Extraction-Line Energy Spectrometer

DESY-Zeuthen Energy Workshop
7 June 2007

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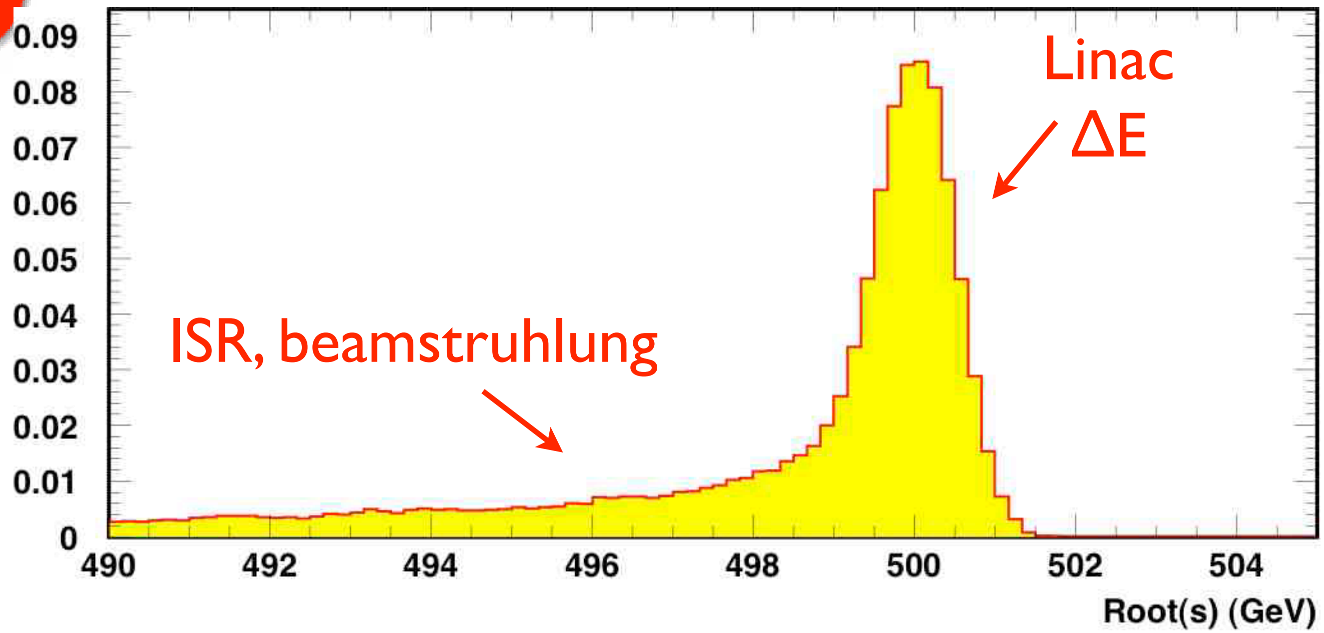
Overview

- XLS Design and Goals
- XLS Performance Studies
- First ESA testbeam run
- Preparations for Second ESA testbeam run

Note: This talk was prepared in a very short amount of time, many figures are not completely up to date.

XLS Goal

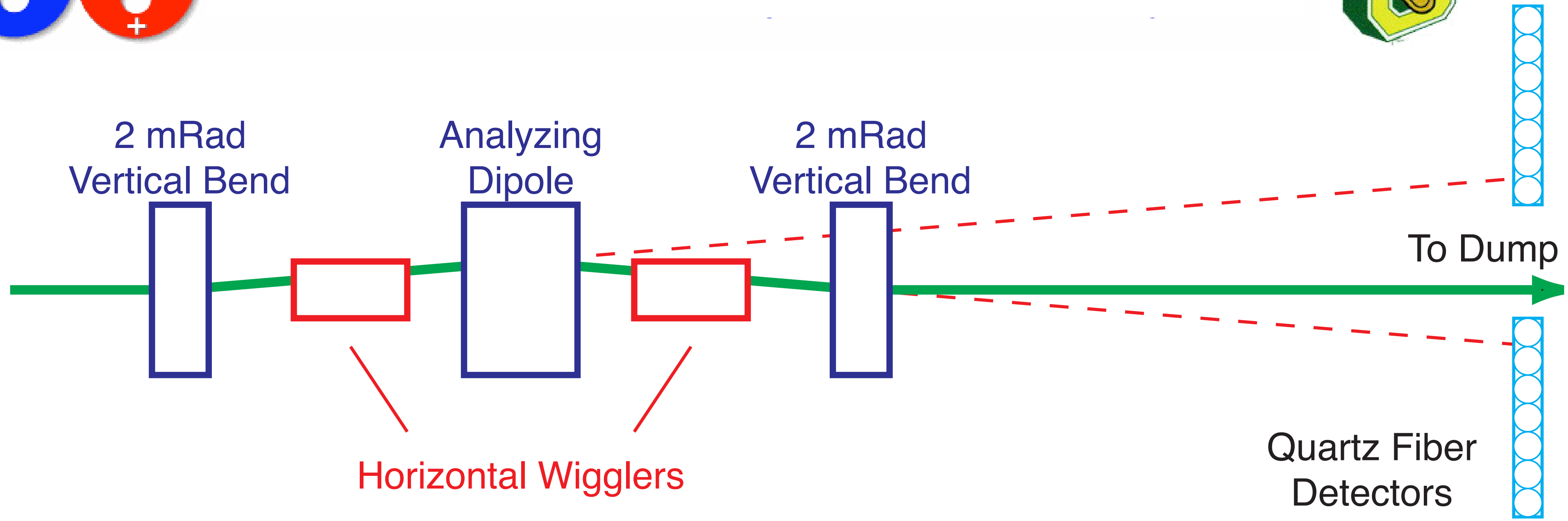


Always some correction between beam-measured quantities and root(s) values

Measure energy to 10^{-4}, core energy width, and beamstrahlung tails

Tail measurement at worst a collision diagnostic, at best can be used to validate collision models (GP)

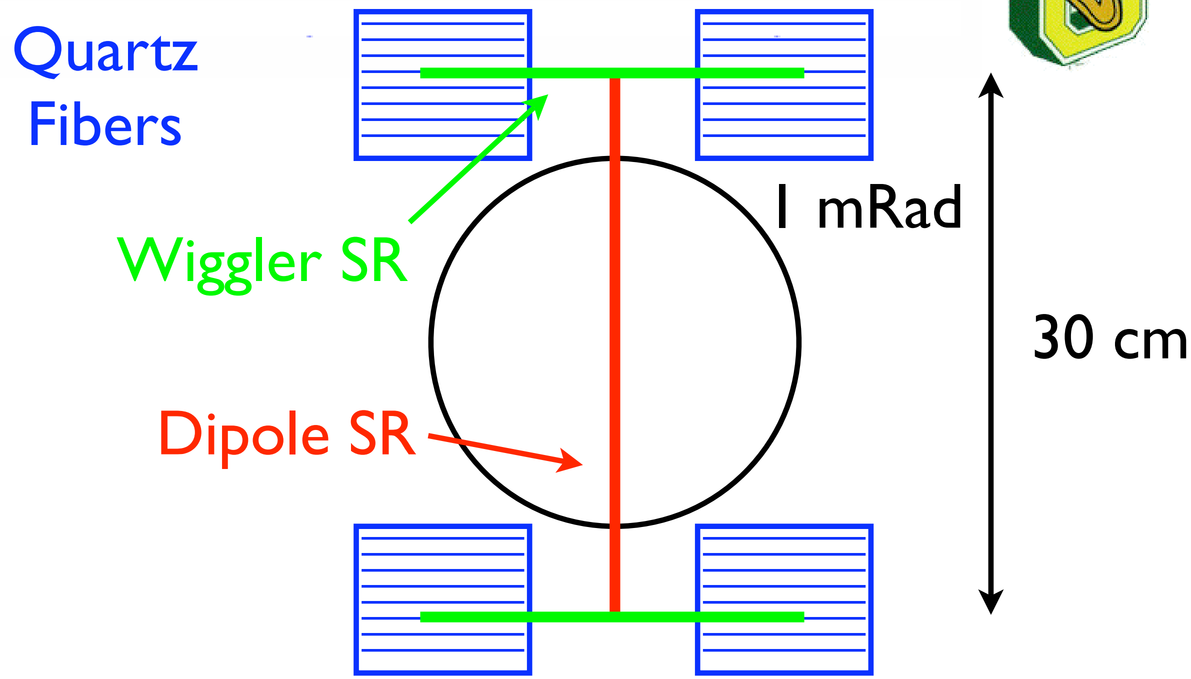
Extraction Line Spectrometer



- Secondary focus at detector plane
- Mean energy independent of energy width to first order
- Wigglers can be turned off for background measurements
- Long flight distance (~75m) to reduce transverse accuracy at position-sensitive photon detector

Detector plane

125 MeV / 100 um
for 250 GeV beam



- 4 mRad bend (+/- 2 mRad) over ~75 meters
- 30 micron accuracy for 100 ppm (optical survey OK)
- Instrument with 100 micron quartz fibers, Multi-anode PMT
- Double detector improves wiggler alignment tolerance

Rad hard and robust, fast and simple readout,
easy gain adjust, no RF pickup, modest cross-talk

Design Features

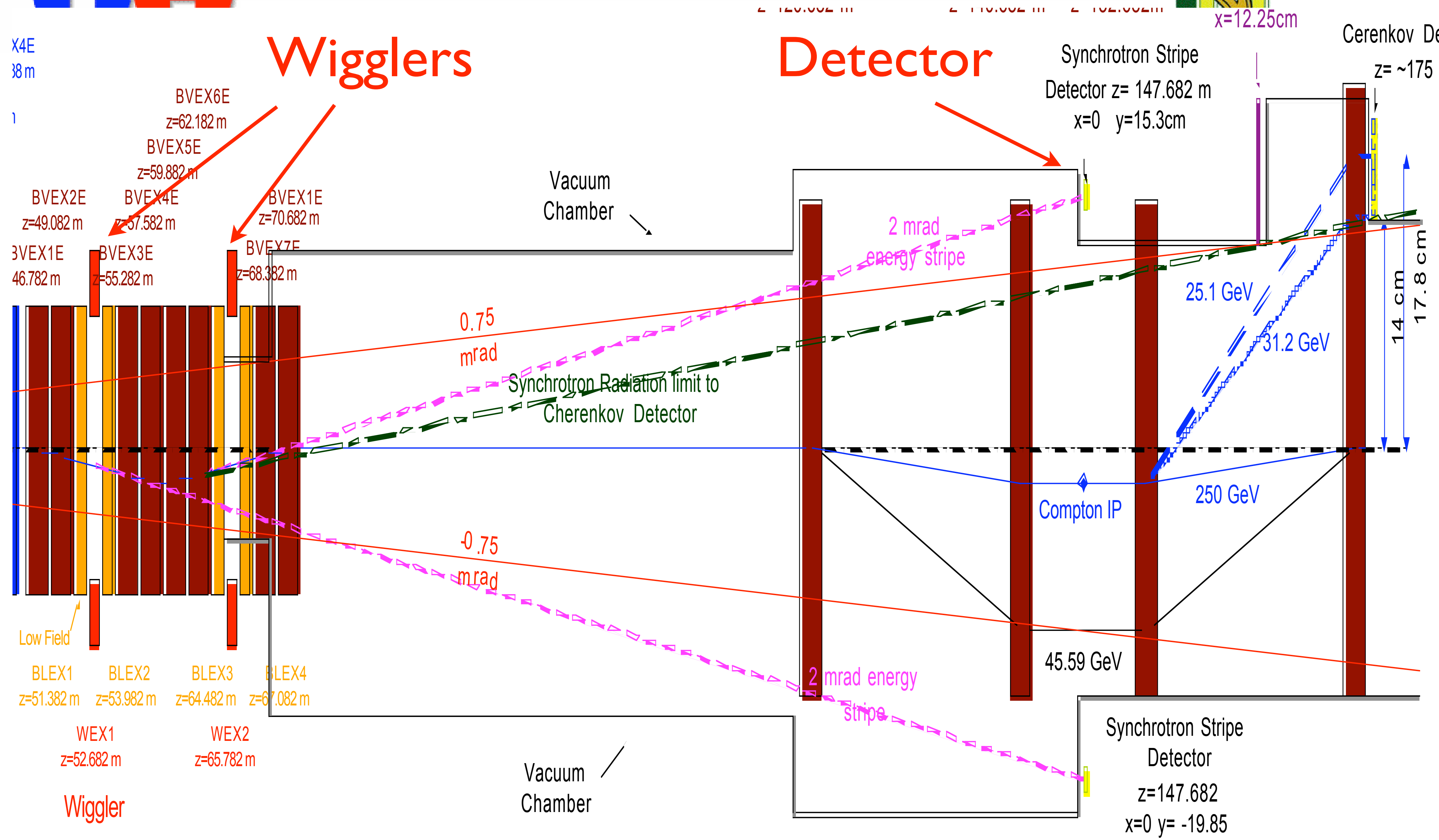
The Good

- Photons insensitive to ambient magnetic fields
- Single plane simplifies survey/alignment requirements
- Longitudinal position needs ~1 cm accuracy
- Passive device, high reliability, pulse-to-pulse possible

The Bad

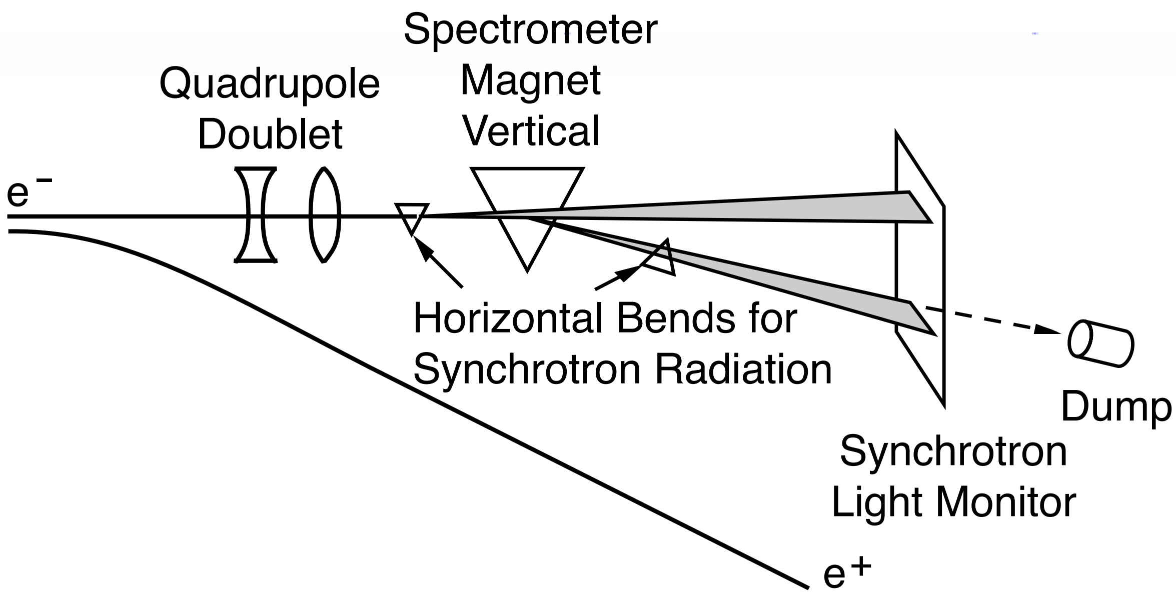
- Must get SR out cleanly to detector
- Need large apertures in X-line
- Very dependent upon optics, alignment
- Must worry about detector backgrounds

ILC CDR Extraction Line



Old design, but basic features correct...

SLC Wisrd

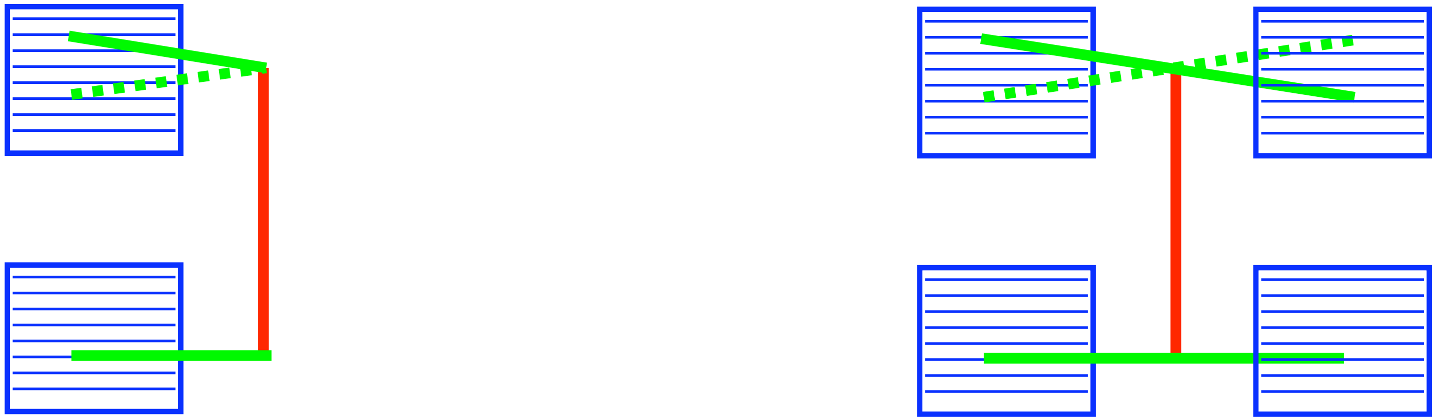


- Not a new idea, operated at SLC for ~10 years
- Achieved few x 10^{-4} accuracy
- Used daily as the primary beam energy monitor

Current design aims to improve upon lessons learned with the SLC Wisrd

WISRD issues

- Alignment systematics

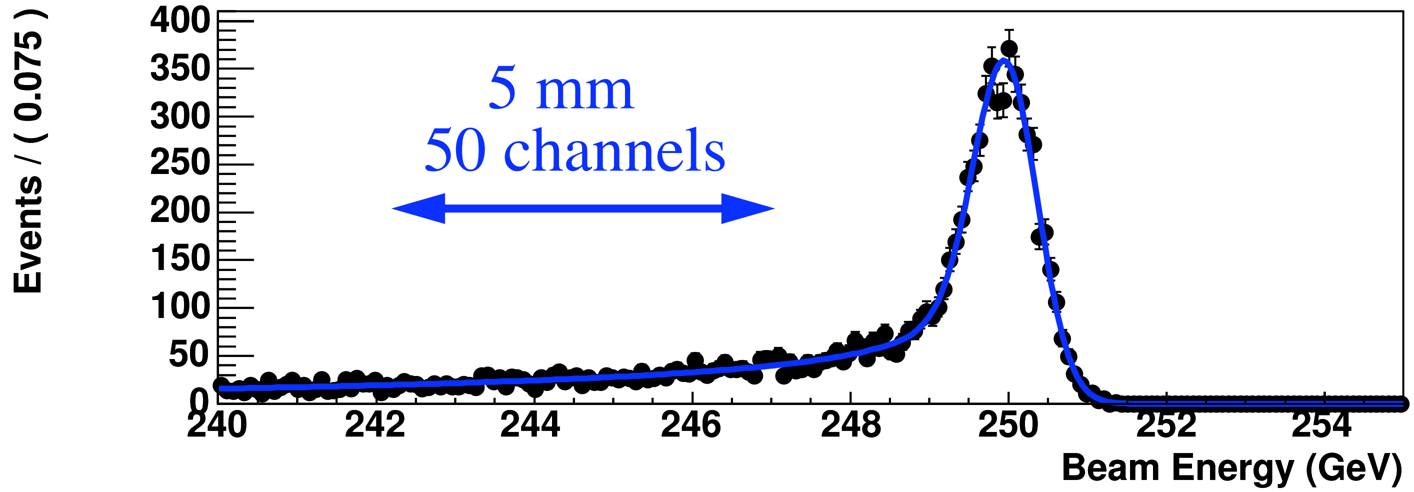


Symmetric design avoids first-order systematic on wiggler-dipole plane angle - 100 ppm for Wisrd
Still need dipole plane-detector orthogonality

- Wire detector

75 micron wires on 100 micron pitch
Crosstalk and electronics tricky
Very low energy threshold (~10 keV)

Detector Module



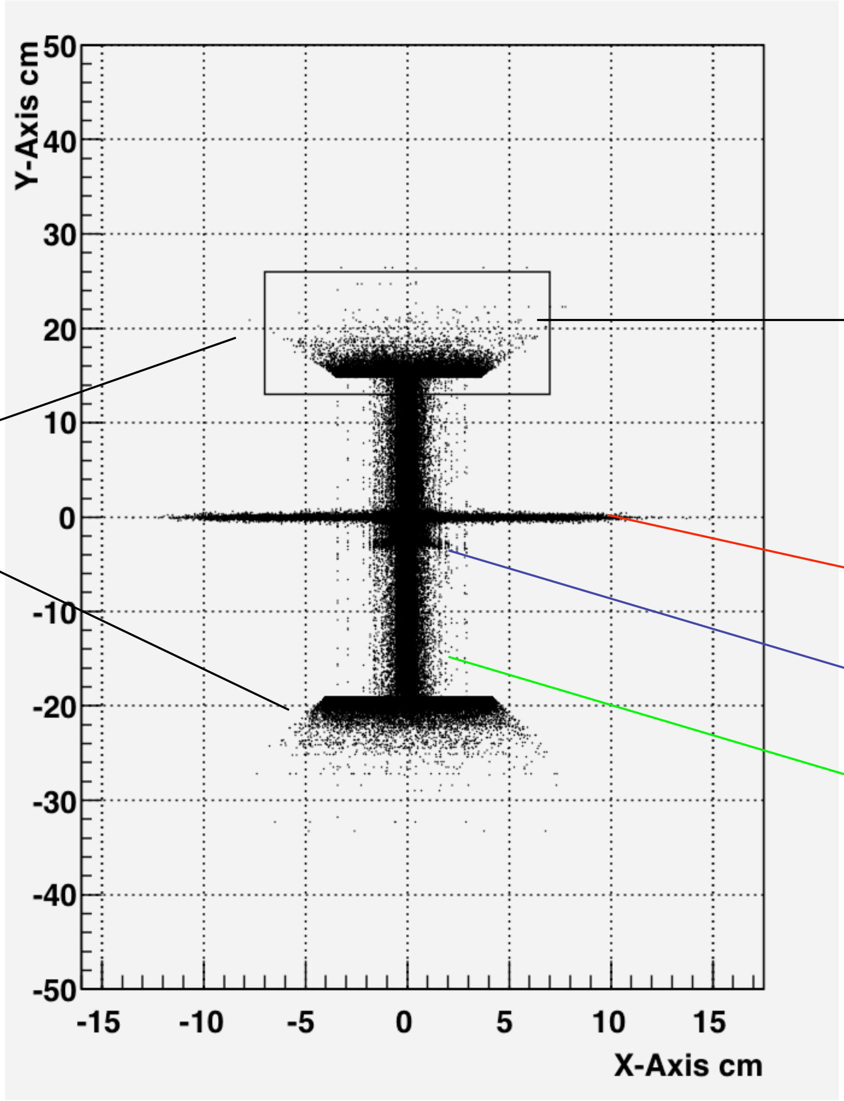
- Fused silica (quartz) fibers, read out with 8x8 MaPMT
- Observe Cerenkov light from secondary electrons
- 100 micron pitch in core region (~2 cm - 128 fibers)
- 1 mm pitch (600 micron fibers) else (~26 cm - 256 fibers)

More signal/channel, lower channel count
~1600 fibers, 24 PMTs per beam
26 cm detector can see to 50% of Enom

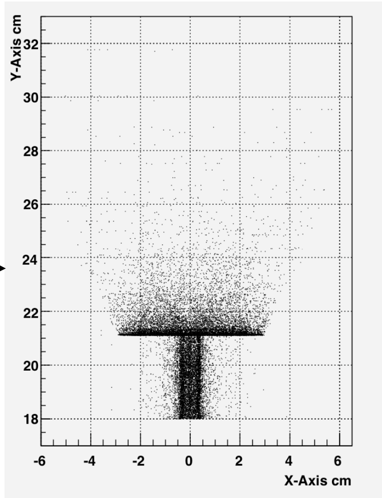
XLS design studies

(w/ Matt Sternberg, UO undergrad)

Radiation at Detector Plane



Wiggler Stripe



Measuring separation between bands allows for precise measurement of bending without having to know precise position relative to beam

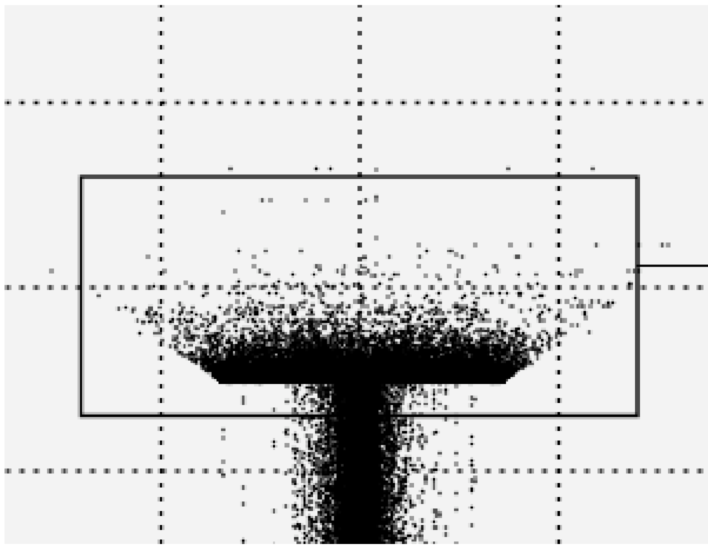
Radiation from quads

From Polarimeter Chicane

From Energy Chicane Bends

Detector Regions and Backgrounds

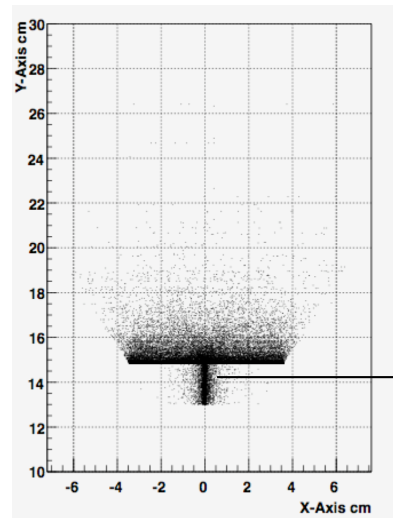
Detector Scheme 1



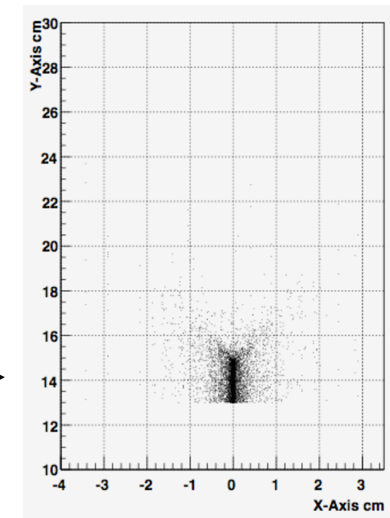
Signal to Noise - Starting at peak signal

20:1

Detector Region



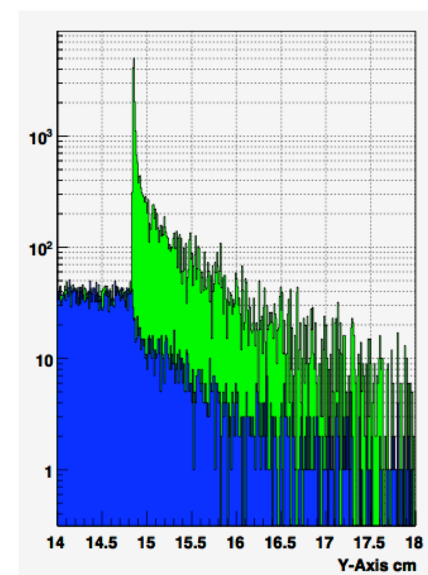
Background From Bends



Detector Signal for 100μm Bins

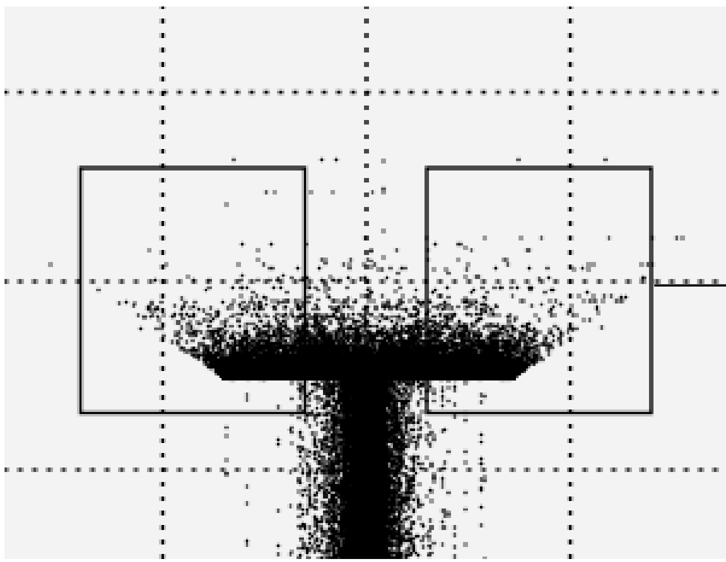
Green - Full Signal

Blue - Background from bends



Detector Regions and Backgrounds

Detector Scheme 2

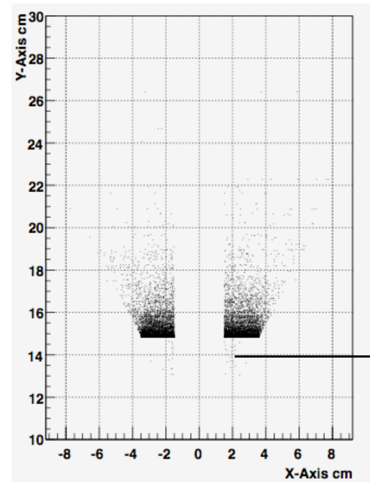


Cutting out $-1.5\text{cm} < x < 1.5\text{cm}$

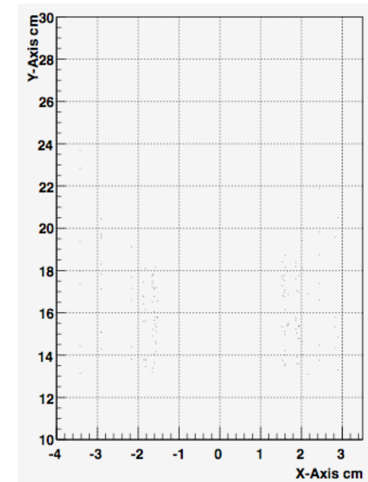
Signal to Noise - Starting at peak signal

466:1

Detector Region



Background From Bends



Detector Signal for 100μm Bins

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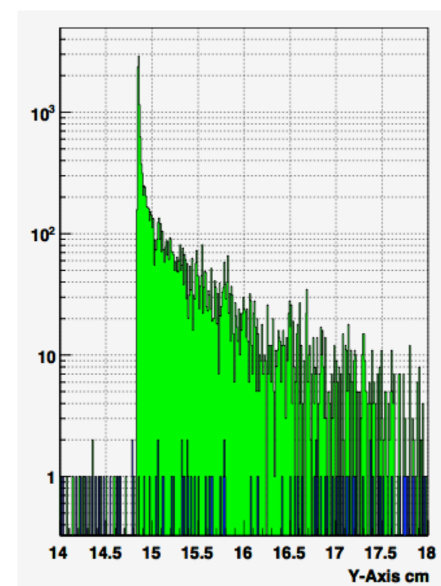
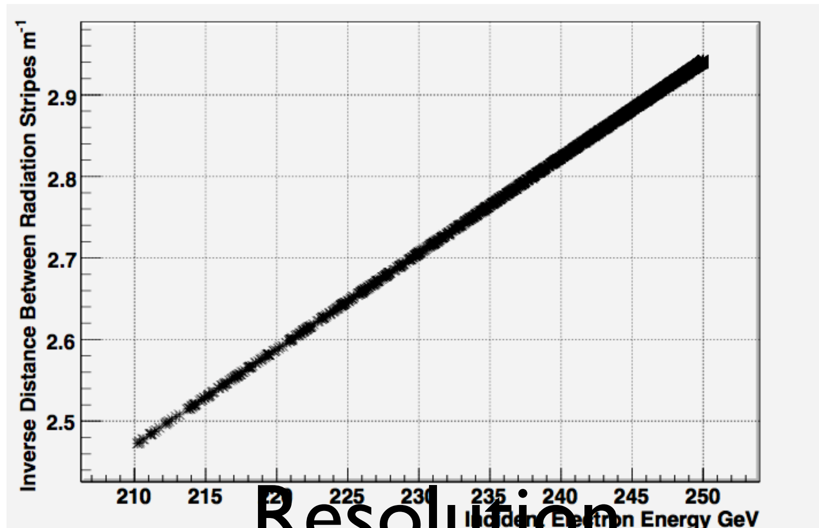


Fitting the Dispersion

- For each incident electron we measure the separation between the average position of photons in upper and lower bands
- Inverse separation is proportional to energy

Detector Scheme 2



Fit from 230GeV to 250GeV

$$\frac{\int B\cdot dl}{E} = \Delta\theta \approx y / d$$

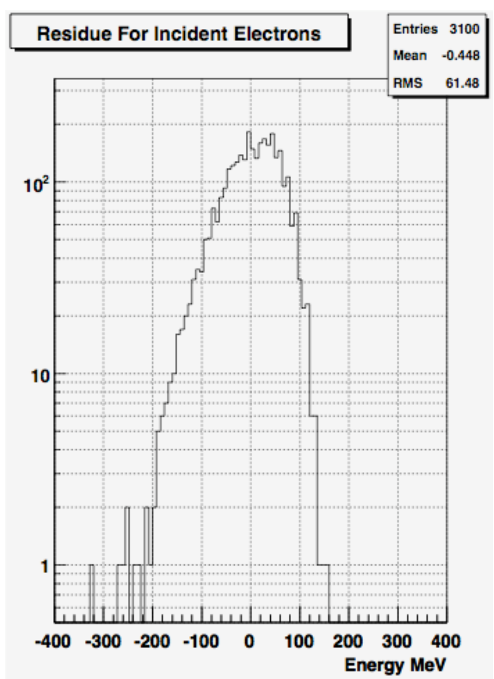
=> E α 1/Separation

Resolution

Residue Against Incident Electron Energy

Mean = -0.45 MeV

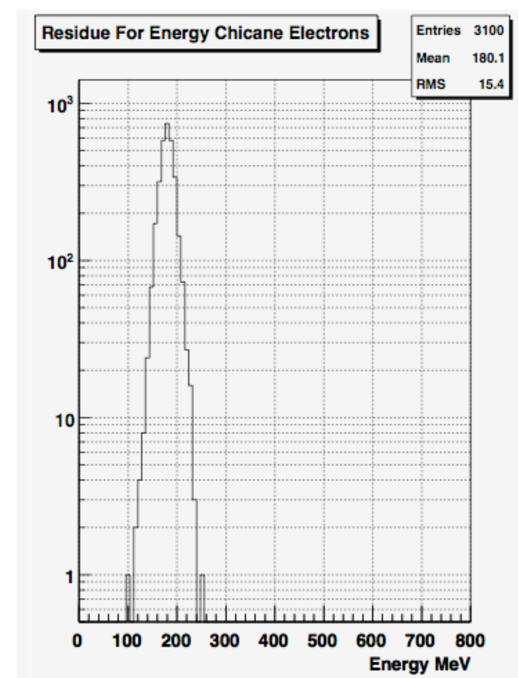
RMS = 61.48 MeV



Residue Against Electrons in Middle of Energy Chicane

Mean = 180.1 MeV

RMS = 15.4 MeV



First ESA Run

w/ Mike Woods, Ray Arnold, SLAC
Paul Csonka, UO Undergrad

ESA motivation

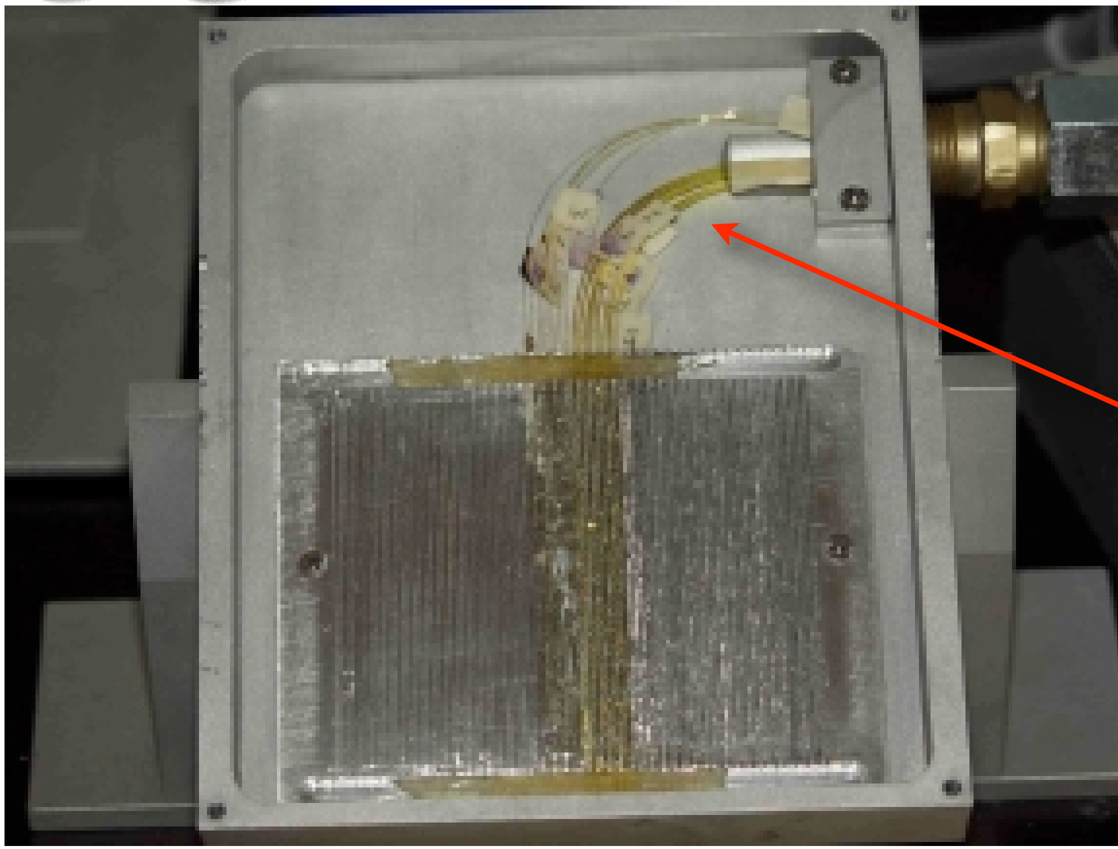
Stage 1

- Check SR detection by Cherenkov in quartz fibers
- Compare efficiency (very small) to MC
- Check for other anomalous background sources
- Operational and design experience

Stage 2

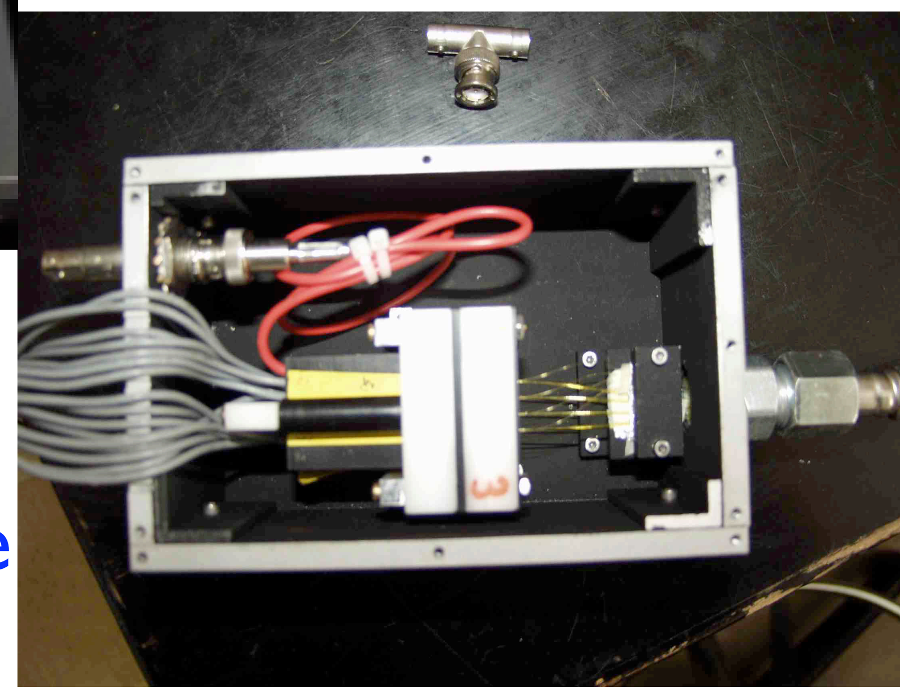
- Refine design to be closer to XLS
- Demonstrate E measurement by this technique
- Demonstrate width measurement
- Compare to BPM-based measurement

T-475 Detector

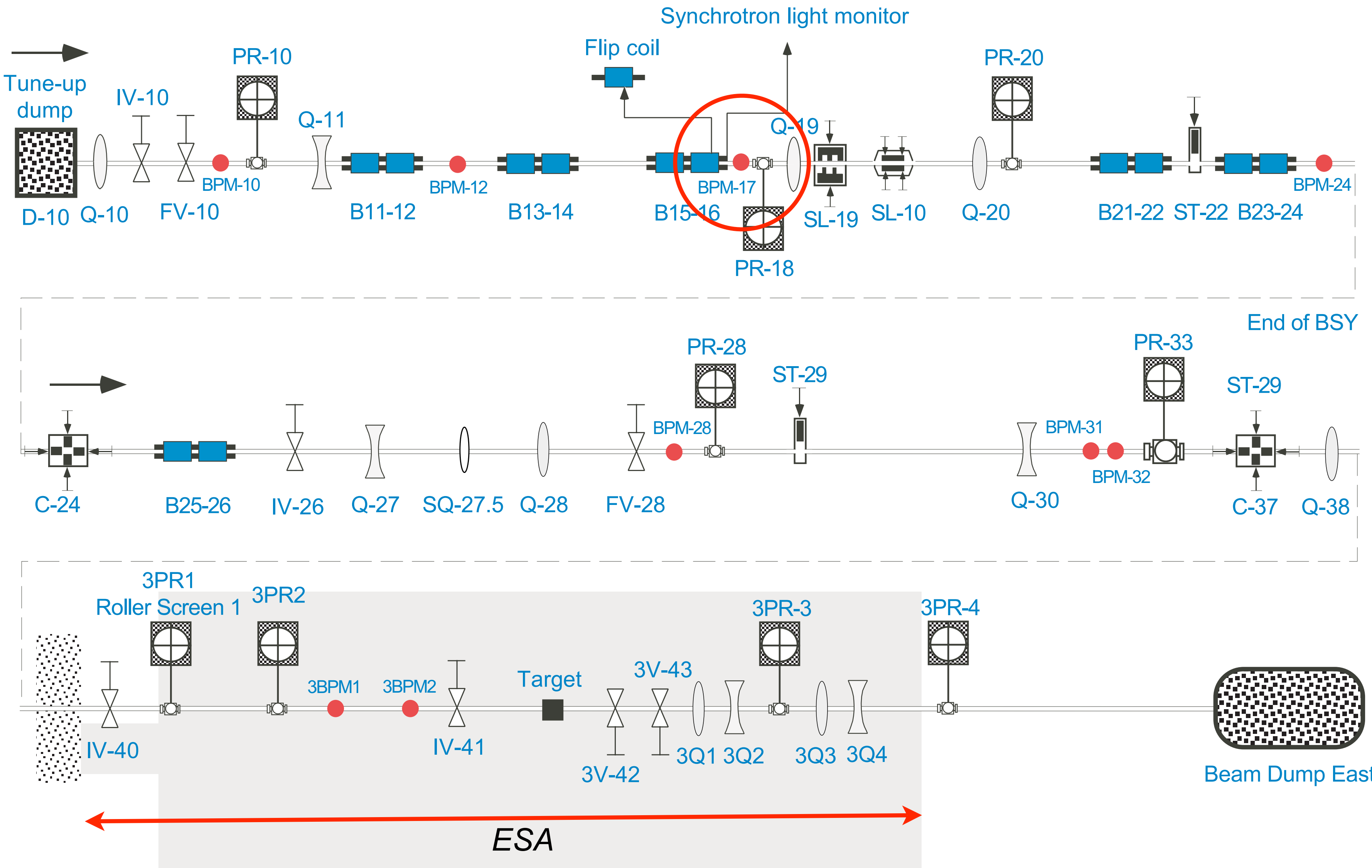


8 100 micron fibers
8 600 micron fibers
(one cut at entry)
1 mm pitch

16 channel R6568 MAPMT
Line driver for long analog cable

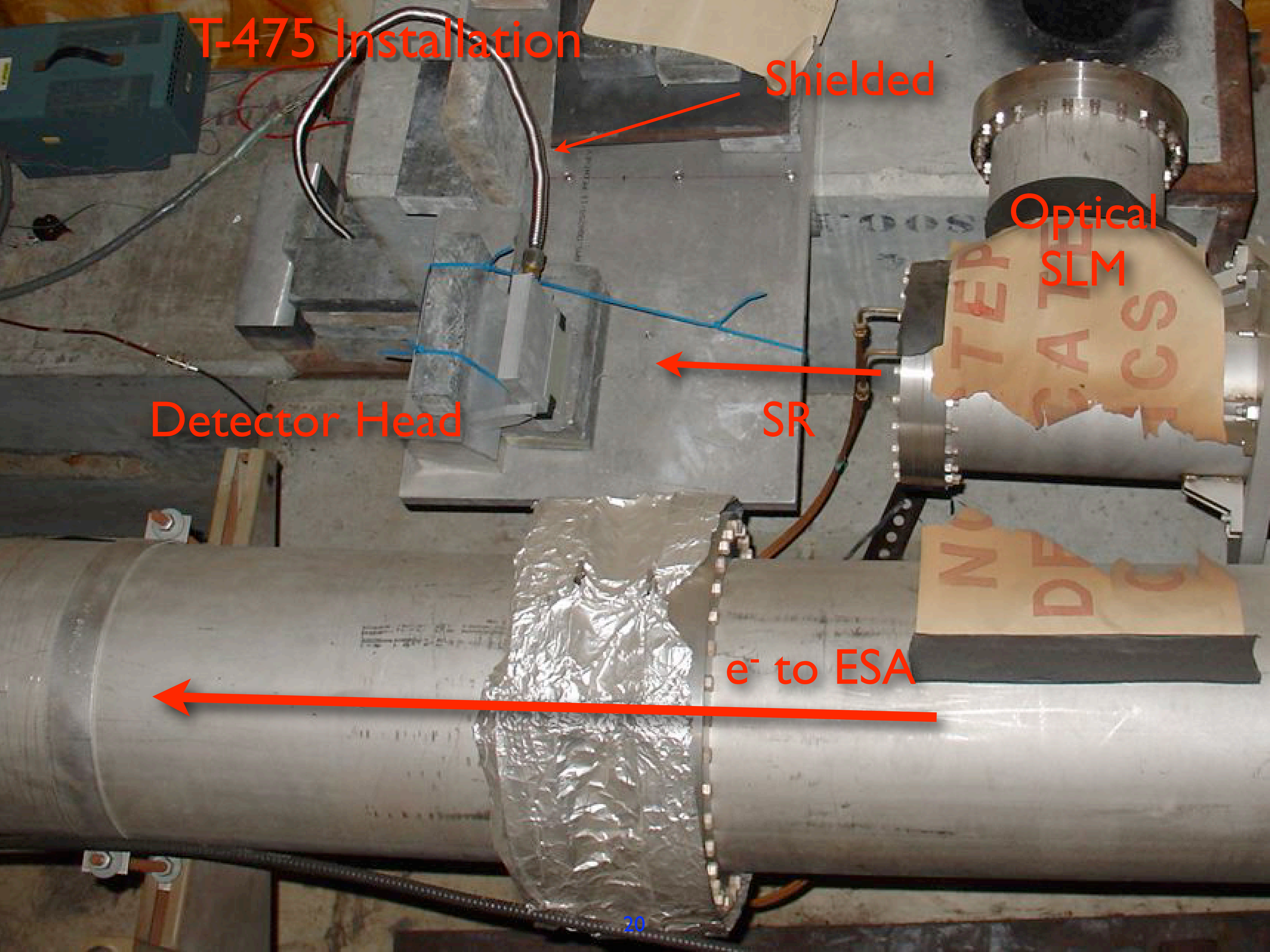


Initial (2006) T-475 Location

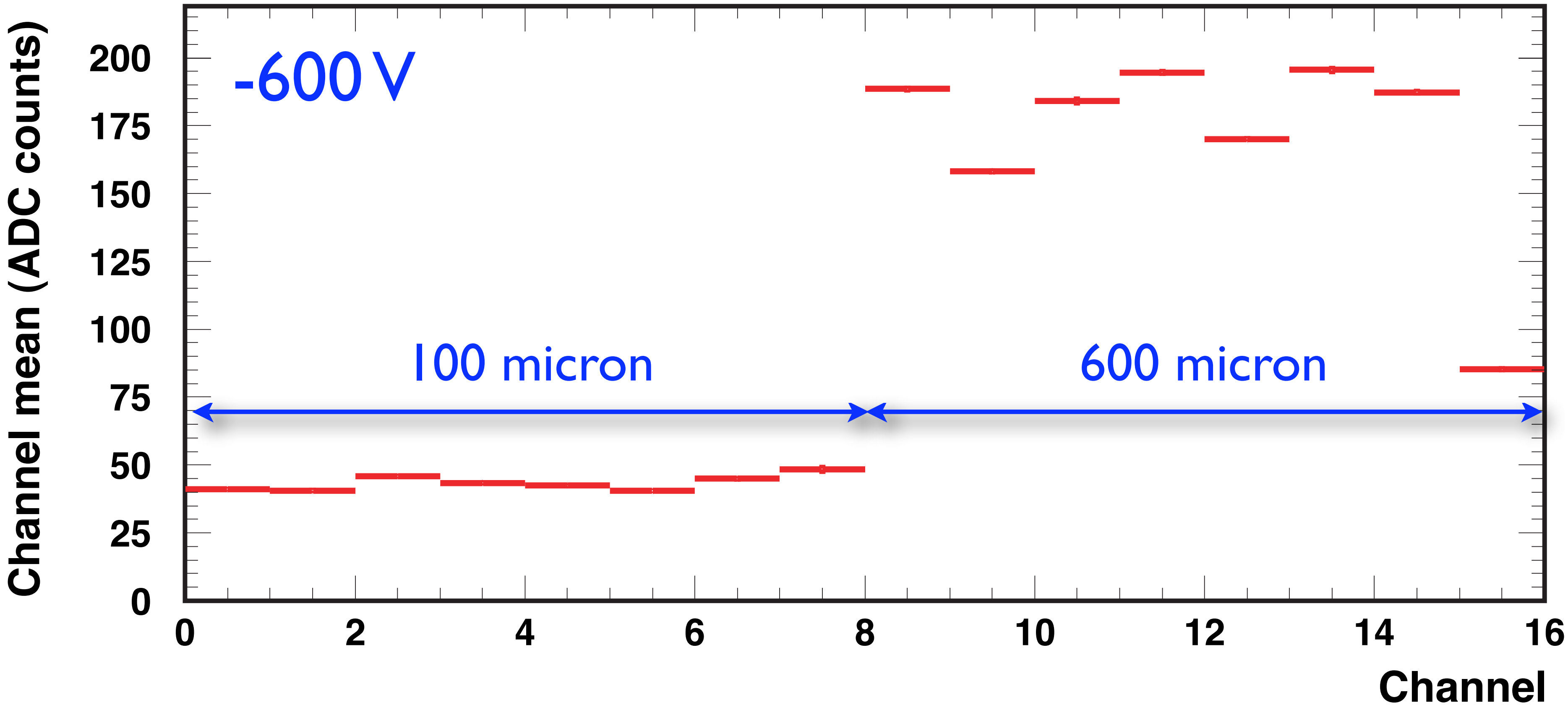


Part of switchyard, access very limited

T-475 Installation



Real Data



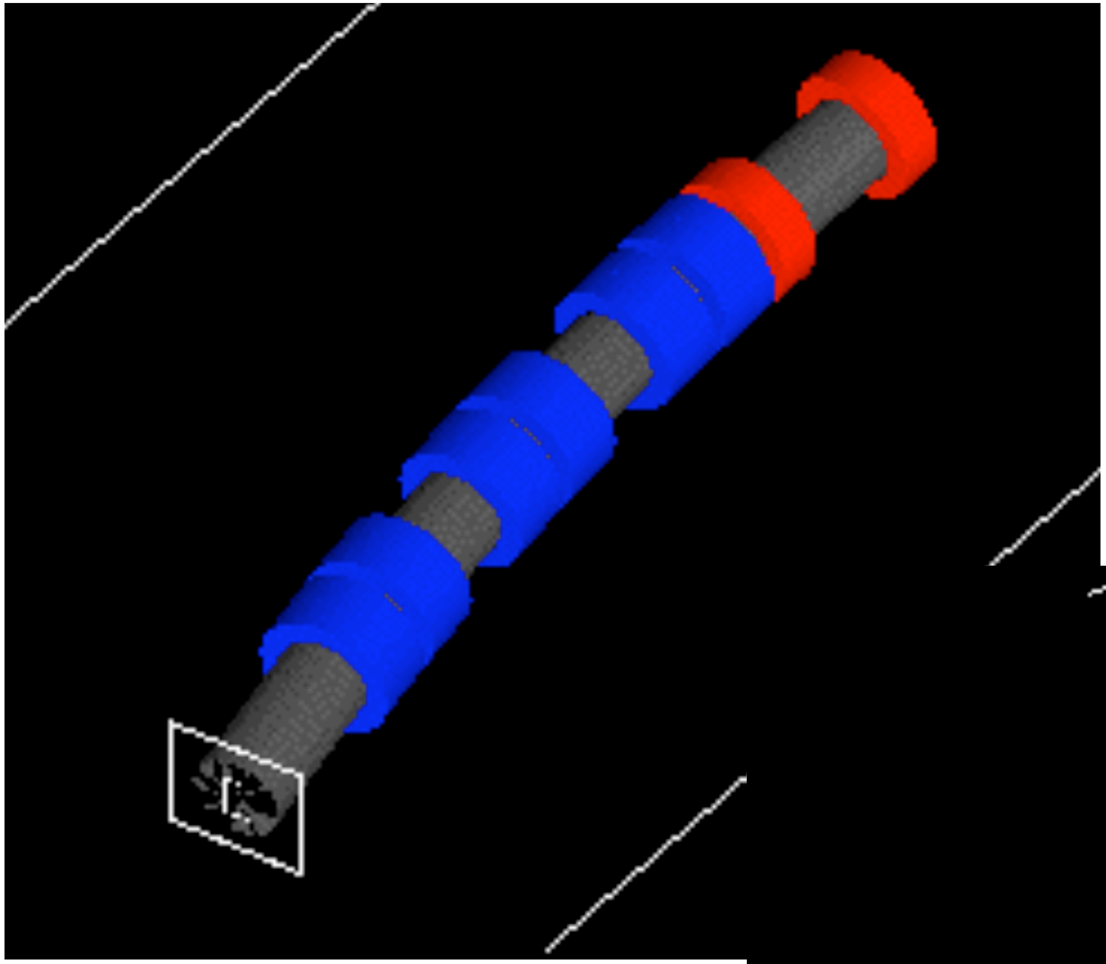
Ch 15 is cut (background monitor)

Signal/Noise ~ 1

Large/Small is not 6^2

Very limited ability to understand data

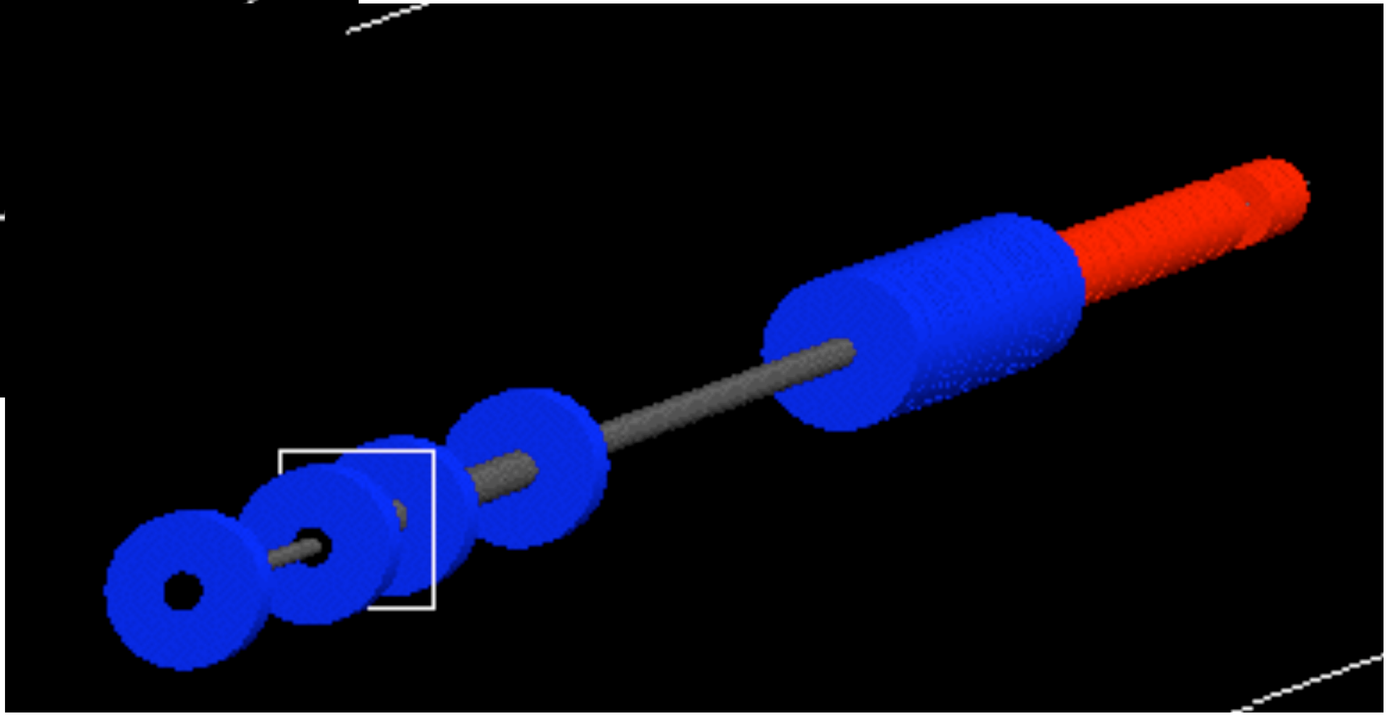
BDSIM Simulations



SLAC A-line dipoles

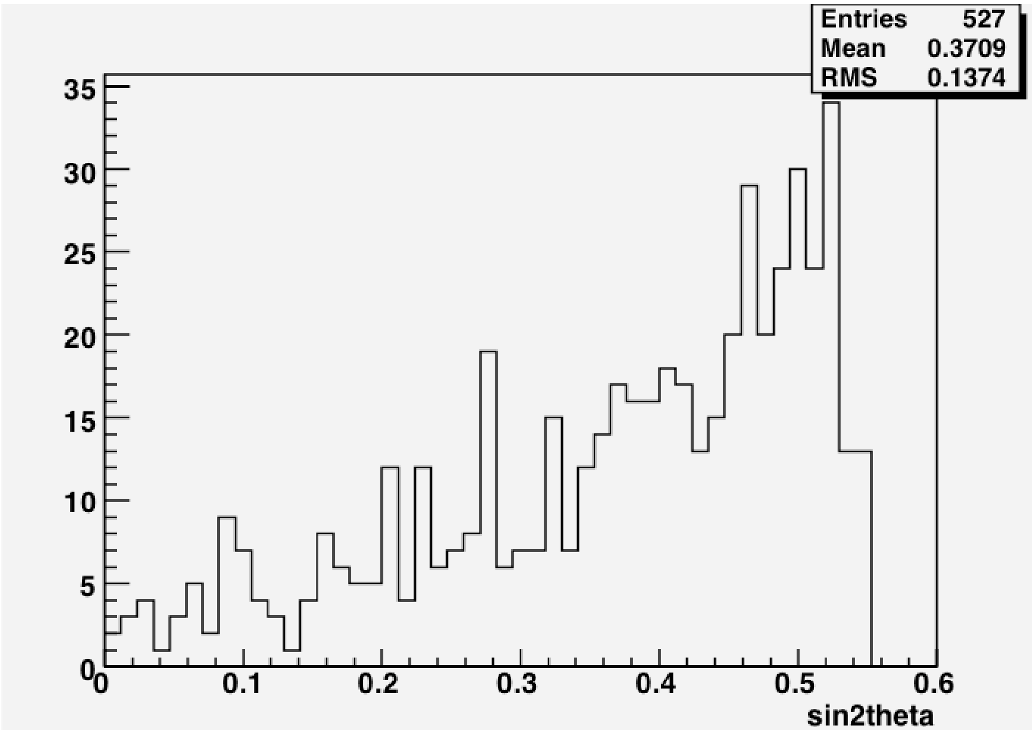
$E_c \sim 1.8$ MeV

$E_c \sim 15$ MeV 14 mRad X-Line

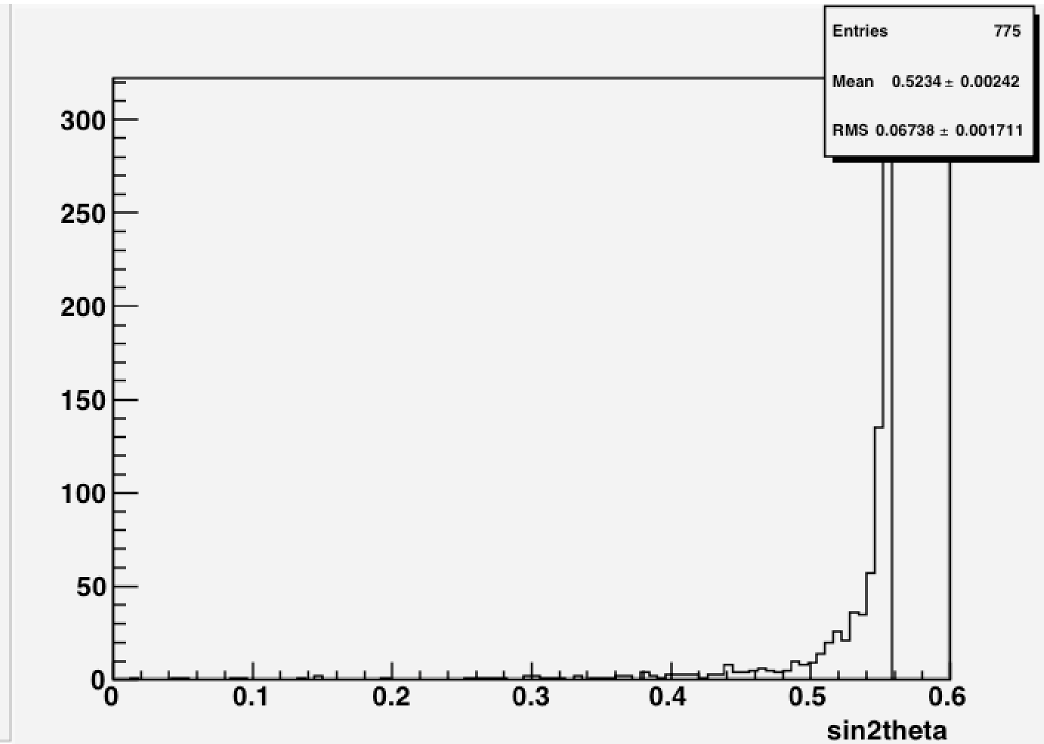


Electron Cerenkov Angle

Aline



X-Line



$\langle \sin^2\theta \rangle = 0.37$

$2\ 10^4$ Ch. $\gamma/10^{10}$ e/fiber

Eff ~ 10^{-6} / fiber + transmission losses!

$\langle \sin^2\theta \rangle = 0.52$

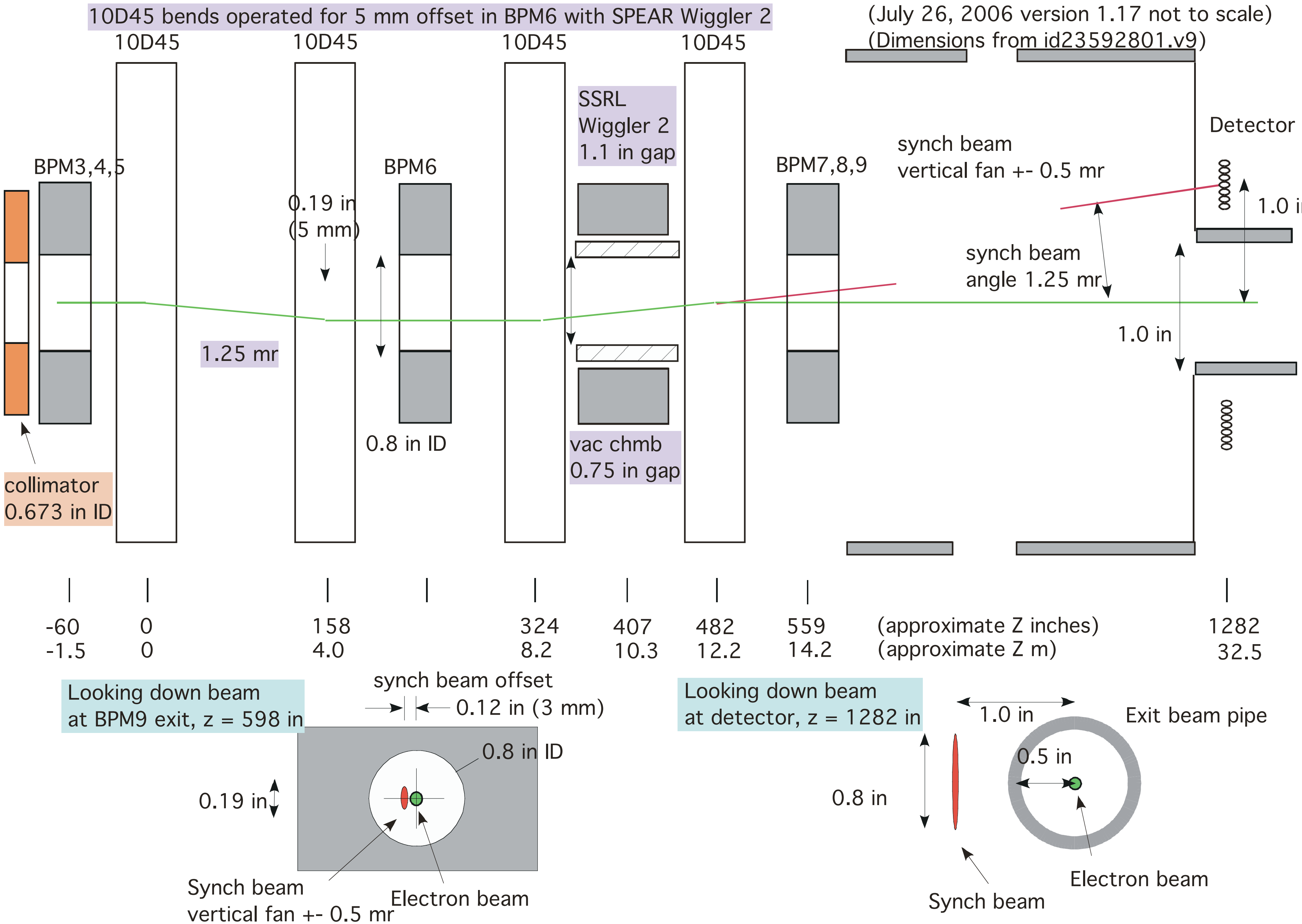
$\sim 10^7$ Ch. $\gamma/10^{10}$ e/fiber

3 orders higher!

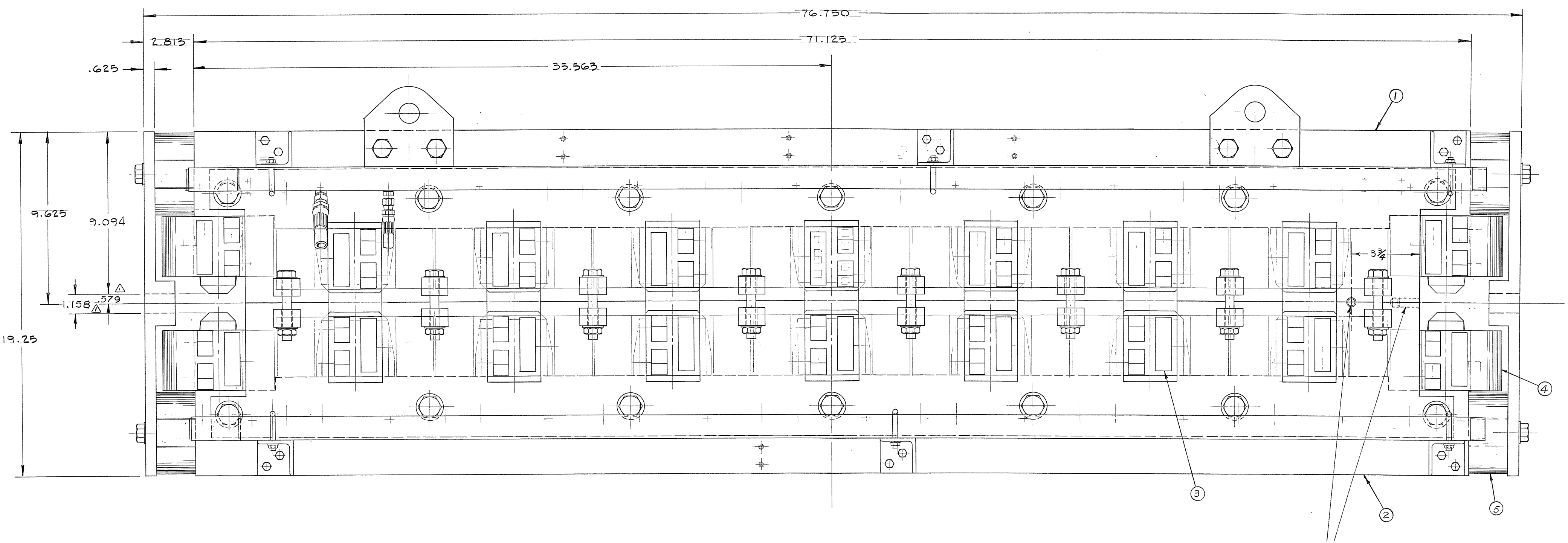
Second ESA Run

w/ Mike Woods, Ray Arnold, SLAC
Liz Ohlson, Jeffrey Garman, UO Undergrads

T474 BPM Spectrometer and T475 Synch Light Spectrometer Plan View



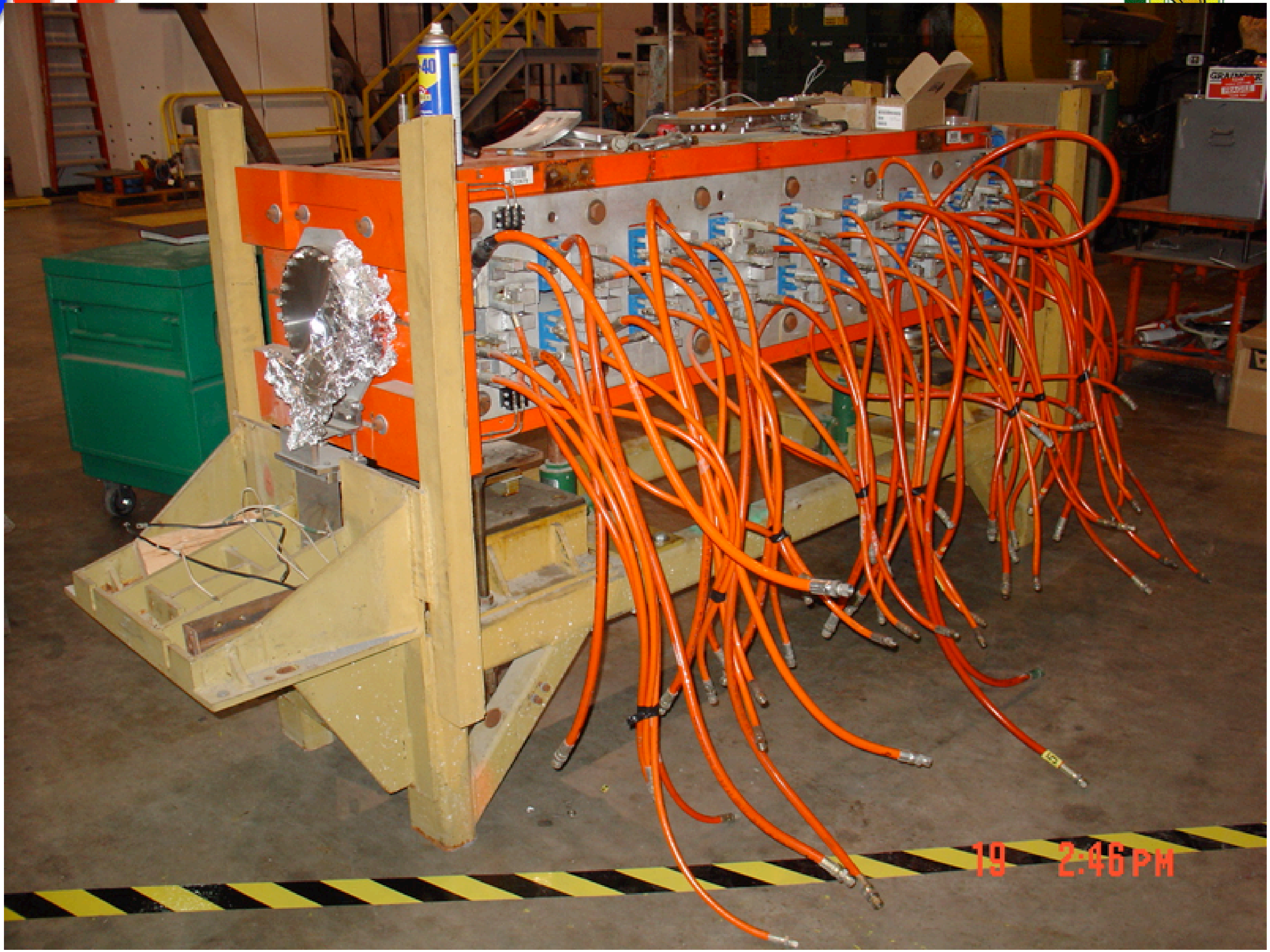
Mk-II Spear wiggler



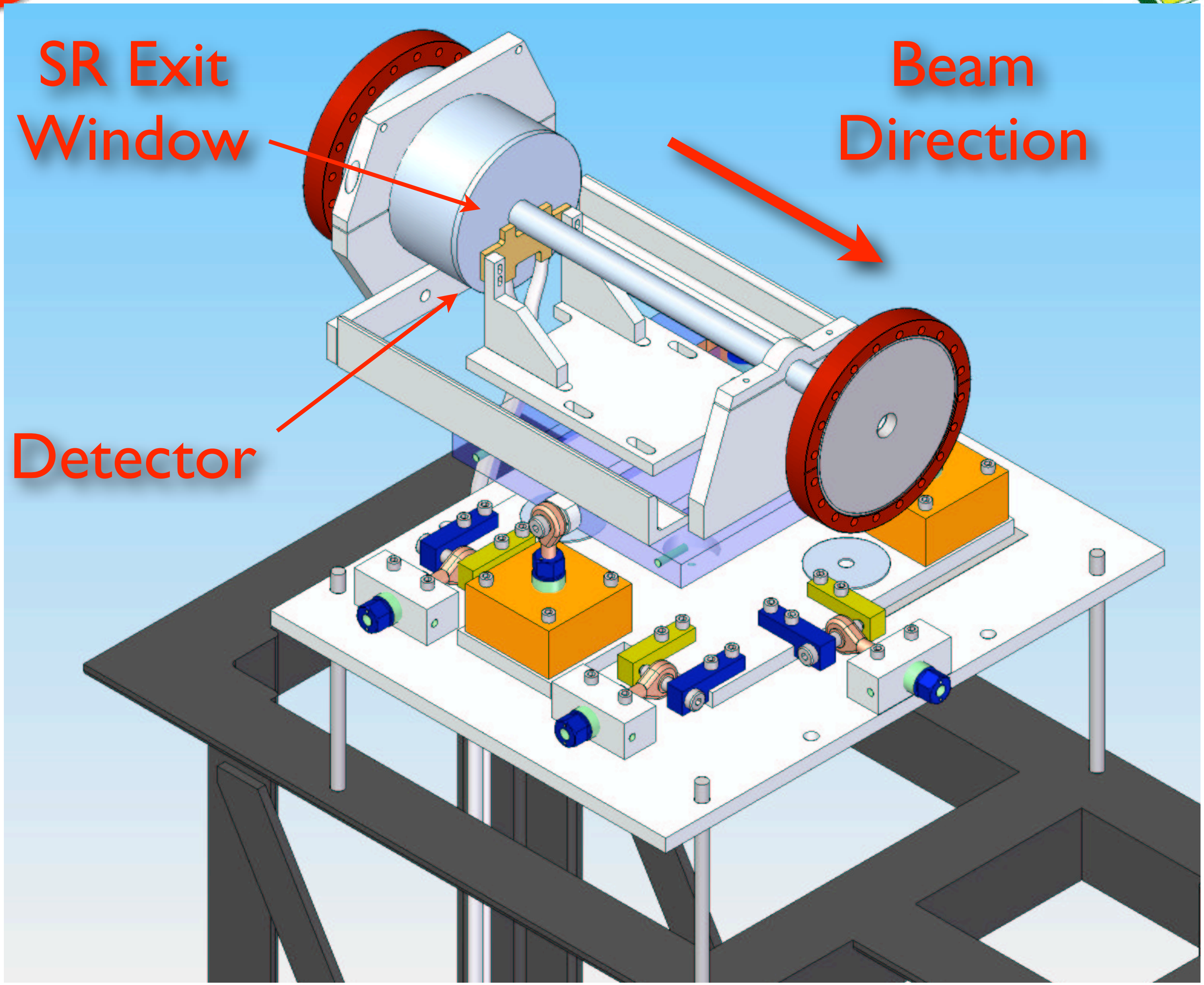
7-pole Mk-II Spear wiggler
20 kGauss field - about 2 meters long
+/- 0.75 mRad vertical stripe
+/- 1.5 cm at detector plane

Mechanical modifications finally done
Just installed in ESA proper!

Wiggler before rotation



Detector Stand



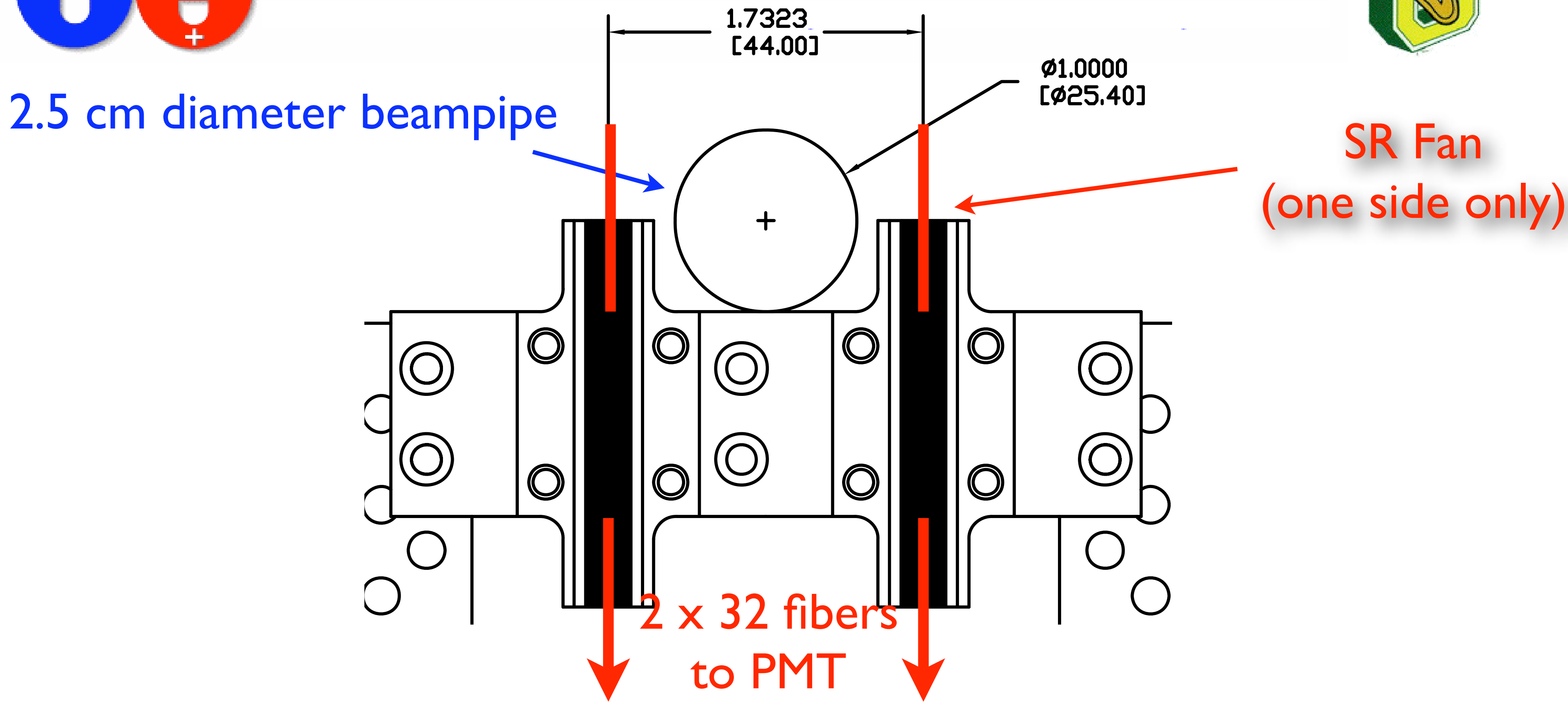
In Beamline

SR Exit Window

Detector Stand

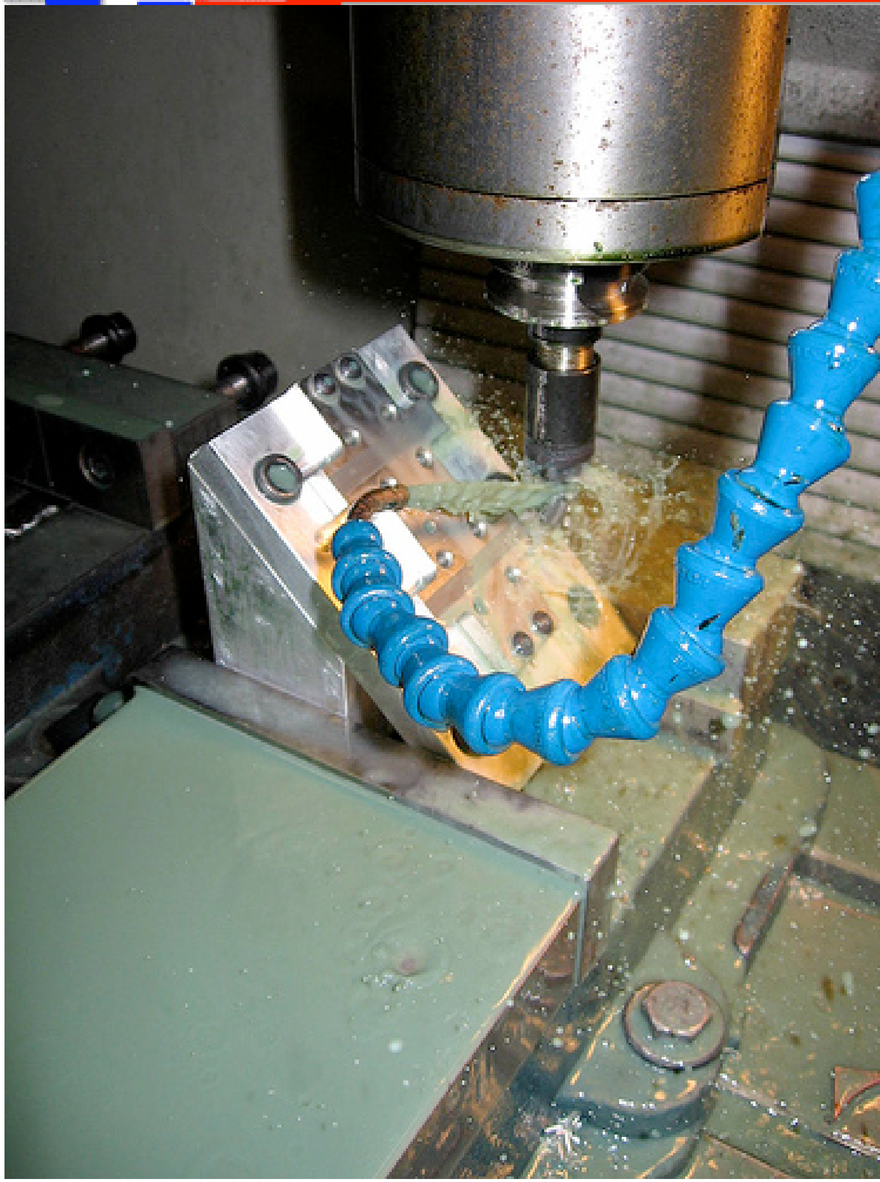
PMT Shelf

2nd prototype detector

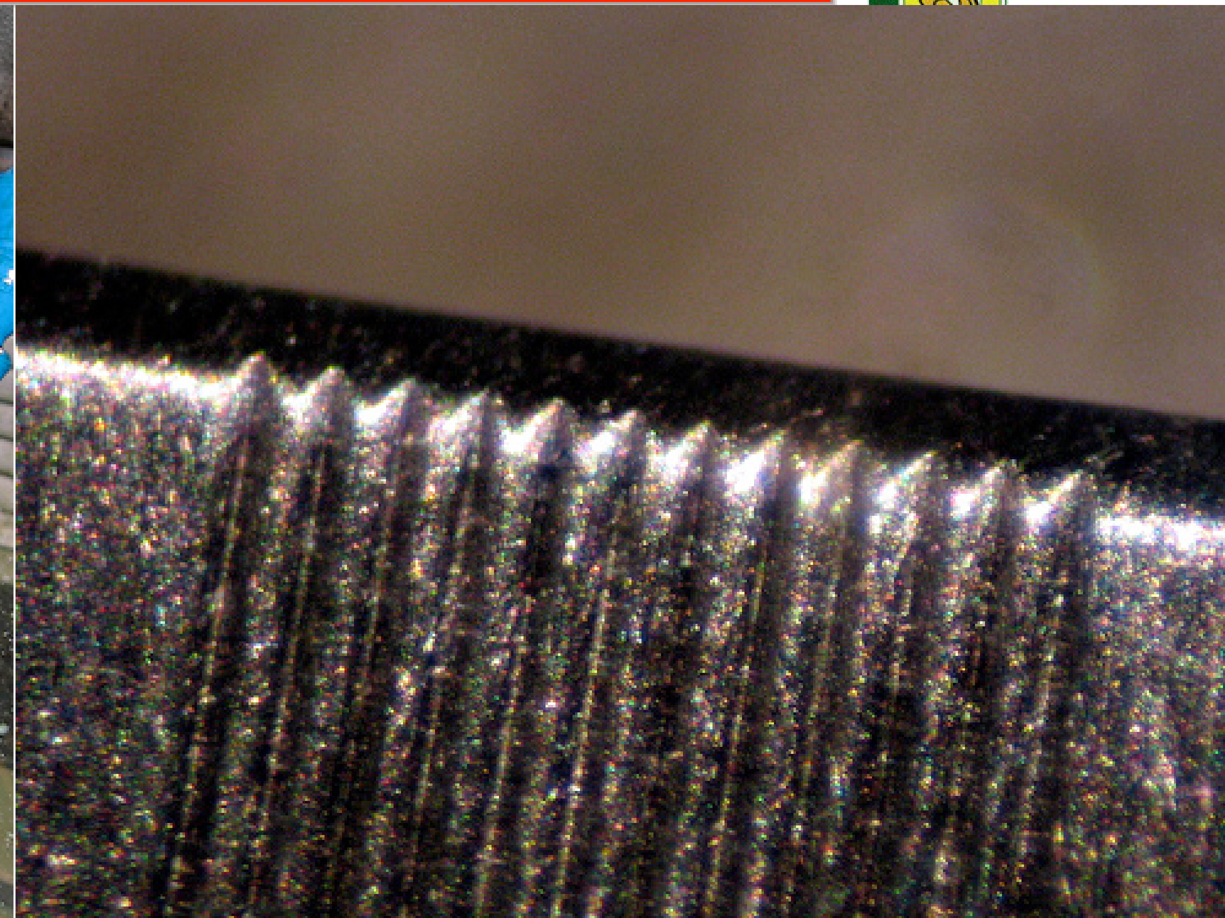


- 64 x 140 micron (100 micron active) deep UV fibers
- Spaced on 200 micron pitch w/ grooves engraved on Invar
- Fibers held in place with Indium foil "gasket"

Construction Photos



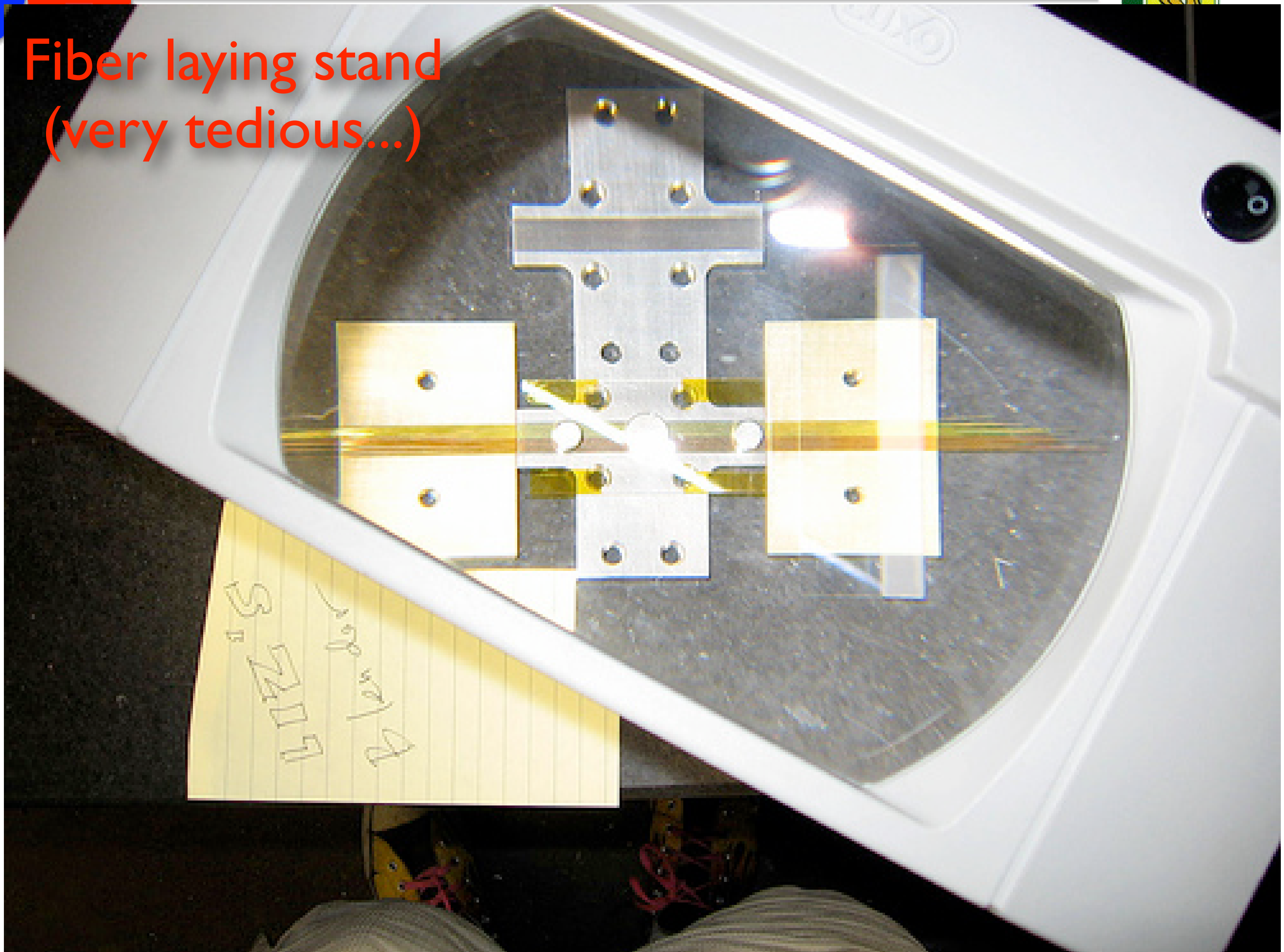
CNC Goodness



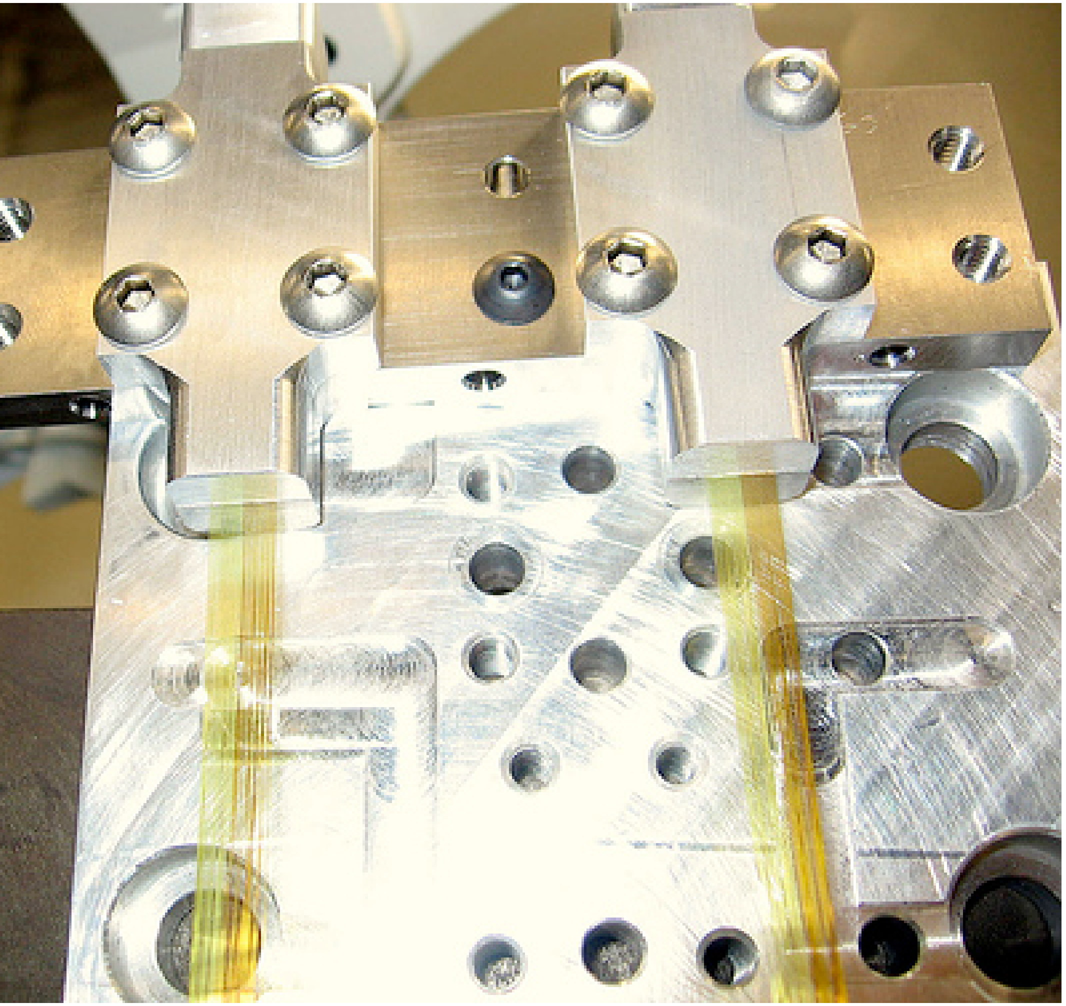
200 micron grooves in Invar

(Photos courtesy J. Garman)

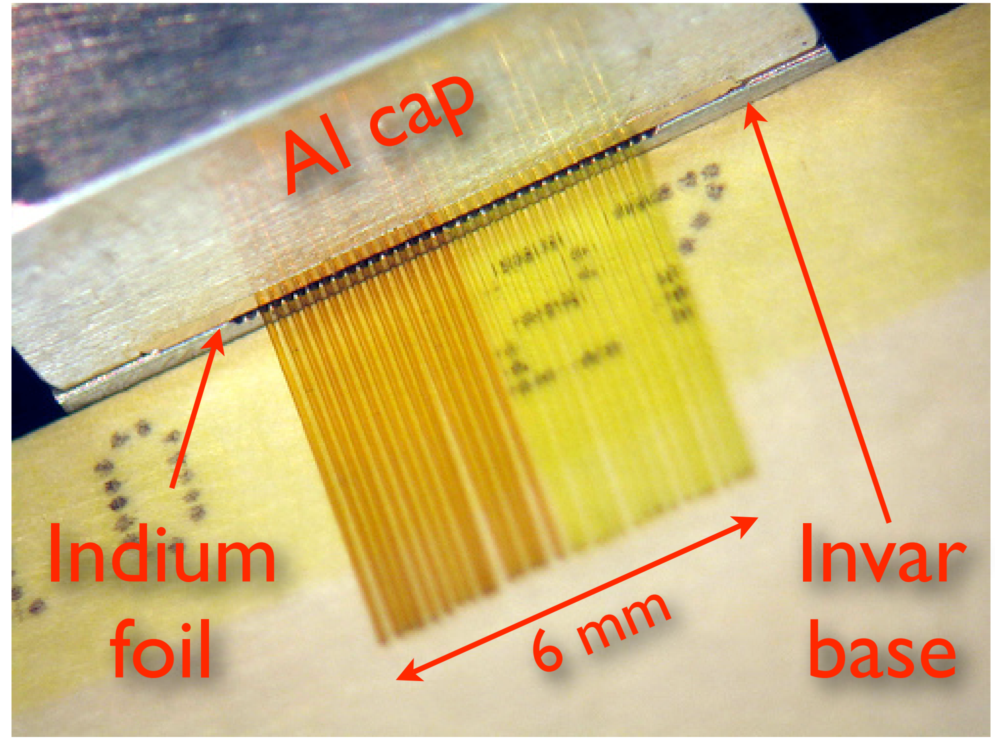
Assembly



Finished Assembly

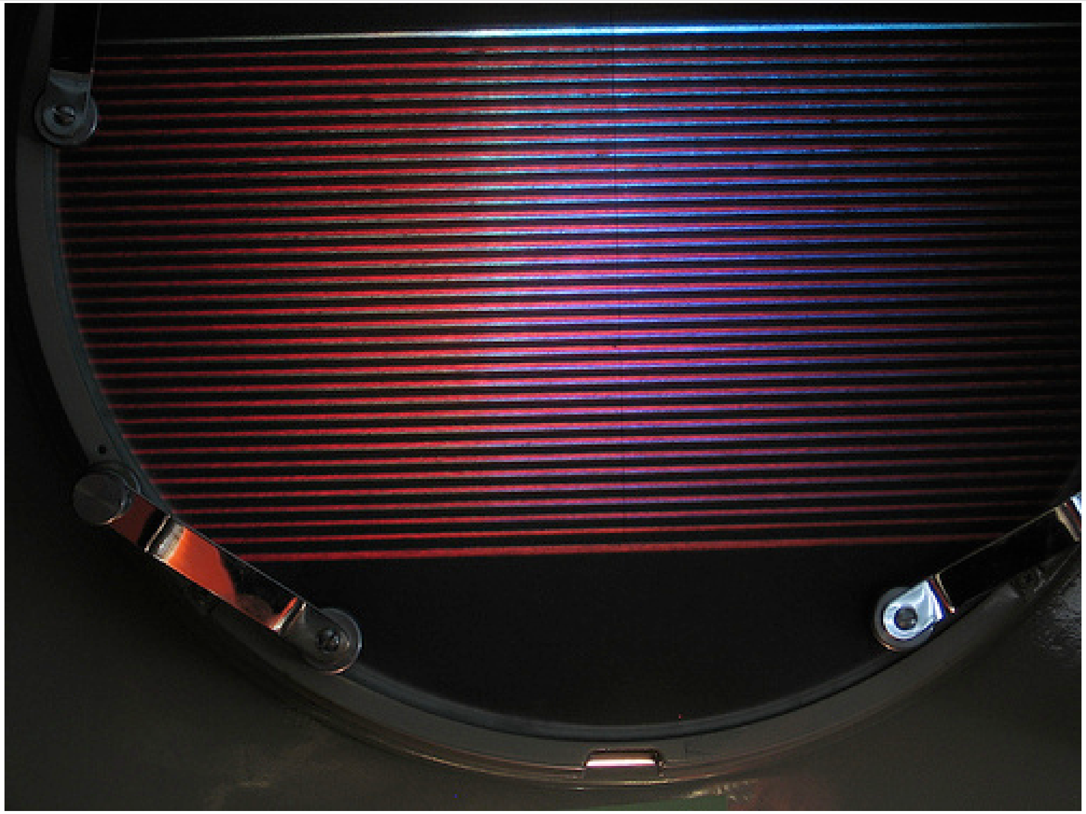


60 fibers in place
(4 background fibers)



Fiber ends
before trimming

Optical Survey



- Length scale determined by dimensions of invar plate
- (Old) optical survey machine good to < 5 microns
- Sample rotation with respect to survey axis limits absolute length to 20 microns over 40 mm (0.5 mRad) or 500 ppm
- Similar constraints on detector axis vs. dipole plane

Summary

- T-475 Detector has seen first beam
- Signal is there, but not exactly as expected

  (Could be fiber differences, under investigation)
- Prototype w/ 64 ch and 200 micron pitch being finished
- ESA run in July will allow first real energy measurement
- Simulation work on ESA and Xline has progressed
- Current accuracy likely limited to 5 10^{-4} by alignment issues