

In[1]:=

```
(*Set initial directory*)
directory = NotebookDirectory[];

(*Display menu for nuclear species selection*)

Print["Select Nuclear Species:"];
Print["1. U-235_Data_JENDL5_CalculationData"];
Print["2. U-233_Data_JENDL5_CalculationData"];
Print["3. U-238_Data_JENDL5_CalculationData"];
Print["4. Th-232_Data_JENDL5_CalculationData"];
Print["5. Np-237_Data_JENDL5_CalculationData"];
Print["6. Pu-239_Data_JENDL5_CalculationData"];
Print["7. Pu-240_Data_JENDL5_CalculationData"];
Print["8. Pu-242_Data_JENDL5_CalculationData"];
Print["9. Am-241_Data_JENDL5_CalculationData"];

(*Get user selection*)
choice = Input["Enter number (1-9): "];

(*Load file based on selection*)
fileName = Switch[choice, 1, "U-235_Data_JENDL5_CalculationData.m", 2,
  "U-233_Data_JENDL5_CalculationData.m", 3, "U-238_Data_JENDL5_CalculationData.m", 4,
  "Th-232_Data_JENDL5_CalculationData.m", 5, "Np-237_Data_JENDL5_CalculationData.m",
  6, "Pu-239_Data_JENDL5_CalculationData.m", 7,
  "Pu-240_Data_JENDL5_CalculationData.m", 8, "Pu-242_Data_JENDL5_CalculationData.m",
  9, "Am-241_Data_JENDL5_CalculationData.m", _, {Print["Invalid selection"];
  Abort[]}]];

(*Load file using full path*)
fullPath = FileNameJoin[{directory, fileName}];
Print["Attempting to load file from: ", fullPath];

If[FileExistsQ[fullPath], Get[fullPath];
  Print["Successfully loaded:", fileName],
  Print["Error: File not found at ", fullPath]];

(*2*)

(*Initial Calculations for Nuclear Parameters*)
fragmentZ1 = atomicNumber/2; (*First fragment atomic number*)
fragmentZ2 = atomicNumber/2; (*Second fragment atomic number*)
reducedMass = N[Sqrt[fragmentZ1 * fragmentZ2 / (fragmentZ1 + fragmentZ2)]];

fitStartZ = 28; (*Starting atomic number for fitting*)
fitEndZ = atomicNumber - fitStartZ; (*Ending atomic number for fitting*)
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fitStartIndex = fitStartZ - 22; (*Starting index for fitting data*)
fitEndIndex = fitEndZ - 22; (*Ending index for fitting data*)
(*Initialize distance parameter*)

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(*Incident Neutron Kinetic Energy*)
neutronEnergy1 = 0; (*0.0253 eV*)
neutronEnergy2 = 0.5; (*500 keV*)
neutronEnergy3 = 14; (*14 MeV*)

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effectiveDistance = .;

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```

(*Initialize energy-dependent distance parameters*)
effectiveDistance0253eV = .;
effectiveDistance500keV = .;
effectiveDistance14MeV = .;

```

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(*Initialize variable lists for each energy region*)
distanceVars0253eV = {};
distanceVars500keV = {};
distanceVars14MeV = {};

```

```

(*Initialize fermi correction lists*)
fermiVars0253eV = {};
fermiVars500keV = {};
fermiVars14MeV = {};

```

```

(*Initialize fermi correction energies*)
fermiEnergy1 = .;
fermiEnergy2 = .;
fermiEnergy3 = .;

```

```

(*Initialize various parameter lists*)
paramList0253eV = {};
paramList500keV = {};
paramList14MeV = {};
paramList5 = {};
paramList6 = {};
paramList7 = {};

```

```

fermiEnergies = {};
variablesList = {};
fissionYields = {};
neutronVars = {};
effectiveDistances = {};
distanceParams = {};

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paramList50 = {};
paramList60 = {};
paramList70 = {};

```

```
Clear[theoreticalYield0253eV, theoreticalYield500keV, theoreticalYield14MeV,
fittedYield0253eV, fittedYield500keV, fittedYield14MeV, optResult0253eV,
optResult500keV, optResult14MeV, fermiVars0253eV, fermiVars500keV, fermiVars14MeV]
```

```
(*Mass retrieval function definition*)
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```
getNuclearMass[Z_, A_] :=
Module[{elementName, isotopeName, mass, numericMass}, (*Validate atomic number*)
If[! NumberQ[Z] || Z < 1 || Z > 118, Return[Missing["NotAvailable"]]];
(*Get element name*) elementName = ElementData[Z, "Name"];
If[elementName === $Failed, Return[Missing["NotAvailable"]]];
(*Format element name*) elementName =
StringReplacePart[elementName, ToUpperCase[StringTake[elementName, 1]], {1, 1}];
(*Create isotope name*) isotopeName = elementName <> ToString[A];
(*Get mass data*) mass = IsotopeData[isotopeName, "AtomicMass"];
(*Return numeric mass or missing value*) If[mass === Missing["NotAvailable"],
Missing["NotAvailable"], numericMass = QuantityMagnitude[mass];
numericMass]
```

```
(*Energy pattern selection*)
```

```
{startEnergyIndex, endEnergyIndex} =
Switch[energyPattern, 1, {1, 1}, (*0.0253 eV only*) 2, {1, 2},
(*0.0253 eV and 500 keV*) 3, {1, 3}, (*All three energies*) 4,
{2, 2}, (*500 keV only*) 5, {2, 3} (*500 keV and 14 MeV*)];
```

```
(*Isotope existence check function*)
```

```
isIsotopeStable[z_, n_] :=
Module[{element, isotope, mass}, element = ElementData[z, "Name"];
element = StringReplacePart[element, ToUpperCase[StringTake[element, 1]], {1, 1}];
isotope = element <> ToString[z + n];
mass = IsotopeData[isotope, "AtomicMass"];
mass != Missing["NotAvailable"] && NumberQ[QuantityMagnitude[mass]]]
```

```
(*3*) (*Main Nuclear Fission Calculation Function*)
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```
CalculateFissionYields[energyPattern_] := Module[{dataTemp, results = {}},
For[energyIndex = startEnergyIndex, energyIndex ≤ endEnergyIndex, energyIndex++,
(*Set parameters for each energy region*) {promptNeutronCount, incidentEnergy,
effectiveDistance, variableList, yieldList, neutronVariables} =
Switch[energyIndex, 1, {promptNeutrons1, neutronEnergy1, effectiveDistance0253eV,
distanceVars0253eV, fissionYield0253eV, fermiVars0253eV}, (*Thermal*)
2, {promptNeutrons2, neutronEnergy2, effectiveDistance500keV,
distanceVars500keV, fissionYield500keV, fermiVars500keV}, (*Intermediate*)
3, {promptNeutrons3, neutronEnergy3, effectiveDistance14MeV,
distanceVars14MeV, fissionYield14MeV, fermiVars14MeV} (*Fast*)];
dataTemp = Reap[For[protonNumber1 = 23, protonNumber1 ≤ atomicNumber - 23,
protonNumber1++, For[neutronCount1 = 0, neutronCount1 ≤ neutronNumber,
neutronCount1++, protonNumber2 = atomicNumber - protonNumber1;
neutronCount2 = neutronNumber - neutronCount1 - Round[promptNeutronCount];
massNumber1 = protonNumber1 + neutronCount1;
massNumber2 = protonNumber2 + neutronCount2;
```

```
If[(protonNumber1 == 22 && 16 ≤ neutronCount1 ≤ 41) ||
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(protonNumber1 == 23 && 17 <= neutronCount1 <= 42) ||
(protonNumber1 == 24 && 18 <= neutronCount1 <= 43) ||
(protonNumber1 == 25 && 19 <= neutronCount1 <= 44) ||
(protonNumber1 == 26 && 19 <= neutronCount1 <= 46) ||
(protonNumber1 == 27 && 20 <= neutronCount1 <= 48) ||
(protonNumber1 == 28 && 20 <= neutronCount1 <= 50) ||
(protonNumber1 == 29 && 23 <= neutronCount1 <= 51) ||
(protonNumber1 == 30 && 24 <= neutronCount1 <= 53) ||
(protonNumber1 == 31 && 25 <= neutronCount1 <= 55) ||
(protonNumber1 == 32 && 26 <= neutronCount1 <= 57) ||
(protonNumber1 == 33 && 27 <= neutronCount1 <= 59) ||
(protonNumber1 == 34 && 31 <= neutronCount1 <= 60) ||
(protonNumber1 == 35 && 32 <= neutronCount1 <= 62) ||
(protonNumber1 == 36 && 33 <= neutronCount1 <= 64) ||
(protonNumber1 == 37 && 34 <= neutronCount1 <= 65) ||
(protonNumber1 == 38 && 35 <= neutronCount1 <= 67) ||
(protonNumber1 == 39 && 37 <= neutronCount1 <= 69) ||
(protonNumber1 == 40 && 38 <= neutronCount1 <= 70) ||
(protonNumber1 == 41 && 40 <= neutronCount1 <= 72) ||
(protonNumber1 == 42 && 41 <= neutronCount1 <= 73) ||
(protonNumber1 == 43 && 42 <= neutronCount1 <= 75) ||
(protonNumber1 == 44 && 43 <= neutronCount1 <= 76) ||
(protonNumber1 == 45 && 44 <= neutronCount1 <= 77) ||
(protonNumber1 == 46 && 45 <= neutronCount1 <= 78) ||
(protonNumber1 == 47 && 46 <= neutronCount1 <= 83) ||
(protonNumber1 == 48 && 47 <= neutronCount1 <= 84) ||
(protonNumber1 == 49 && 48 <= neutronCount1 <= 86) ||
(protonNumber1 == 50 && 49 <= neutronCount1 <= 87) ||
(protonNumber1 == 51 && 52 <= neutronCount1 <= 88) ||
(protonNumber1 == 52 && 53 <= neutronCount1 <= 90) ||
(protonNumber1 == 53 && 55 <= neutronCount1 <= 91) ||
(protonNumber1 == 54 && 56 <= neutronCount1 <= 93) ||
(protonNumber1 == 55 && 57 <= neutronCount1 <= 96) ||
(protonNumber1 == 56 && 58 <= neutronCount1 <= 97) ||
(protonNumber1 == 57 && 60 <= neutronCount1 <= 98) ||
(protonNumber1 == 58 && 61 <= neutronCount1 <= 99) ||
(protonNumber1 == 59 && 62 <= neutronCount1 <= 100) ||
(protonNumber1 == 60 && 64 <= neutronCount1 <= 101) ||
(protonNumber1 == 61 && 65 <= neutronCount1 <= 102) ||
(protonNumber1 == 62 && 66 <= neutronCount1 <= 103) ||
(protonNumber1 == 63 && 67 <= neutronCount1 <= 104) ||
(protonNumber1 == 64 && 70 <= neutronCount1 <= 105) ||
(protonNumber1 == 65 && 71 <= neutronCount1 <= 106) ||
(protonNumber1 == 66 && 72 <= neutronCount1 <= 107) ||
(protonNumber1 == 67 && 73 <= neutronCount1 <= 108) ||
(protonNumber1 == 68 && 75 <= neutronCount1 <= 109) ||
(protonNumber1 == 69 && 76 <= neutronCount1 <= 110) ||
(protonNumber1 == 70 && 78 <= neutronCount1 <= 111) ||
(protonNumber1 == 71 && 79 <= neutronCount1 <= 111) ||
(protonNumber1 == 72 && 81 <= neutronCount1 <= 116) ||

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(protonNumber1 == 73 && 82 ≤ neutronCount1 ≤ 117) ||
(protonNumber1 == 74 && 84 ≤ neutronCount1 ≤ 118) ||
(protonNumber1 == 75 && 85 ≤ neutronCount1 ≤ 119),
(*Check nuclear chart range for second fragment*)
If[ (protonNumber2 == 22 && 16 ≤ neutronCount2 ≤ 41) ||
(protonNumber2 == 23 && 17 ≤ neutronCount2 ≤ 42) ||
(protonNumber2 == 24 && 18 ≤ neutronCount2 ≤ 43) ||
(protonNumber2 == 25 && 19 ≤ neutronCount2 ≤ 44) ||
(protonNumber2 == 26 && 19 ≤ neutronCount2 ≤ 46) ||
(protonNumber2 == 27 && 20 ≤ neutronCount2 ≤ 48) ||
(protonNumber2 == 28 && 20 ≤ neutronCount2 ≤ 50) ||
(protonNumber2 == 29 && 23 ≤ neutronCount2 ≤ 51) ||
(protonNumber2 == 30 && 24 ≤ neutronCount2 ≤ 53) ||
(protonNumber2 == 31 && 25 ≤ neutronCount2 ≤ 55) ||
(protonNumber2 == 32 && 26 ≤ neutronCount2 ≤ 57) ||
(protonNumber2 == 33 && 27 ≤ neutronCount2 ≤ 59) ||
(protonNumber2 == 34 && 31 ≤ neutronCount2 ≤ 60) ||
(protonNumber2 == 35 && 32 ≤ neutronCount2 ≤ 62) ||
(protonNumber2 == 36 && 33 ≤ neutronCount2 ≤ 64) ||
(protonNumber2 == 37 && 34 ≤ neutronCount2 ≤ 65) ||
(protonNumber2 == 38 && 35 ≤ neutronCount2 ≤ 67) ||
(protonNumber2 == 39 && 37 ≤ neutronCount2 ≤ 69) ||
(protonNumber2 == 40 && 38 ≤ neutronCount2 ≤ 70) ||
(protonNumber2 == 41 && 40 ≤ neutronCount2 ≤ 72) ||
(protonNumber2 == 42 && 41 ≤ neutronCount2 ≤ 73) ||
(protonNumber2 == 43 && 42 ≤ neutronCount2 ≤ 75) ||
(protonNumber2 == 44 && 43 ≤ neutronCount2 ≤ 76) ||
(protonNumber2 == 45 && 44 ≤ neutronCount2 ≤ 77) ||
(protonNumber2 == 46 && 45 ≤ neutronCount2 ≤ 78) ||
(protonNumber2 == 47 && 46 ≤ neutronCount2 ≤ 83) ||
(protonNumber2 == 48 && 47 ≤ neutronCount2 ≤ 84) ||
(protonNumber2 == 49 && 48 ≤ neutronCount2 ≤ 86) ||
(protonNumber2 == 50 && 49 ≤ neutronCount2 ≤ 87) ||
(protonNumber2 == 51 && 52 ≤ neutronCount2 ≤ 88) ||
(protonNumber2 == 52 && 53 ≤ neutronCount2 ≤ 90) ||
(protonNumber2 == 53 && 55 ≤ neutronCount2 ≤ 91) ||
(protonNumber2 == 54 && 56 ≤ neutronCount2 ≤ 93) ||
(protonNumber2 == 55 && 57 ≤ neutronCount2 ≤ 96) ||
(protonNumber2 == 56 && 58 ≤ neutronCount2 ≤ 97) ||
(protonNumber2 == 57 && 60 ≤ neutronCount2 ≤ 98) ||
(protonNumber2 == 58 && 61 ≤ neutronCount2 ≤ 99) ||
(protonNumber2 == 59 && 62 ≤ neutronCount2 ≤ 100) ||
(protonNumber2 == 60 && 64 ≤ neutronCount2 ≤ 101) ||
(protonNumber2 == 61 && 65 ≤ neutronCount2 ≤ 102) ||
(protonNumber2 == 62 && 66 ≤ neutronCount2 ≤ 103) ||
(protonNumber2 == 63 && 67 ≤ neutronCount2 ≤ 104) ||
(protonNumber2 == 64 && 70 ≤ neutronCount2 ≤ 105) ||
(protonNumber2 == 65 && 71 ≤ neutronCount2 ≤ 106) ||
(protonNumber2 == 66 && 72 ≤ neutronCount2 ≤ 107) ||
(protonNumber2 == 67 && 73 ≤ neutronCount2 ≤ 108) ||

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(protonNumber2 == 68 && 75 <= neutronCount2 <= 109) ||
(protonNumber2 == 69 && 76 <= neutronCount2 <= 110) ||
(protonNumber2 == 70 && 78 <= neutronCount2 <= 111) ||
(protonNumber2 == 71 && 79 <= neutronCount2 <= 111) ||
(protonNumber2 == 72 && 81 <= neutronCount2 <= 116) ||
(protonNumber2 == 73 && 82 <= neutronCount2 <= 117) ||
(protonNumber2 == 74 && 84 <= neutronCount2 <= 118) ||
(protonNumber2 == 75 && 85 <= neutronCount2 <= 119),
(*Calculate proton number ratio*) chargeRatio =
N[(protonNumber1/massNumber1)/(protonNumber2/massNumber2)];

(*Update variable lists based on energy region*)
Switch[energyIndex, 1, fermiVars0253eV = Union[AppendTo[distanceVars0253eV,
effectiveDistance0253eV[protonNumber1, protonNumber2]]],
2, fermiVars500keV = Union[AppendTo[distanceVars500keV,
effectiveDistance500keV[protonNumber1, protonNumber2]]],
3, fermiVars14MeV = Union[AppendTo[distanceVars14MeV,
effectiveDistance14MeV[protonNumber1, protonNumber2]]];

(*Calculate physical parameters*)
effectiveDistanceVal = effectiveDistance[protonNumber1, protonNumber2];
coulombEnergy = (1.44 * protonNumber1 * protonNumber2)/effectiveDistanceVal;

(*Calculating Q value*)
qValue = (getNuclearMass[atomicNumber, atomicNumber + neutronNumber] -
getNuclearMass[protonNumber1, massNumber1] -
getNuclearMass[protonNumber2, massNumber2] -
promptNeutronCount * 1.008665) * 931.4940954;

effectiveEnergy = coulombEnergy - qValue;

(*Calculate fission probability*)
probability = 1 / (1 + Exp[2 * Pi / (neutronSeparationEnergy + incidentEnergy) *
Sqrt[protonNumber1 * protonNumber2 / (protonNumber1 + protonNumber2)] /
reducedMass * effectiveEnergy]);

Sow[{protonNumber1, probability}, yieldList];]]],
{yieldList}, Rule][[2, All, 1]];
(*Process results*)
fragmentData = Part[yieldList /. dataTemp];
processYields[data_] :=
(Total@#/{Length@#, Total@data[[All, 2]]/2} &) /@ GatherBy[data, First];
AppendTo[results, {energyIndex, processYields[fragmentData]}];];
results]

(*Execute main calculation*)
fissionResults = CalculateFissionYields[energyPattern];

(*Process results based on energy pattern*)
{yieldData0253eVCalc, yieldData500keVCalc, yieldData14MeVCalc} =

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Switch[energyPattern, 1, {fissionResults[[1, 2]], Null, Null},
      2, {fissionResults[[1, 2]], fissionResults[[2, 2]], Null}, 3,
      {fissionResults[[1, 2]], fissionResults[[2, 2]], fissionResults[[3, 2]]},
      4, {Null, fissionResults[[1, 2]], Null}, 5,
      {Null, fissionResults[[1, 2]], fissionResults[[2, 2]]}];

(*4*) (*Optimization and Result Display Program for Fission Parameters*)
For[energyRegion = startEnergyIndex, energyRegion ≤ endEnergyIndex,
  energyRegion++, (*Setup variables and data for each energy region*)
  {neutronVarList, calcYieldData, fitYieldData, experimentalData, energyDescription,
   theoreticalYield, optimizationResult, fittedData} = Switch[energyRegion, 1,
    {paramList0253eV = Union[fermiVars0253eV], yieldData0253eVCalc, fitYield0253eV =
     yieldData0253eVCalc[[fitStartIndex ;; fitEndIndex]], yieldData0253eV[[
      fitStartIndex ;; fitEndIndex]], "1. Incident Neutron Energy: 0.0253eV",
     theoreticalYield0253eV, optResult0253eV, fittedYield0253eV}, 2,
    {paramList500keV = Union[fermiVars500keV], yieldData500keVCalc,
     fitYield500keV = yieldData500keVCalc[[fitStartIndex ;; fitEndIndex]],
     yieldData500keV[[fitStartIndex ;; fitEndIndex]],
     "2. Incident Neutron Energy: 500keV", theoreticalYield500keV,
     optResult500keV, fittedYield500keV}, 3,
    {paramList14MeV = Union[fermiVars14MeV], yieldData14MeVCalc,
     fitYield14MeV = yieldData14MeVCalc[[fitStartIndex ;; fitEndIndex]],
     yieldData14MeV[[fitStartIndex ;; fitEndIndex]],
     "3. Incident Neutron Energy: 14MeV", theoreticalYield14MeV,
     optResult14MeV, fittedYield14MeV}];
  (*Calculate logarithmic difference between theory and experiment*)
  logDifference = (Log@fitYieldData - Log@experimentalData)[[All, 2]];

  (*Optimize parameters using least squares method*)
  Switch[energyRegion, 1,
    fittedYield0253eV = optResult0253eVRe1[[2, All, All]];
    theoreticalYield0253eV = fitYield0253eV /. optResult0253eVRe1[[2, All, All]], 2,
    fittedYield500keV = optResult500keVRe1[[2, All, All]];
    theoreticalYield500keV = fitYield500keV /. optResult500keVRe1[[2, All, All]], 3,
    fittedYield14MeV = optResult14MeVRe1[[2, All, All]];
    theoreticalYield14MeV = fitYield14MeV /. optResult14MeVRe1[[2, All, All]]];

  (*Display results*)
  Print[Style[energyDescription <> ": Effective Fission Distance Reff
    derived from experimental charge distribution", 16]];

  Print["Analysis Results"];
  Print[
    "Calculation results demonstrating that the effective fission distance Reff " <>
    "derived from optimization calculations
    accurately reproduces experimental values " <>

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"(confirming agreement between JENDL-5 experimental and theoretical values, "<>
"and validating calculations using Mathematica ver11.2 FindMinimum)";
```

```
(*Create visualization plot*)
plotOptions = {Joined → {True, True}, PlotRange → {{15, 80}, {10-12, 5}},
  Epilog → Inset[Style[isotopeName, Bold, 20], Scaled@{0.14, 0.9}],
  PlotMarkers → Automatic, PlotStyle →
    {Directive[PointSize[1/100], Red], Directive[PointSize[1/100], Blue]},
  Frame → True, FrameLabel → {"Atomic Number", "Fission Yield (Independent)"},
  LabelStyle → Directive[Black, 19], FrameTicks → Automatic,
  FrameStyle → {Thick, Thick, Thick, Thick},
  PlotLegends → Placed[PointLegend[Automatic, {"JENDL-5", "Theoretical"},
    Joined → {True, True, True}, Joined → {True, True},
    LabelStyle → Directive[Black, 18], LegendFunction → "Frame",
    LegendLayout → "Column", LegendMarkers → Array[{Graphics@Disk[], 10} &, 3]],
    {{0.65, 0.25}, {1, 0.9}}], AspectRatio → 0.8, ImageSize → 450,
  Epilog → Inset[Style[isotopeName, Bold], Scaled@{0.1, 0.92}]];
Print[ListLogPlot[{experimentalData, theoreticalYield}, Evaluate[plotOptions]]];
```

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Print[
```

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"-----
---"];];
```

```
(*5*)
(*Correlation Analysis of Fragment Charge Product and Effective Fission Distance*)
(*Process data for each energy condition*)
Do[With[{condition = Which[i == 1, {energyPattern == 1 || energyPattern == 2 ||
  energyPattern == 3, correlationData0253eV, fittedYield0253eV,
  "1. Analysis for Incident Neutron Energy: 0.0253eV"}, i == 2,
  {energyPattern == 2 || energyPattern == 3 || energyPattern == 4 || energyPattern == 5,
  correlationData500keV, fittedYield500keV,
  "2. Analysis for Incident Neutron Energy: 500keV"}, i == 3,
  {energyPattern == 3 || energyPattern == 5, correlationData14MeV, fittedYield14MeV,
  "3. Analysis for Incident Neutron Energy: 14MeV"}]], If[condition[[1]],
Switch[condition[[2]], correlationData0253eV, correlationData0253eV =
Thread[{condition[[3]][[All, 1, 1]], condition[[3]][[All, 2]]}][[
  fitStartIndex ;; fitEndIndex]], correlationData500keV, correlationData500keV =
Thread[{condition[[3]][[All, 1, 1]], condition[[3]][[All, 2]]}][[
  fitStartIndex ;; fitEndIndex]], correlationData14MeV, correlationData14MeV =
Thread[{condition[[3]][[All, 1, 1]], condition[[3]][[All, 2]]}][[
  fitStartIndex ;; fitEndIndex]]], {i, 1, 3}];
```

```
Print[
```

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"-----
-"];];
```

```
(*Result explanation and plotting*)
Module[{plotOptions = {Joined → {True, True, True}, PlotRange → {{15, 85}, {0.8, 1.3}},
  Frame → True, FrameLabel → {"Atomic Number", "Effective Distance (fm)"},
```



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LabelStyle → Directive[Black, 19], FrameTicks → Automatic,
FrameStyle → {Thick, Thick, Thick, Thick}, AspectRatio → 1.1, ImageSize → 350}},
(*Define fitting function*)analyzeFittingResults[correlationData_, energyLabel_] :=
Module[{distanceFunction, coeffA, coeffB, coeffC, chargeNumber, normalizedFormula},
Print[Style[energyLabel, FontSize → 16]];
(*Fit quadratic function*)distanceFunction =
Fit[correlationData, {1, x, x^2}, x];
(*Extract coefficients*){coeffC, coeffB, coeffA} =
CoefficientList[distanceFunction, x];
(*Calculate characteristic charge number*)kValue = -coeffA;
chargeNumber = coeffB/kValue;
mValue = coeffC;
(*Display formula*)Print[Column[{Style[HoldForm[Reff] ==
N[mValue, 6] + N[kValue, 6] * (N[chargeNumber, 6] - x) * x, FontSize → 16]}]];
distanceFunction (*Return function for later use*)];
Print["\nAnalysis Results:"];
Print["1. The effective fission distance
Reff shows quadratic dependence on fragment charge"];
Print["2. This dependence reflects fundamental laws of charge
distribution in fission process"];
Print["3. Similar dependence is maintained across different incident energies\n"];
(*Create comparison plot*)plotData = Select[{correlationData0253eV,
correlationData500keV, correlationData14MeV}, Length[#] > 0 &];

(*Create data-dependent color and label lists*)colors = {};
labels = {};
If[Length[correlationData0253eV] > 0, AppendTo[colors, Blue];
AppendTo[labels, "0.0253 eV"]];
If[Length[correlationData500keV] > 0, AppendTo[colors, Green];
AppendTo[labels, "500 keV"]];
If[Length[correlationData14MeV] > 0, AppendTo[colors, Red];
AppendTo[labels, "14 MeV"]];

plotData = Select[{correlationData0253eV,
correlationData500keV, correlationData14MeV}, Length[#] > 0 &];

(*Execute plot*)
Print[ListPlot[plotData, Evaluate[plotOptions],
PlotStyle → {Directive[PointSize[1/100], #] & /@ colors},
PlotLegends → Placed[LineLegend[colors, labels, LabelStyle → 14], {0.82, 0.85}],
Epilog → {Inset[Style[isotopeName, Bold, 15], Scaled@{0.15, 0.85}],
Inset[Style[databaseName, Bold, 15], Scaled@{0.15, 0.90}]}]];

(*Define distance functions for each energy level*)
Module[{fitResult}, (*Define fitting and display functions*)
fitAndPrint[correlationData_, energyLabel_] :=
Module[{distanceFunction, coeffA, coeffB, coeffC, chargeNumber, normalizedFormula},
Print[Style[energyLabel, FontSize → 16]];
(*Fit with quadratic function*)
distanceFunction = Fit[correlationData, {1, x, x^2}, x];
(*Extract coefficients*){coeffC, coeffB, coeffA} =

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CoefficientList[distanceFunction, x];
(*Calculate characteristic charge number*) kValue = -coeffA;
chargeNumber = coeffB/kValue;
mValue = coeffC;
(*Display formula*) Print[Column[{Style[HoldForm[Reff] ==
    N[mValue, 6] + N[kValue, 6] * (N[chargeNumber, 6] - x) * x, FontSize -> 16]}]];
distanceFunction (*Return function*);
(*For 0.0253 eV case*)
If[energyPattern == 1 || energyPattern == 2 || energyPattern == 3, distanceFunction0253eV =
    fitAndPrint[correlationData0253eV, "Incident Neutron Energy: 0.0253 eV case"]];
(*For 500 keV case*) If[energyPattern == 2 || energyPattern == 3 ||
    energyPattern == 4 || energyPattern == 5, distanceFunction500keV =
    fitAndPrint[correlationData500keV, "Incident Neutron Energy: 500 keV case"]];
(*For 14 MeV case*) If[energyPattern == 3 || energyPattern == 5, distanceFunction14MeV =
    fitAndPrint[correlationData14MeV, "Incident Neutron Energy: 14 MeV case"]];
Print["\nAnalysis Results:"];
Print["1. The effective fission distance
    Reff shows quadratic dependence on fragment charge number"];
Print["2. This dependence reflects fundamental laws of charge
    distribution in the fission process"];
Print["3. Similar dependence is maintained across different incident energies\n"];

(*6*) (*Display and Analysis of Reff Values by Atomic Number*)
(*Output header for display*) Print[Style[
    "Table of Effective Fission Distance (Reff) Values by Atomic Number [Unit: fm]:",
    Bold, 16]];
Print[Style["Displaying calculated values (pre-fitting)
    and post-fitting values for each energy", 14]];
Print[Style["Fitting calculation used fragment values from atomic number "<>
    ToString[fitStartZ] <> " to " <> ToString[fitEndZ], 14]];

(*Create headers based on energy pattern*)
tableHeaders = Switch[energyPattern, 1,
    {"Z1", "Z2", "Reff [fm]\n(0.0253 eV)\nCalculated", "Fitted Value"},
    2, {"Z1", "Z2", "Reff [fm]\n(0.0253 eV)\nCalculated", "Fitted Value",
        "Reff [fm]\n(500 keV)\nCalculated", "Fitted Value"}, 3,
    {"Z1", "Z2", "Reff [fm]\n(0.0253 eV)\nCalculated", "Fitted Value",
        "Reff [fm]\n(500 keV)\nCalculated", "Fitted Value",
        "Reff [fm]\n(14 MeV)\nCalculated", "Fitted Value"}, 4,
    {"Z1", "Z2", "Reff [fm]\n(500 keV)\nCalculated", "Fitted Value"}, 5,
    {"Z1", "Z2", "Reff [fm]\n(500 keV)\nCalculated", "Fitted Value",
        "Reff [fm]\n(14 MeV)\nCalculated", "Fitted Value"}];

(*Function to get fitted value*)
getFittedDistanceValue[atomicNumber_, distanceFunction_] :=
    If[fitStartZ <= atomicNumber <= fitEndZ,
        NumberForm[N[distanceFunction /. x -> atomicNumber], {6, 5}], "-"];

(*Create data table*)
tableData =
    Table[Module[{z1 = z, z2 = atomicNumber - z}, Flatten[{z1, z2, (*0.0253 eV data*)

```

```

Which[energyPattern == 1 || energyPattern == 2 || energyPattern == 3,
  {NumberForm[N[effectiveDistance0253eV[z1, z2] /. fittedYield0253eV], {6, 6}},
  getFittedDistanceValue[z1, distanceFunction0253eV]}, True, {}],
(*500 keV data*)Which[energyPattern == 2 || energyPattern == 3 ||
  energyPattern == 4 || energyPattern == 5,
  {NumberForm[N[effectiveDistance500keV[z1, z2] /. fittedYield500keV], {6, 6}},
  getFittedDistanceValue[z1, distanceFunction500keV]}, True, {}],
(*14 MeV data*)Which[energyPattern == 3 || energyPattern == 5,
  {NumberForm[N[effectiveDistance14MeV[z1, z2] /. fittedYield14MeV], {6, 6}},
  getFittedDistanceValue[z1, distanceFunction14MeV]},
True, {}]]], {z, 23, 69}];

(*Output formatted table*)
Grid[Prepend[tableData, tableHeaders], Frame → All, Alignment → Center,
  Background → {None, {LightGray, None}}, ItemStyle → {Bold, "Text"},
  Dividers → {Join[{2}, Table[2 i + 2, {i, 1, Length[tableHeaders] / 2 - 1}]] → True,
  {2 → True}}, Spacings → {1.5, 1.2}]

(*7*) (*Generate Effective Fission Distance Functions*)
(*Generate functions for each energy region*)
If[energyPattern == 1 || energyPattern == 2 || energyPattern == 3,
  distanceData0253eV = Table[{x, atomicNumber - x} → distanceFunction0253eV,
    {x, fitStartZ - 6, fitEndZ + 6}]];

If[energyPattern == 2 || energyPattern == 3 || energyPattern == 4 || energyPattern == 5,
  distanceData500keV = Table[{x, atomicNumber - x} → distanceFunction500keV,
    {x, fitStartZ - 6, fitEndZ + 6}]];

If[energyPattern == 3 || energyPattern == 5, distanceData14MeV =
  Table[{x, atomicNumber - x} → distanceFunction14MeV, {x, fitStartZ - 6, fitEndZ + 6}]];

(*Define effective distance functions*)
If[energyPattern == 1 || energyPattern == 2 || energyPattern == 3, effDistanceFunc0253eV =
  Thread[Thread[effectiveDistance0253eV[distanceData0253eV[[All, 1, 1]],
    distanceData0253eV[[All, 1, 2]]]] → distanceData0253eV[[All, 2]]]];

If[energyPattern == 2 || energyPattern == 3 || energyPattern == 4 || energyPattern == 5,
  effDistanceFunc500keV =
  Thread[Thread[effectiveDistance500keV[distanceData500keV[[All, 1, 1]],
    distanceData500keV[[All, 1, 2]]]] → distanceData500keV[[All, 2]]]];

If[energyPattern == 3 || energyPattern == 5, effDistanceFunc14MeV =
  Thread[Thread[effectiveDistance14MeV[distanceData14MeV[[All, 1, 1]],
    distanceData14MeV[[All, 1, 2]]]] → distanceData14MeV[[All, 2]]]];

(*Calculate final yield data*)
If[energyPattern == 1 || energyPattern == 2 || energyPattern == 3,
  finalYield0253eV = fitYield0253eV /. effDistanceFunc0253eV];

If[energyPattern == 2 || energyPattern == 3 || energyPattern == 4 || energyPattern == 5,
  finalYield500keV = fitYield500keV /. effDistanceFunc500keV];

If[energyPattern == 3 || energyPattern == 5,

```

```

finalYield14MeV = fitYield14MeV /. effDistanceFunc14MeV];

(*Display separator*)
Print[
  "-----
  -"];

(*8*)(*Comparison of Experimental and Theoretical Fission Yields*)
(*Display analysis summary*)
Print["Analysis of Fission Yields: Comparison
      between Experimental Data and Theoretical Calculations (Ex=0)"];
Print["\nTheoretical Analysis Results using Effective Fission
      Distance Reff proportional to fragment charge product,"];
Print["with zero Fermi Energy (Ex=0)"];
Print["- Quantitative reproduction of
      experimentally observed asymmetric fission yield distributions"];

(*Create common plot settings*)
commonPlotSettings = {Joined -> {True, True},
  PlotRange -> {{15, 80}, {10^(-12), 100}}, PlotMarkers -> Automatic,
  Frame -> True, FrameLabel -> {"Atomic Number", "Fission Yield (Independent)
  "}, LabelStyle -> Directive[Black, 19], FrameTicks -> Automatic,
  FrameStyle -> {Thick, Thick, Thick, Thick}, AspectRatio -> 0.8, ImageSize -> 450};

(*Legend settings*)
legendSettings = Placed[PointLegend[Automatic,
  {"JENDL-5 (Experimental)", "Theoretical curve (Fermi Energy=0)"},
  Joined -> {True, True}, LabelStyle -> Directive[Black, 15],
  LegendFunction -> "Frame", LegendLayout -> "Column",
  LegendMarkers -> Array[Graphics@Disk[], 10] & 3], {{0.26, 0.23}, {0.2, 0.9}}];

(*Plot style settings*)
plotStyles = {Directive[PointSize[1/100], Red],
  Directive[PointSize[1/100], Blue], Directive[PointSize[1/100], Green]};

(*Generate plots for each energy region*)
If[energyPattern == 1 || energyPattern == 2 || energyPattern == 3,
  Print["1. Analysis for Incident Neutron Energy: 0.0253eV"];
  Print[ListLogPlot[{yieldData0253eV[[fitStartIndex ;; fitEndIndex]],
    finalYield0253eV}, Evaluate[commonPlotSettings],
    PlotStyle -> plotStyles, PlotLegends -> legendSettings,
    Epilog -> {Inset[Style[isotopeName, 20, Bold], Scaled@{0.16, 0.9}]}];];

If[energyPattern == 2 || energyPattern == 3 || energyPattern == 4 || energyPattern == 5,
  Print["2. Analysis for Incident Neutron Energy: 500keV"];
  Print[ListLogPlot[{yieldData500keV[[fitStartIndex ;; fitEndIndex]],
    finalYield500keV}, Evaluate[commonPlotSettings],

```

```

PlotStyle → plotStyles, PlotLegends → legendSettings,
Epilog → {Inset[Style[isotopeName, 20, Bold], Scaled@{0.16, 0.9}]}];];];

If[energyPattern == 3 || energyPattern == 5,
Print["3. Analysis for Incident Neutron Energy: 14MeV"];
Print[ListLogPlot[{yieldData14MeV[[fitStartIndex ;; fitEndIndex]], finalYield14MeV},
Evaluate[commonPlotSettings], PlotStyle → plotStyles, PlotLegends → legendSettings,
Epilog → {Inset[Style[isotopeName, 20, Bold], Scaled@{0.16, 0.9}]}];];];

(*9*) (*Analysis of Effective Fission Distance and Fission Probability*)
(*Display section separator*)Print[
"-----
-"];
Print["Analysis of Effective Fission Distance and Fission Probability"];
Print[""];
Print["Analysis Contents:"];
Print["1. Calculation of Effective
      Fission Distance (Reff) for each incident neutron energy"];
Print["2. Evaluation of fission probability using  $\eta$  function"];
Print["3. Derivation of normalization factor  $\kappa$  (=  $E_x/\text{Reff}$ )"];
Print[""];
Print["The vertical axis  $\kappa$  represents the ratio of Fermi Energy( $E_x$ )"];
Print["to effective fission distance (Reff)."];
Print[
"  $\kappa \approx 1$  suggests the fission Fermi Energy is proportional to effective distance."];
Print[
"-----
-"];

(*Analysis and visualization module*)
Module[{}, (*Process for each incident neutron energy*)
(*1. Calculate effective fission distance function values*)
(*2. Calculate fission probability using  $\eta$  function*)
(*3. Calculate normalization factor  $\kappa$ *)
If[energyPattern == 1 || energyPattern == 2 || energyPattern == 3, distanceData0253eV =
Table[{x, atomicNumber - x} → distanceFunction0253eV, {x, fitStartZ, fitEndZ}];
distanceFunc0253eV = Thread[Thread[effectiveDistance0253eV[distanceData0253eV[[All,
1, 1]], distanceData0253eV[[All, 1, 2]]]] → distanceData0253eV[[All, 2]]];
normFactor0253eV = Thread[{distanceData0253eV[[All, 1, 1]],
fittedYield0253eV[[All, 2]] [[fitStartIndex ;; fitEndIndex]] /
distanceFunc0253eV[[All, 2]]}];];
If[energyPattern == 2 || energyPattern == 3 || energyPattern == 4 || energyPattern == 5,
distanceData500keV =
Table[{x, atomicNumber - x} → distanceFunction500keV, {x, fitStartZ, fitEndZ}];
distanceFunc500keV = Thread[Thread[effectiveDistance500keV[distanceData500keV[[All,
1, 1]], distanceData500keV[[All, 1, 2]]]] → distanceData500keV[[All, 2]]];
normFactor500keV = Thread[{distanceData500keV[[All, 1, 1]],
fittedYield500keV[[All, 2]] [[fitStartIndex ;; fitEndIndex]] /
distanceFunc500keV[[All, 2]]}];];
If[energyPattern == 3 || energyPattern == 5, distanceData14MeV =
Table[{x, atomicNumber - x} → distanceFunction14MeV, {x, fitStartZ, fitEndZ}];

```

```

distanceFunc14MeV = Thread[Thread[effectiveDistance14MeV[distanceData14MeV[[All,
    1, 1]], distanceData14MeV[[All, 1, 2]]]] → distanceData14MeV[[All, 2]]];
normFactor14MeV = Thread[{distanceData14MeV[[All, 1, 1]],
    fittedYield14MeV[[All, 2]][[fitStartIndex ;; fitEndIndex]] /
    distanceFunc14MeV[[All, 2]]}];];
(*Common plot options*)
plotOptions =
{Joined → {True, True}, PlotRange → {{15, 80}, {0.9, 1.1}}, PlotMarkers → Automatic,
    Frame → True, FrameLabel → {"Atomic Number", "Normalization Factor  $\kappa$  = Ex/Reff"},
    LabelStyle → Directive[Black, 19], FrameTicks → Automatic,
    FrameStyle → {Thick, Thick, Thick, Thick}, AspectRatio → 1, ImageSize → 400};
(*Create visualization based on energy pattern*)
Switch[energyPattern, 1, Print[ListPlot[{normFactor0253eV},
    Evaluate[plotOptions], PlotStyle → {Directive[PointSize[1/100], Blue]},
    PlotLegends → Placed[PointLegend[{"0.0253eV"}, LabelStyle → 14,
        LegendFunction → "Frame"], {{0.975, 0.925}, {1, 0.9}}],
    Epilog → {Inset[Style[isotopeName, Bold, 14], Scaled@{0.15, 0.95}],
        Inset[Style[databaseName, Bold, 14], Scaled@{0.15, 0.90}]}], 2, Print[
ListPlot[{normFactor0253eV, normFactor500keV}, Evaluate[plotOptions], PlotStyle →
    {Directive[PointSize[1/100], Blue], Directive[PointSize[1/100], Green]},
    PlotLegends → Placed[PointLegend[{"0.0253eV", "500keV"}, LabelStyle → 14,
        LegendFunction → "Frame"], {{0.975, 0.925}, {1, 0.9}}],
    Epilog → {Inset[Style[isotopeName, Bold, 14], Scaled@{0.15, 0.95}],
        Inset[Style[databaseName, Bold, 14], Scaled@{0.15, 0.90}]}], 3,
Print[ListPlot[{normFactor0253eV, normFactor500keV, normFactor14MeV},
    Evaluate[plotOptions], PlotStyle → {Directive[PointSize[1/100], Blue],
        Directive[PointSize[1/100], Green], Directive[PointSize[1/100], Red]},
    PlotLegends → Placed[PointLegend[{"0.0253eV", "500keV", "14MeV"},
        LabelStyle → 14, LegendFunction → "Frame"], {{0.975, 0.925}, {1, 0.9}}],
    Epilog → {Inset[Style[isotopeName, Bold, 14], Scaled@{0.15, 0.95}],
        Inset[Style[databaseName, Bold, 14], Scaled@{0.15, 0.90}]}], 4, Print[
ListPlot[{normFactor500keV}, Evaluate[plotOptions],
    PlotStyle → {Directive[PointSize[1/100], Green]},
    PlotLegends → Placed[PointLegend[{"500keV"}, LabelStyle → 14,
        LegendFunction → "Frame"], {{0.975, 0.925}, {1, 0.9}}],
    Epilog → {Inset[Style[isotopeName, Bold, 14], Scaled@{0.15, 0.95}],
        Inset[Style[databaseName, Bold, 14], Scaled@{0.15, 0.90}]}], 5, Print[
ListPlot[{normFactor500keV, normFactor14MeV}, Evaluate[plotOptions], PlotStyle →
    {Directive[PointSize[1/100], Green], Directive[PointSize[1/100], Red]},
    PlotLegends → Placed[PointLegend[{"500keV", "14MeV"}, LabelStyle → 14,
        LegendFunction → "Frame"], {{0.975, 0.925}, {1, 0.9}}],
    Epilog → {Inset[Style[isotopeName, Bold, 14], Scaled@{0.15, 0.95}],
        Inset[Style[databaseName, Bold, 14], Scaled@{0.15, 0.90}]}];];];
Print[
"-----
-"];

(*10*) (*Initialize Fermi Energy Variables and Main Calculation Function*)
(*Initialize Fermi Energy*)

```

```

fermiEnergy0253eV = .;
fermiEnergy500keV = .;
fermiEnergy14MeV = .;

(*Initialize parameter lists for each energy region*)
paramList0253eV = {};
paramList500keV = {};
paramList14MeV = {};

paramList5 = {};
paramList6 = {};
paramList7 = {};

(*Nuclear Fission Calculation Main Function*)
CalculateFissionYieldsWithfermi[energyPattern_] := Module[{tempData, results = {}},
  For[energyIndex = startEnergyIndex, energyIndex ≤ endEnergyIndex,
    energyIndex++, (*Set parameters for each energy region*)
    {promptNeutronCount, incidentEnergy, fermiEnergy, parameterList, yieldList,
      neutronVarList, effectiveDist, distanceFunc} = Switch[energyIndex, 1,
      {promptNeutrons1, neutronEnergy1, fermiEnergy0253eV, paramList0253eV,
        fissionYield0253eV, paramList5, effectiveDist0253eV, distanceFunction0253eV},
      (*Thermal*) 2, {promptNeutrons2, neutronEnergy2, fermiEnergy500keV,
        paramList500keV, fissionYield500keV, paramList6, effectiveDist500keV,
        distanceFunction500keV}, (*Intermediate*) 3, {promptNeutrons3,
        neutronEnergy3, fermiEnergy14MeV, paramList14MeV, fissionYield1400keV,
        paramList7, effectiveDist14MeV, distanceFunction14MeV} (*Fast*)];
  tempData = Reap[For[protonNumber1 = 23, protonNumber1 ≤ atomicNumber - 23,
    protonNumber1++, For[neutronCount1 = 0, neutronCount1 ≤ neutronNumber,
      neutronCount1++, protonNumber2 = atomicNumber - protonNumber1;
      neutronCount2 = neutronNumber - neutronCount1 - Round[promptNeutronCount];
      massNumber1 = protonNumber1 + neutronCount1;
      massNumber2 = protonNumber2 + neutronCount2;

      (*Check fragment existence*)

      If[(protonNumber1 == 22 && 16 ≤ neutronCount1 ≤ 41) ||
        (protonNumber1 == 23 && 17 ≤ neutronCount1 ≤ 42) ||
        (protonNumber1 == 24 && 18 ≤ neutronCount1 ≤ 43) ||
        (protonNumber1 == 25 && 19 ≤ neutronCount1 ≤ 44) ||
        (protonNumber1 == 26 && 19 ≤ neutronCount1 ≤ 46) ||
        (protonNumber1 == 27 && 20 ≤ neutronCount1 ≤ 48) ||
        (protonNumber1 == 28 && 20 ≤ neutronCount1 ≤ 50) ||
        (protonNumber1 == 29 && 23 ≤ neutronCount1 ≤ 51) ||
        (protonNumber1 == 30 && 24 ≤ neutronCount1 ≤ 53) ||
        (protonNumber1 == 31 && 25 ≤ neutronCount1 ≤ 55) ||
        (protonNumber1 == 32 && 26 ≤ neutronCount1 ≤ 57) ||
        (protonNumber1 == 33 && 27 ≤ neutronCount1 ≤ 59) ||
        (protonNumber1 == 34 && 31 ≤ neutronCount1 ≤ 60) ||
        (protonNumber1 == 35 && 32 ≤ neutronCount1 ≤ 62) ||
        (protonNumber1 == 36 && 33 ≤ neutronCount1 ≤ 64) ||
        (protonNumber1 == 37 && 34 ≤ neutronCount1 ≤ 65) ||
        (protonNumber1 == 38 && 35 ≤ neutronCount1 ≤ 67) ||

```

```

(protonNumber1 == 39 && 37 <= neutronCount1 <= 69) ||
(protonNumber1 == 40 && 38 <= neutronCount1 <= 70) ||
(protonNumber1 == 41 && 40 <= neutronCount1 <= 72) ||
(protonNumber1 == 42 && 41 <= neutronCount1 <= 73) ||
(protonNumber1 == 43 && 42 <= neutronCount1 <= 75) ||
(protonNumber1 == 44 && 43 <= neutronCount1 <= 76) ||
(protonNumber1 == 45 && 44 <= neutronCount1 <= 77) ||
(protonNumber1 == 46 && 45 <= neutronCount1 <= 78) ||
(protonNumber1 == 47 && 46 <= neutronCount1 <= 83) ||
(protonNumber1 == 48 && 47 <= neutronCount1 <= 84) ||
(protonNumber1 == 49 && 48 <= neutronCount1 <= 86) ||
(protonNumber1 == 50 && 49 <= neutronCount1 <= 87) ||
(protonNumber1 == 51 && 52 <= neutronCount1 <= 88) ||
(protonNumber1 == 52 && 53 <= neutronCount1 <= 90) ||
(protonNumber1 == 53 && 55 <= neutronCount1 <= 91) ||
(protonNumber1 == 54 && 56 <= neutronCount1 <= 93) ||
(protonNumber1 == 55 && 57 <= neutronCount1 <= 96) ||
(protonNumber1 == 56 && 58 <= neutronCount1 <= 97) ||
(protonNumber1 == 57 && 60 <= neutronCount1 <= 98) ||
(protonNumber1 == 58 && 61 <= neutronCount1 <= 99) ||
(protonNumber1 == 59 && 62 <= neutronCount1 <= 100) ||
(protonNumber1 == 60 && 64 <= neutronCount1 <= 101) ||
(protonNumber1 == 61 && 65 <= neutronCount1 <= 102) ||
(protonNumber1 == 62 && 66 <= neutronCount1 <= 103) ||
(protonNumber1 == 63 && 67 <= neutronCount1 <= 104) ||
(protonNumber1 == 64 && 70 <= neutronCount1 <= 105) ||
(protonNumber1 == 65 && 71 <= neutronCount1 <= 106) ||
(protonNumber1 == 66 && 72 <= neutronCount1 <= 107) ||
(protonNumber1 == 67 && 73 <= neutronCount1 <= 108) ||
(protonNumber1 == 68 && 75 <= neutronCount1 <= 109) ||
(protonNumber1 == 69 && 76 <= neutronCount1 <= 110) ||
(protonNumber1 == 70 && 78 <= neutronCount1 <= 111) ||
(protonNumber1 == 71 && 79 <= neutronCount1 <= 111) ||
(protonNumber1 == 72 && 81 <= neutronCount1 <= 116) ||
(protonNumber1 == 73 && 82 <= neutronCount1 <= 117) ||
(protonNumber1 == 74 && 84 <= neutronCount1 <= 118) ||
(protonNumber1 == 75 && 85 <= neutronCount1 <= 119),
(*Check nuclear chart range for second fragment*)
If[(protonNumber2 == 22 && 16 <= neutronCount2 <= 41) ||
(protonNumber2 == 23 && 17 <= neutronCount2 <= 42) ||
(protonNumber2 == 24 && 18 <= neutronCount2 <= 43) ||
(protonNumber2 == 25 && 19 <= neutronCount2 <= 44) ||
(protonNumber2 == 26 && 19 <= neutronCount2 <= 46) ||
(protonNumber2 == 27 && 20 <= neutronCount2 <= 48) ||
(protonNumber2 == 28 && 20 <= neutronCount2 <= 50) ||
(protonNumber2 == 29 && 23 <= neutronCount2 <= 51) ||
(protonNumber2 == 30 && 24 <= neutronCount2 <= 53) ||
(protonNumber2 == 31 && 25 <= neutronCount2 <= 55) ||
(protonNumber2 == 32 && 26 <= neutronCount2 <= 57) ||
(protonNumber2 == 33 && 27 <= neutronCount2 <= 59) ||

```



```

(protonNumber2 == 34 && 31 <= neutronCount2 <= 60) ||
(protonNumber2 == 35 && 32 <= neutronCount2 <= 62) ||
(protonNumber2 == 36 && 33 <= neutronCount2 <= 64) ||
(protonNumber2 == 37 && 34 <= neutronCount2 <= 65) ||
(protonNumber2 == 38 && 35 <= neutronCount2 <= 67) ||
(protonNumber2 == 39 && 37 <= neutronCount2 <= 69) ||
(protonNumber2 == 40 && 38 <= neutronCount2 <= 70) ||
(protonNumber2 == 41 && 40 <= neutronCount2 <= 72) ||
(protonNumber2 == 42 && 41 <= neutronCount2 <= 73) ||
(protonNumber2 == 43 && 42 <= neutronCount2 <= 75) ||
(protonNumber2 == 44 && 43 <= neutronCount2 <= 76) ||
(protonNumber2 == 45 && 44 <= neutronCount2 <= 77) ||
(protonNumber2 == 46 && 45 <= neutronCount2 <= 78) ||
(protonNumber2 == 47 && 46 <= neutronCount2 <= 83) ||
(protonNumber2 == 48 && 47 <= neutronCount2 <= 84) ||
(protonNumber2 == 49 && 48 <= neutronCount2 <= 86) ||
(protonNumber2 == 50 && 49 <= neutronCount2 <= 87) ||
(protonNumber2 == 51 && 52 <= neutronCount2 <= 88) ||
(protonNumber2 == 52 && 53 <= neutronCount2 <= 90) ||
(protonNumber2 == 53 && 55 <= neutronCount2 <= 91) ||
(protonNumber2 == 54 && 56 <= neutronCount2 <= 93) ||
(protonNumber2 == 55 && 57 <= neutronCount2 <= 96) ||
(protonNumber2 == 56 && 58 <= neutronCount2 <= 97) ||
(protonNumber2 == 57 && 60 <= neutronCount2 <= 98) ||
(protonNumber2 == 58 && 61 <= neutronCount2 <= 99) ||
(protonNumber2 == 59 && 62 <= neutronCount2 <= 100) ||
(protonNumber2 == 60 && 64 <= neutronCount2 <= 101) ||
(protonNumber2 == 61 && 65 <= neutronCount2 <= 102) ||
(protonNumber2 == 62 && 66 <= neutronCount2 <= 103) ||
(protonNumber2 == 63 && 67 <= neutronCount2 <= 104) ||
(protonNumber2 == 64 && 70 <= neutronCount2 <= 105) ||
(protonNumber2 == 65 && 71 <= neutronCount2 <= 106) ||
(protonNumber2 == 66 && 72 <= neutronCount2 <= 107) ||
(protonNumber2 == 67 && 73 <= neutronCount2 <= 108) ||
(protonNumber2 == 68 && 75 <= neutronCount2 <= 109) ||
(protonNumber2 == 69 && 76 <= neutronCount2 <= 110) ||
(protonNumber2 == 70 && 78 <= neutronCount2 <= 111) ||
(protonNumber2 == 71 && 79 <= neutronCount2 <= 111) ||
(protonNumber2 == 72 && 81 ≤ neutronCount2 ≤ 116) ||
(protonNumber2 == 73 && 82 ≤ neutronCount2 ≤ 117) ||
(protonNumber2 == 74 && 84 ≤ neutronCount2 ≤ 118) ||
(protonNumber2 == 75 && 85 ≤ neutronCount2 ≤ 119),

```

```

Switch[energyIndex, 1, paramList5 = Union[AppendTo[paramList0253eV,
fermiEnergy0253eV[protonNumber1, protonNumber2]], 2,
paramList6 = Union[AppendTo[paramList500keV, fermiEnergy500keV[
protonNumber1, protonNumber2]], 3, paramList7 = Union[AppendTo[
paramList14MeV, fermiEnergy14MeV[protonNumber1, protonNumber2]]];
(*Calculate fission parameters*)effectiveDistVal =

```

```

distanceFunc /. x → protonNumber1;
coulombEnergy = (1.44 * protonNumber1 * protonNumber2) / effectiveDistVal;
qValue = (getNuclearMass[atomicNumber, atomicNumber + neutronNumber] -
  getNuclearMass[protonNumber1, massNumber1] -
  getNuclearMass[protonNumber2, massNumber2] -
  promptNeutronCount * 1.008665) * 931.4940954;
effectiveEnergy = coulombEnergy - qValue;
(*Calculate fission probability with fermi correction*)
probability = 1 / (1 + Exp[2 * Pi / (neutronSeparationEnergy + incidentEnergy) *
  Sqrt[protonNumber1 * protonNumber2 / (protonNumber1 + protonNumber2)] /
  reducedMass * (effectiveEnergy -
    fermiEnergy[protonNumber1, protonNumber2])]);
 Sow[{protonNumber1, probability}, yieldList];]]], {yieldList}, Rule][[
  2, All, 1]];
(*Process results*) fragmentData = Part[yieldList /. tempData];
processYields[data_] :=
  (Total@# / {Length@#, Total@data[[All, 2]] / 2} &) /@ GatherBy[data, First];
AppendTo[results, {energyIndex, processYields[fragmentData]}];
results]

(*Execute calculation with Pattern selection*)
{startEnergyIndex, endEnergyIndex} =
  Switch[energyPattern, 1, {1, 1}, 2, {1, 2}, 3, {1, 3}, 4, {2, 2}, 5, {2, 3}];

(*Main calculation*)
results = CalculateFissionYieldsWithfermi[energyPattern];
{yieldData0253eVCalc, yieldData500keVCalc, yieldData14MeVCalc} =
  Switch[energyPattern, 1, {results[[1, 2]], Null, Null}, 2, {results[[1, 2]],
    results[[2, 2]], Null}, 3, {results[[1, 2]], results[[2, 2]], results[[3, 2]]}, 4,
    {Null, results[[1, 2]], Null}, 5, {Null, results[[1, 2]], results[[2, 2]]}];

(*11*)

(*Common Plot Generation Functions for Fission Yields*)
(*Define general yield plot function*)
CreateFissionYieldPlot[experimentalData_, calculatedData_, energyLabel_, plotColor_] :=
  ListLogPlot[{experimentalData, calculatedData}, (*Basic plot settings*)
    Joined → {True, True}, PlotRange → {{15, 80}, {10-12, 100}}, PlotMarkers →
    Automatic, (*Style settings*)PlotStyle → {Directive[PointSize[1/100], Red],
    Directive[PointSize[1/100], plotColor]}, (*Frame settings*)
    Frame → True, FrameLabel → {"Atomic Number", "Fission Yield (Independent)"},
    LabelStyle → Directive[Black, 19], FrameTicks → Automatic,
    FrameStyle → {Thick, Thick, Thick, Thick}, (*Legend settings*)
    PlotLegends → Placed[PointLegend[Automatic, {"JENDL-5", "Theoretical Curve"},
    Joined → {True, True, True}, Joined → {True, True},
    LabelStyle → 16, LegendFunction → "Frame", LegendLayout → "Column",
    LegendMarkers → Array[{Graphics@Disk[], 10} &, 3]], {{0.72, 0.25}, {1, 0.9}}],
    (*Layout settings*)AspectRatio → 0.8, ImageSize → 400, (*Title and isotope
    label*)Epilog → Inset[Style[isotopeName, Bold, 18], Scaled@{0.14, 0.94}]];

(*Define data analysis function*)
AnalyzeIsotopeYield[yieldData_, label_] :=
  Module[{maxZ1, maxZ2, maxYield1, maxYield2, peakAvgYield},
    (*Display analysis header*)Print[label];

```

```

(*Find primary peak*)
maxZ1 = Position[yieldData, Max[yieldData[[All, 2]]]][[1, 1]] + fitStartZ - 1;
maxZ2 = atomicNumber - maxZ1;
maxYield1 = Max[yieldData[[All, 2]]];
maxYield2 = yieldData[[maxZ2 - fitStartZ + 1]][[2]];
(*Display isotope information*)
For[atomicNum = 23, atomicNum ≤ 71, atomicNum++,
  If[maxZ1 == atomicNum, Print["Primary Fragment: ", ElementData[atomicNum, "Name"],
    "(Z=", atomicNum, ")", "; Yield: ", maxYield1, " MeV"]];
  If[maxZ2 == atomicNum, Print["Secondary Fragment: ", ElementData[atomicNum, "Name"],
    "(Z=", atomicNum, ")", "; Yield: ", maxYield2, " MeV"]];];
(*Calculate and display average peak yield*)
peakAvgYield = (maxYield1 + maxYield2) / 2;
Print["Average Peak Yield: ", peakAvgYield, " MeV"];
Print[
  "-----
  ---"];];

(*12*) (*Optimization Program for Fermi Energy*) (*Display program description*)
Print[
  "Theoretical Analysis and Experimental Comparison of Fission Yield Distributions"];
Print[""];
Print["Calculation Process:"];
Print["1. Evaluate logarithmic differences between
  JENDL-5 experimental data and theoretical calculations"];
Print["2. Optimize Fermi Energy (Ex) using least squares method"];
Print["3. Generate theoretical curves using optimized Ex"];
Print["4. Compare and verify experimental vs theoretical values"];
Print[""];
Print["Optimization Goals:"];
Print[
  " · Theoretical reproduction of experimentally observed asymmetric fission yields"];
Print[" · Understanding fission mechanisms at each incident neutron energy"];
Print[" · Systematic determination of Fermi Energy (Ex)"];
Print[""];
Print["Evaluation Methods:"];
Print[
  " · Minimize sum of squared logarithmic differences between theory and experiment"];
Print[" · Parameter optimization using FindMinimum function"];
Print[" · Validation of theoretical curves with optimized parameters"];
Print[
  "-----
  -"];];

(*Main optimization loop for each energy region*)
For[energyRegion = startEnergyIndex, energyRegion ≤ endEnergyIndex, energyRegion++,

(*Initialize variables for each energy region*)
If[energyRegion == 1,

```

```

fermiParams0253eV = Union[paramList5] (*Thermal neutron parameters*);
If[energyRegion == 2, fermiParams500keV = Union[paramList6]
  (*Intermediate energy parameters*)];
If[energyRegion == 3, fermiParams14MeV = Union[paramList7]
  (*Fast neutron parameters*)];

(*Prepare experimental data*)
If[energyRegion == 1,
  expData = yieldData0253eV[[fitStartIndex ;; fitEndIndex]] (*JENDL-5 0.0253eV*);
If[energyRegion == 2, expData = yieldData500keV[[fitStartIndex ;; fitEndIndex]]
  (*JENDL-5 500keV*)];
If[energyRegion == 3, expData = yieldData14MeV[[fitStartIndex ;; fitEndIndex]]
  (*JENDL-5 14MeV*)];

(*Prepare theoretical calculation data*)
If[energyRegion == 1,
  yieldData0253eVTheory = yieldData0253eVCalc[[fitStartIndex ;; fitEndIndex]]];
If[energyRegion == 2, yieldData500keVTheory =
  yieldData500keVCalc[[fitStartIndex ;; fitEndIndex]]];
If[energyRegion == 3, yieldData14MeVTheory =
  yieldData14MeVCalc[[fitStartIndex ;; fitEndIndex]]];

(*Store optimized parameters*)
If[energyRegion == 1, fittedParams0253eV = optResult0253eVRe2[[2, All, All]]];
If[energyRegion == 2, fittedParams500keV = optResult500keVRe2[[2, All, All]]];
If[energyRegion == 3, fittedParams14MeV = optResult14MeVRe2[[2, All, All]]];
(*Display optimized parameters*)
If[energyRegion == 1, Print[fittedParams0253eV[[fitStartIndex ;; fitEndIndex]]];
If[energyRegion == 2, Print[fittedParams500keV[[fitStartIndex ;; fitEndIndex]]];
If[energyRegion == 3, Print[fittedParams14MeV[[fitStartIndex ;; fitEndIndex]]];
(*Calculate theoretical yields with optimized parameters*)
If[energyRegion == 1, theoreticalYield0253eV =
  yieldData0253eVTheory /. optResult0253eVRe2[[2, All, All]]];
If[energyRegion == 2, theoreticalYield500keV =
  yieldData500keVTheory /. optResult500keVRe2[[2, All, All]]];
If[energyRegion == 3, theoreticalYield14MeV =
  yieldData14MeVTheory /. optResult14MeVRe2[[2, All, All]]];
(*Generate and display plots for each energy region*)
If[energyRegion == 1, Print["1. Analysis for Incident Neutron Energy: 0.0253eV"];
  Print[CreateFissionYieldPlot[expData,
    theoreticalYield0253eV, "0.0253eV", Blue]]];
If[energyRegion == 2, Print["2. Analysis for Incident Neutron Energy: 500keV"];
  Print[CreateFissionYieldPlot[expData, theoreticalYield500keV, "500keV", Blue]]];
If[energyRegion == 3, Print["3. Analysis for Incident Neutron Energy: 14MeV"];
  Print[CreateFissionYieldPlot[expData, theoreticalYield14MeV, "14MeV", Blue]]];
(*Display separator*)Print[
  "-----
  ---"];];

```

```

(*13*) (*Analysis and Visualization of Optimization Results*)
(*Display analysis title*)
Print["Quantitative Analysis Results of Fermi Energy Ex"];
Print["Based on Optimization Calculations using Experimental Fission Yield Data"];

(*Process and display results for each energy region*)
If[energyPattern == 1 || energyPattern == 2 || energyPattern == 3,
  Print["1. Analysis for Incident Neutron Energy: 0.0253eV"];
  Print[fermiData0253eV = Thread[{fittedParams0253eV[[All, 1, 1]],
    fittedParams0253eV[[All, 2]]}][[fitStartIndex ;; fitEndIndex]]];];

If[energyPattern == 2 || energyPattern == 3 || energyPattern == 4 || energyPattern == 5,
  Print["2. Analysis for Incident Neutron Energy: 500keV"];
  Print[fermiData500keV = Thread[{fittedParams500keV[[All, 1, 1]],
    fittedParams500keV[[All, 2]]}][[fitStartIndex ;; fitEndIndex]]];];

If[energyPattern == 3 || energyPattern == 5,
  Print["3. Analysis for Incident Neutron Energy: 14MeV"];
  Print[fermiData14MeV = Thread[{fittedParams14MeV[[All, 1, 1]],
    fittedParams14MeV[[All, 2]]}][[fitStartIndex ;; fitEndIndex]]];];

Print[
  "-----
  -"];

Print[" Systematic Analysis Results of Fermi Energy Ex"];
Print[" Using Optimized Effective Fission Distance Reff"];

(*Define common plot settings*)
plotBaseSettings = {PlotRange -> {{15, 75}, {-8, 12}}, PlotMarkers -> Automatic,
  Frame -> True, FrameLabel -> {"Atomic Number", "Energy (MeV)"},
  LabelStyle -> Directive[Black, 19], FrameTicks -> Automatic,
  FrameStyle -> {Thick, Thick, Thick, Thick}, AspectRatio -> 1.1, ImageSize -> 400};

(*Create visualization based on energy pattern*)
Switch[energyPattern, 1, (*0.0253eV only*) plotData = {fermiData0253eV, {}, {}};
  Print[ListPlot[Select[plotData, Length[#] > 0 &],
    Joined -> {True, True}, Evaluate@plotBaseSettings, PlotStyle ->
      {Directive[PointSize[1/100], Blue], Directive[PointSize[1/100], Green],
        Directive[PointSize[1/100], Red]}, PlotLegends ->
        Placed[PointLegend[Automatic, {"0.0253eV"}, Joined -> {True, True, True},
          LabelStyle -> 14, LegendFunction -> "Frame", LegendLayout -> "Column",
          LegendMarkers -> Array[{Graphics@Disk[], 10} &, 3]], {{0.955, 0.95}, {1, 0.9}}], 2,
    Epilog -> {Inset[Style[isotopeName, 20, Bold], Scaled@{0.15, 0.95}],
      Inset[Style[databaseName, 20, Bold], Scaled@{0.15, 0.90}]}], 2,
  (*0.0253eV and 500keV*) plotData = {fermiData0253eV, fermiData500keV, {}};
  Print[ListPlot[Select[plotData, Length[#] > 0 &],
    Joined -> {True, True}, Evaluate@plotBaseSettings, PlotStyle ->
      {Directive[PointSize[1/100], Blue], Directive[PointSize[1/100], Green],
        Directive[PointSize[1/100], Red]}, PlotLegends ->
        Placed[PointLegend[Automatic, {"0.0253eV", "500keV"}, Joined -> {True, True, True},

```

```

    LabelStyle → 14, LegendFunction → "Frame", LegendLayout → "Column",
    LegendMarkers → Array[{Graphics@Disk[], 10} &, 3], {{0.955, 0.95}, {1, 0.9}}},
    Epilog → {Inset[Style[isotopeName, 20, Bold], Scaled@{0.15, 0.95}],
    Inset[Style[databaseName, 20, Bold], Scaled@{0.15, 0.90}]}],
3, (*All three energies*)plotData = {fermiData0253eV,
fermiData500keV, fermiData14MeV};
Print[ListPlot[Select[plotData, Length[#] > 0 &], Joined → {True, True},
Evaluate@plotBaseSettings, PlotStyle → {Directive[PointSize[1/100], Blue],
Directive[PointSize[1/100], Green], Directive[PointSize[1/100], Red]},
PlotLegends → Placed[PointLegend[Automatic, {"0.0253eV", "500keV", "14MeV"},
Joined → {True, True, True}, LabelStyle → 14,
LegendFunction → "Frame", LegendLayout → "Column",
LegendMarkers → Array[{Graphics@Disk[], 10} &, 3], {{0.955, 0.95}, {1, 0.9}}},
Epilog → {Inset[Style[isotopeName, 20, Bold], Scaled@{0.15, 0.95}],
Inset[Style[databaseName, 20, Bold], Scaled@{0.15, 0.90}]}],
4, (*500keV only*)plotData = {fermiData500keV};
Print[ListPlot[plotData, Joined → True, PlotRange → {{20, 75}, {-8, 12}},
PlotMarkers → Automatic, PlotStyle → Directive[PointSize[1/100], Blue],
Frame → True, LabelStyle → Directive[Black, 19],
FrameTicks → Automatic, FrameStyle → {Thick, Thick, Thick, Thick},
PlotLegends → Placed[PointLegend[{Blue}, {"500keV"}], Joined → True,
LabelStyle → 14, LegendFunction → "Frame", LegendLayout → "Column",
LegendMarkers → {Graphics@Disk[]}], {{0.955, 0.95}, {1, 0.9}}], AspectRatio →
1.1, Epilog → {Inset[Style[isotopeName, 20, Bold], Scaled@{0.15, 0.95}],
Inset[Style[databaseName, 20, Bold], Scaled@{0.15, 0.90}]}], 5,
(*500keV and 14MeV*)plotData = {{}, fermiData500keV, fermiData14MeV};
Print[ListPlot[Select[plotData, Length[#] > 0 &], Joined → {True, True},
PlotRange → {{20, 75}, {-8, 12}}, PlotMarkers → Automatic, PlotStyle →
{Directive[PointSize[1/100], Green], Directive[PointSize[1/100], Red]},
Frame → True, LabelStyle → Directive[Black, 19], FrameTicks → Automatic,
FrameStyle → {Thick, Thick, Thick, Thick},
PlotLegends → Placed[PointLegend[Automatic, {"500keV", "14MeV"},
Joined → {True, True}, LabelStyle → 14, LegendFunction → "Frame",
LegendLayout → "Column", LegendMarkers → Array[{Graphics@Disk[], 10} &, 3],
{{0.955, 0.95}, {1, 0.9}}], AspectRatio → 1.1,
Epilog → {Inset[Style[isotopeName, 20, Bold], Scaled@{0.15, 0.95}],
Inset[Style[databaseName, 20, Bold], Scaled@{0.15, 0.90}]}];
(*14*) (*Final Analysis and Visualization of Nuclear Species*)
(*Fragment Analysis Function*)
AnalyzeIsotopeYield[yieldData_, label_] := Module[{centerZ = Floor[atomicNumber/2],
(*Calculate center atomic number*)rangeStart = Floor[atomicNumber/2] - 10,
(*Lower bound*)rangeEnd = Floor[atomicNumber/2] + 10, (*Upper bound*)
maxZ1, maxZ2, maxYield1, maxYield2, peakAvgYield, filteredData},
(*Display analysis header*)Print[label];
(*Filter data to only include atomic numbers within our range*)
filteredData = Select[yieldData, rangeStart ≤ First[#] ≤ rangeEnd &];
(*Find maximum yield within our range*)maxYield1 = Max[filteredData[[All, 2]]];
maxZ1 = First[First[Select[filteredData, #[[2]] == maxYield1 &]]];
maxZ2 = atomicNumber - maxZ1;
maxYield2 = yieldData[[maxZ2 - First[yieldData][[1]] + 1, 2]];
(*Display fragment information*)Print["Secondary Fragment: ",
ElementData[maxZ1, "Name"], "(Z=", maxZ1, "); Yield: ", maxYield1, " MeV"];
Print["Primary Fragment: ", ElementData[maxZ2, "Name"],
"(Z=", maxZ2, "); Yield: ", maxYield2, " MeV"];

```

```

(*Calculate and display average peak yield*)
peakAvgYield = (maxYield1 + maxYield2) / 2;
Print["Average Peak Yield: ", peakAvgYield, " MeV"];
Print[
  "-----
  ---"];];

(*Perform isotope analysis for each energy region*)
If[energyPattern == 1 || energyPattern == 2 || energyPattern == 3, AnalyzeIsotopeYield[
  fermiData0253eV, "1. Analysis for Incident Neutron Energy: 0.0253eV"]];

If[energyPattern == 2 || energyPattern == 3 || energyPattern == 4 || energyPattern == 5,
  AnalyzeIsotopeYield[fermiData500keV,
    "2. Analysis for Incident Neutron Energy: 500keV"]];

If[energyPattern == 3 || energyPattern == 5, AnalyzeIsotopeYield[
  fermiData14MeV, "3. Analysis for Incident Neutron Energy: 14MeV"];
Print[
  "-----
  ---"];];

(*Define logarithmic scale transformation function*)
LogScaleTransform[value_] := Rescale[Log10[value], {-8, 1}, {-8, 12}];

(*Common plot settings for combined visualization*)
combinedPlotSettings =
{Joined → {True}, PlotRange → {{15, 75}, {-10, 12}}, PlotMarkers → Automatic,
  Frame → True, FrameLabel → {{Style["Energy (MeV)", 19, Black],
    Style["Fission Yield (Independent)", 19, Black]},
    {Style["Atomic Number", 19, Black], None}},
  LabelStyle → Directive[Black, 19], FrameTicks →
    {{Automatic, {LogScaleTransform[10^#], If[# == 0, 1, Superscript[10, #]]} & } /@
      {-8, -6, -4, -2, 0, 2}}, {Automatic, None}},
  FrameStyle → {Thick, Thick, Thick, Thick}, AspectRatio → 1.1,
  ImageSize → 400, Axes → {True, False}};

(*Plot generation function*)
CreateEnergyPlot[fermiData_, yieldData_, energy_, color_] := Module[{scaledYieldData},
  scaledYieldData = ({#[[1]], LogScaleTransform@#[[2]]} &) /@ yieldData;
  ListPlot[{fermiData, scaledYieldData[[fitStartIndex ;; fitEndIndex]]},
    Evaluate[combinedPlotSettings],
    PlotStyle → {Directive[PointSize[1/100], color], Directive[PointSize[1/100],
      GrayLevel[0.6 - 0.2 * Position[{Blue, Green, Red}, color][[1, 1]]]}},
    PlotLegends → Placed[PointLegend[Automatic, {"Fermi Energy",
      "Charge Distribution (" <> databaseName <> ")"}, Joined → True,
      LabelStyle → 14, LegendFunction → "Frame", LegendLayout → "Column",
      LegendMarkers → Array[{Graphics@Disk[], 10} &, 2], {{0.94, 0.19}, {1, 0.9}}],
    Epilog → {Inset[Style[ToString[isotopeName] <> " " <> energy, 18, Bold],
      Scaled@{0.4, 0.94}]}];];

(*Generate plots for each energy region*)
Module[{}, If[energyPattern == 1 || energyPattern == 2 || energyPattern == 3,
  Print[CreateEnergyPlot[fermiData0253eV, yieldData0253eV, "0.0253eV", Blue]]];
  If[energyPattern == 2 || energyPattern == 3 || energyPattern == 4 || energyPattern == 5,

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Print[CreateEnergyPlot[fermiData500keV, yieldData500keV, "500keV", Green]]];
If[energyPattern == 3 || energyPattern == 5,
  Print[CreateEnergyPlot[fermiData14MeV, yieldData14MeV, "14MeV", Red]]];];

(*Final separator*)
Print[
  "-----
  -"];

Select Nuclear Species:
1. U-235_Data_JENDL5_CalculationData
2. U-233_Data_JENDL5_CalculationData
3. U-238_Data_JENDL5_CalculationData
4. Th-232_Data_JENDL5_CalculationData
5. Np-237_Data_JENDL5_CalculationData
6. Pu-239_Data_JENDL5_CalculationData
7. Pu-240_Data_JENDL5_CalculationData
8. Pu-242_Data_JENDL5_CalculationData
9. Am-241_Data_JENDL5_CalculationData

Attempting to load file from:
C:\Users\HM202\OneDrive\デスクトップ\14用Fermi-mathematica3\Pu-239_Data_JENDL5
_CalculationData.m

Successfully loaded: Pu-239_Data_JENDL5_CalculationData.m

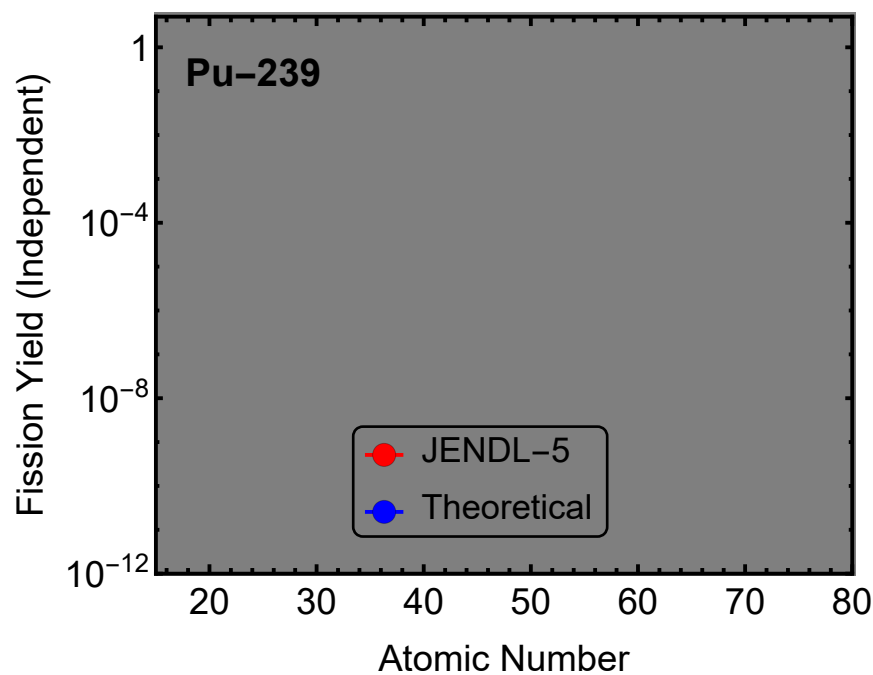
1. Incident Neutron Energy: 0.0253eV: Effective Fission
   Distance Reff derived from experimental charge distribution

Analysis Results

Calculation results demonstrating that the effective fission distance Reff
derived from optimization calculations accurately reproduces experimental
values (confirming agreement between JENDL-5 experimental and theoretical
values, and validating calculations using Mathematica ver11.2 FindMinimum)

```



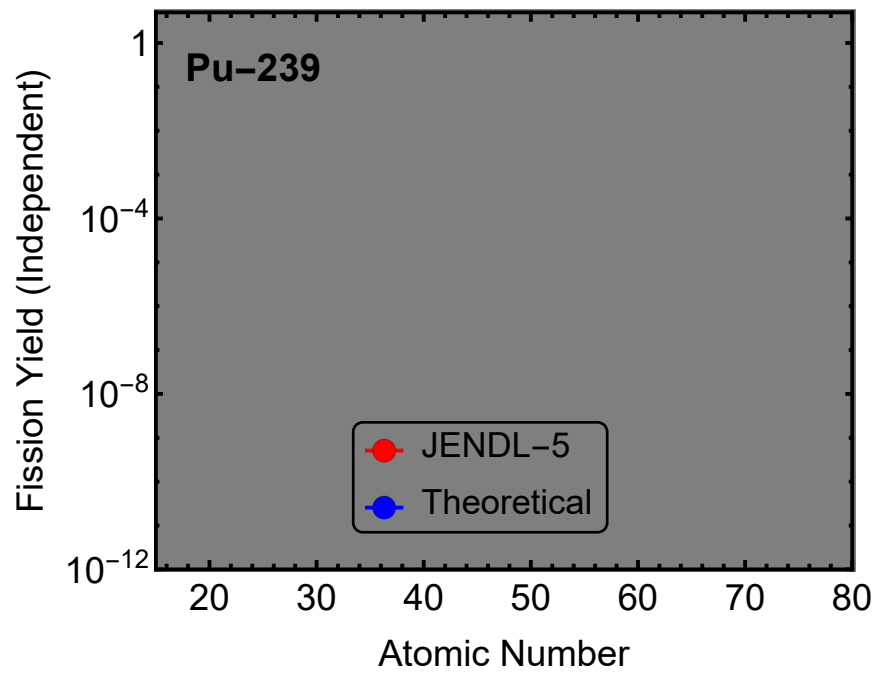


2. Incident Neutron Energy: 500keV: Effective Fission

Distance Reff derived from experimental charge distribution

Analysis Results

Calculation results demonstrating that the effective fission distance Reff derived from optimization calculations accurately reproduces experimental values (confirming agreement between JENDL-5 experimental and theoretical values, and validating calculations using Mathematica ver11.2 FindMinimum)



General:  $\frac{1}{5.31986 \times 10^{307}}$  is too small to represent as a normalized machine number; precision may be lost.

**General:**  $\frac{1}{5.87263 \times 10^{307}}$  is too small to represent as a normalized machine number; precision may be lost.

**General:**  $\frac{1}{1.30135 \times 10^{308}}$  is too small to represent as a normalized machine number; precision may be lost.

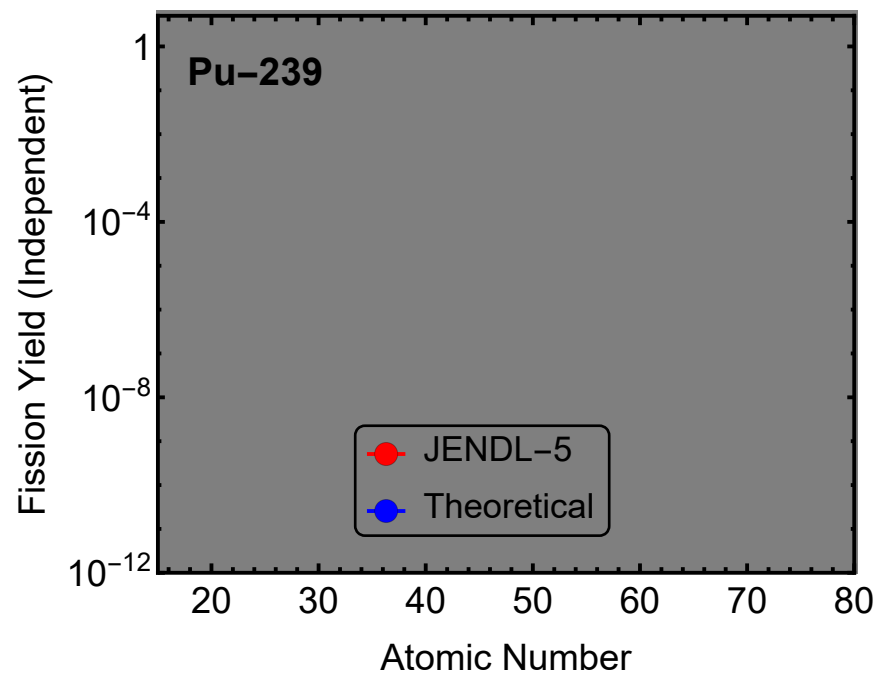
**General:** Further output of General::munfl will be suppressed during this calculation.

### 3. Incident Neutron Energy: 14MeV: Effective Fission

Distance Reff derived from experimental charge distribution

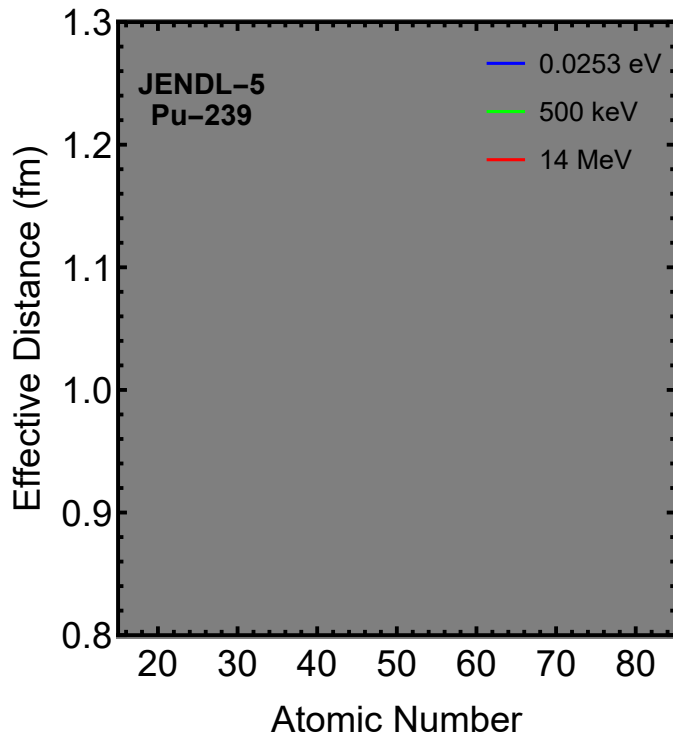
#### Analysis Results

Calculation results demonstrating that the effective fission distance Reff derived from optimization calculations accurately reproduces experimental values (confirming agreement between JENDL-5 experimental and theoretical values, and validating calculations using Mathematica ver11.2 FindMinimum)



#### Analysis Results:

1. The effective fission distance Reff shows quadratic dependence on fragment charge
2. This dependence reflects fundamental laws of charge distribution in fission process
3. Similar dependence is maintained across different incident energies



Incident Neutron Energy: 0.0253 eV case

$$R_{\text{eff}} = -0.40522 + 0.000732871 (94.0015 - x) x$$

Incident Neutron Energy: 500 keV case

$$R_{\text{eff}} = -0.46948 + 0.000759465 (94.0052 - x) x$$

Incident Neutron Energy: 14 MeV case

$$R_{\text{eff}} = -0.452443 + 0.000767127 (94.0126 - x) x$$

Analysis Results:

1. The effective fission distance  $R_{\text{eff}}$  shows quadratic dependence on fragment charge number
2. This dependence reflects fundamental laws of charge distribution in the fission process
3. Similar dependence is maintained across different incident energies

### Table of Effective Fission Distance

( $R_{\text{eff}}$ ) Values by Atomic Number [Unit: fm]:

Displaying calculated values

(pre-fitting) and post-fitting values for each energy

Fitting calculation used fragment values from atomic number 28 to 66

Z1	Z2	$R_{\text{eff}}$ [fm] (0.0253 eV) Calculated	Fitted Value	$R_{\text{eff}}$ [fm] (500 keV) Calculated	Fitted Value	$R_{\text{eff}}$ [fm] (14 MeV) Calculated	Fitted Value
23	71	0.204937	-	0.275829	-	0.027910	-

Out[73]=

24	70	0.568556	-	0.606208	-	0.355318	-
25	69	0.761743	-	0.777903	-	0.698360	-
26	68	0.819800	-	0.826642	-	0.858218	-
27	67	0.876728	-	0.875427	-	0.936559	-
28	66	0.948216	0.94916	0.933893	0.93412	0.963803	0.96548
29	65	0.976200	0.97627	0.962484	0.96223	0.993231	0.99387
30	64	1.001200	1.00193	0.988136	0.98881	1.019680	1.02073
31	63	1.026310	1.02611	1.013900	1.01388	1.046390	1.04605
32	62	1.048570	1.04883	1.036690	1.03743	1.070000	1.06985
33	61	1.070620	1.07009	1.059520	1.05945	1.093550	1.09210
34	60	1.089750	1.08987	1.079540	1.07996	1.113560	1.11282
35	59	1.109470	1.10820	1.099860	1.09895	1.133800	1.13201
36	58	1.125650	1.12505	1.116790	1.11643	1.150290	1.14967
37	57	1.142080	1.14045	1.133770	1.13238	1.167300	1.16578
38	56	1.154950	1.15437	1.147190	1.14681	1.180540	1.18037
39	55	1.167810	1.16683	1.160800	1.15973	1.194400	1.19342
40	54	1.177520	1.17783	1.170760	1.17112	1.204540	1.20494
41	53	1.187500	1.18735	1.181310	1.18100	1.215420	1.21492
42	52	1.194580	1.19542	1.188660	1.18936	1.222580	1.22337
43	51	1.201880	1.20201	1.196290	1.19620	1.230120	1.23028
44	50	1.205930	1.20714	1.200480	1.20152	1.233930	1.23566
45	49	1.210640	1.21081	1.205340	1.20532	1.239120	1.23951
46	48	1.211910	1.21301	1.206830	1.20760	1.240560	1.24182
47	47	1.213930	1.21374	1.208890	1.20836	1.242710	1.24259
48	46	1.211830	1.21301	1.206800	1.20761	1.240710	1.24184
49	45	1.210480	1.21081	1.205330	1.20533	1.239360	1.23954
50	44	1.205950	1.20715	1.200510	1.20154	1.234080	1.23572
51	43	1.201930	1.20202	1.196250	1.19623	1.230120	1.23036
52	42	1.194620	1.19543	1.188670	1.18940	1.222560	1.22346
53	41	1.187530	1.18737	1.181300	1.18105	1.215570	1.21503
54	40	1.177340	1.17784	1.170780	1.17118	1.204570	1.20507
55	39	1.168000	1.16685	1.160810	1.15979	1.194410	1.19357
56	38	1.154920	1.15439	1.147170	1.14688	1.180470	1.18054
57	37	1.142020	1.14047	1.133820	1.13246	1.167240	1.16598
58	36	1.125690	1.12508	1.116760	1.11651	1.150160	1.14988
59	35	1.109490	1.10822	1.099870	1.09905	1.133630	1.13224
60	34	1.089790	1.08990	1.079510	1.08007	1.113390	1.11307
61	33	1.070450	1.07012	1.059510	1.05957	1.093460	1.09237

62	32	1.048380	1.04886	1.036770	1.03754	1.070260	1.07013
63	31	1.026400	1.02615	1.014030	1.01401	1.047170	1.04636
64	30	1.001400	1.00196	0.988392	0.98895	1.020790	1.02106
65	29	0.976348	0.97631	0.962767	0.96237	0.994017	0.99422
66	28	0.948331	0.94920	0.934278	0.93427	0.964028	0.96584
67	27	0.876728	-	0.875427	-	0.936559	-
68	26	0.819800	-	0.826642	-	0.858218	-
69	25	0.761743	-	0.777903	-	0.698360	-

General:  $\frac{1}{6.96566 \times 10^{307}}$  is too small to represent as a normalized machine number; precision may be lost.

General:  $\frac{1}{8.88794 \times 10^{307}}$  is too small to represent as a normalized machine number; precision may be lost.

General:  $\frac{1}{1.12083 \times 10^{308}}$  is too small to represent as a normalized machine number; precision may be lost.

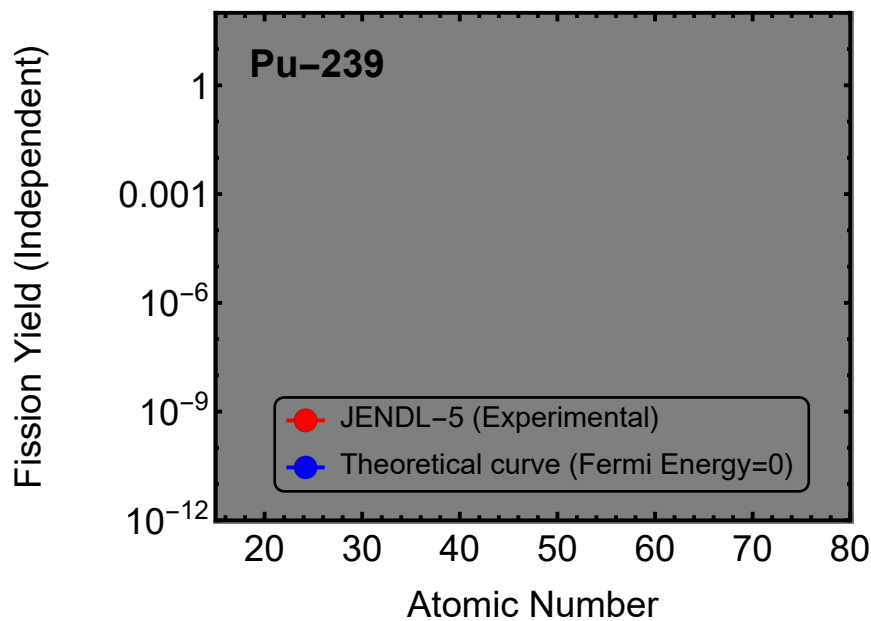
General: Further output of General::munfl will be suppressed during this calculation.

Analysis of Fission Yields: Comparison  
between Experimental Data and Theoretical Calculations (Ex=0)

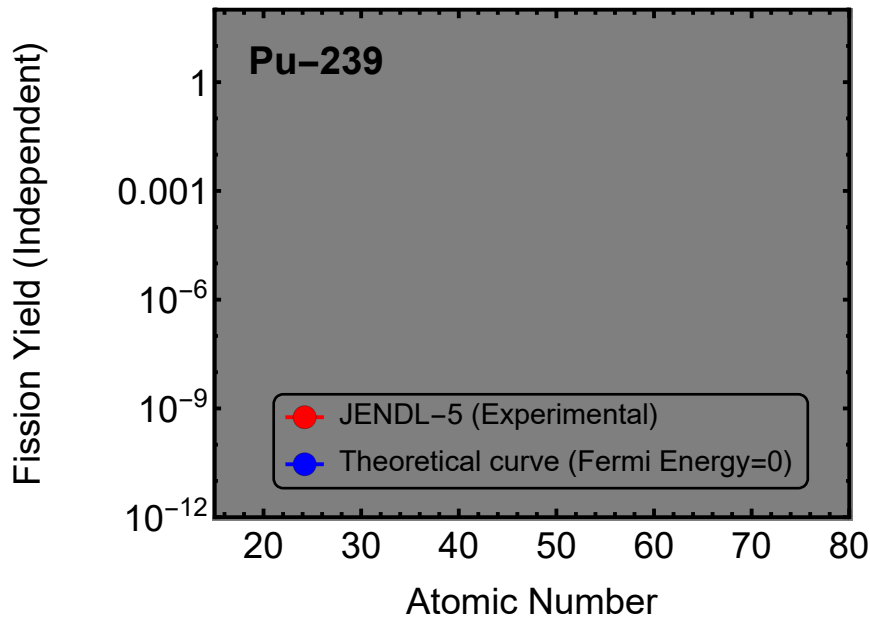
Theoretical Analysis Results using Effective  
Fission Distance Reff proportional to fragment charge product,  
with zero Fermi Energy (Ex=0)

- Quantitative reproduction of experimentally observed asymmetric fission yield distributions

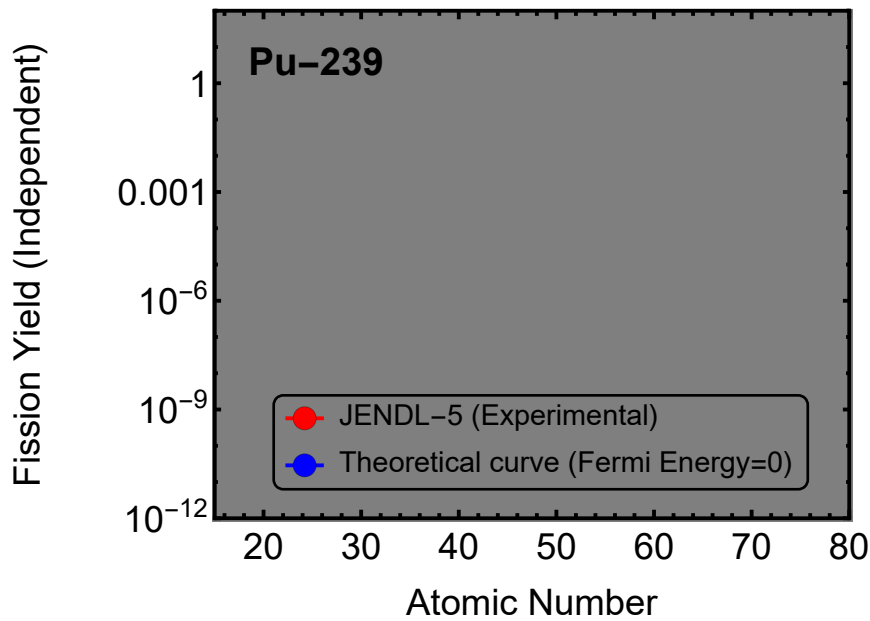
1. Analysis for Incident Neutron Energy: 0.0253eV



2. Analysis for Incident Neutron Energy: 500keV



3. Analysis for Incident Neutron Energy: 14MeV




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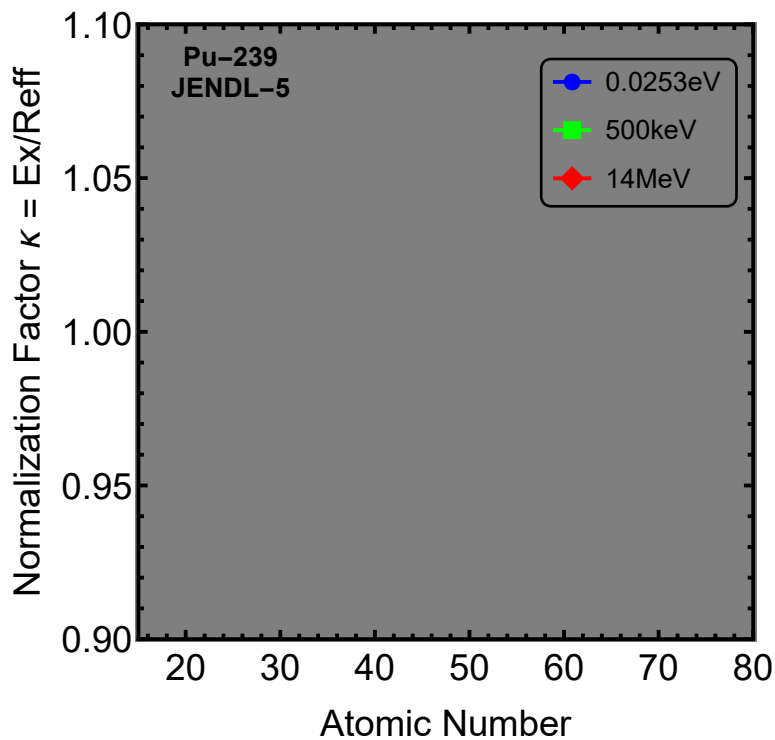
#### Analysis of Effective Fission Distance and Fission Probability

Analysis Contents:

1. Calculation of Effective Fission Distance ( $R_{eff}$ ) for each incident neutron energy
2. Evaluation of fission probability using  $\eta$  function
3. Derivation of normalization factor  $\kappa$  ( $= E_x/R_{eff}$ )

The vertical axis  $\kappa$  represents the ratio of Fermi Energy ( $E_x$ ) to effective fission distance ( $R_{eff}$ ).

$\kappa \approx 1$  suggests the fission Fermi Energy is proportional to effective distance.



#### Theoretical Analysis and Experimental Comparison of Fission Yield Distributions

##### Calculation Process:

1. Evaluate logarithmic differences  
between JENDL-5 experimental data and theoretical calculations
2. Optimize Fermi Energy ( $E_x$ ) using least squares method
3. Generate theoretical curves using optimized  $E_x$
4. Compare and verify experimental vs theoretical values

##### Optimization Goals:

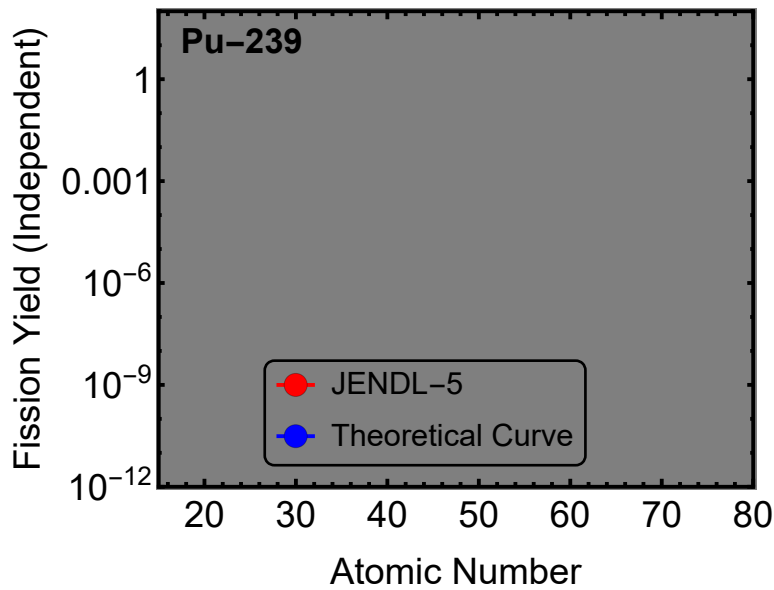
- Theoretical reproduction of experimentally observed asymmetric fission yields
- Understanding fission mechanisms at each incident neutron energy
- Systematic determination of Fermi Energy ( $E_x$ )

##### Evaluation Methods:

- Minimize sum of squared logarithmic differences between theory and experiment
  - Parameter optimization using FindMinimum function
  - Validation of theoretical curves with optimized parameters
-

```
{fermiEnergy0253eV[28, 66] → -1.70503,
fermiEnergy0253eV[29, 65] → 0.853912, fermiEnergy0253eV[30, 64] → -0.939411,
fermiEnergy0253eV[31, 63] → 1.56988, fermiEnergy0253eV[32, 62] → 0.359884,
fermiEnergy0253eV[33, 61] → 2.37852, fermiEnergy0253eV[34, 60] → 0.72752,
fermiEnergy0253eV[35, 59] → 4.08915, fermiEnergy0253eV[36, 58] → 2.41456,
fermiEnergy0253eV[37, 57] → 4.8067, fermiEnergy0253eV[38, 56] → 2.33292,
fermiEnergy0253eV[39, 55] → 3.22645, fermiEnergy0253eV[40, 54] → 0.315864,
fermiEnergy0253eV[41, 53] → 1.31129, fermiEnergy0253eV[42, 52] → -0.843779,
fermiEnergy0253eV[43, 51] → 0.699543, fermiEnergy0253eV[44, 50] → -1.65334,
fermiEnergy0253eV[45, 49] → 0.611396, fermiEnergy0253eV[46, 48] → -1.39422,
fermiEnergy0253eV[47, 47] → 1.37772, fermiEnergy0253eV[48, 46] → -1.57591,
fermiEnergy0253eV[49, 45] → 0.270603, fermiEnergy0253eV[50, 44] → -1.63822,
fermiEnergy0253eV[51, 43] → 0.784162, fermiEnergy0253eV[52, 42] → -0.798546,
fermiEnergy0253eV[53, 41] → 1.34975, fermiEnergy0253eV[54, 40] → -0.124004,
fermiEnergy0253eV[55, 39] → 3.61128, fermiEnergy0253eV[56, 38] → 2.22554,
fermiEnergy0253eV[57, 37] → 4.62713, fermiEnergy0253eV[58, 36] → 2.45611,
fermiEnergy0253eV[59, 35] → 4.07849, fermiEnergy0253eV[60, 34] → 0.750582,
fermiEnergy0253eV[61, 33] → 1.86716, fermiEnergy0253eV[62, 32] → -0.206033,
fermiEnergy0253eV[63, 31] → 1.7311, fermiEnergy0253eV[64, 30] → -0.501097,
fermiEnergy0253eV[65, 29] → 1.16534, fermiEnergy0253eV[66, 28] → -1.48378}
```

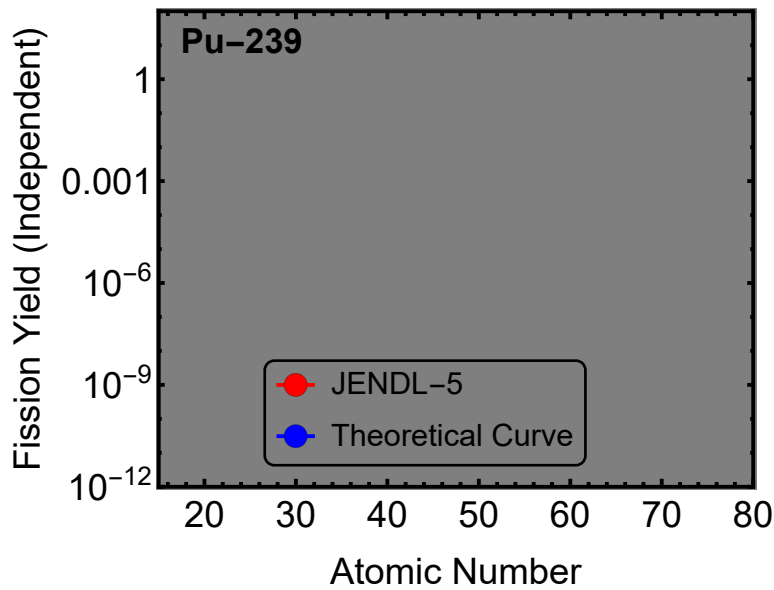
1. Analysis for Incident Neutron Energy: 0.0253eV





```
{fermiEnergy500keV[28, 66] → 0.367537,
fermiEnergy500keV[29, 65] → 1.80948, fermiEnergy500keV[30, 64] → -0.866045,
fermiEnergy500keV[31, 63] → 1.09937, fermiEnergy500keV[32, 62] → -0.925929,
fermiEnergy500keV[33, 61] → 1.19911, fermiEnergy500keV[34, 60] → -0.0571822,
fermiEnergy500keV[35, 59] → 3.24103, fermiEnergy500keV[36, 58] → 1.87444,
fermiEnergy500keV[37, 57] → 4.29433, fermiEnergy500keV[38, 56] → 1.88074,
fermiEnergy500keV[39, 55] → 3.45048, fermiEnergy500keV[40, 54] → 0.168896,
fermiEnergy500keV[41, 53] → 1.67412, fermiEnergy500keV[42, 52] → -0.573445,
fermiEnergy500keV[43, 51] → 1.18355, fermiEnergy500keV[44, 50] → -1.29524,
fermiEnergy500keV[45, 49] → 1.01367, fermiEnergy500keV[46, 48] → -0.706336,
fermiEnergy500keV[47, 47] → 2.12487, fermiEnergy500keV[48, 46] → -0.795929,
fermiEnergy500keV[49, 45] → 0.972372, fermiEnergy500keV[50, 44] → -1.28865,
fermiEnergy500keV[51, 43] → 1.02675, fermiEnergy500keV[52, 42] → -0.645319,
fermiEnergy500keV[53, 41] → 1.54413, fermiEnergy500keV[54, 40] → 0.085546,
fermiEnergy500keV[55, 39] → 3.32852, fermiEnergy500keV[56, 38] → 1.64989,
fermiEnergy500keV[57, 37] → 4.21329, fermiEnergy500keV[58, 36] → 1.59898,
fermiEnergy500keV[59, 35] → 3.03195, fermiEnergy500keV[60, 34] → -0.394289,
fermiEnergy500keV[61, 33] → 0.886428, fermiEnergy500keV[62, 32] → -1.03838,
fermiEnergy500keV[63, 31] → 1.11786, fermiEnergy500keV[64, 30] → -0.52316,
fermiEnergy500keV[65, 29] → 2.21875, fermiEnergy500keV[66, 28] → 1.08115}
```

## 2. Analysis for Incident Neutron Energy: 500keV



```
{fermiEnergy14MeV[28, 66] → -3.70439,
fermiEnergy14MeV[29, 65] → -0.686968, fermiEnergy14MeV[30, 64] → -1.72733,
fermiEnergy14MeV[31, 63] → 1.91705, fermiEnergy14MeV[32, 62] → 1.43825,
fermiEnergy14MeV[33, 61] → 4.56413, fermiEnergy14MeV[34, 60] → 2.78523,
fermiEnergy14MeV[35, 59] → 5.17488, fermiEnergy14MeV[36, 58] → 2.44821,
fermiEnergy14MeV[37, 57] → 4.40097, fermiEnergy14MeV[38, 56] → 1.38525,
fermiEnergy14MeV[39, 55] → 3.12052, fermiEnergy14MeV[40, 54] → 0.162718,
fermiEnergy14MeV[41, 53] → 2.05304, fermiEnergy14MeV[42, 52] → -0.649324,
fermiEnergy14MeV[43, 51] → 0.65321, fermiEnergy14MeV[44, 50] → -2.6108,
fermiEnergy14MeV[45, 49] → 0.20012, fermiEnergy14MeV[46, 48] → -1.60354,
fermiEnergy14MeV[47, 47] → 1.24146, fermiEnergy14MeV[48, 46] → -1.33318,
fermiEnergy14MeV[49, 45] → 0.601575, fermiEnergy14MeV[50, 44] → -2.40747,
fermiEnergy14MeV[51, 43] → 0.493494, fermiEnergy14MeV[52, 42] → -0.903486,
fermiEnergy14MeV[53, 41] → 2.12992, fermiEnergy14MeV[54, 40] → -0.0652234,
fermiEnergy14MeV[55, 39] → 2.80749, fermiEnergy14MeV[56, 38] → 0.858579,
fermiEnergy14MeV[57, 37] → 3.83626, fermiEnergy14MeV[58, 36] → 1.67377,
fermiEnergy14MeV[59, 35] → 4.23782, fermiEnergy14MeV[60, 34] → 1.78213,
fermiEnergy14MeV[61, 33] → 3.69185, fermiEnergy14MeV[62, 32] → 1.3523,
fermiEnergy14MeV[63, 31] → 3.13495, fermiEnergy14MeV[64, 30] → 0.352782,
fermiEnergy14MeV[65, 29] → 0.520162, fermiEnergy14MeV[66, 28] → -4.10641}
```

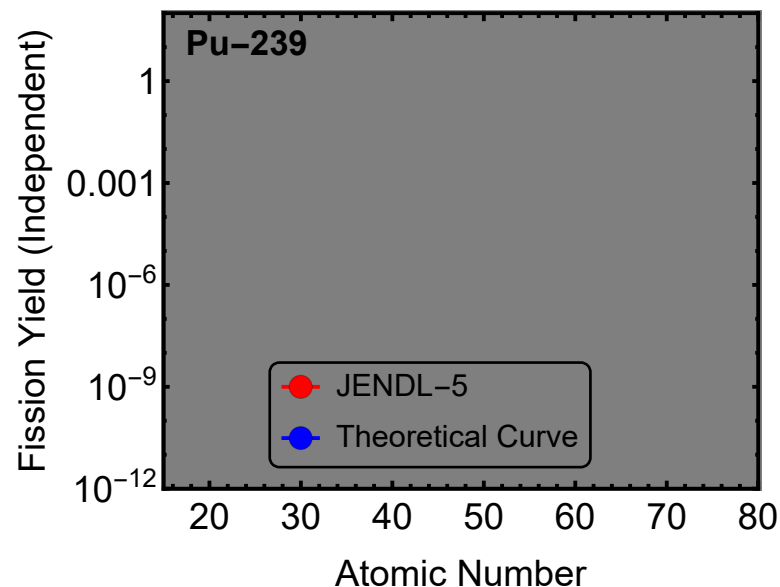
General:  $\frac{1}{9.6076 \times 10^{307}}$  is too small to represent as a normalized machine number; precision may be lost.

General:  $\frac{1}{1.14933 \times 10^{308}}$  is too small to represent as a normalized machine number; precision may be lost.

General:  $\frac{1}{8.52421 \times 10^{307}}$  is too small to represent as a normalized machine number; precision may be lost.

General: Further output of General::munfl will be suppressed during this calculation.

### 3. Analysis for Incident Neutron Energy: 14MeV



### Quantitative Analysis Results of Fermi Energy Ex

Based on Optimization Calculations using Experimental Fission Yield Data

#### 1. Analysis for Incident Neutron Energy: 0.0253eV

```
{ {28, -1.70503}, {29, 0.853912}, {30, -0.939411}, {31, 1.56988}, {32, 0.359884}, {33, 2.37852},
  {34, 0.72752}, {35, 4.08915}, {36, 2.41456}, {37, 4.8067}, {38, 2.33292}, {39, 3.22645},
  {40, 0.315864}, {41, 1.31129}, {42, -0.843779}, {43, 0.699543}, {44, -1.65334},
  {45, 0.611396}, {46, -1.39422}, {47, 1.37772}, {48, -1.57591}, {49, 0.270603},
  {50, -1.63822}, {51, 0.784162}, {52, -0.798546}, {53, 1.34975}, {54, -0.124004},
  {55, 3.61128}, {56, 2.22554}, {57, 4.62713}, {58, 2.45611}, {59, 4.07849}, {60, 0.750582},
  {61, 1.86716}, {62, -0.206033}, {63, 1.7311}, {64, -0.501097}, {65, 1.16534}, {66, -1.48378} }
```

## 2. Analysis for Incident Neutron Energy: 500keV

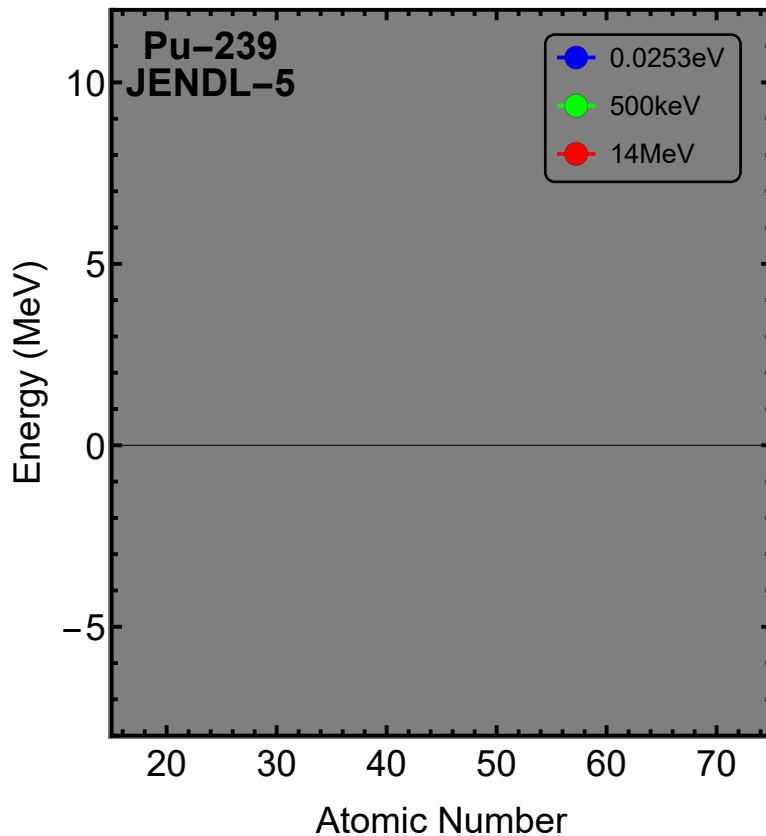
```
{ {28, 0.367537}, {29, 1.80948}, {30, -0.866045}, {31, 1.09937}, {32, -0.925929}, {33, 1.19911},
  {34, -0.0571822}, {35, 3.24103}, {36, 1.87444}, {37, 4.29433}, {38, 1.88074}, {39, 3.45048},
  {40, 0.168896}, {41, 1.67412}, {42, -0.573445}, {43, 1.18355}, {44, -1.29524},
  {45, 1.01367}, {46, -0.706336}, {47, 2.12487}, {48, -0.795929}, {49, 0.972372},
  {50, -1.28865}, {51, 1.02675}, {52, -0.645319}, {53, 1.54413}, {54, 0.085546},
  {55, 3.32852}, {56, 1.64989}, {57, 4.21329}, {58, 1.59898}, {59, 3.03195}, {60, -0.394289},
  {61, 0.886428}, {62, -1.03838}, {63, 1.11786}, {64, -0.52316}, {65, 2.21875}, {66, 1.08115} }
```

## 3. Analysis for Incident Neutron Energy: 14MeV

```
{ {28, -3.70439}, {29, -0.686968}, {30, -1.72733}, {31, 1.91705}, {32, 1.43825}, {33, 4.56413},
  {34, 2.78523}, {35, 5.17488}, {36, 2.44821}, {37, 4.40097}, {38, 1.38525}, {39, 3.12052},
  {40, 0.162718}, {41, 2.05304}, {42, -0.649324}, {43, 0.65321}, {44, -2.6108},
  {45, 0.20012}, {46, -1.60354}, {47, 1.24146}, {48, -1.33318}, {49, 0.601575},
  {50, -2.40747}, {51, 0.493494}, {52, -0.903486}, {53, 2.12992}, {54, -0.0652234},
  {55, 2.80749}, {56, 0.858579}, {57, 3.83626}, {58, 1.67377}, {59, 4.23782}, {60, 1.78213},
  {61, 3.69185}, {62, 1.3523}, {63, 3.13495}, {64, 0.352782}, {65, 0.520162}, {66, -4.10641} }
```

Systematic Analysis Results of Fermi Energy Ex

Using Optimized Effective Fission Distance Reff



1. Analysis for Incident Neutron Energy: 0.0253eV

Secondary Fragment: rubidium(Z=37); Yield: 4.8067 MeV

Primary Fragment: lanthanum(Z=57); Yield: 4.62713 MeV

Average Peak Yield: 4.71691 MeV

---

2. Analysis for Incident Neutron Energy: 500keV

Secondary Fragment: rubidium(Z=37); Yield: 4.29433 MeV

Primary Fragment: lanthanum(Z=57); Yield: 4.21329 MeV

Average Peak Yield: 4.25381 MeV

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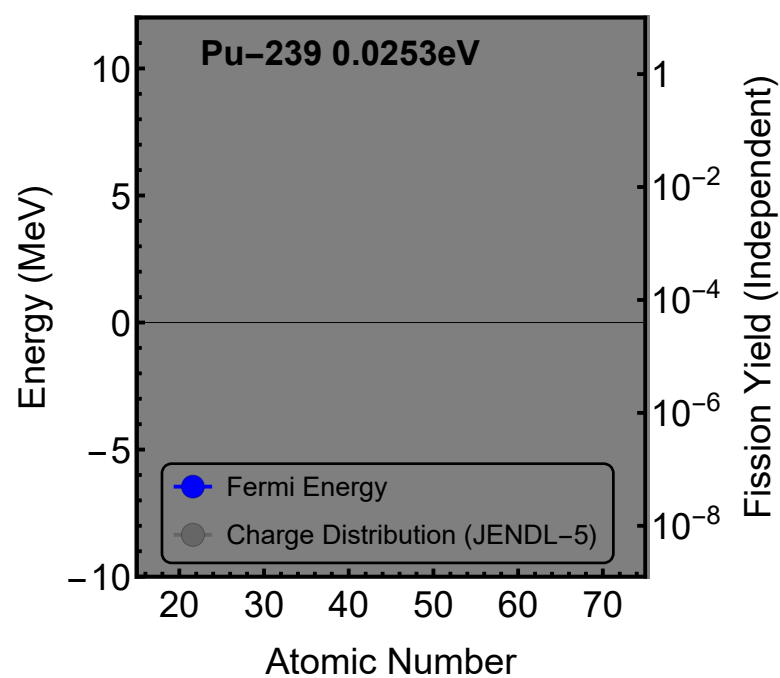
3. Analysis for Incident Neutron Energy: 14MeV

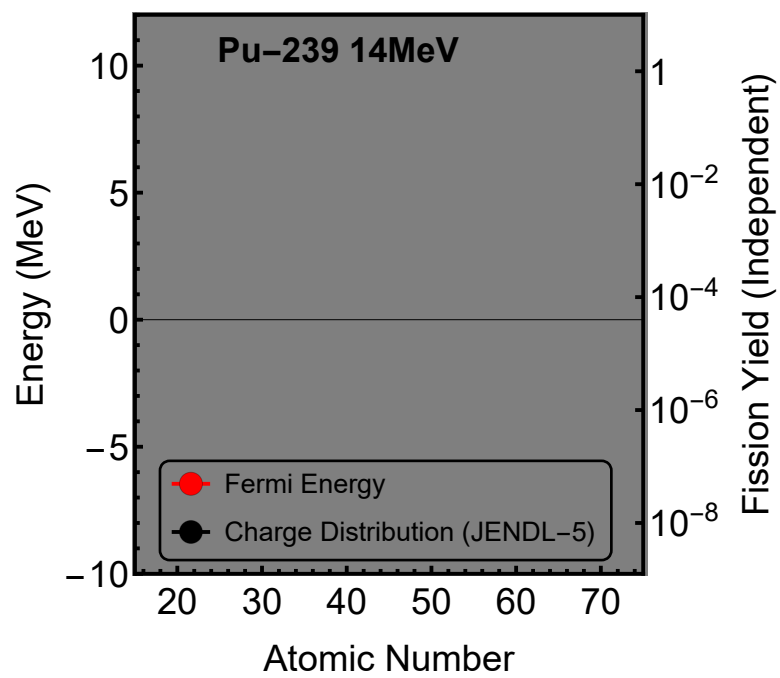
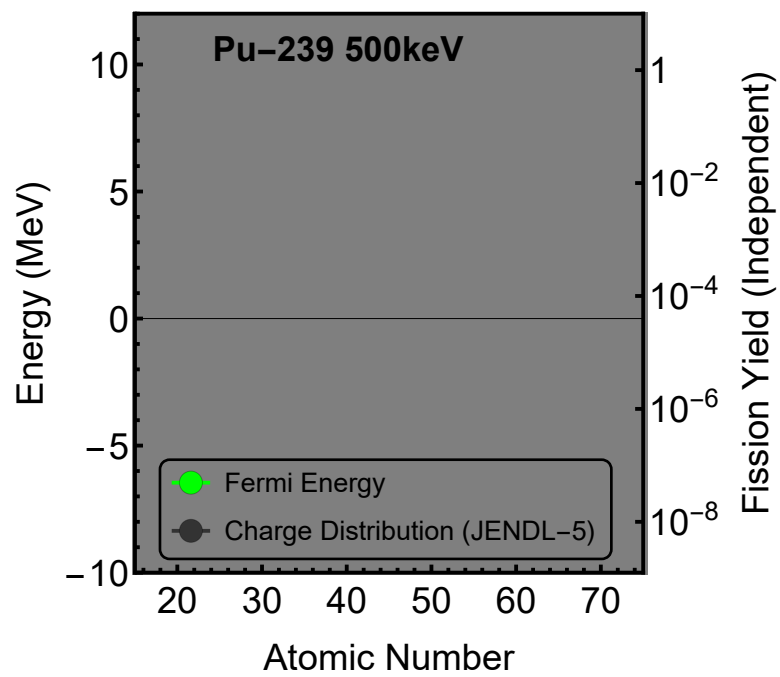
Secondary Fragment: rubidium(Z=37); Yield: 4.40097 MeV

Primary Fragment: lanthanum(Z=57); Yield: 3.83626 MeV

Average Peak Yield: 4.11861 MeV

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In[644]:= EmitSound[Sound[SoundNote[]]]