BROOKHAVEN NATIONAL LABORATORY

Beam Emittance at 3 m for Hg and C Targets

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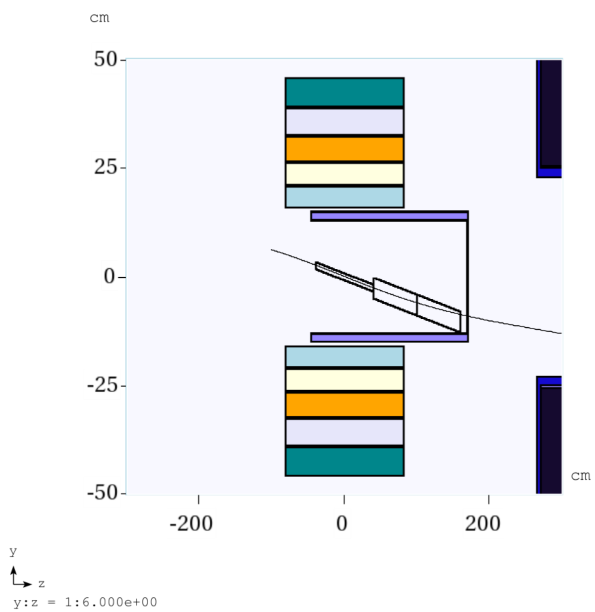
Motivation—Neuffer's Results

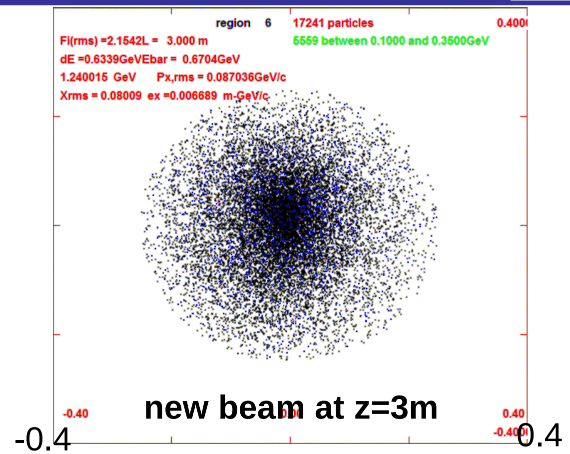
- Neuffer's talk at the MAP 2014 Winter Meeting, Dec. 4, 2014 (next 3 slides)
- Compared results from 8 GeV beam on Hg target to 6.75 GeV beam on C target
- C target had larger emittance by over a factor of 2
- Large increase in loss in first 6 m
- Performance reduction by about a factor of 2

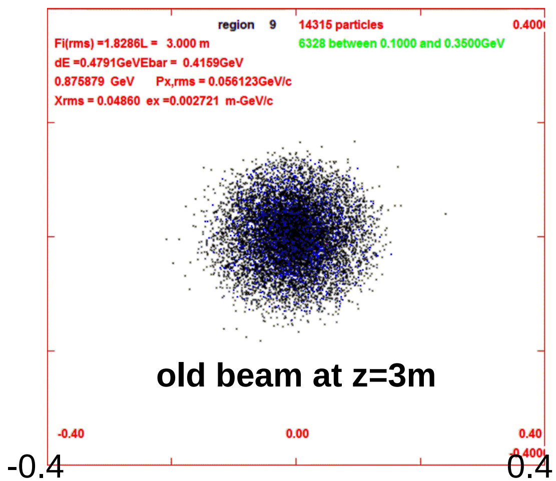
Motivation—Neuffer's Results

Use old FE with new initial beam

- New beam has too large initial size and divergence
  - initial transverse emittance >2X larger
    - 0.0027 → 0.0067 m-GeV/c
  - ~half of initial beam lost in <6m



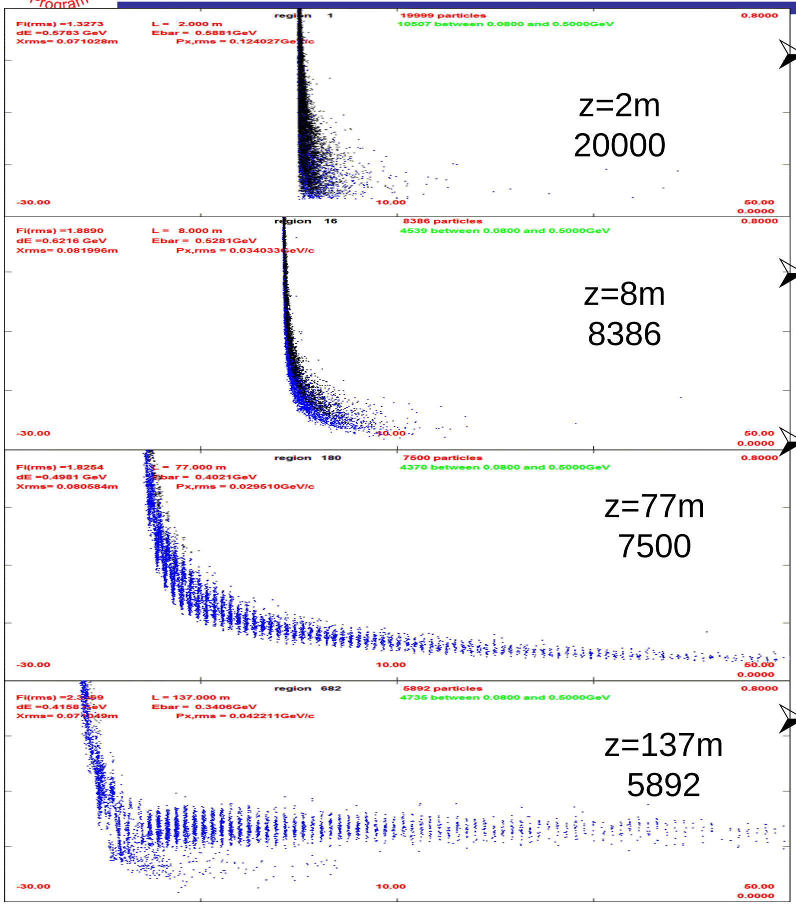




11

Motivation—Neuffer’s Results

First simulations results



- ~60% of initial particles are lost in first 6m
  - previous front end lost ~20%
- Beam starts out very large
  - previous much smaller in
  - front end simulations
- μ/p reduced by factor ~ 2
  - → ~0.0545 μ^+/p
  - ~0.042 μ^-/p
    - μ^- less than μ^+
- Not fully reoptimized for new initial beam

12

Motivation—Neuffer's Results

6.75 GeV p/ C target – First Look

- Much worse than previous 8 GeV p / Hg target
- 6.75 (~25% less), Hg → C …
  - but initial beam has very large phase space
- Causes for early losses ???
  - Long C target not a good match to short taper ?
    - target should be within lens center …
  - "Beam dump" after target blows up π beam ??
- Bugs, errors?
  - Changes in Mars production code ??
  - normalization error ??
  - initialization errors
    - starts from z=2m rather than z=0
- After initial factor of 2 loss, very similar to old front end case
  - not yet reoptimized
- To investigate/debug/reoptimize ..

13

Examine Distributions

- Dug up every 8 GeV Hg in 20 T distribution I could find
  - 28-Oct-2010 https://pubweb.bnl.gov/~kirk/Target_Studies/Icool_for003_decks/
    - From “P11” direction
    - Used by Neuffer
  - 23-Mar-2013, from X. Ding
    - Target angle 137.6 mrad, radius 0.404 cm.
    - RMS beam size 0.1212 cm
    - MARS15(2012)
  - 06-Feb-2014, from H. Sayed
  - Distributions all 0.375 m from field peak

Examine Distributions

- Carbon distributions from X. Ding, 15-Dec-2014
  - 6.75 GeV, target 1 cm radius, beam 0.25 cm RMS, no crossing angle
  - Tilted 65 mrad, or not
  - 1.2 m dump, radius 3 cm, or not
  - Proton beam emittance 5 or 20 μm
  - Distributions 2 m from field peak

Propagate Distributions

- Propagate all distributions to 3 m downstream from field peak
- Use field map from Weggel, 09-May-2014
  - Carbon distributions used this to 2 m
  - Field very close to 20 T at 0.375 m; little impact of profile difference for Hg runs
- Compute vector potential at 3 m to compute canonical emittances
- Compute emittances
  - π KE 60–600 MeV, μ KE 60–400 MeV; energy range at target in which 99% of ultimately captured particles lie
  - 4σ iterative cut

Emittances

	μ^-+	μ^--	μ^++	μ^+-	π^-+	π^--	π^++	π^+-
101028	31.8	31.1	35.6	13.7	23.1	14.9	26.0	15.0
130323-XDing	41.2	16.4	43.8	17.2	33.1	21.4	32.8	21.2
140206-HSayed	44.2	25.0	44.2	25.0	33.8	31.9	32.6	31.0
141215-XDing-00-d	68.1	24.9	68.3	27.2	48.9	32.7	47.8	33.7
141215-XDing-00-n	49.8	22.7	51.2	24.6	35.1	27.1	35.3	28.3
141215-XDing-65-d	58.1	21.4	60.2	23.2	43.6	26.7	43.3	27.9
141215-XDing-65-n	51.5	22.1	52.7	23.9	36.5	26.0	36.6	27.4

- Normalized canonical emittances in mm
- Large sign is sort of helicity
- Difference in emittances is angular momentum
- Names to left are distributions, contain date
    - Carbon: two digit angle, d for dump, n for no dump

Analysis

- Hg distributions
  - 2010 emittances significantly smaller than later runs
  - 2014 run has tiny pion angular momentum
    - Small beam; beam/target interact over small region?
    - Also shows up in muon angular momentum
- Carbon distributions
  - Removing dump improves emittance
  - With dump, lower emittance with tilt
  - Without dump tilt makes emittance a tiny bit worse
  - Proton beam emittance didn't matter (not shown)
- Similar behaviors for centroid
  - Centroid at origin for target without tilt
  - Offsets small: little contribution to emittance

Centroid Position

	− Charge				+ Charge			
	x (mm)	p_x (MeV/c)	y (mm)	p_y (MeV/c)	x (mm)	p_x (MeV/c)	y (mm)	p_y (MeV/c)
101028 π	2.0	0.0	1.5	0.7	−4.8	0.6	−1.4	−3.6
101028 μ	1.5	0.9	0.7	−1.5	−6.0	−0.8	−1.1	−4.7
130323-XDing π	6.3	6.3	7.5	−4.8	−9.3	−6.8	7.6	−6.8
130323-XDing μ	6.1	7.1	9.2	−3.8	−9.3	−7.2	9.3	−5.9
140206-HSayed π	7.9	10.1	11.1	−5.7	−10.4	−10.5	11.5	−7.6
140206-HSayed μ	−7.9	11.2	14.3	−5.3	−10.7	−11.2	13.4	−5.9
141215-XDing-00-d π	0.0	0.0	0.3	0.1	0.1	−0.1	0.2	0.2
141215-XDing-00-d μ	0.0	0.6	0.0	0.2	0.2	0.0	0.0	0.4
141215-XDing-00-n π	0.0	0.0	0.0	−0.2	0.0	0.0	−0.2	0.0
141215-XDing-00-n μ	0.0	0.0	0.0	−0.4	−0.1	0.0	−0.2	0.0
141215-XDing-65-d π	0.0	5.3	7.1	−0.7	−8.8	−5.7	6.1	−6.4
141215-XDing-65-d μ	3.0	11.2	15.8	−0.6	−8.4	−10.1	13.3	−5.3
141215-XDing-65-n π	3.1	8.3	10.3	−10.9	−8.1	−8.7	9.7	−5.2
141215-XDing-65-n μ	3.0	10.5	14.1	−0.9	−7.6	−10.0	12.6	−4.6

Conclusions

- Reasons for differences in Hg distributions unknown
  - Neuffer used the earliest, with the smallest emittance
- C emittances larger than Hg
  - Dump makes worse, tilt improves with dump
  - Cause unknown: larger target?
- Don't see Neuffer's scale of difference, but may be result of different analyses
- More detailed analysis possible, should discuss if desirable
  - Understanding root cause would involve studies in MARS