Carbon Target Optimization for a Muon Collider/Neutrino Factory with a 6.75 GeV Proton Driver

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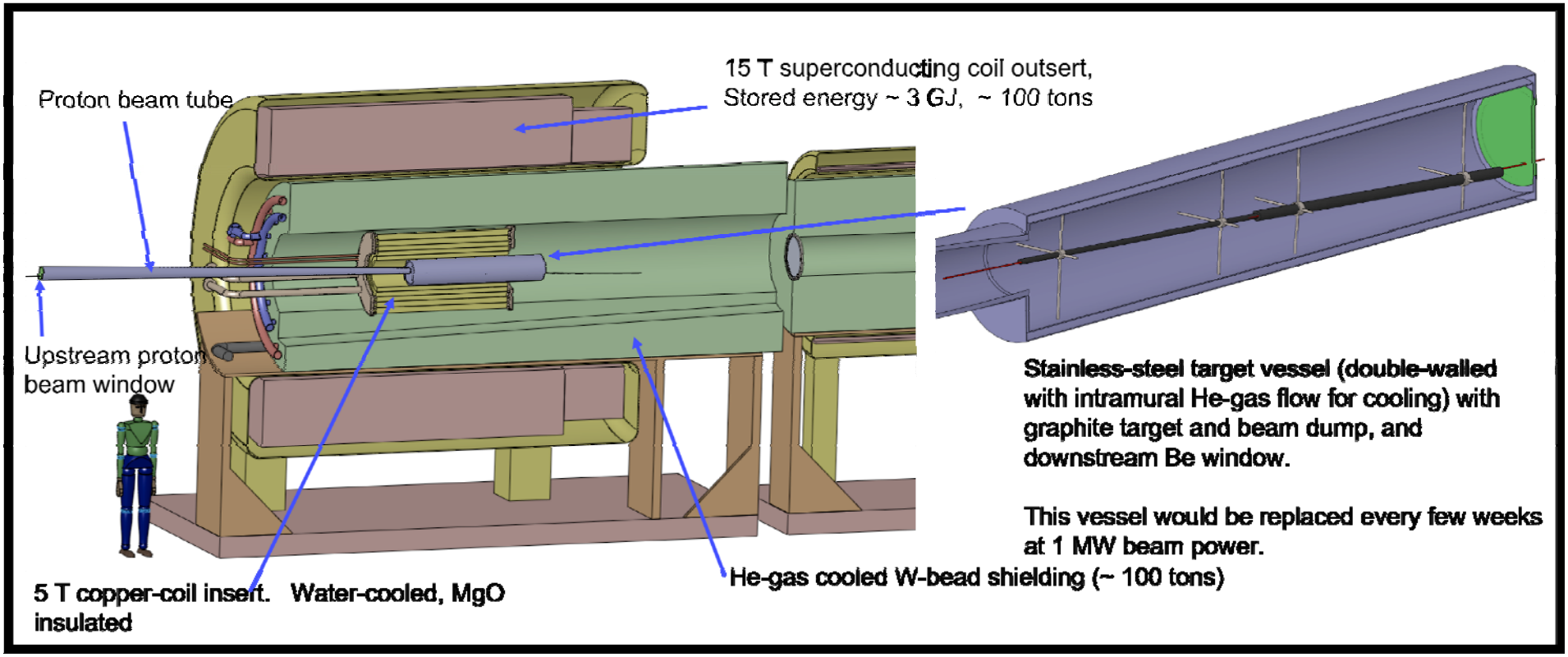
OUTLINE

- Carbon Target Configuration, Fieldmap and Setting
- Carbon target optimization (tilt beam)
- Carbon target yield comparison (no-tilt vs. tilt beam); Yield comparison between C, Hg and Ga target (no-tilt beam)
- Beam Dump Study (no-tilt and tilt beam)
- Summary

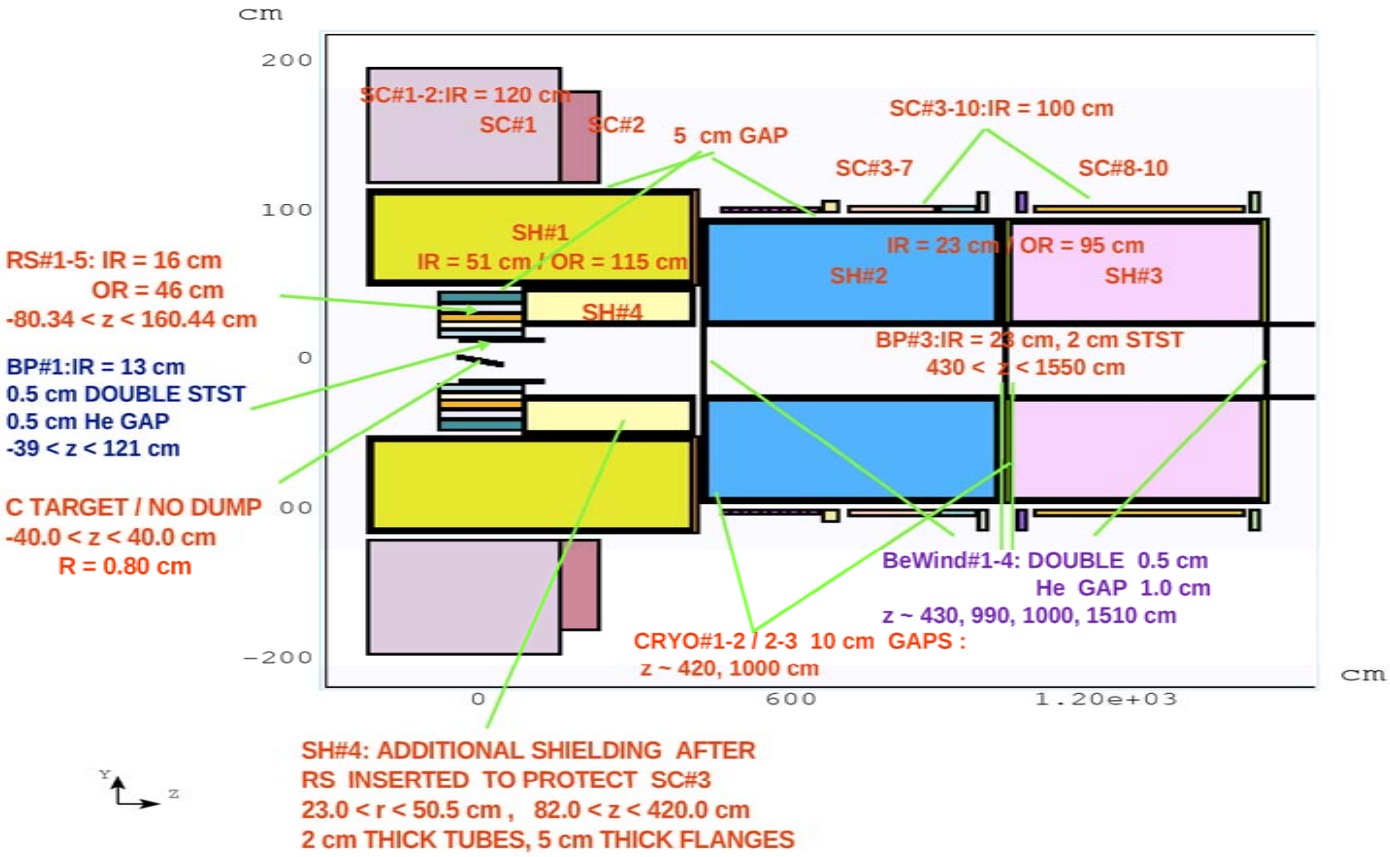
Carbon Target Geometry



http://physics.princeton.edu/mumu/target/hptw5_poster.pdf

Carbon Target Capture Magnets

(20Tto2T5m120cm)

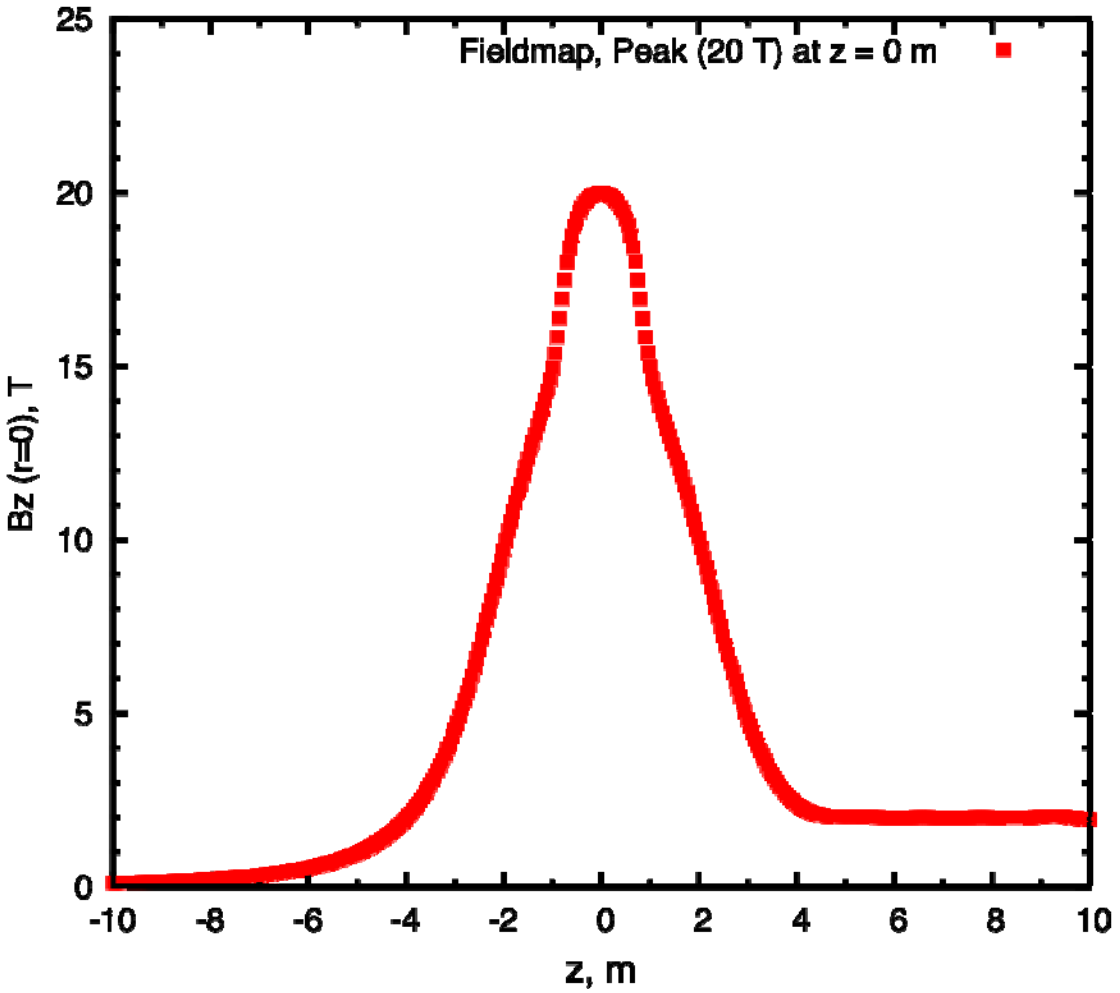


http://physics.princeton.edu/mumu/target/Souchlas/souchlas_140424.pdf

Coils SC#3-7 will have larger radii, but this does not affect the present study.

Fieldmap along SC axis

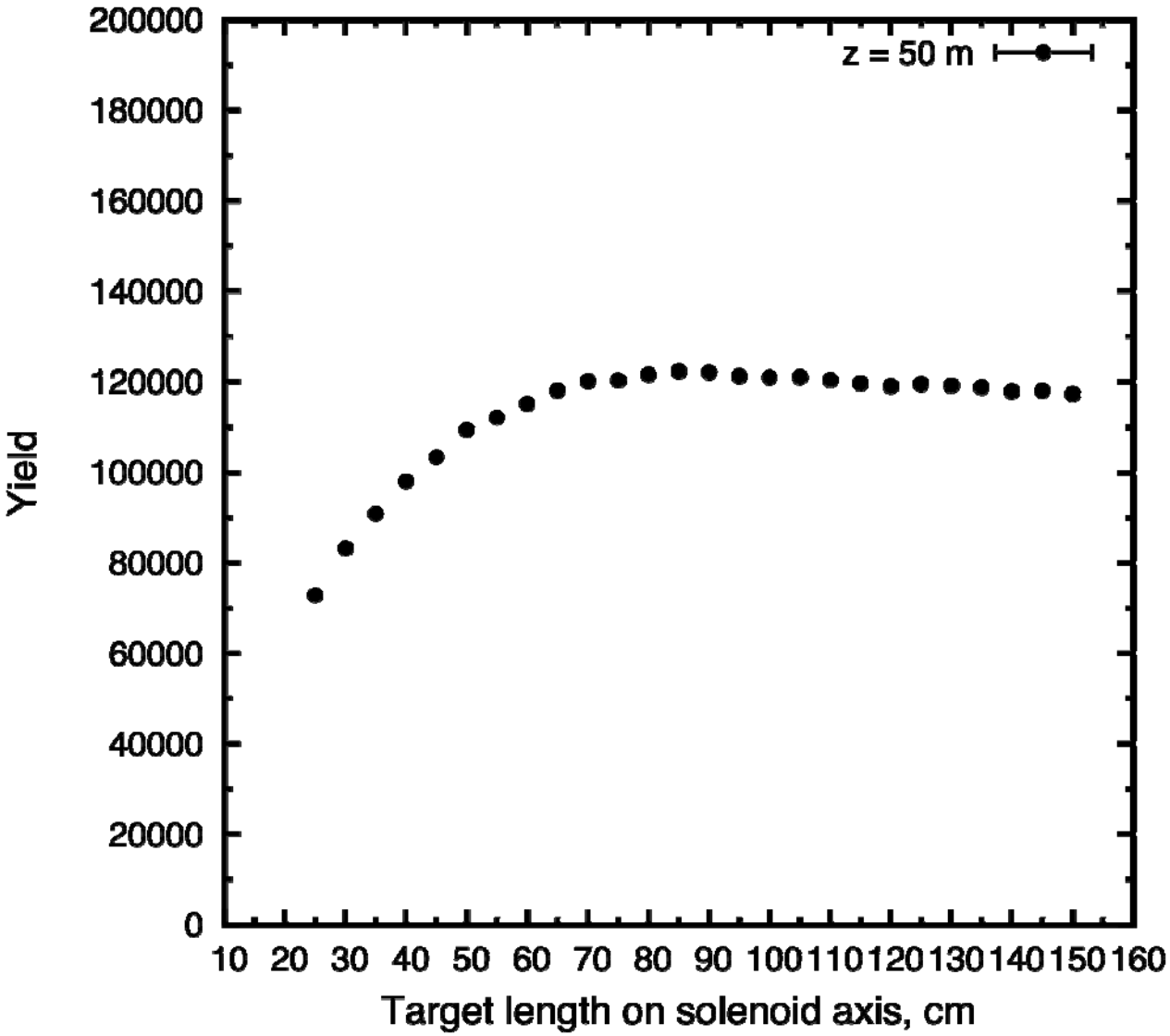
(Magnet 20to2T5m120cm)



Carbon Target Parameter Setting

- Simulation Code: MARS15(2014) with Event Generator Control setting of ICEM 4 = 1 (default) and with Energy Card Setting of ENRG 1 = 6.75, 2 = 0.02, 3 = 0.3, 4 = 0.01, 5 = 0.05, 6 = 0.01, 7 = 0.01 ;
- Fieldmap (20T➔2T) with taper length of 5m;
- Beam pipe radius: 13 cm (initial) and 23 cm (final);
- Proton beam: 6.75 GeV (KE), 1 MW, launched at z = -100 cm with waist at z = 0 m and emittance of 5 μm;
- Graphite density = 1.8 g/cm^3;
- Production Collection: 50 m downstream, 40 MeV < KE < 180 MeV.

Carbon Target Optimization (10^6 events, tilt beam) Particle Production *vs.* Target Length



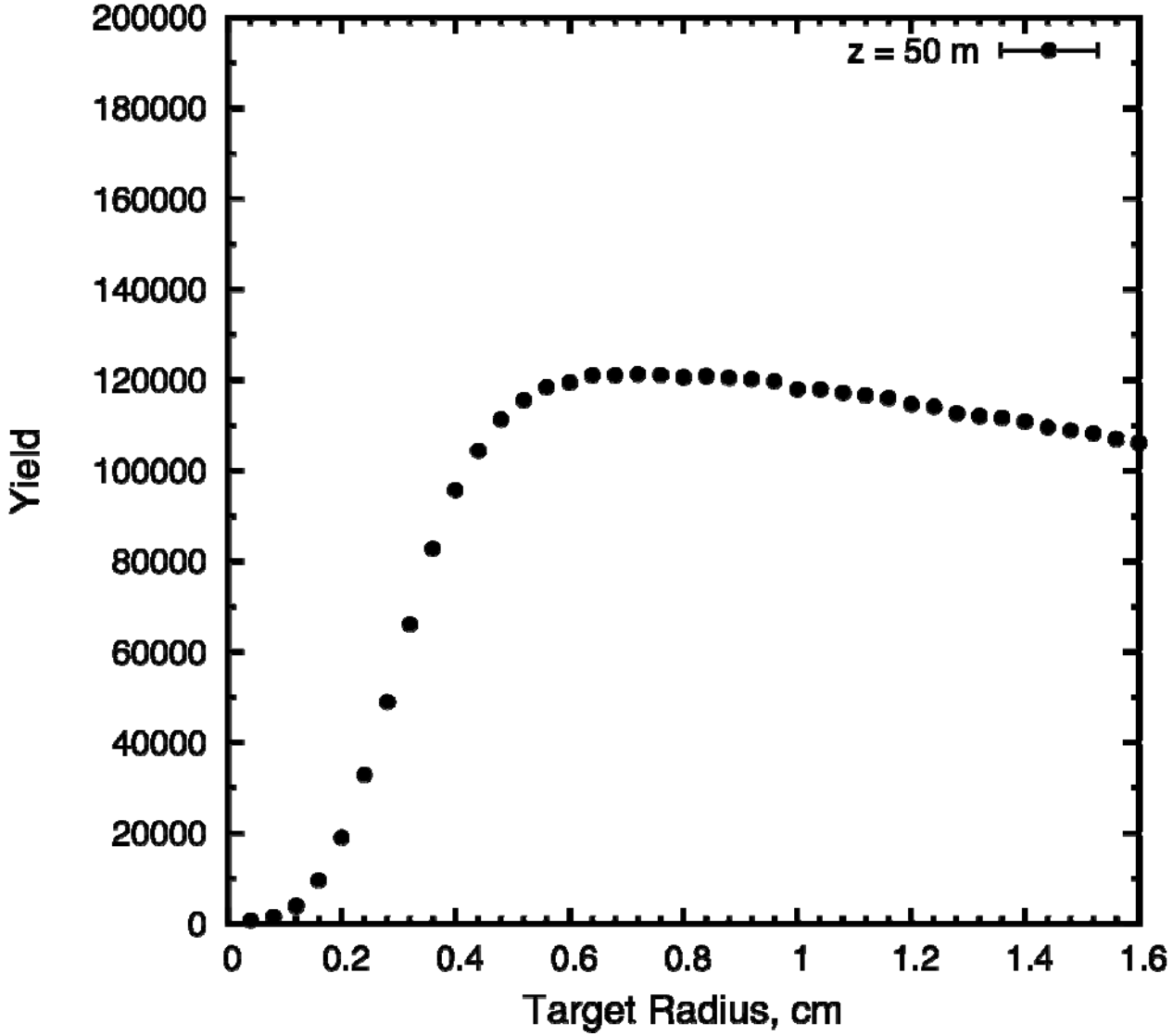
Target radius: 0.8 cm

Beam rms radius = 0.2 cm (TR/BR = 4)

Beam angle to SC axis: 65 mrad

Collinear target and beam

Carbon Target Optimization (10^6 events, tilt beam) Particle Production *vs.* Target Radius



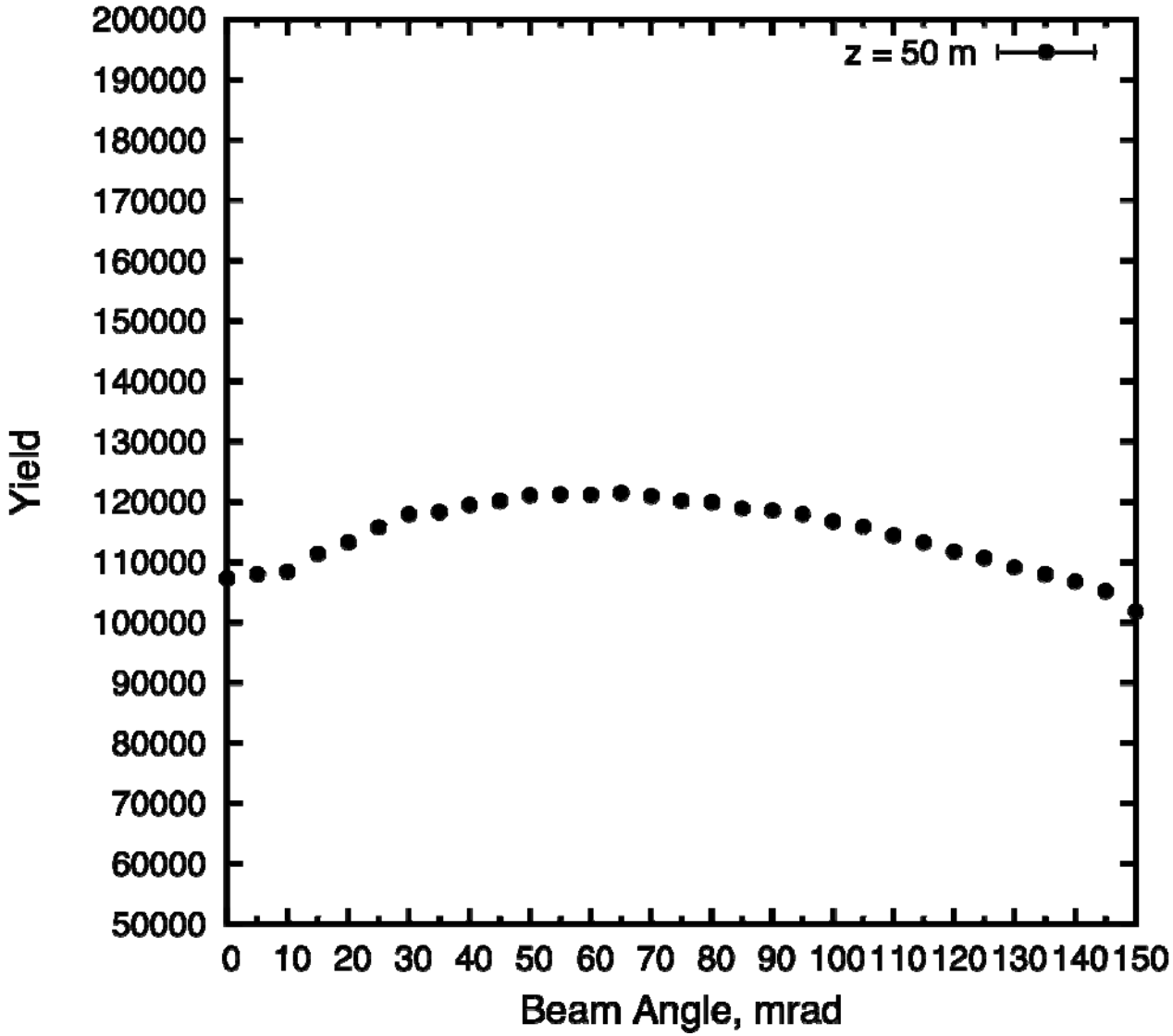
Target length: 80 cm

Beam angle to SC axis: 65 mrad

Collinear target and beam

TR/BR = 4

Carbon Target Optimization (10^6 events, tilt beam) Particle Production *vs*. Beam Angle



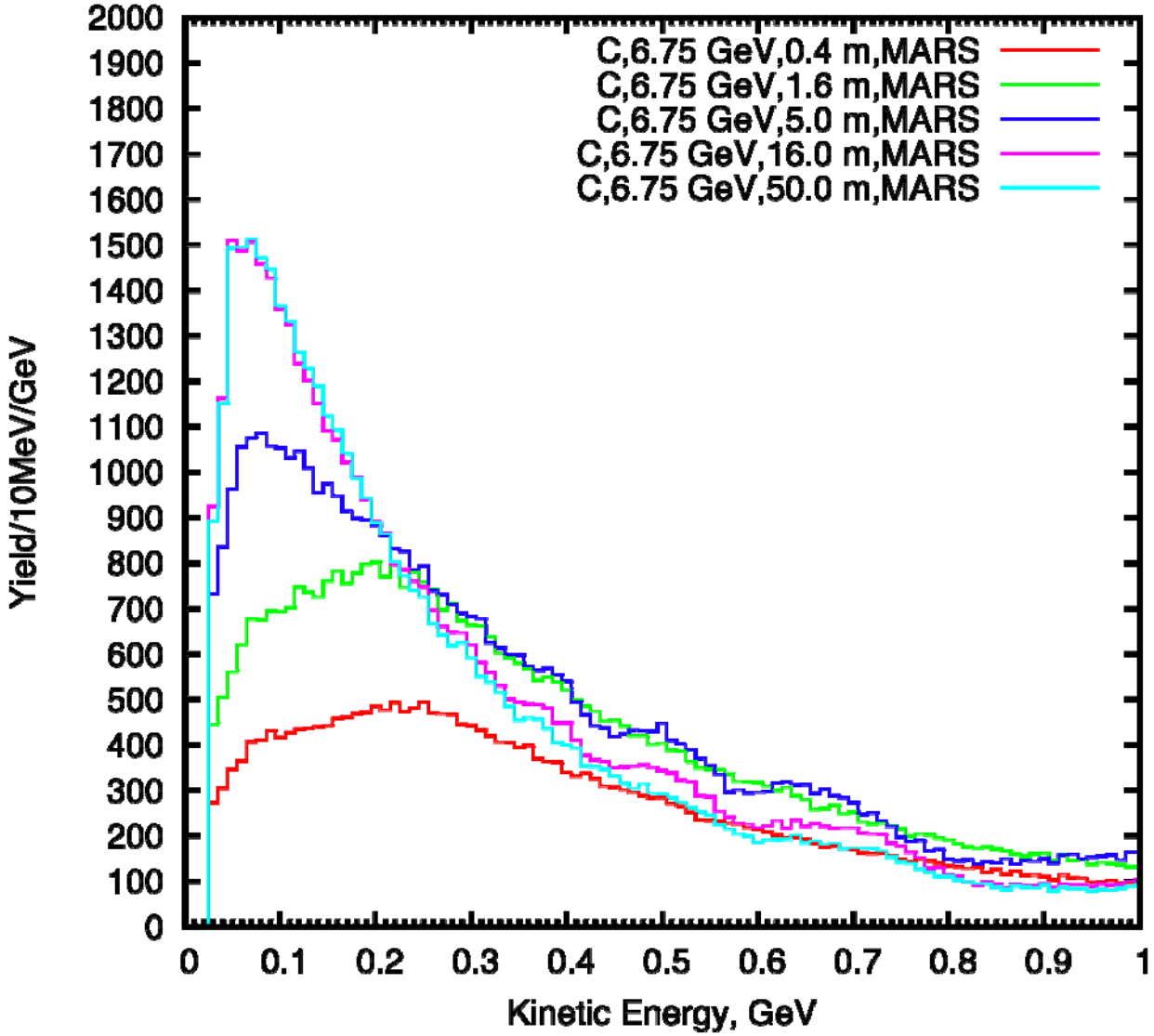
Target length: 80 cm

Target radius: 0.8 cm

Collinear target and beam

TR/BR = 4

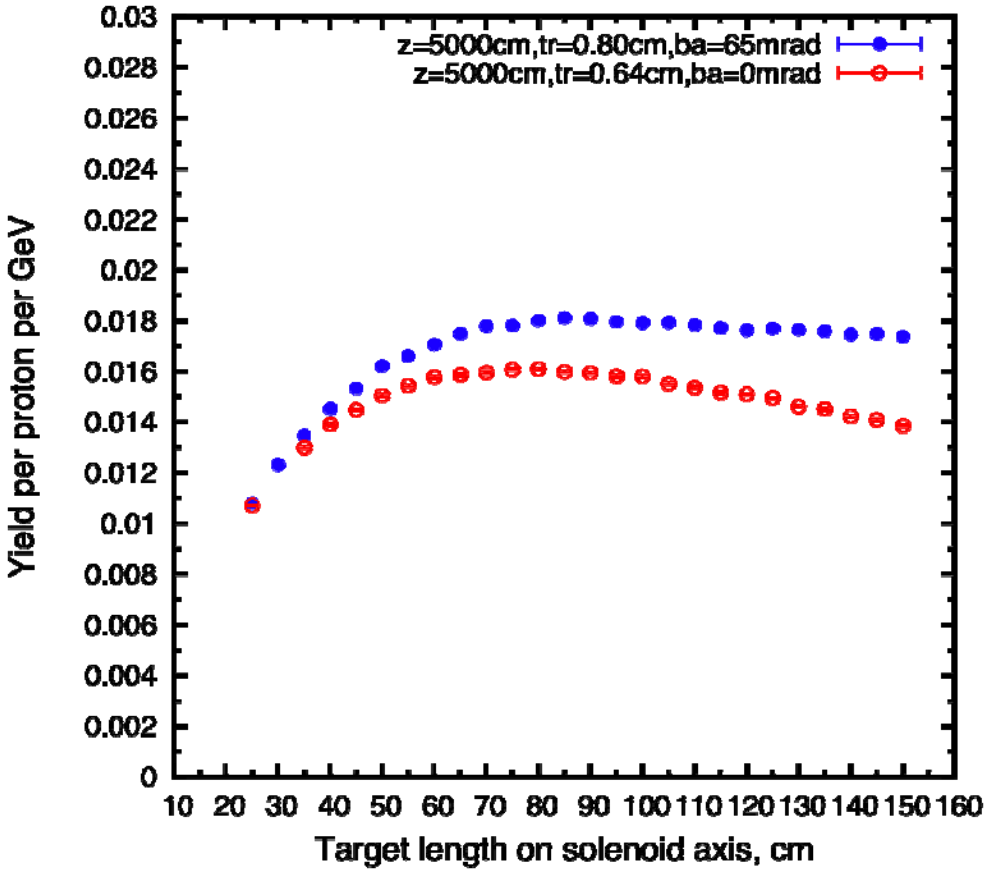
Energy Spectra of $\pi^{\pm}$, $K^{\pm}$, $\mu^{\pm}$ (10^6 events, tilt beam, carbon target)

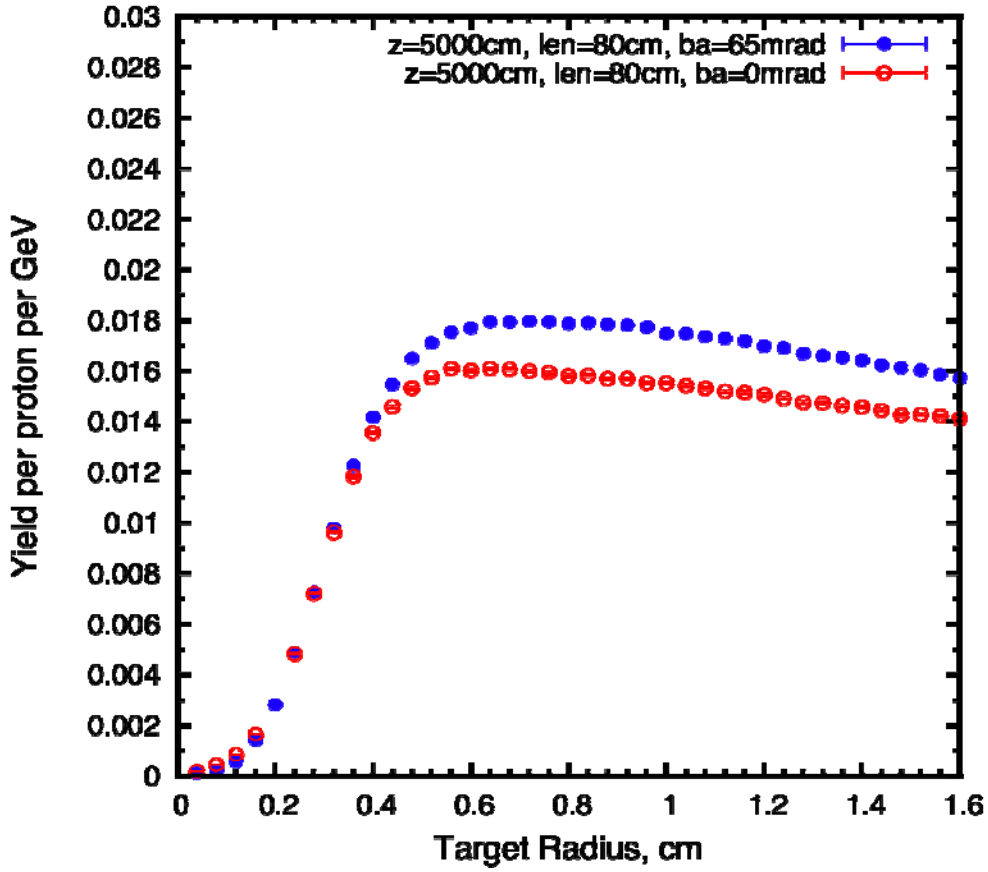


Best parameters:
Target length: 80 cm
Target radius: 0.8 cm
Beam angle: 65 mrad
Collinear target and beam
TR/BR = 4

Yield Comparison

(no-tilt *vs*. tilt proton beam, carbon target)



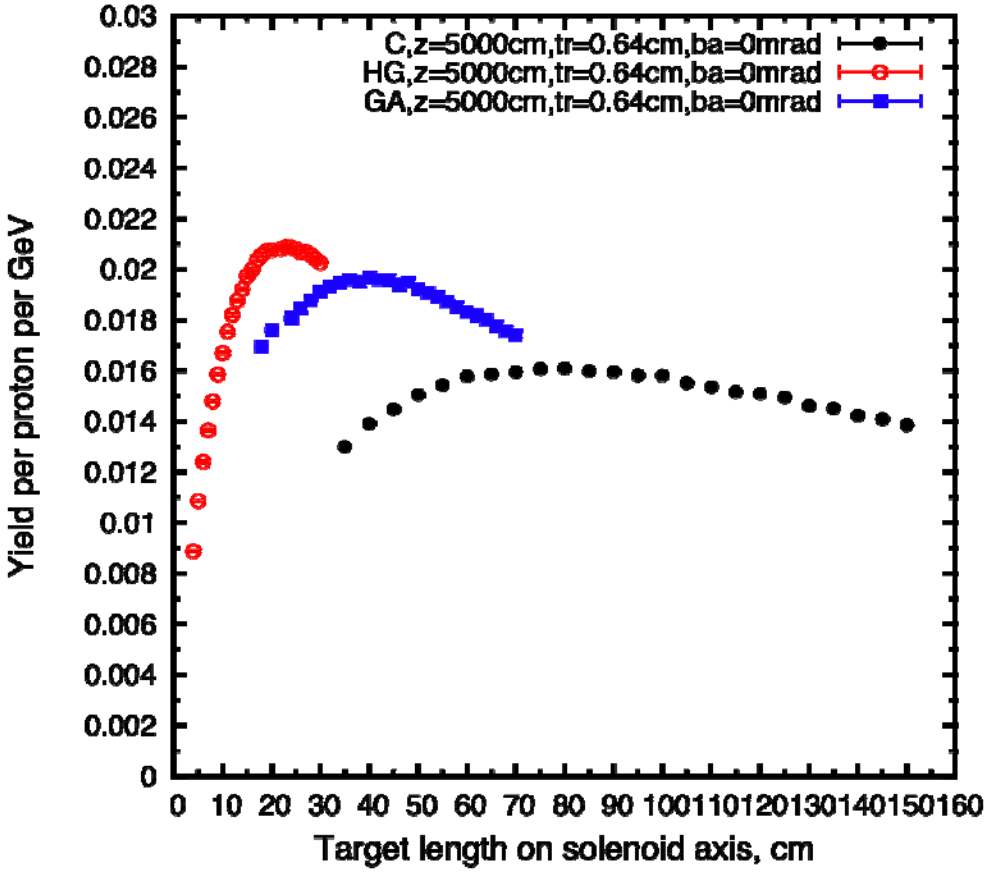


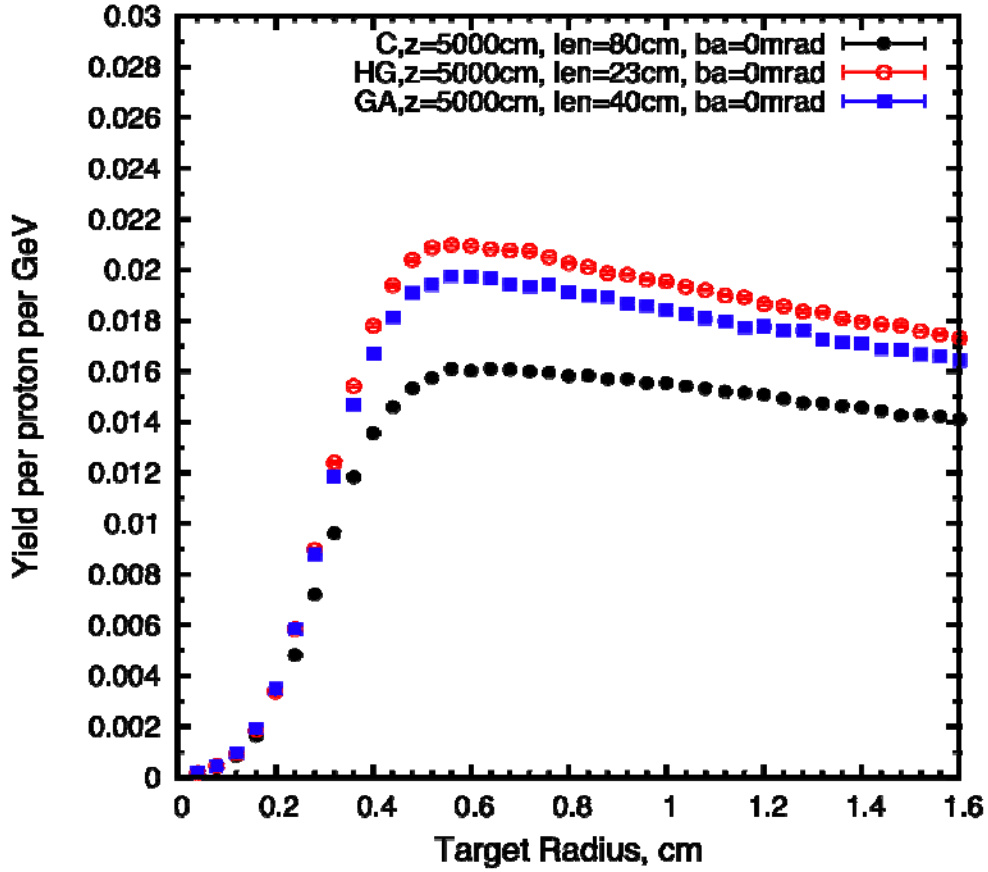
Optimized target length is 80 cm and target radius is 0.64 cm when beam angle is fixed at 0 mrad. Collinear target and beam. TR/BR = 4

~ 13% advantage to tilting the beam/target

Yield Comparison

(C, Hg and Ga targets, no-tilt beam to SC axis)





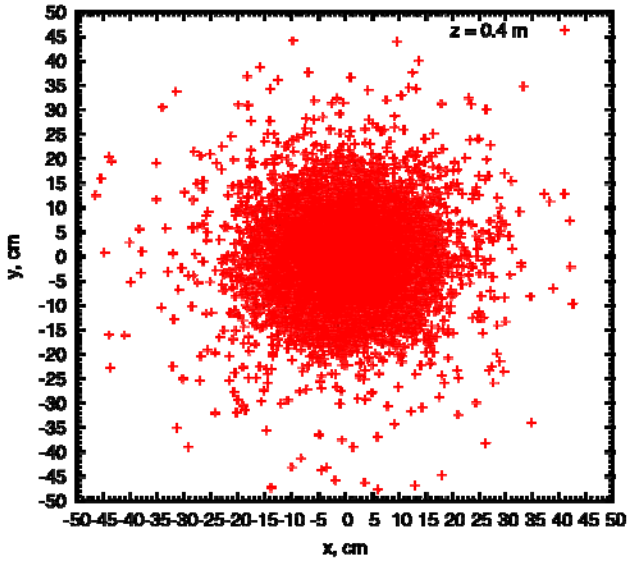
Optimized target length is 80 cm for C, 23 cm for Hg, and 40 cm for Ga.
Target radius is 0.64 cm for all when beam angle is fixed at 0 mrad.
Co-linear target and beam. TR/BR = 4

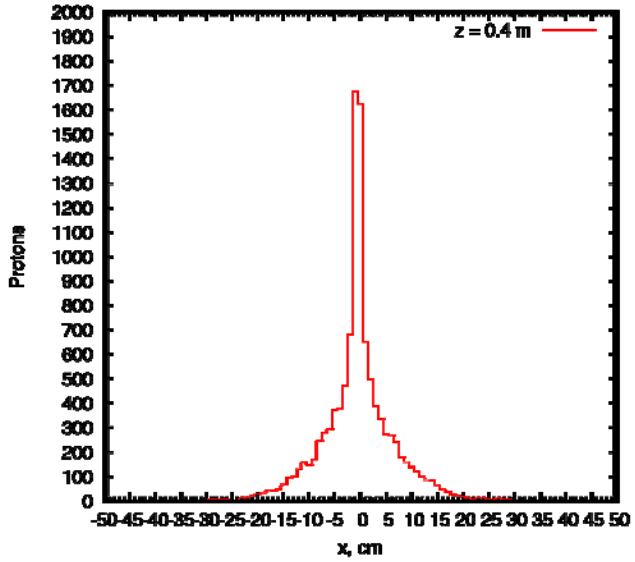
For yield comparison, Hg gives ~ 29.3% higher than C and Ga gives ~ 22.2% higher than C

Remaining Protons (KE > 0)

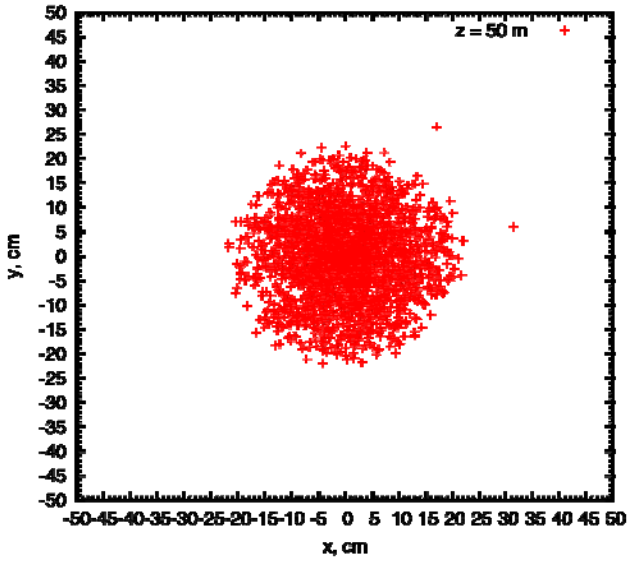
10^4 events, no beam dump, carbon target
beam angle = 0 mrad, target radius = 0.64 cm

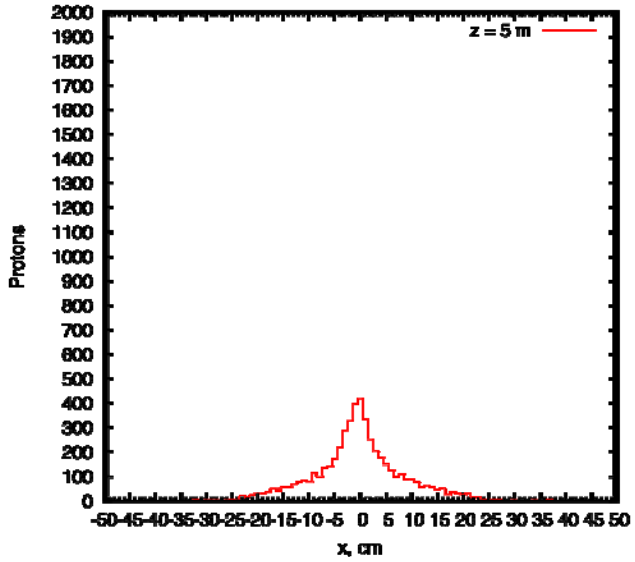
z = 0.4 m





z = 5 m



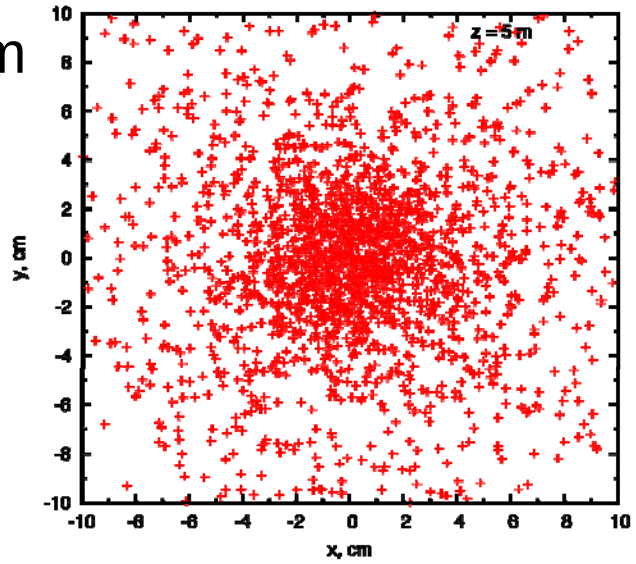


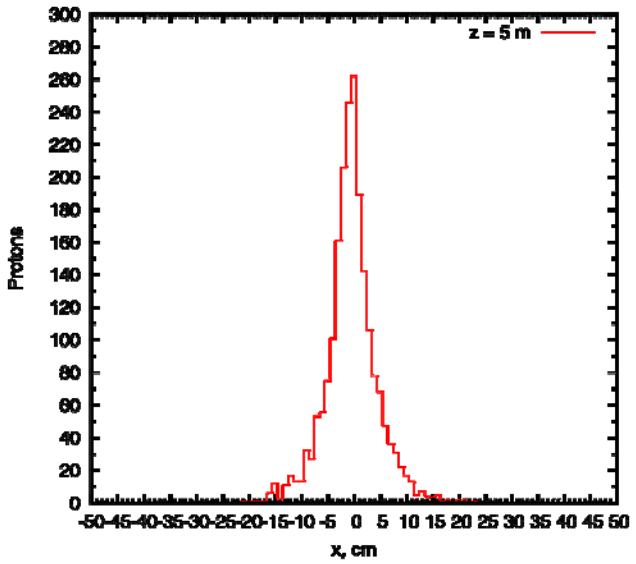
Remaining Protons (KE > 6 GeV)

10^4 events, carbon target

beam angle = 0 mrad, target radius = 0.64 cm

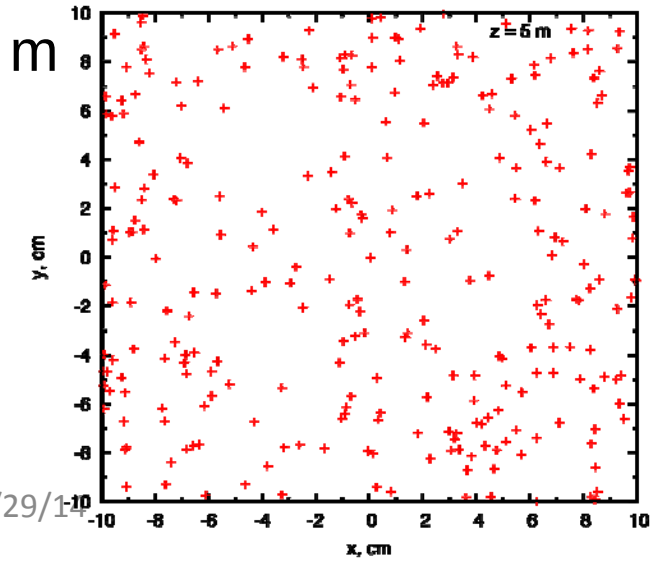
z = 5 m

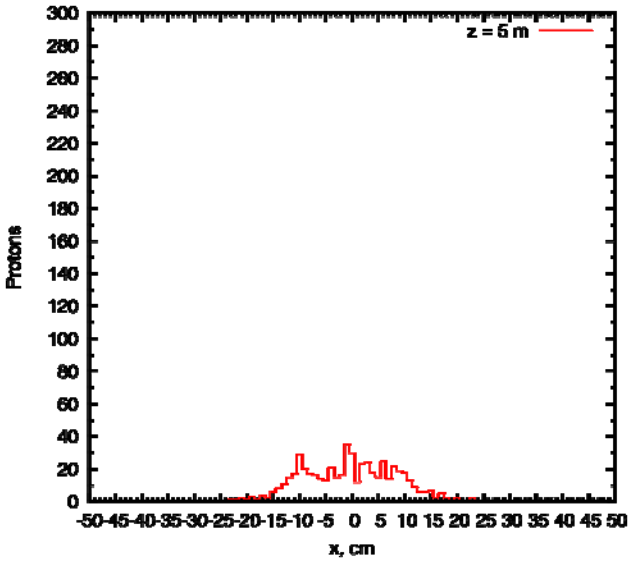




No beam dump

z = 5 m

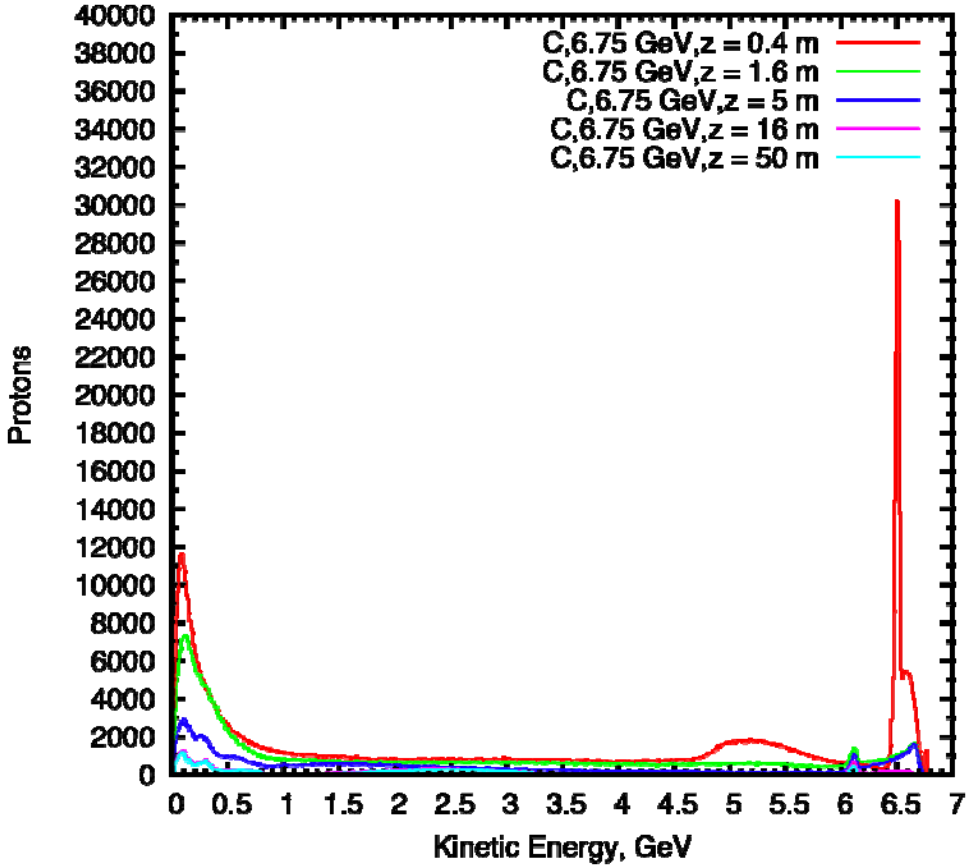


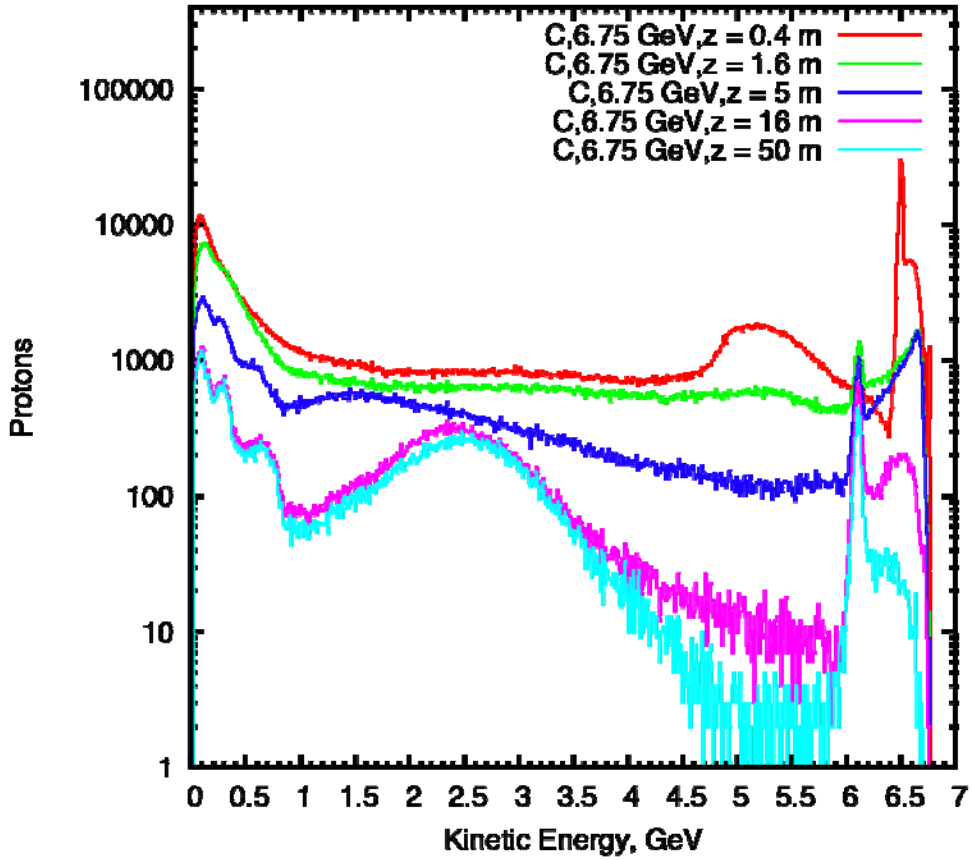


Beam dump:
120 cm long (z = 40 to 160 cm),
Triple of target radius

Remaining Protons with Beam Dump

(10^6 events, carbon target, beam angle = 0 mrad)





Target length: 80 cm (z = -40 cm to z = 40 cm) Target radius: 0.64 cm
Beam angle: 0 mrad Co-linear target and beam TR/BR = 4
Beam dump rod is 120 cm long (z = 40 cm to z = 160 cm)
The radius of beam dump is triple that of the target

This plot shows a peak at 6-6.5 GeV for z = 50 m.

Counting of Carbon Target at z = 5 m

1MW beam **(9.26×10^{14} protons with KE of 6.75 GeV)**

beam angle = 0 mrad, target radius = 0.64 cm

L_{dump} (cm)	R_{dump}/ R_{target}	Total KE (protons) (r < 23 cm) [Watts]	Total KE (non-protons) [Watts]	Protons KE > 6 GeV ($\times 9.26 \times 10^{10}$)	Yield at z = 50 m ($\times 9.26 \times 10^{10}$)
0	0	265270	88258	2078	1063.4
40	1	221590	92222	1543	987
80	1	202506	90564	1419	927
120	1	210141	87216	1452	868.8
40	2	183241	90205	1213	938
80	2	155798	85367	909	780.3
120	2	149733	86754	870	743
40	3	158241	91585	1044	852.7
80	3	119851	85385	607	680.2
120	3	114139	81006	542	590

C, Hg, Ga targets, no beam dump

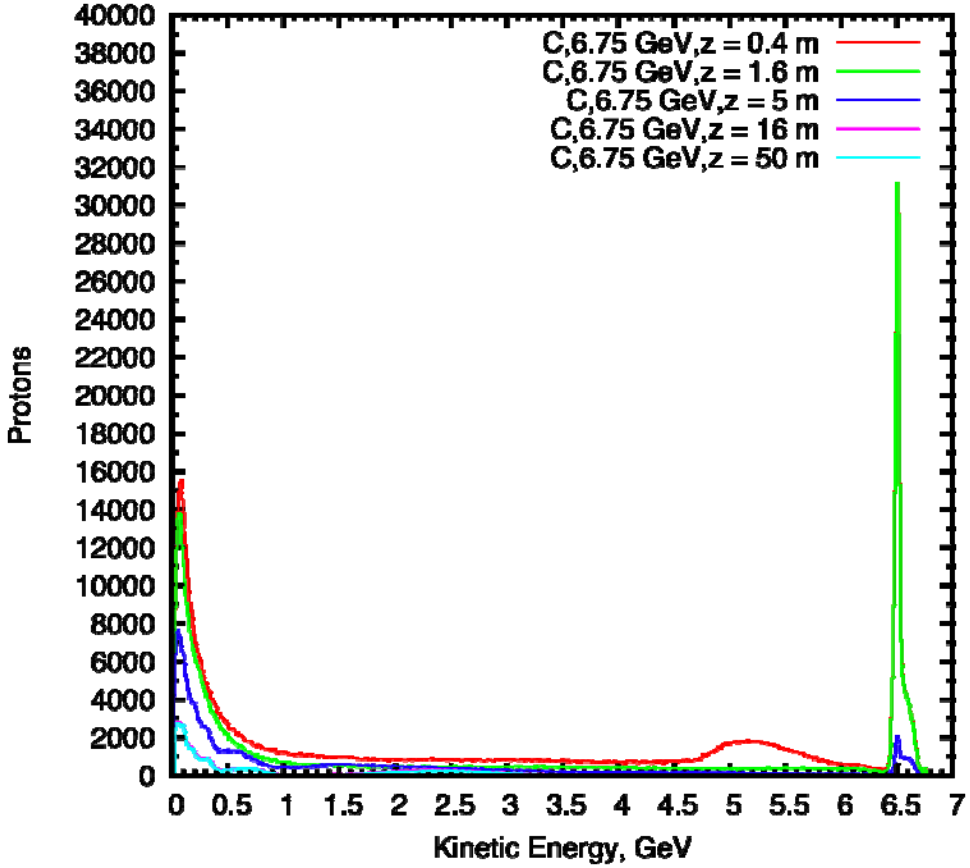
1 MW beam **(9.26×10^{14} protons with KE of 6.75 GeV)**, beam angle = 0 mrad, z = 5 m

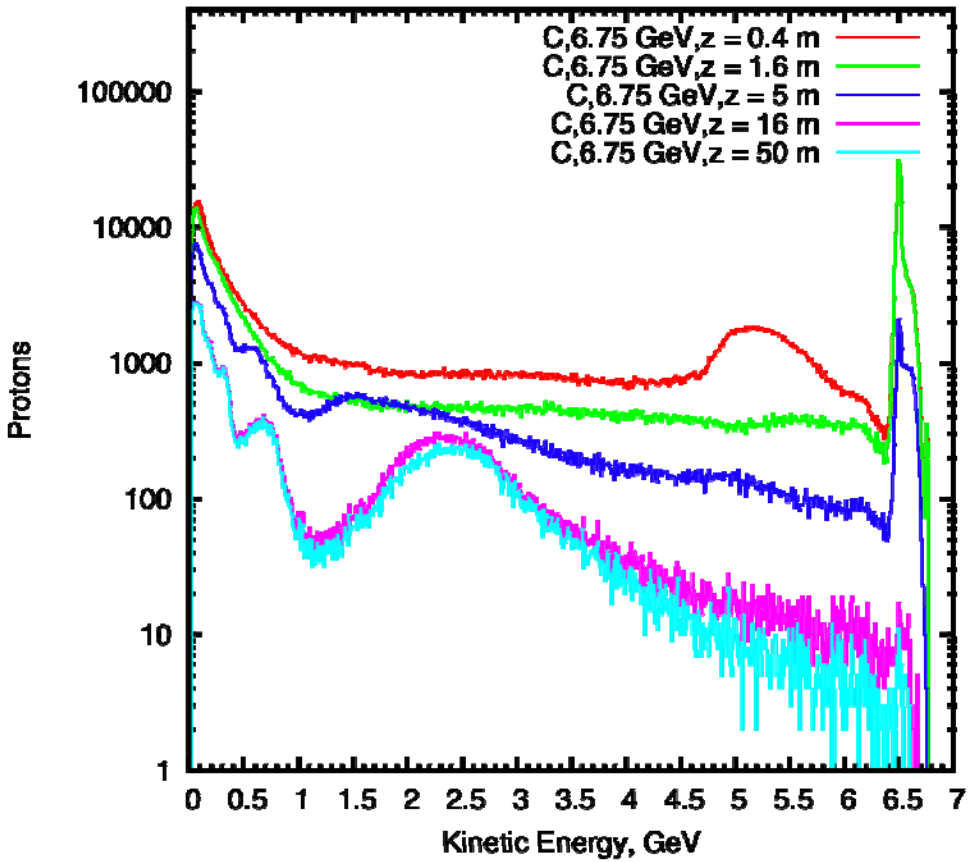
Target length is 80 cm for C, 23 cm for Hg, and 40 cm for Ga and target radius is 0.64 cm for all

	Total KE (protons) (r <23 cm) [Watts]	Total KE (non-protons) [Watts]	Protons KE > 6 GeV ($\times 9.26 \times 10^{10}$)	Yield at z = 50 m ($\times 9.26 \times 10^{10}$)
C	265270	88258	2078	1063.4
Hg	217116	65898	1908	1362.4
Ga	223972	84440	1818	1288.7

Remaining Protons

(10^6 events, carbon target, no beam dump)





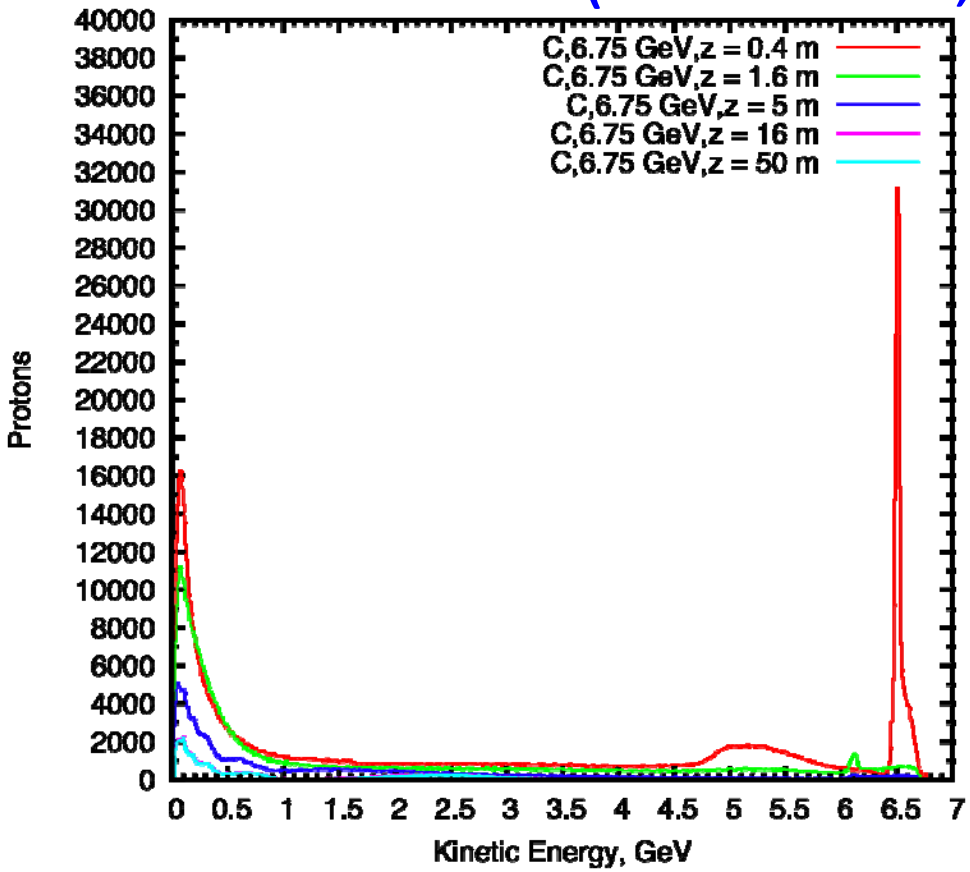
Target length: 80 cm Target radius: 0.80 cm Beam angle: 65 mrad

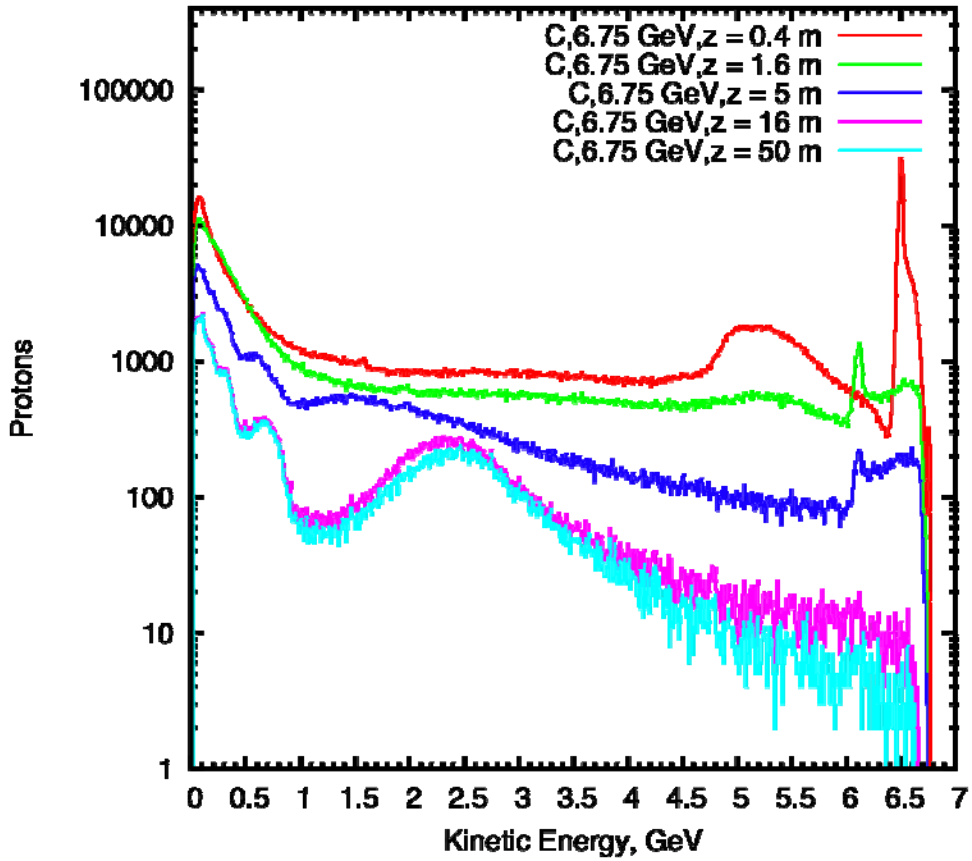
Co-linear target and beam TR/BR = 4

Peak of protons at 6.5 GeV gone at z = 50 m (65 mrad beam angle).

Remaining Protons with Beam Dump

(10^6 events, carbon target)



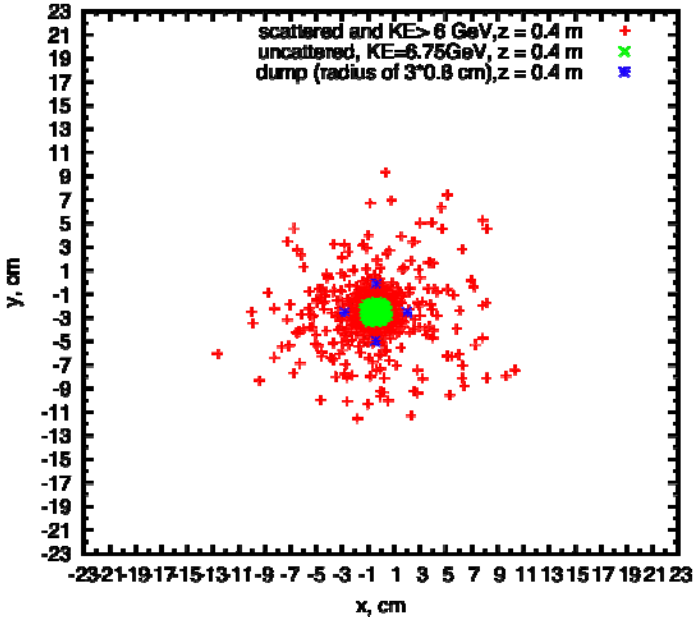


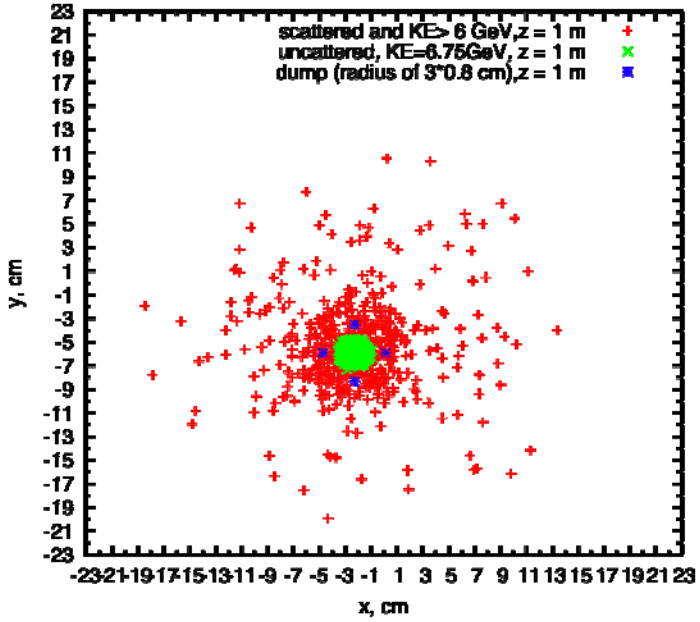
Target length: 80 cm (z = -40 cm to z = 40 cm) Target radius: 0.80 cm
Beam angle: 65 mrad Co-linear target and beam TR/BR = 4
Beam dump rod (z = 40 cm to z = 160 cm, horizontal tilt: 33.7 mrad, vertical tilt: 54.28 mrad)

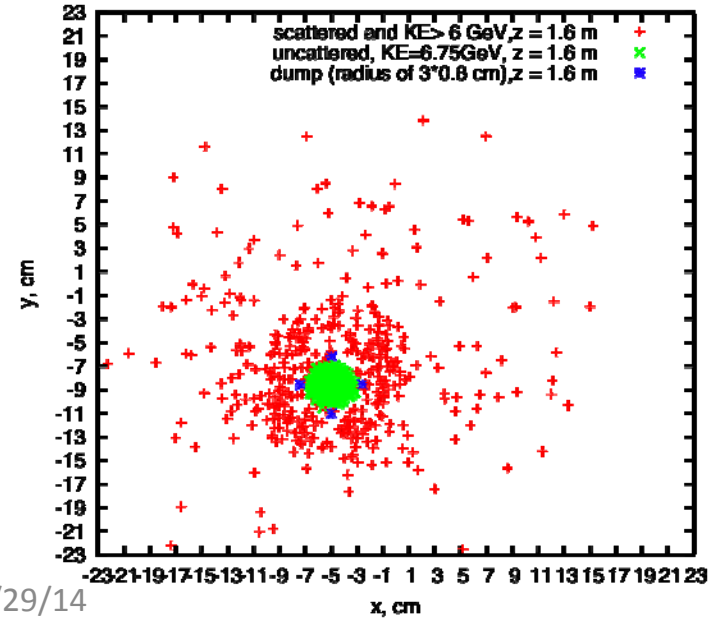
The radius of beam dump is triple that of the target

Coordinates of beam and dump

(carbon target and dump)







Target length: 80 cm (z = -40 cm to z = 40 cm)
Target radius: 0.80 cm
Beam angle: 65 mrad Co-linear target and beam
TR/BR = 4
Beam dump rod: triple of the target radius
(z = 40 cm to z = 100 cm, horizontal tilt: 31.1 mrad, vertical tilt: 56.27 mrad)
(z = 40 cm to z = 100 cm, horizontal tilt: 44.9 mrad, vertical tilt: 44.17 mrad)

Counting of Carbon Target at z = 5 m

1MW beam **(9.26×10^{14} protons with KE of 6.75 GeV)**

beam angle = 65 mrad, target radius = 0.8 cm

L_{dump} (cm)	R_{dump}/R_{target}	Total KE (protons) (r <23 cm) [Watts]	Total KE (non-protons) [Watts]	Protons KE > 6 GeV ($\times 9.26 \times 10^{10}$)	Yield at z = 50 m ($\times 9.26 \times 10^{10}$)
0	0	88359	105454	301	1240.7
40	1	85504	105007	270	1268
80	1	88318	102577	318	1256.2
120	1	85932	100030	299	1230.1
40	2	77262	101664	207	1246.2
80	2	75493	97715	206	1196
120	2	78364	96967	204	1170.5
40	3	72615	101494	176	1084.5
80	3	64610	97569	112	1142.4
120	3	66430	94936	130	1134.6

Summary

- Target System Concept from the Muon Accelerator Staging Scenario: 1 MW, 6.75 GeV (KE) proton beam,

  Magnet 20to2T50m120cm (the 20 T field on target drops to the ~2 T field in the rest of the Front End over ~ 5 m) and graphite target.
- Optima for graphite target (tilt beam):

  length = 80 cm, radius = 8 mm (with 2 mm rms beam radius), tilt angle = 65 mrad.
- Optima for graphite target (no-tilt beam):

  length = 80 cm, radius = 6.4 mm (with 1.6 mm rms beam radius), tilt angle = 0 mrad.

Summary (Cont'd)

- For 6.75 GeV (KE) beam, about 13% higher production by tilting the carbon target/proton beam.
- High-*Z* favored for particle production. Hg gives ~ 29.3% higher than C and Ga gives ~ 22.2% higher than C.
- Graphite proton beam dump, 120 cm long, 24 mm radius to intercept most of the (diverging) unscattered proton beam.