Comparison study of muon sources

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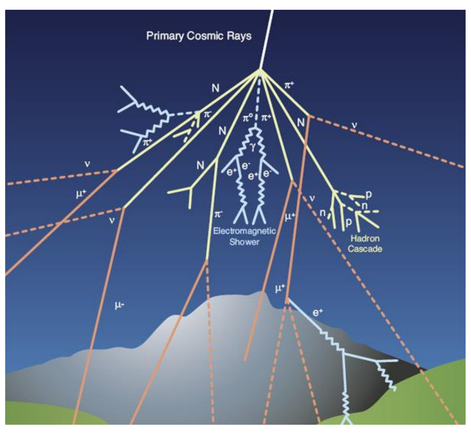
Muon sources

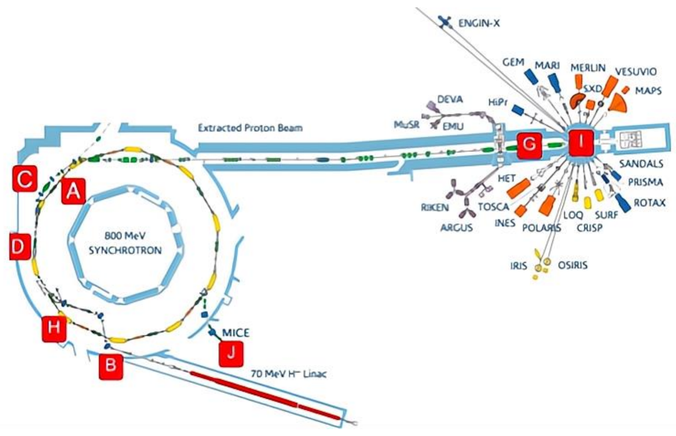
1, Muon plays an import role in fundamental physical researches (such as muon g-2[1]) and applied sciences (μSR[2], etc.)

2, According to production way, the muon sources are divided into cosmic ray muon source[3] and accelerator muon source[4].

3, In addition to proton (e.g. ISIS[4]), other types of particles, such as high-energy electrons[5], gamma rays[6], have been proposed to produce high-intensity muon beams.



cosmic ray muon source[3]

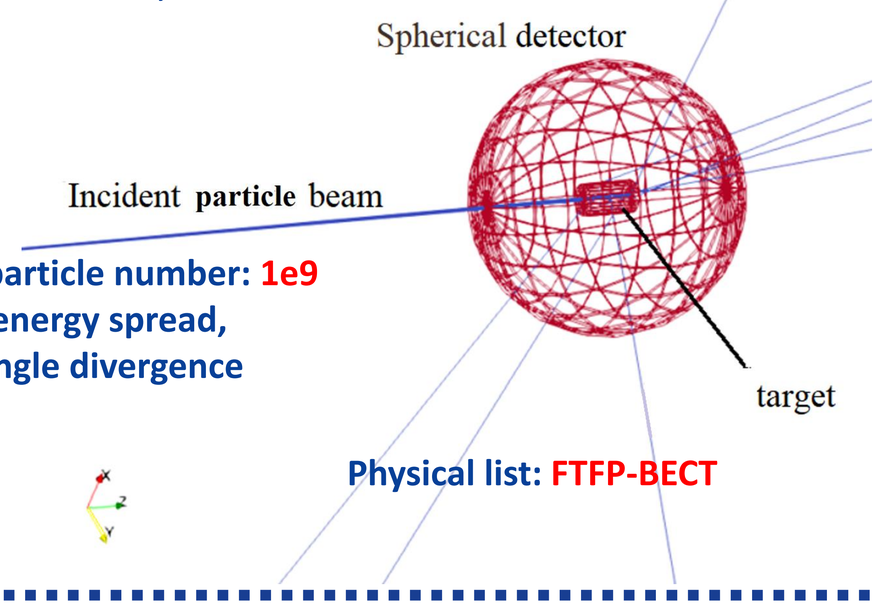


accelerator muon source[4] (ISIS)

Simulation and its Parameters

By using the Geant4 simulation, the number, energy distribution, and angle distribution of positive muons generated under the drive of proton, electron, and photon are compared in research.

The spherical detector is 1 mm thick with vacuum material, and its radius is 50 mm.



Incident particle number: 1e9
No energy spread,
No angle divergence

Physical list: FTFP-BECT

Muon production Channels by proton-driven[4] Vs electron/gamma ray-driven[5,6]

single pion Production(>280MeV)

$$p + p \rightarrow p + n + \pi^+ \qquad p + n \rightarrow p + p + \pi^-$$
$$p + p \rightarrow d + \pi^+ \qquad p + n \rightarrow n + n + \pi^+$$

Double pion Production(>600MeV)

$$p + p \rightarrow p + p + \pi^+ + \pi^- \qquad p + n \rightarrow p + n + \pi^+ + \pi^-$$
$$p + p \rightarrow n + n + \pi^+ + \pi^+ \qquad p + n \rightarrow n + n + \pi^+ + \pi^0$$
$$p + p \rightarrow n + p + \pi^+ + \pi^0 \qquad p + n \rightarrow d + \pi^- + \pi^+$$

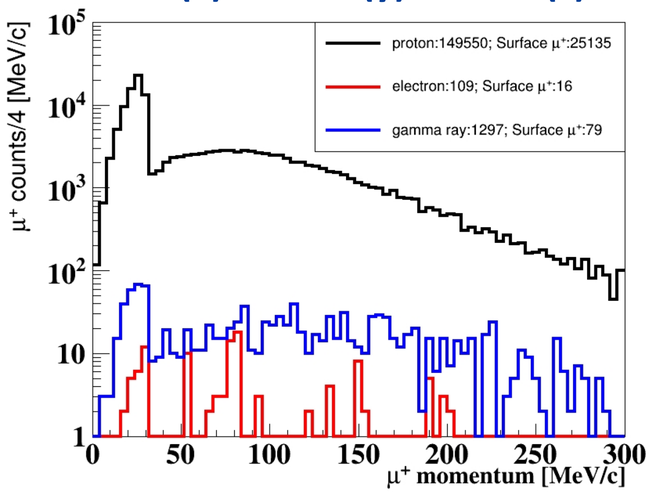
Bremsstrahlung: $e^- + N \rightarrow e^- + N + \gamma$

Photon Nuclear reaction: $\gamma + N \rightarrow N^* \rightarrow \pi^{\pm}/K^{\pm} \rightarrow \mu^{\pm}$

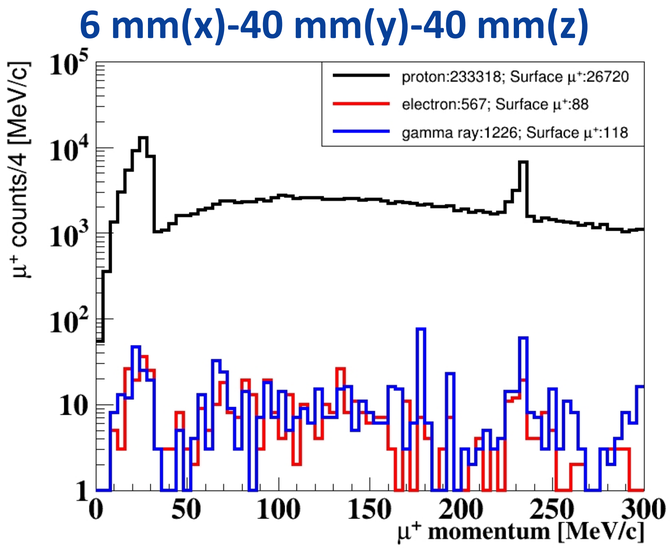
Bethe-Heitler Process: $\gamma + N \rightarrow N + \mu^+ + \mu^-$

Simulation Result

Beam Parameter: 585 MeV, 1e9
Box-shaped carbon target:
6 mm(x)-40 mm(y)-40 mm(z)



Beam Parameter: 8 GeV, 1e9
Box-shaped carbon target:
6 mm(x)-40 mm(y)-40 mm(z)



*surface μ+: muon momentum range: 27 MeV/c~30 MeV/c and 224 MeV/c~236 MeV/c

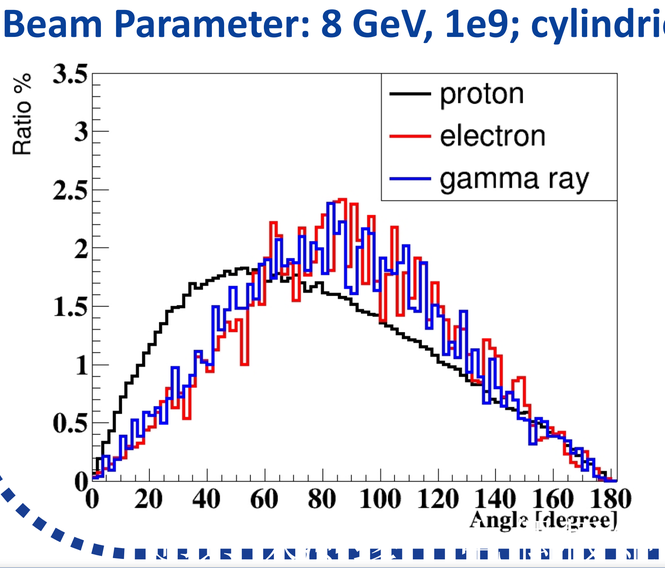
Conclusion

1.The energy and angle distribution of the surface μ+ driven by the three types of particles is similar.

2.For carbon targets, the number of muons driven by electrons and photons is 2 or 3 orders of magnitude smaller than that of protons for the same incident particle number. For tungsten targets, the number of muons increases by one order of magnitude.

3.Using Shanghai SHINE's parameters[7], we estimated the intensity of the surface μ+ beam to be around 10^8 μ^+/s. This research provides a check for the feasibility of using the electron beams of the SHINE to generate muon beams.

Beam Parameter: 8 GeV, 1e9; cylindrical tungsten target: 6 mm(x)-40 mm(y)-40 mm(z)



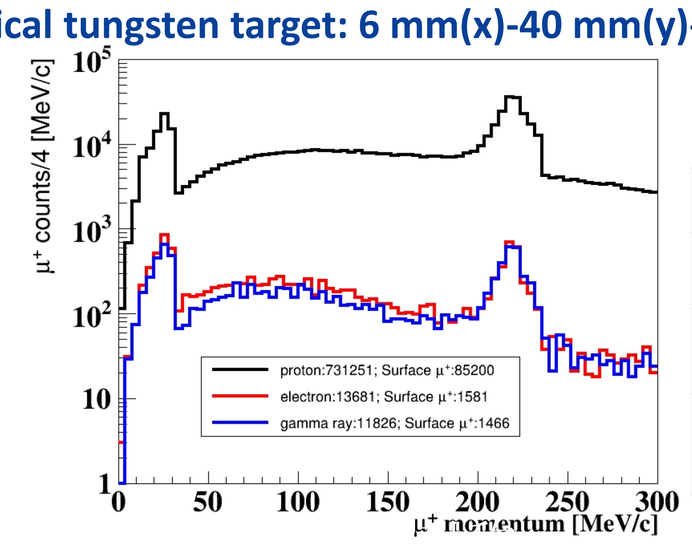


Table 1. The comparison of surface μ+ in three muon facilities.

Facility	Particle	Beam type	Surface μ^+
PSI (run)	585 MeV proton	CW	4 x 10^8 μ^+/s
SHINE (proposed)	8 GeV electron	Pulsed, 1 MHz	8 x 10^8 μ^+/s
CERN (proposed)	400 MeV gamma ray	Pulsed	O(10^{12})μ^+/s

Reference

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