



# **Models for the interpretation of local flux measurements in subcritical systems**

Sandra Dulla, Matteo M.  
Rostagno, Piero Ravetto

Politecnico di Torino, Dipartimento di  
Energetica  
Torino, Italy

# Outline

- Introduction and scope of the work
- Methodology
- Results and discussion
- Future work

# Introduction (1)

- Experiments are under way to study the physics of source-driven systems
- Reactivity reconstruction from local flux measurements is an important aspect
- Pulsed experiments are considered
- Flux interpretation needs to account for spectral and spatial effects

# Introduction (2)

- Inverse methods are easily implemented from point kinetics models
- It has been observed that satisfactory results are obtained if the global system power is used in inverse methods associated to *global* kinetic parameters

However

- Only signals from local flux detectors are available

# Introduction (3)

- Signals from local detectors have to be (importance) averaged
- Strong importance effects can be observed in source-driven problems
- More suitable and problem-oriented weighting procedures must be used in inverse frameworks to construct ad-hoc kinetic parameters

# Scope of the analysis

- *Study importance weighting procedures to generate point models that are adequate to accurately simulate local flux signal evolutions in a pulsed experiment*
- *Redefine time-dependence of source to better represent the physical response*

# Methodology

Integral parameters are derived by taking the factorized balance equations

$$n(\hat{x}, t) = A(t)j(\hat{x}; t)$$

$$\begin{aligned} \frac{d}{dt} \langle A_j \rangle &= \hat{L}_j A + \hat{F}_{pj} A + l C + S \\ \frac{d}{dt} \langle C \rangle &= -l C + \hat{F}_{dj} A \end{aligned}$$

project them on a weight

$$\begin{aligned} \frac{d}{dt} \langle y | j \rangle &= \langle y | \hat{L}_j \rangle A + \langle y | \hat{F}_{pj} \rangle A + l \langle y | C \rangle + \langle y | S \rangle \\ \frac{d}{dt} \langle y | C \rangle &= -l \langle y | C \rangle + \langle y | \hat{F}_{dj} \rangle A \end{aligned}$$

# Methodology

...obtaining a system of equations in time for amplitude functions with a point-like structure

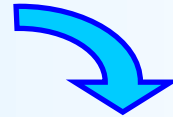
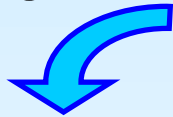
$$\begin{aligned} \frac{dA}{dt} &= \frac{\langle y | \hat{L}j \rangle}{\langle y | j \rangle} A + \frac{\langle y | \hat{F}_p j \rangle}{\langle y | j \rangle} A + l \mathcal{C} + \frac{\langle y | S \rangle}{\langle y | j \rangle} \\ \frac{d\mathcal{C}}{dt} &= -l \mathcal{C} + \frac{\langle y | \hat{F}_d j \rangle}{\langle y | j \rangle} A \end{aligned}$$

Questions:

- Choice of the shape function  $\varphi$ ? **Initial reference configuration**
- Choice of the weighting function?  $\rightarrow$  definition of **various point kinetic models** with different objectives

# Global and Local Point Kinetics (*gpk*) and (*lpk*)

weighting function  $\rightarrow$  adjoint problem



**Source-driven adjoint**

critical adjoint

(eigenvalue)



- the adjoint source can be assumed as the local detector where the flux measurement is taken  $\rightarrow lpk$
- global weighting, i.e. assuming as adjoint source the fission productivity  $v\Sigma_f$ , suitable to predict power evolution  $\rightarrow gpk$

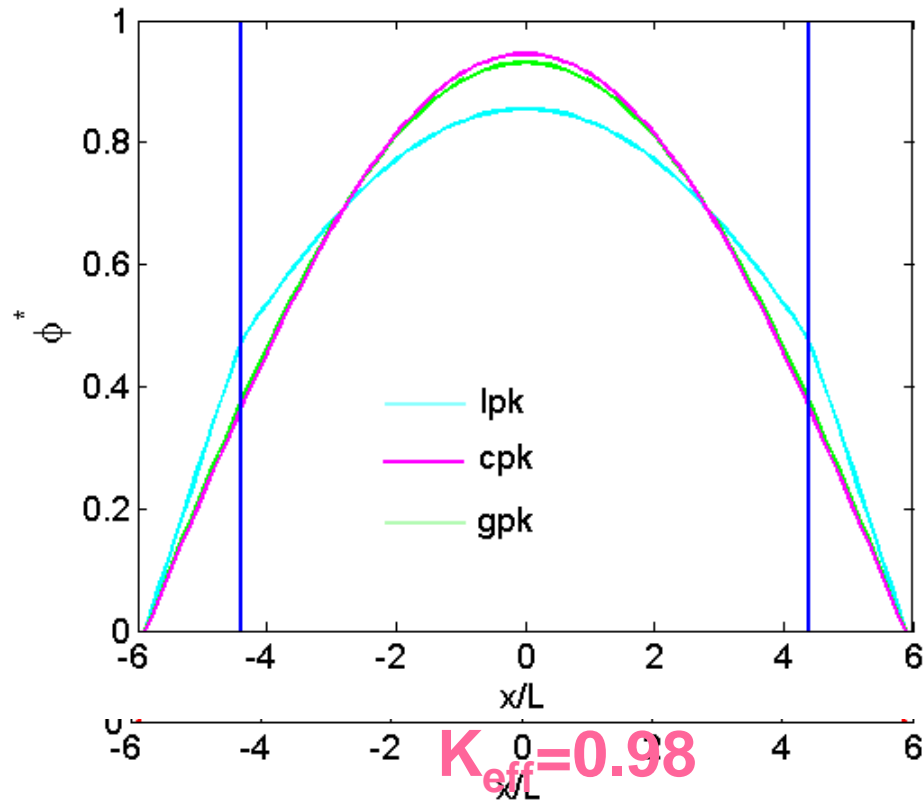
# Pulsed-source experiments

- Localized source in space and time
- Analysis of the evolution of the flux after the source pulse
- Comparison of different options for the construction of the point model adopted in the interpretation of the results

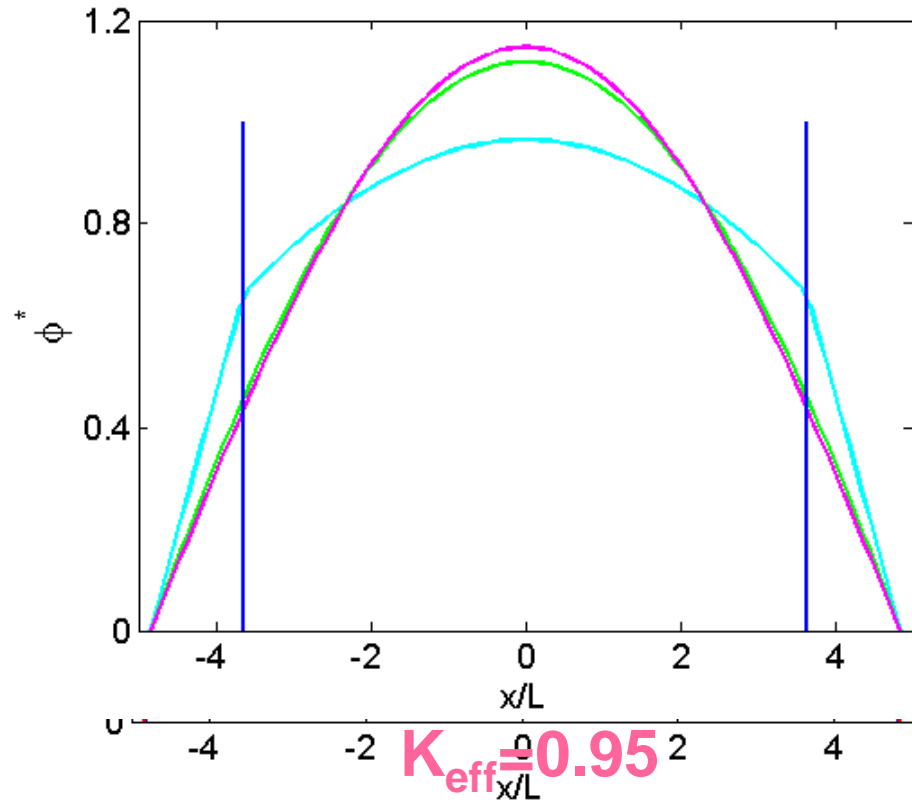
# Pulsed-source experiments

- Analytical and semi-analytical study of a source pulse in a 1D system:
  - Comparison of exact results with point kinetic models;
  - Influence of the distance of the detector from the source:
    - Time-delay of the response of the system
    - Modification of the time behavior of the source

# Pulsed-source experiments

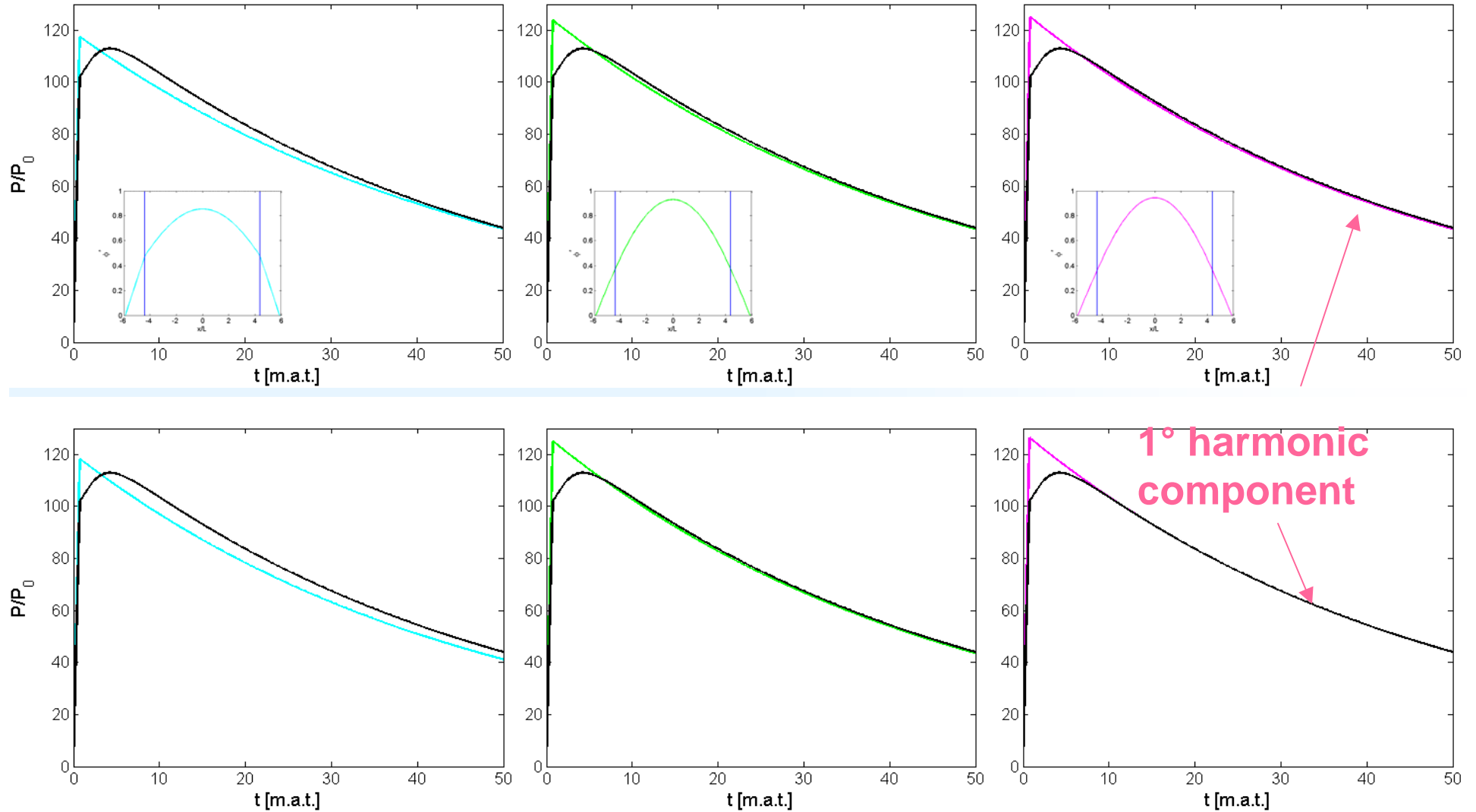


$K_{eff} = 0.98$

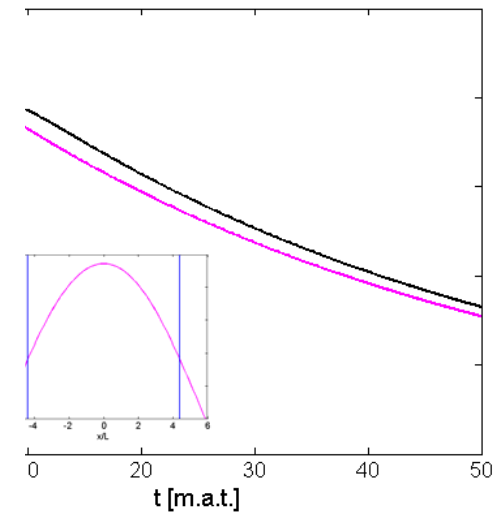
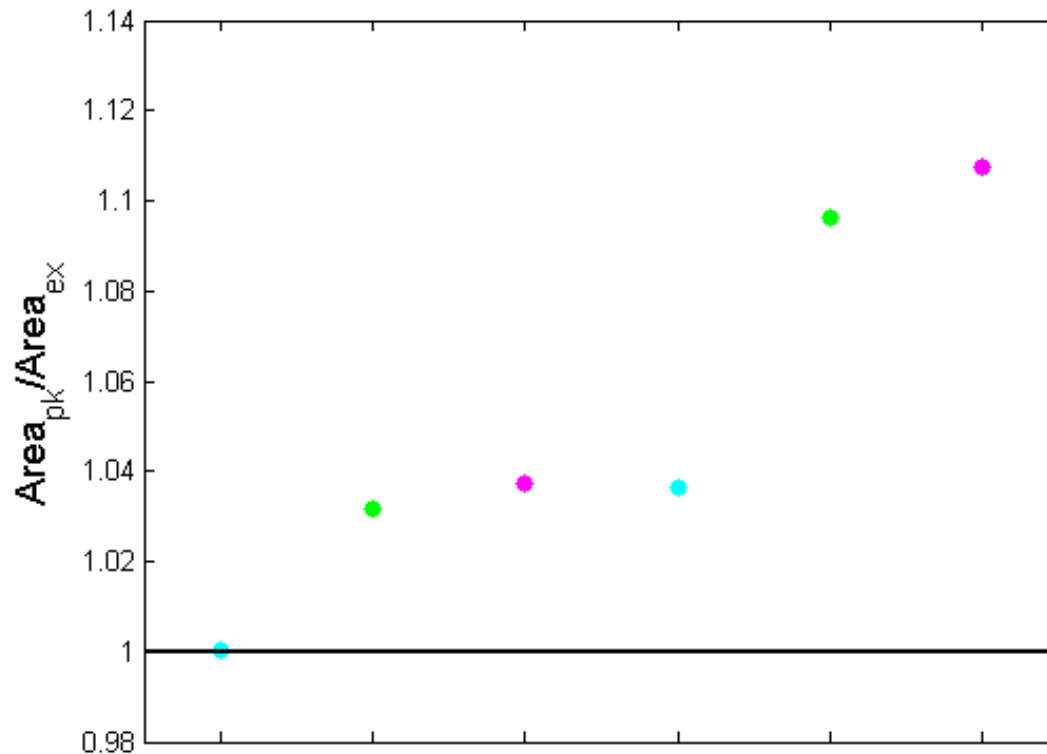
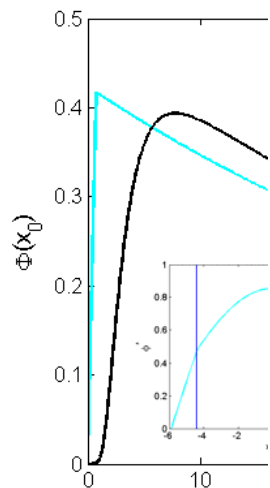


$K_{eff} = 0.95$

# Pulsed-source experiments - Power evolution



# Pulsed-source experiments– Flux at detector position



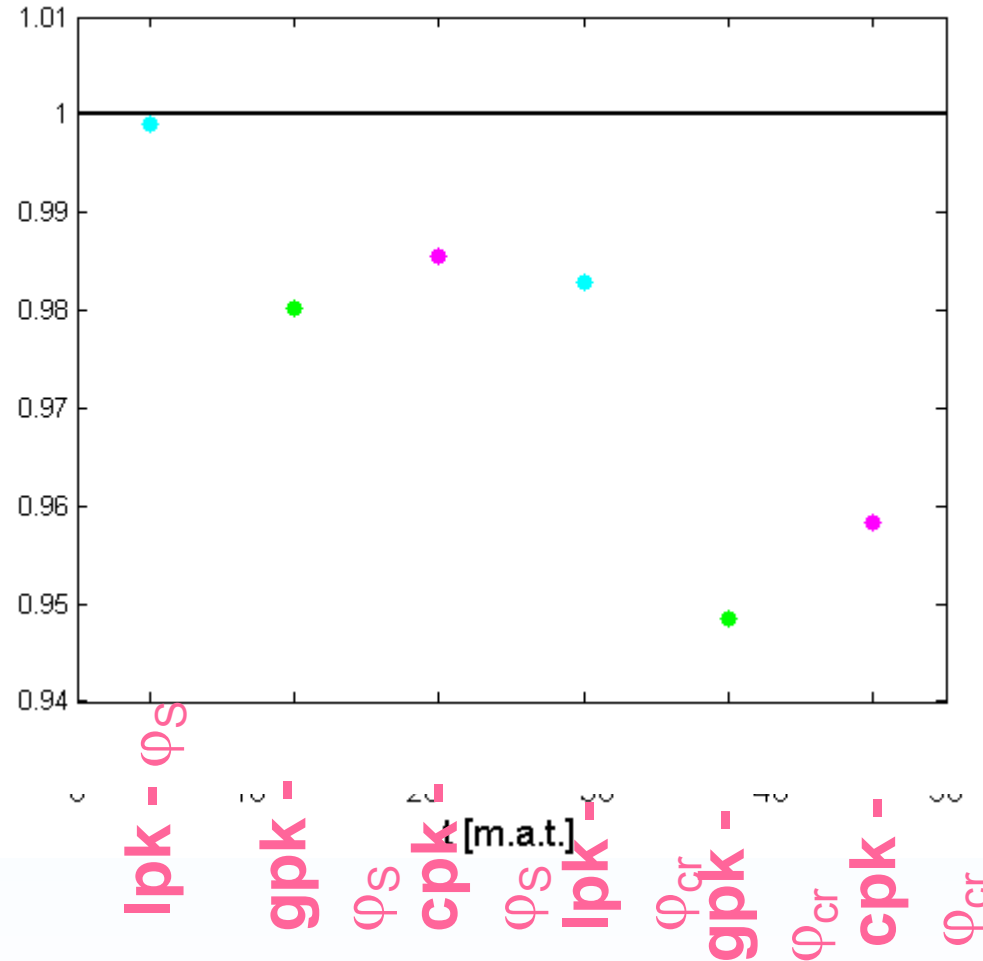
- Flux
- Intensity

areas (important when area methods are used in the interpretation of measurements)

detector  
serving

# Pulsed-source experiments - Power evolution

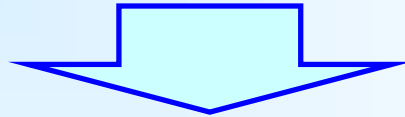
- A de
- cons
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re flux  
in

# Pulsed-source experiments– Flux at detector position

- Flux response at spatial points far from the source is mainly influenced by the time delay of the neutron signal detected

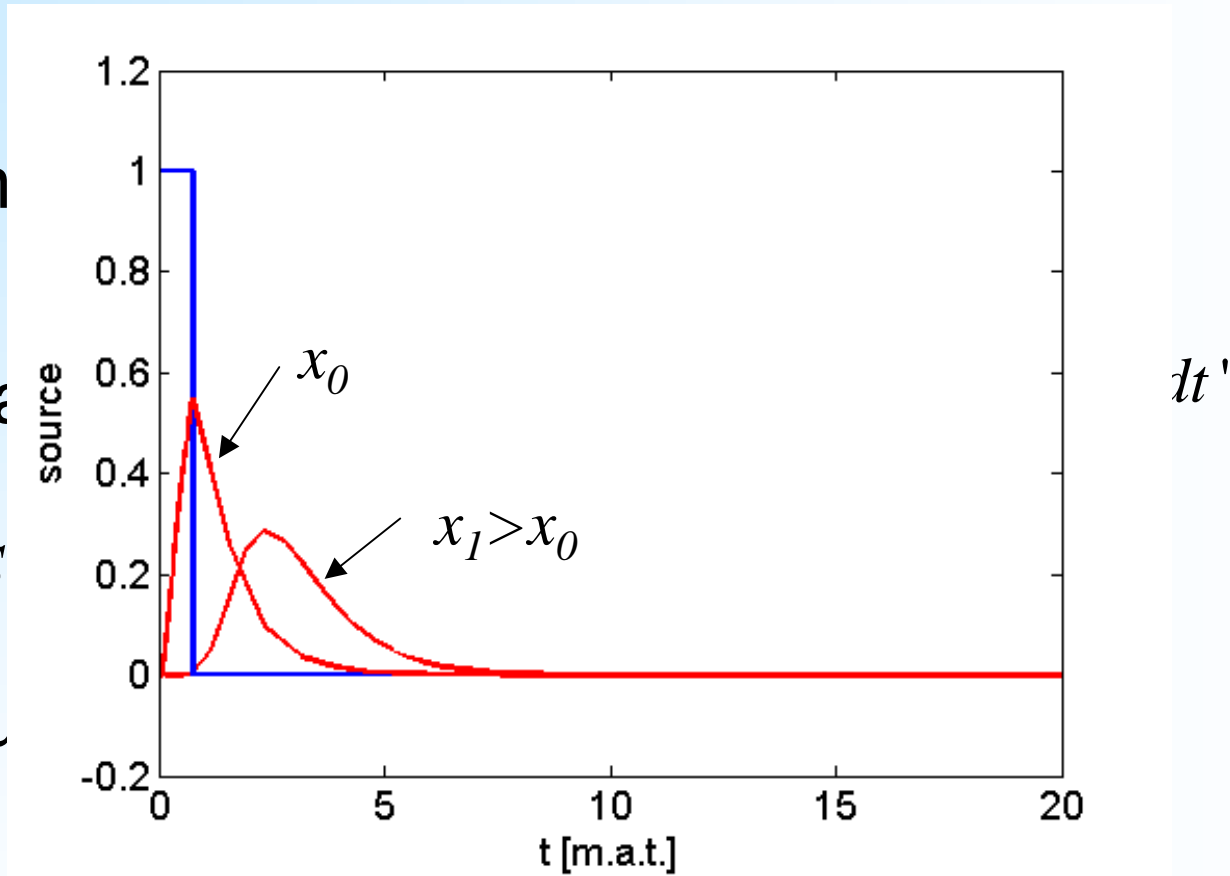


It is necessary to modify the time behavior of the source in order to simulate the real signal

- Evaluation of time of flight to detector position
- Evaluation of mean travel time (which distribution?)
- Convolution of external source with system response (use of Green function)

# Treatment of source delay

- Time
- Mea
- Sou



$$\mathcal{J}(t) = \int_0^t J(t') G(x_0, t' \oplus t) dt'$$

# Treatment of source delay

$$x_0 = 4.4L$$

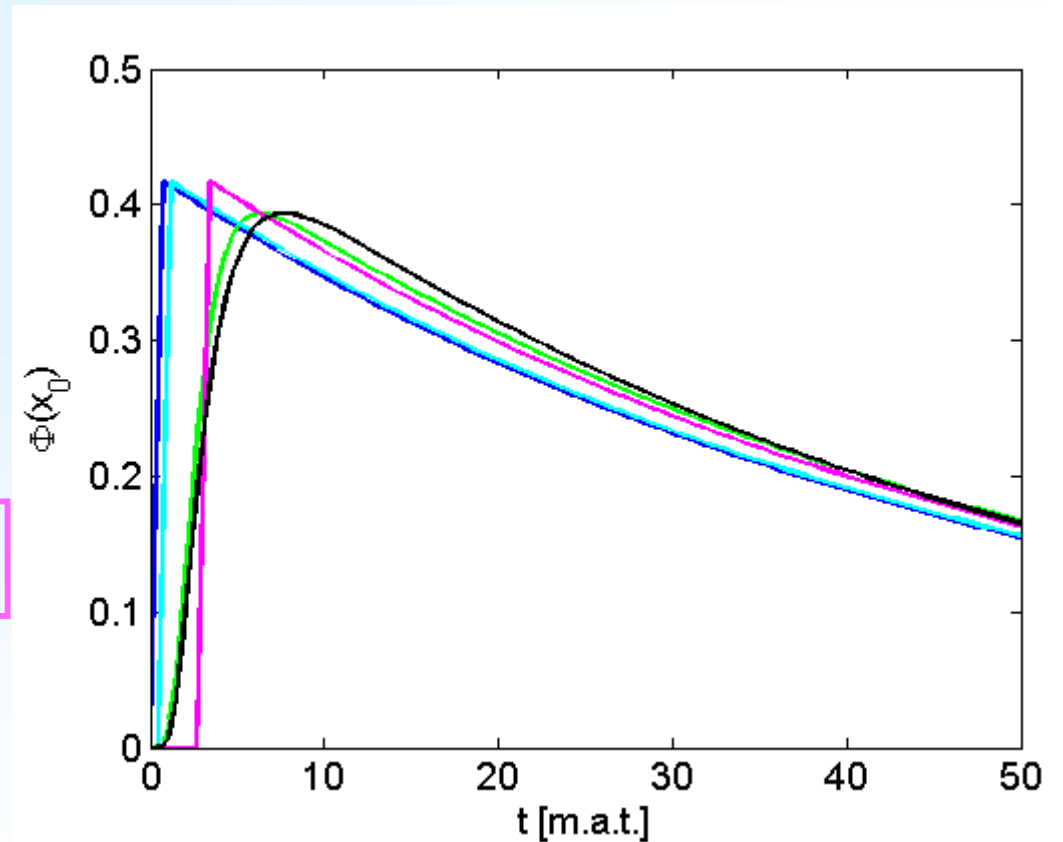
Exact  
solution

Point  
kinetics

$$t_{x_0} = \frac{x_0}{v} = 6.15ms = 0.46 \text{ m.a.t.}$$

$$t_{x_0} = \int_0^{x_0} \frac{1}{v} dt' = 36ms = 2.7 \text{ m.a.t.}$$

Convolution with Green function



# Treatment of source delay

$$x_0 = 0.9L$$

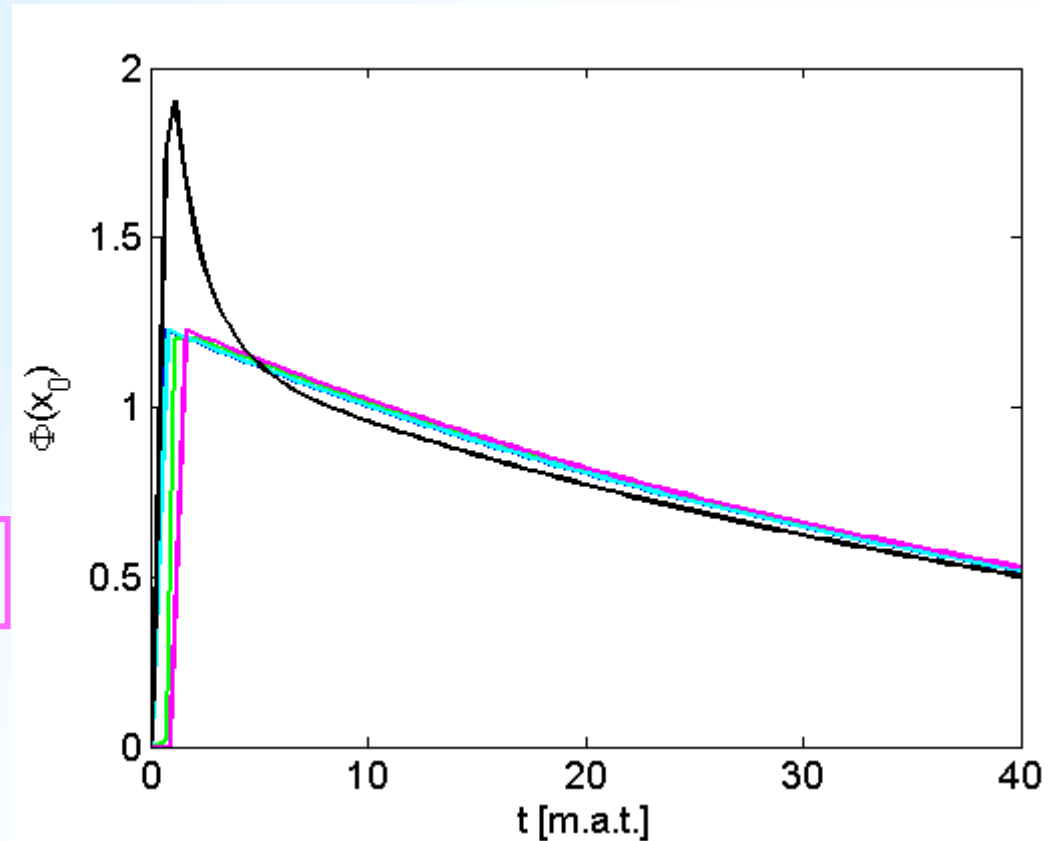
Exact  
solution

Point  
kinetics

$$t_{x_0} = \frac{x_0}{v} = 1.16\text{ms} = 0.087 \text{ m.a.t.}$$

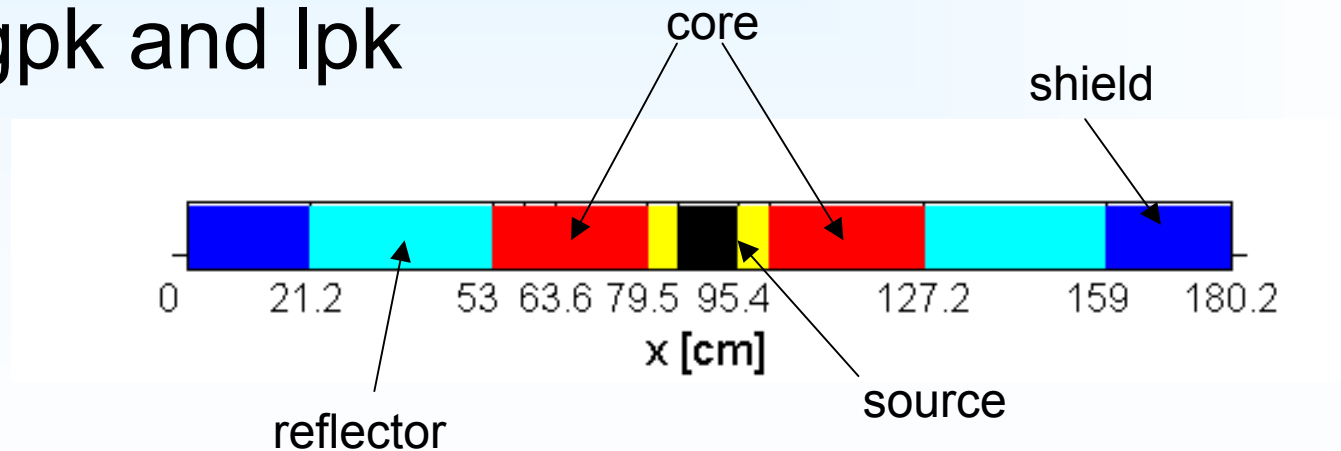
$$t_{x_0} = \int_0^{x_0} t' f(x_0, t') dt' = 12.3\text{ms} = 0.92\text{m.a.t.}$$

Convolution with Green function

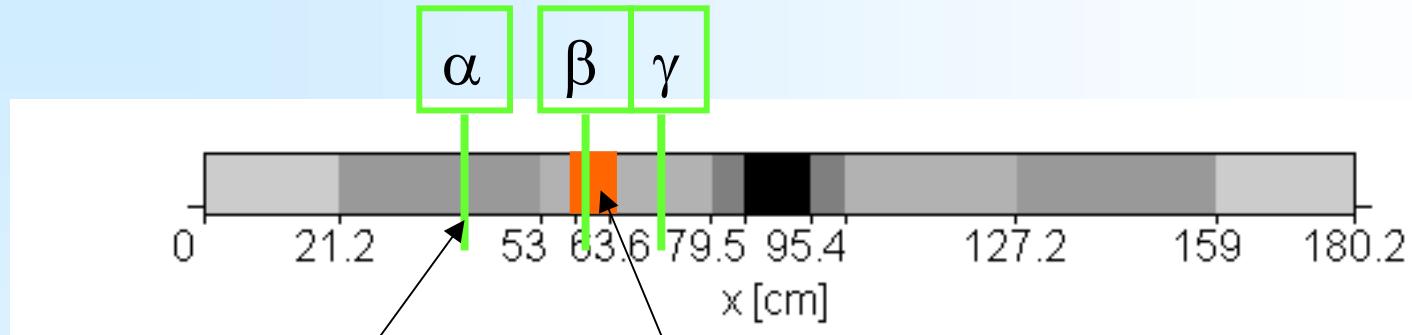


# Use of $l_{pk}$ in transient evaluation

- 3-group solution in a MUSE-like configuration (1D)
- Localized perturbations of cross sections
- Evaluation of power and local flux using  $g_{pk}$  and  $l_{pk}$



# Use of $I_{pk}$ in transient evaluation



Monochromatic detectors  $d_{\alpha,g}$

$$\Delta\Sigma_{a,g} < 0$$

Transient 1:  $\Delta\Sigma_{a,1} < 0$

$$\Delta\rho = 729 \text{ pcm}$$

Improved performances with  $I_{pk}$

- $P/P_0 = 1.286$

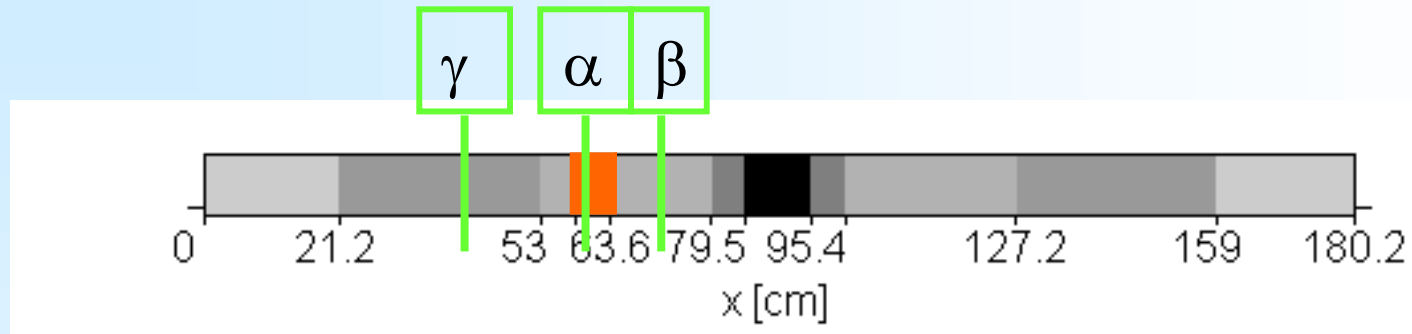
$$\Delta P_{gpk} = (P_{gpk} - P)/P [\%] = -1.78$$

- $\Phi(x_{\beta,g}) / \Phi(x_{\alpha,g}) = 1.300$

$$\Delta \Phi_{gpk} [\%] = -3.55$$

$$\Delta \Phi_{Ipk} [\%] = -0.65$$

# Use of $l_{pk}$ in transient evaluation



Transition 23:  $\Delta \Sigma_{a,2,3} < 0$        $\Delta \rho = 459 \text{ pcm}$   
 $\Delta \rho = 729 \text{ pcm}$

	$\alpha$	$\beta$	$\gamma$
<b>g= 1</b>	<u><del>-0.85</del></u>	<u><del>-0.95</del></u>	<u><del>-0.65</del></u>
<b>g= 2</b>	<u><del>-0.87</del></u>	<u><del>-0.74</del></u>	<u><del>-0.55</del></u>
<b>g= 3</b>	<u><del>-0.58</del></u>	<u><del>-0.79</del></u>	<u><del>-0.75</del></u>