Recent activities regarding TIARA and Oktavian-Cr experiments at JSI

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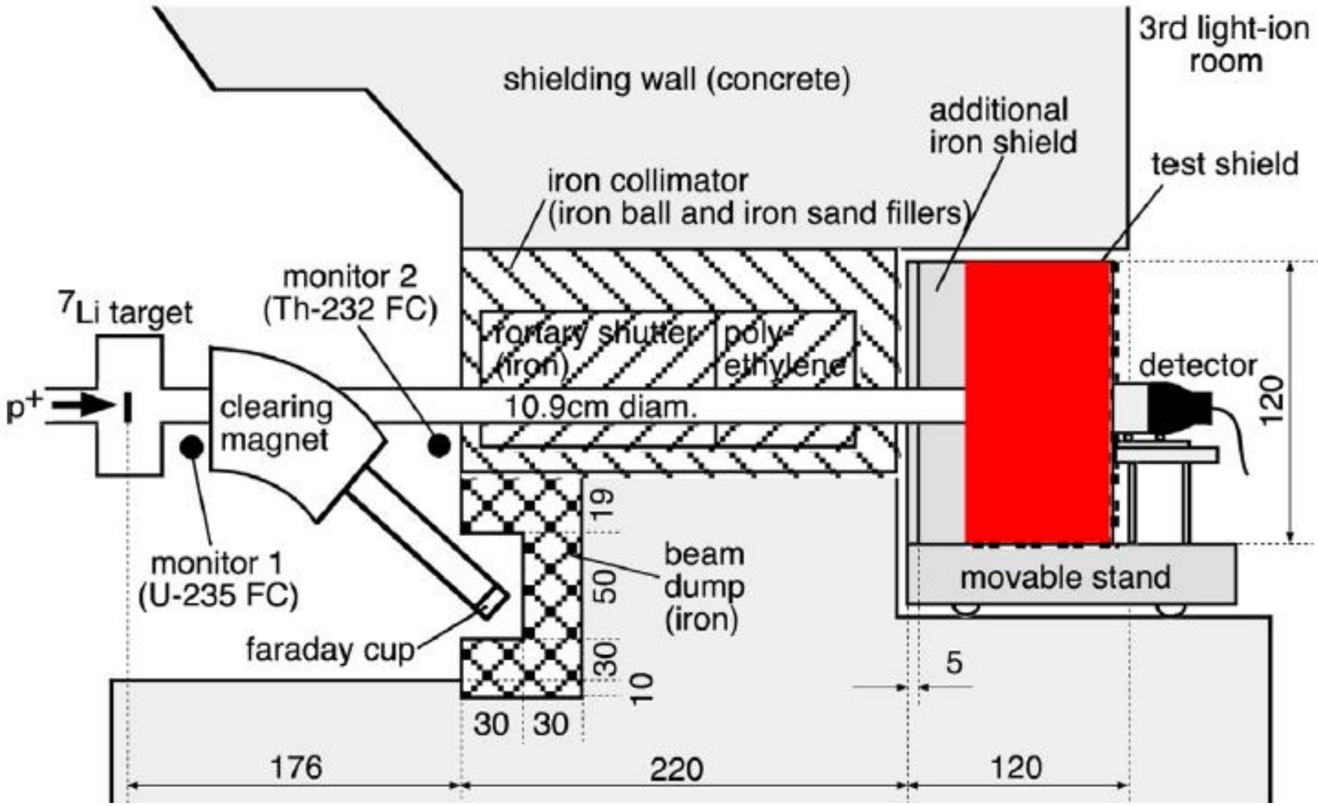
Presentation Overview

- TIARA shielding benchmark
  - Introduction
  - CAD models
  - MCNP models and ADVANTG variance reduction models
  - Remaining uncertainties to be determined
- Oktavian - Chromium
  - Geometry
  - Results with new Chromium evaluation (ENDF)
- Conclusion

TIARA Iron Shielding Benchmark

TIARA (Takasaki Ion Accelerator for Advanced Radiation Application) at JAERI (Japan Atomic Energy Research Institute)

Experimental setup - detailed



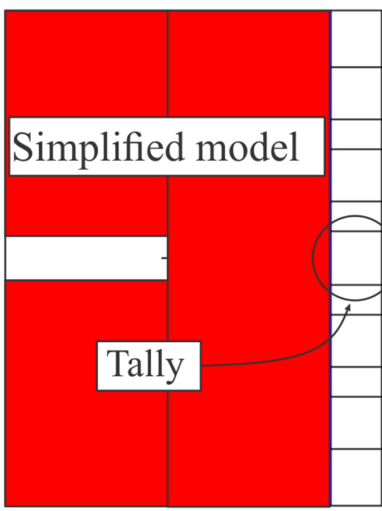
Picture from Konno et al, 2015

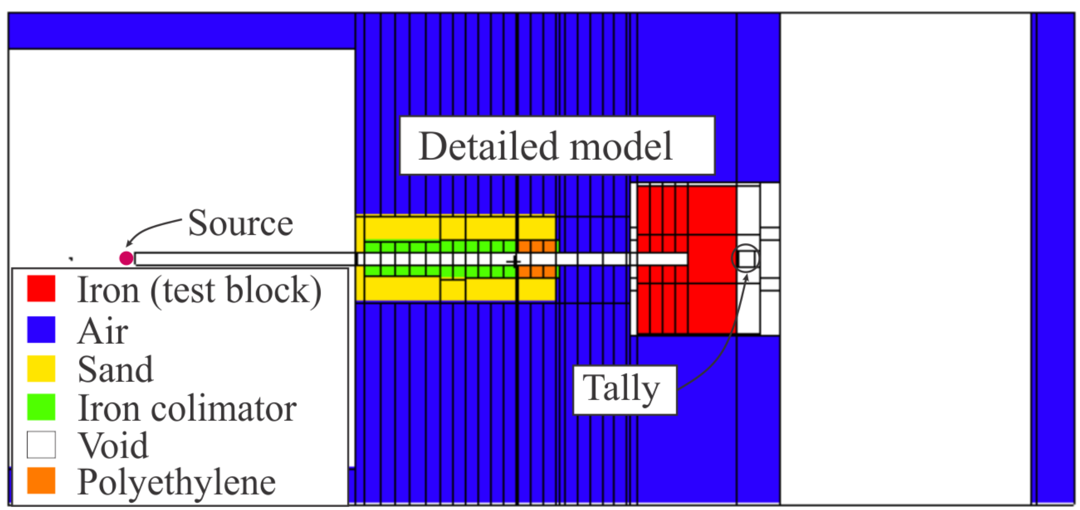
- 43 and 68 MeV proton source
- ^{7}Li target
- Iron collimator
- Iron and concrete test shield
- All information from SINBAD benchmark database

Previous models

MCNP, a General Monte Carlo N-Particle Transport Code

- The simplified model based on LAHET and MCNP4A codes
  - Only neutrons are simulated
- Detailed model from P. Ortego
  - (p,n) reaction for the source
  - No luck in getting reasonable results from this model





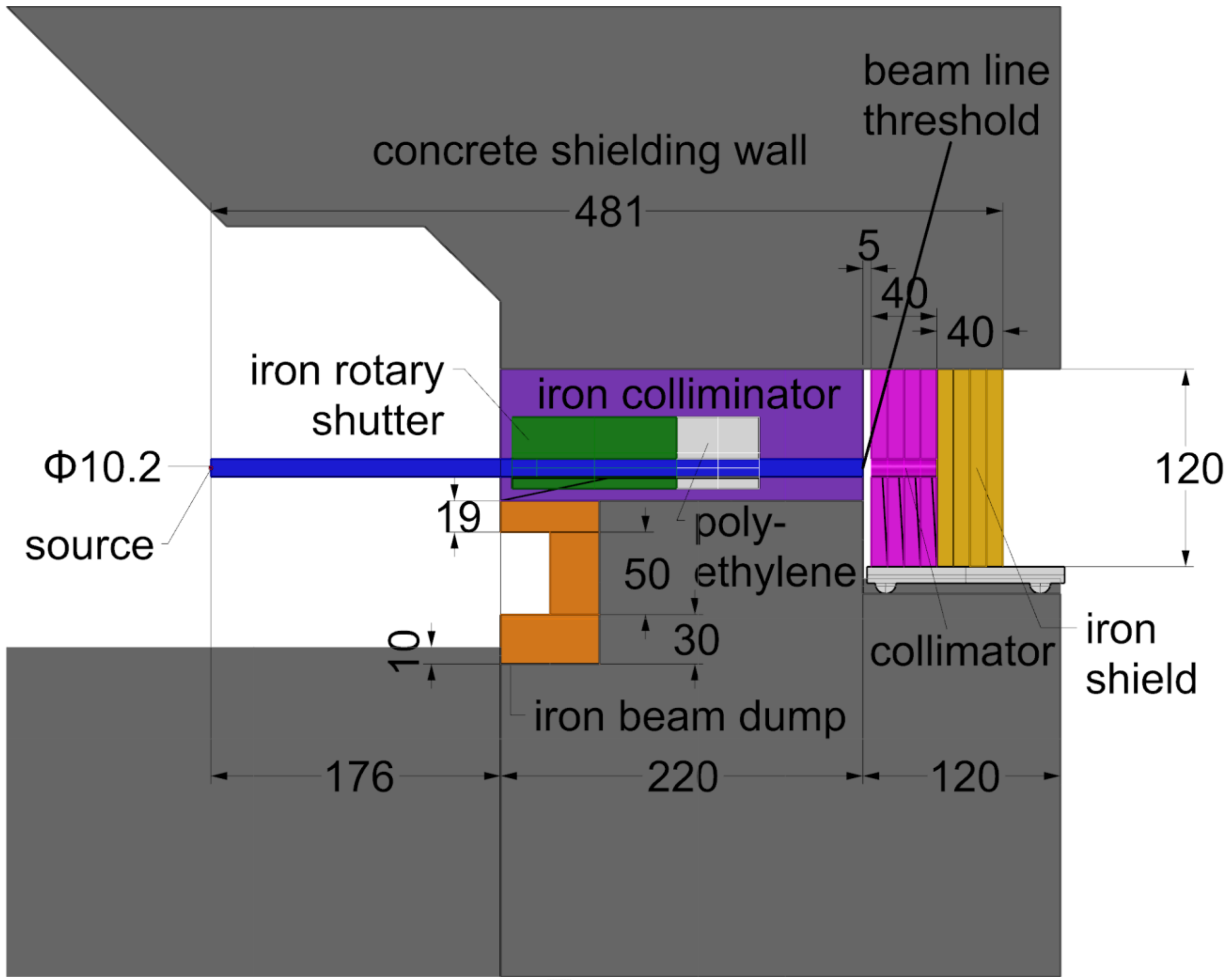
New models based on SINBAD documentation

- CAD models from ground up with Rhinoceros 3D
- Models made for all cases of concrete and iron
- 43 MeV source, 68 MeV source
- Fission cells, Bonner sphere, BC 501A liquid scintillator
- Off and on-axis detectors

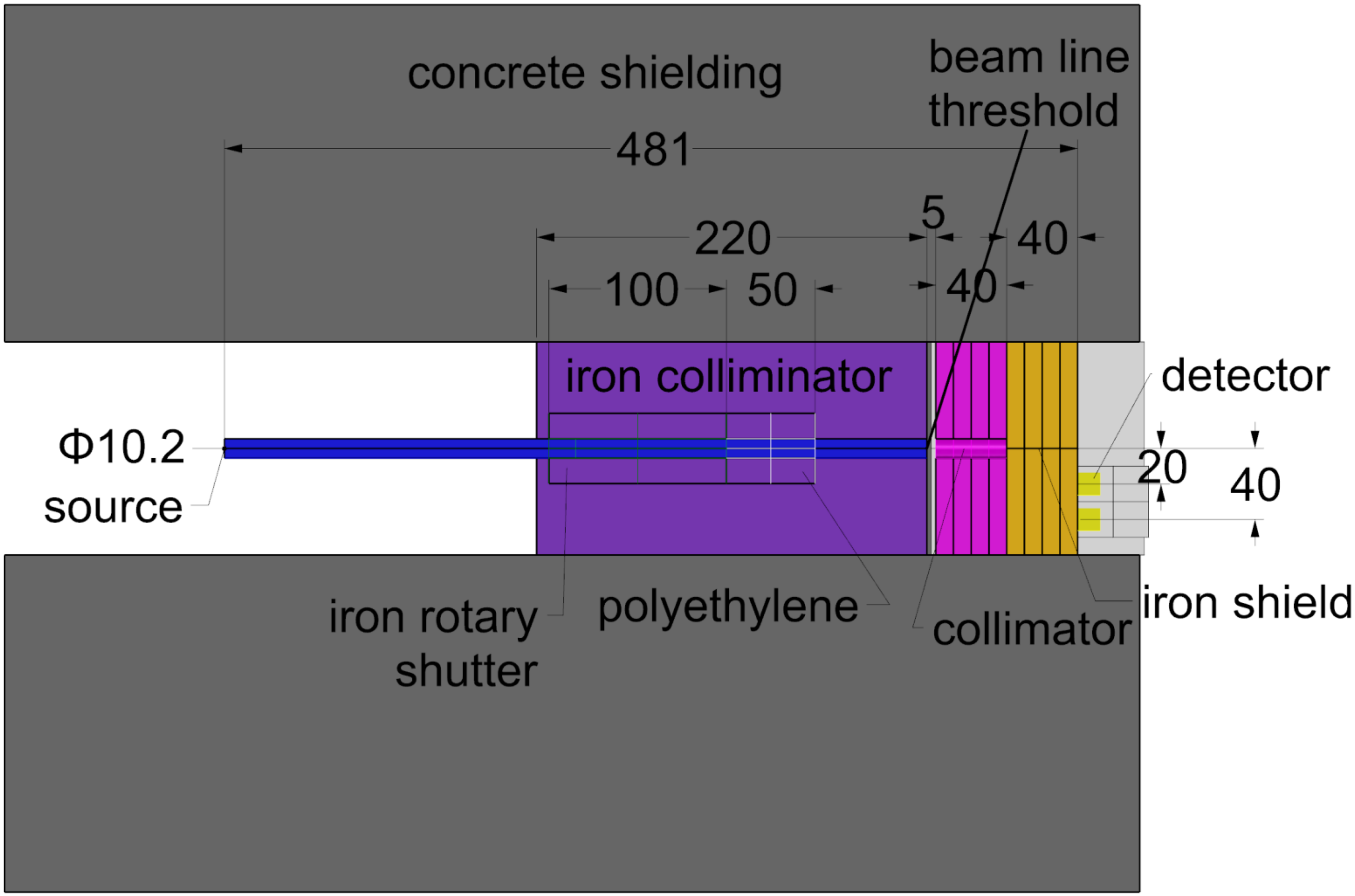
SINBAD documentation for CAD

- JAERI-Data/Code 97-020 EXPERIMENTAL DATA ON CONCRETE SHIELD TRANSMISSION OF QUASI – MONOENERGETIC NEUTRONS GENERATED BY 43 - AND 68 – MeV PROTONS VIA THE 7Li (p,n) REACTION (JOINT RESEARCH) (page 15 of 52)
- JAERI-Data/Code 96-005 EXPERIMENTS ON IRON SHIELD TRANSMISSION OF QUASI – MONOENERGETIC NEUTRONS GENERATED BY 43 - AND 68 – MeV PROTONS VIA THE 7Li (p,n) REACTION (JOINT RESEARCH) (page41 of 53)
- JAERI-Data/Code 96-029 NEUTRON TRANSMISSION BENCHMARK PROBLEMS FOR IRON AND CONCRETE SHIELDS IN LOW, INTERMEDIATE AND HIGH ENERGY PROTON ACCELERATOR FACILITIES (page 11 of 86)
- JAERI-Data/Code 98-013 EXPERIMENTAL DATA ON POLYETHLYENE SHIELD TRANSMISSION ON QUASI-MONOERGETIC NEUTRONS GENERATED BY 43- AND 68 MeV PROTONS VIA 7Li(P,N) REACATION (page 40 of 54)

TIARA, 68 MeV, 40 cm iron shield, 40 cm collimator, BC 501A liquid scin.

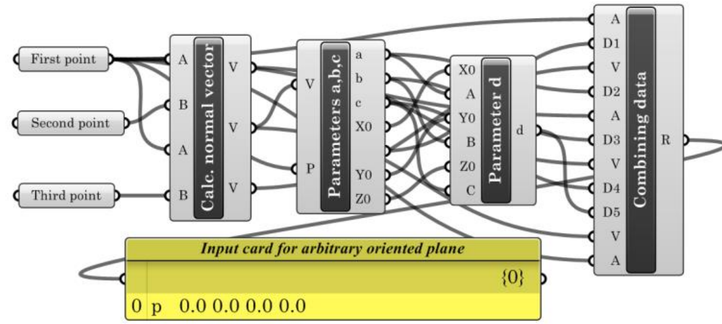


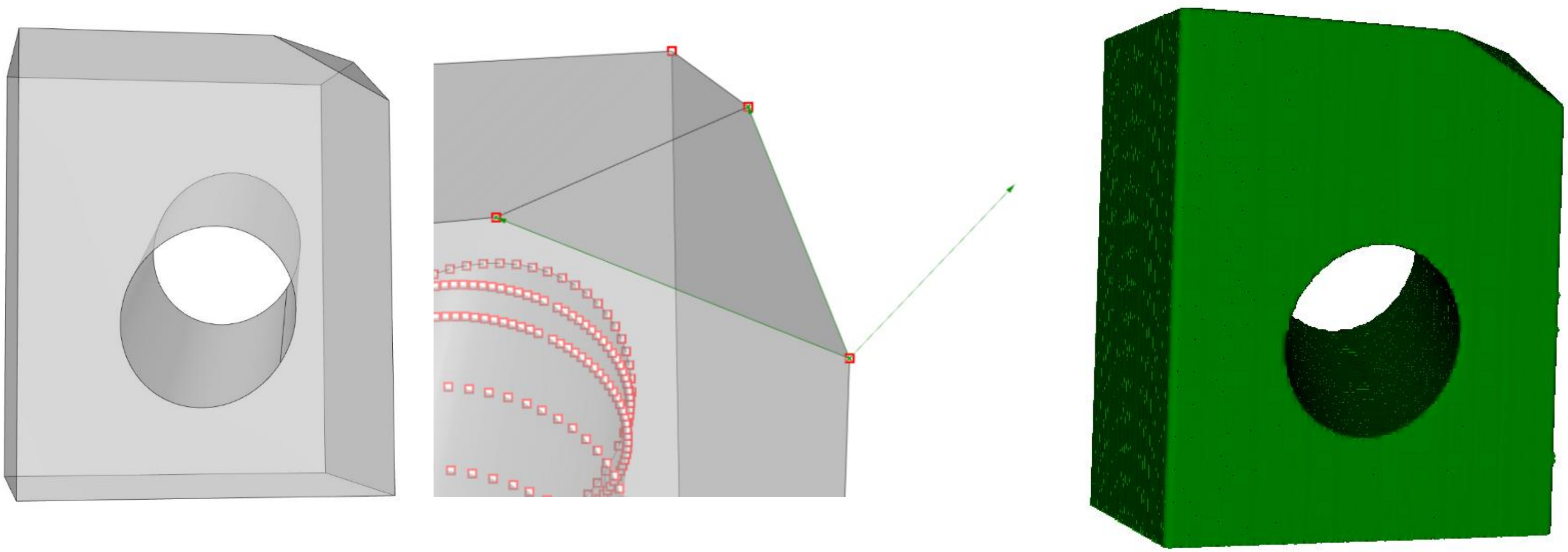
TIARA, 68 MeV, 40 cm iron shield, 40 cm collimator, BC 501A liquid scin.



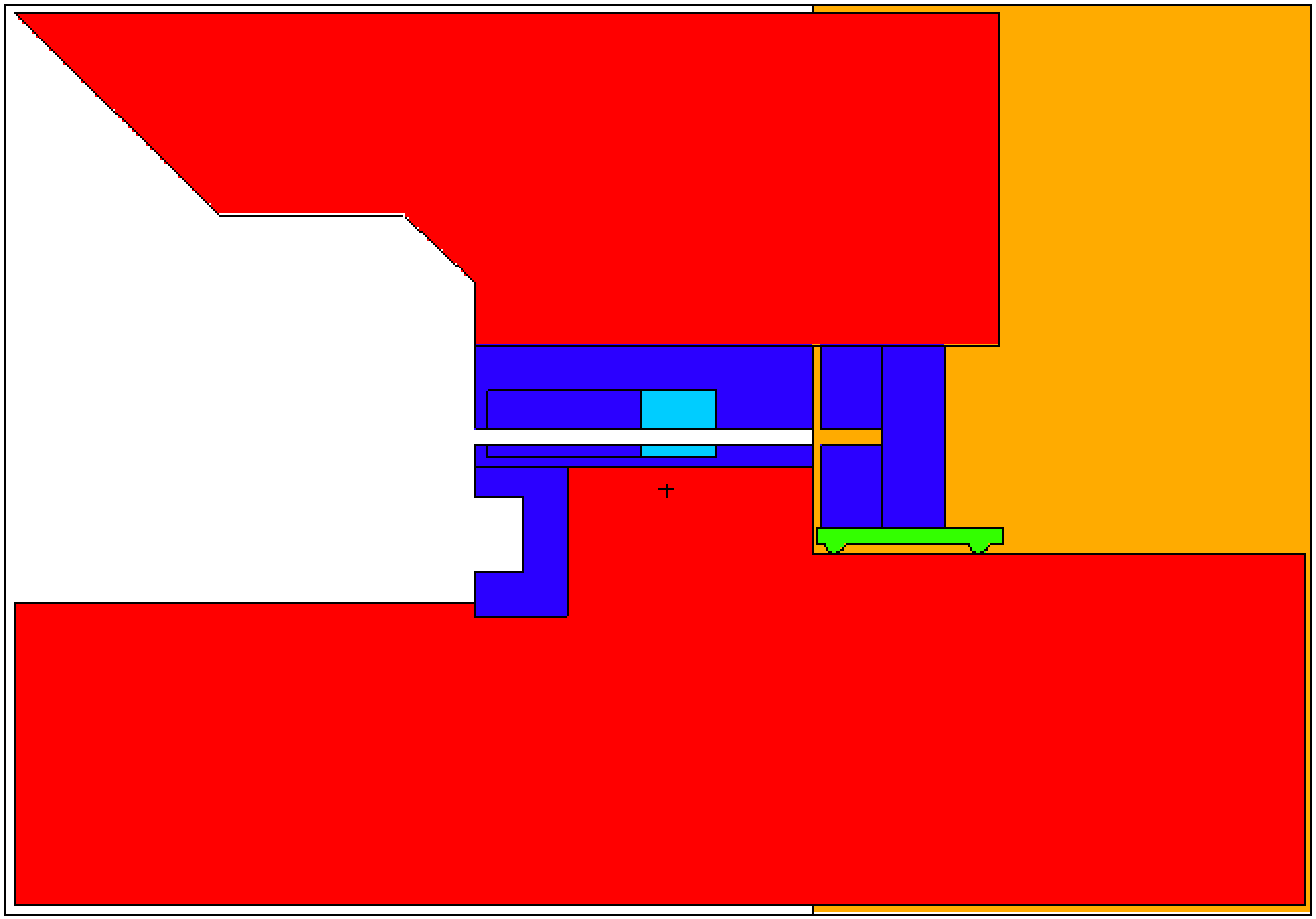
Conversion of CAD to MCNP

- GRASP tool developed at JSI
- Based on Grasshopper (visual-scripting language plugin) and Rhinoceros5 3D

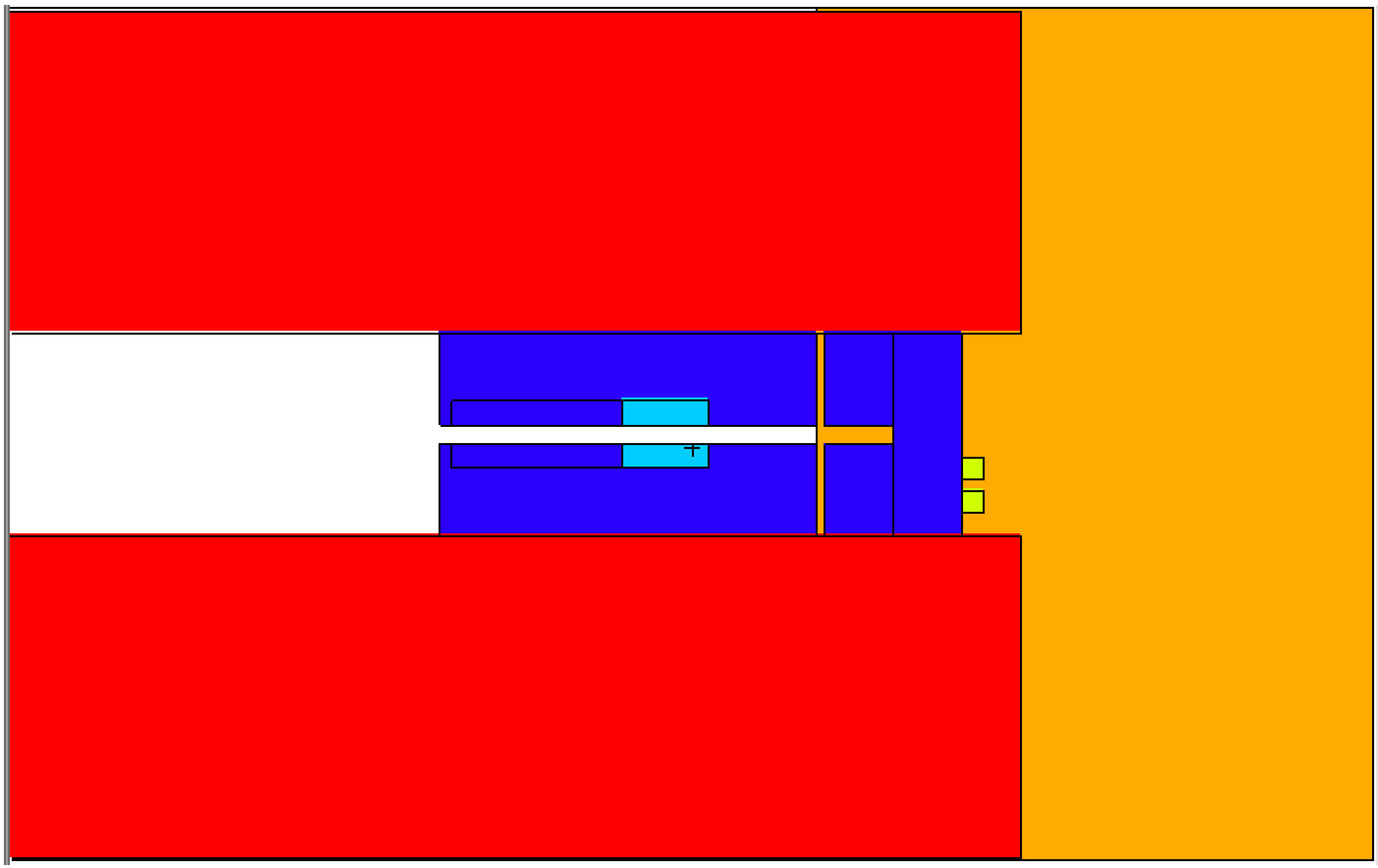




TIARA, 68 MeV, 40 cm iron shield, 40 cm collimator, BC 501A liquid scin.



TIARA, 68 MeV, 40 cm iron shield, 40 cm collimator, BC 501A liquid scin.

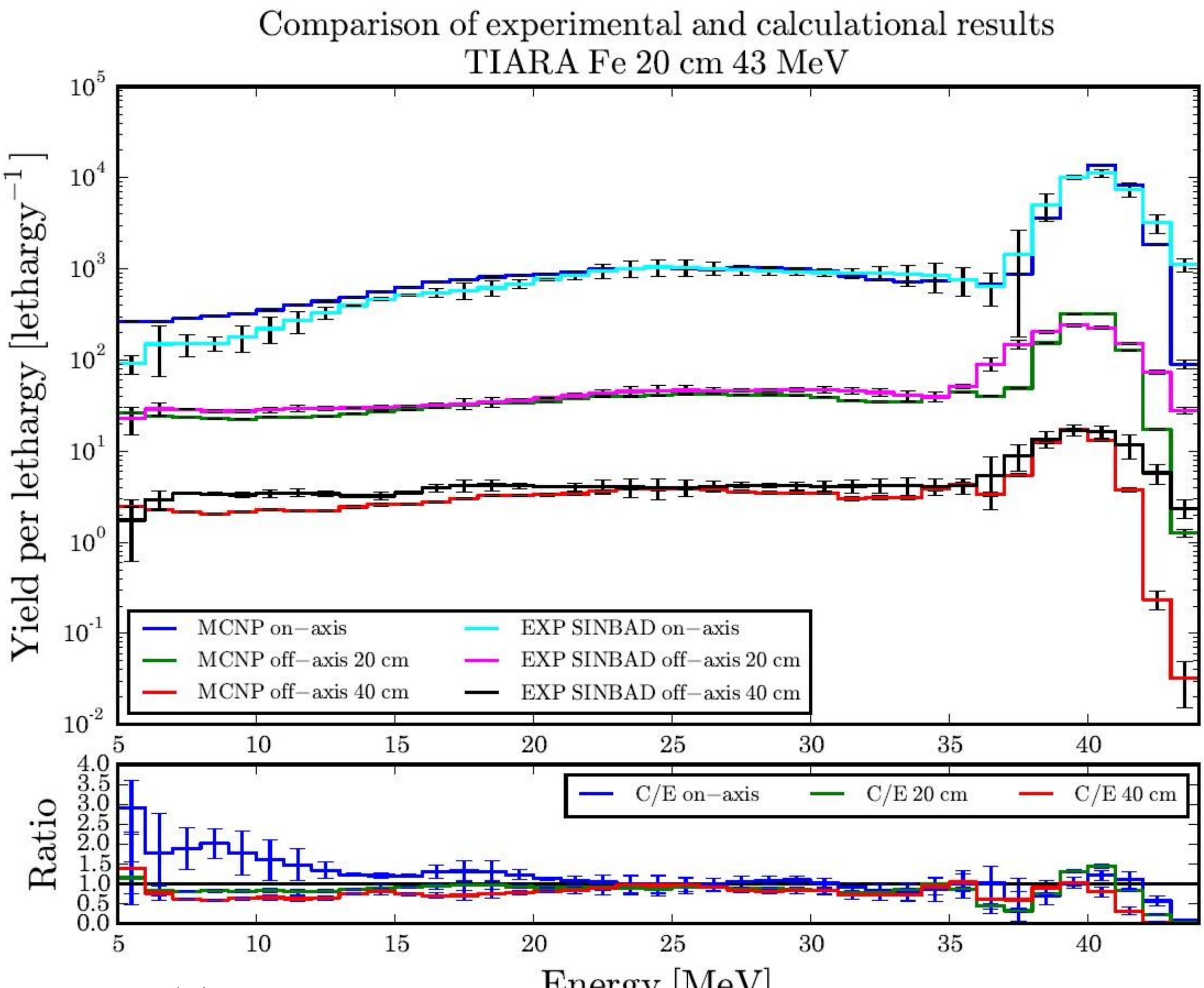


Variance reduction with ADVANTG

- Beneficial for cases with thicknesses higher than 40 cm
- FW-CADIS
- Hilo2k multigroup library used (distributed with ADVANTG)
- Geometrical mesh defined in such a way to encapsulate all details of the models
- Each case takes under 5 min on 40 threads (Intel Xeon E5-2680 v2) for a statistical uncertainty under 2 %

MCNP inputs available

- IAEA INDC publications
  - Report: INDC(NDS)-0785
  - Inputs: INDC(NDS)-0785-SUPPLEMENT
- IAEA NDS CoNDERC website
  - With sample outputs as well!
  - https://nds.iaea.org/conderc/tiara


Comparison of experimental and calculational results
TIARA Fe 20 cm 43 MeV
Yield per lethargy [lethargy^{-1}]
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
MCNP on−axis
MCNP off−axis 20 cm
MCNP off−axis 40 cm
EXP SINBAD on−axis
EXP SINBAD off−axis 20 cm
EXP SINBAD off−axis 40 cm
5
10
15
20
25
30
35
40
Ratio
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
C/E on−axis
C/E 20 cm
C/E 40 cm
Energy [MeV]

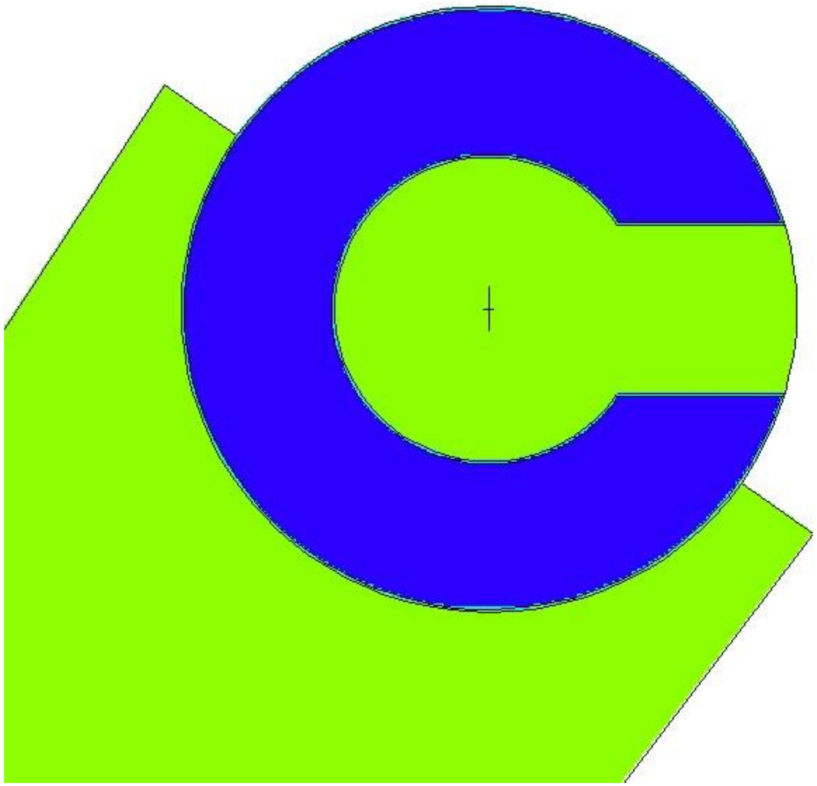
New benchmark experiment evaluation? Not yet!

- Quantify all uncertainties
  - Material compositions sensitivity study
  - Uncertainties in the modelling of the detectors
  - ND uncertainties
- Explicit modelling of the source
  - Recreate proton induced source
  - Compare with measurements
- A possible error in the experimental values or the original and SINBAD documentation can be observed when analyzing the results for the 15 mm Bonner sphere with a Cadmium coating in the case of the 100 cm and 150 cm concrete shield with the 68 MeV source.
- C/E discrepancies for some cases still large! This will need to be investigated

Oktavian - Cr

- Currently not in SINBAD – candidate for inclusion
- Documented in JAERI-M-j94-014 and JAERI-M-j98-024
- Oktavian benchmarks were analyzed previously by Alberto Milocco and Ivo Kodeli (but not Cr)

Oktavian – Cr geometry



- Titanium-Tritium target with copper liner
- Shield liner from stainless steel
- Chromium shield (Cr,Fe,C,Si), 10 cm thick, outside diameter 40 cm
- Source beam opening
- Detector at 55° from beam line, ~ 9 m from source

Oktavian - Cr

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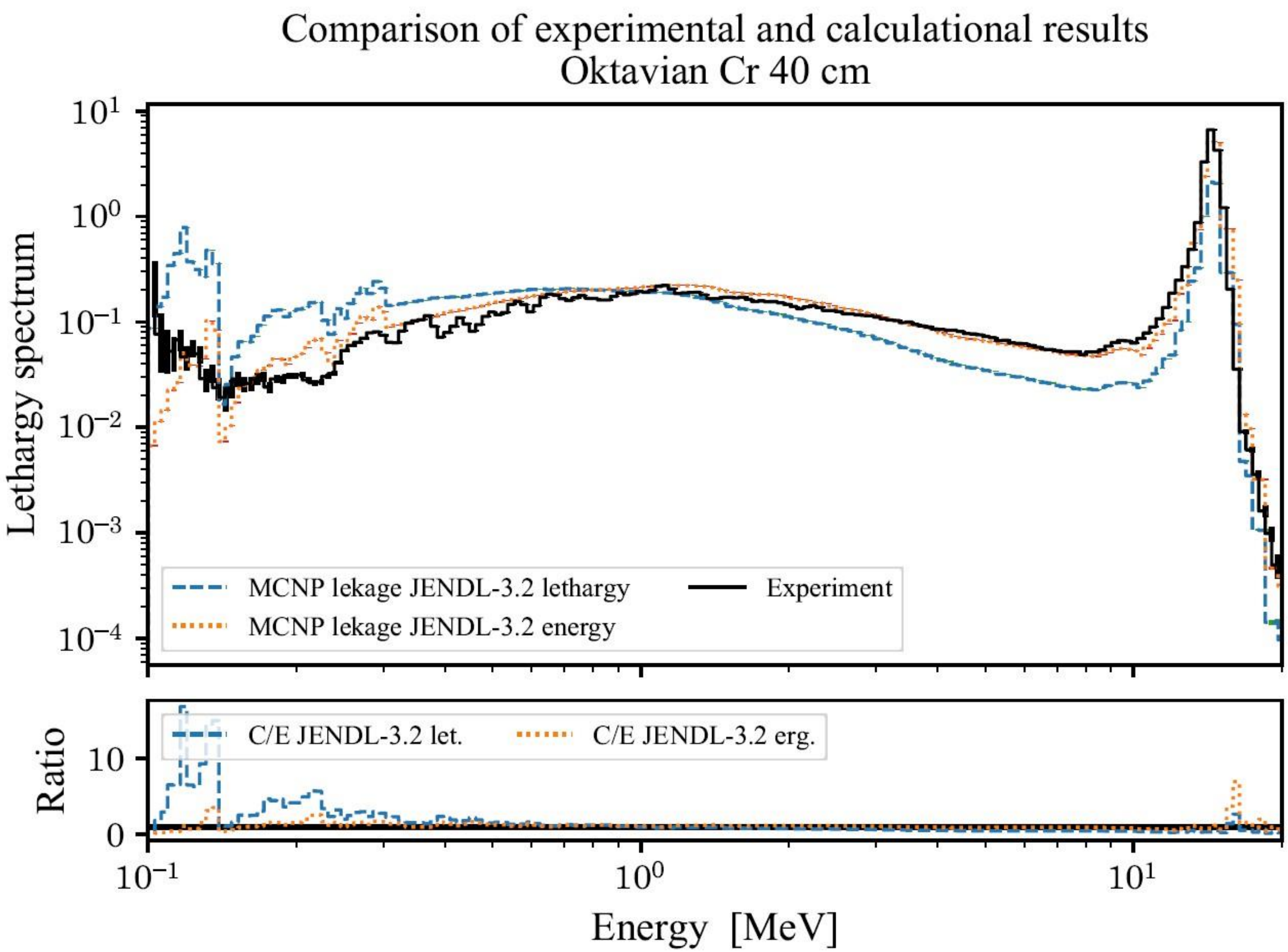
- Source specification in Table 4.6 of j94-014 is in error
  - Source is “per unit energy” (not lethargy)
  - Verified by comparison with Figure 4.11 in JAERI-M-j94-014
- Oktavian benchmarks were analyzed previously by Alberto Milocco and Ivo Kodeli (but not Cr)
  - Source model developed from first principles
  - Analysis in time-domain is **very important**

Table 4.6 of j94-014 per energy or per lethargy?



Oktavian – Cr source validation

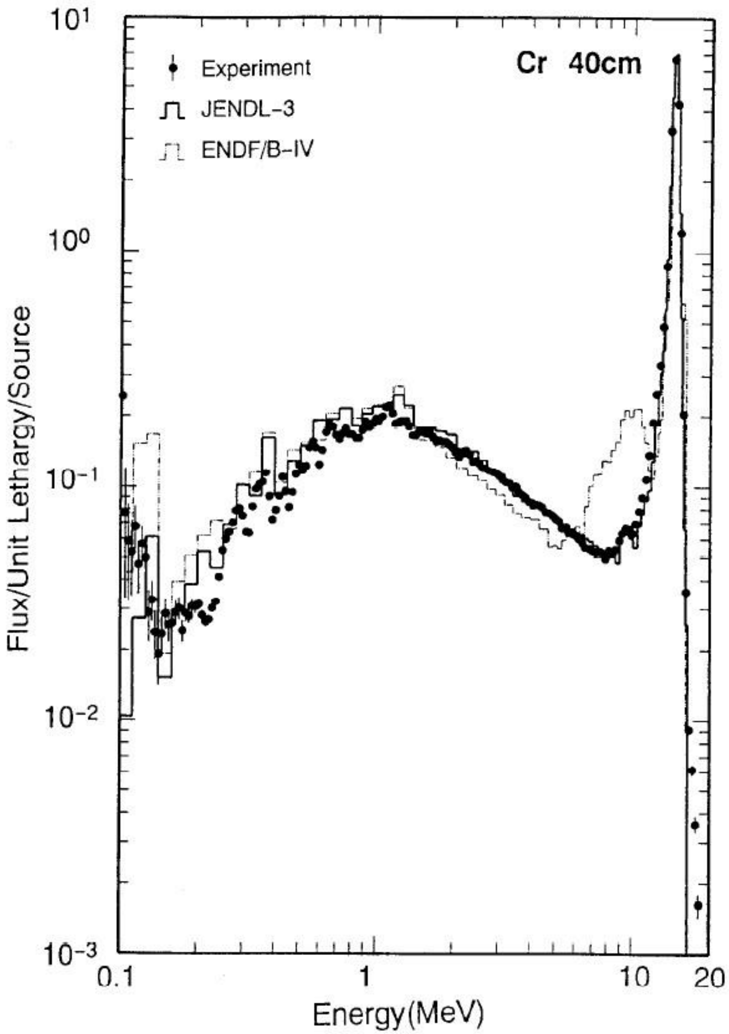
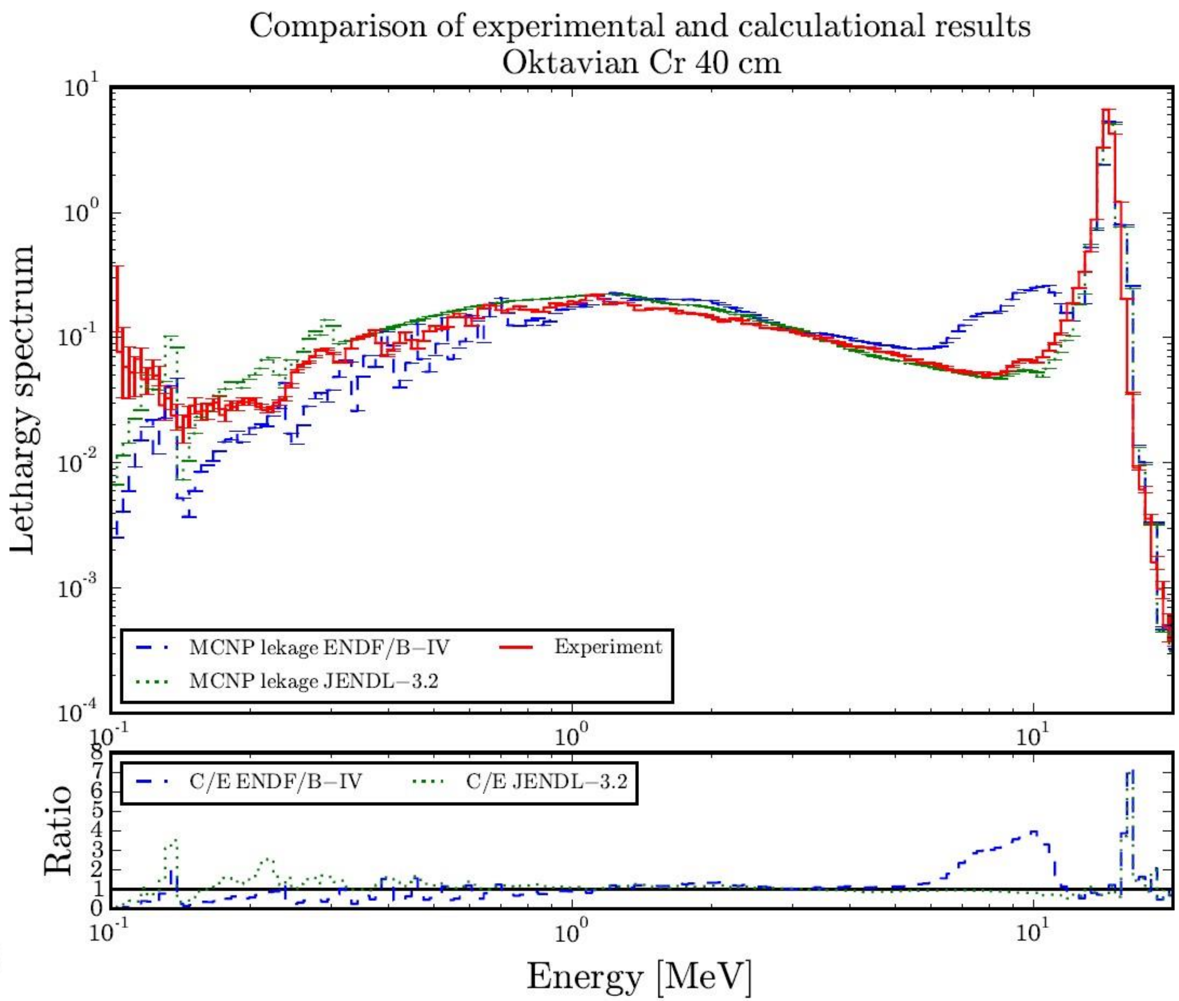
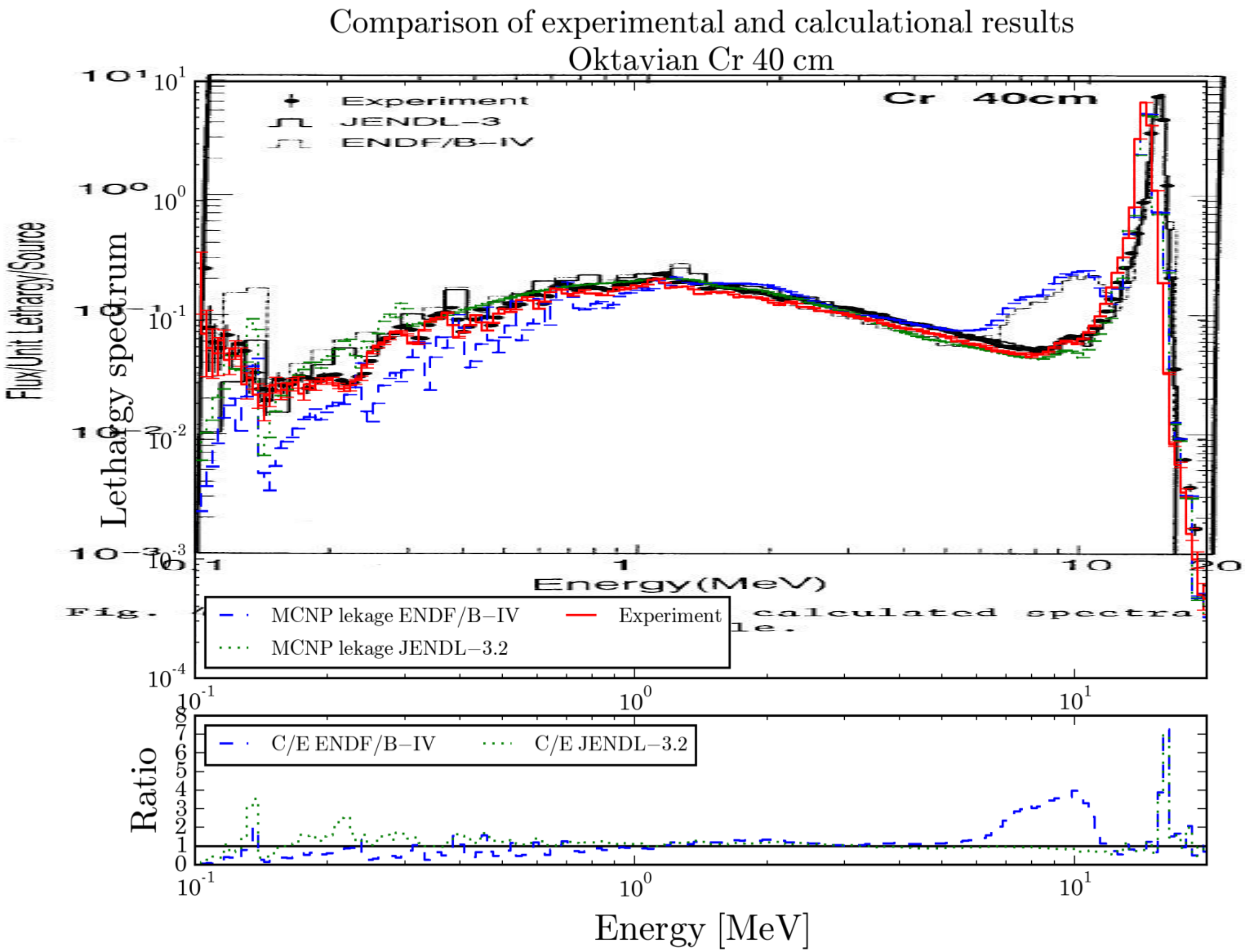


Fig. 4.11 Experimental and calculated spectra from Cr 40 cm pile.



Oktavian – Cr source validation



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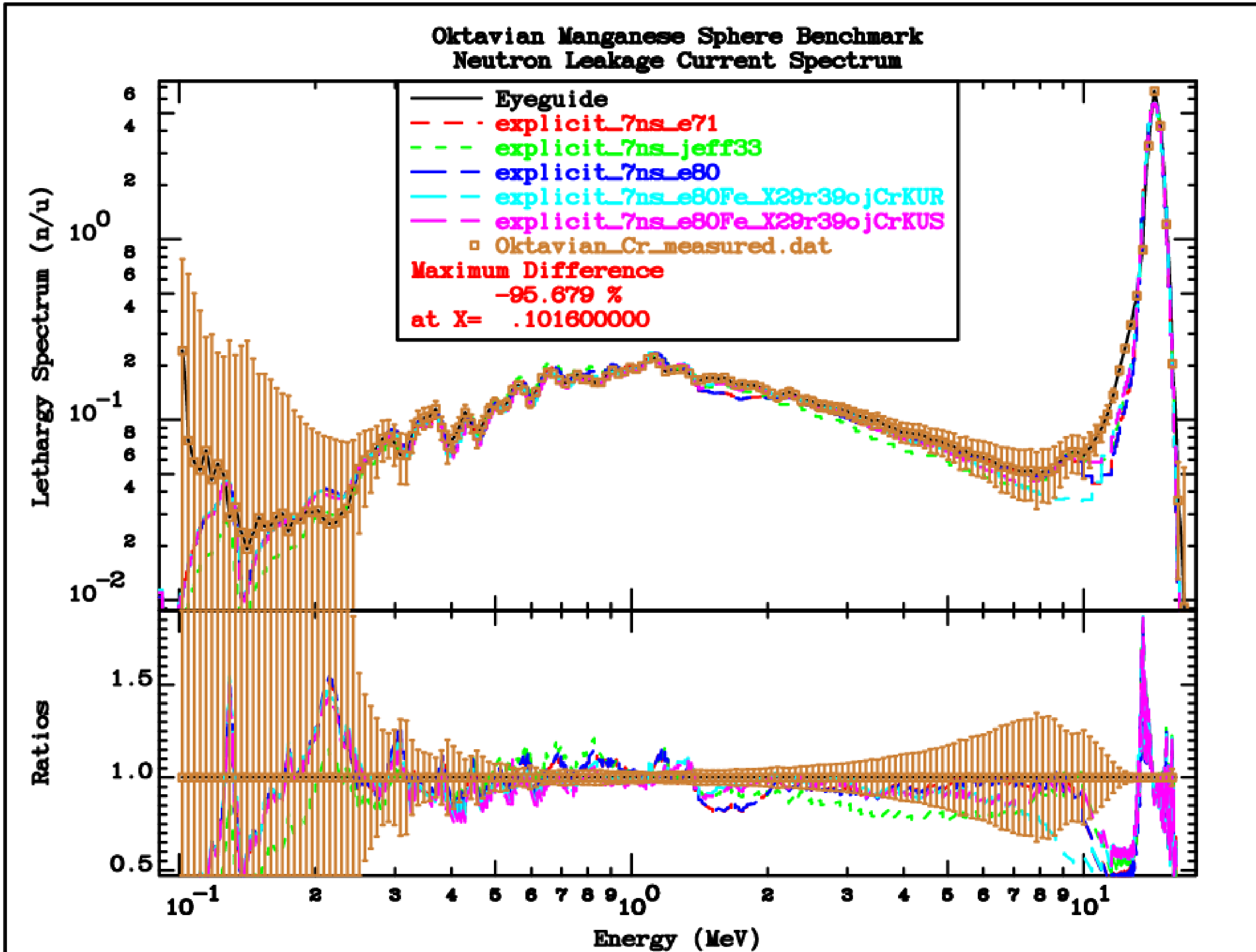
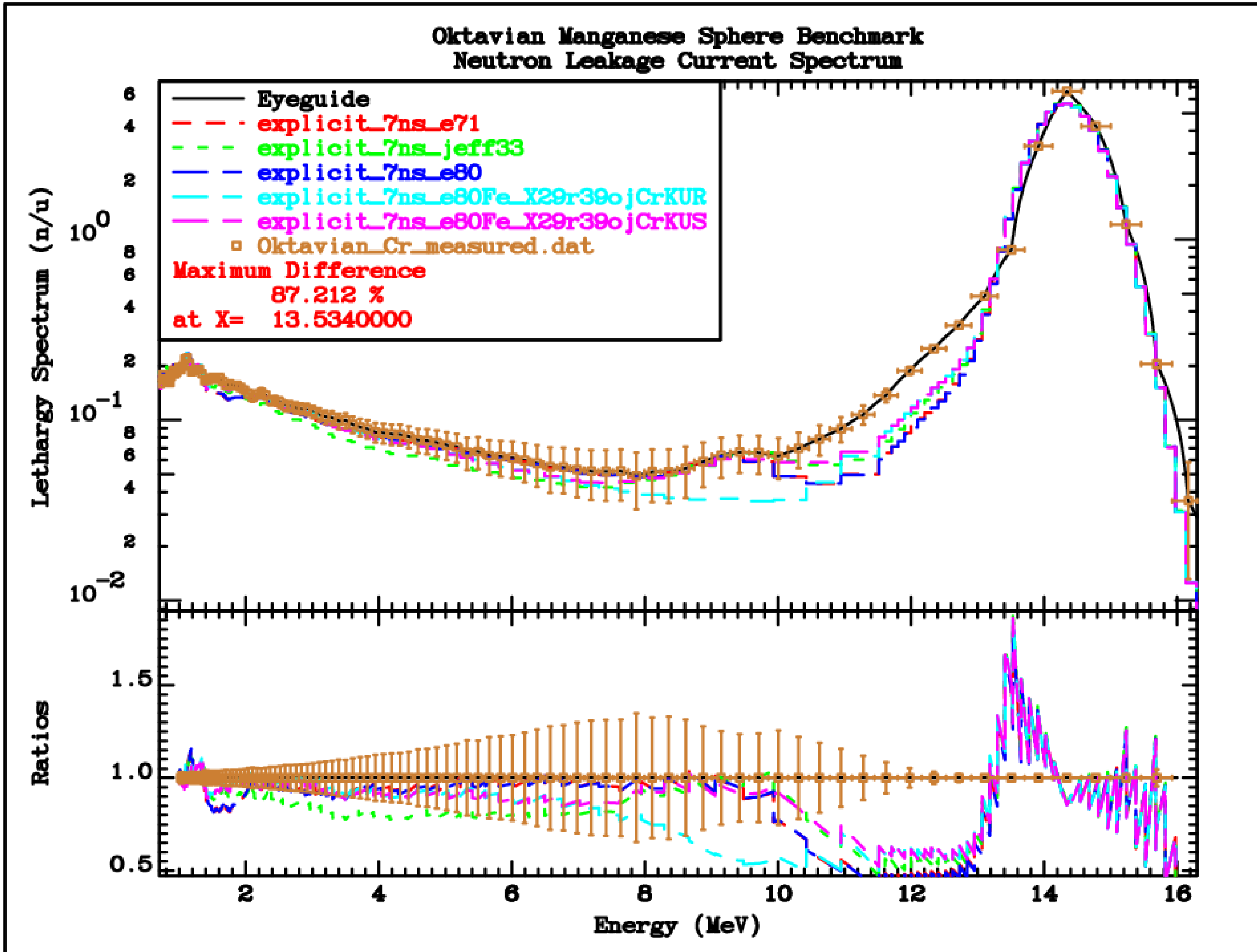
  - Source model developed from first principles
  - Analysis in time-domain is **very important**
- Analysis of the Cr case done for INDEN – article in the pipeline!

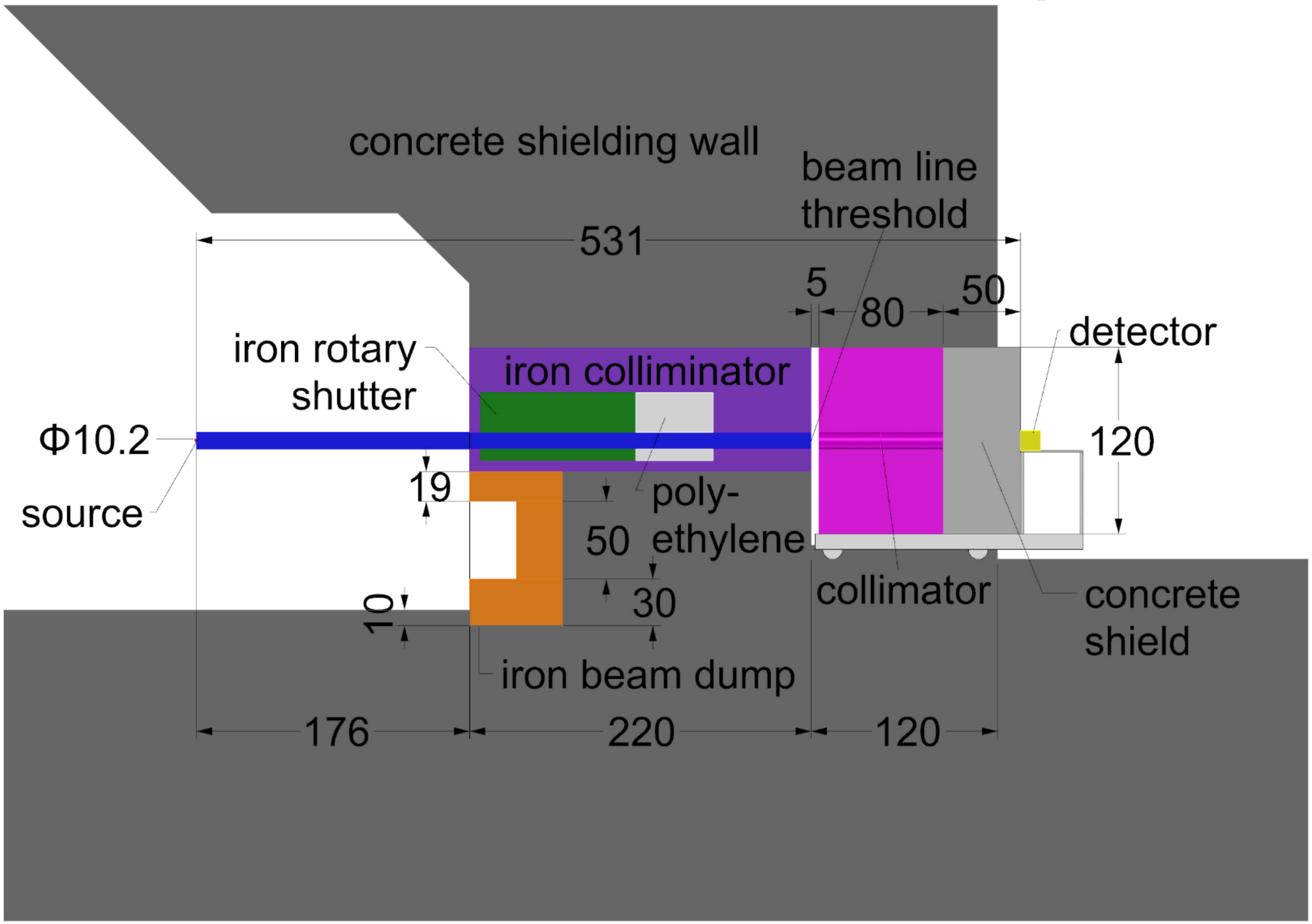

Oktavian Manganese Sphere Benchmark
Neutron Leakage Current Spectrum
Eyeguide
explicit_7ns_e71
explicit_7ns_jeff33
explicit_7ns_e80
explicit_7ns_e80Fe_X29r39ojCrKUR
explicit_7ns_e80Fe_X29r39ojCrKUS
Oktavian_Cr_measured.dat
Maximum Difference
-95.679 %
at X= .101600000
Lethargy Spectrum (n/u)
Ratios
Energy (MeV)

Conclusion

- TIARA candidate for new benchmark evaluation
  - CAD models ✓
  - MCNP models and variance reduction with ADVANTG ✓
  - Source from first principles ✗
  - Quantify uncertainties including ND ✗
  - Sensitivity to material/geometry variations (room effect) ✗
- Oktavian Cr candidate for new benchmark evaluation
  - Source validation – error in documentation! ✓
  - MCNP model based on Milocco and Kodeli methodology ✓
  - Calculation in time domain, covert to energy domain with ACEFLX ✓
  - All uncertainties need to be determines ✗


Oktavian Manganese Sphere Benchmark
Neutron Leakage Current Spectrum
Eyeguide
explicit_7ns_e71
explicit_7ns_jeff33
explicit_7ns_e80
explicit_7ns_e80Fe_X29r39ojCrKUR
explicit_7ns_e80Fe_X29r39ojCrKUS
Oktavian_Cr_measured.dat
Maximum Difference
87.212 %
at X= 13.5340000
Lethargy Spectrum (n/u)
Ratios
Energy (MeV)

TIARA, 68 MeV, 50 cm concrete shield, 80 cm collimator, BC 501A liquid scin.



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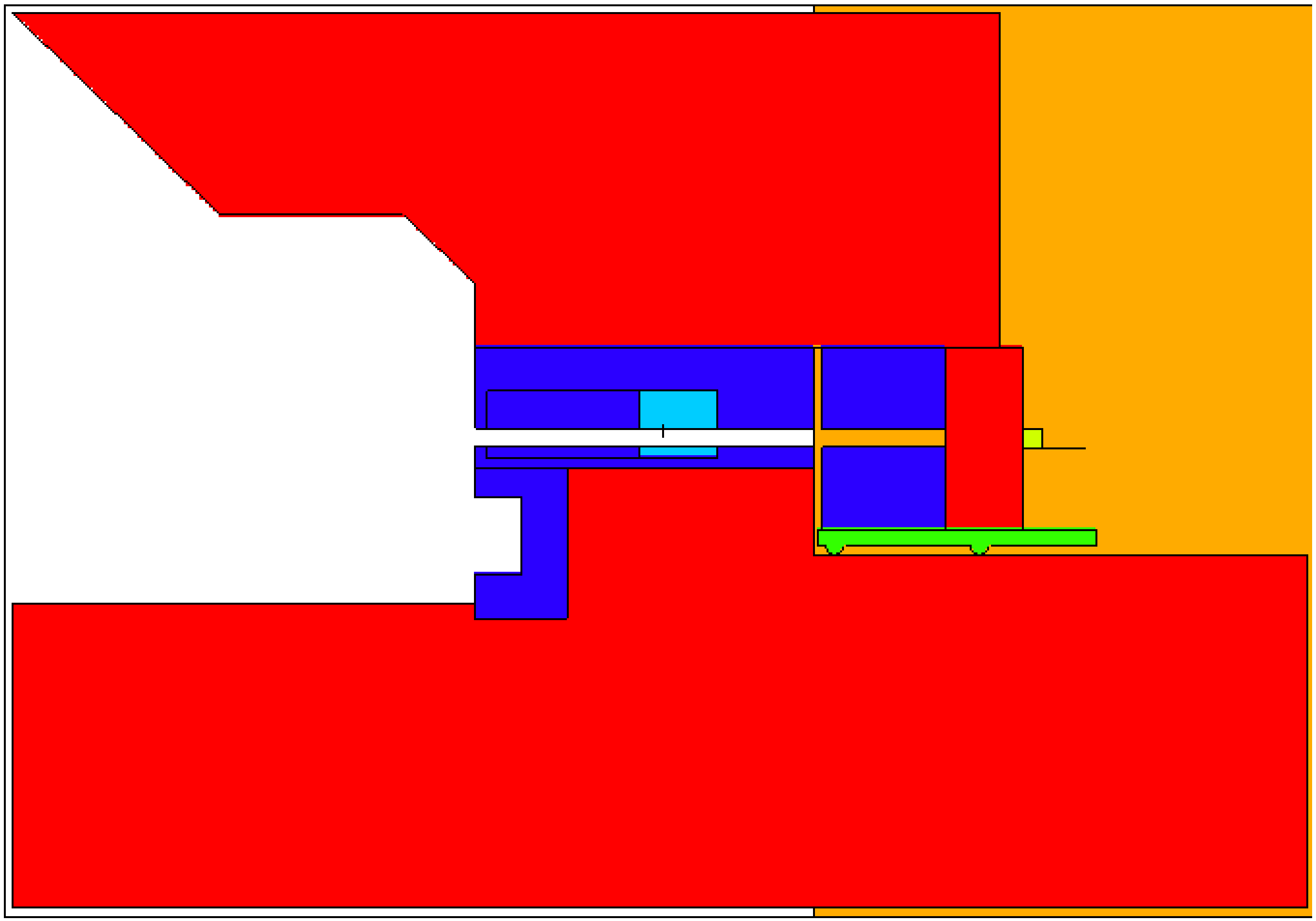

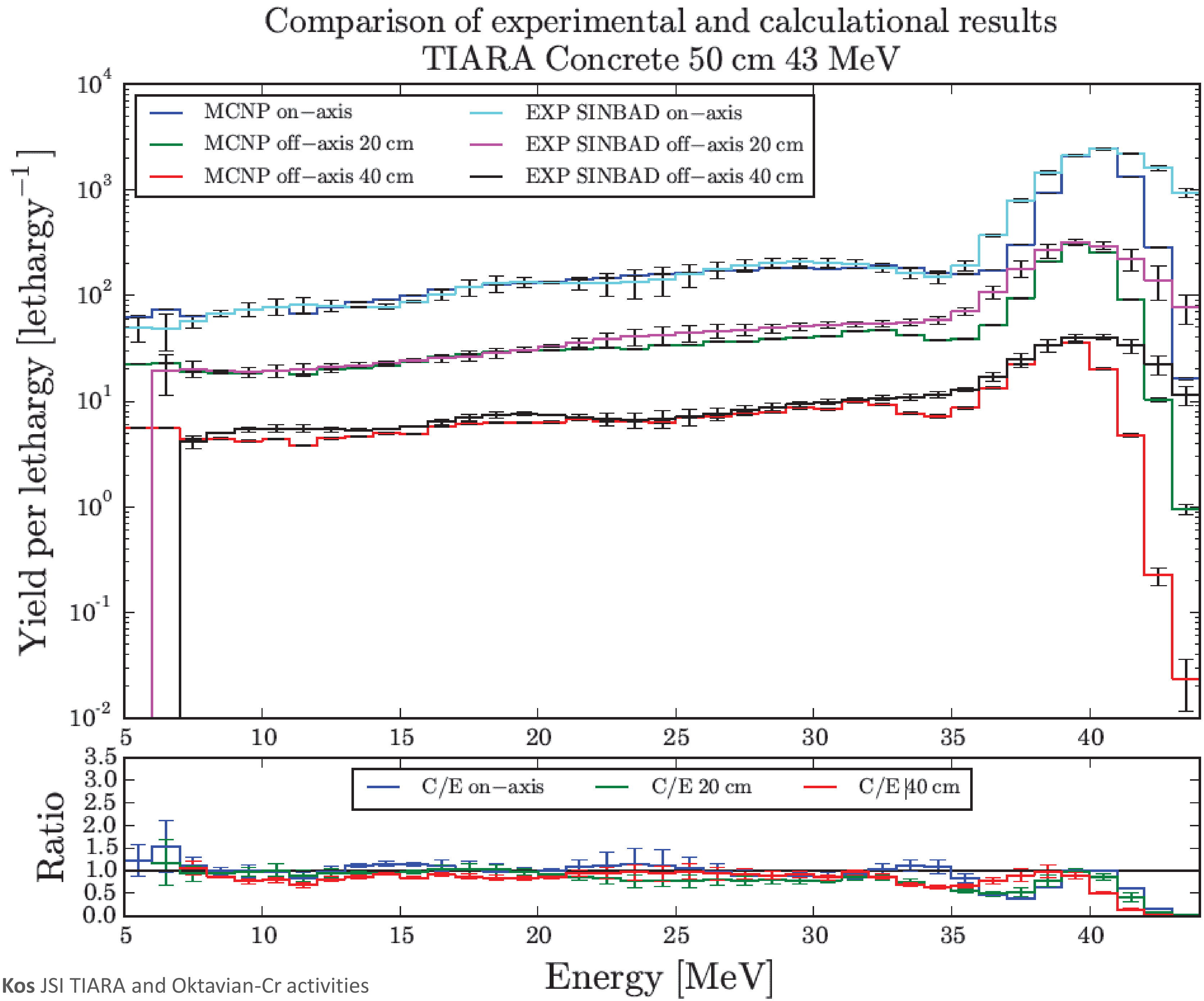

Comparison of experimental and calculational results
TIARA Concrete 50 cm 43 MeV
MCNP on−axis
MCNP off−axis 20 cm
MCNP off−axis 40 cm
EXP SINBAD on−axis
EXP SINBAD off−axis 20 cm
EXP SINBAD off−axis 40 cm
Yield per lethargy [lethargy^{-1}]
C/E on−axis
C/E 20 cm
C/E 40 cm
Ratio
Energy [MeV]