Summary Hadronic Parallel Sessions

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Parallel Session 2A : Hadronic Models Part I

INCL++ - Recent Progress, Status and Plans	*Jean-Christophe David*
F113, Jefferson Lab	16:00 - 16:20
The Bertini Model - Recent Progress, Status and Plans	*Dennis Herbert Wright*
F113, Jefferson Lab	16:20 - 16:40
The FTF and QGS Models - Recent Progress, Status and Plans	*Vladimir Uzhinskii et al.*
F113, Jefferson Lab	16:40 - 17:10
Discussion	
F113, Jefferson Lab	17:10 - 17:30

DPhN
(Nuclear Science Department)

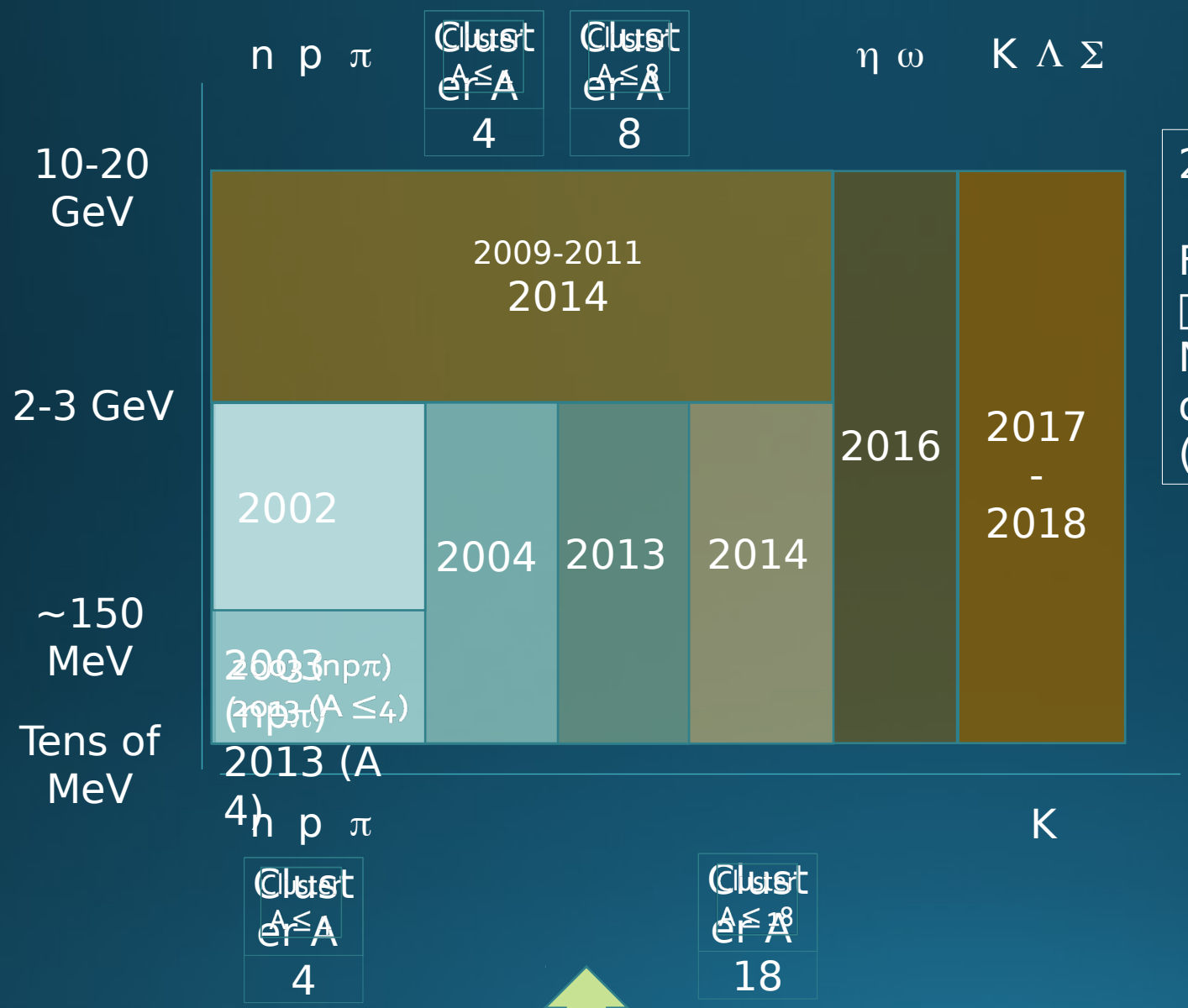
INCL++ - Recent Progress, Status and Plans

Jean-Christophe David

24TH GEANT4 COLLABORATION MEETING

Jefferson Lab

Status



2015-2017

Few nucleon removal

New momentum distribution (quantum effects)

Plan

New projectiles?

- Neutrino
  - FSI (neutrino-nucleus)
    - GENIE collaboration asked us INCL
    - Experimentalists are interested to collaborate with us

- e-, μ-
  - Related to neutrino secondary particles
  - e- JLab strangeness
  - μ- cosmic

- Antiproton
  - FAIR strangeness
  - (old data from LEAR strangeness)
  - Small fraction of cosmic spectum
  - Cern (Antiproton Decelerator - SACUSA, AEgIS, ALPHA, ATRAP) design and analysis

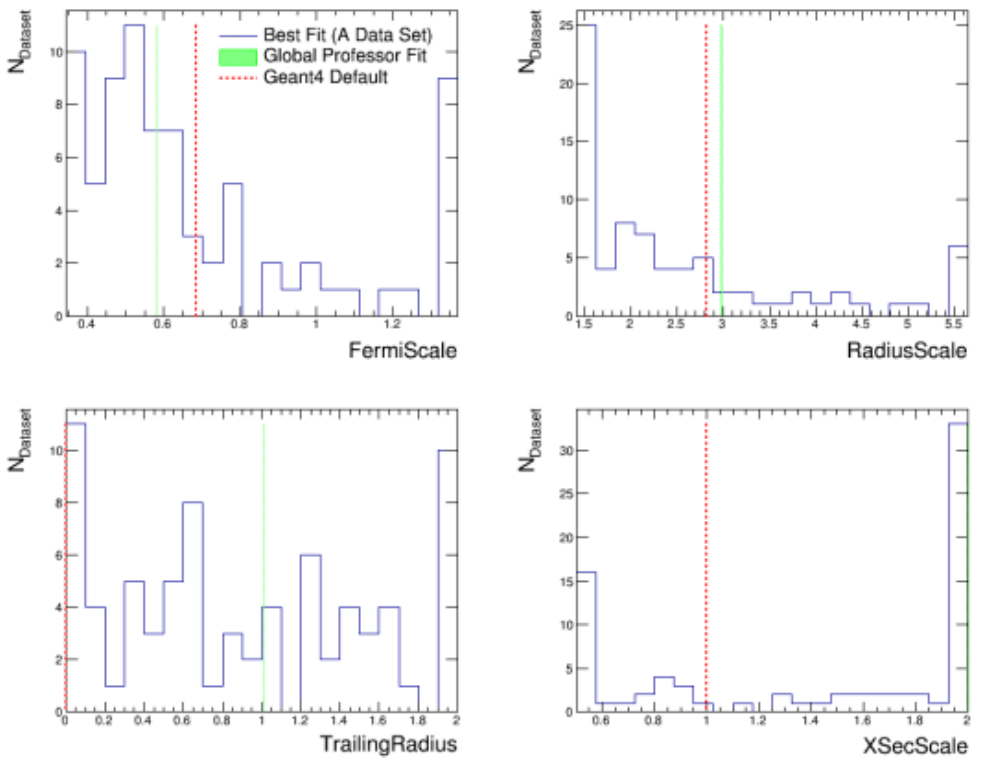
Choices must be made
AND Manpower-Funding are needed…

Parallel Session 3A : Hadronic Models Part II

Varrying Bertini Model Parameters	*Soon Yung Jun*
F113, Jefferson Lab	14:00 - 14:25
FTF Parameter API	*Julia Yarba*
F113, Jefferson Lab	14:25 - 14:50
Validation Using CMS Data	*Sunanda Banerjee et al.*
F113, Jefferson Lab	14:50 - 15:15

Geant4 Physics Models and Configurable Parameters

- Since 10.4, G4eant provides APIs to vary some hadronic model parameters; This allows developers to optimize them or to study systematic errors associated with experimental observables
- Identified most sensitive parameters, and fitted those to a large data set using Professor
- A global fit of Bertini model parameters to a large data set
  - 8 (sensitive) parameters
  - 77 data sets (0.8 – 12 GeV)
  - 1529 observables
- Preliminary results
  - Improved agreement between Geant4 simulation and data for many distributions
  - Run into many challenges



Fermilab

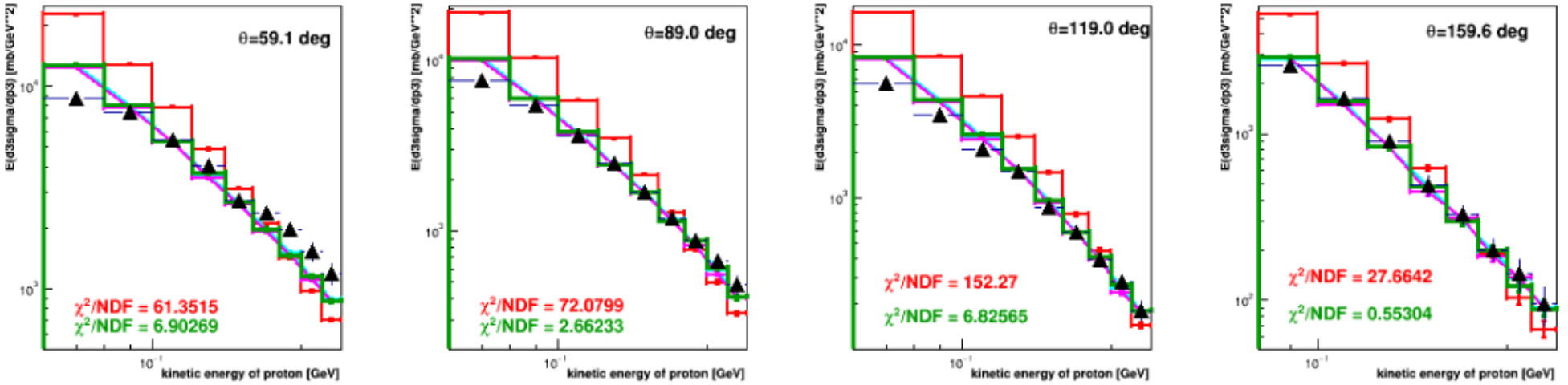
Possible Next Steps

- Parameter optimization
  - Identify more configurable parameters to fit available datasets
  - Include more data sets
  - Use dedicated datasets to optimize selected parameters
  - Extend configurable APIs to cross sections (if uncertainties are known or safely assignable)
  - Consider correlations among datasets and their weights
- Systematic uncertainty
  - Assign uncertainties to configurable model parameters as correctly as possible (based on domain knowledge of developers or statistical inference)
  - Identify observables that are important to an experiment and provide a systematic uncertainty on them
- Results to be submitted to JINST

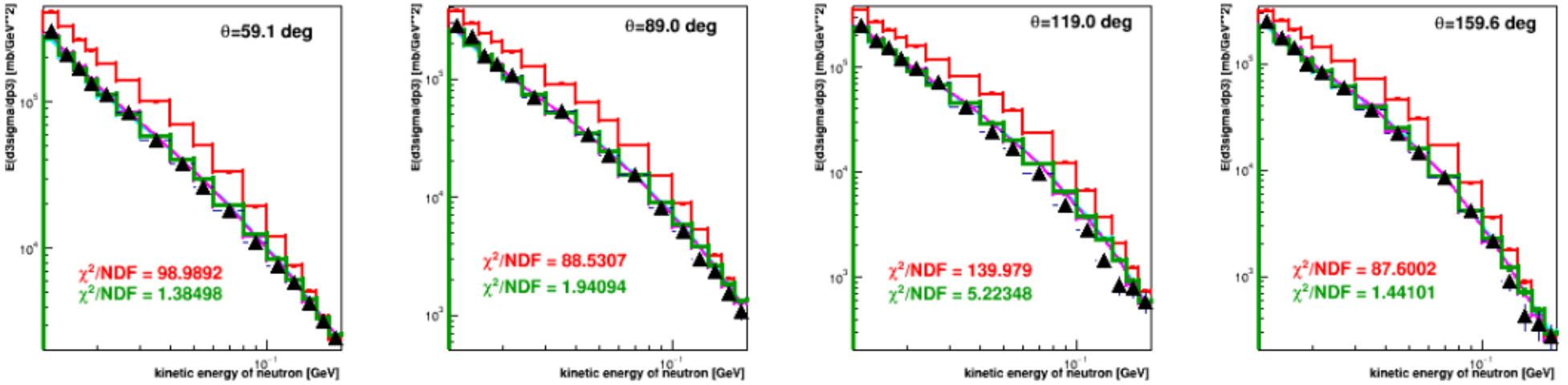
Extending FTF API and Using It to Study Model Parameters for Pion Projectile

- Geant4/FTF configuration interface has been extended, and as of 10.5.ref07 offers a total of 41 numeric parameters and Boolean switches involved in modeling interactions of protons and pions/mesons with nuclei, for the following sub-processes:
  - Projectile or target diffraction dissociation
  - Nuclear destruction
- Paves ways for applying global fitting techniques and for exploring sensitivity of the Geant4 predictions, for a wider range of use cases
- Current studies focus on varying selected parameters for the pion projectile and on exploring such effects as
  - Correlations among parameters of the FTF nuclear destruction model
  - Sensitivity of MC spectra of secondaries produced in pion-nucleus interactions to the variations of parameters of the FTF nuclear destruction
- Some ideas for a near-term work:
  - Include more data in the study
  - Explore effects of varying more parameters, under the guidance of FTF experts

5.0 GeV/c π^- on Pb $\rightarrow$ proton + X; Professor fits vs ITEP771 data



5.0 GeV/c π^- on Pb $\rightarrow$ neutron + X; Professor fits vs ITEP771 data



Plots show: G4/FTF Default simulation, Professor "best fit" approximation using 3rd or 4th order polynomial, and G4/FTF simulation using "best fit" parameters obtained with 4th order polynomial

Using fit results largely improves MC-data agreement for baryon production on heavy targets

For light targets some MC spectra may improve while some other may move away from the data

Validation using CMS data

- CMS uses Geant4 version 10.4.p03 in production version and plans to use the version 10.6 next year and a step to that is10.5.ref08
- CMS carries out validation using 2 sources of data:
  - 2006 test beam with CMS calorimeter prototypes (hadron beams of different types: hadrons, electrons, muons, and different energies: 1-350 GeV)
    - Special action was taken to go to low energy hadron beam down to 1 GeV using a secondary target and the analysis utilized particle identification using data from TOF counters and Cherenkov detectors up to energy of 9 GeV
    - The results consist of mean energy response (measured as the ratio of the total energy in the calorimeter to the beam momentum) as a function of beam momentum for different beam types and also the energy distribution for particles
  - Collision data from the CMS experiment utilizing zero bias or minimum bias triggers from low luminosity runs
    - Select good charged tracks reaching the calorimeter surface and impose isolation of these charged particles from other charged as well as neutral particles
    - Measure energy deposits in a NxN matrix around the impact point in the calorimeter and measure the ratio of the energy to the track momentum. Two versions of NxN matrix are defined for ECAL and HCAL
      - ECAL uses 7x7 or 11x11 matrix
      - HCAL uses 3x3 or 5x5 matrix

Summary of Results

χ^2/d.o.f. between test beam data and Monte Carlo

	negative pions	positive pions	negative kaons	positive kaons	protons	anti-protons
G4 10.4.p03 FTFP_BERT_EMM	0.45	0.73	26.2	26.8	0.80	1.79
G4 10.5.ref08 FTFP_BERT_EMM	0.46	2.67	17.3	15.0	0.77	2.77

- The predictions from 10.5.ref08 show some improvement for kaons, some deterioration for positive pions and anti-protons, and acceptable agreement for negative pions and protons

Mean level of disagreement in the response measurements in collision data

	$(E_{7x7}+H_{3x3})/p$ 10.4.p03	$(E_{7x7}+H_{3x3})/p$ 10.5.ref08	$(E_{11x11}+H_{5x5})/p$ 10.4.p03	$(E_{11x11}+H_{5x5})/p$ 10.5.ref08
Barrel 1	(1.6±0.4)%	(4.7±0.4)%	(2.1±0.4)%	(3.2±0.4)%
Barrel 2	(4.0±0.4)%	(6.9±0.4)%	(2.8±0.4)%	(5.5±0.4)%
Transition	(5.3±0.5)%	(6.6±0.5)%	(3.6±0.5)%	(5.1±0.5)%
Endcap	(5.5±0.5)%	(5.9±0.5)%	(5.0±0.5)%	(6.0±0.5)%

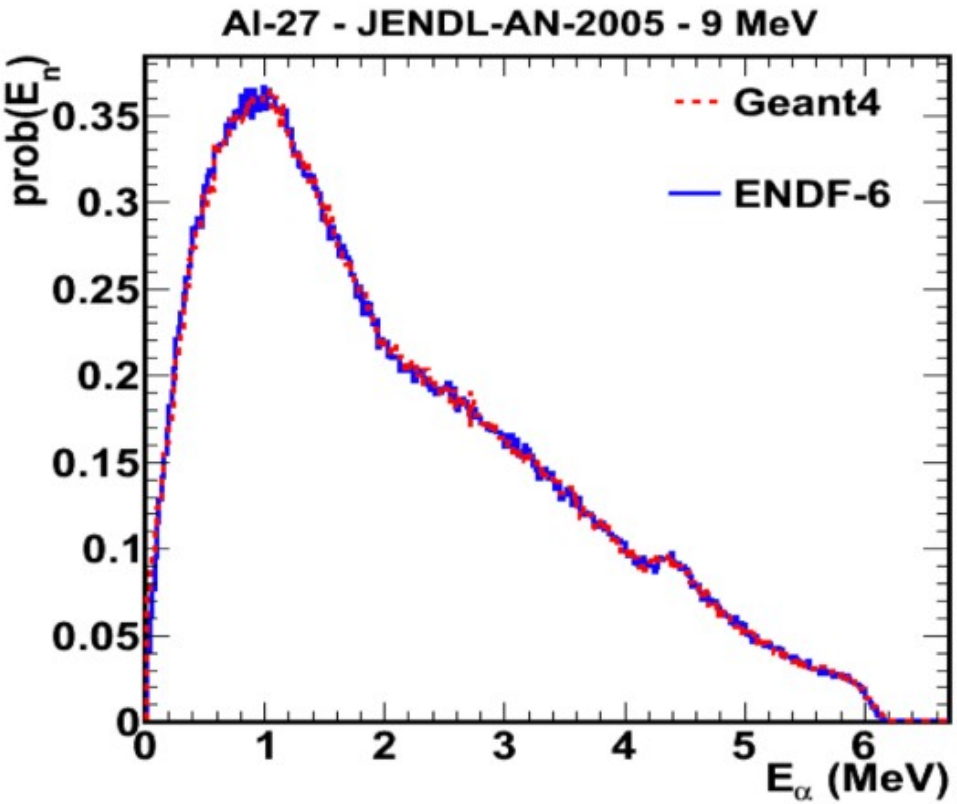
- The level of agreement between data and MC is between 3 to 7% depending on the region of the detector as well as the physics list used
- There is some degradation of results in the version 10.5.ref08

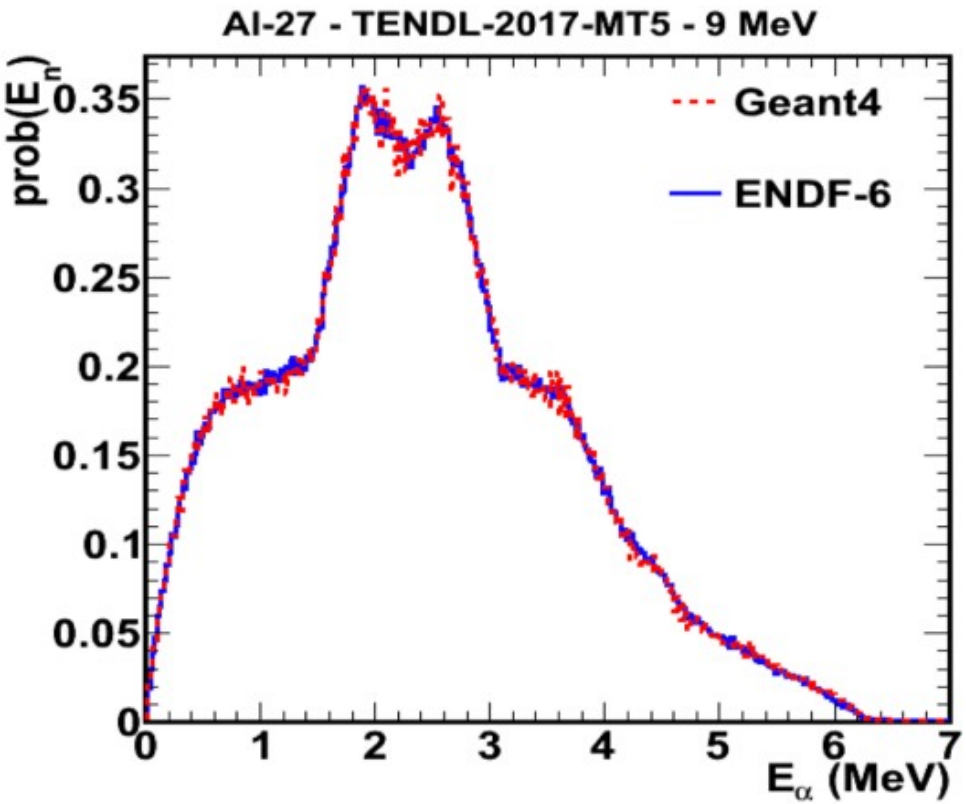
Parallel Session 6A : Nuclear Physics

Status of ParticleHP models	*Emilio Mendoza Cembranos*
F113, Jefferson Lab	14:00 - 14:20
Radioactive Decay status	*Laurent Desorgher*
F113, Jefferson Lab	14:20 - 14:40
Precompound and Deexcitation models status and plans	*Vladimir Ivantchenko*
F113, Jefferson Lab	14:40 - 15:00
Discussion	
F113, Jefferson Lab	15:00 - 15:30

Verification and Validation of ParticleHP

In order to verify the the correctness of the neutron energy spectra produced with Geant4 we have compared several spectra sampled by Geant4 with the original data present in the ENDF-6 format files. This has been done for all the TENDL and JENDL nuclear data libraries used later on in the neutron yield calculations.





Verification and Validation of ParticleHP

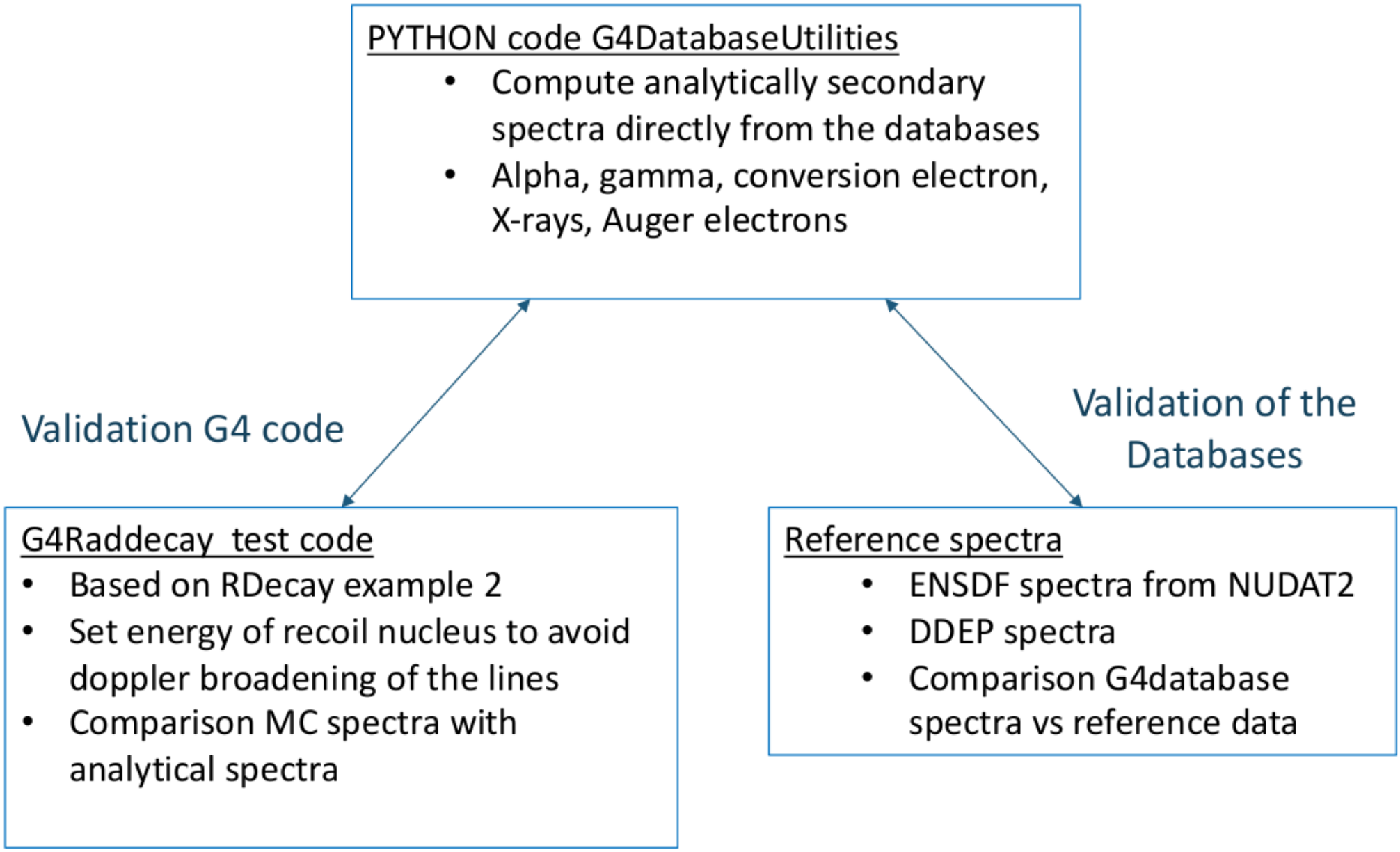
Conclusions

During the last year – 2 years:

- Eight new ENDF-6 format data libraries have been translated into the Geant4 format. Detailed consistency checks were performed. The libraries and more info are available at: https://www-nds.iaea.org/geant4/.
- New verification tests have been performed, by comparing ParticleHP with MCNP6.1 isotope by isotope. Some of the results are available at: INDC(NDS)-0758.
- A detailed study concerning the generation of neutrons from α-decays via (α,Xn) reactions have been performed. The results are available at arXiv:1906.03903.

Future developments are in progress

Testing Suite for Radioactive Decay (L. Desorgher)



Conclusions on RDM Validation

Comparison between spectra computed analytically from the G4 database and spectra obtained from NUDAT2 and DDEP

- Very good agreement for alpha intensities, few keV differences for alpha energies
- Significant differences in gamma spectra for some nuclei, with a better match between DDEP and GEANT4 spectra
- Some inconsistencies exist in ENSDF but also DDEP data that make difficult a 100 % match of GEANT4 with these data

We propose to add the validation code in Geant4-val

Precompound and Deexcitation (V. Ivantchenko)

- Pre-compound/de-excitation were improved in 2019
  - *Number of problem reports were fixed*
  - *Remaining problem reports can be fixed is data files will be improved/extended*
- Few relatively simple developments mentioned in this talk need to be addressed for 10.6
- Detailed validations including full G4MSBG are required
- Some options are promising but cannot be default in 10.6
  - *Extended density level parameterization*
  - *Discrete final states in evaporation*
  - *new GEM model*

Future Developments of ParticleHP

1. Energy/momentum conservation: Energy, momentum, baryonic number … are **in general** not conserved event by event. We will try to implement an option which forces ParticleHP to conserve these quantities event by event. Environmental variables will be removed/reduced.

2. Implement a very detailed physics for organic neutron detectors up to 100 – 200 MeV. At present there is a specific model inside ParticleHP for n+^{12}C reactions up to 20 MeV (*A. García et al., NIMA 868, 73 (2017)*). We are trying to extend it to higher energies.

3. Extend the ParticleHP model to higher energies:

- ENDF/HE-VI: n,p incident (4 isotopes, up to 1 GeV).
- JENDL/HE-2007: n,p incident (106 isotopes, up to 3 GeV)

4. Insert into Geant4 the NuDEX code, which generates EM de-excitation cascades by creating full level schemes + BR of a large variety of nuclei. Similar to PhotonEvaporation but with more detail.

Other ParticleHP Issues

Speeding up ParticleHP:

- fix the temperature of the database so that Doppler broadening does not have to be done
- use Physics Vectors in code

User modification of database

- provide script for unpacking, editing data, then repacking data – Pedro
- do this on a trial basis to see how it goes

Extending TENDL Database

TENDL database used for charged-particle HP and other channels in which there is no data in ENDF

- Important problem: n + $^{11}C \rightarrow {}^{12}C^* \rightarrow 3\alpha$
- Cross section for this goes to zero below 1 MeV
- However, good data exists → add it to TENDL
- First ask TENDL maintainers if they will add it
- If not, add to Geant4 version of TENDL and maintain with regular updating and release period

Parallel Session 7A : Technical Aspects