Targets for test run of "An Electron Fixed Target Experiment to Search for a New Vector Boson A' Decaying to e+e-", SLAC-PUB-13882

Target Working Group

Rouven Essig, Clive Field, John Jaros, Ken Moffeit, Takashi Maruyama, Al Odian, Marco Oriunno, Philip Schuster, Natalia Toro, Dieter Walz, Bogdan Wojtsekhowski

PAC requirements for June 2010 test run at Jefferson Lab

The following conditions were listed that affect target design:

• Run with the zigzag mesh design of the tungsten target and prove that it allows the requested vertex resolution, i.e. spectrometers can predict which 10cm zigzag section the tracks come from. Single wire target will allow measurement of accuracy.

• Prove that the vertical drift chambers (VDCs) can operate at a rate higher that 20 kHz/wire (that, according to the TAC report, is the maximum Hall A has operated till now). This means we need a target with sufficient material that will give us a large enough rate.

• We also would very much like to do a science run with this target in June (i.e. it should allow us to run at a high enough rate).

Goals for June 2010 test

1. Event rate recorded at desired level.
2. Target durability.
3. Meet Calibration requirements.
4. Meet Resolution requirements.
5. Take data

Information

Beam

I=80μamps
σ=200μm
Radiation dose 5cm from beam = 1 kilorad/sec
Raster: Rate 50 kilohertz, dy=5mm, dx=0.5mm
Beam sweep is ~2mm

Target Chamber

Diameter =100cm
Clearance = 15cm outside of dz=50cm, dx=10cm and dy for three targets =30cm.
Magnetic field in target area is <10 gauss.
Vacuum in target chamber is ~10-5 to 10-6 Torr.

Primary Target Dimensions

Length = 50 cm
Five 10 cm long zigzag sections faces alternating at 25 mrad
Width = 10cm
Height = 10cm

Physics Considerations for Target

- Multiple scattering of A' decay particles leaving target is small so that the invariant mass resolution is not degraded too much from double-arm spectrometer mass resolution. This means the material the A' decay particles see is small (~ 0.003 RL).

- Total target thickness needed to give desired luminosity the beam need to see ~10% RL.

- Target material is high-Z reducing pion background relative to QED.

In order for the electron and positron pairs to make it into the spectrometer, we have to make sure that they do not hit the C-section holding up the target.

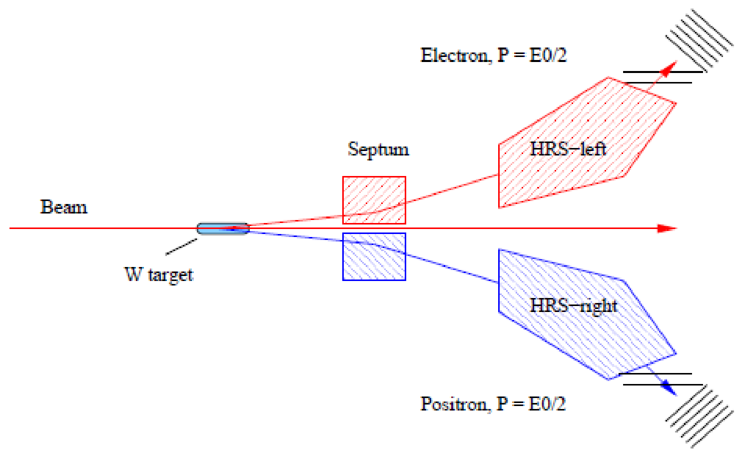
y-coverage

The y-coverage is +- 60 mrad, so over 50 cm this corresponds +- 3 cm, i.e. a gap of 6 cm. To be safe, let's make it a bit larger, say 10 cm.

x-coverage

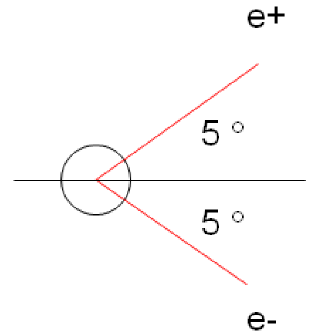
The outer edge of each side of the x-coverage is roughly 130 mrad, corresponding to ~6.5 cm. So the gap between the wires and the inner edge of the C-section should be about 6.5 cm. To be safe, let's make it also 10 cm.

•At the front end of the target, the central angle to the spectrometers is 4.5 degrees, and the angular coverage is from 55 mrad to 102 mrad.
•At the back end of the target, the central angle to the spectrometers is 5.5 degrees, and the angular coverage is from 72 mrad to 119.5 mrad.



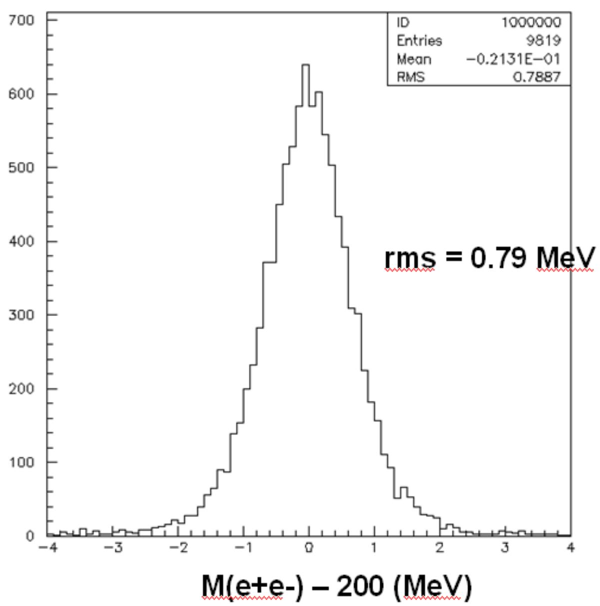
Contribution to invariant mass resolution from multiple scattering in tungsten wire.

A' (200 MeV) decays at the center of W wire

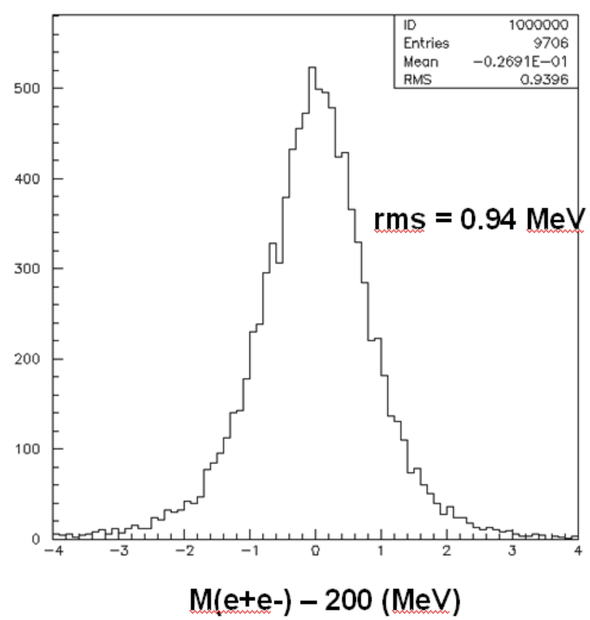


EGS5 with double precision

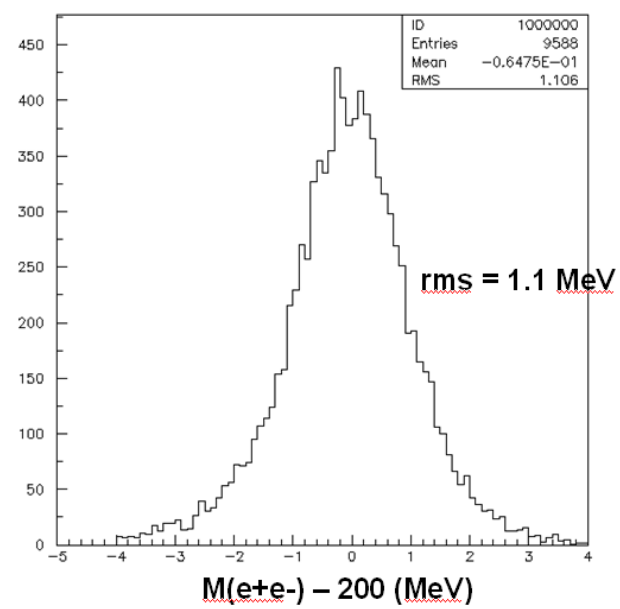
Wire diameter 14 μm



Wire diameter 20 μm

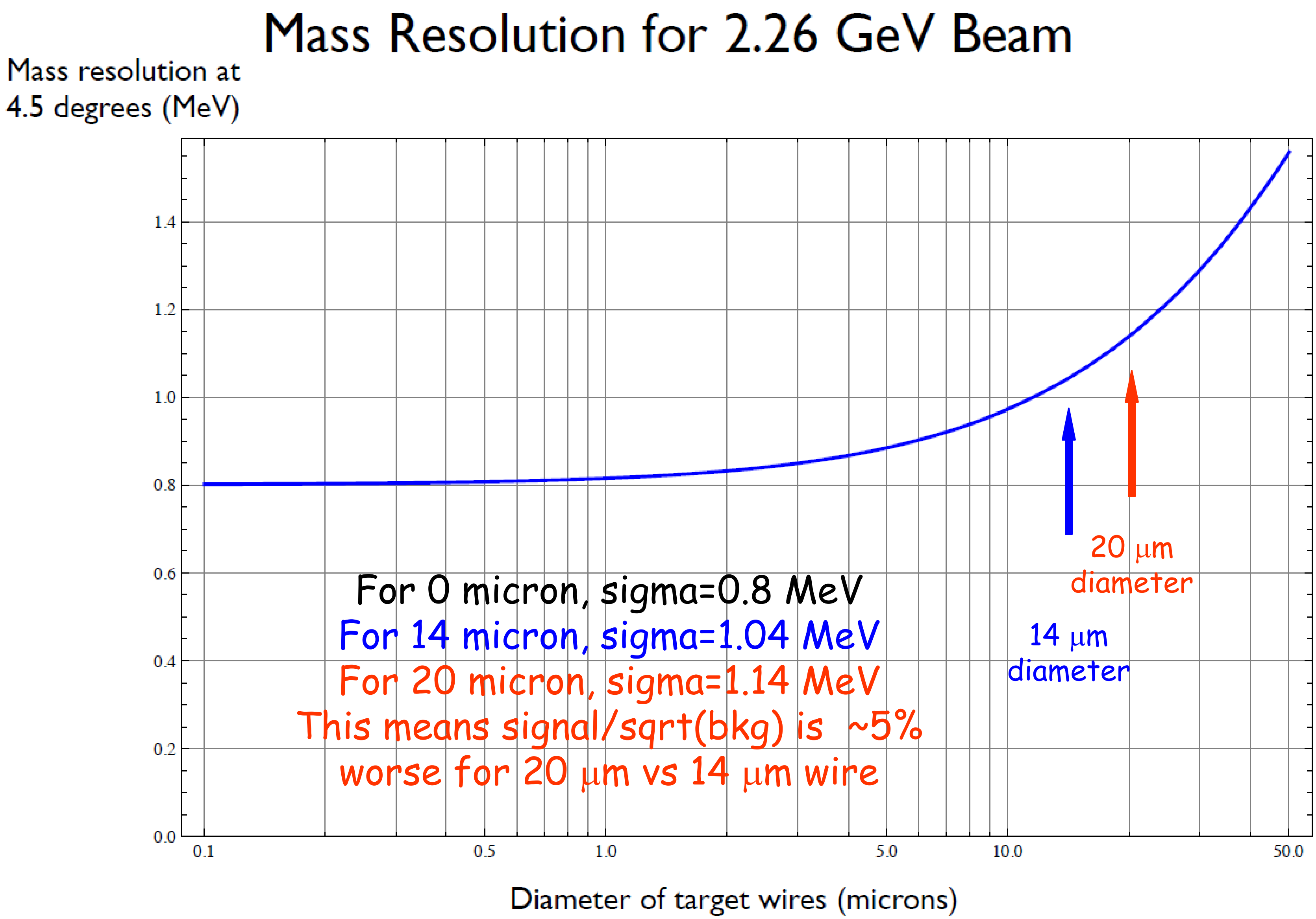


Wire diameter 30 μm



Multiple scattering of decay particles in target material dominates invariant mass error.

Wire diameter and mass resolution



Targets and goals for targets in June test run

1) Primary target

   Demonstrate target survives in 80 μamp beam with σ = 200 μm

   Test data taking at desired rate

   Take physics data

2) Single wire target (diameter 200 μm)

   Measurement of the angles HRS-L and HRS-R

   Check of the target transverse position

3) Carbon foils (11 foils, t = 50 to 100 microns thick, 10 x 30 mm)

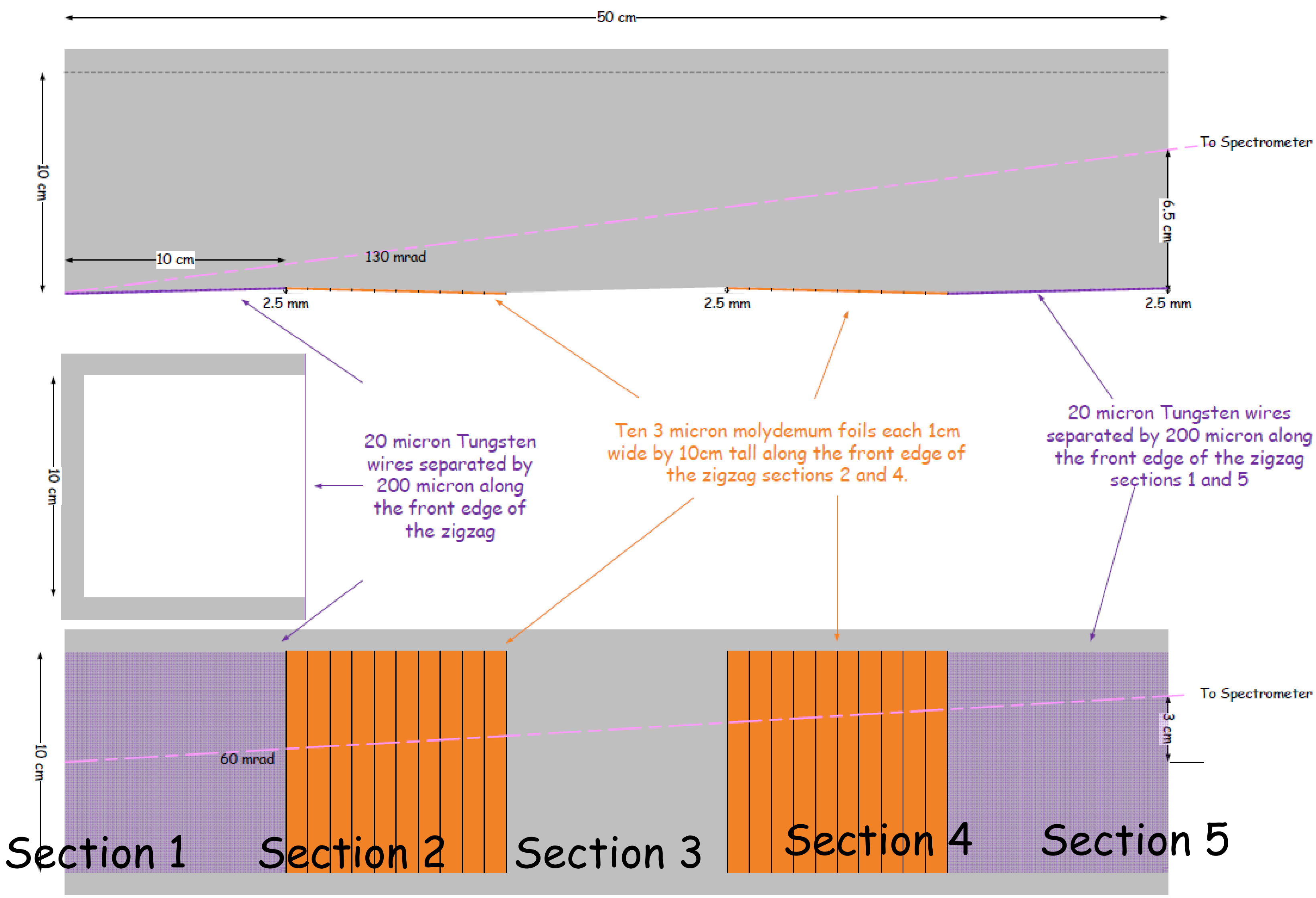
   Calibration of the optics for extended target

   Check of the target ladder alignment by means of the holey targets located at +/- 150 mm

Primary Target for June 10 test run

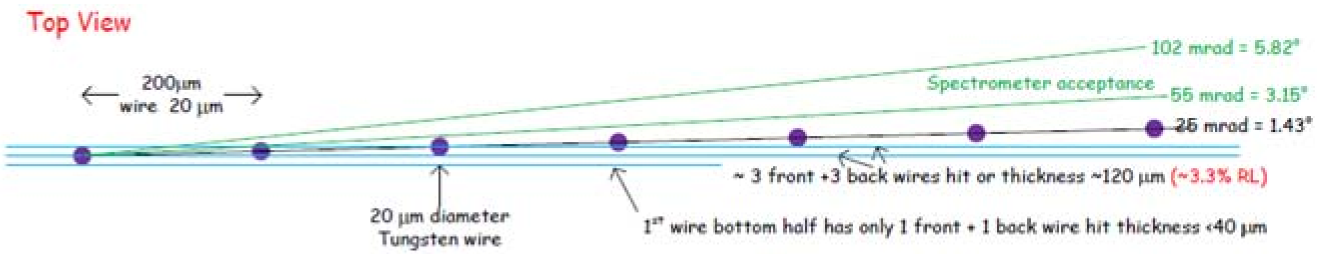
Each of the five 10 cm sections can a different target concept.

Conceptual drawing showing two possible options for test targets. We should build one technique and if time allows back it up with another.

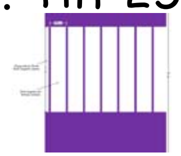


Primary Target Concepts

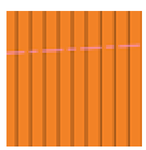
A) Tungsten wires of diameter 20 μm and 200 μm pitch. Tilt 25 mrad wrt to beam.



B) Tungsten foil (10cm wide by ~10 cm tall) of thickness 20 microns with 180 microns by 2 cm tall etched away to form columns 20 by 20 microns separated by 200 microns. Tilt 25 mrad wrt to beam.



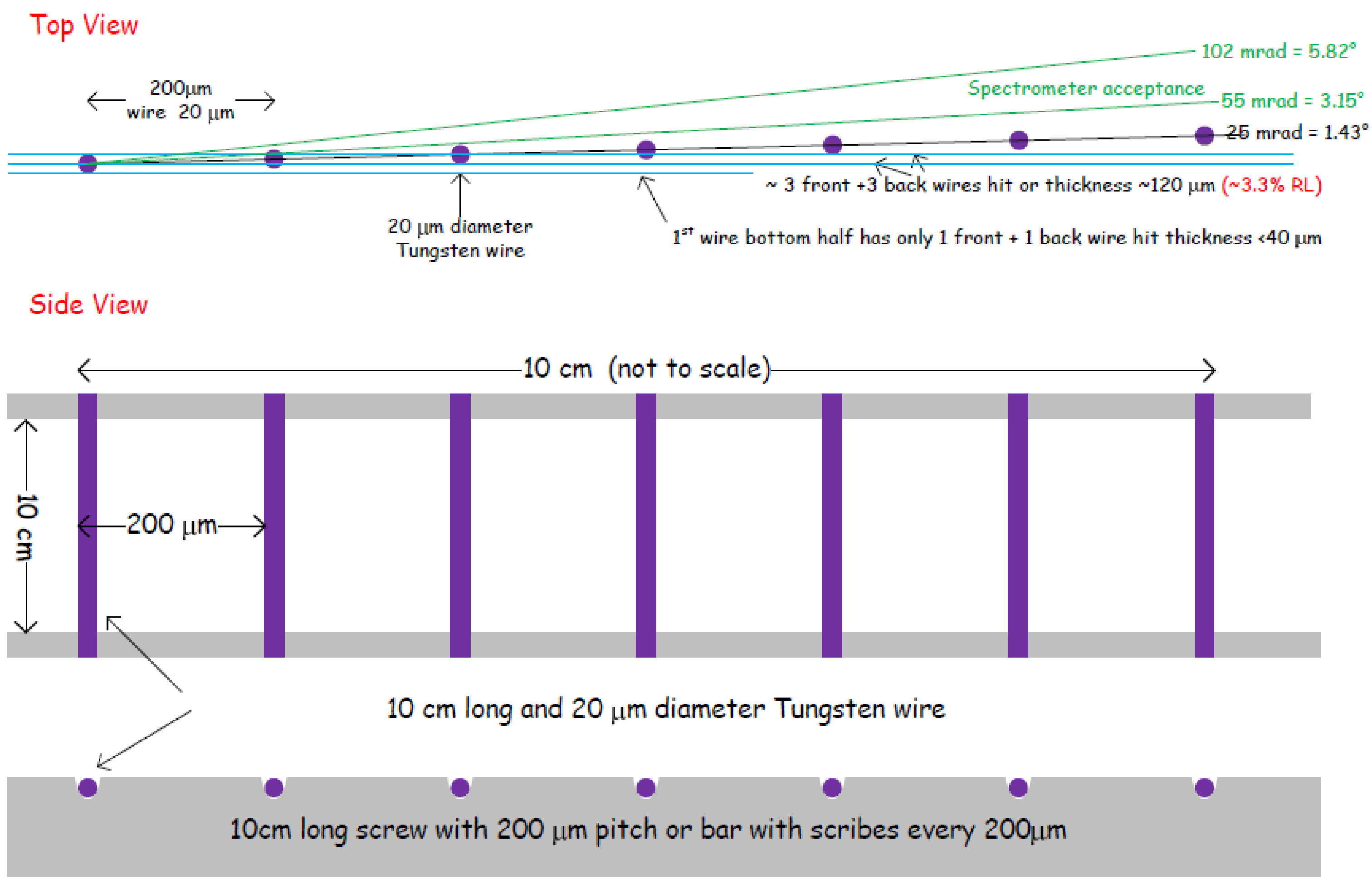
C) Molybdenum foils 3 microns thick (10 cm wide by ~10 cm tall). Tilt 25 mrad wrt to beam.



D) Thin Ta/W strips (11 foils, t = 15 microns, 3x30 mm) mounted perpendicular to beam.

A) Tungsten wires of diameter 20 μm and 200 μm pitch. Tilt 25 mrad wrt to beam.

Tungsten wires:
Vertical tungsten wires (RL of tungsten = 3.5mm)
20 μm diameter spaced every 200 μm
Angle of plane of wires is 25 mrad wrt to beam
Width of target wires beam sees is 2.5 mm
Material is tungsten: Atomic number 74, Atomic Weight 183.5, Melting point 3422 °C
QED processes to hadronic processes goes as $Z^2/A = 29.8$



Beam heating of 20 μm diameter wires

Beam: I=80 μamps σ=200 μm emissivity=0.25

Rastoring of beam at 50 kilohertz, dy=5mm, dx=0.5mm:
Gives 2.4 μamps hitting wire and 90 mwatts deposited.

- T ~ 2130 °C (Melting point of tungsten is 3422 °C)
- Heat radiated 85 to 90 %
- Heat conducted up/down wire 10 to 15%
- T will be a few hundred degrees cooler when heat conducted is accounted for.

No Rastoring:
2.8 μamps% of the beam with σ = 200 μm intercepts one 20 μm diameter wire. Roughly, 111 mW/wire is deposited. Assuming heat is radiated from only 0.5 mm the temperature would be very high, T=3900 degrees K, which would be disastrous. Melting point of tungsten is 3422 °C.

Mitigation to avoid melting wires

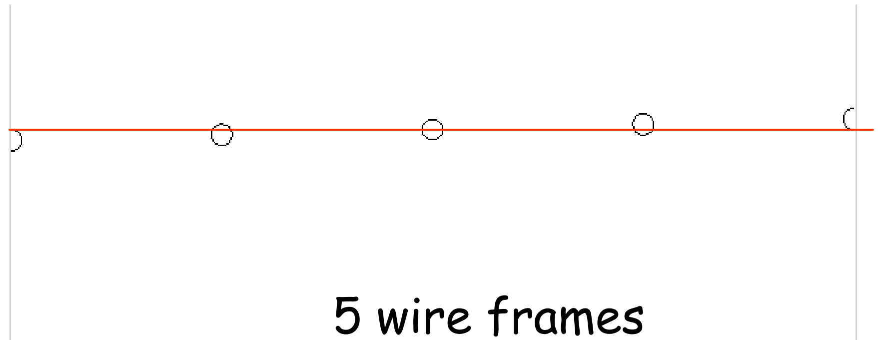
- Increase beam size to ~400 microns?
- Reduce beam current to ~60 μamps?
- Interlock raster
- Thinner wires (use ~14μm wire diameter instead of 20 μm and decrease wire spacing to 100 μm.

Comments:

1) No allowance for delta ray escape -- or for de/dx rise from min (at 2.3 GeV) feeds mostly into the escaping delta rays. The heat load reduction due to the delta-electron escape is about 25%: a factor of 0.75.
2) Horizontal dither quoted of 0.5 mm, together with the 0.2 mm sigma of the beam, is small relative to the present horizontal spread to the wire plane, 2.5 mm. The 0.5 mm is presumably a rectangular distribution, and so beam particles would rarely exceed +/- 0.7 mm.
3) Energy deposition in 4% X0 Tungsten using EGS5. The average energy deposition is 0.290 MeV, which is 7% smaller than particle table's dE/dx. The use of dE/dx is more conservative.

Radiation length beam sees from five 10cm wire planes with 20μm diameter, 200μm space with 25 mrad tilt wrt beam

June test run target may have two 10cm wire planes



25 mrad tilt

5 wire frames

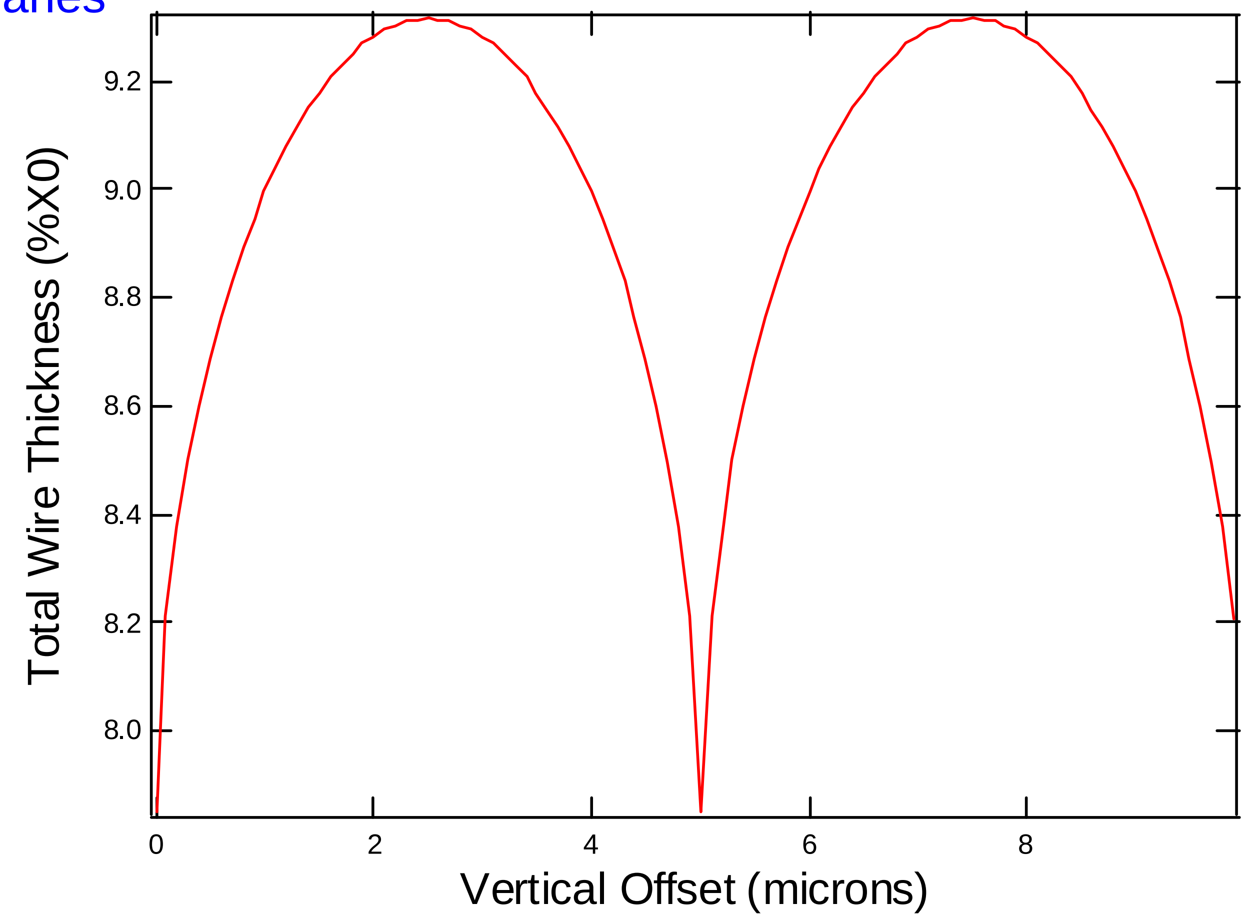
RL from 2 planes

3.68%

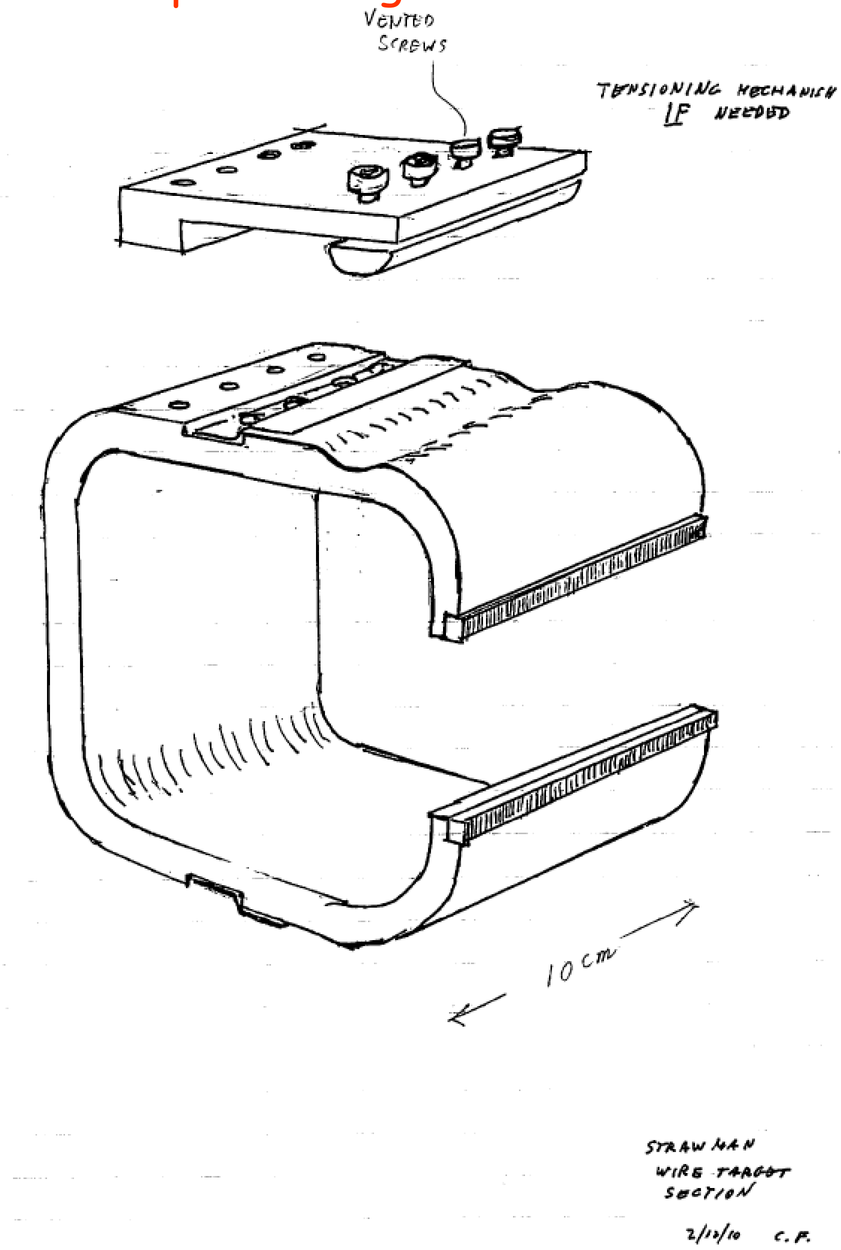
3.52%

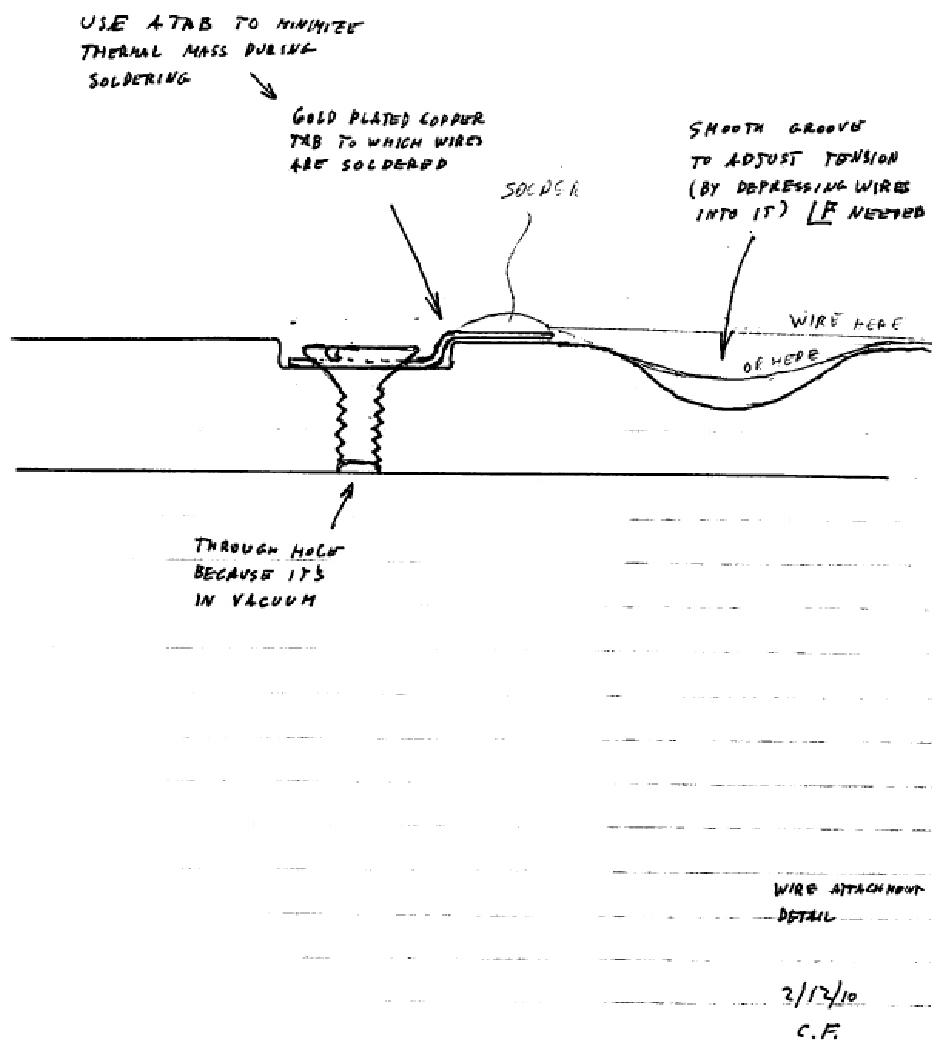
3.36%

3.2%

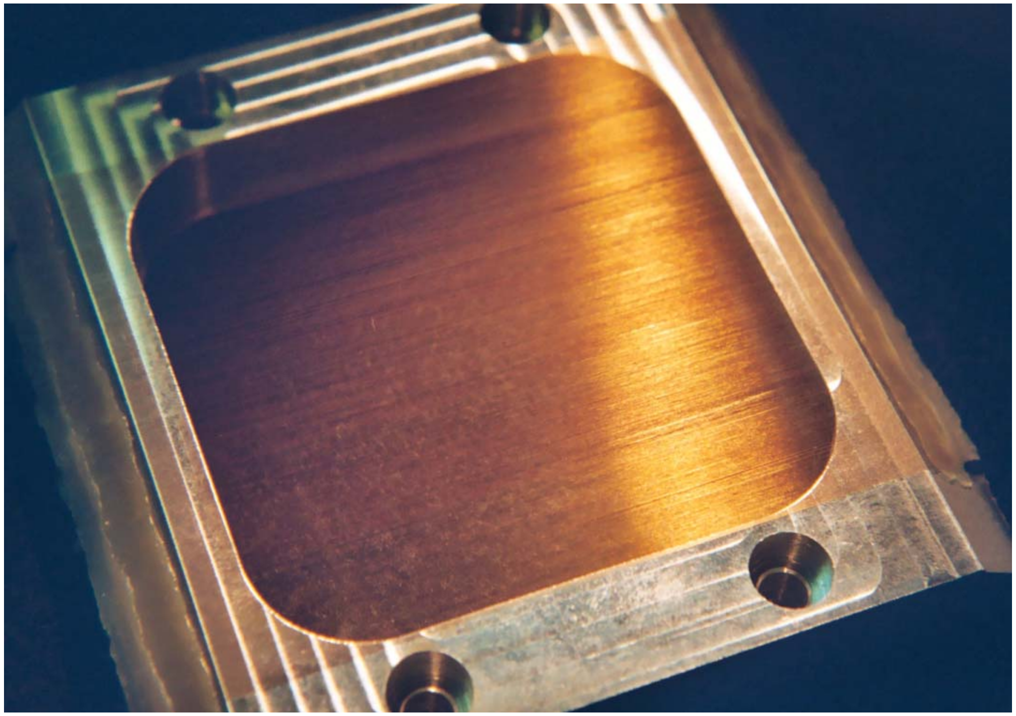


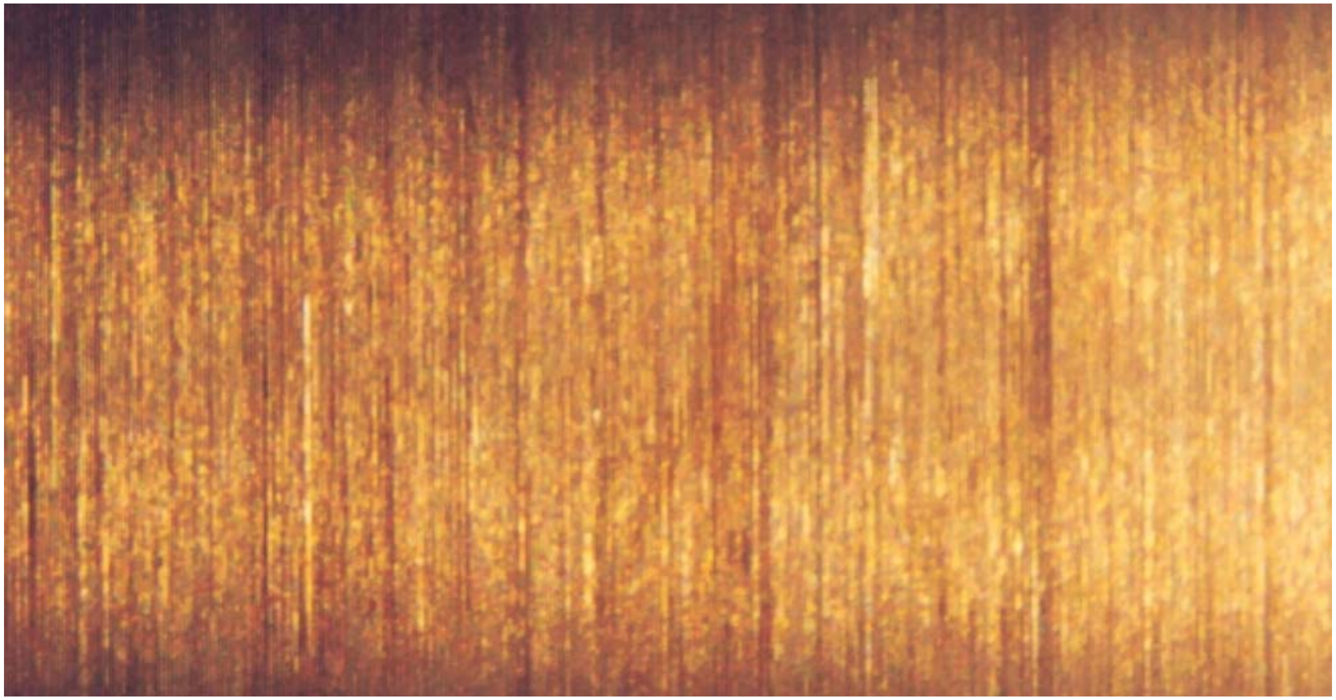
Concept drawings from Clive Field



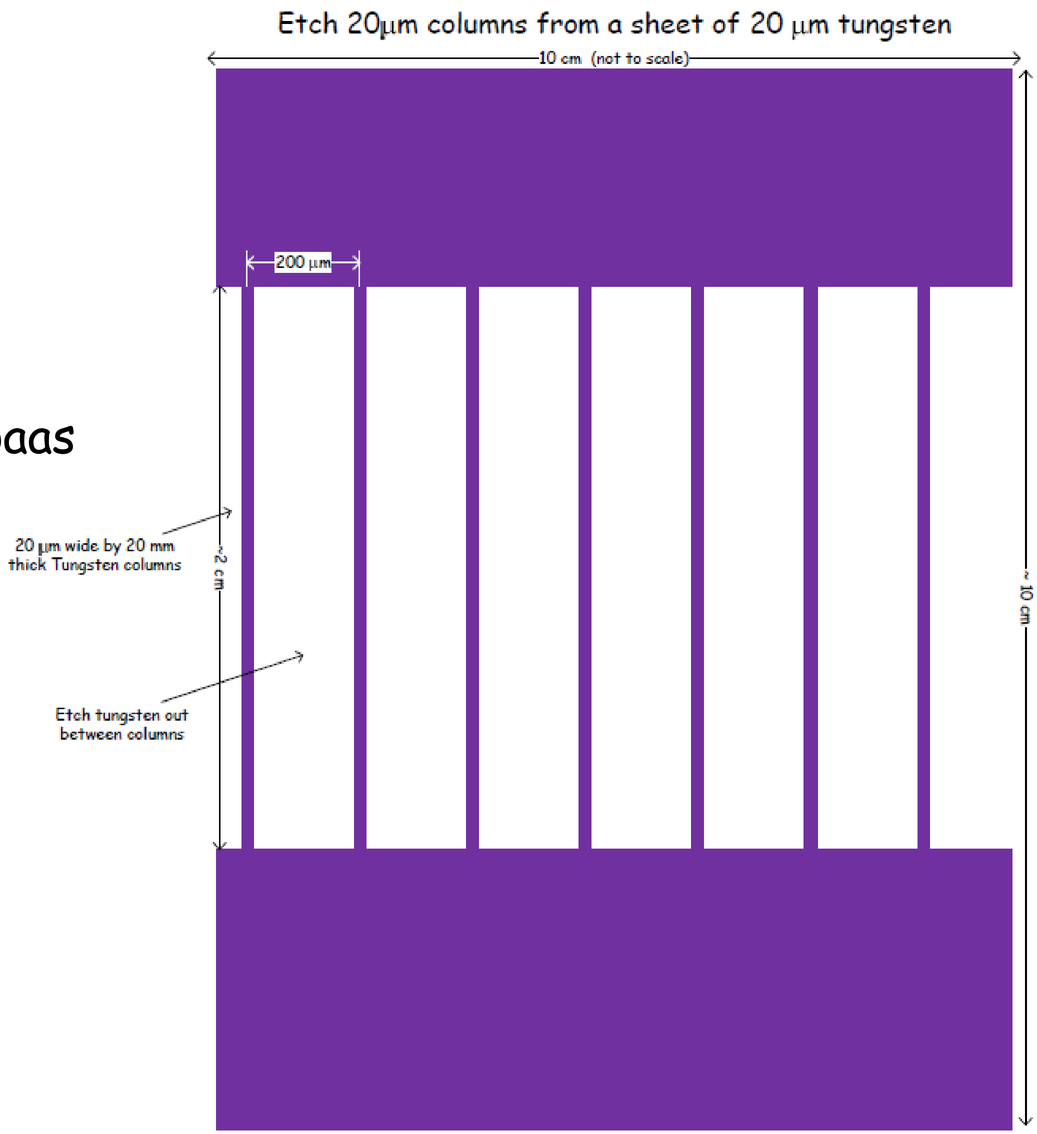


Pictures of wire frames. The pitch was 100 microns. Wire diameter I think was 20 microns. The area covered was 6.8 cm square.
Clive Field





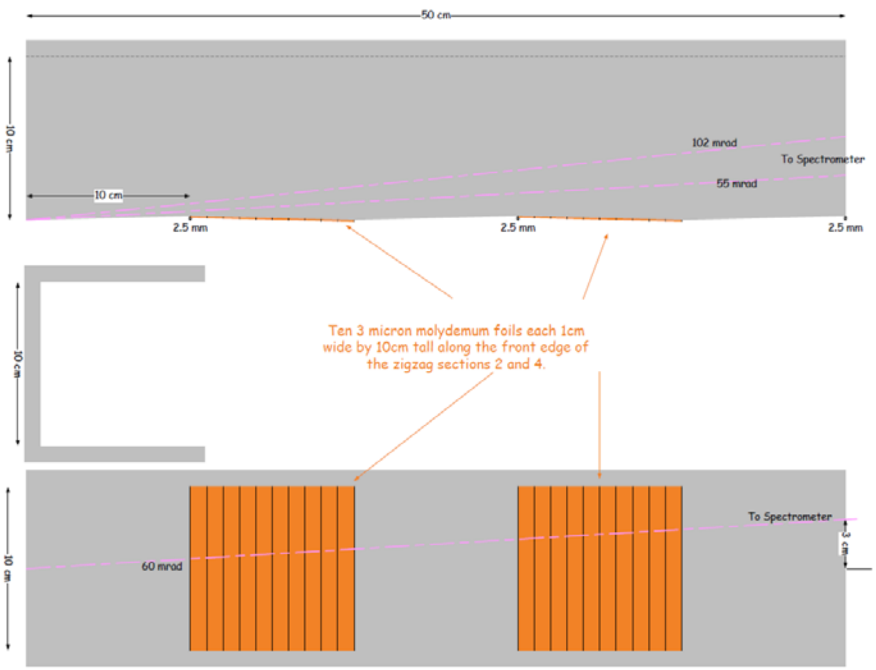
B) Etched tungsten foil (10cm wide by ~10 cm tall) of thickness 20 microns with 180 microns by 2 cm tall etched away to form columns 20 by 20 microns separated by 200 microns. Tilt 25 mrad wrt to beam.

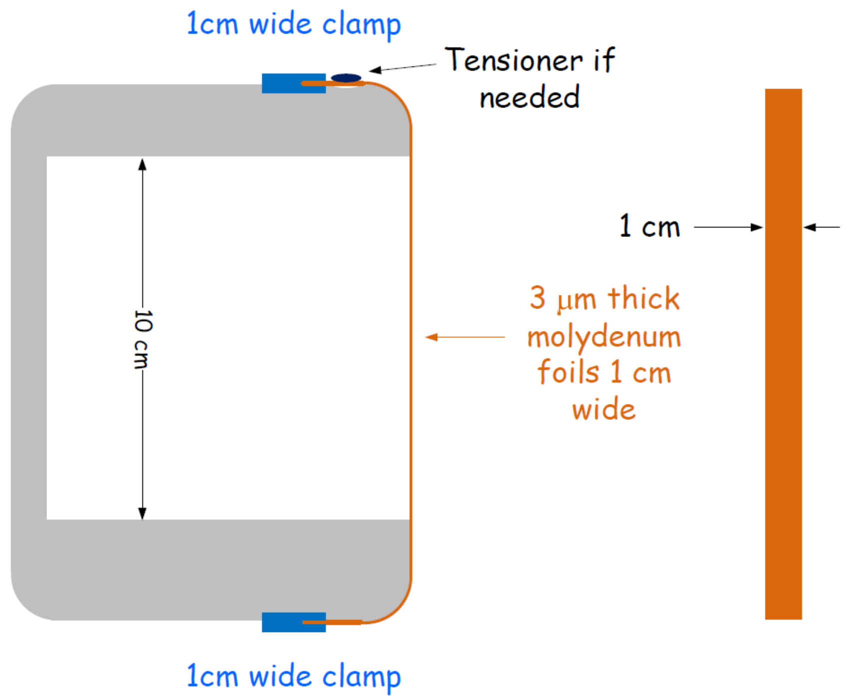


John Jaros and Knut Skarpaas

C) Molybdenum foils 3 microns thick (10 cm wide by ~10 cm tall). Tilt 25 mrad wrt to beam.

Ten 1 cm wide, 3 microns thick Molybdenum foils of 6 cm < length < 10 cm mounted on 2nd and 4th of zigzag faces





Molybdenum, Mo, ribbons

Foil Thickness = 3 μm, width 1 cm, length 10cm

Angle of plane of wires is 25 mrad wrt to beam

Width of target wires beam sees is 2.5 mm

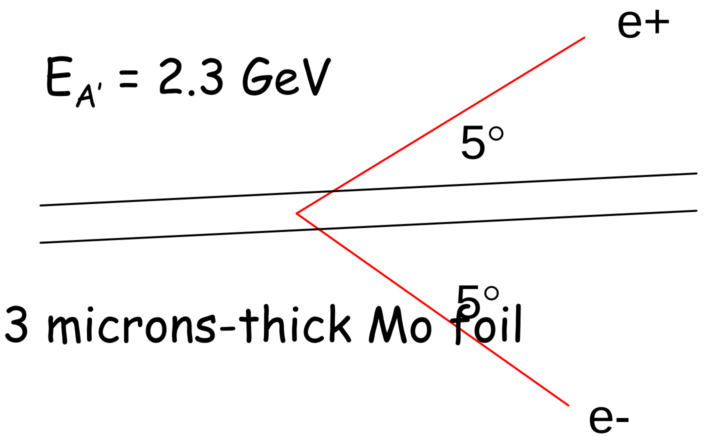
Radiation length = 9.8mm, atomic weight 95.94 gm/mol, atomic number 42, density 10.28 gm/cm3, melting point = 2623 oC, Thermal conductivity at 300 K is 138 W/m/K, Thermal expansion at 25oC is 4.8 mm/m/K, Young's modulus 329 GPa, Bulk modulus 230 GPa

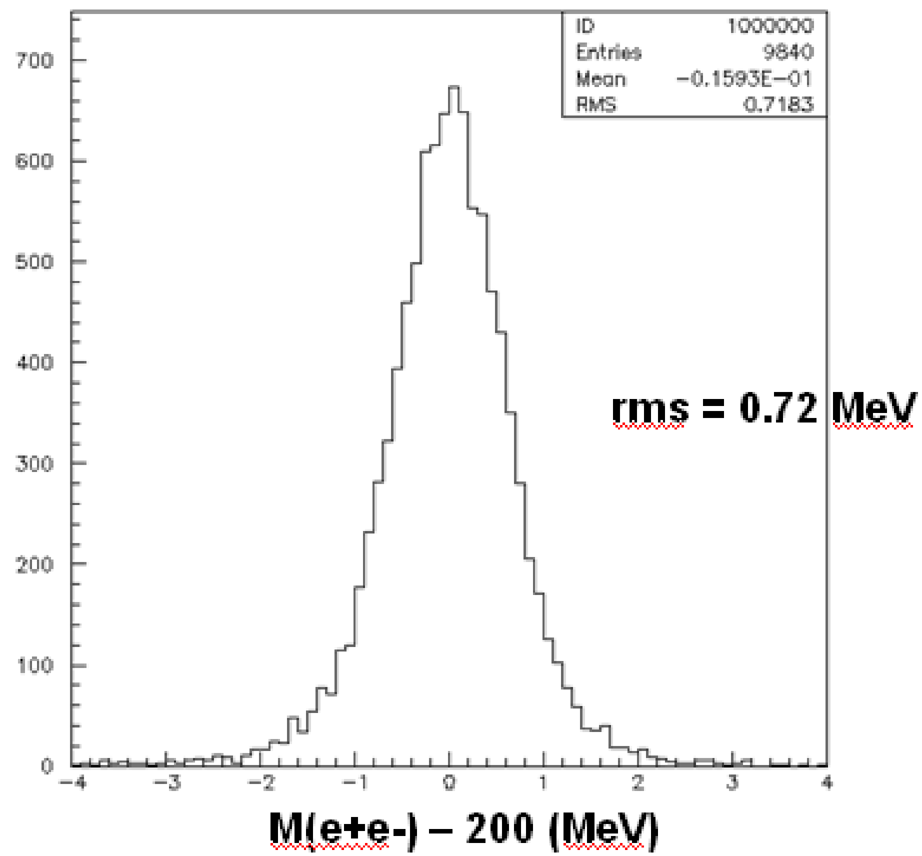
QED to hadronic processes goes as $Z^2/A = 18.8$

Pion background is 1.6 times worse for molybdenum than for tungsten.

Contribution to invariant mass error from 3 microns molybdenum foil at 25 mrad wrt beam

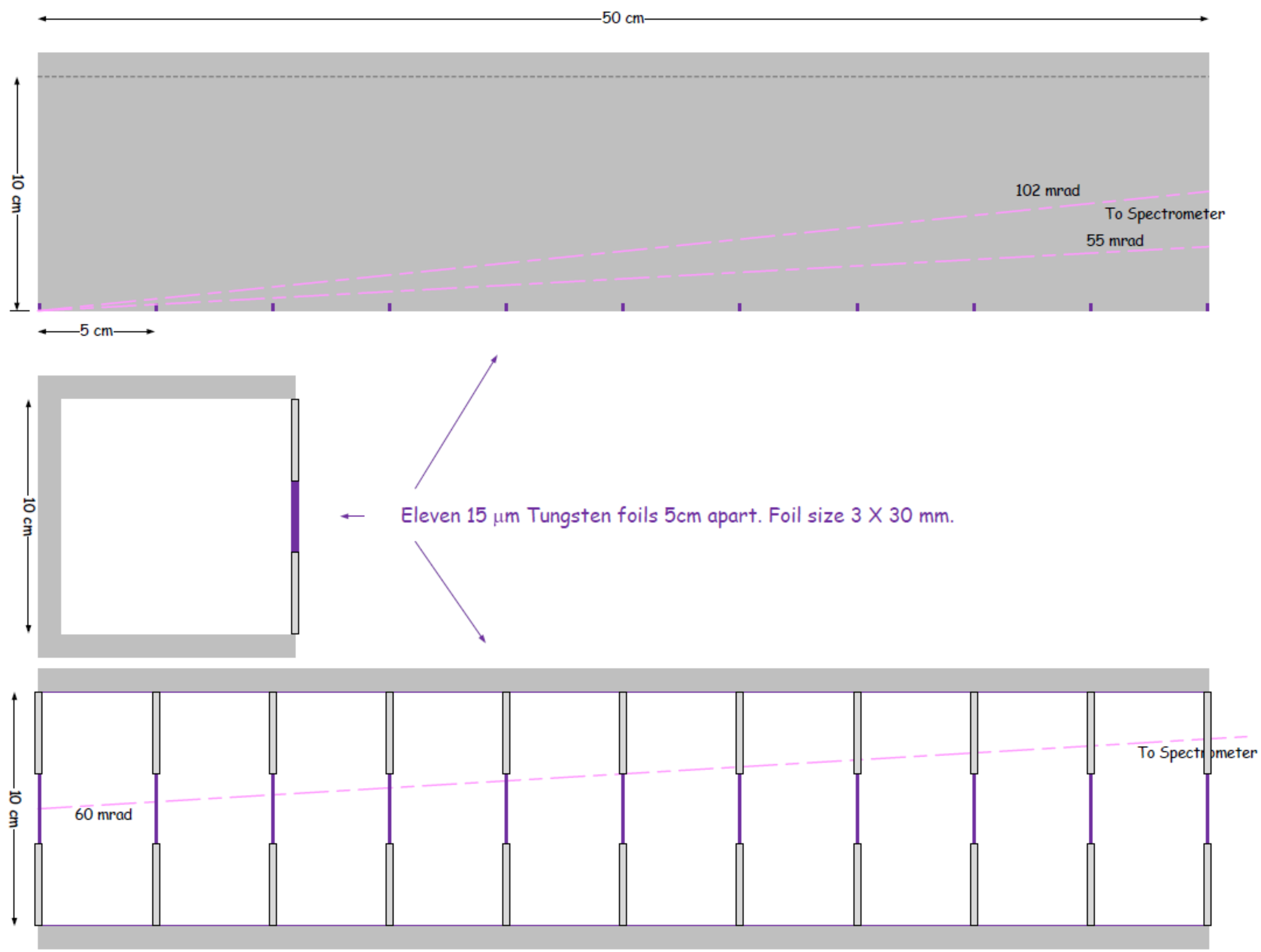
A' (200 MeV) decays at the middle of foil





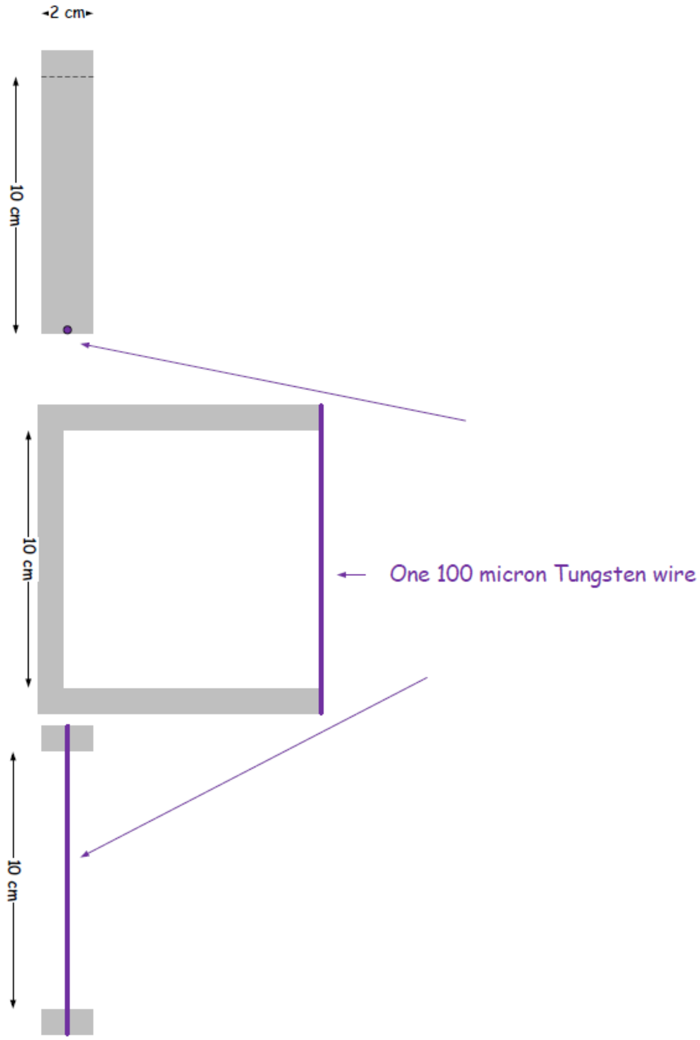
Concept D) Thin Ta/W strips (11 foils, t = 15 microns, 3x30 mm) mounted perpendicular to beam.

	DENSITY	RL	EMISSION	T_melt	Z	A	expansion x 10^{-6}
W	19.3 g/cm^2;	RL = 0.35 cm;	e=026-0.35	3422	74	184	4.5
Ta	16.7			3017	73	181	6.3



Calibration target with single 100 micron tungsten wire

Measurement of the angles HRS-L and HRS-R
Check of the target transverse position



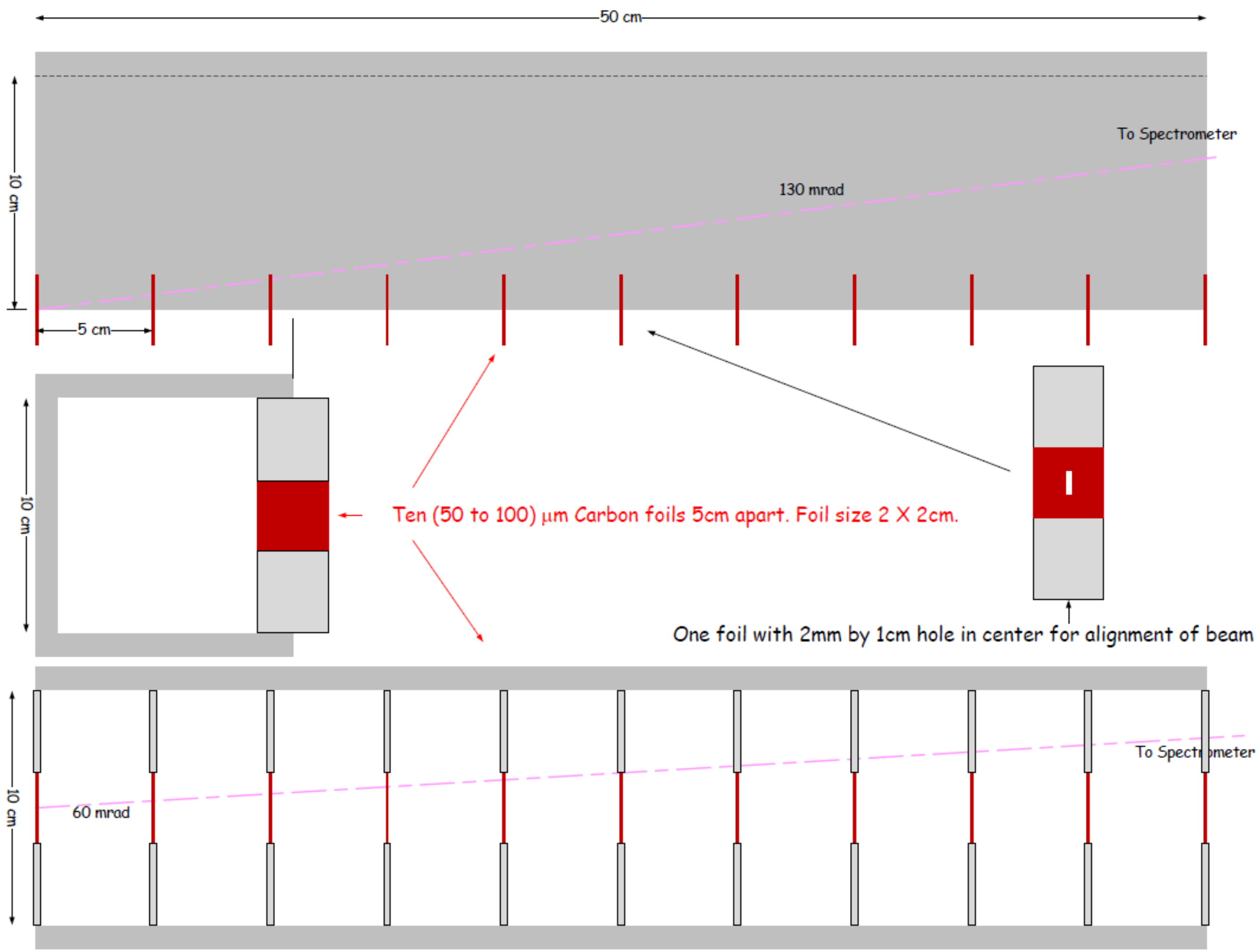
Target with single 100 micron tungsten wire used to measure angle between the two spectrometers.

Beam current during calibration run will be a factor 10 lower than normal running.
Ical ~ 5 μamps

Heat load and damage to wire will not be a problem due to lower beam current.

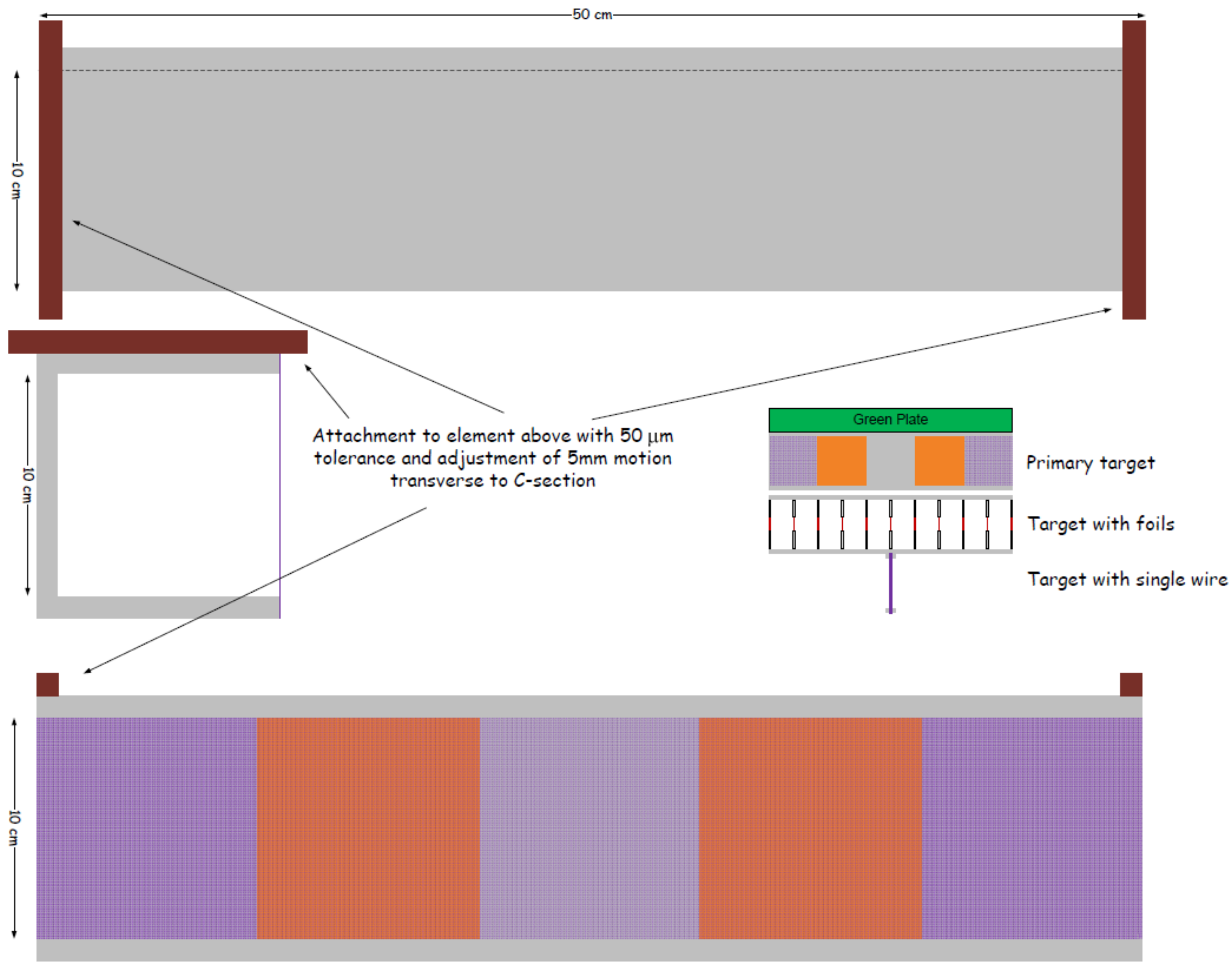
Calibration target with carbon foils

(11 foils, t = 50 to 100 microns, 10 x 30 mm)
Calibration of the optics for extended target
Check of the target ladder alignment by means of the holey targets located at +/- 150 mm
No damage or deformation to foils due to heating from beam due to lower radiation length material and lower beam current of 5μamps.



Mounting 3 targets to Green Plate

The primary target is attached to the green plate in the target assembly at Hall A. Target with foils is attached to the bottom of the primary target and the target with a single wire is attached to the bottom of the target with foils. There needs to be adjustment for alignment at both ends of C – section of 5mm with tolerance of 50 microns for only the primary target.



Schedule for Target construction for May-June 2010 Run

Schedule for Target construction for May-June 2010 Run				
#	Item	Date	Person	Task description
1	Conceptual Design	17-Feb-10	Ken + Group	Produce conceptual design so engineering can proceed
Primary Target				
2	Engineering design C-section, wires, etc			
3	Fabrication of C-section with alignment features wrt to Green Plate and ability to mount wires			
4	Detail plan for wrapping wires			
5	Fabrication of jigs, etc for wrapping wires			
6	Wire wrapping			
7	Attach wires to C-section			
8	Alignment calibration			
9	Test	11-May-10		

Schedule continued

Thin Carbon Foils Target

10	Engineering design for C-section, mounting foils, etc			
11	Fabrication of C-section with alignment features wrt to Primary target and ability to mount thin Carbon foils			
12	Detailed plan for mounting carbon foils			
13	Fabrication of jigs, etc for mounting thin foils			
14	Mount foils to C-section			
15	Alignment calibration			
16	Test	11-May-10		

Schedule continued

Target with single wire

17	Engineering design for C-section, mounting wire, etc			
18	Fabrication of C-section with ability to attach to target with carbon foils			
19	Mount wires in C-section			
20	Test	11-May-10		

Assemble three target together

21	Mount 3-target together	12-May-10		
22	Ship to Jefferson Lab	13-May-10		

Assemble target and mount to Green Plate

23	Assemble and mount targets	19-May-10		
24	Field Alignment	21-May-10		

Conclusions:

Concepts may be in hand, but, many details still not firm.

A lot of design/engineering effort is required in the next few weeks.

Our plan is to evaluate a real candidate for the primary target in the next month, do prototype tests, and build it.

Extra Material

Balance of the power and temperature of the APEX target

The list of targets Bogdan Wojtsekhowski 2/12/2010

Parameters

- Beam current is 80 micro Amp
- 4% radiation length of W, t = 270 mg/cm2
- Beam raster is 0.5 x 5 mm
- Target length is 500 mm, zigzag of 2.5 mm
- Target tilt to the beam is 10 mrad
- Wire pitch is 200 micron

Intermediate results 1

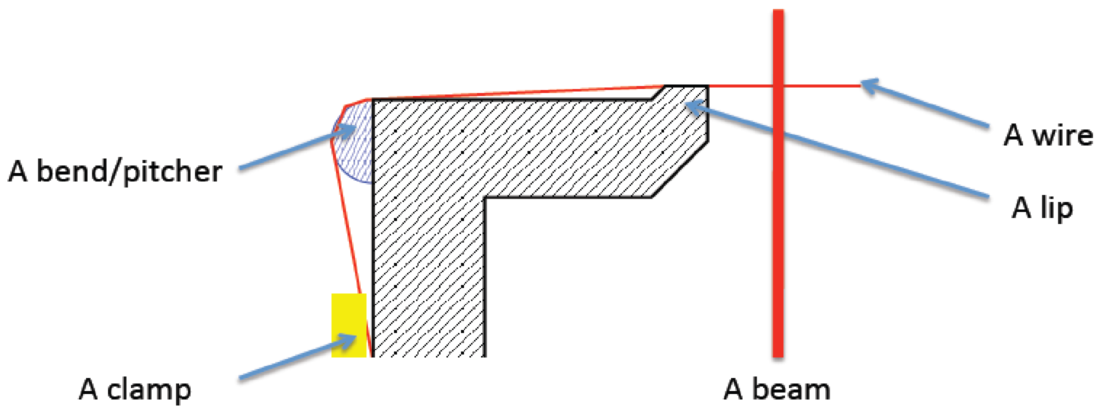
- Total power is 46 W
- Total wires in the target 2500
- Number of zigzags is 2
- Total number of wires in the beam is 500
- Power per wire is 100 mW
- Wire diameter is 14 microns
- Emissivity at 2000 K is 0.25

Intermediate results 2

- Emission power 100 mW at 2000 K needs an area of 0.1/0.25/6/16 = 0.004 cm^2
- Heated wire length is 1 cm long 0.004/3.14/0.0014 = 1. Use 2 cm as it is distance between holders (lips)
- Elongation: 4.4 10^{-6} x 2cm x 1730 => 15 10^{-3} cm
- Fractional elongation per 10 cm = 15 10^{-4} = 0.15%
- Effective stress is 4,000,000 atm * 15 10^{-4} = 6,000 atm. The wire tension is 6000 x 600 10^{-8} = 36 grams
- Tensile strength of W 8,000 atm (wires)

Additional considerations

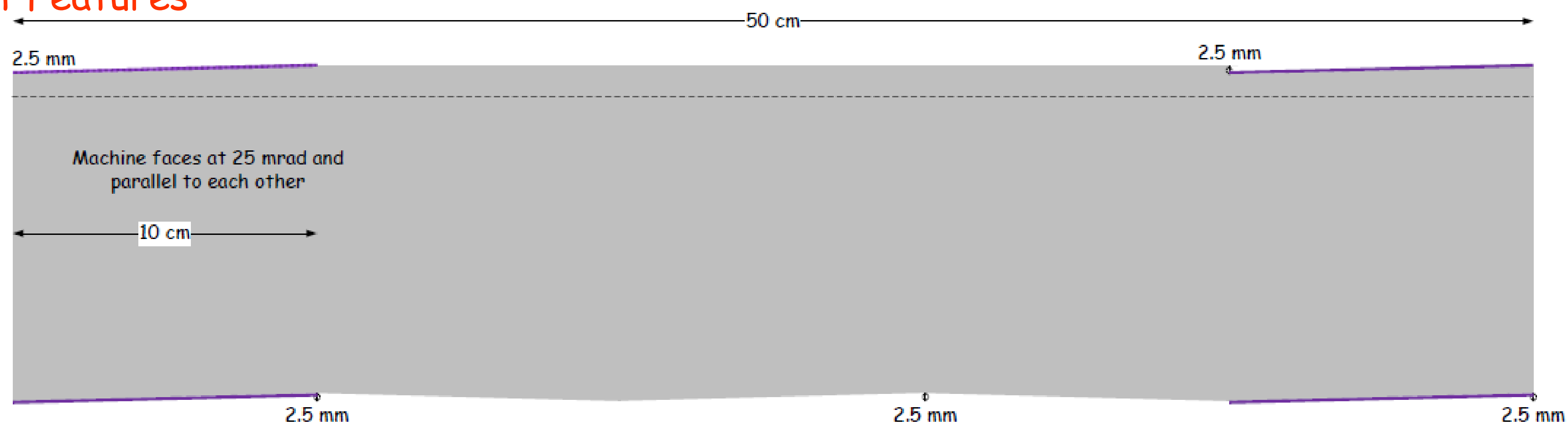
- Geometry of wire holder – 2 cm open space between the lips and 10 cm between bends to the clamp
- 0.4 mm pitch is OK for the demonstration target
- Raster 2.5 x 5 mm is OK => zigzag increase to 5 mm
- Wire plane tilt of 20 mrad for the two zigzag option

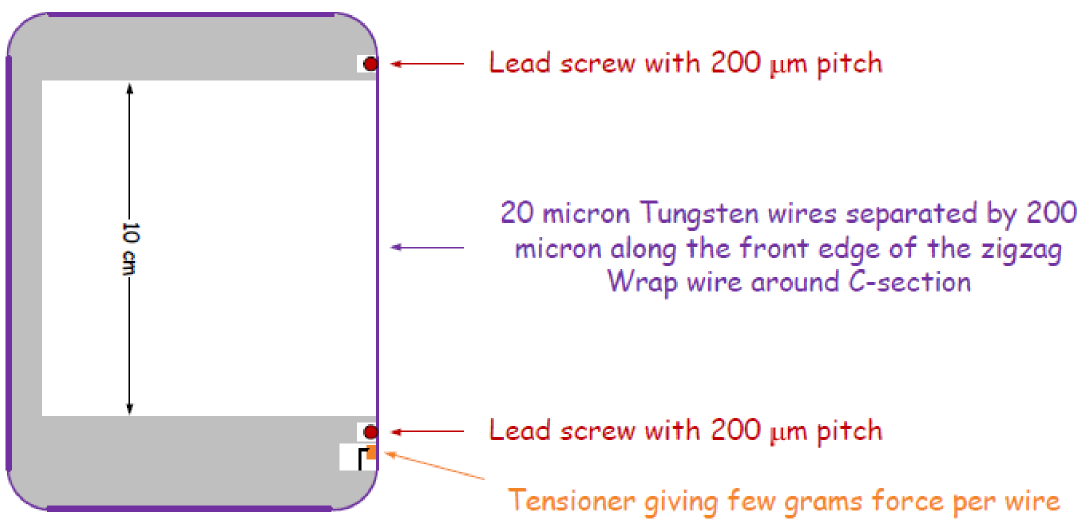


Rough concept for winding 20 μm wires 200 μm apart

- Machine front and back faces parallel in the five 10cm zigzag sections at +-25 mrad.
- Round corners of C-section to have radius of ~ 1.25 cm so wires can bend around corners.
- Place lead screws or bars in recess above and below opening of C-section so wire location is defined
- Add tensioning device giving ~20grams tension to each wire so they stay straight when heated by beam.
- Wrap 10cm length of C-section with continuous wire ~2.5 kilometer length of 20 μm tungsten wire or lay each separately. TBD
- Attach with appropriate material (Rad hard epoxy, solder or plate pressing on all wires. TBD)

Concept Features





Lead screw or scribed bar:

•Vendor with product having ~205mm pitch. Can they produce 10cm long screws, costs, delivery time?   Under evaluation.

•Bar: grinding ~200 μm deep slot of triangular width at top of ~150 μm hole every 200 μm.

Tensioned:

Adjust tension by depressing wires in a smooth groove below wires (see Clive's figures). A 50 gram weight gives dl = 400 μm for a l = 10 cm from a tungsten wire of 20 μm diameter. 50 grams tension may be too much, but, could use ~40 grams. Lengthening of wire due to beam heating may be less than this so active tensioning may not be required.

Stringing Wires:

•Wrap with winding machine from a continuous 1.5 kilometer 20 mm tungsten wire spool around the C-section frame.

• Hand mount each individual wire with weight on end of ~15 cm length. Requires mounting 1000 individual wires.

Rhenium wire:

• Investigating pure rhenium wire and an alloy of tungsten/renium(25%) wire. Gives better wire characteristics at room temperature and is stonger than pure tungsten. Rhenium (Re): Atomic weight 186.207 g/mol, Atomic number 75, melting point 3186 °C, Young's modulus 463 GPa, Bulk modulus 370 GPa, Shear modulus 178 GPa.

Tungsten Wire

From: "Grace E. Cor-Vey" <GCor-Vey@finewire.com>
Date: Mon, February 15, 2010 2:32 pm
To: "'Bogdan Wojtsekhowski'" <bogdanw@jlab.org>
Hi Bogdan, Here is your quote:

10 Micron (Approx .0004") Tungsten 99.95%, Bare Wire, Spooled onto a CFW-101 spool unless otherwise specified.
Price $2.06 per ft
Material 100211
Approx lead time is 10 to 12 working days upon receipt of your order.

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14 Micron (Approx .00055)Tungsten 99.95%, Bare Wire, Spooled onto a CFW-101 spool unless otherwise specified.
Price $1.65 per ft.
Material 100211
Approx lead time is 10 to 12 working days upon receipt of your order.

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16 Micron (Approx .00063")Tungsten 99.95%, Bare Wire, Spooled onto a CFW-101 spool unless otherwise specified.
Price $1.55 per ft.
Material 100211
Approx lead time is 10 to 12 working days upon receipt of your order.
