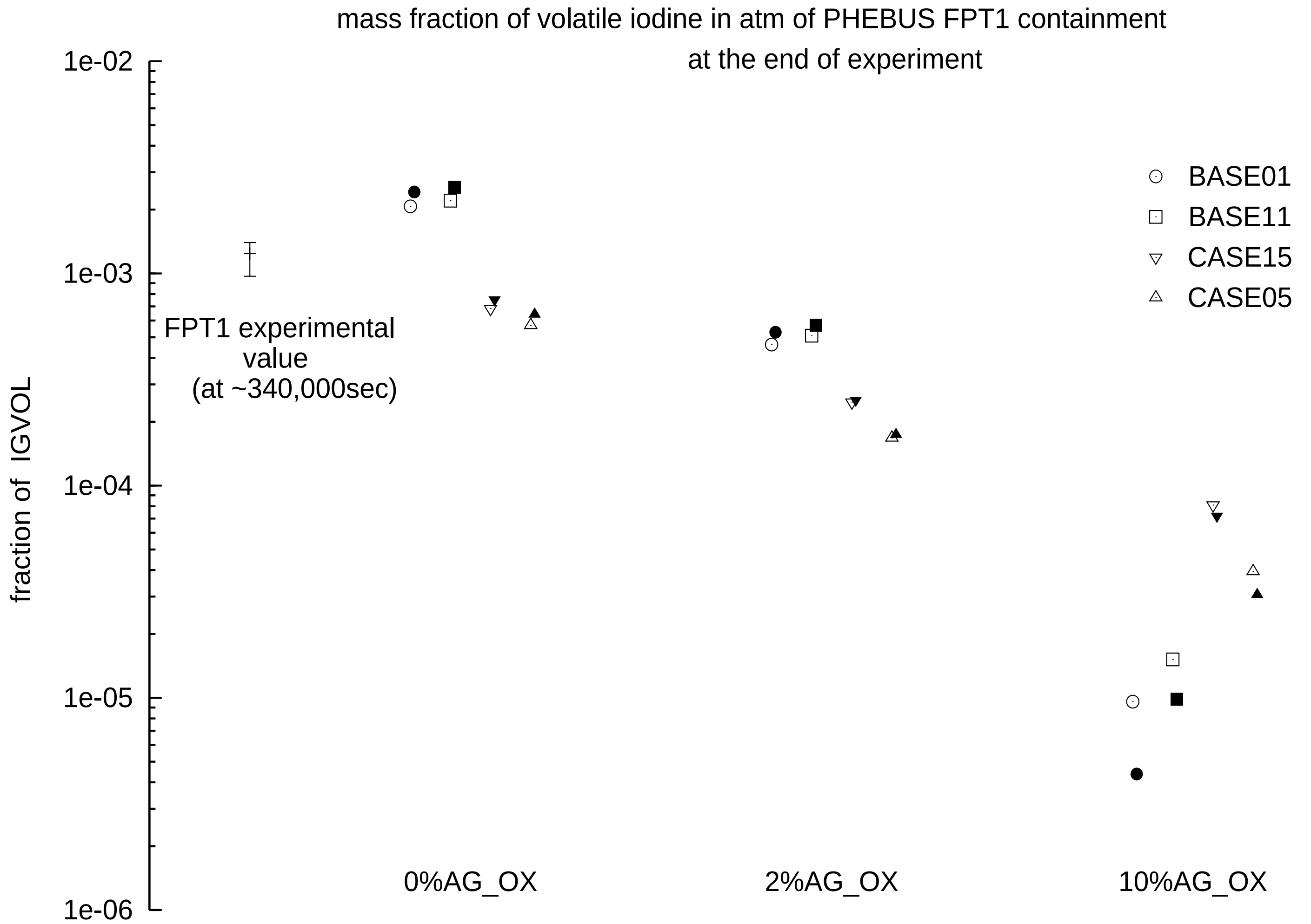
all other relevant PHEBUS FPT1 data were taken from the Final Report on FPT1 and from the ISP-46 Specification

containment iodine event tree —application to PHEBUS FPT1
RESULTS OF SENSITIVITY STUDY (1)

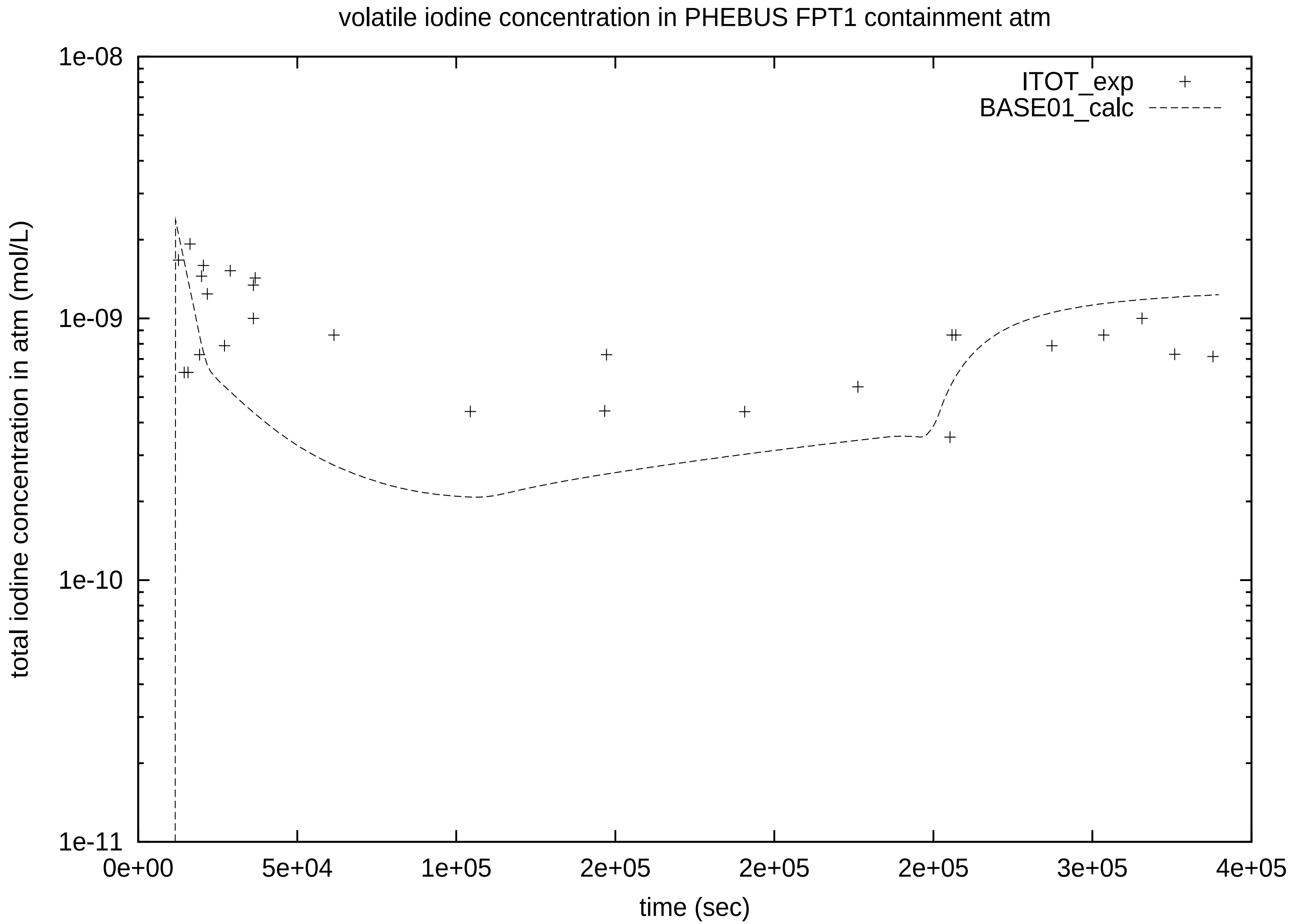


containment iodine event tree —application to PHEBUS FPT1

RESULTS OF SENSITIVITY STUDY (2)



IODE-5.1 PHEBUS FPT1 CALCULATION: BASE01 (0% Ag_ox)



CONCLUSIONS

- simple probabilistic method for evaluation of the containment iodine behavior has been proposed
  - iodine behavior is described with help of a small event tree which is being processed by the EVNTRE code

- proposed approach applied to iodine behavior analysis in the integral PHEBUS FPT1 experiment
  - small iodine event tree served as a framework for the sensitivity study on selected processes affecting the iodine volatility in FPT1
  - containment iodine code IODE used for the calculations of iodine speciation in PHEBUS containment

- final goal of the presented approach should be thorough analyses of the uncertainties of the iodine containment behavior modeling

  using of the iodine codes in this task need not be necessarily useful in all instances, simplified models of the processes in question could be used instead; this would be also easier to apply to more complex tasks such as whole-plant PRAs Level 2

CONCLUSIONS (cont'd)

There are, of course, some problems with the approach used for FPT1 analysis (i.e. using of an iodine code directly in the tree), the biggest being that results of the tree evaluations are much dependent on the chosen code (different codes also need different User Functions of EVNTRE). However, it is very easy to do any parametric study or uncertainty assessment using the same parameters as inputs to different codes and see the sensitivity right off

Moreover, the output files (or parts of them) from single iodine code runs can be stored and labeled $\Rightarrow$ complete results of a given iodine code run (all the iodine speciation and its time dependencies) can be traced back to the individual path through the tree