Moderator neutronics for poisoned and unpoisoned decoupled moderators

M. Harada, M. Teshigawara, T. Kai,
N. Watanabe,*Y.Kinayagi

Japan Atomic Energy Research Institute

**Hokkaido University*

Decoupled moderators

- Function :

  To provide narrow neutron pulses with short tail & keeping high peak intensity

- Type :

  1 poisoned (upstream)

  1 unpoisoned (downstream)

- Moderator material :

  20K Super-critical hydrogen

- Neutron beam extraction:

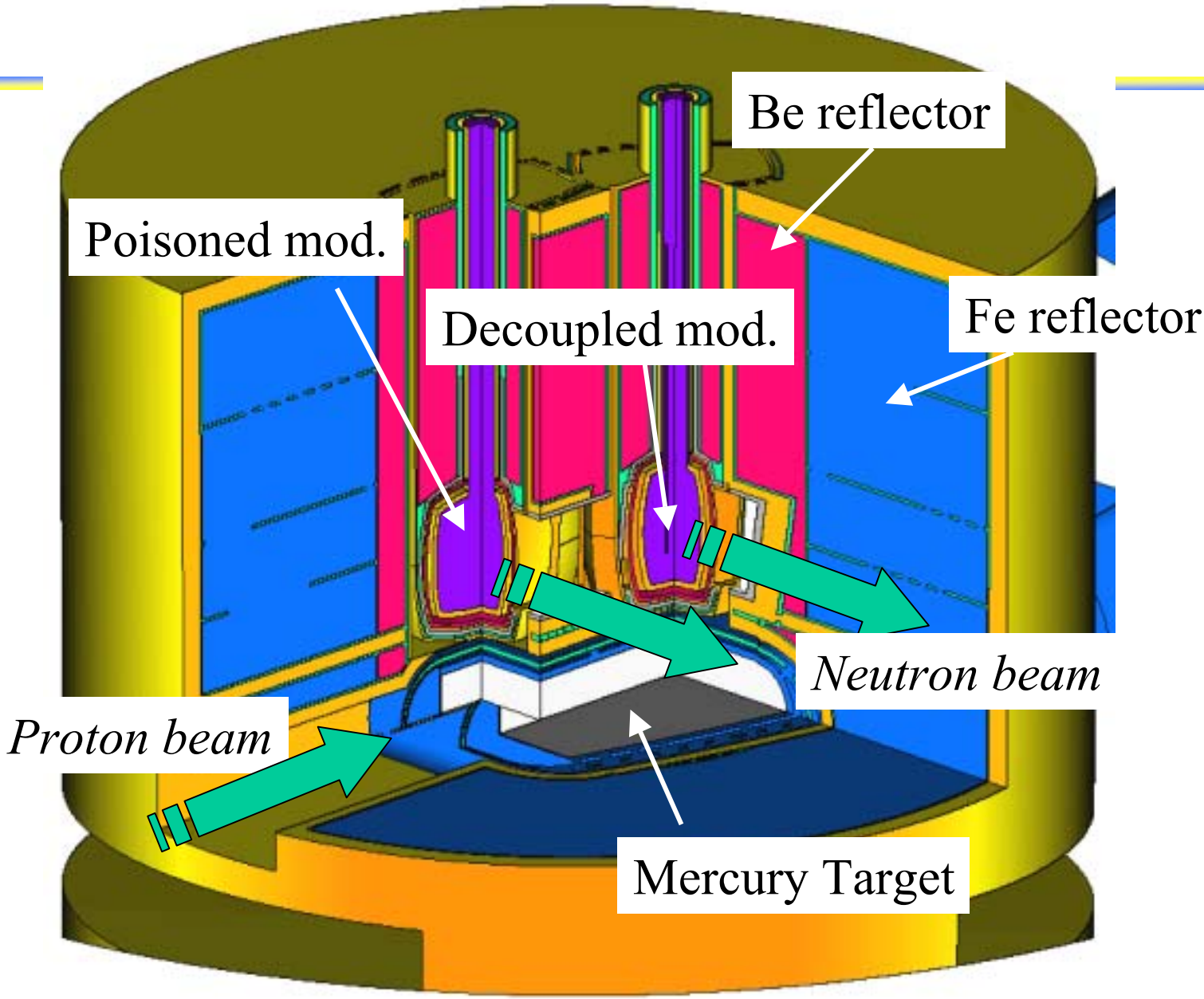
  Both sides from each moderator

  6 beam-lines (3 for each viewed surface x 2) per moderator

Neutronics optimization

- Neutronics optimizations by model calculation were performed
  - Code
    NMTC/JAM code, MCNP-4C code.
  - Model
    Realistic TMRA(Target-Moderator-Reflector-Assembly) model
    Simple model
  - Para-hydrogen ratio :100 %
    - Para-ortho ratio must be stable
    - 100% para will be only selection for stable ratio, provided strong ortho to para catalyst.
  - Average operation temperature of hydrogen : 20K

Realistic TMRA calculation model

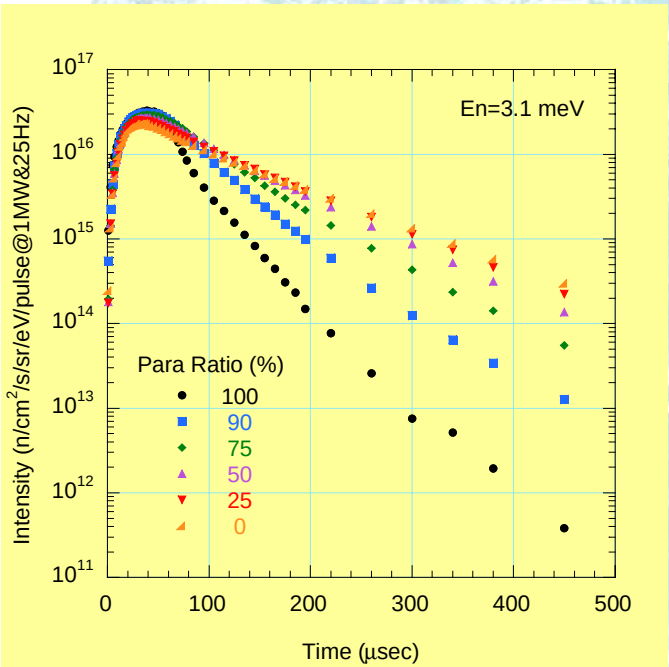


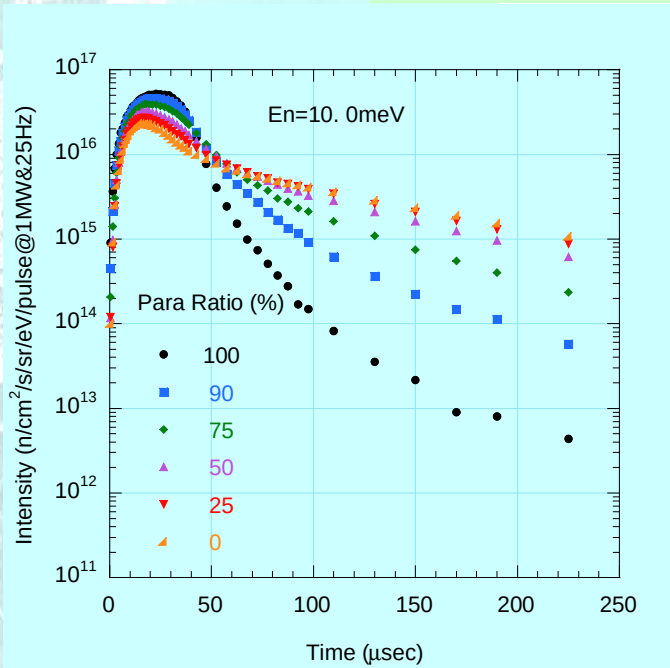
Para-hydrogen ratio dependence

- Para-hydrogen ratio dependence?
  - Pulse characteristics

Para ratio : 0 ~ 100 %

- Para -> Ortho Conversion
  - Nuclear Reaction
  - Chemical reaction
- Ortho -> Para Conversion
  - Catalysis

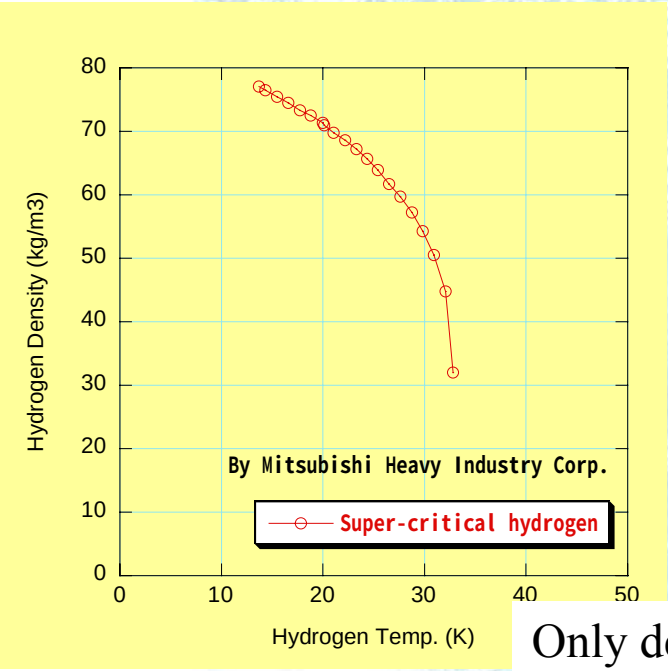




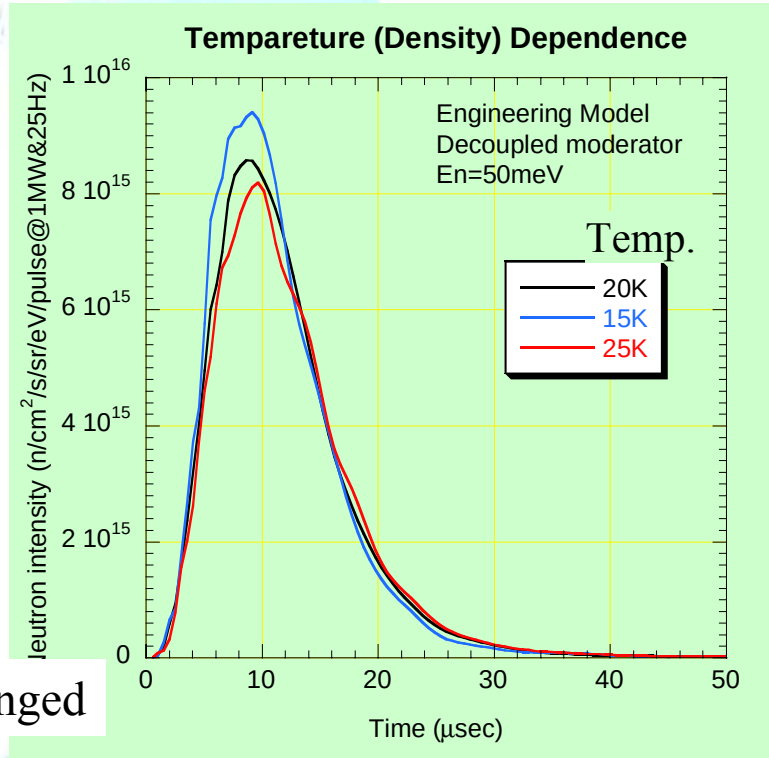
- Pulse characteristics, especially pulse tail, is strongly dependent on para-hydrogen ratio.

Temperature (density) Dependence

- Temperature dependence?
  - Kernel
  - Density



Only density was changed



When hydrogen temperature increases by 1K, hydrogen density decreases by 1%, resulting in 1% decrease of peak intensity

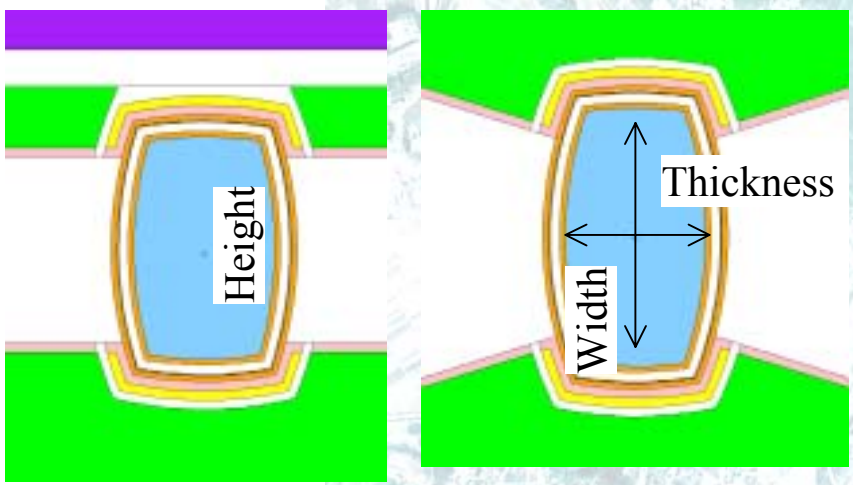
Required Design Parameters

- Major design parameters.
  - Moderator shape & sizes
  - Decoupling Energy (E_d)
  - Angular Coverage
  - Poison material, shape and position
  - Moderator position relative to the target
- Other parameters
  - Decoupler extension along H_2 transfer line
  - Max. beam extraction angle
    - Decoupled
    - Poisoned
  - Effect of cooling water & acceptable water channel width
  - Effect of gap between decoupler & liner

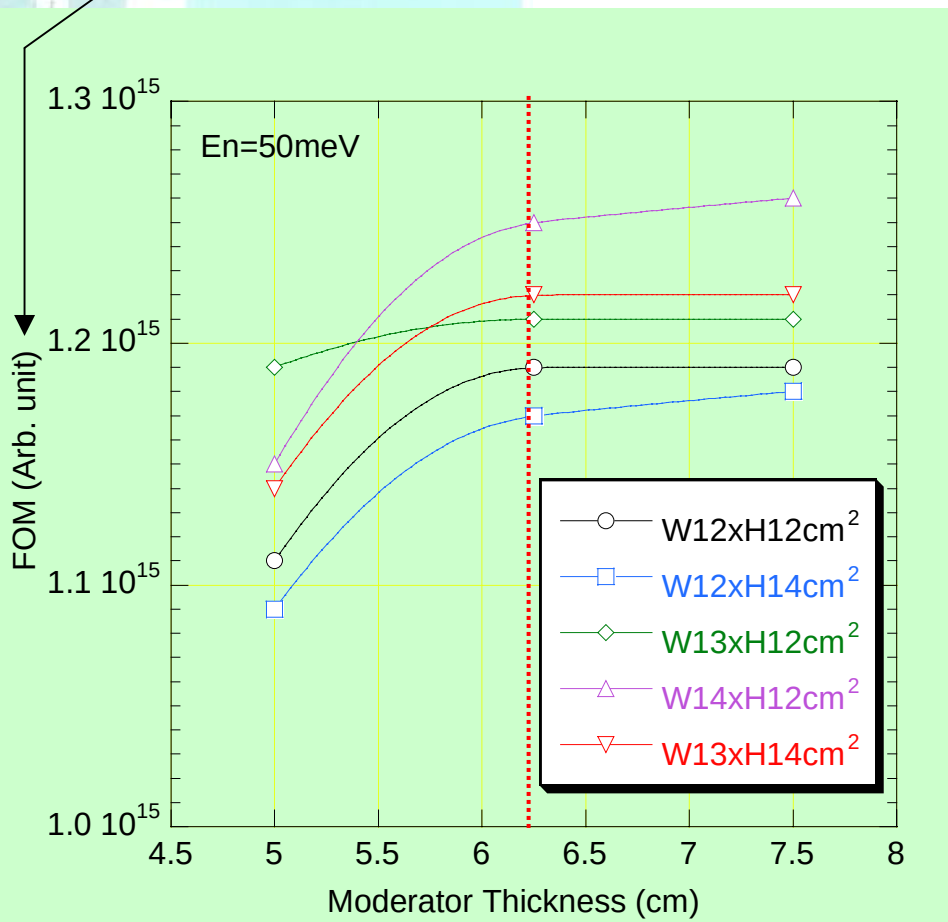
Moderator Size

- Dimensional parameters
  - Lateral dimensions
  - Thickness

- Shape
  - Canteen type
- Unpoisoned moderator
- Viewed surface
  - 10 x 10 cm^2



FOM(Figure Of Merit)=Peak/FWHM



Determination of Moderator Size

- When the thickness is increased to $6.25cm^{T}$, FOM is almost saturated.
- H_2 inventory should be as low as possible.
- $14cm^{W}$ is too large to accommodate 2 decoupled moderators.
- $13cm^{W}$ gives higher FOM than $12cm^{W}$
- $12cm^{H}$ & $14cm^{H}$ give almost the same FOM

- Thus adopt $13^{W} \times 12^{H} \times 6.2^{T}\ cm^{3}$

- The poisoned moderator size and shape were the same as those of the unpoisoned moderator because of the almost same tendency.

Required chamber wall thickness is discussed by Kogawa

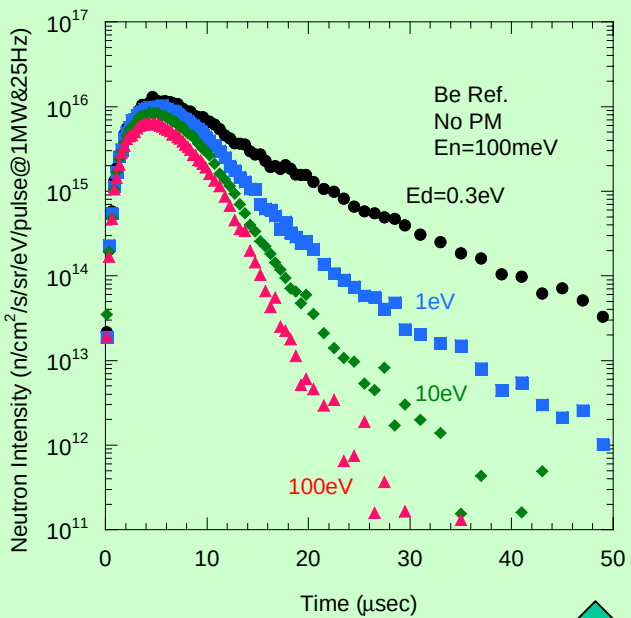
Decoupler

- Design parameters
  - E_d
  - Material

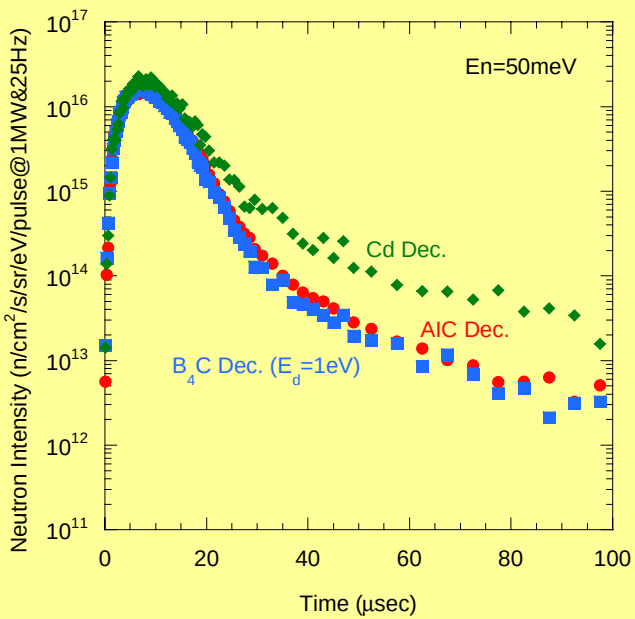
AIC:
Silver-Indium-Cadmium Alloy

Details of decoupler material -> Material session

E_d Dependence



B_4C v.s. AIC



Decoupler materials were compared from several viewpoints, AIC was finally selected.

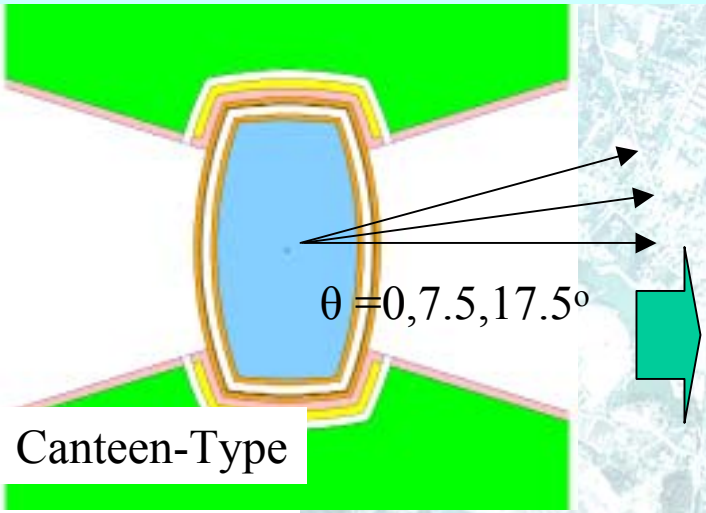
- *Pulse Characteristics, especially pulse tail, is strongly dependent.*

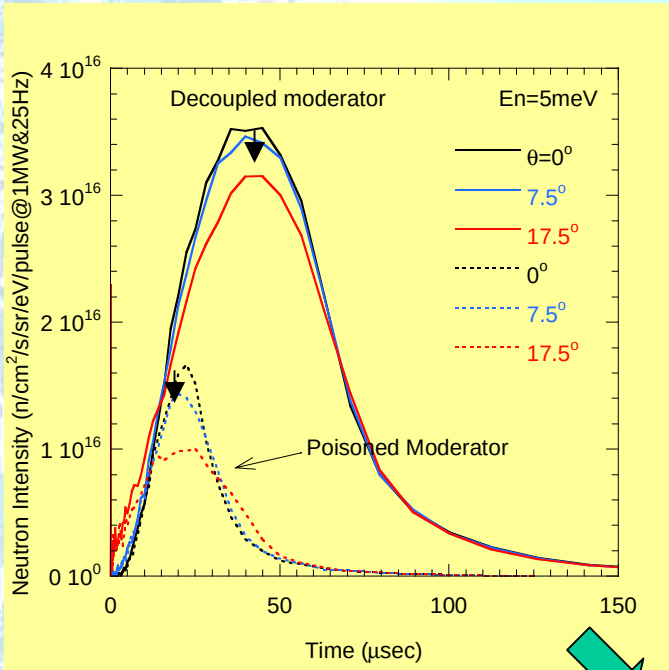
User's requirement : $E_d \geqq 1eV$

Material: AIC
E_d : 1eV

Beam Extraction Angle Dependence on Pulse Shape

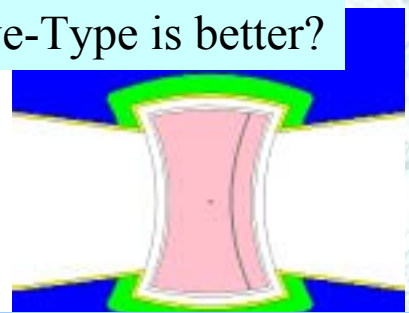
Beam Extraction Angle Dependence?





SNS: Maximum beam extraction angle of each moderator is all 13.75º.

Concave-Type is better?



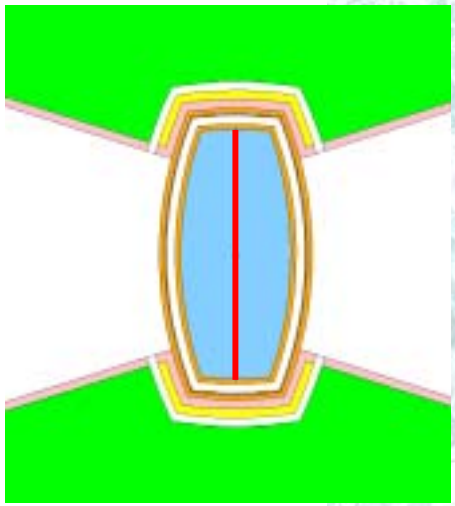
- *Unpoisoned: at θ=17.5º 15% lower peak intensity*
  10% broader FWHM than at θ=0.0º
- *Poisoned: at θ=7.5º 12% lower peak intensity*
  15% broader FWHM than at θ=0.0º

Although the concave-type is superior to the canteen-type from a viewpoint of neutronics, it is given up because feasibility of manufacturing for such a fancy shape is poor.

Moderator Shape : Canteen Type
Maximum Angle (Unpoisoned) : 17.5º
Maximum Angle (Poisoned) : 7.5º

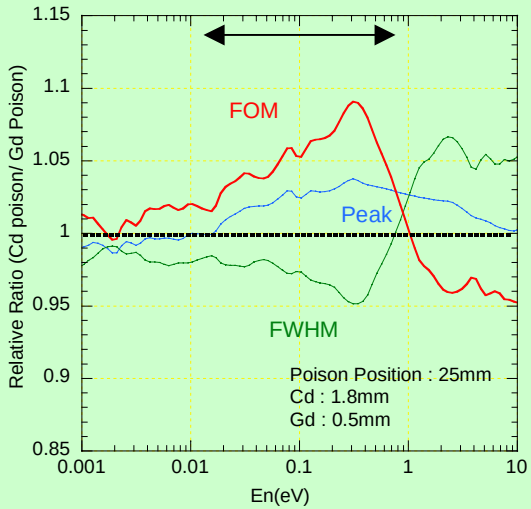
Poison material, shape and position

Design parameters about poison
- Material : Cd or Gd
- Thickness :
- Shape : Flat or Curved
- Position from a viewed surface :

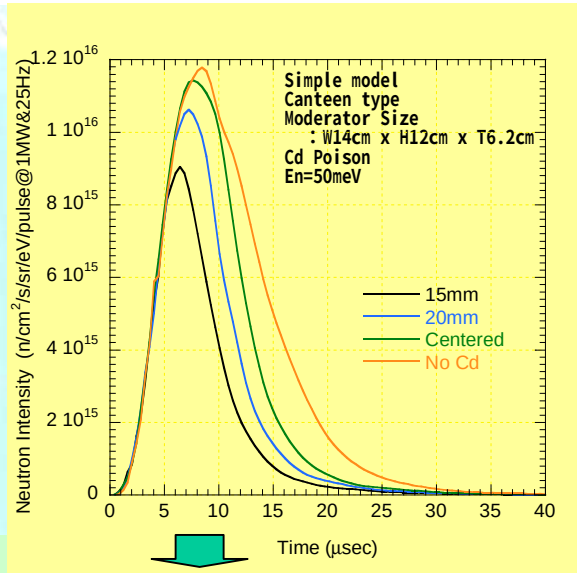


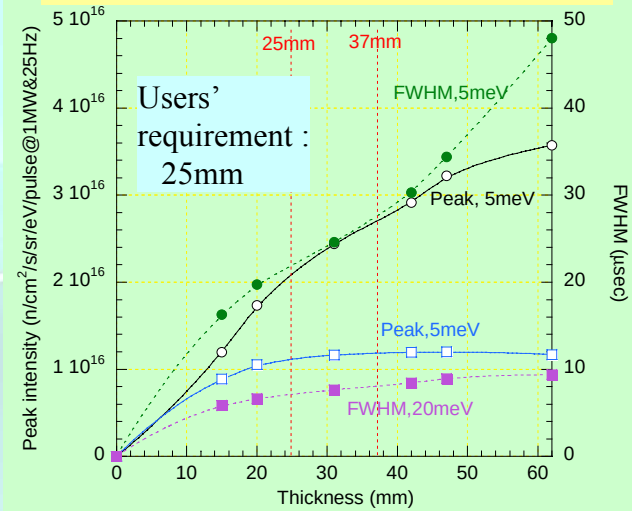
Gd poison v.s. Cd poison

Cd poison is better



Poison position dependence





Material : Cd
Thickness : 1.8mm
Shape : Flat
Position : 25mm from a viewed surface
37 mm from the opposite

Conclusion

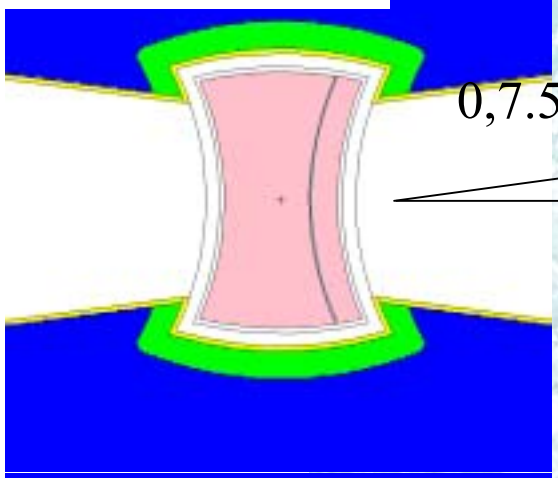
- By neutronics calculations, major design parameters of the poisoned and the unpoisoned decoupled moderators were determined.

- Issue to be solved
  - Effect of decoupler gap for welding
  - Reliability of scattering kernel of liquid hydrogen

etc.

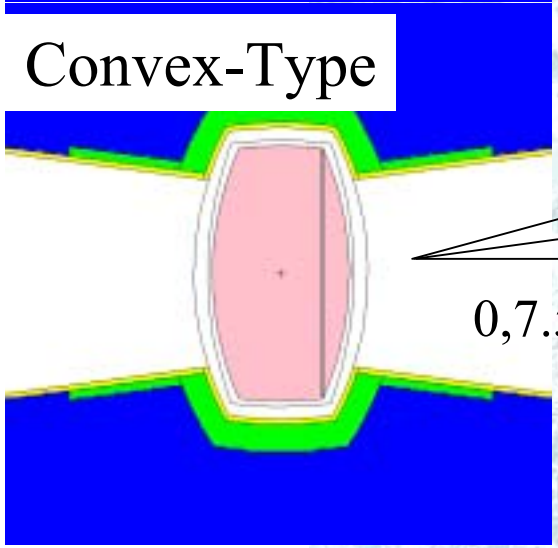
Canteen-type v.s. Convex-Type

Canteen-Type

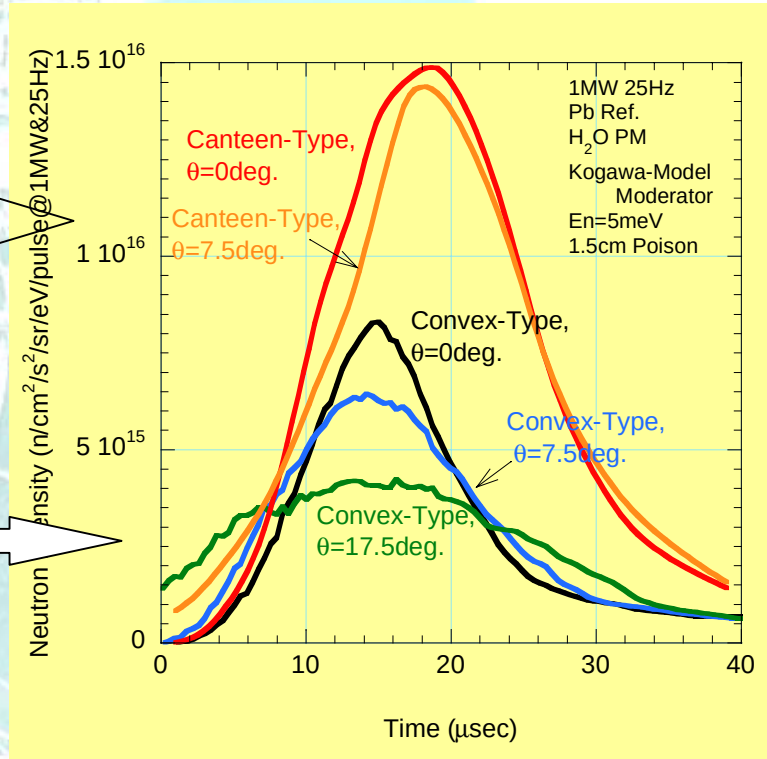


0,7.5deg.

Convex-Type

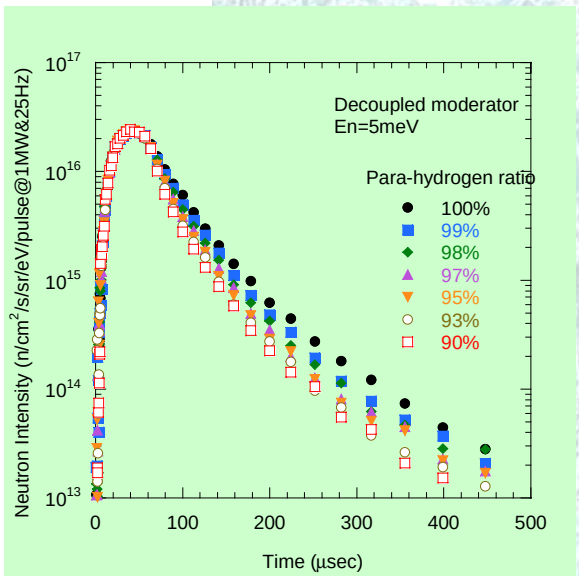


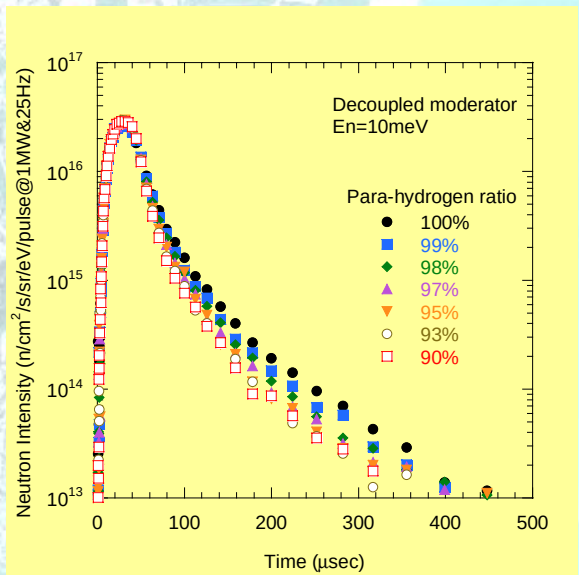
0,7.5,17.5deg.

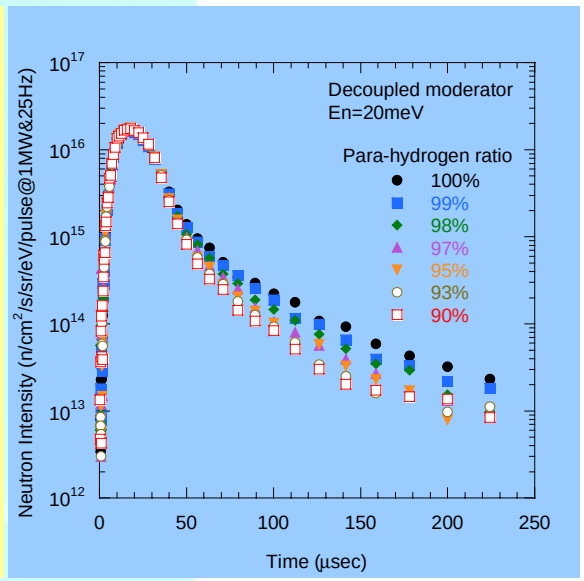


Para-hydrogen ratio dependence

Para ratio : 90 ~ 100 %







Acceptable para hydrogen ratio dependence of pulse characteristics?