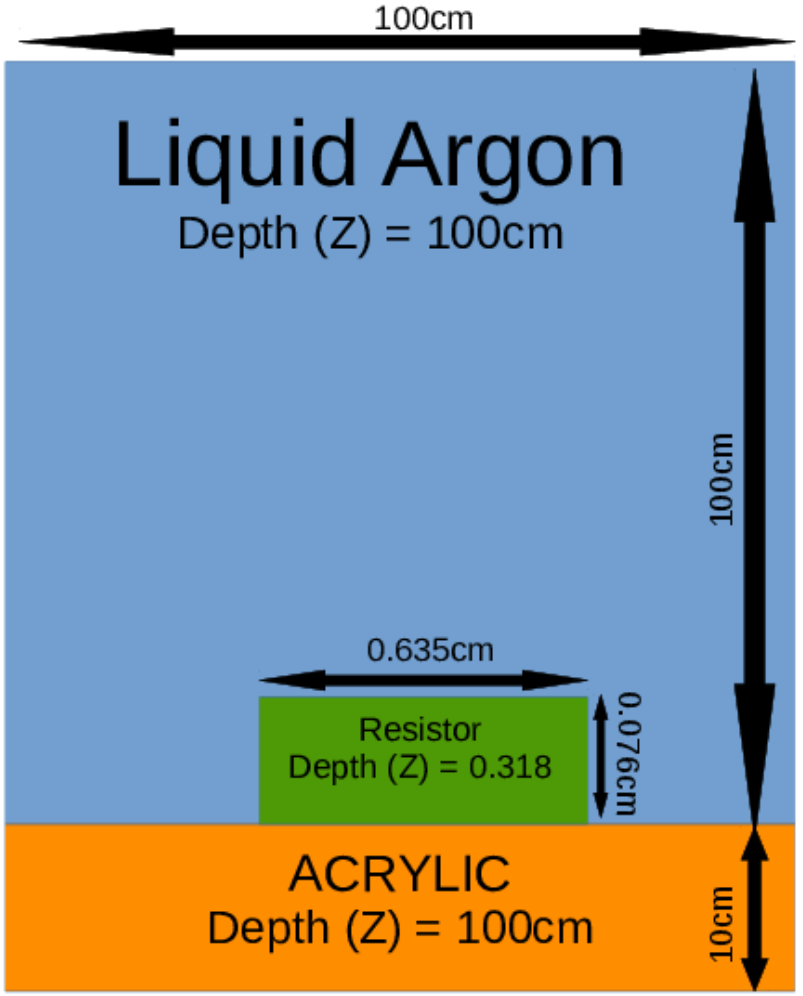
(α, n) from the DS-20k Field Cage

Darkside Materials Group
By Will Bateman-Hemphill

Simulation Geometry

- We defined the volume shown here in SaG4n
- Alphas from the Pb-210 decay chain were generated in the resistor volume



Resistor Composition

We get the composition from the manufacturer's material declaration data sheet

Material Declaration Data Sheet

HVCB2512

High Voltage Thick Film Chip Resistor - Solderable Wraparound

Date: **August 19, 2014** Max Temp: **260°C** (Contact factory for detailed soldering recommendations.)

Component Weight (mg): **44.0042**

BOM Item	Material	CAS Number	Material Weight (mg)	Material PPM of Component	Material % of BOM Item	BOM Item Weight (mg)	BOM Item % of Component
Ceramic substrate	aluminum oxide	1344-28-1	32.8608	746,765	96.00%	34.2300	77.79%
	silicon oxide	7631-86-9	0.6846	15,558	2.00%		
	magnesium oxide	1309-48-4	0.3423	7,779	1.00%		
	calcium oxide	1305-78-8	0.3423	7,779	1.00%		
Inner termination layer	silver	7440-22-4	2.3783	54,047	79.54%	2.9900	6.79%
	palladium	7440-05-3	0.0317	720	1.06%		
	lead borosilicate glass	undefined	0.5800	13,181	19.40%		
Resistive element	ruthenium oxide	12036-10-1	0.3608	8,199	26.71%	1.3508	3.07%
	silver	7440-22-4	0.1956	4,445	14.48%		
	palladium	7440-05-3	0.0573	1,302	4.24%		
	lead borosilicate glass	undefined	0.7371	16,751	54.57%		
Pre-coat	lead borosilicate glass	undefined	2.1669	49,243	89.64%	2.4174	5.49%
	copper oxide	1317-38-0	0.1113	2,529	4.60%		
	magnesium oxide	1309-48-4	0.1392	3,163	5.76%		
Over-coat	epoxy	67762-95-2	1.6060	36,497	100.00%	1.6060	3.65%
Middle termination layer	nickel	7440-02-0	0.5000	11,363	100.00%	0.5000	1.14%
Outer termination layer	tin	7440-31-5	0.9100	20,680	100.00%	0.9100	2.07%
Total Weight			44.0042				

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[illegible]	[illegible]	[illegible]	0.9100	20,680	100.00%	0.9100	2.07%
			44.0042				

The resistor is modelled as a homogeneous mixture of these components!

Resistor Composition

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Total Weight			44.0042				

Lead Borosilicate Glass

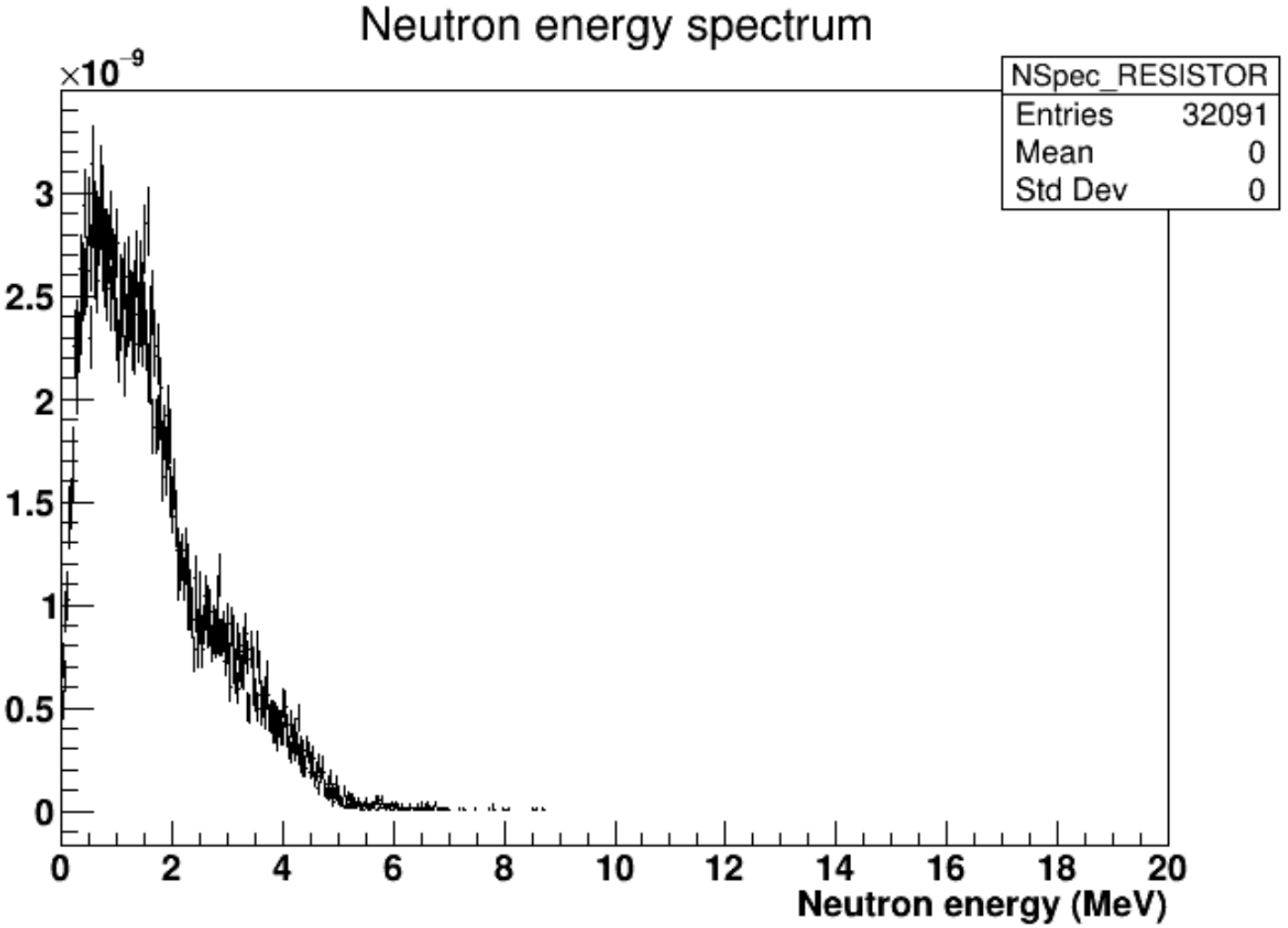
- 80% SiO_2
- 13% B_2O_3 (can range from 8% to 25%)
- 4% Na_2O
- 3% Al_2O_3

These numbers come from the Wikipedia page for Borosilicate Glass

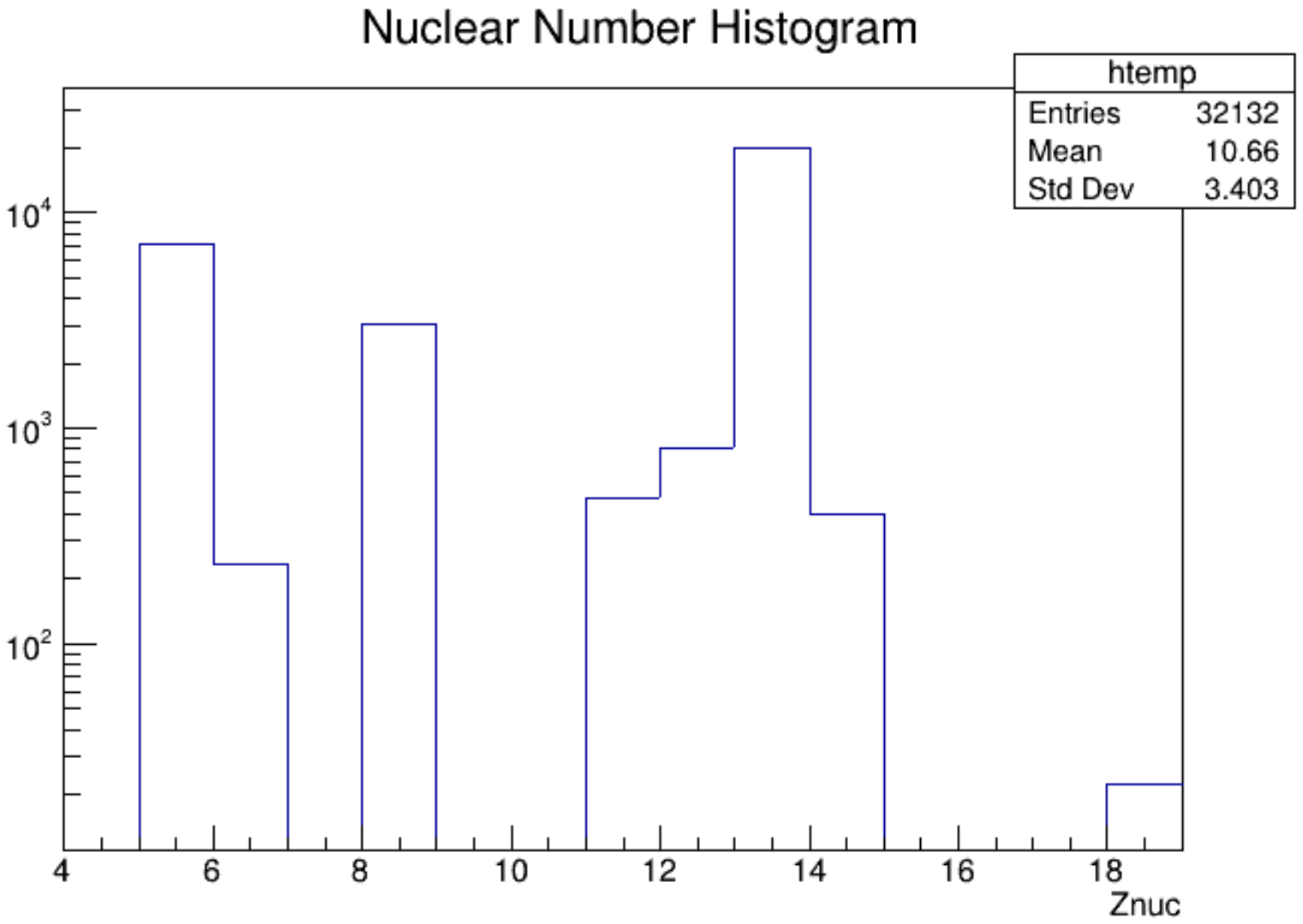
Simulation Results

Yield: 3.22×10^{-7}

- In Resistor: 3.22×10^{-7}
- In LAr: 2.20×10^{-10}
- In Acrylic: 1.10×10^{-10}



Most (α, n) occur with Boron and Aluminum



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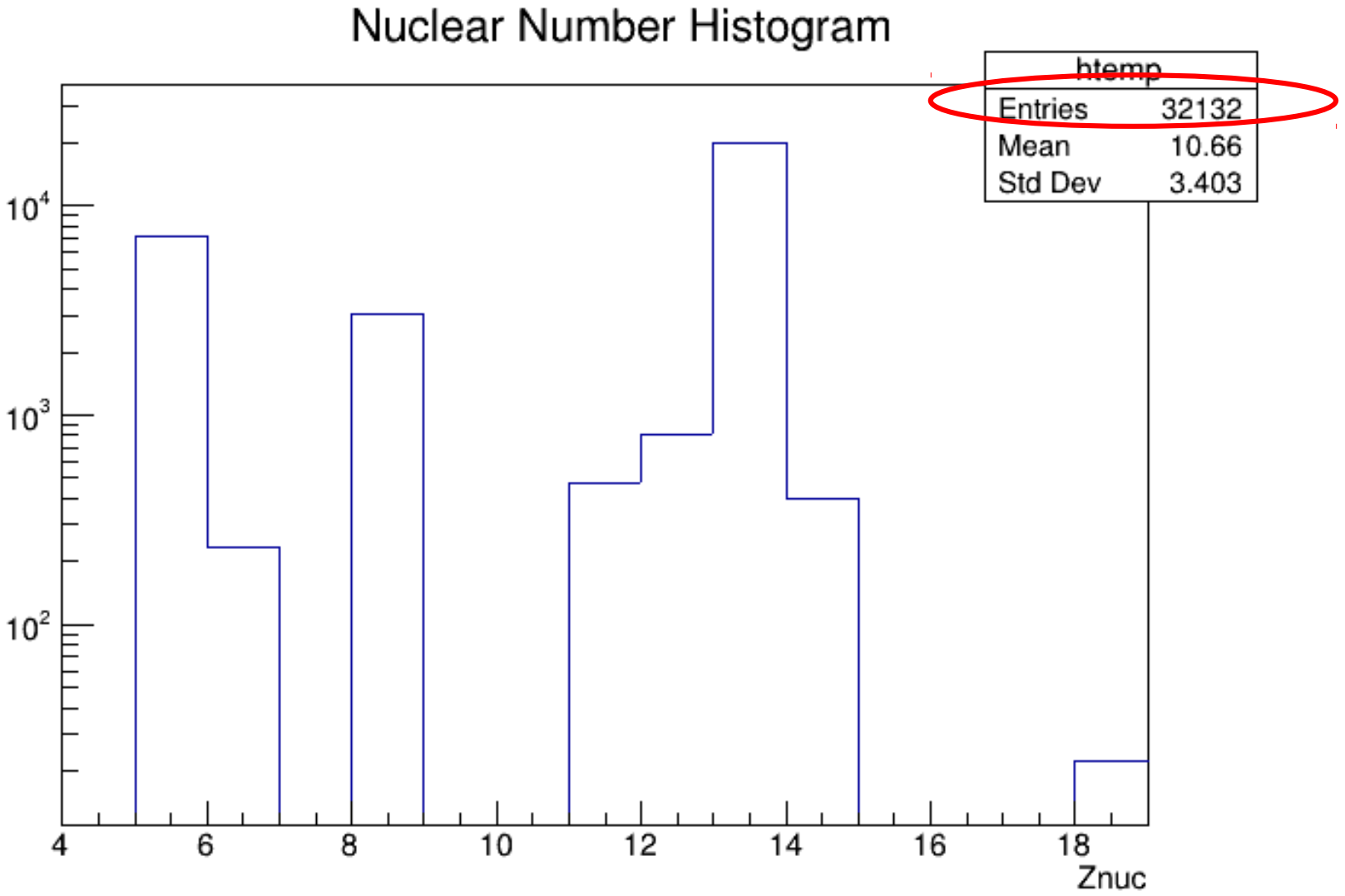

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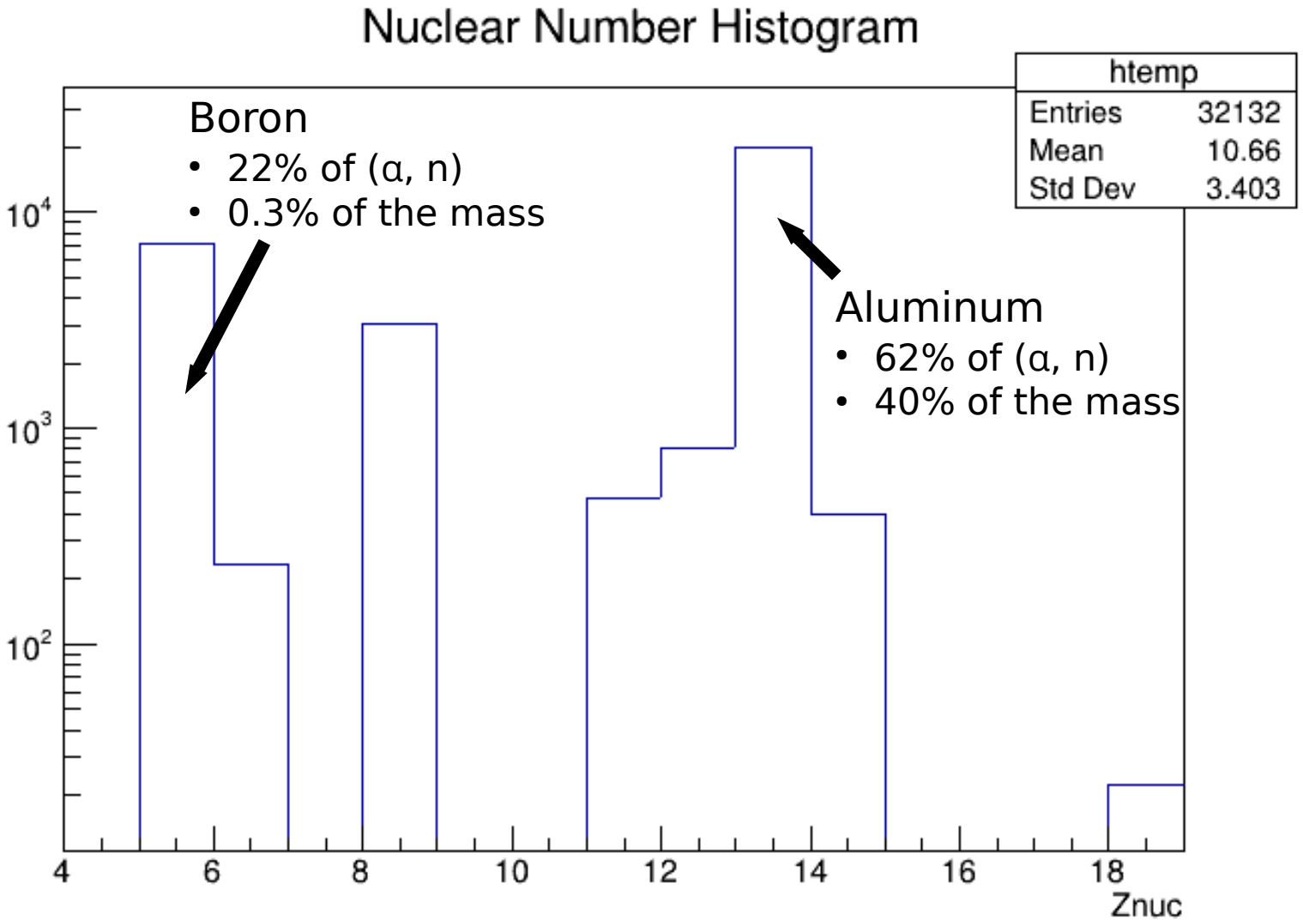

Boron is only found in the glass of the resistor

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Inner termination layer	silver palladium lead borosilicate glass	7440-22-4 7440-05-3 undefined					79%
Resistive element	ruthenium oxide silver palladium lead borosilicate glass	12036-10-1 7440-22-4 7440-05-3 undefined	0.7371	16,751	54.57%	1.3508	3.07%
Pre-coat	lead borosilicate glass copper oxide magnesium oxide	undefined 1317-38-0 1309-48-4	2.1669 0.1113 0.1392	49,243 2,529 3,163	89.64% 4.60% 5.76%	2.4174	5.49%
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Total Weight			44.0042				

This glass is 7.9% of the resistor mass!

Can we treat the resistor as homogeneous?

- **Since lead in the glass will contain Pb-210, we are likely underestimating the yield**

- **What if all the (α, n) occurs with boron in the glass?**
- **Total Yield (Y) : 3.22×10^{-7}**
- **Boron Yield (Y_B) : 7.16×10^{-8}**

Worst case senario

Since glass makes up 7.9% of the resistor, we can approximate the “corrected” yield as:

$$Y_{corrected} = \frac{Y_B}{0.079} + (Y - Y_B) = 1.15 \times 10^{-6}$$

The resistor's internal geometry effects the (α, n) yield

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Comparison

- $Y = 3.22 \times 10^{-7}$
- $Y_{corrected} = 1.15 \times 10^{-6}$
- The yield increased by a factor of 3.6

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Further Work (to be continued…)

- **To deal with other alpha energies (from U-238, Th-232, Ra-226, and U-235) we are simulating each component of the resistor independently**