Optimized Target Parameters and Meson Production by IDS120h with Focused Gaussian Beam and Fixed Emittance

X. Ding, UCLA

Target Studies
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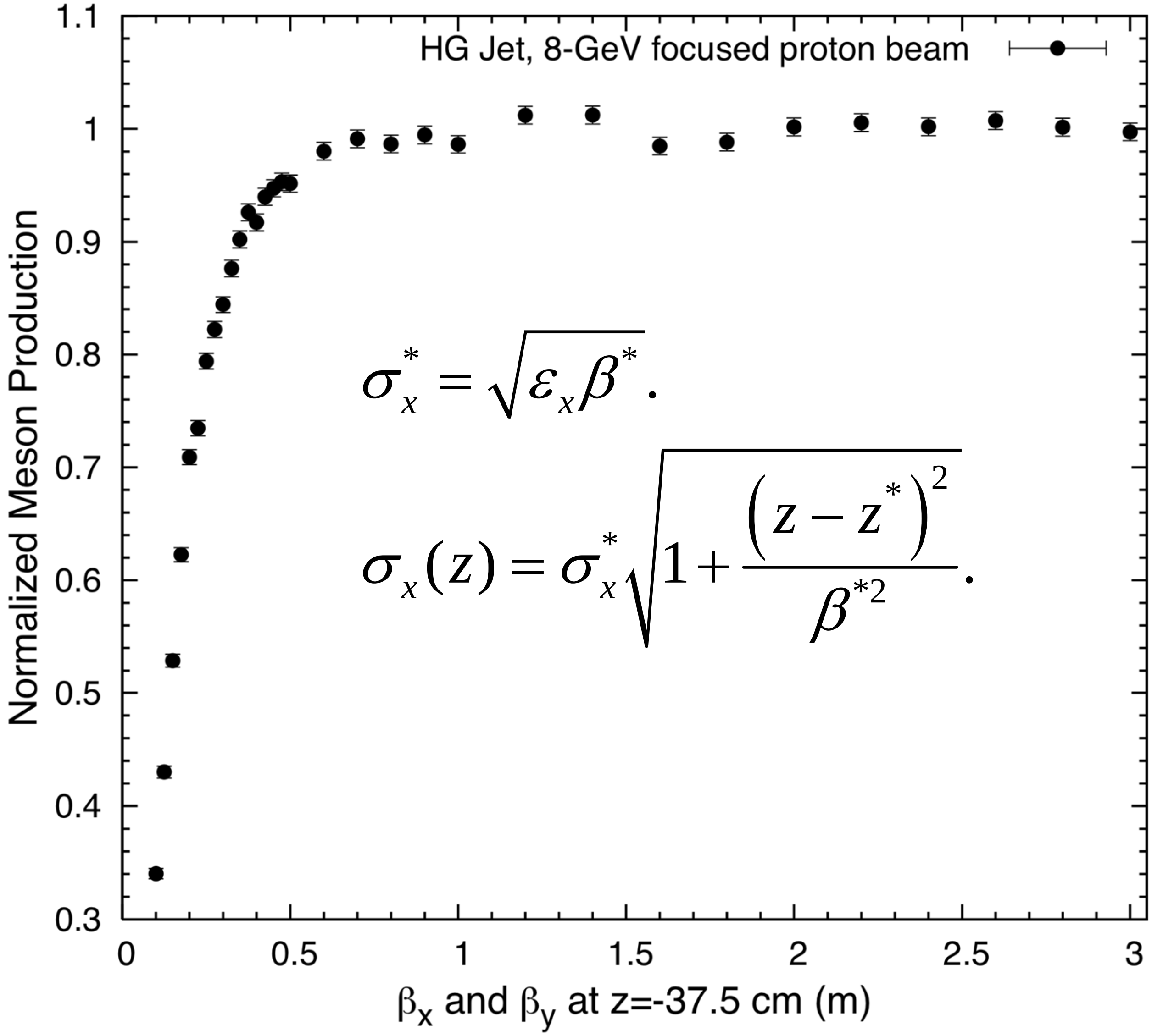
Focused Incident Proton Beam at 8 GeV



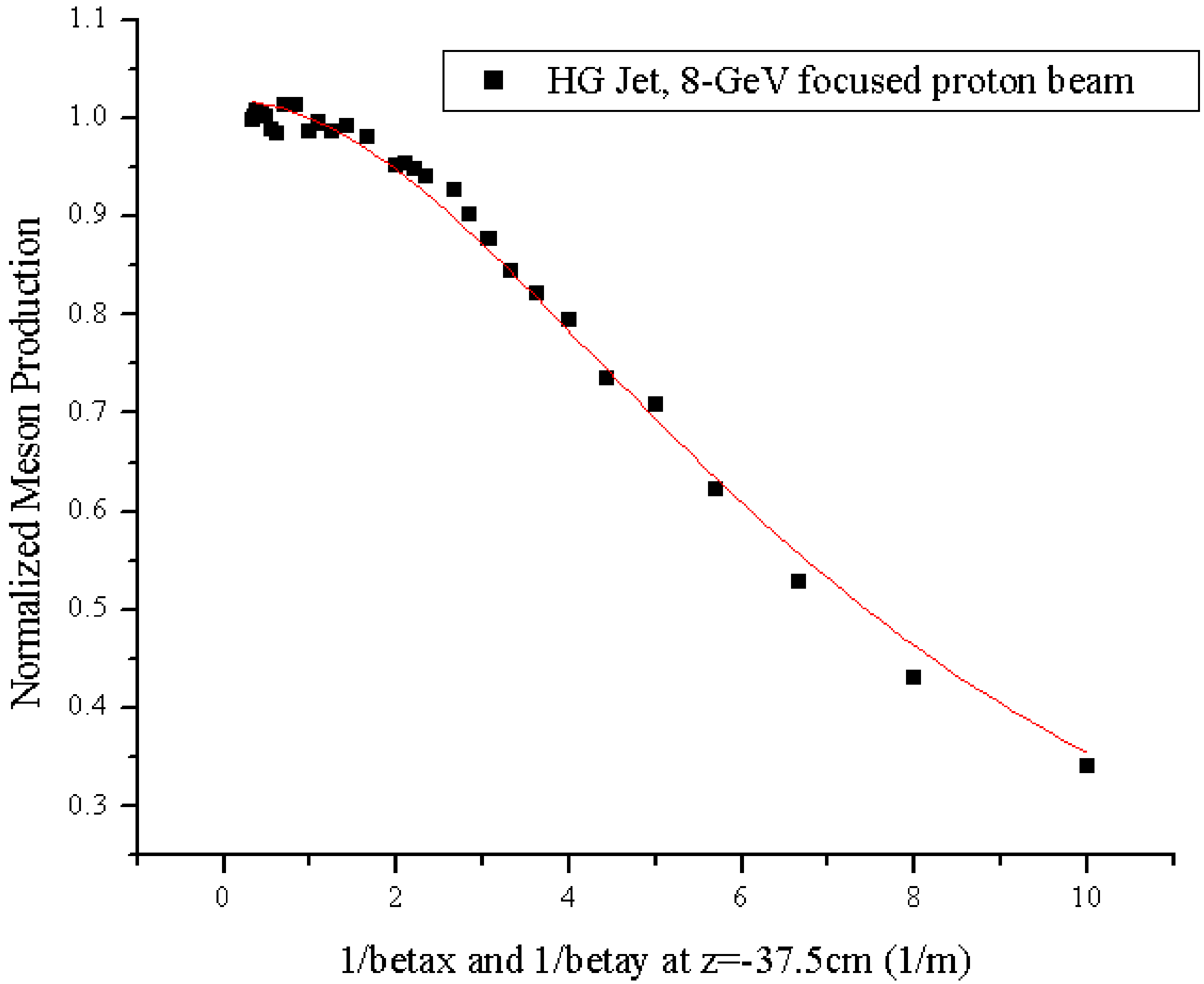
$$\sigma_x^* = \sqrt{\varepsilon_x \beta^*}.$$

$$\sigma_x(z) = \sigma_x^* \sqrt{1 + \frac{\left(z - z^*\right)^2}{\beta^{*2}}}.$$

Relative normalized meson production is 0.84 of max at β^* of 0.3 m for $\varepsilon_x = \varepsilon_y = 5\ \mu$m.

For low β^* (tight focus) the beam is large at the beginning and end of the interaction region, and becomes larger than the target there.

Focused Incident Proton Beam at 8 GeV (Cont'd)



Non-Linear Fit (Growth/sigmoidal, Hill)

$Y=N/(1+K2/beta^{-2})$
N=1.018
Sqrt(K2)=0.1368

Linear emittance is 4.9 μm with beam radius of 0.1212 cm and β* of 0.3 m.

Gaussian distribution (Probability density)

- In two dimensional phase space (u,v):

$$w(u,v) = \frac{1}{2\pi\sigma^2}\exp(-\frac{u^2+v^2}{2\sigma^2})$$

where u-transverse coordinate (either x or y),
$v = \alpha\, u + \beta\, u'$

α, β are the Courant-Snyder parameters at the given point along the reference trajectory.

In polar coordinates (r, θ):
$u = r\cos\theta$ $\quad$ $v = r\sin\theta$
$u' = (v - \alpha\, u)/\beta = (r\sin\theta - \alpha\, u)/\beta$

Distribution function method

$$\theta = 2\pi\xi_1, \qquad \theta \in [0, 2\pi]$$

$$r = \sqrt{-2\sigma^2 \ln \xi_2}, \quad r \in [0, \infty]$$

Random number generator:

Θ = 2π*rndm(-1)
R = sqrt(-2*log(rndm(-1))*σ

Gaussian distribution (Fraction of particles)

- The fraction of particles that have their motion contained in a circle of radius "a" (emittance $\varepsilon = \pi\, a^2/\beta$) is

$$F_{Gauss} = \int_0^a \frac{1}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}} r dr = 1 - e^{-\frac{a^2}{2\sigma^2}}$$

Fraction of particles

$k=a/\sigma$	$\varepsilon_{K\sigma}$	F_{Gauss}
1	$\pi (\sigma)^2/\beta$	39.5%
2	$\pi (2\sigma)^2/\beta$	86.4%
2.5	$\pi (2.5\sigma)^2/\beta$ or $\sim 6\pi \sigma^2/\beta$	95.6%

Normalized emittance: $(\boldsymbol{\beta\gamma})\varepsilon_{K\sigma}$

Focused beam

- Intersection point (z=-37.5 cm):

  $\alpha^* = 0,\ \beta^*,\ \sigma^*$

- Launching point (z=-200 cm):

  L = 200-37.5 = 162.5 cm

  $\alpha = L/\beta^*$

  $\beta = \beta^* + L^2/\beta^*$

  $\sigma = \sigma^* \mathrm{sqrt}(1+L^2/\beta^{*2})$

These relations strictly true only for zero magnetic field.

Setting of simple Gaussian distribution

- INIT card in MARS.INP (MARS code)

INIT XINI YINI ZINI DXIN DYIN DZIN WINIT

XINI = x0 DXIN = dcx0

YINI = y0 DYIN = dcy0

ZINI = z0 DZIN = dcz0 = $\mathrm{sqrt}(1\text{-}dcx0^2\text{-}dcy0^2)$

(Initial starting point and direction cosines of the incident beam)

Setting with focused beam trajectories

- Modeled by the user subroutine BEG1 in m1510.f of MARS code

x_v or x_h (transverse coordinate: u);

x'_v or x'_h (deflection angle: u')

XINI = $x_0 + x_v$ DXIN = $dcx_0 + x'_v$

YINI = $y_0 + x_h$ DYIN = $dcy_0 + x'_h$

ZINI = z DZIN = sqrt(1-DXIN^2-DYIN^2)

Optimization of target parameters

- Fixed beam emittance ($\varepsilon_{K\sigma}$) to $\pi (\sigma)^2/\beta$
- Optimization method in each cycle

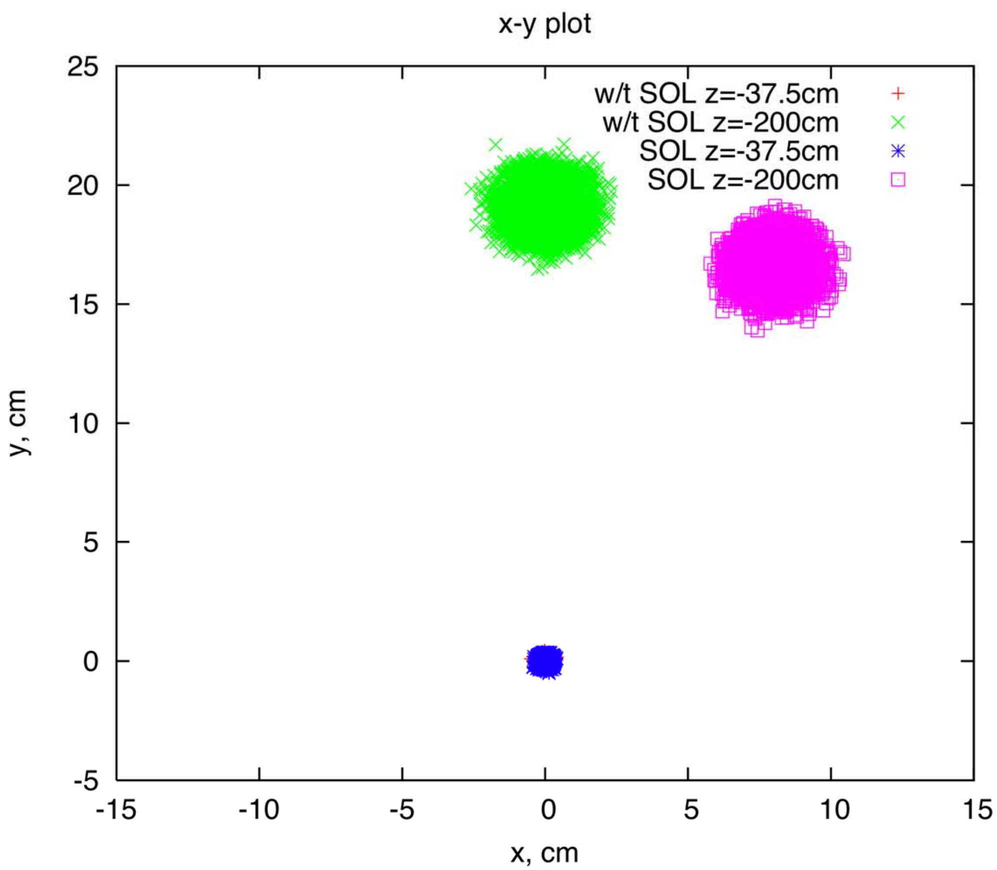
(Vary beam radius or beam radius σ^*, while vary the β^* at the same time to fix the beam emittance; Vary beam/jet crossing angle; Rotate beam and jet at the same time)

We also optimized the beam radius and target radius separately (not fixed to each other).

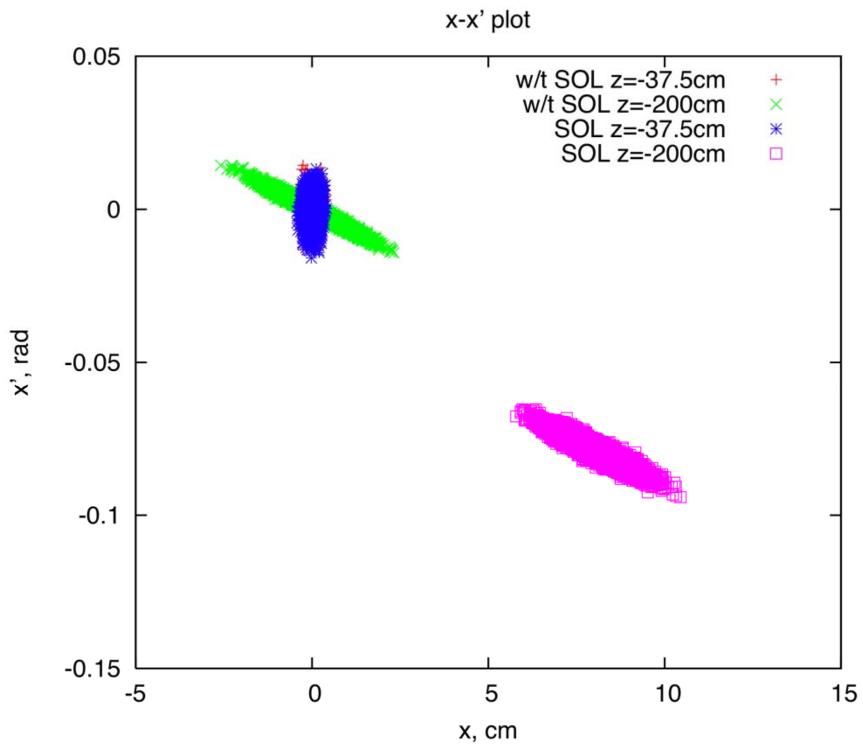
Effect of Solenoid Field

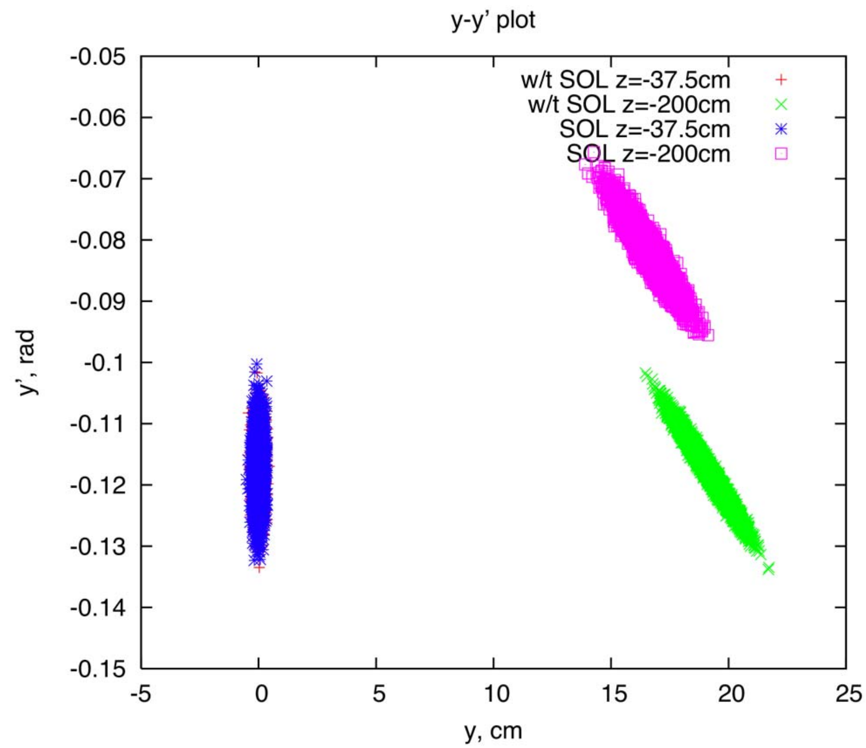
[Backtrack particles from z = -37.5 cm to z = - 200 cm.]

(Could then do calculation of α, β, σ at z = -200 cm, but didn't)

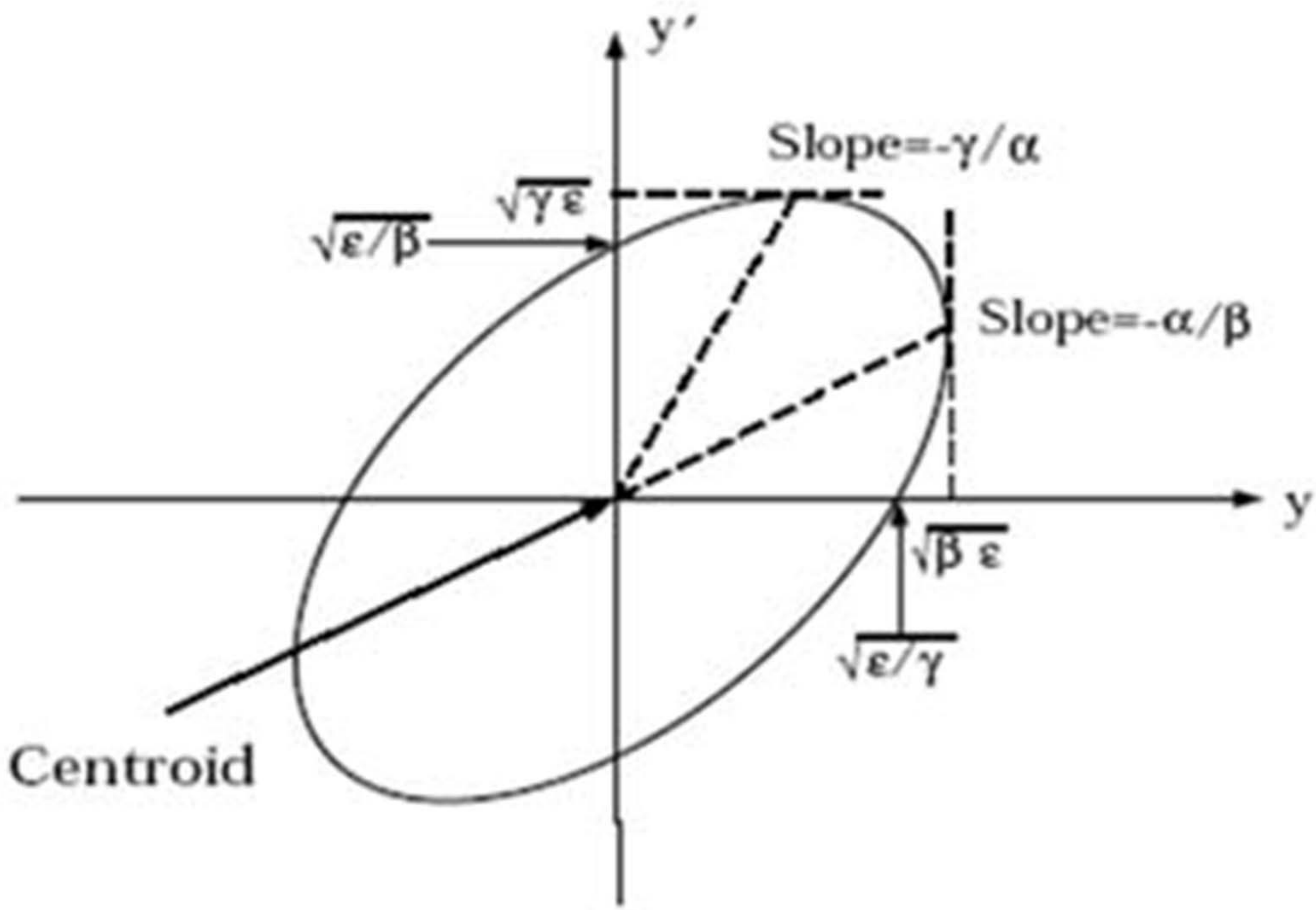


Effect of Solenoid Field





Courant-Snyder Invariant

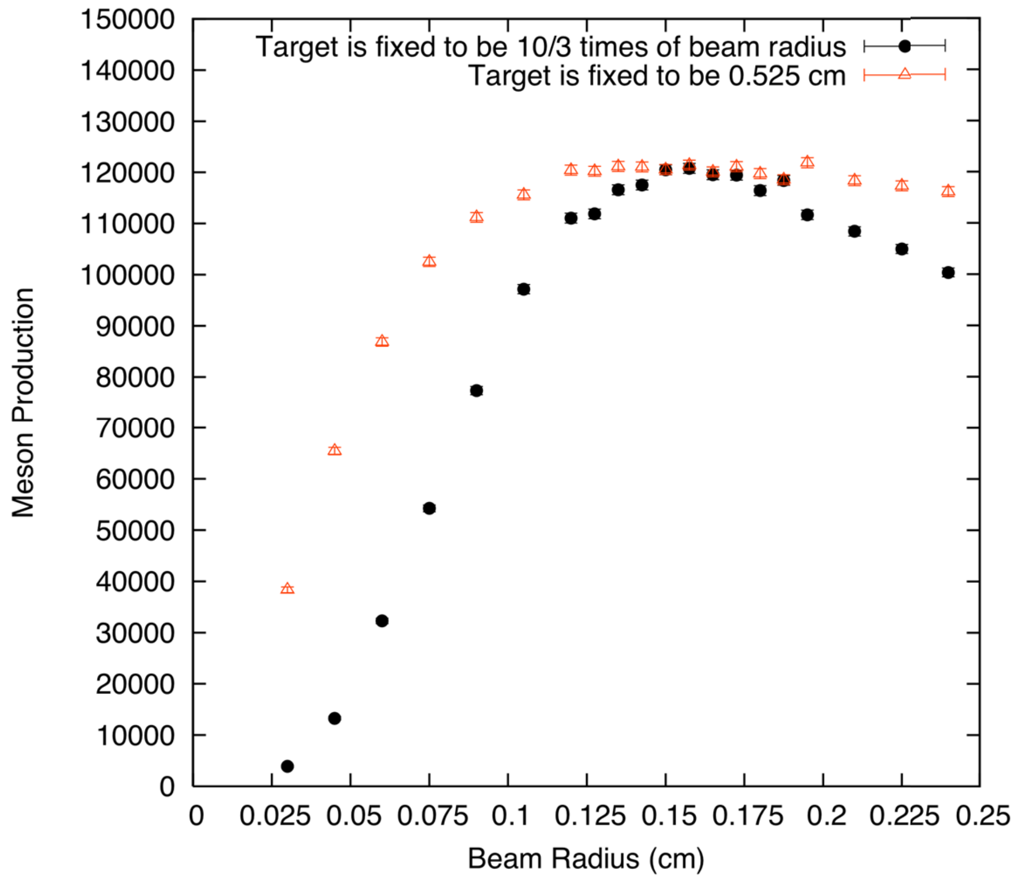


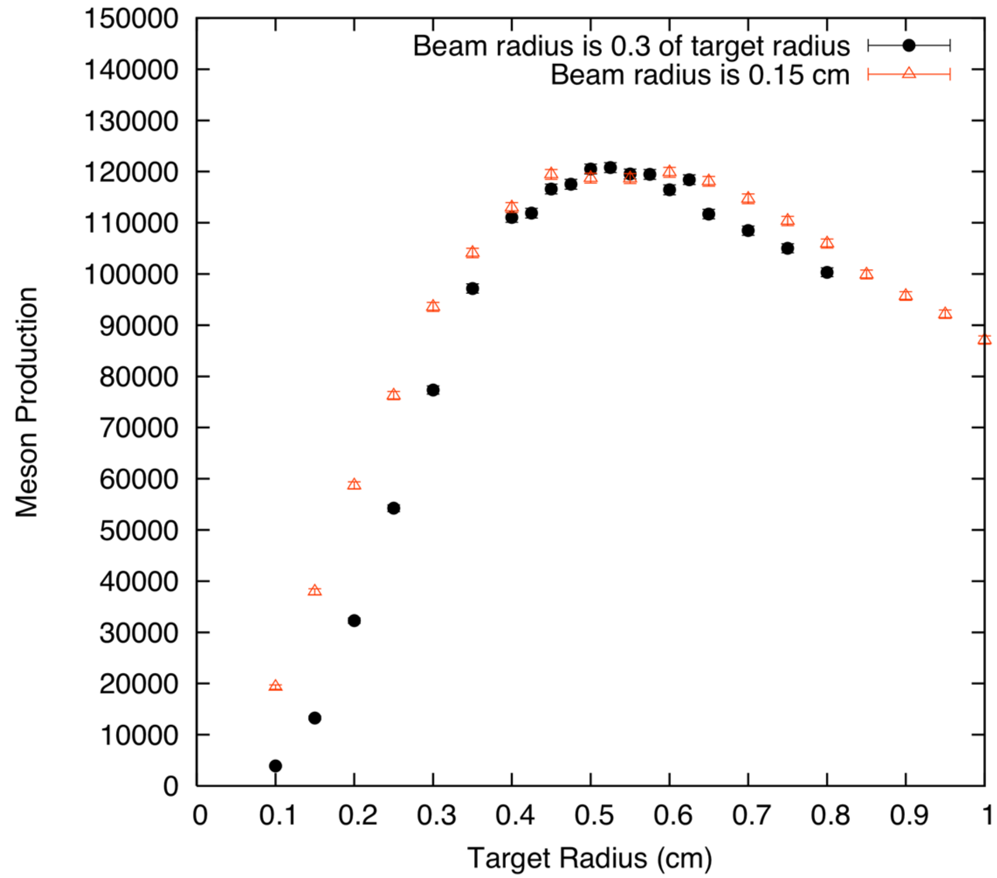
Optimized Target Parameters and Meson Productions at 8 GeV

(Linear emittance is fixed to be 4.9 μm)

	Radius (cm)	Beam/jet crossing angle (mrad)	Beam angle/Jet angle (mrad)
Initial	0.404 (target)	20.6	117/137.6
1st Run	0.525 (target)	25	120/145
Old 2nd Run (vary target radius and beam radius is fixed to be 0.3 of target radius)	0.544 (target)	25.4	120/145.4
New 2nd Run (vary beam radius with fixed target radius of 0.525 cm; vary target radius with fixed beam radius of 0.15 cm.)	Beam radius: 0.15 Target radius: 0.548	26.5	127/153.5

Optimize beam radius and target radius separately





We found almost no improvement in optimized meson production if the beam radius is not fixed at 30% of target radius and optimized separately!

Optimized Meson Productions at 8 GeV

(Linear emittance is fixed to be 4.9 μm)

Gaussian Distribution	Meson Production
Simple (4.04mm/20.6mrad/117mrad)	32563
Focused beam (4.04mm/20.6mrad/117mrad)	27489 (-15.6% less than Simple)
Focused beam with fixed Emittance at 4.9 μm (5.44mm/25.4mrad/120mrad)	30025 (-8.9% less than Simple) (8.4% more than Focused beam)