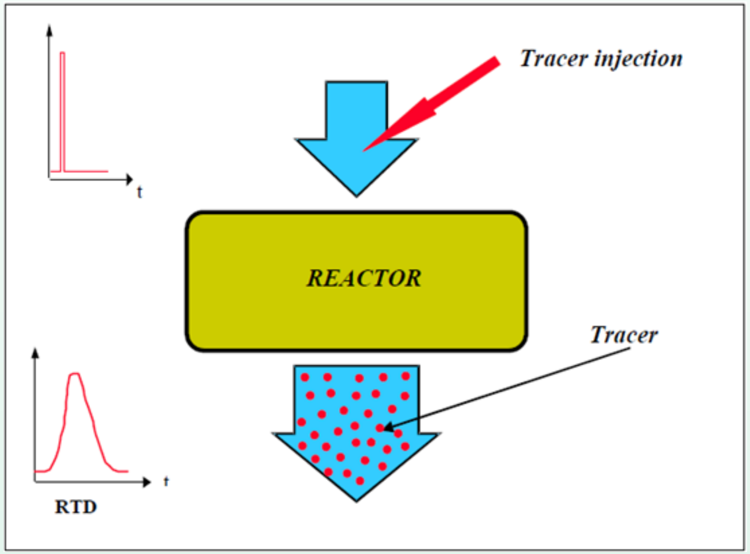
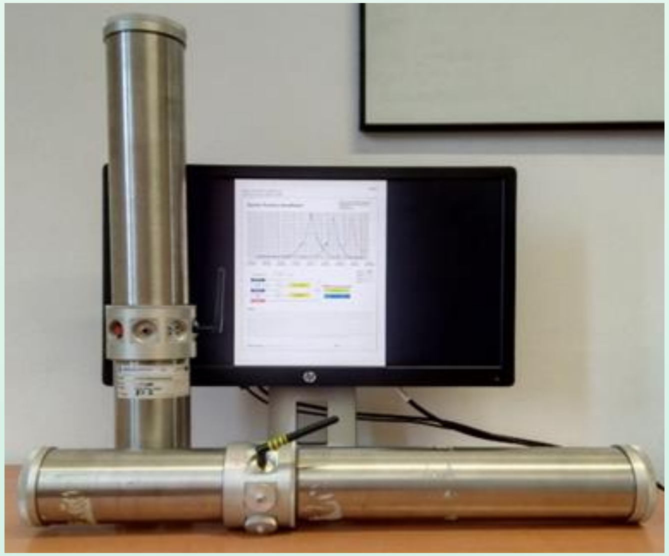
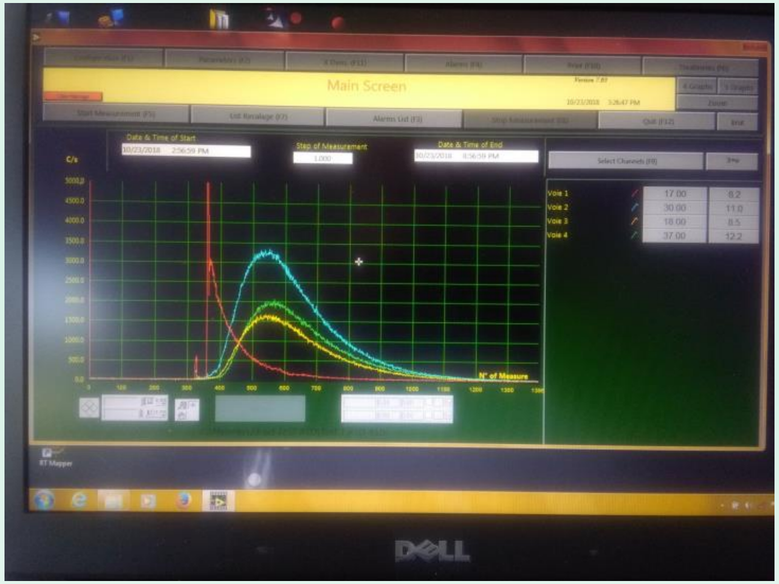
RADIOACTIVE TRACER APPLICATIONS

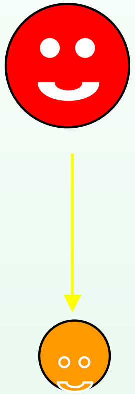






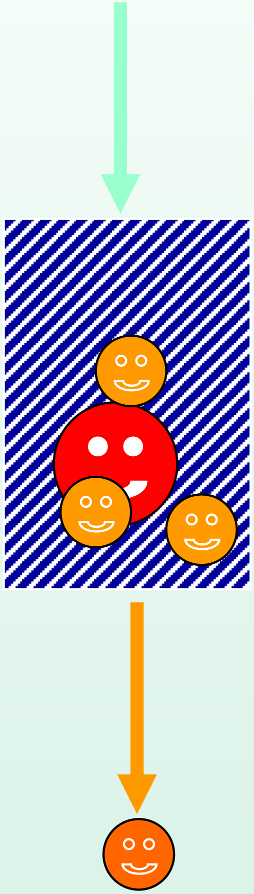
Isotope	Half-life	Main energy (MeV)	Chemical form	Tracing of phase
Sodium-24	15 h	γ: 1.37 (100%) 2.75 (100%)	Sodium carbonate	Aqueous phase
Bromine-82	36 h	γ: 0.55 (70%) 1.32 (27%)	Ammonium bromide, p-dibrombenzene, Dibrombiphenyl CH_3 Br	Aqueous phase Organic phase Organic phase Gas phase
Gold-198	2.7 d	γ: 0.41 (99%)	Chloroauric acid	Solids /aqueous phases
Lanthan- 140	40 h	γ: 1.60	La_2O_3	Solid phase
Iodine-131	8.04 d	γ: 0.36 (80%) 0.64 (9%)	KI & NaI, Iodobenzene	Aqueous phase Organic phase
Iodine-123	13 h	γ: 0.159	KI & NaI, Iodobenzene	Aqueous phase Organic phase
^{99m}Tc from ^{99}Mo/^{99m}Tc generator	6 h	γ: 0.14 (90%)	Sodium pertechnetate (TcO_4^-)	Aqueous phase
^{137m}Ba from ^{137}Cs/^{137m}Ba generator	2.55 min	γ: 0.661	$^{137m}BaCl_3$	Aqueous phase
^{113m}In from ^{113}Sn / ^{113m}In generator	99.5 min	γ: 0.392	$^{113m}InCl_3$ ^{113m}In-EDTA	Solid phase Aqueous phase
^{68}Ga from ^{68}Ge/^{68}Ga generator	68.3 min	γ: 1.08	$^{68}GaCl_3$ ^{68}Ga-EDTA	Solid phase Aqueous phase
Xenon-133	5.27 d	γ: 0.08 (100%)	Xenon	Gas phase
Krypton-79	35 h	γ: 0.51 (15%)	Krypton	Gas phase
Argon-41	110 min	γ: 1.29 (99%)	Argon	Gas phase

Generator principles

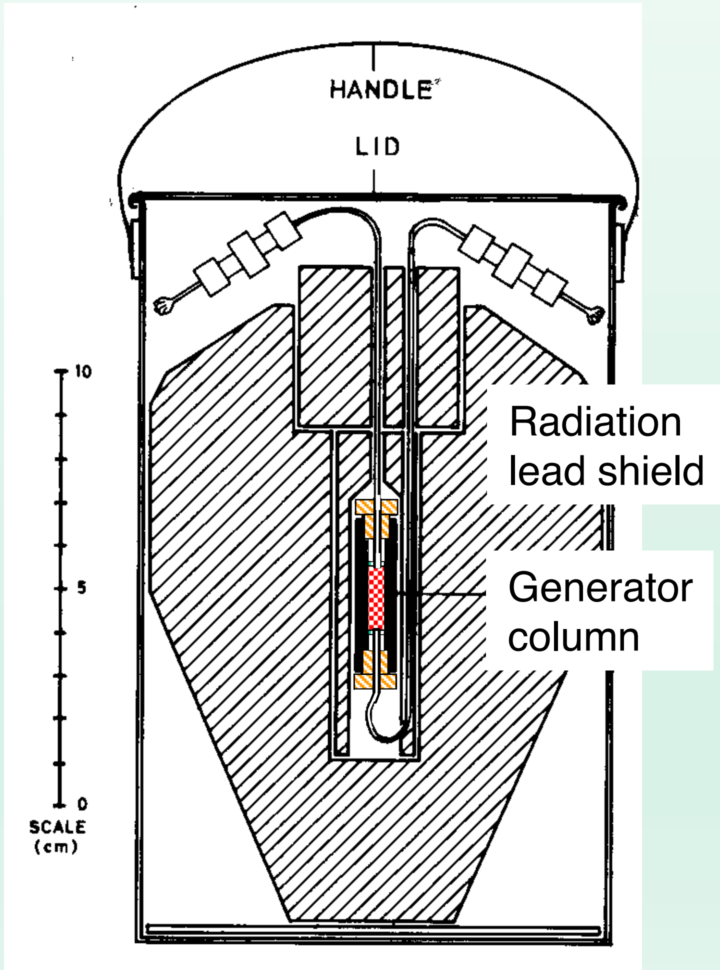


Mother radionuclide

Daughter radionuclide



^{99m}Tc is eluted as an anion TcO_4^- (perthecnetate)



Data acquisition system and NaI(Tl) detectors for Residence Time Distribution (RTD) measurement

Experimental points and final experimental RTD curve

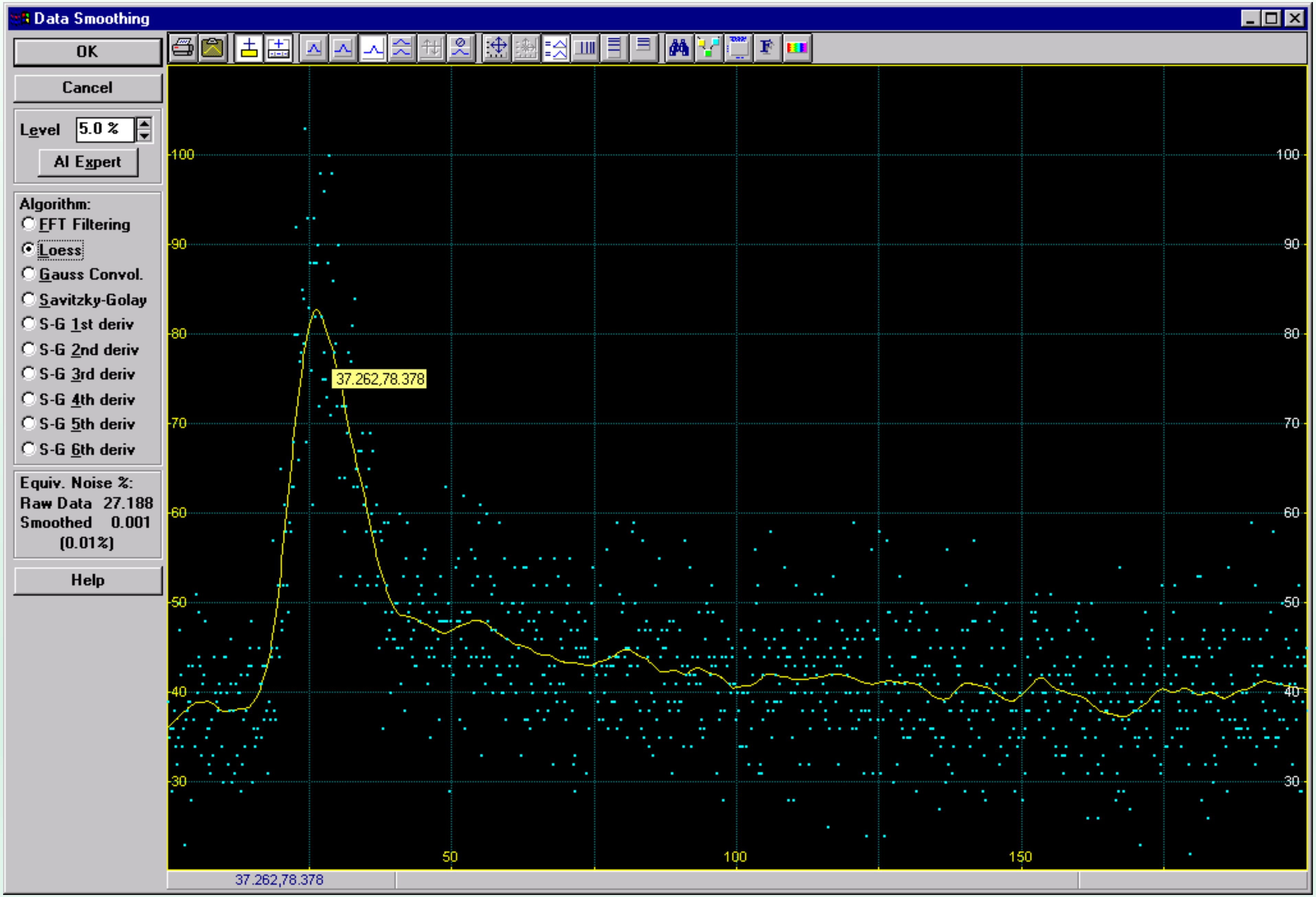


Chart of data acquisition and data processing steps in radiotracer test

Data acquisition

↓

Background correction

↓

Radioactive decay correction

↓

Background rise correction

↓

Re-sampling

↓

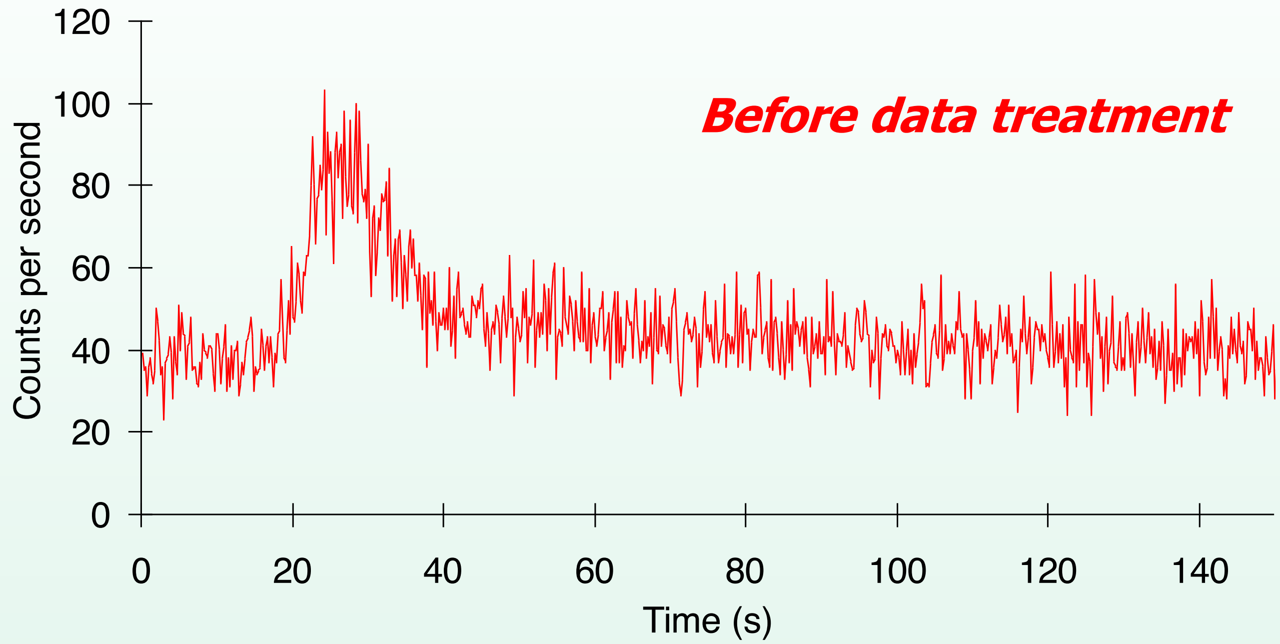
Data extrapolation

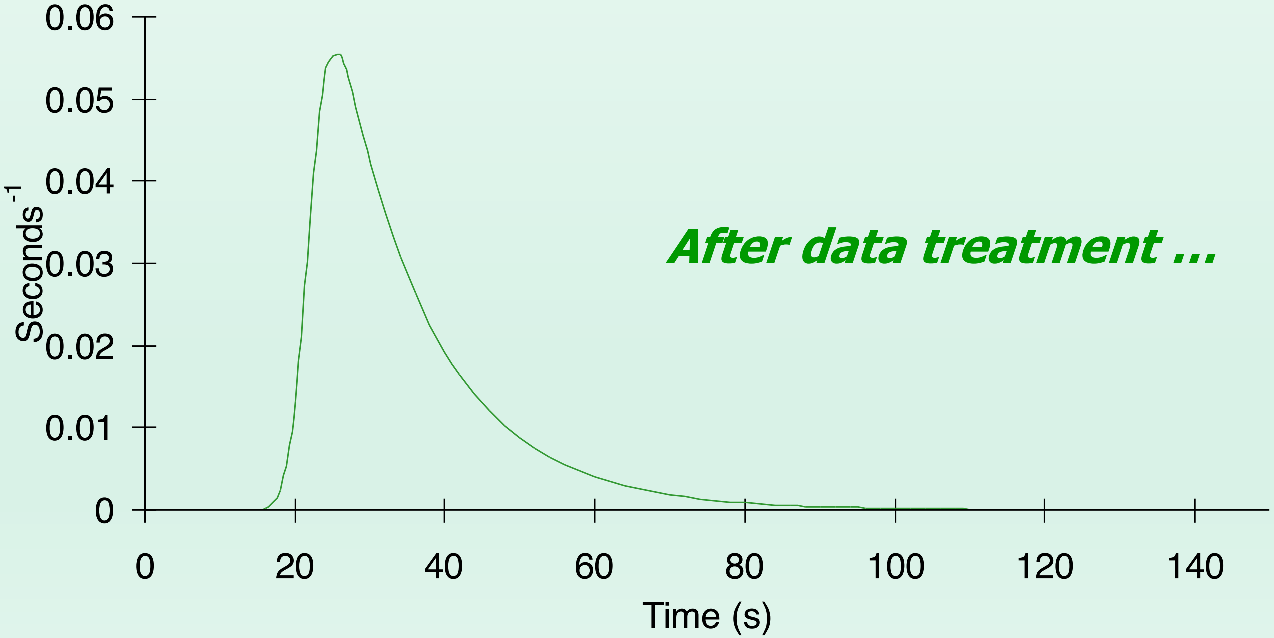
↓

Area normation

↓

Moment analysis&
RTD modelling …

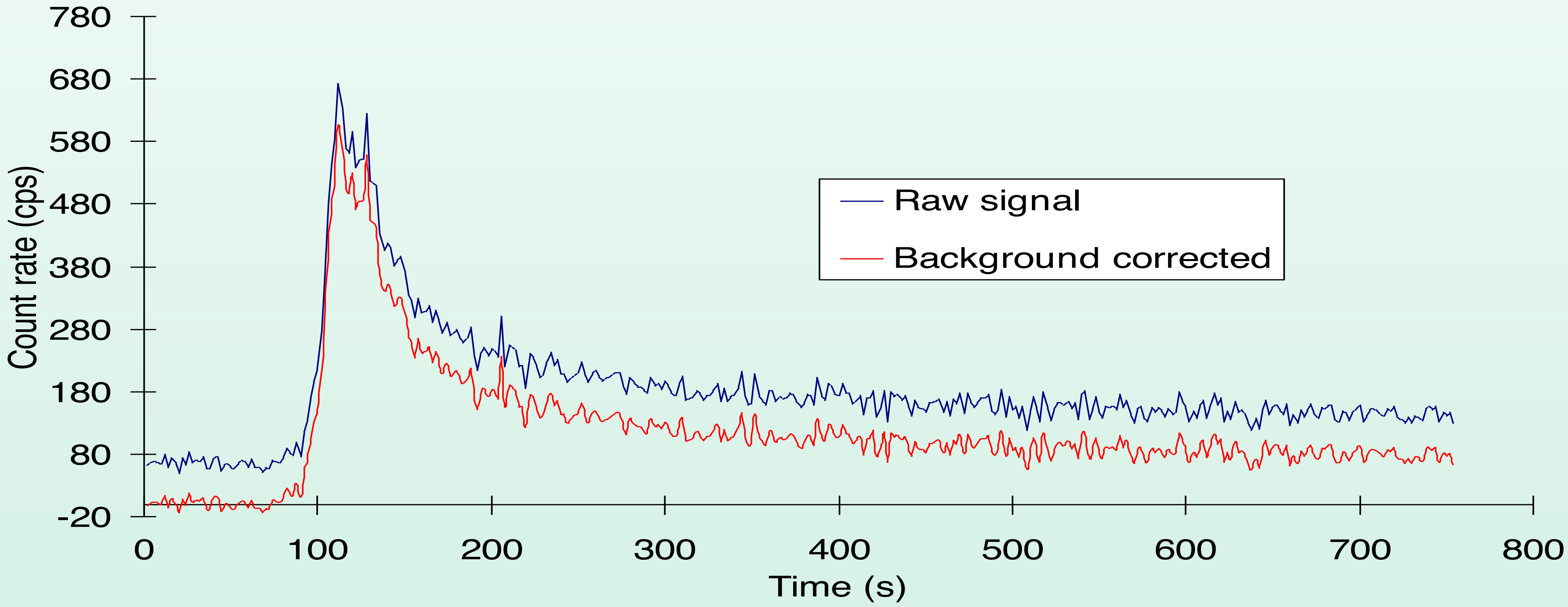

Before data treatment
Counts per second
Time (s)
0
20
40
60
80
100
120
140


After data treatment ...
Seconds^{-1}
Time (s)
0
0.01
0.02
0.03
0.04
0.05
0.06
20
40
60
80
100
120
140

Background correction

Background radiation level that exists (constant value)
Independently of the tracer experiment

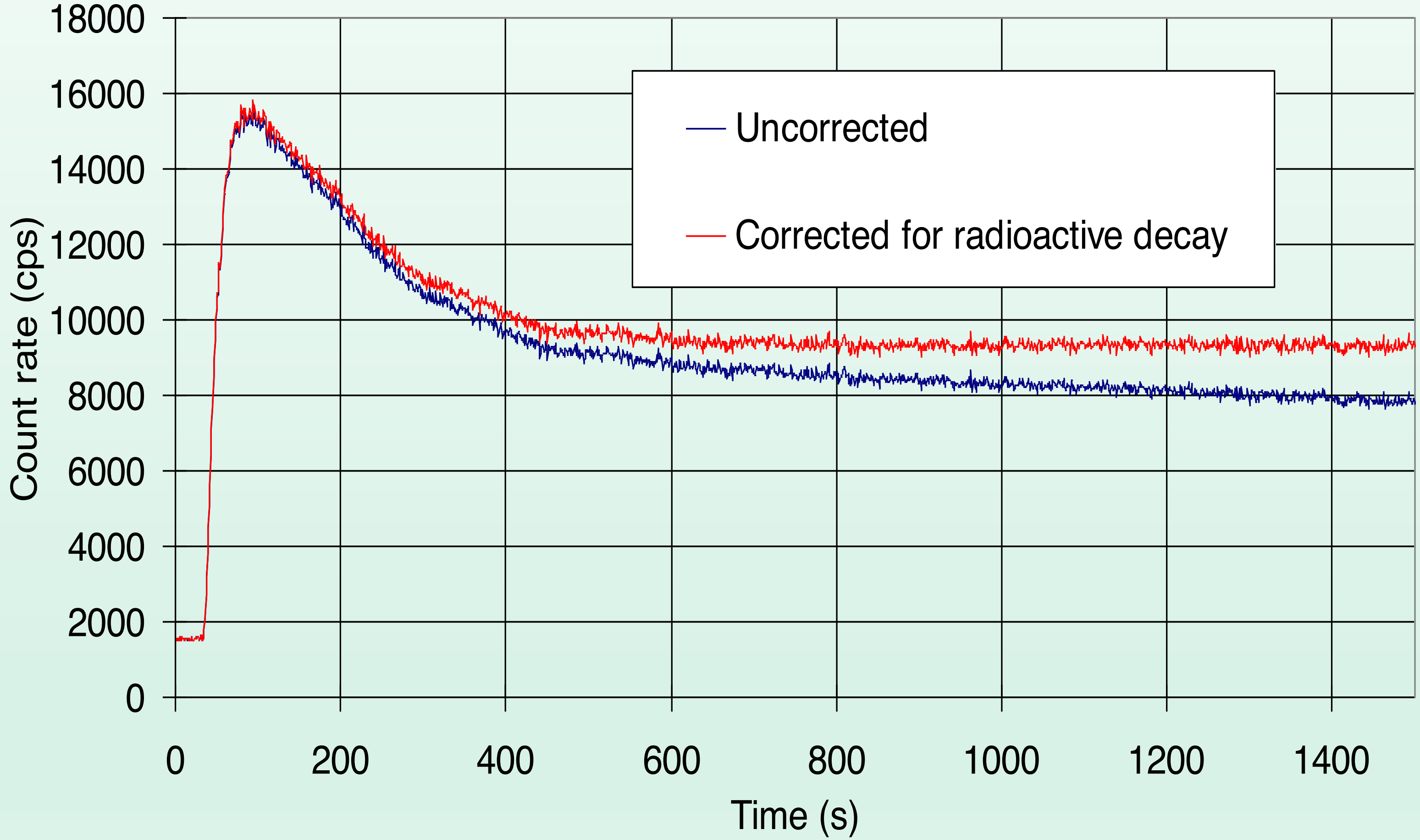
$$\dot{n}_N(t) = \dot{n}_m(t) - \dot{n}_{bg}$$



Tools: spreadsheet, …

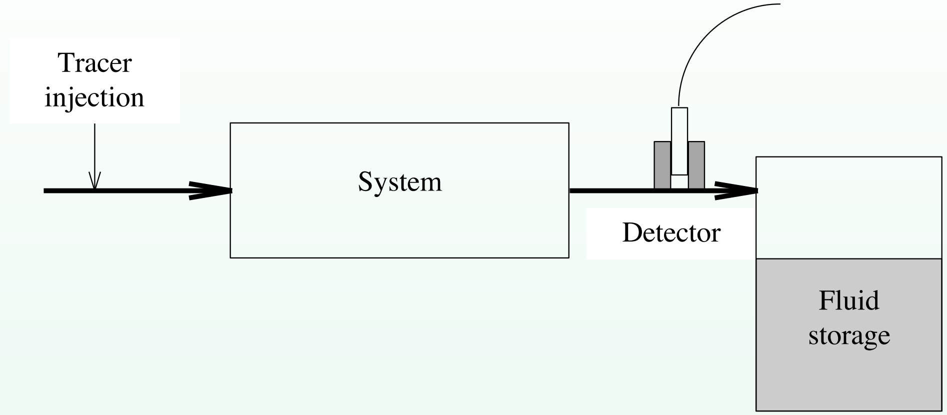
Radioactive decay correction

$$\dot{n}_c(t) = \dot{n}_m(t)\exp(\lambda t) = \dot{n}_m(t)\exp\left(\frac{0.693t}{T_{\frac{1}{2}}}\right)$$



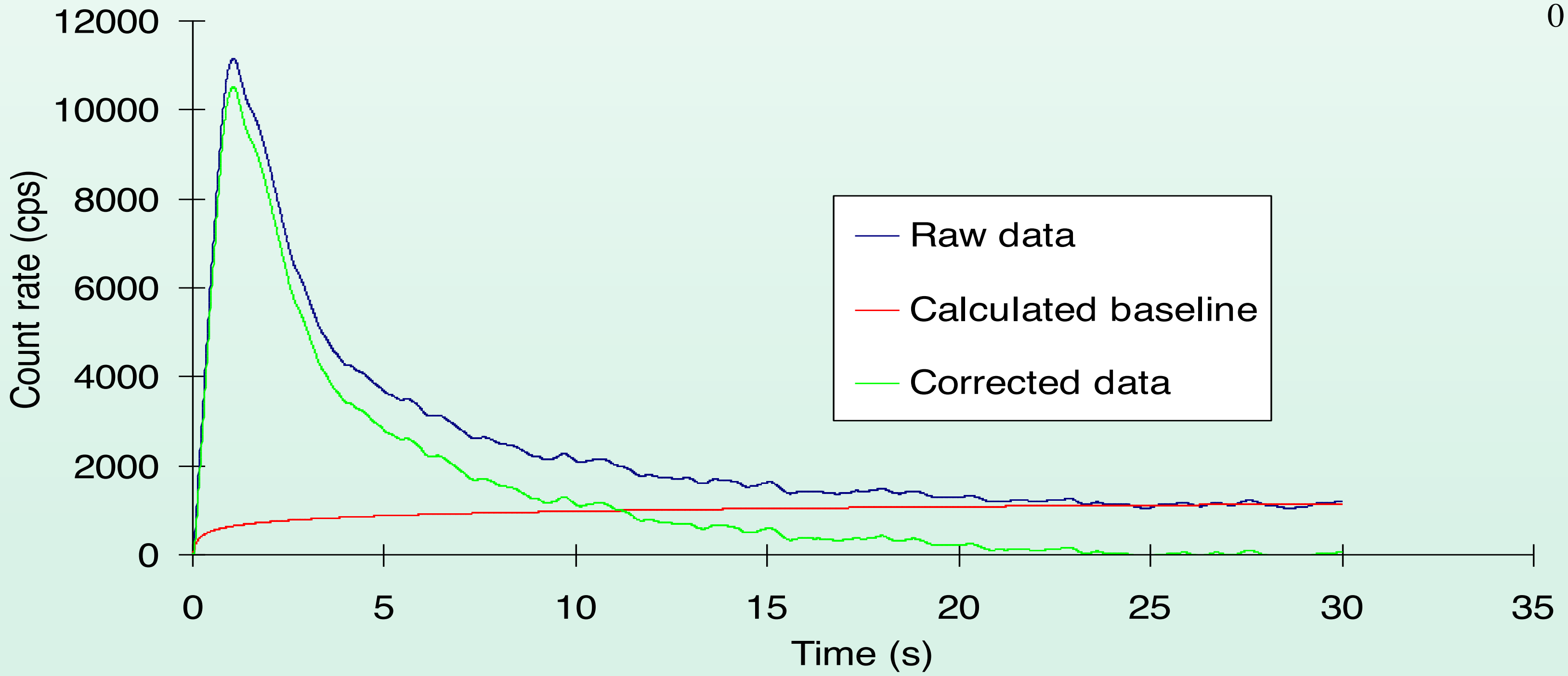
Tools: spreadsheet, Peakfit , DTSPro …

Background rise correction



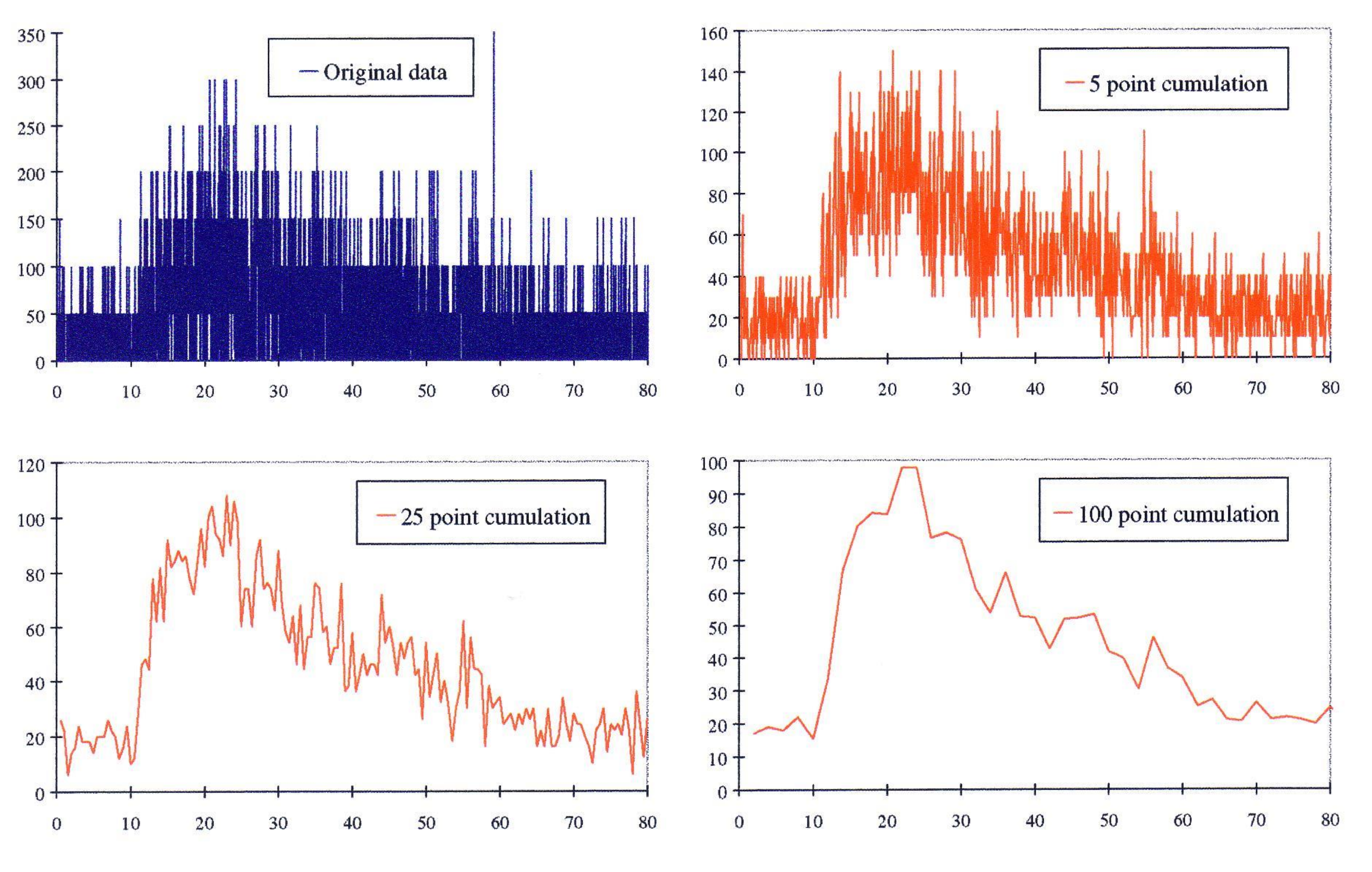
Main reason: Shift in baseline is due to radiotracer accumulation in the neighbourhood of the detector

$$\dot{n}_m(t) = \dot{n}_t(t) + k\int_0^t \dot{n}_t(u)\,du$$

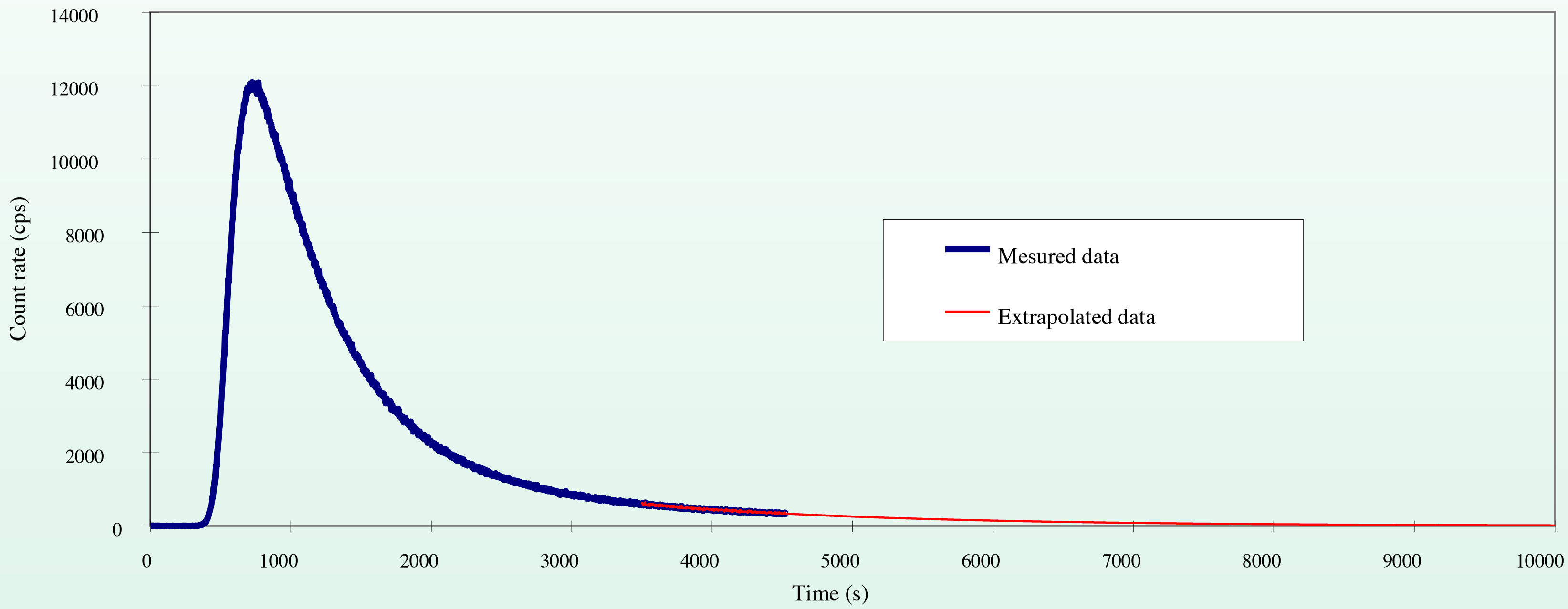


Tools: Peakfit, DTSPro

RTD Experimental curve and its smoothing

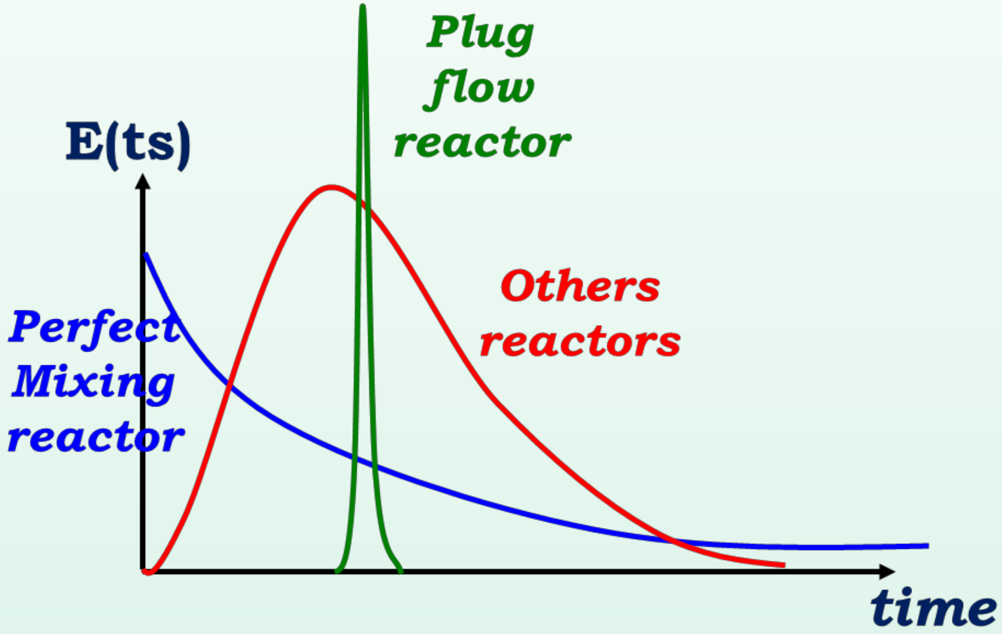


Data extrapolation



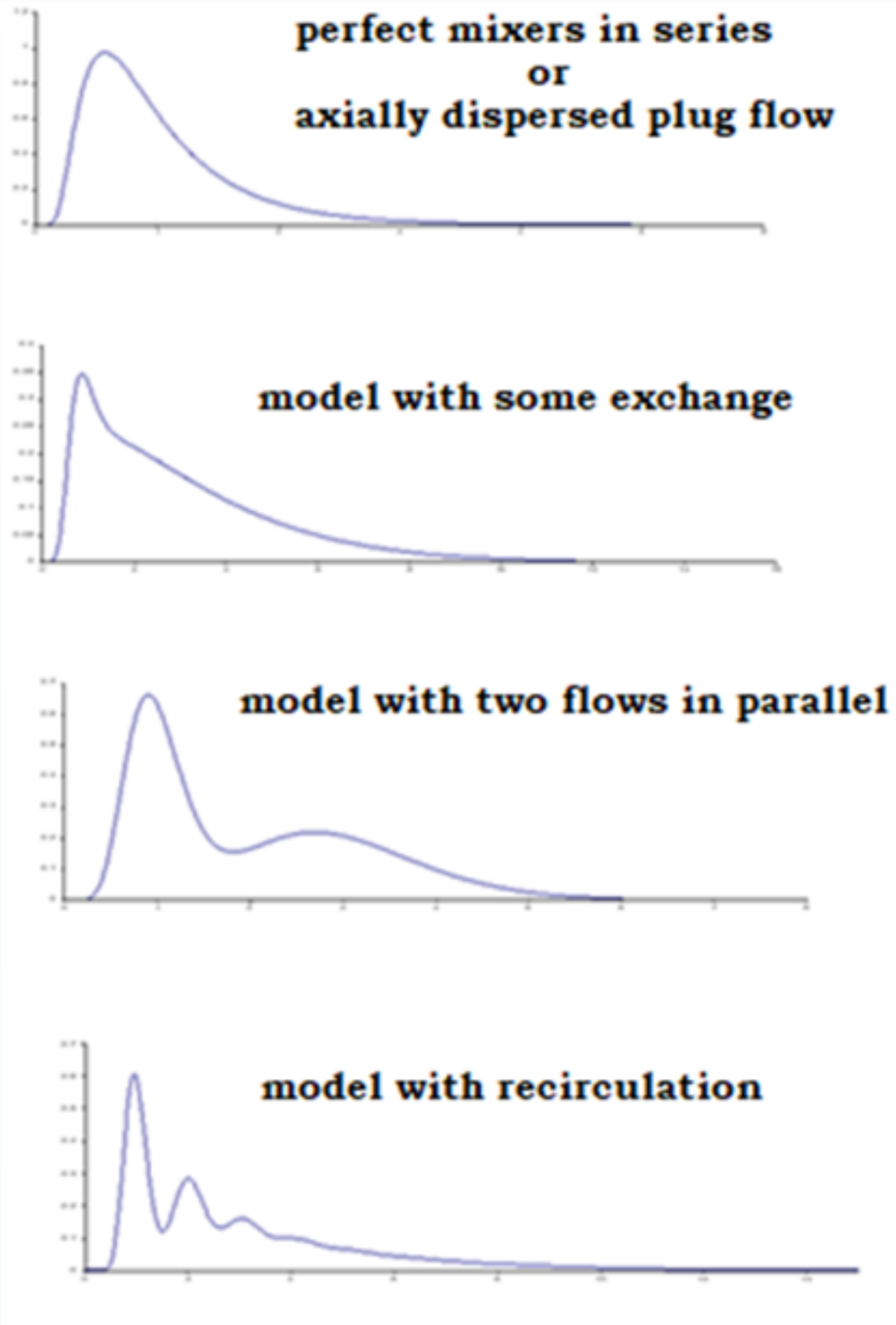
Quantity	Without extrapolation	With extrapolation	% difference
Total count (counts)	$1.22\ 10^{7}$	$1.28\ 10^{7}$	4.7
MRT (s)	1392	1624	17
Variance (s^2)	$6.86\ 10^{5}$	$1.89\ 10^{6}$	180

RTD modelling:
Ideal models:
plug flow and perfect mixer

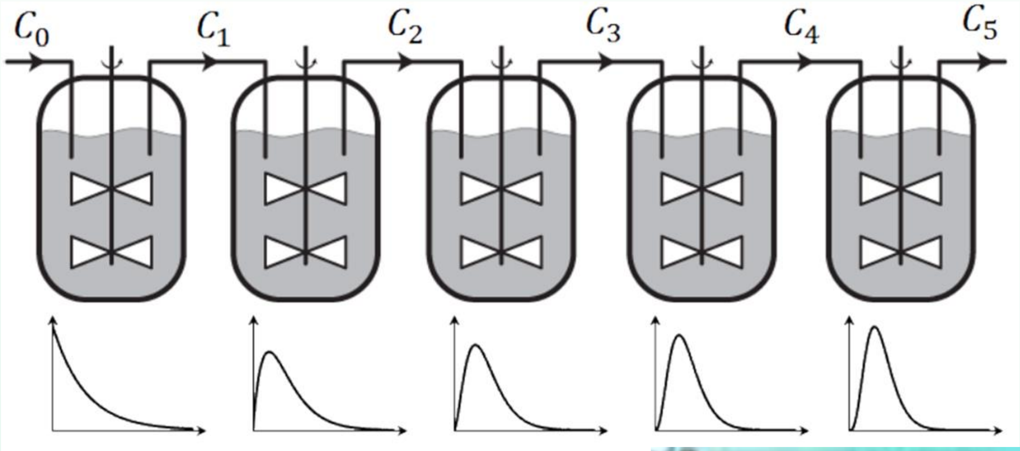


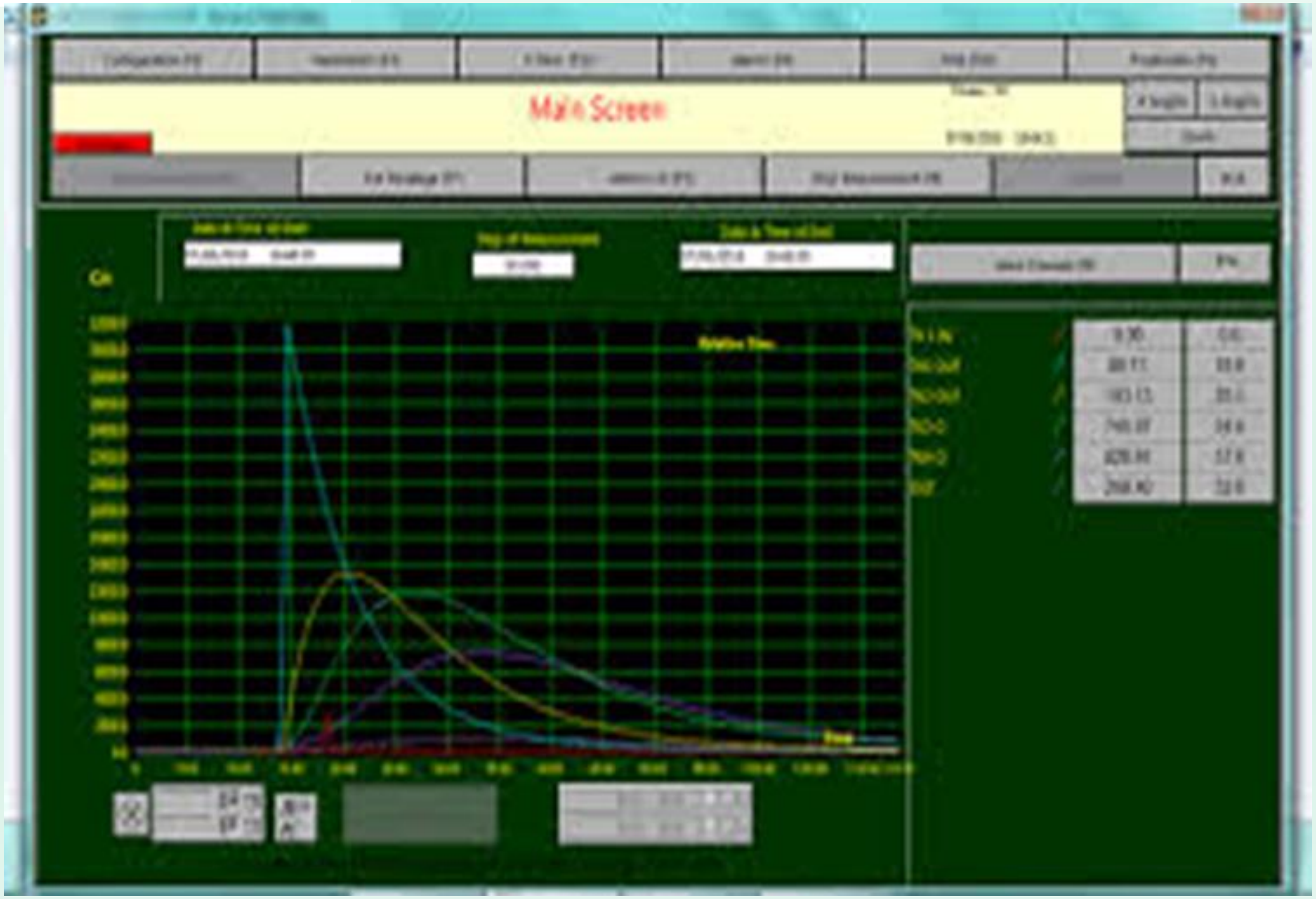
Typical real models

Perfect mixers in series, axially-dispersed plug flow and other combinations



Experimental RTD curves for perfect mixers in series





RTD software

Considering a system with an inlet and an outlet, represented by a model:

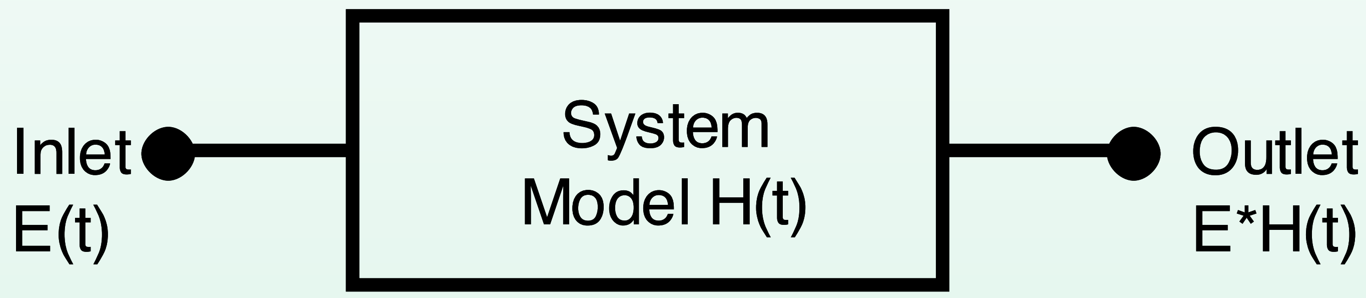


Figure 1: Basic configuration

the RTD software basically does two things:

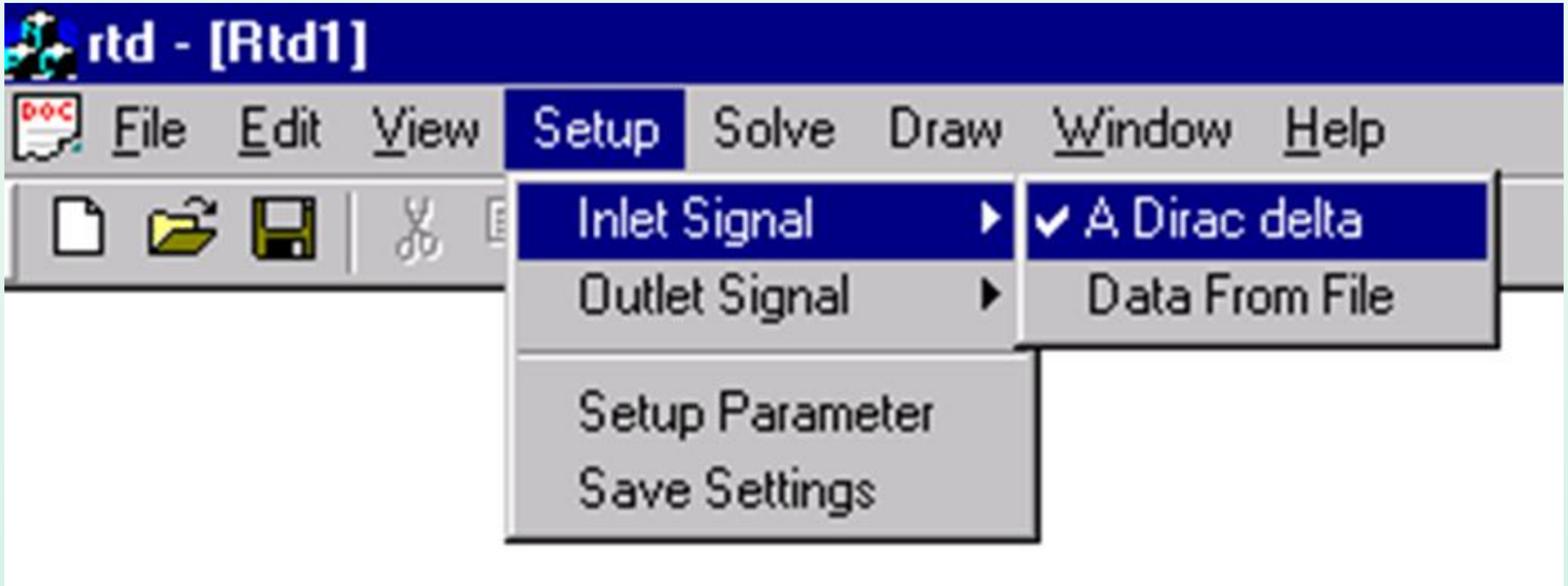
- calculate the response E*H(t) of the model to a given signal E(t); H(t) being the impulse response of the model and * the convolution operation;
- if the actual response of the system, S(t), has been measured, optimise the parameters of the model so that E*H(t) is as close as possible to S(t).

RTD software:
Data input – Preparing the calculation

RTD software needs three things to be specified:

- ***the signal at the inlet, E(t),***
- ***the signal measured at the outlet, S(t),***
- ***the model and the value of its parameters.***

All this is done with the Setup item of the menu. There are two choices for the inlet signal:

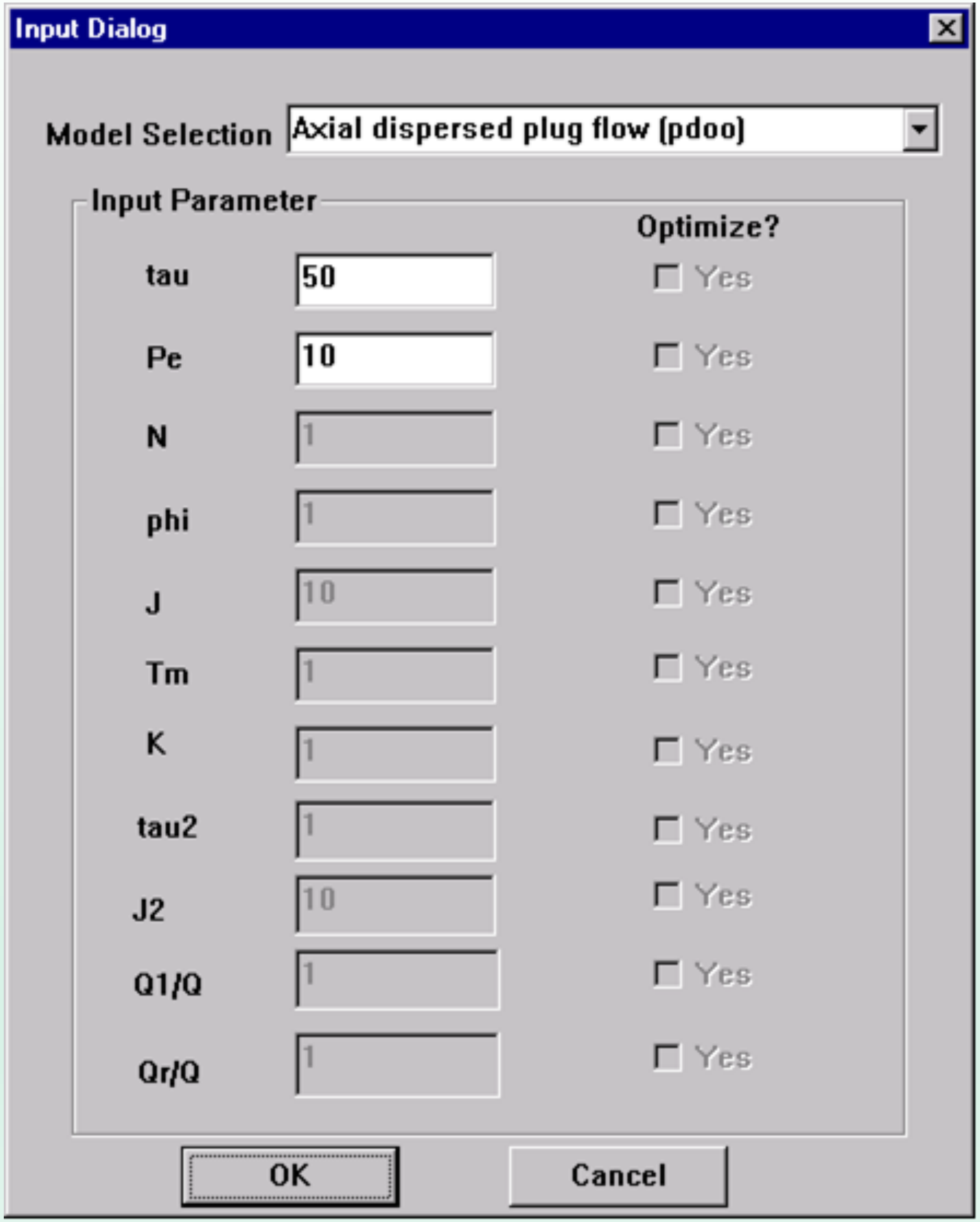


Defining the inlet signal:

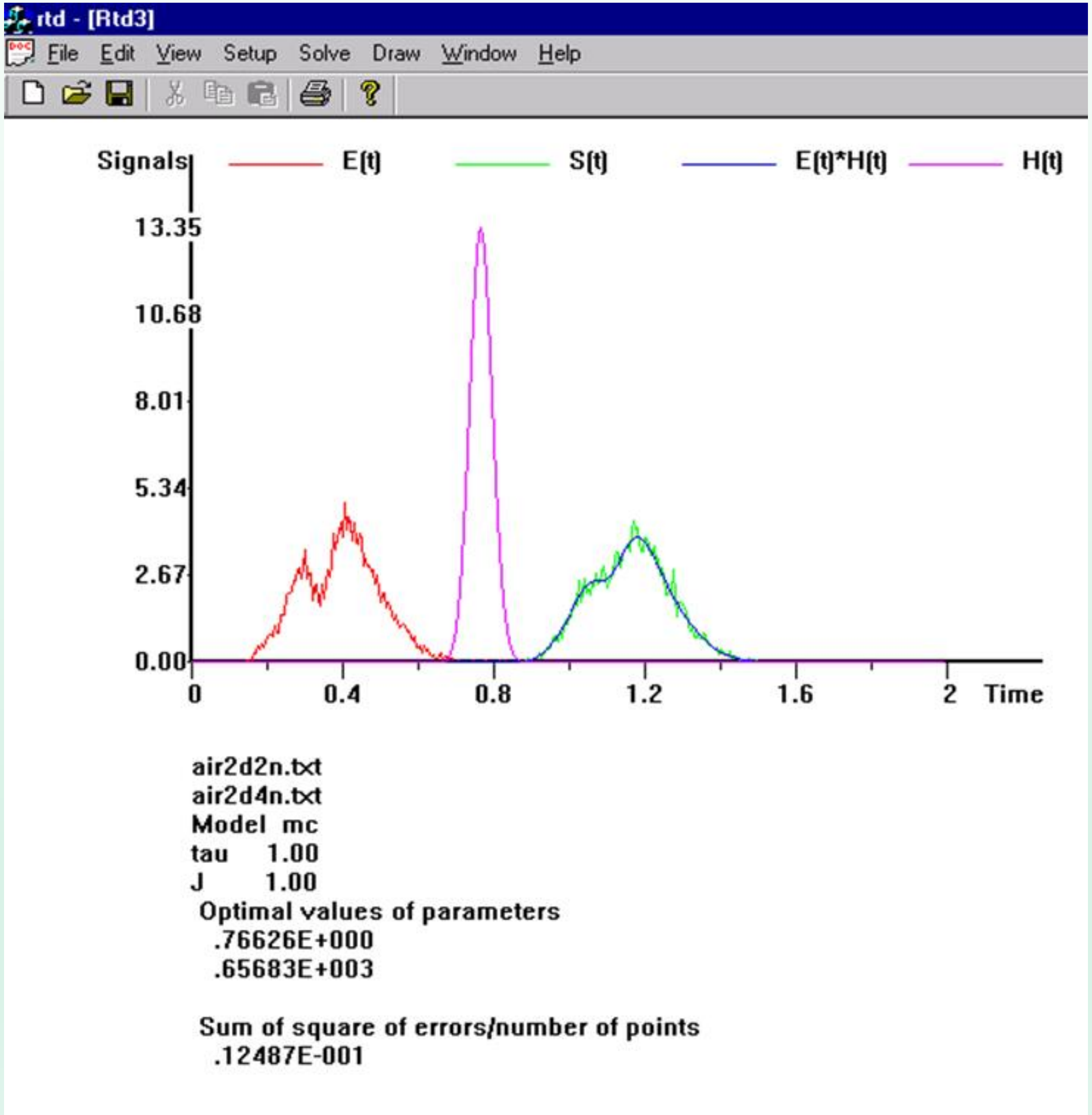
- **A Dirac delta function, corresponding to a very short tracer injection,**
- **data that in stored in a file (Data from file). In this case, the usual dialog box appears to let the user specify where the file is:**

RTD software

Dialog box for the selection of the model



Residence time distribution (RTD) between two section of the pipeline.



The graphs show:
inlet signal E(t),
outlet signal S(t),
*model response E*H(t) and*
model impulse response H(t).

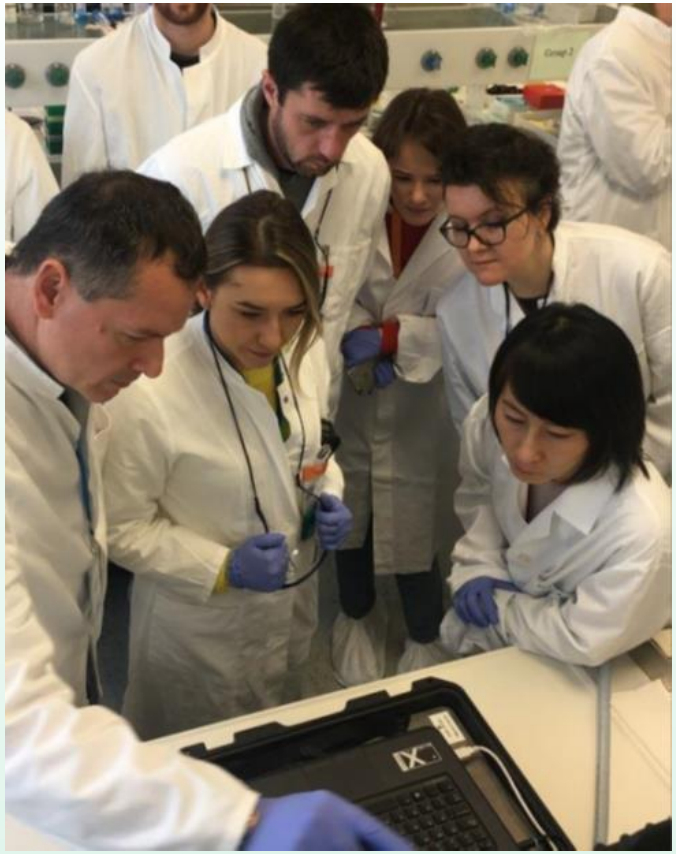
Optimal values of the parameters of the perfect mixers in series model:

- MRT = 0.77 s

- Number of perfect mixers in serties: J = 657 , it means the flow within the pipeline moves as plug (piston) flow model.

The"goodness of fit" criterion, the sum of the square of errors over the number of points= 0.0125, good fitness.

Training and certification
(Laboratory flow rig in Seibersdorfs)

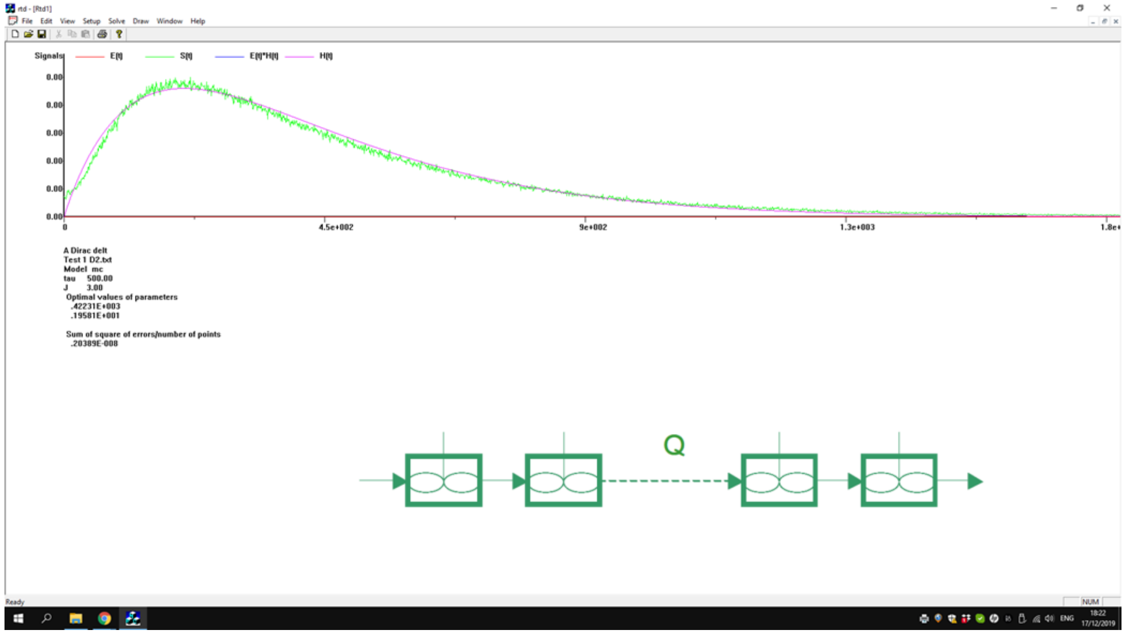


Tracer tests in flow rig:

Flow rate in the vessel: Q= 6 Lpm

Volume of the vessel (three compartments, N=3): V = 39 L

MRT_{th} = V/Q = 39 / 6 = 390 s



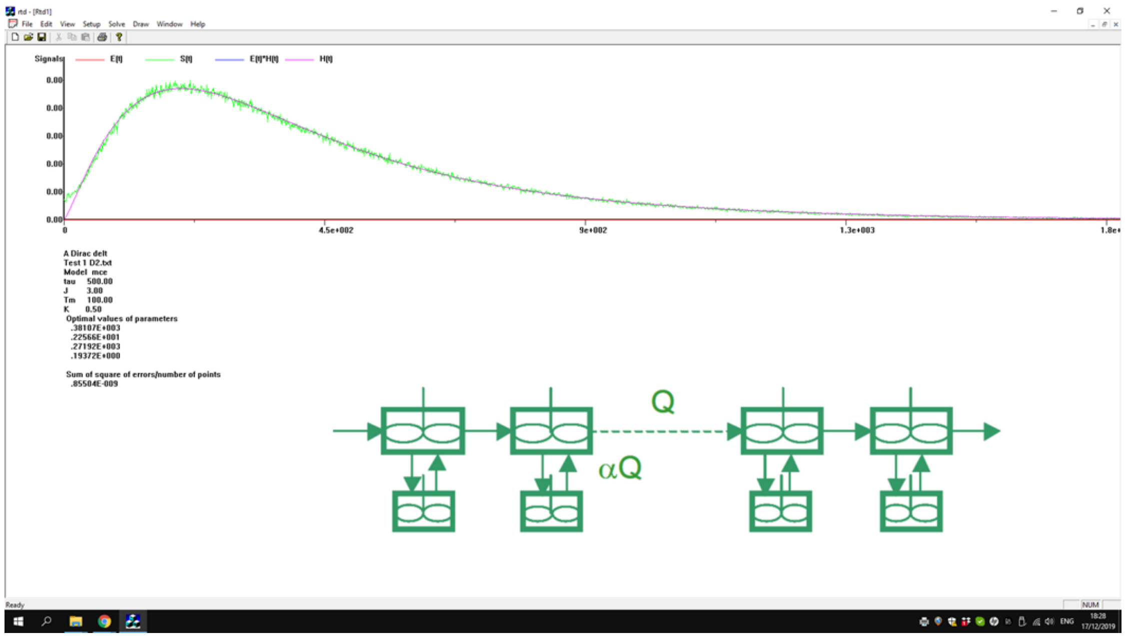
Model: Perfect mixers in series

Not good fitting:

MRT_{exp} = 422 s??? > MRT_{th}

Number of tanks in series:

N = 2 (out of 3 real mixers)



Model: Perfect mixers in series with backmixing

Good fitting:

MRT = 381 s

Number of tanks in series:

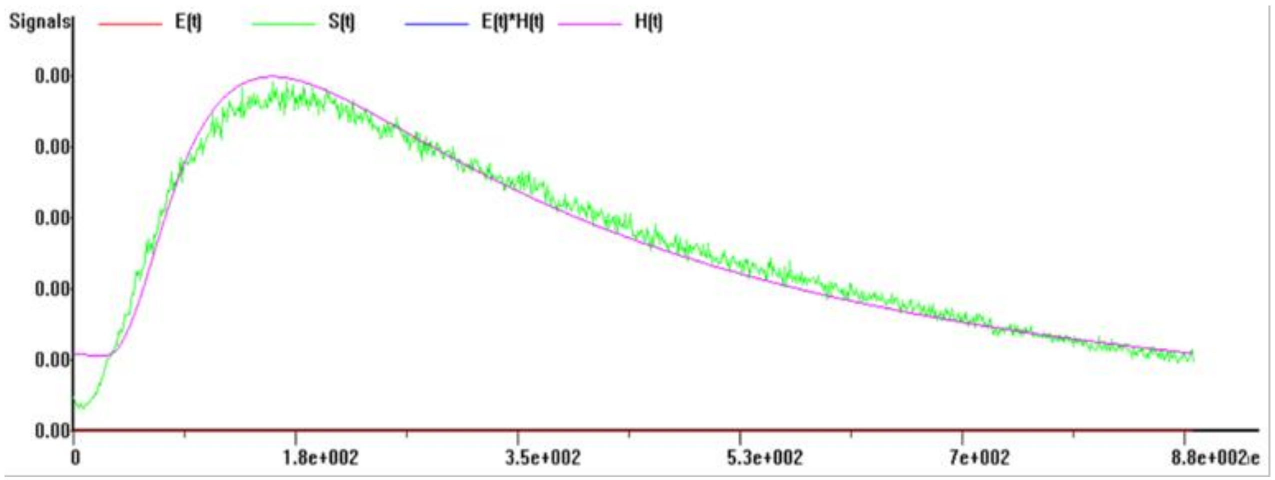
N = 2.3 (out of 3 mixers)

Time of exchange= 272 s

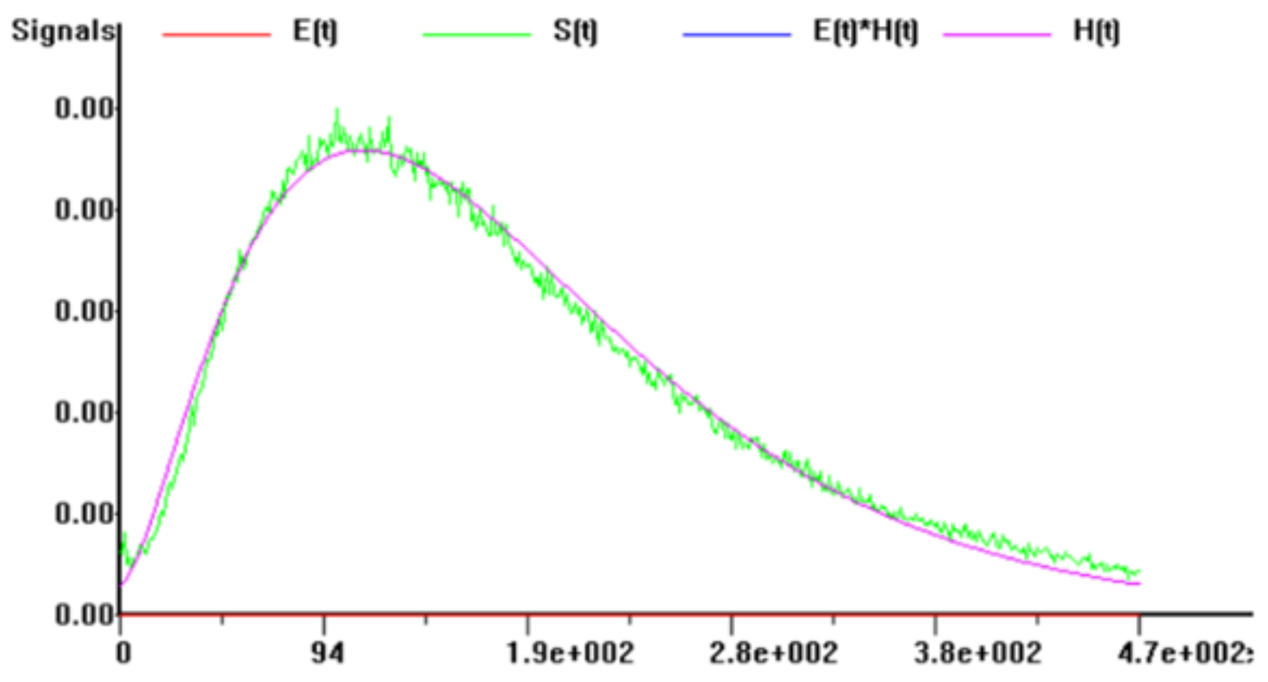
Coeficient of exchange with stagnant zone:

k_{exch} = 19%

Role of mixers in the RTD model of the flow rig tank



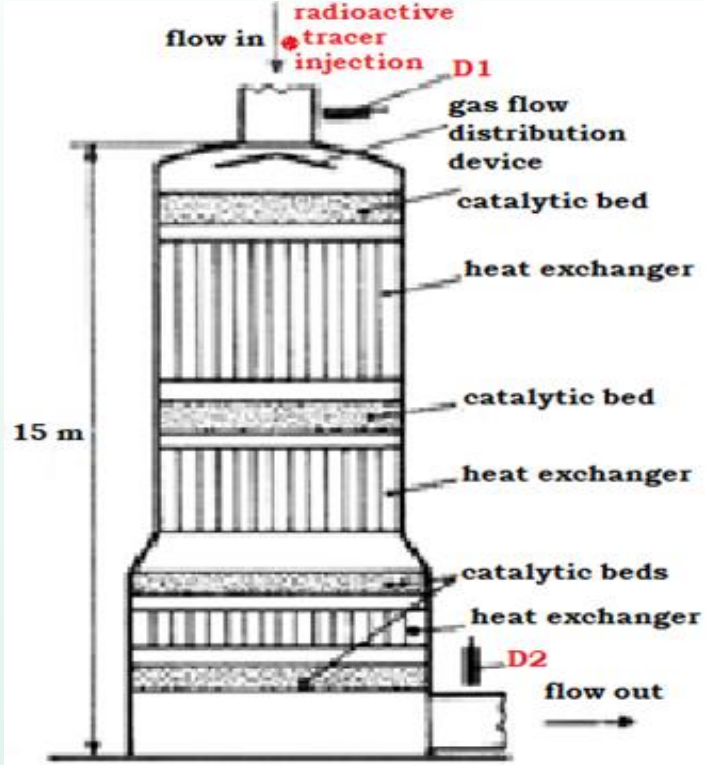
Test 1, Without mixers:
- long tail of experimental RTD curve
- not good fitting
MRT_{exp}= 268 s,
N=1.5 (out of 3 real mixers)



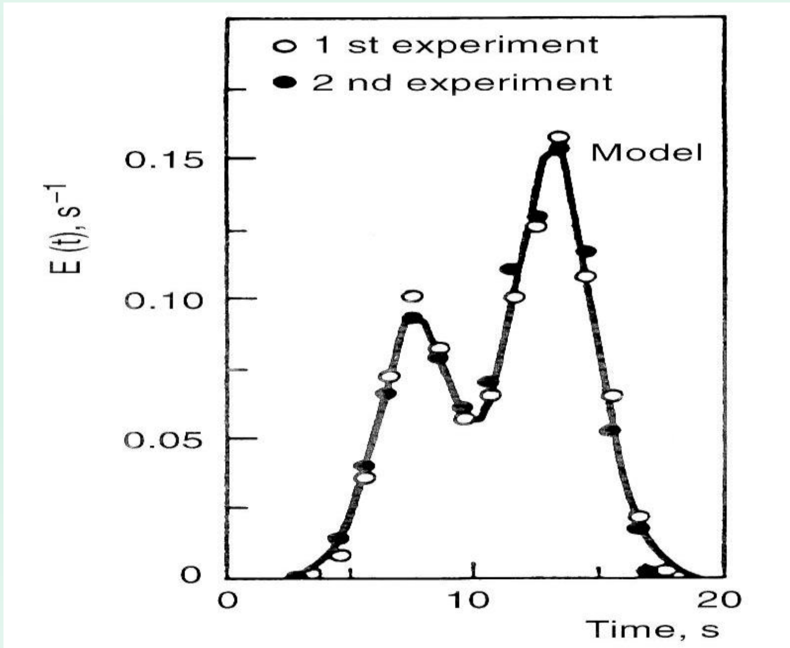
Test 2, With mixers:
- Normal curve
- Good fitting
MRT_{exp}= 187s,
N=2.6 (out of 3 real mixers)

Gas flow distribution in a SO_2 - oxidation industrial reactor

Problem: A reactor for H_2SO_4 production having four catalytic beds and three internal heat exchangers gave a low SO_2 - conversion of 90% instead of 95%

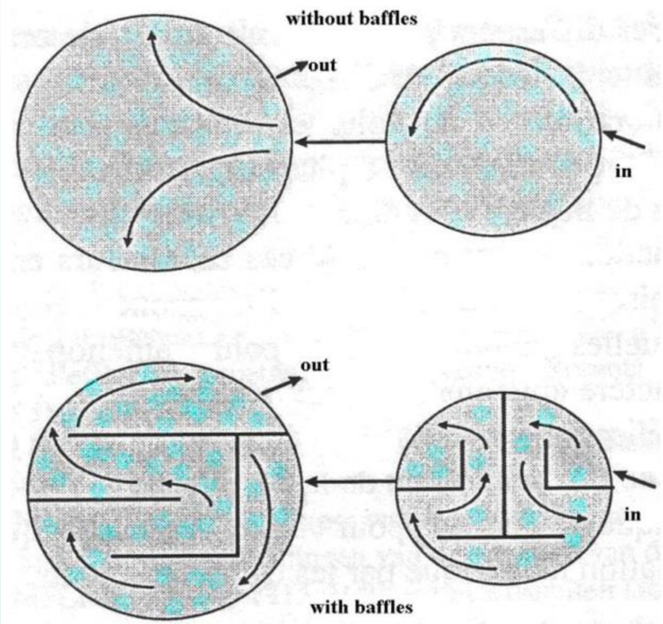


Conclusion: Gas flow distribution device was situated in close proximity to surface of first catalytic bed causing separation of entering gas flow into two zones, annular one and central.

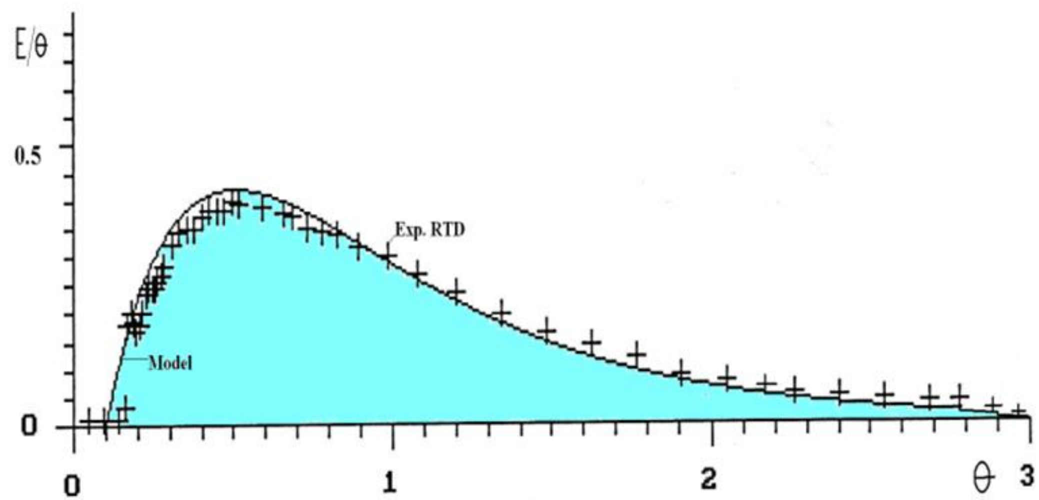


RADIOTRACER INVESTIGATION OF WASTEWATER CHLORINATE PROCESS

Chlorine reactor consisted of two cylindrical reservoirs connected in series with volumes of
V1 = 925 m3 and V2 = 1625 m3



Problem: low efficiency of wastewater chlorinate process



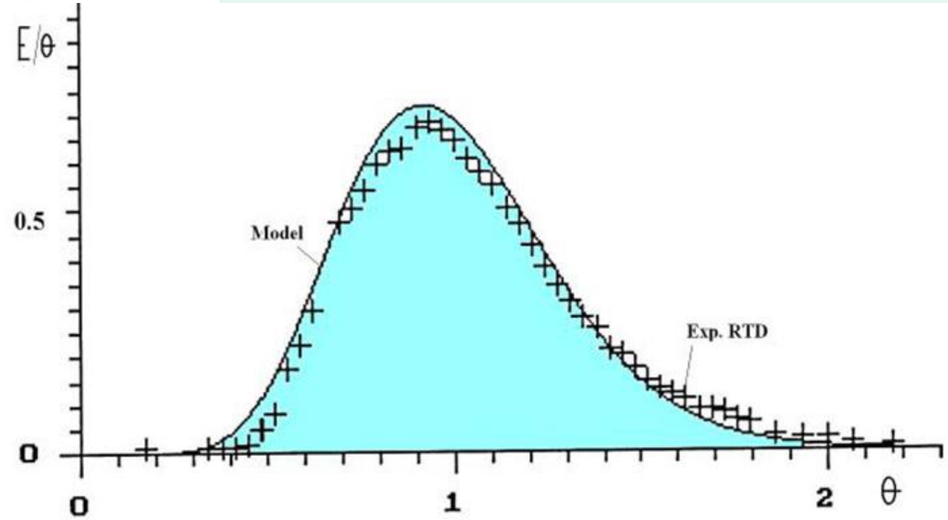
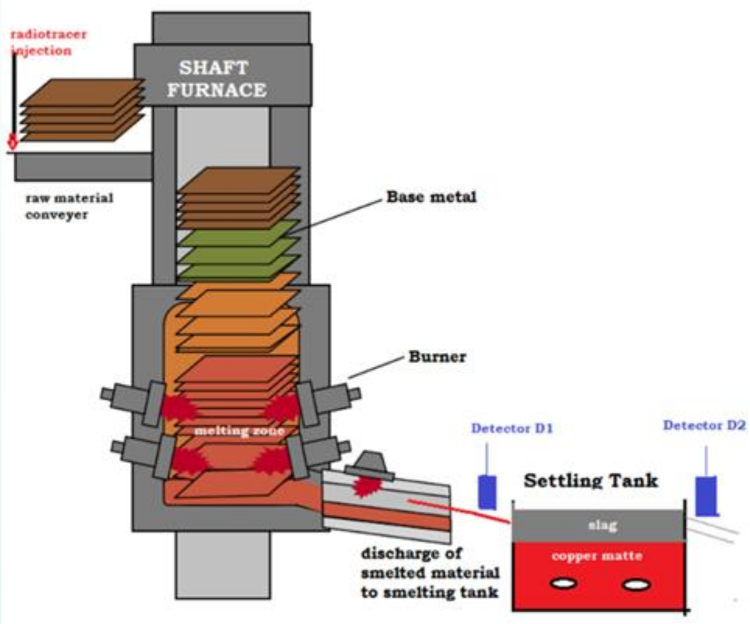


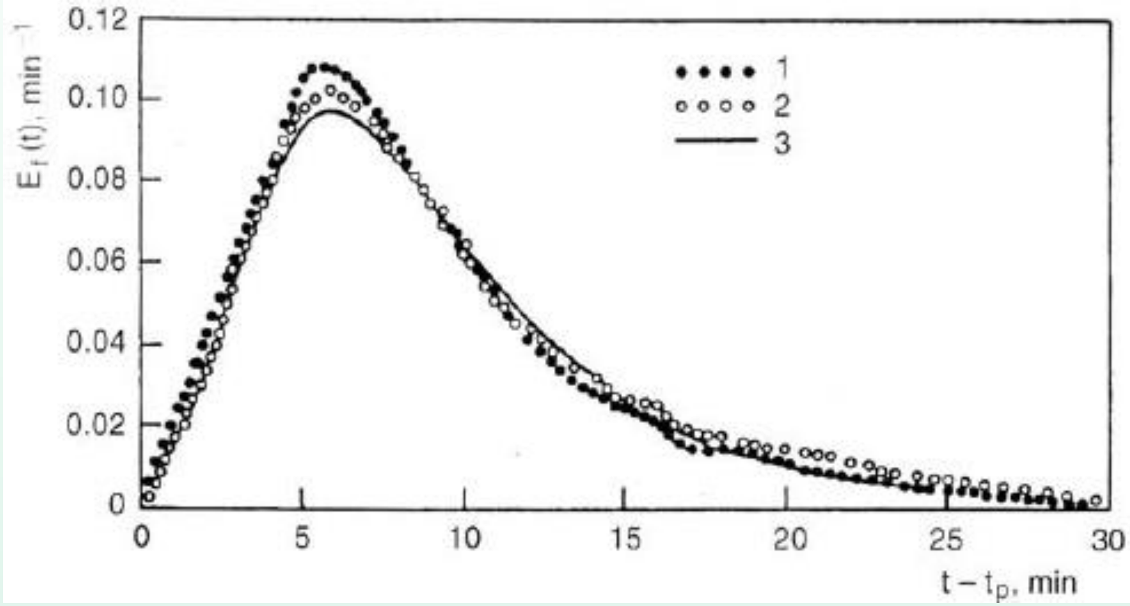
FIG.25. Experimental RTD curves and their models before(left) and after (right) modification

Conclusion: Installation of baffles improved the homogenization

INVESTIGATION OF FLOW DYNAMICS IN A COPPER MELTING PROCESS



Experimental RTD curves of 58CoO and 58CoS at outlet of shaft furnace:
1 – 58CoO, 2- 58CoS,
3- model tanks in series N=3.2



Conclusion:
20% of the volume of settling tank was blocked by solidified material.

Experimental RTD curves at outlet of settling tank
(1 – 58CoO, 2- 58CoS,
3- by-pass model)