Status of particle_hp

Pedro Arce

Emilio Mendoza

Daniel Cano-Ott

(CIEMAT, Madrid)

What is particle_hp?

neutron_hp package uses evaluated nuclear data bases for neutron interactions:

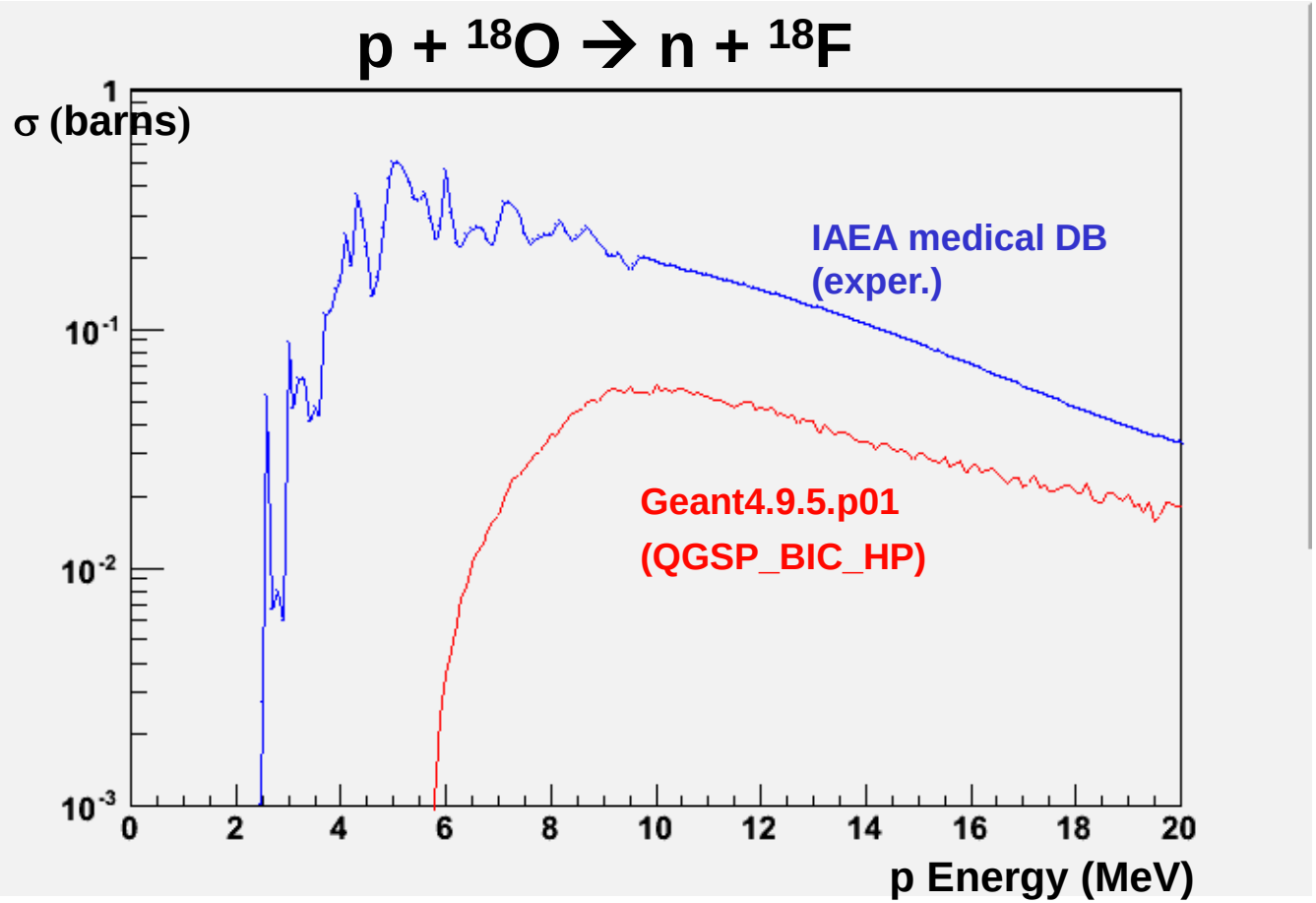
- ✓ Total cross sections
- ✓ Inelastic channel cross sections
- ✓ Double differential spectra of outgoing particles
- ✓ Gamma emission because of nuclear level transitions

particle_hp: do the same for (**inelastic**) interactions of other particles (p, d, t, He3, α, γ)

Inelastic interactions of p/d/t/He3/α/γ particles E < 200 MeV

Why particle_hp?

Theory models or semi-empirical models sometimes cannot reproduce experimental data at low (10-100 MeV), specially for low Z elements (J.M. Quesada agrees):



What nuclear DBs are there?

ENDF-VII:

- Uses experimental data + thorough evaluations
- Only a few isotopes (p:48, d:5, t:3, He3:2)
- Only p → X reactions (MT=5)
  - double differential spectra of resulting particles (n,p,d,…), without channel information (n,nn,np,nna,…)
- Up to 150 MeV for p (d: 50 MeV, t: 20 MeV, He3: 20 MeV)
- ENDF format

TENDL:

- Uses some experimental data + TALYS calculations
- All isotopes (2400)
- All channels (also available a DB with only p → X reactions)
- Up to 200 MeV
- ENDF format

What nuclear DBs are there?

IAEA medical database:

- Only experimental data
- Only a few reaction channels of a few isotopes
- Only channel cross sections
- Simple text format

IBANDL database:

- Only experimental data
- Not all isotopes
- Many experimental measurements channel by channel
- Low energy (up to a few MeV)
- Own format

Code changes

PHYSICS LIST:

```
G4NeutronHPInelastic* theParticleModel=
  new G4NeutronHPInelastic();
```

→

```
 G4ParticleHPInelastic* theParticleModel=
   new G4ParticleHPInelastic(G4Proton::Proton(),"G4PROTONHPDATA");
```

or

```
G4ParticleHPInelastic* theParticleModel=
   new G4ParticleHPInelastic();

G4NeutronHPInelasticData* theNeutronHPInelasticData=
  new G4NeutronHPInelasticData();
```

→

```
G4ParticleHPInelasticData* theProtonHPInelasticData=
  new G4ParticleHPInelasticData(G4Proton::Proton(),"G4PROTONHPDATA");
theProtonHPInelasticData->SetMaxKinEnergy(200.);
```

or

```
G4ParticleHPInelasticData* theNeutronHPInelasticData=
  new G4ParticleHPInelasticData();
```

Code changes

KERNEL CODE CHANGES:

- **No new classes**: only modify neutron_hp package
- Rename **G4NeutronHP* ⟶ G4ParticleHP***
- Thermal scattering only for neutrons
- Eliminate assumptions that projectile is neutron and enviromental variable is "G4NEUTRONHPDATA"

G4ParticleHPInelastic
G4ParticleHPInelasticData
G4ParticleHPorLEInelastic

G4ParticleHP*InelasticFS
G4ParticleHPInelasticBaseFS
G4ParticleHPInelasticCompFS
G4ParticleHPFinalState

G4ParticleHPChannel
G4ParticleHPChannelList

G4ParticleNames

G4ParticleHPEnAngCorrelation
G4ParticleHPContAngularPar
G4ParticleHPContEnergyAngular

Code changes

PARTICLE YIELD CORRECTIONS:

❖ Number of particles of a type produced in an interaction is not sampled in neutron_hp (except for gammas):

- ➢ Integer value is taken 2.43 → 2

❑ Many charged particle data base isotopes do not have channel by channel cross sections, **only particle yields** (also a few neutron files in current Geant4 data)

✓ **Apply Poisson statistics for all particles**

- ➢ Set G4PARTICLEHP_DO_NOT_ADJUST_FINAL_STATE 1 (recommended, else particle yields in DB are not used)
- ➢ Else check that sum of atomic masses and numbers is not bigger than target nucleus
  - If it is, resample particle yields → bias results

Tests

ENDF format files → Geant4 format + code reading Geant4 format

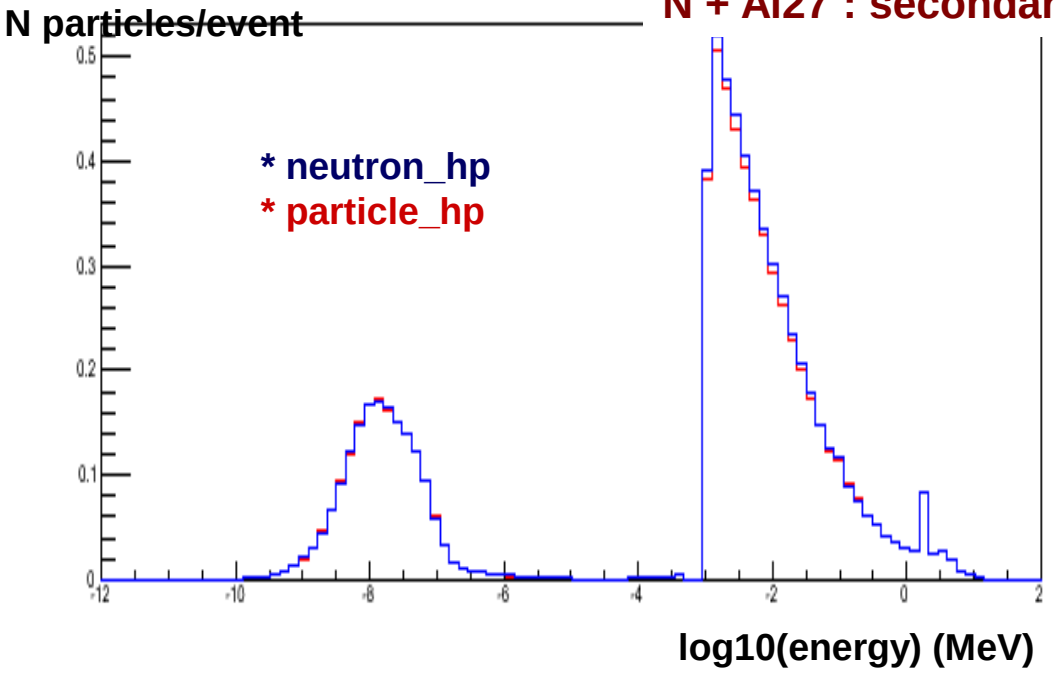
- **Check isotope per isotope, channel per channel**

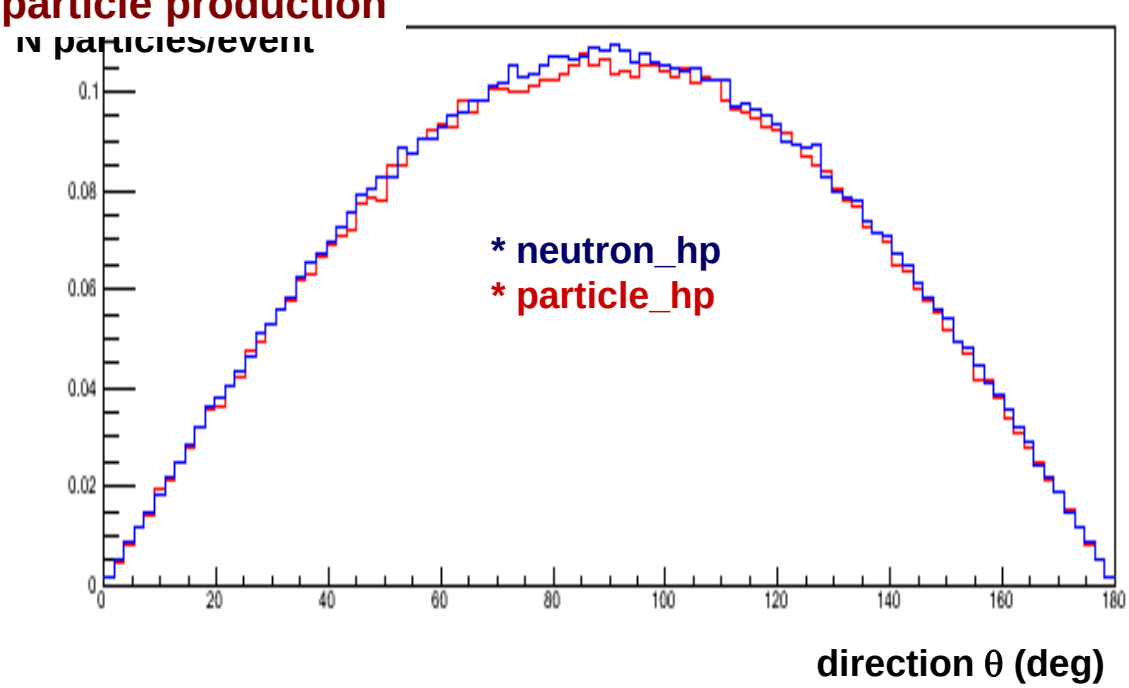
0. Check neutron physics is the same in neutron_hp & particle_hp

Compare:

- Send neutrons with isolethargical energy distribution 1.E-9 → 20 MeV
- Check production of **secondary particles: E, position, direction**

N + Al27 : secondary particle production





TIME: neutron_hp = 3353 sec particle_hp = 3339 sec

Tests

1. Check total cross sections

- Run a Geant4 job. 1 proton per energy
  - Ask for cross sections as in a real Geant4 run (G4HadronicProcess::GetMicroscopicCrossSection)
- Compare to cross sections from TENDL web

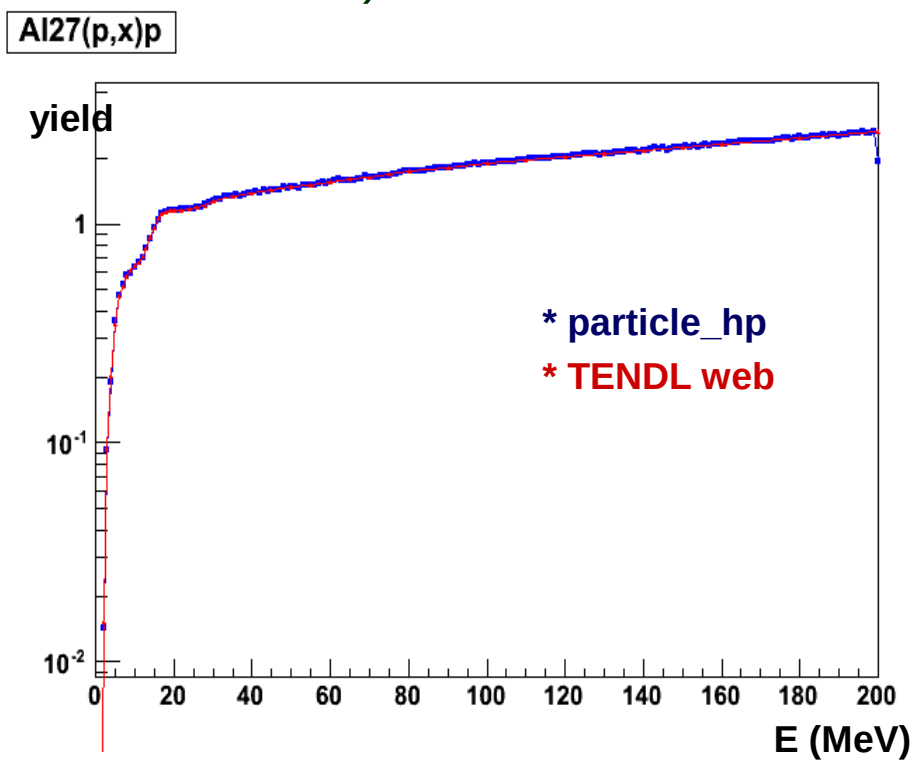
SORRY. I CANNOT DO FTP OR SSH TO GET THE PLOTS

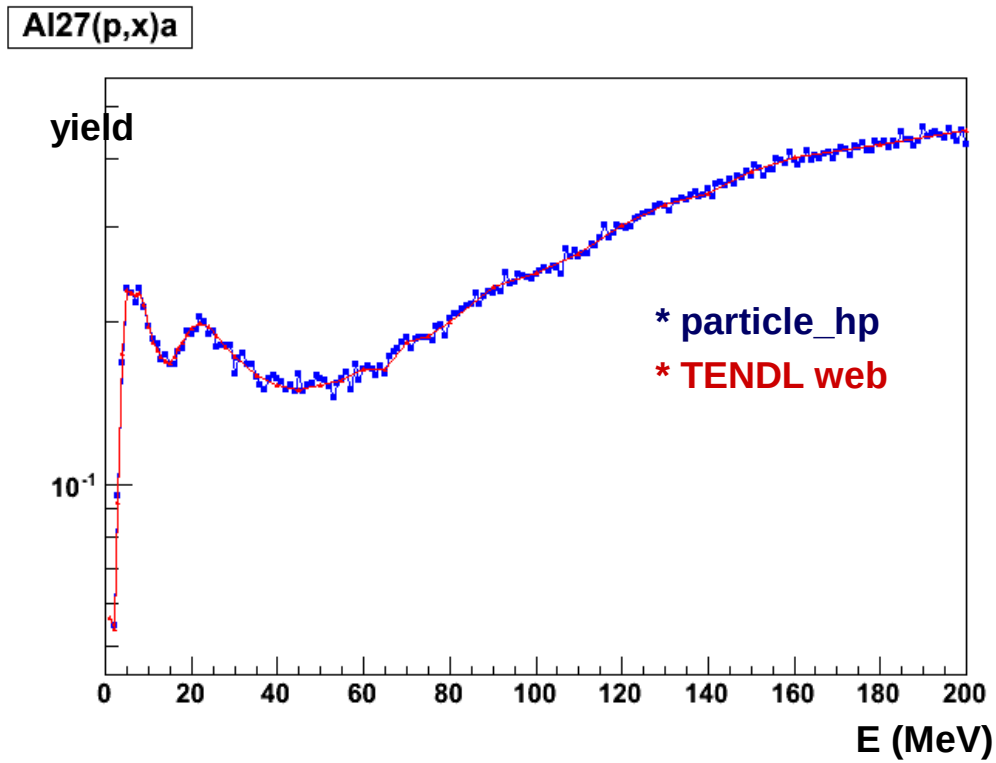
BELIEVE ME THEY ARE OK

Tests

2. Check secondary particle production

- Run Geant4 job: 10k protons at each energy, plot the energy of secondary particles produced
  - Deactivate electromagnetic and proton elastic process
  - Kill proton after first interaction, and all secondaries
- Compare to TENDL web particle yields (number of particles per inelastic interaction)



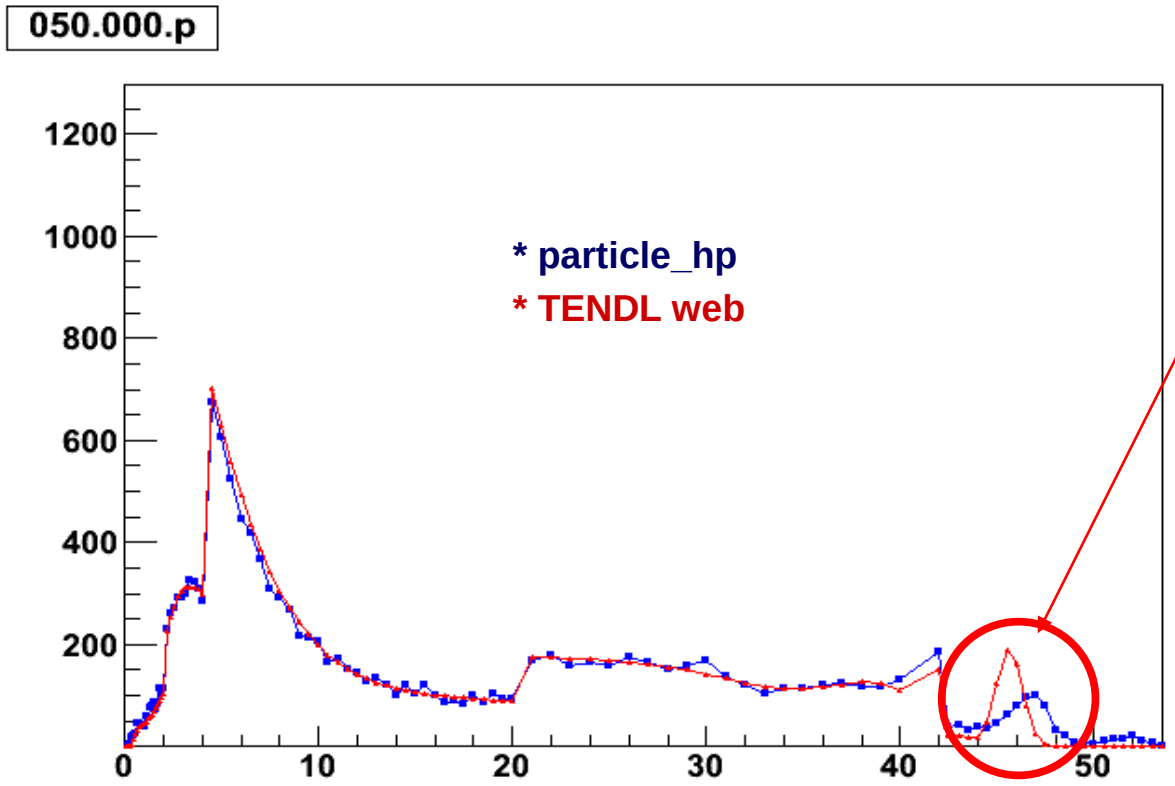


Bug found in TENDL data: wrong particle yields. Wait until TENDL 2012 (December)

Tests

3. Check secondary particle production: energy spectra

- Run Geant4 jobs: 100k protons at one energy, plot the energy of secondary particles produced
  - Deactivate electromagnetic and proton elastic process
  - Kill proton after first interaction, and all secondaries
- Compare to TENDL web secondary particle energy spectra



Data is different in TENDL web file and GEANT4 DB (= TENDL ENDF file)

✓Checked by hand that GEANT4 DB = TENDL ENDF file and that spectrum is = GEANT4 DB

Future: learn to read ENDF file directly, no TENDL web file

Tests

4. Check secondary particle production: emission angle spectra

- Run Geant4 jobs: 100k protons at one energy, plot the emission angle of secondary particles produced
  - Deactivate electromagnetic and proton elastic process
  - Kill proton after first interaction, and all secondaries
- Compare to TENDL web secondary particle energy spectra

Postponed until TENDL web files are corrected

(ENDF files do not contain emission angle spectra, only Kallback-Mann coefficients)

Tests

5. Compare with MCNP

❖ MCNP has the possibility to read evaluated data base for protons

- Own data with a few isotopes (LAH150)
- TENDL data

➢ Compare yield of particles, secondary particles energy and emission angle spectra

✓ Work started with the help of a MCNP expert

Tests

Automatic testing

❖ A set of python and ROOT scripts do the job with one line

sh checkParticleHP.sh Al 27

- Download all files from TENDL web
- Prepare and send Geant4 jobs (may take a few hours, user decides the statistics)
  - Get total cross sections and particle yields
  - Get energy spectra with same binning as TENDL web files
  - Get emission angle spectra with same binning as TENDL web files
- Prepare plots comparing Geant4 particle_hp and TENDL in gif format

Conclusions

- Geant4 (and other MC) theoretical models do not work well for charged particle (p, d, t, He3, α, γ) inelastic interactions at E < 200 MeV

- Alternative implemented: use evaluated data bases
  - Several available (ENDF, TENDL, IAEA medical, IBANDL)
  - Only experimental data for a few isotopes, for others best guess theoretical interpolations

- Geant4 code is working
  - First tests done
  - More tests on progress
  - python code + ROOT scripts will be made public to test your favourite isotope by yourself