Heavy Ion Fusion Modeling Update*

Wayne R. Meier
Lawrence Livermore National Lab

ARIES Meeting
Jan. 10-11, 2002

*** This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.**

Next steps (From October e-meeting)

- Complete driver code modifications (done)
- Re-run for distributed radiator target (done and continuing)
- Propose new HYLIFE point design for ARIES consideration (LBNL meeting on 12/13/01)
- New point design will also be basis for HIF VNL and VLT work on interface design issues (liquid jet configuration, final magnet shielding update, vacuum pumping, target material recovery, etc.)

Summary of final optics algorithm for systems code

- The current final focus algorithm has contribution to the final (elliptical) spot radii from the following sources:
  - Emittance
  - Space-charge (neutralization model)
  - Chromatic aberrations
  - Geometric aberrations
  - Aiming errors
- Rudimentary models are used to calculate:
  - Normalized transverse emittance growth
  - Normalized longitudinal emittance growth
- Not included in the algorithm are:
  - Corrections to geometric aberrations (octupoles)
  - Corrections to chromatic aberrations (sextupoles/dipoles, and time-dependent focusing)

Chromatic aberration/emittance/space charge model

New spot size model has two improvements:

1. Beam can be elliptical
2. Moment equations which include 2nd order chromatic aberrations can be solved for any particular layout of focusing magnets

$$\theta_x^2 \approx \frac{\varepsilon_x^2}{r_x^2} + 2Q\ln\left[\frac{d(\theta_x+\theta_y)}{r_x+r_y}\right] \qquad \theta_y^2 \approx \frac{\varepsilon_y^2}{r_y^2} + 2Q\ln\left[\frac{d(\theta_x+\theta_y)}{r_x+r_y}\right]$$

$$\varepsilon_x^2 = \varepsilon_{x0}^2 + \alpha_x^2 d^2\left(\frac{\Delta p}{p}\right)^2\theta_x^4 \qquad \varepsilon_y^2 = \varepsilon_{y0}^2 + \alpha_y^2 d^2\left(\frac{\Delta p}{p}\right)^2\theta_y^4$$

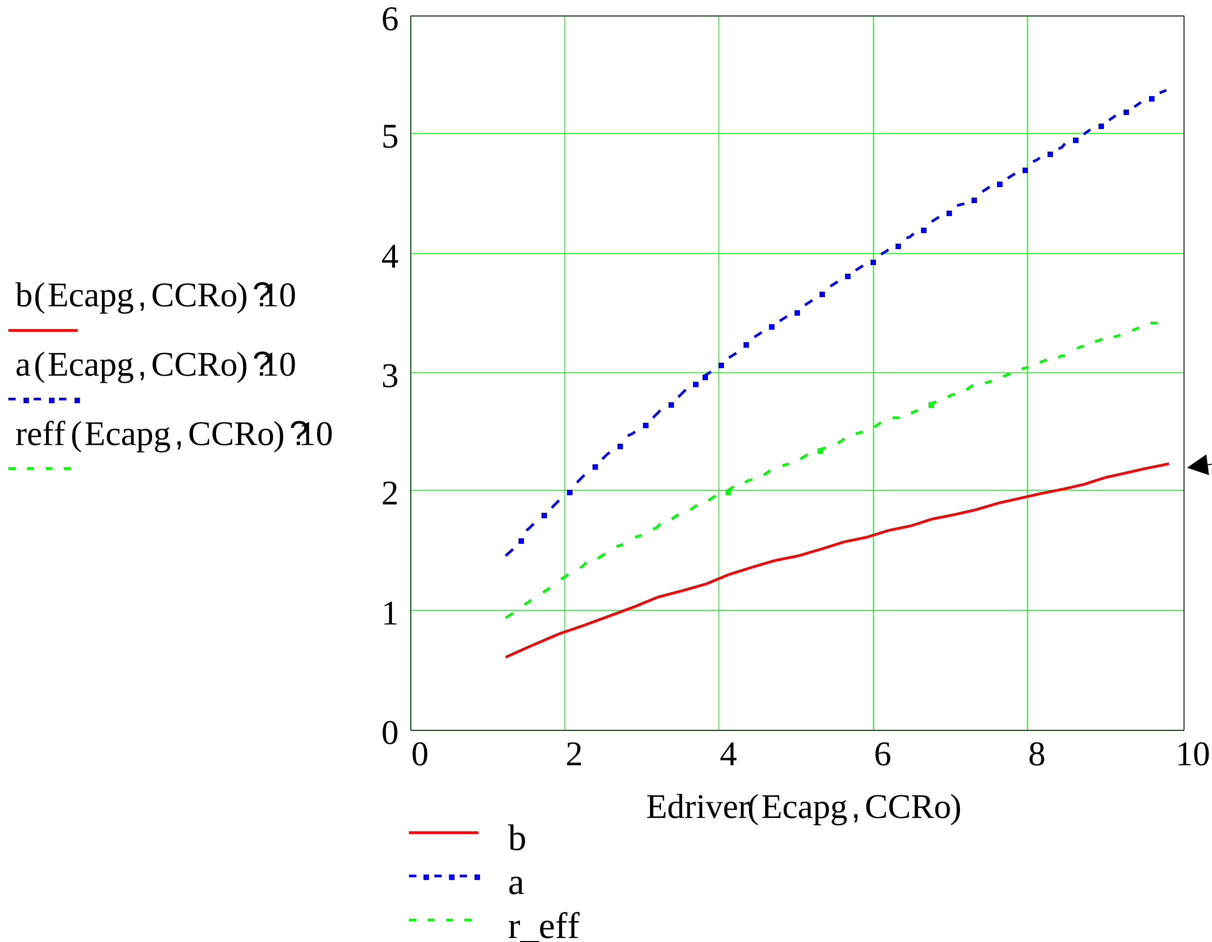
Now there are two final angles θ_x and θ_y to optimize.
Also, α_x and α_y are valid for a particular focusing system and with a particular initial value of the moment $\langle x\delta\rangle$ and $\langle y\delta\rangle$.

Emittance growth model

Transverse: For multipole errors (random from one magnet to next) (from E. Lee HIFAR note 2/19/99):
- The contribution to the (Normalized emittance)^2 from the field errors of each quadrupole magnet adds in quadrature and is proportional to the mean square magnetic field error.

Longitudinal: (based on Warwick and Lee, HIFAR note 214):
- The contribution to the (Normalized longitudinal emittance)^2 from the voltage errors of each gap adds in quadrature and is proportional to the mean square voltage ripple at each acceleration gap (which in turn is proportional to the number of pulsers at each gap).

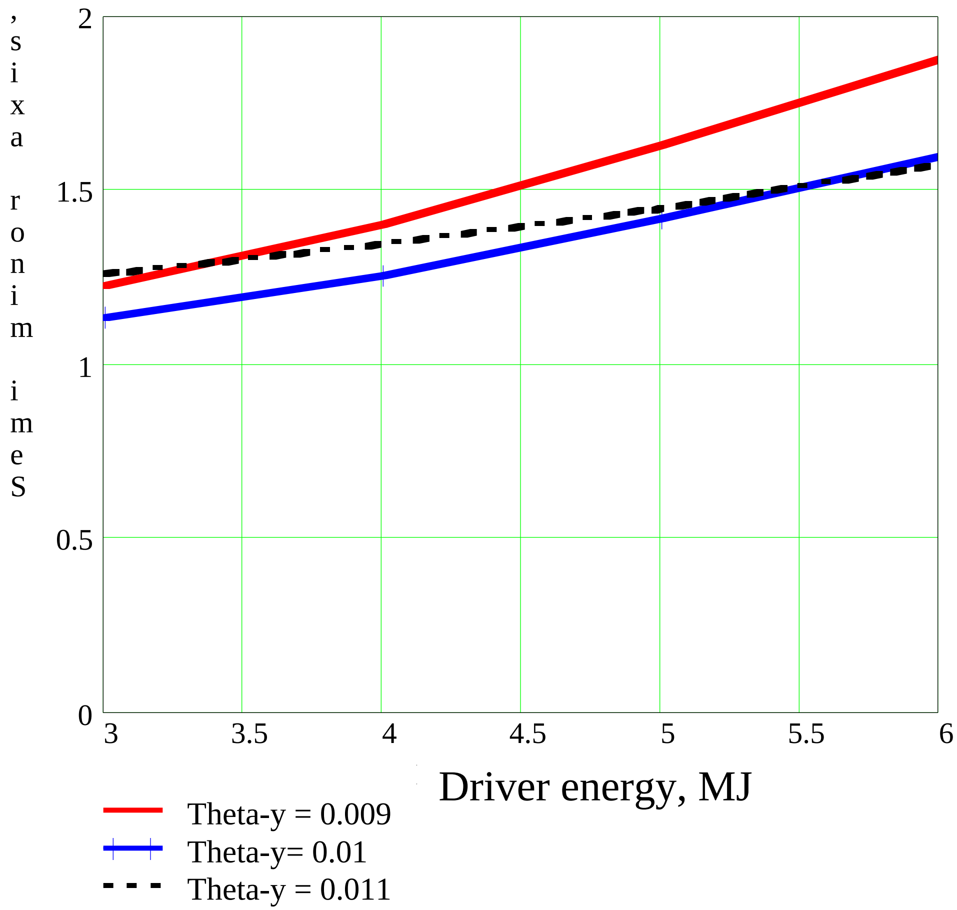
Spot size requirements for standard distributed radiator target



R_hohl = 5.0 mm
R_cap = 2.34 mm
CCR = 2.14

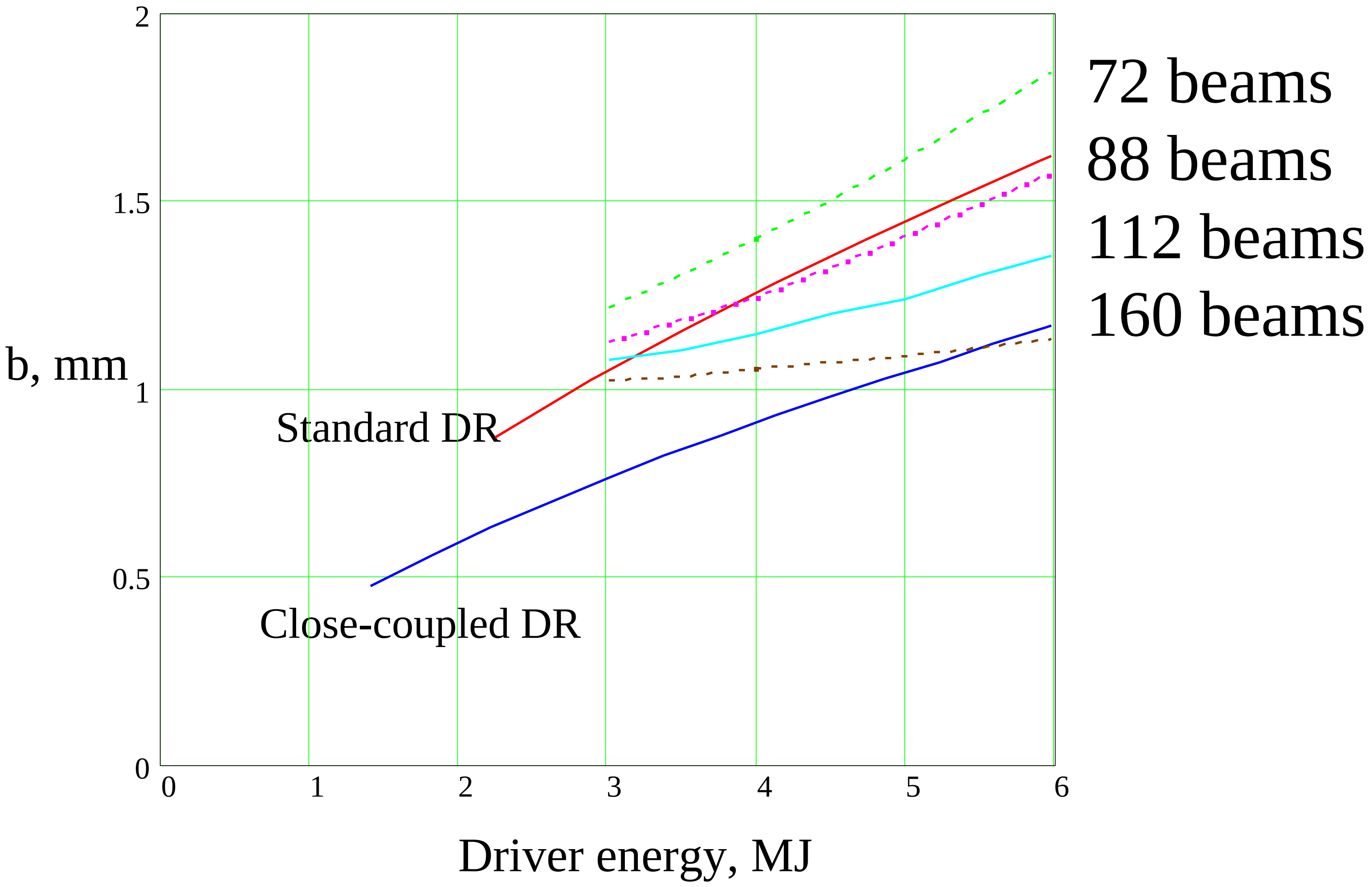
b = Semi-minor axis of elliptical spot

θ_y = 10 mrad is a good choice over broad range of driver energies



L_f = 6 m
N_b = 88 beams

IBEAM spot size scaling for different number of beams compared to DR target requirements



Strawman Point Design for 12/13 discussions at LBNL

Ion mass = 131 (Xe)
Charge state = +1
Total beam energy = 6.0 MJ
Target gain = 61.7
Target yield = 370
Rep-rate = 6.31 Hz
Fusion power = 2337 MWt
Total thermal = 2758 MWt
Gross electric = 1186 MWe (thermal efficiency = 43%)
Driver power = 81 MWe (driver efficiency = 47%)
Pumping power = 58 MWe
Other power = 47 MWe (4% of gross electric)
Net power = 1000 MWe

Some reaction to proposed point design

- Need to account for MRC PIC simulations of spot size (larger than model now predicts)
- Per Peterson working on annular beam arrays and target implications
- Roger Bangerter suggests considering no bore shielding and just accepting lower magnet life