

Preliminary study on Geant4 physics lists applied on PBCT

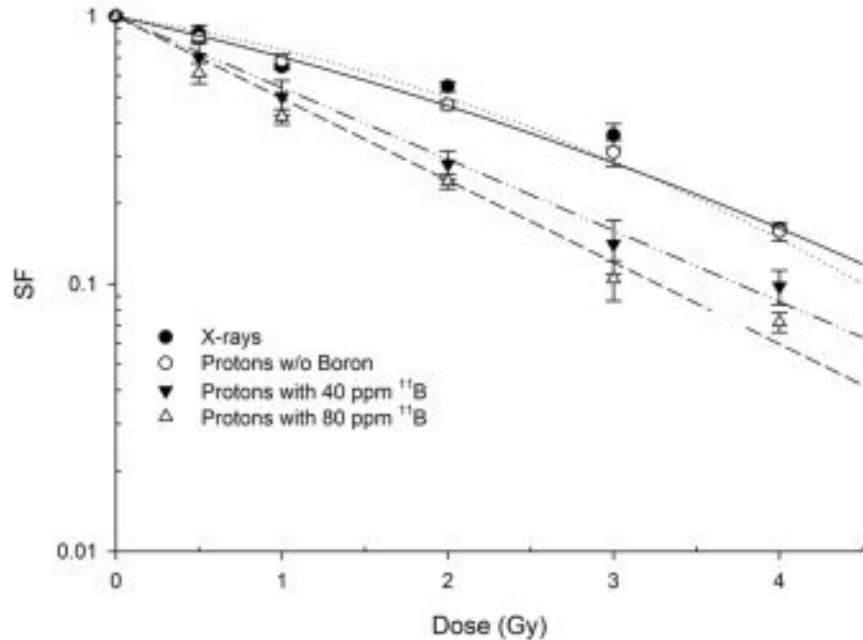
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Outline

- ❑ Why simulations are necessary
- ❑ Experimental available cross sections
- ❑ TALYS and alternative reactions
- ❑ Geant4 physics overview
- ❑ Comparison between different Geant4 hadronic physics lists
- ❑ The ParticleHP problem
- ❑ Goal cross section



Simulation goals

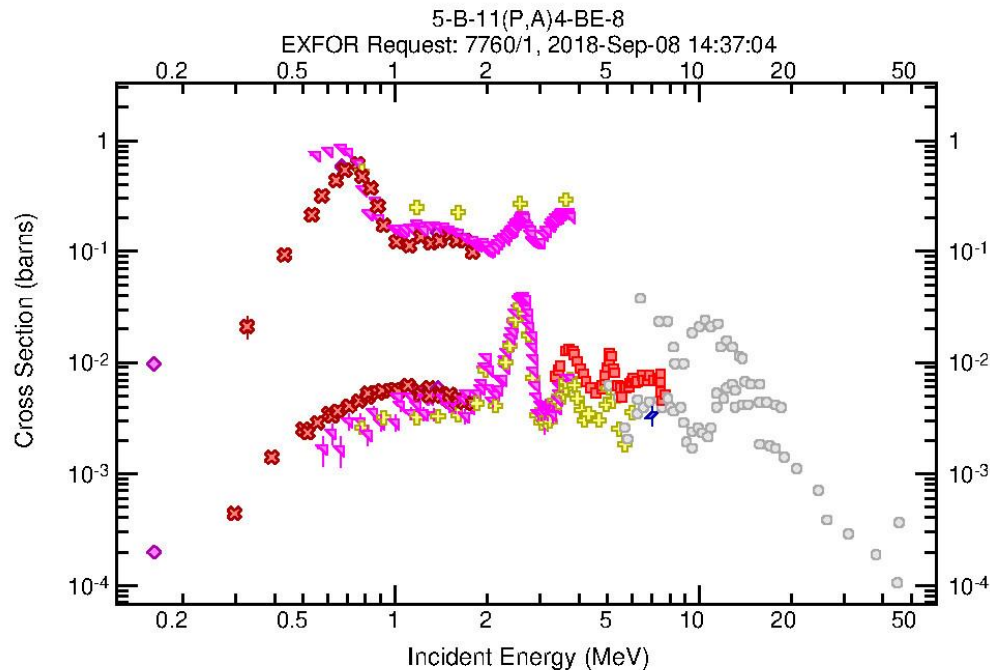


G.A.P. Cirrone et al., “First experimental proof of Proton Boron Capture Therapy (PBCT) to enhance protontherapy effectiveness”, Scientific Reports volume 8, Article number: 1141 (2018)

Can we reproduce this biological effect?
Is it really due to the presence of alpha particles?
Is it due to the presence of other particles?
Which particles do we produce?

How is biological effect related with physics?

Experimental cross section available

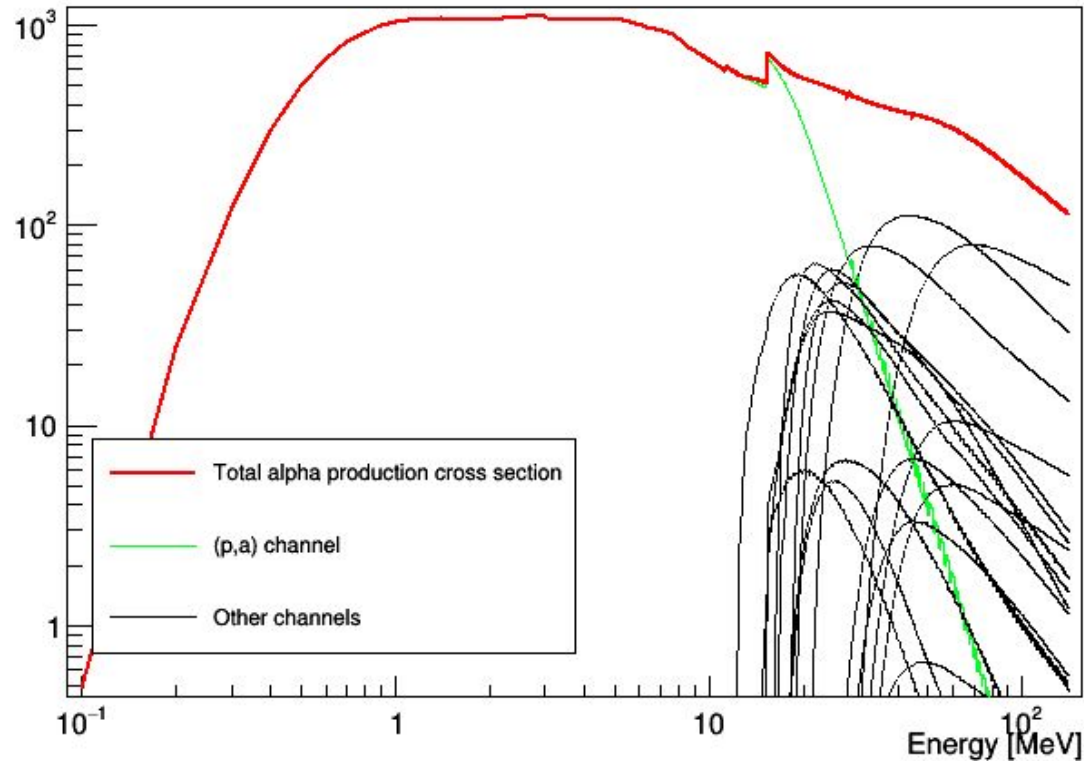


Data taken from
Experimental Nuclear
Reaction Data (EXFOR):
1983 Borchers
1983 Buck
1967 Kamke
1965 Segel
1964 Yanabu
1963 Symons
1953 Beckman

Different channels for alpha production

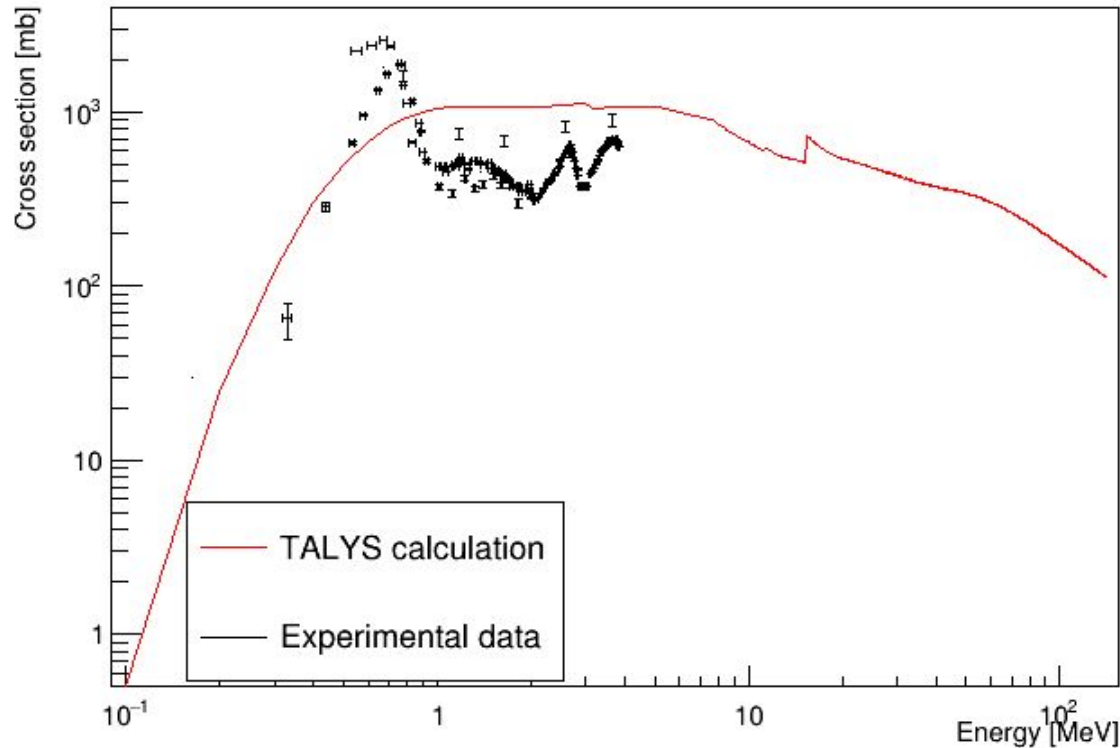
- $p + {}^{11}\text{B} \rightarrow 3 \alpha$
- $p + {}^{11}\text{B} \rightarrow \alpha + {}^8\text{Be}$
- $p + {}^{11}\text{B} \rightarrow p + \alpha + {}^7\text{Li}$
- $p + {}^{11}\text{B} \rightarrow n + \alpha + {}^7\text{Be}$
- $p + {}^{11}\text{B} \rightarrow 2 {}^2\text{H} + {}^8\text{Be}$
- $p + {}^{11}\text{B} \rightarrow n + {}^3\text{He} + {}^8\text{Be}$
- ...

Total alpha production cross section



Plot generated using TALYS to calculate cross sections of protons on ^{11}B giving at least one alpha or a ^8Be

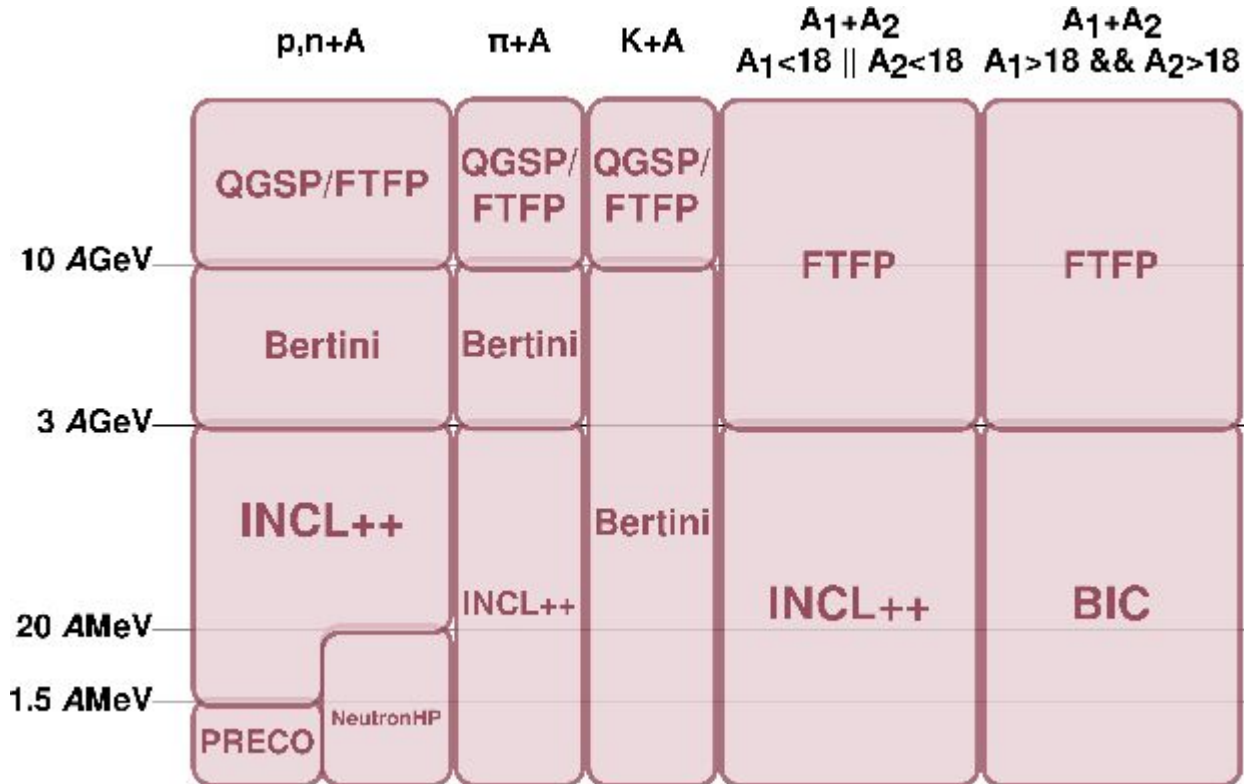
TALYS and experimental data



Hadronic physics in Geant4

- Which particles exist
- Which processes exist
- What are the cross sections
- What are the outgoing particles
- What are the outgoing particles spectra

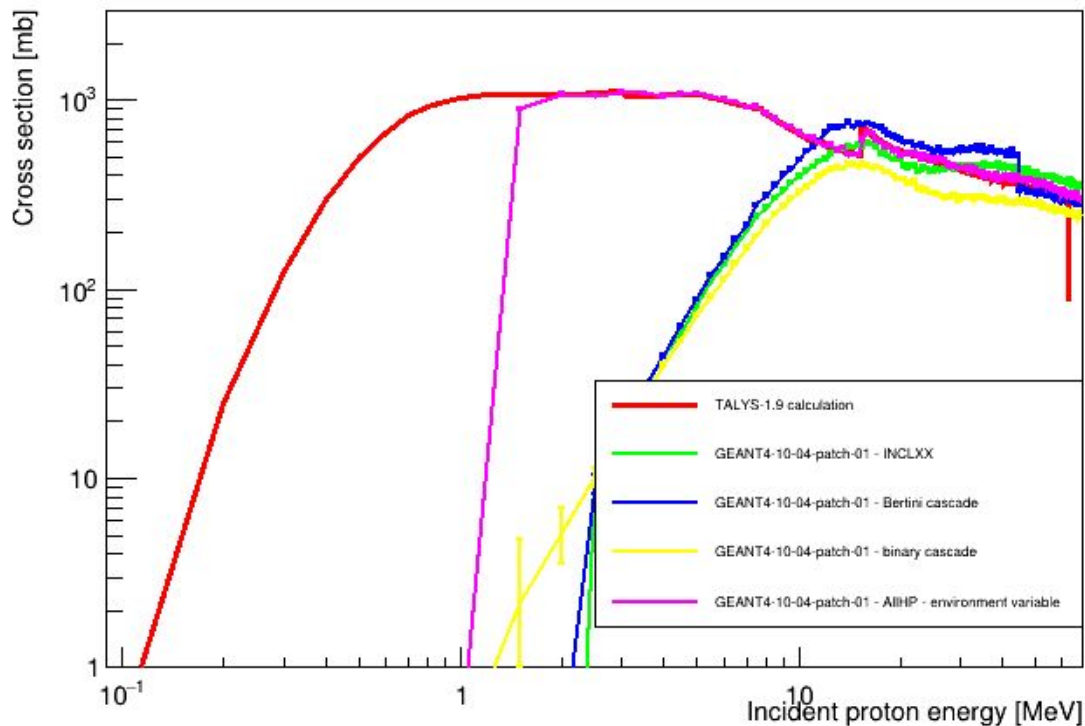
Hadronic physics models



A given modular physics list uses different models for different particles and energy ranges in order to best simulate reactions. Here the hadronic physics list is INCLXX

Geant4 output

Total cross section for alpha production



Different hadronic physics lists are compared with TALYS:

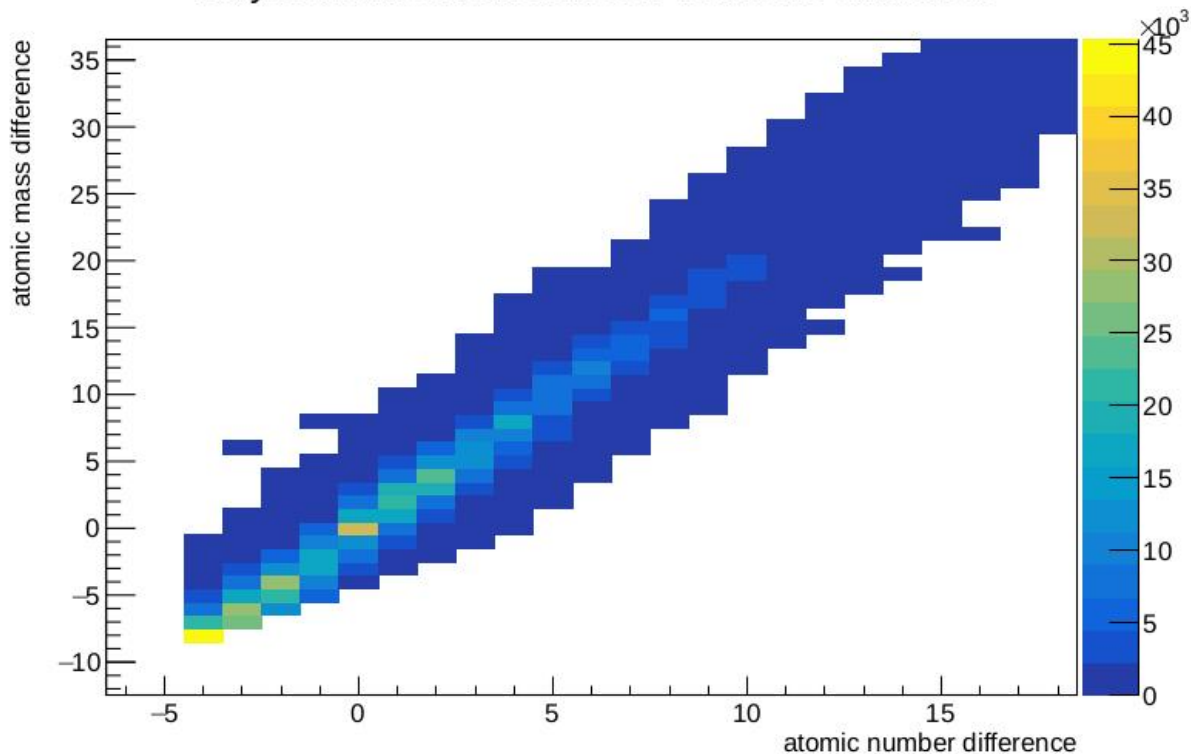
- TALYS
- INCLXX
- Bertini cascade
- Binary cascade
- ParticleHP

ParticleHP

- The first (and only) data driven hadronic physics list
- TENDL libraries
- Cross sections for given processes
- Production yields of given particles
- Energy spectra for outgoing particles
- Angular distribution for outgoing particles

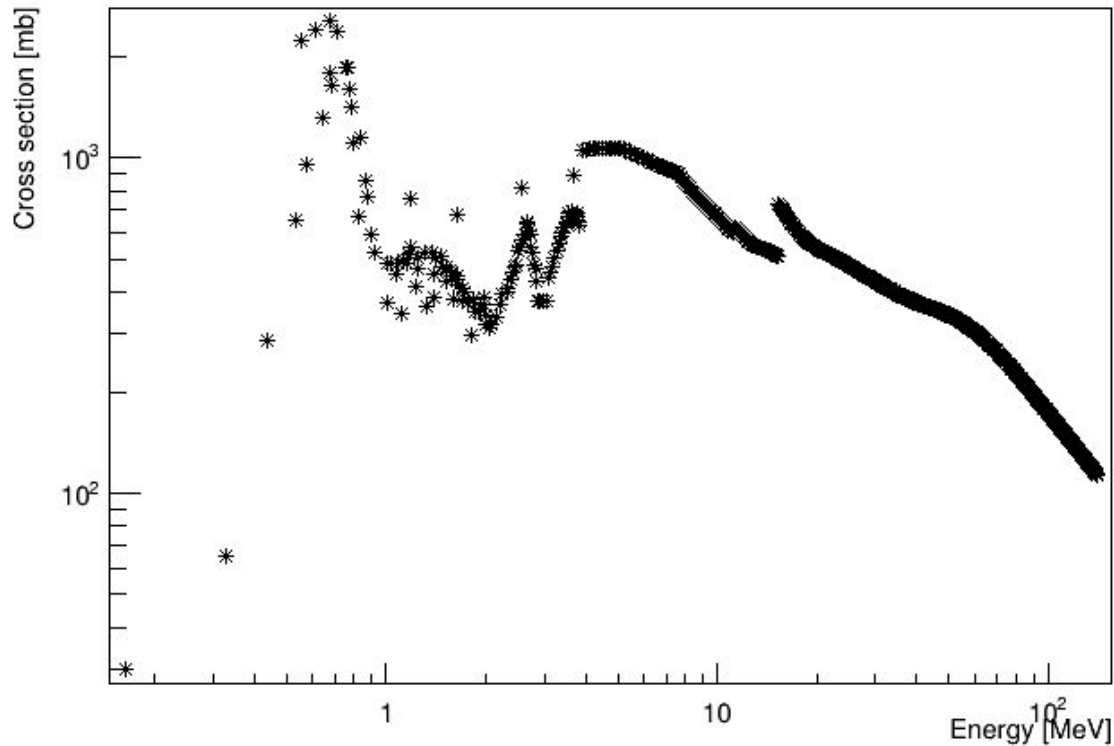
ParticleHP issue

Baryon Number Difference in reactions simulated



Atomic number and atomic mass difference obtained simulating protons on ^{11}B . In other hadronic physics lists all points collapse in (0, 0)

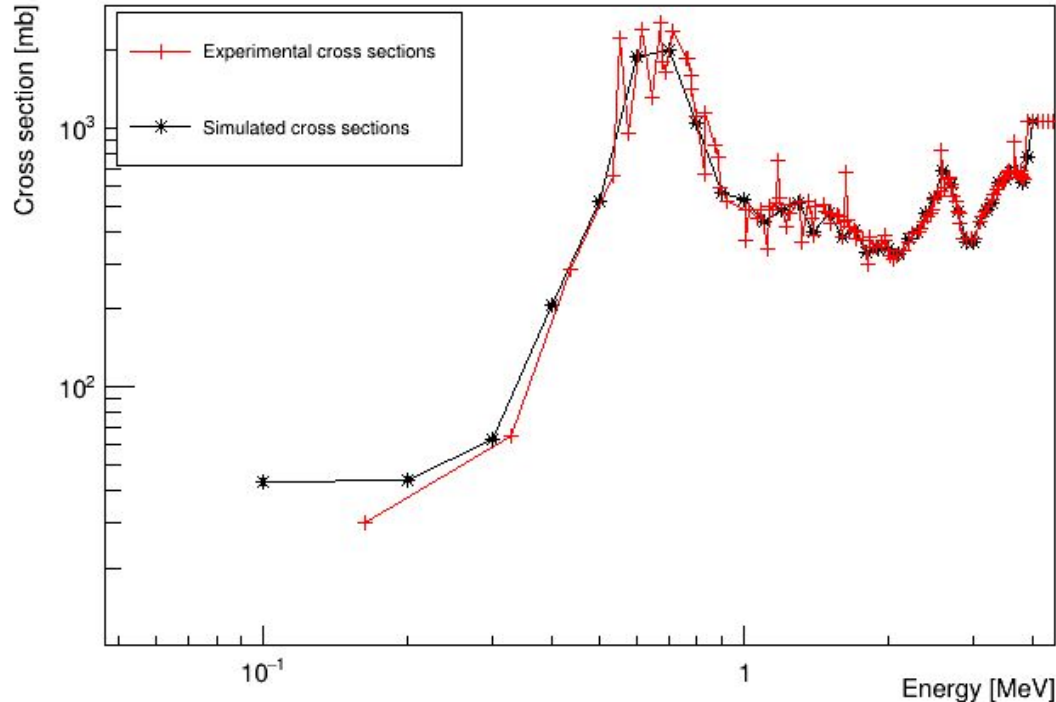
Goal cross section



This is the union between experimental cross sections (where they are good and available, i.e. below 3.85 MeV) and TALYS analytical calculation

New cross section

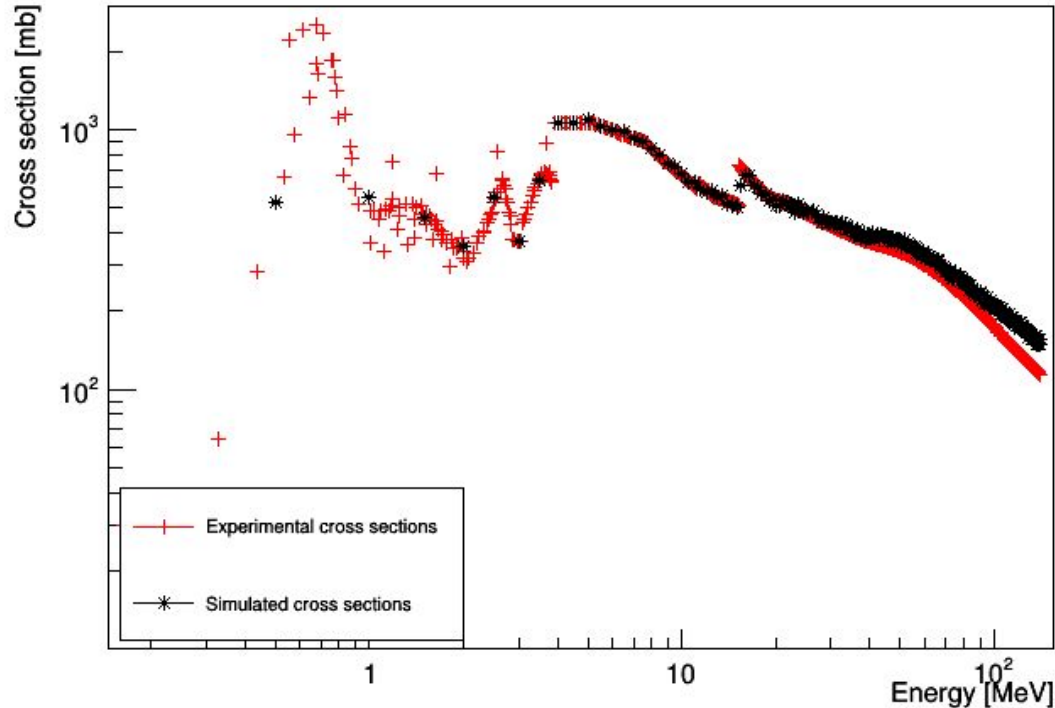
Comparison between experimental and simulated production cross section



Simulated cross section of proton on ¹¹B after physics list has been upgraded. ZOOM on experimental driven values

New cross section

Comparison between experimental and simulated production cross section



Overall view of comparison between “goal” cross section and simulated one.

Thanks for the attention