The Muon Detector for the JLC Experiment

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Muon and Other Specialized Detectors
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Contents

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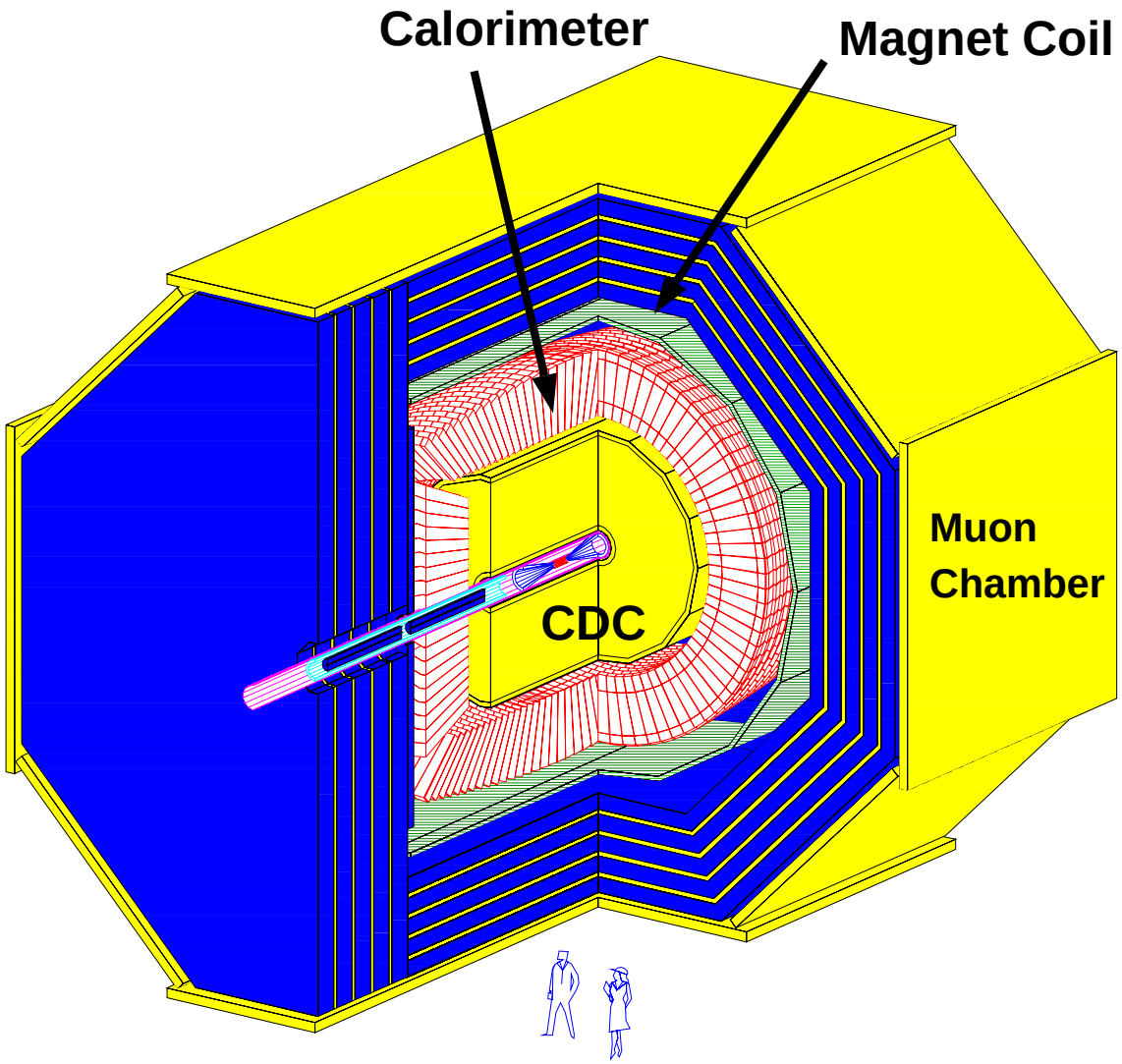
1. Introduction

1. JLC-I ($\sqrt{s} = 300$–500GeV) was proposed in "*the Green Book*" (KEK Report 92-16)
2. Main physics targets were
   - Discovery and Study of Higgs and SUSY
   - Precise Measurements of Top and EW
3. Need for an excellent detector
   - Intensive R&D works on VTX/CDC/CAL
   - **However**, Little attention on the Muon Detector

The JLC Detector



Tracker

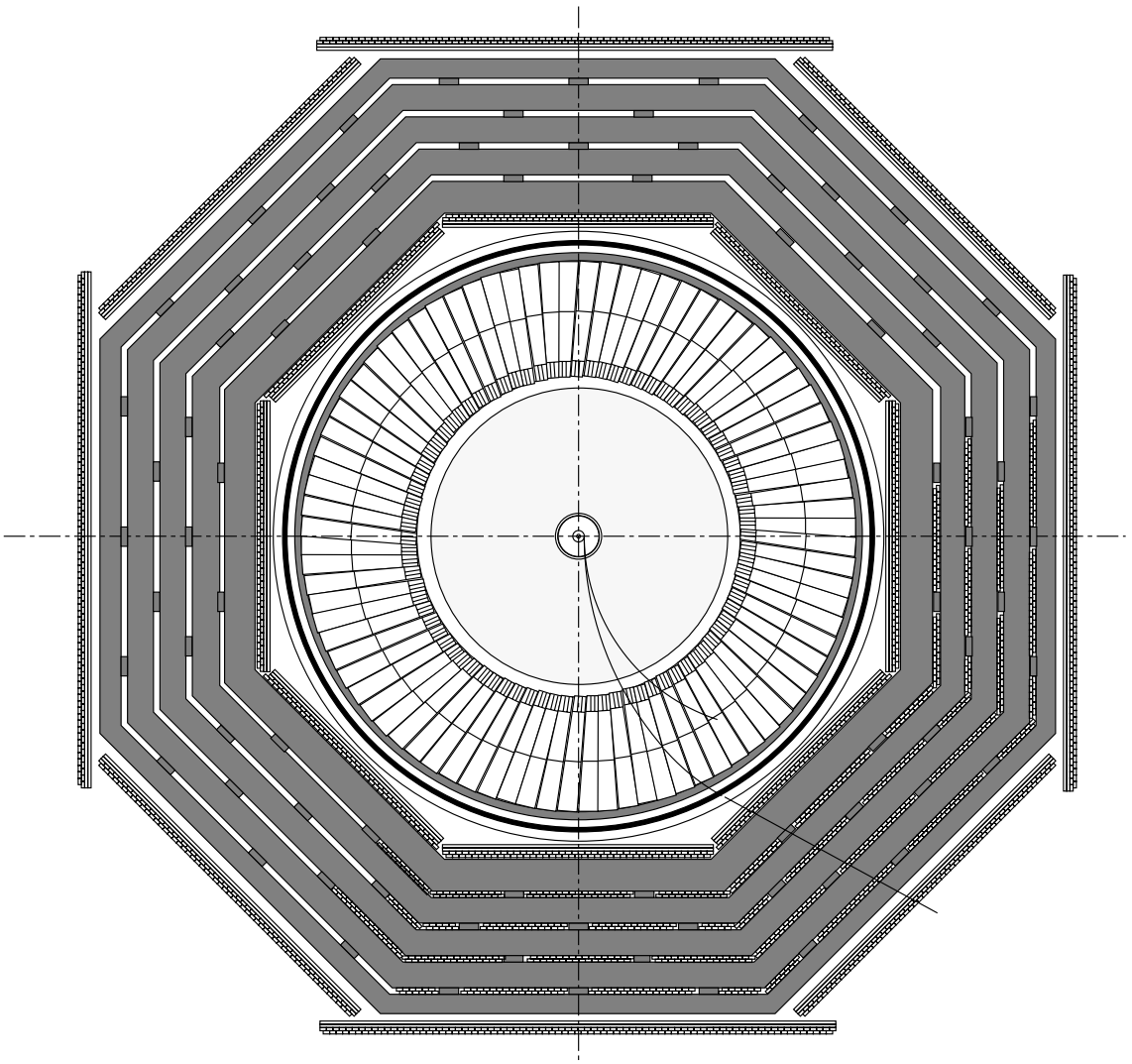
- Excellent momentum resolution
  to reconstruct lepton-pair recoil mass
  in $e^+e^- \to H^0 Z^0$, $Z^0 \to \ell^+\ell^-$
- Realized by
  - 2 Tesla S.C. Solenoid
  - VTX : Silicon CCD
  - CDC : Small-cell Jet Chamber
  - Intermediate Tracker (New)
- Expected Performance
  - $\sigma_{P_t}/P_t = 1.1 \times 10^{-4} P_t \oplus 0.1\%$
    (CDC only)
  - $\sigma_{P_t}/P_t = 5 \times 10^{-5} P_t \oplus 0.1\%$
    (CDC + VTX constraint)
- No need for the Muon Detector to measure momentum

Calorimeter

- Detector Technology
  - Pb/Scinti Sandwich type
  - Tile/Fiber readout
- Expected Performance
  - 1mm Scinti + 4mm Pb plates for ECAL
    $\sigma_E/E = (15/\sqrt{E} \oplus 1)$ %
  - 2mm Scinti + 8mm Pb plates for HCAL
    $\sigma_E/E = (40/\sqrt{E} \oplus 2)$ %
- Material at $\theta = 90°$
  - $r = 260$cm to 400cm
  - $29X_0$ as ECAL
  - $5.6\lambda_0$ as HCAL

Muon Detector

- A total of 6 six super-layers
  - · innermost layer inside the return yoke
  - · four interleaved layers in the return yoke
  - · outermost layer outside the return yoke
- A total area of $\sim$4000 m^2



Muon Detector (cont'd)

What was given in JLC-I (1992)

Detector Criteria :

- Many position measurements with modest position resolution for track matching
- Modest timing resolution for cosmic-ray rejection

As the criteria were not so severe,

- Hoped that existing technology should work,
- Apply new technologies developed for B factory and for LHC if necessary.
- No R&D works since 1992 (no man power)

But, it's time to activate the study !!

2. Effect of Material

- Material at $\theta = 90°$

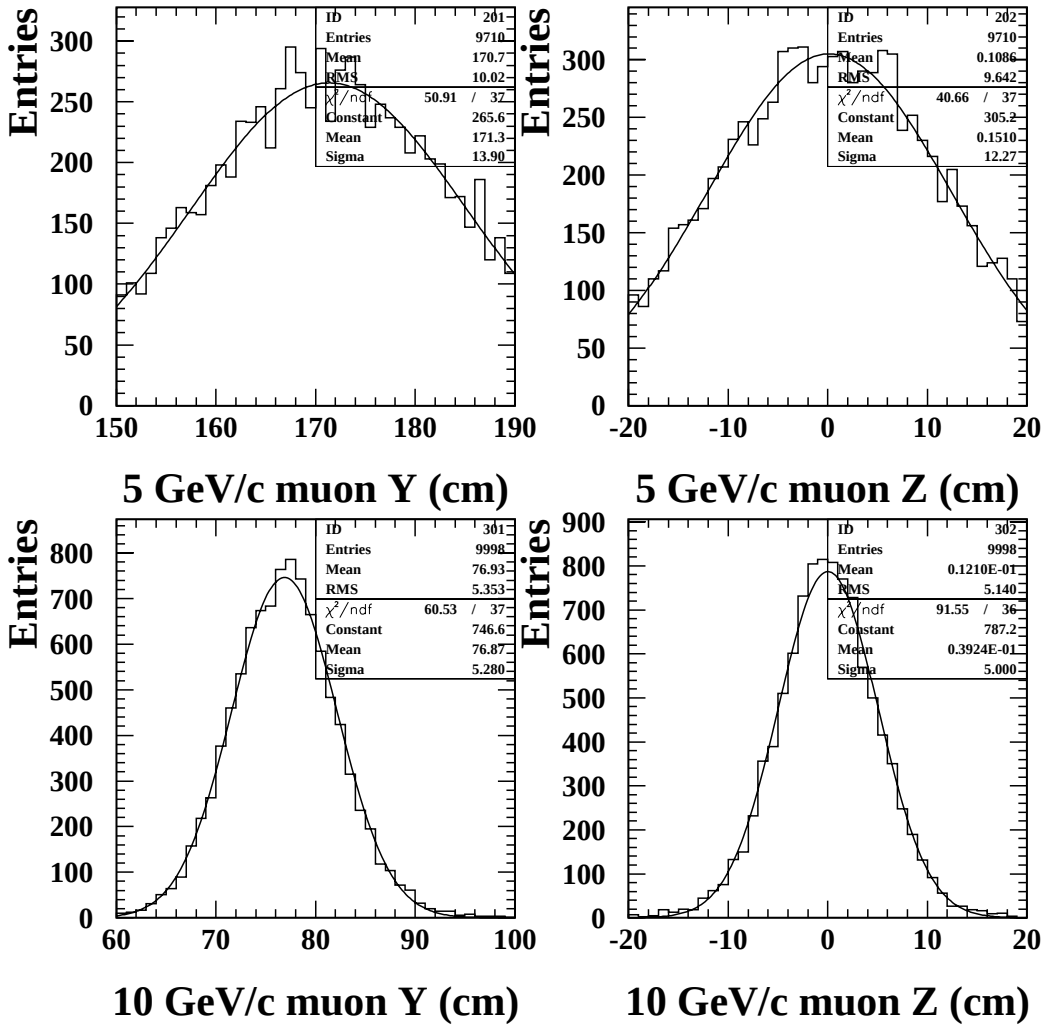
In front	Return Yoke	Total
1.09 kg/cm^2	1.51 kg/cm^2	2.60 kg/cm^2
158 X_0	109 X_0	267 X_0
5.6 λ_0	11.2 λ_0	16.8 λ_0

- Minimum Muon Momentum
  - to reach the return yoke $\sim$ 2.2GeV
  - to penetrate the return yoke $\sim$ 5.2GeV
- Multiple Scattering (studied by JIM)
  - Generate muons at (0,0,0) with momentum (P_x,0,0)
  - Plot y and z distributions at the return yoke (at $x = 500$cm)

c.f. M. Piccolo's talk at Oxford

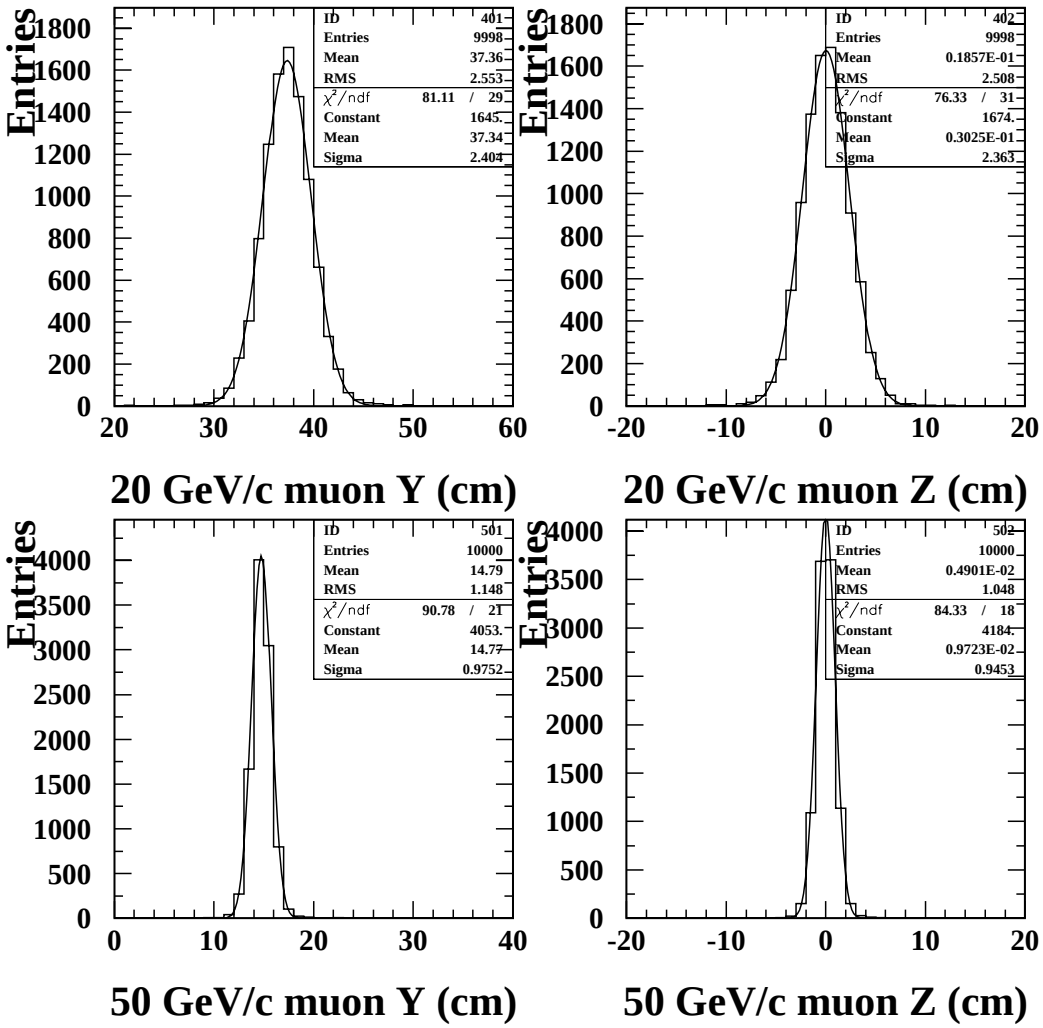
Multiple Scattering (1)

- $P_x = 5\mathrm{GeV/c}$: $\sigma_y = 13.9\mathrm{cm}$, $\sigma_z = 12.3\mathrm{cm}$
- $P_x = 10\mathrm{GeV/c}$: $\sigma_y = 5.3\mathrm{cm}$, $\sigma_z = 5.0\mathrm{cm}$



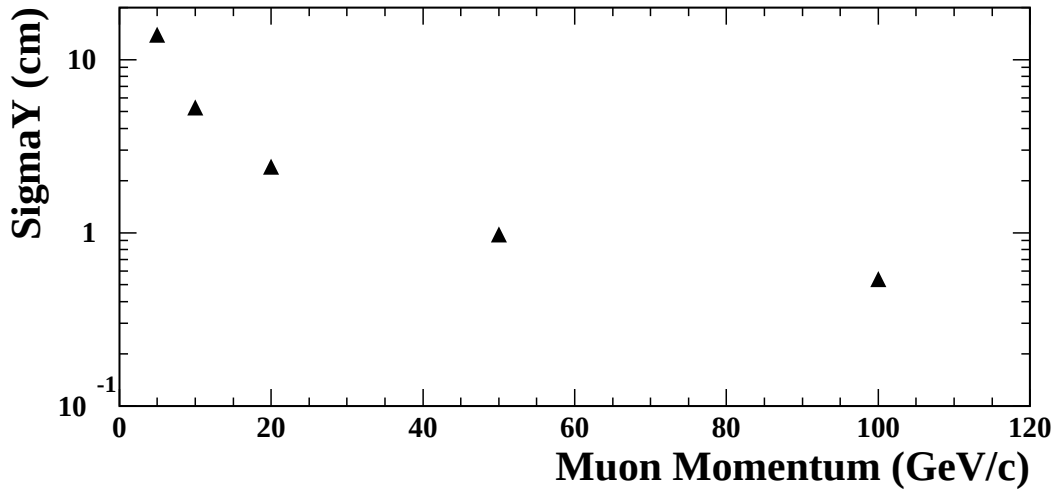
Multiple Scattering (2)

- $P_x = 20\mathrm{GeV/c}$: $\sigma_y = 2.4\mathrm{cm}$, $\sigma_z = 2.4\mathrm{cm}$
- $P_x = 50\mathrm{GeV/c}$: $\sigma_y = 0.98\mathrm{cm}$, $\sigma_z = 0.95\mathrm{cm}$
- $P_x = 100\mathrm{GeV/c}$: $\sigma_y = 0.54\mathrm{cm}$, $\sigma_z = 0.54\mathrm{cm}$

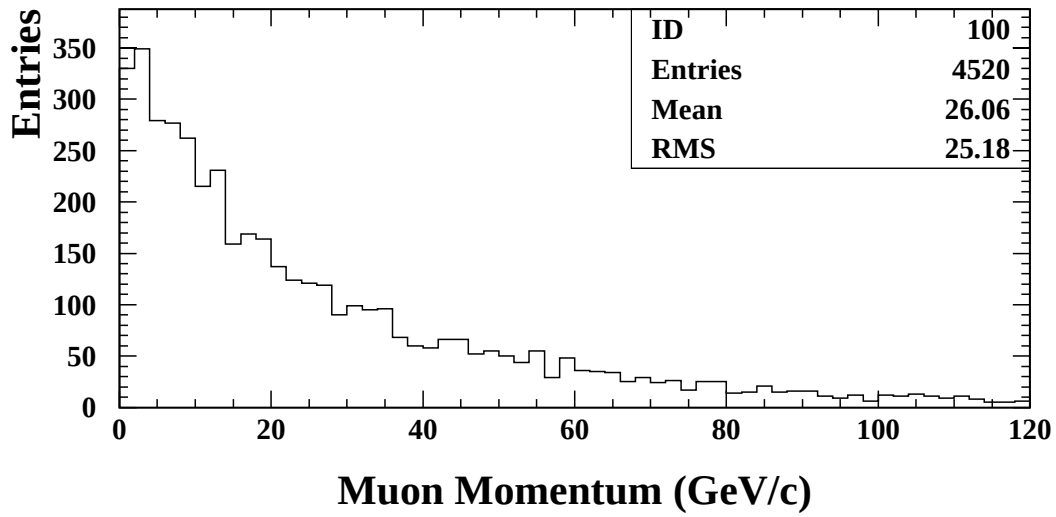


Multiple Scattering (3)

- σ_y as a function of P_x



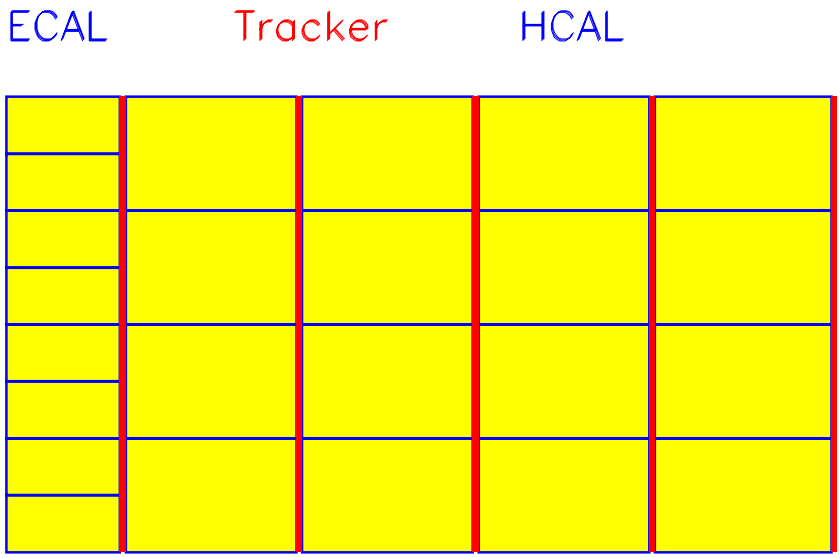
- Muon momentum in $e^+e^- \to b\bar{b}$ at $\sqrt{s} = 500$ GeV (JETSET, 10000 events)



Position resolution of $\sim$ 1 cm is enough.

Tracker in CAL ?

- Large MS in CAL for low P muons
  → Matching CDC and Muon tracks ??
  → Need for thin tracking device in CAL ?



- Candidate tracking devices are
  - Scintillator Strip Counters
  - Resistive Plate Chambers
  - Thin Gap Chambers
- Position Precision, Number of layers ??
  → Need for simulation studies

3. Detector Options

The JLC Muon detector :

- Position resolution ∼1cm or better
- Use well-established technology
- Large area (4000m^2) → low cost

Current candidates :

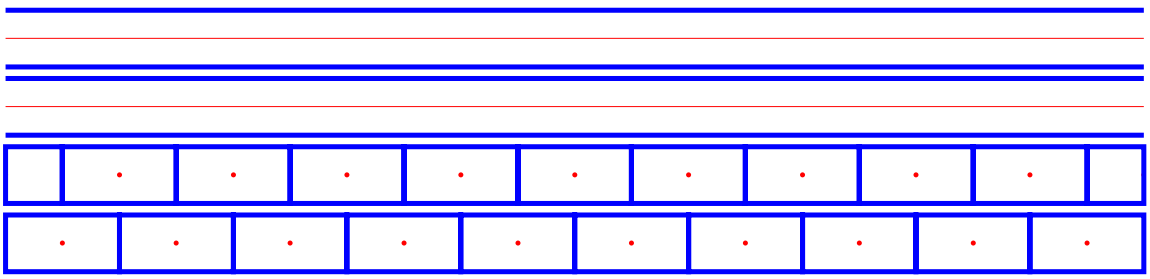
- Single Cell Drift Chambers
- Resistive Plate Chambers (RPC)
- Thin Gap Chambers (TGC)

Single Cell Drift Chambers

Proposed in JLC-I (1992)

- Cell size : 10cm×5cm
  Wire length : 10–15m (need wire supports to reduce wire sag)
- Expected position resolution $\sim 500\mu$m mainly due to wire sag
- Readout channels = 7700 (barrel) + 2400 (endcaps)

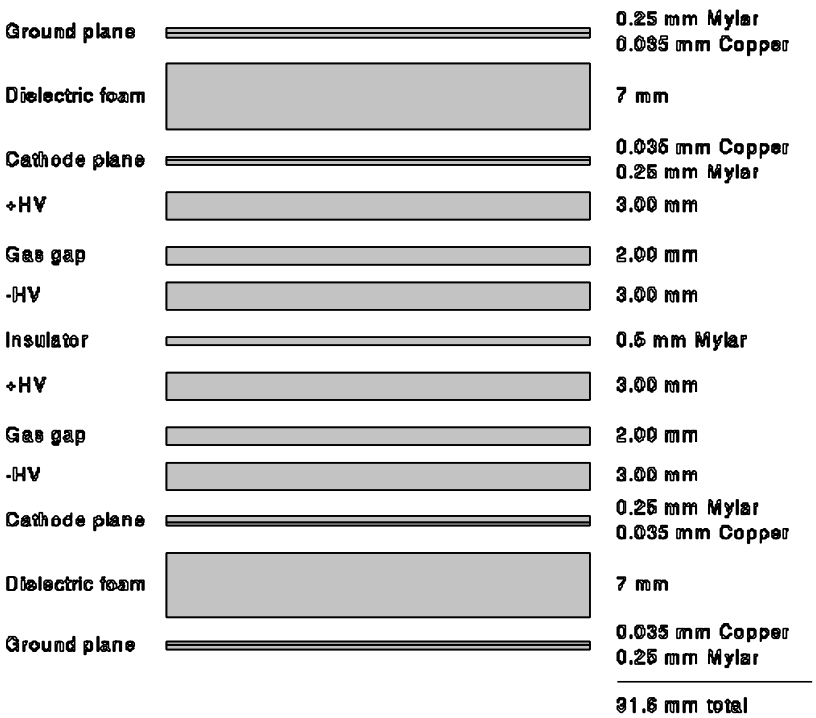
A Superlayer of Single Cell Drift Chambers



Resistive Plate Chambers

(see D. Koltick's talk)

- Widely used in Cosmic-ray and Accelerator Experiments, which include
  - BELLE at KEKB and BaBar at SLACB
  - ATLAS and CMS at LHC
- Low cost because no wires are used.
- Position resolution of $\sim$ 1cm easily achievable (determined by the strip width)

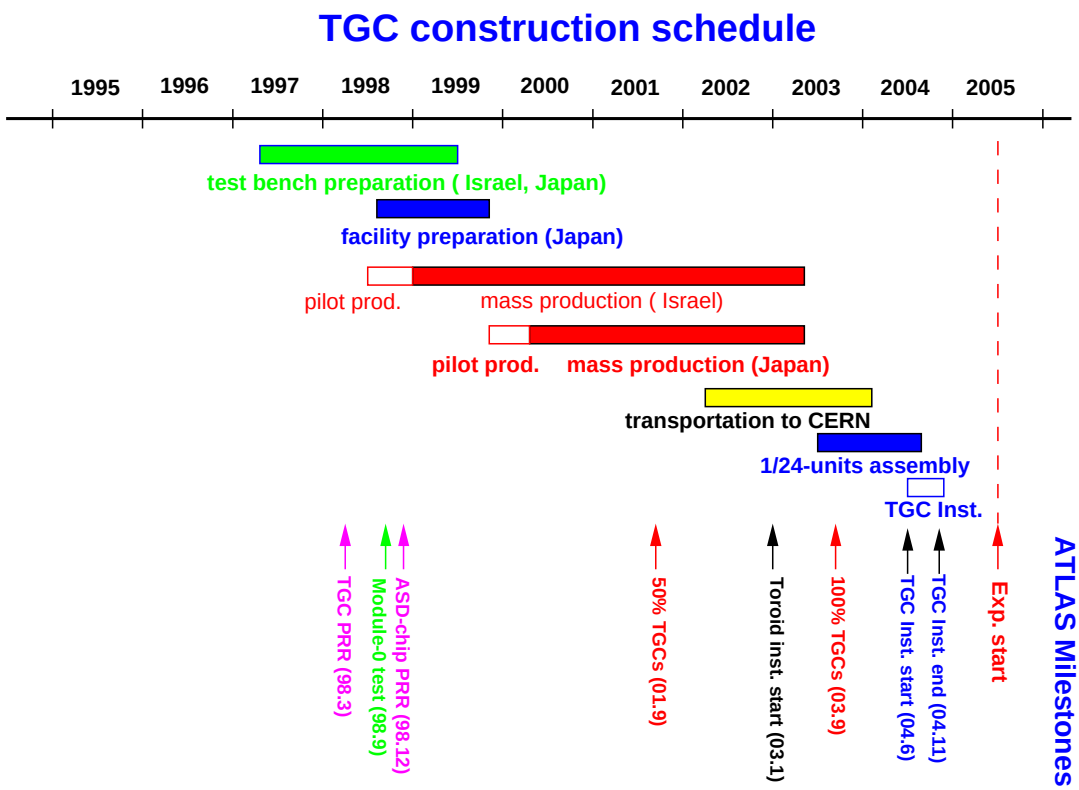


ATLAS TGC

For ATLAS Endcap Muon Trigger,

- A total of 4000 large TGC's to be produced
- Intensive R&D works in Israel and Japan
- Preparation for Production and Test

Schedule of ATLAS TGC



- Excellent experience to construct large-area muon detector
- Facilities may be used for JLC after completion of ATLAS TGC's

4. TODO's

1. Simulation Studies
   - Upgrade JIM to implement
     - Magnetic field in the return yoke
     - Full muon detector
     - Tracker in CAL
   - Studies of
     - Matching with CDC tracks
     - Punch-through hadrons
     - Beam-originated muons
     - Muon identification by calorimeter
2. Choice of Detector Technology
   SCDC, RPC, TGC, or any Other ??
3. Detector Design
4. Cost Estimation
   A "guesstimate" from ATLAS-TGC
   $\rightarrow$ 2$\sim$3 Billion Yen ?

5. Summary

- We are just at the start point for the JLC muon detector.
- There are a lot of TODO's, although no severe problems are expected.
- The TODO's must be done soon to meet the JLC Road Map.