# ECAL BIB reduction with BCH2

## MAIA/10-TeV weekly meeting

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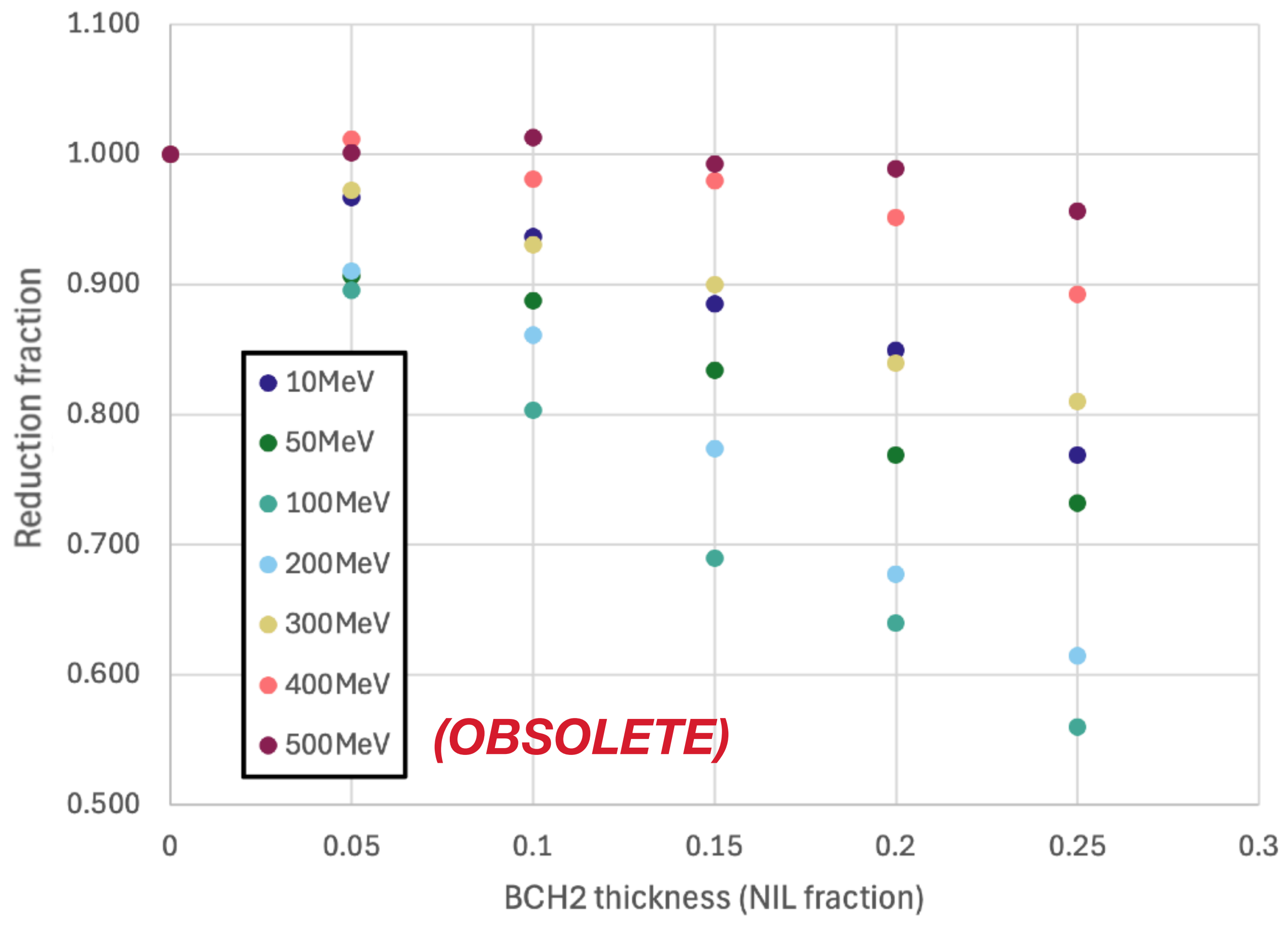
# Early observations

NB: Results here are superseded by HP results!

*All plots are produced from O(10k–100k) collections of **single neutrons** normally incident on one face of the **MuColl_v1** ECAL. A layer of BCH2 inheriting the ECAL geometry is placed in front of ECAL and the HCAL is left on to allow reflections. ECAL simhit energies are integrated out to t=inf.*

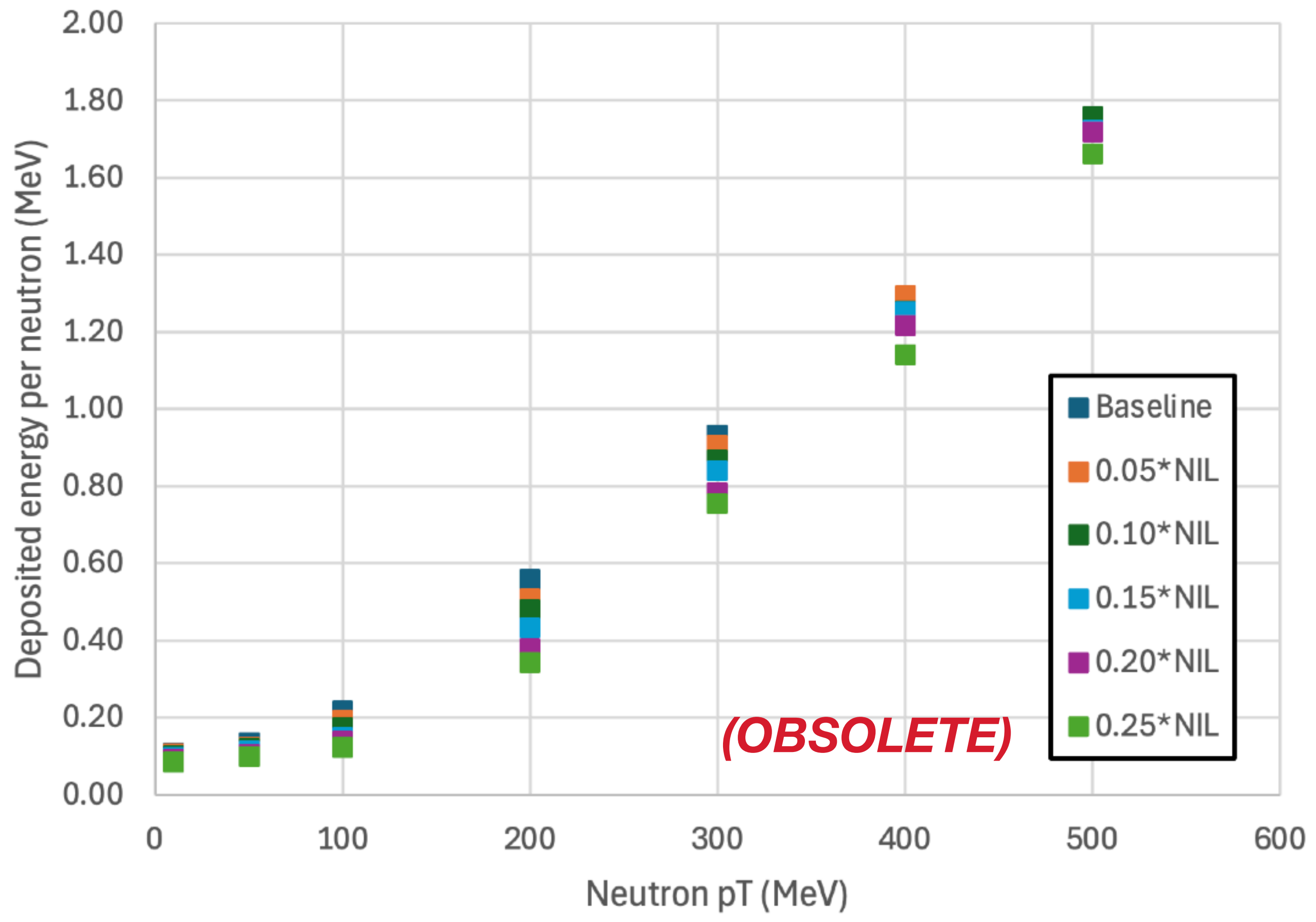
**Observations**

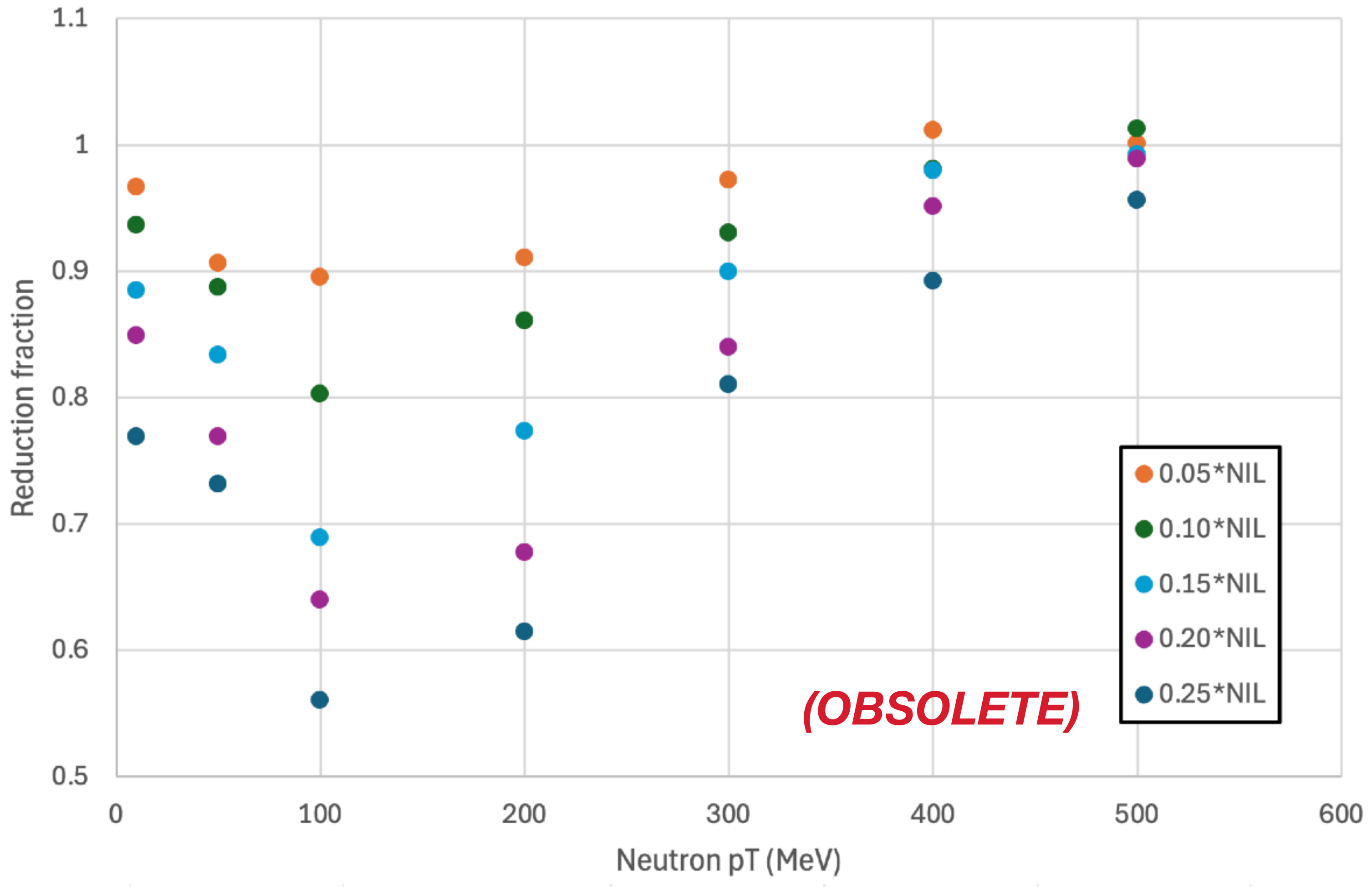
- For $p_T^{neutr.} \leq 300$ MeV, reduction fraction $E_{BCH}^{dep}/E_{ctrl}^{dep}$ scales strictly inversely with shield thickness
- For $p_T^{neutr.} \geq 400$ MeV, low shield thicknesses produce less substantial $E_{BCH}^{dep}/E_{ctrl}^{dep}$
- The **impact** doesn't scale simply with neutron pT → recasting $E_{BCH}^{dep}/E_{ctrl}^{dep}$ in terms of pT we observe a sweet spot in reduction at **~100 MeV**




**Some initial hypotheses…**

- A handful of **elastic n-H collisions** could drop the 100-MeV neutron below the threshold where it would create significant cascades in tungsten…
- **Higher-pT neutrons** create p/π secondaries in BCH2 + require more collisions to drop below thresholds
- Original hypothesis: **low-pT neutrons** depositing minimal energy in W/Si might only produce modest gains… *but this isn't the whole picture!*



# Checking under the hood

## *What is Geant4 doing?*

ddsim is launched with SIM.physics.list = “QGSP_BERT" [1] and SIM.physics.decays = False
In this setup, the following processes are accounted for [2]:

- **hadElastic** = G4 elastic had. scattering process
  - *hElasticCHIPS*: CHiral Inv Phase Space elastic model → cover ultra-cold to ultra-HE n
  - *G4NeutronElasticXS* provides total and diff. elastic XSs over same range

- **neutronInelastic** = nuclear excitation + spallation interactions
  - *BertiniCascade*: intranuclear cascade simulating neutron-nucleon collisions + secondary production
  - *FTFP*: Fritiof string + PreCompound model → bridge gap between cascade & string models
  - *QGSP*: Quark-gluon string + PreCompound model

- **nCapture** = discrete radiative neutron capture
  - *nRadCapture* (G4NeutronRadCapture): final-state generation when neutron is absorbed (nuclear recoil and γ release)
  - *G4NeutronCaptureXS* provides neutron capture XSs

- **nKiller**: prevents infinite tracking by removing neutrons after 10μs (and at 0eV by default)

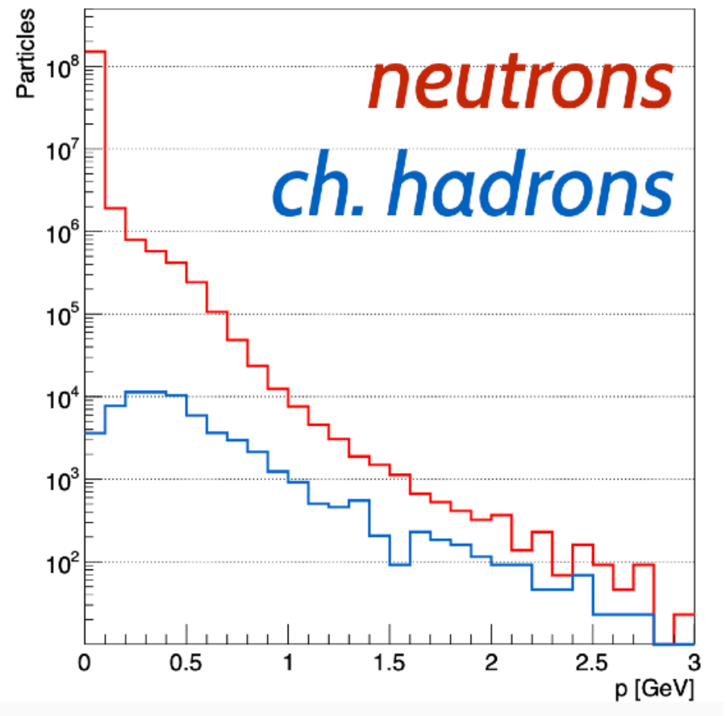
```
=======================================================================
      |     |       HADRONIC PROCESSES SUMMARY (verbose level 1)
-----------------------------------------------------------------------
      |     |     |     |   Hadronic Processes for neutron
 Process: hadElastic
      |  Model:             hElasticCHIPS: 0 eV  ---> 100 TeV
    Cr_sctns:          G4NeutronElasticXS: 0 eV  ---> 100 TeV
 Process: neutronInelastic
      |  Model:                      QGSP: 12 GeV ---> 100 TeV
      |  Model:                      FTFP: 3 GeV ---> 25 GeV
      |  Model:             BertiniCascade: 0 eV  ---> 6 GeV
    Cr_sctns:        G4NeutronInelasticXS: 0 eV  ---> 100 TeV
 Process: nCapture
      |  Model:               nRadCapture: 0 eV  ---> 100 TeV
    Cr_sctns:          G4NeutronCaptureXS: 0 eV  ---> 100 TeV
 Process: nKiller
```

[1] https://geant4.web.cern.ch/documentation/dev/plg_html/PhysicsListGuide/reference_PL/QGSP_BERT.html
[2] https://agenda.infn.it/event/8170/contributions/71806/attachments/52146/61572/Hadronic_Physics.pdf

**Q *So what’s missing?***

# Checking under the hood

## A *High-precision low-energy physics*



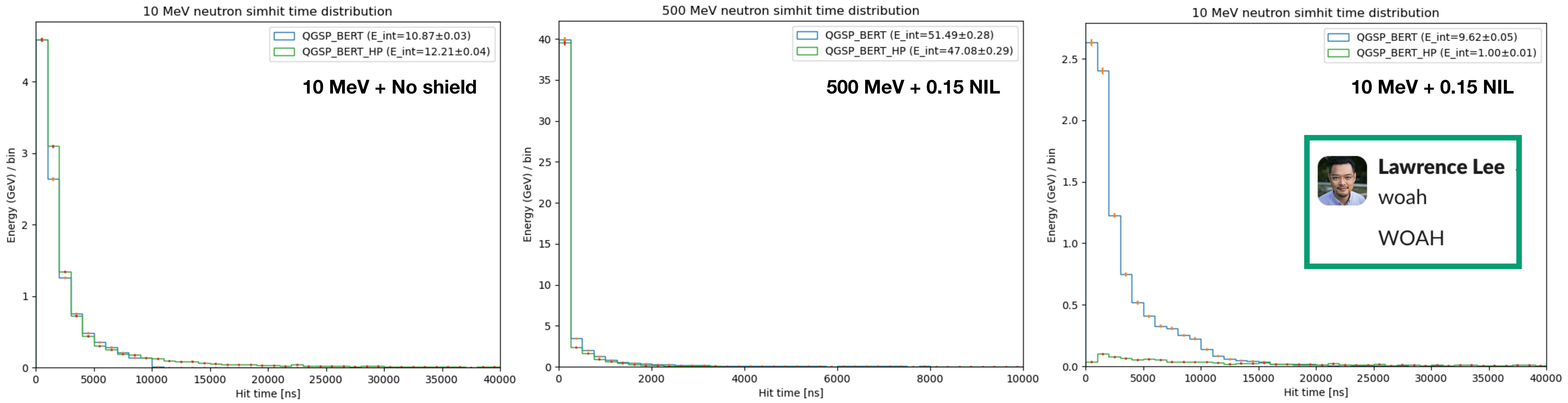

- At low energies, we could do ***better*** since QGSP_BERT relies on **parametrized** rather than **data-driven** cross sections
- Recommended alternative: **QGSP_BERT_HP**
  - Neutrons at **≤20 MeV** use new version of *high-precision* neutron models + XSs to describe elastic/inelastic scattering, capture, and fission + radioactive decay
  - Good for **radiation protection** and **shielding applications** [3]
  - NB: tends to run a bit **slower** than QGSP_BERT

```
=======================================================================
                  HADRONIC PROCESSES SUMMARY (verbose level 1)
-----------------------------------------------------------------------
                        Hadronic Processes for neutron
 Process: hadElastic
        Model:             hElasticCHIPS: 0 eV  ---> 100 TeV
     Cr_sctns:        G4NeutronElasticXS: 0 eV  ---> 100 TeV
 Process: neutronInelastic
        Model:                      QGSP: 12 GeV ---> 100 TeV
        Model:                      FTFP: 3 GeV ---> 25 GeV
        Model:            BertiniCascade: 0 eV  ---> 6 GeV
     Cr_sctns:      G4NeutronInelasticXS: 0 eV  ---> 100 TeV
 Process: nCapture
        Model:               nRadCapture: 0 eV  ---> 100 TeV
     Cr_sctns:        G4NeutronCaptureXS: 0 eV  ---> 100 TeV
 Process: nKiller
```

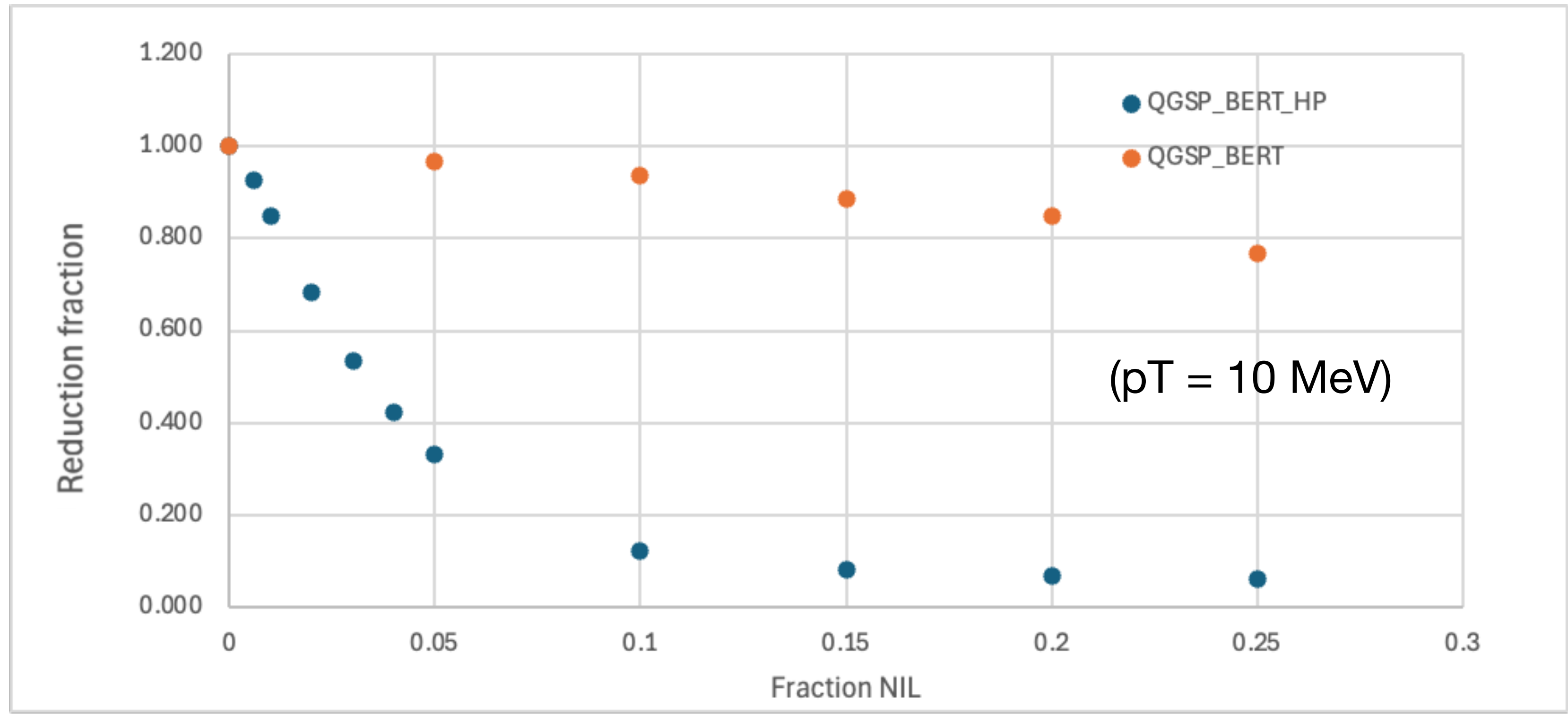
```
                        Hadronic Processes for neutron
 Process: hadElastic
        Model:             hElasticCHIPS: 19.5 MeV ---> 100 TeV
        Model:          NeutronHPElastic: 0 eV  ---> 20 MeV
     Cr_sctns:          neutronElasticHP: 0 eV  ---> 20 MeV
     Cr_sctns:        G4NeutronElasticXS: 0 eV  ---> 100 TeV
 Process: neutronInelastic
        Model:                      QGSP: 12 GeV ---> 100 TeV
        Model:                      FTFP: 3 GeV ---> 25 GeV
        Model:            BertiniCascade: 19.9 MeV ---> 6 GeV
        Model:        NeutronHPInelastic: 0 eV  ---> 20 MeV
     Cr_sctns:        neutronInelasticHP: 0 eV  ---> 20 MeV
     Cr_sctns:      G4NeutronInelasticXS: 0 eV  ---> 100 TeV
 Process: nCaptureHP
        Model:             nRadCaptureHP: 0 eV  ---> 100 TeV
     Cr_sctns:          neutronCaptureHP: 0 eV  ---> 100 TeV
     Cr_sctns:        G4NeutronCaptureXS: 0 eV  ---> 100 TeV
 Process: nFissionHP
        Model:                nFissionVI: 0 eV  ---> 100 TeV
     Cr_sctns:          neutronFissionHP: 0 eV  ---> 100 TeV
     Cr_sctns:                    ZeroXS: 0 eV  ---> 100 TeV
```

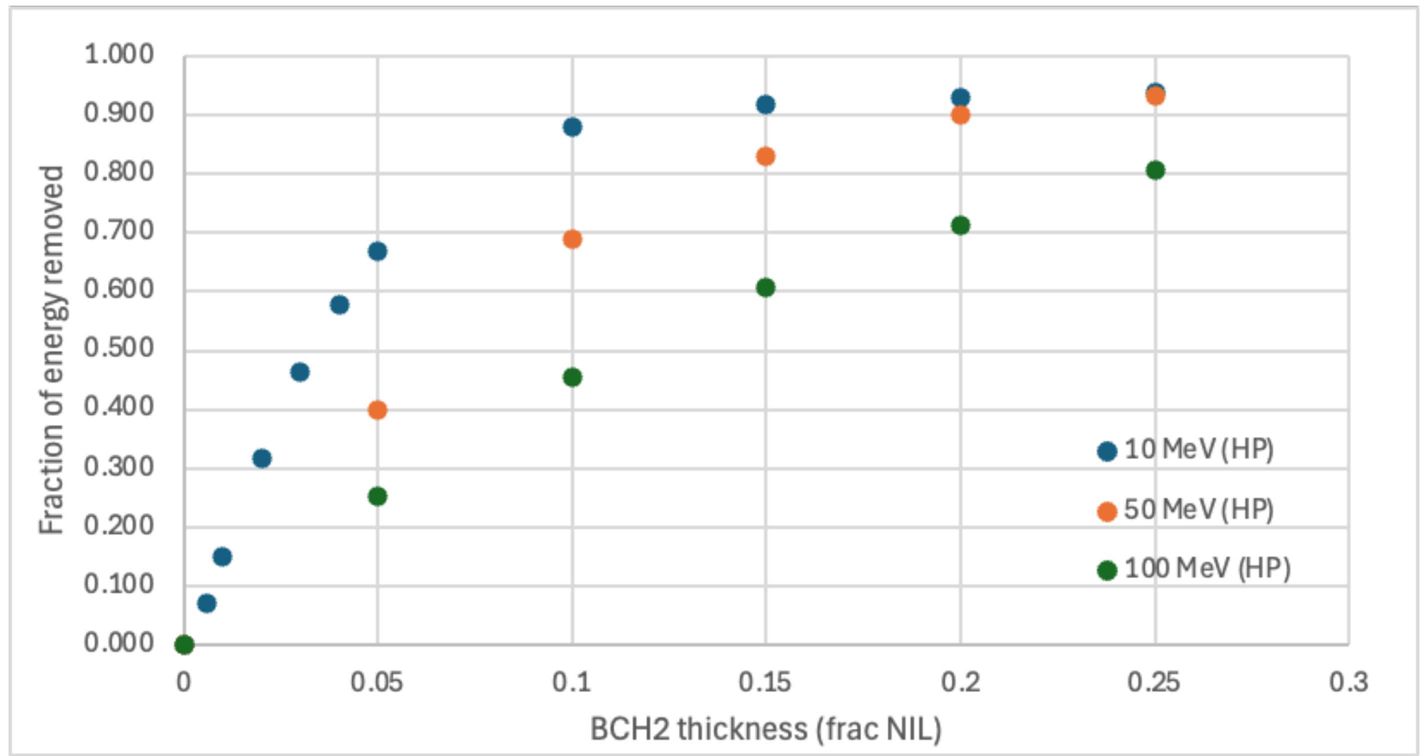
[3] https://geant4.in2p3.fr/IMG/pdf_PhysicsLists.pdf

# How much of an impact does this make?




- At **10 MeV without shielding**, impact of switch to HP is minimal—perhaps not unexpected since this should be dominated by γ generation in tungsten, so gross behavior not changed significantly ✓
- At **500 MeV** with **moderate** (0.15λ) shielding, difference is also minimal—reasonable, since *most* of this behavior is treated by BertiniCascade, which is unchanged ✓
- At **10 MeV** with **moderate** (0.15λ) shielding, we see a *dramatic* improvement in neutron reduction, from **12%** (default) to **~91%** (HP) removed




As we move towards impact on γ resolution…

- Detector setup? Does this cut into ECAL? What sort of optimization problem arises?
- Neutron BIB directionality? Overlay? Composition?