Design Considerations for Beam Port Insulator Rings

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ARIES Meeting

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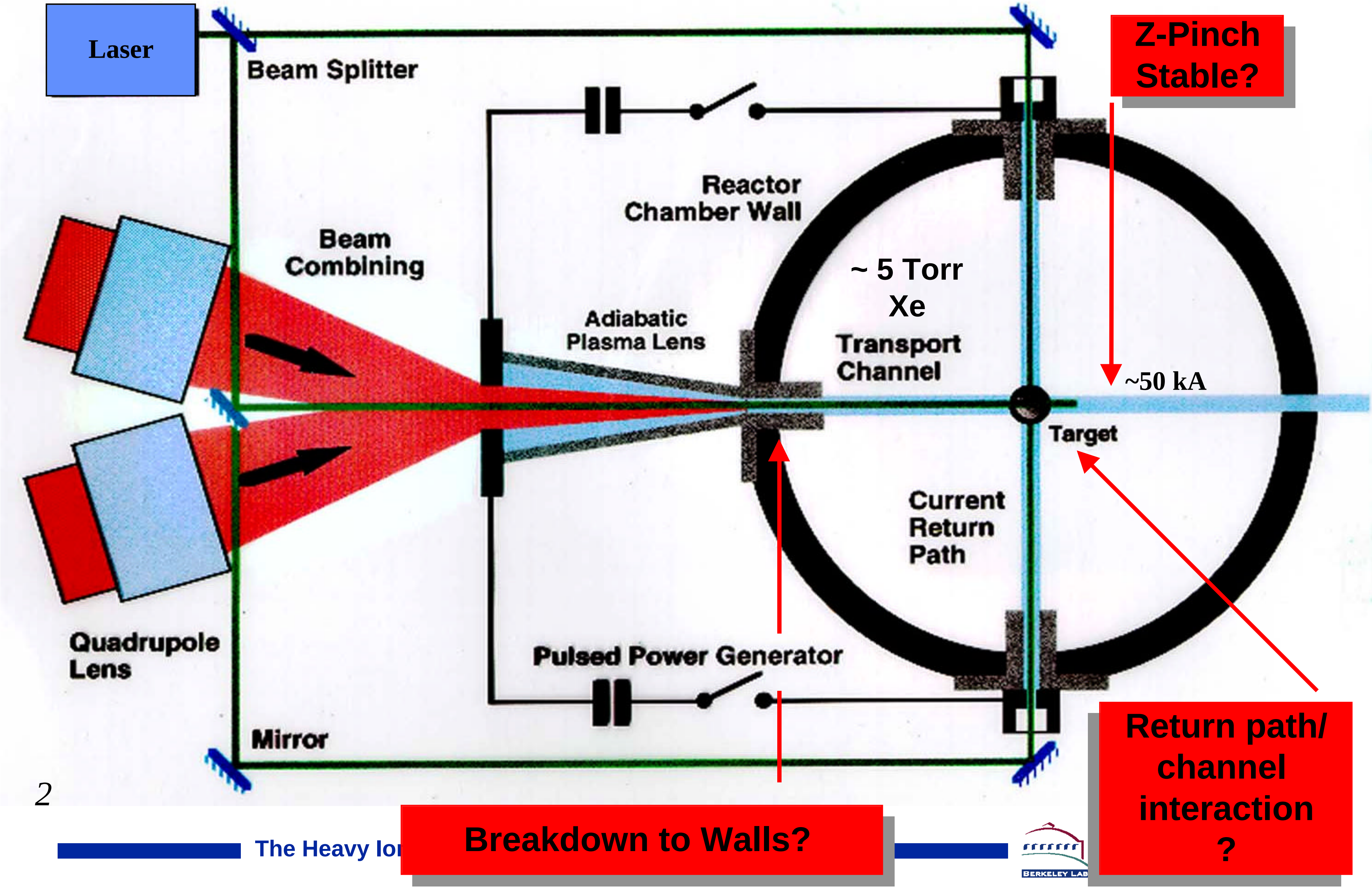
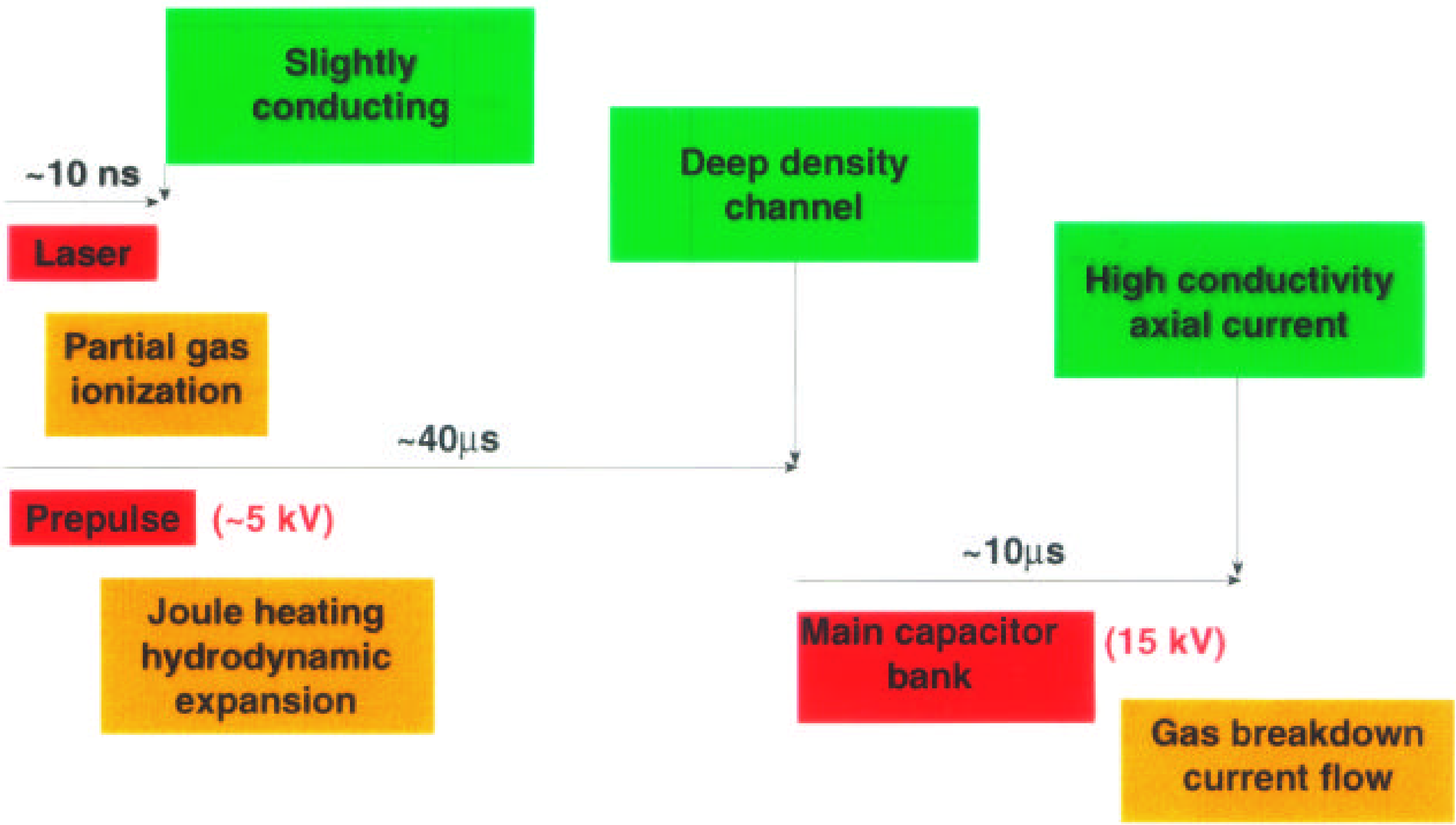
What is the Propagation Window for Channel Assisted Pinch?

- Beam Dynamics (LSP)
  (10 ns timescale)
- Channel Formation
  (10 μs timescale)
- Breakdown Management is a key component of channel formation:
  - breakdown in the channel when voltage is applied
  - no breakdown to the chamber walls
- Beam port insulator rings are designed to inhibit breakdown to chamber walls

Channel transport could ease chamber focus requirements and reduce driver costs



Z-Pinch Formation is a 3-step process



Gas Breakdown Management

- The key parameter for gas breakdown is E/p - (E=electric field, p=gas density)
- For Xenon, breakdown occurs at

$$(E/p)_{Xe} = 60 \text{ V/cm/torr}$$

- Design goal:
  - (1) create reduced density hole (n_{ch}) in channel such that

    $$(E/p)_{ch} > (E/p)_{Xe}$$

  - (2) Maintain low E/p everywhere else in chamber (where gas density is n_0)

    $$(E/p)_0 < (E/p)_{Xe}$$

- Necessary condition:

$$n_{ch} R_{chamber} < n_0 R_{port}$$

where $R_{chamber}$ ≈ length of channel ≈ chamber radius and R_{port} ≈ radius of port insulator

PORT DESIGN

- From breakdown requirement, port size given by ≈ $R_{port} > (\frac{n_{ch}}{n_0})\ R_{chamber.}$
- We have done some hydrodynamics calculations to determine $(n_{ch}/n_o) < 0.1$. (Black body radiation model)
- We need a port design that is acceptable electrically and structurally Two port designs were constructed which were compatible with thick liquid walls.
- We have constructed another port design which MAY be more compatible with dry wall and wet wall concepts.

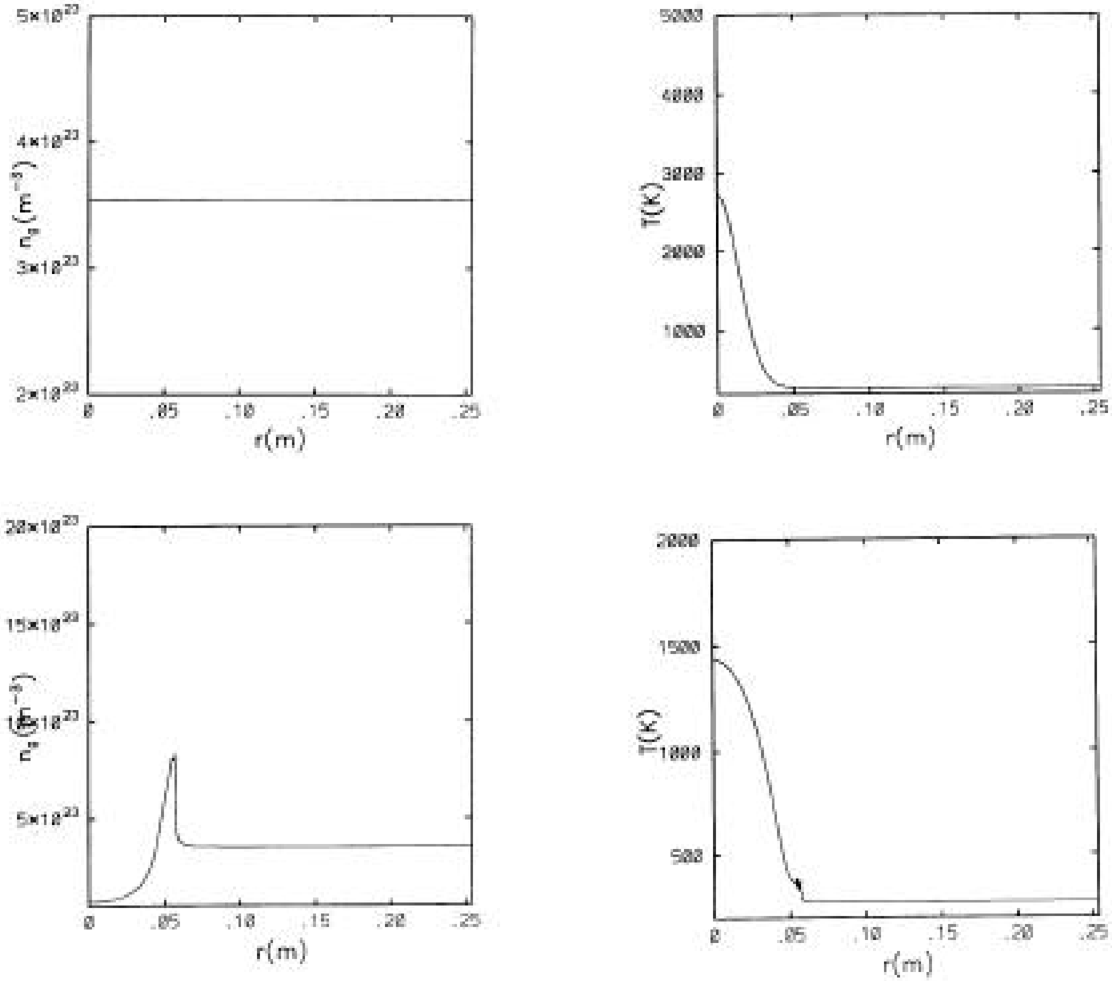
PREPULSE phase - HYDRODYNAMIC EXPANSION

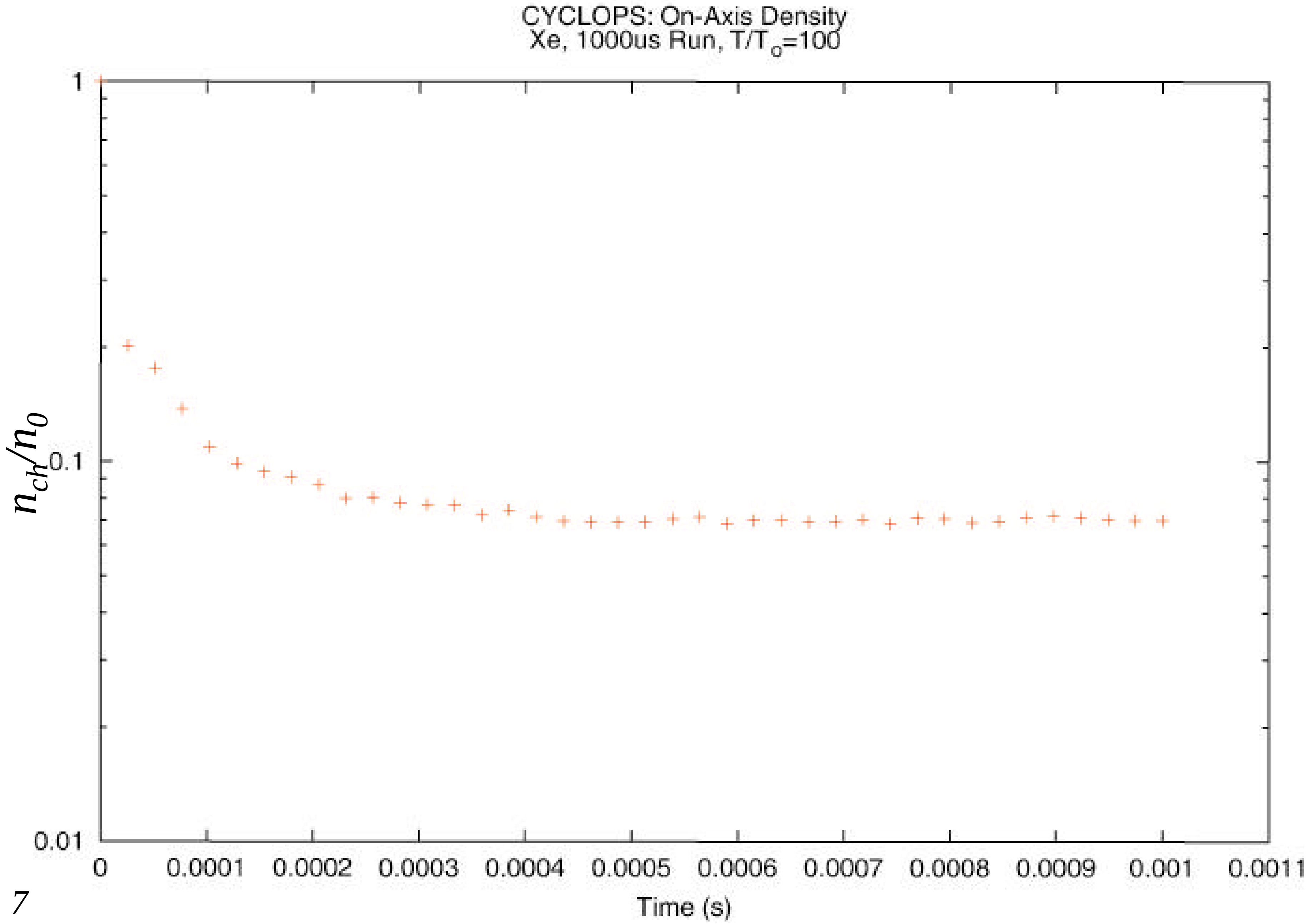
Gas Density

Gas Temperature

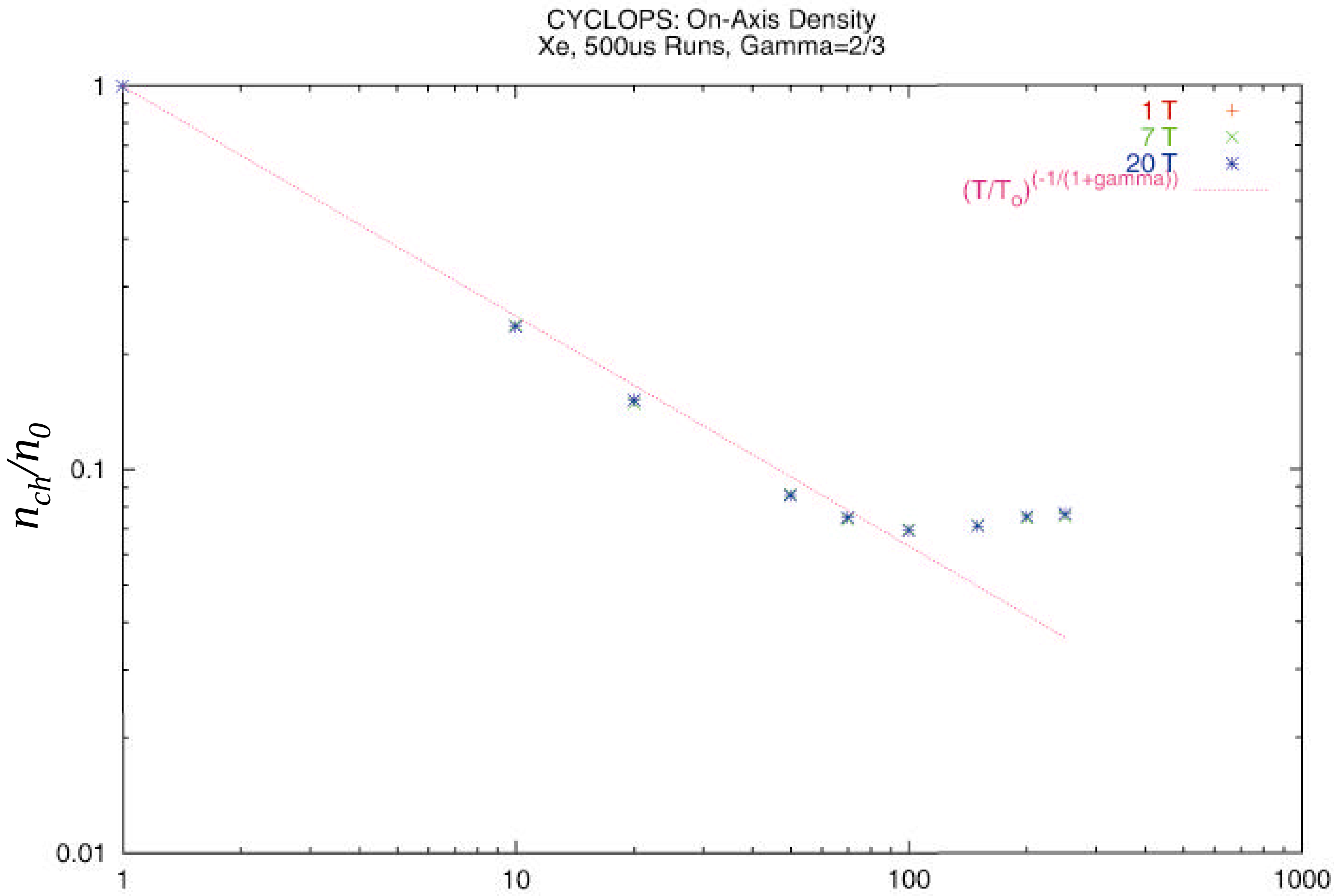
t=0

T=60μs





CYCLOPS: On-Axis Density
Xe, 1000us Run, T/T$_o$=100
n_{ch}/n_0
1
0.1
0.01
0
0.0001
0.0002
0.0003
0.0004
0.0005
0.0006
0.0007
0.0008
0.0009
0.001
0.0011
Time (s)



(Initial temperature /300º K)

Beam Energy Loss Places Constraint on Maximum Density in Channel

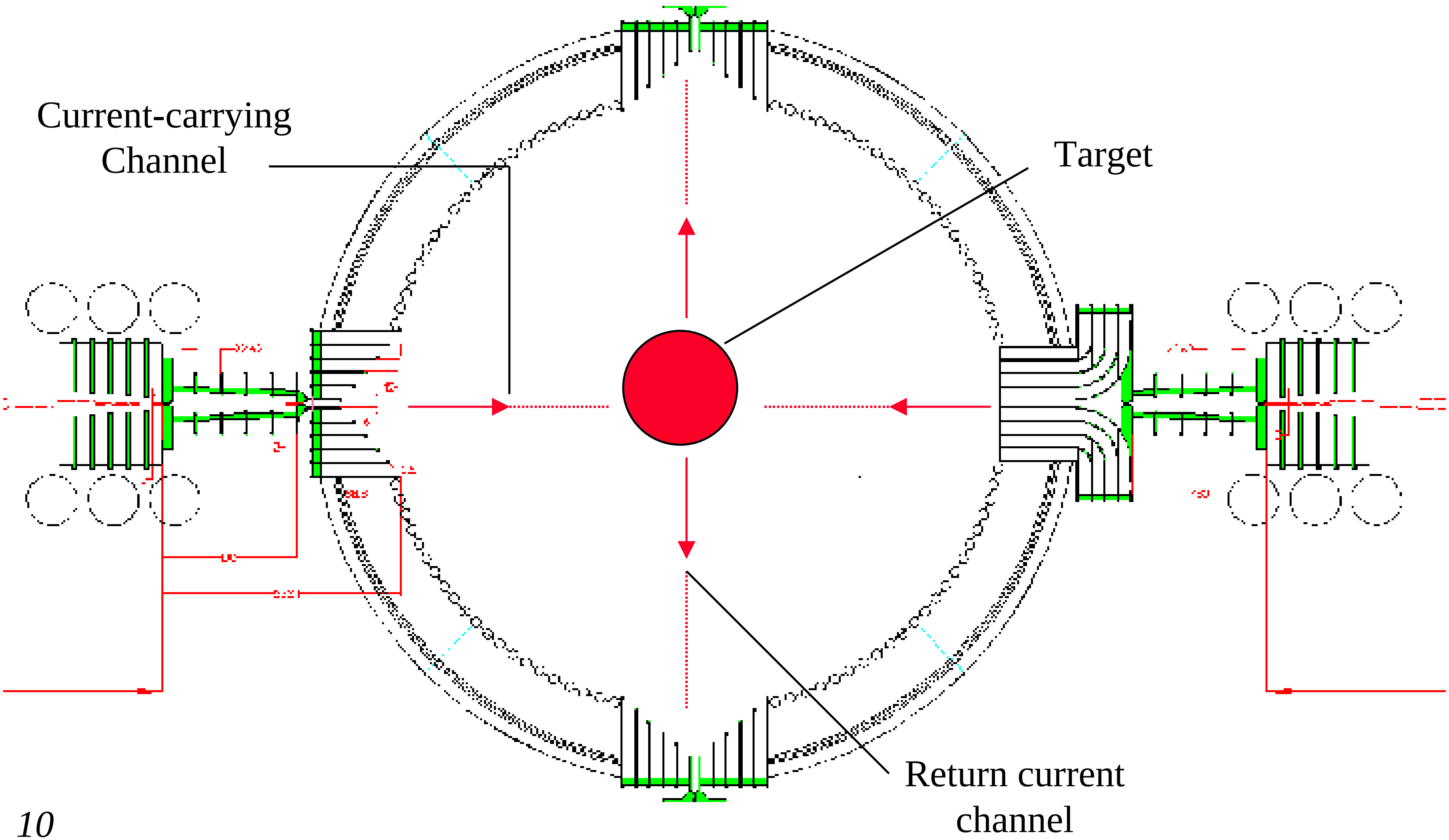
Example: 4GeV Pb ions going through 4 m of 0.5 Torr Xe gas will lose 9 % of its energy.

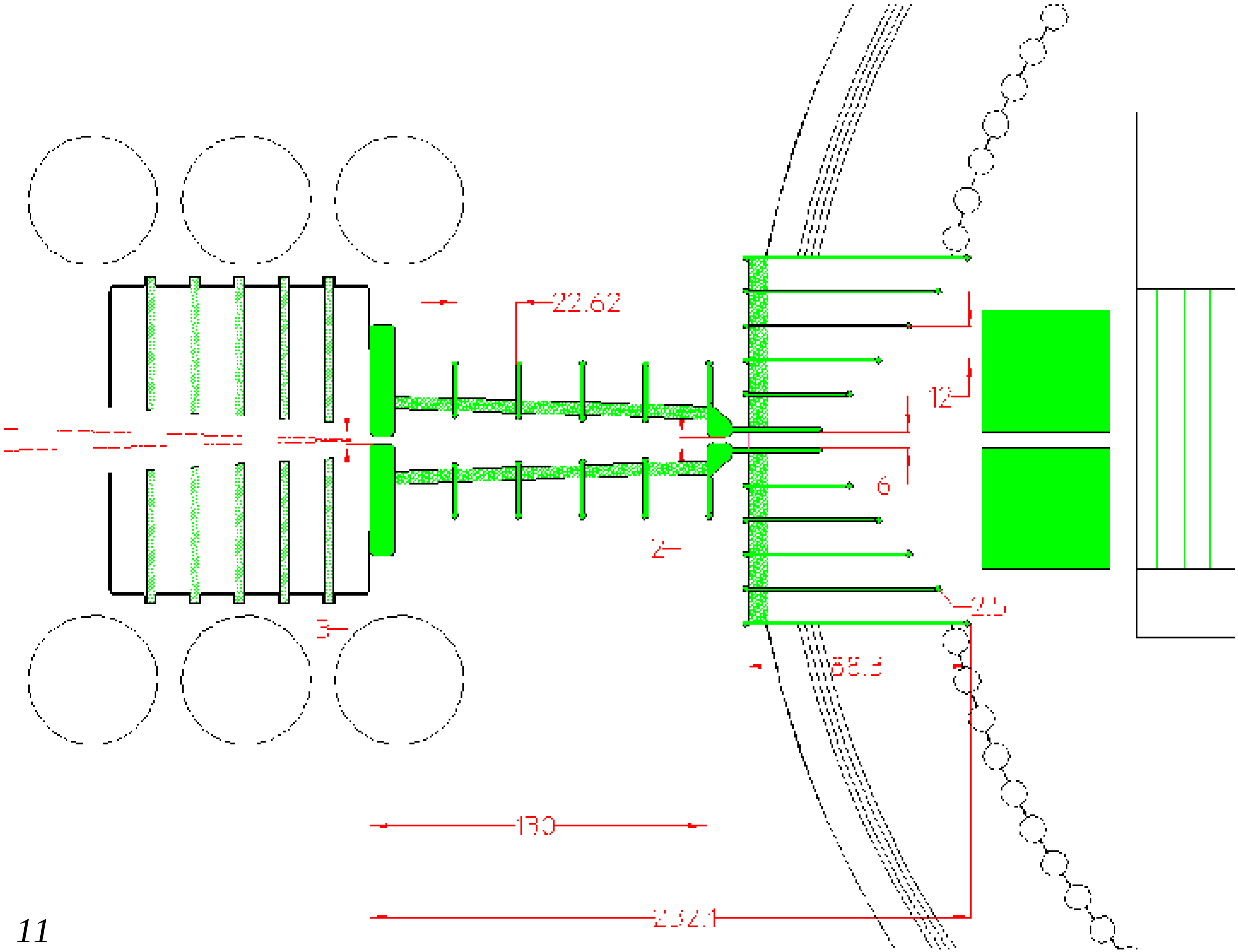
In general

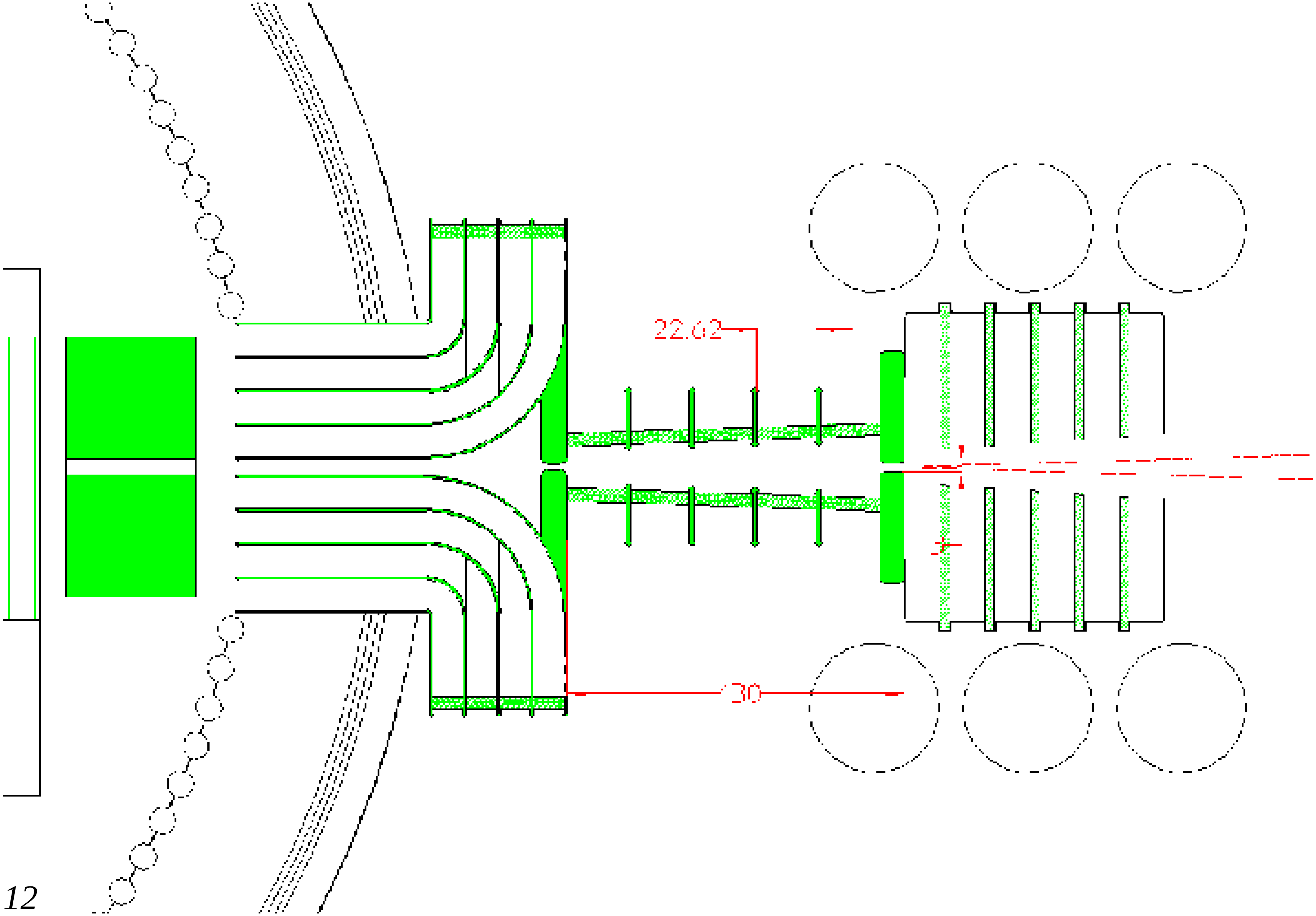
$$\Delta E = 380\, MeV\left(\frac{R_{chamber}}{4m}\right)\left(\frac{n_{ch}}{0.5 Torr}\right)\left(\frac{Zg}{54}\right)\left(\frac{0.2}{\beta}\right)^2\left(\frac{Z_i}{64}\right)^2$$

Where
- Zg - atomic number of gas
- Zi - effective charge state of stripped ion
- β - speed of ion / speed of light

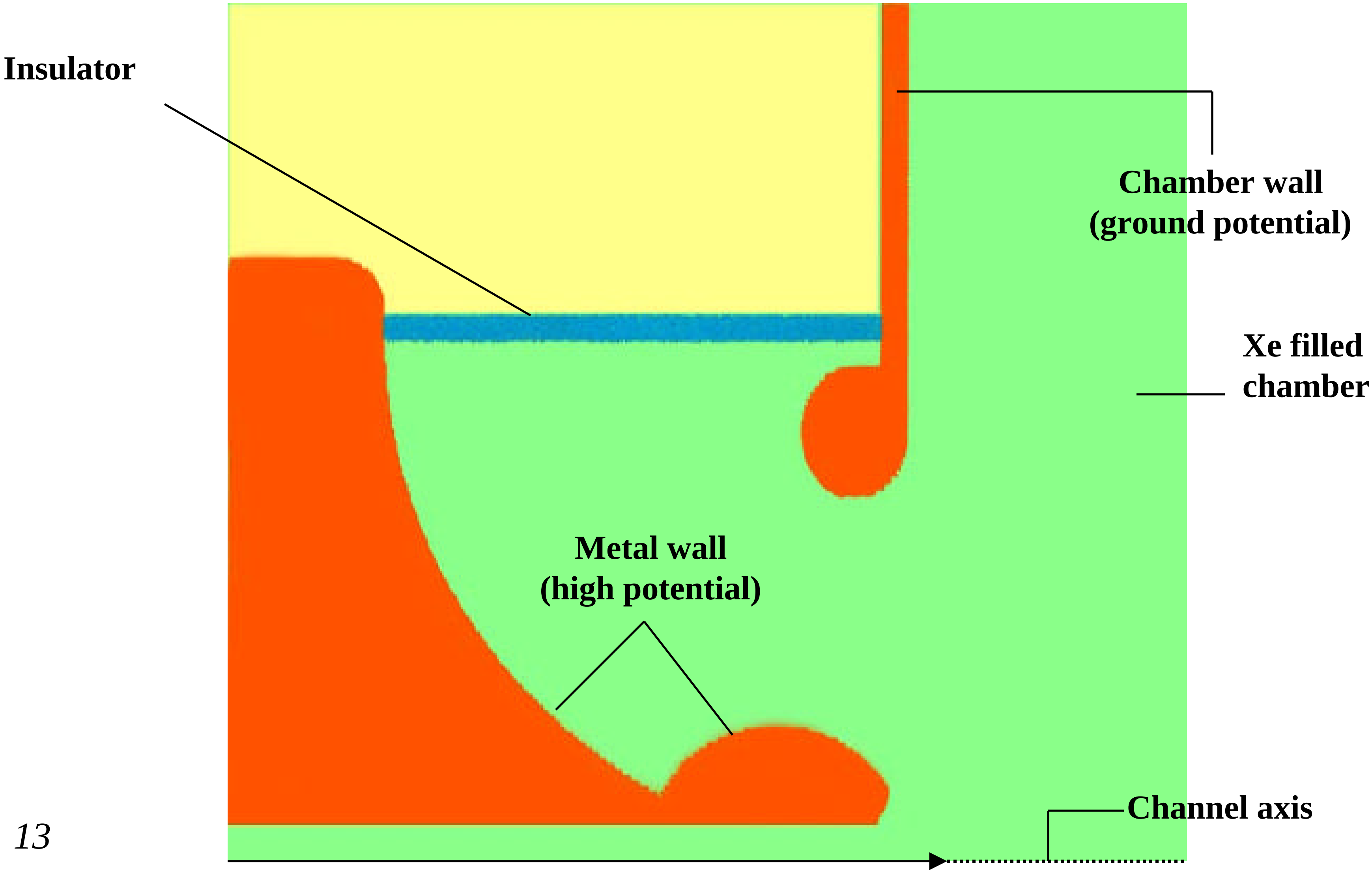
Fusion Chamber for Channel Assisted Pinch



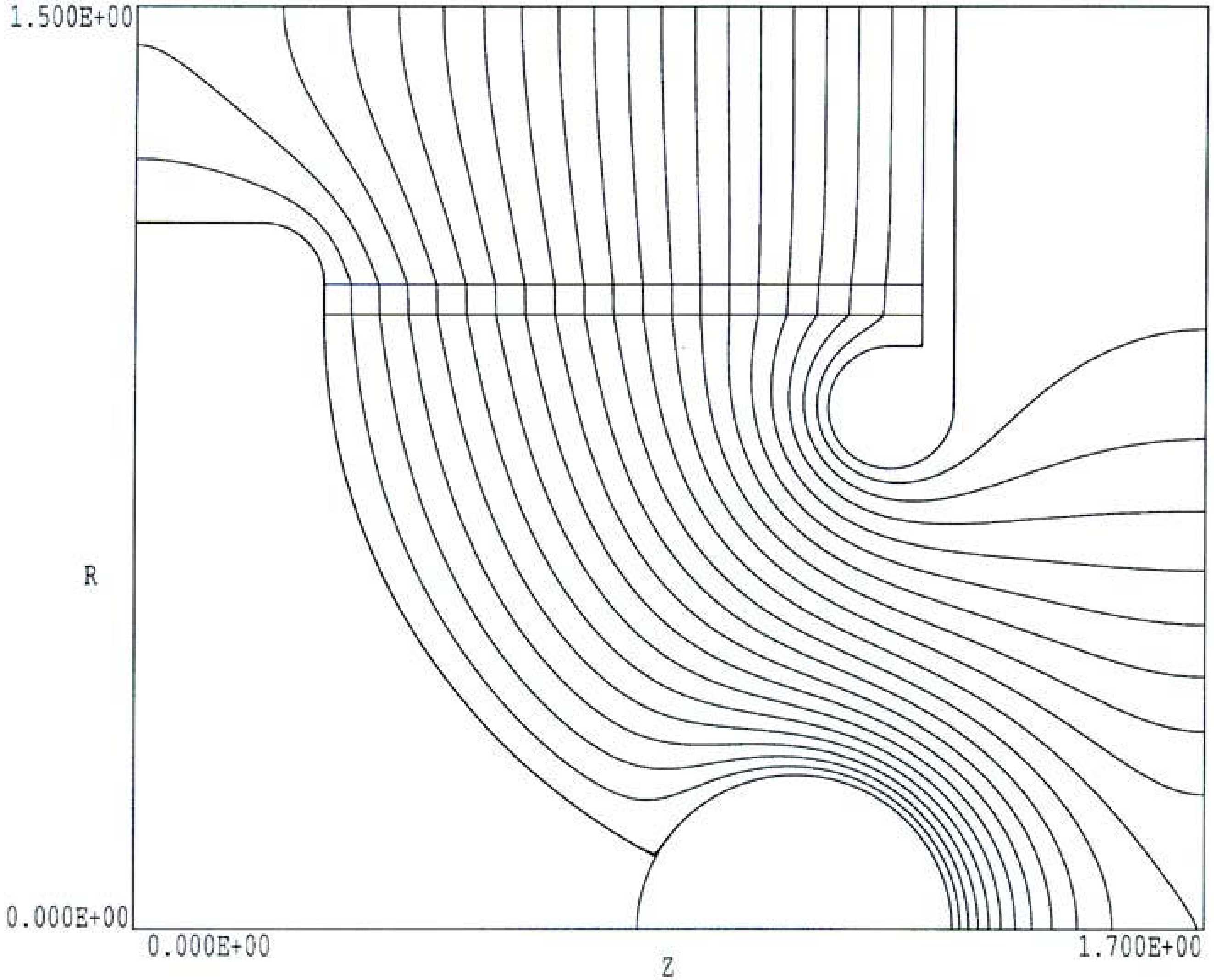

22.62
12
6
2
3
130


22.62
30

New Insulator Geometry



Electric Field Profile (Poisson Calculations)



Near Term Objectives

- Continued studies of channel hydrodynamics to determine n_{ch}/n_0
- Continued electrical optimization of insulator (Poisson)
- Structural integrity and protection of insulator (Raffray et al)