Particle Production of Carbon Target with 20Tto2T5m Configuration at 6.75 GeV (Updated)

X. Ding, UCLA

Target Studies
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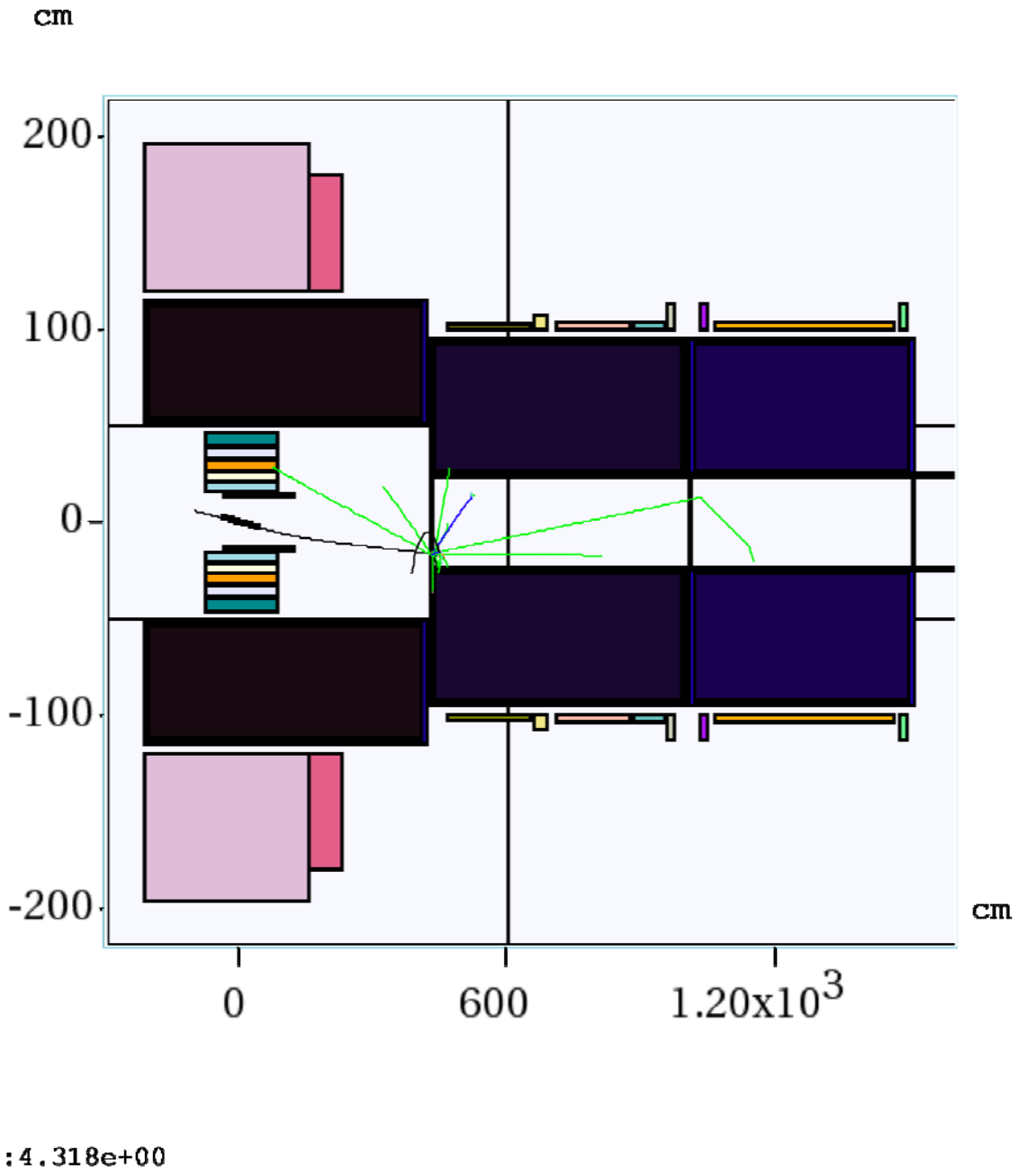
Target Setting

- 20Tto2T5m Configuration (initial beam pipe radius of 13 cm) and Fieldmap (20T➔2T);
- Code: MARS15(2014) with ICEM 4 = 1;
- Proton beam: 6.75 GeV (KE) and launched at z = -100 cm,

  Focal beam with waist at z= 0 m and emittance of 5 μm;
- Production Collection: (50 m downstream, 40 MeV < KE < 180 MeV).
- Graphite density = 1.8

Configuration



Energy Card Setting

- ENRG E0 EM EPSTAM EMCHR EMNEU EMIGA EMIEL

  E0: The incident particle kinetic energy;

  EM: The hadron threshold energy (Default: 0.0145 GeV);

  EPSTAM: The star production threshold kinetic energy (Default: 0.03 GeV);

  EMCHR: The threshold energy applied collectively to muons, heavy ions and charged hadrons (Default: 0.001 GeV);

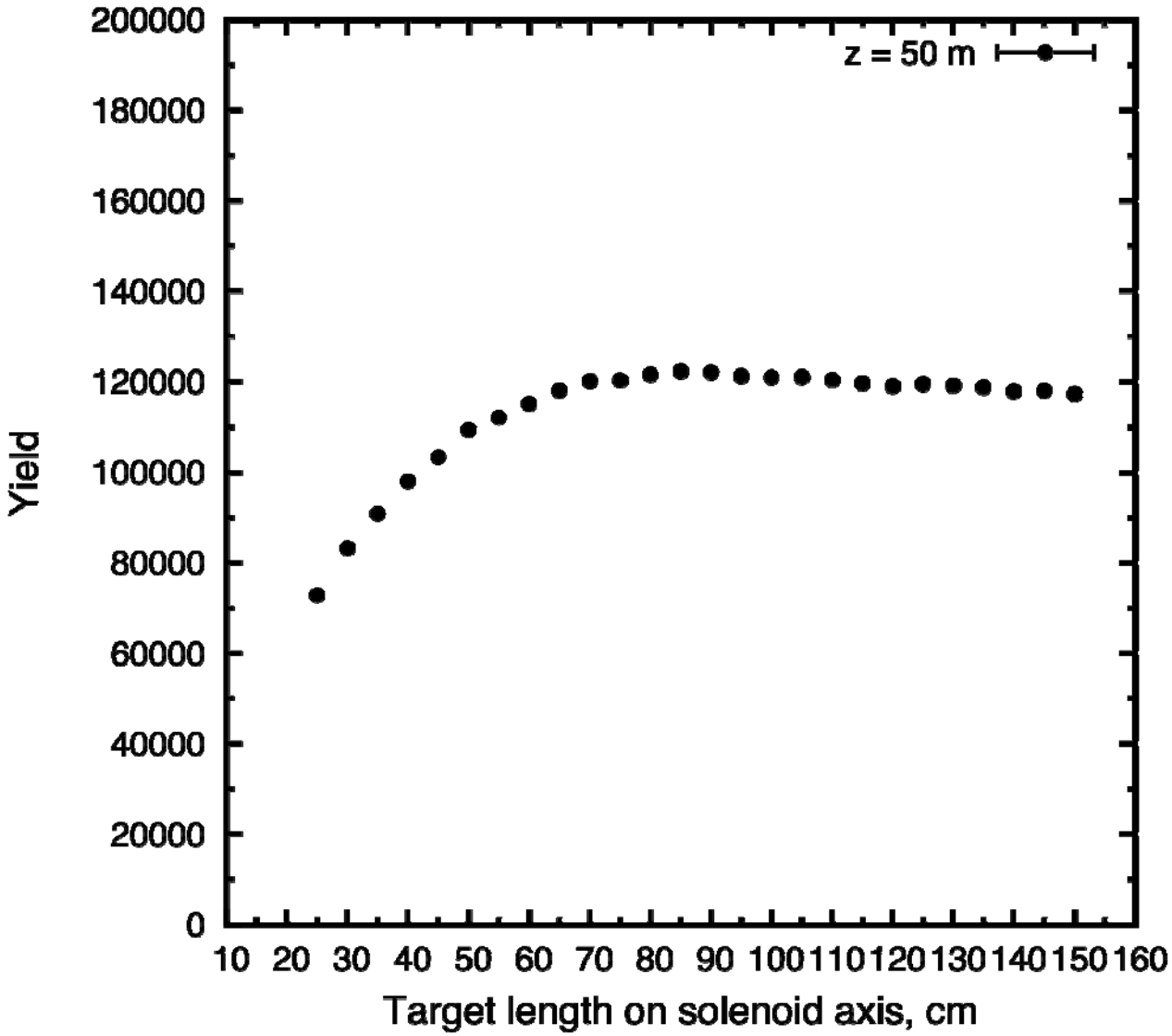
  EMNEU: The threshold energy for neutrons (Default: 10^{-4} GeV)

  EMIGA: The threshold energy for γ (Default: 10^{-4} GeV);

  EMIEL: The threshold energy for $e^{\pm}$ (Default: $5*10^{-4}$ GeV)

  Use non-default setting: ENRG 1 = 6.75, 2 = 0.02, 3 = 0.3, 4 = 0.01, 5 = 0.05, 6 = 0.01, 7 = 0.01

Particle Production *vs.* Target Length (10^6 events, no beam dump)



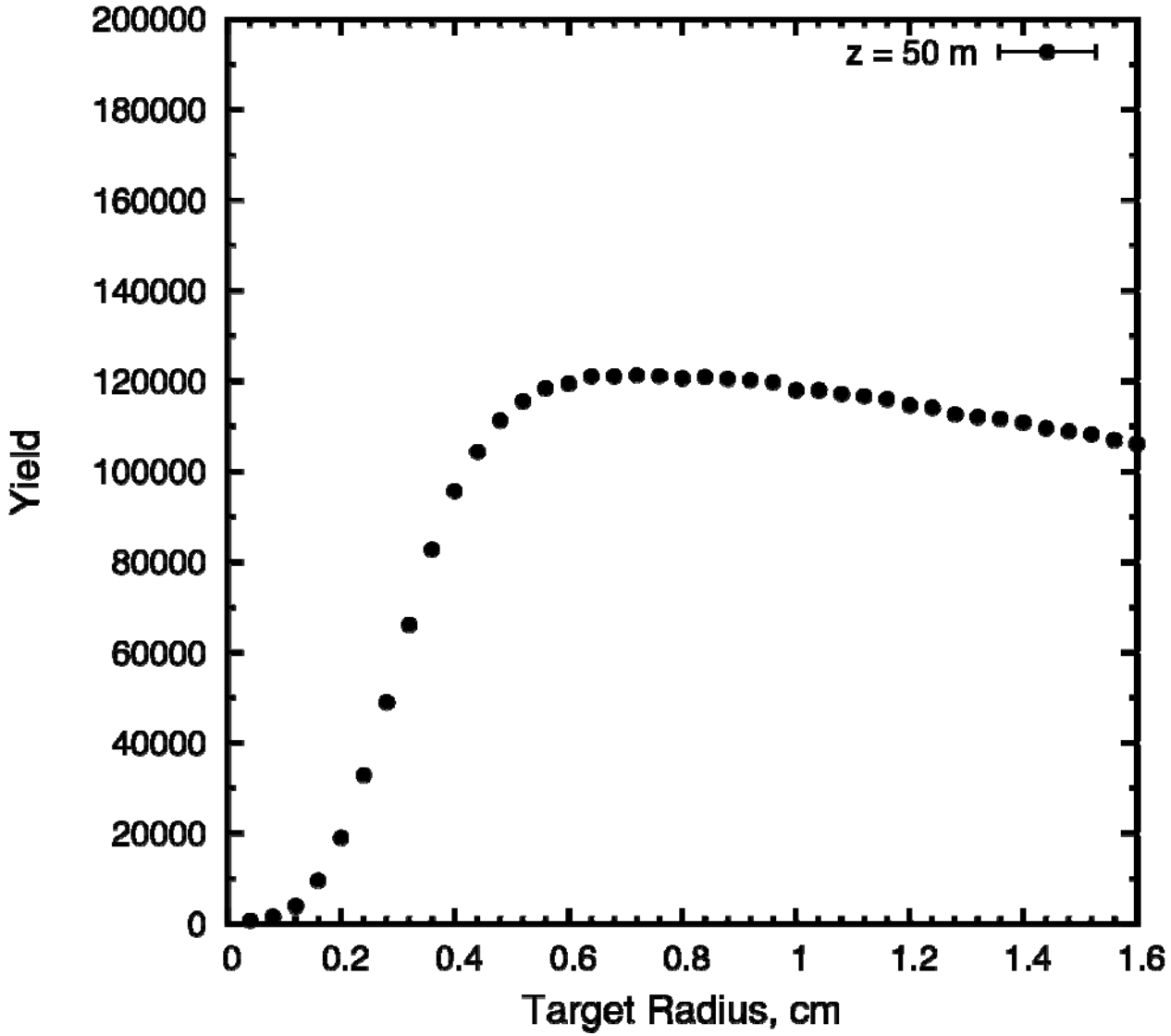
Target radius: 0.80 cm

Beam angle to SC axis: 65 mrad

Co-linear target and beam

TR/BR = 4

Particle Production *vs.* Target Radius (10^6 events, no beam dump)



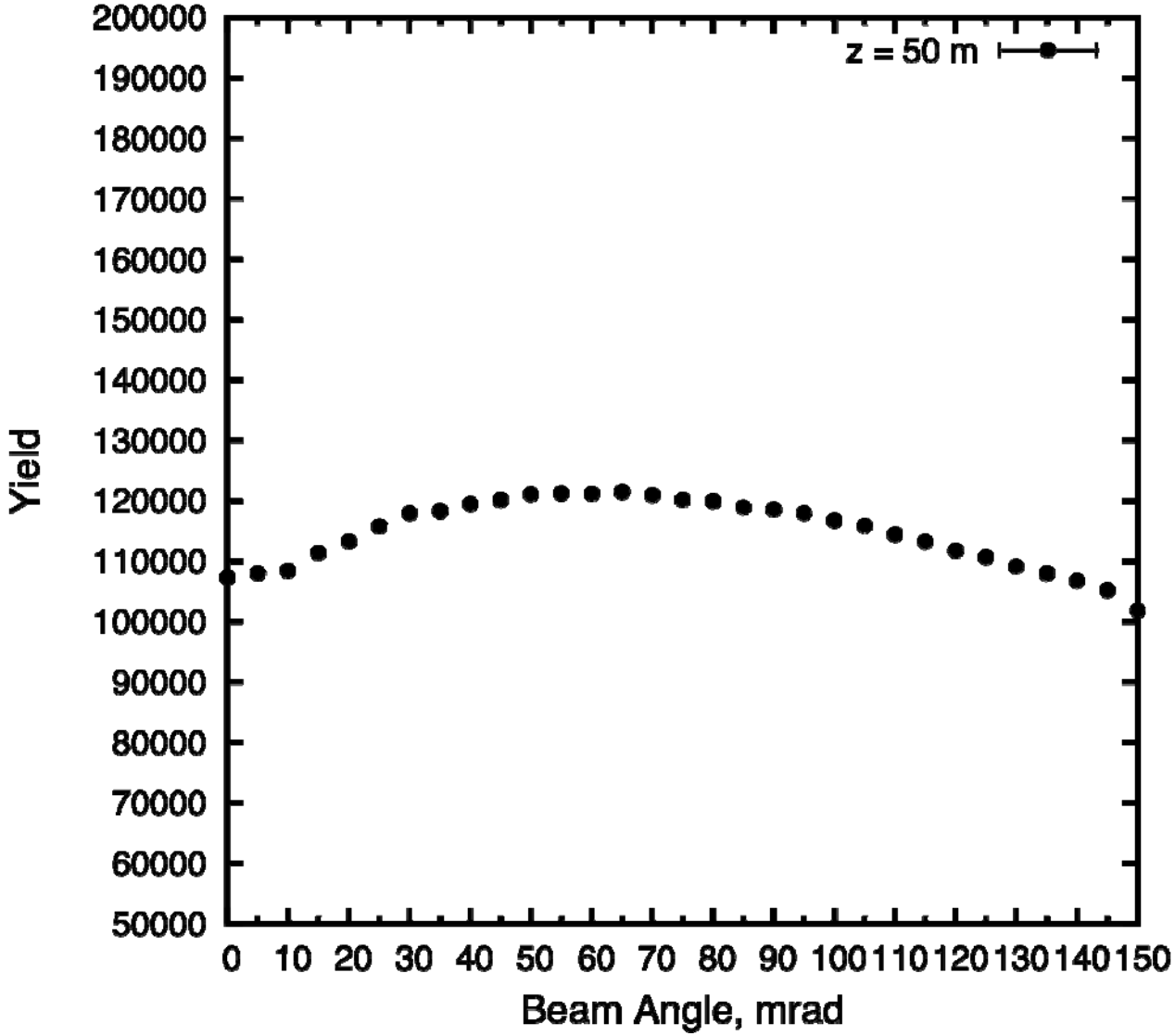
Target length: 80 cm

Beam angle to SC axis: 65 mrad

Co-linear target and beam

TR/BR = 4

Particle Production *vs*. Beam Angle (10^6 events, no beam dump)



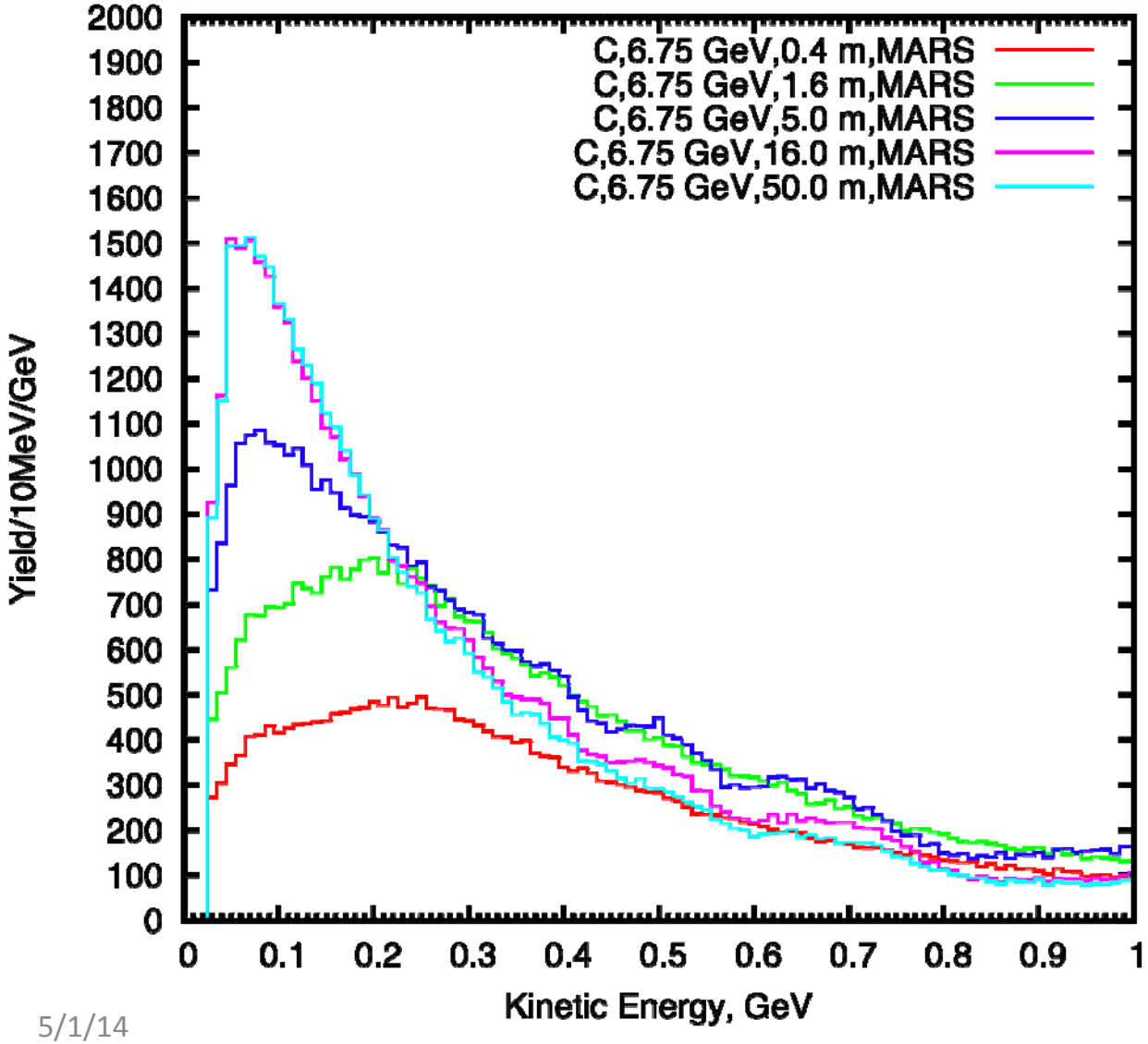
Target length: 80 cm

Target radius: 0.80 cm

Co-linear target and beam

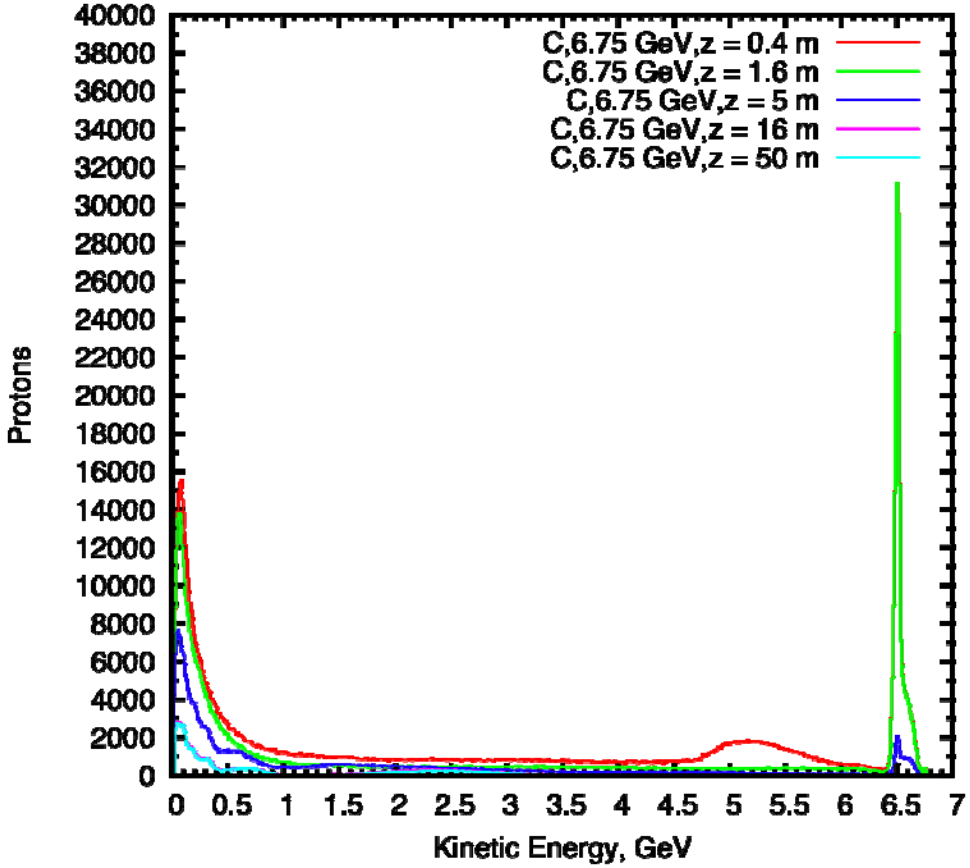
TR/BR = 4

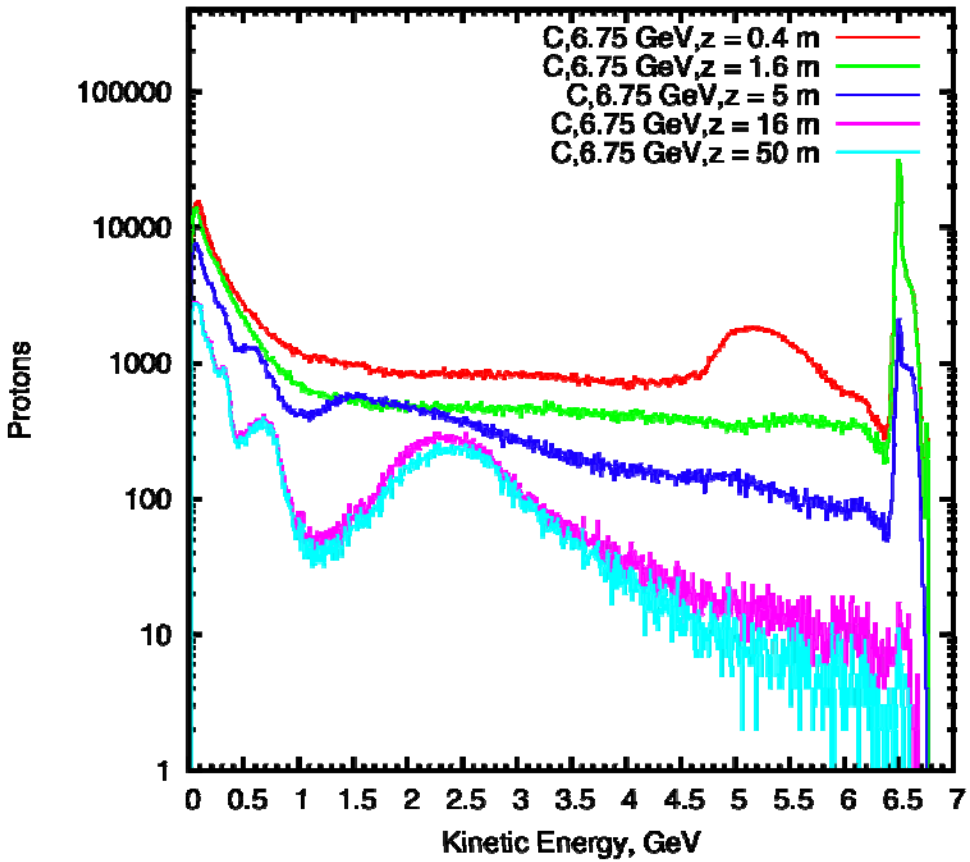
Energy Spectra of $\pi^{\pm}$, $K^{\pm}$, $\mu^{\pm}$ (10^6 events, no beam dump)



Best parameters:
Target length: 80 cm
Target radius: 0.80 cm
Beam angle: 65 mrad
Co-linear target and beam
TR/BR = 4

Remaining Protons
(10^6 events, no beam dump)

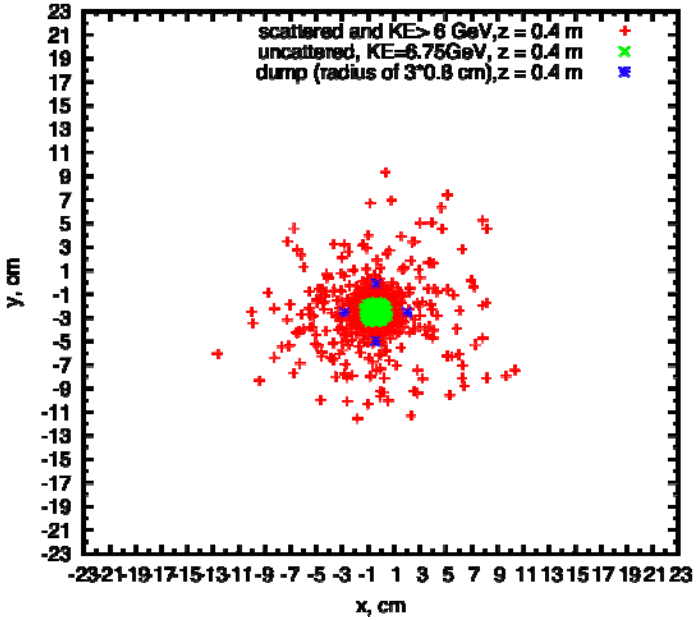


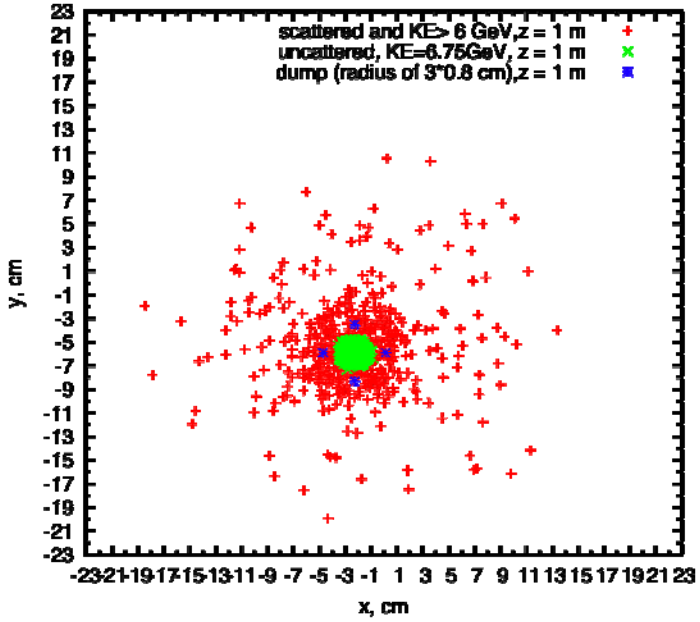


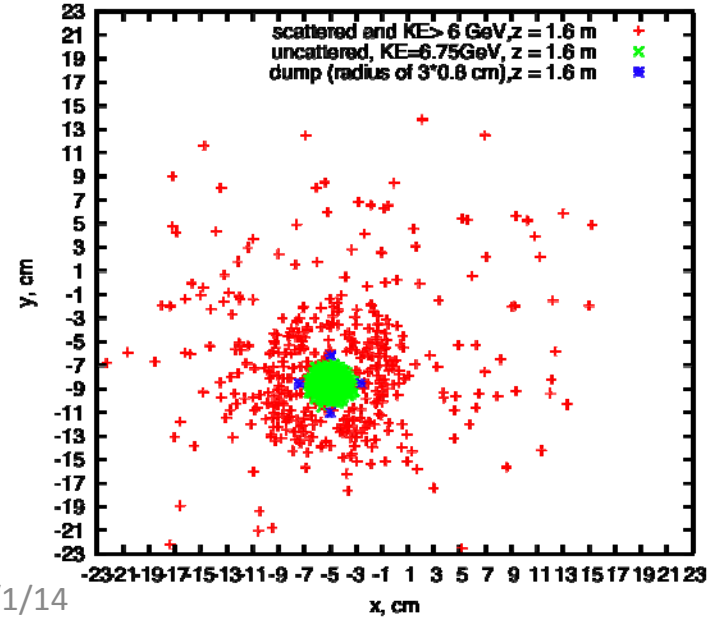
Target length: 80 cm Target radius: 0.80 cm Beam angle: 65 mrad
Co-linear target and beam TR/BR = 4

Peak of protons at 6.5 GeV gone at z = 50 m (65 mrad beam angle).
If true, little/no need for beam dump.

Coordinates of beam and dump



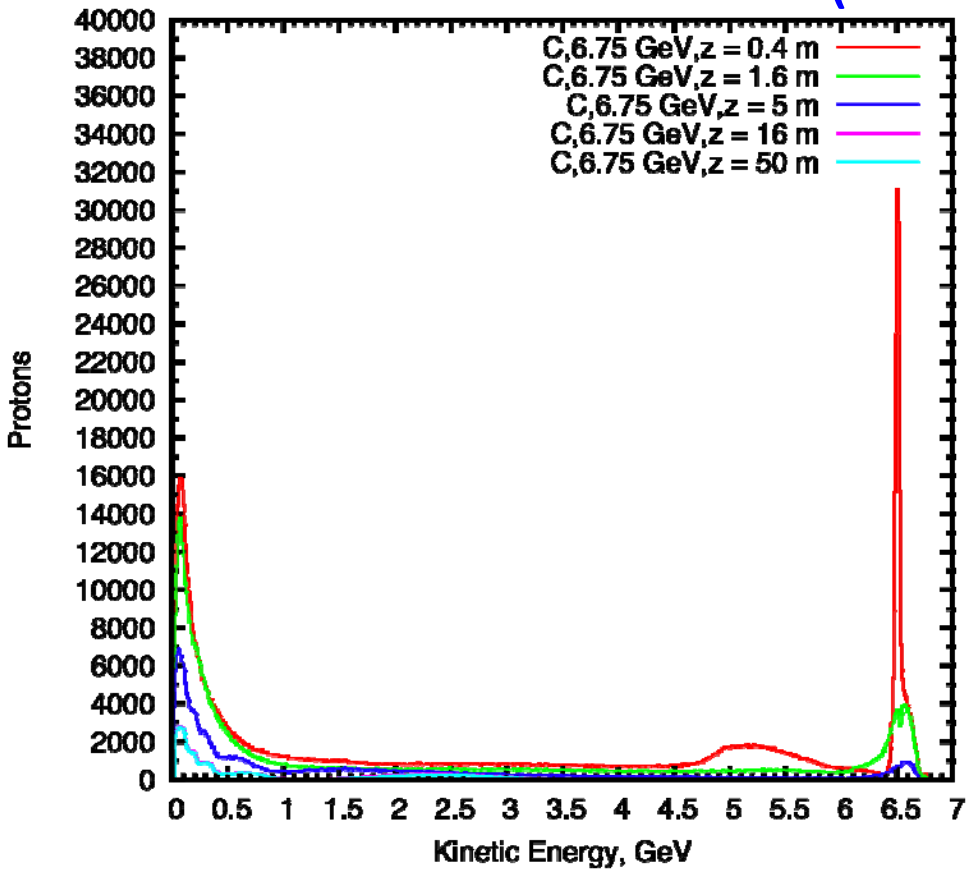


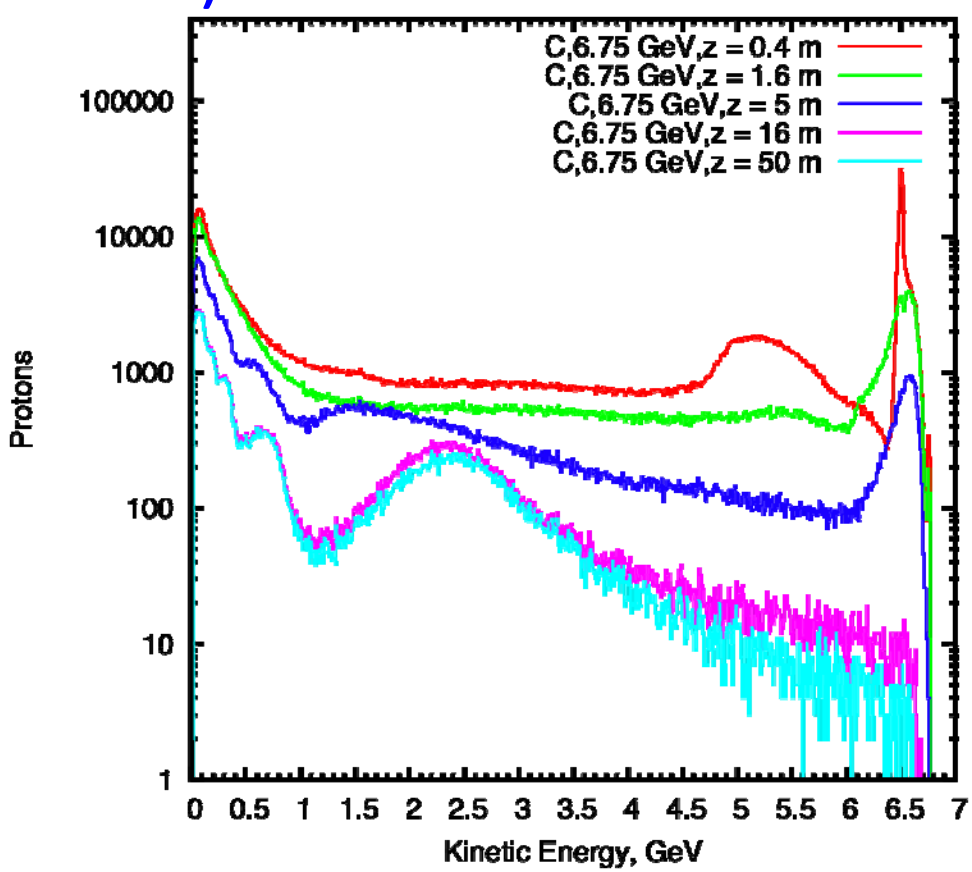


Target length: 80 cm (z = -40 cm to z = 40 cm)
Target radius: 0.80 cm
Beam angle: 65 mrad Co-linear target and beam
TR/BR = 4
Beam dump rod: triple of the target radius
(z = 40 cm to z = 100 cm, horizontal tilt: 31.1 mrad, vertical tilt: 56.27 mrad)
(z = 40 cm to z = 100 cm, horizontal tilt: 44.9 mrad,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

Remaining Protons with Beam Dump

(10^6 events)



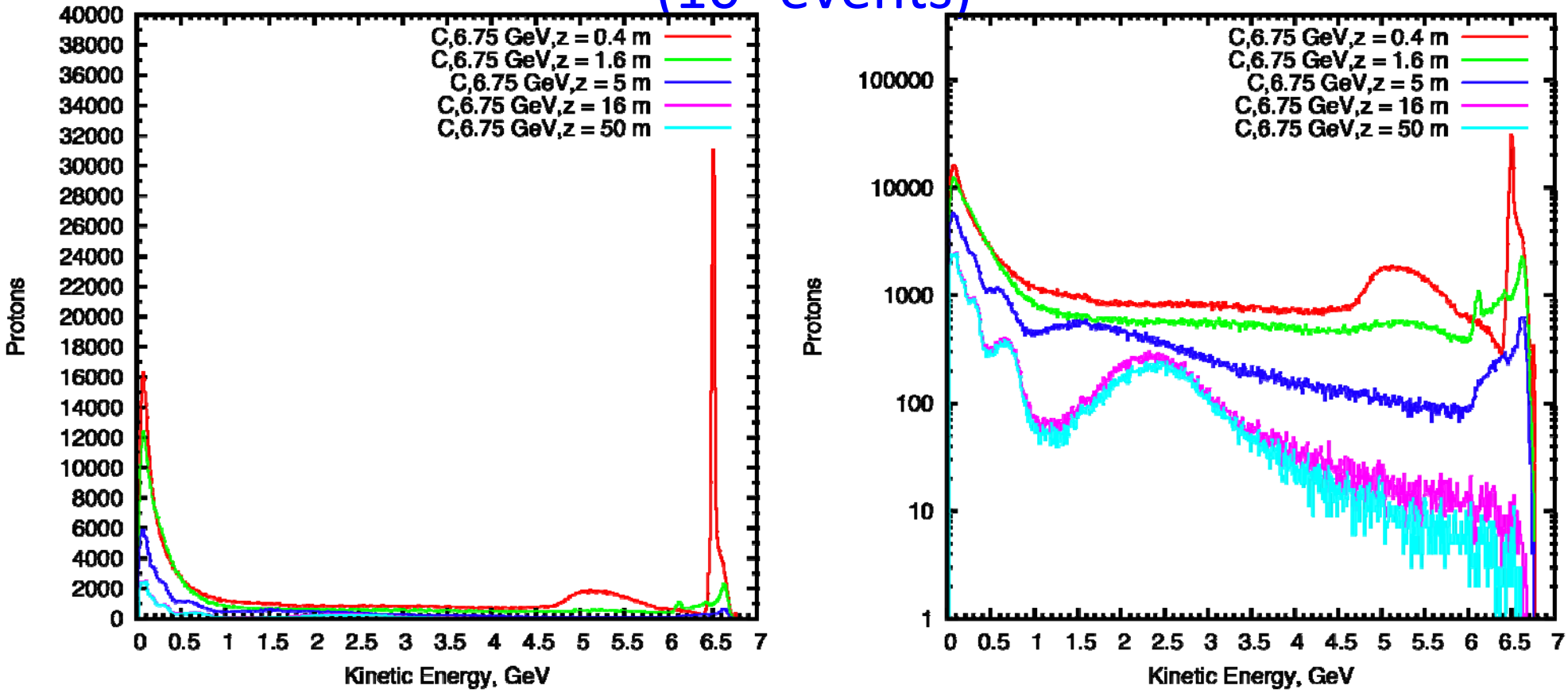


Target length: 80 cm (z = -40 cm to z = 40 cm) Target radius: 0.80 cm
Beam angle: 65 mrad Co-linear target and beam TR/BR = 4
Beam dump rod: (z = 40 cm to z = 160 cm, horizontal tilt: 33.7 mrad, vertical tilt: 54.28 mrad)

The radius of beam dump is same that of the target

Remaining Protons with Beam Dump

(10^6 events)

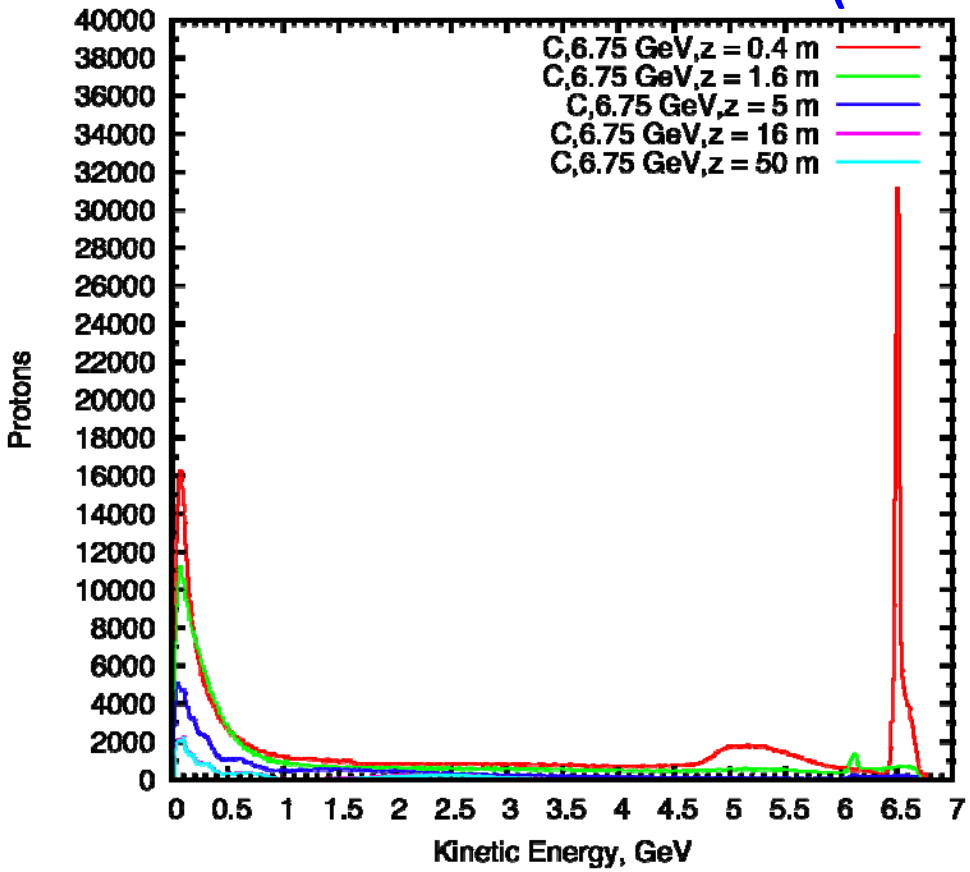


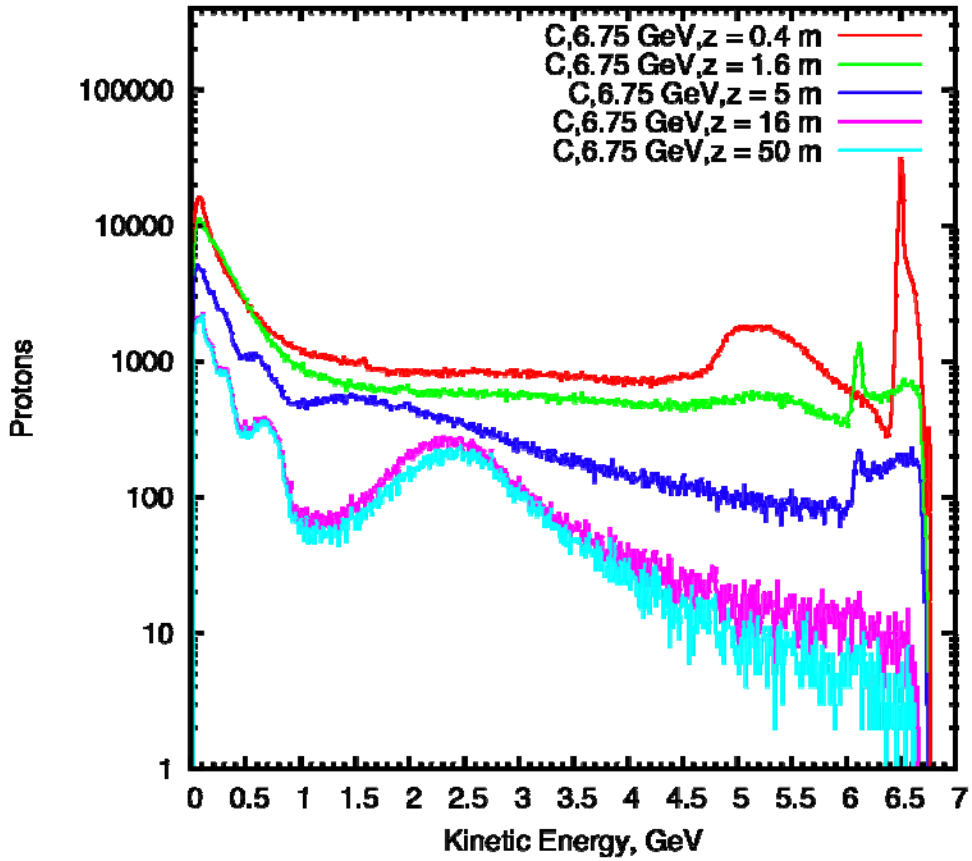
Target length: 80 cm (z = -40 cm to z = 40 cm) Target radius: 0.80 cm
Beam angle: 65 mrad Co-linear target and beam TR/BR = 4
Beam dump rod (z = 40 cm to z = 160 cm, horizontal tilt: 33.7 mrad, vertical tilt: 54.28 mrad)

The radius of beam dump is twice that of the target

Remaining Protons with Beam Dump

(10^6 events)



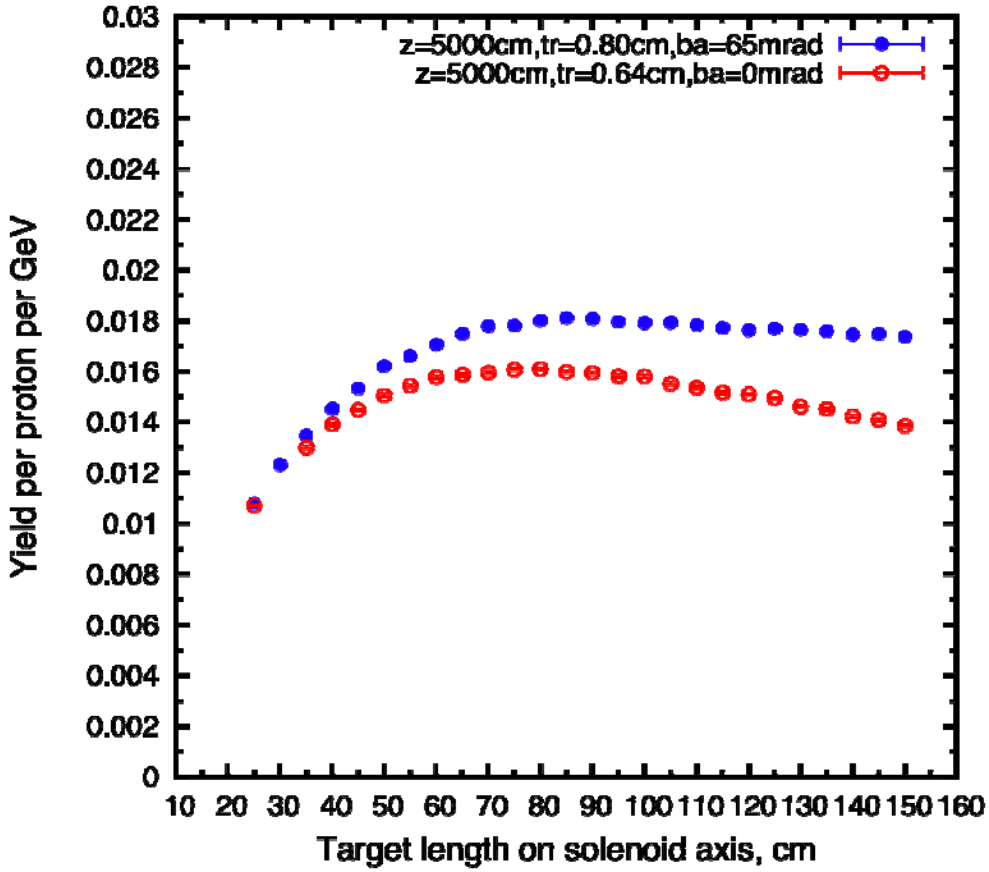


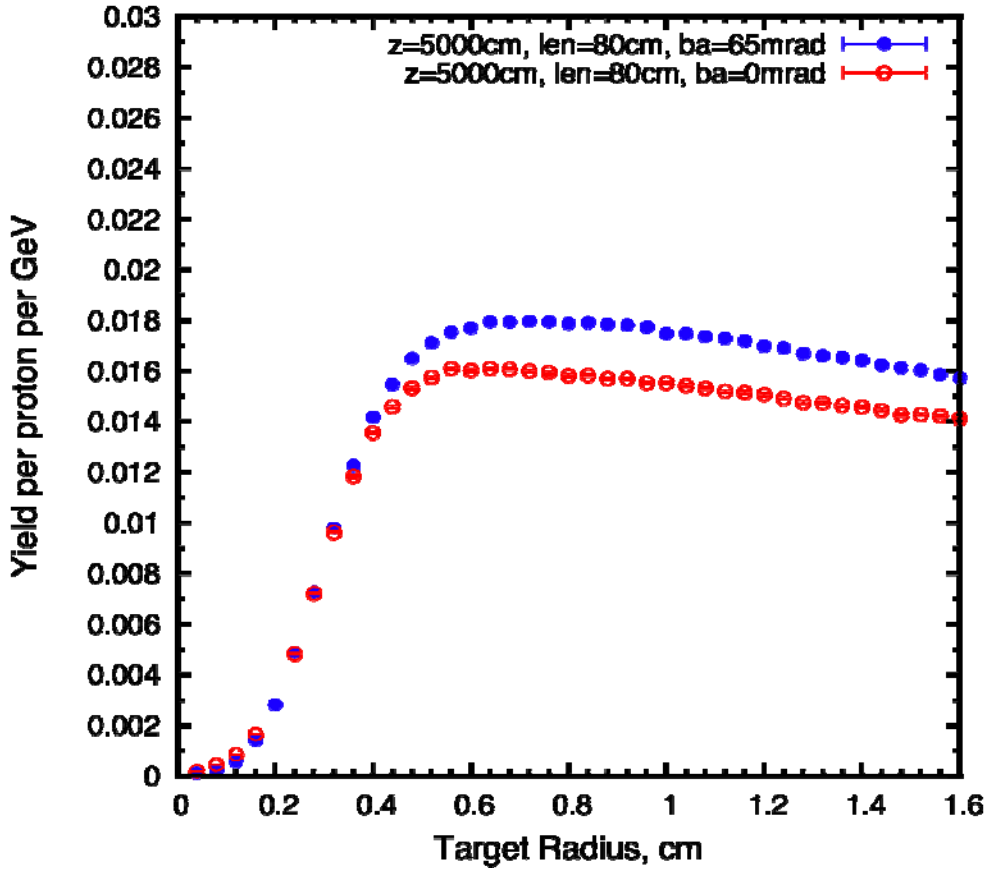
Target length: 80 cm (z = -40 cm to z = 40 cm) Target radius: 0.80 cm
Beam angle: 65 mrad Co-linear target and beam TR/BR = 4
Beam dump rod (z = 40 cm to z = 160 cm, horizontal tilt: 33.7 mrad, vertical tilt: 54.28 mrad)

The radius of beam dump is triple that of the target

Yield Comparison

(no-tilt *vs*. tilt of proton beam to SC axis)





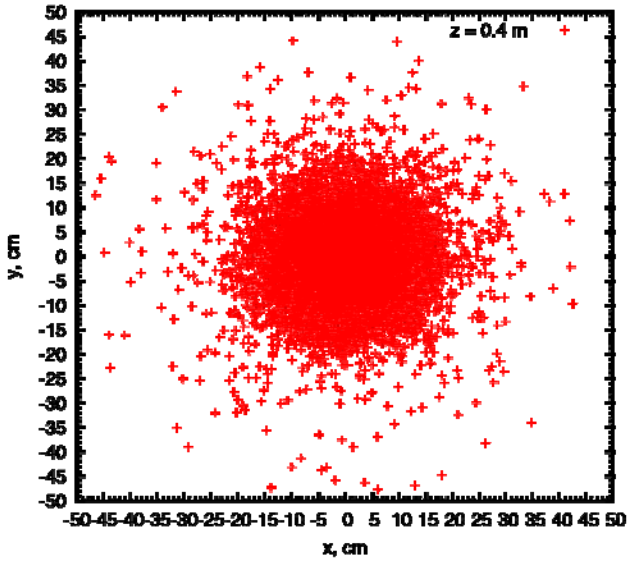
Optimized target length is 80 cm and target radius is 0.64 cm when beam angle is fixed at 0 mrad.
Co-linear target and beam. TR/BR = 4

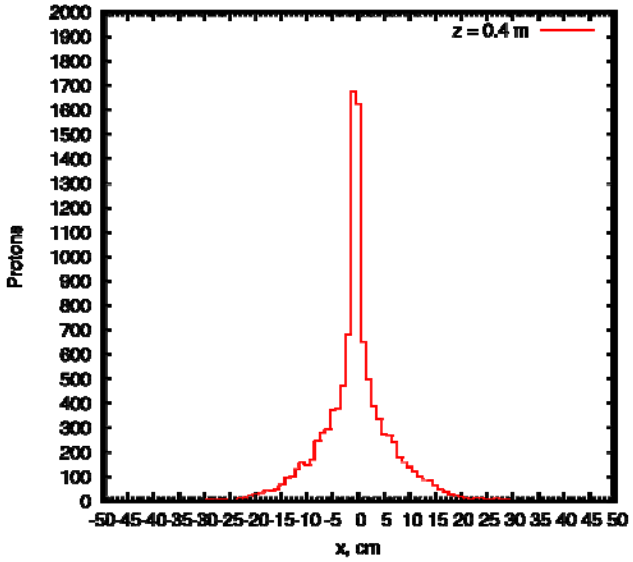
~ 13% advantage to tilting the beam/target

Remaining Protons (KE > 0)

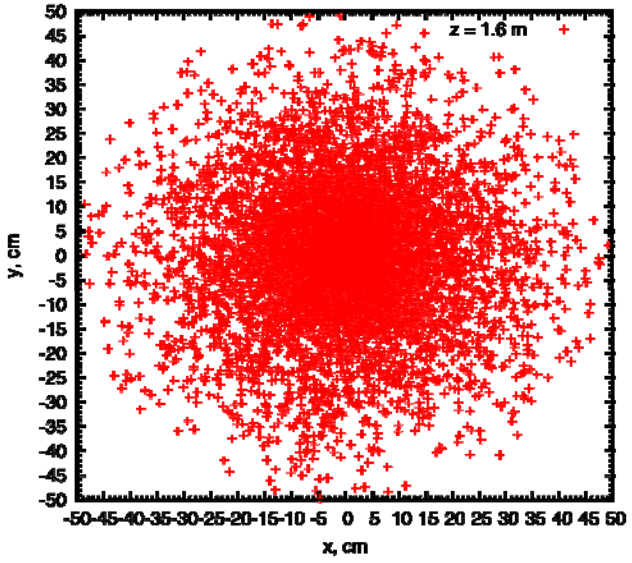
10^4 events, no beam dump, beam angle = 0 mrad

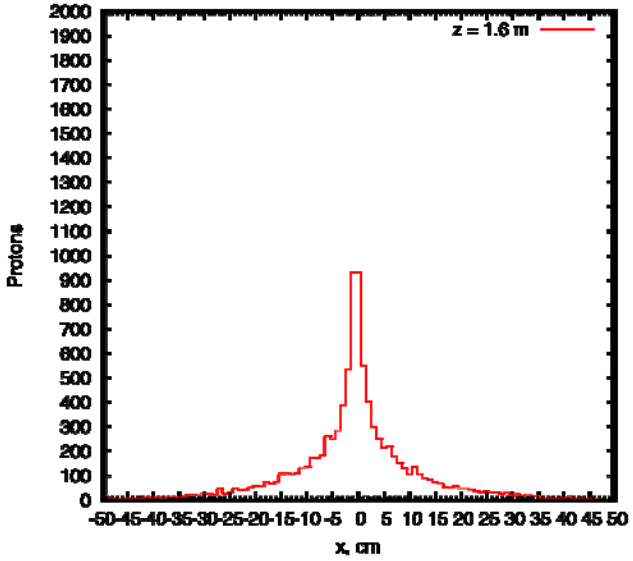
z = 0.4 m





z = 1.6 m

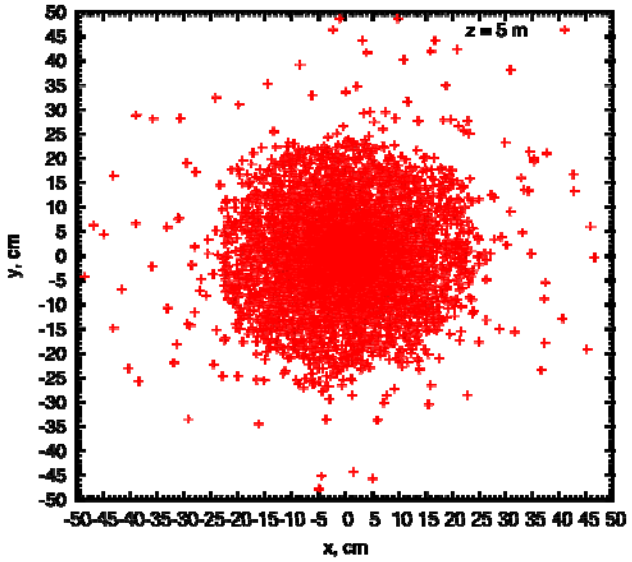


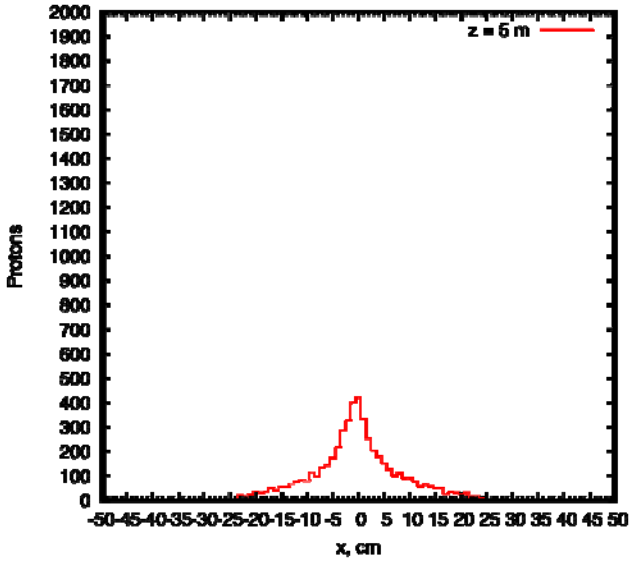


Remaining Protons (KE > 0)

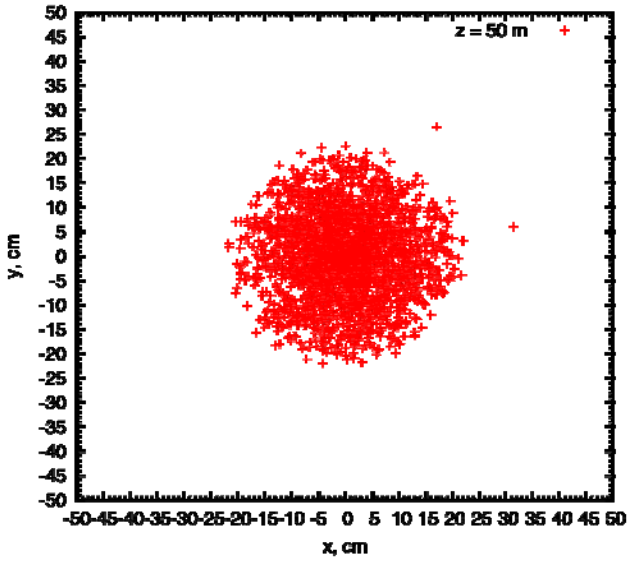
10^4 events, no beam dump, beam angle = 0 mrad

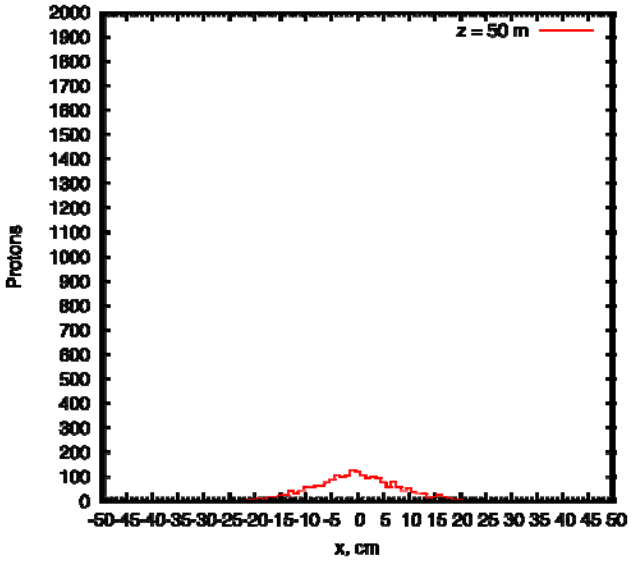
z = 5 m





z = 50 m

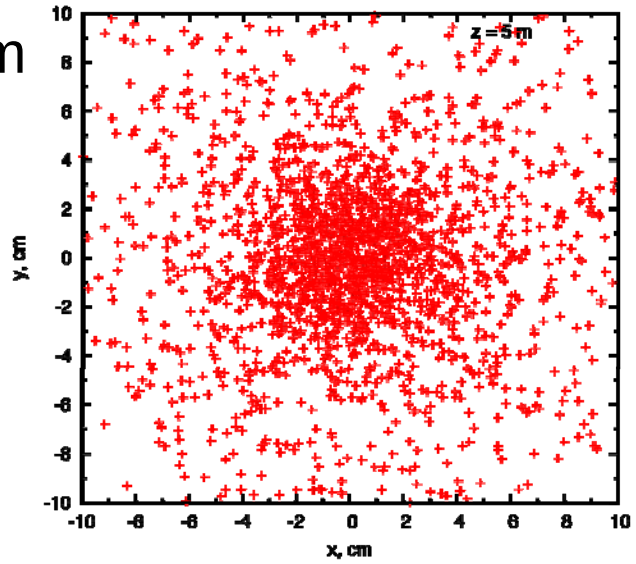


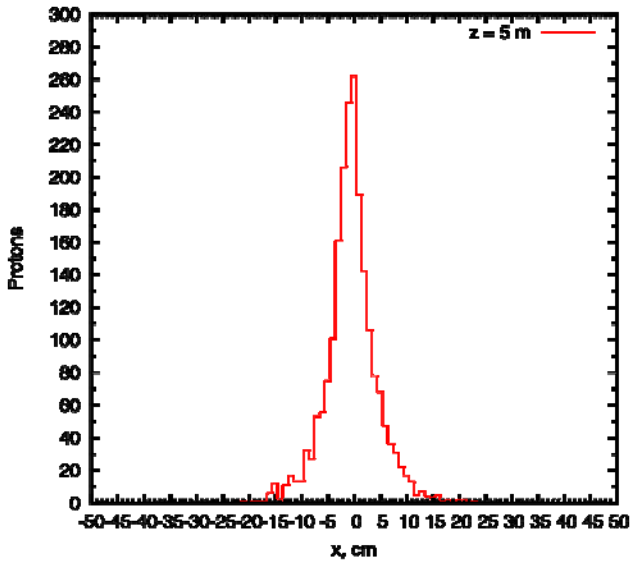


Remaining Protons (KE > 6 GeV)

10^4 events, Beam angle = 0 mrad, target radius = 0.64 cm

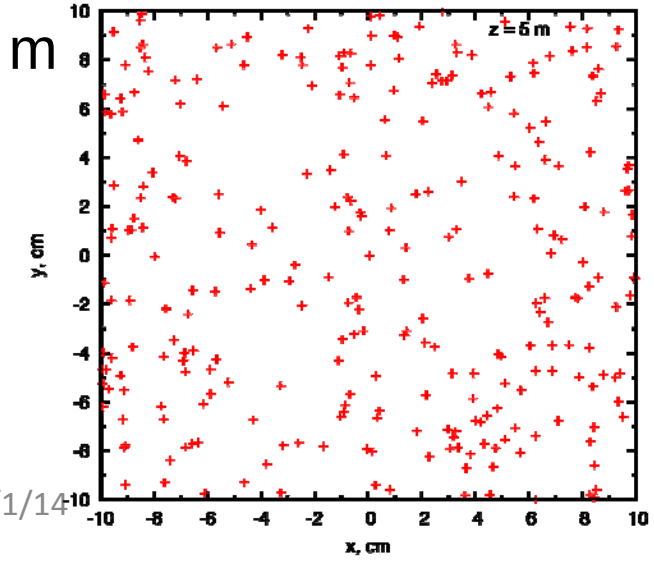
z = 5 m

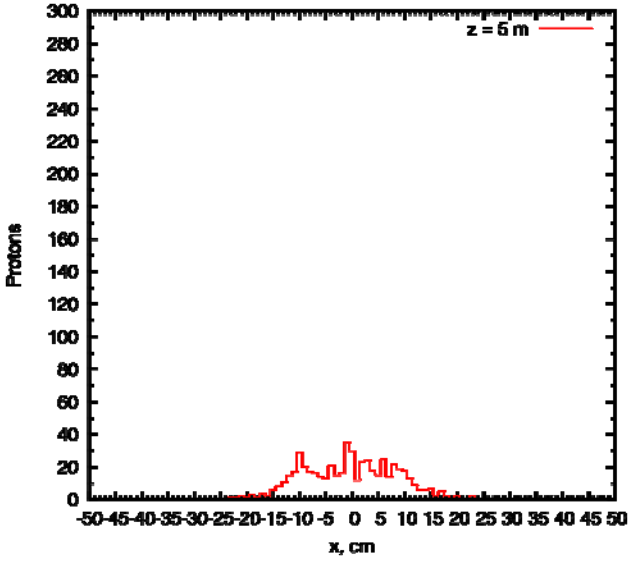




No beam dump

z = 5 m

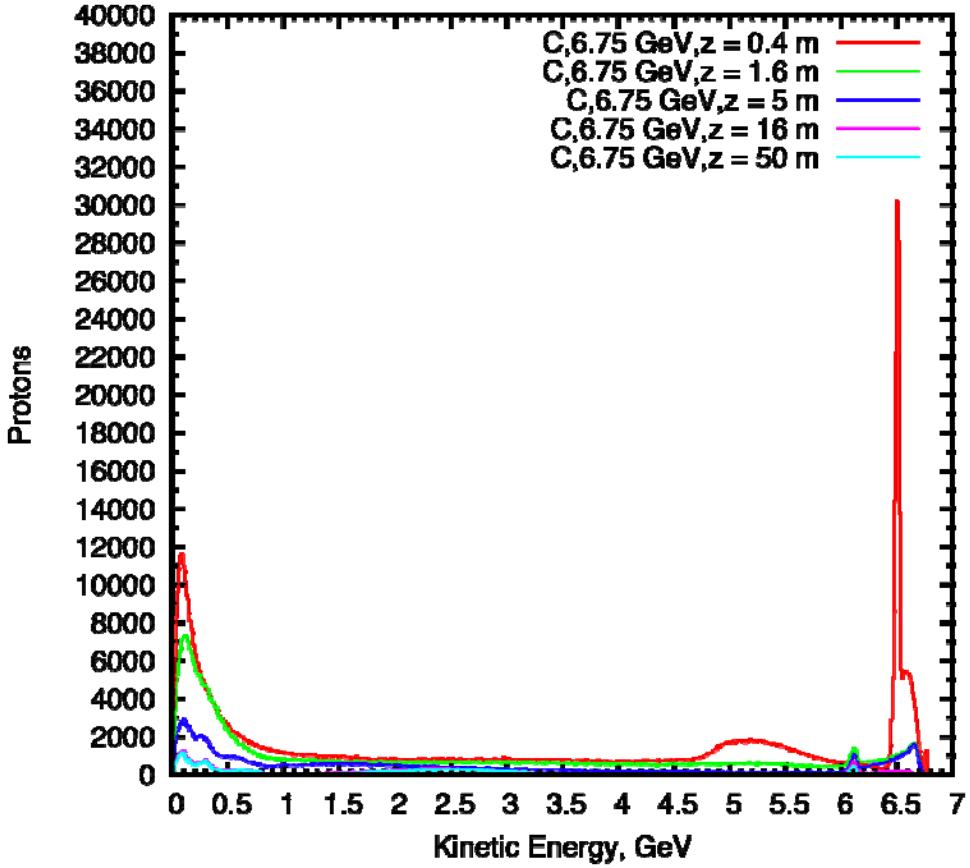


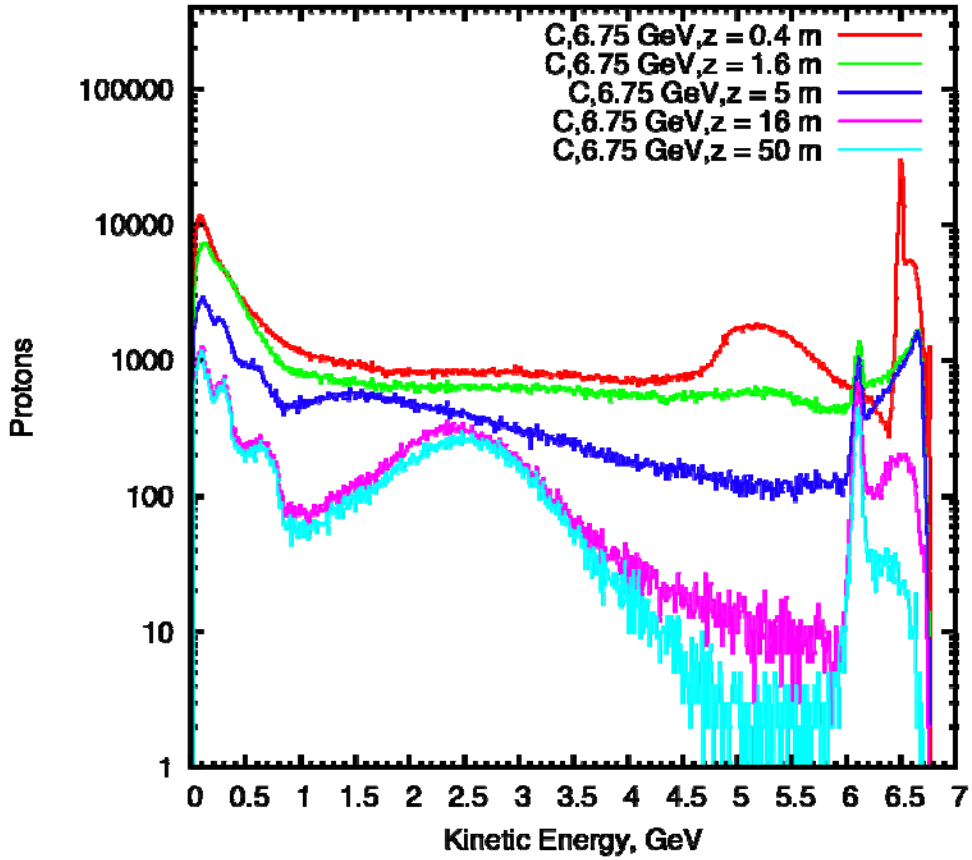


Beam dump:
120 cm long (z = 40 to 160 cm),
Triple of target radius

Remaining Protons with Beam Dump

(10^6 events, 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 (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 ($\times 9.26 \times 10^{10}$)	Protons KE>4.5 ($\times 9.26 \times 10^{10}$)	Yield at z=50m ($\times 9.26 \times 10^{10}$)
0	0	265270	88258	2078	2310	1063.4
40	1	221590	92222	1543	1787	987
80	1	202506	90564	1419	1668	927
120	1	210141	87216	1452	1695	868.8
40	2	183241	90205	1213	1419	938
80	2	155798	85367	909	1114	780.3
120	2	149733	86754	870	1134	743
40	3	158241	91585	1044	1260	852.7
80	3	119851	85385	607	811	680.2
120	3	114139	81006	542	767	590

Counting (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 = 0.8 cm

L_{dump} (cm)	R_{dump}/R_{target}	Total KE (protons) (r <23 cm) [Watts]	Total KE (non-protons) [Watts]	Protons KE>6 ($\times 9.26 \times 10^{10}$)	Protons KE>4.5 ($\times 9.26 \times 10^{10}$)	Yield at z=50m ($\times 9.26 \times 10^{10}$)
0	0	248364	88176	1885	2123	1052.2
40	1	189236	90497	1246	1486	984.5
80	1	173250	90986	1090	1348	933
120	1	164833	88743	1049	1256	840.3
40	2	159065	88299	993	1203	923.5
80	2	128899	86837	666	864	727
120	2	119276	83743	590	789	626
40	3	146394	87828	875	1061	778
80	3	108083	79873	474	643	684.6
120	3	90270	71746	324	507	545

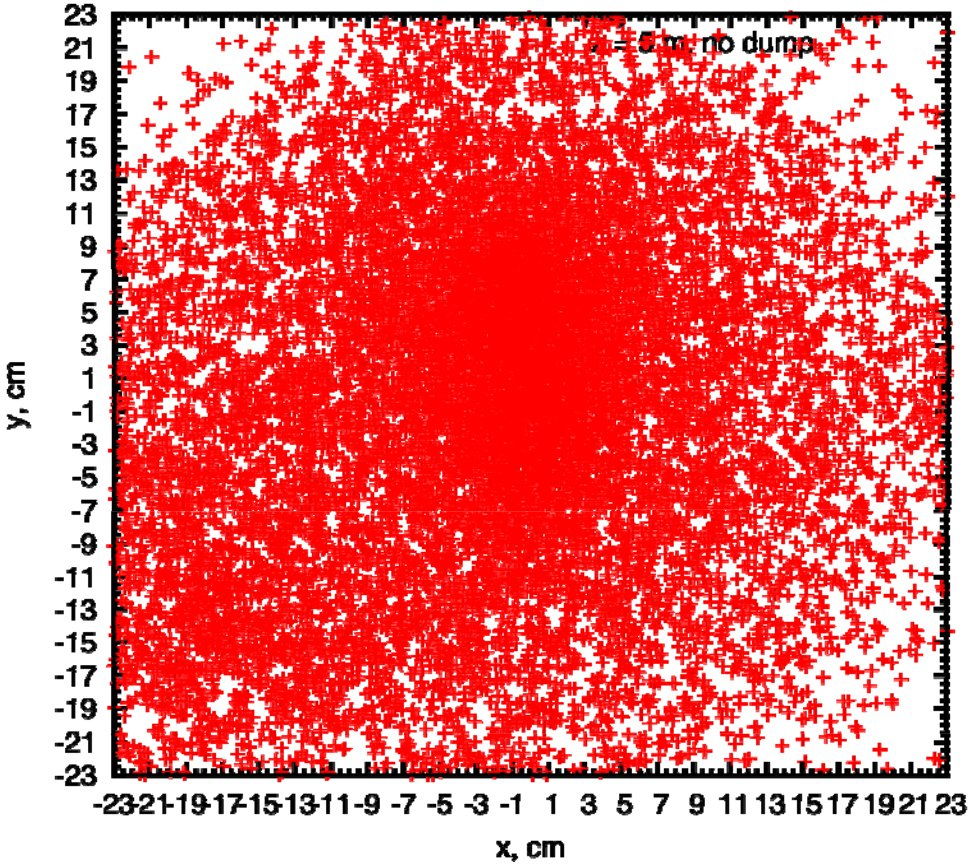
Counting (Carbon target) at z = 5 m

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

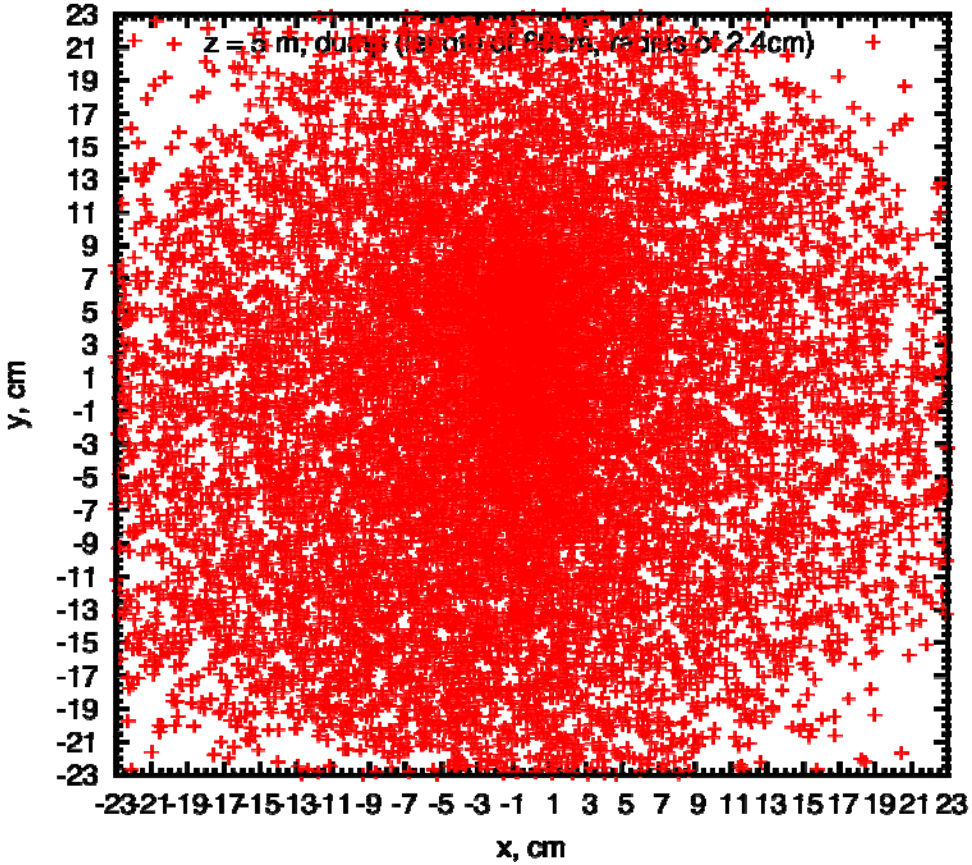
beam angle = 65 mrad, target radius = 0.8 cm

L_{dump} (cm)	R_{dump}/R_{target}	Total KE (protons) (r <23 cm) [Watts]	Total KE (non-protons) [Watts]	Protons KE>6 ($\times 9.26 \times 10^{10}$)	Protons KE>4.5 ($\times 9.26 \times 10^{10}$)	Yield at z=50m ($\times 9.26 \times 10^{10}$)
0	0	88359	105454	301	532	1240.7
40	1	85504	105007	270	466	1268
80	1	88318	102577	318	520	1256.2
120	1	85932	100030	299	496	1230.1
40	2	77262	101664	207	400	1246.2
80	2	75493	97715	206	370	1196
120	2	78364	96967	204	374	1170.5
40	3	72615	101494	176	359	1084.5
80	3	64610	97569	112	271	1142.4
120	3	66430	94936	130	300	1134.6

All charged particles at z = 5 m (10^4 events)

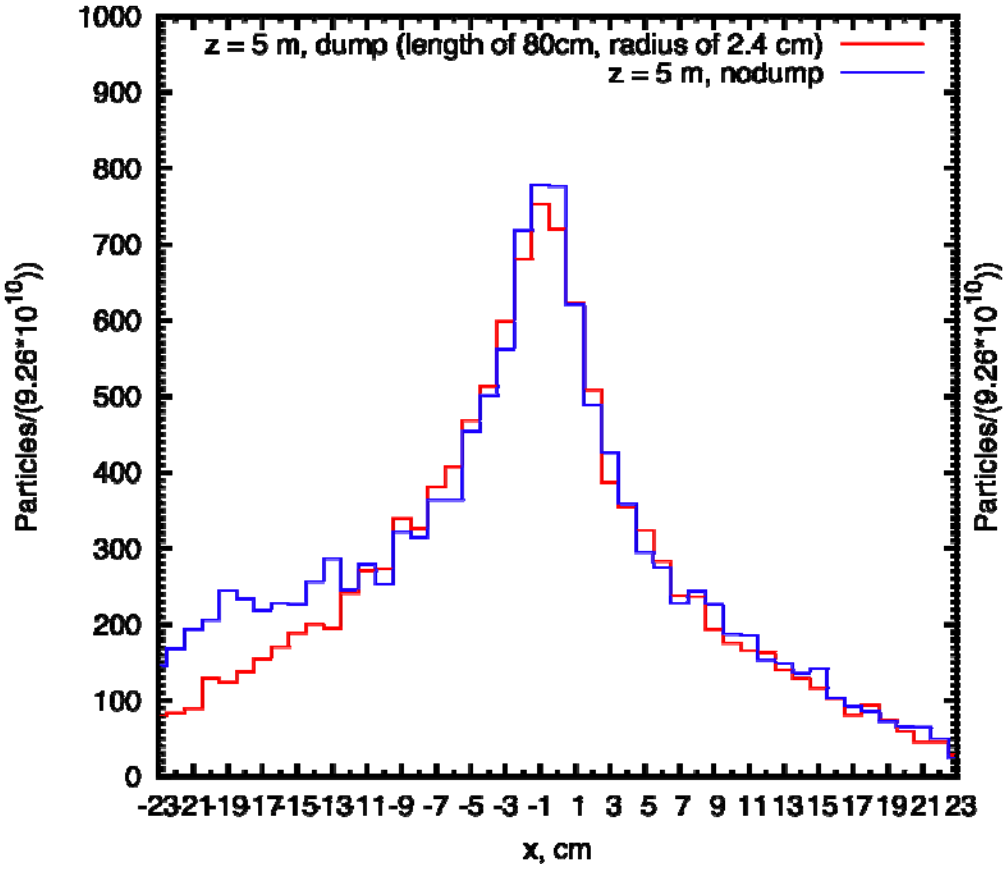


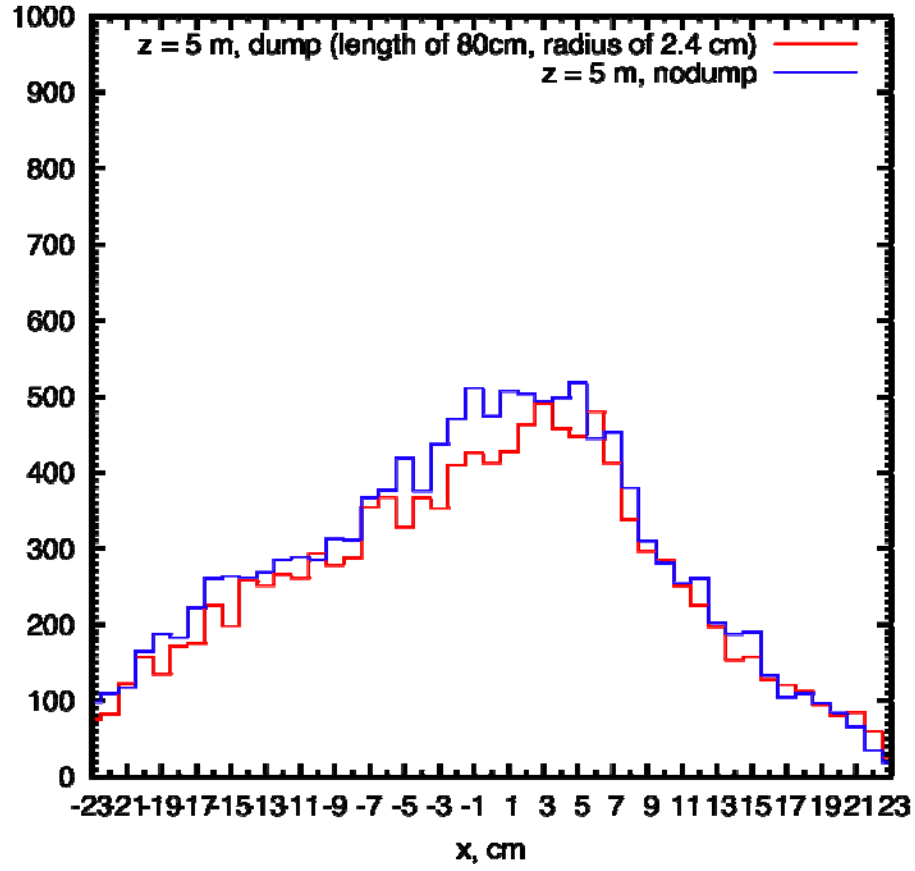
No dump



Dump (length of 80 cm long, radius of 2.4 cm)

All charged particles at z = 5 m (1 MW proton beam)





C, Hg, Ga targets, no dump

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

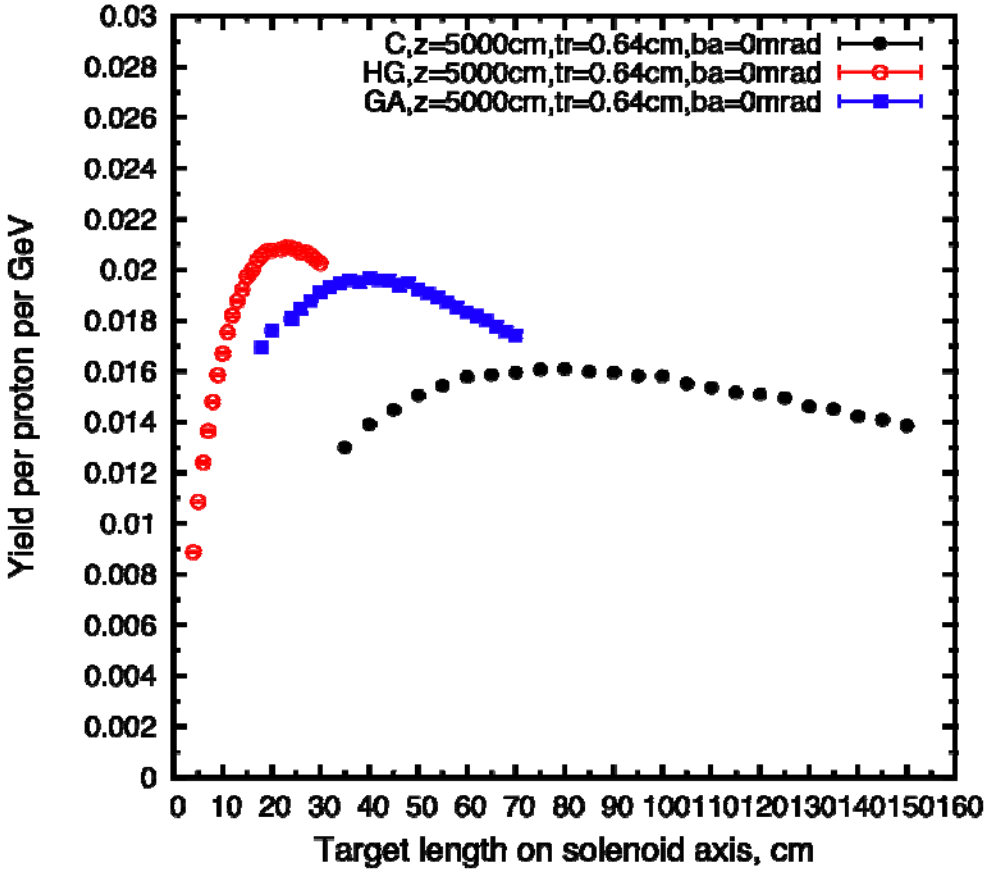
Target length is 80 cm and target radius is 0.64 cm for C, 23 cm for Hg, and 40 cm for Ga

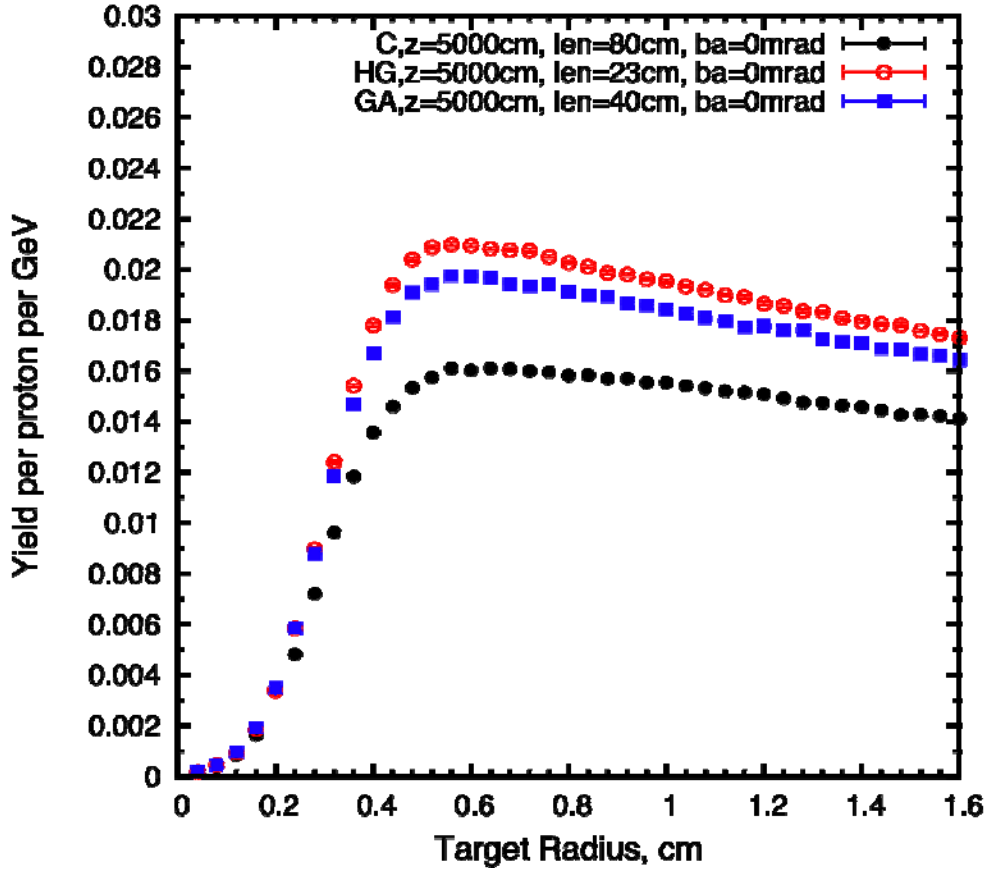
	Total KE (protons) (r <23 cm) [Watts]	Total KE (non-protons) [Watts]	Protons KE>6 ($\times 9.26 \times 10^{10}$)	Protons KE>4.5 ($\times 9.26 \times 10^{10}$)	Yield at z=50m ($\times 9.26 \times 10^{10}$)
C	265270	88258	2078	2310	1063.4
Hg	217116	65898	1908	1974	1362.4
Ga	223972	84440	1818	1945	1288.7

Previous studies for Hg and Ga used a tilted beam such that higher energy protons were not counted, so the total power sent down the beampipe was ~ ½ that seen here.

Yield Comparison

(C, Hg and Ga targets, no tilt of 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