DE LA RECHERCHE À L'INDUSTRIE

PROGRESS ON THE TRIPOLI-4/GEANT4 COUPLING

CEA/DEN/DANS/DM2S/SERMA/LTSD | Davide Mancusi

21ST GEANT4 COLLABORATION MEETING | 15TH SEPTEMBER 2016

DE LA RECHERCHE À L'INDUSTRIE

OUTLINE

context and motivation

capabilities of the T4/G4 coupling

applications

- the APOLLON enclosure
- fast neutrons in Nucifer
- n_TOF spallation source

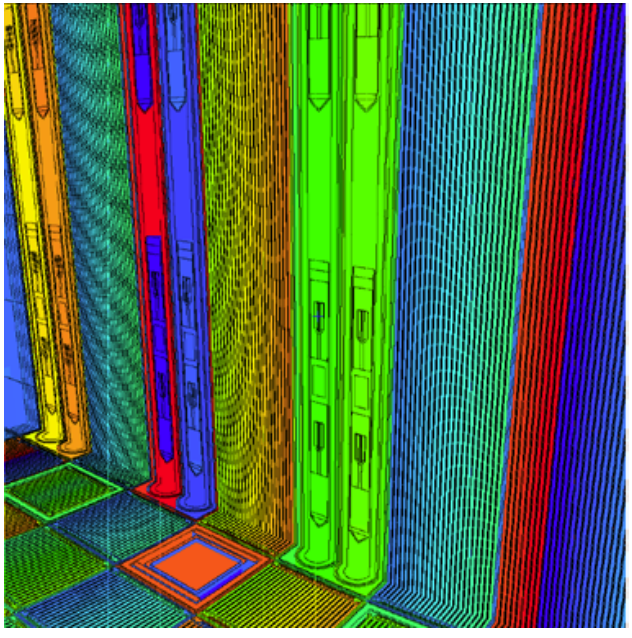
perspectives

DE LA RECHERCHE À L'INDUSTRIE

cea

TRIPOLI-4®

- general-purpose 3D Monte-Carlo code for particle transport
  - developed at CEA-Saclay, SERMA unit
- applications
  - reactor physics
  - criticality-safety studies
  - shielding
  - nuclear instrumentation



Brun *et al.*
Ann. Nucl. Energy 82 (2015) 151

features

- vast V&V database
- advanced variance reduction capabilities
- parallelism
  - multi-core
  - clusters
- transported particles:
  - neutrons (thermal $\rightarrow$ 20 MeV)
  - photons, electrons, positrons ($10^{-3} \rightarrow 10^{3}$ MeV)

GOALS

extend TRIPOLI-4's application scope

- radiation protection
- decommissioning
- instrumentation

. . . via a coupling with Geant4

for Geant4 users

- provide an alternative to NeutronHP (ParticleHP)
- make the most of TRIPOLI-4's variance reduction
- minimise error-prone translation of user data

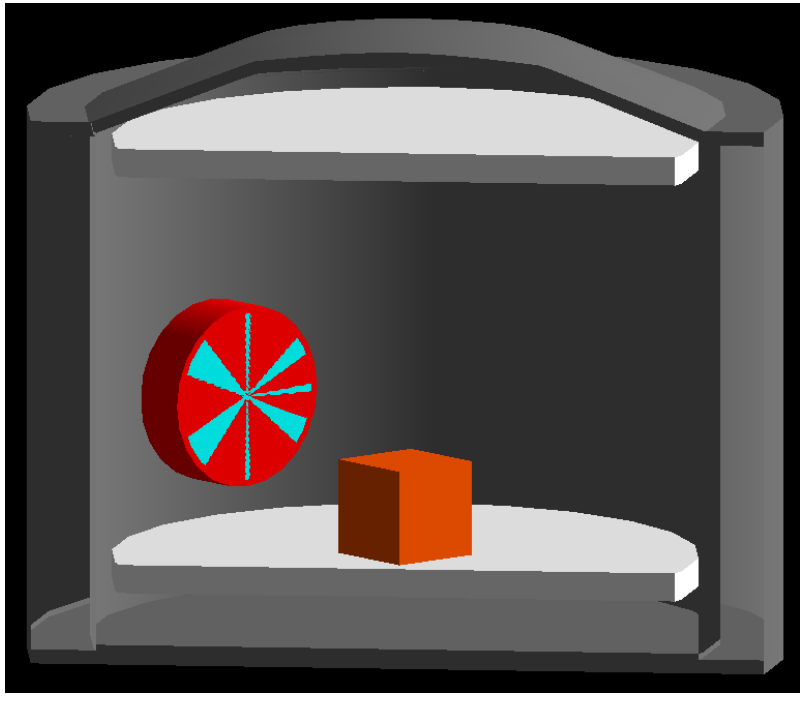
DE LA RECHERCHE À L'INDUSTRIE

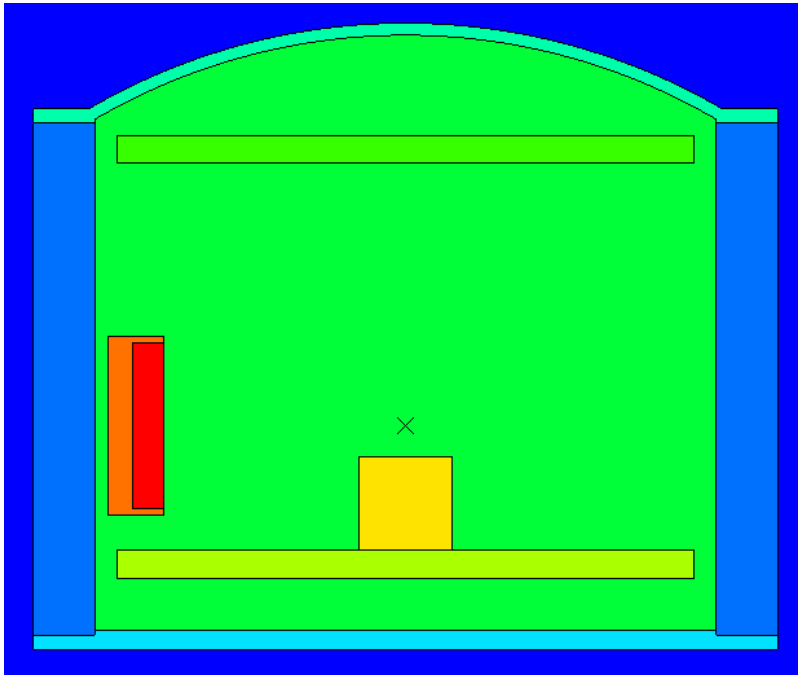
cea

WHAT CAN THE T4/G4 COUPLING DO?

- driven by a TRIPOLI-4 input file
- import and navigate a Geant4 geometry
- import Geant4 compositions
  - minimise user errors
- override Geant4 compositions
  - if needed
- import a Geant4 source
  - minimise user errors
- delegate transport of particles outside TRIPOLI-4's domain
  - Geant4 $\rightarrow$ TRIPOLI-4
- feed the most commonly used scores
  - flux, dose, energy deposition...
  - volume and surface estimators

THE APOLLON ENCLOSURE

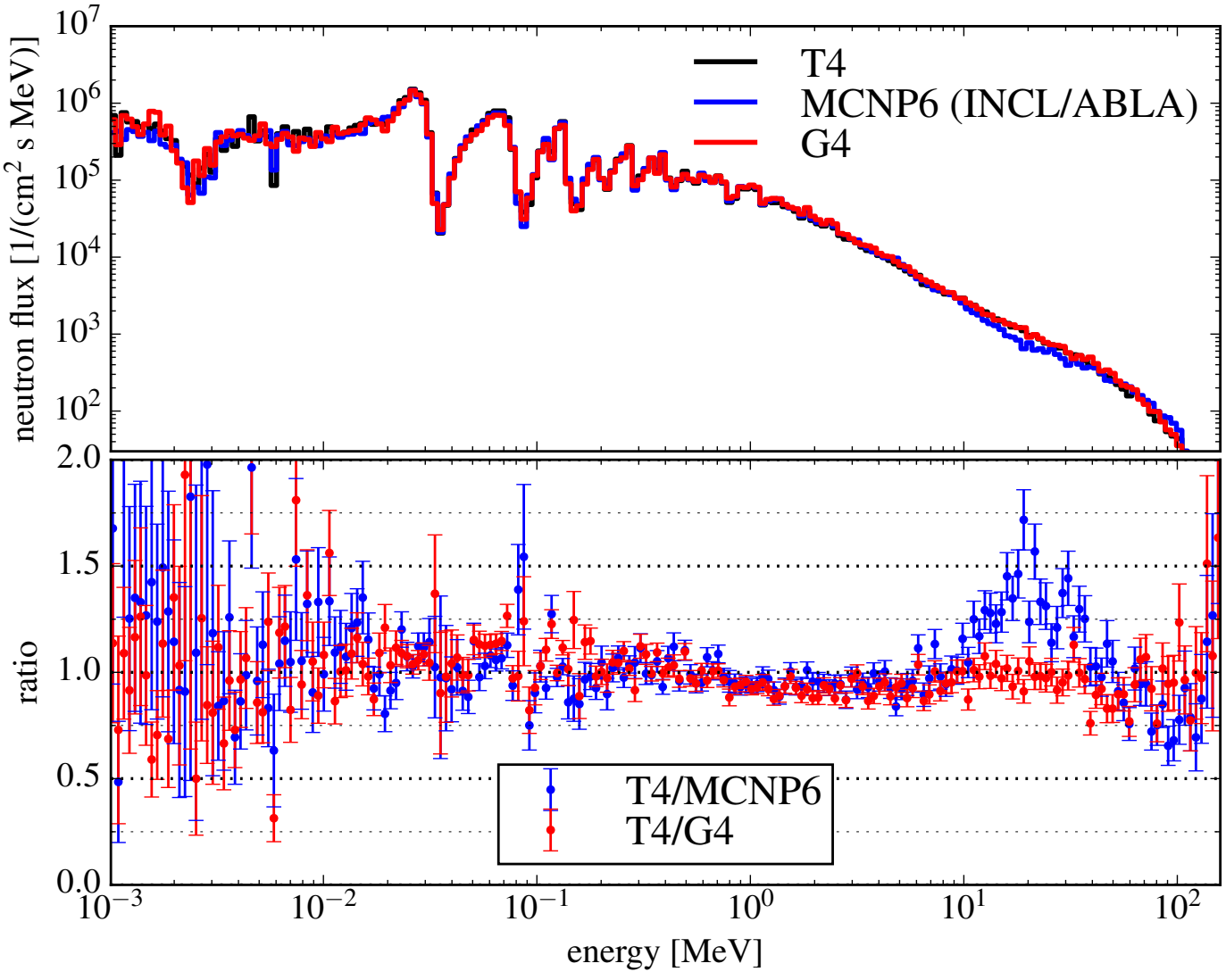




APOLLON

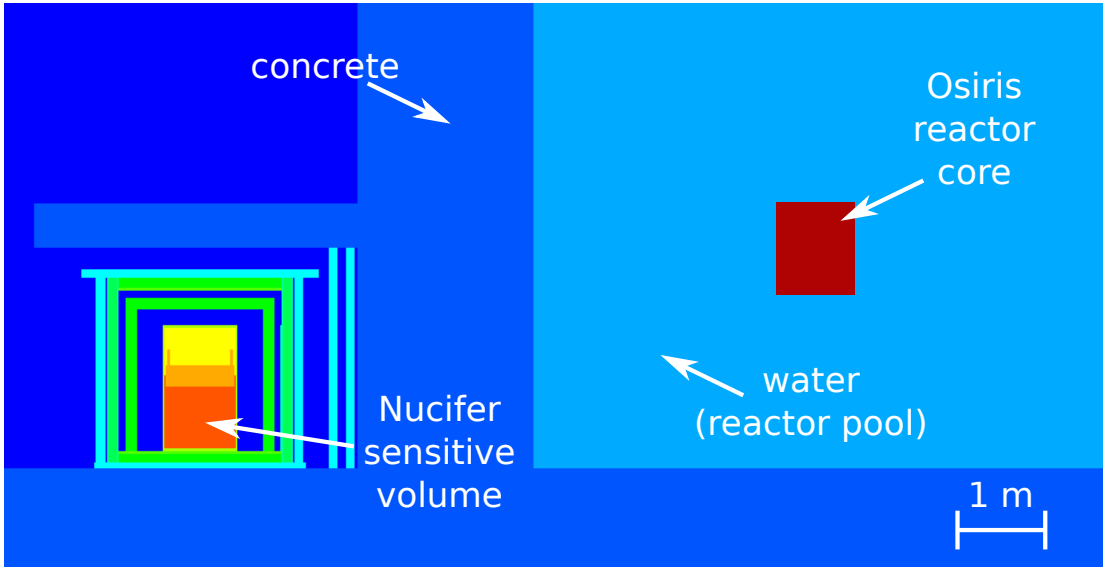
- high-intensity laser (10^{16} W!)
- proton + electron source
- neutron + photon outgoing fluxes

OUTGOING NEUTRON FLUX



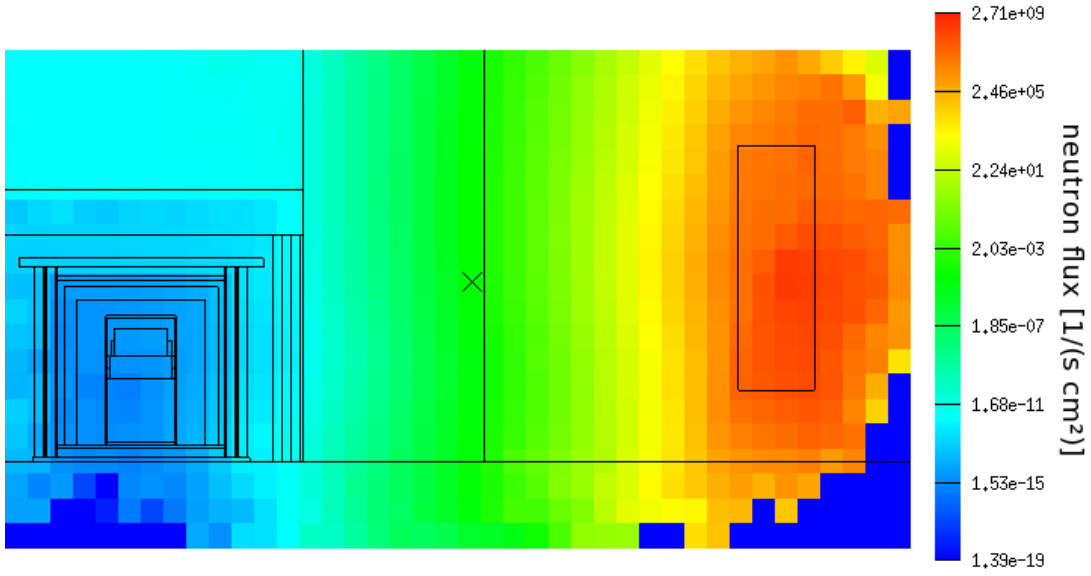
- T4 and G4 in excellent agreement
  - same high-energy sector
- T4/MCNP6 ±50% at high energy
  - comparable to nuclear-reaction-model uncertainty

FAST NEUTRONS FROM OSIRIS TO NUCIFER



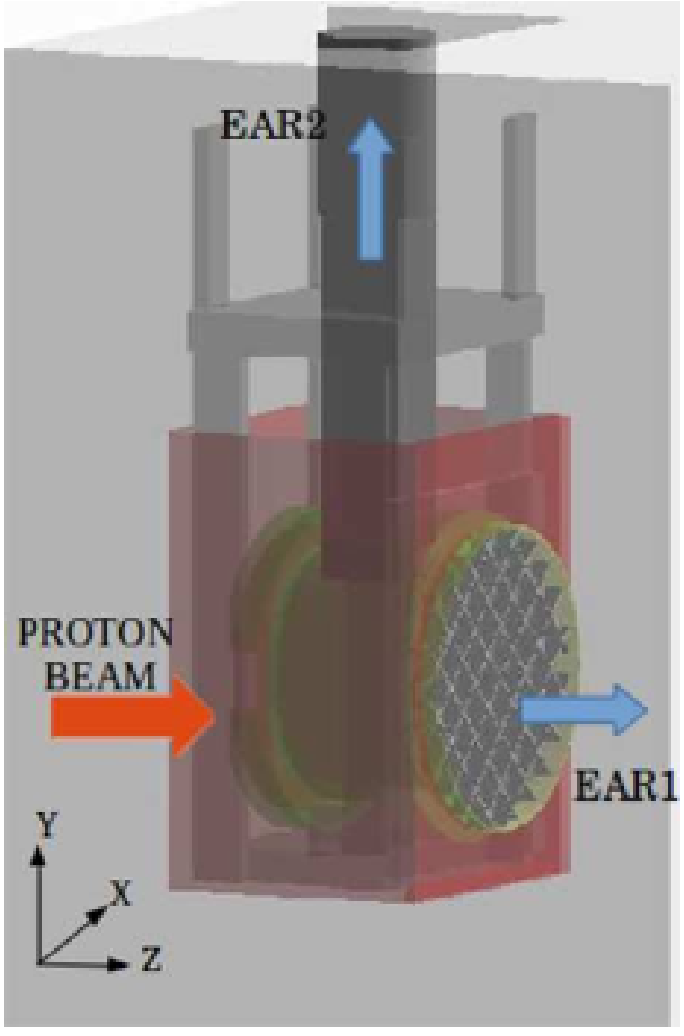
- criticality calculation for the neutron source
- fast ($\gtrsim$ 2 MeV neutron flux response
- $\sim$ 3 m water $+$ $\sim$ 1.5 m concrete $+$ plastic shielding

FAST NEUTRONS FROM OSIRIS TO NUCIFER



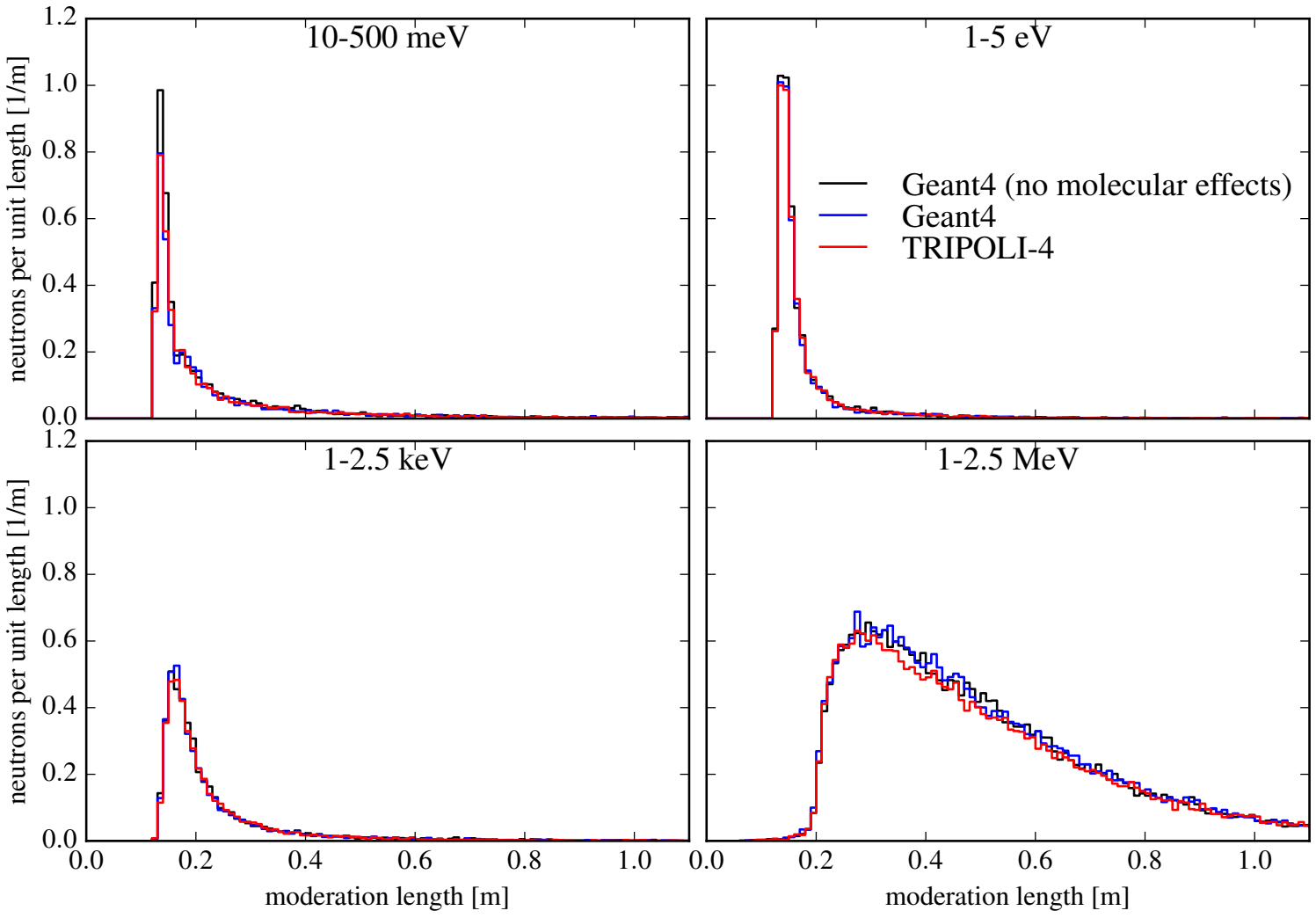
- attenuation $\simeq 10^{-25}$!
  - why, yes, I did use biasing... how did you guess?!

N_TOF SPALLATION SOURCE

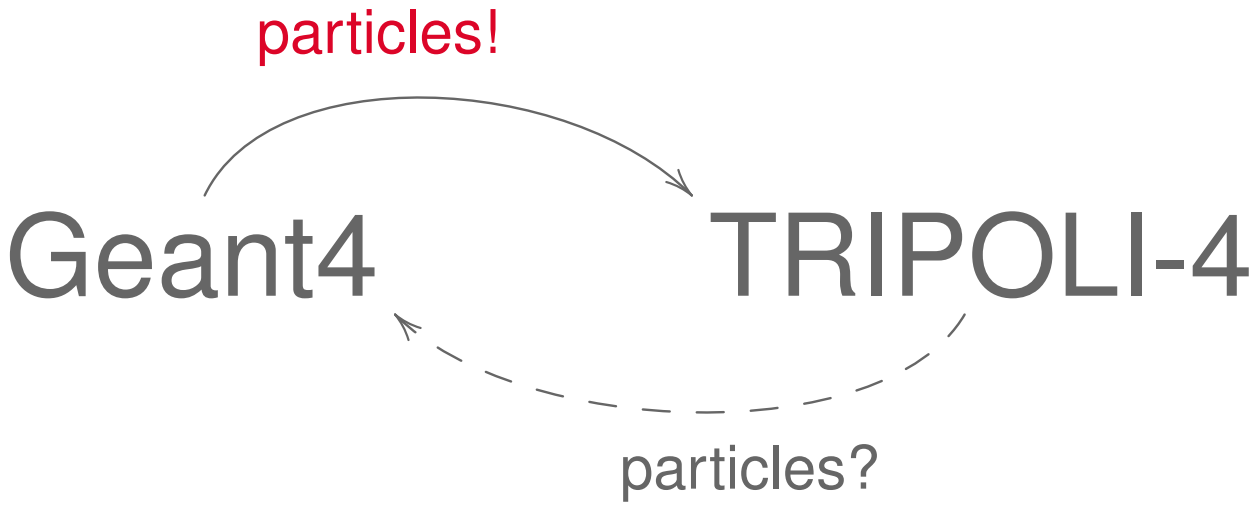


- 20-GeV/c proton beam on Pb spallation target
- neutrons collimated towards experimental areas

preliminary



INSTRUMENTATION



- feed charged particles to Geant4
  - (n, α), $(n, f)\ldots$
- detector response simulation

ABSTRACT NAVIGATION IN GEANT4

current limitation

- Geant4 geometry required
- users must remake their TRIPOLI-4 geometry in Geant4
  - or convert their ROOT geometry to GDML

idea

- make Geant4's navigator geometry-agnostic
- adds capability to navigate any geometry
  - in particular, in TRIPOLI-4's geometry
  - via a plugin mechanism

DE LA RECHERCHE À L'INDUSTRIE

cea

CONCLUSIONS

new features of the TRIPOLI-4/Geant4 coupling

- using a Geant4 geometry in a TRIPOLI-4 calculation
- using a Geant4 source in a TRIPOLI-4 calculation
- delegating high-energy particles, protons, etc. to Geant4
- collect all relevant scores on the TRIPOLI-4 side

OUTLINE

backup slides (hic sunt leones)

DE LA RECHERCHE À L'INDUSTRIE

cea

THE TOOLKIT APPROACH

- several entry points for the coupling
  - actions (`G4User*Action` classes)
  - physics lists
- user data are C++ source files
  - geometry
  - source
  - scores
- need to preprocess user data

IMPORTING GEANT4 GEOMETRIES

- typical Geant4 geometry
  - `MyUserDetectorConstruction.cc`
  - `MyUserDetectorConstruction.hh`
  - any other source file `MyUserDetectorConstruction` depends on
- compile it into a dynamic library with `g42so`

```
$ g42so -I include/ MyDetectorConstruction.cc [...]
```

- declare it in the TRIPOLI-4 input file

```
G4_GEOMETRY
  /path/to/libMyDetectorConstruction.so
END_G4_GEOMETRY
```

TRIPOLI-4 PARTICLE AND ENERGY RANGE

electromagnetic cascade ($e^{\pm}$, γ)

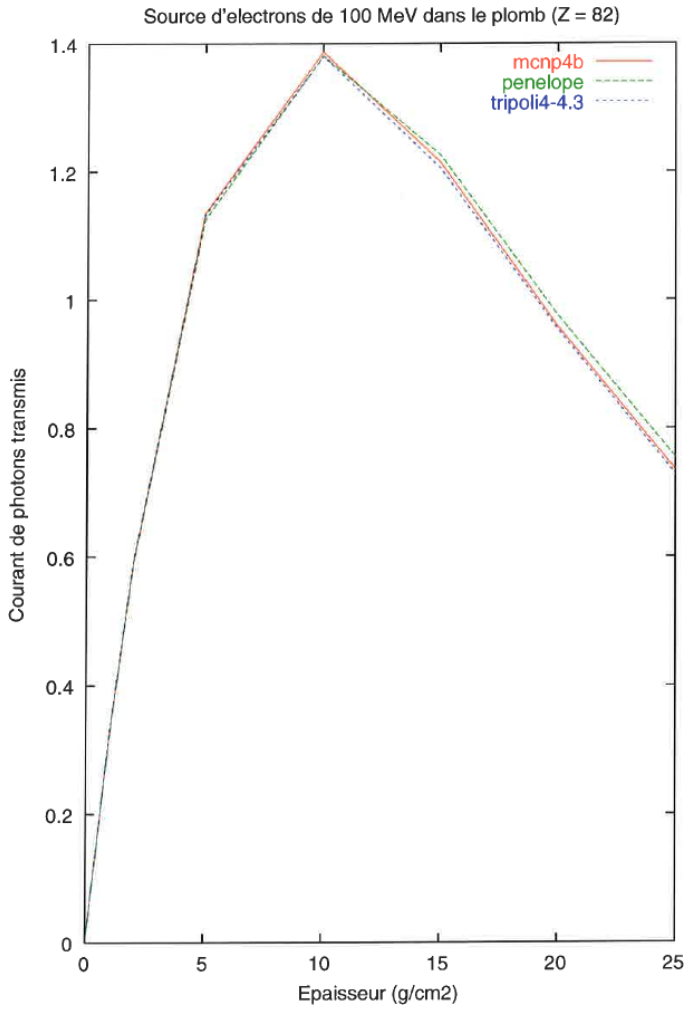
100 keV — **10 MeV** — **1 GeV**

- well validated between
  $\sim$ 100 keV and $\sim$ 10 MeV
- applicable up to 1 GeV
  - some V&V exists

    Y. Pénéliau
    SERMA/LEPP/RT/02-3186/A

hadronic cascade (*p*, *n*)

- not supported



THE g42so UTILITY

what is g42so?

- a small Python utility
- not specific to TRIPOLI-4
- released as free software (MIT license)
- available for download at
  `http://bitbucket.org/arekfu/g42so`

IMPORTING GEANT4 SOURCES

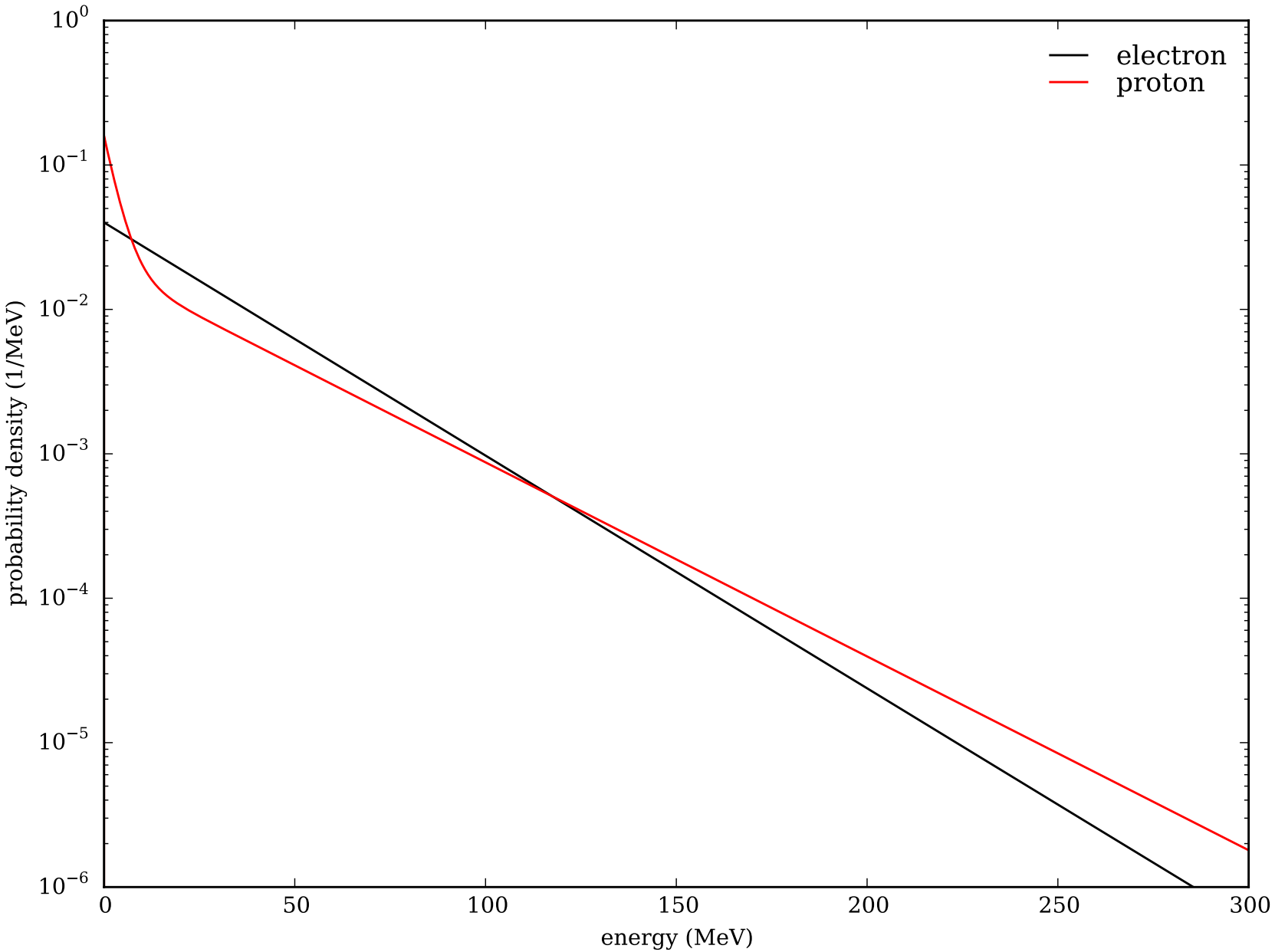
- compile the sources with `g42so`

```
$ g42so -I include/ MyPrimaryGeneratorAction.cc [...]
```

- declare the source in the TRIPOLI-4 input file

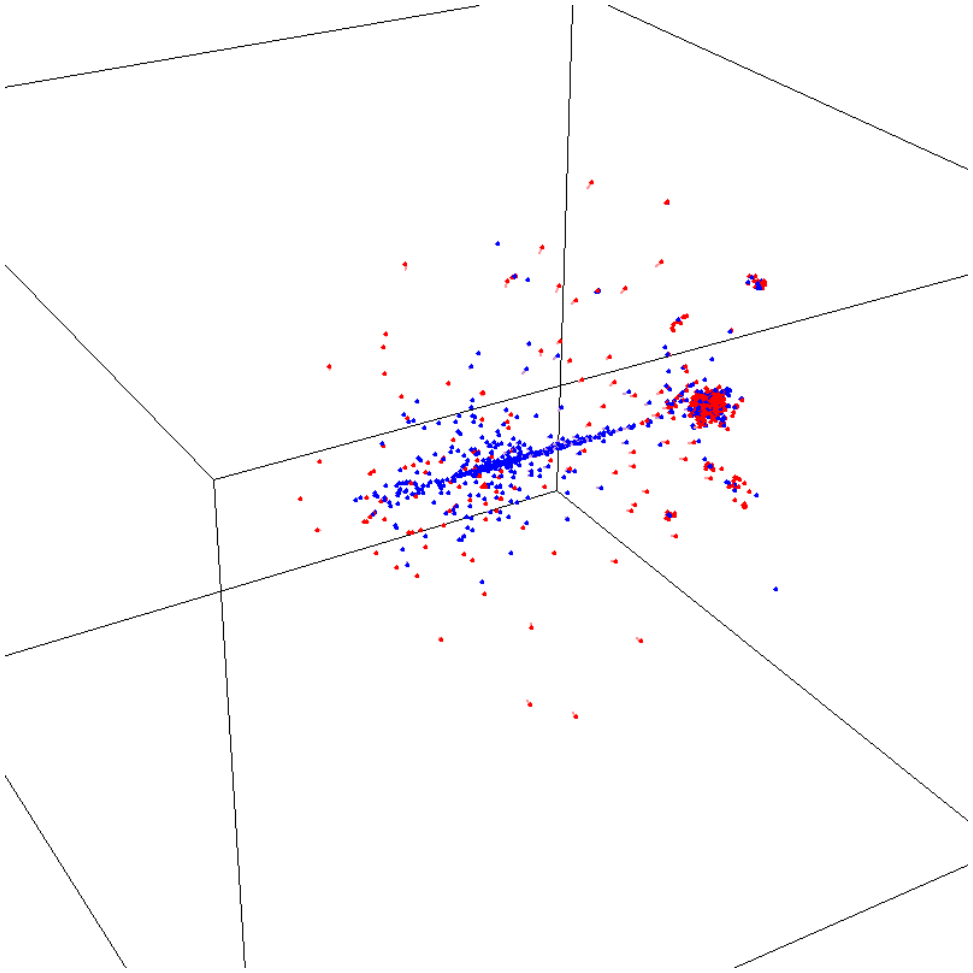
```
SOURCES_LIST 1
  SOURCE
    ALL_PARTICLE
    G4_SOURCE /path/to/libMyPrimaryGeneratorAction.so
  END_SOURCE
END_SOURCES_LIST
```

SOURCE


electron
proton
probability density (1/MeV)
energy (MeV)
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0
50
100
150
200
250
300

PARTICLE TRACKS

1-GeV protons + water



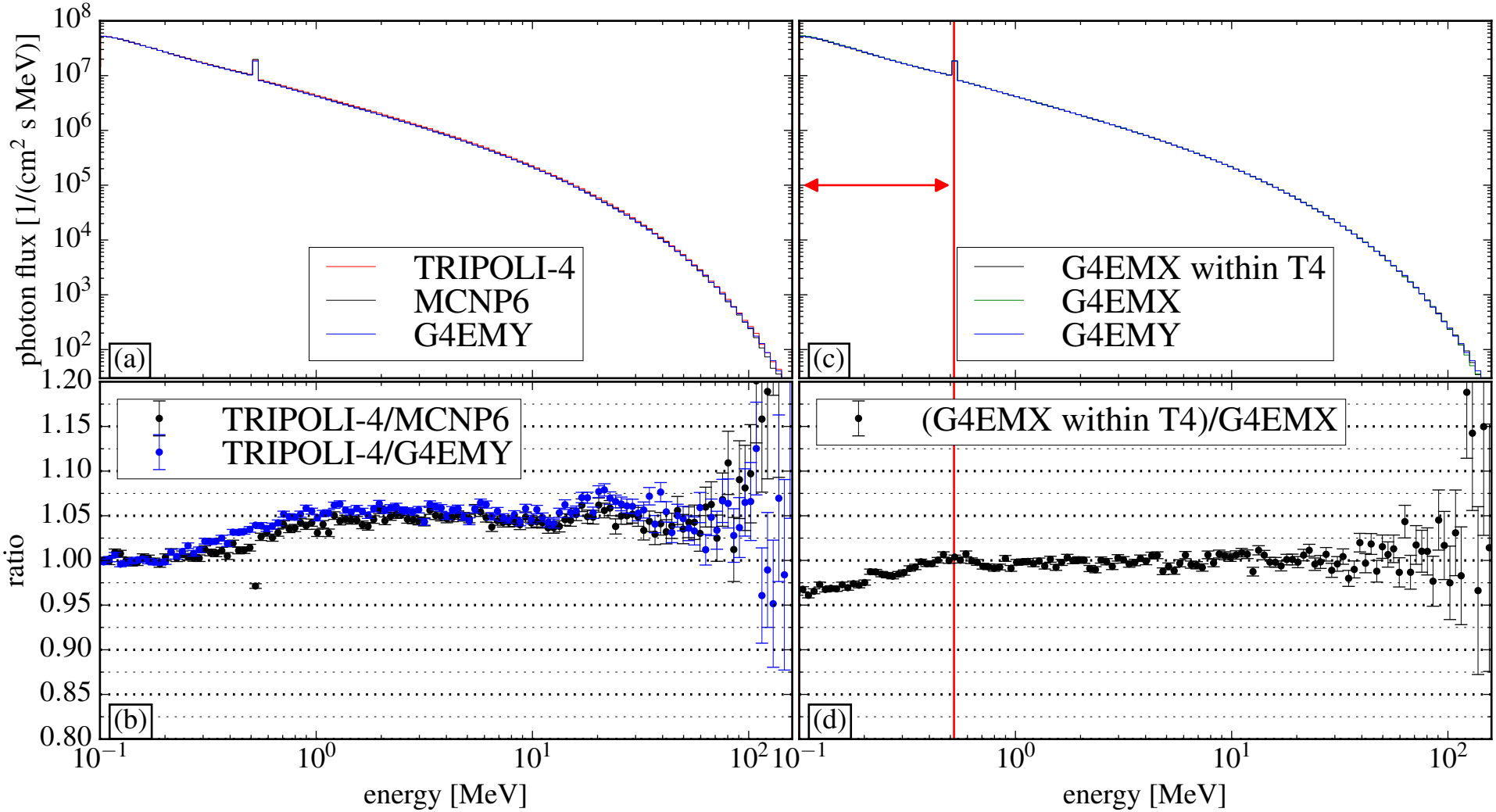
- ROOT tracks post-processing

VERIFICATION STRATEGY

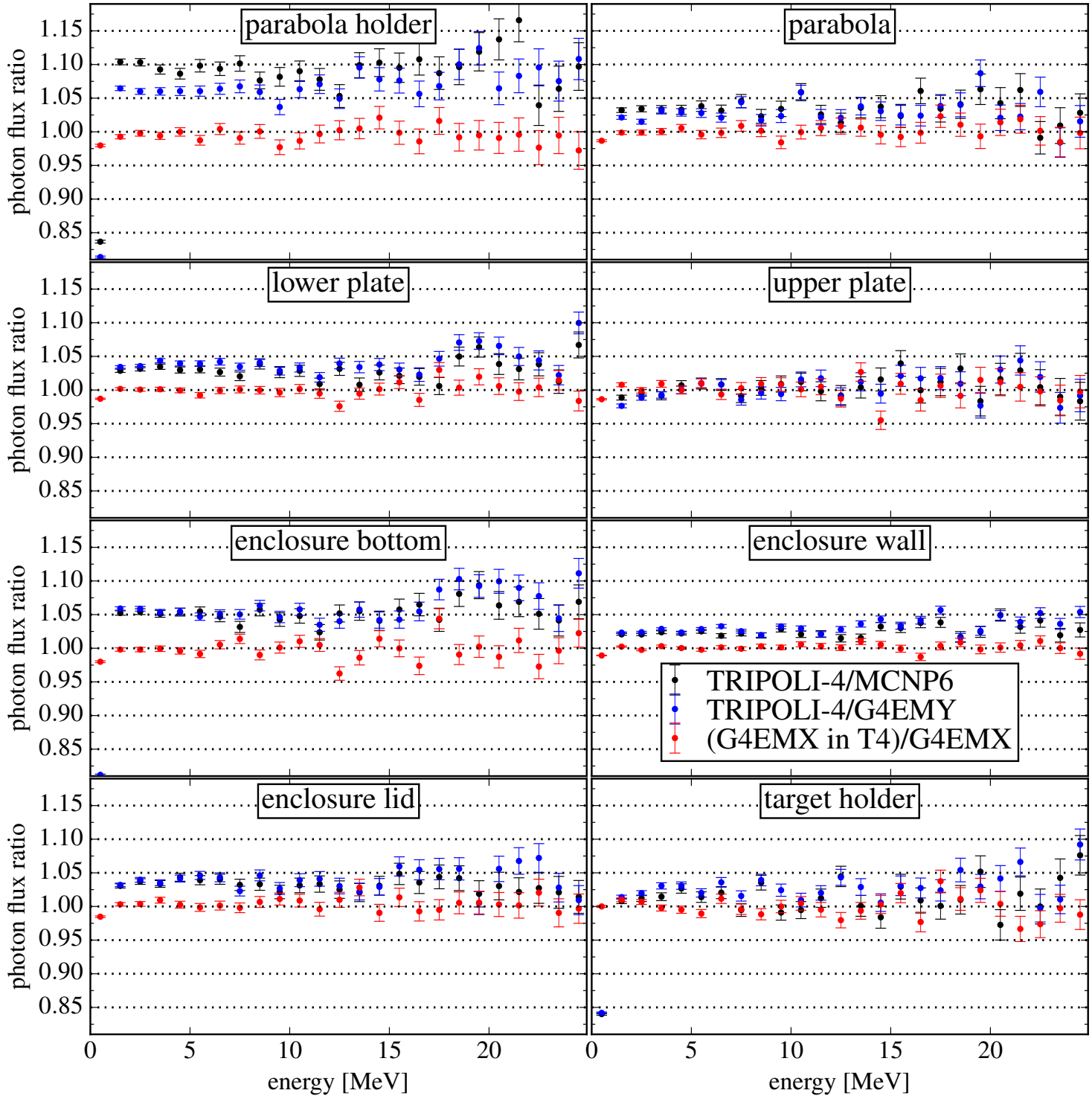
types of calculations

1. pure TRIPOLI-4 ($e^- \rightarrow \gamma$)
2. TRIPOLI-4/Geant4
3. TRIPOLI-4/Geant4 with restricted TRIPOLI-4 energy range
   - "G4 within T4"
   - exercises the plumbing, but not the porcelain
   - verifies that sources are correctly sampled, scores are correctly fed, etc.
4. MCNP6 and Geant4 (`FTFP_INCLXX_HP`) references

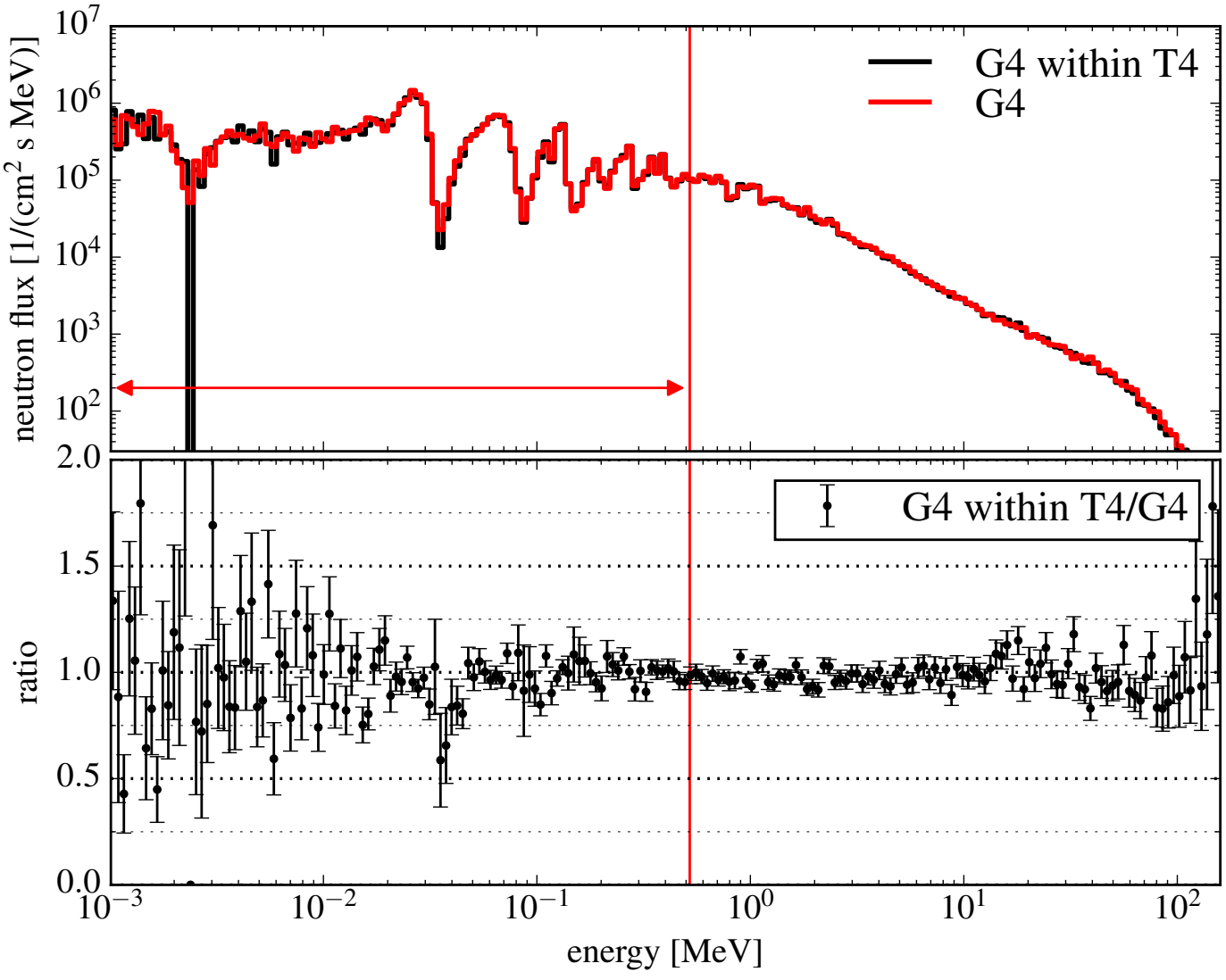
OUTGOING PHOTON FLUX



- perfect agreement “G4 within T4” vs. “G4”
- TRIPOLI-4 yields $\sim$ 5% more than MCNP6 and Geant4

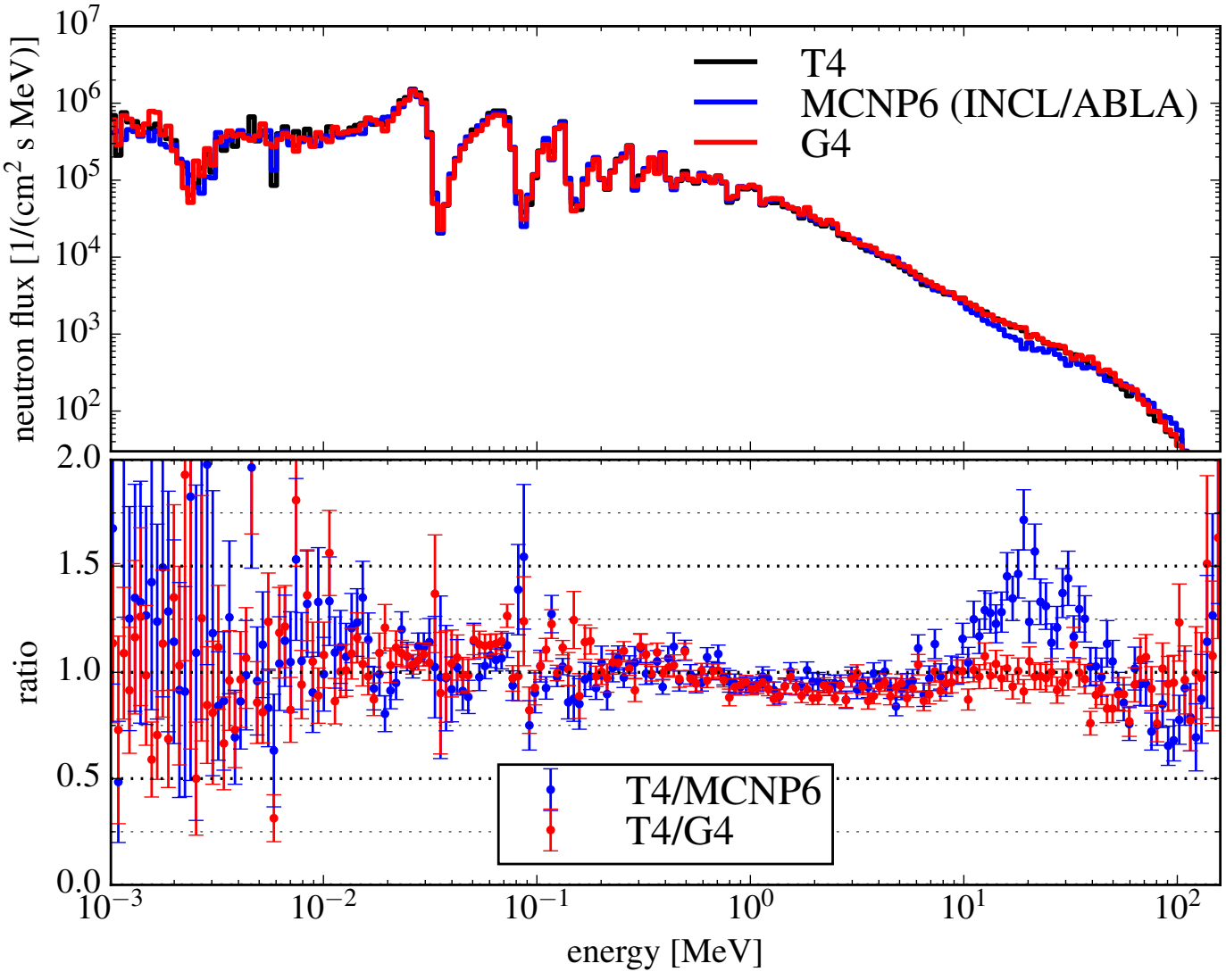

parabola holder
parabola
lower plate
upper plate
enclosure bottom
enclosure wall
enclosure lid
target holder
photon flux ratio
energy [MeV]
TRIPOLI-4/MCNP6
TRIPOLI-4/G4EMY
(G4EMX in T4)/G4EMX

OUTGOING NEUTRON FLUX



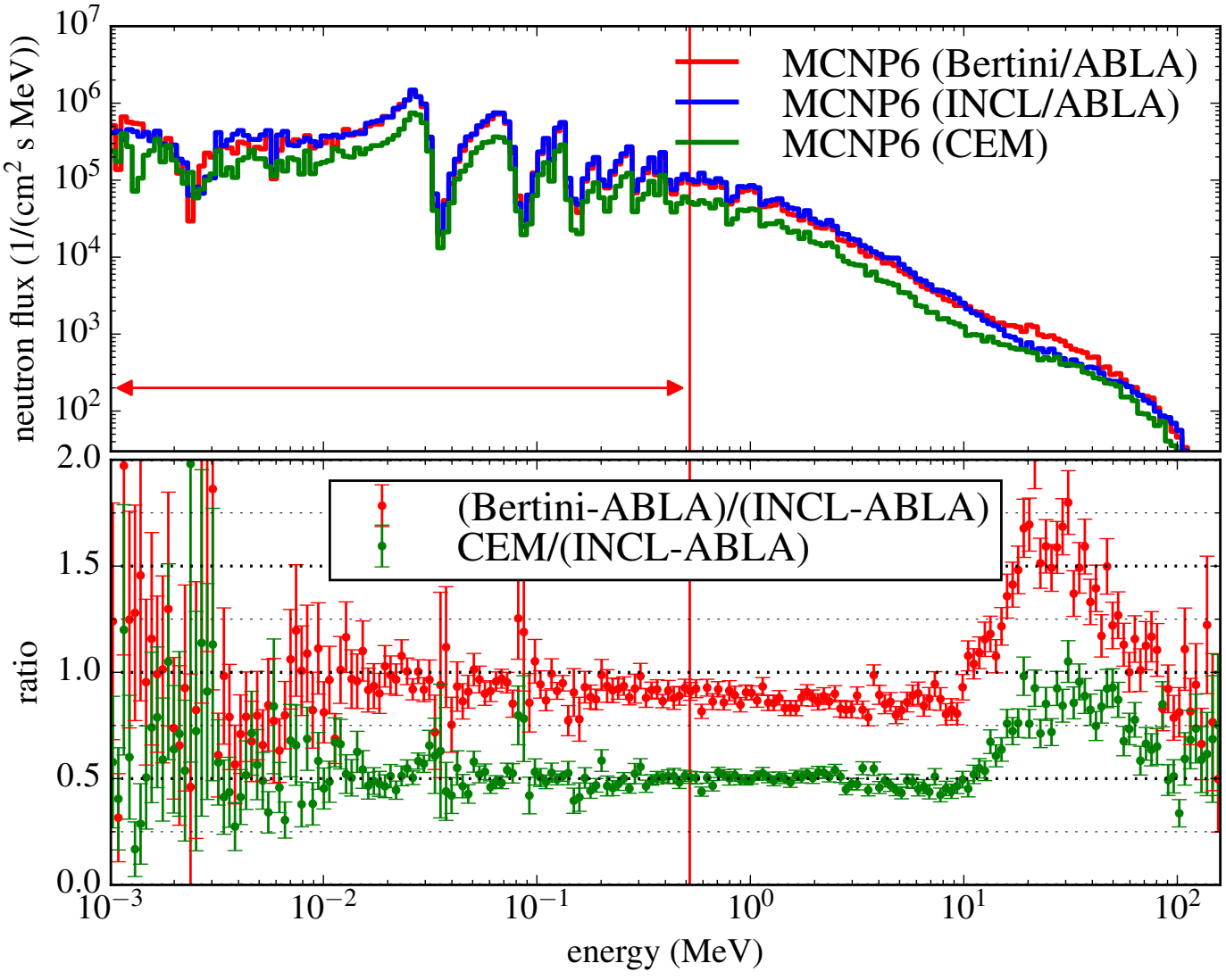
- perfect agreement G4 within T4 vs. G4

OUTGOING NEUTRON FLUX



- T4 and G4 in excellent agreement
  - same high-energy sector
- T4/MCNP6 ±50% at high energy
  - comparable to nuclear-reaction-model uncertainty

OUTGOING NEUTRON FLUX



- different nuclear-reaction models yield ±50% differences

V&V AND USABILITY

work remains to be done to

- extend the verification to other endpoints
  - surface currents
  - surface fluxes
  - energy depositions
  - ROOT tracks
- handle non-native particles in TRIPOLI-4's score syntax

preliminary