Research on Optimization Simulation of High Rep-Rate Pulsed Electron-Driven Muon Beamline

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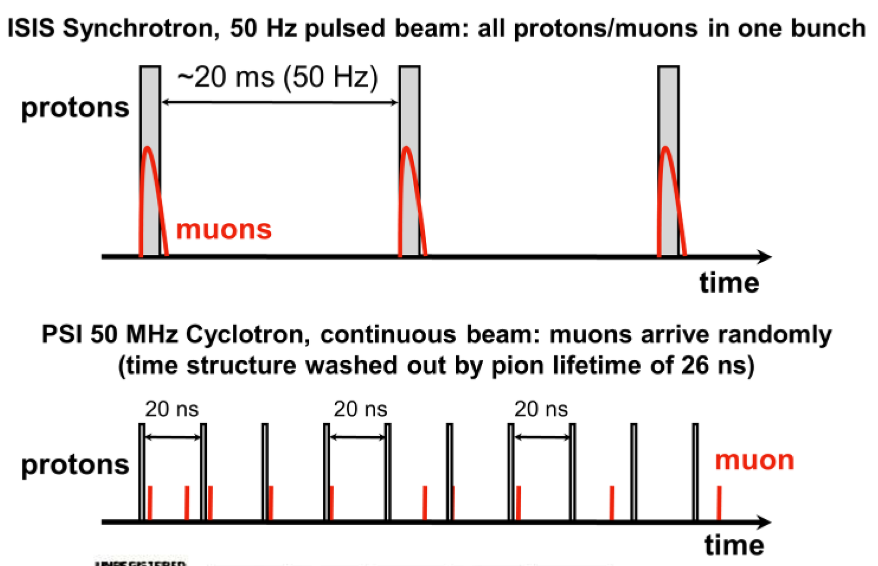
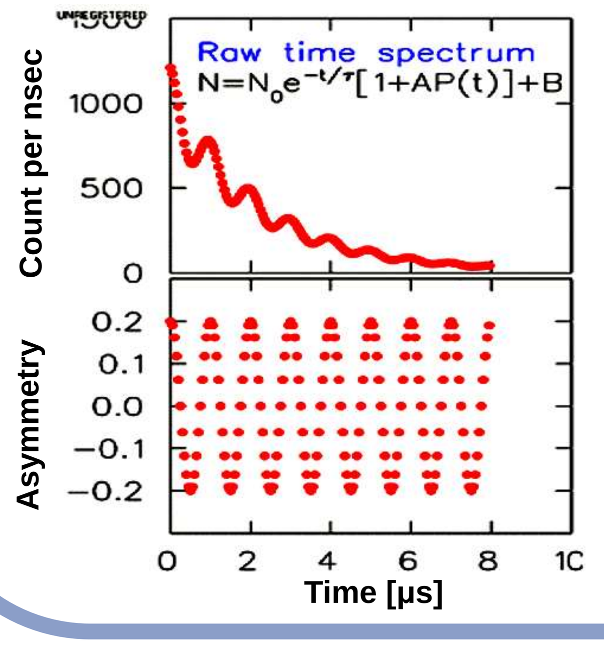
Limitations of Traditional Muon Source

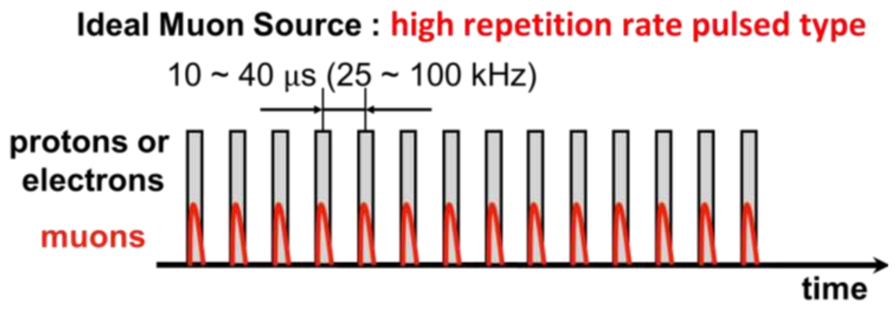
Two types of muon sources





- Optimal measurement duration for μSR[1]:
  10 μs ~ 20 μs (~ 5 to 10 muon lifetimes)
- DC muon source [2]
  - Allows 1 muon per 10 μs
  - Only utilize 0.1% of all muons
- Low Rep-Rate Pulsed muon source [3]
  - Low duty cycle (10 μs out of 40 ms)
  - Detector dead time limitation

Ideal Muon Source : high repetition rate pulsed type

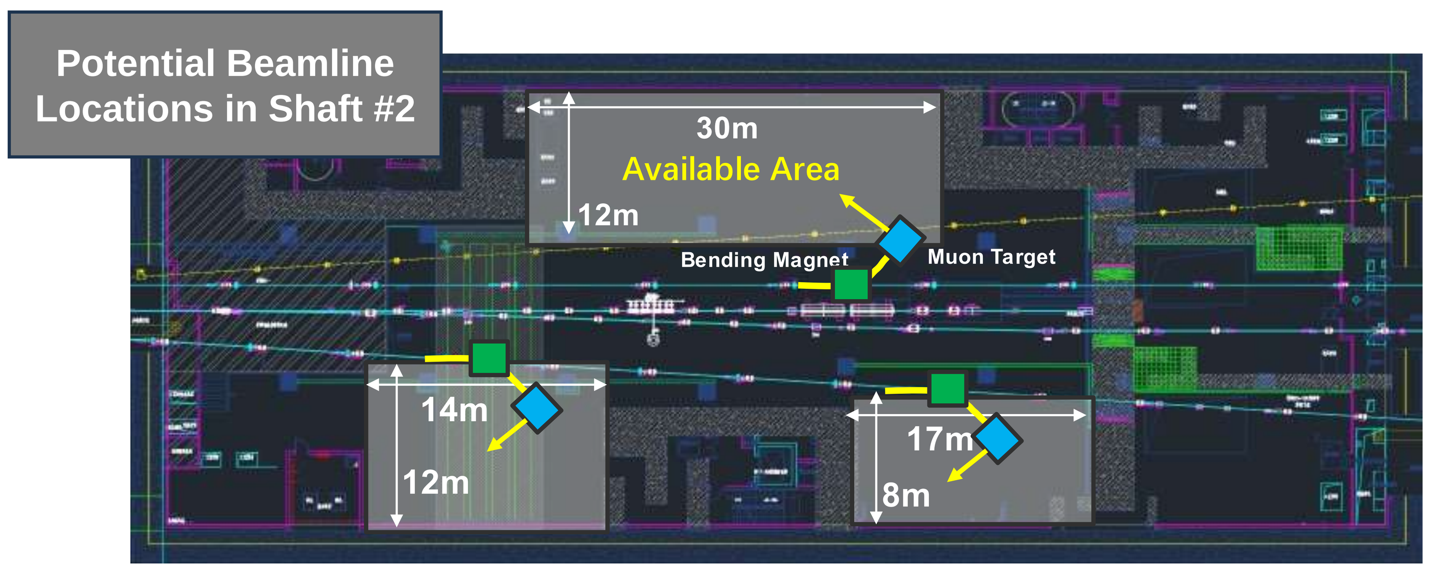


An ideal pulsed muon source would be like[4]:

- Increase bunch frequency: 25-100 kHz
  - Higher duty cycle (>50%)
- Less muon per bunch
  - Less pileup (10^2 ~ 10^3 μ^+ /pulse)
- Closest proton driver: Mu2e[5] at FNAL (600 kHz)

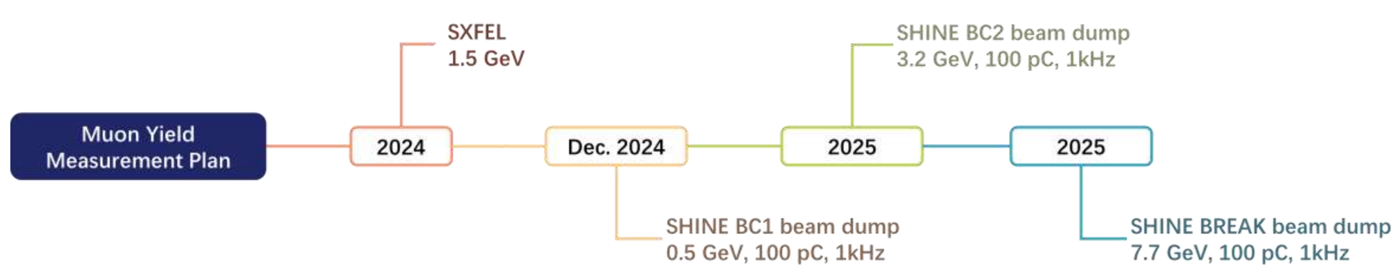
High Repetition-Rate Pulsed Electron-Driven Muon Source

- The **SHINE facility**[6] in Zhangjiang, Shanghai, is designed to deliver photons between 0.4 keV and 25 keV at a repetition rate as high as 1 MHz using a superconducting LINAC.
- A muon source driven by electrons can be constructed utilizing the high-repetition-rate electron beam from SHINE.
- **Electron Beam parameters:**
  - 8 GeV, 1 MHz frequency, 100 pC per bunch, $\delta_{beam} = 2mm$. [7]

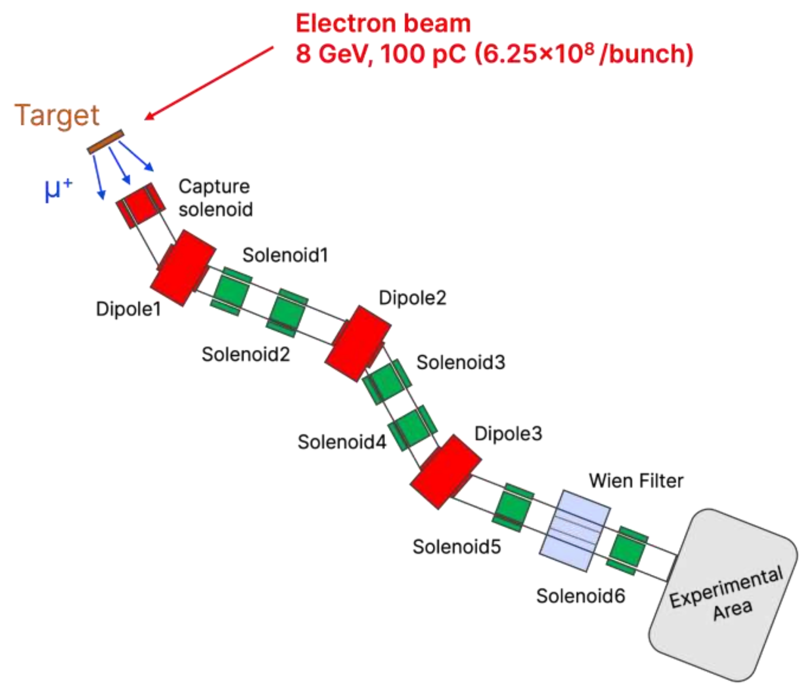


- A copper target can be placed before the dump to produce surface muons.
- The solenoid can be positioned very close to the target as it has lower radiation compared to proton-driven sources.

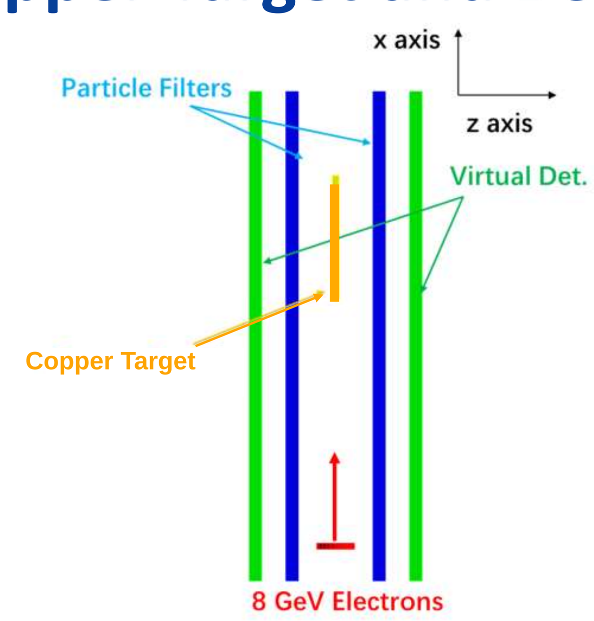
Optimizing the Copper Target and Beamline: A Simulation Study



[Fig. 1 The Muon Yield Measurement Plan based on SHINE Project]



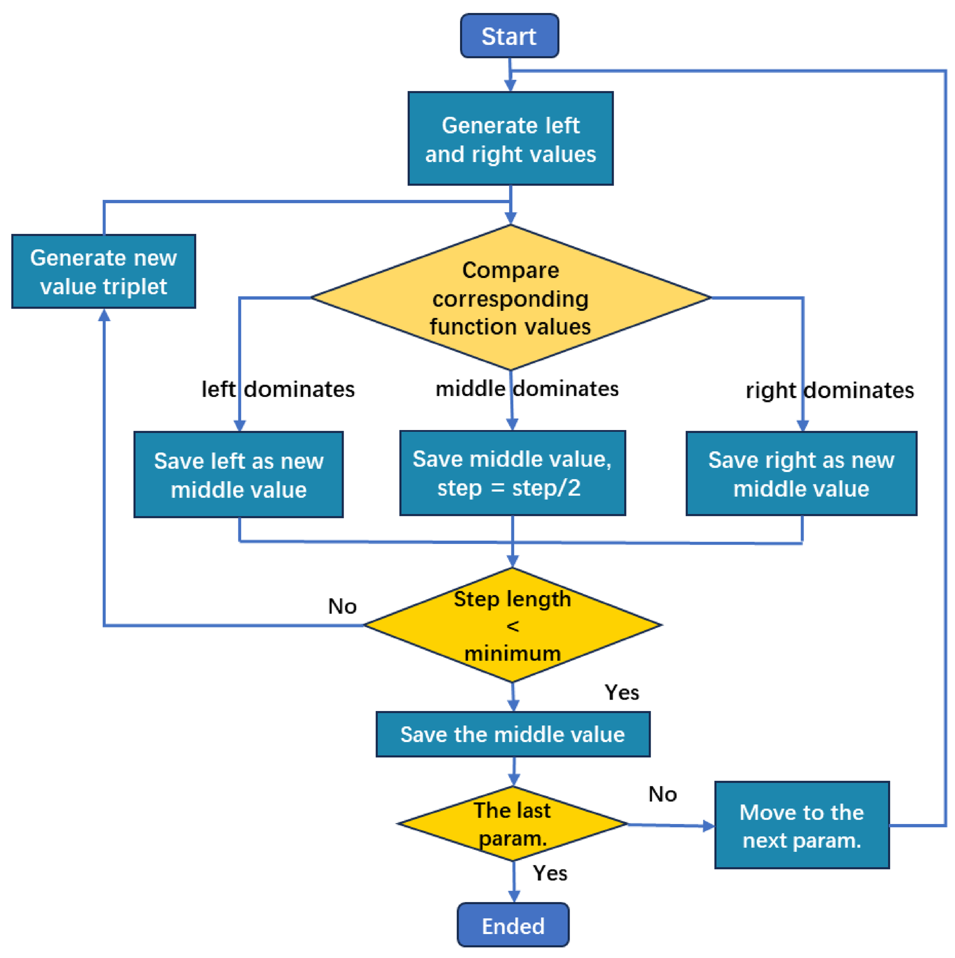
[Fig. 2 The Schematic View of Beamline of SHINE SMS]



[Fig. 3 A Schematic View of the Copper Target and Detector Settings (Top View)]

Goals for Optimization:

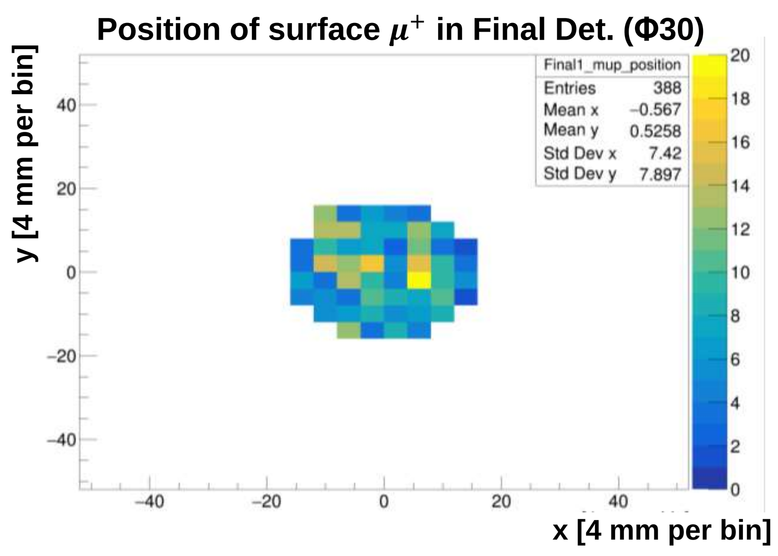
- Ensure the target exhibits the highest surface muon rate in the side direction.
- Achieve the highest surface muon rate at the final detector in the beamline.



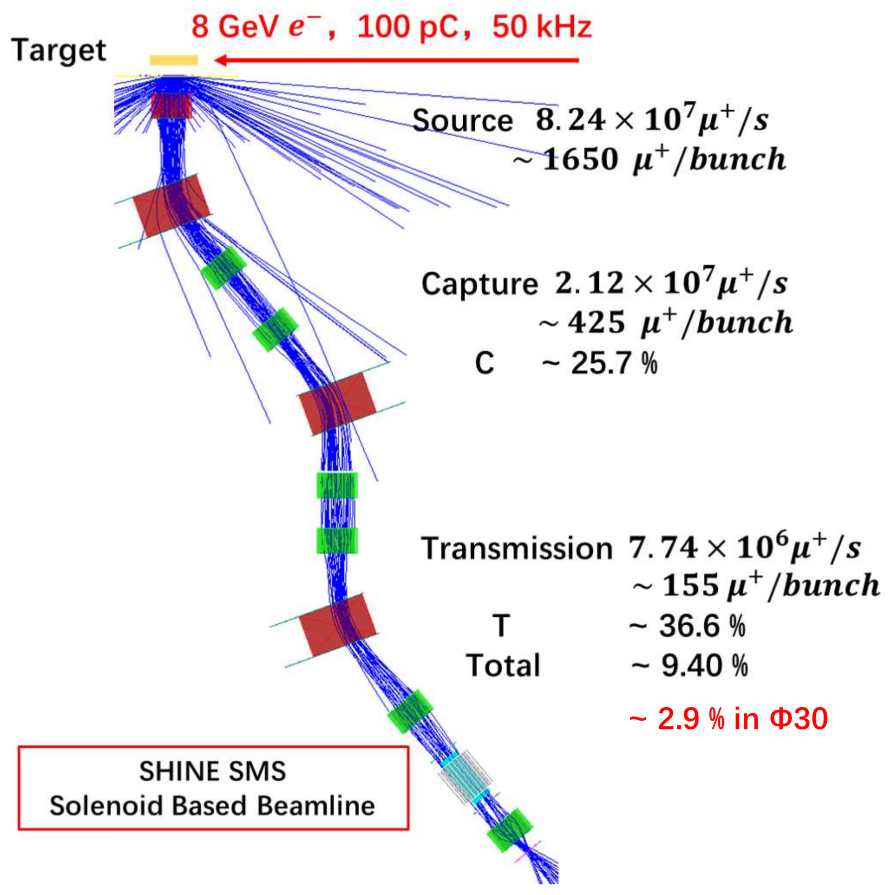
- The flowchart represents a single optimization process. Repeat this process until the function value converges.

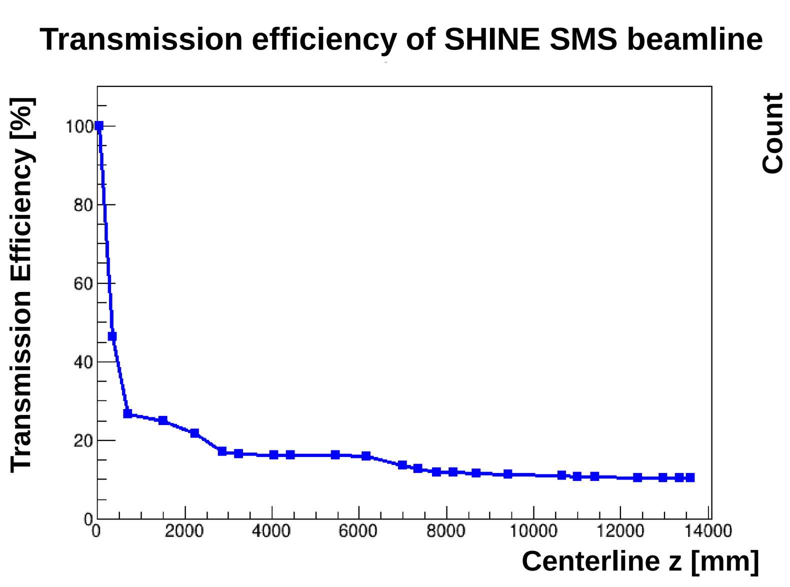
Solenoidal Beamline Optimization

- After further fine-tuning of the final beam spot, the surface muon intensity at the final focus can reach **2.4×10^6 per second** (approximately 50 per bunch) **in a Φ = 30mm area.**

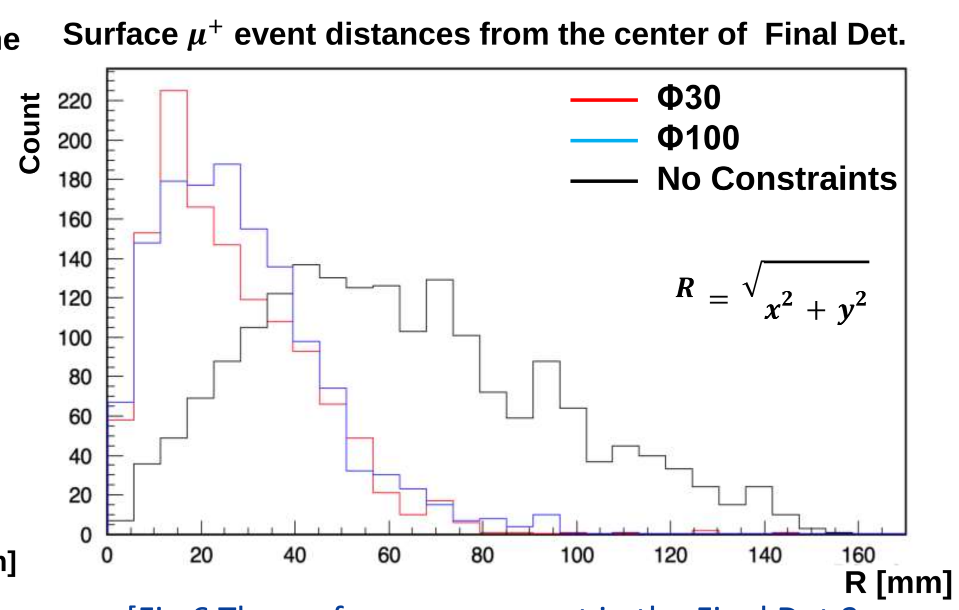


[Fig.4 The beam spot of surface muons in the Final Det. Constraint: Φ = 30 mm, EOT: 5×10^9]



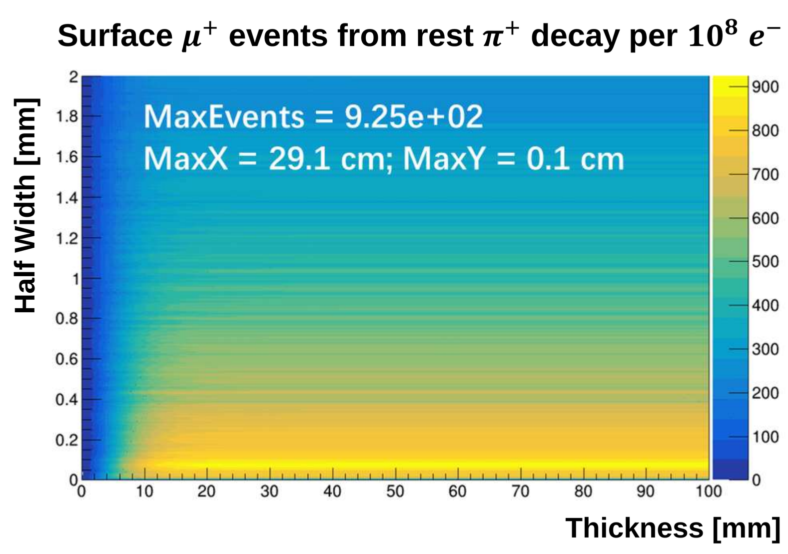


[Fig 5. The Transmission Efficiency along the Centerline of Optimized SHINE SMS Beamline]



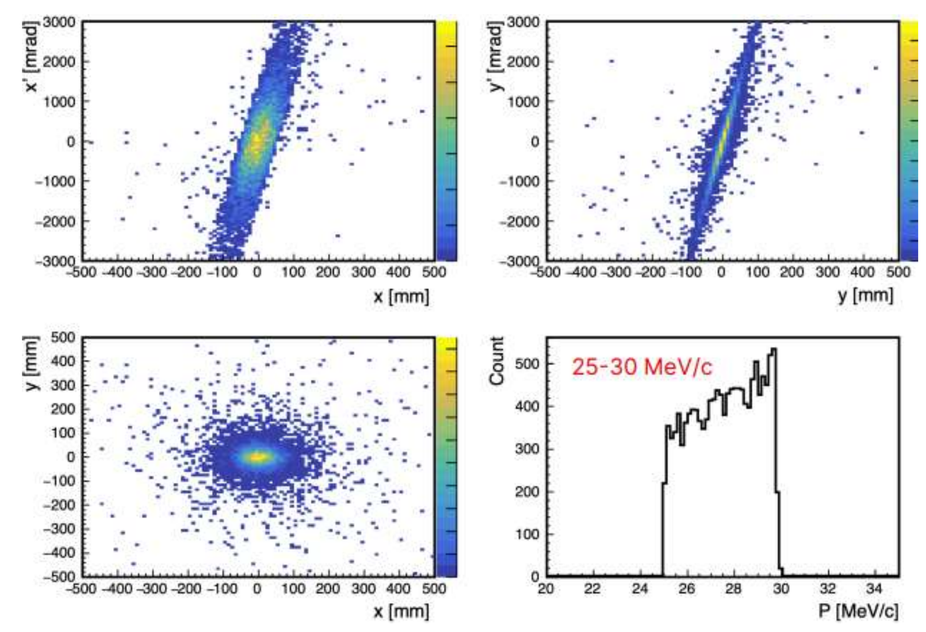
[Fig.6 The surface muon count in the Final Det.2 versus the distance R to the center of Final Det.2]

Box Shaped Target Optimization



[Fig 7. The Surface Muon Yield Distribution per 10^8 8 GeV EOT, Target Height = 1500 mm]

- The radiation length for copper is 1.436 cm, so a 100 mm length can generate considerable surface muons (approximately 500 on one side for an ideal per 10^8 8 GeV EOT).



[Fig 8. Surface muon 35 mm from target @ 90 degrees 25-30 MeV/c (1650 surface μ+/bunch)]

- The adjusted width of target is 5 mm for SHINE with a beam spread (δ_{beam}) of 2 mm .
- In the future, we will conduct research on the slanted target.

Conclusion

- Current proton-driven muon sources are either low-repetition-rate pulsed sources or DC sources, which are not optimal for various types of muon experiments.
- A 25-100 kHz pulsed muon source can be built utilizing the high-repetition-rate electron beam at the SHINE facility.
- From the simulation, our fine-tuned SHINE surface muon beamline has a total efficiency of about 2.9% for surface muons, with a beam intensity of about 2.4×10^6 surface muons per second (μ^+/s) in a Φ30 area.
- In future work, we will optimize the beam size at the final focus.

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References

[1] K. Nagamine, Introductory Muon Science, Cambridge University Press (2003)
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