

INTERACTIVE SESSION II : RPV EMBRITTLEMENT COMPUTING A DUCTILE-TO-BRITTLE TRANSITION TEMPERATURE $T_{K7/T0.9}$ VIA CHARPY TEST

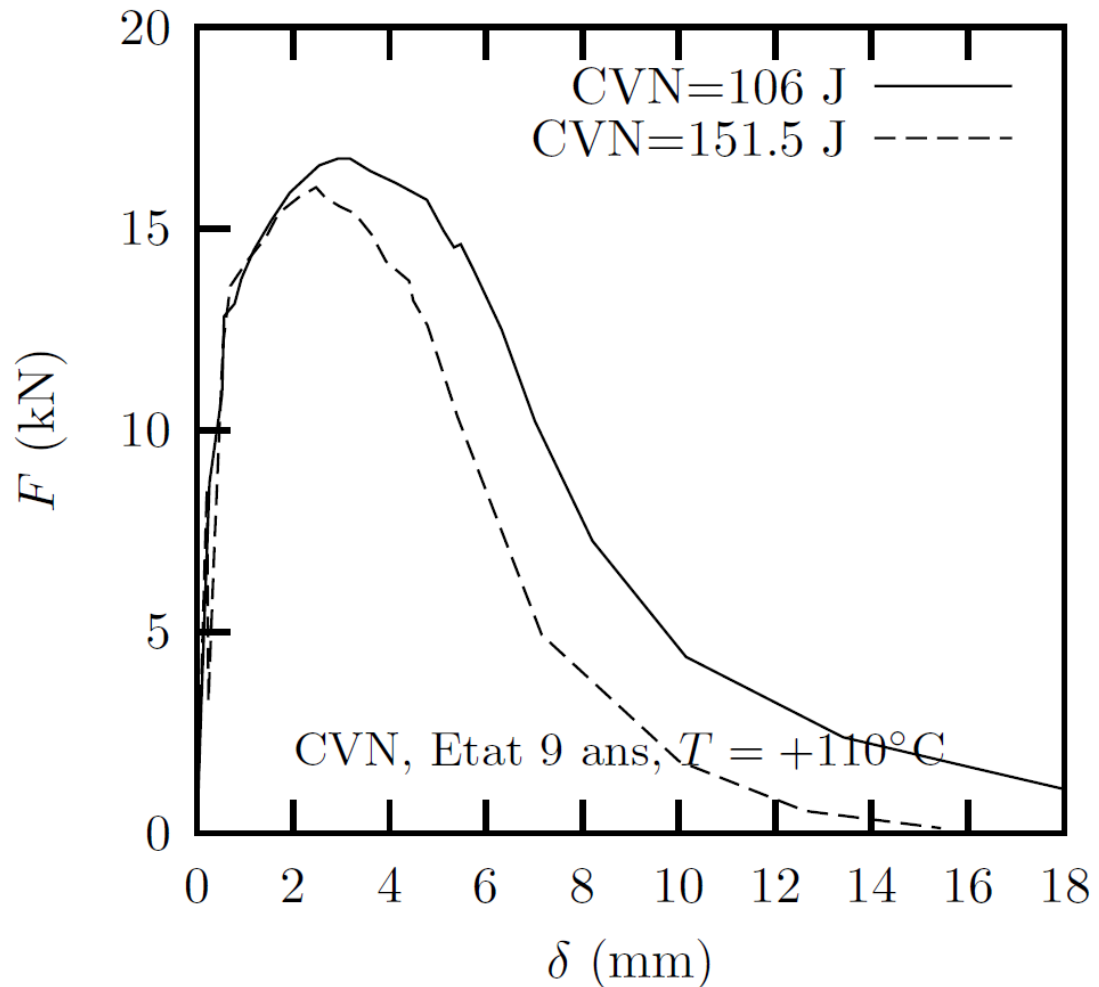
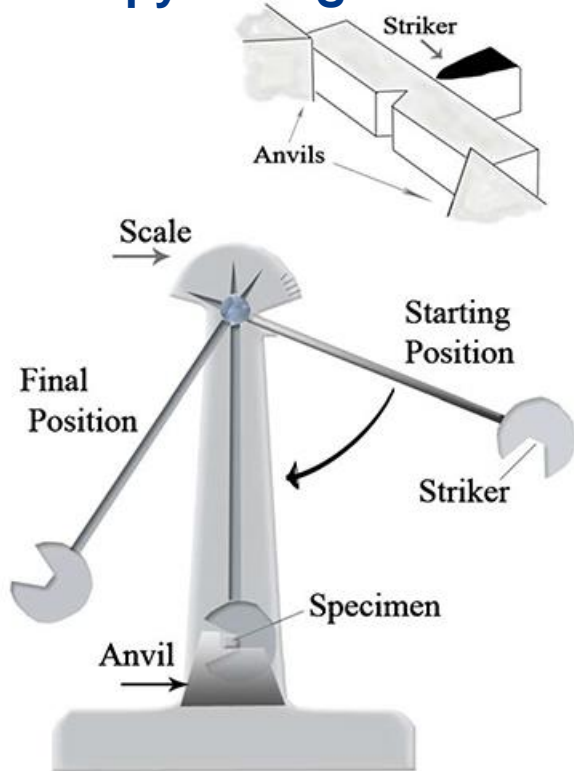
A. Marchenko

P. James

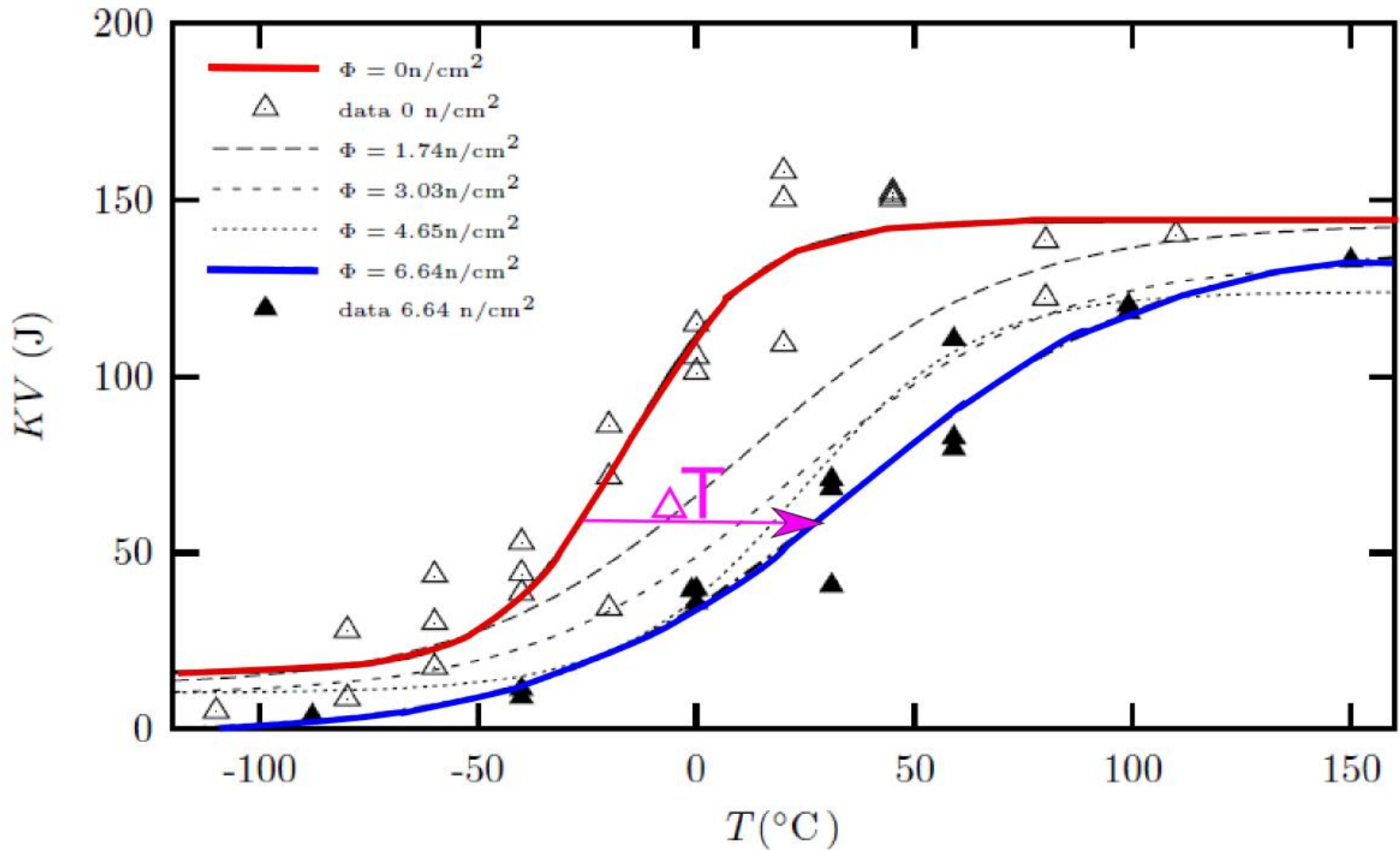


Charpy: classical dynamic test

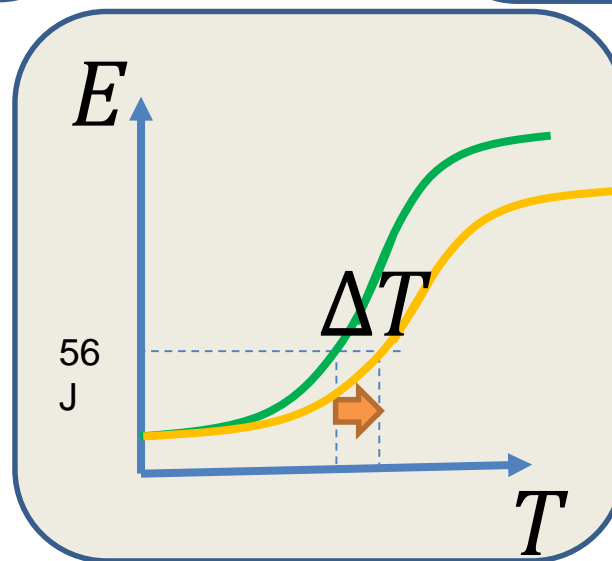
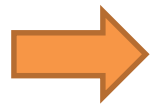
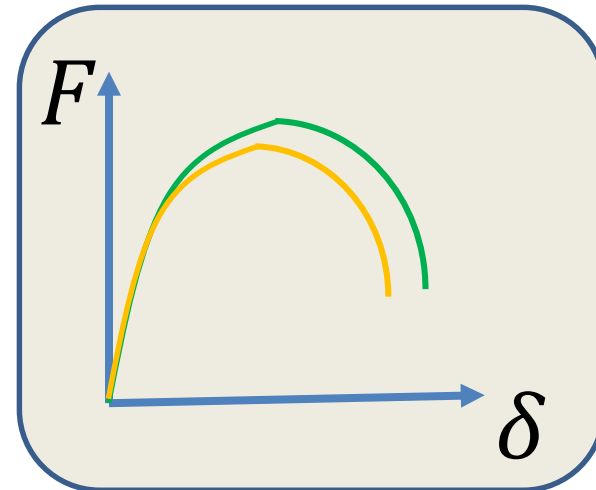
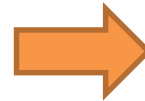
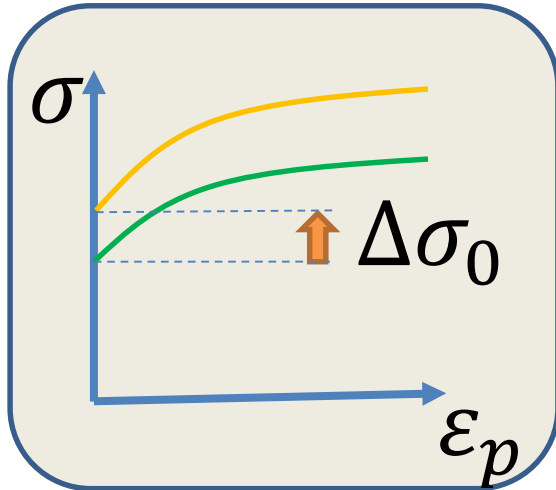
Charpy testing machine



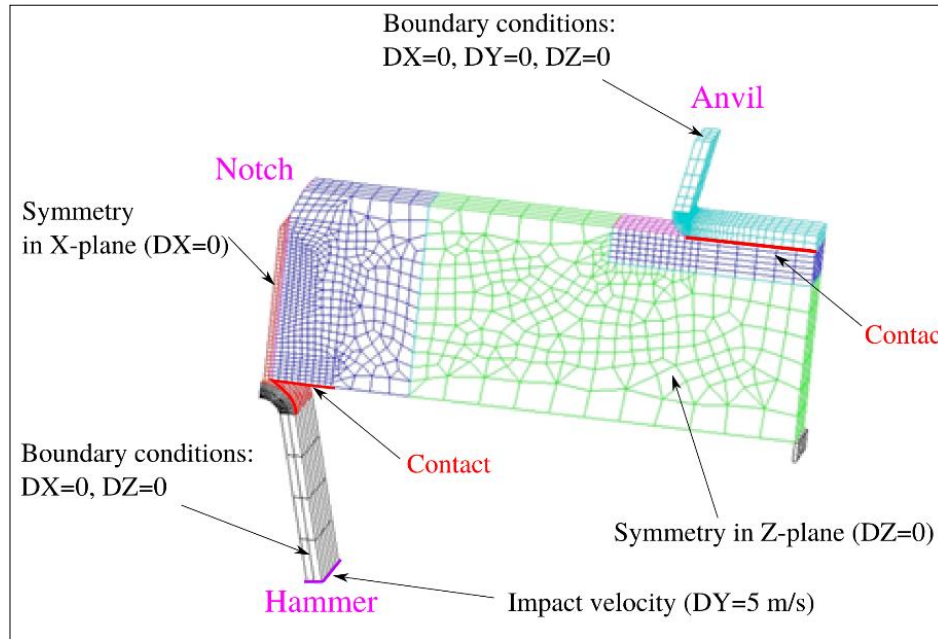
Charpy instrumented curve



Exercise Objective



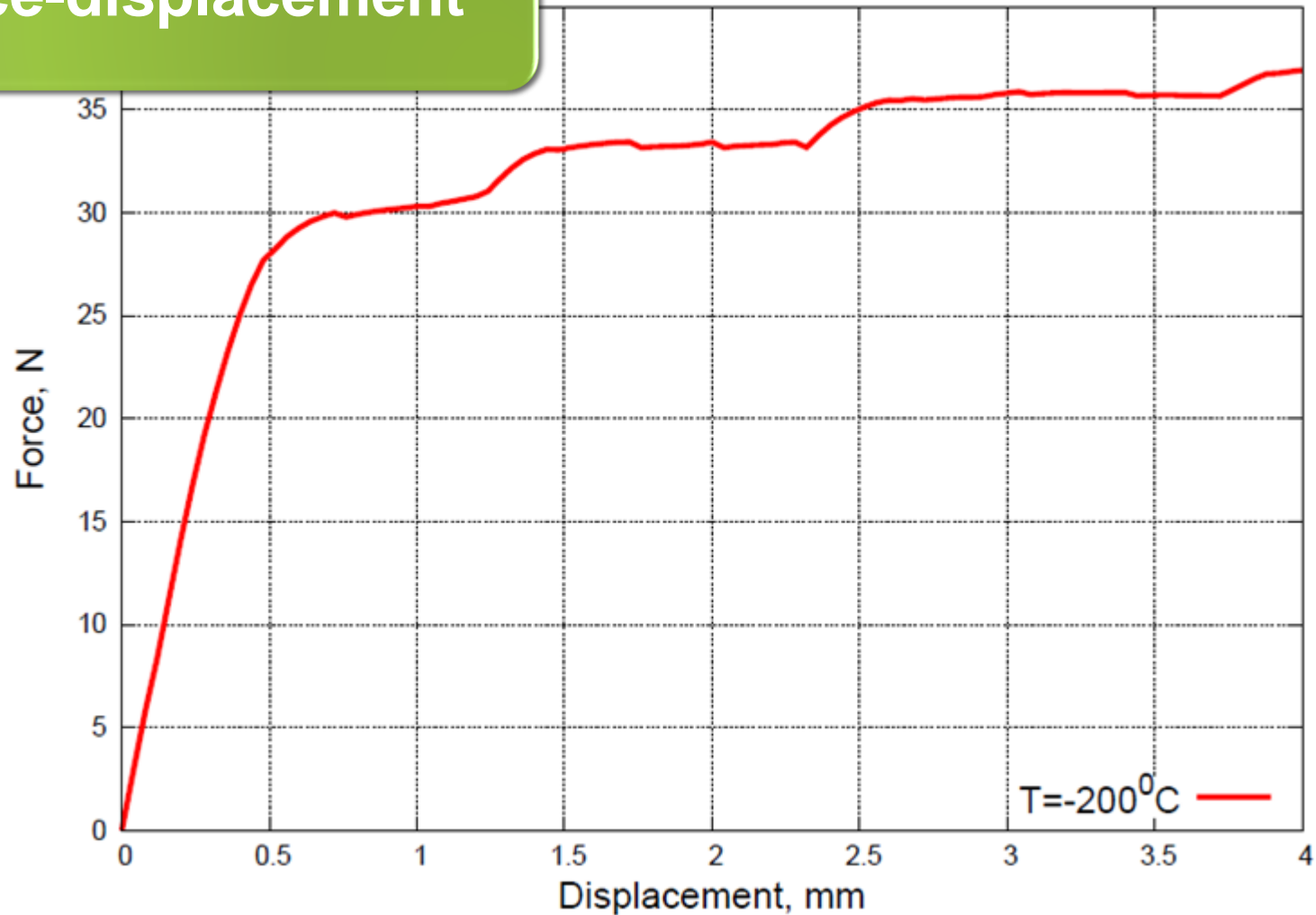
Possibilities with the platform



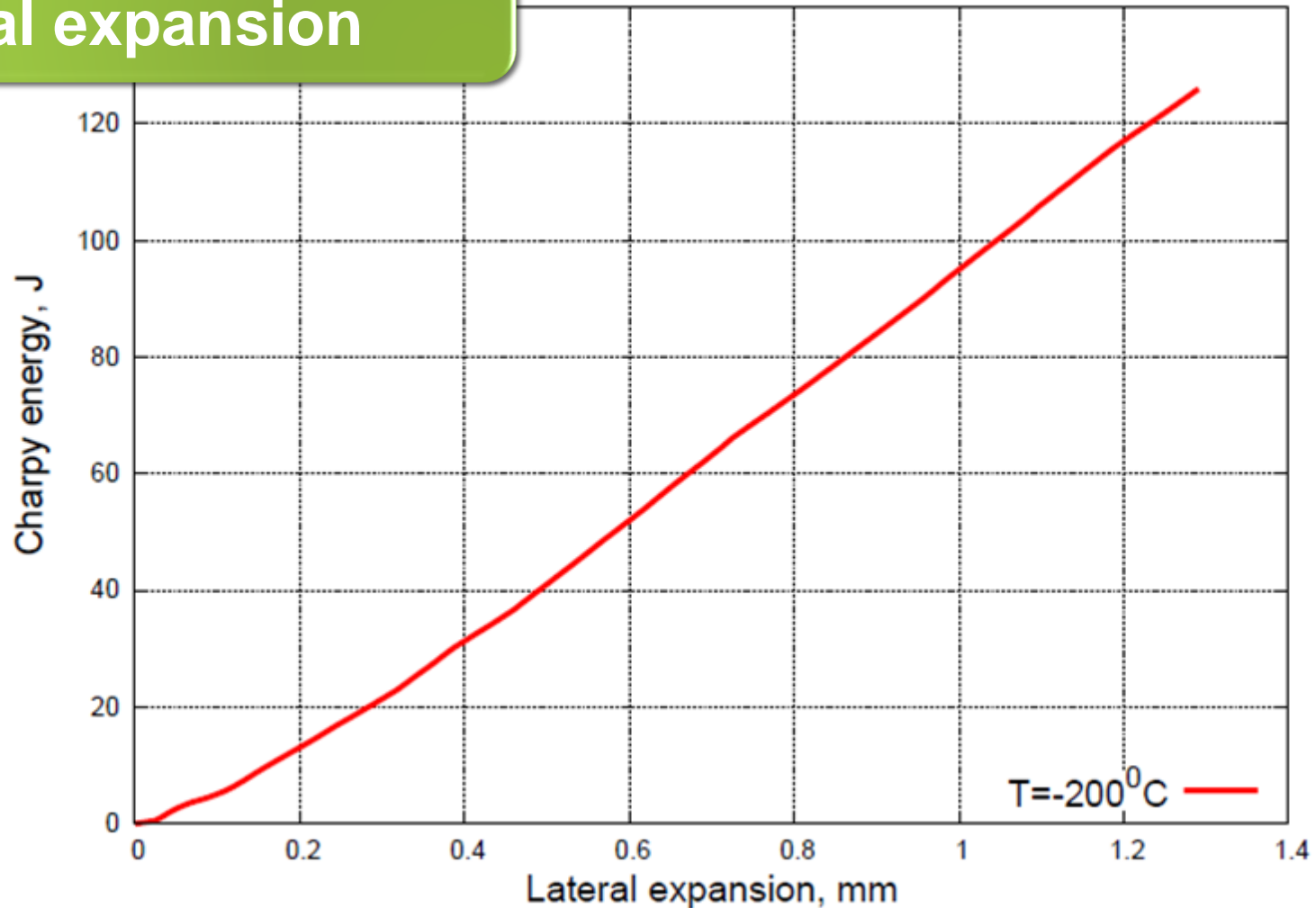
Elasto-viscoplastic model
with damage
(Rousselier model)

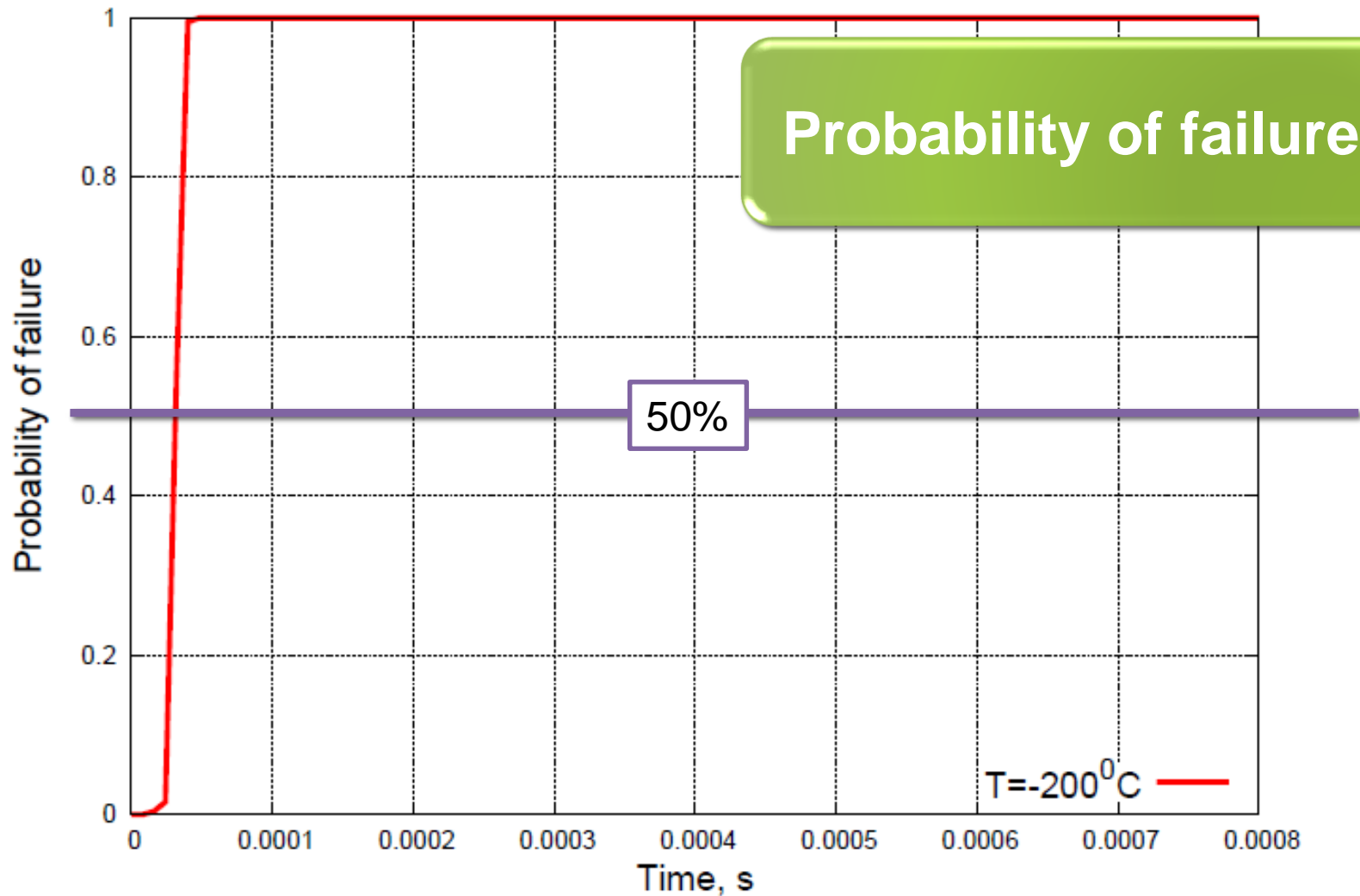
Beremin model in post-processing

Force-displacement

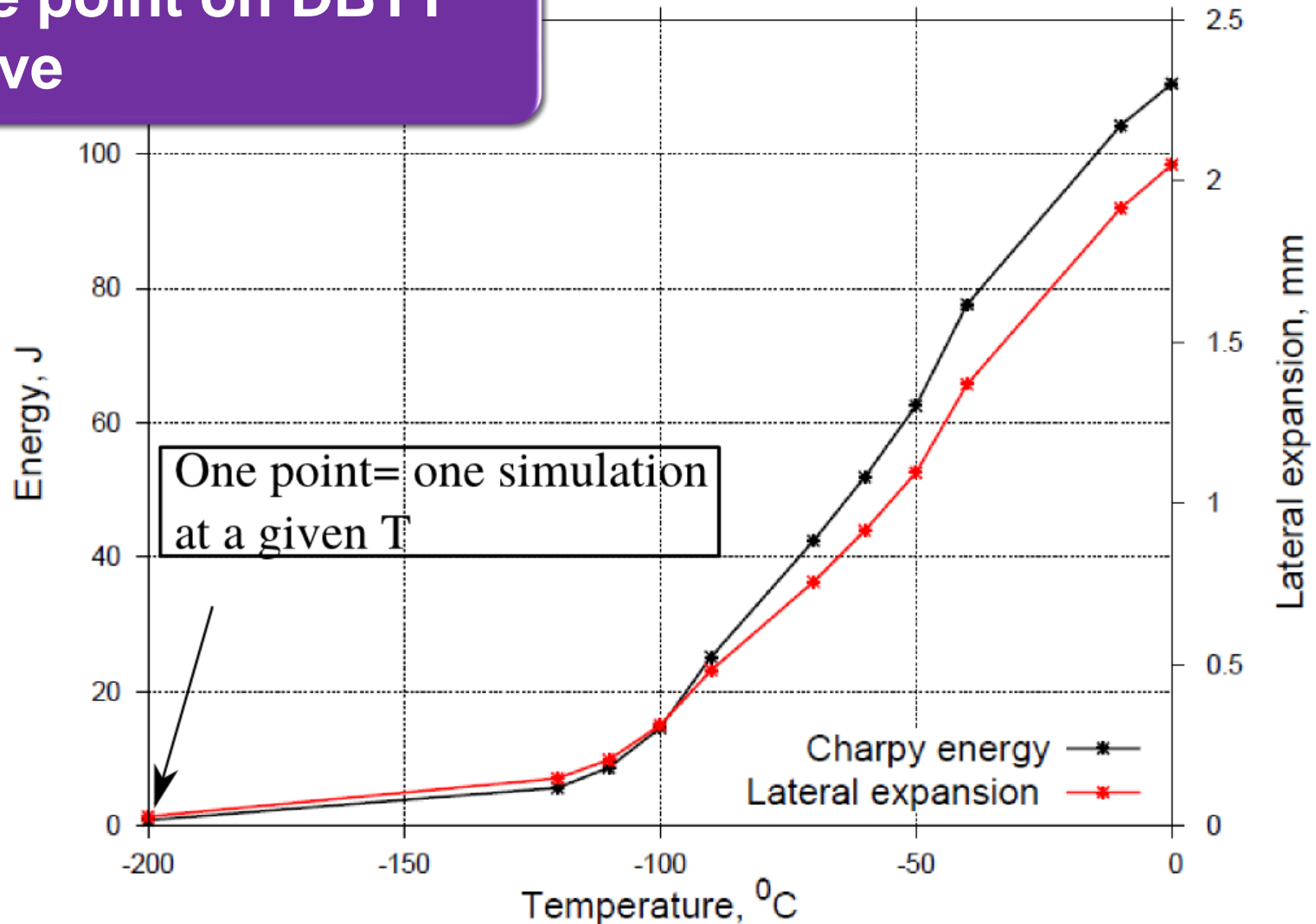


Charpy energy and lateral expansion





One point on DBTT curve



Modules chaining



Study Chain Data Run Graphics

Module Tree View

- Modules
 - RPV
 - RPV3
 - MechanicalSimulationModule
 - FlowBehaviour
 - Aggregate
 - Homogenisation
 - Correlation
 - TensileCurve
 - Analytical
 - Experimental
 - FractureBehaviour
 - Correlation
 - CTLocalApproach
 - CharpyLocalApproach
 - CharpyCalculation
 - PostProcessor
 - Beremin
 - SubModelling
 - INTERNALS

Module Help

Module: nModule.FractureB...

Author: A. Marchenko, F. La...

Version: 01.01.00

End Module: True

Short Documentati...
Beremin post-proce

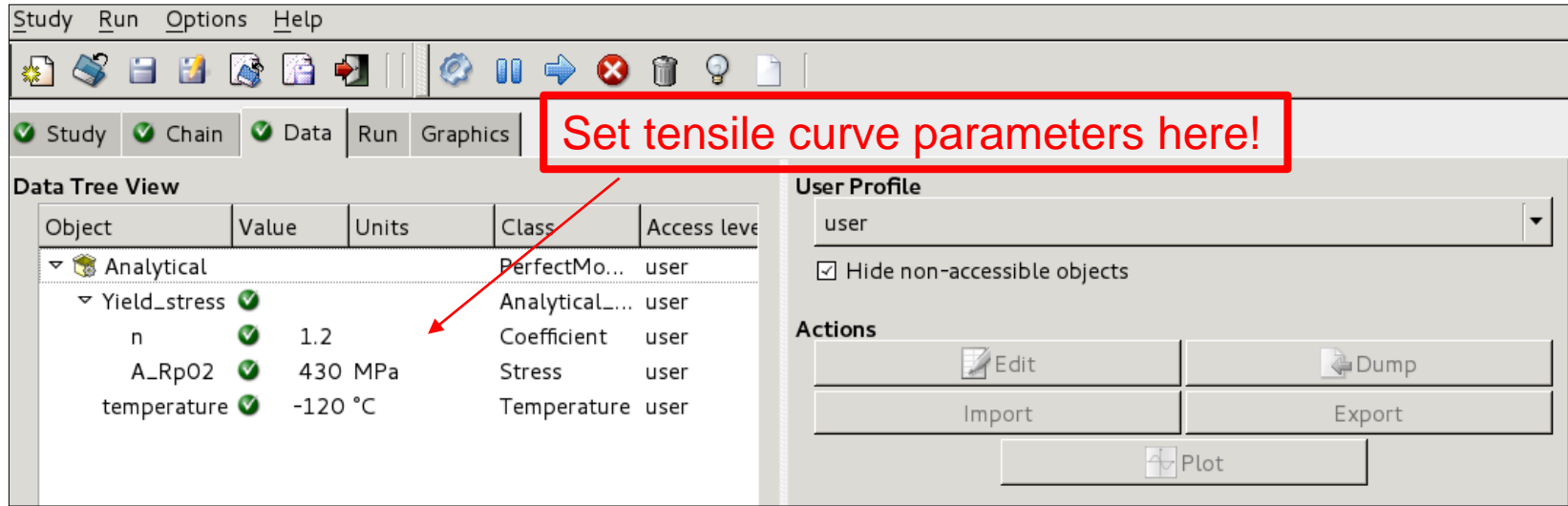
Full Documentation

Selected Modules

Chain

- MechanicalSimulationModule.FlowBehaviour.TensileCurve.Analytical
- MechanicalSimulationModule.FractureBehaviour.CharpyLocalApproach.CharpyCalculation
- MechanicalSimulationModule.FractureBehaviour.CharpyLocalApproach.PostProcessor.Beremin





Yield stress: $\sigma_{Y0}(T) \approx R_{p0.2}(T) = a_{Rp0.2} + b_{Rp0.2} * e^{-cT}$

Flow stress: $R(p) = \sigma_{Y0}(T) + n * [Q_1(T)(1 - e^{-b_1(T)p}) + Q_2(1 - e^{-b_2(T)p})]$

Fitted from $R_{p0.2}$ and R_m by

[S. Renevey, 1997, thesis]

[B. Tanguy, 2001, thesis]

determined for **H1BQ12 (16MND5)**

Charpy calculation



Set here the speed of the pendulum, final step and number of steps for calculation

Object	Value	Units	Class	Access lev
Experimental			PerfectMo...	user
temperature	-120	°C	Temperature	user
tensile_curve_exp			TensileCur...	user
A	2.36e+05	MPa	Coefficient	expert
B	45.9	MPa\$\\cdot...	Coefficient	user
poisson	0.3		Coefficient	user
tensile_curve			TableCoeffi...	user
CharpyCalculation			PerfectMo...	user
charpy_calculation			AsterComp...	user
Machine	dsp0809486		String	user
tracelog	0		Integer	expert
User	d93376		String	user
Memory	256	Mo	Integer	expert
ExePath			PerfectFile	user
time	4000	s	Integer	expert
charpy_loading			CharpyLoa...	user
Disp_rate	0.0016	mm/s	Coefficient	user
Disp_max	1.6e-06	mm	Coefficient	user
Steps	1000	steps	Integer	expert

❑ Viscoplasticity :

$$\dot{p} = \left(\frac{\sigma_{eq} - R(p)}{K(T)} \right)^{N(T)}$$

! Is fixed and included into Charpy calculation module



Beremin post-processing

Set here the Beremin model parameters

▼ Beremin				PerfectMo...	user
▼ beremin	✓			Beremin	user
VO	✓	0.000125	nm ³	Volume	user
quantile	✓			TableCoeffi...	user
m	✓	20		Coefficient	user
sigma_u	✓	2647	MPa	Stress	user
▼ beremin_calculation	✓			AsterComp...	user
Machine	✓	dsp0809486		String	user
tracelog	✓	0		Integer	expert
User	✓	d93376		String	user
Memory	✓	256	Mo	Integer	expert
ExePath	✓			PerfectFile	user
time	✓	1000	s	Integer	expert

Beremin model

$$P_R = 1 - \exp \left[- \left(\frac{\sigma_w}{\sigma_u} \right)^m \right]$$

$$\sigma_w = \left[\int_0^{V_p} \tilde{\sigma}_{Ip}^m \frac{dV}{V_0} \right]^{1/m}$$

σ_u - the normalizing stress

σ_w - the Weibull stress

m - the Weibull shape factor ($m = 20$)

P_R - probability to failure

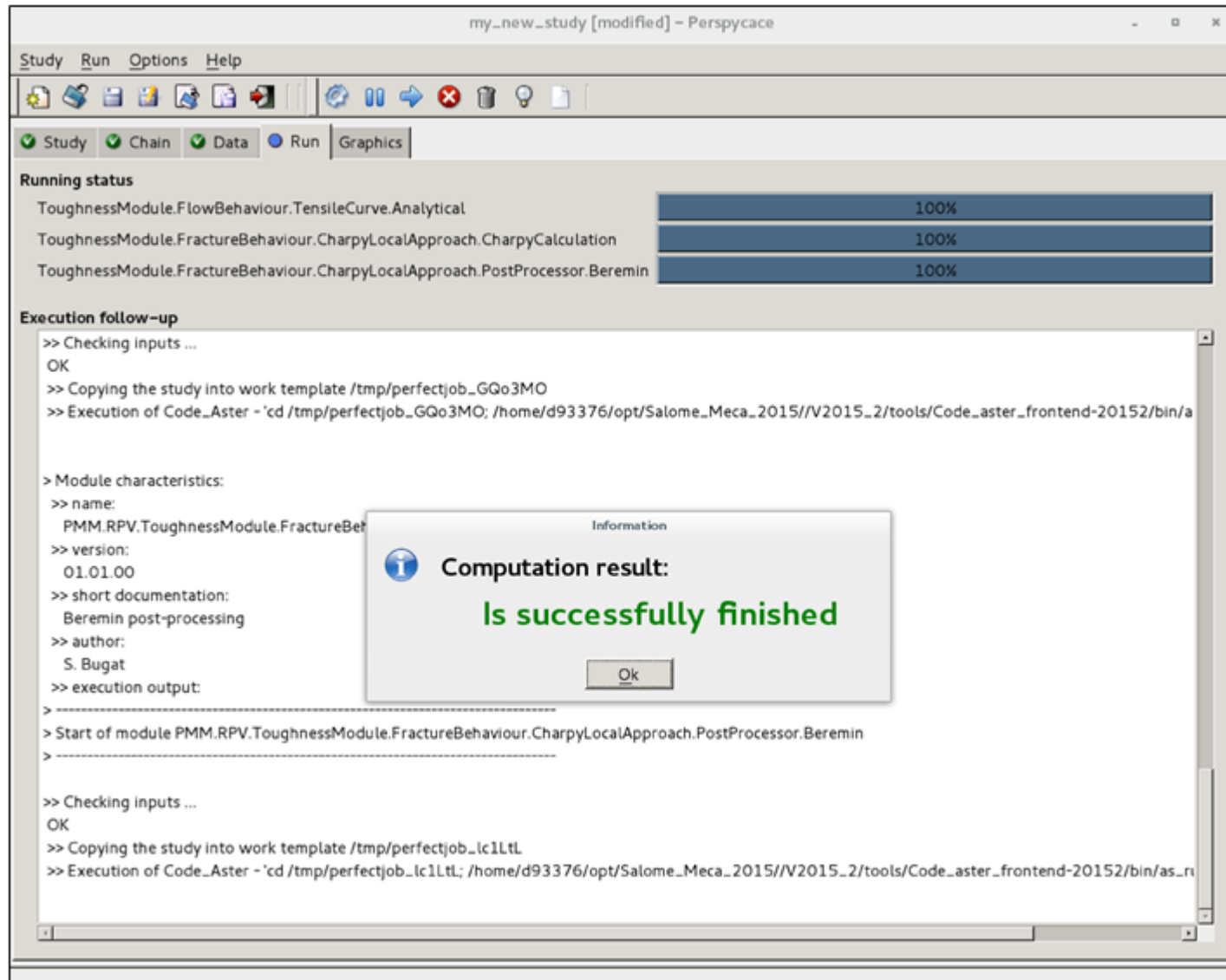
V_0 - the elementary volume element

$\tilde{\sigma}_{Ip}(t) = \max \sigma_{Ip}(t')$ - effective failure stress

$$\sigma_u = a_{\sigma u} + b_{\sigma u} * e^{0.025T}$$

$a_{\sigma u}$ $b_{\sigma u}$ reference values

Execution procedure



The screenshot shows a software window titled "my_new_study [modified] - Perspyspace". The interface includes a menu bar (Study, Run, Options, Help) and a toolbar with various icons. Below the toolbar, there are tabs for "Study", "Chain", "Data", "Run", and "Graphics".

Running status

ToughnessModule.FlowBehaviour.TensileCurve.Analytical	100%
ToughnessModule.FractureBehaviour.CharpyLocalApproach.CharpyCalculation	100%
ToughnessModule.FractureBehaviour.CharpyLocalApproach.PostProcessor.Beremin	100%

Execution follow-up

```
>> Checking inputs ...
OK
>> Copying the study into work template /tmp/perfectjob_GQo3MO
>> Execution of Code_Aster - 'cd /tmp/perfectjob_GQo3MO; /home/d93376/opt/Salome_Meca_2015/V2015_2/tools/Code_aster_frontend-20152/bin/a

> Module characteristics:
>> name:
  PMM.RPV.ToughnessModule.FractureBeh
>> version:
  01.01.00
>> short documentation:
  Beremin post-processing
>> author:
  S. Bugat
>> execution output:
>
> Start of module PMM.RPV.ToughnessModule.FractureBehaviour.CharpyLocalApproach.PostProcessor.Beremin
> -----

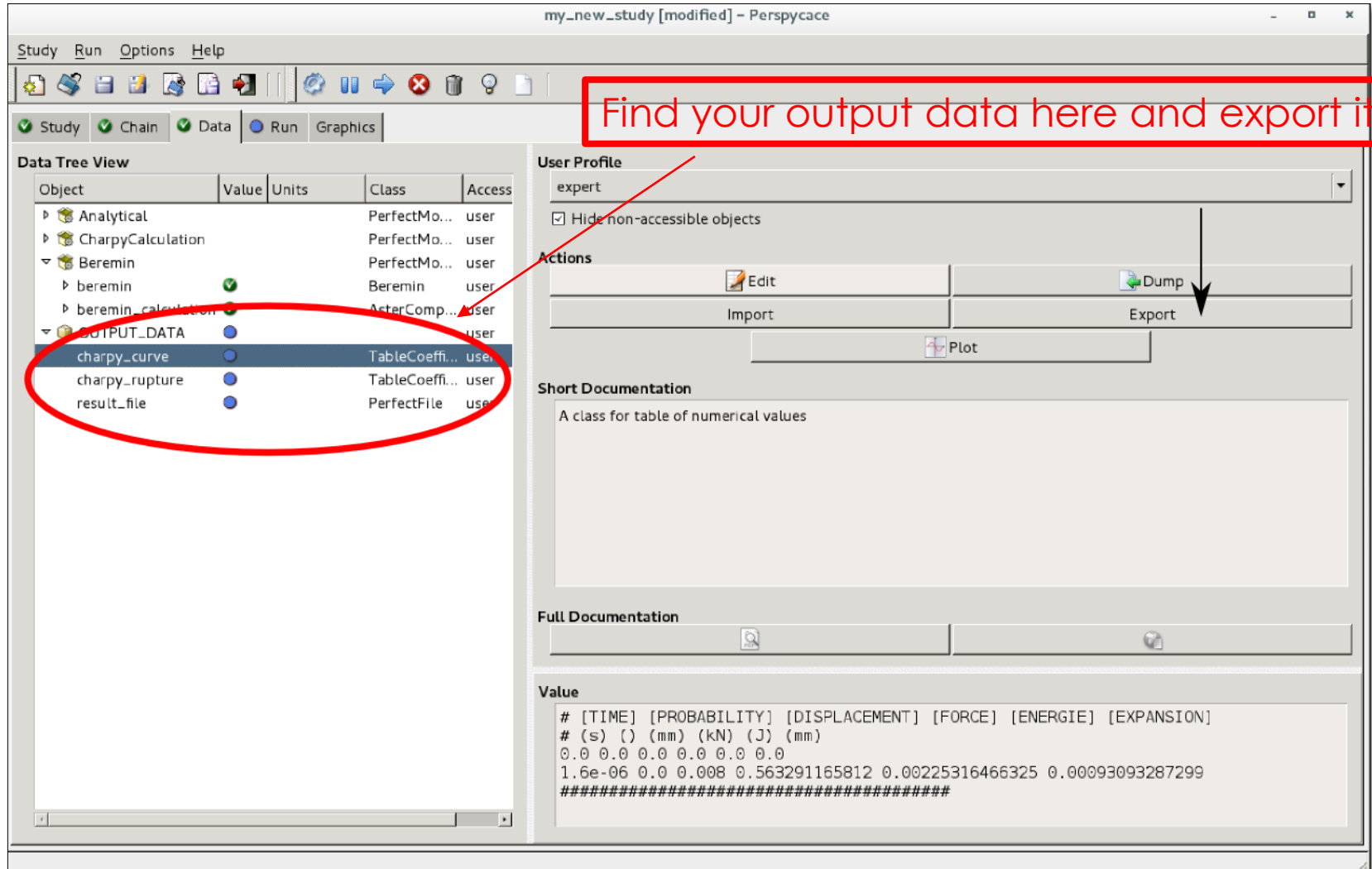
>> Checking inputs ...
OK
>> Copying the study into work template /tmp/perfectjob_lc1LTL
>> Execution of Code_Aster - 'cd /tmp/perfectjob_lc1LTL; /home/d93376/opt/Salome_Meca_2015/V2015_2/tools/Code_aster_frontend-20152/bin/as.r
```

An "Information" dialog box is overlaid on the terminal output, displaying the following text:

Computation result:
Is successfully finished

Ok

Output data



my_new_study [modified] - Perspyspace

Study Run Options Help

Study Chain Data Run Graphics

Data Tree View

Object	Value	Units	Class	Access
▶ Analytical			PerfectMo...	user
▶ CharpyCalculation			PerfectMo...	user
▼ Beremin			PerfectMo...	user
▶ beremin	✓		Beremin	user
▶ beremin_calculation	✓		AsterComp...	user
▼ OUTPUT_DATA	●			user
charpy_curve	●		TableCoeffi...	user
charpy_rupture	●		TableCoeffi...	user
result_file	●		PerfectFile	user

User Profile
expert
 Hide non-accessible objects

Actions

Edit Import Dump Export Plot

Short Documentation
A class for table of numerical values

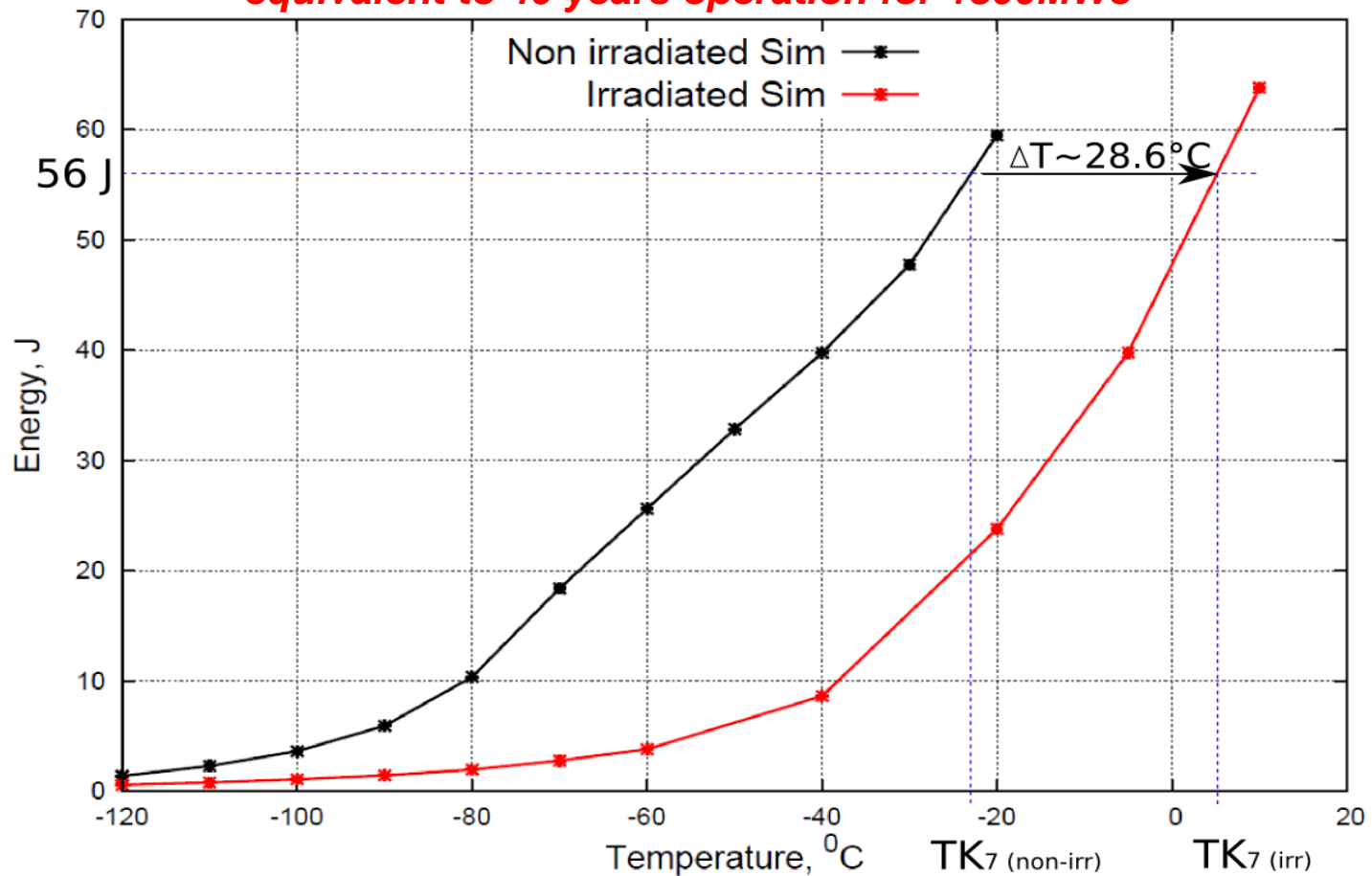
Full Documentation

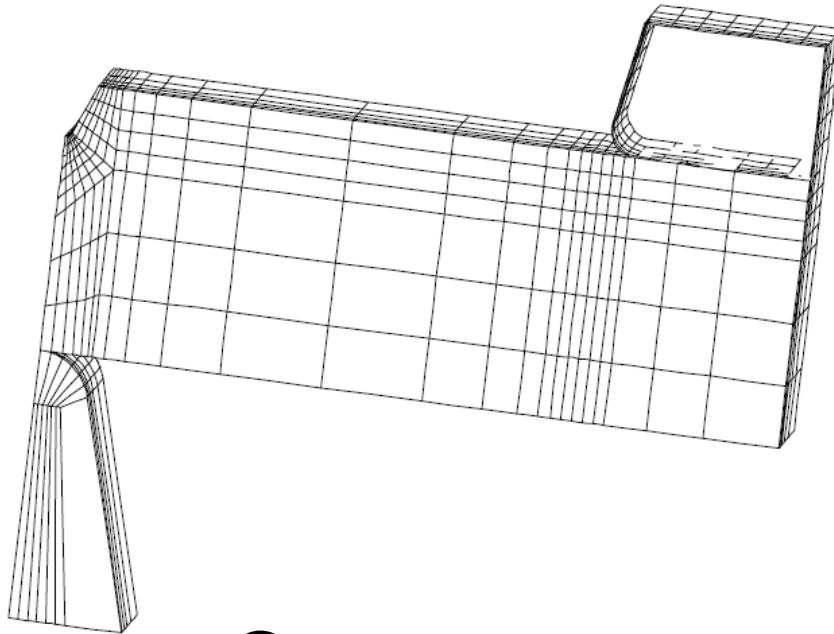
Value

```
# [TIME] [PROBABILITY] [DISPLACEMENT] [FORCE] [ENERGIE] [EXPANSION]
# (s) () (mm) (kN) (J) (mm)
0.0 0.0 0.0 0.0 0.0 0.0
1.6e-06 0.0 0.008 0.563291165812 0.00225316466325 0.00093093287299
#####
```

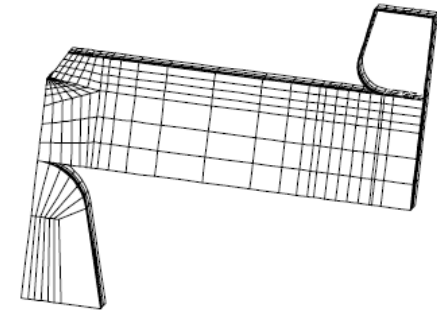
Estimation of the temperature shift due to irradiation

$\phi = 4,3 \cdot 10^{19} \text{ n/cm}^2$
equivalent to 40 years operation for 1300MWe





- Validated micro-mechanical model
- Good prediction of the irradiation effect



- Transferability problem (Constraint effect)
- Empirical correlations only
- Absence of experimental data
- Parameters for local approach models