CHIPS Evaporation and Pre-compound interfaces

Mikhail Kosov, 12th Geant4 Workshop (GB, Sep. 2007)

Old and New functions of G4QNucleus

- CHIPS Evaporation is a stand alone algorithm
  - Published: **Eur. Phys. J. A14 (2002) p.265**
  - EvaporateBaryon(h*,rA*) is an Old One Step function
  - EvaporateNucleus(A*,outHadrons*) is a New function
- The main problem: When to call evaporation?
  - In CHIPS: when quark level fragmentation is exhausted
  - Depends on the number of quark-level decay attempts
- Basic assumptions of the algorithm:
  - Non-relativistic phase space for nucleons - ISOTROPIC
  - Effective Depth of Nuclear Potential Well: **U** = 1.7 MeV
  - **U** is chosen by fitting slopes of evaporation spectra

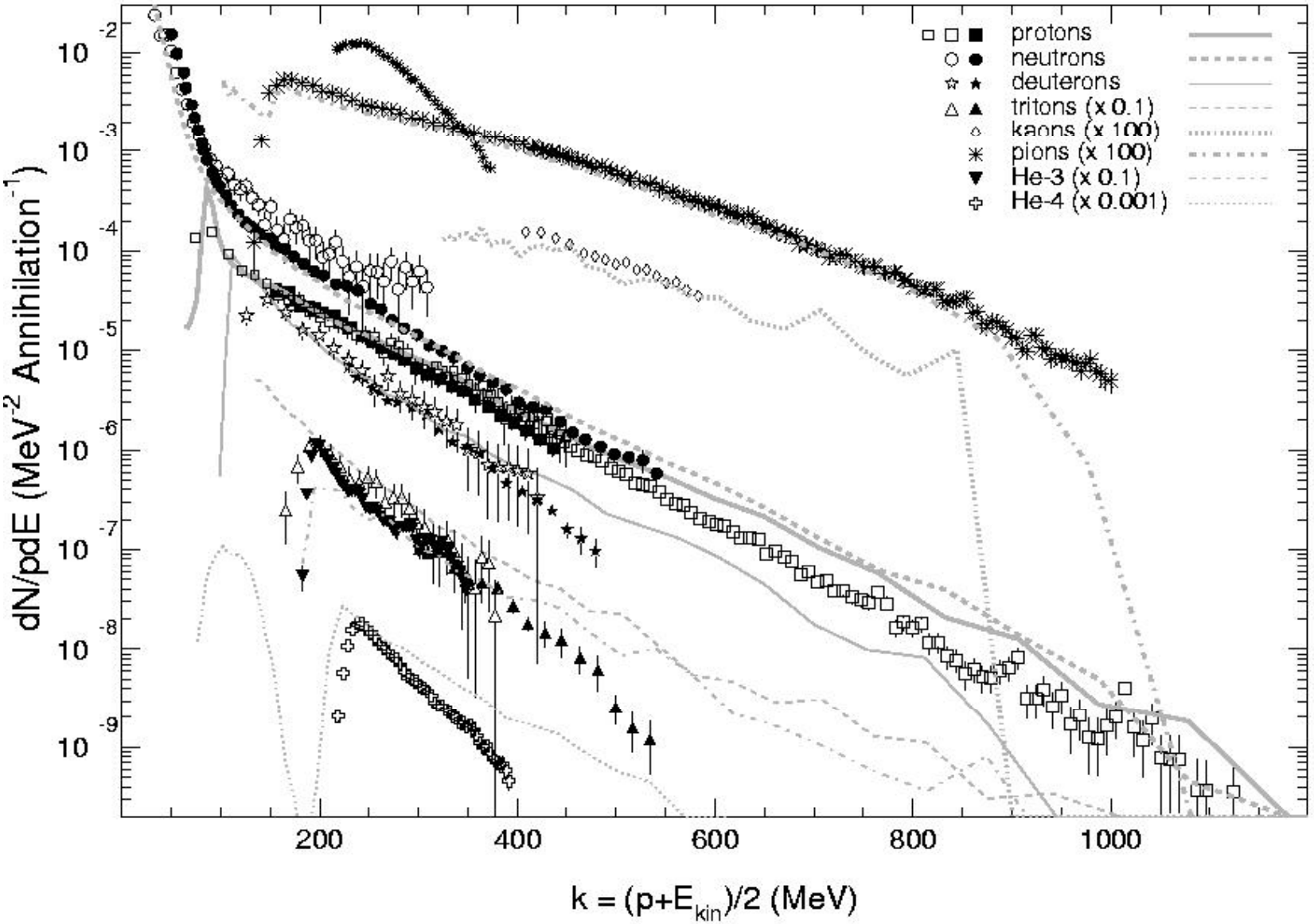
Nonrelativistic phase space distribution

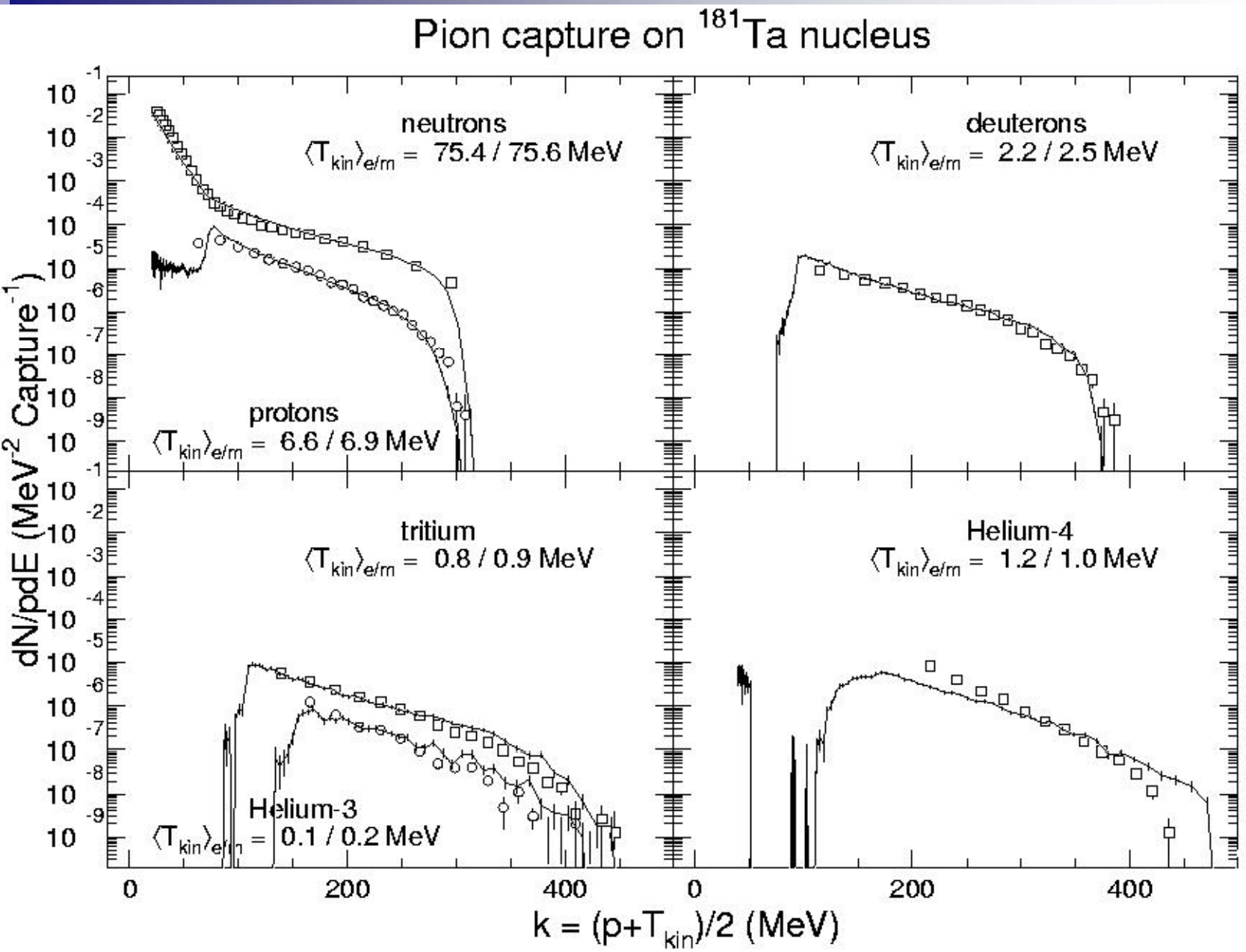
- W_n is a total kinetic energy of **n** nucleons
- Phase space of two particles $\Phi_2(W_2) \sim W_2^{1/2}$
- Phase space of n particles $\Phi_n(W_n) \sim W_n^{(3n-5)/2}$
- Spectrum of nucleons $dN/dT \sim T^{1/2}(1-T/W_n)^{3n/2-4}$
- Each nucleon is considered in a potential **U**
- For nucleus excited by energy E: $W_A = U \cdot A + E$
- Maximum condition: $T < E - \mathbf{B}$ ($\mathbf{B} = m_N + M_{A-1} - M_A$)
- Minimum condition: T>U+**B**+CoulombBarrier
- One should take into account the recoil energy

Problems of evaporation solved by CHIPS

- How to decay when only a few nucleons left? - Yes
- How to evaporate hyper-nuclear final states? - Yes
- Evaporate fragments (d,t,α) (or only nucleons)? - No
- Discrete excitations (isomers) in final states? - No
- Penetration/reflection of/from Coulomb Barrier. - No
- Neutron production on heavy nuclei with high Coulomb Barrier shifts the state from the lane of stability and demands α-deexcitation. - Yes
- Gamma de-excitation or final binary decay? - No
- Fission of heavy nuclei (One Step possibility). - No
- Anti-strange (nK^++normal nucleus) treatment. - Yes

CHIPS: G4QCaptureAtRest (test29,p̄U)




Pion capture on ^{181}Ta nucleus
neutrons
$\langle T_{kin}\rangle_{e/n}$ = 75.4 / 75.6 MeV
deuterons
$\langle T_{kin}\rangle_{e/n}$ = 2.2 / 2.5 MeV
protons
$\langle T_{kin}\rangle_{e/n}$ = 6.6 / 6.9 MeV
tritium
$\langle T_{kin}\rangle_{e/n}$ = 0.8 / 0.9 MeV
Helium-4
$\langle T_{kin}\rangle_{e/n}$ = 1.2 / 1.0 MeV
Helium-3
$\langle T_{kin}\rangle_{e/n}$ = 0.1 / 0.2 MeV
dN/pdE (MeV^{-2} Capture^{-1})
k = (p+T_{kin})/2 (MeV)
0
200
400

Detailes of Evaporation interfaces

- One Step interface is Boolean. It uses the basic class G4QNucleus as an object of evaporation:
  G4QNucleus Nucl(n4Mom,CHIPScode); // input Nucleus
  //CHIPS code 9LZZZNNN is different from PDG codes!
  G4QHadron* evaN = new G4QHadron; // output nucleon
  G4QHadron* residualA = new G4QHadron; // a Hadron!
  if(Nucl.EvaporateBaryon(evaN, residualA))…; // Fill N
- Full Evaporation interface is a void function:
  G4QHadron* Nucl(n4Mom,nPDG); // input Nucleus
  G4QHadronVector* out = new G4QHadronVector; // out
  G4QNucleus anyA; // can be any nucleus in the program
  anyA.EvaporateNucleus(Nucl,out); // User deletes the out

Other useful G4QNucleus decay-functions

- Functions are void, the same as EvaporateNucleus
  - DecayDibarion(G4QHadron*, G4QHadronVector*) // nn,np,pp
  - DecayIsonucleus(G4QHadron*, G4QHadronVector*) // Δ's
  - DecayMultyBaryon(G4QHadron*, G4QHadronVector*) // n*B
  - DecayAntiStrange(G4QHadron*, G4QHadronVector*) // K^+
  - DecayAlphaBar(G4QHadron*, G4QHadronVector*) // He5/Li5
  - DecayAlphaDiN(G4QHadron*, G4QHadronVector*) // Be6
  - DecayAlphaAlpha(G4QHadron*, G4QHadronVector*) // Be8
- All these functions are made for special channels of final fragmentation, when the standard SU(3) evaporation algorithm does not work. As an example they are used in the EvaporateNucleus function, which can be called instead of each of the listed functions.

CHIPS pre-compound Processes

- There are two pre-compound processes
  - G4QCollision for only pA interactions (slow)
    - CHIPS fragmentation (**G4QEnvironment**) + CHIPS quasi-elastic (**G4QuasiElasticRatios**)
    - Angular dependence of secondary fragments is defined by the virtuality of the recoiled (resulting) bounded Quasmon
    - Produces fragments up to He^4 (A=5 nuclei decay immediately)
  - G4QLowEnergy for any AA (as fast as LHEP)
    - Makes three particle decay in different fragments (including γ)
    - All gammas are absorbed by the residual nuclei and evaporate
    - Evaporation is made by the **G4QEvaporation** class
    - The angular dependence is directly parameterized

Conclusion

- The CHIPS Evaporation algorithm is relatively simple and universal. It includes equilibrium and isotropic pre-equilibrium phases. It takes into account Coulomb Barriers for charged fragments. The main problem is how many energy transfer to the residual nucleus after the CHIPS fragmentation is finished? This problem exists for any model.
- CHIPS evaporation algorithm can be used in a One Step form (EvaporateBaryon()) or in a Complete Fragmentation form (EvaporateNucleus())
- CHIPS provides processes for the pre-compound energy region. G4QLowEnergy covers AA reactions