International Neutrino Summer School 2011

18 - 30 July 2011, Geneva, Switzerland

ANALITICAL CALCULATION OF FISSION COEFFICIENTS FOR A PWR REACTOR FOR TWO ENERGY GROUPS

Marcelo J. N. Souza[1*], J.C. Anjos[1], Ronaldo G. Cabral[2]

[1]Centro Brasileiro de Pesquisas Físicas, [2]Instituto Militar de Engenharia.

* Corresponding author

SUMMARY

- MOTIVATION: NUCLEAR SAFEGUARD
- ANGRA NEUTRINO PROJECT
- CALCULATION OF (1+k) TERM

MOTIVATION: NUCLEAR SAFEGUARD

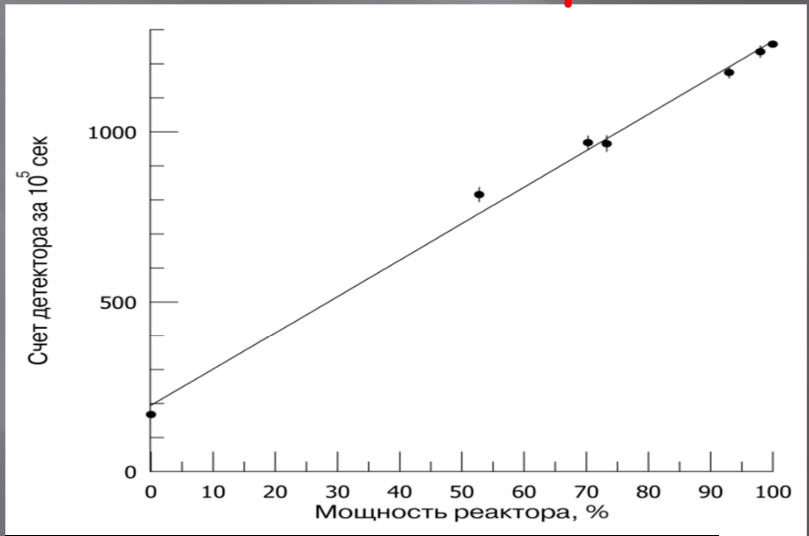
Reactor Thermal Power and Antineutrino flux

How does one calculate it?

$$N_\nu = \gamma \cdot (1 + k) \cdot P_{th}$$

Dependence on detector features

Burn-up: Dependence on fuel composition



Reactor power
in % of nominal value -1375 MW

(fig. from Valery SINEV)

ANGRA NEUTRINO PROJECT

Inverse beta decay reaction

$$\bar{\nu}_e + p \rightarrow e^+ + n$$

ANGRA NEUTRINO PROJECT

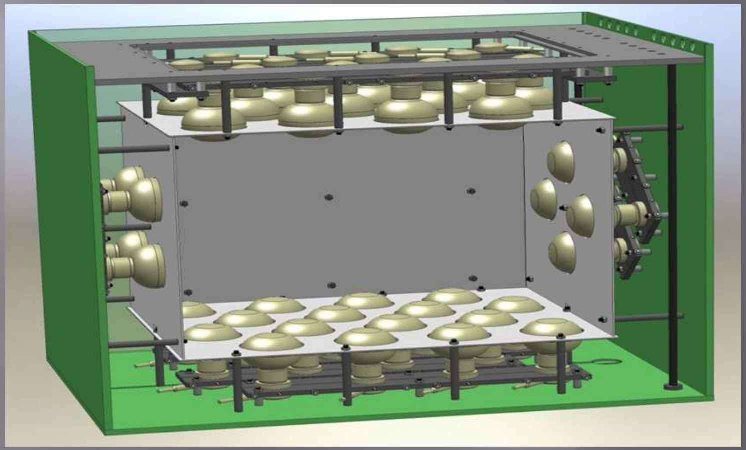
ANGRA II NUCLEAR REACTOR
& NEUTRINO LABORATORY

23/09/2008

conteiner: 1st laboratory in Angra

ANGRA NEUTRINO PROJECT

Central Detector



- Central detector dimensions: ~ 2.00m x 1.60m x 1.40m
- Central detector target: water + 0.2% Gd viewed by 40 PMT’s (8”)
- Target Fiducial volume: 1.36m x 0.98m x 0.90m ~ 1 ton
- External Shield: borated water ;
- Muon veto: extruded plastic scintillator strips;

CALCULATION OF (1+*k*) TERM

$$1 + k = \frac{\left[1 + \sum_{jk} \alpha_{jk} \left(\frac{\sigma^{jk}_{\bar{\nu}_e, p}}{\sigma^{25}_{\bar{\nu}_e, p}} - 1 \right) \right]}{\left[1 + \sum_{jk} \alpha_{jk} \left(\frac{w_{jk}}{w_{25}} - 1 \right) \right]}$$

Fission Coefficients

CALCULATION OF (1+k) TERM

Neutron Balance Equations with Two Energy Groups

$$-D_1\nabla^2\Phi_1 + \Sigma_{R_1}\Phi_1 = \frac{1}{k_{eff}}\left\{\nu_1\Sigma_{f_1}\Phi_1 + \nu_2\Sigma_{f_2}\Phi_2\right\}$$

$$-D_2\nabla^2\Phi_2 + \Sigma_{a_2}\Phi_2 = \Sigma_{s_{12}}\Phi_1$$

Energy Group 1
(0.625 eV ≤ E ≤ 10MeV)

Energy Group 2
(0 eV ≤ E < 0.625 MeV)

where

$$\Sigma_{R_1} = \Sigma_{a_1} + \Sigma_{s_{12}}$$

$$\nu_1\Sigma_{f_1} = \nu_1^{25}\sigma_{f_1}^{25}n^{25} + \nu_1^{28}\sigma_{f_1}^{28}n^{28} + \nu_1^{49}\sigma_{f_1}^{49}n^{49} + \nu_1^{41}\sigma_{f_1}^{41}n^{41}$$

$$\nu_2\Sigma_{f_2} = \nu_2^{25}\sigma_{f_2}^{25}n^{25} + \nu_2^{28}\sigma_{f_2}^{28}n^{28} + \nu_2^{49}\sigma_{f_2}^{49}n^{49} + \nu_2^{41}\sigma_{f_2}^{41}n^{41}$$

$$\Sigma_{a_1} = \sigma_{a_1}^{25}n^{25} + \sigma_{a_1}^{28}n^{28} + \sigma_{a_1}^{29}n^{29} + \sigma_{a_1}^{39}n^{39} + \sigma_{a_1}^{40}n^{40} + \sigma_{a_1}^{41}n^{41} + \sigma_{a_1}^{49}n^{49} + \sigma_{a_1}^{ag}n^{ag}$$

$$\Sigma_{a_2} = \sigma_{a_2}^{25}n^{25} + \sigma_{a_2}^{28}n^{28} + \sigma_{a_2}^{29}n^{29} + \sigma_{a_2}^{39}n^{39} + \sigma_{a_2}^{40}n^{40} + \sigma_{a_2}^{41}n^{41} + \sigma_{a_2}^{49}n^{49} + \sigma_{a_2}^{ag}n^{ag}$$

$$\Sigma_{s_{12}} = \sigma_{s_{12}}^{25}n^{25} + \sigma_{s_{12}}^{28}n^{28} + \sigma_{s_{12}}^{29}n^{29} + \sigma_{s_{12}}^{39}n^{39} + \sigma_{s_{12}}^{40}n^{40} + \sigma_{s_{12}}^{41}n^{41} + \sigma_{s_{12}}^{49}n^{49} + \sigma_{s_{12}}^{ag}n^{ag}$$

CALCULATION OF (1+k) TERM

Deplection Equations

$$\frac{\partial n^{25}}{\partial t} = -\left(\sigma_{a1}^{25}\Phi_1 + \sigma_{a2}^{25}\Phi_2\right) n^{25}$$

$$\frac{\partial n^{28}}{\partial t} = -\left(\sigma_{a1}^{28}\Phi_1 + \sigma_{a2}^{28}\Phi_2\right) n^{28}$$

$$\frac{\partial n^{29}}{\partial t} = \left(\sigma_{\gamma 1}^{28}\Phi_1 + \sigma_{\gamma 2}^{28}\Phi_2\right) n^{28} - \left(\sigma_{a1}^{29}\Phi_1 + \sigma_{a2}^{29}\Phi_2 + \lambda^{29}\right) n^{29}$$

$$\frac{\partial n^{39}}{\partial t} = \lambda^{29} n^{29} - \left(\sigma_{a1}^{39}\Phi_1 + \sigma_{a2}^{39}\Phi_2 + \lambda^{39}\right) n^{39}$$

$$\frac{\partial n^{49}}{\partial t} = \lambda^{39} n^{39} - \left(\sigma_{a1}^{49}\Phi_1 + \sigma_{a2}^{49}\Phi_2\right) n^{49}$$

$$\frac{\partial n^{40}}{\partial t} = \left(\sigma_{\gamma 1}^{49}\Phi_1 + \sigma_{\gamma 2}^{49}\Phi_2\right) n^{49} - \left(\sigma_{a1}^{40}\Phi_1 + \sigma_{a2}^{40}\Phi_2\right) n^{40}$$

$$\frac{\partial n^{41}}{\partial t} = \left(\sigma_{\gamma 1}^{40}\Phi_1 + \sigma_{\gamma 2}^{40}\Phi_2\right) n^{40} - \left(\sigma_{a1}^{41}\Phi_1 + \sigma_{a2}^{41}\Phi_2 + \lambda^{41}\right) n^{41}$$

CALCULATION OF (1+*k*) TERM

Example: PWR (W)

U mass = 90,200kg   Enrichment = 2.4%   Power = 3411MWt

Active core volume =32.800 liters   Radius = 198.56cm

THAT IS ALL FOR NOW.
THANK YOU.