Muon Collaboration

Introduction

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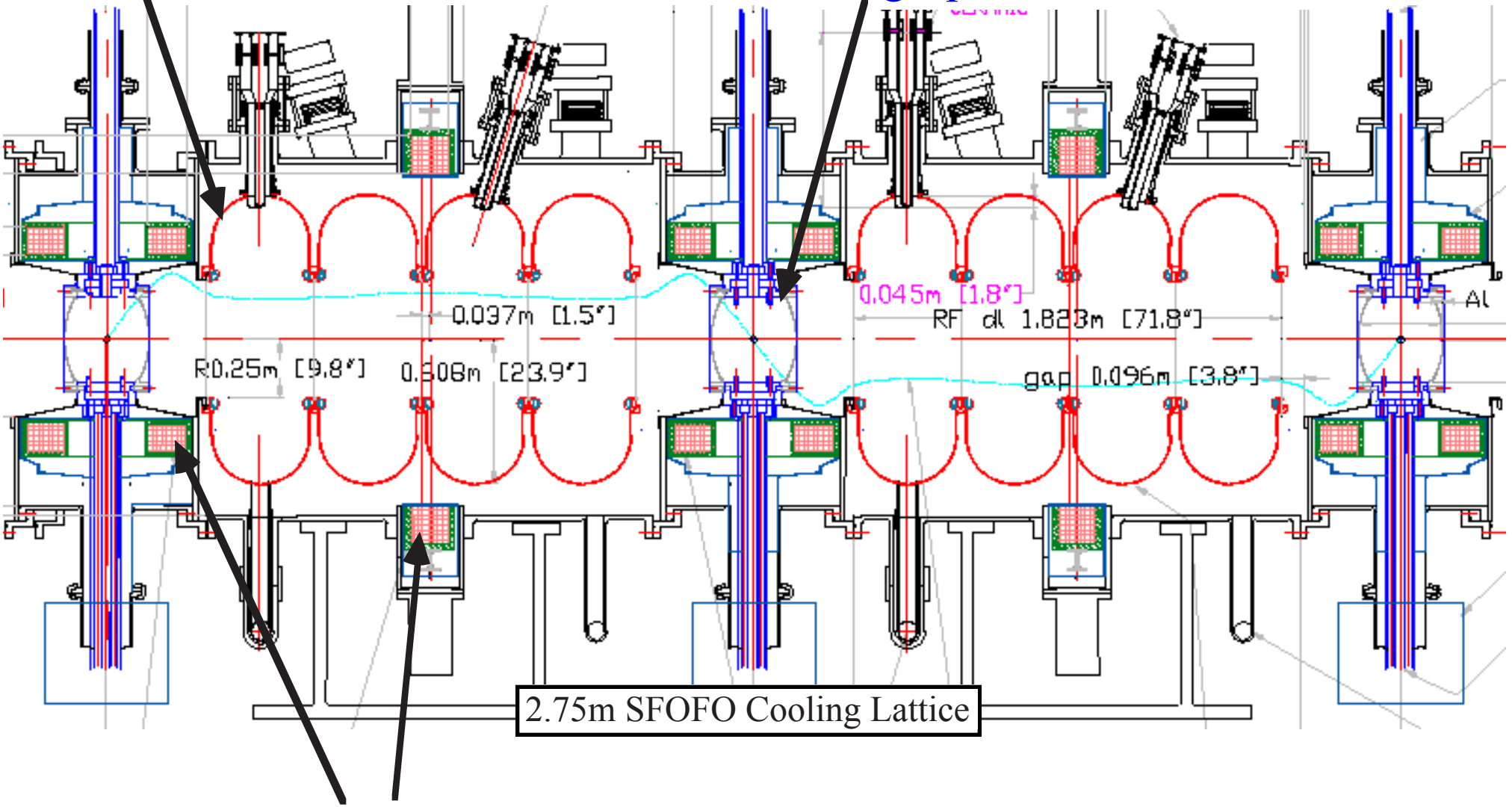
ICAR

Absorber Review
Fermilab
Feb. 21, 2003

Muon ionization-cooling channel

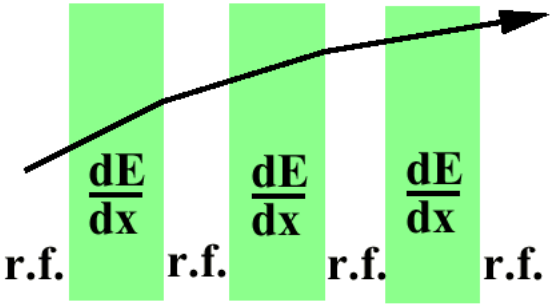
- High-gradient normal-conducting RF
- High-power LH2 absorbers



- Superconducting solenoids

Absorber R&D

- 2D transverse-cooling rate:

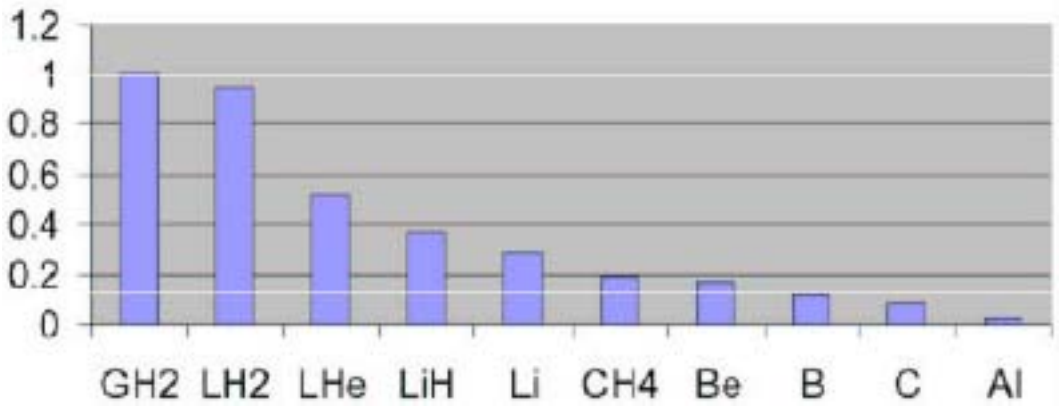


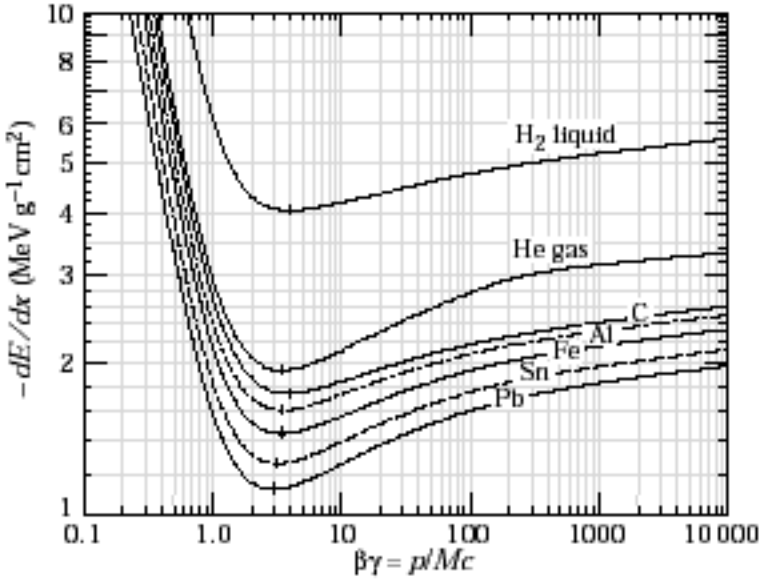
$$\frac{d\varepsilon_{x,N}}{dz} \approx -\frac{1}{\beta^2}\frac{\varepsilon_{x,N}}{E}\left|\frac{dE}{dz}\right| + \beta_\perp \frac{(0.014\,\mathrm{GeV})^2}{2\beta^3 E m_\mu L_R}$$

Competition between energy loss and Coulomb scattering

⇒ Absorber material comparison:

Transverse cooling merit factor $F \propto (L_R\, dE/dx)^2$



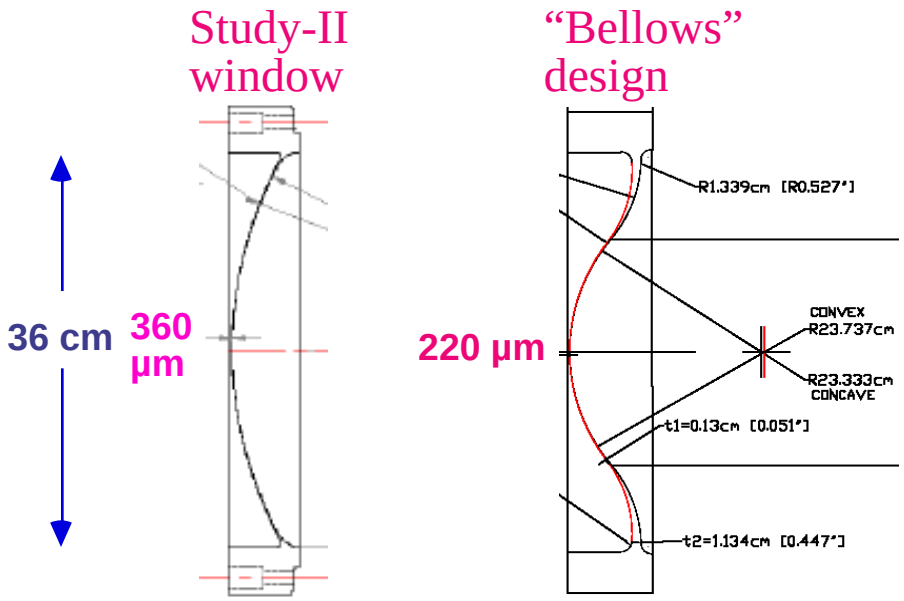


- Hydrogen is best material by factor $\gtrsim 2$

(...all other things being equal, e.g., neglecting effect of containment windows)

Main Absorber R&D Issues:

- Power handling
- Developing thinnest (in R.L.) possible containment windows



  - Bellows design (in 2000-series Al alloy) degrades F_{LH_2} from ≈ 1 to ≈ 0.8

- Coping with safety requirements

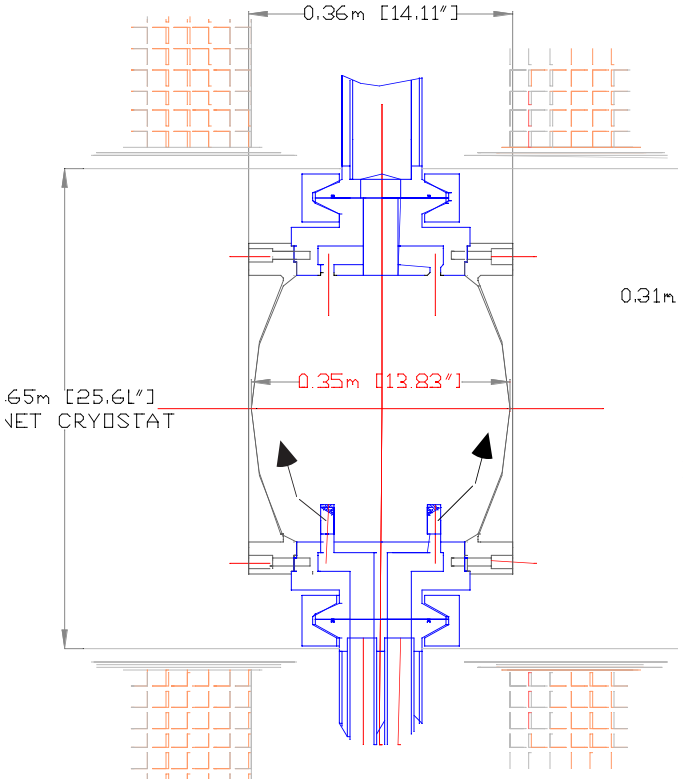
⇒ Progress requires actual prototype tests!

  - These issues are too complex and interrelated to answer on paper with sufficient confidence

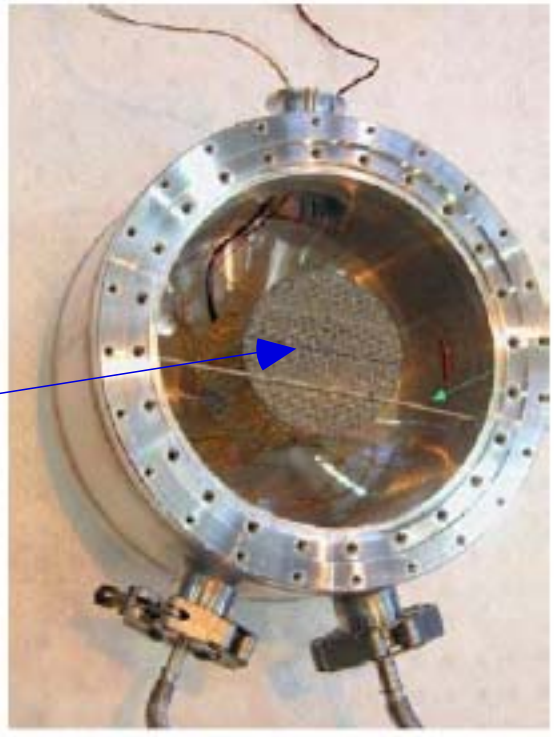
Absorber Power Handling

- Study-II scenario $\Rightarrow \lesssim 300$ watts per absorber – beyond FNAL experience
  - → ~ kW with more ambitious Proton Driver (4 MW instead of 1 MW) and/or Neuffer phase rotation (keeps both μ^+ and μ^- simultaneously)
  - → ~ 10 kW in ring cooler with ~ 10 passes
  - – State of the art is several hundred W in e.g. SLAC E-158 LH_2 target
- Two approaches being pursued:

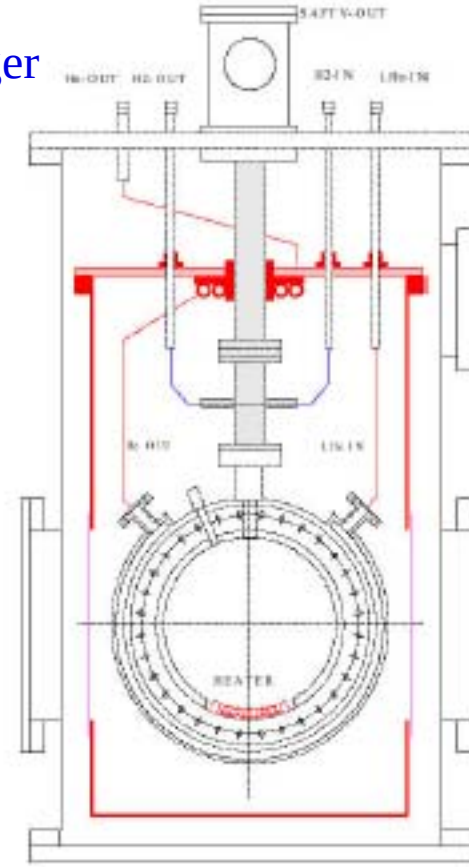
IIT/NIU: Forced-flow absorber with external cooling loop



KEK/Osaka: Convection-cooled absorber with internal heat exchanger



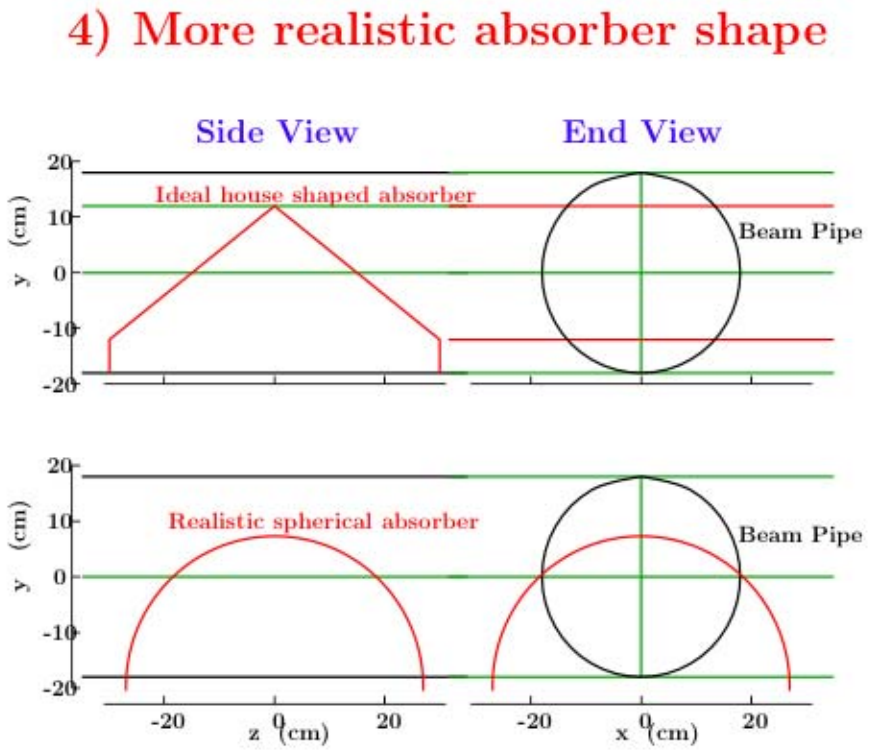
Array of heating wires



- Power-handling limit yet to be established for either approach

Ring-cooler wedge-absorber power handling

- Palmer estimates ≈ 5 kW in RFOFO-ring absorber (4-MW Proton Driver)
- Design approach: hemispherical dome extending halfway into beam:



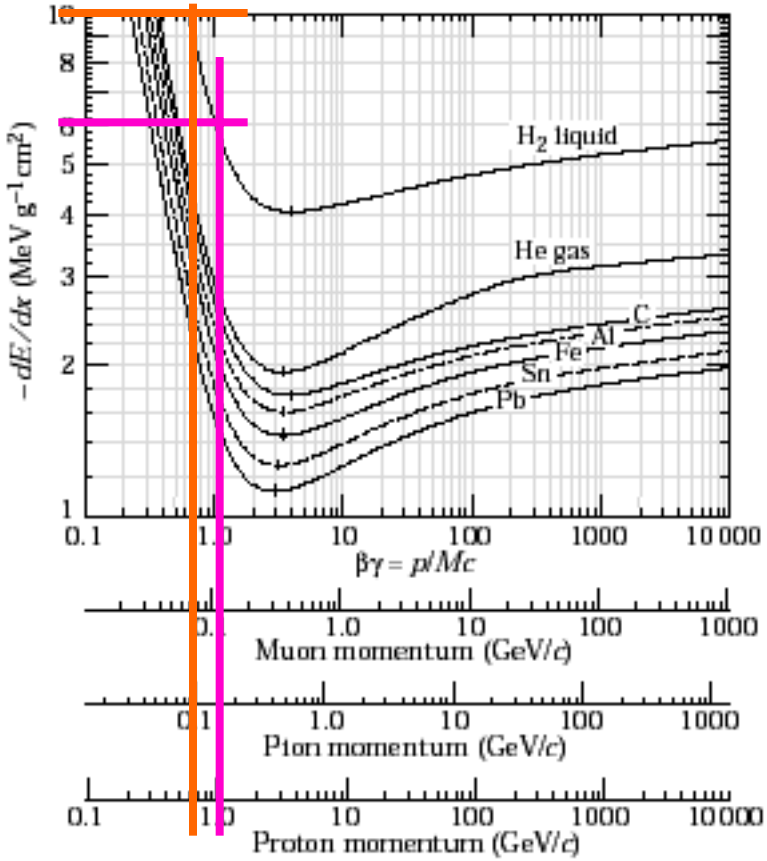
[From Palmer talk at MuTAC Review, Fermilab, 14-15 January 2003]

- Palmer suggests 125-μm-thick AlBeMet windows
  - degrade cooling performance ≈ 5% w.r.t. no windows
  - rated at only ≈ 7 psig vs. FNAL requirement that MAWP ≥ 25 psig

→ Can 5 kW be safely dissipated in such a "sub-atmospheric" absorber?

Testing absorber power handling

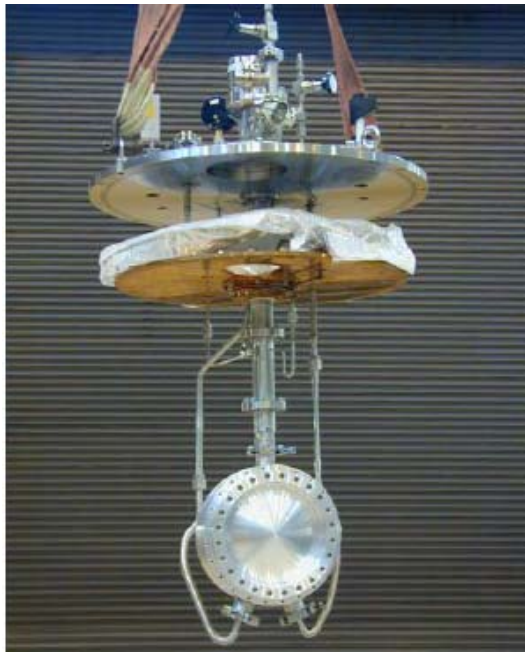
- MuCool Test Area:
  - 400 MeV beam up to 2.4×10^{14} p/s → 570 W in 35-cm LH_2 absorber



  - E = 400 MeV + 938 MeV ⇒ p = 950 MeV/c ⇒ $dE/dx \approx 1.5 \times dE/dx|_{min}$
  - Can perhaps ≈ double this by lowering Linac energy
- Hope for MTA beneficial occupancy ≈Fall ’03
- Install LH_2 cryo & 201-MHz RF power in FY04, beam-line a year later (if funding permits)

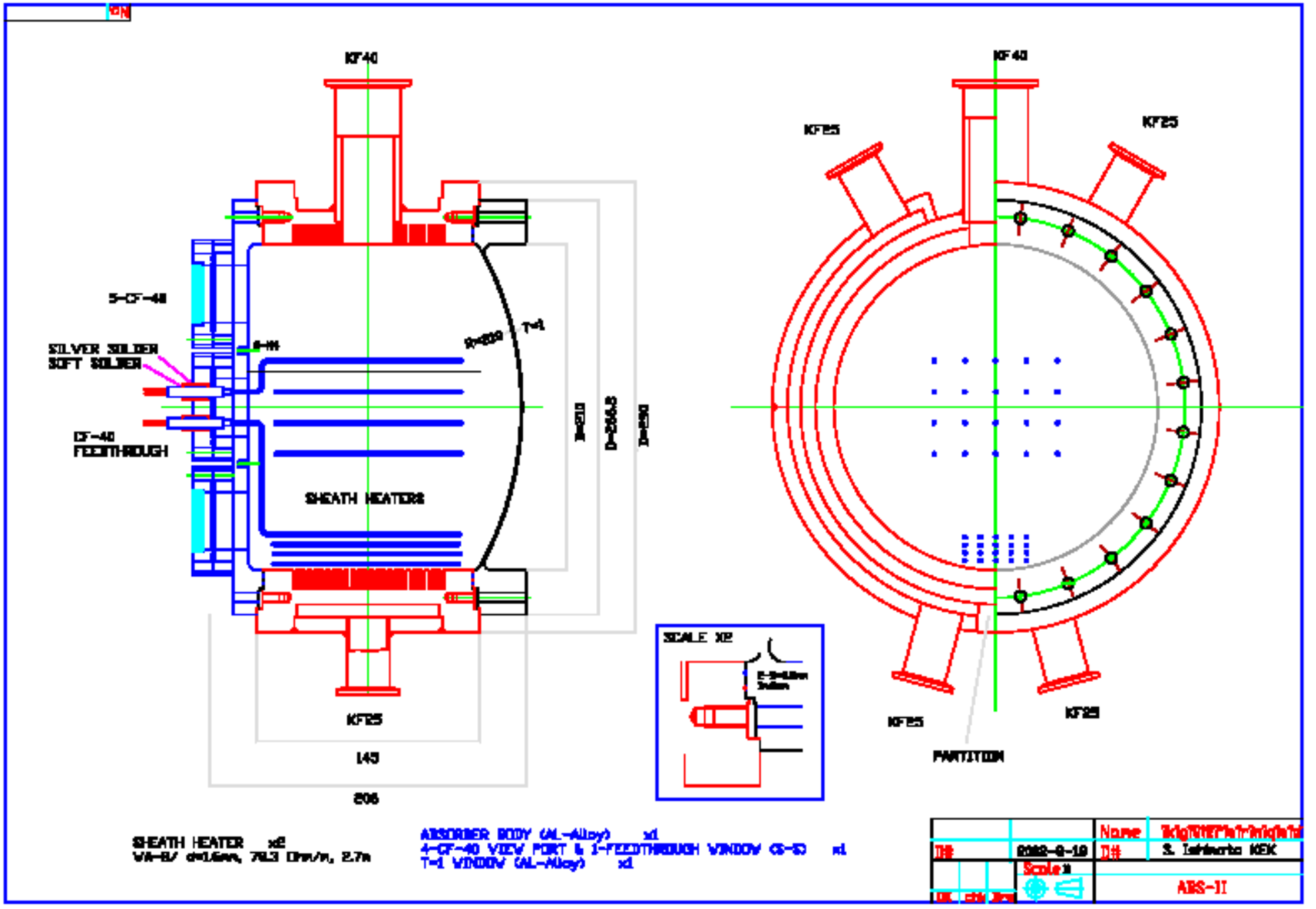
Near-term test?

- Due to stringent safety requirements at KEK, tests so far have used neon



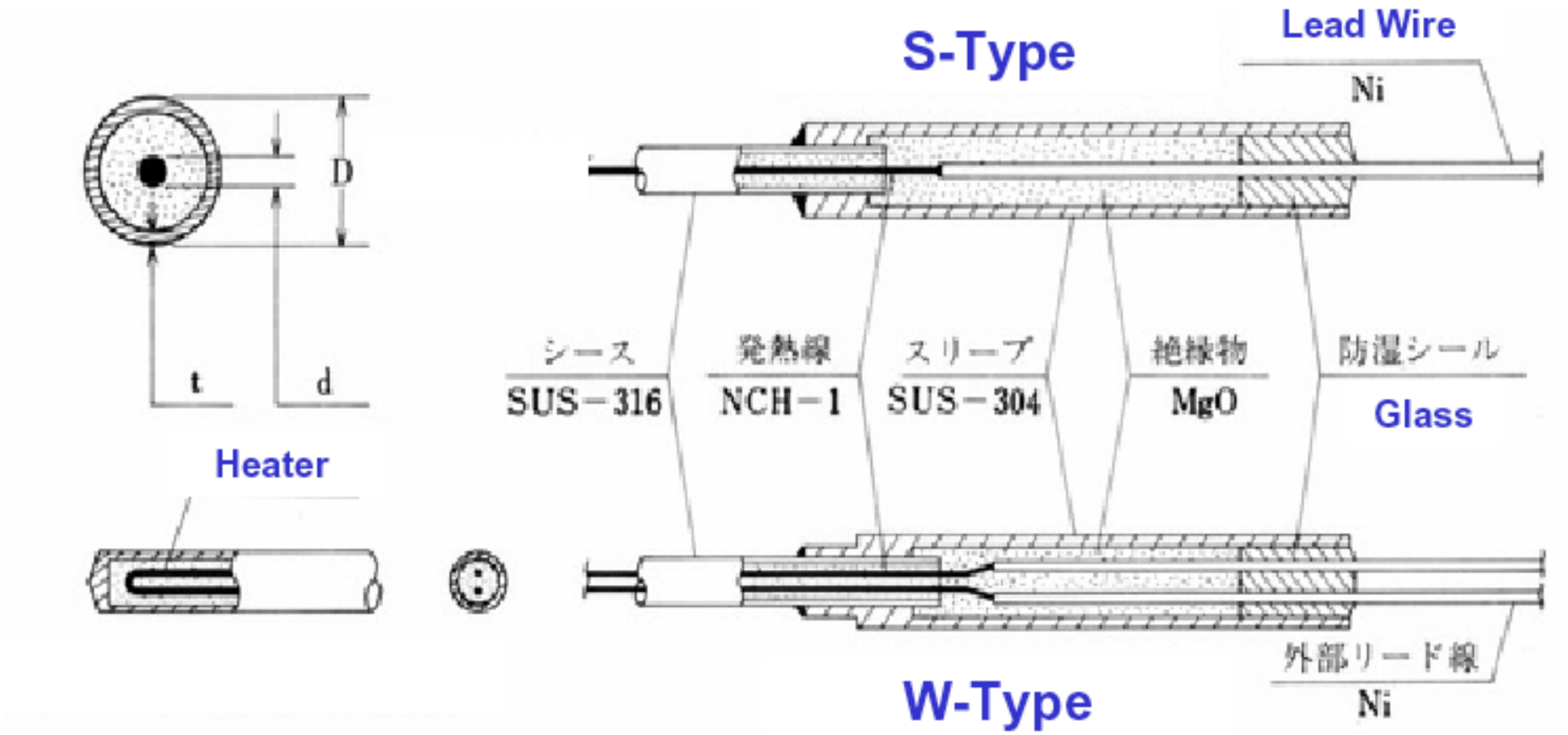
- We need to test power handling using LH_2
  - early test highly desirable in light of 2-year investment (to date) of US-Japan funds
- MTA beam test planned but not before FY05
- KEK LH_2-capable prototype to be shipped to FNAL by this summer
- Cheap, simple, safe, quick test possible at Meson Cryo parking lot (Norris)

“Absorber II” prototype (under construction at KEK)



Safety concern: How heat the hydrogen?

ABSORBER II -- SHEATH HEATER



- Not yet established whether this approach can meet safety guidelines
- If not will need to work out another solution
  - heat windows electrically / optically / “hot” fingers / “warm” gas?

⇒ Do sheaths contribute to meeting safety guidelines, or is it sufficient to stay within a current-voltage envelope that prevents possibility of ignition?

Divide and conquer?

"Intrinsically safe" current–voltage limits:

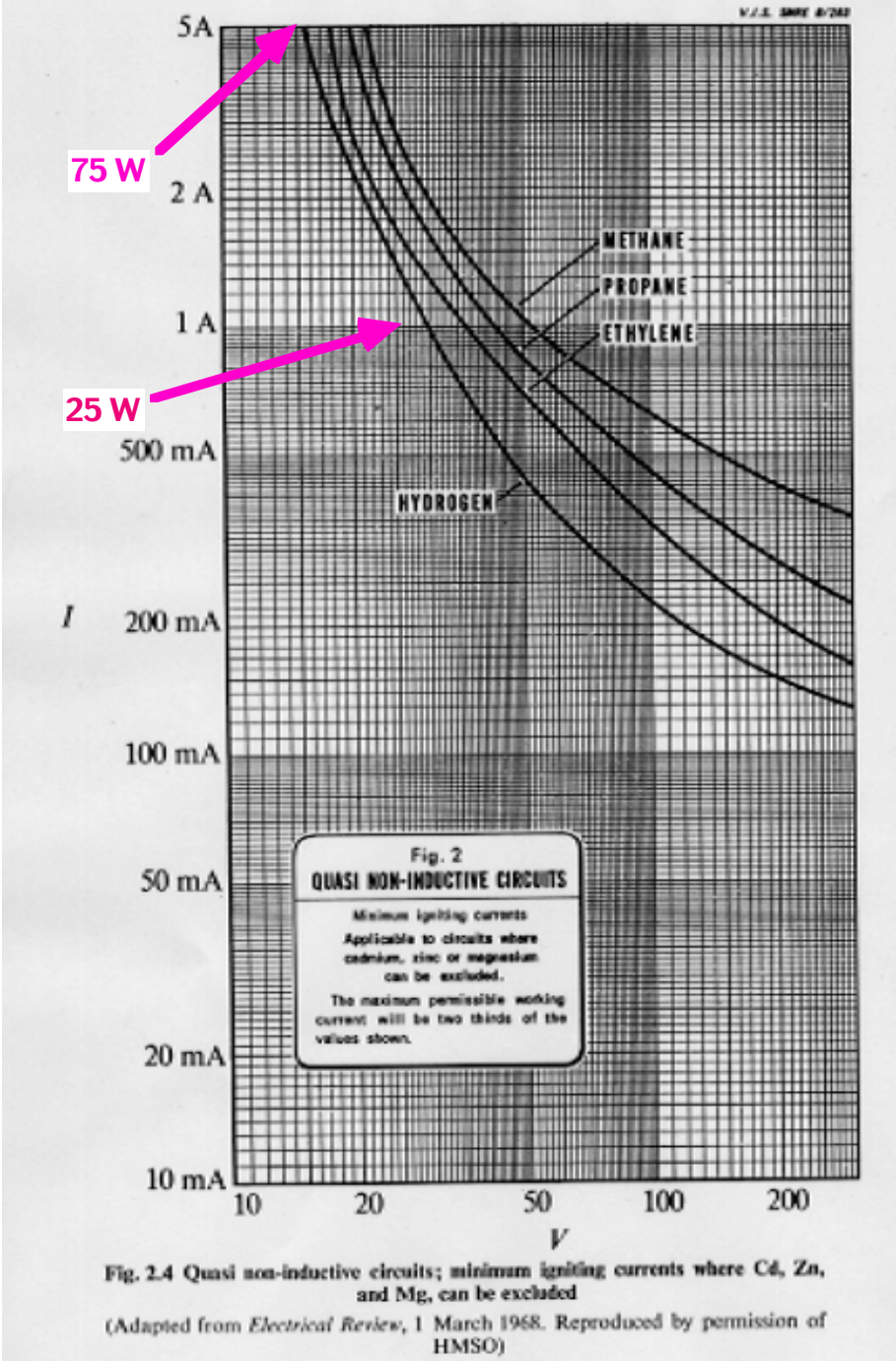


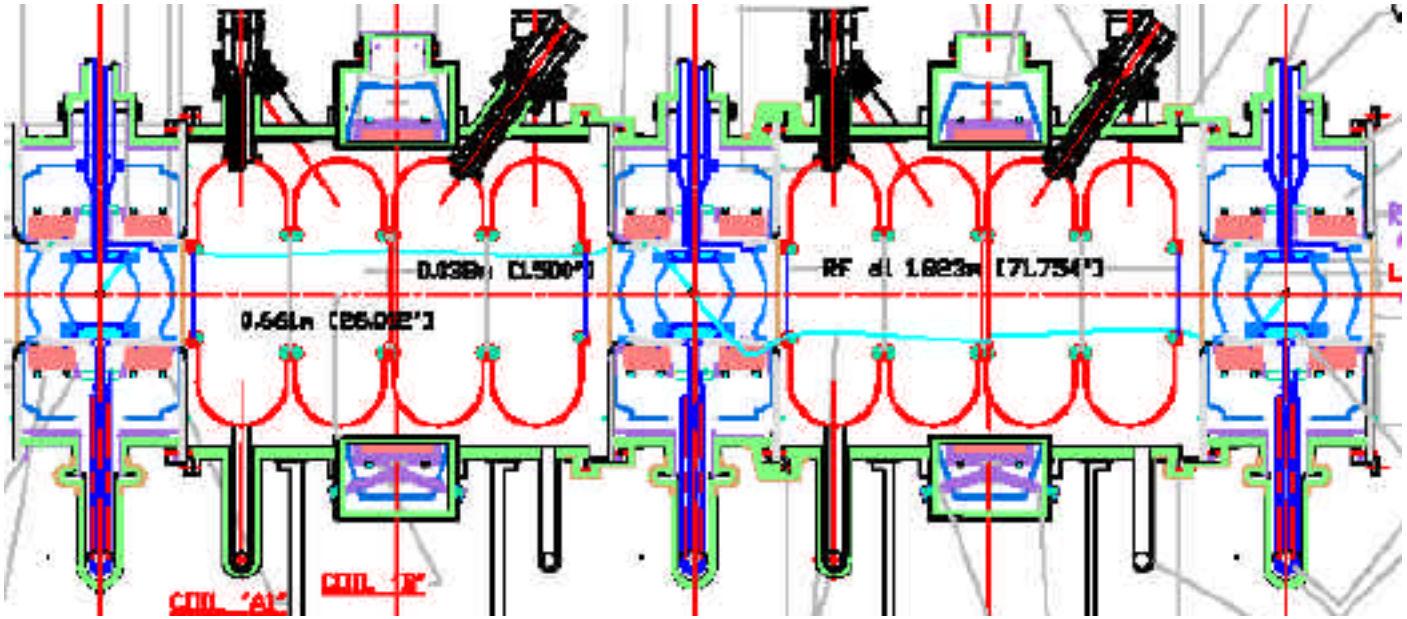
Fig. 2.4 Quasi non-inductive circuits; minimum igniting currents where Cd, Zn, and Mg, can be excluded

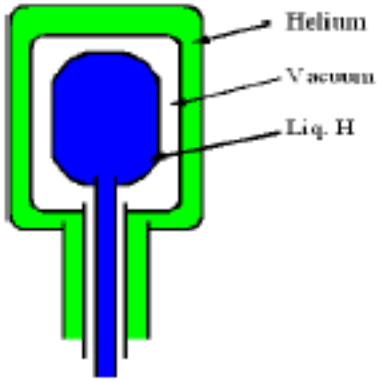
(Adapted from *Electrical Review*, 1 March 1968. Reproduced by permission of HMSO)

Is there a point (off the top of the plot) at which 100 W via 1 conductor pair meets "intrinsically safe" guidelines?

RAL safety issues:

- We have evolved from single to double windows:





ISIS LH2 Moderator

- RAL LH2 experience suggests triple containment
  - avoids undetectable “cryopumping” of O_2 (entering due to leaks) on cold surfaces
  - is this an issue for MTA and absorbers in general?
- We propose instead external argon sheath

Summary:

- Much progress in our understanding
- New conceptual developments (e.g. ring coolers) push us to consider higher power dissipation & thinner, stronger windows
- Experimental tests coming ever closer
- Forcing us to come to grips with nitty-gritty issues of safety & practicality
- Some questions we need to answer:

1. How optimize absorber fluid flow & heat transfer?
2. Are we ready to cut metal on next round of window development?
3. Are high-strength 2000-series alloys practical?
4. How heat absorber for “shakedown” test?
5. How cope with RAL cryopumping concern?
6. Is a ring-cooler LH_2 absorber feasible/effective?