Towards a neutron noise solver based on discrete ordinates method

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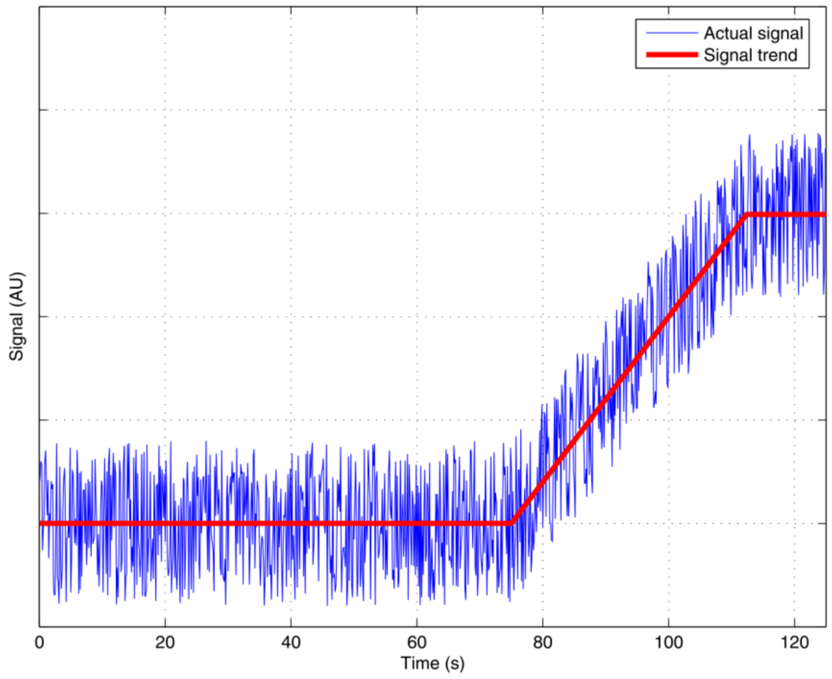
Reactor neutron noise

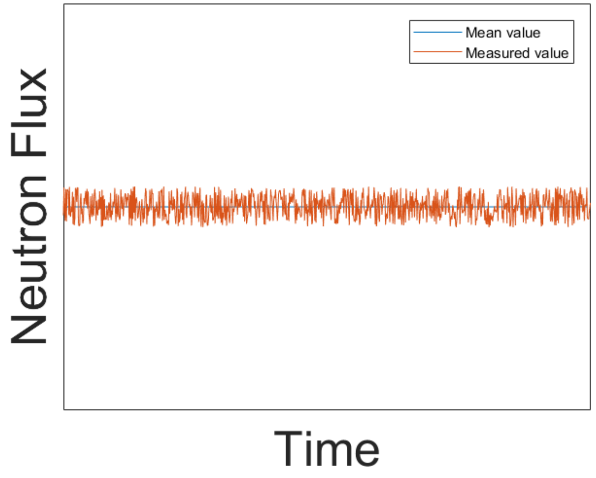
- Fluctuations of the neutron flux around expected values due to stochastics, stationary fluctuations

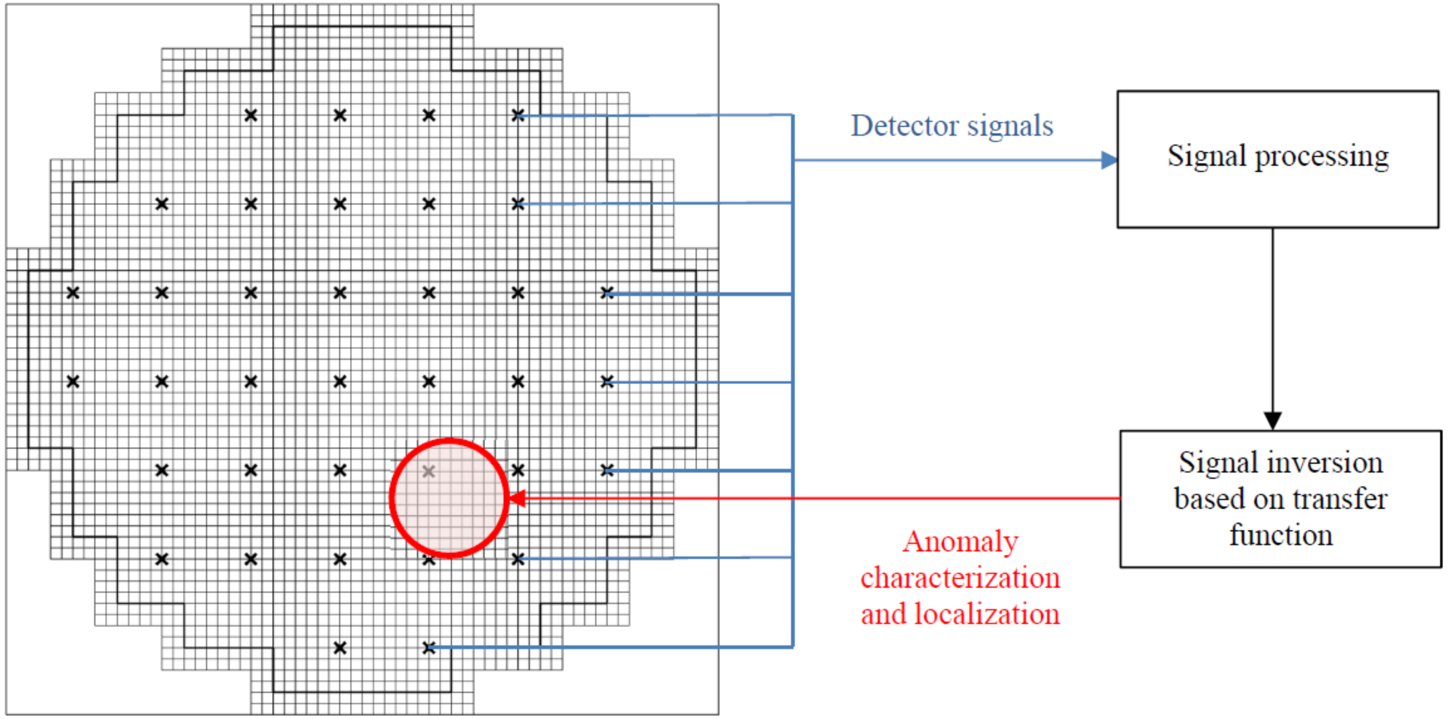


$$X(\mathbf{r},t) = X_0(\mathbf{r},t) + \delta X(\mathbf{r},t)$$

Reactor neutron noise

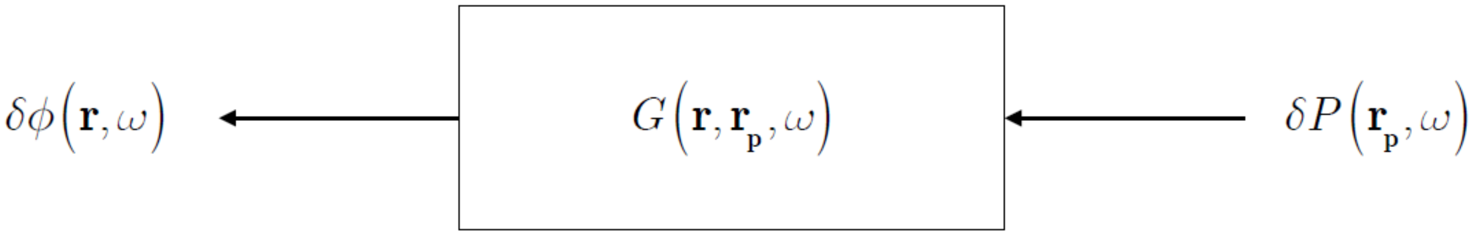
- Neutron noise can be used for core monitoring and diagnostics





Neutron noise simulations

- For the analysis of neutron noise, it is necessary to model the reactor transfer function



System transfer function

Transport neutron noise equation in the frequency domain

$$\left[\hat{\Omega}\cdot\nabla+\Sigma_{t,g,0}(\vec{r})+\frac{i\omega}{v_g}\right]\delta\psi_g\left(\vec{r},\hat{\Omega},\omega\right)=\frac{1}{4\pi}\sum_{g'}\Sigma_{s,g'\to g,0}(\vec{r})\delta\phi_{g'}(\vec{r},\omega)$$

$$+\frac{1}{4\pi k}\left[\chi_{p,g}(\vec{r})\left(1-\sum_q\beta_q(\vec{r})\right)+\sum_q\chi_{q,g}(\vec{r})\frac{\lambda_q\beta_q(\vec{r})}{i\omega+\lambda_q}\right]\sum_{g'}\nu\Sigma_{f,g',0}(\vec{r})\delta\phi_{g'}(\vec{r},\omega)+S_g(\vec{r},\hat{\Omega},\omega)$$

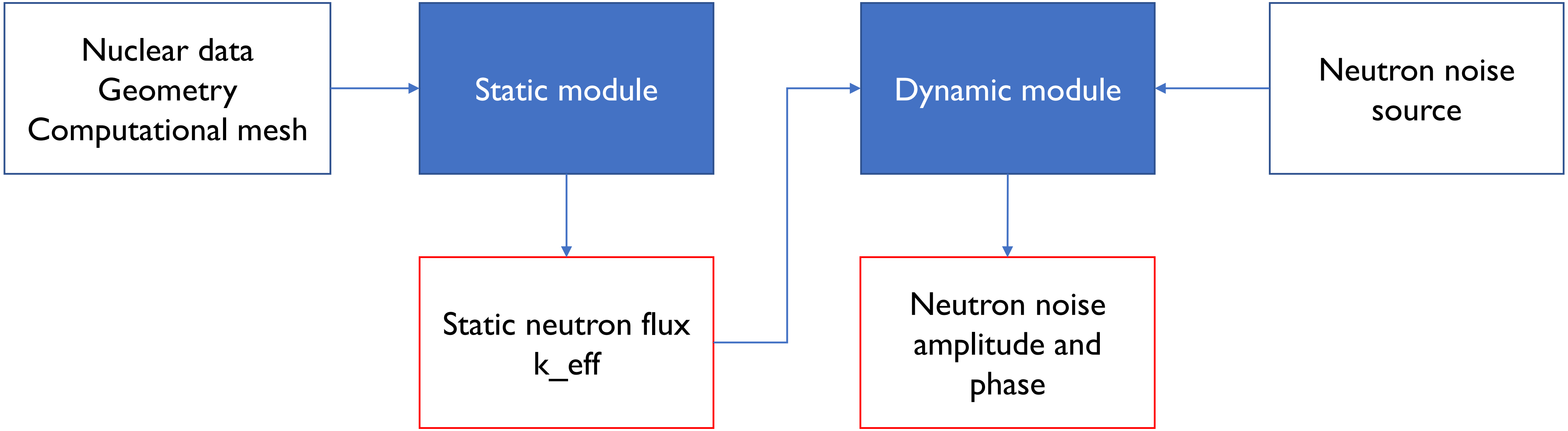
$$S_g\left(\vec{r},\hat{\Omega},\omega\right)=-\delta\Sigma_{t,g}(\vec{r},\omega)\psi_{g,0}\left(\vec{r},\hat{\Omega}\right)+\frac{1}{4\pi}\sum_{g'}\delta\Sigma_{s,g'\to g}(\vec{r},\omega)\phi_{g',0}(\vec{r})$$

$$\frac{1}{4\pi k}\left[\chi_{p,g}(\vec{r})\sum_q\left(1-\beta_q(\vec{r})\right)+\sum_q\chi_{d,q,g}(\vec{r})\frac{\lambda_q\beta_q(\vec{r})}{i\omega+\lambda_q}\right]\sum_{g'}\nu\delta\Sigma_{f,g'}(\vec{r},\omega)\phi_{g',0}(\vec{r})$$

A transport neutron noise solver

- Discrete ordinates method for angular discretization
  - Level symmetric quadrature
- Diamond difference scheme for spatial discretization
- Multi-energy formalism

General scheme of the solver



Acceleration of the scheme

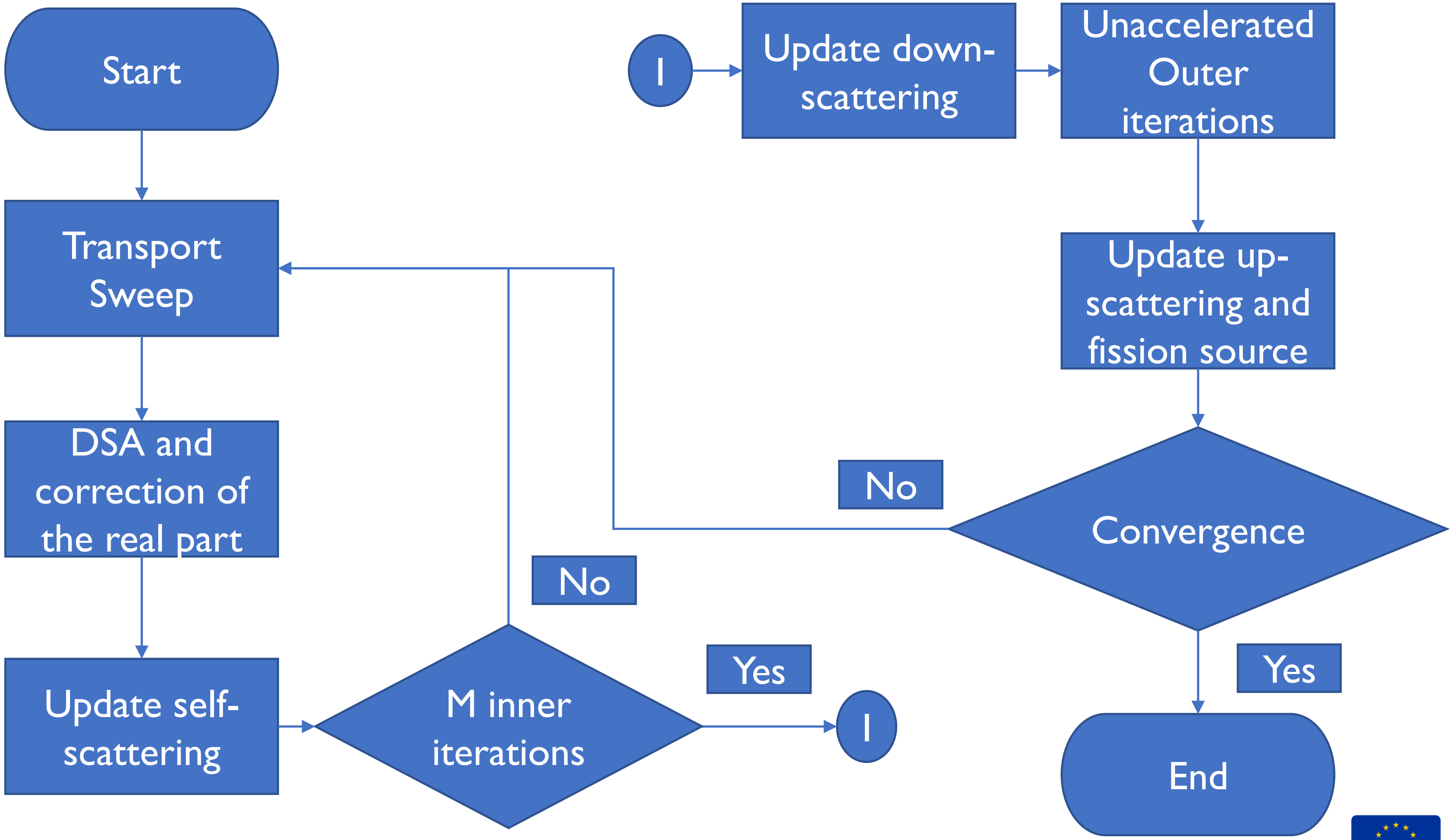
- Static module
  - A large literature is available about acceleration methods for static neutron transport

- Dynamic module
  - Acceleration of neutron transport in the frequency domain

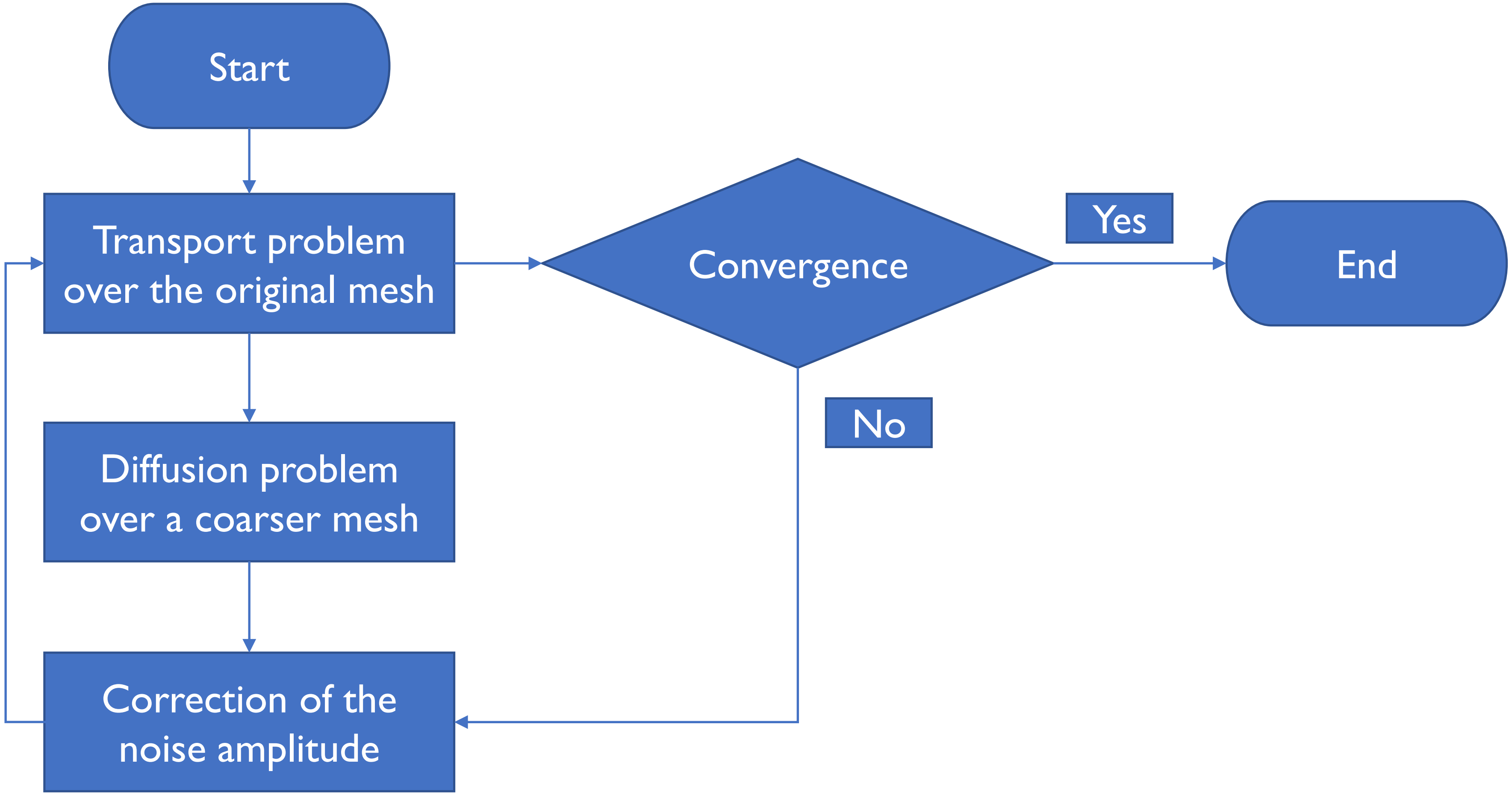
Some tests for the acceleration

- 2-energy group solver with DSA
- Multi-energy group solver with DSA
- Multi-energy group solver with CMFD

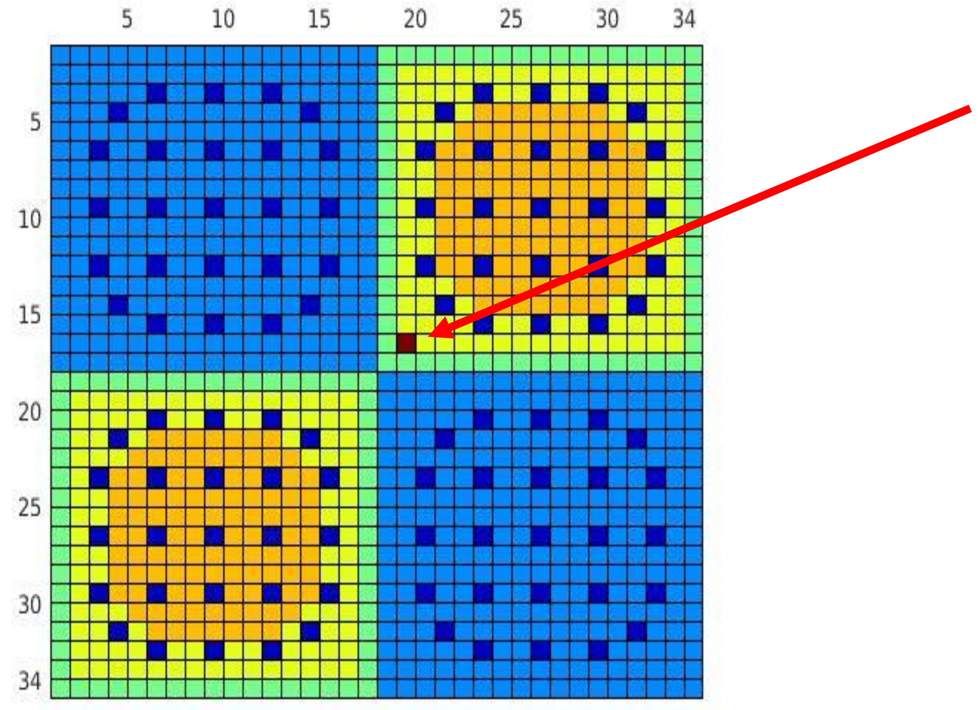
Multi-energy group solver with DSA



Multi-energy group solver with CMFD



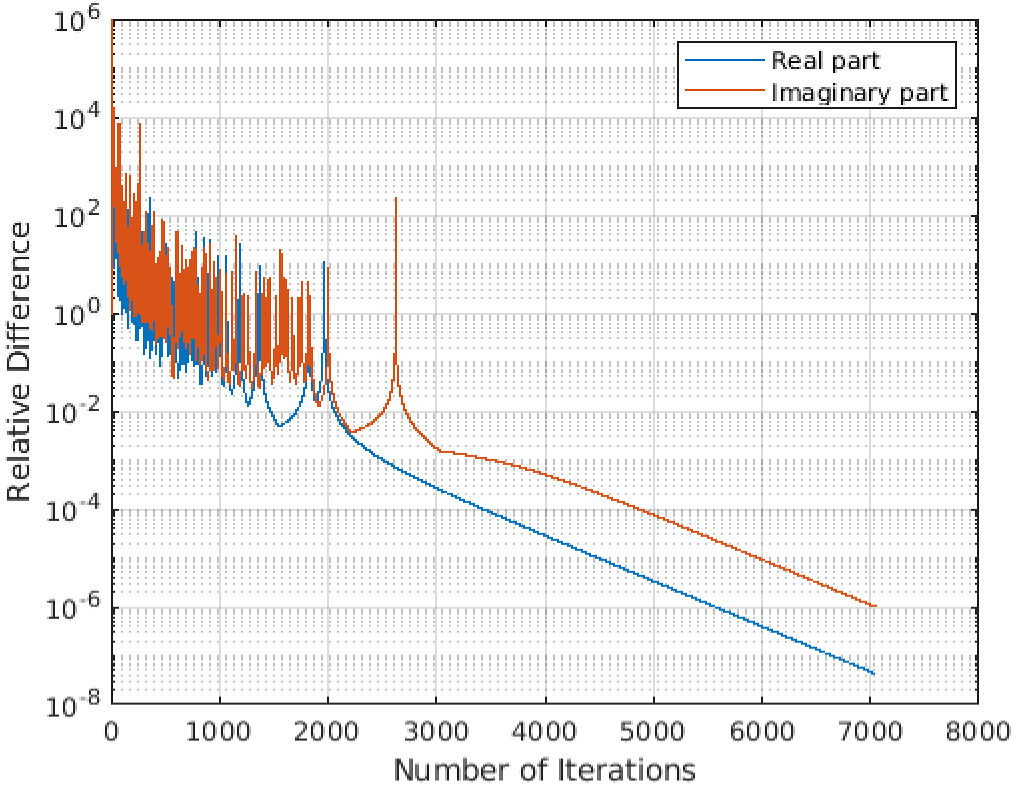
Tests using the C5G7 configuration



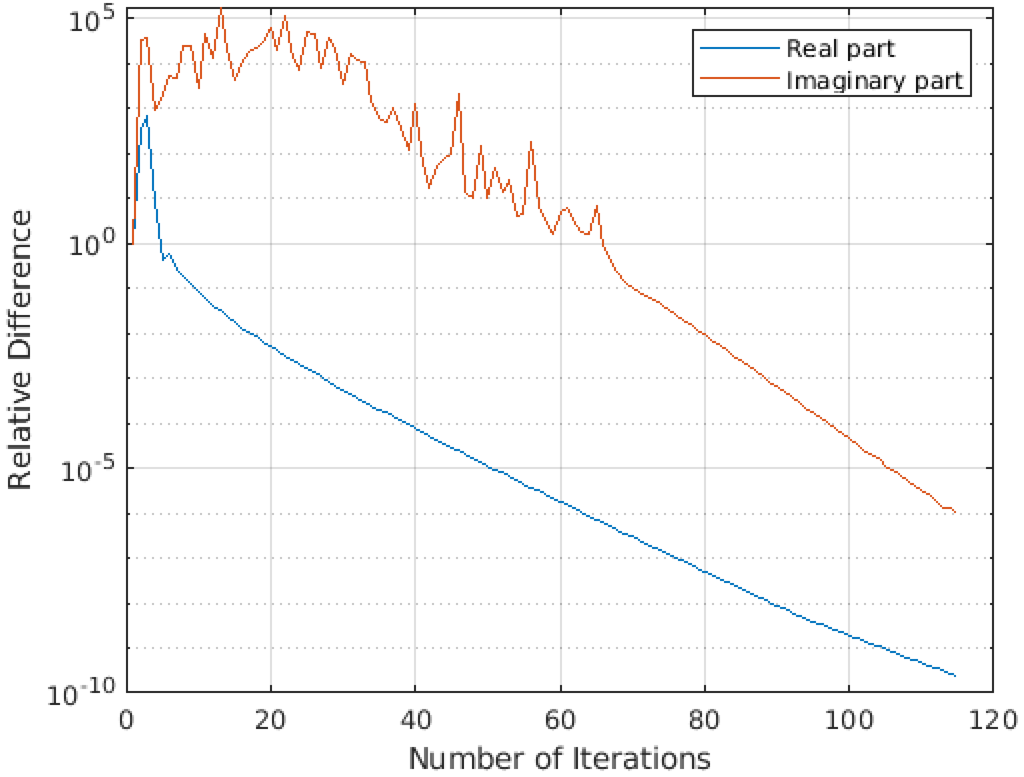
Localized noise source

- $\delta\Sigma_c$
- Amplitude 5% of $\Sigma_{c,0}$
- f = 1 Hz

Multi-energy group solver with DSA



Multi-energy group solver with CMFD



Summary & Outlook

- We are developing a transport neutron noise solver based on a discrete ordinates method in the frequency domain

- For the acceleration of the scheme some tests were performed with DSA and CMFD

- Future work
  - 3-D solver accelerated with CMFD
  - Anisotropic scattering

Thank you