Drift Tubes as Muon Detectors for ILC

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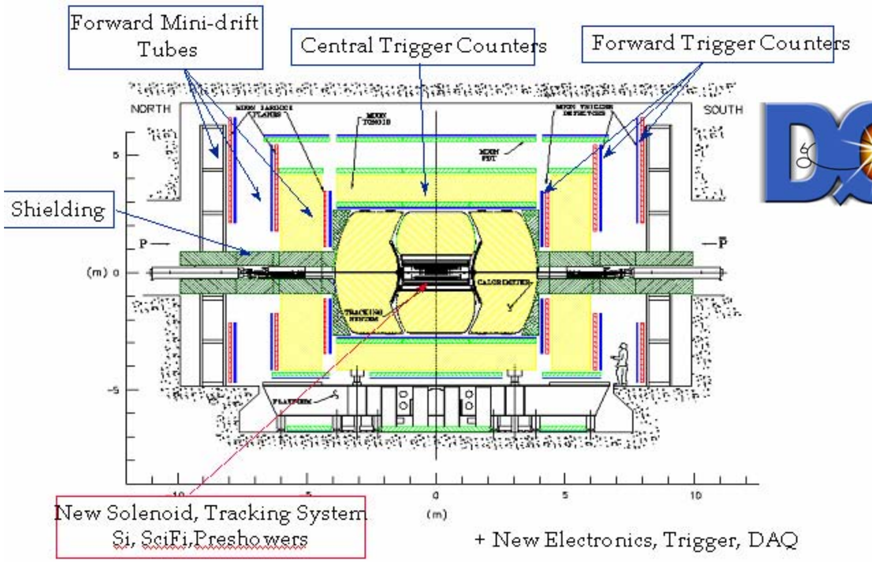
- Major specifications for muon detectors
- D0 muon system tracking detectors
- Advantages and disadvantages of drift chambers as muon detectors
- Summary

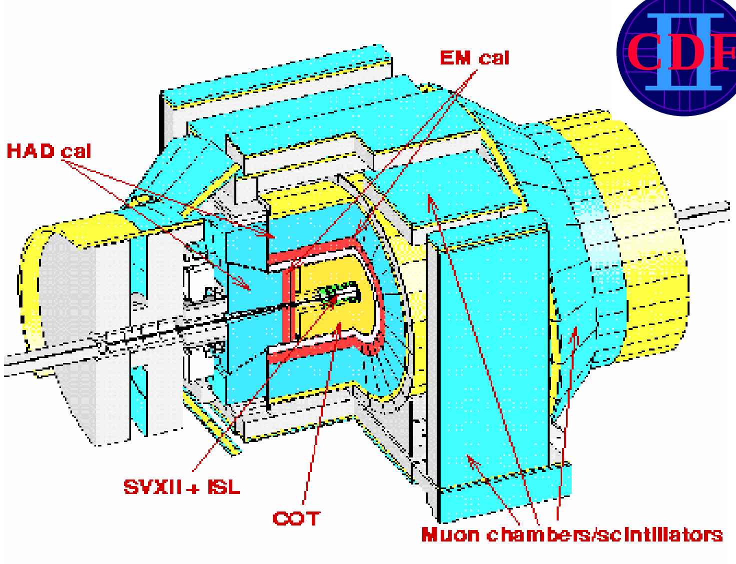
Major Specifications for (ILC) Muon Detectors

- High efficiency of muon hit detection
- Low sensitivity to backgrounds
- Reasonable time resolution
  - Bunches separation
  - Backgrounds rejection
- Reasonably good coordinate resolution
  - Matching central tracker track with muon system hits
  - Momentum resolution

$$\sigma_p/p \sim (p \cdot \sigma_{det})/(B \cdot L_{det}^2) \text{ \& multiple scattering}$$

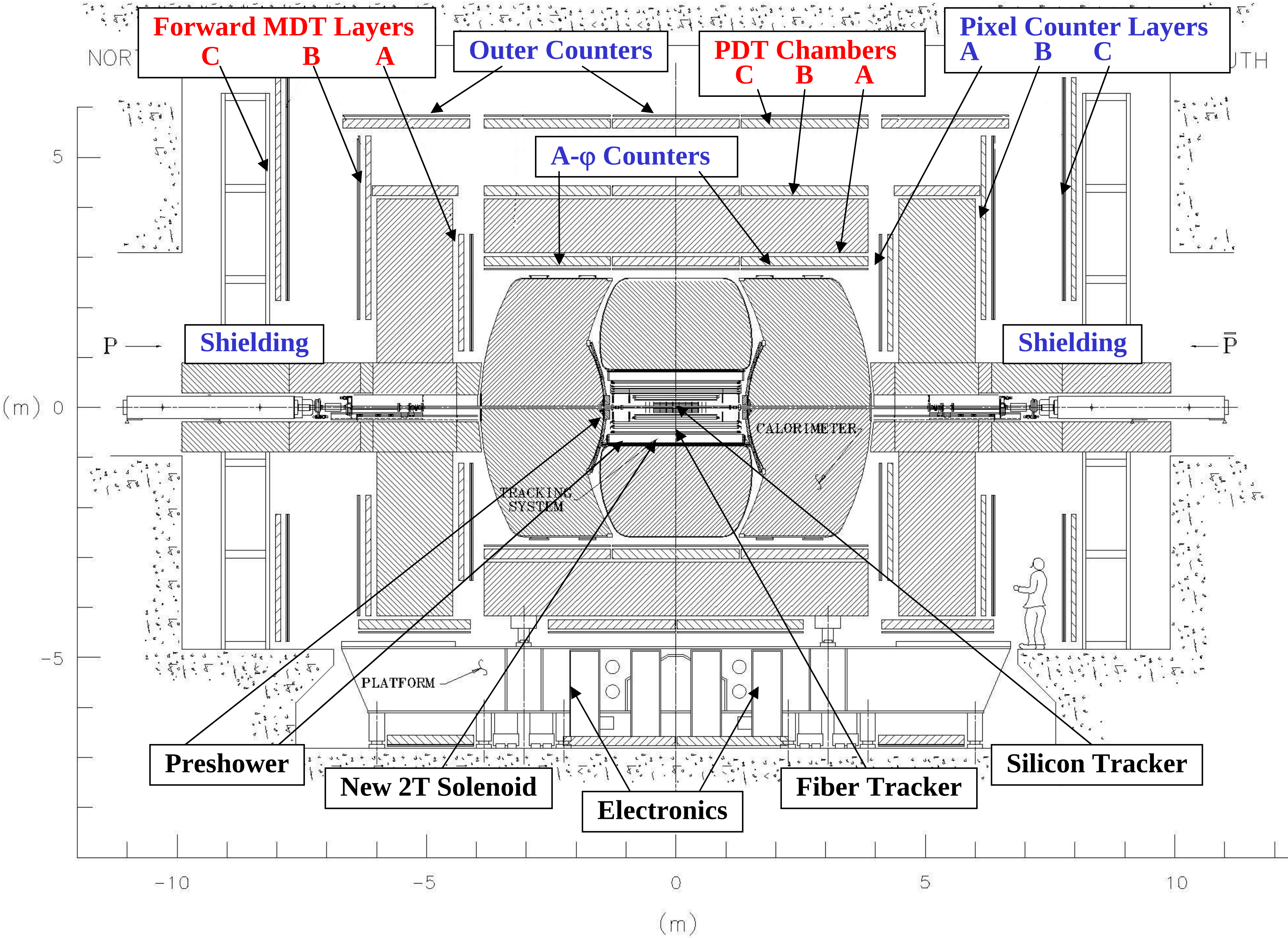
  - Limit is set by multiple scattering of 100GeV/c muon in 1m of steel at ~1mm
- Lack of radiation or other types of aging
- High reliability
- Low construction and operational costs





One of the options for ILC muon detector is drift chambers

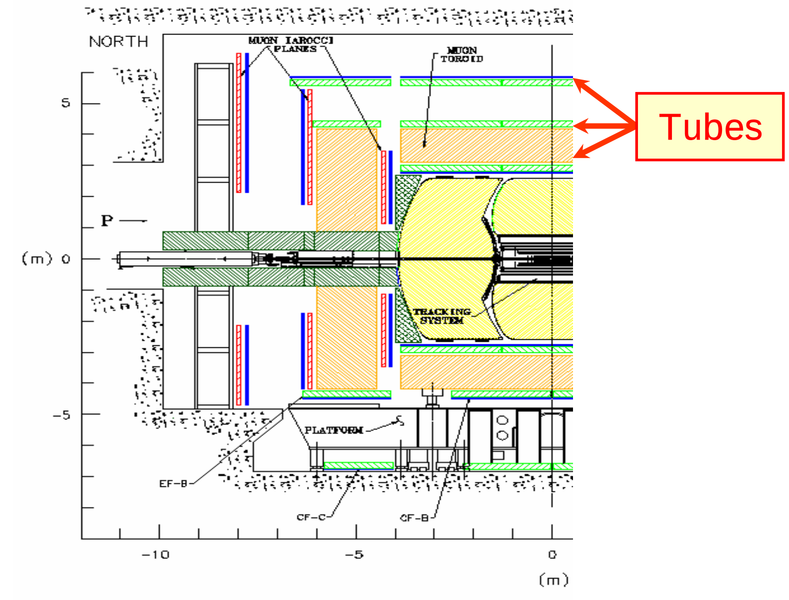
1. Well known technology: many collider experiments used/use this technology, for example D0 and CDF
2. Satisfies reasonably well above specifications
3. Will describe major parameters using the D0 muon system

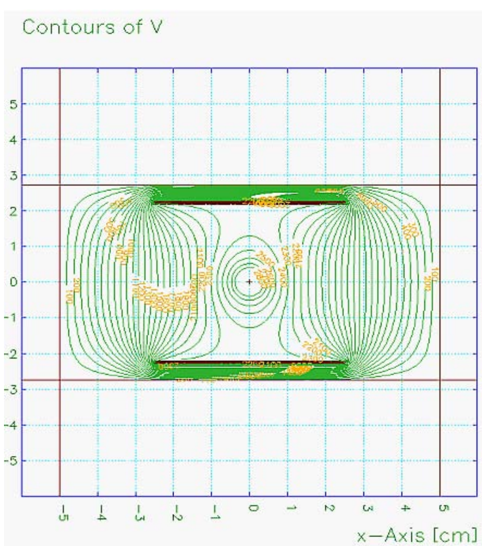


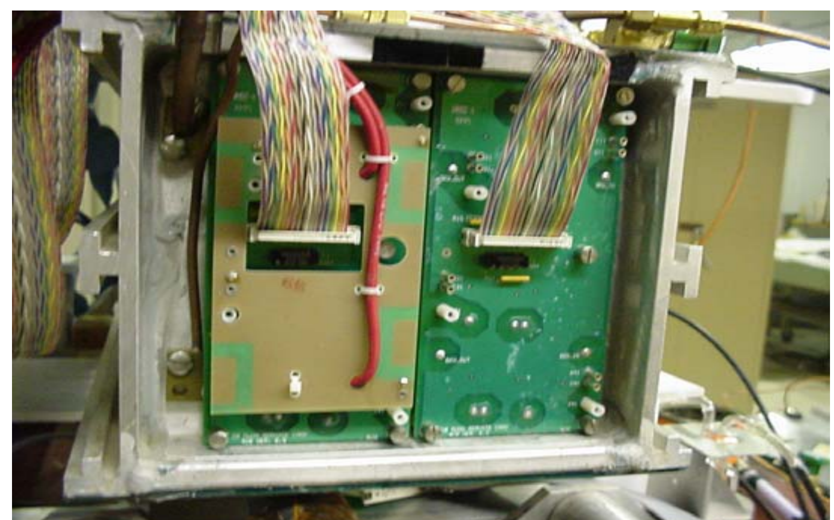
Run II D0 Detector

Proportional Drift Tubes

- Central muon system tracking detector (/eta/ <1.0)
  - Total ~$8\cdot10^3$ cells
    - 3 layers: one before iron (4 planes) and two after iron (3 planes each)
    - Average number of muon hits on track ~10
  - 10x5 cm^2 drift cells with maximum drift time of ~450ns
    - Gas mixture: Ar(84%)+CF_4(8%)+CH_4(8%)
    - Fast, non-flammable, inexpensive
  - Coordinate resolution in drift direction: ~0.5mm
    - Diffusion
    - Amplitude fluctuations
  - Gas gain ~10^5, detection threshold ~1μA

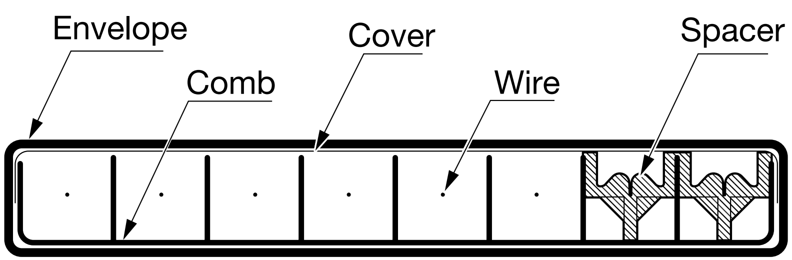


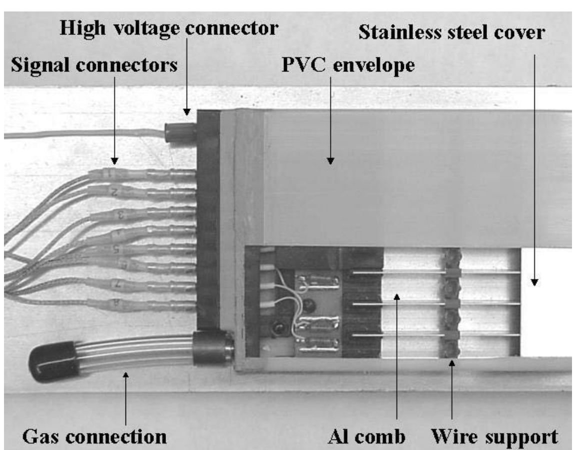


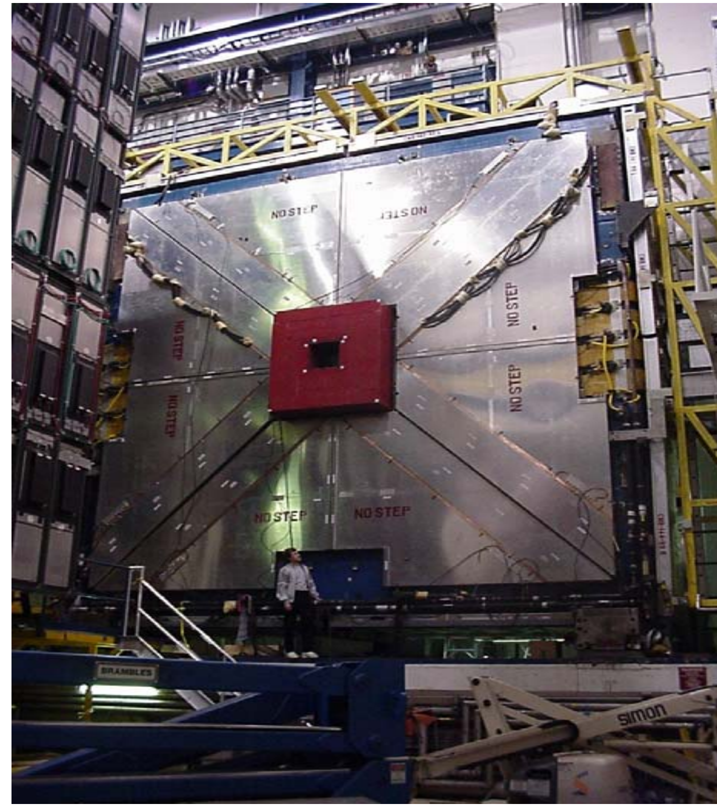


Forward Muon Tracking Detector

- Forward muon tracking detector is based on mini-drift tubes
  - $1\text{x}1\text{cm}^2$ drift cell
  - 8 cell aluminum extrusion comb with 0.7mm thick walls
  - Stainless steel cover and PVC sleeve provide electrical field configuration and gas tight volume
  - $\sim 10^5$ gas gain, $2\mu A$ operating threshold



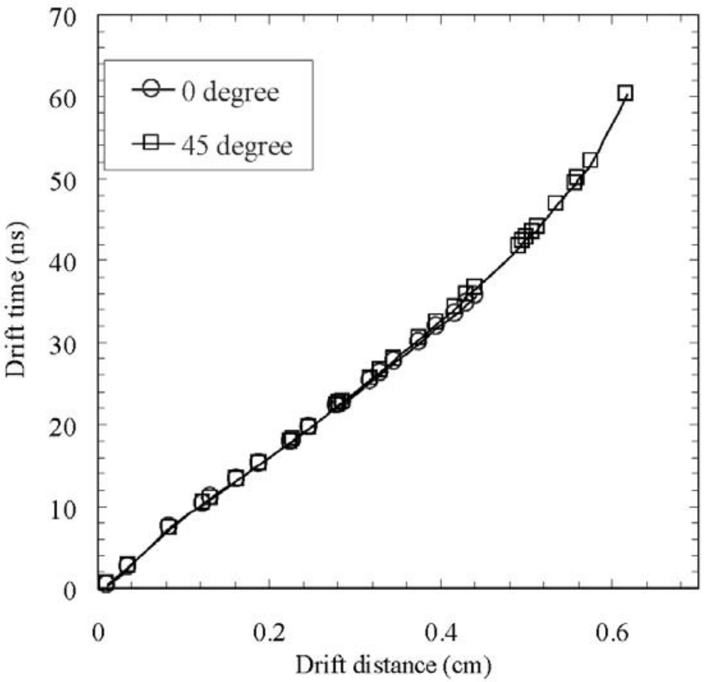




- Tubes are assembled into 8 octants per layer with wires parallel to magnetic field lines
- Total number of wires in the system is 50,000
  - Same cathode HV for all wires
- There are 4 planes of wires in a layer before toroid and 3 planes of wires in each of two layers after toroid
  - muon track has ~10 hits on track

D0 Forward Muon Tracker

- Mini-drift tubes filled with CF_4(90%)+CH_4(10%) gas mixture
  - Non-flammable
  - Very fast (~60ns max drift time)
  - Re-circulation with small losses (~5%) reduces gas cost
  - Wide 100% efficiency mip platou
    - 2.9kV-3.4kV
- Coordinate resolution of the mini-drift tube system is defined by electronics
  - TDC bin is 19ns (cost driven)
  - σ=0.7mm
  - affects "muon system only" coordinate resolution for muon momentum above 50GeV/c
- Reliability
  - total number of disabled wires
    - 0.3% after commissioning
      - dead or noisy
    - Initial increase in number of disabled wires is less then 0.1% per year of operation
    - No increase over last year
    - On average ~1 broken wire per year (out of 50,000) for 5 years of operation



Accumulated charge for integrated luminosity of 15fb^{-1} (twice above Run II goal) is estimated at 30mC/cm
Aging test with Sr^{90} r/a source demonstrates no aging effects up to 2C/cm

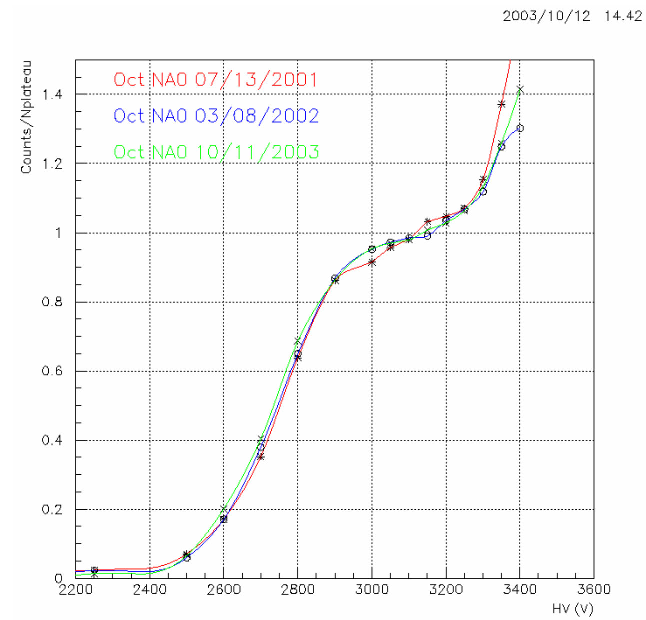
D0 Experience – Gas Detectors Radiation Aging

- Experienced proportional drift tubes radiation aging in Run I (1991-1996)
  - Material with high outgasing was used during construction (by mistake)
  - Increase of gas flow and installation of filters in recirculation system resolved aging issue

- Run II (2001-200X) approach
  - All detectors are carefully tested for aging before the run
    - Wire detectors with r/a sources, real gas mixtures, production modules
      - Slow charge integration – over a year of testing
  - Monitoring of detectors performance
    - Daily for detection efficiency
    - About twice a year cosmic counting curves
      - Check of gas gain

- No unexpected effects so far in Run II

Mini-drift tubes cosmic counting curves



Monitoring gas gain using cosmic ray counting curves (~10% accuracy)

Major Advantages and Disadvantages of Drift Tubes as Muon Detectors

- Advantages
  - High intrinsic coordinate resolution
    - ~0.5mm easily achievable
  - Small sensitivity to backgrounds
    - Density is low, small H concentration
  - High detection efficiency
    - ~10^2 or more primary electron/ion pairs per mip – 99.9...% efficient
  - Large signals
    - Gas gains up to ~10^6
  - Low intrinsic noise
  - Good occupancy characteristics
    - ~10^6 particles/cm^2 sec
  - Multi-hit capabilities in large drift cell
  - Time resolution
    - Single layer ~ max drift time
    - Double layer ~ a few ns
  - Operation in magnetic field
  - 30+ years of construction/operation experience
    - All(?) issues are known
  - Possibility of dE/dx measurements
  - Reasonably low cost
    - ~\$2k/m^2 including all electronics

- Disadvantages
  - Large number of thin wires
    - CMS – over 10^6 wires
  - Need to purge the system with gas mixture
    - Possible gas leaks
    - Need to supply gas during operation
  - Inefficient zones
    - Near wires supports
    - Near ends of the modules
  - Reasonably clean room assembly facility

Summary

- Drift tubes of various configurations have been and are successfully used in muon systems of large collider experiments
- The technology is well known and satisfies requirements for ILC muon detector
- Cost is reasonably low and production factories exist or easy to setup
- Robust detector, reasonably insensitive to many parameters like temperature, pressure, high voltage, etc.
- Reasonably small number of channels
  - $<10^6$ even for small cell sizes
- R&D needed in order to select optimal drift-tube configuration and operating parameters
  - Cell sizes, wire diameter
  - Gas mixture
  - Wires supports and end-caps design
  - Electronics design
  - Cost reduction

Drift-tubes might be successfully used for ILC muon system(s)