Profile Monitor SEM's for the NuMI Beamline

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- Physics of Design:
  - Review of profile monitor requirements -- aperture, accuracy, losses, insertion
  - Data on aging of metals in beam -- Ti is promising (?)
  - Review of evidence for cause of aging -- if it's truly thermal then foils not a bad idea?
  - Conceptual design of foils with strips
- Conceptual Design:
  - Review of materials in the vacuum can
  - Review of materials for linear motion
  - Some rough costs of critical components
  - Drawings of custom items which drive costs
  - Interface to Accelerator Controls
- Engineering Design
  - Awaiting feedback from this review in order to proceed

Intro: Fermilab SEM's

- Thanks to Gianni Tassotto (RF&I?, I?) for tutoring and tour of their SEM's
- Essential features of Fermi SEM's:
  - W-Rh wires, Au plated (75 μm)
  - Ceramic circuit board with Pt-Ag solder pads for stringing wires
  - No clearing field applied
  - Frame is on all four sides of beam
  - Frame swings in-out like a door
  - SEM aging observed (signal decreased by 37% by end of KTeV run), but not studied.
- Issues to be addressed for NuMI
  - Insertion/removal during beam operations
  - Longevity of secondary emission coefficient of W-Rh/Au wires
  - Causes beam loss of order 6E-5 if have 1mm pitch

Building on Past Experience …

While our requirements are different from SEM's (multiwires) built elsewhere here at FNAL, the various ingredients of the SEM we want to explore are not different from instrumentation currently in use here and at other labs.

With time & budget constraints, we did not want to embark on an R&D effort. Thus, going with reasonably proven design choices was desirable.

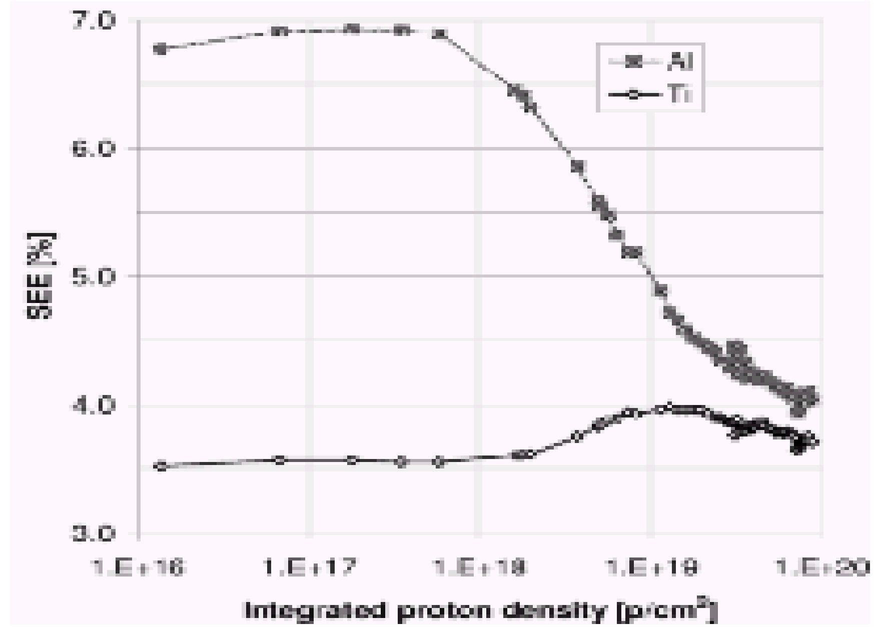
Specifically, you will find the proposed conceptual design has borrowed from:

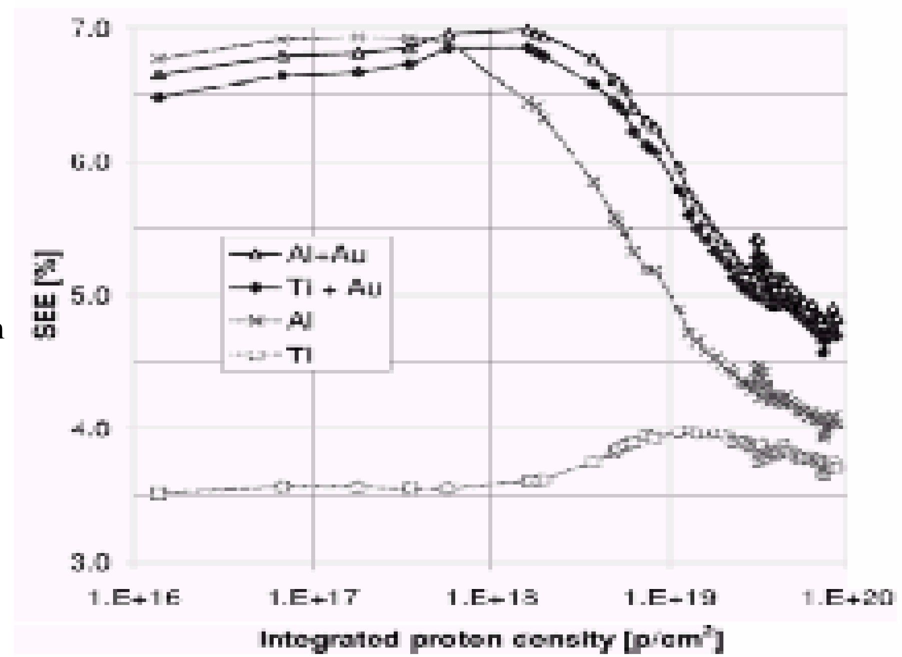
- Active element – 5 μm Ti foils — CERN (G. Ferioli)
- Motion Feedthrough (bellows) — LANL (D. Gilpatrick)
- Stepper Motor – Slow-Syn/Empire Magnetics — FNAL (G. Tassotto)
- Mechanical Travel – Nook ActionJack — FNAL (R. Reilly)
- Feedback – Schaevitz LVDT — FNAL (R. Reilly)
- Stepper Controls, Readback — FNAL (A. Legan)

With some modification, the design presented here might be of general utility.

Aging Effects in SEM's

- Secondary emission coefficient observed to drop after long exposure to beam
  - V. Agoritsas (CERN)
  - R. Witkover (BNL)
  - D. Garwin (SLAC)
  - M. Awschalom (FNAL)
- Eg: Aluminum drops to 20% of original value (from 7% to 1-2%) after 1E20 protons/cm^2
- Note central strip on NuMI SEM would see ~0.8E20 protons/year assuming 1mm pitch and σ_{beam}=1mm and 0.2mm wide strip
- Extensive studies performed in '60's-'70's
  - Oxide layers on SEM's
  - Even CO_2 surface layers important
- Elaborate process techniques to maintain clean foils
  - Handle only in Argon/N2 glovebox (see FNAL TM-0850, for example)
  - Bake under vacuum
  - Glow discharge in 0.1Torr Argon
  - Best 'Golden SEM' lasted to 1E20 p/cm2 with 'no degradation'
- Effect is also tied to beam heating of SEM
  - Observed 'dimpling' of surface on damaged SEM's
- Plots at right are recent results from CERN
  - Foils only handled in air (no Ar)
  - Baked at 200C, but no glow discharge





Thoughts on alternative wire materials

Material	Z	X_0 (cm)	λ_{int} (cm)	SEE (%)	Propose wire/foil	Thickness (μm)	Beam Loss	Comments
Be	4			?				Biohazard ⇒ machining very unattractive
C	6	8.3	38.1	2-2.5	wire	33	2.9E-6	Withstands high temp (LANL), SEE measured by G.Ferioli (CERN), but long-term behaviour in beam?
Al	13	3.3	39.3	~7	Foil	5	2.5E-6	Can't solder, ages badly in beam
Ti	22	0.78	27.5	3.5	Foil	5	3.6E-6	Best known aging properties!
Ni	28			3-5?	Foil	10		Ages in beam (G. Ferioli)
W	74	0.02	9.6	?	Wire	75	6E-5	Breaks if wire is < 75μm (Gianni Tassotto)

- I'm not sure of beam losses purely go with interation lengths – radiation lengths??
- Beam heating clearly goes with Z
- Other labs have used Al, Au, Ag-Al, C, Ti, Ni
- Beam loss assumes σ_{beam}=1mm and 1mm pitch on profile monitor, and 0.2mm wide strips for foil detectors.
- Really want to avoid extensive R&D effort on choosing material.

Properties of alternative wire materials

Material	Z	k_{cond} (W/cm°C)	ρ (g/cc)	C_p (J/g°C)	Melting Point (°C)	CTE ($\times 10^{-6}$/°C)	Emissivity
Be	4	2.18	1.85	1.82	1278	12	??
C	6	0.24	38.1	0.69	3652	0.6-4.3	~0.8
Al	13	2.37	2.70	0.90	660	25	0.1
Ti	22	0.2	4.54	0.52	1660	8.5	0.1 – 0.2 ??
Ni	28	0.899	8.9	0.44	1453	13	0.1?
W	74	1.78	19.4	0.13	3410	4.5	0.1 (if gold-plated)

- Only carbon is a really good black-body emitter of heat from the beam, but Ti is probably a better-than average metal.
- Ti unfortunately does not do real well at conduction through wire
- Ti, Al, C have respectable heat capacity. W has a poor heat capacity.
- Ti expansion under heat will be larger

Wire Heating

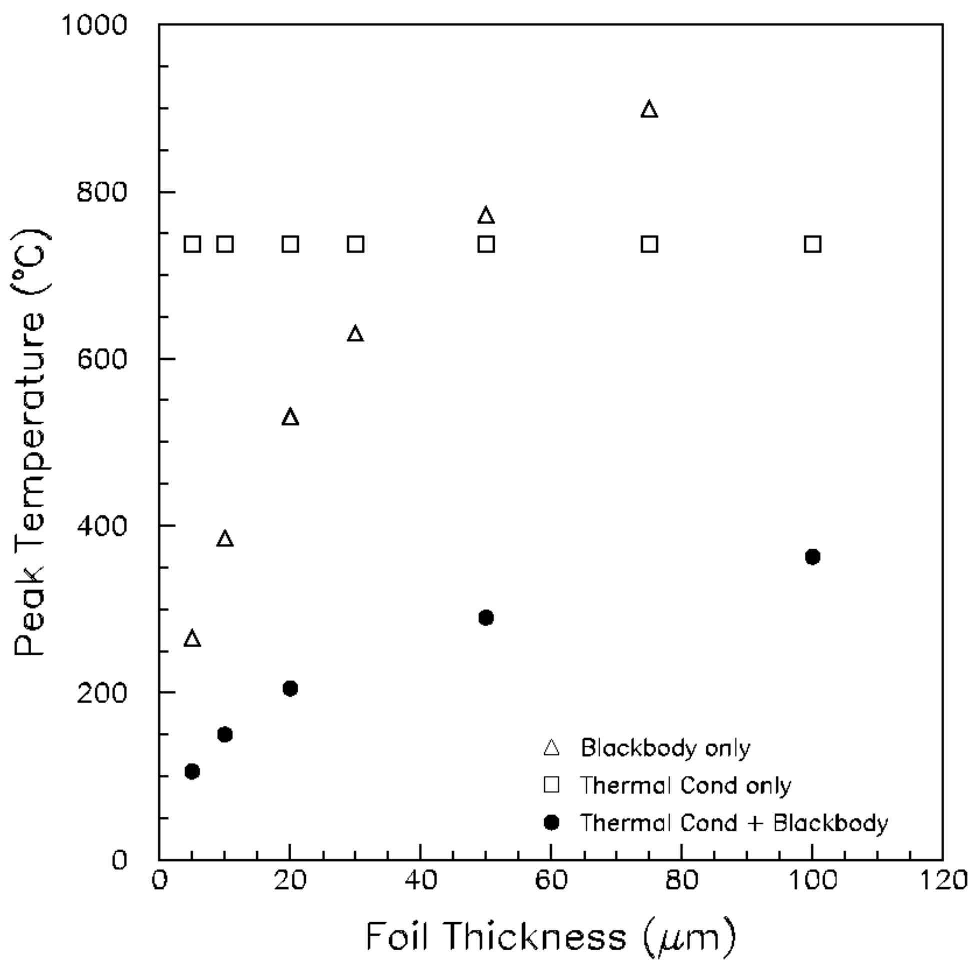
- Wire heating grows with ***volume***
  - For round wire:
    - Wider wire intercepts more beam -- goes like ~r
    - dE/dx dumped into wire grows – goes like ~r
  - For flat foil
    - Wider foil intercepts more beam – goes like width
    - dE/dx dumped in goes like thickness

- Blackbody cooling grows with ***surface area***
  - Gas cooling assumed nil
  - Blackbody radiation goes like surface area ~ *r* (Emissivity of bare Aluminum is poor ~ 0.1)

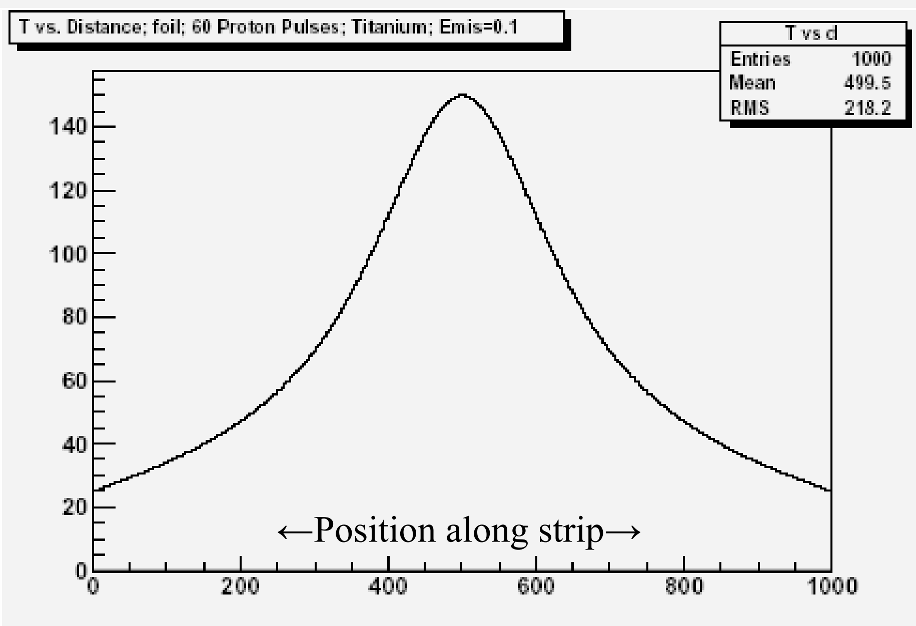
- Conduction to the ends grows with ***cross-sectional area***
  - But note many materials have poor thermal conduction (in W/cm-°C)
  - Don't expect this to be dominant heat loss.

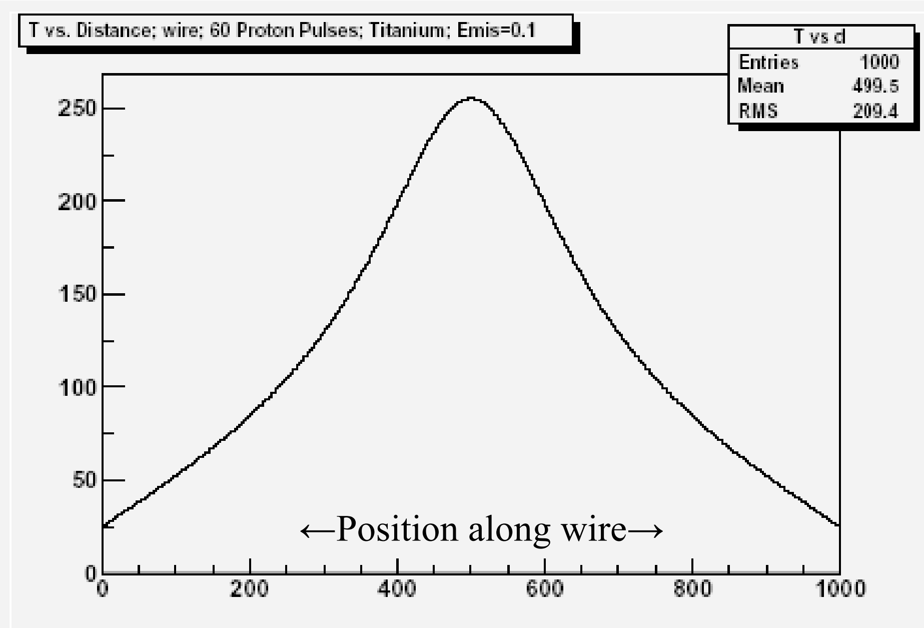
- Suggests that surface to volume ratio is critical
  - Wire surface/volume ~ 2/r
  - Foil surface/volume ~ 1/t

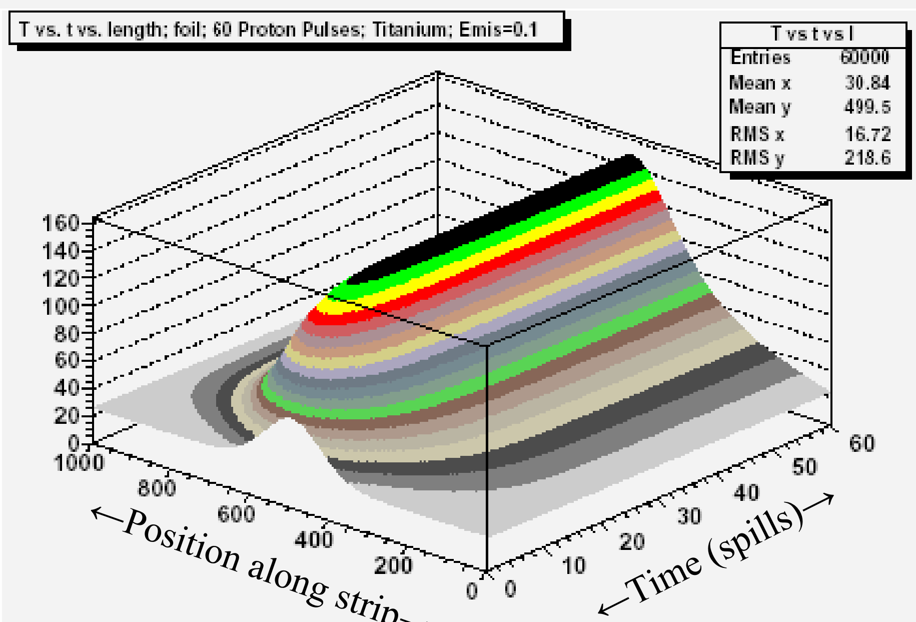
- Crude thermal model of Titanium foil.
- $\sigma \sim$ 1mm beam at 4E13/pulse every 1.9 sec
- Assumed $\varepsilon = 0.2$, $k_{cond} = 0.2$ W/cm°C
- Assumed 0.2mm wide strips at 1mm pitch

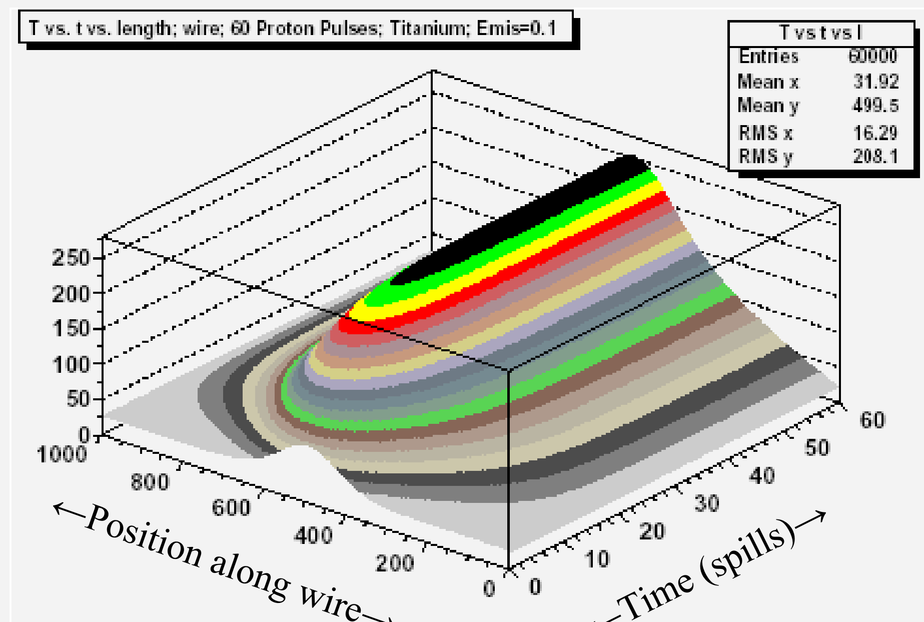


Foil *vs.* Wire?


T vs. Distance; foil; 60 Proton Pulses; Titanium; Emis=0.1
T vs d
Entries 1000
Mean 499.5
RMS 218.2
0 20 40 60 80 100 120 140
0 200 400 600 800 1000
←Position along strip→

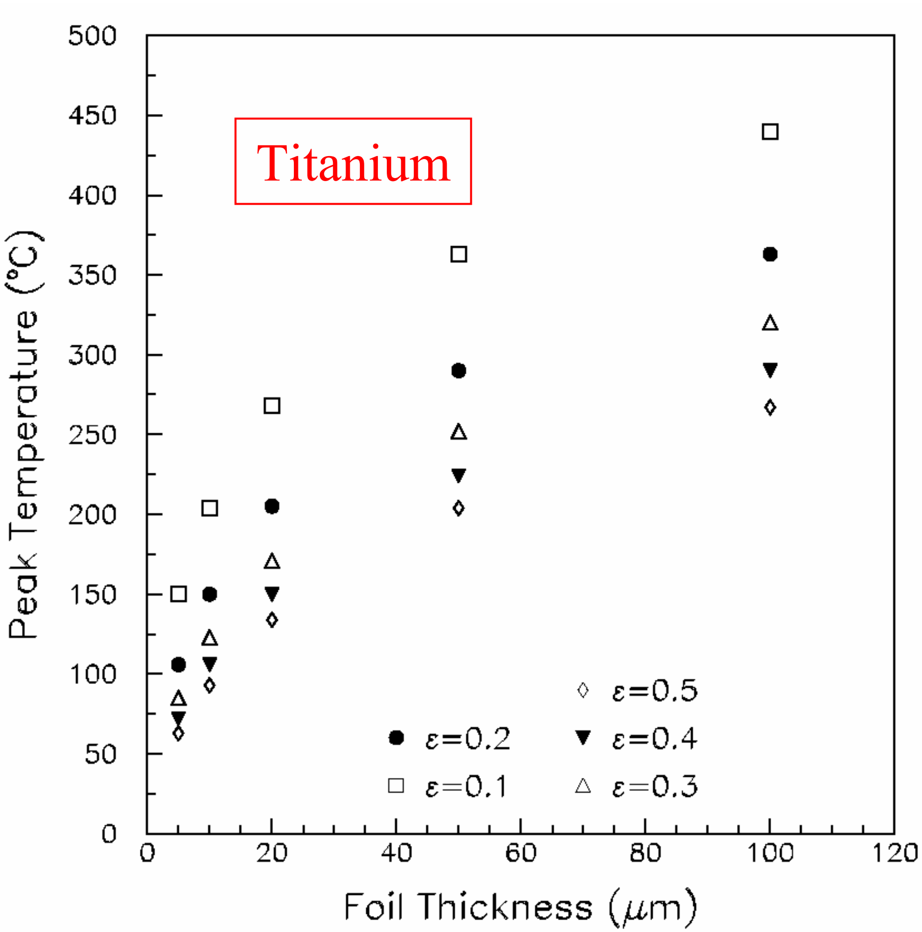

T vs. Distance; wire; 60 Proton Pulses; Titanium; Emis=0.1
T vs d
Entries 1000
Mean 499.5
RMS 209.4
0 50 100 150 200 250
0 200 400 600 800 1000
←Position along wire→

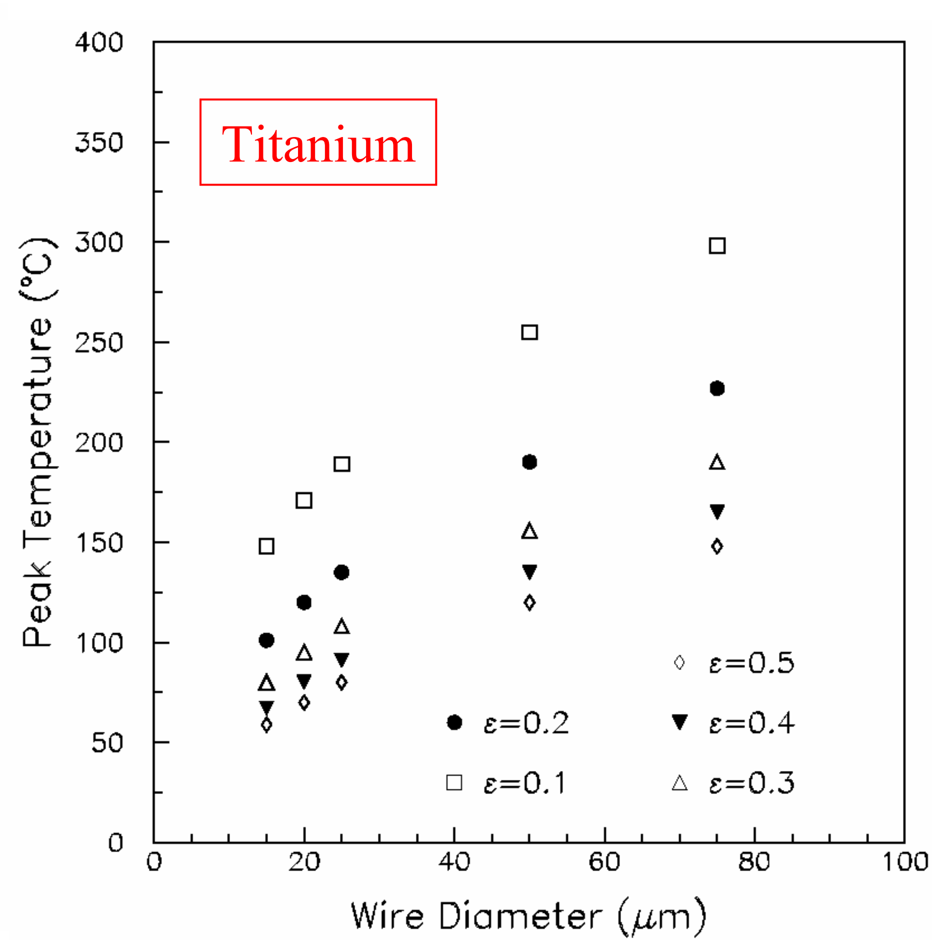

T vs. t vs. length; foil; 60 Proton Pulses; Titanium; Emis=0.1
T vs t vs l
Entries 60000
Mean x 30.84
Mean y 499.5
RMS x 16.72
RMS y 218.6
0 20 40 60 80 100 120 140 160
1000 800 600 400 200 0
0 10 20 30 40 50 60
←Position along strip→
←Time (spills)→


T vs. t vs. length; wire; 60 Proton Pulses; Titanium; Emis=0.1
T vs t vs l
Entries 60000
Mean x 31.92
Mean y 499.5
RMS x 16.29
RMS y 208.1
0 50 100 150 200 250
1000 800 600 400 200 0
0 10 20 30 40 50 60
←Position along wire→
←Time (spills)→

Foil *vs.* Wire?

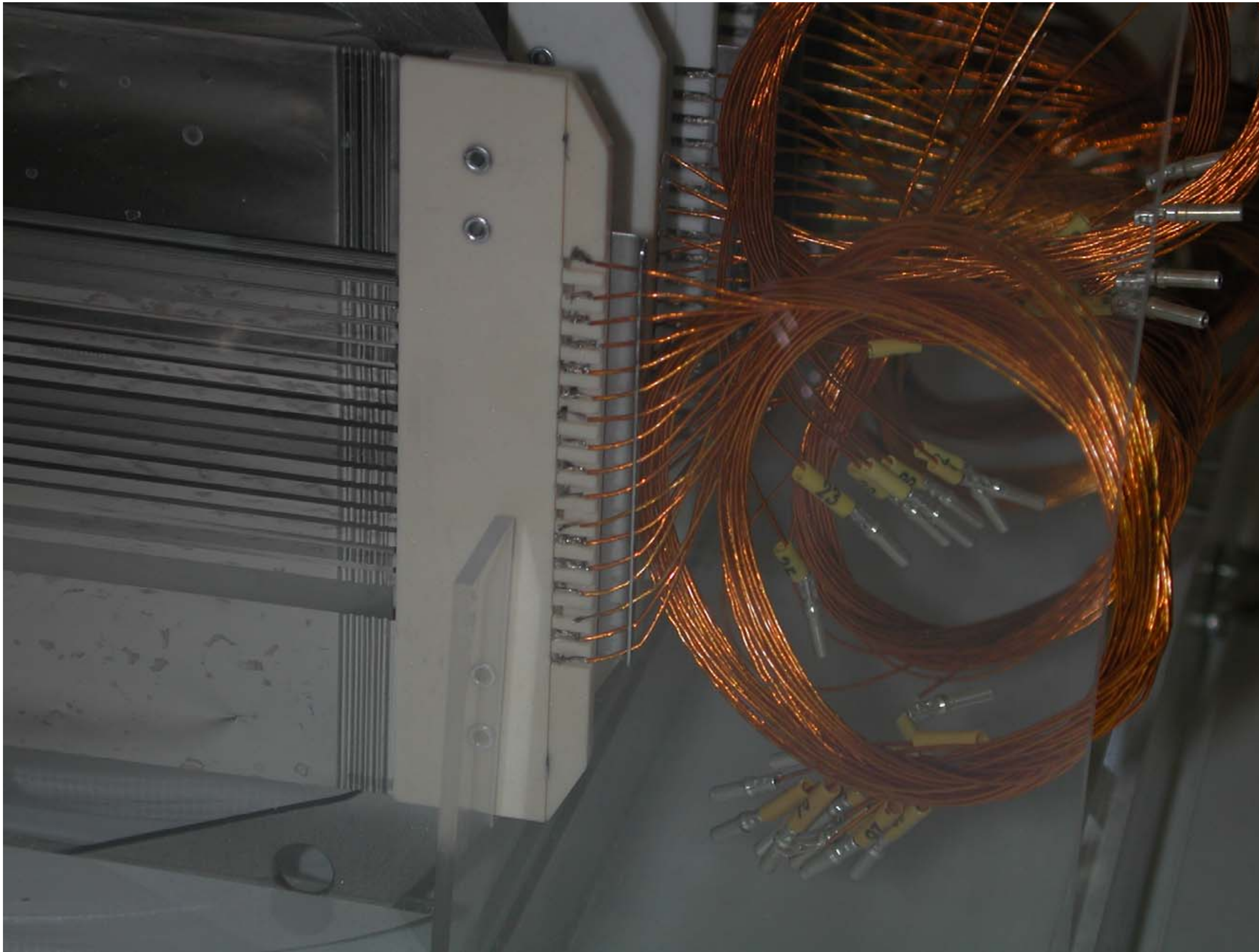
- To keep interaction lengths equal the following are "equivalent"
  - a 50 μm Ø wire
  - a 0.2mm wide, 12.5 μm thick foil
- Flat foil is more efficient at ridding itself of heat, and furthermore foil technology permits pushing the size down more (benefits both beam loss and heating/longevity of SEM).

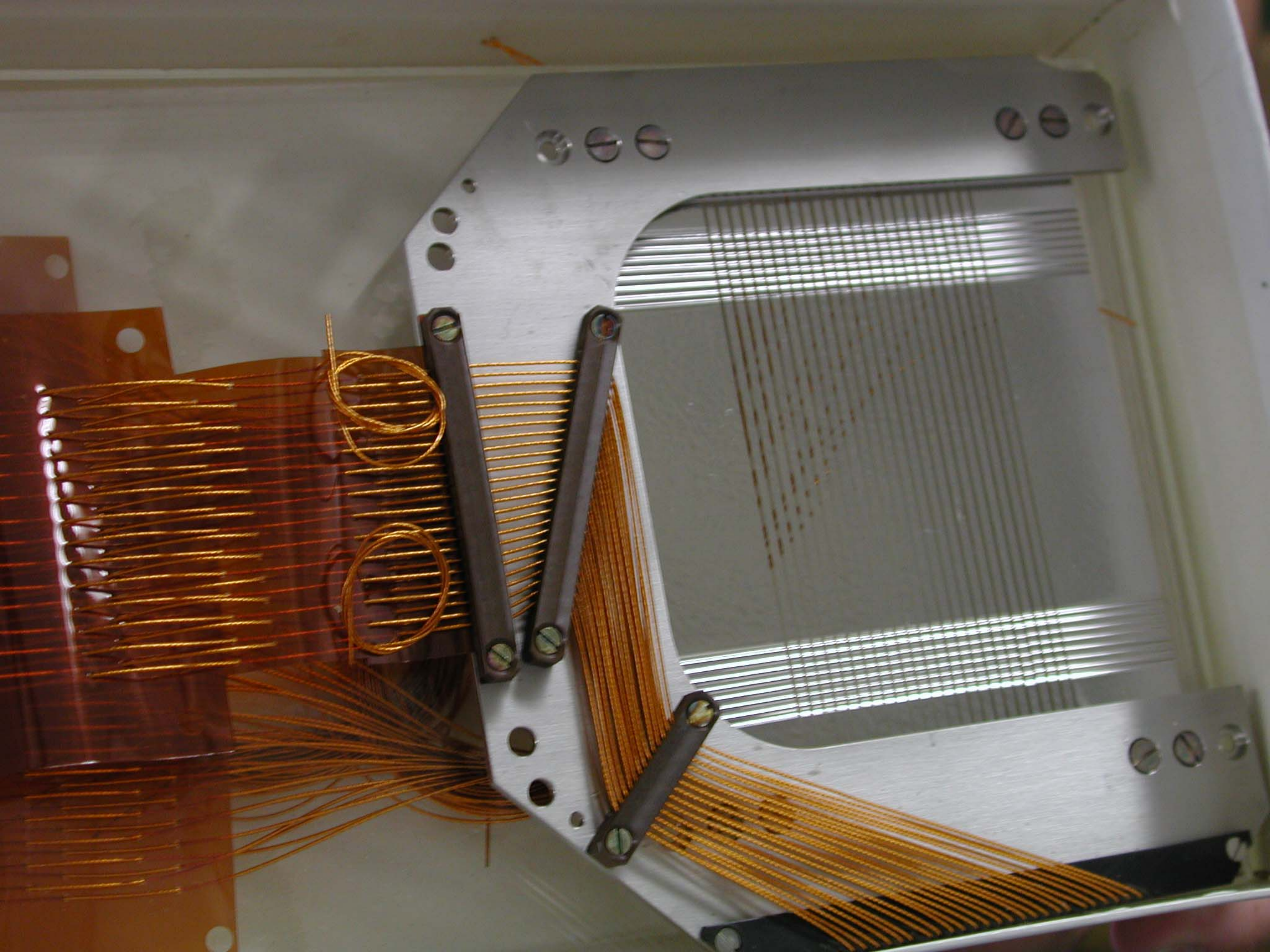




CERN: SEM foils

J.Camas, G.Ferioli, R.Jung





Linear Motion

- LANL, CERN, SLAC all use linear insertion of SEM's and wire scanners
- Shown is photo from LANL halo scraper
- Want to keep as much out of vacuum chamber as possible
  - Limit switches
  - Stepper motor
  - Bearings for lead screw
- Note no bearings inside vacuum; sliding contact only
  - 'lubricate' with PEEK on stainless contact
- KEY POINT:

  Linear insertion of SEM into beam also allows centering new wire onto beam at different time intervals (age all wires equally to avoid dips in SEE)
- Drawback to linear motion
  - Less obviously achieves reproducibility specification of 50 μm
  - We simply have to prototype it and demonstrate accuracy
- LANL swears by this set-up, and we would like to investigate reproducing it, testing it with survey

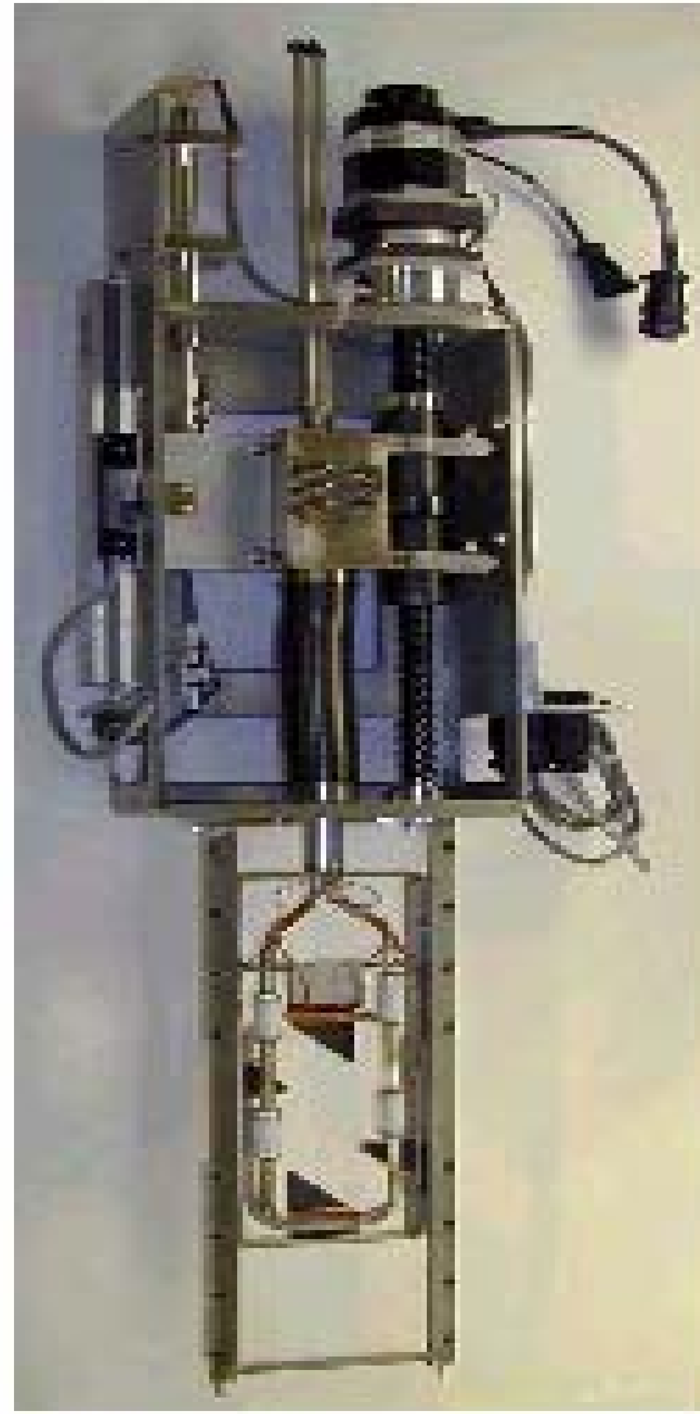
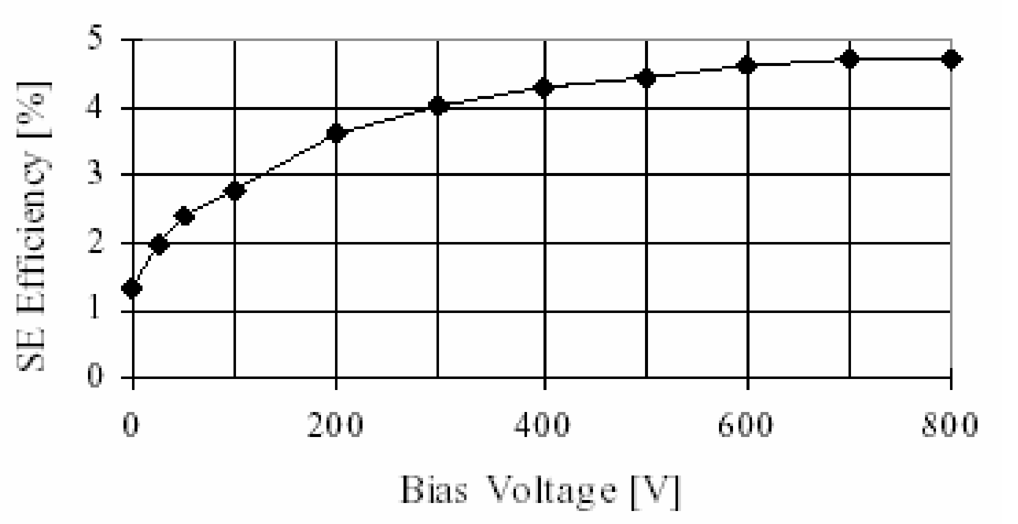


Photo from Gilpatrick, Valdiviez et al (LANL), PAC2001 proceedings

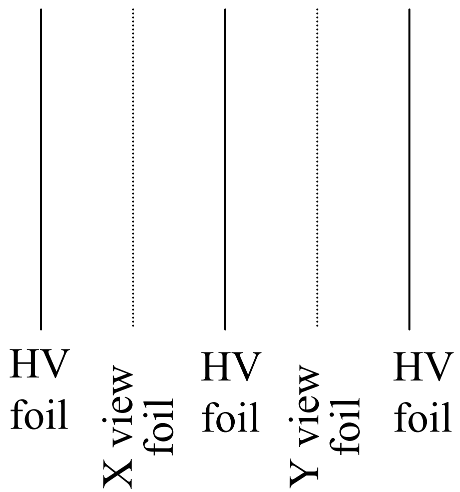
Clearing Fields



- Many SEM's have signal strips at ground, HV foil on either side to draw electrons off signal strip
  - ~1/2 of electrons observed by Agoritsas and Budal to have *E* < 20 eV
  - SEE observed to increase by factor of 2-3 with 100-200V/cm clearing field
- At FNAL, this has not been always employed
  - Signal levels already sufficient
  - No observed peculiarities with beam intensity
- However, FNAL SEM's used most typically in either slow (~1 ms) extraction or fast extraction (~1.5 μs) up to 4-5E12 ppp (Booster batch)

- Plot above shows effect of HV bias on SEE of Aluminum in CERN SPS fast-extracted beam, 1E11 protons/pulse (*G. Ferioli, J.Camas, CERN-SL 95-62 (BI), reported at DIPAC'95*).

Clearing Fields and Signal Stability



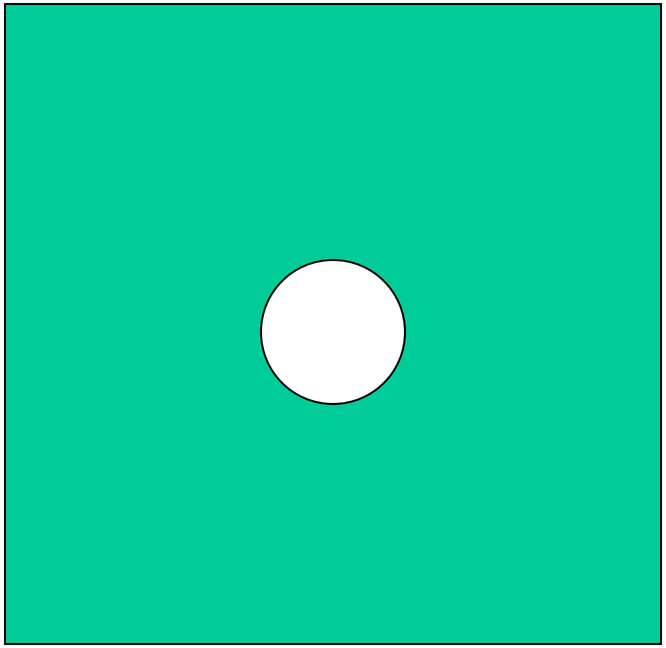
- CERN experience is that fast extracted beams from the SPS develop space charge effect that reduces signal and causes signal instability
- They use clearing fields to prevent artificial enlargement of beam width, extraneous variations of beam parameters pulse-to-pulse which did not track with other instrumentation.
- It seems that these effets arises at a beam intensity beyond what could have been easily tested here at FNAL

- At CERN, they claim they can get away with following:
  - 1E13 ppp in slow (5 sec) extraction requires ~30-50V bias on HV foils
  - 1E10 to 1E11 ppp in fast extraction also needs only 30-50V
- For fast extraction an 2E13 ppp, bias foil must be 200V to get same secondary emission coefficient.
- If no bias used in fast extraction at 2E13, they observe
    - severe drop in signals which are *not* stable in time
    - the apparent beam position is OK
    - The beam profile (width or σ) is not stable spill-to-spill
  - Supposition is that a space charge effect from the beam itself arises -- causes loss of electrons from SEM

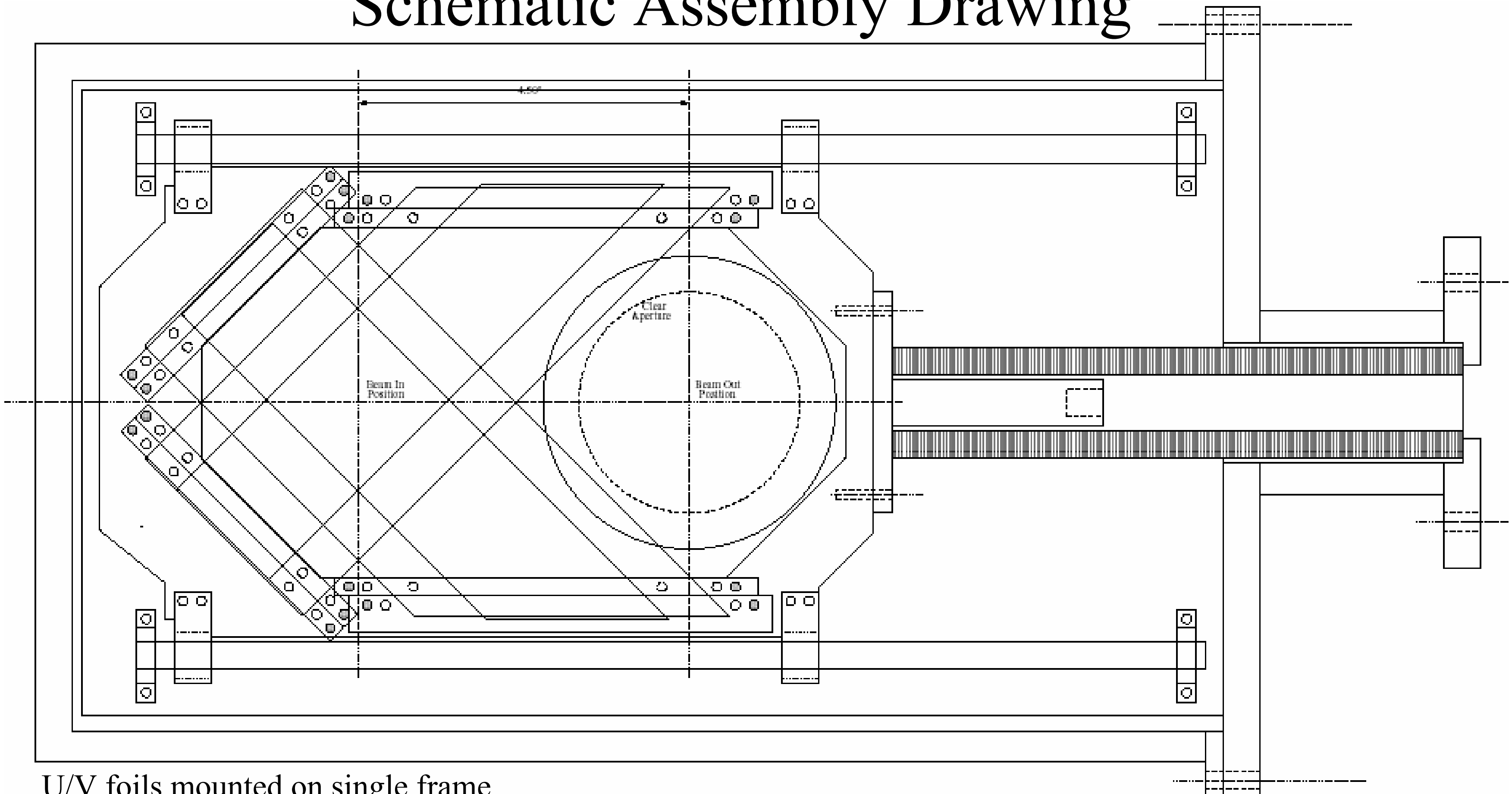
- ***CONCLUSION: use of clearing foil prudent, but its utility will be hard to test directly at FNAL before NuMI***

HV Foils

- In principle HV foils add more material in beam
- A 5 μm Ti foil covering 100% of the beam aperture corresponds to ~1.8E-5 beam loss
- At CERN they solve this by cutting a hole in HV foils allowing ~90-98% of beam to pass through.
- No 'appreciable' loss of signal observed at CERN if have 12mm hole in an HV foil 12mm away from the signal plane
- This is something we'd like to verify with a test (compare different planes with different hole diameters).



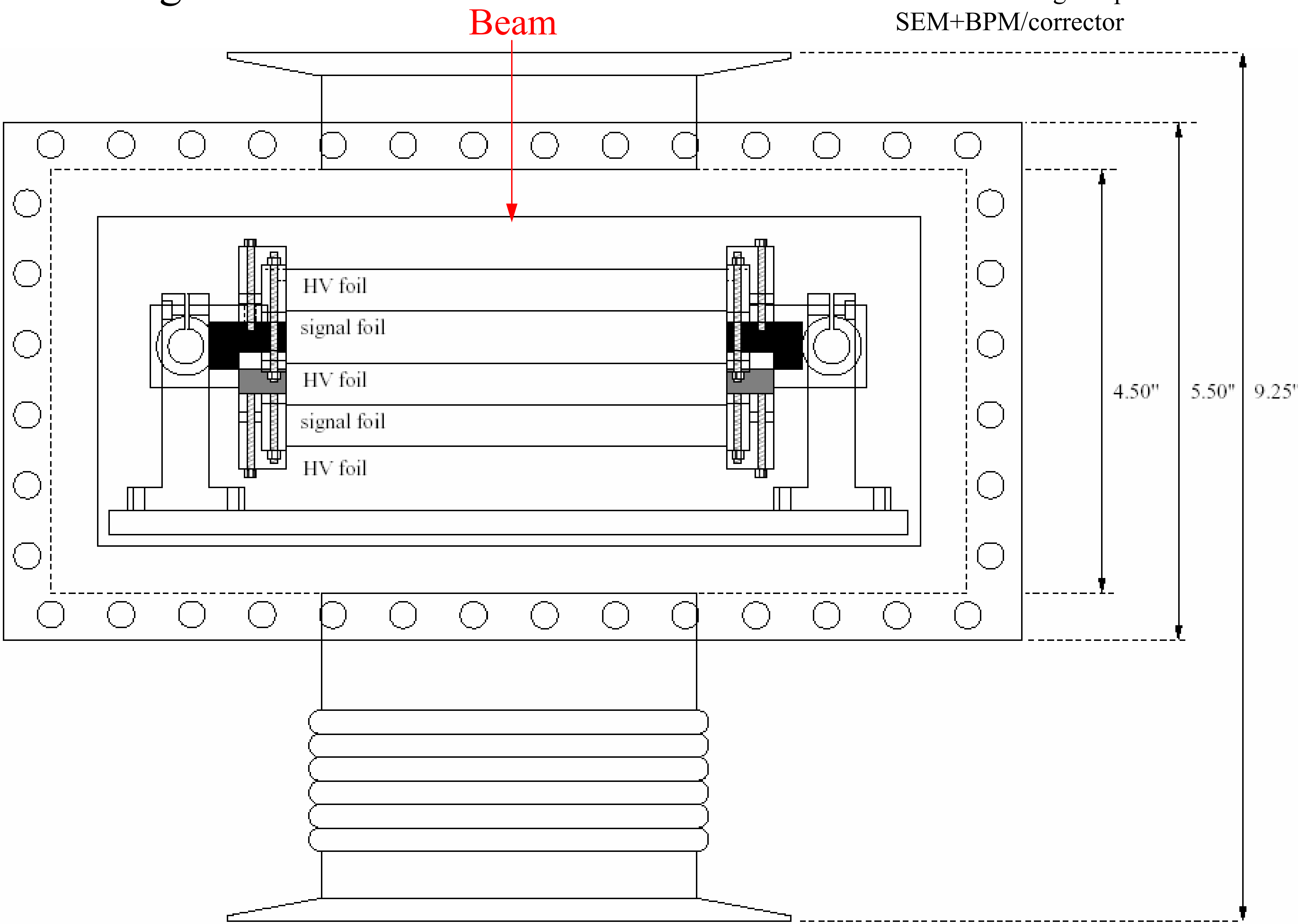
Schematic Assembly Drawing



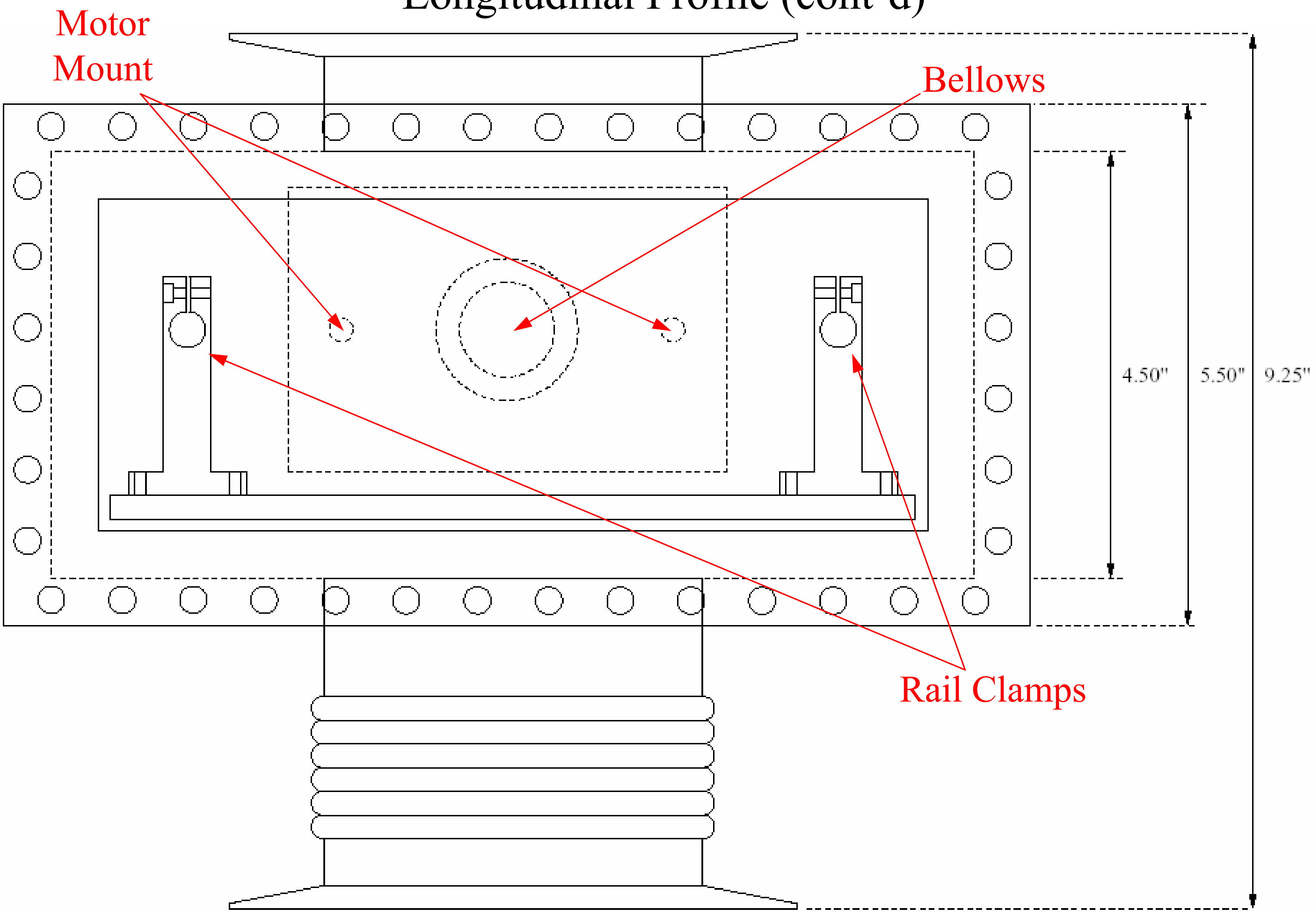
- U/V foils mounted on single frame
- Each foil 44 strips @1mm, 0.6” halo foil
- Ceramic clamps to hold foils
- 3” clear aperture, no massive components inside 4”
- 4.5” travel to go from beam-out to beam-in
- Vacuum can interior is 15.5” x 8.5” (beam direction is 3.5”).
- Lid to vacuum can has Aluminum wire seal similar to beam monitoring chambers.
- Lid has tray welded to it that supports rails (hence frame with foils)
- Simple bellows feedthrough + central pin to guide it and prevent buckling.
  - Always bearing atmospheric pressure ~ 20lbs
- Motor, leadscrew exterior to vacuum can
- Swapping failed profile monitor requires removing lid, not vacuum can.

Longitudinal Profile

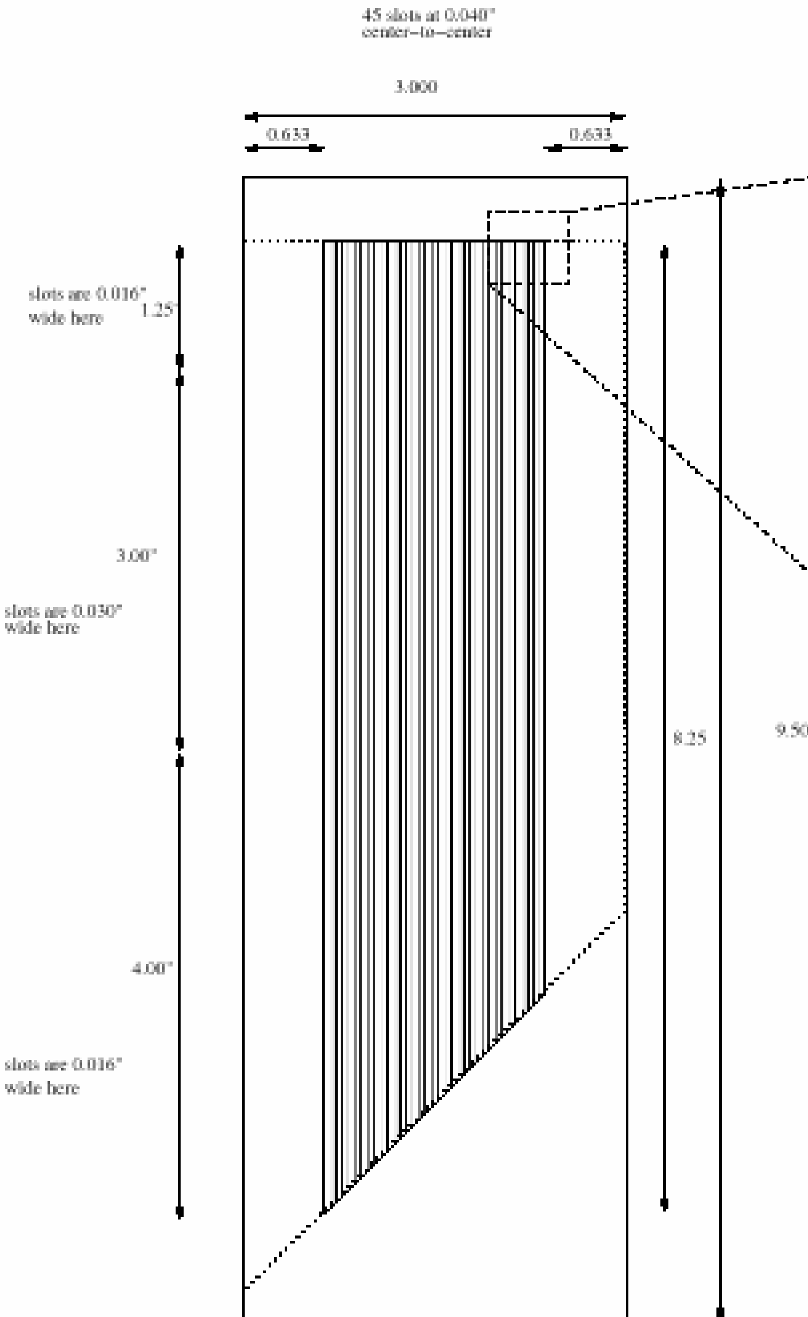
- It is desirable to make our SEM's <10.5" to fit regular pattern of SEM+BPM/corrector

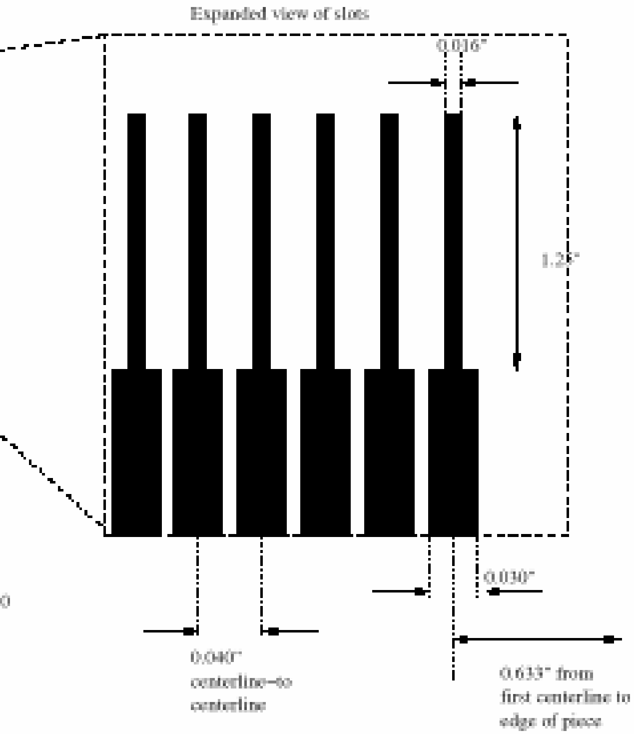


Longitudinal Profile (cont'd)



Foil Specifications





- Have searched for Grade I or II Titanium (same as used at FNAL in beam vacuum windows)
- Thickness of 0.0002” (5 µm)
- Typical tolerance on this is +- 50%!

- Vendors
  - Group Arnold (IL) -- 100 ft (4”) for $3,500
  - Hamilton Precision Metals (PA) -- 100 ft (3.25”) for $4,450
  - Goodfellow (UK) -- 30 m (100mm) for $21,000.
  - Metalmen (NY) -- 100 ft (3.75”) for $5,000

- Seems ~10-20% of material may have pin-hole defects at this thickness

Foil Cutting

1) Laser cutting

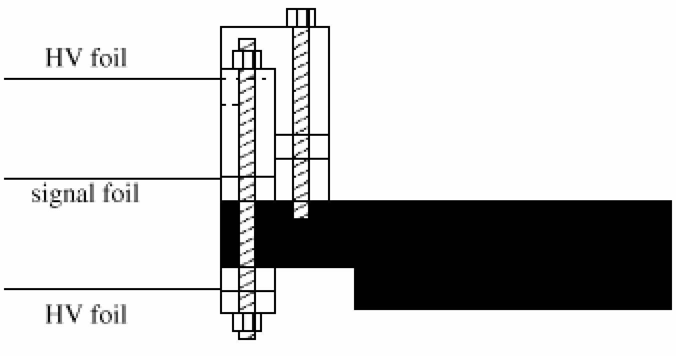
- Much less mechanical handling of part
- Sometimes have "burr" on back side of part where laser beam exits piece (has to be brushed or cleaned off)
- Burr-ing thought to be less worrisome for this 0.0002" thickness
- Typical tolerance ~ 0.0005" on mechanical dimensions
- Spectralytics (MN) quotes $60 / foil

2) Chemical Machining / Etching

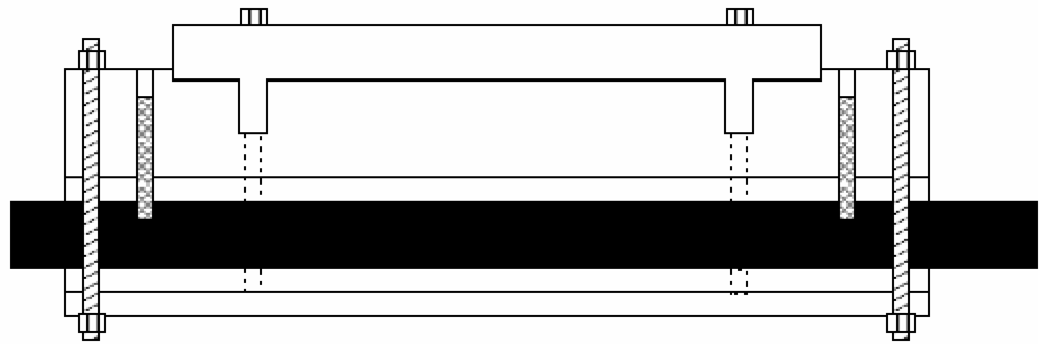
- Requires extensive mechanical handling (cleaning of part prior to photo-resist, application of photo-resist product, cleaning of part after machining)
- Exquisite tolerances (~0.0001")
- Most companies cannot, however, cut Titanium due to scarce available etchants (HCl acid only viable one)
- KEMAC Technologies -- $150 / foil
- Vaga Industries -- $115 / foil

Ceramic Clamps for Foils

Side View



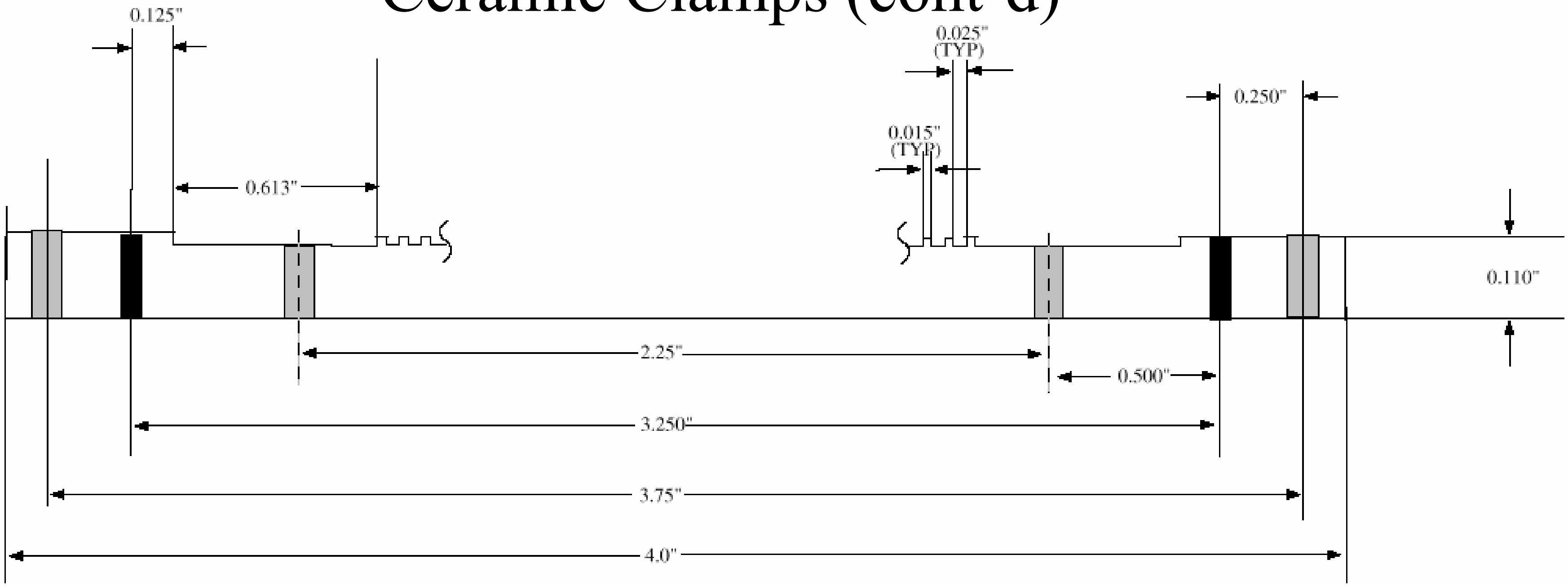
Front View



- This shows only one of two signal foils
- Second signal foil uses similar on reverse side of frame (must be mounted on 0.30” standoffs to maintain spacing to middle HV foil)
- Slotted signal foil held by compression of ceramic (foil snakes through gap in rear ceramic pieces so is crimped between 1st and second row)
- HV foil held by ‘tooth’ in upper ceramic part (corresponding holes cut in HV foil)

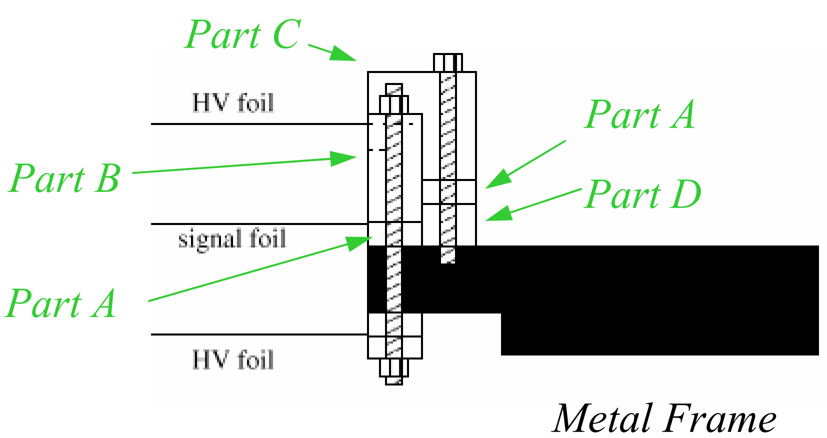
- Signal foil positioning requires accuracy so ceramic positioned by dowel pin
- HV foil position less critical so ceramic positioned only by screw mounts.
- Are nuts with spring washers adequate to maintain compression on ceramic clamps?
- Height of above ceramic pieces is ~ 0.95”, so total inside vacuum chamber beam dimension is about 2” + frame thickness + clearance to walls (1” each side) --> 5-6”.

Ceramic Clamps (cont'd)

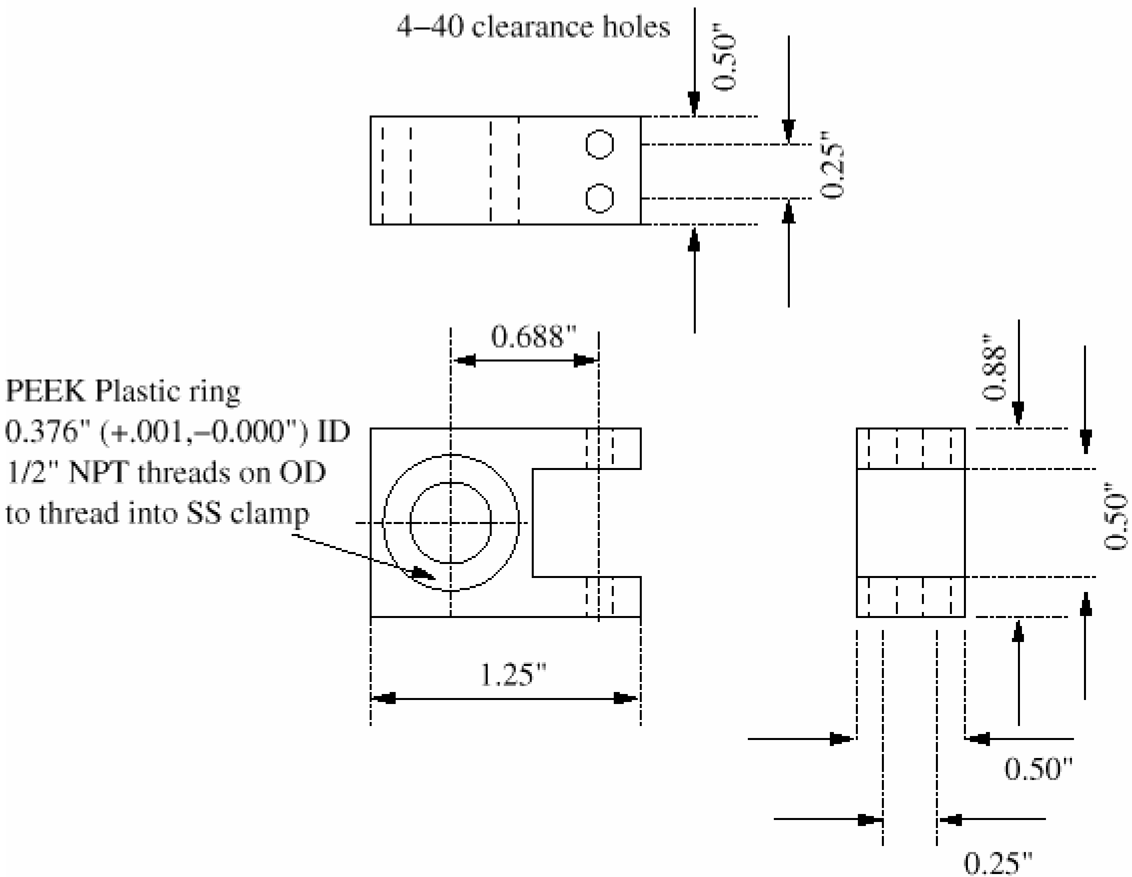


- Grooves in ceramic define profile monitor strip locations, separations
- Groove depths less critical (complementary teeth press part at bottom of groove)
- Obtaining quotations for laser-cut ceramic parts proving to be expensive
  - Part A -- $54 (need 2)
  - Part B -- $69
  - Part C -- $43
  - Part D -- $31

Total: $250 (one view)



Linear Motion Slides (inside vacuum chamber)



- Rely solely on 'lubrication' of soft component sliding over hard rail (rail either stainless or carbon steel).
- PEEK said to be outgassing by some? Terry Anderson quotes outgas rate of virgin PEEK of

  6E-9 Torr-liter/sec-cm^2
- Outgas rates of irradiated PEEK not yet known
  - Test on beam tube still on-going b/c ion pump is broken
  - This was highly activated by spray from Lambertson (now at 50mR/hr on contact)
- Assume this will slide on 3/8" round shafts
  - Hardened carbon steel?
  - Stainless steel?
  - Chrome-plated Carbon Steel?

Home-made Bellows Feedthrough

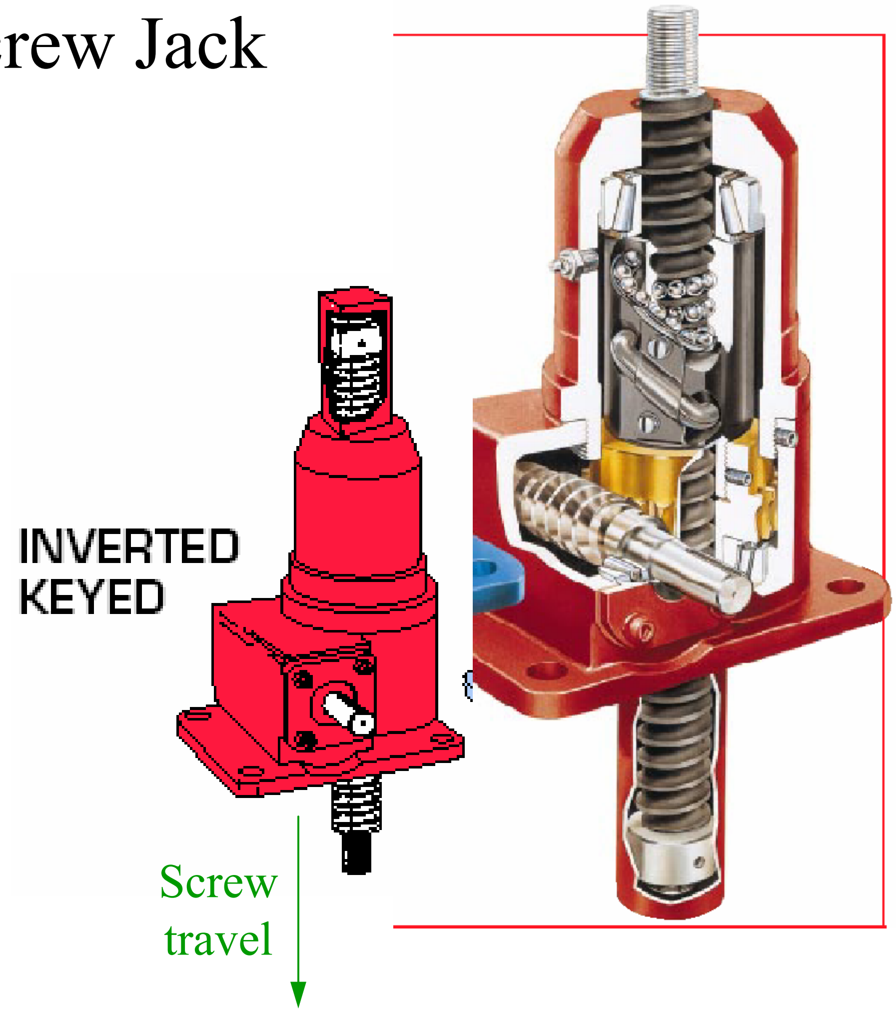
- MDC Vacuum, Inc.
- AM-350 bellows, 304-SS end plate
- Claim is 10^4 cycles if utilize full stroke length (guaranteed)
- No guarantee, but they use rule of thumb that 10^6 cycles possible if only use 1/2 full stroke length.
- Downside of this ‘simple’ feedthrough is atmospheric pressure now weighs on the exterior motor and stage

Model	WB-805	WB-806	WB-823	WB-807
ID (in.)	.750	.750	.830	.937
OD (in.)	1.750	1.750	1.500	1.750
Extended length (in)	3.78	5.02	7.80	10.12
Stroke length (in.)	3.00	4.00	6.20	8.38
Price ($)	210	250	500	535

We thought this was adequate

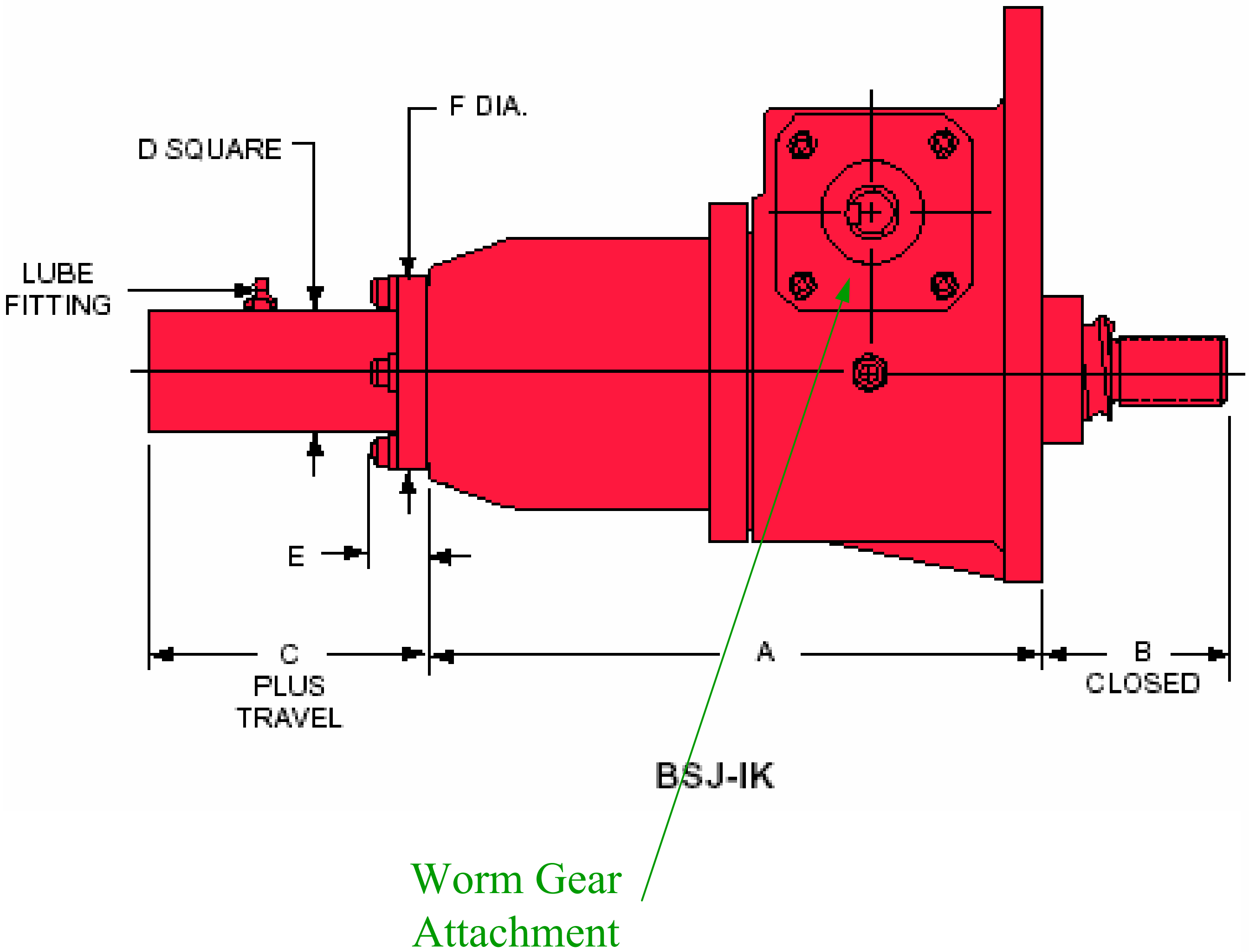
Ball Screw Jack

- Stepper motor will be attached to a worm-gear ball screw jack
- KEY POINT: this is compact means of coupling bellows to motor
- Made by Nook Industries (same item as used by R. Reilly in Tevatron scraper system)
- Will attach lead screw to bellows feedthrough to draw/extend bellows.
- Gear ratio 5:1 (worm:screw) and screw lead is 0.200", so gives 25 worm revolutions/inch travel.
- Lead error is 0.001"/foot travel, which will dominate over stepper motor error (esp. given 0.040" travel per stepper revolution.)
- Lead screw is keyed to prevent it from rotating (will not torque the bellows).
- Torque on worm to raise one pound load on screw is 0.015 oz-in, so our ~40 lb load is ~0.6 oz-in.
- Unit will backdrive if motor is off, but appears stable when motor on.
- Part is ~$400.



- Lubricants will require being cleaned out, replaced with graphite dry lube (Lock-ease, per Dave Pushka).

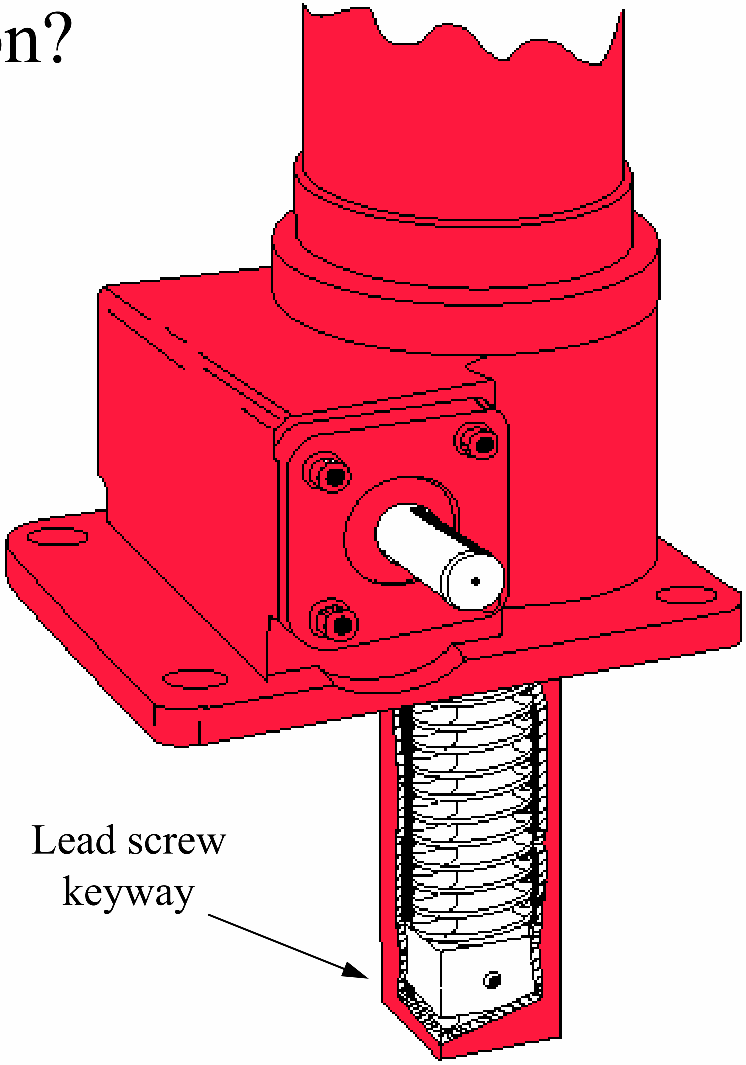
Ball Jack (cont'd)



JAC MODEL	½ BSJ	
CONFIGURATION: UPRIGHT-INVERTED	UK	IK
DIMENSION A		4.00
DIMENSION B		1.13
DIMENSION C		2.50
DIMENSION D		1.25
DIMENSION E		—
DIMENSION F		—
TORQUE TO RAISE ONE LB.- INCH-LBS. STD. RATIO		CONTACT FACTORY
TORQUE TO RAISE ONE LB.- INCH-LBS. OPT. RATIO		CONTACT FACTORY

How to Read Back Position?

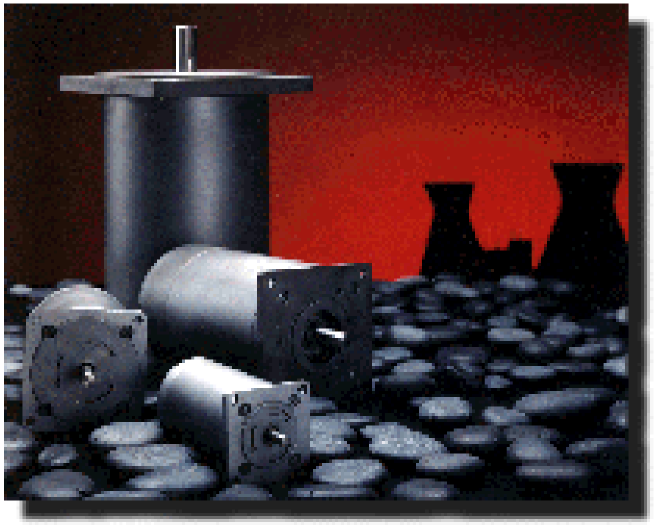
- Because of space constraints, most convenient place is rear side of lead screw on jack (the end that is not attached to the bellows feedthrough)
- However, rear side of leadscrew is nominally hidden – it is embedded in a housing that prevents it from rotating as it advances/retracts.
- We plan to machine a slot in one side of this housing to permit access to the rear of the screw.
- If this is found to weaken the keyway at all, we can later reinforce it on two sides with our own custom-machined part.

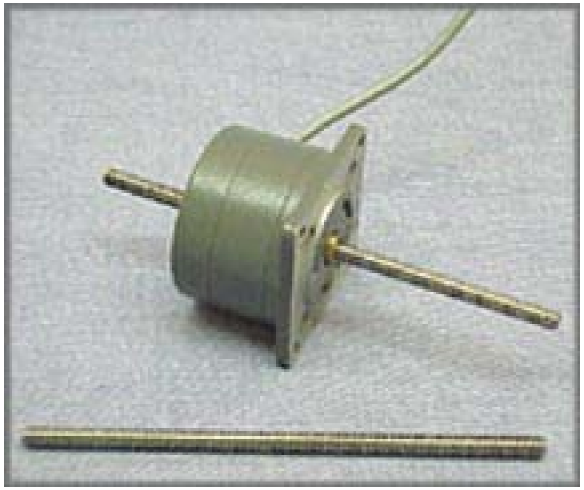


NB: shown is diagram of the 'upright' model, not the 'inverted' model we plan to use.

Stepper Motors -- Empire Magnetics

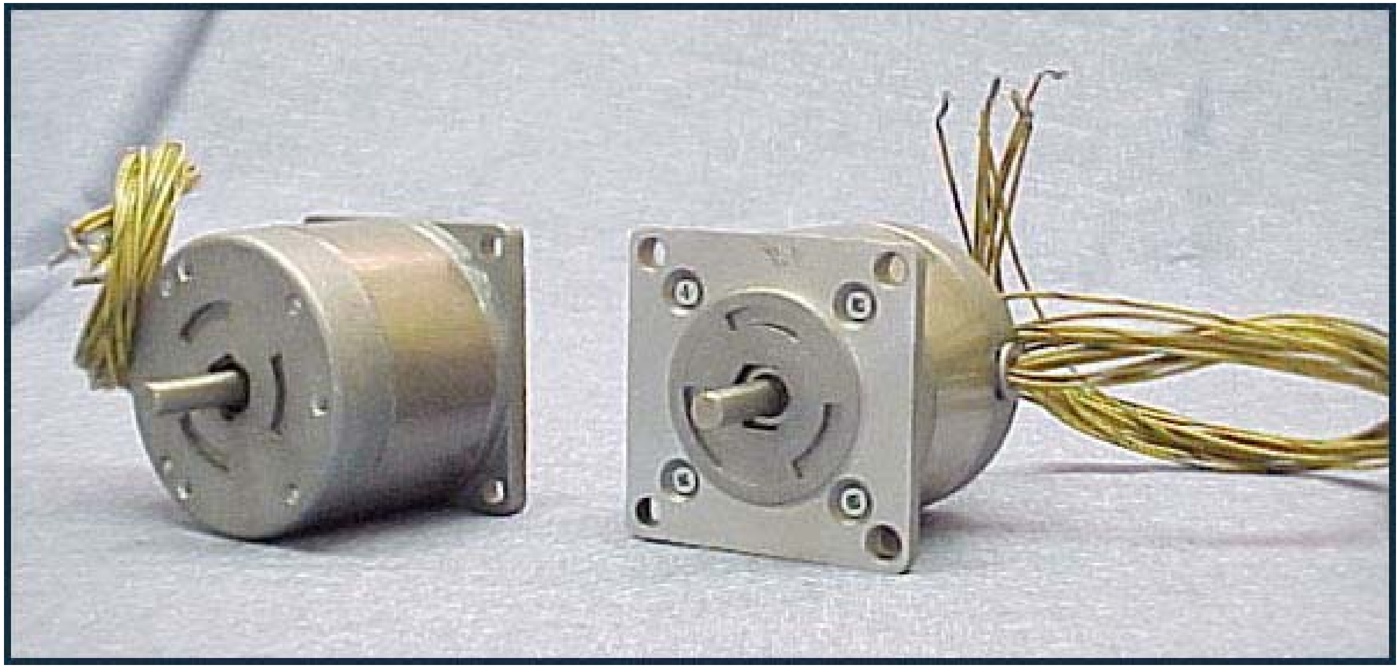
- Series of motors tested at ORNL up to 10^9 Rads -- highest we know of, but adequate near target?
- Standard rating (and pricing) is for 2E8 Rads. If want 1E9 Rad, approx 20-30% larger price

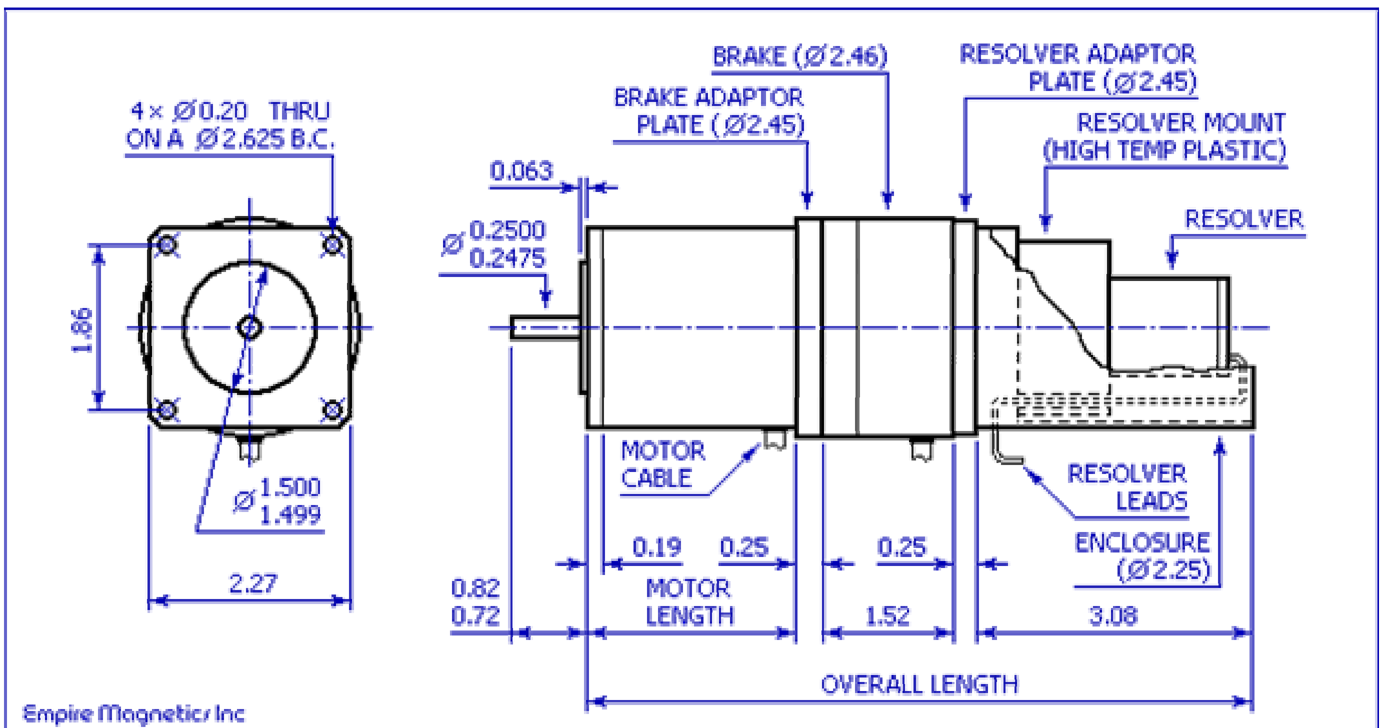




- Some desirable optional features
  - Brake for holding shaft ~ $1200
  - Rotary feedback for shaft (‘resolver’) ~ $1900
  - Temperature sensor
- 1.8° step size -- 200 steps/rev
- Ratings given for different torque ranges
  - U23 -- 130oz-in -- $1200
  - U21 -- 40 oz-in -- $1000
- Because of cost, interface to FNAL controls, we plan to buy the smaller motor and no feedback or brake

- Comes with lead screw directly inserted into an internal ACME bronze nut
- Easily handles issue of how to couple leadscrew to motor
- Susceptible to greater backlash and has greater lead screw error (0.005”/foot)
- Rated are the linear drive forces of different models (assuming 40% screw efficiency)
  - U21 -- 75 lbs -- $1200
  - U22 -- 130lbs -- $1600
  - U23 -- 210 lbs -- $1800





Size Matters

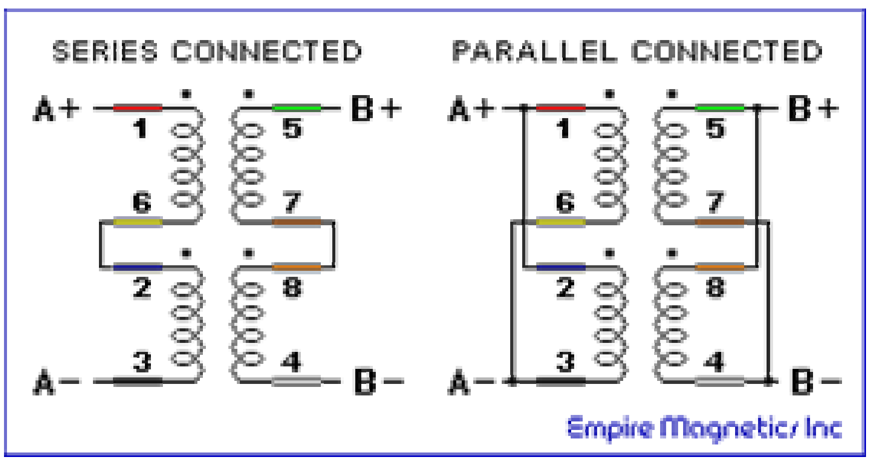
- Concern over adding motor length to transverse size of SEM

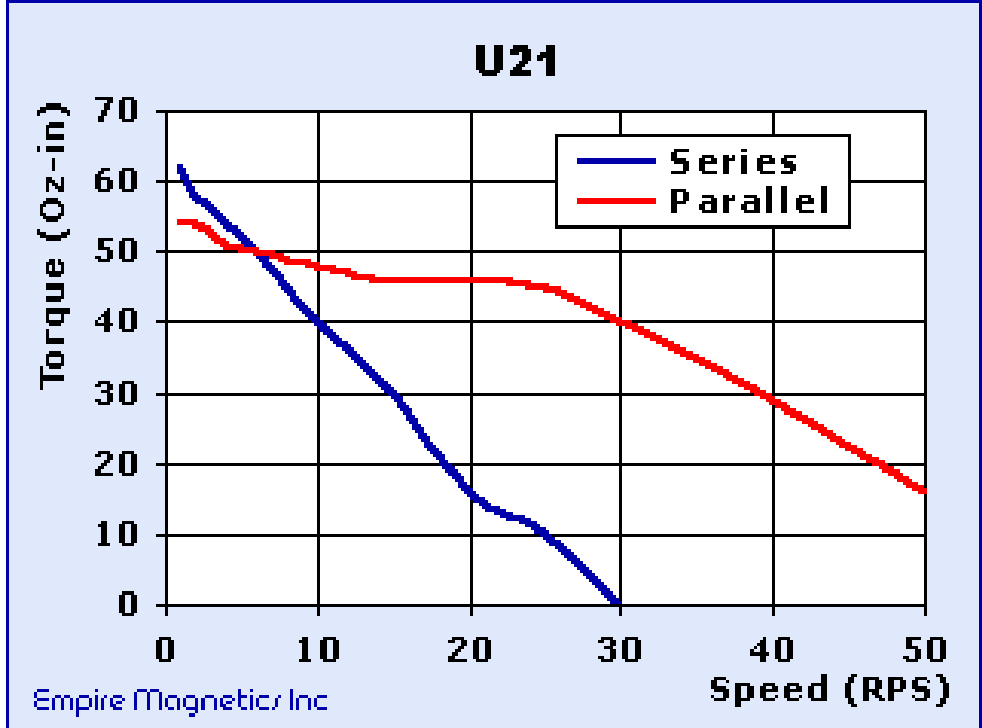
- Motor is 4”
- Resolver adds 3.1”
- Brake adds 1.75”

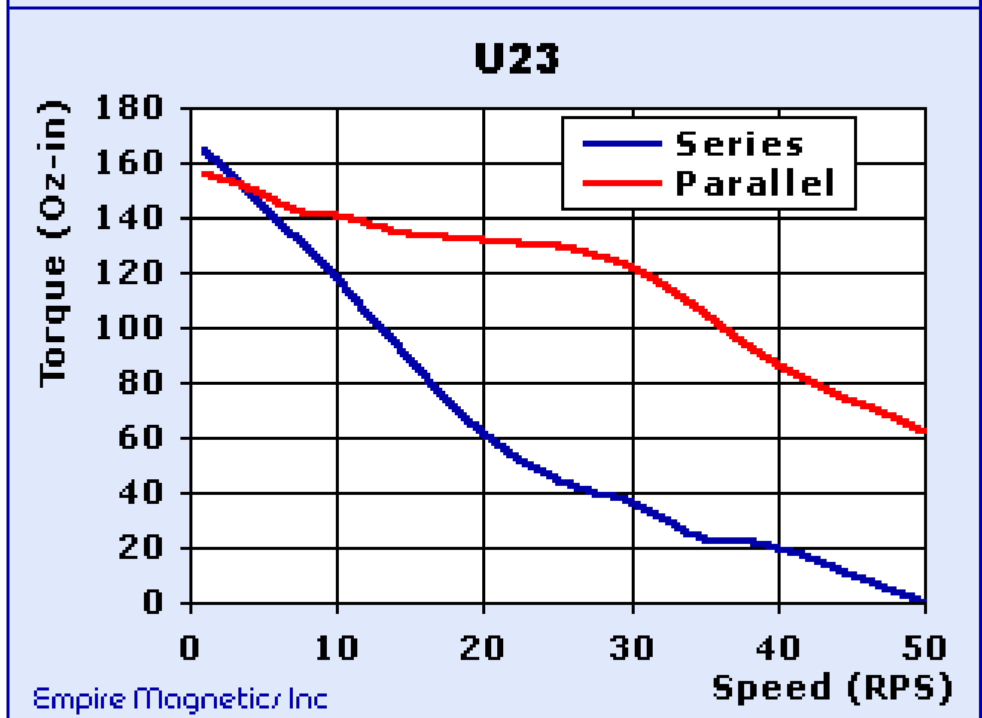
- At present we would like to buy just the motor with no brake or resolver.

Motor Speed Limitations

- Have a choice of parallel/series motor windings
- Parallel draws more current
  - Runs hotter
  - Have to worry more about cooling
  - Greater potential failure?
- Use of this motor with FNAL controls cards requires unipolar wiring scheme (6-wire connection – 2&6 and 7&8 tied together) so will limit torque capability
- This limitation in part motivates use of the ball screw jack with this motor (less need for torque capacity)







HR Series

Readback Mechanism:

General Purpose LVDT

The high reliability HR Series of LVDTs is suitable for most general applications. The HR Series features a large core-to-bore clearance, high output voltage over a broad range of excitation frequencies, and a magnetic stainless steel case for electromagnetic and electrostatic shielding.

Features

- ***Optimum performance for a majority of applications***
- ***Large 1/16 inch radial core-to-bore clearance***
- ***Calibration certificate supplied with all models***
- ***Compatible with all Schaevitz® signal conditioners***
- ***High temperature (220°C) and high pressure (vented case) available – consult factory***

Applications

- ***General***

Options

- ***5.0 kHz excitation frequency testing****
- ***Metric thread core***
- ***Guided core***
- ***Small diameter/low mass core***
- ***Mild radiation resistance (withstands 10^{12} NVT total integrated flux; 10^7 rads Gamma)***

** Performance and electrical specifications for alternative frequencies will differ from the standard specifications listed below which are based on a 2.5 kHz excitation frequency. Consult factory for further information.*

Specifications

Or kapton

phenolic

Input Voltage	3 V rms (nominal)
Frequency Range	400 Hz to 5 kHz
Operating Temperature Range	-65°F to 300°F (-55°C to 150°C)
Null Voltage	<0.5% full scale output
Shock Survival	1,000 *g* for 11 msec
Vibration Tolerance	20 *g* up to 2 kHz
Coil Form Material	High density, glass-filled polymer
Housing Material	AISI 400 series stainless steel
Lead Wires	28 AWG, stranded copper, Teflon-insulated, 12 inches (300 mm) long (nominal)

LVDT sizes available

Performance and Electrical Specifications @ 2.5 kHz[1]

HR Series Model Number	Nominal Linear Range inches	mm	Linearity (±% full range) 50	100	125	150	Sensitivity mV out/V in Per 0.001 in	mm	Dimensions A (Body) in	mm	B (Core) in	mm
050 HR	±0.050	±1.27	0.10	0.25	0.25	0.50	5.8	230	1.13	28.7	0.80	20.3
100 HR	±0.100	±2.54	0.10	0.25	0.25	0.50	4.2	165	1.81	46.0	1.30	33.0
200 HR	±0.200	±5.08	0.10	0.25	0.25	0.50	2.5	91	2.50	63.5	1.65	41.9
300 HR	±0.300	±7.62	0.10	0.25	0.35	0.50	1.3	51	3.22	81.8	1.95	49.5
500 HR	±0.500	±12.70	0.15	0.25	0.35	0.75	0.7	25.6	5.50	139.7	3.45	87.6
1000 HR	±1.00	±25.4	0.15	0.25	1.00	1.30*	0.39	14.2	6.63	168.4	4.00	101.6
2000 HR	±2.00	±50.8	0.15	0.25	0.50*	1.00*	0.23	8.3	10.00	254.0	5.30	134.6
3000 HR	±3.00	±76.2	0.15	0.25	0.50*	1.00*	0.25	9.1	12.81	325.4	5.60	142.2
4000 HR	±4.00	±101.6	0.15	0.25	0.50*	1.00*	0.20	7.1	15.64	397.3	7.00	177.8
5000 HR	±5.00	±127.0	0.15	0.25	1.00*	n/r	0.14	5.5	17.88	454.2	7.00	177.8

Ordering Example:
Model Number 050 HR-018 is an HR Series LVDT with a ±0.05" range (050 HR), with 5 kHz testing (002), Metric thread core (006), and a guided core (010).

HR Model

- 050 HR
- 100 HR
- 200 HR
- 300 HR
- 500 HR
- 1000 HR
- 2000 HR
- 3000 HR
- 4000 HR
- 5000 HR
- 10000 HR

Options

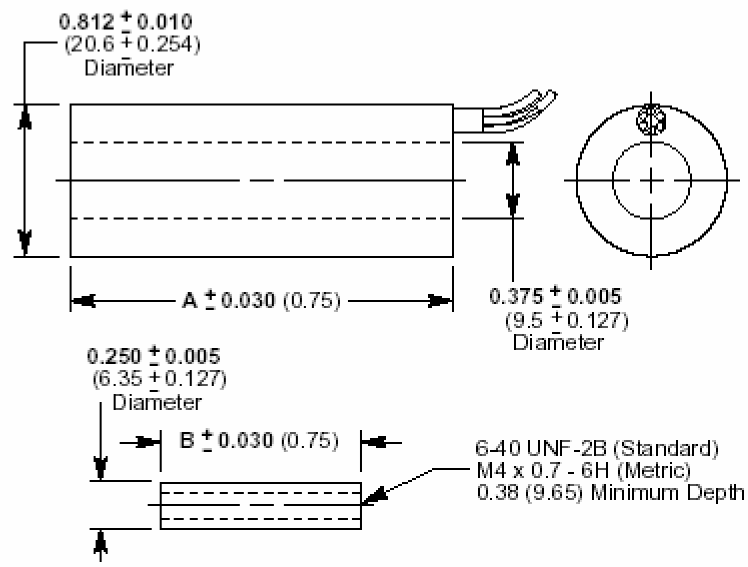
Number	Description
002	5.0 kHz Linearity Test[1]
006	Metric Thread Core
010	Guided Core[2]
020	Small Diameter/Low Mass Core[3]
080	Radiation Resistance[2]

[1]Available on models 050 HR, 100 HR, 200 HR, and 500 HR only.

[2]Guided core and radiation resistance options cannot be ordered together.

[3]Available on models 050 HR - 500 HR only. Consult factory for mass, dimensions and thread size.

Dimensions in (mm)



LVDT Read-out

ATA-2001 LVDT Amplifier

True Analog Conditioner with Digital Calibration

The new Schaevitz® analog transducer amplifier is a general purpose, AC line-powered LVDT/RVDT conditioner featuring state-of-the-art design principles. The new SMT (Surface Mount Technology) design uses an embedded microprocessor to generate a PWM-shaped sine wave and control all calibration functions. The processor is also employed in the demodulation, filtration and synchronization of the LVDT signal. All settings are stored in non-volatile memory for restoration on power up. Zero, Span and Phase adjustments are accomplished via the use of spashproof front panel pushbuttons and digital voltage dividers, eliminating the need for drift-inducing screw adjust potentiometers. All amplifier controls are accessible from the outside of the rugged aluminum enclosure.

The new ATA 2001 is CE certified, and is intended for the most rigorous, industrial applications. The ATA 2001 has been tested to the highest industrial standards for EMI, RFI and ESD.

The ATA 2001 is designed for universal compatibility with all 4, 5, and 6 lead LVDTs. A wide range of oscillator frequencies combined with two excitation voltages, 3.5 and 0.5 Vrms, provide maximum versatility. The high power carrier amplifier has more than twice the drive capability of previous designs. Able to power low impedance LVDTs at higher amplitudes, the ATA 2001 provides measurement resolutions beyond any product currently available.

The ATA 2001 is contained within a rugged, extruded aluminum housing. The one-piece design provides optimal amplifier performance under the most rigorous EMI and RFI conditions. An integral panel mounting system provides for convenient 1/8 DIN standard, panel installation. Pre-punched 19" rack adapters are available from Schaevitz® to accommodate up to eight amplifiers per adapter installation.

Applications

- ❑ ***Control valve position feedback***
- ❑ ***Head box slice lip position control***
- ❑ ***Precision metrology labs***
- ❑ ***Roller gap position feedback***

Auto Fall-Back Synchronization

An auto fall-back synchronization feature allows reliable master/slave operation, for prevention of amplifier cross talk, without the worry of sync signal loss. If the internal processor in a slave amplifier detects an unstable or missing sync signal, the internal clock will take over, continuing at the preselected nominal frequency. Upon restoration of a normal sync pulse, the oscillator will return to the slave mode.

- Controls require a 0-10V or +-10V DC voltage proportional to LVDT position
- Most LVDT's are excited by AC voltage, put out AC signal
- Readback unit provides excitation voltage, converts signal → DC.

ATA1000 Specifications

Common Specifications

Electrical:	
Power Requirements	115 VAC ±10%, 50-400 Hz; 220 VAC ±10%, 50-400 Hz (switch selectable)
Line Voltage Regulation	±10%, no change in output
Transducer Excitation	
Voltage	3.5 V rms nominal (switch selectable for 0.5 V rms)
Frequency	2.5, 5.0 and 10.0 kHz (switch selectable)
Current	45 mA rms (max)
Analog Output:	
Voltage Output	
Bipolar	±10 VDC max (10 mA max)
Unipolar	0-10 VDC max (10 mA max) (with 100% zero suppression)
Output Impedance	<1Ω
Noise and Ripple	<3 mV rms at 2.5 kHz excitation
Current Output	4-20 mA
Maximum Loop Resistance	700 Ω (with internal loop supply); 1000 Ω (with 24 VDC external loop supply)
Noise and Ripple	10 µA rms (max)
Frequency Response (nom):	-3 db at 250 Hz for 2.5 kHz excitation 500 Hz for 5.0 kHz excitation 1000 Hz for 10 kHz excitation
Amplifier Characteristics:	
Sensitivity Range	
High Gain	0.040 to 0.9 VAC rms in = 10 VDC output
Low Gain	0.500 to 10.0 VAC rms in = 10 VDC output Note: -5 VDC output = 4.0 mA current output; +5 VDC output = 20 mA current output; 0 VDC output = 12 mA current output
Input Impedance	100kΩ
Zero Suppression	±110% full scale output
Phase Shift Compensation	±120° maximum
Non-linearity and Hysteresis	<±0.05% of full scale output
Stability	Better than ±0.05% of full scale output (after 20 minutes)
Tempco	<±0.02% of full scale output/°F (0.04%/°C)
Operating Temp. Range	-40° to 185°F (-40° to 85°C)
Weight	2.1 lbs (950 g)

Controls

(*NB: following slides taken from A. Legan – BD Controls Dept)*

- Al's electronics/software system used to control Tevatron scrapers
- Supports DC stepper motors, 6-wires
- Supports 2 limit positions, 1 reference position
- Supports position readback as long as it puts out DC 0-10V or +-10V
- No motor brake is supported

More from Al Legan…

Why Stepper Motors?

- Relatively inexpensive.
- Can be operated “open loop” no position feedback required.
- Non cumulative step error.
- Simple control electronics can be used.
- Brush less construction aids reliability.
- Maintenance free.
- Will not be damaged if stalled.
- High torque output, for their size.
- Maintain position when at rest (stopped).
- Can be purchased with high radiation resistant wiring and lubrication.

Motors

- Any brand of DC stepper motor.
- Torque ratings of the motors should be at least twice the calculated designed torque of the movable device.
- Motors need to have either 6 or 8 wires. Leads or terminals are OK. **We do not support 4 wire motors.**
- Use Unipolar motor specifications, 2 phase on, when choosing motor torque rating.
- Maximum voltage is 10 volts/winding.
- Maximum current is 6.1 amps/winding.

Position Read Back!

- We support either LVDT’s or linear potentiometers as position read back devices.
- LVDT’s should have a **MS3120E10-6P connector. FNAL** #1430-224000.
- Potentiometers will be wired and connected by the controls department. Connectors will be supplied by us.

Limit Switches.

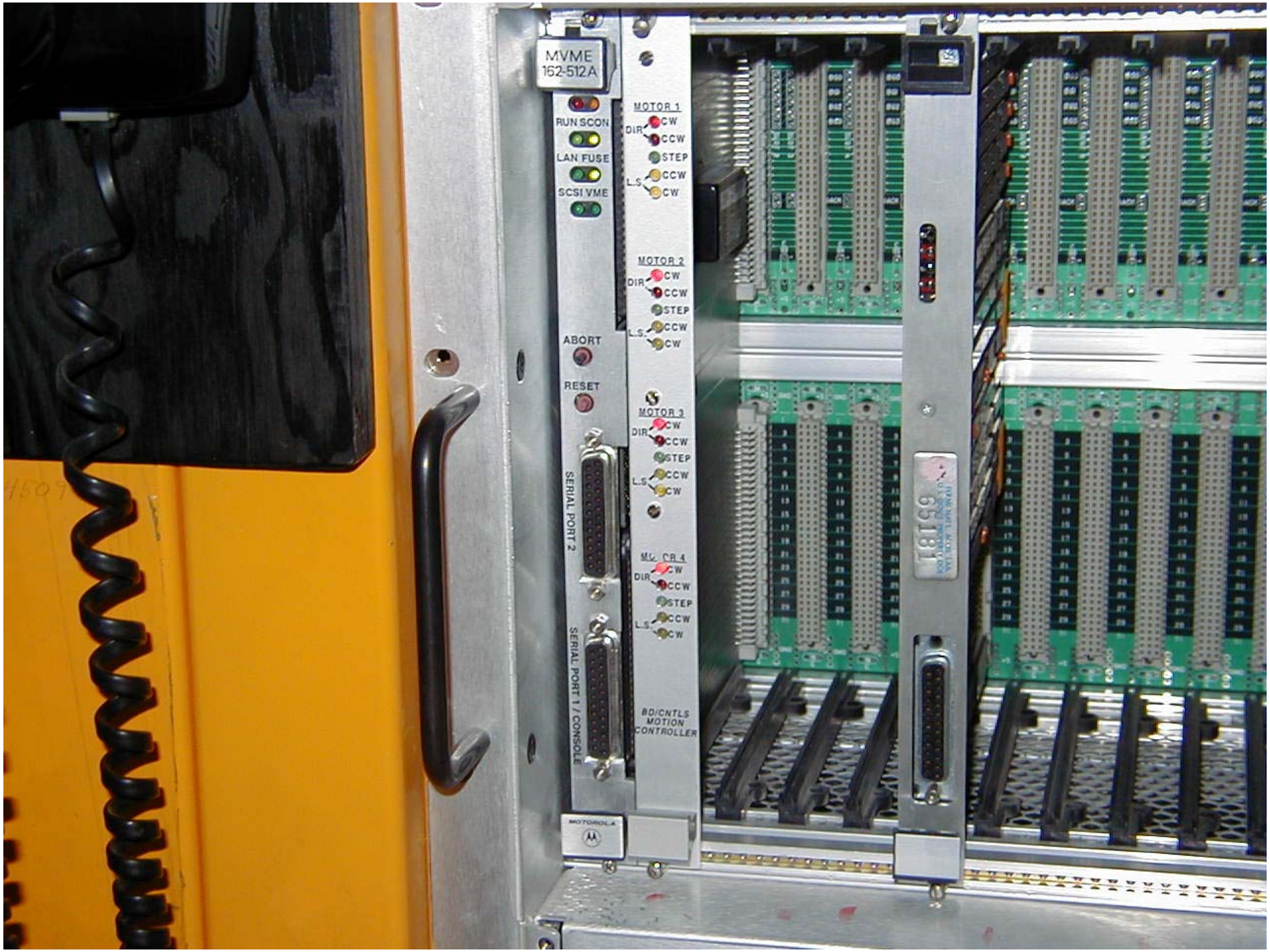
- Consider environment the motion device is going to be place into.
  - Environment. (Resistant to moisture, vibrations or mechanical damage).
  - Consider the size of limit switch. The smaller the switch the more susceptible to damage.
  - Levels of radiation (if known).
  - Limit switches should be form ‘C’ type contacts. We will accept normally closed contacts only.
  - There is no consideration for limit switch current ratings.

Pictures of New STEP/PAK Motion Controls Hardware.

(*A.Legan*)

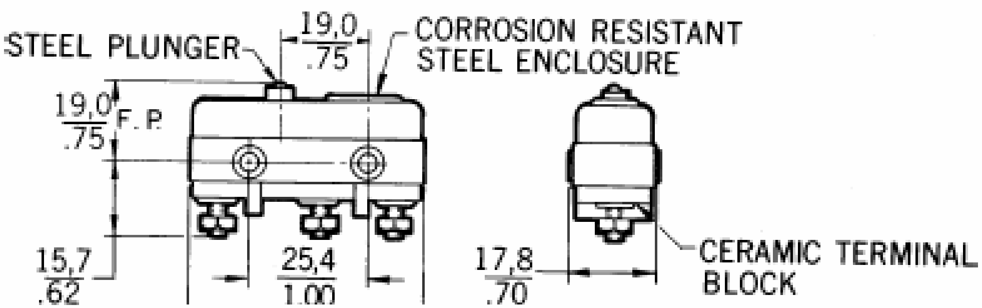
Typical VME Front-end

(*A. Legan*)



Limit Switches

- Manufactured by Honeywell
- High temperature switch manufactured with ceramic insulators
- Same switch used in Tevatron scraper system
- Repeatability of engaging the switch is apparently ~ 0.005”



Dim. Dwg. Fig. 3

Characteristics: O.F. — Operating Force; R.F. — Release Force; P.T. — Pretravel; O.T. — Overtravel; O.P. — Operating Position.

ORDER GUIDE

Catalog Listing	Description	Electrical Rating	O.F. newtons ounces	R.F. min. newtons ounces	P.T. max. mm inches	O.T. min. mm inches	O.P. mm inches
2HT1	Pin plunger side mount	3 Amps	2,78-5,56 10-20	1,67 6	1,27 .050	0,25 .010	16,8 .66 approx.

Where We're At

Active Foils:

- Want to order foil, practice cutting with several of the bidding etchers/laser cutters
- Want to try a ceramic clamp assembly (pricey for one, but…) after a little more refining on the design (still a lot of ceramic)
- Ferioli et al use 'point welds' to attach kapton signal cables to the foils -- we have to show we can do this

Linear Actuator

- Need to acquire a ball screw jack and modify it to meet our needs – does it still work as well?
- Need to acquire limit switches and an LVDT – can we find a 'reference' position with 50 μm repeatability?
- Must build one complete set-up and verify repeatability either with dial indicators or optically (R. Reilly and A. Legan did this for Tevatron scrapers, saw positive results).
- Need to figure out mounting on box -- overall transverse dimensions can run away on us. Now at 2 feet!

Vacuum Chamber

- Well, we have to start on this. Only schematics at this point (see slides)
- Must control transverse and longitudinal dimensions – currently estimate 30" and 9.25", respectively.

Interface to FNAL Controls

- Thanks to available systems, it appears the motors, readback, and switches will be fine.
- A live 'proof' would be desirable.

Milestones approaching:

- January shutdown - need prototype box incorporating some of these design features for MiniBoone line -- are we still on for this?
- January/February 1.1.1 instrumentation review -- we have to have complete drawings to show

Thanks to our NuMI colleagues B. Baller, S. Childress, R. Ducar, D. Pushka
and to J. Camas, G.Ferioli, D. Gilpatrick, A. Legan, G. Tassotto