First steps to use Serpent in medical applications

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Serpent User Group Meeting
30.10.2020

Outline

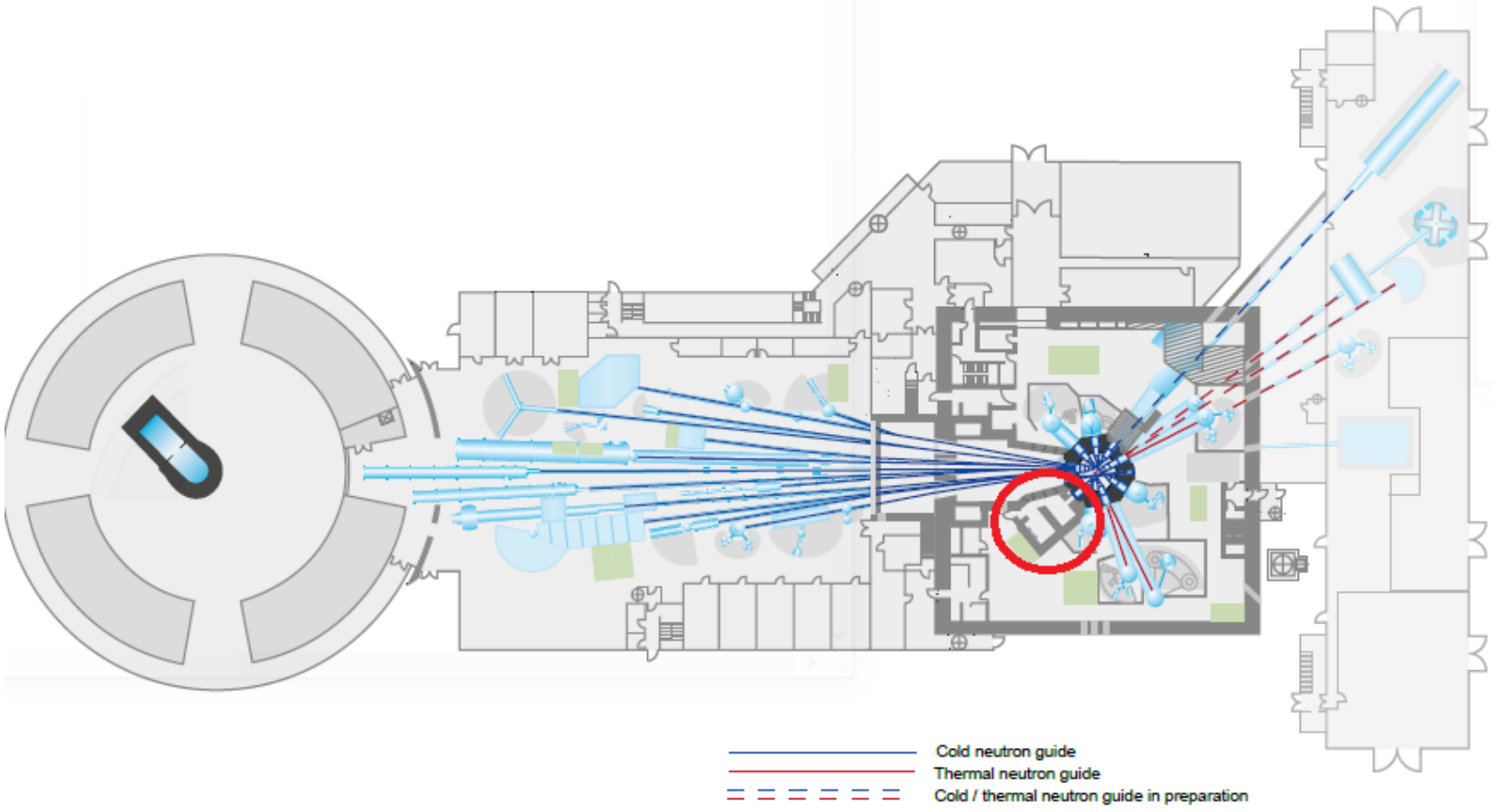
1. NEUTRONS FOR MEDICINE?
2. YES: MEDAPP AT FRM2
3. GEOMETRY AND SERPENT INPUT
4. NEUTRON FLUX. COMPARISON TO MCNP
5. COMPARISON TO EXPERIMENTAL MEASUREMENTS
6. PRELIMINARY GAMMA CALCULATIONS
7. CONCLUSIONS
8. FURTHER STEPS

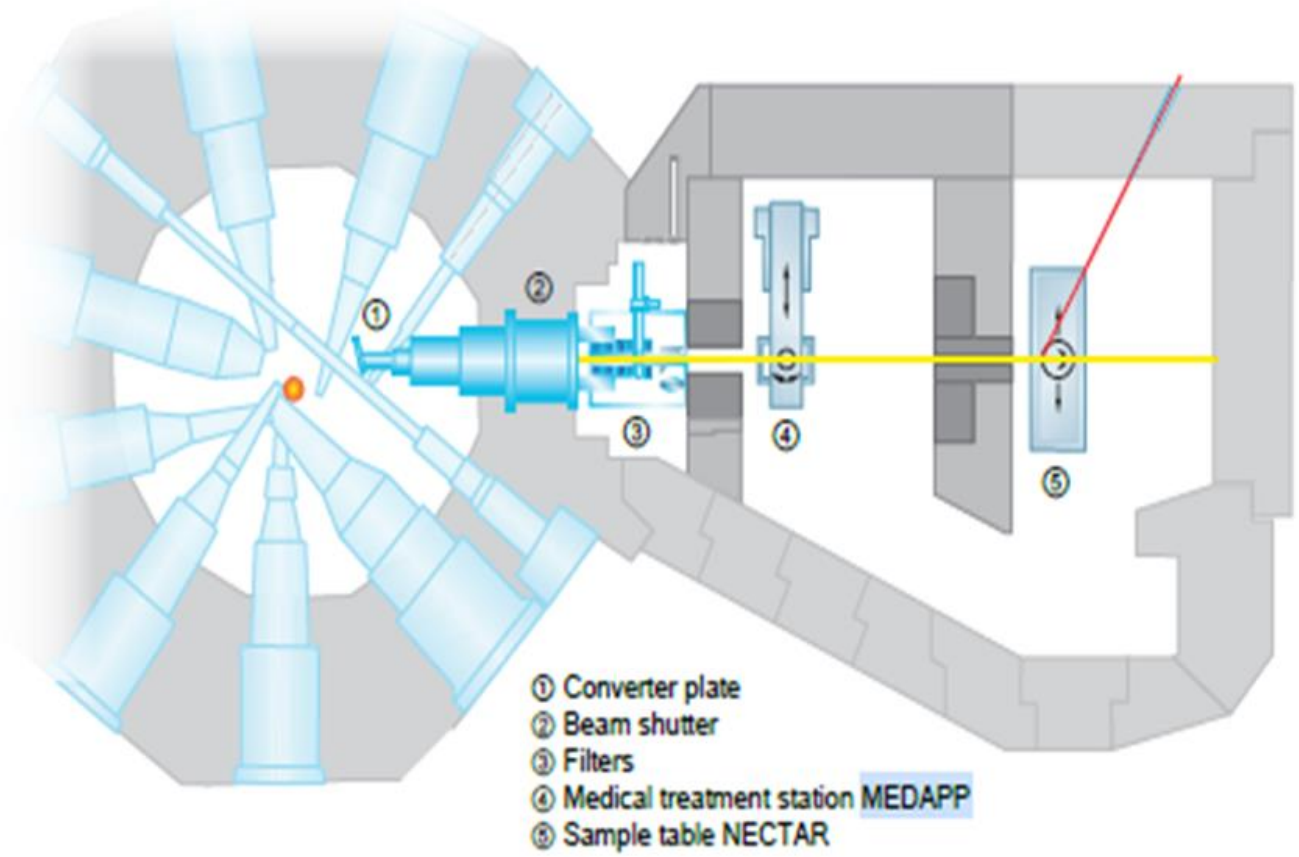
Context: Neutrons for medical applications?

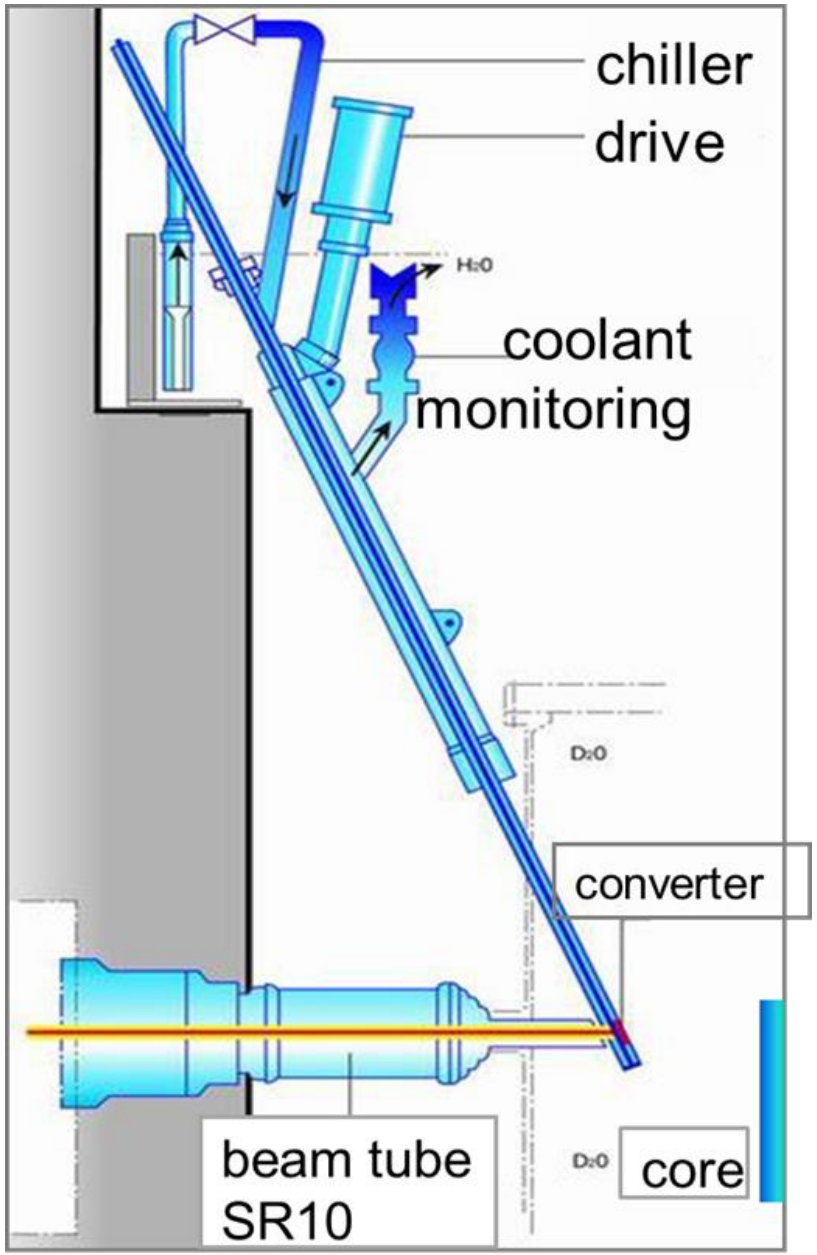
High LET particles → Shallow penetration depth into the human body → Only useful with superficial tumours (skin, breast, etc.)

- Neutrons damage DNA by indirect ionization. Healthy cells can repair themselves much better than tumorous cells: useful in cancer treatment.
- However, secondary effects are sometimes not negligible: only applied to inoperable and radio-resistant tumors, or palliative therapy.
- Fission neutrons (0.1 to 10 MeV) have very high relative biological effectiveness: only 10-12 sessions needed.

MEDAPP AT FRM-II

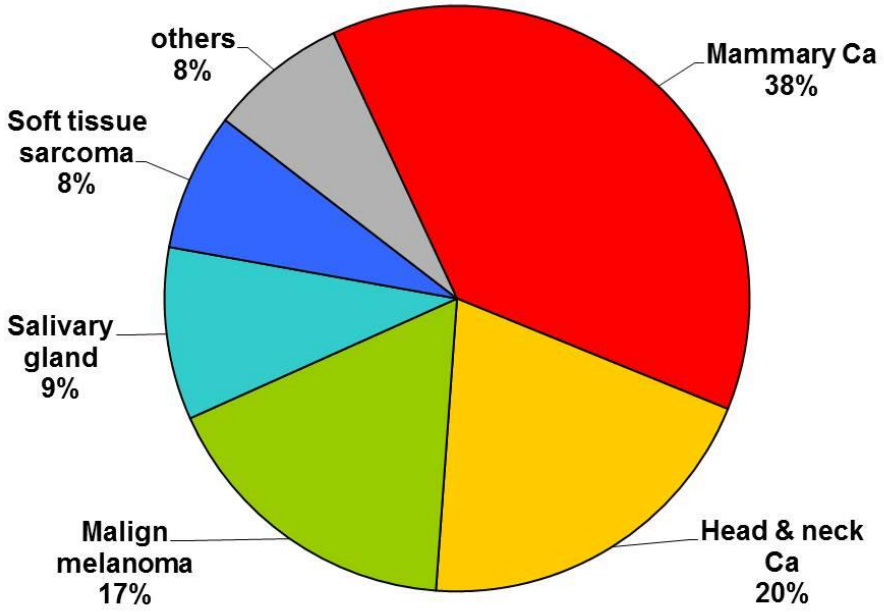



① Converter plate
② Beam shutter
③ Filters
④ Medical treatment station MEDAPP
⑤ Sample table NECTAR


chiller
drive
H₂O
coolant
monitoring
D₂O
converter
beam tube
SR10
D₂O
core

MEDAPP

- Continuation of successful MEDAPP at FRM I
- Patient treatment started in 2007.
- Good response in e.g. breast cancer recurrences.
- Irradiation field size: ~20*30 cm with converter.
- Mean energy of 1.9 MeV with converter.
- Adjustable filters, Multi-Leaf Collimator
- At present, gamma-to-neutron flux ratio is too high for safe medical treatment.
- Also used in biological research, for material characterization, or precise cross-section measurement…



Prof. Molls, Drs. Reuschel, Auberger, Thamm, MRI/TUM. / *Usage of fast and thermal neutrons at beam tube SR10,* F.M. Wagner

MEDAPP patient’s room

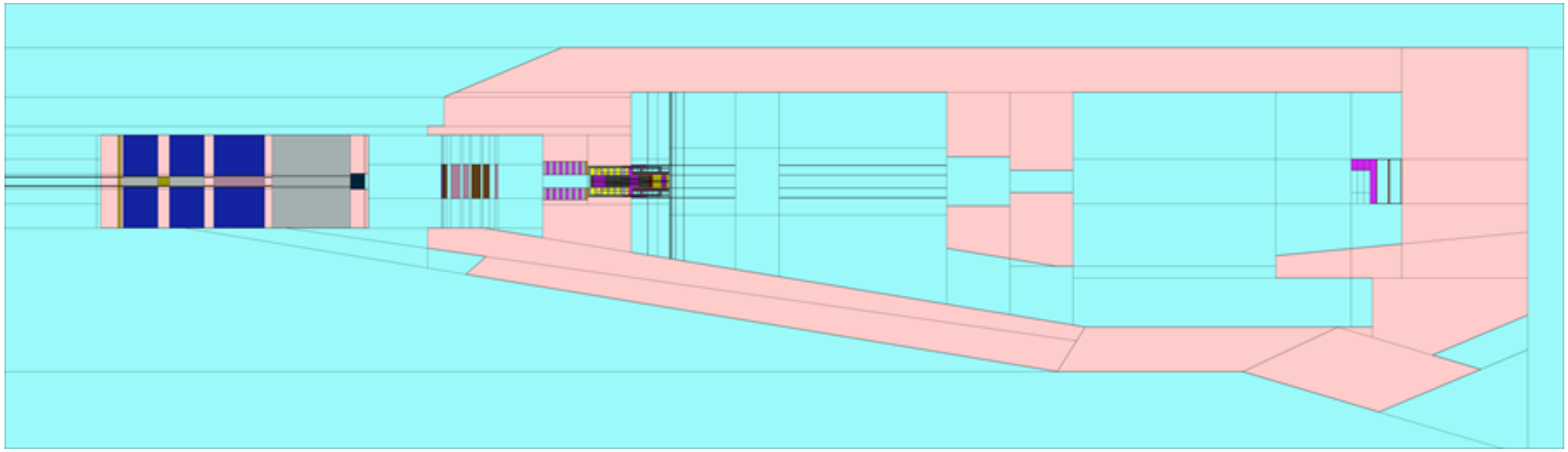
Goal:

Use Serpent 2 to calculate relevant physical quantities for the medical use of MEDAPP.

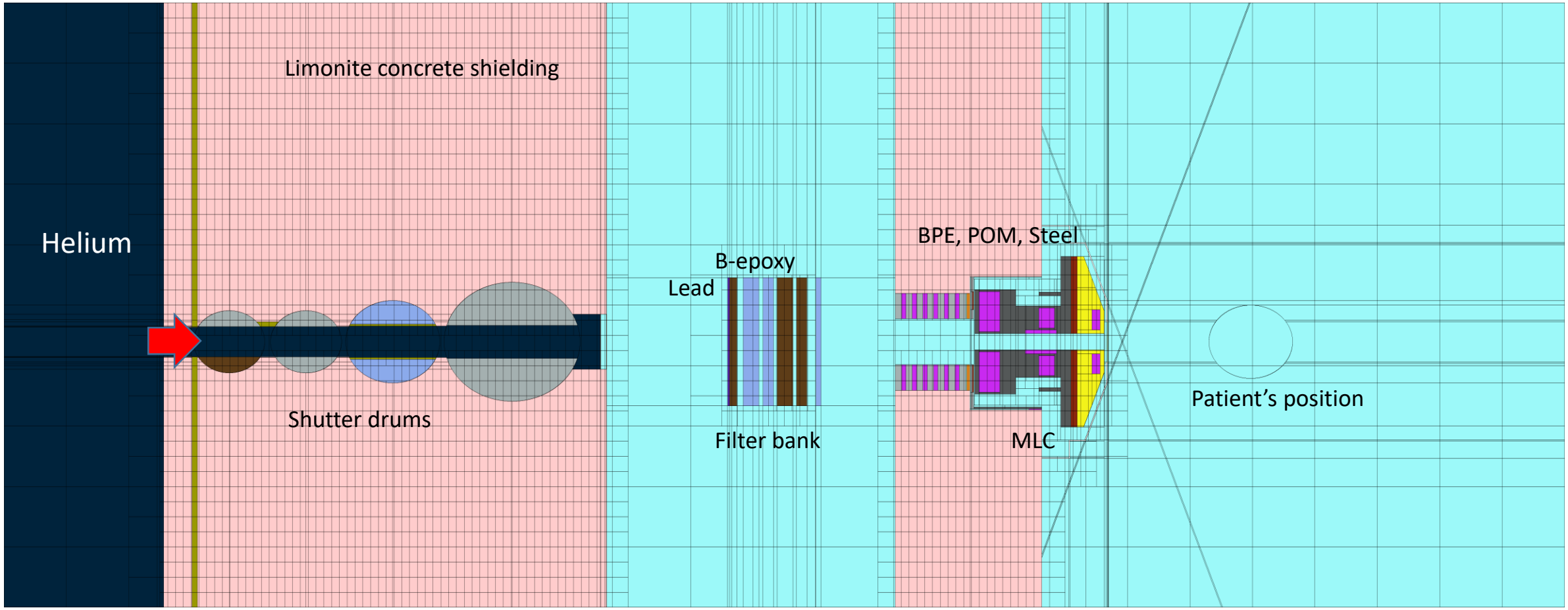
SERPENT INPUT

- External source mode:
  1. Mono-energetic thermal beam impinging on simple uranium plate which yields pure fission spectrum.
  2. Simulation of full reactor tank, collecting neutron score at interface, and using it as source for MEDAPP simulation: fission + moderated spectrum.
- Several neutron flux detectors along the beamline, focus at patient's position.
- Different MLC field sizes and filter set-ups
- Use of Adaptive Global Variance Reduction (3 runs, 4 weight-window iterations) : reduction of average statistical error to at least less than one third compared to Fixed GVR.

1. “Translate” an MCNP model to serpent 2…



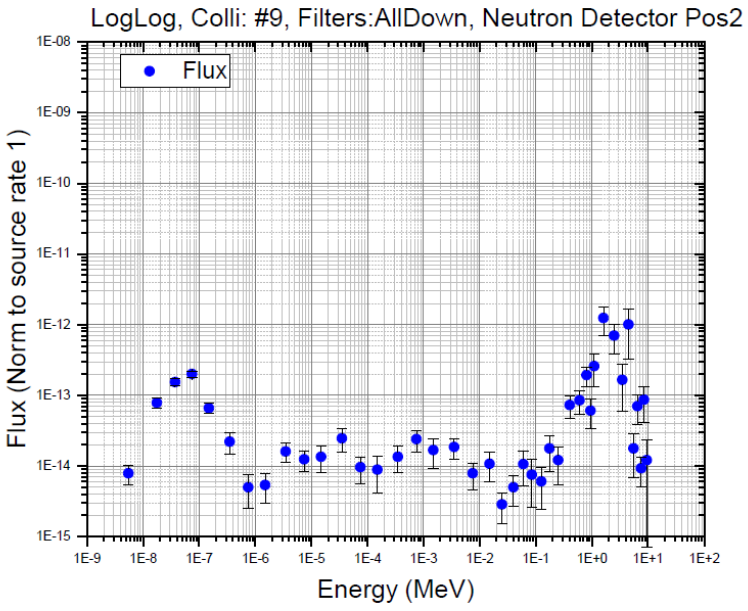
… and create an improved geometry.



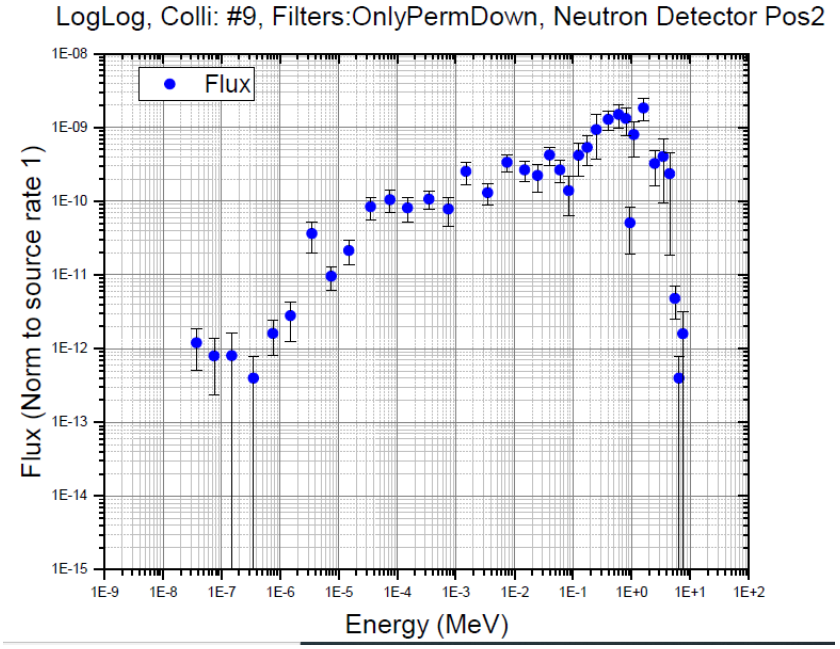
~ 520 cm

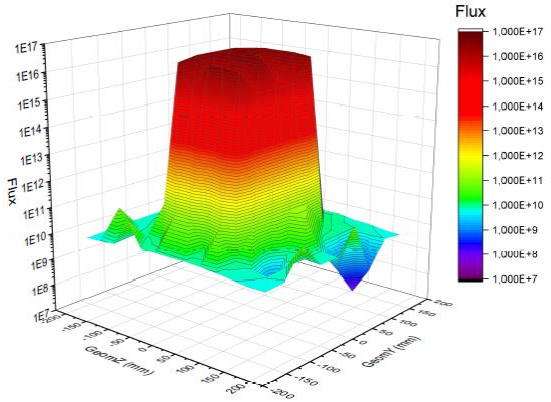
2. Perform preliminary calculations with thermal moderated spectrum on converter plate

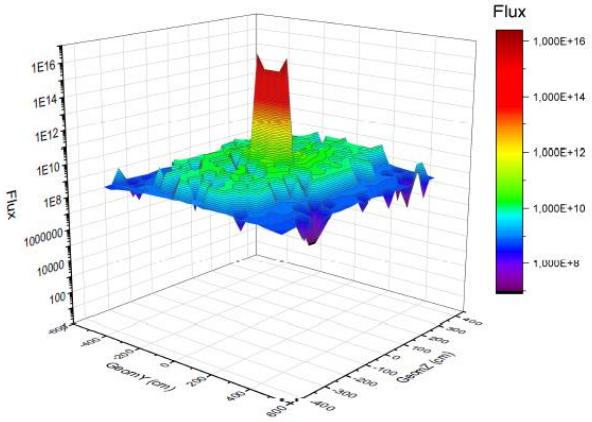
Effect of filters



Effect of MLC

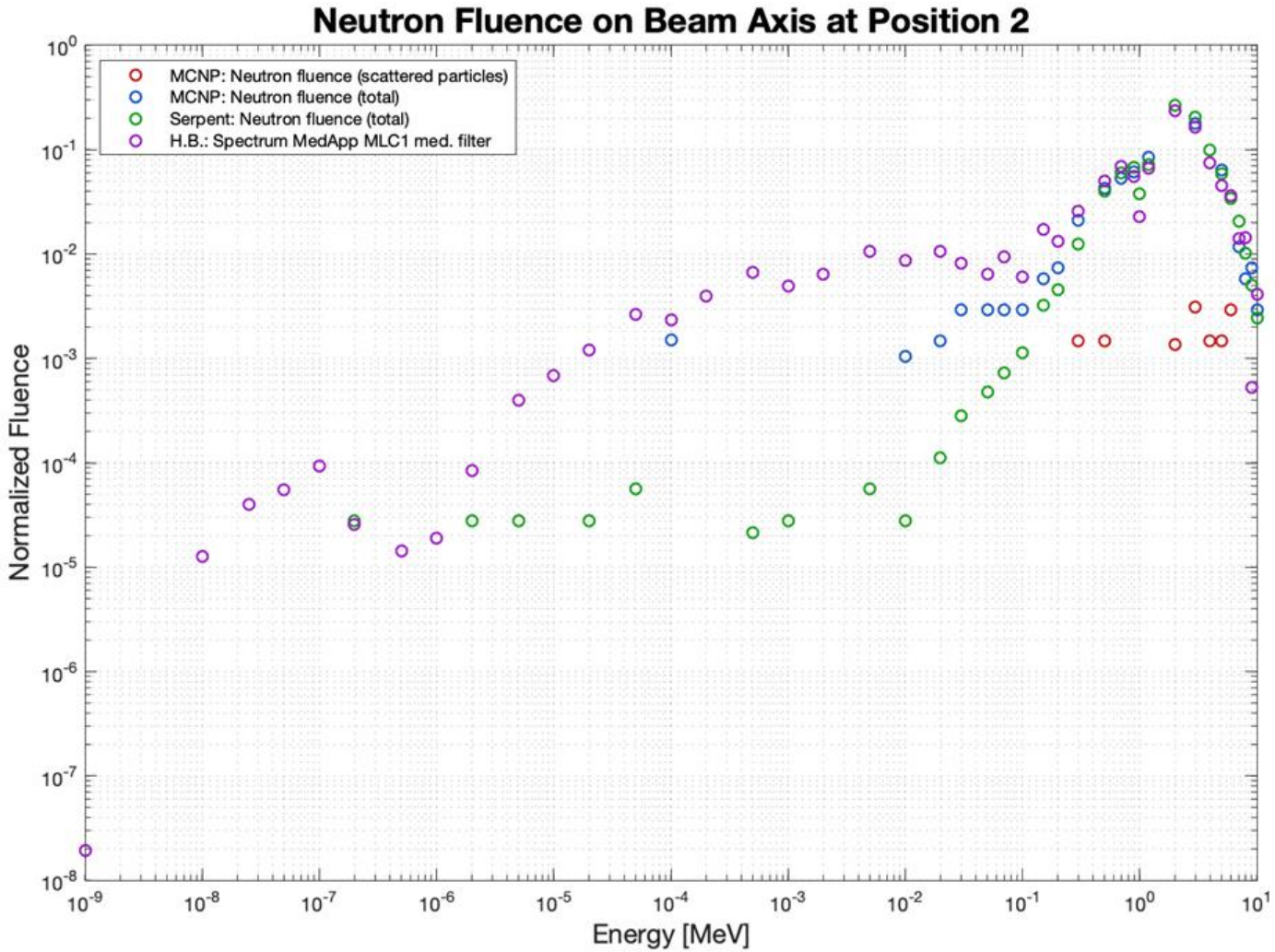




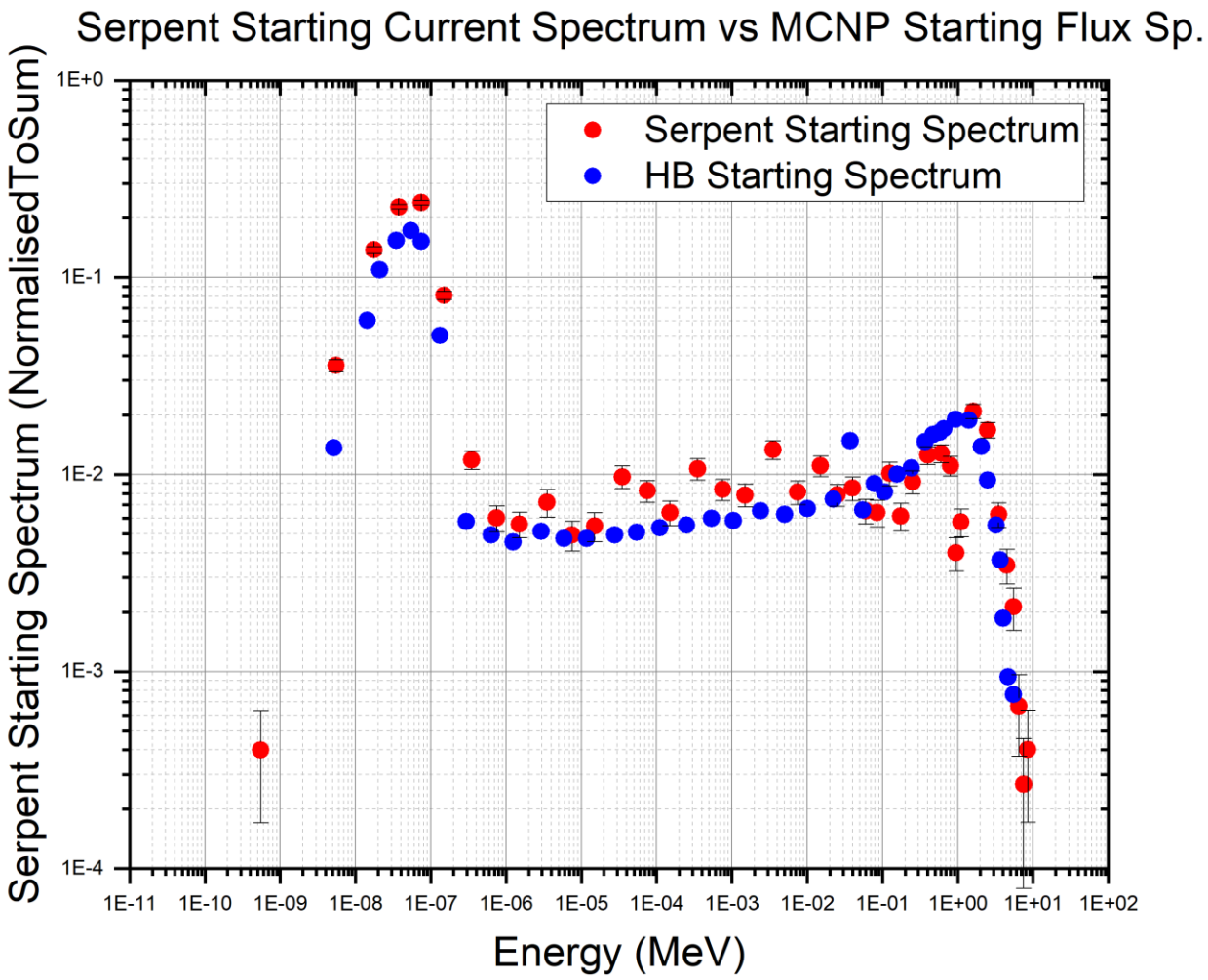


(Arbitrary flux units)

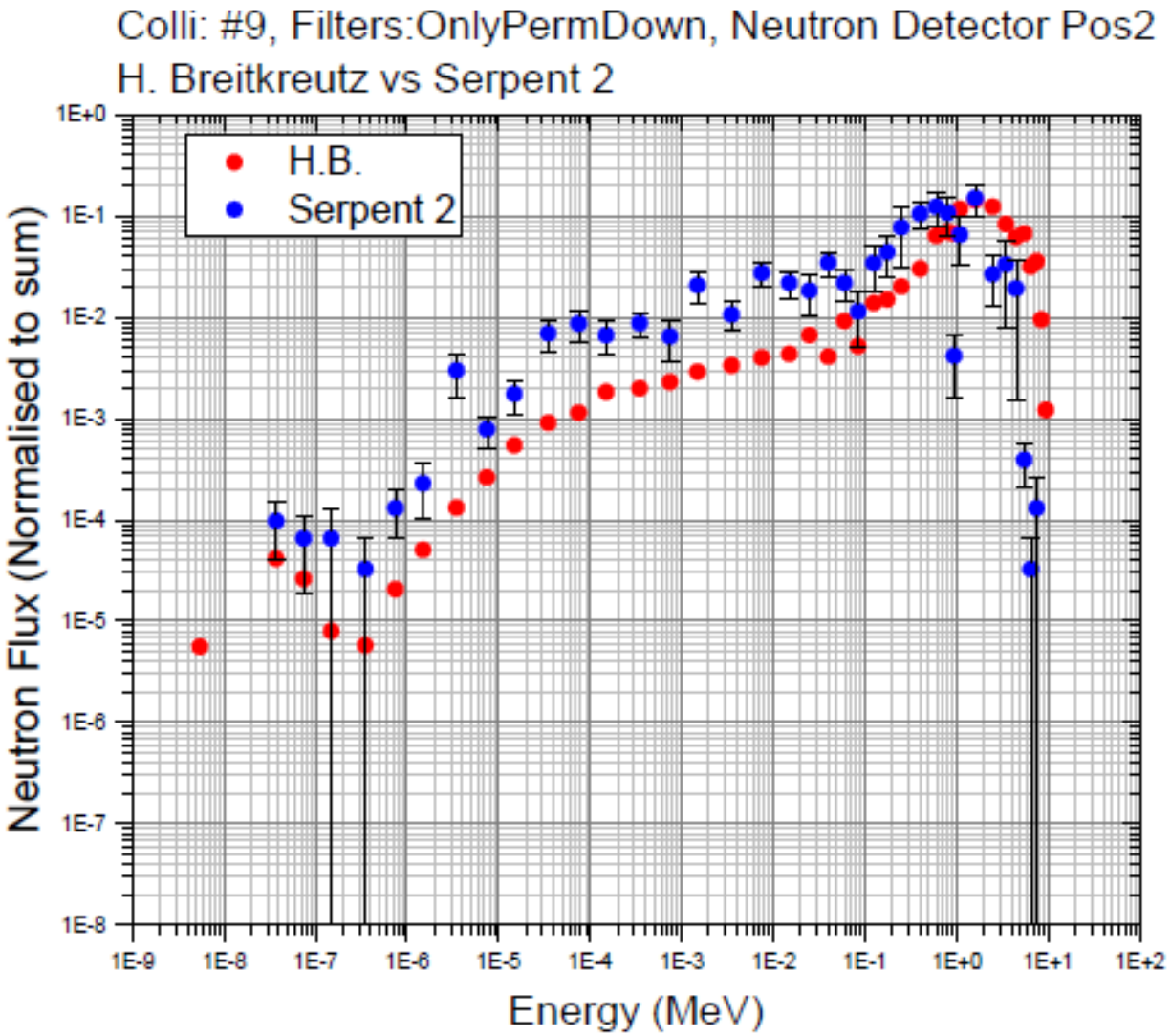
… and qualitative comparison to MCNP spectral flux calculations.



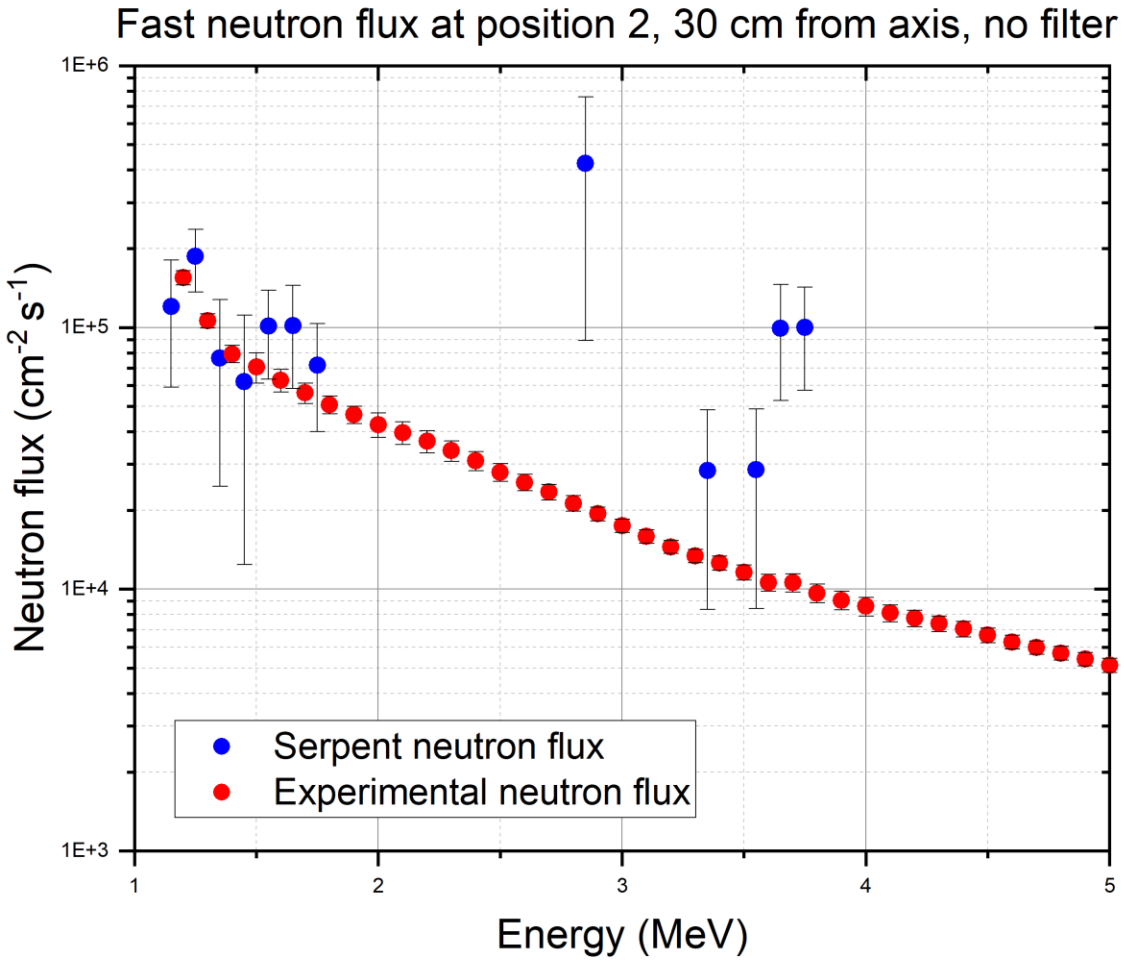
Fission + moderated starting spectrum



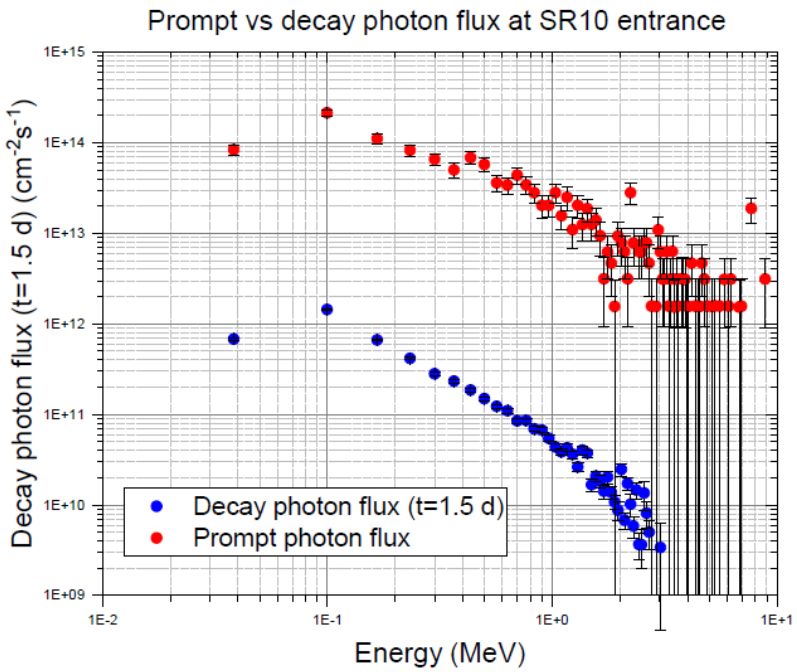
Fission + moderated flux at patient's position

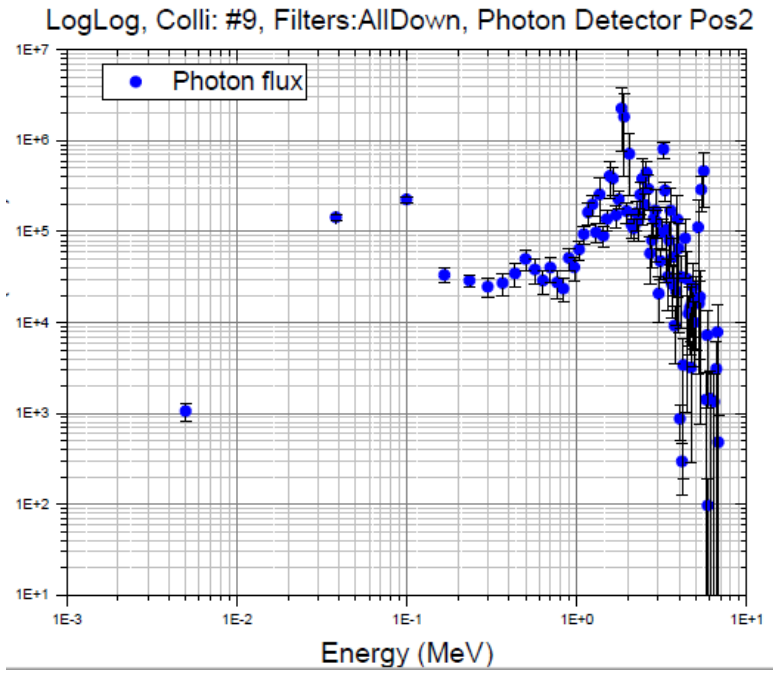


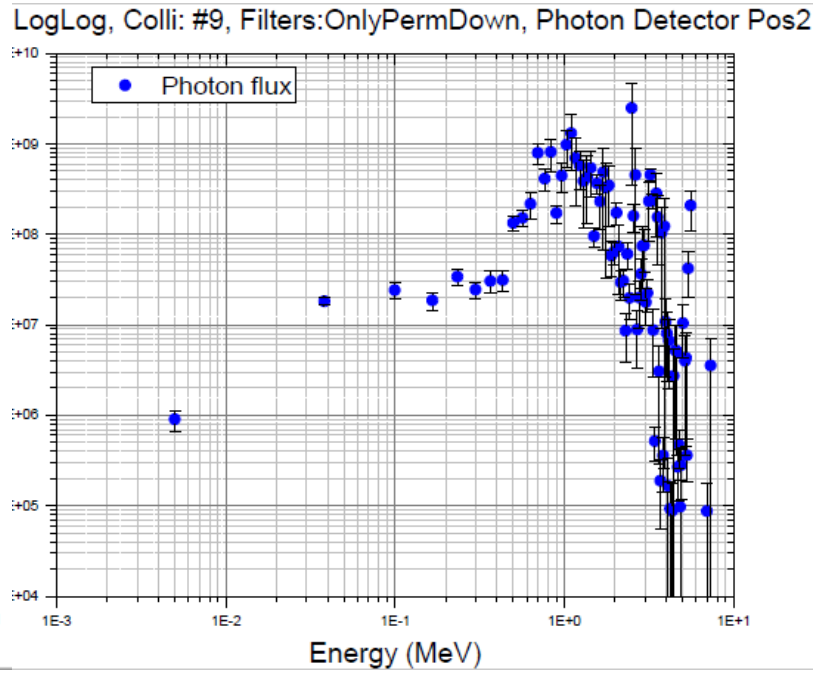
Compare to neutron flux experimental data



Same for photons: preliminary calculations







(common arbitrary flux units)

Conclusions

- Remarkable effects of different filter and collimator configurations
- Adaptive GVR implementation is essential, yet some statistical errors are very high
- Good agreement with MCNP in spectral shape
- Limited experimental validation
  (unfortunately only small spectral region has experimental measurements available)

Further steps

1. Quantitative comparison of neutron quantities to MCNP simulations
2. Calculate gamma flux and dose: neutron-to-gamma ratio comparison
3. Penetration depth analysis, for neutron and gamma on water phantom
4. Comparison of gamma quantities to MCNP

THANK YOU FOR YOUR ATENTION!