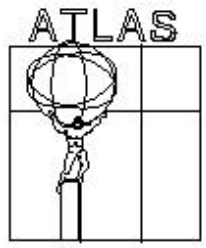
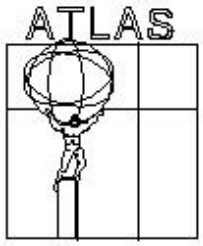


U.S. ATLAS Collaboration Meeting

1.4 Tile Calorimeter

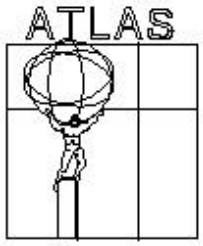
Lawrence Price (ANL)

BNL Meeting
July, 1999



Tilecal Outline

- System Overview
- Deliverables
- Participants
- Tilecal Management
- Technical Progress
- Cost and Schedule
- Issues
- Summary



Tilecal Overview

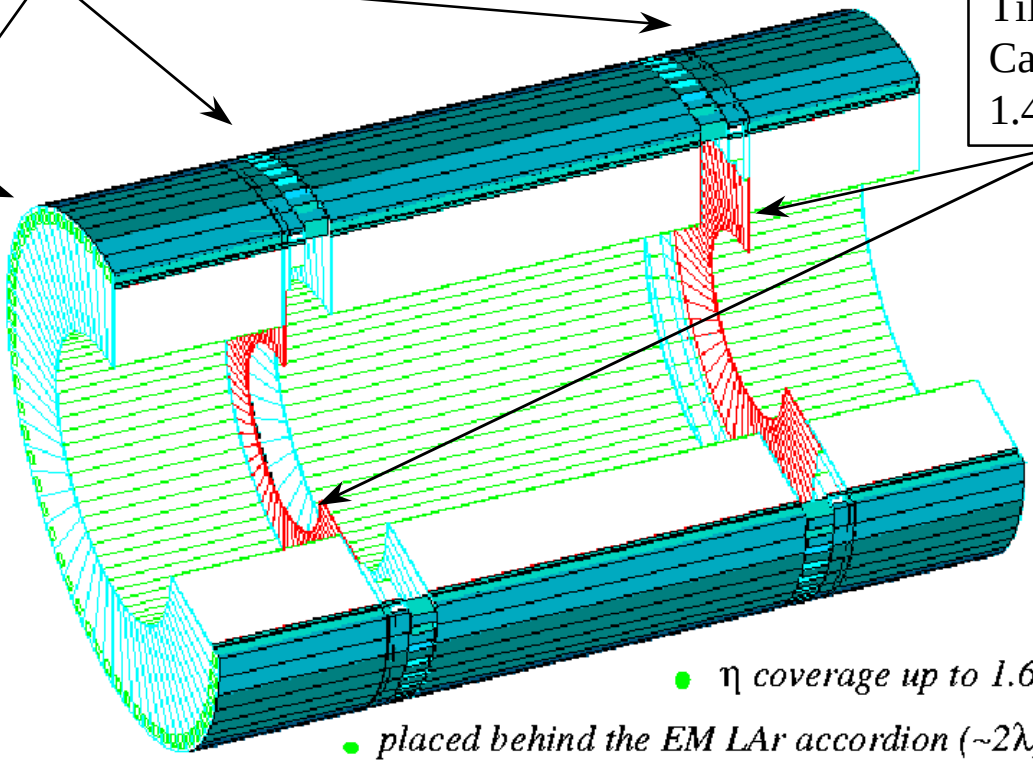
- Tile/Fiber + steel sampling calorimeter
  - Much US experience from SDC, D0 and CDF
- Tiles oriented normal to beam axis
- 2500 tons
- 3 major sections: barrel + 2 extended barrels
  - Each built in 64 modules

ATLAS Tile Calorimeter (1.4)

Readout system in Girder 1.4.3

Extended Barrel Calorimeter
Mechanics 1.4.1
Optics 1.4.2

Intermediate Tile Calorimeter 1.4.4



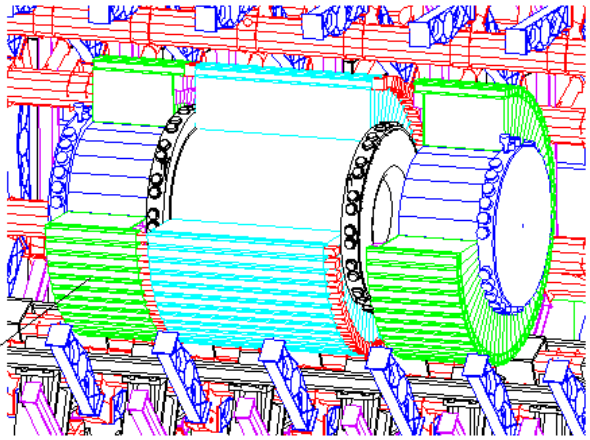
- *η coverage up to 1.6*
- *placed behind the EM LAr accordion (~2λ)*
- *outer diameter 8.5 m, 12.2 m long, 2900 tons, 64 wedges structure*
- *Fe-scintillator sampling calorimeter (ratio ~4:1), WLS fibres readout*
- *unconventional scintillator geometry, with tiles in the radial direction*
- *the calorimeter body and the massive iron outer support act as magnetic flux return for internal solenoid*

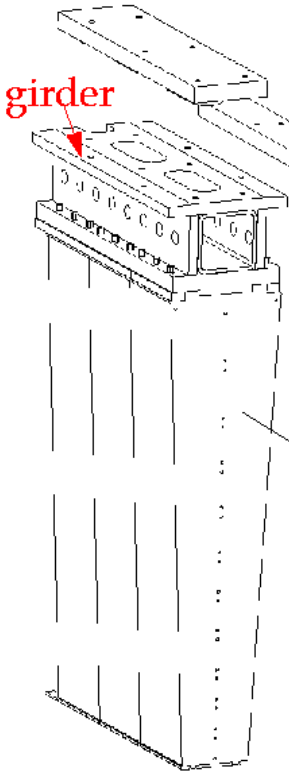
Mechanical Construction (1.4.1)

high degree of modularity:

3 independent cylinders

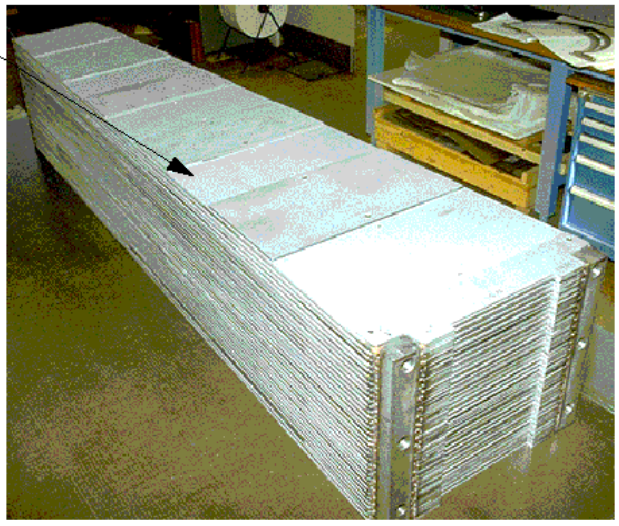
1 barrel + 2 extended barrels





each cylinder built out of identical **modules**

64 modules/cylinder



each module built out of identical **submodules**

19 submod./barrel mod.
10 submod./ext.barrel mod.

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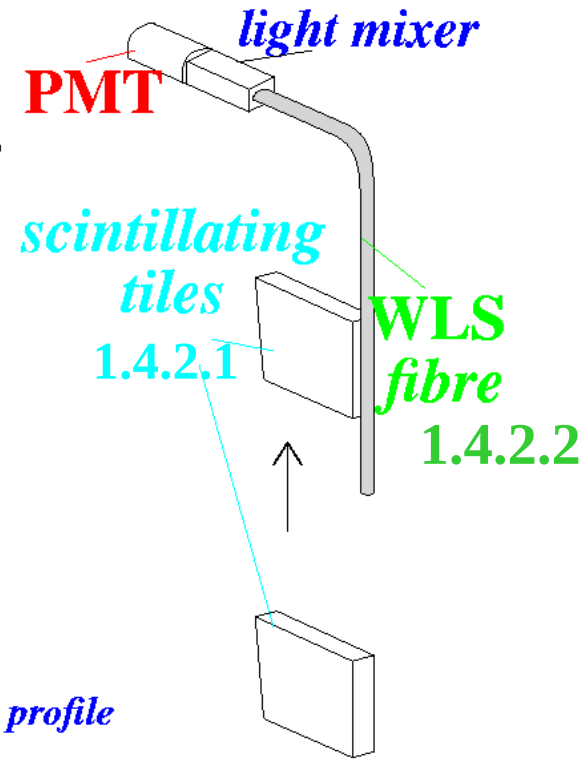
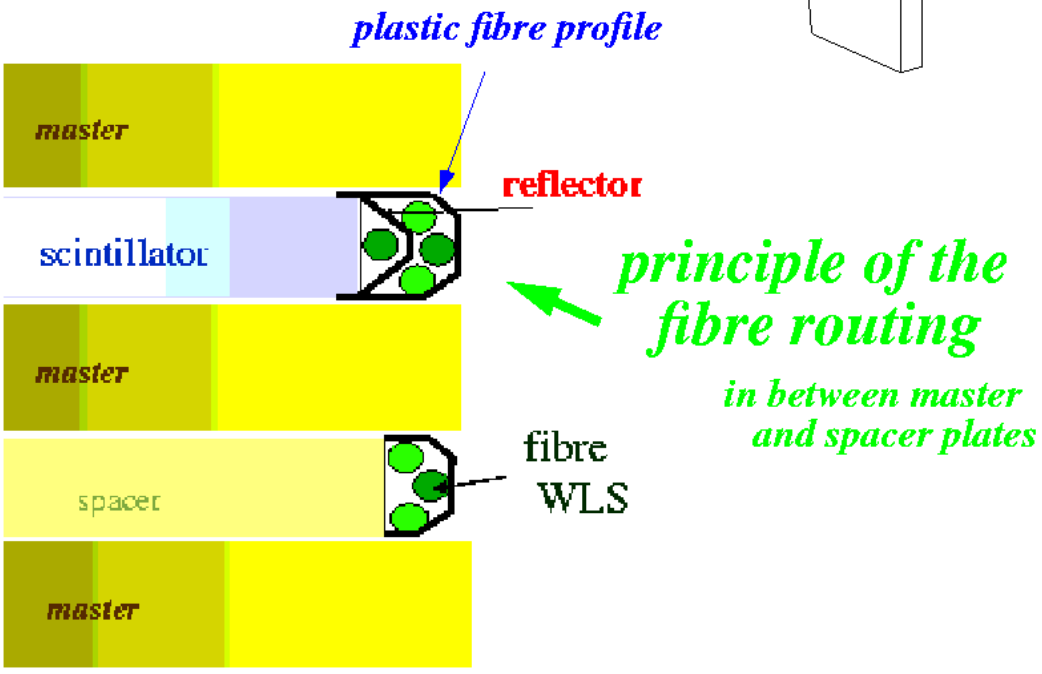
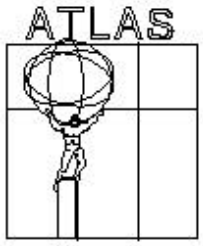
Optical Elements (1.4.2)

Several optical elements, all interdependent

(new: optical instrumentation independent from the mechanical assembly)







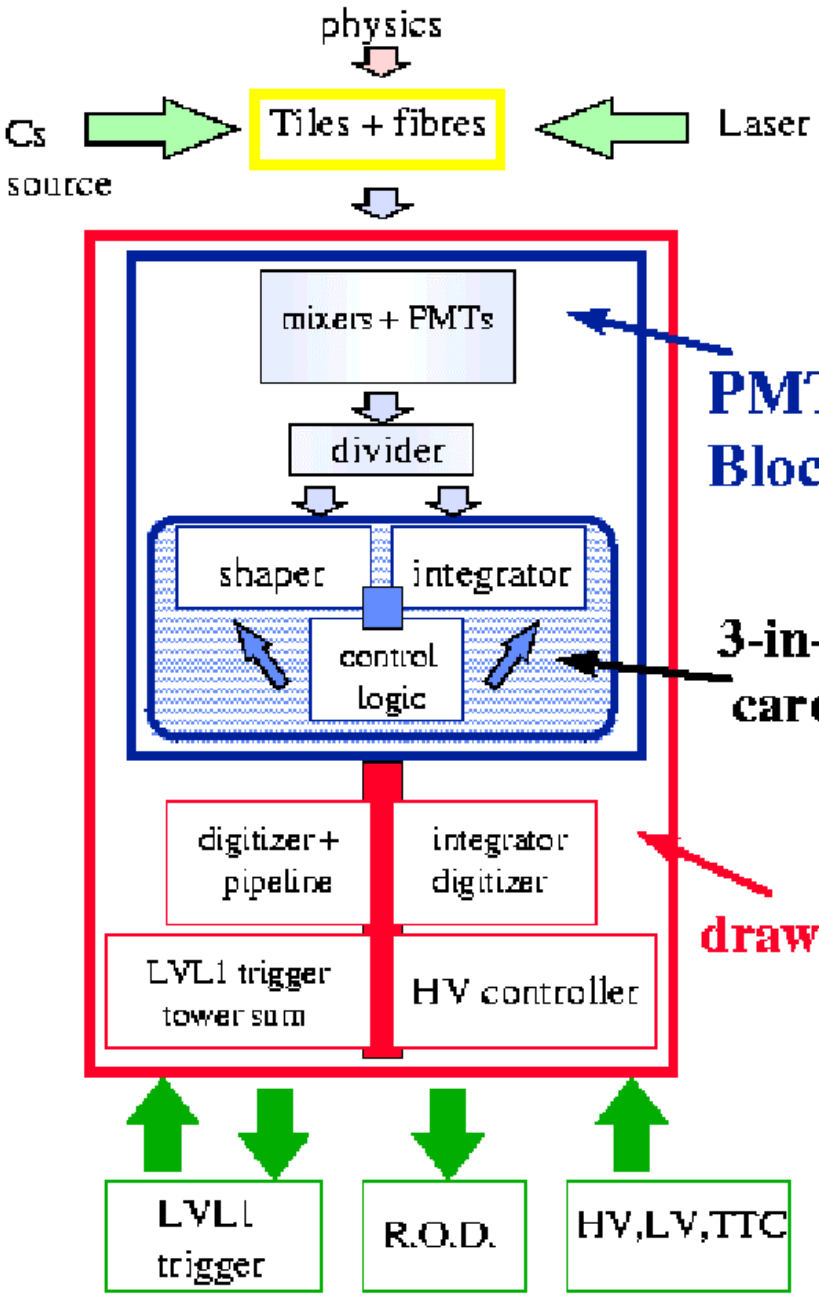
Tilecal Readout

(1.4.3)

- 10,000 PMT readout channels
  - Arranged in pseudo-projective towers
- Front-end electronics integrated in PMT housings
- Multiple calibration and monitoring systems
- Hadronic resolution spec

$$50\%/\sqrt{E}+3\%$$

Readout Organization



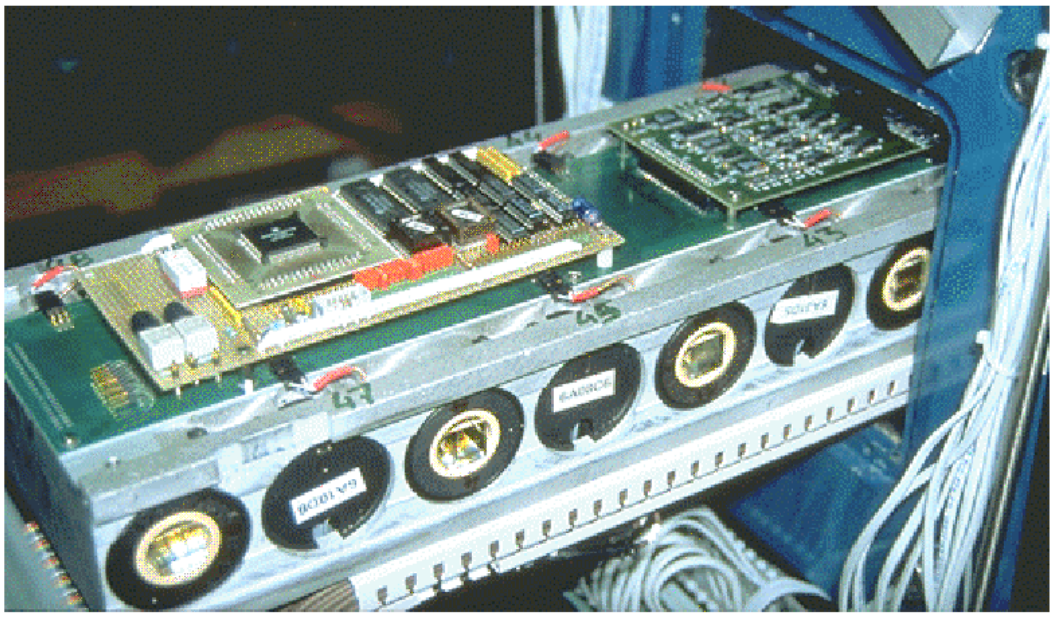
PMT Block **1.4.3.1**

3-in-1 card **1.4.3.2** **1.4.3.3**

drawer **1.4.3.4**

1.4.3.5 (System control and integration)

Readout Packaging



based on **drawers**, to be installed inside the girder

all front-end electronics will be in the drawers

"easy" access during shutdown periods

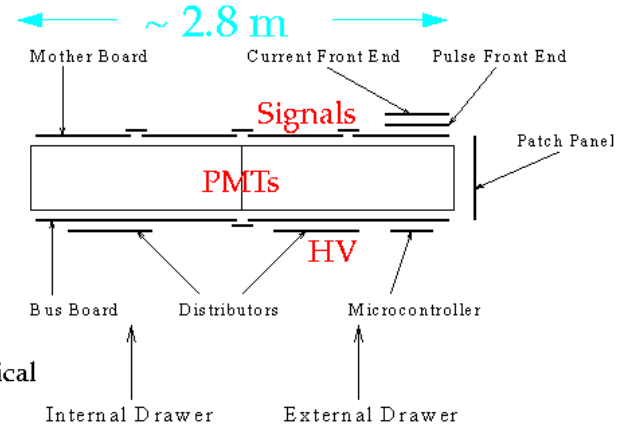
protected environment against B-field and radiation

1 barrel module --> 2 drawers

1 ext. barrel mod --> 1 drawer

each girder is positioned on the fibre bundle mechanical system
Girder rings (very precise "rail")

all transitions between the various optical elements via ~ 1mm air gaps



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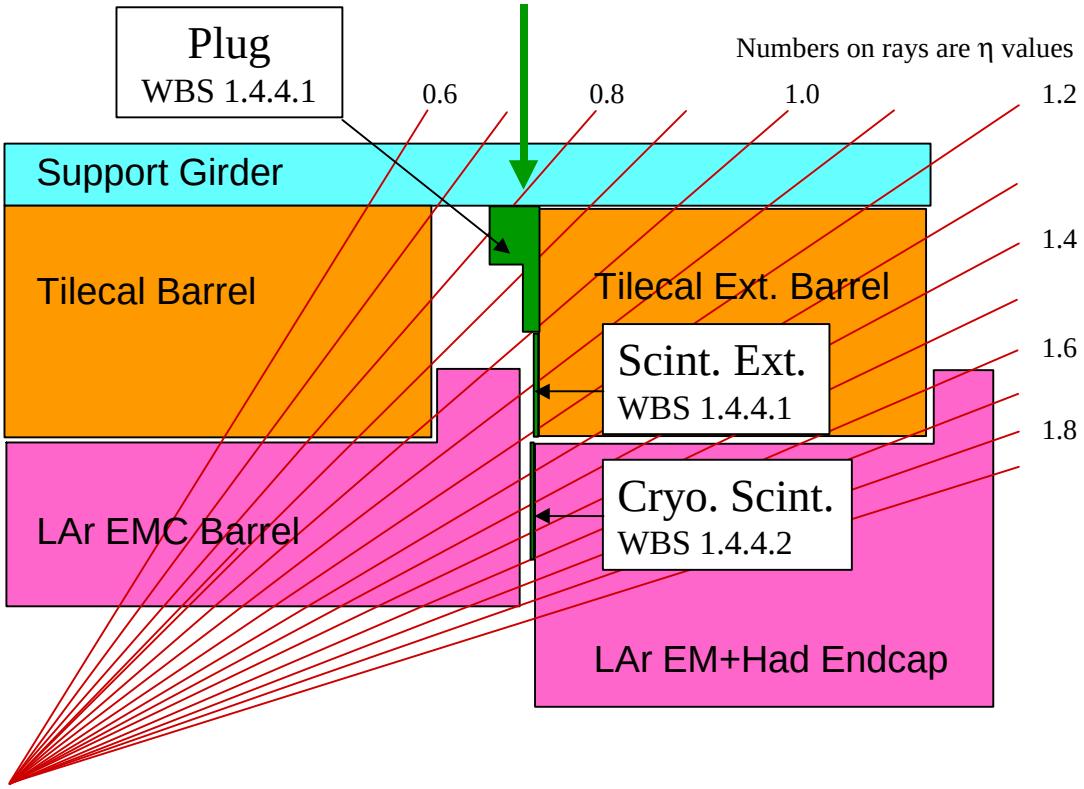
ITC (WBS 1.4.4)

Intermediate Tile Calorimeter Concept



WBS 1.4.4

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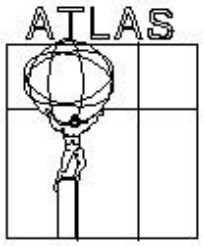


Tilecal Physics

- Higgs

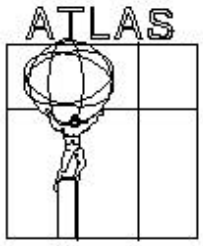
$H \rightarrow \gamma\gamma$	γ-jet background suppression
	Isolation
$WH \rightarrow l\nu\gamma\gamma$	Isolation; missing energy of ν
$WH \rightarrow bb\ \gamma\gamma$	Jet energy measurement; missing energy of ν
$ttH \rightarrow bW\ bW\ bb$	Jet energy measurement
$H \rightarrow ZZ^* \rightarrow ll\ ll$	Isolation; suppress $tt \rightarrow 4l$ by x70
$H \rightarrow ZZ \rightarrow ll\ ll$	Isolation
$H \rightarrow ZZ \rightarrow ll\ \nu\nu$	Missing energy of ν
$H \rightarrow WW \rightarrow l\nu\ jj$	Jet energy measurement; missing energy of ν

- SUSY

$\tilde{g}\ \tilde{g} \rightarrow$ jets + E_T^{miss}	Jet energy measurement; Missing E
$\rightarrow l$ jets + E_T^{miss}	Jet energy measurement; Missing E
$\tilde{\chi}\ \tilde{\chi} \rightarrow$ leptons + E_T^{miss}	Missing E

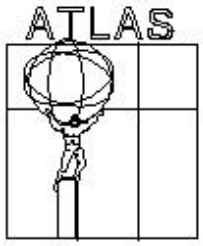
- Quark compositeness

jet pT spectrum	Jet energy measurement



Deliverables

- **Mechanical design** 1.4.1.1.1, 1.4.1.2.1, 1.4.1.2.4, 1.4.1.3.1
- **Tooling, Prototypes** 1.4.1.3, 1.4.2.3
- **Optical components R&D** 1.4.2.1.1, 1.4.2.2.1
- **Master Plates** 1.4.1.1.3.2.1-3
- **Scintillator Wrappers** 1.4.2.1.3.1
- **Assembly and testing of 1 Extended Barrel Calorimeter** 1.4.1, 1.4.2
- **Electronics design and prototypes** 1.4.3.x.1-2
- **Front-end electronics** 1.4.3.2-4
- **1/3 of PMTs** 1.4.3.1, 1.4.4.1
- **Intermediate Tile Calorimeter** 1.4.4

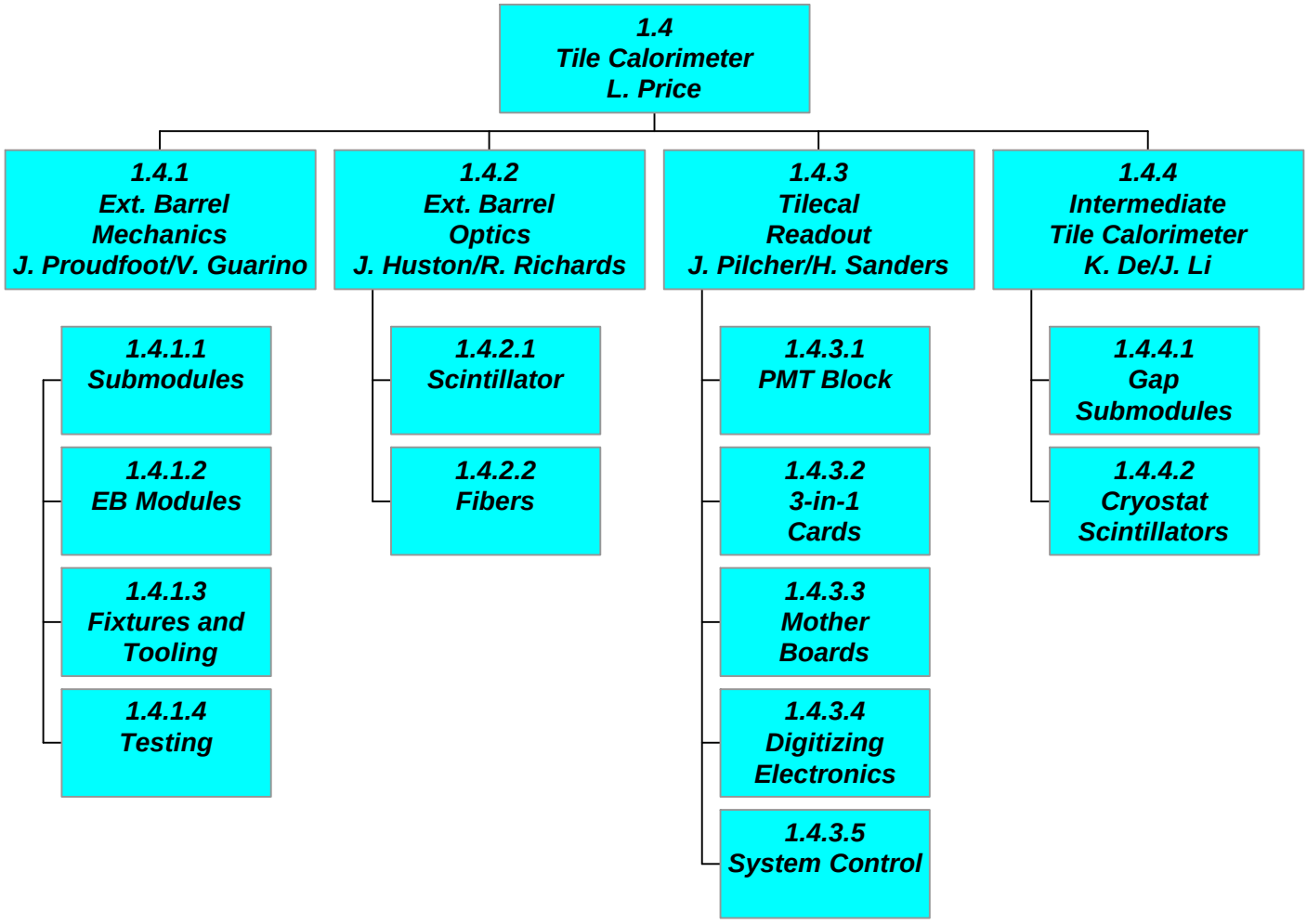


US Tilecal Institutions

6 FTE Physicists;
2.5 FTE Engineers

- Argonne Nat. Lab. (Mechanics, Optics)
  - J. Grudzinski, V. Guarino, L. Kocenko, L. Nodulman, L. Price*, J. Proudfoot, R. Stanek, D. Underwood, R. Wagner, K. Wood
- Univ. Chicago (Submodules, Electronics)
  - K. Anderson, A. Bellerive, E. Blucher, F. Merritt, J. Pilcher*, H. Sanders, M. Shochet, F. Tang, H. Wu
- Univ. Illinois (Submodules, PMTs)
  - F. Cogswell, R. Downing, D. Errede, S. Errede*, M. Haney, V. Simaitis, J. Thaler
- Michigan State Univ. (Optics, ITC Scint.)
  - C. Bromberg, J. Huston*, R. Miller, R. Richards, C. Yosef
- Univ. Texas at Arlington (ITC, Modules)
  - K. De*, R. Stephens, E. Gallas, J. Li, L. Sawyer, A. White
- Non-US Institutions
  - Barcelona, Bucharest, Clermont-Ferrand, CERN, Dubna, Minsk, Yerevan, Lisbon, Prague, Pisa, Rio de Janeiro, Protvino, Valencia, Stockholm

Management of Tilecal



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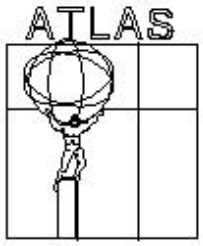


Recent Technical Highlights

- Several Major procurements complete
  - Master Plate Steel; Punching
  - Scintillator Sleeves
- Submodule production started
  - ~ 10% of 576 submodules built
- Scintillator production underway (Russia), 25% delv'd to CERN
- Final prototypes of front-ends designed and in use in summer beam test
- Design of endcap cryostat support and structural analysis complete
- Swap of readout deliverables with Stockholm

Technical Status

- 1.4.1 Mechanics
  - Production and stamping of EB master plates complete
    - U.S. responsibility
    - Quality good
    - Delivery completed to 4 sites

Master plate stamping at Tatra plant

  - Delivery of spacer plates complete
    - Spanish responsibility
    - Production was delayed
    - US plates delivered

Submodule assembly at U. Chicago

Technical Status

- 1.4.1 Mechanics (cont.)
  - Submodule Production Facilities
    - ANL, U. Chicago, U. Illinois all in production
  - Girder
    - Structural reevaluation and iteration of design
    - procurement placed
    - Initial delivery in August
    - Last major procurement for 1.4.1

Automated gluing machine at ANL

Technical Status

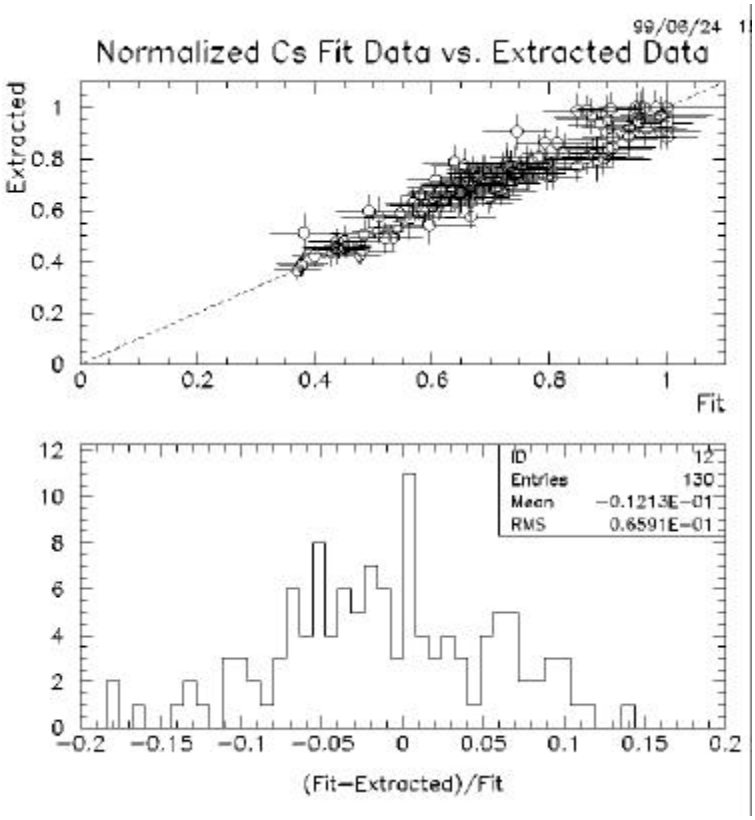
- 1.4.1 Mechanics (cont.)
  - Submodule production
    - New hires at all sites
    - Delays due to spacer plates and submodule height (plates too flat!)
    - 64 submodules stacked (most welded)
      - Rate 4/week/plant
    - Protective paint is issue

Submodule stacking at U. Illinois

Raw materials and stacked submodules at ANL

Technical Status

- Design of endcap cryostat support and structural analysis complete
- Special submodules design complete
- Weld bar in production at UTA
  - Paused while submodule height was evaluated
- Plans for transport of modules to MSU and CERN
- Module Testing and QA plans



Technical Status

- 1.4.2. Instrumentation
  - Tyvek sleeves complete and delivered to CERN
  - Ultrasonic spot-bonding to scintillators tested and delivered
  - Set-ups for instrumentation work being prepared
    - Module Transporter
    - MSU Loading dock

Ultrasonic bonder in operation on tyvek sleeve

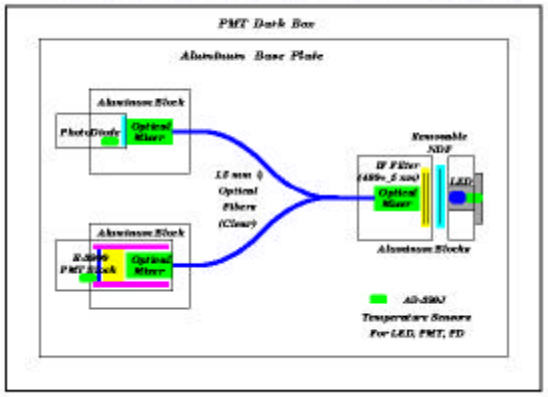
Technical Status

- 1.4.2. Instrumentation
  - Preparation for pre-calibration testing
    - Source driver and readout
    - Light source option
  - Scintillator production underway
  - Fibers ordered
  - Optics PRR 12/98

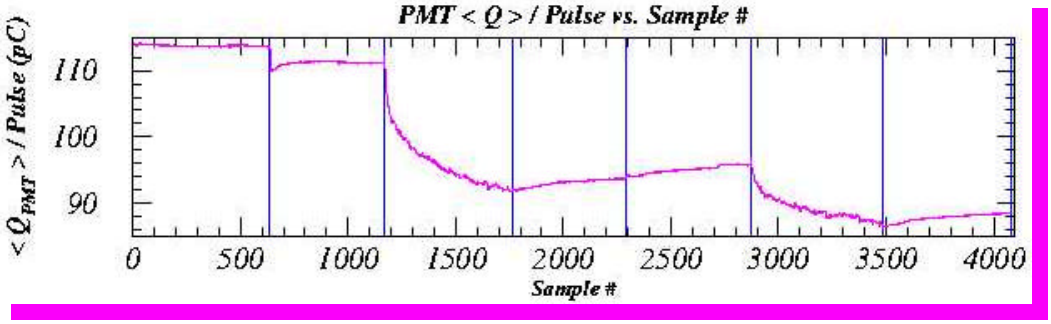
Fiber routing in instrumented module

Technical Status

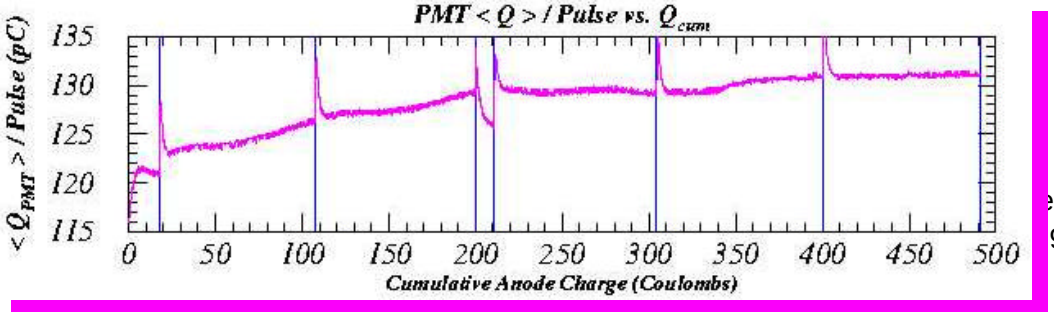
- 1.4.3 Readout
  - Continued development of PMT test facility
    - Agreement on final test systems and protocols
  - Testing of new PMTs
    - Effort to understand time dependencies
  - Preparation for PMT PRR and procurement



Drawing of PMT testing setup



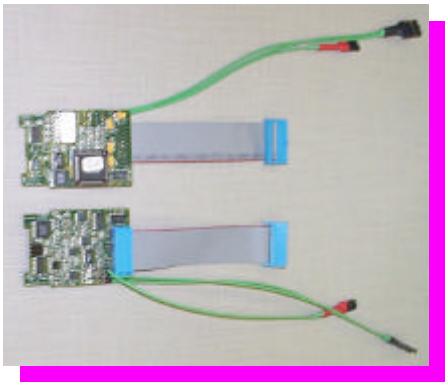
Gain vs sample # in 2nd gen. PMT (cum charge 74 coul.)



Gain vs cum. charge in 4th generation PMT

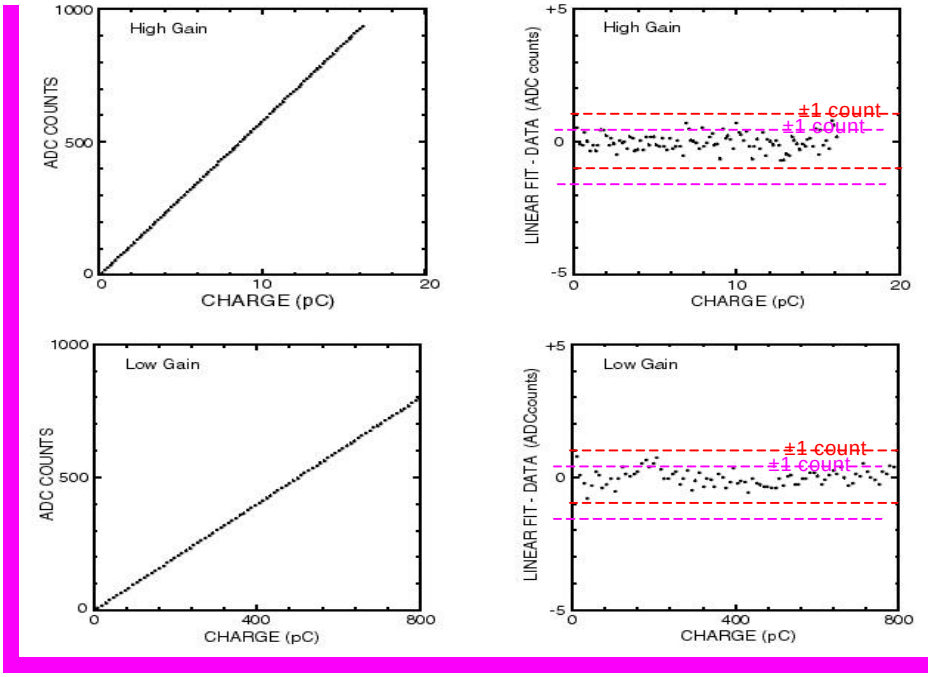
Technical Status

- 1.4.3 Readout (cont.)
  - Final design changes to 3-in-1 cards
    - Iteration after after July '98 test beam run including final optimization of 7-pole shaper
    - Radiation hardness tests complete
    - Thermal management studies complete
    - 150 pre-production cards for '99 test beam now in use



3-in-1 cards

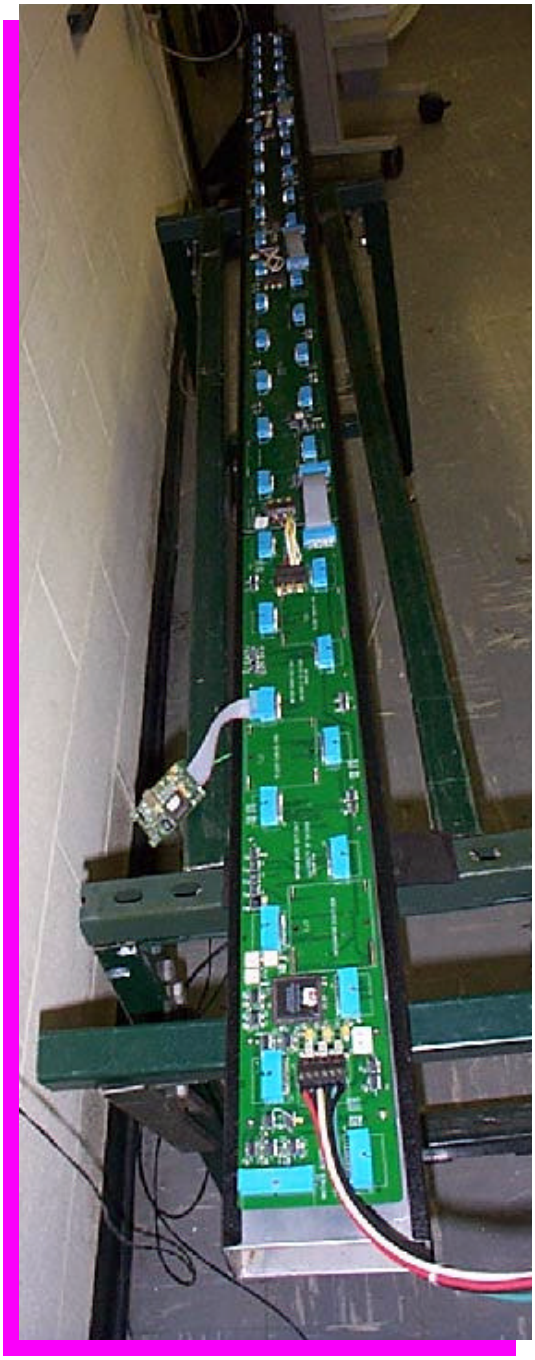
Charge injection linearity test



Technical Status

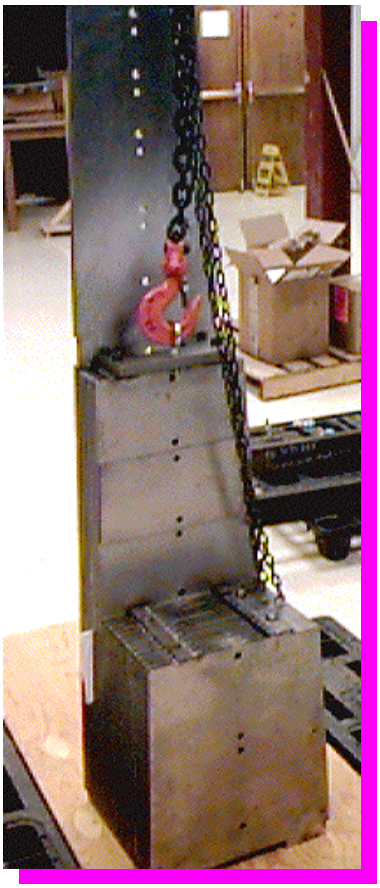
- 1.4.3 Readout (cont.)
  - Iteration of Drawer Mother Board designs with control by TTC and CANbus systems
    - Commercial VME modules for interface instead of custom
  - Front-end design review in Dec. Elect. PRR in June
  - Evaluation of digitizer prototype (Stockholm)
    - New version received from Stockholm
    - Design review in Feb.
  - Swap of production responsibilities with Stockholm now formalized

Drawer mother board prototype



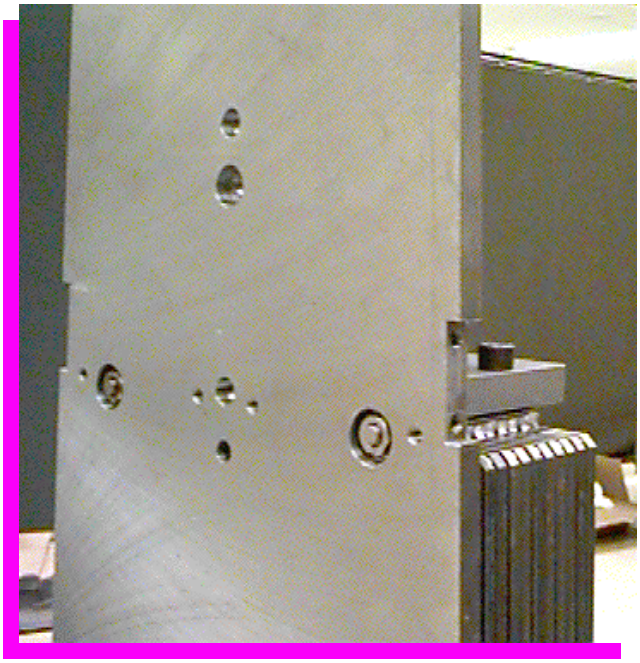
Technical Status

- 1.4.4 Intermediate Tile Calorimeter
  - Endplate design and procurement
  - Plug submodule tooling and setup
    - Complete 4/30
    - Tracking and QA database
  - Final plug submodule prototype



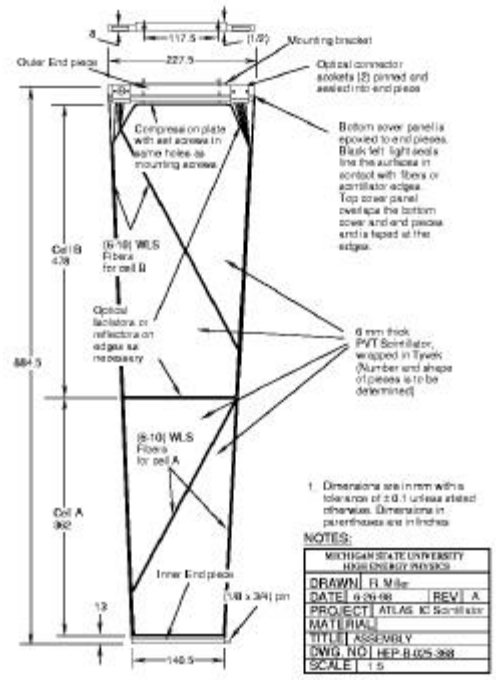
Final ITC plug submodule prototype

Detail showing recent changes to ITC plug submodules



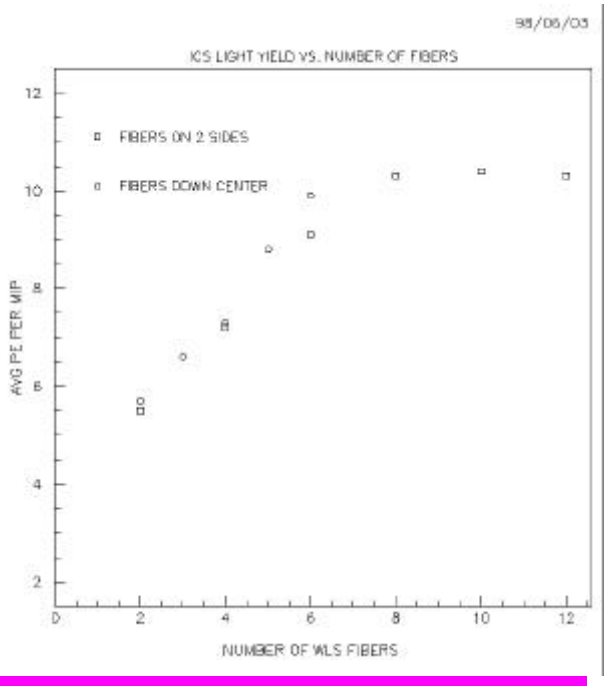
Technical Status

- 1.4.4 Intermediate Tile Calorimeter
  - Master plate cutting started
  - Scintillation Counters
    - PMT testing
    - Plug extension
      - Cosmic ray testing (20 pe/mip) and uniformity scan
    - Cryostat counters
      - Fiber readout assemblies designed and prototyped
      - Mechanical design complete
      - Extensive prototype testing
    - Preparations for the production of the ITC optical fiber assemblies



Light yield testing in cryostat scintillator

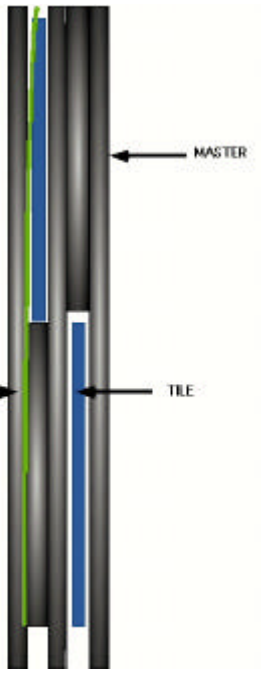
Drawing of cryostat scintillator package



Other Tilecal Developments

- Barrel Module 0 “autopsy” conducted

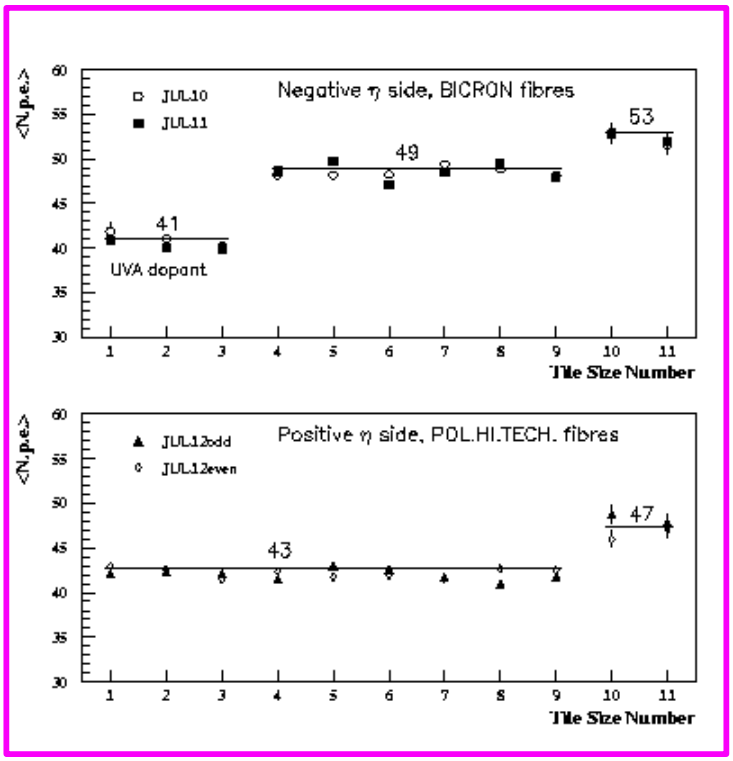
TUBE	CELL	TILE	PROBLEM	Situation
7	bc-4	10	coupling	fixed
7	bc-5	12	coupling	fixed
7	bc-6	12	coupling	
7	bc-8	17	coupling	
7	bc1	15	coupling	fixed
7	bc6	8	coupling	fixed
6	bc-3	8	coupling	
6	bc-7	11	coupling	fixed
6	bc4	12	coupling	fixed
6	bc6	7	coupling	fixed
6	bc7	7	coupling	
6	b9	10	tile	
5	bc-3	8	coupling	
5	bc-5	4	coupling	fixed
5	bc-6	12	coupling	
5	bc-7	11	coupling	
5	bc-8	9	coupling	



Drawing of typical “coupling” problem

Other Tilecal Developments

- Light yield from reinstrumented Barrel Module 0 in '98 beam test
  - 48 pe/mip (muons 90 deg.)
    - Design goal 50; minimum requirement 20



- '98 beam test data stored in Objectivity db
  - Practical analysis system under development with strong boost from US ATLAS computing
- Extensive QA/QC and tracking system established for production
- First subsystem training in GEANT4
- Welding certification process
- Submodule structural testing

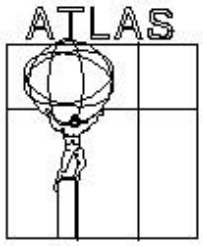
Tilecal Costs

Total cost

WBS Number	Description	Base Cost (k$)	Cont Cost (k$)	Cont %	Total Cost (k$)	EDIA Labor (k$)	Mfg Labor (k$)	EDIA Matls (k$)	Mfg Matls (k$)	FTEs All	FTEs Other
1	U.S. Atlas Project	12100	1934	16	14034	1943	3709	65	6384	97.0	0.0
1.4	TileCal	12100	1934	16	14034	1943	3709	65	6384	97.0	0.0
1.4.1	Extended Barrel Mechanics	5401	622	12	6024	922	1747	29	2704	35.6	0.0
1.4.2	Extended Barrel Optics	1501	257	17	1758	258	729	33	481	19.7	0.0
1.4.3	Readout	3008	622	21	3630	505	439	0	2065	17.8	0.0
1.4.4	Intermediate Tile Calorimeters	2189	433	20	2622	259	794	2	1135	23.9	0.0

Project cost

WBS Number	Description	Base Cost (k$)	Cont Cost (k$)	Cont %	Total Cost (k$)	EDIA Labor (k$)	Mfg Labor (k$)	EDIA Matls (k$)	Mfg Matls (k$)	FTEs Project	FTEs Other
1	U.S. Atlas Project	8977	1500	17	10477	931	2505	47	5493	59.4	37.5
1.4	TileCal	8977	1500	17	10477	931	2505	47	5493	59.4	37.5
1.4.1	Extended Barrel Mechanics	3818	466	12	4285	514	1204	26	2074	22.3	13.3
1.4.2	Extended Barrel Optics	995	170	17	1165	28	646	19	303	15.3	4.4
1.4.3	Readout	2423	519	21	2942	294	123	0	2006	6.5	11.3
1.4.4	Intermediate Tile Calorimeters	1740	345	20	2085	95	532	2	1110	15.4	8.5



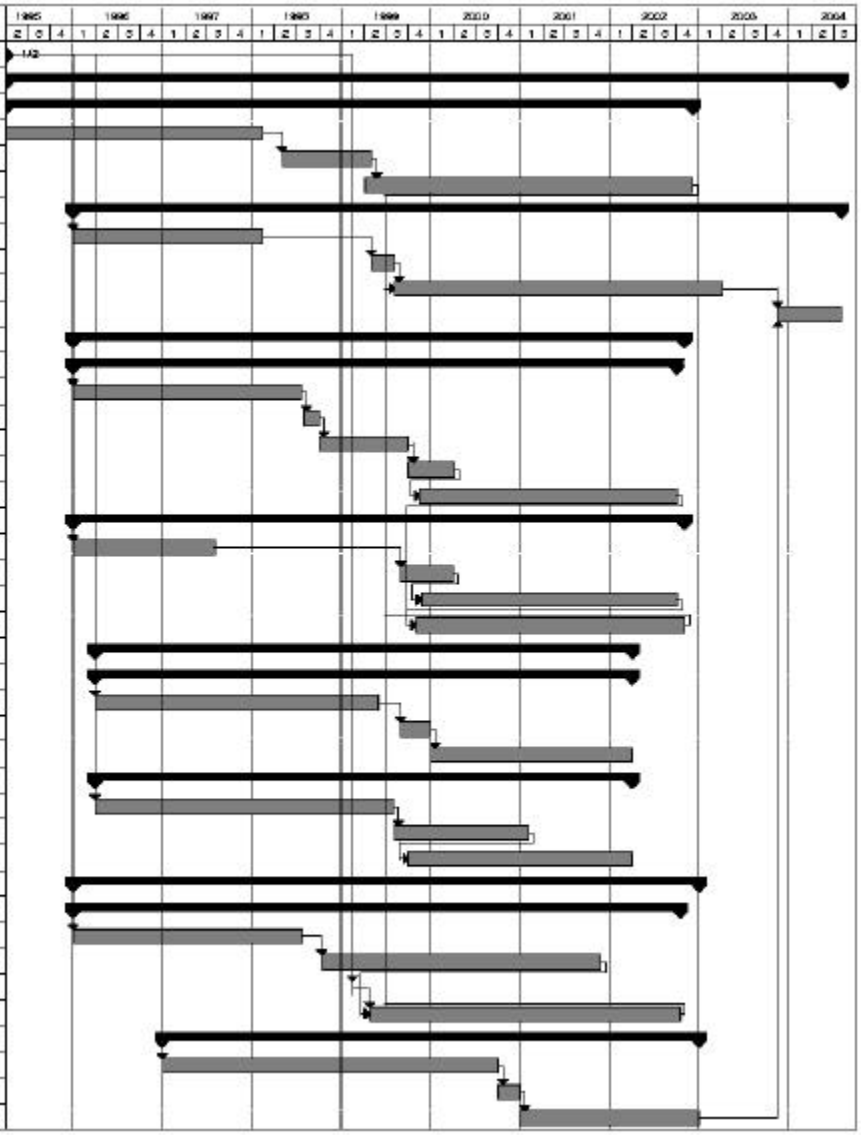
Cost performance

- Steel procurement
  - Budgeted 716 K
  - Actual cost 564 K
  - Savings 152 K
- Cutting and shipping steel
  - Budgeted 318K
  - Actual cost 251K
  - Savings 67 K
  - But travel and QC costs higher
- Tyvek sleeves for scintillators
  - Budgeted 277K
  - Costs ~$15K higher

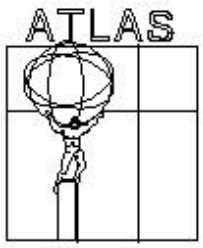
Schedule Overview

- High level schedule

ID	WBS	Task Name
1	1.4	**Start Tile Calorimeter**
2	1.4.1	**Extended Barrel Mechanics**
3	1.4.1.1	**Submodules**
4	1.4.1.1 - 1.4.1.2	Design/Prototypes/PRR
5	1.4.1.1.3	Procurement
6	1.4.1.1.3	Manufacturing @ ANL,UI,UC
7	1.4.1.2	**Extended Barrel Module**
8	1.4.1.2.1 - 1.4.1.2.2	Design/Prototypes/PRR
9	1.4.1.2.3	Procurement
10	1.4.1.2.3	Manufacturing/Ship
11	1.4.1.2.4	Installation at CERN in Atlas Cavern
12	1.4.2	**Extended Barrel Optics**
13	1.4.2.1	**Extended Barrel Scintillator**
14	1.4.2.1.1 - 1.4.2.1.2	Design/Prototype/PRR
15	1.4.2.1.3	Procurement
16	1.4.2.1.3	Manufacture (Sleeve) / Ship to Atlas Collaborator
17	ATLAS	Receive Sleeved Scintillator Tile
18	1.4.2.1.3	Manufacturing (Tile Insertion)
19	1.4.2.2	**Extended Barrel Fibers**
20	1.4.2.2.1 - 1.4.2.2.2	Design/Prototype
21	ATLAS	Procurement (Fibers)
22	1.4..2.2.3	Manufacturing (Fiber Assy Operations)
23	1.4.2.2.3	Module Instrumentation at ANL & MSU
24	1.4.3	**Readout**
25	1.4.3.1	**PMT Block**
26	1.4.3.1.1 - 1.4.3.1.2	Design/Prototypes/PRR
27	CERN - 1.4.3.1.3	Procurement (PMT)
28	CERN - 1.4.3.1.3	Assembly/Test/Ship To CERN
29	1.4.3.2 - 1.4.3.6	**Electronics**
30	1.4.3.2.1 - 1.4.3.5.2	Design/Prototypes/PRR
31	1.4.3.2.3 - 1.4.3.5.3	Procurement
32	1.4.3.2.3 - 1.4.3.5.3	Manufacturing (Test)
33	1.4.4	**Intermediate Tile Calorimeter**
34	1.4.4.1	**Gap Submodules**
35	1.4.4.1 - 1.4.4.2	Design/Prototypes/PRR
36	1.4.4.1.3	Procurement
37	ATLAS	Procurement -Receive Spacers
38	ATLAS - 1.4.4.1.3	Manufacturing/Ship - 1/2 to US, 1/2 to Barcelona
39	1.4.4.2	**Cryostat Scintillators**
40	1.4.4.2.1 - 1.4.4.2.2	Design/Prototypes/PRR
41	1.4.4.2.3	Procurement
42	1.4.4.2.3	Manufacturing/Shipment to CERN



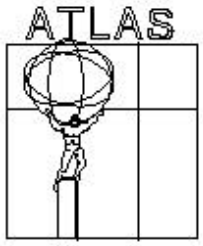
BNL Meeting
July, 1999



Milestones

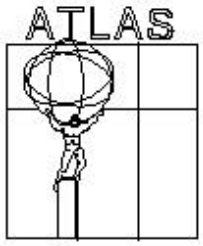
- Major milestones at Level 2

Subsystem	Schedule Designator	Description	Baseline Schedule	Forecast (F) / Actual (A) Date
Tile Cal (1.4)	Tile L2/1	Start Submodule Procurement	01-Sep-97	01-Sep-97 (A)
	Tile L2/2	Technology Choice for F/E Electronics	15-Nov-97	15-Nov-97 (A)
	Tile L2/3	Start Module Construction	01-May-99	15-Aug-99 (F)
	Tile L2/4	Start Production of Motherboards & Digitizer Boards	02-Jul-99	01-Sep-99 (F)
	Tile L2/5	Start Installation at CERN	01-Jun-02	01-Jun-02 (F)
	Tile L2/6	Module Construction Complete	01-Oct-02	10-May-02 (F)
	Tile L2/7	Installation at CERN Complete	01-May-04	01-May-04 (F)



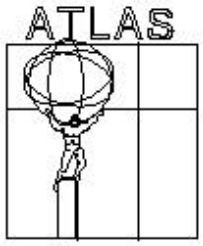
Selected current milestones

Milestones	Baseline	Current	Status
1.4.1.1 Submodules			
ANL Weld bar fab. Complete	Reschedule	30-Sep-99	On Schedule
UTA Weld bar fab. Complete	Reschedule	30-Sep-99	On Schedule
UI, Commence SM Construction	4-Jan-99	3-May-99	Complete
ANL- SM Assembly 1st Series complete	12-Feb-99	30-Apr-99	Complete
UC Commence SM Construction	8-Mar-99	30-April	Complete
All spacers on site	Reschedule	30-June-99	Complete
UC- SM Assembly 1st Series complete	2-July-99	2-July-99	On Schedule
UI- SM Assembly 1st Series complete	30-April-99	9-July-99	**Delayed**
ANL- SM Assembly 2nd Series complete	1-Oct-99	1-Oct-99	On Schedule
1.4.1.2 Modules			
Design of special submodules	21-Sep-98	T.B.D	Ongoing
Module assembly procedure	15-Jun-98	31-May-99	**Delayed**
Place girder contract (65)	18-Dec-98	23-Apr-99	Complete
Commence front plate procurement	4-Jan-99	3-May-99	Complete
Girder- 1st series delivered	Reschedule	2-Aug-99	**Delayed**
Module shipping to MSU – place contract	3-May-99	15-Jun-99	**Delayed**
Module shipping – define CERN plan	3-May-99		Complete
Module assembly –1st series complete	7-May-99	18-June-99	**Delayed**
Receive ITC SM's 1&2	17-May-99	T.B.D.	Delayed
Module Shipping – CERN- Place Contract	1-Oct-99		On Schedule
1.4.2.1 Extended Barrel Scintillator			
End sleeve manufacture	30-Jun-99	31-Dec-98	Complete
Last batch of sleeves to CERN	31-Dec-99	31-Jan-99	Complete
First tiles in sleeves from CERN to ANL and MSU (link)	01-Aug-99	01-Aug-99	On schedule
Start of instrumentation at ANL and MSU	01-Sep-99	01-Sep-99	On schedule
1.4.2.2 Extended Barrel Fibers			
Decision on fiber procurement	05-Jan-99	05-Jan-99	Complete
First fibers in profiles from Lisbon to ANL and MSU (link)	16-Aug-99	16-Aug-99	On schedule
Start of instrumentation at ANL and MSU	01-Sep-99	01-Sep-99	On schedule
Receive fiber bundle polisher from CERN (link)	01-July-99	01-Jul-99	On schedule



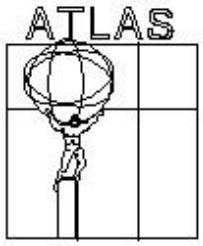
Selected current milestones

Milestones	Baseline	Current	Status
1.4.2.3 Optical Installation Fixtures			
Design of module transporter at MSU complete	31-Dec-98	31-Mar-99	Complete
Upgrades to MSU loading dock complete	31-May-99	15-June-99	Complete
Fabrication of module transporters complete	01-July-99	01-July-99	On schedule
Optical installation fixtures complete	01-June-99	01-July-99	In progress
1.4.3.1 – PMT Block			
Final agreement on test stands	1-Jan-99	1-Jan-99	Complete
PMT PRR	2-Mar-99	18-April-99	Complete
Complete PMT tendering	1-June-99	1-June-99	Complete
1.4.3.2 Front-end 3-in-1 Card			
Complete radiation tests	1-Oct-98	12-June-99	Complete
Digitizer technology decision	1-Dec-98	1-Dec-98	Complete
Design review	3-Dec-98	3-Dec-98	Complete
Electronics PRR	30-Apr-99	15-June-99	Complete
Pre-production boards delivered	1-May-99	1-May-99	Complete
1.4.3.3 Front-end Mother Boards			
Complete radiation tests	1-Oct-98	1-June-99	Delayed
1.4.3.4 Digitizing Electronics			
Complete evaluation of version 1.0	30-Sept-98	31-Dec-98	Complete
Digitizer technology decision	1-Dec-98	15-Nov-98	Complete
Design review	28-Feb-99	28-Feb-99	Complete
1.4.3.5 System Control Modules			
Update design for ’99 beam tests	1-Mar-99	1-Mar-99	Complete
Finish prototypes for ’99 beam tests	1-June-99	1-June-99	Complete
1.4.4.1 Gap Submodules			
Complete specification of Q&A measurements	7-Sep-98	5-Jul-99	**Delayed**
Complete ITC redesign (for stack height)	7-Jun-99	7-Jun-99	Complete
End plate procurement	1-Oct-98	7-June-99	Complete
UTA receives first set of masters and spacers from ANL	22-Jan-99	21-Jun-99	Complete
1st Production Submodule completed	12-Feb-99	5-Jul-99	**Delayed**
16th Production Submodule completed	6-Jul-99	21-Dec-99	**Delayed**
1.4.4.2 Cryostat Scintillators			
ITC fiber assembly production started	June 15, 99	July 15, 99	**Delayed**
First fiber assembly production cycle completed	July 30, 99	July 30, 99	On schedule
Fiber assembly production 25% complete	Nov 30, 99	Nov 30, 99	On schedule
Fiber assembly production 50% complete	Apr 30, 00	Apr 30, 00	On schedule
Fiber assembly production complete	Nov 30, 00	Nov 30, 00	On schedule



Issues

- Submodule protective coating
- PMT time dependence
- Regain submodule and module schedule
- Complete cryostat scintillator optics design
- Fiber delivery from Europe
- Scintillator delivery from Russia



Tilecal Summary

- Mature, elegant design
- Fabrication underway
- Test beam validation of prototypes
- Costs are well understood
- Some questions remain
  - PMT time dependence
  - Complete cryostat scintillator optics design
  - Fiber and scintillator delivery from Europe
- Much info on Web
  - http://atlasinfo.cern.ch/Atlas/SUB_DETECTORS/TILE/production/production.html