Review of the Two American Detector Models

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August 4, 1999

We have been investigating two specific models

- Choosing any particular detector design is a compromise between competing constraints
  Example:
  1. large tracking volume desirable to optimize tracking resolution
  2. small tracking volume minimizes the volume of the electromagnetic calorimeter
     -> allows aggressive EM calorimeter option

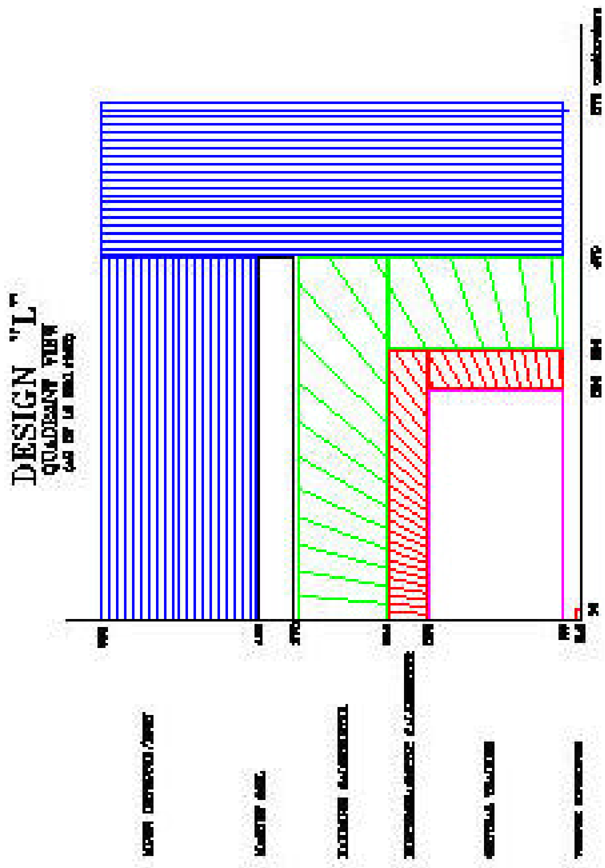
- investigated the <u>two</u> detector models

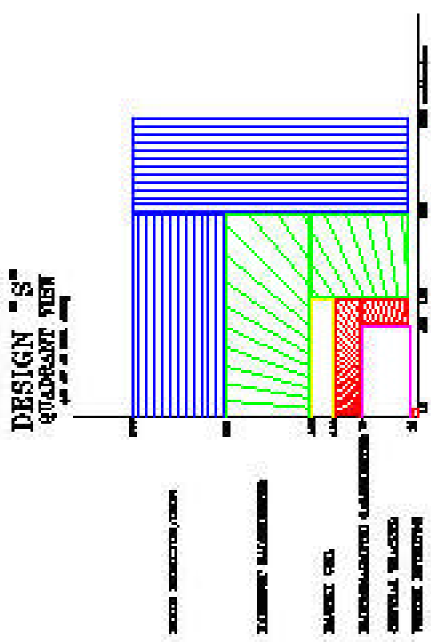
  without prejudice
  to understand trade-offs in performance
  to consider feasibility and identify R&D needs

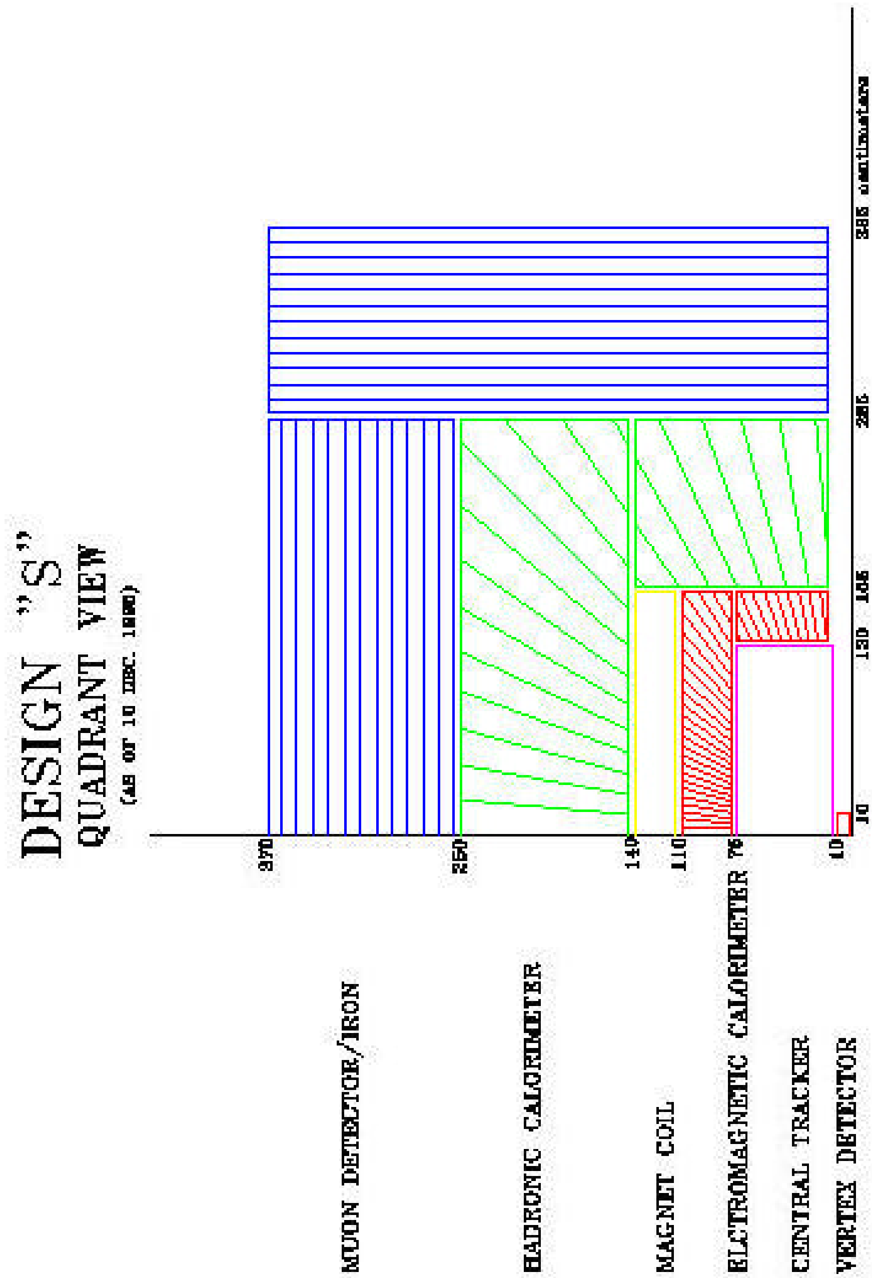
- The Models were selected to test two different choices for detector configuration:

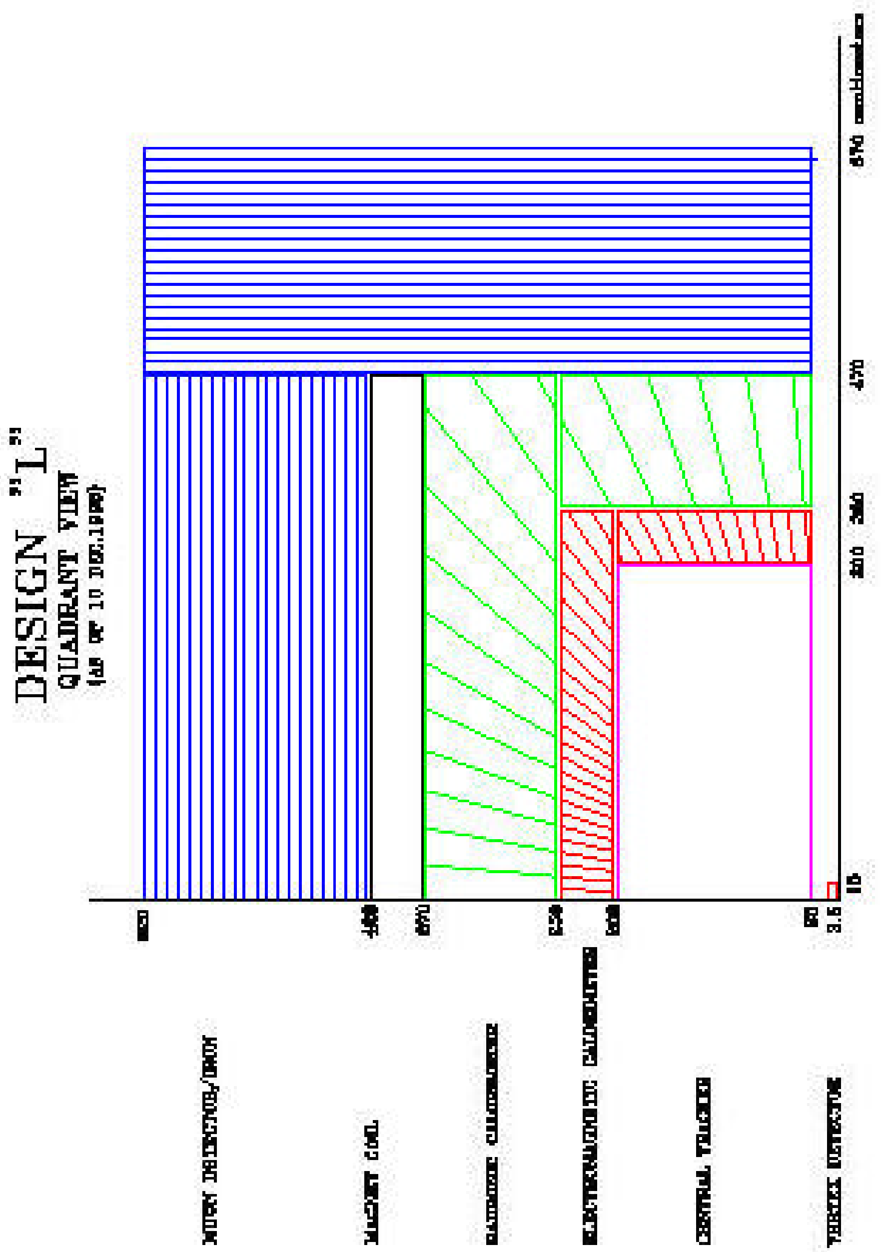
1. Model L
   - large detector
   - large tracking volume
     - -> optimal tracking resolution
   - large radius calorimeter
     - -> optimal separation of calorimeter clusters
   - size limits magnetic field
     - -> limits vertex detector inner radius due to pairs

2. Model S
   - small detector
   - small radius detector
     - -> allows largest magnetic field
   - small radius calorimeter
     - -> allows aggressive calorimeter options
       high granularity EM (Si/W)
   - large magnetic field
     - -> allowing e^- pair containment and close vertex detector


DESIGN "L"
QUADRANT VIEW


DESIGN "S"
QUADRANT VIEW


DESIGN "S"
QUADRANT VIEW
MUON DETECTOR/IRON
HADRONIC CALORIMETER
MAGNET COIL
ELCTROMAGNETIC CALORIMETER
CENTRAL TRACKER
VERTEX DETECTOR
370
250
140
110
76
10
10
130
165
285
385 centimeters


DESIGN "L"
QUADRANT VIEW

Expected level of performance for the two configurations:

Vertex Detector

both detectors assume 5 barrel CCD (5 μm point res.),
with radius adjusted to match the two sizes

Model S

small radius outer detector allows largest
beam-pair constraining with B field
closest to IP (R= 1.2,2.4,3.6,4.8,6.0 cm)

Model L

larger area required for coverage
degraded performance due to more distant
inner layer (R= 2.5,4.4,6.3,8.1,10. cm)
but, is this large a detector feasible?

Vertex Detector Performance

Model S

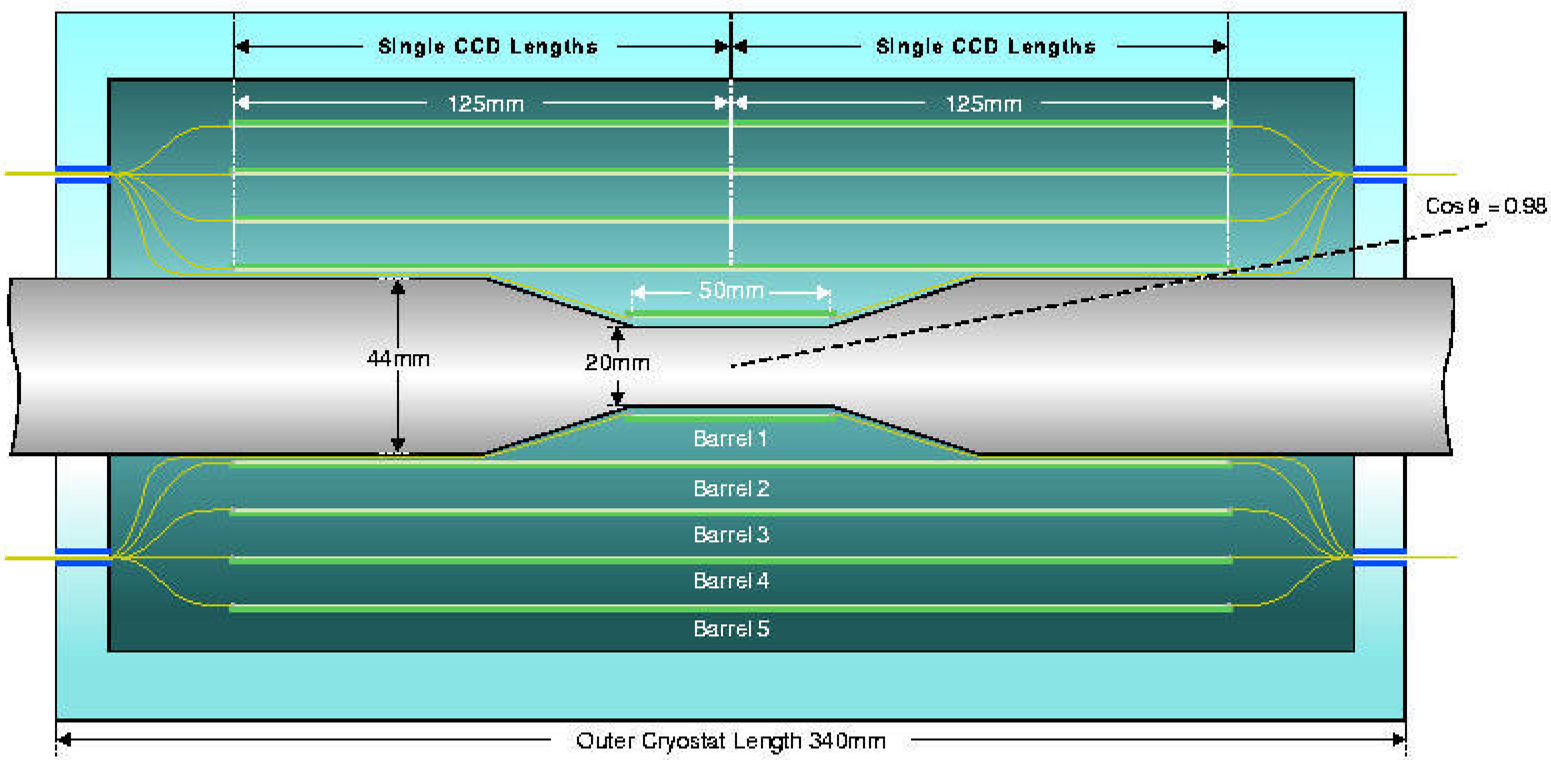
$$\sigma_b = (3\ \mu m \oplus 10\ \mu m / p \sin^{3/2} \theta)$$

Model L

$$\sigma_b = (3.5\ \mu m \oplus 25\ \mu m / p \sin^{3/2} \theta)$$

Both $\rightarrow$ stand-alone tracking

Suggested layout of Vertex Detector for future e^+e^- Linear Collider (Updated November 1998)



Tracking

Model L

- optimal resolution
  σ/BL^2
- large radius allows largest track length, leading to best resolution

Model S

- smaller tracking volume lead to choice
  of high precision measurements (silicon)
- but silicon has unavoidable larger material budget -> multiple scattering
- low momentum resolution compromised by multiple scattering

Tracking Performance

Model S

$\sigma_p / p \;=\; (6 \times 10^{-5}\, p \oplus 0.0022)$

silicon drift (3 double layers)

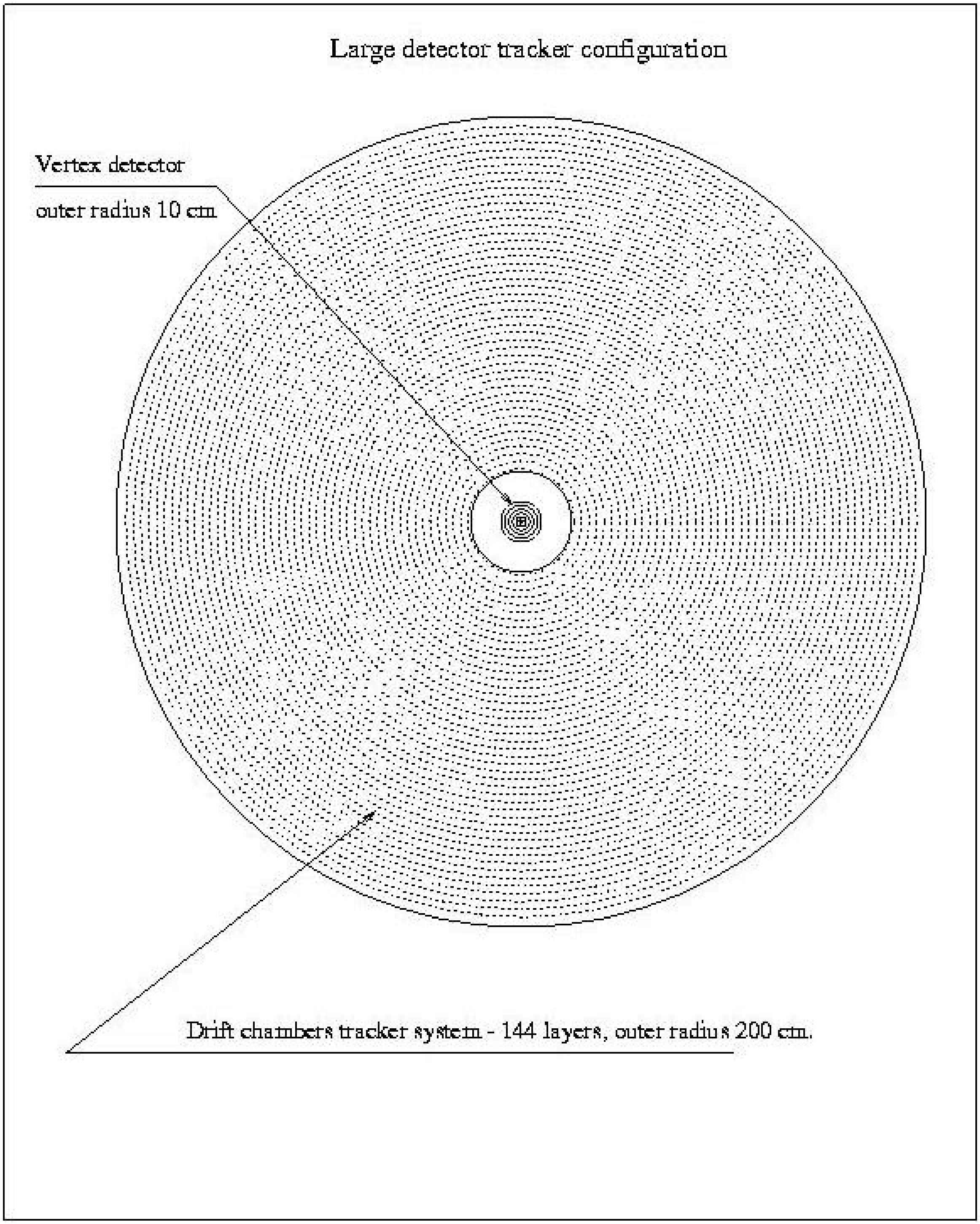
Model L

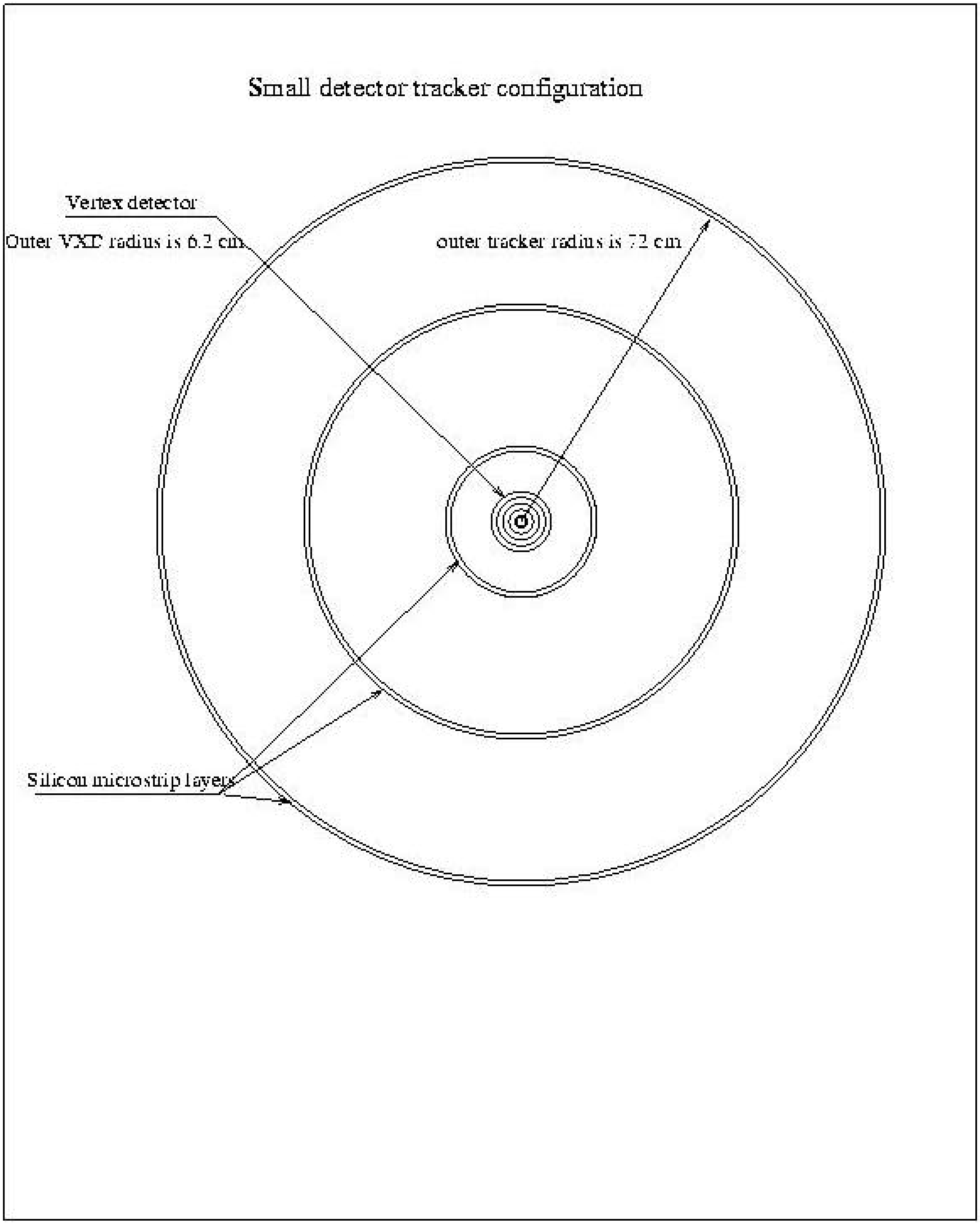
$\sigma_p / p \;=\; (5 \times 10^{-5}\, p \oplus 0.00065)$

TPC (144 points)

comment

high momentum performance similar,
but at low momentum, large multiple scattering
in Model S leads to significant loss of resolution
Forward Tracking – Model S – 5 layers (si strips)


Large detector tracker configuration
Vertex detector
outer radius 10 cm
Drift chambers tracker system - 144 layers, outer radius 200 cm.


Small detector tracker configuration
Vertex detector
Outer VXD radius is 6.2 cm
outer tracker radius is 72 cm
Silicon microstrip layers

Calorimeter

Model S

$\sigma_{EM} / E = (12\% / \sqrt{E}) \oplus (1\%)$

W/silicon pads (1.5×1.5 cm^2 pads)

High granularity!

29 X_0, readout 100 longitudinal (potential)

$\sigma_{Had} / E = (50\% / \sqrt{E}) \oplus (2\%)$

Cu/scintillator (40×40 mrad^2)

76 cm Cu

$l_{EM+Had} = 6.1\ \lambda$

Model L

$\sigma_{EM} / E = (15\% / \sqrt{E}) \oplus (1\%)$

Pb/scintillator (40 x 40 mrad^2)

28 X_0

$\sigma_{Had} / E = (40\% / \sqrt{E}) \oplus (2\%)$

Pb/scintillator (80 x 80 mrad^2)

$l_{EM+Had} = 6.6\ \lambda$

Muon detectors

Model S

10×10 cm Fe plates + gas

$\sigma_{r\theta} \approx 1$ cm (x 10) $\sigma_z \approx 1$ cm (x 2)

Model L

24×5 cm Fe plates + RPCs

$\sigma_{r\theta} \approx 1$ cm (x 24) $\sigma_z \approx 1$ cm (x 4)

coverage to ~ 50 mrad

Magnetic Coil

Model S 6 Tesla

between EM and Hadronic calorimeter

Model L 3 Tesla

outside Hadronic calorimeter

Luminosity Monitor

Si/W

Hermeticity

>99%

Some Trade-offs Needing Further Study

Vertex Detection

R_{inner} => how important?
thickness => 0.12 % X_0 vs. 0.3 - 0.4 % X_0
we want excellent multiple vertex reconstruction
(cascades, eg $H \to b \to c$ vs. $H \to c$)

Tracking

low momentum tracks
=> resolution (multiple scatt.) and efficiency
eg. $e^+e^- \to e^+e^- \to e^+e^-\ X$
effect of tracking resolution on flavor tagging

Calorimetry

"energy flow" jets vs. calorimeter jet clustering?
(energy flow = tracking + EM cal + neut.had.)
how small can R be and still untangle neutrals?
W/Z reconstruction
non-pointing gammas
eg. $\tilde{c} \to \tilde{g} g$

Conclusion

The American study groups have defined two un-like detectors
to explore trade-offs in performance:

Model L
- large detector
- large tracking volume => optimal resolution
- large radius calorimeter => cluster separation
- B field = 3 T

Model S
- small detector
- small radius calorimeter => aggressive EM
- large magnetic field = 6 T
  - good for vertexing and shower separation

The trade-offs are still being studied.