

Technical Design Review
Studying the Proton "Radius" Puzzle
with μp Elastic Scattering:
Cryogenic Target

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Target Considerations

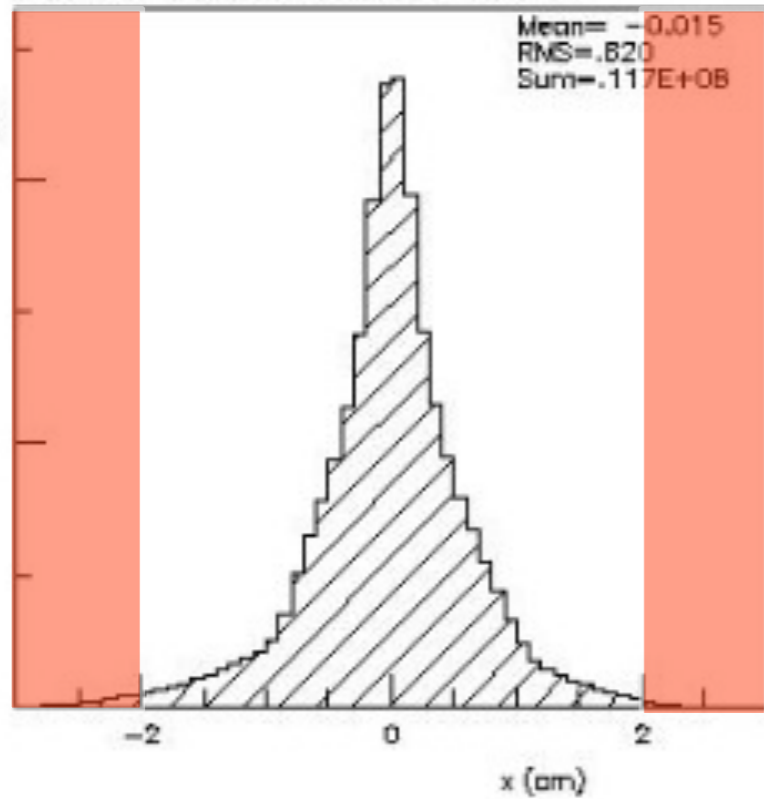
- A liquid hydrogen cryotarget is needed to maximize the ratio of scattering events from protons to events from other materials.
- Low-power cryotargets are a mature technology. Many exist.
 - Power deposited in target is $\approx 7 \text{ MeV}/(\text{g}/\text{cm}^2) \times 0.3 \text{ g}/\text{cm}^2 \times 1.6 \text{ pA} = 3 \text{ } \mu\text{W}$, which is insignificant.
 - But thermal heating of the target would be $\approx 3.5 \text{ W}$, if it were a black body.
- Multiple scattering limits the target length to about 4 cm.
- The beam width requires target diameter of at least 4 and probably 5 cm. This needs to be confirmed this fall before we do a final design.
- Kapton windows are preferred to Aluminum (less nuclear background) or mylar (better to contain hydrogen).

Pions

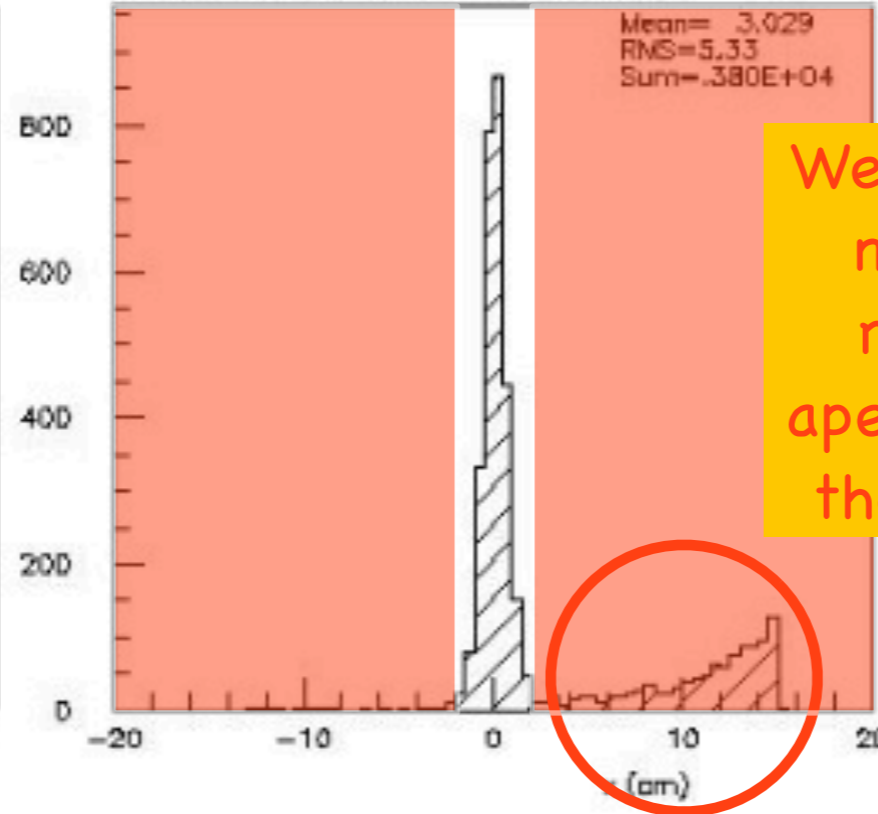
Beam Size

Muons

Histogram 61 (ln) at z= 23.207 m (TARG)

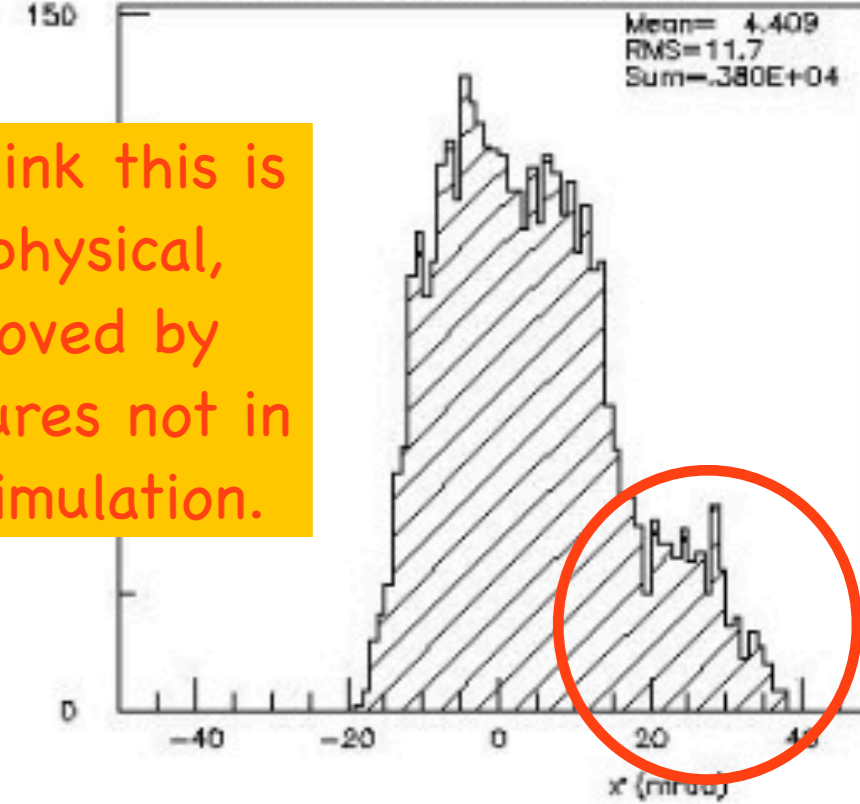


Histogram 73 (ln) at z= 23.207 m (TARG)

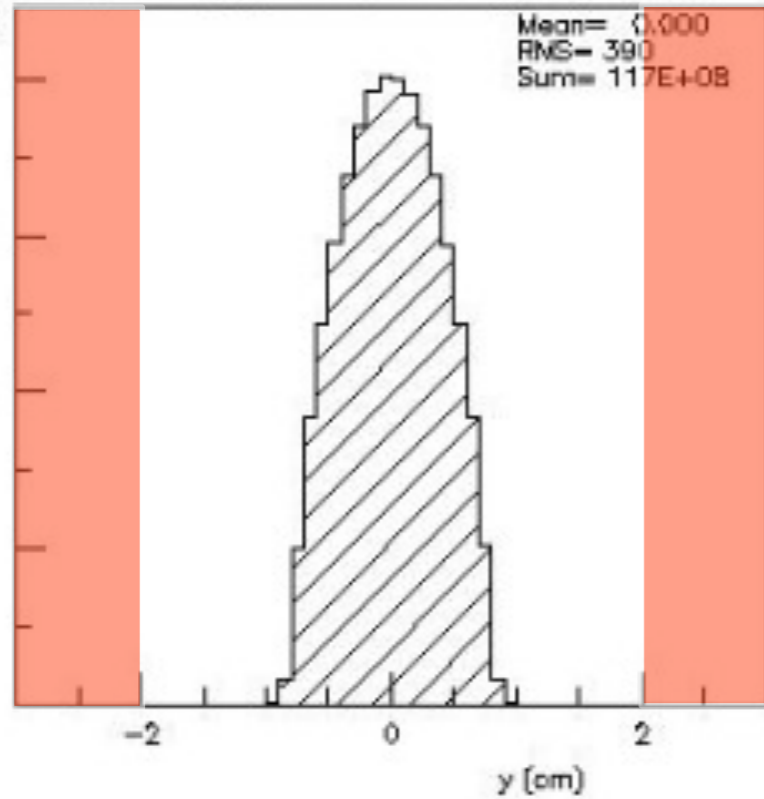


We think this is nonphysical, removed by apertures not in the simulation.

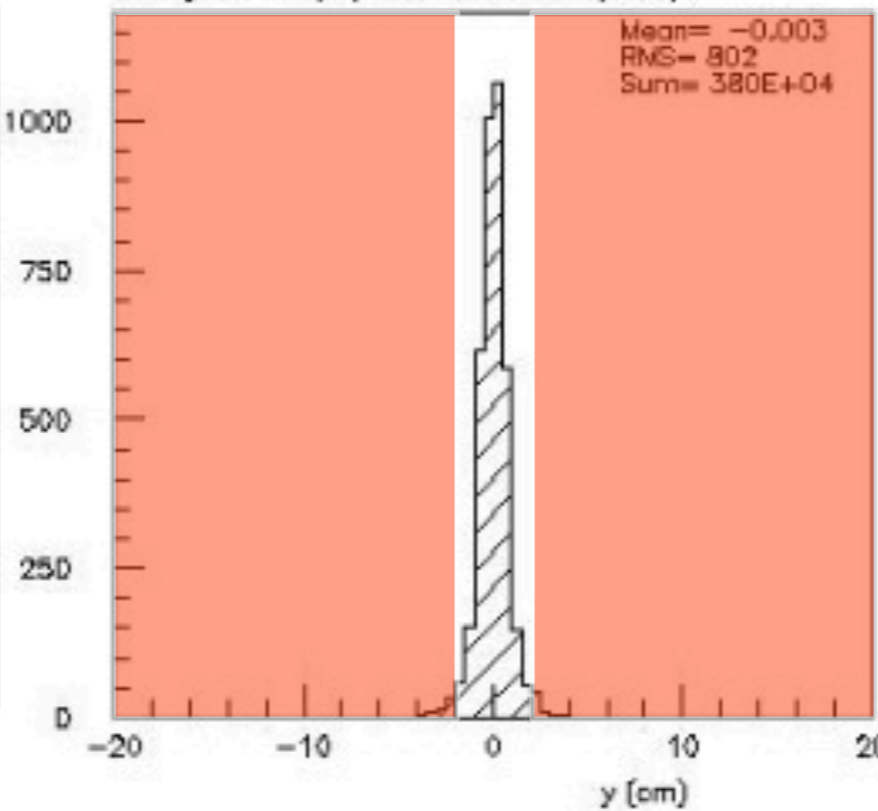
Histogram 74 (ln) at z= 23.207 m (TARG)



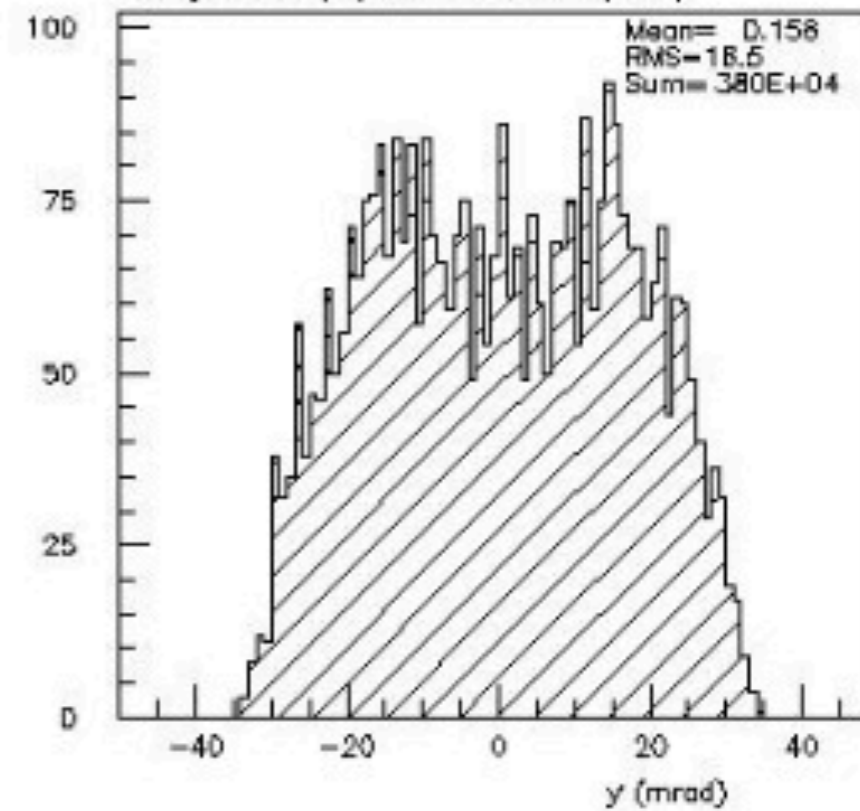
Histogram 63 (ln) at z= 23.207 m (TARG)



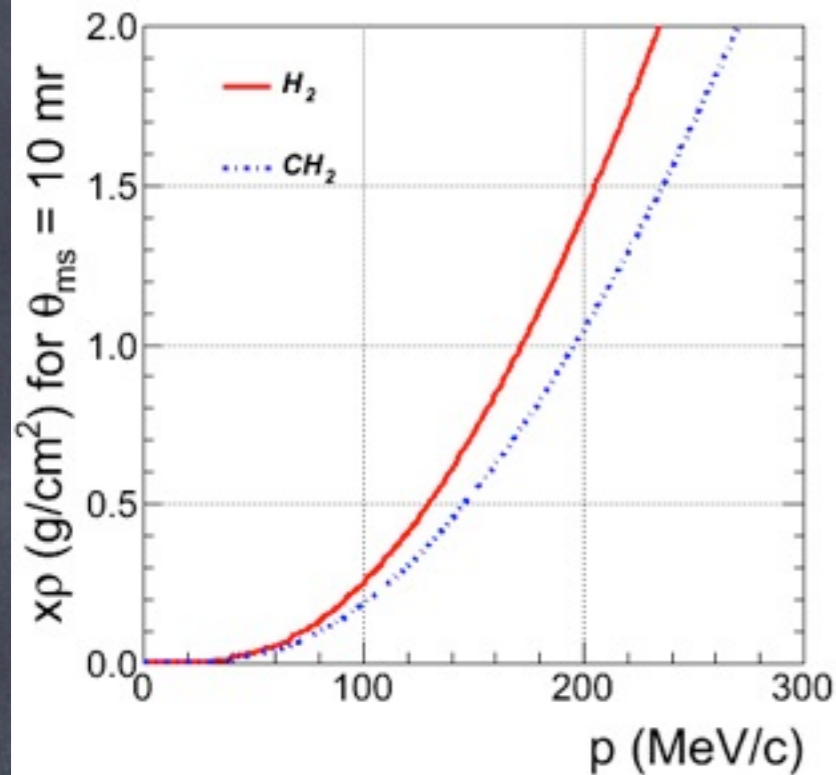
Histogram 75 (ln) at z= 23.207 m (TARG)



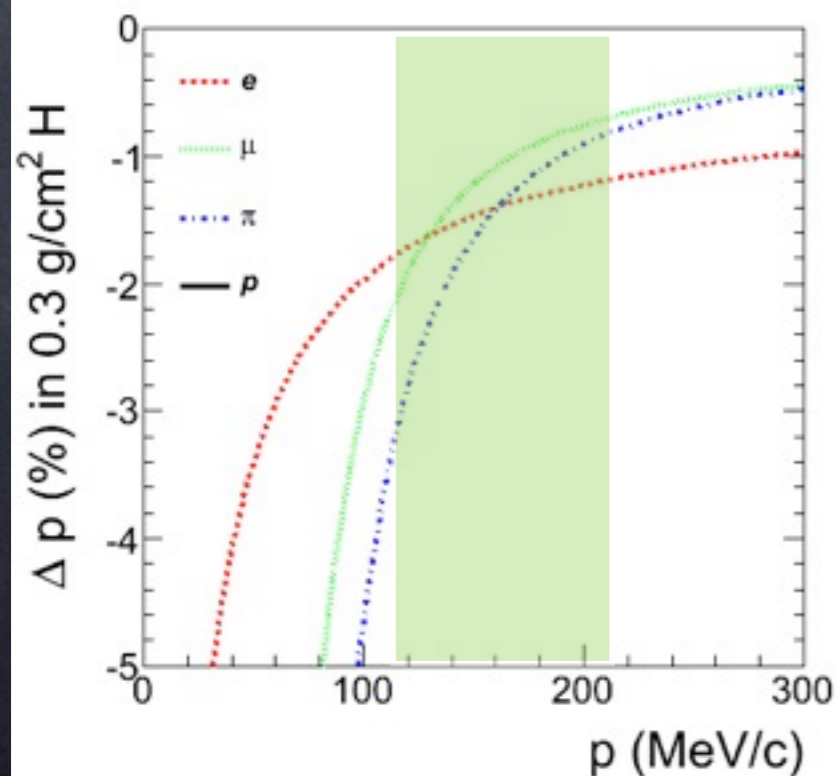
Histogram 76 (ln) at z= 23.207 m (TARG)



Target Multiple Scattering and Energy Loss



- Use 4-cm LH₂ target, ≈ 0.3 g/cm². (0.5% L_{rad})
- $\approx 10\times$ as much H as CH₂ target with same multiple scattering.
- θ_{MS} plane ≈ 10 mr @ 115 MeV/c, 6.5 mr @ 153 MeV/c, 4 mr @ 210 MeV/c.
- Copy recent E906 target design?



Due to E loss in target, μ 's and e 's average over $\approx \pm 0.5 - 1\%$ bin in momentum.

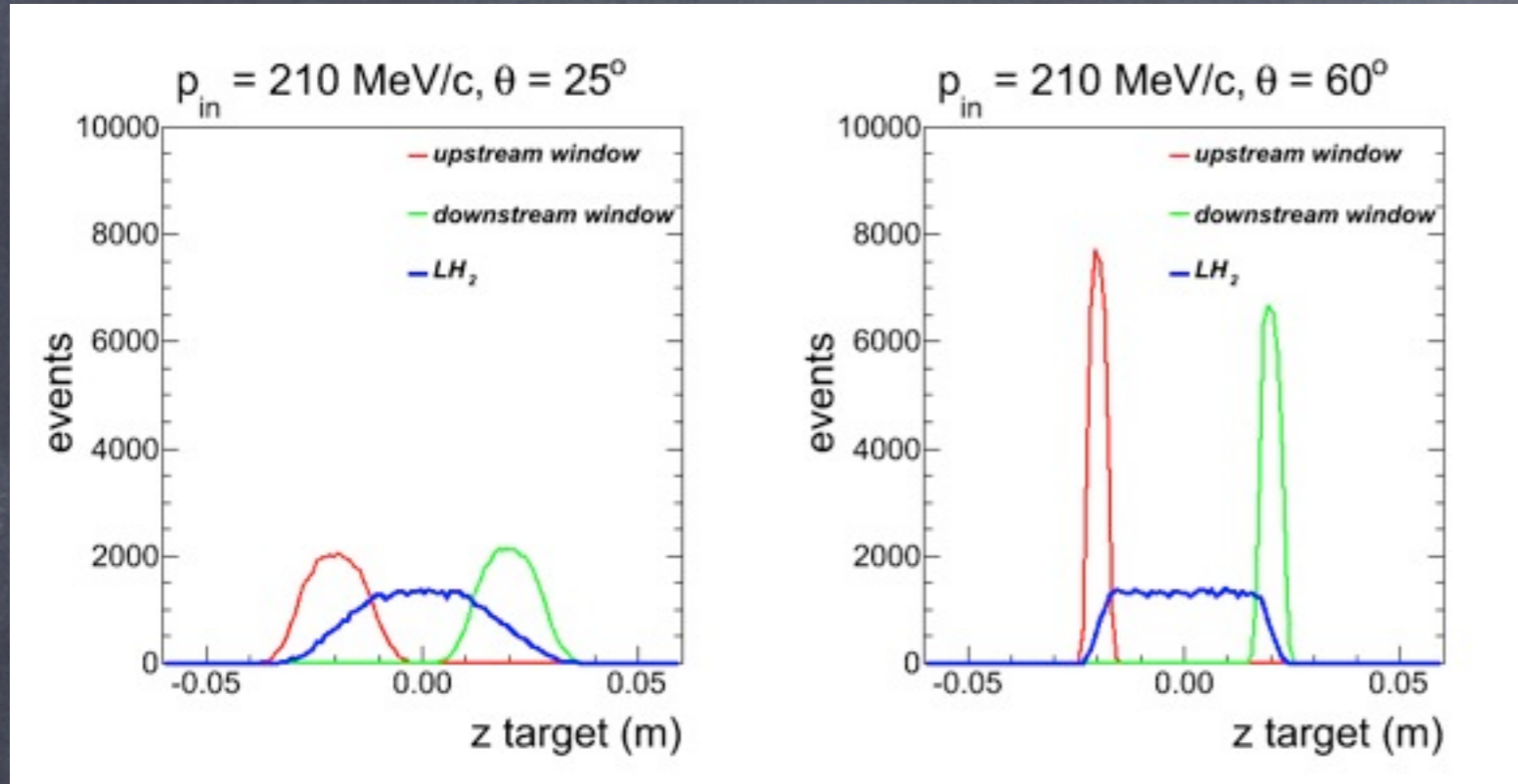
Issues

- As the low-power cryotarget problem has been solved many times before, many of the design choices are fairly obvious & easily copied from earlier efforts. The main design issues here are
 - Matching the target and vacuum system geometry to the experiment.
 - Limiting the amount of LH2 and choosing the right windows to limit multiple scattering and backgrounds.
- Probably the main issue for the project is that, while several groups with experience in cryotargets have some interest in the project, all are at present overcommitted. As a result we are planning for Rutgers U to lead the effort with contributions from St. Mary's U and Hebrew U.

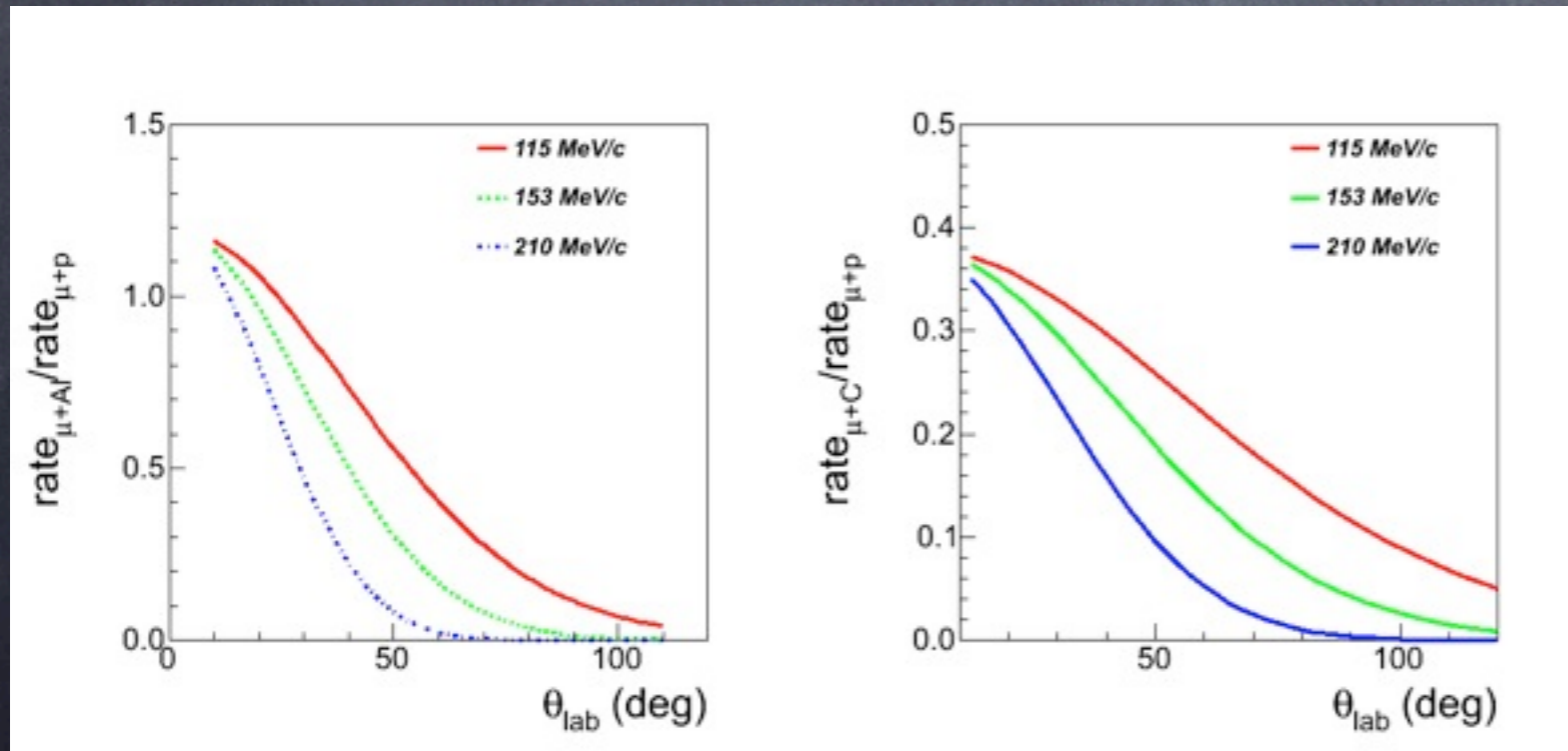
More Copying

- Much of our thinking on the system design is copied from the Fermilab E906 cryotarget, built in the last two years by the Michigan and Maryland groups. This is a stand alone system for 120 GeV proton induced Drell-Yan measurements, with about 25 Watt power capability.
- It has passed Fermilab safety reviews.
- But the vacuum system and cryotarget cell do not fit our geometry or our needs to minimize multiple scattering and non-H₂ materials in the beam.

Some Pictures



Cannot resolve end windows from LH_2 at forward angles



kapton - $C_{22}H_{10}N_2O_5$
approximated as C -
leads to less
background than Al

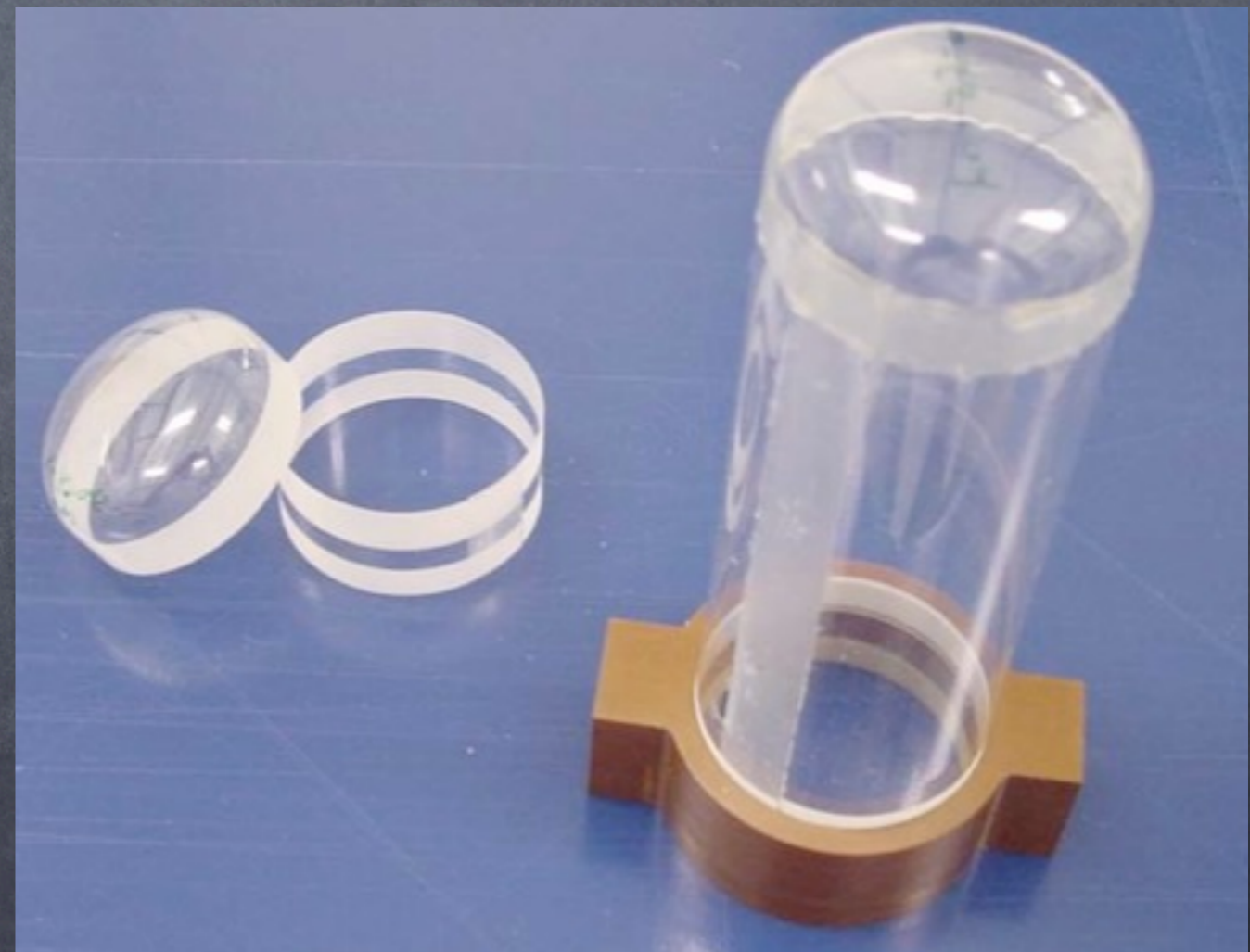
Note - reflects ep, not μp , rates

Some Pictures

"Mainz" design
Kapton cell



Fermilab E907
mylar cell - 2
half-cells glued
into a central
support / fill /
exhaust ring



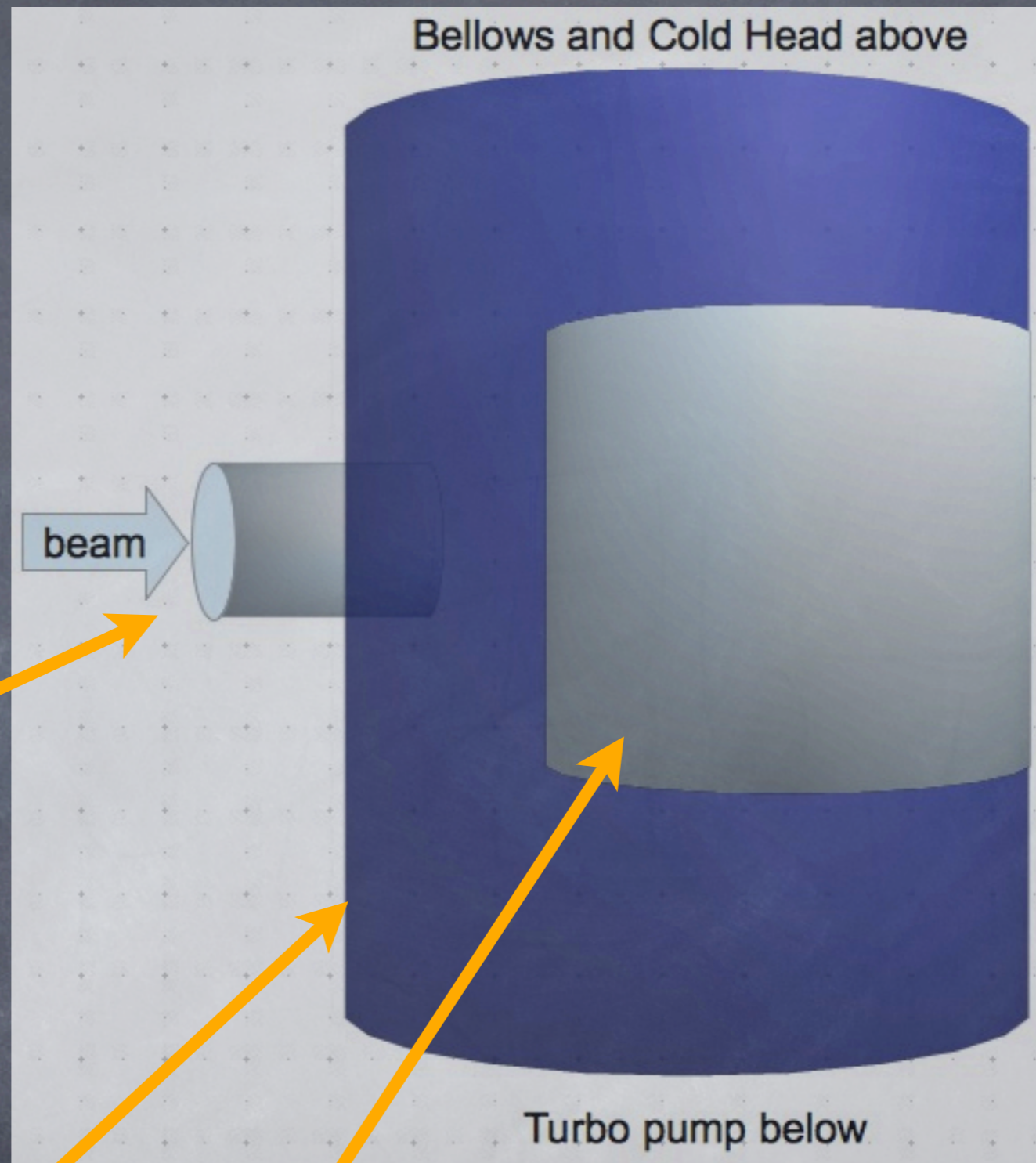
Cryotarget Vacuum System Cartoon

Thin entrance
window, $d \approx 5$ cm,
 $\approx 50 \mu\text{m}$ kapton.

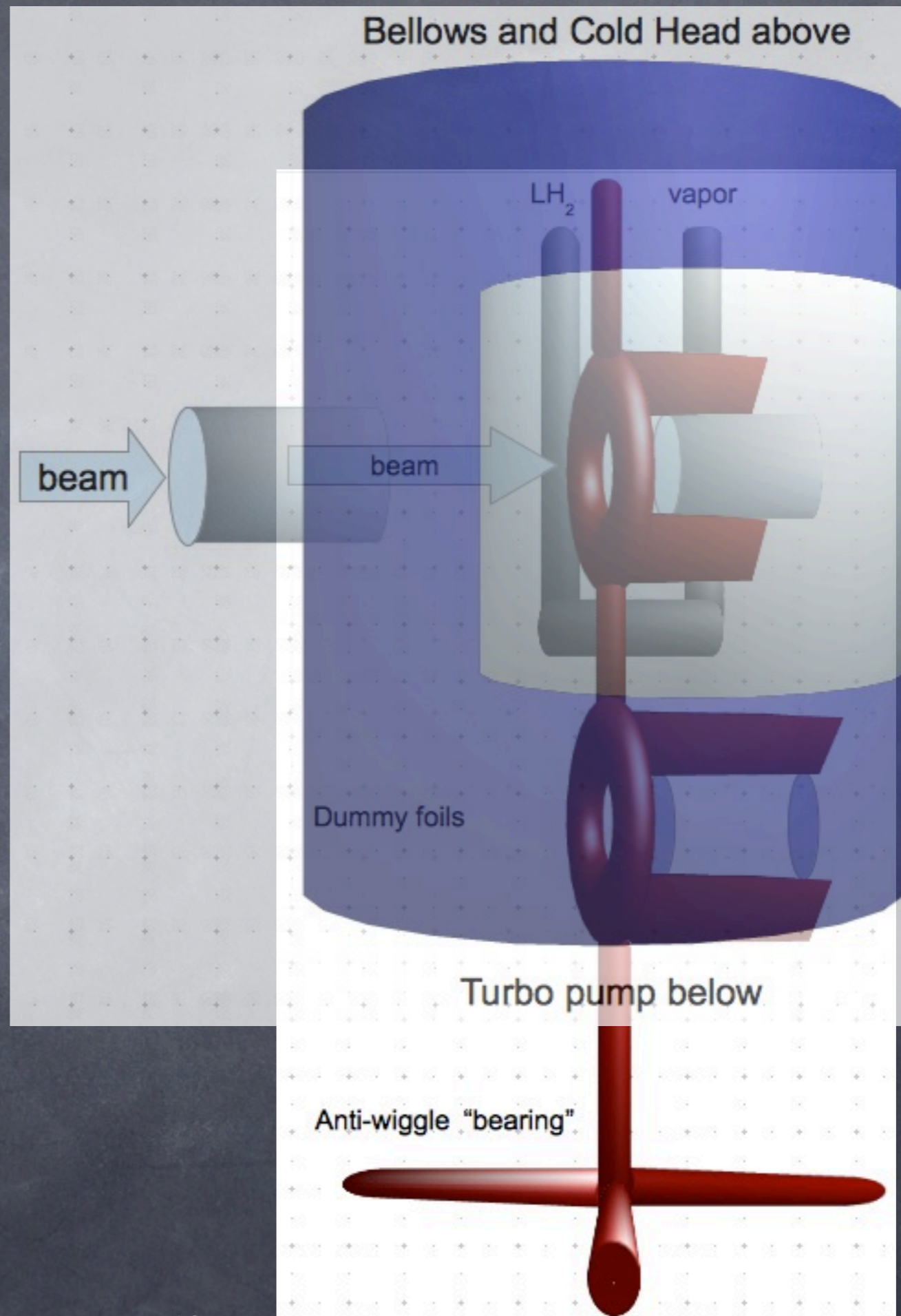
Simulations looking
at interplay
between sizes and
backgrounds; might
lead to offset
entrance window
shown.

Standard vacuum pipe,
 ≈ 6 " diameter. Support posts
might be needed.

Thin exit window, $h \approx 14$ cm,
 $\theta \approx -110^\circ - +110^\circ$,
 $\approx 150 \mu\text{m}$ kapton



Cryotarget Cartoon



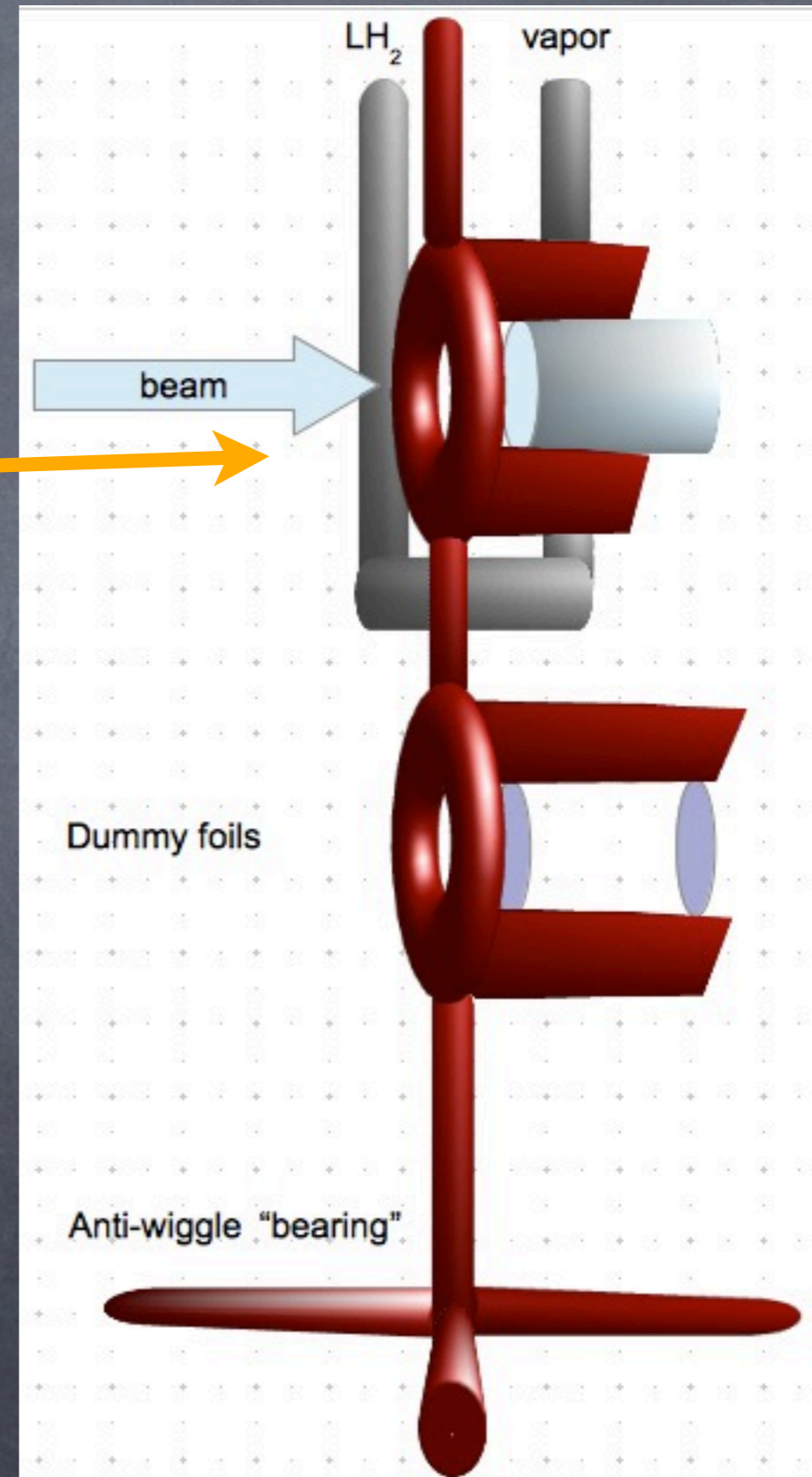
Cryotarget Cartoon

Kapton cell,
 $\approx 125 \mu\text{m}$ walls, "Mainz" design
Al mylar insulation not shown

dummy foils
 $\approx 750 \mu\text{m}$ thick to match L_{rad}

Not shown: additional solid target
positions - cross rods and central foil
for position calibration

Still need to determine whether to
center the target in the vacuum pipe.



System Cost

- Our 300k estimate reflects the total cost of the E906 target system. That system required about 2 FTE's to complete.