Targeting and Capture

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OUTLINE

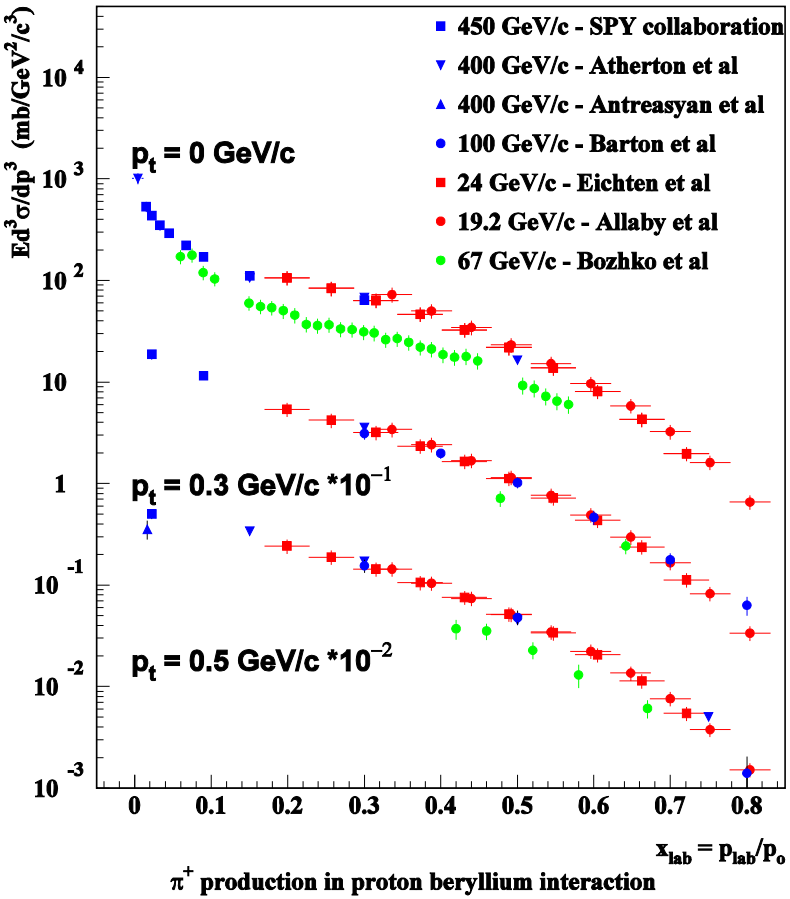
- MARS model verification
- Method description
- Target length and material
- Li lens capture
- Horn capture

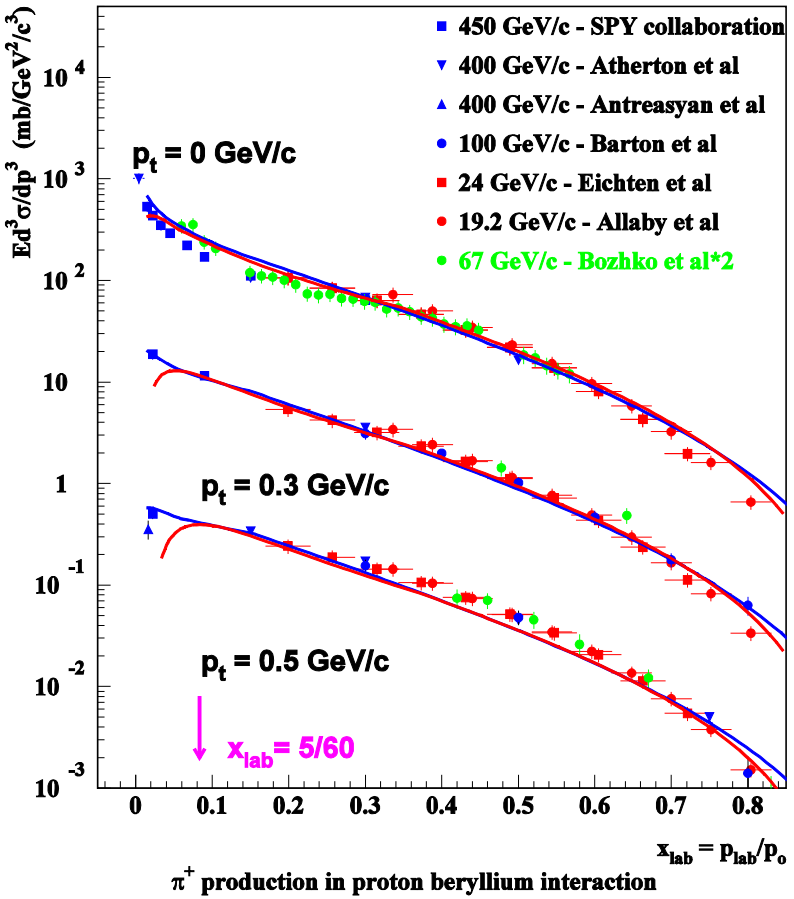
Mars verification

- We are going to calculate yield of pion within small momentum bin around 3 or 5 GeV/c produced by 60 GeV/c protons on thick target using MARS model. How well MARS model agrees with experiment in this region?
- We have a lot of applicable data for light target (Be, C)
- There are only few proper measurement for heavy nuclei

MARS verification - II

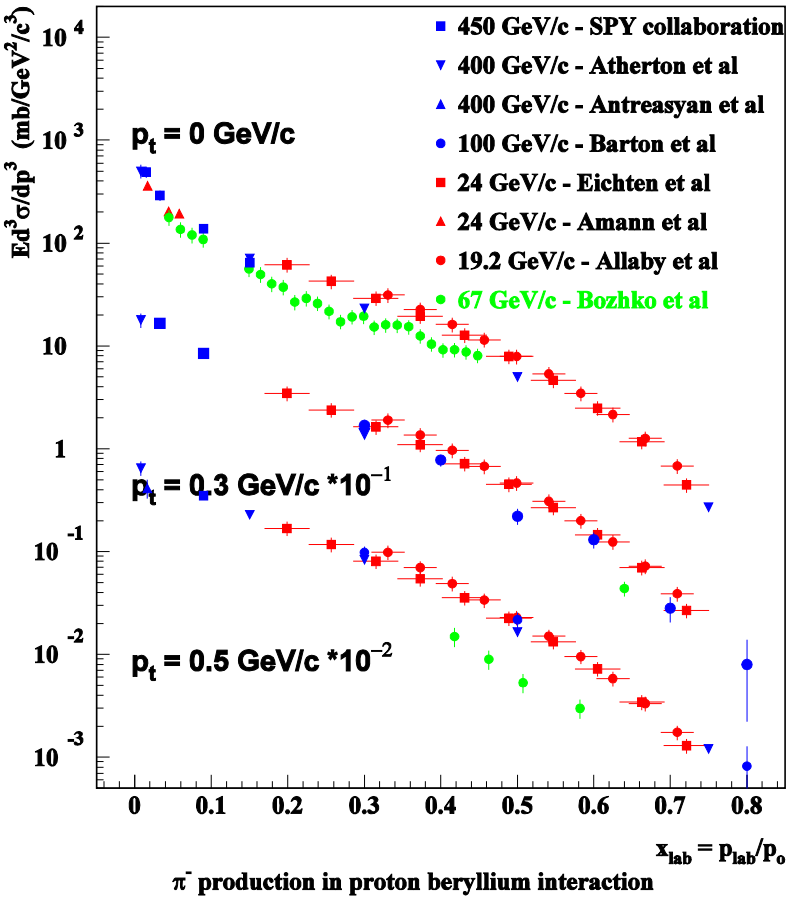
Red line – MARS model at 19.2 GeV/c,
blue line – MARS model at 450 GeV/c

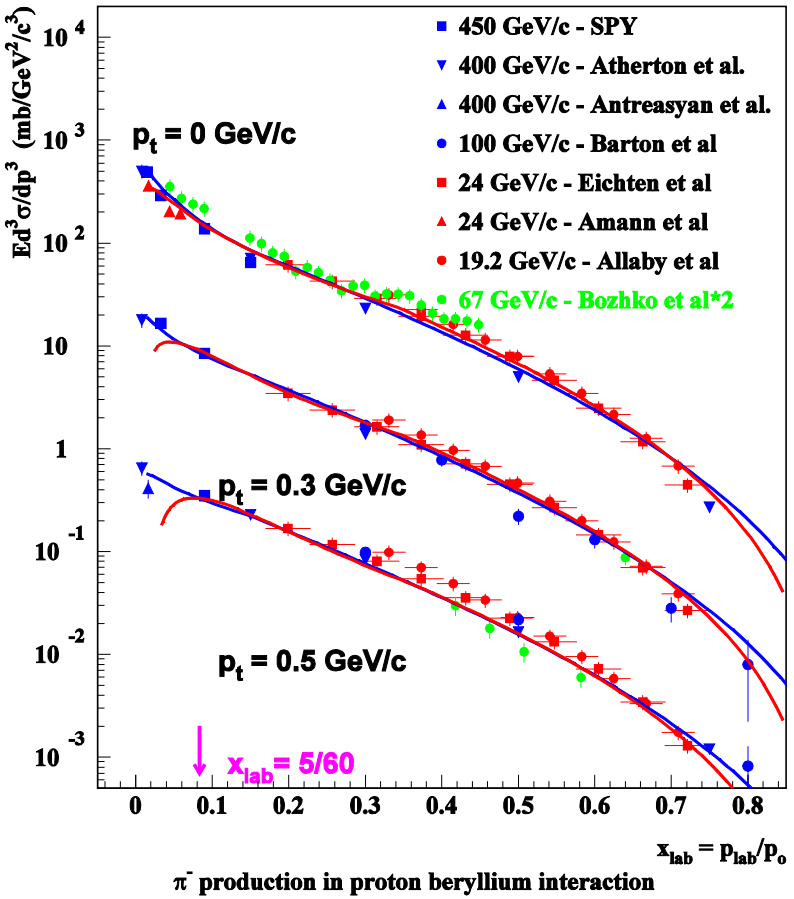




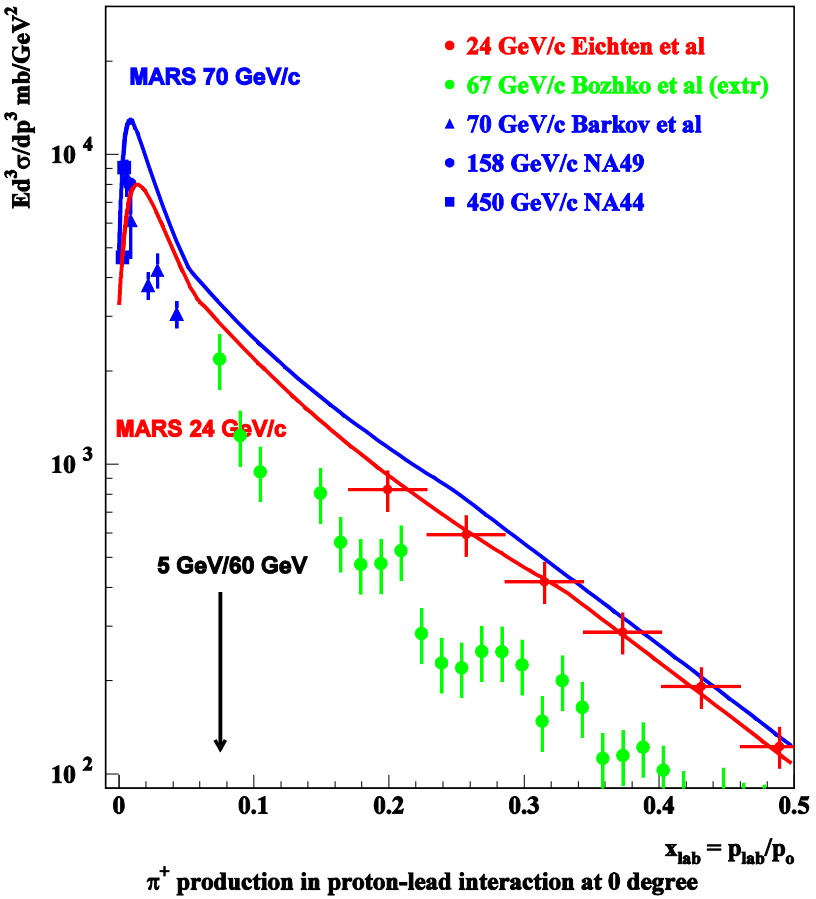
MARS verification - III

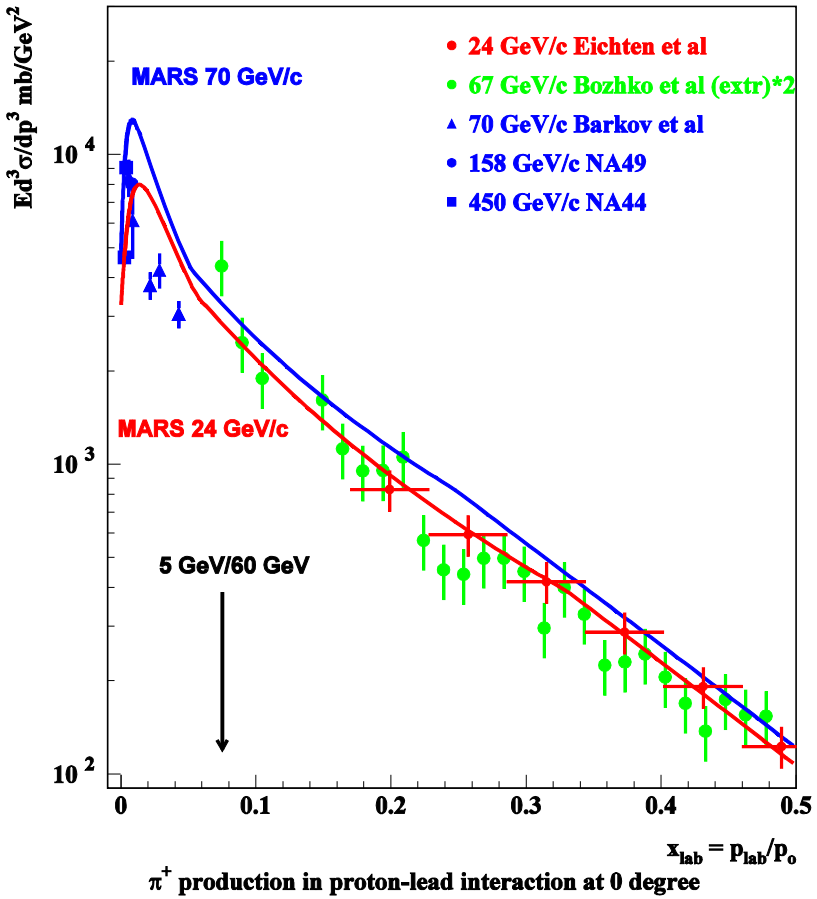
Red line – MARS model at 19.2 GeV/c,
blue line – MARS model at 450 GeV/c



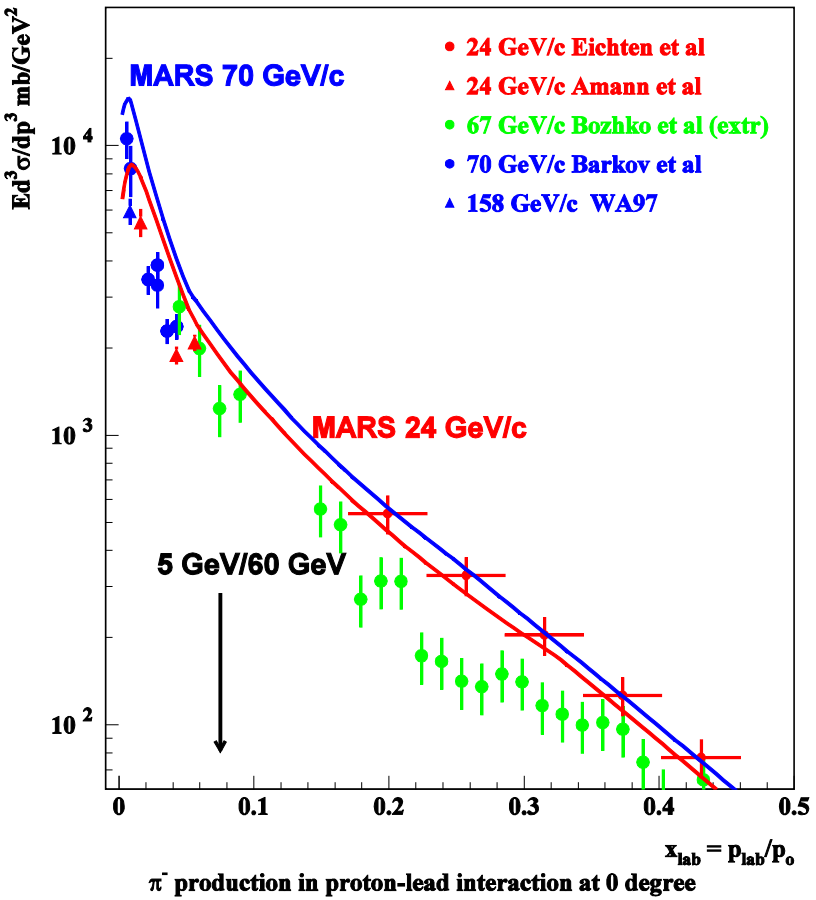


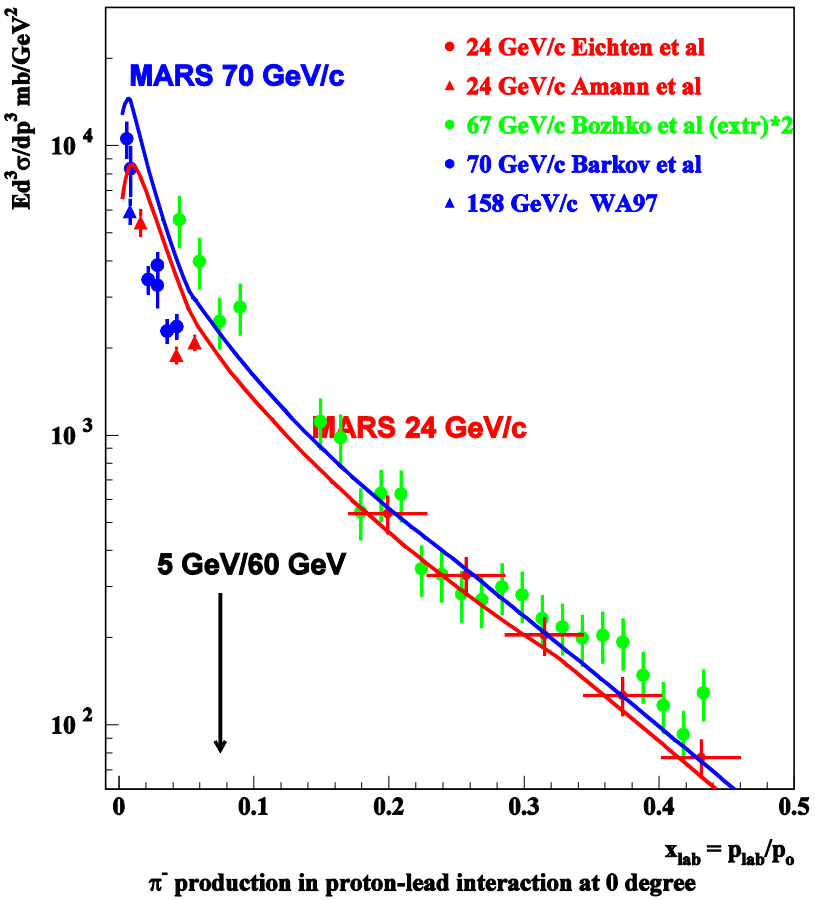
MARS verification - IV





MARS verification - V





Mars verification - conclusion

- Most applicable experimental data has about 50% uncertainty in absolute normalization
- MARS model agrees within 30% with scaling interpolation for lead, but overestimates scaling prediction near 5 GeV/c for positive pion production from beryllium
- Measurements of MIPP and NA61/SHINE collaborations could help to specify precision of MARS model in this momentum range

Pion spectra at 60 GeV/c

Pion production in forward cone of 120 mrad by 60 GeV/c protons was simulated using MARS.

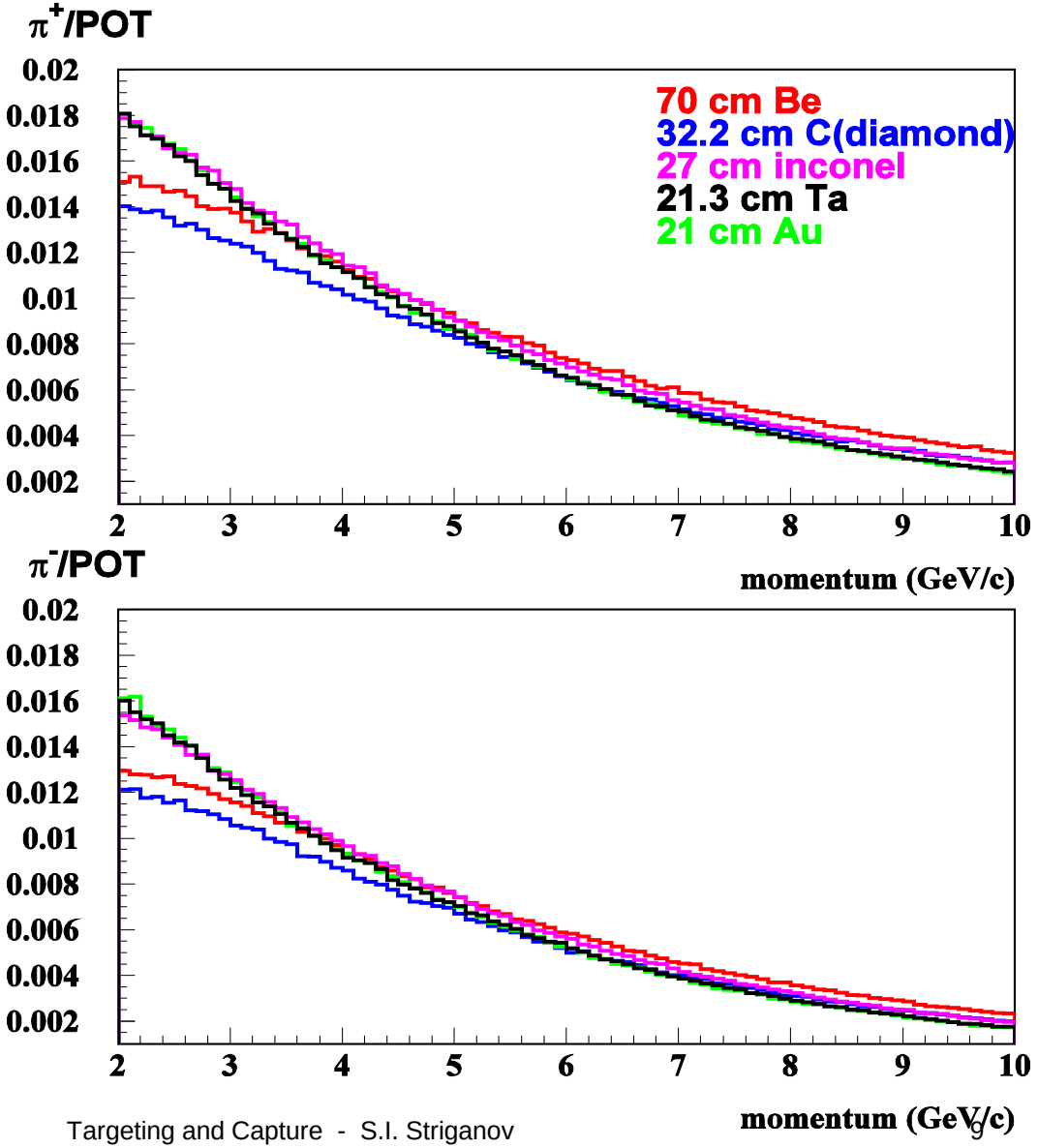
Target length for any material were optimized to get maximum yield into 2 mm rad acceptance.

Pion spectra for optimal target length are weakly depend on target material.

Number of pion produced at 3 GeV/c momentum larger about 60% than number of pion produced at 5 GeV/c.

We are going to collect pion with +- 10% momentum around central 3 or 5 GeV/c.

Momentum bin for 5 GeV = 1/0.6 momentum bin at 3 GeV/c. So, about same number of pion are produced into +-10% bin around 3 and 5 GeV/c.



Method description

Production of positive pion with momentum 5 +- 15%(10%,5%) was simulated using MARS.

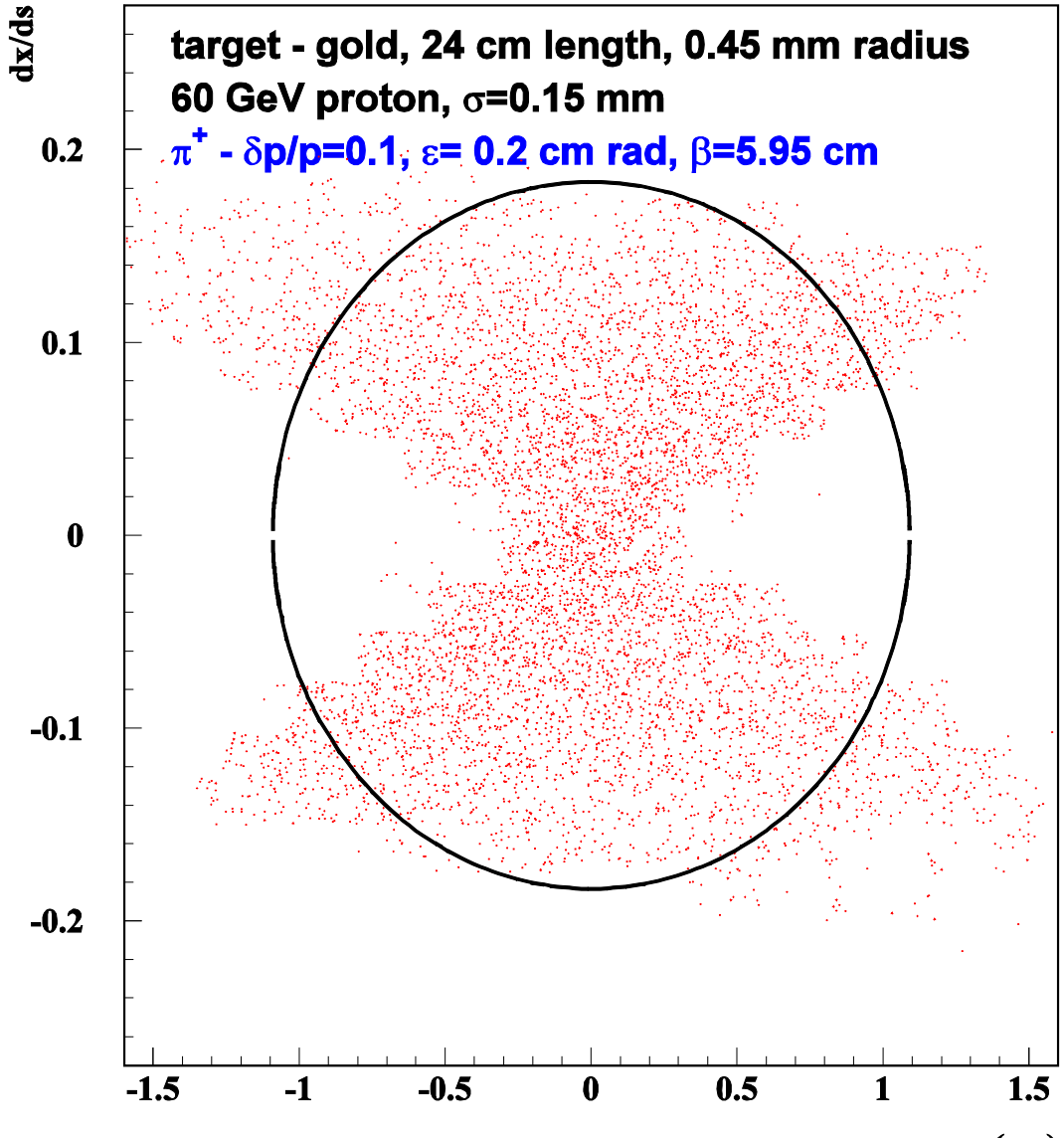
Pion coordinates were translated to the longitudinal coordinate at which second order moments $\langle x\theta_x\rangle=\langle y\theta_y\rangle=0$.

Pion within phase space determined by

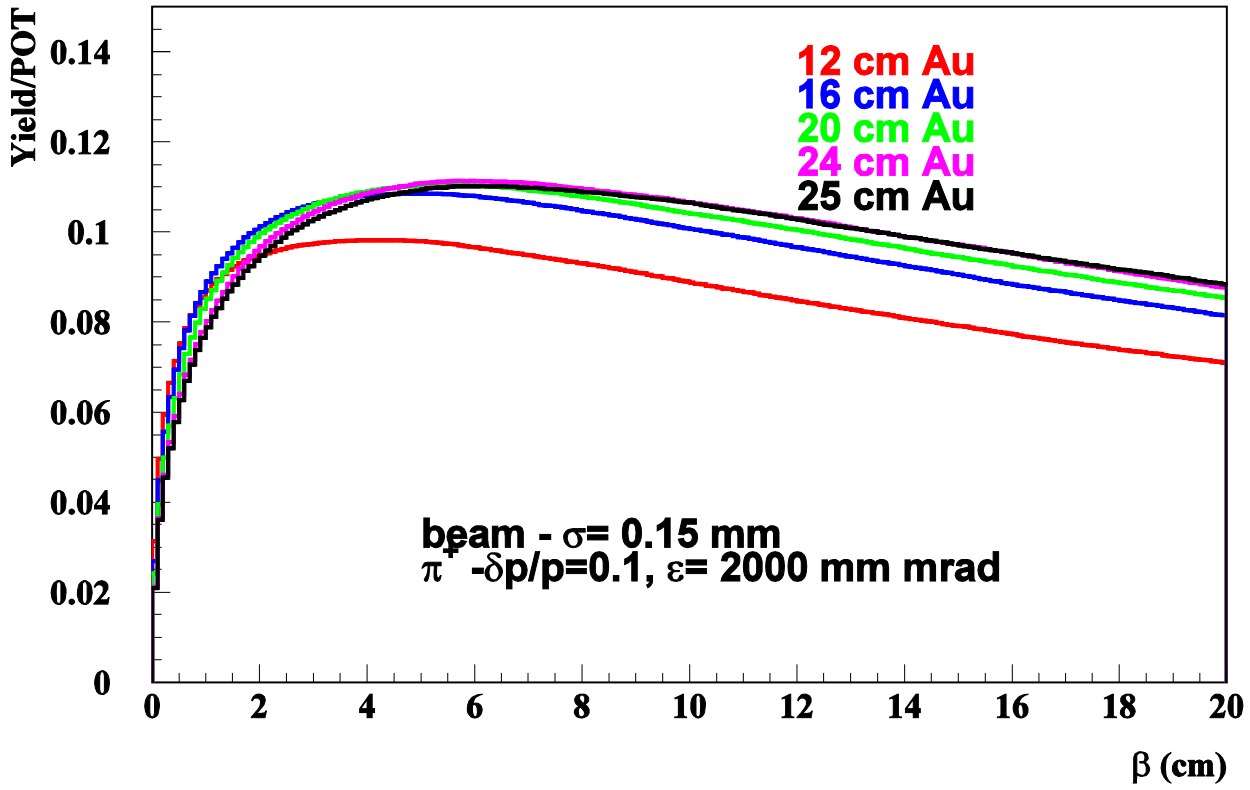
$$\frac{x^2}{b}+x'b+\frac{y^2}{b}+y'b \pounds e$$

are considered to be accepted to the ring. Pion acceptance ε=2000 mm mrad (from D. Neuffer) corresponds to ring with 11 cm internal radius and β=6m.

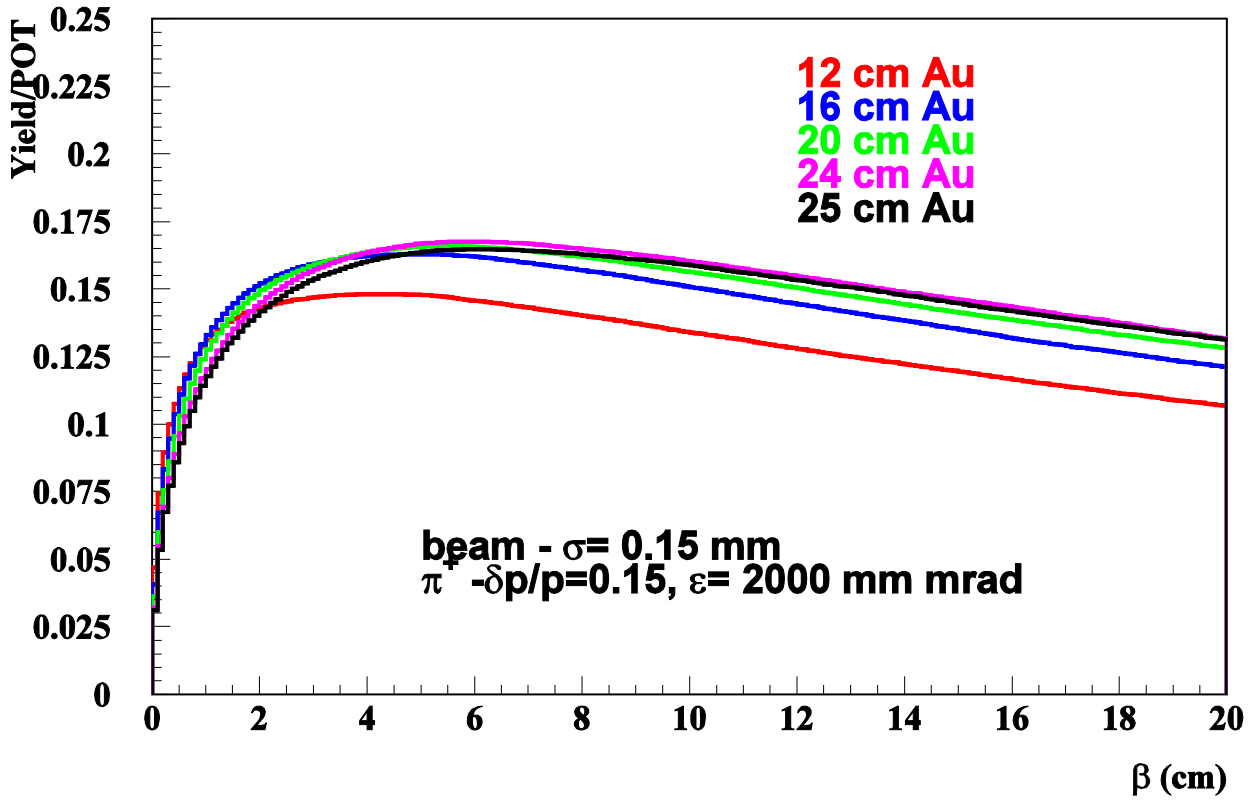
This is maximal number of pion could be collected into considered acceptance if target is not inside magnetic field



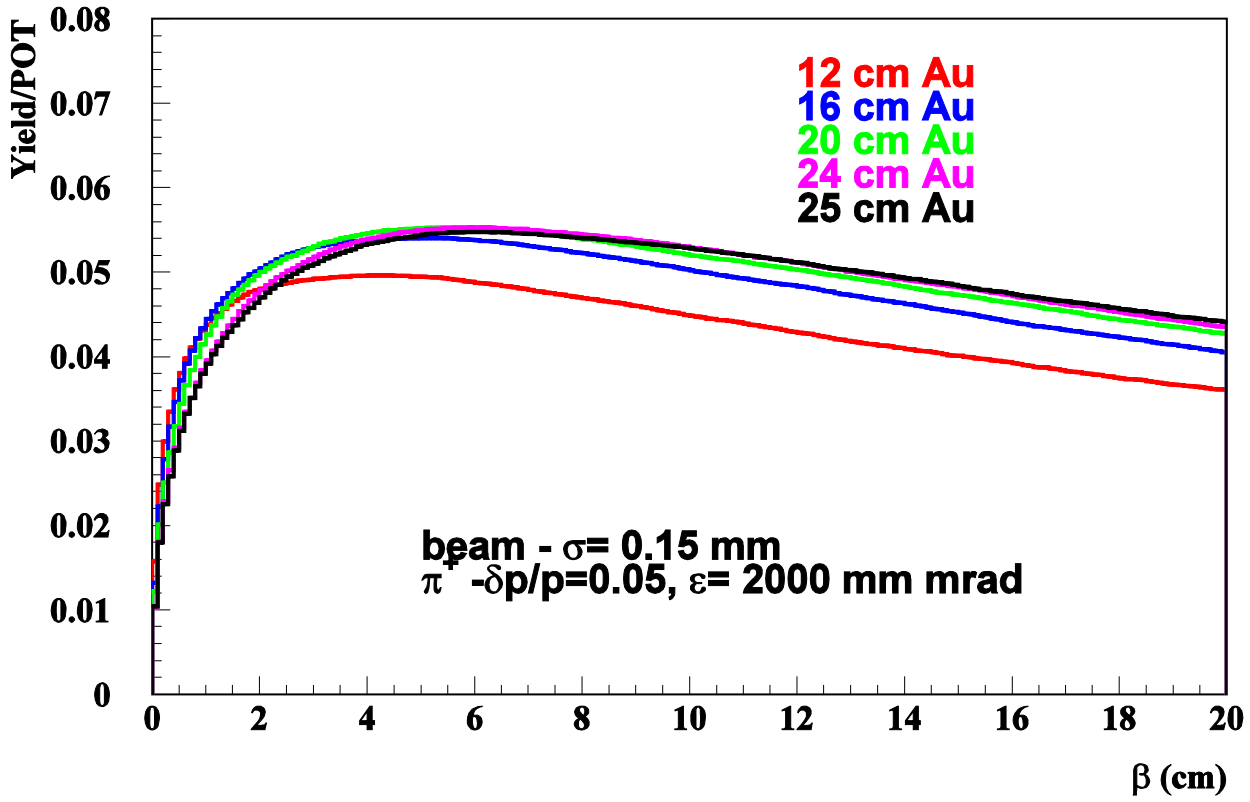
Dependence of positive pion yield on beta function for gold target (5±0.5 GeV/c) at 60 GeV



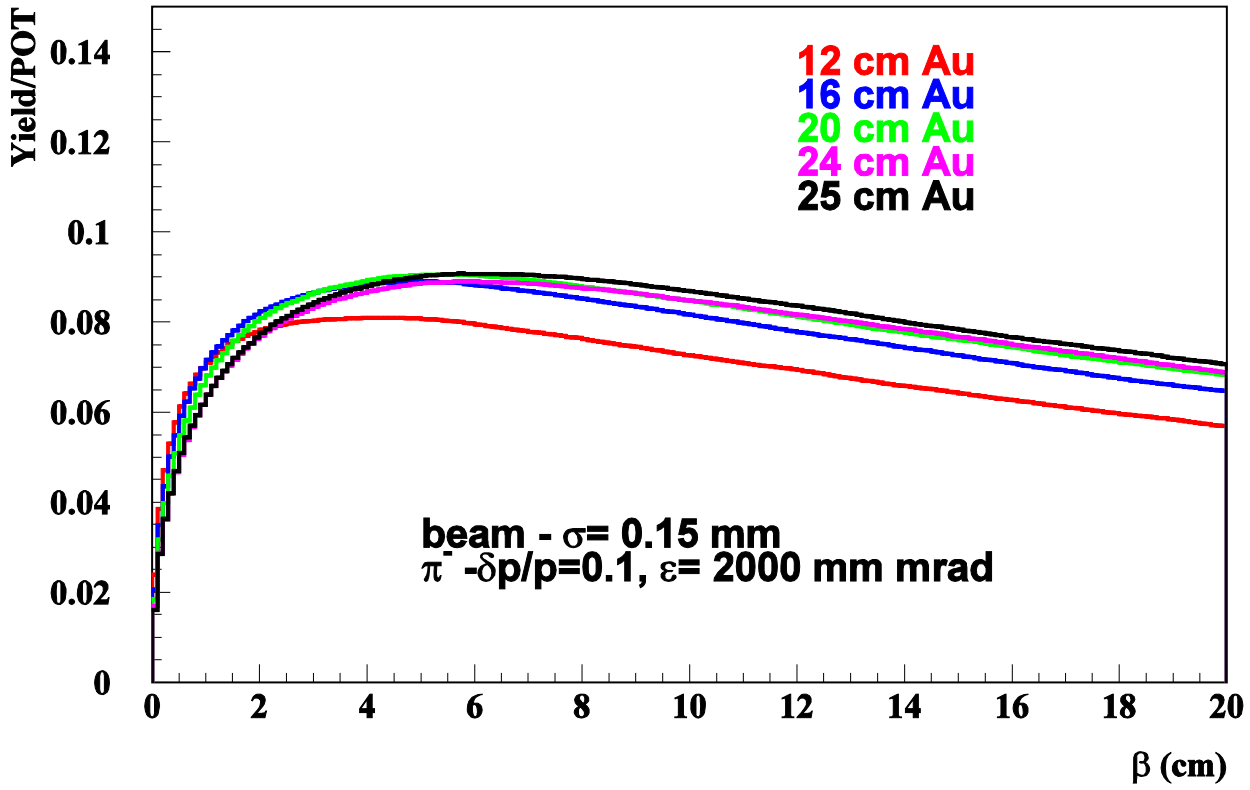
Dependence of positive pion yield on beta function for gold target (5±0.75 GeV/c) at 60 GeV



Dependence of positive pion yield on beta function for gold target (5±0.25 GeV/c) at 60 GeV



Dependence of negative pion yield on beta function for different target (5±0.5 GeV/c) at 60 GeV

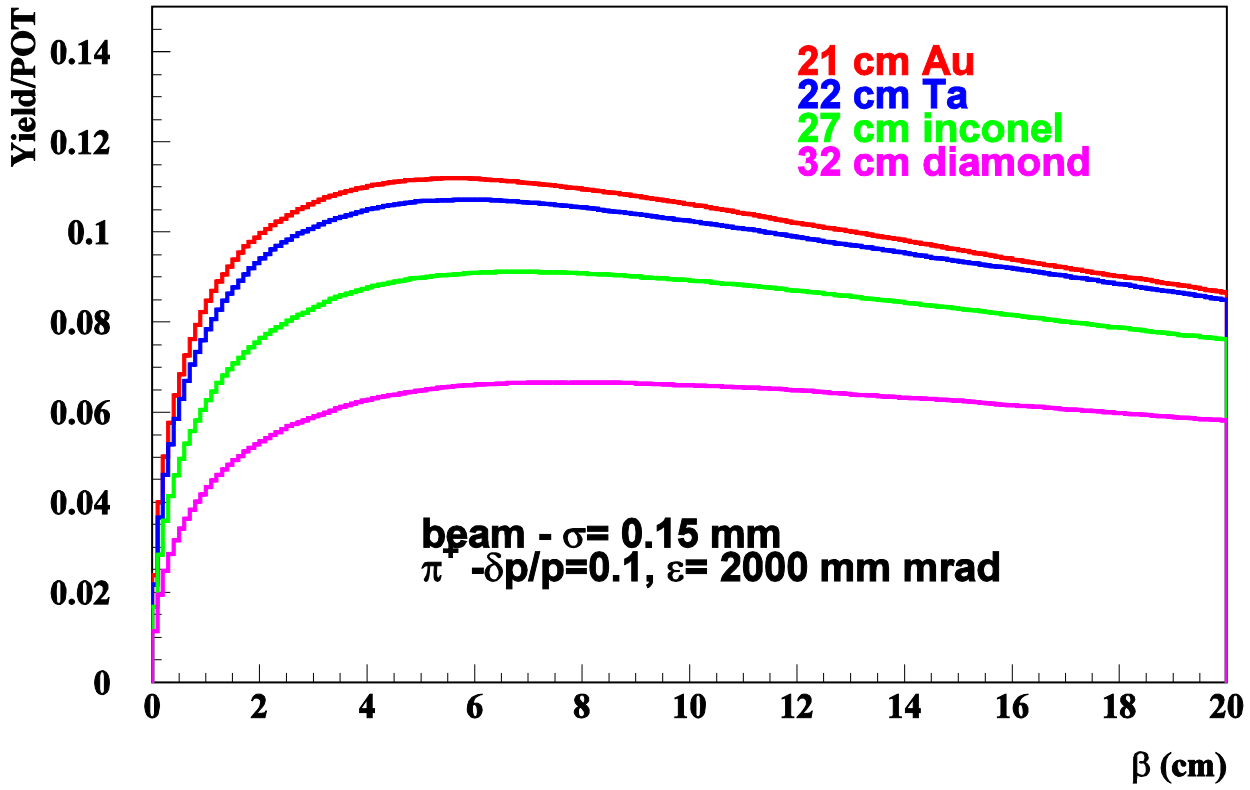


Optimal target length as function of target material and central pion momentum.

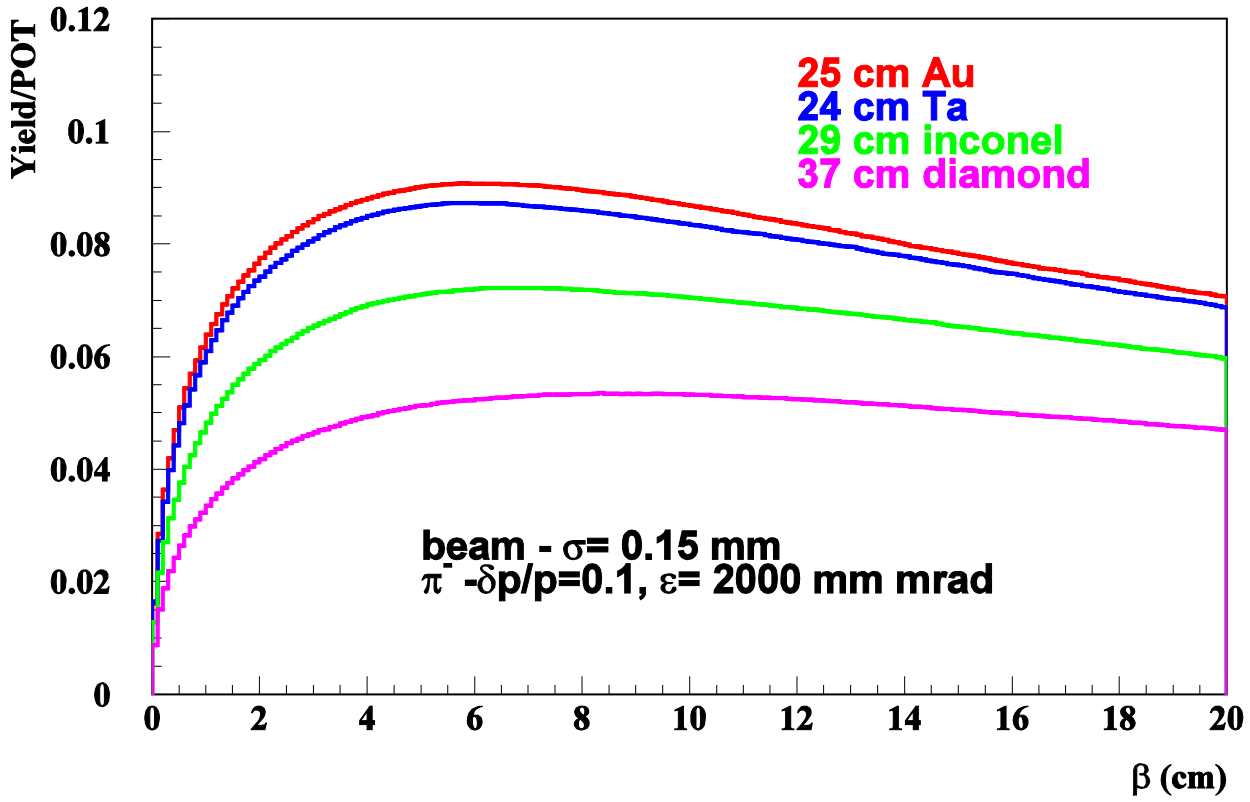
Number of positive pion/POT into 2 mm rad acceptance.

material	momentum (GeV/c)	±15%	±10%	±5%	target length (cm)	density (g/cm^3)
Carbon	3	0.085	0.056	0.028	27.3	3.52
Carbon	5	0.099	0.067	0.033	32.2	3.52
Inconel	3	0.131	0.087	0.044	19.2	8.43
Inconel	5	0.136	0.091	0.045	27.0	8.43
Tantalum	3	0.164	0.109	0.054	15.3	16.6
Tantalum	5	0.161	0.107	0.053	21.3	16.6
Gold	3	0.177	0.118	0.059	18.0	19.32
Gold	5	0.171	0.112	0.056	21.0	19.32

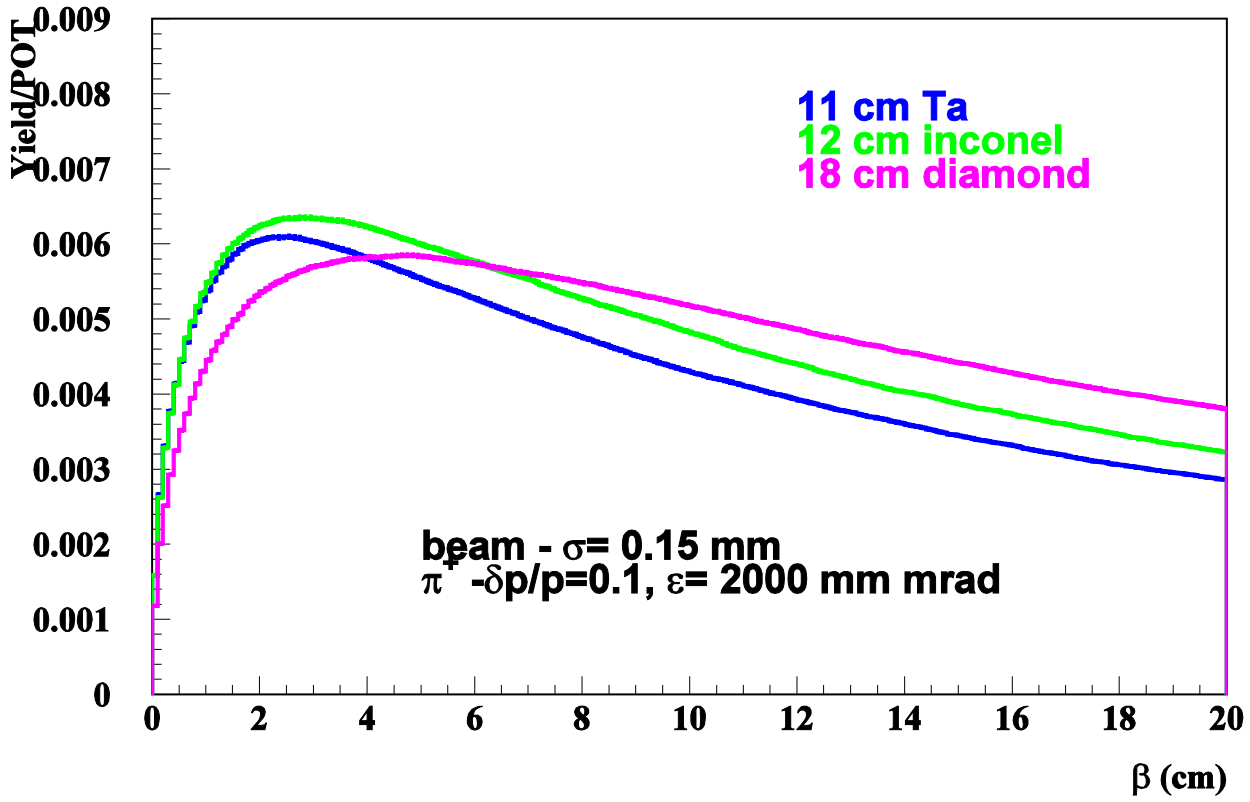
Dependence of positive pion yield on beta function for different target (5±0.5 GeV/c) at 60 GeV



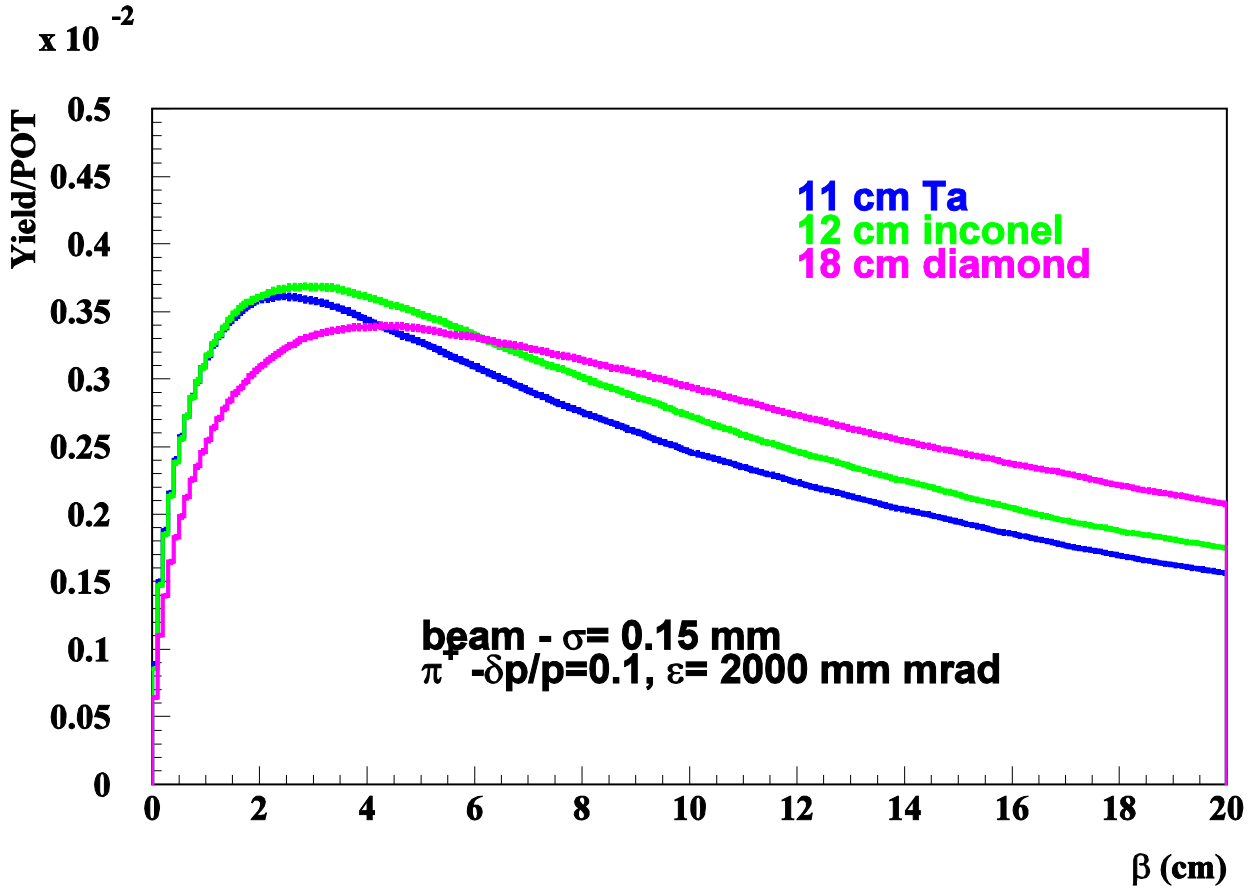
Dependence of negative pion yield on beta function for different target (5±0.5 GeV/c) at 60 GeV



Dependence of positive pion yield on beta function for different target (3±0.3 GeV/c) at 8 GeV



Dependence of negative pion yield on beta function for different target (3±0.3 GeV/c) at 8 GeV



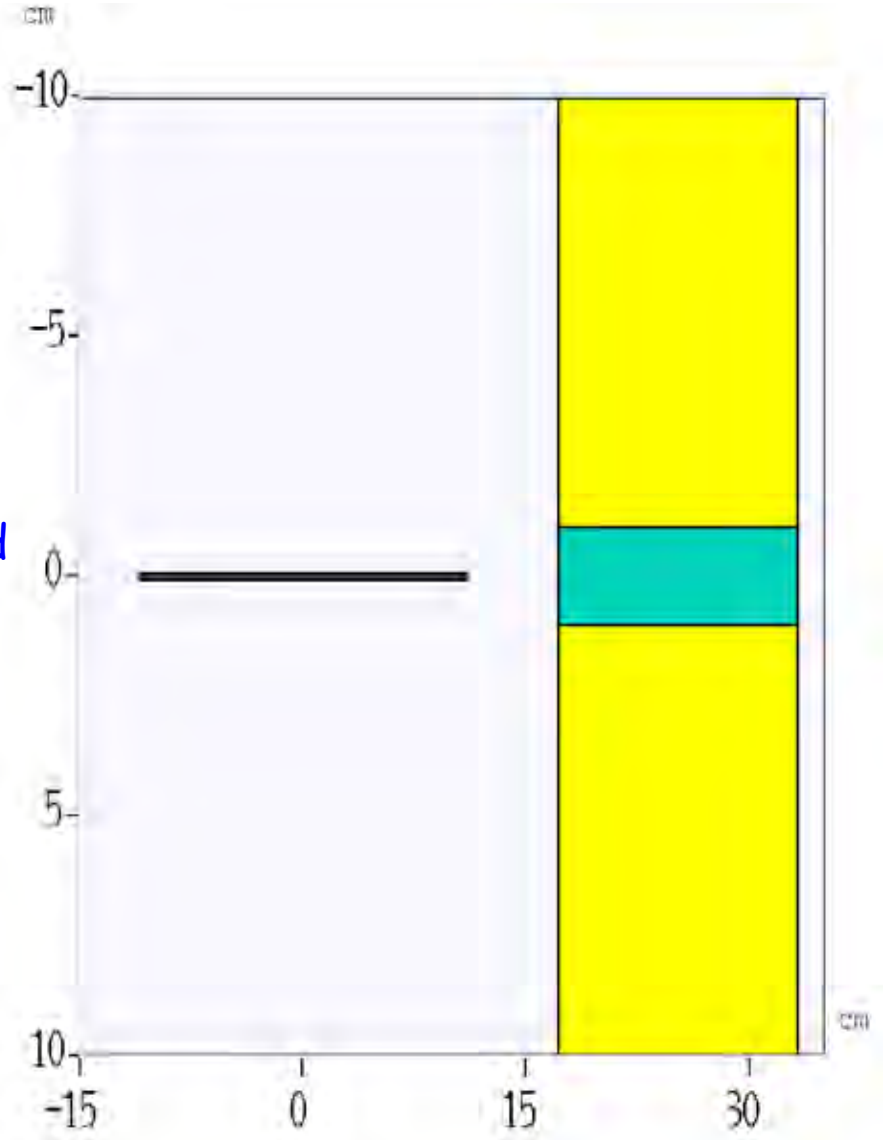
Lithium lens capture

Existing Fermilab lithium lens - 16 cm length and 1 cm radius.
2.6 Tesla/cm gradient at 15 Hz.
Optimal focal distance – distance between target and lens center is about 25 cm.

With current lens we could capture only 40% of pions with 3 ± 10% .

With 2 cm lithium radius transmission could be increased up to 60 %.

With rising field we need to reduce focal distance and reduce target length. With 2 cm radius and 4 Tesla/m transmission could be rise up to 80%. But there are no gap between downstream end of tantalum target and lens in this case.



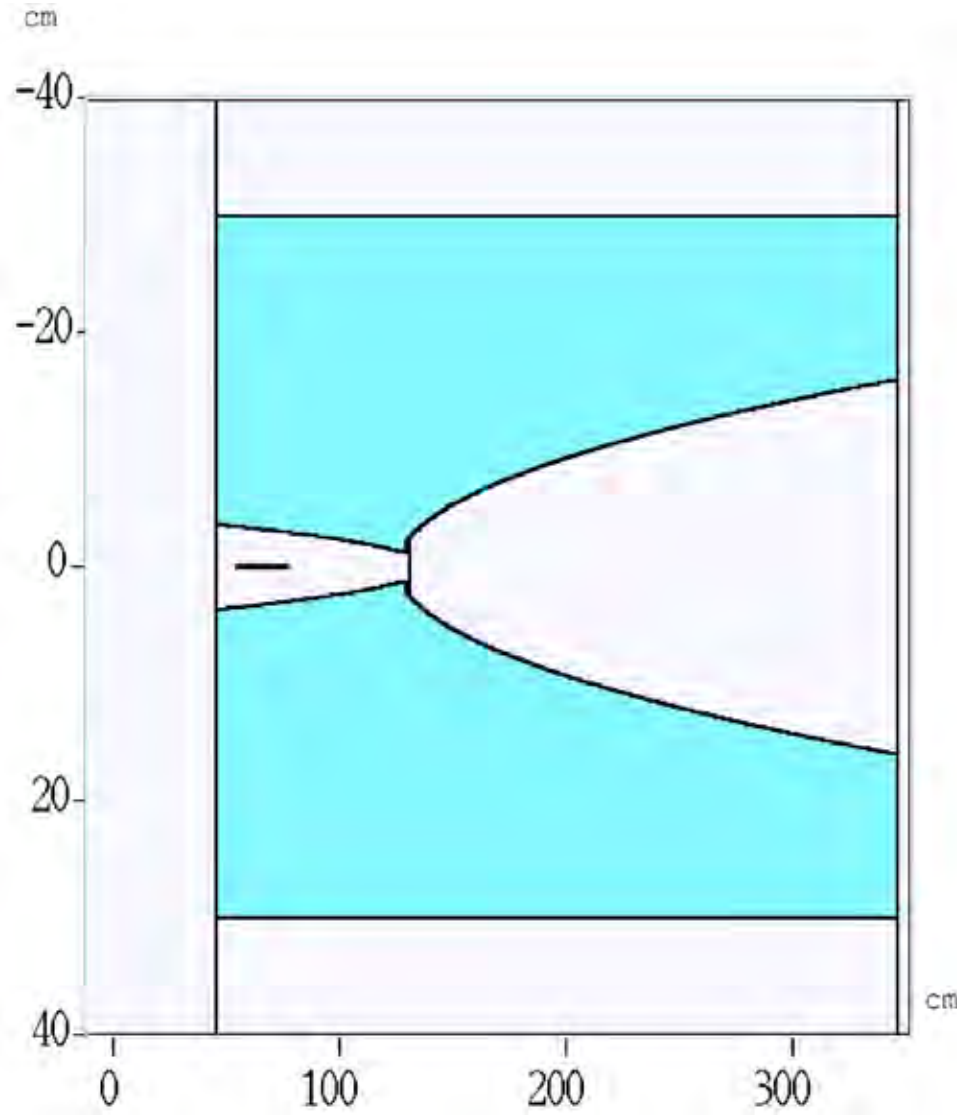
Horn capture

Existing NuMi horn has parabolic shape of the inner conductor. Shape and currents were optimized to maximize neutrino yield with energy less than 12 GeV with second horn.

Recent NuMI horn are using 185 kA current usually. With NuMI target (graphite -94 cm long,7.5x3.2 mm) and 60 GeV beam positive pion yield at 3 +- 10% GeV is 0.042 π^+/POT and at 5 +- 10% GeV is 0.057 π^+/POT.

Reasonable restriction (10 years ago):

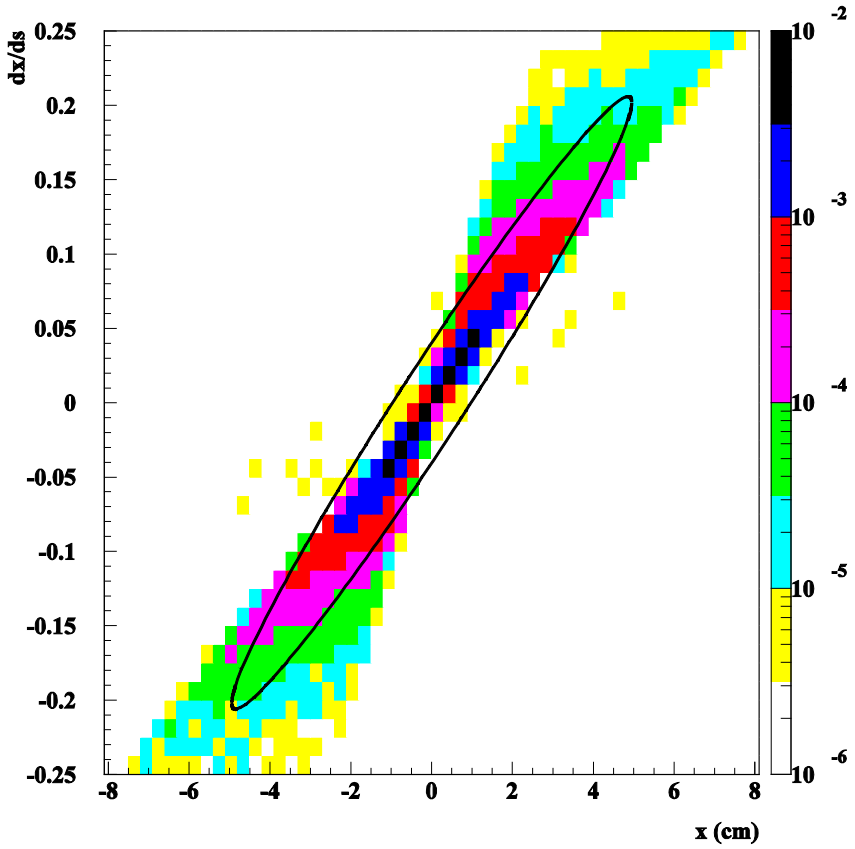
- horn radius does not exceed 50 cm
- horn length is in order of 3 m
- maximum horn current is equal to 300 kA

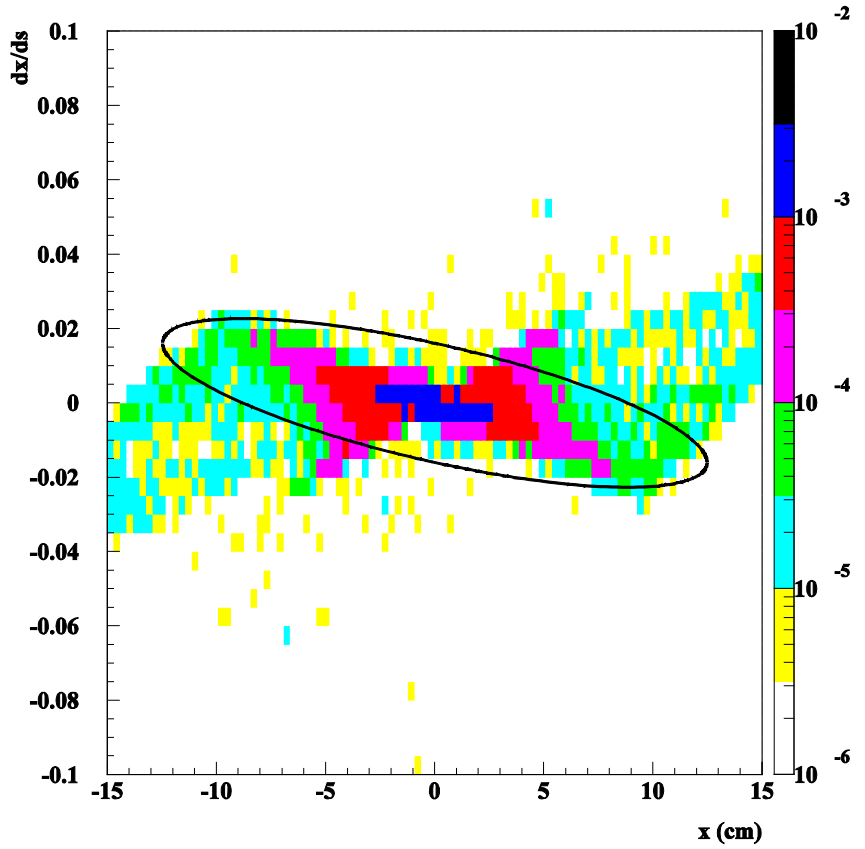


PI+ Yield, 5±0.3 GeV/c, NuMI horn, 60 GeV proton on gold target (20 cm length, 0.45 mm radius), target center shifted on 20 cm inside 3 m horn

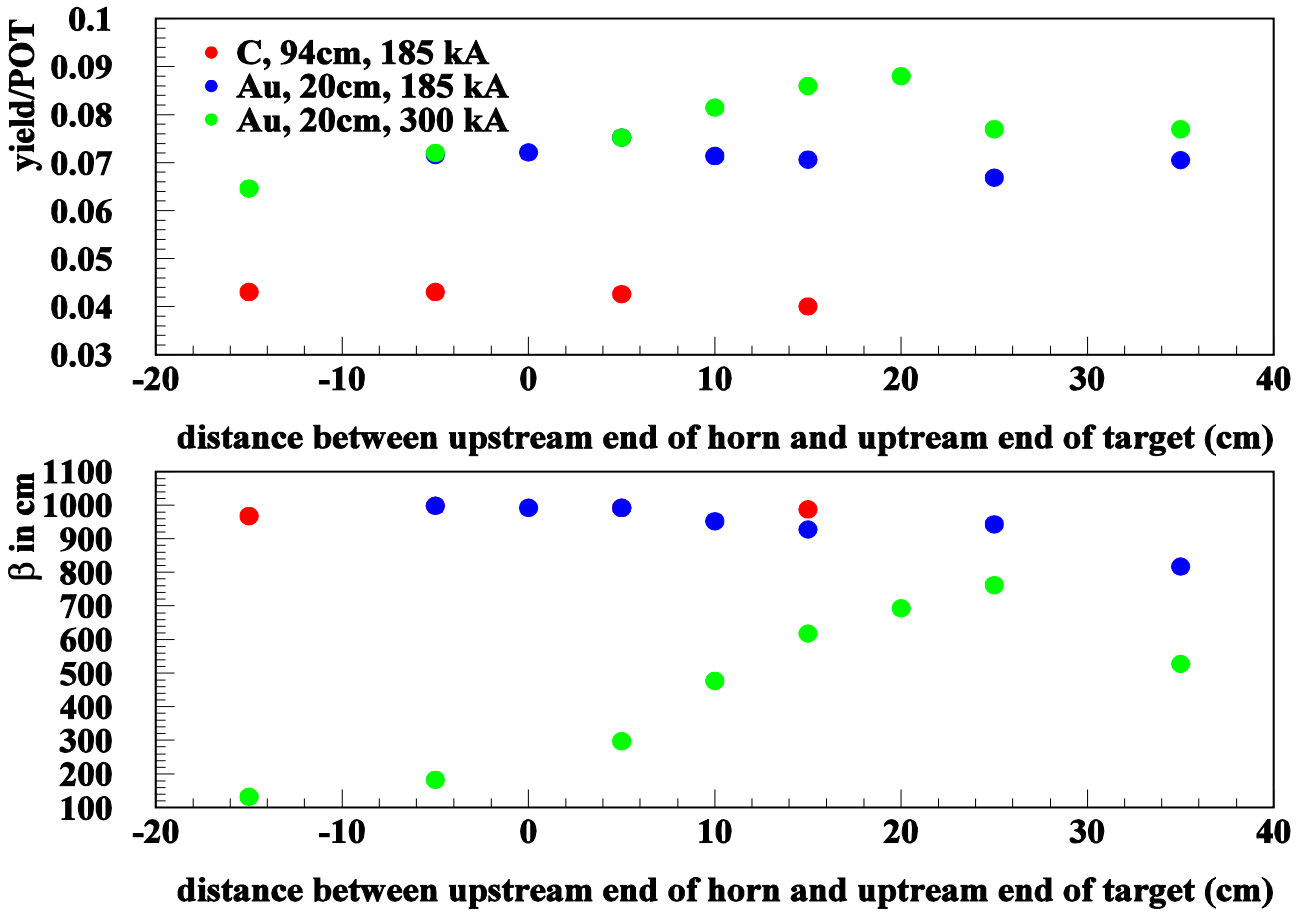
10 cm after target,
1.12 pion inside 2 mm rad

5 cm after horn, 300 kA,
0.82 pion inside 2 mm rad

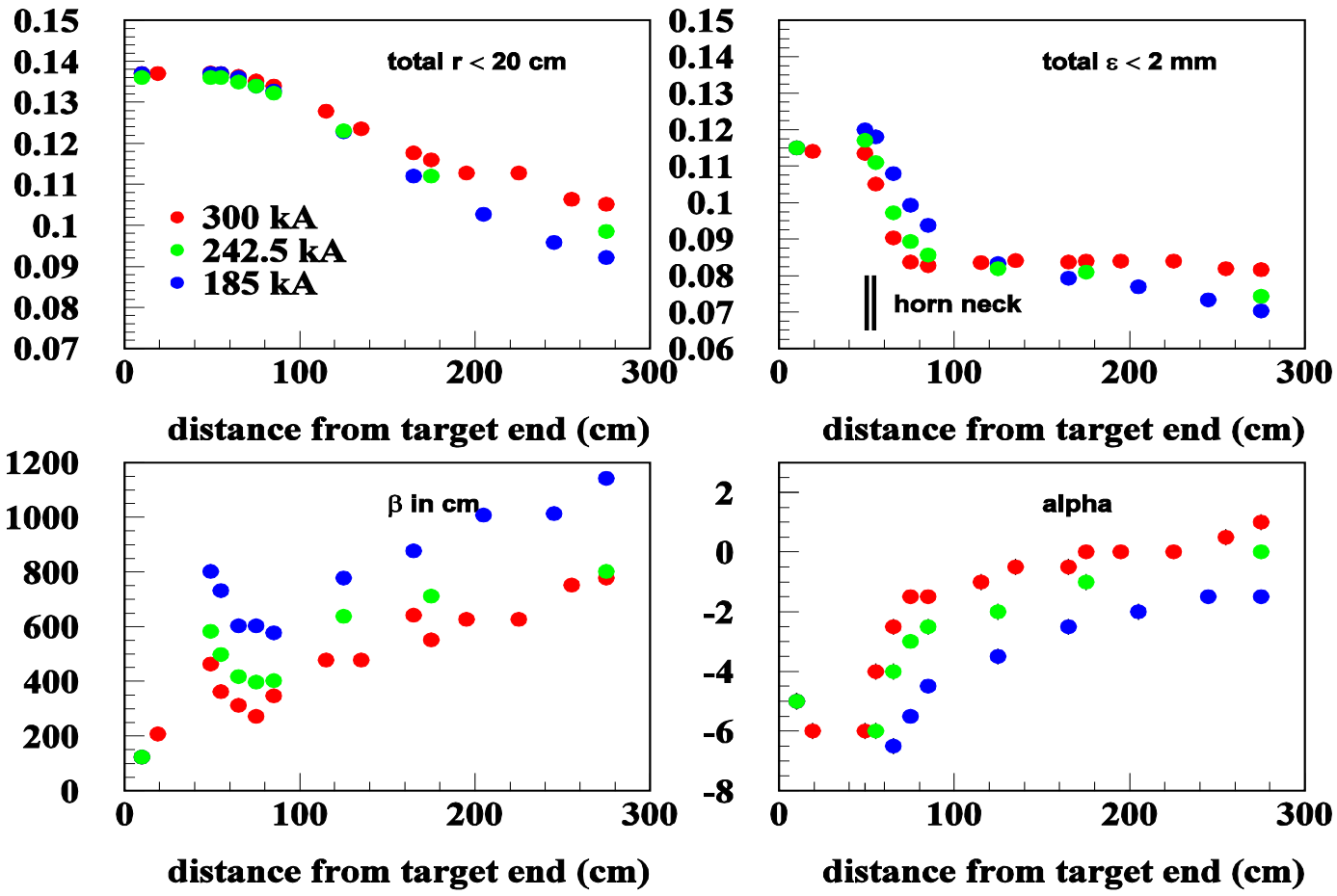




Dependence on target position and current



Dependence on horn length, 20 cm gold target, shift 20 cm



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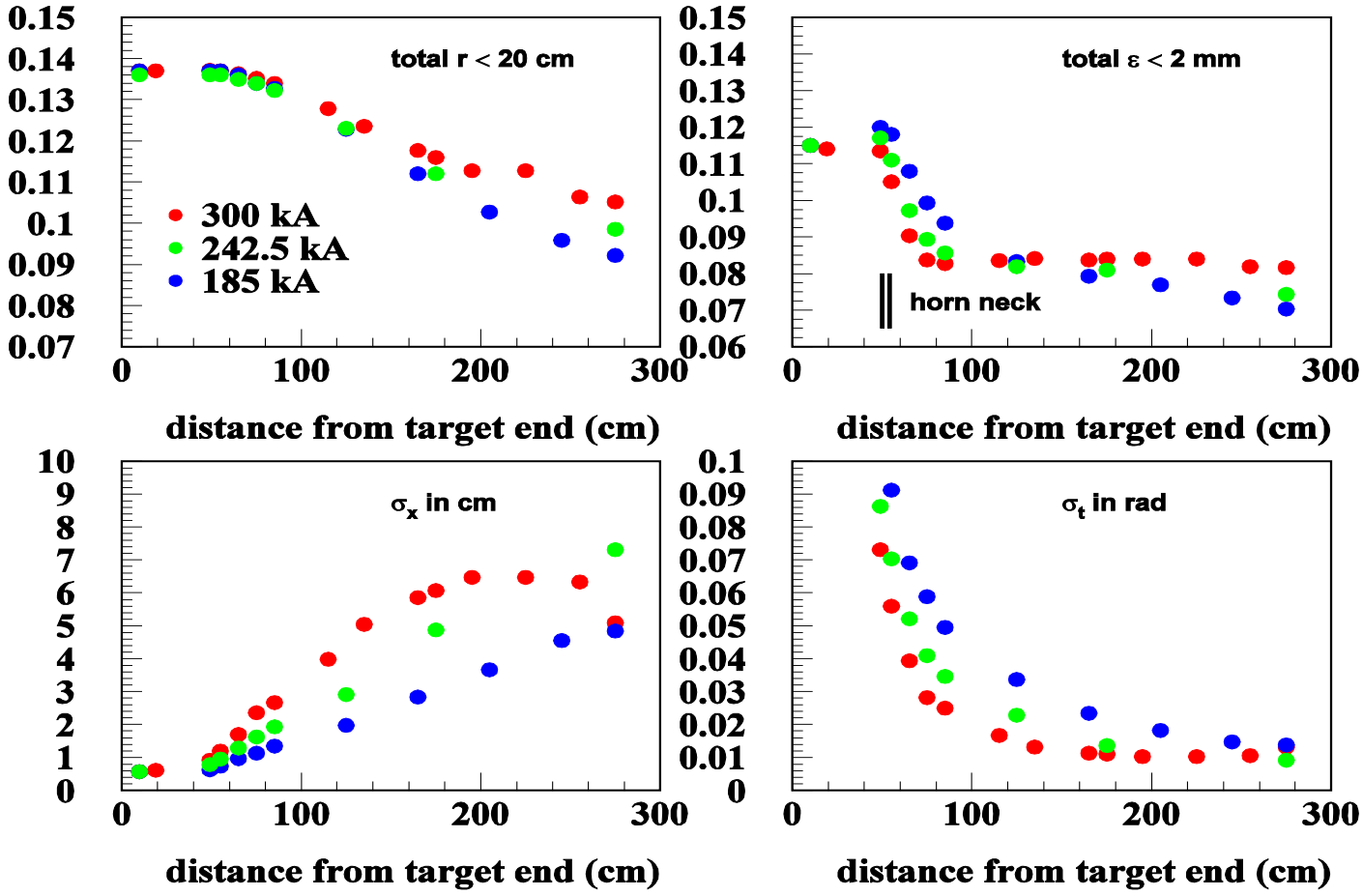


CONCLUSIONS

We could get about 0.11 π+/POT and 0.09 π-/POT with 5 ± 10% GeV/c momentum from gold target at 60 GeV into 2000 mm mrad acceptance with ideal capture. Yield for carbon is about 2 times lower at this energy.

We could get about 0.006 π+/POT and 0.0035 π-/POT with 3 ± 10% GeV/c momentum from gold target at 8 GeV into 2000 mm mrad acceptance with ideal capture. Yield has weak dependence on target material at this energy.

Pion capture using lithium lens looks like problematic due to large radius of pion beam.

Pion capture using horn looks like reasonable. Without optimization of inner surface shape it is possible to get 0.082 π+/POT with 5 ± 0.5 GeV/c momentum using existing NuMI horn at 300kA current.

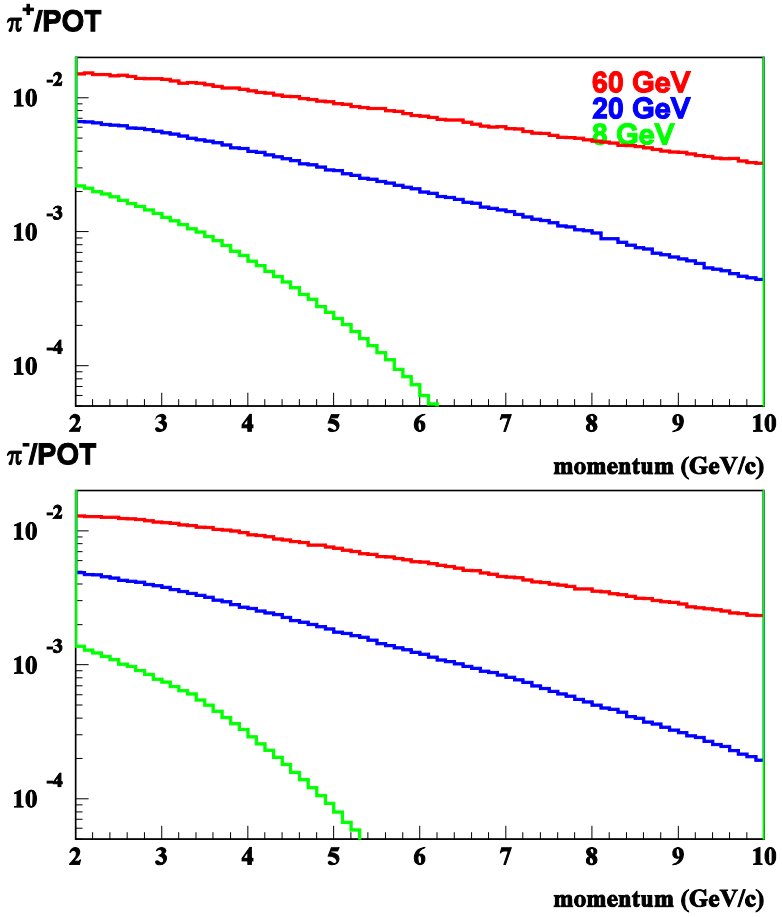
Measurements of charged pion production from heavy target are in 30% agreement with MARS prediction. New measurements of MIPP and NA61/SHINE will help to specify absolute normalization of above simulation.

Could we use large Z target inside horn at 60 GeV?

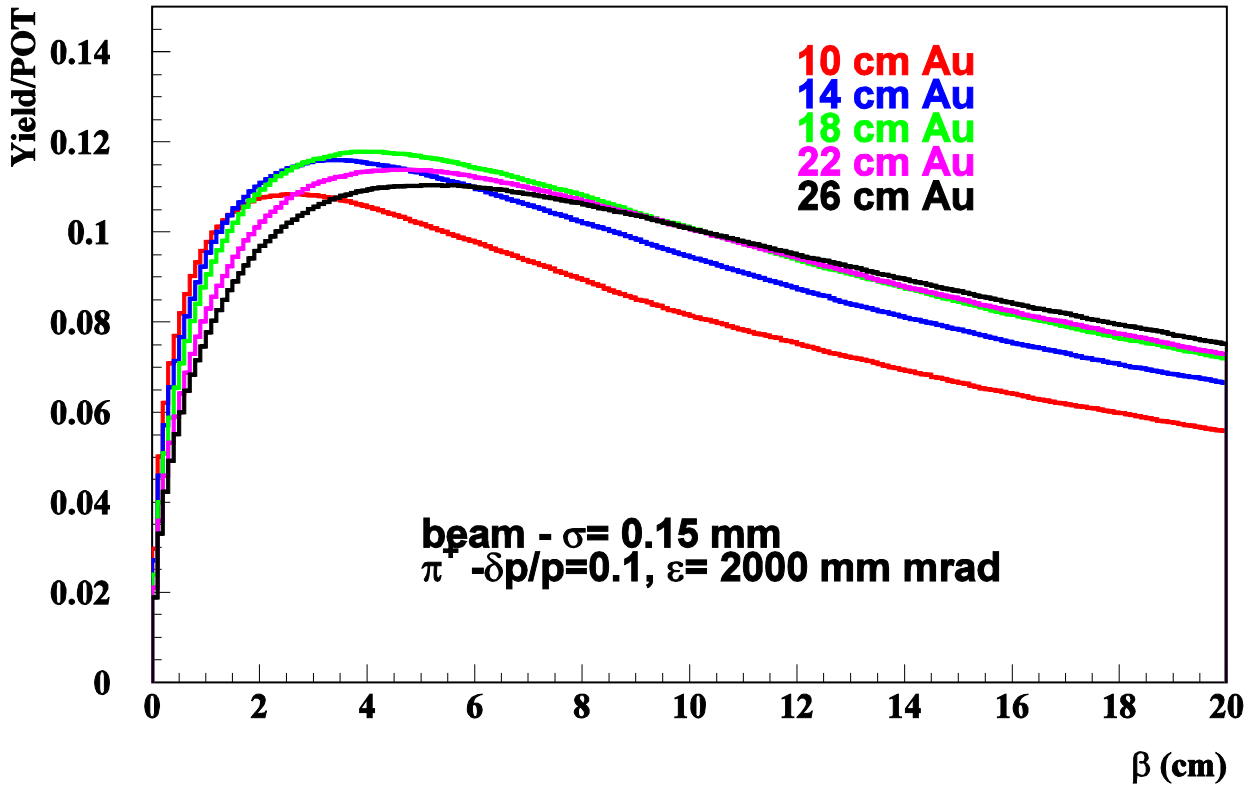
Could we optimize horn shape to get better transmission factor? Very low energy horn with conical shape (Beams-doc-724) provides transmission factor about 0.9, but β = 2000 cm looks like too large.

BACKUP slides

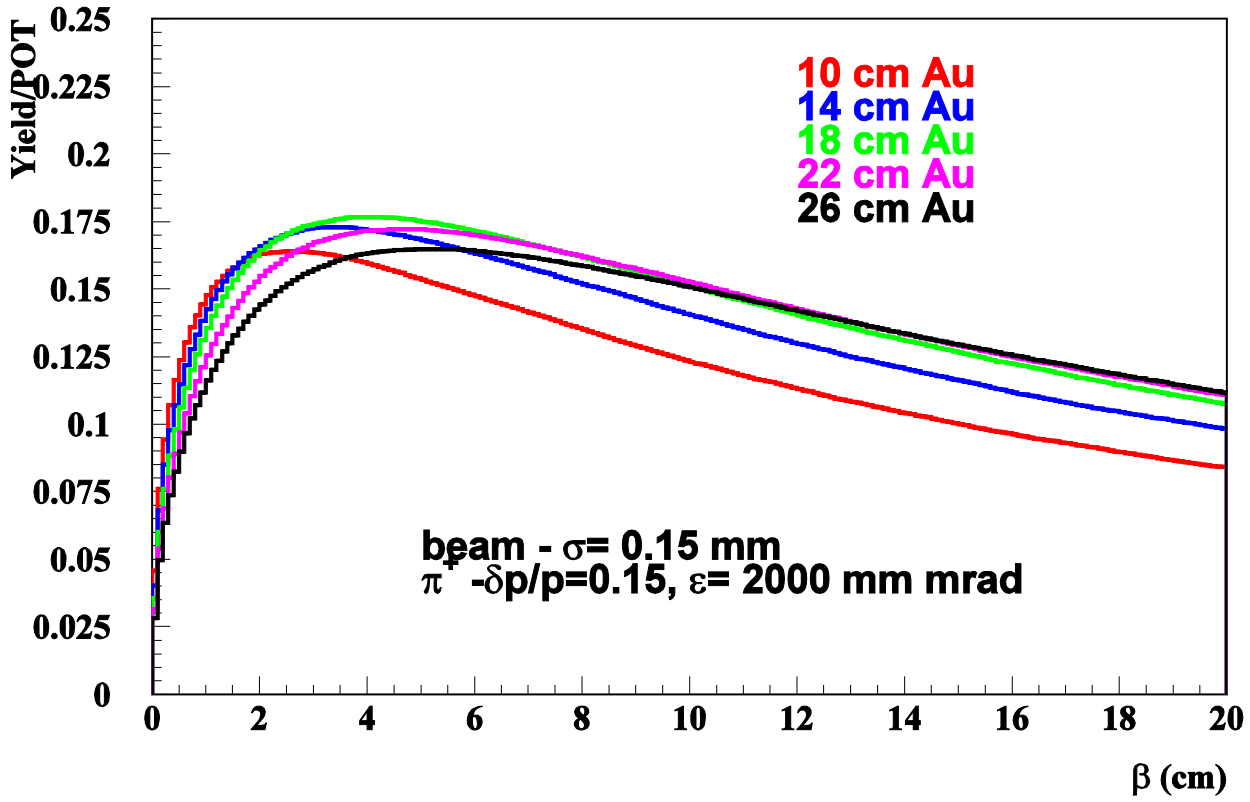
Energy dependence of charged pion production



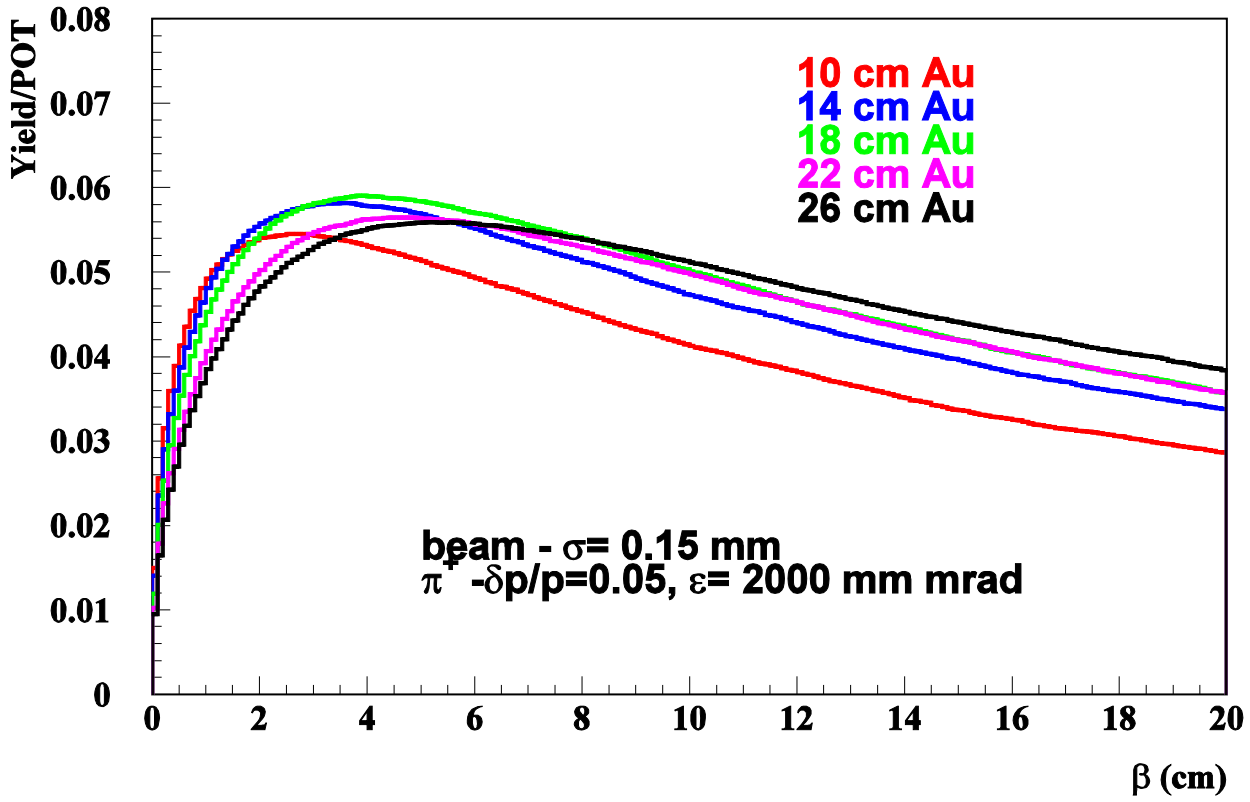
Dependence of positive pion yield on beta function for gold target (3±0.3 GeV/c) at 60 GeV



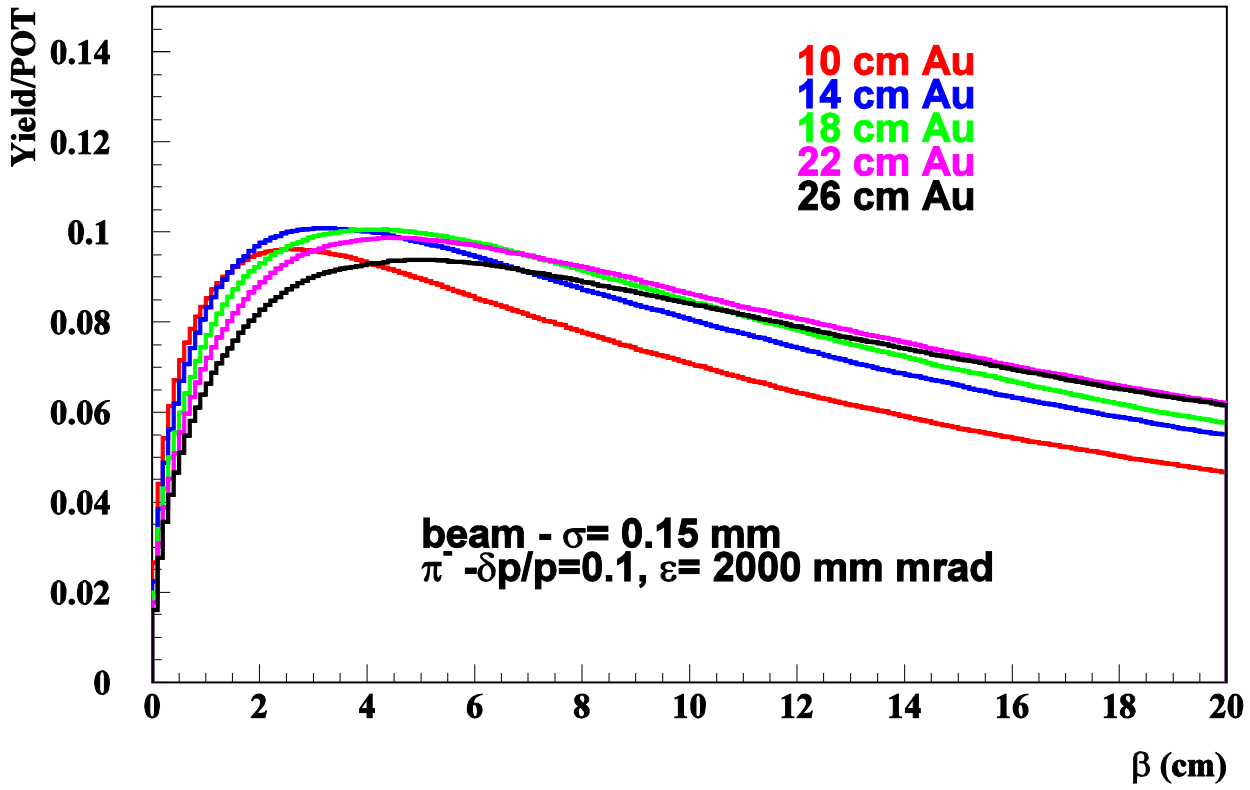
Dependence of positive pion yield on beta function for gold target (3±0.45 GeV/c) at 60 GeV



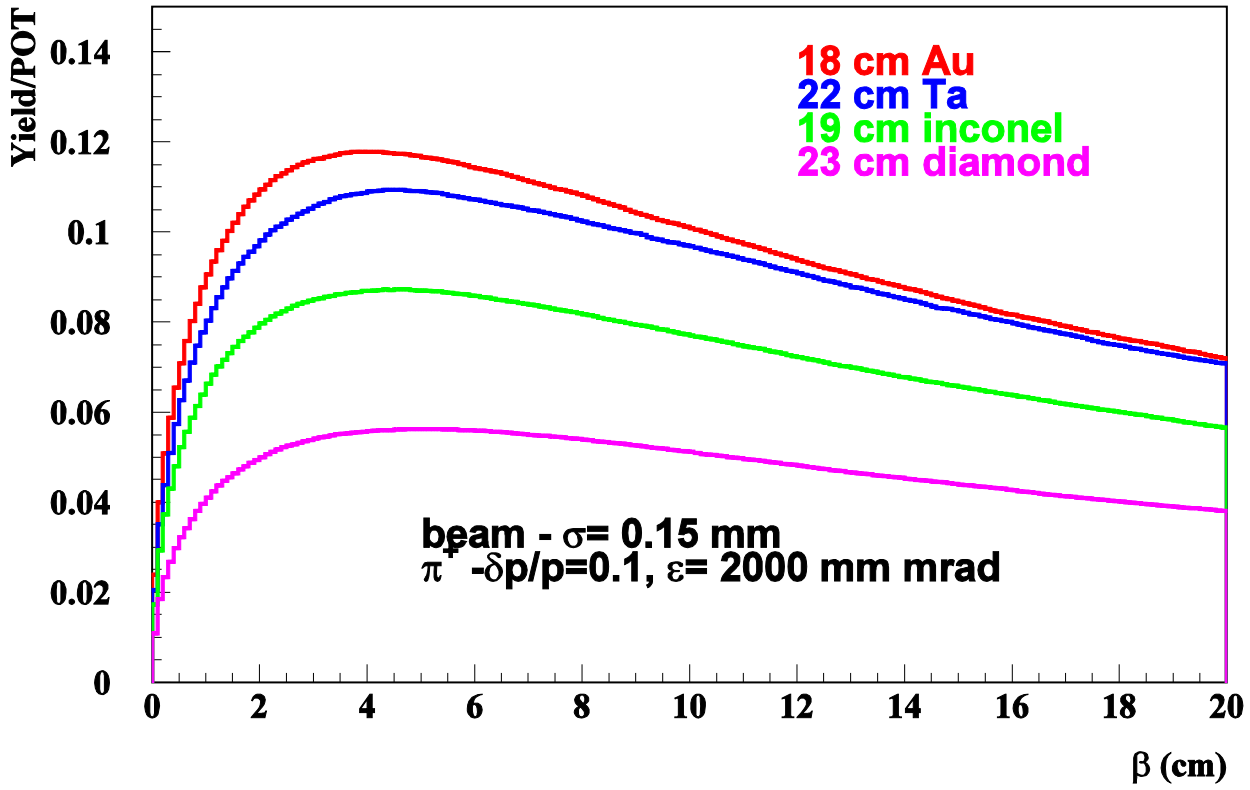
Dependence of positive pion yield on beta function for gold target (3±0.15 GeV/c) at 60 GeV



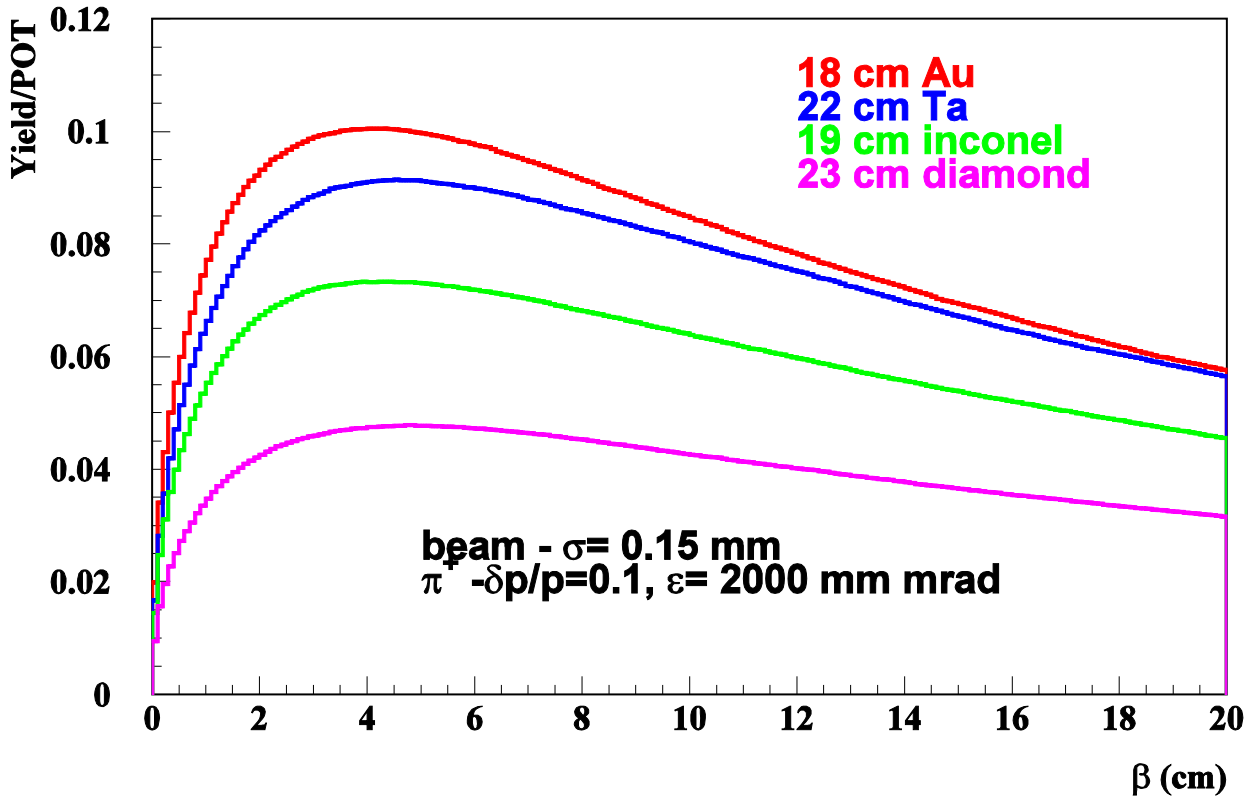
Dependence of negative pion yield on beta function for gold target (3±0.3 GeV/c) at 60 GeV



Dependence of positive pion yield on beta function for different target (3±0.3 GeV/c) at 60 GeV



Dependence of negative pion yield on beta function for different target (3±0.3 GeV/c) at 60 GeV



PI+ Yield, 3±0.3 GeV/c, NuMI horn, 60 GeV

Pion beam size = sqrt(Εβ),
Ε=0.2 cm and β=500 cm => 10 cm radius!