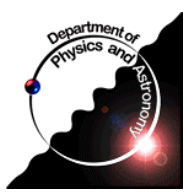
# ATLAS Endcap Signal Feedthrough Project

**NSERC Review**
**TRIUMF, Jan 9th 2000**

- **Overview of the Project**
- **Design**
- **Mechanical Components**
- **Electrical Components**
- **Assembly**
- **Quality Control**
- **Prototypes and Models**
- **Milestones and Schedule**
- **Budget and Management**
- **Conclusions**

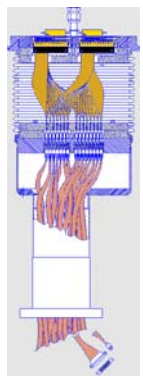



**Michel Lefebvre**
**University of Victoria**
**Physics and Astronomy**

# Overview of the Project

**ATLAS liquid argon calorimetry has over 180k signal channels which must come through the cryostats.**

**Each feedthrough unit carries 1920 electrical channels.**



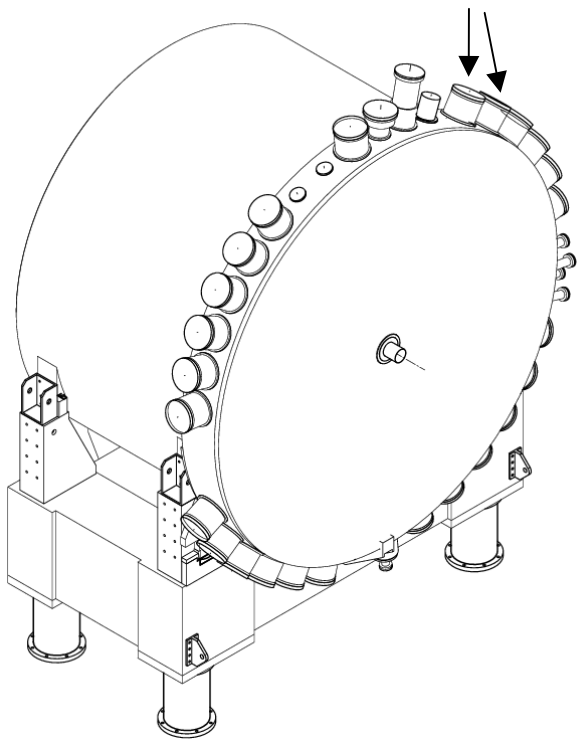
**Barrel: 64 feedthrough units**

**Endcap: 50 feedthrough units total**

**The endcap signal feedthrough project is an ATLAS common fund contribution from Canada**

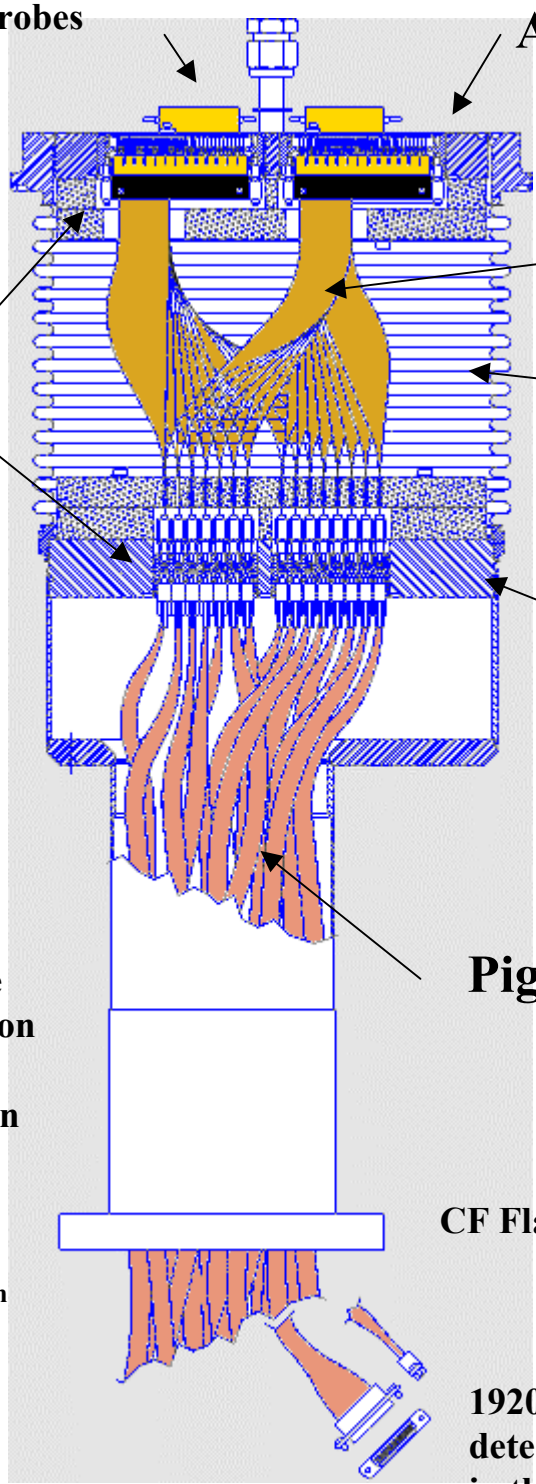
**Part of the ATLAS Cryostat and Cryogenics Project (Leader: Pierre Pailler)**

**Production Readiness Review successfully passed at CERN on Jan 29th 1999**

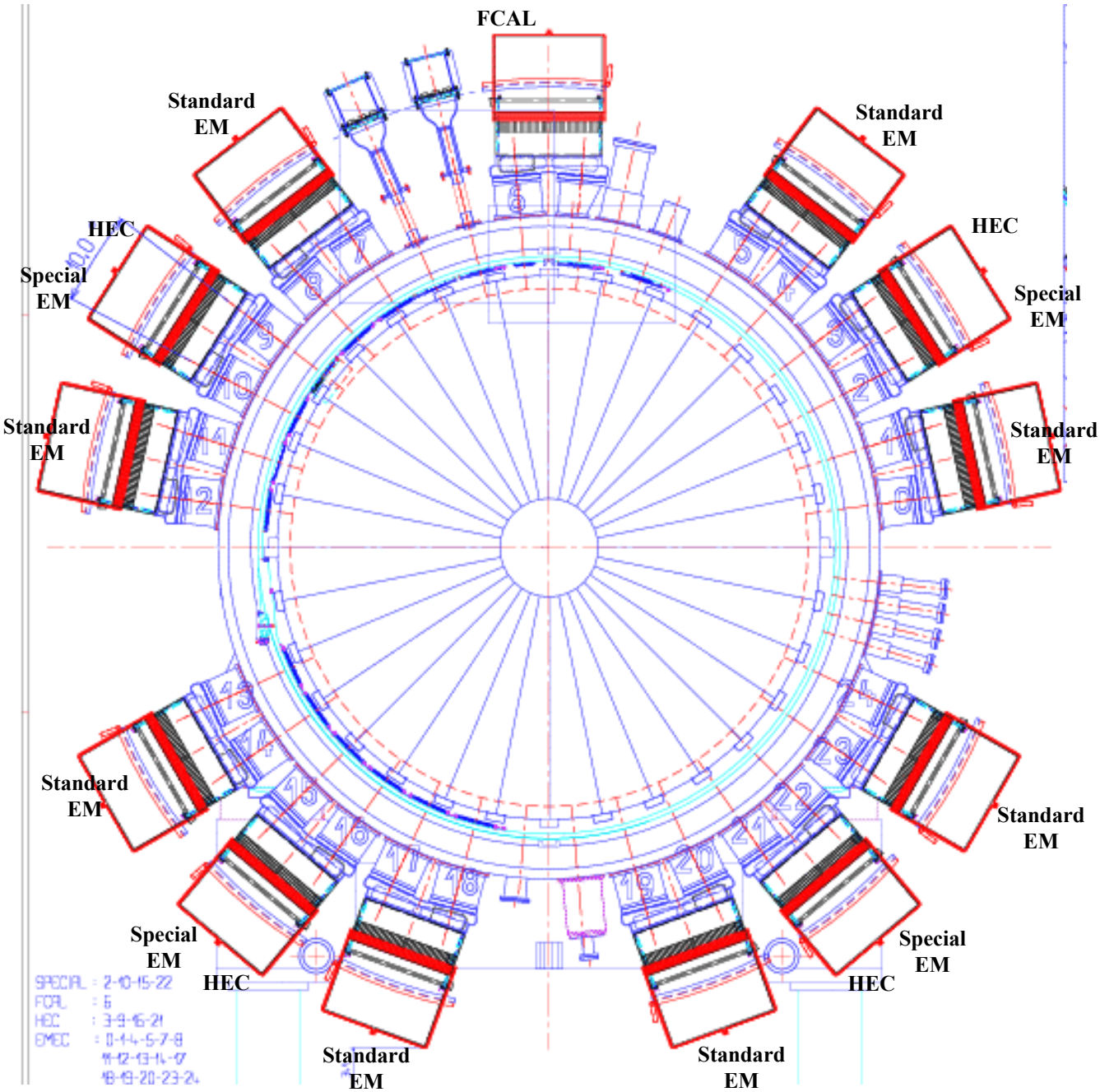


**One endcap cryostat shown during assembly**

# Overview of the Project
## Overall Design



# Overview of the Project
## Position of Units on Cryostat



# Design
# Design Considerations

**The feedthrough design must satisfy many constraints:**

- gas and liquid pressure loads
- stresses caused by temperature gradients
- stresses caused by the cryostat thermal deformations
- welding of the components must not damage the pin carriers
- heat flow through the units must be kept at an acceptable level
- the electrical properties must be adequate
- radiation environment

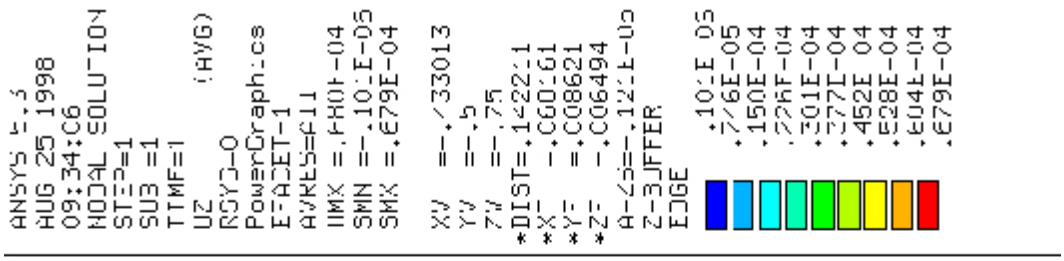
**Specific to the endcap signal feedthroughs:**

- special cables required for HEC preamplifier power:
  - special pigtails
  - special vacuum cables
  - the heat flow for these special cables will be higher than for normal signal cables, but must nevertheless be kept at a reasonable level
- there are 4 different types of endcap feedthroughs
  - 32 “Standard EM”
  - 8 “Special EM”
  - 8 “HEC (HEC and some EM)”
  - 2 “FCAL”

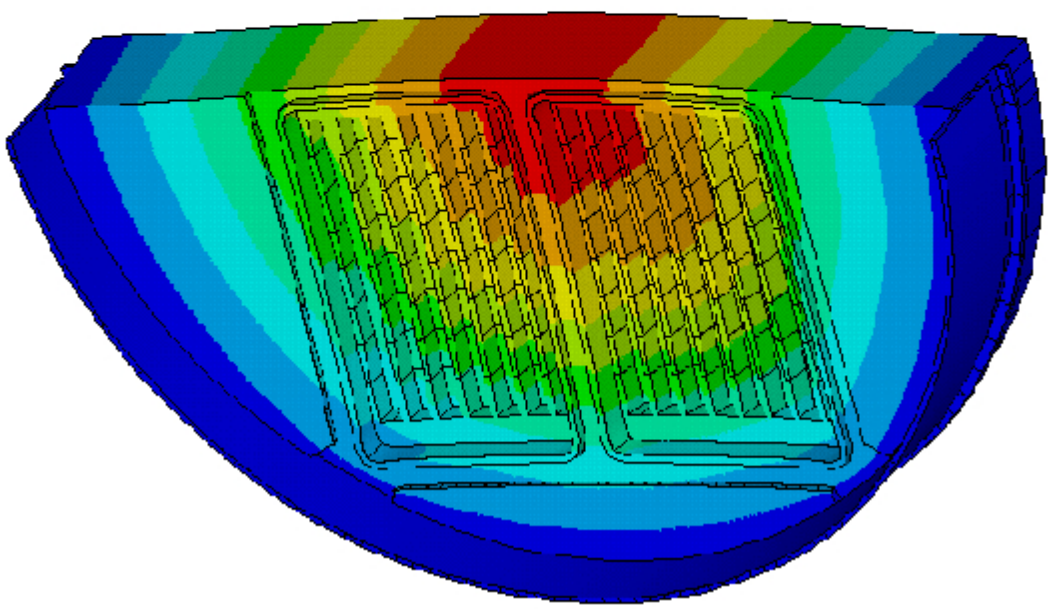
# Design
# Finite Element Analysis

**Extensive FEA analysis of the feedthrough components and assembly has been performed and reviewed**

e.g., Cold Flange Deflection
under 3.5 bar pressure load




maximum deflection of 68 microns

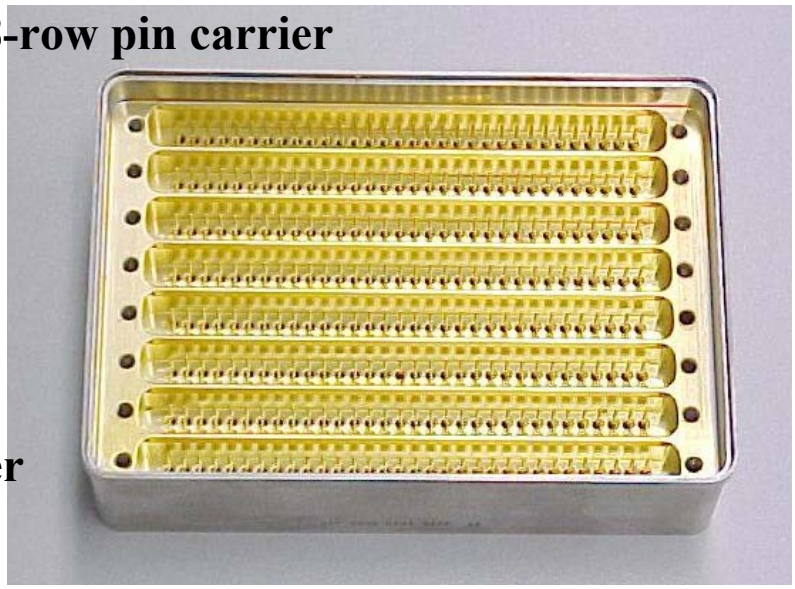


# Mechanical Components
## Pin Carriers and Flanges

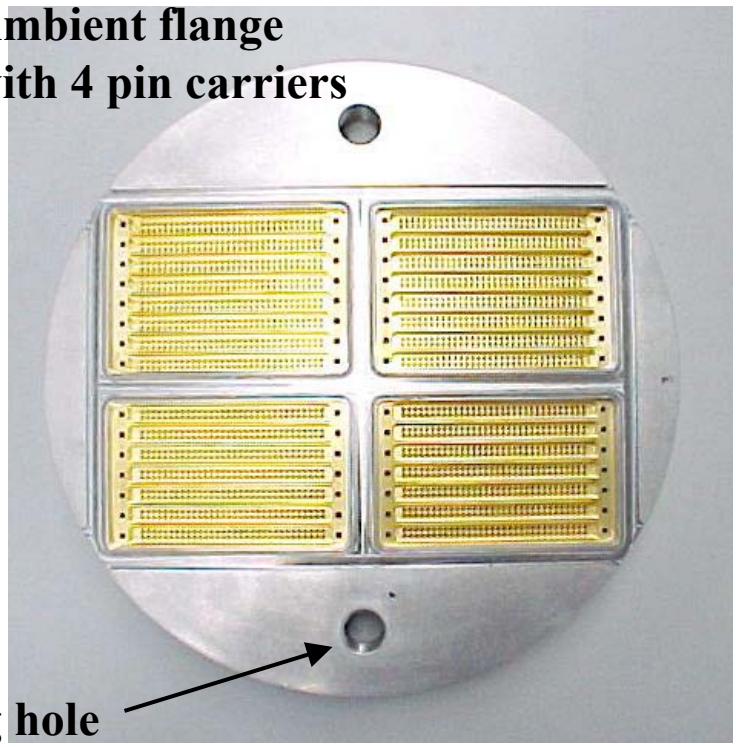
A pin carrier is a low inclusion stainless steel matrix containing 7x64 or 8x64 electrical pins held in glass inserts

Pins and carrier gold plated

8-row pin carrier



Ambient flange with 4 pin carriers

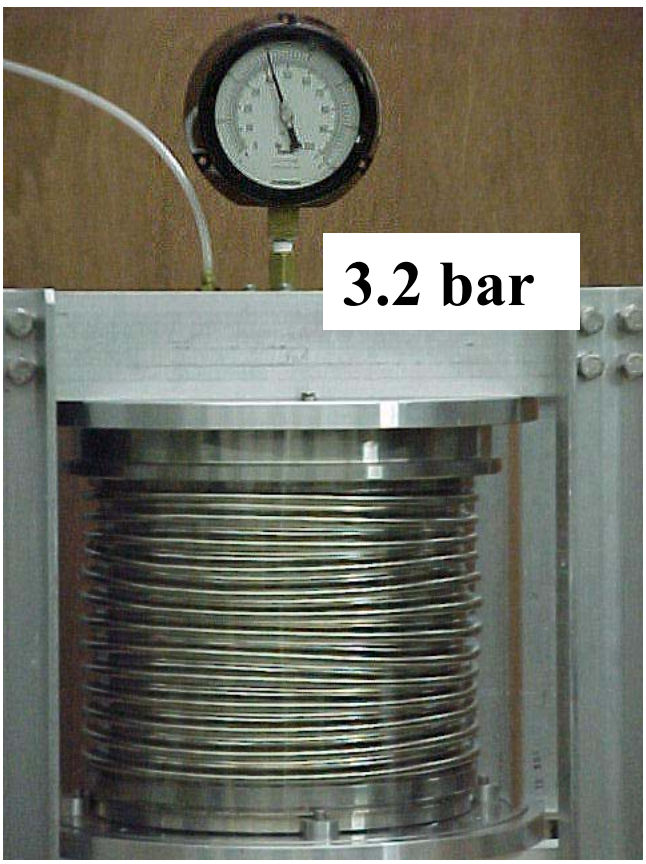


4 pin carriers are welded on the ambient flange and the cold flange, all made of low inclusion SS

Bellows volume pumping hole

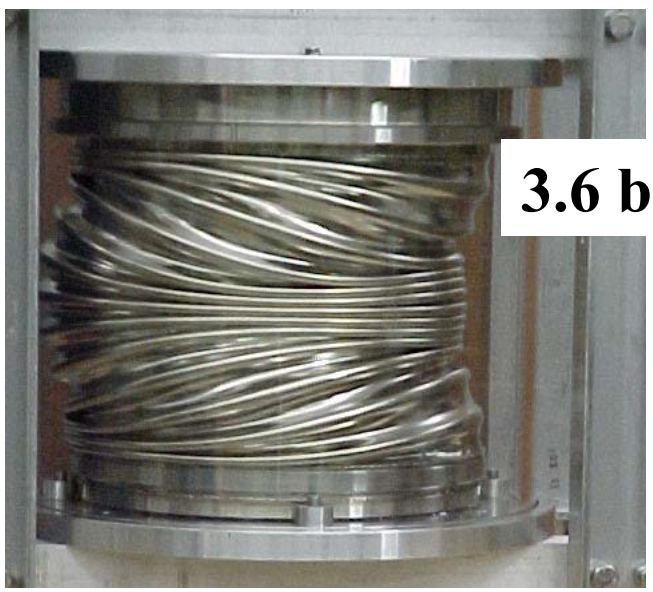
# Mechanical Components
## Bellows Assemblies

**Bellows assemblies are designed to withstand up to the exceptional condition of 3.5 bar without squirming**





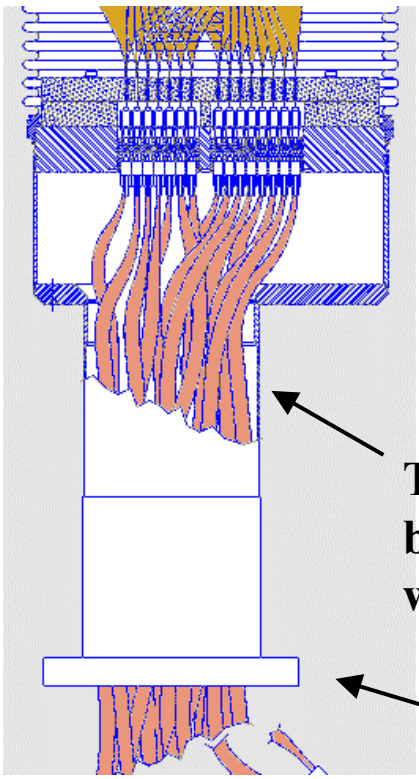
**Bellows still axially stable, therefore not squirmed**




**Both ends of the bellows were offset by 3mm to simulate the cryostat vessels offset**

# Mechanical Components
## Cold Box or Funnel

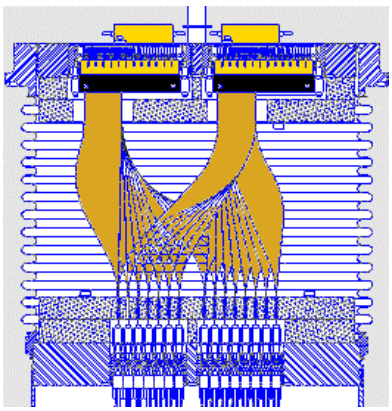
- **Mechanically connects the cold flange to the cold vessel, hence part of the pressure vessel**
- **Assymetric design required because of space constraints**
- **FEA Designed to withstand the inter-vessel relative movements**



**To be cut here by an orbital cutter before welding on bi-metallic junction with cold vessel**

**CF Flange for tests**

# Electrical Components
## Vacuum Cables



**Carry the electrical channels from the ambient flange to the cold flange. Some carry calibration lines**

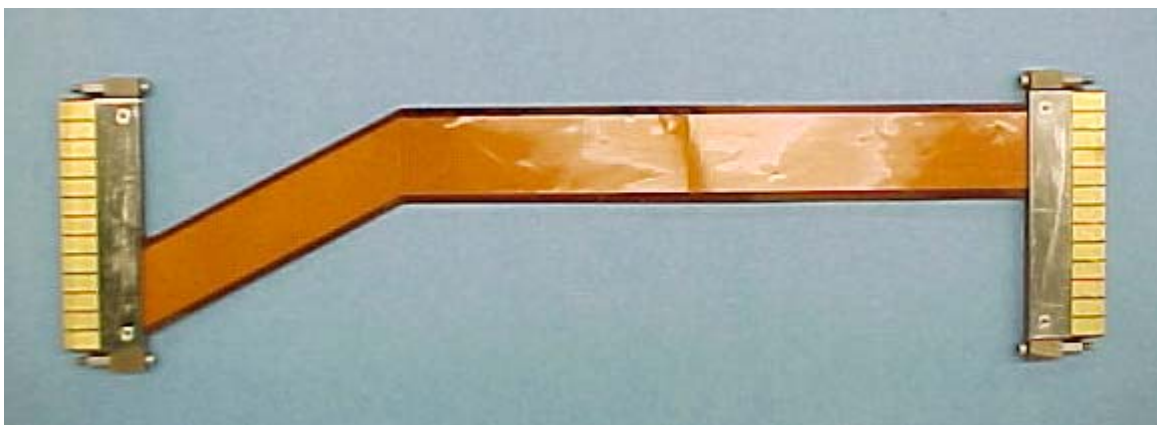
**Inaccessible after the bellows are welded to the flanges**

**Each vacuum cable must satisfy many demanding mechanical and electrical requirements**

**Successful R&D of vacuum cables in Canada with CRPP (E. Neuheimer- STC, M. Fincke-Keeler)**

**Over 100 cables produced and qualified**

**R&D critical in the evolution of the design and expertise.**

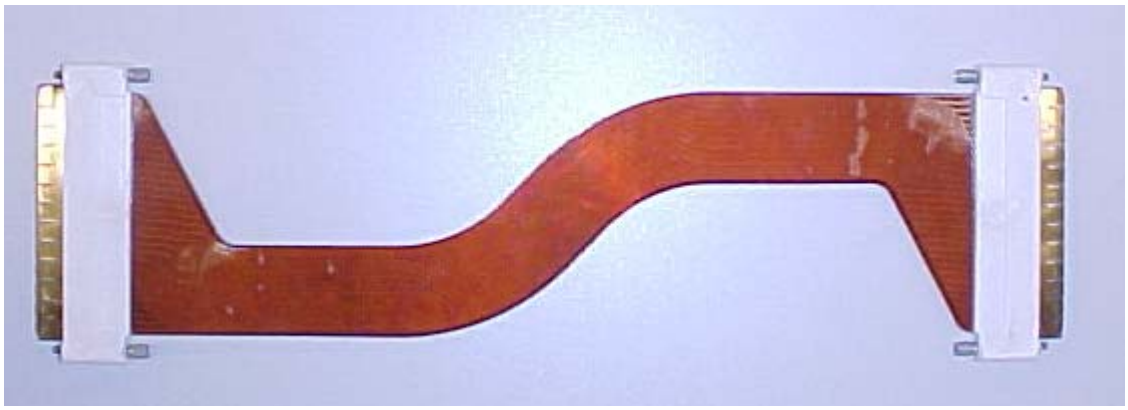


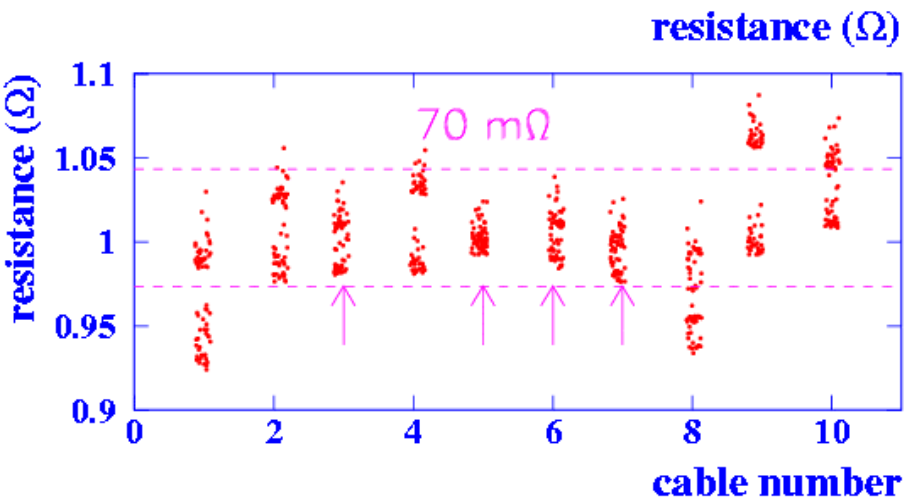
# Electrical Components
## Vacuum Cables

**RFQ replies received fall 1999 from STC and FCI-Berg**

**FCI-Berg prototype cables received Nov 99**

- **mechanical qualification near completion**
- **electrical qualification passed**
- **PRR at the factory Dec 99**

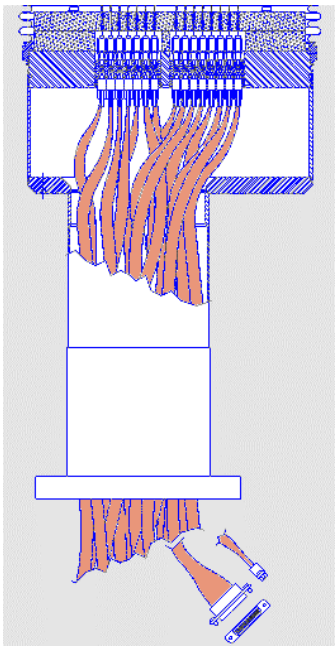





**4 cables out of 10 are of calibration quality**

# Contract to be awarded Jan 2000

# Electrical Components
## Pigtail Cables



**Electrically connects the cold flange to the detector patch panel**

**Located in the cryostat cold vessel**

**Cannot be disconnected from a completed feedthrough**

**Developed by Orsay and Axon for all of ATLAS, along with other cables**

**6 different types of signal pigtails required in the endcap feedthrough**

**MOU signed between Orsay and ATLAS-Canada Dec 98**

**Orsay provides QA on cables**

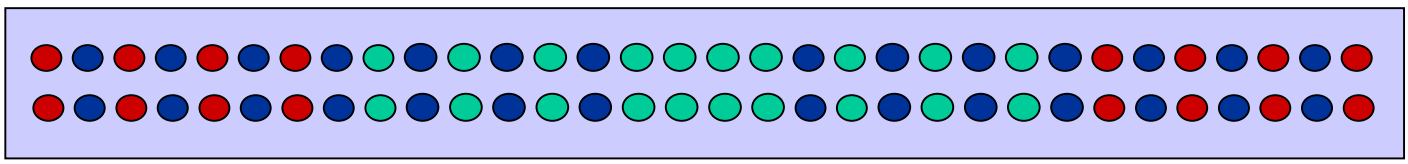
# Electrical Components
## Low Voltage Cables

**Each endcap cryostat has 4 HEC feedthroughs which must supply the power for the HEC preamplifiers located in the LAr. This corresponds to a total of 40A in and out through each HEC feedthroughs**

**Low Voltage Vacuum Cables have been developed (M. Fincke-Keeler):**

- **Carry the required currents without overheating**
- **Allow minimum thermal path**

**Wire harness using 3 different wire gauges:**

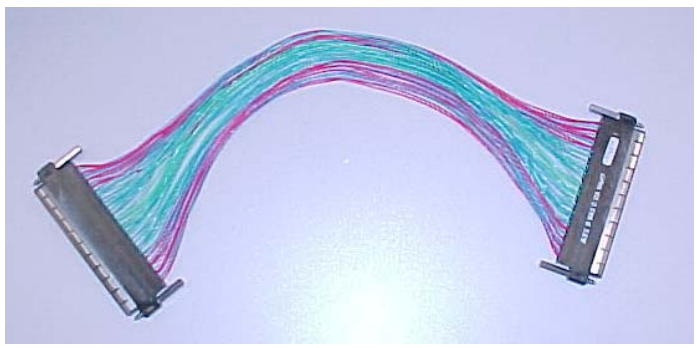


- **AWG 24 - 900mA capacity**
- **AWG 26 - 550mA capacity**
- **AWG 28 - 400mA capacity**

**ATI connectors**
**Polyimide insulation for wires**

$T_{\max} \approx 40^0 C$

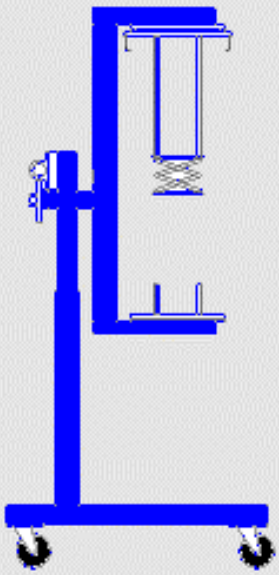
**Detail thermal tests have been performed in Sep 99 in Victoria with HEC MPI personel**



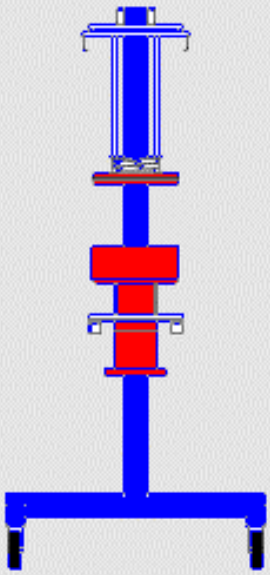
**Heat leakage: 2.21W/cable**
**18.7 W/HEC feedthrough with 4 LV connections**

**Low Voltage Pigtails have also been developed (M. Fincke-Keeler)**

# Assembly
## Assembly Sequence

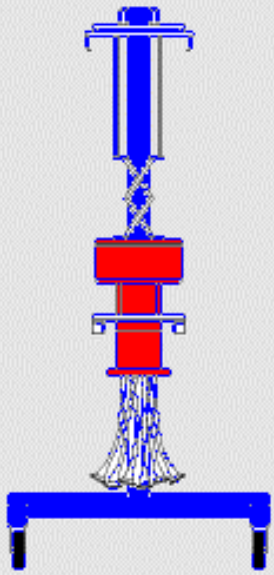


Assembly jig

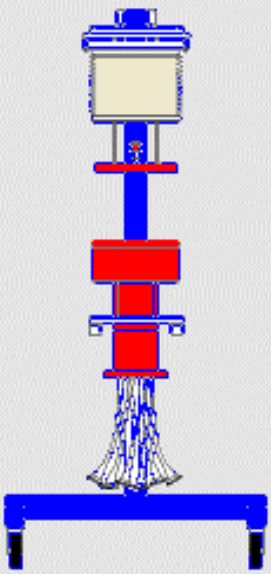


Cold flange
Cold box

Pigtails



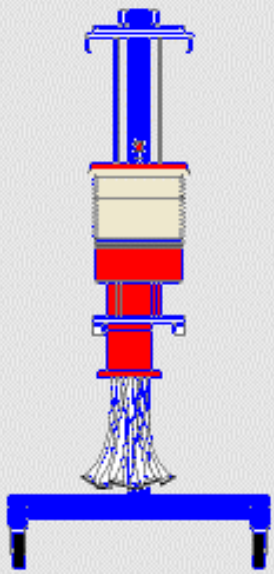
Welding (tacking) of cold flange



Bellows
Ambient flange

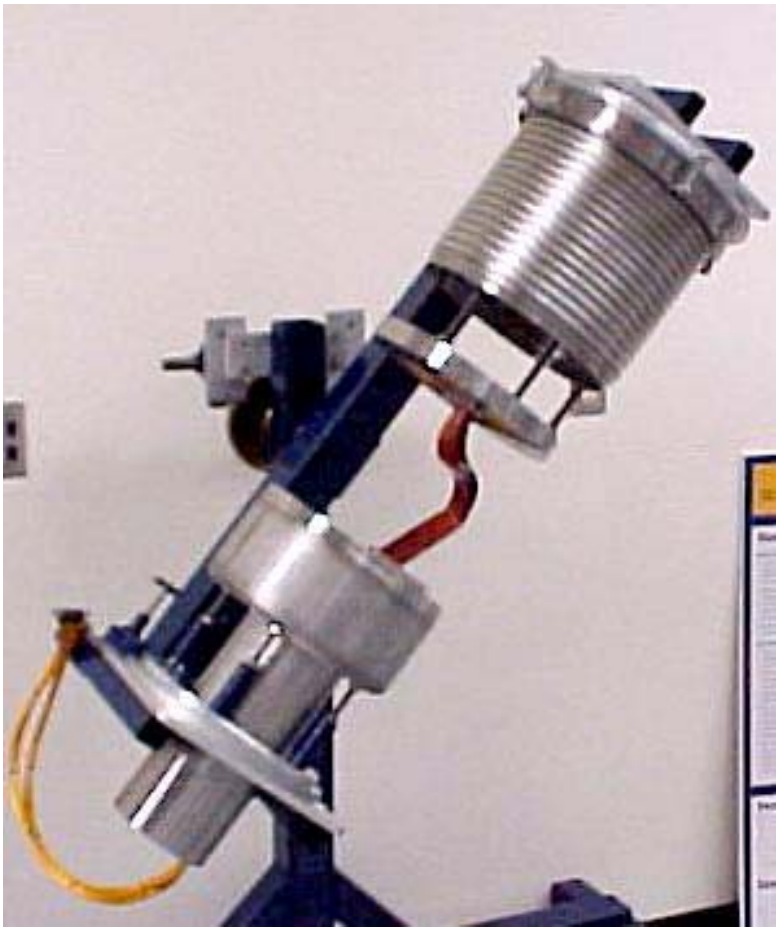
Vacuum cables

90º rotation



Final Welding

# Assembly
## Assembly Jig



**Rotation around two axes for assembly and welding**

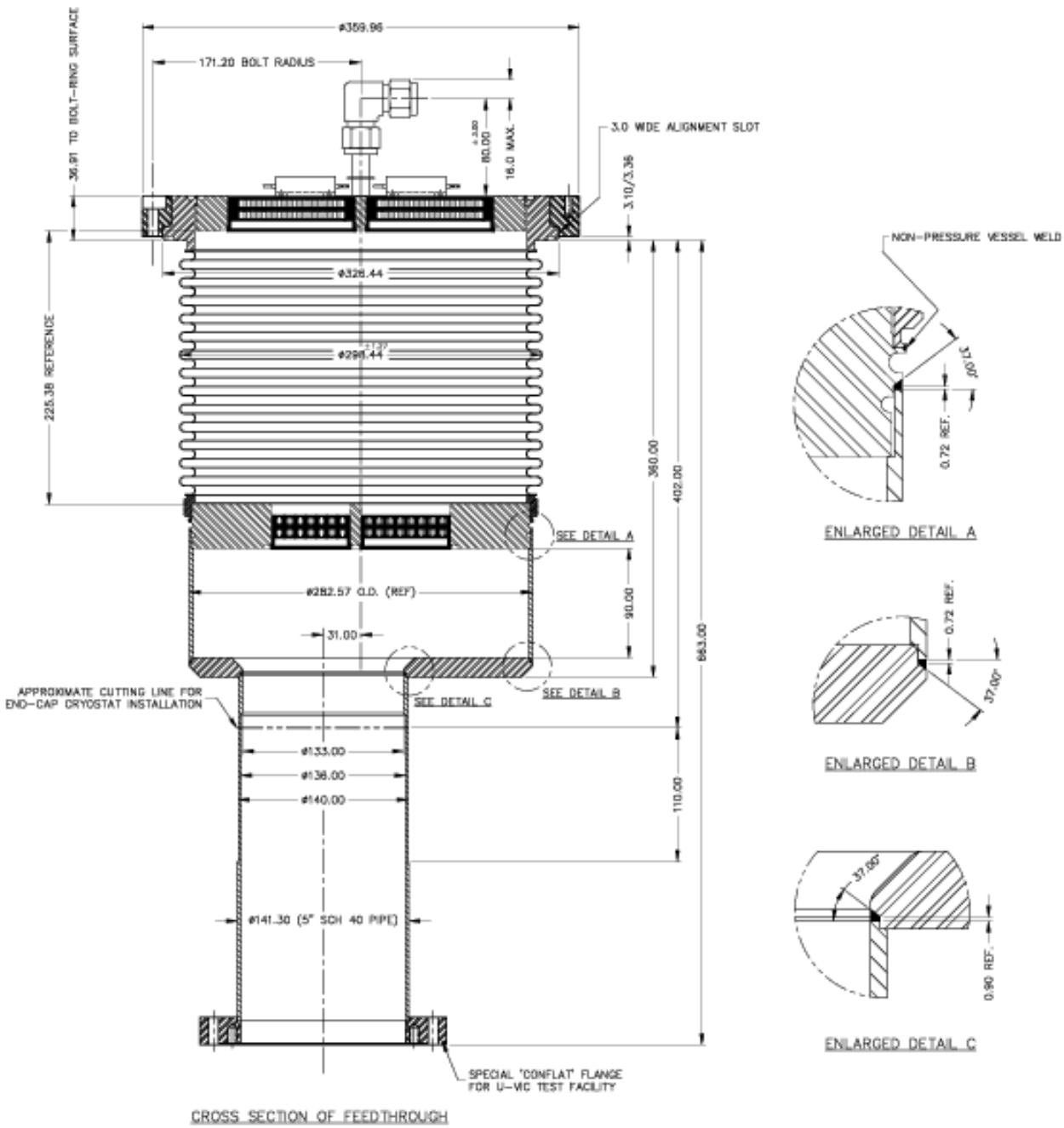
# Assembly
# Welding

**The cold box assembly is part of the pressure vessel**

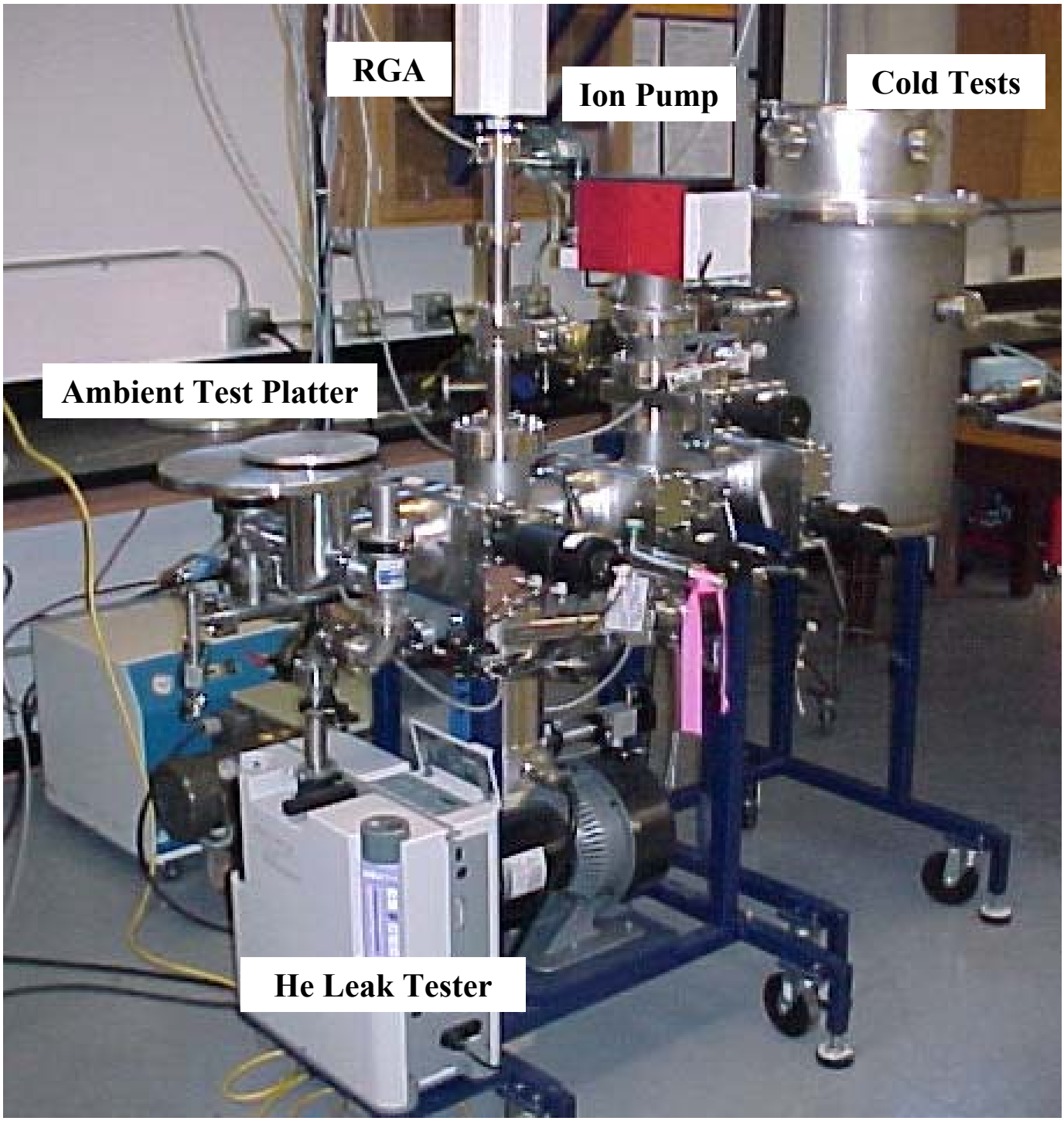
**Negotiations with TIS completed Dec 99**

**Detailed Welding Plan produced**

**Qualification of welds and welders done by Feb 00**



# Quality Control
## Vacuum Test Station

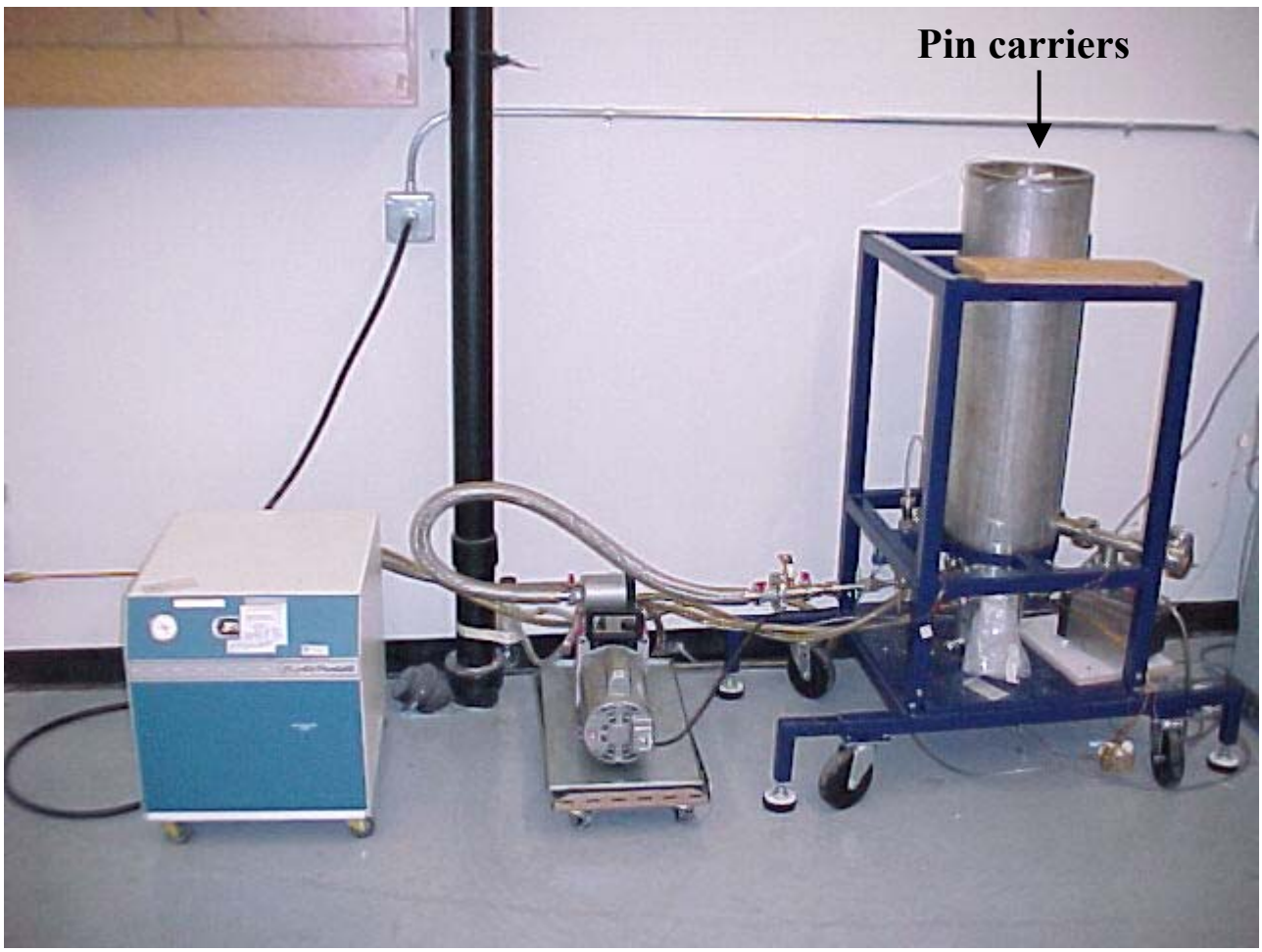


# Quality Control
## Cold Tests Station

**Quality Plan includes full cold tests**

**Prototype being inserted in the cold vacuum test station**

# Quality Control
## Temperature Cycling Apparatus




**Controled temperature cycling of pin carriers**

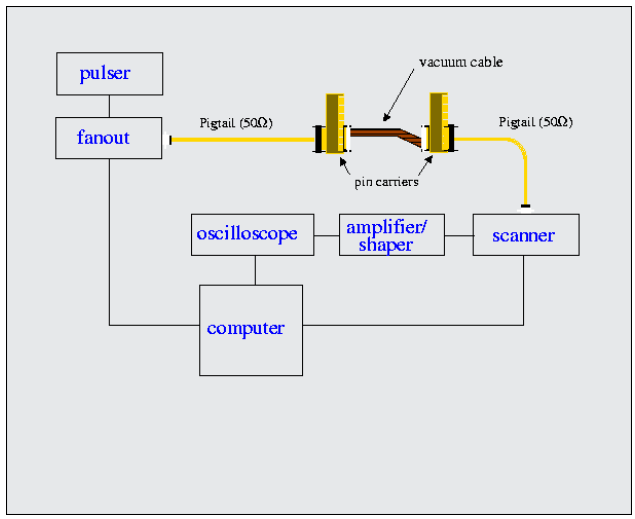
# Quality Control
## Electrical Test Stations

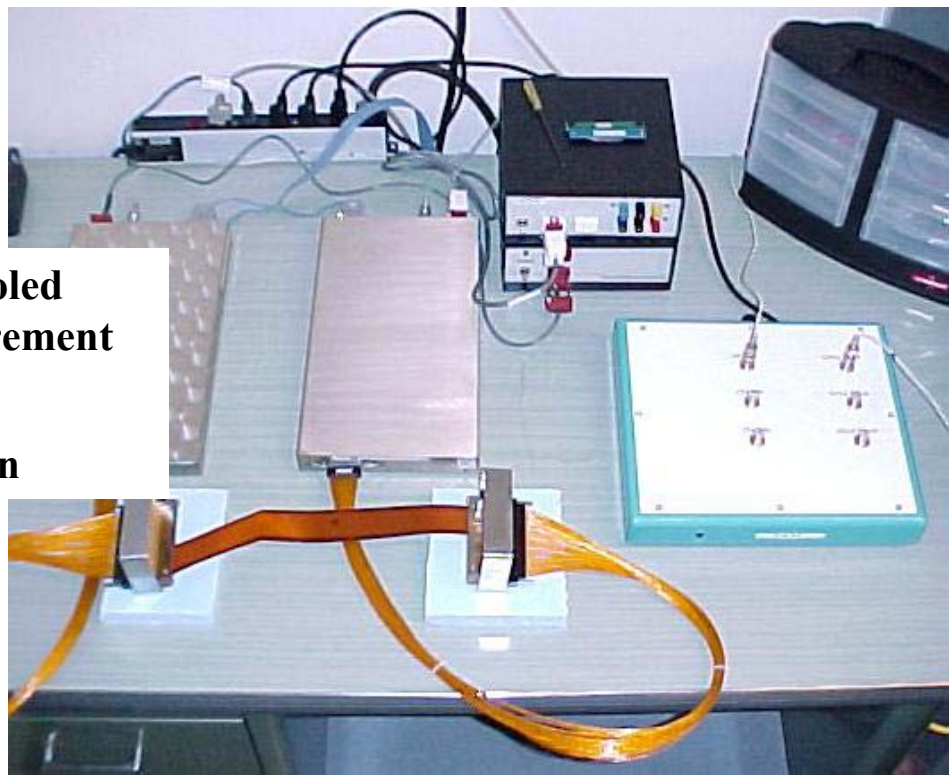
**Quality Plan includes detailed electrical tests at various stages of assembly**

**before assembly welds**
- continuity

**cold tests**
- continuity
- cross talk

**final electrical tests**
- precision resistance
- cross talk

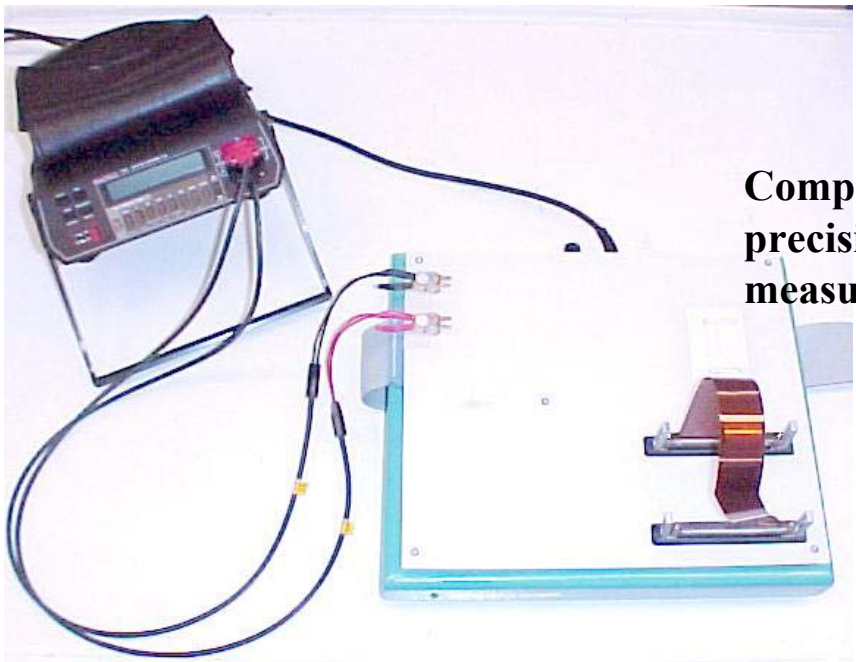


**Computer controled crosstalk measurement apparatus**

**UBC contribution**

# Quality Control
## Electrical Test Stations



**Computer controled precision resistance measurement apparatus**

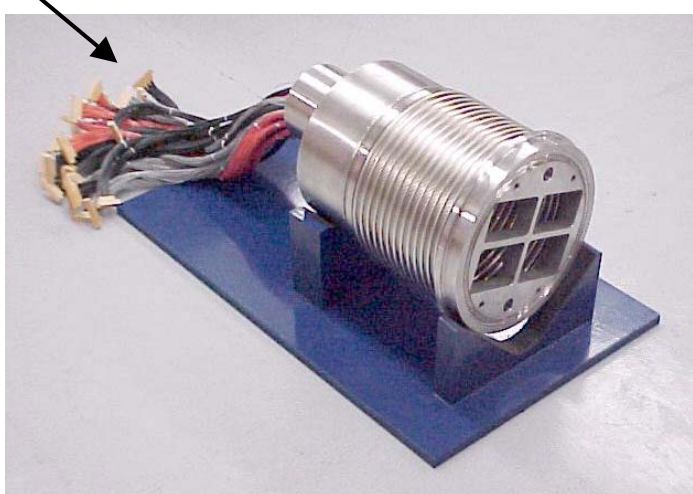
**Signal continuity and wiring apparatus**

# Prototypes and Models

**Prototypes and Models have been crucial:**

- feedthrough design completion
- parts selection
- asembly jigs design and development
- vacuum and electrical testing equipment and procedure

- Unit model (1998)
- Prototype with dismountable flange
- Insertion model
- Pressure test vessel
- Full prototype (Jan 00)



# Milestones and Schedule

## General

- **Production Readiness Review**
  - **Passed in Jan 99**
- **Leak Test Station and Electric Test Station**
  - **Fully operational since Fall 98**
- **Models and Prototypes**
  - **Model done in 98**
  - **Prototype with dismountable flange done in 99**
  - **Insertion model done in Dec 99**
  - **TIS pressure test vessel done by Feb 00**
  - **Full prototype done in Jan 00**
- **Welding**
  - **Welding Plan completed in Dec 99**
  - **Agreement with TIS finalised in Dec 99**
  - **Qualification of welder done by Feb00**
- **Production of Feedthrough Units**
  - **First feedthrough unit done in May 00**
  - **Production of 25 units plus 3 spares by Jun 01**
  - **Shipment and testing at CERN: Jan 01 - Jun 01**
  - **Installation on cryostat : May 01 - Jul 01**
  - **Production of 25 units plus 3 spares by Apr 02**
  - **Shipment and testing at CERN: Nov 01 - Apr 01**
  - **Installation on cryostat : Mar 02 - May 02**

# Milestones and Schedule

## Mechanical Components

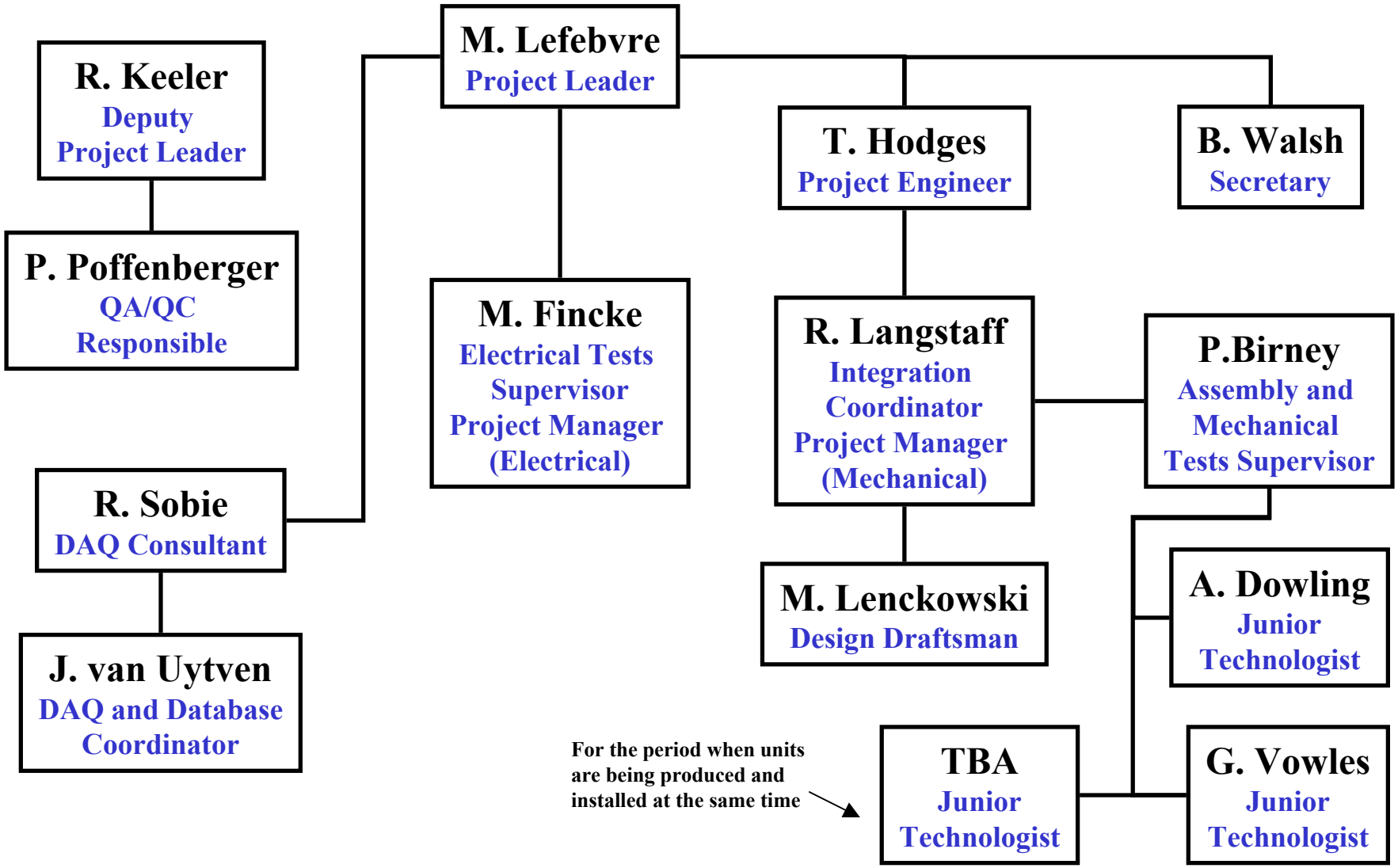
- LowInclusion Steel (Timkin)
  - P.O. out in Jul 99
  - Reception started in Oct 99 and resumed in Dec 99
- Pin Carriers (Glasseal)
  - P.O. out in Jun 99
  - Reception started in Oct 99
- Cold and Ambient Flanges (EBCO)
  - P.O. out in Nov 99
  - Reception in Mar 00
- Funnel Parts and Bolts Rings (SICOM)
  - P.O. out in Nov 99
  - Reception completed in Mar 00
- Funnel Assemblies (Spec. Mech.)
  - P.O. out in Jan 00
  - Reception to start in Apr 00
- Seal and Cuff Rings for Bellows (SICOM)
  - P.O. out in Nov 99
  - Reception completed in Feb 00
- Bellows Assemblies (BOA)
  - P.O. out in Jan 00
  - Reception to start in Apr 00
- Other Components
  - RF Gasket, Pipe fittings, Insulation, Pigtail restraint, Heaters
  - Reception to start in Jan 00

# Milestones and Schedule

## Electrical Components

- **Vacuum Cables**
  - **RFQ reply from STC and FCI-Berg during fall 99**
  - **STC cables passed qualification**
  - **FCI-Berg cables qualification finalised Dec99 - Jan 00**
  - **Final contract to be awarded in Jan 00**
  - **Reception to start in Apr 00**
- **Pigtail Cables (Axon via Orsay)**
  - **MOU with Orsay signed in Dec 98**
  - **Reception at Orsay started in Nov 99**
  - **Reception in Victoria to start in Jan 00**
- **Other Cables (Axon)**
  - **RFQ reply received**
  - **P.O. out in Jan 00**
- **Heaters**
  - **Design finalised before Apr 00**

# Budget and Management
## Organizational Chart



# Budget and Management

## Budget Summary

| PBS | WBS | Description | Sep 00 | MIG COST PROFILE | | | | | | | | Sep 00 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 00-01 | 97-98 | 98-99 | 99-00 | 00-01 | 01-02 | 02-03 | 03-04 | MIG | spent | commit | uncommit | contingency |
| | | | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | % | % | % | $CAN |
| **4** | **1** | **Endcap Signal Feedthroughs** | **$455,694** | **$224,375** | **$261,707** | **$503,577** | **$1,594,824** | **$1,174,668** | **$192,783** | **$28,793** | **$3,980,726** | **36** | **50** | **14** | **$432,753** |
| **4.1** | **2** | **Project Setup** | **$59,648** | **$156,386** | **$202,816** | **$214,831** | **$162,454** | **$52,671** | **$15,574** | **$8,276** | **$813,008** | **78** | **6** | **16** | **$38,329** |
| 4.1.1 | 3 | Leak Test Setup | $37,675 | $102,521 | $29,420 | $6,952 | $45,374 | $19,806 | $9,810 | $4,105 | $217,989 | 81 | 0 | 19 | $9,533 |
| 4.1.2 | 3 | Electric Test Setup | $19,831 | $6,109 | $22,252 | $32,822 | $60,199 | $15,174 | $3,500 | $1,095 | $141,151 | 57 | 0 | 43 | $14,394 |
| 4.1.3 | 3 | Data Acquisition System | $1,003 | $15,198 | $5,308 | $4,690 | $1,400 | $11,585 | $700 | $2,431 | $41,313 | 63 | 1 | 36 | $3,713 |
| 4.1.4 | 3 | FT Assembly Tools | $0 | $0 | $10,135 | $591 | $44,724 | $840 | $211 | $0 | $56,500 | 19 | 76 | 5 | $7,144 |
| 4.1.5 | 3 | FT Prototypes | -$2,636 | $32,558 | $135,094 | $163,028 | $4,057 | $101 | $0 | $218 | $335,055 | 98 | 2 | 0 | $1,077 |
| 4.1.6 | 3 | Misc Project Setup Items | $3,775 | $0 | $607 | $6,748 | $6,700 | $5,165 | $1,353 | $427 | $21,000 | 53 | 0 | 47 | $2,467 |
| **4.2** | **2** | **FT Series Assemblies** | **$333,154** | **$0** | **$0** | **$142,211** | **$1,274,870** | **$913,497** | **$0** | **$0** | **$2,330,579** | **20** | **69** | **11** | **$350,367** |
| 4.2.1 | 3 | Mechanical Components | $120,328 | $0 | $0 | $141,714 | $421,821 | $490,111 | $0 | $0 | $1,053,647 | 25 | 63 | 12 | $129,310 |
| 4.2.2 | 3 | Electrical Components | $212,153 | $0 | $0 | $399 | $832,049 | $362,483 | $0 | $0 | $1,194,932 | 18 | 77 | 5 | $203,318 |
| 4.2.3 | 3 | Shipping Crates | $672 | $0 | $0 | $98 | $21,000 | $60,902 | $0 | $0 | $82,000 | 1 | 21 | 78 | $17,739 |
| **4.3** | **2** | **Test Cryostat Signal FT** | **$0** | **$58,428** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$58,428** | **100** | **0** | **0** | **$0** |
| **4.4** | **2** | **Manpower** | **$62,892** | **$9,561** | **$58,891** | **$146,534** | **$157,500** | **$208,500** | **$177,209** | **$20,517** | **$778,712** | **36** | **42** | **22** | **$44,057** |
| 4.4.1 | 3 | Salaries and Benefits | $57,253 | $9,561 | $55,092 | $129,328 | $131,000 | $185,000 | $156,268 | $11,799 | $678,048 | 37 | 48 | 15 | $26,341 |
| 4.4.2 | 3 | Consultation and Travel | $2,505 | $0 | $1,016 | $17,206 | $19,500 | $18,500 | $18,225 | $8,718 | $83,164 | 25 | 4 | 71 | $14,821 |
| 4.4.3 | 3 | Other | $3,134 | $0 | $2,784 | $0 | $7,000 | $5,000 | $2,716 | $0 | $17,500 | 34 | 0 | 66 | $2,896 |

**Contingencies total $433k and are dominated by exchange rates:**

**+15% on 1.52 $CAN/$US (pin carriers and vacuum cables)**

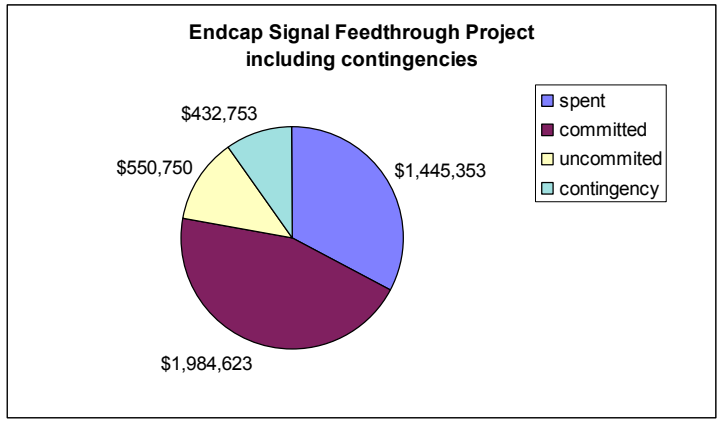
**+25% on 0.200 $CAN/FF (pigtails)**

**+15% on 0.860 $CAN/CHF (orbital cutter contribution)**

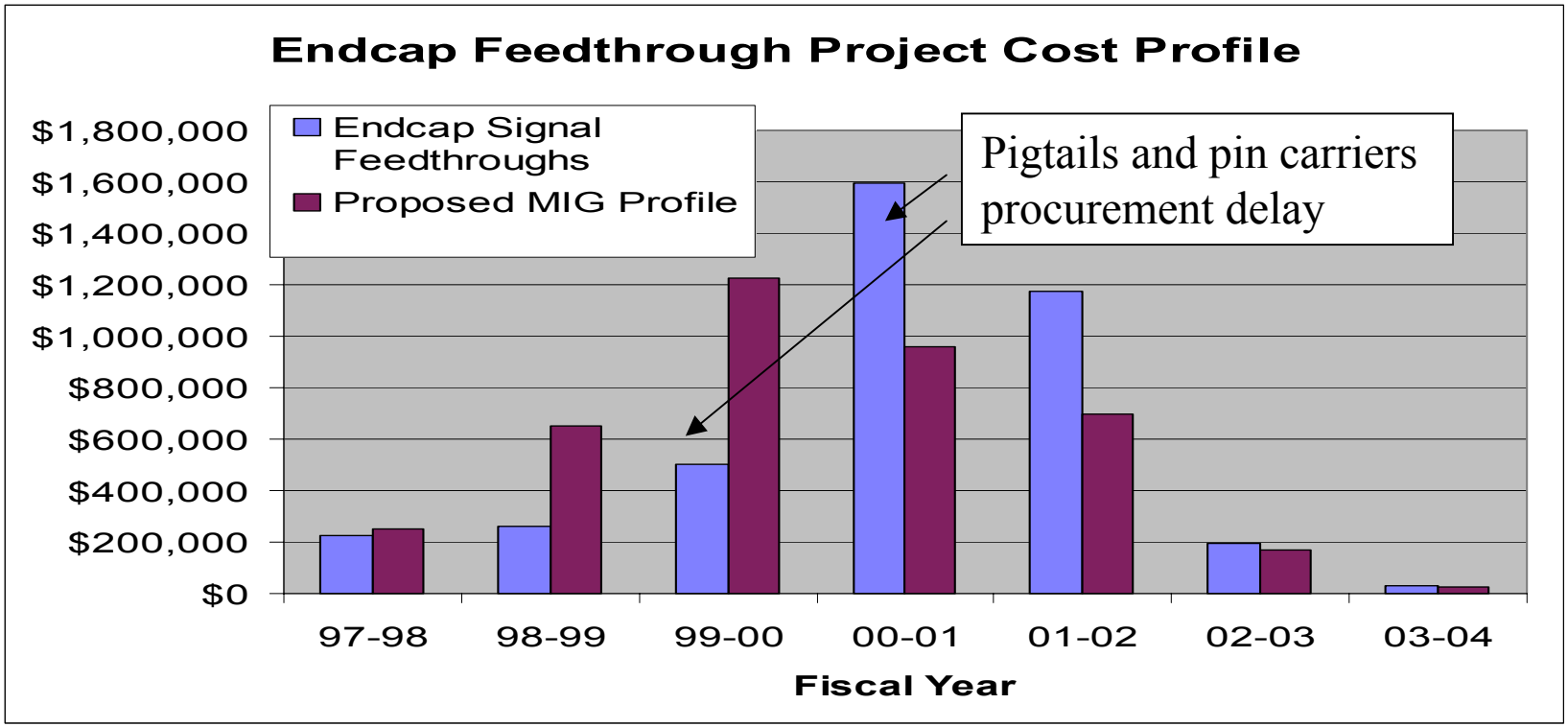
**The budget total net of contingencies is $3.98M**

**36% of which has been spent (Sep 00)**

**50% of which has been committed (Sep 00)**

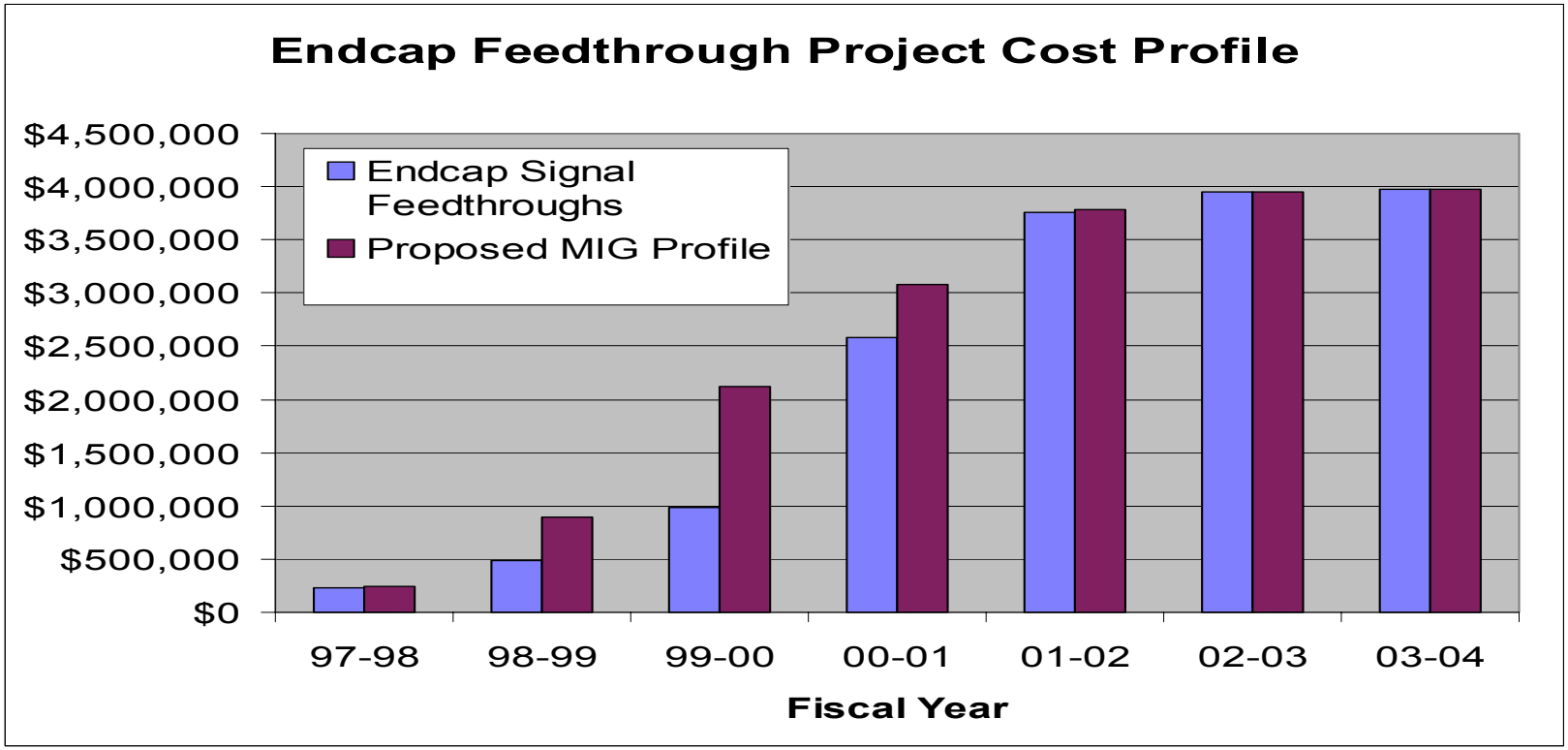


# Budget and Management
## Budget Profile




| | 97-98 | 98-99 | 99-00 | 00-01 | 01-02 | 02-03 | 03-04 | Total |
|---|---|---|---|---|---|---|---|---|
| **Sep-00** | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN |
| Budget | **$224,375** | **$261,707** | **$503,577** | **$1,594,824** | **$1,174,668** | **$192,783** | **$28,793** | **$3,980,726** |
| MIG spent | **$224,375** | **$261,707** | **$503,577** | **$455,694** | **$0** | **$0** | **$0** | **$1,445,353** |
| Proposed MIG Profile | **$249,000** | **$650,000** | **$1,226,880** | **$960,000** | **$700,000** | **$170,000** | **$24,846** | **$3,980,726** |

# Budget and Management
## Integrated Budget Profile




| | 97-98 | 98-99 | 99-00 | 00-01 | 01-02 | 02-03 | 03-04 | Total |
|---|---|---|---|---|---|---|---|---|
| **Sep-00** | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN |
| Budget | **$224,375** | **$486,082** | **$989,659** | **$2,584,483** | **$3,759,151** | **$3,951,933** | **$3,980,726** | **$3,980,726** |
| MIG spent | **$224,375** | **$486,082** | **$989,659** | **$1,445,353** | **$1,445,353** | **$1,445,353** | **$1,445,353** | **$1,445,353** |
| Proposed MIG Profile | **$249,000** | **$899,000** | **$2,125,880** | **$3,085,880** | **$3,785,880** | **$3,955,880** | **$3,980,726** | **$3,980,726** |

# Budget and Management
## Series Assemblies Details

| PBS | WBS | Description | MIG COST PROFILE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 97-98 | 98-99 | 99-00 | 00-01 | 01-02 | 02-03 | 03-04 | MIG | spent | commit | uncommit | contingency |
| | | | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | % | % | % | $CAN |
| **4** | **1** | **Endcap Signal Feedthroughs** | **$224,375** | **$261,707** | **$503,577** | **$1,594,824** | **$1,174,668** | **$192,783** | **$28,793** | **$3,980,726** | **36** | **50** | **14** | **$432,753** |
| **4.1** | **2** | **Project Setup** | **$156,386** | **$202,816** | **$214,831** | **$162,454** | **$52,671** | **$15,574** | **$8,276** | **$813,008** | **78** | **6** | **16** | **$38,329** |
| **4.2** | **2** | **FT Series Assemblies** | **$0** | **$0** | **$142,211** | **$1,274,870** | **$913,497** | **$0** | **$0** | **$2,330,579** | **20** | **69** | **11** | **$350,367** |
| **4.2.1** | **3** | **Mechanical Components** | **$0** | **$0** | **$141,714** | **$421,821** | **$490,111** | **$0** | **$0** | **$1,053,647** | **25** | **63** | **12** | **$129,310** |
| 4.2.1.0 | 4 | Low Inclusion Steel | $0 | $0 | $36,585 | $27,699 | $0 | $0 | $0 | $64,284 | 100 | 0 | 0 | $0 |
| 4.2.1.1 | 4 | Pin Carriers | $0 | $0 | $37,019 | $175,000 | $469,611 | $0 | $0 | $681,630 | 4 | 84 | 12 | $106,130 |
| 4.2.1.2 | 4 | Warm Flanges | $0 | $0 | $0 | $20,818 | $0 | $0 | $0 | $20,818 | 100 | 0 | 0 | $0 |
| 4.2.1.3 | 4 | Cold Flanges | $0 | $0 | $0 | $21,235 | $0 | $0 | $0 | $21,235 | 100 | 0 | 0 | $0 |
| 4.2.1.4 | 4 | Bellow Assemblies | $0 | $0 | $20,564 | $102,369 | $0 | $0 | $0 | $122,932 | 53 | 47 | 0 | $8,662 |
| 4.2.1.5 | 4 | Bolt Flanges | $0 | $0 | $18,370 | $0 | $0 | $0 | $0 | $18,370 | 100 | 0 | 0 | $0 |
| 4.2.1.6 | 4 | Funnel Assemblies | $0 | $0 | $12,813 | $52,160 | $0 | $0 | $0 | $64,973 | 42 | 58 | 0 | $3,773 |
| 4.2.1.7 | 4 | Pipe Fittings | $0 | $0 | $0 | $500 | $500 | $0 | $0 | $1,000 | 0 | 10 | 90 | $235 |
| 4.2.1.8 | 4 | RF Gasket | $0 | $0 | $0 | $1,200 | $0 | $0 | $0 | $1,200 | 0 | 0 | 100 | $300 |
| 4.2.1.9 | 4 | Insulation | $0 | $0 | $4,161 | $839 | $0 | $0 | $0 | $5,000 | 83 | 0 | 17 | $210 |
| 4.2.1.10 | 4 | Welds | $0 | $0 | $0 | $20,000 | $20,000 | $0 | $0 | $40,000 | 0 | 0 | 100 | $10,000 |
| 4.2.1.11 | 4 | CF Flanges | $0 | $0 | $12,203 | $0 | $0 | $0 | $0 | $12,203 | 100 | 0 | 0 | $0 |
| **4.2.2** | **3** | **Electrical Components** | **$0** | **$0** | **$399** | **$832,049** | **$362,483** | **$0** | **$0** | **$1,194,932** | **18** | **77** | **5** | **$203,318** |
| 4.2.2.1 | 4 | Pig Tail Cables | $0 | $0 | $192 | $200,000 | $299,803 | $0 | $0 | $499,995 | 0 | 100 | 0 | $124,866 |
| 4.2.2.2 | 4 | Vacuum Cables | $0 | $0 | $0 | $510,576 | $0 | $0 | $0 | $510,576 | 33 | 67 | 0 | $51,500 |
| 4.2.2.3 | 4 | Low Voltage Pigtail Cables | $0 | $0 | $0 | $30,691 | $30,691 | $0 | $0 | $61,382 | 48 | 49 | 3 | $4,977 |
| 4.2.2.4 | 4 | Low Voltage Vacuum Cables | $0 | $0 | $0 | $19,490 | $19,490 | $0 | $0 | $38,980 | 5 | 90 | 5 | $5,750 |
| 4.2.2.5 | 4 | Heaters | $0 | $0 | $207 | $31,793 | $0 | $0 | $0 | $32,000 | 1 | 20 | 79 | $7,245 |
| 4.2.2.6 | 4 | Extra HEC Pigtails | $0 | $0 | $0 | $12,499 | $12,499 | $0 | $0 | $24,998 | 46 | 46 | 8 | $2,230 |
| 4.2.2.7 | 4 | Temperature Probes | $0 | $0 | $0 | $27,000 | $0 | $0 | $0 | $27,000 | 0 | 0 | 100 | $6,750 |
| **4.2.3** | **3** | **Shipping Crates** | **$0** | **$0** | **$98** | **$21,000** | **$60,902** | **$0** | **$0** | **$82,000** | **1** | **21** | **78** | **$17,739** |
| **4.3** | **2** | **Test Cryostat Signal FT** | **$58,428** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$58,428** | **100** | **0** | **0** | **$0** |
| **4.4** | **2** | **Manpower** | **$9,561** | **$58,891** | **$146,534** | **$157,500** | **$208,500** | **$177,209** | **$20,517** | **$778,712** | **36** | **42** | **22** | **$44,057** |
| 4.4.1 | 3 | Salaries and Benefits | $9,561 | $55,092 | $129,328 | $131,000 | $185,000 | $156,268 | $11,799 | $678,048 | 37 | 48 | 15 | $26,341 |
| 4.4.2 | 3 | Consultation and Travel | $0 | $1,016 | $17,206 | $19,500 | $18,500 | $18,225 | $8,718 | $83,164 | 25 | 4 | 71 | $14,821 |
| 4.4.3 | 3 | Other | $0 | $2,784 | $0 | $7,000 | $5,000 | $2,716 | $0 | $17,500 | 34 | 0 | 66 | $2,896 |

# Budget and Management

## Project Setup Details

| PBS | WBS | Description | MIG COST PROFILE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 97-98 | 98-99 | 99-00 | 00-01 | 01-02 | 02-03 | 03-04 | MIG | spent | commit | uncommit | contingency |
| | | | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | $CAN | % | % | % | $CAN |
| 4 | 1 | Endcap Signal Feedthroughs | $224,375 | $261,707 | $503,577 | $1,594,824 | $1,174,668 | $192,783 | $28,793 | $3,980,726 | 36 | 50 | 14 | $432,753 |
| 4.1 | 2 | Project Setup | $156,386 | $202,816 | $214,831 | $162,454 | $52,671 | $15,574 | $8,276 | $813,008 | 78 | 6 | 16 | $38,329 |
| 4.1.1 | 3 | Leak Test Setup | $102,521 | $29,420 | $6,952 | $45,374 | $19,806 | $9,810 | $4,105 | $217,989 | 81 | 0 | 19 | $9,533 |
| 4.1.1.1 | 4 | He Leak Tester | $29,677 | $4,368 | $91 | $35,000 | $2,500 | $2,310 | $1,055 | $75,000 | 91 | 0 | 9 | $1,606 |
| 4.1.1.2 | 4 | RGA | $17,500 | $0 | $0 | $0 | $0 | $0 | $0 | $17,500 | 100 | 0 | 0 | $0 |
| 4.1.1.3 | 4 | Calibrated He leaks | $2,265 | $1,130 | $0 | $1,674 | $0 | $0 | $0 | $5,069 | 100 | 0 | 0 | $0 |
| 4.1.1.4 | 4 | Cold Cathode / Pirani Gauges | $6,500 | $0 | $5 | $0 | $0 | $0 | $0 | $6,505 | 100 | 0 | 0 | $0 |
| 4.1.1.5 | 4 | Scroll Pump | $0 | $8,219 | $0 | $0 | $8,219 | $0 | $0 | $16,438 | 50 | 0 | 50 | $1,233 |
| 4.1.1.6 | 4 | Cryo Cooler | $13,637 | $0 | $0 | $0 | $0 | $0 | $0 | $13,637 | 100 | 0 | 0 | $0 |
| 4.1.1.7 | 4 | Ion Pump Parts | $1,654 | $0 | $0 | $0 | $0 | $0 | $0 | $1,654 | 100 | 0 | 0 | $0 |
| 4.1.1.8 | 4 | Temperature Probes | $0 | $4,334 | $1,383 | $500 | $1,000 | $500 | $284 | $8,000 | 71 | 0 | 29 | $571 |
| 4.1.1.9 | 4 | Valves | $15,933 | $489 | $0 | $1,000 | $1,000 | $1,000 | $578 | $20,000 | 82 | 0 | 18 | $895 |
| 4.1.1.10 | 4 | Vacuum Parts | $6,891 | $555 | $3,109 | $3,000 | $3,000 | $3,000 | $445 | $20,000 | 57 | 0 | 43 | $2,133 |
| 4.1.1.11 | 4 | Misc Hardware | $1,215 | $8,403 | $346 | $2,000 | $2,000 | $1,000 | $36 | $15,000 | 67 | 0 | 33 | $1,223 |
| 4.1.1.12 | 4 | Temperature Cycling Setup | $1,581 | $571 | $162 | $200 | $87 | $0 | $0 | $2,600 | 89 | 0 | 11 | $72 |
| 4.1.1.13 | 4 | Design Station | $5,670 | $915 | $0 | $0 | $0 | $0 | $0 | $6,585 | 100 | 0 | 0 | $0 |
| 4.1.1.14 | 4 | Liquid Nitrogen | $0 | $436 | $1,857 | $2,000 | $2,000 | $2,000 | $1,707 | $10,000 | 28 | 0 | 72 | $1,801 |
| 4.1.2 | 3 | Electric Test Setup | $6,109 | $22,252 | $32,822 | $60,199 | $15,174 | $3,500 | $1,095 | $141,151 | 57 | 0 | 43 | $14,394 |
| 4.1.2.1 | 4 | DC Test Setup | $0 | $14,058 | $1,746 | $8,043 | $1,000 | $1,000 | $154 | $26,000 | 61 | 0 | 39 | $2,102 |
| 4.1.2.2 | 4 | Transient Test Setup | $263 | $7,778 | $12,509 | $13,500 | $12,174 | $1,500 | $580 | $48,304 | 68 | 0 | 32 | $3,646 |
| 4.1.2.3 | 4 | Pig Tail Cables for tests | $5,846 | $0 | $0 | $6,676 | $0 | $0 | $0 | $12,522 | 100 | 0 | 0 | $0 |
| 4.1.2.4 | 4 | Misc Hardware | $0 | $417 | $3,222 | $2,000 | $2,000 | $1,000 | $361 | $9,000 | 49 | 0 | 51 | $1,151 |
| 4.1.2.5 | 4 | Pig Tail Loop Cables for Tests | $0 | $0 | $15,325 | $0 | $0 | $0 | $0 | $15,325 | 100 | 0 | 0 | $0 |
| 4.1.2.6 | 4 | Digital Scope | $0 | $0 | $20 | $29,980 | $0 | $0 | $0 | $30,000 | 0 | 0 | 100 | $7,495 |
| 4.1.3 | 3 | Data Acquisition System | $15,198 | $5,308 | $4,690 | $1,400 | $11,585 | $700 | $2,431 | $41,313 | 63 | 1 | 36 | $3,713 |
| 4.1.3.1 | 4 | NT Server PC | $5,762 | $0 | $0 | $0 | $5,838 | $0 | $0 | $11,600 | 50 | 0 | 50 | $1,460 |
| 4.1.3.2 | 4 | NT Client PC for DAQ | $3,883 | $0 | $2,469 | $0 | $0 | $0 | $0 | $6,352 | 100 | 0 | 0 | $0 |
| 4.1.3.3 | 4 | NT Licences | $394 | $0 | $0 | $0 | $0 | $0 | $0 | $394 | 100 | 0 | 0 | $0 |
| 4.1.3.4 | 4 | GPIB Interface | $787 | $0 | $1,166 | $0 | $1,047 | $0 | $0 | $3,000 | 65 | 0 | 35 | $262 |
| 4.1.3.5 | 4 | LabView Licenses | $3,853 | $205 | $0 | $900 | $0 | $400 | $142 | $5,500 | 89 | 0 | 11 | $146 |
| 4.1.3.6 | 4 | Colour Printer | $489 | $0 | $0 | $0 | $0 | $0 | $0 | $489 | 100 | 0 | 0 | $0 |
| 4.1.3.7 | 4 | Printer | $0 | $0 | $0 | $0 | $300 | $0 | $0 | $300 | 0 | 0 | 100 | $75 |
| 4.1.3.8 | 4 | Misc Hard/Software and Services | $31 | $424 | $1,055 | $500 | $400 | $300 | $290 | $3,000 | 55 | 14 | 30 | $271 |
| 4.1.3.9 | 4 | NT Client PC for Controls | $0 | $4,679 | $0 | $0 | $0 | $0 | $0 | $4,679 | 100 | 0 | 0 | $0 |
| 4.1.3.10 | 4 | CAMAC controller | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | | | | $0 |
| 4.1.3.11 | 4 | NT Client PC for CERN | $29,677 | $0 | $0 | $0 | $4,000 | $0 | $2,000 | $6,000 | 0 | 0 | 100 | $1,500 |
| 4.1.4 | 3 | FT Assembly Tools | $0 | $10,135 | $591 | $44,724 | $840 | $211 | $0 | $56,500 | 19 | 76 | 5 | $7,144 |
| 4.1.4.1 | 4 | Assembly Jigs | $0 | $2,234 | $226 | $1,000 | $540 | $0 | $0 | $4,000 | 62 | 0 | 38 | $385 |
| 4.1.4.2 | 4 | Welding Station | $0 | $7,900 | $289 | $300 | $300 | $211 | $0 | $9,000 | 91 | 0 | 9 | $203 |
| 4.1.4.3 | 4 | Crane | $0 | $0 | $76 | $424 | $0 | $0 | $0 | $500 | 15 | 0 | 85 | $106 |
| 4.1.4.4 | 4 | Orbital Cutter | $0 | $0 | $0 | $43,000 | $0 | $0 | $0 | $43,000 | 0 | 100 | 0 | $6,450 |
| 4.1.5 | 3 | FT Prototypes | $32,558 | $135,094 | $163,028 | $4,057 | $101 | $0 | $218 | $335,055 | 98 | 2 | 0 | $1,077 |
| 4.1.5.1 | 4 | Model FT | $2,289 | $775 | $0 | $0 | $0 | $0 | $0 | $3,064 | 100 | 0 | 0 | $0 |
| 4.1.5.2 | 4 | Weld Test Flanges and Pin Carriers | $11,815 | $4,297 | $8,650 | $909 | $0 | $0 | $217 | $25,889 | 98 | 0 | 2 | $143 |
| 4.1.5.3 | 4 | Glass Pin Carriers | $0 | $50,818 | $0 | -$2,147 | $0 | $0 | $0 | $48,671 | 100 | 0 | 0 | $0 |
| 4.1.5.4 | 4 | Ceramic Pin Carriers | $0 | $63,446 | $0 | -$2,147 | $0 | $0 | $0 | $61,299 | 100 | 0 | 0 | $0 |
| 4.1.5.5 | 4 | Warm Flanges | $0 | $2,497 | $221 | $0 | $0 | $0 | $0 | $2,718 | 100 | 0 | 0 | $0 |
| 4.1.5.6 | 4 | Cold Flanges | $0 | $2,304 | $246 | $0 | $0 | $0 | $0 | $2,550 | 100 | 0 | 0 | $0 |
| 4.1.5.7 | 4 | Bellows Assemblies | $0 | $3,654 | $10,540 | $5,510 | $0 | $0 | $0 | $19,704 | 72 | 28 | 0 | $826 |
| 4.1.5.8 | 4 | Bolt Flanges | $0 | $0 | $246 | $0 | $0 | $0 | $0 | $246 | 100 | 0 | 0 | $0 |
| 4.1.5.9 | 4 | Funnel Assemblies | $0 | $2,663 | $2,497 | $0 | $0 | $0 | $0 | $5,160 | 100 | 0 | 0 | $0 |
| 4.1.5.10 | 4 | Vacuum Cables | $18,453 | $0 | $120,470 | $359 | $0 | $0 | $0 | $139,282 | 100 | 0 | 0 | $0 |
| 4.1.5.11 | 4 | Low Voltage Vacuum cables | $0 | $4,086 | $0 | $0 | $0 | $0 | $0 | $4,086 | 100 | 0 | 0 | $0 |
| 4.1.5.12 | 4 | Low Voltage Pigtails | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | | | | $0 |
| 4.1.5.13 | 4 | Pipe Fittings | $0 | $554 | $0 | $0 | $0 | $0 | $0 | $554 | 100 | 0 | 0 | $0 |
| 4.1.5.14 | 4 | Pigtails | $0 | $0 | $17,934 | $397 | $0 | $0 | $0 | $18,331 | 100 | 0 | 0 | $0 |
| 4.1.5.15 | 4 | Insulation | $0 | $0 | $2,225 | $1,175 | $101 | $0 | $0 | $3,500 | 73 | 24 | 3 | $108 |
| 4.1.6 | 3 | Misc Project Setup Items | $0 | $607 | $6,748 | $6,700 | $5,165 | $1,353 | $427 | $21,000 | 53 | 0 | 47 | $2,467 |
| 4.2 | 2 | FT Series Assemblies | $0 | $0 | $142,211 | $1,274,870 | $913,497 | $0 | $0 | $2,330,579 | 20 | 69 | 11 | $350,367 |
| 4.3 | 2 | Test Cryostat Signal FT | $58,428 | $0 | $0 | $0 | $0 | $0 | $0 | $58,428 | 100 | 0 | 0 | $0 |
| 4.3.1 | 3 | Pin Carriers | $56,960 | $0 | $0 | $0 | $0 | $0 | $0 | $56,960 | 100 | 0 | 0 | $0 |
| 4.3.4 | 3 | Bolt Flanges | $1,468 | $0 | $0 | $0 | $0 | $0 | $0 | $1,468 | 100 | 0 | 0 | $0 |
| 4.4 | 2 | Manpower | $9,561 | $58,891 | $146,534 | $157,500 | $208,500 | $177,209 | $20,517 | $778,712 | 36 | 42 | 22 | $44,057 |

# Budget and Management Responsibilities

- Design
- Fabrication
  - Signal Pigtails purchased from Orsay
- Commissioning
- Transport
- Reception
  - Electrical and ambient vacuum testing
  - Leak tester provided by ATLAS CERN
- Electrical tests after installation
- Assistance during installation
  - Up to SF50k towards the cost of an orbital cutter
  - Assistance during welding on the cryostat
  - Assistance for leak testing during/after installation

- Still under discussion
  - Who covers cost of T probes
  - Manpower to connect warm cables to ambient flange

# Conclusions
## Endcap Signal Feedthrough Project

- Crucial component of ATLAS LAr
- Complex and manpower intensive
- Production has started
  - First unit constructed in July 00
  - Proceeding cautiously with emphasis on QA/QC
- Extensive QC programme further developed
- All major purchase orders out
- All components (except pigtails, pin carriers and a few cables) likely to be in hand by the end of FY 00-01
- Production rate still in line with cryostat schedule
  - Pin carrier procurement on critical path
  - To be reassessed when pin carrier procurement reaches full rate
- Budget within the allocated MIG
  - Built-in contingencies
  - Purchase of FF for pigtails under investigation
  - Requires close monitoring