GENERAL ATOMICS
AND AFFILIATED COMPANIES

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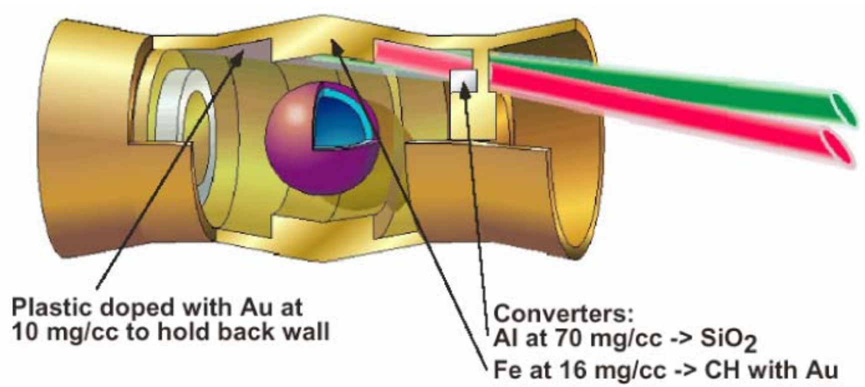
1. ID Target Aerosol limits
2. Tracking and Laser Aerosol Limits
3. Foam Mechanical Properties
4. Target Injection Accuracy
5. Future ARIES Target Task



Ronald Petzoldt

ARIES Meeting, Princeton, NJ **October 2-4, 2002**

Outline

1. Review indirect drive target aerosol limits
   - i.e., Max droplet size and density to allow ex-chamber tracking
2. Effect of particle size on light extinction by Pb and fluoride salts
   - Particle number and mass density limits vs particle radius based on light extinction
3. Foam mechanical properties vs density
   - Young’s modulus, collapse strength
4. Target injection accuracy
   - Requirements, achieved accuracy, improvement possibilities
5. Future ARIES task
   - Hohlraum material selection

If droplet density and size are not excessive, in-chamber tracking should not be necessary for indirect-drive targets

Calculate maximum acceptable single droplet size near edge of 3 m chamber

$$\Delta R = \frac{\Delta v}{v_0} R_c = \frac{m_d}{m_t} R_c \Longrightarrow m_d = \frac{\Delta R}{R_c} m_t = \frac{0.3\ \text{mm}}{3\ \text{m}} 2\ \text{g} = 0.2\ \text{mg}$$

Droplet radius is 0.29 mm (assuming 2 g/cc liquid density).
Chamber density is limited to about 1 g/m^3 for numerous smaller droplets.

1 g/m^3 could cause 0.3 mg/cm^2 accumulation on target passing through a 3 m radius chamber

$$\frac{\rho}{A} = \rho R_c = \left(1 g / m^3\right)\left(3m\right) = 0.3 mg / cm^2$$

This is roughly 1% of ion beam range for 3.5 GeV Pb ions so energy loss is acceptable (<1%) for HIF targets.
Scattering of beam by droplets in chamber may cause more losses.

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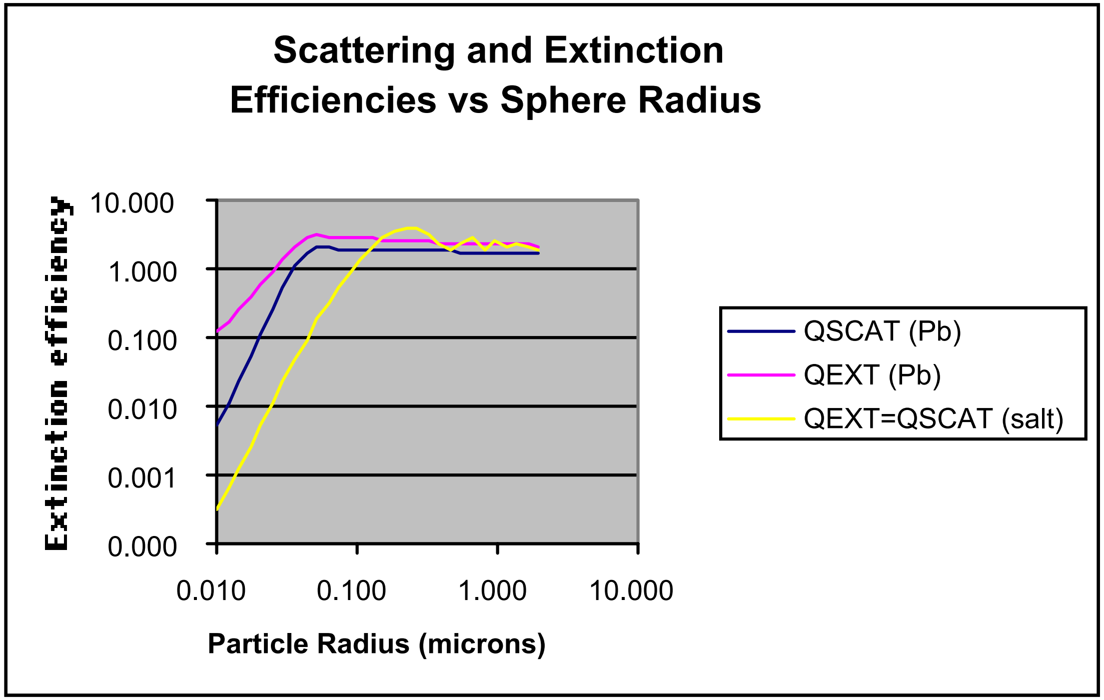
For small particle size, the optical extinction efficiency is much less for salt than for Pb



Cross section = $Q\pi r^2$

Pb
n = 4.4, k = 3.9

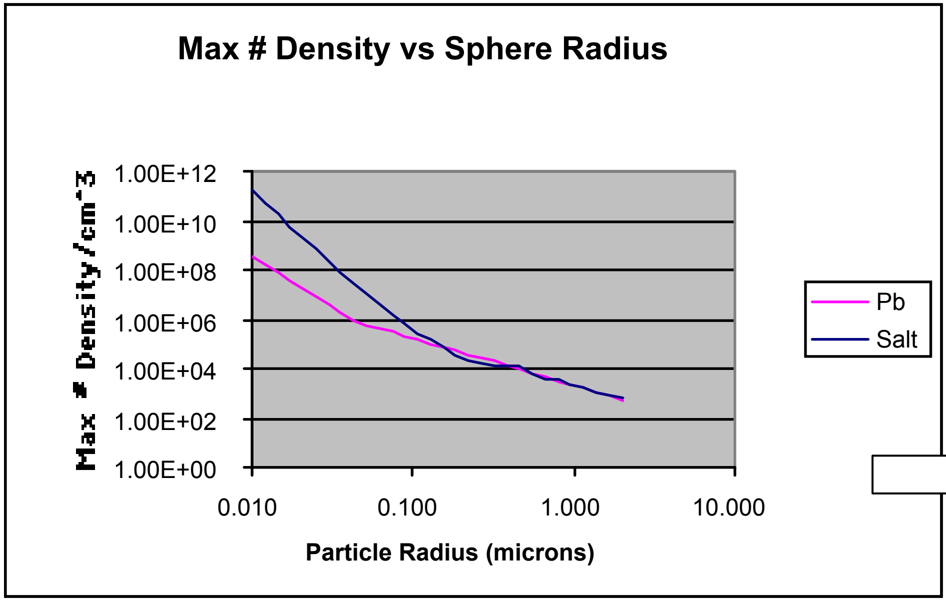
Fluoride salt
n = 1.4, k = 0*

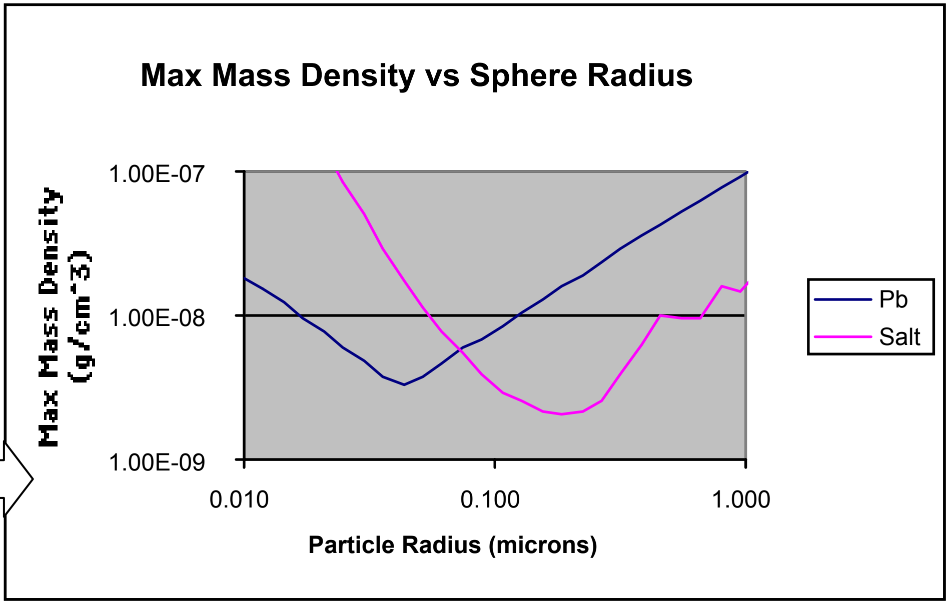
0.3 micron light

Thus very small particles of salt have less affect on light than Pb

***Typical properties of CaF_2, LiF, and MgF_2 given in Handbook of Optical Constants of Solids, Ed Palik, Naval Research Lab, Academic Press, New York, 1985**

Beam extinction places limits on particle number and mass density





These calculations may also be useful for driver beam aerosol limits

Assumes 0.3 micron wavelength
and 90% beam propagation through 6.5 m

We are starting to study foam mechanical properties that relate to target acceleration.

$$\frac{E^*}{E_s} \approx \left(\frac{\rho^*}{\rho_s}\right)^2 \qquad \frac{\sigma^*_{pl}}{\sigma_{ys}} \approx 0.3\left(\frac{\rho^*}{\rho_s}\right)^{3/2} \qquad \frac{\sigma^*_{el}}{E_s} \approx 0.05\left(\frac{\rho^*}{\rho_s}\right)^2$$

for open cell foams where E is Young's modulus, σ^*_{pl} and σ^*_{el} are the plastic and elastic collapse strength of the foam and ρ is density.

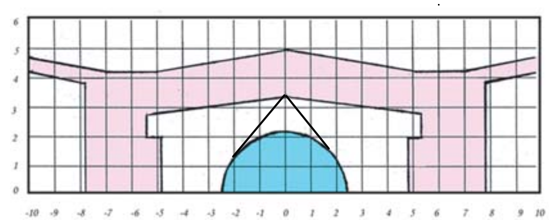
For external foam direct drive targets, the relative density for which Young's modulus and yield (collapse) stress of foam equals that of DT at target temperature can be estimated as follows

$$\left(\frac{\rho^*}{\rho_s}\right) \approx \sqrt{\frac{E(DT)}{E_s(Plastic)}} \approx \sqrt{\frac{40MPa}{7GPa}} = 0.075$$

$$\left(\frac{\rho^*}{\rho_s}\right) \approx \left(\frac{\sigma_y(DT)}{0.3\sigma_y(Plastic)}\right)^{0.67} \approx \left(\frac{50\text{ kPa}}{0.3(150\text{ MPa})}\right)^{0.67} = 0.01$$

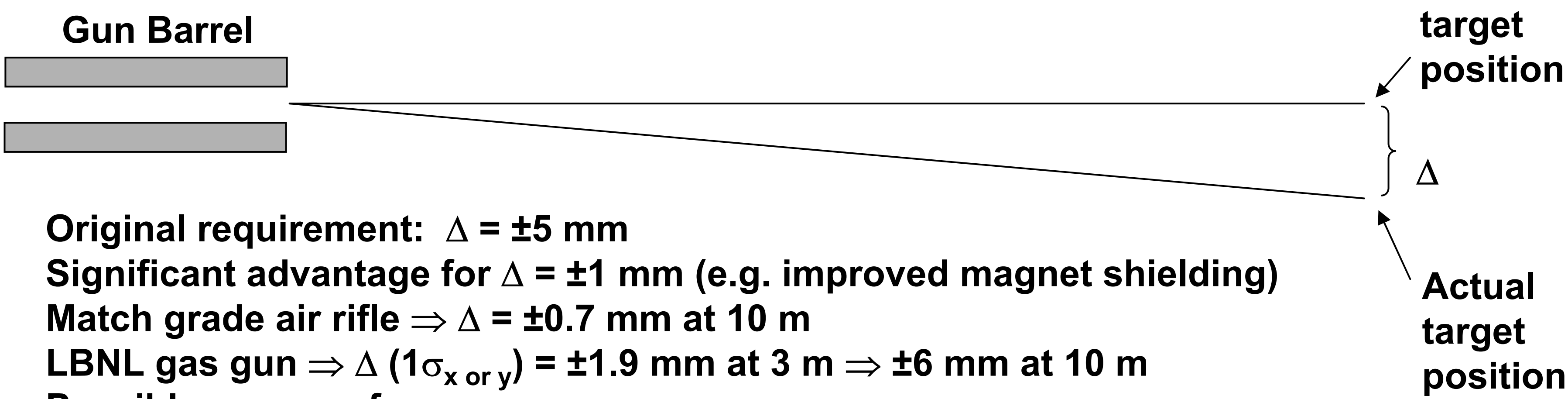
$$\left(\frac{\rho^*}{\rho_s}\right) \approx \sqrt{\frac{\sigma_y(DT)}{0.05E_s(Plastic)}} \approx \sqrt{\frac{50\text{ kPa}}{0.05(7\text{ GPa})}} = 0.01$$

Ref: Gibson and Ashby, Cellular Solids, Second edition, Cambridge University press.

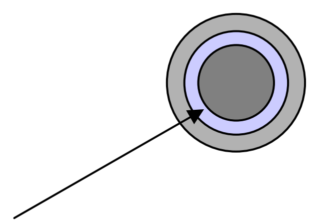


We are also attempting to estimate indirect drive target acceleration limits using these relationships

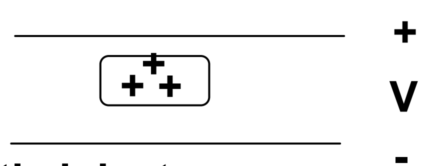
We think better target injection accuracy is possible



Original requirement: $\Delta = \pm 5$ mm
Significant advantage for $\Delta = \pm 1$ mm (e.g. improved magnet shielding)
Match grade air rifle $\Rightarrow \Delta = \pm 0.7$ mm at 10 m
LBNL gas gun $\Rightarrow \Delta\ (1\sigma_{x\ or\ y}) = \pm 1.9$ mm at 3 m $\Rightarrow \pm 6$ mm at 10 m
Possible causes of error
- **Loose fit in barrel**
- **Low density target**
- **Barrel imperfection**



Concepts to improve accuracy
- **Compressible outer target material may allow tight barrel fit**
- **Electrostatic target steering**

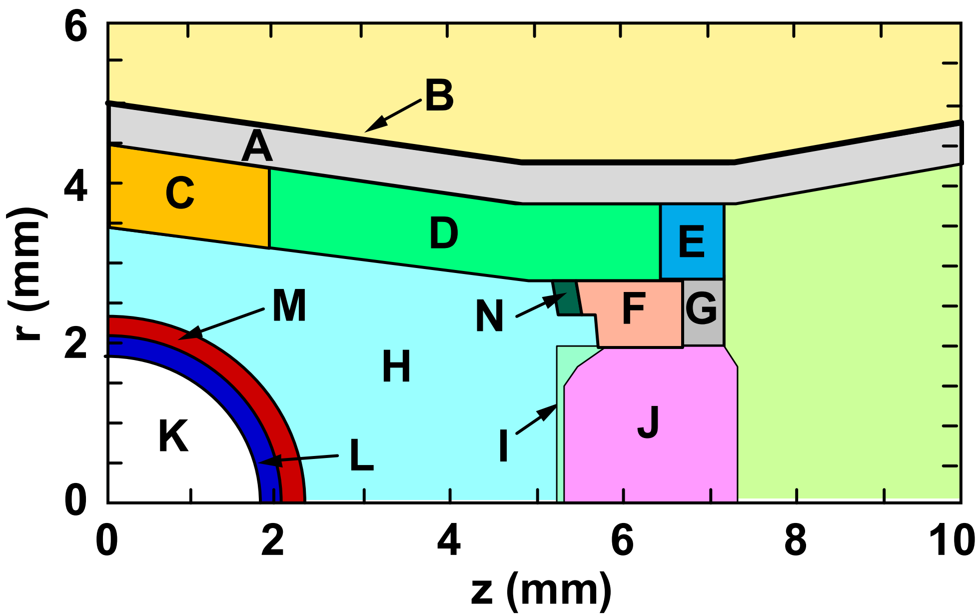


- **Non-contacting electromagnetic injector**

Hohlraum materials selection is a recommended ARIES task

The heavy-ion driven target has a number of unique and challenging materials

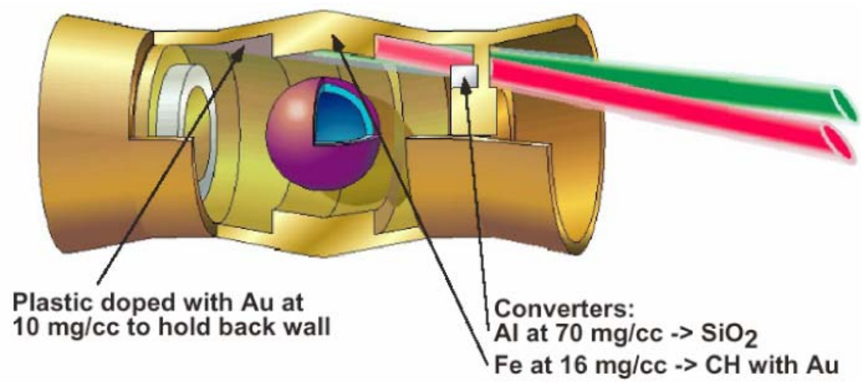
A:	AuGd	0.1 g/cc
B:	AuGd	13.5 g/cc
C:	Fe	0.016 g/cc
D:	$(CH)_{0.97}Au_{0.03}$	0.011 g/cc
E:	AuGd	0.11 g/cc
F:	Al	0.07 g/cc
G:	AuGd	0.26 g/cc
H:	CD_2	0.001 g/cc
I:	Al	0.055 g/cc
J:	AuGd "sandwich"	0.1/1.0/0.5
K:	DT	0.0003 g/cc
L:	DT	0.25 g/cc
M:	$Be_{0.995}Br_{0.005}$	1.845 g/cc
N:	$(CD_2)_{0.97}Au_{0.03}$	0.032 g/cc



Nuclear Fusion 39, 1547

… Simplification and material substitutions are needed to reduce the complexity of the target

Pathways to simplify the target are being defined



Material substitutions are defined in conjunction with target designers to reduce target cost

Part	Material	Alternate Materials
A	AuGd [high-Z only]	*Various* - Au, Pb/Ta, Pb/Ta/Cs, Hf/Hg/Xe/Kr
B	AuGd [high-Z only]	*Various* - Au, Pb/Ta, Pb/Ta/Cs, Hf/Hg/Xe/Kr
C	Fe	Au-doped CH foam
D	$(CH)_{0.97}\ Au_{0.03}$	--
E	AuGd [high-Z only]	*Various* - Au, Pb/Ta, Pb/Ta/Cs, Hf/Hg/Xe/Kr
F	Al	Silica aerogel
G	AuGd [high-Z only]	*Various* - Au, Pb/Ta, Pb/Ta/Cs, Hf/Hg/Xe/Kr
H	CD_2	He gas
I	Al	CH or doped CH
J	AuGd sandwich (high-Z only)	*Various* - Au, Pb/Ta, Pb/Ta/Cs, Hf/Hg/Xe/Kr
K	DT	--
L	DT	--
M	$Be_{0.995}Br_{0.005}$	Polystyrene (CH)
N	$(CD_2)_{0.97}Au_{0.03}$	--

Physics of Plasmas, May 2000, pp. 2083-2091

Recent Material Choices

(Loss compared to Au/Gd D. Callahan)

Au or Pb	~10-15% gain loss
Pb/Hf	~2% gain loss
Pb/Hf/Xe	~0% gain loss

Hohlraum materials selection is an important issue that directly affects……

- Target physics for target gain
- Cost and complexity (even feasibility) of target fabrication
- Cost of equipment and operations to remove the materials from the Flibe
- Compatibility of structural materials with hohlraum components (e.g., primary loop corrosion)
- Radioactive inventory of materials
- Handling operations in the plant (glove box or remote handling/maintenance)
- Decisions to recycle materials or discard them (waste volume, high-level waste generation)
- Heat transfer for layering the targets (if in-hohlraum layering is used)
- Acceleration limit for injecting the targets (strength of materials in needed density and geometry)

This ARIES task will leverage expertise at:

- GA/LANL (target fabrication and injection)
- LBNL (Flibe cleanup and processing)
- UCSD (Flibe chemistry and compatibility)
- UW (waste disposal)
- LLNL (target physics)
- UC Berkeley (Flibe systems)
- LLNL (materials activation)

Conclusions:

- Max aerosol density to avoid in-chamber tracking for ID targets is ~1g/m^3
- For aerosols much smaller than light wavelength, light extinction for salts is much less than for metals ⇒ particle number density may be higher
- Low density (insulating) foams on direct drive targets will likely be strong enough to not limit target acceleration
- Target injection accuracy improvement is an important development goal
- An integrated hohlraum materials selection is recommended for ARIES in FY03