Pion Yields from the Tungsten Powder Jet target

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Contents

Tungsten powder (WJet) background

- Why Tungsten?
  - High density (19.25g/cm³) – **Increased yields** and energy absorption
  - High melting point (3695K) – 4MW beam produces immense heat, W has more tolerance
  - Resistive to radiation – Prolonged exposure is less of an issue
- Why use a powder over a solid or liquid?
  - Better thermal dissipation – More surface area caused by increased particles
  - Self replenishing – As the powder flows around the loop, it cools down
  - Cavitation is impossible – Solid nature means pressure drops cannot form vapour bubbles

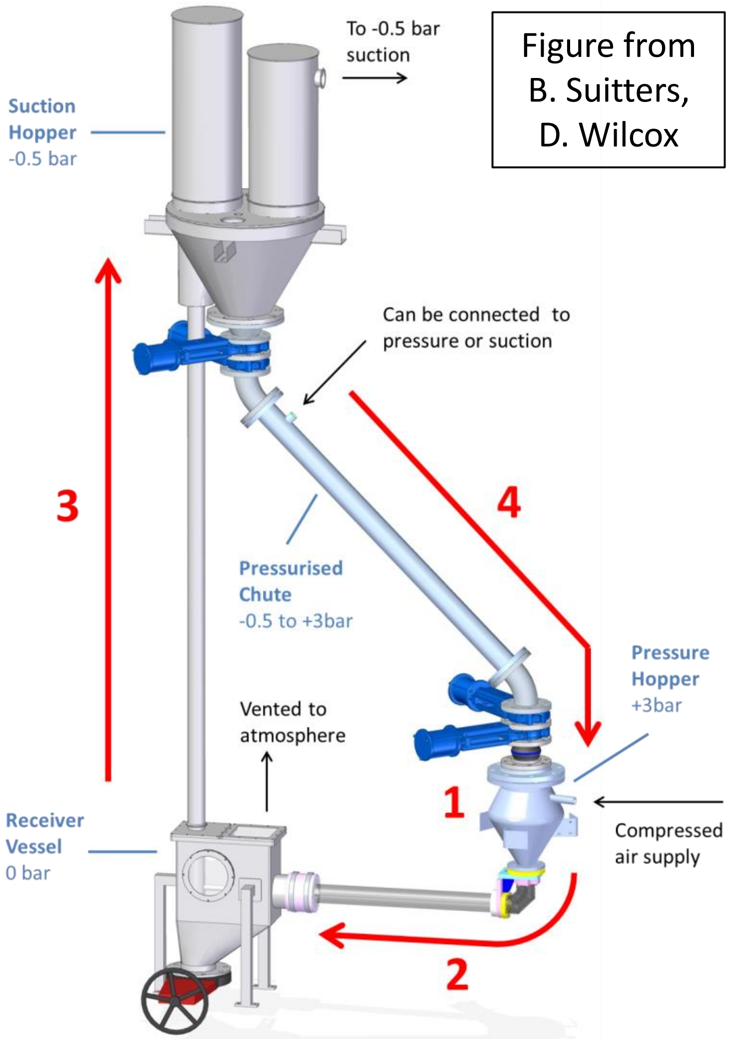
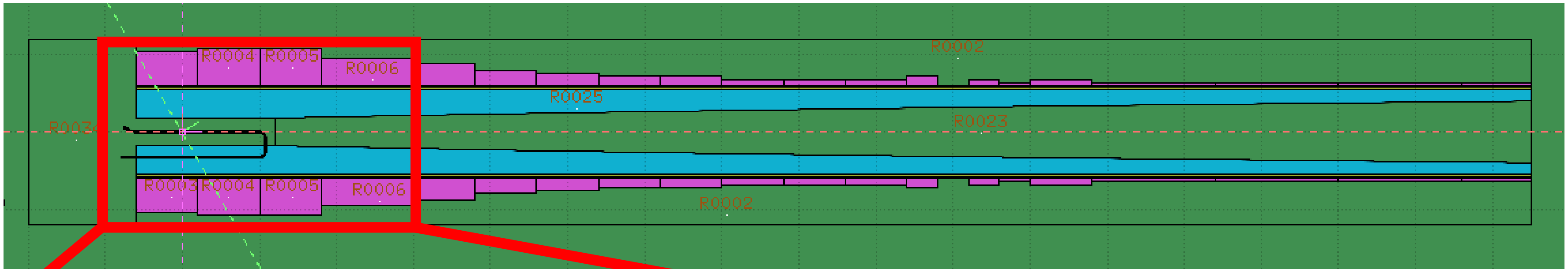


Figure from B. Suitters, D. Wilcox

Pyg4ometry FLUKA design

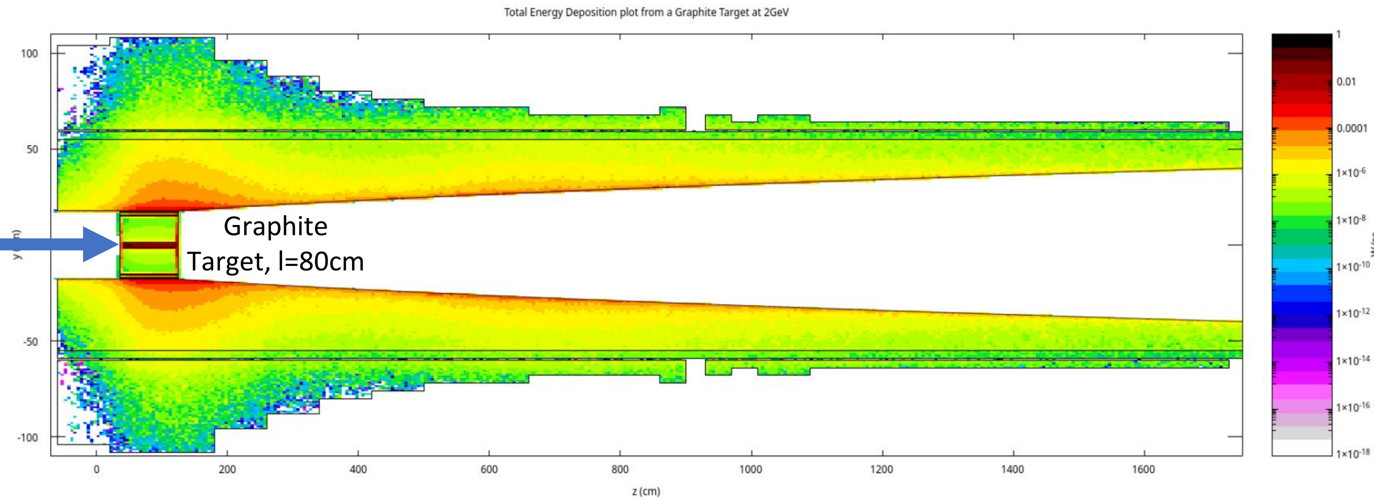


Zoomed view of WJet target region

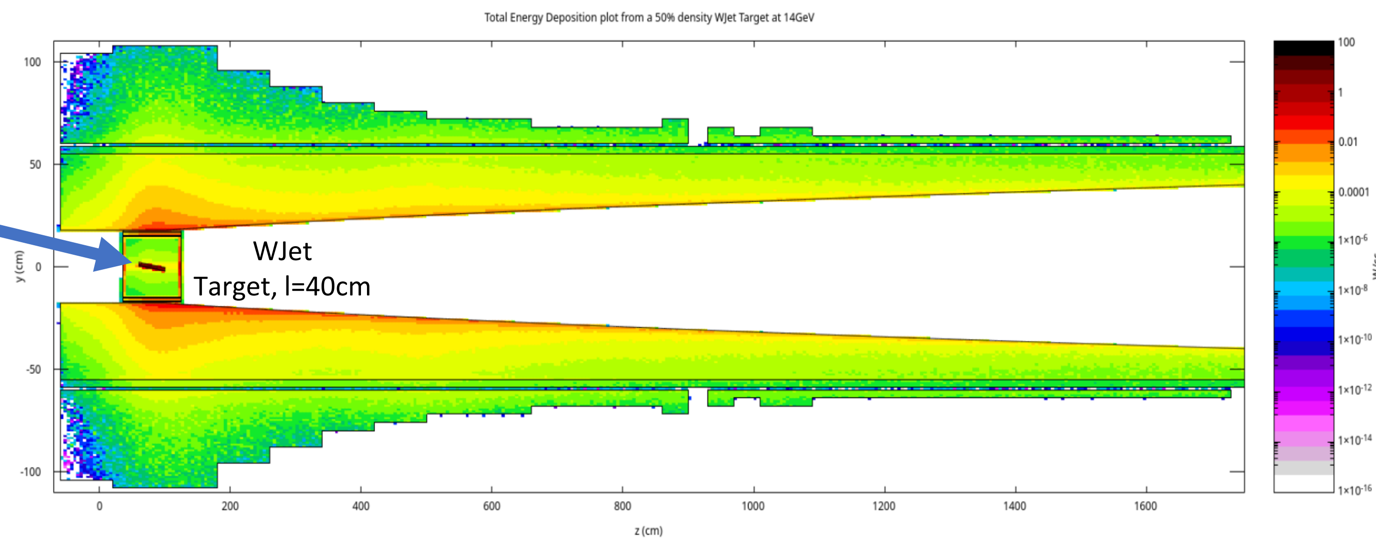
- Adaptation of the CERN Graphite target geometry to implement proposed WJet design
- Failed due to the conversion between pyg4ometry to FLUKA causing parenthesis expansion errors
- Will use the original design to get preliminary results

CERN targets (2 & 14GeV beam) FLUKA energy deposition (E_{dep})

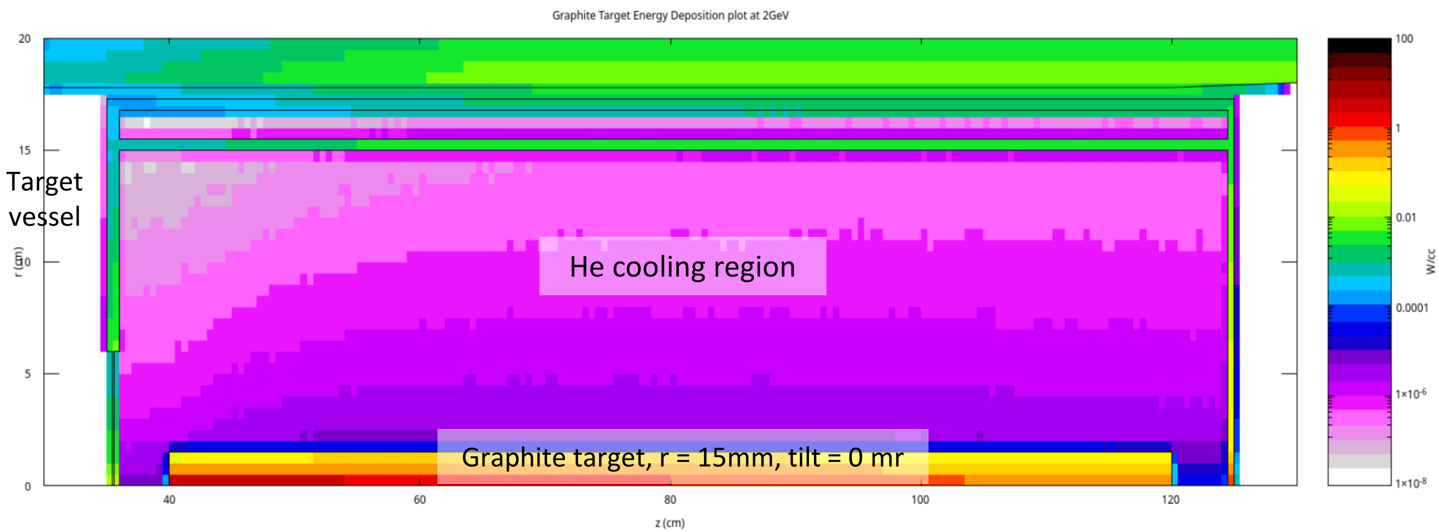
Beam direction



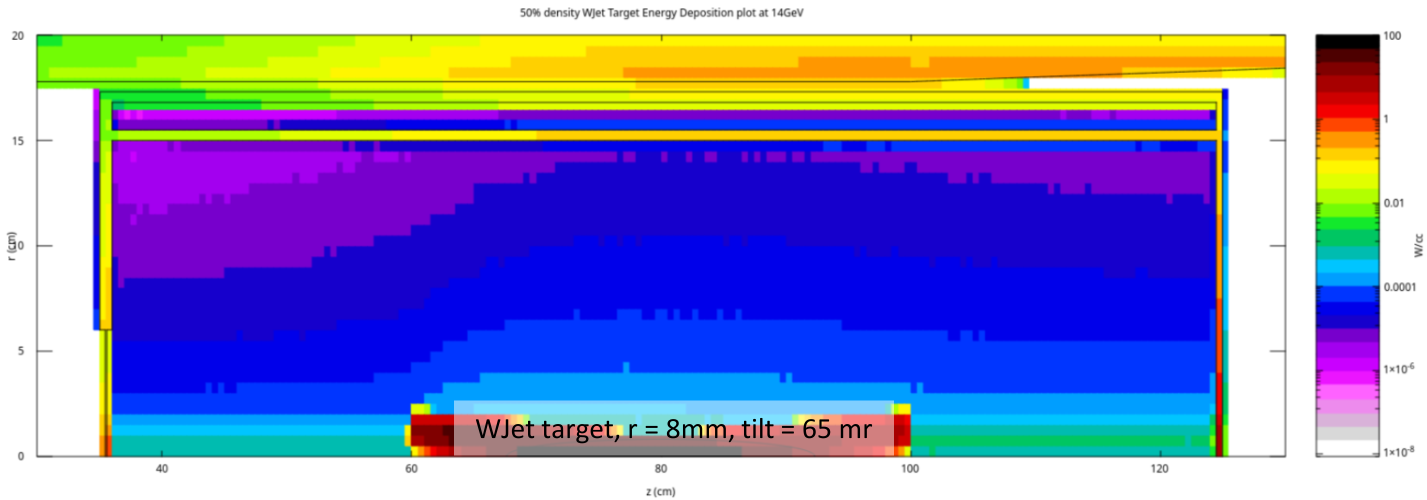
Beam direction



Graphite and WJet Target E_{dep} (2 & 14GeV)

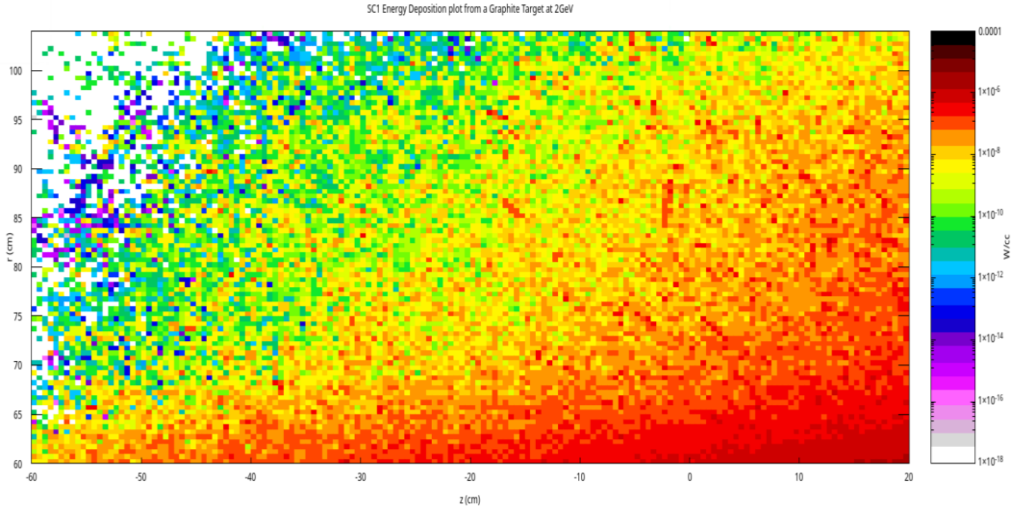


Graphite average power deposition = 229.5±1.6 kW



WJet average power deposition = 590.6±5.0 kW

Superconducting Coil 1 E_{dep} (2 & 14GeV)

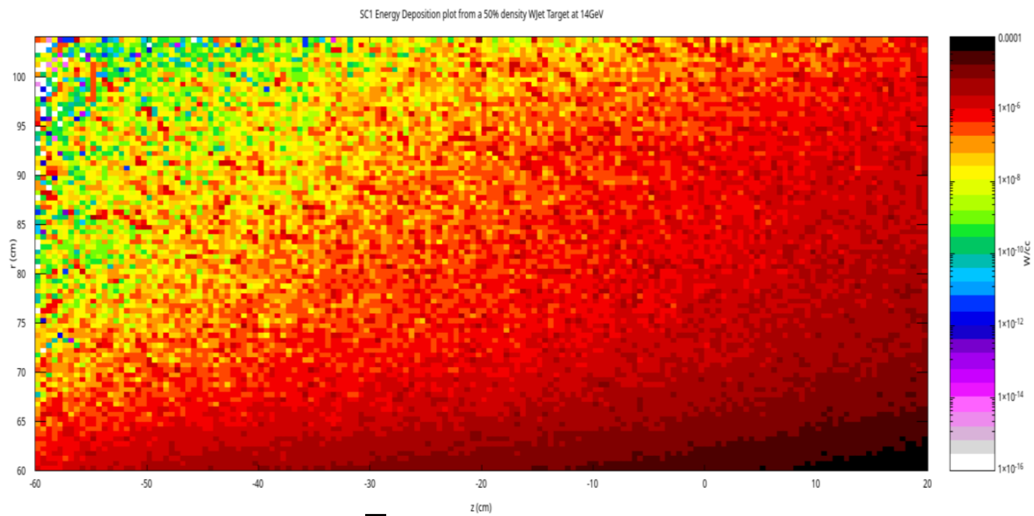


- Shielding shape keeps the energy deposition load on the SC magnets consistent

- Average SC1 energy deposition is ~85% more from the WJet target due to W creating more E_{dep} /secondary particles

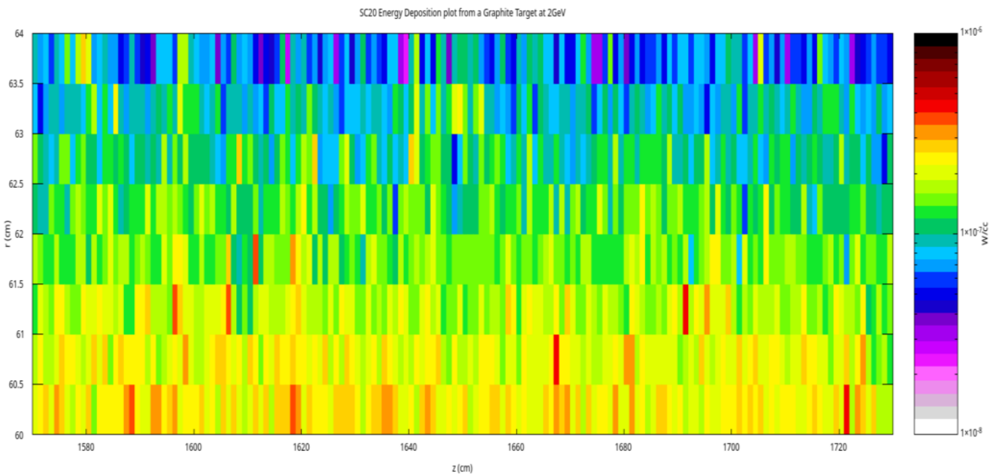
Graphite $\bar{E}_{dep} \approx 0.0080\text{mW/g}$

- Superconducting materials have a maximum energy density of deposition limit of ~0.1mW/
- Both Graphite and Wjet should not quench



WJet $\bar{E}_{dep} \approx 0.015\text{mW/g}$

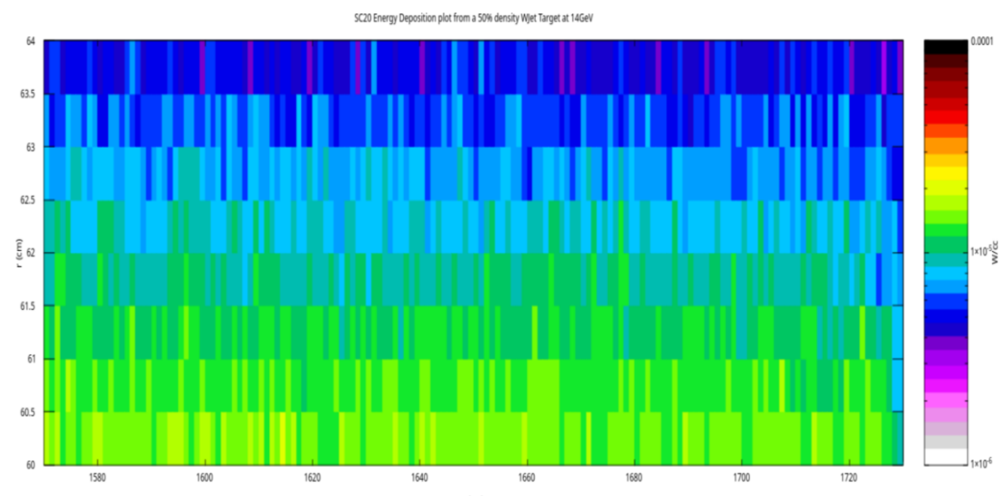
Superconducting Coil 20 E_{dep} (2 & 14GeV)



Graphite $\bar{E}_{dep} \approx$ 0.11mW/g

- Data is less populated, lower interactions with SC20 compared to SC1
- Average SC20 energy deposition is ~25% more from the WJet target due to similar reasoning

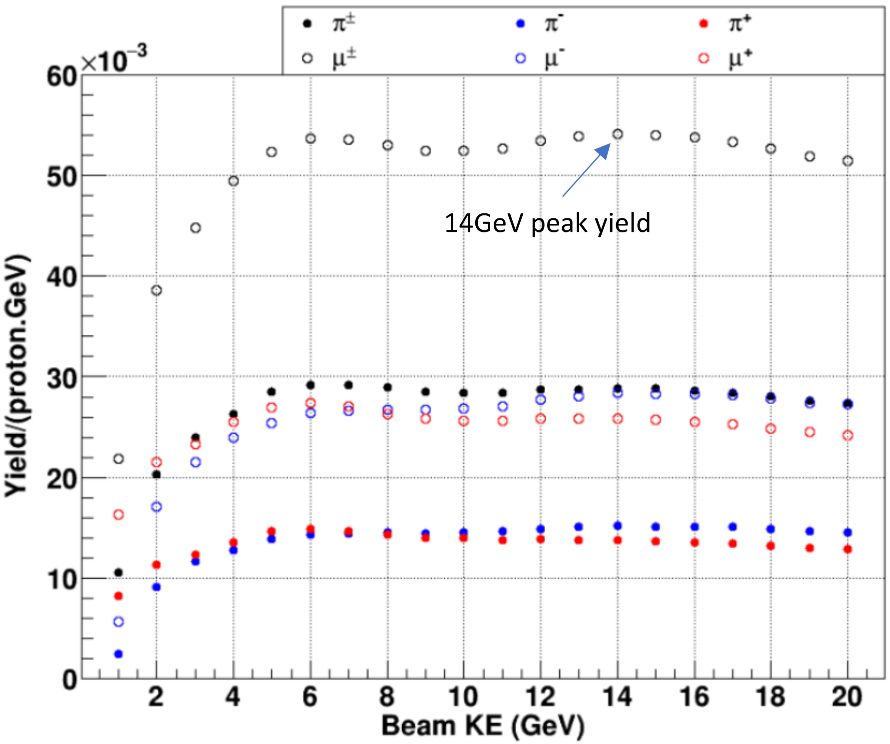
- Both Graphite and WJet causes an increase in energy deposition at SC20 when compared to SC1
- Both Graphite and Wjet will quench



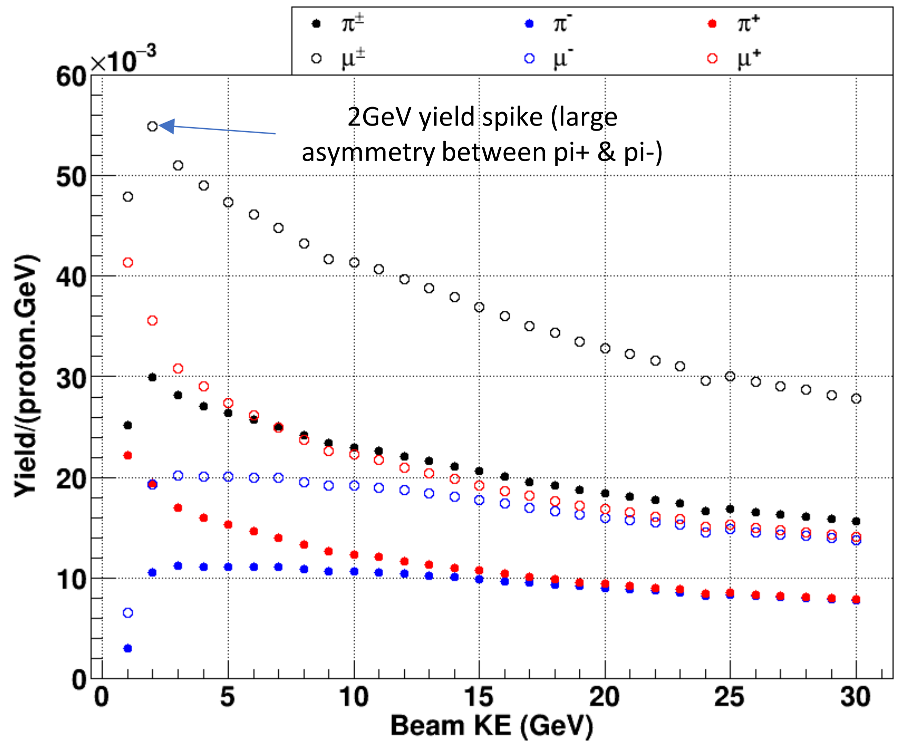
WJet $\bar{E}_{dep} \approx$ 0.14mW/g

Individual Yield plot results comparison (50% vs Graphite)

"Optimal" WJet Simulated data, l=40cm, tilt=65mr, r=8mm



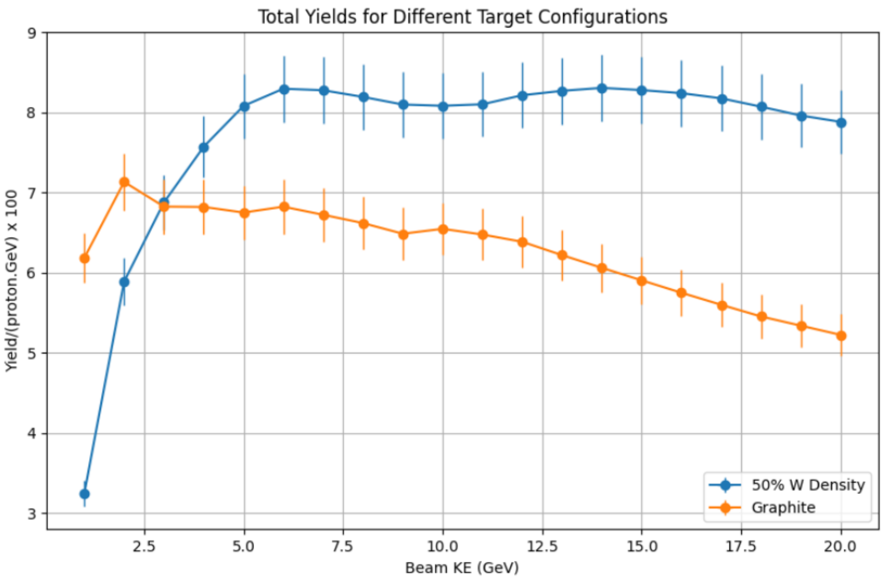
"Optimal" Graphite Simulated data, l=80cm, tilt=0mr, r=15mm



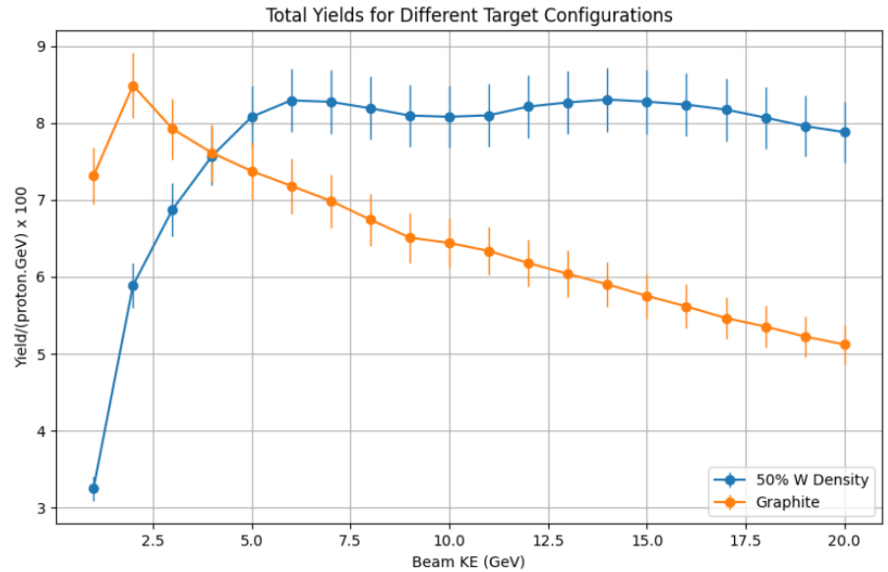
- Both data sets are from a 17.5m Beam Window
- 1 Million events for all GeV, KE acceptance range: 10 to 500MeV
- Pion yields are more substantial when produced from WJet target
- Muon yields dominate at z = 17.5 m compared to pions (pion decay)

Total yield comparison between different geometries

WJet against similar Graphite geometries, l=40cm, tilt=65mr, r =8mm



WJet (l=40cm, tilt=65mr, r =8mm) against Graphite (l=80cm, tilt=0mr, r =15mm) geometries

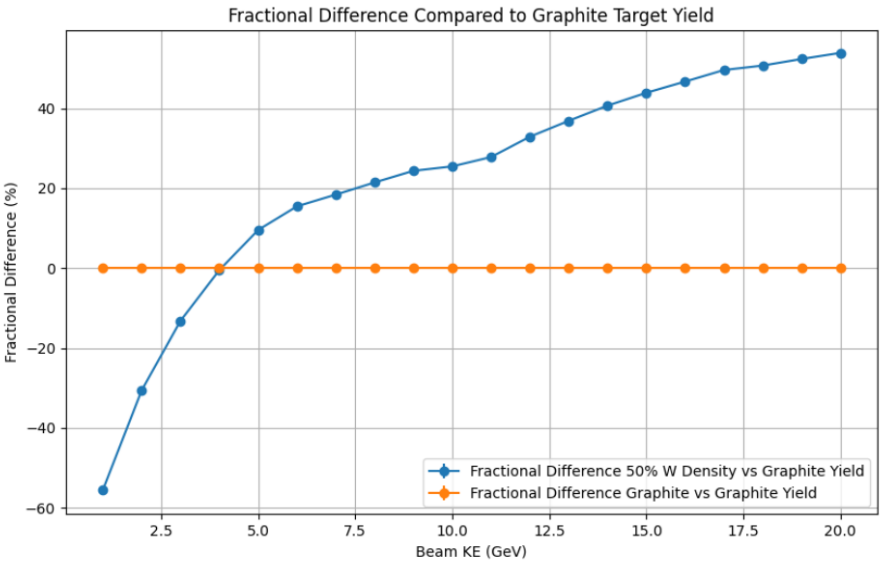


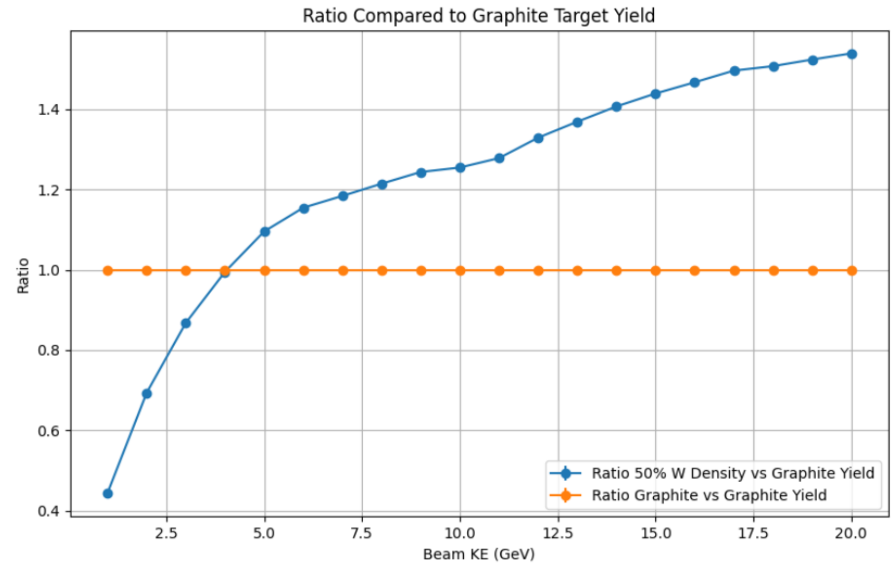
- Graphite does not perform as well with the changed specifications
- WJet performs better on average than the graphite, regardless of configuration
- 4MW beam at 10GeV has higher yields for WJet
- 14GeV gives the maximum yield for WJet

Fractional Difference and ratio plots

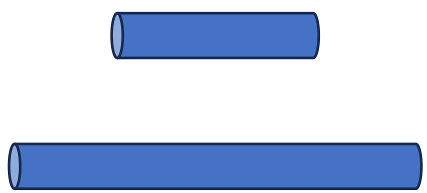
$$\frac{(WJet\ yield\ - Graphite\ yield) \times 100}{Graphite\ yield}$$

$$\frac{WJet\ yield}{Graphite\ yield}$$





- WJet gives up to 55% higher yields when compared to the current graphite configuration
- Further work is needed to determine if reabsorption is accounted for



WJet, L = 40cm, 2λ

Graphite, L = 80cm, 2λ

Future Plans

- May 2025 - June 2025:
  - Get a preliminary spread of data for a range of WJet densities (0-50%) within the current design
    - Create fractional yield plots between the Graphite and WJet data to determine the differences
- June 2025 - October 2025:
  - Adjust the current FLUKA Geometry to implement the proposed WJet design
  - Study yields for different Z materials (SiC, mercury Hg etc.) to create a "Zoo" plot of yields vs atomic Z for different beam energies and target lengths.
- October 2025 onwards:
  - Reintroduce the previous pyg4ometry design to allow for BDSIM simulations
    - Compare the results from BDSIM to FLUKA
- Are there any future changes to the FLUKA geometry being considered?
  - Will the chicane change?
    - If so, will the geometry be updated accordingly?
- Has the KE acceptance range been decided yet?

Summary

- Tungsten powder jet target is a promising target for the Muon Collider
- Energy deposition plots shown for graphite & W jet targets show potential downstream SC quenching
- WJet has a larger energy range in which the yield is larger than graphite
- WJet (l=40cm, tilt=65mr) can potentially produce a 5% higher peak yields than Graphite (l=80cm, tilt=0mr)
- WJet (l=40cm, tilt=65mr) can potentially produce up to 55% more yields than graphite (l=80cm, tilt=0mr) at 14GeV
- 2MW beam is competitive between the two materials but for 4MW, Wjet has better performance

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